# Evolution of TGD

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## Contents

# 1 Introduction

In the following my attempt is to summarize how various ideas about TGD have developed. This is a response to a request of Mark McWilliams. I try to represent the development chronologically but I must confess that I have forgotten precise dates so that the chronology is not exact. Very probably I have also forgotten many important ideas and many side tracks which led nowhere. Indeed, the study of the tables of contents of books and old blog postings and What's New articles at the homepage forces me to wonder how I can forget something so totally.

Unavoidably the emphasis is on the latest ideas and there is of course the risk that some of them are not here to stay. Even during writing process some ideas developed into more concrete form. A good example is the vision about what happens in quantum jump and what the unitarity of U-matrix really means, how M-matrices generalize to form Kac-Moody type algebra, and how the notion of quantum jump in zero energy ontology (ZEO) reproduces the basic aspects of quantum measurement theory. Also a slight generalization of quantum arithmetics suggested itself during the preparation of the article.

In the following I use at least the following shorthands. ZEO for "ZEO", WCW for "World of Classical Worlds", NMP for "Negentropy Maximization Principle", $CD$ for "Causal Diamond". GCI for "General Coordinate Invariance", EP for "Equivalence Principle", HFF for Hyper-Finite Factor of type $II_1$. QFT/CFT/TQFT for "Quantum Field Theory"/ "Conformal Field Theory"/"Topological Quantum Field Theory". SUSY for "Super-Symmetry", SYM for "Supersymmetric Yang Mills theory", CKM for "Cabibbo-Kobayashi-Maskawa", LHC for "Large Hadron Collider".

# 2 The development of basic ideas of TGD

In the following I try to recall the important events during the about 34 years that I have used to develop Topological Geometrodynamics (TGD). I am not at all sure about the chronological orderings and it might be a good idea to try check what has happened by looking the rather few old publications-say my thesis and books. Because TGD has been my life purpose I find it difficult to avoid the temptation to tell also about turning points of my life often closely related to my work. I decided also to tell something about prehistory.

## 2.1 Prehistory: 1970-1977

The time before the discovery of TGD around 1977 was a hard period in my life. My pathological shyness and social fears made my professional life very difficult. Anyone wanting to make scientific career had to build up social networks already at that time. Also communication and discussion are absolutely essential for learning. I was in a rather bad psychological condition: an almost-schizophrenic, almost manic-depressive, and almost-paranoid suffering from panic attacks, and my social behavior was determined by a rich collection of neurotic rules making it very difficult to take contact with people. My relationship with my future wife (we were married 1975) was not happy and this certainly was one of the reasons to my personal problems.

### 2.1.1 Calculus exercises should be taken seriously

I got a position in the Department of Theoretical Physics - maybe at my third student year. This was too early. I had to give calculus exercises. No-one had told me that it is absolutely essential to do the little exercises before going to represent them. I had learned some kind of "live-in-this-moment" artistic philosophy during the period of my life when I had dreamed about becoming a musician, and went before the audience without having evening looked at calculus exercises. I was totally paralyzed. The students expressed very clearly their irritation and I was deeply ashamed. I think this was one of the events which dictated my academic fate to high degree. I can only blame myself.

In the middle of these personal problems I was however keenly interested to read preprints about all kinds of theories which average colleague would haved doomed to be crack-pottery. I did not have patience to learn systematically existing physics or do complex calculations - say absorbing Feynman diagrams to my spine by just shutting-up and calculating. This was probably good. The experience from music had taught to me that this kind of hardwiring can kill creativity: I had learned to play from notes mechanically and had become too lazy to memorize the pieces. But only this makes improvisation possible.

### 2.1.2 Graduate fiasco

At some time I had to do graduate work. I remember that I requested the work from Claus Montonen - who is now one of the very few internationally well-known finnish theoretical physicists (Montonen-Olive duality). He proposed that I would study some mathematical problem related to stringy amplitudes - maybe it was asymptotic behavior. I soon forgot the whole thing. I did not have the required skills and was unable to learn from more skilled ones because of my personal social problems.

Eventually I ended to my own idea which led to a graduate work work was a fiasco and would have been enough to put an end to my academic career if I had had such in my mind. The idea was that vector fields generating volume preserving transformations are somehow fundamental for physics. I did not have any conceptual understanding about elements of Riemann geometry so that I took the volume preserving character as a purely algebraic condition. I had learned the basic formulas of Riemann geometry at the first student year but not the concepts and I have learned that mathematics is for theoretical physicist just "math". Me and my teachers had been completely wrong as this fiasco painfully taught me! I realized the essence of Riemannian geometry in a very painful manner and understood what geometrization of physics might really mean.

The graduate work however contained a couple of ideas which later made re-appearance in a mathematically well-defined form. Volume preserving transformations with the special property that they are Beltrami flows are parametrized by two functions which have interpretations in terms of a position dependent light-like propagation direction and polarization vector emerged only about two years ago in the proposal for what preferred extremals of Kähler action are. These transformations could be also of decisive importance in General Relativity since volume preserving transformations generalize isometries as symmetries. At the time of graduate work I had of course heard not a single word about Beltrami flows.

Another very dreamy visual idea was that elementary particles are like scallops in the flank of ship or some kind of holes in space-time. I remember of explaining this to my room mate in the institute of theoretical physics. He was by the way the only person besides my "finder" with whom I had courage to talk with and try to explain my misty ideas. Particles as topological inhomogenuities was the more refined avatar of this idea years later. For these reasons I try to take a merciful attitude to my youth's sins! I would be happy if colleagues would follow my example.

I spent about five years to a futile play with ideas whose lifetime was usually only a few months. This kind of intellectual drifting would be out of question nowadays when academic assembly line picks up the PhD candidates during the first student year and they must begin the specialization. At seventies the hippish zeitgeist was that intelligent persons must avoid getting caught by the establishment. Graduation would be just this so that it must be prorogued as long as possible. I managed excellently! I think that this drifting was however a period of learning by thinking rather than getting brainwashed by a thesis adviser.

I was very excited by Finkelstein's topological ideas about physics which were avant-garde at that time. I found especially interesting the idea about topological explanation of spin 1/2 particles. Already Dirac had discovered an ingenious manner to demonstrate that spin 1/2 has topological meaning (orientation-entanglement relation). I am still puzzled about how Dirac discovered it. I wrote licenciate work about this and I think this was the first work which had some promise in it. Today I would not try to topologize spin but orientation entanglement relation would be easy to realize in terms of space-time sheets.

## 2.2 Period 1977-1982: writing thesis

The basic idea of TGD emerged towards the end of 1977 - I remember that it was at October because I was born in October 30. The motivation leading to the idea was the loss of Poincare invariance in General Relativity. I had very aesthetic philosophical background since I had dreamed of becoming a musician but had realized that I do not have the patience needed to endlessly polish piece, lack the ability to memorize pieces, and would have no future as a composer. Much later I understood that I had not realized the immense richness of colors in the emotional palette of musicians like Segovia.

This perhaps explains why esteemed aesthetics so high, and the idea of replacing Poincare invariance by General Goordinate Invariance which is gauge invariance rather than an active symmetry to which one can assign conservation laws using Noether's theorem, was to me totally unacceptable. One has of course developed an endless variety of arguments for how one might define the notion of mass without Poincare invariance. I could not believe that Nature could accept this kind of conceptual tricks and sloppiness.

Eventully came the great day when I realized how gravitation might be described in Poincare invariance manner. Assume that space-time is 4-D surface in some higher-dimensional space $M^4 \times S$, where $S$ is some compact internal space. This idea is different from that of Kaluza-Klein since the higher-D imbedding space is not dynamical now.

I got the great idea in October 1977 and soon went to talk with the boss of the Institute of Theoretical Physics and told that I would deserve a research position in The Department of Theoretical Physics. I still wonder how did IU have the courage to do this! These years have conditioned me so painfully that I cannot even think of approaching professor! Within a week or two I was thrown out of my job. He and probably all others regarded me as a totally mad man and he became later one of my worst enemies taking a good care that I got no research position anywhere in Finland. My luck was that I got a kind of unemployment work in the Technical University in Otaniemi allowing me to work quite freely with what I decided to become my thesis work. Nowadays this kind of academic freedom cannot be imagined. I am deeply grateful for the personnel of this lab for tolerating my presence.

These years were a very happy in my life. I remember of waking up around 5 a'clock and going by bus to Otaniemi and returning around midnight. It was physically hard - at some time my weight was between 50 and 60 kg! But I really enjoyed the feeling that community regards my work so valuable that it supports it in this manner.

### 2.2.1 $M^4 \times S^2$ period

The problem was to fix the choice of the compact internal space $S$. My original choice for $S$ was of course the simplest possible option that one can imagine: $S = S^2$.

I began by studying proposals for classical dynamics replacing Einstein's equations. My ingenious looking first guess was that curvature scalar for the induced metric determines the dynamics. The field equations stated the conservation of energy momentum and generalized Einstein's equations and allow to have Poincare invariant gravity. I was really disappointed as it turned out that this option does not work.

For instance, I got as solutions of field equations string like objects with negative string tension. I however discover the generalization of space-time concept. It turned out that one obtains for any general coordinate invariant action certain basic solutions and many of them has finite size as 3-surfaces. This and the experience with string models led to the idea that particles correspond to space-time surfaces with finite spatial size - quanta of space-time. Also the idea of topological condensation emerged. Physical particles are obtained by glueing these free particles to a larger background space-time by topological sum operation (simple touching). This was actually a new formulation for the funny idea that appeared in my graduate pancake as I realized much later.

I do not remember whether I discovered induction of spinor structure meaning also the induction of the spinor connection of $S^2$ to space-time surface. If I did this at this period, my interpretation would have probably been that that the resulting U(1) gauge invariance could correspond to electromagnetism.

Neither do I remember whether I asked already at this period how to get quarks and quark color. At some time I however made this question my proposal for the answer was inspired by the study of the simple solutions of field equations and was that quarks carry magnetic charge (or homological charge meaning that quark like space-time surface has $CP_2$ projection containing a sphere, which cannot be contracted to a point) . The magnetic charges 2,-1,-1 would correspond to color hyper charge 2/3,-1/3,-1/3 for quarks and their sum would vanish so that baryons would be magnetic tripoles. I could have assigned color isospin might have been assigned to the 6-D spinors of $M^4 \times S^2$ as $S^2$ spin. In any case, the homologization of color charge failed but only two years ago I learned that it might well be that color hyper-charge correlates with the Kähler magnetic charge in the proposed manner and that baryons could indeed be magnetic tripoles.

