TGD INSPIRED THEORY OF CONSCIOUSNESS

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Preface

This book belongs to a series of online books summarizing the recent state Topological Geometro-dynamics (TGD) and its applications. TGD can be regarded as a unified theory of fundamental interactions but is not the kind of unified theory as so called GUTs constructed by graduate students at seventies and eighties using detailed recipes for how to reduce everything to group theory. Nowadays this activity has been completely computerized and it probably takes only a few hours to print out the predictions of this kind of unified theory as an article in the desired format. TGD is something different and I am not ashamed to confess that I have devoted the last 32 years of my life to this enterprise and am still unable to write The Rules.

I got the basic idea of Topological Geometrodynamics (TGD) during autumn 1978, perhaps it was October. What I realized was that the representability of physical space-times as 4-dimensional surfaces of some higher-dimensional space-time obtained by replacing the points of Minkowski space with some very small compact internal space could resolve the conceptual difficulties of general relativity related to the definition of the notion of energy. This belief was too optimistic and only with the advent of what I call zero energy ontology the understanding of the notion of Poincare invariance has become satisfactory.

It soon became clear that the approach leads to a generalization of the notion of space-time with particles being represented by space-time surfaces with finite size so that TGD could be also seen as a generalization of the string model. Much later it became clear that this generalization is consistent with conformal invariance only if space-time is 4-dimensional and the Minkowski space factor of imbedding space is 4-dimensional.

It took some time to discover that also the geometrization of also gauge interactions and elementary particle quantum numbers could be possible in this framework: it took two years to find the unique internal space providing this geometrization involving also the realization that family replication phenomenon for fermions has a natural topological explanation in TGD framework and that the symmetries of the standard model symmetries are much more profound than pragmatic TOE builders have believed them to be. If TGD is correct, main stream particle physics chose the wrong track leading to the recent deep crisis when people decided that quarks and leptons belong to same multiplet of the gauge group implying instability of proton.

There have been also longstanding problems.

- Gravitational energy is well-defined in cosmological models but is not conserved. Hence the conservation of the inertial energy does not seem to be consistent with the Equivalence Principle. Furthermore, the imbeddings of Robertson-Walker cosmologies turned out to be vacuum extremals with respect to the inertial energy. About 25 years was needed to realize that the sign of the inertial energy can be also negative and in cosmological scales the density of inertial energy vanishes: physically acceptable universes are creatable from vacuum. Eventually this led to the notion of zero energy ontology which deviates dramatically from the standard ontology being however consistent with the crossing symmetry of quantum field theories. In this framework the quantum numbers are assigned with zero energy states located at the boundaries of so called causal diamonds defined as intersections of future and past directed light-cones. The notion of energy-momentum becomes length scale dependent since one has a scale hierarchy for causal diamonds. This allows to understand the non-conservation of energy as apparent. Equivalence Principle generalizes and has a formulation in terms of coset representations of Super-Virasoro algebras providing also a justification for p-adic thermodynamics.

- From the beginning it was clear that the theory predicts the presence of long ranged classical electro-weak and color gauge fields and that these fields necessarily accompany classical electromagnetic fields. It took about 26 years to gain the maturity to admit the obvious: these fields are classical correlates for long range color and weak interactions assignable to dark matter. The only possible conclusion is that TGD physics is a fractal consisting of an entire hierarchy of fractal copies of standard model physics. Also the understanding of electro-weak massivation and screening of weak charges has been a long standing problem, and 32 years was needed to discover that what I call weak form of electric-magnetic duality gives a satisfactory solution of the problem and provides also surprisingly powerful insights to the mathematical structure of quantum TGD.

I started the serious attempts to construct quantum TGD after my thesis around 1982. The original optimistic hope was that path integral formalism or canonical quantization might be enough to construct the quantum theory but the first discovery made already during first year of TGD was that these formalisms might be useless due to the extreme non-linearity and enormous vacuum degeneracy of the theory. This turned out to be the case.

- It took some years to discover that the only working approach is based on the generalization of Einstein's program. Quantum physics involves the geometrization of the infinite-dimensional "world of classical worlds" (WCW) identified as 3-dimensional surfaces. Still few years had to pass before I understood that general coordinate invariance leads to a more or less unique solution of the problem and implies that space-time surfaces are analogous to Bohr orbits. Still a coupled of years and I discovered that quantum states of the Universe can be identified as classical spinor fields in WCW. Only quantum jump remains the genuinely quantal aspect of quantum physics.

- During these years TGD led to a rather profound generalization of the space-time concept. Quite general properties of the theory led to the notion of many-sheeted space-time with sheets representing physical subsystems of various sizes. At the beginning of 90s I became dimly aware of the importance of p-adic number fields and soon ended up with the idea that p-adic thermodynamics for a conformally invariant system allows to understand elementary particle massivation with amazingly few input assumptions. The attempts to understand p-adicity from basic principles led gradually to the vision about physics as a generalized number theory as an approach complementary to the physics as an infinite-dimensional spinor geometry of WCW approach. One of its elements was a generalization of the number concept obtained by fusing real numbers and various p-adic numbers along common rationals. The number theoretical trinity involves besides p-adic number fields also quaternions and octonions and the notion of infinite prime.

- TGD inspired theory of consciousness entered the scheme after 1995 as I started to write a book about consciousness. Gradually it became difficult to say where physics ends and consciousness theory begins since consciousness theory could be seen as a generalization of quantum measurement theory by identifying quantum jump as a moment of consciousness and by replacing the observer with the notion of self identified as a system which is conscious as long as it can avoid entanglement with environment. "Everything is conscious and consciousness can be only lost" summarizes the basic philosophy neatly. The idea about p-adic physics as physics of cognition and intentionality emerged also rather naturally and implies perhaps the most dramatic generalization of the space-time concept in which most points of p-adic space-time sheets are infinite in real sense and the projection to the real imbedding space consists of discrete set of points. One of the most fascinating outcomes was the observation that the entropy based on p-adic norm can be negative. This observation led to the vision that life can be regarded as something in the intersection of real and p-adic worlds. Negentropic entanglement has interpretation as a correlate for various positively colored aspects of conscious experience and means also the possibility of strongly correlated states stable under state function reduction and different from the conventional bound states and perhaps playing key role in the energy metabolism of living matter.

- One of the latest threads in the evolution of ideas is only slightly more than six years old. Learning about the paper of Laurent Nottale about the possibility to identify planetary orbits as Bohr orbits with a gigantic value of gravitational Planck constant made once again possible to see the obvious. Dynamical quantized Planck constant is strongly suggested by quantum classical correspondence and the fact that space-time sheets identifiable as quantum coherence regions can have arbitrarily large sizes. During summer 2010 several new insights about the mathematical structure and interpretation of TGD emerged. One of these insights was the realization that the postulated hierarchy of Planck constants might follow from the basic structure of quantum TGD. The point is that due to the extreme non-linearity of the classical action principle the correspondence between canonical momentum densities and time derivatives of the imbedding space coordinates is one-to-many and the natural description of the situation is in terms of local singular covering spaces of the imbedding space. One could speak about effective value of Planck

constant coming as a multiple of its minimal value. The implications of the hierarchy of Planck constants are extremely far reaching so that the significance of the reduction of this hierarchy to the basic mathematical structure distinguishing between TGD and competing theories cannot be under-estimated.

From the point of view of particle physics the ultimate goal is of course a practical construction recipe for the S-matrix of the theory. I have myself regarded this dream as quite too ambitious taking into account how far reaching re-structuring and generalization of the basic mathematical structure of quantum physics is required. It has indeed turned out that the dream about explicit formula is unrealistic before one has understood what happens in quantum jump. Symmetries and general physical principles have turned out to be the proper guide line here. To give some impressions about what is required some highlights are in order.

- With the emergence of zero energy ontology the notion of S-matrix was replaced with M-matrix which can be interpreted as a complex square root of density matrix representable as a diagonal and positive square root of density matrix and unitary S-matrix so that quantum theory in zero energy ontology can be said to define a square root of thermodynamics at least formally.

- A decisive step was the strengthening of the General Coordinate Invariance to the requirement that the formulations of the theory in terms of light-like 3-surfaces identified as 3-surfaces at which the induced metric of space-time surfaces changes its signature and in terms of space-like 3-surfaces are equivalent. This means effective 2-dimensionality in the sense that partonic 2-surfaces defined as intersections of these two kinds of surfaces plus 4-D tangent space data at partonic 2-surfaces code for the physics. Quantum classical correspondence requires the coding of the quantum numbers characterizing quantum states assigned to the partonic 2-surfaces to the geometry of space-time surface. This is achieved by adding to the modified Dirac action a measurement interaction term assigned with light-like 3-surfaces.

- The replacement of strings with light-like 3-surfaces equivalent to space-like 3-surfaces means enormous generalization of the super conformal symmetries of string models. A further generalization of these symmetries to non-local Yangian symmetries generalizing the recently discovered Yangian symmetry of $\mathcal{N}=4$ supersymmetric Yang-Mills theories is highly suggestive. Here the replacement of point like particles with partonic 2-surfaces means the replacement of conformal symmetry of Minkowski space with infinite-dimensional super-conformal algebras. Yangian symmetry provides also a further refinement to the notion of conserved quantum numbers allowing to define them for bound states using non-local energy conserved currents.

- A further attractive idea is that quantum TGD reduces to almost topological quantum field theory. This is possible if the Kähler action for the preferred extremals defining WCW Kähler function reduces to a 3-D boundary term. This takes place if the conserved currents are so called Beltrami fields with the defining property that the coordinates associated with flow lines extend to single global coordinate variable. This ansatz together with the weak form of electric-magnetic duality reduces the Kähler action to Chern-Simons term with the condition that the 3-surfaces are extremals of Chern-Simons action subject to the constraint force defined by the weak form of electric magnetic duality. It is the latter constraint which prevents the trivialization of the theory to a topological quantum field theory. Also the identification of the Kähler function of WCW as Dirac determinant finds support as well as the description of the scattering amplitudes in terms of braids with interpretation in terms of finite measurement resolution coded to the basic structure of the solutions of field equations.

- In standard QFT Feynman diagrams provide the description of scattering amplitudes. The beauty of Feynman diagrams is that they realize unitarity automatically via the so called Cutkosky rules. In contrast to Feynman's original beliefs, Feynman diagrams and virtual particles are taken only as a convenient mathematical tool in quantum field theories. QFT approach is however plagued by UV and IR divergences and one must keep mind open for the possibility that a genuine progress might mean opening of the black box of the virtual particle.

  In TGD framework this generalization of Feynman diagrams indeed emerges unavoidably. Light-like 3-surfaces replace the lines of Feynman diagrams and vertices are replaced by 2-D partonic

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2-surfaces. Zero energy ontology and the interpretation of parton orbits as light-like "wormhole throats" suggests that virtual particle do not differ from on mass shell particles only in that the four- and three- momenta of wormhole throats fail to be parallel. The two throats of the wormhole defining virtual particle would contact carry on mass shell quantum numbers but for virtual particles the four-momenta need not be parallel and can also have opposite signs of energy. Modified Dirac equation suggests a number theoretical quantization of the masses of the virtual particles. The kinematic constraints on the virtual momenta are extremely restrictive and reduce the dimension of the sub-space of virtual momenta and if massless particles are not allowed (IR cutoff provided by zero energy ontology naturally), the number of Feynman diagrams contributing to a particular kind of scattering amplitude is finite and manifestly UV and IR finite and satisfies unitarity constraint in terms of Cutkosky rules. What is remarkable that fermionic propagatos are massless propagators but for on mass shell four-momenta. This gives a connection with the twistor approach and inspires the generalization of the Yangian symmetry to infinite-dimensional super-conformal algebras.

What I have said above is strongly biased view about the recent situation in quantum TGD and I have left all about applications to the introductions of the books whose purpose is to provide a bird's eye of view about TGD as it is now. This vision is single man's view and doomed to contain unrealistic elements as I know from experience. My dream is that young critical readers could take this vision seriously enough to try to demonstrate that some of its basic premises are wrong or to develop an alternative based on these or better premises. I must be however honest and tell that 32 years of TGD is a really vast bundle of thoughts and quite a challenge for anyone who is not able to cheat himself by taking the attitude of a blind believer or a light-hearted debunker trusting on the power of easy rhetoric tricks.

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least in principle leak to the publicity through the iron wall of the academic censorship. Without any exaggeration I can say that without the world wide web I would not have survived as a scientist nor as individual. Homepage and blog are however not enough since only the formally published result is a result in recent day science. Publishing is however impossible without a direct support from power holders- even in archives like arXiv.org.

Situation changed for five years ago as Andrew Adamatsky proposed the writing of a book about TGD when I had already got used to the thought that my work would not be published during my life time. The Prespacetime Journal and two other journals related to quantum biology and consciousness - all of them founded by Huping Hu - have provided this kind of loop holes. In particular, Dainis Zeps, Phil Gibbs, and Arkadiusz Jadczyk deserve my gratitude for their kind help in the preparation of an article series about TGD catalyzing a considerable progress in the understanding of quantum TGD. Also the viXra archive founded by Phil Gibbs and its predecessor Archive Freedom have been of great help: Victor Christianto deserves special thanks for doing the hard work needed to run Archive Freedom. Also the Neuroquantology Journal founded by Sultan Tarlaci deserves a special mention for its publication policy. And last but not least: there are people who experience as a fascinating intellectual challenge to spoil the practical working conditions of a person working with something which might be called unified theory: I am grateful for the people who have helped me to survive through the virus attacks, an activity which has taken roughly one month per year during the last half decade and given a strong hue of grey to my hair.

For a person approaching his sixty year birthday it is somewhat easier to overcome the hard feelings due to the loss of academic human rights than for an inpatient youngster. Unfortunately the economic situation has become increasingly difficult during the twenty years after the economic depression in Finland which in practice meant that Finland ceased to be a constitutional state in the strong sense of the word. It became possible to depose people like me from the society without fear about public reactions and the classification as dropout became a convenient tool of ridicule to circumvent the ethical issues. During last few years when the right wing has held the political power this trend has been steadily strengthening. In this kind of situation the concrete help from individuals has been and will be of utmost importance. Against this background it becomes obvious that this kind of work is not possible without the support from outside and I apologize for not being able to mention all the people who have helped me during these years.

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Chapter 1

Introduction

1.1 Background

T(opological) G(eometro)D(ynamics) is one of the many attempts to find a unified description of basic interactions. The development of the basic ideas of TGD to a relatively stable form took time of about half decade [27]. The great challenge is to construct a mathematical theory around these physically very attractive ideas and I have devoted the last twenty-three years for the realization of this dream and this has resulted in seven online books [1, 2, 3, 5, 4, 6, 7] about TGD and eight online books about TGD inspired theory of consciousness and of quantum biology [8, 9, 10, 11, 12, 13, 14, 14].

Quantum T(opological)D(ynamics) as a classical spinor geometry for infinite-dimensional configuration space, p-adic numbers and quantum TGD, and TGD inspired theory of consciousness have been for last decade of the second millenium the basic three strongly interacting threads in the tapestry of quantum TGD.

For few yeas ago the discussions with Tony Smith generated a fourth thread which deserves the name 'TGD as a generalized number theory'. The work with Riemann hypothesis made time ripe for realization that the notion of infinite primes could provide, not only a reformulation, but a deep generalization of quantum TGD. This led to a thorough and extremely fruitful revision of the basic views about what the final form and physical content of quantum TGD might be.

The fifth thread came with the realization that by quantum classical correspondence TGD predicts an infinite hierarchy of macroscopic quantum systems with increasing sizes, that it is not at all clear whether standard quantum mechanics can accommodate this hierarchy, and that a dynamical quantized Planck constant might be necessary and certainly possible in TGD framework. The identification of hierarchy of Planck constants whose values TGD "predicts" in terms of dark matter hierarchy would be natural. This also led to a solution of a long standing puzzle: what is the proper interpretation of the predicted fractal hierarchy of long ranged classical electro-weak and color gauge fields. Quantum classical correspondences allows only single answer: there is infinite hierarchy of p-adically scaled up variants of standard model physics and for each of them also dark hierarchy. Thus TGD Universe would be fractal in very abstract and deep sense.

TGD forces the generalization of physics to a quantum theory of consciousness, and represent TGD as a generalized number theory vision leads naturally to the emergence of p-adic physics as physics of cognitive representations. The seven online books [1, 2, 3, 5, 4, 6, 7] about TGD and eight online books about TGD inspired theory of consciousness and of quantum biology [8, 9, 10, 11, 12, 13, 14, 14] are warmly recommended to the interested reader.

1.2 Basic Ideas of TGD

The basic physical picture behind TGD was formed as a fusion of two rather disparate approaches: namely TGD is as a Poincare invariant theory of gravitation and TGD as a generalization of the old-fashioned string model.

1.2.1   TGD as a Poincare invariant theory of gravitation

The first approach was born as an attempt to construct a Poincare invariant theory of gravitation. Space-time, rather than being an abstract manifold endowed with a pseudo-Riemannian structure, is regarded as a surface in the 8-dimensional space $H = M^4_+ \times CP_2$, where M^4_+ denotes the interior of the future light cone of the Minkowski space (to be referred as light cone in the sequel) and $CP_2 = SU(3)/U(2)$ is the complex projective space of two complex dimensions [16, 31, 34, 19]. The identification of the space-time as a submanifold [33, 30] of $M^4 \times CP_2$ leads to an exact Poincare invariance and solves the conceptual difficulties related to the definition of the energy-momentum in General Relativity [Misner-Thorne-Wheeler, Logunov *et al*]. The actual choice $H = M^4_+ \times CP_2$ implies the breaking of the Poincare invariance in the cosmological scales but only at the quantum level. It soon however turned out that submanifold geometry, being considerably richer in structure than the abstract manifold geometry, leads to a geometrization of all basic interactions. First, the geometrization of the elementary particle quantum numbers is achieved. The geometry of CP_2 explains electro-weak and color quantum numbers. The different H-chiralities of H-spinors correspond to the conserved baryon and lepton numbers. Secondly, the geometrization of the field concept results. The projections of the CP_2 spinor connection, Killing vector fields of CP_2 and of H-metric to four-surface define classical electro-weak, color gauge fields and metric in X^4.

1.2.2   TGD as a generalization of the hadronic string model

The second approach was based on the generalization of the mesonic string model describing mesons as strings with quarks attached to the ends of the string. In the 3-dimensional generalization 3-surfaces correspond to free particles and the boundaries of the 3- surface correspond to partons in the sense that the quantum numbers of the elementary particles reside on the boundaries. Various boundary topologies (number of handles) correspond to various fermion families so that one obtains an explanation for the known elementary particle quantum numbers. This approach leads also to a natural topological description of the particle reactions as topology changes: for instance, two-particle decay corresponds to a decay of a 3-surface to two disjoint 3-surfaces.

1.2.3   Fusion of the two approaches via a generalization of the space-time concept

The problem is that the two approaches seem to be mutually exclusive since the orbit of a particle like 3-surface defines 4-dimensional surface, which differs drastically from the topologically trivial macroscopic space-time of General Relativity. The unification of these approaches forces a considerable generalization of the conventional space-time concept. First, the topologically trivial 3-space of General Relativity is replaced with a "topological condensate" containing matter as particle like 3-surfaces "glued" to the topologically trivial background 3-space by connected sum operation. Secondly, the assumption about connectedness of the 3-space is given up. Besides the "topological condensate" there is "vapor phase" that is a "gas" of particle like 3-surfaces (counterpart of the "baby universes" of GRT) and the nonconservation of energy in GRT corresponds to the transfer of energy between the topological condensate and vapor phase.

1.3   The five threads in the development of quantum TGD

The development of TGD has involved four strongly interacting threads: physics as infinite-dimensional geometry; p-adic physics; TGD inspired theory of consciousness and TGD as a generalized number theory. In the following these five threads are briefly described.

1.3.1   Quantum TGD as configuration space spinor geometry

A turning point in the attempts to formulate a mathematical theory was reached after seven years from the birth of TGD. The great insight was "Do not quantize". The basic ingredients to the new approach have served as the basic philosophy for the attempt to construct Quantum TGD since then and are the following ones:

a) Quantum theory for extended particles is free(!), classical(!) field theory for a generalized Schrödinger amplitude in the configuration space CH consisting of all possible 3-surfaces in H. "All possible" means that surfaces with arbitrary many disjoint components and with arbitrary internal topology and also singular surfaces topologically intermediate between two different manifold topologies are included. Particle reactions are identified as topology changes [35, 32, 29]. For instance, the decay of a 3-surface to two 3-surfaces corresponds to the decay $A \to B + C$. Classically this corresponds to a path of configuration space leading from 1-particle sector to 2-particle sector. At quantum level this corresponds to the dispersion of the generalized Schrödinger amplitude localized to 1-particle sector to two-particle sector. All coupling constants should result as predictions of the theory since no nonlinearities are introduced.

b) Configuration space is endowed with the metric and spinor structure so that one can define various metric related differential operators, say Dirac operator, appearing in the field equations of the theory.

1.3.2 p-Adic TGD

The p-adic thread emerged for roughly ten years ago as a dim hunch that p-adic numbers might be important for TGD. Experimentation with p-adic numbers led to the notion of canonical identification mapping reals to p-adics and vice versa. The breakthrough came with the successful p-adic mass calculations using p-adic thermodynamics for Super-Virasoro representations with the super-Kac-Moody algebra associated with a Lie-group containing standard model gauge group. Although the details of the calculations have varied from year to year, it was clear that p-adic physics reduces not only the ratio of proton and Planck mass, the great mystery number of physics, but all elementary particle mass scales, to number theory if one assumes that primes near prime powers of two are in a physically favored position. Why this is the case, became one of the key puzzless and led to a number of arguments with a common gist: evolution is present already at the elementary particle level and the primes allowed by the p-adic length scale hypothesis are the fittest ones.

It became very soon clear that p-adic topology is not something emerging in Planck length scale as often believed, but that there is an infinite hierarchy of p-adic physics characterized by p-adic length scales varying to even cosmological length scales. The idea about the connection of p-adics with cognition motivated already the first attempts to understand the role of the p-adics and inspired 'Universe as Computer' vision but time was not ripe to develop this idea to anything concrete (p-adic numbers are however in a central role in TGD inspired theory of consciousness). It became however obvious that the p-adic length scale hierarchy somehow corresponds to a hierarchy of intelligences and that p-adic prime serves as a kind of intelligence quotient. Ironically, the almost obvious idea about p-adic regions as cognitive regions of space-time providing cognitive representations for real regions had to wait for almost a decade for the access into my consciousness.

There were many interpretational and technical questions crying for a definite answer. What is the relationship of p-adic non-determinism to the classical non-determinism of the basic field equations of TGD? Are the p-adic space-time region genuinely p-adic or does p-adic topology only serve as an effective topology? If p-adic physics is direct image of real physics, how the mapping relating them is constructed so that it respects various symmetries? Is the basic physics p-adic or real (also real TGD seems to be free of divergences) or both? If it is both, how should one glue the physics in different number field together to get *The Physics*? Should one perform p-adicization also at the level of the configuration space of 3-surfaces? Certainly the p-adicization at the level of super-conformal representation is necessary for the p-adic mass calculations. Perhaps the most basic and most irritating technical problem was how to precisely define p-adic definite integral which is a crucial element of any variational principle based formulation of the field equations. Here the frustration was not due to the lack of solution but due to the too large number of solutions to the problem, a clear symptom for the sad fact that clever inventions rather than real discoveries might be in question.

Despite these frustrating uncertainties, the number of the applications of the poorly defined p-adic physics growed steadily and the applications turned out to be relatively stable so that it was clear that the solution to these problems must exist. It became only gradually clear that the solution of the problems might require going down to a deeper level than that represented by reals and p-adics.

1.3.3   TGD as a generalization of physics to a theory consciousness

General coordinate invariance forces the identification of quantum jump as quantum jump between entire deterministic quantum histories rather than time=constant snapshots of single history. The new view about quantum jump forces a generalization of quantum measurement theory such that observer becomes part of the physical system. Thus a general theory of consciousness is unavoidable outcome. This theory is developed in detail in the books [8, 9, 10, 11, 12, 13, 14, 14].

Quantum jump as a moment of consciousness

The identification of quantum jump between deterministic quantum histories (configuration space spinor fields) as a moment of consciousness defines microscopic theory of consciousness. Quantum jump involves the steps

$$\Psi_i \to U\Psi_i \to \Psi_f \ \ ,$$

where U is informational "time development" operator, which is unitary like the S-matrix characterizing the unitary time evolution of quantum mechanics. U is however only formally analogous to Schrödinger time evolution of infinite duration although there is *no* real time evolution involved. It is not however clear whether one should regard U-matrix and S-matrix as two different things or not: U-matrix is a completely universal object characterizing the dynamics of evolution by self-organization whereas S-matrix is a highly context dependent concept in wave mechanics and in quantum field theories where it at least formally represents unitary time translation operator at the limit of an infinitely long interaction time. The S-matrix understood in the spirit of superstring models is however something very different and could correspond to U-matrix.

The requirement that quantum jump corresponds to a measurement in the sense of quantum field theories implies that each quantum jump involves localization in zero modes which parameterize also the possible choices of the quantization axes. Thus the selection of the quantization axes performed by the Cartesian outsider becomes now a part of quantum theory. Together these requirements imply that the final states of quantum jump correspond to quantum superpositions of space-time surfaces which are macroscopically equivalent. Hence the world of conscious experience looks classical. At least formally quantum jump can be interpreted also as a quantum computation in which matrix U represents unitary quantum computation which is however not identifiable as unitary translation in time direction and cannot be 'engineered'.

The notion of self

The concept of self is absolutely essential for the understanding of the macroscopic and macro-temporal aspects of consciousness. Self corresponds to a subsystem able to remain un-entangled under the sequential informational 'time evolutions' U. Exactly vanishing entanglement is practically impossible in ordinary quantum mechanics and it might be that 'vanishing entanglement' in the condition for self-property should be replaced with 'subcritical entanglement'. On the other hand, if space-time decomposes into p-adic and real regions, and if entanglement between regions representing physics in different number fields vanishes, space-time indeed decomposes into selves in a natural manner.

It is assumed that the experiences of the self after the last 'wake-up' sum up to single average experience. This means that subjective memory is identifiable as conscious, immediate short term memory. Selves form an infinite hierarchy with the entire Universe at the top. Self can be also interpreted as mental images: our mental images are selves having mental images and also we represent mental images of a higher level self. A natural hypothesis is that self S experiences the experiences of its subselves as kind of abstracted experience: the experiences of subselves S_i are not experienced as such but represent kind of averages $\langle S_{ij} \rangle$ of sub-subselves S_{ij}. Entanglement between selves, most naturally realized by the formation of join along boundaries bonds between cognitive or material space-time sheets, provides a possible a mechanism for the fusion of selves to larger selves (for instance, the fusion of the mental images representing separate right and left visual fields to single visual field) and forms wholes from parts at the level of mental images.

Relationship to quantum measurement theory

The third basic element relates TGD inspired theory of consciousness to quantum measurement theory. The assumption that localization occurs in zero modes in each quantum jump implies that the world of conscious experience looks classical. It also implies the state function reduction of the standard quantum measurement theory as the following arguments demonstrate (it took incredibly long time to realize this almost obvious fact!).

a) The standard quantum measurement theory a la von Neumann involves the interaction of brain with the measurement apparatus. If this interaction corresponds to entanglement between microscopic degrees of freedom m with the macroscopic effectively classical degrees of freedom M characterizing the reading of the measurement apparatus coded to brain state, then the reduction of this entanglement in quantum jump reproduces standard quantum measurement theory provide the unitary time evolution operator U acts as flow in zero mode degrees of freedom and correlates completely some orthonormal basis of configuration space spinor fields in non-zero modes with the values of the zero modes. The flow property guarantees that the localization is consistent with unitarity: it also means 1-1 mapping of quantum state basis to classical variables (say, spin direction of the electron to its orbit in the external magnetic field).

b) Since zero modes represent classical information about the geometry of space-time surface (shape, size, classical Kähler field,...), they have interpretation as effectively classical degrees of freedom and are the TGD counterpart of the degrees of freedom M representing the reading of the measurement apparatus. The entanglement between quantum fluctuating non-zero modes and zero modes is the TGD counterpart for the $m - M$ entanglement. Therefore the localization in zero modes is equivalent with a quantum jump leading to a final state where the measurement apparatus gives a definite reading.

This simple prediction is of utmost theoretical importance since the black box of the quantum measurement theory is reduced to a fundamental quantum theory. This reduction is implied by the replacement of the notion of a point like particle with particle as a 3-surface. Also the infinite-dimensionality of the zero mode sector of the configuration space of 3-surfaces is absolutely essential. Therefore the reduction is a triumph for quantum TGD and favors TGD against string models.

Standard quantum measurement theory involves also the notion of state preparation which reduces to the notion of self measurement. Each localization in zero modes is followed by a cascade of self measurements leading to a product state. This process is obviously equivalent with the state preparation process. Self measurement is governed by the so called Negentropy Maximization Principle (NMP) stating that the information content of conscious experience is maximized. In the self measurement the density matrix of some subsystem of a given self localized in zero modes (after ordinary quantum measurement) is measured. The self measurement takes place for that subsystem of self for which the reduction of the entanglement entropy is maximal in the measurement. In p-adic context NMP can be regarded as the variational principle defining the dynamics of cognition. In real context self measurement could be seen as a repair mechanism allowing the system to fight against quantum thermalization by reducing the entanglement for the subsystem for which it is largest (fill the largest hole first in a leaking boat).

Selves self-organize

The fourth basic element is quantum theory of self-organization based on the identification of quantum jump as the basic step of self-organization [26]. Quantum entanglement gives rise to the generation of long range order and the emergence of longer p-adic length scales corresponds to the emergence of larger and larger coherent dynamical units and generation of a slaving hierarchy. Energy (and quantum entanglement) feed implying entropy feed is a necessary prerequisite for quantum self-organization. Zero modes represent fundamental order parameters and localization in zero modes implies that the sequence of quantum jumps can be regarded as hopping in the zero modes so that Haken's classical theory of self organization applies almost as such. Spin glass analogy is a further important element: self-organization of self leads to some characteristic pattern selected by dissipation as some valley of the "energy" landscape.

Dissipation can be regarded as the ultimate Darwinian selector of both memes and genes. The mathematically ugly irreversible dissipative dynamics obtained by adding phenomenological dissipation terms to the reversible fundamental dynamical equations derivable from an action principle can be

understood as a phenomenological description replacing in a well defined sense the series of reversible quantum histories with its envelope.

Classical non-determinism of Kähler action

The fifth basic element are the concepts of association sequence and cognitive space-time sheet. The huge vacuum degeneracy of the Kähler action suggests strongly that the absolute minimum space-time is not always unique. For instance, a sequence of bifurcations can occur so that a given space-time branch can be fixed only by selecting a finite number of 3-surfaces with time like(!) separations on the orbit of 3-surface. Quantum classical correspondence suggest an alternative formulation. Space-time surface decomposes into maximal deterministic regions and their temporal sequences have interpretation a space-time correlate for a sequence of quantum states defined by the initial (or final) states of quantum jumps. This is consistent with the fact that the variational principle selects preferred extremals of Kähler action as generalized Bohr orbits.

In the case that non-determinism is located to a finite time interval and is microscopic, this sequence of 3-surfaces has interpretation as a simulation of a classical history, a geometric correlate for contents of consciousness. When non-determinism has long lasting and macroscopic effect one can identify it as volitional non-determinism associated with our choices. Association sequences relate closely with the cognitive space-time sheets defined as space-time sheets having finite time duration and psychological time can be identified as a temporal center of mass coordinate of the cognitive space-time sheet. The gradual drift of the cognitive space-time sheets to the direction of future force by the geometry of the future light cone explains the arrow of psychological time.

p-Adic physics as physics of cognition and intentionality

The sixth basic element adds a physical theory of cognition to this vision. TGD space-time decomposes into regions obeying real and p-adic topologies labelled by primes $p = 2, 3, 5, ...$. p-Adic regions obey the same field equations as the real regions but are characterized by p-adic non-determinism since the functions having vanishing p-adic derivative are pseudo constants which are piecewise constant functions. Pseudo constants depend on a finite number of positive pinary digits of arguments just like numerical predictions of any theory always involve decimal cutoff. This means that p-adic space-time regions are obtained by gluing together regions for which integration constants are genuine constants. The natural interpretation of the p-adic regions is as cognitive representations of real physics. The freedom of imagination is due to the p-adic non-determinism. p-Adic regions perform mimicry and make possible for the Universe to form cognitive representations about itself. p-Adic physics space-time sheets serve also as correlates for intentional action.

A more more precise formulation of this vision requires a generalization of the number concept obtained by fusing reals and p-adic number fields along common rationals (in the case of algebraic extensions among common algebraic numbers). This picture is discussed in [23]. The application this notion at the level of the imbedding space implies that imbedding space has a book like structure with various variants of the imbedding space glued together along common rationals (algebraics). The implication is that genuinely p-adic numbers (non-rationals) are strictly infinite as real numbers so that most points of p-adic space-time sheets are at real infinity, outside the cosmos, and that the projection to the real imbedding space is discrete set of rationals (algebraics). Hence cognition and intentionality are almost completely outside the real cosmos and touch it at a discrete set of points only.

This view implies also that purely local p-adic physics codes for the p-adic fractality characterizing long range real physics and provides an explanation for p-adic length scale hypothesis stating that the primes $p \simeq 2^k$, k integer are especially interesting. It also explains the long range correlations and short term chaos characterizing intentional behavior and explains why the physical realizations of cognition are always discrete (say in the case of numerical computations). Furthermore, a concrete quantum model for how intentions are transformed to actions emerges.

The discrete real projections of p-adic space-time sheets serve also space-time correlate for a logical thought. It is very natural to assign to p-adic pinary digits a p-valued logic but as such this kind of logic does not have any reasonable identification. p-Adic length scale hypothesis suggest that the $p = 2^k - n$ pinary digits represent a Boolean logic B^k with k elementary statements (the points of the

k-element set in the set theoretic realization) with n taboos which are constrained to be identically true.

1.3.4 TGD as a generalized number theory

Quantum T(opological)D(ynamics) as a classical spinor geometry for infinite-dimensional configuration space, p-adic numbers and quantum TGD, and TGD inspired theory of consciousness, have been for last ten years the basic three strongly interacting threads in the tapestry of quantum TGD. For few yeas ago the discussions with Tony Smith generated a fourth thread which deserves the name 'TGD as a generalized number theory'. It relies on the notion of number theoretic compactifiction stating that space-time surfaces can be regarded either as hyper-quaternionic, and thus maximally associative, 4-surfaces in M^8 identifiable as space of hyper-octonions or as surfaces in $M^4 \times CP_2$ [20].

The discovery of the hierarchy of infinite primes and their correspondence with a hierarchy defined by a repeatedly second quantized arithmetic quantum field theory gave a further boost for the speculations about TGD as a generalized number theory. The work with Riemann hypothesis led to further ideas.

After the realization that infinite primes can be mapped to polynomials representable as surfaces geometrically, it was clear how TGD might be formulated as a generalized number theory with infinite primes forming the bridge between classical and quantum such that real numbers, p-adic numbers, and various generalizations of p-adics emerge dynamically from algebraic physics as various completions of the algebraic extensions of rational (hyper-)quaternions and (hyper-)octonions. Complete algebraic, topological and dimensional democracy would characterize the theory.

What is especially satisfying is that p-adic and real regions of the space-time surface could emerge automatically as solutions of the field equations. In the space-time regions where the solutions of field equations give rise to in-admissible complex values of the imbedding space coordinates, p-adic solution can exist for some values of the p-adic prime. The characteristic non-determinism of the p-adic differential equations suggests strongly that p-adic regions correspond to 'mind stuff', the regions of space-time where cognitive representations reside. This interpretation implies that p-adic physics is physics of cognition. Since Nature is probably extremely brilliant simulator of Nature, the natural idea is to study the p-adic physics of the cognitive representations to derive information about the real physics. This view encouraged by TGD inspired theory of consciousness clarifies difficult interpretational issues and provides a clear interpretation for the predictions of p-adic physics.

1.3.5 Dynamical quantized Planck constant and dark matter hierarchy

By quantum classical correspondence space-time sheets can be identified as quantum coherence regions. Hence the fact that they have all possible size scales more or less unavoidably implies that Planck constant must be quantized and have arbitrarily large values. If one accepts this then also the idea about dark matter as a macroscopic quantum phase characterized by an arbitrarily large value of Planck constant emerges naturally as does also the interpretation for the long ranged classical electroweak and color fields predicted by TGD. Rather seldom the evolution of ideas follows simple linear logic, and this was the case also now. In any case, this vision represents the fifth, relatively new thread in the evolution of TGD and the ideas involved are still evolving.

Dark matter as large $\hbar$ phase

D. Da Rocha and Laurent Nottale [37] have proposed that Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant $\hbar_{gr} = \frac{GmM}{v_0}$ ($\hbar = c = 1$). v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. This is rather near to the peak orbital velocity of stars in galactic halos. Also subharmonics and harmonics of v_0 seem to appear. The support for the hypothesis coming from empirical data is impressive.

Nottale and Da Rocha believe that their Schrödinger equation results from a fractal hydrodynamics. Many-sheeted space-time however suggests astrophysical systems are not only quantum systems at larger space-time sheets but correspond to a gigantic value of gravitational Planck constant. The gravitational (ordinary) Schrödinger equation would provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by

TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale [17].

Already before learning about Nottale's paper I had proposed the possibility that Planck constant is quantized [29] and the spectrum is given in terms of logarithms of Beraha numbers: the lowest Beraha number B_3 is completely exceptional in that it predicts infinite value of Planck constant. The inverse of the gravitational Planck constant could correspond a gravitational perturbation of this as $1/\hbar_{gr} = v_0/GMm$. The general philosophy would be that when the quantum system would become non-perturbative, a phase transition increasing the value of $\hbar$ occurs to preserve the perturbative character and at the transition $n = 4 \rightarrow 3$ only the small perturbative correction to $1/\hbar(3) = 0$ remains. This would apply to QCD and to atoms with $Z > 137$ as well.

TGD predicts correctly the value of the parameter v_0 assuming that cosmic strings and their decay remnants are responsible for the dark matter. The harmonics of v_0 can be understood as corresponding to perturbations replacing cosmic strings with their n-branched coverings so that tension becomes n^2-fold: much like the replacement of a closed orbit with an orbit closing only after n turns. $1/n$-sub-harmonic would result when a magnetic flux tube split into n disjoint magnetic flux tubes. Also a model for the formation of planetary system as a condensation of ordinary matter around quantum coherent dark matter emerges [17].

Dark matter as a source of long ranged weak and color fields

Long ranged classical electro-weak and color gauge fields are unavoidable in TGD framework. The smallness of the parity breaking effects in hadronic, nuclear, and atomic length scales does not however seem to allow long ranged electro-weak gauge fields. The problem disappears if long range classical electro-weak gauge fields are identified as space-time correlates for massless gauge fields created by dark matter. Also scaled up variants of ordinary electro-weak particle spectra are possible. The identification explains chiral selection in living matter and unbroken $U(2)_{ew}$ invariance and free color in bio length scales become characteristics of living matter and of bio-chemistry and bio-nuclear physics. An attractive solution of the matter antimatter asymmetry is based on the identification of also antimatter as dark matter.

p-Adic and dark matter hierarchies and hierarchy of moments of consciousness

Dark matter hierarchy assigned to a spectrum of Planck constant having arbitrarily large values brings additional elements to the TGD inspired theory of consciousness.

a) Macroscopic quantum coherence can be understood since a particle with a given mass can in principle appear as arbitrarily large scaled up copies (Compton length scales as $\hbar$). The phase transition to this kind of phase implies that space-time sheets of particles overlap and this makes possible macroscopic quantum coherence.

b) The space-time sheets with large Planck constant can be in thermal equilibrium with ordinary ones without the loss of quantum coherence. For instance, the cyclotron energy scale associated with EEG turns out to be above thermal energy at room temperature for the level of dark matter hierarchy corresponding to magnetic flux quanta of the Earth's magnetic field with the size scale of Earth and a successful quantitative model for EEG results [22].

Dark matter hierarchy leads to detailed quantitative view about quantum biology with several testable predictions [22]. The applications to living matter suggests that the basic hierarchy corresponds to a hierarchy of Planck constants coming as $\hbar(k) = \lambda^k(p)\hbar_0$, $\lambda \simeq 2^{11}$ for $p = 2^{127-1}$, $k = 0, 1, 2, ...$ [22]. Also integer valued sub-harmonics and integer valued sub-harmonics of λ might be possible. Each p-adic length scale corresponds to this kind of hierarchy and number theoretical arguments suggest a general formula for the allowed values of Planck constant λ depending logarithmically on p-adic prime [24]. Also the value of $\hbar_0$ has spectrum characterized by Beraha numbers $B_n = 4cos^2(\pi/n)$, $n \geq 3$, varying by a factor in the range $n > 3$ [24]. It must be however emphasized that the relation of this picture to the model of quantized gravitational Planck constant h_{gr} appearing in Nottale's model is not yet completely understood.

The general prediction is that Universe is a kind of inverted Mandelbrot fractal for which each bird's eye of view reveals new structures in long length and time scales representing scaled down copies of standard physics and their dark variants. These structures would correspond to higher levels in self

hierarchy. This prediction is consistent with the belief that 75 per cent of matter in the universe is dark.

1. Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [22]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [29, 22]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [22].

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of $\hbar$ at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

2. Dark matter hierarchy and the notion of self

The vision about dark matter hierarchy leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [16, 22]. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T(k) \propto \lambda^k$ of the quantum jump.

Quantum jumps form also a hierarchy with respect to p-adic and dark hierarchies and the geometric durations of quantum jumps scale like $\hbar$. Dark matter hierarchy suggests also a slight modification of the notion of self. Each self involves a hierarchy of dark matter levels, and one is led to ask whether the highest level in this hierarchy corresponds to single quantum jump rather than a sequence of quantum jumps. The averaging of conscious experience over quantum jumps would occur only for sub-selves at lower levels of dark matter hierarchy and these mental images would be ordered, and single moment of consciousness would be experienced as a history of events. The quantum parallel dissipation at the lower levels would give rise to the experience of flow of time. For instance, hadron as a macro-temporal quantum system in the characteristic time scale of hadron is a dissipating system at quark and gluon level corresponding to shorter p-adic time scales. One can ask whether even entire life cycle could be regarded as a single quantum jump at the highest level so that consciousness would not be completely lost even during deep sleep. This would allow to understand why we seem to know directly that this biological body of mine existed yesterday.

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self corresponds at the highest dark matter level to single moment of consciousness. Self would experience the average over the sequence of moments of consciousness associated with each sub-self but there would be no averaging over the separate mental images of this kind, be their parallel or serial. These mental images correspond to sub-selves having shorter wake-up periods than self and would be experienced as being time ordered. Hence the digits in the phone number are experienced as separate mental images and ordered with respect to experienced time.

3. The time span of long term memories as signature for the level of dark matter hierarchy

The simplest dimensional estimate gives for the average increment τ of geometric time in quantum jump $\tau \sim 10^4$ CP_2 times so that $2^{127} - 1 \sim 10^{38}$ quantum jumps are experienced during secondary p-adic time scale $T_2(k = 127) \simeq 0.1$ seconds which is the duration of physiological moment and predicted to be fundamental time scale of human consciousness [26]. A more refined guess is that $\tau_p = \sqrt{p}\tau$ gives the dependence of the duration of quantum jump on p-adic prime p. By multi-p-fractality predicted by TGD and explaining p-adic length scale hypothesis, one expects that at least $p = 2$-adic level is also always present. For the higher levels of dark matter hierarchy τ_p is scaled up by $\hbar/\hbar_0$. One can understand evolutionary leaps as the emergence of higher levels at the level of individual organism making possible intentionality and memory in the time scale defined τ [29].

Higher levels of dark matter hierarchy provide a neat quantitative view about self hierarchy and its evolution. For instance, EEG time scales corresponds to $k = 4$ level of hierarchy and a time scale of .1 seconds [16], and EEG frequencies correspond at this level dark photon energies above the thermal threshold so that thermal noise is not a problem anymore. Various levels of dark matter hierarchy would naturally correspond to higher levels in the hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in question.

The level would determine also the time span of long term memories as discussed in [22]. $k = 7$ would correspond to a duration of moment of conscious of order human lifetime which suggests that $k = 7$ corresponds to the highest dark matter level relevant to our consciousness whereas higher levels would in general correspond to transpersonal consciousness. $k = 5$ would correspond to time scale of short term memories measured in minutes and $k = 6$ to a time scale of memories measured in days.

The emergence of these levels must have meant evolutionary leap since long term memory is also accompanied by ability to anticipate future in the same time scale. This picture would suggest that the basic difference between us and our cousins is not at the level of genome as it is usually understood but at the level of the hierarchy of magnetic bodies [29, 22]. In fact, higher levels of dark matter hierarchy motivate the introduction of the notions of super-genome and hyper-genome. The genomes of entire organ can join to form super-genome expressing genes coherently. Hyper-genomes would result from the fusion of genomes of different organisms and collective levels of consciousness would express themselves via hyper-genome and make possible social rules and moral.

1.4   Bird's eye of view about the topics of the book

This book tries to give an overall view about TGD inspired theory of consciousness as it stands now. In nutshell TGD based view about consciousness relies following ideas and concepts.

1. The basic notions TGD inspired theory of consciousness are quantum jump identified as a moment of consciousness, self identified as sequence of quantum jumps analogous to bound state of particles, self hierarchy with sub-selves experienced by self as mental images, and sharing and fusion of mental images by quantum entanglement.

2. Dark matter hierarchy, the levels of which are labeled by increasing quantized value of Planck constant, suggests that the geometric durations for the moments of consciousness form defined as the scale of the space-time volume from which conscious experience is about, form an increasing hierarchy so that the highest level associated with a given self would correspond to single moment of consciousness. This would actually eliminate the notion of self and self hierarchy would correspond to a fractal hierarchy of quantum jumps.

3. The anatomy of quantum jumps must be consistent with the notions of state preparation, state function reduction, and unitary evolution and this leads to a detailed view what quantum jump means for quantum states of the Universe identified as classical spinor fields in configuration space, the "world of classical worlds". The zero modes of the configuration space geometry which do not contribute to its metric and thus do not quantum fluctuate, correspond to classical observables. A direct connection with quantum measurement theory emerges.

4. Negentropy Maximization Principle (NMP) defines the basic variational principle of TGD inspired theory of consciousness. NMP states that the negentropy gain in quantum jump is maximal. The allowance of a number theoretic variant of Shannon entropy making sense for rational or algebraic entanglement probabilities implies that quantum jump can also generate or increase the amount of entanglement. A possible interpretation is in terms of bound state entanglement to which conscious information can be assigned.

5. A natural characterization of the fundamental qualia is in terms of quantum number increments associated with the quantum jump. The classical non-determinism of Kähler action (in the usual sense of the world) means that the contents of the conscious experience of a given self comes from a 4-dimensional space-time region rather than representing 3-D snapshot of space-time. This together with the new view about energy and time (negative energies and communications to the geometric past are predicted) leads to a new vision about memory, intentional action, and also metabolism.

6. p-Adic physics as physics of cognition and intentionality is a genuinely new element as compared to the existing theories of consciousness and forces to give up the view that cognition is localized in the sense of real physics. Indeed, p-adic space-time sheets representing intentions have literally infinite size since most p-adic integers, in particular those which are infinitesimally small, have infinitely large as real numbers. Cognition would quite literally see the real cosmos from outside. The transformations of p-adic space-time sheets to real ones in quantum jump define an attractive view about what happens when intention transforms to an action and is consistent with TGD based view about energy (also negative inertial energies are possible and the density of inertial energy vanishes in cosmological length scales). The discrete rational projection of p-adic space-time sheets to the real imbedding space is excellent candidate for the realization of cognitive representations at the level of space-time since p-adic numbers define very naturally a generalization of binary logic and for primes satisfying p-adic length scale hypothesis the resulting logic has also Boolean interpretation as a logic in which certain number of statements are taboos so that the number of allowed statements is reduced from 2^k to $p = 2^k - n$.

7. The new view about the relationship between experienced and geometric time inspires a general model of memory, intentional action, and metabolism. In this model time mirror mechanism meaning communications with geometric past using negative energy (phase conjugate photons) is in central role. Also time-like entanglement plays a key role in the model of memories. A precise conceptualization for this vision is provided by zero energy ontology in which M-matrix generalizes S-matrix. M-matrix is identifiable as the "square" root of density matrix defines time like entanglement coefficients between positive and negative energy parts of the zero energy state located at past and future boundaries of the causal diamond defined by the intersection of future and past directed light-cones.

The topics of the book are organized in the following manner.

1. In the first part of the book TGD inspired theory of consciousness is discussed at general level. There are three summarizing chapters give a view about how ideas have evolved. Besides this there are chapters devoted to Negentropy Maximization Principle, to a detailed exposition of the notion of self, and to a model of sensory representations.

2. The second part of the book contains two chapters about the relationship between experienced and geometric time. The first one is more than decade old. The second one - inspired by zero energy ontology and written quite recently - provides a rather detailed vision about how the arrow of geometric time correlating with the arrow of experienced time and the localization of the contents of sensory experience to a narrow time interval emerge. The chapter explaining TGD based view about long term memory is also included.

3. The third part of the book summarizes roughly decade old view about intelligence and cognition. p-Adic physics as physics of cognition and intentionality and many-fermion states as representations of Boolean statements are the key notions. In zero energy ontology also quantal versions of logical rules $A \to B$ realized as quantum variants of Boolean functions emerge at the fundamental level. A chapter about the role of dark matter hierarchy, in particular about topological quantum computation as a universal information processing tool, would be needed to make the picture more complete.

4. The fourth chapter is devoted to remote mental interactions. The theoretical motivation for taking remote mental interactions seriously is that exactly the same mechanisms which are involved with the interaction between magnetic body and biological body apply also to remote mental interactions in TGD Universe. One could also understand why these phenomena are rare: a kind of immune system making it impossible for foreign magnetic bodies to control and communicate with the biological body possessed by a particular magnetic body would be a highly probable (but perhaps not unavoidable) outcome of evolutionary process.

The seven online books about TGD [1, 2, 3, 5, 4, 6, 7] and eight online books about TGD inspired theory of consciousness and quantum biology [8, 9, 10, 11, 12, 13, 14] are warmly recommended for the reader willing to get overall view about what is involved.

1.5 The contents of the book

1.5.1 PART I: BASIC IDEAS OF TGD INSPIRED THEORY OF CON-SCIOUSNESS

TGD Inspired Quantum Theory of Consciousness and of Bio-systems: an Overall View

The purpose of this chapter is to represent a bird eye's of view about the basic ideas of TGD inspired consciousness and its applications to living matter. The notion of many-sheeted space-time, dark matter hierarchy with levels by the values of dynamical quantized Planck constant, and the resulting basic vision about bio-systems as macroscopic quantum systems are summarized. The basic ideas and concepts of TGD inspired theory of consciousness are reviewed. Discussed are also the recent views about how local p-adic physics codes for the long range correlations of the real physics as p-adic fractality and how p-adic space-time sheets provide correlates for cognition and intentionality.

Matter, Mind, Quantum

This chapter is devoted to the TGD inspired theory of consciousness, which can be also regarded as a generalization of quantum measurement theory. TGD inspired theory of consciousness could be seen as a generalization of quantum measurement theory to make observer, which in standard quantum measurement theory remains an outsider, a genuine part of physical system subject to laws of quantum physics. The basic notions are quantum jump identified as moment of consciousness and the notion of self: in zero energy ontology these notions might however reduce to each other. Negentropy Maximization Principle defines the dynamics of consciousness and as a special case reproduces standard quantum measurement theory.

1. Quantum jump as moment of consciousness

TGD suggests that the quantum jump between quantum histories could identified as moment of consciousness and could therefore be for consciousness theory what elementary particle is for physics.

This means that subjective time evolution corresponds to the sequence of quantum jumps $\Psi_i \to U\Psi_i \to \Psi_f$ consisting of unitary process followed by state function process. Originally U was thought to be the TGD counterpart of the unitary time evolution operator $U(-t,t)$, $t \to \infty$, associated with the scattering solutions of Schrödinger equation. It seems however impossible to assign any real Srödinger time evolution with U. In zero energy ontology U defines a unitary matrix between zero energy states and is naturally assignable to intentional actions whereas the ordinary S-matrix telling what happens in particle physics experiment (for instance) generalizes to M-matrix defining time-like entanglement between positive and negative energy parts of zero energy states. One might say that U process corresponds to a fundamental act of creation creating a quantum superposition of possibilities and the remaining steps generalizing state function reduction process select between them.

2. Negentropy Maximization Principle and the notion of self

U-process is followed by a sequence of state function reductions. Negentropy Maximization Principle (NMP) states that in a given quantum state the most quantum entangled subsystem-complement pair can perform the quantum jump. More precisely: the reduction of the entanglement entropy in the quantum jump is as large as possible. This selects the pair in question and in case of ordinary entanglement entropy leads the selected pair to a product state. The interpretation of the reduction of the entanglement entropy as conscious information gain makes sense. The sequence of state function reductions decomposes at first step the entire system to two parts in such a manner that the reduction entanglement entropy is maximal. This process repeats itself for subsystems. If the subsystem in question cannot be divided into a pair of entangled free system the process stops since energy conservation does not allow it to occur (binding energy).

The original definition of self was as a subsystem able to remain unentangled under state function reductions associated with subsequent quantum jumps. Everything is consciousness but consciousness can be lost if self develops bound state entanglement during U process so that state function reduction to smaller un-entangled pieces is impossible.

The existence of number theoretical entanglement entropies in the intersection of real and various p-adic worlds force to modify this picture. The reduction process can stop also if the self in question allows only decompositions to pairs systems with negentropic entanglement. This does not require

that that the system forms a bound state for any pair of subsystems so that the systems decomposing it can be free (no binding energy). This defines a new kind of bound state not describable as a jail defined by the bottom of a potential well. Subsystems are free but remain correlated by negentropic entanglement.

The ordinary state function reductions imply dissipation crucial for self organization and quantum jump could be regarded as the basic step of an iteration like process leading to the asympotic self-organization patterns. One could regard dissipation as a Darwinian selector as in standard theories of self-organization. NMP thus predicts that self organization and hence presumably also fractalization can occur inside selves. NMP would favor the generation of negentropic entanglement. This notion is highly attractive since it could allow to understand how quantum selforganization generates larger coherent structures. Note that state function reduction for negentropic entanglement is highly deterministic since the number of degenerate states with same negative entanglement entropy is expected to be small. This could allow to understand how living matter is able to develop almost deterministic cellular automaton like behaviors.

The chapter is devoted to the discussion of detailed implications of these general ideas. The topics to be discussed include following basic questions.

1. How the general structure for the contents of consciousness of self are determined? The basic assumption is that self hierarchy in which subselves define mental images of self is responsible for the general structure of conscious experience. Zero energy ontology allows to derive the space-time correlates of selves.

2. How the physical realization of the hardware of consciousness differs from that assumed in neuroscience? Here the notion of magnetic body as intentional agent using biological body as motor instrument and sensory receptor is central.

3. What is the precise relationship between the geometric time of physicist and subjective time identified in terms of a sequence of quantum jumps? Zero energy ontology gives the most convincing answer to this question found hitherto.

4. What can one one say about various types of conscious experience in the proposed framework. This includes p-adic description of cognition and intentional action, model for sensory experience and sensory qualia, model for Boolean mind in terms of fermions, a model for directed attention, ideas about emotions, and also a general interpretation for altered states of consciousness based on the special features of negentgropic entanglement.

5. Can one provide solutions to the paradoxes of quantum physics, theories of consciousness, and logic in the proposed conceptual framework?

The discussion differs considerably from the earlier one. The reason is that the developments occurred during period 2005-2010 (zero energy ontology, hierarchy of Planck constants assigned to dark matter, hyper-finite factors of type II_1, implications of the number theoretical negentropies) are introduced from the beginning to the formulation of the theory rather than as additions to the existing text so that the representation is more coherent and the number of internal inconsistencies is minimized.

Negentropy Maximization Principle

In TGD Universe the moments of consciousness are associated with quantum jumps between quantum histories. The proposal is that the dynamics of consciousness is governed by Negentropy Maximization Principle, which states the information content of conscious experience is maximal. The formulation of NMP is the basic topic of this chapter.

Negentropy Maximization Principle (NMP) codes for the dynamics of standard state function reduction and states that the state function reduction process following U-process gives rise to a maximal reduction of entanglement entropy at each step. In the generic case this implies at each step a decomposition of the system to unique unentangled subsystems and the process repeats itself for these subsystems. The process stops when the resulting subsystem cannot be decomposed to a pair of free systems since energy conservation makes the reduction of entanglement kinematically impossible

in the case of bound states. The natural assumption is that self loses consciousness when it entangles via bound state entanglement.

There is an important exception to this vision based on ordinary Shannon entropy. There exists an infinite hierarchy of number theoretical entropies making sense for rational or even algebraic entanglement probabilities. In this case the entanglement negentropy can be negative so that NMP favors the generation of negentropic entanglement, which need not be bound state entanglement in standard sense. Negentropic entanglement might serve as a correlate for emotions like love and experience of understanding. The reduction of ordinary entanglement entropy to random final state implies second law at the level of ensemble. For the generation of negentropic entanglement the outcome of the reduction is not random: the prediction is that second law is not a universal truth holding true in all scales. Since number theoretic entropies are natural in the intersection of real and p-adic worlds, this suggests that life resides in this intersection. The existence effectively bound states with no binding energy might have important implications for the understanding the stability of basic bio-polymers and the key aspects of metabolism. A natural assumption is that self experiences expansion of consciousness as it entangles in this manner. Quite generally, an infinite self hierarchy with the entire Universe at the top is predicted.

The identification of life as a number theoretically critical phenomenon is also consistent with the idea that the transformation of intention to action corresponds to a U-process inducing leakage between different sectors. This leakage makes sense in the intersection where same mathematical expression defines both real and p-adic partonic 2-surfaces which are the fundamental objects in TGD framework. What these statements really mean requires a construction of number theoretical variant of quantum theory applying in the intersection of real and p-adic worlds.

Besides number theoretic negentropies there are also other new elements as compared to the earlier formulation of NMP. Zero energy ontology modifies dramatically the formulation of NMP since U-matrix acts between zero energy states and can be regarded as a collection of M-matrices, which generalize the ordinary S-matrix and define what might be called a complex square root of density matrix so that kind of a square root of thermodynamics at single particle level justifying also p-adic mass calculations based on p-adic thermodynamics is in question. The hierarchy of Planck constants is a further new element having important implications for conciousness and biology. Hyper-finite factors of type II_1 represent an additional technical complication requiring separate treatment of NMP taking into account finite measurement resolution realized in terms of inclusions of these factors.

NMP has important implications for thermodynamics. In particular, one must give up the standard view about second law and replace it with a formulation taking into accoung the hierarchy of causal diamonds assigned with zero energy ontology and dark matter hierarchy labeled partially by the values of Planck constants, as well as the effects due to negentropic entanglement. In particular, in the case of living matter breaking of second law in standard sense is expected to take place and be crucial for the understanding of evolution. Self hierarchy having the hierarchy of causal diamonds as imbedding space correlate leads naturally to a thermodynamical description of the contents of consciousness and quantum jumps is very much analogous to quantum computation. This leads to a vision about the role of bound state entanglement and negentropic entanglement in the generation of sensory qualia. Negentropic entanglement leads to a vision about cognition. Negentropically entangled state consisting of a superposition of pairs can be interpreted as a conscious abstraction or rule: negentropically entangled Schrödinger cat knows that it is better to keep the bottle closed. A connection with fuzzy qubits and quantum groups with negentropic entanglement is highly suggestive. The implications are highly non-trivial also for quantum computation, which allows three different variants in TGD context. The negentropic variant would correspond to conscious quantum computation like process.

Self and Binding

The quantum notion of self solved some longstanding problems of TGD inspired theory of consciousness and led to a breakthrough in quantum theory of consciousness. Self is identified as a sub-system able to not generate bound state entanglement during quantum jumps. Generation of bound state entanglement leads to a loss of consciousness whereas negentropic entanglement possible in the intersection of real and p-adic worlds involves experience about expansion of consciousness.

With the advent of the hierarchy of Planck constants realized in terms of generalized imbedding space and of zero energy ontology emerged the idea that self hierarchy could be reduced to a fractal hierarchy of quantum jumps within quantum jumps. It seems now clear that the two definitions of

self are consistent with each other. The identification of the imedding space correlate of self as causal diamond (CD) of the imbedding space combined with the identification of space-time correlates as space-time sheets inside CD solved also the problems concerning the relationship between geometric and subjective time.

Subjective memory is assumed to correspond to an average of conscious experiences of quantum jumps occurred after the last wake-up of self. This leads to the identification of qualia as averages of the increments of quantum numbers and zero modes in the ensemble of quantum jumps defining self. Summation hypothesis states that self X experiences the experiences of its subselves as abstracted experiences, averages X_{ij} about sub-subselves X_{ij}. Subselves of un-entangled selves can entangle (this is due to the many-sheeted sub-system concept) and this allows fusion and sharing of mental images.

Quantum entanglement provides a mechanism leading to the formation of irreducible wholes at the level of mental images. Entanglement can be entropic bound state entanglement or negentropic entanglement, which need not involve binding energy. The latter is possible only in the intersection of real and p-adic worlds where life can be said to reside. Quantum entanglement is possible also in time direction in zero energy ontology. It is tempting to assign negatively colored emotions to the entropic entanglement and positive emotions to the negentropic one. In TGD framework the standard vision about brain based on reductionistic-holistic dichotomy must be replaced with a trinity in which negentropic entanglement corresponds to a mode of cognition, which does not allow linguistic expression and episodal memories, and various mental feats of synesthetes and idiot savants could be seen as a manifestation of negentropic entanglement. Also meditative consciousness would be negentropic.

Selves are called irreducible if they possess no subselves, otherwise reducible. Subselves correspond to mental images so that irreducible subselves possess no mental images and are in a state of pure self-awareness: it is not clear whether this kind of states are possible in practice. When the subselves of self fuse to single negentropic subself, a state of "one-ness" results in somewhat different sense. This mode of consciousness can be identified as "whole-body" consciousness and differs from ordinary consciousness during which self has large number of mental images. These modes could naturally explain emotional/holistic and rational modes of mind. These two modes could make it possible to understand various dichotomies like brain/left brain, emotional/analytic, religous/rational, Eastern/Western,... One could understand linear cognitive processes like thinking and language as self cascades in which self decomposes into subselves, which in turn decompose into subselves, which ... and self hierarchy implies connection with computationalism.

The possibility of negentropic entanglement has profound implications. It leads to a vision about learning as a basic quantum process possible in the intersection of real and p-adic worlds and made possible because state function reduction ceases to be a random process for negentropically entangled zero energy states. Quite concrete ideas about the role of synaptic transmission and neural transmitters for consciousness emerge. Music experience provides an especially interesting application for the vision about consciousness and zero energy ontology together with number theoretical vision inspires several concrete interpretations. Synchronous firing of neurons- in particular at 40 Hz frequency- is an attractive correlate for the negentropic entanglement and synesthesia can be interpreted as a particular manifestatios of negentropic entanglement.

In TGD framework it is not at all obvious that the highest levels of our personal self hierarchy should correspond to the size of the physical body. Various empirical facts, in particular the observations related to the special effects of excitations of geomagnetic fields and ELF em fields in EEG frequency range on brain, inspire the hypothesis that our selves correspond to topological field quanta of em fields associated with EEG frequencies and thus by Uncertainty Principle have size scale of Earth. This leads to a rather radical modification of the brain centered views about consciousness, and one can quite seriously consider the questions like what physical death means from the point of view of consciousness: it could be that electromagnetic part of self hierarchy could survive after the physical death as a 'soul'.

Quantum Model for Sensory Representations

One of the toughest challenges of quantum theories of consciousness is to understand how sensory representations are constructed at quantum level. It became as a surprise that the vision about sensory representation which resulted from a long lasting thought experimentation is actually very much what the original experience about myself as a computer sitting at its own terminal, when taken

very literally in some aspects, actually suggests. This vision adds to the standard view about brain an additional layer responsible for the sensory representations and brings in the quantum level of control so that nerve pulse patterns are only part of the control loop. In fact, it has turned out that the same basic theory applies to both geometric memories, precognition, sensory perception, and motor actions. The vision goes as follows.

1. As far as our consciousness is considered, primary sensory organs are the seats of sensory qualia and brain only constructs cognitive and symbolic representations. Various objections against this hypothesis can be circumvented by assuming that sensory organs entangle with the brain. The question how imagination differs from the sensory experience becomes trivial, and dreams and hallucinations can be understood as resulting via the back-projection of the imagined mental images to the primary sensory organs.

2. Libet's findings about passive aspects of consciousness lead to the view that sensory percept can be regarded as a geometric memory in time scale of .5 seconds involving entanglement with the geometric past mediated by negative energy MEs. Libet's experiments about the active aspects of consciousness in turn lead to realization that motor actions and sensory perceptions are in a well-defined sense time-reversals of each other: pre-cognition is a definite aspect of motor action. One can say that motor action at the level of negative energy MEs is initiated from the level of muscles rather than brain and motor imagination is just a motor action starting from some level higher than muscles. The transformation of a p-adic ME to negative energy ME realizes the transformation of intention to action in a precisely targeted manner and the emission of negative energy makes possible extreme flexibility by buy now-let others pay mechanism of remote metabolism. This process is the basic step initiating motor action, neural activity leading to imagery, and active memory recall. This picture also explains why geometric memories occur more or less spontaneously whereas precognition is a rare phenomenon (pre-cognizer must *receive* negative energy MEs).

3. In TGD framework one can assign to any material structure a magnetic body having much large size. The closed flux loops composing magnetic bodies allow an elegant realization of the long term memories in terms of negative and positive energy MEs. A stronger hypothesis is that various magnetic bodies define sensory canvases at which various sensory representations are realized. Motor action can be seen as a geometric time reversal of sensory perception. Cortex can be seen as a collection of pre-existing symbolic and cognitive features possibly entangled with sensory mental images at sensory organs, and activated when they appear in the perceptive field or form a part of motor action. The basic task of the central nervous system is to identify these features from the sensory input. The mental images associated with various parts of the physical body are entangled with the points of the correspondin magnetic bodies representing objects of the perceptive field by sharing of mental images and in this manner define attributes of these objects. There is an entire hierarchy of representations corresponding to the hierarchy of magnetic bodies, and also sensory perception involves active selections by entangling a sequences of mental images defining paths along the tree-like structure defined by the hierarchy of magnetic bodies beginning from the personal magnetic body and ending at the roots defined by magnetic bodies of sensory organs. This explains phenomena like sensory rivalry.

4. The decomposition of the perceptive field to objects is one of the basic aspects of sensory experiencing and TGD provides a mechanism generating these objects as space-time sheets: the boundaries of these objects correspond to regions of strong Kähler electric field whose strength is assumed to correlate with the intensity of the neural input. It might be that even the objects of perceptive field or thoughts could be regarded as features. In zero energy ontology causal diamonds become the imbedding space correlates of mental images and one can ask whether Negentropy Maximization Principle -perhaps suitably generalized- could force their generation.

5. The computational activities associated with the construction of the sensory representations (say estimating distances and directions of the objects of perceptive field) and virtual sensory representations representing the goals of motor action are presumably realized as iterated processes in which virtual sensory inputs characterizing the expected experiences are compared with the real world sensory input. In a similar manner the goal of the motor action is compared with the

sensory representation resulting from effect of a virtual motor action on the representation of the recent state of world and body. This comparison does not necessarily require sensory representation at any level of the self hierarchy and could be based on comparison circuits defined by parallel supra currents in which the inputs which are sufficiently near to each other generate constructive interference giving rise to a large Josephson current.

6. Zero energy ontology together with the notion of causal diamond (CD) identified as imbedding space correlate of self and the moduli space of CDs, the description of dark matter in terms of a hierarchy of Planck constants implying a generalization of the notion of the imbedding space, and the vision about living matter as something residing in the intersection of real and p-adic worlds and carrying positive entanglement negentropy allow to make this vision more detailed and lead to surprisingly precise quantitative predictions and connect the basic biological time scales to those assignable to elementary particles in zero energy ontology. The notion of spectroscopy of consciousness can be formulated for the geometric aspects of conscious experience in terms of the moduli space of causal diamonds and the frequencies of the generalized EEG.

1.5.2 PART II: TIME AND CONSCIOUSNESS

Time and Consciousness

In moments of consciousness as quantum jumps between quantum histories picture the basic challenge is to explain how psychological time arises: why the contents of at least sensory experiences are concentrated around a definite value of geometric time and what is the origin of the arrow of psychological time. It has become gradually clear that TGD cannot reproduce the common sense conception of time and that one can only require that the generalized view is consistent with our restricted conscious experiences and shows our position in the hierarchy of consciousness.

The understanding of the notion of psychological time and its arrow - or equivalently, the relationship between subjective and geometric time - turned out to be quite difficult challenge and led to a handful of proposals based on the identification of space-time sheet as a correlate of self and the idea that the experienced flow of geometric correspond to some kind of motion in space-time or in imbedding space. These identifications did not lead to anything practical and generated paradoxes.

The most recent proposal involves no ad hoc assumptions and relies on the formulation of quantum TGD using zero energy ontology. The correlate of self is now so called causal diamond (pair of future and past directed light-cones) which is 8-D sub-manifold of the imbedding space rather than space-time sheet. The flow of geometric time is apparent and due the change of quantum state in quantum jump which in the first approximation means a shift of the quantum superposition of space-time surfaces to the direction of the geometric past of the imbedding space. This proposal allows to understand the asymmetry between geometric future and past at the level of conscious experience and makes also precise quantitative predictions. Also a unification of the definition of self identifying it as a sequence of quantum jumps and of the definition based on the reduction of self hierarchy to a fractal hierarchy of quantum jumps within quantum jumps becomes possible.

The concept of self led to the understanding of the subjective memory as an average over experiences of self experienced after its "wake-up". Subjective memories are always about past. Geometric memories are predictions for the future/past assuming that no quantum jumps would occur after/had occurred before the one giving rise to the geometric memory. Pre-cognitions can be seen as geometric memories about future. Intentions are p-adic variants of precognitions. It seems that long term memories must correspond to geometric memories: this hypothesis, when combined with the spin glass model of brain, the notion of quantum self-organization, and some key aspects of many-sheeted physics, allows to understand the basic aspects of the long term memory and avoids the basic difficulties of the neural net models.

"Ontogeny recapitulates phylogeny" principle suggests that the structure of the many-sheeted space-time represents the structure of the cosmology of consciousness. This heuristic principle together with the concept of self, the hypothesis that also infinite primes are present in the topological condensate and association sequence concept, leads to a Grand Scenario for the cosmology of consciousness. There is no need to assume that different irreducible sub-experiences associated with given moment of consciousness correspond to a common value of the psychological time. Most naturally, the values of psychological time extending from zero to strictly infinite values of time and beyond(!)

are present. This means that cosmology of consciousness has fractal like structure: there are sub-cosmologies which know nothing about each other's existence except in quantum jumps involving entanglement with larger space-time sheets: in this case the conscious experience could be regarded as a religious or mystic experience. Both future and past civilizations participate in each quantum jump. The allowance of infinite primes suggested strongly by various arguments, means that conscious intelligences which are God like as compared to us, participate in each quantum jump.

An especially important general consequence is the paradigm of 4-dimensional brain.

1. This paradigm trivializes the problem of long term memory. The desire to remember would be quantum communicated from the geometric now to the geometric past by sharing of mental images made possible by time-like quantum entanglement of sub-selves. In the case of episodal memories the sharing of mental images gives already rise to the memory. For non-episodal memories the memory is communicated classically to the geometric future. An essential element of the mechanism are negative energy MEs ("massless extremals") which are ideal for generating time-like quantum entanglement with the geometric past. Positive energy MEs are in turn involved with classical communications.

2. Second consequence is a model of cognition relying on the concept of cognitive neutrino pair: cognitive neutrino pair has almost vanishing total energy and consists of neutrino and antineu-trino residing at different space-time sheets. The cornerstone of the model is the negative energy of the condensed matter neutrinos deriving from the classical Z^0 interaction with nuclear Z^0 charges. Thus one can say that TGD predicts that $k = 169$ space-time sheet ($L(169) \simeq 5$ microns) is the length scale in which cognitive consciousness emerges.

Quantum jumps between quantum histories concept explains the peculiar time delays of consciousness revealed in the experiments relating to active and passive roles of consciousness and the causal anomalies revealed by the experiments of Radin and Bierman. TGD predicts "tribar effect" as a general signature for the quantum jump between quantum histories concept.

Quantum Model of Memory

The neural realization of long term memories has remained to a high extent a mystery in the framework of the standard brain science. The TGD based quantum model for memory have developed gradually from the basic realization that in TGD framework the identification of quantum states as quantum histories makes it un-necessary to store information about the geometric past to the geometric now. The process was not by no means a mechanical deduction of the consequences of some basic postulates. For instance, the understanding of the relationship between geometric and subjective time developed through several erratic models and only a formulation of quantum TGD led to a quantitative formulation.

The new view about time has deep implications concerning the understanding of memory.

a) It is possible to separate genuine geometric memory recall from apparent memory recalls such as feature recognition, associations, and implicit and procedural memories. There are no memory storages in brain and only memory representations abstracting the essential aspects of experience are needed.

b) The models of long term memory based on the assumption that information about the geometric past is stored in the recent state of the system predict that the new memories should mask the old ones. It is however known that childhood memories are the stablest ones. In TGD framework this ceases to be a problem.

Mirror mechanism provides a very general mechanism of long term memory. To remember something at a temporal distance T in the geometric past is to look at a mirror at a distance $cT/2$. If the mirror is quantum mirror only a timelike entanglement (allowed by the non-determinism of Kähler action) of the mental image of the geometric past with a mental image in brain now is needed. The un-necessity to communicate memories classically implies extreme generality of the mechanism: all kinds of memories: sensory, cognitive, verbal,.... can be recalled in this manner. Even the mechanism of memory recall by cue can be generalized since the notion of tele association makes in principle sense.

The basic objections against this over-simplified picture is that there is no guarantee that the reflected ME returns to the brain and that there is no control over the time span of long term memories.

The notion of magnetic body allows a more realistic formulation. Brain or the personal magnetic body generates spontaneously negative energy MEs with all fundamental frequencies. These MEs can be also curved and are parallel to the closed flux tubes defining the personal magnetic body and connect geometric now with the brain of the geometric past: multiple reflections are probably required to achieve this. The length of the closed magnetic loop defines the time span of the corresponding long term memory. The sharing of mental images by timelike entanglement allows to communicate the desire to remember to the geometric past, and gives rise to the memory recall in the case of episodal memories. In the case of non-episodal/declarative memories the memory is communicated from the brain of the geometric past by classical communications using positive positive energy MEs which propagate with an effective phase velocity much lower than light velocity along closed magnetic flux tubes and generate in the receiving end symbolic representation of the memory.

Macro-temporal quantum coherence is further important piece of the model. The understanding of how macro-temporal quantum coherence is made possible by the spin glass degeneracy led to a concrete realization of the mirror model and also provided a connection with the ideas of Hameroff and Penrose. When a bound state is formed the zero modes of the bound state entangled subsystems become quantum fluctuating degrees of freedom. This means that state function reduction and state preparation cease to occur in these degrees of freedom. The bound state is in a kind of long-lasting multiverse state, or state of 'oneness' experientially, and the sequence of quantum jumps defined by the duration of the bound state behaves effectively as a single quantum jump. Macro-temporal quantum coherence making possible supercomputer like activities becomes possible.

The spin glass degeneracy associated with the join along boundaries bonds (the space-time correlates for the bound state formation) lengthens the lifetimes of the bound states dramatically and solves thus the basic objections against quantum consciousness. The spin glass degeneracy is due to classical gravitational energy of the system. The quantum jumps between different classical gravitational configurations involve the emission of gravitational (equivalently Z^0) MEs and the intention to remember is realized as a transformation of p-adic ME to negative energy gravitational ME. The fact that classical gravitational fields couple to classical gauge fields with a coupling which is about 10^8 stronger than the ordinary gravitational coupling, could play an important role too. Water clusters and macromolecules with sizes in the range of cell membrane thickness and cell size are good candidates for generating gravitonic MEs responsible for all geometric memories. Also classical Z^0 interaction might be involved since gravitonic MEs can be regarded also as Z^0 MEs.

This picture was not yet quite enough. A generalization of quantum theory based on the introduction of a hierarchy of Planck constants realized in terms of generalization of the concept of imbedding space motivated by anomalies of astrophysics and biology led to a quantitative model for how macroscopic and macro-temporal quantum coherence could be realized in living matter. Also a quantitative view about memory emerges. A rather detailed neuro level model of long term memory is developed and the model conforms nicely with the basic facts known about the relationship of hippocampus and long term memory.

About the Nature of Time

The identification of the experienced time t_e and geometric time t_g involves well-known problems. Physicist is troubled by the reversibility of t_g contra irreversibility of t_e, by the conflict between determinism of Schrödinger equation and the non-determinism of state function reduction, and by the poorly understood the origin of the arrow of t_g. In biology the second law of thermodynamics might be violated in its standard form for short time intervals. Neuroscientist knows that the moment of sensory experience has a finite duration, does not understand what memories really are, and is bothered by the Libet's puzzling finding that neural activity seems to precede conscious decision. These problems are discussed in the framework of Topological Geometrodynamics (TGD) and TGD inspired theory of consciousness constructed as a generalization of quantum measurement theory. In TGD space-times are regarded as 4-dimensional surfaces of 8-dimensional space-time $H = M^4 \times CP_2$ and obey classical field equations. The basic notions of consciousness theory are quantum jump and self. Subjective time is identified as a sequence of quantum jumps. Self has as a geometric correlate a fixed volume of H- "causal diamond"-defining the perceptive field of self. Quantum states are regarded as quantum superpositions of space-time surfaces of H and by quantum classical correspondence assumed to shift towards the geometric past of H quantum jump by quantum jump. This creates the illusion that perceiver moves to the direction of the geometric future. Self is curious about the geometric future

and induces the shift bringing it to its perceptive field. Macroscopic quantum coherence and the identification of space-times as surfaces in H play a crucial role in this picture allowing to understand also other problematic aspects in the relationship between experienced and geometric time.

1.5.3 PART III: INTELLIGENCE, INFORMATION, AND COGNITION

Conscious Information and Intelligence

The notions of information and intelligence are discussed in TGD framework. Possible definitions for the information measures of the configuration space spinor field and information gain of conscious experience as well as the information theoretic interpretation of Kähler action are discussed in detail the first sections of the chapter.

1. The key element of the approach is the number theoretic generalization of entanglement entropy. Quantum entanglement between real and p-adic degrees of freedom makes sense if entanglement coefficients are rational or even algebraic numbers. In this case one can define entanglement entropy using the p-adic variant of the logarithm. p-Adic entropy can be also negative, and the states for which the entropy is negative are stable against self measurements (NMP) and define macrotemporally quantum coherent states. The number-theoretic entropy serves as an information measure for cognitive entanglement, and positive entanglement negentropy can be interpreted as a correlate for the experience of understanding. Number theoretic entanglement measures are natural in what might be called the intersection of real and p-adic worlds (partonic 2-surfaces have mathematical representations making sense both p-adically and in real sense) and this leads to a vision about life as something residing in this intersection.

2. Various measures for the information contents of consciousness are discussed.

   (a) The reduction of entanglement entropy defines a natural measure for conscious information gain in single step of the state of state function reduction process decomposing subsystem to a pair of un-entangled sub-systems. If entanglement is negentropic the entanglement negentropy either increases or the system is stable against state function reduction.

   (b) It seems natural to assume that the information measures are associated with the entire cascade and that they are additive in the sense that information gain is sum over the information gains of the steps of the cascade and that a given step contributes by the sum of the information gains associated with unentangled subsystems which are subject to self measurement in a given step of the cascade.

   (c) One can also assign information measures to the resulting indecomposable systems. For subsystem which is bound state in the normal sense and thus has entropic entanglement, one can consider all possible decomposition of the system to a sub-system and its complement and define the entanglement negentropy as the negative for the minimum value of entropy obtained in this manner. If the system is negentropically entangled one can define entanglement negentropy as the maximum of entanglement negentropy obtained in this manner. This means that one can assign to the final state of state function reduction unique negentropy as the sum of the negative contributions associated with selves which are internally bound state entangled and positive contributions of negentropic selves.

   (d) The information content of the conscious experience associated with self is more interesting practically. Since self defines a statistical ensemble, it is straightforward to define entropies associated with the increments of quantum numbers and zero modes defining non-geometric and geometric qualia. These entropies characterize the fuzziness of the quale and are 'negative' information measures. One can also assign to non-decomposable subselves the information measures and they give either positive or negative contribution to the information content of self.

   (e) In principle this allows to define also the net information gain of quantum jump as the difference of the total negentropies of the final and initial states of quantum jump identified as those produced by the state function reduction process. Initial and final state negentropies would characterize spinor fields of WCW ("world of classical worlds").

3. Information theoretic interpretation of the Kähler function is discussed in detail. Quantum classical correspondence suggests that the magnetic part of Kähler action would correspond to information content of negentropic entanglement and electric part to the negative information content of entropic bound state entanglement. Kähler functiond defined as the negative of the Kähler action can be interpreted as an entropy type measure for the information content of the space-time surface. Without quantum criticality entropic configurations carrying strong Kähler electric fields would be favored. The proposal is that the quantum criticality of Kähler action possible for the critical value of Kähler coupling strength makes possible large degeneracy of the negentropic extremals carrying large Kähler magnetic action and makes TGD universe maximally interesting and maximizes its intelligence so that even infinite negentropy is possible. Number theoretical criticality would relate to this criticality very closely. The proposal that living matter is near vacuum extremal so that the degeneracy of negentropic configurations is high is discussed.

Concerning the modelling of conscious intelligence the following aspects are important.

1. Zero energy states -which replace the earlier notion of association sequence inspired by the failure of strict determinism for Kähler action in standard sense - can be seen as memes with M-matrices characterizing the time-like entanglement representing "laws of physics". Negentropic time like entanglement makes possible for fully state function reduced states to represent rules as quantum superposition of state pairs representing instances a→b for a general rule A→B. Also space-like negentropic quantum entanglement is important piece of the story. For fermion Fock states this gives Boolean rules as a special case. Zero energy states represent geometric memories, simulations for time development whereas selves represent subjective memories and conscious experience involves always the comparison of geometric and subjective memories telling whether expectations were realized. Quantum theory of self-organization applies also to the evolution of consciousness understood as self-organization in the ensemble of association sequences/selves and implies Darwinian selection also at the level of selves and conscious experiences.

2. TGD Universe is quantum computer in a very general sense. Negentropic quantum entanglement stabilizes qubits but makes them fuzzy. This leads to a modification of the standard paradigm of quantum comptuation . Quantum computationalism is shown to reproduce the relevant aspects of computationalism and connectionism without reducing conscious brain to a deterministic machine. Holographic brain is also one of the dominating ideas of neuroscience. TGD based realization of memory allows to reduce hologram idea to its essentials: what matters is that piece of hologram is like a small window giving same information as larger window but in less accurate form. This inspires the concept of neuronal window: each neuron has small window to the perceptive landscape and is typically specialized to detect particular feature in the landscape. Coherent photons emitted by mindlike space-time sheets and propagating along axonal microtubules serving as wave guides, realize neuronal windows quantum physically. Massless extremals allow rather precise definition for the notion of quantum hologram.

   A more refined formulation of these ideas is based on the notion of conscious hologram. Many-sheeted space-time is essentially a fractal Feynmann diagram with lines thicknened to 4-surfaces. The lines are like wave guides carrying laser beams and vertices are like nodes where these laser beams interfere and generate the points of the hologram. The 3-dimensionality of the ordinary hologram generalizes to stereo consciousness resulting in the fusion of mental images associated with various nodes of the conscious hologram. An essential element is the possibility of negative energy space-time sheets analogous to the past directed lines of the Feynmann diagram: negative energy MEs are the crucial element of sensory perception, motor action, and memory.

3. An important element is effective four-dimensionality of brain making possible to understand long term memories, planning and motor activities in a completely new manner. Further important ideas are music metaphor already described and the vision about brain as an associative net. Zero energy ontology and the notion of CD (causal diamond) provides justification for the memetic code and relates it to fundamental elementary particles time scales. The codewords of the memetic code consist of sequences of 126 bits and are represented in terms of nerve pulse sequences or membrane oscillations and time varying quark magnetization, is the key essential element of brain as cognitive system. Codewords can be interpreted either as elements

of a Boolean algebra or as bits in the binary expansion of an integer in the range $(0, 2^{126})$ so that memetic code makes brain able to assign numbers with qualia. An attractive and testable identification for the memetic codewords is as phonemes of language.

p-Adic Physics as Physics of Cognition and Intention

TGD as a generalized number theory vision supports the interpretation of the p-adic physics in terms of physical correlates of cognition and intentionality so that matter-mind dichotomy would correspond to real–p-adic dichotomy at the level of the geometric correlates of mind. This interpretation has far reaching implications for both TGD inspired theory of consciousness and for the general world view provided by TGD. Cognition is predicted to be present in all length scales and the success of the p-adic physics in elementary particle length scales forces to conclude that cognition and intention are present even at this level.

The vision about life and conscious information and intelligence as something in the intersection of real and p-adic worlds is the key guiding principle also in TGD inspired quantum biology. The very fact that the notion of conscious information makes sense only in this intersection supports the proposed interpretation of p-adic physics. Zero energy ontology and the notion of causal diamond (CD) with zero energy states having interpretation as memes in very general sense is also of central importance, and allows a quantitative formulation reducing the fundamental bio-rhythms to fundamental elementary particle time scales. The hierarchy of Planck constants as an explanation of dark matter and energy as macroscopic quantum phases even in astrophysical scales and implying that dark matter is a key actor in the drama of life is the third key element.

In this chapter the implications of this vision are studied from the point of view of cognitive consciousness. The basic ideas behind the proposed vision about intentionality and cognition are following.

1. p-Adic space-time sheets are identified as the correlates of cognition and intention. The possibility to identify the inherent non-determinism of the p-adic field equations as the non-determinism of imagination makes this identification attractive. Only the p-adic space-time sheets in the intersection of real and p-adic worlds allow the transformation of intentions to actions and sensory input to cognitions. Cognitions and intentions are related by time reversal in zero energ ontology. The common algebraic points of real and p-adic partonic 2-surfaces in the algebraic extension or rationals guaranteing that the representation of 2-surface makes sense both in real and p-adic senses define fundamental cognitive representations as finite point sets.

2. The 'phase transition' of a p-adic space-time sheet to a real space-time sheet taking place in quantum jump between quantum histories corresponds to the transformation of a thought into action or sensory experience (during dreams and hallucinations) whereas the reverse transformation corresponds to the transformation of the sensory input into cognition. This transition can be thought to occur in the intersection of real and p-adic worlds where the mathematical representations of partonic 2-surface make sense both in real and p-adic sense. Motor action would correspond to the transformation of p-adic space-time sheets to their real counterparts and during sensory experience the reversal of this transformation would take place. In zero energy ontology these transformations could reduce to quark and lepton level as is suggested by the fact that the time scales assignable to quarks and leptons correspond to 1 ms and .1 s defining fundamental time scales of nerve pulse activity and EEG.

3. The obvious question is how to test p-adic physics empirically. First of all, thinking could be interpreted as p-adic sensory experiencing. Hence the reduction of theories–experimental science dichotomy to p-adic–real dichotomy seems natural: just like experimental science is an extension of everyday real sensory experience, theories represent an extension of everyday p-adic sensory experience (common sense thinking). Thus the basic test is how well p-adic physics based theories describe cognition. Secondly, the p-adic models for physical systems are strictly speaking models for cognitive models for real physics. The successes of these highly predictive models (consider only p-adic elementary particle mass calculations involving only very few integer valued parameters) supports the vision about p-adic physics as physics of cognition. p-Adic–real phase transitions as models for how thought is transformed to action and sensory input to thought provide a further testing ground for the new paradigm.

The following topics are discussed in the chapter.

1. The relationship between p-adic physics, intentionality, and cognition are discussed on general level. Basic cognitive functions such as imagination, hallucinations, formation of cognitive representations, Boolean mind, and learning are discussed in this conceptual framework.

2. Possible -necessarily indirect- evidence for p-adic cognition is considered.

3. In the mathematical sections the relationship between intentionality, cognition and number theory is discussed. Also the relation between p-adic and real physics is discussed at general level with basic vision being that the intersection of real and p-adic space-time sheets in the intersection of real and p-adic worlds consists of points belonging to the algebraic extension of rational needed to guarantee that the mathematical representation of the partonic 2-surface makes sense both in real and p-adic sense.

4. Frontal lobes are known to be the seat of the higher level intentional action and are discussed from p-adic point of view.

5. A generalization of the memetic code to cognitive codes is discussed and some proposals about codes are made. This generalization is based on p-adic length scale hypothesis. If the time scales involved correspond to time scales assignable to the CDs of the known elementary particles, the generalization is not favored. On the other hand, dark matter sector could allow entire fractal hierarchy of elementary particle physics whose existence is reflected as fundamental bio-rhytms and cognitive codes.

6. The intersection of real and p-adic partonic 2-surfaces defining space-like cognitive representations consist of algebraic points. The hypothesis that these intersections obey various kind of symmetries identifiable as molecular symmetries is discussed.

1.5.4   PART IV: PARANORMAL PHENOMENA

Quantum Model of Paranormal Phenomena

The general quantum model for bio-systems leads to a model for bio-control which applies to a very wide variety of hard-to-understand bio-chemical phenomena such as molecular recognition mechanisms, water memory, and homeopathy and leads to a generalization of genetic code explaining the mystery of introns. The same model generalizes to a model of paranormal phenomena such as psychokinesis, remote sensing, remote healing, telepathy, communications with deceased, and instrumental transcommunications. The basic difference is that magnetic body receives information and controls "foreign" biological (or even magnetic) body or "dead" matter system.

The basic notions of the model are magnetic body as an intentional agent controlling biological body and receiving data from living body or even "dead" matter system with massless extremals (MEs) mediating these communications, zero energy ontology and the related notion of causal diamond (CD) serving as an imbedding space correlate of self and assigning to elementary particles fundamental macroscopic time and length scales as those of CD, the hierarchy of Planck constants making possible macroscopic quantum phases and zoom-ups of quantum systems, and the vision about living matter as something residing in the intersection of real and p-adic worlds and the closely related notion of negentropic entanglement crucial for the functioning of living matter and conscious intelligence in TGD Universe.

Negentropic entanglement, which can be both space-like and time-like in zero energy ontology, makes possible quantum superposition of macroscopically different configurations of the target system correlated with the states of operator system. The operator should be able to achieve the negentropic entanglement and intentionally increase the amplitude of the desired outcome in this superposition. Negentropic entanglement need not involve binding energy and I have proposed this as a deeper level explanation for the nebulous notion of high energy phosphate bond crucial for metabolism in living matter. Quite generally, negentropic entanglement would make possible for the operator to transfer metabolic energy and momentum to the target. The hierarchy of values of Planck constant would make possible this process in long time and length scales.

1. Magnetic mirrors (ME-magnetic flux tube pairs) connecting the sender and receiver make possible a universal mechanism for the transfer of intent and action. The pair of flux tubes forms a kind of sensory-motor loop. In biology the fundamental realization could be by a pair of flux sheets going through the strands of DNA with passive strand sending sensory data to the magnetic body and active strand receiving control commands leading to various forms of gene expresion. MEs are ideal for the transfer of both classical information and momentum.

2. p-Adic MEs represent the transfer of a mere intent and real MEs represent a transfer of action. p-Adic ME can be transformed to real ME either by receiver or some higher level magnetic self. This makes sense only in the intersection of real and p-adic worlds.

3. The transfer of intent gives rise to mechanism of remote interaction which can act both endo- and exogenously. Magnetic mirrors characterized by their fundamental frequencies make possible bridges between sender and receiver (say healer and healee) and allow a resonant interaction in which healer can initiate various control commands acting as 4-dimensional templates represented as holograms. Also smaller MEs can be send along the MEs serving as bridges (this is like throwing balls with light velocity!).

4. The ME-magnetic flux tube pair connecting sender and receiver can act as a reference wave which can initiate an arbitrarily complex hologram representing biological program. Sender has the ability to generate and amplify the frequencies which induce holograms representing the control commands. In particular, in living matter sender can initiate complex biological programs without knowing anything about their functioning.

One can distinguish between psychokinesis applied to living matter and "dead" matter.

1. When the target consists of living matter the mechanisms would be same as in communications between magnetic and biological bodies making possible bio-control of biological body by magnetic body and the receival of sensory input from biological body by magnetic body. Hypnosis would be one example of this kind of interaction.

2. Remote mental interactions in the case "dead" could use simpler variants of the fundamental mechanisms utilized in living matter. For instance, zero energy ontology assigns with the CDs of electron and quarks time scales .1 s and 1 ms defining fundamental biorhythms. The CDs assignable to elementary particles could be involved also with psychokinesis. Negentropic entanglement could be essential for the transfer of metabolic energy (say in simple psychokinesis moving an object) and for control actions -say in intentional change of sequences of binary digits produced by random number generator. Target system would not be completely "dead". Thermodynamical restrictions favor large values of Planck constant.

The basic problem in many remote mental interactions such as the intentional effect on random number generator is "Who knows how?". How the mere intent can be transformed to action without any knowledge about the details of the action? The attempt to understand how neuro-feedback affect the behavior of single neuron leads to the same question.

1. Magnetic mirrors make possible also feedback and this feedback could make possible learning. For instance, in psychokinesis (especially so in micro PK), this learning would be crucial and analogous to that what occurs when we learn to drive a car. In healing this kind of feedback might help to find the healing frequency by trial and error.

2. It is quite possible that also multibrained and -bodied higher level colletive selves actively participate in the process as a third party such that the remote mental interactions would act as a relay states. I have suggested similar explanation for Sheldrake's findings about learning at the lelel of species and Tiller's findings about the "transfer of intent". This could make possible coherent amplification effects (TEM, prayer groups) and could make available information resources of all brains involved with the group. This could for instance explain the ability of a remote viewer to see an object on basis of data which need not have any meaning for her.

3. A fast amplitude modulation of alpha waves introducing higher harmonics to the carrier wave is a good candidate for mediating communication between brains and higher level multibrained

selves. Mesoscopic 'features' in brain involve precisely this kind of amplitude modulation and might represent just this kind of messages. Interestingly, also speech is produced by a fast amplitude modulation of 10 Hz basic vibration frequency of speech organs (assignable to electron CD as a fundamental frequency) and kHz (quarks) frequency is a special frequency from the point of view of hearing.

TGD Based Model for OBEs

Out-of-body experiences (OBEs) are often understood as experience of seeing oneself from a position outside of the body. OBEs are poorly understood in the framework of neuro science and pose a challenge for the reductionistic world view.

In TGD framework the notion of magnetic body provides an attractive starting point in attempts to understand what OBEs and related experiences are. The basic idea is that magnetic body serves effectively as a mirror defining a third person view as a cognitive representation also in ordinary wake-up state and that during OBEs this representation becomes sensory representation. Magnetic body need not always be a personal magnetic body but could correspond to a magnetic body receiving information from several brains (collective consciousness), magnetic body of another person, or be even associated with "dead" matter.

The progress in identifying dark matter as a phase of matter with large value of Planck constant making possible macroscopic quantum coherence has led to the vision about dark matter at magnetic flux quanta as quantum controller of ordinary matter in living systems. The Bose-Einstein condensates of dark photons decaying via decoherence to ordinary photons mediate interactions between ordinary and dark matter and the hypothesis is that dark photon "laser" beams from body and brain reflected at magnetic flux quanta give rise to third person aspect of consciousness which in OBEs and related experiences are realized as sensory representations. The identification of bio-photons as end products of the de-coherence of dark photon beams is natural.

Zero energy ontology and the notion of causal diamond (or CD defined roughly as the intersection of future and past directed lightcones) brings additional quantitative ingredients to the model. Sub-CDs define imbedding space ($M^4 \times CP_2$) correlates for selves and by holography the 2-D partonic 2-surfaces at the light-like future and past boundaries of CDs are the ultimate space-time correlates for mental images. The moduli space for CDs makes possible a more detailed view about sensory representations.

A further new element is the vision about life as something in the intersection of real and p-adic worlds. The most important outcome is that the notion of number theoretic entanglement negentropy making sense in this situation is positive so that entanglement carries conscious information. The fusion of selves (in particular mental image) by negentropic entanglement is experienced as expansion of consciousness. It is negentropic entanglement between parts of biological body and corresponding parts of the magnetic body and biological body which makes living system living. This negentropic entanglement between magnetic body and biological body is important also for OBEs.

The model leads also to a model for dreams, hallucinations, sensory feedback from brain to sensory organs, and directed attention. Concrete models for how dark photons can give rise to experiences in various sensory modalities such as vision, hearing, olfaction, and tactile senses, are proposed.

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Part I

BASIC IDEAS OF TGD INSPIRED THEORY OF CONSCIOUSNESS

Chapter 2

Matter, Mind, Quantum

2.1 Introduction

Topological Geometro-Dynamics (TGD) is a unified theory of fundamental interactions. TGD involves a quite far-reaching generalization of the space-time concept and, apart from the notion of quantum jump, reduces quantum theory to infinite-dimensional geometry. Quantum TGD requires the introduction of several new mathematical tools and concepts, in particular p-adic numbers.

TGD based theory of consciousness has developed gradually during the last fifteen years side by side with TGD based quantum measurement theory. For a summary of TGD and p-adic aspects of TGD see [1, 6].

The emergence of the notions of zero energy ontology and hierarchy of Planck constants together with the increased understanding of the special features of number theoretical universality have led to a considerable deepening of the understanding during last half decade. The basic concepts and ideas of TGD based theory of consciousness as I would have formulated them around 2005 are introduced first. After that the ideas that have appeared during the period 2005-2010 are briefly summarized.

2.1.1 Basic ideas of TGD inspired theory of consciousness

In the following basic ideas of TGD inspired theory of consciousness as they were formulate for about half decade ago are summarized.

Identification of quantum states as quantum histories and the notion of quantum jump

General coordinate invariance forces the identification of the quantum states as quantum histories rather than time=constant snapshots of single quantum history. Quantum history can be regarded as a classical spinor field in the world of all classical worlds (WCW) so that rather abstract concept is in question. This identification has several important consequences.

1. The possibility to regard unitary process followed by state function collapse as a quantum jump between quantum histories solves the basic paradox posed by the determinism of the Schrödinger equation contra non-determinism of the state function collapse.

2. A radical reconsideration of the concepts of psychological time and observer becomes necessary and forces a profound generalization of the standard views about time.

If quantum jump occurs between two different time evolutions of Schrödinger equation (understood here in very metaphoral sense) rather than interfering with single deterministic Schrödinger evolution, the basic problem of quantum measurement theory finds a resolution. The interpretation of quantum jump as a moment of consciousness means that volition and conscious experience are outside space-time and state space and that quantum states and space-time surfaces are "zombies". Quantum jump would have actually a complex anatomy corresponding to unitary process U, state function reduction and state preparation at least.

Negentropy Maximization Principle (NMP) codes for the dynamics of standard state function reduction and states that the state function reduction process following U-process gives rise to maximal

reduction of entanglement entropy at each step. In the generic case this implies decomposition of the system to unique unentangled systems and the process repeats itself for these systems. The process stops when the resulting subsystem cannot be decomposed to a pair of free systems since energy conservation makes the reduction of entanglement kinematically impossible in the case of bound states.

The notion of self

Intuitively self corresponds to a sequence of quantum jumps which somehow integrates to a larger unit much like many-particle bound state is formed from more elementary building blocks. It also seems natural to assume that self stays conscious as long as it can avoid bound state entanglement with the environment in which case the reduction of entanglement is energetically impossible. One could say that everything is conscious and consciousness can be only lost when the system forms bound state entanglement with environment.

As will be found, there is an important exception to this vision based on ordinary Shannon entropy. There exists an infinite hierarchy of number theoretical entropies making sense for rational or even algebraic entanglement probabilities. In this case the entanglement negentropy can be negative so that NMP favors the generation of negentropic entanglement, which need not be bound state entanglement in standard sense.

Self is assumed to experience sub-selves as mental images identifiable as "averages" of their mental images. This implies the notion of ageing of mental images as being due to the growth of ensemble entropy as the ensemble consisting of quantum jumps (sub-sub-subselves) increases.

One of the newest ideas related to the notion of self is that the sub-selves of two unentangled selves can entangle although selves remain unentangled. This is possible by the modification of the subsystem concept forced by the p-adic length scale cutoff. The entanglement of sub-selves means fusion and sharing of mental images providing a universal telepathy like quantum communication mechanism and presumably making possible both molecular, cellular, and human societies.

Generalization of quantum measurement theory

One must reformulate quantum measurement theory. The hypothesis that each quantum jump involves localization in the so called zero modes having interpretation as classical variables characterizing the observable geometric properties of the space-time surface, and thus of external macroscopic observer, together with an additional condition guaranteing that the density matrix characterizing the entanglement between quantum fluctuating degrees of freedom and zero modes is diagonal, implies standard quantum measurement theory. Needless to emphasize, the reduction of the standard quantum measurement theory to fundamental quantum physics is a triumph of TGD approach.

This is however not the whole story. The standard quantum measurement is followed by a cascade self measurements inside self, which reduces entanglement between some subsystem and its complement in quantum fluctuating degrees of freedom: again a measurement of the density matrix is in question. This cascade is equivalent with the process of state preparation which is a phenomenological notion in the standard quantum measurement theory. The dynamics of self measurement is governed by Negentropy Maximization Principle (NMP), which specifies which subsystems are subject to quantum measurement in a given quantum jump. NMP can be regarded as a basic law for the dynamics of quantum jumps and states that the information content of the conscious experience is maximized. In p-adic context NMP dictates the dynamics of cognition.

Quantum criticality

The systems possessing self correspond to macroscopic quantum phases. In standard physics context the existence of the required macroscopic quantum phases is not at all obvious whereas the new physics implied by TGD predicts their existence. The point is that the Universe according to TGD is a quantum critical system. Quantum criticality is mathematically very similar to thermodynamical criticality and implies long range quantum correlations in all length scales. This in turn implies the existence of macroscopic quantum phases. TGD Universe is also quantum spin glass with state degeneracy broken only by the classical gravitational energy of the space-time sheets having same induced Kähler field. This degeneracy makes it possible to have quantum coherence over time periods

longer than CP_2 time of order 10^{-39} seconds characterizing the duration of single quantum jump so that biosystems can act as quantum computers in macroscopic time scales.

TGD based space-time concept and the existence of macroscopic quantum phases

TGD implies a radical generalization of the space-time concept in all length and time scales. The concept of many-sheeted space-time leads to fresh proposals for how biosystems manage to be macroscopic quantum systems. Examples of these mechanisms are so called wormhole superconductivity, electronic high T_c super-conductivity, neutrino super-conductivity, ionic and a mechanism for generating coherent light and gravitons [29, 28, 28, 32]. The notion of many-sheeted ionic equilibrium summarizes the basic vision about quantum control and coordination according to which the space-time sheets associated with the superconducting magnetic flux tube structures control ordinary biomatter at the atomic space-time sheets.

The so called massless exremals (MEs), which can be regarded as 'topological light rays', are carriers of especially important exmple of macroscopic quantum states. The lightlike boundaries of MEs act as quantum holograms and carry representations of the superconformal and super-symplectic algebras. These states have gigantic almost-degeneracies, and are genuine quantum gravitational states (state functionals in the configuration space of 3-surfaces, 'the world of worlds') and thus correspond to higher abstraction level than ordinary quantum states. MEs can control the supercurrents at superconducting magnetic flux tube structures by magnetic interactions, act as Josephson junctions, and induce magnetic quantum phase transitions. Therefore the quantum holograms associated with MEs are excellent candidates for quantum correlates of higher level consciousness.

p-Adic numbers and consciousness

p-Adic number fields R_p (one number field for each prime $p = 2, 3, 5, ...$) are analogous to real numbers but differ from them in that p-adic numbers are not well-ordered. p-Adic numbers play an absolutely essential role in the formulation of quantum TGD and of TGD inspired theory of consciousness. The inherent non-determinism of p-adic differential equations motivates the identification of the p-adic space-time sheets as cognitive representations of ordinary matter with p-adic non-determinism identified as non-determinism of imagination. Mind-matter duality is realized at the level of space-time geometry and mind stuff corresponds to p-adic regions of space-time. TGD Universe performs self mimicry in all length scales. Besides p-adic nondeterminism there is nondeterminism of Kähler action: these two nondeterminisms allow to represent some aspects of quantum jump sequences, that is contents of consciousness of selves, at space-time level cognitively and symbolically (language). This in turn makes possible self referentiality of consciousness: it is possible to become conscious about being conscious about...

2.1.2 Implications of zero energy ontology, number theoretical universality, and hierarchy of Planck constants

Zero energy ontology, number theoretical universality, and hierarchy of Planck constants represent ideas, which have developed strongly during last half decade and have led to to a considerable refinement of the overall view about consciousness and inspired also a vision about life as something residing in the intersection of real and p-adic worlds [29].

Zero energy ontology and the notions of quantum jump and self

Zero energy ontology changes considerably the interpretation of the unitary process and state function reduction. In zero energy ontology quantum states are replaced with zero energy states defined as superpositions of pairs of positive and negative energy states identified as counterparts of initial and final states of a physical event such as particle scattering. Zero energy ontology is ideal from the point of view of consciousness and intentionality. Everything can be in principle be created from vacuum so that several frustrating paradoxes plaguing positive energy ontology disappear. Also the quantum jumps between p-adic and real quantum states suggested to correspond to intentional action are mathematically sensible in zero energy ontology.

The matrix defining entanglement between positive and negative - christened as M-matrix- is the counterpart of the ordinary S-matrix but need not be unitary. It can be identified as a "complex square

root" of density matrix expressible as a product of positive square root of diagonal density matrix and unitary S-matrix. Quantum TGD can be seen as defining a "square root" of thermodynamics, which thus becomes an essential part of quantum theory.

U-matrix is defined between zero energy states and cannnot therefore be equated with the S-matrix used to describe particle scattering events. Unitary conditions however imply that U-matrix can be seen as a collection of M-matrices labelled by zero energy states so that the knowledge of U-matrix implies the knowledge of M-matrices. A natural guess is that U is directly related to consciousness and the description of intentional actions. For positive energy ontology state function reduction would serve as a state preparation for the next quantum jump. In zero energy ontology state function preparation and reduction can be assigned to the positive and negative energy states defining the initial and final states of the physical event. The reduction of the time-like entanglement during the state function reduction process corresponds to the measurement of the scattering matrix. In the case of negentropic time-like entanglement the reduction process is not random anymore and the resulting dynamics is analogous to that of cellular automata providing a natural description of the dynamics of self-organization in living matter.

Zero energy ontology leads to a precise identification of the subsystem at space-time level. General coordinate invariance in 4-D sense means that 3-surfaces related by 4-D diffeomorphisms are physically equivalent. It is conventient to perform a gauge fixing by a introducing a natural choice for the representatives of the equivalence classes formed by diffeo-related 3-surfaces.

1. Light-like 3-surfaces identified as surfaces at which the Minkowskian signature of the induced space-time metric changes to Euclidian one - wormhole contacts- are excellent candidates in this respect. The intersections of these surfaces with the light-like boundaries of CD defined 2-D partonic surfaces. Also the 3-D space-like ends of space-time sheets at the light-like boundaries of CDs are very natural candidates for preferred 3-surfaces.

2. The condition that the choices are mutually consistent implies effective 2-dimensionality. The intersections of these surfaces defining partonic 2-surface plus the distribution of 4-D tangent spaces at its points define the basic dynamical objects with 4-D general coordinate invariance reduced to 2-dimensional one. This effective 2-dimensionality was clear from the very beginning but is only apparent since also the data about 4-D tangent space distribution is necessary to characterize the geometry of WCW and quantum states. The descriptions in terms of 3-D light-like or space-like surfaces and even in terms of 4-D surfaces are equivalent but redundant descriptions. This has far reaching implications for the concrete mathematical realization of number theoretic universality [29].

As far as consciousness is considered effective 2-dimensionality means holography and could relate to the fact that at least our visual experience is at least effectively 2-dimensional.

Positive entanglement negentropy is possible in the intersection of real and p-adic worls

Positive entanglement negentropy is possible in the intersection of real and p-adic worlds and is stable against NMP. Giving up the original ad hoc interpretation as a counterpart for bound state entanglement leads to a beautiful vision about the role of negentropic entanglement in cognition and functioning of living matter.

1. The first form of NMP was rather naive. There was no idea about the anatomy of quantum jump and NMP only stated that the allowed quantum jumps are such that the information gain of conscious experience measured by the reduction of entanglement entropy resulting in the reduction of entanglement between the subsystem of system and its complement is maximal. Later it became clear that quantum jump has a complex anatomy consisting of unitary process U followed by the TGD counterpart of state function reduction serving as a state preparation for the next quantum jump.

2. The attempts to formulate NMP in p-adic physics led to the realization that one can distinguish between three kinds of information measures.

   (a) In real physics the negative of the entanglement entropy defined by the standard Shannon formula defines a natural information measure, which is always non-positive.

(b) In p-adic physics one can generalize this information measure to p-adic valued information measure by replacing the logarithms of p-adic valued probabilities with the p-based logarithms $log_p(|P|_p)$ which are integer valued and can be interpreted as p-adic numbers. This p-adic valued entanglement entropy can be mapped to a non-negative real number by the so called canonical identification $x = \sum_n x_n p^n \to \sum_n x_n p^{-n}$. In both cases a non-positive information measure results.

(c) When the entanglement probabilities are rational numbers or at most finitely algebraically extended rational numbers one can still define logarithms of probabilities as p-based logarithms $log_p(|P|_p)$ and interpret the entropy as a rational or algebraic number. In this case the entropy can be however negative and positive definite information measure is possible. Irrespective of number field one can in this case define entanglement entropy as a maximum of number theoretic entropies S_p over the set of primes. The first proposal was that the algebraic entanglement corresponds to bound state entanglement turned out to be wrong.

3. At some stage the importance of the almost trivial fact that bound state entanglement must be kinematically stable against NMP became obvious. One can imagine that the state function reduction proceeds step by step by reducing the state to two parts in such a manner that the reduction of entanglement entropy is maximal.

(a) If a resulting subsystem corresponds to a bound state having no decomposition to free subsystems the process stops for this subsystem. The natural assumption is that subsystems lose their consciousness when U process leads to bound state entanglement whereas bound state itself can be conscious.

(b) If the entanglement is negentropic (and thus rational or algebraic) a more natural interpretation consistent with the teaching of spiritual practices is that subsystems experience a fusion to a larger conscious entity. The negentropic entanglement between free states is stabilized by NMP and negentropically entangled states need not reside at the bottom of potential well forbidding the reduction of entanglement. This makes possible new kinds of correlated states for which binding energy can be negative. Bound state entanglement would be like the jail of organized marriage and negentropic entanglement like a love marriage in which companions are free to leave but do not what it. The existence of this kind of negentropic entanglement is especially interesting in living matter, where metabolism (high energy phosphate bond in particular) and the stability of DNA and other highly charged polymers is poorly understood physically: negentropic entanglement could be responsible for stabilization making possible the transfer of metabolic energy [19].

4. For the negentropic entanglement the outcome of the state function reduction ceases to be random as it is for the standard definition of entanglement entropy. Note however that U process as a creative act yielding superposition of possibilities from which state function reduction selects leaves means non-determinism. This has far reaching consequences. Ordinary state function reductions for an ensemble of systems lead to a generation of thermodynamical entropy and this explains the second law of thermodynamics. In the case of negentropic entanglement situation changes and the predicted breaking of second law of thermodynamics provides a new view to understand self-organization [26], and living matter could be identified as something residing in the intersection of real and p-adic worlds where p-adic intentions can be transformed to real actions.

5. One particular choice involved with state function reduction process could be the choice between generic entanglement and number theoretic entanglement possible only in the intersection of p-adic and real WCWs. If the choice is the generic entanglement, system ends up either to an unentangled state with maximal conscious freedom or to a bound state with a loss of consciousness. If the choice is algebraic entanglement, system ends up to negentropic entanglement and correlations with external world and experiences an expansion of consciousness. Maybe ethical choices are basically choices between these two options. Also positive emotions like love and experience of understanding could directly relate to various aspects of the negentropic entanglement.

Dark matter hierarchy

Basic objection against quantum theories of consciousness and biology relate to the smallness of Planck constant making difficult to imagine macroscopic quantum coherence in the scales of living matter. Zero energy ontology partially resolves the problem by assigning to elementary particles macroscopic length and time scales. For instance, the time scale assignable to the CD of electron is .1 seconds defining the fundamental bio-rhythm.

The anomalies related to the interaction of ELF em fields on living matter and Nottale's observation that planetary orbits correspond approximately to Bohr orbits with a gigantic value of Planck constant led to the hypothesis that Planck constant has a discrete spectrum and can have arbitrarily large values [17, 22]. The identification of dark matter as phases having large value of Planck constant [17, 16, 17] led to a vigorous evolution of ideas. Entire dark matter hierarchy with levels labelled by increasing values of Planck constant is predicted, and in principle TGD predicts the values of Planck constant if physics as a generalized number theory vision is accepted [17].

The hierarchy of Planck constants is realized in terms of a generalization of the causal diamond $CD \times CP_2$, where CD is defined as an intersection of the future and past directed light-cones of 4-D Minkowski space M^4. $CD \times CP_2$ is generalized by gluing singular coverings and factor spaces of both CD and CP_2 together like pages of book along common back, which is 2-D sub-manifold which is M^2 for CD and homologically trivial geodesic sphere S^2 for CP_2 [17]. The value of the Planck constant characterizes partially the given page and arbitrary large values of $\hbar$ are predicted so that macroscopic quantum phases are possible since the fundamental quantum scales scale like $\hbar$. The most general spectrum comes in rational multiples of standard value of Planck constant which corresponds to the unit of rationals. For CDs the scaling of Planck constants means scaling of the size of CD. This could explain why the rational multiples of the fundamental frequency are so special for music experience.

All particles in the vertices of Feynman diagrams have the same value of Planck constant so that particles at different pages cannot have local interactions. Thus one can speak about relative darkness in the sense that only the interactions mediated by the exchange of particles and by classical fields are possible between different pages. Dark matter in this sense can be observed, say through the classical gravitational and electromagnetic interactions. It is in principle possible to photograph dark matter by the exchange of photons which leak to another page of book, reflect, and leak back. This leakage corresponds to $\hbar$ changing phase transition occurring at quantum criticality and living matter is expected carry out these phase transitions routinely in bio-control. This picture leads to no obvious contradictions with what is really known about dark matter and to my opinion the basic difficulty in understanding of dark matter (and living matter) is the blind belief in standard quantum theory. These observations motivate the tentative identification of the macroscopic quantum phases in terms of dark matter and also of dark energy with gigantic "gravitational" Planck constant.

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by the following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of $\hbar$ at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

At least dark matter could be a key player in quantum biology.

1. Dark matter hierarchy and p-adic length scale hierarchy would provide a quantitative formulation for the self hierarchy. To a given p-adic length scale one can assign a secondary p-adic time scale as the temporal distance between the tips of the CD. For electron this time scale is .1 second, the fundamental bio-rhythm. For a given p-adic length scale dark matter hierarchy gives rise to additional time scales coming as $\hbar/\hbar_0$ multiples of this time scale.

2. The predicted breaking of second law of thermodynamics chacterizing living matter - if identified as something in the intersection of real and p-adic words - would be always below the time scale of CD considered but would take place in arbitrary long time scales at appropriate levels of the hierarchy. The scaling up of $\hbar$ also scales up the time scale for the breaking of the second law.

3. The hypothesis that magnetic body is the carrier of dark matter in large $\hbar$ phase has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [22]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [29, 22]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [22].

If one accepts the hierarchy of Planck constants [17], it might be un-necessary to distinguish between self and quantum jump. The hierarchy of Planck constants interpreted in terms of dark matter hierarchy predicts a hierarchy of quantum jumps such that the size of space-time region contributing to the contents of conscious experience scales like $\hbar$. Also the hierarchy of space-time sheets labeled by p-adic primes suggests the same. That sequence of sub-selves/sub-quantum jumps are experienced as separate mental images explains why we can distinguish between digits of phone number. The irreducible component of self (pure awareness) would correspond to the highest level in the "personal" hierarchy of quantum jumps and the sequence of lower level quantum jumps would be responsible for the experience of time flow. Entire life cycle could correspond to single quantum jump at the highest(?) level of the personal self hierarchy and pure awareness would prevail during sleep: this would make it possible to experience directly that I existed yesterday.

There are thus two definitions of self. The first definition introduces self as a notion separate from quantum jump. Second definition reduces the notion of self to a fractal hierarchy of quantum jumps. The equivalence between two definitions of the notion of self will be proposed.

2.2 TGD inspired theory of consciousness

Before continuing some comments about the definition of quantum history concept are in order. In TGD quantum states corresponds to Diff^4 invariant configuration space spinor fields defined in the space of 3-surfaces. By general coordinate invariance the value of the configuration space spinor field is same for all 3-surfaces $X^3 \subset X^4(Y^3)$ related by diffomorphisms, especially by time translations of $X^4(Y^3)$. This means that configuration space spinor field cannot be localized temporally unless $X^4(Y^3)$ has finite time duration and is therefore vacuum 4-surface. Hence it is natural to speak of quantum history. Note that 'quantum history' in this sense does not refer to Schrödinger time evolution (since the Schrödinger evolution operator is generalized by TGD) nor evolution by quantum jumps (since, in TGD, these are jumps between entire quantum histories) but is quantum history with respect to the geometric time of $X^4(Y^3)$ and determined by the requirement of general coordinate invariance. Quantum history is defined in the world of all possible clasical worlds (3-surfaces or equivalently allowed space-time surfaces).

Quantum histories can be also regarded as superpositions of classical space-time surfaces since the definition of the configuration space geometry assigns to each 3-surface Y^3 a unique space-time surface $X^4(Y^3)$ and since configuration space spinor field is invariant under general coordinate transformations. As a consequence, classical TGD becomes an exact part of quantum TGD.

2.2.1 Quantum jumps between quantum histories as moments of consciousness

The individual quantum jump between quantum histories has a complex anatomy which has become obvious only gradually. Quantum jump consists of the unitary, informational "time evolution"

$$\Psi_i \to U\Psi_i$$

of the initial quantum history Ψ_i described by the unitary operator U (essentially S-matrix), followed by the step

$$U\Psi_i \to \Psi_{f_0} \quad ,$$

in which a localization in zero modes occurs. This step is the counterpart of the state function reduction process and gives rise to the ordinary quantum measurement with zero modes playing the role of classical variables.

This step is followed by a sequence of self measurements

$$\Psi_{f_0} \to \Psi_{f_1} \to ....\Psi_f$$

leading to a state Ψ_f in which only bound state entanglement remains. This process is the counterpart of state function reduction for quantum jump in question and of state preparation for the next quantum jump. In a given self measurement sub-system decomposes into two unentangled parts and the decomposition is fixed by the requirement that the reduction of the entanglement entropy is maximal (Negentropy Maximization Principle) and the density matrix serves as a universal observable in the self measurement.

It should be emphasized that the operator U is only the formal counterpart of the Schrödinger time evolution lasting infinite time: there is no actual Schrödinger equation involved and U has nothing to do with geometric time development[1].

The developments taken place in TGD during period 2005-2010 tend to modify slightly this picture.

1. The original belief was that U codes all the statistical predictions of quantum TGD and is the counterpart of S-matrix of quantum field theories. The introduction of zero energy ontology however led to conclusion that so called M-defining the time-like entanglement coefficients between positive and negative energy parts of zero energy states is the counterpart of S-matrix of physicists measured in laboratory and can be regarded as a product of "complex" square root of density matrix expressible as positive diagonal square root of density matrix and unitary S-matrix. In this framework U-matrix is between zero energy states whereas M-matrix is between positive and negative energy parts of zero energy states. It turns out that U-matrix can be regarded as a collection of M-matrices labelled by zero energy states and that unitarity conditions state that these M-matrices define an orthonormal state basis [29]. Therefore U-matrix codes for all predictions of quantum TGD. In zero energy ontology U-matrix can have matrix elements also between different number fields in the intersection of real and p-adic worlds in which the mathematical representation of the partonic 2-surfaces makes sense in both real and p-adic worlds sense. This makes the mathematical description of intentional action as a leakage from p-adic world to real world possible.

2. Second deviation from the original picture comes from the possibility negentropic entanglement when entanglement probabilities are rational or even algebraic numbers. Negentropic entanglement can be also stable against NMP so that both bound state entanglement or negentropic entanglement for all subsystem pairs of system means that the reduction cascade stops. There is no need to identify these entanglements and an attractive hypothesis is that consciousness is lost only in the generation of bound state entanglement whereas the generation of the negentropic entanglement corresponds to an experience about expansion of consciousness. It is natural to assign positive emotions like love and experience of understanding to various forms of the negentropic entanglement. Both negentropic entanglement and intentional action would be possible only in the intersection of real and p-adic worlds, which suggest that life could be seen as a critical phenomenon in number theoretical sense.

Subjective time development understood as a sequence of quantum jumps occurs outside the realm of the geometric space-time. It could be regarded as a non-deterministic hopping in the space of the configuration space spinor fields. Individual quantum jump is however fundamentally irreducible in the sense that one cannot model it by any dynamical time development. The identification of quantum jump as a moment of consciousness defines what might be called microscopic theory of consciousness. The subjective time development presumably obeys some variational principle consistent with the quantum measurement theory, in particular, with its non-determinism[2]. This principle dictates which systems for given initial quantum history can perform quantum jumps and have moments of consciousness. This variational principle will be discussed in section [2.2.2].

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[1]From TGD point of view the identification of the geometric time and the time coordinate appearing in the general Schrödinger equation of quantum field theories quantized using Hamiltonian formalism is wrong. Schrödinger equation is not even needed. The identification of the time coordinate of the Dirac equation as a geometric time however makes sense from TGD point of view.

[2]This means that the variational principle in question must be more akin to the second law of thermodynamics rather than to the ordinary variational principles of physics.

How the world of conscious experience can look classical?

If quantum histories (/states) are quantum superpositions over a huge number of classical space-time surfaces, it is very difficult to understand how the world of conscious experience manages to look classical. The solution of the problem comes out from the requirement that quantum jumps in a well defined sense reduce to quantum measurements performed in a space-time with a fixed macroscopic geometry as in quantum field theory. The macroscopic aspects of the space-time surface are determined completely by the zero modes of the configuration space characterizing the induced Kähler field and geometric size and shape of the four-surface totally. Thus, if each quantum measurement involves a localization in zero modes, then the classicality of the universe of subjective experience is achieved automatically, and as noticed, standard quantum measurement theory follows from quantum TGD proper. In p-adic space-time degrees of freedom complete localization must occur in every quantum jump for purely mathematical reasons, and the interpretation is that intentionality and cognition are completely classical.

During macrotemporal quantum coherence due to the formation of bound state half of the zero modes of two space-time sheets connected by join along boundaries bonds become macroscopic quantum fluctuating degrees of freedom, and in these states consciously experienced world looks non-classical. These states correspond to states of "one-ness" at the level of conscious experience.

There are counter arguments against complete localization. First of all, one can imagine that the reduction could occur to a sub-space of zero modes consisting of a discrete points. Rational bound state entanglement in discrete sub-spaces of zero modes would be stable against state function reduction. Even more generally, the existence of symplectic structure in zero modes allows to consider a hierarchy of $2n$-dimensional sub-manifolds in the space of zero modes with volume element defined by the n:th power of the symplectic form. State function reduction could occur to this kind of sub-manifold since at least the transition amplitude would be well-defined. Preferred sub-manifolds of this kind are sub-manifolds closed with respect to the action of $SO(3) \times SU(3)$ isometries such that only the coordinates associated with a finite number of super-symplectic generators are non-constant.

Standard quantum measurement theory

The assumption that a complete localization occurs in zero modes in each quantum jump implies that the world of conscious experience looks classical. It also implies standard quantum measurement theory without NMP as the following arguments demonstrate.

1. The standard quantum measurement theory a la von Neumann involves the interaction of brain with the measurement apparatus. If this interaction corresponds to entanglement between microscopic degrees of freedom m with the macroscopic effectively classical degrees of freedom M characterizing the reading of the measurement apparatus coded to brain state, then the reduction of this entanglement in quantum jump reproduces standard quantum measurement theory.

2. Since zero modes represent classical information about the geometry of space-time surface (shape, size, classical Kähler field,...), they have interpretation as effectively classical degrees of freedom and are the TGD counterpart of the degrees of freedom M representing the reading of the measurement apparatus. The entanglement between quantum fluctuating non-zero modes and zero modes is the TGD counterpart for the $m - M$ entanglement. Therefore the localization in zero modes is equivalent with a quantum jump leading to a final state where the measurement apparatus gives a definite reading.

3. Unitarity is consistent with the localization in zero modes if the unitary time evolution operator U acts effectively as a flow in zero mode degrees. This means that in some incoming state basis $|n, z\rangle$, where z refers to zero modes, the outgoing states are of form $S^\dagger_{nm}|m, z_1(z, n)\rangle$. The effective flow property means a 1-1 mapping of the outgoing quantum state basis to classical variables (say, spin direction of the electron to its orbit in the external magnetic field). The final state is an eigenstate of the density matrix for the measured system identified as quantum fluctuating degrees of freedom and zero mode degrees of freedom identified as measuring system.

This simple prediction would be of utmost theoretical importance since the black box of the quantum measurement theory would seem to reduce to basic quantum theory if the localization in zero modes occurs automatically.

All visions are vulnerable to criticism and this particular vision is not an exception in this respect.

1. The result follows as a consequences of NMP if one assumes that it applies to the entanglement between zero modes and that zero modes are entangled with quantum numbers. One can argue that if one accepts NMP as a general principle, it does not make sense to assume exceptions to it.

2. The original hypothesis was that the localization of zero modes is a mathematical necessity but it has become clear that a localization to finite $2n$-dimensional orientable sub-manifolds in the space of zero modes is in principle enough since the symplectic form assignable to the zero modes defines a positive definite integration measure (needed for the inner product) in this kind of sub-manifolds. A weaker condition would be the the localization takes place to a finite region of zero mode sector and takes place within finite measurement resolution.

3. There is no proposal for how the correlation between quantum numbers and zero modes is generated. The recent formulation of quantum TGD in terms of the modified Dirac action containing a measurement interaction term linear in conserved quantum numbers provides the coupling between quantum numbers of the state and space-time geometry [46]. Zero modes can be identified quite precisely in terms of the geometry of the partonic 2-surface and its 4-D tangent space and correspond locally to the induced Kähler form of CP_2. Quantum numbers affect the projection of the induced Kähler form to the complement of the tangent space of X^2 in the tangent space of the space-time sheet. This indeed gives hopes about 1-1 coding of quantum numbers to the values of zero modes in terms of the induced Kähler form of the space-time sheet. Note however that classical determinism in the standard sense of the word fails by the special properties of Kähler action.

Also self measurements are possible

TGD allows also second type of quantum measurement following ordinary quantum measurement reducing entanglement in quantum fluctuating degrees of freedom for some sub-system-complement pair inside self which corresponds to a state localized in zero modes. This measurement can be regarded as a self measurement and there is entire cascade of them reducing the state to a completely classical product state. The process is obviously the counterpart of the phenomenological state preparation process in quantum physics. The only universal observable is the *density matrix* of the sub-system, which should be thus measured in the quantum jump. Negentropy Maximization Principle (NMP) governs the dynamics of self measurement and states that the the density matrix of a sub-system of self for which the reduction of entanglement entropy is maximal, is measured in self measurement. In the real context self measurement means a reduction of the entanglement and provides a mechanism of self-repair: NMP [29] says that the biggest hole in the leaking boat is filled first. In p-adic context NMP becomes the basic dynamical principle of cognition.

It is however far from obvious what the notion of quantum measurement means when quantum states are quantum histories. For instance, the precise definition of the sub-system concept involves nontrivial delicacies caused by the classical non-determinism of Kähler action. In absence of this non-determinism, all self measurements could be assigned to the boundary of the future light cone (big bang) in accordance with the quantum holography principle. The resolution of these problems emerged with the advent of zero energy ontology.

1. In zero energy ontology the imbedding space correlates of selves are causal diamonds (CDs) identifiable as intersection of future and past directed light-cones of M^4. As a matter fact, the cartesian product of $CD \times CP_2$ is in question but I will use just the term CD. Also unions of selves are possible and there is a fractal hierarchy of selves if one accepts the hypothesis that the proper time distance between the tips of CD is an octave of CP_2 time scale identifiable as secondary p-adic time scale. The study of the moduli space of self suggests unexpected connections with cosmology: in fact, the proper time distance between the tips is analogous to cosmic time. The understanding of the arrow of this particular time emerges naturally from the fact that this distance is bound to increase during the sequence of quantum jumps. The introduction of the hierarchy of Planck constants brings in also the imbedding space-correlate for the choice of the quantization axes, which is also a vital part of quantum measurement as one particular state function reduction.

2. The light-like 3-surfaces connecting the light-like boundaries of CD are space-time correlates of self. Also the space-like 3-surfaces at these boundaries serve as these correlates. This implies holography: 2-D partonic surfaces plus their 4-D tangent spaces serve are enough for space-time correlates for selves and everything about self hierarchy should be formulated in terms of these plus intersections of CDs, which is assumed to be necessary for the fusion of mental images having as a space-time correlate the formation of flux tubes connecting space-time sheets representing sub-selves.

The relationship of NMP to the second law of thermodynamics can be understood roughly as follows. The reduction of entanglement entropy leads to a random unentangled state pair in the case of entropic entanglement unless it is bound state entanglement in which case no reduction takes place. The outcome at the level of ensemble is increase of entropy. The possibility of negentropic entanglement can however change the situation and the breaking of the second law in the time scale of CD is expected [29].

Quantum jump as quantum computation like process

The Universe according to TGD is a quantum computer in an extremely general sense of the word. Every quantum jump involves unitary informational "time development" U (quantum computation) and state function reduction involving a localization in the zero modes (halting of the computation) and a sequence of self measurements giving rise to state function reduction in genealized sense. It is neither possible nor necessary to assign Schrödinger equation with U. U is however completely analogous to the time evolution operator $U(-t, t)$, $t \to \infty$, defining the S-matrix in quantum field theories. It is important to notice that also in quantum field theories one is interested only in the S-matrix so that new interpretation brings in nothing new at practical level.

There are thus three time developments in TGD:

1. The geometric time development of the space-time surface determined by the condition that the extremals are critical in the sense that they allow an infinite number of deformations with a vanishing second variation of the Kähler action, which also via general coordinate invariance defines in what sense quantum histories are histories;

2. The informational "time development" U-unitary process- analogous to quantum computation (hence the attribute 'informational') represented by S-matrix;

3. The subjective time development by quantum jumps taking outside the realm of the space-time.

These three notions of time development fuse to single "holy trinity" of informational, subjective and geometric time evolutions. This "holy trinity" of time evolutions corresponds to the "holy trinity" of

1. matter in the sense of res extensa identified as 3-surfaces,

2. ideas/objective realities (logos= cosmos) identified as quantum histories (physics= mathematics)[3].

3. and the world of subjective experiences defined by the quantum jump sequences for selves (mathematician exists subjectively in the quantum jumps between mathematical ideas).

Tri-partism allows to overcome the basic difficulties of the monistic and dualistic world pictures. In particular, the theory-reality dualism disappears.

It should be emphasized that in this framework the standard physics identification of the time parameter of Schrödinger evolution with geometric time is wrong. The difficult and many-faceted problem, to be discussed later, is how the value of geometric time associated with the contents of conscious experience is determined.

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[3]Quantum histories can be regarded as superpositions of Boolean statements represented by many fermion Fock states (fermion number=1↔true, fermion number =0↔ false), hence logos=cosmos identification.

2.2.2 Negentropy Maximization Principle

Negentropy Maximization Principle (NMP [29]) stating that the reduction of entanglement entropy is maximal at a given step of state function reduction process following U-process is the basic variational principle for TGD inspired theory of consciousness and says that the information contents of conscious experience is maximal. Although this principle is diametrically opposite to the second law of thermodynamics it is structurally similar to the second law. NMP does not dictate the dynamics completely since in state function reduction any eigen state of the density matrix is allowed as final state. NMP need not be in contradiction with second law of thermodynamics which might relate as much to the ageing of mental images as to physical reality.

Basic form of NMP

Negentropy Maximization Principle (NMP) in its original form codes for the basic rules of the standard state function reduction and implies that system ends up to an eigenstate of the density matrix identified as observable. In TGD framework must ask whether NMP should be restricted only to the entanglement between zero modes of WCW representing classical degrees of freedom and quantum fluctuating degrees of freedom or generalize it to apply to any pair of subsystems so that state function reduction sequence could be regarded as a sequence of self measurements. I have chosen the latter option as a working hypothesis.

NMP that the state function reduction process following U-process gives rise to a maximal reduction of entanglement entropy at each step of the process. State function process could proceed at the level of all CDs. It is not clear whether one can assign any geometric time duration to this process or whether there is any need for this. If the ubsystem allows entangled pairs of free systems (no binding energy) there is more or less unique pair with the maximal entanglement entropy and NMP therefore implies a decomposition to a unique pair of unentangled systems. The process repeats itself for these systems and stops when the resulting subsystem cannot be decomposed to a pair of free systems since energy conservation makes the reduction of entanglement kinematically impossible in the case of bound states. Number theoretic entanglement entropies mean an important modification of this picture.

Number theoretic Shannon entropy as information

The notion of number theoretic entropy obtained by can be defined by replacing in Shannon entropy the logarithms of probabilities p_n by the logarithms of their p-adic norms $|p_n|_p$. This replacement makes sense for algebraic entanglement probabilities if appropriate algebraic extension of p-adic numbers is used. What is new that entanglement entropy can be negative, so that algebraic entanglement can carry information and NMP can force the generation of bound state entanglement so that evolution could lead to the generation of larger coherent bound states rather than only reducing entanglement. A possible interpretation for algebraic entanglement is in terms of experience of understanding or some positive emotion like love.

Standard formalism of physics lacks a genuine notion of information and one can speak only about increase of information as a local reduction entropy. It seems strange that a system gaining wisdom should increase the entropy of the environment. Hence number theoretic information measures could have highly non-trivial applications also outside the theory consciousness.

NMP combined with number theoretic entropies leads to an important exception to the rule that the generation of bound state entanglement between system and its environment during U process leads to a loss of consciousness. When entanglement probabilities are rational (or even algebraic) numbers, the entanglement entropy defined as a number theoretic variant of Shannon entropy can be non-positive (actually is) so that entanglement carries information. NMP favors the generation of algebraic entanglement. The attractive interpretation is that the generation of algebraic entanglement leads to an expansion of consciousness ("fusion into the ocean of consciousness") instead of its loss.

State function reduction period of the quantum jumps involves much more than in wave mechanics. For instance, the choice of quantization axes realized at the level of geometric delicacies related to CDs is involved. U-process generates a superposition of states in which any sub-system can have both real and algebraic entanglement with the external world. If state function reduction involves also a choice between generic and negentropic entanglement (between real world, a particular p-adic world, or their intersection) it might be possible to identify a candidate for the physical correlate for

the choice between good and evil. The hedonistic complete freedom resulting as the entanglement entropy is reduced to zero on one hand, and the algebraic bound state entanglement implying correlations with the external world and meaning giving up the maximal freedom on the other hand. The hedonistic option is risky since it can lead to non-algebraic bound state entanglement implying a loss of consciousness. The second option means expansion of consciousness - a fusion to the ocean of consciousness as described by spiritual practices. Note that if the total entanglement negentropy defined as sum of contributions from various levels of CD hierarchy up to the highest matters in NMP then also subselves should develop negentropic entanglement. For instance, the generation of entropic entanglement at cell level can lead to a loss of consciousness also at higher levels. Life would evolve from short to long scales.

Life as islands of rational/algebraic numbers in the seas of real and p-adic continua?

Rational and even algebraic entanglement coefficients make sense in the intersection of real and p-adic words, which suggests that life and conscious intelligence reside in the intersection of the real and p-adic worlds. This would mean that the mathematical expressions for the space-time surfaces (or at least 3-surfaces or partonic 2-surfaces and their 4-D tangent planes) make sense in both real and p-adic sense for some primes p. Same would apply to the expressions defining quantum states. In particular, entanglement probabilities would be rationals or algebraic numbers so that entanglement can be negentropic and the formation of bound states in the intersection of real and p-adic worlds generates information and is thus favored by NMP.

The identification of intentionality as the basic aspect of life seems to be consistent with this idea.

1. The proposed realization of the intentional action has been as a transformation of p-adic space-time sheet to a real one. Also transformations of real space-time sheets to p-adic space-time sheets identifiable as cognitions are possible. Algebraic entanglement is a prerequisite for the realization of intentions in this manner. Essentially a leakage between p-adic and real worlds is in question and makes sense only in zero energy ontology. The reason is that various quantum numbers in real and p-adic sectors are not in general comparable in positive energy ontology so that conservation laws would be broken or even cease to make sense.

2. The transformation of intention to action can occur if the partonic 2-surfaces and their 4-D tangent space-distributions are representable using rational functions with rational (or even algebraic) coefficients in preferred coordinates for the imbedding space dictated by symmetry considerations. Intentional systems must live in the intersection of real and p-adic worlds.

3. For the minimal option life would be also effectively 2-dimensional phenomenon and essentially a boundary phenomenon as also number theoretical criticality suggests. There are good reasons to expect that only the data from the intersection of real and p-adic partonic two-surfaces appears in U-matrix so that only the data from rational and some algebraic points of the partonic 2-surface dictate U-matrix. This means discretization at parton level and something which might be called number theoretic quantum field theory should emerge as a description of intentional action.

A good guess is that algebraic entanglement is essential for quantum computation, which therefore might correspond to a conscious process. Hence cognition could be seen as a quantum computation like process, a more approriate term being quantum problem solving [24]. Living-dead dichotomy could correspond to rational-irrational or to algebraic-transcendental dichotomy: this at least when life is interpreted as intelligent life. Life would in a well defined sense correspond to islands of rationality/algebraicity in the seas of real and p-adic continua. Life as a critical phenomenon in the number theoretical sense would be one aspect of quantum crticality of TGD Universe besides the criticality of the space-time dynamics and the criticality with respect to phase transitions changing the value of Planck constant and other more familiar criticalities. How closely these criticalities relate remains an open question [26].

The view about the crucial role of rational and algebraic numbers as far as intelligent life is considered, could have been guessed on very general grounds from the analogy with the orbits of a dynamical system. Rational numbers allow a predictable periodic decimal/pinary expansion and are analogous to one-dimensional periodic orbits. Algebraic numbers are related to rationals by a finite

number of algebraic operations and are intermediate between periodic and chaotic orbits allowing an interpretation as an element in an algebraic extension of any p-adic number field. The projections of the orbit to various coordinate directions of the algebraic extension represent now periodic orbits. The decimal/pinary expansions of transcendentals are un-predictable being analogous to chaotic orbits. The special role of rational and algebraic numbers was realized already by Pythagoras, and the fact that the ratios for the frequencies of the musical scale are rationals supports the special nature of rational and algebraic numbers. The special nature of the Golden Mean, which involves $\sqrt{5}$, conforms the view that algebraic numbers rather than only rationals are essential for life.

Hyper-finite factors of type II$_1$ and NMP

Hyper-finite factors of type II$_1$ bring in additional delicacies to NMP. The basic implication of finite measurement resolution characterized by Jones inclusion is that state function reduction can never reduce entanglement completely so that entire universe can be regarded as an infinite living organism. It would seem that entanglement coefficients become $\mathcal{N}$ valued and the same is true for eigen states of density matrix. For quantum spinors associated with $\mathcal{M}/\mathcal{N}$ entanglement probabilities must be defined as traces of the operators $\mathcal{N}$. An open question is whether entanglement probabilities defined in this manner are algebraic numbers always (as required by the notion of number theoretic entanglement entropy) or only in special cases.

2.2.3   Quantum self

In the following the notion of self is introduced. To avoid confusions it must be emphasised that the notion of self is completely general and by no means restricted to brain. Brain consciousness is in this framework only a special form of consciousness.

The notions of self and subjective memory

The simplest hypothesis is that the contents of consciousness are determined by single quantum jump. There are several objections to this view.

1. The idea about self as a continuous stream of consciousness is very attractive and it seems difficult to believe that our consciousness could be actually a sequence of moments of consciousness with gaps between.

2. Furthermore, if the contents of consciousness are determined completely by the initial and final states of single quantum jump, we cannot have any memories about our previous conscious experiences. Hence subjective memories should be only pseudo memories perhaps resulting from the simulations of the subjective past.

  It took quite a long time to realize the real strength of these objections and to discover that a proper quantum definition of the concept of self provides a manner to overcome these obstacles.

1. Entanglement is one of the basic non-classical notions of quantum theory.

    (a) Un-entangled sub-system, as opposed to an entangled one, behaves as its own sub-universe and can be regarded as a pure quantum state. The natural guess is that self should be identified as a sub-system able to remain unentangled in subsequent quantum jumps. The self lasting only single quantum jump can be also regarded formally as self. This kind of a definition looks intuitively satisfactory since me-external world separation is a basic characteristic of everyday consciousness.

    (b) Spiritual practices however speak about quite different states of consciousness in which a fusion to a sea of consciousness takes place. Self in the sense of ego is lost but not consciousness. The generation of negentropic entanglement could be the correlate for these experiences whereas the reduction of entropic entanglement would be characterstic of the experiences with me-external world separation.

2. The entanglement between real and p-adic space-time regions is possible if entanglement proabilities are algebraic numbers [29]. In this case the entangement entropy can be negative and minimum for a unique choice of prime defining the p-adic norm. Negentropic entanglement can become only more negentropic in quantum jump and can be stable against NMP. This means a period of macrotemporal cognitive quantum coherence during which a sequence of quantum jumps is effectively fused to a single quantum jump. A natural hypothesis is that negentropic entanglement is possible in the intersection of real and p-adic worlds which by definition consists of partonic 2-surfaces for which mathematical representation makes sense in both real and p-adic number fields. Rational functions for which the defining polynomials have rational coefficients represents the simplest example of this kind of situation. The interpretation of the negentropic entanglement as a correlate for a conscious rule or association is natural. Negentropically entangled Schrödinger cat knows that it is better to not open the bottle.

3. The hypothesis that the experiences of self associated with the quantum jumps occurred after the "wake-up" (the quantum jump during which U made sub-system unentangled or created unentangled subsystem) sum up to single experience, implies that self can have memories about earlier moments of consciousness. Therefore the self becomes an extended object with respect to the subjective time and has a well defined "personal history". Subjective memory has a natural identification as a short term memory with a duration of order second.

4. If the temporal binding of experiences involves some kind of averaging, that is, if quantum statistical determinism generalizes to the level of the subjective experience, the total experience defined by the heap of the experiences associated with individual quantum jumps is reliable.

5. Self can have sub-selves: this corresponds geometrically to a space-time sheet having smaller space-time sheets glued to it. An irreducible self is defined as a self having no sub-selves. Reducible and irreducible selves give rise to two modes of consciousness identifiable as ordinary and "whole-body" consciousness.

6. The sub-selves of two selves can entangle if one allows the definition of sub-system concept based on p-adic length scale cutoff. Essentially this means that because of the p-adic length scale cutoff, the entanglement of sub-systems is not 'seen' at the level of systems so that they can remain unentangled. p-Adic length scale cutoff is natural since the wormhole contacts associated with topologically condensed space-time sheets are surrounded by 'elementary particle horizons' analogous to blackhole horizons. Therefore the larger space-time sheet 'sees' about topologically condensed space-time sheet only some quantum numbers like mass, spin and charge. There are two types of fusion of mental images corresponding to entropic bound state entanglement and negentropic entanglement. The latter could correspond to conscious mental images about rule, concept, or association with entangled state pairs representing instances of the abstraction. The entanglement of sub-systems makes possible fusion and sharing of mental images crucial for quantum communications. For instance, receiver can understand the message by sharing the mental image of the sender representing the understanding of the message.

7. Sub-system can wake-up (become conscious self) in several manners. The phase transitions $R \leftrightarrow R_p$ inside real/p-adic self generate new p-adic/real sub-selves. In fact, real–p-adic phase transitions could correspond to the transformation of sensory input into cognition and thought into action. Also the transitions $R_{p_1} \to R_{p_2}$ inside p_1-adic self generate new p_2-adic sub-selves.

Summation hypothesis and binding of experiences

The self X behaves essentially as a separate sub-Universe. Also the sub-selves of X_i of X have their own experiences. The question is: how the experience of X and experiences of X_i are related? The following basic hypothesis provides a possible answer to this question.

1. X experiences the sub-selves X_i as separate mental images superposed to the pure self experience of X: this is natural since sub-selves are unentangled and hence behave like separate sub-Universes.

2. The experiences of self X about the experiences of its sub-selves X_i are abstractions. Sub-self X_i experiences its sub-selves X_{ij} as separate mental images. X however experiences them as a

single mental image representing what it is to be a sub-self of X_i, that is the average $\langle X_{ij} \rangle$ of the mental images X_{ij}. Thus the mental images of sub-sub-...selves of X are smoothed out to an average mental image and become effectively unconcious to X. Averaging hypothesis generalizes quantum statistical determinism to the level of subjective experience and is analogous to the hypothesis about averaging related to temporal binding.

Temporal binding with averaging implies that the experiences of the individual selves are reliable and abstraction brings in the possibility of quantum statistical determinism at the level of ensembles. The inability to perceive the flickering of light when the frequency of the flickering is larger than about one Hz is consistent with the hypothesis that subjective sensory memory has duration of order .1 seconds and that temporal averaging indeed occurs. Time averaging could involve weighting such that the conscious experiences associated with the last quantum jumps have the largest weight. This would allow our self to have duration much longer than .1 seconds. For instance, the duration of the ordinary wake-up period could determine the duration of our self. The duration could be even longer: sleep could actually involve awareness and the lack of the sensory memories from sleep period could create the illusion about sleep as an unconscious state.

Summation hypothesis and temporal binding imply a hierarchy of conscious experiences with increasingly richer contents and at the top of the hierarchy is the entire universe, God, enjoying eternal self-consciousness since it cannot entangle with with any larger system. Also we are mental images of some higher level self. This hierarchy obviously has far-reaching consequences.

Binding of the experiencers by entanglement

The binding of experiencers is also possible. The binding of selves by quantum entanglement however means they lose their consciousness. This process naturally corresponds to the formation of wholes from their parts at the level of conscious experiences. The formation of a mental image (sub-self) representing word from the mental images representing letters is example of this process. Also the fusion of the left and right visual fields to a single visual field could occur via the entanglement of the corresponding sub-selves. Note however that right–left entanglement might occur already at neuronal level. Entanglement mechanism provides also a possible mechanism of "enlightment" experiences envolving extension of self [33, 27]. Quantum entanglement could make possible communication between selves belonging to different levels of the self hierarchy.

Stable entanglement and quantum metabolism as different sides of the same coin

The notion of binding has two meanings. Binding as a formation of bound state and binding as a fusion of mental images to larger ones essential for the functioning of brain and regarded as one the big problems of consciousness theory.

Only bound state entanglement and negentropic entanglement are stable against the state reduction process. Hence the fusion of the mental images implies the formation of a bound entropic state-in this case the two interpretations of binding are equivalent- or a negentropic state, which need not be bound state.

1. In the case of negentropic entanglement bound state need not be formed and the interesting possibility is that the negentropic entanglement could give rise to stable states without binding energy. This could allow to understand the mysterious high energy phosphate bond to which metabolic energy is assigned in ATP molecule containing three phosphates and liberated as ATP decays to ADP and phosphate molecule. Negentropic entanglement could also explain the stability of DNA and other highly charged biopolymers. In this framework the liberation of metabolic (negentropic) energy would involve dropping of electrons to a larger space-time sheets accompanying the process $ATP \rightarrow ADP + P_i$. A detailed model of this process is discussed in [19].

2. The formation of bound state entanglement is expected to involve a liberation of the binding energy and this energy might be a usable energy. This process could perhaps be coined as quantum metabolism and one could say that quantum metabolism and formation of bound states are different sides of the same coin. It is known that an intense neural activity, although it is accompanied by an enhanced blood flow to the region surrounding the neural activity,

does not involve an enhanced oxidative metabolism [58] (that is $ATP \rightarrow ADP$ process and its reversal). A possible explanation is that quantum metabolism accompanying the binding is involved. Note that the bound state is sooner or later destroyed by the thermal noise so that this mechanism would in a rather clever manner utilize thermal energy by applying what might be called buy now–pay later principle.

If these interpretations are correct, there would be two modes of metabolism corresponding to two different kinds of fusion of mental images.

How to understand evolution and self-organization?

One could argue that since the quantum jump is random (not actually since selection between the eigenstates of the density matrix occurs), quantum jump as a moment of consciousness identification cannot explain evolution. In standard physics it is difficult to circumvent this objection. Even worse, heat death seems to be the ultimate fate of the universe according to standard physics.

The fact that quantum jump involves localization in zero modes and thus localization into a definite sector D_P of configuration space labelled by infinite prime P, implies evolution as a statistical increase of P. Since infinite primes are in well-defined sense composites of finite primes, this in turn implies that the finite p-adic prime associated with a given sub-system tends to increase and that new space-time sheets labelled by finite primes emerge during the time evolution by quantum jumps.

This means that the concept of nearness defining the effective topology becomes gradually more refined, the complexity of the universe increases, and the maximal information contents of the conscious experience increase in the long run (like $p \times log(p)$ or at least as $log(p)$ as a function of p-adic prime characterizing the system). This is nothing but evolution. NMP, which states that entanglement negentropy gain maximal for allowed quantum jumps, enhances this tendency.

Quantum jumps between quantum histories make also possible genuine quantum self-organization. The concept of self-organization gets quite new additional meaning in TGD framework. Self-organization means also evolution of self-hierarchies (MEs inside MEs inside...). Self-organization by quantum jumps can be regarded as a hopping in the zero modes characterizing the macroscopic aspects of the space-time surface. Each self is a dissipative system which ends up to some asymptotic self-organization pattern in the presence of the external energy feed (or even without it). Dissipation is the ultimate Darwinian selector picking up the winning selves as favoured self organization patterns. Since sub-selves correspond to mental images, the immediate implication is that also memes are subject to similar selection. For instance, the formation of long term memories and habits could be understood as a formation of surviving sub-selves.

The proposed realization of the quantum criticality, besides making macroscopic quantum systems possible, in a well-defined sense maximizes the intelligence and complexity of the universe [41]. TGD universe is quantum spin glass and this adds additional aspect to the self-organization process. For instance, the energy landscape of the spin glass is fractal like structure containing valleys inside valleys and provides an ideal dynamical memory mechanism.

Quantum ethics very briefly

There are many manners to interpret evolution in TGD Universe.

1. p-Adic evolution would mean a gradual increase of the infinite p-adic prime characterizing the entire universe implying the gradual increase of p-adic primes characterizing individual partonic 2-surfaces and therefore their size. The identification of p-adic space-time sheets as representations for intentions and the identification of p-adic-to-real phase transitions as transformations of intentions to real actions gives additional concreteness to this vision.

2. The hierarchy of Planck constants suggests evolution as the gradual increase of the Planck constant characterizing p-adic space-time sheet (or partonic 2-surface for the minimal option). This evolution could be seen as a migration to the pages of the book like structure defined by the generalized imbedding space and has therefore quite concrete geometric meaning. It implies longer time scales of long term memory and planned action and macroscopic quantum coherence in longer scales.

3. The vision about life as something in the intersection of real and p-adic words allows to see evolution information theoretically as the increase of number entanglement negentropy implying entanglement in increasing length scales. This option is consistent with the first one if the effective p-adic topology characterizes the real partonic 2-surfaces in the intersection of p-adic and real worlds. The singular coverings of CD s and CP_2 are characterized by an Abelian group Z_n permuting the sheets of the covering and corresponds naturally to powers of the (quantum) phase $q = exp(i2\pi/n)$ allowing to define the notion of angle in p-adic context but only with a finite resolution since only finite number of angles are represented as phases for a given value of n. The increase of the integers n could be interpreted as the emergence of higher algebraic extensions of p-adic numbers in the intersection of the real and p-adic worlds. These observations suggest that all three views about evolution are closely related.

The third kind of evolution would mean also the evolution of spiritual consciousness if the proposed interpretation is correct. In each quantum jump U-process generates a superposition of states in which any sub-system can have both real and algebraic entanglement with the external world. If state function redution process involves also the choice of the type of entanglement it could be interpreted as a choice between good and evil. The hedonistic complete freedom resulting as the entanglement entropy is reduced to zero on one hand, and the algebraic bound state entanglement implying correlations with the external world and meaning giving up the maximal freedom on the other hand. The selfish option has the risk of leading to non-algebraic bound state entanglement implying a loss of consciousness: death as the prize of sin. The second option means expansion of consciousness - a fusion to the ocean of consciousness as described by spiritual practices.

In this framework one could therefore understand the physics correlates of ethics and moral. The ethics is simple: evolution of consciousness to higher levels is a good thing. Anything which tends to reduce consciousness represents violence and is a bad thing. Moral rules are related to the relationship between indvidual and society and presumably develop via self-organization process and are by no means unique. Moral rules however tend to optimize evolution. As blind normative rules they can however become a source of violence identified as any action which reduces the level of consciousness.

There is an entire hierarchy of selves and every self has the selfish desire to survive and moral rules develop as a kind of compromise and evolve all the time. The newest progress in this evolution is brought by the cosmology of consciousness, which forces to extend the concept of society to four-dimensional society! The decisions of "me now" affect both my past and future and time like quantum entanglement makes possible conscious communication in time direction by sharing conscious experiences. One can therefore speak of genuinely four-dimensional society. Besides my next-door neighbors I had better to take into account also my nearest neighbors in past and future (the nearest ones being perhaps copies of me!). If I make wrong decisions those copies of me in future and past will suffer the most. Perhaps my personal hell and paradise are here and are created mostly by me.

Selves can make plans since they have 4-dimensional geometric memory (conscious experience contains information about a *four-dimensional* space-time region, rather than only time=constant snapshot, and gives rise to a "prophecy", a prediction for the future and past, which would be reliable if the world were completely classical). As a matter fact, it is p-adic space-time sheets which correspond to intentions and plans and act of volition transforms p-adic space-time sheet to a real one. Selves can make decisions and select between various classical macroscopic time developments. Selves are able to remember their choices since they have subjective memories about the previous quantum jumps. Thus selves are genuine moral agents.

Implications of the dark matter hierarchy for the notion of self

The identification of dark matter as phases having large value of Planck constant [17, 16, 24] led to a vigorous evolution of ideas still continuing while I am writing this addendum to the original text. Entire dark matter hierarchy with levels labelled by increasing values of Planck constant is predicted, and in principle TGD predicts the values of Planck constant if physics as a generalized number theory vision is accepted [24]. Also a good educated guess for the spectrum of Planck constants emerges. The implications are non-trivial already at the level of hadron physics and nuclear physics and imply that condensed matter physics and nuclear physics are not completely disjoint disciplines as reductionism teaches us. One condensed matter application is a model of high T_c superconductivity predicting that the basic length scales of cell membrane and cell as scales are inherent to high T_c superconductors.

1. Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [22]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [29, 22]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [22].

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of $\hbar$ at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

2. Dark matter hierarchy and the notion of self

The vision about dark matter hierarchy leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [16, 22]. The hierarchy of dark matter levels is labeled by the values of Planck constant having quantized but arbitrarily large values. For the most general option the values of $\hbar$ are products and ratios of two integers. The products of distinct Fermat primes and power of two are number theoretically favored values for these integers. p-Adic length scale hypothesis favors powers of two. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T \propto \hbar$ of the quantum jump.

Dark matter hierarchy suggests also a slight modification of the notion of self. Each self involves a hierarchy of dark matter levels, and one is led to ask whether the highest level in this hierarchy corresponds to single quantum jump rather than a sequence of quantum jumps. The averaging of conscious experience over quantum jumps would occur only for sub-selves at lower levels of dark matter hierarchy and these mental images would be ordered, and single moment of consciousness would be experienced as a history of events. One can ask whether even entire life cycle could be regarded as a single quantum jump at the highest level so that consciousness would not be completely lost even during deep sleep. This would allow to understand why we seem to know directly that this biological body of mine existed yesterday.

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self corresponds at the highest dark matter level to single moment of consciousness. Self would experience the average over the sequence of moments of consciousness associated with each sub-self but there would be no averaging over the separate mental images of this kind, be their parallel or serial. These mental images correspond to sub-selves having shorter wake-up periods than self and would be experienced as being time ordered. Hence the digits in the phone number are experienced as separate mental images and ordered with respect to experienced time.

2.2.4   About geometric correlates of selves

Space-time sheets with a finite time duration serve as geometric correlates for selves. There are several questions to answer. For instance, one should understand how the conscious experiences associated with the p-adic and real space-time sheets differ. Also one should understand how psychological time and its arrow emerge in this picture.

Cognition, imagination and p-adic physics

The problem about geometric correlates of cognition is not yet completely resolved. An important problem is what one understands with cognition and loose definitions might generate additional confusion. Intuitively it is clear that cognition should correspond to thinking. The simplest model for logical thinking is based on Boolean algebra: one could however argue that 'this is true' experiences are actually much like ordinary sensory experiences. Besides true/false dichotomy there are also

beatiful/ugly and right/wrong dichotomies which suggests that aesthetics, moral, and logic might correspond to various aspects of some Boolean structure having physical interpretation and that cognition involves logic as one aspect only. Imagination is an important aspect of thinking and one could also consider the identification of the most fundamental aspect of cognition as imagination and perhaps even identify cognition as imagination.

The notion of the many-sheeted space-time decomposing into real and p-adic space-time sheets, and the classical non-determinism of the Kähler action making possible experiences with temporally localized information contents, are the key elements of TGD based model of consciousness.

The notions of mindlike space-time sheet (space-time sheet with a finite temporal duration) and association sequence were originally identified as geometric correlates of thoughts quite generally. On the other hand, the inherent non-determinism of p-adic differential equations means that the solutions of p-adic counterparts of field equations consist of pieces which are characterized by ordinary integration constants glued together. This is very much like the non-determinism of imagination and dreams, and inspires the hypothesis that p-adic space-time sheets serve as cognitive representations.

Real mindlike space-time would be the geometric correlates of sensory mental images rather than cognition. The difference between real and imagined experiences would correspond to real–p-adic distinction. One must be however very cautious here: one cannot exclude the possibility that also cognition is one aspect of sensory experience and that the notion of imagined cognition makes sense. It is also somewhat a convention, what is counted as cognition.

What we regard as imagination presumably involves p-adic–to–real transitions giving rise to initial values determining nerve pulse patterns generating almost motor actions and almost sensory perceptions Also cell membrane oscillation patterns could represent imagination whereas nerve pulses give rise to sensory experiences. Thus p-adic physics would represent the core element of imagination and cognition. There are still unclear points: what seems certain that p-adic physics represents intentionality but one can debate about whether it represents also imagination and cognition.

What space-time surfaces look like?

The notion of the space-time surface appears often in the sequel and deserves some explaining. Mathematician's notion of the space-time surface is more general than the intuitive notion about it. For instance, space-time surface can be union of disjoint surfaces (2-D visualization: 2-surface can consist of several disjoint 2-surfaces: sphere here and piece of plane there,..). Space-time sheet is near to what one intuitively would understand with a space-time surface.

The TGD based notion of space-time surface is roughly the following.

1. One obtains piece of Minkowski space as a 4-surface defined by putting CP_2 coordinates constant: this is simplest kind of a vacuum extremal. By suitably deforming one obtains infinitely many vacuum extremals. Vacuum extremals can have finite time duration: in this case they correspond to mindlike space-time sheets.

2. Allowing several values for CP_2 coordinates one obtains several 'parallel' pieces of Minkowski space which can be deformed to more general vacuum extremals. These sheets can be glued together by wormhole contacts and deformed so that they are not vacua anymore.

3. By gluing extremely small surfaces representing elementary particles to this complex one obtains a rough view about what TGD space-time surface looks like.

4. Besides real regions there are also p-adic regions but these look like fractal dust in real topology. p-Adic and real regions are glued together at rational points of imbedding space.

Two-dimensional visualization might also help. Put z-coordinate constant in 3-space and allow several values of z-coordinate: you get several parallel pieces of plane. Deform them and glue them together by wormhole contacts. Glue elementary particle like surfaces, represented by, say, extremely tiny spheres and tori.

Association sequences and mindlike space-time sheets

The concepts of mindlike space-time sheet and association sequence are crucial for TGD based quantum model of intelligent system [41].

Mindlike space-time sheets are geometric correlates of selves (see Fig. 2). They are made possible by the huge vacuum degeneracy of the Kähler action, TGD and more standard theories of physics. By gluing vacuum extremals to nonvacuum space-time surfaces and suitably deforming, one obtains new degenerate absolute minima. One manner to see mindlike space-time sheets is as the classical counterparts of the virtual particles of the quantum field theories (in TGD particles are 3-surfaces!) created from vacuum and returning to it. By definition material space-time sheets have infinite temporal extension whereas mindlike space-time sheets have *finite* temporal extension. Finite temporal extension is possible since classical conserved quantities like energy can flow to mindlike space-time sheet begins and flow back to a material space-time sheet when mindlike space-time sheet ends. The finite temporal extension implies that the information contents of the conscious experiences for selves associated with the mindlike space-time sheets are temporally localized. Thus a rough idea about the origin of the psychological time emerges. Mindlike space-time sheets provide cognitive representations for the material space-time sheets to which they are glued by wormhole contacts and/or join along boundaries contacts. Since the sign of the classical energy in TGD correlates with the time orientation of the space-time sheet, pairs of mindlike space-time sheets with vanishing net energy are possible. Direct mimicry is the simplest possible cognitive representation and this kind of a two-sheeted structure makes it possible! If this is indeed true, TGD universe would be physicist's version of the computer scientist's universe populated by computers emulating each other.

The original belief was that association sequence provides a model for thought understood as a simulation of the classical time development. This model does not necessitate p-adicity and one can ask whether all cognition is p-adic or whether also real cognition based on the classical non-determinism of Kähler action is possible. It is quite possible that the classical non-determinism of Kähler action provides sensory rather than cognitive simulation of the classical time development in the real context. This simulation could be naturally regarded as a symbolic representation whereas p-adic nondeterminism would make possible cognitive representations. Thus real association sequences would make possible language as symbolic representation of thoughts rather than thoughts as believed originally.

1. The original motivation of the association sequence concept is the vacuum degeneracy of the Kähler action. p-Adic non-determinism gives also rise to association sequences. This degeneracy implies classical non-determinism in the sense that the absolute minimum $X^4(Y^3)$ of the Kähler action associated with a given spacelike 3-surface Y^3 on lightcone boundary $\delta M_+^4 \times CP_2$ is not unique in general. In order to get rid of this non-determinism one must generalize the concept of 3-surface. "Association sequences", defined as 3-surfaces consisting of unions of some minimal number of disjoint 3-surfaces with timelike(!) separations, must be allowed (see Fig. 1) in order to fix uniquely which degenerate absolute minimum is in question.

2. A simple model for association sequence is obtained by considering a non-deterministic motion of a point in, say, plane. Suppose that there are N bifurcations. One can clearly fix single branch by fixing $N + 1$ points on the orbit. The union of these points, which have time like distances and are not clearly unique, defines association sequence. Non-determinism brings in finite number of degrees of freedom characterized by a sequence of N binary digits.

3. Association sequence provides a simulation of the classical time evolution and gives rise to what might be called "geometric memory" involved with the intentional aspects of consciousness (planning, expectations, desires,...). Geometric memory can be regarded as a "prophecy" for what will happen and what must have happened earlier provided the world were classical (no quantum jumps replacing the macroscopic classical space-time with a new one). Each quantum jump involves naturally a comparison of the expected time development provided by the "geometric memory" and the actual subjective time development stored in the subjective memory.

4. Association sequences of ... of association sequences are also possible and the average spatial and temporal distances ΔL and ΔT between fundamental building blocks of the association sequence give measures for the temporal and spatial resolutions of the cognitive/sensory representation provided by the association sequence.
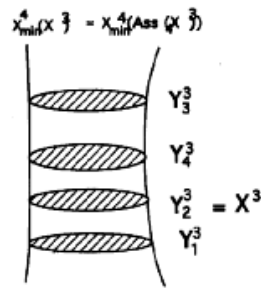
Figure 2.1: 'Association sequence': a geometric model for cognitive/sensory simulation as a sequence of disjoint 3-surfaces with timelike separations.

The notions of mindlike space-time sheet and association sequence are frustratingly abstract concepts. It has however become clear that MEs (massless extremals) provide very general, if not even universal, identification for the geometric correlates of selves. The lightlike boundaries of MEs carry representations of superconformal and super-symplectic algebras and act as quantum holograms. The general concepts of quantum information theory, the notion of quantum hologram in the sense of both quantum information theory and quantum gravity, and perhaps even quantum computation (in a suitably generalized sense) at the lightlike boundaries of MEs, seem to emerge as basic aspects of TGD inspired theory of conscious information processing.

A genuinely TGD based aspect is the possibility of negative time orientations making possible MEs carrying negative energies and representing classical signals proceeding into the direction of the geometric past, and the communication to the direction of the geometric past distinguishes TGD based and ordinary quantum information theory. This is especially interesting from the viewpoint of lightlike quantum computation since the classical restrictions coming from the huge length of MEs for reasonable computation times can be circumvented.

Space-time and imbedding space correlates for selves in zero energy ontology

Quantum jump as a moment of consciousness, self as a sequence of quantum jumps integrating to self, and self hierarchy with sub-selves experienced as mental images, are the basic notions of TGD inspired theory of consciousness. In the most ambitious vision self hierarchy reduces to a fractal hierarchy of quantum jumps within quantum jumps. Quantum classical correspondence demands selves to have space-time correlates both at the level of space-time and imbedding space.

At the level of space-time the first guess for the correlates is as light-like or space-like 3-surfaces. If one believes on effective 2-dimensionality and quantum holography, partonic 2-surfaces plus their 4-D tangent space distribution would code the information about the space-time correlates. By quantum classical correspondence one can also identify space-time sheets as the correlates modulo the gauge degeneracy implied by super-conformal symmetries.

It is natural to interpret CDs as correlates of selves at the level of the imbedding space. CDs can be interpreted either as subsets of the generalized imbedding space or as sectors of WCW. Accordingly, selves correspond to CDs of the generalized imbedding space or sectors of WCW, literally separate interacting quantum Universes. The spiritually oriented reader might speak of Gods. Sub-selves correspond to sub-CDs geometrically. The contents of consciousness of self is about the interior of the corresponding CD at the level of imbedding space. For sub-selves the wave function for the position of tip of CD brings in the delocalization of sub-WCW.

The fractal hierarchy of CDs within CDs is the geometric counterpart for the hierarchy of selves: the quantization of the time scale of planned action and memory as $T(k) = 2^k T_0$ suggest an interpretation for the fact that we experience octaves as equivalent in music experience.

2.2.5   Questions related to the notion of self

I have proposed two alternative notions of self and have not been able to choose between them. A further question is what happens during sleep: do we lose consciousness or is it that we cannot remember anything about this period? The work with the model of topological quantum computation has led to an overall view allowing to select the most plausible answer to these questions. But let us be cautious!

Can one choose between the two variants for the notion of self or are they equivalent?

I have considered two different notions of "self" and it is interesting to see whether the new view about time might allow to choose between them or to show that they are actually equivalent.

1. In the original variant of the theory "self" corresponds to a sequence of quantum jumps. "Self" would result through a binding of quantum jumps to single "string" in close analogy and actually in a concrete correspondence with the formation of bound states. Each quantum jump has a fractal structure: unitary process is followed by a sequence of state function reductions and preparations proceeding from long to short scales. Selves can have sub-selves and one has self hierarchy. The questionable assumption is that self remains conscious only as long as it is able to avoid entanglement with environment.

   Even slightest entanglement would destroy self unless on introduces the notion of finite measurement resolution applying also to entanglement. This notion is indeed central for entire quantum TGD also leads to the notion of sharing of mental images: selves unentangled in the given measurement resolution can experience shared mental images resulting as fusion of sub-selves by entanglement not visible in the resolution used.

2. According to the newer variant of theory, quantum jump has a fractal structure so that there are quantum jumps within quantum jumps: this hierarchy of quantum jumps within quantum jumps would correspond to the hierarchy of dark matters labeled by the values of Planck constant. Each fractal structure of this kind would have highest level (largest Planck constant) and this level would corresponds to the self. What might be called irreducible self would corresponds to a quantum jump without any sub-quantum jumps (no mental images). The quantum jump sequence for lower levels of dark matter hierarchy would create the experience of flow of subjective time.

It would be nice to reduce the original notion of self hierarchy to the hierarchy defined by quantum jumps. There are some objections against this idea. One can argue that fractality is a purely geometric notion and since subjective experience does not reduce to the geometry it might be that the notion of fractal quantum jump does not make sense. It is also not quite clear whether the reasonable looking idea about the role of entanglement as destroyer of self can be kept in the fractal picture.

These objections fail if one can construct a well-defined mathematical scheme allowing to understand what fractality of quantum jump at the level of space-time correlates means and showing that the two views about self are equivalent. The following argument represents such a proposal. Let us start from the causal diamond model as a lowest approximation for a model of zero energy states and for the space-time region defining the contents of sensory experience.

Let us make the following assumptions.

1. Assume the hierarchy of causal diamonds within causal diamonds in a sense to be specified more precisely below. Causal diamonds would represent the volumes of attention. Assume that the highest level in this hierarchy defines the quantum jump containing sequences of lower level quantum jumps in some sense to be specified. Assume that these quantum jumps integrate to single continuous stream of consciousness as long as the sub...-sub-self in question remains unentangled and that entangling means loss of consciousness or at least that it is not possible to remember anything about contents of consciousness during entangled state.

2. Assume that the contents of conscious experience come from the interior of the causal diamond. A stronger condition would be that the contents come from the boundaries of the two light-cones involved since physical states are defined at these in the simplest picture. In this case one could identify the lower light-cone boundary as giving rise to memory.

3. The time span characterizing the contents of conscious experience associated with a given quantum jump would correspond to the temporal distance T between the tips of the causal diamond. T would also characterize the average and approximate shift of the superposition of space-time surfaces backwards in geometric time in single quantum jump at a given level of hierarchy. This time scale naturally scales as $T_n = 2^n T_{CP_2}$ so that p-adic length scale hypothesis follows as a consequence. T would be essentially the secondary p-adic time scale $T_{2,p} = \sqrt{p} T_p$ for $p \simeq 2^k$. This assumption - absolutely essential for the hierarchy of quantum jumps within quantum jumps - would differentiate the model from the model in which T corresponds to either CP_2 time scale or p-adic time scale T_p. One would have hierarchy of quantum jumps with increasingly longer time span for memory and with increasing duration of geometric chronon at the highest level of fractal quantum jump. Without additional restrictions, the quantum jump at n^{th} level would contain 2^n quantum jumps at the lowest level of hierarchy. Note that in the case of sub-self - and without further assumptions which will be discussed next - one would have just two quantum jumps: mental image appears, disappears or exists all the time. At the level of sub-sub-selves 4 quantum jumps and so on. Maybe this kind of simple predictions might be testable.

4. We know that that the contents of sensory experience comes from a rather narrow time interval of duration about .1 seconds, which corresponds to the time scale T_{127} associated with electron. We also know that there is asymmetry between positive and negative energy parts of zero energy states both physically and at the level of conscious experience. This asymmetry must have some space-time correlate. The simplest correlate for the asymmetry between positive and negative energy states would be that the upper light-like boundaries in the structure formed by light-cones within light-cones intersect along light-like radial geodesic. No condition of this kind would be posed on lower light-cone boundaries. The scaling invariance of this condition makes it attractive mathematically and would mean that arbitrarily long time scales T_n can be present in the fractal hierarchy of light cones. At all levels of the hierarchy all contribution from upper boundary of the causal diamond to the conscious experience would come from boundary of same past directed light-cone so that the conscious experience would be sharply localized in time in the manner as we know it to be. The new element would be that content of conscious experience would come from arbitrarily large region of Universe and seing Milky Way would mean direct sensory contact with it.

5. These assumptions relate the hierarchy of quantum jumps to p-adic hierarchy. One can also include also dark matter hierarchy into the picture. For dark matter hierarchy the time scale hierarchy $\{T_n\}$ is scaled by the factor $r = \hbar/\hbar_0$ which can be also rational number. For $r = 2^k$ the hierarchy of causal diamonds generalizes without difficulty and there is a kind of resonance involved which might relate to the fact that the model of EEG favors the values of $k = 11n$, where $k = 11$ also corresponds in good approximation to proton-electron mass ratio. For more general values of $\hbar/\hbar_0$ the generalization is possible assuming that the position of the upper tip of causal diamond is chosen in such a manner that their positions are always the same whereas the position of the lower light-cone boundary would correspond to $\{rT_n\}$ for given value of Planck constant. Geometrically this picture generalizes the original idea about fractal hierarchy of quantum jumps so that it contains both p-adic hierarchy and hierarchy of Planck constants.

The contributions from lower the boundaries identifiable in terms of memories would correspond to different time scales and for a given value of time scale T the net contribution to conscious experience would be much weaker than the sensory input in general. The asymmetry between geometric now and geometric past would be present for all contributions to conscious experience, not only sensory ones. What is nice that the contents of conscious experience would rather literally come from the boundary of the past directed light-cone along which the classical signals arrive. Hence the mystic feeling about telepathic connection with a distant object at distance of billions of light years expressed by an astrophysicist, whose name I have unfortunately forgotten, would not be romantic self deception.

This framework explains also the sharp distinction between geometric future and past (not surprisingly since energy and time are dual): this distinction has also been a long standing problem of TGD inspired theory of consciousness. Precognition is not possible unless one assumes that communications and sharing of mental images between selves inside disjoint causal diamonds is possible. Physically there seems to be no good reason to exclude the interaction between zero energy states associated with disjoint causal diamonds.

The mathematical formulation of this intuition is however a non-trivial challenge and can be used to articulate more precisely the views about what configuration space and configuration space spinor fields actually are mathematically.

1. Suppose that the causal diamonds with tips at different points of $H = M^4 \times CP_2$ and characterized by distance between tips T define sectors CH_i of the full configuration space CH ("world of classical worlds"). Precognition would represent an interaction between zero energy states associated with different sectors CH_i in this scheme and tensor factor description is required.

2. Inside given sector CH_i it is not possible to speak about second quantization since every quantum state correspond to a single mode of a classical spinor field defined in that sector.

3. The question is thus whether the Clifford algebras and zero energy states associated with different sectors CH_i combine to form a tensor product so that these zero energy states can interact. Tensor product is required by the vision about zero energy insertions assignable to CH_i which correspond to causal diamonds inside causal diamonds. Also the assumption that zero energy states form an ensemble in 4-D sense - crucial for the deduction of scattering rates from M-matrix - requires tensor product.

4. The argument unifying the two definitions of self requires that the tensor product is restricted when CH_i correspond to causal diamonds inside each other. The tensor factors in shorter time scales are restricted to the causal diamonds hanging from a light-like radial ray at the upper end of the common past directed light-cone. If the causal diamonds are disjoint there is no obvious restriction to be posed, and this would mean the possibility of also precognition and sharing of mental images.

This scenario allows also to answers the questions related to a more precise definition of volume of attention. Causal diamond - or rather - the associated light-like boundaries containing positive and negative energy states define the primitive volume of attention. The obvious question whether the attention of a given self is doomed to be fixed to a fixed volume can be also answered. This is not the case. Selves can delocalize in the sense that there is a wave function associated with the position of the causal diamond and quantum jumps changing this position are possible. Also many-particle states assignable to a union of several causal diamonds are possible. Note that the identification of magnetic flux tubes as space-time correlates of directed attention in TGD inspired quantum biology makes sense if these flux tubes connect different causal diamonds. The directedness of attention in this sense should be also understood: it could be induced from the ordering of p-adic primes and Planck constant: directed attention would be always from longer to shorter scale.

Does sleep state involve a loss of consciousness?

The ability to avoid entropic entanglement with environment is essential for the original notion of self and in the case of sub-selves it would explain the finite life-time of mental images. Algebraic entanglement can be however negentropic and the idea that its generation does not lead to a loss of consciousness is attractive. If sleep really means a loss of consciousness it must lead to a generation of entropic entanglement. But does this really happen? Could sleep only lead to a loss of consciousness at those levels of self hiererachy responsible for conscious memories, which correspond to mental images and thus sub-CDs located in those space-time regions of CD, where the sleeping occurs?

Is the assumption about the loss of consciousness during sleep really necessary? Can one imagine good reasons for why we should remain conscious during sleep?

1. One could argue that if consciousness is really lost during sleep, we could not have the deep conviction that we existed yesterday.

2. Second argument is based on the assumption that brains are acting as topological quantum computers during sleep. During an ideal topological quantum computation the entanglement with the surrounding world is absent and thus topological quantum computation should correspond to a conscious experience with a vanishing entanglement entropy. Night time is the best time for topological quantum computation since sensory input and motor action do not take metabolic resources and we certainly do problem solving during sleep. Thus we should be conscious at

some level during sleep and perform quite a long topological quantum computation. The problem with this argument is that the ideal topological quantum computation could be performed by a larger system than brain so that ability to perform topological quantum computation does not allow to conclude whether we are conscious during sleep or not. In fact, the idea that large number of brains entangle to a larger unit giving rise to a stereo consciousness about what it is to be human besides performing topological quantum computation like processes, is rather attractive.

Could it then be that we do not remember anything about the period of sleep because our attention is directed elsewhere and memory recall uses only copies of "me" assignable to brain manufacturing standardized mental images? Perhaps the communication link to the mental images during sleep experienced at dark matter levels of existence is lacking or sensory input and motor activities of busy westeners do not allow to use metabolic energy to build up this kind of communications. Hence one can at least half-seriously ask, whether self is actually eternal with respect to the subjective time and whether entangling with some system means only diving into the ocean of consciousness as someone has expressed it. Could we be Gods as also quantum classical correspondence in the reverse direction suggests (p-adic cognitive space-time sheets have literally infinite size in both temporal and spatial directions)?

2.3 Quantum information processing in living matter

The notion of magnetic body leads to a dramatic modification of the views about functions of brain. In the following the discussion the the new vision about life as number theoretically critical phenomenon is not discussed separately.

2.3.1 Magnetic body as intentional agent and experiencer

In TGD Universe brain would be basically a builder of symbolic representations assigning a meaning to the sensory input by decomposing sensory field to objects and making possible effective motor control by magnetic body containing dark matter. A concrete model for how magnetic controls biological body and receives information from it is discussed in the model for the hierarchy of EEGs [22].

Also magnetic body could have sensory qualia, which should be in a well-defined sense more refined than ordinary sensory qualia [24]. The quantum number increments associated with cyclotron phase transitions of dark ion cyclotron condensates at magnetic body could correspond to emotional and cognitive content of sensory input and would indeed have interpretation as higher level sensory qualia. Right brain sings – left brain talks metaphor would characterize this emotional-cognitive distinction for higher level qualia and would correspond to coding of sensory input from brain by frequency patterns *resp.* temporal patterns (analogs of phonemes). These qualia would be somatosensory qualia at the level of magnetic body.

Remote mental interactions between magnetic body and biological body are a key element of this picture. Remote mental interactions in the usual sense of the world would occur between magnetic body and some other, not necessary biological, body. This would include receival of sensory input from and motor control of other than own body. Also "dead" matter possesses magnetic bodies so that also psychokinesis would be based on the same mechanism. Magnetic body for which dissipation is much smaller than for ordinary matter (proportional to $1/\hbar$, would presumably continue its conscious existence after biological death and find another biological body and use it as a tool of sensory perception and intentional action.

2.3.2 Summary about the possible role of the magnetic body in living matter

The notion of magnetic/field body is probably the feature of TGD inspired theory of quantum biology which creates strongest irritation in standard model physicist. A ridicule as some kind of Mesmerism might be the probable reaction. The notion of magnetic/field body has however gradually gained more and more support and it is now an essential element of TGD based view about living matter. In the following I list the basic applications in the hope that the overall coherency of the picture might

force some readers to take this notion seriously. I will talk only about magnetic body although it is clear that field body has also electric parts as well as radiative parts realized in terms of "massless extremals" or topological light rays.

In the following discussion the possible implications of the idea that living matter resides in the intersection of real and p-adic worlds is not taken into account. An attractive working hypothesis is that negentropic entanglement can be assigned to the magnetic bodies. For instance, the ends of the magnetic flux tubes connecting (say) biomolecules could be entangled negentropically. This idea has been already applied to explain the stability of high energy phosphate bond and of DNA polymers, which are highly charged [19].

Anatomy of magnetic body

Consider first the anatomy of the magnetic body.

1. Magnetic body has a fractal onion like structure with decreasing magnetic field strengths and the highest layers can have astrophysical sizes. Cyclotron wave length gives an estimate for the size of particular layer of magnetic body. $B = .2$ Gauss is the field strength associated with a particular layer of the magnetic body assignable to vertebrates and EEG. This value is not the same as the nominal value of the Earth's magnetic field equal to .5 Gauss. It is quite possible that the flux quanta of the magnetic body correspond to those of wormhole magnetic field and thus consist of two parallel flux quanta which have opposite time orientation. This is true for flux tubes assigned to DNA in the model of DNA as a topological quantum computer.

2. The layers of the magnetic body are characterized by the values of Planck constant and the matter at the flux quanta can be interpreted as macroscopically quantum coherent dark matter. This picture makes sense only if one accepts the generalization of the notion of imbedding space.

3. In the case of wormhole magnetic fields it is natural to assign a definite temporal duration to the flux quanta and the time scales defined by EEG frequencies are natural. In particular, the inherent time scale .1 seconds assignable to electron as a duration of zero energy space-time sheet having positive and negative energy electron at its ends would correspond to 10 Hz cyclotron frequency for ordinary value of Planck constant. For larger values of Planck constants the time scale scales as $\hbar$. Quite generally, a connection between p-adic time scales of EEG and those of electron and lightest quarks is highly suggestive since light quarks play key role in the model of DNA as topological quantum computer.

4. TGD predicts also hierarchy of scaled variants of electro-weak and color physics so that ZXG, QXG, and GXG corresponding to Z^0 boson, W boson, and gluons appearing effectively as massless particles below some biologically relevant length scale suggest themselves. In this phase quarks and gluons are unconfined and electroweak symmetries are unbroken so that gluons, weak bosons, quarks and even neutrinos might be relevant to the understanding of living matter. In particular, long ranged entanglement in charge and color degrees of freedom becomes possible. For instance, TGD based model of atomic nucleus as nuclear string suggests that biologically important fermionic could be actually chemically equivalent bosons and form cyclotron Bose-Einstein condensates.

Functions of the magnetic body

The list of possible functions of the magnetic body is already now rather impressive.

1. Magnetic body controls biological body and receives sensory data from it. Together with zero energy ontology and new view about time explains Libet's strange findings about time lapses of consciousness. EEG, or actually fractal hierarchy of EXGs assignable to various body parts makes possible communications to and control by the various layers of the magnetic body. WXG could induce charge density gradients by the exchange of W boson.

2. The flux sheets of the magnetic body traverse through DNA strands. The hierarchy of Planck constants and quantization of magnetic flux predicts that the flux sheets can have arbitrarily large width. This leads to the idea that there is hierarchy of genomes corresponding to ordinary

genome, supergenome consisting of genomes of several cell nuclei arranged along flux sheet like lines of text, and hypergenomes involving genomes of several organisms arranged in a similar manner. The prediction is coherent gene expression at the level of organ, and even of population. In this picture the big jumps in evolution, in particular, the emergence of EEG, could be seen as the emergence of a new larger layer of magnetic body characterized by a larger value of Planck constant. For instance, this would allow to understand why the quantal effects of ELF em fields requiring so large value of Planck constant that cyclotron energies are above thermal energy at body temperature are observed for vertebrates only.

3. Magnetic body makes possible information process in a manner highly analogous to topological quantum computation. The model of DNA as topological quantum computer assumes that flux tubes of wormhole magnetic field connect DNA nucleotides with the lipids of the lipid layer of nuclear or cell membrane. The flux tubes would continue through the membrane and split during topological quantum computation. The time-like braiding of flux tubes makes possible topological quantum computation via timelike braiding and space-like braiding makes possible the representation of memories. The model allows general vision about the deeper meaning of the structure of cell and makes testable predictions about DNA.

   One prediction is the coloring of braid strands realized by an association of quark or antiquark to nucleotide. Color and spin of quarks and antiquarks would thus correspond to the quantum numbers assignable to braid ends. Color isospin could replace ordinary spin as a representation of qubit and quarks would naturally give rise to qutrit, with third quark would have interpretation as unspecified truth value. Fractionization of these quantum numbers takes place which increases the number of degrees of freedom. This prediction would relate closely to the discovery of topologist Barbara Shipman that the model for the honeybee dance suggests that quarks are in some manner involved with cognition. Also microtubules associated with axons connected to a space-time sheet outside axonal membrane via lipids could be involved with topological quantum computation and actually define an analog of a higher level programming language.

4. The strange findings about the behavior of cell membrane, in particular the finding that metabolic deprivation does not lead to the death of cell, the discovery that ionic currents through the cell membrane are quantal, and that these currents are essentially similar than those through an artificial membrane, suggest that the ionic currents are dark ionic Josephson currents along magnetic flux tubes. A high percent of biological ions would be dark and ionic channels and pumps would be responsible only for the control of the flow of ordinary ions through cell membrane.

5. These findings together with the discovery that also nerve pulse seems to involve only low dissipation lead to a model of nerve pulse in which dark ionic currents automatically return back as Josephson currents without any need for pumping. This does not exclude the possibility that ionic channels might be involved with the generation of nerve pulse so that the original view about quantal currents as controllers of the generation of nerve pulse would be turned upside down. Nerve pulse would result as a perturbation of kHz soliton sequence mathematically equivalent to a situation in which a sequence of gravitational penduli rotates with constant phase difference between neighbors except for one pendulum which oscillates and oscillation moves along the sequence with the same velocity as the kHz wave. The oscillation would be induced by a "kick" for which one can imagine several mechanisms.

   The model explains features of nerve pulse not explained by Hodkin-Huxley model. These include the mechanical changes associated with axon during nerve pulse, the outwards force generated by nerve pulse with a correct prediction for its order of magnitude, the adiabatic character of nerve pulse, and the small rise of temperature of membrane during pulse followed by a reduction slightly below the original temperature.

   The model predicts that the time taken to travel along any axon is a multiple of time dictated by the resting potential so that synchronization is an automatic prediction. Not only kHz waves but also a fractal hierarchy of EEG (and EXG) waves are induced as Josephson radiation by voltage waves along axons and microtubules and by standing waves assignable to neuronal (cell) soma. The value of Planck constant involved with flux tubes determines the frequency scale of EXG so that a fractal hierarchy results.

The model forces to challenge the existing interpretation of nerve pulse patterns and the function of neural transmitters. Neural transmitters need not represent actual/only) signal but could be more analogous to links in quantum web. The transmitter would coding the address of the receiver, which could be gene inside neuronal nucleus. Nerve pulses would build a connection line between sender and receiver of nerve pulse along which actual signals would propagate. Also quantum entanglement between receiver and sender can be considered.

6. Acupuncture points, meridians, and Chi are key notions of Eastern medicine and find a natural identification in terms of magnetic body lacking from the western medicine. Also a connection with well established notions of DC currents and potentials discovered by Becker and with TGD based view about universal metabolic currencies as differences of zero point energies for pairs of space-time sheets with different p-adic length scale emerges.

   Chi would correspond to these fundamental metabolic energy quanta to which ordinary chemically stored metabolic energy would be transformed. Meridians would most naturally correspond to flux tubes with large $\hbar$ along which dark supra currents flow without dissipation and transfer the metabolic energy between distant cells. Acupuncture points would correspond to points between which metabolic energy is transferred and their high conductivity and semiconductor like behavior would conform with the interpretation in terms of metabolic energy storages. The energy gained in the potential difference between the points would help to kick the charge carrier to a smaller space-time sheet. It is possible that the main contribution to the of charge at magnetic flux tube is magnetic energy and slightly below the metabolic energy quantum and that the voltage difference gives only the lacking small energy increment making the transfer possible. Also direct kicking of charge carriers to smaller space-time sheets by photons is possible and the observed action spectrum for IR and red photons corresponds to the predicted increments of zero point kinetic energies.

7. Magnetic flux tubes could also play key role in bio-catalysis and explain the magic ability of biomolecules to find each other. The model of DNA as topological quantum computer [24] suggest that not only DNA and its conjugate but also some amino-acid sequences acting as catalysts could be connected to DNA and other amino-acids sequences or more general biomolecules by flux tubes acting as colored braid strands. The shortening of the flux tubes in a phase transition reducing the value of Planck constant would make possible extremely selective mechanisms of catalysis allowing precisely defined locations of reacting molecules to attach to each other. With recently discovered mechanism for programming sequences of biochemical reactions this would make possible to understand the miraculous looking feats of bio-catalysis.

8. The ability to construct "stories", temporally scaled down or possible also scaled up representations about the dynamical processes of external world, might be one of the key aspects of intelligence. There is direct empirical evidence for this activity in hippocampus. The phase transitions reducing or increasing the value of Planck constant would indeed allow to achieve this by scaling the time duration of the zero energy space-time sheets providing cognitive representations.

Direct experimental evidence for the notion of magnetic body carrying dark matter

The list of nice things made possible by the magnetic body is impressive and one can ask whether there is any experimental support for this notion. The findings of Peter Gariaev and collaborators give evidence for the representation of DNA sequences based on the coding of nucleotide to a rotation angle of the polarization direction as photon travels through the flux tube and for the decoding of this representation to gene activation [41], for the transformation of laser light to light at various radio-wave frequencies having interpretation in terms of phase transitions increasing $\hbar$ [40, 49], and even for the possibility to photograph magnetic flux tubes containing dark matter by using ordinary light in UV-IR range scattered from DNA [56].

2.3.3 Brain and consciousness

In the proposed vision the role of brain for consciousness is not so central than in neuroscience view. Brain is not the seat of sensory mental images but builder of symbolic representations and magnetic

body replaces brain as an intentional agent and higher level experiencer. Furthermore, p-adic view about cognition means that only cognitive representations but not cognition itself can be localized in a finite space-time region.

The simplest sensory qualia would be realized at the level of sensory organs so that one can avoid the problematic assignment of sensory qualia to the sensory pathways. The new view about time would allow to resolve the objections against this view. For instance, phantom leg phenomenon would result by sharing of sensory mental images of the geometric past by time like quantum entanglement. For instance, visual colors would correspond to increments of color quantum numbers in quantum jumps at the level of retina. Our sensory mental images do not correspond to the sensory input as such. Rather, the feedback from brain (or from magnetic body via brain) to sensory organs is an essential element in the construction of sensory mental images. For instance, during REM sleep rapid eye movements would reflect the presence of this feedback. The feedback would be also very important in the case of hearing. Visual mental images in absence of eye movements could be interpreted as sharing of visual mental images by quantum entanglement (in particular, time-like entanglement giving rise to episodal memories).

2.4 Time and consciousness

The questions related to the notion of time have turned out to be the most difficult ones encountered during the evolution of TGD inspired theory of consciousness, and the original naive vision has very little. Mention only zero energy ontology, hierarchy of Planck constants and dark matter, time-like entanglement and negentropic entanglement, p-adic as physics of intentionality and cognition, and the notion of magnetic body. It is certainly too early to claim that everything is understood but it seems that no dramatic changes in the overall picture are to be expected anymore.

2.4.1 The relationship between subjective and geometric time

The relationship between experienced time and geometric time has been one of the long-standing problems of TGD inspired theory of conscousness and I have made several proposals about this relationship. The basic questions are however obvious. What gives rise to the arrow of geometric time in various senses (at imbedding space level and at space-time level)? Why the contents of sensory experience are about so narrow time interval? Why also the intentional actions at least apparently is restricted to such a narrow time interval? Quantum classical correspondence predicts that the arrow of subjective time is somehow mapped to that for the geometric time. The detailed mechanism for how the arrow of psychological time emerges has however remained open. Also the notion of self is problematic.

Two times

The notion of quantum jump implies a new view about time. Experienced/subjective time corresponds to a sequence of sub-quantum jumps and cannot be identified with the geometric time defined as the fourth space-time coordinate. This is of course obvious for anyone: consider only the reversibility of geometric time contra irreversibility of experienced time, and the fact that both geometric past and future exist whereas only subjective past exists. The fact that the contents of conscious experience is about 4-D rather than 3-D space-time region, motivates the notions of 4-D brain, body, and even society. In particular, conscious existence continues after biological death since 4-D body and brain continue to exist.

Two earlier views about how the arrow of psychological time emerges

The basic question how the arrow of subjective time is mapped to that of geometric time. The common assumption of all models is that quantum jump sequence corresponds to evolution and that by quantum classical correspondence this evolution must have a correlate at space-time level so that each quantum jump replaces typical space-time surface with a more evolved one.

1. The earliest model assumes that the space-time sheet assignable to observer ("self") drifts along a larger space-time sheet towards geometric future quantum jump by quantum jump: this is

like driving car in a landscape but in the direction of geometric time and seeing the changing landscape. There are several objections.

i) Why this drifting?

ii) If one has a large number of space-time sheets (the number is actually infinite) as one has in the hierarchy the drifting velocity of the smallest space-time sheet with respect to the largest one can be arbitrarily large (infinite).

iii) It is alarming that the evolution of the background space-time sheet by quantum jumps, which must be the quintessence of quantum classical correspondence, is not needed at all in the model.

2. Second model relies on the idea that intentional action -understood as p-adic-to-real phase transition for space-time sheets and generating zero energy states and corresponding real space-time sheets - proceeds as a kind of wave front towards geometric future quantum jump by quantum jump. Also sensory input would be concentrated on this kind of wave front. The difficult problem is to understand why the contents of sensory input and intentional action are localized so strongly to this wave front and rather than coming from entire life cycle.

There are also other models but these two are the ones which represent basic types for them.

The third option

The third explanation for the arrow of psychological time - which I have considered earlier but only half-seriously - looks to me the most elegant at this moment. This option is actually favored by Occam's razor since it uses only the assumption that space-time sheets are replaced by more evolved ones in each quantum jump. Also the model of tqc favors it.

1. In standard picture the attention would gradually shift towards geometric future and space-time in 4-D sense would remain fixed. Now however the fact that quantum state is quantum superposition of space-time surfaces allows to assume that the attention of the conscious observer is directed to a fixed volume of 8-D imbedding space. Quantum classical correspondence is achieved if the evolution in a reasonable approximation means shifting of the space-time sheets and corresponding field patterns backwards backwards in geometric time by some amount per quantum jump so that the perceiver finds the geometric future in 4-D sense to enter to the perceptive field. This makes sense since the shift with respect to M^4 time coordinate is an exact symmetry of extremals of Kähler action. It is also an excellent approximate symmetry for the preferred extremals of Kähler action and thus for maxima of Kähler function spoiled only by the presence of light-cone boundaries. This shift occurs for both the space-time sheet that perceiver identifies itself and perceived space-time sheet representing external world: both perceiver and percept change.

2. Both the landscape and observer space-time sheet remain in the same position in imbedding space but both are modified by this shift in each quantum jump. The perceiver experiences this as a motion in 4-D landscape. Perceiver (Mohammed) would not drift to the geometric future (the mountain) but geometric future (the mountain) would effectively come to the perceiver (Mohammed)!

3. There is an obvious analogy with Turing machine: what is however new is that the tape effectively comes from the geometric future and Turing machine can modify the entire incoming tape by intentional action. This analogy might be more than accidental and could provide a model for quantum Turing machine operating in TGD Universe. This Turing machine would be able to change its own program as a whole by using the outcomes of the computation already performed.

4. The concentration of the sensory input and the effects of conscious motor action to a narrow interval of time (.1 seconds typically, secondary p-adic time scale associated with the largest Mersenne M_{127} defining p-adic length scale which is not completely super-astronomical) can be understood as a concentration of sensory/motor attention to an interval with this duration: the space-time sheet representing sensory "me" would have this temporal length and "me" definitely corresponds to a zero energy state.

5. The fractal view about topological quantum computation strongly suggests an ensemble of almost copies of sensory "me" scattered along my entire life cycle and each of them experiencing my life as a separate almost copy.

6. The model of geometric and subjective memories would not be modified in an essential manner: memories would result when "me" is connected with my almost copy in the geometric past by braid strands or massless extremals (MEs) or their combinations (ME parallel to magnetic flux tube is the analog of Alfwen wave in TGD).

This argument leaves many questions open. What is the precise definition for the volume of attention? Is the attention of self doomed to be directed to a fixed volume or can quantum jumps change the volume of attention? What distinguishes between geometric future and past as far as contents of conscious experience are considered? How this picture relates to p-adic and dark matter hierarchies? Does this framework allow to formulate more precisely the notion of self? Zero energy ontology allows to give tentative answers to these questions.

Can one assign to quantum jump a chronon of geometric time?

Whatever the mechanism correlating the subjective time with geometric time and giving rise to the arrow of geometric timeis, one can ask following kind of questions. Does it make sense to assign a geometric time interval to the quantum jump in statistical sense? Is this interval always the same or does one have a hierarchy of geometric durations for the moment of consciousness.

1. The original guess was that the average increment of the psychological time in a single quantum jump does not depend on properties of the self and is of the order of CP_2 time about 10^4 Planck times. This would mean that consciousness in biological length scales is in a well defined sense macroscopic phenomenon and that single quantum jump corresponds to a microscopic building block of self. A natural assumption is that self hierarchy starts already from selves having duration of few quantum jumps (elementary particles?).

   This vision does not explain convincingly the integration of the moments of consciousness to larger units which resembles formation of bound states to a high degree. In particular, the geometric duration of quantum jump is very much analogous to decoherence time, and it is difficult to understand how Schrödinger equation can make sense if the decoherence time is of order CP_2 time.

2. Zero energy and number theoretic vision encourage to ask whether the generation of -possibly negentropic- time-like entanglement between positive and negative energy parts of zero energy states could be the analog of bound state formation guaranteing that subself would not reduce to an unentangled pair of positive and negative energy states in concomitant quantum jumps but is more analogous to a quantum system obeying a unitary time evolution.

   The hierarchy CDs defining a hierarchy of p-adic length scales and associated dark matter matter hierarchy suggest that there is a fractal hierarchy of quantum jumps such that quantum jumps at the lower level of hierarchy integrate to higher level quantum jumps and in this manner give rise to the experience about flow of time at the higher levels. This would suggest that the geometric duration assigned to single quantum jump for CD with temporal size scale $T_k \propto 2^k$ corresponds to geometric time interval T_k and that it corresponds to to 2^n quantum jumps at the lower level $k - n$ with geometric time interval T_{k-n}. For this option CP_2 time would define the smallest chronon of geometric time.

   What is intriguing that for electron that time scale T_k corresponds to $k = 127$ and is .1 seconds defining the fundamental 10 Hz bio-rhythm. One can indeed say that the chronon of sensory experience is .1 seconds. For u and d quarks with mass around 5 MeV the corresponding time scale would correspond to $k = 120$ and millisecond time scale assignable to kHz cortical synchrony and duration of nerve pulse.

The new concept of the psychological time means a dramatic generalization of the standard view about subjective existence. Mindlike space-time sheets -or CD about which I prefer to talk now- are distributed everywhere and all of them can participate in quantum jumsp. Therefore one can say that the entire space-time is a conscious, living being. Civilizations of the geometric past and future exist

simultaneously with us. We are members of a four-dimensional society in the sense that our actions affect the life of selves of both geometric past and future since each quantum jump performed by us changes the macroscopic space-time in both past and future. It is quite possible that there are new versions of me in the geometric past represented by mindlike space-time sheets drifting in future time direction along the material space-time sheet describing "material me". Therefore this particular life of mine is only one among very many ones. p-Adic evolution implies that in the statistical sense the quality of these lives tends to get better. We in our youth now experience in slightly more deeper manner and live in a society having

2.4.2 Four-dimensional brain and long term memories

Four-dimensionality of brain is crucial for the understanding long term memories as multitime experiences receiving contributions from several moments of geometric time. This identification makes it unnecessary to have any memory storage mechanisms. Rather, the activities of the memory circuits can be seen as increasing the probability that memory recall occurs. Reverberating memory circuits in which experience is echoed indeed do this by extending the deep memory valley in spin glass landscape to a long canyon in time direction. This increases the probability that mindlike space-time sheets enter in the region of four-dimensional spin glass landscape representing the memory. The deepness of the spin glass valley correlates with the emotionality of the memory. Childhood memories are especially emotional and therefore stable. Memories are result of creative action and memory circuit involving hippocampus seem to be active in carving out the art works representing geometric memories worth of remembering. TGD based approach solves the basic problems of the neural net approach resulting from the fact that the formation of new memories destroys old memories and from the fact that it is difficult to understand how the component of experience is known to be a memory.

Long term memories and memories in general can be understood as resulting from a very simple mechanism. When I remember something that happened, say two years ago, I look at a mirror at distance of one light year and see myself in mirror as I am at a distance of two geometric years in the geometric past. Massless extremals (MEs) representing topological light (and graviton) rays and carrying the classical information about the memory are reflected in some kind of a mirror structure. Mirrors could correspond end points, branching points, curved parts or cross sections of magnetic flux tubes and MEs or in case of gravitonic rays to curved parts of the background spatetime surface.

The reflected ME could be seen as topological counterpart of self-energy diagram involving emission and absorption of massless virtual particle such photon or graviton. At quantum level timelike entanglement, which is possible by the non-determinism of the fundamental variational principle, binds the mental images 'now' and 'then' to a single mental image. MEs could be generated in the transitions between almost degenerate quantum spin glass states. Since the energy difference corresponds to the classical gravitational energy, topological gravitonic rays, which also interact very weakly with the external world, are good candidates for MEs responsible for long term memories. The interpretation of these MEs as gravitonic $1/f$ noise suggest itsef strongly.

Note that the continual occurrence of quantum jumps between quantum histories explains why our long term memories are unstable. It seems however that it is probably only sensory and cognitive representations which are altered appreciabely. In human time scales geometric past should be relatively stable in macroscopic length scales: otherwise dramatic changes of the recent reality induced by macroscopic quantum jumps in the geometric past would occur. Four-dimensional brain provides a completely new view about how gemeralized sensory experiences are generated, how generalized motor actions are planned and how memories are constructed. This process is like creating an artwork. *Four*-dimensional spin glass landscape representing a rough scetch is gradually refined by adding details and corrections in increasingly shorter time scales: this corresponds to neural activities of four-dimensional brain generating motion leading to the desired part of spin glass energy landscape. This picture is consistent with the observed $1/f$ noise and fractality of nerve pulse patterns. Absolutely essential is self-organization and related dissipation forcing the Darwinian selection leading to end product which is charicature rather than photo.

Do declarative memories and intentional action involve communications with geometric past?

Communications with geometric past using time mirror mechanism in which phase conjugate photons propagating to the geometric past are reflected back as ordinary photons (typically dark photons with energies above thermal threshold) make possible realization of declarative memories in the brain of the geometric past [25].

This mechanism makes also possible realization of intentional actions as a process proceeding from longer to shorter time scales and inducing the desired action already in geometric past. This kind of realization would make living systems extremely flexible and able to react instantaneously to the changes in the environment. This model explains Libet's puzzling finding that neural activity seems to precede volition [62].

Also a mechanism of remote metabolism ("quantum credit card") based on sending of negative energy signals to geometric past becomes possible [28]: this signal could also serve as a mere control signal inducing much larger positive energy flow from the geometric past. For instance, population inverted system in the geometric past could allow this kind of mechanism. Remote metabolism could also have technological implications.

Episodal memories as time-like entanglement

Time-like entanglement explains episodal memories as sharing of mental images with the brain of geometric past [25]. An essential element is the notion of magnetic body which serves as an intentional agent "looking" the brain of geometric past by allowing phase conjugate dark photons with negative energies to reflect from it as ordinary photons. The findings of Libet about time delays related to the passive aspects of consciousness [60] support the view that the part of the magnetic body corresponding to EEG time scale has same size scale as Earth's magnetosphere. The unavoidable conclusion would be that our field/magnetic bodies contain layers with astrophysical sizes.

p-Adic length scale hierarchy and number theoretically preferred hierarchy of values of Planck constants, when combined with the condition that the frequencies f of photons involved with the communications in time scale T satisfy the condition $f \sim 1/T$ and have energies above thermal energy, lead to rather stringent predictions for the time scales of long term memory. The model for the hierarchy of EEGs relies on the assumption that these time scales come as powers $n = 2^{11k}$, $k = 0, 1, 2,,$ and predicts that the time scale corresponding to the duration of human life cycle is ~ 50 years and corresponds to $k = 7$ (amusingly, this corresponds to the highest level in chakra hierarchy).

2.4.3   Time and self

The proposed overall view leaves still open many questions about time and self.

What distinguishes 'now' from memories and plans?

The new notion of psychological time leads to a very elegant mechanism of long term memory and memories in general: to remember something at temporal distance T in the past is to look the past brain from magnetic body from distance $L = cT$. This looking backwards in time could be realized by sending a negative energy signal reflected back from the past brain as a positive energy signal. A slightly more complex mechanism utilizes negative energy signal sent to the magnetic body at distance $L = cT/2$, where it is reflected in ordinary sense to the brain of the past, where it suffers time-like reflection and returns as a positive energy signal back to the brain along the same route. Also time-like quantum entanglement is possible. In the simpler variant of time mirror mechanism the signal would have fundamental frequency $f = 1/T$. These frequencies correspond to energies $E = hf$ far below the thermal threshold for the ordinary value of Planck constant but for large enough values $\hbar$ the problem can be circumvented. The quantal effects of ELF em fields on brain support this proposal. The conscious experience could in principle contain information from both the geometric past, from the geometric now, and perhaps also from the geometric future (plans, dreams, expectations).

In zero energy ontology there is however an important delicacy involved. Is precognition really possible if one assumes that the space-time sheets assigned to CD are restricted only to the interior of CD? The cautious answer is Yes. CD is imbedded inside a larger CD and this CD could be

responsible for both precognition and for non-personal memories originating from the geometric past not belonging to the CD of self.

If there are also space-time sheets which begin from the future (past) boundaries and continue to fiture (past) precognition and memories extending beyond personal life are certainly plausible and light-like 3-surfaces could at as correlates for time-like entanglement and communications of signals reflected in time direction. For the generalization of Feynman diagrams this is assumed and sub-CDs have at elementary particle level interpretation in terms of radiative corrections.

This asymmetry between interior and exterior of CD could be responsible for the dramatic distinctions between the conscious geometric now, memories, and plans and explain how the illusion about reality as a time=constant snapshot of the geometric time development is created. Also the asymmetry between geometric future and nearby geometric past could be understood. More precisely, the proposed identification of geometric now inspired by zero energy ontology would be in terms of the mental images residing near the future boundary of CD associated with self. In case of electrons these CDs would have size scale of .1 seconds corresponding to the duration of the moment of sensory experience. The personal memories from the period of life-time would correspond to the interior of CD associated with self. Transpersonal memories interpreted in terms of previous lives would correspond to memories about geometric past outside CD. Precognitions would have information contents coming from the geometric future outside CD of self.

Estimate for the "wake-up time" of sensory selves time scale of causal diamonds

The basic question relates to the age of selves representing sensory mental images and also to the age of our own self which at least apparently seems to be of order of our wake-up period. The question is not trivial.

1. It is not at all clear whether the wake-up state is continuous: also our self could exist only a fraction of time and memories could create the illusion about continuity of self.

2. Maximally entropic long-aged sub-selves in thermal equilibrium need not contribute to conscious experience and their disappearance from our consciousness need not mean that they die: they could simply give rise to a background sensory and cognitive noise which is certainly present.

The first question is how to express this wake-up period in terms of geometric time. The model for the arrow of geometric time based on zero energy ontology suggests that the temporal length of space-time sheet (length of the film representing movie running to the geometric past), which flows through the future boundary of CD of self during its wake-up period gives this measure.

1. The simplest dimensional analysis inspired guess would be that this time scale is the time scale of CD assignable to self. This guess could be defended also on basis of quantum classical correspondence but remains still a guess. If sensory mental images indeed correspond to CDs assignable to electrons, this guess looks sensible.

2. The fact that the entropy of an ageing sub-self tends to increase means that mental images get fuzzy. This allows the possibility that our sensory mental images are rather quite long-lived but get rapidly fuzzy so that only the youngest sensory mental images would dominate our consciousness. One can imagine that the mental images created at the future boundary CD drift to the direction of geometric past and get gradually more entropic. The memory feats of synesthetes could provide one exception to this rule and have explanation in terms of long term negentropic entanglement stabilizing the mental images. Large $\hbar$ could be also involved.

3. One could also argue that the wake-up time for the CD assignable to my biological body is same as my biological lifetime. Otherwise I would not know with such a certainty that I existed yesterday. I would not lose totally my consciousness during sleep but would be only unable to remember much about this period. It is known that dreams experienced during some period of time form logical stories so that at least dreaming involves memories about previous dreams.

   This argument looked excellent in the original formulation of the theory but ceases to be water tight in zero energy ontology. Long term memories realized in terms of negative energy signals and time-like entanglement could be enough to create this conviction. There are also good reasons to believe that scaled down variants of the memories compressing long time periods to

shorter time intervals are generated in terms of $\hbar$ reducing phase transitions: this would be one manner to realize conscious holograms. These fractal stories about my life could create the conviction that I existed yesterday.

There are also arguments supporting a short wake-up time.

1. The identification of subjective memory as a short term memory and the fact that sensory sub-selves with too long age cannot provide the needed time resolution of sensory experience encourages the idea that sensory sub-selves have a short wake-up period of order .1 seconds. Since sensory sub-selves seem to have finite wake-up time also our self should have.

2. The duration of short term memory seems to be of order second so that the periods of, at least, sensory wake-up should be of order second. On the other hand, memory sub-selves of sufficiently short duration can give rise to sensory memory with sufficient resolution even if our self has much longer wake-up period.

3. A good guess seems to be that the duration of our self is not longer than wake-up period. But again it could be that I simply do not remember what we experience during sleep: to remember what happened during sleep we must perhaps be in sleep state.

The time scale of .1 seconds assignable to electron's CD corresponds to the time scale of EEG, which also supports the interpretation of the size scale of CD as a duration of sensory mental image. The currents generating EEG certainly create weak electromagnetic radiation fields which in TGD framework correspond to topological field quanta of Earth size. It is known that EEG frequencies are in the same frequency range as so called Schumann frequencies [51] associated with the resonances of the electromagnetic fields in the 80 km thick wave cavity between Earth surface and ionosphere. Magnetic perturbations near Schumann frequencies are known to have profound effects on human brain inducing altered states of consciousness and neural instabilities [77]. Furthermore, the estimate for the thickness of the magnetic flux tubes of Earth's magnetic field based on the quantization of the magnetic flux is about cell size. These observations raise the question whether our "physical" body is only a tip of an iceberg and formed by the topological condensation of the biomatter around electromagnetic topological field quanta serving as templates for the biostructures[19].

Our self hierarchy could contain also higher levels and the fact that we experience continuity of personal existence suggests that this is the case. This consistent with the basic assumptions about conscious experience if the temporal averaging involved with the temporal binding is weighted so that only the most recent experiences are present with large weight. An interesting possibility is that entire fractal hierarchy of magnetic flux tube structures carrying superconducting BE condensates of ions is involved so that also a hierarchy of cyclotron time scales defining a hierarchy of durations for selves (mental images) is involved. Same is true for MEs and Uncertainty Principle suggest that MEs with size of order light life time are involved with our long term memories.

How fast subjective time runs?

An interesting challenge is to understand the relation of the subjectively experienced time to the psychological time (essentially geometric time). In order to experience time self must have a clock. The simplest assumption is that the sequence of quantum jumps defines the sequence of ticks for the clock. Therefore subjective time would be measured as the number n of quantum jumps occurred after the wake-up of the self. The rate for the running of subjective time would be dn/da and just the inverse for the rate of running for psychological time and same for all systems if the average duration of chronon is of order of CP_2 time: this is certainly not consistent with the fact subjectively experienced time can run faster or even stop. One could also kill this naive hypothesis by noticing that self should be able to distinguish between the ticks of the clock: obviously we cannot experience quantum jumps as separate events.

A more realistic model is based on the idea that the average time interval Δa between two wake-ups of a 'clock' sub-self, which exists periodically in a wake-up state defines a natural unit of subjective time. The number N of ticks for the clock is given by the age of self divided by the duration of single wake-up period for the 'clock' self

$$N(a) = \frac{a}{\Delta a} \ .$$

N would naturally define a measure of subjectively experienced time. Slowing down of subjective time would correspond to the slowing down of the internal clock in the sense that Δa increases.

Consider now whether this simple model can explain basic facts about experienced rate of subjectively experienced time.

1. Experienced time is said to run slowly, when we get bored and drowsy. Actually the situation is just the opposite since the number of ticks of the internal clock per unit of psychological time must be large. In order to understand what might be involved, assume that also the internal clock gets drowsy so that the average wake-up period Δa_W for the internal clock gets shorter. If internal clock wakes up spontaneously, one can assume that the average duration Δa_S for the sleeping periods for clock self is not changed. Hence $\Delta = \Delta a_W + \Delta a_S$ is reduced so that $N(a) \propto 1/\Delta a$ increases and geometric time is experienced as longer.

2. Quite different situation is encountered, when person is in the state of whole-body-consciousness. In this kind of situation there is no internal clock and one can indeed say that there is no time! This would explain the reports of meditators about state of 'timelessness' [57] Oliver Sacks has described in his book 'Awakenings' patients who have lived for years in 'no-time' state with frozen contents of conscious experience, which presumably meant that everything in the external world seemed to happen extremely slowly. It would be natural to assume that the lifetime Δa of the 'clock' self was very long in this kind of situation or even that person was in the state of whole-body-consciousness. The only clock is person itself and the entire experience corresponds to single tick of this clock. There are also reports that when person is in dramatic situation like traffic accident, time is experienced to stop. One explanation is that person experiences state of whole-body consciousness. Second possibility is that in this kind of situation involving very high level of alertness Δa becomes very short so that all motions seem to occur very slowly: in this manner person gets a lot of subjective time to react to the situation.