### 2.2.2 Discovery of $CP_2$

The idea about 8-dimensional imbedding space $H = M^4 \times CP_2$ emerged around 1980 as I was reading Physics Reports article T. Eguchi, B. Gilkey, and J. Hanson about topology in physics published at that year.

The article took $CP_2$ as example since it described gravitational instanton. As I looked the description of $CP_2$ spinor connection I suddenly realized that its components correspond to electroweak gauge potentials. Could it be that $CP_2$ could code for electroweak quantum numbers and the induced gauge potentials could correspond to classical electroweak gauge potentials?! Could it be that people like Hawking could have missed this kind of profound discovery?! This was a real turning point in the development of TGD and soon led to a phenomenological picture which has not changed much after my thesis.

It took time before I realized that $CP_2$ isometries describe naturally also quark color and allow to identify classical gluons as projections of color isometry currents - in very Kaluza-Klein like sense. There were however some problems involved that teased me for many years to come and I will describe them below.

In any case I soon ended to a proposal for a geometrization and topologization of elementary particle quantum numbers in terms of $CP_2$ spinor structure and topology of 2-manifolds.

1. Electroweak quantum numbers and color quantum numbers were coded by the geometry of $CP_2$. Quarks and leptons corresponded to different chiralities of $H$-spinors and baryon and lepton numbers were separately conserved. Proton was predicted to be stable against baryon number violating decays.

2. An improtant prediction distinguishing TGD from QCD was that color is not spin-like quantum number but more light orbital angular momentum in $CP_2$ degrees of freedom. Also leptons should have colored excitations - maybe even light ones.

3. The basic topological prediction was that particle families correspond to the handle number characterizing the topological of orientable 2- manifold (sphere with g handles) so that the number of elementary particle families is in principle infinite. Later I discovered a nice argument for why the number of light elementary particles should be three.

   The topological explanation of family replication phenomenon leads to a concrete interpretation of CKM mixing appearing in the standard model as ad-hoc assumption as topological mixing in which the topology of the partonic 2-surface changes during its propagation. This leads to a concrete model for CKM matrix and also fixes to a high degree the definition of vertices of generalized Feynman diagrams as 2-dimensional surfaces at which light-like 3-surfaces representing their orbits meet.

### 2.2.3 Long standing interpretational problems

Already at very early stages the possible problems of the approach became obvious.

1. Is Higgs there or not? Dirac equation for induced spinor fields contains trace of second fundamental form as a term analogous to Higgs term. Is it Higgs or not? Tachyonicity and spatial

dependence of the Higgs field and the impossibility to have exactly constant Higgs field were the problems.

The final solution - I hope so - became during year 2011 [16]! There is no need for Higgs in ZEO. The trace of the second fundamental form has an interpretation as an 8-D acceleration in imbedding space and relates directly to the possibility to assign to geodesic motion a non-vanishing acceleration in imbedding space. Both Newton and Einstein were right. At space-time level one has geodesic motion and at imbedding space level there is genuine force present. We still do not know whether Higgs is there or not but LHC hopefully provides the answer. The recent view in TGD framework is that there is no Higgs but I have learned to avoid making strong statements.

2. Long range electroweak and color gauge fields emerged as a basic prediction of TGD following from the fact that all induced gauge fields are expressible in terms of $CP_2$ coordinates and their gradients. The approximate symplectic symmetry suggests that the presence of symplectic transforms makes all gauge potentials except Kähler gauge potential contributing to electromagnetic and $Z^0$ gauge potential random. What is the interpretation of the long range weak and possibly also color gauge fields? How can one n avoid problems in nuclear physics? Only three years ago I realized that Kähler magnetic confinement leads to a natural mechanism screening the weak isospin and making corresponding interactions short ranged. TGD however predicts scaled variants of weak interaction physics and they might be highly relevant for the understanding of exotic phenomena like cold fusion usually claimed to be pseudo science.

3. TGD leads to a new view about color quantum numbers. Color is not a spin like quantum number but assignable to color partial waves. This new view about color becomes however manifest only in $CP_2$ length scale. What is troublesome is that the solutions of $M^4 \times CP_2$ Dirac equation have a wrong connection between electroweak spin and color. It took almost two decades to realize that conformal invariance can save the situation. The physical states are obtained by acting to the ground states assignable to the solutions of the Dirac equation using generators of Kac-Moody algebra carrying the color and this gives rise to the physical correlation between color and electroweak quantum numbers. The breaking of electro-weak symmetry occurs already at the level of $CP_2$ geometry since the holonomy group of the spinor connection is not isometry group.

4. Is the imbedding space is Cartesian product of $CP_2$ with $M^4$, with its future light-cone, or with something else. Poincare invariance is exact in lab scale but in cosmological scales seems to be broken. This would seem to favor future light-cone option for the imbedding space in cosmological scales. The solution came after 2005. ZEO replaces light-cone with a hierarchy of causal diamonds (CDs) which are intersections of future and past directed light-cones. All their Poincare transforms are allowed so that there is no breaking of Poincare invariance. Four-momentum is in ZEO however a length scaled dependent notion characterizing the positive energy part of the zero energy state. The four-momentum is therrefore apparentely not conserved in cosmological scales.

5. Is Equivalence Principle (EP) realized or not? Do Einstein equations hold true in all length scales or only in long scales as string models suggest? Do Einstein's equations characterize the density of energy momentum of the matter topologically condensed around vacuum extremals?

A generalization of EP emerged around 2005 when I realized that the coset representations of conformal symmetries imply a generalization of EP [32]. This generalization is implied also by effective 2-dimensionality and strong form of holography implied by the strong form of General Coordinate Invariance. GCI becomes the mother of a handful of other deep principles which one might postulate as independent principles.

6. Induced gauge fields are expressible in terms of $CP_2$ coordinates and there are therefore only 4 scalar field degrees of freedom. Perturbation theoretic thinking would therefore suggests that TGD describes a world with 4 scalar fields. In standard model the number of bosonic fields much larger. How could one generalize the perturbation theoretic approach so that it would conform with the actual physical picture?

The solution to this problem was not easy and emerged during 2012 [10]! I realized that the linear superposition of fields is quite too strong an assumption in operationalistic approach. What is superposed are the effects of fields - not necessarily the fields. At classical level it is the net force caused by fields and at quantum level the additive contributions to the interaction of test particles with the fields. The linear superposition of effects of fields associated with parallel space-time sheets on particles carrying the fields.

## 2.3 Period 1982-1985: could there be life after thesis?

At year 1982 I published my thesis. I had sent a long article about TGD for publication in International Journal of Theoretical Physics. David Finkelstein was the chief editor. Much later I learned that David had been one of the organizers of the Esalem conference about consciousness 1980, which initiated consciousness movement to which also I began to participate for decade and half later. The topological ideas of Finkelstein had already earlier inspired me. At least at surface all this looks purely accidental.

Finkelestein had sent the article for Wheeler and he wrote a referee statement in which he regarded the idea as brilliant. This made it possible to propose the article as a thesis work and it went through. My archenemesis was the formal advisor of the thesis and had sent it for evaluation to two professors. The first one found it brilliant, second one claimed that it was totally worthless rubbish. This ambivalent attitude towards my work is continuing still today and even today there are professionals who are ready to argue that TGD is complete rubbish without bothering to read a single line of it.

It would be nice to have the referee statement of Wheeler already because it was written with extremely beautiful chirography. I however lost it mysteriously around 1993 when I became a victim of the docentship scandal. Also the documents related to the thesis disappeared from the room in which I was working at University. It would be really nice to get them back.

I had hoped that after thesis I would get financial support for my work and life would begin. I was wrong. I had a family - three children at that time - and I had to earn money in some manner. I went to a course about computers for unemployed and learned basic skills in computer programming. The reason I had not learned these skills earlier was my sociophoby: I could not learn to use the computers of the university because I had a terrible fear that I would do blunders and would be publicly ridiculed. The course was extremely useful and after it I went to finnish petroleum company to develop models for the removal of sulphur from oil.

I thought that I could live periodic double life. Some months of work to get money followed by few months of work with TGD. It did not work. The painful situation found a natural resolution when I had this great experience - psychologists would call it acute psychosis. After the experience it was easy to make the decision to not continue double life and left the petroleum company. I had become also convinced that modern psychology is to a high extent pseudo-science! As I tried to understand my great experience in terms of AI concepts I discovered a second branch of pseudoscience!

At that time I got an invitation to the centennary of Schrödinger in Potsdam and visited in Einstein's summer house and wrote my name to the guest book. This encouraged me to talk with Claus Montonen - our world lines intersected again - whether I could get a job at University. To my great surprise this was possible and I taught 6 years elementary courses in the department of theoretical physics. I did not like that job because it was boring and I regarded myself as a bad teacher. Roughly year (or two?) and half after the first great experience I had second short lasting great experience and after this I became mature for second big decision. I realized that divorce is the only possible manner to save our family.

## 2.4 Period 1985-1990 after the great experiences

The two great experiences around 1985 sparked a passionate interest on consciousness. The first experience was at May 1995 and second one at December for two years and half later (probably). These experiences changed my life. Both of involved many aspects assigned with mystic experiences.

1. The first experience began with the experience of getting contact with nothing less than God. Later I learned to my surprise that this God was in some sense me. We are Gods in some sense. This was the paradoxical lesson. Much later I realized that this vision corresponds to the Brahman= Atman identity of Eastern philosophies.

In TGD inspired biology the notion of magnetic body as intentional agent using biological body is central and the work of Persinger with God Helmet utilizing very weak magnetic fields suggests that my own magnetic body or perhaps a new layer added to its onion-like structure was what I experienced as contact with God and later realized that it is in some strange sense me [39].

2. I had very powerful vision that number three in some profound sense basic number of the universe. In the experience I was listening history records of future and it was some Russian mathematician who had made this discovery. Number three appears in many manners in physic but - somewhat frustratingly - have failed to discover anything really deep about it.

3. There was also a concrete experience about the change of the arrow of time. I experienced this as frightening and was fighting to prevent it from happening. Much later the understanding of the arrow of geometric time became basic problem both in quantum TGD and TGD inspired theory of consciousness and I will talk later more about this.

4. During the second experience I experience what I would later call "heart consciousness". I experience a kind of moment of mercy in which my past was re-constructed. Later this experience made certainly easier to accept the idea that quantum jumps changes also our geometric past.

   One of the big themes was the theory of infinite magnitudes. In fact, I made an immediate attempt to formulate it but failed completely. Ten years later I discovered infinite primes but it took a long time before I realized that I might have precognized this discovery during the second great experience.

These experiences were something which totally shattered the materialistic world view that I had tried hardly to absorb as a physicist. I finally realized how pitifully wrong this world view is. I wanted passionately to understand what this experience was about and from the books of Krishnamurti - most of them had been translated to finnish - I realized that he was one of the few people that had obviously experienced something similar. I tried also to understand my experienced by reading some books of consciousness according to strong artificial intelligence: I was deeply disappointed and astonished that something like this is regarded as science.

Around 1985 I ended up with the idea of the configuration space geometry- world of the classical worlds (WCW) is the term that I prefer to use now. The idea was to treat 3-surfaces as basic objects. I remember the conference on topological and geometrical methods in field theory held in Finland 1986 and I remember that I was keenly interested on the possible 3-dimensional generalization of Kac-Moody symmetry at that time. Probably I was already at this stage inspired by the fact that in the case of loop spaces the Kähler geometry is unique solely from the condition that it exists and has infinite-dimensional Kac-Moody algebra as its isometry algebra. Later the idea that WCW geometry and thus physics are unique from their mere mathematical existence became a basic principle of TGD.

The attempts to formulate 3-D counterpart of Kac Moody invariance did not however have success. Naive definitions gave horrible delta function singularities. Similar singularities plague canonical quantization of the general relativity. I ended up with my attempts to the outcome that theory reduces to a theory treating 3-surfaces as 2-D objects. The outcome was very disappointing. Amusingly, *effective* 2-dimensionality or strong form of holography is a prediction of the recent theory too. Nowi t however effective means that also the 4-D tangent space of partonic 2-surfaces codes for information about quantum state. The crucial idea that was lacking at that time was the light-likeness of the 3-surface as a manner to make it metrically 2-dimensional making possible to extend the 2-D conformal symmetries.

During this period I learned about the extremals of Kähler action what I have learned about them. After age of 40 years one becomes too lazy to do this kind of endless computational trials and guesswork and prefers to build big visions. I tried several attempts to understand the quantum theory but path integral formalism produced only semiclassical arguments so that I gradually lost my hopes with respect to it.

## 2.5 Period 1990-1993: Quantum physics as geometry of "world of classical worlds"

From the beginning I had made attempts to understand quantization of TGD. The attempts to quantize using canonical Hamiltonian approach and path integral approach failed. The basic mathematical reason was the nature of the variational principle involved. It is something totally different as compared to say YM action. This became clear already during first years after the discovery of the idea.

Non-linearity and the huge vacuum degeneracy was the basic reason. At some stage I realized that the vacuum degeneracy is the analog of spin glass degeneracy and means that one has the counterpart of gauge invariance which is dynamical and exact only for vacuum extrremals. Much later - after 2005 - it turned out that this vacuum degeneracy provides a plausible explanation for the hierarchy of Planck constants that I had postulated on basic of certain facts about astrophysics and biology. Macroscopic quantum coherence crucial for living systems would be due to the large effective values of Planck constant.

I finally decided to check explicitly whether perturbation theory based on path integral might work and concluded that it does not. This led to a burst of ideas.

1. Geometrization of quantum physics in terms of WCW geometry as generalization of Einstein's program served as the basic vision [12]. WCW geometry and therefore also quantum physics should unique from its mere Kähler geometric existence. This led rapidly to a new vision which turned out to be stable.

2. I realized that General Coordinate Invariance in 4-D sense is needed and it must be realized in such a manner that the WCW metric codes for classical physics defined by the dynamics of classical action principle. The Kähler function of WCW must assign to 3-surface a 4-D space-time surface as the analog of Bohr orbit: at this surface 4-D general coordinate transformations act. This led also to the generalization of General Coordinate Invariance to a much stronger form than in Einstein's theory and later his led to strong form of holography and effective 2-dimensionality.

3. Understanding of fermions involved a painful process. I had also worked with failed attempts to understand treatment of fermions at configuration level. I introduced qan infinite-D generalization of super-fields but it failed. The reason was too naive generalization of the notion of fermionic statistics to infinite-D context. The breakthrough came as I realized that WCW gamma matrices can be taken as linear combinations of second quantized fermionic oscillator operators rather than infinite number of "free" gamma matrices behaving like components of vector field.

## 2.6 Period 1993-1995 at countryside after docenship scandal: the idea about p-adic physics

The basic idea of p-adic physics emerged probably around 1993. I spent a year at countryside in my childhood home after I was labeled as a madman by University authorities as I applied for docentship. I enjoyed this time immensely. I made daily walks at summer time and skied in wintertime. Mathematical meditation in winter landscape when Sun was shining was a deep spiritual experience.

Before moving to the countryside I had published preprints about p-adic numbers and they raised a great interest and I got a flood of preprint requests. It was rather expensive to send this preprints but I was happy. I still remember how wonderful it to go the post box and see handful of preprint requests! I belonged to the community even behind the God's back! I even saw dreams about coming to the post box full of these treasures. Nowadays I receive a lot of emails and comments every day but it is nothing when compared to these preprint requests!

# 3 Period 1995-2005: mostly TGD inspired theory of consciousness and quantum biology

I returned back to Helsinki around 1995 and continued as unemployed. This was possible since I had sold my apartment. I spent half a year to p-adic mass calculations around 1995 [18]. It was really hard job. I also decided to start writing a book about consciousness and I spent a considerable fraction of my time with consciousness and quantum biology.

At that time web and discussion groups emerged and I spent a lot of time in discussion groups and to communications with people. It was very intense period. I did not do much in Quantum

TGD proper. Partly because I really thought that the formulation was more or less final and I could not develop the physical picture further. I was completely wrong. Also the situation in string model dominated theoretical physics community was depressing and the lack of experimental progress probably explains why I did not do much work with the applications of TGD to elementary particle physics.

During this period I spent a lot of time to learn basic of biology and neuroscience. Gene Johnson helped me considerably in this challenge by sending abstracts and links. We had also terrific arguments since our philosophies could not have differed more.

## 3.1 Core ideas of TGD inspired theory of consciousness

The motivation for TGD inspired theory of consciousness [30] came from the great experiences that became turning points in my life. I wanted to understand what it was. There were also other motivations than the mystery of consciousness.

As a physicist I wanted to solve the paradox related to state function reduction implied by the quantum measurement theory. The non-determinism of state function reduction is in conflict with the determinism of Schrödinger equation - or more generally, Hamiltonian evolution. The standard way out of the problem is "Shut up and calculate" but I could not be happy with so easy a solution. One can also of try to get rid of state function altogether and this has been tried in the multiverse approach, which I am still unable to understand.

My feeling was that the problem is not that of finding the correct interpretation but at much deeper level: the basic challenge is to modify the basic views in such a manner that the logical conflict is circumvented. I had also the feeling that this problem closely relates to the relationship between well-understood geometric time of physicist and the the must less understood subjective time. These times indeed differ dramatically. Geometric time is reversible and subjective time irreversible. For geometric time both future and past exist but future does not exist for experienced time. For some reason these obvious differences are usually neglected.

### 3.1.1 Quantum jump as a moment of consciousness

The basic idea was that state quantum jump takes place between entire quantum histories - in wave mechanics these would be time evolutions of Schrödinger equation. The basic idea is that in state function reduction the laws of physics do not cease to hold for given time evolution temporarily but that the entire time evolution is replaced with a new one so that both the geometric past and future are changed.

The non-determinism of quantum jumps - and perhaps that of free will - would be completely outside the realm of the geometric space-time and also outside state space - in a kind of no-man's land. Quantum would be between two worlds and would not allow description in terms of deterministic field equations. In particular, the experienced time assigned with a sequence of quantum jumps cannot be identified with the geometric time of Einstein.

The new vision raises many challenges. One should understand how a strong correlation between these two times emerges, how the arrow of subjective time implies an arrow of geometric time and whether this arrow can vary, why the contents of sensory experience are localized into a short time interval of order .1 seconds, and why memories are non-local in geometric time.

The emergence of ZEO around 2005 turned out to be a decisive step forward in the attempts to meet these challenges. The basic concepts of ZEO will be discussed later but some of the basic notions such as unitary matrix U, M-matrix M, and S-matrix and also the notion of causal diamond (CD) will be used in the following arguments.

### 3.1.2 Anatomy of quantum jump

Consider now the anatomy of quantum jump identified as a moment of consciousness in the framework of ZEO [15].

1. Quantum jump begins with unitary process $U$ described by unitary matrix assigning to a given zero energy state a quantum superposition of zero energy states. This would represent the creative aspect of quantum jump - generation of superposition of alternatives.

2. The next step is a cascade of state function reductions proceeding from long to short scales. It starts from some $CD$ and proceeds downwards to sub-CDs to their sub-CDs to ...... At a given step it induces a measurement of the quantum numbers of either positive or negative energy part of the quantum state. This step would represent the measurement aspect of quantum jump - selection among alternatives.

3. The basic variational principle is Negentropy Maximization Principle (NMP) [15] stating that the reduction of entanglement entropy in given quantum jump between two subsystems of $CD$ assigned to sub-$CD$s is maximal. Mathematically NMP is very similar to the second law although states just the opposite but for individual quantum system rather than ensemble. NMP actually implies second law at the level of ensembles as a trivial consequence of the fact that the outcome of quantum jump is not deterministic.

   For ordinary definition of entanglement entropy this leads to a pure state resulting in the measurement of the density matrix assignable to the pair of $CD$s. For hyper-finite factors of type $II_1$ (HFFs) state function reduction cannot give rise to a pure state and in this case one can speak about quantum states defined modulo finite measurement resolution and the notion of quantum spinor emerges naturally. One can assign a number theoretic entanglement entropy to entanglement characterized by rational (or even algebraic) entanglement probabilities and this entropy can be negative. Negentropic entanglement can be stable and even more negentropic entanglement can be generated in the state function reduction cascade.

The irreversibility is realized as a property of zero energy states (for ordinary positive energy ontology it is realized at the level of dynamics) and is necessary in order to obtain non-trivial U-matrix. State function reduction should involve several parts. First of all it should select the density matrix or rather its Hermitian square root. After this choice it should lead to a state which prepared either at the upper or lower boundary of $CD$ but not both since this would be in conflict with the counterpart for the determinism of quantum time evolution.

*1. Unitary process and choice of the density matrix*

Consider first unitary process followed by the choice of the density matrix.