One could also try to understand why persons at older age feel that time runs faster. This statement is clearly not about what person immediately experiences but impression about what has happened. One possible explanation is however that the period Δa of the internal clock indeed gets longer at older age. This could be caused by the increase of the period Δa_S of the sleeping period of the internal clock. This is consistent with the previous idea that the wake-up time of mental images gets shorter, which also explains why old people experience that geometric time flows faster. Thus, if the total fraction of geometric time spend by the person and his/her sub-selves in wake-up state decreases when person gets older, one can understand why the time is experienced to run faster at the older age.

Time delays of consciousness and other anomalies

TGD based concept of time has rather dramatic implications and it is important to show that the new time concept indeed solves the conceptual problems and anomalies of the standard physics. One should also device experiments to test the new time concept.

1. Dissipation is the black sheep in the family of theoretical physics and quantum jump between quantum histories concept explains dissipation in an elegant manner. The ad hoc addition of various parameters characterizing dissipation to the reversible fundamental equations of the classical physics can be understood as a phenomenological model for the subjective time evolution as a sequence of macroscopic space-times defined by the final states of the quantum jumps. Dissipative space-time is kind of an envelope for a sequence of non-dissipative space-times. Dissipation is a signature of quantum jumps which, by the basic assumptions related to the formulation of NMP, correspond to a sequence of quantum measurements and can occur only inside selves. Hence dissipation gives direct evidence for consciousness. TGD predicts the possibility of whole-body consciousness with anomalously low dissipation and this spectacular effect provides a test of TGD approach [19].

2. Quantum jumps between quantum histories concept together with the notion of self explains also the peculiar time delays of consciousness revealed in the experiments [78, 60] relating to the active and passive roles of consciousness and described by Penrose in his book [47]. The basic observation is that quantum jump replaces macroscopic space-time with a new one and

that both the geometric past and future change. For instance, the EEG activity preceding the conscious decision to raise the index finger in experiments of Libet related to the active aspects of consciousness [60] can be interpreted as classical electromagnetic fields present in the geometric past of the new macroscopic space-time generated by the decision to raise the finger.

3. It is also possible to explain the causal anomalies revealed by the experiments of Radin and Bierman [85, 82, 56]. In these experiences pictures with emotionally provocative content generated galvanic skin responses already before they were seen. A natural looking assumption about the contents of conscious experience is that the change of the geometric past is larger for emotional than for non-emotional quantum jumps (e-motion!): this is also consistent with the important role of emotion as a motivator and with the fact that neural transmitters involved with the emotion induce long term synaptic changes. With this assumption the change of the past recordings about galvanic skin response is predicted to be larger for the emotional pictures than for the non-emotional ones. TGD predicts "tribar effect" as a general signature for the quantum jump between quantum histories concept [27].

What after biological death?

One can also speculate about the course of events at the moment of death and after it. The outcome depends strongly on the beliefs about how the arrow of psychological time emerges.

1. If the latest view based on zero energy ontology and on the identification of causal diamond (CD) as a correlate for self is accepted then time flow corresponds to an effective flow of the quantum superposition of space-time sheets assignable to self to the interior of CD through the light-like future boundary of CD. This flow would be induced by a volitional act stimulated by the curiosity to see what is in the geometric future (the space-time sheet associated with a larger CD perceived by self as environment). At the moment of biological death subselves corresponding to sensory mental images would die. If the shifting continues to happen -perhaps by the volition of larger selves of sub-selves- the biological death would propagate as a wave front to the geometric past. After the death of sensory mental images and their symbolic counterparts the mental images of geometric past would dominate the contents of consciousness but after the wave front of biological death would have reached the lower boundary of CD, their contribution to consciousness would cease. This does need not of course mean a loss of consciousness. Self could be ready to direct its attention in a new manner.

   One can represent an objection against this picture. If zero energy states correspond to constant zero momentum plane waves in the degrees of freedom assignable to the center of mass of CD it would seem that the experiences of self are kind of abstraction coming from the experiences assignable to all these CDs. Does this really make sense? Maybe it does not make sense to assign zero momentum to cm degrees of freedom of CD. If one does not perform this assignment the self could redirect its attention to a CD at different spatiotemporal position and with more interesting external world.

2. In the earlier model for the arrow of geometric time space-time sheets drift to the geometric future along larger space-time sheet. For this option this particular sensory "me" would meet the geometro-temporal boundary of the biological body: sensory input would cease and there would be no biological body to use anymore. "Me" might lose its consciousness (if it can!). "Me" has also other mental images than sensory ones and these could begin to dominate the consciousness and "me" could direct its attention to space-time sheets corresponding to much longer time scale, perhaps even to that of life cycle, giving a summary about the life.

What after that? The Tibetan Book of Dead gives some inspiration. A western "me" might hope (and even try use its intentional powers to guarantee) that quantum Turing tape sooner later brings into the volume of attention (which might also change) a living organism, be it human or cat or dog or at least some little bug. If this "me" is lucky, it could direct its attention to it and become one of the very many sensory "me's" populating this particular 4-D biological body. There would be room for a newcomer unlike in the alternative models. A "me" with Eastern/New-Ageish traits could however direct its attention permanently to the dark space-time sheets and achieve what she might call enlightment.

2.5   Various types of conscious experiences

In the following the general structure and classication of conscious experiences is discussed. Most predictions are brain independent. Assuming that zero modes of the configuration space, characterizing the geometry of macroscopic classical space-time, determine the geometric information contents of conscious experience and identifying macroscopic quantum phases as quantum correlates of various sensory modalities, one can make rather far reaching predictions about basic aspects of, say, sensory experience of any experiencer, be it human brain or some strange life form in distant galaxy.

2.5.1   Basic structure of conscious experience

Before continuing, it is perhaps useful to recall the basic anatomy of the quantum jump: $\Psi_i \to U\Psi_i \to \Psi_{f_0} \to ....\Psi_f$, where the final quantum history Ψ_f is a superposition of space-time surfaces, which are macroscopically equivalent and only bound state entanglement is present. Every space-time surface of the superposition consists of parallel space-time sheets (connected by wormhole contacts). Some of these space-time sheets have infinite time extension and some have not. The latter ones are 'mindlike space-time sheets'. One must make a clear distinction between the quantum superposition of the space-time surfaces and the decomposition of the space-time surface to space-time sheets.

Real and imagined experiences

The assumption that p-adic physics is physics of imagination means division of qualia to real qualia and imagined qualia. There are good arguments based on mathematical consistency that in p-adic configuration space degrees of freedom complete localization occurs in each quantum jump (see Appendix). This means that there are no quantum fluctuations in p-adic degrees of freedom and since non-geometric sensory qualia like color correspond to quantum number increments in quantum fluctuating degrees of freedom, there are no p-adic non-geometric qualia. This however leaves p-adic geometric qualia determined by the increments of p-adic configuration space coordinates. This view is certainly consistent with intuitive notion that cognitive qualia are only about the geometric aspects, like shape and size, of the objects of the external world.

   One could debate about whether cognition can be identified as imagination but this is the working hypothesis made. The tranformations of thoughts into actions or sensory experiences and of sensory inputs into thoughts correspond to p-adic–real phase transitions for mindlike space-time sheets so that one can speak about matter-mind interaction in a well-defined sense. Cognition is predicted to be present already at elementary particle length scales and this assumption is crucial for understanding the success of the p-adic length scale hypothesis works and p-adic mass calculations.

   One can identify p-adic space-time sheets as correlates of memes [65] and relate them to the morphic fields of Sheldrake. The p-adic vision about cognition is discussed in [29].

Whole-body consciousness and ordinary consciousness

TGD predicts two basic modes of consciousness.

1. Reducible self is the state in which sub-selves are "falling asleep" and "waking up" all the time, corresponds naturally to the ordinary state of consciousness. Sub-selves represent mental images which pop out and dissappear all the time.

2. In case of irreducible self quantum jumps do not lead to a generation of sub-selves. Thus the sub-systems of irreducible self have only bound state entanglement and self measurement cascade stops at irreducible self. This state is presumably accompanied by the experience of "oneness" and could therefore be called a state of "whole-body consciousness". The absence of the sub-selves means the absence of mental images so that the identification as a state of pure self awareness without any contents is natural. Less ideal situation is that sub-selves are generated but are very short lived and represent short flashes against background awareness. "Whole-body-consciousness" presumably means abnormally low metabolism since dissipation inside sub-selves is not present.

Active and passive aspects of conscious experience

Conscious experience involves two fundamental contributions.

1. The "non-classical" contribution from the quantum measurement reducing quantum entanglement associated with the fermionic degrees of freedom and with the quantum fluctuating configuration space degrees of freedom (as opposed to zero modes).

2. The "classical" contribution determined by the localization in zero modes and by the selection between different degenerate absolute minimum space-time surfaces having different decompositions into p-adic regions.

   The natural guess is that the experienced free will corresponds to the non-determinism of the quantum jump somehow. The standard objection is that the non-determinism of the quantum measurement gives rise to randomness rather than volition. Quantum numbers relate to microscopic aspects of the quantum jump and the average quantum numbers measured in quantum jumps probably sum up to zero in the presence of energy feed and external perturbations. Indeed, if temporal binding for the experiences of self involves averaging, this component of experience need not give rise to an experience of volition since it is expected to average out for large number of quantum jumps (10^{38} per second by the argument for the arrow of psychological time). Therefore the time averaging involved with the temporal binding smooths out this non-determinism.

   Here the special features of TGD however come in rescue.

1. The first candidate for the quantum correlate of volition is the localization in zero modes. This localization corresponds to the spontaneous symmetry breaking of quantum field theories which selects one classical configuration among many degenerate ones. Spontaneous symmetry breaking has been suggested to be a basic aspect of the quantum jump also by Joel Henkel [78]. Asymptotic localization in zero modes seems to be however determined statistically by the self-organization process taking the system to the bottom of some valley of the spin glass energy landscape. Hence volition need not be in question.

2. The second candidate for volition is classical non-determinism of Kähler action (which gives rise to the geometric model of thought as "association sequence"). The selection between the different degenerate alternative classical time evolutions, that is different degenerate absolute minima $X^4(Y^3)$ going through a given 3-surface Y^3, is an excellent candidate for the volitional act. The reason is that absolute minima differ macroscopically so that the choice between degenerate minima dramatically affects the entire geometric future. Note also that the selection between branches of a multifurcation of macroscopic space-time is in question, the choice can be done only when mindlike space-time sheet is located in a narrow time interval around multifurcation and is hence irreversible. The identification of the classical non-determinism as a geometric correlate of the volitional non-determinism is in nice accordance with the "ontogeny recapitulates phylogeny" principle stating that the geometric time evolution at the level of the space-time surface reflects the time evolution by quantum jumps at the level of the configuration space. One can however argue that this kind of volition is still passive in that it is only a selection between given alternatives rather than a transformation of an intention to action. The second objection is that there are actually infinite number of options between which to select in the state function reduction: why do we not experience these alternatives consciously?

3. The third candidate for volition is a quantum jump in which p-adic-to-real transformation for a p-adic space-time sheet representing cognitively intention occurs so that it becomes an action. This identification of the volitional act seems to be the most realistic one and indeed allows to understand how the notion of psychological time emerges. Since complete localization occurs in p-adic degrees of freedom in the state function reduction stage, there is no selection between infinite number of alternatives but only a selection of the p-adic space-time sheet which is transformed to a real one and induces the self-organization process possibly leading to the desired goal.

   An interesting possibility is that the zero modes characterizing the macroscopic features of the macroscopically equivalent space-time surfaces present in the *final* quantum state of quantum jump

determine the contents of at least sensory experiences. This would be in accord with the idea that pure sensory experiences represent quantities which indeed 'are in the world', the world being identified as the macroscopic space-time associated with the final quantum history of the quantum jump. One could however argue that it is only *the increments of zero modes* in quantum jump, which are perceived directly consciously: this claim is consistent with the fact that insects are able to see only the motion and that also human visual consciousness is crucially dependent on saccadic motion. Localization in the zero modes involves the fixing of the parameters characterizing the shape and size of the 3-surface X^3 as well as the Kähler field of $X^4(X^3)$. Kähler field can reduce to a purely electromagnetic or Z^0 type classical gauge field and is in general also accompanied by a classical color field. The spatio-temporal patterns of the induced Kähler field should correlate strongly with the contents of the conscious experience.

2.5.2 Cognition and p-adic physics

p-Adic non-determinism follows from the fact that functions with vanishing derivatives are piecewise constant functions in the p-adic context. More precisely, p-adic pseudo constants depend on the pinary cutoff of their arguments and replace integration constants in p-adic differential equations. In case of field equations this means roughly that the initial data are replaced with initial data given for a discrete set of time values chosen in such a manner that a unique solution of field equations results. Solution can be fixed also in a discrete subset of rational points of the imbedding space. Presumably the uniqueness requirement implies some unique pinary cutoff.

Thus the space-time surfaces representing solutions of p-adic field equations are analogous to space-time surfaces consisting of pieces of solutions of the real field equations. Thus p-adic reality is much like the dream reality consisting of rational fragments glued together in illogical manner or pieces of child's drawing of body containing body parts in more or less chaotic order.

The obvious interpretation for the solutions of the p-adic field equations is as a geometric correlate of imagination. Plans, intentions, expectations, dreams, and cognition in general are expected to have p-adic cognitive space-time sheets as their geometric correlates. A deep principle seems to be involved: incompleteness is characteristic feature of p-adic physics but the flexibility made possible by this incompleteness is absolutely essential for imagination and cognitive consciousness in general.

If one accepts the idea that real and p-adic space-time regions are correlates for matter and cognitive mind, one encounters the question how matter and mind interact. A good candidate for this interaction is the phase transition leading to a transformation of the real space-time regions to p-adic ones and vice versa. These transformations can take place in quantum jumps. p-Adic-to-real phase transition would have interpretation as a transformation of thought into a sensory experience (dream or hallucination) or to an action. The reverse phase transition might relate to the transformation of the sensory experience to cognition. Sensory experiences could be also transformed to cognition by initial values realized as common rational points of a real space-time sheet representing sensory input and a p-adic space-time sheet representing the cognitive output. In this case the cognitive mental image is unique only in case that p-adic pseudo constants are ordinary constants.

The identification of p-adic physics as physics of cognition satisfies quite a number of consistency constraints.

1. Consistency constraints force to assume that p-adic regions of 3-surface do not contribute to the line element of the configuration space. This means that p-adic degrees of freedom are zero modes and thus completely classical in the sense that a localization occurs in p-adic configuration space degrees of freedom in each quantum jump. Thus the word of cognition is completely classical.

2. Classicality of cognition implies that there are no non-geometric cognitive qualia determined by the increments of quantum numbers in quantum jumps but only geometric cognitive qualia determined by the increments of zero modes. Thoughts are indeed non-colored. Same applies to emotions if emotions correspond to rates of the entropies associated with various non-geometric sensory qualia. Since it is not possible to talk about the sign of the p-adic entropy gradient (p-adic numbers are not well-ordered), one cannot classify possible geometric p-adic emotions to positive and negative. p-Adic Boolean mind is however possible and should represent what we call rational mind.

Various identifications for the quantum correlate of volition were already discussed and it was found that the most realistic option is the identification of volition as associated with a quantum jump in which a p-adic space-time sheet representing an intention is transformed to a real region representing action. This identification leads also to the assignment of the psychological time with the phase transition front at which intentions transform to action proceeding to the direction of the geometric future. The difference between intentions and memories would be that intentions are p-adic whereas memories are real.

2.5.3   Reflective- and proto-levels of consciousness

The decomposition into proto consciousness and reflective consciousness (consciousness about being conscious) is one of the fundamental features of conscious experience. Logical thinking is also a fundamental component of conscious mind and probably also the mind unconscious-to-us, in fact so fundamental one that is has inspired the computationalistic approach to consciousness. One can consider two alternative identifications for the reflective level of consciousness.

Boolean mind as reflective mind?

The state basis of the Fock space generated by N fermionic creation operators is isomorphic with the Boolean algebra consisting of 2^N possible statements about N basic statements. This follows from the simple observation that by Pauli exclusion principle the fermion number associated with a given fermion state can have only two values: 0 (false) or 1 (true). This observation leads to the idea that many fermion states give representation for what might be called reflective consciousness in the sense that the information contents for experiences about conscious experiences could correspond to the quantum jumps in the fermionic sector.

A more convincing interpretation is that Boolean mind is onlhy a special case of reflective mind. In p-adic case only quaternion conformal degrees of freedom are possible for configuration space spinors (see appendix) and since pure cognition involves no emotions and no values it must correspond to logic (true/false). In real case the spin associated with the configuration space metric correlates with the sensory experience and naturally corresponds to the logic of aesthetics (beautiful/ugly) whereas real quaternion conformal degrees of freedom having no correlation with the sensory experience correspond naturally to the logic of ethics (right/wrong), or more generally the true/false logic of belief system having strong right/wrong emotional coloring. Thus the Goodness-Truth-Beauty trinity would thus have a reduction to the Boolean algebra defined by the Fock basis for the configuration space spinors.

TGD based model of abstraction process involves a hierarchy of statements about statements about.... starting from 2 basic statements such that the statement represented by empty set in the set theoretic realization of Boolean algebra is thrown away at each step. The model predict besides the genetic code also a memetic code consisting of 127-bit code words such that 126-bit statements form a maximal number of mutually consistent statements. In case of genetic code 7-bit code words represent all possible statements and 64-bit codewords represent mutually consistent statements.

In real context, 6-bit code words for the genetic code and 126 bit code words for the memetic code code form a maximal number of mutually consistent 'this is right thing to do' beliefs. 7-bit resp. 127-bit code words can be interpreted as coding these statements and their negations: all bits must be realized in p-adic case since formal logic requires also the negations of the basic statements. Lying is a cognitive skill. Genetic code would represent in case of the molecular society the moral and social rules whereas memetic code would represent these rules in case of the ordinary society. DNA would provide a symbolic representation for the 64 fundamental truths, kind of a legal code.

Symbolic and cognitive representations as means of becoming conscious about being conscious about?

An alternative identification of the reflective mind is in terms of language and cognitive representations made possible by the nondeterminism of Kähler action and inherent nondeterminism of p-adic differential equations. These nondeterminisms allow to represent contents of consciousness of self (quantum jump sequence) cognitively and symbolically and to become conscious these representations: this is nothing but becoming conscious about being conscious about...

The (inconvincing) Boolean identification of reflective mind predicts a single directly experienced reflective level. In the second case given quantum jump allows the emergence of only single new reflective level. Indeed, it is easy to become conscious about seeing red but one cannot have direct experience of being conscious about being conscious about seeing red. It is also easy to build theorems about theorems (or imagine what happens under given circumstances) but deriving theorems about theorems about theorems looks impossible without paper and pencil.

Zero energy ontology allows to realize the vision about the reflective hierarchy of consciousness in a concrete manner. The basic building blocks would be negentropically entangled systems representing rules with state pairs defining the entangled state interpreted as instances of the rule. One can construct rules about rules as states formed from this kind of states. The many-sheeted space-time would provide geometric correlates for these rules about rules. The hierarchy of infinite primes would also relate to this abstraction hierarchy.

2.5.4 General model for sensory experiences

The concept of self provides considerable insight to the model of sensory experiencing.

1. If temporal binding involves averaging over the experiences occurred after the wake-up, experiences are reliable.

2. Also the averaging over the experiences of separate sensory subsub-selves implied by the summation hypothesis could be involved.

3. Sensory experiences can involve more than the direct experiencing: also a comparison with the earlier sensory data could quite well be involved and is made possible by subjective and geometric memories. Sensory experiences certainly involve computational aspects.

In the following the general model of sensory experiencing is discussed only briefly [33].

Macroscopic quantum phases are needed

Self must be able to remain unentangled in subsequence quantum jumps. The presence of the macroscopic quantum condensate means usually energy gap between ground state and excited states. This can make the generation of real entanglement very slow process and self can exist.

The fact that macroscopic quantum phases have coupling to the classical gauge fields, suggests that the order parameters of the macroscopic quantum phases are compeletely determined by the localization in the zero modes. Thus the contents of the sensory experience should correlate with these order parameters. This motivated the original attempt to identify macroscopic quantum phases as quantum correlates of the sensory qualia. A more refined approach identifies quantum phase transitions of the macroscopic quantum phases as correlates of sensory qualia so that the increments of quantum numbers in the phase transition label various qualia. This identification is completely general and almost brain independent (cell length scale turns however be crucially important p-adic length scale).

Many-sheeted space-time concept makes possible large number of macroscopic quantum phases not possible in standard physics context. In particular, the so called massless extremals (MEs) representing 'topological light rays' provide a model for how linear structures such as DNA and microtubules could act as quantum antennae emitting and absorbing coherent photon distribution fixed completely by localization in zero modes. Coherent photons could realize the concept of global workspace [88] and could make possible "mass media" at neural level. Also the concept of "neural window" abstracting the notion of hologramic brain suggests itself [41, 24]. MEs form a fractal hierarchy and are carriers of super-symplectic representations for which states are genuine functionals in the space of 3-surfaces ('world of worlds') and thus correspond to higher abstraction level than ordinary quantum states. Super-symplectic states have also gigantic almost degenaries. MEs act also as quantum holograms.

For these reasons MEs are ideal candidates for a hierarchy of life forms [24]. In particular, the assignment of 'our' sensory qualia with super-symplectic quantum transitions looks reasonable whereas magnetic quantum phase transitions might well correspond to more primitive chemical qualia not directly conscious to us.

The functions of nerve pulses

The identification of the sensory qualia in terms of the quantum phase transitions associated with macroscopic quantum phases is in conflict with the general belief that neuronal activity determines completely the contents of the sensory experiences. In TGD framework one can understand the role of the nerve pulse activity differently. Brain is quantum spin glass and the evolution of sub-selves/mental images is a dissipative self-organization process leading to some asymptotic self-organization patterns which correspond to the valleys of the spin glass energy landscape. The contents of the sensory experiences are determined by the zero modes which in turn determine the ground state patterns of the order parameters of various macroscopic quantum phases.

The crucial element of the self-organization is external energy feed making possible interesting self-organization patterns. One role of the nerve pulses is to provide this metabolic energy feed. This suggests that the axons are seats of the self-organization patterns coding at least part of the neuronal experience. Brain seems to systematically maximize the length of the axons feeding sensory data (for instance, right ear feed its sensory input to the left hemisphere). Brain anatomy seems also to favour long pyramidal axons. This phenomenon, which seems to be in conflict with the principles of good metabolic economy, is consistent with the maximization of the expressive power of the sensory pathways. Microtubule conformations are excellent candidates for realizers of declarative memory and this would also explain why the lengths of sensory axons tend to be maximized. Myelin sheets guarantee that external perturbations do not affect the self-organization patterns. It is also possible that myelin sheets form together with the axon Josephson junctions for various super conductors predicted by TGD and are thus essential for the generation of neuronal sensory experiences.

Nerve pulses affect also the postsynaptic cell: typically excitation or inhibition is in question. The interpretation is that the incoming nerve pulses push and pull the postsynaptic cell in different directions and in this manner cause frustrations typical for spin glass like systems. The assumption that neural transmitters give rise to some kind of chemical senses at neuronal level as well as neuronal emotions is in accordance with this. Also frequency coding is consistent with the identification of the nerve pulse activity as a control function.

Of course, spatio-temporal patterns of nerve pulses might also code information about sensory experience. There is indeed evidence that various odours are coded into spatio-temporal nerve pulse patterns [55]. For instance, for the neurons of the associative regions of cortex receiving inputs from several sensory modalities this kind of discrimination is obviously highly desirable. One can even consider the possibility that nerve pulse patterns, in some parts of brain at least (in output axons of association regions), provide a precise naming for axonal experiences.

The notion of memetic code encourages to consider this idea quite seriously and the physical model of the memetic code [26]. realizes a precise coding of the nerve pulse patters to 126 bit temporal sequences represented in terms of time-varying Z^0 magnetization direction of cognitive anti-neutrinos. Bits could correspond to Boolean truth values or bits in a binary expansion of a integer providing measure for the intensity of the net presynaptic sensory experience represented by the cognitive neutrino pairs of the postsynaptic axon: this would be essentially a mapping of experience to its symbol. This naming would serve also as the basis of our language and duration of a phoneme could correspond to the predicted duration of codeword of order .1 seconds. A degenerate form of memetic code would be based on nerve pulses an realize frequency coding whereas full memetic code would be based on neuronal membrane oscillations.

The model for sensory qualia and sensory representations [24, 23] assumes that nerve pulse patterns generate EEG MEs (massless extremals) entangling brain with the sensory magnetic canvas. The question where the mental images responsible for the sensory qualia are located, still lacks a convincing answer. Primary qualia could even correspond to mental images associated with the sensory receptors and sensory pathways could serve as cortex-receptor entanglers. Brain would give names for sensory inputs and percepts rather than creating the primary qualia. This would require feedback from brain to the sensory organs.

Frequency coding is not the only manner to code information to nerve pulse patterns and delicate temporal coding mechanisms exist. For instance, frequencies can be coded to peaks of the spike interval distribution by stochastic resonance [45]. Also the coding of spike interval distribution to EEG frequencies is possible (a kick to a harmonic oscillator at the correct half period leads to a resonant amplification [18]).

How qualia are associated with neural pathways?

Since TGD predicts entire hierarchy of selves, it is important to specify whose sensory experience one is talking about. In TGD framework nerve pulse patterns as such need not give rise to our sensory exerience and it is quite possible that also primary sensory organs have sensory experiences.
    Frustratinly, the question about the seat of quale mental images remains unanswered.

1. The assumption that primary qualia are somehow associated with or determined by the sensory receptors would resolve a difficult question about how sensory pathways, which do not seem to have any obvious differences at the level of brain, give rise to qualia. The entanglement of the sensory receptors with brain in turn entangled with the magnetic body would give rise to the sensory representations. Our sensory experience would not be localizable to what happens in the brain region: indeed, MEs in EEG frequency region have size of order Earth size.

   Various objections (hallucinations, experiences generated by the stimulation of the sensory path- ways, phantom leg phenomenon, dreams) against this view can be circumvented if there is a feedback between brain and sensory organs (as there indeed is), and if sensory experiences can also correspond to geometric memories (say in case of phantom leg experience). If sensory recep- tors are the experiencers of the primary sensory qualia, then conscious experience can precede the neural activity in the cortex, as observed by Libet in his classical experiements concerning the timing of the sensory experiencing [60].

2. A more general view is that the neuronal receptors (also "field receptors" responsible for neuronal vision and hearing can be present) along the sensory pathway are specialized to experience only special sensory qualia characterizing the sensory pathway.

How the primary and possible also secondary sensory receptors or sensory pathways could then give rise to particular qualia? Quite generally qualia correspond to average increments of quantum numbers for the quantum jump sequence defining sub-self. In the case of color qualia one has a partial answer. For MEs super-symplectic quantum transitions are characterized by configuration space Hamiltonians carrying spin and color ($SU(3)$) quantum numbers. For configuration space photons state functional in configuration space degrees of freedom is nontrivial and characterized by configuration space Hamiltonian with quantum numbers characterizing a particular quale. This suggests that somehow neural pathway or sensory receptor should be able to generate 'configuration space photons' (MEs) BE condensing on larger MEs and inducing visual color qualia at least. This would mean that configuration space photons would in a well-defined sense carry qualia: the photons generated by sensory receptors and brain could be colored after all!
    The educated guess is that the EEG transition frequencies coded the spike interval distributions associated with the sensory pathway characterize the sensory pathway partially. EEG frequencies in turn determine partially the quantum phase transitions which can be stimulated by that particular sensory pathway. The miminal option is that these transitions relate only with what parts of magnetic body the sensory pathway is entangled with. This would make possible very high functional flexibility in accordance with the observed plasticity of brain.

Only changes are perceived

One of the basic laws about sensory experiencing is that only changes and novelties are perceived. For instance, totally monochromatic illumination is experienced as darkness. The zero modes charac- terizing the macroscopic space-time associated with the final quantum history of the quantum jump should determine the contents of the sensory experience. Part of the zero modes corresponds to the induced Kähler of CP_2 which is nonlinear Maxwell field closely related to the classical electromag- netic and Z^0 fields. There are also zero modes representing the size and shape of 3-surface: these might be related to the discriminative sense of touch. A possible generalization of the law is that sensory stimulus generates Kähler electric field proportional to the gradient of the stimulus. This creates however a problem. Kähler electric flux must be conserved in the approximation that vacuum Maxwell's equations are satisfied (they are not exactly satisfied since vacuum can carry currents of Kähler charge). Suppose that stimulus has a strong gradient: where does the Kähler electric flux go in this kind of situation?

The solution of the problem might be very simple: mindlike space-time sheet is generated and the flux goes to the mindlike space-time sheet through wormhole contacts. Since sensory stimulus varies rapidly at the boundaries of the objects of the external world, this means that the objects of the perceptive field are automatically represented by mindlike space-time sheets and give rise to selves, mental images already at the level of the sensory organ or the sensory pathway leading to thalamus.

The extreme generality of the mechanism suggests that it could be at work also at the level of brain. Understanding of the computational aspects of sensory experience (say stereovision) is not possible unless one assumes that mindlike space-time sheets in sensory pathway combine with the primary sensory organs to form coherent quantum systems. "Ontogeny recapitulates phylogeny" principle requires that these space-time sheets are connected by join along boundaries bonds most naturally associated with axons leading from sensory organ to brain.

Are the ultimate sensory representations realized outside brain?

One of the dramatic almost predictions of TGD inspired theory of consciousness is that our physical body is accompanied by a hierarchy of field bodies, in particular magnetic body. A given field body provides abstract representations about quantum aspects of the physical body, kind of a manual. This prediction plus some general arguments lead to the view that sensory representations are most naturally realized outside the physical body at the personal magnetic body (first person aspect of consciousness) and at the magnetic body of Earth (third person aspect of consciousness).

This vision leads to the interpretation of EEG as being involved with MEs projecting sensory data to the magnetic body. EEG ME would generate quantum entanglement between two mental images: a feature inside brain and a 'simple feeling of existence' mental image at the magnetic body and representing a point of the external world. Thus the main function of brain would be the construction of features and sensory representations would be completely separated from their construction. Note that also in the case of computers the representation of the data is separated from the generation of the data.

2.5.5   Emotions

TGD suggests several visions about emotions and it is not yet completely clear whether these views are really mutually consistent.

Emotions and comparisons

The basic element of mentality is the comparison between the expectations of future and what actually occurred. In TGD framework this tension between potential and actual can be understood. Subjective and geometric memories make it possible to compare the expectations with what really occurred during the time interval since subjective memory is kind of heap of predictions of future arranged with respect to the value of the psychological time. Many higher emotions such as sorrow, depression, frustration, desire, happiness, feeling of relief, pain, fear, anger, envy, hatred, etc... clearly involve comparison of expectations and reality. This could perhaps mean that these emotions are created by the comparison of the predicted or desired geometric time history and subjective time history (what really happened). This would mean that at least higher emotions differ from the sensory qualia, which seem to be determined solely by the localization into zero modes representing the non-quantum fluctuating aspects of space-time geometry.

One might however argue that very primitive emotions such as rage without any object and involving only the activity of the limbic brain could be quale like and that hormones are the quantum correlates of these emotions. These emotions involve however a change of behaviour (e-motion!) so that one could argue that also now there is a simple comparison involved. Perhaps changes in the hormone concentrations could be regarded as consequences of the change of the emotional state. Or vice versa, if hormones are messangers telling to very simple selves of limbic brain whether the real course of events was the desired one or not, then hormones indeed effectively control the emotional state and can be regarded as quantum correlates of emotions.

It is difficult to assign any comparison to an emotion like deep love since it involves a complete acceptance of the object of love and is free of desires. Perhaps the claim of mystics that deep experience of love means that subject and object of love cease to exist as separate objects, makes sense. Lovers

quantum entangle and die as separate selves (for some fraction of time only, of course!) and the higher self consisting of lovers experiences whole-body consciousness. Perhaps more mundane love means that my sub-selves representing me and the loved one entangle to form a sub-self experiencing whole-body consciousness. Perhaps also feelings like empathy belong to this class of emotions.

Emotions and entropy

The concrete model of qualia to be developed in [24] provides an alternative general vision about emotions which allows to understand the difference between comparison type emotions and other emotions as well as the role of emotions in control.

1. The statistical physics approach to qualia leads to the hypothesis that emotions correspond to rates for the generation of various type of entropies for the sub-selves of self. The sign of the rate tells whether emotion is positive or negative. Negative emotions would thus be conscious control variables warning self when some sub-system is generating entropy. The holistic nature of the emotions can be understood easily in this picture and also the fact that they are not directly related to sensory input. One could perhaps also understand higher level emotions like sorrow as reflecting the growing disorder of the virtual world of brain resulting from the primary cause of sorrow.

2. It is known that peptides correlate strongly with emotions and moods [72] and they are even called molecules of emotions. Peptides are also regarded as information molecules. This connection between information and emotions fits nicely with the fact that peptides and other important biomolecules certainly induce strong entropy gradients with respect to subjective time.

3. Sensory qualia can be divided to geometric and non-geometric ones. One can classify also emotions in this manner. Emotions corresponding to the localization in zero modes would perhaps correspond to 'higher level emotions' about external world (say, aesthetic qualia) whereas the non-geometric emotions associated with the state preparation would correspond to 'self-centered' emotions about the state of body (pain, physical pleasure,...).

4. Also pure emotions which seem to involve no obvious comparison (love, joy, excitement,..) are possible. For instance, the emotions produced by music might represent this kind of emotions. The view about emotions as entropy gradients allows to understand also emotions of this kind. In state of deep love, self enters into very low-entropy state and mental images (not necessarily even present in 'enlightened states') become very pure.

5. An interesting question is whether the entropy growth of our sensory sub-selves is only sensory representation for the entropy growth occurring at the level of atomic space-time sheets or corresponds directly to it. The enormous difference of the temperatures associated with the atomic space-time sheets (ordinary matter) and superconducting magnetic flux tube structures would suggest that the growth rates for these entropies are of totally different order of magnitude and our emotions serve have the role of conscious control variables telling whether things are going well at the atomic space-time sheets.

Consider now the comparison type emotions and the relation of emotions to control in more detail.

1. Many emotions are comparison type emotions. These emotions tend to be negative (say envy). The first option is that comparison type emotions result from the comparison of geometric and subjective memories occurring automatically in any quantum jump and thus to some degree with any quale. Unfortunately, it is very difficult to imagine how to concretely test this kind of hypothesis and it is also difficult to see how the connection with entropy gradient could emerge.

2. One must also seriously consider the possibility that emotions result from the comparison of remembered/anticipated experience and real experience rather than the fundamental comparison involved with anticipation and memory: kind of quasi-computerized version of geometric memory would be in question. The result of comparison would be coded to the sign of the growth rate of some entropy variable. The comparison could perhaps be realized in such a

manner that subsequent quantum jumps for comparing sub-system could represent either the anticipated or real quale. If this were the case, the difference between anticipated and real would automatically induce growth of entropy and negative emotion would result. This would be the basic mechanism of dissappointment. In this picture comparison type emotions could be seen as a system of rewards and punishments used to control the self (the controller could be higher level self (conscience) or higher levels selves which also want to survive (the emotions generated by hunger, first, and physical pain). Punish/reward mechanisms could basically involve negentropy/entropy feed to some sub-self.

3. One could also regard emotion as induced by generalized sensory qualia giving information about CNS itself rather than external world or the boundary between external world and body. The regulation involved with the homeostasis involves comparison in an essential manner so that one could perhaps regard emotions as analogous to control variables representing consciously the result of comparison of expected and desired forcing the organism to behave in a manner to reduce this difference and end up to a rest and digest state. This aspect is consistent with the statistical interpretation since the entropy gradients associated with the organism are stronger than those associated with the surrounding world. Also amplification mechanisms exaggerating the entropy gradients might have developed. For instance, our reactions to some odours or tastes could involve this kind of amplification.

4. A hypothesis consistent with these views is that emotional component is involved with all sensory experiences and that we are used to call generalized sensory experiences emotions when they are about body. The emotionality of qualia indeed increases in the sequence of perceptive fields external world – CNS-world boundary – body. The degree of emotionality of experience should be characterized by the deviation of real from expected or desired and this suggests that the emotional component is much stronger for sensory experiences about CNS itself, since the system in question is much less predictable than the external world consisting of dead objects. Interpretation of emotion as measure for entropy gradient explains also this hierarchy.

5. Depression could be seen as a lost ability to experience emotions, be they positive or negative. Depression indeed involves emotional flatness. This state results when mental images become maximally entropic (emotional counterpart of heat death). That depression can follow deep sorrow is natural since negative emotions tend to increase the entropy of the mental images. It is known that depression involves over-activity of the amygdala and under-activity of some forebrain regions and an abnormally small population of glial cells known to be closely involved with metabolism and 'cleansing activities' at brain level. This supports the view that glial cells might be warriors in the war against second law at the level of atomic space-time sheets and the loss of this war is sensorily mapped to the level of mental images and leads to depression. One function of serotonin, dopamin and various other neuropharmaca tending to produce pleasant experiences could be a reduction of entropy either at atomic space-time sheets or, less probably, directly at the level of our sensory sub-selves.

2.5.6   Directed attention

The possibility to interpret self as a statistical ensemble suggests that the entropy of the mental image measures its fuzziness. Thus both attentiveness, alertness and level of arousal should relate very closely to the entropy of the mental images. Attention to a mental image could mean fight against second law to keep the mental image in a low entropy state and this requires metabolism (the icons on the computer screen provide a good example of this). Also alertness means mental images with low entropy content. 7 ± 2 rule of cognitive science suggests that the maximum number of our cognitive sub-selves which can be awake simultaneously, is rather limited. The rule might be based on the metabolic limitations: sub-selves can have low entropy content only in the presence of an external negentropy feed and metabolism must provide the needed negentropy feed. Note however that the needed metabolic energy might be extremely low.

   Directed attention is one of the basic processes of consciousness occurring continually. Directed attention seems to involve free choice but focusing of attention could also occur spontaneously. One can imagine several models for the focusing of attention.

1. One possibility is that subsub-self inside sub-self representing mental image (say 'monitor screen' as average over subsub-selves representing the visual objects) somehow pops up one level higher in the self hierarchy so that it becomes mental image. Geometrically this could correspond to the re-gluing of the corresponding space-time sheet to the space-time sheet of self instead of that of sub-self. In this case attended object would not pre-exist.

2. A further aspect of the focused of attention is as a wake-up of sub-self and keeping it in wake-up state and hence in short term memory. This could occur at the expense of the other sub-selves, which would be in wake-up state for only short times. A possible mechanism of selection is a phase transition changing the topology of chosen region (say from p-adic to real or from p_1-adic to p_2-adic) so that a new sub-self pops up from the background.

3. Self directs automatically its attention only to sub-systems immediately below it in the hierarchy. It seems however possible to direct attention to lower levels of the self hierarchy. For instance, I can direct my attention to the entire sentence, which I am writing here or to some word of this sentence or to individual letters of this word. The phenomenon of bio-feedback demonstrates that it is possible to learn to direct the attention to even single neuron. This suggests that selves are able to modify the hierarchy of selves by raising some sub...sub-self to the role of sub-self temporarily and thus experience the former sub...sub-self as a direct mental image. Formation of the join along boundaries bonds between mindlike space-time sheets at various levels of the self hierarchy provides a general geometric mechanism making possible temporary changes of the structure of the self hierarchy. Also the learning taking place during sleep [54] migh involve interaction between different levels of the self-hierarchy.

Anyone can do a simple but thought provoking experiment suggesting the presence of the macroscopic quantum entanglement at the level of brain and a change of the level of sub-self in the self hierarchy. Look at a mirror, direct your attention at your left eye, and redirect the gaze to the right eye. What you find that it is impossible to perceive the change in the direction of the eye gaze.

1. Consider first what probably happens when we perceive a moving object. A negentropic binding of the mental images of the visual field to single mental image implies that both the parts and the whole can be experienced so that the motion is perceived. If the direction of the gaze is stationary, the object moves relative to the background, and if the direction of the gaze follows the object the background moves with respect to the direction of gaze. In both cases the motion can be perceived.

2. If the eye follows its own rotating mirror image, neither of these options is realized if the environment to which the attention is directed is restricted to be the eye itself. The direction of the gaze should remain the same in order to perceive the change of the direction of the gaze but this is impossible.

3. The perceptive field however contains also other objects and one could argue that if the attention is directed also to these simultanenously, it should be possible to perceive the changing direction of gaze as they move relative to the changing direction of gaze. Does the very act of directing attention to the mirror image of eye separate it from the negentropic entanglement with the other mental images so that the conscious comparison with them is not possible anymore? Or is the visual mental image representing eye at a different level of hierarchy as mental images from the very beginning and cannot negentropically entangle with the other visual mental images? Eye cannot perceive itself! Not even in mirror.

One should also understand what it means to direct the attention to an object of perceptive field. Certainly this process is directed and selective. Could the direction of attention to an object of perceptive field separate the corresponding mental image from the negentropic fusion of mental images as a separate mental image? Could it be that the motion of object can be perceived only if the attention is fixed only temporarily to the object? There are almost incredible sounding experiments demonstrating that the attention directed intensely to a fixed object makes it impossible to perceive what happens in environment.

2.5.7   Altered states of consciousness

The proposed concept of self provides allows rather rich a palette of altered states of consciousness and one cannot avoid the temptation to a concrete modelling of various altered states of consciousness. It seems that negentropic entanglement provides a general explanation for the reported characteristic of these experiences.

Whole-body consciousness and ordinary consciousness

Krishnamurti has described in his books states of consciousness having natural identification as states of 'whole-body consciousness'. For instance, according to Krishamurti, one can achieve this state only if one is able to stop thinking entirely. If thoughts correspond to cascades of selves decomposing into sub-selves during state function reduction proess, then this is just what is required. The characteristic of this state of consciousness as reported by meditators are the experience of one-ness and the absence of all separations. The absence of separation would conform with negentropic entanglement. One-oneness could correspond to irreducible selfness without subselves or to the negentropic fusion of mental images to single mental image. Also 'timelessness' characterizes these experiences: the explanation is that internal clock is provided by some sub-self waking up periodically and since there are no sub-selves there can be no time. Note also that negentropic time like entanglement fuses the subselves assignable to the future and past boundaries of CD to single self.

I have personally experienced states of whole-body consciousness and also states in which whole-body consciousness is limited to some part of body. These states begin with a sudden fall of silence: all the usual 'noise' from the body disappears suddenly although ordinary physical sounds are still heard. This could be interpreted as disappearance of sub-selves from body or as generation of negentropic entanglement stable under quantum jumps. There is experience like thrill in spine going through the entire body. Interesting experience of this kind occurred when my cat was sleeping over my breast: I woke up and realized that my breast was in the state of whole-body consciousness. Could this mean that sleeping cat was also in this state and that my breast had entangled with the quantum state of cat? Could this in turn mean that during sleep we indeed are in a state of whole-body consciousness or even that our entire body is entangled with some large self? Could the absence of neuronal quantum jumps explain why we do not remember anything about these states? Are remembered states of whole-body-consciousness always such that at least some part of brain is awake?

Possession of ego defined as a collection subselves, which repeatedly unentangle themselves from the external world means dissipation, aging and eventual physical death (note however that self lives as a conscious memory realized as a sub-self of higher level self providing kind of summary about the lifetime of self). There would be two manners to getting rid of ego. Get rid of subselves or try to achieve a state in which they negentropically entangle to single mental image.

The absence of neuronal and cell level dissipation during states of whole-body consciousness provides a possible test for the phenomenonon. Test persons could be trained meditators and test should involve the measurement of neural or cellular dissipation occurred during the state of whole-body consciousness. Reduced rate of metabolism could be a measurable signature of whole-body consciousness. Dissipation should be absent or should be very small during this state at least if it is present for sufficiently large fraction of time. The absence of dissipation means that all changes suffered by the cells during whole-body consciousness are reversible and curable. This could explain various miraculous healings. Whole-body consciousness, if possible to arrange artificially, could provide medical means of saving the lifes of victims of accidents (say of victim of heart attack or bleed in brain).

Negentropic entanglement allows the component systems to be free in the sense that there is no binding energy. Even more, negentropic systems could carry metabolic energy but would not liberate it or liberate it in much longer time scale than usually (also large $\hbar$ could be involved). As a matter fact, the high energy phosphate bond assumed in the model of metabolism could correspond to negentropic entanglement carrying metabolic energy [19].

Synchronous neural firing is a possible candidate for whole-body consciousness at the level of brain.

1. The anomalously low value of neuronal oxidative metabolism during synchronous neuronal firing in cortex could be interpreted in terms of negentropic inter-neuronal entanglement during which ATP-ADP Karma's cycle is absent and dissipation is reduced.

2. One could of course argue that metabolic energy is liberated but from other source than ATP.

For instance, the formation of bound state entanglement between the group of firing neurons could liberate the binding energy as metabolic energy. The formation of hydrogen bonds could be the counterpart for the process at molecular level. This mechanism would however imply dissipation and there is no strong reason to assign whole-body consciousness to this kind of state (of course, synchoronous neural firing need not corre.

Whole-body consciousness could explain some spectacular phenomena (not of course taken seriously by skeptics).

1. The claimed ability of yogis to survive for months without eating anything and even without oxygen could have explanation in terms of whole-body consciousness. Oxygen consumption compensates the loss of chemical energy caused by the quantum jumps in biochemical length scales. These quantum jumps occur only if neuronal and lower level chemical selves exist. Under usual circumstances the continuous supply of oxygen makes the ageing of cells slow and the lack of oxygen leads to rapid dissipation and neuronal death. The situation is analogous to Benard flow: if heat feed is stopped, the beautiful flow pattern rapidly dissipates away. If all cells are entangled during whole-body consciousness, no dissipation occurs and the lack of the oxygen supply does not have any irreversible effects and possible effects might be cured automatically. An alternative explanation for the the mystery of yogis who need not eat is that the generation of bound state entanglement involves the liberation of the binding energy as a usable energy possibly compensating for the ordinary metabolic energy.

2. In certain cultures people in trance are able to dance with their bare feet on burning charcoals without any disastrous effects. The disastrous effects of the interaction of heat from burning charcoals with cells in soles of foot must be irreversible changes. If these persons are in a state of whole-body consciousness, then the changes of the invididual cells would reversible.

That-which-is experiences

Irreducible self does not possess any sub-selves. The absence of sub-selves in turn means the absence of mental images. This kind of situation could correspond to that-which-is experience. The reports of Buddhist meditators about pure awareness with discrete twinkles of consciousness identifiable as short-lived sub-selves are in accord with this view.

In principle meditation could make possible to silence the hierarchy sub-selves and make it possible to directly experience quantum jumps occurring at elementary particle level! In zero energy ontology the temporal size scales assignable to elementary particles are time scales of human consciousness (electron corresponds to .1 second time scale and u and d quarks to millisecond time scale) plus the hierarchy of Planck constants as a realization of dark matter hierarchy crucial for living matter and predicting scaled up variants of these time scales, this idea need not be so crazy at it looks at first sight. In this speculative spirit one could even consider the possibility that the abstract theories of elementary particle physics result basically as a summation of the experiences of matter-mind sub-systems entangled with elementary particles! One can even consider the possibility that genetic code is realized in terms of the sub-CDs assignable to the electronic CDs and could form first level realization of the phonemes of language.

One can also considera weaker notion of one-ness in which self has only single mental image. In this case sub-selves would fuse to single subself either by bound state entanglement or negentropic entanglement. The formation of these states is accompanied by the formation of join along boundaries bonds -say magnetic flux tubes- between space-time sheets representing binding sub-systems. State function reduction does not occur in these degrees of freedom anymore, macroscopic quantum coherence is preserved from quantum jump to quantum jump, and the system behaves as macroscopic multiverse with new macroscopic degrees of freedom making possible macroscopic quantum computation. This might be the mechanism for how water, DNA, protein, tubulin,... molecules and even neurons bind to quantum computing macroscopic multiverses [24].

Zen type experiences and negentropic entanglement

Negentropic entanglement is possible in the intersection of real and p-adic worlds. Negentropic states are not eigenstates of measured observables giving information about the quantum numbers of the

system or its complement but about the entire system. Conscious experience is an abstraction about the correlation between states of entangled systems- a rule with instances of the rule being represented as state pairs. Negentropic entanglement can be also time-like and between systems corresponding to space-time sheets in different number fields in the intersection of real and p-adic worlds. The simplest example about negentropic entanglement are fuzzy qubits. Zero energy ontology allows to imagine entire hierarchies of negentropic entanglements between negentropic states and an attractive interpretation is in terms of a reflective hierarchy producing statements about statements.

The reported experience about disappearence of illusions would conform with the interpretation about experience of understanding assignable to the state. The disappearence of the decomposition to observer and observed would correspond to the experience of oneness. Zen Buddhists experiences are often characterized as states of consciousness in which no selection is made between mutually exclusive alternatives. Hofstadter has described this aspect of Zen in hilarious manner in his book 'Gödel, Escher, Bach'. Also this aspect conforms with the basic properties of negentropic entanglement.

The absence of external-world-me separation and absence of desires is also reported to be a characteristic feature of that-which-is and Zen type experiences. Ego separates itself from external world in quantum jump by state function reduction leading to an uncorrelate product state. Ego disappers when the self fuses with external world negentropically. Perhaps also desires could be equated with the tendency to preserve ego.

Extended states of consciousness

Extended states of consciousness seem to be the exact opposite of that-which-experiences. Psi experiments concern subtle connections between subjects removed in space, and occasionally also in time. These experiments are reviewed in [80] and the following representation follows this review closely. The pioneering work related with card and dice-guessing was done by J. B. Rhine in 1930s.

The formation of negentropic entangelement gives a natural general explanation of these experiences. Negentropic sharing and fusion of mental images would be part of the mechanism for extended states of consciousness.

The notions of geometric memory and electromagnetic self allow also to understand basic features of these experiences. For instance, the notion of geometric memory allows to understand memories about previous lives and prenatal experiences in which the the contents of consciousness is time shifted. The model for sensory representations leads to the conclusion that the topological field quanta of ELF fields, having frequencies in EEG range and by Uncertainty Principle having size of Earth, are crucial element of our sensory experience. The formation of join along boundaries contacts between topological field quanta associated with different selves could explain a large variety of paranormal experiences.

1. The experiments of Russel Targ and Harold Puthoff

The experiments of Russel Targ and Harold Puthoff [59] were carried in the 1970's some of the best known experiments on subtle connections among distant subjects in regard to the transference of thoughts and images. Both sender and receiver were closed in a sealed, opaque, electrically shielded chamber so that no sensory communication was possible. Sender was subjected to light flashes at regular intervals. This caused a characteristic pattern in the EEG of the sender. In some cases also the receiver exhibited these rhytms.

In remote vision experiments sender served as a beacon. Receiver tried to describe verbally or by scetches what the beacon saw. Independent judges matched on the average 66 per cent of time with what was actually seen by the beacon. There are also remote viewing experiments from other laboratories. The distances between sender and receiver vary from miles to thousands of miles and it seems that distance does not matter.

Distance independence supports the interpretation of both experiments in terms of fusion and sharing of mental images.

2. The experiments of Stanley Krippner

In the experiments of Stanley Krippner [67] image transmission was studied while receiver was asleep. Experimenter, sender and volunteer met each other in the beginning of the experiment. Sender spent the night concentrating on an art print, which he/she had received in the beginning of the experiment in a closed envelope. The brain waves and eye movements of the volunteer were

recorded. The experimenter woke the volunteer at the end of the REM period by intercom and the volunteer described the dream.

A correlation between the contents of the dream and of the art print was observed. The score was higher on nights, when there were few or no electric storms in the area and sunspot activity was lowest.

The simplest interpretation is again in terms of fusion of mental images of the subject persons. These mental images are perhaps represented at the personal magnetic sensory canvas. Electric storms and sunspot activity affect directly Earth's magnetic field and should affect the communication mechanism since the experiments of Blackman and other suggest that em selves could correspond to magnetic transition frequencies associated with magnetic field of .2 Gauss which is near to the nominal value .5 Gauss of the Earth's magnetic field. In fact, there exists independent evidence for a general correlation of geomagnetic activity with psi experiences [78].

3. The experiments of J. Grinberg-Zylverbaum

In the experiments of J. Grinberg-Zylverbaum [74] the transfer of EEG potentials was studied. Two subject persons were involved. They were closed in Faraday cages. The sender was meditating. Another subject person was subject to a stimulus in random intervals; not even the experimenter knew, when they were applied. Non-stimulated subject person was in a relaxed state. Stimulus was sudden, short light or sound or short electric shock to index and ring fingers of the right hand causing a characteristic pattern in the EEG of the stimulated person.

The EEG's of the subject persons were synchroninized. The possible presence of transferred potentials in the EEG of nonstimulated subject was studied. Transferred potentials were detected in 25 percent of all cases *provided* persons had met before the experiment. A dramatic example was young couple, deeply in love, whose EEGs remained synchronized throughout the experiment.

The fusion of ELF selves means synchronization of ELF em fields and since ELF selves correspond directly to EEG frequencies, synchronization of EEGs is an immediate consequence and can transfer the synchronous firing in brain circuit of the sender to corresponding brain circuit of the receiver. The personal contact before the experiment certainly enchanges the probablity for the fusion of ELF selves. Also quantum entanglement between sub-selves of subject persons might be involved.

It is known that the EEGs of right and left brain are synchronized in deep meditation. There are also experiments of synchronization of EEGs for different subjects in group meditation [58]. The explanation is same as in above case. Also quantum entanglement might be involved. For instance, quantum entanglement is crucial for the fusion of left and right perceptive fields to single perceptive field.

4. Telesomatic effects

Also the tansfer of actual bodily effects from subject person to another has been studied: references to these experiments can be found in [80]. Physiological changes are found to be triggered in the targeted person by the mental process of another. Distance makes little of no difference. Thus the interpretation in terms of quantum entanglement suggests itself.

There are also reports of the transference of pain between persons having very close mutual relationship. Identical twins, mothers and their sons or daughers, couples in love, etc,. Also the relationship between psychiatrist and patient provides example of this kind and is known as projective identification. The general rule seems to the that the relationship between inviduals is always involved with psi effects. This is in accordance with the hypothesis about sharing of mental images having ELF em fields and field bodies as physical correlates. For instance, the field bodies of persons in an intimate relationhip might develop gradually direct contacts (say magnetic flux tubes connecting physical bodies).

5. Grof's experience with altered states of consciousness

Findings of modern psychotherapists, especially the work of Stanislav Grof [70, 80] suggest that besides the ordinary 'biographic-recollective' domain of psyche also perinatal and transpersonal domains of psyche exist. Transpersonal domain can mediate connection between our mind and practically any part or aspect of the phenomenal world. Grof studied for several decades altered states of consciousness induced by psychedelic drugs or holotropic breathing.

In the experience of *'dual unity'*, loosening and melting of the boundaries of the body ego happens but in the merging with another person, own identity is not lost. In the *identification* with another

person loss of own identity occurs. Body image, physical sensations, emotional reactions and attitudes, thought processes, memories, facial expressions, typical gestures and mannerisms, postures, movement and even the inflection of the voice become those of the second person. The other can be someone in the presence or absent. Identification involving time shift is also possible. Part of an experience can come from subject's childhood, his or her ancestry or even of a previous lifetime.

Also group identification and group consciousness is possible. Person can identify with an entire group of people having some racial, cultural, national, ideological, religional, political or professional characteristics. People may experience the totality of suffering of all the soldiers or tenderness of all lovers and dedication of all mothers in regard to their babies.

Identification with animals is possible. This involves body image, specific physiological sensations, instinctual drives, unique perceptions of the environment, emotional reactions, etc.. Person can identify with plants and botanical processes. Also identification with inorganic world can occur. People can identify with rivers, storms, tornadoes, mountains,.... Or stones, quartz crystals, minerals.... Even the identification with structures of atomic and sub-atomic world is claimed to be possible. At the second end of spectrum are racial and collective experiences and identification with entire human species and the experiences in which one identifies with the whole Earth or even entire cosmos. Also out of body experiences, clairvoyance, clairaudience and telepathy are common. Displacement in time is possible. Patient can have embryonical and fetal experiences and even ancestral experiences as well as past incarnation experiences.

Identification experiences can be generally understood as sharing and fusion of mental images. The fusion of mental images can occur between very many inviduals, say members of a species and would give rise to kind of stereo consciousness analogous to the stereo vision resulting in the fusion of left and right visual fields. We could also share this stereo consciousness: for instance, shamanist could share the mental images of animal species.

Perinatal experiences and memories extending beyond the lifetime of individual could be explained in terms of geometric memory and the notion of 4-dimensional body: actually these experiences do not in any significant manner differ from ordinary memories. The content of the conscious experience is multilocal both in subjective and geometric time in the sense that the experience contains contributions from several moments of geometric time simultaneously.

Our personal self hierarchy could actually contain higher levels than the levels represented by ELF emf fields associated with EEG. This hypothesis makes sense if the contribution of the higher levels of our self hierarchy to our conscious experience under normal circumstances is only some kind of general awareness ('silent observer'). These higher levels could actually explain the experienced continuity of self. For instance, during sleep there there would be some kind of basic awareness present: the lack of memories about sleep state would lead to, in this framework, erraneous conclusion that sleep state is unconscious.

2.6   Boolean mind, cognition and intentionality

2.6.1   Fermions and Boolean cognition

Fermionic Fock state basis defines naturally a quantum version of Boolean algebra. In zero energy ontology predicting that physical states have vanishing net quantum numbers, positive and negative energy components of zero energy states with opposite fermion numbers define realizations of Boolean functions via time-like quantum entanglement. One can also consider an interpretation of zero energy states in terms of rules of form $A \rightarrow B$ with the instances of A and B represented as elements Fock state basis fixed by the diagonalization of the density matrix defined by $M-$matrix. Hence Boolean conciousness would be basic aspect of zero energy states. Physical states would be more like memes than matter. Note also that the fundamental super-symmetric duality between bosonic degrees of freedom (size and shape of the 3-surface) and fermionic degrees of freedom would correspond to the sensory-cognitive duality.

This would explain why Boolean and temporal causalities are so closely related. Note that zero energy ontology is certainly consistent with the usual positive energy ontology if unitary process U associated with the quantum jump is more or less trivial in the degrees of freedom usually assigned with the material world. There are arguments suggesting that U is tensor product of of factoring S-matrices associated with 2-D integrable QFT theories [22]: these are indeed almost trivial in momentum degrees

of freedom. This would also imply that our geometric past is rather stable so that quantum jump of geometric past does not suddenly change your profession from that of musician to that of physicist. The maximal diagonality of U-matrix for p-adic-to-real transitions would in turn favor precise realization of intentions as actions. One must however take this kind of arguments with extreme caution.

2.6.2 Fuzzy logic, quantum groups, and Jones inclusions

Matrix logic [48] emerges naturally when one calculates expectation values of logical functions defined by the zero energy states with positive energy fermionic Fock states interpreted as inputs and corresponding negative energy states interpreted as outputs. Also the non-commutative version of the quantum logic, with spinor components representing amplitudes for truth values replaced with non-commutative operators, emerges naturally. The finite resolution of quantum measurement generalizes to a finite resolution of Boolean cognition and allows description in terms of Jones inclusions $\mathcal{N} \subset \mathcal{M}$ of infinite-dimensional Clifford algebras of the world of classical worlds (WCW) identifiable in terms of fermionic oscillator algebras. $\mathcal{N}$ defines the resolution in the sense that quantum measurement and conscious experience does not distinguish between states differing from each other by the action of $\mathcal{N}$.

The finite-dimensional quantum Clifford algebra $\mathcal{M}/\mathcal{N}$ creates the physical states modulo the resolution. This algebra is non-commutative which means that corresponding quantum spinors have non-commutative components. The non-commutativity codes for the that the spinor components are correlated: the quantized fractal dimension for quantum counterparts of 2-spinors satisfying $d = 2cos(\pi/n) \leq 2$ expresses this correlation as a reduction of effective dimension.

The moduli of spinor components however commute and have interpretation as eigenvalues of truth and false operators or probabilities that the statement is true/false. They have quantized spectrum having also interpretation as probabilities for truth values and this spectrum differs from the spectrum $\{1, 0\}$ for the ordinary logic so that fuzzy logic results from the finite resolution of Boolean cognition [24].

2.6.3 p-Adic physics as physics of cognition and intentionality

p-Adic physics as physics of cognition and intentionality provides a further element of TGD inspired theory of consciousness. At the fundamental level light-like 3-surfaces are basic dynamical objects in TGD Universe and have interpretation as orbits of partonic 2-surfaces. The generalization of the notion of number concept by fusing real numbers and various p-adic numbers to a more general structure makes possible to assign to real parton a p-adic prime p and corresponding p-adic partonic 3-surface obeying same algebraic equations. The almost topological QFT property of quantum TGD is an essential prerequisite for this. The intersection of real and p-adic 3-surfaces would consists of a discrete set of points with coordinates which are algebraic numbers. p-Adic partons would relate to both intentionality and cognition.

The transformation of p-adic variant of the partonic 3-surface with bosonic quantum numbers to its real counterpart in quantum jump would represent a transformation of intention to action and the unitary matrix U would govern this process. The larger the number of algebraic points in the intersection, the more precise the realization of intention as action would be.

Real fermion and its p-adic counterpart forming a pair would represent matter and its cognitive representation being analogous to a fermion-hole pair resulting when fermion is kicked out from Dirac sea. The larger the number of points in the intersection of real and p-adic surfaces, the better the resolution of the cognitive representation would be. This would explain why cognitive representations in the real world are always discrete (discreteness of numerical calculations represent the basic example about this fundamental limitation).

All transcendental p-adic integers are infinite as real numbers and one can say that most points of p-adic space-time sheets are at spatial and temporal infinity in the real sense so that intentionality and cognition would be literally cosmic phenomena. If the intersection of real and p-adic space-time sheet contains large number of points, the continuity and smoothness of p-adic physics should directly reflect itself as long range correlations of real physics realized as p-adic fractality. It would be possible to measure the correlates of cognition and intention and in the framework of zero energy ontology [22] the success of p-adic mass calculations can be seen as a direct evidence for the role of intentionality and cognition even at elementary particle level: all matter would be basically created by intentional action as zero energy states.

2.6.4   Infinite primes, cognition and intentionality

Somehow it is obvious that infinite primes must have some very deep role to play in quantum TGD and
TGD inspired theory of consciousness. What this role precisely is has remained an enigma although
I have considered several detailed interpretations, one of them above.

In the following an interpretation allowing to unify the views about fermionic Fock states as a rep-
resentation of Boolean cognition and p-adic space-time sheets as correlates of cognition is discussed.
Very briefly, real and p-adic partonic 3-surfaces serve as space-time correlates for the bosonic super
algebra generators, and pairs of real partonic 3-surfaces and their algebraically continued p-adic vari-
ants as space-time correlates for the fermionic super generators. Intentions/actions are represented
by p-adic/real bosonic partons and cognitions by pairs of real partons and their p-adic variants and
the geometric form of Fermi statistics guarantees the stability of cognitions against intentional action.
It must be emphasized that this interpretation is not identical with the one discussed above since it
introduces different identification of the space-time correlates of infinite primes.

Infinite primes very briefly

Infinite primes have a decomposition to infinite and finite parts allowing an interpretation as a many-
particle state of a super-symmetric arithmetic quantum field theory for which fermions and bosons
are labelled by primes. There is actually an infinite hierarchy for which infinite primes of a given
level define the building blocks of the infinite primes of the next level. One can map infinite primes
to polynomials and these polynomials in turn could define space-time surfaces or at least light-like
partonic 3-surfaces appearing as solutions of Chern-Simons action so that the classical dynamics would
not pose too strong constraints.

The simplest infinite primes at the lowest level are of form $m_B X/s_F + n_B s_F$, $X = \prod_i p_i$ (product
of all finite primes). The simplest interpretation is that X represents Dirac sea with all states filled
and $X/s_F + s_F$ represents a state obtained by creating holes in the Dirac sea. m_B, n_B, and s_F are
defined as $m_B = \prod_i p_i^{m_i}$, $n_B = \prod_i q_i^{n_i}$, and $s_F = \prod_i q_i$, m_B and n_B have no common prime factors.
The integers m_B and n_B characterize the occupation numbers of bosons in modes labelled by p_i and
q_i and $s_F = \prod_i q_i$ characterizes the non-vanishing occupation numbers of fermions.

The simplest infinite primes at all levels of the hierarchy have this form. The notion of infinite
prime generalizes to hyper-quaternionic and even hyper-octonionic context and one can consider the
possibility that the quaternionic components represent some quantum numbers at least in the sense
that one can map these quantum numbers to the quaternionic primes.

The obvious question is whether configuration space degrees of freedom and configuration space
spinor (Fock state) of the quantum state could somehow correspond to the bosonic and fermionic parts
of the hyper-quaternionic generalization of the infinite prime. That hyper-quaternionic (or possibly
hyper-octonionionic primes would define as such the quantum numbers of fermionic super generators
does not make sense. It is however possible to have a map from the quantum numbers labelling
super-generators to the finite primes. One must also remember that the infinite primes considered are
only the simplest ones at the given level of the hierarchy and that the number of levels is infinite.

Algebraic Brahman=Atman identity

The proposed view about cognition and intentionality emerges from the notion of infinite primes [19],
which was actually the first genuinely new mathematical idea inspired by TGD inspired consciousness
theorizing. Infinite primes, integers, and rationals have a precise number theoretic anatomy. For
instance, the simplest infinite primes correspond to the numbers $P_\pm = X \pm 1$, where $X = \prod_k p_k$ is the
product of all finite primes. Indeed, $P_\pm \bmod p = 1$ holds true for all finite primes. The construction
of infinite primes at the first level of the hierarchy is structurally analogous to the quantization of
super-symmetric arithmetic quantum field theory with finite primes playing the role of momenta
associated with fermions and bosons. Also the counterparts of bound states emerge. This process can
be iterated: at the second level the product of infinite primes constructed at the first level replaces X
and so on.

The structural similarity with repeatedly second quantized quantum field theory strongly suggests
that physics might in some sense reduce to a number theory for infinite rationals M/N and that
second quantization could be followed by further quantizations. As a matter fact, the hierarchy of
space-time sheets could realize this endless second quantization geometrically and have also a direct

connection with the hierarchy of logics labeled by their order. This could have rather breathtaking implications.

1. One is forced to ask whether this hierarchy corresponds to a hierarchy of realities for which level below corresponds in a literal sense infinitesimals and the level next above to infinity.

2. Second implication is that there is an infinite number of infinite rationals behaving like real units ($M/N \equiv 1$ in real sense) so that space-time points could have infinitely rich number theoretical anatomy not detectable at the level of real physics. Infinite integers would correspond to positive energy many particle states and their inverses (infinitesimals with number theoretic structure) to negative energy many particle states and $M/N \equiv 1$ would be a counterpart for zero energy ontology to which oneness and emptiness are assigned in mysticism.

3. Single space-time point, which is usually regarded as the most primitive and completely irreducible structure of mathematics, would take the role of Platonia of mathematical ideas being able to represent in its number theoretical structure even the quantum state of entire Universe. Algebraic Brahman=Atman identity and algebraic holography would be realized in a rather literal sense.

This number theoretical anatomy should relate to mathematical consciousness in some manner. For instance, one can ask whether it makes sense to speak about quantum jumps changing the number theoretical anatomy of space-time points and whether these quantum jumps give rise to mathematical ideas. In fact, the identifications of Platonia as spinor fields in WCW on one hand and as the set number theoretical anatomies of point of imbedding space force the conclusion that configuration space spinor fields (recall also the identification as correlates for logical mind) can be realized in terms of the space for number theoretic anatomies of imbedding space points. Therefore quantum jumps would be correspond to changes in anatomy of the space-time points. Imbedding space would be experiencing genuine number theoretical evolution. The whole physics would reduce to the anatomy of numbers. All mathematical notions which are more than mere human inventions would be imbeddable to the Platonia realized as the number theoretical anatomies of single imbedding space point.

In [21, 19] a concrete realization of this vision is discussed by assuming hyper-octonionic infinite primes as a starting point. In this picture associativity and commutativity are assigned only to infinite integers representing many particle states but not necessarily to infinite primes themselves: this guarantees the well-definedness of the space-time surface assigned to the infinite rational. Quantum states are required to be associative in the sense that they correspond to quantum super-positions of all possible associations for the products of (infinite) primes (say $|A(BC)\rangle + |(AB)C\rangle$). The ground states of super conformal representations would correspond to infinite primes mappable to space-time surfaces (quantum classical correspondence). The excited states of super-conformal representations would be represented as quantum entangled states in the tensor product of state spaces $\mathcal{H}_{h_k}$ formed from Schrödinger amplitudes in discrete subsets of the space of 8 real units associated with imbedding space 8 coordinates at point h_k: the interpretation is in terms of a 8-fold tensor power of basic super-conformal representation. Although the representations are not completely local at the level of imbedding space, they involve only a discrete set of points identifiable as arguments of n-point function. The basic symmetries of the standard model reduce to number theory if hyper-octonionic infinite rationals are allowed. Color confinement reduces to rationality of infinite integers representing many particle states.

2.7 Quantum correlates of qualia

The basic theoretical ingredients described above lead to the following general vision about qualia described in detail in [24]. In the following the latest view about theory is summarized. The notion of quale is understood in an extremely general sense: 'primary attribute of conscious experience' might serve as a synonym for 'quale' in the sense as it is used in the following.

2.7.1 Development of ideas

To achieve something which would deserve to be called a general theory of qualia required almost a decade. During the first years, and in lack of any general theory of qualia, I could only make educated

guesses, which were doomed to be wrong.

1. A connection between qualia and EEG MEs emerged, when I learned about the effects of classical electromagnetic fields on brain at frequencies which are cyclotron frequencies or amplitude modulated by cyclotron frequencies [61, 62].

2. The discovery that p-adic physics is physics of cognition (or at least imagination, one should be very cautious in order to avoid over generalizations!) clarified the views about the relationship between cognition and sensory experience [29].

3. The notion of the many-sheeted ionic flow equilibrium was a further important breakthrough [29, 28]. It allowed to realize that MEs, superconducting magnetic flux tubes, and ordinary biomatter at atomic space-time sheets form a three-levelled master-slave hierarchy.

4. The realization that MEs carrying super-symplectic representations at their lightlike boundaries are excellent candidates for the carriers of at least some of our qualia, gave a totally new perspective to the problem of qualia [32]. It seems however that MEs are not all that is needed: our qualia involve both super-symplectic and magnetic quantum phase transitions.

5. The work with the problems related to the precise formulation of Negentropy Maximization Principle led to the realization that each quantum jump defines a quantum measurement followed by a state preparation leading to an unentangled product state. This means the reduction of the quantum measurement theory to basic quantum TGD. The next realization was that the quantum jump sequence defining self defines a statistical ensemble of prepared states. One can identify the fundamental statistical ensembles of statistical physics as selves and implied a deep and precise connection between thermodynamics and the theory of qualia allowing a general classification of qualia and an identification of their thermodynamical correlates.

6. The last breakthrough in development, which is still continuing, was the realization that very general arguments lead to the view that ultimate (conscious-to-us) sensory representations are realized outside the body on the magnetic canvas provided by the magnetic flux tube structures associated with brain and having most plausibly size for which Earth size as a natural unit. One can see cortex as a collection of standard features some of which are associated to the objects of the perceptive field represented as magnetic sub-selves. Frequency place coding (MEs generate magnetic quantum phase transitions) plays a key role in this association.

Music metaphor at axonal level

Music metaphor has been one philosophical quideline behind the identification of the quantum correlates of the sensory qualia.

1. Axons are like strings of a music instrument. What this metaphor means is however not obvious. Frequency coding relates only the intensity of the sensory quale. Nerve pulses induce dropping of various ions to magnetic flux tubes and this generates EEG MEs at EEG frequencies serving as entanglers to the sensory magnetic canvas and the variation of these frequencies could code for the distance to the object of the perceptive field.

   A stronger interpretation of the metaphor is that sensory pathways are like strings of a musical instrument such that the sound produced by the string corresponds to a sensory modality associated with the sensory pathway. Nerve pulse patterns determine the experience as chords from from the notes of various instruments in the same sense as the musician produces the music. This leads to a generalization of the idea about brain as an associative net.

   More concretely, postsynaptic receptors act as neuronal sensory receptors and transmitters emitted and MEs generated by the presynaptic neuron induce neuronal sensory experiences in the postsynaptic neuron. The specialization of the neuronal receptors would be same for the entire sensory pathway and determine the qualia associated with it.

2. Resonance is an essential aspect of music instrument as is resonant frequency modulation which can involve several levels. The frequencies characterizing the hierarchical modulation provides a

partial characterization of the sensory representations. Quantum mechanically resonance corresponds to a harmonic perturbation with frequency which is difference of energies for the states of some sub-system. In this kind of situation quantum jumps can be amplified to quantum phase transitions and sub-self representing mental image wakes up.

Unfortunately, music metaphor is only a metaphor and has led to a plethora of various models for qualia.

ME's and qualia

The identification of MEs as building blocks of sensory and cognitive structures leads to a rather concrete model for long term memory and forces the hypothesis that MEs define an infinite hierarchy of electromagnetic life forms living in symbiosis with each other, magnetic flux tube structures, and the matter at atomic space-time sheets. The realization that MEs serve as quantum holograms and the properties of the super-symplectic stats gave the final justification for this identification. The model allows to understand EEG as a direct physical correlate of mindlike space-times sheets (MEs) associated with ELF selves and provides a general vision about the electromagnetic organization of brain as sensory and motor organ of higher level self. Also what might be called RF (radiofrequency) and MW (microwave) MEs representing our mental images are crucial for the model.

The model of qualia leads to rather detailed view about the sizes of the hierarchy of various MEs defining what might be called our radiation body. Also the notion of magnetic body is needed. It took a long time to answer the question whether we should identify ourselves with the self associated with brain; with the entire body; with ELF ME having size at least of order Earth circumference; or with self having literally infinite size. The last two options seems to be more plausible than the first two: the illusion that we are nothing but our physical bodies is created by the fact that during wake-up state sensory input is about the region surrounding our body. The simplest option is that the relevant magnetic flux tube structures have same sizes as ELF MEs. During sleep our attention might be directed to transpersonal levels of consciousness.

MEs, magnetic superconductors, and many-sheeted ionic flow equilibrium

The lack of clearcut empirical evidence for the predicted supra phases has been a stumbling block for the quantitative development of the theory for a long time. The situation changed dramatically when I learned about the effects of ELF em fields on living matter[4]. This article provided the ingredients making possible a general quantitative model of quantum control and coordination in which self hierarchy has as its dynamical correlate hierarchy of weakly coupled super conductors and massless extremals (MEs) interacting with the ordinary matter at atomic space-time sheets. MEs indeed provide a model of Josephson junction and an explanation for the amplitude windows observed in the experiments of Blackman and others [62, 75].

Later the experimental findings challenging the notions of ionic channels and pumps [63] led to the identification of homeostasis as many-sheeted ionic flow equilibrium in which the ionic concentrations at atomic space-time sheets are controlled by much smaller ionic concentrations at superconducting magnetic flux tubes. MEs control superconducting magnetic flux tubes via magnetic induction, by inducing magnetic phase transitions and by acting as Josephson junctions between magnetic flux tubes.

Magnetic transitions at superconducting magnetic flux tubes serve as seeds for phase transitions in quantum critical quantum spin glass type phase of macroscopic super conductor leading to generation of a region of new kind of phase whose quantum numbers differ from old one by the quantum numbers associated with magnetic transition frequency. Thus quantum transitions are amplified to macroscopic quantum transitions and Bose-Einstein condensation (analogous to induced emission) is the basic mechanism behind the process.

The first natural guess was that magnetic quantum phase transitions correspond to our qualia. That transition frequencies are involved is indeed in nice accordance with quantum jumps between histories as moment of consciousness identification. However, the fact that magnetic states correspond to a lower level of abstraction than super-symplectic states associated with MEs, suggests that magnetic qualia do not correspond to our qualia directly. Rather primitive chemical qualia experienced by cell level selves might be in question.

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[4]I am grateful for Gene Johnson for sending me the popular article of Yarrow [61] about bio-electromagnetism.

The role of super-symplectic algebra

An important step in the development of the theory of qualia was the realization of the importance of super-symplectic symmetries. The answer to this question might have been guessed by taking quantum measurement theory as a starting point.

1. Basic geometric objects is the configuration space of all possible three-surfaces in $M_+^4 \times CP_2$. In absence of non-determinism of Kähler action everything would reduce to the boundary of the future lightcone ($\delta M_+^4 \times CP_2$) carrying representations of super-symplectic and superconformal algebra localized with respect to the ligthlike radial coordinate of the lightcone boundary. These symmetries are obviously cosmological. Also quaternion conformal symmetries are possible and these can be identified as the TGD counterparts of string model conformal symmetries responsible for elementary particle quantum numbers.

2. The non-determinism of Kähler action forces to introduce super-symplectic representations at the lightlike boundaries X^3 of MEs acting as quantum holograms. Thus superconformal and super-symplectic symmetries become macroscopic symmetries and must be crucial for consciousness.

3. There are two kinds of configuration space degrees of freedom: quantum fluctuating non-zero modes and zero modes which can be regarded as classical, non-quantum fluctuating degrees of freedom in complete consistency with the reduction of standard quantum measurement theory to the localization in zero modes occurring in each quantum jump. Zero mode algebra cointains the generators of super-symplectic algebra with even conformal weight. In particular, zero modes contain the points of an infinite-dimensional flag-manifold extended to contain the radial Virasoro algebra of the lightlike boundary of ME localized with respect to CP_2. Radial coordinate corresponds to the lightlike coordinate of the the lightlike boundary of ME. This flag-manifold parametrizes all possible choices of the quantization axes for the canonical Lie-algebra.

2.7.2   Qualia and thermodynamics

The connection between thermodynamics and qualia was the real breakthrough in the development of ideas. In some sense this finding is not a news: the close connection between pressure sense and temperature sense and thermodynamics is basic facts of psychophysics. In TGD framework the contents of consciousness is determined as some kind of average over the sequence of very large number of quantum jump and this suggests strongly that non-geometric qualia allow statistical description generalizing ordinary thermodynamical ensemble to the ensemble formed by the prepared states in the sequence of quantum jumps after the last 'wake-up' of self. This picture allows to see the ageing of self with respect to subjective time as an approach to thermal equilibrium.

1. There are geometric qualia corresponding to zero modes expressing the result of quantum measurement in each quantum jump. All geometric information about space-time surface should reduce to geometric qualia. For instance, geometric data given by visual, auditory, and tactile senses should reduce to conscious information about zero modes or about increments of zero modes in quantum jump.

2. The sequence of the prepared states can be modelled as a statistical ensemble of Fock states, which suggests that thermodynamics is basically part of theory of consciousness. The ensemble of prepared states gives rise to a large number of statistical qualia. The relationship $dE = TdS - PdV + \mu dN + B \cdot dM...$ generalizes to TGD context: note however that in case of ME selves energy is replaced with the Super Virasoro generator L_0 associated with the lightcone boundary of ME. Each intensive-extensive variable pair in the differential should correspond to a non-geometric quale, which results only when there is gradient (flow) of the extensive variable in the direction of the subjective time. Super-symplectic thermodynamics should obviously map ordinary thermodynamics to the level of conscious experience.

3. Since subjective experience corresponds to quantum jumps, it is natural to assume that only the increments of zero modes and quantum numbers are experienced consciously. Statistical interpretation also suggests that an averaging over increments occurs. The possibility of sub-selves makes possible to have mental images of finite time duration and this makes possible

structured subjective memories (for instance, it becomes possible to remember the digits of phone number). A further working hypothesis is universality: qualia associated with quantum phase transitions depend only on the quantum number increments. In particular, the increments of Poincare and color and electroweak quantum numbers define what might be called universal kinestetic qualia.

The thermodynanical expression for dE suggests a general classification of qualia consistent with the 'holy trinity' of existences implied by TGD.

1. Emotions as order-disorder qualia

$T - S$ pair correspond subjective existence and generalizes to disorder-order type, information theoretic qualia qualia about the state of self: hot-cold and pain-pleasure type sensations and also more abstract experiences associated with various sub-selves of self. These qualia are strongly emotional single-pixel holistic qualia measuring whether some kind of an entropy variable is increasing or decreasing. The total entropy for the statistical ensemble defined by self determines how sharp the the mental image is. Low entropy content means alertness and attentiveness. High entropy content means fuzzy mental image. Getting tired means inability to keep mental images in low entropy state.

2. Kinestetic qualia defined by generalized forces

p-V pair corresponds to the geometric existence and is replaced with generalized force-generalized coordinate pairs in quantum fluctuating degrees of freedom. The increments of maximum number of mutually commuting Poincare, color and electroweak quantum numbers define this kind of qualia. The increments of four-momentum code for the sensation of force whereas the increments of orbital angular momentum code for the sensation of torque. Spin flip could code for something else. Tactile senses such as pressure sense and their generalizations involve kinestetic qualia. The increment of energy or equivalently, increment of frequency, can be identified as correlate for hearing in generalized sense responsible for the dynamical nature of auditory experience (hearing is timelike version of force sense). It is not clear whether spin flip has interpretation as torque or possibly as figure background separation. In TGD based model of auditory experience hearing relates to Z^0 magnetic spin flip phase transitions for cognitive neutrino pairs.

The rate for the increase of the two diagonal color quantum numbers should code intensity type variables associated with color sensation. The rate for the increase of electric charge of sub-self should code for electric sense possessed by, say, fishes. Also $B - M$, $\phi\rho$ and $E - P$ pairs correspond to generalized forces since electromagnetic fields are reduced to space-time geometry in TGD framework.

3. Generalized chemical qualia vm

$\mu - N$ pair corresponds to 'objective existence' defined by quantum histories and N is generalized to a number of particle like excitations in the Fock state resulting in the state preparation. In this case there must be a flow of particle number in the direction of the subjective time, that is Bose-Einstein condensation type process for, say Cooper pairs. Quite generally, super-symplectic and quaternion conformal super algebras should define these qualia and the number of these qualia is very large.

i) One can assign particle numbers to phases with various magnetic quantum numbers and these could define generalized chemical qualia which could perhaps be regarded as qualia and subqualia of chemical qualia defined by a particular ion and chemical qualia could actually reduce to magnetic qualia. Since the changes of magnetic field induce these quantum phase transition, it would seem that magnetic and Z^0 magnetic quantum phase transitions at superconducting magnetic flux tubes could correspond to this kind of qualia. In principle, endogenous NMR and its generalizations induced by the interaction of magnetic and Z^0 magnetic fields of MEs with magnetic and Z^0 magnetic flux tube structures are possible. Chemical qualia would very naturally correspond to the Bose-Einstein condensation of ions to the superconducting magnetic flux tubes: these ions could be even the ions of tastant or odorant. Also secondary representations at the level of cortex in terms of superconducting light ions are possible and would give rise to classification of tastes and odours. Magnetic qualia are characterized by definite transition frequencies and this makes possible place-/time coding by magnetic transition frequencies if magnetic or Z^0 magnetic field varies along magnetic flux tube/is a function of time. The activation of a point of living map would generate some quale at that point.

ii) For super-symplectic qualia the number of Bose-Einstein condensed 'configuration space photons' having nontrivial dependence on configuration space degrees of freedom replaces number of

molecules. The condensation rates for the numbers of the configuration space photons with nonvanishing color quantum numbers could be interpreted as correlates of color qualia whereas the condensation rates for color singlet configuration space photons could relate to the intensity of color sensation. If the rates for the trasfer of color quantum numbers define intensity type variables associated with color experience then BE condensation to color singlet states does not give rise to experienced quale so that only non-diagonal color generators correspond to visual colors. Also the BE condensation of the ordinary coherent light should give rise to some kind of quale: perhaps vibratory sense which can be developed to effective vision, could correspond to non-colored vision. Configuration space Hamiltonians are also labelled by 2-dimensional orbital spin quantum number and longitudinal momentum. Polarization sense and sensation about motion of the object of visual field would naturally relate to spin and longitudinal momentum.

iii) Tactile senses involve topological phase transitions involving the creation of join along boundaries contacts between object and skin whose number would thus be the relevant variable. The purely sensory aspect of physical pain could correspond to a topological phase transition involving the splitting of join-along boundaries bonds between space-time sheets (MEs could even define these bonds) so that N would be now the number of join along boundaries bonds. The simplest picture requires that the MEs associated with sensory organs are connected to the MEs responsible for our experience. Of course, splitting and generation of join along boundaries contacts could occur also at the level of sensory representations.

4. Boolean qualia

Boolean qualia

Boolean qualia would be naturally associated with fermion number or fermionic spin degrees of freedom. There are super-symplectic and super-Kac Moody type Boolean qualia. The spin flipping transitions associated with the fermionic generators of super-symplectic algebra might give rise to Boolean consciousness with intrinsic meaning ('This is true') but there are many other possibilities.

A general model for abstraction process based on the Combinatorial Hierarchy [26] not only explains the basic numbers of the genetic code but also suggests an entire hierarchy of codes in accordance with fractality of TGD Universe.

The next code after genetic code in the hierarchy of codes defined by Combinatorial Hierarchy is very attractive candidate for a 'memetic code'. The hypothesis predicts correctly the .1 second time scale for the duration of 'our' self (immediate short term memory, duration of psychological moment). Code-words correspond to the sequences of 126 bits with a duration of 1/1260 seconds: this is slightly below the time scale of nerve pulse so that membrane oscillations are perhaps a more natural realization for the code. The facts that the time scale of causal diamond CD associated with d quark corresponds to 1280 Hz frequency and the time scale of electron's CD corresponds to 10 Hz frequency suggest that quark pairs allow a realization of the memetic code with single quark sub-CD representing and electron CD the code word.

2.7.3   Geometric qualia and zero modes

The zero modes of the configuration space are special in the sense that in each quantum jump localization occurs in this space. Zero modes characterize the size and shape of 3-surface and are excellent candidate to represent information about the state of organism (3-surface itself) geometrically. Zero modes can be parametrized as an infinite-dimensional flag-manifold associated with the algebra of the infinitesimal canonical transformations of $E^2 \times CP_2$, where S^2 is sphere at the lightcone boundary extended by Virasoro algebra acting in radial direction of lightcone boundary. Physically this space corresponds to all possible choices of the quantization axes for generators of super-symplectic Algebra and, in accordance with the basic assumptions of quantum measurement theory, each quantum jump involves this kind of choice. Infinite-dimensional flag manifold contains as sub-flag-manifold $S^2 \times F_3$ parametrizing choices of quantization axes of spin and color ($F_3 = SU(3)/U(1) \times U(1)$). Lorentz invariance suggests the extension of S^2 to 2+2 dimensional flag-manifold $F = SO(3,1)/SO(2) \times R$ parametrizing various choices of the quantization axes for Lorentz quantum numbers [24].

There are continuous, geometric and kinestetic (both geometric in four-dimensional sense) qualia like position and velocity; orientation and angular velocity, and also geometric time and experienced

rate of time flow. All these pairs correspond to mutually in-compatible observables quantum mechanically. The hypothesis motivated by the work of Barbara Shipman [Shipman$_{1,2,3}$] is that some coordinates of F_3 parametrize positions. The generalization of this hypothesis is that the infinite-dimensional flag-manifold associated with the zeromode part super-symplectic algebra somehow gives rise to a conscious representation of continuous, classical qualia basically assignable to the choise of quantization axes. The hypothesis indeed makes sense: the entire isometry group of the configuration space, in particular the sub-group defined by zero modes, leaves induced Kähler form invariant but affects magnetic and Z^0 magnetic fields and hence magnetic transition frequencies. Also color rotations act in F_3 nontrivially and, although they leave Kähler form invariant, they affect magnetic and Z^0 magnetic fields and thus the corresponding magnetic transition frequencies. This means that a curve of the infinite-dimensional flag-manifold can be mapped to a varying cyclotron frequency.

2.8   Solutions to some paradoxes

The TGD inspired theory of consciousness provides a solution to the many paradoxes related to the basic quantum physics and the philosophy of conscious mind. The solution of these paradoxes is basically due to the replacement of the dualistic and monistic world views by the tripartistic world view of TGD.

2.8.1   Paradoxes related to quantum physics

The basic paradox is the conflict between the non-determinism of the state function reduction and the determinism of the Schrödinger equation. At a more general level this paradox is the conflict between the subjectively experienced actuality of the free will and the determinism of the objective world. The resolution of this paradox is simple in TGD context. One must give up the idea of single objective reality and replace it with a deterministic quantum history, which changes in each quantum jump, which is a genuine act of free will occurring outside the realm of the geometric space-time. Thus the objective reality, in the sense of a physical theory, is indeed deterministic, apart from the non-determinism related to the special properties of the Kähler action. In fact, a determinism of the Kähler action is achieved by replacing the ordinary concept of the 3-space with the concept of an association sequence and this naturally leads to a model for thinking systems. Volition seems to correspond to the selection between various degenerate absolute minima of the Kähler action and has thus a direct classical counterpart.

In the context of the deterministic physics, theoretician encounters two rather unpleasant paradoxes. The determinism implies that the unique objective reality corresponds to a single solution of the field equations. The first question is "What determines the initial conditions, say at the moment of the big bang?" and the attempt to answer this question leads necesssarily outside the physical theory: one possibility is to postulate antrophic principle. In TGD objective reality changes at each quantum jump and the localization in zero modes and NMP imply a genuine evolution: therefore the recent objective reality is an outcome of conscious selections. The second problem encountered by a theoretician is that in principle it is not possible to test a deterministic theory since only single solution of the field equations is realized and a genuine testing would require the comparison of the time developments for various initial data. In practice this problem can be circumvented by assuming the existence of identical sub-systems having very weak interactions with the external world but in principle the problem remains unsolved.

The famous Einstein-Bohr debate was related with the question whether God plays dice or not. Amusingly, in TGD context both were correct in their own ways! Quantum histories are indeed deterministic but God can replace the old quantum history with a new one: perhaps one should not however call this act dice playing but simply an act of free will. Einstein was also an advocate of local realism: this led to Einstein-Podolski-Rosen paradox created by the possibility of quantum entanglement between distant system. In TGD framework local realism holds true at the level of the infinite-dimensional configuration space but not at the level of space-time since point like particles are replaced with 3-surfaces.

The Schrödinger cat paradox has also an elegant solution in TGD context. The point is that conscious experience is associated with a quantum jump leading to a final state in which cat is either dead or alive. There is no conscious experience about the situation in which the cat is both dead and

alive giving answer to the question "Dead or alive?". More generally, this feature of consciousness also could explain why the world of our conscious experience looks classical: it simply cannot look but classical since the very moment of consciousness makes it classical. In fact, the world *is* predicted to be genuinely classical to the extent that mutual quantum entanglement between different p-adic sub-Universes seems impossible for purely mathematical reasons. The localization into zero modes occurring in quantum jumps strengthens this conclusion considerably since it implies that the final states of quantum jumps are superpositions of macroscopically equivalent space-time surfaces: the world of conscious experience is genuinely classical.

The phenomenon of dissipation is paradoxal from the point of view of standard physics. It is generally accepted that the fundamental laws of classical physics are reversible whereas everyday reality is manifestly irreversible. Thus the situation is rather schizophrenic. Two worlds, the reversible and extremely beautiful world of the fundamental physics and the irreversible and mathematically rather ugly "real" world, seem to exist simultaneously. The quantum jumps between quantum histories concept solves the paradox and one can understand the dissipative world as an effective description forming an 'almost'-envelope for the sequence of reversible worlds (time developments).

The standard physics is based on positive energy ontology and leads to the paradox caused by conservation laws. Quantum jumps preserve the values of conserved quantum numbers so that the question about initial values of the quantum numbers arises and leads to the necessity to postulate some meta level principle selecting the quantum states of entire universe having the preferred values of total quantum numbers. Of course, the problems are also caused by the fact that one must be able to compare the infinite values of total conserved quantum numbers- at least in the case of energy. Zero energy ontology provides an elegant solution of the problem and implies that any zero energy state is in principle creatable from vacuum.

2.8.2   Paradoxes related to the theories of consciousness

Chalmers describes in his book 'Conscious Mind' [76] several paradoxes related to the materialistic and dualistic theories of mind. A common denominator for these problems is the assumption that consciousness is a property of a physical state: hence these paradoxes disappear in TGD context. These paradoxes are encountered also in the quantum theories of consciousness identifying consciousness as a property of a macroscopic quantum state, say Bose Einstein condensate.

In the materialistic theories of mind, postulating a unique objective reality, consciousness is an epiphenomenon and free will is necessarily a peculiar illusion and one can always ask why the consciousness is needed at all: nothing changes in the physical reality if consciousness is dropped away. It is also very difficult to understand how the contents of consciousness are determined by the state of the material world.

In the dualistic theories postulating a unique objective reality (say the theory of Chalmers [76]), the problems are related to the coupling between matter and mind. The basic problem of the dualistic theories is what Chalmers calls hard problem: how the physical processes in the brain give rise to conscious experience? If the laws of the physics determine the behaviour of the system completely then one ends up immediately either with a complete separation of the mind and matter so that our conscious experience tells nothing about the material world or with materialism and epiphenomenalism. One can also consider a non-trivial coupling between matter and "mind like" fields but assuming a deterministic physics one ends up with a situation in in which the mind fields are effectively just additional physical fields and consciousness is again redundant.

An exotic example of this kind of a paradox is the following one described in [76]. In the dualistic theories in which the physical laws determine the objective reality, all psychological (third person) aspects of the mind are in principle purely physical. The book written by Chalmers about consciousness is obviously an example of a completely physical phenomenon. Therefore the contents of the book need not have anything to do with Chalmers's ideas about consciousness! More generally, the reports about the states of consciousness need not have anything to do with the states of consciousness in the dualistic theories of this kind. The only manner to save the day (and the uniqueness of the objective reality) is to accept materialism and epiphenomenalism.

In TGD framework, which could be called tripartistic, hard problem and other problems of the dualistic theories disappear since there is no need to assign consciousness to quantum history. Moment of consciousness as quantum jump between quantum histories hypothesis allows even to define

measures for the information contents of the conscious experience despite the fact that one cannot write explicit formulas for the contents of conscious experience.

2.8.3 Logical paradoxes and concept of time

Many logical paradoxes could be resolved if one assumes that there are two times: geometric and subjective and that the space-time surface providing linguistic representations changes quantum jump by quantum jump. In particular, during the conscious argument leading to the logical paradox!

The objections of Uri Fidelman [73] against the Platonic vision about reality involve the paradoxes of the cyclic cosmology (one might think that Turing machine in cyclic cosmology might be able to 'know' whether it has halted immediately after starting and thus be much more powerful than ordinary Turing machine). Basic paradox is that in cyclic cosmology allowing time travel one can imagine a son who murders his mother.

It is interesting to consider this paradox as resulting from identification of the identification of subjective time with geometric time, which I see only as an approximation. In TGD the counterpart of time travel would be sequence of quantum jumps changing the entire classical history quantum jump by quantum jump and inducing the shift of the space-time region, where the contents of consciousness of time traveller are concentrated, to the geometric past. No paradoxes result since space-time is not a fixed arena of dynamics but changes in each quantum jump.

As a second example one can take the second objection of Uri Fidelman [73] against Penrose's program known as Berry's paradox. *Non-formalizable theory cannot provide a model of the physical world which includes the brain's cognitive function, since such a model must be lingual, written or spoken. However, such a model implies the following paradox of Berry: Let n be the smallest number which cannot be defined by an English sentence having less than, say, a hundred letters. This number exists, since the number of all possible combinations of a hundred letters is finite. Nevertheless, it has just now been defined by a sentence comprising less than a hundred letters.*

Berry's paradox could be understood when the piece of text is seen as inducing a sequence of quantum jumps in which the space-time region at which the argument is represented symbolically changes. For the initial space-time region representing my cognitive state there is indeed smallest number n which cannot be defined by using less than one hundred words (using the English in that space-time!). After reading the statement quantum history is replaced by a new, more complex one in which this this number can be defined by using less than one hundred words since a new reflective level of cognitive consciousness has emerged and is represented at space-time level.

This example encourages to think the possibility of replacing the idea of a fixed axiomatic system with a living and dynamically evolving system becoming conscious of new axioms from which new theorems can grow. Mathematician would not be anymore an outsider but and active participator affecting the mathematical system he is studying. For instance, when paradoxal statement represented symbolically becomes conscious in quantum jump sequence, also the context in which it was originally stated changes. This dynamical view about mathematical system could allow to solve antinomies.

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Chapter 3

Negentropy Maximization Principle

3.1 Introduction

Quantum TGD involves 'holy trinity' of time developments. There is the geometric time development dictated by the preferred extremal of Kähler action crucial for the realization of General Coordinate Invariance and analogous to Bohr orbit. There is the unitary "time development" U: $\Psi_i \to U\Psi_i \to \Psi_f$, associated with each quantum jump, which is the counterpart of the Schrödinger time evolution $U(-t, t \to \infty)$. There is however no actual Schrödinger equation involved: situation is in practice same also in quantum field theories. Quantum jump sequence itself defines what might be called subjective time development.

Some dynamical principle governing subjective time evolution should exist and explain state function reduction with the characteristic one-one correlation between macroscopic measurement variables and quantum degrees of freedom and state preparation process. Negentropy Maximization Principle is the candidate for this principle, which I have been developing during last fifteen years.

The evolution of ideas related to NMP has been slow and tortuous process characterized by misinterpretations, overgeneralizations, and unnecessarily strong assumptions, and has been basically evolution of ideas related to the anatomy of quantum jump and of quantum TGD itself.

3.1.1 The notion of entanglement entropy

1. The first form of NMP was rather naive. There was no idea about the anatomy of quantum jump and NMP only stated that the allowed quantum jumps are such that the information gain of conscious experience measured by the reduction of entanglement entropy resulting in the reduction of entanglement between the subsystem of system and its complement is maximal. Later it became clear that quantum jump has a complex anatomy consisting of unitary process U followed by the TGD counterpart of state function reduction serving as a state preparation for the next quantum jump.

2. The attempts to formulate NMP in p-adic physics led to the realization that one can distinguish between three kinds of information measures.

   (a) In real physics the negative of the entanglement entropy defined by the standard Shannon formula defines a natural information measure, which is always non-positive.

   (b) In p-adic physics one can generalize this information measure to p-adic valued information measure by replacing the logarithms of p-adic valued probabilities with the p-based logarithms $log_p(|P|_p)$ which are integer valued and can be interpreted as p-adic numbers. This p-adic valued entanglement entropy can be mapped to a non-negative real number by the so called canonical identification $x = \sum_n x_n p^n \to \sum_n x_n p^{-n}$. In both cases a non-positive information measure results.

   (c) When the entanglement probabilities are rational numbers or at most finitely algebraically extended rational numbers one can still define logarithms of probabilities as p-based logarithms $log_p(|P|_p)$ and interpret the entropy as a rational or algebraic number. In this case the entropy can be however negative and positive definite information measure is possible.

Irrespective of number field one can in this case define entanglement entropy as a maximum of number theoretic entropies S_p over the set of primes. The first proposal was that the algebraic entanglement corresponds to bound state entanglement turned out to be wrong.

3. At some stage the importance of the almost trivial fact that bound state entanglement must be kinematically stable against NMP became obvious. One can imagine that the state function reduction proceeds step by step by reducing the state to two parts in such a manner that the reduction of entanglement entropy is maximal.

    (a) If a resulting subsystem corresponds to a bound state having no decomposition to free subsystems the process stops for this subsystem. The natural assumption is that subsystems lose their consciousness when U process leads to bound state entanglement whereas bound state itself can be conscious.

    (b) If the entanglement is negentropic (and thus rational or algebraic) a more natural interpretation consistent with the teaching of spiritual practices is that subsystems experience a fusion to a larger conscious entity. The negentropic entanglement between free states is stabilized by NMP and negentropically entangled states need not reside at the bottom of potential well forbidding the reduction of entanglement. This makes possible new kinds of correlated states for which binding energy can be negative. Bound state entanglement would be like the jail of organized marriage and negentropic entanglement like a love marriage in which companions are free to leave but do not what it. The existence of this kind of negentropic entanglement is especially interesting in living matter, where metabolism (high energy phosphate bond in particular) and the stability of DNA and other highly charged polymers is poorly understood physically: negentropic entanglement could be responsible for stabilization making possible the transfer of metabolic energy [19].

4. For the negentropic entanglement the outcome of the state function reduction ceases to be random as it is for the standard definition of entanglement entropy. Note however that U process as a creative act yielding superposition of possibilities from which state function reduction selects leaves means non-determinism. This has far reaching consequences. Ordinary state function reductions for an ensemble of systems lead to a generation of thermodynamical entropy and this explains the second law of thermodynamics. In the case of negentropic entanglement situation changes and the predicted breaking of second law of thermodynamics provides a new view to understand self-organization [26], and living matter could be identified as something residing in the intersection of real and p-adic worlds where p-adic intentions can be transformed to real actions.

5. One particular choice involved with state function reduction process could be the choice between generic entanglement and number theoretic entanglement possible only in the intersection of p-adic and real WCWs. If the choice is the generic entanglement, system ends up either to an unentangled state with maximal conscious freedom or to a bound state with a loss of consciousness. If the choice is algebraic entanglement, system ends up to negentropic entanglement and correlations with external world and experiences an expansion of consciousness. Maybe ethical choices are basically choices between these two options. Also positive emotions like love and experience of understanding could directly relate to various aspects of the negentropic entanglement.

3.1.2   Zero energy ontology

Zero energy ontology changes considerably the interpretation of the unitary process. In zero energy ontology quantum states are replaced with zero energy states defined as a superpositions of pairs of positive and negative energy states identified as counterparts of initial and final states of a physical event such as particle scattering. The matrix defining entanglement between positive and negative - christened as M-matrix- is the counterpart of the ordinary S-matrix but need not be unitary. It can be identified as a "complex square root" of density matrix expressible as a product of positive square root of diagonal density matrix and unitary S-matrix. Quantum TGD can be seen as defining a "square root" of thermodynamics, which thus becomes an essential part of quantum theory.

U-matrix is defined between zero energy states and cannnot therefore be equated with the S-matrix used to describe particle scattering events. Unitary conditions however imply that U-matrix can be seen as a collection of M-matrices labelled by zero energy states so that the knowledge of U-matrix implies the knowledge of M-matrices. The unitarity conditions will be discussed later. A natural guess is that U is directly related to consciousness and the description of intentional actions. For positive energy ontology state function reduction would serve as a state preparation for the next quantum jump. In zero energy ontology state function preparation and reduction can be assigned to the positive and negative energy states defining the initial and final states of the physical event. The reduction of the time-like entanglement during the state function reduction process corresponds to the measurement of the scattering matrix. In the case of negentropic time-like entanglement the reduction process is not random anymore and the resulting dynamics is analogous to that of cellular automata providing a natural description of the dynamics of self-organization in living matter.

Zero energy ontology leads to a precise identification of the subsystem at space-time level. General coordinate invariance in 4-D sense means that 3-surfaces related by 4-D diffeomorphisms are physically equivalent. It is conventient to perform a gauge fixing by a introducing a natural choice for the representatives of the equivalence classes formed by diffeo-related 3-surfaces.

1. Light-like 3-surfaces identified as surfaces at which the Minkowskian signature of the induced space-time metric changes to Euclidian one - wormhole contacts- are excellent candidates in this respect. The intersections of these surfaces with the light-like boundaries of CD defined 2-D partonic surfaces. Also the 3-D space-like ends of space-time sheets at the light-like boundaries of CDs are very natural candidates for preferred 3-surfaces.

2. The condition that the choices are mutually consistent implies effective 2-dimensionality. The intersections of these surfaces defining partonic 2-surface plus the distribution of 4-D tangent spaces at its points define the basic dynamical objects with 4-D general coordinate invariance reduced to 2-dimensional one. This effective 2-dimensionality was clear from the very beginning but is only apparent since also the data about 4-D tangent space distribution is necessary to characterize the geometry of WCW and quantum states. The descriptions in terms of 3-D light-like or space-like surfaces and even in terms of 4-D surfaces are equivalent but redundant descriptions.

As far as consciousness is considered effective 2-dimensionality means holography and could relate to the fact that at least our visual experience is at least effectively 2-dimensional.

3.1.3   Connection with standard quantum measurement theory

TGD allows to deduce the standard quantum measurement theory involving the notion of classical variables and their correlation with quantum numbers in an essential manner. Configuration space (or "world of classical worlds", briefly WCW) is a union over zero modes labelling infinite-dimensional symmetric spaces having interpretation as classical non-quantum fluctuating classical variables such as the pointer of a measurement apparatus essential for the standard quantum measurement theory [24]. Quantum holography states that partonic 2-surfaces at the light-like boundaries of CDs plus the corresponding distributions of 4-D tangent spaces of space-time surfaces at carry the information about quantum state and space-time sheet. The distribution of values of induced Kähler form of CP_2 at these surfaces defines zero modes whereas quantum fluctuating degrees of freedom correspond to the deformations of space-time surface by the flows induced by Hamiltonians associated with the degenerate symplectic structure of $\delta M_\pm^4 \times CP_2$.

There exists no well-defined metric integration measure in the infinite-dimensional space of zero modes, which by definition do not contribute to the line element of WCW. This does not lead to difficulties if one assumes that a complete localization in zero modes occurs in each quantum jump. A weaker condition is that wave functions are localized to discrete subsets in the space of zero modes. An even weaker and perhaps the most realistic condition is that a localization to a finite-dimensional 2n-dimensional manifold with induced symplectic form defining a positive definite integration volume takes place.

The fundamental formulation of quantum TGD in terms of the modified Dirac action [22, 46] containing a measurement interaction term guarantees quantum classical correspondence in the sense that the geometry of the space-time surface correlates with the values of conserved quantum numbers.

The resulting correlation of zero modes with the values of quantum numbers can be interpreted as an abstract form of quantum entanglement reduced in quantum jump for the standard definition of the entanglement entropy. This reproduces standard quantum measurement theory.

3.1.4 Quantum classical correspondence

Quantum classical correspondence has served as a guideline in the evolution of the ideas and the identification of the geometric correlates of various quantum notions at the level of imbedding space and space-time surfaces has been an important driving force in the progress of ideas.

1. In zero energy ontology causal diamonds (CDs) identified roughly as intersections of future and past directed light-cones are in key role. At imbedding space level CD is a natural correlate for self and sub-CDs serve as correlates of sub-selves identified as mental images. At space-time level the space-time sheets having their ends at the light-like boundaries of CD serve as correlates for self. For a system characterized by a primary p-adic length scale $L_p \propto 2^{k/2}$ the size scale of CD is secondary p-adic scale $L_{p,2} = \sqrt{p}L_p \propto 2^k$. p-Adic length scale hypothesis follows if the proper time distance between the tips of CDs is quantized in powers of 2. This quantization should relate directly to almost equivalence of octaves associated with music experience.

2. At the level of space-time the identification of join along boundaries bonds between space-time sheets (more precisely, between partonic 2-surfaces) as a correlate for bound state entanglement suggests itself. Join along boundaries bonds correspond typically to magnetic flux tubes in the TGD inspired quantum model of living matter. The size scale of the magnetic body of system is given by the size scale of CD and much larger than the size of the system itself.

3. The space-time sheets in the intersection of the real and p-adic WCWs characterized by the property that the mathematical representation of the partonic 2-surfaces at the ends representing holograpically the state allows interpretation in both real and p-adic sense would correspond to the correlates for negentropic entanglement. Rational and algebraic 2-surfaces (in preferred coordinates) would be the common points of realities and p-adicities.

Quantum classical correspondence allows also to generate new views about quantum theory itself. Many-sheeted space-time and p-adic length scale hierarchy force to generalize the notion of sub-system. The space-time correlate for the negentropic and bound state entanglement is the formation of join along boundaries bonds connecting two space-time sheets. The basic realization is that two disjoint space-time sheets can contain smaller space-time sheets topologically condensed at them and connected by join along boundaries bonds. Thus systems un-entangled at a given level of p-adic hierarchy -that is in the measurement resolution defined by the level considered - can contain entanglement subsystems at lower level not visible in the resolution used.

In TGD inspired theory of consciousness this makes possible sharing and fusion of mental images by entanglement. The resolution dependence for the notions of sub-system and entanglement means that the entanglement between sub-systems is not "seen" in the length scale resolution of unentangled systems. This phenomenon does not result as an idealization of theoretician but is a genuine physical phenomenon. Obviously this generalized view about sub-system poses further challenges to the detailed formulation of NMP. Note that the resulting mental image should depend on whether subselves are entangled by bound state entanglement or negentropic entanglement.

3.1.5 Fusion of real and p-adic physics

The fusion of real and p-adic physics to a larger structure has been a long standing challenge for TGD. The motivations come both from elementary particle physics and TGD inspired theory of consciousness, in particular from the attempt to model how intentions proposed to have p-adic space-time sheets as space-time correlates are transformed to actions having real space-time sheets as correlates. The basic idea is that various number fields are fused to a larger structure by gluing them along rationals and common algebraic numbers. The challenge is to imagine what quantum jump and NMP could mean in this framework. The first question is how the unitary process acts.

1. U-process acts in spinorial degrees of freedom of WCW (fermionic Fock space for a given 3-surface) and in WCW degrees of freedom (the space of partonic 2-surfaces roughly). The transformation of intention to action would correspond to a leakage from p-adic to real sector of WCW.

2. At the level of WCW one can only speak about classical spinor fields and the idea about tensor product of states corresponding to different sectors of WCW does not look reasonable at the first glance. Rather, a quantum superposition of WCW spinor fields localized at various sectors would look more appropriate. Therefore the WCW spinor field would be in fixed number field after state function reduction if it involves localization in this sense. This does not look sensible. The tensor product for fermionic Fock spaces is indeed very natural and strongly suggested also by the interpretation of the 3-surfaces as particles. One can indeed consider CDs and their unions and it would seem reasonable to assign to the unions of CDs tensor products of the corresponding WCW spinor fields. Let us assume this.

3. Let us assume that the initial zero energy state state represents an un-entangled tensor product of states in various number fields. The simplest assumption is that U process can induce a leakage between different sectors only in the intersection of real and p-adic worlds. This would also hold true as far as entanglement between different number fields is considered. This would allow to realize intentional action geometrically as a p-adic-to-real transition. The p-adic and real variants of a state quantum entangled with a third (say real) state would define the entangled system and state function reduction would select either p-adic or real variant of the state. The selection would be whether to transform action to its cognitive representation or intention to action. Also a transformation of a real zero energy state to its cognitive representation in p-adic sense is possible as also transformations between p-adic cognitive representations characterized by different primes.

4. For partonic 2-surfaces the quantum superposition of quantum states belonging to different number fields in the intersection would mean a quantum superposition of real and various p-adic variants of the surface with given mathematical representation forming tensor products with the states of second system, which could be real for instance. U-matrix could lead to this kind of quantum superposition. U-matrix between different number fields should be expressible using only the geometric data from the intersection of the real and p-adic variants of the partonic surface- that is rational points and common algebraic points, whose number is expected to be finite. Some kind of number theoretic quantum field theory should describe the U-matrix. State function reduction would involve the selection of whether the outcome is action or intention (or cognitive representation). Note that if the real-real entanglement is non-algebraic the NMP leads to a final state with algebraic entanglement between real system and p-adic cognitive representation of the other system. If real-real entanglement is algebraic, the reduction can lead from intention to action as a more negentropic final state.

5. It has been assumed that entanglement and matrix elements of U between different number fields are possible only in the intersection of the real and p-adic worlds. This is natural if entanglement coefficients between different number fields are represented in terms of the data provided by the intersection of the real and p-adic variants of partonic 2-surfaces involved and consisting of rational points and some algebraic points. Outside the intersection real and p-adic worlds would evolve independently. One could criticize this picture as raising the intersection of real and p-adic worlds to a singular position. Life is however something very special and the interpretation in terms of number theoretical criticality justifies this singular character.

3.1.6   Dark matter hierarchy

The identification of dark matter as phases having large value of Planck constant [17, 16, 17] led to a vigorous evolution of ideas. Entire dark matter hierarchy with levels labelled by increasing values of Planck constant is predicted, and in principle TGD predicts the values of Planck constant if physics as a generalized number theory vision is accepted [17].

The hierarchy of Planck constants is realized in terms of a generalization of the causal diamond $CD \times CP_2$, where CD is defined as an intersection of the future and past directed light-cones of 4-D

Minkowski space M^4. $CD \times CP_2$ is generalized by gluing singular coverings and factor spaces of both CD and CP_2 together like pages of book along common back, which is 2-D sub-manifold which is M^2 for CD and homologically trivial geodesic sphere S^2 for CP_2 [17]. The value of the Planck constant characterizes partially the given page and arbitrary large values of $\hbar$ are predicted so that macroscopic quantum phases are possible since the fundamental quantum scales scale like $\hbar$. The most general spectrum comes in rational multiples of standard value of Planck constant which corresponds to the unit of rationals. For CDs the scaling of Planck constants means scaling of the size of CD. This could explain why the rational multiples of the fundamental frequency are so special for music experience.

All particles in the vertices of Feynman diagrams have the same value of Planck constant so that particles at different pages cannot have local interactions. Thus one can speak about relative darkness in the sense that only the interactions mediated by the exchange of particles and by classical fields are possible between different pages. Dark matter in this sense can be observed, say through the classical gravitational and electromagnetic interactions. It is in principle possible to photograph dark matter by the exchange of photons which leak to another page of book, reflect, and leak back. This leakage corresponds to $\hbar$ changing phase transition occurring at quantum criticality and living matter is expected carry out these phase transitions routinely in bio-control. This picture leads to no obvious contradictions with what is really known about dark matter and to my opinion the basic difficulty in understanding of dark matter (and living matter) is the blind belief in standard quantum theory. These observations motivate the tentative identification of the macroscopic quantum phases in terms of dark matter and also of dark energy with gigantic "gravitational" Planck constant.

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by the following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of $\hbar$ at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

At least dark matter could be a key player in quantum biology.

1. Dark matter hierarchy and p-adic length scale hierarchy would provide a quantitative formulation for the self hierarchy. To a given p-adic length scale one can assign a secondary p-adic time scale as the temporal distance between the tips of the CD. For electron this time scale is .1 second, the fundamental bio-rhythm. For a given p-adic length scale dark matter hierarchy gives rise to additional time scales coming as $\hbar/\hbar_0$ multiples of this time scale.

2. The predicted breaking of second law of thermodynamics chacterizing living matter - if identified as something in the intersection of real and p-adic words - would be always below the time scale of CD considered but would take place in arbitrary long time scales at appropriate levels of the hierarchy. The scaling up of $\hbar$ also scales up the time scale for the breaking of the second law.

3. The hypothesis that magnetic body is the carrier of dark matter in large $\hbar$ phase has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [22]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [29, 22]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [22].

3.1.7   Is it possible to unify the notions of quantum jump and self?

An important step in the process was the realization that the generation of macro-temporal quantum coherence means effective gluing of quantum jumps of quantum jump sequence of sub-system defining mental images to single quantum jump. This means that in appropriate degrees of freedom state function reduction and state preparation cease to occur during macro-temporal quantum coherence. This makes sense if macro-temporal quantum coherence means generation of negentropic or bound state entanglement stable under subsequent U-processes.

The hierarchy of Planck constants and p-adic length scale hypothesis lead to the view that there is an entire hierarchy of durations for effective quantum jumps and this forces to ask whether the quantum jumps sequence decomposes into a hierarchy of effective quantum jumps of increasingly long duration just like physical systems form a hierarchy starting from the level of elementary particles and continuing through hadronic, nuclear, atomic and molecular physics up to level where astrophysical objects take the role of particles.

The usually un-noticed fact that hadrons can be regarded as quantum objects in long length and time scales whereas quark description treats hadrons as dissipative systems forces to ask whether state function reductions and preparations associated with the hierarchy of CDs form a hierarchy and whether the dissipative processes in short scales could occur in quantum parallel manner in longer scales so that one would have quantum superposition of parallel dissipative Universes? Using quantum computer language this would mean the possibility of quantum superposition of classical dissipative quantum computations.

These hierarchies suggest that the notions of self and quantum jump could be identified. Self would correspond to single quantum jump at the highest level and at the lowest levels to sequences of quantum jumps in accordance with the geometric representation in terms of CDs.

3.1.8 Hyper-finite factors of type II$_1$ and quantum measurement theory with a finite measurement resolution

The realization that the von Neumann algebra known as hyper-finite factor of type II$_1$ is tailor made for quantum TGD has led to a considerable progress in the understanding of the mathematical structure of the theory and these algebras provide a justification for several ideas introduced earlier on basis of physical intuition.

Hyper-finite factor of type II$_1$ has a canonical realization as an infinite-dimensional Clifford algebra and the obvious guess is that it corresponds to the algebra spanned by the gamma matrices of WCW. Also the local Clifford algebra of the imbedding space $H = M^4 \times CP_2$ in octonionic representation of gamma matrices of H is important and the entire quantum TGD emerges from the associativity or co-associativity conditions for the sub-algebras of this algebra which are local algebras localized to maximal associative or co-associate sub-manifolds of the imbedding space identifiable as space-time surfaces.

The notion of inclusion for hyper-finite factors provides an elegant description for the notion of measurement resolution absent from the standard quantum measurement theory.

1. The included sub-factor creates in zero energy ontology states not distinguishable from the original one and the formally the coset space of factors defining quantum spinor space defines the space of physical states modulo finite measument resolution.

2. The quantum measurement theory for hyperfinite factors differs from that for factors of type I since it is not possible to localize the state into single ray of state space. Rather, the ray is replaced with the sub-space obtained by the action of the included algebra defining the measurement resolution. The role of complex numbers in standard quantum measurement theory is taken by the non-commutative included algebra so that a non-commutative quantum theory is the outcome.

3. This leads also to the notion of quantum group. For instance, the finite measurement resolution means that the components of spinor do not commute anymore and it is not possible to reduce the state to a precise eigenstate of spin. It is however perform a reduction to an eigenstate of an observable which corresponds to the probability for either spin state.

As already explained, the topology of the many-sheeted space-time encourages the generalization of the notion of quantum entanglement in such a manner that unentangled systems can possess entangled sub-systems. One can say that the entanglement between subselves is not visible in the resolution characterizing selves. This makes possible sharing and fusion of mental images central for TGD inspired theory of consciousness. These concepts find a deeper justification from the quantum measurement theory for hyper-finite factors of type II$_1$ for which the finite measurement resolution is basic notion.

Also the notions of resolution and monitoring pop up naturally in this framework. p-Adic probabilities relate very naturally to hyper-finite factors of type II$_1$ and extend the expressive power of the ordinary probability theory. p-Adic thermodynamics with conformal cutoff is very natural for hyper-finite factors of type II$_1$ and explains p-adic length scale hypothesis $p \simeq 2^k$, k prime characterizing exponentially smaller p-adic length scale.

3.2   Basic view about NMP

The following represents a brief overall view about the notions of quantum jump, self, and NMP.

3.2.1   The general structure of quantum jump

It has gradually become clear that TGD involves 'holy trinity' of dynamics.

1. The dynamics defined by the preferred extremals of Kähler action identifiable as counterparts of Bohr orbits corresponds to the dynamics of material existence, with matter defined as 'res extensa', three-surfaces.

2. The dynamics defined by the action of the unitary "time development" operator U can be regarded as informational "time development" occurring at the level of objective existence. U brings in mind the time evolution operator $U(-t, t)$, $t \to \infty$ associated with the scattering solutions of Schrödinger equation. It seems however un-necessary and also impossible to assign Schrödinger equation with U. Furthermore, U acts between zero energy states in zero energy ontology and is more naturally assigned with intentional action rather than to the description of particle scattering.

3. The dynamics of quantum jumps governed by U and by NMP corresponds to the dynamics of subjective existence.

In accordance with this, quantum jump decomposes into informational time development

$$\Psi_i \to U\Psi_i \ ,$$

followed by a sequence of self measurements (generalization of state function reduction)

$$\Psi_{f_0} \to \Psi_{f_1} ..... \to \Psi_f$$

governed by NMP. At given step subsystem the decomposition to two un-entangled systems is such that maximum reduction of entanglement entropy is achieved. This means that the reduction process proceeds as a binary tree. If subsystem does not allow a decomposition to a pair of free subsystems with entropic entanglement the process stops.

Zero energy ontology means that one must distinguish between M-matrix and U-matrix. M-matrix characterizes the time like entanglement between positive and negative energy parts of zero energy state and is measured in particle scattering experiments. M-matrix need not be unitary and can be identified as a "complex" square root of density matrix representable as a product of its real and positive square root and of unitary S-matrix so that thermodynamics becomes part of quantum theory with thermodynamical ensemble being replaced with a zero energy state. The unitary U-matrix describes quantum transitions between zero energy states and is therefore something genuinely new. It is natural to assign the statistical description of intentional action with U-matrix since quantum jump occurs between zero energy states.

U process is in zero energy ontology something totally new and can be seen as representing an act of genuine re-creation of the Universe. The following metaphors might help to understand what is involved.

1. A good metaphor for the quantum jump is as Djinn leaving the bottle (U) fulfilling the wish realized as a choice between various option that is state function reduction. In the case that final state has negentropic entanglement wish is realized in different manner.

2. A second useful metaphor is as generation of infinite number of quantum parallel potentialities in which entire universe is in a totally entangled holistic state of oneness followed by state function reduction and self measurement cascade analyzing the state into maximally unentangled subsystems. NMP states that the analysis produces maximum amount of conscious information. For irreducible selves analysis process do not continue and the sequences of quantum jumps effectively take the role of single quantum jump. A further element is the expansion of consciousness when negentropic entangelment is generated. Therefore this structure characterizes also conscious experience in macro-temporal time scales. Clearly, quantum measurement theory has fascinating parallels with Krishnamurti's philosophy of consciousness which underlines the competing holistic and reductionistic aspects of consciousness.

3. A third metaphor comes from particle physics. Moment of consciousness can be seen as elementary particle of consciousness and selves as the atoms, molecules, ...galaxies,... of consciousness. Fractality hypothesis allows to get general vision about structure of consciousness even in the time scale of human life.

If quantum jump occurs between two different time evolutions of Schrödinger equation (understood here in very metaphoral sense) rather than interfering with single deterministic Schrödinger evolution, the basic problem of quantum measurement theory finds a resolution. The interpretation of quantum jump as a moment of consciousness means that volition and conscious experience are outside space-time and state space and that quantum states and space-time surfaces are "zombies".

3.2.2   NMP and the notion of self

Negentropy Maximization Principle (NMP) codes for the dynamics of standard state function reduction and states that the state function reduction process following U-process gives rise to a maximal reduction of entanglement entropy at each step. In the generic case this implies decomposition of the system to unique unentangled systems and the process repeats itself for these systems. The process stops when the resulting subsystem cannot be decomposed to a pair of free systems since energy conservation makes the reduction of entanglement kinematically impossible in the case of bound states.

Intuitively self corresponds to a sequence of quantum jumps which somehow integrates to a larger unit much like many-particle bound state is formed from more elementary building blocks. It also seems natural to assume that self stays conscious as long as it can avoid bound state entanglement with the environment in which case the reduction of entanglement is energetically impossible. One could say that everything is conscious and consciousness can be only lost when the system forms bound state entanglement with environment.

There is an important exception to this vision based on ordinary Shannon entropy. There exists an infinite hierarchy of number theoretical entropies making sense for rational or even algebraic entanglement probabilities. In this case the entanglement negentropy can be negative so that NMP favors the generation of negentropic entanglement, which need not be bound state entanglement in standard sense. Negentropic entanglement might serve as a correlate for emotions like love and experience of understanding. The reduction of ordinary entanglement entropy to random final state implies second law at the level of ensemble. For the generation of negentropic entanglement the outcome of the reduction is not random: the prediction is that second law is not universal truth holding true in all scales. Since number theoretic entropies are natural in the intersection of real and p-adic worlds, this suggests that life resides in this intersection. The existence effectively bound states with no binding energy might have important implications for the understanding the stability of basic bio-polymers and the key aspects of metabolism [19]. A natural assumption is that self experiences expansion of consciousness as it entangles in this manner. Quite generally, an infinite self hierarchy with the entire Universe at the top is predicted.

If one accepts the hierarchy of Planck constants [17], it might be un-necessary to distinguish between self and quantum jump. The hierarchy of Planck constants interpreted in terms of dark matter hierarchy predicts a hierarchy of quantum jumps such that the size of space-time region contributing to the contents of conscious experience scales like $\hbar$. Also the hierarchy of space-time sheets labeled by p-adic primes suggests the same. That sequence of sub-selves/sub-quantum jumps are experienced as separate mental images explains why we can distinguish between digits of phone number. The irreducible component of self (pure awareness) would correspond to the highest level in the "personal" hierarchy of quantum jumps and the sequence of lower level quantum jumps would

be responsible for the experience of time flow. Entire life cycle would correspond to single quantum jump at the highest(?) level of the personal self hierarchy and pure awareness would prevail during sleep: this would make it possible to experience directly that I existed yesterday. Whether these two definitions of self are in some sense equivalent will be discussed later.

How the contents of consciousness of self are determined

The hypothesis that the experiences of self associated with the quantum jumps occurred after the last 'wake-up' sum up to single experience, implies that self can have memories about earlier moments of consciousness. Therefore self becomes an extended object with respect to subjective time and has a well defined 'personal history'. If temporal binding of experiences involves kind of averaging, quantum statistical determinism makes the total experience defined by the heap of the experiences associated with individual quantum jumps reliable. Subjective memory has natural identification as a short term memory.

A given self S behaves essentially as a separate sub-Universe with respect to NMP. If one postulates that the conscious experiences of sub-selves S_i of an self S integrate with the self experience of S to single experience, one obtains a filtered hierarchy of conscious experiences with increasingly richer contents and at the top of the hierarchy is entire universe, God, enjoying eternal self-consciousness since it cannot get entangled with any larger system.

An attractive hypothesis is that the experience of self is abstraction in the sense that the experiences of sub-selves S_{ij} of S_i are abstracted to average experience $\langle S_{ij} \rangle$. This implies that the experiences of sub-sub-...selves of S are effectively unconcious to S. This hierarchy obviously has extremely far-reaching consequences. Temporal binding implies that experiences of individual selves are reliable and abstraction brings in the possibility of quantum statistical determinism at the level of ensembles.

The binding of *experiencers* is also possible. The binding of selves by quantum entanglement however destroys the component selves (note however the comment about situation in which the p-adic primes are different for real entangling selves). This process could correspond to the formation as wholes from their parts, say the formation of the mental image representing word from the mental images representing letters, which are all represented as sub-selves. Associative learning might correspond to the generation of entanglement between selves representing objects of the sensory experience and conscious association would correspond to the reduction of this entanglement generating associated sub-selves. The entanglement of sub-selves of two selves is possible if one accepts the length scale dependent notion of subsystem and means sharing and fusion of mental images, binding of experiences. Entanglement might make possible communication between selves belonging to different levels of the self hierarchy and to different number fields: this entanglement would be reduced always in state function reduction step.

Dark matter hierarchy and the notion of self

The vision about dark matter hierarchy as a hierarchy defined by quantized Planck constants leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [16, 22].

The hierarchy of dark matter levels is labeled by the values of Planck constant having quantized but arbitrarily large values. For the most general option the values of $\hbar$ are products and ratios of two integers. The products of distinct Fermat primes and power of two are number theoretically favored values for these integers. p-Adic length scale hypothesis favors powers of two. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T \propto \hbar$ of the quantum jump.

Dark matter hierarchy suggests a modification of the notion of self, in fact a reduction of the notion of self to that of quantum jump alone. Each self involves a hierarchy of dark matter levels, and one is led to ask whether the highest level in this hierarchy corresponds to single quantum jump rather than a sequence of quantum jumps. This indeed looks extremely natural and the hypothesis that self remains un-entangled for a longer duration than single quantum jump un-necessary. It is perhaps un-necessary to emphasize that the reduction of the notion of self to that of quantum jump means conceptual economy and somewhat ironically, would also a return to the original hypothesis but with a quantized Planck constant.

The averaging of conscious experience over quantum jumps would occur only for sub-selves at lower levels of dark matter hierarchy and these mental images would be ordered, and single moment

of consciousness would be experienced as a history of events. One can ask whether even entire life cycle could be regarded as a single quantum jump at the highest level so that consciousness would not be completely lost even during deep sleep. This would allow to understand why we seem to know directly that this biological body of mine existed yesterday.

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self corresponds at the highest dark matter level to single moment of consciousness. Self would experience the average over the sequence of moments of consciousness associated with each sub-self but there would be no averaging over the separate mental images of this kind, be their parallel or serial. These mental images correspond to sub-selves having shorter wake-up periods than self and would be experienced as being time ordered. Hence the digits in the phone number are experienced as separate mental images and ordered with respect to experienced time.

3.2.3   NMP, self measurements, cognition, state preparation, qualia

NMP can be seen as the variational principle governing the dynamics of *self measurements* giving rise to state preparation and reduction finding a unified description as state function reduction in zero energy ontology.

1. NMP applies to any unentangled subsystem resulting in this cascade of self measurements and tells that self measurement is performed for the subsystem (or equivalently, its complement) which gives rise to maximum entanglement negentropy gain in the self measurement.

2. This self measurement process continues until the system decomposes into unentangled subsystems consisting of subsystems for which the entanglement is bound state entanglement or negentropic entanglement.

NMP dictates the anatomy of a single quantum so that there is actually no need to mention the notion of self at all in the context of NMP (note however the possibility that the notions of self and quantum are one and same). Despite this it is useful to briefly introduce the basic concepts related to the notion of self. Self is a subsystem able to remain unentangled in sequential quantum jumps and preserving its identity in some sense: presumably the p-adic prime characterizing self (and also the real space-time sheet associated with self) is what characterizes the self identity. One can define irreducible self as a self which does not decompose to further sub-selves in state preparation process. A second reason for introducing the notion of self is that for a self in a state of macro-temporal quantum coherence the sequence of quantum jumps effectively fuses to single quantum jump representing single long lasting moment of consciousness. With this definition self ceases to exist as it fuses to another self by bound state entanglement of negentropic entanglement. In the latter case self however experiences expansion of consciousness rather than losing it.

Some further comments about NMP are in order.

1. Standard quantum measurement theory does not allow a spontaneous reduction of entanglement between quantum fluctuating degrees of freedom of two subsystems associated with a 3-surface. Only the entanglement between quantum fluctuating and zero mode degrees of freedom, that is between quantum system and observer can be reduced. The question is therefore whether one should restrict NMP to the entanglement between zero modes and quantum fluctuating degrees of freedom or allow also the reduction of entanglement between quantum fluctuating degrees of freedom. Self measurements affecting entanglement between quantum fluctuating degrees of freedom are distinguishable from standard quantum measurements. The working hypothesis is that state function reduction applies to any kind of entanglement.

2. Self measurement involves the division of unentangled subsystem (possibly self, mental image) into two unentangled subsystems. Analytical thought creates separations and comparisons so that this division could be identified as the basic mechanism of cognition. Also sensory experience generates separations and distinctions so that NMP should be identified as the variational principle governing the dynamics of cognition and perception. State reduction process makes the world of conscious experience to look completely classical since only bound state entanglement and negentropic entanglement are stable against self measurement. One can thus say that state function reduction leads from a maximally entangled multiverse state $U\Psi_i$ to a maximally analyzed state: from quantum holism to classical reductionism. At the level of standard quantum

measurement theory this process is equivalent with state preparation process yielding totally unentangled product state as incoming state of particle physics experiment.

3. The fact that self measurement reduces entanglement entropy allows the system to remain conscious (unless it generates bound state entanglement) but leads to a generation of thermodynamical entropy at the level of ensemble. Thermodynamical ensemble of sub-sub-selves means fuzzy mental images at the level of self. Thermodynamical ensemble of sub-selves could give rise to statistical determinism and be essential for sensory representations.

4. Irreducible self *effectively* obeys in quantum fluctuating degrees of freedom a unitary time development defined by n:th power of U for a sequence of n quantum jumps, at least in reasonable approximation. This means fractality of consciousness: one can approximate sequences of quantum jumps with single quantum jump such as one can approximate molecules consisting of elementary particles with a point like particle. This observation is of crucial importance for understanding how quantum computing is possible in TGD universe despite that single quantum jump to an increment of psychological time equal to CP_2 time. Also Penrose-Hameroff hypothesis generalizes to TGD framework and one can understand the purely phenomenological notion of quantum de-coherence at fundamental level and also how the quantum spin glass nature of TGD Universe allows to circumvent the objections against Penrose-Hameroff hypothesis.

5. The fact that state preparation is not a deterministic process, forces a statistical modelling of the state of self using the ensemble formed by the prepared states defined by the sequence of quantum jumps in turn defining the contribution to the contents of consciousness of self as a statistical average. The simplest description is in terms of thermodynamics. Thermodynamical density matrix gives the probabilities for various states of a subsystem in the sequence of quantum jumps occurred after the last 'wake-up'. What is of paramount importance is that the contents of consciousness of self can be modelled using statistical thermodynamics. Non-geometric sensory qualia indeed have a close relationship with conjugate pairs of thermodynamical variables such as temperature-entropy, pressure-volume, chemical potential-particle number,... The sequence of quantum jumps also defines a sequence of quantum jumps in zero modes. Statistical averaging is not so natural for the values of zero modes characterizing the outcomes of the quantum measurements, which suggests that they could be experienced as separate ones by self and would correspond to geometric qualia experienced as being sharp and dynamical.

3.3   Physics as fusion of real and p-adic physics and NMP

In this section the vision about state function reduction and preparation processes as number theoretic necessities is developed: also the chapter "Fusion of p-Adic and Real Variants of Quantum TGD to a More General Theory" contains related topics. The proposal raises NMP to fundamental principle applying also to the state function reduction step.

3.3.1   Basic definitions related to density matrix and entanglement entropy

In this sequel the detailed definitions of density matrix and entropy are discussed. It has become clear that one must distinguish between three kinds of systems systems.

1. Genuinely real systems for which entanglement probabilities are not rational numbers or finitely extended rational numbers. In this case one can regard the probabilities as limiting values of frequencies for outcomes of measurement defined by a time series. This is also the case when the entanglement coefficients are rational or algebraic numbers but the number of entangled state pairs is infinite so that the entanglement probabilities need not be algebraic numbers anymore.

2. A genuinely p-adic system is a p-adic system in which entanglement probabilities are not positive rational numbers so that one cannot interpret the entanglement probabilities as a limit for frequencies defined by any ensemble.

3. Finitely extended rational entanglement probabilities allow an interpretation as ordinary probabilities. In this case one can regard the probabilities as belonging to an extension of rationals

or to any p-adic number field. What is essential is that the number field is now discrete whereas it is continuous in above mentioned cases.

One must use different definition for the real counterpart of the entanglement entropy in these two cases. In the first case standard Shannon's entropy works. In the second case p-adic counterpart of the Shannon entropy mapped to a real number by the canonical identification is the only possibility. In the third case the number theoretic entropies S_p based on p-adic norm can be regarded as extended rational numbers as such. In this case S_p can be negative, and one can fix the value of p used to define the entropy by requiring that entropy is maximally negative and thus identifiable as a genuine information measure.

Density matrix

The density matrix of subsystem, call it A, can be defined using the standard formulas of QM: essentially trace over the degrees of freedom associated with the complement of A, call it B, is performed. B could effectively reduce to a sub-system of the complement. Density matrix is hermitian matrix and can be diagonalized in the real context. Eigenvalues are real and give the weights for various eigen states in the superposition. There is important *duality* present: in the basis of A in which the density matrix for A is diagonal also the density matrix of B is diagonal.

Density matrix actually determines one-one-correspondence between certain states of the system A and system B. The state in eigen state basis can be written as

$$|A, B\rangle \quad = \quad \sum_m c_m |m\rangle \times |M(m)\rangle \quad , \tag{3.3.1}$$

where the map $m \to M(m)$ defines identification of certain states of A with certain states of B.

Quantum measurement of density matrix means that subsystem goes to an eigen state of density matrix. In the p-adic context the diagonalization of the density matrix requires special assumptions about the form of the state since the p-adic number fields are not closed with respect to algebraic operations. There is an algebraic extension obtained by requiring that each 'real' p-adic number has square root [30]. The extension is 4-dimensional for $p \geq 3$ and 8-dimensional for $p = 2$. It can quite well happen that density matrix can be diagonalized only partially in this extension since the eigenvalues of the density matrix are in general algebraic numbers determined as a solution of polynomial eigenvalue equation.

One can however allow the extension of the p-adic number field to allow eigenvalues in an algebraic extension. Unless this is allowed the concepts of density matrix and entropy are not well defined for a generic subsystem. Physically this would mean that quantum state can have irreducible number theoretic entanglement besides the entanglement related to the quantum statistics. The vision about TGD as a generalized number theory encourages the allowance of the algebraic extension. This means that quantum subsystems can be classified using as criterion the dimension of the p-adic algebraic extension needed to define the eigen states and eigenvalues of the density matrix. In well defined sense physical systems generate increasingly complicated number fields as algebraic extensions of the p-adic numbers.

An interesting possibility is that hermiticity in the p-adic context must be defined so that the eigenvalues of the density matrix are *ordinary p-adic numbers*: if this is the case then the algebraic extension is needed only for the diagonalization of the density matrix but the diagonalized density matrix itself is 'p-adically real'. This option seems however un-necessarily restrictive and will not be considered in the sequel.

If entanglement coefficients are algebraic numbers then also entanglement probabilities are algebraic numbers in the case that the number of entanglement state pairs is finite. Even finite-dimensional extensions of p-adic number numbers involving transcendentals such as $e, e^2, ..., e^{p-1}$) can be allowed. If the number of entangled state pairs is infinite, entanglement probabilities need not belong to a finite extension of rationals and it seems that entanglement cannot be regarded as bound state entanglement in this case.

p-Adic entanglement negentropy

In the real context negentropy is defined using the standard formula for Shannon entropy:

$$N \quad = \quad \sum_k p_k \cdot log(p_k) \quad .$$ (3.3.2)

In the real context one could equally well replace the e-based logarithm $log(x)$ by a-based logarithm (a could be any positive real) since this introduces only multiplicative factor ($log_a(x) = \frac{log(x)}{log(a)}$).

p-Adic thermodynamics has turned out to be surprisingly successful for the calculation of elementary particle masses. p-Adic thermodynamics is however naturally based on p-based logarithm log_p rather than the ordinary e-based logarithm since Boltzmann weights are powers of p rather than exponents. This would suggest the following definition

$$N \quad = \quad \sum_k p_k \cdot log_p(p_k) \quad .$$ (3.3.3)

There are however two problems:

1. p-based logarithm exists only for $p_k = p^r$, that is power of p. One should somehow modify the definition of the logarithm so that it is defined for all p-adic numbers.

2. Since the probabilities p_k correspond to eigenvalues of density matrix, they in general belong to some algebraic extension of p-adic numbers. Thus the modified logarithm should also exist for any algebraic extension of p-adic numbers.

The definition of the modified p-based logarithm $Log_p(x)$ should satisfy following constraints.

1. If argument is power of p then modified logarithm must be equal to p-based logarithm:

$$Log_p(p^n) = log_p(p^n) \quad .$$

2. Modified logarithm must be additive in order to make negentropy additive for systems having no interactions:

$$Log_p(xy) = Log_p(x) + Log_p(y) \quad .$$

These requirements fix the definition of logarithm uniquely. The modified logarithm can depend on the p-adic norm of the argument only. Or in terms of canonical identification

$$I : \sum x_n p^n \to \sum x_n p^{-n} \quad ,$$

mapping p-adics to reals and p-adic norm $N_p(x)$ one must have

$$
\begin{aligned}
Log_p(x) \quad &= \quad log_p([x]) \quad , \\
[x] \quad &= \quad I^{-1}(N_p(x)) \quad , \\
&= \quad \left[\sum_{n \geq n_0} x_n p^n \right] = p^{n_0} \quad .
\end{aligned}
$$ (3.3.4)

This definition works also for the algebraic extensions, for which p-adic norm is defined as the p-adic norm for the determinant of the linear map induced by a multiplication with z in algebraic extension: it is easy to see that the determinant of this map is indeed a power of p always (note that this norm is multiplicative, which implies the additivity of modified logarithm and entropy).

For the algebraic extensions of p-adic numbers one must define how the units e_k of algebraic extension $z = x + \sum_k y^k e_k$ are mapped to the reals in the canonical identification map. e_k are typically roots of integers in the range $-1, ..., p$. The rule is following: if e_k is not a root of p then it is mapped to e_k interpreted as a real number: for instance, $2^{1/3}$ is mapped to $2^{1/3}$ for $p \neq 2$ in case

that $2^{1/3}$ does not exist as p-adic number. If e_k is root of p it is mapped to its inverse: for instance, $\sqrt{p}$ is mapped to $\frac{1}{\sqrt{p}}$.

Note that p-adic entanglement entropy can be also expressed as a sum over the derivatives of the p-adic entanglement probabilities with respect to p:

$$S \quad = \quad \sum_i \frac{d}{dp} p_i \ . \tag{3.3.5}$$

The real counterpart of the p-adic entanglement entropy is obtained by canonical identification $x = \sum x_n p^n \rightarrow \sum x_n p^{-n} = x_R$

$$S_r \quad = \quad S_R \times log(p) \ . \tag{3.3.6}$$

$log(p)$ factor must be included in order to make possible the comparison of entropies associated with different values of p.

The value of the p-adic entanglement entropy is always non-negative. It vanishes if the p-adic entanglement entropies have unit p-adic norm. Thus $S = 0$ p-adic entanglement is possible. This entanglement need not be stable since a direct sum of eigen spaces of density matrix with finitely extended rational entanglement probabilities has negative entanglement entropy.

Unless some p-adic probabilities do not have p-adic norm larger than one, p-adic entanglement entropy is of order $O(p)$ for genuinely p-adic systems so that negentropy gain is below $log(p)$ irrespective of the size of the system. This situation is realized in p-adic thermodynamics. There is a nice connection with p-adic mass calculations: p-adic thermal mass squared expectation value is essentially the p-adic entropy. This connection was noticed already earlier [22] and it was suggested that p-adic primes associated with elementary particles could correspond to entropy maxima as function of p. This connection suggests that the proper definition of p-adic entropy is based on the canonical identification.

Remark: Statistics does not give rise to entanglement entropy as one might erratically conclude by considering the symbolic representation of tensor product suggesting the identification of 'left' and 'right' members of the tensor product as subsystems A and B: the concrete representation of the states using oscillator operators associated with Y^3 and its complement shows that there is no statistical entanglement entropy between the subsystem and its complement: if this were the case the entire universe should behave like a single conscious being and this would be a catastrophe as far as NMP is considered.

Systems with finitely extended rational entanglement

In the case of an finitely extended rational entanglement one can map the p-adic entropy to its real counterpart using the identification by common rationals instead of the canonical identification. This gives the formula

$$\begin{aligned}
S_R &= S_p log(p) \ , \\
S_p &= \sum_n p_k Log_p(p_k) log(p) \ , \\
Log_p(x) &= log_p(|x|_p) \ .
\end{aligned} \tag{3.3.7}$$

where the p-adic entropy which can be regarded as a rational number is re-interpreted as a real number. Note that the probabilities p_k are positive numbers. What is remarkable is that in this case entanglement entropy can be a negative rational number or a number in a finite extension of rational numbers. This observation encourages the definition of the number theoretic entanglement negentropy as maximum information in the set of all p-adic number fields and their extensions:

$$I \quad \equiv \quad Max\{-S_p, \ p \ \text{prime}\} \ . \tag{3.3.8}$$

Since the numbers $log(p)$ are independent transcendentals there exists a unique prime for which the maximum is achieved.

The original identification of negentropic entanglement as bound state entanglement is un-necessary and the observation that negentropic entanglement is possible withing binding energy might have far reaching consequences concerning the understanding of metabolism and stability of fundamental bio-polymers.

The consistency with the standard quantum measurement theory requires that the process corresponds to a measurement of the density matrix so that a projection must occur to an eigen space or sub-space of eigen space of the density matrix if this maximizes negentropy gain. The density matrix of the system would become

$$\rho \quad \rightarrow \quad \frac{1}{D_i} P_i \quad . \tag{3.3.9}$$

Here D_i and P_i denote the dimension of the eigen space associated with p_i and corresponding projection operator. Assuming that D_i has the decomposition

$$D_i = \prod_{i \in I} q_i^{n_i}$$

to a product of powers of primes, the negentropy of the final state can be written as

$$N_R \quad = \quad Max\{n_i log(q_i) | i \in I\} \quad . \tag{3.3.10}$$

The maximization of the increment of entanglement entropy gives a criterion selecting the final eigen space or its sub-space. Quantum classical correspondence suggests that one can assign similar inherent negentropy to the space-time sheet consisting of D strictly deterministic regions.

For the negentropic entanglement the state function reduction process is far from being random. It is quite possible that the reduction takes to unique final state for which the common denominator of entanglement probabilities is power of prime. This is achieved if the reduction occurs to a sub-space for which the denominator measuring roughly the number of states is reduced to a number having very large p-adic norm for some prime. This suggests that the quantum behavior of negentropic states resembles more that of cellular automata than of ordinary quantum states.

The eigen spaces of the density matrix with dimensions $D = p^N$ are of special interest. The entanglement negentropy for $D = p^N n_0$, n_0 integer not divisible by p, is $N_R = Nlog(p)$. The reduction to a sub-space of the eigen space can yield higher negentropy gain than the reduction to the entire eigen space and powers of prime are favored as dimensions of these sub-spaces.

The entanglement negentropy per single dimension of eigen space is $N_R/D = Nlog(p)p^{-N}/n_0$. For $D = p^N$ the entanglement negentropy per dimension of eigen space is $N_R/D = Nlog(p)/p^N = log(D)/D$ and maximum as a function of n_0. N_R/D as a function of D has a maximum $N_R/D = .3662$ for $D = 3$ rather than $D = 2$ as one might expect. For $D = 2$ and $D = 4$ one has $N_R/D = .3466$ (note that there are 4 DNA nucleotides). For other values of D N_R/D is smaller.

For extended rational entanglement the measurement of the density matrix can occur only in special cases. For instance, when the probabilities p_k belong to a finite extension of rational numbers and are different, the measurement of the density matrix would reduce the negentropy to zero and NMP does not therefore allow the measurement of density matrix to occur. Degenerate eigen spaces do not correspond to the maximum entanglement negentropy per dimension. $p_k = n_k/p^N$, n_k not divisible by p, gives $N_R = Nlog(p)$ irrespective of dimension D, and $N_R/D = Nlog(p)/2$ for $D = 2$ ($p_1 = m/p^N$ and $p_2 = (p^N - m)/p^N$, m not divisible by p) is the best one can achieve. Since there is no upper bound for N nor p even in the case of a 2-state system, the negentropy gain can be arbitrarily high. One could criticize this result as counter intuitive.

3.3.2   Generalization of the notion of information

TGD inspired theory of consciousness, in particular the formulation of Negentropy Maximization Principle (NMP) in p-adic context, has forced to rethink the notion of the information concept. In TGD state preparation process is realized as a sequence of self measurements and state preparation

for next quantum jump is state reduction for the previous quantum jump. In zero energy ontology one can interpret the state preparation for positive and negative energy parts of the state as reduction and preparation in the sense of standard physics. Each self measurement means a decomposition of the sub-system involved to two unentangled parts unless the system is bound state. The decomposition is fixed highly uniquely from the requirement that the reduction of the entanglement entropy is maximal.

Bound state entanglement is stable against self measurement simply because energy conservation prevents the decay to a pair of free (uncorrelated) subsystems. The generalized definition of entanglement entropy allows to assign a negative value of entanglement entropy to rational and algebraic entanglement, so that this kind of entanglement would actually carry information, in fact conscious information (experience of understanding). This kind of entanglement cannot be reduced in state function reduction. Macro-temporal quantum coherence could correspond to a generation of either bound state entanglement or negentropic entanglement, and is indeed crucial for ability to have long lasting non-entropic mental images. Generation of negentropic entanglement would involve experience about expansion of consciousness and that of bound states entanglement a loss of consciousness.

The mathematical models for quantum computers typically operate with systems for which entanglement probabilities are identical. Also rational numbers are involved. Does this mean that negentropic entanglement makes possible quantum computation? This does not seem to be the case. State function reduction with random outcomes is a central element of quantum computation which suggests that quantum computation must be based on entropic entanglement with large enough value of $\hbar$ to overcome the restrictions caused by the interactions with the external world. The negentropic entanglement in turn would relate to conscious information processing involving experience of understanding represented by negentropic entanglement. Negentropic entanglement would make possible conscious cellular automaton type information processing much closer to that carried out by ordinary computers and this information processing might be equally important in living systems.

3.3.3   Number theoretic information measures at the space-time level

Quantum classical correspondence suggests that the notion of entropy should have also space-time counterpart. Entropy requires ensemble and both the p-adic non-determinism and the non-determinism of Kähler action allow to define the required ensemble as the ensemble of strictly deterministic regions of the space-time sheet. One can measure various observables at these space-time regions, and the frequencies for the outcomes are rational numbers of form $p_k = n(k)/N$, where N is the number of strictly deterministic regions of the space-time sheet. The number theoretic entropies are well defined and negative if p divides the integer N. Maximum is expected to result for the largest prime power factor of N. This would mean the possibility to assign a unique prime to a given real space-time sheet.

The classical non-determinism resembles p-adic non-determinism in the sense that the space-time sheet obeys effective p-adic topology in some length and time scale range is consistent with this idea since p-adic fractality suggests that N is power of p.

3.3.4   Number theoretical Quantum Mechanics

The vision about life as something in the intersection of the p-adic and real worlds requires a generalization of quantum theory to describe the U-process properly. One must answer several questions. What it means mathematically to be in this intersection? What the leakage between different sectors does mean? Is it really possible to formally extend quantum theory so that direct sums of Hilbert spaces in different number fields make sense? Or should one consider the possibility of using only complex, algebraic, or rational Hilbert spaces also in p-adic sectors so that p-adicization would take place only at the level of geometry?

What it means to be in the intersection of real and p-adic worlds?

The first question is what one really means when one speaks about a partonic 2-surface in the intersection of real and p-adic worlds or in the intersection of two p-adic worlds.

1. Many algebraic numbers can be regarded also as ordinary p-adic numbers: square roots of roughly one half of integers provide a simple example about this. Should one assume that all algebraic numbers representable as ordinary p-adic numbers belong to the intersection of the real and p-adic variants of partonic 2-surface (or to the intersection of two different p-adic number

fields)? Is there any hope that the listing of the points in the intersection is possible without a complete knowledge of the number theoretic anatomy of p-adic number fields in this kind of situation? And is the set of common algebraic points for real and p-adic variants of the partonic 2-surface X^2 quite too large- say a dense sub-set of X^2?

This hopeless looking complexity is simplified considerably if one reduces the considerations to algebraic extensions of rationals since these induce the algebraic extensions of p-adic numbers. For instance, if the p-adic number field contains some n:th roots of integers in the range $(1, p-1)$ as ordinary p-adic numbers they are identified with their real counterparts. In principle one should be able to characterize the -probably infinite-dimensional- algebraic extension of rationals which is representable by a given p-adic number field as p-adic numbers of unit norm. This does not look very practical.

2. At the level WCW one must direct the attention to the function spaces used to define partonic 2-surfaces. That is the spaces of rational functions or even algebraic functions with coefficients of polynomials in algebraic extensions of rational numbers making sense with arguments in all number fields so that algebraic extensions of rationals provide a neat hierarchy defining also the points of partonic 2-surfaces to be considered. If one considers only the algebraic points of X^2 belonging to the extension appearing in the definition the function space as common to various number fields one has good hopes that the number of common points is finite.

3. Already the ratios of polynomials with rational coefficients lead to algebraic extensions of rationals via their roots. One can replace the coefficients of polynomials with numbers in algebraic extensions of rationals. Also algebraic functions involving roots of rational functions can be considered and force to introduce the algebraic extensions of p-adic numbers. For instance, an n:th root of a polynomial with rational coefficients is well defined if n:th roots of p-adic integers in the range $(1, p-1)$ are well well-defined. One clearly obtains an infinite hierarchy of function spaces. This would give rise to a natural hierarchy in which one introduces n:th roots for a minimum number of p-adic integers in the range $(1, p-1)$ in the range $1 \leq n \leq N$. Note that also the roots of unity would be introduced in a natural manner.

The situation is made more complex because the partonic 2-surface is in general defined by the vanishing of six rational functions so that algebraic extensions are needed. An exception occurs when six preferred imbedding space coordinates are expressible as rational functions of the remaining two preferred coordinates. In this case the number of common rational points consists of all rational points associated with the remaining two coordinates. This situation is clearly non-generic. Usually the number of common points is much smaller (the set of rational points satisfying $x^n + y^n = z^n$ for $n > 2$ is a good example). This however suggests that these surfaces are of special importance since the naive expectation is that the amplitude for transformation of intention to action or its reversal is especially large in this case. This might also explain why these surfaces are easy to understand mathematically.

4. These considerations suggest that the numbers common to reals and p-adics must be defined as rationals and algebraic numbers appearing explicitly in the algebraic extension or rationals associated with the function spaces used to define partonic 2-surfaces. This would make the deduction of the common points of partonic 2-surface a task possible at least in principle. Algebraic extensions of rationals rather than those of p-adic numbers would be in the fundamental role and induce the extensions of p-adic numbers.

Let us next try to summarize the geometrical picture at the level of WCW and WCW spinor fields.

1. WCW decomposes into WCWs associated with CDs and there unions. For the unions one has Cartesian product of WCWs associated with CDs. At the level of WCW spinor fields one has tensor product.

2. The WCW for a given CD decomposes into a union of sectors corresponding to various number fields and their algebraic extensions. The sub-WCW corresponding to the intersection consists of partonic 2-surfaces X^2 (plus distribution of 4-D tangent spaces $T(X^4)$ at X^2 - a complication which will not be considered in the sequel), whose mathematical representation makes sense in

real number field and in some algebraic extensions of p-adic number fields. The extension of p-adic number fields needed for algebraic extension of rationals depends on p and is in general sub-extension of the extension of rationals. This sub-WCW is a sub-manifold of WCW itself. It has also a filtering by sub-manifolds of QCW. For instance, partonic 2-surfaces representabable using ratios of polynomials with degree below fixed number N defines an inclusion hierarchy with levels labelled by N.

3. The spaces of WCW spinors associated with these sectors are dictated by the second quantization of induced spinor fields with dynamics dictated by the modified Dirac action in more or less one-one correspondence. The dimension for the modes of induced spinor field (solutions of the modified Dirac equation at the space-time surface holographically assigned with X^2 plus the 4-D tangent space-space distribution) in general depends on the partonic 2-surface and the classical criticality of space-time surface suggests an inclusion hierarchy of super-conformal algebras corresponding to a hierarchy of criticalities. For instance, the partonic 2-surfaces X^2 having polynomial representations in referred coordinates could correspond to simplest possible surfaces nearest to the vacuum extremals and having in a well define sense smallest (but possibly infinite) dimension for the space of spinor modes.

4. For each CD one can decompose the Hilbert space to a formal direct sum of orthogonal state spaces associated with various number fields

$$H \quad = \quad \oplus_F H_F \ . \tag{3.3.11}$$

Here F serves as a label for number fields. For the sake of simplicity and to get idea about what is involved, all complications due to algebraic extensions are neglected in the sequel so that only rational surfaces are regarded as being common to various sectors of WCW.

5. The states in the direct sum make sense only formally since the formal inner product of these states would be a sum of numbers in different number fields unless one assigns complex Hilbert space with each sector or restricts the coefficients to be rational which is of course also possible. This problem is avoided if the state function reduction process induces inside each CD a choice of the number field. One could say that state function is a number theoretical necessity at least in this sense.

   (a) Should the state function reduction in this sense involve a reduction of entanglement between distinct CDs is not clear. One could indeed consider the possibility of a purely number theoretical reduction not induced by NMP and taking place in the absence of entanglement with reduction probabilities determined by the probabilities assignable to various number fields which should be rational or at most algebraic. Hard experience however suggests that one should not make exceptions from principles.

   (b) The alternative is to allow the Hilbert spaces in question to have rational or at most algebraic coefficients in the intersection of real and various p-adic worlds. This means that the entanglement is algebraic and NMP need not lead to a pure state: the superposition of pairs of entangled states is however mathematically well defined since inner products give algebraic numbers. Cognitive entanglement stable under NMP would become possible. The experience of understanding could be a correlate for it. The pairs in the sum defining the entangled state defined the instances of a concept as a mapping of real world state to its symbol structurally analogous to a Boolean rule. The entangled states between different p-adic number fields would define maps between symbolic representations.

6. Assume that each H_F allows a decomposition to a direct sum of two orthogonal parts corresponding to WCW spinor fields localized to the intersection of number fields and to the complements of the intersection:

$$\begin{aligned} H \quad &= \quad H_{nm} \oplus H_m \ , \\ H_{nm} \quad &= \quad \oplus_F H_{nm,F} \ , \quad H_m = \oplus_F H_{m,F} \ . \end{aligned} \tag{3.3.12}$$

Here nm stands for 'no mixing' (no mixing between different number fields and localization to the complement of the intersection) and m for 'mixing' (mixing between different number fields in the intersection). F labels the number fields. Orthogonal direct sum might be mathematically rather singular and un-necessarily strong assumption but the notion of number theoretical criticality favors it.

The general structure of U-matrix neglecting the complexities due to algebraic extensions

M-matrix is diagonal with respect to the number field for obvious reasons. U-matrix can however induce a leakage between different number fields as well as entanglement between different number fields when unions of CDs are considered. The simplest assumption is that this entanglement is induced by the leakage between different number fields for single CD but not directly. For instance, the members of entangled pair of real states associated with two CDs leak to various p-adic sectors and induce in this manner entanglement beween different number fields. One must however notice that the part of U-matrix acting in the tensor product of Hilbert spaces assignable to separate CDs must be considered separately: it seems that the entanglement inducing part of U is diagonal with respect to number field except in the intersection.

To simplify the rather complex situation consider first the U matrix for a given CD by neglecting the possibility of algebraic extensions of the p-adic number fields. Restrict also the consideration to single CD.

1. The unitarity conditions do not make sense in a completely general sense since one cannot add numbers belonging to different number fields. The problem can be circumvented if the U-matrix decomposes into a product of U-matrices, which both are such that unitarity conditions make sense for them. Here an essential assumption is that unit matrix and projection operators are number theoretically universal. In this spirit assume that for a given CD U decomposes to a product of two U-matrices U_{nm} inducing no mixing between different number fields and U_m inducing the mixing in the intersection:

$$U \quad = \quad U_{nm}U_m \quad . \tag{3.3.13}$$

Here the subscript 'nm' (no mixing) having nothing to do with the induces of U as a matrix means that the action is restricted to a dispersion in a sector of WCW characterized by particular number field. The subscript 'm' (mixing) in turn means that the action corresponds to a leakage between different number fields possible in the intersection of worlds corresponding to different number fields and that U_m acts non-trivially in this intersection.

2. Assume that U_{nm} decomposes into a formal direct sum of U-matrices associated with various number fields F:

$$U_{nm} \quad = \quad \oplus_F U_{nm,F} \quad . \tag{3.3.14}$$

$U_{nm,F}$ acts inside H_F in both WCW and spin degrees of freedom, does not mix states belonging to different number fields, and creates a state which is always mathematically completely well defined in particular number field although the direct sum over number fields is only formally defined. Unitarity condition gives a direct sum of projection operators to Hilbert spaces associated with various number fields. One can assume that this object is number theoretically universal.

3. U_m acts in the intersection of the real and p-adic worlds identified in the simplied picture in terms of surfaces representable using ratios of polynomials with rational coefficients. The resulting superposition of configuration space spinor fields in different number fields is as such not mathematical sensible although the expression of U_m is mathematically well-defined. If the leakage takes place with same probability amplitude irrespective of the quantum state, U_m is

a unitary operator, not affecting at all the spinor indices of WCW spinor fields characterizing quantum numbers of the state and whose action is analogous to unitary mixing of the identical copies of the state in various number fields.

The probability with which the intention is realized as action would not therefore depend at all on the quantum number fields, but only on the data at points common to the variants of the partonic 2-surface in various number fields. Intention would reduce completely to the algebraic geometry of partonic 2-surfaces. This assumption allows to write U in the form

$$U \quad = \quad U_{nm}U_m \quad , \tag{3.3.15}$$

where U_m acts as an identity operator in H_{nm}.

The general structure of U-matrix when algebraic extensions of rationals are allowed

Consider now the generalization of the previous argument allowing also algebraic extensions.

1. For each algebraic extension of rationals one can express WCW as a union of two parts. The first one corresponds to to 2-surfaces, which belong to the intersection of real and p-adic worlds. The second one corresponds to 2-surfaces in the algebraic extension of genuine p-adic numbers and having necessarily infinite size in real sense. Thefore the decomposition of U to a product $U = U_{nm}U_m$ makes sense also now.

2. It is natural to assume that U_m decomposes to a product of two operators: $U_m = U_H U_Q$. The strictly horizontal operator U_H connects only same algebraic extensions of rationals assigned to different number fields. Here one must think that p-adic number fields represent a large number of algebraic extensions of rationals without need for an algebraic extension in the p-adic sense. The second unitary operator U_Q describes the leakage between different algebraic extensions of rationals. Number theoretical universality encourages the assumption that this unitary operator reduces to an operator U_Q acting on algebraic extensions of rationals regarded effectively as quantum states so that it would be same for all number fields. One can even consider the possibility that U_Q depends on the extensions of rationals only and not at all on partonic 2-surfaces. One cannot assume that U_Q corresponds just to an inclusion to a larger state space since this would give an infinite number of identical copies of same state and imply a non-normalizable state. Physically U_Q would define dispersion in the space of algebraic extension of rationals defining the rational function space giving rise to the sub-WCW. The simplest possibility is that U_Q between different algebraic extensions is just the projection operator to their intersection multiplied by a numerical constant determined number theoretical in terms of ratios of dimensions of the algebraic extensions so that the diffusion between extensions products unit norm states.

One must take into account the consistency conditions from the web of inclusions for the algebraic extensions of rationals inducing extensions of p-adic numbers.

1. There is an infinite inverted pyramide-like web of natural inclusions of WCWs associated with algebraic extensions of ratonal numbers and one can assign a copy of this web to all number fields if a given p-adic number field is characterized by a web defined by algebraic extensions of rationals numbers, which it is able to represent without explicit introduction of the algebraic extension, so that the pyramide is same for all number fields. For instance, the WCW corresponding to p-adic numbers proper is included to the WCWs associated with any of its genuine algebraic extensions and defines the lower tip of the inverted pyramide. From this tip an arrow emerges connecting it to every algebraic extension defining a node of this web. Besides these arrows there are arrows from a given extension to all extensions containing it.

2. These geometric inclusions induce inclusions of the corresponding Hilbert spaces defined by rational functions and possibly by algebraic functions in which case sub-web must be considered (all n:th roots of integers in the range $(1, p-1)$ must be introduced simultaneously). Leakage

can occur between different extensions only through WCW spinor fields located in the common intersection of these spaces containing always the rational surfaces. The intersections of WCWs associated with various extensions of p-adic number fields correspond to WCWs assignable to rational functions with coeffficients in various algebraic extensions of rationals using preferred coordinates of CD and CP_2.

Together with unitarity conditions this web poses strong constraints on the unitary matrices U_m and U_Q expressible conveniently in terms of commuting diagrams. There are two kinds of webs. The vertical webs are defined by the algebraic extensions of rationals. These form a larger web in which lines connect the nodes of identical webs associated with various p-adic number fields and represent algebraic extensions of rationals.

1. One has the general product decomposition $U = U_{nm}U_QU_m$, where U_{nm} does not induce mixing between number fields, and U_m does it purely horizontally but without affecting quantum states in WCW spin degreees of freedom, and $P(H_{nm})$ projects to the complement of the intersection of number fields holds true also now.

2. Each algebraic extension of rationals gives unitary conditions for the corresponding $U_{nm,F}$ for each p-adic number field with extensions included. These conditions are relatively simple and no commuting diagrams are needed.

3. In the horizontal web U_m mixes the states in the intersections of two number fields but connects only same algebraic extensions so that the lines are strictly horizontal. U_Q acts strictly vertically in the web formed by algebraic extension of rationals and its action is unitary. One has infinite number of commuting diagrams involving U_m and U_Q since the actions along all routes connecting given points between p_1 and p_2 must be identical.

4. If algebraic universality holds in the sense that U_m is expressible using only the data about the common points of 2-surfaces in the intersection defined by particular extensions using some universal functions, and U_Q is purely number theoretical unitary matrix having no dependence on partonic 2-surfaces, one can hope that the constraints due to commuting diagrams in the web of horizontal inclusions can be satisfied automatically and only the unitarity constraints remain. This web of inclusions brings strongly in mind the web of inclusions of hyper-finite factors.

3.4   Generalization of NMP to the case of hyper-finite type II_1 factors

The intuitive notions about entanglement do not generalize trivially to the context of relativistic quantum field theories as the rigorous algebraic approach of [56] based on von Neumann algebras demonstrates. von Neumann algebras can be written as direct integrals of basic building blocks referred to as factors [50]. Factors can be classified to three basic types labelled as type I, II, and III. Factors of type I appear in non-relativistic quantum theory whereas factors of type III_1 in relativistic QFT [56]. Factors of type II_1 [48], believed by von Neumann to be fundamental, appear naturally in TGD framework [24].

3.4.1   Factors of type I

The von Neuman factors of type I correspond to the algebras of bounded operators in finite or infinite-dimensional separable Hilbert spaces. In the finite-dimensional case the algebra reduces to the ordinary matrix algebra in the finite-dimensional case and to the algebra of bounded operators of a separable Hilbert space in the infinite-dimensional case. Trace is the ordinary matrix trace. The algebra of projection operators has one-dimensional projectors as basic building blocks (atoms), the notion of pure state is well-defined, and the decomposition of entangled state to a superposition of products of pure states is unique. This case corresponds to the ordinary non-relativistic quantum theory. Ordinary quantum measurement theory and also the theory of quantum computation has been formulated in terms of type I factors. Also the discussion of NMP has been formulated solely in terms of factors of type I.

3.4.2   Factors of type II_1

The so called hyper-finite type II$_1$ factors, which are especially natural in TGD framework, can be identified in terms of the Clifford algebra of an infinite-dimensional separable Hilbert space such that the unit operator has unit trace. Essentially the fermionic oscillator operator algebra associated with a separable state basis is in question. The theory of hyper-finite type II_1 factors is rich and has direct connections with conformal field theories [52], quantum groups [53], knot and 3-manifold invariants [47, 46, 49], and topological quantum computation [54, 29].

The origin of hyper-finite factors of type II$_1$ in TGD

Infinite-dimensional Clifford algebra corresponds in TGD framework to the super-algebra generated by complexified configuration space gamma matrices creating configuration space spinors from vacuum spinor which is the counterpart of Fock vacuum [24]. By super-conformal symmetry also configuration space degrees of freedom correspond to a similar factor. For type hyper-finite II_1 factors the trace is by definition finite and normalized such that the unit operator has unit trace. As a consequence, the traces of projection operators have interpretation as probabilities.

Finite-dimensional projectors have vanishing traces so that the notion of pure state must be generalized. The natural generalization is obvious. Generalized pure states correspond to states for which density matrix reduces to a projector with a finite norm. The physical interpretation is that physical measurements are never able to resolve completely the infinite state degeneracy identifiable in TGD framework as spin glass degeneracy basically caused by the vacuum degeneracy implying non-determinism of Kähler action. An equivalent interpretation is in terms of state space resolution, which can never be complete.

In TGD framework the relevant algebra can also involve finite-dimensional type I factors as tensor factors. For instance, the entanglement between different space-time sheets could be of this kind and thus completely reducible whereas the entanglement in configuration space spin and "vibrational" degrees of freedom (essentially fermionic Fock space) would be of type II_1. The finite state-space resolution seems to effectively replace hyper-finite type II_1 factors with finite-dimensional factors of type I.

The new view about quantum measurement theory

This mathematical framework leads to a new kind of quantum measurement theory. The basic assumption is that only a finite number of degrees of freedom can be quantum measured in a given measurement and the rest remain untouched. What is known as Jones inclusions $\mathcal{N} \subset \mathcal{M}$ of von Neumann algebras allow to realize mathematically this idea [24]. $\mathcal{N}$ characterizes measurement resolution and quantum measurement reduces the entanglement in the non-commutative quantum space $\mathcal{M}/\mathcal{N}$. The outcome of the quantum measurement would still represented by a unitary S-matrix but in the space characterized by $\mathcal{N}$. It is not possible to end up with a pure state with a finite sequence of quantum measurements.

The measurement of components of quantum spinors does not make sense since it due to the non-commutativity it is not possible to talk about quantum spinor with single non-vanishing component. Therefore the measurements must be thought of as occurring in the state space associated with quantum spinors. The possible consequences of non-commutativity are considered from the point of view of cognition in [24] by starting from the observation that the moduli squared of quantum spinor components are commuting hermitian operators possessing a universal rational valued spectrum which suggests interpretation in terms of quantum version of fuzzy belief.

The obvious objection is that the replacement of a universal S-matrix coding entire physics with a state dependent unitary entanglement matrix is too heavy a price to be paid for the resolution of the above mentioned paradoxes. Situation could be saved if the S-matrices have fractal structure. The quantum criticality of TGD Universe indeed implies fractality. The possibility of an infinite sequence of Jones inclusions for hyperfinite type II_1 factors isomorphic as von Neumann algebras expresses this fractal character algebraically. Thus one can hope that the S-matrix appearing as entanglement coefficients is more or less universal in the same manner as Mandelbrot fractal looks more or less the same in all length scales and for all resolutions. Whether this kind of universality must be posed as an additional condition on entanglement coefficients or is an automatic consequence of unitarity in type II$_1$ sense is an open question.

What happens in repeated measurements?

The assumption of the standard quantum measurement theory is that the outcome of state function reduction does not change in further measurements if the combined system consisting of measured system and performer of measurement is isolated. This hypothesis generalizes to the case of hyper-finite type II_1 factors. Suppose that the outcome of a quantum jump represented by a projection operator P. If the combined system is not isolated, P can replaced by an arbitrary projection operator in the next unitary process. If the combined system is isolated, the next unitary process leads to a state in which P is replaced by a state expressible in terms of projection operators P_i projecting to the sub-space defined by P, and one of them is selected in the next state function reduction or state preparation. A never-ending series of quantum jumps forcing the state to a smaller and smaller but always infinite-dimensional corner of the state-space would result in absence of the unitary process regenerating the entanglement. This process could be seen as a counterpart for the process in which state function reduction and state preparation processes propagate from long to short length scales.

The notion of rational entanglement has a natural type II_1 counterpart and corresponds to rational valued traces for the projection operators involved and rational valued coefficients for these projection operators in the expression of the density matrix. The idea about rational entanglement (or algebraic entanglement in algebraic extension of p-adics in question) as bound state entanglement carrying negative entanglement entropy generalizes.

Rational density matrices are in a special role since they can be thought of as being common to the real and p-adic variants of the state space. The information measures based on p-adic norm and allowing negative entanglement entropy make sense also now. The question whether there might be some deeper justification for the stability of the generalized rational (algebraic) entanglement against state function reduction/preparation reducing entanglement negentropy in the context of hyper-finite type II_1 factors, remains to be answered.

Consider a rationally entangled state characterized by projection operators P_i such that the probabilities p_i are rational and remain stable in the unitary process. For factor of type I, a situation in which P_i are replaced by 1-dimensional projectors $Q_i < P_i$ is achieved sooner or later. In the infinite-dimensional case this situation can be approached but never reached.

p-Adic thermodynamics with conformal cutoff and hyper-finite factors of type II_1

For hyper-finite factors of type II_1 the unit matrix has unit trace. Hence real probabilities assignable to finite-dimensional projectors vanish so that the eigenvalues of the density matrix are always infinitely degenerate in the real context. p-Adic probabilities however make sense as finite p-adic numbers even if they vanish as real numbers. This raises the idea that p-adic probabilities are more natural for hyper-finite factors of type II_1 than real ones. Indeed, in p-adic context one could have finite probabilities for even one-dimensional sub-spaces, which would definitely mean an enhanced expressive power of the formalism. Thus hyper-finite factors of II_1 would give the reason why for p-adic thermodynamics [6].

The interpretation of p-adic probabilities is of overall importance from the point of view of physics. When probabilities are rational, the number field does not matter. If not, it seems necessary to map the p-adic probabilities to real ones. One can ask whether this mapping should respect probability conservation without normalization by hand. The variants of canonical identification with some additional conditions on probabilities satisfied for instance in p-adic thermodynamics provide a possible manner to perform this map (see [6]). In [30, 23] it is found that so called canonical identification seems to provide a tool to achieve this.

Canonical identification in its basic form is defined as $I : \sum\limits_{k=0}^{\infty} \alpha_k p^k \mapsto \sum\limits_{k=0}^{\infty} \alpha_k p^{-k}$.

Canonical identification for rational numbers is defined using the unique representation $q = r/s$ as

$$I(\frac{r}{s}) = \frac{I(r)}{I(s)} \quad . \tag{3.4.1}$$

Canonical identification allows a further generalization to the case of p-adic thermodynamics where Boltzmann weights b_n are fundamental and their sum defines partition function as $Z = \sum\limits_{n=0}^{\infty} g_n b_n$,

where g_n is the degeneracy of the state with a given "energy" (or any conserved quantity whose thermal average is fixed). In real thermodynamics Boltzmann weights are given by

$$b(E_n) = g(E_n)exp(-E_n/T) \ , \tag{3.4.2}$$

where E_n is "energy" and $g(E_n)$ the integer valued degeneracy of states with energy E_n. In p-Adic thermodynamics the partition function would not converges for this form of Boltzmann weights, which are therefore replaced by $b(E_n) = g(E_n)p^{E_n/T}$ and E_n/T is integer valued to guarantee the p-adic existence of the conformal weight. The quantization of E_n/T to integer values implies quantization of both T and "energy" spectrum and forces so called super conformal invariance in applications of topological geometrodynamics (see [20, 6]), which is indeed a basic symmetry of the theory [21]. Thus the mere number theoretical existence fixes the physics to a high degree and indeed leads to the understanding of elementary particle mass scales. For applications to the calculations of elementary particle masses see [6].

In p-adic thermodynamics the probabilities would be given by $p_n = b_n/Z$ and N_{max} would be replaced by Z. When b_n are integers it is natural to define the canonical identification as

$$I(p_n) = I(\frac{b_n}{Z}) \equiv \frac{I(b_n)}{I(Z)} \ . \tag{3.4.3}$$

A physically very powerful additional constraint is that the additivity of probabilities for independent events holds true also for the *real* counterparts of the *p*-adic probabilities obtained by canonical identification so that one would obtain also a real probability theory without ad hoc normalization of the real images of p-adic probabilities. This condition is satisfied only if the Boltzman weights b_{n_1} and b_{n_2} for any pair (n_1, n_2) are p-adic integers having no common pinary digits so that no "interference" in the sum of the p-adic probabilities occurs.

The selection of a basis for independent events would correspond to a decomposition of the set of integers labelling pinary digits to disjoint sets and brings in mind the selection of orthonormalized basis of quantum states in quantum theory such that quantum measurement can give only one of these states as an outcome. One can say that the probabilities define distributions of pinary digits analogous to non-negative probability amplitudes in the space of integers labelling pinary digits, and the probabilities of independent events must be orthogonal with respect to the inner product $\sum_n \alpha_n \beta_n p^n$ of integers $x = \alpha_n p^n$ and $y = \beta_n p^n$ defining analogs of wave functions in the space of pinary digits. Or putting it somewhat differently: Boltzman weights b_n for orthogonal quantum states represent them as orthogonal states in the space of binary digits with orthogonality realized as vanishing of the overlap for non-negative "wave functions". This map puts strong constraints on the probabilities of elementary independent events and is therefore highly interesting from the point of view of physics.

p-Adic thermodynamics satisfies the constraint that p-adic probabilities have no common pinary digits provided the degeneracies satisfy the condition $g(E_n) < p$ (later a somewhat more general conditions is deduced). For p-adic mass calculations (see [?]) the degeneracies $g(n)$ of states with conformal weight $L_0 = n$ (taking the role of "energy") however increase exponentially so that the condition is not satisfied for very large values of n. Since $g(n)$ increases exponentially (say as 2^{nx}, where x is some parameter), probability conservation requires a cutoff of order $n_{max} \sim log_2(p)$ to the number of terms in the sum defining the partition function. In practice this cutoff has no implications since already the two lowest terms give excellent approximation to the elementary particle masses.

For instance, the value of p is $M_{127} = 2^{127} - 1 \sim 10^{38}$ in the case of electron so that higher terms in partition function Z are extremely small. The physical interpretation for the cutoff n_{max} would be in terms of p-adic length scale hypothesis (see [30, 23]) stating that the length scales $L_p \propto \sqrt{p}$ with primes $p \simeq 2^k$, k prime, are physically favored and the exponentially smaller p-adic length scale $L_k \propto \sqrt{k}$ defines the size scale of the elementary particle [?].

For the ordinary thermodynamics of strings the exponential increase gives rise to Hagedorn temperature T_H as the maximal temperature possible for strings (see [55]). The interpretation is that the heat capacity of system grows without bound since the number of excited degrees of freedom increases without bound as T_H is approached. Clearly Hagedorn temperature is somewhat analogous to the pinary cutoff in p-adic thermodynamics.

The interpretation of the conformal cutoff in terms of factors of type II_1 factor would be that all conformal weights $n > n_{cr}$ correspond to the same p-adic probability so that it is not possible to distinguish experimentally between these states. This interpretation fits nicely with the notions of resolution and monitoring.

3.4.3   Factors of type III

For algebras of type III associated with non-separable Hilbert spaces all projectors have infinite trace so that the very notion of trace becomes obsolete. The factors of type III_1 are associated with quantum field theories in Minkowski space.

The highly counter-intuitive features of entanglement for type III factors are discussed in [56].

1. The von Neumann algebra defined by the observables restricted to an arbitrary small region of Minkowski space in principle generates the whole algebra. Expressed in a more technical jargon, any field state with a bound energy is cyclic for each local algebra of observables so that the field could be obtained in entire space-time from measurements in an arbitrary small region of space-time. This kind of quantum holography looks too strong an idealization.

   In TGD framework the replacement of Minkowski space-time with space-time sheet seems to restrict the quantum holography to the boundaries of the space-time sheet. Furthermore, in TGD framework the situation is nearer to the non-relativistic one since Poincare transformations are not symmetries of space-time and because 3-surface is the fundamental unit of dynamics. Also in TGD framework M^4 cm degrees of 3-surfaces are present but it would seem that they appear as labels of type II_1 factors in direct integral decomposition rather than as arguments of field operators.

2. The notion of pure state does not make sense in this case since the algebra lacks atoms and projector traces do not define probabilities. The generalization of the notion of pure state as in II_1 case does not make sense since projectors have infinite trace.

3. Entanglement makes sense but has very counter-intuitive properties. First of all, there is no decomposition of density matrix in terms of projectors to pure states nor any obvious generalization of pure states. There exists no measure for the degree of entanglement, which is easy to understand since one cannot assign probabilities to the projectors as their traces.

4. For any pair of space-like separated systems, a dense set of states violates Bell inequalities so that correlations cannot be regarded as classical. This is in a sharp contrast with elementary quantum mechanics, where "de-coherence effects" are believed to drive the states into a classically correlated states.

5. No local measurement can remove the entanglement between a local system and its environment. In TGD framework local operations would correspond to operations associated with a given space-time sheet. Irreducible type II_1 entanglement between different space-time sheets, if indeed present, might have an interpretation in terms of a finite resolution at state space level due to spin glass degeneracy.

On basis of these findings, one might well claim that the axiomatics of relativistic quantum field theories is not consistent with the basic physical intuitions.

3.5   Some consequences of NMP

In the sequel the most obvious consequences of self measurement and NMP are discussed from the point of view of physics, biology, cognition, and quantum computing. The recent discussion differs considerably from the earlier one since several new elements are involved. Zero energy ontology and the hierarchy of CDs, the hierarchy of Planck constants and dark matter, and -perhaps most importantly- the better understanding negentropic entanglement as something genuinely new and making sense in the interection of real and various p-adic worlds at which living matter is assumed to reside.

3.5.1 NMP and thermodynamics

The physical status of the second law has been a longstanding open issue in physics- in particular biophysics. In positive energy ontology the understanding of the origin of second law is simple. Quantum jumps involve state function reduction (or more generally, self measurement) with a random outcome and in the case of ensemble of identical system this leads to to a probability distribution for the states of the members of the ensemble. This implies Boltzmann equations implying the second law. In TGD framework there are many elements which force to question this simple picture: zero energy ontology and CDs, effective four-dimensionality of the ensemble defined by states assignable to sub-CDs, hierarchy of Planck constants, and the possibility of negentropic entanglement.

Zero energy ontology and thermodynamical ensembles

Zero energy ontology means that the thermodynamics appears both at the level of quantum states and at the level of ensembles. At the level of quantum states this means that M-matrix can be seen as a complex square root of the density matrix: $\rho = MM^{\dagger}$, where M is expressible as a product of a positive and diagonal square root of density matrix and unitary S-matrix identifiable as the S-matrix used in quantum physics. U matrix can be seen as a collection of M-matrices as will be found later so that U-matrix fixes M-matrices contrary to what was believed originally. One can say that thermodynamics -at least in some sense- is represented at the level of single particle states. It is natural to assume that this density matrix is measured in particle physics experiment, and that this measurement corresponds to a state function reduction, which in standard physics picture corresponds to a preparation for the initial states and state function reduction for the final states.

The p-adic thermodynamics, which applies to conformal weights rather than energy, predicts successfully elementary particle masses [6] and should reduce to this thermodynamics. That p-adic thermodynamics can be applied at all suggests that even elementary particles reside in the intersection of the real and p-adic worlds so that either p-adic thermodynamics or real thermodynamics with additional constraints on temperature implied by number theory applies.

Thermodynamical ensembles are 4-dimensional

The hierarchy of CDs within CDs defines a hierarchy of sub-systems and sub-CDs define in a natural manner 4-dimensional ensemble. If the state function reduction leads to unentangled states, the outcome is an ensemble describable by the density matrix assignable to the single particle states. The sequence of quantum jumps is expected to lead to a 4-D counterpart of thermodynamical ensemble and thermodynamics results when one labels the states by the quantum numbers assignable to their positive energy part. Entropy is assigned with entire 4-D CD rather than to its 3-dimensional time=constant snapshots. The thermodynamical time is basically the subjective time and measured in terms of quantum jumps but has a correlation with geometric time as explained in [28] and explained briefly below.

This picture differs from the standard views, and this might explain the paradoxical situation in cosmology resulting from the fact that the initial state of the universe in the standard sense of the word looks highly entropic whereas second law would suggest the opposite [19]. The cosmological entropy is assigned with a CD of size scale defined by the value of the age of the universe. In this kind of situation each quantum jump replaces the zero energy state with a new one and also induces a drift in the space of CDs to the direction of larger CDs with size defined by the proper time distance between the tips of CD coming as power of 2. Entropy as a function of cosmic time corresponds in TGD framework to the increase of the 4-D entropy as a function of the quantized proper time distance between the tips of the CD.

In this framework it is possible to understand second law in cosmic time scales apart from the possible effects related to the negentropic entanglement responsible for the evolution and breaking of second law in arbitrarily long time scales. For instance, the number of sub-CDs increases meaning the increase of the size of the ensemble and the emergence of new p-adic length scales as the size of cosmic CD increases. What is fascinating is that the TGD counterpart of cosmic time is quantized in powers of two. This might have predictable effects such as the occurrence of the cosmic expansion in a jump-wise manner. I have discussed an explanation of the accelerated cosmic expansion in terms of quantum jumps of this kind but starting from somewhat different picture [19].

How second law must be modified?

Second law as such does not certainly apply in TGD framework.

1. The hierarchy of CDs forces to introduce a fractal version of the second law taking into account the p-adic length scale hypothesis and dark matter hierarchy. This means that the idea about quantum parallel Universes generalizes to that of quantum parallel dissipating Universes. For instance, the parton model of hadrons based on quarks and gluons relies on kinetic equations and is basically thermodynamical whereas the model for hadron applied at low energies is quantum mechanical. These two views are consistent if quantum parallel dissipation realized in terms of a hierarchy of CDs is accepted. p-Adic length scale hierarchy with p-adic length scale hypothesis stating that primes near powers of two are preferred corresponds to this dissipative quantum parallellism. Dark matter hierarchy brings in a further dissipative quantum parallelism.

2. Second law should always be applied only at a given level of p-adic and dark matter hierarchy and one must always take into account two time scales involved corresponding to the time scale assignable to the system identifiable as the time scale characterizing corresponding CD and the time scale in which the system is observed. Only if the latter time scale is considerably longer than the CD time scale, second law is expected to make sense in TGD framework -this provided one restricts the consideration to the entropic entanglement. The reason is that the Boltzmann equations implying the second law require that the geometric time scale assignable to quantum jump is considerably shorter than the time scale of observation: this guarantees that the random nature of quantum jump allows to use statistical approach.

3. The possibility of negentropic entanglement in time scale of CD brings a further new element strongly suggesting that the mechanical application of second law does to living matter does not make sense. The basic time scales for CDs come as powers of two and the hierarchy of Planck constants in the most general case allows rational multiples of these. If a restriction is made to singular covering spaces of CD and CP_2 (this might well be consistent with experimental inputs), only integer multiples of these time scales are predicted at the level of dark matter. The increase of Planck constant allows to scale up the time scale of quantum coherence associated with the negentropic entanglement and this provides a further good reason for why large values of Planck constant should be favored in living matter.

4. The reduction of entanglement entropy at single particle level implies the increase of thermodynamical entropy at the level of ensemble in the case of entropic non-binding entanglement. This applies also to bound state entanglement leading to a generation of entropy at the level of binding systems and a reduction of the contribution of the bound systems to the entropy of the entire system. Note however the emission of binding energy -say in form of photons- could take care of the compensation so that entropy would be never reduced for ensemble. In the case of negentropic entanglement the situation is different.

   The entropy of the negentropically entangled system is negative and the synenergic aspect of negentropic entanglement means that the system does not contribute to thermodynamical entropy. This means that second law could be broken in the geometric time scale considered. One must of course be careful in distinguishing between geometric and subjective time. In the case of subjective time the negentropic situation could continue forever unless the CD disappears in some quantum jump (highly non-probable for large enough CDs). If not, then endless evolution at the level of conscious experience is possible in the intersection of real and p-adic worlds and heat death is not the fate of the Universe as in ordinary thermodynamics.

5. The breaking of second law must correspond to the breaking of ergodicity. Spin glasses are non-ergodic systems and TGD Universe is analogous to a 4-D quantum spin glass by the failure of strict non-determinism of Kähler action reflecting itself as vacuum degeneracy. Does the quantum spin glass property of the TGD universe imply the breaking of the second law? Gravitation has been seen as one possible candidate for the breaking second law because of its long range nature. It is indeed classical gravitational energy which distinguishes between almost degenerate spin glass states. The huge value of gravitational Planck constant associated with space-time sheets mediating gravitational interaction and making possible perturbative quantum treatment of gravitational interaction would indeed suggest the breaking of second law in cosmological time

scales. For instance, black hole entropy which is inversely proportional to $GM^2/\hbar_{gr}$ would be for the values of gravitational Planck constant involved of the order of unity.

What do experiments say about second law?

That the status of the second law is far from settled is demonstrated by an experiment performed by a research group in Australian National University [44]. The group studied a system consisting of 100 small beads in water. One bead was shot by a laser beam so that it became charged and was trapped. The container holding the beads was then moved from side to side 1000 times per second so that the trapped bead dragged first one way and then another. The system was monitored and for monitoring times not longer than .1 seconds second law did not hold always: entropy could also decrease.

1. What is remarkable that .1 seconds defines the duration τ of the memetic code word and corresponds to the secondary p-adic time scale $T_p(2) = \sqrt{p}L_p/c$ associated with Mersenne prime $p = M_{127}$ characterizing electron. This correspondence follows solely from the model of genetic code predicting hierarchy of codes associated with $p = 3, 7, 127$ (genetic code), $p = M_{127}, \dots$ τ should be the fundamental time scale of consciousness. For instance, average alpha frequency 10 Hz corresponds to this time scale and 'features' inside cortex representing sensory percepts have average duration of .1 seconds.

   For electrons the CDs would have spatial size $L = 3 \times 10^7$ meters, which is slightly smaller than the circumference of Earth ($L = cT$, $T = .1$ s, the duration of sensory moment) so that they would have a strong overlap. One can of course ask whether this is an accident. For instance, the lowest Schumann frequency is around 7.8 Hz and not far from 10 Hz. What is interesting that Bohr orbit model [17] predicts that Universe might be populated by Earth like systems having same distance from their Sun (stars with mass near that of Sun are very frequent). Bohr orbitology applied to Earth itself could also lead to the quantization of the radius of Earth.

2. The first observation was made for more than 15 years ago. Even more remarkable is the recent observation that the time scale of CD associated with electron is .1 seconds. Can one assign the breaking of the second law with the field bodies of electrons?

3. The experiment involves also a millisecond time scale. I do not know whether it is essential that the time scale is just this but one can play with the though that it is. Millisecond time scale is roughly the duration of seventh bit of the genetic codeword if its bits correspond to CDs with sizes coming as subsequence octaves of the basic time scale. Millisecond defines also the time scale for the duration of the nerve pulse and the frequency of kHz cortical synchrony.

   At the level of CDs millisecond time scale would correspond to a secondary p-adic time scale assignable to $k = 120$. Only u and d quarks, which appear with several p-adic mass scales in hadron physics and are predicted to be present as light variants also in nuclear physics as predicted by TGD, could correspond to this p-adic length scale: the prediction for their mass scale would be 5 MeV. Does this mean that the basic time scales of living matter correspond directly to the basic time scales of elementary particle physics?

4. A further interesting point is that neutrinos correspond to .1 eV mass scale. This means that the p-adic length scale is around $k = 167$ which means that the corresponding CD has time scale which is roughly 2^{40} times that for electron and corresponds to the primary p-adic length scale of 2.5 μm (size of cellular nucleus) and tothe time scale of 10^4 years. I have proposed that so called cognitive neutrino pairs consisting of neutrino and antineutrino assignable to the opposite throats of wormhole contact could play key a role in the formation of cognitive representations[27]. This assumption looks now un-necessarily restrictive but one could quite well consider the possibility that neutrinos are responsible for the longest time scales assignable to consciousness for ordinary value of $\hbar$ (not necessarily our consciousness!). Large value of $\hbar$ could make also possible the situation in which intermediate gauge bosons are effectively massless in cell length scale so that electro-weak symmetry breaking would be absent. This would require $\hbar \simeq 2^{33}$. For this value of $\hbar$ the time scale of electronic CD is of the order of the duration of human of human life cycle. This would scale up the Compton length of neutrino to about 10 kilometers and the temporal size of neutrino CD to a super-cosmological time scale.

3.5.2   NMP and self-organization

NMP leads to new vision about self-organization about which adetailed vision is discussed in [26]. Here only some key points are emphasized.

1. Dissipation selects the asymptotic self-organization patterns in the standard theory of self-organization and the outcomes are interesting in the presence of energy feed. The feed of energy can be generalized to feed of any kind of quantum numbers: for instance, feed of quantum numbers characterizing qualia. In fact, energy increment in quantum jump defines one particular kind of quale [24].

2. The notion of self relates very closely to self-organization in TGD framework [26]. Self is a dissipative structure because it has subselves which dissipate quantum parallely with it. Self as a perceiver maps the dissipation at the level of quantities in the external world to dissipation at the level of qualia in the internal world.

3. Dissipation leads to self-organization patterns and in the absence of external energy feed to thermal equilibrium. Thus thermodynamics emerges as a description for an ensemble of selves or for the time average behavior or single self when external energy feed to system is absent. One can also understand how the dissipative universe characterized by the presence of parameters like diffusion constants, conductivities, viscosities, etc.. in the otherwise reversible equations of motion, emerges. Dissipative dynamics is in a well defined sense the envelope for the sequence of reversible dynamical evolutions modelling the sequence of final state quantum histories defined by quantum jumps.

4. Quantum self-organization can be seen as iteration of the unitary process followed by state function reduction and leads to fixed point self-organization patterns analogous to the patterns emerging in Benard flow. Since selves approach 'asymptotic selves', dissipation can be regarded as a Darwinian selector of both genes and memes. Thus not only surviving physical systems but also stable conscious experiences of selves, habits, skills, behaviors, etc... are a result of Darwinian selection.

5. In TGD one must distinguish between two kinds of self organizations corresponding to the entropic bound state entanglement and negentropic entanglement. Biological self-organization could be therefore fundamentally different from the non-biological one. The succes of the p-adic mass calculations suggest that even elementary particles live in the intersection of real and p-adic worlds so that one should be very cautious in making strong conclusions. Certainly the intentional, goal-directed behavior of the system in some time scale is a signature of negentropic self-organization but it is difficult to apply this criterion in time scales vastly different from human time scales. It is the field bodies (or magnetic bodies) , which can be assigned naturally to CDs which suggests that the negentropic self organization occurs at this level. TGD based vision about living matter actually assumes this implicitly.

6. What is new that even quantum jump itself can be seen as a self-organization process analogous to Darwinian selection, which eliminates all unbound entanglement and yields a state containing only bound state state entanglement or negentropic entanglement and representing analog of the self-organization patterns. By macro-temporal quantum coherence effectively gluing quantum jumps sequences to single quantum jump this pattern replicates itself fractally in various time scales. Thus self-organization patterns can be identified as bound states and states paired by a negentropic entanglement and the development of the self-organization pattern as a fractally scaled up version of single quantum jump. Second new element is that dissipation is not mere destruction of order but producer of jewels. A further new element is that dissipation can occur in quantum parallel manner in various scales.

7. The failure of the determinism in standard sense for Kähler action is consistent with the classical description of dissipation. In particular, the emergence of sub-selves inside self looks like dissipation from outside but corresponds to self-organization from the point of view of self. 4-dimensional spin glass degeneracy meaning breaking of ergodicity crucial for self-organization is highly suggestive on basis of the vacuum degeneracy of Kähler action, and this alone predicts

ultrametric topology for the landscape of the maxima of Kähler function defined in terms of Kähler action so that p-adicity emerges naturally also in this manner.

One particularly interesting concrete prediction is that the time scales assignable to CDs come as powers of two. This predicts fundamental frequencies coming as powers of two, and the hierarchy of Planck constants predicts rational or at least integer multiples of these frequencies. Could these powers of two relate to frequency doubling rather generally observed in hydrodynamical self-organizing systems?

3.5.3   NMP and p-adic length scale hypothesis

The original form of the p-adic length scale hypothesis stated that physically most interesting p-adic primes satisfy $p \simeq 2^k$, k prime or power of prime. It has however turned out that all positive integers k are possible. Surprisingly few new length scales are predicted by this generalization in physically interesting length scales. p-Adic length scale hypothesis leads to excellent predictions for elementary particle masses (note that the mass prediction is exponentially sensitive to the value of k) and explains also some interesting length scales of biology: for instance, the thicknesses of the cell membrane and of single lipid layer of cell membrane correspond to $k = 151$ and $k = 149$ respectively.

The big problem of p-adic TGD is to derive this hypothesis from the basic structure of the theory.

1. One argument is based on black hole-elementary particle analogy [22] leading to the generalization of the Hawking-Bekenstein formula: the requirement leading to the p-adic length scale hypothesis is that the radius of the so called elementary particle horizon is itself a p-adic length scale. This argument involves p-adic entropy essentially and it seems that information processing is somehow involved.

2. Zero energy ontology predicts p-adic length scale hypothesis if one accepts the assumption that the proper time distances between the tips of CDs come as powers of 2 [22]. A more general highly suggestive proposal is that the relative position between tips forms a lattice at proper time constant hyperboloid having as a symmetry group discrete subgroup of Lorentz group (which could reduce to a subgroup of the group $SO(3)$ acting as isotropy group for the time-like direction defined by the relative coordinate between the tips of CD [19].

   p-Adic length scale hypothesis could be understood as a resonance in frequency domain -most naturally for massless particles like photons. The secondary p-adic time scale for favored p-adic primes must be as near as possible to the proper time distance between the tips of CD. Mersenne primes $M_n = 2^n - 1$ (n is prime) satisfy this condition. Also $log(p)$ is in this case as near as possible to $log(2^n)$ and in the sense that the unit of negentropy defined as $log(2^n - m(n))/log(2^n)$ is maximized. This argument might work also for Gaussian Mersennes $G_n = (1 + i)^n - 1$ (n is prime also now) if one restricts the consideration to Gaussian primes.

   A more general and more realistic looking hypothesis is that a given CD can have partonic light-like 3-surfaces ending at its boundaries for all p-adic length scales up to that associated with CD: powers of 2 would be favored by the condition of commeasurability very much analogous to frequency doubling.

3. An exciting possibility, suggested already earlier half seriously, is that evolution is present already at elementary particle level. This is the case if elementary particles reside in the intersection of real and p-adic worlds. The success of p-adic mass calculations and the identification of p-adic physics as physics of cognition indeed forces this interpretation. In particular, one can understand p-adic length scale hypothesis as reflecting the survival of the cognitively fittest p-adic topologies.

I have discussed also other explanations.

1. A possible physical reason for the primes near prime powers of 2 is that survival necessitates the ability to co-operate, to act in resonance: this requirement might force commeasurability of the length scales for p-adic space-time sheet (p_1) glued to larger space-time sheet ($p_2 > p_1$). The hierarchy would state from 2-adic level having characteristic fractal length scales coming as powers of $\sqrt{2}$. When $p > 2$ space-time sheet is generated during cosmological evolution $L(p)$ for it must correspond to power of $\sqrt{2}$ so that one must have $p \simeq 2^n$.

2. A model for learning [41] as a transformation of the reflective level of consciousness to proto level supports the view that evolution and learning occur already at elementary particle level as indeed suggested by NMP: the p-adic primes near power of prime powers of two are the fittest ones. The core of the argument is the characterization of learning as a map from 2^N many-fermion states to M association sequences. The number of association sequences should be as near as possible equal to 2^N. If M is power of prime: $M = p^K$, association sequences can be given formally the structure of a finite field $G(p, K)$ and p-adic length scale hypothesis follows as a consequence of $K = 1$. NMP provides the reason for why $M = p^K$ is favored: in this case one can construct realization of quantum computer with entanglement probabilities $p_k = 1/M = 1/p^K$ and the negentropy gain in quantum jump is $Klog(p)$ while for M not divisible by p the negentropy gain is zero.

3.5.4   NMP and biology

The notion of self is crucial for the understanding of bio-systems and consciousness. It seems that the negentropic entanglement is the decisive element of life and that one can say that in metaphoral sense life resides in the intersection of real and p-adic worlds.

Life as islands of rational/algebraic numbers in the seas of real and p-adic continua?

Rational and even algebraic entanglement coefficients make sense in the intersection of real and p-adic words, which suggests that life and conscious intelligence reside in the intersection of the real and p-adic worlds. This would mean that the mathematical expressions for the space-time surfaces (or at least 3-surfaces or partonic 2-surfaces and their 4-D tangent planes) make sense in both real and p-adic sense for some primes p. Same would apply to the expressions defining quantum states. In particular, entanglement probabilities would be rationals or algebraic numbers so that entanglement can be negentropic and the formation of bound states in the intersection of real and p-adic worlds generates information and is thus favored by NMP.

The identification of intentionality as the basic aspect of life seems to be consistent with this idea.

1. The proposed realization of the intentional action has been as a transformation of p-adic space-time sheet to a real one. Also transformations of real space-time sheets to p-adic space-time sheets identifiable as cognitions are possible. Algebraic entanglement is a prerequisite for the realization of intentions in this manner. Essentially a leakage between p-adic and real worlds is in question and makes sense only in zero energy ontology. The reason is that various quantum numbers in real and p-adic sectors are not in general comparable in positive energy ontology so that conservation laws would be broken or even cease to make sense.

2. The transformation of intention to action can occur if the partonic 2-surfaces and their 4-D tangent space-distributions are representable using rational functions with rational (or even algebraic) coefficients in preferred coordinates for the imbedding space dictated by symmetry considerations. Intentional systems must live in the intersection of real and p-adic worlds.

3. For the minimal option life would be also effectively 2-dimensional phenomenon and essentially a boundary phenomenon as also number theoretical criticality suggests. There are good reasons to expect that only the data from the intersection of real and p-adic partonic two-surfaces appears in U-matrix so that only the data from rational and some algebraic points of the partonic 2-surface dictate U-matrix. This means discretization at parton level and something which might be called number theoretic quantum field theory should emerge as a description of intentional action.

A good guess is that algebraic entanglement is essential for quantum computation, which therefore might correspond to a conscious process. Hence cognition could be seen as a quantum computation like process, a more approriate term being quantum problem solving [24]. Living-dead dichotomy could correspond to rational-irrational or to algebraic-transcendental dichotomy: this at least when life is interpreted as intelligent life. Life would in a well defined sense correspond to islands of rationality/algebraicity in the seas of real and p-adic continua. Life as a critical phenomenon in the number theoretical sense would be one aspect of quantum crticality of TGD Universe besides the criticality

of the space-time dynamics and the criticality with respect to phase transitions changing the value of Planck constant and other more familiar criticalities. How closely these criticalities relate remains an open question [26].

The view about the crucial role of rational and algebraic numbers as far as intelligent life is considered, could have been guessed on very general grounds from the analogy with the orbits of a dynamical system. Rational numbers allow a predictable periodic decimal/pinary expansion and are analogous to one-dimensional periodic orbits. Algebraic numbers are related to rationals by a finite number of algebraic operations and are intermediate between periodic and chaotic orbits allowing an interpretation as an element in an algebraic extension of any p-adic number field. The projections of the orbit to various coordinate directions of the algebraic extension represent now periodic orbits. The decimal/pinary expansions of transcendentals are un-predictable being analogous to chaotic orbits. The special role of rational and algebraic numbers was realized already by Pythagoras, and the fact that the ratios for the frequencies of the musical scale are rationals supports the special nature of rational and algebraic numbers. The special nature of the Golden Mean, which involves $\sqrt{5}$, conforms the view that algebraic numbers rather than only rationals are essential for life.

That only algebraic extensions are possible is of course only a working hypothesis. Also finite-dimensional extensions of p-adic numbers involving transcendentals are possible and might in fact be necessary. Consider for instance the extension containing $e, e^2, .., e^{p-1}$ as units (e^p is ordinary p-adic number. Infinite number of analogous finite-dimensional extensions can be constructed by taking a function of integer variable such that $f(p)$ exists both p-adically and as a real transcendental number. The powers of $f(p)^{1/n}$ for a fixed value of n define a finite-dimensional transcendental extension of p-adic numbers if the roots do not exist p-adically.

Numbers like $log(p)$ and π cannot belong to a finite-dimensional extension of p-adic numbers [17]. One cannot of course take any strong attitude concerning the possibility of infinite-dimensional extensions of p-adic numbers but the working hypothesis has been that they are absent. The phases $exp(i2\pi/n)$ define finite dimensional extensions allowing to replace the notion of angle in finite measurement resolution with the corresponding phase factors in finite measurement. The functions $exp(i2\pi q/n)$, where q is arbitrary p-adic integers define in a natural manner the physical counterparts of plane waves and angular momentum eigenstates not allowing an identification as ordinary p-adic exponential functions. They are clearly strictly periodic functions of q with a finite value set. If n is divisible by a power of p, these functions are continuous since the values of the function for q and $q + kp^n$ are identical for large enough values of n. This condition is essential and means in the case of plane waves that the size scale of a system (say one-dimensional box) is multiple of a power of p.

Evolution and second law

Evolution has many facets in TGD framework.

1. A natural characterization of evolution is in terms of p-adic topology relating naturally to cognition. p-Adic primes near powers of two are favored if CDs have the proposed discrete size spectrum. From the point of view of self this would be essentially cosmic expansion in discrete jumps. CDs and can be characterized by powers of 2 and if partonic 2-surfaces correspond to effective p-adic p-adic topology characterized by a power of two, one obtains the commeasurability of the secondary p-adic time scale of particle and that of CD in good approximation.

2. The notion of infinite primes motivates the hypothesis that the many-sheeted structure of space-time can be coded by infinite primes[19]. The number of primes larger than given infinite prime P is infinitely larger than the number of primes than P. The infinite prime P characterizing the entire universe decomposes in a well defined manner to finite primes and p-adic evolution at the level of entire universe is implied by local p-adic evolution at the level of selves. Therefore maximum entanglement negentropy gain for p-adic self increases at least as $log(p)$ with p in the long run. This kind of relationship might hold true for real selves of p-adic physics is physics of cognitive representations of real physics as suggested by the success of p-adic mass calculations. Thus it should be possible to assign definite p-adic prime to each partonic 2-surface.

3. A further aspect of evolution relates to the hierarchy of Planck constants implying that at dark matter levels rational or at least integer multiples of the favored p-adic time scales are realized.

The latter option is favored by the idea that the book like structure with pages consisting of many-sheeted coverings of CD and CP_2, and correlates with the emergence of algebraic extensions of p-adic numbers defined by the roots $exp(i2\pi/n)$ of unity. For the latter option evolution by quantum jumps would automatically imply the drifting of the partonic 2-surfaces to the pages of books labelled by increasing values of Planck constant. For more general option one might argue that drifting to pages with small values of Planck constant is also possible. This would give kind of antizooms of long length scale physics to short scales. Both kind of temporal zooms could be crucial for conscious intelligence building scaled models about time evolution in various scales.

4. The generation of negentropic entanglement between different number fields would of course be the fundamental aspect of evolution. It would give rise to increasingly complex and negentropic sensory perceptions and cognitive representations based on conscious rules coded by negentropic entanglement. This would justify the association concept as it used in neuro-science. Negentropic entanglement could be also crucial for the basic mechanism of metabolism and make possible conscious co-operation even in nano-scales.

Just for fun one can play also with numbers.

1. The highest dark matter level associated with self corresponds to its geometric duration which can be arbitrarily long: the typical duration of the memory span gives an idea about the level of dark matter hierarchy involved if one assumes that the time scale .1 seconds assignable to electrons is the fundamental time scale. If the time scale T of human life cycle corresponds to a secondary p-adic time scale then $T = 100$ years gives the rough estimate $r \equiv \hbar/\hbar_0 = 2^{33}$ if this time scale corresponds to that for dark electron. The corresponding primary p-adic time length scale corresponds to $k = 160$ and is 2.2×10^{-7} meters.

2. If human time scale -taken to be $T = 100$ years- corresponds to primary p-adic time scale of electron, one must have roughly $r = 2^{97}$.

I have already discussed the second law in TGD framework and it seems that its applies only when the time scale of perception is longer than the time scale characterizing the level of the p-adic and dark matter hierarchy. Second law as it is usually stated can be seen as an unavoidable implication of the materialistic ontology.

Stable entanglement and quantum metabolism as different sides of the same coin

The notion of binding has two meanings. Binding as a formation of bound state and binding as a fusion of mental images to larger ones essential for the functioning of brain and regarded as one the big problems of consciousness theory.

Only bound state entanglement and negentropic entanglement are stable against the state reduction process. Hence the fusion of the mental images implies the formation of a bound entropic state- in this case the two interpretations of binding are equivalent- or a negentropic state, which need not be bound state.

1. In the case of negentropic entanglement bound state need not be formed and the interesting possibility is that the negentropic entanglement could give rise to stable states without binding energy. This could allow to understand the mysterious high energy phosphate bond to which metabolic energy is assigned in ATP molecule containing three phosphates and liberated as ATP decays to ADP and phosphate molecule. Negentropic entanglement could also explain the stability of DNA and other highly charged biopolymers. In this framework the liberation of metabolic (negentropic) energy would involve dropping of electrons to a larger space-time sheets accompanying the process $ATP \rightarrow ADP + P_i$. A detailed model of this process is discussed in [19].

2. The formation of bound state entanglement is expected to involve a liberation of the binding energy and this energy might be a usable energy. This process could perhaps be coined as quantum metabolism and one could say that quantum metabolism and formation of bound states are different sides of the same coin. It is known that an intense neural activity, although

it is accompanied by an enhanced blood flow to the region surrounding the neural activity, does not involve an enhanced oxidative metabolism [58] (that is $ATP \rightarrow ADP$ process and its reversal). A possible explanation is that quantum metabolism accompanying the binding is involved. Note that the bound state is sooner or later destroyed by the thermal noise so that this mechanism would in a rather clever manner utilize thermal energy by applying what might be called buy now–pay later principle.

If these interpretations are correct, there would be two modes of metabolism corresponding to two different kinds of fusion of mental images.

3.5.5 NMP, consciousness, and cognition

As already found NMP dictates the subjective time development of self and is therefore the basic law of consciousness. If p-adic physics is the physics of cognition, the most exotic implications of NMP relate to cognition rather than standard physics.

Thermodynamics for qualia

If only entropic entanglement is assumed, second law seems to hold also at the level of conscious experience of self, which can be seen as an ensemble of its subselves assignable to sub-CDs. The randomness of the state function reduction process implies that conscious experience involves statistical aspects in the sense that the experienced qualia correspond to the averages of quantum number and zero mode increments over the sub-selves assignable to sub-CDs. When the number of quantum jumps in the ensemble defining self increases, qualia get more entropic and fuzzy unless macro-temporal quantum coherence changes the situation.

Negentropic entanglement means departure from this picture if sub-CDs can generate negentropic entanglement. This is expected to be true if they overlap if one believes on standard argument for the formation of macroscopic quantum phases. In this case the flux tubes connecting space-time sheets assignable to the sub-CDs would serve as a space-time correlate for the negentropic entanglement.

The basic questions are whether sensory qualia can really correspond to the increments of quantum numbers in quantum jump and whether these quantum jumps are assignable to entropic or negentropic qualia. What is clear that the sensory qualia such as colors are assigned to an object of external world rather predictably. This is not obvious if this process is based on quantum jump.

1. Qualia are determined basically as increments of quantum numbers [24] whereas in ordinary statistical physics measured quantities would correspond to quantum numbers basically. The basic function of sensory organs is to map quantum numbers to quantum number increments so that our sensory perception is in reasonable approximation about world rather than changes of the world.

2. In zero energy ontology the increments must correspond to increments of quantum numbers for (say) positive energy part of the state. A sensation of (say) given color requires a continual feed of corresponding quantum number increment to the positive energy part of the system. Some kind of far from equilibrium thermodynamics seems to be necessary with external feed of quantum numbers generalizing the external feed of energy. The capacitor model of a sensory receptor [24] realizes this idea in terms of generalized di-electric breakdown implying opposite charging of the capacitor plates in question. Note that in zero energy ontology also the positive and negative energy parts of the zero energy state assignable to capacitor plates would be also analogous to a pair of oppositely charged capacitor plates and one can speak about capacitor also in time direction.

3. If entropic entanglement is reduced to zero in quantum jump for individual sensory recepto, the outcome involves all possible values of quale, say different fundamental colors for which I have proposed a model in terms of QCD color [24]. If the probability of particular value of quale is much larger than others, one can have statistical ensemble giving rise to predictable quale as ensemble average.

4. If negentropic entanglement is in question, similar situation is encountered but the perception is a mixture of qualia. For large values of p-adic prime one could have almost complete dominance

of a particular instance of quale also now. One could argue that the perception represents also the definition of the concept of a particular quale as a superposition of pairs of consisting of the state inducing the instance of the quale and the state representing it. The fact that there are very many negentropic superpositions however suggests that the superposition represents both the definition of quale and average value of quale. For instance, the fusion of various colors could rely on negentropic entanglement.

5. Both these representations of qualia could realized and one can ask whether the entropic representation could be aesthetically less pleasing than the negentropic representation involving also the notion of quale.

Questions about various kinds of entropies

There are three kinds of entropies and the basic question is how these entropies relate.

1. Does the entropy characterizing the experience of self relate to the thermodynamical entropy of some system? The fact that non-geometric sensory qualia have a statistical interpretation, suggests that the entropy associated with the qualia of the mental image corresponds to the thermodynamical entropy for a system giving rise to the qualia via the sensory mapping. The thermodynamics of quantities in the external world would thus be mapped to the thermodynamics of qualia, increments of quantities, in the inner world. Selves could also represent the fundamental thermodynamical ensembles since they define also statistical averages of quantum numbers and zero modes although these are not directly experienced.

2. Could one interpret the entropies of the space-time sheets as entropies associated with the symbolic representations of conscious experiences of selves? Could one see the entire classical reality as a symbolic representation? Does the entropy of conscious experience correspond to the thermodynamical entropy of the perceived system, which in turn would correspond to the classical space-time entropy of the system representing the perceived system symbolically? Does this conclusion generalize to the case of p-adic entropy? Quantum-classical correspondence would encourage to cautiously think that the common answer to these questions might be yes.

The arrow of psychological time and second law

The arrow of psychological time is closely related to the second law and I have considered several alternative identifications for the arrow of psychological time. These identifications are discussed in [27, 25, 28]. The latest option favored by zero energy ontology is discussed in [28] and involves two aspects: the one related to the arrow of time coordinate assignable to the space-time sheet and the other one to the relative proper time coordinate between the tips of CD.

A simple argument show that this distance quantized in powers of 2 should increase gradually in statistical sense since the size of CD can also change in quantum jump. This would have have interpretation in terms of a flow of "cosmic time" (CD is analogous to big bang followed by big crunch). Interestingly, CD with time scale of order 10^{11} years (age of the universe) corresponds primary p-adic length scale of only only 10^{-4} meters, the size of a large neuron, and also the length scale in which the blob of water has Planck mass so that the quantization of gravitational Planck constant should become important [17]. Could this mean that the CDs assignable to large neurons make possible to develop the idea about the cosmology and cosmology itself? Could it really be that that our cognitive representations about Universe quite concretely have the size of the Universe itself as p-adic view about cognition requires?

Quantum jump and cognition

The fusion of subselves can take place in two manners: by real bound state entanglement and by negentropic entanglement. The resulting mental images must differ somehow, and the proposal is that the entanglement associated with the negentropic mental defines a conscious cognitive representation: kind of rule. Schrödinger cat negentropically entangled with the bottle of poison knows that it is not a good idea to open the bottle: open bottle-dead cat, closed bottle-living cat. Negentropic entanglement would generate rules and counterparts of conscious associations fundamental in brain functioning. For the mental image associated with bound state entanglement the information about bound systems

would be lost. Bound state entanglement could however give rise to stereo-consciousness essential for (say) stereo vision.