1. There are two natural state basis for zero energy states. The states of these state basis are prepared at the upper or lower boundary of $CD$ respectively and correspond to various M-matrices $M_K^+$ and $M_L^-$. U-process is simply a change of state basis meaning a representation of the zero energy state $M_K^\pm$ in zero energy basis $M_K^\mp$ followed by a state preparation to zero energy state $M_K^\pm$ with the state at second end fixed in turn followed by a reduction to $M_L^\mp$ to its time reverse, which is of same type as the initial zero energy state.

   The state function reduction to a given M-matrix $M_K^\pm$ produces a state for the state is superposition of states which are prepared at either lower or upper boundary of CD. It does not yet produce a prepared state on the ordinary sense since it only selects the density matrix.

2. The matrix elements of U-matrix are obtained by acting with the representation of identity matrix in the space of zero energy states as

$$I = \sum_K |K^+\rangle\langle K^+|$$

   on the zero energy state $|K^-\rangle$ (the action on $|K^+\rangle$ is trivial!) and gives

$$U_{KL}^+ = Tr(M_K^+ M_L^+) \ .$$

   In the similar manner one has

$$U_{KL}^- = (U^{+\dagger})_{KL} = Tr(M_L^- M_K^-) = \overline{U_{LK}^+} \ .$$

   These matrices are Hermitian conjugates of each other as matrices between states labelled by positive or negative energy states. The interpretation is that two unitary processes are possible and are time reversals of each other. The unitary process produces a new state only if its time arrow is different from that for the initial state. The probabilities for transitions $|K_+\rangle \rightarrow |K_-\rangle$ are given by $p_{mn} = |Tr(M_K^+ M_L^+)|^2$.

*2. State function preparation*

Consider next the counterparts of the ordinary state preparation process.

1. The ordinary state function process can act either at the upper or lower boundary of $CD$ and its action is thus on positive or negative energy part of the zero energy state. At the lower boundary of $CD$ this process selects one particular prepared states. At the upper boundary it selects one particular final state of the scattering process.

2. Restrict for definiteness the consideration to the lower boundary of $CD$. Denote also $M_K$ by $M$. At the lower boundary of $CD$ the selection of prepared state - that is preparation process- means the reduction

$$\sum_{m^+n^-} M^{\pm}_{m^+n^-}|m^+\rangle|n^-\rangle \rightarrow \sum_{n^-} M^{\pm}_{m^+n^-}|m^+\rangle|n^-\rangle \quad .$$

The reduction probability is given by

$$p_m = \sum_{n^-} |M_{m^+n^-}|^2 = \rho_{m^+m^+} \quad .$$

For this state the lower boundary carries a prepared state with the quantum numbers of state $|m_+\rangle$. For density matrix which is unit matrix (this option giving pure state might not be possible) one has $p_m = 1$.

*3. State function reduction process*

The process which is the analog of measuring the final state of the scattering process is also needed and would mean state function reduction at the upper end of $CD$ - to state $|n^-\rangle$ now.

1. It is impossible to reduce to arbitrary state $|m_+\rangle|n_-\rangle$ and the reduction must at the upper end of $CD$ must mean a loss of preparation at the lower end of $CD$ so that one would have kind of time flip-flop!

2. The reduction probability for the process

$$|m_+ \equiv \sum_{n^-} M_{m^+n^-}|m^+\rangle|n^-\rangle \rightarrow n_- = \sum_{m^+} M_{m^+n^-}|m^+\rangle|n^-\rangle$$

would be

$$p_{mn} = |M^2_{mn}| \quad .$$

This is just what one would expect. The final outcome would be therefore a state of type $|n^-\rangle$ and - this is very important- of the same type as the state from which the process began so that the next process is also of type $U^+$ and one can say that a definite arrow of time prevails.

3. Both the preparation and reduction process involves also a cascade of state function reductions leading to a choice of state basis corresponding to eigenstates of density matrices between subsystems.

*4. Can the arrow of geometric time change?*

A highly interesting question is what happens if the first state preparation leading to a state $|k^+\rangle$ is followed by a U-process of type $U^-$ rather than by the state function reduction process $|k^+\rangle \rightarrow |l^-\rangle$.

Does this mean that the arrow of geometric time changes? Could this change of the arrow of geometric time take place in living matter? Could processes like molecular self assembly be entropy producing processes but with non-standard arrow of geometric time? Or are they processes in which negentropy increases by the fusion of negentropic parts to larger ones? Could the variability relate to sleep-awake cycle and to the fact that during dreams we are often in our childhood and youth. Old people are often said to return to their childhood. Could this have more than a metaphoric meaning? Could biological death mean return to childhood at the level of conscious experience? I have explained the recent views about the arrow of time in [2].

### 3.1.3 The notion of self

The notion of self is second fundamental concept [25].

1. Originally self was identified as a sequence of quantum jumps which somehow integrates to single coherent whole giving rise to the experience of continuous flow of time instead of discrete flashes of consciousness (note that it is impossible to be conscious about not being conscious!). ZEO allows to get rid of the separate notion of self altogether. The fractal hierarchy of quantum jumps assignable to a corresponding hierarchy of CDs can be identified as a hierarchy selves. The self assignable to $CD$ at given level of hierarchy experiences the quantum jumps assigned with its sub-CDs as a flow of time.

2. Further assumption is that self experiences its sub-selves as mental images and one can make rather natural assumptions about how subselves contribute to the conscious experience. In particular, subselves of subself are experienced as an averaged mental image so that quantum statistical determinism makes sensory perceptions reliable. Negentropic quantum entanglement stable against NMP binds selves to form larger selves and biological evolution might be basically this kind of process leading to molecules to mono-cellulars to multi-cellulars to societies.

3. This framework leads to a rather detailed theory of qualia [11] based on the rule that the increments of quantum numbers in quantum jump for either positive or negative energy part of the state determine qualia in a close analogy with how quantum numbers characterize the quantum states. The basic implication is that qualia reflect directly the basic quantum numbers. For instance, visual colors reflect directly color quantum numbers which is not the only indication that quark color could be highly relevant for quantum biology.

ZEO implies non-locality with respect to geometric time. This is consistent with the general coordinate invariance and resolves the basic paradox but poses also challenges. How the localization of the contents of sensory experience to rather short interval of geometric time of order .1 seconds is possible? What determines the space-time region contributing to the sensory experience? Temporal non-locality has also positive news: a completely new approach to the realization of memories emerges. These challenges lead to rather radical ideas about how the contents of conscious experience is determined in ZEO.

## 3.2 Basic ideas of TGD inspired quantum biology

The basic vision about many-sheeted space-time strongly suggests that space-time sheets are particle like entities identifiable as coherence regions of classical fields and induced spinor fields. The presence of macroscopic quantum coherence would be therefore directly visible to anyone who believes that the objects of everyday physical world correspond to space-time sheets with a macroscopic size. This view inspired the idea that TGD might have important applications to biology. Also the development of TGD inspired theory of consciousness naturally naturally led to the attempts to apply the theory to biology and neuroscience.

Quantum biology - rather than only quantum brain - is an essential aspect of Quantum Mind in TGD Universe. Cells, biomolecules, and even elementary particles are conscious entities in this framework and the biological evolution is evolution of consciousness. The experimental input about photosynthesis since 2007 supports this view.

### 3.2.1 Basic ideas

The basic new physics inspired ideas behind TGD inspired quantum are following.

1. Many-sheeted space-time allows the interpretation of the structures of the macroscopic world around us in terms of space-time topology. Classical fields are subject to topological field quantization and one can assign to a given physical system field identity - its field body or magnetic body [14]. Magnetic/field body acts as intentional agent using biological body as a sensory receptor and motor instrument and controlling biological body and inheriting its hierarchical fractal structure. Fractal hierarchy of EEGs and its variants can be seen as communication and control tools of magnetic body. Also collective levels of consciousness have a natural interpretation in terms of magnetic body. Magnetic body makes also possible entanglement in macroscopic length scales.

2. ZEO (ZEO) makes possible p-adic description of intentions and cognitions and their transformations to action. The associated notion of causal diamond ($CD$) is essential element and assigns to elementary particles new fundamental time scales which are macroscopic: for electron the time scale is .1 seconds, the fundamental biorhythm. An essentially new element is time-like entanglement which allows to understand among other things the quantum counterparts of Boolean functions in terms of time-like entanglement in fermionic degrees of freedom.

3. The assignment of dark matter with a hierarchy of Planck constants [7] gives rise to a hierarchy of macroscopic quantum phases making possible macroscopic and macro-temporal quantum coherence and allowing to understand evolution as a gradual increase of Planck constant. Also negentropic entanglement is essential characteristic of the macroscopic quantum coherence as also super conductor like macroscopic quantum phases. The challenge is to understand how these three views about macroscopic quantum phases integrate to single coherent picture.

4. p-Adic physics can be identified as physics of cognition and intentionality [21, 38]. The hierarchy of p-adic length scales predicts a hierarchy of universal metabolic quanta as increments of zero point kinetic energies. Negentropic entanglement [15] possible for number theoretic entanglement entropy makes sense for rational (and even algebraic) entanglement and leads to the identification of life as something residing in the intersection of real and p-adic worlds.

### 3.2.2 Life as something in the intersection of real and p-adic worlds

Rational numbers belong to the intersection of real and p-adic continua. An obvious generalization of this statement applies to real manifolds and their p-adic variants. When extensions of p-adic numbers are allowed, also some algebraic numbers can belong to the intersection of p-adic and real worlds. The notion of intersection of real and p-adic worlds has actually two meanings.

1. The intersection could consist of the rational and possibly some algebraic points in the intersection of real and p-adic partonic 2-surfaces at the ends of $CD$. This set is in general discrete. The interpretation could be as discrete cognitive representations.

2. The intersection could also have a more abstract meaning. For instance, the surfaces defined by rational functions with rational coefficients have a well-defined meaning in both real and p-adic context and could be interpreted as belonging to this intersection. There is strong temptation to assume that intentions are transformed to actions only in this intersection. One could say that life resides in the intersection of real and p-adic worlds in this abstract sense.

Additional support for the idea comes from the observation that Shannon entropy $S = -\sum p_n log(p_n)$ allows a p-adic generalization if the probabilities are rational numbers by replacing $log(p_n)$ with $-log(|p_n|_p)$, where $|x|_p$ is p-adic norm. Also algebraic numbers in some extension of p-adic numbers can be allowed. The unexpected property of the number theoretic Shannon entropy is that it can be negative and its unique minimum value as a function of the p-adic prime $p$ it is always negative. Entropy transforms to information!