One can imagine several kinds of negentropic entanglements of this kind. Between two real systems, between real and p-adic systems, and between two p-adic systems possibly characterized by different values of p: all these systems assigned with distinct but overlapping CDs. These entanglements would correspond to different aspects of conscious experience. Maybe the real-real entanglement could correspond to a positive emotion- perhaps love-, and the remaining to experiences of understanding generating a connection between two different things: between real world even and its cognitive representation or between two cognitive representations. Note that the entanglement probabilities can vary considerably and one can obtain identical a spectrum of entanglement probabilities by permuting them. This should relate to the character of the experiencence of understanding. Schrödinger cat which is almost dead has strong conviction that it is better to not open the bottle. The optimal situation concerning understanding would be identical probabilities.

Analysis and conceptualization (synthesis) - formation of rules- could be seen as the reductionistic and holistic aspects of consciousness. The interpretation of quantum jump as a creation of a totally entangled holistic state, which is then analyzed to stable entangled pieces allows to interpret self measurement cascade as a conscious analysis. The resulting stable negentropic pieces give rise to experience of understanding and conceptualization - rules and abstractions. Perhaps the holistic character assigned ot right brain hemisphere could be interpreted in terms of specialization to conceptualization and reductionist character of left brain to entropic analysis to smallest possible pieces.

There are rather interesting connections with altered states of consciousness and states of macro-temporal quantum coherence.

1. Making mind empty of mental images could perhaps be interpreted as a mechanism of achieving irreducible self state. If self entangles negentropically with larger conscious entity this would lead to experiences characterized as expansion of consciousness, even cosmic consciousness. One could also consider the possibility the sub-selves representing mental images fuse to single long-lasting negentropic mental image. The absence of dissipation could relate to the reports of meditators about lowered metabolic needs.

2. The ordinary wake-up consciousness is identifiable as the analytical mode in which entropic entanglement dominates so that each U process is followed by a rather complete state function reduction. The reason for this could be sensory input and motor activities, which would create effective heat bath destroying holistic mental images.

3. Krishnamurti has talked a lot about states of consciousness in which no separations and discriminations occur and timelessness prevails. These states could correspond to long-lived negentropic entanglement with large $\hbar$ with larger conscious entities giving rise to very long effective moments of consciousness. In this kind of situation NMP does not force cognitive self measurements to occur and analysis and separations can thus be avoided.

4. Sharing and fusion of mental images by entanglement of sub-selves of separate selves makes possible quantum realization of telepathy and could be a universal element of altered states of consciousness. Also this entanglement could be bound state entanglement or negentropic entanglement.

Cognitive codes

p-Adic length scale hypothesis leads to the idea that each $p \simeq 2^k$, k integer, defines a hierarchy of cognitive codes with code word having duration given by the n-ary p-adic time scale $T(n, k)$ and number of bits given by any factor of k. Especially interesting codes are those for which the number of bits is prime factor or power of prime factor of k. $n = 2$ seems to be in special position in zero energy ontology. This is a strong quantitative prediction since the duration of both the code word and bit correspond to definite frequencies serving as signatures for the occurrence of commutations utilizing these codes.

If k is prime, the amount of information carried by the codon is maximal but there is no obvious manner to detect errors. If k is not prime there are several codes with various numbers of bits: information content is not maximal but it is possible to detect errors. For instance, $k = 252$ gives

rise to code words for which the number of bits is $k_1 = 252, 126, 63, 84, 42, 21_2, 9, 7, 6_2, 4, 3_2, 2$: the subscript $_2$ tells that there are two non-equivalent manners to get this number of bits. For instance, $126 = 42 \times 3$-bit codon can have 42 -bit parity codon: the bits of this codon would be products of three subsequent bits of 126-bit codon. This allows error detection by comparing the error codon for communicated codon and communicated error codon.

Abstraction hierarchy and genetic code

Mersenne primes $M_n = 2^n - 1$, which seem to play fundamental role in elementary particle physics and it has been already found that their emergence is natural consequence of NMP. This would put primes 3, 7, 31, 127, etc. in a special position. Primes appear frequently in various bio-structures and this might reflect the underlying p-adicity for the association sequences providing 'plan' for the development of bio-system. For instance, we have actually 7 (!) fingers: two of them have degenerated during evolution but can be seen in the developing embryo. There are 31 subunits in our spinal chord, etc...

In the model of genetic code based on a simple model of abstraction process [26] the so called Combinatorial Hierarchy $2, 3, 7, 127, 2^{127} - 1, ...$ of Mersenne primes emerges naturally. The construction for a model of abstraction process proceeds as follows.

1. At lowest level there are two digits. The statements Yes and No.

2. At the next level one considers all Boolean statements about these two statements which can be regarded as maps from 2-element set to 2-element set. There are 4 of them. Throw one away and you get 3 statements.

3. At the next level one considers all Boolean statements about these 3 statements and the total number of them is 2^3. Throw one away and you get 7 statements. And so on.

The mystery is why one statement must be thrown away at each level of the construction. The answer might relate to a concrete model of quantum computation.

1. A possible neurolevel realization of a quantum computation is following. Entangle in the proposed manner two memetic codewords represented as temporal sequences of 127 cognitive Z^0 magnetized antineutrino ensembles with bit represented as the magnetization direction. The phase transitions changing the direction of magnetization are assumed to involve classical non-determinism.

2. Nerve pulse (or pulse like membrane oscillation) results from each flip of the direction of the Z^0 magnetization. The temporal sequence for which all Z^0 magnetization are in the the direction of the external Z^0 magnetic field is excluded because this state does not give rise to a nerve pulse pattern (or membrane oscillation pattern). In this manner a quantum computer with $N = 1$ and $p = 2^{127} - 1$ results. Incoming nerve pulse patterns could be taken to be identical memetic codewords and out would go a a pair of memetic codewords representing the initial memetic codeword and the result of the quantum computation. The duration of the computation is .1 seconds and involves $2^{127} - 1$ quantum jumps effectively glued to single quantum jump by macro-temporal quantum coherence.

The concepts of resolution and monitoring

The following considerations represent a rather early idea related to p-adic physics, and I am not sure whether to take it seriously or not. The basic observation is that genuinely p-adic probabilities can sum up to zero, and this might make possible some rather exotic looking effects in genuinely p-adic sectors of state space.

When the fundamental observable (density matrix or entropy operator) has degenerate eigenvalues, one can only speak about probability for quantum jump to a particular eigen space of the the observable since there is no preferred basis in this eigen space. This leads to the concept of cognitive resolution: one cannot distinguish between states belonging to a given eigen space of density matrix and one can make predictions for the probabilities for quantum jumps to given eigen space only.

1. Resolution and monitoring

p-Adic probability concept allows to consider an additional exotic effect.

1. The total real probability for quantum jump to degenerate subspace is the real counterpart for sum of p-adic probabilities rather than sum of the real counterparts of the p-adic probabilities. This can lead to rather dramatic effects: for instance, the sum of p-adic probabilities can be very small even when the sum of the real probabilities is large.

2. The notion of resolution is closely related to the notion of monitoring: resolution can be defined as a decomposition of the p-adic state space to a direct sum of subspaces such that the p-adic density matrix is degenerate inside each subspace. If p-adic probabilities are defined modulo $O(p)$ pinary cutoff this kind of degeneracy is bound to occur if the dimension of the state space is larger than p.

An interesting possibility is that the notions of resolution and monitoring could be important in the physics of cognition. Perhaps the well-known fact that the behavior of cognitive systems is sensitive to monitoring, might have something to do with the density matrix characterizing the entanglement between the monitoring and monitored systems. The behavior of monitored system would depend on the resolution of the monitoring, that is on how interested monitorer is about behavior of monitored system. In the limit that monitorer is not interested at all on the behavior, entanglement probabilities would in general be identical and unless the number of states is power of p, $S = 0$ state would result.

The total probability for a set of independent events to occur depends on the resolution of monitoring: not only the behavior of individual quantum system in ensemble but also the *statistical* behavior of the ensemble of systems characterized by same p-adic prime depends on the resolution of the monitoring.

Standard probability theory, which also lies at the root of the standard quantum theory, predicts that the probability for a certain outcome of experiment does not depend on how the system is monitored. For instance, if system has N outcomes $o_1, o_2, ...o_N$ with probabilities $p_1, ..., p_N$ then the probability that o_1 or o_2 occurs does not depend on whether common signature is used for o_1 and o_2 or whether observer also detects which of these outcomes occurs. The crucial signature of p-adic probability theory is that monitoring affects the behavior of the system. NMP provides precise definition for the concept of monitoring. There are two forms of monitoring depending on whether the fundamental observable, denote it by O, is density matrix or entropy operator.

Consider first the situation in which all entanglement probabilities have p-adic norm different from unity. Physically monitoring is represented by quantum entanglement and differentiates between two eigen states of O (density matrix or entropy operator) only provided the eigenvalues of O are different. If there are several degenerate eigenvalues, quantum jump occurs to any state in the eigen space and one can predict only the total probability for the quantum jump into this eigen space. Hence the p-adic probability for a quantum jump to a given eigen space of density matrix is p-adic sum of probabilities over the eigen states belonging to this eigen space:

$$P_i = \frac{(n(i)P(i))_R}{\sum_j (n(j)P(j))_R} \quad .$$

Here n_i are dimensions of various eigen spaces.

If the degeneracy of the eigenvalues is removed by an arbitrary small perturbation, the total probability for the transition to the same subspace of states becomes the sum for the real counterparts of probabilities and one has in good approximation:

$$P^R = \frac{n(i)P(i)_R}{[\sum_{j \neq i} \sum_j (n(j)P(j))_R + n(i)P(i)_R]} \quad .$$

Rather dramatic effects could occur. Suppose that that the entanglement probability $P(i)$ is of form $P(i) = np$, $n \in \{0, p-1\}$ and that n is large so that $(np)_R = n/p$ is a considerable fraction of unity. Suppose that this state becomes degenerate with a degeneracy m and $mn > p$ as integer. In this kind of situation modular arithmetics comes into play and $(mnp)_R$ appearing in the real probability $P(1 \, or \, 2)$ can become very small. The simplest example is $n = (p+1)/2$: if two states i and j have *very nearly equal but not identical* entanglement probabilities $P(i) = (p+1)p/2 + \epsilon$, $P(j) = (p+1)p/2 - \epsilon$, monitoring distinguishes between them for arbitrary small values of ϵ and the total probability for the quantum jump to this subspace is in a good approximation given by

$$P(1 \ or \ 2) \quad \simeq \quad \frac{x}{\left[\sum_{k \neq i,j}(P_k)_R + x\right]} \quad ,$$
$$x \quad = \quad 2\left[(p+1)p/2\right]_R \quad . \tag{3.5.1}$$

and is rather large. For instance, for Mersenne primes $x \simeq 1/2$ holds true. If the two states become degenerate then one has for the total probability

$$P(1 \ or \ 2) \quad \simeq \quad \frac{x}{\left[\sum_{k \neq i,j}(P_k)_R + x\right]} \quad ,$$
$$x \quad = \quad \frac{1}{p} \quad . \tag{3.5.2}$$

The order of magnitude for $P(1 \ or \ 2)$ is reduced by a factor of order $1/p$!

A test for the notion of p-adic quantum cognition would be provided by the study of the dependence of the transition rates of quantum systems on the resolution of monitoring defined by the dimensions of the degenerate eigen spaces of the subsystem density matrix (or entropy operator). One could even consider the possibility of measuring the value of the p-adic prime in this manner. The behavior of living systems is known to be sensitive to monitoring and an exciting possibility is that this sensitivity, if it really can be shown to have statistical nature, could be regarded as a direct evidence for TGD inspired theory of consciousness. Note that the mapping of the physical quantities to entanglement probabilities could provide an ideal manner to compare physical quantities with huge accuracy! Perhaps bio-systems have invented this possibility before physicists and this could explain the miraculous accuracy of biochemistry in realizing genetic code.

If some entanglement probabilities have unit norm so that their contributions to the p-adic entanglement entropy vanish, quantum jump to an entangled final state can occur: this is genuinely p-adic effect and serves as a second test for p-adic cognition. If density matrix is the fundamental observable, quantum jump can occur to an entangled final state, which corresponds to any $S = 0$ subspace of $S = 0$ eigen space of the entropy operator with is eigen space of the density matrix. If entropy operator is the fundamental observable, quantum jump can occur to any $S = 0$ subspace of entropy operator. Again the total probability for the transition is determined by the p-adic sum of the probabilities and dramatic 'interference' effects at the level of probabilities are possible.

Resolution and monitoring and hyperfinite factors of type II$_1$

The notion of resolution emerges naturally for the hyper-finite factors of type II$_1$. The trace of the unit operator is unit for the infinite-dimensional space in question so that any projector with a finite trace must project to an infinite dimensional space so that there would always an infinite-dimensional degeneracy involved with the eigenvalues of the measured observables.

One could however consider the formulation of the theory in terms of p-adic probabilities and for this formulation resolution and monitoring emerge naturally. One could go even further. For instance, if one can specify the infinite number of degrees of freedom as a p-adic integer, say $N = -1 = (p-1)\sum_{k=0}^{\infty} p^k$, which in a well-defined sense represents the largest p-adic integer, one can say that the p-adic probability for a given state is $1/N$ and finite as a p-adic number. It is finite also as a real number and equal to $1/p$ if canonical identification is used to map N to a real number. For a given finite-dimensional density matrix with finite number of distinct eigenvalues it would be possible to have projections to one-dimensional subspace but there would always infinitely degenerate eigenvalue present in accordance with the notion of finite resolution.

A natural question concerns the implications of the assumption that the map of p-adic probabilities to real ones conserves probabilities without additional normalization.

3.5.6   NMP and quantum computer type systems

TGD Universe can be regarded as an infinite quantum computer. Unitarity process U is analogous to a quantum computation. The state function reduction process represents a stepwise halting of the

computation proceeding until the resulting states are eith bound states or negentropically entangled states. U matrix is between zero energy states and can be regarded as a collection of M-matrices labelled by zero energy states. The possibility of two kinds of entropic and negentropic entanglement makes possible two kinds of quantum computations and negentropic quantum computations based on states which are longlived by the properties of the negentropic entanglement could be the one realized in living matter.

The relationship between U-matrix and M-matrix

Before proceeding it is a good idea to clarify the relationship between the notions of U-matrix and M-matrix. If state function reduction associated with time-like entanglement leads always to a product of positive and negative energy states (so that there is no counterpart of bound state entanglement and negentropic entanglement possible for zero energy states) U-matrix and can be regarded as a collection of M-matrices

$$U_{m_+ n_-, r_+, s_-} = M(m_+, n_-)_{r_+, s_-} \tag{3.5.3}$$

labeled by the pairs (m_+, n_-) labelling zero energy states assumed to reduced to pairs of positive and negative energy states. M-matrix element is the counterpart of S-matrix element $S_{r,s}$ in positive energy ontology. Unitarity conditions for U-matrix read as

$$
\begin{aligned}
(UU^\dagger)_{m_+ n_-, r_+ s_-} &= \sum_{k_+, l_-} M(m_+, n_-)_{k_+, l_-} \overline{M}(r_+, s_-)_{k_+, l_-} = \delta_{m+r_+, n-s_-} \ , \\
(U^\dagger U)_{m_+ n_-, r_+ s_-} &= \sum_{k_+, l_-} \overline{M}(k_+, l_-)_{m_+, n_-} M(k_+, l_-)_{r_+, s_-} = \delta_{m+r_+, n-s_-} \ .
\end{aligned}
$$
$$\tag{3.5.4}$$

The conditions state that the zero energy states associated with different labels are orthogonal as zero energy states and also that the zero energy states defined by the dual M-matrix

$$M^\dagger(m_+, n_-)_{k_+, l_-} \equiv \overline{M}(k_+ l_-)_{m_+, n_-} \tag{3.5.5}$$

-perhaps identifiable as phase conjugate states- define an orthonormal basis of zero energy states.

When time-like binding and negentropic entanglementare allowed also zero energy states with a label not implying a decomposition to a product state are involved with the unitarity condition but this does not affect the situation dramatically. As a matter fact, the situation is mathematically the same as for ordinary S-matrix in the presence of bound states.

How quantum computation in zero energy ontology differs from ordinary quantum computation

Quantum computation in zero energy ontology differs in several respects from ordinary quantum computation.

1. The time parameter defining quantum computation as a unitary time evolution in standard quantum physics disappears and corresponds to the U-matrix for single quantum jump. Quantum computation corresponds to the U-matrix assignable to single quantum jump if one restricts to sub-CDs with given time scale inside larger CD. The quantum jump for given sub-CD would represent single quantum computation and the outcome of the quantum computation would be determined statistically from the distribution of the outcomes of state function reductions for over sub-CDs.

   Quantum classical correspondence encourages to assign to the quantum computation an interval of psychological time equal to the proper time distance between the tips of CD. For instance, .1 seconds would the be time scale assignable to quantum computations possibly assignable to electrons.

The hierarchies of CDs and Planck constants make possible zoomed up variants of quantum computations. This kind of zooming might be essential for intelligent behavior since it is useful to simulate dynamics of the external world in the time scales natural for brain and shorter than the time scale during which it is necessary to react in order to survive. The geometric duration of the shortest possible quantum computation with respect to the psychological time of self is of order CP_2 time about 10^4 Planck times, if the simplest estimate is correct.

2. The classical space-time correlates for the quantum computation are four-dimensional unlike in the case of ordinary quantum compitation. In living matter nerve pulses and EEG frequencies would be very natural correlates of this kind. The model for DNA as topological quantum computer [24] has as its space-time correlates magnetic flux tubes connecting DNA nucleotides and lipids of nuclear and cell membranes defining the braiding coding for the topological quantum computation. Dynamical flow of lipids defines the braiding in time direction and the memory representation is in terms of the braiding of the flux tubes induced by this flow. A good metaphor is in terms of dancers connected to a wall by threads. Dancing is the correlate for the running quantum computer program and the geometric entanglement of threads the correlate for the storage of the program to computer memory.

3. The outcome of quantum computation is described statistically in terms of a large set of quantum computations. The statistical description of the conscious experience of ensemble of sub-selves implies that mathematically the situation is very much analogous with that encountered in the standard quantum computation and it is attractive to assume that conscious experience codes for the outcome of quantum computation via the average quantities assignable to the distribution of zero energy quantum states assignabl to sub-CDs.

4. A further new element is macro-temporal quantum coherence involving several aspects. One of these aspects is that the time scale of CD defines macrotemporal quantum coherence at least at the level of the field body assignable to the physical system such as electron. It is not quite clear whether electrons correspond to distinct overlapping CDs of size scale defined by .1 second time scale and of the order of Earth circumference and thus satisfying the basic criterion of quantum coherence or whether one should speak about anyonic many particle states assignable to single CD or whether both interpretations can make sense depending on situation. In living matter also millisecond time scale is important and would correspond naturally to the CDs assignable to u and d quarks in nuclei and perhaps also with the ends of magnetic flux tubes in the model of DNA as topological quantum computer. In the proposed model quarks and antiquarks at the ends of flux tubes represent genetic codons and their entangelement is responsible for the realization of the program at quantum level. The millisecond time scale of synchronous cortical firing and of nerve pulse could correspond to the time scale of CDs associated with u and d quarks at the ends of the flux tube. Note that larger value of $\hbar$ would scale up this time scale. Quantum parallel dissipation taking place at various size scales for CD is a further new element.

5. One must generalize the standard quantum computer paradigm since ordinary quantum computers represent only the lowest, 2-adic level of the p-adic intelligence. Qubits must be replaced by qupits since for algebraic entanglement two-state systems are naturally replaced with p-state systems. For primes of order say $p \simeq 2^{167}$ (the size of small bacterium) this means about 167 bits, which would mean gigantic quantum computational resources. The secondary p-adic time scale $T_2(127) \simeq .1$ seconds basic bit-like unit corresponds to $M_{127} = 2^{127} - 1$ M_{127}-qupits making about 254 bits. The size of neuron corresponds to CD with time scale equal to the age of the universe and in this case the maximum the number of pinary digits is 171.

The finite measurement resolution for qubits of course poses strong limitations to the actual number of bits since the negentropic zero energy qubits must be in reasonable approximation pure qubits distinguishable from each other and could correspond CDs with time scales coming as powers of two from $n = k_{min}$ to k so that the effective number of qubits would go like 2-based logarithm of the p-adic prime. For instance, electron could correspond to six bits assignable to genetic code plus parity bit corresponding to time scale range from 1 ms to 100 ms. In any case the idea about neuron as a classical bit might be completely wrong!

6. Spin glass degeneracy also provides the needed huge number of degrees of freedom making quantum computations very effective. These degrees of freedom are associated with the join along

boundaries bonds -say magnetic flux tubes- and are essentially gravitational so that a connection with Penrose-Hameroff hypothesis suggests itself. The space-time sheets mediating gravitational interaction are predicted to have a huge gravitational Planck constant $\hbar_{gr} = GMm/v_0$, $v_0/c < 1$, particles at these space-time sheets are predicted to have huge Compton wavelengths and the plausible looking identification is in terms of dark energy [17, 31]. This would make quantum computation like activities possible in super-astronomical time scales.

Three kinds of quantum computations are possible in TGD Universe

In TGD Universe one must distinguish between three kinds of quantum computational modes. Ordinary quantum computation utilizes only the part of U-matrix for which zero energy states involved are unentangled products of positive and negative energy states. In this case quantum coherence is extremely fragile and lasts for single quantum jump only but even in this case one might hope that coherence time correspondences to the time scale CD. U-matrix can calso correspond to the analogous of bound states for real time-like entanglement. If the proposed interpretation makes sense these state pairs would not correspond to conscious rules. Negentropic entanglement in time direction is the third option. For living quantum computers entanglement could correspond to bound state entangelment or negentropic entanglement and NMP takes care that the character of both these states is preserved. Thus bio-systems would be especially attractive candidates for performers of quantum computation like processes.

Negentropic quantum computations, fuzzy qubits, and quantum groups

1. The possibility of negentropic entanglement is certainly the basic distinction making in the intersection of real and p-adic worlds possible conscious process at least analogous to a quantum computation and accompanied by a conscious understanding. What makes this possible is the fact that the negentropically entangled states of N basic states have permutation of the basis states as a symmetry. For instance, states for which bit 1 appears with almost unit probability gives by permutation a state for which bit 0 appears with almost unit probability. This suggests that the outcome of quantum computation is expressed in terms of almost bits with a small mixing implying that the outcome has interpretation both as a rule and as almost bit in the ordinary sense. The conscious quantum computation would utilize states with negentropic entanglement in time direction. Also the analogies of bound states for time-like engtanglement are possible and might make possible the counterpart of ordinary quantum computation without the higher level conscious experience about rules defined by the entangled states.

2. Negentropic entanglement for positive and negative energy parts of bits stable and pinary digits stable under NMP means that the logic is always fuzzy. I have proposed the mathematical description of this in terms of quantum spinors for which the components do not commute anymore implying that only the probability for either spin state is is an observable [24]. This suggests that negentropic entanglement might be describable in terms of quantum spinors and that it would be the unavoidable fuzziness which would make possible the representation conscious rules. What is interesting that for quantum spinors the spectrum of the probabilities for given spin is universal and depends only on the integers characterizing the quantum phase $q = exp(i2\pi/n)$. An alternative interpretation is that fuzzy logic relates to a finite measurement resolution. These interpretation need not be in conflict with each other. Since quantum groups are associated with anyonic systems, this suggests that negentropic quantum computations take place in anyonic systems assignable to phases with large value of $\hbar$. This encourages to consider the possibility that quantum phases define algebraic extensions of p-adic numbers.

3. In living systems it might be more appropriate to talk about conscious problem solving instead of quantum computation. In this framework the periods of macro-temporal quantum coherence replace the unitary time evolutions at the gates of the quantum computer as the basic information processing units and entanglement bridges between selves act as basic quantum communication units with the sharing of mental images providing a communication mode not possible in standard quantum mechanics.

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Chapter 4

Self and Binding

4.1 Introduction

The conflict between the non-determinism of state function reduction and determinism of time evolution of Schrödinger equation is serious enough a problem to motivate the attempt to extend physics to a theory of consciousness by raising the observer from an outsider to a key notion also at the level of physical theory by bringing in the notion of self. Further motivations come from the failure of the materialistic and reductionistic dogmas in attempts to understand consciousness in neuroscience context. There are reasons to doubt that standard quantum physics could be enough to achieve this goal and the new physics predicted by TGD is indeed central in the proposed theory.

4.1.1 Quantum jump as moment of consciousness and the notion of self

If quantum jump occurs between two different time evolutions of Schrödinger equation (understood here in very metaphoral sense) rather than interfering with single deterministic Schrödinger evolution, the basic problem of quantum measurement theory finds a resolution. The interpretation of quantum jump as a moment of consciousness means that volition and conscious experience are outside space-time and state space and that quantum states and space-time surfaces are "zombies". Quantum jump would have actually a complex anatomy corresponding to unitary process U, state function reduction and state preparation at least.

Quantum jump has a complex anatomy since it must include state preparation, state function reduction, and also unitary process characterized by U-matrix. Zero energy ontology means that one must distinguish between M-matrix and U-matrix. M-matrix characterizes the time like entanglement between positive and negative energy parts of zero energy state and is measured in particle scattering experiments. M-matrix need not be unitary and can be identified as a "complex" square root of density matrix representable as a product of its real and positive square root and of unitary S-matrix so that thermodynamics becomes part of quantum theory with thermodynamical ensemble being replaced with a zero energy state. The unitary U-matrix describes quantum transitions between zero energy states and is therefore something genuinely new. It is natural to assign the statistical description of intentional action with U-matrix since quantum jump occurs between zero energy states.

Negentropy Maximization Principle (NMP) codes for the dynamics of standard state function reduction and states that the state function reduction process following U-process gives rise to maximal reduction of entanglement entropy at each step. In the generic case this implies decomposition of the system to unique unentangled systems and the process repeats itself for these systems. The process stops when the resulting subsystem cannot be decomposed to a pair of free systems since energy conservation makes the reduction of entanglement kinematically impossible in the case of bound states.

Intuitively self corresponds to a sequence of quantum jumps which somehow integrates to a larger unit much like many-particle bound state is formed from more elementary building blocks. It also seems natural to assume that self stays conscious as long as it can avoid bound state entanglement with the environment in which case the reduction of entanglement is energetically impossible. One could say that everything is conscious and consciousness can be only lost when the system forms bound state entanglement with environment.

There is an important exception to this vision based on ordinary Shannon entropy. There exists an infinite hierarchy of number theoretical entropies making sense for rational or even algebraic entanglement probabilities. In this case the entanglement negentropy can be negative so that NMP favors the generation of negentropic entanglement, which need not be bound state entanglement in standard sense. Negentropic entanglement might serve as a correlate for emotions like love and experience of understanding. The reduction of ordinary entanglement entropy to random final state implies second law at the level of ensemble. For the generation of negentropic entanglement the outcome of the reduction is not random: the prediction is that second law is not universal truth holding true in all scales. Since number theoretic entropies are natural in the intersection of real and p-adic worlds, this suggests that life resides in this intersection. The existence effectively bound states with no binding energy might have important implications for the understanding the stability of basic bio-polymers and the key aspects of metabolism [19]. A natural assumption is that self experiences expansion of consciousness as it entangles in this manner. Quite generally, an infinite self hierarchy with the entire Universe at the top is predicted.

Self is assumed to experience sub-selves as mental images identifiable as "averages" of their mental images. This implies the notion of ageing of mental images as being due to the growth of ensemble entropy as the ensemble consisting of quantum jumps (sub-sub-subselves) increases.

If one accepts the hierarchy of Planck constants [17], it might be un-necessary to distinguish between self and quantum jump. The hierarchy of Planck constants interpreted in terms of dark matter hierarchy predicts a hierarchy of quantum jumps such that the size of space-time region contributing to the contents of conscious experience scales like $\hbar$. Also the hierarchy of space-time sheets labeled by p-adic primes suggests the same. That sequence of sub-selves/sub-quantum jumps are experienced as separate mental images explains why we can distinguish between digits of phone number. The irreducible component of self (pure awareness) would correspond to the highest level in the "personal" hierarchy of quantum jumps and the sequence of lower level quantum jumps would be responsible for the experience of time flow. Entire life cycle would correspond to single quantum jump at the highest(?) level of the personal self hierarchy and pure awareness would prevail during sleep: this would make it possible to experience directly that I existed yesterday.

There are thus two definitions of self. The first definition introduces self as a notion separate from quantum jump. Second definition reduces the notion of self to a fractal hierarchy of quantum jumps. The equivalence between two definitions of the notion of self will be proposed.

4.1.2 Sharing and fusion of mental images

The standard dogma about consciousness is that it is completely private. It seems that this cannot be the case in TGD Universe. Von Neumann algebras known as hyper-finite factors of type II$_1$ (HFF) [24, 17] provide the basic mathematical framework for quantum TGD and this suggests important modifications of the standard measurement theory besides those implied by the zero energy ontology predicting that all physical states have vanishing net quantum numbers and are creatable from vacuum. The notion of measurement resolution characterized in terms of Jones inclusions $\mathcal{N} \subset \mathcal{M}$ of HFFs implies that entanglement is defined always modulo some resolution characterized by infinite-dimensional sub-Clifford algebra $\mathcal{N}$ playing a role analogous to that of gauge algebra.

This modification has also important implications for consciousness. For ordinary quantum measurement theory separate selves are by definition unentangled and the same applies to their sub-selves so that they cannot entangle and thus fuse and shared mental images are impossible: consciousness would be completely private.

Space-time sheets as correlates for selves however suggests that space-time sheets topologically condensed at larger space-time sheets and serving as space-time correlates for mental images can be connected by join along boundaries bonds so that mental images could fuse and be shared.

HFFs allow to realize mathematically this intuitive picture. The entanglement in $\mathcal{N}$ degrees of freedom between selves corresponding to $\mathcal{M}$ is below the measurement resolution so that these selves can be regarded as separate conscious entities. These selves can be said to be unentangled although their sub-selves corresponding to $\mathcal{N}$ (mental images at upper level) can entangle. Fusion and sharing of mental images becomes possible. For instance, in stereo vision right and left visual fields would fuse together. More generally, a pool of shared stereo mental images might be fundamental for evolution of social structures and development of social and moral rules and language (shared mental images

make possible common meaning for symbols of language). A concrete realization for this would be in terms of hyper-genome making possible collective gene expression [29, 26].

4.1.3 Qualia

Since physical states are labeled by quantum numbers, various qualia correspond naturally to the increments of quantum numbers in quantum jump which leads to a general classification of qualia in terms of the fundamental symmetries [24]. One can speak also about geometric qualia assignable to the increments of zero modes which correspond to the classical variables in ordinary quantum measurement theory and non-quantum fluctuating degrees of freedom which do not contribute to the metric of world of classical worlds (WCW) in TGD framework. Dark matter hierarchy suggests that also qualia form a hierarchy with larger values of Planck constant identifiable as more refined qualia. Rather amusingly, visual colors would correspond to increments of color quantum numbers assignable to quarks and gluons in standard model physics. The term "color", originally introduced as an algebraic joke, would directly relate to visual color.

4.1.4 Self-referentiality of consciousness

Quantum classical correspondence is the basic guiding principle of quantum TGD. Thanks to the failure of a complete determinism of classical dynamics, space-time surface can provide symbolic representations not only for quantum states (as maximal deterministic regions) but also for quantum jump sequences (sequences of quantum states) and thus for the contents of consciousness. These representations are regenerated in each quantum jump, and make possible the self referentiality of consciousness: self can be conscious of what it *was* conscious of.

4.1.5 Hierarchy of Planck constants and consciousness

The hierarchy of Planck constants is realized in terms of a generalization of the causal diamond $CD \times CP_2$, where CD is defined as an intersection of the future and past directed light-cones of 4-D Minkowski space M^4. $CD \times CP_2$ is generalized by gluing singular coverings and factor spaces of both CD and CP_2 together like pages of book along common back, which is 2-D sub-manifold which is M^2 for CD and homologically trivial geodesic sphere S^2 for CP_2 [17]. The value of the Planck constant characterizes partially given page and arbitrary large values of $\hbar$ are predicted so that macroscopic quantum phases are possible since the fundamental quantum scales scale like $\hbar$. All particles in the vertices of Feynman diagrams have the same value of Planck constant so that particles at different pages cannot have local interactions. Thus one can speak about relative darkness in the sense that only the interactions mediated by the exchange of particles and by classical fields are possible between different pages. Dark matter in this sense can be observed, say through the classical gravitational and electromagnetic interactions. It is in principle possible to photograph dark matter by the exchange of photons which leak to another page of book, reflect, and leak back. This leakage corresponds to $\hbar$ changing phase transition occurring at quantum criticality and living matter is expected carry out these phase transitions routinely in bio-control. This picture leads to no obvious contradictions with what is really known about dark matter and to my opinion the basic difficulty in understanding of dark matter (and living matter) is the blind belief in standard quantum theory.

Dark matter hierarchy and p-adic length scale hierarchy would provide a quantitative formulation for the self hierarchy. To a given p-adic length scale one can assign a secondary p-adic time scale as the temporal distance between the tips of the causal diamond (pair of future and past directed light-cones in $H = M^4 \times CP_2$). For electron this time scale is .1 second, the fundamental biorhythm. For a given p-adic length scale dark matter hierarchy gives rise to additional time scales coming as $\hbar/\hbar_0$ multiples of this time scale. These two hierarchies could allow to get rid of the notion of self as a primary concept by reducing it to a quantum jump at higher level of hierarchy. Self would in general consists of quantum jumps inside quantum jumps inside... and thus experience the flow of time through sub-quantum jumps.

4.1.6   Zero energy ontology and consciousness

Zero energy ontology was forced by the interpretational problems created by the vacuum extremal property of Robertson-Walker cosmologies imbedded as 4-surfaces in $M^4 \times CP_2$ meaning that the density of inertial mass (but not gravitational mass) for these cosmologies was vanishing meaning a conflict with Equivalence Principle. In zero energy ontology physical states are replaced by pairs of positive and negative energy states assigned to the past *resp.* future boundaries of causal diamonds defined as pairs of future and past directed light-cones ($\delta M^4_\pm \times CP_2$). The net values of all conserved quantum numbers of zero energy states vanish. Zero energy states are interpreted as pairs of initial and final states of a physical event such as particle scattering so that only events appear in the new ontology.

Zero energy ontology combined with the notion of quantum jump resolves several problems. For instance, the troublesome questions about the initial state of universe and about the values of conserved quantum numbers of the Universe can be avoided since everything is in principle creatable from vacuum. Communication with the geometric past using negative energy signals and time-like entanglement are crucial for the TGD inspired quantum model of memory and both make sense in zero energy ontology. Zero energy ontology leads to a precise mathematical characterization of the finite resolution of both quantum measurement and sensory and cognitive representations in terms of inclusions of von Neumann algebras known as hyperfinite factors of type II_1. The space-time correlate for the finite resolution is discretization which appears also in the formulation of quantum TGD.

At the imbedding space-level CD is the correlate of self whereas space-time sheets having their ends at the light-like boundaries of CD are the correlates at the level of 4-D space-time. The hierarchy of CDs within CDs corresponds to the hierarchy of selves. Zero energy ontology leads also an argument explaining why the arrow of subjective time induces an apparent arrow of geometric time as a result if intentional action and why the contents of sensory consciousness is restricted to such a narrow time interval (located near the future boundary of CD).

4.1.7   Evolution of the ideas about self

For a long time the basic hypothesis of TGD inspired theory of consciousness was that *single* quantum jump between quantum histories determines the contents of conscious experience associated with a particular moment of consciousness. It however became gradually clear that this hypothesis is subject to several objections, the most serious one being that genuine memories about previous conscious experiences (quantum jumps) are not possible if single quantum jump determines everything. These counter arguments served as a pressure forcing the discovery of the quantum notion of self. An essential prerequisite for the notion of self were parallel developments related to the p-adic aspects of quantum TGD.

The understanding of the notion of self did not emerge as an instantaneous flash but has been plagued by some mis-interpretations as the evolution of the new concepts usually is. The progress in the understanding of quantum TGD, initiated by 'TGD as a generalized number theory' vision, has been of importance also in attempts to achieve a more precise definition of the notion of self. The most central clarifications in the conceptual framework have been following ones. p-Adic physics is identified as the physics of imagination, cognition and intention and space-time has a genuine decomposition into regions with a local topology which is real or p-adic (what these p-adic regions really mean turned out to be highly non-trivial question!); quantum jump decomposes into a TGD counterparts of the unitary process followed by the state function reduction process equivalent to state preparation process for the next quantum jump governed by Negentropy Maximization Principle [29]; quantum measurement theory follows as a basic prediction of quantum TGD; the sequences of quantum jumps defining selves define what might be identified as fundamental statistical ensembles growing in size quantum jump by quantum jump; statistical physics becomes part of the theory of consciousness, in particular the theory of qualia.

Further steps in the progress were following.

1. The observation that bound state entanglement is stable in state function reduction process so that the binding of mental images in this manner could involve liberation of usable energy (quantum metabolism);

2. The discovery of a hierarchy of number theoretic entropies which can be also negative making

possible to assign to a rationally or even algebraically entangled system a positive entanglement entropy. In the intersection of real and p-adic worlds this means negentropic entanglement stable under state function reduction. Unfortunately this led first to an erratic conclusion that this entanglement must represent bound state entanglement. There is no need for this and negentropic entanglement can carry positive energy suggesting obvious applications to biology (high energy phosphate bond and purely understood stability of highly charged DNA strands) [19]. Negentropic entanglement is now perhaps the most influental idea of TGD inspired theory of consciousness.

3. The notion many-sheeted space-time led to a realization that sub-selves of two separate selves can entangle and that this corresponds to the fusion and sharing of mental images providing a fundamental mechanism of quantum communication. Note that sharing of mental images can correspond to generation entropic bound state entanglement meaning that subselves lose consciousness and negentropic entanglement meaning that subselves experience an expansion of consciousness. The realization that the sharing of mental images is only possible by adopting a length scale dependent definition of sub-system motivated the fact that topologically condensed space-time sheets resemble black holes in many respects. The discovery that von Neumann algebras known as hyper-finite factors of type II_1 (HFFs) emerge naturally in TGD and that their inclusions define in a natural manner the notion of measurement resolution provided a mathematical justification for the entanglement modulo finite measurement resolution.

4. Zero energy ontology led to a new view about quantum jump as taking place between zero energy states with unitary U-matrix defining a collection of orthonormal M-matrices defining entanglement coefficients between positive and negative energy parts of the zero energy states. Causal diamonds (CDs) identified roughly as intersections of future and past directed light-cones define the imbedding space correlates of selves and space-time surfaces inside CDs defined the space-time correlates of selves. In fact, holography allows to reduce these correlates to partonic 2-surfaces and their four-dimensional tangent space distributions at the future and past boundaries of CDs. This led to a considerable progress in understanding of the relationship between experienced time identified as a sequence of quantum jumps and the geometric time of physicist. p-Adic length scale hypothesis follows if the proper time distance between the tips of CDs is quantized in powers of two. The intriguing prediction is a direct connection between elementary particle physics and macroscopic physics: for electron the temporal size of CD corresponds to .1 seconds defining the fundamental biorhythm and for u and d quarks it is consistent with millisecond time scale defining the rhythm of synchronous cortical neuron firing.

5. The introduction of the hierarchy of Planck constants identified in terms of dark matter hierarchy meant a further step in the progress and it became possible to understand how living matter can act as a macroscopic quantum system. The notion of magnetic body acting as an intentional agent quantum controlling biological boddy is absolutely essential piece of the recent view about living matter and has had a strong impact on the development of ideas about self.

Ironically, the latest step in the progress means an almost return to where all began. The notion of self might be reduced to quantum jump after all by adding to it the attribute "fractal". The idea was motivated by two new concepts: zero energy ontology and the generalization of the notion of imbedding space predicting a hierarchy of Planck constants labeling a hierarchy of phases of matter identified as dark matter. The formation of many particle bound states and negentropically entangled states might allow sequences of quantum jumps to combine to single effective quantum jump making possible macro-temporal quantum coherence and quantum computation type processes for irreducible selves in a state of 'oneness'. In particular, time like negentropic entanglement between the partons at future and past boundaries of CD should be highly relevant for the temporal binding of quantum jumps. It took some years to decide whether the reduction of self to a fractal hierarchy of quantum jumps within quantum jumps can be consistent with the earlier view about self. This seems to be the case. Also it took time to give a real meaning to the phrase "quantum jumps within quantum jumps". The new picture allows surprisingly quantitative answers to a long list of questions about the relationship of geometric and subjective time: this will be summarized later in the introduction and discussed in detail later.

There has been also a lot of pseudo progress. The understanding of the relationship between geometric and subjective time in TGD framework has been especially difficult challenge. By quantum

classical correspondence the arrow of subjective time should be mapped to the arrow of geometric time at the level of conscious experience. In similar manner the asymmetry between subjective future and past should be correspond to an asymmetry between geometric future and past. What this means at the level of details has been far from clear and I have proposed many partial answers to the question about the arrow of geometric time. For instance: the geometric future inside light-cone contains much more room than geometric past so that the space-time region about which the contents of conscious experience are about tends to diffuse to the direction of the geometric future defined by light-cone proper time; perhaps the flow of geometric time corresponds to a wave front of intentional action identifiable as a phase transition changing intentions identified as p-adic space-time sheets transformed to real space-time sheets; maybe the space-time sheet assignable to self topologically condensed to a larger space-time sheet shifts in quantum jumps to the direction of geometric future some average temporal distance perhaps defined by CP_2 length scale. All these proposals have provided only partial answers, have led to paradoxes, and failed to give a firm quantitative grasp about the situation.

Also the original wrong view about the correspondence of real and p-adic numbers has generated a lot of confusion. The natural belief of topologist would be that p-adic space-time sheets are mapped to their real counterparts by a continuous map (some variant of what I called canonical identification making sense in p-adic thermodynamics). This map did not however respect symmetries and was inconsistent with field equations. Finally I was able to accept the natural belief of algebraist: reals and various p-adic number fields must be glued to together along rationals and common algebraic numbers to achieve generalization of the number concept and also that of imbedding space. What was difficult to accept was the highly non-intuitive implication that most points of p-adic space-time sheets are at spatial and temporal infinity in real (but not in p-adic) sense so that cognition and intentionality would be literally cosmic phenomena and only cognitive representations would be realized in a finite space-time volume in real sense (causal diamond) in terms of intersections of real and p-adic space-time sheets consisting of rational and some algebraic points.

The plan of the chapter is as follows.

- Because of its importance NMP [29] is introduced in a separate section.

- The notion of quantum self is the topic of next section. The role of entanglement in binding is analyzed. The basic assumptions about the structure of conscious experience of self and their basic implications are summarized. The question whether the notions of self and quantum jump can be identified is analyzed.

- Some applications at brain level are considered including the differences between left and right brain hemispheres and music experience.

- Negentropic entanglement seems to be the key to the understanding of altered states of consciousness. What I call whole-body consciousness is discussed in this framework. Also EEG synchrony and synesthesia are analyzed in terms of negentropic entanglement.

- Higher levels of biological self hierarchy are discussed. Here the notion of magnetic body is central.

- An attempt to understand what happens in ageing and death is made.

4.2   Negentropy Maximization Principle

Negentropy Maximization Principle (NMP [29]) stating that the reduction of entanglement entropy is maximal at a given step of state function reduction process following U-process is the basic variational principle for TGD inspired theory of consciousness and says that the information contents of conscious experience is maximal. Although this principle is diametrically opposite to the second law of thermodynamics it is structurally similar to the second law. NMP does not dictate the dynamics completely since in state function reduction any eigen state of the density matrix is allowed as final state. NMP need not be in contradiction with second law of thermodynamics which might relate as much to the ageing of mental images as to physical reality.

4.2.1   Basic form of NMP

Negentropy Maximization Principle (NMP) in its original form codes for the basic rules of the standard state function reduction and implies that system ends up to an eigenstate of the density matrix identified as observable. In TGD framework must ask whether NMP should be restricted only to the entanglement between zero modes of WCW representing classical degrees of freedom and quantum fluctuating degrees of freedom or generalize it to apply to any pair of subsystems so that state function reduction sequence could be regarded as a sequence of self measurements. I have chosen the latter option as a working hypothesis.

NMP that the state function reduction process following U-process gives rise to a maximal reduction of entanglement entropy at each step of the process. State function process could proceed at the level of all CDs. It is not clear whether one can assign any geometric time duration to this process or whether there is any need for this. If the ubsystem allows entangled pairs of free systems (no binding energy) there is more or less unique pair with the maximal entanglement entropy and NMP therefore implies a decomposition to a unique pair of unentangled systems. The process repeats itself for these systems and stops when the resulting subsystem cannot be decomposed to a pair of free systems since energy conservation makes the reduction of entanglement kinematically impossible in the case of bound states. Number theoretic entanglement entropies mean an important modification of this picture.

4.2.2   Number theoretic Shannon entropy as information

The notion of number theoretic entropy obtained by can be defined by replacing in Shannon entropy the logarithms of probabilities p_n by the logarithms of their p-adic norms $|p_n|_p$. This replacement makes sense for algebraic entanglement probabilities if appropriate algebraic extension of p-adic numbers is used. What is new that entanglement entropy can be negative, so that algebraic entanglement can carry information and NMP can force the generation of bound state entanglement so that evolution could lead to the generation of larger coherent bound states rather than only reducing entanglement. A possible interpretation for algebraic entanglement is in terms of experience of understanding or some positive emotion like love.

Standard formalism of physics lacks a genuine notion of information and one can speak only about increase of information as a local reduction entropy. It seems strange that a system gaining wisdom should increase the entropy of the environment. Hence number theoretic information measures could have highly non-trivial applications also outside the theory consciousness.

NMP combined with number theoretic entropies leads to an important exception to the rule that the generation of bound state entanglement between system and its environment during U process leads to a loss of consciousness. When entanglement probabilities are rational (or even algebraic) numbers, the entanglement entropy defined as a number theoretic variant of Shannon entropy can be non-positive (actually is) so that entanglement carries information. NMP favors the generation of algebraic entanglement. The attractive interpretation is that the generation of algebraic entanglement leads to an expansion of consciousness ("fusion into the ocean of consciousness") instead of its loss.

State function reduction period of the quantum jumps involves much more than in wave mechanics. For instance, the choice of quantization axes realized at the level of geometric delicacies related to CDs is involved. U-process generates a superposition of states in which any sub-system can have both real and algebraic entanglement with the external world. If state function reduction involves also a choice between generic and negentropic entanglement (between real world, a particular p-adic world, or their intersection) it might be possible to identify a candidate for the physical correlate for the choice between good and evil. The hedonistic complete freedom resulting as the entanglement entropy is reduced to zero on one hand, and the algebraic bound state entanglement implying correlations with the external world and meaning giving up the maximal freedom on the other hand. The hedonistic option is risky since it can lead to non-algebraic bound state entanglement implying a loss of consciousness. The second option means expansion of consciousness - a fusion to the ocean of consciousness as described by spiritual practices. Note that if the total entanglement negentropy defined as sum of contributions from various levels of CD hierarchy up to the highest matters in NMP then also subselves should develop negentropic entanglement. For instance, the generation of entropic entanglement at cell level can lead to a loss of consciousness also at higher levels. Life would evolve from short to long scales.

4.2.3   Can one define measures for the information contents of mental image?

Despite the fact that one cannot write formula for the contents of conscious experience, one can define information measures for conscious experience as differences of the information measures for the initial and final quantum histories. Negentropy gain is the most natural information measure of this kind. For instance, the sum of the net entanglement negentropy gains over the steps of the self measurement cascade could define a quantity characterizing net information gain for a single moment of consciousness at each step.

One could also information measure to selves as the entanglement negentropy after the state function reduction process has ended. This would assign to each subsystem stable under NMP a negentropy. For bound state entanglement this information would be negative but for negentropic entanglement it would be positive. One can ask whether the hypothesis that this information increases during quantum jump sequence is equivalent with NMP. In the case of entire Universe the application of this principle becomes problematic.

Entropy gradients with respect to subjective time could be used to characterize how the information gain of conscious experience of self changes. These gradients approach zero when self approaches thermal equilibrium. In TGD framework entropy gradients correlate with emotions, which means a somewhat counter intuitive connection between emotions and information gain or loss (consistent however with the fact that peptides are both informational molecules and molecules of emotion [72]). Note that the binding of information molecules to receptors means the formation larger bound states accompanied by the experience of oneness at molecular level (are sex and spiritual experiences present already at the molecular level?) and macro temporal quantum coherence so that quantum computer like operations might become possible.

4.2.4   Life as islands of rational/algebraic numbers in the seas of real and p-adic continua?

Rational and even algebraic entanglement coefficients make sense in the intersection of real and p-adic words, which suggests that life and conscious intelligence reside in the intersection of the real and p-adic worlds. This would mean that the mathematical expressions for the space-time surfaces (or at least 3-surfaces or partonic 2-surfaces and their 4-D tangent planes) make sense in both real and p-adic sense for some primes p. Same would apply to the expressions defining quantum states. In particular, entanglement probabilities would be rationals or algebraic numbers so that entanglement can be negentropic and the formation of bound states in the intersection of real and p-adic worlds generates information and is thus favored by NMP.

The identification of intentionality as the basic aspect of life seems to be consistent with this idea.

1. The proposed realization of the intentional action has been as a transformation of p-adic space-time sheet to a real one. Also transformations of real space-time sheets to p-adic space-time sheets identifiable as cognitions are possible. Algebraic entanglement is a prerequisite for the realization of intentions in this manner. Essentially a leakage between p-adic and real worlds is in question and makes sense only in zero energy ontology. The reason is that various quantum numbers in real and p-adic sectors are not in general comparable in positive energy ontology so that conservation laws would be broken or even cease to make sense.

2. The transformation of intention to action can occur if the partonic 2-surfaces and their 4-D tangent space-distributions are representable using rational functions with rational (or even algebraic) coefficients in preferred coordinates for the imbedding space dictated by symmetry considerations. Intentional systems must live in the intersection of real and p-adic worlds.

3. For the minimal option life would be also effectively 2-dimensional phenomenon and essentially a boundary phenomenon as also number theoretical criticality suggests. There are good reasons to expect that only the data from the intersection of real and p-adic partonic two-surfaces appears in U-matrix so that only the data from rational and some algebraic points of the partonic 2-surface dictate U-matrix. This means discretization at parton level and something which might be called number theoretic quantum field theory should emerge as a description of intentional action.

A good guess is that algebraic entanglement is essential for quantum computation, which therefore might correspond to a conscious process. Hence cognition could be seen as a quantum computation like process, a more approriate term being quantum problem solving [24]. Living-dead dichotomy could correspond to rational-irrational or to algebraic-transcendental dichotomy: this at least when life is interpreted as intelligent life. Life would in a well defined sense correspond to islands of rationality/algebraicity in the seas of real and p-adic continua. Life as a critical phenomenon in the number theoretical sense would be one aspect of quantum crticality of TGD Universe besides the criticality of the space-time dynamics and the criticality with respect to phase transitions changing the value of Planck constant and other more familiar criticalities. How closely these criticalities relate remains an open question [26].

The view about the crucial role of rational and algebraic numbers as far as intelligent life is considered, could have been guessed on very general grounds from the analogy with the orbits of a dynamical system. Rational numbers allow a predictable periodic decimal/pinary expansion and are analogous to one-dimensional periodic orbits. Algebraic numbers are related to rationals by a finite number of algebraic operations and are intermediate between periodic and chaotic orbits allowing an interpretation as an element in an algebraic extension of any p-adic number field. The projections of the orbit to various coordinate directions of the algebraic extension represent now periodic orbits. The decimal/pinary expansions of transcendentals are un-predictable being analogous to chaotic orbits. The special role of rational and algebraic numbers was realized already by Pythagoras, and the fact that the ratios for the frequencies of the musical scale are rationals supports the special nature of rational and algebraic numbers. The special nature of the Golden Mean, which involves $\sqrt{5}$, conforms the view that algebraic numbers rather than only rationals are essential for life.

4.2.5   Hyper-finite factors of type II$_1$ and NMP

Hyper-finite factors of type II$_1$ bring in additional delicacies to NMP. The basic implication of finite measurement resolution characterized by Jones inclusion is that state function reduction can never reduce entanglement completely so that entire universe can be regarded as an infinite living organism. It would seem that entanglement coefficients become $\mathcal{N}$ valued and the same is true for eigen states of density matrix. For quantum spinors associated with $\mathcal{M}/\mathcal{N}$ entanglement probabilities must be defined as traces of the operators $\mathcal{N}$. An open question is whether entanglement probabilities defined in this manner are algebraic numbers always (as required by the notion of number theoretic entanglement entropy) or only in special cases.

4.3   Quantum self

The section introduces the definition of self, discusses the role of entanglement in binding, introduces the basic assumptions about the structure of conscious experience of self and some of their consequences and closes with a couple of questions related

4.3.1   Self as a sub-system able to avoid entropic bound state entanglement

The original proposal for circumventing the objections against quantum jump as a moment of consciousness identification was based on the idea that selves are effectively their own sub-Universes, that is sub-systems able to remain unentangled in subsequent quantum jumps consisting of the unitary process U followed by the TGD counterpart of state function reduction process which acts as state function preparation process for the next quantum U-process. The hypothesis was that the self experience of a sub-system lasts for so many quantum jumps as sub-system avoids entangling with some other self.

This picture was however not quite correct. It is plausible that generation of entropic bound state entanglement indeed leads to a loss of consciousness since state function reduction is not possible by energy conservation. In the case of negentropic entanglement the natural interpretation is however as an expansion of consciousness: as a fusion the sea of consciousness as mystics would express it. This would define the "eastern" strategy for remaining conscious and even expand the consciousness. The hedonistic "western" strategy guarantees maximal independence from environment but there is a risk that consciousness is lost.

The unitary process U generates a maximally entangled state, a multiverse superposition of quantum potentialities. State function reduction (or self measurement process) consists of a cascade of self measurements proceeding from long to short length scales and decomposing a given sub-system in a unique manner to two pieces (maximization of negentropy gain) if entanglment is real and stopping if the system does not allow a decomposition to a pair of entropically entangled free states or if it is negentropically entangled. Essentially a conscious analysis is in question.

The highly nontrivial question is what defines the identity of the self as a physical system. Zero energy ontology allows to identify imbedding space and space-time and correlates of selves in terms of causal diamonds and partonic 2-surfaces assignable to their light-like boundaries. Also the p-adic prime characterizing the partonic 2-surfaces serving as the geometric correlate of self could characterize self identity: at least when partonic 2-surface belongs to the intersection of real and p-adic worlds. Holography allows to regard also space-time sheets and 3-surfaces as correlates of selves and in the following I use these different characterizations freely. Also the notion of mind-like space-time sheet which in zero energy ontology brings in nothing new is used. A very natural proposal is that living matter belongs to this intersection and therefore represents a phase which is critical in number theoretical sense. It took amazingly long to end up with this identification although the notion of number theoretic entropy has been known to me for more than half decade.

Space-time surface decomposes into real and p-adic regions in various sectors of the generalized imbedding space obtained by gluing real and various p-adic variants together along rational points and common algebraic points (note that p-adic surfaces have infinite size in real sense!). Rational or even algebraic entanglement between regions corresponding to different number fields is in principle possible. It is natural to assume that this kind of entanglement is possible only if the partonic 2-surfaces in different number fields are in the intersection of real and various p-adic worlds in the sense that they obey same mathematical representation -say in terms of rational functions in preferred coordinates and with polynomials involved having rational or algebraic coefficients. Contrary to the original belief, this entanglement need not be reduced in state function reduction and its algebraic character indeed implies that this cannot be the case [29]. The interpretation is in terms of the formation of cognitive representations -association based rules- in which real states are mapped to p-adic ones or p-adic states with different primes are mapped to each other. U matrix can also induce a leakage between real and p-adic worlds in the intersection. This makes possible the realization of intentional action as transformation of p-adic space-time surface to its real variant. The reversal of the process makes possible formation of cognitive images of real system.

In real context the natural proposal is that the space-time correlates of selves can be identified as space-time sheets with subselves (mental images) represented as smaller space-time sheets fused by topological sum to the larger space-time sheet by wormhole contacts which have Euclidian signature of induced metric and so that their throats can be identified as light-like 3-surfaces. Irreducible self corresponds would correspond to space-time sheets having no smaller space-time sheets of this kind. The corresponding 2-dimensional partonic surfaces are however disjoint and one can wonder whether one should actually restrict the subselves to be partonic 2-surfaces glued to larger partonic 2-surfaces by corresponding wormhole contacts. Quantum holography does not provide an answer to the question. For the partonic option there is however no unique manner to identify subselves geometrically unlike for the first option. Therefore the first option seems to be correct. One could say that topological sum is a correlate for the summation of mental images and joing along boundaries bond (connected sum for partonic 2-surfaces) for the fusion of mental images.

In p-adic context this picture makes sense only as its algebraic variant. The wormhole throats as light-like surfaces and partonic 2-surfaces as intersections of light-like 3-surfaces and light-like boundaries of CDs indeed make sense also in the p-adic context. Self can disappear only by a topological phase transition changing the number field associated with the self, if the space-time sheet disappears, or if a join along boundaries bond connects two space-time sheets and gives rise to a fusion of selves and formation of quantum bound state representing the fused self. Also entire CDs can disappear in quantum jump.

The formation of bound states and negentropically entangled states means that the entire sequence of quantum jumps during which bound state property is preserved, corresponds effectively to a single quantum jump. One might expect that time-like negentropic entanglement is especially interesting in this respect. This means macro-temporal quantum coherence in the time scale of the duration of this kind of state. Otherwise macro-temporal quantum coherence lasts only for the average increment of the geometric time associated with single quantum jump, which can be identified as time scale

assignable to CD and whose minimum value is about CP_2 time roughly equal to 10^{-39} seconds. Macrotemporal quantum coherence makes possible for the self to act as a quantum computer type system. Also the experience of self, which is subjecto-temporal average over quantum jumps, contains in this case useful information since complete thermalization is avoided.

4.3.2 Binding and quantum entanglement

How different components of conscious experiences, such as various sensory qualia and the active components of conscious experience involving thoughts, conscious selections and volition, integrate to single experience, is known as binding problem. In the original approach I distinguished between bindingof conscious experiences and binding of conscious experiencers. Since mental images define experiences and are itself experiencers at a lower level of hierarchy, there seems however to be no need for this kind of distinction.

Quantum entanglement as a mechanism of binding

Quantum entanglement provides a mechanism of binding of selves to larger selves. Depending on whether the resulting entanglement is entropic bound state entanglement or negentropic entanglement, the selves lose consciousness or experience an expansion of consciousness. At the level of mental images (sub-selves) this corresponds to the integration of parts to wholes. Negentropic entanglement could create mental images representing rules as a collection of instances of rule as pairs of quantum states. Negentropically entangled Schrödinger cat would know that it is better to not open the bottle. The entangled mental images (more precisely, corresponding partonic 2-surfaces) can belong to different number fields in the intersection of real and p-adic worlds in which case entanglement is automatically negentropic.

The successes of p-adic physics suggest that it should be possible to label also real selves/space-time sheets by p-adic primes. At least in the intersection of real and p-adic worlds this assumption could make sense. Hence also real selves would form a p-adic hierarchy. Zero energy ontology implies this kind of hierarchy automatically and the hierarchy of Planck constants extends this hierarchy further.

The fusion of selves to a larger self by bound state entanglement means a formation of a bound state and the binding energy could be liberated as a usable energy. Thus quantum metabolism could accompany the negentropic binding of the mental images. In the case of negentropic entanglement the possibility that the binding energy is effectively negative would also make possible liberation of energy, and I have proposed that this might take place in ATP$\rightarrow$ADP+P$_i$ defining the fundamental step of metabolism in which the high energy phosphate bond is believed to liberate metabolic energy quantum [19]. High energy phosphate bond could correspond to a magnetic flux tube carrying the negentropic entanglement. Jail and love are good metaphors for the two kinds of correlations represented by bound state entanglement and negentropic entanglement.

Different components of sensory experience, even sensory qualia, naturally correspond to separate sub-selves, whose individual experiences are separate but combine to form various qualia in our experience. In TGD framework they could correspond to sensory pathways or parts of them and perhaps containing also primary sensory organs: this option looks at this moment the most convincing one. Quite generally, it seems that the reliability of the sensory experiences and the absence of experienced volition is guaranteed by the hypothesis about subjective memory. Experienced volition is most naturally related to the selection between different maxima of Kähler function rather than quantum jumps reducing the entanglement.

For instance, synchronous neuronal firing could be understood as a consequence of almost simultaneous wake-up of neuronal sub-selves near criticality for phase transition changing the local topology of the space-time sheets associated with sub-self. 40 Hz neural synchrony to be discussed later has a nice interpretation in terms of the generation of negentropic entanglement.

If neurons have sub-selves, also subneuronal quantum jumps are possible and this could eventually make synchronous assembly and de-assembly of microtubules and even synchronously occurring biochemical reactions possible. Primary sensory experiences could occur in part of the sensory pathway containing also primary sensory organ and nerve pulse activity could be regarded as resulting from the creation or wake-up of sensory sub-self by quantum jump leading to state able to remain unentangled. It came as a surprise that in TGD universe our sensory representations (an entire hierarchy is

involved) could be realized at the magnetic sensory canvas associated with the electromagnetic body accompanying the physical body and having size much larger than the physical body [23].

A possible example of the bound state entanglement of sub-selves could be the binding of right and left visual fields to single visual field. The visual fields can sometimes fail to bind: this should result from the failure of the corresponding sub-selves to generate mutual entanglement with sufficient rate or at all (the connection between brain hemispheres is lacking).

Bio-feedback is a well-established phenomenon in which person receives feedback from the behaviour of, say, single neuron and learns to control voluntarily its behaviour. A possible mechanism of bio-feedback is based on quantum entanglement generated between the (sub)self of the person and the self of neuron. Socio-feedback at the level of entire society could be important mechanism making possible to establish moral and behavioural rules of the society: this socio-feegback is perhaps the basic function of sleep.

Binding geometrically

Quantum-classical correspondence suggests that the concept of binding should have a counterpart at the level of space-time geometry. The gluing of the space-time sheets by topological sum to larger space-time sheets creates nested hierarchical structures. This suggests that the summation of mental images to a collection of mental images experienced by a given self corresponds geometrically to the gluing of the material space-time sheets of sub-selves to the material space-time sheet of self by topological sum operation involving the formation of 'wormhole contacts' (having physical identification as bosons and their super partners). The topological sum of space-time sheets belonging to different number fields does not seem to make sense, which suggests that mental images belonging to different number fields cannot sum although they can bind by necessarily negentropic entanglement.

The binding of experiences (or experiencers) in turn would naturally correspond to the glueing of 3-surfaces together along their boundaries by join along boundaries bonds (topological sum for boundaries). Join along boundaries contacts translate more or less to magnetic flux tubes in the recent view about TGD and would be correlate for both kinds of entanglement. The entanglement between different number fields cannot be described in terms of join along boundaries bonds. The only reasonable description for the entanglement between the copies of the partonic 2-surface in different number fields seems to be in terms of the data about rational and common algebraic points of the surface defining their "intersection".

The geometric counterpart of self defines a geometric representation for the subjective history of the self. For instance, larger mindlike space-time sheets at the higher level of the hierarchy could contain or generate holes making possible for smaller mindlike space-time sheets to form join along boundaries bonds. This mechanism would provide a concrete geometric realization for the communication between different levels of the hierarchy of selves. For instance, long term memories could become conscious through this kind of mechanism.

There are several arguments supporting the importance of join along boundaries bonds.

1. The dynamical realization of the self hierarchy as a master-slave hierarchy of various kinds of super conductors [40, 31] relies on the identification of the join along boundaries bonds between the space-time sheets belonging to various levels of hierarchy as Josephson junctions. The "biofeedback" made possible by the join along boundaries bond makes it possible for the selves at higher levels of the hierarchy to experience what it is to be lower level self. In particular, our immediate sub-selves are represented by topological field quanta of ELF em fields associated with EEG frequencies and thus have size of order Earth's circumference by Uncertainty Principle, whereas sensory experiences involve in essential manner entanglement with sub..sub-selves with size scale of neuronal circuits.

2. Magnetic flux tubes are perhaps the most interesting join along boundaries contacts in the TGD based quantum model of biology. Wormhole magnetic flux tubes consisting of a pair of space-time sheets with opposite time orientations, carrying magnetic fluxes with opposite directions, and containing also dark matter with large value of Planck constant are especially interesting. They play a key role in TGD inspired view about bio-chemistry and in the model of DNA as topological quantum computer [24].

Cognitive entanglement between real and p-adic variants of the partonic 2-surface should be probable only for preferred primes. The succesful applications of p-adic physics give good reasons to

believe that real partonic 2-surfaces and also space-time regions can be a labelled by p-adic primes characterizing their effective p-adic topology. This should make sense at least in the intersection of real and p-adic worlds. The most natural entanglement is between partonic 2-surface and its p-adic counterpart and has maximum for a unique prime. One expects that this negentropy is expressible solely in terms of rational and common algebraic points of real and p-adic surfaces and thus using only the data about real partonic surface. If this entanglement negentropy has a space-time correlate, one could expect that it is maximum for the same prime and that the geometry of the partonic 2-surface and perhaps also of corresponding light-like 3-surface and even of a 4-D space-time region reflects this p-adic topology. This prime could characterize the local p-adic topology to which the real region can be transformed easily (, that is criticality against this kind of transition). This easiness could be measured by the total number of rational and common algebraic points of the partonic 2-surface if the transition amplitude is expressible in terms of the information coming from the common points.

Wholes and parts

The basic feature of higher level cognition is formation of wholes from parts. Quantum entanglement between selves representing parts provides an attractive model for this process. Two types of entanglements can be considered but negentropic entanglement is highly suggestive in the case of cognition. One can wonder whether positive-negative dichotomy for emotions could reflect the negentropic-entropic dichotomy for entanglements. This would conform with the idea that the transformation of negentropic entanglement to bound state entanglement liberates metabolic energy and information and transforms nutrient to entropic waste. Therefore emotions would not reduce to special kind of qualia.

Sub-selves represent symbolically the components of conscious experience, say letters of the word: in absence of entanglement between these 'letter' selves the sum experience is set of letters whereas higher level experiences is about average letter. If sub-selves get entangled, there are no sub-self-experiences and sum-experience is about the word as is also the higher level experience. Understood word or written language could correspond to a negentropic entanglement between the mental images representing letters. This entanglement could be also time like and by light-like 3-surfaces connecting a temporal sequence of causal diamonds.

Entanglement can be also time-like in zero energy ontology and this could relate closely to the differences between right and left hemispheres. For right brain hemisphere time-like (and also space-like) negentropic entanglement could occur in longer time scales than for the left one as the saying right brain sings-left brain talks and the fact that spatial thinking is associated with the right hemisphere suggests.

This overall picture will be applied to the modelling of music experience later. The hypothesis will be also applied to explain paradoxical result of certain experiment testing righ-left brain differences.

Entanglement and directed attention

Directed attention is one of the basic processes of consciousness occurring continually. Directed attention seems to involve free choice but focusing of attention could also occur spontaneously. One can approach the problem of identifying the physical correlates of directed attention from several angles.

1. The possibility to interpret self as a statistical ensemble suggests that the entropy of the mental image measures its fuzziness. Thus both attentiveness, alertness and level of arousal should relate very closely to the entropy of the mental images. Attention to unentangled mental image could mean fight against second law to keep the mental image in a low entropy state and this requires metabolism (the icons on the computer screen provide a good example of this). Negentropic fusion of mental images would be alternative strategy to keep them alive. Also alertness would naturally mean negentropic mental images. 7 ± 2 rule of cognitive science suggests that the maximum number of our cognitive sub-selves which can be awake simultaneously, is rather limited. The rule might be based on the metabolic limitations: sub-selves can have low entropy content only in the presence of an external negentropy feed and metabolism must provide the needed negentropy feed. Note however that the needed metabolic energy might be extremely low. One could interpret the focused of attention as a wake-up of sub-self and keeping it in

wake-up state and hence in short term memory. This could occur at the expense of the other sub-selves, which would be in wake-up state for only short times.

2. One possibility is that subsub-self inside sub-self representing mental image (say 'monitor screen' as average over subsub-selves representing the visual objects) somehow pops up one level higher in the self hierarchy so that it becomes mental image. Geometrically this could correspond to the re-gluing of the corresponding space-time sheet to the space-time sheet of self instead of that of sub-self. Negentropic entanglement could be in question.

3. Self experiences automatically the sub-systems immediately below it in the hierarchy or perhaps to the entire collection of mental images. This might however not be what attention is basically. Rather, attention seems to select one particular mental image and put other mental images to background. It seems possible to direct attention to lower levels of the self hierarchy than the one immediately below. For instance, I can direct my attention to the entire sentence, which I am writing here or to some word of this sentence or to individual letters of this word. The phenomenon of bio-feedback demonstrates that it is possible to learn to direct the attention to even single neuron. This suggests that selves are able to modify the hierarchy of selves by raising some sub...sub-self to the role of sub-self temporarily and thus experience the former sub...sub-self as a direct mental image.

4. The formation of the flux tubes between mindlike space-time sheets belonging to different levels of the self hierarchy provides a candidate for the geometric correlate of directed attention. A formation of flux tube connecting partonic 2-surface assignable to self with a partonic 2-surface assignable to sub-self would be in question. Both the directed character of attention and the selection of a particular mental image would have clear geometric correlates. The attention to an object of perceptive field would separate the corresponding mental image from the fusion of mental images. In the case of bound state entanglement this would require the feed of metabolic energy. In the case of negentropic fusion carrying energy it could liberate metabolic energy.

Anyone can do a simple but thought provoking experiment suggesting the presence of the macroscopic quantum entanglement at the level of brain and a change of the level of sub-self in the self hierarchy. Look at a mirror, direct your attention at your left eye, and redirect the gaze to the right eye. What you find that it is impossible to perceive the change in the direction of the eye gaze.

1. Consider first what probably happens when we perceive a moving object. A negentropic binding of the mental images of the visual field to single mental image implies that both the parts and the whole can be experienced so that the motion is perceived. If the direction of the gaze is stationary, the object moves relative to the background, and if the direction of the gaze follows the object the background moves with respect to the direction of gaze. In both cases the motion can be perceived.

2. If the eye follows its own rotating mirror image, neither of these options is realized if the environment to which the attention is directed is restricted to be the eye itself. The direction of the gaze should remain the same in order to perceive the change of the direction of the gaze but this is impossible.

3. The perceptive field however contains also other objects and one could argue that if the attention is directed also to these simultanenously, it should be possible to perceive the changing direction of gaze as they move relative to the changing direction of gaze. Does the very act of directing attention to the mirror image of eye separate it from the negentropic entanglement with the other mental images so that the conscious comparison with them is not possible anymore? Or is the visual mental image representing eye at a different level of hierarchy from the very beginning and cannot negentropically entangle with the other visual mental images? Eye cannot perceive itself! Not even in mirror.

4. This argument raises the question whether it is possible to perceive the the motion of object if the attention is permanently directed to it? Is it necessarily to direct the attention only temporarily to the object and whether the saccadic motion of eyes could relate to this? There are almost incredible sounding experiments demonstrating that the attention directed intensely to a fixed object makes it impossible to become aware what happens in environment.

Entanglement and altered states of consciousness

The negentropic entanglement might provide the Royal Road to the understanding of altered states of consciousness. Entanglement can take place both at the level of self and sub-selves, In the latter case one can consider the possibility that self can choose in state function reduction whether the mental images are entangled entropically or negentropically. For self the negentropic entanglement would be kind of moment of mercy by higher level self. Both space-like and time-like entanglement are possible and this can lead to transpersonal experiences and memories extending past the own life time. The entanglement can occur also between different number fields. Also the increases of p-adic prime or Planck constant could be be involved with these experiences. Clearly, a wide repertoire of expanded states of consciousness is predicted. This picture conforms with the view that a certain kind of personal moral and intellectual evolution is a prequisite for enlightment experiences.

Examples of altered states of consciousness are transpersonal experiences and enlightment experiences in which one identifies with some larger consciousness. For instance, prenatal experiences could result from a time-like negentropic entanglement of a sub-self with self having a temporal extension of order lifetime or longer and having kind of abstracted experience about the period of life before birth. Experiences like "sharing the sorrow of all mothers of dead soldiers" could involve the entanglement of sub-self with a collective mental image resulting in the entanglement with a collective mental images having quite concretely as mental images of mothers. If the notion of field body having size at least of order Earth size makes sense, this idea does not look so implausible anymore.

Direct eye contact as an example of quantum entanglement between experiencers?

Direct eye contact is fundamental in the communication between living creatures. The naive intuitive picture of cartoon drawings about direct eye contact is is as rays connecting the eyes of persons involved. TGD suggests that this naive picture actually represents fundamental mechanism for the temporal fusion of selves to form larger selves. What could happen is that join along boundaries bonds are formed between eyes, and, if the neural window hypothesis holds true, also between brains and eventually between sensory canvases.

MEs are optimal for this purpose. The coherent photons associated with them would be the required macroscopic quantum phase associated with the entire higher level self. Thus it is perhaps not accident that extended states of consciousness are so often described as experiences about radiance of light. A weaker hypothesis is that eye contact involves only the formation of join along boundaries bonds along which classical communication based on propagation of classical signals occurs. Also for this option MEs are optimal candidates for join along boundaries bonds.

The reader has possibly noticed that these arguments open up the possibility that our visual field in some sense corresponds to the actual visual field rather than only its cognitive representation provide by the visual pathways. The photons arriving along MEs connecting our brain with the objects of the perceptive field could provide the join along boundaries bonds extending our sensory self to contain part of the external world. Our visual field would still be determined by the light entering to our eyes so that no contradictions with well established empirical facts about vision are encountered. This kind of extension of visual self could however provide completely new manners for brain to compute the distances to the objects of the perceptive field since the basic information would not be mere two-dimensional picture in retina. The most plausible option seems to be however the one in which ultimate sensory representations are realized outside brain at the sensory canvas provided by the magnetic flux tube structures which can be even of the order of Earth size. This option is discussed in [32].

Semitrance mechanism

The notion of semitrance allows to understand how higher level selves can communicate to and control and coordinate the behaviour of lower levels selves. If individual contains at least part of time at least single sub-self, this sub-self can entangle with higher level self and in this trance state can communicate with the self and possible sub-selves and transmit commands, advices or messages. Communication is here quite generally understood as a generation of mental images, waking-up of sub-selves, these sub-selves could be p-adic sub-selves of real selves in accordance with the idea that communication is part of cognition. The wake-up process initiates self-organization leading to a final state pattern

representing the message. Final state pattern depends only weakly on the stimulus serving as message: this is as it should be.

The entanglement of the right or left brain hemisphere (or some part of it, perhaps the linguistic regions with respect to which human brain has highest asymmetry) with a collective self could be the basic mechanism making it possible to communicate the commands of the collective self to left and/or right hemisphere as 'hallucinations'. This leads to a TGD variant of the vision of Jaynes about bicamerals and schizophrenics as persons who differ from the average modern man in that they are able to receive commands and advice from collective levels of consciousness as hallucinations [57]. The notion of semitrance leads to very general views about how various societies (cells as societies of proteins, organisms as societies of cells, societies of various animals) develop and allows also to understand various altered states of consciousness [21, 30].

The semitrance mechanism involves the generation of a bound state entanglement accompanied by the liberation of the binding energy as a usable energy. This non-metabolic energy might have something to do with the miraculous architectural feats of the ancient bicameral cultures (consider only pyramides) and the unusual physical strength of schizophrenics discussed in [57].

Entanglement and sleep

What happens for our self during sleep? One can imagine several alternative answers to the question.

1. We really lose consciousness during sleep. This means that our self entangles negentropically with some other self. One can however ask why negentropic entanglement should not be possible and whether it could be the reason for healing effects of sleep.

2. Long term memory representations are not constructed during sleep so that we do not remember anything about sleep time consciousness except when we wake up from REM sleep: note that in this case the memories fade rapidly in accordance with the idea that long term memories are not constructed. Synchronous hippocampal theta is indeed absent during sleep and synchronous firing would be a natural candidate for both the communications of mental images to magnetic body and for the generation of memory representations as negentropic fusions of mental images. If these memory representations are nor formed there is nothing to remember.

3. We are able to remember what happened during sleep only if we are asleep. Perhaps synchronous theta and delta oscillations are involved with the construction of negentropic memory representations experienced only during sleep just as theta synchrony is essential for memories about daytime experiences. The mirror mechanism of long term memories might allow this kind of possibility. These memory representations would be incomprehensible from the point of daytime consciousness. The strange mental images experienced just at the verge of falling asleep or waking up, which have meaning before transition but lose it during the transition, might reflect this.

Irrespective of whether the entanglement is bound state entanglement or negentropic entanglement, an important function of sleep could be the formation of larger collective selves. During sleep our selves could entangle to form a kind of a stereo consciousness representing human condition. This process could involve either phase transition changing local topology or a formation of join along boundaries contacts with much larger space-time sheets characterized by the same local topology. This mechanism could make possible subconscious communication between the members of society and also establish conscience and moral. The topological field quanta associated with photons generated by EEG during sleep have frequency smaller than 7 Hz [26]. This suggests that the higher level selves in question correspond to these topological field quanta and thus have a wake-up time of order .5 seconds during delta wave sleep. Mental images would not disappear but would become more abstract during sleep.

4.3.3   General structure of conscious experience

Combining summation hypothesis and the hypothesis about subjective memory one can understand quite a lot about the phenomenology of consciousness.

Summation hypothesis

Binding of selves by entanglement and summation hypothesis are the basic assumptions about the structure of contents of consciousness of self. Unentangled sub-system X possessing self behaves essentially as a separate sub-Universe with respect to NMP. This means that unentangled sub-systems X_i of X, in particular sub-selves, participate in each quantum jump. If one postulates that the conscious experiences of sub-systems X_i of unentangled sub-system X integrate with the self experience of X to form single experience, one obtains a filtered hierarchy of conscious experiences with increasingly richer contents. The integrated experience cannot a simple sum of individual experiences of sub-selves (we do not experience the conscious experiences of neurons separately). Rather, the experience of X is most naturally sum of abstractions about experiences of X_i. A natural hypothesis is that X forms kind of abstraction or average $\langle X_{ij} \rangle$ about the experiences of sub-selves X_{ij} of X_i representing what it is to be average X_{ij}, that is average over the mental images of X_i.

This kind of mechanism would explain why we do not experience the experiences of individual neurons, microtubules, DNA:s, etc... as a huge multitude of separate experiences and do note get drowned to useless information. Combining summation hypothesis with the hypothesis about subjective memory (described in previous section), one can understand self as an object having genuine extension in subjective time. In particular, it is possible to identify short term memory as a subjective memory. Also temporal average in geometric sense is possible since mindlike space-time sheets can have also timelike separation.

A challenge for the hypothesis of self and summation hypothesis is provided by split brain patients [70]. It seems that in most serious cases either right or left half dominates the behavior of the split brain patient and communication between brain hemispheres is lacking. It is known that brain hemispheres learn to communicate indirectly. Is the hypothesis about summation of the right and left selves to form mental images of a higher self ireally consistent with the behaviour of split brain patients?

1. The dominance of either hemisphere is highly analogous to the dominance of a person over another one. The sudden changes of personality can be understood as result of different cognitive specializations of the two hemispheres. The lacking information transfer between hemispheres explains why right and left brain behave so differently (to the extend that they can have different future plans!). It is well known that in early childhood hemispheres behave as separate personalities and certain period in the learning of language seems to involve communication between brain hemispheres: left hemisphere comments what right hemisphere is doing. This kind of direct communication usually ceases, when the direct physical connection between brain hemispheres has developed.

2. One must of course ask what 'dominance' really means. A possible definition is based on the notion of self hierarchy and magnetic body as intentional agent. Magnetic body could direct its attention in normal circumstances to either left hemisphere or right hemisphere or both if they are entangled (entropically or negentropically). The unattended hemisphere could be conscious but would not contribute to the conscious experience of the magnetic body representing us. Corpus callosum- the axon bundle connecting right and left hemisphere- would serve as a natural correlate for their entanglement, which should be negentropic in the normal situation. Quite generally, axons would serve as correlates for the entanglement so that also sensory receptors would be in this sense part of the brain. Note that this would make possible macroscopic quantum coherence between distance parts of body and brain and the regions of quantum coherence would be highly irregular.

3. The alternating hemisphere dominance characterizes also healthy persons and could provide magnetic body with three different views about world corresponding to hawks and doves and those between. Problems begin when either hemisphere dominates for too long time. For instance, for schizophrenics the time of dominance is longer than normally. For split brain patients the absence of physical connection between hemispheres makes impossible quantum entanglement binding the hemispheres together to form single coherent whole and the body of the patient is inhabited by two persons. The length of time-interval during which given hemisphere contributes to our conscious experience could be rather short. Interestingly, in the case of dolphins and some birds the second hemisphere sleeps. Is this for metabolic reasons or is the second hemisphere entangled with the collective consciousness of the dolphin horde? The theory of

bicameral mind assumes that human consciousness before the evolution of language was dominated by another hemisphere entangled with collective level of consciousness. I have discussed a model of bicamerality in the earlier formulation of TGD inspired theory of consciousness in [21, 30]. One can of course whether that dolphins could represent a modern example about bi-cameral consciousness.

Self as a statistical ensemble, emotions, and qualia

The sequence of quantum jumps defining self defines also a sequence of completely unentangled quantum states resulting in the state reduction process governed by NMP. This set of states, which grows in size quantum jump by quantum jump, defines in a natural manner a statistical ensemble identifiable as the fundamental realization of the otherwise fictive notion of statistical ensemble fundamental in the formulation of statistical physics. As far as conscious experience is involved, it seems that it is the increments of quantum numbers and zero modes which are the relevant statistical variables.

This observation anchors the theory of conscious experience to statistical physics [24]. For instance, the increments of zero modes resp. quantum numbers are responsible for geometric resp. non-geometric qualia. More precisely, the gradients with respect to subjective time for the zero modes and for the net quantum numbers associated with selves correspond to qualia. One can classify non-geometric qualia to kinestetic qualia (sense of pressure and force and, more generally, gradient of any conserved (with respect to geometric time) quantity associated with self with respect to subjective time); and generalized chemical qualia (rates for the changes of numbers of particles with various quantum numbers). Various entropies associated with self and sub-selves in turn characterize the sharpness of the mental images, and one can relate concepts like attentiveness, alertness and the level of arousal to these variables.

Statistical aspect could be involved with sensory experiences also in the sense of ensemble averaging. For instance, various cones of retina are sensitive to different wavelength regions (red, green, blue) and their experiences must correspond to different colors. Therefore our color experience, which corresponds to average color, should be abstraction about experiences of a small group of retinal cells. Ensemble averaging could be present in case of sense such as temperature and pressure sense. Also temporal averaging with respect to *geometric* time would be made possible by mindlike space-time sheets and could be present.

The original proposal was that emotions some kind of qualia since also ordinary qualia have the characteristic black-white dichotomies. What is clear that emotions relate very closely to information. For instance, peptides are both informational molecules and molecules of emotion [72]. This suggests that positive-negative dichotomy for emotions correlates directly with negentropic-entropic dichotomy for entanglement. For instance, the neurotransmitters producing positive (negative) emotions would generate negentropic (entropic) entanglement. The fate of the right amygdala would be a specialization to experience negative emotions by entangling mostly by bound state entanglement whereas left amygdala specialized to positive emotions would enjoy the negentropic entanglement.

In positive energy ontology it seems impossible to have quantum coherence in human time scales. The occurrence of 10^{39} quantum jumps per second probably means that at the lowest level of self hierarchy corresponding to time scale which is 10^4 Planck times statistical averaging thermalizes sub-selves completely so that mental images would contain no information. Decoherence is the physical counterpart of this process. In zero energy ontology the situation changes. The time scale assignable to CD assumed to be an octave of CP_2 time represents a completely new time scale which is macroscopic even for elementary particles. This time scale provides a simple estimate for the average increment of psychological time per quantum jump. For electron and quarks the time scales are .1 seconds and 1 millisecond and correspond to basic time scales of nervous system. The hierarchy of Planck constants allows to scale up these time scales and makes possible communication using photons with arbitrarily low wave lengths since large enough Planck constant implies that the energy of photon is above the thermal threshold. Negentropic entanglement makes possible the formation of completely new kind of macroscopic quantum systems. Time-like entanglement makes possible fusion of quantum jumps to longer quantum jumps and thus macrotemporal quantum coherence.

The feed of metabolic energy could destroy entropic entanglement and feed negentropic entanglement as such: for a simple model see [19]. Interestingly, there is a well-documented disease in which the patient can live for decades in single frozen moment of consciousness. Is negentropic entanglement with abnormally large value of Planck constant in question? Or is entropic entanglement with abnor-

mally large binding energy and therefore not possible to destroy by the feed of standard metabolic energy quanta in question?

Reducible and irreducible selves

Sub-selves correspond to mental images of self. Irreducible selves do not posses sub-selves and have thus no mental images. The interpretation of this kind of experience -if possible in practice- would be as a pure awareness without content. Whether this kind of states are really possible is not obvious since any spacetime sheet contains smaller space-time sheets. When all sub-selves of self fuse (negentropically) together to yield a kind of stereo-consciousness (fusion of left and right visual fields gives rise to 3-D stereo vision), something exceptional results also. One might interpret this kind of state as whole-body consciousness, a state of oneness in very literal sense. Synchronous neuronal firing could be a signature of this kind of states at neuronal level. Reducible selves have several sub-selves experienced as mental images. One can model conscious processing as cascades leading to creation of sub-selves of sub-selves of ... : selves are interpretable as symbolic representations of objects of sensory experience and a close parallelism with computationalism and connectivism emerges. In zero energy ontology negentropically entangled zero energy states form this kind of hierarchy.

4.3.4 Basic consequences

Summation hypothesis, when combined with the mechanism for the formation of abstractions and mechanism of subjective memory, has rather nontrivial consequences.

Infinite hierarchy of selves with God at the top

A rather dramatic prediction is a Russian doll like hierarchy of conscious experiencers having the entire Universe, God, at the top. The necessary localization in zero modes making the Universe of conscious experience classical together with the proposed concept of self allows to understand both active and passive aspects of consciousness and a general classification of various types of conscious experiences becomes possible. Summation hypothesis, sharing of mental images and 'enlightment' by the generation of negentropic entanglement hypothesis provide a general framework for interpreting various transpersonal experiences and altered states of consciousness as resulting from entanglement with larger units of consciousness.

Self, evolution and, self-organization

Quantum jumps between quantum histories make also possible genuine quantum self-organization. The concept of self-organization gets quite new additional meaning in TGD framework. Self-organization means also evolution of self-hierarchies. Self-organization by quantum jumps can be regarded as a hopping in the zero modes characterizing the macroscopic aspects of the space-time surface. Each self is a dissipative system which ends up to some asymptotic self-organization pattern in the presence of the external energy feed (and even without it). Dissipation is the ultimate Darwinian selector picking up the winning selves as favored self organization patterns. Since sub-selves correspond to mental images, the immediate implication is that also memes are subject to similar selection. For instance, the formation of long term memories and habits could be understood as a formation of surviving sub-selves.

The time evolution by quantum jumps has many facets. One of them relates to effective p-adic topology and is expected to be of speciall importance if live resides in the intersection of real and p-adic worlds. Simple arguments leads to the conclusion that evolution for a given space-time sheet must correspond to a sequence of p-adic primes increasing in a statistical sense. This means that the concept of nearness defining the effective topology becomes gradually more refined, the complexity of the universe increases, and the maximal information contents of the conscious experience increase in the long run (like $p \times log(p)$ or at least as $log(p)$ as a function of p-adic prime characterizing the system). This is nothing but evolution. NMP, which states that entanglement negentropy gain maximal for allowed quantum jumps, enhances this tendency.

The TGD based realization of the quantum criticality, besides making macroscopic quantum systems possible, in a well-defined sense maximizes the intelligence and complexity of the universe [41]. In biosystems a concrete realization of quantum criticality is in terms of magnetic flux tube structures

and electret type space-time sheets representing solutions of field equations dual to each other and having opposite signs of Kähler action density.

TGD universe is quantum spin glass and this adds additional aspect to the self-organization process. For instance, the energy landscape of the spin glass is fractal like structure containing valleys inside valleys and provides an ideal dynamical memory mechanism. Spin glass degeneracy also provides a mechanism increasing the lifetimes of the bound states formed by join along boundaries condensates and thus could allow macrotemporally quantum coherent states able to perform quantum computation like activities. The impossibility of macrotemporal quantum coherence is indeed the main objection against quantum theories of consciousness.

This looks nice but one can ask whether the framework of standard quantum theory is all that is needed to formulate quantum TGD and the notion of quantum criticality. The original motivations for introducing the hierarchy of Planck constants and the generalization of the imbedding space to a book like structure having as pages the almost copies of the imbedding space were purely physical. Now it seems that this generalization is required by a need to have a proper formulation of quantum criticality of TGD Universe. The hierarchy of Planck constants leads to a whole bundle of ideas about quantum biology and evolution of consciousness and also to a detailed model for how living matter can perform topological quantum computation like activities [24, 19, 32, 36].

State function reduction reducing entanglement is a random process unlike that producing negentropic entanglement and implies quantum decoherence. Therefore the unentangled sub-selves of self define a statistical ensemble in a natural manner and dissipation is naturally related to the ageing of self since the statistical ensemble in question grows quantum jump by quantum jump. The averaging over quantum jumps means that the contents of consciousness of self thermalize with mental images becoming more and more fuzzy.

Haken's classical theory of self-organization applies almost as such if only entropic entanglement is considered since time development by quantum jumps means hopping around the space of zero modes characterizing the size and shape and induced Kähler fields associated with the space-time surface $X^4(X^3)$. Negentropic entanglement of mental images changes however the situation in time scale which could be the time scale assignable to the CDs associated with the entangled selves.

Self-organization involves Darwinian selection performed by dissipation inside each self. Dissipation selects also surviving sub-selves having interpretation as mental images. Hence the selection of memes is also in question.

Subjective ageing results from dissipation and is the price paid for having autonomous self separated from environment. Very concretely, the mental image of self represented by sub-self gets more and more entropic during ageing. One can also formulate questions about what happens in death in terms of physical concepts. Does only the bodily sub-self (mental image about body) cease to exist in the physical death so that only the field body consisting of magnetic flux tube structures and massless extremals (MEs, topological counterparts of light rays) remains? Can one identify the field body as the counterpart of what is called soul? Could the field body get interested of some new biological body and use it as sensory and motor organ (re-incarnation)? Is entanglement with some larger self generated after death (and during sleep)? Or does only the crucial p-adic-to-real phase transition for MEs (say) representing the transformation of intentions to actions cease during sleep and in death so that neither sensory mental images nor memories are formed but consciousness might still continue?

Quantum model for intelligent system

The concept of self provides justification for the assumptions behind the quantum model for intelligent systems [41]. One can understand at very general level the mechanism for how universe forms abstractions about itself. Even the basic hierarchical structures of language could be identified in terms of Russian doll like structure formed by selves with phonemes possibly representing the lowest level selves in case of language. The possibility of negentropic entanglement possible in the intersection of real and p-adic worlds is perhaps the most important new element and makes possible the identification of quantum correlates of rules and abstractions. This kind of pairs formed by quantum states belonging to different number fields would defined cognitive from real world to symbolic representtions and between symbolic representations. The time-like negentropic entanglement in fermionic degrees of freedom is possible only within given number field and would provide a natural representation for a Boolean rule $A \rightarrow B$ with paired instances of A and B represented by state pairs.

The close connection with the computationalistic approach to psychology and consciousness is obvious. The hierarchy of selves is analogous to a hierarchy of higher level computer languages. Note also the analogy with the the hierarchy of the modules of a computer program. Selves could be interpreted as symbolic representations for the objects of external (and internal) world and cascades of selves generating selves inside selves provide a model for sensory experience and cognition. This model provides also a possible representation for logical implication sequences as temporally ordered sequences generating sub-selves. Negentropic quantum entanglement between selves is a good candidate for representing how wholes are formed from parts consciously as also for the formation of associations. Abstraction process emerges naturally as a formation of quantum average selves about the sub-subselves of self. Zero energy ontology is ideal for construction of hierarchies as negentropically entangled states formed from zero energy states formed from....

Quantum statistical determinism makes possible reliable thinking and sensory experiencing at the level of self and one could in principle model brain and sensory organs as ensembles of sub-subsystems for which quantum measurement of certain observables occurs in quantum jump leading to the thought or sensory experience[41]. For negentropic entanglement the outcome of the state function reduction is rather deterministic but U process can generate ensemble since one can obtain from a given negentropically entangled state new ones by permuting the entangled state pairs. This kind of transformation makes possible to realize quantum computations using negentropic qubits formed by entangled positive and negative energy parts of the state [29]. Biological quantum computation could be rely on this kind of fuzzy qubits and the model of DNA as a topological quantum computer [24] can be formulated in terms of negentropic qubits. What is especially nice is that temporal statistical averages become possible since mindlike space-time sheets can have also timelike distance: thus individual can learn form experience if temporal ensemble of cognitive space-time sheets is available.

Self as a moral agent

There are many manners to interpret evolution in TGD Universe.

1. p-Adic evolution would mean a gradual increase of the infinite p-adic prime characterizing the entire universe implying the gradual increase of p-adic primes characterizing individual partonic 2-surfaces and therefore their size. The identification of p-adic space-time sheets as representations for intentions and the identification of p-adic-to-real phase transitions as transformations of intentions to real actions gives additional concreteness to this vision.

2. The hierarchy of Planck constants suggests evolution as the gradual increase of the Planck constant characterizing p-adic space-time sheet (or partonic 2-surface for the minimal option). This evolution could be seen as a migration to the pages of the book like structure defined by the generalized imbedding space and has therefore quite concrete geometric meaning. It implies longer time scales of long term memory and planned action and macroscopic quantum coherence in longer scales.

3. The vision about life as something in the intersection of real and p-adic words allows to see evolution information theoretically as the increase of number entanglement negentropy implying entanglement in increasing length scales. This option is consistent with the first one if the effective p-adic topology characterizes the real partonic 2-surfaces in the intersection of p-adic and real worlds. The singular coverings of CD s and CP_2 are characterized by an Abelian group Z_n permuting the sheets of the covering and corresponds naturally to powers of the (quantum) phase $q = exp(i2\pi/n)$ allowing to define the notion of angle in p-adic context but only with a finite resolution since only finite number of angles are represented as phases for a given value of n. The increase of the integers n could be interpreted as the emergence of higher algebraic extensions of p-adic numbers in the intersection of the real and p-adic worlds. These observations suggest that all three views about evolution are closely related.

The third kind of evolution would mean also the evolution of spiritual consciousness if the proposed interpretation is correct. In each quantum jump U-process generates a superposition of states in which any sub-system can have both real and algebraic entanglement with the external world. If state function redution process involves also the choice of the type of entanglement it could be interpreted as a choice between good and evil. The hedonistic complete freedom resulting as the entanglement

entropy is reduced to zero on one hand, and the algebraic bound state entanglement implying correlations with the external world and meaning giving up the maximal freedom on the other hand. The selfish option has the risk of leading to non-algebraic bound state entanglement implying a loss of consciousness: death as the prize of sin. The second option means expansion of consciousness - a fusion to the ocean of consciousness as described by spiritual practices.

In this framework one could therefore understand the physics correlates of ethics and moral. The ethics is simple: evolution of consciousness to higher levels is a good thing. Anything which tends to reduce consciousness represents violence and is a bad thing. Moral rules are related to the relationship between indvidual and society and presumably develop via self-organization process and are by no means unique. Moral rules however tend to optimize evolution. As blind normative rules they can however become a source of violence identified as any action which reduces the level of consciousness.

There is an entire hierarchy of selves and every self has the selfish desire to survive and moral rules develop as a kind of compromise and evolve all the time. The newest progress in this evolution is brought by the cosmology of consciousness, which forces to extend the concept of society to four-dimensional society! The decisions of "me now" affect both my past and future and time like quantum entanglement makes possible conscious communication in time direction by sharing conscious experiences. One can therefore speak of genuinely four-dimensional society. Besides my next-door neighbors I had better to take into account also my nearest neighbors in past and future (the nearest ones being perhaps copies of me!). If I make wrong decisions those copies of me in future and past will suffer the most. Perhaps my personal hell and paradise are here and are created mostly by me.

Selves can make plans since they have 4-dimensional geometric memory (conscious experience contains information about a *four-dimensional* space-time region, rather than only time=constant snapshot, and gives rise to a "prophecy", a prediction for the future and past, which would be reliable if the world were completely classical). As a matter fact, it is p-adic space-time sheets which correspond to intentions and plans and act of volition transforms p-adic space-time sheet to a real one. Selves can make decisions and select between various classical macroscopic time developments. Selves are able to remember their choices since they have subjective memories about the previous quantum jumps. Thus selves are genuine moral agents.

Self, psychological time and its arrow

There are many difficult questions related to the relationship between subjective and geometric time. How the arrow of subjective time is mapped to the arrow of geometric time? How to understand the sharp distinction between geometric future and past at the level of conscious experience? What is the average interval of geometric time assignable to quantum jump and how it depends on the p-adic prime p characterizing system and on the value of Planck constant? Can one assign to quantum jumps space-time region about which the contents of conscious experience are, and how the temporal and spatial scales of this region depend on p and the value of Planck constant?

The emergence of zero energy ontology and hierarchy of Planck constants provides to my opinion the most convincing answers to these questions found hitherto.

1. Zero energy state is identifiable in positive energy ontology as a physical event, say elementary particle scattering such that positive and negative energy parts of the state correspond to the initial and final states of the event. The geometric correlate is a causal diamond formed by a pair of future and past directed light-cones of M^4 and corresponds to a region of the imbedding space rather than that of space-time.

2. The temporal distance T between the tips of the causal diamond brings to physics a new time scale and simple argument predicts p-adic length scale hypothesis (favored primes p satisfy $p \simeq 2^k$, k prime), and that T corresponds to secondary p-adic time scale $T_{2,p} = \sqrt{p}T_p$. For nonstandard values of $\hbar$ T scales like $\hbar/\hbar_0$. In the case of zero energy state describing electron this time scale is .1 seconds and corresponds to the 10 Hz frequency defining the fundamental biorhythm, and the duration of moment of sensory experience.

3. The simplest explanation for the arrow of geometric time assumes that the attention of self is directed to a fixed volume of imbedding space defined by the causal diamond. In other words, self has this causal diamond as a geometric correlate at imbedding spave level besides space-time sheet (actually partonic 2-surfaces at the light-like boundaries of CD serving as a space-time

correlate. The conscious experience of self is about space-time sheets inside this CD and its sub-CDs.

4. If the quantum superposition of space-time surfaces in the first approximation shifts in a given quantum jump to the direction of geometric past a distance given by T, the arrow of geometric time can be understood and T defines the lapse of geometric time in quantum jump. The hierarchy of quantum jumps inside quantum jumps corresponds to both p-adic and $\hbar$ hierarchies and the experience of flow of time can be understood in terms of sequences of sub-quantum jumps defining mental images. A more precise formulation allows also to understand why sensory experience is about narrow time interval. The absolutely essential element of this explanation is the representability of the space-time as a 4-D surface of a higher-dimensional imbedding space, multi-verse picture and quantum coherence in macroscopic scales, as well as the assignment of unique space-time surface to given 3-surface required by General Coordinate Invariance. The original defining assumptions relate to the notion of self can be assumed to hold true for sub-selves identified as sub-quantum jumps.

5. There is arrow of geometric time emerges also at the level of the imbedding space. CDs are characterized by their temporal size scale coming as powers of two and quantum jump sequences induces diffusion of CD in the moduli space of CDs leading to the increase of this size. There is a strong analogy with cosmic time and a natural proposal is that the quantum counterpart for cosmic time correspond to this kind of parameter for a very large CD. The relative positions of the of tips define part of the moduli space of CD and this space could be discrete and correspond to a union of lattice assignable to cosmic time constant hyperboloidsa having subgroup of Lorentz groups as symmetry group. This would predict quantization of redshifts in cosmology.

Space-time as a 4-dimensional living being

The new concept of the psychological time means a dramatic generalization of the standard view about subjective existence. mindlike space-time sheets are distributed everywhere around material space-time sheets of infinite time duration and all of them can participate in a given quantum jump. Therefore one can say that the entire space-time is a conscious, living being. Civilizations of the geometric past and future exist simultaneously with us. We are members of a four-dimensional society in the sense that our actions affect the life of selves of both geometric past and future since each quantum jump performed by us changes the macroscopic space-time in both past and future.

Everyday experience suggest that the geometric past is relatively rigid. Although changes in a given time scale can occur below some length scale, changes in larger scales are probably rare. Sensory representations could however change and this could explain the instability of long term memories. Turning point decisions are probably not possible for the me of my geometric past: otherwise dramatic quantum jump changing completely my personal identity would occur.

The notion of the four-dimensional body (both material and field bodies) becomes natural and only the concentration of consciousness to the psychological now during the physical life creates the illusion that the reality corresponds to the time=constant snapshot of the time evolution. Near death experiences indeed support the view that life is experienced as a temporal whole when the dominating contribution from the p-adic-to-real phase transitions and sensory input is absent. 4-dimensional body is not static but changes quantum jump by quantum jump which suggests that life is like a four-dimensional sculpture which is gradually refined. We in our youth now experience in slightly more deeper manner and live in a society having slightly higher level of moral. Note that the newest view about arrow of time means that the creation of this 4-D sculpture can be also seen as classical time evolution in the first approximation.

4.3.5 Can one choose between the two variants for the notion of self or are they equivalent?

I have considered two different notions of "self" and it is interesting to see whether the new view about time might allow to choose between them or to show that they are actually equivalent.

1. In the original variant of the theory "self" corresponds to a sequence of quantum jumps. "Self" would result through a binding of quantum jumps to single "string" in close analogy and actually

in a concrete correspondence with the formation of bound states. Each quantum jump has a fractal structure: unitary process is followed by a sequence of state function reductions and preparations proceeding from long to short scales. Selves can have sub-selves and one has self hierarchy. The questionable assumption is that self remains conscious only as long as it is able to avoid entanglement with environment.

Even slightest entanglement would destroy self unless on introduces the notion of finite measurement resolution applying also to entanglement. This notion is indeed central for entire quantum TGD also leads to the notion of sharing of mental images: selves unentangled in the given measurement resolution can experience shared mental images resulting as fusion of sub-selves by entanglement not visible in the resolution used.

2. According to the newer variant of theory, quantum jump has a fractal structure so that there are quantum jumps within quantum jumps: this hierarchy of quantum jumps within quantum jumps would correspond to the hierarchy of dark matters labeled by the values of Planck constant. Each fractal structure of this kind would have highest level (largest Planck constant) and this level would corresponds to the self. What might be called irreducible self would corresponds to a quantum jump without any sub-quantum jumps (no mental images). The quantum jump sequence for lower levels of dark matter hierarchy would create the experience of flow of subjective time.

It would be nice to reduce the original notion of self hierarchy to the hierarchy defined by quantum jumps. There are some objections against this idea. One can argue that fractality is a purely geometric notion and since subjective experience does not reduce to the geometry it might be that the notion of fractal quantum jump does not make sense. It is also not quite clear whether the reasonable looking idea about the role of entanglement as destroyer of self can be kept in the fractal picture.

These objections fail if one can construct a well-defined mathematical scheme allowing to understand what fractality of quantum jump at the level of space-time correlates means and showing that the two views about self are equivalent. The following argument represents such a proposal. Let us start from the causal diamond model as a lowest approximation for a model of zero energy states and for the space-time region defining the contents of sensory experience.

Let us make the following assumptions.

1. Assume the hierarchy of causal diamonds within causal diamonds in a sense to be specified more precisely below. Causal diamonds would represent the volumes of attention. Assume that the highest level in this hierarchy defines the quantum jump containing sequences of lower level quantum jumps in some sense to be specified. Assume that these quantum jumps integrate to single continuous stream of consciousness as long as the sub...-sub-self in question remains unentangled and that entangling means loss of consciousness or at least that it is not possible to remember anything about contents of consciousness during entangled state.

2. Assume that the contents of conscious experience come from the interior of the causal diamond. A stronger condition would be that the contents come from the boundaries of the two light-cones involved since physical states are defined at these in the simplest picture. In this case one could identify the lower light-cone boundary as giving rise to memory.

3. The time span characterizing the contents of conscious experience associated with a given quantum jump would correspond to the temporal distance T between the tips of the causal diamond. T would also characterize the average and approximate shift of the superposition of space-time surfaces backwards in geometric time in single quantum jump at a given level of hierarchy. This time scale naturally scales as $T_n = 2^n T_{CP_2}$ so that p-adic length scale hypothesis follows as a consequence. T would be essentially the secondary p-adic time scale $T_{2,p} = \sqrt{p} T_p$ for $p \simeq 2^k$. This assumption - absolutely essential for the hierarchy of quantum jumps within quantum jumps - would differentiate the model from the model in which T corresponds to either CP_2 time scale or p-adic time scale T_p. One would have hierarchy of quantum jumps with increasingly longer time span for memory and with increasing duration of geometric chronon at the highest level of fractal quantum jump. Without additional restrictions, the quantum jump at n^{th} level would contain 2^n quantum jumps at the lowest level of hierarchy. Note that in the case of sub-self - and without further assumptions which will be discussed next - one would have just two quantum

jumps: mental image appears, disappears or exists all the time. At the level of sub-sub-selves four quantum jumps and so on. Maybe this kind of simple predictions might be testable.

4. We know that that the contents of sensory experience comes from a rather narrow time interval of duration about .1 seconds, which corresponds to the time scale T_{127} associated with electron. We also know that there is asymmetry between positive and negative energy parts of zero energy states both physically and at the level of conscious experience. This asymmetry must have some space-time correlate. The simplest correlate for the asymmetry between positive and negative energy states would be that the upper light-like boundaries in the structure formed by light-cones within light-cones intersect along light-like radial geodesic. No condition of this kind would be posed on lower light-cone boundaries. The scaling invariance of this condition makes it attractive mathematically and would mean that arbitrarily long time scales T_n can be present in the fractal hierarchy of light cones. At all levels of the hierarchy all contribution from upper boundary of the causal diamond to the conscious experience would come from boundary of same past directed light-cone so that the conscious experience would be sharply localized in time in the manner as we know it to be. The new element would be that content of conscious experience would come from arbitrarily large region of Universe and seing Milky Way would mean direct sensory contact with it.

5. These assumptions relate the hierarchy of quantum jumps to p-adic hierarchy. One can also include also dark matter hierarchy into the picture. For dark matter hierarchy the time scale hierarchy $\{T_n\}$ is scaled by the factor $r = \hbar/\hbar_0$ which can be also rational number. For $r = 2^k$ the hierarchy of causal diamonds generalizes without difficulty and there is a kind of resonance involved which might relate to the fact that the model of EEG favors the values of $k = 11n$, where $k = 11$ also corresponds in good approximation to proton-electron mass ratio. For more general values of $\hbar/\hbar_0$ the generalization is possible assuming that the position of the upper tip of causal diamond is chosen in such a manner that their positions are always the same whereas the position of the lower light-cone boundary would correspond to $\{rT_n\}$ for given value of Planck constant. Geometrically this picture generalizes the original idea about fractal hierarchy of quantum jumps so that it contains both p-adic hierarchy and hierarchy of Planck constants.

The contributions from lower the boundaries identifiable in terms of memories would correspond to different time scales and for a given value of time scale T the net contribution to conscious experience would be much weaker than the sensory input in general. The asymmetry between geometric now and geometric past would be present for all contributions to conscious experience, not only sensory ones. What is nice that the contents of conscious experience would rather literally come from the boundary of the past directed light-cone along which the classical signals arrive. Hence the mystic feeling about telepathic connection with a distant object at distance of billions of light years expressed by an astrophysicist, whose name I have unfortunately forgotten, would not be romantic self deception.

This framework explains also the sharp distinction between geometric future and past (not surprisingly since energy and time are dual): this distinction has also been a long standing problem of TGD inspired theory of consciousness. Precognition is not possible unless one assumes that communications and sharing of mental images between selves inside disjoint causal diamonds is possible. Physically there seems to be no good reason to exclude the interaction between zero energy states associated with disjoint causal diamonds.

The mathematical formulation of this intuition is however a non-trivial challenge and can be used to articulate more precisely the views about what configuration space and configuration space spinor fields actually are mathematically.

1. Suppose that the causal diamonds with tips at different points of $H = M^4 \times CP_2$ and characterized by distance between tips T define sectors CH_i of the full configuration space CH ("world of classical worlds"). Precognition would represent an interaction between zero energy states associated with different sectors CH_i in this scheme and tensor factor description is required.

2. Inside given sector CH_i it is not possible to speak about second quantization since every quantum state correspond to a single mode of a classical spinor field defined in that sector.

3. The question is thus whether the Clifford algebras and zero energy states associated with different sectors CH_i combine to form a tensor product so that these zero energy states can interact.

Tensor product is required by the vision about zero energy insertions assignable to CH_i which correspond to causal diamonds inside causal diamonds. Also the assumption that zero energy states form an ensemble in 4-D sense - crucial for the deduction of scattering rates from M-matrix - requires tensor product.

4. The argument unifying the two definitions of self requires that the tensor product is restricted when CH_i correspond to causal diamonds inside each other. The tensor factors in shorter time scales are restricted to the causal diamonds hanging from a light-like radial ray at the upper end of the common past directed light-cone. If the causal diamonds are disjoint there is no obvious restriction to be posed, and this would mean the possibility of also precognition and sharing of mental images.

This scenario allows also to answers the questions related to a more precise definition of volume of attention. Causal diamond - or rather - the associated light-like boundaries containing positive and negative energy states define the primitive volume of attention. The obvious question whether the attention of a given self is doomed to be fixed to a fixed volume can be also answered. This is not the case. Selves can delocalize in the sense that there is a wave function associated with the position of the causal diamond and quantum jumps changing this position are possible. Also many-particle states assignable to a union of several causal diamonds are possible. Note that the identification of magnetic flux tubes as space-time correlates of directed attention in TGD inspired quantum biology makes sense if these flux tubes connect different causal diamonds. The directedness of attention in this sense should be also understood: it could be induced from the ordering of p-adic primes and Planck constant: directed attention would be always from longer to shorter scale.

4.4   Some applications at brain level

In this section the notion of self and related notions are applied to brain at general level. Due to the introduction of the notion of negentropic entanglement the representation differs from the earlier one decisively.

4.4.1   A simple model for cognition

The hierarchy of selves and summation hypothesis allows to construct a very general model for cognitive processes including as a special case thinking, analysis of visual experience, and language. In nutshell: cognitive process could be regarded as cascade like process leading to a generation of selves followed by generation of sub-selves for these leading to... . Quantum jump becomes the building block of cognition and thought but is not sufficient alone. p-Adic space-time sheets as correlates of cognition provide geometric correlates for thoughts, intentions, plans, etc.. are a fundamental element of cognition. The intersection of real and p-adic worlds understood as partonic 2-surfaces allowing an interpretation in both real and p-adic sense and the intersections of real and p-adic partonic 2-surfaces consisting of rational and common algebraic points define cognitive representations. Negentropic entanglement is possible only in the intersection in accordance with with the vision that cognitive representations carry the information.

Quantum criticality of TGD and existence of selves

The model of cognition provides a new view to the role of quantum criticality of TGD. One consequence of the quantum criticality could be the existence of a lot of sub-systems which are near the critical line at which phase transition changing the local topology (real or p-adic) occurs. TGD universe would be in a state of maximal alertness ready to generate cascades of selves representing cognitive acts. Our cognitive acts would be only part of the cognitive acts of the entire Universe proceeding from top to bottom as infinite trees with branches representing new selves and nodes representing moments of wake-ups for the selves. Or expressing it in the terminology of AI: we would be like subprograms of infinite program represented by entire universe. The presence of higher level selves means that cognitive acts can proceed from the level of even entire biosystem to the level of DNA. This encourages to interesting speculations: for instance, the ideas of Sheldrake about learning at the level of species and even biosphere might find justification [26].

Number theoretical criticality is an important aspect of quantum criticality and is taken to mean that life and conscious intelligence reside in the intersection of real and p-adic worlds, where discrete cognitive representations and transformation of intention to action and vice versa are possible.

Quantum jump as cognitive process

U process followed by a cascade of state function reductions will be identified as the basic cognitive act.

1. State function reduction can be characterized as a binary tree. At each step of the state function reduction cascade some subselves manage to remain unentangled, some subselves lose their consciousness by developing entropic bound state entanglement, or experience expansion of consciousness by entangling negentropically. A particular branch of the process stops if subself allows no decomposition to entropically entangled but otherwise free pieces. What is new is that the entanglement is also time-like and time-like entanglement turns out to be central for understanding of what happens in learning.

2. The binary tree of state function reduction has a natural ordering. This ordering need not have any correlate at the level of geometric time. At the level of subjective time and conscious experience the correlate for ordering could exist but if self experiences its subselves as averages of sub-sub-selves this cascade is experienced only partially by given subself. One can of course argue that self wakes up in each quantum jump separately and quantum jump sequence should be seen as a sequence of "awakenings" (I used this term earlier): this awakening is however something different from the emergence of mental image. Maybe time-like negentropic entanglement is which binds this sequence of "awakenings" to a continuous stream of consciousness that we experience.

3. The outcome of the state function reduction is random when it leads to un-entangled subself but statistical determinism implies reliability at the level of ensemble. For negentropic entanglement state function reduction is nearly deterministic process and in this case one can speak in reasonable approximation about an iteration of a unitary processes defined by the powers of U. This iterative process defines a self-organization process expected to be also behind learning.

4. One possible interpretation of the self cascade is as a representation for an abstraction process representing thoughts about thoughts about... Our poor ability to form statements about statements about ... would correspond to the fact that self experiences only its sub-selves directly. Another interpretation is as analysis, in which initial experience gradually sharpens and gets more and more structured during the decomposition into sub-selves. Sub-selves could be thought as symbols of language or as logical statements or objects in picture: interpretation depends on what kind of cognitive process is in question. This process occurs in several time scales- even in the time scale defined by human life cycle. The modular structure of cognitive acts is also analogous to the modular structure of a computer program: starting of subprogram means the reduction of entanglement for the corresponding subsystem.

One can see this process also at the level of imbedding space correlates.

1. Selves wake up and begin to perform quantum jumps. The imbedding space counterpart for self is CD (causal diamond) characterized by time scale coming as powers of two and is scaling like the value of Planck constant. Subselves correspond to sub-CDs. Wake-up requires a feed of metabolic energy to destroy the bound state entanglement. Self could be also created from vacuum or disappear to it in a quantum jump generating a completely new CD or annihilating it.

2. Cognitive process proceeds in a cascade like manner starting from the root of tree formed by CDs and going downwards along the tree choosing at each node some branches. For instance, understanding of a sentence would correspond to waking up of large self A representing sentence in its entirety, words its sub-selves B_i, phonemes to sub-selves C_{ij} of B_i, etc... waking-up in this order. Similarly, the act of decomposing the figure to objects and of objects to sub-objects would correspond to a temporal sequence generating selves within selves. Negentropic entanglement

would be crucial for experiencing both the whole and the parts simultaneously. Background would be the largest conscious self and objects would correspond to a sequence of selves. Selves C_{ij} and further sub-selves can be generated before generation of next C_{i+1}: this should occur in case linguistic mental image: generation of word self would be followed by the generation of syllables and phonemes and only after this would next word be generated. Time nonlocality of self experience with respect to geometric and subjective time would be essential.

4.4.2 Cognition, learning, and negentropic entanglement at the level of brain

Negentropic entanglement is information carrier and learning is gaining information. Does this mean that learning takes place automatically in the intersection of real and p-adic worlds? Unitary U-matrix between zero energy states characterizes single step of quantum jump sequences and for negentropic states the state function reduction is not random process and in the first approximation U^N characterizes the outcome of N subsequent quantum jump so that learning process should be characterized by the iteration defined by the powers of U.

In neuroscience synaptic contacts are believed to be crucial for cognition, learning, and memory and it is interesting to try to relate this picture to the TGD based vision about conscious information and learning. How negentropic entanglement could be realized at the level of brain? Is it time-like, space-like, or both? Can one assign the generation of negentropic entanglement between neurons to the attachement of neurotransmitter to receptor? Can one relate the general quantum model of learning to the neuroscience based model of learning relying on the growth of brain cells, synaptic contacts, and synaptic plasticity?

The picture of the standard neuroscience about learning

It is good to summarize first the vision of standard neuroscience about the neural correlates of learning.

    1. Basic notions

Synaptic transmission[81, 73] is believed to be a key element of brain consciousness. Synaptic transmission takes place as synaptic vesicles carrying neural transmitter. Given neuron can release several transmitters. The transmitter molecules bind to the receptors at the postsynaptic cell membrane. Depending on whether this process leads to a depolarization or hyper-polarization one speaks of excitatory or inhibitory receptors (activation potentials). Since most transmitters attach mostly to either kind of receptor, one speaks about excitatory and inhibitory transmitters although this terminology is misleading. Receptors can be classified to relatively simple ion channel receptors and more complex receptors involving second messenger proteins.

The belief is that the primary process does not involve communications with genome but if one accepts the DNA as topological quantum computer picture-in particular, on the existence of magnetic flux tubes connecting cell membrane and DNA nucleotides- the possibility that these communications are an essential element of process and that a new kind of gene expression at cell membrane level is involved. The communication to the DNA could take with light velocity if massless extremals are involved.

The synaptic strength characterizes the sensitivity of the postsynaptic neuron to the firing of the presynaptic neuron. It depends on the density of receptors and their activity as well as the total amount of neural transmitter transferred between neurons determined by the number of synaptic vesicles transmitted. This in turn depends on the size of the synaptic button. All these parameters are affected in learning understood as a change of synaptic strengths. It must be emphasized that learning in this sense should be seen as a neural correlate for conscious (or unconscious-to-us) learning and possibly of memory. What is essential that the respose of the postsynaptic neuron changes. This picture relies on the technical assumption that learning reduces to the changes of synaptic strengths. This assumption is probably an over-idealization: much more probably happens.

    2. Learning at brain level

Learning in the sense as it is defined above can take place at the level of both anatomy and physiology. Learning at the level of anatomy can mean growth of new synaptic connections and of even new neurons. For instance, the growth of new neurons in hippocampus is now understood to

be essential prerequisite for learning. It is believed that the information from the connections of old neurons is transferred to those of cortical neurons. This can of course happen but in TGD framework this is not necessary since the new view about time allows to interpret memory as communications with the brain of the geometric past.

Learning at the level of physiology is known as synaptic plasticity [75] and involves several mechanisms. Synaptic plasticity means that the sensitivity of the postsynaptic neuron to the signals from presynaptic neuron can change.

1. Sensivity means essentially the probability for the firing as a response to the firing of presynaptic neuron and this is controlled by the sign and magnitude of the activation potential and the increase of the sensitivity means a generation of stronger depolarization or weaker hyperpolarization. Postsynaptic neuron can become more or less sensitive to the presynaptic neuron whereas presynaptic neuron can send stronger signal by increasing the number of synaptic vesicles.

2. The change of the sensitivity of the postsynaptic neuron can take place several mechanisms [75].

   (a) The first mechanism involves the modification of protein kinases whose function is to phosphorylate the receptor which means essentially providing it with metabolic energy. The effectiveness of the protein kinases is regulated. Second mechanism depends on second messenger neurotransmitters regulating gene transcription and regulates the levels of key proteins at synapses. Gene expression is affected in this mechanism and the effect is long-lasting.

   (b) Third mechanism affects the number of ion channels (ion transfer between cell interior and exterior is basically responsible for the activation potential) and is involved with long term potentiation (LTP [70]) and - depression (LTD [80]) believed to be central mechanisms of learning memory. LTP is believed to be of central importance in hippocampus. The change of the density of receptors is one manner to achieve LPT or LTD. For so so called AMPA receptors [82] to which glutamate binds this mechanism is well-established. Also phosphorylation and dephosphorylation of AMPA receptors and change in the probability of glutamate release is a decisive factor.

3. The notion of Hebbian learning [69] applies to LTP. Hebbian rules summarizes the above picture as simple mathematical rules allowing computer modelling. When pre-synaptic and postsynaptic neurons fire simultaneously, synaptic connections are affected. Weak stimulations of several pathways add up. Also temporal summation takes place if the frequency of firing is high enough. Strong stimulation of one pathway affects also other pathways. More general formulation of the rules does not require the firing of the postsynaptic neuron. For anti-Hebbian learning desensitization takes place. Also non-Hebbian learning is believed to take place.

4. The change of the postsynaptic action potential need not be the only outcome of learning. If this were the case, the huge number of neural transmitters and receptors inducing different responses would not be needed. The change of the sensitivity is only one aspect of learning and as its relationship to conscious learning is unclear.

TGD based vision about cognition and learning

In the following a brief summary about TGD inspired view concerning cognition and learning in general and at brain level is given.

1. Basic ideas

The general ideas about cognition have been also discussed but is useful to summarize them again.

1. Subself interpreted as a mental image is key notion. Subselves wake-up, fall asleep, and fuse together losing consciousness or experiencing expansion of consciousness.

2. The cascade of state function reductions can be regarded as an analysis leading to a final state in which subselves are either entropically or negentropically entangled systems. The latter systems can be seen as negentropic mental images resulting as subselves fuse together. In the case that two sub-selves are involved, the resulting mental image can be regarded as an abstraction or

rule such that the state pairs appearing in the superposition correspond to the instances of the rule. If one state pair dominates then association in classical sense is in question in good approximation.

3. Negentropic entanglement can take place between systems which belong to same or different number fields and gives rise to various kinds of conscious experiences. At least in the case that the other system is p-adic, negentropic entanglement should be a correlate for the conscious experience of understanding.

4. Zero energy states for brain represent rules as pairs of positive energy (initial) and negative energy (final) states. M-matrix characterizes zero energy state and defines a rule representing "laws of physics" at the level of conscious experience. Different M-matrices are orthonormal with respect to each other and in ensemble all of them appear and each of them can be also regarded as representing one particular instance of a rule.

A new element is that unitary time evolution characterized by U-matrix forces the learning to occur in the sector of state space containing zero energy states for which positive and negative energy parts of the states are negentropically entangled. U-matrix and its powers characterize the learning process. When the states are negentropically entangled, state function reduction for M-matrix is not a random process but leads to a unique state maximing negentropy and in a good approximation the restriction of U matrix to these states codes for the evolution of M-matrix. U^N restricted in this manner characterizes the M-matrix after N quantum jumps. Therefore learning is unvoidable in the case of negentropic states and U^N at the limit of large number of quantum jumps characterizes the learning. The value of N is of course limited by the size of CD assigned to the learning system. One can of course wonder whether the unitary period is following by a return to unentagled state via the liberation of metabolic energy associated with the negentropic entanglement.

The powers of U define an iterative map and iterative maps are the key element of self organization and also one of the main tools of generating fractals [26]. Quantum classical correspondence therefore suggests that 4-D fractal self-organization patterns define the space-time correlates for learning.

2. General view about learning at the level of brain

M-matrix for brain codes its view about laws of physics. In diagonal form represents pairing of initial and final states as rules $A \to B$. For instance, in fermionic degrees of freedom these rules can be interpreted as Boolean rules. More generally, the interaction as quantum associations containing superposition of instances of the associations are in question. Huge quantum superposition of rules is possible since the number of neurons large and the information storage capacity of entanglement increases exponentially with the number of neurons.

U-matrix approximated as a matrix restricted to represent unitary evolution of negentropic zero energy states assignable to brain provides the first principle description for learning as the sequence of powers U^N. In the models of associative learning learning is reduced to a local process expressible in terms of changes of the synaptic contacts. This suggests that the basic building block of U matrix is synaptic transmission. This means an analogy with the basic braiding operation of the neighboring strands represented as R-matrix defining the unitry matrix for topological quantum computation [24]. There is also an analogy with generalized Feynman diagrams. The incoming particles would be neurons. Synaptic transmission analogous to particle exchange between two neurons. U matrix can be regarded as a quantum superposition over all possible diagrams containing arbitrary number of synaptic transfers. Multiverse picture at neural level thus results as one might expect since macrotemporal and macroscopic quantum coherence is involved. If the situation reduces in a reasonable approxiation to a description in terms of synaptic transfers one can in principle describe synaptic plasticity, LTP, and LTD and other mechanisms to in terms of the basic building block of U associated with the synaptic transmission and mathematically analogous to Feynman propagator. The binding to the receptor could induce communications with genome and also the U-matrix assignable to topological quantum computations at the DNA level might be involved.

As such this picture provides only a first principle formulation for what conscious learning is and it requires a work to deduce predictions testing this vision or at least to gain understanding using this vision. A key aspect of negentropic entanglement is that it carries metabolic energy. This has been already proposed to provide a first principle explanation for the notion of the high energy phosphate

bond crucial for the understanding of $ATP \rightarrow ADP + P_i$ process defining the key stop of metabolism [19].

Also space-like negentropic entanglement is possible for positive (negative) energy parts of the states. In particular, negentropic entanglement between presynaptic neuron and postsynaptic genome generated by the attachment of the transmitter to the receptor might make sense. There is temptation to assign to this connection a magnetic flux tube identified as a carrier of metabolic energy released in the process and inducing ionic currents leading to the processes affecting the synaptic strength as well as the states of neurons involved. The larger the metabolic energy release is, the more intense are the ionic currents involved and the stronger the modification is. This would provide a first principle explanation for why more effective phosphorylazation of the receptor as a correlate for learning. Of course, the explanation works even without the heavy conceptual machinery if one is ready to accept the somewhat nebulous notion of high energy phosphate bond.

4.4.3   Negentropic entanglement and the role of neurotransmitters

Soon after starting to develop TGD inspired theory of consciousness, I somehow ended up to an email correspondence with Gene Johnson who insistently emailed me links to abstracts about neuroscience. I read the classic Bible about brain by Kandel *et al* [72] and tried to make sense of it in my own conceptual framework. This was of course hopeless task since I had only the notions of quantum jump and self. The feeling that something very simple -about which I do not and perhaps cannot ever have a slightest clue- must be behind this incredible complexity made the situation really frustrating. The deeper meaning of EEG, nerve pulse neurotransmitters, hormones- actually of entire brain chemistry and also biochemistry- remained a total mystery.

Development of ideas

After the required number of years however some concrete ideas began to emerge.

1. The notion of magnetic body with fractal onionlike structure meant a decisive step of progress. Also the hierarchy of Planck constants and dark matter as controller of visible matter in living systems emerged. The function of EEG as communication and control tool of magnetic body using biological body as a motor instrument and sensory receptor looked very natural. This led also to a proposal that there is an entire hierarchy of EEGs and their variants. After several trials a vision about nerve pulses as concomitants of quantum level communications emerged as also a vision about DNA as topological quantum computer based on the flux tubes connecting DNA nucleotides with the lipid layers of cell membrane emerged and providing a function for the intronic portions of genome as carriers of quantum computer programs [24].

2. Also a vision about the biochemical role of dark matter evolved. In particular, phase transitions reducing Planck constant for a magnetic flux tube would induce its contraction and force biomolecules near to each other. This would explain the miracles of DNA replication, translation, and transcription and quite generally the processes known as aggregation of proteins. The reconnection of magnetic flux tubes changing the topology of the biological Indra's net would be also a central mechanism.

3. The model of nerve pulse and the vision about living matter as a kind of dynamical Indra's net led to a first clear idea about the role of neural transmitters. Transmitters are classified to inhibitory or excitatory depending on whether they increase or reduce the magnitude of the membrane potential. This property is however a property of the receptor rather than that of the transmitter. The same transmitter can have both excitatory and inhibitory receptors although often either receptor type dominates. The proposal was that neural transmitters are associated with the ends of the links of the 4-dimensional web connecting neurons to each other. Neurotransmitter attaches to the plug defined by the receptor connecting the communication wire from presynaptic neuron to the flux tube leading to the passive portion of postsynpatic DNA strand acting as sensory receptor. This would make possible rapid communications to DNA. The corresponding active portion of DNA strand could then respond by generating an activity at the level of cell membrane. This conforms with the general idea that proteins represent only one particular outcome of the gene expression. This left open the question whether the excitatory-inhibitory dichotomy could have some deeper meaning.

4. Also it became clear the emotions and information are closely related and that peptides acting both as neurotransmitters and hormones are crucial for emotions [72]. I proposed that emotions are "entropic" qualia. Although I realized the importance of negentropic entanglement I did not have time or I was not able to realize how far reaching this notion actually is.

Is genome a fractal counterpart of brain?

Fractality replaces standard reductionism in TGD Universe. An old idea inspired by p-adic length scale hypothesis is that the binary structures associated with p-adic scales $L(k) \propto 2^{k/2}$ and $L(k+2)$ define a fractal hierarchy. Brain hemispheres would represent one example of this kind of pair, lipid layers ofe cell mebrane second one, and DNA double strand third one. Just for fun one could assume that the structure and functions of brain hemispheres have fractal analogs at the level of DNA double strand and vice versa and look what kind of questions this inspires.

1. Could the identical structures of DNA strands correspond to the anatomical similarity of right and left brain and could the functional asymmetry of the strands correspond to the lateralization of brain function? Could the genome act as the brain of cell? Could various brain areas have counterparts at the level of DNA? Could the hydrogen bonds between nucleotides serve as the counterpart of corpus callosum? Could the splitting of these bonds during transcription and replication correspond to what happens to a split brain patient?

2. Before continuing it must be made clear that the global identification of right-left dichotomy with holistic-reductionistic dichotomy is wrong. One can however consider its local variant with holism and reductionism assigned do the pairs of right and left brain areas. For instance, in contrast to the naive rule the emotional right (left) brain (amygdala) would be reductionistic (holistic,negentropic) whereas the intellectual right (left) would be holistic (reductionistic,entropic). The practical reason to the division to the entropic and negentropic pieces could relate to the metabolism. The entropic regions could provide the binding energy as a usable energy to the positive energy negentropic entanglement. Good is not possible without Evil! There are no winners without loosers!

   Right brain is specialized in spatial thinking and left brain to verbal thinking and arithmetics: the geometry-algebra division of mathematics! Right brain is not so good in motor actions as left brain as any right-handed person knows. Right brain is however better in tactile sensing: right handed persons tend to use left hand for touching objects to get an idea about their shape. Also this can be understood in holistic-reductionistic picture.

3. Apart from reflex actions almost all activities of the body seem to be controlled to a high degree by brain. Could also the activitites of cell be regarded as motor actions of the genome acting as the brain of cell receiving sensory imput from the cell membrane? Could one identify the analogs of sensory areas receiving information from cell membrane, processing, and sending it to the association areas? Could the analogs associative areas be identified as intronic portions of DNA performing topological quantum computations and communicating the outcome to the higher motor areas at the intronic portions of the of the complementary strand, wherefrom they would be communicated to the primary motor areas identifiable as the regions of DNA expressing themselves either chemically (RNA and proteins), as activitites generated directly at the level of cell membrane, or electromagnetically? For instance, could neurotransmitter in the receptor generate the feed of sensory input to the genome inducing the change of the membrane potential as the counterpart of motor action. Could prokaryotes without introns be analogous to brain with only primary sensory and motor areas or to mere ladder-like nervous system?

   One could argue that the analogy between DNA are brain fails because second DNA strand is completely passive whereas both brain hemispheres express themselves via motor actions. This is not the case! Both DNA strand has regions expressing themselves but the transcription takes place in opposite directions. Hence DNA strands have motor and sensory areas as also brain does, and the natural guess is that primary motor areas correspond to the areas expressing themselves in terms of RNA, proteins, and possibly also as actions at the level of cell membrane. Primary sensory areas would correspond to to regions complementary to the primary motor regions.

4. What right brain sings-left brain talks metaphor could mean in this picture? Pitch-rhythm dichotomy is more technical expression for this dichotomy. Function providing local data and its Fourier transform providing global data is more abstract representation for this dichotomy and Uncertainty Principle for momentum and position relates closely to these two representations of information. This dichotomy could reflect the presence of two different natural time scales and millisecond time scale for nerve pulses and .1 second time scale for moments of sensory experience are the natural candidates.

If so, this dichotomy could directly reflect the different time scales assignable to u and d type quarks (1 millisecond) and to electron (100 ms) and reduce to the level of elementary particle physics. This dichotomy would also have fractally scaled up variants made possible by the hierarchy of Planck constants. The analog of Fourier transform would be the negentropic unentanglement of sub-CDs (assignable to quarks) to single mental image inside electron's CD. The analog of function itself would be a collection of sub-CDs representing separate unentangled mental images assignable to individual nerge pulses in millisecond time scale. Also the topological quantum computations assigned to the intronic portions correspond to different time scales due and reflect quark-lepton dichotomy. The quarks in question could be the quarks assigned to the ends of flux tubes in the model of DNA as topological quantum computer.

5. This raises some questions. Could the gene expressions of the two strands somehow reflect this dichotomy? For instance, could the flux tube structures assignable to the aminoacid sequences correspond to the millisecond and 100 ms scales assignable to quarks and electron have the property that also the functioning of these proteins is characterized by these typical time scales? According to [61] the time scales of protein folding vary from .1 s to 10^3s. According to Wikipedia [60] the typical time scale is 1 millisecond which suggests that the time scales correspond to two ranges beginning from ms and 100 ms respectively. There are also short proteins for which the folding takes place in microsecond time scales which might relate to the CD of proton.

What can one say about the function of neurotransmitters?

Can one say anything interesting about the function of neurotransmitters if one combines this highly speculative picture- which can be defended only by the belief on fractality as universal principle- with the idea that bound state and negentropic entanglement make possible the fusion of mental images.

1. Suppose that the fusion of neuronal mental images is required to build higher level mental images that we experience. Suppose that neuronal mental images involve DNA in an essential manner. Suppose that magnetic flux tubes serve as correlates for the entanglement so that the transmission of nerve pulse from pre-synaptic neuron to post-synaptic one creates a flux tube connection between neurons possibly extending to the genome of the post-synaptic neuron. The transmitter at the end of flux tube attached to the receptor acting as a plug would build this connection to some part of DNA specialized to receive particular kind of sensory data from a particular region of cell membrane with complementary strand activating as a response a motor function inducing gene expression at cell membrane level. Gene expression as build-up of proteins would not be necessary and is also too slow for neural activities.

2. Suppose that the entanglement between neurons generated in this process is always negentropic as the interpretation as the idea about neural correlate for a conscious association suggests. One could also ask whether the neurons could entangled entropically and whether the entropic-inhibitory association could make sense. This does not lead to anything interesting and entropic entanglement between neurons should be regarded as a pathological condition. Note that neuron-neuron entanglemement would be naturally time-like and in this case only negentropic entanglement might be meaningful.

   (a) To gain some perspective consider the activation of cell in general by some external perturbation from the resting state to the active state (here I have learned a lot from email correspondence with Vladimir Mateev) In the resting state the proteins inside cell are passive -or rather, forced to be passive- as one might expect on basis of the general vision about homeostasis. The unfolded proteins and unfolded portions of the folded proteins are connected by hydrogen bonds to ordered water so that the folding occurring otherwise

spontaneously is prevented. One can say that the cellular winter prevails. The situation is however nearly critical and if external perturbation occurs cell liberates metabolic energy melting the ice and spring comes. Also the outer surfaces of globular proteins are hydrogen bonded and when the ordered water melts, spontaneous melting of the protein takes place leading to a partial unfolding.

The resulting folded proteins and partially unfolded globular proteins interact by forming aggregates and this activity would naturally involve $\hbar$ reducing phase transitions and flux tube reconnections. In TGD based model the mechanism of both folding and melting would be the liberation of metabolic energy destroying the hydrogen bonds and the energy for this comes from the ATP containing positive energy negentropic bond between O=s of phosphates.

(b) Similar situation could prevail at the cell membrane. One can imagine that cell membrane is like a particle at the bottom of a small potential well. At the other side there is a deep well representing the generation of nerve pulse and at the other side a high wall corresponding to hyper-polarization requiring energy. Both polarization and hyperpolarization are prevented by the freezing of protein activities needed to induce them. The flux tubes connecting the presynaptic neuron and receptor and possibly genome are always negentropic and their formation can as such serve as the signal leading to the partial melting of the ordered water making possible to generate action leading to either depolarization or hyperpolarization. The signal could be just the additional metabolic energy making it possible for these transitions to occur.

(c) This picture does not require any communications from the receptor to the genome and in the simplest situation the resulting action could be seen as the analog of reflex action. These communications could of course be present and the negentropic entanglement could make it easier to induce depolarization also now. Also the question whether excitatory-inhibitory dichotomy for the receptors has some deeper meaning apart from taking the neuron nearer to or farther from criticality for firing remains unanswered.

4.4.4   Differences between left and right brain hemisphere

The differences between left and right brain hemisphere or lateralization of brain functions -as the more technical term states it - represent a challenge for any theory of consciousness. This difference is often stated by saying that right brain is holistic and left brain reductionistic - or more concretely - that left brain talks and right brain sings, left brain is linear and right brain parallel, or that left brain is algebraist while right brain is geometer. The assignment of the holism-reductionism to the hemispheres as whole is probably an exaggeration. For instance, right limbic brain is specialized to negative emotions and left limbic brain to positive emotions and it is not clear whether this has anything to do with holism or reductionism. It could however be that pairs of various left and right brain regions could be characterized in terms of this dichotomy or perhaps trinity in which reductionism, holism, and their fusion are possible but that a given region of given hemisphere can favor any of these options.

Holism, reductionism and their fusion, entanglement, and zero energy ontology

In TGD framework the basic mechanism responsible for reductionism-holism dichotomy would be the possibility of the mental images to fuse to larger mental images. Depending on the nature of entanglement the resulting mental images are either negentropic or entropic. Entropic entanglement represents a holism as the antipode of reductionism whereas negentropic entanglement seems to represent a fusion of holism and reductionism. It would be tempting to assign positive emotions to the negentropic entanglement and negative emotions to the entropic entanglement. Both limbic hemispheres could be holistic but negentropic-entropic dichotomy would distinguish between them.

For the purposes of survival it is good to have both all these three views about reality. In politics hawks, doves and compromize makers would be a counterpart for this phenomenon. This would favor lateralization in a more general sense that a brain region in given hemisphere favours unentangled emotionally neutral mental images, negentropically fused mental images with positive emotional coloring, or entropically fused mental images with negative emotional coloring. Also metabolism could

favor formation of the unpleasant entropic mental images since this liberates energy which could be stored in metabolic entanglement as a metabolic energy. Interestingly, it has been proposed that the simultaneous presence of holism and reductionism could explain the amazing mental feats of idiot savants. The irony is that these persons are usually unable to describe their experiences using language, which brings in mind the reports of meditators telling that it is impossible to tell anything about englightment experience using language. Maybe language relates crucially both to the ability to decompose the mental images to smaller pieces and to form entropically entangled wholes of them.

I might be self-contradictory here. On one hand, I have proposed that the feats of idiot savants are possible because they do not conceptualize and in this manner replace reality with the names of the objects of the reality: something extremely economical if one counts bits. On the other hand, I am proposing that the formation of concepts corresponds to the negentropic entanglement. It seems that I should distinguish between two kinds of conceptualizations: the negentropic entanglement without language on one hand achieved in meditative practices and the combination of both entropically entangled and non-entangled representations making possible language but losing the insight of genius.

Zero energy ontology suggests a quantitative formulation of this vision based on the observation that the time scale of electron's CD corresponds to the .1 second time scale defining fundamental biorhythm whereas millisecond time scale defining the fundamental time scale of nerve pulse activity could relate closely to the time scale of CDs assignable to u and d quarks predicted to play a key role in quantum information processing in the model of DNA ast topological quantum computer. There are also shorter times scales, in particular the time scales assignable to proton which can be estimated to be of order 10^{-7} seconds. Also p-adically scaled up variants of these time scales are possible as well as zooming of these time scales at the pages of the Big Book defining generalized imbedding space and partially labeled by the values of Planck constant. The first guess is that quark and lepton time scales are behind the reductionism-holism division. Holism would mean temporal binding of the mental images assignable to nerve pulse patterns and characterized by millisecond time scale to negentropic (or possibly entropic) subselves characterized by .1 second time scales. Quark like sub-CDs of electronic CDs would serve as imbedding space correlates for these mental images.

Objection against simplistic view about lateralization

The hypothesis that right brain is more holistic than left brain can be tested and a considerable support for the hypothesis have been found. There is however a rather paradoxical experimental result challenging the hypothesis in its simplest form and suggesting that the roles of various processing levels of brain hemispheres in the specialization to geometric shapes and linguistic symbols can vary. In [68] there is report about two experimental situations testing right-left differences.

1. Subject persons saw figure S consisting of smaller figure F:s. On basis of neural firing left brain seemed to recognize smaller F:s whereas right brain seemed to recognize the entire figure S: just as expected.

2. For control purposes figure S consisting of small F:s was replaced with a figure of anchor consisting of small cups. What happened was that left brain recognized the anchor and right brain recognized the cups! Also firing patterns were essentially the same! It was conjectured that the smallness of cups -smaller than letter F:s- might have something to do with the unexpected result.

Apparently the replacement of letters with geometric shapes means that the roles of brain hemispheres changed. This suggests that the naive vision about roles of hemispheres must be replaced with something more complex in which one has scale hierarchy of levels such that each level has its own specialization.

1. Suppose first that at the lowest level of the hierarchy the left hemisphere is better in recognizing letters than familiar shapes and right hemisphere better in recognizing familiar geometric shapes than letters.

2. The subject persons are asked to concentrate on either the entire figure or details which repeat themselves. This raises the question whether a single detail becomes actually the whole since the attention is directed to details. If this is the case, the first assumption would explain why

right brain hemisphere fires as cup is recognized. Same applies to the left hemisphere in the case of letter F.

3. When the figure as a whole must be recognized, the recognizing hemisphere seems to be the one for which the recognition should be more difficult! The hierarchy of CDs allows to consider the possibility that there is a fractal hierarchy of levels corresponding to different size scales for the structures appearing in the figure. The very fact that subject person is conscious about the existence of smaller details means that smallest structures are mapped to the first level of the hierarchy so that in both cases the figure as a whole would be mapped to the second level of the hierarchy. If one takes the experimental result at a face value, letters should be more familiar to the right hemisphere and geometric shapes of everyday objects to the left hemisphere at the second level of the hierarchy.

4. That the roles of brain hemispheres in lateralization depend on the level of the hierarchy might have an explanation in terms of basic information processing involving communications between hemispheres. Maybe there is a mapping from the first level of hierarchy of a given hemisphere to the second level of hierarchy at the opposite hemisphere and so on. At higher levels of the hierarchy the hemispheres would perceive each others visual percepts. Right hemisphere at the n:th level would receive sensory signals from $n - 1$:th level of left brain and vice versa. In this kind of situation the maximal effectiveness of the information processing would be achieved if these two ladders rather than hemispheres have similar specializations.

Some examples

This framework explains various aspects of holism-reductionism dichotomy when given pair of brain regions is considered but it is not meant to apply to brain hemispheres as a single pair.

1. Linear-parallel dichotomy suggests that in a given time scale left hemisphere corresponds to large number of un-entangled subselves whereas right hemisphere would correspond to a larger number of entangled subselves with entropic (at least in case of limbic brain) or negentropic entanglement. For instance, the unentangled subselves can correspond to letters of written text at left hemisphere. At right hemisphere they could correspond to objects of everyday life or even understood words of written text with mental images representing letters entangling negentropically in time direction to form a single mental image. Also much smaller details such as edges an lines of figure having no direct meaning are certainly involved.

   Left brain seems to be skilled in forming mental images about structures consisting of well defined components whereas right brain can grasp the general shape and size of the structure (note however the previous example in conflict with this belief). This could be understood if left brain represents structures linguistically as associative linear structures consisting of parts represented as sub-selves. Thus a structure could be realized as a reverberating neural circuit in which sub-selves representing parts of the structure keep each other awake.

2. Right hemisphere is also claimed to be less analytic. It might be that also this might hold true only for the right-left-right-.. information processing hierarchy when compared with left-right-left... hierarchy beginning from left brain hemisphere. Certainly the entanglement of mental images would explain this.

3. That left brain talks whereas right brain (almost) sings is more than a loose metaphor. It is known that people who have left brain injury and cannot talk can sometimes express themselves by singing. Linear-parallel dichotomy would suggest that left brain is specialized to subjecto-temporal sequences of parallel small-sized mental images of short duration (say words of speech): this would correspond rhythm and other temporally local aspects of music which dominate in speech. Right brain is specialized to large selves formed by the fusion of parallel sub-selves formed by, say, separate notes of music which can last long time and have no linguistic content. These mental images should carry conscious information about non-local aspect such as pitch of the sound. Although the notes of song are heard one in time, they would continue to live in right brain as parallel mental images and make possible to experience the melody as sad or joyfu or to remember the key of the music piece.

4. The poor temporal and spatial resolution assigned to the right hemisphere can be seen as a price paid for the holism of entanglement. Again one must however remember that a scale hierachy might be involved.

5. The claim that right brain is more emotional should be taken with a caution. It seems better to say that the right limbic brain is dominated by negative emotions and left limbic brain by positive ones. The interpretation would be in terms of entropic *resp.* negentropic entanglement: in this sense left brain would have higher emotional intelligence. On the other hand, right brain is claimed to have better skills in recognizing and expressing emotions. This is not in conflict with the fact that left brain hemisphere is the happier hemisphere. These skills could be understood as a more holistic expression of emotions and their perception, and migh also relate to the ability of the right hemisphere to generate negentropic entanglement with other brains.

Dr. P. and twins who saw primeness

Oliver Sack's book 'The man who mistook his wife for a hat' [79] contains fascinating stories about those aspects of brain and consciousness which are more or less mysterious from the view point of neuroscience. There are two stories which relate very closely to reductionism-holism tension of conscious experiencing.

The first story is about Dr. P. who suffered visual agnosia and could not recognize concrete objects, say faces unless some nonvisual association was involved. He could however recognize abstract symbols or objects containing some symbolic details making possible the recognition (he recognized Einstein's face, which has indeed become a symbol of wisdom!). Sacks tells about how his patient tried to recognize glove. 'A curved shaped containing five small bags' was his abstract analysis: he could not identify the glove as a glove unless he got it in his hand! He could however define glove as an abstract geometric shape allowing simple linguistic description. Dr. P. could identify abstract shapes and symbols like letters and geometric objects but could not recognize real world objects. Amazingly, Dr. P. used musical associations as a manner to cope with the complexities of everyday life. He singed through all his everyday activities and lost control totally if this was for some reason not possible. He could also continue teaching of this music class. For instance, he could recognize his music students only when they moved by recognizing their 'body music'.

As discussed, reductionism-holism duality provides the deep reason for why we have two brain lobes. This allows to understand what might be possibly involved with Dr. P:s case. Dr. P:s right visual areas had been damaged and he could not recognize faces and concrete objects of the visual field. Left visual areas were in good condition and he could identify abstract objects. Other than visual areas were still in good condition in both hemispheres and he could perform recognition using musical associations, associations created by smells, etc... Sacks notices also a deep analogy with Dr. P.:s case and neuroscience. Expressing rather freely what Luria said, entire neuroscience up to seventies provided analytic description of left brain about left brain. It had indeed turned out very difficult to assign any easily identifiable cognitive dysfunctions with localized right brain injuries and Luria's opinion was that this necessitated completely different approach which he called 'romantic' (stories of right brain about both right and left brain!).

In fact, one can formulate new kind of Uncertainty Principle, perhaps it might be called Uncertainty Principle of cognition. Same mental image cannot be both holistic and reductionistic simultaneously. The combination of reductionistic and holistic descriptions (and all possible intermediate descriptions combining parts to subwholes in various manners) to single description is impossible even in principle! Science and Art as descriptions of the world are very much like mutually incompatible observables of Uncertainty Principle! The obvious reaction of the alert reader is that negentropic entanglement might allow to achieve both reductionism and holism simultaneously. Maybe this is the case but in this case there is no manner to communicate the mental using language if the proposed interpretation is correct.

Sacks tells also about twins, John and Michael, who had mysterious ability to 'see' large numbers. For instance, matchbox was dropped from the table and its contents were spread along the floor. Both twins shouted immediately '111!'. Then John mumbled '37', Michael repeated it and John said '37' third time. Obviously this was their cognitive representation for the decomposition 111=3x37 of number 111 to a product of primes!

How John and Michael did these numerical feats? The first thing to notice is that twins had

intelligence quotient of about 60 and could not perform even simplest arithmetical operations. They did not even understand what the concepts of prime and decomposition into prime factors mean conceptually. They however experienced primes as especially interesting numbers and even played a game in which they invented new primes. One can safely assume that they did not consciously calculate the decomposition of number 111 to a product of primes. When asked how they were able to tell the number of matches, they told that they 'saw' it. In fact, their eyes moved in strange manner always when they were performing numerical tasks and stopped when the solution was found. Also the decomposition of 111 to a product of 3 primes '37' seemed to occur completely spontaneously 'in front of their eyes'.

The mysterious ability of twins is not a mere curiosity but could provide a crucial clue to the problem of understanding of how numbers are realized as mental images. Indeed, also ordinary human beings are able to experience directly 'N-ness', when the size of N is small. A sensory memory associating the visual mental image with the verbal representations of 'N' could be in question. This association resembles synesthetic associations, which are also completely automatic.

Thus the problem transforms to a more general question 'How integers are experienced directly?'.

1. In TGD framework the answer to the question is obvious. Experiencing of 'N-ness' means experiencing 'N' separate objects as a single whole and corresponds quantum physically to the generation of negentropic entanglement between the cognitive representatives of individual objects. If the resulting mental image associates automatically with a linguistic expression for 'N-ness', say '$N = 5 \leftrightarrow five$', reportable recognition of 'N-ness' occurs. 7 ± 2 law suggests that this entanglement and association usually occurs only for maximal number of objects not larger than $N = 7 \pm 2$. In case of a numerical genius this number seems to be drastically higher. The generation of this entanglement should be spontanous self-organization process in either brain hemisphere and entangled objects could correspond to separate neuron groups or neurons.

2. The decomposition of integer $N = N_1 \times N_2$ to a product of integers must in this picture correspond to the spontaneous formation of identical 'sub-wholes'. This process must be a quantum self-organization process. It could favour the decomposition of $N = N_1 \times N_2$ objects to N_1 'sub-wholes' consisting of N_2 entangled basic objects or decomposition of N_2 sub-wholes consisting of N_1 basic objects or something else depending on factors of N. This kind of final states of self-organization are natural since they are very symmetrical consisting of a repetition of an identical basic unit. This kind of self-organization patterns are analogous to the lattice-like self-organization patterns of Benard flow.

3. NMP [29] could be involved in the following manner. Suppose that the perception of the number of N objects generates in brain an ensemble consisting of N mental images, which entangle negentropically. If so, then the simplest expectation is that entanglement probabilities are proportional to $1/N$ and the number theoretical entanglement entropy is large only for p-adic primes dividing N. The prime divisor of N giving rise to the largest number theoretic negentropy would determine the p-adicity involved and this could correspond to a perception about the decomposition of the visual representation of N to N/p pieces.

The model also explains the ability of twins to see whether a given number is prime or not. Primes are stable against decomposition into sub-wholes and are therefore 'elementary particles of cognition'. Hence primeness is a 'visible' property: primes are numerical mental images stable against decay to a set of identical numerical mental images. Note that this dynamical process breaks the symmetry between the factors of integer. This clearly occurred in 111= 3×37 example. Twins did not 'see' '3': they saw only some 37's and did not explicitly tell that there were precisely three 37:s!

In [33] a more concrete model for how real space-time sheets could represent integers and their prime factorization by their effectively p-adic topology, is discussed.

4.4.5   Music and consciousness

Music experience provides an interesting testing ground for several assumptions of quantum TGD and TGD inspired theory of consciousness. The notion of self is especially interesting in this respect.

Some aspects of music experience

It is good to list first some elementary characteristics of music experience that the model should be able to explain. Both rhytmic aspects and pitch of the sound are important. Rhytmic aspects correspond to time domain representation for the intentisity of sound carrying local information about sound wave whereas pitch carries global information. The relationship between these two elements of music is like that of function and its Fourier transform. Harmony enters the game when several frequencies are present.

1. Rhythm

There are two basic types of views about rhythm, additive and divisive, and they correspond to the multiplication and sum as basic arithmetic operations.

1. In western music rhythm corresponds to a division of longer periods of time divived into smaller rhytmic units. Rhythm is basically a clock and rhytm is essentially a decomposition of integer to a product of integers defining the rhythmic unit and their number. Classical western music is relatively simple rhythmically (consider only the music of Bach). In the music of Chopin tempo rubato makes the duration of the basic rhythmic unit and of its basic structural elements dnamical but rhythms are still relatively simple altough simultaneous 3/4 and 3/8+3/8 appears often. In jazz and various forms of popular music rhythms tend to be highly clocklike but are very complex.

2. In Indian music for instance, rhytms are additive and larger periods of time are constructed from smaller rhythmic unis added to the end of the previous unit. This division corresponds to addition rather than multiplication algebraically. Also intermediate forms can appear and do so often in folk music (say folk music of Greece, Balkan, and Spain). For instance, one can have the sum of 3/4+3/8+3/8 as a repeating rhytmic unit. In flamenco form known as Bulerias [76] the basic rhytmic unit consists of 12 beats and the collective performance creates a very complex and emotionally catching rhythm, which is almost impossible to analyze to pieces. It is easy to believe the claim that artists often fall in trance during the flamenco sessions.

2. Pitch

Pitch can be identified as the fundamental frequency of note. Pure sine wave is aesthetically unpleasing and harmonics are always present and characterize the music instrument. Not only frequencies but also phase relationships between them are important. For instance, they distinguish between the phonemes of spoken language and in the case of singing this brings in an important additional element not so important for non-electronic instrumental music. Furthermore, melody is never a mere sequence of precisely defined frequencies. For instance, slow modulations of the pitch reducing mathematically to a superposition of closely separated frequencies and glissandos have emotional affect.

The model of music experience should explain also the following aspects related to pitch understand as fundamental frequency.

1. Octaves of the fundamental are experienced as equivalent. The presence of higher harmonics is needed to make pure sinus wave a musical note. Higher harmonics determine the character of the pitch chracterizing the music instrument.

2. There exists a large number of different scales to which one assigns attributes like diatonic, minor, chromatic, whole tone, pentatonic, diminished... All these scales have quite specific emotional coloring and they characterize different music styles. The minimum frequency interval corresponds to a minimal scaling of the frequency and depends on music style. Western classical music uses semitone as the basic unit correwponding to the scaling $2^{1/12}$ in equally tempered scale but also microintervals are used and the only limitation comes the from ability to discriminate between different frequencies. The scales have special notes such as tonic, supertonic, mediant, subdominant, dominant, submediant, subtonic with special roles in harmony. For instance, listener is often able to remember the basic scales even if the tonic of the scale has suffered several modulations during the music piece. Deviations from basic scale have important emotional effects (say in the case of minor scale).

3. Ancient mathematicians believed that the presence of rational multiples of fundamental frequencies are essential for harmony. It is possible to construct the basic scales involving only rational multiples of the fundamental in terms of selected harmonics. For instance, Pythagorean construction uses only powers of 3/2 and octaves to construct the basic scale (C,G,D,A,E,H,...). Although the pitch is distinguished only within a finite resolution and equally tempered 12-note scale uses only powers of $2^{1/12}$ of the fundamental, rational multiples of the fundamental might relate deeply to the basic physics of cognition and to the frequencies generated in brain as opposed to those used to produce the music.

4. The expectation of an engineer is that the transposition of the scale should not effect on the music experience and one could think that it could be done in a continuous manner. Many composers, for instances Sibelius, experienced different modes differently and as synesthetes assigned to them different visual associations. Many people are able to recognize the ratios of notes but there is also the much rare phenomenon of absolute ear meaning that subject person is able to tell the pitch of the note directly. A synesthesia like phenomen is probably in question.

5. An interesting question the notion of absolute scale could make sense to some degree? The fundamental frequency of sound producing organs is 10 Hz and the region of audible frequencies begins at 20 Hz and consists of approximately 10 octaves. kHz frequency is the resonance frequence of head sized object and at this frequency the mechanism allowing to deduce the direction of sound source changes. The biological basis for this would be that 10 Hz and 1 kHz define fundamental biorhythms. The quantum physical basis for this could relate to the p-adic length scale hypothesis predicting that 10 Hz and 1280 Hz could correspond CDs of electron and quarks. To get a contact with concretia note that soprano C corresponds to 1046.50 Hz. Also the cyclotron frequencies assignable to various biologically important ions in endogenic magnetic fields could defined preferred scales. The A above middle C corresponds by convention to 440 Hz, which is integer multiple of 10 Hz but by pure convention and fifth octave of 8.175 Hz which is not too far from the lowest Schumann resonance. An interesting question is whether the transposition to a scale for which the fundamental is simple rational multiple of 10 Hz or lowest Schumann resonance might have some specific emotional effect.

3. Harmony and other collective aspects of music

Harmony relates closely to the interaction of different frequencies and is therefore one particular collective aspect of music experience.

In the terminology of physicists, harmony is a phenomenon of many particle physics with particles replaced notes of the scale and many-particle states with chords. Depending on the ratios of the frequencies certain chords are aesthetically pleasing and emotionally significant and there are also principles governing aesthetically pleasing chord progressions. Harmony might be seen as the vertical aspect of the music whereas melody would correspond to horizontal one. Dissonance is the opposite of harmony and tritonus was forbidden in the early western music but is nowadays used to create tension. Polyphony -say in Bach's music- and simple chords used to accompany singing represent two opposite views about harmony. Chopin's music has especially rich harmonies and emotional expressive power.

While listening music one typically selects some instrument as figure and the rest as a background. In romantic piano concertos the competition between the solist and orchestra about the attention of the listener creates the basic tension. In polyphonic music one must also select the tone progression to which attention is directed and it is difficult -perhaps even impossible- to simultaneously grasp the separte tone progressions. Same applies to other elements of music.

Zero energy ontology, hierarchy of Planck constants, and number theoretic physics

The number theoretic vision brings interesting new physics elements which might help to understand music experience.

1. The hierarchy of selves has as an imbedding space correlate the hierarchy of CD is basic prediction. p-Adic length scale hypothesis suggests that quantization of size scales of CDs as octaves and the question is whether this relates directly to the preferred role of octaves in music experience. The time scales of CDs define preferred fundamental frequencies coming as octaves and

the hierarchy of Planck constants defines scaled variants of these as rational or integer multiples (depending on generalization of the imbedding space).

2. The question is whether these fundamental frequencies also define fundamental keys so that music experience would depend on absolute frequency scale. Even if CDs define fundamental keys, the frequency scale associated with sub-CD as experienced in the rest system of CD can be scaled continuously by performing a Lorentz boost for CD. Even glissando could be achieved for CD by performing to the sub-CD a Lorentz boost continuously and leaving the other tip of CD invariant. The boost would be the hyperbolic analog of an ordinary rotation and act like acceleration from rest to constant velocity inside sub-CD. If one takes this picture seriously also Lorentz boosts would be important part of the representation of music at the level of magnetic body (presumably using MEs). Quantum TGD proper suggests the quantization of these boosts.

3. Number theoretic vision predicts an infinite number of algebraic extensions of p-adic numbers -in particular those corresponding to roots of unity. In the p-adic context the proper representation of sine waves requires the introduction of these algebraic extensions and the prediction is that rational multiples of the fundamental frequencies assignable to p-adic length scales should have a special role from the point of view of cognition.

   This might justify the belief that the notes of the scale should be expressible in the optimal situation as rational multiples of the fundamental note. The cognitive representation of the music in the intersection of real and p-adic worlds should map the physical frequencies or rather the sine waves at a discrete set of time values to their p-adic counterparts. One has to deal with phase factors defined by plane waves $exp(ift_n)$ at discrete set of points t_n such that the exponent equals to $exp(i2\pi m/N)$ and belongs to the algebraic extension. The harmonics of f obviously satisfy the same condition. The representation of pitch in terms of algebraic extensions of rationals requires that the corresponding partonic 2-surfaces correspond to complex enough algebraic extensions of rationals containing high enough roots of unity. The modulation of the pitch as superposition of two nearby rational frequencies could is possible without leaving this framework.

4. One can consider also different but not exclusive explanation for why scales define preferred collections of frequencies. Pythagorean scale involves rational multiples of fundamental obtained as powers of 3/2 and 2 so that the frequencies involved correspond to rationals of form $3^m 2^n$ for which only 3-adic and 2-adic norms differ from one. Small-p p-adicity associated with $p = 2$ and $p = 3$ could select the preferred frequencies.

Why octaves are experienced similarly?

The model should explain the basic features of music experience. There are many interesting questions related to this. One of the most important is why frequencies which are 2^k- multiples of the fundamental frequency, notes differing by octaves, are experienced as identical notes.

   1. p-Adic length scale hypothesis, zero energy ontology, and octaves

   Thus the phenomenon of octaves could relate to the p-adic length scale hypothesis, which implies that physically preferred p-adic primes correspond to primes near prime power powers of two. For instance, this implies that the massless extremals (MEs) associated with physically important p-adic primes have fundamental frequencies which are octaves of each other. Therefore a classical resonance via the formation of join along boundaries bonds becomes possible and real space-time sheets corresponding to preferred p-adic primes can form larger resonant structures. This universal resonance could explain why octaves are experienced similarly. The problem of this argument was that primary p-adic time scales would come as half octaves instead of octaves.

   Octaves seem to have much deeper significance than I thought originally and seem to emerge at the level of fundamental formulation of quantum TGD rather than characterizing only a very special kind of sensory experience. In the recent formulation of quantum TGD using zero energy ontology [21, 22] one uses zero energy states which have their positive and negative energy parts at the light-like boundaries of causal diamonds consisting of future and past directed light-cones.

   Physics as a generalized number theory vision, in particular the assumption that real physics and various p-adic physics result as algebraic completions of rational physics, motivates the hypothesis

that the temporal distance T between the tips of the causal diamond is quantized and corresponds to powers of 2 using time scale defined by CP_2 size as a basic unit. This assumption allows to deduce p-adic length scale hypothesis ($p \simeq 2^k$, k integer), and to identify T as a secondary p-adic time scale. For electron this time scale is .1 seconds and corresponds to the fundamental 10 Hz biorhythm. For non-standard values of Planck constant T is scaled by a factor $\hbar/\hbar_0$. Thus octaves become a key element of fundamental physics. One can say that causal diamonds as space-time correlates of self appear naturally as octaves. Also rational multiples of fundamental frequency emerge via the hierarchy of Planck constants: in principle all rational scalings of the basic hierarchy are allowed.

2. Is sensory experience 2-adic in some sense?

A stronger hypothesis for the phenomenon of octaves is that cognitive music selves are 2-adic or that real music selves can transform easily to 2-adic selves. One might even consider the possibility that the phenomenon is much more general. Music metaphor has indeed turned out to be of crucial importance for the theory of qualia. Thus music metaphor could reflect the underlying 2-adicity of the sensory experience (at some level of self hierarchy). Perhaps at least some aspects of our experience result from a mimicry of the lowest level of the p-adic self-hierarchy. Taking 2-adicity seriously, one is forced to ask for the possible consequences of 2-adicity. For instance, could it be that at the level of primary qualia the intensity of sensation as function of stimulus depends on the 2-adic norm of the 2-adic counterpart of the stimulus and is thus a piecewise constant function if sensory input?

An observation supporting this speculation is following. When overlearning occurs in tasks involving temporal discrimination, the intensity of sensation as a function of stimulus deviates from smooth logarithmic form in small scales by becoming piecewise continuous function [70] such that the plateus, where response remains constant are octaves of each other.

This observation suggests a generalization inspired by 2-adic version of music metaphor. Primary quale has a multiple of cyclotron frequency as its correlate and, being integer valued, is essentially 2-based logarithm of the 2-adic norm for the 2-adic counterpart of the intensity of the sensory input. Hence the increase of intensity of the sensory input by octave correspond to a jumpwise replacement of the n:th harmonic by $n + 1$:th one and should be seen in EEG. Our experience usually corresponds to the average over a large number of this kind of primary experiences so that underlying 2-adicity is smoothed out. In case of overlearning or neurons involved act unisono and the underlying 2-adicity is not masked anymore.

At the level of MEs this would mean generation of higher harmonic when the number of nerve pulses per unit of time achieves threshold value allowing the amplification of corresponding frequency by the mechanism discussed already earlier. This certainly would mean that cognition is an important part of music experience. The strongest assumption is that the real note selves are able to transform to 2-adic selves by a phase transition changing local topology from real to 2-adic. Note however that p-adic length scale hypothesis might be enough.

Does harmonic complexity reduce to 3-adicity?

An interesting question relates to the conditions guaranteing that a chord is experienced as harmonious in the Pythagorean sense [64]. Pythagorean tuning is based on the notion of perfect fifths identified as scalings by 3/2 producing the sequence C,G,D,A,E,.. In this tuning major-C scale corresponds to ratios $C = 1/1, D = 9/8, E = 81/64, F = 4/3, G = 3/2, A = 27/16, B = 243/128, C = 2/1$. E_b and $F_\#$ correspond to ratios $2^5/3^3$ and $3^6/2^9$. All notes are expressible as powers of two and three. Since the multiplication of any note by a power of two does not affect the harmony it should be to drop the powers of two from the integers characterizing the notes in the ratio of three notes. For instance, C-E-G reduces $3 : 3^4 : 1$, $C - E_b - G$ to $3^4 : 1 : 3^3$, and tritonus $C - E_b - F_\#$ to $3^9 : 1 : 3^3$. The problem of Pythagorean tuning is that one cannot represent 2 as an exact integer power of 3/2 and the scalings give infinite number of tones. If the construction starts from G_b then $F_\#$ and G_b correspond to frequencies, which are not quite identical in Pythagorean tuning. One could make compromize by introducing the geometric mean of $F_\#$ and G_b but this would bring in $\sqrt{3}$ and would force to leave the world of pure rationals. For string instruments and electronic instruments the Pythagorean tuning is practical but for instruments like piano the transposition of the scale is impossible.

One should be able to characterize a given chord harmonically by a function $F(a, b, c)$, which is symmetric under the permutations of the reduced pitches a, b and c obtained by dropping powers of two and is invariant under over all scaling of the reduce frequencies. The elementary symmetric

functions $F(a, b, c) = [a^2(b + c) + b^2(a + c) + c^2(a + b)]/abc$ and $G(a, b, c) = [a^3 + b^3 + c^3]/abc$ are the simplest functions of this kind. Either of these functions or their product or ratio could be considered as a measure for the harmonic complexity. The value of the denominator abc equals to 3^n, $n = 3, 7, 12$ in the cases considered. The numerator has in all cases 3-adic norm equal to one for both F and G. This suggests that the 3-based logarithm of the 3-adic norm $1/|abc|_3 = |F|_3 = |G|_3$ having the values 3,7, and 12 for C-major, C-minor, and tritonus could serve as the measure for the complexity. It is indeed smallest for major and largest for tritonus. 3-adic norm for the product $1/a_1 a_2 ... a_n$ of n notes of the chord defines a measure of complexity in more general case. A good guess is that the 3-adic norms of the elementary symmetric functions give rise to the same measure.

For the chords C-E-G, F-A-C, and G-H-D appearing as basic chords in C- major scale the values of the harmonic measure are 3, 2, and 8. This means that the basic chords are not harmonically equivalent in Pythagorean system whereas in equally tempered system they would be. One might think that this explains why the tonic is remembered. The anomalously low value for F-A-C relates to the fact that it is only tone for which the power of 3 is negative. Situation changes of F is identified as a minimal power of 3 giving F equivalent with Pythagorean F within the resolution of ear to pitch which is about $|\Delta f/f| = 4.3$ per cent . $F = 3^5/2^8$ gives $|\Delta f/f| = 4.8$ per cent. This F would give for F-A-C the harmonic measure 8 which equals to that for G. This looks more reasonable than the purely Pythagorean value. This definition would also allow to find a unique choice of powers of three for 12-chord system. For instance, $F_\#$ is favored over G_b since it corresponds to a positive power of 3.

The notion of self and music

The music experience allows also to test the ideas related to the notion of self.

1. Summation hypothesis states that self is a sum of abstracted experiences of sub-selves and thus representing kind of averages about the experiences of sub-sub-selves.

   (a) The conscious experience induced by music decomposes in a clear manner to basic elements identifiable as subselves. For instance, melody and more generally various tone progressions could define such subselves and the experiences of these subselves would sum up to music experience. In the same manner rhytmic patterns define their own subselves. Therefore it might make sense to speak about "frequency subselves" and "rhythm subselves".

   (b) At space-time level the magnetic body and massless extremals (MEs) are the natural candidate for the representation of "frequency subselves". One can say that MEs provide a universal music instrument at the level of magnetic body since they allow arbitrary superposition of collinear waves proceeding in the same direction which is non-dispersive (shape of the pulse is preserved) so that arbitrary harmonics are possible for a ME with fixed length. Maybe the the temporal duration of subselves assignable to MEs is what distinguishes between these representations.

   (c) A collection of subselves associated with ME at precisely defined periodically appearing positions could define rhythm whereas frequency selves would correspond to MEs with relatively long temporal duration. Interpreting MEs in terms of communications to the magnetic body, one expects that the rhythm automatically generates short-lasting MEs communication the pulses defining the rhythm to the magnetic body whereas pitch corresponds to long lasting MEs.

   (d) This picture challenges the assumption that the mental images created during music experience are localized to brain. Rather, MEs and magnetic body would be the carriers of the mental images. Maybe one could say that nerve pulse patterns induce these MEs. In left hemisphere nerve pulse patterns induced by the beats of rhythm and having a total duration considerably below .1 second would send single ME to the magnetic body. In right hemisphere the pulse patterns would integrate to single ME having duration of the note.

2. The hypothesis that entanglement creates wholes from parts and that there are three cognitive modes corresponding to reductionistic and holistic cognition and their hybrid based on negentropic entanglement is of special interest in the context of music experience.

(a) Even admitting the dangers of naive right-left thinking it would seem natural to assign the rhythmic aspects of the music to the reductionistic regions of brain and various aspects related to pitch to the right brain hemisphere. At least in the latter case MEs are highly suggestive as a fundamental representation of music at the level of magnetic body. Perhaps music experience actually involves in a very essential manner also magnetic body. That "eastern" music favors additive instead of divisive rhythm could be understood as higher right brain dominance. The extremely mechanical rhytms characterizing the popular music today, the lack of melodic aspects, and the use of the volume of music as the basic means to induce emotional effect, could in turn interpreted in terms of extreme left brain dominance.

(b) Music can have a strong emotional effects and this allows to test the hypothesis that the character of entanglement correlates with the emotional color. Maybe just the fact that these emotions are enjoyable irrespective of whether they are sad or joyful and have an undeniable healing effect can be interpreted in terms of the presence of the negentropic entanglement. For instance, the ability of good music to generate vibrations in spine could relate to this negentropic aspects. Music as purely intellectual experience could induce essentially an analysis of what was heard based on the use of holistic-reductionistic dichotomy. Chopin's music has especially strong healing effect. Tempo rubato might reflect the profound integration of rhytmic aspects, melodic, and harmonic to single organic whole both at the level of representation and music experience.

3. The model of subjective memory and the new view about time might be relevant for the understanding of how the basic key of the music piece can be remembered. If conscious experience for a given self is about the space-time region defined by corresponding CD, one could understand how Mozart was able to experience the entire composition as a single whole. If the music piece defines in the ideal case the fundamental CD inside which the sub-selves representing the elements of the music oiece reside, this CD could also define the fundamental "key " and would be more or less sensorily experienced and need not even to be remembered. This would explain why the return to the original key in classical is so important to relieve the tension created by modulations.

Harmony and self-organization

The phenomenon of harmony should be somehow related to quantum self-organization: perhaps the often used metaphor of harmonious co-existence could be turned around. Various notes correspond to sub-selves in the population of sub-selves and it might be that self-organization favours simultaneous conscious existence of sub-selves corresponding to subsets of frequencies defining basic chords. One could even consider some kind of co-operation between the frequency selves belonging to same basic chord.

The simplest model for the phenomenon of harmony relies on the identification of the chords as 'chord selves' formed by entangled 'note selves' consisting of negentropically entangled 'frequency selves'. The listener is self having as sub-selves (mental images) note selves and chord selves which correspond to the same level of the self hierarchy. The entanglement between note selves could occur even at the level of ear between the mindlike space-time sheets sensitive to various frequencies. Topologically it would correspond to the formation of magnetic flux tubes between corresponding partonic 2-surfaces. The ability of the 'note selves' of the chord to have stable flux tube bonds between themselves should depend crucially on the fact that the frequencies of the notes of the basic chords have simple rational ratios so that the oscillations involved are commensurate and match together. Hence a resonance phenomenon ins spirit of classical physics involving rational ratios of frequencies would be in question. During listening the chord self continually decomposes into sub-selves when listener consciously concentrates attention to some notes in the chord.

The ability of the music to occasionally create thrills in spine could correspond to whole-body consciousness in unusually large length scale. Note the this scale could correspond also to the secondary time length scale assignable to CD. It presumably involves a resonant fusion of also other than note sub-selves to larger negentropic sub-selves by the formation of stable join along boundaries bonds identifiable as magnetic flux tubes. The ability of certain sounds ('Om') to promote the emergence of whole-body consciousness could be due to the ability to very effectively generate negentropic entanglement direction. Perhaps the frequency spectrum of 'Om' contains resonant frequencies of several

sub-selves and induces large sub-selves. Also the healing effect of music and sounds could rely on this mechanism.

Focusing attention to some instrument producing melody creates kind of figure-background relationship. This requires that entire instrument playing the melody is represented by 'instrument self'. An interesting possibility is that various instruments give rise to their own ensembles of frequency-selves. Note that the model makes it easy to understand why experienced performance is not simply the sum of invididual performances. Music experience is a complicated self-organization process in which parts compose to wholes by quantum entanglement and vice versa according to how the listener directs his/her attention.

4.5 Whole-body consciousness: physical evidence and tests

Whole-body consciousness is one of the predictions of the proposed theory and anomalously low dissipation can be regarded as the most dramatic physical signature of whole-body consciousness. This prediction provides a manner to test the theory.

4.5.1 Dissipation and consciousness

The state function reduction sequence is a binary process which at a given step splits a subsystem into a unique pair of un-entangled subsystems if the subsystem allows decomposition to free entropically entangled systems. The process is random and explains second law and dissipation as a transformation of ordered energy to non-ordered energy. In standard view about self-organization the generation of structures requires a feed of ordered energy to compensate the dissipation.

In TGD framework the function of the metabolic energy feed would be more complex than this. Energy feed is necessary in order to avoid the formation of large sized entropically bound subselves. The feeded energy need not be ordered. The rate of dissipation depends on how small the scale of the non-decomposable systems is. If negentropic entanglement binds mental images to larger ones, the rate of dissipation is expected to be low. Ordered metabolic energy can be also transformed to the energy carried by negentropic entanglement and liberated as the entanglement transforms to ordinary free or bound state entanglement.

The overall picture is also made more complex by the simultaneous presence of several length scales in which the state function reduction process proceeds so that it makes sense to speak about quantum parallel dissipation.

EEG waves and parallel information processing

Parallel information processing requires a large number of correlated units acting in parallel. If the units correspond to sub-selves which are bound state entangled, the whole system acts like a single neuron so that the information processing is very un-effective. If the system consists of unentangled subselves, the correlations are absent and the system is analogous to a statistical ensemble rather than a quantum parallel computer. If the entanglement is negentropic, one achieves parallel information processing since subselves are correlated but have not lost their degrees of freedom.

In synesthesia synchronous firing is observed and the cognitive and memory feats of synesthetes suggest that parallel information processing and negentropic entanglement are involved. Therefore synchronous firing and its EEG counterpart define candidates for the physical correlates of the negentropic entanglement. TGD inspired model for EEG and nerve pulse predicts both propagating EEG waves associated with neural circuits and non-propagating EEG waves associated with entire regions of brain (say gap junction connected cell groups) [18].

It would be natural to assign non-propagating EEG waves to synchronous firing of neurons forming a single coherent unit. However, if neurons form a bound state they act in unisono and the information processing is very uneffective. Hence both propagating and non-propagating EEG waves should be present during parallel information processing periods and add up coherently. Synchrony would mean that standing wave part of EEG is for neurons like the rhythm of music for a ballet group. Coherence of EEG, one form of 'oneness', would be the correlate for presence of both reductionistic and holistic aspects of consciousness.

Evidence and tests for a reduced metabolism as concomitant of whole-body consciousness

Consider now possible evidence and tests for the reduced metabolism as a signature of whole-body consciousness.

1. In synesthesia different sensory modalities are associated with a regular manner just as thoughts are associated with speech. A dramatic signature of synesthesia is the lowering of the cortical metabolism by as much as about 18 per cent from the average (synesthete should become blind or paralyzed if standard wisdom would hold true!). This is what is expected if the neurons of left cortex get entangled. Also a large scale entanglement weith parts of limbic brain, with sensory organs associated with coupled sensory modalities, and magnetic body is possible. The extended self in state of oneness does not dissipate significantly.

2. The metabolism of trained yogis provides a test for the hypothesis: measure some signatures for neuronal or cellular dissipation occurred during the meditative state and find whether the dissipation is reduced during meditation. The lowered dissipation rate could even lead to the lowering of the body temperature or the temperature of nearby region.

3. There are even anecdotal claims about the ability of the dead bodies of gurus to resist natural decay. I am not certainly trying to convince any sceptic and, still having very living personal body, I have no personal opinions about the reality of the claimed phenomena. It would be however good to be open-minded.

4. There is (I believe well documented) phenomenon in which persons in trance are able to dance on burning charcoals without any disastrous consequences. Certainly there are standard science explanations for this. A possible nonstandard sicence explanation is that state of a whole-body consciousness is involved and no dissipation in cellular scale occurs. Since dissipation is not possible, the irreversible effects caused by the heatflow from burning charcoals are not possible and only reversible and curable effects can occur.

5. The reduction of the dissipation rate in some length scales should occur also during sleep, which is one example of this kind of state (obviously a reduction of metabolism occurs).

6. Also hypnosis might involve (possibly negentropic) quantum entanglement between some part of the brain of subject person and hypnotizer. This could reflect itself as correlations between EEGs of hypnotizer and subject person.

4.5.2   EEG synchrony and negentropic entanglement

If one accepts the vision about life as something in the intersection of real and p-adic worlds 40 Hz EEG synchrony can be interpreted as a correlate for the generation of negentropic entanglement between cortical neurons. Before proposing this interpretation let us first describe the experimental findings of a finnish neuroscientist Antti Revonsuo [63].

Findings

The interpretation for 40 Hz EEG frequency inspired by the binding hypothesis is as a synchronizing frequency necessary for the generation of unified percepts. This hypothesis has been studied using auto-stereograms [63]. There was no detectable difference in the power spectrum at 36-44 Hz range in the situation when auto-stereogram was experienced as a set of random dots as compared to the situation when it was perceived as a coherent, symmetrical gestalt. The situation was same also in 8-13 Hz and 13-20 Hz beta bands. The finding is consistent with the place coding hypothesis.

On the other hand, when the conscious percept was transformed from a random set of points to a coherent gestalt, there was a detectable increase in 40 Hz power in the occipital and right posterior sites for EEG electrodes in a time window 500-300 ms before the unified percept was reported. There could be also some time lapse between the unified percept and the report about it but probably this cannot explain the entire lapse. No increase of power in beta bands was detected: this might be due to the fact that the widths of the measured bands are much wider than the widths of the narrow sub-bands reported masked by other EEG activity according to [59]. Note that in the model for a

hierarchy of EEGs based on dark matter hierarchy beta band correspond to data communicated to the magnetic body [22].

That the change in activity is associated with the emergence of a new percept suggests that the temporary increase of the EEG power could be assigned to the communications of the forming percept to the magnetic body.

Interpretation in terms of generation of negentropic entanglement

A fresh view about what really happens during 40 Hz synchrony came with the realization that negentropic entanglement is possible in the intersection of real and p-adic worlds. The generation of negentropic entanglement between two subselves means that the corresponding mental images are fused [8, 29]. The process is experienced by the fusing subselves as an expansion of consciousness whereas consciousness is lost when when bound state entanglement is generated. Also the meditative states begin with enchanged 40 Hz activity and the interpretation would be same. Quite generally, the generation of negentropically entangled neuron groups could be a correlate for the emergence of a new idea or a new holistic pattern emerging from a chaos. Synchronous firing would be a natural correlate for the synergic state resulting in this manner. The paradoxical looking reduction of the oxiditative metabolism associated with 40 Hz firing could be seen as a signature of reduced dissipation when dissipating ensemble of neurons forms a single quantum coherent system.

What could then be the interpretation of the 300-500 ms time scale and synchronous firing in TGD framework?

1. If one assumes that only brain is involved, one must answer whether the new percept emerges after such a long time period. One would naively expect that negentropic entanglement immediately gives rise to the percept. Negentropic entanglement however means that a quantum superposition of several alternative percepts is involved. In the beginning the new percept is present with only small probability so that one would only know that the moment of heureka is quite near (this is indeed the experience that one has) and in the final situation it dominates but not completely since it requires conscious effort to preserve the percept.

2. Also magnetic body should be involved in TGD framework. The natural question is "Why this synchronous neuronal firing?". The natural answer would be that it allows to communicate the new percept as a consequence of a generation of negentropic entanglement to the magnetic body. The frequency scale of 40 Hz corresponds to a time scale of 25 milliseconds and corresponds to a length scale involved is about $.75 \times 10^7$ m, a good candidate for the size of the part of the magnetic body involved. This time scale is much shorter than 300-500 seconds. If the layer of the magnetic body in question corresponds to the fundamental 100 millisecond time scale assignable to electron as is natural in case of sensory percepts, the time lapse could be essentially due to the communication. If one takes the time scale literally the value of Planck constant which is about 3 to 5 larger than its standard value would suggest itself. Of course, the development of the percept from a fuzzy inkling to the final heureka could involve several communication loops between brain and magnetic body so that the interpretation as a lapse due the slowness of communications need not be inconsistent with the first interpretation.

3. The time scale 300-500 ms could characterize the duration of negentropic entanglement but this is not necessarily the case since negentropic entanglement would be un-necessary after the percept has been represented symbolically so that one knows what is lurking behind the chaos.

4.5.3 Synesthesia

Synesthesia [44] seems to give a direct experimental evidence for a reduced rate of metabolism in 'negentropic' states of mind. Synesthesia provides an excellent counter argument against the idea that sensory organs are primary experiencers unless one is ready to believe that cross-modal associations involve macroscopic quantum systems formed by the primary sensory organs involved and parts of brain.

TGD based quantum model for EEG and nerve pulse suggest that synesthesia is a natural by-product of the negentropic states of mind involving enchanced EEG in large regions of brain. Coherent large amplitude EEG induces synchronous neural firing in memory circuit containing hippocampus

and thalamus. This leads to a 'leakage' or nerve pulse activity in lateral thalamic nuclei from inducing sensory pathway to the indced sensory pathway.

An interesting possibility is that the non-propagating EEG waves predicted by TGD [18] and possibly explaining the ability of right brain hemisphere to process information in a parallel manner are involved in synesthesia. The left brain hemisphere of synesthetes would be in some aspects like the right one during synesthesia and right and left brain could act like single conscious unit during synestesia.

Does synesthesia involve left cortex whole-body consciousness?

The following aspects of synesthesia suggest that left cortex whole-body consciousness might be involved with it.

1. Synesthesia depends on left brain hemisphere only. A dramatic signature of synesthesia is the lowering of the metabolism in the left cortex by about even 18 per cent compared to the baseline (synesthete should become blind or paralyzed if standard wisdom holds true!). This is accompanied by relatively enhanced limbic expression. Hippocampus, which is believed to be crucial for long term memories, is critical for the synesthetic experience.

2. Synesthesia is emotional: the experiences are accompanied by a sense of certainty ('this is it') feeling. This is in accordance with the observation that limbic brain expression is enhanced.

3. Holism is an important aspect of synesthesia. Synesthetes can precisely remember entire passages of text (which actually means that also reductionistic aspect is present), re-experience entire episodes of previous life, remember precise locations of various objects in a room. Synesthetic experiences are emotional. Synesthetes also tend to have 'unusual experiences' like deja vu, clairvoyance and pre-cognitive dreams. This kind of personality constellation characterizes temporal-limbic epileptics.

4. Synesthetes have un-even cognitive skills. Dyslexia, dyscalculia in some degree, inability to transform words to digits, right-left confusion, etc.. Synesthetes are also non-right-handed.

A possible TGD based interpretation is that part of the left cortex is in whole-body consciousness in the sense that mental images have fused negentropically to very few larger mental images and there are very few unentangled sub-selves (mental images).

1. In this state left cortex does not dissipate as much as usually. Negentropic entanglement explains why the metabolism can be reduced during synesthesia below the level causing death under normal circumstances. The relative enhancement of metabolism in left limbic brain could relate to emotionality but does not favor negentropic entanglement in left limbic brain.

2. Also the cognitive impairments can be understood. The negentropic entanglement is both time-like and space-like so that these sub-selves have also a long duration. The resulting experience is holistic both in spatial and time direction with overall gestalt being more important than details. A good temporal resolution is essential for the mentioned cognitive skills and the explanation for cognitive dis-abilities is that entangled left cortex does not generate temporal sequences of sub-selves of short duration defining the mental clock readings or beacons. The mental images are extremely informative but the the lack of linguistic expression based on the replacement of the percept with a collection of distinct objects mapped to linguistic symbols disfavors this mode of consciousness. Therefore linguistic cognition is favored by the practicalities of the everyday social life. The lack of asymmetry between brain hemispheres behind holism-reductionism dichotomy essential for language would naturally relate to non-right-handedness and the difficulty to distinguish between right and left. This inability would also conform with the view that some regions of right and left hemisphere are negentropically entangled.

3. The exceptional episodal memory achievements could be understood as a formation of large scale negentropic mental images which are stable so that long sequences of events of geometric past are re-experienced. In [32] a model for long term episodal memories as questions sent to the geometric past inducing time-like entanglement with the self of the geometric past making

possible episodal memory as a shared sensory experience is discussed. The question sent to the geometric past is coded to the lightlike vacuum current associated with a stationary ME, usually in right brain but in left brain in case of synesthesia. The time like entanglement of the space-time sheets located in the geometric now and past (or future in case of clairvoyance) makes possible the episodal memory.

The proposed mechanism could also explain both the extraordinary memory feats of some autistic persons and their difficulties with the challenges of the everyday life. Dramatic example is a person able to draw from memory an area of London with size of several square kilometers as seen from air. The same person draws from memory a building having hundreds of windows and the number of windows comes out correctly although this same person is not able to count corretly the number of three objects. As in the case of synesthetes cognitive impairments could be necessary prequisites of the extraordinary gifts. Although the person cannot count how many windows the mental image of the building has, he can draw them correctly just by drawing along the image he sees in full concreteness.

Basic observations

The following observations provide a valuable information making possible to construct a more detailed model of synesthesia.

1. Synesthesia is in-voluntary and usually uni-directional: for instance, auditory experience creates visual association but not vice versa. Cross-modal associations, just like ordinary associations, do not change in the course of time. It has not been possible to find any rule telling which kind of associations are possible. It seems that cross-associated experiences are however generic and simple so that one can speak of form invariants which are kind of primitive building blocks of perception: for instance, visual associations tend to be blobs, lines, spirals and lattice shapes.

2. Synesthesia is projected: synesthetes experience their secondary sensory experiences in the space in the immediate surroundings of the body, never at large distances as is in principle possible in the case of vision and hearing. For instance, visual associations are seen on screen near to eyes.

3. The reduction of the metabolism is concentrated in the cortical regions whereas relatively enhanced metabolism occurs in the limbic brain, in particular hippocampus. Seizure discharges in hippocampus induce synesthesia in non-synesthetes: associations are simple experiences and become more complicated if seizures spread to the temporal lobes. The exceptional activity of hippocampus correlates with the exceptional ability to have precise episodal memories.

4. According to [44] it is very rare that taste or smell is a synesthetic response or trigger of it. In fact that author of the articles knows no case in which smell alone would be the inducing sensory modality. This could relate to the fact that olfactorion is exceptional sensory modality in the sense that there are two olfactory pathways: the first one projects directly to amygdala whereas second projects to cortex via thalamus as do also the sensory pathways associated with order sensory modalities [72]. Furthermore, the olfactory pathway to the thalamus projects to the medial dorsal nuclei whereas other sensory pathways project to the lateral dorsal nuclei.

5. Synesthesia can also generate sensory-motor associations. For instance, visual input can generate well defined motor outputs and synesthete can express sensory experiences by dancing!

Memory coordination circuit and Papez circuits as brain circuits possibly involved with synesthesia

Hippocampus is believed to be crucial for the formation and experiencing of long term memories. This suggests that an enhanced activity in some neural circuits involving hippocampus in a form of increased EEG amplitudes (at theta frequencies) is essential for generating the sensory leakage between neural circuits and sensory pathways leading to synesthesia. For this kind of mechanism synesthetic mode need not be the only mode of experiencing: ordinary and synesthetic modes could also alternate. If synesthetic and non-synesthetic periods alternate, synesthesia cannot interfere radically with the real experience. This is clearly the safest option and perhaps favoured by natural selection. The ability to control theta wave amplitudes in hippocampus could make possible an artificial generation of synesthesia.

There are two important circuits going through hippocampus [88]. The first circuit is memory coordination circuit having the following structure:

1. Lateral dorsal nucleus and anterior nuclear group of the thalamus

2. Cingulate cortex

3. Subiculum and the rest of the hippocampal formation with input via entorhinal cortex and output via the subiculum and fornix

4. Back to 1.

Fornix is known to be the circuit responsible for slow theta rhytm of about 3-7 Hz, which does not correspond to a conscious experience: thus memory coordination circuit is believed to be unconscious to us under normal circumstances [88]. Temporal cortex contains a region which projects to hippocampus and receives input from all sensory modalities. Memory circuit is believed to somehow to provide a handle to the memory constellations believed to reside in the temporal lobes. That the EEG amplitude associated with the fornix would be exceptionally large during synesthesia is in accordance with the fact that that synesthetes tend to have personal constellation of limbic-temporal epileptics. Also the abnormal episodal memories (Nabokov is one of the best known synesthetes with miraculous memory) supports resonance in this circuit. Only memory circuit projects to the thalamic nuclei receiving both sensory and motor input. Hence also the occurrence of the motor synesthesia supports the view that the sensory leakage occurs in the thalamic nuclei contained by the memory circuit.

Papez circuit is second circuit containing hippocampus. Papez circuit has following structure:

1. Anterior nuclear group of the thalamus

2. Cingulate cortex

3. Hippocampal formation

4. Hypothalamus

5. Back to 1.

The enhanged activity of the Papez circuit induced by the hippocampus could correlate with the emotionality of the synesthetic experience.

The general picture about the sensory leakage

These observations and facts suggests the following general model for synesthesia.

1. Contrary to the original expectations, the hypothesis that the primary sensory qualia are associated with the sensory organs can be be defended against various objections if one assumes that brain and sensory organs quantum entangle so that a fusion of sensory mental images with cognitive mental images occurs. The hypothesis explains elegantly the differences between imagination, dreaming, hallucinations, and ordinary sensory experience. Dreams and hallucinations would involve a back projection from brain to sensory organs giving rise to a "qualiafication" of the cognitive mental images represented by the nerve pulse patterns. In the case of synesthesia the back projection would assign to a sensory input from the inducing sensory modality an artificial sensory input in the induced sensory modality.

2. If the cross-modal communication between sensory organs occurs through thalamic nuclei common to the cross-associated sensory modalities, one can understand why smells alone are never the inducing sensory modalities. Lateral dorsal thalamic nuclei would be the sites of the sensory leakage. Furthermore, in the case of hearing, vision, and tactile senses it is easy to produce artificial sensory experience than in case of chemical senses (molecules attaching to the sensory receptors would be required).

3. The possibility of the sensory-motor synesthesia suggests that the back-projection involves artificial sensory input to the motor organs inducing a motor activity, which in TGD framework corresponds to a geometric time reversal of the sensory perception starting from the level of motor organs and proceeding in a time reversed direction. Only memory coordination circuit involves thalamic nuclei receiving both sensory and motor inputs. Memory coordination circuit involves lateral dorsal nuclei (all modalities except olfaction) but not medial dorsal nuclei (olfaction). This leads to the hypothesis that the exceptionally high activity of the memory coordination circuit induces a sensory leakage in the lateral dorsal nuclei of the thalamus belonging to the memory coordination circuit.

Synesthesia as a sensory leakage between thalamic nuclei common to the memory coordination circuit and primary sensory pathways

Synesthesia could be a byproduct of an abnormally large EEG amplitude in the memory coordination circuit and possibly also Papez circuit inducing a 'leakage' of nerve pulses between sensory pathways in thalamus in turn giving rise to synesthetic crossmodal associations. That synesthetic associations are projected, is consistent with the sensory leakage hypothesis.

   The resonant EEG amplitude associated with the thalamic nuclei of the resonating memory coordination circuit spreads out to the primary sensory or motor pathways in the physical vicinity of the resonating pathway and generates a sensory leakage and a back projection to the sensory organs of the induced modality thus inducing synesthesia. The structure of the synesthetic association is determined by the pattern of neurons activated and thus creating the virtual sensory input backprojected to the sensory organ of the induced sensory modality. One can imagine each neuron as a pixel of a sensory picture and the pattern of activated pixels determines the synesthetic association.

   The model makes testable predictions.

1. The assumption that the sensory leakage occurs in the thalamus could be tested. One could study whether the crossmodal associations change, when the sensory input from right or left side of body is lacking. For instance, one could find what happens if audio-to-visual synesthete blocks left/right ear during audio-to-visual synesthesia.

2. The generation of artificial sensory experience by back-projection to the sensory organ of the induced sensory modality means that a permanent or an artificially induced temporal loss of the induced sensory modality (by a local anaesthesia of the axons of the sensory pathway) should lead to the loss of the synesthesia.

How to understand the memory feats of synesthetes and the reduced metabolism in the left hemisphere?

Negative energy MEs can be interpreted as classical signals sent to the geometric past, and they could be crucial for an active memory recall involving a question sent from the magnetic body to the brain of the geometric past as a negative energy ME. Also chemical signals- say very slow Ca^{++} wave inside brain- could be involved and could define the classical response to the negative energy signal.

   1. Memories and time mirror mechanism

   Time mirror mechanism, which was first developed in the framework of positive energy ontology, is the simplest quantum mechanism of memory. Its recent formulation goes as follows.

1. The mechanism of episodal memory is assumed to involve only a sharing of mental images by negentropic time-like quantum entanglement. The notion of bound state entanglement in time direction need not make sense at all: the reason is that bound state energy is assigned with the entire system rather than sub-systems and for zero energy states total energy is always zero. Hence it seems better to assume that only negentropic entanglement and non-binding real entanglement in time direction is possible.

2. The basic question is what really distinguishes between verbal (declarative) and episodal memories. Is the difference between verbal and episodal memories related only to the temporal size scale of the negentropically entangled subsystems? In this case declarative memory would consist of a sequence of short lasting episodal memories with contents which are symbols rather

than direct sensory perceptions with emotional content. Or can one interpret verbal memories as purely classical communications between geometric past and future? This would make sense if declarative memories result when an entropic entanglement between future and past selves is reduced to zero so that the communications would reduce to those between non-living systems. Episodal memories would be possible in the intersection of the real and p-adic worlds and declarative memories everywhere. This interpretation is consistent with the earlier vision.

One can model the memory recall as follows.

1. The view about memory recall is that a 'question' realized as a negative energy ME is sent from magnetic body to the brain of the geometric past, it is reflected back as a positive energy signal, and returns back to the magnetic body. It is essential that the signal is between different CDs - say CD and its and sub-CD- rather than future and past boundaries of single CD.

2. One must be very careful with what negative energy signal really means. This signal would be generated in quantum jump and should connect the past boundary of CD to the future boundary of a CD in the geometric past- say for definiteness a sub-CD of CD itself if personal memory is in question. The condition that the positive energy of the past boundary of CD remains unchanged means that the energy flowing to the direction of future inside CD is increased as a recoil effect. The same applies in the case of sub-CD. This interaction could be seen as an interaction between two CDs implying an exchange of energy between the positive energy parts of the states.

3. The transfer of negative energy to the past can transform the positive energy part of the state of the geometric past to a bound state in the ordinary sense of the word. If positive energy negentropic entanglement is in question this need not happen although the energy of the state is reduced. Therefore negentropically entangled mental images are especially interesting from the point of view of episodal memories. The question and answer fuse to a single negentropically entangled mental image shared by the hemispheres of the geometric past and now. The negentropy of the past state is expected to reduced as its energy is reduced so that quite literally a flow of information to future is in question.

4. Duality between memory and recognition suggests itself. What is memory from the point of view of future CD could be precognition from the point of view of past CD.

The generation of negative energy MEs would involve a phase transition to a state in which the positive MEs propagating along axons with a subluminal effective phase velocity transform to negative energy MEs leaving the brain and are reflected back in time direction. Synchronous membrane oscillations could accompany negative energy MEs [18]. If negative energy MEs are sent by the region of the left brain hemisphere, it gains some energy by pay now-let others pay mechanism.

2. Reduction of metabolism during synesthesia

Episodal memories could relate to the reduction of the metabolism by 18 per cent during synesthesia.

1. The original interpretation proposed before the formulation of zero energy ontology was that the generation of the negative energy MEs is forced by the starvation of the neurons induced by the over-activity of the neurons of the memory coordination circuit. The miraculous ability of synesthetes to remember episodally could be understood to result as a by-product of a neuronal emergency reaction. The starving cortical neurons of the left hemisphere would send negative energy MEs to the direction of the geometric past inducing entanglement bridges by the mirror mechanism with the brain of the geometric past in turn inducing episodal long term memories by the sharing of the mental images. The same mechanism might work also in the normal situation but involve a less dramatic artificial starvation.

2. The reduction of the metabolism could be also mostly due to the negentropic entanglement for the mental images in the left cortex "now" so that the episodal memories realized in the proposed manner would give only an additional reduction to metabolism.

3. Non-episodal memories

Also in the case of non-episodal memories the question to the geometric past could be communicated by the mirror mechanism using negative energy MEs but now time-like entanglement would be entropic free entanglement and would be reduced to zero in quantum jump so that the real answer would be communicated classically.

1. The classical signal could return to the magnetic body along reflected positive energy ME so that the question and answer could use the same cognitive code.

2. Second possibility is that signal returns back without leaving the brain. The classical signal sent by the left hemisphere of the geometric past to the left hemisphere of the future would propagate a finite distance L within brain in a time interval T defining the temporal span of the memory (say years) so that the ME would propagate with an effective phase velocity $v = L/T$. The velocities of Ca^{++} waves span an extremely wide spectrum and provide a natural candidate for the physiological excitations in question [69].

3. Ca^{++} waves could be also be accompanied MEs with ultraslow phase velocities.

4.6   Self hierarchy and the notion of magnetic body

TGD not only predicts infinite hierarchy of selves but also strongly suggests that "me" as an intentional agent should be identified as my field body, or perhaps better to say, my magnetic body having an astrophysical size. Magnetic body would also serve as an intentional agent and controlling biological body by time mirror mechanism. An entire hierarchy of magnetic bodies is predicted since the flux quanta of each body part define corresponding magnetic body. Also the magnetic body of Earth should define a conscious unit, kind of Magnetic Mother Gaia perhaps responsible for some third person aspects of our consciousness. The role of the magnetic body would be like that of a manual of an electronic instrument, that is it would provide a higher level representation for the body and its environment. Magnetic body would also serve as template for the formation of bio-structures. Magnetic body would share the mental images produced by brain as symbolic representations of the sensory input. The basic theoretical arguments supporting the notion of magnetic body derive from p-adic physics as physics of intention and cognition. Also time mirror mechanism of long term memories and Uncertainty Principle applied to EEG provide support for the notion. Some experimental findings supporting the notion of field body are Libet's findings, the role of Schumann resonance frequency for consciousness about time delays of consciousness, and the effects em radiation on brain and living matter at cyclotron frequencies.

This original version of this section was written much before the emergence of the zero energy ontology. A first principle justification for the notion of magnetic body is provided by zero energy ontology predicting that primary p-adic length scales are accompanied by secondary p-adic length scales (as well as time scales). For instance, in case of electron the secondary time scale is .1 seconds and correspond to a length scale of order Earth's circumference. It is natural to assign this time scale to the flux tubes of the magnetic body. This aspect will not be discussed explicitly in the sequel but should be kept in mind.

Am important question concerns about actual biological realization of the self hierarchy predicted to begin already at elementary particle level and continuing indefinitely. TGD indeed leads to rather concrete ideas about how this hierarchy is possibly realized.

4.6.1   Higher level selves in biological self hierarchy

The basic inputs for the speculations about the higher levels of the biological self hierarchy are topological field quantization, the idea of memetic code and the observations about the effects of EFL em fields to brain suggesting that the higher levels correspond to em selves with sizes of order wavelength of photons generated by EEG currents having size of order of Earth and realized as topological field quanta. The general view about symbiosis of hierarchies of massless extremals (MEs) and superconducting magnetic flux tube structures with the ordinary matter at atomic space-time sheets provides strong constraints on the speculations. The general vision about sensory representations realized in

terms of magnetic flux tube structures outside brain [32] and having sizes of ELF wavelengths leads to rather concrete ideas about the self hierarchy and about our position in it.

Topological field quantization

Topological field quantization [18] implies that various notions of quantum field theory have rather precise classical analogies. Topological field quantization provides the correspondence between the abstract Fock space description of elementary particles and the description of the elementary particles as concrete geometric objects detected in the laboratory. In standard quantum field theory this kind of correspondence is lacking since classical fields are regarded as a phenomenological concept only. Topological field quanta define regions of coherence for the classical fields and classical coherence is the prequisite of the quantum coherence.

The energies and other classical charges of the topological field quanta are quantized since only preferred extremals of Kähler action allow infinite number of deformations with a vanishing second variation: this makes classical space-time surfaces the counterparts of the Bohr orbits. Feynmann diagrams become classical space-time surfaces with lines thickened to 4-manifolds. For instance, "massless extremals" [32] representing topologically quantized classical radiation fields are the classical counterparts of gravitinos and photons. Topologically quantized non-radiative nearby fields give rise to various geometric structures such as magnetic and electric flux tubes.

The virtual particles of quantum field theory have also classical counterparts. In particular, the virtual particles of quantum field theory can have negative energies: this is true also for the TGD counterparts of the virtual particles. The fundamental difference between TGD and GRT is that in TGD the sign of energy depends on the time orientation of the space-time sheet: this is due to the fact that in TGD energy current is vector field rather than part of tensor field. Therefore space-time sheets with negative energies are possible. This could have quite dramatic technological consequences: consider only the possibility of generating energy from vacuum and classical signalling backwards in time along negative energy space-time sheets [19]. Also biosystems might have invented negative energy space-time sheets: in fact, so called "massless extremals" provide an ideal manner to generate coherent motions as recoil effects caused by the creation of negative energy massless extremals [19]. An interesting possibility is that quantum entanglement has the formation of the join along boundaries bonds as its geometric correlate.

The hypothesis of topological self-referentiality stating that the topological field quanta of classical fields form a symbolic representation for the system's properties, provides a strong interpretative tool. For instance, bound state entanglement is represented by negative energy MEs and the generation of macroscopic bound states essential for the binding of the mental images is accompanied by the liberation of the binding energy as a usable energy. Hence the ability of the system to behave as a single coherent whole and nonlocal quantum metabolism are different sides of the same coin. The concept of field body (or electromagnetic body) consisting of the topological field quanta is also of central importance. Field body could be seen as a 'manual' for the system providing a classical, topological representation for the quantum aspects of the material part of the system. The size of this field body is much larger than the material body of the system.

Topological field quanta (field bodies) could serve as templates for the formation of the biostructures. Thus topologically quantized classical electromagnetic fields could be equally important for the functioning of the living systems as the structures formed by the visible biomatter and the visible part of biosystem might represent only a tip of an ice berg.

Topologically quantized classical fields as templates for self hierarchy?

The web like structure formed by topological field quanta representing classical fields, in particular em fields, is remiscent of structures formed by microtubules and collagens forming the connecting tissue of living systems. It has been already earlier suggested that magnetic flux tubes and other topological field quanta serve as templates for various biostructures in the sense that ordinary matter is topologically condensed on the flux tube like structures. This would mean that living systems would be only part of much larger web formed by Earth's classical em field forming one particular sub-self of Mother Gaia.

The thickness for the flux tubes of Earth's magnetic field is about $2/\sqrt{eB} \simeq 4 \times 10^{-6}$ meters for $B = .5 \times 10^{-4}$ Tesla. If magnetic flux tubes of Earth have direct geometric coupling with brain one

could perhaps understand the miraculous ability of birds and bees to navigate using Earth's magnetic field. The proteins navigating along microtubules, cells navigating along collagen fibres and birds navigating along Earth's magnetic field lines would all be guided by higher level self! One could see also humans and the societies formed by them as continually self-organizing organs in the body of electromagnetic Mother Gaia. In this picture the so narrow wave cavity of radius 80 km between Earth's surface and ionosphere could be like brain of Earth, which is very sensitive to the conditions of ionosphere and biosphere and has "biofeedback" coupling with living systems. The effect of oscillatory phenomena (sound, radiations and magnetic fields) at frequencies Schumann resonances on brain to be discussed below supports also the direct interaction of our brain with Mother Gaia via Earth's electromagnetic field.

It is interesting to notice that the ratio of the thickness of solar corona (10^6 m) to the radius of Sun (5×10^8 m), the height of the wave cavity of Earth (80 km) to Earth radius (7×10^6 m), the ratio of the thickness of grey matter of cortex (1 mm) to the size of human brain lobe (10 cm) as well as the the ratio of the thickness of cell membrane (10^{-8} m) to the radius of neuron (2.5×10^{-6}) have roughly the same value of order 10^{-2}. Thus it seems that cell membrane, cortex, electromagnetic cavity of Earth and solar corona might have similar role in the self hierarchy.

The web formed by topological field quanta of the classical em and fields continues to arbitrary long length scales. For instance, the flux tube structure of solar magnetic field provides an explanation for the anomalously high temperature of solar corona and a model for solar spot cycle [17]. Perhaps also Sun is a conscious self forming part of "Indra's net" representing electromagnetic and other classical fields of cosmos. Since the four CP_2 coordinates are the primary dynamical variables, one must consider the possibility that topologically quantized classical gauge fields and classical gravitational field could form rather independent sub-selves.

Possible geometric correlates of entanglement?

The geometric correlate for the entanglement between sub-systems is the generation of join along boundaries bonds combining the corresponding 3-surfaces to single 3-surface: this is nothing but the direct touching of the 3-surfaces. Actually, all that is needed is the fusion of the space-time sheets of same local topology (real or p-adic) to single sheet. The entanglement generated in this manner can be preserved even when direct geometrical contact between 3-surfaces is not present anymore. In TGD based model for brain these bonds are formed between parts of brain and sensory organs.

One can consider several models for join along boundaries bonds. Topological field quantization providing general description of classical gauge and gravitational fields in TGD framework implies that magnetic and electric flux tubes and "massless extremals" (MEs) are the basic building blocks of classical em fields. All these structures can serve as join along boundaries bonds.

MEs are especially interesting candidates for space-time correlates of time like entanglement between positive and negative energy parts of zero energy states. MEs are very general solutions of field equations of TGD and have properties making them ideal for realizing basic functions of biosystems.

1. MEs represent propagation of classical gauge fields with light velocity and can carry non-vanishing vacuum em currents and hence give rise to coherent photons. A tentative identification is as biophotons of Popp [42]. The hypothesis is that MEs make possible generation of quantum entanglement between brain and sensory organs. In this manner they provide a realization for neuronal window idea generalizing the idea about hologramic brain [41]. MEs could make possible both classical (quantum) communication by the propagation of classical fields (coherent photons) along them and neuron could literally have a window to external world via sensory organ.

2. In TGD framework space-time sheets with negative time orientation are possible and carry negative classical energies (in General Relativity this is not possible). The generation of negative energy MEs provides "buy now, pay later" type mechanism for energy production. Generation of negative energy ME is classical counterpart for the generation of virtual particle and it is to be expected that the subjective lifetime of negative energy MEs is finite number of quantum jumps. Thus organism must eventually "pay", that is to compensate for the dissipation of the energy gained by the generation of the ME by metabolism. Therefore metabolism is still needed. Even more, organism must be able to give guarantees that it can pay! The ability to provide these guarantees is perhaps one of the great achievements of the biological evolution.

3. MEs carry large momentum since all Fourier components of the gauge fields have parallel lightlike momenta. Since classical 4-momentum is lightlike, the amount 3-momentum per energy is maximal. Thus, if the system is able to generate ME by quantum jump, it gains automatically large recoil momentum. Hence MEs could provide the fundamental mechanism making possible the coherent macroscopic motion of living systems. Negative energy ME of this kind might be identifiable as a mindlike space-time sheet representing the geometric correlate for the conscious decision to move.

4. MEs represent dispersionless propagation of a pulse preserving its shape and are thus ideal for classical communication. If negative energy MEs are possible, one can imagine a mechanism of "real subjective time" communication between selves of either geometric past or future having arbitrarily large timelike distance. This idea is not conflict with standard classical causality at given space-time sheet. Needless to say, this kind of possibility would realize concretely the idea about four-dimensional society and revolutionize our view about universe: living beings separated by billions of light years could in principle have "real subjective time" chat.

4.6.2 Support for the notion magnetic body

There exists both theoretical and empirical support for the notion of magnetic body.

Theoretical support

1. EEG and Uncertainty Principle

There are good reasons to expect that EEG is accompanied by radiation, which in TGD framework has topological light rays as space-time correlates. Typical EEG frequencies correspond to wavelengths $\lambda = c/f$ which for which natural length scale unit is Earth size. Thus Uncertainty Principle suggests that structures of at least this size are involved with the self hierarchy associated with the brain.

2. p-Adic physics as physics of cognition and intentionality

p-Adic physics as physics of intentionality and cognition is a fundamental key idea of TGD inspired theory of consciousness. p-Adic space-time sheets as correlates for intentions and p-adic-to-real transformations of them as correlates for the transformation of intentions to actions allow deeper understanding of also psychological time as a front of p-adic-to-real transition propagating to the direction of the geometric future. Negative energy MEs are absolutely essential for the understanding of how precisely targeted intentionality is realized.

Intentional behavior means that there is unpredictability in short time scales but predictability in long time scales because system can realize its long term plans and use its partially free will to cope with the changing challenges of the everyday life.

p-Adic topology differs radically from real topology in the sense that p-adically infinitesimal is infinite in real sense.

1. The rational values of real and p-adic imbedding space coordinates correspond to the same points of the generalized imbedding space (essentially union of real and p-adic imbedding spaces for various values of p with rational points common to all number fields and also points, in particular points with algebraic number valued coordinates, shared by different number fields in a pair-wise manner identified).

2. The points, which are p-adically close to each other can have arbitrarily long real distance since the points x and $x + kp^n$, $k \in \{0, p-1\}$, become arbitrarily near to each other p-adically and arbitrarily far way in real sense as n increases for the p-adic topology characterized by prime p.

This means that intentionality and cognition are literally cosmic phenomena and evolution of cognition and intentionality proceeds from long p-adic length scales to short ones in real sense (but from short to long scales in p-adic sense). The carving of a statue by starting from a rough sketch and adding details gradually is a good metaphor for what is involved. Development of any motor skill, say piano playing, is an excellent example of what happens.

Intentions are transformed to action in a phase transition changing p-adic space-time sheet to a real one. This process is most probable when real and p-adic space-time sheets have maximal number

of common rational points. Hence one expects that intentions can be transformed to large space-time sheets and topological field quanta are best candidates for these space-time sheets. Pairs of positive and negative energy topological light rays and negative energy topological light rays generated in the dropping of particles to larger space-time sheets, provide an example realizations of intentions. Also wormhole magnetic fields consisting of pair of space-time sheets carrying magnetic fields of equal intensity and having opposite time orientations could be generated intentionally.

3. Time mirror mechanism of long term memories

TGD based model of long term memory requires no storage of memories of past to the brain of the geometric now. The memories are in the geometric past as dynamical self organization patterns and subject to changes.

1. In the case of active memory recall the desire to remember is communicated to the geometric past by sharing and fusion of mental images made possible by entanglement. In the case of episodal memories also the memory recall would result in this manner. For non-episodal memories the memory would be communicated from the geometric past using classical communications.

2. In the case of episodal memories active precisely targeted memory recall might be difficult since the entanglement with a correct mental image seems to require good luck. In principle it is possible to select the distance T to the geometric past where the memory comes from by selecting the fundamental frequency of ME.

3. The most natural manner to realize the time mirror mechanism is to regard magnetic body as the system communicating with the brain of the geometric past serving as mirror. The fundamental frequency $f = c/L$ of associated with a topological light ray of length L would naturally code for the time span of the long term memory as $T = L/c$ in the sense that only these memories would be communicated resonantly. Thus the distance from brain along magnetic flux tubes would code the time span of the memory. Long term memories with a span of order lifetime however require that the size of the magnetic body involved is measured in light decades.

Experimental support for the notion of magnetic body

The work of Blackman and other pioneers of bio-electromagnetism concerning the effects of ELF (extremely low frequency) em fields on brain [61, 62] discussed in [22], provides dramatic support for this idea and also a concrete view about how brain manages to act as macroscopic quantum system. The currents generating EEG certainly create weak electromagnetic radiation fields which in TGD framework correspond to topological field quanta of size of Earth having natural coupling to the magnetic flux tubes.

The lowest Schumann frequency is roughly $c/2\pi R$, R radius of Earth, and equal to $\omega \simeq 8$ Hz. It is known that EEG frequencies are in the same frequency range as so called Schumann frequencies 8, 14, 21 ,... Hz [51] associated with the resonances of the electromagnetic fields in the 80 km thick wave cavity between Earth surface and ionosphere. The higher EEG frequencies seem to correlate with higher Schumann resonance frequencies: in particular, the frequencies 13 and 39 Hz which are also cyclotron resonance frequencies of Na_+, are very near to Schumann frequencies. Schumann frequencies vary in time and it has been found that also the variations of EEG frequencies correlate with this variation.

Magnetic perturbations near Schumann frequencies are known to have profound effects on human brain inducing altered states of consciousness and cortical instabilities such micro-seizures and epilepsies [81]. The photons generated by Josephson currents associated with macroscopic ionic BE condensates have wavelengths of order Earth size and the topological field quanta representing classically the radiation field have size of Earth.

The explanation of the effects related to water memory [58, 53] suggests that similar magnetic effects appear at much wider frequency range than ELF frequencies which would mean that the super-conducting magnetic flux tube circuitries form a fractal hierarchy. The findings challenging the notions of ionic pumps and channels [63] provide additional strong support for the notion of many-sheeted space-time and hierarchy of super-conducting of magnetic flux tubes. The evidence for the fractal hierarchy of magnetic flux tubes is discussed in [29, 28].

These observations support the view that our "physical" body is only a tip of an iceberg and formed by the topological condensation of the bio-matter around electromagnetic topological field quanta serving as templates for the bio-structures.

The findings of Libet [49] about time delays associated with the passive aspects of conscious experience suggest that our sensor perceptions are a fraction of second old (.3-.5 seconds). This could be understood if the sensory percepts from brain are communicated to the magnetic body identiable as 'us'. This particular time scale would correspond to a layer of magnetic body which has 3-5 times the size scale of electron's CD which is about .78 times the circumference. A possible interpretation is in terms of dark electrons with a value of Planck constant which is 3-5 times the standard value. The corresponding EEG frequencies would vary in region .33-.2 Hz.

Cyclotron resonances as key to quantum consciousness

The estimate for the thickness of the magnetic flux tubes of Earth's magnetic field based on the quantization of the magnetic flux is about cell size. There is direct evidence for the hypothesis that ions in the magnetic field of .2 Gauss (Earth' magnetic field has nominal strength of $B_E = .5$ Gauss) form quantum states with the characteristic energies of order 10^{-14} eV and size of the orbit being of order $2/\sqrt{eB}$, that is cell size: in fact, the value $.5 \times 10^{-4}$ Tesla for Earth's magnetic field corresponds to the length scale $L(169) \simeq 5$ μm rather precisely. This length scale is indeed the p-adic length scale which seems to correspond to our sensory consciousness and various macroscopic quantum phases seem to reside at $k = 169$ space-time sheets probably forming join along boundaries condensates. The work of Blackman and other pioneers of bioelectromagnetism concerning the effects of ELF (extremely low frequency) em fields on brain [61] provides dramatic support for this idea and also a concrete view about how brain manages to act as macroscopic quantum system.

The discovery of Blackman means that frequencies having special effect on biomatter correspond to cyclotron resonances for ions like Ca_{++}, Na_+, K_+ and Cl_- in magnetic field $B = 2B_E/5 = .2$ Gauss. The cyclotron frequency for Ca_{++} is 15 Hz whereas the remaining frequencies are in the range $7 - 13$ Hz (theta waves) at which also the most important Schumann resonances lie. The cyclotron frequency 5.5 Hz of iron is also a bio-active frequency and is the lower edge of theta region of EEG. Also lower frequencies resonant frequencies such as 2.4 (Iodium ion) are present. Even more remarkably, the pattern of data forces to conclude that the interaction occurs at quantum level. This conclusion is is dramatic conflict with the predictions of the standard quantum theory and with the standard view about space-time but consistent with the many-sheeted space-time concept of TGD.

A confession is in order: for years I erratically believed that the magnitude of the magnetic field assignable to the biological body is $B_E = .5$ Gauss, the nominal value of the Earth's magnetic field. Probably I had made the calculational error at very early stage when taking Ca^{++} cyclotron frequency 15 Hz as a standard. I am grateful for Bulgarian physicist Rossen Kolarov for pointing to me that the precise magnitude of the magnetic field implying the observed 15 Hz cyclotron frequency for Ca^{++} is .2 Gauss and thus slightly smaller than the minimum value .3 Gauss of B_E. This value must be assigned to the magnetic body carrying dark matter rather than to the flux quanta of the Earth's magnetic field. This field value corresponds roughly to the magnitude of B_E at distance 1.4R, R the radius of Earth.

$B = .2$ Gauss would corresponds to a flux tube radius $L = \sqrt{5/2} \times L(169) \simeq 1.58L(169)$, which does not correspond to any p-adic length scale as such. $k = 168 = 2^3 \times 3 \times 7$ with $n = 5$ would predict the field strength correctly as $B_{end} = 2B_E/5$ and predict the radius of the flux tube to be $r = 25$ μm, size of a large neuron. However, $k = 169$ with flux $2h_5$ would be must more attractive option since it would give a direct connection with Earth's magnetic field. Furthermore, the model for EEG forces to assume that also a field $B_{end}/2$ must be assumed and this gives the minimal flux h_5. Note that $n = 5$ is the minimal value of n making possible universal topological quantum computation with Beraha number $B_n = 4cos^2(\pi/n)$ equal to Golden Mean [29].

The conclusion that the effect of ELF fields on brain represents quantum effects associated with the transitions of ions confined in magnetic field in the direction of axon carrying $B = 2B_E/5 = .2$ Gauss , is supported by the following observations.

1. The frequencies $15, 30, 45, 60, 75$ Hz having effect on primates are multiples of the same basic frequency $f = 15$ Hz, which turns out to be the cyclotron frequency of Ca_{++} ion. That these frequencies come in multiples is a direct signature of quantum: in classical world only basic

frequency $f = 15$ Hz should have effects (forcing ions to rotational motion around field lines with this frequency.

2. Even multiples of 15 Hz have a weak but non-vanishing effect. This can be understood as resulting from parity conservation for the simplest transitions induced by that part of the interaction Hamiltonian which does not depend on the longitudinal coordinate of the axon. The reason is that odd and even values of n for harmonic oscillator states have opposite parities and the interaction hamiltonian describing the transition has odd parity. The simplest possibility is that these transitions occur in second via intermediate virtual intermediate state and correspond to second order in perturbation theory. This observation provides additional strong support for the hypothesis that quantum transitions are involved.

These observations are consistent with the following interpretation. Ions with charge Z, spin S and mass m in the external magnetic field behave quantum mechanically like harmonic oscillator with energies quantized as multiples of

$$
\begin{aligned}
E &= (n+\frac{1}{2})\omega_c + \frac{S_z}{S}\omega_L \ , \\
\omega_c &= \frac{ZeB}{m} \ , \quad (\hbar=1, c=1) \ , \\
\omega_L &= \frac{gS\omega_c}{4} \ .
\end{aligned}
\tag{4.6.1}
$$

Here S and S_z denote total spin and its projection to the direction of the magnetic field. The contribution to energy coming from longitudinal motion has not been written explicitly. Here g is so called Lande factor which for free elementary fermions equals to $g = 2$. The experimental findings suggests strongly that external em field induces resonant transitions from between magnetic states. By the quantization of the magnetic flux, predicted by TGD also classically, the minimal size of the magnetic flux tube for the magnetic field of Earth is of order cell size. An attractive hypothesis is that the magnetic field in question is associated with axon and is parallel to it.

It must be emphasized that this vision is forced by hard experimental facts and is in dramatic contradiction with the standard physics view about brain. The wave functions of ions in magnetic field are confined in a region of size of order

$$r_n \sim \sqrt{n/eB} \ ,$$

which is of the order of cell size for B=.2 Gauss: macroscopic quantum state is in question. In fact, the value $.5 \times 10^{-4}$ Tesla for Earth's magnetic fields corresponds to the length scale $L(169) \simeq 4$ μm rather precisely for minimal value of the magnetic flux quantized as $ZeBS = n2\pi$ obtained for $n = 1$ (S denotes the area of the flux tube) and $Z = 2e$. $L(169)$ seems to correspond to our sensory consciousness and various macroscopic quantum phases seem to reside at $k = 169$ space-time sheets probably forming join along boundaries condensates.

The binding energies of ions in Earth's magnetic field are extremely small: of order 10^{-14} eV, which is ridiculously small energy when compared with the natural energy scale of one eV and corresponds to a temperature of order 10^{-10} Kelvin. According to standard quantum physics, Earth's magnetic field should have absolutely no detectable effects in hot, wetty and noisy environment provided by brain. Many-sheeted space-time concept provides the solution to the riddle. Ions are not on the molecular space-time sheets but have dropped to the cellular space-time sheet and it is indeed very cold, dry and silent here: an ideal place for the formation of macroscopic quantum phases. The energy scale implies the upper bound $T < 10^{-10}$ Kelvin for the temperature at cellular space-time sheets.

A further empirical input of crucial importance were the observations challenging the cherished notions of ionic pumps and channels [63]. These findings lead to a concrete view about biosystems as three-levelled structures involving massless extremals (MEs), super conducting magnetic flux tube structures, and atomic space-time sheets containing the ordinary matter. MEs control the dynamics of the superconducting ions inside magnetic flux tube structures. Magnetic flux tubes in turn are in a many-sheeted ionic flow equilibrium with the atomic space-time sheets and thus control the ionic concentrations at these space-time sheets.

This general framework leads to a rather detailed model for the generation of nerve pulse and EEG; to a model of sensory representations based on the notion of sensory canvas realized in terms of magnetic flux tube structures outside body with MEs serving as projectors of the cortical sensory representations to this sensory canvas; to a model of cognition including the realization of the memetic code in terms of cognitive antineutrinos and a physical mechanism translating nerve pulse sequences to the 126 bit long codewords of the memetic code; and finally, to a model for the quantum correlates of the sensory qualia and to what deserves to be called spectroscopy of consciousness.

Electromagnetic selves

Rather remarkably, the time scale of .1 seconds predicted by the model of the memetic code and defining in the zero energy ontology a fundamental time scale of electron as well as the time scales of the photons associated with the magnetic transition frequencies, in particular cyclotron frequencies, of ions correspond to the time scale of EEG. The currents generating EEG certainly create weak electromagnetic radiation fields which in TGD framework correspond to topological field quanta of size of Earth: the lowest Schumann frequency is roughly $c/2\pi R$, R radius of Earth, and equal to $\omega \simeq 8$ Hz. It is known that EEG frequencies are in the same frequency range as so called Schumann frequencies 8, 14, 21 ,... Hz [51] associated with the resonances of the electromagnetic fields in the 80 km thick wave cavity between Earth surface and ionosphere.

The higher EEG frequencies seem to correlate with higher Schumann resonance frequencies: in particular,, the frequencies 13 and 39 Hz which are also cyclotron resonance frequencies of Na_+, are very near to Schumann frequencies. Schumann frequencies vary in time and it has been found that also the variations of EEG frequencies correlate with this variation. Magnetic perturbations near Schumann frequencies are known to have profound effects on human brain inducing altered states of consciousness and cortical instabilities such microseizures and epilepsies [81]. The photons generated by Josephson currents associated with macroscopic ionic BE condensates have wavelengths of order Earth size and the topological field quanta representing classically the radiation field have size of Earth.

These observations suggests the identification of the relevant selves in our self-hierarchy are electromagnetic selves having the size of Earth and correspond to EEG frequencies. What happens is that Josephson currents generate classical ELF em fields represented by topological field quanta of this size (by uncertainty principle alone) which in turn couple resonantly to ions. These observations raise the question whether our "physical" body is only a tip of an iceberg and formed by the topological condensation of the biomatter around electromagnetic topological field quanta serving as templates for the biostructures [19]. There is also neuropsycological evidence for the importance of ELF fields. In particular, the work of Michael Persinger is especially important [77, 78, 85, 81] [26].

One possible scenario inspired by these observations is following.

1. The magnetic transition frequencies for the superconducting ions at the flux quanta of magnetic field B=.2 Gauss correspond to personal sensory consciousness. The magnetic flux tubes emanating more or less vertically from brain and accompanied by massless extremals could act as projectors defining personal sensory representations at the magnetic sensory canvas formed by the flux tubes (or possibly shell like topological quanta) of Earth's magnetic field.

2. Schumann frequencies associated with the oscillations of the flux tubes of Earth's magnetic field would in turn correspond to transpersonal aspect of consciousness. Schumann resonances could indeed induce a synchrony of the vertical magnetic flux tube structures associated with separate brains and even entangle them during sleep. This view is supported by some observations. In hypnagogic states (states between wake and sleep) EEG is peaked near the lowest Schumann frequency 7.8 Hz. During these states it is possible to experience hallucinations and identification experiences (I have now and then fleeting but completely 'real' experiences of being someone else). The so called sleeping spindles correspond to EEG patterns at 14 Hz which is the second Schumann frequency. A possible interpretation is that during sleep collective consciousness begins to dominate and brains form a highly synchronous whole. It would be interesting to test whether there are correlations between EEGs of different persons during sleep.

4.6.3   Some functions of magnetic body

The magnetic bodies associated with various body parts, including cellular and even molecular magnetic bodies, could have several functions besides defining a hierarchy of intentional agents (for this aspect see [25]).

Topologically quantized classical fields as templates for the formation of bio-structures?

Magnetic bodies could serve as templates of bio-structures. For instance, blood circulation and central nervous system could have magnetic circuitries as templates. The web like structure formed by topological field quanta representing classical fields, in particular em fields, is reminiscent of structures formed by micro-tubuli and collagens forming the connective tissue of living systems. It has been already earlier suggested that magnetic flux tubes and other topological field quanta serve as templates for various bio-structures in the sense that ordinary matter is topologically condensed on the flux tube like structures. This would mean that living systems would be only part of much larger web formed by Earth's classical em field forming one particular sub-self (mental image!) of Mother Gaia.

The thickness for the flux tubes of Earth's magnetic field is about $2/\sqrt{eB} \simeq 4 \times 10^{-6}$ meters. There is direct evidence for the hypothesis that ions in a magnetic field $B_{end} = 2B_E/5 = .2$ Gauss, where $B_E = .5$ Gauss is the nominal value of the Earth's magnetic field, form quantum states with the characteristic energies of order 10^{-14} eV and size of the orbit being of order $2/\sqrt{eB}$, that is cell size. It must be emphasized that B_{end} is not equal to B_E as I erratically believed for a long time. The model for dark matter as macroscopic quantum phases with Planck constant equal to an integer multiple of the ordinary Planck constant [17] leads to the working hypothesis that B_{end} corresponds to the dark counterpart of B_E [22].

For $B_{end} = 2/5B_E = .2$ Gauss interpreted as a dark magnetic field with $\hbar = 5\hbar_0$ carrying 2 units of flux (the unit is $h_5 = 5h_0$) and corresponding also to the p-adic length scale $L(169)$, the radius is 25 μm, the size of a large neuron. This possibly relates to the fact that the effects of ELF em fields are observed for vertebrates (for details see [22]).

The coupling of the neuronal layers of cortex and perhaps all cells with the flux tubes of Earth's magnetic field could make possible entanglement between brain and Mother Gaia. If magnetic flux tubes of the dark counterpart of B_E have direct geometric coupling with brain one could perhaps understand the miraculous ability of birds and bees to navigate using Earth's magnetic field. The proteins navigating along micro-tubuli, cells navigating along collagen fibres and birds navigating along Earth's magnetic field lines would all be guided by higher level selves.

One could see also humans and the societies formed by them as continually self-organizing organs in the body of electromagnetic Mother Gaia. In this picture the narrow wave cavity of radius 80 km between Earth's surface and ionosphere could be like brain of Earth, which is very sensitive to the conditions of ionosphere and biosphere and has "biofeedback" coupling with living systems. The effect of oscillatory phenomena (sound, radiations and magnetic fields) at frequencies Schumann resonances on brain to be discussed below supports also the direct interaction of our brain with Mother Gaia via Earth's electromagnetic field.

It is interesting to notice that the ratio of the thickness of solar corona (10^6 m) to the radius of Sun (5×10^8 m), the height of the wave cavity of Earth (80 km) to Earth radius (7×10^6 m), the ratio of the thickness of grey matter of cortex (1 mm)to the size of human brain lobe (10 cm) as well as the the ratio of the thickness of the cell membrane (10^{-8} m) to the radius of neuron (2.5×10^{-6}) have roughly the same value of order 10^{-2}. Could this mean that cell membrane, cortex, electromagnetic cavity of Earth and solar corona might have similar role in the self hierarchy? The general ideas about self-organization indeed support this view: boundary regions are subject to the most intense external energy feed and thus self-organize most effectively.

The web formed by topological field quanta of the classical em and fields continues to arbitrary long length scales. For instance, the flux tube structure of solar magnetic field provides an explanation for the anomalously high temperature of solar corona and a model for solar spot cycle [17]. Perhaps also Sun is a conscious self forming part of "Indra's net" representing electromagnetic and other classical fields of cosmos. Since the four CP_2 coordinates are the primary dynamical variables, one must consider the possibility that topologically quantized classical gauge fields and classical gravitational field could form rather independent sub-selves.

Dark magnetic fields and living matter

A considerable sharpening of the above discussed speculative picture came with the development of TGD inspired vision about dark matter as macroscopic quantum phases with quantized value of Planck constant having arbitrarily large values coming as integer multiples of the ordinary Planck constant [17].

Dark matter hierarchy leads to a detailed quantitative view about quantum biology with several testable predictions [22].

1. The most general hypothesis is allowed by the proposed generalization of the notion of imbedding space is that the values of $r = \hbar/hbar_0$ come as rationals [17] . A less general alternative is that the values r of come as integers: $r = n$, where n characterizes the quantum phase $q = exp(i\pi/n)$ characterizing Jones inclusion [24]. In this case n would be a product of integers characterizing the number of sheets for singular coverings of CD and CP_2 .

2. The values of n for which quantum phase is expressible in terms of squared roots are number theoretically preferred and correspond to integers n expressible as $n = 2^k \prod_n F_{s_n}$, where $F_s = 2^{2^s} + 1$ is Fermat prime and each of them can appear only once. The lowest Fermat primes are $F_0 = 3, F_1 = 5, F_2 = 17$.

The prediction is that also rational or at least integer multiples of p-adic length scales are possible as preferred length scales. The unit of magnetic flux scales up as $h_0 \rightarrow h = rh_0$ in the transition scaling the Planck constant by r: one manner to achieve this is by scalings $L(k) \rightarrow rL(k)$ and $B \rightarrow B/r$.

$B = .2$ Gauss would corresponds to a flux tube radius $L = \sqrt{5/2} \times L(169) \simeq 1.58L(169)$, which does not correspond to any p-adic length scale as such. $k = 168 = 2^3 \times 3 \times 7$ with $n = 5$ would predict the field strength correctly as $B_{end} = 2B_E/5$ and predict the radius of the flux tube to be $r = 18$ μm, size of a large neuron. However, $k = 169$ with flux $2h_5$ would be must more attractive option since it would give a direct connection with Earth's magnetic field. Furthermore, the model for EEG forces to assume that also a field $B_{end}/2$ must be assumed and this gives the minimal flux h_5. Note that $n = 5$ is the minimal value of n making possible universal topological quantum computation with Beraha number $B_n = 4cos^2(\pi/n)$ equal to Golden Mean [29].

An natural working hypothesis is that B_{end} defines the dark counterpart of the ordinary magnetosphere and that the relationship $B_{end} = 2B_E/5$ holds as a time average in the entire magnetosphere. The flux quanta of B_{end} would carry dark matter and would be responsible for the quantum control of the living matter.

Magnetic flux tubes and metabolism

Magnetic flux tubes could define super-conducting circuitry making possible a many-sheeted control of homeostasis: this aspect is discussed in [28]. The hierarchy of magnetic flux tubes could also define many-sheeted lasers, and the dropping of particles to the larger space-time sheets would define a hierarchy of metabolic energy currencies as zero point kinetic energies liberated in the process. Process would also generate radiation at the harmonics of cyclotron frequencies at the larger space-time sheet . These frequencies could define a considerable part of EEG. Also fractally scaled up versions of EEG having similar band structure are predicted. The findings of Peter Gariaev [41] are consistent with this prediction [33]. The dropping of particles to larger space-time sheets for population inverted lasers would be also ideal for the realization of bio-control by time mirror mechanism and make possible remote metabolism and remote motor control.

Magnetic flux tubes as Nature's own bio-laboratory

Magnetic flux tubes could be ideal structures for the isolation and purification of various bio-molecules, and make also possible precise targeting of the reactants to reaction volumes defined by the nodes of the magnetic flux tube circuitry. Purification is made possible by the weight of the molecule if quantum-classical correspondence holds true in the sense that a magnetic flux tube carrying super-conducting bosons of mass m deforms so that it runs along a classical orbit of the particle with radius proportional to m. This would make sense for a many-sheeted magnetic field for which the fluxes associated with the magnetic flux tubes along which particles move return along much larger space-time sheets and define the average magnetic field in which the particles move. This kind of Nature's

own bio-laboratory might explain the miraculous selection of bio-molecules essential for the pre-biotic evolution. In accordance with the p-adic vision about the evolution of cognition, the evolution would have been proceeded from and guided by the magnetic flux tube structures of the Earth's magnetic field to the bio-chemical level [19].

4.6.4 The magnetic fields associated with body parts and higher levels of consciousness

The basic vision is that magnetic flux tubes containing ionic super-conductors, MEs carrying exotic representations of p-adic Super Virasoro algebra, and biological organisms live in a fractal symbiosis. MEs can induce cyclotron transitions amplified to quantum phase transitions inside magnetic flux tubes provided they have length above the wavelength defined by the cyclotron frequency. The exotic p-adic Super Virasoro representations with MEs have wavelength determined by the fundamental frequency which is of same order as the cyclotron frequency. The interaction of MEs and magnetic flux tubes by SQUID mechanism requires that magnetic flux of ME generates a current inside a circuit formed by magnetic flux tubes. Magnetic flux tubes to have arbitrary size scales below the size scale of ME.

Some body parts are carriers of static magnetic fields. The value of the static magnetic field associated with eye is slightly below 10^{-11} Tesla whereas the strength of Earth's magnetic field is about $.5 \times 10^{-4}$ Tesla. Also pineal gland ('third eye' also in a rather literal sense, see [24]) contains magnetic material. Unfortunately I do know the value of the corresponding dipole strength: for a dipole having size of order micrometer the maximal dipole strength would be very roughly 10^{-9} times corresponding dipole strength for Earth's magnetic field which would mean field of order 10^{-13} T. Also head and entire body could act as static magnetic dipoles.

For purely sensory consciousness .1 seconds is the characteristic time scale and EEG is closely related with this form of consciousness. In case of B_e the magnetic cyclotron frequencies are in the range obtained by scaling the range of cyclotron frequencies in Earth's magnetic field by a factor about 2×10^{-7}. This means that the periods of the ionic cyclotron frequencies are roughly in the range 12 hours-1.6 years for ionic cyclotron frequencies corresponding to the range of frequencies $90 - 0.1$ Hz in Earth's magnetic field. These time scales are typical for the contents of higher level self consciousness involving self narrative. Notice however that these fields are perhaps not sufficiently weak for a self narrative in the time scale of several years.

The minimal thickness of the flux tubes for ULF selves associated with B_e would be roughly of the order of few millimeters, as one finds by scaling the radius for the flux tube of Earth's magnetic field which is about 5 microns.

Also bodily magnetic fields B_b could be involved. By scaling one obtains for the head's magnetic field an estimate $(mm/headsize)^2 B_e \sim 10^{-4} B_e$, which gives fT which is slightly above the thermal noise produced by body. The flux tube would have minimal thickness about 10 cm, the size scale of the head. The cyclotron frequency range would be scaled by a further factor of 10^4 factor meaning that the time scale range would be between 10 years and 10^4 years!

Higher levels of self hierarchy as levels of dark matter hierarchy

Higher levels of dark matter hierarchy provide neat quantitative view about self hierarchy and its evolution. The integer $n = 2^{k11}$, $k = 0, 1, 2, ...$ seem to define favored values of Planck constant in living matter. This means a hierarchy in which time and length scales are zoomed up by a factor of 2048 in the transition to the next level of hierarchy. This integer represents also fundamental constant in TGD Universe [17].

For instance, EEG time scales corresponds to $k = 4$ level of hierarchy and a time scale of .1 seconds [16], and EEG frequencies correspond at this level dark photon energies above the thermal threshold so that thermal noise is not a problem anymore. Various levels of dark matter hierarchy would naturally correspond to higher levels in hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in questions. $k = 7$ would correspond to a duration of moment of conscious of order human lifetime which suggests that $k = 7$ corresponds to the highest dark matter level relevant to our consciousness whereas higher levels would in general correspond to transpersonal consciousness. $k = 5$ would correspond to time scale of short term memories measured in minutes and $k = 6$ to a time scale of memories measured in days.

The emergence of these levels must have meant evolutionary leap since long term memory is also accompanied by ability to anticipate future in the same time scale. This picture would suggest that the basic difference between us and our cousins is not at the level of genome as it is usually understood but at the level of the hierarchy of magnetic bodies [29, 22]. In fact, higher levels of dark matter hierarchy motivate the introduction of the notions of super-genome and hyper-genome. The genomes of entire organ can join to form super-genome expressing genes coherently. Hyper-genomes would result from the fusion of genomes of different organisms and collective levels of consciousness would express themselves via hyper-genome and make possible social rules and moral.

Could the flux tubes of bodily magnetic fields correlate with more abstract levels of self consciousness?

The previous observations combined with the general speculative vision about Indra's web of consciousness stimulate several questions and ideas relating to the role of various magnetic fields associated with body.

1. Could it be that the ULF selves associated with the ionic super-conductors residing at the flux tubes of the bodily magnetic fields B_e and B_b (notice also the static magnetic fields of pineal gland and of other organs) belong to the self hierarchy and represent higher level selves contributing to our non-sensory consciousness under ordinary circumstances? This translates to the question whether the flux tubes of the corresponding topological quantized magnetic fields are closed in a relatively small volume as in case of an ideal dipole field or whether part of flux tubes have astrophysical lengths.

2. The above arguments do not pose restrictions on the strengths of the magnetic fields. In case of Earth's magnetic field the magnetic flux tubes have sizes of order of the wavelength associated with a typical cyclotron frequency. Could it be that the interacting MEs and magnetic flux tubes have sizes comparable to the wavelength defined by cyclotron frequency? If this is the case for B_e and B_b, the sizes of flux tubes would be astronomical with light day serving as lower bound. One could see the flux tubes of B_e and B_b as kind of umbilical cords connecting human bodies with magnetic structures of astronomical size and perhaps also with other organisms. Could one assign the more abstract levels of human consciousness and long term memories with the ULF selves associated with both the flux tubes of B_e and B_b and with MEs? In this view biological organisms would be like sensory-motor organs of this magnetic super organism.

3. Could one possibly test this hypothesis in case of B_e by studying the interaction of ULF em fields with frequencies above the time scale defined by day? Is the daily rhythm somehow relevant at the level of these em fields? For instance, could the natural 24 hour period certainly associated with ULF em fields of eye define the analog of alpha peak in EEG? Could the strength of the magnetic fields of eye be seen as a result of adaptation to the daily rhythm or is it dictated by the size of eye and flux quantization (there is roughly unit flux over an area of order millimeter squared)?

Objection

The bodily magnetic field change with time if the location orientation of the magnetic dipoles are fixed with body. Already the rotation of Earth induces periodic rotation of the magnetic flux tubes B_e and B_b. The volitional motion during wake-up period induces further effects.

There are several manners to circumvent this objection.

1. The most convincing manner to avoid the objection is that the flux tubes relevant for ULF consciousness have size at least of order of the wavelength defined by the cyclotron frequency and thus of the same order of magnitude as the size of the corresponding MEs. In this scale the rotating motion for the end of the magnetic flux tube of B_e or B_b would have absolutely no significance and magnetic flux tubes would be somewhat like magnetic umbilic cords (like the tunnel involved with the NDE experiences connecting patient to the deceased relatives!).

2. If the magnetic flux tubes in question have sizes comparable or smaller than Earth size, the situation changes. Only in the very special case that the flux tubes rotate around Earth in the

direction of equator, B_e and B_b could remain stationary and it makes sense to speak about stationary states.

3. One could also consider the possibility that magnetic flux quanta are layer like structures around Earth rather than rotating tubular structures, and have rotational symmetry with respect to the rotations around Earth axis so that it is body which is rotating with respect to these structures rather that these structures rotating with body. In this case it would make sense to assign cyclotron frequencies to the super-conducting ions in question since local magnetic states are certainly possible. In super-conductors of type I near critical temperature complicated layer like flux structures are indeed possible and in [29, 28] it has been suggested that epithelial sheets formed by cell membrane inside cells correspond to this kind of flux structures.

The obvious question is how the rotation of Earth affects localized stationary states of the super-conducting ions inside co-rotating magnetic flux tubes with sizes smaller than Earth size. Does the description of the system in terms of cyclotron states make sense anymore? Quantum mechanically the ion in a stationary magnetic magnetic field is in radial degrees of freedom like a harmonic oscillator.

1. A simple analog system would be a harmonic oscillator rotating with an Earth and having an oscillation period which is longer than 12 hours. By separating center of mass degrees of freedom one finds that the particle in the rotating oscillator well feels besides the ordinary harmonic force a harmonic force $m\omega^2 \overline{r}_{cm}$ which means that the complete solution to the equations of motion is superposition of the harmonic oscillator motion plus a periodic oscillatory term with the frequency of the external force. The average motion is therefore just the rotating harmonic oscillator motion.

2. In quantum case one has harmonic oscillator coupled to an external harmonic force having a frequency much larger than the oscillator frequency. Time dependent perturbation theory allows transitions only between the states whose energy difference $n\omega_0$ equals to the forcing frequency and transitions thus possible only if one has $\omega = n\omega_0$. Thus no quantum jumps would occur in the generic case.

3. The guess motivated by these considerations is that the magnetic state in a rotating magnetic field is in a good approximation obtained by applying time dependent rotation to the ordinary magnetic state and that in the time scale defined by the cyclotron frequency the average effects to the state cancel also now. Thus effective adiabaticity holds true.

Further questions related to vision

One can make several interesting questions related to vision and the magnetic fields of eye.

1. What is the role of the rapid eye movements during REM sleep, in particular during dreams? Could it be that the communication of long term memories from ULF level is involved with dreams and that the rhythmic eye movements are essential for establishing this communication?

2. The motor control associated with eyes is decoupled from the motor control of the remaining body. Therefore persons who are totally paralyzed can still move their eyes and can even communicate in this manner. Could the special role of the eye-motorics relate to the remaining ability to stay in contact with ULF selves associated with eyes?

3. What is the interpretation of the rays of light characterizing the visual perception of intense light. Perhaps there is some natural explanation for this but since I do not know about it, I can entertain myself with the idea that these rays could directly correspond to MEs representing rays of light and connecting me with the objects of the external world. The correspondence between sensory experience and reality would be amazingly simple, if this is true.

NDE experiences and magnetic consciousness

NDE experiences [81, 76] involve vision in an essential manner. This suggests that the dominating component of NDE consciousness could correspond to ULF selves associated with B_e and or B_b and give rise to the typical bird's eye of view about own body involved with the OBE and NDE experiences.

The cyclotron frequency time scale associated with B_b would indeed fit with the life review experienced in NDE experiences. Body would be seen by ULF selves in bird's eye of view through the magnetic flux tubes of B_e and B_b. There would be a strange resiprocity resembling to the resiprocity encountered in the techniques of radio communications where the antennae sending messages can also serve as receiving antennae. NDE experiences involve also meeting of the dead relatives. Magnetic flux tubes can connect patient also to other organisms. and it would not be too surprising if magnetic flux tubes starting from the body could serve as an umbilic cord connecting the patient with living relatives or magnetic structures representing deceased relatives.

NDE experiences involve also the experience of travelling through a tunnel. The tunnel is experienced also during epilepsy and migraine, during meditation and relaxed state of mind, and with certain drugs like LSD, philocybin and mescaline.

I have also personal 'tunnel experiences' every-daily: when I close my eyes in a half-meditative state achieved by writing at computer terminal, I can see a dim flow consisting of points. Typically this flow enters to or emergences from a tunnel. It can be rotating spiral like flow or simple sink or source. Source or sink can be also linear structure. The experience is not stable and tends to fade away all the time, and after few minutes I am not anymore able to achieve it. During my great experiences this flow was much more complicated and completely visible and formed a stable background of the ordinary visual experience and of hallucinatory visual images.

There is however no experience of entering into the tunnel in this case so that the tunnel need not be the same as encountered in NDEs. I have pondered quite a many times about the possible interpretation of this background flow. The basic observation was that it resembles liquid flow to a very high extent. Liquid flows are usually incompressible in an excellent approximation and this means that the velocity field is divergence free. This is the basic property of also magnetic fields and means that magnetic flux through a circuit moving along magnetic flux lines is conserved. This has stimulated the obvious guess that the background flow indeed represents magnetic field. The question which I have not made is whether this magnetic field resides inside my brain or outside it. In light of the above considerations the most natural answer to the question is that the magnetic field visualized by the flow is precisely where it seems to be. The flow would represent nothing but the magnetic field associated with my own eyes or more probably head, or rather how the self associated with the flux tubes of this magnetic field experiences the world.

The thickness of the flux tubes of B_b would be roughly the size of the head and this fits with idea that the tunnel experience represents directly the magnetic flow without any scaling factors involved. The fractality of TGD Universe suggests that these magnetic fields contain flux tubes of stronger magnetic fields inside them, so that the tunnel experience would represent the flux tubes of these magnetic fields experienced as sub-selves by the ULF self contributing to my visual consciousness in this altered state of consciousness. Of course, it might well be that also during the ordinary consciousness the experiencer is this magnetic ULF self and that sensory input dominates the content of the conscious experience and creates the illusion about body as self. In the absence of a sensory input the contents of consciousness of a clinically dead person is determined by these magnetic field and bird's eye of view about body results.

What remains after the physical death could therefore be determined by the magnetic fields involved with body. Magnetic flux conservation allows configurations of the closed magnetic flux loops containing ionic super-conductors as the counterpart of soul continuing existence after death. Wormhole magnetic fields and p-adic variants of these magnetic fields would also make it possible to store information about the magnetic fields originally associated with body. The overall view suggesting itself that our bodies are like sensors and motor organs of a gigantic electromagnetic organisms of astrophysical size and represent its sub-selves (mental images). This interpretation conforms with the fact that in EMDR method rhythmic eye movements induce experiences involving the meeting of deceased relatives [54].

The experimental study of what happens to the magnetic fields associated with eyes, head and other body parts after the physical death would obviously provide interesting information in this respect, perhaps one can someday even develop refined methods of communication with the deceased.

What about magnetic fields of heart?

The magnetic fields associated with eyes are not the only bodily magnetic fields with peak intensities higher than the non-static magnetic fields generated by brain. Heart generates a periodically oscillating

magnetic field B_h of order $.5 \times 10^{-10}$ Tesla which is almost ten times higher than the static magnetic field generated by eyes. I do not know whether B_h contains a static component and if so, what is its strength. In any case, the absence of the static component means that the possibly super-conducting ions inside flux tubes of heart's magnetic field are in a periodically oscillating dipole field (most probably with respect to the geometric time!).

Also here my 'great experience', which has turned out to be an extremely valuable repertoire of altered states of consciousness, provides an illustrative example. During the second great experience which lasted only one night, I experienced what might be called 'heart consciousness'. In the beginning of the experience my whole consciousness was filled by the rhythmic '..aqua-aqua-aqua..'. It took some time to recognize that this rhythm was the rhythm of my own heart. Involved was also the mystical experience about the fundamental importance of water for life (said jokingly, heart is an organ specialized to deal with liquid!) and the precognition of the notion of infinite primes. Could it be that the MEs associated with heart dominated the contents of my consciousness during this experience.

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Chapter 5

Quantum Model for Sensory Representations

5.1 Introduction

This - as also the other chapters of "TGD Inspired Theory of Consciousness"- was written for the first time for more than a decade ago. The recent version is an outcome of an updating motivated by the progress taken place in quantum TGD proper during the period 2005-2010. Several new elements are involved. The improved understanding of the quantum TGD itself at the fundamental level; zero energy ontology including the notion of causal diamond (CD) defined as the intersection of future and past directed lightcones; the hierarchy of Planck constants requiring a generalization of the notion of imbedding space and involving the identification of dark matter as phases with non-standard values of Planck constant; and the progress in the undersaning of p-adic physics- especially the realization that life could be seen as something residing in the intersection of real and p-adic worlds. The fact that number theoretic entanglement negentropy has a positive value in the intersection has profound implications for the TGD inspired theory of consciousness and quantum biology since the quantum measurement theory is modified profoundly.

5.1.1 Overall view about TGD inspired theory of consciousness

TGD inspired theory of consciousness allows to construct a general model of conscious experiences based on some very general principles.

1. The original view was that notion of quantum jump defines "microscopic" theory of consciousness whereas the notions of self and self hierarchy allow to understand "macroscopic" aspects of consciousness absolutely essential for brain consciousness. It however seems that zero energy ontology and the hierarchy of Planck constants allow to identify these notions by replacing the quantum jump as a fractal structure consisting of quantum jumps within quantum jups. Despite this I will prefer to talk about these notions as separate ones in the sequel. The assumptions about how the contents of consciousness of self is determined allow to understand the basic structure of conscious experience at general level. One can understand intentionality and volition as closely related to the p-adic nondeterminism. Negentropic quantum entanglement is stable under state function reduction if governed by Negentropy Maximization Principle (NMP) so that state function reduction is not a random process anymore. The implications are obvious for understanding how conscious intelligence emerges. Theory leads to a very general model of sensory experience -including a vision about qualia- and the so called whole-body consciousness involving in an essential manner negentropic entanglement explains the basic characteristics of altered states of conscousness.

2. The understanding of the relationship between subjective and geometric time has evolved via several proposals and leads to the notion of psychological time involving in an an essential manner the new view about space-time. Symbolic representations at space-time level required by quantum classical correspondence are made possible by the classical nondeterminism of Kähler

action. All space-time sheet are assigned to CDs in zero energy ontology and correspond to mind-like space-time sheets in the earlier terminology. They serve as geometric correlate of selves. The notion of psychological time forces to view the entire many-sheeted space-time surface as a living system so that the standard notion of linear time is illusory and reflects the restricted information content of our conscious experience rather than fundamental 4-dimensional reality.

The paradigm of 4-dimensional brain provides a completely new understanding of the long term memory: no memory storage mechanisms are needed and one avoids the basic difficulties of neural net models. There are two kinds of memories: subjective and geometric. Also geometric memories come in two types: episodal and declarative. Time-like negentropic entanglement make possible episodal memories as a direct re-experiencing in the intersection of real and p-adic worlds, and state function reduction trivializing time-like entropic entanglement gives rise to declarative, verbal memories mediated by classical communications. Massless extremals (MEs) are proposed to serve as space-time correlates for both kinds of memories. The fact that the temporal duration of the light-like self associated with ME can be arbitrarily long, is very probably of significance. The hierarchy of Planck constants allows to overcome the objection due to the fact that the photons with the required extremely low frequencies are below the thermal threshold in living matter and therefore should not have any role for consciousness. Emotions might be understood as resulting from the comparison of geometric memories (the expectation) with the subjective memories (what really happened). The positive-negative coloring of the emotions could relate directly to whether the mental images corresponds to a system with negentropic or entropic entanglement.

3. An essential element is macrotemporal quantum coherence accompanying the formation of bound and negentropically entangled states. Already zero energy ontology assigns macroscopic time scales of coherence to elementary particles and the hierarchy of Planck constants and the stability of negentropic entanglement against state function reduction bring in additional elements. Quantum spin glass degeneracy lengthens the lifetimes of the resulting bound states.

4. Subjective time development by quantum jumps implies quantum self-organization which can be regarded as a sequence of quantum jumps between quantum histories. This evolution corresponds to a sequence of superposition of macroscopic space-time surfaces associated with the final state quantum histories assignable to the hierarchy of CDs. Quantum jumps imply dissipation at fundamental level. As in standard approach dissipation serves as a Darwinian selector of self-organization patterns, which can represent both genes and memes. Jumping from the bottom of a valley of the 4-D quantum spin glass energy landscape to the bottom of another valley by a temporary delocalization in zero modes explains phase transition like processes ranging from a change of protein conformation to the replacement of a habit routine by a new one. Further new elements to the standard view about self-organization are brought by zero energy ontology, negentropic entanglement, and hierarchy of Planck constants implying that second law does not hold true in the standard form anymore. An especially interesting prediction is that the CDs assignable to elementary particles correspond to macroscopic time scales. For instance, electron corresponds to the fundamental .1 second bio-rhythm.

The role of energy feed in self-organization becomes more complex in TGD framework. Learning becomes a fundamental process since state function reduction for negentropically entangled states is not random process anymore and in the first approximation the powers of unitary process define an iterative self-organization process. In this framework one can in principle understand how habits, skills and behavioral patterns are gradually learned. The possibility of the reversal of the arrow of the geometric time below p-adic time scale characterizing the system brings in time reversed dissipation identifiable as a healing. Bio-rhytms could quite generally correspond to dissipation-healing cycles. Motor action could be understood as geometric time reversal for the build-up of sensory representation in an appropriate time scale.

This process gives deep insight to a repertoire of widely different phenomena.

1. The formation of bound and negentropically entangled states implies subjectotemporal fractality of consciousness meaning that the basic anatomy of quantum jump is replicated in various time scales, even that of human life cycle.

2. Both kinds of entanglements mean fusion of mental images. In entropic fusion subselves lose their consciousness whereas negentropic fusion accompanies the experience about expansion of consciousness. Depending on the character of entangling selves (real or p-adic for some p), one can assign to the negentropic entanglement some positively colored experience, say experience of understanding or experience of love. Telepathic sharing of mental images and remote mental interactions become possible. Sexual and spiritual experiences can be seen manifestations of the same basic process of fusion of selves and sex would be present even at the molecular level. For instance, information molecules and receptors entangling negentropically could be seen as having opposite molecular sexes with the binding of the information molecule to receptor giving rise to the experience of 'oneness' and favoring co-operation instead of competition.

3. If the randomness of the outcome of the ordinary state function reduction means free choice, then self can choose to some degree whether subself ends up to a state in which it can decompose to subselves by state function reduction or becomes a entropic or negentropic subself stable against state function reduction. Maybe this choice could be seen as a choice between good and evil.

4. For negentropically bound states the powers of unitary process U define a sequence quantum computer type processes. More concretely, the combination of the notions of magnetic body and hierarchy of Planck constants leads to a model of DNA as topological quantum computer [24]. Zero energy ontology and 4-dimensionality of the ensemble of computations assignable to sub-CDs mean deviations from the standard model for quantum computation.

5. The binding energy liberated in the formation of bound state entanglement is usable energy: this means quantum metabolism based on buy now-pay later mechanism. Negentropic entanglement in turn can carry positive energy and there is a large temptation to assume that metabolic energy is transferred in this manner so that the somewhat nebulous notion of high energy phosphate bond would involve new physics.

The general vision about different types of conscious experiences and about qualia was discussed in [31]. In this chapter a general model of personal sensory representations is considered: in [24] a more detailed model for these representations is discussed. The so called magnetospheric sensory and memory representations possibly responsible for the third person aspect of consciousness are discussed in [23].

5.1.2 The quantum hardware

The model involves the following basic notions and ideas about the quantal hardware of consciousness.

1. TGD universe is quantum spin glass and the plasticity of the brain is in accordance with a model of brain as point moving in an infinite-dimensional spin glass energy landscape. Inhibitory and excitatory nerve pulses induce motion in the energy landscape and justify the notion of frustration characterizing spin glass. The picture differs from ordinary neural net in that spin glass energy landscape has also time as one dimension in a well defined sense (this is due to the failure of the classical determinism in standard sense for the Kähler action defining the dynamics of the system). This allows a new view about what happens in learning.

2. The general model of sensory experience relies on the music metaphor. Axons are like strings of a music instrument. What this metaphor means is however not obvious. Frequency coding relates only the intensity of the sensory quale. Nerve pulses induce dropping of various ions to magnetic flux tubes in magnetic fields of $\simeq .2$ Gauss (Earth's magnetic field has nominal value .5 Gauss) and this generates EEG MEs at EEG frequencies serving as entanglers to the sensory magnetic canvas, and the variation of these frequencies could code for the distance to the object of the perceptive field.

A stronger interpretation of the metaphor sould be that sensory pathways are like strings of a musical instrument such that the sound produced by the string corresponds to a particular sensory modality and corresponding higher level cognitive representations associated with it. Primary sensory qualia can be associated with sensory receptors or primary sensory organ if brain and sensory organs are quantum entangled with each other. Nerve pulse patterns would

build up what could be regarded as notes representing the music whereas the music (primary sensory qualia) is produced by the primary sensory organs. This leads to a generalization of the idea about brain as an associative, cognitive net.

3. The notion of self hierarchy is central for the model and allows to understand quantum correlates of the sensory qualia.

   (a) Self hierarchy is very much analogous to the hierarchy of subprograms of a computer program and defines a hierarchy of increasingly abstract experiences. Self hierarchy allows to understand computational aspects of brain although connectionistic picture realized as quantum association network seems to work at various levels of the hierarchy.

   (b) The empirical results [61, 62] about the effects of oscillating em fields on brain suggest that cyclotron frequencies, and more generally magnetic transition frequencies, of biologically important ions in magnetic field $B \simeq .2$ Gauss, which is by a factor $2/5$ weaker then the magnetic field of Earth, correspond to important oscillation frequencies of Josephson currents or some other perturbations acting on the system. Also the magnetic transition frequencies of electronic Cooper pairs seem to be important as perhaps also Z^0 magnetic transition frequencies of neutrino and various ions and atoms and even molecules. Classically cyclotron frequency for Josephson current corresponds to resonance.

   (c) The role of massless extremals (MEs) have become more and more central in TGD inspired theory of consciousness as I have gradually understood their properties. Very briefly, MEs are ideal for both classical and quantum communications, they give rise to quantum holograms both in quantum gravitational and 'technological' sense. MEs make also possible the realization of long term memories as communications between future and past. The notion of conscious hologram makes these ideas very concrete.

   (d) The strange findings challenging the notions of ionic channels and pumps lead to the view about biosystem as a symbiosis of MEs, superconducting magnetic flux tube structures, and atomic space-time sheets. The latter two are in many-sheeted ionic flow equilibrium controlled by MEs and very elegant control mechanisms based on the classical em interaction between MEs and flux tubes inducing supra currents emerges.

   (e) Self hierarchy has as its geometric correlate the hierarchy of CDs the level of imbedding space and the hierarchy of space-time sheets at space-time level. The fact that Josephson currents associated with ELF frequencies generate photons with wavelengths of size of Earth which by uncertainty principle correspond to topological field quanta with size of Earth. The only possible conclusion seems to be that our subselves correspond to (at least) these topological field quanta so that we are much more than our neurons.

   (f) It took years to arrive to the conclusion that also magnetic flux tube structures associated with various parts of brain could have same size as EEG MEs and serve as sensory canvas in the sense that the positions of objects of perceptive field are represented as subselves at the magnetic flux tubes of varying thickness woken-up by MEs generating magnetic transition frequencies. Obviously MEs and magnetic flux tubes associated with the sensory projectors must be very closely related (perhaps they are parallel to achieve Alfwen wave resonance). Various attributes associated with the object of the perceptive field are associated with these magnetic subselves and brain, or rather entire central nervous system, can be seen as a collection of pre-existing features of perceptive field which can be activated. Also long term memory recall can be understood in this framework as a communication between geometric now and geometric past made possible by MEs (which correspond to lightlike selves) and magnetic flux tube structures associated with brain, both having astrophysical sizes.

5.1.3   Me as a computer sitting at its own terminal?

It became as a surprise that the vision resulting from a long lasting thought experimentation is actually very much what the original, now twenty five year old, altered state of consciousness experience about myself as a computer sitting at its own terminal, when taken very literally in some aspects, actually suggests. This vision adds to the standard view about brain an additional layer responsible for the

sensory representations and brings in the quantum level of control (possibly from magnetic body) so that nerve pulse patterns are only part of the control loop.

1. Magnetic flux tube structures serve as a sensory canvas analogous to the computer screen. The control commands realized by activating MEs, in which state they create coherent states of photons and possibly also other gauge bosons, generate magnetic quantum phase transitions, and induce supra currents, Josephson currents and Ohmic currents, provide a realization for the keyboard of this computer. Brain serves as central processing unit: the computations carried out are parallel computations and program modules are replaced by various self-organization patterns.

2. Motor actions and sensory representations differ in that they are time reversals of each other in a relevant p-adic time scale.

3. What imagined motor actions and sensory experience mean is not quite clear.

   (a) The first view is that for imagined motor actions and sensory experiences the first (rather than last as one might think!) step in the sequence of commands is simply not realized. For sensory experiences the first step means sensory input assuming that primary sensory qualia are at the level of sensory receptors. A real motor action proceeds like a geometric time reversal of the sensory input and starts from motor organs if it is real, and from some higher level if it is imagined. p-Adic-to-real phase transition is the basic step initiating neural activity leading to imagery.

   (b) A more quantal view about imagination is based on the notion zero energy states with time-like negentropic entanglement. In this case qubits and more general states are always fuzzy so that Schrödinger cat is never completely alive or completely dead. Suppose one takes a zero energy for which nothing happens and adds to it a little bit of state for which the imagined event happens. The higher the probability of the imagined event is, the nearer the imagined event is to a real event.

4. Cortex can be seen as a collection of pre-existing cognitive features which are activated when they appear in the perceptive field or form a part of motor action. The basic task of cortex is to identify these features from the sensory input, entangle them with sensory input, and project to the magnetic body.

5. The decomposition of the perceptive field into objects is one of the basic aspects of sensory experiencing and TGD provides a mechanism generating these objects as mindlike space-time sheets: the boundaries of these objects correspond to regions of strong Kähler electric field whose strength is assumed to correlate with the intensity of the neural input. It might be that even the objects of perceptive field or thoughts could be regarded as features. At the neuronal level one ends up to a model in which neurotransmitters at the ends of magnetic flux tubes attach to receptors at the ends of magnetic flux tubes connecting cell membrane and DNA and give in this manner rise to a fusion of the pre- and post-synaptic mentl images. In contrast to standard neuroscience view, gene level would be involved in an essential manner in the information processing. U process could be described as a generalized Feynman diagram in which synaptic transmissions replace particle exchanges and for negentropically entangled states learning would correspond to a sequence of powers of U.

6. The computational activities associated with the construction of the sensory representations (say estimating distances and directions of the objects of perceptive field) and virtual sensory representations representing the goals of motor action are presumably realized as iterated processes in which virtual sensory inputs characterizing the expected experiences are compared with the real world sensory input. In a similar manner the goal of the motor action is compared with the sensory representation resulting from effect of a virtual motor action on the representation of the recent state of world and body. This comparison does not necessarily require sensory representation at any level of the self hierarchy and could be based on comparison circuits defined by parallel supra currents in which the inputs which are sufficiently near to each other generate constructive interference giving rise to a large Josephson current. The fractal hierarchy of CDs coming as octaves of CD size and the hierarchy of Planck constants in principles makes possible

zooming up and down possible so that simulations can be carried out in time scales smaller than that characterizing self.

7. The neural realization of long term memories has remained to a high extent a mystery and TGD suggests that the fundamental realization is not in fact neural. TGD allows the geometric memory storage in the geometric past, where the things happened and still happen. MEs suggest several candidates for the memory recall mechanisms and the quantum communication between geometric future and past is one of the most promising ones. Active memory recall might involve a question sent to the geometric past as a classical signal, perhaps MEs are involved at this stage. In the case of episodal memory the answer would involve the generation of time-like negentropic quantum entanglement: the recalled experience is shared by the experiencer now and in the geometric past. For declarative memories outside the intersection of real and p-adic worlds the communication of the memory would be classical.

8. The model of intentionality is mirror image of the model of long term memories obtained by real$\rightarrow$ p-adic and geometric past$\rightarrow$ geometric future replacements.

5.2   General ideas about hardware of consciousness

In this section general ideas and metaphors about what quantum brain and quantum brain functioning might be, are summarized. These ideas have developed gradually during last decade and continue to do so. The recent view about brain conforms with the great sixteen years old vision about self as a computer sitting at its own terminal.

This vision, if taken completely seriously, means that the ultimate sensory representation conscious-to-us is outside the brain: that this is the case became clear quite recently (the geometric now when I am writing this is October, 2001). The title of this section is 'General ideas about hardware of consciousness'. rather than 'General ideas about brain'. The reason is that brain and body in TGD Universe form only a tiny part of a system involving hierarchy of MEs and magnetic flux tube structures having astrophysical sizes controlling the matter at the atomic space-time sheets defining brain and body in the usual sense of the world.

I defend this radical deviation from the standard wisdom by the fact that the world 'consciousness' has ceased to be a taboo only during the last decade. It would be really astonishing if the materialistic view about consciousness as an illusion and brain as a computer would generalize to a general theory of consciousness just by adding one candle to the birthday cake of one century of brain science. Just like the creation of physics at the times of Kepler meant revolution in Earth centered world picture, also the creation of the general theory of consciousness is bound to mean thoroughgoing changes in the basic prejucides about human consciousness.

5.2.1   Brain as a computer

Brain as a computer metaphor in sense of Turing machine has been one of the dominating metaphors about brain functioning. In TGD this metaphor makes sense as far as general functional architecture of modern computer is considered. Programs must be however replaced by self-organization patterns.

Brain as a computer sitting at its own terminal

My personal great experience involved the realization that I am in some sense a computer sitting at its own terminal. It took more than one and half decades to realize what this self-referential idea having deep mystic coloring in it might mean in practice. Actually I realized the connection only after having ended up to this kind of view about brain by quite different routes.

To be precise, 'computer' does not mean in the recent context the abstract Turing machine, but a real world personal computer. The concrete functional and geometric architecture seems to be mimicked by personal computers, not the detailed data processing. the deterministic computer programs are replaced by much more flexible self-organization patterns.

1. Brain corresponds to the central processing unit of this computer. The data in computer memory are typically represented at computer monitor which is outside the central unit, can have much

larger size and be located arbitrary far away. In the case of brain this means that the ultimate, conscious-to-me sensory representations are realized outside brain at superconducting magnetic flux tube structures associated with various parts of brain. This view is inspired by very simple observation: when my eyes or my head move, I do not experience that the sensory image of external world moves although its physical representation in brain moves. As if I were an external observed looking the projection of sensory data on canvas inside brain so that the motion of canvas does not matter.

The standard argument is that the fact that brain constructs sensory representations about the motion of eyes, head, and body, is enough to generate the experience that the world is not moving. At least in TGD framework it is extremely difficult to understand how the sensory image of the external world in motion would not give rise to the experience that the world is in motion. I see the failure to realize this point as one of the fatal consequences of computationalism decoupled from physics: the ability to calculate what really happens does not simply give rise to the experience what really happens in the world of physics.

2. In computer the representation of the data on monitor, printing of data, and even various control actions such as the control of a robot reduces to sending of files to various kinds of receivers: the data is just expressed in various manners. In case of brain this means that that the processes leading to sensory experience or motor action differ only in their last steps. If the last step is not present, imagined motor action or sensory experience is in question. Imagination would involve as a seed p-adic cognitive representation, which is transformed by a p-adic-to-real phase transition to a real form, which in turn serves as initiating cell membrane oscillation pattern leading to an almost sensory experience or almost motor action (also nerve pulse patterns might be involved).

This picture leads to a very general view about sensory representations and motor actions. In this picture also "features" reduce to MEs and this might be too strong an assumption.

1. Brain can be regarded as a collection of standard feature records represented by MEs. These features represent basic features of objects of perceptive field and primitive elements of motor actions. The set of feature MEs is pre-existing and realization of the sensory image or motor action only activates a subset of these MEs. In principle the locations of feature MEs could be more or less random which means extreme flexibility and ability to adapt to new situations.

2. The basic frequency associated with a particular sensory ME codes for the distance of the object of the perceptive field and the direction of ME codes for its direction. Sensory MEs are naturally organized in radial bundles, files, representing various directions for the objects of perceptive field at given distance. Feature MEs with nearly the same frequency generate magnetic quantum phase transitions waking up magnetic self in the desired distance on the magnetic sensory canvas and thus assign to the object of the perceptive field various kinds of attributes. This means nothing but frequency binding and leads to what might be called spectroscopy of consciousness: EEG acts like a spectrogram allowing to deduce information about the functional state of brain.

3. Support for the view that sensory input and motor activities are very similar comes from motor synesthesia in which person can represent the sensory input by dancing it! More concretely, the realization of intention as motor action reduces to generation of MEs propagating along axons and generating desired membrane oscillation and nerve pulse patterns. There might be however a crucial difference also: motor action could be a geometric time reversal for the construction of a sensory representation and start from a rough sketch in the geometric now and develop quantum jump by quantum jump to a detailed plan in the geometric past. Time reversed dissipation would polish a sketch to a precise plan. Motor action would start from the motor organs and proceed to the level of brain.

4. Brain can be said to contain a collection of passive sensory and motor features which it activates selectively. This brings in mind computer game containing large number of extremely simple files, for instance sound files producing *Aaaargh*'s and *Auuuch*'s. The activation of ME record could mean ME is color rotated by coherent state of configuration space photons to electromagnetic ME which in turn generates coherent state of photons and configuration space photons acting

as a control command; activates magnetic quantum phase transitions; induces supra currents; or something else. Similar mechanism works even at the level of DNA where genes can be coded to various kinds of control commands by activating the associated MEs.

What this view implies that there is no need to worry about how brain realizes ultimate sensory representations inside brain as neural activities. What remains to be understood how brain develops into a collection of the standard features; how brain recognizes the standard features from the incoming sensory input; how brain evaluates the distances and orientations and other data related to the objects of the perceptive field; how brain decomposes the perceptive field into objects; and many other things not listed here.

1. Feature recognition might be based on comparison circuits based on supra current circuits. Expected features would be represented as standard patterns of supra currents. When the pattern of supra currents associated with the sensory input and running parallel to those of expected sensory input is sufficiently near to the expected one, a resonant generation of Josephson currents occurs and gives rise to a recognition of the feature.

2. The positions and other geometric data about the objects of perceptive field are presumably estimated by an iterative process in which the sensory input from the virtual world construct of the perceptive field is compared with the real sensory input which could be sustained in the sensory circuits. Cortico-thalamic communications might relate to this iteration. The comparison takes place by comparison circuits and when the two inputs resemble each other sufficiently, a sensory output at the magnetic canvas is generated. The consistency of these two representations should be gained gradually through learning and by the requirement of consistency between different sensory inputs. Similar comparisons are involved with the development of motor action to yield the final action giving rise to the desired goal.

Brain as a motor and sensory organ of higher level selves

Certainly the most dramatic deviation from the standard neuroscience implied by this view is the prediction of an entire hierarchy of MEs and magnetic selves using brain as a generalized sensory and motor organ. We correspond to only one level in this hierarchy making decisions and controlling the behavior of our body in certain time scale. For instance, long term goals and socially acceptable behavior could be seen as forced by selves at the higher levels of the hierarchy. Drives could perhaps seen as activities forced by lower level selves in the hierarchy (amygdala and other parts of paleobrain contra neocortex). What makes this so dramatic is that the sizes of our magnetic bodies could be astrophysical (here one must of course be very cautious: the realization of long term memories however encourages strongly this view). For instance, EEG ME and corresponding magnetic flux tube structures would both have sizes measured using Earth size as a unit.

A possible mechanism for the motor control from our own sensory canvas as well as from the sensory canvases of higher level selves is provided by MEs. The classical gauge fields entering to brain and body would represent very high level commands, and might be transformed to endogenous sounds by piezoelectric effect identifiable as internal speech (internal speech could also correspond to p-adic MEs). This is only one possibility. The construction of the model of nerve pulse and EEG leads to quite general model for the interaction of MEs as bridges between two space-time sheets characterized by different p-adic primes, and inducing a flow of charge between the two space-time sheets, inducing in turn a flow of em charge, and in case of cell membrane a change of membrane potential leading to the triggering of the nerve pulse. The reduction of the effective phase velocity of ME to the conduction velocity of nerve pulse or of some other excitation involves the shift of entire ME to future occurring in each quantum jump. If the shift occurs in the direction of geometric past, a super-luminal effective phase velocity results. Both cases might be involved, and would correspond naturally to propagating and standing EEG waves and to the spacelike and timelike soliton sequences predicted by the model for Josephson junctions.

Boolean mind and memetic code

The original proposal for the realization of Boolean mind was in terms of sequences cognitive neutrino pairs. These can be interpreted as wormhole contacts carrying neutrino and antineutrino at the light-like wormhole throats and would thus represent boson like entities. In the framework of the standard

model the proposal looks of course completely non-sensical. TGD however predicts the existence of long range classical electro-weak fields, and one might imagine that inside neutrino- whose Compton length corresponds to length scale of cell- intermediate gauge bosons behave like massless fields. Although neutrinos could be important, the time scale of corresponding CD - about 10^4 years - suggests that cognitive neutrinos might be important in much longer time scale than the .1 second time scale assignable to the memetic code.

The recent view about TGD allows a much more general view. Zero energy ontology allows to interpret the fermionic parts of zero energy states as quantum superpositions of Boolean statements of form $a \rightarrow b$ with a and b represented in terms of positive and negative energy parts of the zero energy state. If one has negentropic entanglement this kind of state has interpretation as an abstraction - a "law of physics"- representing as a quantum superposition various instances of a more general law.

The simplest situation corresponds to a CD having only single positive energy fermion and negative energy fermion at its light-like boundaries. The fermion number or spin or isospin of the fermion could represent qubit. The hypothesis that memetic code corresponds to the next level of Combinatorial Hierarchy, when combined with p-adic length scale hypothesis, led to a prediction of order .1 seconds for the duration of the 'wake-up' period of subself corresponding to the codeword of the memetic code. Since the CD assignable to electron has time scale .1 seconds and the CD assignable to u and d quarks has time scale $1/1.28$ milliseconds there is a temptation to proposed that the quark-like sub-CDs of electronic CD give to a realization of memetic code word as a sequence of 126 quark like sub-CDs. u and d quarks would be assigned to the magnetic flux tubes connecting DNA and the lipids of the cell membrane in the model of DNA as topological quantum computer. Clearly, beautiful connection between new elementary particle physics, genetic code, nerve pulse activity, DNA as topological quantum computer, logical thought, and the basic time scales of speech are suggestive.

This codeword consists of 126 bits represented by quarks such that the two possible magnetization directions correspond to the two values of Boolean statement. This implies that the duration of single bit should $1/1260$ seconds. The duration of the nerve pulse is slightly longer than this which might mean that the full memetic code is realized as membrane oscillations rather than nerve pulse patterns. Both hearing and vision have .1 second time scale as a fundamental time scale and sounds are indeed coded to membrane oscillations in ear.

One can consider also the realization of genetic code with six bits of the codon represented by various scaled up versions of quark CD coming as size powers of 2. In this case the ordering of the bits would come from the size of sub-CD whereas in previous example temporal ordering would define the ordering. It is not however clear whether the powers of two can be realized physically.

One can understand the number 126 as related to the total number of separately experienced frequencies in the interval $20 - 20.000$ Hz spanning 10 octaves. $10 \times 12 = 120$ is not far from 126: here 12 corresponds to 12 tones of basic music scale. Also speech has 10 Hz frequency as fundamental frequency. In visual primary cortex replicating triplets, 4-,5- and 6-plets of spikes with highly regular intervals between spikes have been detected. The triplets are accompanied by ghost doublets. This would suggest a coding of some features of visual experience to reverberating mental images. The time scale for various patterns is .1 seconds. This could be seen as a support for the realization of some degenerate version of the memetic code as nerve pulse patterns.

The model for the memetic code encourages the following conclusions.

1. Membrane oscillation/nerve pulse patterns correspond to temporal sequences of magnetization directions for quarks representing yes/no Boolean statements.

2. The spin polarization of quarks is changed from the standard direction fixed by the spontaneous magnetization in the direction of axon by a ME moving parallel to axon, and inducing membrane oscillation or even a nerve pulse. Nerve pulses could correspond to a degenerate memetic code resulting by frequency coding for which the number of distinguishable code words is 64, and would thus naturally correspond to the reduction of the memetic code to the genetic code.

A very precise correspondence with the basic structures of the genetic code results. mRNA $\rightarrow$ protein translation corresponds to the translation of temporal sequences o magnetization directions to conscious cognitive experiences. Under very natural constraints the mapping to cognitive experiences is not one-to-one and the predicted degeneracy (2^{126} sequences correspond to $(2^{126} - 1)/63$ cognitive experiences) can be understood.

One might think that the full memetic code is an evolutionary newcomer and involved only with the logical thought: this would explain the completely exceptional characteristics of human brain. The full memetic codecould be realized for certain regions of brain only. These regions certainly include auditory pathways responsible for the comprehension of speech [26, 18, 18, 27].

5.2.2   Brain, MEs, and quantum holograms

MEs represent a communication link in the control hierarchy formed by the magnetic body having onion like structure consisting of superconducting magnetic flux tube structures and flux sheets carrying dark matter, and space-time sheets carrying visible matter, and would be thus involved with the fundamental control operations. EEG MEs and they fractal variants could mediate classical signals and act as time-like entanglers assigning mental images to the points of the magnetic body with distance to the magnetic body being coded by the length of ME and the direction of the point by the direction of ME. Of course, also the deformations of magnetic flux tubes could mediate classical signals as counterparts of Alfwen waves, and magnetic flux tubes are natural space-like entanglers - the model of DNA as topological quantum computer as an example about this function.

A possible vision about how MEs act as communication links between magnetic body and biological body

One can imagine large number of options for how the MEs are concretely involved with biology and I have done so. The recent view about TGD inspired biology allows to consider a highly unique model for how MEs could perform their role as a communication link.

1. The most plausible one is that MEs associate with the communications between biological body and magnetic body are generated by genome acting as a kind of relay station. For this option MEs attached to the flux tube going through the passive DNA strand would mediate sensory data from the cellular environment to the magnetic body. The sensory data from environment would arrive through magnetic flux tubes connecting biomolecules and lipids of cell membrane to the passive DNA strand analogous to sensory areas of cortex.

2. Magnetic body could induce nerve pulse activity as one particular form of gene expression by ME attached to the flux sheet going through the active DNA strand. Rapid signalling along flux tubes connecting DNA nucleotides and lipids would make this gene expression much faster than the ordinary one. Also nerve pulse activity would be communicated to the magnetic body from the lipid layers of neuron membrane via genome and magnetic body could generate it It is of course possible that also reflex like nerve pulse activity which does not involve magnetic body is present. From the time scale of the nerve pulse the size scale of the layer of the magnetic body involved with nerve pulse activity must correspond to quark CDs and would be about 10^{-5} meters. This fits nicely with the vision about DNA as topological quantum computer.

3. EEG MEs could be automatically generated as an outcome of nerve pulse activity, when ions drop to the flux quanta of magnetic field $B \simeq .2$ Gauss (Earth's magnetic field has nominal value .5 Gauss), and entangle mental images with the points of the sensory magnetic canvas.

This vision is of course not the only one that one can imagine. As discussed in [18], genetic/memetic code could also have translation to control commands represented by pairs of MEs orthogonal to DNA strand/axon. In latter case orthogonal pairs of MEs must move along axon with the same velocity as nerve pulse pattern. Stationary EEG MEs translate the nerve pulse patterns to the patterns of lightlike vacuum currents. TGD based model of EEG and nerve pulse [18] predicts two kinds of EEG waves: moving and stationary, and it might be that they correspond to these two kinds of codings. The properties of moving/stationary EEG waves suggest their association to left/right brain hemisphere. Left brain might favour the coding of memetic codons to moving EEG ME pairs whereas right brain might favour the coding of nerve pulse patterns to stationary EEG MEs.

The notion of neural window

The notion of neural window, which was the original form of the hologram idea, allows to see information processing in brain from a slightly different point of view.

1. Massless extremals act as quantum antennae and generate coherent light and also provide waveguides along which BE condensed photons can propagate like Cooper pairs in super conductor. The photons radiated by the space-time sheets representing objects of the perceptive field and propagating along microtubules could provide neurons with a neuronal window. This picture would abstract just the bare essentials of the idea of hologrammic brain: small piece of hologram is like a small window yielding the same picture as larger window but in blurred form.

2. Massless extremals associated with neural activity could also represent or be accompanied by association sequences making possible geometric memories representing simulations of future and past. What is mysterious from the point of view of the standard neuroscience is that left part of the body sends sensory stimuli to the right brain hemisphere and vice versa. In TGD framework the mystery disappears: the maximization of the axonal lengths maximizes the durations of the association sequences and hence optimizes geometric memory.

3. Neuronal window idea would perhaps make it possible to realize the idea about iterative computation of conscious experiences involving guesses and comparisons. Neuronal windows would generate representations of various perceptive landscapes in disjoint parts of thalamus (sensory organs feed their input in separate parts of thalamus) and mental imagery would construct guesses for the cognitive representations for the objects of the external world realized in the cortex as mindlike space-time sheets radiating coherent light. The neural pathways from cortex to thalamus would provide thalamus with a neural window to cortex and comparison of the landscapes from cortex and sensory organ would be possible. Simple comparison circuits might be at work: neuron would fire when its neural windows to the cortex and sensory organ give sufficiently similar views.

4. One can sharpen the neuronal window idea by combining it with the music metaphor. This would mean that the massless extremal associated with a given axon would correspond to a Bose-Einstein condensate of photons (or configuration space photons) with one particular frequency. This would mean vision at neuronal level (nothing to do with our vision realized in EEG frequency scale). Thus one can say that each neuronal window is either covered by curtains or provides a view to single sensory landscape at single frequency.

The experiments of Mark Germine

MEs could also serve as a communication link between living matter and magnetic bodies representing levels of collective consciousness responsible for the cultural aspects of our consciousness.

The experiments of Mark Germine [69] provide evidence for the notion of ELF self and associated collective memory. What was studied was the evoked EEG response to a series of random quantum stimuli, which consisted of series of identical stimuli with randomly located deviant stimulus. Two subject persons, A and B, were involved, the first one experienced stimuli as pictures in computer monitor, the second one as sounds. In case that A observed the differing stimulus 1 second before B, the evoked EEG response of B became incoherent. Since evoked stimulus was oscillation at EEG frequency of about 11 Hz in case that A had not observed the stimulus, one could understand the mechanism as a direct evidence for collective 'ELF ME' at this frequency interacting with brains of both A and B. When ELF ME had already heard the stimulus once, it did not react to it in similar manner. Rather interestingly, 11 Hz corresponds to the 10.7 Hz cyclotron frequency associated with Fe_{++} ion in a magnetic field of .2 Gauss (Earth's magnetic field has nominal value of .5 Gauss). Ca^{++} cyclotron frequency in this field is equal to 15 Hz and would explain the effects of ELF fields on vertebrate brain occurring at harmonics of this frequency.

MEs and long term memory

MEs provide a mechanism of long term memory which differs from ordinary sensory perception only in that the ME giving rise to a geometric memory has much longer duration with respect to the geometric time than the ME giving rise to ordinary sensory perception. To remember classically is to look at a mirror located at a distance of light years. The ends and branching points of magnetic flux tubes are good candidates for the mirrors where MEs are reflected.

In TGD framework synaptic strengths code only cognitive representations and learned associations, not genuine information about events of the geometric past. Long term memory is coded in the

classical em field and in coherent light generated by ME in hologram like manner. Any finite space-time region receiving the classical em field of coherent light generated by it gets hologram like picture containing info about entire geometric time interval spanned by ME. If vacuum current is localized to some restricted space-time region (it can be!), the hologrammic information is about this region and receiver anywhere along the ME gets more or less the same information since hologram is in question. ELF selves can perhaps control this localization. Note also that the lightlikeness of the boundary of ME implies that ME selves have temporal extension defined by the length of ME.

The fact that memory is stored to the moment of geometric time at which event occurred explains why we know that mental image is memory. It is quite possible that MEs are involved with sensory perception, say vision and auditory experience, and make possible to develop time-like entanglement (possibly negentropic) with the sources of light as belonging to the external world. Geometric memory allows also understand identification experiences and transpersonal experiences in which person can experience events of the distant past not related to the personal history. Anticipation of future in turn could be also understood as particular kind of geometric memory, the MEs involved are now p-adic representation intentions, plans, and expectations. Later a more detailed model of long term memories will be developed.

5.2.3   Generalized notions of sensory experiencing and motor activity

The general view about brain is as a system moving of a fractal energy landscape of quantum spin glass containing valleys inside valleys inside... Brain is not only an on observer of the external world but also of its own position in the spin glass landscape. Brain is not only activator of ordinary motor programs but generates also movements in the spin glass energy landscape. Thus the general functional division sensory experience-motor action generalizes and provides completely new insights to the brain circuitry and functioning. For instance, one could perhaps understand why neural loops are bi-directional. The first loop provides sensory information about the position of brain region in its spin glass landscape and the second loop mediates the motor action: just like in case of the spinal chord.

The sensory experiences giving information about spin glass landscape can be interpreted as giving rise to a generalized sensory and emotional input. Emotions correspond to entropy gradients of various types for selves. A mental image with a positive/negative emotional color results from negentropy/entropy feed to subself. If the sign of entropy feed to mental images correlates with the entropy gradient of the system represented by subself, emotions become sensory qualia. Emotions provide perhaps the most important 'Is it going well' type information about the state of brain and body. Entropy gradients can be also used as an active control tool: subselves are rewarded by negentropy feed and punished by a entropy feed. Note that the generalized motor action inducing motion in the spin glass landscape is identifiable as emotional expression and generates entropy gradients and thus emotions.

5.2.4   The paradigm of four-dimensional brain

Four-dimensionality of brain is crucial for the understanding long term memories as multitime experiences receiving contributions from several moments of geometric time. This identification makes it unnecessary to have any memory storage mechanisms. Rather, the activities of the memory circuits can be seen as increasing the probability that memory recall occurs. Reverberating memory circuits in which experience is echoed indeed do this by extending the deep memory valley in spin glass landscape to a long canyon in time direction. This increases the probability that mindlike space-time sheets enter in the region of four-dimensional spin glass landscape representing the memory. The deepness of the spin glass valley correlates with the emotionality of the memory. Childhood memories are especially emotional and therefore stable. Memories are result of creative action and memory circuit involving hippocampus seem to be active in carving out the art works representing geometric memories worth of remembering. TGD based approach solves the basic problems of the neural net approach resulting from the fact that the formation of new memories destroys old memories and from the fact that it is difficult to understand how the component of experience is known to be a memory.

Four-dimensional brain provides a completely new view about how gemeralized sensory experiences are generated, how generalized motor actions are planned and how memories are constructed. This process is like creating an artwork. *Four*-dimensional spin glass landscape representing a rough scetch

is gradually refined by adding details and corrections in increasingly shorter time scales: this corresponds to neural activities of four-dimensional brain generating motion leading to the desired part of spin glass energy landscape. This picture is consistent with the observed $1/f$ noise and fractality of nerve pulse patterns. Absolutely essential is self-organization and related dissipation forcing the Darwinian selection leading to end product which is charicature rather than photo.

5.2.5   Music metaphor and the function of the nerve pulses and EEG

Music metaphor allowing to see brain as a music instrument. gradually changed from a guiding principle to a prediction of TGD inspired theory. In case of brain the music played is EEG and ZEG spectra. EEG frequencies serve as resonant frequencies at which various quantum phase transitions occur resonantly. Various sensory qualia correlate with EEG frequencies and place coding and possibly also temporal coding by cyclotron frequency scale is possible. Stochastic resonance and pendulum metaphor, which are discussed in [18], allow to understand the mechanisms for the transformation of EEG waves to nerve pulse patterns and vice versa.

The picture about brain as self-organizing system suggests that neurons are subject to strong selective pressures and specialize to produce highly specialized fixed components of our experience so that music metaphor holds true. If music metaphor holds true generally, the nerve pulses involving fast transmitters can be said to pick the strings of the sensory instrument represented by axons and spatio-temporal patterns of nerve pulses determine the overall pattern of the sensory experience. Nerve pulses inducing motor action in sensory landscape represent pushes and pulls in spin glass energy landscape. These pushes and pulls induce motion in the spin glass landscape and generate both neuronal and our emotions. It seems that simplest emotions with no association telling the cause or object of emotion, are determined by the nerve pulse pattern only.

This picture suggests for neurotransmitters two obvious basic functions: they mediate nerve pulses from presynaptic neuron to postsynaptic neuron and modify the properties of synapse and postsynaptic neuron. Fast neurotransmitters controlling directly ion channels are involved with mediation and the relevant time scale is one millisecond: no long term change of the postsynaptic neuron is involved. Sensory experiences and motor actions are mediated by direct neurotransmitters. Slow neurotransmitters involving second messanger action are involved with modulation of the response of the postsynaptic neuron and the time scales can be of order minutes. In this case the properties of the postsynaptic neuron are changed.

Emotional reactions involve typically slow transmitters and the effect of them can be regarded as a generalized motor action inducing motion of neuron in the spin glass energy landscape of the neuron. The large information flows associated with neurotransmitters imply entropic gradients and thus also emotions. Some neurotransmitters such as serotonin and dopamine, which generate sensations of pleasure, should reduce entropy and thus fight against the second law of thermodynamics. This presumably occurs at the neuronal level and could be only represented at the level of the sensory selves, where some other mechanisms of the entropy reduction and generation could be at work. An interesting question relates to the warriors in the war against second law. Could glial cells play key role here as is suggested by the observations that depression (in which mental images becomes very entropic and emotional flatness and emptiness results) involves abnormally small amount of glial cells in forebrain and abnormally strong emotional reactions of amygdala.

One can see associations at neuronal level as formed by the pairs of input and output. Input corresponds to the sensory experiences associated with active presynaptic neurons and output to the activity in the axons. The postsynaptic receptors serve as sensory receptors and each neuron could be specialized to its own sensory modalities which are same for the entire sensory pathway. Alternatively, primary qualia are associated with the sensory receptors or sensory organs: this option provides very elegant understanding of what imagination and dreams are. Boolean axons give rise to 'Boolean modality' representing thoughts. Typically sensory-Boolean associations are associated with the associative regions of brain and are realized as a fusion of mental images. The formation of an association corresponds to the fusion of space-time sheets representing pre- and post-synaptic neurons to single space-time sheet. The space-time sheets formed by the orbits of synaptic vesicles form the 4-dimensional join along boundaries bond. Fusion to single space-time sheet makes possible conscious association containing both inputs and output as a single experience. This picture also explains the time directedness of association. 'Our' associations are superpositions of neuronal associations associated with various neuronal circuits.

5.2.6   Connection with the functionalistic view about brain

The basic counter argument against quantum theories of consciousness is that the so called classical theories of brain can quite well explain all the relevant aspects of brain functioning whereas quantum theories of consciousness seem to add very little if anything to this understanding. It seems that huge misunderstandings are involved on both camps.

The notion of self is fundamental for consciousness. For some reason the proponents of quantum consciousness (including me hitherto) have however failed to realize that they should perhaps try to formulate this notion as a quantum-physical concept. Indeed, 'What is the quantum counterpart of self' was the bottleneck question in TGD approach and led to the final breakthrough.

Neuroscientists (and also many quantum physicists) in turn seem to have wrong view about what the term 'classical' means. This wrong view reflects the wrong view about time and dissipation, which in TGD framework can be understood elegantly in terms of the subjective time development identified as a sequence of quantum jumps between quantum histories. It is of crucial importance that this development can occur only inside selves! Dissipation is the basic correlate of consciousness and consciousness is the basic prerequisite of 'classicality' understood in the erratic manner. Thus, from the TGD point of view, Hodkin-Huxley equations have nothing to do with genuinely classical world. Rather, they model phenomenologically the development of neurons by quantum jumps between quantum histories. Quantum jumps (and dissipation) inside neurons is possible only because neurons act as subselves and dissipate. Our self can be regarded as a system making something like 10^{38} quantum jumps per second. This implies macrotemporality but this macrotemporality has absolutely nothing to do with classicality in the sense as it appears in the field equations of say General Relativity.

The notion of self as quantum self-organizing system justifies the use of cybernetic notions such as circuits, loops, feedback, feedforward, inhibition and excitation. The general neuroscientist's view about brain as a complex neuronal circuitry finds justification and one ends up with rather concrete identifications for what kind of conscious (not necessary conscious to us –) experiences are associated with various brain circuits. The essentially new elements are 4-dimensionality of brain and realization of qualia and Boolean mind in terms of macroscopic quantum phases and these additional elements lead to genuine understanding of what happens in brain.

The randomness of the quantum jump is certainly a strong argument against quantum theories of consciousness and for me it took quite a long time to realize how serious this objection actually is. One can quite well claim that it leaves only one option: standard non-equilibrium thermodynamics in which dissipation in the presence of external energy feed selects the self-organization patterns. The possibility of negentropic entanglement in the intersection of real and p-adic worlds is what changes the situation and removes the randomness of quantum jump so that unitary process U and its powers define an iterative self-organization process leading to generation of fractal structures and quantum computation like processes possible. This makes also possible conscious goal directed actions and the existence of genuine information rather than only lack of dis-information is what makes possible also learning at the fundamental level.

5.2.7   Brain as an associative net

Brain can be regarded as an associative net. At neural level association is a pair of incoming axons and outgoing axon: during synaptic transfer the space-time sheets of pre- and postsynaptic neuron fuse to form a larger space-time sheets and the corresponding conscious experience is association formed by the experiences determined by pre- and postsynaptic neurons. Neurons have their own sensory qualia associated with transmitter-receptor combinations: also neuronal seeing and hearing is possible. These qualia are probably not ours. From the point of view of our consciousness, nerve pulse patterns are most important and give rise to symbolic representations of sensory input. Frequency coding is involved and memetic code is reduced to genetic code. Membrane oscillations correspond to full memetic code and higher level cognition. Emission of at least slow neural transmitter gives rise to neuronal emotion. During synaptic firing the association pair becomes conscious. The most elegant option is that sensory qualia are at the level of primary sensory organs.

Also motor actions, in particular the transformation of Boolean statements to speech, can be regarded as associations of this kind. Motor action would be time reversal of sensory perception in appropriate time scales, and the motor actions initiated from some level higher than muscle cells correspond to motor imagination. Speech represents translation of memes to motor actions analogous to

the translation of genes to proteins. For instance, logical reasoning develops as associations respecting basic rules of logic. This could explain why we are so poor in performing conscious logical deduction. On the other hand, rules of logic could be unconsciously inherited at the level of experience pairs from the physical world which obeys logic.

The most general possibility is that he output of a complex neuron is some function of the inputs. Music metaphor however suggests much simpler possibility: output is the same always and represented by nerve pulse pattern inducing postsynaptic qualia which depend on the receptor-transmitter combinations involved. This assumption has very strong consequences. Especially interesting are the sequences of associations associated with closed neural loops. The assumption that projections are topographically organized and that given axon is always in the same state mean that all closed circuits are reverbatory. Thus elementary single neuron association sequences associated with various brain circuits would be fixed and nerve pulse patterns should be determined the content of various conscious experiences constructed from these elementary experiences: the analogy with music would be very close. This would have quite strong consequences as far as the general structure of the brain circuits are considered.

1. Memories could quite correspond to asymptotic nerve pulse patterns reverberating in memory circuits. Nerve pulse patterns in closed would determine the content of memory and memories would result as fixed point patterns of self-organization. Very probably also microtubular representations of long term memories are important.

2. Motor plans would be represented by nerve pulse patterns reverberating in motor circuits and selected by self organization and realized as genuine motor actions only in case that the geometrically time reversed process starts from the muscle cells.

3. In case of Boolean thoughts reverberating circuits correspond to tautologies so that one can question the hypothesis that axons are permanently in the same state. Of course, there is no need to assume that thoughts correspond to closed circuits.

Negentropic space-like quantum entanglement between neurons, neuronal membranes and DNA strands, and DNA strands and magnetic body adds to this picture a further element necessary if one wants to speak about conscious brain able to learn. Synaptic transmission becomes the molecular counterpart of enlightment experience in which neuronal subselves experience an expansion of consciousness. Learning as gradual evolution of synaptic strengths can be understood as the space-time correlate for the evolution defined by the unitary process U and its powers in the space of zero energy states representing M-matrices allowing an interpretation as abstractions describing the "laws of physics" as experienced by brain.

5.3 Quantum tools for biocontrol and -coordination

Coordination and control are the two fundamental aspects in the functioning of the living matter. TGD suggests that at quantum level deterministic unitary time evolution of Dirac equation corresponds to coordination whereas time evolution by quantum jumps corresponds to quantum control. More precisely, the non-dissipative Josephson currents associated with weakly coupled super conductors would be the key element in coordination whereas resonant dissipative currents between weakly coupled super conductors would make possible quantum control.

This view allows to considermore detailed mechanisms. What is certainly needed in the coordination of the grown up organism are biological clocks, which are oscillators coupled to the biological activity of the organ. Good examples are the clocks coordinating the brain activity, respiration and heart beat [45]. For example, in the heart beat the muscle contractions in various parts of heart occur in synchronized manner with well defined phase differences. Various functional disorders, say heart fibrillation, result from the loss of this spatial coherence. For a control also biological alarm clocks are needed. An alarm clock is needed to tell when the time is ripe for the cell to replicate during morphogenesis. Some signal must tell that is time to begin differentiation to substructures during morphogenesis: for example, in case of the verterbrates the generation of somites is a very regular process starting at certain phase of development and proceeding with a clockwise precision.

5.3.1   Massless extremals, magnetic flux tubes, and electrets

Massless extemals (MEs), magnetic flux tubes and magnetic body, and electrets define the basic new notions of TGD inspired theory of consciousness and quantum biology and it is good to introduce them first before discussing the quantum tools.

Massless extremals

The identification of mindlike space-time sheets as 'massless extremals' (MEs) together with the notion of magnetic body leads to a very general vision about bio-consciousness and an explanation for the fact that the effects of ELF em fields on biomatter occur only for certain amplitude windows [62] (these effects are discussed in detail in [29, 28]

1. What MEs are?

Massless extremals (MEs) define a very general solution set of field equations associated with Kähler action [18] and representing various gauge fields and gravitational fields[32]. Being scale invariant, MEs come in all size scales. The geometry has axial symmetry in the sense that CP_2 coordinates are arbitrary functions of two variables constructed from Minkowski coordinates: lightlike coordinate $t - z$ and arbitary function of the coordinates of the plane orthogonal to the z-axis defining the direction of propagation. The polarization of the electromagnetic field depends on the point of the plane but is temporally constant. MEs represent waves propagating with velocity of light in single direction so that there is no dispersion: preservation of the pulse shape makes MEs ideal for classical communications.

Electric and magnetic parts of various gauge fields are orthogonal to each other and to the direction of propagation. Classical gauge has as its source lightlike vacuum current. The time dependence of the vacuum current is arbitrary, this is only possible by its lightlikeness. This makes it possible to code all kinds of physical information to the time dependence of the vacuum current. MEs can have finite spatial size and in this case they are classical counterparts of virtual photons exchanged between charged particles and represent classical communication between material space-time sheets. MEs carry gravitational waves and various classical color and electroweak gauge fields propagating with light velocity.

MEs can also carry constant electric and magnetic fields but in this case the boundaries of ME contain necessarily the sources of this field. Lightlike vacuum currents or elementary particles in massless phase could serve as sources MEs could also form double-sheeted structures with wormhole contacts serving as effective sources. It took quite a time to realize that the wormhole contacts have interpretation as gauge bosons and their super partners. Therefore quantum classical correspondence between classical fields and field quanta emerges automatically. In the case of single-sheeted MEs the interpretation is as a space-time correlate for fermion or a super-partner of fermion.

TGD allows the possibility that the two sheets have opposite time orientations and therefore also opposite classical energies. In zero energy ontology this might be always the case for the double sheeted MEs assigned to bosons and their super-partners. The opposite sign of the energy makes it possible to realize virtual particles as pairs of on mass shell particles of opposite sign of energy and this of utmost importance in the recent formulation of quantum TGD [17]. A natural guess would be that pairs of positive (negative) energy MEs correspond to massless on mass shell particles and pairs of MEs with opposite energies represent naturally virtual particles. The objection is that it idifficult to understand how the spin of on mass shell gauge boson could be represented in terms of fermion and antifermion spins associate with the throats of the wormhole contact. Massless Dirac equation seems to allow only longitudinal net polarization for the resulting gauge bosons. The resolution of the problem is based on modified Dirac action which mixes M^4 chiralities. This mixing is also behind the massivation of elementary particles. Quite generally, the exchange of a double-sheeted ME between material space-time sheets can correspond to arbitrary value of the exchanged momentum. Also fermions and their superpartners are assumed to topological condense in in the interaction region and become temporarily double-sheeted but the other sheet need not be ME anymore.

This kind of structures are obvious candidates for cognitive structures since classical nondeterminism is localized in a finite space-time volume and direct connection with the notion of virtual particle characterizing the non-determinism of quantum theories emerges. World should be full of MEs with all possible sizes since they have vanishing action: addition of ME with finite time duration yields

new absolute minimum of Kähler action since Kähler action does not change in this operation. This suggests that MEs should be of crucial importance in TGD Universe.

2. Interaction of MEs with matter

The basic interaction mechanisms of MEs with superconducting flux tubes are magnetic induction generating supracurrents, the action of MEs as Josephson junctions between magnetic flux tubes, and magnetic quantum phase transitions stimulating radiation of coherent light which in turn BE-condenses on MEs and defines a feedback loop.

Many-sheeted ionic flow equilibrium defines the basic control mechanism with superconducting magnetic flux tubes taking the role of master and atomic space-time sheets taking the role of slave. Magnetic phase transitions could make possible chemical senses based on an endogenous NMR type spectroscopy. Also other than magnetic quantum transitions, such as changes of protein (in particular enzyme-) conformations, could occur coherently at superconducting space-time sheets, so that super-conducting space-time sheets could allow an extremely effective high precision quantum control of the biochemistry. Magnetic quantum phase transitions make possible place coding by if the thickness of magnetic flux tube varies and this coding is crucial in the model for how various features are associated with objects of perceptive field at a given position.

MEs allow at their lightlike boundaries representations of super conformal– and super-symplectic algebras with gigantic almost-degeneracies of states due to the almost-commutativity of Poincare algebra and super-symplectic algebra. Super-symplectic states define genuine quantum gravitational state functionals in the space of three-surfaces, the 'world of classical worlds', and correspond to a higher abstraction level than ordinary quantum states defined in the 'world' (space-time). This 'world of classical worlds' aspect of quantum gravitational states explains why quantum gravity is crucial for consciousness.

3. Possible functions of MEs

MEs serve as receiving and sending quantum antennae [32]. Lightlike vacuum current generates coherent light. Also coherent gravitons are generated. MEs serve also as templates for BE condensation of photons and gravitons with momenta parallel to the lightlike vacuum current. Linear structures, say DNA and microtubules, are natural but not the only candidates for structures accompanied by MEs. Since MEs are massless, they carry maximal possible momentum. This makes exchange of ME ideal mechanism for locomotion. The possibility of negative energy MEs is especially fascinating since it suggests 'buy now, pay later' mechanism of energy production: perhaps living matter uses MEs to generate coherent motions [40, 31].

Perhaps the most important function of MEs in living matter is communication and control. MEs can connect different parts of biological body at various levels. For instance, they can be attached to magnetic flux tubes. MEs would be also involved with the communications between magnetic body and biological body and EEG would represent one particular example of this kind of communication. MEs would be also ideal quantum entanglers in time direction and could serve as correlates for the mediators of negentropic quantum entanglement. The communication of sensory data to magnetic body could take via MEs and also the control actions of magnetic body could be mediated by MEs to biological body via MEs.

The original idea was that MEs could induce Josephson junctions and more general current carrying bridges between bio-structures. This is possible but magnetic flux tubes are more natural looking structures in this respect because they can be stationary.

1. Since the electric field of ME is orthogonal to the direction of the propagation of vacuum current, the Josephson junction with potential difference is formed most naturally when super conductors are joined by join along boundaries bonds to ME in the direction of the electric field associated with ME. MEs can in principle be arbitrary thin so that the thickness of Josephson junction can be much smaller than the dominating wavelength of ME.

2. The electric field of ME can contain also a constant component. This is possible if there is a vacuum charge density or ordinary elementary particles in a massless phase in the time scale considered (Higgs field vanishes) at the boundaries of ME generating the field. If this charge density is absent, ME is necessary double sheeted with the constant electric and magnetic fields created by the wormhole throats at the boundaries of ME serving as effective charges.

Both single and double sheeted MEs could give rise to the Josephson junctions with a constant potential difference. The coding of the transversal potential difference associated with ME to Josephson frequency could be a fundamental information coding mechanism in living matter. ME can contain also oscillating electric field over Josephson junction at magnetic or some other transition frequency so that MEs are ideal for control purposes.

4. MEs and the interaction of the classical em fields with biomatter

MEs acting as Josephson junctions and containing oscillating em field at ELF frequency give rise to a harmonic perturbation inducing quantum jumps of the magnetic states of ions and explains the effect of ELF em fields on biomatter. Also the presence of the mysterious intensity windows [63, 62, 65] can be understood. Josephson current paradigm allows to understand this effect if radiofrequency or microwave MEs associated with the external field act as Josephson junctions.

1. The external electric field oscillating with frequency ω (now radio frequency) defines slowly varying potential difference over Josephson junction of length d acting as Josephson junction provided that the condition

$$\omega \ll \omega_J(max) = ZeV = ZeEd$$

   holds true. This gives

$$d \gg \frac{\omega}{ZeE} \quad .$$

   For $E \sim .1$ V/m and $\omega \sim GHz$ which are typical values used in experiments [62], this condition gives $d \gg 10^{-6}$ meters which is satisfied if Josephson junctions have size not smaller than cell length scale.

2. For fixed length of Josephson junction amplitude window results if the maximal Josephson frequency $\omega_J(max)$ is slightly above some transition frequency since in this case the stationary maxima and minima of amplitude lead to long lasting resonant excitation of quantum transitions. Denoting the relative width of the resonance by $\Delta\omega/\omega = P$, the ratio of the time spent in resonance at $\Omega_J(max)$ to the time spent off resonance at Ω_J is of order

$$\frac{t(max)}{t} \sim \sqrt{1 - \frac{\Omega_J^2}{\Omega_J^2(max)}} \times \frac{1}{\sqrt{P}} \quad .$$

   For a narrow resonance width this ratio can be very large so that amplitude window results for fixed value of d.

3. Amplitude window results if there is a correlation between the thickness of ME and transversal electric field so that $\omega_J(max) = ZeEd(E)$ satisfies resonance condition for some values of E only, if any. In absence of this correlation Josephson junctions must have discrete spectrum of effective lengths for amplitude window to result.

4. For electric fields in the range .1 V/m the frequencies ω_J are above GHz for d larger than 3×10^{-5} meters and correspond to the frequencies for the conformational dynamics of proteins. There are obviously a large number of frequencies of this kind and several intensity windows. EM fields with these strengths should have special effects on living matter: it could be even that some kind of feature recognition process involving self-organization occurs at these field strengths. Note that the minimal size of Josephson junctions corresponds to the p-adic length scale $L(173) \simeq 1.6 \times 10^{-5}$ meters characterizing structures next to cells in the p-adic length scale hierarchy.

5. MEs and quantum holography

Sokolov and collaborators [55] have proposed a model of quantum holographic teleportation in which the *classical* photocurrents from the sender to receiver take the role of a dynamical hologram. The connection with MEs is obvious.

1. MEs are carriers of classical lightlike vacuum currents (one of the basic differences between TGD and Maxwell theory). This suggests that MEs could be interpreted also as *classical* holograms, which are *dynamical* as in quantum information theory. Lightlike current would be like a dynamical (four-dimensional) diffraction grating. Lightlike vacuum currents and vacuum Einstein tensor generate also coherent states of photons and gravitons and MEs serve as templates for the topological condensation of photons and gravitons to the Bose-Einstein condensate of photons collinear with ME. The Bose-Einstein condensation of collinear photons and their generalizations to colored configuration space photons should affect the vacuum current by adding to the reference current what might be called evoked response. This condensation process could generate conscious experience and higher level qualia. Thus it would seem that MEs have a triple role as receiving and sending quantum antennae as well as classical holograms.

2. The proposal of [55] generalizes to the case of MEs provided one can device a method of coding quantum states of photon field to the vacuum currents. The high efficiency photodetector matrix is in which each pixel gives rise to a photocurrent [55], is replaced with ME or set of parallel MEs. The neural window hypothesis states that neuronal axons are accompanied by parallel MEs carrying information between sensory organs and brain and various parts of brain. This is only a less standard manner to say that ME represents classical dynamical hologram. The possibility of local lightcone coordinates allows also MEs which define curved deformations of the simplest cylindrical MEs.

   The concrete realization of holographic teleportation proposed in [55] brings strongly in mind the architecture of the visual pathways. Thus one can wonder whether brain is perfoming internal teleportation of photonic quantum states with spike patterns being directly coded to the pattern of the vacuum currents flowing along MEs. If spike patterns code the dynamical hologram, a surprisingly close relationship with Pribram's views about hologrammic brain results. Nerve pulse patterns could be seen as specifying the necessary classical aspects of the quantum teleportation (in TGD classical physics is essential part of quantum physics, rather than some effective theory).

3. The lightlike vacuum current at a 3-dimensional timelike section of ME as a function function of time defines a dynamical 3-dimensional hologram. This is consistent with the fact that our visual experience is two-dimensional: the information is always about outer boundaries of the objects of the perceptive field. The values of the vacuum current at a given point are non-deterministic which means that vacuum current is ideal for coding information. Classical data also propagate without dispersion with light velocity obeying the laws of geometric optics and MEs imply channelling so that MEs are taylor-made for classical information transfer.

4. Space-time sheets can have both positive and negative time orientations and the sign of energy depends on time orientation in TGD framework. This means that classical communication can occur both in the direction of the geometric future and past: this is essential for the classical model of the long term memories as a question commmunicated to the geometric past followed by answe. The dynamical nature of the holograms means that there is no need to combine 2- or 3-dimensional holograms associated with several moments of geometric time to single hologram. To remember is to perceive an object located in the geometric past. Of course, fractality might make possible temporally scaled down versions of the geometric past but the principle would remain the same.

5. Quantum hologram view suggests that the super-symplectic representations at the lightlike boundaries of MEs characterized by gigantic almost-degeneracies are the real carriers of biological information. According to the general theory of qualia [24] this information would become conscious since elementary qualia would correspond to quantum jumps for which increments of the quantum numbers correspond to the quantum numbers labelling super-symplectic generators in the complement of Cartan algebra. In this view superconducting magnetic flux tubes could perhaps be seen as intermediate level in the control circuitry controlled by MEs and controlling atomic level.

6. The model for visual qualia leads to the hypothesis that, besides ordinary photons, also colored configuration space photons are possible and characterized by configuration space Hamiltonian

which is labelled by orbital spin quantum number J (in two-dimensional sense) and by color quantum numbers. The coherent states of these massless configuration space photons would be responsible for visual colors and polarization sense and the corresponding holograms might be the crux of quantum control in living matter.

Magnetic flux tubes and the notion of magnetic body

The notion of magnetic/field body is one of the features of TGD inspired biology challengin the standard views about living matter.

1. Magnetic body has a fractal onion like structure with decreasing magnetic field strengths and the highest layers can have astrophysical sizes. Cyclotron wave length gives an estimate for the size of particular layer of magnetic body. $B = .2$ Gauss is the field strength associated with a particular layer of the magnetic body assignable to vertebrates and EEG. This value is not the same as the nominal value of the Earth's magnetic field equal to .5 Gauss. It is quite possible that the flux quanta of the magnetic body correspond to those of wormhole magnetic field and thus consist of two parallel flux quanta which have opposite time orientation. This is true for flux tubes assigned to DNA in the model of DNA as a topological quantum computer.

2. The layers of the magnetic body are characterized by the values of Planck constant and the matter at the flux quanta can be interpreted as macroscopically quantum coherent dark matter. This picture makes sense only if one accepts the generalization of the notion of imbedding space.

3. In the case of wormhole magnetic fields it is natural to assign a definite temporal duration to the flux quanta and the time scales defined by EEG frequencies are natural. In particular, the inherent time scale .1 seconds assignable to electron as a duration of zero energy space-time sheet having positive and negative energy electron at its ends would correspond to 10 Hz cyclotron frequency for ordinary value of Planck constant. For larger values of Planck constants the time scale scales as $\hbar$. Quite generally, a connection between p-adic time scales of EEG and those of electron and lightest quarks is highly suggestive since light quarks play key role in the model of DNA as topological quantum computer.

4. TGD predicts also hierarchy of scaled variants of electro-weak and color physics so that ZXG, QXG, and GXG corresponding to Z^0 boson, W boson, and gluons appearing effectively as massless particles below some biologically relevant length scale suggest themselves. In this phase quarks and gluons are unconfined and electroweak symmetries are unbroken so that gluons, weak bosons, quarks and even neutrinos might be relevant to the understanding of living matter. In particular, long ranged entanglement in charge and color degrees of freedom becomes possible. For instance, TGD based model of atomic nucleus as nuclear string suggests that biologically important fermionic could be actually chemically equivalent bosons and form cyclotron Bose-Einstein condensates.

The list of possible functions of the magnetic body is rather impressive.

1. Magnetic body controls biological body and receives sensory data from it. Together with zero energy ontology and new view about time explains Libet's strange findings about time lapses of consciousness. EEG, or actually fractal hierarchy of EXGs assignable to various body parts makes possible communications to and control by the various layers of the magnetic body. WXG could induce charge density gradients by the exchange of W boson.

2. The flux sheets of the magnetic body traverse through DNA strands. The hierarchy of Planck constants and quantization of magnetic flux predicts that the flux sheets can have arbitrarily large width. This leads to the idea that there is hierarchy of genomes corresponding to ordinary genome, supergenome consisting of genomes of several cell nuclei arranged along flux sheet like lines of text, and hypergenomes involving genomes of several organisms arranged in a similar manner. The prediction is coherent gene expression at the level of organ, and even of population. In this picture the big jumps in evolution, in particular, the emergence of EEG, could be seen as the emergence of a new larger layer of magnetic body characterized by a larger value of Planck constant. For instance, this would allow to understand why the quantal effects of ELF em fields

requiring so large value of Planck constant that cyclotron energies are above thermal energy at body temperature are observed for vertebrates only.

3. The strands of DNA could serve as intermediary structure analogous to brain hemispheres with active strand analogous to motor areas and passive strand analogous to sensory areas of cortex. The passive strand would serve as a relay station through which sensory data about the cellular environment is transferred to the magnetic body. Here MEs topologically condensed to the flux sheets could be in key role. The flux tubes connecting DNA nucleotides and cell membrane and various biomolecules would mediate the sensory data to the passive DNA strand.

4. Magnetic body makes possible information process in a manner highly analogous to topological quantum computation. The model of DNA as topological quantum computer assumes that flux tubes of wormhole magnetic field connect DNA nucleotides with the lipids of the lipid layer of nuclear or cell membrane. The flux tubes would continue through the membrane and split during topological quantum computation. The time-like braiding of flux tubes makes possible topological quantum computation via timelike braiding and space-like braiding makes possible the representation of memories. The model allows general vision about the deeper meaning of the structure of cell and makes testable predictions about DNA.

   One prediction is the coloring of braid strands realized by an association of quark or antiquark to nucleotide. Color and spin of quarks and antiquarks would thus correspond to the quantum numbers assignable to braid ends. Color isospin could replace ordinary spin as a representation of qubit and quarks would naturally give rise to qutrit, with third quark would have interpretation as unspecified truth value. Fractionization of these quantum numbers takes place which increases the number of degrees of freedom. This prediction would relate closely to the discovery of topologist Barbara Shipman that the model for the honeybee dance suggests that quarks are in some manner involved with cognition. Also microtubules associated with axons connected to a space-time sheet outside axonal membrane via lipids could be involved with topological quantum computation and actually define an analog of a higher level programming language.

5. The strange findings about the behavior of cell membrane, in particular the finding that metabolic deprivation does not lead to the death of cell, the discovery that ionic currents through the cell membrane are quantal, and that these currents are essentially similar than those through an artificial membrane, suggest that the ionic currents are dark ionic Josephson currents along magnetic flux tubes. A high percent of biological ions would be dark and ionic channels and pumps would be responsible only for the control of the flow of ordinary ions through cell membrane.

6. These findings together with the discovery that also nerve pulse seems to involve only low dissipation lead to a model of nerve pulse in which dark ionic currents automatically return back as Josephson currents without any need for pumping. This does not exclude the possibility that ionic channels might be involved with the generation of nerve pulse so that the original view about quantal currents as controllers of the generation of nerve pulse would be turned upside down. Nerve pulse would result as a perturbation of kHz soliton sequence mathematically equivalent to a situation in which a sequence of gravitational penduli rotates with constant phase difference between neighbors except for one pendulum which oscillates and oscillation moves along the sequence with the same velocity as the kHz wave. The oscillation would be induced by a "kick" for which one can imagine several mechanisms.

   The model explains features of nerve pulse not explained by Hodkin-Huxley model. These include the mechanical changes associated with axon during nerve pulse, the outwards force generated by nerve pulse with a correct prediction for its order of magnitude, the adiabatic character of nerve pulse, and the small rise of temperature of membrane during pulse followed by a reduction slightly below the original temperature.

   The model predicts that the time taken to travel along any axon is a multiple of time dictated by the resting potential so that synchronization is an automatic prediction. Not only kHz waves but also a fractal hierarchy of EEG (and EXG) waves are induced as Josephson radiation by voltage waves along axons and microtubules and by standing waves assignable to neuronal (cell) soma. The value of Planck constant involved with flux tubes determines the frequency scale of EXG so that a fractal hierarchy results.

The model forces to challenge the existing interpretation of nerve pulse patterns and the function of neural transmitters. Neural transmitters need not represent actual/only) signal but could be more analogous to links in quantum web. The transmitter would coding the address of the receiver, which could be gene inside neuronal nucleus. Nerve pulses would build a connection line between sender and receiver of nerve pulse along which actual signals would propagate. Also quantum entanglement between receiver and sender can be considered.

7. Acupuncture points, meridians, and Chi are key notions of Eastern medicine and find a natural identification in terms of magnetic body lacking from the western medicine. Also a connection with well established notions of DC currents and potentials discovered by Becker and with TGD based view about universal metabolic currencies as differences of zero point energies for pairs of space-time sheets with different p-adic length scale emerges.

Chi would correspond to these fundamental metabolic energy quanta to which ordinary chemically stored metabolic energy would be transformed. Meridians would most naturally correspond to flux tubes with large $\hbar$ along which dark supra currents flow without dissipation and transfer the metabolic energy between distant cells. Acupuncture points would correspond to points between which metabolic energy is transferred and their high conductivity and semiconductor like behavior would conform with the interpretation in terms of metabolic energy storages. The energy gained in the potential difference between the points would help to kick the charge carrier to a smaller space-time sheet. It is possible that the main contribution to the of charge at magnetic flux tube is magnetic energy and slightly below the metabolic energy quantum and that the voltage difference gives only the lacking small energy increment making the transfer possible. Also direct kicking of charge carriers to smaller space-time sheets by photons is possible and the observed action spectrum for IR and red photons corresponds to the predicted increments of zero point kinetic energies.

8. Magnetic flux tubes could also play key role in bio-catalysis and explain the magic ability of biomolecules to find each other. The model of DNA as topological quantum computer [24] suggest that not only DNA and its conjugate but also some amino-acid sequences acting as catalysts could be connected to DNA and other amino-acids sequences or more general biomolecules by flux tubes acting as colored braid strands. The shortening of the flux tubes in a phase transition reducing the value of Planck constant would make possible extremely selective mechanisms of catalysis allowing precisely defined locations of reacting molecules to attach to each other. With recently discovered mechanism for programming sequences of biochemical reactions this would make possible to understand the miraculous looking feats of bio-catalysis.

9. The ability to construct "stories", temporally scaled down or possible also scaled up representations about the dynamical processes of external world, might be one of the key aspects of intelligence. There is direct empirical evidence for this activity in hippocampus. The phase transitions reducing or increasing the value of Planck constant would indeed allow to achieve this by scaling the time duration of the zero energy space-time sheets providing cognitive representations.

The list of nice things made possible by the magnetic body is impressive and one can ask whether there is any experimental support for this notion. The findings of Peter Gariaev and collaborators give evidence for the representation of DNA sequences based on the coding of nucleotide to a rotation angle of the polarization direction as photon travels through the flux tube and for the decoding of this representation to gene activation [41], for the transformation of laser light to light at various radio-wave frequencies having interpretation in terms of phase transitions increasing $\hbar$ [40, 49], and even for the possibility to photograph magnetic flux tubes containing dark matter by using ordinary light in UV-IR range scattered from DNA [56, 26].

Electrets

Electrets are by definition spontaneously electrically polarized structures. Living matter is full of electrets. Practically all important biomolecules are electrets. Cell membrane is an electret and liquid crystal. Microtubules are electrets as are also various larger structures such as collagens.

The dipolar nature of bio-molecules and induced polarization are basis prerequisites for the formation of gels. Ling raises the cohesion between water and protein molecules caused by electric dipole forces as a fundamental principle and calls this principle association-induction hypothesis [48]. This cohesion gives rise to liquid crystal [41] like structure of water implying among other things layered structures and internal electric fields orthogonal to the plane of the layers [48, 46, 53]. For instance, cell membranes can be understood as resulting from the self-organization of liquid crystals [19]. The fundamental importance of electret nature of biomatter was also realized by Fröhlich [63] and led him to suggest that macroscopic quantum phases of electric dipoles might be possible. This concept, which is in central role in many theories of quantum consciousness, has not been established empirically.

In TGD framework electrets could serve as sensory receptors. In capacitor model of sensory qualia the flow of quantum numbers between the plates of this kind of capacitor would give rise to sensory qualia. The process would be self-organization process with energy flow replaced with a more general flow of quantum numbers.

5.3.2 Homeostasis as many-sheeted ionic flow equilibrium?

The experimental work of Ling, Sachs and Qin [48, 55] and other pioneers [44, 47] challenges the notions of ionic channels and pumps central to the standard cell biology. Ling has demonstrated that the ionic concentrations of a metabolically deprived cell are not changed at all: this challenges the notion of cell membrane ionic pumps. The work of Sachs and Qin and others based on patch-clamp technique shows that the quantal ionic currents through cell membrane remain essentially as such when the membrane is replaced by a silicon rubber membrane or by a cell membrane purified from channel proteins! this challenges the notion of cell membrane ionic channels. A further puzzling observation is much more mundane: ordinary hamburger contains roughly 80 per cent of water and is thus like a wet sponge: why it is so difficult to get the water out of it?

These puzzling observations can be understood if the homeostasis of cell and its exterior is regarded as an ionic flow equilibrium in the many-sheeted space-time. Ionic super currents from superconducting controlling space-time sheets flow to controlled atomic space-time sheets and back. Currents are of course ohmic at the atomic space-time sheets. One can understand how extremely small ionic densities and super currents at cellular space-time sheets can control ionic currents and much higher ionic densities at atomic space-time sheets. Immense savings in metabolic energy are achieved if the ohmic currents at the atomic space-time sheets flow through the cell membrane region containing the strong electric field along superconducting cell membrane space-time sheet (rather than atomic space-time sheets) as a non-dissipative supra current. This clever energy saving trick makes also the notion of ionic channels obsolete for weak ionic currents at least.

Superconducting space-time sheets contain a plan of the biosystem coded to ion densities and magnetic quantum numbers characterizing the super currents. Biocontrol by em fields affects these super currents and one can understand the effects of ELF em fields on biosystem in this framework. The model relies crucially on the liquid crystal property of biomatter (hamburger mystery!) making possible ohmic current circuitry at the atomic space-time sheets as a part of the many-sheeted control circuitry. There is a considerable evidence for this current circuitry, Becker is one of the pioneers in the field [67]: among other things the circuitry could explain how acupuncture works.

One can add several new elements to this picture.

1. The phase transition changing the value of Planck constant induces a change of the length of the magnetic flux tube scaling as $\hbar$. Therefore the reduction of the Planck constant for a flux tube connecting two biomolecules can bring them near to each other. This suggests that biomolecules form a kind of Indra's net and that these phase transitions together with the reconnection of magnetic flux tubes changing the topology of this net are the basic mechanisms explaining the miracles of bio-catalysis and induce various phases transitions typically accompanying contractions and expansions of the matter in the cell interior. One could actually see the phase transitions of living matter as being induced from the motor actions of the magnetic body.

2. Zero energy ontology predictis that the CDs assignable to elementary particles have temporal size scale given by the secondary p-adic time scale. For electron and quarks (assigned to the ends of magnetic flux tubes in the model of topological quantum computation) these time scales are 100 milliseconds and 1 millisecond respectively and identifiable as fundamental biological time scales. A deep connection betweeen biology and elementary particle physics seems to exist.

3. Negentropic entanglement transforms the bio-molecules from dead matter to conscious enti-
   ties so that the nano-scaled molecules are just what they seem to be in light of experimental
   nano-biology: intelligent conscious entities having intentions and plans and willing and able to
   collaborate.

5.3.3   Quantum model for pattern recognition

The general neuroscience based model for recognition relies one learning made possible by synaptic
plasticity. It is expected to have a TGD based quantum variant [33]. The model of pattern recognition
to be discussed below relies on supra currents and Josephson currents assignable to cell membrane and
various other binary structures, and could define a building brick of the general model. For instance,
the model of nerve pulse relies on Josephson currents [18].

Time translation invariant pattern recognition circuit can be realized by using two coupled super
conductors. The first superconductor contains the reference supra current and second superconductor
contains the supra current determined by the sensory input. Supra currents are assumed to have
same spatially and temporally constant intensity. If the supra currents have spatially constant phase
difference, also Josephson currents are in the same phase and sum up to a large current facilitating
synchronous firing. The temporal phase difference of supra currents does not matter since it affects
only the overall phase of the Josephson current. Therefore patterns differing by time translations are
treated as equivalent. Quite generally, the requirement of time translational invariance, favours the
coding of the sensory qualia to transition frequencies.

The destructive interference of supra currents provides an tool of pattern cognition in situations
when the precise timing is important. The pattern to be recognized can be represented as a refer-
ence current pattern in some neuronal circuit. Input pattern determined by sensory input in turn is
represented by supra current interfering with the reference current. If the interference is destructive,
synchronoous generation of nerve pulses in the circuit occurs and leads to a conscious pattern recog-
nition. Obviously the loss of time translation invariance makes this mechanism undesirable in the
situations in which the precise timing of the sensory input does not matter. One can however imagine
situations when timing is important: for instance, the deduction of the direction of the object of the
auditory field from the phase difference associated with signals entering into right and left ears could
correspond to this kind of situation.

In both cases one can worry about the regeneration of reference currents. The paradigm of four-
dimensional quantum brain suggests that sensory input leads by self-organization to a stationary
spatial patterns of supracurrents and this process depends only very mildly on initial values. Thus
self-organization would generate automatically pattern recognizers.

5.3.4   General mechanism making possible biological clocks and alarm clocks, comparison circuits and novelty detectors

Weakly coupled super conductors and auantum self-organization make possible very general models
of biological clocks and alarm clocks as well as comparison circuits and novelty detectors.

The Josephson junction between two superconductors provides a manner to realize a biological
clock. Josephson current can be written in the form [43]

$$
\begin{aligned}
J &= J_0 sin(\Delta\Phi) = J_0 sin(\Omega t) \ , \\
\Omega &= ZeV \ ,
\end{aligned}
\tag{5.3.1}
$$

where Ω is proportional to the potential difference over the Josephson junction. Josephson current
flows without dissipation.

In BCS theory of superconductivity the value of the current J_0 can be expressed in terms of
the energy gap Δ of the super conductor and the ordinary conductivity of the junction. When the
temperature is much smaller than critical temperature, the current density for a junction is given by
the expression [43]

$$
J_0 = \frac{\pi}{2e}\frac{\sigma_s\Delta}{d} \ .
\tag{5.3.2}
$$

Here σ_s is the conductivity of the junction in the normal state assuming that all conduction electrons can become carriers of the supra current. d is the distance between the super conductors. The current in turn implies a position independent(!) oscillation of the Cooper pair density inside the two super conductors. By the previous arguments the density of the Cooper pairs is an ideal tool of biocontrol and a rhytmic change in biological activity expected to result in general. Josephson junctions are therefore good candidates for pacemakers not only in brain but also in heart and in respiratory system.

In the presence of several parallel Josephson junctions quantum interference effects become possible if supra currents flow in the super conductors. Supra current is proportional to the gradient of the phase angle associated with the order parameter, so that the phase angle Φ is not same for the Josephson junctions anymore and the total Josephson current reads as

$$J \quad = \quad \sum_n J_0(n) sin(\Omega t + \Delta \Phi(n)) \ \ . \tag{5.3.3}$$

It is clear that destructive interference takes place. The degree of the destructive interference depends on the magnitude of the supra currents and on the number of Josephson junctions.

There are several options depending on whether both super conductors carry parallel supra currents or whether only second super conductor carries supra current.

1. If both super conductors carry supra currents of same magnitude but different velocity, the phases associated with the currents have different spatial dependence and destructive interference occurs unless the currents propagate with similar velocity. This mechanism makes possible comparison circuit serving as a feature detector. What is needed is to represent the feature to be detected by a fixed supra current in the second super conductor and the input as supra current with same charge density but difference velocity. The problem is how the system is able to generate and preserve the reference current. If case that feature detector 'wakes-up' into self state when feature detection occurs, the subsequent quantum self-organization should lead to the generation of the reference current representing the feature to be detected.

2. If only second super conductor carries supra current and of this supra current for some reason decreases or becomes zero, constructive interference occurs for individual Josephson currents and net Josephson current increases: current causes large gradients of Cooper pair density and can lead to the instability of the structure. When the supra current in the circuit dissipates below a critical value, instability emerges. This provides a general mechanism of biological alarm clock.

   Assume that the second super conductor carriers a supra current. As the time passes the reference current dissipates by phase slippages[42, 43]. If the reference current is large enough, the dissipation takes place with a constant rate. This in turn means that the Josephson current increases in the course of time. When the amplitude of the Josephson current becomes large enough, the density gradients of the charge carriers implied by it lead to a nonstability of the controlled system: the clock rings. Since the dissipation of (a sufficiently large) Josephson current takes place at constant rate this alarm clock can be quite accurate. It will be found that a variant of this mechanism might be at work even in the replication of DNA. The unstability itself can regenerate the reference current to the clock. If the alarm clock actually 'wakes-up' the alarm clock to self state, self-organization by quantum jumps must lead to an asymptotic self-organization pattern in which the supra current in the circuit is the original one. Actually this should occur since asymptotic self-organization pattern depends only weakly on the initial values.

3. Novelty detector can be build by feeding the outputs of the feature detectors to an alarm clock circuit. In alarm clock circuit only the second super conductor carries supra current, which represents the sum of the outputs of the feature detectors. Since the output of a feature detector is nonvanishing only provided the input corresponds to the feature to be detected, the Josephson current in additional circuit becomes large only when the input does not correspond to any familiar pattern.

5.4   Sensory representations

In this section concrete model for the sensory representations is developed on basis of the general vision already outlined. What is new as compared to the earlier vision is the role of zero energy ontology and CDs as imbedding space correlates for sub-selves.

5.4.1   Where me is?

The motion of eye or head does not induce the sensation that the world is moving although the sensory image moves around the cortex. Rather, brain acts like a (possibly moving) canvas at which the sensory input is projected and monitored by an external observer. This very simple observation is a strong objection against the idea that the ultimate sensory representations reside inside brain, and leads to the view that the magnetic flux tube structures associated with the primary and secondary sensory organs define a hierarchy of sensory representations outside brain. The question is where these representations are realized and one can imagine two alternatives.

Are higher level sensory representations realized at the magnetic body?

Magnetic flux tube structures would serve as the sensory canvas to which sensory images are projected from brain and possibly sensory organs and even neurons. MEs serve as projectors and place coding by magnetic transition frequency associated with ME wakes-up sensory subselves at various positions of magnetic flux tubes having varying thickness and associate thus various sensory qualia and even more complex attributes to the objects of the perceptive field.

   This view can be defended also by the neat separation of the information processing from its representation occurring also in case of the ordinary computers as well as by Uncertainty Principle for EEG waves. If primary qualia are at the level of primary sensory organs and entangled with cortex, one can understand why imagination, which involves much the same neural processes as perception, does not give rise to sensory qualia.

   EEG MEs correspond to our level in this hierarchy of projections. The simplest possibility is that the sizes of these sensory selves are of the order of EEG ME sizes ($L(EEG) = c/f(EEG)$) and thus can be of the order of Earth size! Thus the ultimate sensory representations are magnetic gigants in TGD and diametrical opposites of the neurophysiological dwarfs of standard neuroscience populating also TGD brain.

   The known strange effects of large scale perturbations of Earth's magnetic field on consciousness (say, statistics about the effects of magnetic storms in mental state and tectonic activity inducing UFO experiences) provide a rich palette of anomalies supporting this view. The conservation of magnetic flux makes the magnetic flux tube structures of Earth size (or even larger) very stable: thus physical death presumably means only that our magnetic body redirects its attention to something more interesting. Near death experiences discussed in more detail in [19] indeed support this view.

   Two requirements must be satisfied for this scenario to work.

1. The projectors to the magnetic body cannot rotate when head rotates so that a fixed direction of perceptive field corresponds to the fixed direct at the magnetic body. This can be achieved if the projectors are magnetic structures with a fixed orientation with respect to the Earth's magnetic field.

2. Retinae must act like windows for this scenario to work. This means that the primary qualia mental images (subselves) at retina are entangled with the corresponding cognitive mental images at cortex, keep their attention directed to that part of the perceptive field that they represent as the direction of the gaze changes. Perhaps the retinal mental images are stationary with respect to the liquid phase not comoving with the eye ball. The retina-external world entanglement would also keep retinal attention fixed. This applies also to the saccadic motion, and the loss of visual consciousness when saccadic motion is prevented, could mean simply that retinal mental images lose consciousness when their motor activity with respect to eye ball is prevented: just like we lose our consciousness if not allowed to move!

Could the sensory representations about position of the object be realized in the perceptive field?

There is also a more conservative realization of sensory representations (if I had invented it first, I would probably have never considered the representations at the magnetic body!).

1. If retina-external world entanglement is present as suggested by the argument above, sensory canvas for the primary sensory representations could be provided by the perceptive field itself. The series of quantum entanglements from sensory organs to brain to magnetic body would define the entire sensory-cognitive representation involving also the cognitive aspects. There would be no absolute need for topographic representations at the magnetic body although the appearance of a hierarchy of topographic representations in brain suggest that topographic representations continues. The magnetic representations could however be more abstract higher level representations: somewhat like the manual of an electronic instrument as compared with the photograph of the instrument.

2. One can also imagine that the magnetic body is not involved at all since also in this case the sensory representation would be organized topographically by the entanglement with the objects of the perceptive field. Now brain would entangle to the objects of the external world cognitive mental images. One could say, that me is the entire perceptive field plus physical body. In this case however the function of EEG remains unclear. Also the model of long term memories also suggests that EEG MEs in length scales of light life-time are involved.

Of course, neither of these views about human consciousness is new. In particular, the first one is shared by all spiritual practices. What is new is the concrete physical model realizing this view physically. Here I cannot avoid the temptation to fall for a moment in manifesto mood: what makes me sad is that the materialistic neuroscience so strongly advocates the brain centered view about consciousness with physical death meaning the absolute end. The belief in this world view deprives life from its meaning and reduces it to a vulgar fight for survival or, depending on one's tastes, to a pre-determined performance of a robot. It is also deeply frustrating that the stubborn belief on materialism prevails despite the fact that this dogma contains so many internal contradictions that it would not even deserve to be called world view.

5.4.2   Concrete realization of sensory representations

The vision about the concrete realization of the sensory representations conscious-to-us has developed rather slowly. A good measure for the uncertainties involved is that the sizes of the primary sensory organs and EEG ME lengths $L(EEG) = c/f$ have represented the two extreme options for the size scale of the sensory representations conscious-to-us. It seems however more and more clear that TGD forces a dramatic deviation from the prevailing view about cortex as the seat of the ultimate sensory representations. The sensory representations conscious-to-us are outside the body and that the relevant length scale could be most naturally the length scale $L(EEG) = c/f$ defined by the EEG frequencies. In case of long term memories much longer length scales in the range of the light lifetime are necessarily involved and the realization of long term memories forces to conclude that human sensory consciousness is a cosmic phenomenon.

Qualia as quantum phase transitions and as discharges of quantum capacitor

In TGD framework the meaning of the primary quale is associated with the mental images created by the self-organization process. If the quale corresponds to an average increment of quantum numbers or zero modes in a long quantum jump sequence, the quantum jump with same increment must occur repeatedly. One can imagine at least two mechanism inducing qualia.

1. Quantum phase transition produce qualia

Quantum phase transition in which single particle transition occurs coherently for some macroscopic quantum phase produces qualia defined by the increments of quantum numbers in the transition. Quantum phase transition could be induced by the transition frequency: quantum phase transition leading to the generation of new kind of macroscopic quantum phase is in question. Transition frequencies themselves as such serve as symbols initiating this process, much like sub-program call initiates

subprogram. They act like the name of dog: when dog hears its own name, dramatic self-organization process is initiated.

2. Discharge of quantum capacitor produces primary qualia

Quantum capacitor discharge provides an attractive model for how the primary sensory qualia at the level of sensory receptors emerge.

The flow of particles with fixed quantum numbers between "electrodes" of what might be called a quantum capacitor induces qualia defined by the quantum numbers of the particles involved. The "electrodes" carry opposite net quantum numbers. Second electrode corresponds to the sub-self defining the quale mental image. Obviously cell interior and exterior are excellent candidates for the electrodes of the quantum capacitor. Also neuron and postsynaptic neuron. In fact, living matter is full of electrets defining capacitor like structures. The model of sensory receptor as a quantum capacitor will be discussed later. The model applies to various chemical qualia and also to color vision and predicts that also cells should have senses. Ordinary cells would sense only the nearby chemical environment whereas neurons would experience via synapses also representations of external world chemically: at our level of conscious experience these representations could give rise to emotions. The strange behavior of ionic currents leads to the view that even ionic channels and pumps are actually ionic and voltage receptors.

3. Higher level qualia at the level of brain and magnetic body

Higher level sensory qualia at the level of magnetic body are expected to relate to the geometric aspects of sensory input such as shape or size of objects of the perceptive field.

The capacitor model in principle generalizes to the level of brain and magnetic body. What is needed is a phase transition transforming one Bose-Einstein condensate type phase with definite quantum numbers to a second one. Music metaphor suggests that only the ratios of transition frequency to, say, cyclotron frequency can code for qualia. Only the ratios of Larmor and cyclotron frequencies and frequencies characterizing CDs and the intensities of the Fourier components for various harmonics can affect self-organization process. Furthermore, quale together with its emotional aspects depend on a simultaneous occurrence of several quantum phase transitions induced by the EEG pattern containing several magnetic transition frequencies. Different values of Planck constant could define a hierarchy of epresentations.

Zero energy ontology and geometric qualia

Zero energy ontology is a new element of quantum TGD and states that all physical states have vanishing net values of conserved quantum numbers. Zero energy ontology provides a firm justification for the notion of negative energy signals consisting of (say) phase conjugate photons propagating to the geometric past. These negative energy signals are crucial element of the time mirror mechanism playing a central role in the general mechanism for intentional action, remote metabolism, and long term memory.

Causal diamond (CD) defined roughly as the intersection of future and past directed lightcones serves as an imbedding space correlate for zero energy state. Space-time sheets representing zero energy states are inside CD and the future *resp.* past boundaries of CD carry positive *resp.* negative energy parts of zero energy states. What is important from the point of view of consciousness theory is that CDs serve as imbedding space correlates of selves and sub-CDs as those for sub-selves (mental images). Sub-CDs are very much analogous to music instruments in the sense that the frequencies which come as harmonics of the fundamental frequency defined by the proper time distance between tips of CD (coming as powers of two) resonate with the geometry of CD and put it to "ring". Sub-CDs could be seen as an analog of radio receiver as far as sensory representations are considered and sending antenna as far as the motor control of biological body is involved. This allows to communicate sensory data from brain to sub-CDs at magnetic body CD in a highly selective manner. MEs (massless extremals) mediating the communications between magnetic body and biological body are also very much like strings of a music instrument. This picture generalize the earlier music metaphor applied to axonal pathways.

A more precise definition of CD is as the Cartesian product of the intersection of future and past directed light-cone with CP_2. The hierarchy of Planck constants brings in additional structure. There is identification of preferred $M^2 \subset M^4$ defining a preferred time direction (rest system/quantization

axis for energy) and spin quantization axis. The preferred geodesically trivial sphere $S^2 \subset CP_2$ and the selection of point assigned with CP_2 at the future and past boundaries of CD gives rise to a selection of quantization axes of color isospin and hyper charge.

Sensory representations are a key element of the consciousness theory and the moduli space of CDs charactering what kind of CDs are possible brings in new representational resources.

1. The moduli space of sub-CDs involves the position for the either tip of the sub-CD and the naive expectation is that this position could code for the position of the perceptive field. If so the representation would be very concrete and since the size of CD is already for electron with .1 lightseconds the representations is realized automatically in astrophysical scale.

2. The moduli space of sub-CDs assignable to the mental images with another tip fixed could represent geometric qualia. Without any further restrictions this space corresponds to proper time constant hyperboloid of future light cone. The values of time parameter come in powers of two. One can however quite well consider the possibility that only a discrete lattice of the hyperboloid is realized.

3. A Lorentz boost for sub-CD induces scaling of frequency and scaling of the object in the direction of the boost. Therefore boost coded to the fundamental frequency of CD could code for various shapes of a figure obtained by scaling. Boost of sub$-CD$ leaving the other tip of sub$-CD$ invariant could also code for the velocity of object.

4. The moduli space of CDs contains also the choice of quantization axes of energy (preferred rest system) and spin as well as the choice of quantization axes of color isospin and hyper-charge identifiable as flag manifold $SU(3)/U(1) \times U(1)$. Mathematician Barbara Shipman has proposed that this flag manifold is involved with the representation of geometric data in honeybee dance [34] and I have proposed a model for what might be involved [24].

The moduli space of CDs is thus highly relevant for the representation of the geometric data associated with the objects of the perceptive field and the this data would be communicated using MEs with harmonics of the fundamental frequency of sub-CD so that sub-CD would act like radio receiver. This includes the position of the real object codable to the position of sub-CDs at magnetic body, the velocity of the object of the perceptive field codable to the Lorentz boost changing the shape of sub-CD and represented as scaling of the frequency assigned with the stationary object. Also the shape of perceptive field would represent this kind of geometric data. This picture supports the interpretation of sub-CDs as spotlights of attention giving information about many-sheeted space-time inside the regions defined by the sub-CDs. It would seem that sub-CDs are dynamical objects created, destroyed, and shifted in quantum jumps. This picture is also consistent with the explanation for the arrow of psychological time based on zero energy ontology [27].

Place coding by cyclotron frequency scale

One of the basic aspects of conscious information processing is concrete geometric representation of even very abstract concepts and information as imagined objects of perceptive field. The observations about geometric qualia suggest to magnetic transition frequencies code for positions of subselves represented by magnetic flux tubes. Particular EEG frequency wakes-up particular subself in a specific position and orientation and gives rise to a 'feeling of existence' in some part of the virtual world of brain of magnetic body. The sensation of motion of object of perceptive field cold result automatically when subself moves inside self. Alternatively, Lorentz boost for the sub-CD could represent the velocity of motion of object represented by it. For instance, one could represent coordinate curves as magnetic flux tubes with varying thickness: by magnetic flux conservation thickness codes the coordinate to magnetic field strength to cyclotron frequency.

Cortex as a collection of attributes assigned to the objects of perceptive field represented at magnetic canvas

One of the basic problems related to the understanding of the information processing in brain is how various attributes are assigned to the object of the perceptive field. What is known that brain recognizes features and these features/attributes seem to be located in a more or less random looking

manner all around cortex. This brings strongly in mind random access memory or computer game in which various little program modules realized as records in random access memory represent collection of standard sound effects. A strong hint is the empirical evidence for the view that the resonance frequencies associated with the autocorrelation functions of nerve pulse patterns, and thus presumably also coding EEG frequencies, are same for the features associated with a given object of the perceptive field. The challenge is to understand how the picture based on a collection of MEs projecting features to the magnetic canvas could allow to understand what is behind these observations.

The view about MEs associating attributes to the object of the perceptive field by waking up subselves in the magnetic flux tube structure serving as a sensory canvas suggests an elegant interpretation for these facts.

1. Cortex can be regarded as a collection of regions specialized to represent various kinds of standard features. Features need not be simple qualia: arbitrary complicated collections of them, such as familiar faces are also possible features. Even entire dynamical processes (selves) could serve as features.

2. Basic feature-regions are like computer records. The information about the position of the feature in perceptive field could be represented by the entanglement of the feature with a particular part of, say, primary sensory area representing a point of the perceptive sphere.

3. The direction of the point of the perceptive field could be coded basically by the direction of the magnetic flux tube emerging from the particular position of the sensory area providing map for solid angles of the perceptive field. The mechanism would be based on resonance with Alfven waves associated with the magnetic flux tubes of personal magnetic body amplifying MEs in the direction of magnetic flux tubes. The length (fundamental frequency) of ME would code for the distance of the point of the perceptive field to the distance of the point of the sensory magnetic canvas. Frequency coding could be achieved by varying the local value of the magnetic field responsible for generating the cyclotron frequency. This coding could be either dynamical or static in which case distance could be most naturally coded to linear structures, most naturally in direction orthogonal to the cortical surface.

4. Features would be basically associated with sensory organs, various neural pathways and brain areas and coded partially by nerve pulse patterns. Features could be practically all kinds of subselves generated by brain activity. Primary qualia could be realized at the level of sensory receptors if entire sensory pathways entangle with the magnetic body.

5. Projector MEs would be orthogonal to the sensory area where they emanate. The topographic mapping of the perceptive field to sensory areas would guarantee that sensory images would remain stationary under rotations of head: although sensory magnetic sensory canvas would move the image projected to it would be stationary. MEs and magnetic flux tubes must be parallel if Alfwen wave resonance is involved. In this manner the sensory experiences can be private and the contribution from the other brains remains negligible. Note however that people in very intimate contact could gradually share there magnetic sensory canvases: the anecdotes about gradually developing telepathic communications between the teachers and students of the meditative practices could involve this kind of sharing of computer screen between several users.

6. In this coding EEG MES would entangle with essentially all information about the perceptive field and the spectroscopy of consciousness to be discussed below would be realized in rather strong sense.

7. The model becomes even more predictive if it is assumed that DNA double strands act as a relay station. This encourages to think that also the decomposition of brain to motor and sensory areas has a counterpart at the level of the magnetic body so that the sensory input coming from the cell membrane is mediated through flux sheets going through the passive strand to the sensory magnetic body and motor actions of the motor magnetic body are mediated through theflux sheets going through active strand. One would have a closed loop in which the phase transition induced by the sensory input coming via the passive DNA strand to the sensory magnetic body generates cyclotron radiation inducing a phase transition in the motor part inducing cyclotron radiating inducing effect in the active DNA strand.

Of course, the extreme flexibility of the entanglement mechanism of binding means that one can imagine almost unlimited number of variants about this basic option and the proposed variant can be defended only as the simplest one found hitherto. One can also allow the possibility that the sequence of entanglements begins from the perceptive field with the primary mental images at the level of sensory organs being entangled with objects of perceptive field.

Fractality suggests that there is a hierarchy of sensory representations. In particular, cortex areas, brain nuclei and even cells could possess their own sensory representations. The inactivity of the primary sensory areas during REM sleep could mean that during dream state sensory representations are non-cortical lower level representations or realized at higher sensory areas. Of course, lower level structures could define the projections to the magnetic sensory canvas also during wake-up consciousness. For instance, relay station like nuclei could act as relay stations for the projections realized at the magnetic body. Any brain area defining topographical map of sensory data is could candidate for defining a sensory representation.

The projector regions would serve as kind of central entanglers. Also the nuclei believed to somehow generate EEG resonance frequencies responsible for the binding of mental images are good candidates for the central entanglers. In standard neuroscience thalamus is believed to generate 40 Hz rhytm and is thus a good candidate for the central sensory entangler and projector. In TGD framework this rhythm would be more naturally generated by the magnetic body assignable to thalamus. Hippocampus -or more naturally its magnetic body- generates hippocampal theta and could be the central memory entangler and projector. Frontal lobes generate slow EEG waves during cognitive activities and could act as cognitive entanglers and projectors.

This kind of architecture is expected to be realized at various length scales. The metaphor for consciousness as a computer sitting at its own terminal, which originally stimulated my attempts to understand consciousness, conforms this picture. Computer screen would correspond to the sensory magnetic body. The one who sits there presumably could be identified as the motor part of the magnetic body (as far as conscious-to-me intentions are considered). The central unit corresponds to the brain and DNA double strands are the fundamental hardware responsible for communication and control and through which all information flows. They intronic parts of DNA strands would also provide the hardware for topological quantum computation programs. Sensory projector MEs are generated automatically by the nerve pulse activity and code the picture at the monitor. MEs would be active quantum holograms acting as control commands on the active DNA strand serving as the keyboard generating nerve pulse patterns. Thus it would seem that those aspects of the computer (monitor, keyboard, etc), which are usually not regarded as fundamental in Turing machine paradigm are the most crucial for understanding the consciousness and computer programmers could be mimicking what happens inside (and outside) their own brain.

Anomalous visual percepts and sensory canvas hypothesis

Sensory canvas hypothesis means that at the perceptual level we see using ELF– rather than visible light. Of course, if primary sensory qualia are at the level of sensory receptors, this seeing has the character of imagination. Even in this case brain could use feedback to the sensory receptors assign sensory qualia with the imagination like perception. This would occur during dreaming and what is regarded as hallucinations.

One can also consider the possibility of "vision" based solely on the ELF input from brain and body having no correlate with the visible light entering into retina or even with neural activity. Even genuinely three-dimensional vision in which own body is seen as it would be seen by the external world suggests itself. The dropping of ions from the atomic space-time sheets to the magnetic flux tubes so that they end up to high n cyclotron states decaying via the emission of photons at frequencies which are harmonics of the cyclotron frequency would generate the projector MEs needed for the sensory representation of the physical body or part of it as seen by the environment.

There is some evidence for this kind of anomalous vision.

1. Yogis have reported altered states of consciousness in which they see their own body three-dimensionally, that is simultaneously from all directions. This might have interpretation as ELF vision involving a feedback from magnetic sensory canvas to brain to "qualiafy" the percept.

2. Becker tells in his book "Cross currents" [56] about a young cancer patient who told that he can see the interior of his own body. The patient could also locate the remnant of the tumour

correctly. If sensory receptors are necessary for visual qualia, the needed data must be received from somewhere by brain, and be projected to the visual receptors like during dreaming. The simplest option is that body parts can in some sense "see" each other. In particular, brain can "see" body parts (note that bacteria possess a primitive IR vision based on microtubules). Bio-holography provides support for the body as a hologram. For instance, an electric stimulation of ear during Kirlian imaging of a finger tip creates a Kirlian photo from which it is possible to abstract a hologram of ear (see [36] and [34].

3. Also the OBE experiences, for instance those associated with NDEs, could have an analogous interpretation. The sensory input from eyes would be absent but brain would give feedback to visual receptors to "qualiafy" the the input which it might receive from other levels of self hierarchy. If even the input from neural activity is absent during NDEs so that the visual experience should be determined by the background ELF component emanating from the brain and body. The third person perspective associated with OBEs might be always present but be masked by the strong sensory input or by the absence of feedback to visual receptors. It is possible to have experiences about contact with deceased by a therapy based on rhythmic eye movements [54, 86]. The function of eye movements might be to establish a feedback to certain brain regions serving as receivers of input from magnetic bodies of deceased or from magnetosphere.

4. I have proposed thousand and one explanations for the beautiful flow visible when I close my eyes in a calm state of mind. During my "great experience" this background flow was accompanied by extremely vivid visual hallucinations. An additional item to the long list of explanations is following. The information characterizing the flow enters from or via brain to the visual receptors and is in this manner "qualiafied".

What has been said about magnetospheric third person aspect applies also to other senses. Interestingly, I often wake-up partially and realize that I hear my own snoring as an outsider (quite a dramatic experience!). Sometimes I have an experience which might be interpreted by saying that the hearing in the first perspective is superposed with the hearing in the third person perspective. The third person hearing has a time lag so that a kind of double breathing results.

Place coding of features inside brain

Place coding for various geometric parameters characterizing simple geometric 'features' inside brain could be realized using the variation of the cyclotron frequency along a magnetic flux tube of varying thickness. The hierarchy of the sensory canvases allows a modular structure in which a geometric feature such as triangle, line, or ellipse represented at a lower level sensory canvas is projected to a *single* point of 'our' sensory canvas.

Becker tells in his book "Cross Currents" [56] about a technique discovered by Dr. Elizabeth Rauscher, a physicist, and William Van Bise, an engineer. The technique uses magnetic fields generated by two coils of wire, each oscillating at a slightly different frequency and directed so as to intersect at the the head of the subject person. When two energy beams with different frequencies intersect at some point in space, a third frequency, so called beat frequency is formed as the difference of the frequencies. What Bise and Rauscher found that this ELF frequency (unfortunately, I do not know what the precise frequency range was) generates simple visual percepts like circles, ellipses and triangles and that the variation of the second frequency induces the variation of the shape of the percept.

The simplest interpretation is that the beat frequency is extracted by nonlinear effects in brain and induces a magnetic quantum phase transition at magnetic tubes whose thickness varies and codes for a parameter (say scaling in some direction) characterizing the geometry of the primitive percept (or 'feature'). An analogous phenomenon occurs also for auditory inputs with slightly different frequencies fed into ears and makes it possible to 'hear' sounds below the audible range. The mechanism could be the same.

If primary sensory qualia are realized only at the level of the primary sensory organs, one can make two conclusions. ELF wave wakes up a "feature" analogous to an imagined percept, and presumably realized as a particular nerve pulse pattern. ELF wave also induces a projection from the brain to

the retinae "qualiafying" this feature. Blind subjects should not have these extra-sensorily induced percepts.

One can imagine two options concerning the ultimate representation of a simple geometric feature depending on whether the feature corresponds to a *collection* of points or *single* point at 'our' sensory canvas.

1. The visual percept corresponds to a *collection* of activated points at 'our' sensory canvas and activated geometric point corresponds to a standard mental image represented at brain level and assigned to a point of sensory canvas. The magnetic phase transition would initiate a process eventually activating particular projectors and the position of the quantum phase transition at the magnetic flux tube would determine the shape of the feature. One can criticize this option. The brain applies modular hierarchy in the information processing and simple percepts like triangles and circles which are also fundamental in the elementary geometry, are ideal for basic features assignable with a *single* point of 'our' sensory canvas rather than being represented as composites of elementary features (points). The very fact that the place coding for the geometric shape of the feature is involved, suggests the same.

2. The visual percept is represented as a mental image inside brain or, more probably, at some lower level sensory canvas so that the hierarchy of the sensory canvases would directly relate to the modularity of our sensory representations and sensory canvases would be in an intense interaction by quantum entanglement much like various subprograms of a computer program. This geometric mental image is assigned with a *single* point of 'our' sensory canvas by quantum entangling it with a projector ME projecting to a particular point of 'our' sensory canvas. The position of the feature at the sensory canvas might be determined by the position of the volume of intersection for the beams.

Since sinmple objects are in question and the change of the shape corresponds to a scaling in one direction, the representation of the change of shape of the object could be in terms of a Lorentz boost of sub-CD representing the object and leaving the tip of the sub-CD invariant.

The relation of mental imagery to sensory experiences

Mental imagery is something which is difficult to understand in the framework of the standard neuro science. There are empirical results suggesting that mental images correspond to patterns of activity inside cortex, which are three-dimensional and continuous so that neural activation provides a concrete recognizable image about object [87]. Rather remarkably, also imaginative thought resembles very much visual imagery as is clear from the fact that language is full of visual metaphors [87]. It is also known that imagery uses same regions of the cortex as real sensory experience and the problem is to understand why there is almost sensory experience involved with imagery.

In the framework of the standard neuroscience the obvious question is why the pattern of the imagery activity is not accompanied by a direct sensory experience. Also the boundary between direct sensory experience and imagination is sometimes problematic. For instance, in the state between sleep and awake sensory images often enter into mind. During dreams one can have sensory images and eidetic memory is essentially sensory memory. I have a personal experience about an extended state of consciousness, or rather whole-body consciousness (this experience actually made me consciousness theoretician!). During this state I could see my thoughts as vivid visual images and had also peculiar odour and taste experiences also reported to occur during mystic experiences.

Imagination could involve p-adic-to-real phase transitions transforming p-adic imagery to nerve pulse patterns or membrane oscillations. The genuinely p-adic aspect of imagination could be analogous to a free choice of initial values in a computer simulation, which are then transformed to their real counterparts initiating neural activity.

Why imagination does not involve sensory qualia could be explained in several manners.

1. Primary sensory qualia are realized at the level of sensory receptors and brain constructs only higher level symbolic representations of the sensory input and quantum entanglement binds these representations together. For imagination sensory receptor level is absent. This would also explain rapid eye movements during dreams as being related to the construction of visual qualia. Dreaming is indeed a cognitive activity which is learned gradually (at young age dreamer

sees only static images). One could understand why motor activities are not accompanied by sensory experiences associated with motor pathways. The obvious reason for why sensory imagination should not create lively images is that this would lead to a dangerous mixing of the real and virtual. If this interpretation is correct, the study of whether feedback from brain to sensory organs occurs during sensory hallucination, provides a manner to test whether sensory hallucination is a telepathic experience resulting from the sharing of mental images or whether it might be constructed in brain by feedback to sensory receptors.

2. Imagination could rely on membrane oscillations just as higher level cognition. The finding that imagination does involve patterns of activity at visual cortex similar to those associated with ordinary visual perceptions does not support this idea.

3. If higher level sensory representations are realized at the magnetic canvas, the difference between imagination and real sensory experience could result from the absence of the projection to the sensory canvas. Also the absence of negentropic entanglement could be the reason. This state of affairs could have a detectable EEG correlate: for instance, in 40 Hz resonance band. The projector MEs responsible for the cognitive representation could be activated but be p-adic and project only cognitive images. One can however wonder why magnetic body is at all conscious about imagined mental images if it does not share these mental images.

   If this explanation is correct would be also possible to have sensory experiences at brain level only. For instance, unconscious seeing would would be possible. This kind of blind vision is indeed known to be possible and will be discussed later.

Motor output and the ultimate output giving rise to our sensory experience might be very closely related: motor action could be like printing or some control activity and sensory and cognitive representations like pictures at the monitor screen. This picture looks attractive but might neglect some deep differences suggested already by the anatomy of the central nervous system. There are reasons to expect that the construction of sensory percepts and motor activity could be geometric time reversals of each other at some levels of the self hierarchy (MEs in certain time scales). This view would mean that motor action starts from a rough sketch for the outcome of the motor action and quantum jump by quantum jump ends up to the complete performance by a process which might be regarded as a gradual carving of a four-dimensional sculpture relying on both ordinary and time reversed dissipation serving as a Darwinian selectors so that the very many sketches would lead to the same outcome. Both these views might make sense: which view is correct depends on what time scale one is considering.

Are the space-time sheets and sub-CDs representing objects of the perceptive field generated automatically?

One of the poorly understood aspects of sensory perception is how objects of the perceptive field are generated at the level of cognitive representations. The problem is especially difficult in the computational approach to consciousness. Natural idea is that the objects of cognitive representation directly reflect the objects of the physical world and that direct physical interaction creates these objects automatically. Various visual illusions demonstrate that also apparent objects are generated by sensory experience which suggests that it is nerve pulse patterns at the level of cortex which give rise to the objects of the perceptive field. In neural net approach to brain consciousness it is however far from trivial what these objects could be.

In TGD approach objects of the perceptive field correspond to mental images and thus subselves. subselves in turn naturally correspond to mindlike space-time sheets. Therefore the problem reduces to that of understanding how sensory input gives rise to mindlike space-time sheets: in particular, how the sensory input or nerve pulse activity induced by it determines the boundaries of the mindlike space-time sheets.

On of the basic laws about sensory experiencing is that only changes are experienced. Quantum model for the contents of consciousness of self implies this law at quantum level: only the averages of the increments of quantum numbers and zero modes are experienced consciously. By 'Ontogeny recapitulates phylogeny' principles this law should have realization also at the level of dynamics of the space-time surface.

A possible space-time level counterpart of this law is that the primary at the level of primary sensory organ or secondary sensory stimulus at the level of cortex generates Kähler electric field

proportional to the gradient of the stimulus. This creates however a problem. Kähler electric flux must be conserved in the approximation that vacuum Maxwell's equations are satisfied (they are not exactly satisfied since vacuum can carry currents of Kähler charge). Suppose that stimulus has a strong gradient: where does the Kähler electric flux go? The answer is simple: mindlike space-time sheet is generated and the flux goes to the mindlike space-time sheet through wormhole contacts! Since sensory stimulus varies rapidly at the boundaries of the objects of the external world, this means that the objects of the perceptive field are automatically represented by mindlike space-time sheets and give rise to selves, mental images in the cognitive representation! Several cognitive representations with different decomposition into objects are possible.

Also an alternative formulation of the title is as a question whether the sub-CDs serving as imbedding space correlates for the mental images are generated automatically. One could argue that quantum jump sequence generates these sub-CDs and that directed attention could induce them. Negentropy Maximization Principle suitably generalized to state that the difference for the negentropies of the final and initial state is as large as possible for a given CD might favor the generation of negentropic sub-CDs. Also the argument for the arrow of psychological time suggests that NMP should have this kind of generalization.

Spectroscopy of consciousness

In its original form the spectroscopy of consciousness stated that one could assign to various qualia -say colors, tastes, or odors- frequencies so that the frequency patterns would provide a spectroscopic signature of the microscopic structure of conscious experience just like frequency patterns allow to deduce highly detailed information about the structure of a distant star. Spectroscopy of consciousness could be for the brain science what atomic spectroscopy has been for physics and chemistry.

In its original form this idea turned out to be un-realistic. Sensory qualia as such do not seem to correspond to frequencies. Rather, frequencies would code for the geometric data. For the cyclotron frequencies at least only the frequency ratios seem to have a deeper meaning. The fundamental frequencies assignable to CDs however define an exception in this respect. Spectroscopy of consciousness in a more realistic form would relate to the coding of geometric data such as positions, size scales and state of motion for the objects of the perceptive field. Frequency scales could also distinguish between higher level sensory representations assigned to brain regions of various size scales. The basic frequencies would be fundamentals and their harmonics assignable to CDs, cyclotron frequencies, and Josephson frequencies.

1. Spectroscopy of consciousness and size scales of brain structures

The size scales for various parts of brain could mapped to frequency scales characterizing the sizes of the parts of dark magnetic body so that a kind of collection of zoomed up images of brain regions would be obtained. Images of brain regions would be mental images assignable to them to the sensory receptors entangled with them.

1. In [18] it is found that a simple scaling law $v = \lambda f$ relating the apparent wavelength and phase velocity of EEG wave and more general em waves with its frequency allows to understand the basic anatomical structure of the central nervous system as reflecting evolution regarded as the emergence of new p-adic length scales. Scaling law allows also to predict which frequencies correspond to qualia experienced at a given level of the p-adic self hierarchy for a given conduction velocity of nerve pulses identified as an effective propagation velocity of EEG waves. Scaling law could also relate the sizes $L(magn) \sim L(EEG)$ of the radial magnetic flux tube structures (magnetic canvas or magnetic body) associated with the secondary sensory organs of size $L \sim \lambda$: $L(magn) \sim L(EEG) = c/f = (c/v)L$. Wave length of EEG could code for the size of the structure defining a kind of zoom-up of the brain region in question at the magnetic body.

2. The hierarchy of Planck constants allows to understand how photons for which the energies $E = hf$ are much below the thermal energy in standard quantum theory can be so important biologically. EEG photons would obviously have a rather large value of Planck constant. This hypothesis encourages the identification of the above defined velocity ratio as $r = c/v = \hbar/\hbar_0$. $\hbar$ would be Planck constant for say ELF photons communicating the signal to the corresponding dark layer of the magnetic body. In brain the dark photons could be transformed to ordinary short wave length photons by a leakage to $r = 1$ page of the Big Book in an energy conserving

manner. The part of the magnetic body at a particular page of the Big Book would represent an r-fold zoom up of the brain region considered. If one takes seriously the proposal that DNA double strands act as relay stations between the brain and magnetic body, these values of Planck constants could be assigned with the flux tubes assigned to DNA nucleotides. I have proposed a similar scenario but with motivations coming from an attempt to understand how the realization of the genetic code at the level of dark nucleon physics discovered for few years ago could relate to the biochemistry and DNA [26, 20, 38].

3. The fundamental frequencies would be most naturally cyclotron frequencies of charged elementary particles and biologically important ions at the magnetic flux tubes with large $\hbar$. TGD based nuclear physics predicts also the possibility of exotic chemically equivalent bosonic counterparts of the ordinary fermionic ions so that Bose-Einstein condensate of also these ions at cyclotron states could define macroscopic quantum phases. The corresponding higher level qualia would correspond to phase transitions changing cyclotron quantum numbers. Cyclotron energies scale as $\hbar$ so that energy scale would distinguish between different pages of the Big Book whereas frequency would be the same form them if the strength of the magnetic field is same for all the pages. Energy coding would be in question. These photons would be naturally generated at the magnetic flux tubes which suggests that they could be used for communications from the magnetic body to biological body.

2. Spectroscopy of consciousness, CDs, and Josephson junctions

Zero energy implies the notion of CD as imbedding space correlate of self and the moduli space of CDs should play a key role in the understanding of the geometric qualia. Hence the spectroscopy of consciousness could relate very closely to the scales of CDs.

1. For a fixed value of $\hbar$ rather few size scales for CDs would be involved (nuclei, quarks, electron plus their possibly existing p-adically scaled up variants). The fundamental frequencies assignable to CDs would correspond to the time scales of CDs and would scale like $1/\hbar$ whereas energy would not be affected in the scaling of $\hbar$.

2. The problem is that for energies above thermal energy at physiological temperatures the size scale of CD should correspond to those assignable to very heavy particles. If only photon energies above thermal energy are relevant for biology the frequencies 10 Hz and 1 kHz assigned to electron and quarks would be excluded. If the leakage of classical em oscillations of given frequency leaking between different pages of the Big Book automatically generates photons with scaled up energies, the problem disappears. Each of the r sheets of the many-sheeted covering would carry single quantum with the original frequency. The frequency would be r-fold harmonic of the frequency of the fundamental for the scaled up CD.

3. Also Josephson frequencies associated with the cell membrane identified as Josephson junction (also flux tubes connecting the membrane to DNA strand could serve as Josephson junctions) are involved. Josephson energies do not depend on $\hbar$ since the frequencies behave like $1/\hbar$ so that a hierarchy of representations at the pages of the Big Book in different time scales would be obtained as kind of spatio-temporal zoom-ups. In this case the communications would be naturally from the biological body tothe magnetic body and sensory data could be communicated in this manner.

4. The photon energy $E \sim .05$ eV assignable to the cell membrane potential energy is at the border of the thermal threshold and corresponds to a wave length $\lambda = 2.4 \times 10^{-5}$ meters. For M_{89} corresponding to intermediate gauge bosons one has $L(89, 2) = L(178) \simeq 1.2 \times 10^{-4}$ m - the size scale of a large neuron and only 5 time longer than λ so that $r = 5$ would allow to overcome the thermal threshold. Could even intermediate gauge boson length scale be relevant for biology? The lifetime of intermediate gauge boson is much shorter than this time scale but one can ask whether photons could correspond to M_{89}.

3. Spectroscopy of consciousness and the moduli space of CDs

Consider next the concrete realization of the spectroscopy of consciousness in terms of the moduli space of CD.

1. The moduli space of CDs which is Cartesian product of part associated with M^4 degrees of freedom and CP_2 dgrees of freedom.In M^4 degrees of freedom one has the position of say lower tip parameterized by M^4 and the coordinates for the relative position of tips defining sub-set of the future directed light-cone M^4_+. The position in M^4 for the lower tip of sub-CD could code for the position of the object of the perceptive field.

2. The quantization of the proper time distance between the tips in octaves reduces the situation to a union of hyperboloids and a further discretization to a lattice of hyperboloid is suggestive by number theoretical considerations. The interaction of a photon with this kind of hyperboloid representing sub-CD is resonant if the frequency corresponds to the temporal difference between the tips as measured in the rest system of CD so that frequency coding of the Lorentz boost performed for sub-CD results.

3. One particular application would be the coding of the velocity (including its direction) of an object of perceptive field to the boost applied to sub-CD leaving its lower tip invariant. The positions of sub-CDs would not be updated continually and the sensation about continuous motion would result from the separate representation of the velocity. This interpretation is supported by a syndrome in which patient does not perceive motion and the positions for the objects of the perceptive field are updated with so long time intervals that the ordinary street traffic is too dangerous for the patient. The size scales of sub-CDs would give rise to a natural length scale hierarchy characterizing the sizes of the details of the representation. $M^2 \subset M^4$ fixed partially by the tips of CD defines preferred quantization axes for energy and spin and this choice would be be relevant for purely quantal aspects of the sensory representation. The Lorentz boosts of discrete spectroscopies would code for the motion of the objects of perceptive field.

4. In CP_2 degrees of freedom moduli would correspond to $CP_2 \times CP_2$ such that for both factors a preferred point and a homologically trivial geodesic sphere S^2 has been selected. Thes choices give rise to flag manifold $SU(3)/U(1) \times U(1)$ labeling the choices of the quantization axes. In the recent case color rotations for the tips would represent the geometric data at the basic level. Also now discretization for the CP_2 points assignable with the second tip would be natural. $M^8 - H$ duality is fundamental element of quantum TGD and means that CP_2 points code for hyper-quaternionic planes of hyper-octonionic M^8 containing a preferred M^2. This would suggest that CP_2 could also code for geometric data as is suggested by the findings of Barbara Shipman concerning the role of the flag-manifold $SU(3)/U(1) \times U(1)$ in the model of honeybee dance [34]. The hyper-quaternionic plane assignable to the point of space-time surface at given point identified as a plane spanned by the modified gamma matrices would correspond to a point of CP_2.

Spectroscopy of consciousness is considered in detail in [18] - the spirit is of course extremely adventurous since so little is known and potential reader can take this as a mere exercise perhaps helping to identify the rules of the game. Especially fascinating is the possible connection of the theory of the magnetic qualia with atomic and nuclear spectroscopy: the structure of the periodic table could reflect itself directly itself in the spectroscopy of consciousness via cyclotron frequencies inversely propotional to the masses of ions. Various full electronic shells (He, Ne, Ar, Kr, Xe) correspond to a hierarchy of geometric qualia relating directly with the band structure of EEG. The periods also could also relate to the five-layered structure of sensory cortex (primary, secondary, etc... areas).

5.4.3 Is the pain in the toe in the toe, in brain, or somewhere else?

The basic question concerns about the seat of the primary sensory experience. There are three options.

1. Standard neuroscience says that our sensory experience can be localized to cortex.

2. The apparently very naive view is that sensory experience receives a contribution also from the primary sensory organs. Certainly primary sensory organs could be experiencers in TGD framework (and probably are) but this experience need not contribute to our sensory consciousness unless there is a negentropic entanglement between brain and sensory organs. Let us assume further that magnetic body plays no role.

3. The notion of magnetic suggests that sensory representations conscious-to-us correspond to a sequence of entanglements connecting the magnetic body and the primary sensory organ and perhaps including even to the object of the external world. This pictures differs in even more radical manner about the view of standard neuroscience. As far as the analysis of the sensory data is considered, this view need not differ in an essential manner from the standard view: magnetic sensory canvas could be analogous to a passive monitor screen. Magnetic body could also participate actively to the construction of the percept by sending virtual sensory feed-back through brain to the sensory organs.

The view 2) is not automatically excluded in TGD framework as it is in standard neuroscience.

1. The experiments of Libet about passive aspects of consciousness [60] could be seen as supporting the hypothesis that the data is sent to the magnetic body, which causes the time lapse meaning that the sensory data is .3-.5 seconds old [27].

2. The location of primary qualia to the level of sensory receptors would also allow to understand why sensory pathways are specialized to definite qualia despite the fact that there seems to be no obvious structural or functional differences at neuronal level. As already found, one could also understand the difference between imagination and sensory experience and why feedback to visual receptors (REM) is present during dreaming.

3. The identification of long term memories as multitime experiences containing contributions from the distant geometric past forces to consider the possibility that sensory organs are primary sensory experiencers whereas the standard dogma of the neuro science is that all sensory experiences occur at brain level at geometric now. The idea that also primary sensory organs are seats of the primary sensory experiences, could explain Libet's experiments, explains the observation that persons who have become blind gradually, lose their ability to have dreams and also the rapid eye movements and feedback from brain to auditory organs during REM sleep. It must be emphasized that these phenomena can be understood also in options 1) and 3).

One can represent several objections against the identification of the primary sensory organs as seats of our primary sensory experience (Option 2)[1].

1. The first class of objections is that our sensory perception involves a lot of computation (consider stereo vision as an example) and this computation cannot be performed at the level of the sensory organ. These objections look at first rather convincing but relate only to the cognitive aspects of sensory perception, not the to the primary sensory qualia. The computation can be carried out and involve also magnetic body and the back-projection to the primary sensory organs could allow to construct the percept as an artwork at the level of primary sensory organ.

2. The second class of objections is related to the explanatory power of the idea of standard neuroscience that entire sensory pathways containing also neurons of cortex are seats of the sensory experience (For option 1) they are involved with the construction of the sensory experience). This idea allows to regard brain as kind of musical instrument such that each neuron produces its characteristic sensory experience so that our experiences are combinations of the primitive neuronal experiences. For conscious information processing this is a crucial advantage: for instance, incoming nerve pulse patterns in associative regions of brain are consciously differentiated from each other as different modalities so that same nerve pulse pattern can have different meaning as sensory modalities. This objection suggests that the idea of restricting sensory experiences at the level of primary sensory organs is wrong. On the other hand, neuronal pathways and brain could be specialized to build cognitive representations and primary sensory qualia could be at the level of sensory receptors. The feedback from brain to the sensory receptor level could also make possible to manipulate the sensory input.

3. The view about brain as a collection of standard features which are activated by the sensory input and projected to the magnetic canvas and thus associated with the objects of perceptive field is in conflict with the idea that our experience receives a direct contribution from the

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[1]The topic of discussion might look rather academic from the point of view of neuro science but it is not that in TGD framework: it took years to decide whether this idea could make sense or not.

primary sensory organs. Situation of course changes if one allows entanglement of brain with sensory organs.

4. The phenomena like dreams, hallucinations, synesthesia, phantom limb, and the experiences generated by stimulating neurons of sensory pathways and projected pain are obvious counter arguments against the idea that sensory organs are primary sensory experiencers (or form parts of them). The identification of the long term memories as multitime experiences allows in principle to overcome these objections, and a more detailed discussion of this point is in order.

In the following the explanations of various strange phenomena of sensory consciousness are studied and the explanations provided by the options 1), 2) and 3) are compared. It must be emphasized that the possibility that even sensory organs (and even neurons) have senses is not excluded by these arguments: what is however clear that *our* sensory landscape is constructed in cortex.

Back projections and cross projections

During REM sleep rapid eye movements occur and are thought to accompany dreaming. It is not however clear to me whether the correlation between rapid eye movements and visual dreaming is one-to-one. The ringing of the ears is a real physical process occurring in ear and these otoacoustic emissions, as they are called, can be sometimes heard by even outsider [27]. Rapid eye movements during dreams and otoacoustic emissions can be regarded as backprojections from brain to primary sensory organs.

1. These phenomena can be understood without any difficulties in the options 1) and 3). For instance, rapid eye movements could be understood as feedback generated by a visual dream.

2. For the option 2) rapid eye movements could be seen as necessary prerequisite of dreaming and to "qualiafy" imagined mental images.

Synesthesia involves cross-modal associations of form $A \to B$ (say visual to auditory).

1. In option 2) both dreams, hallucinations, and synesthesia rely on the feedback from brain to sensory organs to "qualiafy" the mental images. The prediction is that there should be a feedback, not only between sensory areas, but between sensory organs or the cross-associated qualia. This prediction is certainly testable. For instance, auditory-visual synesthesia should be lost if eyes are damaged.

2. The simplest view allowed by options 1) and 3) is that this kind of sensory leakage occurs at the level of neuronal connections.

Projected pain and phantom leg

Projected pain and phantom leg provide a further test for the proposed options.

1. For the standard explanation (option 1)) one must assume that the experience of pain is localized to the somato-sensory map in brain. The explanation of the projected pain is based on the observation that projected pain is felt in the body part which was very near to the body part contain the actual cause during early developmental stages. If somatosensory maps are not updated properly, projected pain becomes possible. This applies also to option 2).

2. For option 2) the explanation of phantom pain as a remembered pain and thus as a real pain in the geometric past when the limb still existed, is the simplest one. Projected pain cannot be however interpreted as a remembered pain since the physical cause of pain is in the geometric now. The assumption that the sensory pain (as distinguished from psychic pain) is a cortical sensation whereas only pure sensory experiences would be located in the primary sensory organs looks rather strange taking into account the universality of emotions as entropic qualia. What goes wrong with this argument is that the experience of pain is confused with the experience about where the pain is. The wrong location could result when the mental image about pain is projected in a wrong manner to the body map. A leakage between sensory pathways could cause the wrong localization.

3. Also for option 3) the simplest explanation of the phantom leg phenomenon is that the pain is geometrically remembered pain from the period when the leg still exists and thus would have a real cause. Also other possibilities can be imagined. The loss of the physical limb need not mean the loss of its magnetic counterpart so that phantom pain might be caused by either by a sensory input from other parts of leg projected to the part of the magnetic sensory canvas representing the lost leg. This could explain also the projected pain. The magnetic map of body coded by MEs could be partially out-of-date so that some parts of this map correspond to the structure of biological body during the early developmental periods. The pain in left arm during heart attack could be understood in this manner.

Color constancy and sensory organs as primary experiencers

The phenonenon of color constancy [57], which forms one of the most important aspects of vision, is a further objection against the identification of sensory organs as primary sensory experiences. At least if one believes that colors are primary sensory qualia. If the object of the visual field is illuminated with a monochromatic light of constant intensity, its color does not change. This is quite contrary to what one might expect on basis of what is expected to happen in the color sensitive cones in retina detecting wavelenghts concentrated around blue, red and green. A particular case of the color constancy phenomenon arises when entire visual field is illuminated with a monochromatic light of a constant intensity: what is experienced is complete darkness. The ability to see the real colors of the objects of the external world, which is made possible by the color constancy phenomenon, is of course extremely valuable for survival purposes.

1. For option 1) color constancy is a challenge. Color constancy suggests that retina cannot be the primary sensory experiencers of color qualia since in this case our subjectively experienced world would be changing its colors continually. This conclusion might be too hasty. In fact, one could defend the hypothesis about sensory organs as primary sensory experiencers and use color constancy as a guide line in the attempts to guess how sensory representations for the objects of the external world are generated as sub-CDs residing at the retina.

2. In option 2) and 3) it can be assumed that the subtraction of the background involves computational processing at the level of brain. If the objects of the perceptive field are generated at the level of brain by nerve pulse patterns, this is probably the case. The subtraction of the background is possible to realize by excitatory and inhibitory projections and mathematically one can regard the sensory image of a colored object of a perceptive field as an integral function for the gradient of the intensity of the sensory input. For a monochromatic constant input the derivative vanishes as also integral function. The task therefore is to realize this integral function in terms of a neural circuit using excitatory and inhibitory inputs and outputs.

The explanation of the color constancy could reduce to the hypothesis that sensory qualia correspond to increments of quantum numbers rather than quantum numbers themselves.

1. If the color perception generated by the illumination at a particular wavelength depends only on the spatial gradient of the illumination, color constancy follows as a consequence. Since the eye is performing saccadic motion, this translates to a temporal gradient of illumination. The temporal change of the illumination at a particular wavelength should thus induce a particular color quale. But this is consistent with the assumption that color qualia correspond to the increments of color quantum numbers in the quantum jump. This model explains also why the saccadic motion is necessary to generate color qualia, and qualia at all. Quite sensory percepts result only when physical change is involved. Saccadic motion maps the gardients of illumination to increments of color quantum numbers.

2. One might also understand why a rotating Benham top containing only black and white regions can produce color sensations. Since both the saccadic motion and the motion of disk are involved, one can imagine that for a rotating disk the proportions of various primary qualia are affected such that a net color is perceived. For instance, the intensity of the perceived color could depend on the velocity with which the eye crosses the intensity gradient and this dependence could depend on wavelength.

All geometric aspects of sensory experiences should reduce to representations generated by zero modes, in particular zero modes characterizing classical Kähler field, which can reduce to pure electromagnetic (vision?) or Z^0 field (auditory experience?). Color constancy could be understood if the incoming light intensities associated with the wavelengths around three basic colors generate Kähler electric fields proportional to the gradient of the intensity. If the gradient is strong, as it is on the boundary of the retinal or neural image of the object, the conservation of the Kähler electric flux forces the generation of mindlike space-time sheet at which part of the flux goes.

Thus retina would automatically create representation for the objects of the visual field as mindlike space-time sheets, which in turn could give rise to subselves representing objects of the visual field as mental images! These objects need not however correspond to our conscious experiences. In fact, the boundaries of all objects of perceptive field should be generated by strong gradients and same principle would apply also to the higher level representations of sensory information. A gradient of Kähler (electric) field proportional to the gradient of primary/secondary sensory stimulus is generated in primary/secondary sensory organ and automatically generates mindlike space-time sheets, which give rise to subselves representing the decomposition of the perceptive field to objects.

Blind sight and Anton's syndrome

In blind sight cortically blind patient claims to be blind but is actually able to locate objects in the visual field when asked to do that. By training the patient can even develop some kind of primitive conscious experience of motion, shape and color.

1. For option 1) blind sight looks first problematic since the basic assumption is that primary visual qualia are generated at the level of retina. If the entanglement with retina is lost the visual qualia at retina are not assigned with the magnetic sensory canvas and the person is not conscious that his eyes see. The primitive conscious experiences of motion, shape and color would arise at the sub-cortical level make it possible to locate objects in the visual field. Blind sight would be also vision without cortical cognition (such as feature recognition). Training would generate gradually entanglement between sub-cortical areas and the cortical areas responsible for projections to the sensory magnetic canvas.

2. In option 2) the explanation for the blind sight would be the existence of two separate visual systems. Possible candidates for these systems as regions of cortex have been even identified[57].

3. In option 3) blind sight has several explanations. The simplest explanation is that the negentropic entanglement between magnetic body and brain is absent so that brain would see consciously but not the magnetic body representing us. Blind sight could thus be interpreted as a support for the notion of magnetic body. A test for the magnetic canvas hypothesis might be based on the elimination of the MEs responsible for the sensory projection to the magnetic canvas somehow. This option is of course not the only possible one. There is entire p-adic hierarchy of increasingly refined visions involving retinal vision, amygdalar vision, and various visions corresponding to sensory areas of cortex.

The patient suffering from Anton's syndrome is cortically blind but claims that he sees but behaves as if he were blind and confabulates all kinds of explanations for his behavior.

1. The advocate of option 1) could argue that patient sees at the subcortical level and hence has pure experience of vision without any cortical cognitive processing of what he is seeing. Person is cognitively blind. There would be no recognition of objects in the visual field, to say nothing about associations and memories related to these objects. Therefore sensory (or subcortical) seeing would not help the patient much and he would behave effectively as a blind person. One could even consider the possibility that patient gradually loses the ability to see because this ability is not useful anymore. A possible test (probably already carried out) for the hypothesis is to check whether patient can show the direction of an intensive light source (even this might require "cognitive seeing").

2. The standard explanation (option 2) is that patient is not conscious about being blind: the fact that patent seems to gradually accept the situation that he does not see, supports this explanation. It would be possible to have the experience of seeing without actually seeing.

3. Option 3) would allow the possibility that the parts of the cortex responsible for projecting sensory data to the sensory magnetic canvas remain intact and that the visual images are visual memories. It would not be surprising that this useless vision would be gradually lost. Note however that lower level visual systems might work.

Woman without body

In his book 'The man who mistook his wife for a hat' [79] Oliver Sacks tells about a tragic situation in which his patient lost totally her body image. Body image is provided by proprioception together with vision and sense of balance. The sensory neurite suffered by the patient destroyed patient's proprioceptive sensory pathways. Patient did not however lose tactile senses. The proprioceptive homunculi in patient's parietal lobes suffered no injury. Patient learned to cope with everyday activities by using vision and sense of balance and all kinds of clever feedback and feedforward mechanisms to compensate the lost proprioception. For instance, patient regained her ability to speak, to keep her bodily posture and walk. She however lost her balance immediately if she closed her eyes. Patient did not however get back her phenomenal body image in this manner.

The loss of body image is not a problem for option 2) since neural pathways are prerequisites of quantum entanglement between brain and sensory receptors (also these might have been destroyed). Options 1) and 3) can explain the loss of body image without difficulties. These options could even allow to regain the body image artificially, for instance by artificial neuronal stimuli providing a representation for the positions of various body parts. In both cases artificial electric stimulation of cortex should generate tactile sensations of some kind.

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Part II

TIME AND CONSCIOUSNESS

Chapter 6

Time and Consciousness

6.1 Introduction

The identification of moments of consciousness as quantum jumps between quantum histories suggests that our common sense picture about the time evolution of universe might be badly misguided by the restrictions posed by the basic features of our conscious experience. What one can do is to try to develop the most general picture about the cosmology of consciousness consistent with our own conscious experiences and try to identify our position in this picture. Already in its recent form TGD inspired theory of consciousness can give quite restrictive constraints on this Grand Scenario.

The understanding of how psychological time and its arrow emerge has been perhaps the most longstanding problem of quantum TGD and TGD inspired theory of consciousness. By quantum classical correspondence the arrow of subjective time should be mapped to the arrow of geometric time at the level of conscious experience. In similar manner the asymmetry between subjective future and past should be correspond to an asymmetry between geometric future and past. What this means at the level of details has been far from clear and I have proposed many partial answers to the question about the arrow of geometric time. For instance: the geometric future inside light-cone contains much more room than geometric past so that the space-time region about which the contents of conscious experience are about tends to diffuse to the direction of the geometric future defined by light-cone proper time; perhaps the flow of geometric time corresponds to a wave front of intentional action identifiable as a phase transition changing intentions identified as p-adic space-time sheets transformed to real space-time sheets; maybe the space-time sheet assignable to self topologically condensed to a larger space-time sheet shifts in quantum jumps to the direction of geometric future some average temporal distance perhaps defined by CP_2 length scale. All these proposals have provided only partial answers, have led to paradoxes, and failed to give a firm quantitative grasp about the situation.

Also the original wrong view about the correspondence of real and p-adic numbers has generated a lot of confusion. The natural belief of topologist would be that p-adic space-time sheets are mapped to their real counterparts by a continuous map (some variant of what I called canonical identification making sense in p-adic thermodynamics). This map did not however respect symmetries and was inconsistent with field equations. Finally I was able to accept the natural belief of algebraist: reals and various p-adic number fields must be glued to together along rationals and common algebraic numbers to achieve generalization of the number concept and also that of imbedding space. What was difficult to accept was the highly non-intuitive implication that most points of p-adic space-time sheets are at spatial and temporal infinity in real (but not in p-adic) sense so that cognition and intentionality would be literally cosmic phenomena and only cognitive representations would be realized in a finite space-time volume in real sense (causal diamond) in terms of intersections of real and p-adic space-time sheets consisting of rational and some algebraic points.

I have tried to tidy up the chapters so that they would not contain too many mammoth bones. Since I can use only a finite amount of time to documentation purposes, I have not been completely successful and this chapter as also others might contain statements which represent earlier archeological strata. I hope that reader could forgive this. Benevolent reader might even take these chapters as documents about how ideas have developed.

6.1.1 The concepts of self and subjective memory

Self is identified as a subsystem able to remain unentangled during quantum jumps consisting of unitary processes U defining informational "time evolutions" followed by a state function reduction which in zero energy ontology includes also state preparation occurring for the negative energy part of the state (zero energy state corresponds to physical event in positive energy ontology with negative and positive energy parts of the state being identified as the counterparts of the initial and final states of the event). Bound state entanglement is stable against state function reduction so that conciousness would be lost the bound state entanglement is generated. This would stop the sequence of state function reductions initiated after the U-process. The notion of number theoretic entropy allows to assign entanglement negentropy to algebraic entanglement probabilities so that NMP favors the generation of entanglement in this kind of situation. This encourages the hypothesis that subsystem does not lose consciousness if it generates algebraic entanglement with environment. This would correspond to the fusion to the sea of consciousness in the spiritual terminology. Algebraic entanglement is possible in the intersection of real and p-adic worlds which in turn encourages the proposal that living matter corresponds to this intersection, and is therefore a critical phenomenon in number-theoretical sense so that evolution involves in an essential manner the generation of algebraic entanglement.

One can say that self is a subsystem behaving like its own sub-Universe (with respect to NMP). What this really means quantitatively is far from obvious and detailed view requires the introduction of zero energy

The hypothesis that the experiences of self associated with the quantum jumps occurred after the 'wake-up' sum up to single experience, implies that self can have memories about earlier moments of consciousness. Therefore self becomes extended object with respect to subjective time and has a well defined 'personal history'. If temporal binding of experiences involves kind of averaging, quantum statistical determinism makes the total experience defined by the heap of the experiences associated with individual quantum jumps reliable. Subjective memory associated with sensory mental images has duration of about .1 seconds from the temporal resolution of sensory experience: it is quite possible that our self has much longer duration. The subjectotemporal sequences of sub-selves make possible to remember the digits of a phonenumber.

Subsystem X possessing self behaves essentially as a separate sub-Universe with respect to NMP. An attractive hypothesis is that the experience of self is abstraction in the sense that the experiences of sub-selves X_{ij} of X_i are abstracted to average experience $\langle X_{ij}\rangle$. This implies that the experiences of sub-sub-...selves of X are effectively unconscious to X. This self hierarchy is infinite and has entire Universe, God at the top. Temporal binding with averaging implies that experiences of individual selves are reliable and abstraction brings in the possibility of quantum statistical determinism at the level of ensembles.

6.1.2 Psychological time and its arrow

Quantum classical correspondence requires that the flow of subjective time identified as a sequence of quantum jumps should have the flow of geometric time as a space-time correlate. The understanding of the detailed relationship between these two times has however remained a long standing problem, and I have proposed several models involving ad hoc assumptions. Only the emergence of zero energy ontology allows an ad hoc free model for how the experienced flow and arrow of geometric time emerge, and answers why the relationship between geometric past and future is so asymmetric and why sensory experience is about so narrow interval of geometric time. Also the notion of self reduces in well-defined sense to the notion of quantum jump with fractal structure [28].

The basic idea about the correspondence between subjective and geometric time is very simple. Configuration space spinor field represents a quantum superposition of space-time surfaces. Assume that the attention of self is directed to a fixed volume of the 8-D imbedding space. Quantum classical correspondence requires that this quantum superposition in the first approximation shifts towards geometric past of the imbedding space so that self experiences effective flow of the geometric time associated with the space-time surface. This explanation works only if macroscopic quantum coherence holds true so that one cannot regard the space-time surface as a fixed arena of dynamics. Also the representability of the space-time surfaces as sub-manifolds of 8-D imbedding space is essential. The identification of the fundamental volume of attention as a causal diamond inspired by zero energy ontology based formulation of quantum TGD provides answers to more detailed questions. This iden-

tification means also that causal diamond of imbedding space rather than space-time sheet becomes the space-time correlate of self.

6.1.3   Cosmology of consciousness

The idea about cosmology of consciousness is inspired by the prediction of the infinite self hierarchy and by quantum-classical correspondence principle [29]. The expectation is that the fractal structure of the many-sheeted space-time should directly reflect the general structure for the cosmology of consciousness. For instance, the p-adic evolution of consciousness should have its counterpart at the space-time level. Indeed, there are good reasons to believe that 4-surfaces have decomposition into real regions and p-adic regions and that one can assign to each real region a finite prime p characterizing the effective p-adic topology of the real space-time region (or of light-like 3-surface or partonic 2-surface) and the p-adic topology which the real region is near criticality to transform to. In zero energy ontology this transformation indeed makes sense. Just like configuration space is conjecture to have a decomposition into regions D_P labelled by infinite p-adic primes P, the space-time surface decomposes into real regions labelled by finite primes appearing in the decomposition of P.

Fractality suggests that there are conscious universes within conscious universes and the nested structure of the topological condensate suggests that experiences of universes involve kind of abstractions about the experiences of the sub-universes they contain. The prediction of infinite hierarchy of selves and summation hypothesis for the experiences of selves is in accordance with this expectation.

Mind-like space-time sheets were introduced originally as space-time sheets of finite temporal duration or alternatively as space-time sheets for which the classical determinism in the standard sense of the word fails. In zero energy ontology all space-time sheets have finite temporal scale and zero energy states associated with them have mind-like aspects. For instance, the positive and negative energy parts of the fermionic state define a quantum representation for an abstraction for the Boolean statement $A \rightarrow B$ with various instances of a and b appearing in the superposition.

Since mind like space-time sheets have a bounded time duration, one cannot assign to a quantum jump a single value of the geometric time. Rather, our psychological time would be associated with one of the infinitely many irreducible sub-experiences associated with mind like space-time sheets and the values of the psychological time range from zero to infinity. Since selves contain sub-selves with various values of psychological time, experiences are actually multitime experiences with respect to both geometric and subjective time. The entire 4-dimensional space-time is a living system: both the geometric future and past are living and participate in each moment of consciousness. Selves have increasingly longer geometric and subjective memories and that at the limit of entire universe selves have infinitely long subjective memory.

6.1.4   Four-dimensional brain

The hypothesis that entire space-time surface is populated by mind like space-time sheets realized in concrete manner in zero energy ontology in terms of causal diamonds (CDs) representing systems participating in every moment of consciousness, means also dramatically new manner to understand brain. For instance, the problem of memory trivializes. Geometric memory provides simulations and expectations for what happened and will happen whereas subjective memory has interpretation as immediate short term memory. The most plausible interpretation of long term memories is as geometric memories represented by multitime snapshots. This hypothesis explains the practically unlimited capacity of autobiographical memory and also other basic aspects of long term memories and avoids the counter arguments against the neural net models of long term memory. The paradigm of four-dimensional brain (and body!) forces to reconsider the basic dogma of neuroscience stating that sensory consciousness is associated with brain only and explains nicely the results of Libet's experiments. A concrete model of the long term memory is based on quantum mirror mechanism: experience long term memory means looking at a quantum mirror at a distance of say light years. The attribute 'quantum' means that there is no need to code information to a classical signal, just time like entanglement made possible by the classical nondeterminism of Kähler action and by p-adic nondeterminism is enough.

6.1.5   Evidence for TGD based time concept

The new concept of time follows from the quantum jump between quantum histories concept so that tests for the latter are indirect tests for the former. Perhaps the strongest support for the new concept of time comes from the requirement of the internal consistency of the world view. The phenomenon of dissipation is paradoxical from the point of view of standard physics. It is generally accepted that fundamental laws of classical physics are reversible whereas everyday reality is manifestly irreversible. Thus the situation is rather scitzophrenic. Two worlds, the reversible and extremely beautiful world of fundamental physics and the irreversible and mathematically rather ugly, irreversible "real" world, seem to exist simultaneously. Quantum jumps between quantum histories concept solves the paradox and one can understand dissipative world as an effective description forming "almost" envelope for the sequence of reversible worlds understood as entire time evolutions.

Quantum jumps between quantum histories concept explains the peculiar time delays of consciousness revealed in the experiments of Libet and Kornhuber relating to active and passive roles of consciousness [78, 49] and the causal anomalies revealed by the experiments of Radin and Bierman [85, 82, 56]. TGD predicts "tribar effect" as a general signature for the quantum jump between quantum histories concept.

A further implication is quantum theory of self-organization. Self-organization means the organization of selves leading to fixed point patterns analogous to those generated in Benard flow. This means that dissipation serves as a Darwinian selector of both genes and memes. Dissipation is present also at the elementary particle level and leads to the selection of the p-adic effective topologies of elementary particle space-time sheets. Black-hole elementary particle analogy suggests that the allowed p-adic primes are given the p-adic length scale hypothesis $p \simeq 2^k$, k power of prime.

6.2   TGD based concept of time

TGD based notion of time involves several new aspects. Quantum jump as occurring between entire quantum histories rather than time=constant snapshots of a single history is certainly the most decisive new element. The necessity to differentiate between subjective and geometric time is immediate implication of this identification. The classical non-determinism of Kähler action is second fundamental ingredient: without it time would be lost in the sense that the contents of our conscious experience would not be localized with respect to geometric time and one could not understand the emergence of psychological time and its arrow. The new view about time leads also to the notion of four-dimensional brain implying a new manner to see what long term memories are, and the vision about space-time as a four-dimensional organism. A further new element is related to the possibility of negative energy space-time sheets and classical communications also to the direction of geometric past. The final important ingredient is p-adic physics as physics of cognition and intention having rather exotic implications, such as replication of p-adic memes by time reflection, their instantaneous propagation by the same mechanism, and time reversed cognition. p-Adic physics as physics of intentionality is crucial for understanding of the psychological time as a front of p-adic-to-real phase transition transforming intentions to actions [29].

6.2.1   'Holy trinity' of time developments

Quantum jump between quantum histories was originally believed to be something irreducible and structureless. Gradually the view about quantum jump has however become more and more structured and as a result a connection the quantum standard measurement theory follows as a prediction of quantum TGD. In what sense quantum jumps remains irreducible is that one cannot build any dynamical model for the non-deterministic steps appearing in quantum jump.

The general structure of quantum jump

It has gradually become clear that TGD involves "holy trinity" of dynamics.

1. The dynamics defined by the preferred extremals of Kähler action corresponds to the dynamics of material existence, with matter defined as "res extensa", three-surfaces. What preferred extremals really are has been a long standing open question. The recent formulation of the

quantum theory using modified Dirac action leads to the proposal that the preferred extremals are critical in the sense that they allow an infinite number of deformations for which the second variation vanishes. This serves as space-time counterpart for quantum criticality of TGD Universe fixing the fundamental variational principle uniquely.

2. The dynamics defined by the action of the unitary 'time development' operator U in the space of quantum histories, is the counterpart of the ordinary Schrödinger time evolution $U \equiv U(-t,)$, $t \to \infty$ and can be regarded as "informational" time development occurring at the level of objective existence. It seems however un-necessary and in fact impossible to assign real Schrödinger time evolution with U. U defines the S-matrix of the theory.

3. The dynamics of quantum jumps between quantum histories corresponds to the dynamics of subjective existence.

Quantum jump was originally seen as something totally irreducible. Gradually the structure of quantum jump has revealed itself.

1. The first step in quantum jump is informational 'time development'

$$\Psi_i \to U\Psi_i \quad,$$

where U is the counterpart of the unitary process of Penrose. The resulting state is a completely entangled multiverse state, the entire universe being in a holistic state of 'oneness'.

2. Then follows the TGD counterpart of state function reduction realized as a localization in zero modes:

$$U\Psi_i \to \Psi_f^0 \quad.$$

The assumption that localization occurs in zero modes of the configuration space would pose very important consistency condition on U: it must effectively correspond to a flow in zero modes such that there is one-one correlation between the quantum numbers in quantum fluctuating degrees of freedom in some state basis and the values of the zero modes. This together with the fact that zero modes are effectively classical variables, would imply that the localization in zero modes corresponds to a state function reduction. All p-adic configuration space degrees of freedom are zero modes so that in this sense cognition is classical. One must however be cautious: also wave functions in zero modes are possible as will be argued below.

3. The state function reduction is followed by a cascade of self measurements in quantum fluctuating degrees of freedom (zero modes do not change during this stage)

$$\Psi_f^0 \to \ldots. \to \Psi_f \quad,$$

whose dynamics is governed by the Negentropy Maximization Principle (NMP). For a generic entanglement probabilities his process leads to bound states or a completely unentangled state or bound states identifiable as prepared states for the next quantum jup. This process can be regarded as an analysis or even decay process. If entanglement probabilities are algebraic numbers, the state function reduction can lead to an entangled state with a positive entanglement entropy.

4. Measurement theory requires an entanglement between zero modes and quantum jumps of the physical state. The addition of a measurement interaction term to the modified Dirac action coupling to four-momentum and color quantum numbers of the state and also to more general conserved quantum numbers allows an explicit realization of this coupling and induces the addition of an analogous measurement interaction term to Kähler action [46]. This term implies the entanglement of the quantum numbers of the physical states with zero modes.

A good metaphor for quantum jump is as Djinn leaving the bottle (informational time development), fulfilling the wish (quantum jump involving choice) and returning to, possibly new, bottle (localization in zero modes and subsequent state preparation process). One could formally regard each quantum jump as quantum computation lasting infinitely long time $t \to \infty$ followed by a state preparation of the initial state of the next quantum computation.

Is the complete localization in zero modes really necessary?

The detailed inspection of what happens in quantum jumps forces to consider the possibility that quantum jump involves always a compelete localization in zero modes. This was indeed the original proposal. It however seems that a localization modulo finite measurement resolution might be a more realistic assumption. Certinly it is enough to explain why the perceived Universe looks classical.

1. QFT picture strongly suggests that sub-system must be defined as a tensor factor of the space of configuration space spinors at given point Y^3 of the configuration space. This suggests that subsystem should be defined as a function of Y^3 and should be a local concept. An important consequence of this definition is that entanglement entropy gives information about space-time geometry.

2. Configuration space spinor field can be formally expressed as superposition of quantum states localized into the reduced configuration space consisting of 3-surfaces belonging to light cone boundary. Hence configuration space spinor field can be formally written as

$$\sum_{Y^3} C(Y^3)(n, N)|n\rangle|N\rangle$$

   for any subsystem-complement decomposition defined in Y^3. Clearly, configuration space coordinates appear in the role of additional indices with respect to which entanglement coefficients are diagonal. The requirement that final state is pure state would suggest that quantum jump reducing entanglement must involve complete localization of the configuration space spinor field to some Y^3 plus further quantum jump reducing entanglement in Y^3. Complete localization in the configuration space is however not physically acceptable option since the action of various gauge symmetries on quantum states does not commute with the complete localization operation. In particular, the requirement that physical states belong to the representations of Super Virasoro and super-symplectic algebras, is not consistent with this requirement.

3. Configuration space has fiber space structure. Configuration space metric is non-vanishing only in the fiber degrees of freedom and since the propagator for small fluctuations equals to the contravariant metric, fiber degrees of freedom correspond to genuine quantum fluctuations. Configuration space metric vanishes in zero modes, which can be identified as fundamental order parameters in the spirit of Haken's theory of self organization. The requirement that various local symmetries act as gauge symmetries, provides good reasons to expect that *entanglement coefficients in the fiber degrees of freedom are gauge invariants and depend on the zero modes parametrically*. The one-one correlation between quantum numbers of the state assignable to fiber degrees of freedom and classical variables identified as zero modes would encourate the assumption the a complete localization occurs in zero modes. A weaker condition is that localization occurs only modulo a finite measurement resolution.

4. The original argument was that the nonexistence of metric based volument element in zero modes forces the wave functions in zero modes to have a discrete locus. There however exists a symplectic measure defined by the symplectic form in zero modes. It does not however allow a complexification to Kähler form as it does in quantum fluctuating degreees of freedom. This symplectic from could define a hierarchy of integration measures coming as restrictions of $J \wedge J ... \wedge J$ with n factors to $2n$-dimensional sub-manifolds. Under some additional conditions- maybe the homological non-triviality of J and the orientability of the sub-manifold are enough, this measure would define a positive definite inner product and one would have a hierarchy finite-dimensional sub-spaces of zero modes. The maxima of Kähler function with respect to zero modes replace naturally the continuum with a discrete set of points and define the counterpart of the spin glass energy landscape consisting of the minima of free energy. Effective finite-dimensionality and even effective discreteness would be achieved.

5. The time development by quantum jumps in zero modes is effectively classical: Universe is apparently hopping around in the space of the zero modes. This looks very attractive physically since zero modes characterize the size, shape and classical Kähler fields associated with 3-surface.

Therefore each quantum jump gives very precise conscious geometric information about space-time geometry and about configuration space in zero modes. This also means that Haken's classical theory of self-organization generalizes almost as such to TGD context. The probability for localization to given point of zero mode space is given by the reduced probability density Q defined by the integral of the probability density R defined by configuration space spinor field over fiber degrees of freedom. The local maxima of Q with respect to zero modes appear as attractors for the time development by quantum jumps. Dissipative time development could be regarded as a sequence of quantum jumps leading to this kind of local maximum.

6. Effective localization in zero modes is completely analogous to spontaneous symmetry breaking in which scalar field attains vacuum expectation value with the difference that the number of degrees of freedom is infinite unlike in typical models of symmetry breaking. Thus the general structure of the configuration space spinor field together with TGD based quantum jump concept automatically implies spontaneous symmetry breaking in its TGD version (note however that particle massivation results from both p-adic thermodynamics and coupling to Higgs like field of purely geometric origin in TGD framework). TGD Universe is superposition of parallel classical universes (3-surfaces). Therefore quantum entangled state can can be regarded as a superposition of parallel entangled states, one for each 3-surface. Formally entanglement coefficients can be regarded as coefficients containing the configuration space coordinates of 3-surfaces as additional index. The analogy with the spin glass also supports the localization in the zero modes.

7. Effectie localization in the zero modes provides simple explanation for why the universe of conscious experience looks classical: moment of consciousness makes it classical. It also explains why the physics treating space-time as a fixed arena of dynamics has been so successful. As already found, a further important consequence is first principle description of the state function reduction.

6.2.2 Quantum jump as moment of consciousness and the notion of self

If quantum jump occurs between two different time evolutions of Schrödinger equation (understood here in very metaphoral sense) rather than interfering with single deterministic Schrödinger evolution, the basic problem of quantum measurement theory finds a resolution. The interpretation of quantum jump as a moment of consciousness means that volition and conscious experience are outside space-time and state space and that quantum states and space-time surfaces are "zombies". Quantum jump would have actually a complex anatomy corresponding to unitary process U, state function reduction and state preparation at least.

Quantum jump has a complex anatomy since it must include state preparation, state function reduction, and also unitary process characterized by U-matrix. Zero energy ontology means that one must distinguish between M-matrix and U-matrix. M-matrix characterizes the time like entanglement between positive and negative energy parts of zero energy state and is measured in particle scattering experiments. M-matrix need not be unitary and can be identified as a "complex" square root of density matrix representable as a product of its real and positive square root and of unitary S-matrix so that thermodynamics becomes part of quantum theory with thermodynamical ensemble being replaced with a zero energy state. The unitary U-matrix describes quantum transitions between zero energy states and is therefore something genuinely new. It is natural to assign the statistical description of intentional action with U-matrix.

Intuitively self corresponds to a sequence of quantum jumps which somehow integrates to a larger unit much like many-particle bound state is formed from more elementary building blocks. It also seems natural to assume that self stays conscious as long as it can avoid bound state entanglement with the environment: everything is conscious and consciousness can be only lost. This view predicts infinite self hierarchy with the entire Universe at the top.

If one accepts the hierarchy of Planck constants [17], it might be un-necessary to distinguish between self and quantum jump. The hierarchy of Planck constants interpreted in terms of dark matter hierarchy predicts a hierarchy of quantum jumps such that the size of space-time region contributing to the contents of conscious experience scales like $\hbar$. Also the hierarchy of space-time sheets labeled by p-adic primes suggests the same. That sequence of sub-selves/sub-quantum jumps are experienced as separate mental images explains why we can distinguish between digits of phone number. The irreducible component of self (pure awareness) would correspond to the highest level

in the "personal" hierarchy of quantum jumps and the sequence of lower level quantum jumps would be responsible for the experience of time flow. Entire life cycle would correspond to single quantum jump at the highest(?) level of the personal self hierarchy and pure awareness would prevail during sleep: this would make it possible to experience directly that I existed yesterday. Whether these two definitions of self are in some sense equivalent will be discussed later.

Self is assumed to experience sub-selves as mental images identifiable as "averages" of their mental images. This implies the notion of ageing of mental images as being due to the growth of ensemble entropy as the ensemble consisting of quantum jumps (sub-sub-subselves) increases.

There are thus two definitions of self. The first definition introduces self as a notion separate from quantum jump. Second definition reduces the notion of self to a fractal hierarchy of quantum jumps. The equivalence between two definitions of the notion of self will be proposed later.

6.2.3   Some aspects of classical non-determinism

The general view about the classical non-determinism of Kähler action and its role in TGD and TGD inspired theory of consciousness has developed gradually and still does so. The newest developments relate to the application of quantum gravitational hologram principle in TGD framework. What has been however clear for a long time is that TGD inspired theory of consciousness falls or stands with the classical non-determinism.

Vacuum extremals

Any 4-surface which belongs to $M_+^4 \times Y^2$, where Y^2 is so called Legendre manifold of CP_2 representable as

$$P_i = \nabla_i f(Q_1, Q_2), \quad i = 1, 2 \ ,$$

where f is arbitrary function and (P_i, Q_i) are some canonical coordinates of CP_2, is vacuum extremal of Kähler action. For these vacuum extremals the signature of the induced metric can be either Minkowskian or Euclidian. There are also vacuum extremals with Euclidian signature of the induced metric. The so called CP_2 type extremals are vacuum extremals having light like random curve as light cone projection. These extremals are isometric with CP_2 so that the signature of the induced metric is Euclidian. These extremals provide a model for elementary particle.

Only the non-vacuum deformations of the vacuum extremals are physical. The remnants of the huge vacuum non-determinism are expected to give rise to the non-determinism required by symbolic representations of conscious experience at the level of space-time dynamics giving rise to language as a special case. Of course, classical nondeterminism of the Kähler action might also relate to the nondeterminism of volition although it seems that p-adic-to-real phase transitions are responsible for the transformation of intentions to actions. It seems that the CP_2 type extremals representing cognitive neutrino pairs are crucial for our cognitive consciousness and its transformation to symbolic representations.

Mind-like space-time sheets as deformations of vacuum extremals

The original proposal that mind-like space-time sheets and matter-like space-time sheets differ in the sense that the first ones are non-deterministic and consist of a collection of 3-surfaces with time-like separations whereas the latter are deterministic or at least have infinite size in time direction by standard conservation laws. In zero energy ontology mind-likeness in this sense holds true quite generally.

Physical intuition suggests that the gluing vacuum extremals to a material space-time sheet $X^3(Y^3)$ by # (topological sum) contacts, an interaction results and deforms vacuum extremal slightly and that in some cases this leads to a new preferred extremal with a slightly larger value of Kähler function and hence a larger value of the vacuum functional making the 3-surface more probable. These deformed vacuum extremals are expected to be still non-deterministic although the non-determinism should be reduced considerably. Via their interactions with the environment, (mind-like) space-time sheets provide sensory and symbolic representations for some aspects of the surrounding world. Hence they are quite generally natural geometric counterparts of selves. For instance, the time evolution of our body would correspond to this kind of deformed vacuum space-time sheet with a finite time duration.

The space-time surfaces $X_i^4(Y^3)$ are expected to be very nearly identical outside the time-interval characterizing the size of the mind like space-time sheet: this in turn implies time localization for the non-determinism of quantum jump and therefore for the contents of conscious experiences associated with the mind like space-time sheet.

In zero energy ontology mind-like space-times sheets correspond to a collection of 3-surfaces belonging to boundaries of causal diamond (CD) and its sub-CDs corresponding to the classical correlate for radiative corrections. Generalized causality makes it possible to avoid paradoxical situation: assuming that space-time surface $X^4(Y^3)$ is preferred extremal of the Kähler action for Y^3 one might always find a new 4-surface giving rise to a smaller Kähler action by gluing suitable vacuum extremal to $X^4(Y^3)$.

Massless extremals as quantum gravitational holograms

Massless extremals (MEs) belong to the fundamental solutions of field equations. It has become also clear that they play the role of quantum gravitational holograms. The hologram principle of quantum gravitational theories roughly states that the quantum theory in space-time with boundary reduces to a conformal quantum field theory at the boundary. If Kähler action were deterministic, precisely this would happen. The construction of configuration space geometry relies crucially on the assumption that the complications due to the non-determinism of Kähler action does not radically modify the construction based on the assumption of a complete determinism.

It has indeed turned out that the basic construction in which everything reduces to the light like boundary of M_+^4 (moment of big bang) acting as a hologram in quantum gravitational sense and defining conformal quantum theory, generalizes. This construction survives as a template in a more general construction in which also the light like boundaries of MEs having always light like M_+^4 projection are taken into account besides δM_+^4 as surfaces at which initial values can be fixed arbitrarily. This brings in also time absent in a strictly deterministic theory. Thus the quantum gravitational hologram defined by δM_+^4 is replaced by a fractal structure formed by δM_+^4 and Russian doll hierarchy of the light like boundaries of MEs inside MEs. The super-canonical and super-conformal invariances of the light like boundaries indeed generalize in an elegant manner thanks to the basic properties of MEs.

There are good reasons to expect that the light like selves defined by the boundaries of MEs are fundamental in TGD inspired theory of consciousness. The super-canonical quantum states associated with these boundaries are genuine quantum gravitational states defined by configuration space functionals, whose dependence on the bosonic fiber degrees of freedom of the configuration space does not reduce to a mere vacuum functional given by the exponent of Kähler action. This means that these states do not possess any quantum field theoretic counterparts. They are state functionals in the world of worlds, so to say, and therefore should represent highest level in the hierarchy of quantum control in living systems. Thus it is the higher abstraction level of quantum gravitational states which connects conscious intelligence and quantum gravitation.

6.2.4   Two times

The notion of quantum jump implies a new view about time. Experienced/subjective time corresponds to a sequence of sub-quantum jumps and cannot be identified with the geometric time defined as the fourth space-time coordinate. This is of course obvious for anyone: consider only the reversibility of geometric time contra irreversibility of experienced time, and the fact that both geometric past and future exist whereas only subjective past exists. The fact that the contents of conscious experience is about 4-D rather than 3-D space-time region, motivates the notions of 4-D brain, body, and even society. In particular, conscious existence continues after biological death since 4-D body and brain continue to exist.

6.2.5   About the arrow of psychological time

Quantum classical correspondence predicts that the arrow of subjective time is somehow mapped to that for the geometric time. The detailed mechanism for how the arrow of psychological time emerges has however remained open. Also the notion of self is problematic.

Two earlier views about how the arrow of psychological time emerges

The basic question how the arrow of subjective time is mapped to that of geometric time. The common assumption of all models is that quantum jump sequence corresponds to evolution and that by quantum classical correspondence this evolution must have a correlate at space-time level so that each quantum jump replaces typical space-time surface with a more evolved one.

1. The earliest model assumes that the space-time sheet assignable to observer ("self") drifts along a larger space-time sheet towards geometric future quantum jump by quantum jump: this is like driving car in a landscape but in the direction of geometric time and seeing the changing landscape. There are several objections.

   i) Why this drifting?

   ii) If one has a large number of space-time sheets (the number is actually infinite) as one has in the hierarchy the drifting velocity of the smallest space-time sheet with respect to the largest one can be arbitrarily large (infinite).

   iii) It is alarming that the evolution of the background space-time sheet by quantum jumps, which must be the quintessence of quantum classical correspondence, is not needed at all in the model.

2. Second model relies on the idea that intentional action -understood as p-adic-to-real phase transition for space-time sheets and generating zero energy states and corresponding real space-time sheets - proceeds as a kind of wave front towards geometric future quantum jump by quantum jump. Also sensory input would be concentrated on this kind of wave front. The difficult problem is to understand why the contents of sensory input and intentional action are localized so strongly to this wave front and rather than coming from entire life cycle.

 There are also other models but these two are the ones which represent basic types for them.

The third option

The third explanation for the arrow of psychological time - which I have considered earlier but only half-seriously - looks to me the most elegant at this moment. This option is actually favored by Occam's razor since it uses only the assumption that space-time sheets are replaced by more evolved ones in each quantum jump. Also the model of tqc favors it.

1. In standard picture the attention would gradually shift towards geometric future and space-time in 4-D sense would remain fixed. Now however the fact that quantum state is quantum superposition of space-time surfaces allows to assume that the attention of the conscious observer is directed to a fixed volume of 8-D imbedding space. Quantum classical correspondence is achieved if the evolution in a reasonable approximation means shifting of the space-time sheets and corresponding field patterns backwards backwards in geometric time by some amount per quantum jump so that the perceiver finds the geometric future in 4-D sense to enter to the perceptive field. This makes sense since the shift with respect to M^4 time coordinate is an exact symmetry of extremals of Kähler action. It is also an excellent approximate symmetry for the preferred extremals of Kähler action and thus for maxima of Kähler function spoiled only by the presence of light-cone boundaries. This shift occurs for both the space-time sheet that perceiver identifies itself and perceived space-time sheet representing external world: both perceiver and percept change.

2. Both the landscape and observer space-time sheet remain in the same position in imbedding space but both are modified by this shift in each quantum jump. The perceiver experiences this as a motion in 4-D landscape. Perceiver (Mohammed) would not drift to the geometric future (the mountain) but geometric future (the mountain) would effectively come to the perceiver (Mohammed)!

3. There is an obvious analogy with Turing machine: what is however new is that the tape effectively comes from the geometric future and Turing machine can modify the entire incoming tape by intentional action. This analogy might be more than accidental and could provide a model for

quantum Turing machine operating in TGD Universe. This Turing machine would be able to change its own program as a whole by using the outcomes of the computation already performed.

4. The concentration of the sensory input and the effects of conscious motor action to a narrow interval of time (.1 seconds typically, secondary p-adic time scale associated with the largest Mersenne M_{127} defining p-adic length scale which is not completely super-astronomical) can be understood as a concentration of sensory/motor attention to an interval with this duration: the space-time sheet representing sensory "me" would have this temporal length and "me" definitely corresponds to a zero energy state.

5. The fractal view about topological quantum computation strongly suggests an ensemble of almost copies of sensory "me" scattered along my entire life cycle and each of them experiencing my life as a separate almost copy.

6. The model of geometric and subjective memories would not be modified in an essential manner: memories would result when "me" is connected with my almost copy in the geometric past by braid strands or massless extremals (MEs) or their combinations (ME parallel to magnetic flux tube is the analog of Alfwen wave in TGD).

This argument leaves many questions open. What is the precise definition for the volume of attention? Is the attention of self doomed to be directed to a fixed volume or can quantum jumps change the volume of attention? What distinguishes between geometric future and past as far as contents of conscious experience are considered? How this picture relates to p-adic and dark matter hierarchies? Does this framework allow to formulate more precisely the notion of self? Zero energy ontology allows to give tentative answers to these questions.

6.2.6   What really distinguishes between future and past?

Our knowledge about geometric future is very uncertain as compared to that about geometric past. Hence we usually use words like plan/hunch/hope/... in the case of geometric future and speak about memories in the case of geometric past. We also regard geometric past as something absolutely stable. Why we cannot remember geometric future as reliably as the geometric past? Is it that geometric future is highly unstable as compared to the geometric past? Why this should be the case? This provides a possible TGD based articulation for the basic puzzles relating to time experience. These questions have been already discussed in this chapter but I want to close the chapter with considerations inspired by the latest progress in the understanding of quantum TGD.

Is p-adic-to-real phase transition enough?

The basic idea is that the flow of subjective time corresponds to a phase transition front representing a transformation of intentions to actions and propagating towards the geometric future quantum jump by quantum jump. All quantum states have vanishing total quantum numbers in zero energy ontology which now forms the basis of quantum TGD [22] and this ontology allows to imagine models for what could happen in this process.

This starting point is the interpretation of fermions as correlates for cognition bosons as correlates for intentions/actions [23]. Fermions correspond to pairs of real and p-adic space-time sheets with opposite quantum numbers with p-adic space-time sheet providing a cognitive representation of the real space-time sheet. Bosonic space-time sheets would be either p-adic or real and thus represent intentions or actions. Fermionic world and its cognitive representations would be common to future and geometric past and the asymmetry would relate only to the intention-action dichotomy.

Geometric future contains a lot of p-adic space-time sheets representing intentions which transform to real space-time sheets allowing interpretation as desires inducing eventually neuronal activities. Time mirror mechanism for intentional action assumes that the phase transition gives rise to negative energy space-time sheets representing propagation of signals to geometric past where they induce neuronal activities. From Libet's experiments relating to neuronal correlates of volition the time scale involved is a fraction of second but an infinite hierarchy of time scales is implied by fractality.

Conservation of quantum numbers poses strong conditions on p-adic-to-real phase transition. Noether charges are in the real context given by integrals over partonic 2-surfaces. The problem is that these integrals do not make sense p-adically. There are two options.

1. Give up the notion of p-adic Noether charge so that it would not make sense to speak about four-momentum and other conserved quantum numbers in case of p-adic space-time sheet. This implies zero energy ontology in the real sector. All real space-time sheets would have vanishing conserved quantum numbers and p-adic-to real transition generates real space-time sheet complex with vanishing total energy. Negative energy signal must be somehow compensated by a positive energy state.

2. It might be however possible to assign charges to p-adic space-time sheets. The equations characterizing p-adic space-time sheet representing intention and corresponding real space-time sheet representing action are assumed to be given in terms of same rational functions with coefficients which are algebraic numbers consistent with the extension of p-adic numbers used so that the points common to real and p-adic space-time sheets are in this extension. If real charges belong to the algebraic extension used, one could identify the p-adic charges as real charges. Zero energy ontology requires the presence of positive energy real space-time sheets whose charges compensate those of negative energy space-time sheets. One possibility is that real and corresponding p-adic space-time sheets appear in pairs with vanishing total quantum numbers just as fermionic space-time sheets are assumed to occur [23]. In the case of fermions p-adic-to-real phase transition is impossible by Exclusion Principle so that a stable cognitive representation results.

The minimal option would be that p-adic space-time sheets possess negative energy and are transformed to negative energy signals inducing neuronal activities. The flow of subjective time would involve a transformation of the universe to zero energy universe in the sense that total conserved quantum numbers vanish in the real sense in bosonic sector but in fermionic sector real and p-adic charges compensate each other.

This picture is probably too simple. Robertson-Walker cosmology has vanishing density of inertial energy. Hence it would seem that real bosons and fermions should appear in both positive and negative energy states and the arrow of time defined by the direction of the propagation of the intention-to-action wave front would be local.

The transition of the geometric past back to intentional phase would involve transformation of real bosons to p-adic ones and is in principle possible for this option. For the first option the transition could occur only for real states with vanishing total quantum numbers which would make this transition highly improbable and thus imply irreversibility.

The basic criticism is that since intentions in the proposed sense do not involve any selection, one could argue that this picture is not enough to explain the instability of the geometric future unless the instability is due to the instability of p-adic space-time sheets in quantum jumps.

Does intentional action transform quantum critical phase to non-quantum critical phase?

It is far from clear whether the proposed model is not able to explain the uncertainty of the geometric future and relative stability of the geometric past related very intimately to the possibility to select between different options. TGD based view about dark matter as a hierarchy of phases characterized by M^4 and CP_2 Planck constants quantized in integer multiples of minimum value $\hbar_0$ of $\hbar$ [17] suggests a more refined view about what happens in the quantum jump transforming intention to action.

1. The geometric future of the living system corresponds to a quantum critical state which is a superposition of (at least) two phases. Quantum criticality means that future is very uncertain and universe can be in dramatically different macroscopic quantum states.

2. Experienced flow of time corresponds to a phase transition front proceeding towards the geometric future quantum jump by quantum jump. In this transition intentional action represented by negative energy bosonic signals transforms the quantum critical phase to either of the two phases present. This selection between different phases would be the basic element of actions involving choice. The geometric past is stabilized so that geometric memories about geometric past are relatively stable. This picture applies always in some time scale and there is an entire hierarchy of time and spatial scales corresponding to the hierarchies of p-adic length scales and of Planck constants. Note that Compton length and time are proportional to $\hbar$ as is also the span of long term memories and time scale of planned actions.

The (at least) two phases present at quantum criticality would have different values of Planck constants. In the simplest case the values of M^4 and CP_2 Planck constants for the second phase would correspond to the minimal value $\hbar_0$ of Planck constants. For instance, cell could be in quantum superposition of ordinary and high T_c super-conducting phase, with high T_c superconductor characterized by a large M^4 Planck constant.

Intentional action would induce a transition to either of these two phases. Sub-system would chose either the lower or higher level in the hierarchy of consciousness with level characterized by the values of Planck constants. This unavoidably brings in mind a moral choice. Intentional actions involve often a choice between good and bad and this choice could reduce to a choice between values of Planck constant. Good deed would lead to higher value of Planck constant and bad deed to a lower one. This interpretation conforms with the earlier view about quantum ethics stating that good deeds are those which support evolution. The earlier proposal was however based on the assumption that evolution means a gradual increase of a typical p-adic length scale and seems to be too restricted in the recent framework.

For instance, in cell length scale the cells of the geometric future could be in quantum critical phase such that large $\hbar$ phase corresponds to high T_c super-conductivity and low $\hbar$ phase to its absence. In quantum jump cell would transform to either of these phases. The natural interpretation for the transition to low $\hbar$ phase is as cell death since the communications of the cell to and quantum control by the magnetic body are lost. Ageing could be seen as a process in which the transitions to small $\hbar$ phase begin to dominate or even the quantum criticality is lost. A model for the quantum criticality based on zeros of Riemann zeta developed in [23, 21, 29] allows a more quantitative view about what could happen in the phase transition.

6.2.7 Memory and time

Do declarative memories and intentional action involve communications with geometric past?

Communications with geometric past using time mirror mechanism in which phase conjugate photons propagating to the geometric past are reflected back as ordinary photons (typically dark photons with energies above thermal threshold) make possible realization of declarative memories in the brain of the geometric past [25].

This mechanism makes also possible realization of intentional actions as a process proceeding from longer to shorter time scales and inducing the desired action already in geometric past. This kind of realization would make living systems extremely flexible and able to react instantaneously to the changes in the environment. This model explains Libet's puzzling finding that neural activity seems to precede volition [78].

Also a mechanism of remote metabolism ("quantum credit card") based on sending of negative energy signals to geometric past becomes possible [28]: this signal could also serve as a mere control signal inducing much larger positive energy flow from the geometric past. For instance, population inverted system in the geometric past could allow this kind of mechanism. Remote metabolism could also have technological implications.

Episodal memories as time-like entanglement

Time-like entanglement explains episodal memories as sharing of mental images with the brain of geometric past [25]. An essential element is the notion of magnetic body which serves as an intentional agent "looking" the brain of geometric past by allowing phase conjugate dark photons with negative energies to reflect from it as ordinary photons. The findings of Libet about time delays related to the passive aspects of consciousness [49] support the view that the part of the magnetic body corresponding to EEG time scale has same size scale as Earth's magnetosphere. The unavoidable conclusion would be that our field/magnetic bodies contain layers with astrophysical sizes.

p-Adic length scale hierarchy and number theoretically preferred hierarchy of values of Planck constants, when combined with the condition that the frequencies f of photons involved with the communications in time scale T satisfy the condition $f \sim 1/T$ and have energies above thermal energy, lead to rather stringent predictions for the time scales of long term memory. The model for the hierarchy of EEGs relies on the assumption that these time scales come as powers $n = 2^{11k}$,

$k = 0, 1, 2,,$ and predicts that the time scale corresponding to the duration of human life cycle is ~ 50 years and corresponds to $k = 7$ (amusingly, this corresponds to the highest level in chakra hierarchy).