In the case of number theoretic entanglement entropy there is a natural interpretation for this. Number theoretic entanglement entropy would measure the information carried by the entanglement whereas ordinary entanglement entropy would characterize the uncertainty about the state of either entangled system. For instance, for $p$ maximally entangled states both ordinary entanglement entropy and number theoretic entanglement negentropy are maximal with respect to $R_p$ norm. Entanglement carries maximal information. The information would be about the relationship between the systems, a rule. Schrödinger cat would be dead enough to know that it is better to not open the bottle completely.

Negentropy Maximization Principle (NMP) [15] coding the basic rules of quantum measurement theory implies that negentropic entanglement can be stable against the effects of quantum jumps unlike entropic entanglement. Therefore living matter could be distinguished from inanimate matter also by negentropic entanglement possible in the intersection of real and p-adic worlds. In consciousness theory negentropic entanglement could be seen as a correlate for the experience of understanding or any other positively colored experience, say love.

Negentropically entangled states are stable but binding energy and effective loss of relative translational degrees of freedom is not responsible for the stability. Therefore bound states are not in question. The distinction between negentropic and bound state entanglement could be compared to the difference between unhappy and happy marriage. The first one is a social jail but in the latter case both parties are free to leave but do not want to. The special characteristics of negentropic entanglement raise the question whether the problematic notion of high energy phosphate bond [1] central for metabolism could be understood in terms of negentropic entanglement. This would also allow an information theoretic interpretation of metabolism since the transfer of metabolic energy would mean a transfer of negentropy [9].

## 3.3 Work with Riemann hypothesis

Around 2002 I got the idea about a proof of Riemann hypothesis [24]. The Hilbert-Polya hypothesis states that the zeros correspond to eigenvalues of Hamiltonian. The problem is that the eigenvalues would be complex rather than real: of form $E = 1/2 + iy$. My idea was that the zeros of zeta cpud correspond to complex numbers characterizing coherent states and I developed what I called a strategy for proving Riemann hypothesis.

My word line intersected that of Claus still once. Certain professor of theoretical physics encouraged to publish the preprint about Riemann Hypothesis. If I would succeed I would get a job as a researcher! I also discussed with Claus about the idea and I think that he regarded it as original. I published the work but I was told by the professor that the journal is not respected enough so that it is better to forget dreams about enjoying monthly salary. I think that at that time I lost finally my belief on the possibility of intelligent life in academic environments. At least in my home country.

# 4 Period 2005-: a burst of new ideas

Around 2005 I made a return back to physics with a burst of many ideas. I do not remember in in which order the ideas popped up. At that time I also started to write in blog . The possibility to communicate the ideas without any censorship was indeed very inspiring. Anyone expressing something in some manner wants audience or at least an imagined audience and so did I. I had had also founded homepage for several years before this but cannot remember the precise date. I think that the web has done enormous service to science by making it possible to circumvent the censorship by academic powerholders. At least in my case web has playedabsolutely vital role.

## 4.1 Vision about physics as generalized number theory

The vision about physics as generalized number theory emerged probably after 2005 and involves three threads. Fusion of real and various p-adic physics to single coherent whole [28], the role of classical number fields in the basic structure of TGD [29], and the notion of infinite primes generalizing the notion of infinite numbers by bringing in the notion of divisibility [27].

### 4.1.1 Fusion of real and p-adic physics to a larger coherent structure

I had carried out the successful p-adic mass calculations for the first time around 1995. This led to several challenges which are still only partially met.

1. *Basic ideas*

One should be able to fuse real physics and various p-adic physics together to a more general structure. Kind of number theoretical universality would be needed and algebraic continuation of rational physics to real and p-adic number fields suggested itself. Eventually I ended up to a generalization of number concept by fusing reals and various p-adic number fields along common rationals. This process allows also a generalization based on quantum rationals.

This in turn led to profound ideas in biology.

1. For rational or even algebraic entanglement probabilities one can define number theoretic entropy using p-adic norm as the argument of logarithm in Shannon formula. This entropy satisfied the same basic conditions as the ordinary Shannon entropy but can have also negative values in which case one can say that entanglement is negentropic.

2. If one believes on NMP [15] stating that the amount of conscious information is maximized in state function reduction, one can conclude that negentropic entanglement is stable against quantum jumps. The implications for biology and quantum computation are more than obvious. One could say that living matter in some sense resides in the intersection of real and p-adic worlds. I developed a model for DNA as topological quantum computer around 2008-2009.

3. At space-time level- for partonic 2-surfaces - the intersection of real and p-adic worlds could mean that points which are common to real and p-adic space-time sheets define the end points of braid strands which are carriers of fermion number. These common points belong to some - not necessarily algebraic - extension of rationals. At the level of WCW the intersection could mean that partonic 2-surfaces are given as solutions of equations which are given in terms of rational functions and therefore polynomials having rational or algebraic coefficients.

4. The most recent outcome of this burst of ideas is a model for metabolism relying on negentropic entanglement [13]. Since 2007 support for high $T_c$ super conductivity and long range entanglement in living matter has been accumulating and can be seen as a support for this vision.

2̂. How to identify canonical identification?

The so called canonical identification mapping reals to p-adics and vice versa is central for p-adic mass calculations and maps p-adic mass squared values to real ones [18]. The deeper understanding of this map and its precise definition remained long standing problems and only during last year I found a solution that is simple and elegant and allows also to speak about p-adic and real space-time surfaces as well as p-adic and real scattering amplitudes.

1. Quantum arithmetics [38] is a generalization of ordinary arithmetics of rationals and applies to quantum rationals and is characterized by p-adic prime. 2-adic quantum arithmetics has ordinary rationals as basic numbers but for $p > 2$ the quantum rationals are not anymore rationals. I think that this is probably one of the most far reaching discoveries in the evolution of number theoretical vision. It also gives a direct connection with quantum groups and leads to the identification of the "classical" counterparts of quantum groups and the idea that all mathematical structures relying on rational numbers have quantum counterparts. The discovery of quantum arithmetics was preceded by the development of a model for Shnoll effect [1] which in the framework of the model has interpretation as a direct evidence for the underlying p-adicity.

2. An interesting question is whether the map $q \rightarrow q_p$ from rationals to quantum rationals characterized by prime $p$ can be extended to a map from reals to quantum reals and whether this map could be used to map preferred extremals to their quantum counterparts to give a realization for the notion of quantum space-time. It is possible to define the completions of quantum rationals to obtain quantum p-adics and quantum reals for any p. It is of course quite possible that quantum reals are just ordinary reals in the representation allowed by quantum rationals by allowing infinite number of prime powers in the expansions of the rationals involved.

3. If one has a map from rationals to rationals, it can be modified to a map of quantum rationals to quantum rationals and completed to maps from quantum reals to quantum reals. This would suggest that one can define partonic two surfaces for quantum p-adics corresponding to prime

$p$. It is not clear whether the corresponding quantum real surface is independent of $p$. In any case, for p-adic counterpart one could speak about quantum space-time with commutative coordinates. What would be nice that real space-time surface would be accompanied by p-adic space-time surfaces. It would be even nicer if the value of $p$ would be unique for a given real surface.

*3. Quantum p-adic deformations of space-time surfaces as a representation of finite measurement resolution?*

A mathematically fascinating question is whether one could use quantum arithmetics as a tool to build quantum deformations of partonic 2-surfaces or even of space-time surfaces and how could one achieve this. These quantum space-times would be commutative and therefore not like non-commutative geometries assigned with quantum groups. Perhaps one could see them as commutative semiclassical counterparts of non-commutative quantum geometries just as the commutative quantum groups discussed in [38] could be seen commutative counterparts of quantum groups.

As one tries to develop a new mathematical notion and interpret it, one tends to forget the motivations for the notion. It is however extremely important to remember why the new notion is needed.

1. In the case of quantum arithmetics Shnoll effect is one excellent experimental motivation. The understanding of canonical identification and realization of number theoretical universality are also good motivations coming already from p-adic mass calculations. A further motivation comes from a need to solve a mathematical problem: canonical identification for ordinary p-adic numbers does not commute with symmetries.

2. There are also good e motivations for p-adic numbers? p-Adic numbers and quantum phases can be assigned to finite measurement resolution in length measurement and in angle measurement. This with a good reason since finite measurement resolution means the loss of ordering of points of real axis in short scales and this is certainly one outcome of a finite measurement resolution. This is also assumed to relate to the fact that cognition organizes the world to objects defined by clumps of matter and with the lumps ordering of points does not matter.

3. Why quantum deformations of partonic 2-surfaces (or more ambitiously: space-time surfaces) would be needed? Could they represent convenient representatives for partonic 2-surfaces (space-time surfaces) within finite measurement resolution?

    (a) If this is accepted there is not compelling need to assume that this kind of space-time surfaces are preferred extremals of Kähler action.

    (b) The notion of quantum arithmetics and the interpretation of p-adic topology in terms of finite measurement resolution however suggest that they might obey field equations in preferred coordinates but not in the real differentiable structure but in what might be called quantum p-adic differentiable structure associated with prime $p$.

    (c) Canonical identification would map these quantum p-adic partonic (space-time surfaces) to their real counterparts in a unique a continuous manner and the image would be real space-time surface in finite measurement resolution. It would be continuous but not differentiable and would not of course satisfy field equations for Kähler action anymore. What is nice is that the inverse of the canonical identification which is two-valued for finite number of pinary digits would not be needed in the correspondence.

    (d) This description might be relevant also to quantum field theories (QFTs). One usually assumes that minima obey partial differential equations although the local interactions in QFTs are highly singular so that the quantum average field configuration might not even possess differentiable structure in the ordinary sense! Therefore quantum p-adicity might be more appropriate for the minima of effective action.

    The conclusion would be that commutative quantum deformations of space-time surfaces indeed have a useful function in TGD Universe.

Consider now in more detail the identification of the quantum deformations of space-time surfaces.

1. Rationals are in the intersection of real and p-adic number fields and the representation of numbers as rationals $r = m/n$ is the essence of quantum arithmetics. This means that $m$ and $n$ are expanded to series in powers of $p$ and coefficients of the powers of $p$ which are smaller than $p$ are replaced by the quantum counterparts. They are quantum quantum counterparts of integers smaller than $p$. This restriction is essential for the uniqueness of the map assigning to a give rational quantum rationals.

2. One must get also quantum p-adics and the idea is simple: if the pinary expansions of $m$ and $n$ in positive powers of $p$ are allowed o become infinite, one obtains a continuum very much analogous to that of ordinary p-adic integers with exactly the same arithmetics. This continuum can be mapped to reals by canonical identification. The possibility to work with numbers which are formally rationals is utmost importance for achieving the correct map to reals. It is possible to use the counterparts of ordinary pinary expansions in p-adic arithmetics.