6.2.8   Cosmology of consciousness

Cosmology of consciousness scenario is inspired by the notion of infinite self hierarchy and by the quantum-classical correspondence principle stating that the fractal structure of the many-sheeted space-time should directly reflect the general structure for the cosmology of consciousness. For instance, the p-adic evolution of consciousness should have its counterpart at space-time level: indeed, there are good reasons to believe that 4-surfaces have decomposition into regions obeying real or finite-p p-adic topology just like configuration space has decomposition into real regions and regions D_P labelled by infinite primes characterizing the appropriate functions space topology. Fractality suggests that there are conscious universes within conscious universes and that the experiences of universes involve kind of abstractions about the experiences of the sub-universes they contain. Summation hypothesis for the experiences of selves indeed states just this.

Each self corresponds geometrically to its own subset of mind like and matter like space-time sheets, separate conscious cosmology. Mind like space-time sheets are bounded in time direction: the sheet of 3-space is born when a tiny energy flows into the sheet from some larger sheet and dies when this energy flows back to the larger background sheet. p-Adic length scale L_p gives a first guess for the typical duration $T_p = L_p/c$ of the space-time sheet. Even human body could correspond to mind like space-time sheet: time duration would be of order of lifetime. Note however that the visible body might be only dip of iceberg, and it indeed seems that our magnetic body could have size for which light life is natural unit of size. Since selves contain sub-selves with various values of psychological time, the experiences are actually multi-time experiences with respect to both geometric and subjective time. The most natural identification of the psychological time is kind of center of mass coordinate associated with the sensory selves.

If quantum entanglement in the direction of time is a relatively rare phenomenon (it is completely absent in standard theories), entangled mind like space-time sheets correspond to nearly the same value of time so that our conscious experience gets dominant contribution from time values around the mean value of the time coordinate for our space-time sheet of finite duration. Entanglement in time direction gives rise to multi-snapshot experiences which would resemble vivid long term memories. The interpretation as genuine memories is however not correct. Rather, multi-time experiences with contents coming from geometric past and recent are in question.

The conclusion would be that the entire 4-dimensional space-time is a living system in TGD universe: both the geometric future and past are living and participate in each moment of consciousness. Each moment of consciousness decomposes into infinite number of sub-moments of consciousness of selves in the self hierarchy with the values of psychological time varying from zero to infinity. The value of our own psychological time of roughly 10^{11} years is just an accident. Entire civilizations can live in different geometric times without knowing anything about each other unless they happen to have entanglement in time direction. If they have, the resulting experiences could be interpreted as memories, dreams, religious or mystic experiences or simply as hallucinations. The inhabitants of sufficiently but not sufficiently advanced sub-cosmologies tend to believe that they are the only conscious beings in the Universe, construct their own cosmology and try desperately to understand why the value of cosmological time happens to be what it is and, to certain degree quite correctly, conclude that Anthropic Principle is the only explanation.

The civilizations of past could still exist and participate to each quantum jump. Also the civilizations of future coexist consciously with us. The hierarchy of selves implies that selves have increasingly longer geometric and subjective memories. The hypothesis about infinite primes implies a hierarchy of literally infinite values of psychological time and God like conscious beings with infinitely long geometric and subjective memories is possible if infinite primes. At the top of the hierarchy is the entire universe having infinitely long geometric and subjective memories and integrating all experiences at the lower levels of the hierarchy in single abstracted experience. Note that this picture gives hopes to understand how universe is able to construct theory about itself. Notice also that any theory of consciousness should be able to predict its own discovery and the infinite hierarchy of selves gives good hopes in this respect.

One can represent an objection against this picture. p-Adic-to-real phase-transition front should be common to the entire biosphere at our level of self hierarchy at least. It is not clear in what

time scale this is true and whether the geometric past can generate intentions which can effectively re-create the geometric past. If p-adic-to-real phase transition occurs in entire cosmology then one could say that there is universal psychological time. A concrete model for p-adic cognition at neuronal level however suggests that there is no deep reason to assume that psychological time would be more than local. The paradoxes related to the transformation of intentions to actions in the geometric past are avoided if the effects of this nondeterminism are bounded to a time scale not longer than p-adic length scale. This would also conform with the hypothesis that the second law of thermodynamics holds true only in time scales longer than the p-adic length scale characterizing the space-time sheet in question.

6.2.9 Communications in four-dimensional society

The idea about four-dimensional society makes sense only if communication between members of this society is possible. It would be even better if communication could occur in "real subjective time". This seems to be possible in principle as the following arguments show.

Communication method

A simple model for real time communication between societies of the geometric future and past is based on the possibility of space-time sheets of negative time orientation having negative energy density. It seems natural to assume that at least classical signals propagate from geometric future to geometric past along these space-time sheets. As suggested in [19, 32] "massless extremals" could make possible coherent motion of living systems. It seems that they could make possible also "real subjective time" communications in four-dimensional society.

1. Signals to the geometric future propagate along space-time sheets of positive time orientation. These space-time sheets can correspond to ordinary material space-time sheets but also almost vacuum space-time sheets can be considered. In particular, so called "massless extremals" [32] are possible.

2. Signals to the geometric past propagate along space-time sheets of negative time orientation. Negative energy massless extremals are the optimal choice as far as classical communication is involved. The reason is that signal propagates with maximal signal velocity and consists of Fourier components with same momentum direction so that the shape of pulse is preserved. Polarization direction at a given point of the massless extremal is constant and depends on the transversal coordinates only. Solution involves two arbitrary functions and linear superposition of parallel Fourier components with identical polarization directions is possible. Therefore all possible pulse shapes are possible.

3. What happens in the communication is following. Sender performs quantum jump in which massless extremal of positive/negative energy is generated representing signal propagating to geometric future/past. Some standardized alphabet formed by the pulse forms for massless extremals: two basic pulse shapes identifiable as binary digits is the simplest choice. Receiver interacts with the massless extremal purely classically to receive the message and generates a massless extremal propagating to geometric past/future as a reply. The difference between sender and receiver is that sender performs quantum jump whereas receiver just acts purely classically to receive the message.

4. The communication is on-line "real subjective time" communication. There is no need to wait for next billion years for reply and members of cultures separated by billions of light years can have real time chat about their family problems! Also communication with effective signal velocity larger than light velocity becomes possible by using a 'radio mast' in the geometric future able to send past-directed signals: the mast receives a signal from the geometric past and sends it to the second receiver in the geometric past.

Anomalies related to spinning astrophysical objects as empirical support for the idea

The proposed communication method could be regarded as mere wild science fiction unless there were some empirical support for the possibility of communication from geometric future to geometric past.

In the articles [38, 37] various anomalies related to spinning objects are reviewed. These anomalies are discussed in [16]. There are also anomalies related to spining astrophysical objects. Kozyrev [41] has conducted astronomical observations using a receiving system of a new type. These observations have been replicated later by other groups [40, 43]. These anomalies give also support for the possibility of the signal propagation backwards in time.

1. When a telescope was directed at a certain star, the detector positioned within the telescope registered the incoming signal even if the main mirror of the telescope was shieded by metal screens. This indicated that electromagnetic waves were accompanied by some waves not shielded by the metal screens.

2. When the telescope was directed to the true position, the signal became stronger. As if there had been almost instantaneous propagation of signal with velocity billions times greater than the velocity of light!

3. When the telescope was directed to a position symmetrical with respect to the visible position, again signal was detected: the imaginative interpretation was that the signal came from future position of the star!

Leaving aside the objections of a typical sceptic and the question whether the effect is real or not, one can ask whether the concepts of many-sheeted space-time concept and classical Z^0 field could somehow give rise to this kind of effect in strong conflict with the conventional wisdom.

1. Propagating photons (extremely tiny 3-surface glued to macroscopic space-time sheet) affect the space-time sheet and could generate propagating classical Z^0 field causing the effect in the detector. Of course, one cannot exclude the possibility of negative energy photons although the experimental arrangement eliminating the ordinary photons should eliminate also these.

2. The strong signal from the true position could have explanation in terms of a coherent classical Z^0 field of astronomical size. This kind of coherence is forced by the imbeddability requirement and was coined as topological field quantization in [18]. One can intuitively understand it as follows. In TGD elementary particle is replaced with 3-surface, which can have arbitrarily large size and absolution minimization of Kähler action forces 3-surface to behave coherently like single particle (in case that it does not so, it decomposes into disjoint components!). The results of Kozyrev are not the only evidence for this kind of behavior. Total eclipses of the Sun by the Moon reach maximum eclipse about 40 seconds before Sun's and Moon's gravitational forces on Earth align [39]. If gravity is a propagating force, this 3-body test implies that gravity propagates at least 20 times faster than light. The result is consistent with the assumption that the acceleration of Earth is towards the true instanteous direction of the Sun now, rather than being parallel to the direction of the arriving solar photons now. The TGD based explanation is that the changes of the classical gravitational field are not propagating effects but that the classical gravitational field behaves like single coherent whole (it could of course contain also small propagating part).

3. The signal in the symmetric position could indeed come from geometric future. An attractive possibility is that classical Z^0 field propagated along space-time sheet with negative time orientation: for negative time orientation the propagation is expected to occur backwards in time.

There are also reports about the anomalies related to rotated magnetic systems in laboratory scale and these effects are under intensive study (for instance in Faraday Lab in Russia). The TGD based explanation of the anomalies reported in [54] is developed in [16]. The model involves in an essential manner the generation of both negative energy space-time sheets and many particle states with negative single particle energies residing at these sheets and some of the observed strange effects involved support the generation of the negative energy particles. The model allows to seriously consider the possibility that even ordinary ions and atoms could have negative energy counterparts.

6.3   Four-dimensional brain

The paradigm of 4-dimensional brain is the most important consequence of the Grand Scenario. The non-determinism of the Kähler action (non-determinism is understood here in the conventional sense of the word) is the quintessential, purely TGD based element of the Grand Scenario: without there would not be any evolution, the contents of conscious experience would be diffused around entire quantum histories and there would be no systems with strongly time-localized contents of consciousness. A second key element is p-adic nondeterminism making possible intentionality and cognition.

6.3.1   The paradigm of four-dimensional brain

The cosmology of consciousness implies that each conscious experience decomposes into separate sub-experiences with the values of the psychological time varying from zero to infinity. Furthermore, the experiences are in general multitime experiences both with respect to both geometric and sub-jective time. This picture forces the paradigm of 4-dimensional brain having profound consequences concerning the understanding of the brain functioning.

The difficult problems related to the understanding of conscious memory recall could trivialize. No separate mechanisms of memory storage or retrieval are needed and the difficult problems related to the interpretation of the stored memories are circumvented. There are two basic types of memories: geometric and subjective memories. Geometric memories provide as simulation for what happened and will happen provided no quantum jumps occur and has occurred and subjective memories tell what actually occurred. Actual memories are indeed known to be creative reconstructions of past and hence it seems that geometric memories are an essential part of construction. The comparison of expectations and actuality made possible by the two memory types gives rise to the emotions involving comparison aspect.

Subjective memory corresponds to immediate short term memory and the only possible identification of the *genuine* long term memories is as subjective memories at the higher level of self hierarchy, where the time span of subjective memory is longer. One possibility is periodic wake-up of sub-selves representing mental images and giving in this manner rise to long term memories: this requires some kind of periodic neural activity giving rise to the same sub-self periodically. Of course, it is not at all obvious whether long term memories are genuine! It is indeed known that long term memories are a result of a creative process and are not reliable. This would suggest that long term memories are actually geometric memories and are reasonably reliable because our geometric past is rather stable under quantum jumping. Of course, we do not usually test the reliability of our long term memories but take them as granted. The notion of mind like space-time sheet allows multitime experiences containing simultaneous contributions from both geometric present and past and the memories of, say, childhood could be genuine multitime experiences.

The "averaging" associated with the subjective memory implies that volition cannot correspond to the quantum jump occurring in the measurement of the density matrix. Rather, volitional activities must correspond to a localization in zero modes, most naturally selections between degenerate maxima of Kähler function. Besides volition associated with the motor activities, also the focusing of attention and even the selection of premises of logical thought very probably involve this kind of selection. The most probable function of the motor nerve pulses is the generation of multi-furcations in an initial value sensitive system between which the choice occurs. Various motor programs correspond to various branches of the multi-furcation. Just as sensory experience, motor activity is predicted to be a top-down self cascade of quantum jumps starting from the level of the entire body. Each selection of the space-time branch creates self inside which subsystems perform quantum jumps as long as self is awake and these quantum jumps in turn lead to even smaller sub-selves: in this manner a precise and flexible coordination and control of the movement involving volition at all length scales becomes possible whereas in the standard neuroscience picture body would act like a robot with fixed motor programs.

6.3.2   Geometric and subjective memories

TGD predicts two kinds of memories corresponding to two different time developments. There is deterministic (in generalized sense) geometric time development and the non-deterministic subjective

time development by quantum jumps. The memories with respect to subjective time are about previous conscious experiences and "real" whereas geometric "memories" are prophecies giving simulation of geometric past and future assuming that quantum jumps do not alter the macroscopic properties of the space-time surface.

A good visualization is following: each quantum jump represents particular geometric memory whereas the heap of these memories gives rise to subjective memory. The comparison between expectations and reality is obviously a central part of mentality and the heap structure of conscious experience implies that this comparison is a basic function of conscious mind not reducible to anything simpler. It is wellknown that our memories involve a lot of construction and are more like stories consistent with what we actually have experienced than actual documents of what happened. This suggests that geometric memories, possibly constrainted by subjective memories, give rise to the "story" about past.

6.3.3   Memories with respect to geometric time as simulations

Geometric memories are about both future and past and are predictions/simulations for what would happen if no further quantum jumps would occur and what would have happened if no quantum jumps had occurred in past. Geometric memories are also about past: we continually make guesses about the sequences of events which could have led to some event and this is nothing but predicting the geometric past. Of course, geometric memories are simulations rather than real memories. Geometric "memories" are real in the classical limit, when the effect of quantum jumps becomes negligible. In classical physics geometric memory is all that is needed to make predictions of past and future. We can indeed predict rather reliably what will happen in the solar system during the next decade. Also the computational approach to mind assumes only geometric memories. p-Adic geometric memories about future give rise to intentionality often regarded as a basic characteristic of conscious mind: beliefs, expectations, plans, etc. can be understood in terms of the p-adic geometric memory of future.

Intentionality manifests itself in many ways: as expectations of future, planning, goals, desires, fears, imagination, disappointments, etc.. The basic element of mentality is the comparison between the expectations of future and what actually occurred. In TGD framework this tension between potential and actual can be understood. The temporal extension of the mind like space-time sheet makes possible expectations of what happens in the future assuming that no quantum jumps occur or at least that quantum jumps do not change the macroscopic space-time. Single quantum jump contains information about this kind of expectations. Subjective memory in turn tells what happened actually. Therefore it seems natural, and this is the only possibility given the fact that it is not possible to know anything about future quantum jumps, to assume that all aspects of intentionality are made possible the predictions of the expected geometric future and past provided by the mind like space-time sheest.

What is nice is that subjective memory makes it possible to compare the expectations with what really occurred since subjective memory is kind of heap of predictions of future arranged with respect to the value of the psychological time. The origin of at least some emotions, which often involve a comparison of what happened and what was expected to happen, is perhaps here. It is quite well possible that all comparisons must be realized as comparisons of the subjective and geometric time developments (it could be that self is also able to compare its sub-selves).

The possibility of this comparison perhaps provides a solution to the paradox raised by the innocent question "How do I know that the me of today is the same as the me of the yesterday? How do I even know that I existed yesterday?". The solution might be simple: mind like space-time sheets have extension which can be much longer than the duration of the subjective memory. Therefore subjective memories contain information about the geometric me of the yesterday and geometric me of today and since these me's resemble each other quite a lot, the conclusion is that also the yesterday's me was a conscious self living in this same body. It is however quite possible that temporal entanglement with higher selves still remembering my past wake-up states is also involved and realized as a formation of join along boundaries bonds between the mind like space-time sheets of my self and of higher level self. Higher level self could also communicate directly the subjective memories about my existence to me.

6.3.4   Are long term memories geometric or subjective memories?

The answer to the question whether long term memories are geometric memories and thus only simulations or genuine subjective memories of higher level self somehow communicated to us, is not obvious.

Long term memories as geometric memories?

Geometric memories realized as multitime experiences involving mind like space-time sheets located around several moments of the geometric time, provide the simplest realization for the long term memories.

1. The model solves the basic difficulties of the neural net models of long term memory. In the neural net models long term memories are represented by synaptic strengths. The problem is that the learning of new memories destroys old memories. In particular, the stability of the childhood memories is difficult to understand. It is also hard to understand how brain knows that the experience represents memory. One cannot avoid the difficulty by saying that novelty detection tells that experience occurs for the first time since the notion of novelty does not make sense if conscious experience contains only information from single moment of geometric time.

2. TGD model is consistent with neural net models and actually generalizes them. Neural net in the spirit of TGD corresponds to brain as system moving in spin glass energy landscape. Self-organization by quantum jumps leads the system to a bottom of an energy valley representing memory. This model is consistent with the fact that there is no upper bound for autobiographical memory. One can also understand how learning occurs. The repetition of an experience means that energy valley becomes a canyon in time direction so that mind like space-time sheets in the geometric past have a large probability to end up to the region representing memory. In particular, reverberating nerve pulse patterns are ideal for representing cognitive long term memories.

3. Highly emotional experiences generate deep valleys and increase the probability of the system of the geometric past to stay at the bottom of valley. This explains why cildhood experiences are so stable. In fact, one could identify primitive emotions of pleasure and pain as related to the motion in the spin glass energy landscape. Pleasure and pain could even directly correlate with the sign of the increment of the Kähler function in the hopping motion in the spin glass energy landscape. Note that primitive pleasure and pain are are very much like sensory experiences and one could regard them as sensory experiences of brain about its own motion in spin glass energy landscape. This leads to the generalization of the notions of sensory experience and motor action to include the motion in spin glass energy landscape and to a considerably new insight about the meaning of the brain architecture.

There are also perinatal experiences, memories about previous lives and transpersonal experiences having natural explanation in terms of geometric memory realized as multitime experiences associated with mind like space-time sheets located at different values of the geometric time.

Transpersonal experiences suggests that self is dynamical: if prenatal experiences, memories about previous lives and transpersonal experiences are really what they seem to be, the geometric time extension of self should dramatically increase during these experiences.

Long term memories as subjective memories of higher level self?

The natural identification of the immediate short term memory as subjective memory predicts that the life time of a human sensory self cannot be much longer than .1 seconds, the duration of psychological moment of time. Our long term memories correspond to much longer time interval and cannot thus correspond to our subjective memories. Entire hierarchy of subjective memories is however predicted and a possible model for *genuine* long term memories (whose existence is questionable) is as resulting from temporary entanglement with selves belonging to the higher level of the hierarchy. Also this identification is consistent with the fact that there seems to be no upper bound on autobiographical memory.

Quantum-classical correspondence principle suggests that entanglement could correspond geometrically to temporary join along boundaries bonds between the mind like space-time sheets of self and higher level self. Summation hypothesis implies that our genuine long term memories would be sums over a large number of wake-up periods of self in the subjective past of the self. Therefore one could perhaps understand how ageing self gains gradually wisdom from experience: also the identification of the long term memories as geometric memories explains this. It would seem that our self must be able to shift the hierarchy level in order to remember details on one hand and to form abstractions on the other hand and that the detailed memories about the wake-up periods of self are unavoidably lost.

There are however serious counter arguments against this identification.

1. It is not at all clear why the experiences of the higher level selves during entangled state could be ours! For instance, during sleep without dreams entanglement with some higher level self should occur and we do not remember anything about this. Trance is a second example of this: subject person does not remember anything about the trance state.

2. The averaging involved with the temporal binding means that the subjective memories of the higher level selves cannot possess the details of our long term memories.

3. It is not obvious how to understand learning and the role of emotions in learning.

The entanglement with the higher level self is not necessary to have genuine long term memories. One could consider also the possibility that higher level self could somehow communicate the long term memories to the lower level selves. One function of sleep might be the generation of the entanglement with higher selves making in turn possible the communication of genuine memories of subjective past to our mind. This communication could realize these memories as thoughts about the experiences of past realized as nerve pulse patterns regenerating these thoughts. The lack of a precise realization of this mechanism makes the realization of the long term memories as geometric memories much more attractive option.

Long term memories as a communication between now and geometric past

The basic challenge is to identify concrete mechanisms of long term memory recall. According to the idea of magnetic sensory canvas discussed in [32], the positions of objects of perceptive field are coded by the frequency scale of the magnetic transitions occurring at the magnetic flux tube structures having size of wave lengths associated with EEG frequencies. The slowly varying thickness of the magnetic flux tube codes for the position of the object of the perceptive field.

This encourages to consider the possibility that also the temporal position of the object of perceptive field could be coded in this manner. There are however two difficulties involved:

1. Since the time scales are of order life time T, the needed frequency resolution is $\Delta f/f \sim \Delta T/T$, if the time resolution is ΔT. This requires frequency resolutions of order $\Delta f/f \sim 10^{-8}$ at least and this kind of resolution is certainly not achievable in the neuronal circuits.

2. If ELF MEs (massless extremals) are involved it is difficult to understand how one could circumvent the fact that the ME represents geometrically a light ray escaping from the system. This ray should be reflected somewhere. Kind of mirror would be required. Magnetic flux tubes could serve as this kind of mirror and allow the radiation to travel in zigzag curve in space-time to to geometric past.

There is however a much more elegant mechanism of long term memory recall based on MEs. First, of all what makes MEs so interesting from the point of view of long term memories, is that light like selves has a temporal extension, which can be arbitrary long in given rest system. Secondly, the pairs of MEs resulting when ME reflects from some structure such as magnetic flux tube structure serving as a mirror, provide a TGD based model of long term memories relying on the idea that long term memory recall involves a 'question' sent to the geometric past as a classical signal reflected back to brain in a magnetic mirror, and a subsequent quantum entanglement in which the selves of the geometric past and now as well as ME selves entangle to single self so that the self of the geometric now can share the experience of the self of the geometric past. What is so elegant in this mechanism is that

there is no necessity of sending the information as a classical signal, only the time like entanglement is needed. In this case the MEs would have a length of order lifetime so that long term memories would be astrophysical phenomena involving magnetic flux tube structures and MEs. The temporal location T of the memory (or rather, shared conscious event) of the geometric past would be coded by the length L of ME: $L = cT/2$. The TGD based notion of time indeed allows geometric time scales of order lifetime to be involved with subjective experiences in psychological time scale of a fraction of second. Certainly this mechanism is completely out of question in standard physics.

6.4 Time delays of consciousness and quantum jumps between histories

TGD based concept of time has rather dramatic implications and it would be important to show that the new time concept indeed solves conceptual problems and anomalies. One should also device experiments to test the new time concept. Dissipation is the black sheep in the family of theoretical physics and quantum jump between quantum histories concept explains dissipation in elegant manner. Quantum jumps between quantum histories concept together with the notion of self explains also the peculiar time delays of consciousness revealed in the experiments relating to the active and passive roles of consciousness [78, 49] and described by Penrose in his book [47]. It is also possible to explain the causal anomalies revealed by the experiments of Radin and Bierman [85, 82, 56]. TGD predicts "tribar effect" as a general signature for the quantum jump between quantum histories concept.

6.4.1 Dissipation as evidence for consciousness

TGD based picture about time relies crucially on the notion that quantum jumps occur between quantum histories, objective realities. This hypothesis obviously means giving up the materialistic idea about single objective reality behind our experiences. It took quite long time to realize that our everyday experiences reveals directly the occurrence of quantum jumps between quantum histories! The phenomenon of dissipation is paradoxical from the point of view of standard physics. It is generally believed that fundamental laws of classical physics are reversible whereas everyday reality is manifestly irreversible. This leads to a rather schizophrenic situation. Two worlds, the reversible and extremely beautiful world of fundamental physics and the irreversible and the mathematically horribly ugly "real" world, seem to exist simultaneously. Quantum jumps between quantum histories concept solves the paradox and one can understand dissipative world as an effective description forming "almost" envelope for the sequence of reversible worlds (understood as entire time evolutions).

Dissipation can be also regarded as a direct evidence for the presence of the self hierarchy. One can imagine quite spectacular tests for the idea. NMP predicts that self can be in two modes of consciousness: quantum jumps reduce either matter-mind like entanglement or reduced matter+mind-matter+mind type entanglement leading to an unentangled subsystem giving rise to two new self candidates (sub-system and its complement inside self). The first mode corresponds to "whole-body" consciousness and in this mode matter-mind like dissipation in short length scales should be completely absent. The lowered dissipation should reflect itself as lowered metabolism. The measurement of cell level dissipation occurred during meditative states could provide a test for this picture. TGD explanation for the phenomenon of synesthesia [44] discussed in[33] relies on the hypothesis that left brain or considerable parts of it get quantum entangled and spends part of time in "whole-body consciousness". Indeed, synesthesia can involve lowering of left brain metabolism by as much 18 per cent [44]: this should lead to paralysis if standard wisdom about brain functioning would hold true!

6.4.2 Experiments related to the active role of consciousness

The first class of experiments [78] is related to the active role of consciousness. For example, the human subject flexes his finger at free will. What happens is that neurophysiological processes (changes in EEG) start about one second before the conscious decision to flex the finger is made. Decision seems to be followed by the action rather than the action by decision! This is in apparent accordance with the point of view that consciousness is indeed a passive spectator and the act of free will is pure illusion.

Quantum jump between histories picture explains the time delays associated with the active aspect of consciousness nicely and also gives an example of two kinds of causalities.

1. The simplest assumption is that the subjective experience of the finger flexing corresponds to the moment, when subject person experiences finger flexing occurs.

2. The new quantum history differs in detectable manner from the old quantum history already before the moment of finger flexing since otherwise the new history would contain an instantaneous and discontinuous jump from non-flexed finger to flexed finger configuration, which is not allowed by field equations. ΔT of order one second seems to be the relevant time scale. It is important to notice that the difference is at the level of classical physics rather than, say, in the form of synchronous neural firing which might involve quantum jumps of lower level selves: in TGD framework EEG activity is indeed classical phenomenon.

3. The attempt of the experimenter to be objective means that in an ideal experiment the observations correspond to the new deterministic history in the associated quantum jump and hence experimenter sees neurophysiological processes as the (apparent) cause of the finger flexing with respect to geometric time. With respect to the subjective time the cause of the finger flexing is the decision of the subject person.

4. This explanation is based on the hypothesis that volitional actions are top-down actions starting from the level of the entire body. A less radical variant of this argument is that the time associated with the conscious decision to flex the finger corresponds to a discontinuous configurational change at the level of brain: the jump from non-flexed to flexed configuration would occur at the representational level and induce continuous flexing of finger. This does not however change the core of the argument.

6.4.3   Experiments related to the passive role of consciousness

Libet's experiments [49] about the strange time delays related to the passive aspects of consciousness serve as a continual source of inspiration and headache. Every time one reads again about these experiments, one feels equally confused and must start explanations from scratch. The following explanation is based on the model of the sensory representations on the magnetic canvas outside the body and having size measured by typical EEG wave lengths [32].

The basic argument leading to this model is the observation that although our brain changes its position and orientation, the mental image of the external world is not experienced to move: as if we were looking some kind of sensory canvas inside cortex from outside so that the motion of canvas does not matter. Or equivalently: the ultimate sensory representation is outside brain at a fixed sensory canvas. In this model the objects of the perceptive field are represented on the magnetic canvas. The direction of the object is coded by the direction of ME located on brain whereas its distance is coded by the dominating frequency of ME which corresponds to a magnetic transition frequency which varies along the radial magnetic flux tubes slowly so that place coding by magnetic frequency results.

According to the summary of Penrose in his book 'Emperor's New Mind' these experiments tell the following.

1. With respect to the psychological time of the external observer subject person becomes conscious about the electric stimulation of skin in about .5 seconds. This leaves a considerable amount of time for the construction of the sensory representations.

2. What is important is that subject person feels no time delay. For instance she can tell the time clock shows when the stimulus starts. This can be understood if the sensory representation which is basically a geometric memory takes care that the clock of the memory shows correct time: this requires backwards referral of about .5 seconds. Visual and tactile sensory inputs enter into cortex essentially simultaneously so that this is possible. The projection to the magnetic canvas and the generation of the magnetic quantum phase transition might quite well explain the time lapse of .5 seconds.

3. One can combine an electric stimulation of skin with the stimulation of the cortex. The electric stimulation of the cortex requires a duration longer than .5 seconds to become conscious. This

suggests that the cortical mental image (sub-self) is created only after this critical period of stimulation. A possible explanation is that there stimulation generates quantum phase transition "waking up" the mental image so that threshold is involved.

4. If the stimulation of the cortex begins (with respect to the psychological time of the observer) for not more than .5 seconds *before* the stimulation of the skin starts, both the stimulation of the skin and cortex are experienced separately but their time ordering is experienced as being reversed!

   A crucial question is whether the ordering is changed with respect to the subjective or geometric time of the subject person. If the ordering is with respect to the subjective time of the subject person, as it seems, the situation becomes puzzling. The only possibility seems to be that the cortical stimulus generates a sensory mental image about touch only after it has lasted for .5 seconds. In TGD framework sensory qualia are at the level of of sensory organs so that the sensation of touch requires back-projection from cortex to the skin. If the formation of back projection would takes about .5 seconds the observations can be understood. Genuine sensory stimulus creates cortical mental image almost immediately: this mental image is then communicated to magnetic body (time like entanglement).

5. If the stimulation of the cortex begins in the interval $T \in [25 - .5]$ seconds *after* the stimulation of the skin, the latter is not consciously perceived. This effect - known as backward masking - looks really mysterious. It would be interesting to know whether also in this case there is a lapse of .5 seconds before the cortical stimulation is felt.

   According to the TGD based vision sensory mental images are at the level of sensory organs and brain constructs symbolic representations about them using intensive back-projections to the sensory organs. These representations give rise to a decomposition of the perceptive field to standardized sensory mental images. The most effective manner to achieve back-projection is by using negative energy signals propagating backwards in geometric time just like in the case of intentional action. Accepting this framework one can at least make questions.

   i) Could the stimulation of the cortex induce a negative energy back-projection signal to the skin representing a stimulus effectively interfering to zero with the real stimulus? That the skin stimulus is perceived consciously for $T < .25$ seconds means that the compensating back projection is sent only if cortex has received information about skin stimulation. One can imagine that it takes .25 seconds to form a symbolic representation about the sensory mental images at sensory organ. Why the back-projection would compensate the skin stimulus?

   It is known that brain acts like a highly selective gardener applying strong inhibition to certain sensory stimuli and strong excitation to others in order to build percepts. If this principle applies also in time domain - as it should if the paradigm of 4-D brain is accepted- the elimination of the sensory stimulus could be seen as a tendency to build sensory percepts which are sharply localized in time. A precise localization in time is indeed important in the case of sensory percepts.

   Second explanation would be based on compensating back-projection. Everyone who has been swimming in windy sea, feels the waves for a long time after coming to the shore. This sensation would correspond to back-projection in TGD framework but it is not clear to me whether this back-projection tends to compensate the actual sensation in order to achieve metabolic economy.

   ii) Could it be that the skin stimulus is actually consciously perceived but that this experience is not remembered? In TGD framework the memory about skin stimulus would be realized as a skin stimulus still continuing in the geometric past. If the cortical stimulation for some reason modifies the geometric past by destroying the skin stimulus using back-projection, there would be no memory about the skin stimulus.

1. Two options for the communications to the magnetic canvas

Consider now possible constraints from Libet's experiments on the model of sensory representations based on the notion of magnetic canvas. MEs induce magnetic quantum phase transitions via the classical magnetic field associated with them and oscillating with a multiple of the cyclotron frequency. There are two possibilities.

1) The classical signal is thought to propagate along an existing em ME to the magnetic canvas and induces the magnetic quantum phase transition.

2) MEs behave like topological field quanta. A passive Z^0 ME is replaced with a an active em ME in single quantum jump so that the signal propagates to the magnetic canvas effectively instantaneously.

2. Various time lapses involved

Let us first analyze various time lapses which can be involved in the process leading from the sensory stimulus to the sensory experience.

1. The propagation of the classical signal along ME to the magnetic sensory canvas takes some time. This gives upper bound for the possible sizes L of MEs. The lapse is however for $T_{cl} \sim L/c = 1/f$, which is about .1 seconds for earth-sized MEs and of same order as the time lapse $T_b \simeq .01$ seconds due to the conduction of the nerve pulses from skin to somatosensory cortex.

2. The time T_m for the magnetic quantum phase transition to occur should be $T_m \sim 1/\Gamma$, where Γ is the rate Γ for cyclotron transitions for ions in the harmonic perturbation defined by the classical magnetic field B associated with ME. If the magnetic quantum transitions occur incoherently, Golden Rule implies that the rate Γ should be of order

$$\Gamma \sim N(\frac{B^2}{B_e})^2 f_c \ ,$$

where B is the amplitude of the oscillating magnetic field associated with ME, B_e is Earth's magnetic field, f_c is the corresponding cyclotron frequency, and N is the number of ions participating in the transition.

If T_m indeed represents a lapse of conscious experience then the magnetic field associated with the radial ME inducing the magnetic quantum phase transition should be very strong as compared with the typical intensities in MEG unless N is large. The relative intensity of the fluctuations of Earth's magnetic field is about $\Delta B/B_e \sim 10^{-8}$ and gives an estimate for the intensity of B. The lower bound for the number of ions participating to the quantum phase transition is $N = 10^{16}$. Since the magnetic flux tube has thickness of order cell size, and since there are not much more than about 10^2 ions per cellular volume, the required length of the magnetic flux tube participating in the quantum transition would be longer than 10^8 meters and is definitely too long.

Quantum coherence can however come in rescue here. If the magnetic transitions occur coherently, the rate is given by

$$\Gamma \sim N^2(\frac{B^2}{B_e})^2 f_c \ ,$$

where N is the number of the ions participating in the transitions. For $N > B_e/B$ ($\sim 10^8$ for $B \sim 10^{-8}B_e$) the rate is high enough if the length of the magnetic flux tube participating in which quantum phase transition occurs longer than 10^2 meters. Since the intensity of the magnetic field varies extremely slowly along the magnetic flux tube in the proposed model, the number of the ions participating the transition could indeed be large enough and T_m would become an unimportant factor.

3. The total lapse of time is $T = T_b + T_{cl} + T_m + T_p$, where $T_b \sim .01$ seconds is the time for the signal to propagate to the somatosensory area and T_p is the time used by cortex to estimate the position of the sensory stimulus and activate the MEs taking care of the sensory projection to the magnetic canvas. Since the coding of the position of skin is topographic, there is no need to compute the distance and orientation of the stimulus and one has T_p is minimal. This gives $T = T_b + T_{cl} + T_m + T_p$ for the classical option 1) and $T = T_b + T_m + T_p$ for the quantum option 2).

3. Constraints from Libet's experiments

It is interesting to look what Libet's experiments mean for various options about what precedes the magnetic quantum phase transition giving rise to the sensory experience. The basic observation is that the classical signal propagation time along ME, which is .1 seconds for magnetic flux tube at distance of order Earth circumference, is much shorter than the time .5 seconds between the sensory stimulus and conscious experience. Thus it does not strong constraints on the model based on option 1).

1. If one assumes that the formation of the sensory representations involves the propagation of a classical signals along MEs (option 1)), and that the sensory representation of the skin is at distance of, say, one fourth of Eearth's radius corresponding to the frequency $f = 10$ Hz, the lapse is about $T \simeq T_b + T_{cl} + T_m + T_p = .1 + T_m$ seconds. This allows $T_m + T_p \simeq .4$ seconds. For $T_m \ll T_b$ $T_p \simeq .4$ seconds is allowed. In classical case there are however bounds on the distance of the magnetic canvas, five Earth circumferences is the upper bound.

2. Second option is that the process does not involve classical signalling in the proposed sense so that the distance of magnetic canvas does not matter at all. ME behaves as a single particle and is transformed from passive Z^0 ME to active em ME in single quantum jump. Suppose the arrival of the neuronal signal induced by the electrical stimulation of the skin to the somatosensory area induces this kind of quantum jump, which becomes thus capable of inducing magnetic quantum phase transition. If this is the case, then the sensory representation of the stimulus could result after $T \sim T_b + T_m + T_p$ after the arrival of the neural signal to the cortex. If T_m is negligible one has $T \simeq T_p \simeq .5$ seconds. The fact that the stimulation of cortex by .5 seconds is needed to produce artificially the sensory stimulus suggests that T_m is indeed negligible.

3. The third option is that there is a ME associated with the entire sensory pathway fused with the ME associated with the sensory projection to the magnetic canvas and that already the sensory stimulus at the skin initiates the magnetic quantum phase transition. In this case one has $T = T_m \simeq .5$ seconds.

6.4.4   The experiment of Radin and Bierman as evidence for quantum jump between quantum histories concept

The experiments of Radin [56] and the later experiments by Radin and Bierman [85, 82] gave evidence for anomalous unconscious emotional responses preceding their cause. Radin monitored the sympathetic and parasympathetic behavior of the autonomic nervous system with skin conductance, heart rate and fingertip blood volume measurements. Subjects were asked to look at a computer monitor and press a button to start a trial. Button press caused the display of a blank screen for five seconds, then a randomly selected calm or emotional picture was shown for three seconds, and this was followed by ten seconds of a blank screen. In three studies, Radin found significant differences in autonomic physiology, most notably skin conductance, *preceding* the exposure of emotional vs. calm pictures. Radin examined a number of possible normal explanations for the result and concluded that they did not apply.

Radin and Bierman interpreted the result of the experiment as evidence for a reversal of the arrow of time. The constancy of the arrow of psychological time is by no means obvious in TGD Universe and one of the basic challenges of TGD inspired theory of consciousness is to understand how the (probably statistical) arrow of psychological time emerges. Moment of consciousness as quantum jump between quantum histories concept provides however an elegant explanation of the effect without any need to assume the reversal of the arrow of psychological time. What is important that one can also avoid the poorly defined concept of effects propagating backwards in time, which is needed in explanations based on quantum state as time=constant snapshot concept.

Consider now the TGD based explanation. In quantum jump deterministic quantum history is replaced with a new one: this means that, not only the future, but also the *past* changes. Therefore, if the mean galvanic skin response of the subject person provides a faithful representation for some aspects of subject person's deterministic quantum history, the entire time record about skin response must change to a new one in any quantum jump. If subject person experiences a highly emotional stimulus, the moment of consciousness is expected to be more intensive than for calm stimulus in the sense that the non-determinism associated with the quantum jump is expected to cause observable effects in a larger space-time volume of the quantum history (represented to a good approximation as

quantum average space-time surface geometrically). Therefore also the change of the quantum past is expected to be more dramatic as it indeed seems to be according to the results of the experiment.

At first it might seem that there are no means to test whether the past has changed at the moment of consciousness. The experimental arrangement of Bierman and Radin, although certainly not originally planned to test quantum jumps between histories concept, circumvents in an ingenious manner this difficulty by comparing the skin responses associated with calm and emotional trials. Standard physics, which is based on assumption that there is no signal propagation backwards in time, predicts that the average skin responses before the stimulus should be identical for calm and emotial trials. This is not the case so that the results of the experiments indeed support TGD based world view.

One can in fact imagine even more dramatic test based on a modification of Radin-Bierman experiment. In quantum-mind discussion group Stan Klein [48] suggested a modification of Radin-Bierman experiment [85, 82, 56] providing a test for Stapp's and Sarfatti's theories of consciousness [70, 53]. One could perhaps consider the following further modification of Radin-Bierman experiment so that it would simultaneously discriminate between Stapp's and Sarfatti's theories and TGD.

1. It might be possible for computer to perform a comparison of the presponse with average calm and emotional presponses *before* the subject person A sees the picture and, depending on whether the presponse is nearer to calm or emotional average presponse, to print C or E to a computer screen such that the printing result is seen by person B *before* A sees the picture.

2. The theories explaining phenomenon in terms of effects propagating backwards in time (say Sarfatti's theory [53]) would predict that computer record and the sequence of letters remembered by B are identical and contain both C:s and E:s. According to [48] Stapp's theory would predict that both computer record and B's memories contain only C:s.

3. TGD predicts that B would *see* only C:s. The concept of subjective memory implies that B also *remembers* of seing only C:s whereas computer records would contain both C:s and E:s. This would provide dramatic support for quantum jump between quantum histories concept and for the notion of subjective memory.

In TGD framework one can also consider an alternative explanation for the result of Radin-Bierman experiment. If this explanation is correct, the report of B is consistent with the computer record just as in Sarfatti's theory. The argument goes as follows.

1. Given moment of consciousness contains several irreducible subexperiences besides the experience corresponding to the "real I", which presumably corresponds to "I" able to communicate using language and possessing long term memories. These "I":s are usually collectively identified as subconscious mind. The phenomenon of blind sight and related phenomena [57] give support for the idea that there is second "I", most naturally at the same level of self hierarchy. One can even imagine entire population of selves at some lower level of self hirarchy giving rise to "Zombi within us" or shortly Z. In the latter case the response of Z is dictated by statistical determinism at the level of ensemble. Deterministic response has definite value in fight for survival.

2. The values of the psychological times associated with these various "I":s need not be same in given quantum jump. Suppose that Z has psychological time slightly larger than the psychological time of the ordinary "I" so that Z sees the state of the world at time $t + \Delta t$ whereas "the real I" sees it at time t in given quantum jump. The order of magnitude for Δt is roughly one second. Assume further that Z is able to assign emotional content to the picture. If the decision about what picture is shown is purely mechanical involving no quantum jump (and hence only effectively random) then Z can perceive the picture before the ordinary "I" perceives it with the result that galvanic presponse is created. Galvanic presponse is deterministic in case that Z is an entire population of "I":s.

Some remarks about the model are in order.

1. The criticism against this kind of model is that Z is perhaps not able to assign any emotional content to the pictures. The experiments supporting the existence of Z mildly suggest that Z sees the things "as they are" (for instance Z cannot be fooled by visual illusions) which in turn suggests that emotional response is perhaps not involved.

2. Z could also receive the information about the picture by precognition in principle made possible by the diffuse contribution to the contents of conscious experience coming from entire initial and final quantum histories. If this is the mechanism, one can however wonder why the "real" I is not capable to same so that also "real" "I" would have *conscious experience* about the nature of the picture before seing it.

3. In case of Kornhuber experiments similar explanation would lead to the veto model: the conscious decision to raise index finger is preceded by the conscious decision of Z to raise it and the "real I" can decide whether to allow various neural processes to continue or not.

4. In principle (probably only in principle) one could test the model by allowing the selection of the figure to be shown to A be determined by a quantum jump rather than by deterministic process. If this quantum jump occurs only very short time before A sees the picture, response should disappear.

An effect resembling Radin-Bierman effect might occur in much more conrete situation. There is a legend about the ability of the short distance runners to anticipate the shot of the starting pistol and start already before the gun shot. Perhaps this really occurs but in the following sense. When short distance runners hear the shot they perform a quantum jump to a new history. For obvious reasons they might have developed a skill to jump to a quantum history at which they started before the gun shot. Whether this effect occurs could be tested by using video camera or some more sophicated arrangement (gun shot can be accompanied or even replaced by light signal to make the timing precise). What could happen is that the man with the gun honestly claims that the runner started after the shot whereas videocamera tells that runner started before the shot. This effect deserves the nickname "tribar effect" (tribar is the famous nonexisting triangle like structure formed from three bars): in its various forms the effect could provide very general hard evidence for TGD based view about space-time.

Notice that the paradox of ping pong game described in the book of Penrose [47] can be resolved in quantum jumps between quantum histories picture. The problem is that the time delays of consciousness are so long that no conscious action seems to be possible in ping pong game. The resolution is simple. The players can quite well miss the ball time on the old history but perform a jump to a new history: on this history they do not miss the ball thanks to the rapid deterministic reflex action.

6.5 Good and Evil, Life and Death

In principle the proposed conceptual framework allows already now a consideration of the basic questions relating to concepts like Good and Evil and Life and Death. Of course, too many uncertainties are involved to allow any definite conclusions and one could also regard the speculations as outputs of the babbling period necessarily accompanying the development of the linguistic and conceptual apparatus making ultimately possible to discuss these questions more seriously.

Even the most hard boiled materialistic sceptic mentions ethics and moral when suffering personal injustice. Is there actual justification for moral laws? Are they only social conventions or is there some hard core involved? Is there some basic ethical principle telling what deeds are good and what deeds are bad?

Second group of questions relates to the biological death. What happens in the biological death? Is self preserved in the biological death in some form? Is there something deserving to be called soul? Are reincarnations possible? Are we perhaps responsible for our deeds even after our biological death? Could the law of Karma be consistent with physics? Is liberation from the cycle of Karma possible?

In the sequel these questions are discussed from the point of view of TGD inspired theory of consciousness. It must be emphasized that the discussion represents various points of view rather than being a final summary. Also mutually conflicting points of view are considered. The cosmology of consciousness, the concept of self having mind like space-time sheet and causal diamond as its correlates, and the vision about the fundamental role of negentropic entanglement provide the building blocks needed to make guesses about what biological death could mean from subjective point of view.

6.5.1 Life and Death

One can interpret ageing in two senses. The ageing with respect to geometric time and the ageing with respect to the subjective time. Before discussing ageing in the sense of geometric time one must specify what one means with geometric time and what one believes its relationship to subjective time to be.

1. There are two geometric times corresponding to the times assignable to space-time surface and imbedding space.

   (a) The recent argument for the arrow of psychological time allows to understand the flow of geometric time assignable to space-time surface in manner rather different from the standard one. The causal diamond CD representing self is actually stationary and space-time surface effectively flows into it from geometric future. A generalized form of NMP implying that selves are curious and want to know what is in the space-time future outside the CD implies that selves perform quantum jumps drawing the space-time surface inside CD. The argument explains also why mental images tend to be located near the future boundary of CD and thus why sensory input is mostly about a rather narrow time interval. The arrow of time emerges spontaneously but the CP breaking of quantum TGD might help to establish global choice of the arrow of time.

   (b) One can speak also about the arrow of cosmic time identified as a gradual growth of the size of CD quantum jump by quantum jump so that the past boundary of CD recedes. There are reasons to believe that this cosmic time is discontinuous and its values come as powers of two.

2. Subjective ageing could correlate closely with the entropy growth due to the randomness of state function reduction leading to thermalization or the ensemble of mental images. This would correspond also to second law. Also entropic mental images are generated by bound state entanglement. On the other hand, life as something in the intersection of real and p-adic worlds with negentropic engtanglement carrying conscious information might change the situation. Both the growth of negentropy of conscious experience reflecting itself as evolution and the growth of entropy as physicist identifies it and reflecting itself as biological againe would be involved. NMP suggests that negentropy of conscious experience tends to increase and the biological death is only a transformation to some new form of existence. The dark matter hierarchy with levels labeled by the values of Planck constants has become a key element of TGD inspired theory of consciousness and one can imagine that during ageing these levels of existence begin gradually dominate consciousness.

What interests us mostly is obviously the subjective ageing and biological death. What dying person might experience? Is there a continuity of subjective experience or does suffering end with a loss of consciousness. What follows after biological death? How our deeds affect what happens in biological death and to the experiences after the biological death? Here are some possible answers.

1. Perhaps the only thing that happens in biological death is that the contribution of biological body to the contents of consciousness disappears so that other contributions usually masked to a high degree by sensory input and motor activities become into full light of consciousness. In fact biological body and magnetic body are 4-dimensional and there are good reasons to expect that it continues to contribute to the consciousness of some self- not necessarily the self which possessed the body. The question is however about what this particular self that I have experiences in biological death and after it.

2. The notion of negentropic entanglement suggests allows to consider an answer to what might happen in biological death from the point of subjective time. Depending on the choices of self which has the dying person as sub-self, dying person generates bound state entropic entanglement with a loss of consciousness or negentropic entanglement accompanied by an expansion of consciousness. What option the higher level self chooses depends on the probability of the size of the contribution of the state with negentropic entanglement.

3. If the dying person has a strong negentropic entanglement with external world, it tends to be preserved in quantum jumps and only a small entropic contribution is present and there is only a small probability to lose consciousness. Another manner to see this is that a subself having very entropic subselves (mental images) is experienced by self as something unpleasant and by generalized NMP self might want to get rid of this kind of mental image. This would reduce the chances of experiencing an expansion of consciousness. Perhaps death could be seen as the price for sins.

4. One could also argue that although consciousness might be lost it might be not be in any manner different from sleep. It could gained back in wake-up but as something different from ordinary wake-up consciousness and determined by the 4-D biological and magnetic bodies and the deceased could remember his former life by still existing 4-D body. The notion of electromagnetic body, when combined with the view about psychological time, allows to consider a general answer to these questions. Magnetic body probably survives the biological death, and since it serves as the sensory canvas, there are all reasons to expect that subjective consciousness continues after the biological death. The contents of consciousness would be determined by the 4-dimensional physical and electromagnetic bodies and the dominating contribution creating the illusion about reality as a time=constant snapshot would be absent. Kind of timeless consciousness would be in question in accordance with the life review experiences associated with NDEs.

5. One can also ask what might be the physical correlate of self after the biological death. The 4-D space-time sheet representing self very probably does not disappear in biological death and the 4-D character of the perceptive field suggests that this 4-D body continues to exist as a conscious entity and the sub-CDs of the geometric past representing mental images still exist. Only at the future boundary of CD the flow of 4-D biological body ceases but the sub-CDs representing existing mental images float to the direction of geometric past in the river of time and remain consciousness.

Ageing as a price for having self

In standard quantum theory framework not allowing negentropic entanglement self can be regarded as a statistical ensemble of mental images defined by the unentangled final states of the quantum jumps. Since the size of this ensemble increases quantum jump by quantum jump, the approach of this ensemble to thermal equilibrium is unavoidable although living matter has probably invented manners to fight against the second law of thermodynamics. Thus ageing of self means dissipation.

The hierarchy of Planck constants and negentropic entanglement mean deviations from this picture.

1. For higher levels of dark matter hierarchy the dissipation rate is expected to be slower: the naive expectation is that the rate is inversely proportional to Planck constant.

2. Negentropic entanglement means second exception to the rule and for given CD second law can be broken in time scales shorter than the time scale characterizing CD [29].

Each p-adic length scale defines its characteristic dissipation rates. In case of a self decomposing into sub-selves the rate of dissipation is sum over the real dissipation rates associated with the nested system formed by the self, its sub-selves, their sub-selves, etc.... The dissipation associated with states of whole-body consciousness can be anomalously small since only negentropic mental images are absent and if there is only one such mental image (or no mental images at all) there is no generation of ensemble entropy. A possible test for this is the study of total rate of metabolism during meditation.

Dissipation causes the ageing of self: getting old at least at the level of biological body would be the price for having self. More concretely, the entropies associated with various distributions of quantum number and zero mode increments increase during ageing so that mental images are gradually blurred. Note that also our self which defines a mental image of a higher level self is blurred. Also biological death, or at least death experience, seems to be unavoidable fate of self.

Ageing and death from the point of view entanglement generation

The possibility of negentropic entanglement allows to see ageing from different point of view. Sub-selves generate either entropic or negentropic entanglement and also the generation of entropic entanglement

should contribute besides the generation of ensemble entropy of mental images to ageing of the bio-logical body. The generation of negentropic entanglement-perhaps with higher levels of self hierarchy-would be also an aspect of again. This is suggested if NMP is taken analog of second law holding in the realm of subjective existence.

1. Ageing as an entropic process could be seen also as a process analogous to the process of getting drowsy and falling asleep but in much longer time scales. Bodily sub-self would not remember anything about these periods in the case that the entanglement was entropic. Also sleep could represent a similar conscious state without bodily mental image and the impossibility to remember anything about this period of consciousness might be simply due to the fact that one can remember something about sleep state only in sleep state. The periods during which negentropic entanglement prevails would be experienced as enlightment like experiences. During ageing bodily sub-self would spend more and more time near the critical line at which this kind of phase transition occurs.

2. Ageing could be seen as a process of personal growth generating negentropic entanglement. The negentropic entanglements generated with larger selves would give rise to larger selves and the metaphor 'awakening' would thus be much more than a metaphor. Time-like negentropic entanglement would mean longer time span of attention. Person would spend more and more time in extended state of consciousnesss and in death finally leave the confines of the biological body. Note that person need not, and probably doesn't, remember anything about the periods of entanglement in which the local topology of self changes. This would make possible the evolution of selves continuing after death to higher levels of conscious existence.

This picture is rather optimistic: one must also consider the possibility that the evolution of self is not always a continuous personal growth! The fact that the individual development of most people seems to be a process of continual abstraction suggests that biological death is only one step in the process of abstractions and that our self consciously experiences the final transition to higher level of existence in biological death.

Why childhood memories are recalled so intensely?

The first manner to see ageing is as a subjective experience: as ageing with respect to subjective time. Our self contains sub-selves representing our memories, sensory input from the geometric now and future plans. At the old age it often happens that childhood memories begin to dominate whereas the recall of more recent memories is gradually lost. Of course, the contribution of future plans becomes also gradually negligible. This suggests that the contents of consciousness for our self can suffer a gradual transformation such that the childhood begins to dominate: of course, this need not happen always. That the childhood dominates is not easy to understand if the memories of the past are stored in the geometric now as assumed in the standard brain science. In TGD framework the very fact that the childhood consciousness is very intense and un-conceptual, explains the dominance of the episodal memories of childhood.

Who is the subjective experiencer in this kind of situation? Is it the old person with vivid memories or a child with some very diffuse ideas about future? The view about psychological time would suggest that the general experience gradually becomes some kind of a 4-dimensional life review such that the very intense childhood memories dominate but that the person in the psychological now is still the only one who can transform intentions to actions effectively whereas the 4-D body of the past is more or less frozen.

Death as disappearance of the mental image representing the biological body?

If one takes seriously the following two assumptions behind the TGD based model of quantum control and coordinate based on the symbiosis of MEs, magnetic flux tube structures, and matter at the atomic space-time sheets, one ends up with rather concrete view about what happens after the biological death. The ultimate sensory representations are realized on the sensory canvas provided by magnetic flux tube structures of similar size, so that we have magnetic body providing sensory representation of the biological body and external world [32]. Our magnetic self very probably survives in the biological death by the conservation of the magnetic flux.

In this picture the body of after-life body would consists of the magnetic body plus MEs possibly surviving the death of the biological body. The only difference as compared to the life before death would be that the sensory and cognitive mental images representing the biological body (sub-selves) would disappear and the attention of our self would be directed to something else. Possibly to the entire time span of 4-D biological body since sensory input and motor actions at the upper boundary of peresonal CD are absent. Near death experiences indeed support this view [19]. In this picture re-incarnation is possible and even plausible and means only that the magnetic flux tube structure representing our bodily self turns its attention to some other biological body and uses it as a sensory and motor organ. This new biological body could be plant, animal, human, or perhaps something else. In this picture the metaphor about biological body as a cloth becomes very concrete.

Since self has an extension with respect to geometric time, it has memories about its earlier history and one could perhaps identify the continuation of self after the death as that self which has the memories of self with respect to geometric time before death. In this extended state of consciousness self could experience the subjective past of the space-time sheet of self and associate it with self's recent mindlike space-time sheet.

Near death experiences

Near death experiences provide a testing ground for the general ideas about what might happen in the physical death. Experiences resembling near death experiences can be produced now in controlled manner in laboratory circumstances for people well and alive and irrespective of their belief structure subject persons tell about light tunnels and meeting of deceased relatives [54]. These experiences have been found to be therapeutic and are indeed used as therapy to cure severe psychic traumas. Therefore the materialistic explanation as a hallucination associated with dying brain seems to be excluded. Near death experiences involve experiences like being in light tunnel, seeing beautiful and rich landscapes and meeting dead relatives. Also out-of-body experiences are involved. The model of NDEs are discussed in detail in [21] and here only some brief comments are represented.

The proposed picture about physical death allows a lot of room to interpret these experiences. For instance, OBEs allow two explanations.

1. The first explanation is based on the fact that in TGD based model of sensory representations the magnetic sensory canvas far outside body basically sees the brain in ELF light. This light usually comes from brain and provides a sensory represention for the external world. TGD predicts also a mechanism producing background ELF radiation from the entire body at magnetic transition frequencies and this background would make possible to see the body 3-dimensionally from outside when the sensory input is absent and does not mask this weak contribution. NDE OBEs might correspond to this kind of vision reported also by yogis.

2. The experience looking one's body from outside could mean that some higher level self corresponding to slow EEG waves and higher em selves formed physically by the personnel of hospital in the hospital room begins to dominate. This self could perhaps see patient's body with the combined eyes of the hospital personnel. Indeed, since the sensory input from the biological body ceases, the illusory identification of 'me' with the biological body ceases and attention can be directed to this higher level sensory input.

Geometrically the em bodies of our dead relatives would exist in the geometric past and now, perhaps already in a re-incarnated form. This allows several explanation for the experience of meeting dead or living relatives. A very concrete model would be based on electromagnetic bridges formed by magnetic mirrors and connecting us with our relatives and friends. This would make possible for us to see them in ELF light just like we would see ourselves.

The experience about meeting deceased relatives could be also understood as a special kind of geometric memory. Generation of the long term memory means classically looking to a magnetic mirror at classical level and seing the me of the past in the mirror. It is however possible to see someone else in the mirror since the magnetic fluxtube from the mirror could continue to the body of the deceased relative of friend instead of my body. In the usual states of consciousness the sensory input from the psychological now dominates and this contribution is masked. In near death experiences sensory input from the geometric now is diminished and the transpersonal background contribution becomes unmasked.

What after biological death?

Biological death could mean the loss of sub-self representing body image and involve extension of the physical self: this would explain out of body experiences and near death experiences (person near death looking his body from outside). In fact, an attractive hypothesis, motivated by the quantum model of brain, is that the topological field quanta associated with photons generated by EEG currents having size of order Earth by Uncertainty Principle, could correspond to selves in our personal self hierarchy. Also magnetic flux tube structures associated with body and brain could have similar sizes and serve as a magnetic body [32]. In biological death these ELF selves could continue to oscillate as Schumann resonances in the wave cavity between Earth's surface and ionosphere interacting with magnetic flux tube structures!

Neutrinos which are proposed to play important role in living matter would correspond to CD with time scale of order 10^4 years for the standard value of Planck constant and just this fact suggest that they could indeed be important. If one believes that even cell sized structures have their own CDs then the primary p-adic length scale defined by the size scale of a large neuron (10^{-4} meters) would correspond to a time scale of the order of the age of the Universe! It seems implausible that these CDs could disappear totally although zero energy ontology in principle allows it.

Biological body is accompanied by magnetic body and radiation body which provide representation for the physical (or better to say, material) body. The latter consists of radiation selves (massless extremals representing topologically rays of light) representing classically the ELF radiation fields generated by EEG currents, one is led to ask what happens for these em selves in biological death. Some of them correspond to resonant frequencies of the em fields in the 80 km thick wave cavity between Earth surface and ionosphere known as Schumann frequencies and one can consider the possibility that that something which might be called soul remains after the biological death and is represented as Schumann resonances.

The most plausible hypothesis is that both ULF MEs and magnetic flux tube structures remaining after physical death together with the 4-dimensional body of geometric past define our self after the biological death. This leads to the following speculative vision about consciousness after the biological death.

1. The transformation of intentions to actions as p-adic-to-real transitions ceases in the biological death so that the dominating contribution of the psychological now to the experience disappears and conscious experience becomes kind of four-dimensional life review in which also the contributions from other bodies (say deceased relatives) appear as unmasked.

2. The geometric past, or rather experiences about it, can be gradually refined but no big changes are possible, so that a totally new life based on different decisions does not seem to be possible. The assumption about totally new life would also lead to paradoxes. On the other hand, the unstability of the long term memories suggests that the memories about the past life could be edited. The conscious experience contains also the contribution of the magnetic body continuing to exist.

3. The surviving magnetic body could attach to some new organism which it begins to use as a sensory and motor organ. The re-incarnation would have the memories of the past life as an unconscious background masked strongly by the sensory input and coming clearly conscious only in some altered states of consciousness. The reports about children remembering they previous life could be understood in this conceptual framework. This of course makes one wonder whether young children could remember their past lives. Perhaps someone should ask!

Does soul exist in some sense?

An open question is what happens for the space-time sheet (or CD) assignable to self after biological death.

1. Could this space-time sheet or CD be called soul? Does this soul continue drift in lightcone and get attached to some new material system. Or can it disappear in quantum jump? This would not be a reincarnation in the usual sense of the word. The re-incarnation in the usual sense if the word would mean that one has memories about the life of someone whose has lived in past. In TGD Universe this is quite possible since the mechanisms of remote mental interactions

are basically the same as the interaction mechanisms making possible for the magnetic body to control the biological body receive information from it.

2. ”Ontogeny recapitulates phylogeny” principle suggests that the evolution of an individual is image for the evolution of the entire universe. Biological death would be only a metamorphosis to some new form of existence, perhaps as topologically quantized classical fields associated with the biological body. Magnetic flux tube structures having sizes measured in scale of light lifetime are especially promising candidates for the components of electromagnetic body surviving in the death of what is usually identified as the biological body. Some experimental facts lead to rather precise ideas about the geometric representation of our selves and also suggest that our existence continues in electromagnetic form after death [19].

Indirect support for the survival of mindlike space-time sheets after death comes from rather unexpected direction.

1. The phenomenon of phantom DNA suggesting that mindlike space-time sheets associated with DNA remain in the chamber which contained DNA: in the experiments of Poponin [44] the signature of phantom DNA is its interaction with laser light at visible frequencies. Phantom DNA would be represented by mindlike space-time sheets with size of at least the wavelength of visible light (10^{-7} meters). The em selves remaining after our death would have consirably larger size! One can however consider the possibility that some detectable interaction between EFL frequency em fields and 'phantom brain' ('em soul') could be possible and make it possible to prove experimentally the presence of em soul!

2. The claimed successes of homeopathy (for phantom DNA and homeopathy see [20] and [20]). could also have explanation in terms of the mindlike space-time sheets. Homepathic drugs are fabricated by a repeated dilution of the active drug so that the concentration of the drug in solution becomes extremely low. The method of fabrication could however imply that final product contains quite many mindlike space-time sheets of the drug molecules. These mindlike space-time sheets might be able to affect the sickness since the mindlike space-time sheets provide a cognitive representation for drug and this mimicry could 'cheat' the patient to cure. The law of similarities could have something to do with the mechanism involved.

   More concretely, a given quantum transition frequency characterizing the medicine would be represented as ME with length equal to the wavelength associated with the transition frequency. The electromagnetic body of the molecule could be mimicked by liquid crystal water blobs producing similar transition frequencies and thus containing similar MEs in their electromagnetic bodies. The effect of the medicine would be mediated by the electromagnetic body so that the 'fake' medicine could indeed cure.

Some support for the extension of self in death is provided by near death experiences. For instance, looking one's body from outside could mean that self is entangled with a larger self formed by the personnel of hospital in the hospital room and sees patient's body with the eyes of the personnel. This experience could be understood as experience of, say self representing hospital room: in this experience the visual experiences of persons in the hospital room would fuse to the experience experienced by patient entangled with the hospital room. Meeting one's relatives and elders could mean entanglement with a larger self formed by the selves of dead and living relatives. This larger self could experience the abstracted experiences of dead and living relatives. Also the ability of subjects of surgical operations to occasionally remember about events occurred during unconscious state, supports this view. Magnetic flux tube structures are the most plausible candidates for the 'body' remaining in physical death: this point is discussed in more detail in [19].

Is it possible to get into contact with deceased?

There is a lot of subjective evidence consistent with life after death. Near-death experiences are not the only manner to get convinced for life after death. So called eye-movement desensitization and reprocessing (EMDR) discovered by Francine Shapiro [86, 54] induces what could be interpreted as after-death communications.

1. The experiences of subject persons can be induced by this therapy in highly reliable manner: according to [54] 98 per cent of patients willing to participate the therapy had after death communication experience It does not matter what the religious convictions of the subject person are and the experiences are actually rather easy to induce. It does not matter if the loss is traumatic or not or whether it is recent or occurred for decades in past.

2. The experiences resemble near death experiences (light tunnels, beautiful landscapes) and involve spiritual contact with the deceased. The EMDR technique involves getting the patient to move his or her eyes in a particular rhytmic fashion while at the same time attending to a particular aspect of the traumatic memory.

3. How EMRD works is poorly understood as yet: possibly the fact that the shifting of eyes leads to increased brain processing is of importance. Notice that rapid eye movements REM are also involved with dreams. A possible explanation is that EMDR experiences could involve communication with the recent selves of the deceased ones located possibly in the geometric recent or past and represented by magnetic flux tube structure and MEs interacting with them.

6.5.2   Good and Evil

The vision about life as something in the intersection of real and p-adic worlds together with the notion of negentropic entanglement gives hopes for understanding the quantum correlates of evolution and even ethics. The basic principle would be that good deeds generate negentropic entanglement and Negentropy Maximization Principles- perhaps suitably generalized from its original form- would define the basic principle of ethics.

Quantum ethics very briefly

There are many manners to interpret evolution in TGD Universe.

1. p-Adic evolution would mean a gradual increase of the p-adic primes characterizing individual partonic 2-surfaces and therefore their size. The identification of p-adic space-time sheets as representations for intentions and the identification of p-adic-to-real phase transitions as transformations of intentions to real actions gives additional concreteness to this vision.

2. The hierarchy of Planck constants suggests evolution as the gradual increase of the Planck constant characterizing p-adic space-time sheet (or partonic 2-surface for the minimal option). This evolution could be seen as a migration to the pages of the book like structure defined by the generalized imbedding space and has therefore quite concrete geometric meaning. It implies longer time scales of long term memory and planned action and macroscopic quantum coherence in longer scales.

   The singular coverings of CDs and CP_2 are characterized by an Abelian group Z_n permuting the sheets of the covering and corresponds naturally to powers of the (quantum) phase $q = exp(i2\pi/n)$ allowing to define the notion of angle in p-adic context but only with a finite resolution since only finite number of angles are represented as phases for a given value of n. The increase of the integers n could be interpreted as the emergence of higher algebraic extensions of p-adic numbers in the intersection of the real and p-adic worlds. These observations suggest that all three views about evolution are closely related.

3. The vision about life as something in the intersection of real and p-adic words allows to see evolution information theoretically as the increase of number entanglement negentropy implying entanglement in increasing length scales. This option is consistent with the first one if the effective p-adic topology characterizes the real partonic 2-surfaces in the intersection of p-adic and real worlds.

   The third kind of evolution would mean also the evolution of spiritual consciousness if the proposed interpretation is correct. In each quantum jump U-process generates a superposition of states in which any sub-system can have both real and algebraic entanglement with the external world. If state function redution process involves also the choice of the type of entanglement it could be interpreted as a choice between good and evil. The hedonistic complete freedom resulting as the entanglement

entropy is reduced to zero on one hand, and the algebraic bound state entanglement implying correlations with the external world and meaning giving up the maximal freedom on the other hand. The selfish option has the risk of leading to non-algebraic bound state entanglement implying a loss of consciousness: death as the prize of sin. The second option means expansion of consciousness - a fusion to the ocean of consciousness as described by spiritual practices.

In this framework one could therefore understand the physics correlates of ethics and moral. The ethics is simple: evolution of consciousness to higher levels is a good thing. Anything which tends to reduce consciousness represents violence and is a bad thing. Moral rules are related to the relationship between indvidual and society and presumably develop via self-organization process and are by no means unique. Moral rules however tend to optimize evolution. As blind normative rules they can however become a source of violence identified as any action which reduces the level of consciousness.

There is an entire hierarchy of selves and every self has the selfish desire to survive and moral rules develop as a kind of compromise and evolve all the time. The newest progress in this evolution is brought by the cosmology of consciousness, which forces to extend the concept of society to four-dimensional society! The decisions of "me now" affect both my past and future and time like quantum entanglement makes possible conscious communication in time direction by sharing conscious experiences. One can therefore speak of genuinely four-dimensional society. Besides my next-door neighbors I had better to take into account also my nearest neighbors in past and future (the nearest ones being perhaps copies of me!). If I make wrong decisions those copies of me in future and past will suffer the most. Perhaps my personal hell and paradise are here and are created mostly by me.

How the law of Karma could be realized?

The existence of self hierarchy means that our deeds are remembered also after our death at higher level of self hierarchy although only as an abstracted summary. One can therefore ask whether the law of Karma or something akin to it might be implied by basic principles of consciousness theory.

First of all, self has two life strategies: be a sinner or saint.

1. Self can fight for the metabolic energy feed giving rise to the self organization of self. This strategy works as long as self is a young, brisk and arrogant sinner. Sinners are not desirable mental images from the point of view of higher level self since they induce a lot of entropic mental images (pain). This strategy is also in conflict with the possible goal of the higher level self to achieve fusion of its own mental images.

2. Self can attempt to share mental images by quantum entangling its sub-selves with the sub-selves of other, possibly, higher level selves. This mechanism gives rise to quantum metabolism and expanded states of consciousness, favors the generation of social structures, and means fusion of mental images from the point of view of higher level self. The cognitive mental images of the saintlike self are highly negentropic and favored by p-adic NMP.

On basis of these findings the policy for higher level selves looks obvious: try to get rid of the unpleasant mental images represented by sinners. Higher level self could apply this policy for purely selfish reasons: too bad sinners might affect like a poison to the moral level of the higher level self and, since the law of Karma is universal, could eventually lead to the decline of the higher level self to a lower level of the hierarchy: the world would seem to be a tough place also after death!

What 'liberation' might mean?

The strong analogies with eastern spirituality encourage to ask whether the TGD inspired quantum counterpart for the concept of liberation might make sense.

1. Quantum-classical correspondence principle suggests that the endless evolution at the level of the entire universe corresponds to endless evolution at the level of individual so that the notion of liberation would make sense only as kind of transformation to a higher level of consciousness.

2. In the real context selves having only single mental image or no mental images at all are in state of 'oneness' and experience no divisions and separations since the analysis process represented by state function reductions and self measurements is absent. This kind of state realized at the level of field body is a possible candidate for enlightened state. Certainly it cannot last forever.

3. Liberation experience might also relate to the experience of "cosmic consciousness". Most naturally a generation of negentropic entanglement fusing self to a self at higher level of self hierarchy. The fear about the loss of consciousness is what gives self an ego, since ego is something which can be lost. This can happen via the generation of entropic bound state entanglement with some other system. This can happen for any subsystem of Universe but not for the entire Universe enjoying an eternal state of consciousness. The state of cosmic consciousness thus means being a self without ego. The counterpart for this would be negentropic entangelement. Leaving aside the question whether we are able to experience ideal cosmic consciousness, one can consider the possibility that even human beings could achieve a state of consciousness in which the loss of consciousness is highly un-probable and that this loss of ego is synonymous with the experience of liberation.

The term "cosmic consciousness" looks somewhat pompous notion to anyone identifying himself with his suffering biological body and it would be certainly very difficult to sell this concept to a neuroscientist. This notion might however have a rather literal meaning in the intersection of real and p-adic worlds representing life. If p-adic- and real-rational imbedding space points are related via the identification of common rational points, p-adic space-time sheets typically have an infinite size with respect to the real topology since p-adically infinitesimally small distances necessarily correspond to infinite real distances. In this cognitive sense cosmic consciousness would have surprisingly concrete meaning.

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Chapter 7

Quantum Model of Memory

7.1 Introduction

The ideas related to the quantum model of memory have developed gradually from very general ideas to reasonably concrete models and a connection with biological quantum computer type systems has emerged. It is good to list the basic ideas and notions briefly to get and idea about this process which is still continuing.

7.1.1 Geometric and subjective memories

The identification of moment of consciousness as quantum jump between histories implies two kinds of time developments, subjective and geometric, and therefore also two causalities and memories. By the 4-dimensional general coordinate invariance of quantum TGD, geometric memories contain information about entire quantum and classical histories. This means that there is no absolute need to store memories of the geometric past to the geometric now. This has dramatic implications for the modelling of brain and allows to get rid of the basic problem of the memory models, namely the fact that the storage of new memories unavoidably tends to destroy the old memories whereas it seem that childhood memories are actually the most stable ones.

7.1.2 p-Adic physics as physics of intentionality

In purely real contex one ends up with the problem that there is no clear difference between memories and intentions: intentions are just memories about the geometric future. Why the memories/predictions of geometric future and past are so different? The solution of the problem came when I realized that p-adic physics is physics of cognition, imagination, and intention. p-Adic spacetime regions represent intentions and are about geometric future. In quantum jumps transforming intentions to actions p-adic regions are transformed to real spacetime regions representing geometric memories and inducing self-organization patterns giving rise to macroscopic actions. This amplification process is possible by the quantum criticality of TGD universe implying initial value sensitivity. Psychological time corresponds to the front of a p-adic-to-real phase transition proceeding to the direction of geometric future.

7.1.3 Spin glass model of memories

One of the relatively early ideas was that the 4-dimensional quantum spin glass property of TGD universe must have fundamental role in the realization of memories. Spin glass property predicts fractal energy landscape in which there are valleys inside valleys inside valleys and memories correspond to self-organization patterns associated with subself having interpretation as processes leading to bottoms of various valleys. In TGD framework energy minima are replaced by the maxima of Kähler function defining configuration space geometry as a function of zero modes which are effectively classical variables in the sense that in each quantum jump a complete localization occurs in these variables. One can also consider the interpretation of 'energy' as binding energy of bound states as function of zero modes. The higher the value of the binding energy, the deeper the valley, and the

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higher the probability that system ends up to the bound state and the longer the time spent in the bound state.

One can also regard life as a process of carving a 4-dimensional statue gradually quantum jump by quantum jump. The longer the extension of the valley in the temporal direction and the larger the number of copies of the valley is, the more reliable the memory recall is. The best manner to learn to remember is to remember. The depth of emotion determines how deep and long in temporal direction the valleys representing memories are.

7.1.4   Mirror mechanism

MEs provide a mechanism of long term memory which differs from ordinary sensory perception only in that the ME giving rise to a geometric memory has much longer duration with respect to the geometric time than the ME giving rise to ordinary sensory perception. To remember something at temporal distance T in the past is to look at a mirror with length $L = cT/2$. The mirrors in question must have astrophysical sizes measured in light years typically and this of course raises obvious objections against the model. Although this mechanism as such is too strong an idealization, it can serve as a starting point. For instance, MEs can be also curvilinear and could propagate along closed magnetic flux loops of the personal magnetic body serving effectively as wave cavities and suffer few reflections: this would make possible high precision targeting.

At quantum level remembering means sharing of mental images: this corresponds to the quantum entanglement between the subselves of the geometric now and of the geometric past. The classical non-determinism of Kähler action is essential in making possible entanglement between systems having timelike separation. This would be the mechanism of episodal memory, For non-episodal memories only the the mental image representing the desire to remember would be shared, and the answer from the geometric past could be realized as classical communications using MEs. Commmunication would be based on some code, perhaps memetic code, and would generate a conscious experience in the receiving end, typically verbal memory. Positive energy MEs would propagate with ultra low effective phase velocity inside brain or along magnetic flux tubes of astrophysical size with sub-luminal effective velocity (say alpha wave effective velocity). The most often needed non-episodal memories, say short term memories, could be communicated automatically: in this case the memory recall would be a geometro-temporally local operation, much like taking a sample from a data stream representing particular kind of memories with a particular time span. The option is probably not realized for all non-episodal memories since this would require large energy expenditure.

In this framework synaptic strengths code only cognitive representations and learned associations, not genuine information about the events of the geometric past. Brain can be seen as kind of a collection of standardized features serving as building blocks of sensory and memory representations. Long term memory is coded in the classical em/gravitational fields associated with and in coherent light/gravitons generated by MEs in hologram like manner. Any finite spacetime region receiving the classical em field of coherent light/gravitons generated by it gets hologram like picture containing info about entire geometric time interval spanned by ME. If vacuum current is localized to some restricted spacetime region (it can be!), the hologrammic information is about this region and receiver anywhere along the ME gets more or less the same information since hologram is in question. Note also that the lightlikeness of the boundary of ME implies that ME selves have temporal extension defined by the length of ME.

7.1.5   Third person aspects of memory

Topological quantization implies the notion of field body: field body accompanies any system be it molecule or human body. Field body serves as kind of a manual providing higher level abstract representations about the quantum aspects of the physical body. The model of sensory representations realized at personal magnetic body and at Earth's magnetic body explains both the first and the third person aspects of our sensory experience. Also memories should have third person and transpersonal aspects realized at the magnetic body of Earth. This prediction is testable: moon traveller consciousness should have different third person aspect or this aspect could be even absent. Third person aspect should be crucial for the generation of social structures and the rapid weakening and reversal of Earth's magnetic field predicted to occur within next 2 millenia might have dramatic effects for the future of the civilization.

The sharing of mental images is crucial for the model of the third person aspect of memories. What happens is that subself of brain entangles with with the subself of the magnetic sensory canvas in the geometric past. One could perhaps interpret spontaneous episodal memories as a basic example of memories communicated by some subself of magnetic Mother Gaia to us.

7.1.6 Symbolic and cognitive representations of memories

Most of our memories are not direct re-experiences. In fact, it would be difficult to tell whether memory is really in question if this were the case. Rather, memories are highly conceptual and based on symbolic representations making possible huge filtering and compression of information. Only in some special cases direct re-experiencing occurs. The inherent nondeterminism of the p-adic field equations and the classical non-determinism of Kähler action make possible to represent sequences of quantum jumps determining the contents of consciousness of self at spacetime level in terms of p-adic or real spacetime sheets, that is cognitively and symbolically. Symbolic representations are crucial for memories whereas cognitive representations are crucial for intentions. Symbolic representations allow to store information about geometric past to geometric now: history writing is just this kind of activity. Also brain is doing history writing: to remember is also to form a new memory representation.

It is highly plausible that memory representations are highly abstracted and that the signals from the geometric past do not recreate directly the experience but serve as names for standardized self-organization patterns of neuronal activity, 'features' giving charicature of the experience. This means that it is not easy to distinguish between TGD based model and standard model of memories.

7.1.7 Biosupercomputers and memories

The most recent but certainly not the last step in the development of ideas was the realization of a connection between macrotemporal quantum coherence, quantum spin glass property of the TGD universe, classical and quantum gravitation, and the mirror model of geometric memories.

The interpretation of quantum jump as a creation of a totally entangled holistic state $U\Psi_i$ which is then analyzed to pieces allows to interpret self measurement cascade as a conscious analysis. The temporal fractality of consciousness suggest that the lifecycle of any self can be seen as a generation of multiverse of potentialities followed by analysis (and decay) process. One can see the situation also differently. The conscious experience of self is average over moments of consciousness and the eventual thermalization induced by the quantum jump sequence destroys all conscious information. There must be some mechanism hindering this and making macrotemporal quantum coherence possible.

To achieve macrotemporal quantum coherence self must be irreducible self for which self measurements and analysis do not occur. The self must also have large number of zero modes transformed to quantum fluctuating degrees of freedom and this is achieved if self corresponds at spacetime level to a join along boundaries condensate. In this process the zero modes of the condensing spacetime sheets become quantum fluctuating degrees of freedom. In this 'state of oneness' self is able to carry out quantum computer like information processing which is the diametrical opposite of analysis. The decay of this bound state to its components corresponds to the analysis period at the level of self.

Macrotemporal quantum coherence is possible by the quantum spin glass property of TGD universe making the lifetimes of bound states much longer than in the universe obeying standard physics. Different almost degenerate vacuum spacetimes differ only because they have different classical gravitational energies. The quantum transitions between these almost degenerate states involve emission of MEs representing gravitons. These topological graviton rays are reflected from the curved almost vacuum spacetime sheet acting as a gravitational mirror and self energy diagrams involving emission and absorption of the gravitonic ME have interpretation as correlates for the geometric memory recall. The time scale of human memories is between millisecond and 100 years and this time scale characterizes the gravitational energies for systems having sizes between cell size and cell membrane thickness (the number theoretical miracle is that all p-adic length scales in this reange correspond to Gaussian Mersennes). Microtubules are excellent candidates for realizing long term declarative memories at bit level so that a connection with Penrose-Hameroff views emerges.

7.2   Different types of memories

TGD predicts two kinds of memories corresponding to two different time developments. There is deterministic (in generalized sense) time development with respect to the geometric time and the non-deterministic time development by quantum jumps with respect to the subjective time. The memories with respect to subjective time are about previous conscious experiences and 'real' whereas geometric 'memories' are prophecies giving simulations of the geometric past and future assuming that quantum jumps do not alter the macroscopic properties of the spacetime surface. A good visualization is following: each quantum jump represents particular geometric memory whereas the heap of these memories gives rise to subjective memory. The comparison between expectations and reality is obviously a central part of mentality and the heap structure implies that this comparison is a basic function of conscious mind not reducible to anything simpler. It is wellknown that our memories involve a lot of construction and are more like stories consistent with what we actually have experienced than actual documents of what happened. Perhaps geometric memories constrainted by subjective memories give rise to the 'story'.

One can distuinguish between several memory types such as short term memory and long term memory, episodal memory, procedural memory, implicit memory and associative memory, and it is interesting to try to find whether these memories could be understood in the proposed conceptual framework. In the discussion below concrete mechanisms for the realization of geometric memory are not discussed: the reader interested on this aspect of geometric memory can consult [24].

7.2.1   Geometric and subjective memories

There are two times in TGD: subjective and geometric. In accordance with this there are also two kinds of memories: subjective and geometric[1].

1. The temporal binding of the experiences associated with quantum jumps occurred after the last "wake-up" of the self gives rise to subjective memory defined as memory about earlier conscious experiences and is identifiable as an immediate conscious memory, "phychological now", presumably of duration of fraction of second in case of sensory experiences. There is infinite hierarchy of subjective memories and if long term memories are genuine subjective memories (this need not be the case!), they could correspond to conscious short term memories of higher level selves somehow communicated to the lower level. An essential element is the possibility of subselves inside self having much shorter lifetime and organized in a subjecto-temporal sequence: without them the average over the quantum jumps would destroy the information and it would not be possible to remember the digits of a phone number. Various rhythmic actions (such as micro tremor of eyes at 80 Hz frequency and muscle tremor) could generate a sequence of subselves with constant duration and thus a clock measuring subjective time.

2. Geometric memories are like a classical physics based model for the universe. They are memories with respect to geometric rather than subjective time and predict what must have happened in the geometric past and what will happen in the geometric future assuming that world is classical (no quantum jumps). The temporal extension of the mindlike spacetime sheets and the notion of the association sequence (3-surfaces consisting of a sequence of spacelike 3-surfaces with timelike separations providing a simulation of classical history) make possible geometric memories. A natural hypothesis is that the macroscopic spacetime associated with the final state of the quantum jump represents the geometric memory. Of course, only part of it becomes conscious and temporal binding implies that self experiences kind of temporal average of the geometric memories associated with the quantum jumps. An attractive possibility is that our long term memories, which have narrative character and are unreliable, correspond to geometric memories. This would mean that there is no need for memory storage mechanisms, four-dimensional brain would take automatically care of memory storage.

Intentionality manifests itself in many ways: as expectations of the future, planning, goals, desires, fears, imagination, intuition etc.. It seems natural, and this is the only possibility given the fact that it

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[1]The attribute 'subjective', as it is used in TGD context, does not have quite the same meaning as it usually has as something non-objective and unreliable: 'subjective' derives its meaning from 'subjective time' as consciously experienced time as opposed to the geometric time of physics.

is not possible to know anything about future quantum jumps, to identify all aspects of intentionality with the predictions of the expected geometric future provided by the mindlike spacetime sheet. Geometry as such contains nothing intentional. Rather, the intentional aspects of the conscious experience reflect the attitudes towards the expectations provided by the geometric memory.

'Memories' with respect to geometric time as simulations

Geometric memories are predictions/simulations for what would happen if no further quantum jumps would occur and what would have happened if no quantum jumps had occurred in the past. Simulations and expectations rather than real memories are in question. Geometric memories become reliable in the classical limit, when the effect of quantum jumps becomes negligible. In the deterministic world of classical physics geometric memories would be absolutely reliable. It is indeed possible to predict rather reliably what will happen in the solar system during the next decade. Geometric memories are a prequisite of the intentionality often regarded as a basic characteristic of conscious mind: beliefs, expectations, plans, etc. involve geometric memory in an essential manner. The computational approach to mind assumes only geometric memories.

The memory with respect to geometric time is possible even assuming that single quantum jump determines the contents of conscious experience completely. However, if the contents of conscious experience are determined completely by the initial and final quantum histories of single quantum jump, it is in principle impossible to have genuine memories about previous conscious experiences. This does not make it impossible to have a model for the most probable subjective life history through simulation. Quantum statistical determinism could make these simulations possible. One must however admit that the hypothesis about subjective memory, naturally identifiable as a short term immediate memory defining the duration of psychological moment, makes things extremely simple and natural. One could also argue that in a universe without subjective memory it would not be possible to discover the notion of quantum jump so that internal consistency of the theory of consciousness requires genuine memory about earlier conscious experiences.

Mindlike spacetime sheets and simulations

It is a fact that we can plan future in the time scale of life time. We can also quite reliably extrapolate to the past without direct memory of what happened. The simplest explanation is that the time extension associated with those mindlike spacetime sheets, which we have access to, is of the order of lifetime or perhaps even longer. The simplest model for the simulation would be based on an ensemble of thoughts scattered around entire material spacetime history defined by, say, my body. Quark sub$-CD$s could realize thoughts as Boolean algebra of statements and could be present everywhere in condensed matter, in particular in water, which is expected to have very rich hierarchy of spacetime sheets. Self would experience the sum of the abstracted experiences of ensemble members and experience a simulation about what happens in future and what happened in past assuming that quantum jumps will not occur in future and did not occur in past.

Of course, selves could also do what computers do, namely mimick other selves by building cognitive representations about them at their own spacetime sheets. This would make it un-necessary to jump between the levels of the self hierarchy. These representation could have quite different temporal and spatial scales and the presence of the time scaled versions about time development of other selves would realize the fractality aspect related to the idea about Universe as a hologram. DNA could be an example of this kind of simulation of the entire lifespan of individual in molecular length and time scales. Monte Carlo simulation of elementary physics experiment could be also regarded as a simulation of this kind.

The difference between intentions and geometric memories

Intentionality, understood here as time-directedness, manifests itself in many ways: as expectations of future, planning, goals, desires, fears, imagination, etc.. The basic element of mentality is the comparison between the expectations of future and what actually occurred. In TGD framework this tension between potential and actual can be understood. The temporal extension of the mindlike spacetime sheet makes possible expectations of what happens in the future assuming that no quantum jumps occur or at least that quantum jumps do not change the macroscopic spacetime. Single quantum jump contains information about this kind of expectations. Subjective memory in turn tells what

happened actually. Therefore it seems natural, and this is the only possibility given the fact that it is not possible to know anything about future quantum jumps, to identify the predictions of the expected geometric future provided by the mindlike spacetime sheet as a basic prequisite of intentionality.

Subjective memory makes it possible to compare the expectations with what really occurred since subjective memory is kind of a heap of predictions of future arranged with respect to the value of the psychological time. The origin of at least some emotions, which often involve a comparison of what happened and what was expected to happen, is perhaps here. It is quite well possible that all comparisons must be realized as comparisons of the subjective and geometric time developments. It seems that self can also compare its subselves, which correspond to simultaneous mental images.

The possibility of this comparison provide a solution to the paradox raised by the innocent question 'How do I know that the me of today is the same as the me of the yesterday? How do I even know that I existed yesterday?'. The solution might be simple: mindlike spacetime sheets have extension which can be much longer than the duration of the subjective memory. Therefore subjective memories contain information about the geometric me of the yesterday and geometric me of today and since these me's resemble each other quite a lot, the conclusion is that also the yesterday's me was a conscious self living in this same body. It is however quite possible that temporal entanglement with higher selves still remembering my past wake-up states is also involved and realized as a formation of join along boundaries bonds between the mindlike spacetime sheets of my self and of higher level self. Higher level self could also communicate directly the subjective memories about my existence to me.

The difference between intentions and memories remained a puzzle for a long time. The answer was finally provided by the view about psychological time as a value of the geometric time characterizing the position of the p-adic-to-real phase transition front propagating to the direction of the geometric future. The MEs representing intentions are p-adic whereas those representing memories are real.

What is the temporal extension of mindlike spacetime sheets?

With respect to subjective time self and its subselves can be characterized by the typical durations of the wake-up state. With respect to the geometric time self (or rather, mindlike spacetime sheet) can be characterized by its own duration and the durations of the mindlike spacetime sheets which it contains. The time span for the predictions and memories provides an estimate for the duration of mindlike spacetime sheets. mindlike spacetime sheets can have timelike separations. mindlike spacetime sheets of geometric past could represent memories so that conscious memories could be regarded as multitime experiences and the distances between mindlike spacetime sheets could be quite large, of order lifetime.

Durations of mindlike spacetime sheets representing subselves

Sensory experiences seem to correspond to a well defined geometric now having perhaps duration of order .1 seconds. Thus it seems that mindlike spacetime sheets representing my sensory subselves have rather short time extension, of order .1 seconds. 'Ontogeny recapitulates phylogeny principle' (ORP) suggests that the extension is of same order as the duration of the immediate subjective memory, something like .1 seconds. This prediction is certainly consistent with the typical resolution of the sensory experience, say the ability of the visual system to discriminate subsequent pictures as separate pictures. Quite generally, the p-adic time scale $T_p = L_p/c$ characterizing the mindlike spacetime sheets gives the first guess for the duration of the mindlike spacetime sheet and duration of geometric memory provided by it. Note that .1 seconds gives for the p-adic length scale L_p and estimate which is about circumference of Earth!

The fact is that we have childhood memories, plan future and make reliable predictions. This is not in contradiction with the duration of the mindlike spacetime sheets associated with sensory subselves. The mindlike spacetime sheets representing subselves (mental images) can be located in geometric past or future so that multitime experiences with mindlike sheets of past and future contributing to the experience are possible.

The duration of .1 seconds is the duration of typical subselves representing our mental images. The geometric duration of the mindlike spacetime sheet representing our 'main self' should be much longger since it contains mindlike spacetime sheets distributed along entire life span.

The subselves which have fallen asleep, wake-up again generating new wave of sensory experience. For instance, mental images (after images) typically re-appear periodically. We are also mental images of larger self in the hierarchy and the periodical appearenc e of of our mental images suggests that

also we appear periodically as mental images of this larger self. This would mean reincarnation in the geometric past so that our life would be lived again and again. Entire trains of mindlike spacetime sheets could wander through time again and and experience what it is to live in a particular body. Therefore my body could live again and again: by p-adic evolution each life would tend to be slightly better than the previous one. The civilizations of past could be still well and alive and even more civilized! This picture could perhaps explain why persons in their old age sometimes begin to live their childhood again.

What is the subjective duration of 'our' self?

Our conscious experience is some kind of an averaged sum over all conscious experiences associated with the quantum jumps occurred after the last 'wake-up'. If the averaging is completely democratic, the only possibility is that our sensory subselves have duration not much longer than the the time resolution of the sensory experience of order .1 seconds. Contrary to the original beliefs, this does not in principle pose any limitation to the duration of 'our' self.

There are thus several options concerning the duration of our self.

1. Our self could have duration not much longer than the duration of immediate short term memories of order .1 seconds. The ability to remember digits of a phone number requires that the duration is indeed longer. For this option it is not at all obvious how the subjective experience of personal continuity is possible.

2. The duration could also correspond to the wake-up period. Also now the problem is how we know that this self existed already yesterday. Note that the gradual thermalization of subselves means that subjective memories represented by subselves get gradually fuzzy so that the digits of a phone number are forgotten even if our self has duration of order wake-up time.

3. Our self has a duration of order lifetime, or even longer and only the mental image representing our physical body has duration of order lifetime. A possible objection is that the mental image representing our self becomes gradually more and more entropic unless it manages to fight against second law. This might of course correspond to ageing.

Third option deserves a more detailed consideration.

1. The geometric duration of our 'main' mindlike spacetime sheet should be of the order of life span if geometric memory explains long term memories. 'Ontogeny recapitulates phylogeny' principle would suggest that also the subjective duration of our 'main' self is of order life time. This option would explain elegantly the fact that we possess subjective identity: this kind of subjective identity would be a logical deduction in case that our main self has duration shorter than life time.

2. This option would mean that we are not actually unconscious during sleep but are only unable to remember anything about what happened during sleep. This would be rather natural since various sensory and cognitive subselves are not conscious during sleep periods so that also multitime experiences in which sensory subselves wake-up in night time are rare! It might be also possible to remember events occurred during sleep state only during sleep.

3. Note that the claims about near death experiences in which entire life is experienced as a kind of film, could be interpreted as very intensive experiences in which mindlike spacetime sheets along the entire life span 'wake-up' and give rise to multitime geometric memories. Alternatively, if bodily self with a duration of order lifetime is a subself of our self (perhaps identifiable as the self associated with our magnetic body), the bodily self representing entire life cycle could be experienced as a mental image. Also shorter bodily subselves forming a subjectotemporal sequence, 'film', could be experienced in the absence of the ordinary sensory input.

7.2.2 Habits, skills, associations

The universe of TGD is quantum spin glass [26]. This provides extremely general conceptual framework for understanding how memories/habits/learned skills/asso- ciations are formed.

1. Mental images (in particular memories) correspond to subselves undergoing self-organizing time development by quantum jumps leading to self-organization patterns selected by dissipation. Thus both memes and genes, in particular long term memories, can be regarded as winners in the fight for survival in which dissipation is the ultimate Darwinian selector. Inhibitory and excitatory nerve pulses might physically realize "frustrations" which make possible large number of almost degenerate energy valleys.

2. The universe of TGD is quantum spin glass characterized by a fractal "energy" landscape having valleys inside ... inside valleys (directories inside...inside directories). This structure is ideal for a hierarchical representation of memories. Memories must correspond to valleys of the spin glass "energy" landscape into which dissipation takes the system. Memory formation is active process and memories are charicatures rather than photos and deep valleys of the energy landscape represent these charicatures. Hippocampus, known to be involved with the formation of the long term memories, could control the rate of motion in these control variables. The plastic regions of the brain are the most spin-glassy ones and are the most probable seats of the long term memories.

3. System has some territory in the energy landscape. The motion in the zero modes serving as control variables causes a slow shift of the entire territory. Synaptic strengths corresponds naturally to the slow control variables characterizing the position of the territory. In the presence of a metabolic energy feed and sensory input system moves around this territory.

Is genuine subjective memory really necessary?

For a long time the basic hypothesis of TGD inspired theory of consciousness was that the contents of conscious experience are determined totally by the initial and final states of *single* quantum jump. A heavy objection against this assumption is that the hypothesis makes it impossible to have genuine memories about previous conscious experiences. The concept of self however allows the possibility that the connected series of sequential quantum jumps performed by self after its last "wake-up" integrates to single conscious experience. This hypothesis realizes self as an extended object in subjective time allowing it to have memories about previous conscious experiences rather than only memories with respect to geometric time. An attractive additional assumption is that the conscious experiences of self are kind of subjecto-temporal statistical averages. This would make experiences reliable. In particular, sensory experiences can give objective reliable knowledge despite the fact that the outcomes of individual quantum jumps are not predictable. The undesired implication is that for long sequences of quantum jumps averaging leads to a total loss of information.

The original vision was that geometric memory is made possible by the finite temporal duration of the what I called mind-like sheets. The emergence of zero energy ontology led to the conclusion that all space-time sheets are mind-like since one can assign them to the interior of CDs. Depending on one's tastes one could of course refer to p-adic space-time sheets as mind-like (or cognitive). p-Adic space-time sheets are identified correlates of intentions, plans, desires,... whereas real space-time sheets would correspond to sensory experience and sensory memories. Geometric memories are about geometric past and serve as prophecies telling what would have happened if quantum jumps were not constantly replacing macroscopic space-time with a new one. Precognitions which can be only geometric tell what would happen if no further quantum jumps take place. Subjective memory makes it possible to compare what actually happened with what was expected to happen. It might be that this comparison is one of the fundamental irreducible mental acts. There is a sharp difference between ordinary memories on one hand and precognition and memories about time before birth (the region in the geometric past of the CD assignable to the 4-dimensional biological body) since the interior of 'personal' CD is in a preferred position. Interestingly, the CD corresponding to a life time of order 100 years corresponds to a primary p-adic length scale of order 10^{-7} meters and the age of the universe to 10^{-4} meters, the size scale of a large neuron.

A natural identification of the subjective memory is as immediate short term conscious memory, or actually a hierarchy of short term memories corresponding to the hierarchy of selves. This identification requires that the subjective durations of our sensory selves are typically of a fraction of second, .1 seconds is suggested by various arguments relating to the ability to experience subsequence stimuli as separate ones and corresponds to the duration of psychological moment. This time scale corresponds to the temporal size scale of the CD of electron. The narrative character of the long term memories

suggests their identification as geometric memories: long term memories could correspond to multi-time experiences with contributions coming also from the geometric past (say childhood). It turns out that this identification explains basic facts about long term memories. Declarative memories are assumed to involve negative energy signals suffering a time reflection from the brain of the geometric past. The condition that the energies of the corresponding photons are above thermal threshold can be satisfied if the value of Planck constant is large enough. The emergence of long term memory and planned action would involves in an essential manner the emergence of large values of Planck constant [17].

7.2.3 Spin glass model of learning and long term memories

The universe of TGD is quantum spin glass [26]. This provides extremely general conceptual framework for understanding how memories/habits/learned skills/associations are formed.

1. Mental images (in particular memories) correspond to subselves undergoing self-organizing time development by quantum jumps leading to self-organization patterns selected by dissipation. Thus both memes and genes, in particular long term memories, can be regarded as winners in the fight for survival in which dissipation is the ultimate Darwinian selector. Inhibitory and excitatory nerve pulses might physically realize "frustrations" which make possible large number of almost degenerate energy valleys.

2. The universe of TGD is quantum spin glass characterized by a fractal "energy" landscape having valleys inside ... inside valleys (directories inside...inside directories). This structure is ideal for a hierarhical representation of memories. Memories must correspond to valleys of the spin glass "energy" landscape into which dissipation takes the system. Memory formation is active process and memories are charicatures rather than photos and deep valleys of the energy landscape represent these charicatures. Hippocampus, known to be involved with the formation of the long term memories, could control the rate of motion in these control variables. The plastic regions of the brain are the most spin-glassy ones and are the most probable seats of the long term memories.

3. System has some territory in the energy landscape. The motion in the zero modes serving as control variables causes a slow shift of the entire territory. Synaptic strengths corresponds naturally to the slow control variables characterizing the position of the territory. In the presence of a metabolic energy feed and sensory input system moves around this territory.

One can consider two general models of learning and memory recall in this framework, the TGD version of the neural network model and the genuinely TGD based mechanism on the notion of the geometric memory. Consider first the TGD based version of the neural network model of memory.

1. The possible memories of the system correspond its territory in the "energy" landscape. Learning means slow change of the shape of the territory so that memory valleys get gradually deeper and system ends up to them with larger probability in future.

2. Repeated simulated annealing provides a promising memory recall mechanism. The feed of energy from metabolism kicks the system into a motion and dissipation leads it into some valley. If the valley is quite not correct (correct subdirectory but wrong subsubdirectory), a smaller kick leads the system to the bottom of some nearby valley which might be correct. By applying a sequence of increasingly smaller kicks system finally finds the correct memory valley. The conscious attempt to remember corresponds naturally to an external force forcing the system to move in a correct direction.

There are several objections to this scenario. The first mystery is how system knows that the experience is a memory: there seems to be nothing which would distinguish memory from the experience occurring for the first time. Second problem is that the formation of the new memories tends to destroy the old ones: the new territory is simply not the old one. Even if one could circumvent this paradox, it is difficult to understand why the lively episodal memories of childhood are the most stable ones.

If long term memories are geometric memories then memory recall mechanism corresponds to multitime experiences involving generation of mindlike spacetime sheets in both geometric now and past.

1. Learning by repetition means keeping some subsystem in some deep valley for a long period of geometric time (system is still in that valley in the geometric past!). This corresponds to reverberating patterns in neuronal circuits generated automatically or by learning by repetition. In this picture the modification of synaptic strengths is not learning of memories but just what it seems to be: a modification of responses to sensory inputs necessary for survival.

2. The attempt to remember creates mindlike spacetime sheets located in the geometric past. The probability that a newly created mindlike spacetime sheet is located in the memory valley of long time duration is high and thus conscious memory recall becomes probable. Also very emotional and 'catchy' experiences generating long lasting memory valleys are easily remembered. Childhood memories are often very emotional ones and therefore also the most stable ones.

No final vision about what memories are in TGD framework exists yet. What is certain is that one can distinguish between geometric and subjective memories. The idea that episodal memories are ordinary sensory experiences with the object of the perceptive field in the geometric past is very attractive and speculative hypothesis which might work in TGD Universe, but more conventional explanation sounds more realistic in the context provided by the standard neuroscience. What is lacking still is a clear vision about the precise physical realization of long term memories.

7.2.4   Long term memories

An important question is whether our long term memories correspond to either geometric or subjective memories or whether they involve both aspects somehow.

Long term memories as geometric memories?

The unreliability and narrativeness of the long term memories would support strongly the interpretation of at least episodal long term memories as geometric memories, that is multitime experiences involving active mindlike spacetime sheets scattered along entire life span. This option is consistent with the short duration of subjective memories, which can be even of order .1 seconds characterizing the duration of immediate sensory memories.

Geometric memories could be realized as multitime experiences involving mindlike spacetime sheets located around several moments of the geometric time, provide the simplest realization for the long term memories.

1. The model solves the basic difficulties of the neural net models of long term memory. In the neural net models long term memories are represented by synaptic strengths. The problem is that the learning of new memories destroys old memories. In particular, the stability of the childhood memories is difficult to understand. It is also hard to understand how brain knows that the experience represents memory. One cannot avoid the difficulty by saying that novelty detection tells that experience occurs for the first time since the notion of novelty does not make sense if conscious experience contains only information from single moment of geometric time.

2. TGD model is consistent with neural net models and actually generalizes them. Neural net in the spirit of TGD corresponds to brain as system moving in spin glass energy landscape. Self-organization by quantum jumps leads the system to a bottom of an energy valley representing memory. This model is consistent with the fact that there is no upper bound for autobiographical memory. One can also understand how learning occurs. The repetition of an experience means that energy valley becomes a canyon in time direction so that mindlike spacetime sheets in the geometric past have a large probability to end up to the region representing memory. In particular, reverberating nerve pulse patterns are ideal for representing long term memories.

3. Highly emotional experiences generate deep valleys and increase the probability of the system of the geometric past to stay at the bottom of valley. This explains why cildhood experiences are so stable. In fact, one could identify primitive emotions of pleasure and pain as related to the

motion in the spin glass energy landscape. Pleasure and pain could even directly correlate with the sign of the increment of the Kähler function in the hopping motion in the spin glass energy landscape. Note that primitive pleasure and pain are are very much like sensory experiences and one could regard them as sensory experiences of brain about its own motion in spin glass energy landscape. This leads to the generalization of the notions of sensory experience and motor action to include the motion in spin glass energy landscape and to a considerably new insight about the meaning of the brain architecture.

There are also perinatal experiences, memories about previous lives and transpersonal experiences having natural explanation in terms of geometric memory realized as multitime experiences associated with mindlike spacetime sheets located at different values of the geometric time. Transpersonal experiences suggests that self is dynamical: if prenatal experiences, memories about previous lives and transpersonal experiences are really what they seem to be, the geometric time extension of self should dramatically increase during these experiences.

If 'our' self has duration of order lifetime, also subjective memories can contribute to our long term memories. As already found, this option does not exclude the possibility that our long term memories correspond to subjective memories.

Geometric memories as sensory experiences with the object of the perceptive field in the geometric past?

The general theory of qualia to be developed in [24] leads to the conclusion that geometric memories could be regarded as special kind of sensory experiences for which some objects of the perceptive field located in the geometric past. One also ends up with a concrete models for the mechanism making long term memories possible by 'waking up' subselves of the geometric past in selective manner by EEG frequencies. The unavoidable conclusion is that massless extremals (MEs) with durations of order lifetime, and hence with sizes which are measured in light years, are necessarily involved. Needless to say, one must give up the idea that we are nothing but our brains.

The fact that the lightlike boundaries of MEs serve as quantum holograms and have gigantic information storage capacities by the almost degeneracy of the states fits nicely with view. Lightlikeness means that 3-dimensional time=constant slice of Minkowski space is replaced with a slice which can have arbitrary long temporal duration so that memories become indeed possible. The fact that at least vision represents directly information about outer surfaces of 3-dimensional objects rather than objects themselves but contains information about time development over an interval of order .1 seconds fits nicely with this view.

The realization of long term memories in terms of magnetic quantum phase transitions induced by ME frequencies requires incredibly high frequency resolution. The resolution is of order $\Delta f/f \sim \Delta T/T$ giving $\Delta f/f \sim 10^{-9}$ for time resolution of about $\Delta T = 1$ seconds. An unrealistically high frequency resolution is required if temporal coding by EEG frequencies is assumed. There is also another problem: if the signal to the geometric past and back is between parts of brain, one cannot avoid zigzag type MEs effectively representing a repeated reflection between two mirrors. In the p-adic context these zigzag MEs are allowed by conservation laws (this might relate with the fact that long term memories are mostly cognitive) but not in the real context.

These observations suggests that one should allow MEs and magnetic flux tube structures with length scales of order light lifetime and try to invent a more elegant mechanism of long term memory. One might start from the mirror idea and consider the possibility that memory recall involves a question sent to the geometric past as a classical signal reflected back to brain in a mirror formed by a magnetic flux tube: perhaps passive MEs are involved at this stage. Thus MEs with lengths of order of light lifetime ($L = cT$) would be required. The answer could involves a transformation of passive MEs to active em MEs and the generation of quantum entanglement unless it is present already: the recalled experience is shared by the experiencer now and experiencer in the geometric past. The mechanism involves several purely TGD based features: the lightlike character of the boundaries of MEs making possible lightlike selves; spacetime sheets with a negative time orientation allowing classical signals to propagate backwards in time; the magnetic flux tube structures associated with brain having sizes of order light years making possible MEs to form mirrors. Precognition is the temporal mirror image of this mechanism.

If long term memories are in some sense sensory experiences with the object of the perceptive

field in the geometric past, the notion of the magnetic canvas should work also in these astrophysical length and time scales. Consider first the constraints on this mechanism.

1. The sensory experiences at different levels of the magnetic hierarchy cannot be identical. This means that standard sensory representation using magnetic canvas must be applied to realize the episodal memory. This leaves only two possibilities. Either the experience is coded to a lightlike vacuum current and this information, when sent into future, regenerates the sensory experience there. Alternatively, future self could entangle with the self of the geometric past and share its experience.

2. Since MEs correspond to 3-surfaces moving with light-velocity, the only possible realization of the communications between geometric past and geometric now is in terms of 'laser mirrors' connected by MEs representing geometrically the light reflected in the mirror. The length of ME is given by $L = cT$: $2T$ is the moment of the geometric past which gives rise to the memory. Interestingly, Peter Gariaev has suggested that laser mirrors are involved also with DNA [62]. This means that a ME extending from the brain of the geometric now to the geometric past and the ME from the brain of the geometric past fuse with the same magnetic flux tube to form a representation for light reflected in a cosmic mirror. The MEs and magnetic flux tube structures associated with the relevant parts of brain must form pre-existing, tightly correlated structures since the probability for the formation of this kind of mirrors accidentally is extremely small and there is no guarantee that they connect parts of the same brain. Second mirror would be obviously defined by the join along boundaries contact of ME with the magnetic flux tube. Hippocampus is a natural candidate for the brain structure, at which the first mirror is located. The fact that MEs represent channelled energy means that distance is not a problem as far as energetics is considered.

3. Active memory recall must involve a question sent to the geometric past followed by an answer communicated to future in some manner. There must be some difference between precognition and memory recall so that the question and answer cannot be realized in the same manner. This serves as an important guideline. Various arguments lead to the view that the desire to remember is communicated to the geometric past by sharing and fusion of mental images made possible by entanglement. In the case of episodal memories also the memory recall would result in this manner. For non-episodal memories the memory would be communicated from the geometric past using classical communications.

   Sharing of mental images if time-like quantum entanglement is generated between the selves of the geometric past and geometric now. This is possible in TGD framework, thanks to the non-determinism of Kähler action making also MEs quantum holograms in quantum gravitational sense. The fact that MEs represent lightlike selves, would be essential for this realization. The beauty of this realization is that the information need not be transferred classically. This realization is actually a special case of the realization in terms of zigzag ME in much shorter length scale: in this case a huge number of reflections in the mirror pair would be required and it is difficult to understand how one could control the temporal position of the self of the geometric past in this kind of situation.

This picture deserves some further comments.

1. If the higher levels of the magnetic self hierarchy are intelligent as one might expect (and even more intelligent than us), one can also consider the possibility that the step in which the interaction of ME representing a question sent to the geometric past with the magnetic flux tube at the higher level of the hierarchy is far from a mechanical interaction. Rather, the magnetic flux tube structure could act as an intelligent conscious system rather than a mechanical relay station.

2. The process could also have interpretation as an exchange of two virtual MEs between brain and magnetic flux tube structure: kind of a very low frequency counterpart of self energy Feynmann diagram realized as a generalized Bohr orbit. The Feynmann diagrams for the emission of parallel photons are infrared divergent. This encourages the expectation that the probability for the presence of MEs parallel to the magnetic flux tubes is very high and increases with the

increasing length of ME. The spontaneity of the episodal memories is in accordance with this view. An interesting question is how these MEs relate to $1/f$ noise.

3. The assumption that the lengths scales of MEs and magnetic structures are identical implies that the frequency of EEG ME equal to the magnetic transition frequency f_m fixes the length of the two MEs involved and thus the temporal location of the long term memory in the geometric past:

$$T = \frac{2}{f_m} \quad .$$

This represents a frequency coding for the temporal location but in a manner different from the one proposed originally. In particular, this coding does not require ME frequencies to be in EEG range and defined with a relative accuracy of order $E - 9$. In standard physics the idea about brain generating MEs with a frequency scale of the order of the inverse of lifetime does not make sense: in TGD context situation is different since this process occurs in subjective time.

If this picture has captured something essential from the nature of the long term memories, the conclusion is that we are not at the top of the magnetic sensory hierarchy. Human body and brain generates extremely weak magnetic fields and the corresponding magnetic flux tube structures could serve as a sensory canvas making possible long term memories. Near death experiences [19] could be understood in this framework if the weak magnetic fields associated with the higher levels of the fractal hierarchy of magnetic structures utilize brain and body as kind of sensory and motor organs. Note that there is flux tubes inside flux tubes structure so that ordinary sensory experiences can be associated also with these flux tubes.

Long term memories as memories of higher level self?

The natural identification of the immediate short term memory as subjective memory predicts that the life time of a human sensory self cannot be much longer than .1 seconds, the duration of psychological moment of time. Our long term memories correspond to much longer time interval and cannot thus correspond to our subjective memories. Entire hierarchy of subjective memories is however predicted and a possible model for *genuine* long term memories is as resulting from temporary entanglement with selves belonging to the higher level of the hierarchy. Also this identification is consistent with the fact that there seems to be no upper bound on autobiographical memory. Summation hypothesis implies that our genuine long term memories would be sums over a large number of wake-up periods of self in the subjective past of the self. Therefore one could perhaps understand how ageing self gains gradually wisdom from experience: also the identification of the long term memories as geometric memories explains this.

Higher level selves could communicate their subjective and geometric memories as well as the emotions generated by their comparison to us. The first idea to come into mind is that communications occur during totally entangled state, sleep or trance. For this option it is not at all clear how the experiences of the higher level selves during entangled state could be ours! In fact, we should lose our selves during entanglement with self characterized by larger p-adic prime. For instance, during sleep without dreams entanglement with some higher level self should occur and we do not remember anything about this. Trance is a second example of this: subject person does not remember anything about the trance state. Thus it seems that this mechanism cannot give rise to conscious long term memories. This does not however exclude the possibility that cognitive representations are formed during the communication and lower level self experiences them later as memories. One function of sleep might be the generation of the entanglement with higher selves making in turn possible the communication of genuine memories of subjective past to our mind. This communication could realize these memories as thoughts about the experiences of past realized as nerve pulse patterns regenerating these thoughts.

The so called semitrance mechanism [21] avoids the objections against communications occurring in totally entangled state. During semitrance parts of brain are entangled with some higher level self. These selves can communicate their memories to that part of brain which is awake (communication means generation of mental images). Ancient men received these communications as sensory hallucinations ('God's voice'), very much like schizophrenics, whereas modern man experiences them as

thoughts and emotions which are often 'hallicinatory' in the sense that they are not automatic reactions to the sensory input. The TGD based vision for the development of language and civilization modifies Jaynes's vision about bicameral man as a schizophrenic of modern society and relies on the notion of semitrance. Semitrance mechanism is extremely general and could be present in all length scales. For instance, semitrance could provide the inhabitants of cell societies (organisms) and protein societies (cells) with a personal self narrative (genetic determination of cell as self narrative!).

Semitrance mechanism survives the most obvious counter arguments.

1. The general objection is that the memories of the higher level selves are rather abstract. The assumption communication mechanism is restricted to thoughts and emotions is however consistent with the abstract nature of the non-episodal long term memories. The most natural identification of episodal memories is indeed as personal geometric memories or possibly as artificially generated sensory hallucinations stimulated by higher level self during semitrance.

2. Since semitrance mechanism is only a communication method, geometric and subjective memories remain the fundamental memory mechanisms. Therefore the nice features of the geometric memory are not lost. For instance, one can understand learning and the role of emotions and repetition in learning.

More complicated scenarios

One can consider also more complicated scenarios for realizing long term memories.

1. Ensemble of mindlike spacetime sheets could generate continuously cognitive representations remaining in ideal case unchanged and memories as ability to re-experience would be carried by mindlike spacetime sheet when it wanders to the direction of future. This would require that mindlike spacetime sheets replicate just as material spacetime sheets (DNA, cells, members of species) do. If mindlike spacetime sheets responsible for memories of this kind have finite lifetime, say of order one second, short term memories could be realized in this manner without cognitive population explosion. In fact, cell division might realize long term memories in cell populations. Perhaps also DNA replication might be regarded as this kind of memory.

2. The realization of long term memory and communication relying on replication is rather primitive and the fact is that neurons do not replicate. A natural explanation is that neurons have discovered procedural memory, which means that long term memories could be realized dynamically: standardized nerve pulse patterns generate standardized temporal patterns of quark magnetization. This implies ability to regenerate the thought stimulated by the primary experience and associative learning would associate memories to experiences as thoughts. This picture would correspond to that of ordinary associative nets and is subject to the standard counter arguments such as the loss of old memories caused by the learning of the new ones.

3. Sustainment of the mental images is indeed one of the basic mechanisms behind human intelligence and can be also seen as a manner to enhance the probability that a geometric memory in the past is recalled. Sustained mental images are analogous to the icons of the computer screen, which in fact supports the idea that the evolution of computers mimics in many respects the evolution of the brain. At program level icons correspond to program loops. At neural level to periodic neural process generating again and again the same mental image (not necessarily directly conscious to us).

4. Written language and symbols are the next step to the internal sustainment and make possible to achieve a given sensory and cognitive experience in a controlled manner. Program files are obviously analogous to the written language (the electronic control systems preceding the computer era were effectively computer programs but were not written as computer code, externalized). DNA could be seen also as ROM type memory of living systems.

7.2.5   Implicit memories

A possible definition of implicit memories is as memories which exist but are not created in conscious experience of the subject person. Also implicit learning could be defined in this manner. A good

example of implicit memory is provided by a situation in which unaesthetized patient can quite accurately remember what has been said during the operation [47]. An example of implicit learning is the learning of grammatical rules without any explicit (conscious) representation for them. The status of the implicit memories and learning is not established. A possible reason for this is that it is not easy to understand them in computational paradigm of consciousness. Connectionism explains implicit learning and memories as unconscious formation of associations and mathematically modelled by the dynamics of the neural networks.

In TGD framework implicit learning and memories could correspond to learning and memories at the lower levels of the self hierarchy not usually conscious to us. In case that the mindlike spacetime sheet corresponding to our subself forms join along boundaries bond with a lower level self so that lower level self fuses with the subself in question, its memories can become our conscious memories. ORP suggests that this process involves also the formation of quantum entanglement and this indeed must occur. Biofeedback could be understand as a special case of this process. In the TGD based model for the quantum correlates of the sensory qualia this process is key role. The memories communicated by semitrance mechanism can indeed be and probably often are implicit.

One can consider also formation of join along boundaries bonds between our subselves and subselves of other persons. This is quite possible if our subselves indeed correspond to topological field quanta representing ELF photons associated with the EEG frequencies having size of even size of Earth. Formation of join along boundaries contacts between topological field quanta of this size would make for us to experience the memories of other persons. This kind of mechanism could explain the memories of anesthetized patient about what happened during the operation as memories of subselves of the persons participating the operation. An open question is whether the mechanism could also explain also out-of body experiences, in which patient looks himself from outside, sometimes involved with this kind of situations.

Implicit learning could also correspond to the development of various cognitive skills realized as self-organized self cascades so that no explicit representation of the skill is needed: when initial value self wakes up, the cascade proceeds with highly predictable manner due to quantum statistical determinism. Even the ontogeny could be regarded as this kind of skill implicitely coded in DNA!

7.2.6 Procedural memories

Procedural memories seem to be mostly stabilized sequences of thoughts and mental images and the proposed model for cascade like generations of selves provides therefore a model for procedural memory. Procedural memories could be simple cognitive acts occurring again and again as a reaction to some specific stimulus. mindlike spacetime sheet would carry them while drifting into the future. For an ensemble of selves with each self initiating cognitive acts is in question, reliability of memories would result.

Quantum spin glass model of brain explanains for formation of the procedural as resulting from quantum self-organization. Dissipation caused by quantum jumps would automatically select skills, habits and eigen behaviours as surviving self-organizing patterns. These patterns would correspond to deep valleys in the fractal energy landscape of the spin glass landscape, which is effectively four-dimensional. Repetition would automatically lead to the learning of procedural memories since it would extend the valleys in time direction so that mindlike spacetime sheets would have larger probability to enter to the valley and give rise to memory. For instance, reverbrating nerve pulse patters in the memory circuits of brain would realize this repetition.

7.3 Model for long term memories

In the following an attempt is made to understand how long term memories could be realized at neuronal level. I hope that my fragmentary knowledge about the details of brain science would not mask from the reader the beauty and simplicity of the general mechanism. The model is constructed first at general level and then basic facts about long term memory are discussed in the framework of the model.

7.3.1   General ideas

In TGD framework one can make a precise distinction between genuine memories and apparent memories such as procedural and implicit memories, associations, feature recognition, and standardized neuronal 'features' serving as building blocks of memories. The basic question is whether the representations of the long term memories are realized in the brain geometrically now or in the brain of the geometric past. In TGD the latter option is allowed by timelike quantum entanglement made possible by the non-determinism of Kähler action. The very fact that the memory storage of past memories to the geometric now is not needed, means that there is no need to carve long term memories to associative structures so that geometric now would contain representations about moments of the geometric past. Only the representation of the event at time when it occurred is needed. For example, this implies that long term potentiation (LTP) is just learning and adaptation to a new situation and can only be related to the modification of memory representations and possibly the construction of new standardized features.

Mirror mechanism

Mirror mechanism is the simplest quantum mechanism of episodal memories and involves only a sharing of mental images by entanglement. The brain hemisphere sends a negative energy ME to the geometric past reflected at a large distance and returning back to the hemisphere and induces a sharing of mental images. The desire to remember something and the memory of the past fuse to a single mental image shared by the brains of the geometric past and now. The desire to remember would be communicated to the geometric past also in case of non-episodal memories whereas memory itself would be communicated classically by positive energy MEs.

In a more realistic situation multiple reflections for a curvilinear negative energy ME along a closed magnetic flux loop would occur and guarantee precisely targed communications to the geometric past. The sizes of these loops would be measured in light years. MEs and magnetic flux loops associated with the personal magnetic body are the most realistic candidates since in this case the interaction with matter is minimized.

The notion of memory field supports this idea. Retrograde amnesia leads to a selective loss of memories in some time interval, and the notion of memory field provides a possible explanation. This means that brain structures with a given memory field entangle with those events of the geometric past which are located in some time interval ΔT at temporal distance T in the past. A closed magnetic flux tube with a given length $L(T)$ would obviously be a correlate for a memory field with a given time span T.

The sharing of mental images mechanism requires only that gravitational MEs take care of only quantum entanglement and because it allows arbitrary kinds of episodal long term memories. The electric stimulation of neurons can induce complex episodal memories. This can be understood if the episodal memory recall involves only the entanglement by the negative energy ME and the field pattern associated with ME does not matter at all. The unique experimental signature of the quantum entanglement mechanism is that no direct correlates for the memories themselves are necessary in the brain geometrically now. One can wonder what distinguishes the resulting experience from precognition by the self of the geometric past: could it be that to precognize now is to remember in the geometric future?

The direct sharing of sensory experience is non-economical in the sense that the amount of the irrelevant information is very high. The conceptualization involved with the symbolic representation allows to represent only the absolutely essential aspects. In case of classical communications symbolic representations is of course the only practical possibility. Since the brain of the geometric past serves as a passive entangler and does not have the possibility to process the communicated information, the sharing of the mental images is not flexible enough and does not allow an active precisely targeted memory recall. It is also very difficult to tell whether sensory experience represents memory or a genuine experience.

Classical communications and non-episodal memories

For non-episodal memories classical communication mechanism suggests itself as a more appropriate mechanism. Classical signalling requires the coding of the data to the shape of the field pattern propa-

gating along positive energy ME, which could be curvilinear and analogous to a radiation propagating in a wave cavity defined by a magnetic loop of the magnetic body.

MEs are indeed optimal for the coding of the classical signal since the vacuum current for given moment of geometric time is non-deterministic. Classical communications would allow and also require the minimization of the data communicated. These memories would not be sensory unless back-projection to the sensory organs is involved at the receiving end. The formation of the symbolic representation is subject to errors: for instance, temporal order of events can change. It is known that declarative memories can often involve changes of the temporal order. It must be emphasized that declarative need not be synonymous with non-episodal. Declarative memories could be also episodal and correspond to sharing of a symbolic mental images of the geometric past. The "features" of Freeman [47] having during of about .1 seconds are good candidates for the representation of the classical signals and the time scale suggests that electron's causal diamond is involved as also quark CDs with time scale of 1 ms. If EEG MEs are involved, the modulation of hippocampal theta frequency is a candidate for the representations of classical signal.

There are are two basic options for how the classical communication could occur.

1. Positive energy ME would not leave brain at all and would therefore have ultra slow effective phase velocity along the brain structure in question, say axon, so that it would not leave brain during its travel to the geometric future.

2. Positive energy ME would be curvilinear and parallel with magnetic flux loop of the personal magnetic body serving effectively as a wave guide. In this case the reduction of the phase velocity to EEG wave phase velocity would be enough. For instance, for the phase velocity of alpha waves propagating along loops with the size of the order of the Earth's circumference, the time span of the memory would be of the order of one year. In this picture one of the functions of the part of EEG representing evoked responses could be classical communications making possible non-episodal memories. Only part of these memories would be conscious to us. The length of the magnetic loops is expected to directly correlate with the period of EEG frequency involved with the classical communication via the relationship $L = vT$ would provide a second correlate for the notion of the memory field. There are indeed reasons to expect that the structures communicating signals to the geometric future are specialized to communicate signals to a certain distance.

The most plausible neurophysiological excitations associated with the received signal are Ca^{++} waves known to have extremely wide velocity spectrum. For the option a) the required velocity would be of order neuronal sizes per year, and this is perhaps unrealistically low velocity. It is also difficult to see how the neuronal noise would not spoil the signal. For the option b) the positive energy ME entering brain at the moment of memory receival would induce Ca^{++} waves in turn inducing neural activity.

For classical signalling the transformation of the classical signal to a conscious experience is needed. MEs could directly generate membrane oscillations and nerve pulse patterns via the general mechanism of nerve pulse and EEG discussed in [18]. EEG MEs could in turn induce cyclotron transitions at the magnetic flux tubes of the Earth's magnetic field in turn affecting nerve pulse generation. Also a transformation of the signal to Ca^{++} waves could be possible. The conscious experience does not involve sensory component unless there is back-projection to the level of sensory organs involved.

Interesting questions relate to the interpretation of the ultraslow effective phase velocity of MEs acting as bridges connecting two space-time sheets.

1. The classical fields from a larger spacetime sheet A can be transferred to a smaller spacetime sheet B topologically condensed on A by inducing the motion of the wormhole contacts, which in turn generate classical fields at the smaller space-time sheet. The fields can also penetrate along join along boundaries bonds connecting the boundaries of two space-time sheets.

2. Quite generally, the "topological" half of Maxwell's field equations implies that tangential component of E and normal component of B are continuous at the junctions connecting the boundaries of two space-time sheets. One could assume that quantum effects can be modelled phenomenologically by introducing the phenomenological D and H fields introduced also in the Maxwell's theory. In the Maxwell's theory the discontinuity of the normal component of the D field equals

to the density of the free surface charges and the discontinuity of the tangential component of the H field equals to the free surface current. These conditions can be assumed also now, at least as the first approximation.

3. One could model the propagation of MEs topologically condensed at a spacetime sheet labelled by a p-adic prime $p \simeq 2^k$, k prime or power of prime, by introducing the di-electric constant $\epsilon(k)$ and the relative permeability $\mu(k)$ satisfying the condition $\epsilon(k)\mu(k) = 1/v^2 > 1/c^2 = 1$, where v is the effective phase velocity of ME depending in general on its fundamental frequency. The fields D and H would be defined as $D = \epsilon(k)E$, $H = B/\mu(k)$: this condition generalizes to that for the Fourier components of the fields. The reduction of the effective velocity for the propagation of the topologically condensed MEs to say alpha wave phase velocity does not seem plausible.

4. The propagation of MEs which serve as bridges between boundaries of two spacetime sheets (say cell membrane spacetime sheet and cell exterior spacetime sheet) must be modelled differently. One could introduce a generalized di-electric constant $\epsilon(k_1, k_2)$ and permeability $\mu(k_1, k_2)$ characterizing the pair of spacetime sheets such that the effective phase velocity $v(k_1, k_2)$ of MEs acting as bridges satisfies $\epsilon(k_1, k_2)\mu(k_1, k_2) = 1/v^2(k_1, k_2)$, and also now depend on the fundamental frequency of ME. A very large value of $\epsilon(k_1, k_2)$ implying the needed very small value of the effective phase velocity would mean that the orthogonal component of the electric field does not appreciably penetrate inside ME from either spacetime sheet. Since MEs are the fundamental topological field quanta, this looks a natural assumption. The extremely low effective phase velocity should be due to the replacement of the wormhole contact coupling with the join along boundaries coupling causing the "stucking" of MEs. Note that the join along boundaries coupling is topological sum coupling for boundaries whereas wormhole contacts represent topological sum coupling for interior. Furthermore, join along boundaries contacts can have a macroscopic size whereas wormhole contacts are CP_2-sized: this could explain the huge reduction of the effective phase velocity for the boundary MEs.

Negative energy MEs as ideal entanglers with the geometric past

MEs with negative energies are especially favoured for quantum communications. The reasons are many-fold. The interaction with the matter is very weak in long length scales but strong in cellular length scales, negative energy implies that ME is identifiable as a virtual particle and analogous to a part of a Feynmann diagram so that no dissipation is involved and quantum communication is possible. The reversal of the arrow of geometric time means also that there is not macroscopic dissipative dynamics which would spoil the quantum coherence.

The requirement that the entanglement process is highly selective suggests a resonance mechanism. This requires that receiving and sending structures are similar and generate ULF MEs with fundamental frequencies measured typically in cycles per year. If negative energy energy ME is in question, as suggested by the idea that a classical communication to the geometric past is involved, it cannot be emitted unless there exists a receiver absorbing the negative energy and in this manner providing energy for the sender by buy now-let others pay mechanism. For negative energy MEs resonance mechanism plus a simple classical signal serving as a a password could also guarantee that correct part of the brain receives the signal.

Negative energy MEs represent time reversed level of the p-adic length scale hierarchy so that the dissipative effects associated with the space-time sheets with the normal arrow of time should not interfere with the quantum communication. This at least, when the energy of the negative energy ME has a magnitude larger than the thermal energy associated with the space-time sheets with which it interacts: there is simply no system which could make a transition to a lower energy state by the absorption of a negative energy ME. Furthermore, since the systems with reversed arrow of geometric time are expected to have extremely low density, the dissipative effects in the reversed direction of time are expected to be small.

Since the generation of negative energy MEs does not require energy feed, the memory recall to the geometric past occurs more or less spontaneously, and the scanning of the geometric past becomes possible. The intentionality of the memory recall would be realized as generation of a p-adic ME transforming to a negative energy ME, when the real system jumps to a higher energy state. This process makes possible precisely targeted intention also in the case of memory recall since the

transitions in question cannot occur spontaneously. In the case of precognition precognizer must intentionally receive negative energy MEs from the geometric future so that energy feed is needed. This perhaps explains why precognition is so rare. Note that p-adic variant of pre-cognition having interpretation as intentionality occurs easily since p-adic energy is conserved only in a piecewise manner.

The most often needed non-episodal memories, say short term memories, could be communicated automatically: in this case the memory recall would be a geometro-temporally local operation, much like taking a sample from a data stream representing particular kind of memories with a particular time span. The option is probably not realized for all non-episodal memories since this would require large energy expenditure.

7.3.2 Could gravitation have something to do with long term memories?

Could classical gravitation stabilize irreducible bound state entanglement?

Bound state entanglement gives rise to a 'state of oneness' in which quantum computing system is totally bound-state entangled and does not decay into subselves in self measurement process and can thus behave effectively as a non-dissipating system and quantum compute. The estimates for the duration of this kind of bound states tend to be much shorter than required [39]. The question is whether classical gravitational interaction could somehow stabilize these bound states.

The extremely low value of the gravitational binding energy is an objection against the view that gravitational interaction could help to stabilize the bound states. The huge degeneracy of the bound states could however change the situation.

1. Suppose that spin glass degeneracy gives rise to a huge number of almost degenerate bound states for which only the classical gravitational energy is different and that for non-bound states this degeneracy is much smaller. The dominant part of the binding energy is of course something else than gravitational. If this is the case, the number of the bound states is so large as compared to the number of unbound states that the branching ratio for the decay to unbound state is very small and bound state entanglement can last for much longer time as usually. Although the lifetime of an individual bound state need not increase, the time spent in bound states and defining decoherence time become much longer than predicted by standard physics.

2. If the join along boundaries bonds are sufficiently near to vacuum extremals, they indeed allow immense spin glass degeneracy with slightly different gravitational interaction energies and the desired situation can be achieved.

3. This argument can be refined by using unitarity. If the net rate for the transitions to bound states is enhanced by the degeneracy of the bound states, probability conservation implies that the probability for the occurrence of decohering decays is reduced correspondingly.

A rough order of magnitude estimate for the gravitational binding energy for a cubic blob of water (that is living matter) having size given by p-adic length scale $L(k)$ is

$$E_{gr}(cubic, k) \sim \frac{GM^2}{L(k)} = G\rho^2 L^5(k) \sim \frac{Gm_p^2}{L(137)} \frac{L^5(k)}{L^5(137)} \simeq 2^{-127} 2^{5/2(k-137)} \frac{1}{L(137)} \quad .$$

Gravitational binding energy is larger than the p-adic energy $2\pi/L(k)$ for $L(k = 179) \simeq .169$ mm. In the range $L(163) = 640$ nm and $L(167) = 2.56$ μm gravitational binding frequency varies between 1 Hz and 1 kHz, that is over EEG range up to the maximal frequency of nerve pulses. If the binding energy gives estimate for the lifetime of the gravitationally bound states, this might fit nicely with EEG energies in typical cell length scales!

For $k = 157$ and $k = 151$ (the range from cell 10 nm-80 nm, microtubules are at the lower end of this range) the gravitational binding frequency corresponds to a time scale of 8.5 hours and 32 years respectively so that the time scales relevant for life are spanned by the Gaussian Mersennes. What sounds paradoxal is that short length scales would correspond to long time scales but this indeed follows from the inverse square law for the gravitational force.

One can perform a similar estimate for linear structures. Parametrizing the microtubular transversal area to be $d = x^2 L^2(151)$, $L(151) = 10$ nm, one has

$$E_{gr}(lin, k) = x^5 \times E_{gr}(cubic, 151) \frac{L(k)}{L(151)} \quad .$$

This gives for $L(k) \sim 1$ meter, the frequency of $.1 \times x^5$ Hz. The time scale varies between $10/x^5$ seconds and $32/x^5$ years and certainly covers the time scale for human long term memories. Of course, this rough estimate involves numerical factor which can increase the upper bound.

Note that the increments of the gravitational energy between transitions between almost degenerate bound states are some fraction of the gravitational binding energy. Also the gravitational interaction energy associated with the classical em fields could contribute significantly to the density of the gravitational energy in TGD framework and tend to increase the overall energy scale. The reason is that the gravitational constant associated with classical fields is roughly 10^8 times larger than the ordinary gravitational constant [19]. Thus, if the energy of classical fields is more than $10^{-8}m_p \sim 10$ eV per proton the classical field energy of, say, join along boundaries bonds becomes significant factor. Since hydrogen ground state binding energy is about 13 eV, this kind of energy density per atomic volume looks quite reasonable in case of water.

TGD universe is quantum critical system in the sense that spacetime sheets representing magnetic and electric fields with arbitrary large sizes are present and correspond to two phases in equilibrium (compare with ice and water at melting point). Electric-magnetic duality is second fundamental symmetry of quantum TGD. Magnetic flux tubes carrying constant magnetic field (in lowest order approximation) have as their duals spacetime regions carrying electric fields (constant in lowest order approximation). In biosystems various electrets and magnetic flux tube structures are the concrete realization of these two phases. Classical gravitational effects generate vacuum 4-currents near the boundaries of these structures serving as sources of magnetic resp. electric fields. The boundaries of these structures are singularities of the classical gravitational fields and these gravitational fields are good candidates for generating gravitional MEs responsible for long term memories.

Long term memory and gravitational MEs

Interestingly, MEs (topological light rays) with fundamental frequencies with time scale measured using year as a unit are needed in the mirror model of long term memories (to remember event at a distance of T in past is to look in mirror at a distance $L = cT/2$). The gravitational transitions between huge number of almost degenerate spin glass states could be coded to the fundamental frequencies of MEs. In particular, structures with sizes slightly above cell membrane thickness, such as microtubules, could generate these MEs as the topological correlates of graviton emission with frequency equal to the increment of the gravitational binding energy in quantum jump involved. Thus there would be a direct correlation with long term memories and microtubules: microtubule conformations could code for long term memories.

The mirror mechanism of long term memory has beautiful interpretation in terms of topological correlates for virtual graviton exchange with vacuum.

1. The light reflected in mirror corresponds to topological light rays assignable to gravitons and is reflected from the curved vacuum. Topological counterpart of virtual graviton is emitted by (say) tubulin, absorbed by vacuum and and emitted again by vacuum, and finally absorbed by tubulin. Curved vacuum acts as a mirror for gravitons and you see yourself in this mirror.

2. Why gravitons are the only possibility in time scale of years is simply that they interact so weakly that they can propagate light years before absorbed by curved vacuum. Time scales come out correctly and microtubules are known to be crucial for long term memories (Altzheimer's disease involves changes at microtubular level).

3. There are also genuine vacuum extremals interpretable as topological graviton rays. These graviton rays could reduce to vacuum MEs except in the turning point. This would mean 'self-reflection' without scattering from background and interpretable as an absorption and emission of a virtual graviton. In case of nonvacuum extremals, classical momentum conservation however requires that the topological graviton exchanges momentum with the background spacetime surface and thus is mirrored from it.

4. One could interpret the low energy topological graviton rays responsible for long term memory as a particular kind of $1/f$ noise accompanying all critical systems, in particular TGD Universe, which can be regarded as a quantum critical quantum spin glass. Gravitonic $1/f$ noise would be emitted in the transitions between almost degenerate spin glass states and would be kind of analog for gravitational brehmstrahlung.

If this view is correct, the time scales of long term memory at DNA level would correspond to very long time scales characterizing consciousness at the level of species. As a matter fact, the gravitational binding energy associated with $L(139) \sim .1$ nm (atomic physics) corresponds to the age of the universe: perhaps this explains why Schröedinger equation applies to the description of atom. $1/R$ dependence of the gravitational interaction energy would explain why very short length scales code biological information about very long time scales rather than vice versa.

7.3.3   Is the right brain hemisphere the quantum entangler?

There are some reasons to suspect that the quantum communications with the geometric past occur more dominantly in the right brain hemisphere whereas classical communications would occur in the left hemisphere. This would explain among other things the holistic aspects of right brain consciousness. Left brain hemisphere is specialized more to symbolic processing of information and would indeed be more suitable to classical communication of this information.

Clearly, right brain would be passive receiver whereas left brain would be active expresser. DNA strands would be an example of this dichotomy at molecular level. This dichotomy would be realized also at the level of gene expression using MEs as the model of biophotons involving in essential manner negative and positive energy MEs suggets. Of course, this statement must be take only in the spirit of fractality and wuold hold true only in certain range of p-adic time scales.

The following arguments lend some support for the proposed division of labour between right and left brain hemispheres.

Synesthesia as a key to the mechanism of episodal memory

What forces brain region to send negative energy MEs and thus to remember? "Hunger!" is the possible answer! During synesthesia the metabolism in the left cortex is reduced by by 18 per cent due to the abnormally high metabolism in memory circuit (for the model of synesthesia see [33]). Perhaps the generation of the negative energy MEs is forced by the starvation of the neurons of the left cortex induced by the over-activity of the neurons of the memory coordination circuit. The starving cortical neurons of the left hemisphere would send massive amounts of negative energy MEs to the direction of the geometric past inducing entanglement bridges by the mirror mechanism with the brain of the geometric past in turn inducing episodal long term memories by the sharing of the mental images. Thus the miraculous ability of synesthetes to remember episodally could be understood to result as a by-product of a neuronal emergency reaction.

There are good reasons to expect that same mechanism might be at work also in the normal situation but involve a less dramatic artificial starvation of the neurons of the right brain hemisphere. Clearly, the role of hippocampus is dramatically different from what is usually believed and also forces to question the naive belief that neuronal activity is a measure of the contribution of brain area to the conscious experience. While building long term memory representations as classical signals hippocampus and memory circuit would steal energy from certain areas of cortex, and the resulting metabolic starvation would force them to send negative energy MEs to gain energy in this manner. This in turn would lead to the generation of long term episodal or non-episodal memories as a side product. Quite generally it is known that limbic brain and cortex tend to work in complementary modes: when the cortex is in a high state of arousal, limbic brain is in a state of low arousal and vice versa. Perhaps the passive brain region is involved with memory recall and the active one with the construction of sensory or memory representations.

Left-handedness and episodal memory

It is known that persons with many left-handed family members have better ability for episodal memory recall and that this probably relates closely to the communication between left and right hemispheres. We begin to have verbal memories only after the age of four: at this time also the

connection between right and left hemispheres has matured. The proposed mechanism of non-episodal memories requires that the right brain hemisphere shares the mental image representing the desire to remember and the left brain hemisphere communicates the memory classically. Als the communication between right and left hemisphere is necessary for this process to occur. Children before the age of four could live in a kind of a dream time experiencing mostly sensory episodal memories and presumably not being able distinguish memories from genuine experiences. This would also explain why we do not have declarative memories dating to the time before the age of four.

How could one understand the tendency of persons with many left-handed family members to have better episodal memory recall? The ability to have sensory memories can appear also when a damage occurs to the regions of the left hemisphere. It could be that classical communications between the hemispheres are worser than usually when episodal memory recall is favoured, and are replaced by quantum communications. The mental images in the left brain hemisphere would entangle with those in the right hemisphere entangling in turn with the geometric future and give rise to episodal memories. Thus the quantum communications between hemispheres might be better than usually. This kind of persons would be more "holistic" than ordinary persons.

NDEs and long term memories

That negative energy MEs could be responsible for episodal long term memories is supported by near death experiences. Persons having near death experiences are clinically dead: in particular, EEG is absent. If these persons indeed have conscious experiences and if they are able to remember them as it seems, and since EEG signals are out of question, only MEs generated during NDE remains as a viable alternative in TGD framework. Brain or possibly body should be involved with the receival of geometric memories if spin glass degeneracy is essential for the time-like entanglement by MEs.

Life review is one important aspect of the NDE experiences: entire 4-dimensional body is experienced simultaneously. The starvation of neurons forcing them to generate negative energy MEs could explain the episodal memory feats of synesthetes and the eidetic memory, and would naturally be at work also during NDE experience. This is not the only possibility. This experience might also be partially due to the absence of the dominating p-adic-to-real phase transition changing intentions to actions. This life review memory could be interpreted as geometric memories not masked by the normal contributions to the contents of consciousness. An interesting possibility is that this contribution is generated by theta and delta bands of EEG during lifetime and is present also normally but, being strongly masked, is not recognized.

Dejavu experiences and memory feats

Dejavu experiences provide a challenge for any realistic model of memory. In Dejavu the sensory experience is accompanied by the feeling 'I have experienced this already earlier'.

A natural working hypothesis is that purely sensory memories, sensory re-experiences, do not contain information about the value of the geometric time associated with the sensation. This means that sensory memories cannot be distinguished from real experiences. On the other hand, cognitive and symbolic memories differ so radically from the sensory experiences that there is no difficulty of distinguishing them from genuine experiences. Therefore one knows that the experience represented by this kind of memory occurred in geometric past or represents an expectation of future. Symbolic (real) and cognitive (p-adic) representations are very probably continually transformed to each other. If this view is correct, then the simultaneous occurrence of the sensory and cognitive memories implies dejavu experience. The event giving rise to the sensory and cognitive memories might have occurred only few seconds earlier.

This view has some nontrivial implications concerning the character of conscious experience of children. Cognitive abilities are thought to appear only after the age of four or five years. If also symbolic memories are absent, small children might live in a kind of dream time, as also members of primitive cultures, such as aboriginals, are believed to live in. Also dream consciousness could involve in an essential manner sensory memories as suggested by temporal acontinuity of dream consciousness. One could also see dreams as transformations of cognitive representations to sensory ones and such reverse to what occurs in wake-up consciousness so that surreal dream logic could basically result from p-adic non-determinism. The back projection to the sensory organs would be an essential element of the mechanism.

The absence of a temporally organized consciousness would explain why we do not possess memories from the age before four. Perhaps also the bicameral consciousness, which according to Jaynes preceided modern consciousness, was kind of dream time consciousness in which memories were direct sensory experiences, like voices experienced as voices of gods and visual hallucinations. According to Jaynes, also schizophrenics are modern bicamerals.

Some time ago I saw a TV document about some autistic persons, who have very serious cognitive defects like inability count the number of objects if it exceeds two, are capable of miraculous memory feats. One of these fascinating individuals was an artist who could draw in full detail a picture about an area of London containing thousands of buildings after havin seen the area once from a helicopter. Another autistic artist, virtuoso pianist, could reproduce every piece he had heard with highly personal style. Perhaps also great musical wunderkinds like Mozart have had similar direct sensory memory for music. Also a brain damage spoiling cognitive abilities can lead to the blossoming of exceptional artistic gifts. If the neuronal metabolic starvation forces the generation of negative energy MEs in turn giving rise to long term episodal memories then one could indeed understand how brain damage could have this kind of positive consequences.

The explanation suggesting itself is that the loss of cognitive memory is compensated by sensory memory in this kind of situations. A plausible reason for why average human being has dominantly cognitive memories is simple. Sensory memory contains huge amounts of un-necessary data: symbolic and cognitive memories have much higher survival value since only the relevant data are stored. Sensory genii have very hard time in the modern society unless they work as artists!

In light of foregoing, the poor cognitive abilities of animals suggest that also animals remember predominantly sensorily and live in dream time (note however that rats have hippocampal theta). For instance, dogs might have sensory memory dominated by odours. The challenge is to invent tests for this hypothesis. One could also try to device a non-destructive method leading to a temporary loss of cognitive consciousness and making possible to spend a day as a dog.

7.3.4   Going to the neuronal level

The following attempt to develop the model of long term memory at the neuronal level is made involves many uncertainties and must be taken as an exercise in order to get accustomed with the ideas involved.

Which parts of the brain are the quantum entanglers?

It is known that the electrical stimulation of amygdala, hippocampus, and temporal lobes can generate lively sensory memories. The simplest explanation is that quantum entanglement with the sensory representations of the geometric past is in question. The role of the electric stimulation would be only the generation of time like entanglement, not providing any information characterizing the memory. This would mean that large portions of brain can participate to the generation of episodal memories.

The fact that the part of body must be able to generate negative energy MEs with a proper ULF time scale, poses constraints on the system involved. Cellular sub-systems and microtubules are good candidates in this respect since the transition frequencies for the transitions involving change of classical gravitational are in the required range. Since resonance mechanism is probably involved, there are good reasons to believe that similar system is is involved with both the receival and sending of the message. Microtubular structures are good candidates adn accompany both neurons and glial cells.

Energetics poses also constraints. The receivers of negative energy MEs should have an easy access to the metabolic energy resources compensating the negative energy. In fact, the receiver must be in an excited state, which decays when negative energy ME is received (dropping ions to a larger space-time sheet could be also involved). Glial cells serve as metabolic resources of the brain and interact with neurons via Ca^{++} waves and are the first guess for the system entangling with negative energy MEs. Other parts of brain and body, even sensory organs, can get metabolic energy by entangling with astrocytes via negative energy MEs so that the desired sharing of mental images would indeed result.

The notion of memory field [43] was derived from the study of short term memory and applies to the neurons of the frontal lobes at least. The span T of the memory field is essentially the time span of the long term memory. T correlates strongly with the fudamental frequency associated with

the negative energy ME if quantum entanglement is involved, and the length of magnetic loop and curvilinear negative energy ME satisfies $L \sim cT = c/f$, where f is a frequency related to a transition in which gravitational energy of the system is question changes.

When f is expressed in terms of the size of the water blob generating gravitational negative energy ME in spin glass transition this gives $T \propto L^{-5}$, where L is the size of the water blob serving as a gravitational quantum antenna. MEs with T varying in the range 8.5 hours- 32 years in the length scale range 80 nm-10 nm are generated. One day (24 hours) would correspond to a length scale 33 nanometers: 3.3 times the thickness of the cell membrane. In case of neurons only the intracellular structures having much larger sizes and much higher gravitational binding energies might serve as entanglers (larger spacetime sheets would be in question) and give rise to short term memory. The time scale of 1 minute corresponds to about .3 micrometers, millisecond corresponds to $L(167) \simeq 2.3$ micrometers, whereas $L(163)$ corresponds to a time scale of 1 second. This would suggests that sub-neuronal water blocks larger than the size of cell nucleus could generate short term memories which need not be conscious-to-us. Perhaps the flux loops of the magnetic body of the cell nucleus are involved.

For linear structures like microtubules one has $T \propto 1/L$. Even in this case a rather strong dependence on the time span of the long term memory on the system generating negative energy MEs results. The fact that microtubules are ideal for representing conscious information symbolically, suggests that neuronal/astrocytic microtubules serve as the entanglers at sending/receiving end of the quantum communication line responsible for long term memories. This picture also suggests that the magnetic flux loop of a given astrophycal length scale is associated with a microtubule of a given length.

Where the classical signals are generated and received?

There are several bits of information helping to guess how long term memories might be realized.

1. The damage of the hippocampus leads only to a loss of the ability to generate new declarative memories but does not lead to a loss of long term memories from the period when hippocampus was intact. Thus it seems that hippocampus plays essential role in the communication of our non-episodal declarative memories to the geometric past and that at least a dominant part of the receivers are somewhere else than in hippocampus. Since the stimulation of both amygdala, hippocampus and temporal lobes induces long term episodal memories, it would seem that all these structures can serve as quantum entanglers.

2. New neurons and glial cells are regenerated in hippocampus and the regeneration is especially intense during ischemia which can destroy a lot of neurons [42]. This would suggest that both glial cells and neurons are essential for the realization of long term memories.

These pieces of data give some guide lines in the attempt to build a more detailed model of long term memories.

1. The generation of classical signals requires metabolic energy and this suggests that the generation occurs as near as possible to energy resources. Glials cells are known to be the providers of the metabolic energy. Synchronously firing neuron groups are accompanied by astrocytes forming gap junction connected structures. For a long time it was believed that astrocytes play only the role of passive energy storages but it has become clear that there is signalling between astrocytes and neuronal groups based on Ca_{++} waves. Astrocytes couple also strongly to sounds: for instance, it is known that very mild blow in head inducing sound waves can lead to a loss of consciousness. Perhaps the astrocyte structures associated with hippocampal neurons generate positive energy MEs responsible for the classical communications making our non-episodal memories possible.

2. The receival of the classical signal does not require metabolic energy. If astrocytes are involved with the sending of the classical signal, then neurons would be naturally the receivers of the signal and the energy received with the signal would partially explain why synchronous firing of neuronal groups seems to require less metabolic energy than expected. Of course, quantum entanglement by negative energy MEs wither energy sources could also explain this.

Is memetic code used to code declarative long term memories?

Memetic code is a good candidate for the coding of declarative long term memories. The duration of single memetic codeword would be about .1 seconds and the duration of a single bit would be about 1 millisecond. This hypothesis fits nicely with the facts that many cyclotron frequencies are around 10 Hz and the frequency of neuronal synchronal firing is about kHz.

Quite recently it became clear that TGD predicts counterpart of Tesla's scalar waves [40, 31]. These waves represent a pulse of electric field propagating with a velocity of light and an electric field in the direction of propagation. These waves corresponds in TGD to spacetime sheet of finite length and duration ($L = cT$) carrying constant electric field and propagating with velocity of light to the direction of the field. This solution type is extremely general and dual to the magnetic flux tubes. Electrets are one manifestation of these structures in living matter (membrane potential is one example of this kind of structure).

One could consider the hierarchy of MEs representing geometrically a hierarchical structure of commands and that memetic code corresponds to the lowest level with bit represented by a electric pulses whose polarity determines whether '1' or '0' is in question: very much like in case of computers. Electret sequences would ultimately give atomic nuclei kicks in a direction depending on the value of the bit.

What about other synchronous EEG frequencies?

Genuine theta (hippocampal theta which spans both theta and alpha bands) and delta bands could correspond to more abstract levels of consciousness not directly experienced by us usually. During slow wave sleep theta and delta bands dominate and the interpretation in terms of the binding of the mental images to memory representations is highly suggestive. Hence these bands would contribute to our consciousness in the geometric future rather than in the geometric now.

1. Theta band might relate to long term memory consolidation by a construction of temporal replicas of ordinary long term memory representations generated already during the wake-up period. Sleep state is certainly ideal in this respect.

2. Naive extrapolation suggests that delta band memories correspond to a rather long temporal distance T (that is very low frequency $f = 1/T$ for gravitonic MEs). Delta band memories would be therefore generated by structures with sizes below the thickness of cell membrane. One could understand why delta band is strongest in childhood and weakens towards old age. If delta band memories correspond to very long temporal distances T, it is useless to generate these memories at the old age since there would be no brain receiving these memories. The long time span of the delta band memories would explain why childhood memories are stable and why some persons 'return' to their childhood at the old age. The return to the sensory world of childhood at old age suggests that delta band memories must be sensory memories. Delta band representations might even give rise to transpersonal memories experienced during the later lives. The absence of ordinary sensory input masking delta band memories would explain why earlier life cycles can be recalled in meditative states.

3. The contribution of theta and delta band memories to our consciousness could also relate to the third person aspect of consciousness. Theta and delta waves could be associated with the magnetospheric sensory representations giving rise to multibrained selves. The entanglement between sleeping brains inducing a loss of personal consciousness would induce a kind of collective stereo consciousness in which a large number of invididual views about world fuse together would be in question. The search for correlations between the EEGs of sleepers having a close personal relationship might be rewarding. For istance, DNA could quantum entangle and give rise to conscious memories in very long time scale at the level of species.

Note that the presence of synchronous or asynchronous EEG correlate of memory generation is present also during memory recall does not seem to be necessary since the memory is indeed in the geometric past.

Questions

One important question is whether positive energy EEG MEs are involved with long term memories or only with sensory representations (assuming that sensory representations are realized at the magnetic body). The idea that MEs take care of memories and EEG MEs of sensory representations is attractive idea at least.

Fascinating questions relate to cognitive representations since these involve p-adic physics. Frontal lobes are known to be the seat of planning, volition and cognition. Therefore p-adic cognitive representations, p-adic entanglement and the p-adic selves characterized by positive entanglement negentropy should be realized in the neural circuits involving frontal lobes. These circuits have been even proposed to be 'conscious circuits' but this probably reflects the erranous identification of consciousness as cognitive consciousness only. Cognitive representations could be realized at magnetic cognitive canvas using beta frequencies as resonant frequencies and beta MEs would entangle with the points of the cognitive magnetic canvas p-adic mental images representing intentions and plans. The transformation of these p-adic mental images to real ones would somehow generate generalized motor actions, in particular ordinary motor actions. That frontal lobes contain motor areas conforms with this view.

7.3.5   Hippocampus and long term memories

The findings about hippocampal system provide a good test for the general ideas about long term memory. For a review about the role of hippocampus in long term memory see [40].

Anatomy of hippocampal system

The anatomy of hippocampus is discussed in [46]: here only very rough summary is given: possible inaccuracies are due to my amateurish knowledge of brain science.

Hippocampus is located with the inferior medial wall of the temporal lobe posterior to the amygdala. Hippocampus decomposes into anterior and posterior regions. Hippocampus consists of a number of subcomponents, and adjoining structures, such as the parahippocampal gyrys, entorhinal and perirhinal cortex and uncus. The main body of the hippocampus consists of the detante gyrus (here brain cells are regenerated), the subiculum and the sectors referred to as CA1,CA2,CA3 and CA4. The uncus is a bulbar allocortical protrusion located in the anterior-inferior medial part of the temporal lobe.

There are three major neural pathways leading to and from the hippocampus. These include the fornix-fimbrial fiber system, and a supracallosal pathway which passes through the cingulate, and via the entorhinal area: this is the mesocortical gateway to the hippocampus. Through the fornix-fimbrial pathways hippocampus makes major interconnections with the thalamus, septal nuclei, medial hypothalamus, and exerts either inhibitory or excitatory influences on these nuclei.

The entorhinal cortex acts to relay information to and from the hippocampus. The hippocampus maintains via the entorhinal cortex interconnections with the neocortical multi-modal associations areas of the temporal, frontal, and parietal lobes, including surrounding structures, e.g., the parahippocampal gyrus, and allocortical tissues, the perirhinal cortex, septal nuclei and amygdala. The parahippocampal gyrus, entorhinal and perirhinal cortex, being directly interconnected with the hippocampus and the neocortex, act to relay input from the neocortical association areas to this structure.

The entorhinal cortex consists of 7 to 8 layers rather than only 6 layers. The entorhinal cortex maintains massive interconnections with all multi-modal neocortical association areas (as well as with the amygdala, hippocampus, septal nuclei, olfactory bulb, etc.) but none of the primary sensory areas which presumably relates to the fact that hippocampus is responsible for declarative rather than sensory memories.

Memory deficits and hippocampus

Memory deficits provide important information about the role of hippocampus with respect to the memory. In anterograde amnesia the ability to generate new long term declarative memories is lost and it is known that a damage to the hippocampus can cause this defect. Thus it seems that hippocampus is crucially involved with the construction of long term memories. Also the damage to the medial temporal lobes and subcortical structures such as medial thalamus and mammillary bodies

can destroy the ability to generate long term memories. This supports the view that hippocampus is kind of a central entangler binding together mental images from various parts of brain: most naturally entanglement occurs along the three neuronal pathways going through hippocampus and presumably associated with toruslike magnetic flux tubes.

In retrograde amnesia memories about some period of time in past are lost. It seems that this deficit does not correlate with the damage of hippocampus. Thus the cautious conclusion is that long term memory recall occurs also elsewhere in brain. The selectivity of the retrograde amnesia suggests that the notion of the memory field applying in the case of short term memory [43] generalizes. The brain structures responsible for the receival of long term memories are specialized in the sense that they entangle with the mental images of the geometric past located only in an interval around certain temporal distance T. If the memories involve only few reflections along a closed magnetic flux loop, the corresponding MEs have fundamental frequency $f = 1/T$ and correspond to spin glass transition for microtubules or for 3-dimensional sub-neuronal structures at a length scale between cell size and cell membrane thickness if the simplest estimate makes sense. This kind of resonant selectivity might be possible to achieve if the receiving system is driven to the bottom of the spin glass landscape with a depth which corresponds to the gravitonic energy $E = 2\pi f$ If memories involves large number of reflections, it is difficult to imagine, how this kind of selectivity could be achieved.

Hippocampus and declarative memory

It is known that there are several memory types and hippocampus is responsible for the construction of only declarative memories, which are verbal and highly symbolic representations of the geometrical aspects external world. Hippocampus is not essential for the recognition of familiar objects nor for procedural/motor memories which are implicit memories. The natural identification of declarative memories is as memories communicated classically using some coding but one cannot exclude sharing of mental images. Memetic code or its scaled up/scaled down is a good candidate in this respect. The modulation of hippocampal theta might provide the coding.

Sensory memories can be induced by the electric stimulation of both hippocampus, amygdala and temporal lobes. This suggests that lower levels of self hierarchy which we do not experience directly can have sensory memories. The entanglement by negative energy ME with the geometric past giving rise to an episodal memory is the most natural interpretation for the effect. Neural loops are the geometric correlates for entanglement at the level of CNS, and timelike quantum entanglement of parts of the electrically stimulated structures with primary sensory areas with the mediary of these loops should be involved. If the stimulation is too strong, hallucinations result. In this case the sensory representations in thhe brain geometrically now are presumably activated and back projection to the sensory organs would occur. An interesting possibility is that the strength of stimulation correlates with the temporal distance of the sensory representation in the geometric past activated in the stimulation.

Hippocampus provides spatial and temporal context

The right hippocampus of the taxi drivers in London is enlargened. This supports the view that hippocampus provides kind of a symbolic map of the spatial layout of the environment. Studies in animals suggest that hippocampus adds a spatial context to the mental images from cortex entangled with mental images in subhippocampal structures entangled with the mental images in hippocampus. The spatial map is based on various spatial cues serving as landmarks. Left hippocampus is in turn involved with the verbal memories and this suggests that it is responsible for providing a temporal context and time ordering of events. This suggests that hippocampus is responsible for the temporal and spatial organization of conscious experience besides generating memory representations. Perhaps a high level sensory representations at the magnetic body is in question.

Hippocampus is known to contain place cells providing cognitive representations for the objects of perceptive field. These place cells are pyramidal cells containing magnetic crystals which suggests that they act as projectors to the magnetic memory canvas. All kinds of features could be associated with these landmarks, and more generally, with the symbolic objects of the memory field.

Long term potentiation (LTP) does not occur in hippocampus but hippocampus is highly dynamical with synaptic contacts being generated all the time and even the size of hippocampus continually changing. It would seem that hippocampus provides by its own dynamical structure a context for various data coming from cortex, kind of a geometro-symbolic model for the external world. The

mental image associated with this model of external world quantum entangles with the mental images in cortex, amygdala, hypothalamus, etc...

Not only spatial but also temporal context is important and hippocampus should provide also this. Purely sensory memories do not carry any information about whether memory is in question or not. For symbolic representations the situation is different. Symbolic representations would be realized as association sequences, perhaps in the time scale of hippocampal theta such that each 3-surface of association sequence contains lower level association sequences contains.... Memetic code words of duration .1 seconds would be at the lowest level and perhaps correspond to mesoscopic features of Freeman [47].

The intronic portion of DNA could provide the fundamental hardwave representation of memes in terms of sequences of 21 DNA triplets: spoken language would be only a tip of an iceberg if this picture is correct [26]. Positive energy em and MEs could realize these memes in the shape of vacuum current, which at given moment of time is non-deterministic and therefore optimal in this respect. Memetic code realized in terms of magnetization direction for quark sub-CDs is a further candidate for realizing the symbolic representations. This highest level representation adding context to the other data located in the geometric past would entangle via MEs with the brain of the geometric now in case of episodal memories. The fact that hippocampus is thought to be involved with the trassfer of items in short term memory to long term memory in cortex conforms with the mirror mechanism.

Entorhinal cortex serves as somekind of a relay station between hippocampus and neocortex. Entorhinal cortex has very special structure being 7-to-8 layered rather than 6-layered. Entorhinal cortex maintains rich connections to various multimodal regions in temporal, parietal and frontal cortices but not to the primary sensory areas. This is consistent with the idea about three-leveled hierarchy *multimodal areas$\rightarrow$ entorhinal $\rightarrow$ cortex-hippocampus*, with the fact that the mental images associated with hippocampal memory representations are symbolic rather than sensory, and with the assumption that multimodal areas, entorhinal cortex, and hippocampus entangle.

Hippocampal theta corresponds to EEG frequency range varying from about 4 Hz to 12-14 Hz and thus spans both theta and alpha bands. Hippocampal theta can be seen as a correlate for the binding of various cortical and subcortical mental images to a single mental image representing both that aspect of consciousness which makes possible organized view about space and time and declarative memory. MEs at hippocampal theta frequencies could project to the magnetic memory canvas providing an abstract representation about world analogous to sensory representation but without sensory qualia. It must be emphasized that the memory representation should provide an essential part of our everyday consciousness making possible space and time categories of everyday conscious experience. Novel and painful stimuli indeed induce hippocampal theta as well as orienting reactions, learning, selection and discrimination.

Remote emotions and associations?

Amygdala seems to be responsible for the formation of emotional aspects of the memories in accordance with entanglement paradigm. Amygdala is known to be sensitive to emotional contextual cues which can trigger perceptive experiences similar to previous ones. Associative memories seem to be in question.

Whether the associative memory is in the geometric now or past is not obvious and timelike quantum entanglement might perhaps allow to induce remote associations in the geometric past. If the cue is entangled with the cue in the geometric past, the activation of this cue by quantum entanglement could activate neural process generating the memory in the geometric past. This kind of mechanism would provide a general mechanism of active memory retrieval. The active scanning of memory neurons with memory fields characterized by different values of T would be a second mechanism of this kind. In fact, there need not be any sharp difference between ordinary associations and associations in past.

Memory consolidation and long term potentiation

The notions of memory consolidation and long term potentiation relate to the more standard views about long term memory and it is interesting to try to interpretthem in TGD framework. Memory consolidation means the strengthening of memories by 'replaying' them. Certainly a repetion of mental image provides a manner to learn and establishing a long term memory also in TGD. The

mere generation of gravitational MEs associated with a given mental image means consolidation: no modification of the existing neural connectivity is needed. Of course, standardized mental images are probably generated but this is not construction of memories in the strict sense of the word.

Memory consolidation involves hippocampal theta. In TGD framework hippocampal theta is a correlate for that part of consciousness which gives rise to an organized view about space and time: not necessarily in the geometric now however. Mirror mechanism implies that this process defines automatically memory representations about the state of brain so that memory consolidation is an automatic side effect.

It has been proposed that during REM sleep hippocampus is 'replaying' the memories unconsciously [38]. The fact that there is no sensory input at night time would suggest that sleeping brain is like an empty magnetic tape freely usable for the memory construction. Theta and delta bands could relate to the memory representations replayd during sleep period but could be also responsible for the construction of higher level sensory representations important for non-episodal memories.

There are however objection against the idea that REM sleep is specialized with the replaying. First, hippocampal theta, believed to be crucial for the formation of long term declarative memories, is not synchronous during REM sleep. Secondly, during dreams only the posterior portion of the hippocampus is active whereas during learning the active part is the anterior portion of the hippocampus.

TGD based vision suggests a first principle explanation for the activity of hippocampus during sleep and dreams. Both classical communications to the geometric future and the receival of negative energy MEs from the geometric future require metabolic energy feed. Since the metabolism related to the motor activity and sensory preception is absent during sleep, the optimal realization of the long term memories is based on the entanglement with the sleeping brain of the geometric past. This would also explain why we do not have conscious experiences about memory recalls from the geometric future. Sleeping brain can also help the situation by performing memory recalls itself. REM sleep would not be in any special role except that it could make possible episodal sensory memories.

The memories about dream experience fade out rapidly after wake-up. This suggests that the lengths of the magnetic flux tubes along which classical communications occur during dreams, are short and therefore also the time span of the resulting declarative memories is brief. This as it should be since otherwise dreams would make possible pseudo memories. We could be conscious during dreams but would not remember it since long term memories would not be generated during this period. Alternatively, dream memory representations could be generated by the larger self to which we are fused during sleep. The above mentioned findings about the hippocampal activity during dreams could mean that magnetic flux loops of declarative memory get longer in posterior-anterior direction: this would mean a concrete identification for the neurophysiological correlates of the declarative memory fields. Also the dominating frequency of EEG/ZEG would become lower in this direction.

The basic question relates to the intepretation of the hippocampal theta. There are two options.

1. Hippocampal theta is associated with the MEs responsible for the classical communications to the geometric future making possible long term memories.

2. MEs take care of the classical communications to the geometric future (memetic code) whereas hippocampal theta contributes to the conscious experience of the geometric now by generating high level sensory representations at the personal magnetic body.

For the latter option hippocampal theta could be also involved with the generation of entanglement between various parts of brain crucial for the construction of long term memories making possible an organized view about space and time. This assumption conforms with the idea that EEG rhytms are responsible for the synchrony and entanglement. This would not happen during REM sleep since hippocampal theta is asynchronous during dreaming and during cortical synchrony (not much sensory input). Visual dream consciousness is indeed sensory consciusness without an organized view about space and time categories. This applies also to the non-REM verbal dreams. Furthermore, the desynchronization of both hippocampal and cortical EEGs implies a confused state of mind. This would suggest that hippocampus indeed contributes also to our consciousness in the geometric now, and makes possible the organized view about space and time by constructing higher level sensory representations.

Long term potentiation (LTP) has been suggested as a mechanism by which hippocampus generates long term memories by strengthening the synaptic communications between neurons. In TGD

framework this interpretation does not make sense: rather LTP can be seen as a special case of associative learning which is just gradual modification of the brain structure as a response to the conscious experience. Of course, LTP modifies gradually memory representations but these memory representations do not contain information about past.

As noticed, LTP does not occur in hippocampus itself. Instead, hippocampus grows rapidly in neuron number and synaptic connections during long term memory generation. This conforms with the view that hippocampus is more or less a real time dynamical representation for what might be called changing context. In particular, new neurons generated in hippocampus could be essential in representing the context and could generate gravitonic MEs crucial for the entanglement.

Relationship between cortical and hippocampal EEGs

Cortical desynchronization accompanies hippocampal synchronization and vice versa. The simultaneous desynchronization of cortical and hippocampal EEGs involves distractability and hyper-responsiveness so that person becomes owerwhelmed, confused, and may orient to and approach several stimuli.

These findings can be understood in TGD framework.

1. During cortical asynchrony there are good reasons to build long term memories so that hippocampus should be in synchronized state and bind various mental images to long term memories.

2. During cortical synchrony there is nothing to represent as long term memories and hippocampus can do something else. Perhaps participate in imagination and day dreaming as suggested by the fact that also during REM sleep hippocampal theta is asynchronous.

3. When both cortical and hippocampal theta are desynchorized, not only the long term memory representations fail to be generated but also the construction of spatial and temporal context and this leads to confusion and difficulties with orientation to various stimuli.

7.3.6   Microtubuli and long term memory

When I began consciousness theorizing whole-daily around about 1994, I became deeply fascinated about microtubuli (as probably most others in the field of quantum consciousness). I launched off by developing a rudimentary model about how microtubuli could act as quantum antennae in the TGD universe: massless extremals were the key element of the model. Needless to say, too much of the general theory of consciousness and of biosystems as macroscopic quantum systems needed for a deeper understanding was unconscious-to-me at that time.

After the rapid self-organization of the theory during this year and still continuing (I am living last days of August 2002 while writing this), it occurred to me that it might be a good idea to take a fresh look on the role of the microtubuli. While re-reading the wonderfully inspiring article of Nanopoulos dating back to 1995 [63], I realized that the TGD based view about macrotemporal quantum coherence, the mirror mechanism of long term memory, and the quite recent discovery of cognitive codes and their physical realization, provide the tools for developing a view about the role of microtubuli in long term memory.

What made me somewhat skeptic about the importance of the microtubuli for *our* consciousness was the naive view that the size L of the system system generating the memory increases when the geometrotemporal distance T of the long term memory increases. Microtubuli would be conscious but from our point of view this would represent something analogous to bit level in computers.

The understanding of how the macrotemporal quantum coherence is generated however challenged this view. TGD Universe is quantum spin glass and spin glass degeneracy is broken only by the classical gravitational binding energy. Quantum transitions between almost degenerate quantum spin glass states correspond to frequencies defined by the differences of the classical gravitational binding energy and generate gravitational MEs responsible for the quantum mirror mechanism. Gravitational binding energy increases with the system's size and this means an effective inversion of the length scale hierarchy, so that systems like microtubuli can contribute to our conscious experience much more signicantly than some subsub....subself level at the bottom of the self hierarchy might be expected to do.

Basic findings about the correlation between long term memory and microtubuli

A basic difference between ordinary cell and neuron is that the microtubuli associated with the T shaped centriole in case of the ordinary cell, are in neuron replaced by long microtubule bundles starting in a region near nucleus and connecting it to dendrites and axonal ends. The natural guess is that at least these microtubuli are closely involved with the brain consciousness.

What happens in microtubuli is indeed very intimately related to what happens in synapses. The minimal modification of the standard neuroscience belief system is that microtubuli control how synapses, still assumed to be responsible for the memory representations, are modified during learning identified as generation of long term memories. In [63] a lot of basic facts about microtubuli plus the evidence for the correlation between microtubuli and long term memory is discussed and references can be found in this article. Here I just summarize the basic points of the discussion of [63].

1. The production of tubulin and MT activities correlate with peak learning, memory and experience in baby chick brains. Experiments with baby rats show that when they first open they eyes, neurons in their visual cortex begin producing vast quantities of tubulin.

2. The experiments with trained goldfishes show that the drug colchicine produces retrograde amnesia. The interference with MTs responsible for the structural modification of certain synapses is believed to affect memory fixation. In TGD framework one must carefully distinguish between learning and memory: microtubuli could provide both the long term memory representations and also control learning by controlling synaptic strengths.

3. The selective dysfunction of animal brain MTs by the drug colchicine causes defects in learning and memory which mimick the symptons of Alzheimer's disease (AD). It has been reported that in rats a continuous MT disruption induced by a chronic colchicine administration results in a dose-dependent learning deficit, and memory retention is also impaired. It has also been stressed that these colchicine-induced cognitive defects resemble those of AD, e.g., amnesia of the recent learning and loss of formerly established memories. These findings encourage to think that that microtubuli are involved both with the generation of the memory representations and long term memory recall by mirror mechanism in accordance with the idea that microtubuli act as both receiving and sending quantum antennae in the sense that they generate MEs making possible timelikequantum entanglement. MEs generate coherent photons or gravitons according to the original definition of quantum antenna [32]. Certainly, the antenna which sends is also optimal for receiving.

4. It has been suggested and also supported by detailed experimental studies that the impairment of MTs, leading to tangled and dysfunctional neural cytoskeleton, may be one explanation for the pathogenesis of AD.

5. In specific hippocampal regions of the brain of schizophrenic patients, distorted neuronal architecture has been found due to a lack of 2 MAPs. This suggests that the splitting of consciousness characterizing schizophrenia has a geometric correlate already at the microtubular level: macroscopic bound state entanglement responsible for the binding to longlived holistic microtubular mental images and the generation of memory representations would not occur as they should.

How microtubuli could relate to declarative long term memories?

For several reasons microtubuli are taylor-made for the realization of long term declarative memories in TGD Universe (the structure of microtubuli is discussed in some detail in [29], where the realization of cognitive codes is discussed). Microtubuli are however not the only candidates: also 2-D membrane like structures and genuinely 3-D structures could be involved and correspond to different types of long term memories.

1. Microtubuli can entangle with each other and with the surrounding world in conformational degrees of freedom to yield macrotemporal quantum coherence. Microtubule associated proteins (MAPs) can mediate naturally bound state entanglement between conformational patterns of different microtubuli. This makes possible macrotemporal quantum coherence and processes resembling quantum computation when bound states are formed. MAPs can act as switches

initiating quantum computation and halting it. The simplest possibility is that MAP protein becomes just disconnected at some levels of the hierarchy of spacetime sheets.

2. Tubulin dimers allow two different conformations and the patterns of tubulin conformations are ideal for binary representations of data natural for the representation of long term declarative memories. In [29] a cognitive code explaining the numbers associated with microtubular geometry is discussed and a model for how the conformational patterns are coded into conscious experience in the phase transition in which spontaneus electric polarization occurs and forces all tubulin dimers to the ground state conformation. That microtubuli allow the realization of the symbolic counterparts of cognitive representations realized using cognitive neutrinos and possibly also by p-adic MEs, conforms with the fact that colchicine which affects MTs, induces cognitive defects characteristic of Alzheimer's disease. The linearity of microtubuli would be obviously essential and at least parts of the sensory pathways could be responsible for the representations of these memories.

3. In the standard view about long term memories one cannot identify microtubuli as seats of long term memory representations. The reason is simply that microtubule conformations are quite too short-lived for this purpose. This leaves only the identification of the synaptic strengths as a representation of long term memories. In TGD the situation is just the reverse and flexibility requires fast enough dynamics. The time scale defining sensory resolution is obviously a bottle neck time scale. The time scale for the phase transition leading to ground state of tubulin dimer in an external electric field and the time scale related to the control of the external electric field at the microtubular spacetime sheet are the most obvious guesses. The first time scale should be of order of the time scale of conformational dynamics, about nanosecond. The latter time scale would be basically the duration of nerve pulse if nerve pulses are responsible for the phase transition in question. In TGD framework the modification of synaptic strengths can be more naturally seen as representing generation of new 'habit routines' rather than memory representations which are much more involved and information rich.

4. Microtubuli are ideal for quantum mirror mechanism of long term memories. As already found, in case of spherical structures the dependence of gravitational binding energy on size of the structure is $E_{gr} \propto L^5$, whereas the gravitational binding energy depends on the length L of a linear structure as $E_{gr} \propto L$. For membrane like structures $E_{gr} \propto L^3$. Since microtubule lengths vary in the range 10 nm- 1 mm, this means that the temporal distance $T \propto 1/L$ of long term memory varies between 32 years 2.8 hours (very roughly; increase of the overall time scale due to the fact that increment of the gravitational binding energy in the transition is smaller than the gravitational binding energy itself). Inside axons microtubuli can bind to longer structures by MAPs and even meter sized structures associated with sensory pathways are possible. This lowers the lower bound for the time span to 10 seconds. The longest microtubuli are responsible for the representation of the shortest term memories realizable in this manner. Of course, memory circuits should regenerate again and again microtubular memory representation and in this sense synaptic strengths become an essential part of the memory representation.

5. Colchicine affects both memory recall and memory generation. This inspires the working hypothesis that microtubuli of a given length $L \propto 1/T$ in the geometric past entangle with a microtuble of same length in the geometric now during memory recall. For instance, the receiver in the geometric now could correspond to a postsynaptic microtubule whereas the sender in the geometric past corresponds to a presynaptic tubule. This is not the only alternative, receiving cells could be even glial cells.

6. That the memories of childhood are the most stable ones could be interpreted as reflecting the fact the microtubuli act both as receiving and sending quantum antennae, and that the long microtubuli responsible for generating the short term memory representations and for receiving them deteriorate towards the old age with much higher probability than the shorter ones. It could be possible to induce selective amnesiae restricted to memories with a temporal distance $\sim T$ by a treatment which affects microtubuli of given length $\sim L \propto 1/T$.

7. Microtubuli could be also ideal for the communication of non-episodal memories involving classical communication by ultra slow MEs perhaps accompanied by Ca^{++} waves known to have an

extremely wide velocity spectrum. Ca^{++} ions are associated with the outer surface of the micro-tubuli and dynamically comparable to a crop field in a wind. Ultra-slow orientational waves for these Ca^{++} ions representing sensory inputs and propagating along axons could make possible a classical communication of data from the geometric past as declarative memories. For sensory pathways the sequences of microtubuli could have a total length of order one meter. For the average length $L_0 = 10$ μm of the microtubule in brain, the time span $T_0 = 10$ seconds would give $v_0 \sim 1\mu m/s$, a typical velocity of in cellular level. In this case 10 nm length of microtubule would correspond to 10^{-2} seconds of time. This would mean that roughly 13 parallel sequences of 13 bits of information about 10 millisecond period. The bit rate of one bit per millisecond corresponds to the information storage capacity of the memetic code. For longer time intervals T and microtubule lengths L the bit rate would scale like $(L/L_0) \times (T_0/T) = v/v_0$. For $T = 1$ year and $L = L_0$ one would have roughly one bit per hour. It seems that this mechanism can be at work only for short term memories whereas long term memories would involve closed magnetic loops.

Relation to the general model of long term memories

It is interesting to relate the proposed model with the general model of long term memories.

1. Long term memory is lost when tubulins return to ground state unless there is some mechanism regenerating the conformational state. In brain the function of neuronal loops generating the nerve pulse patterns repeatedly would take care of regenerating the memory representation. If this view is correct, then also memories of childhood involve this kind of continual regeneration. Sensory pathways do give rise to long term memories unless the feedback from brain to primary sensory organs (otoacoustic sounds and the movement of eyes during REM sleep) regenerates these memory representations. During dream long term memories correspond to small value of T: does this allow to conclude that the feedback to the primary sensory organs during dreams results in long term memories with T about few minutes? The maximation of the lengths of the sensory pathways (left side of the body is connected to right brain hemisphere and vice versa) would relate to the maximization of the representational capacity if this mechanism is at work. Notice that the continual regeneration of memories with say temporal distance of $T = 15$ minutes does not seem sensical since these memories would not be received by that part of the 4-D brain which corresponds to the p-adic-to-real phase transition front. The most natural assumption is that sensory representations are regenerated for time interval of order T so that the maximal values of T and stablest memories correspond to relatively short microtubuli in the interior of neuron.

2. Hippocampus is believed to be crucial for the generation of long term declarative memories and responsible for spatio-temporal organization of perceptive field. Hippocampus could act as a kind of entanglement center entangling with 'features' at various brain areas and project them to the sensory magnetic canvas (the episodal component representing spatial relationships might accompany also non-episodal memories!). Feature subselves would have microtubular selves as subselves: this would mean entanglement between hippocampal and other microtubular memory representations. The microtubuli acting as central entanglers in hippocampus should be relatively short, with lengths not much longer than the length determined by the lower bound for temporal distance T for long term memories. The maximal length L of hippocampal axons should correspond to this T and $L \sim 10^{-2}$ meters from the size of the hippocampus might be a reasonable guess giving a time scale of about 15 minutes (these estimates are just orders of magnitude).

3. The recall of long term memories could basically correspond to a transition of a neuronal microtubule to a higher energy state by an emission of negative energy ME. The process would be preceded by the emission of a p-adic ME representing the intention to remember and transformed to a real negative energy MEs in the jump to a higher energy state. The neuronal/astrocytic microtubules of the right brain hemisphere could be specialized to send/receive negative energy MEs, whereas the astrocytic/neuronal microtubules of the left hemisphere would be specialized to send/receive positive energy MEs. Of course, this is just a naive guess inspired by the

right/left–holistic/reductionic dichotomy. What is however clear that microtubuli with abnor-
mally small metabolic energy feed would be responsible for generating long term memory recalls
and those with abnormally large energy feed responsible for generating long term memories.

4. Tubulin dimers correspond to the Mersenne prime $p = M_k = 2^k - 1$, $k = 13$, and the n-ary 13-
adic time scale nearest to p-adic prime nearest to .1 second time scale of the memetic code word
is $T(20, 13) \simeq .8$ seconds whereas single bit lasts for $T(20, 13)/13 \simeq 61$ milliseconds. .8 seconds
is rather natural time scale from the point of view of human consciousness. Corresponding
frequencies are 1.25 Hz in delta band, and 16.25 Hz in the lower end of the beta band which
conforms with the fact that cognition correlates with the beta band activity of EEG. That delta
frequency alone does not give rise to conscious experience would be due to the fact that no phase
transition giving rise to a conscious experience occurs if all tubulins possess same ground state
conformation. The facts that delta band weakens during ageing and also memory generation
mechanisms deteriorate towards the old age, conform with the idea that this band is responsible
for the generation of memory codewords. If this view is correct, hippocampal theta should be
responsible for the binding of mental images rather than coding of our long term memories. Of
course, also a lower level representations in time scale of hippocampal theta could be in question.

5. At this stage it is not possible to answer the question whether microtubuli correspond to subselves
or subsub....selves. If the entangled microtubuli correspond to our subselves, the microtubuli
belonging to different neurons should be able to entangle with each other. This requires the
presence of join along boundaries bond contacts between pre- and postsynaptic microtubuli.
MEs with lengths of neuron length scale could serve as this kind of contacts and generate time
like entanglement between the microtubuli of neurons along the neural pathway.

What about effectively 2-D and 3-D memory representations?

Microtubuli need not be solely responsible for our long term memory representations. The fact
that microtubuli seem to correlate with cognition and declarative memories which involve typically
representations linear with respect to time suggests that the effective dimension D of the structure
involved determines the character of the long term memory and also that of sensory experience.
Moreover, it is quite possible that a large number of entangled neurons results in a kind of 'stereo
consciousness' fusing a large number of slightly different views about the same sensory input. This
would mean large number of entangling Grandmother neurons.

1. Cell membranes consist of a large number of parallel rather than serially ordered units. Hence
cell membranes could be responsible for the storage of sensory memories, which are 2-dimensional
at the basic level, say visual images. The neuron size of 10^{-4} meters corresponds to the lower
bound of about millisecond for $T \propto L^3$.

2. Three-dimensional blobs of biomatter in length scale range 1 micron-10 nanometers span the
range 1 millisecond-32 years for temporal distance T. This allows to consider the possibility
that 3-D structures could be also responsible for long term memory representations. If one takes
seriously the dimensional rule, 3-D structures should give to genuinely three-dimensional sensory
memories and make 3-D spatial imagination and sensory experience possible. It is not obvious
whether neurons contain any 3-D lattice like structures besides liquid crystal blobs of ordered
water. Effectively 3-D structures could also result as composites of 2-D structures.

7.4   Hyper-finite factors of type II$_1$, dark matter hierarchy, and long term memories

This section is devoted to the progress that has occurred during the period 2004-2006 and represents
new material which has not yet been fully integrated with the older material. The realization that the
von Neumann algebra known as a hyper-finite factor of type II$_1$ is tailor made for quantum TGD has
led to a considerable progress in the understanding of the mathematical structure of the theory and
these algebras provide a justification for several ideas introduced earlier on basis of physical intuition.
One of the most important outcomes is a prediction of a hierarchy of quantum phases with arbitrarily

large values of quantized Planck constant identified as dark matter and assumed to be the quintessence of living matter.

7.4.1 Hyper-finite factors of type II$_1$ and quantization of Planck constant

Hyper-finite factor of type II$_1$ has a canonical realization as an infinite-dimensional Clifford algebra and the obvious guess is that it corresponds to the algebra spanned by the gamma matrices of the configuration space of 3-surfaces ("world of classical worlds"). As a matter fact, it seems that the infinite-dimensional character of this algebra implies the rest of TGD. 4-D space-time, imbedding space $M^4 \times CP_2$, and the entire quantum TGD could emerge from the extension of the hyper-finite factor of type II$_1$ to a local algebra. This extension is local with respect to an octonionic coordinate whose non-associativity guarantees that the algebra does not reduce back to a mere hyper-finite factor of type II$_1$. The dynamics of quantum TGD would follow from the associativity condition: in particular, space-time surface would be maximal associative or co-associate sub-manifolds of imbedding space.

The quantization of Planck constants assignable to M^4 and CP_2 degrees of freedom as integer multiples of the ordinary Planck constant is strongly suggestive in this framework and the phases with large Planck constant are interpreted as a dark matter quantum controlling ordinary matter in living matter. The average geometric durations of quantum jumps are naturally quantized as multiples of the integer characterizing M^4 Planck constant. This allows the reduction of the notion of self to that of quantum jump at higher level of hierarchy. A strong quantitative prediction for the preferred geometric durations of quantum jumps emerges.

The topology of the many-sheeted space-time encourages the generalization of the notion of quantum entanglement in such a manner that unentangled systems can possess entangled sub-systems. This makes possible sharing and fusion of mental images central for TGD inspired theory of consciousness. These concepts find a justification from the quantum measurement theory for hyper-finite factors of type II$_1$.

Also the notions of resolution and monitoring pop up naturally in this framework. p-Adic probabilities relate very naturally to hyper-finite factors of type II$_1$ and extend the expressive power of the ordinary probability theory. p-Adic thermodynamics with conformal cutoff is very natural for hyper-finite factors of type II$_1$ and explains p-adic length scale hypothesis $p \simeq 2^k$, k prime characterizing exponentially smaller p-adic length scale.

7.4.2 Dark matter hierarchy

The identification of dark matter as phases having large value of Planck constant [17, 16, 24] led to a vigorous evolution of ideas still continuing while I am writing this addendum to the original text. Entire dark matter hierarchy with levels labelled by increasing values of Planck constant is predicted, and in principle TGD predicts the values of Planck constant if physics as a generalized number theory vision is accepted [24]. Also a good educated guess for the spectrum of Planck constants emerges. The implications are non-trivial already at the level of hadron physics and nuclear physics and imply that condensed matter physics and nuclear physics are not completely disjoint disciplines as reductionism teaches us. One condensed matter application is a model of high T_c superconductivity predicting that the basic length scales of cell membrane and cell as scales are inherent to high T_c superconductors.

Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [22]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [29, 22]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [22].

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of $\hbar$ at all. Secondly, the failure

of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

Jones inclusions and quantization of Planck constant

The Clifford algebra spanned by gamma matrices of infinite-dimensional space defines standard example of a von Neumann algebra known as hyper-finite factor of type II_1. The characteristic property of this algebra is that unit matrix has unit trace. Jones inclusions of hyperfinite factors of type II_1 combined with simple anyonic arguments turned out to be the key to the unification of existing heuristic ideas about the quantization of Planck constant [17].

1. Quantum TGD emerges from the infinite-dimensional Clifford algebra extended to an analog of a local gauge algebra with respect to hyper-octonionic coordinate [24]. In particular, the notions space-time as a hyper-quaternionic four-surface of imbedding space emerges.

2. One can understand how and why Planck constant is quantized and gives an amazingly simple formula for the separate Planck constants assignable to M^4 and CP_2 and appearing as scaling constants of their metrics as integer multiples of standard value $\hbar_0$ of Planck constant: $\hbar(M^4) = n_a\hbar_0$ and $\hbar(CP_2) = n_b\hbar_0$. This in terms of a mild generalization of standard Jones inclusions [24]. The emergence of imbedding space means that the scaling factor of these metrics given by the scaling factor of Planck constant have spectrum: their is no landscape as in M-theory. Also the fusion of real and various p-adic variants of imbedding space along common rational (algebraic) points is involved.

3. In ordinary phase Planck constants of M^4 and CP_2 are same and have their standard values. Large Planck constant phases correspond to situations in which a transition to a phase in which quantum groups occurs. These situations correspond to standard Jones inclusions in which Clifford algebra is replaced with a sub-algebra of its G-invariant elements. G is product $G_a \times G_b$ of subgroups of $SL(2,C)$ and $SU(2)_L \times \times U(1)$ which also acts as a subgroup of SU(3). Space-time sheets are $n(G_b)$-fold coverings of M^4 and $n(G_a)$-fold coverings of CP_2 generalizing the picture which has emerged already. An elementary study of these coverings fixes the values of scaling factors of M^4 and CP_2 Planck constants to orders of the maximal cyclic sub-groups. Mass spectrum is invariant under these scalings.

4. This predicts automatically arbitrarily large values of Planck constant and assigns the preferred values of Planck constant to quantum phases $q = exp(i\pi/n)$ expressible using only iterated square root operation: these correspond to polygons obtainable by compass and ruler construction with integer n expressible as $n = 2^k \prod_i F_{s_i}$, where $F_{s_i} = 2^{2^{s_i}} + 1$ are distinct Fermat primes: the lowest Fermat primes are given by $3, 5, 17, 127, 2^{16} + 1$. In particular, experimentally favored values of $\hbar$ in living matter should correspond to these special values of Planck constant. This model reproduces also the other aspects of the general vision. The subgroups of $SL(2,C)$ in turn can give rise to re-scaling of $SU(3)$ Planck constant. The most general situation can be described in terms of Jones inclusions for fixed point subalgebras of number theoretic Clifford algebras defined by $G_a \times G_b \subset SL(2,C) \times SU(2)$.

5. These inclusions (apart from those for which G_a contains infinite number of elements) are represented by ADE or extended ADE diagrams depending on the value of index. The group algebras of these groups give rise to additional degrees of freedom which make possible to construct the multiplets of the corresponding gauge groups. For $\beta \leq 4$ the gauge groups A_n, D_2n, E_6, E_8 are possible so that TGD seems to be able to mimick these gauge theories. For $\beta = 4$ all ADE Kac Moody groups are possible and again mimicry becomes possible: TGD would be kind of universal physics emulator but it would be anyonic dark matter which would perform this emulation.

7.4.3 Dark matter hierarchy and the notion of self

The introduction of dark matter matter hierarchy forces to also reconsider the definition of self and in the following the original definition and modified definition are discussed. The vision about dark matter hierarchy as a hierarchy defined by quantized Planck constants leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [16, 22].

The hierarchy of dark matter levels is labelled by the values of Planck constant having quantized but arbitrarily large values. It seems that the most important hierarchy comes as $\hbar(k) = \lambda^k \hbar_0$, where $\lambda \simeq 2^k$ is integer. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T(k) \propto \lambda^k$ of the quantum jump.

Dark matter hierarchy suggests a modification of the notion of self, in fact a reduction of the notion of self to that of quantum jump alone. Each self involves a hierarchy of dark matter levels, and one is led to ask whether the highest level in this hierarchy corresponds to single quantum jump rather than a sequence of quantum jumps. This indeed looks extremely natural and the hypothesis that self remains un-entangled for a longer duration than single quantum jump un-necessary. It is perhaps un-necessary to emphasize that the reduction of the notion of self to that of quantum jump means conceptual economy and somewhat ironically, would also a return to the original hypothesis but with a quantized Planck constant.

The averaging of conscious experience over quantum jumps would occur only for sub-selves at lower levels of dark matter hierarchy and these mental images would be ordered, and single moment of consciousness would be experienced as a history of events. One can ask whether even entire life cycle could be regarded as a single quantum jump at the highest level so that consciousness would not be completely lost even during deep sleep. This would allow to understand why we seem to know directly that this biological body of mine existed yesterday.

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self corresponds at the highest dark matter level to single moment of consciousness. Self would experience the average over the sequence of moments of consciousness associated with each sub-self but there would be no averaging over the separate mental images of this kind, be their parallel or serial. These mental images correspond to sub-selves having shorter wake-up periods than self and would be experienced as being time ordered. Hence the digits in the phone number are experienced as separate mental images and ordered with respect to experienced time.

If one accepts the hypothesis that CP_2 time defines the typical geometric duration of quantum jump then moments of consciousness with duration longer than CP_2 time would be associated with dark matter. This would require quite huge value of n for human consciousness and does not seem a plausible option since the time scale of .1 seconds corresponds to integer $n \simeq 2^{256} \simeq 10^{38}$. A more reasonable looking option is that n-ary p-adic time scales $T(n, p)$ for a given value $\hbar = m\hbar_0$ define the typical geometric duration so that for a given prime p one would have the hierarchy $T(m, n, p) = mT_p(n) = m\sqrt{p}^n T_{CP_2}$ of geometric durations of moment of consciousness, with favored values of m given by $m = 2^k \prod_i F_{s_i}$: as already explained, $F_{s_i} = 2^{2^{s_i}} + 1$ are distinct Fermat primes and the lowest Fermat primes are given by $3, 5, 17, 127, 2^{16} + 1$. T_{CP_2} corresponds to CP_2 time about 10^4 Planck times. The geometric durations give a natural first guess for the duration of long term memories. Second interpretation is as the increase of geometric time coordinate in single quantum jump in the drift towards geometric future which should accompanying quantum jump making possible to understand the experience about flow of time.

7.4.4 The time span of long term memories as signature for the level of dark matter hierarchy

If one accepts the hypothesis that CP_2 time defines the typical geometric duration of quantum jump then moments of consciousness with duration longer than CP_2 time would be associated with dark matter. This would require quite huge value of n for human consciousness and does not seem a plausible option since the time scale of .1 seconds corresponds to integer $n \simeq 2^{256} \simeq 10^{38}$. A more reasonable looking option is that n-ary p-adic time scales $T(n, p)$ for a given value $\hbar = m\hbar_0$ define the typical geometric duration so that for a given prime p one would have the hierarchy $T(m, n, p) = mT_p(n) = m\sqrt{p}^n T_{CP_2}$ of geometric durations of moment of consciousness, with favored values of m given by $m = 2^k \prod_i F_{s_i}$: as already explained, $F_{s_i} = 2^{2^{s_i}} + 1$ are distinct Fermat primes and the lowest Fermat primes are given by $3, 5, 17, 127, 2^{16} + 1$. T_{CP_2} corresponds to CP_2 time about 10^4 Planck times.

The geometric durations give a natural first guess for the duration of long term memories. Second interpretation is as the increase of geometric time coordinate in single quantum jump in the drift towards geometric future which should accompanying quantum jump making possible to understand the experience about flow of time.

Higher levels of dark matter hierarchy provide a neat quantitative view about self hierarchy and its evolution [22]. EEG frequencies correspond at this level dark Josephson photon energies above the thermal threshold so that thermal noise is not a problem anymore. Various levels of dark matter hierarchy would naturally correspond to higher levels in hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in question. The level in the would determine also the time span of long term memories as discussed in [22].

The emergence of these levels must have meant evolutionary leaps since long term memory is also accompanied by ability to anticipate future in the same time scale. This picture would suggest that the basic difference between us and our cousins is not at the level of genome as it is usually understood but at the level of the hierarchy of magnetic bodies [29, 22]. In fact, higher levels of dark matter hierarchy motivate the introduction of the notions of super-genome and hyper-genome. The genomes of entire organ can join to form super-genome expressing genes coherently. Hyper-genomes would result from the fusion of genomes of different organisms and collective levels of consciousness would express themselves via hyper-genome and make possible social rules and moral.

Quantum classical correspondence predicts that the arrow of subjective time is somehow mapped to that for the geometric time. The detailed mechanism for how the arrow of psychological time emerges has however remained open. Also the notion of self is problematic.

7.4.5   Remote metabolism, long term memory, and zero energy ontology

The notion of negative energy signals and time mirror mechanism emerged before zero energy ontology. Since the mechanisms of remote metabolism, of memory, and of intentional action rely on time mirror mechanism, one should check that this mechanism is indeed consistent with zero energy ontology. Zero energy ontology could also yield new insights to these mechanisms.

Zero energy ontology

Zero energy ontology states that physical states have vanishing net conserved quantum numbers and states decompose to positive and negative energy state and that the latter one can be said to be located in the geometric future with of the positive energy state at the time-like boundary of the space-time sheet representing the system. It is possible to speak about energy of the system if one identifies it as the average positive energy for the positive energy part of the system.

The matrix ("M-matrix") representing time-like entanglement coefficients between positive and negative energy states unifies the notions of S-matrix and density matrix since it can be regarded as a complex square root of density matrix expressible as a product of real squared of density matrix and unitary S-matrix. The system can be also in thermal equilibrium so that thermodynamics becomes a genuine part of quantum theory and thermodynamical ensembles cease to be practical fictions of the theorist. In this case M-matrix represents a superposition of zero energy states for which positive energy state has thermal density matrix.

1. If the positive energy parts of zero energy states appearing in the superposition have only single value of energy, the notion of remote metabolism is certainly well-defined. Even in the case that the system is thermalized remote metabolism makes sense since average energy can be increased by remote metabolism. One can even imagine a statistical variant of the process in which the temperature increases.

2. The critical question is whether crossing symmetry prevails in the sense that the positive energy signal propagating to the geometric future is equivalent to a negative energy signal propagating to geometric past. The eigen modes of the modified Dirac operator appearing in the first principle formulation of quantum TGD are characterized by the eigenvalues λ, which are complex. $|\lambda|^2$ has interpretation as a conformal weight mathematically analogous to a vacuum expectation value of Higgs field. There are reasons to believe that the eigenvalues relate closely to the zeros of Riemann zeta and/or its generalizations. If the eigenvalue and its complex conjugate correspond

to a state and its phase conjugate, crossing symmetry fails and would mean also breaking of time reversal symmetry.

Is zero energy ontology consistent with time mirror mechanism

Energy conservation and geometric arrow of time poses strong conditions on the mechanism. If positive energy part of state sends negative energy signal, then negative energy part of state must send a compensating positive energy signal. Furthermore, positive (negative) energy signals propagate towards geometric future (past).

1. If only single space-time sheet is involved, either negative energy signal S_-: $X_-^4 \to Y_-^4$ or positive energy signal S_+: $X_+^4 \to Y_-^4$ is possible. The energy of both states is reduced in magnitude. For instance, this process tends to reduce destroy long term memories represented as bit sequences with bit represented by population inverted laser system.

2. Second possibility is that X^4 are Y^4 are disjoint and X^4 is in the geometric future of Y^4.

   The first possibility is S_+: $X_+^4 \to Y_-^4$ and negative energy signal S_-: $X_-^4 \to Y_-^4$: the energy of both X^4 and Y^4 is reduced in this case.

   Second possibility is S_-: $X_+^4 \to Y_+^4$ and S_+: $Y_-^4 \to X_-^4$. X^4 would suck energy from Y^4 in the geometric past. This option could correspond to both remote metabolism, memory recall, and intentional action. The presence of topological light ray connecting two systems would be also a correlate for time-like quantum entanglement making possible sharing and fusion of mental images and creating a sensation about flow of time just like it creates sensation of depth in stereo vision by fusion of right and left visual fields. Depending on the sign of the energy of the signal one would have memory or precognition. Precognition would require use of metabolic energy and this might be one reason for why it is rather rare.

3. Suppose next that the zero energy space-time sheet, call it X^4, is inside larger space-time sheet, call it Y^4: $X^4 \subset Y^4$. In this case one can have S_-: $X_+^4 \to Y_+^4$ accompanied by S_+: $X_-^4 \to Y_-^4$. $X^4 \subset Y^4$ would suck energy from a larger system Y^4. It is of course possible to replace signals with signals of opposite energy in opposite time direction.

   A possible interpretation is as a metabolic charging of smaller space-time sheets by sucking energy from longer scales or by active pumping of energy to shorter scales. The transformation of long wavelength photons with large Planck constant to short wavelength photons with smaller Planck constant is an analogous process and might realize metabolic charging in biology. For instance, Sun-Earth system could correspond to Y^4 and biosphere to X^4.

To sum up, zero energy ontology completes the picture in the sense that it also provides a process making possible metabolic charging.

Thermodynamical considerations

It is not at all obvious whether the proposed picture is consistent with the standard thermodynamics. The transfer of energy from long to shorter length scales making possible to gain metabolic energy and realize the mechanism of long term memory indeed seems a genuinely new element. This process resembles dissipation in the sense that energy is transferred from long to short length scales. In an approach to thermal equilibrium temperature gradients are however reduced whereas remote metabolism favors the active generation of "hot spots".

These considerations relate closely to the notions of entropy and syntropy by Italian mathematician Luigi Fantappie [49] assigned with the two arrows of time. I learned from the work of Fantappie in SSE conference held in Röros from Antonella Vannini [48] and Ulisse Di Corpo [50].The discovery of Fantappie was that in living systems entropic processes seem to be accompanied by syntropic processes which seem to be finalistic. He assigned these processes to the advanced solutions of wave equations.

It would seem that entropy and syntropy do not relate directly to the notion of remote metabolism.

1. Syntropy growth would indeed be the mirror image of entropy growth associated with negative energy mirror image of positive energy dynamics. This dynamics could be seen as sequences of downwards scalings leading from long time scale to short time scale. This sequence would define

time sequences proceeding in opposite directions of time for positive and negative energy parts of states. Thus entropy growth would be accompanied by syntropy growth.

2. Syntropy growth could be also seen as a consequence of generalized second law applying with respect to subjective time and growth of syntropy would be growth of entropy but manifesting itself at space-time level in reversed direction of geometric time. For instance, the spontaneous assembly of bio-molecules from their parts could be seen as a decay process in the reverse direction of geometric time controlled by phase conjugate control signals.

3. Remote metabolism as generation of "hot spots" does not seem to reduce to these notions and might represent a genuine breaking of standard thermodynamical view about the world.

One must also distinguish the notions of entropy and syntropy from the notion of number theoretic entanglement negentropy N assignable with quantum entanglement with algebraic entanglement probabilities.

1. N is defined as the maximum of the p-adic entanglement negentropy $N(p)$ as a function of the p-adic prime p and thus assigns to an entangled system a unique prime p_{max}. $N(p)$ is obtained by replacing in the definition of the Shannon entropy the argument of logarithm with its p-adic norm. N is in general positive and thus defines a genuine measure of information.

2. The non-negative negentropy defined in this manner characterizes entanglement as a carrier of information rather than the state of either of systems and has nothing to do with the ordinary (non-positive) entropy characterizing the lack of knowledge about the state of either subsystem. Negentropy Maximization Principle [29] favors the increase of the number theoretic negentropy and thus formation of entanglement quantum systems and generation of quantum coherence. Depending on the character of entanglement negentropic entanglement might be interpreted as a correlate for some conscious experience with positive content: say experience of understanding (time-like entanglement implying causal structure), of love (space-like entanglement), etc...

It is not obvious to me whether the remote metabolism as a manner to build hot spots and diversity could be reduced to NMP or whether it should be regarded as something completely independent.

7.4.6   Applying computer analogy to the model for long term memories

The general model for long term memories does not say anything detailed about how memory recall can take place effectively. Taking seriously the idea that we made computers as our images, one can try to see whether the basic facts about memory storage and recall in the case of computers could help to guess how the memory recall is realized in TGD Universe.

The basic metaphor is 4-D brain as a kind of magnetic tape in time direction carrying memories as a text consisting of letters with fixed width (temporal duration) and decomposing into paragraphs, sections, etc... just like written text. Rhythms of generalized EEG would realize the decomposition to letters, and larger sub-units.

Computer analogy suggests also the analog of directory system allowing an easy and rapid access to a particular record in a particular file. Fractality would automatically make possible fractally scaled down variants of the system with life span scaled down to a second but details absent or not visible in the cognitive resolution available.

Web suggests a link system in temporal direction realizing temporal associations automatically and topological light rays which would be vacuum extremals in passive state could realize the link system.

The two kinds of memories seem to be closely related

There are two kinds of memories. The proposal is that the sharing of mental images of the geometric past gives rise to episodal memories, re-experiences. These memories would correspond to mental images identified as quantum jumps containing quantum jumps containing... for zero energy states. This hierarchy would correspond to dark matter hierarchy and hierarchy of Planck constant.

One can criticize this idea.

1. Does the quantum entangled zero energy state of the magnetic body and brain of the geometric past really give rise to the episodal memory as sharing of mental images? The sharing aspect would certainly give rise to experience of time as analog for the depth experience in stereo vision assumed to result from the sharing of left and right visual mental images. But why not interpret this kind of state as a representation for a "law of nature" telling that state pairs in the superposition of states are causally related? Isn't state function reduction reducing entanglement necessary to experience sharp sensory qualia? The answer to these questions is that it is entangled system whose qualia are in question, not either of the individual systems. In quantum context this would mean that the sum of observables giving rise to the qualia of separate systems are measured in quantum jump.

2. What it really means to have an episodal memory? For sharing of mental images by space-like entanglement of sub-selves the space-time correlate is the join along boundaries bonds connecting the space-time sheets condensed at larger disjoint space-time sheets. In the case of episodal memories it would seem that the experiencer-now and and experiencer-then must correspond to disjoint space-time sheets and containing smaller space-time sheets connected by a topological light ray. Hence also classical communications would be an essential part of the mechanism of memory and the distinction between episodal and declarative memories does not seem so sharp as thought originally.

3. The mere re-experiencing of events of the geometric past by quantum entangling with a sub-system representing sensory mental image is not very effective mechanism. A more effective manner to remember is to represent memories symbolically as bit sequences with bits represented as population inverted state and ground state of laser (say many-sheeted laser). In this case metabolism is required to keep the representations intact.

Memory recall as communications between magnetic body and brain of geometric past

Memory recall would be communications between magnetic body and brain of the geometric past. Magnetic body can be visualized as a kind of onion with several layers: the larger the radius of layer the longer temporal distance T to the geometric past it corresponds. In memory recall the size of the active layer would correspond naturally to the temporal distance to the brain of the geometric past where the memory is stored. The frequencies of large Planck constant photons involved with communications would correspond to this distance ($f \sim 1/T$) and a de-coherence to photons with much shorter wavelength would take place in the process.

Neuroscience suggests that theta waves, which still have wavelength of order Earth size scale, are involved. They could result in de-coherence of waves with wavelength of order $\lambda = cT$ reducing the value of Planck constant.

The most primitive memory recall would rely on the scanning of brain of geometric past by using negative energy signal with a slowly varying carrier frequency. One can however consider MEs which are present permanently as vacuum extremals and activated to non-vacuum extremals during memory recall: this would mean a realization of a link system.

How could one realize links in time-like direction?

Links are certainly one of the most powerful functions of the web. Links are always present and activated when used. The obvious counterpart for the web link would be a topological light ray connecting two subsystems with a time-like separation. Topological light rays can also reduce to vacuum extremals and the activation of the the link could correspond to a feeding of energy to a topological light ray deforming it to a non-vacuum extremal. This kind of links would be naturally associated with long term memories and would make it un-necessary to scan the entire geometric past in the search of a particular episodal or declarative memory.

Dreams and building up of copies of memories

Important memories should be stored in several copies since would increase the probability that the scanning of the geometric past allows to build ME bridge to the subsystem representing the memory

mental image. Memories represented as bit sequences can be also lost in a repetitive recall since they might fail to receive metabolic energy feed.

Dreams might be a manner to build this kind of copies. The copies built up in this manner can involve a considerable processing and it could even happen that for painful memories large number of less painful variants are constructed. Also the original memory could be transformed to less painful during the period of time-like entanglement. When it is important that memory remains unchanged, PS might in fact be not favorable and it is known that PS deprivation can help of keeping memory intact [45].

There is a lot of evidence that memory processing indeed occurs during sleep (memory consolidation): in particular during paradoxical sleep (PS, REM periods with dreams) and during periods of deep slow wave sleep (SWS) preceding them. The sequential model for memories [45] assumes that both periods are necessary. The first guess is that dreams and preceding SWS periods could build copies of both episodal and declarative memories.

The sensory experience associated with a dream possibly resulting partially by sharing of sensory mental image of geometric past (say previous day) could give rise to a symbolic representation realized as a kind of record. If also a copy of sensory mental image is created, the dream would involve virtual visual input generated by sending signals from brain to retina and other sensory organs involved (in TGD sensory organs carry fundamental sensory qualia). This back projection is present also during wake-up state and essential part of building sensory representation from the raw sensory data. The fact that dreams are by no means direct copies of the sensory inputs of the geometric past suggests that an active buildup of sensory mental images indeed takes place. One could however stretch the limits of imagination and argue that the dreams could be composed of sequences of shared mental images from different times: this would conform with the short time range of "dream logic".

If the brain can be regarded as a kind of magnetic tape in the temporal direction, SWS period might be interpreted as a kind of empty interval in the tape telling that a memory record comes next (kind of silence before concert). Second function of SWS pattern would be to divide the time axis to frames analogous to letters appearing as units in computer memory. The SWS interval might also contain a temporal pattern defining among other things what might be regarded as a name of the record in question. The temporal pattern of the negative energy signal used in memory recall should have such a pattern that it would "resonate" with this pattern. Note that vacuum extremal MEs could define "static" links to memory mental images activated during memory recall to non-vacuum extremals and one can imagine also sequences of these extremals building a sequence of links.

Directory system, holograms, and p-adic fractality

Directory system is necessary in order to handle computer memory effectively. Basically the directory would be a scaled down fractal variant of the geometric past with a reduction of details leaving only titles of sections and subsections, so to say. These directories would make possible an effective scanning of the brain of the geometric past by going directly to the correct directory coded roughly by the temporal distance. The fact that we can construct mentally fractally scaled down memory representations about what happened during day and even during lifetime without effort suggests that this kind of fractal representation indeed is there.

The obvious idea is that the items of directories serve as links to subdirectories so that it is possible to active link in each directory item leading to a subdirectory associated with that item.

The fact that p-adically small is large in the real sense would automatically realize small time scale representations of long temporal intervals. This would suggest that the memory storage mechanism is hologram like so that copies of memories in various time scales are present. Effective p-adic topology would indeed suggest the presence of this kind of representation with various copies appearing as p-adically scaled variants of basic pattern for given p. For this option declarative memory recall would not require a precisely targeted signal to a particular moment of geometric past whereas sensory memories would require it (note however the possibility that dreams build more or less faithful copies of sensory memories).

One could imagine a fractal coding of names of directories and subdirectories by temporal distances in various p-adic length scales. Here effective p-adic topology giving rise to a hierarchy of p-adic length scales might play key role in the coding. Also dark matter hierarchy and hierarchy of Planck constants would be involved in an essential manner and code for various scales of long term memory. The fact that favored value of Planck constants and p-adic length scales come in octaves suggests a close

interaction between the two hierarchies.

The p-adic view about cognition suggests that p-adic numbers give a representation for the addresses of records and that effective p-adic topology for real space-time sheets is essential. Their space-time counterparts would be discrete intersections field bodies and p-adic space-time sheets having literally infinite size. The density of points of intersection would reduce as one moves away from biological body both in temporal and spatial direction and the fact that p-adic numbers correspond always to non-negative real numbers would conform with the fact that memories are about geometric past and the memories of nearest past are the most precise and for time scales which are fractions of second become sensory experiences which are actually very short term memories as findings of Libet demonstrate.

What is the role of generalized EEG rhythms from the point of view of memory?

TGD predicts entire hierarchy of EEG rhythms which are predicted to correlate with various biorhythms. One challenge is to understand the precise role of EEG rhythms, in particular theta band known to be involved with memory consolidation. Functional magnetic resonance imaging led to the discovery of so called so called spontaneous fluctuations in BOLD (blood oxygen level dependent) signal having 1/f spectrum in average sense [44] (I am grateful for Vesa Kiviniemi (who is also working in this field [37]) for sending me this review article). The frequency spectrum of these fluctuations is in the range range $.1 - .001$ Hz.

This activity is regarded as spontaneous in the sense that it is not induced by stimulus, motor output, or task but is something independent and thus conflicts with the paradigm that EEG corresponds directly to the brain state dictated by the input to brain and motor output and by cognitive tasks. For this reason spontaneous BOLD fluctuations were originally interpreted as noise but it has become clear that the fluctuation patterns possess both spatial and temporal coherence and that it is possible to assign regions of spatial coherence with brain functions in various brain areas.

The variation of spontaneous BOLD fluctuations explains also the variation of responses in experimental situations involving fixed stimulus or tasks. Spontaneous BOLD fluctuations seem to superpose linearly with the effect due to stimulus or task. BOLD fluctuations seem correlate with the slow fluctuations in EEG known to modulate the power spectrum in various EEG bands. Interestingly, there are also ~ 1 Hz slow fluctuations of membrane potential, which could be related to the cyclotron frequencies of DNA nucleotides (carrying constant negative charge density).

These findings conform with the fact that TGD predicts a fractal hierarchy of EEGs corresponding to the hierarchy of values of Planck constant. A further prediction would be that scaled variants of alpha band and its harmonic should appear in BOLD fluctuations as also the counterparts of beta and theta bands whose positions cannot however predicted without further assumptions.

EEG and its generalization would allow to interpret EEG rhythms as dividing the magnetic tape in time direction to a linear lattice of separate frames which each could represent a record in turn containing further records. This would be much like a fractal variant for the decomposition of a written text to letters with an approximately constant width. SWS would define kind of empty lines between paragraphs in this text and during wake-up state similar empty lines might be present.

Of course, the strict linear lattice is an idealization. It could be perturbed by insertions just like written text by pictures. These insertions could represent sensory mental images due to sensory input. Another analogy for sensory input would be as external force inducing kicks to the harmonic oscillator changing the amplitude of oscillation and inducing phase increments.

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Chapter 8

About the Nature of Time

8.1 Introduction

The notion of time remains one of the most problematic concepts of physics. In classical physics the different properties of the time of Newton's equations and thermodynamical time are puzzling. In special relativity and general relativity the notion of simultaneity becomes a problematic concept and challenges the naive Newtonian view about time flow as a motion of 3-D time=constant snapshot of 4-D space-time. The replacement of time=constant 3-surface with past directed light-cone assignable to the world-line of observer resolves this problem. In general relativity the problem is that past light-cones need make sense only locally. In quantum measurement theory the localization of the state function reduction process into a finite space-time volume is in conflict with the determinism of Schrödinger equation. In biology the presence of self-organization processes like self assembly challenge second law of thermodynamics in short time scales. In neuroscience the finding of Libet suggesting that neural activity seems to precede conscious decision forces to give up the notion of free will or the naive identification of experienced and geometrical time.

In this essay I will consider a new view about time based on Topological Geometrodynamics [18], which can be regarded as an attempt to unify fundamental interactions assuming that space-times are representable as 4-dimensional surfaces of certain higher-dimensional space-time $H = M^4 \times CP_2$ (M^4 denotes 4-D Minkowski space and CP_2 complex projective space of 2 complex dimensions) fixed by the requirement that the theory explains standard model symmetries and provides a geometrization of classical gauge fields and gravitational fields.

The construction of quantum TGD leads to a radical revision of space-time concept (many-sheeted space-time and topological field quantization), and forces also to generalize the original view about imbedding space. p-Adic physics as physics of cognition and intentionality is part of TGD inspired theory of consciousness and the need to fuse real and p-adic physics to single coherent whole forces to revise the notions of number and space-time. It has been also necessary to replace the standard positive energy ontology with what I call zero energy ontology. These generalizations are of special importance in TGD inspired theory of consciousness and of quantum biology.

There are several first principle approaches to quantum TGD and following gives only a very concise summary of them.

1. Generalization of Einstein's program of geometrizing classical physics so that quantum theory can be seen as a theory of *classical* spinor fields in the world of classical worlds (WCW) consisting of light-like 3-surfaces and possessing Kähler geometry [24, 22]. By general coordinate classical physics becomes an exact part of quantum theory in a well-defined sense. A geometrization of Fermi statistics is obtained, and the Clifford algebra associated with the spinors of WCW can be regarded as a direct sum of von Neumann algebras known as hyper-finite factors of type II_1 (HFFs) closely related to quantum groups and non-commutative geometry;

2. Quantum TGD as almost topological field theory (TQFT) with fundamental objects identified as light-like 3-surfaces and having generalized super-conformal symmetries as symmetries [21, 22]: the notion of braid is the basic building block of this approach;

3. There are two kinds of conformal symmetries corresponding to the boundary of light-cone of Minkowski space and light-like 3-surfaces, and these symmetries alone dictate to high degree the physics. Quite recently it turned that also a symplectic analog of conformal field theory emerges naturally in TGD framework (super-symplectic symmetries) and this led to a concrete proposal for how to construct n-point functions needed to calculate M-matrix [18];

4. Physics as a generalized number theory involving three different threads corresponding to need fuse real and various p-adic physics to single coherent whole by using a generalization of number concept obtained by gluing reals and various p-adic number fields and their extensions together along rationals and common algebraics [23]; the observation that standard model symmetries and dynamics of quantum and classical TGD are to high degree dictated by classical number fields [20]; and the ideas inspired by the notion of infinite prime [19];

5. The identification of WCW Clifford algebra elements as hyper-octonion (subspace of complexified octonions spanned by real unit and octonionic imaginary units multiplied by the commuting additional imaginary unit) valued conformal fields having values in HFF provides a justification for the concept of number theoretic braid needed both in the fusion of real and p-adic physics and in TGD as almost TQFT approach;

6. The hierarchy of Planck constants realizing quantum criticality [17] forces a generalization of the notion of imbedding space by replacing it with a book like structure having as its pages singular coverings and factor spaces of H and allowing to realize geometric correlates for the choice of quantization axis in quantum measurement: the particles at different pages of this book are "relatively dark" since they do not possess local interaction vertices which means a radically new manner to interpret dark matter;

7. Zero energy ontology and the notion of finite measurement resolution formulated in terms of inclusions of HFFs fix quantum dynamics highly in terms of Connes tensor product allowing to interpret quantum theory as a square root of thermodynamics [18, 22]: finite measurement resolution has number theoretic braid as its space-time correlate so that various approaches to TGD are closely related;

8. Quantum theory of consciousness as a generalization of quantum measurement theory to include observer to the theory [32].

The notion of number theoretic braid is a common denominator of various approaches to quantum TGD and leads to effective discretization of the imbedding space which is however due to the finite measurement resolution and number theoretic constraints rather than being something fundamental so that there are no problems with standard conservation laws.

The article series about TGD and its applications to biology and consciousness [18, 32, 31, 28, 29, 27, 30, 26] gives an overall view about quantum TGD. In the following I will concentrate only on the aspects of quantum TGD relevant for the notion of time. I will first describe zero energy ontology and p-adicization program and after that consider the problem of time.

8.2 The most recent vision about zero energy ontology and p-adicization

The generalization of the number concept obtained by fusing real and p-adics along rationals and common algebraics is the basic philosophy behind p-adicization. One must be able to speak about rational points common to real and various p-adic variants of H. The basic objection is the necessity to fix some special coordinates in turn implying the loss of a manifest general coordinate invariance. The isometries of the imbedding space could save the situation provided one can identify some special coordinate system in which isometry group reduces to its discrete subgroup. The loss of the full isometry group could be compensated by assuming that WCW is union over sub-WCWs obtained by applying isometries on basic sub-WCW with discrete subgroup of isometries.

The combination of zero energy ontology realized in terms of a hierarchy of causal diamonds (CDs) and hierarchy of Planck constants providing a description of dark matter and leading to a generalization of the notion of imbedding space suggests that it is possible to realize this dream. The

article [18] provides a brief summary about recent state of quantum TGD helping to understand the big picture behind the following considerations.

8.2.1 Zero energy ontology briefly

1. The basic construct in the zero energy ontology is the space $CD \times CP_2$, where the causal diamond CD is defined as an intersection of future and past directed light-cones with time-like separation between their tips regarded as points of the underlying universal Minkowski space M^4. In zero energy ontology physical states correspond to pairs of positive and negative energy states located at the boundaries of the future and past directed light-cones of a particular CD.

2. CDs form a fractal hierarchy and one can glue smaller CDs within larger CDs. This construction recipe when combined with TGD inspired theory of consciousness allows to understand the asymmetry between positive and negative energies and why the arrow of experienced time corresponds to the arrow of geometric time and why the contents of sensory experience is located to so narrow interval of geometric time. One can imagine evolution to occur as quantum leaps in which the size of the largest CD in the hierarchy of personal CDs increases in such a manner that it becomes sub-CD of a larger CD. p-Adic length scale hypothesis [18] follows if the values of temporal distance T between tips of CD come in powers of 2^n: $T = 2^n T_0$. All conserved quantum numbers for zero energy states have vanishing net values. The interpretation of zero energy states in the framework of positive energy ontology is as physical events, say scattering events with positive and negative energy parts of the state interpreted as initial and final states of the event.

3. In the realization of the hierarchy of Planck constants $CD \times CP_2$ is replaced with a Cartesian product of book like structures formed by almost copies of CDs and CP_2s defined by singular coverings and factors spaces of CD and CP_2 with singularities corresponding to intersection $M^2 \cap CD$ and homologically trivial geodesic sphere S^2 of CP_2 for which the induced Kähler form vanishes. The coverings and factor spaces of CDs are glued together along common $M^2 \cap CD$. The coverings and factors spaces of CP_2 are glued together along common homologically non-trivial geodesic sphere S^2. The choice of preferred M^2 as subspace of tangent space of X^4 at all its points and interpreted as space of non-physical polarizations, brings M^2 into the theory also in different manner. S^2 in turn defines a subspace of the much larger space of vacuum extremals as surfaces inside $M^4 \times S^2$.

4. Configuration space (the world of classical worlds, WCW) decomposes into a union of sub-WCWs corresponding to different choices of M^2 and S^2 and also to different choices of the quantization axes of spin and energy, color isospin and hyper-charge for each choice of this kind. This means breaking down of the isometries to a subgroup. This can be compensated by the fact that the union can be taken over the different choices of this subgroup.

5. p-Adicization requires a further breakdown to discrete subgroups of the resulting sub-groups of the isometry groups but again a union over sub-WCWs corresponding to different choices of the discrete subgroup can be assumed. Discretization relates also naturally to the notion of number theoretic braid.

8.2.2 WCW spinor fields

In TGD framework zero energy states correspond to the modes of completely classical WCW spinor fields with fermionic second quantization at space-time level having purely geometric interpretation at the level of WCW. The analysis of the degrees of freedom involved demonstrates that WCW spinor fields are analogous to ordinary quantum fields but hav infinite number of components.

1. WCW decomposes to a sub-WCWs association with unions of causal diamonds (CDs). Individual CD is partially characterized by the moduli defined by the positions of its upper and lower tips. The proposal is that the temporal distances between the tips are quantized in octaves of CP_2 time scale and thus coming in good approximation as secondary p-adic time scales for primes very neary to power of two. The most general proposal is that also the position of the upper tip at proper time = constant hyperboloid of future lightcone M_+^4 is quantized for positive

energy states. For negative energy states this happens to the lower tip. This disrete set would provide a discretized quantum version of Robertson-Walker cosmology with discretized lattice like structure replacing the continuum. The interpretation would be that first tip corresponds to the usual Minkowski space-time of special relativity and the discretized position of second tip - or rather the space M_+^4 representing the relative position of the tips- to the space-time of cosmology. This implies very strong predictions such as the quantization of cosmic redshifts which is indeed observed [19]. Similar quantization would take place in CP_2 degrees of freedom for either tip. WCW spinor fields for single CD would depend on these moduli and for positive (negative) states one would have wave functions in the space formed by sub-WCWs with wave function basis consisting of products of plane waves in M^4 with a wave function in the discrete subset of $M_\pm^4$. These degrees of freedom generalize those of a quantum field in Minkowski space. If the upper tip is assigned with observer, the sub-CDs in the interior of CD correspond to astrophysical objects and M_+^4 as empty Robertson-Walker cosmology predicts automatically cosmic redshift.

2. The notion of generalized imbdding space forces to assign to a given CD a selection of quantization axis of energy and spin which in the case of M^4 boils down to a choice of a preferred plane $M^2 \subset M^4$ plus a choice of time direction (rest system). In the case of CP_2 the choice of quantization axes of color isospin and hypercharge means a choice of a homologically trivial geodesic sphere of CP_2 plus preferred isospin quantization axes. The space for possible choices of quantization axis defines additional moduli. The selection of quantization axes in state function reduction means a localization in these degrees of freedom. The space characterizing the selections of color quantization axis represents an example of so called flag manifold. It has already earlier appeared in TGD inspired biology with a motivation coming from the observation of topologists Barbara Shipman that the mathematical model for honeybee dance leads naturally to the introduction of this space. Shipman speculated that quarks have some role in biology [34]. Dark matter hierarchy indeed makes indeed possible scaled up copies of QCD type theory in biological length scales.

3. WCW spinor fields restricted to a CD with fixed moduli have infinite number of bosonic and fermionic degrees of freedom. Spin-like degrees of freedom for these fields correspond to WCW spinors, which describe many-fermion states consisting of quarks and leptons and bosons defined as their bound states. This Fock state is assigned to each 3-surface and the dependence on 3-surface defines purely bosonic ('orbital') degrees of freedom, which can be coded by using a state basis whose elements have well-defined spin and color quantum numbers. The bosonic and fermionic degrees of freedom are super-symmetrically related.

Is it really possible to speak about zero energy states for a given sector defined by generalized imbedding space with fixed M^2 and S^2? Classically this is possible and conserved quantities are well defined. In quantal situation the presence of the light-cone boundaries breaks full Poincare invariance although the infinitesimal version of this invariance is preserved. Note that the basic dynamical objects are 3-D light-like "legs" of the generalized Feynman diagrams glued together along their ends at generalized vertices.

8.2.3   Definition of energy in zero energy ontology

The approach relying on the two super conformal structures of quantum TGD gives hopes of defining the notion of energy for positive and negative energy parts of the state.

1. CD allows translational invariance only in its interior and since partonic two surfaces are located to the boundary of CD, one can argue that translations assigned to them lead out from CD. One can however argue that if it is enough to assign eigentates of four-momentum to partons and require that only the total four-momentum generators acts on the physical state by shifting CD. Since total four-momentum vanishes for CD this would mean that wave function in cm degrees of CD is just constant plane wave. Super-conformal invariance would indeed allow to assign momentum eigenstates to the super-conformal representations.

2. A more stringent condition would be that four-momentum generators act as translation like operators on partons themselves. Since light-like 3-surfaces assignable to incoming and outgoing legs of the generalized Feynman diagrams are the basic objects, one can hope of having enough translational invariance to define the notion of energy. If translations are restricted to time-like translations acting in the direction of the future (past) then one has local translation invariance of dynamics for classical field equations inside $\delta M_{\pm}^4$ as a kind of semigroup. Also the M^4 translations leading to interior of X^4 from the light-like 2-surfaces surfaces act as translations. Classically these restrictions correspond to non-tachyonic momenta defining the allowed directions of translations realizable as particle motions. These two kinds of translations have been assigned to super-symplectic conformal symmetries at $\delta M_{\pm}^4 \times CP_2$ and and super Kac-Moody type conformal symmetries at light-like 3-surfaces. Equivalence Principle in TGD framework states that these two conformal symmetries define a structure completely analogous to a coset representation of conformal algebras so that the four-momenta associated with the two representations are identical [21].

Finite M^4 translations to the interior of CD do not respect the shape of the partonic 2-surface. Local M^4 translations vanishing at the boundary of CD however act as Kac-Moody symmetries of the light-like 3-surfaces and reduce physically to gauge transformations: hence one could allow also the deformations of the partonic 2-surface in the interior of the light-like 3-surface. This corresponds to the effective metric 2-dimensionality stating that all information both about the geometry of WCW and quantum physics is carried by the partonic 2-surfaces X^2 resulting as intersections of the light-like 3-surfaces X_l^3 and space-like 3-D surfaces X^3 at the boundaries of CD and the distribution of 4-D tangent planes of X^2.

3. The condition selecting preferred extremals of Kähler action is induced by a global selection of $M^2 \subset M^4$ as a plane belonging to the tangent space of X^4 at all its points [21] and interpreted as a plane of nonphysical polarizations so that direct connection with number theory and gauge symmetries emerges. The M^4 translations of X^4 as a whole in general respect the form of this condition in the interior. Furthermore, if M^4 translations are restricted to M^2, also the condition itself - rather than only its general form - is respected. This observation, the earlier experience with p-adic mass calculations, and also the treatment of quarks and gluons in QCD encourage to consider the possibility that translational invariance should be restricted to M^2 translations so that mass squared, longitudinal momentum and transversal mass squared would be well defined quantum numbers. This would be enough to realize zero energy ontology. Encouragingly, M^2 appears also in the generalization of the causal diamond to a book-like structure forced by the realization of the hierarchy of Planck constant at the level of the imbedding space.

4. That the cm degrees of freedom for CD would be gauge like degrees of freedom sounds strange. The paradoxical feeling disappears as one realizes that this is not the case for sub-CDs, which indeed can have non-trivial correlation functions with either upper or lower tip of the CD playing a role analogous to that of an argument of n-point function in QFT description. One can also say that largest CD in the hierarchy defines infrared cutoff.

8.2.4   p-Adic variants of the imbedding space

The need to fuse p-adic physics with TGD emerged originally from the discovery that p-adic mass calculations based on p-adic thermodynamics give excellent predictions for elementary particle masses if one assumes p-adic length scale hypothesis stating that primes near integer powers of 2 are physically favored [18]. Later came the interpretation of p-adic physics as cognition cognition and intentionality. The following somewhat technical construction of p-adic variants of the imbedding space provides new insights concerning the understanding of the arrow of geometric time.

1. Rational values of p-adic coordinates are non-negative so that light-cone proper time $a_{4,+} = \sqrt{t^2 - z^2 - x^2 - y^2}$ is the unique Lorentz invariant choice for the p-adic time coordinate near the lower tip of CD. For the upper tip the identification of a_4 would be $a_{4,-} = \sqrt{(t-T)^2 - z^2 - x^2 - y^2}$. In the p-adic context the simultaneous existence of both square roots poses additional conditions on T. For 2-adic numbers $T = 2^n T_0$, $n \geq 0$ (or more generally $T = \sum_{k \geq n_0} b_k 2^k$), would allow to satisfy these conditions, which would be one additional reason for $T = 2^n T_0$ implying p-adic

length scale hypothesis. The remaining coordinates of CD are naturally (hyperbolic) cosines and sines of the spherical coordinates θ and ϕ (hyperbolic angle $\eta_{\pm,4}$).

2. The existence of the preferred plane M^2 of un-physical polarizations would suggest that 2-D light-cone proper times $a_{2,+} = \sqrt{t^2 - z^2}$ $a_{2,-} = \sqrt{(t-T)^2 - z^2}$ can be also considered. The remaining coordinates would be naturally $\eta_{\pm,2}$ and cylindrical coordinates (ρ, ϕ).

3. The p-adically transcendental values of a_4 and a_2 are literally infinite as real numbers and could be visualized as points in infinitely distant geometric future so that the arrow of time might be said to emerge number theoretically.

4. The selection of the preferred quantization axes of energy and angular momentum unique apart from a Lorentz transformation of M^2 would have purely number theoretic meaning in both cases. One must allow a union over sub-WCWs labeled by points of $SO(1,1)$. This suggests a deep connection between number theory, quantum theory, quantum measurement theory, and even quantum theory of mathematical consciousness.

5. In the case of CP_2 there are three real coordinate patches involved [34]. The compactness of CP_2 allows to use cosines and sines of the preferred angle variable for a given coordinate patch.

$$
\begin{aligned}
\xi^1 &= tan(u)exp(i\frac{(\Psi + \Phi)}{2})cos(\frac{\Theta}{2}) \ , \\
\xi^2 &= tan(u)exp(i\frac{(\Psi - \Phi)}{2})sin(\frac{\Theta}{2}) \ .
\end{aligned}
\tag{8.2.1}
$$

The ranges of the variables u, Θ, Φ, Ψ are $[0, \pi/2], [0, \pi], [0, 4\pi], [0, 2\pi]$ respectively. Note that u has naturally only positive values in the allowed range. S^2 corresponds to the values $\Phi = \Psi = 0$ of the angle coordinates.

6. The rational values of the (hyperbolic) cosine and sine correspond to Pythagorean triangles having sides of integer length and thus satisfying $m^2 = n^2 + r^2$ $(m^2 = n^2 - r^2)$. These conditions are equivalent and allow the well-known explicit solution [33]. One can construct a p-adic completion for the set of Pythagorean triangles by allowing p-adic integers which are infinite as real integers as solutions of the conditions $m^2 = r^2 \pm s^2$. These angles correspond to genuinely p-adic directions having no real counterpart. Hence one obtains p-adic continuum also in the angle degrees of freedom. Algebraic extensions of the p-adic numbers bringing in cosines and sines of the angles π/n lead to a hierarchy increasingly refined algebraic extensions of generalized imbedding space. Since the different sectors of WCW directly serve as correlates of selves, this means a direct correlation with the evolution of the mathematical consciousness. Trigonometric identities allow to construct points which in the real context correspond to sums and differences of angles.

7. Negative rational values of the cosines and sines correspond as p-adic integers to infinite real numbers and it seems that one use several coordinate patches obtained as copies of the octant $(x \geq 0, y \geq 0, z \geq 0,)$. An analogous picture applies in CP_2 degrees of freedom.

8.3 Zero energy ontology, self hierarchy, and the notion of time

Consider now the formulation of TGD inspired quantum theory of consciousness [32] and quantum biology [31] in terms of zero energy ontology.

One should understand the asymmetry between positive and negative energies and between two directions of geometric time at the level of conscious experience, the correspondence between experienced and geometric time, and the emergence of the arrow of time. One should explain why human sensory experience is about a rather narrow time interval of about .1 seconds and why memories are about the interior of much larger CD with time scale of order life time. One should have a vision

about the evolution of consciousness: how quantum leaps leading to an expansion of consciousness occur.

Negative energy signals to geometric past - about which phase conjugate laser light represents an example - provide an attractive tool to realize intentional action as a signal inducing neural activities in the geometric past (this would explain Libet's classical findings), a mechanism of remote metabolism, and the mechanism of declarative memory as communications with geometric past. One should understand how these signals are realized in zero energy ontology and why their occurrence is so rare.

In the following I try to demonstrate that TGD inspired theory of consciousness and quantum TGD proper indeed are in tune.

8.3.1 Space-time and imbedding space correlates for selves

Quantum jump as a moment of consciousness, self as a sequence of quantum jumps integrating to self, and self hierarchy with sub-selves experienced as mental images, are the basic notions of TGD inspired theory of consciousness. In the most ambitious vision self hierarchy reduces to a fractal hierarchy of quantum jumps within quantum jumps. Quantum classical correspondence demands selves to have space-time correlates both at the level of space-time and imbedding space.

At the level of space-time the first guess for the correlates is as light-like or space-like 3-surfaces. If one believes on effective 2-dimensionality and quantum holography, partonic 2-surfaces plus their 4-D tangent space distribution would code the information about the space-time correlates. By quantum classical correspondence one can also identify space-time sheets as the correlates modulo the gauge degeneracy implied by super-conformal symmetries.

It is natural to interpret CDs as correlates of selves at the level of the imbedding space. CDs can be interpreted either as subsets of the generalized imbedding space or as sectors of WCW. Accordingly, selves correspond to CDs of the generalized imbedding space or sectors of WCW, literally separate interacting quantum Universes. The spiritually oriented reader might speak of Gods. Sub-selves correspond to sub-CDs geometrically. The contents of consciousness of self is about the interior of the corresponding CD at the level of imbedding space. For sub-selves the wave function for the position of tip of CD brings in the delocalization of sub-WCW.

The fractal hierarchy of CDs within CDs is the geometric counterpart for the hierarchy of selves: the quantization of the time scale of planned action and memory as $T(k) = 2^k T_0$ suggest an interpretation for the fact that we experience octaves as equivalent in music experience.

8.3.2 Why sensory experience is about so short time interval?

CD picture implies automatically the 4-D character of conscious experience and memories form part of conscious experience even at elementary particle level. Amazingly, the secondary p-adic time scale of electron is $T = 0.1$ seconds defining a fundamental time scale in living matter. The problem is to understand why the sensory experience is about a short time interval of geometric time rather than about the entire personal CD with temporal size of order life-time. The explanation would be that sensory input corresponds to subselves (mental images) with $T \simeq .1$ s at the upper light-like boundary of CD in question. This requires a strong asymmetry between upper and lower light-like boundaries of CDs.

The localization of the contents of the sensory experience to the upper light-cone boundary and local arrow of time could emerge as a consequence of self-organization process involving conscious intentional action. Sub-CDs would be in the interior of CD and self-organization process would lead to a distribution of CDs concentrated near the upper or lower boundary of CD. The local arrow of geometric time would depend on CD and even differ for CD and sub-CDs.

1. The localization of contents of sensory experience to a narrow time interval would be due to the concentration of sub-CDs representing mental images near the either boundary of CD representing self.

2. Phase conjugate signals identifiable as negative energy signals to geometric past are important when the arrow of time differs from the standard one in some time scale. If the arrow of time establishes itself as a phase transition, this kind of situations are rare. Negative energy signals as a basic mechanism of intentional action and transfer of metabolic energy would explain why living matter is so special.

3. Geometric memories would correspond to subselves in the interior of CD, the oldest of them to the regions near "lower" boundaries of CD. Since the density of sub-CDs is small there geometric memories would be rare and not sharp. A temporal sequence of mental images, say the sequence of digits of a phone number, would correspond to a temporal sequence of sub-CDs.

4. Sharing of mental images corresponds to a fusion of sub-selves/mental images to single sub-self by quantum entanglement: the space-time correlate could be flux tubes connecting space-time sheets associated with sub-selves represented also by space-time sheets inside their CDs.

8.3.3   Arrow of time

TGD forces a new view about the relationship between experienced and geometric time. Although the basic paradox of quantum measurement theory disappears the question about the arrow of geometric time remains. There are actually two times involved. The geometric time assignable to the space-time sheets and the M^4 time assignable to the imbedding space.

 Consider first the the geometric time assignable to the space-time sheets.

1. Selves correspond to CDs. The CDs and their projections to the imbedding space do not move anywhere. Therefore the standard explanation for the arrow of geometric time cannot work.

2. The only plausible interpretation at classical level relies on quantum classical correspondence and the fact that space-times are 4-surfaces of the imbedding space. If quantum jump corresponds to a shift for a quantum superposition of space-time sheets towards geometric past in the first approximation (as quantum classical correspondence suggests), one can understand the arrow of time. Space-time surfaces simply shift backwards with respect to the geometric time of the imbedding space and therefore to the 8-D perceptive field defined by the CD. This creates in the materialistic mind a temporal variant of train illusion. Space-time as 4-surface and macroscopic and macro-temporal quantum coherence are absolutely essential for this interpretation to make sense.

 Why this shifting should always take place to the direction of geometric past of the imbedding space? Does it so always? The proposed mechanism for the localization of sensory experience to a short time interval suggests an explanation in terms of intentional action.

1. CD defines the perceptive field for self. Selves are curious about the space-time sheets outside their perceptive field and perform quantum jumps tending to shift the superposition of the space-time sheets so that unknown regions of space-time sheets emerge to the perceptive field. Either the upper or lower boundary of CD wins in the competition and the arrow of time results as a spontaneous symmetry breaking. The arrow of time can depend on CD but tends to be the same for CD and its sub-CDs. Global arrow of time could establish itself by a phase transitions establishing the same arrow of time globally by a mechanism analogous to percolation phase transition.

2. Since the news come from the upper boundary of CD, self concentrates its attention to this region and improves the resolution of sensory experience. The sub-CDs generated in this manner correspond to mental images with contents about this region. Hence the contents of conscious experience, in particular sensory experience, tends to be about the region near the upper boundary.

 The emergence of the arrow of time at the level of imbedding space reduces to a modification of the oldest TGD based argument for the arrow of time which is wrong as such. If physical objects correspond to 3-surfaces inside future directed light-cone then the sequence of quantum jumps implies a diffusion to the direction of increasing value of light-cone propert time. The modification of the argument goes as follows.

1. CDs are characterized by their moduli. In particular, the relative coordinate for the tips of CD has values in past light cone M^4_- if the future tip is taken as the reference point. An attractive interpretation for the proper time of M^4_- is as cosmic time having quantized values. Quantum states correspond to wave functions in the modular degrees of freedom and each U process

creates a non-localized wave function of this kind. Suppose that state function reduction implies a localization in the modular degrees of freedom so that CD is fixed completely apart from its center of mass position to which zero four-momentum constant plane wave is assigned. One can expect that in average sense diffuction occurs in M_-^4 so that the size of CD tends to increase and that the most distant geometric past defined by the past boundary of CD recedes. This is nothing but cosmic expansion. This provides a formulation for the flow of time in terms of a cosmic redshift. This argument applies also to the positions of the sub-CDs inside CD. Also their proper time distance from the tip of CD is expected to increase.

2. One can argue that one ends up with contradiction by changing the roles of upper and lower tips. In the case of CD itself is only the proper time distance between the tips which increases and speaking about "future" and "past" tips is only a convention. For sub-CDs of CD the argument would imply that the sub-CDs drifting from the opposite tips tend to concentrate in the middle region of CD unless either tip is in a preferred position. This requires a spontaneous selection of the arrow of time. One could say that the cosmic expansion implied by the drift in M_-^4 "draws" the space-time sheet with it to the geometric past. The spontaneous generation of the asymmetry between the tips might require the "curious" conscious entities.

8.3.4 Can selves interact and evolve?

Interesting questions relate to how dynamical selves are.

1. Is self doomed to live inside the same sub-WCW eternally as a lonely god? This question has been already answered: there are interactions between sub-CDs of given CD, and one can think of selves as quantum superposition of states in CDs with wave function having as its argument the tips of CD, or rather only the second one since T is assumed to be quantized.

2. Is there largest CD in the personal CD hierarchy of self in an absolute sense? Or is the largest CD present only in the sense that the contribution to the contents of consciousness coming from very large CDs is negligible? Long time scales T correspond to low frequencies and thermal noise might mask these contributions. Here however the hierarchy of Planck constants and generalization of the imbedding space could come in rescue by allowing dark EEG photons to have energies above thermal energy.

3. Can selves evolve in the sense that the size of CD increases in quantum leaps so that the corresponding time scale $T = 2^k T_0$ of memory and planned action increases? Geometrically this kind of leap would mean that CD becomes a sub-CD of a larger CD - either at the level of conscious experience or in absolute sense. The leap can occur in two senses: as an increase of the largest p-adic time scale in the personal hierarchy of space-time sheets or as increase of the largest value of Planck constants in the personal dark matter hierarchy. At the level of individual organism this would mean emergence of new lower frequencies of generalized EEG and levels of personal dark matter hierarchy with larger value of Planck constant.

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Part III

INTELLIGENCE, INFORMATION, AND COGNITION

Chapter 9

Conscious Information and Intelligence

9.1 Introduction

This chapter is a fusion of two separate chapters, the first one devoted to information measures for conscious experience and second summarizing a quantum model for intelligent systems. This reflects in its own way the fact that the development of the related ideas has not been a linear process and has involved many weird twists typical for a mathematical thinking without strong connection with empiria.

The motivation for the recent updating are the developments in basic quantum TGD occurred during last five years (I am writing this towards the end of March, 2010). In the following I shall summarize TGD inspired view about information, intelligence and consciousness. Some of the memes of the previous version written around 2003 have lost the game and new memes - or rather an overall vision about conscious intelligence- has emerged.

9.1.1 Magnetic body as intentional agent and experiencer

The notion of magnetic body has a central role in TGD inspired biology. Magnetic body has an onionl ike fractal structure and astrophysical size with wavelength of EEG wave defining the size scale of the magnetic body with which it is associated. Magnetic body acts as as an intentional agent using biological body as a motor instrument and sensory receptor. Magnetic body receives sensory and other information from biological body through EEG and its fractal counterparts and controls biological body via EEG type signals sent to the genome, where they induce chemical or electromagnetic gene expression. This allows to imagine also a mechanism of collective learning. The spatio-temporal nerve pulse patterns defining topological quantum computations are mediated via EEG and its fractal counterparts to the magnetic body of organism and from it to the magnetic body of another organism [22].

The magnetic body of Earth - magnetic Mother Gaia- could serve as a relay station and Schumann resonances and alpha band could allow broadcasting of the nerve pulse pattern to a large number of magnetic bodies of organisms. From the latter magnetic body the field representation of nerve pulse pattern would induce via EEG type signal from magnetic body to the receiver genome the original nerve pulse pattern in the brain of the receiver. Nerve pulse patterns would be quite generally induced by magnetic bodies via appropriate part of the intronic genome as electromagnetic gene expression. This mechanism could be also involved with telepathy and remote mental interactions.

Magnetic flux tubes and flux sheets are basic building bricks of the magnetic body and DNA as topological quantum computer hypothesis assumes that DNA nucleotides are connected to cell membrane by flux tubes defining braids playing a key role in topological quantum computation [24]. Therefore magnetic body is essential for realizing the software of biological intelligence. The essential assumption is that magnetic body carries dark matter consisting of ordinary with a non-standard value of Planck constant. The phase transition changing the value of Planck constant change the size scale of the flux tube and this process together with reconncetion of the flux tubes would define

mechanisms of bio-catalysis.

9.1.2   What is conscious intelligence

The following summary tries to give a brief summary about how conscious intelligence could be understood in TGD Universe. The view relies heavily on the developents that have occurred during the last five years in the understanding of TGD. The vision about life and conscious information and intelligence as something in the intersection of real and p-adic worlds is certainly the most important aspect in this respect. Zero energy ontology and the notion of causal diamond (CD) with zero energy states having interpretation as memes in very general sense is also of central importance.The hierarchy of Planck constants as an explanation of dark matter and energy as macroscopic quantum phases even in astrophysical scales and implying that dark matter is a key actor in the drama of life is the third key element.

Zero energy ontology, causal diamonds, and quantum states as memes

Zero energy ontology was forced by the interpretational problems created by the vacuum extremal property of Robertson-Walker cosmologies imbedded as 4-surfaces in $M^4 \times CP_2$ meaning that the density of inertial mass (but not gravitational mass) for these cosmologies was vanishing meaning a conflict with Equivalence Principle. In zero energy ontology physical states are replaced by pairs of positive and negative energy states assigned to the past *resp.* future boundaries of causal diamonds (CDs) defined as pairs of future and past directed light-cones ($\delta M_{\pm}^4 \times CP_2$). The net values of all conserved quantum numbers of zero energy states vanish. Zero energy states are interpreted as pairs of initial and final states of a physical event such as particle scattering so that only events appear in the new ontology.

Zero energy ontology combined with the notion of quantum jump resolves several problems. For instance, the troublesome questions about the initial state of the universe and about the values of conserved quantum numbers of the Universe can be avoided since everything is in principle creatable from vacuum. Communication with the geometric past using negative energy signals and time-like entanglement are crucial for the TGD inspired quantum model of memory and both make sense in zero energy ontology. Zero energy ontology leads to a precise mathematical characterization of the finite resolution of both quantum measurement and sensory and cognitive representations in terms of inclusions of von Neumann algebras known as hyperfinite factors of type II$_1$ [24]. The space-time correlate for the finite resolution is discretization which appears also in the formulation of quantum TGD in terms of the modified Dirac action [46].

At the imbedding space-level CD is the correlate of self whereas space-time sheets having their ends at the light-like boundaries of CD are the correlates at the level of 4-D space-time. The hierarchy of CDs within CDs corresponds to the hierarchy of selves. Zero energy ontology leads also to an argument explaining why the arrow of subjective time induces an apparent arrow of geometric time as a result if intentional action and why the contents of sensory consciousness is restricted to such a narrow time interval (located near the future boundary of CD) [28].

The original interpretation of the space-time correlates of mental images was as mind-like space-time sheets identified as space-time sheets with a finite temporal size. In zero energy ontology all space-time sheets have a finite size and serve as correlates for zero energy states, which could be interpreted as representations of laws of physics as superpositions of pairs of initial and final states given by M-matrix. In state function reduction process these states are reduced to states for which only negentropic time-like entanglement is possible and one might say that the negentropy measures the conscious information associated with the final state of the reduction process. One can interpret negentropic quantum states as memes or morphogenetic fields [58, 26] These negentropic quantum states are possible only in the intersection of real and p-adic worlds so that living systems are the systems carrying information and intelligence.

Boolean mind and fermions

The connection of fermionic Fock space basis with Boolean algebra was one of the first ideas related to the quantum modelling of intelligent systems. The state basis for the fermionic Fock space has a natural interpretation as Boolean algebra (fermion number $=1/0 \leftrightarrow$ yes/no). In this manner ordinary

Boolean algebra is extended to a vector space spanned by fermionic states. Fermion number conservation poses an obvious problem for this scenario in positive energy ontology. Zero energy ontology resolves this problem quite generally and zero energy states resulting as an outcome of state function reduction process represent Boolean statements of type A$\rightarrow$ B in terms of time-like negentropic entanglement in fermionic degreees of freedom.

The original proposal was to use cognitive fermion pairs instead of fermions with fermion and antifermion located at the opposite throats of wormhole contact. In the recent formulation of quantum TGD bosons and their super counterparts correspond to wormhole contacts. An interesting question is whether one could consider ordinary Boolean logic as some kind of limit for the complex quantum logic and whether our logical mind could have something to do with Boolean algebra. For instance, could primary 'this is true' experiences correspond to Boolean qualia having increments of fermionic quantum numbers as physical correlates. Boolean truth values could also correspond to spin directions of fermions. In this case fermion number conservation does not pose any constraints and the macrosopic realization replaing single spin as a representative of bit with a magnetized ensemble of fermions, makes the realization robust.

Negentropic entanglement means that qubits are always fuzzy and the fuzziness depends on the situation. The positive aspect is that the quantum superposition gives rise to an abstraction, rule about pairing of say initial and final states represented as positive and negative energy parts of zero energy state with the pairs of superposition representing the instances of the rule. p-Adic-real entanglement with positive definite number theoretical entanglement entropy in the intersection of real and p-adic worlds could give rise the experience of understanding and makes possible cognitive quantum computation like processes.

p-Adic physics as physics of cognition and intention

The vision about p-adic physics as physics of cognition has gradually established itself as one of the key idea of TGD inspired theory of consciousness. There have been several motivations for this idea.

Perhaps the strongest motivation is the vision about living matter as something residing in the intersection of real and p-adic worlds. One of the earliest motivations was p-adic non-determinism identified tentatively as a space-time correlqte for the non-determinism of imagination. p-Adic non-determinism follows from the fact that functions with vanishing derivatives are piecewise constant functions in the p-adic context. More precisely, p-adic pseudo constants depend on the pinary cutoff of their arguments and replace integration constants in p-adic differential equations. In the case of field equations this means roughly that the initial data are replaced with initial data given for a discrete set of time values chosen in such a manner that unique solution of field equations results. Solution can be fixed also in a discrete subset of rational points of the imbedding space. Presumably the uniqueness requirement implies some unique pinary cutoff.

Thus the space-time surfaces representing solutions of p-adic field equations are analogous to space-time surfaces consisting of pieces of solutions of the real field equations. Thus p-adic reality is much like the dream reality consisting of rational fragments glued together in illogical manner or pieces of child's drawing of body containing body parts in more or less chaotic order.

The obvious looking interpretation for the solutions of the p-adic field equations is as a geometric correlate of imagination. Plans, intentions, expectations, dreams, and cognition in general are expected to have p-adic space-time sheets as their geometric correlates. This in the sense that p-adic spacetime sheets somehow initiate the real neural processes providing symbolic counterparts for the cognitive representations provided by p-adic spacetime sheets and p-adic fermions. A deep principle seems to be involved: incompleteness is characteristic feature of p-adic physics but the flexibility made possible by this incompleteness is absolutely essential for imagination and cognitive consciousness in general.

p-Adic space-time regions can suffer topological phase transitions to real topology and vice versa in quantum jumps replacing space-time surface with a new one. This process has interpretation as a topological correlate for the mind-matter interaction in the sense of transformation of intention to action and symbolic representation to cognitive representation. p-Adic cognitive representations could provide the physical correlates for the notions of memes [65] and morphic fields [58]. p-Adic real entanglement makes possible makes possible cognitive measurements and cognitive quantum computation like processes, and provides correlates for the experiences of understanding and confusion.

Although p-adic space-time sheets as such are not conscious, p-adic physics would provide beautiful mathematical realization for the intuitions of Descartes. The formidable challenge is to develop

experimental tests for p-adic physics. The basic problem is that we can perceive p-adic reality only as 'thoughts' unlike the 'real' reality which represents itself to us as sensory experiences. Thus it would seem that we should be able generalize the physics of sensory experiences to physics of cognitive experiences. The developments related to the p-adic view about cognition are left to [29].

Life as something in the intersection of real and p-adic worlds and negentropic entanglement

In the p-adic context one must modify Shannon's definition of entropy by replacing the ordinary logarithm based on p-adic norm. This definition gives rise to a real valued entropy in both real and p-adic contexts if entanglement coefficients are rational/algebraic numbers. For irrational/non-algebraic entanglement standard Shannon formula and its p-adic variant must be used and gives rise to non-negative entropy. Unlike Shannon entropy, the p-adic entropies (one for each p) can be also negative so that the entanglement entropy defines a genuine information measure whose sign tells whether the system contains information or dis-information. For the p-adic entropies Negentropy Maximization Principle [29] tends to preserve the quantum coherence if p divides the common denominator of the entanglement probabilities. The states with rational/algebraic entanglement can be regarded as new kind of bound states, which are not at all fragile like the states with irrational/non-algebraic entanglement are. In particular, these states need not be bound due to the binding energy.

For instance, the problematic notion of high energy phosphate bond could be understood in terms of negentropic entanglement making possible correlations without binding energy so that the ATP→ADP process defining fundamental step of metabolism could be interpreted in terms of negentropy transfer. Negentropic entanglement is highly stable in state function reduction process so that the randomness of quantum jump does not apply to it. As a consequence, the second law of thermodynamics is broken in the scale defined by the size of CD involved. A natural interpretation is that subselves lose consciousness as ordinary entropic bound state entanglement is generated but experience expansion of consciousness when negentropic entanglement is generated. Positive emotions like love, experience of understanding would naturally accompany the generation of negentropic entanglement.

These observations lead to a purely number-theoretic characterization of life: life is in the intersection of real and p-adic worlds: life corresponds to islands of rational/algebraic numbers in the seas of real and p-adic continua. This vision have rapidly become the most important source of insight in attempts to develop TGD based vision about conscious intelligence.

Hierarchy of Planck constants and consciousness

The hierarchy of Planck constants is realized in terms of a generalization of the causal diamond $CD \times CP_2$, where CD is defined as an intersection of the future and past directed light-cones of 4-D Minkowski space M^4. $CD \times CP_2$ is generalized by gluing singular coverings and factor spaces of both CD and CP_2 together like pages of book along common back, which is 2-D sub-manifold which is M^2 for CD and homologically trivial geodesic sphere S^2 for CP_2 [17]. The value of the Planck constant characterizes partially given page and arbitrary large values of $\hbar$ are predicted so that macroscopic quantum phases are possible since the fundamental quantum scales scale like $\hbar$. All particles in the vertices of Feynman diagrams have the same value of Planck constant so that particles at different pages cannot have local interactions. Thus one can speak about relative darkness in the sense that only the interactions mediated by the exchange of particles and by classical fields are possible between different pages. Dark matter in this sense can be observed, say through the classical gravitational and electromagnetic interactions. It is in principle possible to photograph dark matter by the exchange of photons which leak to another page of book, reflect, and leak back. This leakage corresponds to $\hbar$ changing phase transition occurring at quantum criticality and living matter is expected carry out these phase transitions routinely in bio-control. This picture leads to no obvious contradictions with what is really known about dark matter and to my opinion the basic difficulty in understanding of dark matter (and living matter) is the blind belief in standard quantum theory.

Dark matter hierarchy and p-adic length scale hierarchy would provide a quantitative formulation for the self hierarchy. To a given p-adic length scale one can assign a secondary p-adic time scale as the temporal distance between the tips of the causal diamond (pair of future and past directed light-cones in $H = M^4 \times CP_2$). For electron this time scale is .1 second, the fundamental biorhythm. For a given p-adic length scale dark matter hierarchy gives rise to additional time scales coming as

$\hbar/\hbar_0$ multiples of this time scale. These two hierarchies could allow to get rid of the notion of self as a primary concept by reducing it to a quantum jump at higher level of hierarchy. Self would in general consists of quantum jumps inside quantum jumps inside... and thus experience the flow of time through sub-quantum jumps.

The hierarchy of Planck constants means the possibility of temporal zooms of the event sequences of the external world making possible 'stories' as either zoomed up or zoomed down versions of the actual course of events. This makes possible simulation in the time natural time scales of neuronal activity and is expected to be a key element of conscious intelligence.

9.1.3 The meanings of sensory, cognitive, symbolic

With my physicist's background I have used the attributes sensory, cognitive and symbolic somewhat sloppily and the precise meanings of these become only gradually clear. The recent view is that p-adic space-time sheets correspond to cognition and that their intersections with real space-time sheets in the intersection of real and p-adic worlds define cognitive representations. These representations are defined in terms of data coming from the rational and algebraic points common to real and partonic 2-surfaces with the algebraic extension in question characterized by the mathematical representation of the partonic 2-surfaces making sense for both real and p-adic 2-surfaces simultaneously. Discrete set of points is always in question. A number theoretic variant of quantum field theory is needed in order to have a first principle description of conscious intelligence and intentionality.

The classical non-determinism of Kähler action quite generally implies that space-time surfaces define what might be called symbolic representations realizing quantum classical correspondence. This applies irrespective of the number field used and in p-adic context p-adic non-determinism is an additional ingredient. For instance, nerve pulse patterns define symbolic real physics representations of the sensory input but do not give rise to sensory qualia which reside at the level of the primary sensory organs (contrary to the expectations raised by various findings of neuro-science). Sensory experience is always a multiverse experience since sensory qualia have quantum jump increments as quantum correlates, and is thus not reducible to the level of space-time.

9.1.4 Topics of the chapter

The topics of the chapter is as follows.

1. Various measures for conscious information are discussed. The basic information measure being the reduction of entanglement entropy in state function process for given subsystem as it splits to two parts. Negentropic entanglement is also possible and this kind of systems are stable against state function reduction to a pair of unentangled states. It is tempting to characterize self by this entanglement negentropy which is well-defined and positive in the intersection of real and p-adic worlds.

2. Frieden's proposal that action principles, inclucing also Maxwell action, could have information theoretic interpretation is discussed in TGD framework in the hope that this would provide additional insights about quantum classical correspondence and living matter.

3. The realization of quantum variant of Boolean logic in terms of zero energy fermion states is discussed.

4. The next sections are devoted to the relationship of TGD based visions about brain as computer, hologram, and association machine. Also the connection with the neuro science view about brain is discussed.

5. The notions of meme and morphic field are discussed in TGD framework.

9.2 How to define measures for the information content of consciousness?

In this section my aim is to discuss different approaches to the problem how to define the information contents of conscious experience rather than advocating any final truth. Of course, just at this moment

the information measures based on entanglement negentropy and associated with self seem to be the most realistic ones to me personally, but during these 32 years of TGD I have learned that it it is better to tolerate all views about the solution of the problem even when their mutual consistency is not obvious. Negentropy Maximization Principle provides the conceptual background and is briefly summarized before the discussion of information measures.

Negentropy Maximization Principle

Negentropy Maximization Principle (NMP [29]) stating that the reduction of entanglement entropy is maximal at a given step of state function reduction process following U-process is the basic variational principle for TGD inspired theory of consciousness and says that the information contents of conscious experience is maximal. Although this principle is diametrically opposite to the second law of thermodynamics it is structurally similar to the second law. NMP does not dictate the dynamics completely since in state function reduction any eigen state of the density matrix is allowed as final state. NMP need not be in contradiction with second law of thermodynamics which might relate as much to the ageing of mental images as to physical reality.

Basic form of NMP

Negentropy Maximization Principle (NMP) in its original form codes for the basic rules of the standard state function reduction and implies that system ends up to an eigenstate of the density matrix identified as observable. In TGD framework must ask whether NMP should be restricted only to the entanglement between zero modes of WCW representing classical degrees of freedom and quantum fluctuating degrees of freedom or generalize it to apply to any pair of subsystems so that state function reduction sequence could be regarded as a sequence of self measurements. I have chosen the latter option as a working hypothesis.

   NMP that the state function reduction process following U-process gives rise to a maximal reduction of entanglement entropy at each step of the process. State function process could proceed at the level of all CDs. It is not clear whether one can assign any geometric time duration to this process or whether there is any need for this. If the ubsystem allows entangled pairs of free systems (no binding energy) there is more or less unique pair with the maximal entanglement entropy and NMP therefore implies a decomposition to a unique pair of unentangled systems. The process repeats itself for these systems and stops when the resulting subsystem cannot be decomposed to a pair of free systems since energy conservation makes the reduction of entanglement kinematically impossible in the case of bound states. Number theoretic entanglement entropies mean an important modification of this picture.

Number theoretic Shannon entropy as information

The notion of number theoretic entropy obtained by can be defined by replacing in Shannon entropy the logarithms of probabilities p_n by the logarithms of their p-adic norms $|p_n|_p$. This replacement makes sense for algebraic entanglement probabilities if appropriate algebraic extension of p-adic numbers is used. What is new that entanglement entropy can be negative, so that algebraic entanglement can carry information and NMP can force the generation of bound state entanglement so that evolution could lead to the generation of larger coherent bound states rather than only reducing entanglement. A possible interpretation for algebraic entanglement is in terms of experience of understanding or some positive emotion like love.

   Standard formalism of physics lacks a genuine notion of information and one can speak only about increase of information as a local reduction entropy. It seems strange that a system gaining wisdom should increase the entropy of the environment. Hence number theoretic information measures could have highly non-trivial applications also outside the theory consciousness.

   NMP combined with number theoretic entropies leads to an important exception to the rule that the generation of bound state entanglement between system and its environment during U process leads to a loss of consciousness. When entanglement probabilities are rational (or even algebraic) numbers, the entanglement entropy defined as a number theoretic variant of Shannon entropy can be non-positive (actually is) so that entanglement carries information. NMP favors the generation of algebraic entanglement. The attractive interpretation is that the generation of algebraic entanglement leads to an expansion of consciousness ("fusion into the ocean of consciousness") instead of its loss.

State function reduction period of the quantum jumps involves much more than in wave mechanics. For instance, the choice of quantization axes realized at the level of geometric delicacies related to CDs is involved. U-process generates a superposition of states in which any sub-system can have both real and algebraic entanglement with the external world. If state function reduction involves also a choice between generic and negentropic entanglement (between real world, a particular p-adic world, or their intersection) it might be possible to identify a candidate for the physical correlate for the choice between good and evil. The hedonistic complete freedom resulting as the entanglement entropy is reduced to zero on one hand, and the algebraic bound state entanglement implying correlations with the external world and meaning giving up the maximal freedom on the other hand. The hedonistic option is risky since it can lead to non-algebraic bound state entanglement implying a loss of consciousness. The second option means expansion of consciousness - a fusion to the ocean of consciousness as described by spiritual practices. Note that if the total entanglement negentropy defined as sum of contributions from various levels of CD hierarchy up to the highest matters in NMP then also subselves should develop negentropic entanglement. For instance, the generation of entropic entanglement at cell level can lead to a loss of consciousness also at higher levels. Life would evolve from short to long scales.

Can one define measures for the information contents of mental image?

Despite the fact that one cannot write formula for the contents of conscious experience, one can define information measures for conscious experience as differences of the information measures for the initial and final quantum histories. Negentropy gain is the most natural information measure of this kind. For instance, the sum of the net entanglement negentropy gains over the steps of the self measurement cascade could define a quantity characterizing net information gain for a single moment of consciousness at each step.

One could also information measure to selves as the entanglement negentropy after the state function reduction process has ended. This would assign to each subsystem stable under NMP a negentropy. For bound state entanglement this information would be negative but for negentropic entanglement it would be positive. One can ask whether the hypothesis that this information increases during quantum jump sequence is equivalent with NMP. In the case of entire Universe the application of this principle becomes problematic.

Entropy gradients with respect to subjective time could be used to characterize how the information gain of conscious experience of self changes. These gradients approach zero when self approaches thermal equilibrium. In TGD framework entropy gradients correlate with emotions, which means a somewhat counter intuitive connection between emotions and information gain or loss (consistent however with the fact that peptides are both informational molecules and molecules of emotion [72]). Note that the binding of information molecules to receptors means the formation larger bound states accompanied by the experience of oneness at molecular level (are sex and spiritual experiences present already at the molecular level?) and macro temporal quantum coherence so that quantum computer like operations might become possible.

Life as islands of rational/algebraic numbers in the seas of real and p-adic continua?

Rational and even algebraic entanglement coefficients make sense in the intersection of real and p-adic words, which suggests that life and conscious intelligence reside in the intersection of the real and p-adic worlds. This would mean that the mathematical expressions for the space-time surfaces (or at least 3-surfaces or partonic 2-surfaces and their 4-D tangent planes) make sense in both real and p-adic sense for some primes p. Same would apply to the expressions defining quantum states. In particular, entanglement probabilities would be rationals or algebraic numbers so that entanglement can be negentropic and the formation of bound states in the intersection of real and p-adic worlds generates information and is thus favored by NMP.

The identification of intentionality as the basic aspect of life seems to be consistent with this idea.

1. The proposed realization of the intentional action has been as a transformation of p-adic space-time sheet to a real one. Also transformations of real space-time sheets to p-adic space-time sheets identifiable as cognitions are possible. Algebraic entanglement is a prerequisite for the realization of intentions in this manner. Essentially a leakage between p-adic and real worlds is in question and makes sense only in zero energy ontology. The reason is that various quantum

numbers in real and p-adic sectors are not in general comparable in positive energy ontology so that conservation laws would be broken or even cease to make sense.

2. The transformation of intention to action can occur if the partonic 2-surfaces and their 4-D tangent space-distributions are representable using rational functions with rational (or even algebraic) coefficients in preferred coordinates for the imbedding space dictated by symmetry considerations. Intentional systems must live in the intersection of real and p-adic worlds.

3. For the minimal option life would be also effectively 2-dimensional phenomenon and essentially a boundary phenomenon as also number theoretical criticality suggests. There are good reasons to expect that only the data from the intersection of real and p-adic partonic two-surfaces appears in U-matrix so that only the data from rational and some algebraic points of the partonic 2-surface dictate U-matrix. This means discretization at parton level and something which might be called number theoretic quantum field theory should emerge as a description of intentional action.

A good guess is that algebraic entanglement is essential for quantum computation, which therefore might correspond to a conscious process. Hence cognition could be seen as a quantum computation like process, a more approriate term being quantum problem solving [24]. Living-dead dichotomy could correspond to rational-irrational or to algebraic-transcendental dichotomy: this at least when life is interpreted as intelligent life. Life would in a well defined sense correspond to islands of rationality/algebraicity in the seas of real and p-adic continua. Life as a critical phenomenon in the number theoretical sense would be one aspect of quantum crticality of TGD Universe besides the criticality of the space-time dynamics and the criticality with respect to phase transitions changing the value of Planck constant and other more familiar criticalities. How closely these criticalities relate remains an open question [26].

The view about the crucial role of rational and algebraic numbers as far as intelligent life is considered, could have been guessed on very general grounds from the analogy with the orbits of a dynamical system. Rational numbers allow a predictable periodic decimal/pinary expansion and are analogous to one-dimensional periodic orbits. Algebraic numbers are related to rationals by a finite number of algebraic operations and are intermediate between periodic and chaotic orbits allowing an interpretation as an element in an algebraic extension of any p-adic number field. The projections of the orbit to various coordinate directions of the algebraic extension represent now periodic orbits. The decimal/pinary expansions of transcendentals are un-predictable being analogous to chaotic orbits. The special role of rational and algebraic numbers was realized already by Pythagoras, and the fact that the ratios for the frequencies of the musical scale are rationals supports the special nature of rational and algebraic numbers. The special nature of the Golden Mean, which involves $\sqrt{5}$, conforms the view that algebraic numbers rather than only rationals are essential for life.

Hyper-finite factors of type II$_1$ and NMP

Hyper-finite factors of type II$_1$ bring in additional delicacies to NMP. The basic implication of finite measurement resolution characterized by Jones inclusion is that state function reduction can never reduce entanglement completely so that entire universe can be regarded as an infinite living organism. It would seem that entanglement coefficients become $\mathcal{N}$ valued and the same is true for eigen states of density matrix. For quantum spinors associated with $\mathcal{M}/\mathcal{N}$ entanglement probabilities must be defined as traces of the operators $\mathcal{N}$. An open question is whether entanglement probabilities defined in this manner are algebraic numbers always (as required by the notion of number theoretic entanglement entropy) or only in special cases.

9.2.1 Various kinds of information measures

The concepts of information, information flow and information gain of conscious experience would seem to have a natural place in theories of consciousness. It seems intuitively obvious that configuration space spinor fields must contain information. Configuration space spinor fields have indeed interpretation as both objective realities and Platonic Ideas, the latter interpretation being suggested strongly by the possibility to interpret fermionic Fock state basis as a Boolean algebra of statements about statements. The basic statements are most naturally statements about space-time geometry

since fermionic oscillator operators for X^3 are determined by the second quantized free quantum field theory for the induced spinors on space-time surface $X^4(X^3)$ [31].

State function reduction process consists of a sequence of self measurements both in zero modes and in quantum fluctuating fiber degrees of freedom ultimately leading to a competely unentangled state decomposing to a product of entropically entangled bound states and states for which every decomposition to a pair of subsystems is negentropically entangled. At each step when system decomposes to a unique pair of unentangled subsystems. The entanglement probabilities defined by the density matrix for either subsystem characterize the probabilities for the outcomes of the self measurement. Both unentangled subsystems resulting in the first step are again subject to self measurements and the process continues until an unentangled state results. Consider now the information measures.

1. The reduction of entanglement entropy defines a natural measure for conscious information gain in single step of the state of state function reduction process decomposing subsystem to a pair of un-entangled sub-systems. If entanglement is negentropic the entanglement negentropy either increases or the system is stable against state function reduction.

2. It seems natural to assume that the information measures are associated with the entire cascade and that they are additive in the sense that information gain is sum over the information gains of the steps of the cascade and that a given step contributes by the sum of the information gains associated with unentangled subsystems which are subject to self measurement in a given step of the cascade.

3. One can also assign information measures to the resulting indecomposable systems. For subsystem which is bound state in the normal sense and thus has entropic entanglement, one can consider all possible decomposition of the system to a sub-system and its complement and define the entanglement negentropy as the negative for the minimum value of entropy obtained in this manner. If the system is negentropically entangled one can define entanglement negentropy as the maximum of entanglement negentropy obtained in this manner. This means that one can assign to the final state of state function reduction unique negentropy as the sum of the negative contributions associated with selves which are internally bound state entangled and positive contributions of negentropic selves.

4. The information content of the conscious experience associated with self is more interesting practically. Since self defines a statistical ensemble, it is straightforward to define entropies associated with the increments of quantum numbers and zero modes defining non-geometric and geometric qualia. These entropies characterize the fuzziness of the quale and are 'negative' information measures. One can also assign to non-decomposable subselves the information measures and they give either positive or negative contribution to the information content of self.

5. In principle this allows to define also the net information gain of quantum jump as the difference of the total negentropies of the final and initial states of quantum jump identified as those produced by the state function reduction process. Initial and final state negentropies would characterize spinor fields of WCW ("world of classical worlds").

NMP in its recent form is a purely local principle and leads to a unique sequence of state function reductions. The argument for how the arrow of psychological time emerges involves the notion of "curious self", which need not reduce to NMP in its recent form. One can also ask whether NMP is general enough to explain the emergence of new CDs as spot-lights of attention and their dynamics. For instance, should (could) NMP be replaced with a variant in which the maximized negentropy gain is the difference of negentropies for initial and final states of the quantum jump such that one allows the appearence of new sub-CDs defining subsystems.

9.2.2   Information concept at space-time level

Quantum-classical correspondence suggests that the notion of information is well defined also at the space-time level. The non-determinism of Kähler aciton and p-adic non-determinism plus algebraic information measures suggest a natural approach tot the problem of defining the information concept. This approach provides also a new light to the problem of assigning a p-adic prime to a given real space-time sheet.

How to assign an information measure to a space-time sheet?

In the presence of the classical non-determinism of Kähler action and p-adic non-determinism one can indeed define ensembles, and therefore also probability distributions and entropies. For a given space-time sheet the natural ensemble consists of the deterministic pieces of the space-time sheet regarded as different states of the same system. The probability for the appearance of a given value of observable is of the general form $p_i = m_i/N$, $m_i < N$, where N is the number of deterministic pieces and S_p is always negative, when p divides N.

 Obviously the primes dividing N define natural candidates for the information measures but the problem is which criterion selects one of them. There are three options.

1. Require that the information measure corresponds to the prime p for which S_p is smallest. Obviously p must divide N.

2. Define the information as sum

$$I = -\sum_{p|N} S_p \ ,$$

   (here $p|N$ means that p divides N) so that all contributions are positive.

3. Include all primes dividing N or m_i in $p_i = m_i/N$:

$$I = -\sum_{p|N \ or \ p|m_i} S_p \ ,$$

   In this case also negative contributions are present. This defition is actually equivalent with a definition

$$I = -\sum_{p} S_p \ ,$$

   in which the summation appears over all primes. One could say that the information decomposes into different kinds of informations labelled by primes.

   What is interesting is that, the ordinary Shannon entropy S for rational probabilities can be expressed as a sum of all p-adic entropies using the adelic decomposition $|x| = \prod_p |x|_p^{-1}$:

$$S = -\sum_{p} S_p = I \ .$$

   The sum of real and p-adic entropies vanishes. Real dis-information and the p-adic information would compensate each other completely. Whether the adelic formula for information theory might have some deeper interpretation remains open.

How to assign p-adic prime or primes to a real space-time sheet?

A long-standing problem of quantum TGD is how to associate to a given *real* (not only p-adic) space-time sheet a unique p-adic prime (or possibly several of them) as required by the p-adic length scale hypothesis.

1. One could achieve this by requiring that for this prime the negentropy associated with the ensemble is maximal. The simplest hypothesis is that a real space-time sheet consisting of N deterministic pieces corresponds to the p-adic prime defining the largest factor of N.

2. One could also consider a more general possibility. If N contains p^n as a factor, then the real fractality above n-ary p-adic length scale $L_p(n) = p^{(n-1)/2}L_p$ corresponds to smoothness in the p-adic topology. This option is more attractive since it predicts that the fundamental p-adic length scale L_p for a given p can be effectively replaced by any integer multiple NL_p, such that N is not divisible by p. There is indeed a considerable evidence for small p p-adicity

in long length scales. For instance, genetic code and the appearance of binary pairs like cell membrane consisting of liquid layers suggests 2-adicity in nano length scales. This view means that the fractal structure of a given real space-time sheet represents both an integer N and its decomposition to prime factors physically. This would also mean that one can assign several p-adic information measures to the real space-time sheet. This obviously conforms with the physics as a generalized number theory vision.

3. Intuitively it seems obvious that there must be a physical mechanism selecting one prime amongst all possible primes which characterizes the information measure associated with the ensemble of the deterministic pieces associated with the real space-time sheet. Conscious information requires the presence of cognition: the real space-time sheet must be entangled with a p-adic space-time sheet. Quantum-classical correspondence means that the ognitive entanglement of the real system with p-adic system has as a space-time correlate join along boundaries bond connecting the real and p-adic space-time sheet and glued to the boundary of the real space-time sheet along common rational points. One could argue that the p-adic join along boundaries bonds are most probable when the p-adic prime is such that it defines an effective p-adic topology for the real space-time sheet. This would mean that the prime-power factors of N define preferred p-adic length scales to the real space-time sheet.

4. The hypothesis that the prime factorization of N determines the effective p-adic topologies associated with the real space-time sheet inspires the hypothesis that the rational (or algebraic) p-adic-real entanglement necessary for cognitive quantum measurements is probable/possible only for the p-adic primes dividing N.

Does classical space-time physics represent factorization of integers?

Quantum-classical correspondence suggests that quantum computation processes might have counterparts at the level of space-time. An especially interesting process of this kind is the factorization of integers to prime factors. The classical cryptography relies on the fact that the factorization of large integers to prime factors is a very slow process using classical computation: the time needed to factor 100 digit number using modern computer would take more than the recent age of the universe. For quantum computers the factorization is achieved very rapidly using the famous Shor's algorithm. Does the factorization process indeed have a space-time counterpart?

Suppose that one can map the integer N to be factored to a real space-time sheet with N deterministic pieces. If one can measure the powers $p_i^{n_i}$ of primes p_i for which the fractality above the appropriate p-adic length scale looks smoothness in the p-adic topology, it is possible to deduce the factorization of N by direct physical measurements of the p-adic length scales characterizing the representative space-time sheet (say from the resonance frequencies of the radiation associated with the space-time sheet). If only the p-adic topology corresponding to the largest prime p_1 is realized in this manner, one can deduce first it, and repeat the process for N/p_1^n, and so on, until the full factorization is achieved. A possible test is to generate resonant radiation in a wave guide of having length which is an integer multiple of the fundamental p-adic length scale and to see whether frequencies which correspond to the factors of N appear spontaneously.

Seeing the prime factorization might be also possible via a direct sensory perception. Oliver Sacks tells in his book 'The man who mistook his wife for a hat' [79] about twins, John and Michael, who had a mysterious ability to 'see' large numbers and their prime factorizations despite the fact that their intelligence quotient was about 60 and they did not have any idea about the notions of integer and prime. For instance, matchbox was dropped from the table and its contents were spread along the floor. Both twins shouted immediately '111!'. Then John mumbled '37', Michael repeated it and John said '37' third time. Obviously this was their sensory representation for the decomposition $111 = 3 \times 37$ of number 111 to a product of primes! The explanation of these strange feats suggested in [33] is a less general idea about physical representation of the factorization. The proposed mechanism could indeed explain prime factorization as a sensory perception involving no algorithmic cognition at all.

9.2.3   Information theoretic interpretation of Kähler function

An important stimulus in the development of ideas was the Jan 30, 1999 issue of New Scientist [56] in which the work of Roy Frieden [51, 52] about information theoretical interpretation of the variational principles of physics was discussed at popular level. The work of Frieden relies on the concept of Fisher information. One can find a precise definition of the Fisher information in Mathematical Handbooks but this definition does not help too much without any further knowledge about Frieden's work. There is also a book available about Frieden's work [52].

Although the article in New Scientist [56] does not give any mathematical details about Frieden's work, it becomes clear that Fisher's theory as such does not apply to TGD framework. Frieden's basic idea seems however extremely attractive. Indeed, TGD inspired theory of consciousness leads to a hypothesis concerning the information theoretic interpretation of the Kähler function.

Frieden's hypothesis inspired the idea that Kähler function (Kähler action for a preferred extremal) has information theoretic interpretation. The recent view about quantum TGD indeed suggests that a modified form of this idea might work.

Information theoretic interpretation of action in Frieden's theory

Frieden [51, 52, 56] introduces two kinds of information concepts. Fisher information, usually denoted by I, is defined as the information which can extracted from a physical phenomenon by measurements of a specific type. Information J is defined as the information contained by the phenomenon and in general $J - I \geq 0$ holds true.

The action defining the dynamical equations of a physical theory decomposes into a difference $I - J$, where J is the total information contained by the state and I is the available information. I and J depend on what is measured. Minimization of $I - J$ for position measurement leads to classical Newton's equations.

In classical mechanics J corresponds typically to the integral of potential energy V and I corresponds to the integral of kinetic energy I, in accordance with the decomposition

$$S = \int L dt, \quad L = T - V \ .$$

Maxwell action is obtained by considering position measurement in presence of charge. For Maxwell action

$$S = \int (B^2 - E^2) d^4 x \ ,$$

the entire integral of B^2 corresponds to I whereas total (or potential) information J is non-vanishing only provided there is coupling to external currents.

Information theoretic interpretation of Kähler function

Information theoretic interpretation of Kähler function -albeit not in the sense proposed by Frieden-might make sense in TGD framework. Quantum classical correspondence suggests that Kähler function could serve as a classical correlate for quantal information measure defined by negentropy. It is however essential that one accepts the number theoretic vision that conscious information is possible in the intersection of real and p-adic worlds.

1. Entanglement negentropy is the proper information measure and is negative outside the intersection of real and p-adic worlds and would therefore correspond to the negative term $-J$ assignable to Kähler electric fields in the case of Minkowskian signature. For negentropic entanglement the negentropy would be positive and would correspond to the term I assignable to magnetic fields.

   (a) If this interpretation is correct, magnetic flux tubes would be the carriers of information and the regions carrying electric fields- typically electrets in living matter- would be carriers of entropy. Magnetic flux tubes define the basic building block of DNA as topological quantum computer and carry negentropically entangled quarks at their ends. Magnetic bodies are also central in the TGD based model of living matter. One must be however be very cautious in drawing conclusion since the roles of magnetic and electric fields could be opposite and the fact is that standard biology "sees" only the electric fields.

(b) For regions with Euclidian signature representing generalized Feynman graphs with lines represented as deformations of CP_2 type vacuum extremals one must be very careful with sign factors. Now however both electric and magnetic contributions would represent either positive or negative information. It would be attractive to assign positive information with elementary particles. This would conform with the interpretation of magnetic flux tubes -in particular cosmic strings- as particle like objects.

(c) The conjecture inspired by thermodynamical analogy and quantum classical correspondence would be that Kähler function identified as negative of Kähler action for the preferred extremal is analogous to entropy and equals to the total entanglement entropy associated with the fermionic degrees of freedom for a given 3-surface. This principle favors entropic configurations carrying electric fields unless the number of preferred extremals is small for them and large for negentropic configurations involving magnetic flux tubes and CP_2 type vacuum extremals belonging to the intersection of real and p-adic worlds. The criticality of Kähler action might imply this. For instance, for CP_2 type vacuum extremals the light-like randomness of the 1-D M^4 projection implies large degeneracy. Also the small deformations of vacuum extremals are expected to have large degeneracies. Also quantum criticality favors large degeneracies. At quantum level number theoretical criticality favoring negentropic entanglement would be the counterpart for this criticality. NMP understood in general enough sense could drive the system to the intersection of real and p-adic worlds.

(d) Without further assumptions the total negentropy of the Universe should be finite since otherwise the exponent of Kähler action becomes zero. The large degeneracy of the states at criticality -basically due to the vacuum degeneracy- could however prevent the cancellation of the vacuum functional even at the limit when vacuum functional vanishes. The 4-D spin glass degeneracy would allow the Universe to have an infinite information content and thus escape the expectation based on second law. If this picture is correct magnetic flux quanta should dominate the action at criticality at least in living matter.

2. Frieden's approach puts position measurement in a special role and the idea that every measurement type defines its own physical law was not consistent with the original interpretation of quantum TGD [46].

(a) The formulation of quantum TGD in terms of the modified Dirac action forces to bring in measurement interaction terms coupling induced spinor fields to various conserved charges by a term linear in charge and conserved fermionic current implied by the criticality of the preferred extremals of Kähler action.

(b) This induces also coupling term to Kähler action coding information about conserved charges to the geometry of space-time surface. There is infinite number of observables defined as conserved charges and each of them defines different dynamics.

(c) The conjecture is that all the allowed measurement interactions introduce to Kähler function only a real part of a holomorphic function of the complex coordinates of WCW (world of classical worlds) so that the Kähler geometry of WCW is not affected although the preferred extremals of Kähler action are affected. One could argue that for asymptotic self-organization patters the field equations reduce to those for Kähler action. One can consider also a form of the principle for which the conserved charges affect the preferred extremals only through the boundary conditions in the interior of space-like 3-surfaces at the boundaries of CDs. This conforms with the notion of holography stating that the 2-D partonic surfaces defined as intersections of the light-like 3-surfaces with the future and past boundaries of CDs and the distributions of their 4-D tangent spaces code for what is physically relevant.

The p-Adic version of Kähler action does not make sense nor is needed at all at configuration space level. All that is needed is that the p-adic variants of the field equations stating the preferred extremal property of Kähler action are satisfied. At quantum level the non-existence of p-adic integration measure suggests that that each quantum jump involves a complete localization in p-adic configuration space zero modes: p-adic physics at the space-time level would be completely classical. Complete

localization in zero modes has been assumed to take place also in real degrees of freedom but is not actually necessary since the symplectic form associated with zero modes defines a hierarchy of finite-dimensional integration measures.

Quantum criticality and Kähler function

The $I - J$ decomposition of the Kähler function makes sense in TGD framework although the interpretation of I and J differs from that in in Frieden's theory. The formal similarity of the vacuum functional with thermodynamical partition function suggests the interpretation of the vacuum functional as an exponent for the negative of some kind of entropy type variable so that the negative of the Kähler function would correspond to entropy.

The exponent $exp(-K_{cr})$ of the negative of Kähler function, for a suitable choice of the value α_{cr} of the Kähler coupling strength, should somehow measure the number of some kind of microstates. A natural identification of the 'microstates' is as a degeneracy caused by the classical non-determinism of the Kähler action, which implies that configuration space integration over 3-surfaces Y^3 at the light cone boundary involves summation over all possible association sequences going through the same 3-surface Y^3 on the light-cone boundary and having the same value of the Kähler function. This summation brings in a degeneracy factor, which will be referred to as N_d.

An educated guess is that the degeneracy factor N_d is in a good approximation proportional to the exponent of the negative of the Kähler function, when Kähler coupling strength has critical value α_{cr}:

$$N_d \quad \simeq \quad exp(-K_{cr}) \ . \tag{9.2.1}$$

Note that α_{cr} depends on the sector D_p of the configuration space since Kähler coupling strength depends on p-adic length scale in a logarithmic manner typically predicted by $U(1)$ gauge theories. This hypothesis allows to answer to the basic questions related to the definition of the Kähler function.

This hypothesis throws also new light to the precise mechanism of the quantum criticality. At quantum criticality the degeneracy factor N_d in the functional integral over the configuration space compensates the exponent of the negative Kähler function even when its value is infinite! Criticaliaty would make possible Universes with infinite conscious information content. Below quantum criticality the probabilities for 3-surfaces having negative Kähler function suffer exponential cutoff so that only the 3-surfaces for which the value of Kähler function per volume vanishes, are important. The resulting universe is obviously much less interesting than quantum critical universe, which maximizes complexity. Also the maximum for the total information content of the quantum jump is always finite for subcritical universe unlike for quantum critical universe. Above quantum criticality the degeneracy dominates over vacuum functional and configuration space integral of the vacuum functional diverges so that the theory becomes mathematically ill defined. Therefore quantum critical universe possesses maximal complexity and is as interesting and intelligent as universe can be! Note that quantum criticality was already earlier realized to be crucial for consciousness since it makes possible long range quantum correlations and hence arbitrarily large macroscopic quantum systems.

It deserves to be noticed that the proposed estimate for the value of the degeneracy factor N_d -if correct- would give for the TGD inspired theory of consciousness a status of a quantitative theory. Once the value of the Kähler function is known, then also the representational (symbolic representations seem to be in question) capacities associated with the 3-surface are known. A reasonable guess is that this criterion makes sense also for finite space-time regions.

Is it possible to interpret Kähler electric part of action as a potential information?

Frieden interprets J as a potential information. The motivation comes from classical mechanics, where energy conservation implies that a situation in which potential energy dominates can transform to that dominated by the kinetic energy. The regions carrying electric fields would somehow correspond to potential information. In the case of Maxwell action LC circuit would be a system in in which Maxwell action reduces to an action for harmonic oscillator defined as difference of magnetic energy $LI^2/2$ and electro-static energy $CV^2/2$. The total action for an integer multiple of cycles obviously vanishes. Frieden's interpretation would be that potential information actualizes when electric energy becomes magnetic. What looks strange is that the information is created and disappears periodically.

This interpretation is not needed in TGD framework. Despite this one can ask whether this interpretation could make sense also in TGD framework and whether it could provide additional insights.

1. Classical electric fields are in a fundamental role in biochemistry and living biosystems are typically electrets containing regions of spontaneous electric polarization and one can ask whether this might be understood in using Frieden's interpretation. Fröhlich [63] proposed that oriented electric dipoles form macroscopic quantum systems with polarization density serving as a macroscopic order parameter. Several theories of consciousness share this hypothesis. Experimentally this hypothesis has not been verified.

2. TGD suggests much more profound role for the unique di-electric properties of the biosystems: the presence of strong electric dipole fields is a necessary prequisite for cognition and life and could even force the emergence of life. Strong electric fields imply also the presence of the charged wormhole BE condensates: the surface density of the charged wormholes on the boundary is essentially equal to the normal component of the electric field so that wormholes are in some sense 'square root' of the dipole condensate of Fröhlich! Wormholes make also possible pure vacuum polarization type dipole fields: in this case the magnitudes of the em field at the two space-time sheets involved are same whereas the directions of the fields are opposite. The splitting of wormhole contacts creates fermion pairs which might be interpreted as cognitive fermion pairs. Also microtubules carry strong longitudinal electric fields.

Cell membrane is the basic example about electret and one of the basic mysteries of cell biology is the resting potential of the living cell. Living cell membranes carry huge electric fields: something like 10^7 Volts per meter. This corresponds to about .06 eV energy gained when unit charge travels through the membrane potential. During the nerve pulse the electric field of the cell membrane changes sign and therefore goes through zero. This process certainly induces magnetic field and would define a candidate for a process in which potential information is transformed to actual one twice during the duration of nerve pulse. In TGD framework it is however not at all clear whether the presence of strong electromagnetic field necessitates the presence of strong Kähler field. The extremely strong electric field associated with the cell membrane is not easily understood in Maxwell's theory and almost vacuum extremal property could change the situation completely in TGD framework.

1. The configuration could be a small deformation of vacuum extremal so that the system would be highly critical as one indeed expects on basis of the general visiona about living matter as a quantum critical system. For vacuum extremals classical em and Z^0 fields would be proportional to each other. The second half of Maxwell's equations is not in general satisfied in TGD Universe but if one assumes that this is the case approximately, the presence of Z^0 charges creating the classical Z^0 fields is implied. In TGD framework one cannot however exclude the presence of vacuum charge densities in which case elementary particles as sources of the field would not be necessarily. Neutrinos are the most natural candidates for the carrier of Z^0 charge if one assumes that elementary particles act as sources. Dark variants of ordinary elementary particles interacting via dark variants of intermediate gauge bosons could make possible the presence of the needed Z^0 charge densities.

2. The unavoidable presence of long range Z^0 fields would explain large parity breaking in living matter, and the fact that neutrino Compton length is of the order of cell size would suggest the possibility that within neutrino Compton lengths electro-weak gauge fields could behave like massless fields. These weak interactions within space-time sheet should be distinguished from those mediated by exchanges between space-time sheets. The description of interactions as exchanges of virtual particles assigned as wormhole contacts connecting positive and negative energy MEs which behave like massless states individually could be consistent with the massivation of electroweak gauge fields. If the transversal size of MEs is of order Compton length of intermediate gauge boson then long ranged interactions are possible but the low probability that the second particle absorbs the narrow ME emitted by a particle makes the interaction cross section small.

3. From the equations for classical induced gauge fields in terms of Kähler form and classical Z^0 field [42]

$$\gamma = 3J - \tfrac{p}{2}Z^0 \quad , \quad Q_Z = I_L^3 - pQ_{em} \quad , \quad p = sin(\theta_W) \quad . \tag{9.2.2}$$

it follows that for the vacuum extremals the part of the electroweak force proportional to the electromagnetic charge vanishes for a vanishing value of Weinberg angle parameter p so that only left-handed couplings to weak gauge bosons remain. The absence of electroweak symmetry breaking and vanishing of p would make sense below the Compton length of dark weak bosons. It is more questionable whether it makes sense in the interior of neutrino. If this picture makes sense it has also implications for astrophysics and cosmology since small deformations of vacuum extremals are assumed define the interesting extremals. Dark matter hierarchy might explain the presence of unavoidable long ranged Z^0 fields as being due to dark matter with arbitrarily large values of Planck constant so that various elementary particle Compton lengths are very long.

4. The simplest option is that the dark matter -say quarks with Compton lengths of order cell size and Planck constant of order $10^7\hbar_0$ - are responsible for dark weak fields making almost vacuum extremal property possible. The quarks involved with with DNA as topological quantum computer model could be in question and membrane potential might be assignable to the magnetic flux tubes. The ordinary ionic currents through cell membrane -having no coupling to classical Z^0 fields and not acting as its sourse- would be accompanied by compensating currents of dark fermions taking care that the almost vacuum extremal property is preserved. The outcome would be large parity breaking effects in cell scale from the left handed couplings of dark quarks and leptons to the classical Z^0 field. The flow of Na$^+$ ions during nerve pulse could take along same dark flux tube as the flow of dark quarks and leptons. This near vacuum extremal property might be fundamental property of living matter at dark space-time sheets at least.

5. The resting state of the cell space-time sheet would represent a situation in which the information content is nearly zero also locally. Nerve pulse might change this situation somewhat and generate net Kähler magnetic action serving as a correlate for a negentropic entanglement created by nerve pulse. This negentropy could be assigned with sub-CD representing the mental image created and having a duration of order 1 ms. For almost vacuum extremals the nerve pulse could be as a color rotation not affecting the induced Kähler field but affecting the em and Z^0 contributions to the Kähler field. DNA as topological quantum computer suggests that the nerve pulse induces a two-dimensional flow of the liquid crystal phase defined by lipids of the cell membrane and this in turn would braiding of the magnetic flux tubes connecting lipids to DNA nucleotides. This would induces topological a piece of a quantum computation program by time-like braiding and also space-time braiding coding the nerve pulse sequence to memory.

6. At the level of metabolism the picture about the situation could be following. In the resting state of the cell unfolded proteins, unfolded portions of proteins, and folded globular proteins are surrounded by ordered water and strong hydrogen bonds freeze them. Kind of cellular winter prevails. The melting of the ordered water makes possible folding of unfolded portions of proteins and partial melting of globular proteins crucial for the aggregation of proteins defining basic biological functions at molecular level. Nerve pulse would induce a kind of cellular summer for a time of order millisecond. The melting of the ordered water would be due to the liberation of metabolic energy destroying hydrogen bonds and transforming bonds to negentropic bonds. The needed energy and negentropic entanglement would be provided by ATP molecules. It would be tempting to see the process as a generation of negentropic sub-CD lasting a time of order 1 ms. This interpretation does not require the assumption that Kähler electric energy is transformed to Kähler magnetic energy.

To my opinion this argument favors the assumption that Kähler fields are weak but I could be of course wrong. If the membrane potential is not accompanied by a classical Z^0 field and if Frieden is right, nerve pulse should have an interpretation as a temporary transformation of the potential information to a genuine information taking place twice during nerve pulse. A magnetic pulse with field lines rotating around axon would be generated: perhaps the topologically quantized field consists of flux tubes moving with the velocity of nerve pulse. It is not obvious how to assign to it negentropic

entanglement unless one assumes that wormhole throats within it are entangled negentropically. At quantum level this could mean that bound state entanglement is transformed to negentropic entanglement as the membrane potential goes to zero (twice during the pulse) so that negentropic sub-CD representing mental image is formed. Interpretation as a transition to a number theoretical criticality from nearly critical state could be appropriate. This picture does not have any obvious connections with the overall vision about living matter.

The cautious conclusion which is different from the earlier one is that strong electric fields in living matter relate to quantum criticality rather than to the possibility to interpret them in terms of potential information.

1. The criticality for the generation of nerve pulse would correspond to the criticality against long range fluctuactions implied by nearly vacuum extremal property.

2. Epileptic seizures involve anomalously large electric fields in some brain regions and reduction of membrane potential near to the critical value for the generation of action potential. Perhaps epilepsy is the price paid for exceptionally high criticality (recall the characters of Dostojevksi's novels having their epileptic attacks!). Epilepsy has always been the professional disease of prophets: perhaps precognition necessitates exceptionally strong electric fields!

Generation of artificial life by generating almost vacuum extremals with strong electric fields?

If strong em and Z^0 electric fields with almost vanishing Kähler fields really characterize living matter one might have the counterpart of the $E = mc^2$ formula in consciousness theories and make possible the construction of artificial life. Also the symbiosis of living systems with electronic systems containing similar strong electric fields could be considered. It is however far from trivial whether the existing electronic systems correspond to almost vacuum extremals. Nanotechonology could be perhaps used to build strong electric fields in short length scales. Of course, even ordinary computers might have some conscious intelligence, not for the reasons proposed by AI people, but because their circuits contain electric fields.

One could consider the possibility of testing TGD inspired theory of consciousness by studying whether the presence of strong electric fields could lead to any phenomena characteristic for life. Parity breaking is certainly one such signature. Criticality would be second signature. The total Maxwell action for these systems gives a precise estimate for their representative resources. In [31] an explanation of $1/f$ noise [43, 42, 58] based on quantum criticality and quantum control of the behaviour of material space-time sheets performed by mind-like space-time sheets, will be proposed. If this explanation is correct, $1/f$ noise serves as a signature for the presence of nearly critical space-time sheets. Electronic circuits are characterized by $1/f$ noise as a rule, which indeed suggests that some kind of primitive cognition is present. One testable prediction is that the generation of electric fields should increase the intensity of $1/f$ noise. The simplest, but not the only possible, explanation for the effect of anesthetics is that their presence reduces electric fields of, say, microtubules and cell membranes. One could also test the effect of anesthetics on $1/f$ noise appearing in biosystems.

Adaptive robots as an electronic life form?

The construction of artificial life by building initial value sensitive robots might be a possible breakthrough application of the p-adic cognition. What would be needed is just initial value sensitivity: p-adic memes would take care of the resst.

Mark Tilden is a wellknown builder of robots working in the nuclear physics laboratory of Los Alamos. Tilden builds his robots by using pieces of used electronics. The robots do not run any computer program so that the basic philosophy is more or less a diametrical opposite of AI. Rather, the wiring of the robots is such that in a new situation robot tries for different behaviors. For instance, if robot leg gets stuck, the robot changes the orbit of motion of leg. What is remarkable that the robots seem to behave like living organisms in some aspects.

Unfortunately, I do not have any scientific articles about Tilden's work apart from short description in his homepage [80]. In fact, I encountered competely accidentally about Tilden's work by reading an article in the Finnish version of Reader's Digest August 1998 after having seen Stetsoned Tilden and his tiny robots in a popular science program in Finnish TV telling about the recent situation in

robotics, AI, and artificial life. The robots of Tilden have surprising abilities to adapt and compete for energy which they get from the sunlight. Robots seem to literally fight for the sunlight. For instance, an electronic fellow called Turbot, kills other robots from his territory and collects them to form a wall against the invasion of other invaders!

The claimed adaptive feats of these robots suggest that a primitive lifeform is in question and this is also the belief of Mark Tilden. A general handwaving explanation for the adaptive behavior is that these systems are at the borderline between chaos and order and adaptive behavior 'emerges'. Of course, what 'emergence' means is a complete mystery in the deterministic physics with quantum effects absent in macroscopic length scales.

That primitive life form might be in question, fits nicely with the TGD view. First of all, all forms of self-organization involve quantum jumps and consciousness, and the question is only how important is the role of cognitive consciousness in the behavior of the system. Cognitive consciousness can become important only if the system is sufficiently flexible and initial value sensitive so that the realization of intentional motor actions becomes possible by p-adic-to-real transformations inducing critical perturbations to the initial-value sensitive behavior.

The in-built flexibility of the robot behavior (a strict opposite of pre-programmed behavior), and initial value sensitivity make in principle possible self-organization by quantum jumps and effective quantum control. For instance, robots could contain modules controlled by genuine random number generators which would be affected by p-adic memes. If p-adic physics is physics of cognition, Nature itself guarantees, that robots form cognitive representations, and by the flexibility of their motor system, they are able to transform cognitive representations to motor actions. If p-adic space-time sheets are indeed memes floating around and waiting for the opportunity to materialize themselves to action, the robots of Tilden could provide an excellent opportunity for a meme to reincarnate!

The extreme generality of the p-adic physics means that one cannot exclude the possibility that electronic systems could quite generally develop p-adic cognitive representations about itself. If so, can one guarantee that the old electronic components recycled by Tilden do not differ cognitively from electronic components coming directly from fabric? If they do, two identical robots built from old and new components might behave differently. Thus a test for whether the robots have mentality and some kind of developing personality is whether two physically identical robots behave differently under similar circumstances.

Quite generally, one can identify p-adic cognitive representations as the mechanism which gives the physical system personality and allowing to distinguish even between two electrons p-adically: of course, Fermi statistics does not allow a state consisting of two electrons in states differing only cognitively. Quite generally, this kind of test could be the counterpart of Turing test allowing to deduce whether physical system has cognitive self or not.

Also now negentropic entanglement and the universality of CD time scales raise the hopes that it might be possible to understand what is involved.

9.3   Logic and fermions

The state basis for the fermionic Fock space has a natural interpretation as a Boolean algebra (fermion number =1/0↔ yes/no). In this manner ordinary Boolean algebra is extended to vector space spanned by fermionic states. When cognitive fermion pairs are used instead of fermions, fermion number conservation does not pose any constraints and full linear superposition of the Boolean algebra elements is possible. An interesting question is whether one could consider ordinary Boolean logic as some kind of limit for the complex quantum logic.

The simplest TGD based model for thinking systems leads to the result that thoughts correspond to quantum states in discrete spaces. The reason is that slightly non-deterministic classical time evolution means a finite number of multi-furcations. These additional dynamical degrees of freedom correspond to N-element set labelling the different time evolutions associated with given initial values. This suggests that a suitably defined *binary* Hilbert space having Z_2 rather than complex numbers as a coefficient field could provide a simple quantum model for a thinking system. This raises the following question.

What would a quantum field theory in discrete space and with the field of complex numbers replaced with binary numbers Z_2 (0,1/Yes,No) look like?

The answer is following.

1. The state basis of the quantum field theory defined in N-element set is nothing but a Boolean algebra consisting of 2^N elements: all possible statements about the N elements interpreted as propositions! Bosons and fermions are one and the same thing and behave like fermions since occupation number can have only the values 0 and 1.

2. The requirement that triangle equality for the inner product is satisfied, does not allow linear superposition and one must choose some orthogonal basis for the space. The absence of quantum superposition means that theory is completely classical. Thus it seems that Boolean QFT is completely classical and the transition from classical mechanics to quantum theory could be regarded as a transition from binary QFT to complex QFT or from a binary logic to complex logic.

3. Quantization means construction of statements about statements: the simplest model for an abstraction process one can imagine! One can of course continue this quantization: second, third, etc., quantization is possible and this corresponds to a construction of statements about statements about..... Hence a direct connection with the ideas about genetic code emerges.

4. Also the state basis in the Fock space of the ordinary fermions has interpretation as a Boolean algebra, all possible statements about some propositions (particle with a definite spin component is at point x).

9.3.1 The state basis of fermionic Fock space as Boolean algebra

The state basis of a fermionic Fock space can be interpreted as a basis of a Boolean algebra. In quantum TGD all elementary particles are constructed using fermionic oscillators operators. This suggests that entire quantum field theory is actually a representation of Boolean algebra and N-fermion states have interpretation as statements about basic propositions labelled by the indices labelling fermionic oscillator operators. In particular, configuration space spinor structure is constructed in terms of the fermionic oscillator operators for the second quantized spinor fields on space-time and this suggests a deep connection between spinor geometry and logic. Perhaps one could say that quantum logic is C-valued in the sense that all complex superpositions of a statement and its negation are possible.

In Boolean algebra one can select the maximum number of 2^{N-1} mutually consistent statements as axioms. An interesting possibility is that only these mutually consistent statements are physically realized so that the number of states is reduced by a factor of one half. Amusingly, in the ordinary fermionic field theory the states created by a finite number of oscillator operators are the counterparts of the mutually consistent statements, their negations would correspond to a vacuum state obtained as an infinite product of all creation operators annihilated by creation operators. The states created by annihilation operators from this states are not allowed in QFT since they would have infinite energy.

One can identify the complex valued linear space of fermions as a generalization of Boolean algebra to complex Hilbert space. Cognitive fermion pairs could provide realization for this space as pairs of fermion and antifermion belonging to different space-time sheets and representing logical statement and its negation: the automatic presence of negation is rather natural from the point of view of consciousness theory. The splitting of the wormhole contacts connecting the space-time sheets gives rise to annihilation process generating fermion and antifermion pair (fermionic quantum numbers reside on the boundary components of the split wormhole contact). In this manner one avoids problems related to fermion number conservation encountered otherwise in physical realization of the fermionic logic. Alternative possibility is to assume fixed number of fermions and associate truth values with the direction of spin.

9.3.2 Boolean algebra as Boolean QFT

Boolean algebra $B(N)$ is generated by all possible yes/no statements about N propositions. It consists of sequences of N binary digits of form $(..., 1, 0, 0, .., 1)$ having value of 0 or 1. Addition is with respect to Z_2 so that $1 + 1 = 0$. Boolean algebra is Z_2 linear space and the elementwise multiplication of the binary digits in the string makes it algebra. $(0, 0, 0, ..)$ and $(1, 1, ...,)$ are zero and unit elements of the algebra.

Geometrically Boolean algebra $B(N)$ corresponds to all possible subsets of an N-element set. Sum corresponds to a symmetric difference (take the union of sets and throw away the common elements). Multiplication corresponds to the intersection of the sets. Entire set represents unit element and empty set zero. Empty set is not physically realizable, or equivalently, the zero element of the Boolean algebra does not correspond to a physical state in the Z_2 Hilbert space defined by the Boolean algebra.

Quantum field theory in N-element set formed by the basic propositions (analogous to 3-space in QFT) means associating to each element of the N-element set creation and annihilation operators and postulating standard commutation relations with them:

$$[a^\dagger(i), a(j)] = 1 \ \ .$$

One can also consider fermions that is anticommutation relations but since -1=1 in Boolean algebra, they are equivalent with the bosonic commutation relations so that Boolean bosons and fermions are one and the same thing in the Boolean QFT.

The states of this QFT are constructed in the usual manner. The only difference is the occupation numbers are Z_2 valued and are either one or zero just as in the case of fermions. Thus Boolean particles are fermions always. Since N creation operators are involved one obtains a space generated by 2^N states. The proposition and its negation correspond to the states created by, say I oscillator operators and the dual of this state created by the remaining $N-I$ oscillators operators. Statement corresponds to I particles and its negation to I holes in the dual ground state containing all N oscillator operators.

Thus the state basis is nothing but the Boolean algebra associated with the N element set! Thus the state basis of Z_2 valued quantum field theory in the set of N propositions is nothing but the formation of all possible statements about these statements: a model for abstraction process. One can apply this process to the $2^N - 1$ element set and by continuing this process get a sequence of second quantizations as a sequence of abstractions.

The assumption of unrestricted linear superposition in Z_2 Hilbert space leads to difficulties with Schwartz and triangle inequalities. The physical interpretation of the theory requires that inner product satisfies Schwartz inequality

$$|(x, y)| \leq |x||y| \ \ .$$

Linear superposition allows states, say y, with zero norm since any superposition of even number of orthonormal states has zero norm in Z_2. The norm of the inner product of one of the basis states appearing in zero norm state, call it x, with the zero norm state y equals to one and is not smaller than the product of the norm of the basis state and state with vanishing norm: one obtains $1 < 0$, which does not make sense if inner product is interpreted as real number (as a Z_2 valued number one could perhaps say $1 = -1 < 0$). One ends up to difficulties also with the triangle inequality: $|x + y| \leq |x| + |y|$ if x and y are zero norm states with single common element of orthonormal basis so that one has $|x + y| = 1$.

The only possible manner to save Schwartz and triangle inequalities is to assume that linear superposition is not allowed for Z_2 Hilbert space. This in turn means that situation is completely classical! If the set generating Boolean algebra consists of entire 3-space, this means that every state is gauge equivalent with an N-particle state of completely localized particles. This in turn implies that Boolean QFT should be more or less equivalent with classical mechanics and one could understand the transition from classical physics to quantum physics as the replacement of Z_2 with complex numbers C as the coefficient field of the state space.

One can change state basis by unitary transformations. Unitary matrices are obtained from orthogonal Z_2 valued unit vectors possessing entries equal to 1 or 0. Any unitary matrix corresponds to a matrix representing the permutation of 2^N elements of the basis of the Boolean algebra. Time development operator in this quantum field theory is always defined for a *finite* time interval only (the length of the 'chronon' is fixed naturally in p-adic QFT) and represents a permutation of this basis. In particular, a nonlinear transformation of the oscillator operators in general occurs. All unitary transformations are permutations, which do *not* lead to state basis involving superpositions of the basic states. This is in accordance with the observation that Boolean QFT is completely classical.

9.3.3   Fermions, zero energy ontology, and Boolean cognition

Fermionic Fock state basis defines naturally a quantum version of Boolean algebra. In zero energy ontology predicting that physical states have vanishing net quantum numbers, positive and negative

energy components of zero energy states with opposite fermion numbers define realizations of Boolean functions via time-like quantum entanglement. One can also consider an interpretation of zero energy states in terms of rules of form $A \to B$ with the instances of A and B represented as elements Fock state basis fixed by the diagonalization of the density matrix defined by M−-matrix. Hence Boolean conciousness would be basic aspect of zero energy states. Physical states would be more like memes than matter. Note also that the fundamental super-symmetric duality between bosonic degrees of freedom (size and shape of the 3-surface) and fermionic degrees of freedom would correspond to the sensory-cognitive duality.

This would explain why Boolean and temporal causalities are so closely related. Note that zero energy ontology is certainly consistent with the usual positive energy ontology if unitary process U associated with the quantum jump is more or less trivial in the degrees of freedom usually assigned with the material world. There are arguments suggesting that U is tensor product of of factoring S-matrices associated with 2-D integrable QFT theories [22]: these are indeed almost trivial in momentum degrees of freedom. This would also imply that our geometric past is rather stable so that quantum jump of geometric past does not suddenly change your profession from that of musician to that of physicist. The maximal diagonality of U-matrix for p-adic-to-real transitions would in turn favor precise realization of intentions as actions. One must however take this kind of arguments with extreme caution.

9.3.4 Negentropic entanglement, fuzzy logic, quantum groups, and Jones inclusions

Matrix logic [48] emerges naturally when one calculates expectation values of logical functions defined by the zero energy states with positive energy fermionic Fock states interpreted as inputs and corresponding negative energy states interpreted as outputs. Also the non-commutative version of the quantum logic, with spinor components representing amplitudes for truth values replaced with non-commutative operators, emerges naturally. The finite resolution of quantum measurement generalizes to a finite resolution of Boolean cognition and allows description in terms of Jones inclusions $\mathcal{N} \subset \mathcal{M}$ of infinite-dimensional Clifford algebras of the world of classical worlds (WCW) identifiable in terms of fermionic oscillator algebras. $\mathcal{N}$ defines the resolution in the sense that quantum measurement and conscious experience does not distinguish between states differing from each other by the action of $\mathcal{N}$.

The finite-dimensional quantum Clifford algebra $\mathcal{M}/\mathcal{N}$ creates the physical states modulo the resolution. This algebra is non-commutative which means that corresponding quantum spinors have non-commutative components. The non-commutativity codes for the that the spinor components are correlated: the quantized fractal dimension for quantum counterparts of 2-spinors satisfying $d = 2cos(\pi/n) \leq 2$ expresses this correlation as a reduction of effective dimension.

The moduli of spinor components however commute and have interpretation as eigenvalues of truth and false operators or probabilities that the statement is true/false. They have quantized spectrum having also interpretation as probabilities for truth values and this spectrum differs from the spectrum $\{1, 0\}$ for the ordinary logic so that fuzzy logic results from the finite resolution of Boolean cognition [24].

9.3.5 Cognitive codes and fermions

p-Adic length scale hypothesis leads to the idea that each $p \simeq 2^k$, k integer, defines a hierarchy of cognitive codes with code word having duration given by the n-ary p-adic time scale $T(n, k)$ and number of bits given by any factor of k. Especially interesting codes are those for which the number of bits is prime factor or power of prime factor of k. $n = 2$ seems to be in special position in zero energy ontology. This is a strong quantitative prediction since the duration of both the code word and bit correspond to definite frequencies serving as signatures for the occurrence of commutations utilizing these codes.

If k is prime, the amount of information carried by the codon is maximal but there is no obvious manner to detect errors. If k is not prime there are several codes with various numbers of bits: information content is not maximal but it is possible to detect errors. For instance, $k = 252$ gives rise to code words for which the number of bits is $k_1 = 252, 126, 63, 84, 42, 21_2, 9, 7, 6_2, 4, 3_2, 2$: the subscript $_2$ tells that there are two non-equivalent manners to get this number of bits. For instance, $126 = 42 \times 3$-bit codon can have 42 -bit parity codon: the bits of this codon would be products of

three subsequent bits of 126-bit codon. This allows error detection by comparing the error codon for communicated codon and communicated error codon.

Mersenne primes are especially interesting as far as cognitive codes are considered the Mersenne prime M_{127} assignable to electron is of special interest since the corresponding time scale for CD is .1 seconds whereas the duration of bit corresponds to the time scale of 1 ms assignable to quark CDs.

Combinatorial Hierarchy as a hierarchy of 'genetic codes'

The simplest model for abstraction process is based on the process in which one forms first all possible Boolean statements about N basic statements, 2^N alltogether. If one drops one of the statements one has $M_N = 2^N - 1$ statements: M_N is Mersenne number. The motivation for the dropping of one statement might be that in set theoretical realization one of the statements corresponds to empty set and is not realizable. Alternatively, in the realization based on many-fermion states, vacuum state could correspond to this kind of state. One can form also statements about statements: the first level of abstraction. This leads to $M_{M_N} = 2^{M_N} - 1$ many-fermion states. Construction is especially intersting if the numbers $M(M_N)$ are primes, so called Mersenne primes. Indeed, in some cases one obtains hierarchies of Mersenne primes by repeating the construction as long as it works.

The so called Combinatorial Hierarchy, shown already earlier to provide an explanation for the numbers of the Genetic Code, emerges as the most notable hierarchy. The Combinatorial Hierarchy [44] consists of the Mersenne numbers $2, M(1) = 3, 7, 127, 2^{127} - 1, ..$ constructed using the rule $M(n + 1) = M_{M(n)} = 2^{M(n)} - 1$. The explicitely listed ones are known to be primes. Combinatorial Hierarchy emerges from a model of abstraction process as subsequent transitions from level to metalevel by forming Boolean statements about Boolean statements of level n and dropping one statement away and starting from $n = 2$ basic statements. Combinatorial Hierarchy results also by constructing the sets of all subsets with empty set excluded starting from two element set.

The set of statements at level n can be given a structure of Finite Field $G(M(n), 1)$ if $M(n)$ is prime. The multiplicative groups $Z_{M(n)-1}$ form a nested hierarchy and the coset spaces $Z_{k_n} \equiv Z_{M(n+1)-1}/Z_{M(n)-1}$ are cyclic groups. Combinatorial Hierarchy based model of Genetic Code explains the number of DNA:s and aminoacids and the representation of words of the GC as triplets of 4 different codons. Aminoacids correspond to $k_{n=3} = 21$ axioms of a formal system defined by $n = 3$ level of Combinatorial Hierarchy having a unique imbedding as the group $Z_{k_n} \subset Z_{M(n)-1} = Z_{126}$ and DNA:s correspond to the set $X_{N(DNA)} \subset Z_{M(n)-1}$ of $N(DNA) = (M(n) + 1)/2 = 64$ mutually consistent statements at level n regarded as special cases of general theorems. GC corresponds to the mapping $x \to x^{k_{n-1}} = x^6$ in $Z_{M(n)-1}$ mapping DNA type statements to aminoacid type statements. The numbers of DNA:s coding single aminoacid are reproduced in a symmetry breaking mechanism involving the finite groups $Z_{p_{n-1}}$ and Z_{k_n} and symmetry breaking is in a well defined sense minimal. The infinite hierarchy of possible genetic codes suggests the possibility of an infinite hierarchy of increasingly complicated lifeforms or forms of intelligence.

Boolean mind and memetic code

The original proposal for the realization of Boolean mind was in terms of sequences cognitive neutrino pairs. These can be interpreted as wormhole contacts carrying neutrino and antineutrino at the light-like wormhole throats and would thus represent boson like entities. In the framework of the standard model the proposal looks of course completely non-sensical. TGD however predicts the existence of long range classical electro-weak fields, and one might imagine that inside neutrino- whose Compton length corresponds to length scale of cell- intermediate gauge bosons behave like massless fields. Although neutrinos could be important, the time scale of corresponding CD - about 10^4 years - suggests that cognitive neutrinos might be important in much longer time scale than the .1 second time scale assignable to the memetic code.

The recent view about TGD allows a much more general view. Zero energy ontology allows to interpret the fermionic parts of zero energy states as quantum superpositions of Boolean statements of form $a \to b$ with a and b represented in terms of positive and negative energy parts of the zero energy state. If one has negentropic entanglement this kind of state has interpretation as an abstraction - a "law of physics"- representing as a quantum superposition various instances of a more general law.

The simplest situation corresponds to a CD having only single positive energy fermion and negative energy fermion at its light-like boundaries. The fermion number or spin or isospin of the fermion could

represent qubit. The hypothesis that memetic code corresponds to the next level of Combinatorial Hierarchy, when combined with p-adic length scale hypothesis, led to a prediction of order .1 seconds for the duration of the 'wake-up' period of subself corresponding to the codeword of the memetic code. Since the CD assignable to electron has time scale .1 seconds and the CD assignable to u and d quarks has time scale $1/1.28$ milliseconds there is a temptation to proposed that the quark-like sub-CDs of electronic CD give to a realization of memetic code word as a sequence of 126 quark like sub-CDs. u and d quarks would be assigned to the magnetic flux tubes connecting DNA and the lipids of the cell membrane in the model of DNA as topological quantum computer. Clearly, beautiful connection between new elementary particle physics, genetic code, nerve pulse activity, DNA as topological quantum computer, logical thought, and the basic time scales of speech are suggestive.

This codeword consists of 126 bits represented by quarks such that the two possible magnetization directions correspond to the two values of Boolean statement. This implies that the duration of single bit should $1/1260$ seconds. The duration of the nerve pulse is slightly longer than this which might mean that the full memetic code is realized as membrane oscillations rather than nerve pulse patterns. Both hearing and vision have .1 second time scale as a fundamental time scale and sounds are indeed coded to membrane oscillations in ear.

One can consider also the realization of genetic code with six bits of the codon represented by various scaled up versions of quark CD coming as size powers of 2. In this case the ordering of the bits would come from the size of sub-CD whereas in previous example temporal ordering would define the ordering. It is not however clear whether the powers of two can be realized physically.

One can understand the number 126 as related to the total number of separately experienced frequencies in the interval $20 - 20.000$ Hz spanning 10 octaves. $10 \times 12 = 120$ is not far from 126: here 12 corresponds to 12 tones of basic music scale. Also speech has 10 Hz frequency as fundamental frequency. In visual primary cortex replicating triplets, 4-,5- and 6-plets of spikes with highly regular intervals between spikes have been detected. The triplets are accompanied by ghost doublets. This would suggest a coding of some features of visual experience to reverberating mental images. The time scale for various patterns is .1 seconds. This could be seen as a support for the realization of some degenerate version of the memetic code as nerve pulse patterns.

The model for the memetic code encourages the following conclusions.

1. Membrane oscillation/nerve pulse patterns correspond to temporal sequences of magnetization directions for quarks representing yes/no Boolean statements.

2. The spin polarization of quarks is changed from the standard direction fixed by the spontaneous magnetization in the direction of axon by a ME moving parallel to axon, and inducing membrane oscillation or even a nerve pulse. Nerve pulses could correspond to a degenerate memetic code resulting by frequency coding for which the number of distinguishable code words is 64, and would thus naturally correspond to the reduction of the memetic code to the genetic code.

A very precise correspondence with the basic structures of the genetic code results. mRNA $\rightarrow$ protein translation corresponds to the translation of temporal sequences o magnetization directions to conscious cognitive experiences. Under very natural constraints the mapping to cognitive experiences is not one-to-one and the predicted degeneracy (2^{126} sequences correspond to $(2^{126} - 1)/63$ cognitive experiences) can be understood.

One might think that the full memetic code is an evolutionary newcomer and involved only with the logical thought: this would explain the completely exceptional characteristics of human brain. The full memetic code could be realized for certain regions of brain only. These regions certainly include auditory pathways responsible for the comprehension of speech [26, 18, 18, 27].

How nerve pulse patterns and membrane oscillations could be coded to Boolean statements?

The original proposal for the realization of the memetic code was based on the notion of cognitive neutrino pair. Zero energy ontology however disfavors this identification since the time scale assignable to CD of neutrino is of order 10^4 years. Therefore neutrinos would most naturally correspond to a time scale of consciousness much longer than the time scale of .1 seconds predicted to be present. If the proposed view about cell membrane is correct, classical weak fields should be important within the Compton length of any particle and therefore the interactions of neutrinos with Z^0 fields should be important as also the large chiral asymmetry in living matter suggests.

The realization of memetic codewords in terms of sub-CDs assignable to u and d quarks look much more attractive option since they have time scale of $1/1.28$ millisecond.

1. The bit would correspond to quark existing in this kind of sub-CD. Memetic codon would correspond to electron's sub-CD containing a row of 127 quark sub-CDs. Standard physics interpretation could be as quantum fluctuation generating virtual pair of quark and negative energy antiquark. For non-standard values of $\hbar$ the durations of codewords and bits would be scaled up.

2. The time-like row of quark sub-CDs resides in em (and possibly also Z^0) field associated with the cell membrane and having the direction of the axon. There is a time-like row of quark sub-CD at some points of axon with one sub-CD per millisecond time interval between sub-CDs. DNA as topological quantum computer hypothesis suggests that each lipid could correspond to quark sub-CD so that many-quark system would be in question. The minimization of the magnetic energy for a given sub-CD fixes the direction of spin and one has spontaneous magnetization in the case that the direction of magnetic field inside quark sub-CD does not change during the pulse.

3. The time that it takes for a nerve pulse to traverse the point is slightly longer than millisecond. If the time which magnetic field has reversed direction is of order millisecond then the magnetic field experienced by quark can preserve its direction during the time interval that quark exists from the point of view of outsider. This is achieved if the temporal center of mass positions of the quark sub-CDs are given by $t_n = nz_0/v$, where z_0 is the distance between lipids containing quark sub-CD and the position of nerve pulse is given by $z = vt$, where v is the conduction velocity of nerve pulse. Unless this condition is satisfied, the direction of magnetic field changes during the time interval associated with sub-CD. In this case a superposition of bits identifiable as a qubit results.

4. This means that nerve pulse sequence defines a (qu-)bit sequence with the direction of spin telling whether there was nerve pulse present in particular sub-CD. The presence/absence of nerve pulse corresponds to true/false statement in accordance with neuro science intuition.

9.4 Quantum computationalism

TGD Universe can be formally regarded as infinite quantum computer like structure in the sense that each quantum jump involves the unitary process U analogous to a Schrödinger evolution lasting infinite time and is followed by state function reduction and state preparation process. Therefore TGD suggests what might be called quantum computationalism. Universe would be performing huge quantum computation and the computation like processes performed by us or by our brains would be only a ridiculously small portion of this computation. Of course, this must be taken as a rough metaphor, the quintessence of the conscious quantum computation like processes could be quite different from the essence of the ordinary quantum computation.

The average increment of the psychological time in quantum jump is rather small: the simplest guess suggest that the average quantum of psychological time is or order 'CP_2 time', about 10^4 Planck times. This means that the relation of the information processing performed by biosystems to quantum jump would be the same as the relationship of macroscopic physics to physics in CP_2 scale about 10^4 Planck length scales. This would however mean an extremely short decoherence time in an obvious conflict with the experimental facts. Macrotemporal quantum coherence, which corresponds to the formation of bound states, however effectively fuses a sequence of quantum jumps to a single quantum jump so that the decoherence occurring otherwise in CP_2 time scale can be circumvented.

The notion of self is absolutely crucial for TGD approach to consciousness and makes possible to understand consciousness in macroscopic time scales. A very natural notion is that of cascades of selves within selves generated spontaneously or by quantum jumps. This implies a connection with the basic conceptual structure of computationalism. The cascades have natural modular structure, which is quintessential for the understanding of the symbol processing performed by brain. A very attractive hypothesis is that selves within selves are conscious counterparts of computational agents or more or less equivalently, of the subroutines of computer program. Selves can perform two kinds of quantum jumps and a natural identification of these modes is as computational and sensory (input)

modes. Subjective memory takes automatically care of ouput in the sense that the subjective history of subself is experienced as an abstracted memory by self.

Communication between selves could occur as it does between human beings. Also 'mass media' at neuronal level seem to be possible and would make possible the concept of global workspace. Quantum jumps can be regarded hopping in the space of zero modes identifiable as fundamental order parameters and Haken's theory of feature recognition generalizes. Quantum entanglement in turn provides elegant realization of association concept so that the basic ideas of connectionism emerge naturally from quantum computationalism. There are also drastic differences with between TGD and computationalism, basically implied by the different concept of psychological time which implies that cognition has holistic aspect also with respect to time. Thoughts are definitely not deterministic computations and living systems are definitely not robots.

9.4.1 Computationalism and connectionism

Computational approach to cognition [87] is the dominating approach in cognititive and neuro sciences and has had undeniable successes. Computationalism is often identified as traditional AI based on the concept of truth preserving manipulation of symbols according to some fixed rules of the formal system. This approach indeed explains nicely computational aspects of mind. Combinatorial explosion is the basic failure of the approach at practical level. Connectionism relies on the concept of association and associative neural net provides a quantitative model for how brain learns. Connectionism is often regarded as a variant of the computationalism and it is believed that neural nets provide models for unconscious parallel information processing whereas conscious information processing is best modelled by hierarchical program like structures. The general philosophical shortcomings of these approaches are obvious: they cannot provide any insights to the problem how meaning, understanding, emotions and volition, which are factors crucially important for the functioning of conscious brain, arise. This has even led some advocates of this approach [87] to believe that human brain, being computer basically, is simply uncapable of understanding the problem of consciousness! This would probably be the case if human beings were robots: fortunately we are not!

Traditional AI approach

In the traditional AI approach brain is modelled as a complicated computer. Computation is realized using rigid algorithms, which are hierarchical structures consisting of subprograms. Using more abstract terminology, the basic concepts are symbols and agents, 'demons'. Symbols are inputs for 'demons', subroutines of program manipulating symbols and creating new outputs as symbols. One could however interpret also agents themselves as symbols. The concept of global work-space [88] realizes the intuition that short-term memory is available to many users. Also the concepts of belief and desire can be formulated without referring to consciousness. Beliefs are inscriptions about the world and desires are identified as goals. For instance, problem solving means simply making trials with the aim of minimizing the difference between goal and result of trial. The concept of representation is central. It is known that brain realizes several types of representations [87]. Visual mosaic like representations, phonological representations in short-term memory consisting of few phonemes (say remembering phone number for some time), grammatical language like representations with hierarchical structures and 'mentalese', which is the most abstract representation type summarizing in very implicit manner the essentials of, say, mathematical model.

Computationalism explains nicely the general features of language by providing a representation for the hierarchical structure of language. One can also easily think brain as a population of (possibly) conscious demons. Some demons receive sensory input, some demons process it and the ouputs of some demons are realized as motor outputs. It seems that this approach models quite satisfactorily those aspects of cognition, which can be realized as purely mechanical truth preserving symbol manipulation modellable universally by Turing machine. The best proof for the claim that computers have catched something about the basic structure of cognition is that computers are already now able to beat chess champions. The weak point of the computationalism is its extreme rigidity: minor input error or programming error and program fails to work. Combinatorial explosion is second shortcoming. For instance, all possible melodies formed from finite number of musical notes with finite number of durations for each and lasting the typical length of musical piece is immense. In computer chess combinatorial explosion makes the simple-minded trial and error approach completely unpractical and

the only possible manner to proceed is to teach the computer by mechanizing the human intuitions about good chess.

Connectionism and neural nets

Connectionism provides a modern version of associationism proposed by British philosophers Locke, Hume, Hartley, Berkeley and Mills. Behaviorism was the first purely mechanistic version of this approach but was quite too simplistic to work. Associationism consists of two laws. The first law states that the ideas which are often experienced together get associated: when one is activated also the other one gets activated. Second law states that similar ideas activate each other. Connectionism tries to realize these two aspects of associationism mathematically and construct practical realizations for associative thinking. Typical application would be feature recognition and machines learing automatically from their inputs some predetermined tasks.

Neural nets provide a mathematical model for the concept of association and associative learning. The simplest model for learning simply associates unique self-organized state of a dissipative neural net to the state of the external world represented as an external force driving the neural net. Dissipation realizes also the second law: if input is sufficiently similar to the standard input generating given standard output, the standard output is indeed generated. Also Haken's model for feature recognition realizes second law as a feature recognition based on nonequilibrium thermodynamics. Features correspond to equilibrium states of a nonlinear dissipative system (free energy minima for order parameters). If input creates initial output belonging to the attractor of the feature, dissipative dynamics takes care that the asymptotic output is feature.

Associative net can be regarded as a many-layered structure, in which the states of some nodes correlate strongly with the states of some other nodes. The state of node is characterized by a component of vector, whose components give the values of the amplitude in the nodes. For a given input the net rapidly achieves equilibrium in which the associations created by the input are determined by those nodes in which the amplitude is large. The equilibrium states of neural nets with coupling to external are identified as representations for stable mental states representing some states of the external world.

The flexibility of the neural nets is the strength of connectionism. Also combinatorial explosion can be avoided. Neural nets might indeed model lower level cognition which is mostly unconscious to us. The absence of the hierarchical structures means the loss of 'expressive power' essential for higher cognition and leads to the problems decribed in [87].

1. Connectionistic approach is not able to distinguish between individual and class: what is created from the inputs is some kind of average individual: neural network can learn to recognize human face but not a particular human face or to recognize particular human face but not to make abstraction about what human face looks like.

2. Second problem is so called compositionality: the ability of the representation to be build out of parts and represent the meaning of the whole deriving from the meanings of parts. A related problem are the difficulties in the identification of the meaning of linguistic expressions. For instance, the meanings of the expressions consisting of words 'the child', 'ate' and 'the slug' depend on the order in which the words are represented and connectionism is not able to distinguish between 'the child ate the slug' and 'the slug ate the child'. The natural ordering of symbols provided by hierarchical tree solves this problem in AI approach. Simple neural network learns easily to recognize picture containing horse but if the picture contains two horses, network fails completely!

3. The third problem is a combination of these two. An example from [87] illustrates this. Network can learn to sum 1 and 3 to 4. When it learns to sum 2 and 2 to 4 it can lose the already learned ability. Second example: consider the exression 'Every forty five seconds some-one in the United States sustains a head injury'. Human brain can easily realize the meaning of this sentence which suggests that quantification occurs in brain and human brain transforms the sentence either to expression "Every forty-five seconds {there exists an X[who gets injured]}" instead of "There exists an X{who every forty-five seconds[gets injured]}"

4. What multiplies human thoughts is recursion. We can take proposition and give it a role in another prosition and so on. In this manner a combinatorial explosion of propositions is gener-

ated. To get propositions-inside-propositions network, one could add a new layer of connections but this solution is clumsy and non-economical. The addition of a new level of abstraction would mean a new network containing additional level. In computationalism the solution of the problem is much more elegant. Each proposition is represented in long term memory once. One can of course combine computationalism and connectivism and use simple neural networks as basic modules of computer program like modular structure.

5. Neural net models, which realize connectionistic philosophy in practice, have serious problems in modelling long term memory. If its is assumed that long term memories are coded into the matrices defining output of the node in terms of its inputs, which are modified during learning process, the unavoidable conclusion is that new memories destroy the old ones. Childhood memories seem however to be the most stable ones.

9.4.2 How connectionism emerges from TGD framework?

Brain as an associative net in TGD

TGD leads to a variant of connectionism which differs from the standard version in some crucial respects. Brain as a quantum self-organizing system moving in spin glass energy landscape generalizes the neural net realization of connectionism. The plasticity of the neural substrate corresponds directly to the spin glass property and the notion of frustration fundamental for spin glass type systems is guaranteed by the inhibitory/excitatory nature of nerve pulses. Neural net becomes dynamical rather than being a fixed structure. One can view brain as system moving in the space of neural nets and perceiving and affecting its own position in this abstract space.

Brain can be regarded as a conscious associative net developing by quantum self-organization to asymptotic self-organization patterns which correspond to recognized features, learned habits, skills $\cdots$: dissipation can be said to serve as fundamental Darwinian selector in this process. By music metaphor each neuron, when it fires, generates a characteristic neuronal experience possibly contributing to our conscious experience: only the intensity of this experience depends on the nerve pulse pattern. The firing of a neuron gives rise to a conscious neuronal association $A \to B$.

This would suggest that brain is like a conscious music instrument, or rather, entire orchestra, played by the nerve pulse patterns and our experiences corresponds to the sound patterns created by this orchestra. It has turned out that this view is probably quite not correct. Brain and body are much more. The music is at the level of sensory organs as sensory qualia, and neural activity cognizes, that is analyses the sensory music to notes and represents the notes. This view, which is certainly not possible in the standard neuroscience framework and surprisingly close to what a layman knowing nothing about neuroscience would think spontaneously, makes sense in TGD framework if one assumes that entanglement between brain and sensory organs binds sensory qualia with the cognitive associations generated by the sensory input. This view also allows to understand elegantly the differences between sensory experience, dreaming, hallucinations, and imagination. An essential element is the feedback from brain to sensory organs enabling "qualifacation" during dreaming and hallucinations. This feedback is also active during the ordinary wake-up consciousness.

Spin glass energy landscape is four-dimensional in a well defined sense and the identification of the long term memories as geometric memories solves the basic paradox of the neural net models of memory. One can also understand how brain knows that the mental image represents memory and why repetition and reverberation of nerve pulse patterns in neural circuits leads to learning and why emotional experiences are easily remembered.

Feature recognition

The first law of associationism states that similar ideas tend to induce each other. For instance, a part of familiar face in the visual field induces a memory about the entire face. In computational approach feature recognitition is believed to involve unconscious low level parallel processing. Haken [53] has proposed an elegant model of feature recognition based on non-equilibrium thermodynamics. The features to be recognized represent the minima of the potential depending on order parameteres and the presence of dissipative terms implies that system ends up to potential minimum representing feature.

Haken's theory generalizes to TGD context almost as such. Dissipative time evolution is replaced with quantum self-organization by quantum jumps and in each step entire macroscopic space-time surface is replace by a new one. The zero mode degrees of freedom of the configuration space are identifiable as fundamental order parameters and each quantum jump involves complete localization in continuous zero modes. The localization in discrete zero modes characterizing cognitively degenerate space-time surfaces need not be complete: what is needed is localization to a subset of space-time sheets for which the eigenvalues of the p-adic density matrix are degenerate. This means that the time evolution by quantum jumps corresponds to hopping in the space of zero modes, which leads to that part of zero mode sector, where configuration space spinor field has largest value. The maxima of Kähler function are excellent candidates for the attractors of the quantum self-organization process.

A more concrete brain level model of feature detection based on the realization of the self-hierarchy as a hierarchy of Josephson currents frequency-modulating each other perhaps helps to clarify the abstract general ideas about conscious feature detection.

1. The feature to be detected is represented as a reference supra current flowing in a neural circuit and weakly coupled to a parallel neural circuit representing the input. When the supra currents are identical, constructive interference of the Josephson currents flowing between the two circuits occurs and induces large modulation of the rest potentials of neurons of the circuit and leads to a synchronous generation of nerve pulses. Synchronous neural firing can start under rather wide limits depending on the alertness of the neural circuit (how near to the threshold value resting potential is) controlled by the modulating Josephson currents also.

2. Synchronous neural firing wakes-up subself which starts to self-organize and develops into an asymptotic pattern representing a mental image about the detected feature. The final state depends only weakly on the initial state of the neural circuit representing self so that genuine feature detection is in question. For instance, some minimal number of neurons firing in the neural circuit leads to given final state pattern so that the constructive interference of the Josephson currents need not be maximal.

3. The self-organization parterns in neural circuits define a population of sub-selves defining cognitive mental images, features. These sub-selves wake-up and fall asleep (even periodically during their lifetime (after images)). Falling asleep occurs, when the sub-system generates a bound state entanglement with some other sub-system, and wake-up by a reduction of the bound state entanglement.

4. Self-organizating neural circuit starts to approach the maximum of 'subsystem' Kähler function (recall that approximate representability of Kähler function as a sum of subsystem Kähler functions is probably possible) is accompanied by the wake-up of subself. This corresponds to the motion of neural circuit in its spin glass energy landscape induced by various neural transmitters inducing short term or long term changes in the synaptic contacts. Thus self-organization induces also a generalized motor action shifting the position of the neural circuit in the spin glass energy landscape.

5. Feature detection involves kind of *Eureka!* experience. Perhaps the subself representing the mental image about recgonized object remains for some time irreducible and hence does not possess any subselves (and is in 'enlightened' state). This could be the situation for some time until subselves are generated during self-organization and lead to the analysis of of the recognized feature.

It seems that the presence of an algebraic p-adic-real entanglement with a positive entanglement negentropy a is a physical correlate for the experience of understanding and Eureka experience. Real bound state entanglement can give rise to experiences like seeing beauty, feeling truth, and feeling love. Thus both p-adic and real physics, cognitive and symbolic representations, must be involved. Cognitive representations realized in terms of p-adic cognitive neutrinos are generated from the real physics based symbolic representations. The entanglement between cognitive and symbolic would give rise to the Eureka experience. The need to separate cognitive and symbolic representations from each other is highly non-trivial implication.

Learning of associations

The second law of associationism states that ideas experienced simultaneously tend to form associations. TGD suggests two mechanisms for realizing associative learning.

1. The purely quantal mechanism realizes associations in terms of quantum entanglement. This mechanism would be extremely elegant because super position principle allows huge capacity of forming associations. Quantum entanglement however seems to associate parts to form wholes with the ensuing loss of conscious information about parts rather than giving rise to conscious associations $A \to B$. One could say that the association in question is spatial rather than temporal. Note also that quantum entanglement lacks the directional character of association. It seems that this mechanism is essential for associating various cognitive features at the level of brain with sensory qualia at the level of sensory organs.

2. In second mechanism the classical neural net type realization is replaced by a process in which subself wakes up another sub-self. A process in which presynaptic neuron wakes up postsynaptic neuron and the mental images of these neurons form the association, could indeed serve as building blocks of our associations.

It has turned out that these mechanisms are actually not mutually exclusive, and that both are involved with the association mechanism. The TGD based notion of sub-system, relying on the topological non-triviality of the many-sheeted space-time, makes possible for separate selves (unentangled systems) to share mental images via the entanglement of their sub-selves. Topologically this corresponds to the following situation. Two selves (say sensory mental image and cognitive mental image) are realized as disjoint space-time sheets S_i, $i = 1, 2$ and their sub-selves as smaller space-time sheets S_{ij} glued by wormhole contacts to the space-time sheets S_i. When sub-self space-time sheets S_{1j} and S_{2k} are connected by join along boundaries bonds, the fusion and sharing of these mental images occurs.

The neural network model for the formation of associations relies on the idea that some states of the neural net are in a correspondence with the states of the external world. Also the states of different layers of neural net have natural mutual correspondence. Association basically creates one-one map. In neural net models the interaction with external world occurs via driving force and dissipation leads to asymptotic states, which can be interpreted as association of net-states with the states of the external world. The problem of the neural network models is how the learning process could be realized in living brain. In particular, how two simultaneous ideas represented by the substates of neural net get associated with each other. This seems to require that the presence of two active nodes present in the net tends to strengthen their mutual coupling. There is a lot of empirical supports for this and neural transmitter action is an essential element of this process. In TGD framework this process corresponds to the gradual movement of neurons and brain in their spin glass energy landscape induced by neural transmitter action.

In TGD framwork the formation of association $A \to B$ would mean that the stimulus A alone can generate B. This means that the subself representing mental image A tends to wake up the subself representing mental image B. At the neuronal level this simply means that the firing presynaptic neuron excites postsynaptic neuron so that it also fires: the long term changes of the synaptic connection promotes this ability. At the level of our mental images the waking up process must involve nerve pulse transmission from neural circuit representing subself A to the neural circuit representing subself B. Josephson current model suggests that during learning period, when A and B are experienced simultaneously, they are mapped to reference currents in feature recognition network $A + B$. Later when only A serves as input, part A of the circuit $A + B$ begins to fire when it receives A as input. If the synaptic connections between circuits A and B have been strenghtened during learing period, the firing spreads out to B and also B wakes up. This in turn leads to the self-organization process generating experience $A + B$.

Many associations are bi-directional: for instance, symbols for real world objects are bi-directional associations. In TGD framework one can model the generation of the bi-directional associations in classical sense along following lines. Denote by A and B the symbols to be associated: A and B correspond to subselves of say self X. Neural net philosophy suggests that A and B should co-operate to keep each other in wake-up state (alive!): self-organization by quantum jumps could lead to this kind of co-operation. This is achieved if sensory experiences stimulate automatically co-operative

self-populations, whose members tend to keep each other awake. This model is consistent with the fact that associations do not involve conscious thought. For instance, A could generate nerve pulse patterns waking up B and vice versa. Note that at the next level of the self hierarchy this could be regarded as a formation of self-association $X \to X$ possibly giving rise to a stable short term memory and also as survival of self X guaranteed by co-operation of subselves.

9.4.3   Computationalism and TGD

Computationalism in strong sense (brains as deterministic machines) does not emerge from TGD. The basic reason is that the time concept is totally different from that of computationalism. One can say that quantum jumps select between different time evolutions and the overall-important modular structures result from self cascades.

How computationalism and TGD approach differ?

A good example is provided by vision discussed in [87]. Vision builds representation or description of the world from sensory data. Since inverse optics is not possible, implicit assumptions about the structure of the external world are necessary. Typically illusions rely on the breaking of these implicit assumptions. Illusions are not always undesirable. Two-dimensional pictures are an example of an illusion making possible visual communication! Auto-stereograms [87] consisting of diffuse soup of points are a particularly striking example of illusion: looking the picture for a sufficient time, one can experience a dramatic reshapening of the experience: beautiful 3-dimensional picture emerges from the chaos. Auto-stereograms support the hypothesis that vision involves computational activities or quantum counterparts of them. This process can be seen as a school example about how brain adds to a pure sensory input symbolic and cognitive representations.

In TGD universe brain does not probably deduce the representation of the world from picture by a straightforward computation. Certainly the data and implicit or learned assumptions about the world appear as an input in some sense. Some kind of iterated guessing based on implicit assumptions seems to involved: guess is made and compared with the actual picture. Quantum self-organization indeed makes possible the iteration, being in itself an iterative process. Guesses are very probably based on the existing abstract data about possible configurations of the world. The paradigm of 4-dimensional brain allowing to realized long term memoryes as geometric memories could be crucial in this respect. One can wonder whether the implicit assumptions might also develop from temporal entanglements with larger selves (during sleep) giving rise to information about world in longer length and time scales.

Control of motion is second good example of what might happen. There is no deterministic program proceeding with respect to geometric time and selecting what happens next and creating the quantum history step by step. Rather, the entire pattern of motion is selected by the creation of the main program self by quantum jump. The subsequent quantum jumps occur in the cascade proceeding in top-to-bottom type manner to shorter spatial and temporal scales. Thus the main program corresponds to, say the pattern of large scale motion, and sub-programs correspond to the details of the motion. What is new as compared to computationalism is that the program is created while it runs.

At the level of CNS anatomy sensory perceptions and motor actions loook mirror images of each other. TGD suggests that they could be mirror images at much deeper level. Motor actions would be time reversal of sensory perception in appropriate time scales for MEs (topological light rays, "massless extremals") and routinely involve breaking of the second law in this p-adic time scales. This assumption implies that motor action results like a painting starting from a rough sketch. Dissipation and its time reversal automatically perform Darwinian selection leading quantum jump by quantum jump to the final motor action. No detailed planning is needed. Motor imagination is motor action starting from some level above the muscles and motor skills can be learned by imagining them.

Real selves as symbols

The ability to think in terms of symbols is certainly one of the key features of intelligence. The hierarchical structure of selves within selves and the possibility of cascades creating selves within selves allows to interpret subselves of self as conscious representations for symbols, at least under

certain additional conditions. The condition seems to be that symbol subself and the primary subself representing the real object must be able to wake-up each other bi-directionally. Symbol self and 'real self' could also belong to different levels of the hierarchy. For instance, single neuron could serve as a representative of neuron group in the sense that neuron and neuron group can wake-up each other. Perhaps Grandma neuron serves as a symbol for a complicated experience of entire neuron group. Linguistic associations would certainly be subselves representing this kind of representative function very effectively. This kind of symbol neurons would correspond to leaders at the level of human society. Indeed, words can generate actions and word selves are excellent candidates for the leaders of the neuronal society!

Selves allow also other interpretations. In very general sense they can be identified as agents or 'demons' in the sense of computationalism. Agents can be also regarded as counterparts of submodules of main program. The call of subroutine from main program could be regarded as a wake-up of subprogram self. The main program forms automatically abstraction of the entire subjective history of subprogram self. The input data of submodules realized as subselves is most naturally realized as sensory input. For instance, neurons are expected to have chemical senses making communication between neuronal selves possible [24]. Nerve pulses provide obvious candidate for a communication mode.

The concept of global workspace [88] is one of the basic concepts used in the modelling of cognition and short term memory. The model visualizes short term memory as a global workspace, kind of common blackboard seen by various agents. The agents in turn can add write data to the global work space. Communication via global workspace is clearly analogous to mass media. Communication via global work space could be realized as chemical communication. Hormonal system could be an example of mass media operating at the level of our conscious experience. A surprisingly large volume of brain is free of neurons and glial cells and there is experimental evidence for chemical communication occurring via this free volume [64]. In TGD framework global work space could be also realized in terms of coherent photons if selves act as quantum antennas able to receive and send messages: this would be very much like mass media in neuronal and subneuronal length scales.

Wholes and parts, classes and individuals

Wholes contra parts and classes contra invividuals are basic concepts of computationalism and should allow representation as quantum level concepts. Also in TGD framework these concepts emerge naturally. The subselves X_i of self X are individuals and a natural hypothesis is that X experiences X_i as separate subselves. The self Y at the next level of hierarchy containing X in turn experiences the set $\{X_i\}$ of subselves of X as an average $\langle X_i \rangle$, typical representative of class X. For instance, if subselves of X represent different faces, then Y forms abstraction about the concept of face.

'Whole' is a concept different from class. A good example of 'whole' is letter F formed from smaller F:s. Whole is something more than a sum of invividuals and the problem is to understand how this whole is represented at quantum level. A very natural hypothesis is that the whole formed by subselves is formed by quantum entanglement between subselves leading to the disappearance of the invidual subselves. When entanglement is destroyed, subselves or some of them are experienced as separate: this mechanism could also be regarded as a quantum mechanism for the formation of associations. Sensory experiences would wake up sensory selves involving sensory organ and parts of brain giving rise to different representations of sensory data and the analysis of sensory experience would involve the decomposition of these selves to subselves.

Our body consciousness provides testing ground these ideas. Contrary to the basic dogma of neuroscience, in TGD framework the fundamental representation of the body is formed by the body itself as is clear also on basis of the concept of self. Of course, representations at the level of brain are also involved and make possible the analysis of the body experience. We do not however experience our bodies as a huge number of separate cells. The explanation is that our subselves correspond to structures that are much larger than cell. Various parts of our body could obviously correspond to the subselves of our self. The fact that we recognize all parts of our body as such suggests that our self is at least as large as our body or perhaps even larger. Interestingly, in some brain disorders patient does not admit that some part of body, say left side of the body, belongs to them. This would suggest that the self of these persons is reduced to the self of the other side of the body rather than that of entire body.

Predictions and memories

The paradigm of 4-dimensional brain (and of 4-dimensional body and even of 4-dimensional Universe!) differentiates between TGD based computationalism and classical computationalism. One of the most important predictions is the possibility of two kinds of memories: geometric 'memory' generating simulations of past and future and subjective memory making it possible to have genuine memories about previous moments of consciousness. The comparison of the predictions with what actually happened seems to be basic activity of conscious mind. The fundamental realizations of both subjective and geometric memory elegantly circumvent the memory storage problems encountered in the computationalistic approach and multiplied by the combinatorial explosion.

These basic memory types allow several realizations. The identification of immediate short term memories as subjective memories is very natural. Geometric memories seem to be the only reasonable candidate for long term memories. Procedural memories relying on association of say nerve pulse patterns with experiences are possible.

Self at a given level of hierarchy forms automatically abstractions about the wake-up periods of the lower level selves. This makes possible to form abstractions about the time development of subselves and to gain wisdom given by experience. Long term memories involve both the formation of abstractions as some kind of time averages and detailed information. This is difficult to realize in the neural network approach.

Boolean logic and logical deductions

One can easily invent models of logical reasoning but probably the most realistic model is based on representing the premises of the logical deduction using Boolean statements realized in terms of cognitive (that is p-adic) neutrinos. These cognitive representations are transformed by p-adic-to-real transition to symbolic ones, and generate a neural activity representing the logical deduction which is basically realized using learned associations. The outcome is represented again in terms of cognitive neutrinos. Thus only the inputs and outputs of the deduction process are represented in terms of cognitive neutrinos (this must be so since the experience of understanding requires p-adic-real entanglement with a positive entanglement negentropy). This model involves minimum amount of p-adic physics, is essentially isomorphic with the model of imagination, and is consistent with neuro-science facts.

An interesting possibility is that many particle states of cognitive neutrino pairs providing representation of logical thoughts could replicate. This might be possible. If the macroscopic phase determined by cognitive neutrino pairs is compeletely fixed by the structure of mindlike space-time sheets then the replication of the material space-time sheet and mind-like space-time sheet would lead to the replication of thought. DNA replication seems to occur in too short length length scale to be associated with this process. Cell replication could however quite well involve replication of thoughts. Cell replication does not seem to occur at the level of brain. Presumably nerve pulses generating standardized patters of cognitive neutrino pairs have replaced direct decay of cell as a more effective manner to replicate thoughts and eventually even communicate them.

Beliefs and desires

Computational approach does not have much to say about emotions. Beliefs and desires are however concepts allowing symbolic (one might say computational) representation: this of course does not explain what gives for belief or desire its emotional content.

Beliefs could be very generally regarded as basic axioms of formal system from which various deductions by truth preserving symbol manipulations are obtained. The mathematical model behind numerical calculation is a nontrivial example of this kind of belief system. Desires can be realized in computational science in terms of goals assigned with the initial state. For instance, the desire of the problem solver is to solve the problem that is get from initial state to the desired final state by applying fixed rules. Initial state could correspond to the assumptions of a theorem and final state to the theorem itself. If it is possible to solve the problem at the level of symbolic representation, the solution of problem can be mapped to the real world. Beliefs and desires could easily be represented symbolically in terms of neural activity using associations. A Boolean representation of beliefs could be in terms of logical statements using cognitive neutrinos or real neutrinos.

It is not so easy to understand what gives rise to the conscious experience of belief or desire. The geometric time development can be regarded as a prediction of future (and past) whereas "reality" corresponds to the subjective time development. The belief about what happens in the future is a special belief and could be seen as 'memories' with respect to the geometric time: seeing to the future. Intention would be the p-adic counterpart of this kind of belief, seeing to the p-adic future. A wide class of emotions could result from the comparison of the predicted and real. That predicted and real coincide, could correspond to nearly identical sub-selves able to form a bound state accompanied by a a period of macrotemporal quantum coherence and a positive emotion like understanding.

The fundamental desire of the subself is to stay conscious, to survive. Cognitive, symbolic, and Boolean representations would give for the desire of the mental images of the conscious world model to survive an interpretation as a higher level desire. Also beliefs might be determined to a large extend by the desire of the sub-selves to survive: giving up a belief means death of the corresponding mental images and unpleasant mental images are a threat for mental images defining the self model. We tend to have beliefs which do not threat our ego.

Simple model for problem solving

Problem solving is certainly quite high level cognitive skill. A good test for the proposed scenario is how simple conscious problem solving could proceed. The basic desire of problem solver is to achieve the goal given the initial state. Problem solver makes trials and when goal and achieved state are sufficiently near to each other problem can be said to be solved. The model for this activity could be roughly like follows:

1. Goal is represented as a physical state of some subsystem and the basic problem is how problem solver can compare the result of trial with the goal. It seems that all conscious comparisons must reduce at fundamental level to the comparisons of geometric and subjective time developments of some subself. Thus it seems that problem solver self must directly experiences whether the goal was achieved by experiencing how much the hoped for geometric time development and subjective time development generated by the trial resembled each other.

2. This approach as such is not practical. Standard computationalism would the comparison of the result of a trial to the goal necessitates circuit which carries out comparisons. This kind of circuit is easy to realize. For intance, Josephson junctions could physically realize the difference between the result of trial and goal as the phase difference between weakly coupled superconductors. To know whether the trial was succesful, problem solver must compare the desire represented by a binary digit one in geometric memory with the result of comparison represented by a binary digit having one one or zero in subjective memory. For instance, limbic brain could be the seat of these binary digits and comparison could occur there.

3. Problem-solver subself generates solution trials. Most naturally this involves quantum jump leading to decomposition of problem solver self to two subsystems. This decomposition represents the trial. Good problem solver must be able to generate very many different trials: this means that entanglement entropy is almost constant function of subself generated in quantum jump.

4. Problem solver self performs the comparison. When output is 'No' problem-solver self generates a new trial. System must have a *Eeureka!* experience, when the problem is solved. This is achieved if 'problem solver' self is 'enlightened' when it receives ouput 'yes' from the comparison circuit. This means that problem-solver selves begins to make quantum jumps reducing matter-mind entanglement and does not generate trials anymore. Note that the Eureka requires a generation of p-adic-real entanglement with positive entanglement negentropy.

5. The trials could be representable as p-adic space-time sheets defining the initial states of the symbolic representation defining the world model and realized as patterns of neural activity based on association mechanism. Their transformation to real ones would initiate the simulation. Also this process is very similar to that behing logical reasoning and imagination.

There is no need to add that in reality problem solving is much more complicated procedure! The above model could however provide insight about the conscious experiences related to the problem solving.

Quantum computationalism in TGD Universe

Macrotemporal quantum coherence makes also quantum computation like processes possible since a sequence of quantum jumps effectively binds to a single quantum jump with a duration, which corresponds to the lifetime of the bound state. Quantum computation like process starts, when the quantum bound state is generated and halts when it decays. Spin glass degeneracy increases the duration of the quantum computation to time scales which are sensical for human consciousness. In case of cognitive quantum computation like processes the quantum coherence is stabilized by NMP.

1. Spin glass degeneracy provides the needed huge number of degrees of freedom making quantum computations very effective. These degrees of freedom are associated with the join along boundaries bonds and are essentially gravitational so that a connection with Penrose-Hameroff hypothesis emerges.

2. Bio-systems would be especially attractive candidates for performers of both non-cognitive and cognitive quantum computation like processes. The binding of molecules by lock and key mechanism is a basic process in living matter and the binding of information molecules to receptors is a special case of this process. All these processes would involve new physics not taken into account in the standard physics based biochemistry.

3. The possibility of cognitive quantum computation like information processing forces generalize the standard quantum computer paradigm also because ordinary quantum computers represent only the lowest, 2-adic level of the p-adic intelligence. Qubits must be replaced by qupits since for algebraic $R - R_p$ entanglement two-state systems are naturally replaced with p-state systems and for $R_{p_1} - R_{p_2}$ entanglement with $p_1 \times p_2$ state systems. For primes of order say $p \simeq 2^{167}$ (the size of small bacterium) this means about 167 bits, which means gigantic quantum computational resources. The secondary p-adic time scale $T_2(127) \simeq .1$ seconds basic bit-like unit corresponds to $M_{127} = 2^{127} - 1$ M_{127}-qupits making about 254 bits. The idea about neuron as a classical bit might be a little bit wrong!

4. It might be more appropriate to talk about conscious problem solving instead of quantum computation. In this framework the periods of macrotemporal quantum coherence replace the unitary time evolutions at the gates of the quantum computer as the basic information processing units and entanglement bridges between selves act as basic quantum communication units with the sharing of mental images providing a communication mode not possible in standard quantum mechanics.

The progress taken place in quantum TGD during the period 2005-2010 allows to add to this picture several new elements.

1. The hierarchy of Planck constants and identification of ordinary particles at magnetic flux tubes with arbitrarily large value of Planck constant as dark matter leads to the vision about DNA and nuclear and cell membrane acting as topological quantum computer with the braiding of flux tubes defining the space-time correlate for the quantum computation [24]. The intronic portions of genome are natural candidates for the parts of genome specialized to quantum computation like activities and for these purposes the exact nucleotide content of the DNA sequence is not crucial so that DNA looking like "junk" is not junk from the point of view of quantum computation.

2. Zero energy ontology brings in naturally the 4-D ensemble of quantum computations assignable to sub-CDs of given CD. The classical correlates for quantum computations are 4-D classical field patterns assignable to space-time surfaces inside CDs. Causal diamonds bring in the time scales of 1 ms and .1 s associated with quarks and leptons, which are also the time scales of nerve pulse activity and of memetic code. This supports the view that dark quarks at the ends of magnetic flux tubes connecting DNA nucleotides and the lipids of the cell membrane are indeed the key element of computation.

3. In the intersection of real and p-adic worlds negentropic entanglement is possible. This stabilizes qubits but makes them fuzzy. This requires reformulation of topological quantum computation in terms of the U-matrix characterizing U-process for zero energy states and restricted to the states with negentropic entanglement.

9.4.4 How brain builds the model of the external world?

What we experience is not completely determined by the sensory data: a lot of computation like processes at the level of cortex is involved. In TGD generation of symbolic representations would perhaps be more appropriate term. The phenomenon of illusions, most importantly, our ability to see planar pictures as 3-dimensional, shows that this computation involves a model of external world based on definite assumptions [87]. Stereo vision [87] is a good example of a sensory experience involving a lot of cognitive processing at the level of cortex. Depth cannot be experienced directly and the deduction of the actual positions for the points of the visual field must involve large amount of cognitive processing carried out in cortex. At the level of conscious experience the fusion of right and left visual fields to single visual field seems to be responsible for the emergence of the 3-D visual experience.

That complicated information processing is involved is demonstrated by autostereograms, in which a chaotic set of points experienced as a planar picture organizes to a beautiful 3-dimensional picture after intensive concentration (all subject persons are not able to see the 3-dimensional picture). It is known that stereo vision develops in age of few months at the same time when some cortical neurons specialize to receive input from only single eye instead of superposing the inputs from both eyes. Brain is also able to estimate the state of motion of objects of visual field from sensory data and this must involve a lot of computation. The fact that some people cannot experience motion in the visual field provides a support for the claim that this experience is a result of a complicated neuronal processing. At first, the computational aspects of the conscious experience would seem to be in conflict with the idea that sensory organs are the primary sensory experiencers. The situation is however not so simple as the closer examination of the computational aspects of the visual experience demonstrates. The basic point is that brain quantum entangles to the sensory representation various symbolic and cognitive representations giving meaning to what is sensed.

TGD based view about construction of sensory representations

The motion of eye or head does not induce the sensation that the world is moving although the sensory image moves around the cortex. Rather, brain acts like a (possibly moving) canvas at which the sensory input is projected and monitored by an external observer. This very simple observation is a strong objection against the idea that the ultimate sensory and cognitive representations reside inside brain, and leads to the view that the magnetic flux tube structures associated with the primary and secondary sensory organs define a hierarchy of sensory and symbolic representations outside brain. Magnetic flux tube structures would serve as the sensory canvas to which sensory images are projected from brain and possibly from sensory organs and even neurons. MEs serve as projectors and place coding by magnetic transition frequency associated with ME wakes-up sensory subselves at various positions of magnetic flux tubes having varying thickness and associate thus various sensory qualia and even more complex attributes to the objects of the perceptive field. Thus the experiencer would the complex containing so called material body and hierarchy of field bodies.

EEG MEs correspond to our level in this hierarchy of projections. The simplest possibility is that the sizes of these sensory selves are of the order of EEG ME sizes ($L(EEG) = c/f(EEG)$) and thus can be of the order of Earth size! Thus the ultimate sensory representations are magnetic gigants in TGD and diametrical opposites of the neurophysiological dwarfs of standard neuroscience populating also TGD brain.

The known strange effects of large scale perturbations of Earth's magnetic field on consciousness (say, statistics about the effects of magnetic storms in mental state and tectonic activity inducing UFO experiences) provide a rich palette of anomalies supporting this view. The conservation of magnetic flux makes the magnetic flux tube structures of Earth size very stable: thus physical death presumably means only that our magnetic body redirects its attention to something more interesting. Near death experiences discussed in more detail in [19] indeed support this view. Of course, this view about human consciousness is not new, it is shared by all spiritual practices. What is new is the concrete physical model realizing this view physically.

It would seem that the generation of the visual experience involves some kind of iterative computational process laeding to an optimal conscious sensory representation of the external world. This process must involve a model of the external world, which is improved iteratively. Each computational step must provide an estimate for the various positional coordinates of the object and features associ-

ated with it and a subsequent comparison of the real sensory data with the virtual sensory data yielded by the model world. The virtual world sensory input yielded by this model is compared with the real world sensory input in comparison circuit and when virtual and real inputs are sufficiently near each other synchronous neural firing leading to a wake-up of sensory subself and conscious recognition of the object of the perceptive field occurs. This could also involve intermediate cognitive, symbolic, and sensory representations not conscious to us who see only the final product of this process. In case of vision the model suggests that both eyes yield actually stereovision separately in ordinary circumstances. This might be the case: one must hold second eye closed for sufficiently long time before the picture gradually flattens.

This quasi-computational process is cognitive process involving imagined sensory, motor and Boolean representations ('this is true' experiences) realized. If the primary qualia are at the level of sensory organs it is easy to understand why imagination lacks the sensory qualia. Only during dreams and hallucinations would the back-projection to the sensory organs occur and "qualiafy" the symbolic representations generated by imagination. Imagination involves p-adic-to-real phase transitions transforming p-adic space-time sheets to the initial value nerve pulse patterns serving as symbolic representations and initiating an associative simulation. The genuinely p-adic aspect of imagination would be thus analogous to the free choice of initial values in a computer simulation. If motor actions is a geometric time reversal of sensory perception in relevant p-adic time scales, motor actions are initiated at some level above muscles and proceed to higher levels so that there is no danger that real motor actions are generated. Dissipation and its time reversal implying a Darwinian selection of mental images are probably the basic tools of imagination and problem solving: second law becomes an ally rather than an enemy. Problem solving and motor actions quite generally start from a rough sketch and there is no need for rigid and bureucratic program structures as in case of AI. Program develops as it runs.

There are several information sources at use when cortex deduces the positional coordinates for the objects of the perceptive field. In case of vision the decomposition of the right and left visual fields to objects is an essential element of the approach. For instance, simple estimate for the distance of object results from the comparison of the positions of the images of object in the retina. If illumination is constant, the comparison of the intensities of the reflected light coming from various planar pieces of the surface representing object gives estimate for the normal direction of the planar piece. Also the fact, that some points of the object are not seen simultaneously by right and left eye can be used as a constraint. In case of autostereograms there is no decomposition into objects and the problem is to identify, which points of the right eye and left eye correspond to same point of the external world: the color of the points is obvious clue. Also long term memories about objects seen earlier are obviously involved.

In the simple situation that the visual world consists of simple objects, no comparison of the model world with the real world is needed provided that cortex is able to perform some simple arithmetics (which is not at all obvious!). In the general situation experience is yielded by the iterative computation like process (actually a rather long sequence of quantum computations if single quantum computation lasts about 10^4 Planck times).

A possible model for the computational aspects of sensory experience

The mind-like space-time sheets in the regions of cortex and various brain nuclei could see each other in the illumination provided by the Bose-Einstein condensed photons propagating along axonal (possibly also microtubular) wave guides. This would make possible comparison circuits in which inputs from two different areas of brain to area of brain are compared. The comparison circuit based on Josephson currents is ideal for this purpose. In case that inputs are identical, synchronous neural activity results. The comparison of the images could be crucial in realizing the iterative evaluation of the computational aspects of sensory experience. This iterative comparison process need not be conscious to us.

From our point of view brain seems to generate only symbolic representations. Cortex might however also generate virtual world sensory experiences at lower levels of the self hierarchy and not conscious to us. These could be compared with the genuine sensory input in (say) thalamus and convergent iteration would lead to a resonant firing and conscious experience of recognition. This would explain the observed adaptive resonance phenomenon in which thalamo-cortical feedback loop directs conscious attention to those aspects of sensory percept which agree with the expectation.

Direction of attention would mean generation of a sensory subself representing the recognized part of perceptive field. Novelty detection could occur at higher information processing level and could be based on inhibitory projections from feature detectors to the novelty detecting neural circuit.

Just to concretize the idea, one could imagine the following rough scenario for how the comparison involving neuronal sensory qualia (not ours) could proceed.

1. Neurons in some parts of brain, most naturally in the thalamus, have neural window to the primary sensory organ radiating coherent light propagating along microtubular waveguides to thalamus. Besides vision and perhaps even hearing, neurons would also have chemical senses and receptor-transmitter complexes would define different qualia. Different sensory modalities feed different regions of thalamus with difference wavelengths characterizing the sensory modality so that the neuronal window based on coherent light might be used by all sensory modalities to achieve this comparison. This is consistent with the fact that microtubuli are present in all axons. There is an intensive feedback from cortex to thalamus and this feedback could quite generally be related to the cognitive representations generated in cortex and communicated to thalamus for comparison. The results of the comparison are sent back to the cortex coded in nerve pulse patterns and change the properties of the model world to give a better fit.

2. The imagery model world consisting of neuronal mindlike space-time sheets in cortex represents the results of a cortical computation. Mind-like space-time sheets radiate coherent light with the intensity determined by the model of the external world specifying the intensity of the reflected light from a particular object. The simplest possibility is that the representation consists of mind-like space-time sheets whose size and shape are deduced from the size and shape of the objects and from the estimated values of the height function. Only the active cortical neurons send coherent light along microtubules to thalamus. The result of the comparison is coded to nerve pulse pattern and sent back to cortex to make possible next trial.

Connection with the observations of Barbara Shipman

There is also an interesting connection with the model the model of Barbra Shipman for the dance of honeybee [49, 50, 47].

1. The model relies on the puzzling observation that the manifold $F_3 = SU(3)/U(1) \times U(1)$ parametrizing different choices of color quantum numbers seems to be involved with the dance [24]. In TGD framework color rotations do not leave classical Z^0 and em fields invariant although induced Kähler field is color invariant. For instance, in a color rotation a pure Z^0 ME is in general transformed to a ME carrying a lightlike vacuum em current generating a hologram possibly acting as a biological control command. This suggests an explanation for the observations of Shipman and also that the canonical coordinates (P_i, Q_i) for the 6-dimensional symplectic space F_3 play crucial role in the construction of sensory representation. In fact, in Shipman's model the Hamiltonians associated with color isospin and hypercharge take the role of planar coordinates for the dance floor at which the dance of honeybee takes place. More generally, it might be possible to represent the position of the object of a perceptive field using some coordinates of F_3. The optimal situation would be that both the velocity and position would be coded to a point of F_3 so that CP_2 orientation of space-time sheet would represent position for an object of a perceptive field.

2. If this view is correct, the values of the positional coordinates and the velocity of the object of the perceptive field should correlate with the CP_2 orientation of the active neuron and/or ME(s) associated with it. First of all, the level of hologrammic activity for ME measured by the strength of the lightlike em current depends on its CP_2 orientation. Secondly, different CP_2 orientations correspond to slightly different values of the membrane potential and could be directly mapped to the degree of alertness of neuron. For instance, if a moving object of the perceptive field is in nearby space and moves towards the perceiver, the (P_i, Q_i) values could be such that the resting potential is lowered and nearer to the critical value for firing. Also the lightlike em currents associated with MEs would be stronger in this kind of situation.

9.5   Holographic brain and quantum TGD

Brain as a hologram paradigm states that one cannot locate the information in brain in any specific region. There is indeed considerable empirical support for this hypothesis [71, 83, 74].

9.5.1   Evidence for holographic brain

The first empirical motivations for holographic brain came from the experiments of Lashley [71] with rats. Psychologist Karl Lashley started 1920 lifelong study of the effect of brain vaults in memory. Lashley studied the behaviour of rats in mazes and found that the reduction of the brain tissue did not destroy the visual memory of rats totally, only the intensity of the memory was weakened. This led to the introduction of the terms mass action and equipotentiality. Mass action says that the intensity of the memory depends on the amount of the brain tissue present and equipotentiality says that each neuron carries the memory traces. The experiments of Lashley lead to the idea that the memory storage mechanism in brain is nonlocal and hologram like.

In 1948 physicists Dennis Gabor discovered the idea of optical hologram and within twenty years the same principles had been applied to brain. What hologram stores is the information about both amplitude and phase of incoming light wave, quantum mechanically identifiable as the order parameter characterizing coherent light. What makes holographic information storage so attractive is its extreme robustness and flexibility: a small piece of hologram carries same information as entire hologram, albeit in blurred form. Philip Westlake [68] was one of the first mathematicians to argue that hologram priciple matches with what brain does with the information. Karl Pribram [83] and colleagues have done a lot of experimental work with monkeys using the holographic theory to see in detail how the theory makes it possible for brains to remember. The book 'Shuffle brain' [Pietch] popularizes in an enjoyable manner the idea of holographic brain and the work Pietch with salamanders. The experimental work of Pietch provides rather convincing experimental support for the idea of holographic data storage [74]. The experiments of Pietch with salamanders involved the cutting the brain of the salamander to pieces, shuffling the pieces randomly and putting them back together: no detectable changes in the behaviour of salamander occurred as a result of this operation! It is hard to imagine a computer which would function after this kind of treatment.

Holographic data storage is extremely flexible and stable. Since brains have developed in jungle rather than in safe computer laboratory, these properties make the idea of holographic brain much more attractive than the paradigm of computer brain. Also transformations between sensory modalities are easily realized. For instance, acoustic holograms can be transformed to optic holograms. One can however also invent objections against holographic data and memory storage.

1. The creation of hologram is based on the interference of a reference beam of light with the beam of light reflected from the object. The reading of the hologram is done by using reference beam to regenerate the original picture. It is however not clear whether this kind of mechanism is possible to realize at the level of brain. Furthermore, in reality it is the real beam which stimulates memory recall rather than the hypothetical refence beam! It seems that comparison of reference pattern representing the expected experience with input is what happens in brain rather than illumination of holograms.

2. In order to have holographic memory, it should be possible to code very many holograms simultaneously to single hologram. Multiple holograms are indeed possible [74]. One must however admit that the idea about storing large number of temporal events to same multiple hologram does not look very attractive. The identification of the long term memory as geometric memory solves these problems in TGD framwork so that hologram idea could survive as a a restricted principle determining how the experience is generated.

3. The structure of the human brain suggests that data representation is not completely hologram like. For instance, the various phonemes are recognized by well defined regions located in linguistic areas of the brain like potatoes in the field. The differences between right and left brain are a challenge for the hologram idea in its simplest form. One must however notice that it is brain functions that are localized whereas data storage could quite well be hologram like. Of course, it could quite well be that brain decomposes into regions in which data represented as a hologram is different: for instance, different sensory modalities seem to use different regions

of brain. In particular, the existence of various sensory homunculi in brain is consistent with the holographic data representation.

9.5.2 Three explanations for the hologram like properties of brain

The fact is that brain seems to be extremely flexible and this does not fit nicely with the idea that brain is some kind of extremely complicated electronic circuit. Hologram like data storage in which each neuron is like a part of hologram provides only one explanation for the empirical data. The common feature of TGD based explanations is that conscious experience is not so strongly dependent on the neurophysiogical state of the neural substrate as the vision about brain as a computer would suggest.

1. Quantum self-organization implies that systems self-organize to dynamical patterns which do not depend very much on the initial state. For sufficiently simple brains, whose presence is not absolutely crucial for the 'household' activities of the organism, this could be all that is needed. For instance, the ability of a lizard to generate a new head supports this view. Salamanders are simple creatures and the mere quantum self-organization without recourse to hologram memory could explain the results of the experiments of Pietch.

2. TGD based model of conscious brain relies on self hierarchy realized in terms of various Josephson currents forming a master-slave hierarchy. Josephson currents do not depend very strongly on the material substrate of brain. Josephson currents and associated supra currents allow also basic wave like phenomena like interference crucial for hologram model. Comparison circuits formed by weakly coupled super conductors and constructive interference of Josephson currents provide a quantum model of brain which resembles hologram model but also differs from it in certain crucial aspects. In particular, reference ray is replaced by reference current representing expected experience. Also comparison circuits in which parallel supra currents of same intensity flow in coupled superconductors, are possible. In this case large Josephson net current is generated by constructive interference of Josephson currents when the phases of supra currents differ by a constant phase.

3. It might be that brain is indeed hologram like in some sense although reference rays are probably not involved. In TGD framework it seems to be possible to abstract from the hologram idea its essentials, namely the fact that a piece of hologram is like a small window. This makes it possible to circumvent the most obvious objections against the idea.

   i) The essential feature of the hologram is that a small piece of a hologram acts like a window. The visual experience is not changed much even when one perceives through a small window. Hence one could give up the assumption that brain prepares holograms. Rather, one could consider the possibility that neurons see part of the same sensory scene through neuronal windows. Seing would be made possible by some field like quantity whose values would be determined by its sources in the same nonlocal manner as electromagnetic field is determined by its sources. Sources could be either objects of the external world or of model world generated by sensory experience, constisting perhaps of mind-like space-time sheets. Massless fields are especially attractive alternative since the form of the wave is preserved during propagation. Hence coherent photons generated by so called massless extremals [32] assumed to be associated with the linear structures like microtubules contained inside every axon, are especially promising as a tool of neuronal vision.

   ii) TGD framework provides extremely general mechanisms of subjective and geometric memory corresponding to actual memories and expectations for what will happen and possibly happened. In principle it is possible to avoid memory storage completely. The experiments of Lashley could be understood by assuming only that the sensory data are experienced through neuronal windows. Thus there is no need to store memories in multiple holograms and even holograms are un-necessary. All boils down to the idea of neural window and TGD based quantum model of memory.

   iii) The existence of sensory homunculi is not in conflict with the holographic data representation. What happens is that single neuron sees part of the perceptive landscape through a window. Each neuron could be specialized to particular task, such as recognizing whether particular

feature is present in the the sensory landscape. This would involve simple comparison circuit making possible feature recognition perhaps involving neuronal wake-up. Feature recognition could rely basically on the generalization of Haken's theory [26].

9.5.3   From holographic brain to neuronal window?

The notion of neural window

All sensory experiences should reduce to representations generated by zero modes, in particular zero modes characterizing classical Kähler field, which can reduce to pure electromagnetic (vision?) or Z^0 field (auditory experience?). If the primary or secondary stimuli generate Kähler electric fields proportional to the gradient of the intensity one can understand the generation of the objects of the perceptive field. If the gradient is strong, as it is on the boundary of the image of the object, the conservation of the Kähler electric flux forces the generation of mind-like space-time sheet at which part of the flux goes. Thus secondary sensory organ would automatically create representation for the objects of the perceptive field as mindlike space-time sheets, which in turn could give rise to selves representing objects of the perceptive field as mental images.

The idea that parts of brain automatically form a model for the objects of the external world as mind-like space-time sheets suggests an interesting connection with the holographic model of brain [74] and with micro-tubules as quantum antenna hypothesis [32].

1. If mind-like space-time sheets are massless extremals, they act as quantum antennae and generate coherent photons. Axons contain microtubules and this leads to ask whether these axons could serve as wave guides for the coherent light generated by the mind-like space-time sheets representing the objects of the external world. Also the vacuum currents associated with these microtubular massless extremals could code the intensity of the coherent light emitted by the mind-like space-time sheets. If either of these guesses is correct, axons provide neurons with a direct sensory window to the representation of the external world formed by the mind-like space-time sheets residing at sensory organs. Coherent photons would also give rise to neuronal lingua franca realized as a direct neuronal/microtubular vision.

2. Sensory window would be in question in a rather literal sense. The fact that a piece of hologram provides the representation given by the entire hologram, albeit in a somewhat blurred form, is essentially equivalent with the possibility to see through a small window. Therefore the idea about neuronal window is in accord with the holographic model of brain [83, 74], which is based on the idea that all neurons receive more or less the same sensory input, analogous to the visual experience generated by a piece of hologram. Clearly, coherent photons would serve as kind of mass media at the level of brain.

3. What is interesting is that the decomposition of the neuronal vision to a large number of different views represented by small groups of light sensitive neurons could even help to build monocular stereoscopic vision since much more information would be used about the visual field.

4. Music metaphor provides a considerable restriction to the neuronal window idea. The Bose-Einstein condensed photons should correspond to single frequency equal to some cyclotron frequency. Thus it would seem that the sensory input of single neutron is yes/no type. The neuronal window however makes however still sense for neuronal groups: in this case the input would be determined by light and dark pixels. Various nuclei or brain could thus have neuronal windows to cortex and other nuclei of brain.

Neural window and imagery

Mental imagery is something which is difficult to understand in the framework of the standard neuro science. There are empirical results suggesting that mental images correspond to patterns of activity inside cortex, which are three-dimensional and continuous so that neural activation provides a concrete recognizable image about object [87]. Rather remarkably, also imaginative thought resembles very much visual imagery as is clear from the fact that language is full of visual metaphors [87]. It is also known that imagery uses same regions of cortex as real sensory experience and the problem is to understand why there is genuine sensory experience involved with imagery.

In the framework of the standard neuroscience the obvious question is why the pattern of the imagery activity is not accompanied by a direct sensory experience. Also the boundary between direct sensory experience and imagination is sometimes problematic: for instance, in the state between sleep and awake, sensory images often enter into mind. During dreams one can have sensory images and eidetic memory is essentially sensory memory. I have a personal experience about extended state of consciousness, or rather whole-body consciousness (this experience actually made me consciousness theoretician!). During this state I could see my thoughts as vivid visual images and had also peculiar odour and taste experiences also reported to occur during mystic experiences. Could the correct interpretation be that thalamus, cortex and sensory organs temporarily formed a larger self during this experience?

If one accepts that sensory qualia are at the level of sensory organs and neural activity only builds symbolic and cognitive representations, it is easy to understand the difference between imagination and sensory perception. Sensory imagination is sensory perception without sensory qualia. Quantum entanglement between sensory organs and cortex and TGD based view about long term memory resolves the obvious objections against this view.

This does not exlude the possibility that neurons have chemical senses and even see and hear. Neurons would not only contribute to our experience. Neurons able to perceive sensorily would be probably much more effective information processors than neurons which are blind and deaf. Therefore the notion of neuronal window could be useful metaphor in the modelling the neuronal basis of the mental imagery. For instance, the understanding of processes like rotation of an imagined object of visual field provides an exciting challenge. The rotation of mind-like space-time sheet should induce the rotation of the region containing nerve pulse activity. Neuronal window idea suggest that the imagined rotation of the object involves virtual sensory experience generated in the somatosensory-auditory-visual association region of the neocortex (note that only humans have these associatin regions). This region would be able to form representations of the basic objects of the perceptive field and manipulate them. The imagined rotation of the object could occur here and would be observed by the primary sensory regions.

Sensory perceptions involve a lot of computation like processing at the level of cortex (consider stereo vision as an example), which can be naturally identified as imagination yielding successive models for the external world as consisting of familiar objects. Both the imagined world represented by the mind-like space-time sheets inside cortex and the mindlike space-time sheets in the sensory organ could be seen by the secondary sensory organs in thalamus and compared to see whether the imagined world yields the same sensory input as the real world. The result of the comparison would be fed back to cortex as a nerve pulse pattern serving as a feedback modifying the model.

Neuronal window and blind sight

The phenomenon of blind sight [67] suggests that there is kind of a Zombi within us [76], which can see but that this vision does not give rise to a conscious vision. Typically persons who have blind sight can grasp the object of the visual field once they have been told that it contains the object. The Zombi within us seems to be much more rapid and reliable than the conscious 'I' in its responses but it seems to be much less flexible. It also seems that Zombi within us cannot be cheated by illusions unlike conscious 'I', which suggests that much less theorizing and pattern recognition is involved. Rapid responses of Zombies within us are certainly consistent with the fact that cortical processing is not involved. Nonflexibility would be the price paid for the reliability and absence of higher level cognitive processing.

One can imagine many models for Zombi within us and probably there are many of them (and they are actually not Zombies at all!).

1. Thalamus projects sensory data to amygdala which is often called brain inside brain, or emotional brain. Amygdala would thus have neuronal window to to thalamus and could give rise to unconscious-to-us mental activity responsible also for the blind sight. Also the sensory perception at the level of retinae might be enough if one assumes that primary sensory qualia are at the level of sensory organs.

2. Formation of the symbolic representations for the objects of the perceptive field could occur also in the thalamic nuclei.

3. The decomposition of the perceptive field to objects could occur for the first time already at the level of retina and the coherent light from the mind-like space-time sheets provides a representation of the visual field seen by neurons of thalamus, whose regions serve as secondary secondary organs identifiable Zombies within us (Zombies only from our view point!).

9.5.4   Possible evidence for the neuronal window idea

To find whether the neuronal window based on coherent light hypothesis could make sense, it would be important to eliminate the effects of the higher level information processing. This requires the study of simple organisms having primitive sense of vision. There is indeed experimental support for identifying the coherent states of photons as associated with vision. It is known that some monocellulars possess elementary vision based on the microtubules [62]. The emergence of the multicellulars during the Cambrian explosion was preceded by the appearance of the microtubules. If the emergence of the microtubules meant the emergence of the visual consciousness in the length scale of the cell, then the formation of the multicellulars as cell societies can be understood as a natural consequence.

The length distribution of the microtubules in the rods and cones of the eye is concentrated in the region of the visible wavelengths. The coherent light in question could be identifiable as bio-photons of Popp [59]. The architecture of retina is 'wrong' from the engineering point of view. The ganglial axons feeding sensory input to brain are in front of the retina. This is in accordance with the TGD based model of vision in which the photons of incoming light Bose-Einstein condense on the ganglial axons and amplify the signal to the thalamus.

A further piece of evidence comes from the work of Callahan about the sense of smell of insects [39]. Many insects, such as moths and ants, are known to be attracted by light, say candles and electric lamps and Callahan took as his challenge to understand what is involved. Callahan discovered that insect's olfaction is not based on chemistry (alone) but to a maser like emission of infrared light generated by various molecules such as pheromones, scent molecules and many other biomolecules. Insects see rather than smell the sources of the infrared light. The sensillae of the insects serve as receiving antennas and amplify the incoming infrared radiation. Callahan also observed that the oscillation of insect antennae induce maser like emission from scent/etc. molecules by creating an oscillating emf. Thus sensory experiencing seems to involve active participation from the part of insect. In any case, the results of Callahan suggest that coherent light could be important also in our neuronal sensory experiencing.

The infrared light emissions from pheromones mediate sexual messages in case of insects. Quite remarkably, pheromones are known to mediate sexual and social signals also in case of many mammals. For instance, certain chemical messages from a female mouse can make male mouse to mate immediately while certain chemical messages from other males make him agresive. Many mammals, for instance rodents, are known to possess vomeronasal organs, small cigar like sacks containing neurons and having length of order few millimeters [45], giving rise to an accessory olfactory system, which is known to have much more primitive structure and to work in different way than the ordinary olfactory system. It is also known that this systems bypasses cerebral cortex in rodents. There is evidence that even humans have the ability to sniff certain chemicals mediating social and sexual signals without being aware of it and there is already now an entire perfume industry based on this evidence. The chemicals giving rise to sexual attraction are probably pheromones. The fact that pheromones mediate sexual signals in case of both insects and mammals, is hardly an accident and suggests that the sensory mechanism must be the same and be based on the infrared emissions by phreromones. If the response is at neuronal level and if the cortex is not involved, one could understand why these messages are not experienced consciously. One could test this hypothesis by finding whether coherent infared radiation at frequencies emitted by pheromones can affect the behaviour of higher mammals including humans.

There is a further peculiar co-incidence: the cascade of transduction events occurring in the absorption of photon in retina is repeated in a remarkably similar way in olfactory receptor cells, which respond to odours whereas the receptor cells that respond to sound use a very different system [45]. Could this mean that also the experience of odour primarily involves the detection of (also) infrared light so that humans would not basically differ from insects or that olfactory system has evolved from the receptor neurons originally sensing infrared light? This would conform with the idea that the Kähler field generated in ear corresponds to classical Z^0 field, which does not generate coherent photons but couples with neutrinos. One must however notice that the resemblances between visual and

linguistic imagery suggest that some part of ear generates cognitive representation based on coherent light and experienced by the secondary sensory organs in the thalamus.

9.5.5 Massless extremals as quantum holograms

It took long time to really understand what MEs really and along with this understanding came the vision about precisely how MEs could act as holograms and what biological functions these holograms could correspond to. It indeed seems that massless extremals (MEs) are perhaps the most fundamental solutions of the field equations as far as TGD inspired theory of consciousness is considered. What is important is that MEs play both the roles of quantum gravitational holograms [54] and dynamical holograms [55].

The hologram principle of quantum gravitational theories roughly states that the quantum theory in space-time with boundary reduces to a conformal quantum field theory at the boundary. If Kähler action were deterministic, precisely this would happen. The construction of the configuration space geometry relies crucially on the assumption that the complications due to the non-determinism of Kähler action do not radically modify the picture resulting assuming complete determinism.

It has indeed turned out that the basic construction in which everything to the lightlike boundary of M^4_+ (moment of big bang) acting as a hologram in quantum gravitational sense and defining conformal quantum theory, generalizes. The basic construction survives as a template of a more general construction in which also the lightlike boundaries of MEs having always lightlike M^4_+ projection are taken into account besides δM^4_+ as surfaces at which initial values can be prescribed arbitrarily. This brings in also time effectively absent in a strictly deterministic theory. The quantum gravitational hologram defined by δM^4_+ is replaced by a fractal structure formed by δM^4_+ and Russian doll hierarchy of the lightlike boundaries of MEs inside MEs. The super-symplectic and superconformal invariances of the lightlike boundaries generalize in an elegant manner on basis of the basic properties of MEs.

There are good reasons to expect that the lightlike selves defined by the boundaries of MEs are fundamental in TGD inspired theory of consciousness. The super-symplectic quantum states associated with the lightlike boundaries are genuine quantum gravitational states defined by configuration space spinor fields, whose dependence on configuration space fiber degrees of freedom does not reduce to mere vacuum functional, and therefore do not possess any quantum field theoretic counterparts. They are state functionals in the world of worlds, so to say, and therefore should represent highest level in the hierarchy of quantum control in living systems.

MEs carry lightlike vacuum currents. In passive state these currents are Z^0 currents whereas in active state, obtained by a color $SU(3)$ rotation, the current is electromagnetic and generates coherent state of photons. One can say that the lightlike current provides a dynamical variant of the diffraction grating defined by the ordinary static hologram. This leads to a model of living matter in which the coherent states of ordinary photons and colored configuration space photons act as control commands. Their phase conjugates (time reversals) in turn correspond to the time reversed commands. What is especially beautiful is that simple reference wave can activate arbitrarily complex hologram acting as a control command. This provides new visions about healing by time reversed reference waves forcing the biological program responsible for an illness like cancer to run backwards in time. One can also construct a general theory of sensory representations based on MEs [32]. To sum up, it seems that the hologram principle is they key element of brain and biological functioning but in a sense somewhat different from what it was believed to be by the pioneers.

9.5.6 The notion of conscious hologram

The notion of conscious hologram is the last step in the development of ideas related to bioholograms. The basic challenge is to generalize the notion of the ordinary hologram to that of a *conscious* hologram, about which bio-holograms would be examples. The notion of quantum gravitational hologram is defined at the level of geometric, purely physical existence whereas conscious holograms exist at the level of subjective existence defined by the sequence of quantum jumps and giving rise to the self hierarchy. Of course, these two notions of hologram must be closely related.

The notion of conscious hologram combines the saint and sinner aspects of consciousness to single concept: macrotemporal quantum coherence due to the generation of bound state entanglement and giving rise to co-operation on one hand, and the dissipative self-organization giving rise to Darwinian selection and competition on the other hand.

In nutshell, the notion of conscious hologram follows from the topological field quantization. Classical fields and matter form a Feynmann diagram like structure consisting of lines representing matter (say charged particles) and bosons (say photons). The matter lines are replaced by space-time sheets representing matter (elementary particles, atoms, molecules,...), and virtual bosons are replaced by topological light rays ("mass-less extremals", MEs). Also magnetic flux tubes appear and together with MEs they serve as correlates for bound state quantum entanglement.

The classical fields associated with MEs interfere only at the nodes, where they meet, and one has a hologram like structure with nodes interpreted as the points of a hologram. Thus one avoids the loss of information caused by the interference of all signals everywhere. This aspect is crucial for understanding the role of em fields in living matter and brain. The MEs corresponding to 'real photons' are like laser beams entering the hologram and possibly reflected from it. What is new that the nodes can be connected by 'virtual photon' MEs also analogous to laser beams. Hence also 'self-holograms' with no laser beam from external world are possible (brain without sensory input).

The hologram has a fractal structure: there are space-time sheets at space-time sheets and high frequency MEs propagating effectively as mass-less particles inside low frequency MEs serving as quantum entangling bridges of even astrophysical length. The particle like high frequency MEs induce 'bridges' between magnetic flux tubes and atomic space-time sheets at the receiving end. This makes possible the leakage of supra currents from magnetic flux tubes to atomic space-time sheets analogous to the exposure of film producing hologram. The leakage induces dissipation, self-organization, and primitive metabolism as a cyclic flow of ionic currents between the two space-time sheets, and thus a Darwinian selection of the self-organization patterns results. Under certain conditions the leakage followed by dropping back to the larger space-time sheet can also give rise to a many-sheeted laser. The low frequency MEs are responsible for the bound state entanglement, macroscopic quantum coherence and co-operation whereas high frequency MEs are responsible for self-organization and competion.

The 3-D vision associated with ordinary holograms generalizes to stereo consciousness resulting in the fusion of mental images associated with the points of conscious hologram [33].

9.6 Four-dimensional fractal brain as an associative net

The identification of brain as 4-dimensional fractal associative net seems to provide a promising paradigm for the understanding of brain functioning. The associative net structure and mere real physics considerations are certainly not all that is needed. p-Adic physics as physics of cognition means that fundamental cognitive representations correspond to p-adic space-time regions, and, needless to say, in this respect huge amount of work remains to be done in order to build connections between theory and observations. In the following only the real physics aspects of brain as an associative net are considered.

9.6.1 Brain as an associative net

The notion of associative net suggests a general paradigm making it possible to understand brain functioning. The subjective time development of an associative net consists of experiences representing associations $A \to B$. In case of brain associative net is a network of neurons. "A$\to$ B" association is made possible because the emission of synaptic vesicles implies that postsynaptic and presynaptic neuronal space-time sheets form a connected space-time sheet. A is represented by the various presynaptic inputs and B corresponds to the output of the postsynaptic neuron. A and B can correspond to various sensory qualia or Boolean statements represented in terms of memes which in turn decompose into sequences of codons consisting of 126 binary digits and represented in terms of cognitive neutrino-antineutrino sequences. Memetic codons could also have interpretation as binary representations of integers providing quantitative measures for qualities. In Boolean case associations are experienced as logical implications "If A then B" is true. A and B can represented arbitrarily complicated statements composed of elementary statements. Neuron receives the conclusions of postsynaptic neuron as premises and feeds its own conclusion as premises to its own postsynaptic neuron.

Self-organization by quantum jumps selects gradually the allowed "A $\to$ B" correspondences as asymptotic self- organization patterns. Quantum self-organization and quantum statistical determinism suggest a natural Darwinian selection of the memes caused by the dissipation inside self and completely analogous to protein folding. The correspondences $A \to B$ would be determined by chem-

ical macro variables characterizing the state of the neuron and chemical transmitters would play a crucial part in the learning of the responses. Syncronization is necessary for the function of the network. Emotional control can modify the associations "A→ B" in long time scale (conditioning and desensitization): for instance, some conditions belonging to premises A of Boolean association drop away or B can change.

9.6.2 4-dimensional fractal brain

One needs two additional principles in order to have vision about brain a la TGD.

1. Brain is 4-dimensional in well-defined and very restricted sense. This follows from the classical non-determinism of Kähler action. Self-organization by quantum jumps replaces the classical space-time surface repeatedly with a new one and the final result represents classically the activity as it would be detected by a compeletely mechanical instrument. One can say that the classical time development describing say sensory experience, long term memory, motor activity or logical thought is gradually refined by starting from a rough sketch and making successively finer corrections iteratively. The process is like making a painting stating from a rough scetch. The four-dimensionality of the brain and difference between subjective and geometric time is absolutely essential element.

2. Fractality is second element. The successive refinement process proceeds from long to short time and spatial lenght scales. Thus large and slow neural circuits correspond to rough sketches and small and rapid circuits to small details. Small circuits are simultaneously active (in sense of subjective time) in the entire space-time region defining the duration of the activity. Thus again the 4-dimensionality of brain is crucial.

The notion of associative net suggests a very general view about how brain functions and gives rise to conscious experiences. Brain itself is a huge associative circuit but decomposes into more or less autonomous subcircuits.

9.6.3 Sensory experiences, logical thinking, associations and simulations

The notion of associative net allows readily to understand what happens in sensory experiencing, logical thinking, formation of associations and imagination

1. Sensory representations are formed by an iterative process involving comparison which takes also care about the computation of unknown data such as distances of the objects of the perceptive field. For instance, various cortico-thalamic loops could be related this process. The updating of the zero modes of the sensory inputs from sensory organs is performed in the thalamic neurons receiving real sensory input from the sensory organ and expected sensory input from cortex. An automatic comparison process possibly realized at quantum level in terms of two weakly coupled super conductors is in question [40, 31]. This process involves also the concentration of attention to specific features of the sensory experience.

2. Neuronal input represents in general case several sensory modalities and conscious output single sensory modality or 'Boolean quale' represented by memetic codon. Thus associative circuits can represent the formation of associations in associative regions of brain. Note however that pre- and postsynaptic neurons in principle represent always an association at the neural level and neuronal associations are basic building blocks of 'our' associations involving entire groups of neurons and entire neural circuits. Also the formation of associations is very probably an iterative process.

3. The circuits of the associative net provide an ideal realization for predictive simulations of type $A \to B \to ....$ in terms of various kinds of sensory qualia. This makes possible imagination. The difference with respect to the standard neural net is that conscious neuron represents some sensory modality or Boolean modality: this makes the simulation "real" and assigns meaning to nerve pulse patterns: note that the generation of meaning is basic problem of the neural net models of consciousness. This kind of simulation circuits are expected to be related with frontal lobes and to be crucial for the planning of the future activities. Motor circuit involving basal

ganglia, thalamus and prefrontal cortex is also a possible example of this kind of circuit. Again iteration bringing in more and more details to the motor plan is involved.

4. Logical deductions do not differ from simultation in an essential manner: the only difference is the replacement of the temporal causation by logical causations. In case of logical deductions premises and conclusions are coded to memetic codons represented by cognitive neutrino pairs. Much of our logical thinking might be actually habitual and almost deterministic deduction sequences associated with circular loops and unconscious to us. Logical consistency is thus not guaranteed and, unless the brain of a ideal mathematician is not in question, and results only from the logical consistency of the external world.

9.6.4   Formation of long term memories

Associative circuit give rise to learning of long term memories. Short term memories correspond to reverberating nerve pulse patterns in closed circuits giving rise to a repetition of the same component of experience again and again. In Boolean case periodic association sequences represented by closed loops $A \to B \to ...A$ correspond to tautologies. Reverberating memories are remembered with high probability if long term memories are realized as geometric memories. The reason is that there is high probability for a randomly generated cognitive space-time sheet in geometric past to reside on the region occupied by a reverbarating loop. Repetition is the manner to learn. It is rather plausible that Nature has discovered effective learning in this manner and there are indeed circuits associated with long term learning.

A quite recent finding in neuroscience is that during the learning of spatial tasks hippocampus and some other parts of brain generate long spike sequences. Typical interval between spikes varies between 1-2 milliseconds. This would mean that a sequence of 126 spikes would correspond to .1-.25 seconds which is of the same order of magnitude as the duration of our self identified as the duration of immediate sensory memory. Also long term memories are constructed as kind of artworks or charicatures.

9.6.5   Planning and realization of motor programs

Associative circuits are associated with planning and realization of the motor programs.

1. Motor activity is the reverse of sensory experiencing in a well-defined sense. The imagined motion of the object in the working memory representing perceptive field is transformed to the motion of the real world counterpart of the object so that motor organs are like puppets bound to axonal strings and moved by the little man in the brain. The perceptive field, where imagined motion occurs is located in the frontal cortex with primary motor cortex excluded. Several copies of the perceptive field providing different representation of the perceptive field are probably involved as 'working memories'. These working memories are formed by topographical maps between different parts of brain.

2. Planning of the motor action is almost motor action: the only difference is that the last stage when nerve pulse patterns characterizing the motion are fed to motor organs is not performed. Plan is essentially four-dimensional pattern of nerve pulse activity.

3. The ability to realize plan seems to require that it is memorized: this would require that the performance of the motor activity is repeatedly imagined and finally allowed to occur. Thus the nerve pulse activity representing plan becomes a periodical nerve pulse pattern and the actual motion starts when the coupling to primary organs is turned on. As a matter fact, 4-dimensional brain allows to give up the assumption about reverberation. Also the activation of a motor plan in the geometric past could be possible! This would be consistent with the results of the experiments of Libet about active aspects of consciousness: what was observed that neural activity started before the conscious decision to raise index finger. The relevant time scale would be of the order of second. Of course, an interesting question is whether adult person could initiate in the geometric childhood a motor action affecting dramatically the geometric present, say leading to traffic accident! This possibility would seem to lead to paradoxal looking consequences.

4. Learning of a motor skill presumably means that motor plans very rapidly self-organize to their final shapes. Learned skills correspond to motor plans which are winners in the Darwinian selection associated with self-organization.

5. The realization of the motor plan requires initial value sensitivity and muscles indeed provide an excellent example of an initial value sensitive system in which single nerve pulse generates macroscopic motion.

Motor action is planned and performed as a four-dimensional pattern. Construction of the motor plan means that *four-dimensinal* virtual perceptive landscape is gradually deformed into the desired shape. Motor activity can be seen as a fractal top-down process analogous to the construction of a space-time fractal: fractal classical determinism of Kähler action is absolutely crucial for this and $1/f$ noise [31] is one of the consequences of the fractality. The non-determinism of the p-adic differential equations is very probably a direct correlate of the classical non-determinism of the Kähler action.

Macroscopic motor activity starts from a rough 4-dimensional sketch of motion which is gradually refined to the final artwork and possibly memorized to represent a reverberating structure. The sketch and its various refinements are represented at the virtual perceptive landscape of the premotor cortex. More concretely:

1. First a large quantum jump realizing in rough sense the motor action occurs (for instance, hand grasps the object): this corresponds to certain classical time development starting in geometric past on new space-time surface. This stage corresponds to the activation of slow and large neural circuits with time scale characterizing the entire motion. This is like construction of the first sketch of a 4-dimensional fractal representing motor plan.

2. After this a cascade of smaller scale quantum jumps adding details to the motor plan occur: this is like adding further details to a four-dimensional fractal. The neural circuits involved are smaller and faster. Addition of details takes places in the entire time interval T of the geometric time associated with the full motion. This involves multitime moments of consciousness so that also neural circuits are active in the geometric interval defined by T.

9.6.6 Language

Memetic codons represented as temporal sequences of 126 binary digits should be the basic building blocks of the linguistic consciousness. The value of single binary digit is represented at the neural level by the presence/absence of nerve pulse and at the level of cognitive consciousness by the direction of the spin of the cognitive antineutrino. Boolean interpretation is not necessary: the interpretation of the sequences of 126 bit as integers providing quantitative measures for, say the intensities of the sensory experiences, is also possible. The proposed quantum models for the quantum correlate of hearing and for Boolean mind [24, 26, 29] suggest that sound frequencies are mapped to Z^0 magnetic cyclotron frequencies of ions whereas thinking corresponds to Z^0 magnetic cyclotron frequency which is above the range of the audible sound frequencies. This supports the idea that memetic codons are as such experienced as some kind of internal speech and also that only certain brain regions allow Boolean mind: the generation of cognitive neutrino pairs indeed requires strong axonal Z^0 magnetic fields which could be present only in the postsynaptic axons of the associative regions of cortex.

The differences between right and left brain suggest that the output axons in the associative regions of left brain represent information using cognitive neutrino pairs whereas the corresponding axons in the right brain hemisphere could represent information in terms of Z^0 cyclotron frequency varying above the audible frequency range (left brain talks and right brain sings!). If audible frequencies are involved, Josephson frequencies must be sufficiently far from cyclotron frequencies so that right brain imagines of hearing the thoughts rather than actually hears them. Unless higher harmonics of the cyclotron frequency are used (which is quite possible!), this requires parallel mode of representation since music metaphor suggests that the Z^0 cyclotron frequency of the axon is not variable.

Language circuits would be involved with the translation of the Boolean statements to linguistic expressions coded eventually to motor activities yielding speech. This process is only special case of a motor activity and thought as an internal speech is like a motor plan. Language represents one possible realization of the memetic code analogous to the translation of DNA sequences to proteins. It is instructive to look what contraints the memetic code poses on the general structure of language.

The first empirical fact is that the meaning of the linguistic experience is insensitive to the local variations in the speed of speech. In particular, the repetion of a phoneme is usually interpreted as providing no additional purely linquistic information. On the other hand, the linguistic meaning of speech is determined by its purely local structure.

These facts are consistent with the hypothesis that phonemes are the basic codons of speech having fixed duration and that a repeated phoneme has the same linguistic meaning as single phoneme. This supports the identification of the phonemes as representations of the memetic codons: phoneme would thus represent single linguistic subself. By the previous estimate the duration of the memetic codon should have duration in the range $.1 - .25$ seconds. A more precise estimate comes from the detailed model for the physical realization of the memetic code and from the model of nerve pulse [26, 18]: the resulting estimate for the duration of the memetic codon is about .14 seconds. The facts that a frequency $f \sim 10$ Hz represents the fundamental frequency associated with speech organs and that 20 Hz frequency represents the lower limit for the audible frequencies are consistent with the identification of the phonemes as linguistic images of the memetic codons.

Note that cognitive neutrino pairs of duration of order one millisecond are not experienced as separate components of conscious experience if time averaging is involved with temporal binding. This is consistent with the fact that language does not contain any smaller consciously experienced constituents than phonemes. Not that speech represents (very-!) many-to one expression of the menetic code (faithful coding would require language with 2^{126} different phonemes: this gives good idea about the present evolutional level of human culture!). Genetic code is not unique and some cell organelles, such as mitochondria, possess their own genetic code. Various languages could correspond to different translations of the memetic code to nerve pulse patterns in turn coded to motor activities representing expressions of language. The Mersenne prime $2^{127} - 1$ could be clearly re-christened to be the number of Babel!

9.7 Connection with the neuro science view about brain

In the following an attempt to formulate a connection with the brain as it is seen in neuroscience is made. Learning is basic aspect of intelligence and the discussion concentrates on this aspect of intelligence.

9.7.1 A simple model for cognition

The hierarchy of selves and summation hypothesis allows to construct a very general model for cognitive processes including as a special case thinking, analysis of visual experience, and language. In nutshell: cognitive process could be regarded as cascade like process leading to a generation of selves followed by generation of sub-selves for these leading to... . Quantum jump becomes the building block of cognition and thought but is not sufficient alone. p-Adic space-time sheets as correlates of cognition provide geometric correlates for thoughts, intentions, plans, etc.. are a fundamental element of cognition. The intersection of real and p-adic worlds understood as partonic 2-surfaces allowing an interpretation in both real and p-adic sense and the intersections of real and p-adic partonic 2-surfaces consisting of rational and common algebraic points define cognitive representations. Negentropic entanglement is possible only in the intersection in accordance with with the vision that cognitive representations carry the information.

Quantum criticality of TGD and existence of selves

The model of cognition provides a new view to the role of quantum criticality of TGD. One consequence of the quantum criticality could be the existence of a lot of sub-systems which are near the critical line at which phase transition changing the local topology (real or p-adic) occurs. TGD universe would be in a state of maximal alertness ready to generate cascades of selves representing cognitive acts. Our cognitive acts would be only part of the cognitive acts of the entire Universe proceeding from top to bottom as infinite trees with branches representing new selves and nodes representing moments of wake-ups for the selves. Or expressing it in the terminology of AI: we would be like subprograms of infinite program represented by entire universe. The presence of higher level selves means that cognitive acts can proceed from the level of even entire biosystem to the level of DNA.

This encourages to interesting speculations: for instance, the ideas of Sheldrake about learning at the level of species and even biosphere might find justification [26].

Number theoretical criticality is an important aspect of quantum criticality and is taken to mean that life and conscious intelligence reside in the intersection of real and p-adic worlds, where discrete cognitive representations and transformation of intention to action and vice versa are possible.

Quantum jump as cognitive process

U process followed by a cascade of state function reductions will be identified as the basic cognitive act.

1. State function reduction can be characterized as a binary tree. At each step of the state function reduction cascade some subselves manage to remain unentangled, some subselves lose their consciousness by developing entropic bound state entanglement, or experience expansion of consciousness by entangling negentropically. A particular branch of the process stops if subself allows no decomposition to entropically entangled but otherwise free pieces. What is new is that the entanglement is also time-like and time-like entanglement turns out to be central for understanding of what happens in learning.

2. The binary tree of state function reduction has a natural ordering. This ordering need not have any correlate at the level of geometric time. At the level of subjective time and conscious experience the correlate for ordering could exist but if self experiences its subselves as averages of sub-sub-selves this cascade is experienced only partially by given subself. One can of course argue that self wakes up in each quantum jump separately and quantum jump sequence should be seen as a sequence of "awakenings" (I used this term earlier): this awakening is however something different from the emergence of mental image. Maybe time-like negentropic entanglement is which binds this sequence of "awakenings" to a continuous stream of consciousness that we experience.

3. The outcome of the state function reduction is random when it leads to un-entangled subself but statistical determinism implies reliability at the level of ensemble. For negentropic entanglement state function reduction is nearly deterministic process and in this case one can speak in reasonable approximation about an iteration of a unitary processes defined by the powers of U. This iterative process defines a self-organization process expected to be also behind learning.

4. One possible interpretation of the self cascade is as a representation for an abstraction process representing thoughts about thoughts about... Our poor ability to form statements about statements about ... would correspond to the fact that self experiences only its sub-selves directly. Another interpretation is as analysis, in which initial experience gradually sharpens and gets more and more structured during the decomposition into sub-selves. Sub-selves could be thought as symbols of language or as logical statements or objects in picture: interpretation depends on what kind of cognitive process is in question. This process occurs in several time scales- even in the time scale defined by human life cycle. The modular structure of cognitive acts is also analogous to the modular structure of a computer program: starting of subprogram means the reduction of entanglement for the corresponding subsystem.

One can see this process also at the level of imbedding space correlates.

1. Selves wake up and begin to perform quantum jumps. The imbedding space counterpart for self is CD (causal diamond) characterized by time scale coming as powers of two and is scaling like the value of Planck constant. Subselves correspond to sub-CDs. Wake-up requires a feed of metabolic energy to destroy the bound state entanglement. Self could be also created from vacuum or disappear to it in a quantum jump generating a completely new CD or annihilating it.

2. Cognitive process proceeds in a cascade like manner starting from the root of tree formed by CDs and going downwards along the tree choosing at each node some branches. For instance, understanding of a sentence would correspond to waking up of large self A representing sentence in its entirety, words its sub-selves B_i, phonemes to sub-selves C_{ij} of B_i, etc... waking-up in this

order. Similarly, the act of decomposing the figure to objects and of objects to sub-objects would correspond to a temporal sequence generating selves within selves. Negentropic entanglement would be crucial for experiencing both the whole and the parts simultaneously. Background would be the largest conscious self and objects would correspond to a sequence of selves. Selves C_{ij} and further sub-selves can be generated before generation of next C_{i+1}: this should occur in case linguistic mental image: generation of word self would be followed by the generation of syllables and phonemes and only after this would next word be generated. Time nonlocality of self experience with respect to geometric and subjective time would be essential.

9.7.2   Cognition, learning, and negentropic entanglement at the level of brain

Negentropic entanglement is information carrier and learning is gaining information. Does this mean that learning takes place automatically in the intersection of real and p-adic worlds? Unitary U-matrix between zero energy states characterizes single step of quantum jump sequences and for negentropic states the state function reduction is not random process and in the first approximation U^N characterizes the outcome of N subsequent quantum jump so that learning process should be characterized by the iteration defined by the powers of U.

In neuroscience synaptic contacts are believed to be crucial for cognition, learning, and memory and it is interesting to try to relate this picture to the TGD based vision about conscious information and learning. How negentropic entanglement could be realized at the level of brain? Is it time-like, space-like, or both? Can one assign the generation of negentropic entanglement between neurons to the attachement of neurotransmitter to receptor? Can one relate the general quantum model of learning to the neuroscience based model of learning relying on the growth of brain cells, synaptic contacts, and synaptic plasticity?

The picture of the standard neuroscience about learning

It is good to summarize first the vision of standard neuroscience about the neural correlates of learning.

1. Basic notions

Synaptic transmission[81, 73] is believed to be a key element of brain consciousness. Synaptic transmission takes place as synaptic vesicles carrying neural transmitter. Given neuron can release several transmitters. The transmitter molecules bind to the receptors at the postsynaptic cell membrane. Depending on whether this process leads to a depolarization or hyper-polarization one speaks of excitatory or inhibitory receptors (activation potentials). Since most transmitters attach mostly to either kind of receptor, one speaks about excitatory and inhibitory transmitters although this terminology is misleading. Receptors can be classified to relatively simple ion channel receptors and more complex receptors involving second messenger proteins.

The belief is that the primary process does not involve communications with genome but if one accepts the DNA as topological quantum computer picture-in particular, on the existence of magnetic flux tubes connecting cell membrane and DNA nucleotides- the possibility that these communications are an essential element of process and that a new kind of gene expression at cell membrane level is involved. The communication to the DNA could take with light velocity if massless extremals are involved.

The synaptic strength characterizes the sensitivity of the postsynaptic neuron to the firing of the presynaptic neuron. It depends on the density of receptors and their activity as well as the total amount of neural transmitter transferred between neurons determined by the number of synaptic vesicles transmitted. This in turn depends on the size of the synaptic button. All these parameters are affected in learning understood as a change of synaptic strengths. It must be emphasized that learning in this sense should be seen as a neural correlate for conscious (or unconscious-to-us) learning and possibly of memory. What is essential that the respose of the postsynaptic neuron changes. This picture relies on the technical assumption that learning reduces to the changes of synaptic strengths. This assumption is probably an over-idealization: much more probably happens.

2. Learning at brain level

Learning in the sense as it is defined above can take place at the level of both anatomy and physiology. Learning at the level of anatomy can mean growth of new synaptic connections and of even new neurons. For instance, the growth of new neurons in hippocampus is now understood to be essential prerequisite for learning. It is believed that the information from the connections of old neurons is transferred to those of cortical neurons. This can of course happen but in TGD framework this is not necessary since the new view about time allows to interpret memory as communications with the brain of the geometric past.

Learning at the level of physiology is known as synaptic plasticity [75] and involves several mechanisms. Synaptic plasticity means that the sensitivity of the postsynaptic neuron to the signals from presynaptic neuron can change.

1. Sensivity means essentially the probability for the firing as a response to the firing of presynaptic neuron and this is controlled by the sign and magnitude of the activation potential and the increase of the sensitivity means a generation of stronger depolarization or weaker hyperpolarization. Postsynaptic neuron can become more or less sensitive to the presynaptic neuron whereas presynaptic neuron can send stronger signal by increasing the number of synaptic vesicles.

2. The change of the sensitivity of the postsynaptic neuron can take place several mechanisms [75].

   (a) The first mechanism involves the modification of protein kinases whose function is to phosphorylate the receptor which means essentially providing it with metabolic energy. The effectiveness of the protein kinases is regulated. Second mechanism depends on second messenger neurotransmitters regulating gene transcription and regulates the levels of key proteins at synapses. Gene expression is affected in this mechanism and the effect is long-lasting.

   (b) Third mechanism affects the number of ion channels (ion transfer between cell interior and exterior is basically responsible for the activation potential) and is involved with long term potentiation (LTP [70]) and - depression (LTD [80]) believed to be central mechanisms of learning memory. LTP is believed to be of central importance in hippocampus. The change of the density of receptors is one manner to achieve LPT or LTD. For so so called AMPA receptors [82] to which glutamate binds this mechanism is well-established. Also phosphorylation and dephosphorylation of AMPA receptors and change in the probability of glutamate release is a decisive factor.

3. The notion of Hebbian learning [69] applies to LTP. Hebbian rules summarizes the above picture as simple mathematical rules allowing computer modelling. When pre-synaptic and postsynaptic neurons fire simultaneously, synaptic connections are affected. Weak stimulations of several pathways add up. Also temporal summation takes place if the frequency of firing is high enough. Strong stimulation of one pathway affects also other pathways. More general formulation of the rules does not require the firing of the postsynaptic neuron. For anti-Hebbian learning desensitization takes place. Also non-Hebbian learning is believed to take place.

4. The change of the postsynaptic action potential need not be the only outcome of learning. If this were the case, the huge number of neural transmitters and receptors inducing different responses would not be needed. The change of the sensitivity is only one aspect of learning and as its relationship to conscious learning is unclear.

TGD based vision about cognition and learning

In the following a brief summary about TGD inspired view concerning cognition and learning in general and at brain level is given.

1. Basic ideas

The general ideas about cognition have been also discussed but is useful to summarize them again.

1. Subself interpreted as a mental image is key notion. Subselves wake-up, fall asleep, and fuse together losing consciousness or experiencing expansion of consciousness.

2. The cascade of state function reductions can be regarded as an analysis leading to a final state in which subselves are either entropically or negentropically entangled systems. The latter systems can be seen as negentropic mental images resulting as subselves fuse together. In the case that two sub-selves are involved, the resulting mental image can be regarded as an abstraction or rule such that the state pairs appearing in the superposition correspond to the instances of the rule. If one state pair dominates then association in classical sense is in question in good approximation.

3. Negentropic entanglement can take place between systems which belong to same or different number fields and gives rise to various kinds of conscious experiences. At least in the case that the other system is p-adic, negentropic entanglement should be a correlate for the conscious experience of understanding.

4. Zero energy states for brain represent rules as pairs of positive energy (initial) and negative energy (final) states. M-matrix characterizes zero energy state and defines a rule representing "laws of physics" at the level of conscious experience. Different M-matrices are orthonormal with respect to each other and in ensemble all of them appear and each of them can be also regarded as representing one particular instance of a rule.

A new element is that unitary time evolution characterized by U-matrix forces the learning to occur in the sector of state space containing zero energy states for which positive and negative energy parts of the states are negentropically entangled. U-matrix and its powers characterize the learning process. When the states are negentropically entangled, state function reduction for M-matrix is not a random process but leads to a unique state maximing negentropy and in a good approximation the restriction of U matrix to these states codes for the evolution of M-matrix. U^N restricted in this manner characterizes the M-matrix after N quantum jumps. Therefore learning is unvoidable in the case of negentropic states and U^N at the limit of large number of quantum jumps characterizes the learning. The value of N is of course limited by the size of CD assigned to the learning system. One can of course wonder whether the unitary period is following by a return to unentagled state via the liberation of metabolic energy associated with the negentropic entanglement.

The powers of U define an iterative map and iterative maps are the key element of self organization and also one of the main tools of generating fractals [26]. Quantum classical correspondence therefore suggests that 4-D fractal self-organization patterns define the space-time correlates for learning.

  2. General view about learning at the level of brain

M-matrix for brain codes its view about laws of physics. In diagonal form represents pairing of initial and final states as rules $A \rightarrow B$. For instance, in fermionic degrees of freedom these rules can be interpreted as Boolean rules. More generally, the interaction as quantum associations containing superposition of instances of the associations are in question. Huge quantum superposition of rules is possible since the number of neurons large and the information storage capacity of entanglement increases exponentially with the number of neurons.

U-matrix approximated as a matrix restricted to represent unitary evolution of negentropic zero energy states assignable to brain provides the first principle description for learning as the sequence of powers U^N. In the models of associative learning learning is reduced to a local process expressible in terms of changes of the synaptic contacts. This suggests that the basic building block of U matrix is synaptic transmission. This means an analogy with the basic braiding operation of the neighboring strands represented as R-matrix defining the unitry matrix for topological quantum computation [24]. There is also an analogy with generalized Feynman diagrams. The incoming particles would be neurons. Synaptic transmission analogous to particle exchange between two neurons. U matrix can be regarded as a quantum superposition over all possible diagrams containing arbitrary number of synaptic transfers. Multiverse picture at neural level thus results as one might expect since macrotemporal and macroscopic quantum coherence is involved. If the situation reduces in a reasonable approximation to a description in terms of synaptic transfers one can in principle describe synaptic plasticity, LTP, and LTD and other mechanisms to in terms of the basic building block of U associated with the synaptic transmission and mathematically analogous to Feynman propagator. The binding to the receptor could induce communications with genome and also the U-matrix assignable to topological quantum computations at the DNA level might be involved.

As such this picture provides only a first principle formulation for what conscious learning is and it requires a work to deduce predictions testing this vision or at least to gain understanding using this vision. A key aspect of negentropic entanglement is that it carries metabolic energy. This has been already proposed to provide a first principle explanation for the notion of the high energy phosphate bond crucial for the understanding of $ATP \rightarrow ADP + P_i$ process defining the key stop of metabolism [19].

Also space-like negentropic entanglement is possible for positive (negative) energy parts of the states. In particular, negentropic entanglement between presynaptic neuron and postsynaptic genome generated by the attachment of the transmitter to the receptor might make sense. There is temptation to assign to this connection a magnetic flux tube identified as a carrier of metabolic energy released in the process and inducing ionic currents leading to the processes affecting the synaptic strength as well as the states of neurons involved. The larger the metabolic energy release is, the more intense are the ionic currents involved and the stronger the modification is. This would provide a first principle explanation for why more effective phosphorylazation of the receptor as a correlate for learning. Of course, the explanation works even without the heavy conceptual machinery if one is ready to accept the somewhat nebulous notion of high energy phosphate bond.

9.7.3 Negentropic entanglement and the role of neurotransmitters

Soon after starting to develop TGD inspired theory of consciousness, I somehow ended up to an email correspondence with Gene Johnson who insistently emailed me links to abstracts about neuroscience. I read the classic Bible about brain by Kandel *et al* [72] and tried to make sense of it in my own conceptual framework. This was of course hopeless task since I had only the notions of quantum jump and self. The feeling that something very simple -about which I do not and perhaps cannot ever have a slightest clue- must be behind this incredible complexity made the situation really frustrating. The deeper meaning of EEG, nerve pulse neurotransmitters, hormones- actually of entire brain chemistry and also biochemistry- remained a total mystery.

Development of ideas

After the required number of years however some concrete ideas began to emerge.

1. The notion of magnetic body with fractal onionlike structure meant a decisive step of progress. Also the hierarchy of Planck constants and dark matter as controller of visible matter in living systems emerged. The function of EEG as communication and control tool of magnetic body using biological body as a motor instrument and sensory receptor looked very natural. This led also to a proposal that there is an entire hierarchy of EEGs and their variants. After several trials a vision about nerve pulses as concomitants of quantum level communications emerged as also a vision about DNA as topological quantum computer based on the flux tubes connecting DNA nucleotides with the lipid layers of cell membrane emerged and providing a function for the intronic portions of genome as carriers of quantum computer programs [24].

2. Also a vision about the biochemical role of dark matter evolved. In particular, phase transitions reducing Planck constant for a magnetic flux tube would induce its contraction and force biomolecules near to each other. This would explain the miracles of DNA replication, translation, and transcription and quite generally the processes known as aggregation of proteins. The reconnection of magnetic flux tubes changing the topology of the biological Indra's net would be also a central mechanism.

3. The model of nerve pulse and the vision about living matter as a kind of dynamical Indra's net led to a first clear idea about the role of neural transmitters. Transmitters are classified to inhibitory or excitatory depending on whether they increase or reduce the magnitude of the membrane potential. This property is however a property of the receptor rather than that of the transmitter. The same transmitter can have both excitatory and inhibitory receptors although often either receptor type dominates. The proposal was that neural transmitters are associated with the ends of the links of the 4-dimensional web connecting neurons to each other. Neurotransmitter attaches to the plug defined by the receptor connecting the communication wire from presynaptic neuron to the flux tube leading to the passive portion of postsynpatic DNA

strand acting as sensory receptor. This would make possible rapid communications to DNA. The corresponding active portion of DNA strand could then respond by generating an activity at the level of cell membrane. This conforms with the general idea that proteins represent only one particular outcome of the gene expression. This left open the question whether the excitatory-inhibitory dichotomy could have some deeper meaning.

4. Also it became clear the emotions and information are closely related and that peptides acting both as neurotransmitters and hormones are crucial for emotions [72]. I proposed that emotions are "entropic" qualia. Although I realized the importance of negentropic entanglement I did not have time or I was not able to realize how far reaching this notion actually is.

Is genome a fractal counterpart of brain?

Fractality replaces standard reductionism in TGD Universe. An old idea inspired by p-adic length scale hypothesis is that the binary structures associated with p-adic scales $L(k) \propto 2^{k/2}$ and $L(k+2)$ define a fractal hierarchy. Brain hemispheres would represent one example of this kind of pair, lipid layers ofe cell mebrane second one, and DNA double strand third one. Just for fun one could assume that the structure and functions of brain hemispheres have fractal analogs at the level of DNA double strand and vice versa and look what kind of questions this inspires.

1. Could the identical structures of DNA strands correspond to the anatomical similarity of right and left brain and could the functional asymmetry of the strands correspond to the lateralization of brain function? Could the genome act as the brain of cell? Could various brain areas have counterparts at the level of DNA? Could the hydrogen bonds between nucleotides serve as the counterpart of corpus callosum? Could the splitting of these bonds during transcription and replication correspond to what happens to a split brain patient?

2. Before continuing it must be made clear that the global identification of right-left dichotomy with holistic-reductionistic dichotomy is wrong. One can however consider its local variant with holism and reductionism assigned do the pairs of right and left brain areas. For instance, in contrast to the naive rule the emotional right (left) brain (amygdala) would be reductionistic (holistic,negentropic) whereas the intellectual right (left) would be holistic (reductionistic,entropic). The practical reason to the division to the entropic and negentropic pieces could relate to the metabolism. The entropic regions could provide the binding energy as a usable energy to the positive energy negentropic entanglement. Good is not possible without Evil! There are no winners without loosers!

   Right brain is specialized in spatial thinking and left brain to verbal thinking and arithmetics: the geometry-algebra division of mathematics! Right brain is not so good in motor actions as left brain as any right-handed person knows. Right brain is however better in tactile sensing: right handed persons tend to use left hand for touching objects to get an idea about their shape. Also this can be understood in holistic-reductionistic picture.

3. Apart from reflex actions almost all activities of the body seem to be controlled to a high degree by brain. Could also the activitites of cell be regarded as motor actions of the genome acting as the brain of cell receiving sensory imput from the cell membrane? Could one identify the analogs of sensory areas receiving information from cell membrane, processing, and sending it to the association areas? Could the analogs associative areas be identified as intronic portions of DNA performing topological quantum computations and communicating the outcome to the higher motor areas at the intronic portions of the of the complementary strand, wherefrom they would be communicated to the primary motor areas identifiable as the regions of DNA expressing themselves either chemically (RNA and proteins), as activitites generated directly at the level of cell membrane, or electromagnetically? For instance, could neurotransmitter in the receptor generate the feed of sensory input to the genome inducing the change of the membrane potential as the counterpart of motor action. Could prokaryotes without introns be analogous to brain with only primary sensory and motor areas or to mere ladder-like nervous system?

   One could argue that the analogy between DNA are brain fails because second DNA strand is completely passive whereas both brain hemispheres express themselves via motor actions. This is not the case! Both DNA strand has regions expressing themselves but the transcription takes

place in opposite directions. Hence DNA strands have motor and sensory areas as also brain does, and the natural guess is that primary motor areas correspond to the areas expressing themselves in terms of RNA, proteins, and possibly also as actions at the level of cell membrane. Primary sensory areas would correspond to to regions complementary to the primary motor regions.

4. What right brain sings-left brain talks metaphor could mean in this picture? Pitch-rhythm dichotomy is more technical expression for this dichotomy. Function providing local data and its Fourier transform providing global data is more abstract representation for this dichotomy and Uncertainty Principle for momentum and position relates closely to these two representations of information. This dichotomy could reflect the presence of two different natural time scales and millisecond time scale for nerve pulses and .1 second time scale for moments of sensory experience are the natural candidates.

   If so, this dichotomy could directly reflect the different time scales assignable to u and d type quarks (1 millisecond) and to electron (100 ms) and reduce to the level of elementary particle physics. This dichotomy would also have fractally scaled up variants made possible by the hierarchy of Planck constants. The analog of Fourier transform would be the negentropic unentanglement of sub-CDs (assignable to quarks) to single mental image inside electron's CD. The analog of function itself would be a collection of sub-CDs representing separate unentangled mental images assignable to individual nerge pulses in millisecond time scale. Also the topological quantum computations assigned to the intronic portions correspond to different time scales due and reflect quark-lepton dichotomy. The quarks in question could be the quarks assigned to the ends of flux tubes in the model of DNA as topological quantum computer.

5. This raises some questions. Could the gene expressions of the two strands somehow reflect this dichotomy? For instance, could the flux tube structures assignable to the aminoacid sequences correspond to the millisecond and 100 ms scales assignable to quarks and electron have the property that also the functioning of these proteins is characterized by these typical time scales? According to [61] the time scales of protein folding vary from .1 s to 10^3s. According to Wikipedia [60] the typical time scale is 1 millisecond which suggests that the time scales correspond to two ranges beginning from ms and 100 ms respectively. There are also short proteins for which the folding takes place in microsecond time scales which might relate to the CD of proton.

What can one say about the function of neurotransmitters?

Can one say anything interesting about the function of neurotransmitters if one combines this highly speculative picture- which can be defended only by the belief on fractality as universal principle- with the idea that bound state and negentropic entanglement make possible the fusion of mental images.

1. Suppose that the fusion of neuronal mental images is required to build higher level mental images that we experience. Suppose that neuronal mental images involve DNA in an essential manner. Suppose that magnetic flux tubes serve as correlates for the entanglement so that the transmission of nerve pulse from pre-synaptic neuron to post-synaptic one creates a flux tube connection between neurons possibly extending to the genome of the post-synaptic neuron. The transmitter at the end of flux tube attached to the receptor acting as a plug would build this connection to some part of DNA specialized to receive particular kind of sensory data from a particular region of cell membrane with complementary strand activating as a response a motor function inducing gene expression at cell membrane level. Gene expression as build-up of proteins would not be necessary and is also too slow for neural activities.

2. Suppose that the entanglement between neurons generated in this process is always negentropic as the interpretation as the idea about neural correlate for a conscious association suggests. One could also ask whether the neurons could entangled entropically and whether the entropic-inhibitory association could make sense. This does not lead to anything interesting and entropic entanglement between neurons should be regarded as a pathological condition. Note that neuron-neuron entanglemement would be naturally time-like and in this case only negentropic entanglement might be meaningful.

(a) To gain some perspective consider the activation of cell in general by some external perturbation from the resting state to the active state (here I have learned a lot from email correspondence with Vladimir Mateev) In the resting state the proteins inside cell are passive -or rather, forced to be passive- as one might expect on basis of the general vision about homeostasis. The unfolded proteins and unfolded portions of the folded proteins are connected by hydrogen bonds to ordered water so that the folding occurring otherwise spontaneously is prevented. One can say that the cellular winter prevails. The situation is however nearly critical and if external perturbation occurs cell liberates metabolic energy melting the ice and spring comes. Also the outer surfaces of globular proteins are hydrogen bonded and when the ordered water melts, spontaneous melting of the protein takes place leading to a partial unfolding.

The resulting folded proteins and partially unfolded globular proteins interact by forming aggregates and this activity would naturally involve $\hbar$ reducing phase transitions and flux tube reconnections. In TGD based model the mechanism of both folding and melting would be the liberation of metabolic energy destroying the hydrogen bonds and the energy for this comes from the ATP containing positive energy negentropic bond between O=s of phosphates.

(b) Similar situation could prevail at the cell membrane. One can imagine that cell membrane is like a particle at the bottom of a small potential well. At the other side there is a deep well representing the generation of nerve pulse and at the other side a high wall corresponding to hyper-polarization requiring energy. Both polarization and hyperpolarization are prevented by the freezing of protein activities needed to induce them. The flux tubes connecting the presynaptic neuron and receptor and possibly genome are always negentropic and their formation can as such serve as the signal leading to the partial melting of the ordered water making possible to generate action leading to either depolarization or hyperpolarization. The signal could be just the additional metabolic energy making it possible for these transitions to occur.

(c) This picture does not require any communications from the receptor to the genome and in the simplest situation the resulting action could be seen as the analog of reflex action. These communications could of course be present and the negentropic entanglement could make it easier to induce depolarization also now. Also the question whether excitatory-inhibitory dichotomy for the receptors has some deeper meaning apart from taking the neuron nearer to or farther from criticality for firing remains unanswered.

9.8   Could TGD provide justification for the ideas of Rupert Sheldrake?

Rupert Sheldrake [58] has developed a theory of learning and memory based on the concepts of morphic fields and morphic resonance. In the following I describe briefly the theory of Sheldrake and consider a TGD variant of of the theory.

9.8.1   Sheldrake's theory

The following summarizes very briefly the basic ideas of Sheldrake's theory.