3. One can defined quantum p-adic derivatives and the rules are familiar to anyone. Quantum p-adic variants of field equations for Kähler action make sense.

   (a) One can take a solution of p-adic field equations and by the commutativity of the map $r = m/n \rightarrow r_q = m_q/n_q$ and of arithmetic operations replace p-adic rationals with their quantum counterparts in the expressions of quantum p-adic imbedding space coordinates $h^k$ in terms of space-time coordinates $x^\alpha$.

   (b) After this one can map the quantum p-adic surface to a continuous real surface by using the replacement $p \rightarrow 1/p$ for every quantum rational. This space-time surface does not anymore satisfy the field equations since canonical identification is not even differentiable. This surface - or rather its quantum p-adic pre-image - would represent a space-time surface within measurement resolution. One can however map the induced metric and induced gauge fields to their real counterparts using canonical identification to get something which is continuous but non-differentiable.

4. This construction works nicely if in the preferred coordinates for imbedding space and partonic (space-time) surface itself the imbedding space coordinates are rational functions of space-time coordinates with rational coefficients of polynomials (also Taylor and Laurent series with rational coefficients could be considered as limits). This kind of assumption is very restrictive but in accordance with the fact that the measurement resolution is finite and that the representative for the space-time surface in finite measurement resolution is to some extent a convention. The use of rational coefficients for the polynomials involved implies that for polynomials of finite degree WCW reduces to a discrete set so that finite measurement resolution has been indeed realized quite concretely!

Consider now how the notion of finite measurement resolution allows to circumvent the objections against the construction.

1. Manifest GCI is lost because the expression for space-time coordinates as quantum rationals is not general coordinate invariant notion unless one restricts the consideration to rational maps and because the real counterpart of the quantum p-adic space-time surface depends on the choice of coordinates. The condition that the space-time surface is represented in terms of rational functions is a strong constraint but not enough to fix the choice of coordinates. Rational maps of both imbedding space and space-time produce new coordinates similar to these provided the coefficients are rational.

2. Different choices for imbedding space and space-time surface lead to different quantum p-adic space-time surface and its real counterpart. This is an outcome of finite measurement resolution. Since one cannot order the space-time points below the measurement resolution, one cannot fix uniquely the space-time surface nor uniquely fix the coordinates used. This implies the loss of manifest general coordinate invariance and also the non-uniqueness of quantum real space-time surface. The choice of coordinates is analogous to gauge choice and quantum real space-time surface preserves the information about the gauge.

### 4.1.2 Classical number fields and TGD

The infinite-dimensional geometric symmetries necessarily for WCW geometry to exist should be somehow very special and a good guess is that they have a number theoretical origin. This directs the attention immediately to classical number fields with dimensions 1,2,4, 8 appearing naturally in TGD. I remember that the discussions with Tony Smith were very enlightening.

1. A longstanding challenge had been to understand the origin of $CP_2$ at deeper level. The basic realization was that $M^4 \times CP_2$ might be understood in terms of complexified octonions. I ended up with the idea of $M^8 - -M^4 \times CP_2$ duality [29] stating that one could regard space-time as a 4-surface either in$M^8$ or $M^4 \times CP_2$. I have not been able to prove the proposed duality which was originally inspired by the mathematics of quantum groups and so called R-matrix defining the representation of braiding mathematically: the complex coordinates of $CP_2$ parameterize braiding matrices.

2. A further idea was to reduce the laws of classical physics reduced to preferred extremal property of Kähler action in TGD framework to pure number theory. In conformal field theories associativity for n-point functions of conformal fields is in key role and this suggested that preferred extremal property might reduce to associativity in some sense. One can identify quaternionic sub-algebras as maximal associative algebras of octonions and this generalizes to complexified octonions. The obvious guess it that preferred extremals are quaternionic space-time surfaces. But what does this mean?

   (a) The natural guess is that the tangent space at each point of space-time surface is quaternionic or sub-space of complex quaternions (the Minkowskian signature forces to perform complexification). One can also defined the notion of co-associativity: in this case the normal space is associative and thus quaternionic in some sense.

   (b) One can construct what might be called octonionic representations of gamma matrices: now one can of course only speak of "matrices" since octonion units do not possess matrix representation by their non-associativity.

   (c) The alternative guess could be called "romantic". Real octonion-analytic maps of octonions to octonions could be a proper generalization of complex real-analytic functions of complex plane to itself [29]. One can add, subtract, multiply, and divide them and also composition of these functions is possible. Could it be that the surfaces obtained by putting the imaginary or real part of these functions to zero could be associative or co-associative? I have been ready to give up this idea but quite recently it popped up again.

### 4.1.3 Infinite primes and repeated second quantization of an arithmetic QFT

The attribute "infinite" might create the impression that the notion is an outcome of a purely academic thought exercise. Infinite primes [27] are however infinite only in real topology . In various p-adic topologies their magnitude is equal to one. For quantum physics the notion of infinite-dimensional Hilbert space is indispensable although in numerical calculations everything is necessarily finite: this fact is in fact extremely valuable guideline in attempts to understand consciousness and also the notion of finite measurement resolution in TGD Universe.

The original motivation for infinite primes came from quantum consciousness theory.

1. The idea was that evolution corresponds to the gradual increases of the p-adic prime assumed to characterize any physical system. The number of primes smaller than given prime is however finite. This would suggest that the number of quantum jumps that have already taken place is finite. This looks very unnatural and the conclusion is that the prime characterizing the entire universe must be literally infinite.

2. How to define infinite primes? The answer to the question turned out be surprisingly simple. Their construction is very much analogous to a repeated second quantization of what might be called arithmetic super-symmetric quantum field theory. The elementary bosons and fermions of this theory are characterized by primes just as four-momentum values are assigned with ordinary elementary particles. At the first level of hierarchy one can construct infinite primes which are

analogs of many-particle states containing bosons and fermions. Surprisingly, one also obtains infinite number of states having interpretation as bound states.

Since the formation of bound states is one of the poorly understood aspects of quantum physics the question is whether infinite primes and integers could actually correspond to physical states and this is indeed the proposal.

One can construct also infinite integers and rationals.

1. Infinite primes form an infinite hierarchy. One can replace ordinary primes with infinite primes and repeat the construction andrepeat this process ad infinitum. The proposal is that this hierarchy of infinite primes corresponds to the hierarchy formed by sheets of many-sheeted space-time. At each level one encounters new elementary particles and one could see even galaxies as elementary particles at certain level of hierarchy. The interpretation as a level of abstractions consisting of statements about statements about... is also possible. Also as hierarchy of n:th order logics could be considered.

2. One can generalize the construction from rational numbers to complex rationals and construct infinite Gaussian primes. Also the construction of infinite quaternionic and even octonionic primes is possible and I have proposed a concrete interpretation of infinite primes in terms of elementary particle quantum numbers.

One can construct also infinite rationals and together with ZEO this leads to what I have used to call number theoretical Brahman=Atman identity of algebraic holography.

1. In particular, one obtains infinite number of infinite rationals for which real norm is unity. One can therefore say that real unit and therefore all real numbers have an infinitely rich number theoretical anatomy which is not seen when one is only interested in the magnitude of real number - as one has been since the days of Newton. Assigning to the numbers mere magnitude actjually reflects the materialistic vision about the world. The parallel is seeing everything as business as one does in the modern market economy. One must however not forget that already Leibniz saw the numbers differently and talked about monads. One might say that real numbers represent the flesh and number theory brings in the spirit.

2. One can generalize the idea infinite rationals and even algebraic numbers of unit magnitude to complex numbers, quaternions, and perhaps even octonions. One can also generalize 8-D imbedding space by replacing points with generalized numbers obtained by allowing the number theoretical anatomy. Imbedding space would have at its each point infinite-dimensional space of number theoretical anatomies and one can ask whether these anatomies could represent all physical states of the universe.

3. The "world of classical worlds" (WCW) would be represented by the number theoretical anatomy of single space-time point. Or something like this. WCW and WCW spinor fields would not be abstract mathematical construct but would exist as concretely as the physical world around us! I have called this vision number theoretical Brahman=Atman identity and algebraic holography.

4. ZEO in turn encourages the proposal that quantum states correspond to infinite rationals with unit norm. This would realize the old idea of mysticism about world as One and about reality as emptiness. Different real units would correspond to different zero energy states and therefore to different vacua.

## 4.2 TGD and von Neumann algebras

I am not quite sure how I ended up with von Neuman algebras [34]. Certainly I found first so called hyper-finite factors of type $II_1$ which represent only one particular von Neumann algebra whose building bricks come in three basic varieties.

1. The first kind of building brick is factor of type I assigned naturally with wave mechanics and corresponds to operators in the finite- or even infinite-dimensional separable Hilbert space assigned to a simple system like hydrogen atom.

2. The belief has been that factors of type II do not have anything to do with physics and the approach of Dirac involving somewhat questionable notions like Dirac delta function has been the approach of physicists who are pragmatists. Hyper-finite factors of type $II_1$ (HFFs) however appear naturally in the context of braids and therefore topological quantum computation and also quantum groups relate closely to them. The strange looking feature of HFFs is that the trace of infinite-dimensional unit matrix is definite in such a manner that it equals to one. For HFFs it would be infinite as a dimension of infinite-dimensional Hilbert space.

3. The (hyperfinite) factors of type $III$, which Neumann himself regarded as pathological, have been assigned to Lorentz invariant quantum field theoretic systems and statistical systems and here the trace of unit matrix is infinite. The obvious question is whether the problems related to infinities in quantum field theory might relate to the use of wrong factor. Could it be that quantum field theorists have been fighting with infinities for all these decades only because they have not bother to learn mathematics developed already by von Neumann?

Hyper-finite factors are of special interests. Physically hyper-finiteness means that infinite-dimensional system allows excellent approximation as finite-dimensional system. Clearly, hyper-finiteness is extremely desirable property from the point of view of theoretician wanting to calculate predictions in time interval shorter than his or her life-span!

It took some time to realize that hyper-finite factors of type $II_1$ appear extremely naturally in TGD framework.

1. The point is that the infinite-dimensional Fock space of fermions is a canonical example of HFF. The oscillator operators of second quantized induced spinor fields assignable to partonic 2-surfaces would define a HFF and in finite measurement resolution this algebra would be finite-dimensional and its operators would be assignable to the strands of braid effectively replacing the 3-D orbit of partonic 2-surface.

2. What is intriguing that this approximate description seems to be an inherent property of quantum physics in TGD framework. The physics is such that this approximate description produces exactly what measurements can give!