1. The basic hypothesis is that learning occurs also at the level of species. If some individuals of the species have learned some habit then it becomes easier for the remaining individuals of the species to learn the same habit. The individuals who learned the habit first need not even live anymore or can live in a distant part of the world. Collective learning is claimed to occur in a morphic resonance analogous to a phase transition leading from a small seed of invididuals with new habit to a population having the same habit. Morphic field provides a representation for a habit and resemble the concept of meme in this respect. Sheldrake states the basic assumptions of his theory in the following manner:

   The idea is that there is a kind of memory in nature. Each kind of thing has a collective memory. So, take a squirrel living in New York now. That squirrel is being influenced by all past squirrels.

And how that influence moves across time, the collective squirrel-memory both for form and for instincts, is given by the process I call morphic resonance. It's a theory of collective memory throughout nature. What the memory is expressed through are the morphic fields, the fields within and around each organism. The memory processes are due to morphic resonance.

2. Sheldrake defines morphic fields in the following manner:

   Basically, morphic fields are fields of habit, and they've been set up through habits of thought, through habits of activity, and through habits of speech. Most of our culture is habitual, I mean most of our personal life, and most of our cultural life is habitual. "We don't invent the English language. We inherit the whole English language with all its habits, its turns of phrase, its usage of words, its structure, its grammar.

3. 'Alike likes alike' rule states that learning induces learning only in the members of *same* species. This suggests that the morphic fields correlate strongly with genome.

4. Sheldrake represents the learning of language as a good example of morphic resonance.

   Occasionally people invent new words, but basically, once we've assimilated it, it happens automatically. I don't have to think when I'm speaking, reaching for the next word. It just happens, and the same is true about physical skills, like riding a bicycle, or swimming, or skiing if you can ski, these kinds of things. So I think the more often these things happen the easier they become for people to learn. Things like learning language have happened over- well, we don't know how long human language has been around, at least 50,000 years, so there's a tremendously well-established morphic field for language-speaking. Each particular language has its own field which is usually established over centuries at least.

5. Sheldrake notices also that morphic resonance and morphic fields are not all what is needed to understand evolution.

   The whole idea of morphic resonance is evolutionary, but morphic resonance only gives the repetitions. It doesn't give the creativity. So evolution must involve an interplay of creativity and repetition. Creativity gives new forms, new patterns, new ideas, new art forms. And we don't know where creativity comes from. Is it inspired from above? Welling up from below? Picked up from the air? What? Creativity is a mystery wherever you encounter it, in the human realm, or in the realm of biological evolution, or of cosmic evolution. We know creativity happens. And then what happens is a kind of Darwinian natural selection. Not every good idea survives. Not every new form of art is repeated. Not every new potential instinct is successful. Only the successful ones get repeated. By natural selection and then through repetition they become probable, more habitual.

9.8.2 TGD based interpretation of morphic fields and collective memory

I have proposed for more than decade ago a TGD based formulation justifying the basic ideas of Sheldrake to some degree. The recent formulation involves several new elements. Zero energy ontology implying that WCW ("world of classical worlds") spinor fields allow an interpretation as memes or morphic fields, the model for living matter in which the notion of magnetic body plays a key role, and the model of DNA as topological quantum computer allowing to identify the morphic quanta relevant for living matter.

WCW spinor fields

In TGD framework zero energy states correspond to the modes of completely classical WCW spinor fields with fermionic second quantization at space-time level having purely geometric interpretation at the level of WCW. The analysis of the degrees of freedom involved demonstrates that WCW spinor fields are analogous to ordinary quantum fields but hav infinite number of components.

1. WCW decomposes to a sub-WCWs association with unions of causal diamonds (CDs). Individual CD is partially characterized by the moduli defined by the positions of its upper and lower tips. The proposal is that the temporal distances between the tips are quantized in octaves of CP_2 time scale and thus coming in good approximation as secondary p-adic time scales for

primes very neary to power of two. The most general proposal is that also the position of the upper tip at proper time = constant hyperboloid of future lightcone M^4_+ is quantized for positive energy states. For negative energy states this happens to the lower tip. This disrete set would provide a discretized quantum version of Robertson-Walker cosmology with discretized lattice like structure replacing the continuum. The interpretation would be that lower tip corresponds to the usual Minkowski space-time of special relativity and the discretized position of upper tip to the space-time of cosmology. This implies very strong predictions such as the quantization of cosmic redshifts which is indeed observed [19]. Similar quantization would take place in CP_2 degrees of freedom for either tip. WCW spinor fields for single CD would depend on these moduli and for positive (negative) states one would have wave functions in the space formed by sub-WCWs with wave function basis consisting of products of plane waves in M^4 with a wave function in the discrete subset of $M^4_\pm$. These degrees of freedom generalize those of a quantum field in Minkowski space.

2. The notion of generalized imbdding space forces to assign to a given CD a selection of quantization axis of energy and spin which in the case of M^4 boils down to a choice of a preferred plane $M^2 \subset M^4$ plus a choice of time direction (rest system). In the case of CP_2 the choice of quantization axes of color isospin and hypercharge means a choice of a homologically trivial geodesic sphere of CP_2 plus preferred isospin quantization axes. The space for possible choices of quantization axis defines additional moduli. The selection of quantization axes in state function reduction means a localization in these degrees of freedom. The space characterizing the selections of color quantization axis represents an example of so called flag manifold. It has already earlier appeared in TGD inspired biology with a motivation coming from the observation of topologists Barbara Shipman that the mathematical model for honeybee dance leads naturally to the introduction of this space. Shipman speculated that quarks have some role in biology [34]. Dark matter hierarchy indeed makes indeed possible scaled up copies of QCD type theory in biological length scales.

3. WCW spinor fields restricted to a CD with fixed moduli have infinite number of bosonic and fermionic degrees of freedom. Spin-like degrees of freedom for these fields correspond to WCW spinors, which describe many-fermion states consisting of quarks and leptons and bosons defined as their bound states. This Fock state is assigned to each 3-surface and the dependence on 3-surface defines purely bosonic ('orbital') degrees of freedom, which can be coded by using a state basis whose elements have well-defined spin and color quantum numbers. The bosonic and fermionic degrees of freedom are super-symmetrically related.

WCW spinor fields as morphic fields

The interpretation of the WCW spinor fields as memes or morphic fields is encouraged by two observations.

1. Zero energy states have an interpretation as Boolean rules $A \to B$ as well as self-organization patterns. Fermion number 1 and 0 for a given fermion mode represents values of one particular Boolean statement in positive *resp.* negative part of the state. The instances of A are assigned to the positive energy (initial) state and those of B to the negative energy (final) state and the quantum superposition of the paired instances defines the rule. Since time-like entanglement coefficients define M-matrix, the interpretation as a law of physics coded to the structure of the physical state itself is possible. Fermionic degrees of freedom correspond to the spin indices of WCW spinor fields. Besides this there are "orbital" degrees of freedom in the moduli space for CDs and in the space of deformations of light-like 3-surfaces. It is natural to assign these degrees of freedom to sensory perception.

2. The p-adic description of cognition and intentional action involves a generalization of the notions of number and of imbedding space. The hierarchy of Planck constants means a further generalization of the notion of imbedding space by replacing it with a book like structure. It seems that the discrete intersection of real and p-adic space-time surfaces consisting of rational points (possibly also algebraic points) is crucial from the point of view of consciousness theory. This is true also for the intersection of real and p-adic variants of WCW identified as 3-surfaces

whose mathematical representation makes sense in both real and p-adic number fieldsin preferred coordinate fixed by symmetries.

The first intersection is expected to be relevant at quantum field theory limit, which involves the replacement of the partonic 2-surfaces with a discrete subset of points carrying quantum numbers. The second intersection is relevant in the full quantum theory. The notion of number theoretic Shannon entropy having negative values makes sense in both intersections since entanglement probabilities must make sense in both number fields so that they are rational or belong to an algebraic extension of rationals. In these intersections of realities and various p-adicities the evolution of memes is expected to take place.

One manner to understand the special role of rationals and algebraics relies on the observation that rationals represent islands of order in the sea of chaos defined by reals since their pinary expansion is predictable and analogous to a periodic orbit of a dynamical system whereas for a generic real number there is no manner to predict the pinary expansion.

Morphic fields relevant to living matter

All zero energy states have interpretation as memes or quanta of morphic fields in TGD framework. One can however ask what zero energy states are relevant for biological systems.

1. The memes relevant to living matter must have a very concrete connection to biology. DNA as topological quantum computer hypothesis states the magnetic flux tubes connecting nucleotides to lipids of nuclear and cell membranes define braid strands needed to realize topological quantum computations. Nerve pulse patterns induce fluid flows of cytoplasma and of lipids in turn inducing timelike braidings defining running topological quantum computation programs and their memory representations as space-like braidings in the final state. These programs living (in very literal sense) in the brains of geometric future and past define a 4-D population of memes. The intronic part of the genome is specialized to topological quantum computations and the time scale in this case can be and must be faster than for the chemical gene expression. The repetitive character of many intronic DNA sequences regarded as evidence for their junk character does not mean any restriction for topological quantum computation.

2. The notion of magnetic body has a central role in TGD inspired biology. Magnetic body has an onionl ike fractal structure and astrophysical size with wavelength of EEG wave defining the size scale of the magnetic body with which it is associated. Magnetic body acts as as an intentional agent using biological body as a motor instrument and sensory receptor. Magnetic body receives sensory and other information from biological body through EEG and its fractal counterparts and controls biological body via EEG type signals sent to the genome, where they induce chemical or electromagnetic gene expression. This allows to imagine also a mechanism of collective learning. The spatio-temporal nerve pulse patterns defining topological quantum computations are mediated via EEG and its fractal counterparts to the magnetic body of organism and from it to the magnetic body of another organism. The magnetic body of Earth - magnetic Mother Gaia- could serve as a relay station and Schumann resonances and alpha band could allow broadcasting of the nerve pulse pattern to a large number of magnetic bodies of organisms. From the latter magnetic body the field representation of nerve pulse pattern would induce via EEG type signal from magnetic body to the receiver genome the original nerve pulse pattern in the brain of the receiver. Nerve pulse patterns would be quite generally induced by magnetic bodies via appropriate part of the intronic genome as electromagnetic gene expression. This mechanism could be also involved with telepathy and remote mental interactions.

3. Morphic resonance and alike likes alike rule can be understood from the condition that the intronic parts of genomes must be similar enough to allow the realization of the topological quantum computation. Also neuronal pathways involved must resemble each other in order that spatial nerve pulse patterns can be re-produced faithfully enough. Also the evolutionary levels must be more or less the same in order that the topological quantum computation has same meaning for the receiver and sender. Therefore the collective memory might be restricted to the level of species. This might be however too strong an assumption. For instance, shamanism could represent an example of interspecies memory. The TGD based view about memory allows

also the possibility to use the memories of the already deceased members of species which can in principle continue to exist in the geometric past.

4. The general vision about evolution as recreation of the quantum Universe implies that creativity is in very literal sense a basic aspect of TGD Universe. The U process represents the creative aspect of consciousness generating quantum super-position of Universes from which generalized state function reduction process selects the outcome. Both volitional actions and sensory perception involves the selection but quantum statistical determinism implies that sensory percepts are usually predictable.

Collective memory, geometric memory and self hierarchy

The notion of species memory is rather radical departure from the teachings of standard neuroscience so that TGD based view about memory deserves a separate discussion.

TGD predicts infinite hierarchy of selves and if this hierarchy has levels between living systems and entire universe, the idea about collective memory makes sense and generalizes to an entire hierachy of them.

Geometric memory provides a promising candidate for the mechanism of a long term memory. Geometric memory is made possible by the fact that self can have multitime experiences such that the space-time sheets associated with various values of the geometric time give contributions to the experiences and past contributions are experienced as memories. In zero energy ontology these space-time sheets are associated with sub-CDs of CD associated with self. Both time-like entanglement betweeen sub-CDs of recent and past implying sharing and fusion of mental images an classical communications between these CDs are possible and give rise to episodal memories (direct re-experiences) and symbolic memories.

Since both geometric past and future change in each quantum jump these memories are not stable: long term memories are certainly unreliable. The memory formation mechanism of brain however tends to stabilize these memories. There is in principle no upper bound for the span of the geometric memories and one can consider the possibility of racial memory and even species memory. Under suitable conditions organism could be able to have the space-time sheets of the geometric past as its subselves and experiences these memories. Thus geometric memory is consistent with Sheldrake's claims and to some degree supports them.

Language learning and morphic resonance

The easiness of children to learn language could have explanation in terms of morphic resonance. The strong quantum entanglement between the child and parents, especially mother, could make the morphic resonance possible in the proposed sense. One can even imagine that mother's magnetic body directly induces nerve pulse sequences representing linguistic memes in the brain of child.

One can of course wonder why it is so difficult for the older people to learn language. Do we force us to learn the language at reflective level although it could occur at proto-level also. Older people learn rules but find difficult to apply them whereas child learns to apply the rules without learning the rules themselves. Are older people so far from quantum criticality that the large fluctuations leading to the generation of the new level of self-organization are not possible anymore? The reason could also relate to the degeneration of the magnetic flux tubes circuits due to ageing so that new topological quantum computation programs are not establishes so easily anymore.

Self hierarchy, bio-feedback and sociofeedback

Magnetic bodies act as intentional agents in the proposed model. They form also a hierarchy analogous to master-slave hierarchy. The proposed mechanism of collective learning involves the magnetic body of Earth in an essential manner. Also magnetic bodies of larger structures could be involved: there is indeed evidence that remote cognition involves galactic magnetic fields [21, 85].

The phenomenon of bio-feedback provides direct evidence for this phenomenon in a length scale familiar to us. By monitoring the behavior of say single neuron, it is possible to learn to affect the behavior of neuron volitionally. No knowledge about how this happens is needed: the volition is enough. The explanation would be that the information provided by the monitoring goes to the magnetic body of the person which reacts by sending control signals to the brain. The already existing

magnetic flux tube connections guarantee that the volitional act affects the neuron. The possibility of biofeedback suggests the possibility of socio-feedback and feedback even at the level of species and entire biosphere.

An interesting test for the idea that people very close to each other could directly affect the brain function of each other would be biofeedback in which subject person tries to affect the behavior of a neuron of a close friend or relative. Mother and child might be an optimal choice in this respect.

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Chapter 10

p-Adic Physics as Physics of Cognition and Intention

10.1 Introduction

TGD as a generalized number theory vision stimulates the hypothesis about p-adic physics provides the physical correlates of intention, cognition and imagination. This interpretation has far reaching implications for both TGD inspired theory of consciousness and for the general world view provided by TGD. Intentionality and cognition is predicted to be present in all length scales and the success of the p-adic physics in elementary particle length scales forces to conclude that intentionality, cognition are present even at this level. In this chapter these implications are studied from the point of view of cognitive consciousness.

The view about cognition relies also heavily on the developents that have occurred during the last five years in the understanding of TGD. The vision about life and conscious information and intelligence as something in the intersection of real and p-adic worlds is certainly the most important aspect in this respect and the very fact that the notion of conscious information makes sense only in this intersection supports the proposed interpretation of p-adic physics. Zero energy ontology and the notion of causal diamond (CD) with zero energy states having interpretation as memes in very general sense is also of central importance. The hierarchy of Planck constants as an explanation of dark matter and energy as macroscopic quantum phases even in astrophysical scales and implying that dark matter is a key actor in the drama of life is the third key element.

10.1.1 Clarifying some basic concepts

Before continuing it is could to clarify basic conceps. The recent view is that p-adic space-time sheets correspond to cognition and that their intersections with real space-time sheets in the intersection of real and p-adic worlds define cognitive representations. These representations are defined in terms of data coming from the rational and algebraic points common to real and partonic 2-surfaces with the algebraic extension in question characterized by the mathematical representation of the partonic 2-surfaces making sense for both real and p-adic 2-surfaces simultaneously. Discrete set of points is always in question. A number theoretic variant of quantum field theory is needed in order to have a first principle description of conscious intelligence and intentionality.

The classical non-determinism of Kähler action quite generally implies that space-time surfaces define what might be called symbolic representations realizing quantum classical correspondence. This applies irrespective of the number field used and in p-adic context p-adic non-determinism is an additional ingredient. For instance, nerve pulse patterns define symbolic real physics representations of the sensory input but do not give rise to sensory qualia which reside at the level of the primary sensory organs (contrary to the expectations raised by various findings of neuro-science). Sensory experience is always a multiverse experience since sensory qualia have quantum jump increments as quantum correlates, and is thus not reducible to the level of space-time.

I have use also the notions of meme and morphic field. One could defend the identification of the geometric correlates of memes and morphic fields as p-adic space-time sheets. On the other, all

negentropic quantum states in zero energy ontology have the character of a rule A→B, where quantum superposition represents various instances $a \to b$ of the rule and one could say that every negentropic zero energy state can be seen as a meme. I leave the choice between these interpretations for the reader.

10.1.2 Basic vision

It is useful to summarized the recent TGD inspired view about quantum biology and conscious intelligence since it serves as background for the chapter.

Magnetic body as intentional agent and experiencer

The notion of magnetic body has a central role in TGD inspired biology. Magnetic body has an onion like fractal structure and astrophysical size with wavelength of EEG wave defining the size scale of the magnetic body with which it is associated. Magnetic body acts as as an intentional agent using biological body as a motor instrument and sensory receptor. Magnetic body receives sensory and other information from biological body through EEG and its fractal counterparts and controls biological body via EEG type signals sent to the genome, where they induce chemical or electromagnetic gene expression. This allows to imagine also a mechanism of collective learning. The spatio-temporal nerve pulse patterns defining topological quantum computations are mediated via EEG and its fractal counterparts to the magnetic body of organism and from it to the magnetic body of another organism [22].

The magnetic body of Earth - magnetic Mother Gaia- could serve as a relay station and Schumann resonances and alpha band could allow broadcasting of the nerve pulse pattern to a large number of magnetic bodies of organisms. From the latter magnetic body the field representation of nerve pulse pattern would induce via EEG type signal from magnetic body to the receiver genome the original nerve pulse pattern in the brain of the receiver. Nerve pulse patterns would be quite generally induced by magnetic bodies via appropriate part of the intronic genome as electromagnetic gene expression. This mechanism could be also involved with telepathy and remote mental interactions.

Magnetic flux tubes and flux sheets are basic building bricks of the magnetic body and DNA as topological quantum computer hypothesis assumes that DNA nucleotides are connected to cell membrane by flux tubes defining braids playing a key role in topological quantum computation [24]. Therefore magnetic body is essential for realizing the software of biological intelligence. The essential assumption is that magnetic body carries dark matter consisting of ordinary with a non-standard value of Planck constant. The phase transition changing the value of Planck constant change the size scale of the flux tube and this process together with reconncetion of the flux tubes would define mechanisms of bio-catalysis.

Zero energy ontology, causal diamonds, and quantum states as memes

In zero energy ontology physical states are replaced by pairs of positive and negative energy states assigned to the past *resp.* future boundaries of causal diamonds (CDs) defined as pairs of future and past directed light-cones ($\delta M_\pm^4 \times CP_2$). The net values of all conserved quantum numbers of zero energy states vanish. Zero energy states are interpreted as pairs of initial and final states of a physical event such as particle scattering so that only events appear in the new ontology.

Communication with the geometric past using negative energy signals and time-like entanglement are crucial for the TGD inspired quantum model of memory and both make sense in zero energy ontology. Zero energy ontology leads to a precise mathematical characterization of the finite resolution of both quantum measurement and sensory and cognitive representations in terms of inclusions of von Neumann algebras known as hyperfinite factors of type II$_1$ [24]. The space-time correlate for the finite resolution is discretization which appears also in the formulation of quantum TGD in terms of the modified Dirac action [46].

At the imbedding space-level CD is the correlate of self whereas space-time sheets having their ends at the light-like boundaries of CD - more precisely, partonic 2-surfaces and the distributions of the 4-D tangent spaces of space-time sheet associated with them- are the correlates at the level of 4-D space-time. The hierarchy of CDs within CDs corresponds to the hierarchy of selves. Zero energy ontology leads also to an argument explaining why the arrow of subjective time induces an apparent

arrow of geometric time as a result if intentional action and why the contents of sensory consciousness is restricted to such a narrow time interval (located near the future boundary of CD) [28].

The original interpretation of the space-time correlates of mental images was as mind-like space-time sheets identified as space-time sheets with a finite temporal size. In zero energy ontology all space-time sheets have a finite size and serve as correlates for zero energy states, which could be interpreted as representations of laws of physics as superpositions of pairs of initial and final states given by M-matrix. In state function reduction process these states are reduced to states for which only negentropic time-like entanglement is possible and one might say that the negentropy measures the conscious information associated with the final state of the reduction process. One can interpret negentropic quantum states as memes or morphogenetic fields [58, 26] These negentropic quantum states are possible only in the intersection of real and p-adic worlds so that living systems are the systems carrying information and intelligence.

Boolean mind and fermions

The connection of fermionic Fock space basis with Boolean algebra was one of the first ideas related to the quantum modelling of intelligent systems. The state basis for the fermionic Fock space has a natural interpretation as Boolean algebra (fermion number $=1/0 \leftrightarrow$ yes/no). In this manner ordinary Boolean algebra is extended to a vector space spanned by fermionic states. Fermion number conservation poses an obvious problem for this scenario in positive energy ontology. Zero energy ontology resolves this problem quite generally and zero energy states resulting as an outcome of state function reduction process represent Boolean statements of type A$\rightarrow$ B in terms of time-like negentropic entanglement in fermionic degreees of freedom.

The original proposal was to use cognitive fermion pairs instead of fermions with fermion and antifermion located at the opposite throats of wormhole contact. In the recent formulation of quantum TGD bosons and their super counterparts correspond to wormhole contacts. An interesting question is whether one could consider ordinary Boolean logic as some kind of limit for the complex quantum logic and whether our logical mind could have something to do with Boolean algebra. For instance, could primary 'this is true' experiences correspond to Boolean qualia having increments of fermionic quantum numbers as physical correlates. Boolean truth values could also correspond to spin directions of fermions. In this case fermion number conservation does not pose any constraints and the macrosopic realization replaing single spin as a representative of bit with a magnetized ensemble of fermions, makes the realization robust.

Negentropic entanglement means that qubits are always fuzzy and the fuzziness depends on the situation. The positive aspect is that the quantum superposition gives rise to an abstraction, rule about pairing of say initial and final states represented as positive and negative energy parts of zero energy state with the pairs of superposition representing the instances of the rule. p-Adic-real entanglement with positive definite number theoretical entanglement entropy in the intersection of real and p-adic worlds could give rise the experience of understanding and makes possible cognitive quantum computation like processes.

p-Adic physics as physics of cognition and intention

The vision about p-adic physics as physics of cognition has gradually established itself as one of the key idea of TGD inspired theory of consciousness. There are several motivations for this idea.

The strongest motivation is the vision about living matter as something residing in the intersection of real and p-adic worlds. One of the earliest motivations was p-adic non-determinism identified tentatively as a space-time correlqte for the non-determinism of imagination. p-Adic non-determinism follows from the fact that functions with vanishing derivatives are piecewise constant functions in the p-adic context. More precisely, p-adic pseudo constants depend on the pinary cutoff of their arguments and replace integration constants in p-adic differential equations. In the case of field equations this means roughly that the initial data are replaced with initial data given for a discrete set of time values chosen in such a manner that unique solution of field equations results. Solution can be fixed also in a discrete subset of rational points of the imbedding space. Presumably the uniqueness requirement implies some unique pinary cutoff. Thus the space-time surfaces representing solutions of p-adic field equations are analogous to space-time surfaces consisting of pieces of solutions of the real field equations. p-Adic reality is much like the dream reality consisting of rational fragments glued together

in illogical manner or pieces of child's drawing of body containing body parts in more or less chaotic order.

The obvious looking interpretation for the solutions of the p-adic field equations is as a geometric correlate of imagination. Plans, intentions, expectations, dreams, and cognition in general are expected to have p-adic space-time sheets as their geometric correlates. This in the sense that p-adic spacetime sheets somehow initiate the real neural processes providing symbolic counterparts for the cognitive representations provided by p-adic spacetime sheets and p-adic fermions. A deep principle seems to be involved: incompleteness is characteristic feature of p-adic physics but the flexibility made possible by this incompleteness is absolutely essential for imagination and cognitive consciousness in general.

p-Adic space-time regions can suffer topological phase transitions to real topology and vice versa in quantum jumps replacing space-time surface with a new one. This process has interpretation as a topological correlate for the mind-matter interaction in the sense of transformation of intention to action and symbolic representation to cognitive representation. p-Adic cognitive representations could provide the physical correlates for the notions of memes [65] and morphic fields [58]. p-Adic real entanglement makes possible makes possible cognitive measurements and cognitive quantum computation like processes, and provides correlates for the experiences of understanding and confusion.

At the level of brain the fundamental sensory-motor loop could be seen as a loop in which real-to-p-adic phase transition occurs at the sensory step and its reverse at the motor step. Nerve pulse patterns would correspond to temporal sequences of quark like sub-CDs of duration 1 millisecond inside electronic sub-CD of duration .1 s with the states of sub-CDs allowing interpretation as a bit (this would give rise to memetic code). The real space-time sheets assignable to these sub-CDs are transformed to p-adic ones as sensory input transforms to thought. Intention in transforms to action in the reverse process in motor action. One can speak about creation of matter from vacuum in these time scales.

Although p-adic space-time sheets as such are not conscious, p-adic physics would provide beautiful mathematical realization for the intuitions of Descartes. The formidable challenge is to develop experimental tests for p-adic physics. The basic problem is that we can perceive p-adic reality only as 'thoughts' unlike the 'real' reality which represents itself to us as sensory experiences. Thus it would seem that we should be able generalize the physics of sensory experiences to physics of cognitive experiences.

Life as something in the intersection of real and p-adic worlds and negentropic entanglement

In the p-adic context one must modify Shannon's definition of entropy by replacing the ordinary logarithm based on p-adic norm. This definition gives rise to a real valued entropy in both real and p-adic contexts if entanglement coefficients are rational/algebraic numbers. For irrational/non-algebraic entanglement standard Shannon formula and its p-adic variant must be used and gives rise to non-negative entropy. Unlike Shannon entropy, the p-adic entropies (one for each p) can be also negative so that the entanglement entropy defines a genuine information measure whose sign tells whether the system contains information or dis-information. For the p-adic entropies Negentropy Maximization Principle [29] tends to preserve the quantum coherence if p divides the common denominator of the entanglement probabilities. The states with rational/algebraic entanglement can be regarded as new kind of states analogous to bound, which are not at all fragile like the states with non-algebraic entanglement are. In particular, these states need not be bound due to the binding energy.

For instance, the problematic notion of high energy phosphate bond could be understood in terms of negentropic entanglement making possible correlations without binding energy so that the ATP→ADP process defining fundamental step of metabolism could be interpreted in terms of negentropy transfer. Negentropic entanglement is highly stable in state function reduction process so that the randomness of quantum jump does not apply to it. As a consequence, the second law of thermodynamics is broken in the scale defined by the size of CD involved. A natural interpretation is that subselves lose consciousness as ordinary entropic bound state entanglement is generated but experience expansion of consciousness when negentropic entanglement is generated. Positive emotions like love, experience of understanding would naturally accompany the generation of negentropic entanglement.

These observations lead to a purely number-theoretic characterization of life: life is in the intersection of real and p-adic worlds: life corresponds to islands of rational/algebraic numbers in the seas of real and p-adic continua. This vision have rapidly become the most important source of insight in

attempts to develop TGD based vision about conscious intelligence and cognition.

Hierarchy of Planck constants and consciousness

The hierarchy of Planck constants is realized in terms of a generalization of the causal diamond $CD \times CP_2$, where CD is defined as an intersection of the future and past directed light-cones of 4-D Minkowski space M^4. $CD \times CP_2$ is generalized by gluing singular coverings and factor spaces of both CD and CP_2 together like pages of book along common back, which is 2-D sub-manifold which is M^2 for CD and homologically trivial geodesic sphere S^2 for CP_2 [17]. The value of the Planck constant characterizes partially given page and arbitrary large values of $\hbar$ are predicted so that macroscopic quantum phases are possible since the fundamental quantum scales scale like $\hbar$. All particles in the vertices of Feynman diagrams have the same value of Planck constant so that particles at different pages cannot have local interactions. Thus one can speak about relative darkness in the sense that only the interactions mediated by the exchange of particles and by classical fields are possible between different pages. Dark matter in this sense can be observed, say through the classical gravitational and electromagnetic interactions. It is in principle possible to photograph dark matter by the exchange of photons which leak to another page of book, reflect, and leak back. This leakage corresponds to $\hbar$ changing phase transition occurring at quantum criticality and living matter is expected carry out these phase transitions routinely in bio-control. This picture leads to no obvious contradictions with what is really known about dark matter and to my opinion the basic difficulty in understanding of dark matter (and living matter) is the blind belief in standard quantum theory.

Dark matter hierarchy and p-adic length scale hierarchy would provide a quantitative formulation for the self hierarchy. To a given p-adic length scale one can assign a secondary p-adic time scale as the temporal distance between the tips of the causal diamond (pair of future and past directed light-cones in $H = M^4 \times CP_2$). For electron this time scale is .1 second, the fundamental biorhythm. For a given p-adic length scale dark matter hierarchy gives rise to additional time scales coming as $\hbar/\hbar_0$ multiples of this time scale. These two hierarchies could allow to get rid of the notion of self as a primary concept by reducing it to a quantum jump at higher level of hierarchy. Self would in general consists of quantum jumps inside quantum jumps inside... and thus experience the flow of time through sub-quantum jumps.

The hierarchy of Planck constants means the possibility of temporal zooms of the event sequences of the external world making possible 'stories' as either zoomed up or zoomed down versions of the actual course of events. This makes possible simulation in the time natural time scales of neuronal activity and is expected to be a key element of conscious intelligence and cognition.

10.1.3   Topics of the chapter

The topics of the chapter is as follows.

1. The relationship between p-adic physics, intentionality, and cognition is discussed on general level.

2. Possible evidence for p-adic cognition is considered.

3. In the mathematical sections the relationship between intentionality, cognition and number theory is discussed. Also the relationship between p-adic and real physics is discussed at general level with basic vision being that the intersection of real and p-adic space-time sheets in the intersection of real and p-adic worlds consists of points belonging to the algebraic extension of rational needed to guarantee that the mathematical representation of the partonic 2-surface makes sense both in real and p-adic sense.

4. Frontal lobes are known to be the seat of the higher level intentional action and are discussed from p-adic point of view.

5. A generalization of the memetic code to cognitive codes is discussed and some proposals about codes are made. This generalization is based on p-adic length scale hypothesis and the condition that the time scales involved correspond to time scales assignable to the CDs of the known elementary particles does not favor the generalization. On the other hand, the dark matter sector could allow entire fractal hierarchy of elementary particle physics whose existence is reflected as fundamental bio-rhytms and cognitive codes.

6. The intersection of real and p-adic partonic 2-surfaces defining space-like cognitive representations consist of algebraic points. The hypothesis that these intersections obey various kind of symmetries identifiable as molecular symmetries is discussed.

10.2   p-Adic physics, intentionality, and cognition

The basic vision is that volitional acts are realized as phase transitions of a p-adic space-time region to a real space-time region. These phase transitions are 4-dimensional and induces in quantum jumps.

10.2.1   The three non-determinisms

TGD Universe is characterized by a 'holy trinity' of non-determinisms. The first non-determinism is associated with quantum jumps between quantum histories and is what makes possible subjective existence and consciousness. One achieve determinism by giving up the assumption that initial values at fixed time define the time evolution and replaces 3-dimensional sections of space-time surface with what I have called mind-like space-time sheets. The attempt to realized this picture geometrically led to zero energy ontology. Second non-determinism is classical non-determinism of Kähler action and is to symbolic representations and perhaps also with macroscopic volition. The third non-determinism is inherent to all p-adic field equations and might correspond to the non-determinism of imagination and thus makes possible cognition and intentionality. There is no conscious experience associated with classical nor with p-adic non-determinism as dualist might think. These three non-determinisms have turned out to be basic building bricks of TGD inspired theory of consciousness.

The original identification of the geometric correlates of selves was as mind like space-time sheets. In zero energy ontology all real space-time sheets satisfy the criterion for mind-likeness and therefore serve as correlates for selves. In the p-adic context this restriction is in principle un-necessary. Classical and p-adic non-determinisms make it natural to introduce the notion of association sequence defined as a sequence of space like 3-surfaces with time like separations determining uniquely the absolute minimum space-time surface going through these 3-surfaces. In the case of CP_2 vacuum type extremals discrete association sequences become in principle continuous sequences of 3-surfaces but topological condensation is expected to reduce this non-determinism to its discrete version.

10.2.2   Classical non-determinism and symbolic representations

In the special case that classical non-determinism gives rise to macroscopic multifurcations of the time development of 3-surface, it is tempting to identify the branches of the multifurcations as alternative choices involved with volitional acts. Contrary to the long held beliefs, it however seems that classical non-determinism is most naturally associated with symbolic representations understood in a very general sense (one could even understand classical space-time surfaces as symbolic representations of quantum dynamics). The assignment of sensory experiences with real mind like space-time sheets explains why the contents of sensory experiences are localized with respect to geometric time.

The book "Gödel, Escher, Bach" by Douglas Hofstadter about self-reference has been perhaps the most fascinating of my intellectual arm chair adventures and it stimulated the dream about the identification of the physical counterpart of self-reference. The physics as a generalized number theory vision stimulated concrete ideas about how this self-reference might be realized in terms of quantum universe repeatedly re-creating itself. The quantum jump building sensory and cognitive representations about the Universe means the replacement of the Universe with a new one containing these representations. Hence the paradoxical infinite regress resulting from the assumption that it is possible to be conscious about what one is conscious of is avoided with a simple modification of this assumption by replacing 'is' with 'was'. By quantum classical correspondence this vision requires also the failure of classical determinism in the conventional sense of the word.

In accordance with the crossing symmetry of standard quantum field theories, one can interpret the elements of M-matrix (generalization of S-matrix in TGD framework) as time-like entanglement coefficients between positive and negative energy parts of the zero energy state with incoming and outgoing particles having positive and negative energies respectively. Thus the classical non-determinism and zero energy ontology make possible for the TGD Universe according to represent the laws of

physics in the structure of the zero energy physical states. That all possible vacua provide representation for physics is very much akin to the ideas of Eastern philosophies, and is bound to have deep implications from the point of view of TGD inspired theory of consciousness.

10.2.3   p-Adic non-determinism and cognition

p-Adic non-determinism follows from the fact that functions with vanishing derivatives are piecewise constant functions in the p-adic context.

1. p-Adic pseudo constants depend on the pinary cutoff of their arguments and replace integration constants in p-adic differential equations. In the case of field equations this means roughly that the initial data are replaced with initial data given for a discrete set of time values chosen in such a manner that unique solution of field equations results. Since the fundamental formulation of quantum TGD [24] indeed relies on the notion of finite measurement resolution, a highly attractive interpretation of this cutoff is in terms of measurement resolution of some kind.

2. Solution can be fixed in a discrete subset of rational (algebraic) points of the imbedding space. In the case of space-time surfaces this set is expected to have inherent cutoff since the condition of rationality (or algebraicity in the extension of p-adic numbers used) posed separately for all imbedding space coordinates is very strong. Note that preferred imbedding space coordinates are required and this kind of coordinate systems indeed existence thanks to the isometries of the imbedding space.

Clearly, the space-time surfaces representing solutions of p-adic field equations are analogous to space-time surfaces consisting of pieces of solutions of the real field equations. p-Adic reality is much like the dream reality consisting of rational fragments glued together in illogical manner or pieces of child's drawing of body containing body parts in more or less chaotic order.

The obvious interpretation for the solutions of the p-adic field equations would be as geometric correlates of intentionality. Plans, intentions, expectations, dreams, and possibly also cognition as imagination in general are expected to have p-adic cognitive space-time sheets as their geometric correlates. A deep principle seems to be involved: incompleteness is the characteristic feature of p-adic physics but the flexibility made possible by this incompleteness is absolutely essential for imagination and cognitive consciousness in general. One must be very cautious in order to not misinterpret the role of p-adic physics. Imagination and cognition, as they are defined in the neuro-science, have also definite neural correlates at the level of real physics so that obviously both p-adic and real physics are involved. p-Adic space-time sheets would define the initial values with respect to subjective time for the neural processes responsible for imagination and intentions whereas in the case of cognitive representations p-adic space-time sheets would correspond to the final values.

1. For instance, the following argument provides support for the p-adic description of cognition. p-Adic-real entanglement (as also other kinds of non-diagonal entanglements) is possible in fermionic degrees of freedom if one assumes that the entanglement coefficients are algebraic numbers. Negentropic entanglement is stable against self measurements so that macro-temporal quantum coherence results. The natural guess is that this kind of entanglement is a correlate for the experience of understanding. This would strongly encourage the interpretation as a cognitive entanglement so that the corresponding self measurement could be called cognitive measurement.

   Thus the core element of cognition (intentionality) would be the p-adic space-time sheet representing the final (initial) values of the neural process with respect to subjective time, which in turn could be seen as a symbolic representation of cognition or imagination. In this conceptual framework cognitive representations are p-adic and symbolic representations real and brain mostly builds symbolic representations from the sensory input and from cognitive representations and vice versa.

2. There should be some distinction between the p-adic correlates of intentionality and cognition. This kind of distiction corresponds to time reversal. Motor and sensory representations are time reversals of each other in TGD framework and therefore intention (cognition) giving rise to motor representation (resulting from sensory representation) are naturally time reversals of each

other. In zero energy ontology they would correspond to positive and negative energy states. Note that for virtual bosons can be regarded as pairs of positive and negative energy particles so that for pairs of p-adic positive and negative energy massless extremals cognition and intention can couple to a kind of sensory-motor time-loop.

Basic vision about qualia

Before proceeding it is useful to summarize the basic view about qualia [24].

1. Geometric qualia correspond to the increments of configuration space zero modes in quantum jump and are cognitive qualia. Shape, size,length duration, ... etc. are good examples of geometric qualia. Real geometric qualia could be also called symbolic qualia. The universe of symbolic representations is completely classical if a complete localization in the zero modes occurs in each quantum jump. It is not completely clear whether this must be the case also in the real WCW degrees of freedom. In p-adic configuration space degrees (WCW, "the world of classical worlds") of freedom it must take place so that cognition would be completely classical. The moduli space for CDs is an excellent candidate for the fundamental geometric qualia [33, 32].

2. Sensory qualia correspond to the increments of quantum numbers related to the quantum fluctuating degrees of freedom, non-zero modes. They are genuine multi-verse qualia since the final states of quantum jumps are superpositions of space-time surfaces with varying values of non-zero modes. One cannot understand color red in terms of space-time geometry.

3. The trinity sensory-symbolic-cognitive is central for understanding consciousness in TGD framework. Also the division to fermionic (configuration space spinor) and configuration space degrees of freedom at the level of qualia is important. Fermionic qualia correspond to Boolean qualia (both p-adic and real and associated with conformal and quaternion conformal fermionic degrees of freedom). Configuration space qualia correspond to geometric and sensory qualia in the real case and only geometric qualia in the p-adic case (cognition has no colors).

p-Adic–real phase transitions and matter-mind interaction

If one accepts the idea that real and p-adic space-time regions are correlates for matter and intentionality, one encounters the question how matter and mind interact. A good candidate for this interaction is the phase transition leading to a transformation of the real space-time regions to p-adic ones and vice versa. These transformations can take place in quantum jumps. p-Adic-to-real phase transition would have interpretation as a transformation of thought into a sensory experience (dream or hallucination) or intention to an action. The reverse phase transition would relate to the transformation of the sensory experience to cognition.

1. The real↔p-adic transformations -and more generally, p_1-adic↔ p_2-adic transformations would occur in the intersection of real and p-adic worlds. In other words, the mathematical representation of the partonic 2-surfaces plus the distribution of their 4-D tangent planes would make sense in all number fields or at least suitable algebraic extensions of them. Therefore the leakage between different number fields would have a precise mathematical meaning. The unitary U-matrix characterizing the unitary process must describe these transitions and its matrix elements should involve only data about the intersection of partonic 2-surfaces belonging to different number fields: that is from points of real 2-surface at points belonging to the algebraic extension of rationals considered. Hence the description of intention and cognition should be in terms of what might be called number theoretic quantum field theory. A rudimentary formulation of U-matrix in this manner is discussed in [29].

2. The mere p-adic–transitions do not seem to be enough for understanding intentional action and one can also consider the generation of real and p-adic zero energy states from vacuum. This is required also by a reasonable model for intentional action realized in terms of p-adic–real transition. The fact that 1 ms and .1 s time scales correspond to important biological time scales as well as time scales assignable to quark and electron CDs suggests that this process takes place routinely in living matter.

3. Although zero energy ontology in principle allows a creation of zero energy states with arbitrarily large energies of positive energy part of the state as analogs of quantum fluctuations, the condition that the entanglement is negentropic poses energetic constraints since negentropic entanglement carries "negative binding energy" having interpretation as ordered energy. The interpretation as metabolic energy allows to understand the somewhat foggy concept of energetic phosphate bond central for ATP-ADP process [19]. What is transferred in this process would be negentropy rather than mere energy.

4. Em fields, in particular ELF em fields, are crucial for TGD inspired model of brain and a natural question is whether p-adic–real phase transitions occur also for massless extremals (MEs). These transitions could occur also for elementary particles. I have proposed the generation MEs as a mechanism of coherent locomotion made possible by the maximally coherent momentum carried by ME and resulting as a recoil momentum of material system absorbing second ME. In fact, the mechanism is optimal since the momentum of ME is completely coherent. Thus a possible interpretation is as a transformation of intention to real motion. Of course, it is difficult to say whether this mechanism occurs in cellular or micro-tubular length scales or perhaps even in macroscopic lengths scales. And there are certainly also other mechanisms.

A more refined picture about the realization of intentions emerges, when one asks how a precisely targeted intention could be realized at the atomic or molecular level.

1. The change must involve energetic changes in the scale of the entire system so that the quantum numbers characterizing the positive energy part of the state change. This includes energy and momentum. It seems safe to assume that zero energy states are created in rather small length scales and that macroscopic systems cannot transform between real and p-adic states. Hence the bottle neck step of the process would be the generation of zero energy states from vacuum as sub-CD with a rather short characteristic time scale and their subsequent interaction with the existing state inducing the desired action.

2. This favors the generation of zero energy states representing elementary particles and electrons and quarks are excellent candidates in this respect for reasons that should be already clear. The sub-CD created from vacuum could be p-adic and transform to a real one and interact with the background to induce the transition. Protons and electrons are key actors in bio-catalysis and TGD forces to consider the possibility that at least electron and quarks exist only in the sense of zero energy ontology.

3. The creation of sub-CD can be interpreted direction of attention of CD to a particular spatiotemporal region inside it. If this region is near vacuum extremal it is critical and the subsequent interaction of sub-CD with 4-D environment can induce a large change of the entire system.

Another view about motor action is as negative energy signal send to the geometric past and inducing a neural activity leading to the motor action as a consequence. This view conforms with the findings of Libet and others [78]. It should be possible to fuse these two views together.

1. The intention can be realized in a precisely targeted manner only for the transitions which do not occur spontaneously, and thus involve the emission of negative energy MEs. For a transition involving emission of positive energy, the direction of ME is random so that targeted intentional action is not possible.

2. The emission of negative energy ME translates to a quantum jump in which the energy of the positive energy part of zero energy state increases in the interaction with sub-CD or some other CD. The generation of negative energy MEs would utilize the quantum credit card mechanism of metabolism implying extreme flexibility.

3. Credit card mechanism requires the existence of a system analogous to a population reversed laser. The TGD based model for metabolism assumes that electrons or protons kicked to a small space-time sheet provide this system and that their dropping to a larger space-time liberates zero point kinetic energy as metabolic energy. Hence sensory, cognitive and memory representations would be realized in terms of positive energy MEs spontaneously whereas intentionality and motor actions would be much like time reversed sensory representations and realized in terms of negative energy MEs.

Cognition and intention at elementary particle length scales?

The success of p-adic mass calculations [18, 17, 20] does not leave much room for the interpretations if one identifies p-adic physics as a physics of cognition: cognitive representations must be present already at elementary particle level. This is true if elementary particle reside in the intersection of the real and p-adic worlds quite generally. This would mean that p-adic–real phase transitions occur and transform real zero energy states to p-adic ones and vice versa. The mathematical description of this process in terms of U-matrix as a leakage between sectors of WCW ("world of classical worlds") corresponding to different number fields is discussed in [29].

If the interpretation of nerve pulse patterns as a manner to generate memetic codons is correct, not only the real-p-adic transitions would be possible but also the creation of zero energy states representing electrons and quarks could occur completely routinely in living matter. In the standard physics framework the interpretation would be as quantum fluctuations generating fermion pairs from vacuum. In TGD framework these quantum fluctuations become quantum states with precisely defined characteristics.

What makes this hypothesis testable is the prediction that the time scales of CDs assignable to electron and quarks should define fundamental time scales of living matter. This seems to be the case. kHz neuronal synchrony is only one example. kHz frequency and 10 Hz frequency would be associated also with "dead" matter if cognition is present at elementary particle level. A particular prediction is the failure of second law below these time scales. This kind of failure has been indeed observed [44] and the effect indeed involves millisecond and .1 second time scales [29].

The experience has taught that physical system can be understood throughly only after the characteristic time scales have been understood. In case of biology the prevailing reductionistic attitude has led to the belief that living matter is a basic example of a "non-tidy" system so that the time and length scales associated with living matter are more or less accidental as also genetic code and the miracles of bio-chemistry. My own belief is that this attitude is wrong and explains why the progress in the theoretical understanding of living matter has been so slow.

Cognitive degeneracy and the survival of the fittest

Quantum classical correspondence leads to the proposal that Kähler function defined as the negative for Kähler action for a preferred extremal and proportional to the integral of $B_K^2 - E_K^2$ equals to the total entanglement negentropy assignable to the selves resulting the state function reduction sequence [41]. The vacuum functional identified as the exponent entropy- that is Kähler function - would disfavor negentropic states unless they have large degeneracy. The analog of this situation is encountered already in string models where Hagedorn temperature defines a limiting temperature because the density of states as function of mass increases exponentially. The proposal is that this degeneracy behaves as the exponent of the negative of the Kähler function for the critical value of Kähler coupling strength so that the negentropy content of the Universe can be infinite at criticality. Below it it is finite and above it the theory is ill-defined mathematically. This could hold true in the intersection of real and p-adic worlds but not generally and would thus raise living systems in a special role.

Physical systems with large degenerary would be favored. 4-D spin glass degeneracy suggests that these systems correspond to small deformations of vacuum extremals. If the final states of quantum jumps have roughly the same probabilities, this means that quantum jumps lead with highest probability to those states for which cognitive degeneracy is highest. The mere ability to imagine would mean winning in the fight for survival. A physical system with high degeneracy would also have a large repertoare of transformations of p-adic space-time sheets to real space-time sheets and is thus highly adaptive and survives for this reason.

The emergence of symbols

p-Adic non-determinism gives rise to cognitive representations whereas the non-determinism of the real Kähler action gives rise to symbolic representations in terms of association sequences consisting of space like 3-surfaces with time like separations: the individual space like 3-surfaces play the role of words of sentence.

Conscious activities are indeed highly symbolic: a push of button can initiate a nuclear war. The reduction of the p-adic-to-real phase transitions to some fundamental level, perhaps to the level of nerve

pulse transmission, indeed makes possible a build-up of very complex actions by using a repertoare of very simple basic actions serving p-adic memes translatable to symbols in case that system is initial value sensitive. p-Adic MEs and p-adic variants of elementary particles and corresponding CDs provide an excellent candidate for the cognitive representations defining the buttons and would initiate neural processes defining symbolic representations. Also memetic code and quarks would be involved.

The idea that motor actions are time reversed perceptions allows a simple view about imagined motor activities. Imagined motor actions would be initiated by a transformation of p-adic MEs to real negative energy MEs at some level above muscles and proceed to the cortex as time reversed activities as far as the MEs controlling these activities are considered. Negative energies make possible precisely targeted intention. There is no need to stop the imagined motor action so that it is not a safety risk. It is possible to learn motor actions by initiating them from a level above the muscles. Time reversal means negative energies for MEs and buy now-let others pay mechanism implies extreme flexibility. Time reversed dissipation can be interpreted as a healing mechanism since entropy decreases in the standard direction of the geometric time. Thus the motor action can be thought of as a carving of a four-dimensional statue by a gradual refinement and error corrections using dissipation as a Darwinian selector. No detailed planning is needed: only a rough sketch is enough in the time scale of the motor action and Nature takes care of the rest.

p-Adic fractality suggests that cognitive representations are present at all length scales: in particular, p-adic MEs are excellent candidates for cognitive representations. Symbolic representations are obtained from these by p-adic-to-real phase transitions. Nothing however forbids a repertoare of simple MEs serving as symbols, typically frequencies or field patterns, and generating neural activities in turn amplitied to macroscopic actions.

10.2.4   What cognitive representations are and how they develop?

It is far from clear what cognitive representations are and how they develop. The recent vision about generalized imbedding space and about life as something in the intersection of real and p-adic worlds provides one answer to the question but p-adic mass calculations force to ask whether also cognitive representations mapping the external world the space-time sheet of system and absed on some variant of canonical identification could exist.

Questions about cognitive representations

1. What are the basic types of cognitive representations. There are two basic correspondences between reals and p-adics induced by common rationals and canonical identification or some map akin to it. One might guess that self-representations are induced by common rationals whereas representations of the external world could be induced by a proper generaliz of canonical identification mapping rationals to themselves up to some power of p. In both cases there is some pinary cutoff determining the goodness of the representation. For the identification based on common rationals or algebraics the geometry of the surfaces would dictate the resolution inherently.

2. How cognitive representations evolve? p-Adic field equations are same as real field equations so that one can say that Nature determines the p-adic cognitive representation once the p-adic integration constants, which are pseudoconstants, are given. p-Adic pseudoconstants are the basic input of the cognitive representation determined more or less completely by the sensory input coded into nerve pulse patterns and EEG waves.

3. What is the mechanism of the reality testing? There must be somekind of reality testing for cognitive representations allowing to gradually tune up the values of the p-adic integration constants. p-Adic-to-real phase transitions in principle make possible this kind of testing. For instance, cognitive representation can be transformed to real (symbolic) one and compared with the sensory input represented by nerve pulse and propagating in a closed loop in neural circuits. An iterative procedure converging rapidly to a fixed point representation could be involved. At least in some case ideal representation is the one for which p-adic pseudo constants reduce to genuine constants. This kind of iterated comparison process could be also seen as a self-organization process leading to standardized final state patterns.

4. What is the relationship to the memetics of Susan Blackmore [65]? p-Adic cognitive representations are excellent candidates for the physical realization of memes . Susan Blackmore sees memes as independent objects using brain as a tool of replication. One can wonder whether p-adic cognitive representations could also have equally independent existence and use brain as at tool for the materialization and replcation, and whether there are p-adic memes floating all around and waiting for a materialization. TGD based interpretation of DNA as a material realization of association sequences suggests also that DNA should could have a p-adic counterpart possibly able to replicate. A further interesting question is is the role of the p-adic ghostly DNA double helix as as a template in the replication of the physical DNA.

Two kinds of cognitive representations

At the level of the space-time surfaces and imbedding space the construction of cognitive map boils down to the task of finding a map mapping real space-time region to a p-adic space-time region. These regions correspond to definite regions of the rational imbedding space so that the map has a clear geometric interpretation at the level of rational physics.

The basic constraint on the map is that both real and p-adic space-time regions satisfy field equations: p-adic field equations make sense even if the integral defining the Kähler action does not exist p-adically. p-Adic non-determinism makes possible this map when one allows a finite pinary cutoff characterizing the resolution of the cognitive representation. The fact that field equations are satisfied implies that physics laws are automatically built into the cognitive representation.

There are two basic types of cognitive representations, which might be called self-representations and representations of the external world and the map mediating p-adicization is different for these two maps. The correspondence induced by the common rational points (or those in algebraic extension of rationals) respects algebraic structures and defines self-representation. Given real and p-adic space-time surfaces have a subset of rational points as common. The identification of the common rationals can be extended to a unique correspondence between real and p-adic 2-surfaces if the 2-surfaces belong to the intersection of the real and p-adic worlds. This correspondence is however not between all points of the real and p-adic varint of the 2-surface. The number of rational points is an inherent property of the partonic 2- and allows to define also the notion of number theoretic braid natural when the measurement resolution is finite [22]. The common points define a cognitive representation and the quality of the representation is defined by the resolution of the map and the pinary cutoff for the rationals in the pinary expansion is a possible measure for the resolution just as the decimal cutoff is a natural measure for the resolution of a numerical model.

Consider next candidate for a cognitive map based on a modification of the canonical identification and having the property that it maps all points of real 2-surface to the points of p-adic 2-surface and vice versa in locally continuous manner.

1. Canonical identification or its variant applied to entire space-time sheet would not respect the basic symmetries of quantum TGD nor field equations. Therefore it is necessary to restrict to a map to partonic 2-surfaces plus their 4-D tangent space distributions. The failure to realize this led to the skepticism concerning the usefulness of this map at space-time level. Later it however turned out that it could make sense at the level of momentum space for Feynman diagrams [25].

2. The variant of the canonical identification defined as $p^{rk}(m/n) \to p^{-rk}I_k(m)/I_k(n)$, with $m \geq 0$ and $n \geq 0$ not divisible by p^k, and $I_k(x)$ defined as $x = \sum x_n p^{nk} \to \sum x_n p^{-nk}$ maps p-adics to reals and its inverse has the same form. It maps rationals to rationals. It also maps rationals satisfying $m < p^k$, $n < p^k$, to themselves apart from scaling by p^{-2rk} so that co-incides with identification along common rationals in the subset of rationals with $r = 0$. One can say that arithmetics and symmetries are respected in the resolution defined by p^k. The map is also continuous. A hybrid of canonical identication and identification along common rationals is in question. The map can be also modified by mapping p^{rk} to itself rather than its inverse.

3. The inverse of the map from real rationals to p-adics can be made single valued. The continuation to reals is not single valued since the map from p-adics maps three points to single point in the general case. As an example consider $p = 2$ and two representations of real unit as 1 and $\sum_{k \geq 1} 2^{-k}$ mapped to p-adic units and p-adic -2 respectively. The multiplication of the numerator and denominator by these representations of unit gives 3 different images for real

number and even real rational unless one selects the finite 2-adic expansion. Similar results holds generally.

4. A possible interpretation is that the power p^k for m and n characterizes the measurement resolution. The points common to the p-adic 2-surface and its real counterpart would define the resolution and in in shorter length scales one could use either p-adic or real topology without losing anything.

5. General coordinate invariance at imbedding space level is not obvious. CP_2 is a compact manifold and a possible technical problem relates to CP_2 coordinates. The complex coordinates transforming linearly under $U(2) \subset SU(3)$ and defining a unique choice of quantization axes for color isospin and hypercharge have the required range of variation allowing the proposed construction. In the case of M^4 linear Minkowski coordinates with origin at either tip of CD are the unique choice apart from Lorentz transformations. The choice of these coordinates specifies the choice of quantization axis of various isometry charges. In a well-defined sense the choice of the quantization axis and a special coordinate system implies the breaking of color symmetry and general coordinate invariance. The realization of the hierarchy of Planck constants however forces this kind of choice in both M^4 and CP_2 degrees of freedom and the moduli space for CDs includes also the space for the choices of quantization axis so that fundamental symmetries are not broken. One could perhaps say that the cognition affects real physics via the imbedding space points shared by real and p-adic space-time sheets and that these common points define an approximation of the real space-time surface as a discrete set of points. This discretization would be analogous to the discretization needed in any numerical computation.

In the intersection of real and p-adic worlds this map defines naturally a map from real partonic 2-surface to another real partonic 2-surface which is p-adic fractal and a possible interpretation might be as symbolic representation.

1. At the first step one maps real partonic 2-surface to its p-adic counterpart by a mere re-interpretation of the defining equation defining a map from real to p-adic world. At the second step the modified canonical identification maps the p-adic 2-surface back to a real 2-surface. This map is unique. If the cutoff p^k is choosen high enough the map maps rational points $p^{rk}m/n$ to their scaled variants $p^{-rk}m/n$.

2. By its continuity the modified of canonical identification would map arbitrary distant points of the real imbedding space (in the sense of having distance which is proportional to a power of p^k) near to each other and would be analogous to a Fourier transform combining data about arbitrary distant points. Above (below) the cutoff the representation is hologram (photograph) like representation of the original 2-surface. The map would assign to the original 2-surface a continuous 2-surface which is not expected to reside in the intersection of real and p-adic worlds. The map between the points of these surfaces is however discontinuous but has long range correlations in the sense that points whose coordinates differ by a power of p^k are mapped near each other. Hence one can regard the map between the original and final 2-surface as a p-adic fractal. Same might apply to the corresponding space-time surfaces. The map takes long length scales to short length scales and vice versa for points for the points with m and n below the cutoff.

3. Also the tangent space distribution of the p-adic partonic 2-surface would be mapped by a canonical identification to give a continuous distribution. In the set of common rational points p-adic continuity could induce p-adic fractality as long range correlations between points for which coordinates differ by a power p^k and short distance chaos. Also the resulting space-time surface could reflect this fractality. One can also construct at the p-adic surface p-adically smooth induced spinor field and map both the 2-surface and the induced spinor field back by the modified canonical identification to obtain spinorial p-adic fractal. Since partonic 2-surfaces in zero energy ontology have components at both future and past boundaries of CD this map can scale down the CD to much smaller CD. Note also the presence of sub-CDs. A possible problem is that the real 2-surface resulting in the proposed map need not be differentiable. If this is not the case the induced gauge fields are not well defined and it might be necessary to pose a cutoff to achieve this.

4. These observations raise some questions. Does also the 4-D space-time surface assignable to the image of the partonic 2-surface obtained in this manner define a hologram like representation of the orginal space-time surface having interpretation as a p-adic fractal? In the case of brain this would mean a prediction for the dynamical evolution based on visual input. Could brain construct this kind of representations of the external world? One can imagine that the following iterative process leads to the final percept. First the visual data about external world define a 2-surface at retina belonging to the intersection of real and p-adic worlds. This surface is mapped by using the proposed map or its suitable variant to a neuronal image in the visual cortex and is partly photograph like and partly hologram like. This image defines in turn a virtual visual input to retina giving again rise to a 2-surface in the intersection. This process continues and leads to an approximate fixed point defining the visual percept.

One can ask whether that cognitive self-maps and maps of the external world at the level of human brain are basically realized by variants of this kind of mappings which can be regarded as p-adic fractals perhaps even at the level of space-time surfaces. We indeed experience our life as narrative and as having a purpose despite the fact that there is micro-temporal chaos which suggests that this kind of maps could define cognitive representations even in 4-D sense. For instance, long periods of life cycle could be mapped to short temporal intervals giving summary of life cycle. Future plans are also included to this map. Interior to exterior mapping could also gives bird's eye of view about entire life perhaps becoming conscious in NDE experiences. The map would provide a holistic view about the geometry of the partonic 2-surfaces defining space-time sheet.

An interesting basic feature of p-adics is that p-adic axis is analogous to non-negative real axis. One can wonder whether this might have something to do with the asymmetry of the future and past with respect to geometric memories. The fact that the evolution of the notion of negative number has required quite a long time might correlate with the fact that the notion of negative p-adic number is not well-defined: if so, the limitations of our instinctive mathematical thinking would directly reflect the properties of the p-adic numbers. The ability to imagine spaces of arbitrary high dimension mathematically might correlate with the fact that p-adic space-time regions can arbitrarily high algebraic dimension (as opposed to physical dimension) as algebraic extensions of the p-adic numbers.

p-Adic cognitive representations should be extremely detailed (but faithful only above some length scale) and contain immense amounts of unconscious-to-us information. Brain research has indeed demonstrated that only part of sensory information is conscious-to-us.

The notion of pinary cutoff

The subset of rationals common to given real and p-adic partonic 2-surfaces might be regarded as a cognitive representation. In the intersection of real and p-adic worlds this number is maximal. The set of all rational points of the real 2-surface is its inherent property measuring its cognitive resources. The number and the average distance between rational points (common to the two surfaces involved) would serve as a measure for the resolution of the cognitive representation.

Number theoretic braids provide a space-time correlate for the finite measurement resolution realized in terms of inclusions of hyper-finite factors at quantum level. The intersection of number theoretic braid with the partonic 2-surface could be identified as a subset of rational points.

The concept of pinary cutoff is crucial for the p-adic counterpart of the Negentropy Maximization Principle [29]. p-Adic negentropy vanishes identically when all entanglement probabilities are rational numbers with a p-adic norm equal to one. The intuitive view is that if the p-adic norm is smaller than one for all p-adic probabilities, then p-adic negentropy must also vanish. This suggests that p-adic negentropy should be defined using $O(p^k) = 0$ for $k > 0$ pinary cutoff. This definition would fix uniquely the notion of subcritical entanglement in the p-adic context.

10.2.5   Quantization phenomena in psychophysics

p-Adicity might provide understanding of some phenomena of psychophysics related to the discrimination between different intensities of stimuli and to threshold phenomena of sensory perception. I am grateful to Robert Gazerro for telling me about these strange effects.

1. When over-learning occurs in tasks involving temporal discrimination, the memory images about the intensity of sensation as a function of stimulus deviates from smooth logarithmic form in small scales by becoming piecewise continuous function [70] such that the plateaus where response remains constant are octaves of each other. This suggests that the memory image about the sensation depends only on the 2-adic norm of the 2-adic image of the ratio I/I_0 of the intensity of the stimulus to the threshold stimulus under canonical identification.

   This observation suggests a generalization inspired by 2-adic version of music metaphor. Primary quale has multiple of cyclotron frequency as its correlate and, being integer valued, is essentially 2-based logarithm of the 2-adic norm for the 2-adic counterpart of the intensity of the sensory input. Hence the increase of intensity of the sensory input by octave correspond to a jumpwise replacement of the n:th harmonic by n+1:th one and should be seen in EEG. Our experience usually corresponds to the average over a large number of this kind of primary experiences so that underlying 2-adicity is smoothed out. In case of overlearning or neurons involved act unisono and the underlying 2-adicity is not masked anymore. At the level of ELF selves this would mean generation of higher harmonic when the number of nerve pulses per unit of time achieves threshold value allowing the amplification of corresponding frequency by the mechanism discussed already earlier.

   There is a an analogous quantization effect related to the discrimination of brightness about which I learned from Robert Gazerro. If one compares brightnesses of object at two subsequent values of time, one can distinguish the brightness difference if the ratio of brightnesses is above 2. If one compares two objects simultaneously, one can distinguish between brightnesses whose ratio even when it is below 2. This would suggest that cognitive memory about brightness is coded by the 2-adic norm of 2-adic counterpart of brightness whereas experience about brightness corresponds to a real number. Note that in case of discrimination of a pitch of a sound situation is different although also now two subsequent frequencies can be discriminated only if they differ by some minimum amount.

2. According to Robert Gazerro, the resolution of the sensory experience seems to be of order $\Delta I/I \sim 1/100$, where I is the intensity of the stimulus. When the signal-to-noise ratio is below roughly 100 visual picture is regarded as having poor quality. The natural order of magnitude estimate for the relative accuracy of p-adic cognition is $\Delta I/I = 1/p$. This number provides also an estimate for the relative accuracy of perception involving real space-time sheets characterized by p-adic prime p. Since $p = 127$ can be interpreted as p-adic prime associated naturally with genetic code, one might think that $p = 127$ is fundamental p-adic prime in living matter. Thus a possible explanation of magic number $\Delta I/I \sim 1/100$ is in terms of 127-adicity.

10.3 Various aspects of cognition

10.3.1 p-Adic physics and imagination

p-Adic non-determinism makes it natural to interpret p-adic space-time sheets as geometric correlates of intentions and cognitions. The wildest vision generalizing the memetics of Susan Blackmore [65] is that the world is full so p-adic space-time sheets serving as geometric correlates for plans, expectations, intentions,etc.. and waiting for their materialization to real space-time sheets. Also new CDs of this kind would be created and disappear in quantum jumps. Quantum field theoretic interpretation for the creation of sub-CDs of this kind would be as radiative corrections so that QFT approach would give also a quantitative approximate view about the situation.

It would be natural to guess that p-adic physics is also physics of imagination but one must very carefully define what this means. It seems that the transformation of the p-adic variants of elementary particles, MEs and CDs to real ones sets only the initial values (with respect to subjective time) of the neural activity leading to a generation of an imagined sensory experience or motor action. If sensory organs are the seats of the primary sensory qualia, one can understand imagined sensory experience as a perception, which does not start from the level of sensory organs but some higher level and gives rise only to cognitive representations. Dreaming and hallucinations would involve a feedback to the primary sensory organs "qualiafying" the cognitive representations. If motor action can be identified as a time reversal of the sensory perception in a relevant time scale for MEs then imagine motor

actions would differ from real ones only in that they would be initiated from some higher level than muscles.

10.3.2   How dreams and hallucinations relate to sensory experiences?

Dreams could be seen as processes in with cognition is transformed into sensory experience. This would mean that the transformation of p-adic space-time sheets to real mind like real space-time sheets initiates a process leading to imagination or dream depending on the situation. Clearly, the generation of dream would be a process reverse to the generation of cognition from sensory experience [32]. If primary sensory qualia are realized at the level of sensory organs, then the reversal process continues down to the level of the primary sensory organs and "qualiafies" the cognitive mental images. Rapid eye movements and otoacoustic sounds would be a signature of this qualiafication. Spontaneous movements during dreaming would in turn be the signature of "qualiafication" of the imagined motor activities. This view about dreams as a de-abstraction process have been represented already earlier and explains nicely the observations of Claude Rifat about lucid dreaming [60]. The strange piecewise logical consistency of dreams is indeed consistent with the p-adic non-determinism. De-abstraction process could be initiated from some higher level of self hierarchy so that dreams could really be messages from higher level selves.

   This view about dreaming is in accordance with the observations (reviewed in [67]) that dreaming is not produced by random inputs from brain stem to cortex but is cognitive skill learned gradually during infancy. The most primitive dreams represent static pictures, then these pictures become dynamical, and at the age of about eight the dreamer becomes a participant of the dream. In lucid dreaming the dreamer has taken active role in transforming cognitive representations to sensory experiences.

   One must actually distinguish between two kinds of "hallucinations": a genuine sharing of sensory mental images involving no "qualiafication" and interpretable as telepathy, and the receival of cognitive information, which is then qualiafied by the receiver like during dreaming. The presence/absence of a feedback to the sensory organs allows to discriminate between these options. The semitrance model for the bicameral mind is based on the idea that these experiences are communicated by higher levels of the self hierarchy during semitrance. This communciation could be purely telepathic.

10.3.3   Are cognitive representations generated from sensory input?

Brain certainly generates symbolic representations from the real sensory input and from p-adic cognitive representations. Essentially a transformation of action to intention and of a real symbolic representation to a p-adic cognitive representation would be in question.

1. The transformation of action to intention could be seen as (subjective) time reversed volition. This kind of process could serve as a healing and error correction mechanism.

2. The experience of understanding accompanies naturally p-adic-real negentropic entanglement. The transformation of symbolic representations to cognitive ones might be needed for the purpose of understanding. More generally, meaning might result only via the symbolic to cognitive transformation.

3. Symbolic representations could be enough to decompose the world to objects and actions. Objects and actions would naturally correspond to real space-time sheets serving as correlates for mental images (sub-selves). On the other hand, one might argue that the ultrametricity of the p-adic topology making p-adic world 'granular' might be essential for this decomposition into objects. A possible fundamental definition for an spatiotemporal object could be as a region of p-adic space-time for which integration constants of field equations are genuine constants. This granularity should have also real counterpart and p-adic fractality, possible realized as the invariance of the union of partonic 2-surface under the variant of canonical identification $m/n \rightarrow I_k(m)/I_k(n)$ already discussed, is a good candidate for this correlate.

10.3.4   Cognition, sensory experience, and Boolean mind

Thoughts have not color and pure thoughts seem to be free of emotions, with aesthetic experiences induced by abstract ideas being perhaps an exception. Pure thoughts involve often the experience

that something is true or false but not beautiful or ugly or right or wrong. These simple observations provide tests for the identification of the p-adic physics as physics of cognition and for the model of sensory qualia, Boolean qualia, and emotions. These observations also lead to a concrete identification of the physical realizations for the Boolean algebras of ethics, aesthetics, and logics.

Does cognition have colors?

Sensory qualia have been identified as averages of quantum number increments associated with the quantum jump sequence defining the subself representing sensory mental image. Quantum number increments relate to the quantum fluctuating configuration space degrees (WCW) of freedom. The difficulties related to the definition of p-adic integral are magnified in infinite-dimensional context. Unless one can reduce to integral to a sum or to an algebraic continuation of its real counterpart in the intersection of real and p-adic worlds, one must assume that wave functions have discrete locus also in p-adic WCW degrees of freedom.

If complete localization occurs in all p-adic configuration space degrees of freedom in each quantum jump, these degrees of freedom are purely classical and one cannot even speak of quantum number increments in p-adic WCW degrees of freedom. There would be no p-adic variants of sensory qualia and cognition would be colorless. All p-adic configuration space degrees of freedom would be geometric degrees of freedom in the classical sense of the word.

One must of course take this kind of arguments very cautiously since the real mathematically rigorous formulation of p-adic TGD in WCW degrees of freedom is lacking and also because the assumption of this kind of asymmetry does not conform with number theoretical universality. The possibility to use algebraic continuation might allow the perturbative formulation of the p-adic TGD around the real maxima of Kähler function in the intersection of real and p-adic worlds and p-adic WCW could be actually defined in this manner by algebraic continuation.

Does cognition involve emotions?

It is a fact of neuroscience that emotions and information are closely related [72]. I have considered two views trying to mathematisize this finding.

1. Emotions could correlate with the rates of change for the entropies associated with various quantum number increments in quantum jump sequence determining self. If there are no quantum number increments in p-adic WCW of freedom, corresponding emotional component is absent from cognition. In p-adic contex the definition of rate of change for entropy is possible only if the p-adic value entropy is mapped to its real counterpart by canonical identification. Without this map one cannot assign emotions to $p - p$ type entanglement.

2. Emotions could also correlate directly with the negentropy of the entanglement. Negentropic subselves would define mental images with positively colored emotions and entropic ones those with negatively colored emotions. In this case positive emotions -perhaps experience of understanding- would be associated with p-adic real entanglement and quite generally with $p_1 - p_2$ entanglement for different p-adic primes p_i. For entanglement diagonal with respect to number field also entropic entanglement would be possible [29].

A naive view about three dichotomies

Beautiful/ugly, right/wrong, and true/false dichotomies relate to the comparison of experience with some standard. Beautiful/ugly relates to sensory experience, right/wrong characterizes deeds, and true/false logical statements. What comes in mind that these dichotomies could be interpreted as Boolean qualia assignable to quantum jumps in purely fermionic degrees of freedom.

1. The first guess is that these dichotomies could reduce to negentropic/entropic dichotomy. If this makes sense, one can consider the following kinds of qualia of this kind corresponding to entanglements of type $R - R$, $p - p$, $R - p$, and $p_1 - p_2$. For the first to kind of entanglements the emotional coloring could be either positive or negative. Could beautiful/ugly characterize space-like diagonal entanglement with R-R and p-p corresponding to sensory beauty and beauty of idea? Could right/wrong dichotomy correspond to time-like R-R and p-p entanglement (deeds

and intentions)? For the non-diagonal entanglement the emotional coloring would be always positive and this might relate to experience of understanding.

2. This identification does not explain true-false aspect. The very naive idea is that the reality is the positive standard which which to compare in case of p-adic quantum states. If so then p-adic quantum states should be compared with reality. If the phase transition transforming the quantum state to its real counterpart is possible then one can assign to the p-adic quantum state the characteristic 'true'. This is certainly not the case if entanglement is genuinely padic and thus entropic so that also now the dichotomy would reduce to negentropic/entropic dichotomy.

10.3.5   Replication of memes, and morphic fields

The notion of quantum teleportation is one of the ideas accompanying the development of the theory of quantum computation. The notion of p-adic teleportation suggests itself very naturally as a more flexible mechanism of teleportation. p-Adic teleportation in fact provides a model for the replication of memes and Sheldrake's morphic fields can be seen as a generalization of memetics in this framework.

Replication of p-adic cognitive representations

Memes are in central role in the theory of Susan Blackmore [65] and p-adic space-time sheets are excellent candidates for memes understood in a more general sense. Contrary to the vision of Susan Blackmore, memes would be conscious selves rather than unconscious deterministically behaving objects, and brain would not be an un-conscious machine used by memes but serving as conscious transformation vehicle materializing cognitive representations to real action and vice versa.

Although the notions of the meme and meme replication are very attractive, the mechanism of imitation is only partially known. The so called mirror neutrons are certainly an important of it. In the p-adic context learning by imitation could be understood as a two-step process. First of all, a high-level p-adic cognitive representation is formed as in sensory perception. Secondly, this representation is transformed back to motor action to yield an imitation. Thus it could be that the enhanced ability to generate p-adic-to-real transformations in prima vista manner distinguishes between humans and other species.

Time reversed cognition and reverse speech

Time reversed cognition and reverse speech are interesting phenomena allowing possibility to test the theory.

1. Time reversed cognition

Time reflection yields time reversed cognitive representations. The interpretation is as representations of intentions if the sign of energy is negative. Also spatially reflected cognitive representations could result in spatial reflections. Same applies to symbolic representations. The observation of these representations could serve as a test of the theory. There is indeed some evidence for this rather weird looking time and spatially reversed cognition.

1. I have a personal experience supporting the idea about time reversed cognition. During the last psychotic episodes of my 'great experience' I was fighting to establish the normal direction of the experienced time flow. Could this mean that for some sub-CDs the standard arrow of time had reversed?

2. The occurrence of mirror writing is well known phemonenon [61]. Spatial reflections of MEs are also possible and might be involved with mirror writing.

3. Reverse speech would be also a possible form of reversed cognition. Time reversed speech has the same power spectrum as ordinary speech and the fact that it sounds usually gibberish means that phase information is crucial for storing the meaning of speech. Therefore the hypothesis is testable.

2. Reverse speech

Interestingly, the Australian David Oates claims that so called reverse speech is a real phenomenon [68], and he has developed entire technology and therapy (and business) around this phenomenon. What is frustrating that it seems impossible to find comments of professional linguistics or neuro-scientits about the claims of Oates. I managed only to find comments by a person calling himself a skeptic believer but it became clear that the comments of this highly rhetoric and highly arrogant commentator did not contain any information. This skeptic even taught poor Mr. Oates in an aggressive tone that serious scientists are not so naive that they would even consider the possibility of taking seriously what some Mr. Oates is saying. The development of science can often depend on ridiculously little things: in this case one should find a shielded place (no ridiculing skeptics around) to wind tape recorder backwards and spend few weeks or months to learn to recognize reverse speech if it really is there! Also computerized pattern recognition could be used to make speech recognition attempts objective since it is a well-known fact that brain does feature recognition by completing the data into something which is familiar.

The basic claims of Oates are following.

1. Reverse speech contains temporal mirror images of ordinary words and even metaphoral state-ments, that these words can be also identified from Fourier spectrum, that brain responds in unconscious manner to these words and that this response can be detected in EEG. Oates classifies these worlds to several categories. These claims could be tested and pity that no pro-fessional linguist nor neuroscientist (as suggested by web search) has not seen the trouble of finding whether the basic claims of Oates are correct or not.

2. Reverse speech is complementary communication mode to ordinary speech and gives rise to a unconscious (to us) communication mechanism making lying very difficult. If person consciously lies, the honest alter ego can tell the truth to a subself understanding the reverse speech. Reverse speech relies on metaphors and Oates claims that there is general vocabulary. Could this taken to suggest that reverse speech is communication of right brain whereas left brain uses ordinary speech? The notion of semitrance used to model bicameral mind suggests that reverse speech could be communication of higher levels of self hierarchy dispersed inside the ordinary speech. There are also other claims relating the therapy using reverse speech, which sound rather far-fetched but one should not confuse these claims to those which are directly testable.

Physically reverse speech corresponds to phase conjugate sound waves which together with their electromagnetic counterparts can be produced in laboratory [43, 52]. Phase conjugate waves have rather weird properties due the fact that second law applies in a reversed direction of geometric time. For this reason phase conjugate waves are applied in error correction. TGD based description of both electromagnetic and sound wave phase conjugation is based on negative energy space-time sheets representing classically electromagnetic fields and Z^0 fields [21].

Negative energy topological light rays are in a fundamental role in the TGD based model for living matter and brain. The basic mechanism of intentional action would rely on time mirror mechanism utilizing the TGD counterparts of phase conjugate waves producing also the nerve pulse patterns generating ordinary speech. If the language regions of brain contain regions in which the the arrow of psychological time is not always the standard one, they would induce phase conjugates of the sound wave patterns associated with the ordinary speech and thus reverse speech.

Space-time sheets near vacuum extremals are especially interesting biologically since they are maximally critical [41]. Maybe the criticality is a prerequisite of criticality with respect to the reversal of the arrow of psychological time. For vacuum extremals classical Z^0 field is non-vanishing and em field is proportional to it: $\gamma = -sin^2(\theta_W)Z^0$. The large electroweak symmetry breaking in living matter could be due to the classical Z^0 fields generated by dark matter identified in terms of the macroscopic quantum phases with so large value of Planck constant that Compton lengths of weak gauge bosons are of order cell size scale or even longer. If sound waves correspond to space-time sheets near vacuum extremals, the corresponding em fields are proportional to Z^0 fields unless Weinberg angle vanishes for them (this might be due to the absence of electroweak symmetry breaking). This encourages to ask whether Z^0 MEs could serve as space-time counterparts of sound waves so that the strength Z^0 electric field could determine the amplitude of sound wave.

A connection with the ideas of Sheldrake

In [26] I have discussed a possible TGD based justification of Sheldrake's ideas about learning at the level of species. The discussion can be easily rephrased in terms of p-adic cognition and p-adic teleportation and leads to a more detailed variant of the original model.

If one assumes that memes correspond to p-adic cognitive representations, that the replication of memes by zigzag mechanism is possible, and that MEs involved can have even sizes of order Earth size, it is not too difficult to imagine how species memory could be realized. p-Adic space-time sheets take the role of the morphic fields in TGD framework and represent habits, skills, ideas,... Susan Blackmore would call these morphic fields memes but basically only a naming convention and generalization is in question (amusingly, skeptics honourize Sheldrake as a pseudoscientist but Blackmore as a serious scientist, perhaps because she has empasized her skepticism in the publicity!).

The meme associated with the development of a particular skill could be realized in a particular brain and replicate itself. When the replicas would encounter other brains of the same species by p-adic teleportation, the skill could be manifested as a real action and lead to learning without direct the mediation of a direct sensory communication. Sheldrake's theory thus generalizes memetics and thus make Sheldrake pseudo scientist. That a given meme could be realized only in brains of the same species might be understood in this framework by using resonance argument: morphic resonance is the notion used by Sheldrake. It is also possible that stochastic resonance [45] to be discussed later in more detail could be involved with the morphic resonance. The individuals that learned the habit first, need not even live anymore since p-adic memes remain and replicate by zigzag mechanism even when the physical body dies. Amusingly, TGD predicts that the memes could travel also in the direction of geometric past so that also the geometric past could learn the skill! Creativity would obviously correspond to the p-adic non-determinism. Memes are continually changing and those which are transformable to real action are realized and correspond to discoveries.

10.3.6   Learning

There are many forms of learning. Although the learning by associations is perhaps the simplest form of learning, even logical reasoning might be basically rely on sequences of associations. Learning by trial and error is second mode of learning. Imitation in in turn a higher, essentially social, form of learning. Susan Blackmore believes that imitation is a characteristically human form of learning and sees imitation as a replication of memes. There is however evidence that also animals are able to imitate although imitation is certainly not the dominating form of learning. p-Adic teleportation already discussed could be fundamental mechanism in this kind of learning. Learning as construction of cognitive models is basic view of Piaget and of constructivists and fits nicely with the idea about p-adic physics as physics of cognition.

Associative learning

It is not clear whether there is any need to assign any cognition to these associations when they occur completely automatically. The p-adic representations, if needed at all, for these associations $A \rightarrow B \rightarrow ...$ could be regarded as a space-time sheet consisting of deterministic pieces representing A, B,... Perhaps the learning of rules $A \rightarrow B$ about the behaviour of the external world might correspond to establishment of this kind of p-adic cognitive representations. The generation of a model of the external would could also correspond to a formation of much more detailed p-adic space-time sheets for which p-adic pseudoconstants are gradually transformed to genuine constants. Only very limited amount of information about this p-adic world model need become conscious.

Trial and error

At least higher level learning involves an evolution of a cognitive model. Learning by trial and error is a good example of this. The naive expectation is that p-adic cognitive representation can be transformed to real action if p-adic pseudoconstants are actual constants. If this is true, then the learning of a skill by trial and error can be understood as a gradual development of a p-adic cognitive representations such that p-adic pseudo constants become genuine constants. This is in accordance with the fact that if skill is well-learned, a 'flow-state' in which performance is almost unconscious and occurs 'naturally'

results. The testing of the learned skill serves obviously as a feedback loop modifying the cognitive representation. This means changing the values of the pseudo constants of the imagined p-adic action.

Constructivism

The basic vision of constructivism is that higher level learning means gradual construction of cognitive representations, maps or schemes. This means that the world is seen as consisting of objects and events classified into categories having mutual relations. Also a dynamical model of world involving rules for the behaviour of the world develops. The ultrametricity of the p-adic topology was proposed already by Parisi [48] to make possible classification of objects into categories. p-Adic pseudoconstants define a natural division of p-adic space-time sheets into four-dimensional objects (events). The emergence of the causal models is automatic and due to the fact that p-adic physics obeys the same field equations as the real physics.

   Piaget entered by empirical means to his model of learning which is rougly the following.

1. The first two life years correspond to a sensorimotor period during which childs builds a set of concepts about world and a model for how it works. During this period sensory world and real world are identified (child believes that the object does not exist if it is not in the visual field). This period could be identified as period for the formation of symbolic p-adic cognitive representations coding layman physics in terms of p-adic physics for cognitive images of real world objects.

2. During pre-operational stage (2-7 years), child is not yet able to conceptualize abstractly and needs concrete situations.

3. During the period of concrete operations (7-11 years) the child starts to conceptualize, creating models that explain her physical experiences. Abstract problem solving becomes possible: for instance, mathematical equations can be solved with numbers, not just by using concrete objects (say counting by fingers).

4. During the period of formal operations (11-..) the cognitive abilities of child are like those of adult. For instance, abstract reasoning and formal problem solving of mathematical equations using abstract variables rather than only numerical values becomes possible.

   Various stages in the development could be seen as gradual establishment of p-adic cognitive representations based on reality testing leading gradually to relatively stable and realistic cognitive representations.

Social aspects of learning

The social aspects of learning are certainly of utmost importance and higher level learning can be also seen as a fundamentally social phenomenon. The notion of self-hierarchy suggests that learning process occurs at several levels of self hierarchy simultaneously and involves communications between various levels. For instance, the learning of social behaviour and development of a model of self as seen by others might involve this kind of interactions in an essential manner. Imitation can be seen as an important mechanism of social learning: Susan Blackmore raises meme replication as the fundamental process instead of learning. Sheldrake's morphic fields would make possible even more general form of learning. As far as p-adic cognition is considered, the same mechanisms are at work at each level and p-adic teleportation makes in principle possible both meme replication and the learning at the level of species.

10.3.7   Some special aspects of cognition from p-adic point of view

In the following some basic aspects of cognition like the formation of concepts and classification into categories, long term memories, logical reasoning, and problem solving are discussed.

Formation of concepts

The most natural model for the formation of concepts is as temporal ensembles of sufficiently similar mind like space-time sheets (real or p-adic) defining an ensemble of sub-sub-selves experienced as average subself (mental image). The idea about concept as average is is accordance with the fact that conceptual thinking emerges gradually when child gathers experiences.

The observations of Claude Rifat [60] about lucid dreaming suggest that lucid dreaming is a de-abstraction process in which lucid dreamer goes one level lower in self hierarchy and experiences the instances giving rise to a particular concept as separate mental images. For instance, the experience of this kind could consist of a set of clocks seen by the subject person during some period of his lifetime. This transformation would involve also p-adic-to-real phase transition transforming cognitive representation to sensory image.

The basic question is whether conceptualization in the sense of classification and averaging can occur both at real and p-adic level. If one assumes that the world of pure sensory experience does not consist of objects, then concepts emerge at cognitive level only and are averages over p-adic sub-selves forming of p-adic subself. The averaging of purely sensory experiences represented by real mind like space-time sheets would not give rise to anything useful in this picture. A more general view is objects correspond to sub-selves of subself, and that concepts make sense at both cognitive and sensory level. At sensory level emotions could be the counterparts of concepts and emotional intellect would correspond to emotional conceptualization. Emotions indeed represent in a well-defined sense the average color of a pixel in a picture containing large number of pixels. Thus cognition-emotions dichotomy would correspond to the p-adics-reals dichotomy.

How cognitive are long term memories?

It is known that purely visual memories have a very short duration whereas conceptualize visual scene consisting of objects can be remembered for much longer time. This suggests that long term memories are realized as p-adic space-time sheets rather than real sensory space-time sheets. This would also explain why our sensory experience is located around a definite value of geometric time whereas as conceptual memories are scattered around entire life cycle. There are however also episodic, almost relived long term memories and these memories could be perhaps regarded as genuine multitime sensory experiences perhaps resulting in p-adic-to-real transformations of cognitive space-time sheets responsible for conceptual memories.

Of course, p-adic cognitive representations in principle make possible to scale down of the conceptual representation of the entire life cycle in a fraction of second and it is an open question whether conceptual memories result as averages of the p-adic sub-sub-selves over life cycle or whether temporal p-adic scaling contracting the lifehistory to a pocket size could be involved. p-Adic fractality suggests the possibility of this kind of hologram like representation.

Reasoning based on temporal logic

p-Adic space-time surfaces allow representations of the temporal logic as rules of type $A \to B$. Various instances A could be represented symbolically as standard irreducible pieces of the p-adic space-time surface characterized by genuine integration constants. Logical reasoning could be based on the generation of this kind of surfaces. Reliability could be achieved by using ensembles of this kind of surfaces representing causation sequences $A \to B \to ....$ [41]. Replication of cognitive representation by the zigzag mechanism could generate ensembles of memes. These sequences are by no means stable and can change in quantum jumps. Thus some kind of stabilizing mechanism is required. Perhaps some kind of reality testing mechanism based on sensory input is at work. Logical consistency is a higher level test of this kind.

Problem solving

p-Adic cognition suggest a formal definition for the problem solving as a process in which one tries to find a p-adic space-time surface connecting initial p-adic space-time surface with the final one. This surface is constructed using some rules. In case of a learned skill this space-time surface corresponds to p-adic constants which are genuine constants and thus realizable as real space-time surface by phase transition. In case of a mathematical proof the p-adic space-time surface would perhaps be constructed

from standard pieces (symbols) with genuine integration constants representing symbolically the steps of the deduction sequence and using the rules $A \rightarrow B$ of the cognitive model of the mathematical system. A mouse in a maze might construct and memorize by trial and error a p-adic cognitive representation of the maze with rules stating which branchings lead to a dead end.

10.4 Frontal lobes and p-adic physics

p-Adic quantum entanglement with a positive entanglement negentropy is possible and is stable against self measurement if NMP holds true. This very encouraging finding suggests that cognition is necessarily p-adic. For instance, it becomes possible to understand what it is to understand! To have an experience of understanding is to have a p-adic subself (cognitive mental image) with a positive entanglement negentropy.

Frontal lobes are regarded as seats of the highest mental functions such as cognition, intention, volition, attention, evaluation of actions, self model, and perception of and reaction to social situations. Long term memory and language are largely independent of frontal lobes whereas working memory can be located to the dorsolateral parts of prefrontal lobes. Thus the concrete model both p-adic physics of intention and cognition might boil down to a model of frontal lobe function: presumably also the notion of field body and magnetic cognitive canvas are needed to understand the highest levels of the control. In particular, social control could be performed basically by the multibrained collective selves by activation of social habit routines as suggested by the fact that the persons who have lost these routines are able to deduce the correct social behaviour.

10.4.1 Basic functional anatomy of frontal lobes

Frontal lobes involve the most complex association networks of brain. In fact so complex, that the diagostics based on simple reflex schema and the idea about exact locations of mental functions applied to subjects having serious frontal lobe damage suggested that frontal lobes have no function at all! Only a view in which brain is regarded as self-regulating and self-organizing system allowed to develop diagnostic tools revealing the effects of frontal lobe damage.

Dorsolateral frontal lobes seem to be specialized with various aspects of cognition such as problem solving, judgement, reasoning, and discrimination. In particular, what is identified usually as working memory is located here. These areas are also involved with imagination and corresponding loops extend to sensory areas. In TGD framework dreams can be seen as a particular kind of imagination in which imagined sensory features are mapped to the magnetic sensory canvas.

The medial and ventral frontal lobes are involved with intention, planning, volition, and attention. These regions are also crucial for the routine perception of and reaction to social situations. Affect and motivation are crucial concepts here and the complex circuits connnecting frontal lobes, amygdala/brain stem and cortex are essential for planning and decision making. Salience detection or rather, selective amplification of those aspects of percepts which are significant seems to be basic function of these loops. The lesion for these loops implies effective loss of volition as well as emotional flatness.

Phineas P. Gage is a classic example of a person with serious damage for the circuits. He did not lose either his intellectual abilities nor memory but lost the ability of planning and the access the previously acquired social conventions and rules, and became childish and irresponsible. Gage was also well aware that he did was not anymore able to react emotionally. Gage was also able to use to theoretically deduce what would be the appropriate behaviour in social situations but in everyday life this was impossible.

These findings suggest that frontal lobes perform high level control and habit routines are the basic tools of cognition and planning, and that frontal lobes both active, generate, modify and replace these habit routines by new ones. Using brain as computer metaphor one might say that working memory provides the initial values of the parameters of the habit routines.

10.4.2   Some neurophysiological findings related to the functioning of frontal lobes

The notion of cortical tone characterizes the state of cortex and is maintained by CNS. In so called inhibitory phase state the tone is low and brain responds with similar response to both strong and weak stimuli. This phase is also called equalization phase. In paradoxal phase weak stimuli can give rise to strong responses and vice versa. In this state no organized thought appeares and selective associations are replaced by non-selective and more or less random associations. REM sleep is regarded as an example of paradoxal phase. The interaction between medial frontal lobes, reticular activating system and cortex controls the cortical tone.

Gray Walter found that any expectation elicits characteristic slow waves emanating from frontal lobes and spreading to other regions. Expectancy wave diminishes if the the probability of expected signal diminishes. When the instruction that elicited the expectation states is negated, the wave ceases. Similar wave phenomenon is detected during concentration, say during an attempt to solve a complex mathematical problem. The interpretation as a correlate for binding by quantum entanglement suggests itself.

Orienting reaction is a vegetative and electrophysiological reaction to stimulus. Constriction of the vascular system to the arms, dilation of the vascular system to the head, galvanic skin changes and alpha wave amplitude reduction are involved. Habituation to the simulus reduces orienting reaction. Orienting reaction can be however increased and stabilized by verbal instruction that links meaning to the stimulus. If frontal lobe lesion affects attention, the orienting reaction fails to be stabilized by this mechanism. The interpretation is that for polar, medial and mediobasal section of the frontal lobe, the physiological tools for the regulation of attention are deranged.

10.4.3   TGD based view about frontal lobes

The TGD based model for how frontal lobes cognize forces some new interpretations of classic experiments. Also a new view about working memory is unavoidable.

Paper, pencil, and eraser metaphor

The unability to modify existing routines or replace them with new ones rather than loss of these routines seems to accompany the lesions of ventromedial frontal lobes. Or more precisely, new routines can be acquired but instantaneus replacement of active routines with new ones is not possible. In a classic experiment already performed by Pavlovian school a person having a frontal lobe lesion in the ventromedial area started to plane an plank and continued until there was no plank anymore and continued ot plane the bench. In the so called Wisconsin card sorting test the subject is presented with a series of stimulus cards and a deck of response cards. The cards bear coloured geometric patterns and can be matched by categories such as colour, form or number. The experimenter selects category but does not inform subject person who guesses rapidly the category by trial and error. After ten cards experimenter changes the category without informing the subject person about the change. Patient is not able to revise his strategy and continues to make wrong guesses.

These persons can adopt strategy but cannot change it. This is something very essential. The proposed interpretation is however that these persons do not have motor imagination and therefore cannot construct new habit routine. This seems to be wrong since in the beginning card experiment the subject was able to achieve this. Something more delicate is involved: patient is not able to replace an activated strategy with a new one instantaneousy The activated strategy however becomes deactivated spontaneously sooner or later.

This leads to pencil, paper, and eraser metaphor as a model for what frontal lobes are doing. Creation of habit routines is creation of symbolic representations and frontal lobes both create and erase habit routines just as we do when we do our calculations or type text to computer file. The patient with dorsolateral frontal lobe lesion must wait until the erasure happens spontaneously to establish a new habit routine. Of course, stucking into habit routines seems to a part of human condition, in particular at the old age.

Interestingly, during psychedelic experiences frontal lobes are very active. Habit routines are what one gets rid in these experiences and also during meditation. The interpretation would thus be that a very intense erasure of old and generation of new habit routines is going on.

Working memory quantum mechanically

The notion of working memory does not seem to be an appropriate concept in TGD framework. The proper interpretation seems to be as erasure and replacement mechanism for habit routines. Short term geometric and subjective memories are automatic side products. Mirror mechanism is also now the natural mechanism for geometric memories but one cannot exclude the interpretation of working memory as subjective memory. Note that it does not make sense to construct long term memory representations of all intermediate stages of habit routine construction (just as it does not make sense to publish all intermediate and often erratic stages of a long mathetical calculation).

Erasure and replacement mechanism corresponds in spin glass metaphor to the kicking of the system out from the bottom of a potential well. In quantum framework this means a formation of a delocalized state in zero modes followed by a localization to the bottom of some other potential well representing the new habit routine. Delocalized states in zero modes are however not possible. Rather, a generation of a bound state implying a temporary transformation of the zero modes in question to quantum fluctuating macroscopic quantum degrees of freedom is required. This is the TGD counterpart of Penrose-Hameroff mechanism. State of oneness, quantum computing macro-temporally qcoherent system, moment of consciousness effectively lasting very many quantum jumps: all these characterizations apply to the resulting state.

The creation of new habit routine might even mean the changing synaptic connections. This would mean a multiverse state of multineuron system with different synaptic strengths such that one of these states is selected when the bound state decays. Interestingly, it is known that the synaptic connections related to the somatosensory representations of rat's whiskers change in an incredibly short millisecond time scale. The explanation as a macroscopic quantum effect strongly suggests itself.

Also quantum superposition of entangled axons with varying membrane potentials near axonal hillock and thus with a varying firing probability could be considered. Also the ends of axons might be in entangled quantum superposition: Ca^{++} waves and sol-gel transition might be involved.

Cognitive quantum computation like processes at neurolevel

If one assumes that an eigenstate of the density matrix or of the negentropy operator results in self measurement, the system must end up to an entangled state corresponding to some eigenspace of the density matrix. The requirement that the increase of entanglement negentropy is maximal, fixes this eigenspace uniquely. For the resulting state density matrix is proportional to unit matrix and entanglement negentropy is maximal $N_R = Nlog(p)$, when the number of states is $n = p^N n_0$, n_0 not divisible by p, $N > 0$: otherwise it vanishes. Quantum computers indeed operate with systems for which entanglement probabilities are identical. A very strong prediction is that the dimension of the state space should be divisible by p^N.

A possible neurolevel realization of a cognitive quantum computation is following.

1. Information is represented as a sequence of p-adic and real memetic qupits along axon. If the effective phase velocity ofME is sufficiently low quite high number of qupits can be realized as already found. Incoming p-adic and real memetic codewords can be taken to be identical un-entangled sequences of p-adic and real memetic codewords. The unitary time development is discrete with a time step of 1/1270 seconds and lasts an integer multiple of $T_2(127) = .1$ seconds (127 steps). Thus the minimal quantum computation involves $2^{127} - 1$ quantum jumps effectively glued to a single quantum jump by macro-temporal quantum coherence. The outcome of the cognitive self-measurement is a pair of memetic codewords representing the initial memetic codeword and the result of the cognitive quantum computation.

2. A conscious experience results, when the spin directions of the real oddball qubits flip to the direction of the external magnetic field at the cell membrane space-time sheet. The spatial sequences of qubits in the direction of the magnetic field are excluded because these states do not give rise to any spin flips. In this manner a quantum computer with $p = 2^{127} - 1$ results. The spin flips of the real qubits induce MEs which in turn induce membrane oscillations and perhaps even nerve pulses.

10.4.4   Goal structures and emotions

Daniel Pouzzner has proposed quite an interesting theory of emotions relating most emotions to cognitive models and goal structures [71]. Goal structures are also cognitive models assumed to have correlates at the level of neurophysiology.

Quite many emotions originate basically from comparisons of expectations or goals with reality and Pouzzner's model of emotions relates emotions to the dynamics of the goal structure. The failure to reach a goal or giving up a goal is accompanied by a disappointment or sadness; realization of a goal is accompanied by a feeling of success; fear or rage is experienced when the achievement of a goal is threatened. The failure of a model is accompanied by a surprise; the success of a model which has been questioned by experience involves a feeling of relief; etc..

There are of course exceptions: for instance, physical pain and pleasure, excitement, love and perhaps also pure rage without any object. The basic question is whether the comparison type emotion accompanies inherently comparison or whether emotions as such have nothing to do with comparisons and brain has only evolved to associated emotions to comparison results to guide the behaviour. In the model of Pouzzner the latter view is adopted and various neurotransmitters are identified as correlates of emotions. The problem is to understand how cognitive models and goals could be represented in real physics.

In TGD framework negative emotions relate to the increase of the entropies associated with various quantum number and zero mode increments defining qualia and are automatically generated by quantum decoherence. There are no emotions associated with cognitive (p-adic) degrees of freedom unless one counts the experiences of understanding and lack of it as emotions. Positive emotions relate to the decrease of these entropies. The formation of negentropic generating sub-selves are obviously excellent candidates for quantum correlates of positive emotions. The challenge is two-fold.

1. Construct a concrete model for intentions and goal structures analogous to the model of long term memories.

2. Develop a model for the comparison process explaining why a quantum coherent subself results if the mental images about the predicted and actual states of the world are nearly identical and decohering subself results if these mental images are too different.

p-Adic model of goal structures

The models for geometric memories and intentions should be very symmetrical the basic difference being that real numbers are replaced by p-adics and geometric past with the geometric future in the model for intentions. This has nontrivial implications.

1. Intentions and goals should correspond to time like p-adic entanglement of the brain of the geometric now with the brain of the geometric future.

2. It should be possible to speak about intention fields characterizing various brain cells according to how long is the temporal distance T to the event of the geometric future representing the intention. The cells corresponding to the highest values of T should be found in frontal lobes.

3. p-Adic counterparts of the gravitational MEs should be the entanglers unless one allows necessary negentropic entanglement between real and p-adic systems. Perhaps the transformation of real gravitational MEs emitted by systems with spin glass degeneracy to p-adic ones can occur routinely.

In TGD cognitions and intentions should appear also at brain level and have definite correlates. A good first guess is that cognitive representations are realized using memetic code in terms of MEs (of course, also em MEs might be involved). The construction of the symbolic representations means the transformation of the p-adic MEs to real ones. The real MEs in turn induce further symbolic representations in terms of time varying quark magnetization and cell membrane oscillations or nerve pulse patterns.

How comparison type emotions could result?

The challenge is to understand how comparison type emotions could result from the comparison of a p-adic cognitive model with the reality. What is needed is a concrete model for the comparison process.

1. The information about real world state is provided by sensory input represented as real sub-selves whereas the prediction of the cognitive model is represented by a p-adic subself. Therefore the real subself representing the relevant data must be transformed to a p-adic subself. Or alternatively, cognitive subself must be transformed to a symbolic subself. Both transformations presumably occur and correspond to different comparison processes with different outcomes at the level of conscious experience. The fact that p-adic physics should not give rise to emotions plus the assumption that brain performs the comparison more or less automatically, favours the comparison of the real mental images realized in terms of nerve pulse patterns. It allows also to understand why emotions have definite neurophysiological correlates.

2. The comparison of symbolic (real) sub-selves generates an emotion: if two sub-selves are identical, the emotion is positive. If they are too different, the emotion tends to be negative. In the comparison process the nearly identical real sub-selves representing the mental images to be compared should be able to form a negentropically entangled state with a high probability and this would give rise to a quantum coherent state accompanied by positive emotion. Too different sub-selves should not form negentropic state at all. The increase of the various entropies of the unbound mental images quantum jump by quantum jump should give rise to an emotions with a negative coloring.

3. In p-adic context the formation of a state with positive negentropy should give rise to an experience of understanding rather than positive emotion. The experience of understanding or lack of it would result in a comparison process in which a real mental image representing real world is transformed to a cognitive one and compared with a p-adic mental image representing a prediction of a cognitive model.

Comparison process at neuronal level

The fundamental comparison giving rise to comparison type emotions should be between nerve pulse patterns representing symbolically the mental images. Nerve pulse patterns define association sequences, that is temporal sequences of space like 3-surfaces with time like separations analogous to the words in a sentence. There should be some kind of resonant interaction between two nearly identical nerve pulse patterns giving rise to bound states.
   One can imagine two mechanisms.

1. Transversal negative energy MEs created during the generation of the nerve pulse might give rise to a bound state interaction between nerve pulse patterns propagating in parallel axons.

2. The second candidate for the resonant interaction relies on the TGD counterparts of non-Hertzian scalar waves.

Both mechanisms could generate metabolic energy by buy now-pay later mechanism and the observed anomalously low oxidative metabolism during syncrhonous firing could be due to this mechanism.
   The non-Hertzian option deserves a more detailed discussion.

1. TGD predicts a huge family of electret type solutions dual to magnetic flux tubes characterized by a constant density of Kähler action. Living matter is indeed full of liquid crystal electrets, cell membrane being the basic example.

2. The solution family contains also counterparts of the non-Hertzian scalar waves of Tesla. These solutions represent a pulse of electric field having a finite duration and spatial extent and resemble MEs in the sense that they correspond to a finite space-time sheet moving with light velocity. Electric field is in the direction of propagation and almost constant.

3. Non-Hertzian scalar waves are believed to be generated by short but very strong pulses of electric field. Nerve pulses certainly satisfy these criteria and could thus create scalar waves propagating in directions orthogonal to axons and inducing a resonant interaction between two nerve pulse patterns in parallel axons. This suggests that the comparison of two sub-selves could involve join along boundaries bonds defined by negative energy scalar wave space-time sheets between parallel bundles of nerve fibers. Topologically this mechanism would not differ from that based on negative energy MEs. If the nerve pulse patterns are identical, the scalar waves give rise to a maximum number of join along boundaries bonds responsible for the resonant interaction and representing the bound state energy. Neural synchrony in millisecond time scale plus millisecond duration for the nerve pulses might be enough to guarantee that this interaction mechanism works.

4. The energies involved would correspond to kHz scale and correspond to gravitational binding energies for cell sizes structures: note that non-Hertzian scalar are accompanied by anomalously strong classical gravitational fields due to the facts that classical gravitational field couples to classical field energy 10^8 times stronger than to ordinary matter and that scalar wave space-time sheets carry very strong classical gravitational field at their boundaries.

10.4.5 Experimental support for binocular rivalry as a quantum phenomenon

For years ago I constructed a quantum model for binocular rivalry and generalized it to a general model of volitional act as a quantum jump selecting not only between alternative motor actions but also between percepts. In this model different alternatives were represented as superpositions of neural firing patterns. The model allows to see sensory perception as an active volitional process (at some level of hierarchy of selves) and explains sensory rivalry as a quantum phenomenon.

The work of Efstratios Manaosakis

I learned from New Scientist [59] that physicist Efstratios Manousakis has now published an interesting work [69] about binocular rivalry providing experimental support for this model.

Recall that the classical demonstration of binocular rivalry [64] is a pattern experienced either as a vase or two opposite faces. The two percepts alternate with some frequency and it is not possible to consciously experience both patterns simultaneously. This has led Manousakis to consider the idea that binocular rivalry could provide direct evidence for the notion of quantum consciousness. The obvious idea is that either of the percepts results by a state function reduction from the superposition of both percepts.

The model predicts that the flip rate correlates with neuronal firing rate. The prediction is confirmed by using as subjects persons who have a reduced firing rate due to the use of LSD. The work of Manousakis might turn out to be an important step of progress in the development of theories of quantum consciousness and might help also main stream physicists to get rid of their atavistic fears relating quantum consciousness.

Justification for the model in TGD framework

The finding conforms with TGD view about quantum jump in which U process creates a quantum superposition and state function reduction selects either of the percepts. TGD however brings in new elements.

1. In the conceptual framework of the standard quantum mechanics there is no known mechanism making possible macroscopic quantum coherence in the time scales involved. If dark matter with large $\hbar$ is involved with the formation of conscious percept there is no problem in understanding the time scales in question. Actually a hierarchy of rivalries of various kinds in various time scales is predicted corresponding to the p-adic time scale hierarchy and hierarchy of Planck constants.

2. Another ingredient which is new from the point of view of standard quantum mechanics is that the hierarchy of Planck constants implies self hierarchy actually identifiable actually as a hierarchy of quantum jumps having quantum jumps within quantum jumps ..... The fractal

structure of state function reduction process means that it is possible have macroscopic quantum behavior in given time scale but dissipative self-organization in shorter time scales.

This is actually not new: in hadron physics hadrons are described as quantum systems whereas parton dynamics in the shorter time scales is assumed to be dissipative. In the recent case this means the possibility of quantum superposition of dissipative self-organization processes involved with the formation of neuronal correlates of percepts and proceeding in time scales of order milliseconds considerably shorter than the time scale of binocular rivalry.

TGD based model for rivalry and its generalization

The TGD based quantum model for binocular rivalry relies on the idea that the formation of quantum superposition of competing percepts is somewhat analogous to quantum computing in which large number of quantum parallel computations are carried out and one computation is selected as the computation halts.

In TGD framework one does not assign a conscious experience to the mere state function reduction part of quantum jump and the question arises whether the transitions periods are experienced consciously as a kind of inability to disentangle what is there and if so what is the subjective time duration of these periods and is it very short in absence of some other periodic sensory input defining a clock. The TGD prediction would be that the mental image defined by the percept is absent but consciousness is not lost.

The formation of quantum superposition of right and left percepts has evolutionary advantages which suggest also a generalization to a model of volitional action as a selection between neural firing patterns leading to alternative motor actions.

1. The formation of superposition would be metabolically advantageous. In the classical world one should form both right and left percept simultaneously. The associated self-organization process requires a metabolic energy feed. When only single brain hemisphere forms the percept and one has quantum superposition of right and left percepts metabolic energy feed is reduced by factor $1/2$. A highly synchronous neural firing distinguishes the perceived stimulus from non-perceived so that a quantum superposition of patterns of two neural firing patterns would be in question.

2. This picture leads naturally to a proposal that one function of sleep is to make possible quantum superposition of large number of neural firing patterns via quantum entanglement with external systems (perhaps other sleeping brains) so that sleep would be a process analogous to quantum computation.

3. The formation of alternative percepts would have an obvious evolutionary advantage in a situation in which several percepts are consistent with the sensory input. For instance, bipolar mood disorders seem to involve sticking of consciousness to either hemisphere. This generalizes also to cognition: of course, percepts actually consist of sensory input plus cognition.

4. This framework is behind TGD based model of volitional action applying to both motor actions and selection of sensory percepts. For a brain living in jungle it would be highly advantageous to develop in a difficult situation a quantum superposition of alternative motor actions and select the proper one only at the eleventh moment.

5. Sensory rivalry is analogous to an ability to move fluently between - say - skeptic and new age views about world. There is also a parallel at the level of society and in TGD framework the rivalry of various views (religions, political parties, competing scientific theories,...) might perhaps be seen as counterpart of binocular rivalry at the level of collective consciousness. The complete dominance of only single view - be it religious or materialistic world view, market economy or communism, or super-string model or loop quantum gravity - would be something comparable to a bimodal mood disorder.

10.5 p-Adic cognition at the level of DNA and proteins

I learned from Tidjani Negadi about some new ideas related to the attempt to understand the basic numbers of the genetic code [44]. Some of these ideas stimulated some speculations about genetic code

and its relationship to cognition and led to a discovery of two number theoretical miracles related to the realization of cognition at DNA and protein level.

10.5.1   Symmetry breaking generates conscious information

What is very attractive in Negadi's approach is the interpretation of the reduction of the entropy in the symmetry breaking as information [45]. This kind of a philosophy fits nicely with the general TGD based view about the generation of the macro-temporal quantum coherence.

1. Macro-temporal quantum coherence corresponds to a formation of bound states and is accompanied by a dramatic reduction of entanglement entropy since bound state entanglement is not entropic.

2. The generation of macro-temporal quantum coherence involves a breaking of symmetry in the zero mode sector transforming some zero modes to quantum fluctuating zero modes. On the other hand, state function reduction (localization in zero modes) and self measurements giving rise to state preparation do not occur in bound state. The localization in zero modes is counterpart of Higgs mechanism and its absence can be seen as the absence of symmetry breaking induced by quantum jump. Hence the loss of symmetry at the level of configuration space is accompanied by a gain in symmetry at the level of conscious experience and vice versa.

3. In the p-adic context bound state entanglement is negentropic [29]. This suggests that the information resulting in the symmetry breaking involved with the establishment of the genetic code could be realized as a conscious cognitive information associated with the p-adic bound state entanglement.

10.5.2   Cognitive codes as a realization of the information generated by DNA-protein symmetry breaking?

Before the establishment of the genetic code the assignments of DNA triplets to amino-acids are random. This means that the symmetry group is a direct product of the permutation groups permuting 64 DNA triplets and 20 amino-acids. The symmetry entropy is logarithm about the number of elements of the symmetry group

$$S_{max} = log(w) \ , \quad w = 64! \times 20! \ . \tag{10.5.1}$$

One obtains $S_{max} \simeq 4 \times 61.8789$.

The work of Negadi inspired the question about whether one could interpret protein-DNA symmetry breaking as a process in which the information $I = S_{max} - S$ is generated and represented in a concrete manner as an additional conscious cognitive information associated with DNA and protein sequences. In case of DNA sequences the symmetry breaking is maximal so that one has $I = S_{max}$. In case of protein sequences symmetry breaking is partial and $I = S_{max} - S$, where S corresponds to the entropy due to the fact that DNA triplets coding for the same amino-acid are equivalent from the viewpoint of protein. This means that DNA sequences carry more cognitive information than protein sequences.

p-Adic physics as physics of cognition predicting that cognition is present already in elementary particle length scales provides clues about how this additional information could be represented.

1. p-Adic bound states for which kp^N states entangle with similar states are automatically quantum computer type states with identical entanglement probabilities (this guarantees stability against self measurements [29]. Most importantly, they carry positive entanglement entropy and genuine information. In the real context entanglement negentropy is always non-positive and is assumed to vanish for bound state entanglement (of course, one could criticize this assumption).

2. If p is Mersenne prime: $p = M_k = 2^k - 1$, temporal sequences of k magnetization directions for quark blocks provide a concrete mechanism of quantum computation (for $k = 127$ associated with the memetic code at least. This suggests that DNA triplets or amino-acids could be accompanied by $p = M_k$-fold degeneracy resulting from the assignment of a sequence of k blocks of magnetized quark blocks to each DNA triplet and/or amino-acid.

3. This representation of information should relate somehow to the realization of the memetic code in terms of DNA and amino-acid sequences. In the model of the memetic code sequences of 21 DNAs are a natural candidate for the realization of the memetic code words since the number of different sequences is $64^{21} = 2^{126}$, which is the number of the memetic code words representing maximal number of mutually consistent statements in the Boolean algebra represented by sequences of 127 bits. The sequences of 21 proteins are a natural candidate for defining the memetic counterpart of the DNA-protein translation if one assumes that the translation of genetic code induces directly the translation of the memetic code to proteins. A test is to find whether sequences of 21 DNAs/proteins might appear in the tertiary structure of DNAs/proteins.

4. The argument above suggests that one should try to find a representation of the cognitive information by assigning a temporal sequence of $p = M_k$ quark magnetization directions to each DNA/protein in the the sequence of 21 DNAs/proteins. This representation makes sense if the condition

$$I \quad = \quad 21 \times log(M_k) \simeq 21 \times k \times log(2) \tag{10.5.2}$$

giving

$$k \quad = \quad \frac{I}{21 \times log(2)} \ , \tag{10.5.3}$$

is satisfied for k Mersenne prime. The condition is obviously extremely restrictive and a number theoretical miracle is required since k has exponential sensitivity to the value of I. Even more, this miracle is required to occur twice: for both DNA and proteins!

10.5.3 M_7^2 and M_{17} codes

It turns out that the number theoretical miracle indeed occurs twice. The complete symmetry breaking occurring at the level of DNA corresponds to the Mersenne prime M_{17} whereas the partial symmetry breaking occurring at the protein level corresponds to the square of Mersenne prime M_7 defining genetic code.

Is M_{17} code realized for DNA sequences?

In case of DNA sequences the symmetry breaking is complete so that one has $I = S_{max}$. For k one obtains

$$k \quad = \quad 17.0043 \simeq 17 \ . \tag{10.5.4}$$

$k = 17$ holds true with a relative accuracy of 2.5×10^{-4}! Both S_{max} and I correspond to 357 bits of information. What is fascinating is that M_{17} is indeed a Mersenne prime, even a very special one, since $k = 17$ is the largest Fermat prime $F_4 = 2^4 + 1 = 17$. Thus one has $M_{17} = M_{F_4}$, somewhat analogously with the basic definition of Combinatorial Hierarchy: $M(n + 1) = M_{M(n)}$.

Is M_7^2 code realized in case of proteins?

The DNA triplets coding for the same protein are equivalent from the point of view of proteins. Therefore symmetry breaking reduces the symmetry group to the subgroup $S_1^2 \times S_2^9 \times S_3^2 \times S_4^5 \times S_6^3$ of S_{64}. Here the subindex n of S_n denotes the number of DNA triplets coding a given amino-acid and the exponent m in S_n^m denotes the number the proteins with degeneracy n. The symmetry entropy is in this case

$$S \quad = \quad log(2!^9 \times 3!^2 \times 4!^5 \times 6!^3) = 4 * 11.0584 \ . \tag{10.5.5}$$

Information gain in the symmetry breaking is $I = S_{max} - S = 4 \times 50.8205$. The value of k for proteinic cognitive representations becomes

$$k \;=\; 13.9654 \simeq 14 = 2 \times 7 \;. \tag{10.5.6}$$

$k = 2 \times 7$ holds true with the relative accuracy of 8.5×10^{-4}. $k = 14$ equals twice the Mersenne prime 7 defining Mersenne prime $M_7 = 2^7 - 1 = 127$ defining the genetic code! A p-adic representation containing p^2 states with $k = 7$ and $p = M_7 = 127$ could be thus considered as a realization of this code. There is internal consistency in the sense that the time scale .1 seconds associated with the memetic code corresponds to a secondary rather than primary p-adic time scale associated with M_{127}.

M_{17} and M_7^2 codes as degenerate forms of the memetic code?

The natural guess is that M_{17} and M_7^2 codes represent degenerate forms of 127-bit memetic code to 17- resp. 14-bit code, some kind of a predecessors of the memetic code. If so, then the duration of the M_{17} and M_7^2 codewords is (roughly) the duration .1 seconds of the memetic codeword.

1. Internal consistency requires that the p-adic time scales in question can be regarded as n-ary p-adic time scales for M_7 and M_{17} for some value of n. For M_7 one has $M_7^{36} \simeq M_{127}^2$ in the approximation $M_n \simeq 2^n$ so that .1 seconds corresponds to 36-ary M_7 time scale. For M_{17} one has $M_{17}^{15} \simeq 2M_{127}^2$ in the same approximation so that M_{17} corresponds to the $15 - ary$ M_{17} time scale equal to $\sqrt{2} \times .1 \simeq .14$ seconds. The corresponding frequencies are 10 Hz (mean alpha frequency) for M_7 and 7.07 Hz for M_{17}, which is just below the alpha band and Schumann frequency 7.8 Hz and cyclotron frequencies 7.5 Hz for K^+ in magnetic field .2 Gauss. This value of magnetic field is suggested by the observations that ELF fields have effects on vertebrate brain at harmonics of Ca^{++} cyclotron frequency of 15 Hz. Note that Earth's magnetic field has nominal value of .5 Gauss so that the magnetic field assignable to the magnetic body would be slightly below the minimal value of Earth's magnetic field about .3 Gauss.

2. Single bit of M_{17} code would last $\tau = .14/17 \simeq 8.3$ milliseconds. For M_7 code the duration of bit is $\tau = 14.3$ milliseconds. It would be interesting to look whether electromagnetic oscillations with roughly 121 Hz resp. 70 Hz frequency are involved with DNA resp. protein dynamics and perhaps also with neuronal firing.

3. If one assumes that the duration .1 seconds is the precise duration of the memetic codeword, the duration of a single bit is about $100/127 = .79$ milliseconds. This would require that the temporal distance between the nerve pulses realizing memetic codeword at neural level is .79 milliseconds. It might be that brain is too slow to achieve this in its recent developmental stage: M_7^2- and M_{17} codes are however not problematic in this respect. The representative capacity of the full memetic code is enormous: consider only the fact that all files in the computer systems of world are planned to be named by 128-bit sequences giving them kind of fingerprints! Thus it might be that 17-bit or even 14-bit code is quite enough: for instance, the number of phonemes of the spoken language is ridiculously small as compared to the number of memetic codewords.

Interpretation of the memetic code word

The memetic codeword consisting of 127 bits allows elegant interpretation as an intention to promote or inhibit the expression of DNA sequence of 21 DNAs coded by 126 bits. The last bit tells whether the expression is promoted or inhibited. Memetic code codes same things as cognitive code for proteins but in a different manner making it possible to activate genetic expressions directly without the mediation of the information-molecule-receptor complex.

The model of the millisecond neuronal synchrony based on MEs suggests that memetic code is not realized as nerve pulse patterns nor as miniature potentials but as oscillations of the membrage potential. The model of nerve pulse and EEG leads to this same picture. One should also notice that the duration of nerve pulses is somewhat longer than 1/1270 seconds so that memetic code cannot be realized in terms of nerve pulses if the duration of codon is .1 seconds. This oscillation could be transferred to nuclear membrane along micro-tubuli and induce in turn the activation of genes coding promoters and inhibitors of the expression of some genes. The realization of the memetic code in terms of nerve pulses would be degenerate. Frequency coding suggests that only the number of nerve pulses per codon matters. If the average duration of nerve pulse is about 2 milliseconds, the number of

pulses is at most 64 and one would have genetic code. Genetic code realized in this manner might well be enough to code the phonemes of the language. There is also a second kind of frequency coding. If nerve pulses occur with a constant interval between them (this could be induced by stochastic resonance, the degenerate memetic codons would correspond to different nerve pulse frequencies and also now a 6-bit code would result.

10.5.4   Cognitive codes and bio-systems as molecular societies

The presence of cognition at DNA and protein level gives additional support for the vision about bio-systems as a molecular society. In the following only the term cognitive code is used although one should in principle speak about cognitive and symbolic codes.

Is p-adic cognitive information static or dynamical?

The general question is whether p-adic cognition degenerates to a representation of a static information analogous to genetic information or does it represent a dynamic information. There are several arguments supporting that the information in question is dynamical and that this is what makes the soup of bio-molcules a molecular society.

1. The basic character of the p-adic physics is non-determinism and it is difficult to imagine that cognitive representations could be static DNA like representations.

2. The cognitive information at DNA and protein level is essentially like the cognitive information at brain level and should be therefore highly dynamical.

3. The fractality of consciousness suggest that one should look the situation at higher level. In human society books represent static information analogous to that coded by DNA whereas conscious brains carry dynamical information which is not a faithful copy of what one can find in books.

 This view allows to answer to several related questions.

1. M_{17} codeword would be a temporal sequence of 17 bits possibily represented in terms of sub-CDs assignable to eleementary fermions. Note that M_{17} code would define 16-bit sequences as maximal set of mutually consistent Boolean statements. M_7^2 codewords could be represented as a pair of temporal sequences of 7 magnetization directions for fermions. The maximal number of the statements consistent with given atomic statement would be 64 so that a cognitive version of the genetic code would be realized at the level of proteins. Might it be useful for a protein to remember the DNA sequence which coded it? This kind of information has no obvious relevance and conflicts with the dynamical character of p-adic cognition.

2. Is there a translation of M_{17} code to M_7^2 code analogous to DNA-protein translation in which some information is lost and proteins carry part of the cognitive information carried by DNAs? The ratio of cognitive information contents for protein and DNA sequences is

$$\frac{I(DNA)}{I(protein)} \quad = \quad \frac{log(M_{17})}{2 * log(M_7)} \simeq .822 \tag{10.5.7}$$

whereas for DNA-protein translation it is $log(21)/(6log(2)) \simeq .7321$. That proteins would not carry independent cognitive information, would be in conflict with the dynamical character of p-adic cognition. The only possible conclusion seems to be that one cannot reduce biological information to the information represented at DNA level so that the central dogma fails even in its generalized form.

Cell membrane as a cognizing structure?

The physical realization of the proposed cognitive codes deserves some comments.

1. M_{17} resp. M_7^2 cognition would add an enormous amout of conscious information to genes resp. protein sequences. DNA triplet *resp.* amino-acid would contain 17 resp. 2×7 additional bits of cognitive information dominating over the chemically coded information. This additional information might allow to understand the paradoxical finding that humans and wheat have roughly the same amount of DNA if the number of DNA sequences longer than 21 DNA triplets is higher in the human genome.

2. The minimal length of 21 amino-acids corresponds to a minimal length of 21 nm for the information molecule. Neurotransmitters and -modulators have lengths much shorter than 21 amino-acids. The molecular weights of hormones (in particular peptides) are measured typically using 10^4 proton masses as unit and this means that the number of amino-acids is larger than 21. Thus it would seem that very many peptides, regarded often as 'information molecules' and 'molecules of emotion', could be regarded as intelligent messengers. Various receptors of the information molecules associated with cell membranes have typically sizes larger than the lower limit 21 nm and could thus behave as cognizing entities making cell membrane an intelligent and cognizing structure. The number of receptors in the cell membrane would serve as a kind of an intelligence quotient of the cell membrane.

10.5.5 Peptides as molecules of emotion and code of intentionality

The view about peptides and proteins as cognizing and intentional entities allows to translate to TGD language often used expressions like 'emotions are expressed', 'blocked emotions are released', 'emotions are stored to the body as traumatic body memories', 'peptides are molecules of emotion and information molecules'. Most importantly, a concrete code for intentionality emerges in which elementary intention represents inhibition or facilitation of gene expression.

Unasked questions

The interactions of the information molecules involve the formation of receptor-information molecule complex either at cell surface or in the cell plasma inside cell. Receptor-information molecule complex inside cell can move to genome and induce gene transcription. In case that the complex is formed at the surface of cell, second messenger action is involved. One can also speak about N:th messenger action. There are many poorly understood aspects related to the mechanisms of information molecule action [57].

1. There are only few second messenger pathways and relatively few receptors but large number of different functions. This phenomenon is known as pleiotropy or multi-functionality. For instance, given second messenger causes different effects depending on the hormone that activated it (the phenomenon is somewhat analogous to the phenomenon in which message can be understood in several manners depending on the state of receiver).

   At purely chemical level the problem is how second messenger knows what hormone activated it? In steroid action the complex formed by information molecule and receptor in turn activates some gene. Now the question is: How the activated RNA polymerase knows which gene has to be activated? Pleiotropy appears also at level of hormones. Same hormone can have multiple effects and the border between hormone, neuropeptide or even neurotransmitter is unclear. For instance, a hormone which by definition transmits long distance communications, can have effects in nearby cells and thus acts like a neuropeptide. How hormone knows what function it must perform? Also drugs and treatments can have different effects and side effects.

2. There is also functional redundancy: the same function is performed by several second messenger molecules. For instance, glucagon, growth hormone, adrenaline and corticosteroids elevate glucose levels. This suggests that there is deeper level of communication involved and that second messenger molecules are more like computer passwords than subprogram calls. Now the question is: What these subprogram calls do correspond physically?

3. Biological functions can be initiated also in nonchemical manner. The phenomena of healing by touch and the effects of meditation and biofeedback are examples of biological self-organization processes are initiated in nonchemical manner. Even other treatments like massage, acupuncture or meditation can decrease or inhibit pain. These observations suggest that chemical level is not the deepest level involved with biological functions and the question is: What is this deeper control level?

Simple lock and key mechanism cannot provide answer to the questions raised above. If information molecules carry p-adic intentions about say gene level expression of emotions, situation changes since additional information transfer is involved.

The code of intentionality

The expressions of emotions are usually symbolic. Emotions involve often intentions (not always benevolent!. This intention could be represented by p-adic MEs and translated to a symbolic and cognitive representation in terms of real and p-adic antineutrinos (bit being represented by the direction of magnetization). For instance, when the opinion of a quantum consciousness theorist about reductionism and materialism cannot be expressed, the p-adic intention does not transform to real ones and does not generate the nerve pulse patterns or other activity responsible for the symbolic expression.

What it means that peptides are responsible for the expression of emotions? Perhaps information molecules transfer the intentions to express emotions at molecular level between body parts. It is indeed known that nervous system, immune system, and endocrine system are in an intense information exchange using information molecules. Information molecule would literally act as a postman transferring intentions to the proteins of the body which are also carriers of p-adic cognition.

Emotions are eventually expressed at the gene level. M_7^2 code consists of sequences of 7-bits and 7 bits is enough to tell both the name of the gene and whether the expression of this gene is to be facilitated or inhibited. Certainly the simplest possible biologically relevant intention is the intention to facilitate or inhibit the expression of some gene! The doubling of the intention to translate DNA sequence to protein brings strongly in mind the double strand structure of DNA. There might be good reasons for the doubling to occur also at the level of intentions and 7-bit sequences would represent DNA and its conjugate. Doubling might allow error correction as in the case of double DNA strand.

If information molecules carry more or less standardized intentions, the intentions carried by the information molecules cannot be directly transformed to actions. Rather, a process similar to the translation of DNA to protein would occur. A copy of the second intention is formed (generation of mRNA) and transferred near the nucleus where it is tranformed to action (translation of DNA to protein). Of course, p-adic physics at protein level has also other aspects. Doubling would make possible p-adic quantum computations at the protein level since 7-bit sequences could entangle to form p-adic bound states. At DNA level p-adic quantum computations would be made possible by the bound-state entanglement of the 17-bit sequences associated with the two DNA strands: this would also partially explain why two strands are needed.

A model for what happens information-molecule receptor complex

There is evidence for M_7^2 code. It is known that membrane proteins are in a helical conformation (so that the pair of p-adic intentions forms a helical structure just like DNA double strand!) such that the number of proteins in the portion connecting the cell exterior and interior is 20 [55]. This is not quite 21. It could be that the cell membrane space-time sheet is 5 percent thicker than the join along boundaries condensate of the atomic space-time sheets so that 21 proteins are actually involved. A more plausible explanation is based on the observation that the sequences of $10 \times n$ DNA triplets are very special in that the net helical rotation along the sequence is a multiple of 2π. Perhaps the sequences of 20 DNA and thus also of 20 amino-acids carry the relevant genetic information. 21st amino-acid would contains a control intention which, when realized, attaches the information molecule or receptor to the cell membrane such that the follower of the control amino-acid is the first one inside the cell membrane.

The interpretation would be that the portions of proteins inside cell membrane contain cognitive antineutrinos. This interpretation conforms with the model of the memetic code based on the assumption of almost zero energy neutrino pairs are assumed to have neutrino at $k = 169$ space-time

sheet and antineutrino at $k = 151$ space-time sheet. There should be a $k = 151$ space-time sheet associated also with the information molecule making possible the realization of memetic codewords. This is important constraint and could mean that the transversal size of the information molecule is of order $L(151) = 10$ nm. Alternatively, the molecule to which information molecule is bound during its travel to the target molecule could provide the $k = 151$ space-time sheet.

These findings allow to make guesses and questions about what might happen in the information molecule-receptor complex.

1. Cell membrane-information molecule-receptor complex

The cognitively active parts of the receptors corresponds to the parts of these proteins traversing the cell membrane. Often the receptors are proteins which traverse the cell membrane many times and the interpretation would be that each portion of 20 amino-acids defines one elementary intention defining a portion of DNA sequence to be translated and initiating a process leading to an expression of some gene(s). 7-bit code suggests that the codeword activates control genes which promote or disfavor the expression of some gene(s). An interesting question is whether DNA sequences consisting of 21 DNA triplets have some very special role in the control part of the genome.

2. What are the contributions of the receptor and information molecules to the intention?

Does receptor molecule form only a copy about the intention of the information molecule to the segments of the receptor going through the cell membrane or do both the receptor and information molecule contribute to the intention? Could it be that the static quasi-static part of the intention is coded by the receptor and the varying part is coded by the information molecule? Selection among not too different intentions would give flexibility without a loss of safety. Quasi-static part would bring in some context dependence. This would allow also to understand what happens in synaptic contacts: in the case of standard neurotransmitters, which cannot be intelligent messengers because of their small size, there would be only a quasi-static receptor contribution to the intention determined by the postsynaptic neuron.

3. How the intention to express the gene is realized?

Generalizing the ideas about the realization of the memetic code one ends up with the following picture. The contribution of the information molecule to the intention is possibly copied in the interaction with the receptor to the receptor molecule or transformed directly to action. After the p-adic system is transformed to a real one and this process automatically generates a sequence of electric signals when the spins of real antineutrinos flip to the direction of magnetic field associated with the cell membrane space-time sheet. This does not yield nerve pulses but weaker signals, presumably completely analogous to miniature potentials generated in the receptors of the postsynaptic neurons, and these potentials code for the gene expression. In principle there would be no difference to what happens in the postsynaptic neuron.

Micro-tubular cytoskeleton which is piezoelectric structure claimed to allow 64 bit code [56, 63] could mediate the electric electric signal to the nucleus and activate the desired genes. Massless extremals and TGD counterparts of scalar waves of Tesla could be involved. Recall that scalar waves correspond to electric pulses propagating with light velocity with electric field in direction of propagation: now these pulses would propagate to the interior of the cell and generate miniature potentials in the membrane potential of nucleus. The generation of the second messenger would represent a standardized part (there are relatively few second messenger pathways) of the process of realizing gene expression no responsible for the transfer of the intention.

Failure to express emotions

It seems that the expression of emotions can fail at several levels. If the intention to express emotion at brain level fails to be realized, information molecules are not generated and transferred around the body. The un-expressed emotion would be stored in the brain of the past. The second possibility is that the intention to express emotion is transformed to action and the peptides flow around entire body but for some reason the intentions carried by the information molecules are not expressed. For instance, the information molecules could fail to bind to their receptors for some reason or the transfer of information inside thre receiving cell would fail for some reason. In this case the unexpressed emotion would be stored to the body. In both cases the 4-D body changes gradually more and more p-adic,

and becomes full of unrealized intentions and the carving of 4-D body, self-realization, is inhibited.

An important function of sleep and dreams might be the expression of the un-expressed emotions of the geometric past. Also meditation and various therapies might have the same effect. Neuropharmacological approach, as long as it tries to affect only the geometric now, cannot change the geometric past and would not seem therefore very useful healing method for emotional traumas. My own rather traumatic academic past provides a good testing ground for this hypothesis. As a scientific heretic I lost my academic human rights for long time ago. It became clear that if I react to this, I will be labelled as an asocial paranoid. Apart from few exceptions, when the psychic pain was simply too intolerable, I managed to avoid this. This left a lot of unexpressed emotion to my geometric past and the reward for a civilized behavior was a label of a stupid sissy. Gradually it became also clear that there is no hope: the academic decision makers have unlimited power. It is hard to imagine a more effective mechanism for generating deep frustration and long term depression! Gradually I however realized that the coin had also the other side: the role of an academic zombie gave me an unlimited intellectual freedom which those professors did not possess and I had actually ideal circumstances for carrying out my mission optimally. Besides the incredible stupidity of the academic power holders I have been wondering second strange phenomenon during these years. Why do I spend practically all my dream time in my past? Could a partial answer be that I have been busily trying to express these un-expressed emotions: during sleep it is easier to break the academic etiquette.

10.5.6 Questions relating to the M_{17} code

There are many questions related to the interpretation of the M_{17} code.

1. What seems clear is that DNA double strands cognize and p-adically quantum compute by bound state-entangling the neutrino sequences of the two strands: the nucleus is the cognitive brain of the cell. 17 bits means much more information than two 7 bit sequences. This suggests that DNA has emerged in the evolution after proteins, and also after cell membrane, which results from self-organization and needs no coding. Also membrane proteins can quantum compute when they are not making sex with the information molecules. Cell is full of membranes and this maximizes the cognitive and intentional activities in the protein sector.

2. The realization of the DNA neutrino sequences requires the presence of $k = 151$ space-time sheets. Cromosomes are indeed rather thick and there are helices inside helices indicative of a hierarchy of space-time sheets. All the four space-time sheets characterized by Gaussian Mersennes ($k = 151, 157, 163, 167$), could be carriers of cognitive antineutrinos whereas neutrinos would reside at the $k = 169$ space-time sheet. Thus a four-levelled hierarchy of cognition is in principle possible and perhaps partially realized by a hierarchy of helices inside helices. The hierarchy of DNA helical structures could contain $k = 151$ and $k = 157$.

3. The outcomes of DNA quantum computations can be interpreted as intentions which, when realized, represent the result of the computation symbolically as the activity of the organism and/or as a conscious experience at some level. There is no reason to assume that these intentions would be realized only inside genome. Rather, they could be represented MEs which are already earlier assumed to give an additional contribution to the genetic information. Also the TGD counterparts of scalar waves of Tesla suggest themselves and could transform this information to nerve pulse patterns by generating miniature potentials first. If the duration of the DNA cognitive codon is .14 seconds it is not clear whether these intentions could relate to the 'features', which have duration between .8-.12 seconds. The corresponding frequency is about 7.1 Hz and slightly smaller than the nominal value of Schumann frequency. This information projected by MEs could be unconscious-to-us and realized as magnetospheric sensory representations contributing to the conscious experience of the multi-brained higher level selves. An interesting question relates to the interpretation of the 17 bits of the cognitive codeword. It would be interesting to try to find evidence for features lasting about .14 seconds and modulated by sequences of 17 yes/no pulses.

10.6 What might be the basic principles behind molecular cognitive and sensory representations?

The challenge of understanding how intentions and cognitions are realized at the molecular level is a fascinating and potentially very rewarding challenge. The work with genetic and memetic codes based on the notion of Combinatorial Hierarchy [26, 29, 27] represents first steps in this direction but does not yet involve p-adic aspects. The ideas of preceding section provide a lot of additional insight but do not provide any general theory. This section is devoted to an attempt to develop a general theory of cognitive and symbolic representations at the molecular level assuming that even molecular structures have intentions and cognition and are able to transform intentions to actions.

The basic hypothesis is that molecules provide both static and dynamic symbolic representations for cognitive codes. Cognitive codes are characterized by the symmetry groups of finite geometries and their projective counterparts. The requirement that cognitive quantum computation is possible raises the primes defining Mersenne primes to a preferred position. The symmetry groups of finite geometries are assumed to act as the symmetries of the molecular structures responsible for the symbolic representations. This leads to strong predictions as some examples treated below demonstrate and one might even speak about Golden Road to the understanding of cognition and intentionality at molecular level.

10.6.1 Number theoretical ideas

The predictive power of the model to be proposed derives basically from number theoretical constraints. Mersenne primes are in a unique position as far as p-adic quantum computation is considered. One can imagine a good reason for why Gaussian Mersennes should have a unique role. Fibonacci numbers characterize often the structure of biological systems, and there are reasons to believe that they might relate very intimately also to the evolution of cognitive representations.

Mersenne primes an cognitive hierarchies

The findings about new cognitive codes initiated by the idea of symmetry entropy of DNA-protein system can be compressed to a generalized notion of abstraction hierarchy, which was introduced years earlier. Any Mersenne prime M_p, p prime defines an abstraction hierarchy containing at most two levels. The $2^p - 1$ elements of the finite field $G(M_p, 1)$ represent all possible statements about p basic statements except the one which is not representable for some physical reason. Hierachies start from some prime which is $2, 5, 13, 17, 19, 31, 89, 107$ in the range of p-adic time scales of interest and can have several levels.

1. Combinatorial hierarchy $p = 2, 3, 7$ (single base pair), 127 (genetic code), M_{127} (memetic code whose mutually consistent statements are realized also as sequences of 21 DNAs) is the longest hierarchy. It is not known whether $M_{M_{127}}$ is prime: Hilbert conjecture states the entire infinite hierarchy consists of Mersenne primes. This would mean that universe possesses infinite ability of cognitive abstraction.

2. The next hierachy starts from prime 5 and contains three levels $p = 5$, $M_5{=}31$, and $M_{31} = 2^{31} - 1 \simeq 2 \times 10^9$.

3. The remaining known to me hierarchies are two-step hierarchies and any Mersenne prime defines such a hierarchy. The largest Mersenne prime hierarchy of this kind relevant for human consciousness is M_{127} which is the p-adic prime characterizing electron and memetic code. M_{521} is the next Mersenne prime and corresponds to a completely super-astrophysical time scale.
   i) The first abstraction pair (p, M_p) corresponds to $p = 13$. Micro-tubuli are excellent candidates for the realization of M_{13}^{13} representations with $13^2 = 169$ bits of information (recall that $k = 169$ characterizes the p-adic length scale associated with neutrinos!).
   ii) Next Mersenne M_p prime corresponds to $p = 17$ and was deduced by the argument relating to the information gain in complete symmetry breaking of the DNA-protein system.
   iii) Also the Mersenne primes M_p associated with $p = 19, 31, 61, 89, 107$ should be there.

The beauty of Mersenne representations is that one can construct from them product representations containing M_p^k cognitive states and bits replaced by pinary digits M_p. Furthermore, by fractality any time scale $2^{pm/2}T_{M_p}$ is possible for sufficiently small primes p so that these representation can be present in and a wide spectrum of time scales ranging from the time scales relevant for the conformational dynamics of molecules to the time scales relevant for neural activity and EEG and even time scales measured in years.

What about Gaussian Mersennes?

The Gaussian Mersennes $G_n = (1+i)^n - 1$, n some prime, are expected to be also of fundamental importance and one expects that they give rise to complex cognitive representations. The Gaussian Mersennes possibly relevant to life correspond to primes $n = 2, 3, 5, 7, 11, 19, 29, 47, 73, 79, 113,$ $151, 157, 163, 167,\ 239, 241, 283$. The length scale range between cell membrane thickness and size of small bacterium contains only Gaussian Mersennes: they are $n = 151, 157,\ 163, 167$. The norm squared of the Gaussian Mersenne $G_{n=2k+1}$ is $p_n = 2^{21+1} + 2^{k+2} + 1$ and larger than 2^n.

One might guess that the number of Gaussian integers with norm smaller than the norm squared of Gaussian prime G_n defines the number of states in this kind of representation and that this number must be prime. Some very beautiful cognitive structures might be involved with Gaussian Mersennes and it remains to be found what this structure is. Obviously the idea that one could use sequences of n bits to realize $p_n = 2^n - 1$ points as phase transitions by spontaneous magnetization to an analogous representation of $p_{n=2k+1} = 2^{2k+1} + 2^{k+1} + 1$ points. One can write p_n in a form which gives hints about what kind of physics this representation might require:

$$p_{n=2k+1} \equiv N_1 + N_2 + N_3 \ ,$$

$$N_1 = 2^{2k+1} - 1 \ , \qquad\qquad N_2 = 2 \times 2^k - 1 \ , \quad N_3 = 2 \times 2 - 1 \ .$$

p_n is sum over numbers of magnetization phase transitions for three phases of the fermion system. N_1 corresponds to a system of $2k+1$ fermions. N_2 corresponds to a system consisting of one fermion plus k Cooper pairs: by the indistinguishability of fermions the combinatorial factor k is absent from N_2. N_3 corresponds to a system consisting of one fermion and a Bose-Einstein condensate of all k Cooper pairs behaving like a single particle. Neutrinos at $k = 169$ space-time sheet suggest themselves strongly as a realization of this phase.

Fibonacci numbers and the evolution of cognition

Fibonacci numbers proliferate living matter (logarithmic spirals) and emerge in the simplest models of growth: living matter is full of logarithmic spirals and also micro-tubular structure involves the sequence $3, 5, 8, 13$ of Fibonacci numbers. The natural guess is that Fibonacci numbers are also involved with cognitive growth and evolution: especially so if this biological growth is basically intentional and involves growth of plans from rough sketches to more detailed ones and if this development is seen in the structure of intention. In particular, 21 DNA/protein codeword could decompose to ordered hierarchy of subsequences of $1, 2, 3, 5, 8, 13, 21$ DNAs and these sequences with increasing length gradually give better and better representation of codeword. The development of the full cognitive code word or intention, would be like an interactive growth of a population of 21 cognitive organisms, primitive intentions associated with single DNA. Older unit intentions react to the presence of new ones by generating new unit of intention each. When, say, a generation consisting of 5=2+3 unit has been established, 3 units of previous generation generate new units (5+3=8) as a response to the presence of new 2 units.

For intance, single micro-tubule would represent only the 13 first DNAs and would not give faithful coding of the codeword. The wall of a double micro-tubule with 21 tubulin strands at its wall would do it. Interestingly, triple micro-tubules seem to contain the total of 33 or 34 micro-tubules, whether the number is 34=21+13, the next Fibonacci in the micro-tubular series, is not clear on basis of material that I have seen. Because of its Fibonacci structure of micro-tubule could automatically represent 5, 8 and 13 DNA approximations to the full intention represented by a sequence of 21 DNAs.

10.6.2   Representations

Representations are fundamental notions in geometry and physics and, as it seems, also sensory, symbolic, and cognitive representations make sense. The basic idea is that Nature codes its mathematical cognition to various kinds of symbolic representations. The fascinating possibility is that practically every bio-structure which results in genetic expression represents some cognitive/intentional structure somehow. We have been used to think that our theories represent those structures we see: it might be fruitful to see the situation as just the opposite! DNA and proteins would be only particular hardware realization of finite geometries associated with cognition. This view might be general enough and certainly practical: one can deduce the symmetry groups associated with various structures and look whether one can assign them to finite geometries or their projective counterparts and thus to p-adic cognition.

Various types of representations

One can distinguish between several kinds of representations.

1. There are cognitive representations in terms of temporal sequences of p-adic neutrinos. Sequences of 21 DNA triplets could realize any representation defined by Mersenne prime since the temporal character of the sequences means that the density of neutrinos needed does not depend on the Mersenne prime. Thus there is no really deep reason for making too restrictive assumptions at this stage.

2. There are symbolic representations resulting when p-adic many neutrino states associated with p-adic MEs transform to real ones. This transformation means transformation of intention to action or cognitive representation to a symbolic representation. The realization of this representation has been already discussed.

3. The symbolic representations can transform further to dynamical representations as either nerve pulses or oscillations of membrane potential. This representation generalizes: what is needed are two-state systems in an external field which forces a process analogous to spontaneous magnetization.

4. One can also consider the possibility of static geometric representations in terms of molecular geometry. These kind of representations could be realized for any prime p and in case that M_p is Mersenne prime, the structure characterized by p parts related by a cyclic symmetry Z_p could serve as a template for dynamical representations obtained by attaching a two-state system at every unit of the system. For instance, DNA triplets realize statically the mutually consistent statements of $M_7 = 127$ cognitive representation and single DNA triplet could realize $M_3 = 7$ representation if each basepair can be in two states. Clathrin molecule gives 12-fold product of $p = 5$ representation in terms of 12 disjoint pentagon faces whose vertices carry a two-state system (the polarization of the triskelion protein could define the two states).

The basic principle for realizing dynamical representations

According to TGD inspired theory qualia, primitive qualia correspond to spin flips, and more generally, to phase transitions changing the direction of spin or some other quantity characterizing the state of the two-state system. In case of neutrino representations the essential elements are the presence of magnetic field, the fact that the neutrino is a two-state system which flips in the direction of externa magnetic field, and the fact that the number of representable states is $M_n = 2^n - 1$ rather than 2^n states since the state in which all spins are parallel does not give rise to spontaneous magnetization and conscious experience.

The replacement of single particle states with say spontaneously magnetized states guarantees rigidity and robustness. Spin glass type phase is optimal for the representative purposes and TGD universe is indeed a quantum spin glass. Dynamic representations can be realized in terms of molecular conformations instead of using fields. Micro-tubule representations provide a fundamental example but there are a lot of others. If magnetic flux tubes and electrets are indeed fundamental building blocks of living systems (they represent fundamental solutions of field equations of TGD), living system

should be a huge fractal collection of these representations. Also cell membrane is expected to carry representations of this kind.

What this means is that the projective finite geometry with $M_n + 1 = 2^n$ points is represented dynamically by n two state systems such that the point at infinity is not realizable as spin flip pattern since it corresponds to the spontaneous magnetization or electret state in which all n two-state systems have spin /polarization/... direction parallel to external field and nothing happens. This is indeed what is required by the realization of qualia as quantum number increments. At the level of set theoretical Boolean algebra representation the point at infinity corresponds to the empty set.

If the strength of the background field can be controlled, the representation could be generated by weakening the field temporarily so that there results either a spin glass phase at criticality optimal for the storage of bits or a phase above criticality optimal for signal propagation. The transformation inducing 'spontaneous magnetization' responsible for the conscious experience could be generated by increasing the strength of the magnetic/electric field to its original value. For instance, in case of micro-tubular conformational representations reading would result by introducing strong electric field forcing the conformations to ground state conformations.

Magnetic flux tubes and their electric duals provide these background fields. In case of magnetic flux tubes cyclotron transitions are these transitions and spins of Cooper pairs define the bits. This allows a deeper understanding of also sensory representations.

Fractal hierarchy of time scales

The beauty of the realization of cognitive representation in terms of Mersenne primes is that all fractal powers $T(p, n) = p^{(n-1)/2}T_p$ of p-adic time scale T_p are a priori possible and correspond in good approximation to the square roots of the octaves of the fundamental time scale. The first implication is that the entire span of biologically relevant time scales can be realized using relatively few fundamental time scales defined by small Mersenne primes. This means also that for large Mersenne primes corresponding to relatively long time scales there can be several small Mersenne representations with essentially the same time scale. The signatures for these time scales are resonance frequencies corresponding to the time scales defining the duration of the codeword and also the duration of single bit. How much the duration of the codeword can vary around the p-adic time scale is still an open and important question: the width of alpha band suggests that the variation is about $\pm$ 20 per cent.

10.6.3   Finite geometries and cognition

Finite geometries defined by Galois fields $G(p, n)$ with p^n elements and identifiable as integers in an algebraic extension of p-adic numbers modulo p and corresponding projective geometries are the natural mathematical framework for simplest cognition. The primes p defining Mersenne primes $M_= 2^p - 1$ and Gaussian Mersennes and these primes themselves are preferred primes for the reasons already explained.

1. The evolution of mathematics represents the evolution of cognition since ontogeny recapitulates phylogeny also at the level of cognition. This means that ancient mathematicians constructed also models for the basic structures of cognition. The Platonic solids could represent basic cognitive structures rather than only vice versa as it is usually thought.

2. Symmetry group characterizes a given geometry. This group is cyclic group Z_p for the simplest finite geometries defined by finite fields $G(p, 1)$, p prime, and finite projective group for for their projective counterparts obtained by adding the point at infinity.

3. One can interpret spatial and temporal sequences of quark magnetization directions as representing points of finite geometries or their projective counterparts defined by Mersenne primes. The point at infinity corresponds to all spins in the direction of magnetic field so that no membrane oscillation is generated: infinity is un-reachable. Operational infinity is something which one is not able to achieve or perceive. This finding generalizes to a more general representational principle using two-state systems in an external field which forces the two-state systems to the same state. The cognitive state is coded to a conscious experience resulting in the phase transition to the ground state. If there are p two-state systems such that M_p is Fermat prime this system codes the points of the finite geometry M_p to conscious experiences.

If this view is correct, the mathematicians were studying their own cognitive consciousness when they were proving theorems about Platonic and Archimedean solids or doing ruler and compass constructions. In fact, I realized for years ago that Pythagorean triangles which pop up naturally in p-adic context, represent the very early view about world as mere rational numbers. The simplest mathematical cognition relies on finger counting: amusingly, decimal code pops up already at the level of DNA: 10 DNA triplets correspond to a helical twist which is minimal multiple of 2π.

Finite geometries

Ordinary finite geometry understood as having a structure of number field involves only a set of p (prime) ordered points defining the finite field $G(p, 1)$ and subsets of points of this geometry. The projective counterpart involves also the point at infinity and contains thus $p + 1$ points. Also the algebraic extensions $G(p, n)$ of $G(p, 1)$ containing p^n points are possible but not discussed here. The symmetry group of the finite geometry $G(p, 1)$ is cyclic group Z_p and the sequences of magnetization directions of p quark blocks represent the subsets of $G(p, 1)$ as ordered sets. In case of projective finite geometry containing also the point infinity projective transformations induced by 2×2 unimodular matrices

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix} \tag{10.6.1}$$

induce projective transformations via the formula

$$x \to \frac{ax + b}{cx + d} \ . \tag{10.6.2}$$

By studying the unimodularity condition $ad - bc = 1$ in finite field one easily finds that the number of elements in the projective group is

$$N \quad = \quad (p-1) \times [(p-1) \times (p-2) + 4 \times (p-1) + 2]/2 \ . \tag{10.6.3}$$

For $p = 5$ one obtains $N = 60$ corresponding to the number of vertices in truncated icosahedron representing thus the symmetry group of 6-point projective finite geometry consisting of the group A_5 of even permutations of five objects. For $p = 3$ the number of elements is $N = 224$ and corresponds to the group S_4 of permutations of four objects whereas for $p = 2$ the number of elements is $N = 6$ and corresponds to the group S_3 of the permutations of three objects.

The projective transformations of finite projective geometries are counterparts of Lorentz transformations. One can assign to finite geometries also a spinor structure. Spinors have two-components and the action of the projective transformation on the spinor is by matrix multiplication. It was actually this finding which led to the realization that there might be a deep connection between cognitive representations using fermion sub-CDs and finite (projective) geometries.

Representations of finite geometries

An interesting question is what finite geometries can be realized as polygons in plane or as Platonic or Archimedean solids. This requires that the symmetry group of the finite geometry or of its projective counterpart acts as a subgroup of the rotation group $O(3)$. For finite geometries having Z_p as a symmetry group regular polygons of plane with p vertices and edges provide this realization. At molecular level a realization by helical twisting is natural. If the number of units corresponding to a full helical twist of multiple of 2π is p or power of p one has a geometric realization of a finite geometry.

1. Polygons obtainable by ruler and compass construction

Of special interest are the polygons which can be constructed using only ruler and compass: for these structures lengths of various edges are either integers or involve iterated square roots of integers. The well-known theorem of Euler states that the only structures of this kind correspond to regular polygons with n vertices and sides of identical length having vertices at circle. The allowed values of n are given by

$$n = 2^k \prod_k F_k \ ,$$

where k is any non-negative integer and F_k is Fermat prime

$$F_k = 2^{2^k} + 1 \ , \quad k = 1, 2, 3, 4 \ .$$

The list of Fermat primes is $3, 5, 17, 287, 2^{16} + 1$. Interestingly, the lowest three Fermat primes define Mersenne primes M_{F_k} so that they are expected to be of special interest from the point of view of cognition. These structures are not finite geometries but could be regarded as Cartesian products of finite geometries $G(2, k)$ and $G(F_i, 1)$. These structures can be seen as Cartesian products of finite geometries.

A possible geometric representation of these structures is based on many-sheeted space-time so that various factors in the decomposition correspond to different space-time sheets characterized by appropriate p-adic topology (also real space-time sheets are characterized by p-adic prime). The hierarchical helical structures containing helices inside helices correspond to many-sheeted space-time structures and the numbers of basic units corresponding to single period at various levels could correspond to the prime factors appearing in the decomposition.

Bio-systems are full of helical structures. Five finger code and decimal code are included as almost simplest codes. 10 DNA molecules define a structures for which the total helical winding is multiple of 2π. Perhaps here is linear realization of the decimal code: that twist is multiple of 2π indeed says that one can form from DNA a loop where that cyclic group of 10 elements acts. One should look systematically through all helical structures and find the number of units which correspond to a minimal multiple of 2π rotation to see whether ruler and compass codes are realized.

2. Quantized Planck constant, dark matter, and Fermat polygons

One ends up with Fermat polygons from the quantization of Planck constant as $\hbar = \lambda \hbar_0$. Number theoretical arguments suggest a general formula for the allowed values of λ [17] as $\lambda = n$ where the integer n characterizes the quantum phase $q = exp(i\pi/n)$ characterizing Jones inclusion [24]. The values of n for which quantum phase is expressible in terms of squared roots are number theoretically preferred and correspond to integers n expressible as $n = 2^k \prod_n F_{s_n}$, where $F_s = 2^{2^s} + 1$ is Fermat prime and each of them can appear only once. The lowest Fermat primes are $F_0 = 3, F_1 = 5, F_2 = 17, F_3 = 257, F_4 = 2^{16} + 1$. The prediction is that also n-multiples of p-adic length scales are possible as preferred length scales.

The p-adic vision about cognition suggests that algebraic extensions of p-adic numbers define a cognitive hierarchy and the lowest levels of this hierarchy correspond to algebraic extensions of p-adic numbers involving only iterated square root operation. These should emerge first in the evolution and therefore dark matter systems assignable to Fermat polygons should be the most abundant ones.

There is a lot of evidence for the presence of integers characterizing Fermat integers in living systems. For instance, the so called scaling law of homeopathy [20] states that radiation with frequency f_l is accompanied by a radiation with frequency $f_h \simeq 2 \times 10^{11} f_l$. The scaling factor 2×10^{11} corresponds with 1.5 per cent accuracy to the integer $n_F = 2^{36} \times 3 \simeq 2.03 \times 10^{11}$ defining a Fermat polygon. This suggests an interpretation in terms of a decay of dark photon with a given wave-length to a bundle of n_F ordinary photons with the same wavelength. The energy of the dark photon would be by a factor n_F higher. This process could serve as an effective tool of bio-control. Dark photon could also transform to an ordinary photon with wavelength shorter by factor $1/n_F$. Quite generally, integers n_F defining Fermat polygons are a reasonable guess for the generalization of the scaling law of homeopathy and the search for these scaling factors could provide an experimental means of identifying the values of Planck constant relevant for living matter.

Even the time units of everyday life could reflect the properties of the dark matter hierarchy responsible for the control of living matter, in particular those of the sub-hierarchy defined by Fermat polygons. Indeed, one year corresponds to $n_F = 4 \times 3$ months, one month to $n_F = 2 \times 3 \times 5$ days, one day to $n_F = 8 \times 3$ hours, one hour to $n_F = 60 = 4 \times 3 \times 5$ minutes, and one minute to $n_F = 60$ seconds.

3. Chromosomes and exotic quarks?

Helices within helices could give rise to hierarchies of cognitive representations. Magnetic flux tubes can have complex helices inside helices hierarchies and in this case the number of units basically consisting of super-conducting ions or of their Cooper pairs per single period at given level of hierarchy should be prime for a given loop.

Chromosomes are characterized by this kind of hierarchy of coiling and looping which helps to pack chromosome DNA (about 2 meters in humans) in a small volume. This hierarchy could give also make possible a hierarchy of cognitive codes corresponding to the space-time sheets defining the hierarchy. What makes this hierarchy so interesting is that the p-adic length scales in question correspond to the miracle length scales defined by Gaussian Mersennes corresponding to $k = 151, 157, 163$ and 167. The diameter of the largest structure involved with chromosomes is about .7 micrometers whereas the smallest structure has diameter of 11 nanometers. Thus all three primary p-adic length scales $k = 151, 157, 163$ could be realized and three levelled hierarchy is possible.

1. If the principle of realization is same as for the memetic code based on the pair $k = 127, 120$ (electron CD containing a sequence of quark CDs), the following picture suggests itself. $k = 157$ codon has $n = 2^{157-151} = 64$ bits of duration $T(2, 151)$, $k = 163$ codon has $n = 64$ bits of duration $T(2, 157)$, and $k = 167$ codon has $n = 2^{167-163} = 4$ bits of duration $T(2, 163)$.

   The realization in terms of exotic light quarks quarks would involve only temporal sequences of n sub-CDs. The secondary p-adic time scales determining the time scale of the corresponding CD and thus the time duration of codon are rather long: about 2×10^6 s for $k = 151$ and 10^8 seconds for $k = 157$. A test for this idea is whether the numbers of the basic units per period of helix at various levels are given $n = 32, 32$, and 8 DNA nucleotides (not that these numbers do not correspond to full number of codons).

2. The realization analogous to genetic code would involve $n = 157 - 151 = 6$ bits (genetic code) , $n = 163 - 57 = 6$ bits, and $167 - 163 = 4$ bits.

3. One can also consider the possiblity that the number of bits is determined by the p-adic prime characterizing the space-time sheet involved and thus equal to $k = 151, 157, 163$. In this case the duration of bit would not correspond to a secondary p-adic time scale as it does for the memetic code.

Realization of finite projective geometries using Platonic and Archimedean solids

For projective geometries the realization as Platonic solids in the sense that the projective symmetry group acts as group of symmetries of the Platonic solid are possible only for $p = 2, 3, 5$ cases. The 5 Platonic solids are tedrahedron, cube and octhedron, and icosahedron and dodecahedron. The basic transformation is duality changing faces and vertices. Tedrahedron (4 vertices and 4 faces) is self dual whereas cube (8 vertices and 6 faces) and octahedron (6 vertices and 8 faces) are duals of each other, as are also icosadedron (12 vertices and 20 faces) and dodecahedron (20 vertices and 12 faces). The number of edges is fixed by the Euler characteristic of sphere (solids are topologically spheres) given in terms of the numbers of vertices, edges, and faces by $V - E + F = 2$ and one has $E = V + F - 2$ giving for the number of edges $E = 6, 12, 30$ in the three cases respectively. Archimedean solids allow different types of faces and hexagons, octagons and decagons are possible (note that the number of vertices for faces is not prime anymore). Archimedean solids have same symmetry groups as Platonic solids from which they are obtained by 'truncations'.

It is interesting to look how the symmetry groups of finite geometries can be realized as symmetries of Platonic and some Archimedean solids.

1. For $p = 2$ the group of projective symmetries corresponds to the 6-element group S_3 of permutations of three objects acting on triangle and being generated by 2- and 3-fold symmetries. The 3 vertices represent the 3 points of the projective geometry and the generator of Z_2 acts as a reflection permuting any pair of these points with the third point representing the point at infinity. The three faces of tedrahedron give rise to a representation of $p = 2$ finite geometry too. By assigning to each of these vertices a two-state system one obtains a representation for M_2. Tedrahedron allows M_2^2 representation with information content of 4 bits.

2. $p = 3$ projective geometry has four points and has the permutation group S_4 of four objects as a symmetry group. This group is the symmetry group of tedrahedron and the vertices of any face realize the finite geometry with three points with the fourth vertex taking the role of the point at infinity. Also octahedron and cube having symmetry group generated by 2-, 3- and 4-fold symmetries allow realization of the $p = 3$ finite geometry but not an isometric realization of the

projective geometry since the tedrahedron defined by the 3 vertices nearest to a given vertex is not regular. 3-fold symmetries are rotations along diagonals. M_3 cognitive representation results by assigning to the 3 vertices of triangle, tehdahedron or cube two-state systems.

3. The symmetry group of $p = 5$ finite projective geometry and thus also the geometry are represented by dodecahedron and icosahedron which are dual to each other by vertex-face transformation, as well as by a truncated icosahedron, 'bucky ball', having 60 vertices and directly representing the projective group associated with the corresponding finite geometry [43]. This group is isomorphic with the group A_5 of even permutations of 5 objects and contains 2-,3-, and five-fold elements. The coset space of $A_5/Z_2 \times Z_5$ represents the projective space and consists of 6 pairs of opposite and disjoint pentagons representing the points of the finite projective geometry.

The points of the finite geometry are represented by a single pentagon as is clear from the fact that the cyclic group Z_5 acts on these pentagons) M_5 representation results by assigning to the vertices of any pentagon a two-state system. System allows actually much more: there are 12 disjoint pentagons so that M_5^{12} code can be realized with information content of 60 bits! Thus truncated icosahedron has an exceptional capacity for coding intentions and this might be the reason for why it is the geometry of the clathrin molecules which take care of logistics in cellular systems.

Platonic solids allow also lattice structures. Therefore cognitive structures allowing symbolic representations in terms of molecular and lattice structures based on Platonic solids are expected to be of fundamental importance. These correspond to correspond to 2,3, and 5 bit codes and Mersennes M_2, M_3, M_5. M_2 corresponds to geometry of a line interval/triangle, M_3 to triangle/tedrahedron, and M_5 to pentagon/icosahedron, dodecahedron or truncated icosahedron depending on whether one requires projective extension or not. The codes would be represented by assigning to the substructures representing the finite geometry a two-state system. For instance, electric polarization of the protein structure in electric field at larger space-time sheet could define the spinlike variable. By using lattice like structure formed by basic units one obtains products of representations of type M_n^k.

10.6.4 Application of ideas to micro-tubuli and clathrin molecules

The proposed general principle allow to develop detailed views about what kind of cognitive representations that various molecular structure can accommodate. There is a considerable freedom concerning the choice of the representative system and spin flips or analogous transitions can be amplified to magnetization type quantum phase transitions at higher levels of the self hierarchy.

Micro-tubular representations

Micro-tubuli [63, 62] are formed as hexagonal lattices of tubulin dimers on cylinder. The two conformations of a tubulin dimer define the two states of the micro-tubular representations. In an external electric field along micro-tubule at the larger space-time sheet the second tubulin conformation is unstable and the codeword is realized as a phase transition leading to the ground state. Spontaneous electric polarization of all tubulins in the same direction forced by an electric field in the direction of the micro-tubule defines the ground state. The ground state itself cannot give rise to conformational flips and thus cannot define a codeword and one obtains M_{13} rather than 2^{13} codewords realizable as a signal resulting in the flip to the ground state.

1. Basic picture Micro-tubuli have helical structure: there are two helical strands with 13-micro-

tubule periodicity. A full 2π twist for a tubulin dimer strand corresponds to 13 dimers and corresponds to vertical distance of 8 resp. 5 micro-tubules for the two arrays involved. Thus a full 2π twist defines naturally the codeword and corresponds to 13-bit M_{13} codeword. Each tubulin dimer strand defines a codeword: M_{13}^{13} representations with an information content of $13^2 = 169$ bits associated with single 13-plet of codewords results.

The small value of $p = 13$ means an extreme flexibility concerning the duration of the cognitive code word. All $2^{13k/2} \sim 90.51^k$ multiples of T_{13} are possible. An interesting working hypothesis is that the number N of the tubulin strands contributing to the codeword defined by single connected structure defines the duration of the codeword as $T(N) = 2^{N \times 13/2} T_{13}$.

1. If the $k = 21$ micro-tubules at the wall of micro-tubule doublet contribute give rise to the DNA representation, this rule would predict the duration of the code word to be $T = 2^{(21-13) \times 13/2} T(169) \simeq$ 67.7 seconds with the duration of bit about 5.6 seconds, which is somewhat longer than the mysterious time scale of 5 seconds associated with the Comorosan effect [20]. $k = 20$ would give a codeword with a duration of .8 seconds and with the duration of bit about 62 milliseconds. DNA should control the behavior of micro-tubules in a rather long time scale (translation of single amino-acid takes 1/20 seconds) and these timescales sound rather reasonable.

2. For triplets of micro-tubuli the number of tubuli in the wall is something like 29 and the rule would predict completely unrealistic duration of the codeword about 10^7 years. It seems that the time scale should be same as for doublet: note that only pairs of tubuli have direct contact in the triplet.

3. Micro-tubular representation would correspond to the duration $T(13^2) = T(169)$ the cognitive codeword which is about 1.7×10^{-14} seconds, which is much shorter than the time scale of conformational dynamics and corresponds to the time scale of infrared transitions. This time scale is considerably shorter than the time scale $\sim$ .1 nanoseconds associated with the protein conformational dynamics so that some other spin or rpolarization type variable should define the representation if it is realized at all. Neutrino spin is an excellent candidate in this respect. By increasing $k = 13$ to $k = 15$ gives time scale of order .1 nanoseconds. It seems that the working hypothesis could give rough ideas about orders of magnitude but cannot be taken literally.

2. Cilia and centriole

Centriole resp. cilia are arrangements of micro-tubules containing 9 bundles of 3 resp. 2 micro-tubules at the boundary of cylinder like structure and possibly also a doublet of micro-tubuli in the center [62].

Micro-tubule doublets are associated with cilia crucial for the movement of monocellulars. Cilia consists of nine micro-tubule doublets at the surface of cylinder and one doublet in the center: also two separate micro-tubules are possible in the center. Some tubulin strands (usually three) are lacking from the second fused micro-tubule. According to some sources, the total number of tubulin dimer strands in doublet is 24 and 21 at the outer surface of doublet. 21 is Fibonacci number associated with the micro-tubular sequence of Fibonacci numbers and also the number of DNA triplets in cognitive codes. The complex of 21 tubulin dimer strands would be ideal for coding of M_{13}-bit sequences possibly associated with DNA or amino-acid sequences of 21 units and containing $21 \times 13 = 273$ bits of information. The code words associated with the wall of the cilium define $M_{13}^{9 \times 21}$ representation with $13 \times 9 \times 21 = 2457$ bits.

Centriole are crucial for the control of the movement of the cell and are present only in motile cells (not in plants). If nucleus controls the movement of cell, centrioles and cilia should communicate with DNA in both directions in the act of transforming intentions to actions. T shaped centriole form an ideal antenna structure and could communicate both classically and quantally in terms of MEs. Centriole have 9 micro-tubule triplets at the boundary of a cylinder. Various sources give different values for the total number of strands but it seems that the total number of tubulin strands is about 33-34 and outer wall contains about 4 strands. Perhaps it deserves to be noticed that the total number of strands is near to Fibonacci number 34 associated with the micro-tubular sequence of Fibonacci numbers. In case of centriole the 9 fused triplets of micro-tubules at the boundary each triplet containing about 33 tubulin dimer strands should give rise to a representation $M_{13}^{9 \times 33}$ with $13 \times 9 \times 33 = 3861$ bits. Huge amounts of information are involved.

3. Neuronal micro-tubuli

Neurons, which are not motile cells, do not have the usual T shaped centriole structure. Micro-tubuli are however there and start from the region near nucleus and connect this region to the dendrites and to the end of the axon. The micro-tubuli associated with the axons can be very long, up to millimeters and are connected together by MAPs, micro-tubule associated proteins. This strongly suggests that micro-tubuli participate in an essential manner to neuronal communications or to short term information storage. For instance, the propagation of the nerve pulse could alter the electric field of the micro-tubule space-time sheet temporarily and give rise to spin glass state and thus induce representations of cognitive states in terms of tubulin conformations. The return of the membrane

potential to the normal value would induce the conscious reading of the resulting representations. The minimal reason for this would be that axonal micro-tubules are responsible for the transfer of neurotransmitters to the axonal end and they must be cognizant about the overall nerve pulse activity.

Against the impressive representational capacity of micro-tubules the idea that nerve pulse involves the transfer of only single bit of information seems weird. Rather, the picture about micro-tubules would suggest that nerve pulse propagation are accompanied by a propagation of conformational spin glass state in the depolarized portion of the axon carrying information, and that one important function of the nerve pulse is to allow the propagation of the conformational wave carrying the information. Of course, also cell membrane could carry informational wave by same mechanism and one could see the events in the axonal membrane also as a realization of p-adic intentions basically. An objection against this view is related to the problem how the micro-tubular signal is transferred between micro-tubuli at MAPs. This is obviously needed if information from micro-tubuli is transferred to postsynaptic neuron. One must seriously consider the possibility is that the information is received only by micro-tubuli and their form an essential part of the conscious sensory pathway. This would explain why the lengths of micro-tubuli associated with sensory pathways are maximized (the information from given side of the body goes to the opposite brain hemisphere).

Clathrin molecule and cognition

Clathrin molecule [62] is involved with the transfer of various kinds of cargo through the cell membrane and also through intracellular membranes. Even viruses use clathrin molecule coating. Clathrin molecule induces a pit in the cell membrane and membrane pinches so that clathrin molecule providing coating for a piece of cell membrane and containing the cargo ends up to the cell interior. An area of cell membrane of football plane corresponding to that contained by entire brain is generated during one hour when clathrins coat cell membrane containing receptors and take it inside the cell. The generation of new cell membrane with this gigantic rate should involve huge dissipative losses unless macro-temporal quantum coherence is involved in the process.

Perhaps this argument alone convinces one day anyone about the presence of macro-temporal quantum coherence in brain. Clathrin molecule has the geometry of a truncated icosahedron, also the geometry of the soccer ball and fullerene or buckyball molecule C_{60} containing 60 carbon atoms arranged to the vertices of the truncated icosahedron. In clathrin molecule carbon atoms are replaced by three-legged triskelion molecules consisting of proteins. It is interesting to take a more careful look on the geometry of truncated icosahedron defining the geometry of the clathrin molecule, if not anything else, the for the purpose to get a glimpse about the amazing number theoretical regularities of this structure. Truncated icosahedron has 60=59+1 vertices, 90=89+1 lines, and 12=11+1 pentagonal and 20=19+1 hexagonal faces. Pentagonal faces are disjoint. 6 pentagonal face pairs can be naturally interpreted as points of a finite projective geometry associated with finite field $G(5,1)$.

What it is interesting is that all these numbers are of form $p+1$, p prime. With one exception (59) these primes also define Mersennes of Gaussian Mersennes. As a matter fact, the number of faces, edges, and vertices are of this form for all Platonic solids and also for several Archimedean solids. The interpretation in terms of a finite projective geometries suggests itself but the requirement that the symmetries of finite geometry are realizable as rotations excludes this interpretation since these substructures are not representations of the corresponding projective group realized in terms of rotations. Of course, one must keep mind open for the possibility that the imbedding of the symmetry group to rotation group is not necessary.

Clathrin molecule is an excellent candidate for a very effective realization of molecular cognition and intention. If the triskelion proteins at the vertices of disjoint pentagons are electrically polarizable, a dynamical M_5^{12} representation with information content of 60 bits becomes possible by controlling the electric field at the space-time sheet at which the triskelions are condensed at. This information could relate to the basic function of clathrin molecules but also the idea that clathrin molecules transfer also information besides matter must be considered. For instance, this representation could be involved with the transfer of not only the neurotransmitters but also of (micro-tubular?) information from post- to pre-synaptic neurons.

What about cell membrane?

Cell membrane electric field makes it ideal for the realization of cognitive representations. Lipid molecules and membrane proteins are natural good candidates for representing the bit sequences represented as two different electric polarizations of proteins. The propagation of nerve pulse could generate a representation during depolarization phase which would be read when membrane potential has returned to its original value. The function of the nerve pulse would be thus to inform entire axon consciously.

10.7 Intentionality, cognition, and number theory

The identification of p-adic physics as physics of cognition and intention suggests strongly connections between cognition, intentionality, and number theory. The new idea is that also real transcendental numbers can appear in the extensions of p-adic numbers which must be assumed to be finite-dimensional at least in the case of human cognition. This idea, when combined with a more precise model for how intentions are transformed to actions, leads to a series of number theoretical conjectures. Also new insights about the number theoretical origin of the universal dynamics of conformally invariant critical systems emerge. The earlier approaches to the proof of Riemann hypothesis can be understood in a unified manner and the assumption that Riemann Zeta exists in all number fields when finite extensions are allowed for p-adic numbers leads to the view that that the zeros of Riemann Zeta correspond to the universal number theoretically quantized spectrum of scaling momenta associated with critical conformally invariant systems.

10.7.1 Should one allow also transcendentals in the extensions of p-adic numbers?

TGD inspired theory of consciousness leads to the identification of p-adic physics as physics of cognition and intention. This identification leads to a rather fascinating new ideas concerning the characterization of intentional systems.

The basic ingredient is the new view about numbers: real and p-adic number fields are glued together like pages of a book along common rationals representing the rim of the book. This generalizes to the extensions of p-adic number fields and the outcome is a complex fractal book like structure containing books within books. This holds true also for manifolds and one ends up to the view about many-sheeted space-time realized as 4-surface in 8-D generalized imbedding space and containing both real and p-adic space-time sheets. The transformation of intention to action corresponds to a quantum jump in which p-adic space-time sheet is replaced with a real one.

One implication is that the rationals having short distance p-adically are very far away in real sense. This implies that p-adically short temporal and spatial distances correspond to long real distances and that the evolution of cognition proceeds from long to short temporal and spatial scales whereas material evolution proceeds from short to long scales. Together with p-adic non-determinism due the fact that the integration constants of p-adic differential equations are piecewise constant functions this explains the long range temporal correlations and apparent local randomness of intentional behavior. The failure of the real statistics and its replacement by p-adic fractal statistics for time series defined by varying number N of measurements performed during a fixed time interval T allows very general tests for whether the system is intentional and what is the p-adic prime p characterizing the "intelligence quotient" of the system. The replacement of $log(p_n)$ in the formula $S = -\sum_n p_n log(p_n)$ of Shannon entropy with the logarithm of the p-adic norm $|p_n|_p$ of the rational valued probability allows to define a hierarchy of number theoretic information measures which can have both negative and positive values.

Since p-adic numbers represent a highly number theoretical concept one might expect that there are deep connections between number theory and intentionality and cognition. The discussions with Uwe Kämpf in CASYS′2003 conference in Liege indeed stimulated a bundle of ideas allowing to develop a more detailed view about intention-to-action transformation and to disentangle these connections. These discussions made me aware of the fact that my recent views about the role of extensions of p-adic numbers are perhaps too limited. To see this consider the following arguments.

1. Pure p-adic numbers predict only p-adic length scales proportional to $p^{n/2}l$, l CP_2 length scale about 10^4 Planck lengths, $p \simeq 2^k$, k prime or power of prime. As a matter fact, all positive integer values of k are possible. This is however not enough to explain all known scale hierarchies. Fibonacci numbers $F_n : F_n + 1 = F_n + F_{n-1}$ behave asymptotically like $F_n = kF_{n-1}$, k solution of the equation $k^2 = k+1$ given by $k = \Phi = (1+\sqrt{5})/2 \simeq 1.6$. Living systems and self-organizing systems represent a lot of examples about scale hierarchies coming in powers of the Golden Mean $\Phi = (1 + \sqrt{5})/2$. According to Selvam [53] also meteorological phenomena involve spiral waves characterized by Golden Mean.

   By allowing the extensions of p-adics by algebraic numbers one ends up to the idea that also the length scales coming as powers of x, where x is a unit of algebraic extension analogous to imaginary unit, are possible. One would however expect that the generalization of the p-adic length scale hypothesis alone would predict only the powers $\sqrt{x}p^{n/2}$ rather than $x^k p^{n/2}$, $k = 1, 2, ...$ Perhaps the purely kinematical explanation of these scales is not possible and genuine dynamics is needed. For sinusoidal logarithmic plane waves the harmonics correspond to the scalings of the argument by powers of some scaling factor x. Thus the powers of Golden Mean might be associated with logarithmic sinusoidal plane waves.

2. Physicist Hartmuth Mueller has developed what he calls Global Scaling Theory [47] based on the observation that powers of e (Neper number) define preferred length scales. These powers associate naturally with the nodes of logarithmic sinusoidal plane waves and correspond to various harmonics (matter tends to concentrate on the nodes of waves since force vanishes at the nodes). Mueller talks about physics of number line and there is great temptation to assume that deep number theory is indeed involved. What is troubling from TGD point of view that Neper number e is not algebraic. Perhaps a more general approach allowing also transcendentals must be adopted. Indeed, since e^p is ordinary p-adic number in R_p, a finite-dimension transcendental extension containing e exists.

3. Classical mathematics, such as the theory of elementary functions, involves few crucially important transcendentals such as e and π. This might reflect the evolution of cognition: these numbers should be cognitively and number theoretically very special. The numbers e and π appear also repeatedly in the basic formulas of physics. They however look p-adically very troublesome since it has been very difficult to imagine a physically acceptable generalization of such simple concepts as exponent function, trigonometric functions, and logarithm resembling its real counterpart by allowing only the extensions of p-adic numbers based on algebraic numbers.

4. Number theoretic entropies measured in bits are proportional to $log(p)/log(2)$. The idea that these entropies are rational fractions of bit is attractive and implies that $log(p)$ for all primes is proportional to the same transcendental number. This would mean that logarithm of the rational number field would be a transcendental multiple of rationals.

These considerations stimulate the question whether, besides the extensions of p-adics by algebraic numbers, also the extensions of p-adic numbers involving e, and perhaps even π and and other transcendentals might be needed. The intuitive expectation motivated by the finiteness of human intelligence is that these extensions might have finite algebraic dimensions. On the other hand, if one is only interested in quantities derived from phases $exp(i2\pi/n)$, a finite-dimensional algebraic extension is enough. π is needed only if one wants to deal with say length of circle's circumference in the p-adic context, and one could argue that p-adic Riemann geometry is local and only about angles and infinitesimal distances.

Second question is whether there might be some dynamical mechanism allowing to understand the hierarchy of scalings coming in powers of some preferred transcendentals and algebraic numbers like Golden Mean. Conformal invariance implying that the system is characterized by a universal spectrum of scaling momenta for the logarithmic counterparts of plane waves seems to provide this mechanism. This spectrum is determined by the requirement that it exists for both reals and all p-adic number fields assuming that finite-dimensional extensions are allowed in the latter case. The spectrum corresponds to the zeros of the Riemann Zeta if Zeta is required to exist for all number fields in the proposed sense, and a lot of new understanding related to Riemann hypothesis emerges and allows to develop further the previous TGD inspired ideas about how to prove Riemann hypothesis [42, 54].

10.7.2   General number theoretical ideas inspired by the number theoretic vision about cognition and intentionality

The following two ideas serve as guide lines in the attempt to relate cognition, intentionality and number theory to each other so that number theory would allow to construct a more detailed view about the realization of intentionality and cognition. As a matter fact, the general ideas about intention and cognition in turn generate very general number theoretical conjectures.

1. Real and p-adic number fields form a book like structure with pages represented by number fields glued together along rationals forming the rim of the book. For the extensions of p-adic numbers further common points result and the book becomes fractal if all possible extensions are allowed. This picture generalizes to the level of the imbedding space and allows to see space-time surfaces as consisting of real and p-adic space-time sheets belonging to various extensions of these numbers. This generalized view about numbers gives hopes about an unambigious definition of what some number, say e, appearing in an extension of p-adic numbers really means.

2. The first new idea is roughly that the discovery of notion of any algebraic or transcendental number x (such as Φ or e) involves a quantum jump in which there is generated a p-adic space-time sheet for which the existing finite-dimensional extension of p-adic numbers is replaced by a finite-dimensional extension involving also x. Also some higher powers of the number are involved. For instance, for e $p-1$ powers are necessarily needed (e^p exists p-adically).

3. The p-adic-to-real transition serving as a correlate for the transformation of intention to action is most probable if the number of common rational valued points for the p-adic and real space-time sheet is high. The requirement of real and p-adic continuity and even smoothness however forces upper and lower p-adic length scale cutoffs so that common points are in certain length scale range.

4. The points of M_+^4 with integer valued Minkowski coordinates using CP_2 length related fundamental length scale as a basic unit is a good guess for the subset of M_+^4 defining the rational points of the M_+^4 involved. CP_2 coordinates as functions of M_+^4 coordinates should be rational or belong to some finite-dimensional extension of p-adics. Of course, also rational points of M_+^4 are possible, and the evolution of cognition should correspond to the increase of the algebraic dimension of the extension.

5. A very powerful hypothesis is that the p-adic and real functions have the same analytic form besides coinciding at the chosen rational points defining the p-adic pseudo constant involved. Since the pseudo constant defines the corresponding real function in rational points, there are indeed good hopes that the transformation of p-adic intention to real action is possible. This assumption favors functions which allow at some point (most naturally origin) a Taylor series with rational valued Taylor coefficients.

Is e an exceptional transcendental?

Neper number is obviously the simplest one and only the powers e^k, $k = 1, ..., p-1$ of e are needed to define p-adic counterpart of e^x for $x = n$. In case of trigonometric functions deriving from e^{ix}, also e^i and its $p-1$ powers must belong to the extension.

An interesting question is whether e is a number theoretically exceptional transcendental or whether it could be easy to find also other transcendentals defining finite-dimensional extensions of p-adic numbers.

1. Consider functions $f(x)$, which are analytic functions with rational Taylor coefficients, when expanded around origin for $x > 0$. The values of $f(n)$, $n = 1, ..., p-1$ should belong to an extension, which should be finite-dimensional.

2. The expansion of these functions to Taylor series generalizes to the p-adic context if also the higher derivatives of f at $x = n$ belong to the extension. This is achieved if the higher derivatives are expressible in terms of the lower derivatives using rational coefficients and rational functions or functions, which are defined at integer points (such as exponential and logarithm) by construction. A differential equation of some finite order involving only rational functions with

rational coefficients must therefore be satisfied (e^x satisfying the differential equation $df/dx = f$ is the optimal case in this sense). The higher derivatives could also reduce to rational functions at some step ($log(x)$ satisfying the differential equation $df/dx = 1/x$).

3. The differential equation allows to develop $f(x)$ in power series, say in origin

$$f(x) = \sum f_n \frac{x^n}{n!}$$

such that f_{n+m} is expressible as a rational function of the m lower derivatives and is therefore a rational number.

The series converges when the p-adic norm of x satisfies $|x|_p \leq p^k$ for some k. For definiteness one can assume $k = 1$. For $x = 1, ..., p-1$ the series does not converge in this case, and one can introduce and extension containing the values $f(k)$ and hope that a finite-dimensional extension results.

Finite-dimensionality requires that the values are related to each other algebraically although they need not be algebraic numbers. This means symmetry. In the case of exponent function this relationship is exceptionally simple. The algebraic relationship reflects the fact that exponential map represents translation and exponent function is an eigen function of a translation operator. The necessary presence of symmetry might mean that the situation reduces always to either exponential action. Also the phase factors $exp(iq\pi)$ could be interpreted in terms of exponential symmetry. Hence the reason for the exceptional role of exponent function reduces to group theory.

Also other extensions than those defined by roots of e are possible. Any polynomial has n roots and for transcendental coefficients the roots define a finite-dimensional extension of rationals. It would seem that one could allow the coefficients of the polynomial to be functions in an extension of rationals by powers of a root of e and algebraic numbers so that one would obtain infinite hierarchy of transcendental extensions.

Does the integration of complex rational functions lead to rationals extended by a root of e and powers of π?

These cold showers suggest that the best one might hope is that the numbers like $log(p)$ and $log(\Phi)$ could be proportional to some power π with a coefficient which belongs to a finite extension of p-adic numbers containing e. This might make it possible to continue the theory to p-adic context and also make very strong predictions.

The elementary differential and integral calculus provides important hints for as how to proceed. Derivation takes rational functions to rational functions unlike integration since the integrals of $1/x$ and and $1/(1 + x^2)$ give $log(x)$ and $arctan(x)$ leading outside the realm of rational numbers. One can go to complex plane and consider the integrals of complex rational functions with complex rational coefficients and here one encounters integrals over closed curves and between two points. The rational approach is to consider rational complex plane, and first restrict to Gaussian integers which allow primes.

1. The first observation is that residy calculus for rational functions gives always integrals which are of form $2\pi i q$, q a rational number.

2. The integral $I = \int_a^b dz/z$, $a = m_1 + in_1$, $b = m_2 + in_2$ in turn gives

$$I = log(a/b) = \tfrac{1}{2} \left(log(m_2^2 + n_2^2) - log(m_1^2 + n_1^2) \right)$$

$$+i(arctan(n_2/m_2) - arctan(n_1/m_1)) \ .$$

1. The strongest hypothesis would be that logarithm and arctan are also rationally proportional to π so that all integrals of this kind lead to an infinite-dimensional transcendental extension of p-adic numbers containing π. The strong hypothesis cannot be correct. Consider arcus tangent as an example. $arctan(m/n) = r\pi/s$ would imply $tan(r\pi/s) = m/n$, and this cannot hold true since it would imply that s:th powers of Gaussian integer $n + im$ would give an ordinary integer.

This would be also true for Gaussian primes and the decomposition of Gaussian integers as products of Gaussian primes would become non-unique. There is this kind of uniqueness but this is due the units $exp(i\pi/4)$ and its powers. Indeed, $arctan(1) = \pi/4$ and proportional to π.

2. One can overcome this difficulty by replacing the ansatz with

$$arctan(q) = e^{q_1(q)}q_2\pi$$

such that $q_1(q)$ is non-vanishing for $q \neq \pm 1 \pm i$ corresponding to the units of Gaussian primes. This ansatz is completely analogous to the ansatz for $log(p)$. The beauty of this ansatz would be that the imaginary parts for the integral of $1/(z - z_0)$ between complex rational points would be proportional to π irrespective of whether the integration is over a closed or open curve. The real parts of complex integrals in turn would be proportional to $1/\pi$ of $log(p) \propto 1/\pi$ ansatz holds true.

The requirement that complex integrals are powers of π could also mean quantization of topology in TGD framework. For instance, the conformal equivalence classes of Riemann surfaces of genus g are represented by period integrals of 1-forms defining elements of cohomology group H^1 over the circles representing the elements of homology group H_1. Restricting the cohomology to a rational cohomology, the periods with standard normalization would be quantized to complex rationals multiplied by a power of π. For surfaces characterized by a given power of π one might perhaps perform the p-adicization finite-dimensionally by suitable normalizations by powers of π.

p-Adicization of vacuum functional of TGD and infinite primes

A further input comes from TGD. The basic challenge is to continue the exponent $exp(K)$ of the Kähler function to p-adic number fields. K can be expressed as

$$K = \frac{S_K}{16\pi\alpha_K} \quad ,$$

where α_K is so called Kähler coupling strength and $S_K = \int J_{\mu\nu}J^{\mu\nu}\sqrt{g}d^4x$ is Kähler action, which is essentially the Maxwell action for the induced Kähler form. The dream is that an algebraic continuation from the extensions of rational numbers defining finite extensions of p-adic numbers allows to define the theory in various number fields. The fulfillment of this dream requires that physically important quantities such as the exponent of Kähler function for CP_2 extremal and other fundamental extremals exist in a finite-dimensional extension of p-adic numbers.

   1. What is the value of Kähler coupling strength?

   The value of Kähler coupling strength is analogous to a critical temperature and can have only discrete values.

1. The discrete p-adic evolution of the Kähler coupling strength follows from the requirement that gravitational coupling constant is renormalization group invariant [17]. When combined with the requirement that the exponent of CP_2 action is a power of prime, the argument would give

$$\frac{1}{\alpha_K(p)} = \frac{4}{\pi}log(K^2) \quad , \quad K^2 = \prod_{q=2,3,\dots23} q \times p$$

with $\alpha_K(p = M_{127}) \simeq 136.5585$ and $\alpha/\alpha_K \simeq .9965$. Note that M_{127} corresponds to electron length scale. If the action is a rational fraction of CP_2 action, and the extension of p-adic numbers is by an appropriate root of p is enough to guarantee the existence of the Kähler function.

2. One can consider also an alternative ansatz based on the requirement that Kähler function is a rational number rather than a logarithm of a power of integer K^2. This requires an extension of p-adic numbers involving some root of e and a finite number of its powers. S_R must be rational valued using Kähler action $S_K(CP_2) = 2\pi^2$ of CP_2 type extremal as a basic unit. In fact, not only rational values of Kähler function but all values which differ from a rational value by a

perturbation with a p-adic norm smaller than one and rationally proportional to a power of e or even its root exist p-adically in this case if they have small enough p-adic norm. The most general perturbation of the action is in the field defined by the extension of rationals defined by the root of e and algebraic numbers.

Since CP_2 action is rationally proportional to π^2, the exponent is rational if $4\pi\alpha_K$ satisfies the same condition. If the conjecture $log(p) = q_1(p)exp\left[q(p_2)\right]/\pi$ holds , then the earlier ansatz $1/\alpha_K(p) = (4/\pi)log(K^2)$ does not guarantee this, and $4/\pi$ must be replaced with a rational number $Q \simeq 4/\pi$. The presence of $log(K^2)$, K^2 product of primes, is well motivated also in this case because it gives the desired $1/\pi$ factor.

This gives for the Kähler function the expression

$$
K \;\; = \;\; Q \left[q_1(p)exp\left[q_2(p)\right] + \sum_i q_1(q_i)exp\left[q_2(q_i)\right] \right] \frac{S}{S_{CP_2}} \;\; . \tag{10.7.1}
$$

$exp(K)$ exists p-adically only provided that K has p-adic norm smaller than one. For given p this poses strong conditions unless one assumes that the condition $S/S_{CP_2} = p^n r$, r rational. In the case of many-particle state of CP_2 extremals this would mean that particle number is divisible by a power of p.

For single CP_2 extremal, the fact that p cannot divide $q_1(p)$ means that either Q contains a power of p or the sum of terms is proportional to a power of p. Obviously this condition is extremely strong and allows only very few primes. One might wander whether this could provide the first principle explanation for p-adic length scale hypothesis selecting primes $p \simeq 2^k$, k integer, and with prime power powers being preferred.

Since $k = 137$ (atomic length scale) and $k = 107$ (hadronic length scale) are the most important nearest p-adic neighbors of electron, one could make a free fall into number mysticism and try the replacement $4/\pi \to 137/107$. This would give $\alpha_K = 137.3237$ to be compared with $\alpha = 137.0360$: the deviation from α is .2 per cent (of course, α_K need not equal to α and the evolutions of these couplings are quite different). Thus it seems that $log(p) = q_1 exp(q_2)/\pi$ hypothesis is supported also by the properties of Kähler action and might lead to an improved understanding of the origin of the mystery prime $k = 137$. Of course, one must be extremely cautious with the numerics. For instance, one could replace $137/107$ with the ratio of $137/log(M_{107}$ and in this case the M_{107} would become an "easy" prime.

2. Could infinite primes appear in the p-adicization of the exponent of Kähler action?

The difficulties related to the p-adic continuation of Kähler function to an arbitrary p-adic number field and the fact that infinities are every day life in quantum field theory bring in mind infinite primes discussed in [19].

Infinite primes are not divisible by any finite prime. The simplest infinite prime is of form $\Pi = 1 + X$, $X = \prod_i p_i$, where product is over all finite primes. The factor $Y = X/(1+X)$ is in the real sense equivalent with 1. In p-adic sense it has norm $1/p$ for every prime. Thus one could multiply Kähler function by Y or its positive power in order to guarantee that the continuation to p-adic number fields exists for all primes. Of course, these states might differ physically in p-adic sense from the states having $Y = 1$. Thus it would seem that the physics of cognition could differentiate between states which are in real sense equivalent.

More general infinite primes are of form $\Pi = nX/m + n$, such that $m = \prod_i q_i$ and $n = \prod_i p_i^{n_i}$ have no common factors. The interpretation could be as a counterpart for a state of a super-symmetric theory containing fermion in each mode labelled by q_i and n_i bosons labelled in modes labelled by p_i. Also positive powers of the ratio $Y = X/\Pi$, Π some infinite prime, are possible as a multiplier of the Kähler function. In the real sense this ratio would correspond to the ratio m/n.

If this picture is correct, infinite primes would emerge naturally in the p-adicization of the theory. Since octonionic infinite primes could correspond to the states of a super-symmetric quantum field theory more or less equivalent with TGD, the presence of infinite primes could make it possible to code the quantum physical state to the vacuum functional via coupling constant renormalization.

One could also consider the possibility of defining functions like $exp(x)$ and $log(1+x)$ p-adically by replacing x with Yx without introducing the algebraic extension. The series would converge for all

values of x also p-adically and would be in real sense equivalent with the function. This trick would apply to a very general class of Taylor series having rational coefficients. One could also say that p-adic physics allowing infinite primes would be very similar to real physics.

The fascination of infinite primes is that the ratios of infinite primes which are ordinary rational numbers in the real sense could code the particle number content of a super-symmetric arithmetic quantum field theory. For the octonic version of the theory natural in the TGD framework these states could represent the states of a real Universe. Universe would be an algebraic hologram in the sense that space-time points, something devoid of any structure in the standard view, could code for the quantum states of possible Universes!

The simplest manner to realize this scenario is to consider an extension of rational rational numbers by the multiplicative group of real units obtained from infinite primes and powers of X. Real number 1 would code everything in its structure! This group is generated as products of powers of $Y(m/n) = (m/n) \times [X/\Pi(m/n)]$ which is a unit in the real sense. Each $Y(m/n)$ would define a subgroup of units and the power of $Y(m/n)$ would code for the number of factors of a given integer with unit counted as a factor. This would give a hierarchy of integers with their p-adic norms coming as powers of p with the prime factors of m and n forming an exception and being reflected in p-adic physics of cognition, Universe would "feel" its real or imagined state with its every point, be it a point of space-time surface, of imbedding space, or of configuration space.

In fact, one can any pair of infinite primes having finite ratio given by rational number can be divided by the prime in question to give a unit in real sense. These units are not units in the p-adic sense and have a finite p-adic norm which can be differ from one. Infinite primes form an infinite hierarchy so that the points of space-time and imbedding space can be seen as infinitely structured and able to represent all imaginable algebraic structures. Certainly counter-intuitively, single space-time point is even capable of representing the quantum state of entire physical Universe in its structure. For instance, in real sense surfaces in the space of units correspond to the same real number 1, and single point, which is structure-less in the real sense could represent arbitrarily high-dimensional spaces as unions of real units. For real physics this structure is completely invisible and is relevant only for the physics of mathematical cognition. One can say that Universe is an algebraic hologram, and there is an obvious connection both with Brahman=Atman identity of Eastern philosophies and Leibniz's notion of monad.

10.7.3 Infinite primes, cognition and intentionality

Somehow it is obvious that infinite primes must have some very deep role to play in quantum TGD and TGD inspired theory of consciousness. What this role precisely is has remained an enigma although I have considered several detailed interpretations, one of them above.

In the following an interpretation allowing to unify the views about fermionic Fock states as a representation of Boolean cognition and p-adic space-time sheets as correlates of cognition is discussed. Very briefly, real and p-adic partonic 3-surfaces serve as space-time correlates for the bosonic super algebra generators, and pairs of real partonic 3-surfaces and their algebraically continued p-adic variants as space-time correlates for the fermionic super generators. Intentions/actions are represented by p-adic/real bosonic partons and cognitions by pairs of real partons and their p-adic variants and the geometric form of Fermi statistics guarantees the stability of cognitions against intentional action. It must be emphasized that this interpretation is not identical with the one discussed above since it introduces different identification of the space-time correlates of infinite primes.

Infinite primes very briefly

Infinite primes have a decomposition to infinite and finite parts allowing an interpretation as a many-particle state of a super-symmetric arithmetic quantum field theory for which fermions and bosons are labelled by primes. There is actually an infinite hierarchy for which infinite primes of a given level define the building blocks of the infinite primes of the next level. One can map infinite primes to polynomials and these polynomials in turn could define space-time surfaces or at least light-like partonic 3-surfaces appearing as solutions of Chern-Simons action so that the classical dynamics would not pose too strong constraints.

The simplest infinite primes at the lowest level are of form $m_B X/s_F + n_B s_F$, $X = \prod_i p_i$ (product of all finite primes). The simplest interpretation is that X represents Dirac sea with all states filled

and $X/s_F + s_F$ represents a state obtained by creating holes in the Dirac sea. m_B, n_B, and s_F are defined as $m_B = \prod_i p_i^{m_i}$, $n_B = \prod_i q_i^{n_i}$, and $s_F = \prod_i q_i$, m_B and n_B have no common prime factors. The integers m_B and n_B characterize the occupation numbers of bosons in modes labelled by p_i and q_i and $s_F = \prod_i q_i$ characterizes the non-vanishing occupation numbers of fermions.

The simplest infinite primes at all levels of the hierarchy have this form. The notion of infinite prime generalizes to hyper-quaternionic and even hyper-octonionic context and one can consider the possibility that the quaternionic components represent some quantum numbers at least in the sense that one can map these quantum numbers to the quaternionic primes.

The obvious question is whether configuration space degrees of freedom and configuration space spinor (Fock state) of the quantum state could somehow correspond to the bosonic and fermionic parts of the hyper-quaternionic generalization of the infinite prime. That hyper-quaternionic (or possibly hyper-octonionic) primes would define as such the quantum numbers of fermionic super generators does not make sense. It is however possible to have a map from the quantum numbers labelling super-generators to the finite primes. One must also remember that the infinite primes considered are only the simplest ones at the given level of the hierarchy and that the number of levels is infinite.

Precise space-time correlates of cognition and intention

The best manner to end up with the proposal about how p-adic cognitive representations relate bosonic representations of intentions and actions and to fermionic cognitive representations is through the following arguments.

1. In TGD inspired theory of consciousness Boolean cognition is assigned with fermionic states. Cognition is also assigned with p-adic space-time sheets. Hence quantum classical correspondence suggests that the decomposition of the space-time into p-adic and real space-time sheets should relate to the decomposition of the infinite prime to bosonic and fermionic parts in turn relating to the above mention decomposition of physical states to bosonic and fermionic parts.

   If infinite prime defines an association of real and p-adic space-time sheets and this association could serve as a space-time correlate for the Fock state defined by configuration space spinor for given 3-surface. Also spinor field as a map from real partonic 3-surface would have as a space-time correlate a cognitive representation mapping real partonic 3-surfaces to p-adic 3-surfaces obtained by algebraic continuation.

2. Consider first the concrete interpretation of integers m_B and n_B. The most natural guess is that the primes dividing $m_B = \prod_i p^{m_i}$ characterize the effective p-adicities possible for the real 3-surface. m_i could define the numbers of disjoint partonic 3-surfaces with effective p_i-adic topology and associated with with the same real space-time sheet. These boundary conditions would force the corresponding real 4-surface to have all these effective p-adicities implying multi-p-adic fractality so that particle and wave pictures about multi-p-adic fractality would be mutually consistent. It seems natural to assume that also the integer n_i appearing in $m_B = \prod_i q_i^{n_i}$ code for the number of real partonic 3-surfaces with effective q_i-adic topology.

3. Fermionic statistics allows only single genuinely q_i-adic 3-surface possibly forming a pair with its real counterpart from which it is obtained by algebraic continuation. Pairing would conform with the fact that n_F appears both in the finite and infinite parts of the infinite prime (something absolutely essential concerning the consistency of interpretation!).

   The interpretation could be as follows.

   i) Cognitive representations must be stable against intentional action and fermionic statistics guarantees this. At space-time level this means that fermionic generators correspond to pairs of real effectively q_i-adic 3-surface and its algebraically continued q_i-adic counterpart. The quantum jump in which q_i-adic 3-surface is transformed to a real 3-surface is impossible since one would obtain two identical real 3-surfaces lying on top of each other, something very singular and not allowed by geometric exclusion principle for surfaces. The pairs of boson and fermion surfaces would thus form cognitive representations stable against intentional action.

   ii) Physical states are created by products of super algebra generators. Bosonic generators can have both real or p-adic partonic 3-surfaces as space-time correlates depending on whether they correspond to intention or action. More precisely, m_B and n_B code for collections of real and

p-adic partonic 3-surfaces. What remains to be interpreted is why m_B and n_B cannot have common prime factors (this is possible if one allows also infinite integers obtained as products of finite integer and infinite primes).

iii) Fermionic generators to the pairs of a real partonic 3-surface and its p-adic counterpart obtained by algebraic continuation and the pictorial interpretation is as fermion hole pair. Unrestricted quantum super-position of Boolean statements requires that many-fermion state is accompanied by a corresponding many-antifermion state. This is achieved very naturally if real and corresponding p-adic fermion have opposite fermion numbers so that the kicking of negative energy fermion from Dirac sea could be interpreted as creation of real-p-adic fermion pairs from vacuum.

If p-adic space-time sheets obey same algebraic expressions as real sheets (rational functions with algebraic coefficients), the Chern-Simons Noether charges associated with real partons defined as integrals can be assigned also with the corresponding p-adic partons if they are rational or algebraic numbers. This would allow to circumvent the problems related to the p-adic integration. Therefore one can consider also the possibility that p-adic partons carry Noether charges opposite to those of corresponding real partons sheet and that pairs of real and p-adic fermions can be created from vacuum. This makes sense also for the classical charges associated with Kähler action in space-time interior if the real space-time sheet obeying multi-p p-adic effective topology has algebraic representation allowing interpretation also as p-adic surface for all primes involved.

iv) This picture makes sense if the partonic 3-surfaces containing a state created by a product of super algebra generators are unstable against decay to this kind of 3-surfaces so that one could regard partonic 3-surfaces as a space-time representations for a configuration space spinor field.

4. Are alternative interpretations possible? For instance, could $q = m_B/n_B$ code for the effective q-adic topology assignable to the space-time sheet. That q-adic numbers form a ring but not a number field casts however doubts on this interpretation as does also the general physical picture.

Number theoretical universality of S-matrix

The discreteness of the intersection of the real space-time sheet and its p-adic variant obtained by algebraic continuation would be a completely universal phenomenon associated with all fermionic states. This suggests that also real-to-real S-matrix elements involve instead of an integral a sum with the arguments of an n-point function running over all possible combinations of the points in the intersection. S-matrix elements would have a universal form which does not depend on the number field at all and the algebraic continuation of the real S-matrix to its p-adic counterpart would trivialize. Note that also fermionic statistics favors strongly discretization unless one allows Dirac delta functions.

10.7.4   Cognition, logic, and p-adicity

There seems to be a nice connection between logic aspects of cognition and p-adicity. In particular, p-valued logic for $p = 2^k - n$ has interpretation in terms of ordinary Boolean logic with n "taboos" so that p-valued logic does not conflict with common sense in this case. Also an interpretation of projections of p-adic space-time sheets to an integer lattice of real Minkowski space M^4 in terms of generalized Boolean functions emerges naturally so that M^4 projections of p-adic space-time would represent Boolean functions for a logic with n taboos.

2-adic valued functions of 2-adic variable and Boolean functions

The binary coefficients f_{nk} in the 2-adic expansions of terms $f_n x^n$ in the 2-adic Taylor expansion $f(x) = \sum_{n=0} f_n x^n$, assign a sequence of truth values to a 2-adic integer valued argument $x \in \{0, 1, ..., 2^N\}$ defining a sequence of N bits. Hence $f(x)$ assigns to each bit of this sequence a sequence of truth values which are ordered in the sense that the truth values corresponding to bits are not so important p-adically: much like higher decimals in decimal expansion. If a binary cutoff in N:th bit of $f(x)$ is introduced, B^M-valued function in B^N results, where B denotes Boolean algebra

fo 2 elements. The formal generalization to p-adic case is trivial: 2 possible truth values are only replaced by p truth values representable as $0, ..., p-1$.

p-Adic valued functions of p-adic variable as generalized Boolean functions

One can speak of a generalized Boolean function mapping finite sequences of p-valued Boolean arguments to finite sequences of p-valued Boolean arguments. The restriction to a subset $x = kp^n$, $k = 0, ..., p-1$ and the replacement of the function $f(x)$ with its lowest pinary digit gives a generalized Boolean function of a single p-valued argument. If $f(x)$ is invariant under the scalings by powers of p^k, one obtains a hologram like representation of the generalized Boolean function with same function represented in infinitely many length scales. This guarantees the robustness of the representation.

The special role of 2-adicity explaining p-adic length scale hypothesis $p \simeq 2^k$, k integer, in terms of multi-p-acidic fractality would correlate with the special role of 2-valued logic in the world order. The fact that all generalizations of 2-valued logic ultimately involve 2-adic logic at the highest level, where the generalization is formulated would be analog of p-adic length scale hypothesis.

$p = 2^k - n$-adicity and Boolean functions with taboos

It is difficult to assign any reasonable interpretation to $p > 2$-valued logic. Also the generalization of logical connectives AND and OR is far from obvious. In the case $p = 2^k - n$ favored by the p-adic length scale hypothesis situation is however different. In this case one has interpretation in terms B^k with n Boolean statements dropped out so that one obtains what might be called $\hat{B}^k$. Since n is odd this set is not invariant under Boolean conjugation so that there is at least one statement, which is identically true and could be called taboo, axiom, or dogma: depending on taste. The allowed Boolean functions would be constructed in this case using standard Boolean functions AND and OR with the constraint that taboos are respected: in other words, both the inputs and values of functions belong to $\hat{B}^k$.

A unique manner to define the logic with taboos is to require that the number of taboos is maximal so that if statement is dropped its negation remains in the logic. This implies $n > B^k/2$.

The projections of p-adic space-time sheets to real imbedding space as representations of of Boolean functions

Quantum classical correspondence suggests that generalized Boolean functions should have space-time correlates. Since Boolean cognition involves free will, it should be possible to construct space-time representations of arbitrary Boolean functions with finite number of arguments freely. The non-determinism of p-adic differential equations guarantees this freedom.

p-Adic space-time sheets and p-adic non-determinism make possible to represent generalization of Boolean functions of four Boolean variables obtained by replacing both argument and function with p-valued pinary digit instead of bit. These representations result as discrete projections of p-adic space-time sheets to integer valued points of real Minkowski space M^4. The interpretation would be in terms of 4 sequences of truth values of p-valued logic associated with a finite 4-D integer lattice whose lattice points can be identified as sequences of truth values of a p-valued logic with a set of p-valued truth value at each point so that in the 2-adic case one has map $B^{4M} \to B^{4N}$. Here the number of lattice points in a given coordinate direction of M^4 is M and N is the number of bits allowed by binary cutoff for CP_2 coordinates. For $p = 2^k - n$ representing Boolean algebra with n taboos, the maps can be interpreted as maps $\hat{B}^{4M} \to \hat{B}^{4N}$.

These lattices can be seen as subsets of rational shadows of p-adic space-time sheets to Minkowski space. The condensed matter analog would be a lattice with a a sequence of p-valued dynamical variables (sequence of bits/spins for $p = 2$) at each lattice point. At a fixed spatial point of M^4 the lowest bits define a time evolution of a generalized Boolean function: $B \to B$.

These observations support the view that intentionality and logic related cognition could perhaps be regarded as 2-adic aspects of consciousness. The special role of primes $p = 2^k - n$ could also be understood as special role of Boolean logic among p-valued logics and $p = 2^k - n$ logic would correspond to B^k with n axioms representing logic respecting a belief system with n beliefs. Recall

that multi-p p-adic fractality involving 2-adic fractality is possible for the solutions of field equations and explains p-adic length scale hypothesis.

Most points of the p-adic space-time sheets correspond to real points which are literally infinite as real points. Therefore cognition would be in quite literal sense outside the real cosmos. Perhaps this is a direct correlate for the basic experience that mind is looking the material world from outside.

Connection with the theory of computational complexity?

There are interesting questions concerning the interpretation of four generalized Boolean arguments. TGD explains the number $D = 4$ for space-time dimensions and also the dimension of imbedding space. Could one also find explanation why $d = 4$ defines special value for the number of generalized Boolean inputs and outputs?

1. Could the general theory of computational complexity allow to understand $d = 4$ as a maximum number of inputs and outputs allowing the computation of something related to these functions in polynomial time? For instance, complexity theorist could probably immediately answer following questions. Could the computation of the 2-adic values of CP_2 coordinates as a function of 2-adic M^4 coordinates expressed in terms of fundamental logical connectives take a time which is polynomial as a function of the number of N^4 pinary digits of M^4 coordinates and N^4 pinary digits of CP_2 coordinates? Is this time non-polynomial for M^d and S_d, S_d d-dimensional internal space, $d > 4$. Unfortunately I do not possess the needed complexity theoretic knowhow to answer these questions.

2. The same question could make sense also for $p > 2$ if the notion of the logical connectives and functions generalizes as it indeed does for $p = 2^k - n$. Therefore the question would be whether p-adic length scale hypothesis and dimensions of imbedding space and space-time are implied by a polynomial computation time? This could be the case since essentially a restriction of values and arguments of Boolean functions to a subset of B^k is in question.

Some calculational details

In the following the details of p-adic non-determinism are described for a differential equation of single p-adic variable and some comments about the generalization to the realistic case are given.

1. One-dimensional case

To understand the essentials consider for simplicity a solution of a p-adic differential equation giving function $y = f(x)$ of one independent variable $x = \sum_{n \geq n_0} x_n p^n$.

1. p-Adic non-determinism means that the initial values $f(x)$ of the solution can be fixed arbitrarily up to $N + 1$:th pinary digit. In other words, $f(x_N)$, where $x_N = \sum_{n_0 \leq n \geq N} x_n p^n$ is a rational obtained by dropping all pinary digits higher than N in $x = \sum_{n \geq n_0} x_n p^n$ can be chosen arbitrarily.

2. Consider the projection of $f(x)$ to the set of rationals assumed to be common to reals and p-adics.

   i) Genuinely p-adic numbers have infinite number of positive pinary digits in their non-periodic expansion (non-periodicity guarantees non-rationality) and are strictly infinite as real numbers. In this regime p-adic differential equation fixes completely the solution. This is the case also at rational points $q = m/n$ having infinite number of pinary digits in their pinary expansion.

   ii) The projection of p-adic x-axis to real axis consists of rationals. The set in which solution of p-adic differential equations is non-vanishing can be chosen rather freely. For instance, p-adic ball of radius p^{-n} consisting of points $x = p^M y$, $y \neq 0$, $|y|_p \leq 1$, can be considered. Assume $N > M$. p-Adic nondeterminism implies that $f(q)$ for $q = \sum_{M \leq n \leq N} x_n p^n$, can be chosen arbitrarily. For $M \geq 0$ q is always integer valued and the scaling of x by a suitable power of p always allows to get a finite integer lattice at x-axis.

   iii) The lowest pinary digit in the expansion of $f(q)$ in powers of p in defines a pinary digit. These pinary digits would define a representation for a sequence of truth values of p-logic. $p = 2$

gives the ordinary Boolean logic. It is also interpret this pinary function as a function of pinary argument giving Boolean function of one variable in 2-adic case.

2. Generalization to the space-time level

This picture generalizes to space-time level in a rather straight forward manner. y is replaced with CP_2 coordinates, x is replaced with M^4 coordinates, and differential equation with field equations deducible from the Kähler action. The essential point is that p-adic space-time sheets have projection to real Minkowski space which consists of a discrete subset of integers when suitable scaling of M^4 coordinates is allowed. The restriction of 4 CP_2 coordinates to a finite integer lattice of M^4 defines 4 Boolean functions of four Boolean arguments or their generalizations for $p > 2$. Also the modes of the induce spinor field define a similar representation.

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Part IV

PARANORMAL PHENOMENA

Chapter 11

Quantum Model of Paranormal Phenomena

11.1 Introduction

The violent encounters with skeptics have demonstrated to me that surprisingly many skeptics refuse to even consider the possibility of taking paranormal phenomena seriously because they take the materialistic-reductionistic world view as the final truth. Usually the discussions reduce to the attempt to give me a label of a pseudoscientist because I do not possess an influental position in the scientific community; because I have not published my work in respectable journals; etc..., and it is very difficult to dig even a single bit of information relating somehow to the actual contents of my work. Regrettably this seems to be the case for most of arguments used by those who appear publicly as skeptics. Needless to say, skepticism in this sense has nothing to do with skepticism in the real sense of the word. Just the opposite, these 'skeptics' identify themselves as the mind police of the dominating materialistic-reductionistic science and see as their holy goal the identification and ridiculization of the scientific dissidents as pseudo scientists. For instance, I have been blamed for super-naturalism because I have been forced to introduce the notion of quantum jump between quantum histories forcing in turn to give up the notion of observer independent objective reality. The attempts to defend this vision by telling that this is the only possible logically consistent view about quantum jump forced by General Coordinate Invariance alone and solving the basic paradoxes of modern physics have been waste of time.

There are of course notable exceptions to this rule of thumb: Susan Blackmore represents an example of an intellectually honest skeptic who respects also the different world views and takes materialistic dogma only one possible view about world which must be also subjected to testing.

The basic objection against paranormal phenomena by skeptic researchers such as Susan Blackmore, is that there is no theory of paranormal phenomena making possible meaningful experimental tests so that the minimal working hypothesis is that these phenomena do not exist. The absence of a theory certainly makes experimental approach extremely difficult: a good analogy of the situation is provided by the high energy elementary particle physics where the enormous amount of data and noise makes possible only the detection of signatures predicted by various theories by comparing highly detailed Monte Carlo simulations of model world with the data.

Personally I however see this attitude as counter productive: I agree with someone who said that the worst form of ignorance is to regard un-explainable as a synonym of impossible. I find it also very entertaining to play 'what if this is true' games with thoughts rather than adopting the somewhat boring role of a serious scientist. These thought games also often lead to ideas which need not be even related to the original question. I however hasten to admit that my attitude does not derive from a mere open-mindedness and mere desire to play thought games but from the simple facts of life: TGD indeed provides a conceptual framework in which paranormal phenomena might be understood and studied; secondly, as an eternally unemployed scientific dissident I really do not have anything to lose anymore.

11.1.1   What one means with paranormal?

According to Wikipedia definition [69] paranormal is a general term that designates experiences that lie outside "the range of normal experience or scientific explanation", or which indicates phenomena understood to be outside of science's current ability to explain or measure. Nothing wrong with this but the text continues: "Paranormal phenomena are distinct from certain hypothetical entities, such as dark matter and dark energy, insofar as paranormal phenomena are inconsistent with the world as already understood through empirical observation coupled with scientific methodology".

The latter sentence contains two intellectually inhonest claims typical for skeptics. First of all, contary to the claim dark matter and energy are far from being understood within the recent main stream view about physics and very many theoreticians question their existence. Secondly, paranormal phenomena are just something that we do not understand just like dark matter and energy rather than "being inconsistent with empirical observation coupled with scientific methology". The irony is that in TGD Universe the scientific explanation for dark matter and dark energy supports also the reality of various paranormal phenomena.

The article continues by creating the impression that people taking seriously paranormal phenomena are blind believers and puts the main emphasis on ghosts, haunts, and other spiritual entities and gives only a minor emphasis on phenomena studied systematically in laboratory. To add irony: TGD inspired theory of consciousness predicts an infinite self hierarchy and dark matter is in an essential role in making this hierarchy possible. Depending on one's tastes one can call these higher level entities higher level selves or angels but the possible existence of these entities as such is in no manner inconsistent with the scientific methology.