   Indeed, the modified Dirac equation allows only finite number of solutions at light-like 3-surfaces and this would mean that physics in some sense takes care that the approximation is exact! These solutions are localized at braid strands identifiable as so called Legendrian braids known one the space-time surface is known. When one increases the number of braids to increase measurement resolution, the space-time surface changes and becomes more complex. This is of course nothing but holography. One simply cannot speak of a fixed space-time containing a varying number of fermions. As one adds fermion space-time reacts to it and changes! It is like a living organism reacting to a touch!

3. The replacement of orbits of partonic 2-surfaces with braids reflects finite measurement resolution. It can be seen as a space-time correlate for finite measurement resolution in quantum sense. This notion can be realized in terms of inclusions of hyper-finite factors. The included algebra applied to physical states creates states which cannot be distinguished from the original ones in the measurement resolution used.

   This leads to the idea that one can replace the infinite-D state space with effectively finite-dimensional one obtained as a factor space by regarding all states obtainable by the action of included algebra as identical. This factor space is finite-dimensional in algebraic sense but there is an important distinction to ordinary finite-dimensional state space. The coordinates of this space are non-commutative and one can assign to it a fractal dimension which is not integer valued and equals to so called quantum dimension encountered for quantum groups.

4. What is intriguing that the quantum integers characterized by a p-adic prime appear however also in quantum arithmetics albeit in slightly different sense as in quantum group theory. Therefore number theoretic vision seems to have a deep contact with the vision emerging from hyper-finite factors.

## 4.3 Dark matter hierarchy as hierarchy of Planck constants

The original justification for the hierarchy of Planck constants [7] came from the indications that Planck constant could have large values in both astrophysical systems involving dark matter and also in biology. The realization of the hierarchy in terms of the singular coverings of CDs $CD \times CP_2$ ($CD$ denotes causal diamond defined as intersection of future and past directed light-cones emerged from consistency conditions [12]). In the sequel $CD$ denotes $CD \times CP_2$.

The hierarchy of Planck constants is realized in terms of a generalization of the 8-D imbedding space obtained by gluing almost copies of $H = M^4 \times CP_2$ together like the pages of book along its back. The different coverings of $CD$ form a book like structure which might be called Big Book. The formula for the Planck constant as an integer multiple of ordinary Planck constant involves heuristic guess work and physical plausibility arguments. 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 $\hbar$. Only a finite number of pages of the Big Book whose pages correspond to a given value of Planck constant.

In this framework biological evolution corresponds to a gradual dispersion to the pages of the Big Book with larger Planck constant, and a connection with the hierarchy of infinite primes and p-adicization program based on the mathematical realization of finite measurement resolution emerges.

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.

### 4.3.1 The hierarchy of Planck constants

The motivations for the hierarchy of Planck constants come from both astrophysics and biology. The biological motivations have been already discussed. In astrophysics the observation of Nottale [1] that planetary orbits in solar system seem to correspond to Bohr orbits with a gigantic gravitational Planck constant motivated the proposal that Planck constant might not be constant after all [26, 22].

This led to the introduction of the quantization of Planck constant as an independent postulate. It has however turned that quantized Planck constant in effective sense could emerge from the basic structure of TGD alone. Canonical momentum densities and time derivatives of the imbedding space coordinates are the field theory analogs of momenta and velocities in classical mechanics. The extreme non-linearity and vacuum degeneracy of Kähler action imply that the correspondence between canonical momentum densities and time derivatives of the imbedding space coordinates is 1-to-many: for vacuum extremals themselves 1-to-infinite.

A convenient technical manner to treat the situation is to replace imbedding space with its n-fold singular covering. Canonical momentum densities to which conserved quantities are proportional would be same at the sheets corresponding to different values of the time derivatives. At each sheet of the covering Planck constant is effectively $\hbar = n\hbar_0$. This splitting to multisheeted structure can be seen as a phase transition reducing the densities of various charges by factor $1/n$ and making it possible to have perturbative phase at each sheet (gauge coupling strengths are proportional to $1/\hbar$ and scaled down by $1/n$). The connection with fractional quantum Hall effect [1] is almost obvious. At the more detailed level one finds that the spectrum of Planck constants would be given by $\hbar = n_a n_b \hbar_0$.

This has many profound implications, which are welcome from Quantum Mind perspective.

1. Quantum coherence and quantum superposition become possible in arbitrary long length scales. One can speak about zoomed up variants of elementary particles and zoomed up sizes make it possible to satisfy the overlap condition for quantum length parameters used as a criterion for the presence of macroscopic quantum phases. In the case of quantum gravitation the length scale involved are astrophysical. This would conform with Penrose's intuition that quantum gravity

is fundamental for the understanding of consciousness and also with the idea that consciousness cannot be localized to brain.

2. Photons with given frequency can in principle have arbitrarily high energies by $E = hf$ formula, and this would explain the strange anomalies associated with the interaction of ELF em fields with living matter [1]. Quite generally the cyclotron frequencies which correspond to energies much below the thermal energy for ordinary value of Planck constant could correspond to energies above thermal threshold.

3. The value of Planck constant is a natural characterizer of the evolutionary level and biological evolution would mean a gradual increase of the largest Planck constant in the hierarchy characterizing given quantum system. Evolutionary leaps would have interpretation as phase transitions increasing the maximal value of Planck constant for evolving species. The space-time correlate would be the increase of both the number and the size of the sheets of the covering associated with the system so that its complexity would increase.

4. The phase transitions changing Planck constant change also the length of the magnetic flux tubes. The natural conjecture is that biomolecules form a kind of Indra's net connected by the flux tubes and $\hbar$ changing phase transitions are at the core of the quantum bio-dynamics. The contraction of the magnetic flux tube connecting distant biomolecules would force them near to each other making possible for the bio-catalysis to proceed. This mechanism could be central for DNA replication and other basic biological processes.

   Magnetic Indra's net could be also responsible for the coherence of gel phase and the phase transitions affecting flux tube lengths could induce the contractions and expansions of the intracellular gel phase. The reconnection of flux tubes would allow the restructuring of the signal pathways between biomolecules and other subsystems and would be also involved with ADP-ATP transformation inducing a transfer of negentropic entanglement [9]. The braiding of the magnetic flux tubes could make possible topological quantum computation like processes and analog of computer memory realized in terms of braiding patterns [6].

5. p-Adic length scale hypothesis and hierarchy of Planck constants suggest entire hierarchy of zoomed up copies of standard model physics with range of weak interactions and color forces scaling like $\hbar$. This is not conflict with the known physics for the simple reason that we know very little about dark matter (partly because we might be making misleading assumptions about its nature).

   Dark matter would make possible the large parity breaking effects manifested as chiral selection of bio-molecules. What is required is that classical $Z^0$ and $W$ fields responsible for parity breaking effects are present in cellular length scale. If the value of Planck constant is so large that weak scale is some biological length scale, weak fields are effectively massless below this scale and large parity breaking effects become possible.

   For the solutions of field equations which are almost vacuum extremals $\mathrm{Z}^0$ field is non-vanishing and proportional to electromagnetic field. The hypothesis that cell membrane corresponds to a space-time sheet near a vacuum extremal (this corresponds to criticality very natural if the cell membrane is to serve as an ideal sensory receptor) leads to a rather successful model for cell membrane as sensory receptor with lipids representing the pixels of sensory qualia chart. The surprising prediction is that bio-photons [2] and bundles of EEG photons can be identified as different decay products of dark photons with energies of visible photons. Also the peak frequencies of sensitivity for photoreceptors are predicted correctly [23].

### 4.3.2 Hierarchy of Planck constants and consciousness

Dark matter hierarchy and p-adic length scale hierarchy would provide a quantitative formulation for the notion of self hierarchy inTGD inspired theory of consciousness. To a given p-adic length scale one can assign secondary p-adic time scale as the temporal distance between the tips of the $CD$ (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.

## 4.4 ZEO and its implications

In standard ontology of quantum physics physical states are assumed to have positive energy. In ZEO physical states decompose to pairs of positive and negative energy states such that all net values of the conserved quantum numbers vanish. The interpretation of these states in ordinary ontology would be as transitions between initial and final states, physical events. By quantum classical correspondences zero energy states must have space-time and imbedding space correlates.

1. Positive and negative energy parts reside at future and past light-like boundaries of $CD$ defined as intersection of future and past directed light-cones and visualizable as double cone. The analog of $CD$ in cosmology is big bang followed by big crunch. $CD$s for a fractal hierarchy containing $CD$s within $CD$s. Disjoint $CD$s are possible and $CD$s can also intersect.

2. p-Adic length scale hypothesis [19] motivated the hypothesis that the temporal distances between the tips of the intersecting light-cones come as octaves $T = 2^n T_0$ of a fundamental time scale $T_0$ defined by $CP_2$ size $R$ as $T_0 = R/c$. One prediction is that in the case of electron this time scale is .1 seconds defining the fundamental biorhythm. Also in the case $u$ and $d$ quarks the time scales correspond to biologically important time scales given by 10 ms for $u$ quark and by and 2.5 ms for $d$ quark [3]. The outcome is a direct coupling between microscopic and macroscopic scales.

3. It has turned out that the natural hypothesis is $T = nT_0$. The preferred values of $n$ as powers of two follow from quantum arithmetics characterized by a prime. For $p = 2$ quantum rationals reduce to ordinary rationals and this must rise $T = 2^n T_0$ in preferred physical role.

### 4.4.1 Basic implications

ZEO has also other nice implications.

1. ZEO conforms with the crossing symmetry of quantum field theories meaning that the final states of the quantum scattering event are effectively negative energy states. As long as one can restrict the consideration to either positive or negative energy part of the state ZEO is consistent with positive energy ontology.

   This is the case when the observer characterized by a particular $CD$ studies the physics in the time scale of much larger $CD$ containing observer's $CD$ as a sub-$CD$. When the time scale sub-$CD$ of the studied system is much shorter that the time scale of sub-$CD$ characterizing the observer, the interpretation of states associated with sub-$CD$ is in terms of quantum fluctuations.

2. ZEO solves the problem of what was the initial state of cosmic evolution. Problem becomes obsolete since in principle any zero energy state is obtained from any other state by a sequence of quantum jumps without breaking of conservation laws. The fact that energy is not conserved in general relativity based cosmologies can be also understood since each $CD$ is characterized by its own conserved quantities. As a matter fact, one must be speak about average values of conserved quantities since one can have a quantum superposition of zero energy states with the quantum numbers of the positive energy part varying over some range.