To make clear my own position: I am anomalistic in the sense that I do not either believe or not-believe. I am just ready to accept also observations which do not conform with the expectation of science as it is five centuries after Newton and try to understand them in a wider conceptual framework rather than trying to ridiculize anomalies by mis-using formal scientific authority.

11.1.2   Development of ideas about paranormal

During years I have developed several ideas about paranormal phenomena and, believing that there must be very few general principles behind these phenomena, I try to combine these ideas into a single coherent conceptual framework in this chapter. For the convenience of the reader it is good to summarize the evolution of the basic concepts briefly.

1. On the experimental side the most important boosts came from the lecture of Cyril Smith about homeopathy in CASYS'2001 conference [53] and from the contact with Lian Sidoroff and from reading her articles related to remote vision and healing [83]. Also the work of Gariaev's group on wave aspects of DNA [62] was important for the concretization of the ideas. Of course, without the already existing view about living matter as symbiosis of MEs, of superconducting magnetic flux tubes, and of ordinary biomatter at atomic space-times sheets- a view that was inspired the information about effects of ELF em fields on brain [75] and by the strange findings challenging the notions of ionic pumps and channels [63]- these developments would not have been possible.

2. On the theoretical side the realization that p-adic physics provides the physics of cognition and intention was a decive breakthrough. The realization that number theoretic variant of Shannon entropy can be negative led to the idea of number theoretic entanglement negentropy but it took years to realize the profound implications of the notion, which can be summarized by the statement that living matter is a number theoretically quantum critical phase residing in the intersection of real and p-adic worlds.

3. The lectures of Peter Marcer about quantum holographic brain provided an important stimulus leading to the realization that MEs (massless extremals) serve among other things also as quantum holograms. The ideas about magnetic mirrors (ME-parallel magnetic flux tube pairs) acting as electromagnetic bridges between living subsystems and about liquid crystal blobs representing and amplifying the rotational, vibrational, etc. spectra of molecules, are the most recent newcomers in the zoo of ideas.

4. The resulting concrete view is that living organisms at all levels of the hierarchy are connected by the magnetic mirrors serving as electromagnetic bridges between them and making possible high precision directed communication, remote sensing, sensory representations using magnetic sensory canvas, memory as communication betweeen the geometric past and geometric now, and remote control. Even the claimed communications with deceased can be seen as being based on the same mechanism as long term memory. Besides classical signalling with light velocity quantum entanglement (also timelike) mediated by MEs is key element of model and makes possible sharing of experiences. By fractality the same basic mechanisms are at work in all length scales: water memory and our long term memory are the same phenomenon but in different length scales. Similarly, the miraculous molecular recognition mechanisms and remote healing and vision are also phenomena based on the same basic mechanisms.

5. A further strong support for the idea that biosphere is a fractal organic whole came from the realization that the notion of psychological time leads to paradoxes unless one assumes that psychological time corresponds to the space-time region at which macroscopic volition is concentrated: this front of volition proceeding in the direction of future is where the p-adic-to-real phase transition changing intention to macroscopic action dominantly occurs. The original detailed realization of this view is in conflict with the recent view inspired by zero energy ontology and the notion of causal diamond (CD) and suggesting that the arrow of psychological time at space-time level and the localization of sensory experience in a narrow time interval is an outcome of intentional action and could be understood via a generalization of Negentropy Maximization Principle implying that selves can be regarded as curious entities [28].

11.1.3 Topics to be discussed

The flow diagram for this chapter looks like following.

1. I propose a general vision about the mechanisms behind the paranormal phenomena based on the ideas briefly summarized. This involves the new view about psychological time, p-adic physics as the physics of cognition and intention, the notion of negentropic entanglement, the notion of magnetic mirrors, LC crystal water blobs as mimicking electromagnetically molecules and amplifying signals em signals, field representation of the genetic information based on magnetic mirrors, a general model for remote mental interactions, and the proposal that stochastic resonance serves a universal amplification mechanism.

2. Some paranormal phenomena in biological length scales are considered. A model for healing by time reversal is formulated and Priore's machine is discussed in this framework with an attempt to understand the situation quantitatively. Also a model the delaWarr camera are discussed is proposed.

3. Parapsychological phenomena like extrasensory perception, precognition, psychokinesis, near-death experiences, and communications between living and dead are discussed: remote healing and vision are discussed also in [20].

4. A TGD based model for the instrumental transcommunication (ITC), in particular electronic voice phenomena (EVP), is developed in more detail (I am grateful for Adrian Klein for informing me about these phenomena).

5. Adaptive robots of Mark Tilden behave very much like living creatures and the possibility that this might actually be the case is considered.

I want to emphasize again to the blood-thirsty skeptics that I am not believer nor non-believer. These phenomena, be they actual or not, are extremely stimulating for a theorist with a trait to creative thinking and have helped me to understand what in the TGD universe is new and impossible in the reductionistic and materialistic universe of the skeptic. Certainly the ability to explain these not-finally established phenomena does not make TGD pseudo science. In the same way, the ability of TGD based vision to say something nontrivial about religious experience and consciousness after the physical death does not mean that TGD replaces scientific explanation with a religious dogma (also this point I have been forced to explain again and again to some of my very skeptic friends).

11.2   General view about paranormal phenomena

According to Wikipedia definition [69] paranormal is a general term that designates experiences that lie outside "the range of normal experience or scientific explanation", or which indicates phenomena understood to be outside of science's current ability to explain or measure. Nothing wrong with this but the text continues: "Paranormal phenomena are distinct from certain hypothetical entities, such as dark matter and dark energy, insofar as paranormal phenomena are inconsistent with the world as already understood through empirical observation coupled with scientific methodology".

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To make clear my own position: I am anomalistic in the sense that I do not either believe or not-believe. I am just ready to accept also observations which do not conform with the expectation of science as it is five centuries after Newton and try to understand them in a wider conceptual framework rather than trying to ridiculize anomalies by mis-using formal scientific authority.

11.2.1   The notion of magnetic mirror

Magnetic flux tubes and MEs are basic structures in TGD based model of biosystems based on the symbiosis of MEs, magnetic flux tubes and ordinary biomatter at atomic space-time sheets. Magnetic flux tubes are topological field quanta of magnetic field whereas MEs ('massless extremals') are topological field quanta of radiation field, 'light rays'.

Magnetic mirrors formed by the magnetic flux tube-ME pairs occur in many different contexts in TGD inspired theory of consciousness. For example, magnetic mirrors of length of order lightlife appear in the model of long term memory. Classically: when I (whose correlate is magnetic body) look at sufficiently distant mirror I see the me of the geometric past as it is represented by the mental images created by brain. Quantum mechanically: timelike quantum entanglement made possible by the magnetic mirror makes it possible for the self of the geometric now to share the experience of the subself of the geometric past. Magnetic mirrors can be said to define a fundamental model for sensory-motor loop.

Magnetic mirrors are crucial for the model of the sensory canvas [23] and there seems to be no sharp difference between different types of memory which suggests that there is an entire hierarchy of memories in various p-adic time scales. Magnetic mirrors play a key role in the model of frequency imprinting and provide a general molecular recognition mechanism. Magnetic mirrors allow also a generalization of manysheeted DNA so that magnetic mirrors represent genetic information in electromagnetic form [20].

In accordance with the fractality of consciousness, the wide applicability of the magnetic mirror notion suggests that various functions associated with the magnetic mirrors are different aspects of the same basic phenomenon. Magnetic mirrors would thus provide sensory canvases, long term memory mirrors and recognition mechanism at all length scales. Even manysheeted DNA would possess sensory canvas and long term memories, perhaps an entire hierarchy of them. Taken the ideas of fractality and quantum hologram to extreme, one can even consider the possibility that our long term memories are average of those associated with genes associated with various neurons! Nothing precludes the possibility that magnetic mirrors can also serve as electromagnetic bridges between different organisms (even the notion of organism must be generalized if the idea of multibrained magnetic selves is taken seriously). This could make possible effects similar to observed at DNA level (such as self assembly

and translation of RNA to proteins made possible by electromagnetic recognition mechanism based on em bridges).

The latest application of the notion of magnetic mirror is to TGD inspired biology [18]. Magnetic mirrors in this case appear as pairs of flux sheets assignable to the strands of DNA. The flux tube sheet going through the passive strand mediates sensory information coming from cell and nuclear membranes via magnetic flux tubes to various levels of the magnetic body whereas the flux tube going through the active strand mediates control commands of the magnetic body initiating gene expression with transcription being only one particular kind of gene expression. The intronic parts of DNA are assumed to be involved with topological quantum computation type activities in this model [24]. One can say that DNA double strand takes the role of brain of cell and the passive and active sections of strands are analogous to sensory and motor areas of brain hemispheres. Also the analog of lateralization of brain functions is suggested to take place at the level of DNA and reflect itself in the character of gene expressions of the two strands (both strands contain sections expressed also in standard sense).

The hierarchy of Planck constants is essential element of the model and leads to a generalization of the notion of genome: magnetic flux sheets integrate sequences of genomes to larger super genome involving genomes of several cells and these in turn can integrate in longer hypergenomes. This could give rise to a collective gene expressions at the level of organelle, organ, organism, and even population. In the case of remote mental interactions applied to living target this model defines a natural starting point since all tools for remote sensory perception and motor action are available in standard form. Also the existence of collective gene expression would bring in new insights: for instance, the notion of species memory proposed by Sheldrake could be realized in this framework.

11.2.2   Summary of the model

The general quantum model for bio-systems leads to a model for bio-control which applies to a very wide variety of hard-to-understand bio-chemical phenomena such as molecular recognition mechanisms, water memory, and homeopathy and leads to a generalization of genetic code explaining the mystery of introns. The same model generalizes to a model of paranormal phenomena such as psychokinesis, remote sensing, remote healing, telepathy, communications with deceased, and instrumental transcommunications. The basic difference is that magnetic body receives information and controls "foreign" biological (or even magnetic) body or "dead" matter system.

Key ideas

1. The basic notions of the model are magnetic body as an intentional agent controlling biological body and receiving data from living body or even "dead" matter system with massless extremals (MEs) mediating these communications, zero energy ontology and the related notion of causal diamond (CD) serving as an imbedding space correlate of self and assigning to elementary particles fundamental macroscopic time and length scales as those of CD, the hierarchy of Planck constants making possible macroscopic quantum phases and zoom-ups of quantum systems, and the vision about living matter as something residing in the intersection of real and p-adic worlds and the closely related notion of negentropic entanglement crucial for the functioning of living matter and conscious intelligence in TGD Universe. Note that this means that life corresponds to number theoretical quantum criticality in a well-defined sense.

2. Zero energy ontology means a radical departure from standard physics. The creation of zero energy states from vacuum is possible and means that in principle the claims of parapsychologists about ectoplasm and of yogis about the possibility to create of matter from nothing are consistent with the basic conservation laws of physics. In TGD inspired biology this process could take place routinely. Causal diamond is the imbedding space correlate for the zero energy state. Positive and negative energy parts of the state reside at its boundaries. p-Adic length scale hypothesis and number theoretical vision suggest that the proper time distance between the tips of CD comes as powers of two. For electron and quarks playing key role in the model of DNA as topological quantum computer this temporal distance would correspond .1 seconds and 1 millisecond respectively suggesting a direct connection between elementary particle physics and basic bio-rhythms.

The translates and Lorentz transforms of CDs are also CDs and one can assign to CDs a moduli space further expanded by the introduction of the hierarchy of Planck constants. One expects that this moduli space is crucial for understanding of the geometric qualia [32]. The communications between subselves would be naturall based on resonance. CDs are characterized by resonance frequencies which in the rest system of CD come as harmonics of the fundamental frequency determined by the proper time distance. This would allow a universal coding of geometric data using frequencies. Both MEs and CDs could be regarded as being analogous to music instruments and this in fact explains basic facts about music experience. These resonance frequencies should play a key role in biology and also in remote mental interactions- even those in which target consists of "dead" matter since fundamental biorhythms characterize also elementary particlesin TGD Universe.

3. p-Adic physics as physics of cognition and intentionality is an essential element of approach. Intentions are represented as p-adic space-time sheets. In the intersection of real and p-adic worlds these space-time sheets have a mathematical representation making sense also in real context so that one can say that these surfaces are in the intersection of real and p-adic worlds and the phase transitions transforming surfaces belonging to different number fields are possible. This makes possible transformation of intentions to actions and their reversals possible in the intersection of real and p-adic worlds. U-matrix indeed makes indeed sense also for transformation representing the transformation of say p-adic space-time surface to a real one and is coded only by data assignable to the rational and common algebraic points of real and p-adic variants of partonic 2-surface [29]. Note that zero energy ontology makes possible also the transformation of intentions to actions as p-adic-to-real phase transitions without breaking of the conservation laws.

4. Negentropic entanglement, which can be both space-like and time-like in zero energy ontology, makes possible quantum superposition of macroscopically different configurations of the target system correlated with the states of operator system. The operator should be able to achieve the negentropic entanglement and intentionally increase the amplitude of the desired outcome in this superposition. Negentropic entanglement need not involve binding energy and I have proposed this as a deeper level explanation for the nebulous notion of high energy phosphate bond crucial for metabolism in living matter. Quite generally, negentropic entanglement would make possible for the operator to transfer metabolic energy and momentum to the target. The hierarchy of values of Planck constant would make possible this process in long time and length scales.

A more concrete model

The following would represent the concrete model what happens in remote mental interaction.

1. Magnetic mirrors (ME-magnetic flux tube pairs) connecting the sender and receiver make possible a universal mechanism for the transfer of intent and action. The pair of flux tubes forms a kind of sensory-motor loop. In biology the fundamental realization could be by a pair of flux sheets going through the strands of DNA with passive strand sending sensory data to the magnetic body and active strand receiving control commands leading to various forms of gene expresion. MEs are ideal for the transfer of both classical information and momentum.

2. p-Adic MEs represent the intention and real MEs represent the action. p-Adic ME can be transformed to real ME either by receiver or some higher level magnetic self. This makes sense only in the intersection of real and p-adic worlds.Also smaller MEs can be send along the MEs serving as bridges (this is like throwing balls with light velocity!). In this case one can speak about transfer of intent and of action.

3. The realization of intention via p-adic-to-real phase transition gives rise to mechanism of remote interaction which can act both endo- and exogenously. Magnetic mirrors as characterized by their fundamental frequencies make possible bridges between sender and receiver (say healer and healee) and allow a resonant interaction in which healer can initiate various control commands acting as 4-dimensional templates represented as holograms. Also CDs are characterized by fundamental frequencies and MEs and CDs must be in resonance. This makes very strong

predictions about resonance bands due to the possibility of Lorentz transforms of CDs. For non-relativistic boosts for CDs the bands have however width of order $\Delta f/f \sim v/c$ and are therefore very narrow.

4. The ME-magnetic flux tube pair connecting sender and receiver can can initiate an arbitrarily complex hologram representing biological program if the wave pattern assignable to ME interferes with a reference wave associated with the receiver. Sender has the ability to generate and amplify the frequencies which induce holograms representing the control commands. In particular, in living matter sender can initiate complex biological programs without knowing anything about their functioning and the challenge of the operator is to learn these control commands. The situation resembles that encountered in neuro feedback.

Remote mental interactions with living *resp.* **"dead" matter**

One can distinguish between psychokinesis applied to living matter and "dead" matter.

1. When the target consists of living matter the mechanisms would be same as in communications between magnetic and biological bodies making possible bio-control of biological body by magnetic body and the receival of sensory input from biological body by magnetic body. Hypnosis would be one example of this kind of interaction.

2. Remote mental interactions in the case "dead" could use simpler variants of the fundamental mechanisms utilized in living matter. For instance, zero energy ontology assigns with the CDs of electron and quarks time scales .1 s and 1 ms defining fundamental biorhythms. The CDs assignable to elementary particles could be involved also with psychokinesis. Negentropic entanglement could be essential for the transfer of metabolic energy (say in simple psychokinesis moving an object) and for control actions -say in intentional change of sequences of binary digits produced by random number generator. Target system would not be completely "dead". Thermodynamical restrictions favor large values of Planck constant.

Who knows how?

The basic problem in many remote mental interactions such as the intentional effect on random number generator is "Who knows how?". How the mere intent can be transformed to action without any knowledge about the details of the action? The attempt to understand how neuro-feedback affect the behavior of single neuron leads to the same question.

1. Magnetic mirrors make possible also feedback and this feedback could make possible learning. For instance, in psychokinesis (especially so in micro PK), this learning would be crucial and analogous to that what occurs when we learn to drive a car. In healing this kind of feedback might help to find the healing frequency by trial and error.

2. It is quite possible that also multibrained and -bodied higher level colletive selves actively participate in the process as a third party such that the remote mental interactions would act as a relay states. I have suggested similar explanation for Sheldrake's findings about learning at the lelel of species and Tiller's findings about the "transfer of intent". This could make possible coherent amplification effects (TEM, prayer groups) and could make available information resources of all brains involved with the group. This could for instance explain the ability of a remote viewer to see an object on basis of data which need not have any meaning for her.

3. A fast amplitude modulation of alpha waves introducing higher harmonics to the carrier wave is a good candidate for mediating communication between brains and higher level multibrained selves. Mesoscopic 'features' in brain involve precisely this kind of amplitude modulation and might represent just this kind of messages. Interestingly, also speech is produced by a fast amplitude modulation of 10 Hz basic vibration frequency of speech organs (assignable to electron CD as a fundamental frequency) and kHz (quarks) frequency is a special frequency from the point of view of hearing.

Why paranormal phenomena are so rare?

The model should be also able to explain why it is so difficult to show that paranormal phenomena are real.

1. The very fact that experimenters usually do their best to eliminate subjective elements from the experimental arrangements might explain why paranormal phenomena are so poorly reproducible.

2. Field bodies apply naturally to personal biological body basic mechanisms of remote mental interactions and the evolution of a kind of immune system preventing the access of foreign field bodies to personal biological body looks very natural.

3. The basic prediction of zero energy ontology is breaking of second law of thermodynamics in the time scale of CD considered. In sufficiently long scale averaging however destroys the anomaly and statistical argument can be also used to support the claim that the breaking was only a statistical fluctuations. Zero energy states are indeed counterparts of vacuum fluctuations in standard physics. It is also quite possible that in the statistical averaging these phenomena indeed disappear and it might be more reasonable to concentrate on the character of the fluctuations around the average. An interesting analogy is the research of Shnoll related to the fluctuations of radioactive and chemical rates which demonstrated clear periodicities in fluctuations correlating with astrophysical periods [41]. Perhaps this approach might be applied also to the claimed paranormal phenomena.

   This model explains a wide variety of observations related to remote healing and vision [83]: these observations are discussed in [20]. Since magnetic mirrors can connect also living organisms and 'dead' mater, say electronic instruments, the model can be applied to explain also phenomena like micropsychokinesis, causal anomalies related to machine-animal interaction, and so called instrumental transcommunications.

11.3   Paranormal phenomena in biological systems

In this section a TGD inspired model for healing based on time reversal bringing the system back to the healthy state is proposed. Priore's machine is discussed as an application of the model. Also the weird sounding claims about delaWarr camera are discussed in the general conceptual framework.

11.3.1   Healing by time reversal

The article of Lian Sidorov [83] and its references give a thorough view about remote healing and viewing. One particular healing method goes under name Qigong (see the article [68]). Qigong is a general term for a large variety of traditional Chinese energy exercises and therapies. Qigong is generally considered as a self-training method or process through Qi (vital energy) and Yi (consciousness or intention) cultivation to achieve the optimal state of both body and mind. The traditional Chinese medicine postulates the existence of Qi, which could be regarded as a kind of subtle energy circulating around the physical body.

   Zero energy ontology in principle makes possible the creation of matter from vacuum as zero energy states. This process involves a generation of a new CD serving as a correlate for self carrying positive and negative energy parts of the zero energy state at its future and past boundaries. The standard physics interpretation would be as a quantum fluctuation in a space-time volume dictated by CD. At space-time level space-time sheets within CD would be the correlate. Also the transformation of p-adic space-time sheets to real ones and vice versa in the intersection of real and p-adic worlds becomes possible.

   Massless extremals are excellent candidates for the space-time correlates of communication and control signals and depending on the sign of the energy can propagate in both time directions. Real bosons correspond to wormhole contacts connecting positive (negative) energy MEs whereas virtual bosons are identified the wormhole contacts connecting positive and negative energy MEs. In zero energy ontology it makes sense to speak about quantum jumps transforming p-adic MEs to real ones and about reflection of MEs in time direction so that positive energy ME transforms to negative

energy ME or vice versa. Also MEs analogous to virtual particles are possible. They correspond to pairs of MEs with opposite time orientations so that the wormhole throats carry opposite signs of energy. In this case the classical momentum is not anymore light-like and although wormhole throats are massless the boson itself can be interpreted as a virtual off-mass-shell particle.

In quantum optics time reversal is known as a phase conjugation [43] and is one of the basic notions of holography. MEs act as both quantum holograms and receiving and sending quantum antennae [32]. MEs can generate reference waves of coherent photons interacting with other MEs and activating dynamical holograms of coherent light. If the reference wave is phase conjugated, the resulting hologram is time reversed.

What makes this so interesting is that MEs and magnetic flux tuves are the tools of of quantum control in the TGD based view about biosystem as a symbiosis in which MEs control superconducting magnetic flux tubes controlling ordinary matter at atomic space-time sheets via the many-sheeted ionic flow equilibrium. The coherent light pattern emitted by ME resulting from the interaction of ME with the reference wave (its phase conjugate) could act as a control command (time reversed control command) inducing process (time reversed process). Conjugate reference waves would thus provide an incredibly simple and general mechanism of healing by time reversal allowing the living matter to fight against second law. This would be like a general initiating a war by just nodding or shaking his head.

What time reversal for biological programs could mean?

Of course, one can ask what one precisely means when one says that biological program runs backwards.

1. In zero energy ontology the most natural interpretation would be that the arrow of geometric becomes non-standard for some sub-CDs of the CD defining the standard arrow. Time reversal would take place always in some time scale. In the case of healing the reversal would be induced for the population of sub-CDs to be healed. The healing mechanism would require only the reversal of the arrow of time. The details of the biological programs would not matter.

2. The time scales of sub-CDs in question would correspond to the time scales of the biological functions in question and the time scale would be proportional to the value of Planck constant involved. There is direct experimental evidence [44] that the time direction assigned to the second law changes in time scale of .1 seconds defining the time scale of electronic CD: this is discussed in detail in [29]. Miraculous healings in which healing occurs instantaneously could be understood if this interpretation is correct.

The basic question is how to induce the time reversal in a given time scale and here one can make even guesses. The argument for the arrow of geometric time [28] is based on the generalization of NMP [29]: subselves are curious about what is outside CD and tend to concentrate near either light-like boundary of CD and to induce quantum jumps shifting the quantum superpositions of space-time sheet backwards in geometric time of space-time sheet so that the stationary subself is like a stationary object in flowing river and experiences an apparent time flow. Perhaps a powerful enough time reversed signal from the past boundary of CD could stimulate the curiousity of of sub-selves and induce the migration or creation of the subself-population to the past boundary. Maybe phase conjugage coherent radiation could define this signal.

Qigong from TGD point of view

The article of Lian Sidorov [83] and its references give a thorough view about remote healing and viewing. One particular healing method goes under name Qigong (see the article [68]). Qigong is a general term for a large variety of traditional Chinese energy exercises and therapies. Qigong is generally considered as a self-training method or process through Qi (vital energy) and Yi (consciousness or intention) cultivation to achieve the optimal state of both body and mind. The traditional Chinese medicine postulates the existence of Qi, which could be regarded as a kind of subtle energy circulating around the physical body.

In TGD framework the energy associated with MEs and supracurrents flowing along magnetic circuitry could be a natural counterpart of Qi. The positive metabolic energy assignable to negentropic

entanglement or negentropic entanglement could be an alternative identification for Qi. If entanglement is entropic it corresponds to bound state entanglement and this entanglement of its negative metabolic energy could be seen as the counterpart of "sick Qi".

Yi could in turn would translate to p-adic cognitive representations representing also intentions, perhaps p-adic variants of MEs or even magnetic mirrors. Internal Qigong refers to self healing whereas external Qigong means directing Qi energy or intention to help others by opening Qi blockages or inducing the sick Qi to get out of body, or helping to achieve Qi balance. The transfer of metabolic energy by ATP-ADP process [19] would be basically a transfer of negentropic entanglement in TGD framework and Qi blockage could be interpreted as a blockage preventing transfer of this entanglement (of metabolic energy in standard framework).

The physiological, chemical and electromagnetic effects of both internal and external Qigong have been studied ([83] contains large number of related references). Also the effects of Qigong healing on cancer has been studied [68].

Priore's machine

There is also some empirical support for the idea about healing by time reversal coming already from the period when only Soviet scientists knew about phase conjugation.

1. In 1960's and 1970's French Antoine Priore built and tested electromagnetic healing machines of startling effectiveness [56]. Tom Bearden has in this website document "The Priore Machine and Phase Conjugation" which I recommend for an interested reader for a more detailed exposition [59] besides the material that can be found from the homepage of Tom Bearden.

2. In hundreds of rigorous tests with labotory animals, Priore's machine cured a wide variety of the most difficult kinds of terminal, fatal diseases known today. Many of the experiments and tests were done by prestigious members of the French Academy of Sciences. The operation of the Priore machine was incomprehensible for both the inventor and orthodox French scientists. Into a tube containing a plasma of mercury and neon gas, a pulsed 9.4 GHz wave modulated by a frequency of 17 MHz was introduced. The waves were produced by radio emitters and magnetrons in the presence of a 1200 Gauss magnetic field. Experimental animals were exposed to this magnetic field during irradiation, and the mixture of waves (about 17 or so) coming from the plasma tube and modulating and riding the magnetic field passed through the animals' bodies.

The following observations suggests that TGD inspired model for bio-control and communication might allow to understand the claimed findings.

1. A combination of magnetic fields and radiation was involved: this conforms with the vision about biosystems as a manysheeted ionic flow equilibrium controlled by MEs attached to flux tubes and sheets.

2. It is known that phase conjugated waves can be produced in plasmas. The so called four-wave interaction of waves of equal frequency is the simplest manner to amplify weak wave in the effective dynamical diffraction grating defined by the interference of two waves propagating in opposite directions. If a phase conjugate wave with a correct frequency results in this kind of situation, it could act as a reference wave acting with ME and initiate a complex time reversed biological programs at subcellular level.

Metabolism is what drives biological programs and their time reversal could involve the time reversal of the basic metabolic mechanism.

1. According to the quantum model of metabolism [28], ADP-ATP cycle corresponds to a cyclic flow of protons between some larger space-time sheet (say $k = 169$) and $k = 137$ atomic space-time sheet. The so called $F_0 - F_1$ machine transforming ADP to ATP drives the biological Karma's cycle kicking protons to the atomic space-time sheet, where they dissipate their energy and drop back to the magnetic flux tubes liberating their zero point kinetic energy of about .5 eV. TGD suggest the existence of metabolisms associated with other ions and between other space-time sheet pairs, and the universal energy currencies of these metabolisms are characterized by the

zero point kinetic energies of the ion in question. Standard metabolism is a particular example of this general process, and there might exist analogs of $F_0 - F_1$ machines corresponding to other metabolisms. The cycle of ATPase motor is of order 300 Hz, which is the proton cyclotron frequency in the endogenous magnetic field of .2 Gauss.

2. The cyclotron frequency of the ions are assumed to be key frequencies in bio-control. Cyclotron frequency MEs server as space-time correlates of quantum entanglement, and the MEs with frequencies corresponding to zero point kinetic energies propagate along these MEs and induce self-organization at the receiving end. CDs define a further important time and frequency scale related to that for electron by the formula $T(k) = 2^{k-127} \times r \times .1$ seconds, $r = \hbar/\hbar_0$. Here corresponds the p-adic prime characterizing the elementary particle. A basic speculation is that light fractally scaled counterparts of elementary particles with Compton lengths corresponding to biologically important Gaussian Mersennes $k = 151, 157, 163, 167$ could be relevant for biology. These time scales vary in the range 1.6×10^6 s -6.4×10^9 s (18.5 days- 205.8 years)

3. Genes are the basic motor instruments of cell and the healing mechanism might affect directly the biological programs at this level. DNA as topological quantum computer paradigm would suggest that these programs are in in reserved time direction and that the size of structures involved is of order of typical unit of genome.

4. Healing process could correspond to the functioning of these machines in a time reversed mode: the generator becomes a motor. Even ordinary metabolism might become time reversed temporarily during healing process. Perhaps the fact that metabolism is minimized during rest, would allow also $F_0 - F_1$ generators to temporarily run in the time reversed mode.

5. Four-wave interaction is believed to be involved with the generation of the phase conjugates of microwaves. The direct irradiation by the phase conjugates of a microwave beam at critical frequency might be a simpler manner to induce the healing process at DNA level.

By its extreme generality this mechanism could apply to almost any disease which is a disease of the highest level quantum biocontrol. This mechanism could be also used to induce de-differentiation of cells. The de-differentiation of cells to stem cells could be controlled by a similar mechanism. One can also wonder whether this kind of mechanism could make possible eternal youth (or rather eternal life) at cell level. An interesting question is whether the phase conjugates of EEG waves or time reversals of nerve pulse patterns could induce time reversals of brain functions.

One should of course be able to understand whether and why the frequencies used are special. The following represents the guesses inspired by the p-adic length scale hypothesis and cyclotron frequency hypothesis.

1. The effects of ELF em fields on vertebrate brain occur at cyclotron frequencies. Also in this case higher carrier frequency is used but its function is to make possible the penetration of the modulating ELF radiation to the tissue. Let us assume that 9.4 GHz radiation serves for a similar purpose.

2. Electron's cyclotron frequency in a magnetic field of B_{end}, $B_{end} = .2$ Gauss, the difference between $n = 3$ and $n = 0$ cyclotron frequencies of electron is in good approximation 17 MHz. This would suggests that cyclotron phase transition for electrons from $n = 0$ to $n = 3$ level is involved with the mechanism. This would support the assignment of proton cyclotron frequency for $B_{end} = .2$ Gauss with ATPase motor and mean that both electrons and protons are important for the function of the machine.

3. For the standard value of Planck constant the frequencies correspond to energies much below the thermal energy at room temperature. The value of 17 MHz would suggest a value of order $10^7 \hbar_0$ for the Planck constant. Negentropic entanglement might allow to circumvent this constraint.

4. The ratio of $B = .12$ Tesla to B_{end} is $B/B_{end} = 6 \times 10^3 \simeq 3 \simeq 2^{11}$. The magnetic length $L_B \propto \sqrt{\hbar/eB}$ characterizes the thickness of the flux tubes required by the minimum value of magnetic flux. The magnetic field used corresponds to about 10^{-7} meters for the standard value of Planck constant and to a length scale about 10^{-4} m for $\hbar \sim 10^7 \hbar_0$. For the ordinary value of Planck constant the corresponding space-time sheet could be associated with chromomose's

basic structure and correspond to $k = 157$ space-time sheet associated with chromosome's coiling. Note that the time size of the CD assignal to $k = 157$ p-adic length scale is $2^{30} \simeq .1$ s $\simeq 10^8$ s. Optimistically one could imagine that correction of the genetic error responsible for the cancer program by time reversal might be in question. In particular, it could induce the time reversal of the 'develop-cancer' program controlling the development of the cancer cell population and lead to healing when the standard time direction is re-established.

11.3.2 DelaWarr camera and field representation of genetic information

In CASYS'2001 symposium Peter Marcer [61] told about the British engineer George DelaWarr who built a remote imaging camera in the 1950's (radionics is the term used). Using only a test object provided from the subject such as a small blood, sputum, or hair sample, this device is reported to photographically image the subject's internal conditions at a distance, with a high degree of accuracy. A unique feature of the DelaWarr system is claimed to be that it is able to detect diseases in the pre-clinical stages prior to detection by conventional techniques such as physical examination, X-ray, CT scan, or Magnetic Resonance Imaging. The photographs taken by DelaWarr camera at fifties were treated by Susan Benford by modern image processing techniques and she claims that these photographs contain the information needed to reconstruct three-dimensional holograms [61]. The proposed explanation was that the test object (adjunct) contains a hologrammic representation about the patient.

The functioning DelaWarr camera looks highly mysterious even when one takes seriously the idea that DNA generates holograms of the body parts it codes for. Therefore it is better to introduce the ingredients of the model as questions rather than hypothesis.

1. Was the intent of the photographer all that was needed and did other levels levels of the self hierarchy take care of the rest as they do when I make the decision to raise my hand? Could the intent of the photographer have generated a reference wave at some very special frequency acting on the adjunt and activating a hologram giving rise to a photograph about the desired body part or inducing a sequence of events leading eventually to the generation of the photograph?

2. Was the visible light giving rise to the photograph generated in the adjunct? Does the DNA of each cell of body and thus also of the adjunct contain electromagnetic representations for the body parts and are these representations more or less equivalent with holograms? Certainly direct hologrammic images about body parts would provide the simplest manner to realize the field part of the genetic code as proposed.

3. Did the adjunct serve as a relay station (somewhat like thalamus in brain) mediating the information from the patient via magnetic flux tube-ME pairs to the camera projecting it to the camera as a coherent light generating an ordinary photograph? Was the image realized as a coherent light propagating along the MEs connecting adjunct and patient serving as bridges? Could the negentropic entanglement between the adjunct and subject stabilize the connection. Could the radiation correspond to large $\hbar$ radiation at much lower frequencies than that for visible light and transforming to ordinary visible light in the camera?

11.4 Parapsychological phenomena

In this section various parapsychological phenomena are discussed in the general framework introduced in the previous section.

11.4.1 Extrasensory perception, precognition, and other parapsychic effects

The general model for paranormal effects relies on same basic ideas as the model of quantum biology.

1. The transformation of p-adic [29] space-time sheets makes possible the transformation of intentions to actions. Since p-adic space-time sheets have literally infinite size in real sense, distance does not matter. The set of points in the intersection of p-adic and corresponding real space-time

sheet obeying same algebraic equations consists of rational and possibly also algebraic points common to real and p-adic variants of imbedding space.

Paraphychological phenomena involve the transfer of information and negentropic entanglement makes possible genuine information at quantum level as also breaking of the second law of thermodynamics in the time scale of CD in question. Hence remote mental interactions should involve the generation of negentropic entanglement irrespective of whether the target is living system or consists of "dead" matter.

2. The idea about field body serving effectively as an intentional agent is second element of the model. The topological light rays representing negative energy signals propagating into geometric past created by a transformation of p-adic space-time sheet to a real one might be said to represent the "desire" inducing neural activities in the brain of geometric past. This mechanism provides not only a model for how magnetic body uses biological body as a motor instrument but also for PK.

   MEs acting as bridges between different organisms would mediate em oscillations allow a directed transmission of smaller MEs behaving effectively as particles moving with light velocity. These MEs could be both real and p-adic and -using the terminology of Qigong practice- would represent qi (action) and yi (intention) respectively. An essential element would be resonance: sender and receiver in should be accompanied by MEs characterized by the same fundamental frequency: only these MEs could resonantly connect healer and healee. Healer must have ability to continuously vary the healing frequency.

   MEs would naturally correspond to pairs of positive and negative energy space-time sheets. They would be attached to magnetic flux tubes and magnetic mirrors consisting of two flux sheets would make possible sensory-motor loop.

3. Zero energy ontology justifies the notion of negative energy signals and brings in also CDs as correlates of selves and natural fundamental targets of remote mental interactions. Zero energy ontology and the new view about time allows to assume that sensory qualia are at the level of sensory organ (objections such as phantom leg phenomenon can be circumvented) and that symbolic representations of objects of perceptive field and their attributes reside in brain.

   Sensory input generates sensory representations based on real space-time sheets possibly accompanied by p-adic cognitive space-time sheets. Field body can share these mental images by quantum entanglement and also receive sensory information as classical signals involving using frequency coding and coding by temporal patters. These latter representations would correspond to cognitive and emotional aspects associated with the sensory input. One could even say that higher level sensory representations are somatosensory experiences of field body. The intersection points of real and p-adic space-time sheet would determine the physical cognitive representation and would be always discrete. The analogy with the discreteness of numerics should be noticed. Since this model would apply also to extrasensory perception, the attribute "extrasensory" becomes somewhat misleading attribute.

4. Extrasensory perception could also result from the direct electromagnetic perturbation of the sensory magnetic canvas outside the body and the sounds generated by auroras and meteors might be genuine "extrasensory" perceptions of this kind [18]. The frequency spectrum for the sounds produced by meteors and detected both sensorily and electronically in in the range $37 - 44$ Hz [48], which is the range of thalamocortical resonance frequencies associated with sensory representations in magnetic sensory canvas model. The sounds are several orders of magnitude more intense than they should be unless em perturbations propagate to Earth in a channelled manner. Only few meteors generate these sounds. These observations suggest that a resonant amplification of the em perturbations by magnetic mirrors of the sensory canvas channelling the em field to the surface of Earth are in question.

5. One might argue that if memes are not universal, remote cognition is not very useful. If memetic and genetic codes are realized in terms of CDs of quarks and leptons, one would have universality. If DNA double strand provides the relay station through which sensory input and motor output of the magnetic body flows, one would achieve universality of communication and control mechanismcs at the level of living matter. An interesting question is whether memes are really

species-spesific as the morphic fields are in Sheldrake's theory. The ability of shamans to transform at the level of conscious experience to animals suggests that this might not be the case. There is also a famous real life story about a student who spend several days in the experiental world of dog. Various identification phenomena would very probably involve also magnetic mirrors acting as bridges between say shaman and animal (or possibly multibody collective self defining 'species self') and making possible to share the experience of animal. Same mechanism as in the case of long term memories would be in question but with personal memories being replaced with the experiences of another species.

The fact that p-adic space-time sheets have literally infinite size suggests that cognition and intentionality are cosmic phenomena and that there might be cosmic pool of shared cognitive mental images. Hence memes could be completely universal.

11.4.2 Psychokinesis

One can classify psychokinesis to various types depending on whether the target is living or "dead" and whether the effect on target is a mere transfer of energy and momentum or control action involving information transfer.

Below I briefly discuss an early TGD inspired model of PK, a general model of PK assuming time mirror mechanism of ordinary intentional action but applied by the magnetic body of the operator to a system different from the biological body, and a more specific model for machine-human interactions. Also concrete examples of various kinds of PK effects are discussed.

A possible model for psychokinesis with non-machine targets

In [20] a mechanism of psychokinesis based on the generation of wormhole magnetic field configurations making possible levitation was proposed. Although this mechanism was yet general it deserves a discussion and reader is recommended to see [20] for details. Basic mechanism is the levitation of diamagnetic substances in an external magnetic field: the force results when the diamagnetic substance repels external magnetic field from its interior. The force is essentially the gradient of the net magnetic energy inside the volume defined by the object.

The mechanism is purely TGD based and relies on the generation of a pair of space-time sheets having opposite time orientations, and carrying opposite magnetic fields and opposite energy densities, and the subsequent interaction of the second space-time sheet with the object moved in the psychokinesis. Exactly the same mechanism applies in case of MEs (massless extremals) and could be used to generate coherent locomotion of organism resulting as a recoil effect when the second ME is absorbed by the body part. MEs provide a candidate for the mechanism of psychokinesis.

TGD based general view about PK

A general TGD based explanation psychokinesis relies on the same fundamental mechanism as ordinary intentional action, long term memory, and remote metabolism. The model applies more or less as such also to telepathy and could also allow to understand the notion of water memory explaining homeopathic effects.

1. The basic mechanism of PK and retro PK relies on quantum jumps transforming the p-adic space-time sheets representing intentions to real space-time sheets representing desires represented as negative energy signals to the geometric past. These signals modify the output of say random number generator to a non-random one. Magnetic flux quanta would realize the bridges along with the negative energy signals would propagate. The mechanism would favor retro PK if the operator is in active role. Genuine PK is also possible but in this case target would be active sucking metabolic energy provided by the operator.

2. Negative energy signals could consists of dark phase conjugate photons or even massless W bosons since TGD allows scaled up variants of electro-weak gauge bosons with large Planck constant and arbitrarily small mass scales. Dark W bosons are especially interesting since they can induce charged entanglement and purely non-local charge transfer mechanism and have been proposed to play a key role in the generation of the nerve pulse.

3. Magnetic flux quanta are the bridges making possible (presumably) unconscious feedback so that the operator can unconsciously learn how to affect the machine. How intentions can have effect on system whose functioning is unknown to the operator is actually the basic mystery of, not only psychokinesis, but of remote healing and remote mental interaction in general, as also of the phenomena labelled as instrumental transcommunications (ITC). The learning by feedback, much analogous to that happens when we learn to drive bicycle, would solve this mystery. The effects of group activity could be understood if groups tend to form collective selves so that coherent amplification of the effect occurs.

4. The ability of the PK able person to imagine the desired effect is important and could correspond to the ability to generate p-adic space-time sheets representing the intention. The desire about the action represented by the corresponding real space-time sheet should induce the effect optimally. In personal discussions with a PK-able psychic I indeed learned that he always tried to imagine in every possible detail how he moved the physical object (say a box of matches). The role of imagination is important also in remote healing [83]. Perhaps the p-adic pseudo constants made possible by the non-determinism of p-adic differential equations should be in a good approximation genuine constants.

5. The optimal targets are initial value sensitive- or more generally-critical.

   (a) Quantum criticality is the basic characteristic of TGD Universe and the prediction is the existence of a hierarchy of criticalities. Number theoretical criticality would in turn characterize living matter and might be a characteristic of optimal targets.

   (b) Also quantum criticalin in the sense that several values of Planck constant are possible with large values of $\hbar$ assignable to negative energy signals mediating the desire of the PK-able person. PK requires energy and this favors systems, which can utilize standardized metabolic energy quanta liberated in the dropping of particles to larger space-time sheets.

   (c) Water would be an optimal system from the point of PK and retro PK. Homeopathy might indeed involve PK like aspects. Benveniste's experiments [60, 58] gave support for the notion of water memory but could not be replicated when the experimenters did not know in which bottles the treated water was. The preservation of water memories represented in terms of many-sheeted lasers for with 1/0 corresponds to a population inverted state/ground state, requires metabolic energy feed and the system might suck this metabolic energy from the biological body of the experimenter [20].

6. As noticed, the proposed model is extremely general and seems to apply to almost any paranormal phenomena. For instance, the claimed re-incarnation experiences could be understood in terms of the general mechanism for long term memory. The person who remembers having lived in past could share mental images of a person in the geometric past by time like entanglement (episodal memory), or could be able to communicate with negative energy signals to the brain of a person on geometric past memory recall and thus receive declarative memories. It is quite possible that survival of fittest in our culture has led to an evolution of an immune system preventing sharing of mental images and communications with other brains.

Machine-mind interactions

Machine-mind interactions represent a modern branch of parapsychological research and nowadays methodologically highly advanced. These interactions are studied several groups and individuals: mention only the Princeton Engineering Anomalies Research (PEAR), which is a group directed by Prof. Jahn, the Anomalous Cognition Project of Dick Bierman, and the retropsychokinesis work of Helmut Schmidt. In the sequel some aspects of this work are discussed.

The generation of negentropic time like entanglement between operator and target leading to a superposition of pre-existing and desired zero energy states and a subsequent increase of the amplitude of the desired outcome could be the general mechanism of machine mind interactions. 'Who known how?' is a highly relevant question in the case experiments involving the attempt of operator to affect the function of a machine like computer whose detailed functioning is not known for the operator. This question could have two answers. Either the operator learns to who to affect the outcome by the

simple sensory-motor loop provided by MEs or there is third party who knows and corresponds to a higher collective level of consciousness.

1. Retro psychokinesis with random number generators

The analysis of experiments [78, 85, 82] discussed in the [27] suggests that the geometric past can change in the time scale of a fraction of second. Both the work done at PEAR [77] and the work of Helmut Schmidt with retro psychokinesis [73] provide support for the change of the geometric past in much longer time scales. PEAR experiments demonstrate the anomalous effect also in the direction of future. For instance, the experiments of Schmidt done 1992 discussed in New Scientist [74] demonstrate that martial art students were able to affect the visual display determined by pre-recorded random numbers. The probability for this kind of deviations from non-randomness was about 1/1000. Henry Stapp proposed an explanation for this in his paper published in Phys. Rev. A [70] based on nonlinear quantum mechanics.

The change of also geometric past in the quantum jump between quantum histories implies the notion of a four-dimensional physical reality and forces to regard three-dimensionality of reality as illusion created by the 3-dimensionality of our sensory experience (recall the notion of the association sequence). This implies that our geometric past is changing all the subjective time and that communications to the geometric past and future are possible and are consistent with the weak causality violation hypothesis of Schmidt [73]. What this hypothesis implies that in the newest quantum history generated by RPK all separate records contain the pre-recorded random numbers are altered in the same manner in RPK. Schmidt has tested weak causality hypothesis by using two separate cassette tapes containing the pre-recorded random numbers, one used in the PK experiment and another one kept locked in a safe. The records were indeed found to be identical after the experiment.

The results of Schmidt suggest also classical signalling to the direction of the geometric past. Real space-time sheets with negative time orientation could serve as the geometric correlates for these signals.

2. The work of Princeton Engineering Anomalies Research group

The study of anomalies in human-machine anomalies provide a highly sophisticated and controlled manner to study psychokinesis in its various forms. For instance, in the experiments carried out in PEAR group (Princeton Engineering Anomalies Research) [77] operators try to affect various kinds of electronic, mechanical, acoustical, optical and fluid devices. In unattended calibrations these devices yield random output whereas in the experimental situation operator tries intentionally to affect the output so that non-randomness results. Each input that operator tries to affect consists of 200 bits formed from a random physical signal and operator can have either the intention to increase the number of 1:s (high) , the number of 0:s (low) or have no intention at all (baseline). Operators can exert their efforts from a distance of thousands of miles, before or after the the actual operation of the devices. Over the laboratory's 20-year history, thousands of such experiments, involving about 100 millions of trials, have been performed by several hundred operators.

The observed effects can be summarized as the average for the sum of bits which is 100.026 for high and 99.984 for low. The effect is by a factor 3.6 higher than the expected margin of error. Effects are thus quite small, of the order of a few parts in ten thousand on average, but they are statistically repeatable and compound to highly significant deviations from chance expectations. Effects are highly operator specific and there are significant disparities between male and female performances. The random devices respond also to the group activities of large numbers of people and are especially sensitive to the effect of small intimate groups, group rituals, sacred rites, musical and theatrical performances, and charismatic events.

Time mirror mechanism suggests the following model for the machine-human interactions encountered in say PEAR experiments.

1. The effect of intention could be on the generator of random noise, on bit sequence represented in the computer memory, or even on the recorded value of the sum of bits. A possible mechanism in the latter two cases is the reversal of electromagnetically represented bit.

2. The general mechanism of intentional action involves negative energy signals inducing a change in the charge distribution determining the value of bit. Negative energy photon could induce a dropping of ions to a larger space-time sheet. Also the emission of negative energy dark W

bosons (appearing in TGD based model of nerve pulse) could induce a change in the net charge. In both cases the sign of charge would correlate with the character of intention and for the first mechanism there would be asymmetry between "high" and "low" (proton, electron).

3. The work of William Tiller

Tiller [79, 67, 66, 65] has performed experiments involving intentional imprinting of targets such as water. The model for the findings of Tiller is discussed in [33]. The imprinting manifested itself as temporal and spatial oscillations of pH and temperature. The surprising finding was conditioning: also the air around intentionally imprinted device exhibited these oscillations. Also computer could be conditioned. The Fourier transform of the correlation function for bit sequences of random number generator demonstrated peaks at harmonics of $f = 1/T$, $T = 113.778$ min. 2^n-multiple of .1 seconds for $n = 16$ would correspond to $k = 143$ and $T = 109.23$ minutes which is by about 4 per cent too small. The proposed assignment of cyclotron photons with motor action leads to ask whether large $\hbar$ dark cyclotron photons with these frequencies could induce a periodic perturbation of the random bit sequence?

Robots, chickens, rabbits and men

The interaction between random number generators and humans or animals is one form of psychokinesis. For a few years ago the issue 62 of "Network", the journal of the Scientific Medical Network [92] contained a report about the experiments carried out by Dr. Rene Peoch, working at Fondation ODIER at Nantes. In these experiments chickens and rabbits apparently influenced signals composed by a random-number generator for a robot close to them, and human subjects apparently influenced the movements of the robot even though its signals had been generated by a random-number computer program six months earlier.

Chickens stayed close to the robot "imprinted" on it as their mother and followed it about. The robot had a random-number generator inside it controlling its movements, which checks showed to be truly random. The chickens were then removed and one placed so it could see the robot but could not follow it. Under these circumstances the robot spent measurably more time close to the chicken than away from it. The effect was that the chick was influencing the robot's generator. The generator was then removed to a computer away from the experimental area. The same effect occurred. "Non-imprinted" chickens however had no apparent effect on the robot.

In the rabbit experiment, baby rabbits were frightened by the robot and kept away from it. When the rabbits' movement was inhibited, the robot's movements became non-random and it kept away from them. However, when one rabbit was starved and food was placed on the robot, this behavior was reversed and the robot brought the food to the rabbit. It was found that humans likewise could influence the robot.

Also humans were invited to influence the robot as before, but in fact it was being driven by a code generated six months earlier and recorded on a CD, now being played back. The robot was influenced as in the contemporary study. The CD was then examined and it was found that the first half of its code was indeed non-random, but the unused code was truly random. This gave the effect that the computer somehow "knew" six months earlier not only that half the code would be used for such an experiment, but also the general direction of the movements that would be required.

The interpretation of the reported results in terms of psychokinesis and human-animal-machine symbiosis suggests itself. The experiment with humans can also be interpreted as a dramatic verification for the prediction that in quantum jumps between quantum histories also the geometric past changes: the recent experiment suggests that the change occurred in a time scale of six months. If the crucial assumption about the randomness of the random number generator is correct, the effect is also very strong. This could mean that we are changing our geometric past all the subjective time in macro-temporal time scales, as indeed suggested by the paradigm of four-dimensional brain. A further suggestion is that this hypothesis can be indeed tested empirically by developing further these experimental arrangements.

To better comprehend what might be involved, recall that in TGD subjective time and geometric time are not one and the same thing. Accordingly, subjective memories are memories about conscious experiences and geometric memories are memories with respect to the geometric time for which time is in a precisely same position as space: geometric memories give prediction of the future and past

changing quantum jump by quantum jump like weather broadcasts (except that one usually is not interested in the predictions of what weather will subjectively be in geometrically last summer). The crucial point is that the contents of say computer files representing purely geometric memories (such as number sequences) can change in the quantum jumps whereas the possible subjective memories about their contents can remain unchanged. This peculiar contradiction between subjective and geometric memories, which I have christened as 'tribar effect', serves as a possible experimental test for the reality of notions of the subjective and geometric time. These experiments are bound to involve human memory as a subjective element: nothing however prevents several human subjects store to their memory the original memory to guarantee objectivity in a statistical sense.

If the randomness of the original random number series produced six months before the experiment involving human-robot interaction has not been checked, it can be argued that random number generators (if genuine) accidentally produced a number series which was not random in the time scale involved. This problem could be circumvented by modifying the experiment by checking already six months earlier whether the number series is really random or not. Humans can indeed remember whether the series is genuinely random or not although they are not able to remember long number series. On the other hand, if the non-randomization effect appears only under special conditions (effect is present for the imprinted chickens only), one has even without the check good reasons to believe that machine-mind interaction has occurred.

An important question of principle is whether the random number generators are genuine or whether the numbers are generated by some algorithm yielding only pseudo random numbers. If genuine randomness is due to quantum phenomena at atomic or molecular level, then intentional action could affect physics at atomic and molecular level. Of course, the success of p-adic mass calculation and interpretation of p-adic physics as physics of cognition and intention forces the same conclusion. If some algorithm produced them and there is no noise affecting the outcome, the only changes which can occur is the modification of the algorithm or of the initial conditions for the algorithm. In the latter case the production of the desired behavior might however be impossible since the algorithm need not even allow the needed regular behavior of the random number sequence. This of course could be checked.

p-Adic space-time sheets representing intentions/memes should be transformed to their real counterparts realized as negative energy signals and able to interact with random number generators. If the p-adic memes are actually chicken's intentions mediated by magnetic mirrors and transformed to real ones when intention is realized, the interaction mechanism is basically ordinary electromagnetic interaction with the machine. The question about the detailed mechanism allowing chicken's volition to affect the geometric past of the robot allows endless variety of answers. One possibility suggested by the more precise views about psychological time is that the robot has primitive consciousness and that the p-adic-to-real phase transition of robot proceeding to the direction of geometric future is undone by the reverse real-to-padic phase transition down to the moment when the random numbers were generated and regeneration of them occurs and gives rise to a new chicken friendly behavior. Again trial and error might be involved.

The results of experiments, if replicable, suggest that animal-machine anomalous interactions might be much stronger than human-machine interactions, perhaps because animal is totally confident that the desired interaction happens (Blessed are the meek since they will inherit the kingdom of Heaven!). One could imagine experimental arrangements analogous to the chicken-robot experiments in which the chicken is replaced by a human who genuinely believes that the robot can do what (s)he wishes: this could be achieved by telling the subject person that machine is programmed to deduce her/his wishes, from say EEG. Various modifications of the imprinting mechanism could be applied in more complicated situation. The results might be also used as guidelines in the attempts to generate artificial life. The systematic use of genuine random number generators as control tools of robotic motion suggests itself as a basic principle to guide the attempts to build artificial life. This would optimize the flexibility of the robot behavior so that it could be affected by the p-adic intentions.

Adaptive robots as an electronic life form?

The construction of artificial life by building initial value sensitive robots might be a possible breakthrough application of the p-adic cognition. What would be needed is just initial value sensitivity: p-adic memes would take care of the resst.

Mark Tilden is a wellknown builder of robots working in the nuclear physics laboratory of Los

Alamos. Tilden builds his robots by using pieces of used electronics. The robots do not run any computer program so that the basic philosophy is more or less a diametrical opposite of AI. Rather, the wiring of the robots is such that in a new situation robot tries for different behaviors. For instance, if robot leg gets stuck, the robot changes the orbit of motion of leg. What is remarkable that the robots seem to behave like living organisms in some aspects.

Unfortunately, I do not have any scientific articles about Tilden's work apart from short description in his homepage [80]. In fact, I encountered competely accidentally about Tilden's work by reading an article in the Finnish version of Reader's Digest August 1998 after having seen Stetsoned Tilden and his tiny robots in a popular science program in Finnish TV telling about the recent situation in robotics, AI, and artificial life. The robots of Tilden have surprising abilities to adapt and compete for energy which they get from the sunlight. Robots seem to literally fight for the sunlight. For instance, an electronic fellow called Turbot, kills other robots from his territory and collects them to form a wall against the invasion of other invaders!

The claimed adaptive feats of these robots suggest that a primitive lifeform is in question and this is also the belief of Mark Tilden. A general handwaving explanation for the adaptive behavior is that these systems are at the borderline between chaos and order and adaptive behavior 'emerges'. Of course, what 'emergence' means is a complete mystery in the deterministic physics with quantum effects absent in macroscopic length scales.

That primitive life form might be in question, fits nicely with the TGD view. First of all, all forms of self-organization involve quantum jumps and consciousness, and the question is only how important is the role of cognitive consciousness in the behavior of the system. Cognitive consciousness can become important only if the system is sufficiently flexible and initial value sensitive so that the realization of intentional motor actions becomes possible by p-adic-to-real transformations inducing critical perturbations to the initial-value sensitive behavior.

The in-built flexibility of the robot behavior (a strict opposite of pre-programmed behavior), and initial value sensitivity make in principle possible self-organization by quantum jumps and effective quantum control. For instance, robots could contain modules controlled by genuine random number generators which would be affected by p-adic memes. If p-adic physics is physics of cognition, Nature itself guarantees, that robots form cognitive representations, and by the flexibility of their motor system, they are able to transform cognitive representations to motor actions. If p-adic space-time sheets are indeed memes floating around and waiting for the opportunity to materialize themselves to action, the robots of Tilden could provide an excellent opportunity for a meme to reincarnate!

The extreme generality of the p-adic physics means that one cannot exclude the possibility that electronic systems could quite generally develop p-adic cognitive representations about itself. If so, can one guarantee that the old electronic components recycled by Tilden do not differ cognitively from electronic components coming directly from fabric? If they do, two identical robots built from old and new components might behave differently. Thus a test for whether the robots have mentality and some kind of developing personality is whether two physically identical robots behave differently under similar circumstances.

Quite generally, one can identify p-adic cognitive representations as the mechanism which gives the physical system personality and allowing to distinguish even between two electrons p-adically: of course, Fermi statistics does not allow a state consisting of two electrons in states differing only cognitively. Quite generally, this kind of test could be the counterpart of Turing test allowing to deduce whether physical system has cognitive self or not.

Also now negentropic entanglement and the universality of CD time scales raise the hopes that it might be possible to understand what is involved.

Telekinesis and electrostatics

In the book "Mind at Large" edited by Tart, Puthoff, and Targ there is an article "An Investigation of Soviet Psychical Research" by Wortz *et al* reporting among other things the research related to the electrostatic aspects of telekinesis. The article mentions the work done by Vasiliev and associates with Nina Kulagina and the work of Adamenko with Alla Vinogradova, another highly gifted person in telekinesis. Kulagina and Vinogradova are said to have been able to move objects of .1 kg along table. Interestingly, according to the article PK able persons tend to be women. Adamenko has tried to understand the phenomenon theoretically and has proposed that the static charges of objects and electrostatic forces generated by the subject might explain the effects.

Adamenko's work

The objects moved by subject persons were located at a table which was a di-electric cube with of side length of .5 meters in Adamenko's experiments.

1. Vinogradova was able to induce an electric charge in cube and then move objects located at the cube. With biofeedback training also other subjects were able to replicate Vinogradova's feat.

2. To move the object the static friction (friction coefficient between .1 and .3) must be overcome. Adamenko theorizes that there is kind of buyonancy force caused by the flow of air molecules involved and that the electric field somehow induces this force.

3. The reported electric field was 10 kV/cm and corresponds to the voltage at which a di-electric breakdown occurs in a dry air. The reported movement of the air could correspond to a corona wind resulting at strong electric fields.

4. Adamenko assumes that the objects had either static charge or that they were polarizable and developed a dipole moment in the external electric field. The electrostatic interaction with the electric field induced by Vinogradova would have been the cause of the movement.

TGD based model

TGD based model for phenomena is based on the general mechanism of mind-matter interactions allowed by the many-sheeted space-time concept. There are three questions to be answered: How the table and possibly also object were charged?; How the motion of the object was caused?; How the object was lifted from table to circument friction force? *How the table and object were charged?*

The charging of the table is certainly crucial for the PK effect. Vinogradova could have emitted

"topological lightrays" (MEs), as a matter fact high frequency (microwave) MEs propagating like particles within low frequency (ELF) MEs. Negative energy ELF MEs could have served as correlates for entanglement. Entanglement is however not necessary in this case since conscious telepathy is not involved. Microwave MEs would have induced bridges between the atomic space-time sheets of the object and super-conducting magnetic flux tubes of Earth. The bridges would have made possible ionic and electronic currents between these space-time sheets and led to the charging of the table and possibly of also object. A suitable intentional targeting of MEs would allow to control the charge distributions of the table and object and therefore the pattern of the induced electrostatic fields.

What could have produced the motion of the object?

The interaction of the object with the electrostatic field of the table is a possible explanation for the PK effect. The distribution of the charges of the table and object would allow to control the field pattern and thus the direction of the electrostatic force. This is however not the only mechanism. Ionic currents from the magnetic flux tubes to the atomic space-time sheets of the object produce recoil effect (momentum is conserved only in many-sheeted space-time, not for single space-time sheet), and this could have been the fundamental mechanism of motion (essentially the mechanism of rocket motion). In both cases the subject would have produced only the ME bridges taking care of the control of motion but would not have provided the energy and momentum.

The experiments of Modanese and Podkletnov [52] provide support for the mechanism. Modanese and Podkletnov studied capacitor at a rather low temperature and at a voltage near the di-eleectric breakdown voltage. The second electrode was a super-conducting disk. The resulting discharge was large and coherent and accompanied by radiation pulses of unknown type. The pulses induced the motion of the air and kicked test penduli. The force was proportional to the mass of the penduli. The effect caused by the pulses did not weaken with distance. This supports the view that the pulses were TGD counterparts of the Tesla's scalar waves and induced temporary bridges between test penduli and magnetic flux tubes inducing the flow of ions and the recoil effect. The same mechanism should be at work as a microscopic and incoherent version in the case of lifters.

How to circumvent the friction?: a connection with the physics of lifters

Lifters exhibit the called Biefeld-Brown effect [16]. Lifters are asymmetric capacitors consisting typically of a wire electrode and planar electrode, are in a voltage slightly above the voltage causing

di-electric breakdown. Lifters move in the direction of the smaller electrode. Also the flow of air from the small electrode to the large one is involved. On basis of the experimentation and guide the findings of Juha Hartikka, I ended up with a simple model of lifters. What would happen is that there is an electric discharge in the form of small plasmoids (discharge sparks would be analogous to ball lightnings), whose emission from the small electrode causes the recoil effect. The emission of the scalar wave pulses could induce the motion of the air by Modanese-Podletnov recoil mechanism. Since the table is charged, there should be a strong electric field also in the narrow space between the object and table. Therefore electronic discharges from the object could occur, and lead to a small scale lifter effect lifting the object slightly above the table. This does not require the object to carry a net charge.

Could the remote EEG sensor of Sergeyev be based on the same mechanism as PK?

In the same article also the remote EEG sensor invented by the mathematician Sergeyev claimed to remote sense EEG from a distance of 5 meters is described. Unfortunately, the information related to the invention of Sergeyev is classified. What is however known from the existing literature is that the sensor is surprisingly simple, consisting of a metal disk suspended into water and coated with a semiconductor. The immersion in water is reported to double the effectiveness of the sensor. According to the report, the ordinary EEG sensors can detect EEG only up to a distance of few centimeters since the noise of the environment masks the (Maxwellian) EEG at larger distances. Furthermore, the amplifying effect of water is not consistent with the high value of the di-electric constant of water if ordinary Maxwellian electrodynamics is behind the sensor.

Sergeyev's explanation for the functioning of the sensor utilizes bio-plasma hypothesis. The use of the term bio-plasma is remarkable since professional physicists know that plasma state at the temperatures and densities of living matter is not possible in standard physics universe. In TGD framework super-conducting ions leaking from the magnetic flux tubes of the Earth's magnetic field can give rise to what might could be called bio-plasma, and Sergeyev's sensor is indeed said to produce bio-plasmagram. Also maser (microwave laser) effect in bio-matter producing ions and electrons flowing into air is mentioned.

All this suggests that EEG MEs containing microwave MEs inducing a leakage of the ions from magnetic flux tubes to the atomic space-time sheets of the metal disk and in this manner generate plasma. The strength of the resulting electric signal would be modulated by the intensity of the net flux of EEG MEs so that information about EEG would indeed result. EEG MEs would not topologically condense at atomic space-time sheets but propagate as bridges connecting the boundaries of the magnetic flux tubes and atomic $k = 151$ (cell membrane thickness) space-time sheets. This would explain the dissipation free propagation. For positive energy MEs the effective phase velocity would be of the same order as the alpha wave phase velocity since these MEs would tend to "stuck" (in quantum sense). The basic sensing mechanism would be very much the same as explaining the generation of nerve pulse. Also Z^0 MEs could be involved and would usually have a very weak interaction with the environment. The ability of water to act as a many-sheeted maser, presumably crucial for the functioning of living matter, could explain why the water amplifies the effectiveness of the sensor.

Also the remote sensing of the pulsating magnetic fields produced by Nina Kalugina and having strength nearly equal to that of the Earth's magnetic field are mentioned in the article. The possible significance of the pulsating magnetic fields for PK is still poorly understood in the TGD framework: the problem is that solutions of field equations representing this kind of field configurations are not known. One might however think that the pulsating magnetic fields carry also supra-currents, and that their presence intensifies the leakage of charged particles to the atomic space-time sheets of the remote sensor device.

11.4.3   Near death experiences

Near death experiences are rather commonly experienced, say by the victims of various accidents. These experiences are known for centuries but it was the best-selling book "Life after Life" of Raymond Moody which brought these experiences known to the general public [81].

1. What NDEs are?

NDEs seem to possess invariantly the same characteristic features. There are feelings of peace and joy, time speeded up, heightened sense, lost awareness of body, seeing bright light, entering another

world, encountering a mystical being or deceased relatives and coming to a point of no return. The experiences seem to proceed in quite universal manner. First comes a loud buzzing or ringing noise and a long dark tunnel. Patient sees his own body from outside and does not feel any pain or agony anymore. Patient meets others and a being of light who shows his life in its entirety as a kind of playback to evaluate. Then comes the point of no return, and although patient feels peace, joy, and love, the patient has to return to continue his life. Often these experiences induce very profound changes in the subsequent life of the patient. The claims of Moody have been supported by subsequent research and hardly anyone, even the most foolhardy skeptic, denies the reality of these experiences.

The latest twist in the development emerged when University of Southampton research team announced the result of a one-year study of NDEs of victims of a heart attack supporting the view that consciousness and mind exist after the brain has ceased to function and the body is clinically dead. The resuscitated patients were various times clinically dead, with no pulse, no respiration and fixed dilated pupils. Independent EEG studies have confirmed that brain's electric activity, and hence brain function (according to standard dogmas of neuro science) ceases in this kind of situation. 11 per cent of patients who survived the heart arrest however recalled emotions and visions during this state. This announcement has created considerable excitement in various consciousness related discussion groups and the question whether some of the basic dogmas of neuroscience are badly wrong has been raised by the neuroscientists themselves.

2. TGD based view about life after death very concisely

It is good to summarize the latest TGD based view about consciousness after physical death before comparison with other theories and detailed analysis of NDEs. The view, which is certainly not the only possible one can imagine, is supported by the improved view about psychological time.

The basic notion is that of 4-D body involving both the physical body and the magnetic mirror structures associated with it. 4-D body is gradually carved like an artwork via p-adic-to-real phase transitions representing the progress of front of volition to the geometric future and by the reverse phase transitions deconstructing the 4-D body or its parts. This fractal trial-and-error construction of the 4-D body occurs in various time and length scales. Gradually increasingly stable 4-D body results. The volition is concentrated to the front of the p-adic-to-real phase transition so that the experience of 4-D body for which deconstruction processes occurs only in the time scales short compared to the duration of lifecycle, would be about entire lifecycle and in this sense 'timeless'.

The simplest view assumes that the front of volition does not propagate after the physical death. One could however consider the possibility that the front of volition continues to propagate by transforming p-adic magnetic mirror structures to real ones: volitional life would continue in electromagnetic form. This would make possible the communications of the deceased with living since the resulting real magnetic mirrors could connect the deceased with the living. On the other hand, the repertoare of possible p-adic mgentic mirror structures would be very wide because of the p-adic non-determinism.

Since magnetic mirror structures are fundamental for the field realization of the genetic code, one can quite well consider the possibility that this process induces also the self-organization of the ordinary living matter around the magnetic mirror structures. This would have interpretation as a reincarnation. Buddhas able to resist the temptation to reincarnate would continue their life at the field level. Interestingly, the development of physics from Newtonian physics of the material bodies to Maxwellian physics of fields would mirror the evolution of consciousness from concrete biological life to life at the field level.

3. Astral plane theories for NDEs

There are several theories of NDEs. A theory enjoying popularity in New Age circles is based on the notions of the astral projection and next world stating that we have another body that is vehicle of our consciousness which leaves the body at the moment of death. Although completely respectable as such, this kind of theory is not based on existing or even postulated physics, and is therefore hard to test. The notions of 'higher vibrational level' and 'astral plane' are simply devoid of a physical meaning.

In TGD framework the idea about 'vibrational levels' generalizes in an astonishing concreteness to an entire hierarchy of electromagnetic life forms and electromagnetic bodies whose sizes vary to astronomical length scales [24, 18]. In this framework the idea about brain as a seat of consciousness is an illusion resulting from the fact that sensory data is mostly about the immediate region around

body. Of course, even the idea that consciousness (as opposed to its information contents) can be localized to some part of space-time, is basically wrong in TGD approach.

A possible test for the astral projection theories is a weighing of the body after death to deduce the weight of the astral body (assuming of course that astral planes obey ordinary physics!). If 'astral planes' correspond to the p-adic space-time sheets, this test of course does not make sense. Magnetic mirror structures are obvious candidates for astral body and are real but their separation from body is impossible so that this kind of measurents do not make sense. The notion of 4-D body also suggests that the physical body remain in the geometric past in the physical death wherefrom it can communicate with the living ones via the magnetic mirrors of magnetic body which continues to be generated by p-adic-to-real phase transition.

Extrasensory perception via astral bodies is a second possible test. This test might make sense if extrasensory perception can be generated by patterns of ELF em fields as supposed in the TGD inspired model of qualia. Magnetic mirrors connecting organisms to each other and also to 'nonliving' matter make possible ESPs. Also direct electromagnetic perturbations of the magnetic sensory canvas can give rise to ESPs: in [23] the possibility that the strange sounds produced by meteors [48] could correspond to ESPs is discussed.

4. Tunnel experience

The theory of Grof and Halifax [90] is based on the observation that NDE involves elements which might be assigned to the moment of birth. Perhaps NDE is reliving the moment of birth. The counter argument is that the newly born baby does not see anything unless she is able to perceive extrasensorily. 'Nothing but hallucinations' theories are of course no explanations at all and belong to the same category as 'consciousness as mere illusion' theories. In neuroscience framework also the wake-up reality is seen basically as a hallucination produced by brain and coupled with sensory input to guarantee correspondence with what is out there.

The tunnel is experienced also during epilepsy and migraine, during meditation and relaxed state of mind, and with certain drugs like LSD, philocybin and mescaline. I have also personal 'tunnel experiences' every-daily: when I close my eyes in a half-meditative state achieved by writing at computer terminal, I can see a dim flow consisting of points. Typically this flow enters to or emergences from a tunnel. It can be rotating spiral like flow or simple sink or source. Source or sink can be also linear structure. Earlier this experience was not stable and tends to fade away all the time, and after few minutes I was not anymore able to achieve it. Situation has changed quite recently: I can have the experience almost anytime in peaceful state of mind. During my great experiences this flow was much more complicated and completely visible and formed a stable background of the ordinary visual experience and of hallucinatory visual images.

There is however no experience of entering into the tunnel in this case so that the tunnel need not be the same as encountered in NDEs. It has been suggested that the physiology of brain could explain the properties of near death experiences [64]. The theory of Cowan [64] states that the tunnel results from a failure of the inhibition leading to brain induced activity yielding visual experiences. What is however questionable is why person would feel falling into the tunnel, to say nothing about meeting deceased relatives. Blackmore and Troschienko have proposed a theory in which also the motion along tunnel could be understood as a visual illusion [89].

TGD based explanation for tunnel experience might be simply as a direct visual experience about magnetic flux tube structures resulting from the perturbation of the magnetic sensory canvas outside body. Thus a genuine ESP would be in question. Magnetic field obeys indeed same basic equation as incompressible liquid flow. Both retinas and pineal gland ('third eye' literally since it contains retinal pigments and serves as a genuine third eye in some species [24] are magnetic structures. The practically always present vortex in center ('third eye' in my private terminology) could correspond to the magnetic flux tube structure emanating from the pineal gland whereas the very dynamical flow could correspond to the contribution of retinas. If the magnetic mirrors are universal electromagnetic bridges connecting us to other living beings, in particular to our friends and relatives, the meeting of the 4-D bodies of the deceased relatives would happen at the level of fields.

The movement along the tunnel could correspond to the propagation of p-adic-to-real phase transition along this kind of magnetic mirror structure transforming it from p-adic to real: thus the tunnel would be created after the physical death. During lifetime these em bridges would be p-adic and physical death be followed via the transformation of these bridges to real ones.

5. OBE aspect

Blackmore explains OBEs [76] as resulting from the replacement of ordinary self-center experience of world with bird's eye of view model where brain sees own body from above. Bird's eye of view is only a memory model so that extrasensory perceptions are predicted to be impossible during OBEs. There is however some evidence that patients can report very precise visual perceptions during OBE. It has been indeed argued, that some other senses than vision, namely hearing [76], could create indirectly these perceptions. It is however difficult for even the most hardborn materialist to understand how a clinically dead person could be able to effectively see by hearing, since this feat is impossible for even completely healthy person.

The idea of Blackmore about bird's eye of view is very attractive as such and can be interpreted in TGD framework in quite different manner. Cognitive maps based on the canonical identification map [17] typically exterior to inside and vice versa. Thus both a p-adic map of the external world realized inside brain and a p-adic map of body and its surrounding realized outside the body are possible and would give models of the external world and self. The inside-to-exterior map could provide a bird's eye of view about body and its immediate surroundings.

Both exterior→interior and interior→exterior maps could contribute to the conscious experience even under the normal wake-up consciousness and the exterior contribution would thus represent genuinely extrasensory contribution to the conscious experience. When the ordinary sensory input and volitional activity ceases as during NDE, the contribution of the model of external world to the conscious experience becomes negligible. The ability to experience tunnel unstably during relaxed wake-up consciousness with eyes closed is consistent with the interpretation that these two components are competing. It is quite possible that during sleep the bird's eye of view component also dominates but that no memories about this period are generated for the simple reason that the brain functions necessary for the generation of the memories are not active. My own remembrances about the long depressive period after the great experience caused by the extreme dullness of the normal wake-up consciousness suggest at least to me that these kind of memories might make it too painful to continue the daily life.

The notion of magnetic sensory canvas implies that we actually see at ELF frequencies. Same applies to other senses. This implies the possibility of experiences without any sensory input or even without any neuronal activity. The needed ELF MEs acting as sensory projectors would be generated in the dropping of ions from atomic space-time sheets to the magnetic flux tubes of magnetic body carrying field strength .2 Gauss (Earth's magnetic field has nominal value .5 Gauss). If the ion drops in high n cyclotron state the subsequent decay of the state by cyclotron transitions generates a bundle of parallel ELF MEs giving rise to the sensory projection. This representation can be generated by the entire body and would give rise to a three-dimensional vision about body as seen by the environment. There is some evidence for this kind of anomalous vision.

1. Yogis have reported altered states of consciousness in which they see their own body three-dimensionally, that is simultaneously from all directions.

2. Becker tells in his book "Cross currents" [56] about a young cancer patient who told that he can see the interior of his own body. The patient could locate the calcium deposit left as tumor vanished. This supports the view that ELF MEs could project from the entire body to the sensory canvas.

3. Also the OBE experiences, for instance those associated with NDEs, could have a similar interpretation. The sensory input from eyes and even the input from neural activity could be absent during NDEs so that the visual experience should be determined by the background ELF component emanating from the brain and body. The third person perspective associated with OBEs might be always present but be masked by the strong sensory input.

What has been said applies also to other senses. Interestingly, I often wake-up partially and realize that I hear my own snoring as an outsider. Sometimes I have experience which might be interpreted by saying that the hearing in the first perspective is superposed with the hearing in the third person perspective. The third person hearing has a time lag so that a kind of double breathing results.

Sensory canvas hypothesis provides a more concrete view about the situation. p-Adic-to-real phase transition of a p-adic magnetic sensory canvas to real one could also be part of the fundamental volitional process. The magnetic mirrors connecting brain to sensory canvas should be there also in

the absence of sensory input. Could it be that the out of body view is always involved but masked by the from the body view and after the physical death only out of body view remains?

The competition between bird's eye of view and sensory view has also EEG correlate. Delta waves in the EEG spectrum are natural EEG correlates for the external part of cognition. The reason is that this part of EEG frequency spectrum has a shape and intensity very similar to that for the so called sferics [49], which correspond to meteorological electromagnetic perturbations typically associated with thunder storms. Could sferics be the electromagnetic correlates of discarnates?! The degree of the sensory alertness correlates directly with the the ratio of the EEG net intensities in the delta band and in higher EEG bands [49]. This is consistent with the competition predicted by NMP. Certainly in the NDE experiences studied by the Southampton team only delta band is present in EEG. Note that delta waves dominate also during deep sleep.

Also alpha band is a good candidate for communicating sensory information to higher level selves having magnetic sensory canvas receiving sensory input from several brains simultaneously. It is indeed alpha band in which detectable changes occur in remote vision and remote healing [83]. Could it be that higher than alpha consciousness somehow transforms to alpha consciousness in physical death and could it be that alpha consciousness relates with the fact the lowest Schumann frequency associated with the perturbations of Earth's magnetic field is in the alpha band? It might be that magnetic transition frequencies are involved with the 'vertical' communications from brain to the sensory canvas whereas Schumann resonances would be involved with the lateral communications between different sensory canvases. The fact that hypnagogic experiences involving also identification with other persons (personal experience) appear in the borderline between wake and sleep when dominating EEG frequencies are around 7.8 Hz supports this view.

6. Life review

Blackmore explains the life review as an effect analogous to the lively episodal memories generated by stimulating temporal lobes. This explanation leaves open what exactly happens in the stimulation of the temporal lobes and what episodal memories are. To say nothing about the systematic review and evaluation.

In TGD framework brain and perceptive field are four-dimensional and it is quite possible that episodal memories are multitime experiences involving input which comes from the moment of the geometric time when the recalled experience happened and happens again at the level of sensory representation but not as real life event since this would involve macroscopic volition and induce miracle life events in the geometric future. The notion of 4-D body makes this idea concrete. In the physical death 4-D body becomes in some sense mature (about possible de-construction processes in shorter time scales). The volitional contribution essential for the illusion that world is 3-dimensional is not anymore present and entire 4-D body is experienced as a whole. Perhaps this is just what life review is.

Since geometric memories are in question, the review is only a narrative since our geometric past changes all the subjective time and the review is about geometric past subjectively now. Life review would be a temporal counterpart of the OBE experience in the sense that one sees one's geometric life history from outside in a 4-dimensional sense. This is possible since p-adic cognitive representations are four-dimensional and four-dimensional bird's eye of view could begin to dominate at the moment of death.

Also genuine subjective memories about time interval equal to the wake-up period of self and of order lifetime could be in question. This requires the occurrence of what might be called a p-adic phase transition to higher level self with much longer subjective memory: this view is in accordance with the vision about the physical death as a birth to a life in 'other world'. p-Adic phase transition could mean that the p-adic magnetic mirrors after the geometric time after physical death correspond to higher value of p and quite concretely, have lengths which are longer than during the physical life. This makes possible both geometric and subjective memories in much longer time scale.

7. Positive emotions

With the motivation coming from the OBEs associated with the temporal-lobe epilepsy, it has been suggested that brain-stress near NDE episode leads to the release of neuropeptides and neuro-transmitters (in particular endogenous endorphins) which are responsible for positive emotional states like joy, peace, and love. Again the question concerns about the deeper mechanism. Presumably these neurochemicals are only correlates for the experiences in which extra-sensory component of the expe-

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rience begins to dominate. It has been also suggested that the lack of oxygen is what gives rise to the NDE experiences [76]. The observations of the Southampton team seem to exclude these explanations. Of course, one could claim that some core parts of brain are working even when the patient is clinically dead (no respiration, no heart beat, dilated pupils) and that these functioning parts of brain are able to generate NDE. If so, spiritual experiences would represent the lowest possible levels of consciousness, and even reptiles would have them: perhaps a vulgar skeptic could applaude here but I do not find this idea very convincing.

In TGD framework clinical death naturally implies that extrasensory component of the conscious experience begins to dominate. This picture is consistent with the view about brain as p-adic–real transformer rather than the seat of the entire conscious experience. The dominance of the positive emotions would simply mean that the negative emotions coming from sensory input would be absent.

8. Other worlds

The experiencing of 'other worlds' requires a considerable amount of hand weaving in the standard neuroscience framework. Blackmore claims that imagined worlds are experienced as real because these experiences are the most stable. I believe that Blackmore is right in the sense that mental images (sub-selves) correspond to self-organization patterns which are stable asymptotic states of self-organization. I do not however believe that this is an essential point, and certainly Blackmore's explanation fails if the interpretation of the Southampton team about NDEs is correct.

In TGD framework the other worlds might correspond to the emergence of magnetic mirror structures which correspond to higher value of p-adic prime than during the physical life. They would have much longer lengths and give rise to much longer subjective and geometric memories. Note that the MEs associated with magnetic mirrors are classical representation for light (which brings in mind Tibetan book of death!) so that one could say that the deceased becomes a light being in a well-defined sense. The meeting of the light being might mean an ability to communicate with and sensorily experience the presence of other light beings, natural if the deceased herself has transformed to a light being (but having still 4-D body in the geometric past, this is perhaps why angels have human body!).

Note also that the absence of sensory and corresponding cognitive mental images during NDE is analogous to the empty mind free of mental images which is the goal of the meditation practices. Perhaps soul could be identified as a self having no subselves, 'irreducible self' as suggested in[33].

9. After effects

The after effects induced by the spatio-temporally extended consciousness in which one sees one's own life from outside are often dramatic. It is difficult to reduce these after effects to brain pharmacology.

My own great experience had many aspects common to NDEs and induced profound (not at all pleasant!) changes in my own life. In my case the direct experience of the higher levels of reality made possible the realization how magnificent the almost-boring everyday reality really is when seen through sharpened senses, how pathetically narrow the zone of wake-up consciousness is, and how ridiculously little the celebrated big science tells about reality. This realization resulted in a strong conviction that I am on a right track, and has given the courage to work these fifteen years as a ridiculed scientific dissident in a country in which vulgar skepticism is in the role of a scientific state religion and vulgar skeptics have taken the role of the mind police of science.

11.4.4   Are communications between living and deceased possible?

The vision about psychological time suggests that the life after the physical death could be purely electromagnetic so that the memes and memeplexes represented by p-adic cognitive space-time sheets (magnetic mirrors say) associated with the organism continue to transform to their real counterparts after the physical death. Since these magnetic mirrors can connect the 4-D body of the deceased to living physical bodies, communications between deceased and living become possible and the mechanism of communications is same as the mechanism of long term memories. It is also possible that the transformation of the magnetic mirror structures to real form induce generation of biological organisms around them and this would give rise to re-incarnation.

In the language used in the spiritistic circles, 4-D bodies of the deceased together with the magnetic mirror structure associated with them also after the physical death would correspond to 'discarnate'

or 'ethereal' entities belonging to the 'etheric level'. Perhaps the proper interpretation for p-adic space-time sheets representing thoughts and intentions is as not-yet-born entities.

Since the p-adic copies of all real physical systems are possible, even the most far-fetched claims of psychics about materialization and communication phenomena could in principle make sense. It however seems that what is materialized by p-adic-to-real transition is the plan for organism represented by magnetic flux tube structures.

Mediums and materializations

In spiritualistic circles mediums have been traditionally seen to mediate communications between deceased and alive. This includes also claimed materializations of physical objects besides the bodies of the deceased. Often direct voices emerging from empty space are claimed to been heard during the sittings: trumpets and accordions flow in the air and produce music. Analogous direct voice phenomena are associated with the claimed poltergeist phenomena. The explanation goes that medium is able to somehow to draw 'ectoplasm' from her (quite often her) own body and from the bodies of the participants which then materializes as the bodies of deceased and as material objects.

For a physicist this explanation is empty as long as a physical and mathematical definition of the ectoplasm is lacking. In TGD frame work mediums could be seen as persons able to act as relay stations communicating with both deceased and with the participants of the sitting via magnetic mirror bridges. Perhaps these bridges are generated during sitting and medium helps to transform them to real form so that communications along these bridges become possible. The transformation of the p-adic space-time sheets to real ones is of course the natural candidate for the materialization process.

Zero energy ontology allows also a direct generation of CD in quantum jump is in principle possible and TGD inspired theory of consciousness support this possibility indirectely since the generation of a mental image corresponds to generation of sub-CD and thus creation of zero energy state from vacuum. In this framework ectoplasm would be ordinary biomatter.

My own great experience, which involved several parapsychological elements, was a parade of deep ideas, and one of them was the notion 'flogiston' as something new for the existing physics and absolutely essential for the living matter. According to the vision, living organisms were fighting and killing to get 'flogiston', and the greatest minds had been able to get it (even steal!) more than the lesser souls. I have considered several identification of this mysterious 'flogiston'. p-Adic space-time sheets is one possible identification. Second interpretation as negentropic entanglement possible in the intersection of real and p-adic worlds and crucial for TGD inspired view about metabolism.

One cannot exclude the possibility that the transformation of the p-adic plan for a material body represented by magnetic mirror structures could induce a self-organization of the ordinary matter around this template to form material objects or at least mimicries of them. This is essentially what biological growth is assumed to be. The p-adic-real transitions in the intersection of real and p-adic worlds would provide a concrete realization of this mimicry.

If is of course difficult to take seriously materialization of entire physical objects by p-adic-to-real transitions (the phenomenon would have enormous technological impact!). It would seem more probable to me that memes transform directly to real space-time sheets causing what are usually regarded as hallucinatory experiences, which is now however completely real communication. If this can happen, it could happen also collectively so that all participants have the same paranormal experience. This does not look strange if one accepts the possibility of magnetic sensory canvases receiving sensory input from several brains and also inducing hallucinatory perceptions.

Usually the spiritistics sittings have been held in the darkness and this allows excellent opportunities for a fraud. On the other hand, alpha band in EEG begins to dominate in darkness and might make possible the communications. There are several reasons to think that it is fast amplitude modulation of alpha frequencies producing harmonic multiples of the alpha frequency, which could be the communication mechanism between our level and higher levels of self hierarchy. The so called mesoscopic features appearing in EEG correlates and corresponding to 1-2 cm areas of cortex [47] could be direct physical correlates for these communications [18]. The model of bicameral mind based on the notion of semitrance relies on the same idea [21]. Note that the minimization of the sensory input (sittings are arranged in dark room) might be just what is needed for the extrasensory input to dominate.

EMDR method as a mechanism to communicate with deceased

Near-death experiences are not the only manner to get convinced about life after death. So called eye-movement desensitization and reprocessing (EMDR) discovered by Francine Shapiro [86, 54] induces what could be interpreted as after-death communications. The experiences of subject persons can be induced by this therapy in highly reliable manner: according to [54] 98 per cent of patients willing to participate the therapy had after death communication experience It does not matter what the religious convictions of the subject person are and the experiences are actually rather easy to induce. It does not matter if the loss is traumatic or not or whether it is recent or occurred for decades in past. The experiences resemble near death experiences (light tunnels, beautiful landscapes) and involve spiritual contact with the deceased. The EMDR technique involves getting the patient to move his or her eyes in a particular thythmic fashion while at the same time attending to a particular aspect of the traumatic memory. How EMRD works is poorly understood as yet: possibly the fact that the shifting of eyes leads to increased brain processing is of importance. Notice that rapid eye movements REM are also involved with dreams.

A possible explanation is that EMDR experiences could involve communication with the 4-D bodies of the deceased ones located possibly in the geometric recent or past via the magnetic mirrors associated with them. One might think that rapid thythmic eye movements induce fast modulations of some alpha frequency and generate the above mentioned features which somehow help to get a contact with deceased, perhaps rhythmic eye movements somehow induce the p-adic-to-real transition of the p-adic magnetic mirror bridges. Essentially the same mechanism as involved with long term episodal memories would be in question: the only difference would be that the magnetic mirrors now mediate information not from own 4-D body from the 4-D body of the deceased.

11.5 TGD based model for instrumental transcommunications

11.5.1 Introduction

The so called instrumental transcommunications (ITC) and electronic voice phenomena (EVP) [72, 88] belong to the borderline of even paranormal phenomena, and skeptically oriented scientists probably find it rather difficult to take the claimed phenomena seriously. Personally I do not have any strong opinions and I am just interested in finding whether TGD view about paranormal phenomena might allow the claimed phenomena. Quite generally, ITC can be defined as messages communicated by some conscious entities other than humans using various kinds of electronic instruments. Electronic voices (EVP) are only a special case of the claimed communications and can be realized as signals appearing in a magnetic tape, as voices heard directly from radio receivers, or even phone calls from dead. Also images appearing in a computer screen are reported. The article of Ralf Determayer in the ITC journal [88], whose chief editor Anabela Cardoso is also ITC experimenter, helps to get an overview about the ITC phenomena.

Friedrich Jurgenson is usually mentioned as the pioneer or EVP. In 1959 Jurgenson recorded bird song in the morning to a tape recorder and to his surprise found that the tape contained also something else. He started a systematic research of the voices which he interpreted as messages from deceased. This work materialized in two books, "Voices from Space" and "Radio-link with the Dead". Kostantin Raudive, professor of philosophy and psychology and a student of Carl Jung met Jurgenson in 1965, got interested in the phenomenon, and started an intensive recording and study. He published his results in book "Breakthrough" [72]. As a matter fact, Jurgenson and Raudive had predecessors, Raymond Bayless, Attila Szalay published 1959 an article about the phenomenon in Journal of the American Society of Psychical Research, few months before Jurgensen made is discovery. Later begun experimenting also with other forms of EVP and ITC [88]. EVP involves recorded phone calls from deceased, direct radio voices, voices both heard by experimenter and tape recorded, and "paranormal" voices not heard but recorded. ITC involves also also other communication modes such as receival of images via computer screen. If one takes seriously all these reports, it would seem that both analog and digital communications are involved.

EVP and ITC very briefly

My own knowledge abut EVP and ITC is very restricted. According to the articles published in ITC journal, for instance the articles [88, 95, 93] there seems to be a consensus about the following aspects of ITC.

1. The role of the experimenter is important. The ability to receive messages is learned only gradually. The receiving system which works for one experimenter does not work for another. For instance, if two radios are used simultaneously they usually work at different frequencies. This all suggests that experimenter serves as a kind of medium, relay station, or "radio link".

2. The naive idea about spirits serving as radio stations is not probably correct [95, 93]. The voices from radio receivers tend to be located in silent periods containing only the background noise and somehow the sender is able to use the energy of the noise to generate the message. This suggests that stochastic resonance in which a weak signal is amplified using noise to provide the energy might be involved. The transformation of noise to voice raises the question about the possible breaking of the second law of thermodynamics, and TGD indeed allows breaking of second law below p-adic time scales [28].

3. The spectral analysis of the electronic voices by Paolo Presi [93] shows that usually the voices have an acoustical structure similar to that of human voices. The temporal sequence of vowels, their duration, the duration of the pauses, and the accent of certain vowels of the voices determine a speech thythm similar to ours. The transfer of information is based exclusively on the sequence of the vowel formants and the integration, made by listener, of the missing consonants. Consonants are produced by a sudden interruption of the air flow coming from the lugns or by an obstruction of the vocal tract. The spectrograms contain no fundamental frequency [95, 93] unlike speech for which the fundamental frequency defines the pitch. In principle this does not mean a loss of information but together with the absence of the consonants would mean that the primary source of the message is probably not speech organs. This makes hoax as an explanation of the voices less plausible.

Questions

There are several questions to be answered. *1. How could one tell whether the ITC messages are real or not?*

Brain tries to generate standard percepts from sensory inputs: by looking at clouds at the sky one realizes that brain almost inevitably tends to see faces or other patterns. Therefore this question is highly non-trivial. One can try to answer the question by analyzing whether (say) the electronic voices have spectra resembling that of human voices, and carry the minimum information to be recognized as a speech. It is relatively easy to distinguish an artifact produced by an intelligent life-form (say quartz clock) from a "dead" matter (say a piece of rock). In the similar manner, the differences between the electronic voices and "dead sounds" provide a criterion for whether they are produced intentionally. The information content of the signal is an obvious criterion for this but it is far from trivial, how to define and measure the information content.

Standard real-number based statistical physics allows only the notion of entropy. Entropy is always non-negative so that the information defined as negentropy would be non-positive always: the best one can achieve would be to know nothing! TGD inspired theory of consciousness strongly encourages a number theoretic modification of the standard notion of information, which is based on Shannon's definition of entropy [29]. The resulting p-adic entropies (one for each prime p) obey the same axioms as the Shannon's entropy but can have both positive and negative values, and depending on the sign can be interpreted as measures of either dis-information or information. These information measures might apply to the analysis of EVP messages. The conclusion of Paolo Presi [95, 93] on basis of his analysis is that the voices represent a real attempt to communicate. In the following I will assume the messages are real and look whether TGD based view about remote mental interactions allows to model the phenomenon.

2. What could we speculate about the senders of the messages?

In TGD Universe everything is conscious and consciousness can be only lost by quantum entangling. Thus everything is living, and the question is only about how effectively system can control its own state and the state of its environment and about the time scale of the control.

1. Ordinary humans could send these messages unconsciously: human brain and body act as both receiving and sending electromagnetic antennae and in view of the topological quantization of classical em field, it would not be too surprising if these electromagnetic messages could be received electronically under some conditions.

2. TGD predicts that our electromagnetic bodies will survive so that the conscious experience of a discarnate receives a contribution from the 4-dimensional body of the deceased (life review reported in near death experiences) plus a contribution from electromagnetic body still existing.

3. Also the magnetosphere is predicted to be a conscious entity containing collective multi-brained selves.

4. The model for crop formations [37, 22] leads to rather detailed ideas about exotic life-forms residing at various boundary layers of the magnetosphere, where energy currents driving self-organization are strong. In particular, the mantle-core and core-inner core boundary layers are good candidates for the seats of lifeforms (intra-terrestrials, ITs) quantum-controlling the liquid and/or liquid-crystal phases of quartz or iron from very cold and super-conducting space-time sheets.

3. What is the communication mechanism? TGD based model of remote mental interactions is based on same mechanism as communications inside biological organisms. The mechanism involves quantum entanglement having low frequency MEs (massless extremals, "topological light rays") as a space-time correlate, and remotely induced self-organization based on high frequency MEs propagating along low frequency MEs like mass-less particles. If magnetic mirrors act as bridges between the deceased and the experimenter and between the experimenter and the electronic instrument so that the experimenter takes the role of a relay station (or medium), the phenomenon ceases to look totally implausible. Long term memory, telepathy, remote healing,..., and communications with exotic life-forms and deceased become special cases of the same general phenomenon. For instance, TGD predicts mechanisms for how body and brain seem can act as lasers in wavelength range extending from ELF range to visible and UV wavelengths. This kind of laser action could amplify the incoming signal, say microwaves at GHz region, which could the be detected in turn by the electronic instrument with which the experimenter has quantum entanglement bridges, and then transformed to sounds.

4. How the sender can handle modern information technology to generate the desired messages?

In case of a tape recorder or telephone the electric signal is only em variant of sound wave but in case of radio situation changes. The carrier frequency of the sound changes and amplitude modulation can be replaced with frequency modulation. If signal is to be transformed to visual images, a transformation to binary code is needed. The question is where this technological knowhow comes? There are two possibilities.

1. A feedback from the electronic instrument via the brain of experimenter listening say the magnetotape and thus trial-and-error learning of how to send desired messages becomes possible. The simplest feedback is based on the sharing of the mental images of the experimenter by quantum telepathy. TGD allows also history editing, which means that the message to the instrument in the geometric past is modified again and again so that a repeated listening of the message could make it more comprehensible.

2. The existing knowledge about remote mental interaction suggests that they often involve magnetospheric multi-brained selves acting as kind of relay stations. For instance, remote viewer knows only the coordinates of the target, which as such are completely meaningless numbers to her: it is enough that the person who gave the coordinates of the target to the viewer knows their meaning. If ITC occurs in this manner, the information about how to translate the message to say bit sequences in the computer memory might be available. A direct remote mental interaction with the electronic system might be involved at least in some cases and the question is how the proposed general scenario allows to realize this.

5. How the intention of the sender is realized as action?

Remote mental interactions involve also the transformation of intention to action. In TGD framework this corresponds to p-adic-to-real transformation for some space-time sheets. Natural candidates are systems for which the energy of the resulting real system is small so that external energy feed can provide it. If the primary message comes from the magnetic body of the deceased, p-adic MEs are perhaps the most natural candidates for the representations of intentions. These p-adic MEs must first be transformed to real MEs; the real MEs interact with the magnetospheric self; the real MEs originating from the magnetosphere interact with the brain and/or body of experimenter, which in turn interacts with the receiving instrument.

Detailed models for the transformation of the p-adic ME to a basic signal (represented by light or sound) or directly to an electric signal (say in magnetic tape recorder) are not possible at this stage. The mere occurrence of this transformation involves an active volition, and here the role of the experimenter who believes and wants that the transformation occurs, might be decisive. If this is the case, the phenomenon might be also regarded as a particular form of psychokinesis and disappear if the experimenter has a skeptic attitude. Also feedback via the brain of the experimenter to the sender is required and is strongest when the experimenter listens or sees whether the message is there and possibly recognizes it.

11.5.2 Universe as a conscious hologram and a general mechanism remote mental interactions

The idea about brain and perhaps all bio-matter, and even Universe, as a hologram in some sense (see for instance, the articles of Miller and Webb [91] and of Gariaev *et al* [41]) has a long history but the question in which precise physical sense this holds true has remained without a satisfactory answer. The notion of conscious hologram provided by TGD approach allows to understand bio-control and remote mental interactions as particular cases of the same basic interaction. The notion of conscious hologram leads also naturally to the notions of magnetic body and magnetospheric sensory representations.

The general model of remote mental interactions

The mechanism of remote mental interaction involves two parts. The entanglement, which made possible by low frequency ME in even astrophysical length scales, means that sender and receiver of the message become effectively a single system. This is enough to explain remote viewing as sharing of mental images implied by the fusion of mental images of viewer and target system. The active remote realization of intention requires high frequency MEs propagating like mass-less particles along the low frequency ME and inducing the leakage of the supra currents from larger to smaller space-time sheets, dissipation and possibly also amplifying laser action. This mechanism works also in ordinary bio-control: remote mental interaction is now between some biostructures such as cells or organs.

The scaling law of homeopathy, stating that high and low frequency MEs accompany each other and the frequencies are in some fixed proportions, plus p-adic length scale hypothesis make the hypothesis highly predictive. There is no need to emphasize that the reduction of both homeostasis and remote mental interaction to the same basic mechanism gives support for the reality of the remote mental interactions.

The notion of conscious hologram

The concrete Maxwellian idea about hologram plate resulting as a result of interference of the reference beam and light scattered from an object can serve only as a guiding metaphor. First of all, coherence occurs only in what are called coherence regions and the problem is that Maxwellian theory does not really provide a first principle definition for the coherence regions. In quantum theory similar problem is encountered. Secondly, in living matter it is not at all clear whether reference beam exists at all. Third, living matter is a dynamic granular structure and far from a homogeneous hologram plate. Fourth, the idea about storing memories, one of the basic motivations of the hologram paradigm, has its own problems although multi-holograms are certainly possible.

In TGD framework topological quantization provides a precise first principle description of coherence. Topological field quanta are the coherence regions of the classical field and classical decoherence

means the splitting of the space-time surface to topological quanta. This process gives rise to the granular structure of matter and space-time sheets in various length scales are excellent candidates for basic units of hologrammic structures at the this level of the p-adic length scale hierarchy. At quantum level bound state quantum entanglement having join along boundaries bonds as a space-time correlate is responsible for the macroscopic and macrotemporal quantum coherence. The notion of conscious hologram combines two dual aspects of consciousness to single concept: macrotemporal quantum coherence due to the generation of bound state entanglement and giving rise to co-operation on one hand, and the dissipative self-organization giving rise to Darwinian selection and competition on the other hand. In nutshell, the notion of conscious hologram follows from the topological field quantization.

1. Classical fields and matter form a Feynmann diagram like structure consisting of lines representing matter (say charged particles) and bosons (say photons). The matter lines are replaced by space-time sheets representing matter (elementary particles, atoms, molecules,...), and virtual bosons are replaced by topological light rays ("mass-less extremals", MEs). Also magnetic flux tubes appear and together with MEs they serve as correlates for bound state quantum entanglement.

2. The classical fields associated with MEs interfere only at the nodes, where they meet, and one has a hologram like structure with nodes interpreted as the points of a hologram. Thus one avoids the loss of information caused by the interference of all signals everywhere. This aspect is crucial for understanding the role of em fields in living matter and brain. The MEs corresponding to 'real photons' are like laser beams entering the hologram and possibly reflected from it. What is new that the nodes can be connected by 'virtual photon' MEs also analogous to laser beams. Hence also 'self-holograms' with no laser beam from external world are possible (brain without sensory input). The hologram has a fractal structure: there are space-time sheets at space-time sheets and high frequency MEs propagating effectively as mass-less particles inside low frequency MEs serving as quantum entangling bridges of even astrophysical length.

3. The particle like high frequency MEs induce 'bridges' between magnetic flux tubes and atomic space-time sheets at the receiving end. This makes possible the leakage of supra currents from magnetic flux tubes to atomic space-time sheets analogous to the exposure of film producing hologram. The leakage induces dissipation, self-organization, and primitive metabolism as a cyclic flow of ionic currents between the two space-time sheets, and thus a Darwinian selection of the self-organization patterns results. The low frequency MEs are responsible for the bound state entanglement, macroscopic quantum coherence and co-operation whereas high frequency MEs are responsible for self-organization and competition.

4. Also the notion of laser action finds its place: many-sheeted space-time provides natural mechanism of laser interaction: when the system is irradiated with coherent light with a frequency which corresponds to the energy difference for the ions at the space-sheets corresponding to different p-adic primes, induced dropping of the ions to a larger space-time sheet occurs and implies a stimulated emission. Thus the light beam can be amplified.

5. At the level of conscious experience the fusion of subselves gives rise to a fusion of mental images. In case of right and left visual fields this fusion gives rise to stereovision analogous to what results in hologram. In the general case kind of stereo consciousness results if the mental images are sufficiently similar.

Magnetic sensory canvas hypothesis

The magnetic sensory canvas hypothesis is perhaps the most radical hypothesis of TGD inspired theory of consciousness. It states that sensory representations are realized outside brain at magnetic flux tube structures associated with brain and have sizes measured perhaps in the size scale of Earth. The realization is based on the same mechanism as remote mental interactions: the simple feeling of existence mental images fuses with the more complex mental images produced in brain.

Possible extra-sensory perceptions induced by atmospheric phenomena might provide support for this hypothesis. Auroras are known to induce sounds not detected by electronic means: could these be extrasensory perceptions induces by auroras on sensory canvas. Also meteors could induce sounds [48].

If one takes very seriously the model for sensory representations, one can imagine that the meteors could kick electromagnetically the magnetic flux tube-ME pairs of sensory canvas and force them to resonantly oscillate at harmonics of the thalamocortical resonance frequencies in interval 37-44 Hz.

These magnetic mirrors might also mediate the electric perturbations to Earth in a channelled manner so that no attenuation would be involved. The mirrors could mediate un-attenuated or even amplified ELF waves also also to electronic instruments. And what is of special interest now, if electronic instruments couple to the magnetic sensory canvas, machine-man interactions would become possible. The test is to look whether meteors induce sounds heard without time lag due to finite propagation velocity of sound and whether also electronic instruments detect these sounds.

Amazingly, there is evidence just for this kind of strange effects. For centuries it is known that meteors can generate audible 'pop' like sound. Sound is heard instantaneously so that either we hear it as ESP through magnetic sensory canvas or ELF em waves are transformed to sounds at Earth and heard after that. Quite recently also electronic instruments have detected these sound [48]. Amazingly, the frequencies were 37-44 Hz range contrary to the expectation that they would be in the range 20-20.000 Hz and have much weaker intensity. The generation of sounds with the observed intensity is theoretically possible only if the electric perturbations from ionosphere have propagated to Earth as essentially unattenuated (along magnetic mirrors) or being even selectively amplified (magnetic mirrors as wave cavities).

Thus there is some support, not only for the sensory canvas hypothesis, but also for the machine-mind interactions at thalamocortical resonance frequencies. One could also look whether there are correlations between human EEG and electromagnetic perturbations of electromagnetic instruments in thalamocortical frequency range (and perhaps also at the higher harmonics of it). This interaction might be of fundamental technological important since it might make possible to control electronic instruments directly by thought.

11.5.3 Who are the senders?

In TGD Universe everything is conscious and consciousness can be only lost. Therefore it is possible to imagine several kinds of senders.

Deceased and/or living humans?

In some messages the senders tell that they are deceased. There are two possibilities: either the senders live in the geometric now in some other than the usual physical form or they live in the geometric past where their physical body still exists. Both options seem to be possible.

1. The conservation of magnetic flux suggests that the magnetic flux tube structure associated with the electromagnetic body survives the physical death so that both the 4-dimensional physical body of the deceased in the geometric past and also electromagnetic body in geometric present would exist. If the p-adic MES associated with the electromagnetic body continue to transform from p-adic to real form, electromagnetic bridges between the 4-D body of the deceased and physically living creatures or electronic instruments could make possible ITC.

2. Also the entanglement with and signals from the geometric past from the physical bodies of the deceased must be considered (say the communications by Kostantin Raudive). TGD based model of long term memories (all memories, even water memory) is based on the mirror idea: when I remember I look at me at a magnetic mirror located at a huge distance of light years. Therefore I see the me of the geometric past in the mirror [25]. Magnetic mirrors can however connect me to some other person and this means communications with the persons having 4-D body in the geometric past, receiving their memories. This communication is more probable between persons have had (and still have) a close relationship generating the required magnetic mirror bonds.

3. Also the brains and bodies of living could act as sending antennae and generate unconsiously ITC messages. Thus one cannot expect that all messages would have a deep spiritual tone.

Magnetospheric selves?

The model for the sensory representations realized at magnetic bodies of astrophysical size inspires the hypothesis that also the magnetosphere of Earth acts as sensory magnetic canvas and is a living, conscious system. Magnetosphere could be a seat for multi-brained conscious entities receiving information from human and other brains and bodies serving as neurons of these life-forms. Various EEG frequencies correlate for various parts of the magnetosphere by resonance conditions. Especially interesting seats for em life-forms are various boundary layers of the magnetosphere, such as the plasma sheet at the night side magnetosphere and magnetopause serving also as a kind of magneto-immune system.

Remote mental interactions such as remote viewing involve aspects which suggests that they proceed via the mediary of multi-brained selves providing information necessary for the localization of the target not possessed by the remote viewer herself. Also ITC might involve these collective levels of consciousness. Empirical support for the notion of multi-brained collective levels of consciousness comes from the experiments of Mark Germine [94].

An operator and a subject person were involved. The stimulation of the subject person consisted of a sequence of identical sounds containing now and then an odd-ball stimulus (now silence). The odd-ball stimulus generated an event related potential (ERP) visible in EEG and reflecting the conscious reaction. The operator was in a second room and by simple toss of coin decided whether to observe the stimuli in the computer monitor or not. The stimuli appeard in the computer monitor one second before they were heard by the subject person. What was found that when the operator saw the odd ball stimulus from the computer monitor, the ERP was weaker on the average. An 11 Hz periodicity was the major component in the difference profiles. The simplest explanation is that the brains of both the operator and of the subject person belong to a larger multi-brained self and that the evoked response represented partially the reaction of this self. When this multi-brained self had already seen the stimulus through the operator's eyes, it was not so surprised to hear this stimulus again through the ears of the subject person, and ERP was weaker. The appearance of the 11 Hz periodicity suggests that this frequency is an important correlate for the entanglement of the subject person's mental images with those of the multi-brained magnetospheric self.

ETs and/or ITs?

The interior of Earth contains almost empty and cold space-time sheets and the magnetic flux tube structure in the core of Earth serves as a kind of thalamus like relay station. The cavity resonance frequencies associated with core and inner core are in the range 14-15 Hz and 40-50 Hz and correspond to two important frequencies of EEG. Thus also the interior of Earth might be important for consciousness.

The general TGD based view about life implies that various boundary layers containing strong energy currents driving self-organization are optimal for the emergence of life. The mantle-core and core-inner core boundary layers containing possibly liquid-crystal phases of quartz (glass) and iron, are especially interesting seats for life-forms controlling the hot liquid-crystal phase from larger space-time sheets which are very cold and super-conducting. A support for these speculations comes from the strange findings associated with crop circles. In particular, Chilbolton and Crabwood crop formations [51, 50] can be interpreted as messages providing information about these life forms: even the genetic codes of these life-forms can be deduced and a general model for our genetic code emerges as a by-product [37, 22]. One cannot exclude a quantum symbiosis between us and these life-forms based on a telepathic sharing of mental images, and this kind of symbiosis conforms with shamanistic and religious mythologies and the Freudian super-ego-ego-id trinity. Therefore one must consider the possibility that the senders of ITCs are ITs (intraterrestrials). Of course, quantum entanglement mechanism allows also ETs as the senders of the messages.

11.5.4 Knowhow problem

How it is possible to code the information sent by the discarnate entity to say computer picture. It is difficult to imagine that the sender would be able to same as a group of IT specialists and computer engineers. There are two manners to overcome this problem.

Higher level multibrained selves acting as relay stations

Higher level multi-brained magnetospheric selves could act as relay stations entangling the sender of the message with the experimenter in turn entangled with the electronic instrument. The knowhow about how to encode the primary signal to various forms such as AM or FM modulated radiowave or even signal represented as a binary code could be possessed by some brains of this higher level self.

The role of these selves would be same as in the proposed realization of memes and morphic resonances of Sheldrake in terms of magnetic bodies responsible for collective consciousness [26]. The possibility of collective gene expression based on hyper genes would make this kind of mechanism possible in the case of biological matter and would provide completely standardized communication and control tools for magnetic bodies.

Feedback and history editing

The proposed model is consistent with the fact that EVP and ITC skills develop only gradually and require patience and that some persons are more gifted than others. The generation of the magnetic mirror bridges between senders and experimenter and experimenter and electronic instrument require time. Also the sender must learn by feedback how to code desired messages to the electronic instrument. The simplest form of feedback is a sharing of the mental images generated by say the listening of the magnetic tape in the experimenter's brain.

History editing provides quite a science fictive sounding manner to make corrections to the message. Each quantum history changes the geometric past so that history editing becomes possible in principle. There is an experiment in which a chicken confined to move in small area became imprinted to a robot [92]. The motion of the robot was coded to a random number sequence half year before. After the imprinting the motion the robot tended to stay near the chicken which suggests that the bleak chicken was able to alter the random number sequence and thus edit history in a time scale of half year. Our long term memories are unstable and can be altered by suggestions. In TGD framework also this can be regarded as history editing applied to the sensory representations of the brain of the geometric past.

During the listening period the sender of the message could receive the information about the conscious experience of the experimenter by the sharing of the mental images induced by the message. The sender could make a quantum jump to a new history which would imply a modification the message to the electronic instrument located in the geometric past (the geometric past changes in each quantum jump in TGD framework), the experimenter would perceive the improved message, and so on. This iterative loop would lead finally to a message which generates the experience of recognition of message in the receiver. During repeated sessions sender would learn the code and would be able to send messages more easily.

11.5.5 Experimenter as a medium and amplifier of the signal

Experimenter could act as receiver of the ITC signal, amplify it, and send it further to the receiving instrument. Experimenter might also make possible feedback from the instrument to the sender. Both various experimental findings and TGD based view about bio-systems lend support for this hypothesis.

Magnetic mirror as electromagnetic bridge

The experimenter in ITC seems to play a role similar to that of the medium in spiritistic sittings. The idea about experimenter as a relay station between electronic instrument, making possible both the sending of the classical message to the instrument, and receiving the conscious response of the receiver during the reading/listening session, might indeed help to understand ITC at general level.

Magnetic mirrors are by definition magnetic flux tubes accompanied by MEs parallel to them. The Alfwen waves, which represent oscillations of magnetic flux tube analogous to those of violin string, resonate with the classical em wave propagating along ME and amplify the signal. To be precise, one should speak about a mirror pair: the mirrors are the points of magnetic flux tube where ME is attached to the flux tube. The existence of magnetic mirror bridges between experimenter and electronic instrument would not be surprising. MEs and magnetic flux tubes represent topological field quanta of electromagnetic field and it would be more surprising if they would not interact with electronic instruments since these instruments interact already in Maxwell theory with external electromagnetic

fields. What is new is that MEs make possible channelled transfer of energy and information: in Maxwell's theory signals would be transmitted to all directions as 'mass communications' and distance would be the limiting factor unlike in case of MEs. The presence of kind of interaction would suggest that humans and electronic instruments are already now in an intense interaction and that the electronic revolution is more like a symbiotic process in which both machines and men are active participants.

The generation of electronic (and also acoustic) signal requires energy. Magnetic mirror quantum entangles the discarnate, experimenter, and the electronic instrument. Only bound state entanglement is preserved in quantum jump and thus binding energy is liberated when bound state entanglement is generated. This energy is usable energy and could provide the energy needed to generate the signal. If stochastic resonance is involved, the noise acts as an amplifier of the signal. In the case of an acoustic signal the body of the experimenter could generate the sound and energy could come from metabolism.

Body and brain as antennae

TGD based view about living systems indeed predicts that brain and body act as receiving and sending quantum antennae in a very wide range of frequencies. For instance, EEG can be regarded as radiation emitted by brain acting as an antenna. TGD predicts that EEG MEs are accompanied by high frequency MEs, most probably at microwave frequencies and induces self-organization at magnetic body and thus give rise to sensory representations. For instance, microwave hearing [38] lends support for the hypothesis that brain is a receiving microwave antenna. The microwave frequency spectrum relevant for microwave audition is in the range $.2 - 3$ GHz. A receiving antenna can also act as sending antenna and it is known that at the sunset a microwave static of unknown but presumably biological origin emerges and correlates strongly with the so called taos hum [35]. Taos hum is a humming sound heard during night time, which can become intolerable and has no identified origin. The most plausible explanation of taos hum is as a special case of the microwave hearing.

Are alpha waves in special role?

The general communication mechanism between the sender and experimenter could be based on fast amplitude modulation of alpha waves involving higher harmonics of ~ 10 Hz wave (this is like adding small riples in long wavelength water wave). This mechanism could in fact be equivalent with the propagation of higher frequency MEs inside 10 Hz ME serving as the quantum entangler.

1. Schumann resonance frequencies correspond to cavity resonances in size scale of Earth and thus might mediate telepathic communications between different selves. The lowest Schumann frequency of about 7.8 Hz is especially interesting in this respect.

2. It seems that the 10 Hz fundamental frequency assignable to electron's CD provides a first principle explanation for this frequency appearing also as fundamental biorhythm. This also explains harmonics of 10 Hz frequency naturally. The hierarchy of Planck constants allows also sub-harmonics and even rational multiples of 10 Hz frequency and one can ask whether 5 Hz theta frequency corresponds to dark electrons.

3. Originally the 10 Hz frequency emerged from the memetic code but zero energy ontology provides a first principle justification for it. One realization of memetic code would be in terms of 7 quark-like CDs of duration $1/1.28$ ms with bits represented as states of quark and 7:th bit representing a check bit. Genetic code could be realized in terms of 6 scaled down variants of electronic CD but it is not clear whether this requires that quarks appear with masses coming as half octaves of the basic p-adic mass scale corresponding to 5 MeV mass scale. Memetic code could act as universal code making possible communications also with "dead" matter. One can even consider the possibility that electron possesses primitive intelligence. The success of p-adic mass calculations could be indeed understood if elementary particles reside in the intersection of real and p-adic worlds and are therefore quite generally able to entangle negentropically.

Our speech uses the same mechanism (10 Hz frequency is the basic vibration frequency of speech organs, which is not the fundamental frequency which is above 20 Hz) and so called features [47] identified in EEG patterns can be also regarded as a fast amplitude modulation of the alpha wave

(low amplitude higher harmonics of the alpha wave appear as ripples of the alpha wave). This suggests that speech is an expression of genetic or perhaps even memetic code (the number of codewords seems to be however enormous and genetic code seems to be quite enough.

The structure of the mesoscopic features of EEG [47] suggests that the harmonics up to the 8:th harmonic of alpha wave are present in EEG. This amplitude could modulate a carrier wave which should have frequency above 80 Hz: the presence of the carrier wave is however not absolutely necessary (the fundamental frequency defining the pitch of the voice and produced by speech organs indeed tends to be absent in EVP [93]). Interestingly enough, the frequency interval for so called taos hum is in in the interval 40-80 Hz [18]. The duration of nerve pulse is consistend with the assumption that entire memetic code is realized at the level of nerve pulse patterns.

These features could communicate information to higher level multibrained selves. It has been found, that healer's alpha wave activity intensifies during healing process and magnetic emissions in ELF range have been observed. Also correlations and synchronization between alpha wave activities of Qigong masters and healees has been reported [83]. If the brain of the experimenter serves as a relay station, the deceased (identifiable as the electrommagnetic body remaining after the physical death or as the physical body in the geometric past) could use the same code as it has used while controlling its own material body from magnetic sensory canvas during life time to both send and receive mental images. If magnetic sensory canvas is able to produce visual hallucinations and dreams it might be also able to produce visual images by sending similar commands to the brain of the experimenter serving as a relay station and preserving the topological structure of images.

Could the body and brain act as lasers?

According to the experimental findings of Peter Gariaev and his group, the irradiation of DNA by visible laser light induces radiowave emission at frequencies ranging from ELF frequencies to MHz range [41]. The TGD based model of the phenomenon relies on the hypothesis brain and body could act as a laser in a wide range of frequencies extending from EEG frequencies up to UV. The idea is simple: when an ion drops from a smaller to a larger space-time sheet it liberates the difference for the energies of the initial and final state. For free ions this energy is in the simplest situation essentially the difference of zero point kinetic energies. For magnetic flux tubes it is the difference of magnetic energies, which is very small and can correspond to even ELF frequencies. This leads to a many-sheeted laser mechanism: if the system is irradiated with a radiation, whose frequency is same as for the radiation liberated in the dropping, stimulated emission occurs and incoming coherent radiation can be amplified. The difference with respect to the ordinary laser is that the ions does not drop from a higher to a lower energy state of an atom but from a smaller to a larger space-time sheet. The many-sheeted laser could make possible for a body and/or brains to amplify the incoming ITC signal represented by high frequency MEs propagating along low frequency MEs generating the entanglement.

11.5.6   Could stochastic resonance be involved with ITC?

EVP research support the view that certain background noise is necessary for receiving messages. Skeptic would of course argue that the noise provides the source from which brain as a builder of familiar patterns constructs the signal. On basis of this observation it has been however proposed that stochastic resonance (the article [45] is an excellent review about the principles and applications of the stochastic resonance) is the mechanism of EVP. Stochastic resonance requires a bistable system (for instance, double potential well) or an excitable system having metastable states. An essentially nonlinear phenomenon is in question.

Stochastic resonance

Stochastic resonance works if the message to be amplified is represented as an amplitude modulation of a carrier wave with a basic frequency f and serves as a harmonic perturbation of a bistable system which is also subject to white noise. In the resonance, f must be one half of the average frequency $f(spont)$ for the jumps between two states of the bistable system: $f = f(spont)/2$. This condition has a simple physical interpretation: the height of the potential barrier separating the two potential wells varies periodically with a period which is half of the period defined by f, and the best opportunity to

get to another potential well is to hop when the potential barrier is lowest possible. For the mechanical analog system the rate $f(spont) = r_0 A$ is proportional to an 'Arrhenius factor' $A = exp(-\Delta V/D)$, where ΔV is the height of the potential barrier and D characterizes the intensity of the white noise. $f(spont)$ is also proportional to a factor $r_0 = \omega\omega_b/\gamma$ where ω is the frequency of small oscillations at either bottom of the symmetric potential well, ω_b is the analogous quantity at the top of barrier, and γ characterizes the linear dissipative force (overcritial damping is assumed).

Thus, when the white noise has a correct intensity, a weak harmonic perturbation with a given frequency is amplified in the sense that the Fourier expansion of the system's time development regarded as jumps between the two states contains a peak at the multiples of the frequency of the amplitude modulated harmonic perturbation. Neuroscientists refer to this phenomenon as a phase locking. The peaks for the higher multiples of the input frequency f are exponentially suppressed. The notion of stochastic resonance makes sense also in the quantum context: now quantum tunneling replaces the jumps induced by the stochastic noise.

Stochastic resonance and brain

There is a considerable empirical support for the hypothesis that stochastic resonance is responsible for both the so called temporal coding of the sensory inputs to neurons (see the references in [45, 46]) and for the ability of the brain to extract very weak signals from a noisy bacground. For instance, crickets seem to detect the signals caused by their predators from a strong background noise using this mechanism. More generally, stochastic resonance is a very attractive candidate for a quantum level neuronal mechanism for amplifying very weak EEG waves to a firing pattern in turn amplifying the original EEG waves amplified again by the stochastic resonance... citeeegII. Amplification of em fields associated with ELF MEs is analogous to physical growth would be basically in question and p-adic MEs (memes) could use any means to achieve this. The development of individual indeed involves the gradual emergence of higher frequency ELF waves above the delta band background.

Stochastic resonance and people seeing elves and auras

It is interesting to apply the stochastic resonance model also to other experiences usually believed to be hallucinatory and purely brain generated. Some of us claim to have the ability to see elves and auras, and an interesting question is whether one could artificially induce this kind of ability by tuning the noise level of the visual perceptive field suitably. My own strange and often frightening OBE type experiences induced by the noise of refrigerator or central heating batteries could be partially understood in terms of stochastic resonance. From the visual hallucinations during my great experience I remember the strange conviction that this what I see is always present in the visual field and that I have in some strange manner only become conscious about its presence, much in the same manner as one suddenly becomes conscious of a well-defined pattern in the autostereogram containing only what looks random points.

A stochastic resonance created by the brain itself and making possible the perception of an already existing weak visual input would conform with this interpretation. The same general explanation might apply as such to the case of EMDR experiences: the EMDR method could optimize the level of the background visual noise making possible to amplify weak signals always present in the visual and other perceptive fields. Finally, the claimed encounters with the deceased induced by the presence of a medium could also be explained by the ability of medium to induce a situation in which an actual weak visual signal is amplified to a conscious perception.

It is easy to guess the reaction of a skeptic to these unconventional interpretations, and it might well be that pattern completion indeed generates information which it is not actually present originally. It is however good to remember that until quite recently the dominating theory about dreams was that cortex does its best to cook up something from a random input coming from the brain stem. For a non-skeptic person with some spiritual traits and taking his/her dreams as an essential part of the personal subjective existence this kind of interpretation seems highly absurd and even humiliating. The revision of this view has been forced by the accumulating knowledge supporting the view that dreaming is a cognitive ability learned before the age of eight, and also by the observation that dreaming as a virtual world life has an obvious survival value. Continuining in spirit of this section, one might even see the role of brain stem as a producer of the background noise making possible the

amplification of the weak signals from the higher levels of the self hierarchy to dreams (at least in some cases).

$1/f$ noise amplifying itself via white noise?

What are the physical correlates of the MEs representing memes and being perhaps amplified by both brain and by the electronic instruments in ITC? Besides white noise there is also $1/f$ noise encountered practically everywhere [42]. The origin of the $1/f$ noise is poorly understood. In TGD framework $1/f$ noise could be seen as a signature of real mindlike space-time sheets (giving rise to sensory qualia). $1/f$ noise is a good candidate for the physical correlate for the real counterparts of memes realized as MEs with the information represented by an amplitude modulated carrier wave. Also EEG could be seen as resulting from the amplification of $1/f$ noise (delta band for EEG resembles the spectrum of the so called spherics [49]). The real counterparts of these opportunistic memes would correspond to amplitude modulated ELF waves using all possible means of self expression and using also stochastic resonance mechanism to amplify remote mental interactions (this brings in mind the mysterious sea in the scifi novel 'Solaris' of Stanislaw Lem!).

Stochastic resonance and ITC

An important question is how the message is amplified and filtered from the background noise possibly present. A possible answer to this question is stochastic resonance. Stochastic resonance could occur in the receiving instrument and/or in the brain of the receiver. ITC, in particular EVP research indeed supports the view that certain background noise is necessary for receiving messages. On basis of this observation it has been proposed that stochastic resonance (the article [45] is an excellent review about the principles and applications of the stochastic resonance) is the mechanism of EVP.

Stochastic resonance requires a bistable system (for instance, double potential well) or an excitable system having metastable states. An essentially non-linear phenomenon is in question. Signal is in a role of the harmonic external force: the output of the bistable system is interpreted as a transformed signal. If one takes seriously the claim about the positive effects of the white noise on tape recordings, bistable system must reside either in the electronic system transforming sound signal to an electric signal or in the brain of the experimenter serving as a relay station between the sender and electronic instrument in the proposed model.

TGD Universe is quantum spin glass which means that any system should be characterized by fractal spin glass energy landscape containing valleys (energy minima) inside valleys inside... This of course means that there is plenty of bistable systems. TGD also predicts new kinds of dynamical degrees of freedom not predicted by standard physics, so called zero modes, which typically characterize the shape and size of 3-surface and also so called Kähler field (essentially Maxwell type field) of space-time surface. These new degrees of freedom could provide the required new degrees of freedom possibly making also the relevant parts of electronic instruments bistable systems.

1. Does the brain of the receiver contain the bistable systems?

Skeptic would argue that the noise used to promote the receival of the messages is what cheats the brain of the poor pseudoscientist to recognize a feature which is not actually present in the incoming signal. The skeptic might be quite right although after listening the some of recordings I have a tendency to believe that there are actual messages there. One could however turn around the argument of skeptic. Perhaps it is indeed the brain of the experimenter where the bistable system resides and amplifies the very weak signal from the sender and sends it to the electronic instrument in electronic form. Stochastic resonance in experimenter's brain would be involved also with the receival of the feedback signals from the instrument by the sender of the message. This model has several satisfactory features.

1. The model is consistent with the latest facts about brain science [45, 46]. The model is also universal in the sense that if does not require discarnate entities to be ingenious electric engineers: they can learn by trial and error how to generate desired messages by affecting the electronic instrument.

2. The model would explain why some experimenters are better than the others in receiving messages. They are like crickets able to distinguish very weak input from the high noise. If feedback

from experimenter's brain to the sender is involved this in turn helps the sender to learn to generate desired messages. The model is also consistent with the fact that the highly tuned system which works perfectly for a particular experimenter, does not work for the other experimenters. Note that the magnetic mirror bridges between experimenter and electronic instrument are essential part of the system.

The hypothesis could be tested by purposefully building EVP and ITC instruments for which the background noise can be varied.

2. Do electronic systems contain bistable systems?

The hypothesis that the electronic system contains the bistable system is subject to so strong additional constraints that it does not look too plausible in standard physics framework. If the leakage of ionic currents from the magnetic flux tubes to the wires of the electronic induced by MEs gives rise to the electronic signal, stochastic resonance is perhaps not needed since the background noise is very weak. It must be however emphasized that many-many-sheeted space-time plus spin glass degeneracy might provide new physics mechanisms of transforming the ITC signal to electronic signal.

The very fact that the electronic information transfer systems should not induce large distortions of the signal, requires that the system is effectively linear. Bistable systems are highly non-linear systems unless the signal fed into the system represents sufficiently strong external force in which case system is analogous to a one-dimensional particle in an external harmonic force: archetypal model is the potential well $V(x) = -x^2 + x^4$. In case of magnetic tape the direction of magnetization would naturally represent the two potential wells and hopping of the particle between wells would correspond to the changing direction of magnetization. Thus, if bistable systems are involved, ordinary signals must represent strong external forces for which the system is effectively linear and non-linearity can be important only for very weak signals. In case of EVP this requires that possible messages should be contained by the portions of the magnetic tape, where ordinary signal is reduced to mere noise and the noise is sufficiently weak. Already this requirement might kill the hypothesis.

To test this option, one should find whether the electronic system transforming the sound to electric current contains portions modellable as bistable systems fed by an external signal for sufficiently weak input signals. If this is the case, then model could be tested by varying the intensity of the external noise to see whether this has any effect on the probability of receiving the messages.

11.5.7   How the signal is transformed to a signal in electronic instrument

One should also understand how the transformation of the ITC signal to the signal appearing in electronic instrument such as tape recorder, telephone, or radio receiver occurs.

Direct radio signal

The simplest situation is direct radio signal. It is known that the voices tend to appear in the silent portions of radio signal containing only noise. This is of course natural since in this manner the masking of the signal can be avoided and might allow also stochastic resonance. If the sender or magnetospheric multi-brained conscious entity has managed to code the signal to AM or FM radiowave, and if the brain or body of the experimenter has managed to amplify it and redirect it to the instrument, then the transformation to an audible signal is not a problem.

"Paranormal" signal to a magnetic tape

The first possibility is that primary messages appear as ME having a Fourier decomposition resembling sufficiently that of the sound wave, and giving rise to the required vibrations of atoms. MEs are the basic candidates for the carriers of these waves and the Fourier spectrum of the voice with respect to frequency could be coded into the Fourier spectrum of em or Z^0 fields associated with ME. Hence ELF frequency range would be in question. Phase information is crucial: anyone can easily verify that a reversed speech usually consists of a gibberish despite the fact that the Fourier spectra are same for speech and reverse speech. This suggests an amplitude modulation of the carrier wave or fast amplitude modulation producing ripples to the carrier wave as a candidate for the representation of the information contained by ME.

The sound frequency range involved with the sounds heard by humans is in the interval $20 - 20.000$ Hz meaning the lengths of ME would vary between Earth radius and 10 kilometers. This spectrum is also claimed to be important for water memory and the mechanism of homeopathy [60].

A concrete model for the process might look like following.

1. The signal is first transformed to an electric current, which subsequently induces a shortlasting magnetization of a soft electromagnet which in turn induces a permanent local magnetization of hard ferromagnet (magnetic tape). The strength and sign of the local magnetization depends on the strength of the current which in turn codes the strength of the sound signal. A similar transformation to an electric current occurs also for the signal in case of visual ITC.

2. A concrete manner to generate the electric current inducing the magnetization would be by inducing a leakage of a supra current from magnetic flux tubes to the atomic space-time sheets of the current wire responsible for the magnetization of the soft electro-magnet. This leakage could be induced by microwaves by a mechanism discussed in [20]. The modulation of the microwave by sound wave would imply the modulation of the current automatically. An analogous mechanism could be at work for the radio receiver.

Transformation of em signal to sound signal before entering the tape recorder

Classical EVP suggests that the basic signal enters to the magnetic tape as an electric signal. On the other hand, the experimental results reported by Alec MacRae [71] are consistent with the assumption that real sounds generate the signal and that electromagnetic signal does not generate a signal in the microphone. The latter conclusion comes from the observation that Faraday cage around microphone does not affect the communication. In TGD framework this conclusion cannot be made since Faraday cage is not expected to affect MEs. The acoustic insulation of another microphone however weakens the voice so that it seems that a genuine acoustic signalling is in question. This does not of course imply that the generation of real sounds is the only mechanism: in the presence of feedback the best communication mode available could be used.

TGD based model for the real sounds generated by meteors heard both directly and recorded by microphones is based on electromagnetic signals coming along magnetic mirrors associated with the sensory magnetic canvas and acting as wave guides and transformed to ordinary sounds via the coupling with objects at the surface of Earth. Whatever the details of em signal-sound transformation are, it certainly exists, and could be involved also now: the electromagnetic signal could come either from the magnetic sensory canvas of the experimenter, of the sender, or from the magnetosphere containing the multi-brained self serving as a relay station. Higher harmonics of the frequencies 37-43 Hz appearing in case of meteors [48] would be however required to generate the voices or shorter magnetic mirrors should be involved.

One can imagine several mechanisms for the transformation of the primary signal to sounds.

1. The mechanism transforming electromagnetic signal to sound wave could rely on piezo-electricity and frequency resonance. Quartz crystals are excellent piezo-electrets and used in radio receivers and senders. Also body acts as a piezo-electret and the body of the experimenter could transform the signal to sound. Human body could act also as a Z^0-piezo-electric transforming the Z^0 signal to an ordinary sound. The so called oto-acoustic sounds (audible sounds emanating from ears) could result in the same manner. Also material objects of the acoustic environment could serve the same purpose.

2. The phenomenon of microwave hearing suggests that brain and/or body could also transform microwave signals propagating along ELF ME to ordinary sounds.

11.5.8 Tests for the model of ITC

Most tests of the ITC reduce to tests for the general mechanism of remote mental interactions, which should be also at work in length scales below body size (bio-telepathy) and for sensory representations realized at the magnetic body. This is good news in the sense that good models usually explain many apparently unrelated phenomena and bad news in the sense that predictions are not ITC specific.

  1. Tests for the motion of electromagnetic bridges.

1. Since the development of the magnetic mirror bridges between experimenter and electronic instrument takes time, the replacement of the magnetic tape in EVP with identical one, might make the performance poorer.

2. One could test the importance of the magnetic flux tubes by varying the strength of the local magnetic field (note that magnetic tape has a natural coupling to the magnetic flux tube structures of Earth's magnetic field) to see whether Earth's magnetic field plays a role in the effect. One could test whether the appearance of ITC messages and perturbations of magnetic field appearing at Schumann frequencies correlate. The correlations of paranormal phenomena with sunspot activity are well-known and could be tested in case of ITC.

3. Maxwell's electrodynamics, which is not equivalent with TGD, would suggest that MEs cannot penetrate Faraday's cage so that ITC would not be possible inside Faraday cage. In many-sheeted space-time this argument is lost because MEs by definition are em bridges outside the atomic space-time sheets where the Faraday cage acts. If MEs cannot penetrate Faraday cage, the TGD based model for sensory representations would fall down since it would predict that person in ideal Faraday cage could not have sensory experiences! Be as it may, one can test this aspect by putting the experimenter and/or the instrument in Faraday cage.

4. One should also test directly whether body and brain act as laser like amplifiers of em radiation at, say, audible frequencies. The work of Gariaev [41] shows that irradiation of DNA with visible light produces radiowaves also at audible frequencies. The work of Blacman and others [75] shows that the irradiation with ELF waves at EEG frequency range induces biological effects.

2. Tests for the ionic leakage mechanism. For instance, the appearance of ions not originally in the system by the leakage of the supra currents and the dissipative effects caused by the leakage would be a good signature for the effect. These tests are discussed in [20]. In the recent case one such system would the current wire inducing the magnetization of the magnetic tape.

3. Tests for the ideas about the communication method.

1. In remote healing the changes of alpha waves in EEG are reported to correlate with the intentions communicated by the healer. Alpha waves dominate when sensory input is absent, in particular the closing of eyes stimulates alpha waves. This is consistent with the fact that EVP requires silent and dark room. A possible test would be to record the EEG of the experimenter and look whether there is a clear change in the activity in alpha band both when the tape is on and when the tape is listened to and find whether there are recognizable changes of alpha activity. In particular, one could see whether alpha activity changes at the time when the message appears to the magnetic tape. The lowest Schumann frequency 7.8 Hz is especially interesting in this respect. On basis of the experiments of Mark Germine, also the 11 Hz frequency is interesting [94].

2. The sounds detected from meteors [48] are in the thalamocortical 37-44 Hz frequency band [18] suggesting that magnetic sensory canvas mediates ELF perturbations to both brains and to electronic instruments at this frequency range. One could in principle test whether thalamo-cortical resonance band in the EEG of the experimenter contains something correlating with the received message.

3. Are persons able to receive the ITC messages also able to hear microwaves.

4. Are the sounds in EVP are received electronically or acoustically. Both mechanisms might be involved. Alec MacRae has demonstrated and in his experiments signal is received as a sound [71]. One could also test whether the pitch of the sound correlates with the acoustic environment (big room–small room).

5. One could test the role of the stochastic resonance by varying the level of the acoustic or radio noise. Here explicit formulas for the noise optimal for a signal of given frequency are available [45].

4. Tests for the notion of magnetospheric selves.

The notion of magnetospheric selves might be crucial for the solution of the knowhow problem and the experiments of Mark Germine [94] can be seen as a pioneer work in the testing of this hypothesis.

5. Tests for the notion of history editing. History editing is not necessary for understanding of ITC but one could test whether it is involved. Let an outsider, presumably not able to act as a relay station, listen to the magnetic tape first and document whether he/she received any message. Suppose that he/she detects no recognizable message. Next let the experimenter listen the same tape, and report what he/she found: during this session the feedback mechanism could transform the message to a recognizable form by affecting the geometric past at the moment the magnetic tape was on. Suppose that the experimenter indeed recognizes a message. Let an outsider listen the tape again to see whether there is any recognizable message now. If the proposed mechanism is correct, the outsider who did not hear any message in the first trial, should hear now a clear message. Note that one cannot replace external person with a computer since the computer records change in quantum jumps too! Note also that even the geometric memories of the external person might change if they are comparable to mechanical records: genuine subjective memories are required. Also the repeated listening of the tape by the experimenter could improve the quality of the message and the above experimental arrangement could be iterated.

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Chapter 12

TGD Based Model for OBEs

12.1 Introduction

Out-of-body experiences (OBEs) [52, 55, 47, 51] are often understood as experience of seeing oneself from a position outside of the body. According to Susan Blackmore [47], OBEs are rather common: from 5 to 35 percent of subjects reports of having had at least one OBE. According to studies persons having OBEs seem to be perfectly healthy. OBEs are poorly understood in the framework of neuro science and pose a challenge for the reductionistic world view.

In TGD framework the notion of magnetic body provides an attractive starting point in attempts to understand what OBEs and related experiences are. The basic idea is that magnetic body serves effectively as a mirror defining a third person view as a cognitive representation also in ordinary wake-up state and that during OBEs this representation becomes sensory representation. Magnetic body need not always be a personal magnetic body but could correspond to a magnetic body receiving information from several brains (collective consciousness), magnetic body of another person, or be even associated with "dead" matter.

The progress in identifying dark matter as a phase of matter with large value of Planck constant making possible macroscopic quantum coherence has led to the vision about dark matter at magnetic flux quanta as quantum controller of ordinary matter in living systems. The Bose-Einstein condensates of dark photons decaying via decoherence to ordinary photons mediate interactions between ordinary and dark matter and the hypothesis is that dark photon "laser" beams from body and brain reflected at magnetic flux quanta give rise to third person aspect of consciousness which in OBEs and related experiences are realized as sensory representations. The identification of bio-photons as end products of the de-coherence of dark photon beams is natural.

Zero energy ontology and the notion of causal diamond (or CD defined roughly as the intersection of future and past directed lightcones) brings additional quantitative ingredients to the model. Sub-CDs define imbedding space ($M^4 \times CP_2$) correlates for selves and by holography the 2-D partonic 2-surfaces at the light-like future and past boundaries of CDs are the ultimate space-time correlates for mental images. The moduli space for CDs makes possible a more detailed view about sensory representations discussed in the chapter "Quantum Model for Sensory Representations" [32].

A further new element is the vision about life as something in the intersection of real and p-adic worlds. The most important outcome is that the notion of number theoretic entanglement negentropy making sense in this situation is positive so that entanglement carries conscious information. The fusion of selves (in particular mental image) by negentropic entanglement is experienced as expansion of consciousness. It is negentropic entanglement between parts of biological body and corresponding parts of the magnetic body and biological body which makes living system living. This negentropic entanglement between magnetic body and biological body is important also for OBEs.

The model leads also to a model for dreams, hallucinations, sensory feedback from brain to sensory organs, and directed attention. Concrete models for how dark photons can give rise to experiences in various sensory modalities such as vision, hearing, olfaction, and tactile senses, are proposed.

I am grateful for Tiaan Brink for sending a little summary about OBEs. This article inspired the attempt to fuse the TGD inspired ideas related to OBEs to a coherent theory.

12.2   OBEs, autoscopy, heautoscopy, and other strange experiences

12.2.1   Phenomenological characterization

The phenomenological characterization of OBEs [49] has been discussed in [51]. A precise definition of OBE is to have sensation of being outside the body. Autoscopic experience involves a also a sensation of seeing a mirror double of the body or part of it or at least experiencing its presence. There is a form of AS in which some internal organs are perceived. In one form form of AS only the presence of double is experienced. AS experiences are often accompanied by physical difficulties such as migraine episodes and epilepsy.

Heautoscopy refers to an experience of meeting one's alter ego, doppelganger. The main differences to AS is that in AS the double is mirror image and that alter ego is experienced to have also duplicated features of psychological self.

OBEs are classified to parasomatic and asomatic experiences according to whether the person experiences of having body or not. In aparasomatic experience a detachment from both the physical and parasomatic body is experienced. Blackmore suggest that OBE starts when sensory input from the body ceases while person remains conscious [47]. This brings in mind the notion of subtle body of spiritual practices identified as the body experienced during lucid dreaming [43]. The notions of guardian angle and ba-ka double of ancient Egypt, could relate to the double body too.

There is also a classification of OBEs to asensory, naturalistic and supernaturalistic ones. Asensory experience lacks sensory percepts about environment, naturalistic one involves perception of familiar surroundings, and supernaturalistic other-worldly realms like heaven or visits to other planets and contacts with aliens.

One can distinguish between natural and enforced OBEs. Natural OBEs are triggered by exhaustion, illness, traumatic events, NDEs, meditation, etc.. Enforced experiences can result from intoxication, anesthesia, hypnosis, etc..

12.2.2   OBEs induced by electric stimulation

Relatively recently OBEs and AS experiences have been produced by an electric stimulation of the angular gyrus [53]. Angular gurus is located in the parietal lobe, near the superior edge of the temporal lobe, and is involved in processes related to verbal communication and cognition and also with the transformation of written language to internal monologue. The experience developed to a full fledged OBE as the intensity of electric stimulation was increased. The electric stimulation induced responses in vestibular and sensory-motor systems, two of three systems which govern body balance.

According to experimenters, OBE and AS frequently involves what they call pathological sensations of position, movement and perceived completeness of one's own body. These include vestibular sensations such as floating, flying, elevation and rotation, visual body-part illusions (illusory shortening, transformation or movement of an extremity) and the experiences of seeing one's body only partially during OBE or AS. Authors believe that these experiments yield neurological evidence about the common neurological mechanism behind OBEs and AS experiences.

Neppe [50] has criticized the interpretation of experiments.

1. Only single subject person was studied. She suffered from temporal lobe epilepsy and the epileptic region was at distance of about 2 cm from angular gyrus. Hence one can ask whether genuine OBEs were in question and whether the results generalize to healthy persons.

2. The OBE was not typical. For instance, body was seen only partially and the conscious attempt of the subject person to examine it more closely led to its disappearance. The environment was not perceived.

3. The claimed localization of the spot inducing OBEs to angular gyrus might be an illusion. Same researchers have represented results in which the OBE is induced in a different manner. Interestingly, the experience is associated with the generation of 4 Hz theta wave, which corresponds to the dominating EEG band during sleep.

4. The reductionistic conclusion that OBEs can be reduced to neuropathology and are thus "only" hallucinations is not justified. What has been shown is that electric stimulation of angular gyrus helps to induce the OBE and this leaves a lot of room for theorizing.

12.2.3 Explanations of OBEs and related experiences

The explanations for OBEs can be divided to two classes.

1. Something is assumed to leave the body.
This something could be something physical or non-physical ("astral"). In some cases people who have had OBE share reported of having perceived objects that were actually there and having experienced events and dialogue that truly happened. Charles Tart has documented the case of Miss Z [55] who in controlled experiments was able to deliver the randomly selected five digit number which was in a position which could be seen only from the position out of her body. Telepathy would be an alternative explanation for this.

2. Nothing leaves the body.
Parapsychological explanations involve remote sensing and hallucinations. Psychological explanations regard OBEs as basically hallucinations. The observation that electrical stimulation generates both AS and OBE could be seen as a support for this interpretation. Of course, one can ask what hallucinations really are. Furthermore, the reports about seeing internal organs during AS experience [56] are not easily explainable as hallucinations.

TGD based model does not fit into either category. The model involves the notion of magnetic body serving as the third person receiving visual stimulus from the body and reflecting it back to the brain where its is processed. In this model the conflict between hallucinatory character of AS and OBEs and a real perception of body from outside is only apparent. The basic mechanism allows to develop also a more detailed model for dreams, hallucinations, third person aspect of wake-up consciousness, and directed attention.

12.3 TGD inspired model for OBEs and related experiences

It is good to develop the model for OBEs by first listing the basic TGD specific ingredients of the model and then proceed by making questions (I hope that reader does not feel them to be leading).

12.3.1 Basic ingredients of the TGD inspired model

The model of OBEs involves several ingredients that are specific to TGD.

1. Magnetic bodies and field bodies are excellent candidates for the "third person" seeing the ordinary body. Magnetic body could receive a visual stimulus from ordinary body and reflect it back as a visual stimulus during OBE processed by the brain of the subject person. Thus body would see itself from the perspective of the magnetic body. Also dreams and hallucinations might involve the same mechanism. In the case of hearing sounds created by subject person could be reflected back to her ears or more plausibly, microwave hearing [38] could be involved.

2. Topological light rays ("massless extremals", MEs) are an element of TGD having no counterpart in Maxwell's ED and play a key role in TGD inspired theory of consciousness. The interpretation of MEs has remained somewhat obscure. The development of TGD based model for dark matter residing at magnetic flux tubes and characterized by large value of Planck constant implying quantum coherence in even macroscopic length and time scales changed the situation in this respect. The model for dark matter as macroscopically quantum coherent phase is discussed briefly in this book in chapter [31] and more extensively in the book "Genes, Memes, Qualia, and Semitrance" [16]. MEs can be identified as space-time correlates of Bose-Einstein condensates ("laser beams") of dark photons. It is however still unclear whether ordinary laser beams actually correspond to dark photon Bose-Einstein condensates and become visible only in de-coherence to ordinary photons. Negative energy MEs can be identified as correlates for phase conjugate laser beams of dark photons. The so called time mirror mechanism is universal building block of basic biological and brain functions [25].

3. Bio-systems as conscious holograms is one of the key ideas of TGD approach [33]. Bio-holograms [36] suggest themselves as primary sensory stimuli quite generally. Biological body could generate dark photon "laser beams" received by magnetic bodies and reflected back to retina or perhaps to pineal gland [46], the "third eye". This would explain AS as well as the images of internal organs [56]. Also other systems, at least living systems, could be seen from the perspective of the magnetic body. Remote vision hypothesis testable by using living targets not visible in ordinary sense. This would give also rise to telepathy if reflection occurs from magnetic bodies of another person.

4. In TGD framework sensory organs are identified as seats of primary sensory experience and brain only constructs symbolic representations about percept, in particular identifies objects of perceptive field. This does not exclude a considerable back projection to sensory organs modifying the sensory input. Dreaming involves back projection to sensory organs inducing artificial sensory experiences as simulation. One possibility is that dreams and hallucinations represent direct back projection to sensory organs along neural pathways. An alternative view is that the projection involves dark photon beams generated by brain and reflected back from the magnetic body. If OBEs are hallucinations, the visual sensory memories of the subject person about herself could serve as building blocks to generate simulation about what person looks like when seen from outside.

5. Sharing and fusion of mental images is one of the basic notions of TGD inspired theory of consciousness [25, 33]. One can ask whether OBE involves sharing of the visual experience of other persons involved about subject person. If this were the case, the presence of other persons would be necessary to have OBE. Sharing of mental images would explain the case of Miss Z as telepathy.

12.3.2   Questions

In the following the model is developed by posing questions about OBEs.

Where the information processing giving meaning to what is seen is carried out?

Seeing is much more than just receiving the photons on retina, since a lot of information processing is needed to give meaning to what is seen. This essentially involves a decomposition of visual input to recognized objets having relations to each other and to the past of perceiver. This applies also to the visual percepts during OBEs. The most natural candidate for the system processing the visual stimulus and giving it meaning is the brain of the subject person.

Sharing of mental images allows to consider an alternative interpretation based on telepathy. The sensory organs in other bodies receive the visual stimulus and and other brains do the information processing. For instance, "unconscious" victim of accident could share the fused mental images of people around the place of accident. This would explain the case of Miss Z studied by Tart [55] as telepathy.

Are OBEs "only" hallucinations?

In TGD framework the first possibility is that the sensory stimulus is always artificial and comes from brain to eyes and other sensory organs by back projection. OBE would be a dream like cognitive representation, simulation rather than a real percept. REM is expected to always accompany OBEs in this case.

There is an objection against this idea. If person is unconscious or has NDE, it is questionable whether she is able to construct such high level cognitive representation as the representation of the state of her own body as seen by outsider is, and even transform it to a sensory representation. One can also ask what hallucinations really are. In TGD framework hallucinations must be generated by an artificial sensory stimulus so that hallucinations and genuine OBEs might involve the same basic mechanism.

Does OBE originate from an actual sensory stimulus?

The well-known fact that body parts indeed contain holograms about other body parts [36] (see the discussion in [20]) and the TGD view about the relationship between dark and living matter [16] allows to consider seriously the possibility that OBE originates from an actual sensory stimulus.

The dark photon laser beams emanating from the body would be received by a magnetic body containing dark matter at some level in the hierarchy of magnetic bodies and would be reflected back to the receiving sensory organs along MEs possibly parallel to magnetic flux tubes rather than space-time sheets along which ordinary visual input arrives.

It is quite possible that several magnetic bodies in the hierarchy are involved. The magnetic bodies involved need not always correspond to a personal magnetic body and could receive input from several biological bodies and remote vision and telepathy might involve signals from brain reflected to a second brain via multi-brainy magnetic body. Magnetic bodies could be associated also with "dead" matter.

In this picture the case of Miss Z could be understood in two alternative manners. A dark photon beam possibly created by the visual representation of the random number (does "dead" matter generate sufficiently intense beams of this kind?) and reflected by personal magnetic body could be in question. Alternatively, the magnetic body involved could receive the information about random number from the brain of the experimenter and reflect it to the brain of the subject person.

Why does electrical stimulation induce OBEs?

Electrical stimulation of angular gyrus induces OBEs just as the stimulation of neurons of temporal lobe induces long term sensory memories. In neurological "brain only" approach the interpretation would be that the responses in the vestibular and somatosensory system induce the AS and OBE as hallucinations. In TGD framework the response in vestibular and somatosensory system would be interpreted as a response to an actual experience of being in a detached position and orientation, and brain would processes genuine sensory data about being in detached position.

One might think that the temporal ordering between the experiences and these responses would allow to decide which causes what. In TGD framework negative energy signals propagating backwards in the geometric time are however a basic element of brain functioning and this criterion need not be apply.

One imagine two mechanism generating OBEs.

1. The mechanism inducing visual OBE and related experiences could simply turn off the ordinary sensory input so that only the dark photon beams from the magnetic body and reflected back from biological body would contribute to the visual stimulus. This would occur automatically during dreams and NDE experiences.

2. The sensory input from the magnetic body could be amplified. Time mirror mechanism could be responsible for this amplification [25]. During epilepsy strong electric fields generated by brain during epilepsy induce starvation of neurons and the electrical stimulation of angular gyrus could have the same effect. Starving neurons would generate a beam of phase conjugate (negative energy) dark photons received by magnetic body in order to get metabolic energy. The magnetic body would be in a state analogous to a population inverted (possibly many-sheeted) laser defining a hologram like representation of the body. The receival of negative energy photons would induce a cascade like induced return to the ground state and amplify the dark photon beam arriving from magnetic body so that it would not be masked by the ordinary visual input anymore and would give rise to a percept.

12.3.3 A more detail model for OBEs

In the following a more detailed model for various aspects of OBEs is developed.

Do bio-photons result from the de-coherence of dark photon beams?

Bio-holography provides support for the body as a hologram (more precisely, dark photon hologram). For instance, an electric stimulation of ear during Kirlian imaging of a finger tip creates a Kirlian

photo from which it is possible to abstract a hologram of ear [36] (for a TGD based model see [33, 20]). This suggests that body parts can in some sense "see" each other. In particular, brain can "see" body parts (note that bacteria possess a primitive IR vision based on micro-tubules): this of course need not correspond to a conscious vision at our level of self hierarchy.

The biological function of bio-photons [42] is poorly understood, and they are an excellent candidate for ordinary photons resulting when dark photon beam de-coheres. TGD based model of bio-photons can be found in [28] and the identification as dark photons is discussed in [16]. The findings of Peter Gariaev about the effects of visible laser light on DNA [41] and so called phantom DNA effect [40] provide a further support for the biological importance of biophotons (see the discussions in [28, 16]).

What is the mechanism of out-of-body hearing?

Mechanism could be even more general and work also in the case of other qualia. In particular, hearing might involve similar reflection of sound waves at larger space-time sheets from the magnetic body and heard as "other-worldly" sounds.

A more plausible option is that the auditory sensation is generated by dark microwave photons reflected back from magnetic body. Microwave hearing [38] is indeed a well-known but poorly understood phenomenon and the generation of microwaves by plants after sunset correlates also with taos hum [35] (see the discussion in [23]) which does not generate any response in microphones but reflects the features of the acoustic environment.

The auditory and visual hallucinations of schizophrenic persons would represent in this framework a genuine sensory input. The notion of bicameral mind introduced by Jaynes [57] discussed in TGD framework in [30] would fit also nicely with this picture. The "god" controlling the behavior of bicameral by giving explicit commands would correspond to some magnetic body, not necessarily that of the subject person, but a magnetic body receiving input from several brains in the social group and representing collective consciousness.

Where are the sensory receptors giving rise to the primary sensory experience?

The simplest guess is that the visual stimulus from the magnetic body is received by eyes. The fact that REM accompanies visual dreaming supports this view in the case of dreams. The receiving sensory organ could be also pineal gland [19, 18], "third eye", the seat of the soul according to Descartes [46]. Pineal gland is known to contain retinal pigments and its counterpart in more primitive animals is known to function as a genuine eye. A simple test in the case of artificial OBEs is to look whether the electric stimulation of OBEs generates also REM.

If OBE hearing is indeed microwave hearing, the identification of the primary sensory receptors is not obvious, although their existence cannot be denied.

The insect olfaction relies on infrared light as discovered by Callahan [39] (see the discussion in [24]). One might therefore wonder whether also humans possess olfactory receptors sensitive to IR light, and whether the emission of dark IR photons reflected from magnetic body could play some role in olfaction and in the generation of olfactory hallucinations. One can even ask, whether the molecular recognition mechanism underlying chemical senses relies on IR light. It is known that human nose contains so called vomeronasal organ [45] sensitive to odors having sexual or social meaning but that these odors do not give rise to a conscious experience.

It is known that blind persons can learn to "see" when their skin is stimulated by electromagnetic fields representing the environment. Perhaps dark photon beams could induce also tactile sensations. Quite generally, the earlier proposal that information in all sensory modalities can be transformed to field patterns represented by MEs could sharpen to the hypothesis that the information in various sensory modalities allows a representation as dark photon beams inducing corresponding sensory qualia in the interaction with appropriate sensory receptors.

What is the mechanism causing the kinesthetic sensations during OBEs?

The model should also explain sensations of lifting, flying experiences, and the experiences of being in translational or rotational motion. The motion of the magnetic body with respect to the physical body should induce this kind of sensations. The basic idea is simple: generalize the mechanism allowing to hear the motion of a sound source. Generalizing from sound waves to dark photon beams, the sensation

in question would be basically due to the Doppler shift of the dark photon beams travelling between biological body and the moving magnetic body. The change of the dynamical hologram resulting in the interference of a bodily reference beam and Doppler shifted reflected beam in quantum jumps could be responsible for the sensation.

This model could also resolve an objection against the hypothesis that sensory receptors experience the primary qualia. The objection is based on train illusion. When you sit on a train and look at second train which starts to move, you can have an illusion that it is your train that moves. The illusion is not a mere belief but involves a sensation of acceleration in the entire body. There are two options.

1. The sensation is a response to various bodily activities induced by the belief of being in an accelerated motion.

2. The sensation is caused by a primary sensory input induced by the acceleration. This sensory input must be produced artificially in the case of train illusion.

Consider first a genuine accelerated motion of the biological body. One could argue that in absence of visual, auditory or other sensory information about being in accelerated motion, there is no belief about being in accelerated motion so that acceleration is not perceived at all for option a). This makes option a) implausible. For option b) the acceleration of the biological body with respect to the object defining the rest system is directly perceived. The Doppler shift of the dark photon beams radiated from biological body and reflected back from the rest system would induce the sensation. Reflection could occur either from the rest system or a magnetic body associated with it.

One can imagine two mechanisms creating an illusory acceleration for option b).

1. If the fixation of the attention to the moving train means the presence of dark photon laser beams connecting biological body and train or a magnetic body associated with it, the Doppler shift of dark photon beams could induce the sensation of acceleration.

2. Directed attention could cause a personal magnetic body to mimic the motion of train so that the relevant part of it deforms in the direction of moving train to keep the distance to the moving train fixed. This would induce train illusion by the same mechanism as in case 1).

For both mechanisms the reflection of dark photon beams becomes the fundamental mechanism of directed attention. Attention would mean a formation very concrete bonds between subject and object or a representation of object at the personal magnetic body: the rays connecting the eyes of cartoon characters would represent a very profound idea about consciousness. Both views about attention mean a clear-cut deviation from the prevailing neuro-scientific thinking according to which the experienced world is virtual and completely detached from the real world.

Cliff illusion might be an appropriate name for the disgusting feeling in stomach which one feels on the brink of a precipice. Sensory imagination about falling down is in question and could be induced by the deformation of the personal magnetic body such that it mimics free fall.

The floating sensations and strange deformations of personal body during OBEs could also correspond to the deformation dynamics of the magnetic body which could be also caused by external influences. If the size of the magnetic body is measured using Earth radius as a natural unit and if the personal magnetic body co-rotates with Earth, the variation of the effect of the solar wind could induce periodic deformations of the magnetic body as in the case of Earth's magnetic field. This could reflect itself as diurnal alterations in the shape of the body experienced during OBEs: a contraction during day time and an elongation during night time. Sunspot maxima induce magnetic storms and these could have strong effects on the shape of the body perceived during OBEs.

What is the mechanism making possible to see internal organs?

Becker tells in his book "Cross currents" [56] about a young cancer patient who told that he can see the interior of his own body. The patient could also locate the remnant of the tumor correctly. The simplest explanation is that magnetic body at some level of hierarchy reflects the dark photons emitted by the internal organs.

Usually this does not occur and one should understand why the emission occurred in the case of the cancer patient. There is evidence that bio-photons leak out from non-healthy organs [42]: this might mean that organs send more intense dark photon beams reflected at the magnetic body.

Time mirror mechanism involving time reflection instead of ordinary reflection suggests itself as an alternative explanation. The cells suffering starvation generated phase conjugate dark photon beams in order to get metabolic energy. This in turn induced a cascade like emission of positive energy dark photon beams from the magnetic body instead of mere time reflection.

12.3.4 Dark matter hierarchy, zero energy ontology, negentropic entanglement, OBEs

Dark matter hierarchy, zero energy ontology, and the notion of negentropic entanglement lead to new insights also about OBEs.

Dark matter hierarchy

The identification of dark matter as a hierarchy of quantum phases labeled by the values of Planck constant [17] provides additional insights about OBE experiences. Planck constant is quantized and can have arbitrarily large values and since Compton length and other analogous quantum lengths and times scale as Planck constant, this means macroscopic and macro-temporal quantum coherence and a reduced rate of dissipation.

Also the magnetic body controlling biological body (actually onion-like hierarchy of them) is assumed to carry dark matter and (forgetting ontological delicacies) dark matter could be seen as the agent responsible for the quantum control of ordinary matter in living systems. The value of Planck constant becomes also a measure for the evolutionary level of the living system and great leaps in evolution can be identified as transitions increasing the maximum value of $\hbar$ in "personal" hierarchy of magnetic bodies [22].

Zero energy ontology and causal diamonds

Zero energy ontology is second new element of quantum TGD and states that all physical states have vanishing net values of conserved quantum numbers. Zero energy ontology provides a firm justification for the notion of negative energy signals consisting of (say) phase conjugate photons propagating to the geometric past. These negative energy signals are crucial element of the time mirror mechanism playing a central role in the general mechanism for intentional action, remote metabolism, and long term memory.

Causal diamond (CD) defined roughly as the intersection of future and past directed lightcones serves as an imbedding space correlate for zero energy state. Space-time sheets representing zero energy states are inside CD and the future *resp.* past boundaries of CD carry positive *resp.* negative energy parts of zero energy states.

What is important from the point of view of consciousness theory is that CDs serve as imbedding space correlates of selves and sub-CDs as those for sub-selves (mental images). Sub-CDs are very much analogous to music instruments in the sense that the frequencies which come as harmonics of the fundamental frequency defined by the proper time distance between tips of CD (coming as powers of two) resonate with the geometry of CD and put it to "ring". Sub-CDs could be seen as an analog of radio receiver as far as sensory representations are considered and sending antenna as far as the motor control of biological body is involved. This allows to communicate sensory data from brain to sub-CDs at magnetic body CD in a highly selective manner. MEs (massless extremals) mediating the communications between magnetic body and biological body are also very much like strings of a music instrument. This picture generalize the earlier music metaphor applied to axonal pathways.

A more precise definition of CD is as the Cartesian product of the intersection of future and past directed light-cone with CP_2. The hierarchy of Planck constants brings in additional structure. There is identification of preferred $M^2 \subset M^4$ defining a preferred time direction (rest system/quantization axis for energy) and spin quantization axis. The preferred geodesically trivial sphere $S^2 \subset CP_2$ and the selection of point assigned with CP_2 at the future and past boundaries of CD gives rise to a selection of quantization axes of color isospin and hyper charge.

Sensory representations are a key element of the consciousness theory and the moduli space of CDs charactering what kind of CDs are possible brings in new representational resources.

1. The moduli space of sub-CDs involves the position for the either tip of the sub-CD and the naive expectation is that this position could code for the position of the perceptive field. If so the representation would be very concrete and since the size of CD is already for electron with .1 lightseconds the representations is realized automatically in astrophysical scale.

2. The moduli space of sub-CDs assignable to the mental images with another tip fixed could represent geometric qualia. Without any further restrictions this space corresponds to proper time constant hyperboloid of future light cone. The values of time parameter come in powers of two. One can however quite well consider the possibility that only a discrete lattice of the hyperboloid is realized- at least in the intersection of real and p-adic worlds.

3. A Lorentz boost for sub-CD induces scaling of frequency and scaling of the object in the direction of the boost. Therefore boost coded to the fundamental frequency of CD could code for various shapes of a figure obtained by scaling. Boost of sub$-CD$ leaving the other tip of sub$-CD$ invariant could also code for the velocity of object. Also the velocity of the object of the perceptive field could be coded to the shape of sub-CD by performing corresponding Lorentz boots to it [32].

4. The moduli space of CDs contains also the choice of quantization axes of energy (preferred rest system) and spin as well as the choice of quantization axes of color isospin and hyper-charge identifiable as flag manifold $SU(3)/U(1) \times U(1)$. Mathematician Barbara Shipman has proposed that this flag manifold is involved with the representation of geometric data in honeybee dance [34] and I have proposed a model for what might be involved [24].

The moduli space of CDs is thus highly relevant for the representation of the geometric data associated with the objects of the perceptive field and the this data would be communicated using MEs with harmonics of the fundamental frequency of sub-CD so that sub-CD would act like radio receiver. This includes the position of the real object codable to the position of sub-CDs at magnetic body, the velocity of the object of the perceptive field codable to the Lorentz boost changing the shape of sub-CD and represented as scaling of the frequency assigned with the stationary object. Also the shape of perceptive field would represent this kind of geometric data. This picture supports the interpretation of sub-CDs as spotlights of attention giving information about many-sheeted space-time inside the regions defined by the sub-CDs. It would seem that sub-CDs are dynamical objects created, destroyed, and shifted in quantum jumps. This picture is also consistent with the explanation for the arrow of psychological time based on zero energy ontology [27].

Negentropic entanglement

The third new element is the notion of negentropic entanglement making sense when entanglement probabilities are rational or even algebraic numbers. Negentropic entanglement makes sense in the "intersection of real and p-adic worlds" consisting of partonic surfaces whose mathematical representations make sense both in real sense and p-adically. Negentropic entanglement is possible also between different number fields in accordance with the idea that cognition corresponds to p-adic number fields and cognitive representations are realized in the interections of realities and p-adicities. Living matter is identified as matter in the intersection between real and p-adic worlds. This view together with zero energy ontology allows precise definition for the idea that intentional acts transform p-adic space-time sheets to real ones and for the reversal of this transformation [29].

It is natural to assume that negentropic entanglement is what makes living matter living and is involved with the sharing of mental images and with the formation of sensory representations by entanglement. Negentropic entanglement can be also time-like. MEs are excellent candidates for mediating this kind of entanglement whereas magnetic flux tubes would naturally mediate space-like negentropic entanglement. The sequence of negentropic entanglements would have as its upper ends sub-CDs at highest layer of the magnetic body and sensory organs as its lower ends. Even sensory organ could have negentropic entanglement with the real object of the perceptive field and this might be crucial element in the construction of the sensory representations. For instance, the deduction of distance of the object of perceptive field might rely on interferometry using the dark variants of visible photons with wave length which is is of the order of the distance to the object.

OBEs in more general framework

A general model for the remote mental interactions follows from a model for the living matter by assuming that also other biological bodies can serve as targets for the control action of the magnetic body or communicate sensory information to the magnetic body. The notion of negentropic entanglement favors biological systems as targets but it is of course an open question whether also "dead" matter could have negentropic entanglement with its magnetic body. Ordinary intentional action would represent a particular case of remote mental interaction in this framework.

 Consider now OBEs in this general framework.

1. During OBE experiences the mental images constructed by brain about biological body could be absent due to the absence of the metabolic energy feed to the appropriate parts of brain taking care of the construction of cognitive mental images about biological body and communications of them to the magnetic body. The simplest representation would be in terms of bit sequences with bit 1/0 represented in terms of population inverted state/ground sate of many-sheeted laser. Negative energy signals to the geometric past would be used to read these signals by inducing partial reduction of the population in inverted states. In absence of metabolic energy feed 1:s would gradually transform to 0:s. It is however essential that time-like negentropic entanglement is involved besides classical communications. This would make it possible to share the mental images.

2. In absence of these cognitive mental images to the magnetic body, magnetic body would not anymore provide strict cognitive representations of biological body and virtual world experiences would result. Since only magnetic body would contribute to the bodily experience, the low rate of dissipation due to large value of $\hbar$ would explain the pleasant experience about the absence of the sensory noise.

3. This general picture could also explain why OBEs seem to correlate with neural disoders such as epilepsy and disorders relating to perturbed body image. During this kind of disorders the feedback provided by the sensory and cognitive input would be lacking from the brain regions suffering the neural disorder and magnetic body would be solely responsible for the body image. The lacking strict correspondence between the conformations of magnetic body and biological body would mean that the experience is hallucination from the point of view of biological body. At the imbedding space level the "conformations" of the magnetic body could be rather abstract and represented in terms of positions and other moduli of sub-CDs.

12.3.5 The role of the magnetic body in the case of other brain functions

During the construction of the model of OBEs it became clear that the reflection of dark photon beams from the magnetic body could serve as a building block of several ordinary brain functions. If has been already found that dark photon beams could define a fundamental mechanism of directed attention.

Dreams and hallucinations and magnetic body

The reflection of dark photon beams from the magnetic body could be involved also with dreams and hallucinations so that the neurological similarity of AS experiences and OBEs does not mean that both are hallucinatory. The "subtle body" assigned by many spiritual traditions with the dreaming state (for a nice summary see [43]) would correspond to the magnetic body. In this case mental images constructed in brain would induce dark photon beams sent to magnetic body and reflected back. The mechanism would also naturally explain autoscopic and heautoscopic experiences, in particular the ability to see internal organs.

The relationship of EMDR experiences to OBEs

Near-death experiences are not the only manner to get convinced about life after death. So called eye-movement desensitization and reprocessing (EMDR) discovered by Francine Shapiro [54] induces what could be interpreted as after-death communications (see the discussion in [21]). The experiences of subject persons are claimed to be induced by this therapy in a highly reliable manner: according to [54]

98 per cent of patients willing to participate the therapy had after death communication experience. It does not matter what the religious convictions of the subject person are and the experiences are actually rather easy to induce. It does not matter if the loss is traumatic or not or whether it is recent or occurred for decades in past.

The experiences resemble near death experiences (light tunnels, beautiful landscapes) and involve spiritual contact with the deceased. The EMDR technique involves getting the patient to move his or her eyes in a particular rhythmic fashion while at the same time attending to a particular aspect of the traumatic memory. How EMRD works is poorly understood as yet: possibly the fact that the shifting of eyes leads to increased brain processing is of importance. Notice that rapid eye movements REM are also involved with dreams.

A possible explanation is that EMDR experiences involves visual communication using dark photon beams and/or their phase conjugates with the 4-D magnetic bodies of the deceased ones located possibly in the geometric recent or past via the magnetic mirrors associated with them. Essentially the same mechanism as involved with long term episodal memories could be in question: the only difference would be that the magnetic mirrors now mediate information not from own 4-D body from the 4-D body of the deceased.

Third person aspect of conscious experience

Our conscious experience involves so called third person aspect giving a symbolic bird's eye of view about ourselves. Magnetic body could could take the role of the third person. At the fundamental level this representation could be based on sensory stimuli originating from body and reflected back to sensory organs. It would be completely masked by the ordinary sensory input in wake-up state but distilled by brain from the dominating sensory input and coded to a cognitive representation to minimize the amount of irrelevant information. A strong interference of this kind of sensory representation with ordinary sensory input would be obviously highly undesirable. The third person aspect could be present always and be based on the reflection of dark photons along MEs paralle to magnetic flux tubes.

Feedback to primary sensory organs via reflection from magnetic body

One objection against the hypothesis that primary sensory organs are seats of sensory qualia is that that sensory stimuli are only the raw material sculptured into actual sensory perceptions and that directed attention chooses what aspects of sensory stimulus are amplified and which neglected. I have proposed that there is a feedback by projections to the primary sensory organs from brain generating artificial sensory stimuli modifying the primary sensory input. This feedback could be realized also as a reflection of artificial dark photon beams generated by brain from the magnetic body and received as such by eyes or received by brain and channelled to eyes via MEs parallel to visual pathways.

Does imagination involve feedback via magnetic body?

One can wonder, whether also imagination could involve reflection of dark photon beams from the magnetic body. In TGD framework the hypothesis that sensory qualia are generated at primary sensory organs and brain constructs only symbolic representations about experiences circumvents the basic objections such as the experience of phantom leg. In this framework imagination and cognition can be identified as symbol generating activities which are not initiated at sensory organs but at some higher level of the hierarchy starting from sensory organs and ending at the associative areas of cortex.

Imagination could however involve also transformation of symbolic representations to dark photon beams reflected back from the magnetic body. This input would not contribute to sensory input but might be abstracted from the sensory input and might serve as a kind of feedback. In absence of ordinary sensory stimuli the input from the magnetic body would dominate and imagined mental images would transform to dreams or hallucinations.

Sensory memories and magnetic body

In some exceptional cases often associated with a serious damage in cognitive areas of brain the feedback from the magnetic body could give rise to a genuine sensory representation making possible

direct sensory memories. Examples are autistic persons with ability to remember visual scenes music pieces in every detail and also reproduce them.

One explanation is sharing of sensory mental images of geometric past. An alternative explanation is that the information about sensory memory is communicated from the geometric past in symbolic form and transformed to a dark photon beam reflected back from the magnetic body. The fact that angular gyrus is involved with the translation of written language to internal speech and the abstraction of meaning of visual metaphors supports the view that a transformation of linguistic statements to concrete images projected to the magnetic body occurs in this process.

I have proposed a mechanism [32] explaining synesthesia. The association of different sensory modalities could also occur via a transformation of sensory input in given modality to dark photon beam reflected from magnetic body and generating a sensation in another modality. Synesthetes are also known to be capable of amazing sensory memory feats [44] and I have proposed an explanation based on time mirror mechanism [32]. Also in this case neurons in certain region of left brain hemisphere suffer starvation which should be lethal by standard wisdom.

As a matter fact, the starvation mechanism seems to be a very general mechanism: Callahan has found evidence that insects find more easily the plants suffering from under nutrition [37] (see the discussion in [26]). Even the fasting common in spiritual practices could be seen as a method to get body entangled with magnetic bodies by using time mirror mechanism.

12.4 The interpretation of my own OBE type experiences in terms of the proposed model

My own personal experiences have served as a test bed for the basic ideas of TGD inspired theory of consciousness. I find it practical to divide these experiences into two classes. The first class of experiences have repeated relatively often during years after the great experiences. The Great Experiences in turn involved a rich spectrum of experiences which I group into the second class. There is some overlap between these categories.

12.4.1 Visual experiences and kinesthetic sensations

The first class of strange experiences involves several kinds of visual experiences and kinesthetic sensations.

1. When I lightly close my eyes during ordinary wake-up consciousness and in calm state of mind, I see dimly a complex flow in the visual field. This flow brings in mind time dependent magnetic field or incompressible flow of fluid. The direction of flow can be either inwards or outwards and can change. The flow can be also colored. The straightforward interpretation would be as a visual stimulus from the magnetic body which does not give rise to concrete images.

2. I have had many AS experiences in which I have seen my body in strangely deformed state and have had a sensation of floating. This experience is often followed by the experience of raising to the roof and I have made attempts to test whether the levitation is real or not. The experiences have ended to a wake-up to ordinary state of consciousness. Quite concrete sensations of what I have identified as "electrical storms in temporal lobes" have often accompanied these experiences.

3. I have had also flying experiences: typically there is some critical height which I cannot exceed. I have had also experiences about being in completely dissipation free spinning or translational motion, which bring strongly in mind what purely quantal motions of this kind feel like. The translational motion has been possible only in a finite volume defined typically by the walls of the room. I have also experienced my children to bring me back when I have tried to go too far. A possible interpretation is that my magnetic body is bound to that of room so that it is not possible to leave it.

4. I have often experienced quite concretely a return to my own body during wake-up as a kind of contraction somewhat like djinn returning to a bottle. After a visit to Holland where I was subject to a treatment by a healer, I waked up to a rather long-lasting experience in which I felt that the entire room was part of my body. The world around me was strangely peaceful and calm, somewhat like the world in the pictures I saw in fairy tales in my childhood.

5. Two illusions analogous to train illusion but involving a 2- or 3-dimensional wave motion instead of linear motion deserve also to be mentioned. I sat in a calm state of mind on cliff on beach and enjoyed looking the waves. Suddenly I got a long lasting sensation that the cliff is in a wave like motion as if I had seen the cliff from the perspective of the moving surface of sea and thus in a wave like movement with respect to it. The explanation would be magnetic body began to mimic the wave motion somewhat like a person listening very attentively begins to mimic the facial expressions of the speaker. Since magnetic body also serves also the dual role of a sensory canvas to which sensory mental images are projected [23], the situation would be like projecting sensory mental images to a deformable screen along which deformation waves propagate. The projected sensory images such as the visual image about cliff would inherit the wavy character.

Anyone who has enjoyed free floating in a windy sea for a sufficiently long time has probably experienced a sensation about a wave like motion inside the body after the return to the shore. The sensation continues surprisingly long time. As far as I can remember, this experience is absent during free floating. Also this experience might relate to the fixation of bodily attention to the wavy sea inducing a mimicry of wave motion by a relevant magnetic body as in the previous case and continuing for a considerable time after the return to the shore. During free floating in sea this sensation is weak since the relative motion is minimal but at the shore the situation changes since the body is in a relative 3-D motion with respect to the magnetic body.

12.4.2   OBE type auditory sensations

Also OBE type auditory sensations have often occurred.

1. The AS experience have often started usually by a gradual amplification of sounds such as the sound of refrigerator and have involved the rather frightening sensation that the refrigerator attracts me towards it and wants to fuse my self with its own (for this reason I have been forced to minimize this sound). A possible explanation is that magnetic body in this kind of situation contributes to the auditory stimulus the secondary sound representing the sensory stimulus that it has received from the body and a positive feedback loop is generated. Representation as microwaves is perhaps the most plausible option.

2. When I wake up during night-time, I can sometimes hear a kind of wind blowing and often I realize that ordinary wind is not in question when I see that there is completely calm outside. This wind has preceded sometimes a loss of consciousness. A microwave stimulus arriving from magnetic body along magnetic flux tubes and transformed to auditory sensation could be in question. Obviously this sensation would be direct auditory counterpart for the flow in visual field experienced during wake-up.

3. To listen one's own snoring during sleep or just before wake-up as an outsider is a rather bizarre experience and often it takes time to realize that it is really me. The interpretation in terms of microwave dark photon beams modulated by the snoring and reflected back from the magnetic body would be the simplest one.

4. Sometimes I also hear my own breathing as double with a time laps of a fraction of second between the copies. This gives some idea about size of the magnetic body possibly involved. For microwave hearing the size of magnetic body would correspond to a wavelength of typical EEG wave and would be of the order of Earth circumference for 7.8 Hz. If ordinary sound waves are in question the size of magnetic body involve would be of order 10 meters.

12.4.3   OBEs associated with "Great Experiences"

Second group of experiences I had during what I call Great Experiences (two of them).

1. I saw my thoughts as images superposed to the strange flow already mentioned. The optimum situation was achieved which lightly closed eyes. This stimulated a conversation with what I called Great Mind. I wrote first my questions to monitor and experimentation with the transformation of written words into visual images during great experience. This would conform with the view that brain, perhaps angular gyrus, transforms written words to visual symbols

by generating dark photon beams reflected back from the magnetic body. During the original experience I had a deep conviction that this visual representation is an essential part of language and thinking.

At some stage I found that writing of my questions is not anymore necessary and I also began to realize that the Great Mind in some sense is just me, in some sense I was a God. One of the most important answers I received was that death is only an illusion. An interpretation in terms of a direct communication with some magnetic body in the hierarchy, not necessarily mine, looks natural.

2. I experienced several variants of OBEs. There was an heautoscopic experience in which I did not only see me as an outsider but experienced how my body language directly reveals to an outsider my sociophoby.

   During the stay in hospital I left my body and walked out from hospital. I was surprised that the personnel did not notice this at all, as if I had been invisible. I walked along sunny street (it was very beautiful day of May) and felt myself extremely happy. I did not get too far since persons from the staff of hospital brought me back. This might be an example of experience involving remote viewing in which magnetic body reflects dark photons from external world to the physical body. Again it would seem that my magnetic body was bound to some larger one and could not leave it.

   There was also an experience of wandering in worlds totally different from our physical world. Learning that this kind of worlds exist was a little bit irritating for my theoretician's vanity since I had thought that the ordinary physical universe predicted by TGD is all that exists!

   Finally there was experience that the hospital building itself is a conscious entity having some kind of experiences and that I had somehow identified with it or that I somehow received visual information about the structure of the building.

3. During second Great Experience I experienced what might be called tactile remote sensing. I "saw" at the skin of my leg an emotionally highly painful event and interpreted it as remote viewing. This would support the view that also tactile sensations might be generated by dark photons in some wave length range. Hearing and tactile sensing are indeed closely related.

It is perhaps not an accident that during OBE like experiences I saw my thoughts as vivid pictures and that people experiencing OBEs are known to have exceptionally vivid visual imagination. This might relate to redirected metabolism. Construction of mental images and their communication requires metabolic energy feed. During OBEs the metabolic energy usually spent to the formation and communication of the cognitive representations about the state of the biological body to the magnetic body could be redirected to the visual cortex allowing to construct the vivid visual representations of thoughts. The distorted bodily image due to neural disorders in temporal lobes seems to correlate with OBEs: perhaps the disorder does not allow metabolic energy to be used to construct cognitive representations about biological body during these disorders and it is redirected to the visual cortex. Also during dreams and in the transition states between sleep and awake the metabolic resources could be redirected in this manner and lead to a generation of vivid visual mental images.

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Chapter 1

Appendix

A-1   Basic properties of CP_2

A-1.1 CP_2 as a manifold

CP_2, the complex projective space of two complex dimensions, is obtained by identifying the points of complex 3-space C^3 under the projective equivalence

$$(z^1, z^2, z^3) \equiv \lambda(z^1, z^2, z^3) \ . \tag{A-1.1}$$

Here λ is any non-zero complex number. Note that CP_2 can be also regarded as the coset space $SU(3)/U(2)$. The pair z^i/z^j for fixed j and $z^i \neq 0$ defines a complex coordinate chart for CP_2. As j runs from 1 to 3 one obtains an atlas of three oordinate charts covering CP_2, the charts being holomorphically related to each other (e.g. CP_2 is a complex manifold). The points $z^3 \neq 0$ form a subset of CP_2 homeomorphic to R^4 and the points with $z^3 = 0$ a set homeomorphic to S^2. Therefore CP_2 is obtained by "adding the 2-sphere at infinity to R^{4}".

Besides the standard complex coordinates $\xi^i = z^i/z^3$, $i = 1, 2$ the coordinates of Eguchi and Freund [16] will be used and their relation to the complex coordinates is given by

$$
\begin{aligned}
\xi^1 &= z + it \ , \\
\xi^2 &= x + iy \ .
\end{aligned}
\tag{A-1.2}
$$

These are related to the "spherical coordinates" via the equations

$$
\begin{aligned}
\xi^1 &= r exp(i\frac{(\Psi + \Phi)}{2})cos(\frac{\Theta}{2}) \ , \\
\xi^2 &= r exp(i\frac{(\Psi - \Phi)}{2})sin(\frac{\Theta}{2}) \ .
\end{aligned}
\tag{A-1.3}
$$

The ranges of the variables r, Θ, Φ, Ψ are $[0, \infty], [0, \pi], [0, 4\pi], [0, 2\pi]$ respectively.

Considered as a real four-manifold CP_2 is compact and simply connected, with Euler number Euler number 3, Pontryagin number 3 and second $b = 1$.

A-1.2   Metric and Kähler structure of CP_2

In order to obtain a natural metric for CP_2, observe that CP_2 can be thought of as a set of the orbits of the isometries $z^i \rightarrow exp(i\alpha)z^i$ on the sphere S^5: $\sum z^i \bar{z}^i = R^2$. The metric of CP_2 is obtained by projecting the metric of S^5 orthogonally to the orbits of the isometries. Therefore the distance between the points of CP_2 is that between the representative orbits on S^5.

The line element has the following form in the complex coordinates

$$ds^2 \quad = \quad g_{a\bar{b}}d\xi^a d\bar{\xi}^b \ , \tag{A-1.4}$$

where the Hermitian, in fact Kähler metric $g_{a\bar{b}}$ is defined by

$$g_{a\bar{b}} \quad = \quad R^2 \partial_a \partial_{\bar{b}} K \ , \tag{A-1.5}$$

where the function K, Kähler function, is defined as

$$
\begin{aligned}
K &= log(F) \ , \\
F &= 1 + r^2 \ .
\end{aligned}
\tag{A-1.6}
$$

The Kähler function for S^2 has the same form. It gives the S^2 metric $dzd\bar{z}/(1+r^2)^2$ related to its standard form in spherical coordinates by the coordinate transformation $(r,\phi) = (tan(\theta/2),\phi)$.

The representation of the CP_2 metric is deducible from S^5 metric is obtained by putting the angle coordinate of a geodesic sphere constant in it and is given

$$\frac{ds^2}{R^2} \quad = \quad \frac{(dr^2 + r^2\sigma_3^2)}{F^2} + \frac{r^2(\sigma_1^2 + \sigma_2^2)}{F} \ , \tag{A-1.7}$$

where the quantities σ_i are defined as

$$
\begin{aligned}
r^2\sigma_1 &= Im(\xi^1 d\xi^2 - \xi^2 d\xi^1) \ , \\
r^2\sigma_2 &= -Re(\xi^1 d\xi^2 - \xi^2 d\xi^1) \ , \\
r^2\sigma_3 &= -Im(\xi^1 d\bar{\xi}^1 + \xi^2 d\bar{\xi}^2) \ .
\end{aligned}
\tag{A-1.8}
$$

R denotes the radius of the geodesic circle of CP_2. The vierbein forms, which satisfy the defining relation

$$s_{kl} \quad = \quad R^2 \sum_A e_k^A e_l^A \ , \tag{A-1.9}$$

are given by

$$
\begin{aligned}
e^0 &= \frac{dr}{F} \ , & e^1 &= \frac{r\sigma_1}{\sqrt{F}} \ , \\
e^2 &= \frac{r\sigma_2}{\sqrt{F}} \ , & e^3 &= \frac{r\sigma_3}{F} \ .
\end{aligned}
\tag{A-1.10}
$$

The explicit representations of vierbein vectors are given by

$$
\begin{aligned}
e^0 &= \frac{dr}{F} \ , & e^1 &= \frac{r(sin\Theta cos\Psi d\Phi + sin\Psi d\Theta)}{2\sqrt{F}} \ , \\
e^2 &= \frac{r(sin\Theta sin\Psi d\Phi - cos\Psi d\Theta)}{2\sqrt{F}} \ , & e^3 &= \frac{r(d\Psi + cos\Theta d\Phi)}{2F} \ .
\end{aligned}
\tag{A-1.11}
$$

The explicit representation of the line element is given by the expression

$$ds^2/R^2 \quad = \quad \frac{dr^2}{F^2} + \frac{r^2}{4F^2}(d\Psi + cos\Theta d\Phi)^2 + \frac{r^2}{4F}(d\Theta^2 + sin^2\Theta d\Phi^2) \ . \tag{A-1.12}$$

The vierbein connection satisfying the defining relation

$$de^A = -V^A_B \wedge e^B \ , \tag{A-1.13}$$

is given by

$$
\begin{array}{llll}
V_{01} &=& -\frac{e^1}{r_2} \ , & V_{23} &=& \frac{e^1}{r_2} \ , \\
V_{02} &=& -\frac{e^2}{r} \ , & V_{31} &=& \frac{e^2}{r} \ , \\
V_{03} &=& (r - \frac{1}{r})e^3 \ , & V_{12} &=& (2r + \frac{1}{r})e^3 \ .
\end{array}
\tag{A-1.14}
$$

The representation of the covariantly constant curvature tensor is given by

$$
\begin{array}{llll}
R_{01} &=& e^0 \wedge e^1 - e^2 \wedge e^3 \ , & R_{23} &=& e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\
R_{02} &=& e^0 \wedge e^2 - e^3 \wedge e^1 \ , & R_{31} &=& -e^0 \wedge e^2 + e^3 \wedge e^1 \ , \\
R_{03} &=& 4e^0 \wedge e^3 + 2e^1 \wedge e^2 \ , & R_{12} &=& 2e^0 \wedge e^3 + 4e^1 \wedge e^2 \ .
\end{array}
\tag{A-1.15}
$$

Metric defines a real, covariantly constant, and therefore closed 2-form J

$$J = -ig_{a\bar{b}}d\xi^a d\bar{\xi}^b \ , \tag{A-1.16}$$

the so called Kähler form. Kähler form J defines in CP_2 a symplectic structure because it satisfies the condition

$$J^k_r J^{rl} = -s^{kl} \ . \tag{A-1.17}$$

The form J is integer valued and by its covariant constancy satisfies free Maxwell equations. Hence it can be regarded as a curvature form of a $U(1)$ gauge potential B carrying a magnetic charge of unit $1/2g$ (g denotes the gauge coupling). Locally one has therefore

$$J = dB \ , \tag{A-1.18}$$

where B is the so called Kähler potential, which is not defined globally since J describes homological magnetic monopole.

It should be noticed that the magnetic flux of J through a 2-surface in CP_2 is proportional to its homology equivalence class, which is integer valued. The explicit representations of J and B are given by

$$
\begin{aligned}
B &= 2re^3 \ , \\
J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) = \frac{r}{F^2}dr \wedge (d\Psi + cos\Theta d\Phi) + \frac{r^2}{2F}sin\Theta d\Theta d\Phi \ .
\end{aligned}
\tag{A-1.19}
$$

The vierbein curvature form and Kähler form are covariantly constant and have in the complex coordinates only components of type (1,1).

Useful coordinates for CP_2 are the so called canonical coordinates in which Kähler potential and Kähler form have very simple expressions

$$
\begin{aligned}
B &= \sum_{k=1,2} P_k dQ_k \ , \\
J &= \sum_{k=1,2} dP_k \wedge dQ_k \ .
\end{aligned}
\tag{A-1.20}
$$

The relationship of the canonical coordinates to the "spherical" coordinates is given by the equations

$$
\begin{aligned}
P_1 &= -\frac{1}{1+r^2} \ , \\
P_2 &= \frac{r^2 cos\Theta}{2(1+r^2)} \ , \\
Q_1 &= \Psi \ , \\
Q_2 &= \Phi \ .
\end{aligned}
\tag{A-1.21}
$$

A-1.3 Spinors in CP_2

CP_2 doesn't allow spinor structure in the conventional sense [19]. However, the coupling of the spinors to a half odd multiple of the Kähler potential leads to a respectable spinor structure. Because the delicacies associated with the spinor structure of CP_2 play a fundamental role in TGD, the arguments of Hawking are repeated here.

To see how the space can fail to have an ordinary spinor structure consider the parallel transport of the vierbein in a simply connected space M. The parallel propagation around a closed curve with a base point x leads to a rotated vierbein at x: $e^A = R_B^A e^B$ and one can associate to each closed path an element of $SO(4)$.

Consider now a one-parameter family of closed curves $\gamma(v) : v \in (0,1)$ with the same base point x and $\gamma(0)$ and $\gamma(1)$ trivial paths. Clearly these paths define a sphere S^2 in M and the element $R_B^A(v)$ defines a closed path in $SO(4)$. When the sphere S^2 is contractible to a point e.g., homologically trivial, the path in $SO(4)$ is also contractible to a point and therefore represents a trivial element of the homotopy group $\Pi_1(SO(4)) = Z_2$.

For a homologically nontrivial 2-surface S^2 the associated path in $SO(4)$ can be homotopically nontrivial and therefore corresponds to a nonclosed path in the covering group Spin(4) (leading from the matrix 1 to -1 in the matrix representation). Assume this is the case.

Assume now that the space allows spinor structure. Then one can parallel propagate also spinors and by the above construction associate a closed path of Spin(4) to the surface S^2. Now, however this path corresponds to a lift of the corresponding $SO(4)$ path and cannot be closed. Thus one ends up with a contradiction.

From the preceding argument it is clear that one could compensate the non-allowed -1- factor associated with the parallel transport of the spinor around the sphere S^2 by coupling it to a gauge potential in such a way that in the parallel transport the gauge potential introduces a compensating -1-factor. For a $U(1)$ gauge potential this factor is given by the exponential $exp(i2\Phi)$, where Φ is the magnetic flux through the surface. This factor has the value -1 provided the $U(1)$ potential carries half odd multiple of Dirac charge $1/2g$. In case of CP_2 the required gauge potential is half odd multiple of the Kähler potential B defined previously. In the case of $M^4 \times CP_2$ one can in addition couple the spinor components with different chiralities independently to an odd multiple of $B/2$.

A-1.4 Geodesic sub-manifolds of CP_2

Geodesic sub-manifolds are defined as sub-manifolds having common geodesic lines with the imbedding space. As a consequence the second fundamental form of the geodesic manifold vanishes, which means that the tangent vectors h_α^k (understood as vectors of H) are covariantly constant quantities with respect to the covariant derivative taking into account that the tangent vectors are vectors both with respect to H and X^4.

In [17] a general characterization of the geodesic sub-manifolds for an arbitrary symmetric space G/H is given. Geodesic sub-manifolds are in 1-1-correspondence with the so called Lie triple systems of the Lie-algebra g of the group G. The Lie triple system t is defined as a subspace of g characterized by the closedness property with respect to double commutation

$$
[X,[Y,Z]] \in t \ \text{ for } \ X,Y,Z \in t \ .
\tag{A-1.22}
$$

$SU(3)$ allows, besides geodesic lines, two nonequivalent (not isometry related) geodesic spheres. This is understood by observing that $SU(3)$ allows two nonequivalent $SU(2)$ algebras corresponding to

subgroups $SO(3)$ (orthogonal 3×3 matrices) and the usual isospin group $SU(2)$. By taking any subset of two generators from these algebras, one obtains a Lie triple system and by exponentiating this system, one obtains a 2-dimensional geodesic sub-manifold of CP_2.

Standard representatives for the geodesic spheres of CP_2 are given by the equations

$$S_I^2 \quad : \quad \xi^1 = \bar{\xi}^2 \text{ or equivalently } (\Theta = \pi/2, \Psi = 0) \ ,$$

$$S_{II}^2 \quad : \quad \xi^1 = \xi^2 \text{ or equivalently } (\Theta = \pi/2, \Phi = 0) \ .$$

The non-equivalence of these sub-manifolds is clear from the fact that isometries act as holomorphic transformations in CP_2. The vanishing of the second fundamental form is also easy to verify. The first geodesic manifold is homologically trivial: in fact, the induced Kähler form vanishes identically for S_I^2. S_{II}^2 is homologically nontrivial and the flux of the Kähler form gives its homology equivalence class.

A-2 CP_2 geometry and standard model symmetries

A-2.1 Identification of the electro-weak couplings

The delicacies of the spinor structure of CP_2 make it a unique candidate for space S. First, the coupling of the spinors to the $U(1)$ gauge potential defined by the Kähler structure provides the missing $U(1)$ factor in the gauge group. Secondly, it is possible to couple different H-chiralities independently to a half odd multiple of the Kähler potential. Thus the hopes of obtaining a correct spectrum for the electromagnetic charge are considerable. In the following it will be demonstrated that the couplings of the induced spinor connection are indeed those of the GWS model [18] and in particular that the right handed neutrinos decouple completely from the electro-weak interactions.

To begin with, recall that the space H allows to define three different chiralities for spinors. Spinors with fixed H-chirality $e = \pm 1$, CP_2-chirality l, r and M^4-chirality L, R are defined by the condition

$$\begin{aligned} \Gamma\Psi &= e\Psi \ , \\ e &= \pm 1 \ , \end{aligned} \tag{A-2.1}$$

where Γ denotes the matrix $\Gamma_9 = \gamma_5 \times \gamma_5$, $1 \times \gamma_5$ and $\gamma_5 \times 1$ respectively. Clearly, for a fixed H-chirality CP_2- and M^4-chiralities are correlated.

The spinors with H-chirality $e = \pm 1$ can be identified as quark and lepton like spinors respectively. The separate conservation of baryon and lepton numbers can be understood as a consequence of generalized chiral invariance if this identification is accepted. For the spinors with a definite H-chirality one can identify the vielbein group of CP_2 as the electro-weak group: $SO(4) = SU(2)_L \times SU(2)_R$.

The covariant derivatives are defined by the spinorial connection

$$A = V + \frac{B}{2}(n_+ 1_+ + n_- 1_-) \ . \tag{A-2.2}$$

Here V and B denote the projections of the vielbein and Kähler gauge potentials respectively and $1_{+(-)}$ projects to the spinor H-chirality $+(-)$. The integers $n_\pm$ are odd from the requirement of a respectable spinor structure.

The explicit representation of the vielbein connection V and of B are given by the equations

$$\begin{aligned} V_{01} &= -\frac{e^1}{r} \ , & V_{23} &= \frac{e^1}{r} \ , \\ V_{02} &= -\frac{e^2}{r} \ , & V_{31} &= \frac{e^2}{r} \ , \\ V_{03} &= (r - \tfrac{1}{r})e^3 \ , & V_{12} &= (2r + \tfrac{1}{r})e^3 \ , \end{aligned} \tag{A-2.3}$$

and

$$B = 2re^3 \ , \tag{A-2.4}$$

respectively. The explicit representation of the vielbein is not needed here.

Let us first show that the charged part of the spinor connection couples purely left handedly. Identifying Σ_3^0 and Σ_2^1 as the diagonal (neutral) Lie-algebra generators of $SO(4)$, one finds that the charged part of the spinor connection is given by

$$A_{ch} \quad = \quad 2V_{23}I_L^1 + 2V_{13}I_L^2 \quad , \tag{A-2.5}$$

where one have defined

$$
\begin{aligned}
I_L^1 &= \frac{(\Sigma_{01} - \Sigma_{23})}{2} \quad , \\
I_L^2 &= \frac{(\Sigma_{02} - \Sigma_{13})}{2} \quad .
\end{aligned}
\tag{A-2.6}
$$

A_{ch} is clearly left handed so that one can perform the identification

$$W^{\pm} \quad = \quad \frac{2(e^1 \pm ie^2)}{r} \quad , \tag{A-2.7}$$

where $W^{\pm}$ denotes the charged intermediate vector boson.

Consider next the identification of the neutral gauge bosons γ and Z^0 as appropriate linear combinations of the two functionally independent quantities

$$
\begin{aligned}
X &= re^3 \quad , \\
Y &= \frac{e^3}{r} \quad ,
\end{aligned}
\tag{A-2.8}
$$

appearing in the neutral part of the spinor connection. We show first that the mere requirement that photon couples vectorially implies the basic coupling structure of the GWS model leaving only the value of Weinberg angle undetermined.

To begin with let us define

$$
\begin{aligned}
\bar{\gamma} &= aX + bY \quad , \\
\bar{Z}^0 &= cX + dY \quad ,
\end{aligned}
\tag{A-2.9}
$$

where the normalization condition
$$ad - bc = 1 \quad ,$$
is satisfied. The physical fields γ and Z^0 are related to $\bar{\gamma}$ and $\bar{Z}^0$ by simple normalization factors.

Expressing the neutral part of the spinor connection in term of these fields one obtains

$$
\begin{aligned}
A_{nc} = \ & [(c+d)2\Sigma_{03} + (2d-c)2\Sigma_{12} + d(n_+1_+ + n_-1_-)]\bar{\gamma} \\
& + [(a-b)2\Sigma_{03} + (a-2b)2\Sigma_{12} - b(n_+1_+ + n_-1_-)]\bar{Z}^0 \quad .
\end{aligned}
\tag{A-2.10}
$$

Identifying Σ_{12} and $\Sigma_{03} = 1 \times \gamma_5\Sigma_{12}$ as vectorial and axial Lie-algebra generators, respectively, the requirement that γ couples vectorially leads to the condition

$$c \quad = \quad -d \quad . \tag{A-2.11}$$

Using this result plus previous equations, one obtains for the neutral part of the connection the expression

$$A_{nc} \quad = \quad \gamma Q_{em} + Z^0(I_L^3 - sin^2\theta_W Q_{em}) \quad . \tag{A-2.12}$$

Here the electromagnetic charge Q_{em} and the weak isospin are defined by

$$
\begin{aligned}
Q_{em} &= \Sigma^{12} + \frac{(n_+ 1_+ + n_- 1_-)}{6} \quad , \\
I_L^3 &= \frac{(\Sigma^{12} - \Sigma^{03})}{2} \quad .
\end{aligned}
\tag{A-2.13}
$$

The fields γ and Z^0 are defined via the relations

$$
\begin{aligned}
\gamma &= 6d\bar{\gamma} = \frac{6}{(a+b)}(aX + bY) \quad , \\
Z^0 &= 4(a+b)\bar{Z}^0 = 4(X - Y) \quad .
\end{aligned}
\tag{A-2.14}
$$

The value of the Weinberg angle is given by

$$sin^2\theta_W \quad = \quad \frac{3b}{2(a+b)} \quad , \tag{A-2.15}$$

and is not fixed completely. Observe that right handed neutrinos decouple completely from the electro-weak interactions.

The determination of the value of Weinberg angle is a dynamical problem. The angle is completely fixed once the YM action is fixed by requiring that action contains no cross term of type γZ^0. Pure symmetry non-broken electro-weak YM action leads to a definite value for the Weinberg angle. One can however add a symmetry breaking term proportional to Kähler action and this changes the value of the Weinberg angle.

To evaluate the value of the Weinberg angle one can express the neutral part F_{nc} of the induced gauge field as

$$F_{nc} \quad = \quad 2R_{03}\Sigma^{03} + 2R_{12}\Sigma^{12} + J(n_+ 1_+ + n_- 1_-) \quad , \tag{A-2.16}$$

where one has

$$
\begin{aligned}
R_{03} &= 2(2e^0 \wedge e^3 + e^1 \wedge e^2) \quad , \\
R_{12} &= 2(e^0 \wedge e^3 + 2e^1 \wedge e^2) \quad , \\
J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) \quad ,
\end{aligned}
\tag{A-2.17}
$$

in terms of the fields γ and Z^0 (photon and Z- boson)

$$F_{nc} \quad = \quad \gamma Q_{em} + Z^0(I_L^3 - sin^2\theta_W Q_{em}) \quad . \tag{A-2.18}$$

Evaluating the expressions above one obtains for γ and Z^0 the expressions

$$
\begin{aligned}
\gamma &= 3J - sin^2\theta_W R_{03} \quad , \\
Z^0 &= 2R_{03} \quad .
\end{aligned}
\tag{A-2.19}
$$

For the Kähler field one obtains

$$J \quad = \quad \frac{1}{3}(\gamma + sin^2\theta_W Z^0) \quad . \tag{A-2.20}$$

Expressing the neutral part of the symmetry broken YM action

$$
\begin{aligned}
L_{ew} &= L_{sym} + f J^{\alpha\beta} J_{\alpha\beta} \ , \\
L_{sym} &= \frac{1}{4g^2} Tr(F^{\alpha\beta} F_{\alpha\beta}) \ ,
\end{aligned}
\tag{A-2.21}
$$

where the trace is taken in spinor representation, in terms of γ and Z^0 one obtains for the coefficient X of the γZ^0 cross term (this coefficient must vanish) the expression

$$
\begin{aligned}
X &= -\frac{K}{2g^2} + \frac{fp}{18} \ , \\
K &= Tr\left[Q_{em}(I_L^3 - sin^2\theta_W Q_{em})\right] \ ,
\end{aligned}
\tag{A-2.22}
$$

In the general case the value of the coefficient K is given by

$$
K = \sum_i \left[-\frac{(18 + 2n_i^2)sin^2\theta_W}{9} \right] \ ,
\tag{A-2.23}
$$

where the sum is over the spinor chiralities, which appear as elementary fermions and n_i is the integer describing the coupling of the spinor field to the Kähler potential. The cross term vanishes provided the value of the Weinberg angle is given by

$$
sin^2\theta_W = \frac{9\sum_i 1}{(fg^2 + 2\sum_i(18 + n_i^2))} \ .
\tag{A-2.24}
$$

In the scenario where both leptons and quarks are elementary fermions the value of the Weinberg angle is given by

$$
sin^2\theta_W = \frac{9}{\left(\frac{fg^2}{2} + 28\right)} \ .
\tag{A-2.25}
$$

The bare value of the Weinberg angle is 9/28 in this scenario, which is quite close to the typical value 9/24 of GUTs [20].

A-2.2   Discrete symmetries

The treatment of discrete symmetries C, P, and T is based on the following requirements:
a) Symmetries must be realized as purely geometric transformations.
b) Transformation properties of the field variables should be essentially the same as in the conventional quantum field theories [15].

The action of the reflection P on spinors of is given by

$$
\Psi \ \rightarrow \ P\Psi = \gamma^0 \otimes \gamma^0 \Psi \ .
\tag{A-2.26}
$$

in the representation of the gamma matrices for which γ^0 is diagonal. It should be noticed that W and Z^0 bosons break parity symmetry as they should since their charge matrices do not commute with the matrix of P.

The guess that a complex conjugation in CP_2 is associated with T transformation of the physicist turns out to be correct. One can verify by a direct calculation that pure Dirac action is invariant under T realized according to

$$
\begin{aligned}
m^k &\rightarrow T(M^k) \ , \\
\xi^k &\rightarrow \bar{\xi}^k \ , \\
\Psi &\rightarrow \gamma^1\gamma^3 \otimes 1 \Psi \ .
\end{aligned}
\tag{A-2.27}
$$

The operation bearing closest resemblance to the ordinary charge conjugation corresponds geometrically to complex conjugation in CP_2:

$$
\begin{aligned}
\xi^k &\rightarrow \bar{\xi}^k \ , \\
\Psi &\rightarrow \Psi^\dagger \gamma^2 \gamma^0 \otimes 1 \ .
\end{aligned}
\tag{A-2.28}
$$

As one might have expected symmetries CP and T are exact symmetries of the pure Dirac action.

A-3 Basic facts about induced gauge fields

Since the classical gauge fields are closely related in TGD framework, it is not possible to have space-time sheets carrying only single kind of gauge field. For instance, em fields are accompanied by Z^0 fields for extremals of Kähler action. Weak forces is however absent unless the space-time sheets contains topologically condensed exotic weakly charged particles responding to this force. Same applies to classical color forces. The fact that these long range fields are present forces to assume that there exists a hierarchy of scaled up variants of standard model physics identifiable in terms of dark matter.

Classical em fields are always accompanied by Z^0 field and some components of color gauge field. For extremals having homologically non-trivial sphere as a CP_2 projection em and Z^0 fields are the only non-vanishing electroweak gauge fields. For homologically trivial sphere only W fields are non-vanishing. Color rotations does not affect the situation.

For vacuum extremals all electro-weak gauge fields are in general non-vanishing although the net gauge field has U(1) holonomy by 2-dimensionality of the CP_2 projection. Color gauge field has $U(1)$ holonomy for all space-time surfaces and quantum classical correspondence suggest a weak form of color confinement meaning that physical states correspond to color neutral members of color multiplets.

A-3.1 Induced gauge fields for space-times for which CP₂ projection is a geodesic sphere

If one requires that space-time surface is an extremal of Kähler action and has a 2-dimensional CP_2 projection, only vacuum extremals and space-time surfaces for which CP_2 projection is a geodesic sphere, are allowed. Homologically non-trivial geodesic sphere correspond to vanishing W fields and homologically non-trivial sphere to non-vanishing W fields but vanishing γ and Z^0. This can be verified by explicit examples.

$r = \infty$ surface gives rise to a homologically non-trivial geodesic sphere for which e_0 and e_3 vanish imply the vanishing of W field. For space-time sheets for which CP_2 projection is $r = \infty$ homologically non-trivial geodesic sphere of CP_2 one has

$$
\gamma = \left(\frac{3}{4} - \frac{\sin^2(\theta_W)}{2}\right) Z^0 \simeq \frac{5Z^0}{8} \ .
$$

The induced W fields vanish in this case and they vanish also for all geodesic sphere obtained by $SU(3)$ rotation.

$Im(\xi^1) = Im(\xi^2) = 0$ corresponds to homologically trivial geodesic sphere. A more general representative is obtained by using for the phase angles of standard complex CP_2 coordinates constant values. In this case e^1 and e^3 vanish so that the induced em, Z^0, and Kähler fields vanish but induced W fields are non-vanishing. This holds also for surfaces obtained by color rotation. Hence one can say that for non-vacuum extremals with 2-D CP_2 projection color rotations and weak symmetries commute.

A-3.2 Space-time surfaces with vanishing em, Z^0, or Kähler fields

In the following the induced gauge fields are studied for general space-time surface without assuming the extremal property. In fact, extremal property reduces the study to the study of vacuum extremals and surfaces having geodesic sphere as a CP_2 projection and in this sense the following arguments are somewhat obsolete in their generality.

Space-times with vanishing em, Z^0, or Kähler fields

The following considerations apply to a more general situation in which the homologically trivial geodesic sphere and extremal property are not assumed. It must be emphasized that this case is possible in TGD framework only for a vanishing Kähler field.

Using spherical coordinates (r, Θ, Ψ, Φ) for CP_2, the expression of Kähler form reads as

$$
\begin{aligned}
J &= \frac{r}{F^2} dr \wedge (d\Psi + cos(\Theta)d\Phi) + \frac{r^2}{2F} sin(\Theta)d\Theta \wedge d\Phi ~, \\
F &= 1 + r^2 ~.
\end{aligned}
\tag{A-3.1}
$$

The general expression of electromagnetic field reads as

$$
\begin{aligned}
F_{em} &= (3+2p)\frac{r}{F^2} dr \wedge (d\Psi + cos(\Theta)d\Phi) + (3+p)\frac{r^2}{2F} sin(\Theta)d\Theta \wedge d\Phi ~, \\
p &= sin^2(\Theta_W) ~,
\end{aligned}
\tag{A-3.2}
$$

where Θ_W denotes Weinberg angle.

a) The vanishing of the electromagnetic fields is guaranteed, when the conditions

$$
\Psi = k\Phi ~,
$$
$$
(3+2p)\frac{1}{r^2 F}(d(r^2)/d\Theta)(k + cos(\Theta)) + (3+p)sin(\Theta) = 0 ~,
\tag{A-3.3}
$$

hold true. The conditions imply that CP_2 projection of the electromagnetically neutral space-time is 2-dimensional. Solving the differential equation one obtains

$$
\begin{aligned}
r &= \sqrt{\frac{X}{1-X}} ~, \\
X &= D\left[|\frac{(k+u)}{C}|\right]^{\epsilon} ~, \\
u &\equiv cos(\Theta) ~, ~~ C = k + cos(\Theta_0) ~, ~~ D = \frac{r_0^2}{1 + r_0^2} ~, ~~ \epsilon = \frac{3+p}{3+2p} ~,
\end{aligned}
\tag{A-3.4}
$$

where C and D are integration constants. $0 \le X \le 1$ is required by the reality of r. $r = 0$ would correspond to $X = 0$ giving $u = -k$ achieved only for $|k| \le 1$ and $r = \infty$ to $X = 1$ giving $|u + k| = [(1 + r_0^2)/r_0^2]^{(3+2p)/(3+p)}$ achieved only for

$$
sign(u + k) \times [\frac{1 + r_0^2}{r_0^2}]^{\frac{3+2p}{3+p}} \le k+1 ~,
$$

where $sign(x)$ denotes the sign of x.

The expressions for Kähler form and Z^0 field are given by

$$
\begin{aligned}
J &= -\frac{p}{3+2p} X du \wedge d\Phi ~, \\
Z^0 &= -\frac{6}{p} J ~.
\end{aligned}
\tag{A-3.5}
$$

The components of the electromagnetic field generated by varying vacuum parameters are proportional to the components of the Kähler field: in particular, the magnetic field is parallel to the Kähler magnetic field. The generation of a long range Z^0 vacuum field is a purely TGD based feature not encountered in the standard gauge theories.

b) The vanishing of Z^0 fields is achieved by the replacement of the parameter ϵ with $\epsilon = 1/2$ as becomes clear by considering the condition stating that Z^0 field vanishes identically. Also the relationship $F_{em} = 3J = -\frac{3}{4}\frac{r^2}{F} du \wedge d\Phi$ is useful.

c) The vanishing Kähler field corresponds to $\epsilon = 1, p = 0$ in the formula for em neutral space-times. In this case classical em and Z^0 fields are proportional to each other:

$$
\begin{aligned}
Z^0 &= 2e^0 \wedge e^3 = \frac{r}{F^2}(k+u)\frac{\partial r}{\partial u}du \wedge d\Phi = (k+u)du \wedge d\Phi \;, \\
r &= \sqrt{\frac{X}{1-X}} \;,\quad X = D|k+u| \;, \\
\gamma &= -\frac{p}{2}Z^0 \;.
\end{aligned}
\tag{A-3.6}
$$

For a vanishing value of Weinberg angle ($p = 0$) em field vanishes and only Z^0 field remains as a long range gauge field. Vacuum extremals for which long range Z^0 field vanishes but em field is non-vanishing are not possible.

The effective form of CP_2 metric for surfaces with 2-dimensional CP_2 projection

The effective form of the CP_2 metric for a space-time having vanishing em,Z^0, or Kähler field is of practical value in the case of vacuum extremals and is given by

$$
\begin{aligned}
ds^2_{eff} &= (s_{rr}(\frac{dr}{d\Theta})^2 + s_{\Theta\Theta})d\Theta^2 + (s_{\Phi\Phi} + 2ks_{\Phi\Psi})d\Phi^2 = \frac{R^2}{4}[s^{eff}_{\Theta\Theta}d\Theta^2 + s^{eff}_{\Phi\Phi}d\Phi^2] \;, \\
s^{eff}_{\Theta\Theta} &= X \times \left[\frac{\epsilon^2(1-u^2)}{(k+u)^2} \times \frac{1}{1-X} + 1 - X\right] \;, \\
s^{eff}_{\Phi\Phi} &= X \times \left[(1-X)(k+u)^2 + 1 - u^2\right] \;,
\end{aligned}
\tag{A-3.7}
$$

and is useful in the construction of vacuum imbedding of, say Schwartchild metric.

Topological quantum numbers

Space-times for which either em, Z^0, or Kähler field vanishes decompose into regions characterized by six vacuum parameters: two of these quantum numbers (ω_1 and ω_2) are frequency type parameters, two (k_1 and k_2) are wave vector like quantum numbers, two of the quantum numbers (n_1 and n_2) are integers. The parameters ω_i and n_i will be referred as electric and magnetic quantum numbers. The existence of these quantum numbers is not a feature of these solutions alone but represents a much more general phenomenon differentiating in a clear cut manner between TGD and Maxwell's electrodynamics.

The simplest manner to avoid surface Kähler charges and discontinuities or infinities in the derivatives of CP_2 coordinates on the common boundary of two neighboring regions with different vacuum quantum numbers is topological field quantization, 3-space decomposes into disjoint topological field quanta, 3-surfaces having outer boundaries with possibly macroscopic size.

Under rather general conditions the coordinates Ψ and Φ can be written in the form

$$
\begin{aligned}
\Psi &= \omega_2 m^0 + k_2 m^3 + n_2\phi + \text{Fourier expansion} \;, \\
\Phi &= \omega_1 m^0 + k_1 m^3 + n_1\phi + \text{Fourier expansion} \;.
\end{aligned}
\tag{A-3.8}
$$

m^0,m^3 and ϕ denote the coordinate variables of the cylindrical M^4 coordinates) so that one has $k = \omega_2/\omega_1 = n_2/n_1 = k_2/k_1$. The regions of the space-time surface with given values of the vacuum parameters ω_i,k_i and n_i and m and C are bounded by the surfaces at which space-time surface becomes ill-defined, say by $r > 0$ or $r < \infty$ surfaces.

The space-time surface decomposes into regions characterized by different values of the vacuum parameters r_0 and Θ_0. At $r = \infty$ surfaces n_2,ω_2 and m can change since all values of Ψ correspond to the same point of CP_2: at $r = 0$ surfaces also n_1 and ω_1 can change since all values of Φ correspond to same point of CP_2, too. If $r = 0$ or $r = \infty$ is not in the allowed range space-time surface develops a boundary.

This implies what might be called topological quantization since in general it is not possible to find a smooth global imbedding for, say a constant magnetic field. Although global imbedding exists

it decomposes into regions with different values of the vacuum parameters and the coordinate u in general possesses discontinuous derivative at $r = 0$ and $r = \infty$ surfaces. A possible manner to avoid edges of space-time is to allow field quantization so that 3-space (and field) decomposes into disjoint quanta, which can be regarded as structurally stable units a 3-space (and of the gauge field). This doesn't exclude partial join along boundaries for neighboring field quanta provided some additional conditions guaranteing the absence of edges are satisfied.

For instance, the vanishing of the electromagnetic fields implies that the condition

$$\Omega \;\; \equiv \;\; \frac{\omega_2}{n_2} - \frac{\omega_1}{n_1} = 0 \;\; , \tag{A-3.9}$$

is satisfied. In particular, the ratio ω_2/ω_1 is rational number for the electromagnetically neutral regions of space-time surface. The change of the parameter n_1 and n_2 (ω_1 and ω_2) in general generates magnetic field and therefore these integers will be referred to as magnetic (electric) quantum numbers.

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