3. For thermodynamical states this is indeed the case and this leads to the idea that quantum theory in ZEO can be regarded as a "complex square root" of thermodynamics obtained as a product of positive diagonal square root of density matrix and unitary $S$-matrix. $M$-matrix defines time-like entanglement coefficients between positive and negative energy parts of the zero energy state and replaces $S$-matrix as the fundamental observable. In standard quantum measurement theory this time-like entanglement would be reduced in quantum measurement and regenerated in the next quantum jump if one accepts Negentropy Maximization Principle (NMP) [15] as the fundamental variational principle. Various $M$-matrices define the rows of the unitary $U$ matrix characterizing the unitary process part of quantum jump. From the point of

view of consciousness theory the importance of ZEO is that conservation laws in principle pose no restrictions for the new realities created in quantum jumps: free will is maximal.

### 4.4.2 Generalization of S-matrix

ZEO forces the generalization of S-matrix with a triplet formed by U-matrix, M-matrix, and S-matrix. The basic vision is that quantum theory is at mathematical level a complex square roots of thermodynamics. What happens in quantum jump was already discussed.

1. U-matrix as has its rows M-matrices , which are matrices between positive and negative energy parts of the zero energy state and correspond to the ordinary S-matrix. M-matrix is a product of a hermitian square root - call it $H$ - of density matrix $\rho$ and universal S-matrix $S$ commuting with $H$: $[S, H] = 0$. There is infinite number of different Hermitian square roots $H_i$ of density matrices which are assumed to define orthogonal matrices with respect to the inner product defined by the trace: $Tr(H_iH_j) = 0$. Also the columns of U-matrix are orthogonal. One can interpret square roots of the density matrices as a Lie algebra acting as symmetries of the S-matrix.

2. One can consider generalization of M-matrices so that they would be analogous to the elements of Kac-Moody algebra. These M-matrices would involve all powers of $S$.

   (a) The orthogonality with respect to the inner product defined by $\langle A|B\rangle = Tr(AB)$ requires the conditions $Tr(H_1H_2S^n) = 0$ for $n \neq 0$ and $H_i$ are Hermitian matrices appearing as square root of density matrix. $H_1H_2$ is hermitian if the commutator $[H_1, H_2]$ vanishes. It would be natural to assign $n$:th power of $S$ to the $CD$ for which the scale is $n$ times the $CP_2$ scale.

   (b) Trace - possibly quantum trace for hyper-finite factors of type $II_1$) is the analog of integration and the formula would be a non-commutative analog of the identity $\int_{S^1} exp(in\phi)d\phi = 0$ and pose an additional condition to the algebra of M-matrices.

   (c) It might be that one must restrict M matrices to a Cartan algebra for a given U-matrix and also this choice would be a process analogous to state function reduction. Since density matrix becomes an observable in TGD Universe, this choice could be seen as a direct counterpart for the choice of a maximal number of commuting observables which would be now hermitian square roots of density matrices. Therefore ZEO gives good hopes of reducing basic quantum measurement theory to infinite-dimensional Lie-algebra.

*1. The first guess is wrong*

The definition of U-matrix elements as a matrix inducing a change of basis requires two natural state basis. The first guess is that the following two state basis are natural and unitarily related.

1. The pairs of positive and negative energy states with same quantum numbers.

2. The states obtained by entangling positive and negative energy states with various M-matrices.

If these state basics are in one-one correspondence then the orthogonality of the rows of U-matrix means that different M-matrices are orthogonal. The orthogonality of columns of U-matrix means that for the pair $|m_1\rangle_+|n_1\rangle_-$ and $|m_2\rangle_+|n_2\rangle_-$ of zero energy states gives

$$\sum_K M^K_{m_1n_1}\overline{M^K}_{m_2n_2} = \delta_{m_1,m_2}\delta_{n_1,n_2} \quad .$$

The first guess is however not physically acceptable. The assumption that all pairs $|m_1\rangle_+|n_1\rangle_-$ are allowed as a complete set of states would mean complete non-determinism since correlations between the counterparts of initial and finals states would be absent apart from those induced by zero energy property.

*2. Second guess for the two state basis*

A better guess is that the collections of M-matrices defined as time reversals of each other define the sought for two natural state basis.

1. As for ordinary S-matrix, one can construct the states in such a manner that either positive or negative energy part of the state has well defined particle numbers, spin, etc... resulting in state function preparation. Therefore one has two kinds of M-matrices: $M_K^{\pm}$ and for both of these the above orthogonality relations hold true. This implies also two kinds of U-matrices call them $U^{\pm}$. The natural assumption is that the two M-matrices differ only by Hermitian conjugation so that one would have $M_K^- = (M_K^+)^{\dagger}$.

   One can assign opposite arrows of geometric time to these states and the proposal is that the arrow of time is a result of a process analogous to spontaneous magnetization. The possibility that the arrow of geometric time could change in quantum jump has been already discussed.

2. Unitary U-matrix $U^{\pm}$ is induced from a projector to the zero energy state basis $|K^{\pm}\rangle$ acting on the state basis $|K^{\mp}\rangle$ and the matrix elements of U-matrix are obtained by acting with the representation of identity matrix in the space of zero energy states as $I = \sum_K |K^+\rangle\langle K^+|$ on the zero energy state $|K^-\rangle$ (the action on $K^+$ is trivial!) and gives

$$U_{KL}^{+} = Tr(M_K^+ M_L^+) \ .$$

   Note that finite measurement resolution requires that the trace operation is q-trace rather than ordinary trace.

3. As the detailed discussion of the anatomy of quantum jump demonstrated, the first step in state function reduction is the choice of $M_K^{\pm}$ meaning the choice of the hermitian square root of a density matrix. A quantal selection of the measured observable takes place. This step is followed by a choice of "initial" state analogous to state function preparation and a choice of the "final state" analogous to state function reduction. The net outcome is the transition $|K^{\pm}\rangle \rightarrow |L^{\pm}\rangle$. It could also happen that instead of state function reduction as third step unitary process $U^{\mp}$ (note the change of the sign factor!) takes place and induces the change of the arrow of geometric time.

4. As noticed, one can imagine even higher level choices and this would correspond to the choice of the commuting set of hermitian matrices $H$ defining the allowed square roots of density matrices as a set of mutually commuting observables. This would fix the choices of $U$.

## 4.5 Weak form of electric magnetic duality

The notion of electric-magnetic duality [1] was proposed first by Olive and Montonen and is central in $\mathcal{N} = 4$ supersymmetric gauge theories. It states that magnetic monopoles and ordinary particles are two different phases of theory and that the description in terms of monopoles can be applied at the limit when the running gauge coupling constant becomes very large and perturbation theory fails to converge. The notion of electric-magnetic self-duality is more natural since for $CP_2$ geometry Kähler form is self-dual and Kähler magnetic monopoles are also Kähler electric monopoles and Kähler coupling strength is by quantum criticality renormalization group invariant rather than running coupling constant. The notion of electric-magnetic (self-)duality emerged already two decades ago in the attempts to formulate the Kähler geometric of WCW. Quite recently a considerable step of progress took place in the understanding of this notion [4]. What seems to be essential is that one adopts a weaker form of the self-duality applying at partonic 2-surfaces [5].

Every new idea must be of course taken with a grain of salt but the good sign is that this concept leads to precise predictions. The point is that elementary particles do not generate monopole fields in macroscopic length scales: at least when one considers visible matter. The first question is whether elementary particles could have vanishing magnetic charges: this turns out to be impossible. The next question is how the screening of the magnetic charges could take place and leads to an identification of the physical particles as string like objects identified as pairs magnetic charged wormhole throats connected by magnetic flux tubes.

1. The first implication is a new view about electro-weak massivation reducing it to weak confinement in TGD framework. The second end of the string contains particle having electroweak isospin neutralizing that of elementary fermion and the size scale of the string is electro-weak scale would be in question. Hence the screening of electro-weak force takes place via weak confinement realized in terms of magnetic confinement.

2. This picture generalizes to the case of color confinement. Also quarks correspond to pairs of magnetic monopoles but the charges need not vanish now. Rather, valence quarks would be connected by flux tubes of length of order hadron size such that magnetic charges sum up to zero. For instance, for baryonic valence quarks these charges could be $(2, -1, -1)$ and could be proportional to color hyper charge.

3. The highly non-trivial prediction making more precise the earlier stringy vision is that elementary particles are string like objects in electro-weak scale: this should become manifest at LHC energies.

## 4.6 TGD as almost topological QFT

TGD as almost topological QFT is one of those idea that one cannot be sure of. I think it emerged around 2005. I have been even ready to give it up but it experienced re-incarnation as I discovered the weak form of electric-magnetic duality.

1. Holography in the sense that data at 3-D surfaces code for the quantum state is an idea which emerged already at 1990 or so since 3-surfaces are indeed basic objects in quantum TGD. General Coordinate Invariance indeed implies this and the highly non-trivial implication is that space-time surface associated with a given 3-surface is analogous to Bohr orbit. Therefore semiclassical quantization is an exact part of quantum TGD.

2. The question is whether it is light-like 3-surfaces or space-like 3-surfaces at the ends of space-time sheet defined by $CD$ can be identified as the 3-surfaces that carry the data. Strong form of General Coordinate Invariance states that both choices are equally good. Only the intersections of these surfaces at the boundaries of CDs and their 4-D tangent spaces carry the data. This implies effective 2-dimensionality and strongly suggests conformal invariance and coset representation meaning that the actions of conformal generators of light-like 3-surface and those associated with the boundary of $CD$ cancel each other. This implies EP in generalized form.

3. Already effective 3-dimensionality suggests but does not imply that the Kähler action reduces to 3-D Chern-Simons term. If this occurs, the theory simplifies enormously calculationally and there are good hopes of calculating even without knowing details about preferred extremals. Chern-Simons action defines a topological QFT for braids and braids indeed replaced the 3-D light-like orbits of partonic 2-surfaces in TGD Universe in finite measurement resolution.

### 4.6.1 The reduction of Kähler action to 3-D integrals

To achieve reduction to Chern-Simons term the Kähler action for preferred extremals must reduce to a total divergence. This is achieved if in the decomposition of action to a total divergence and term $j \cdot A$, where $j$ is Kähler current the latter term vanishes: $j \cdot A = 0$. This takes place in the following situations.

1. Empty space Maxwell equations $j = 0$ stating the vanishing of Kähler current hold true.

2. $j$ and $A$ are light-like and in the same direction so that their product vanishes. This is true for so called "massless extremals" (topological light rays).

3. $j$ is proportional to the instanton current $j = \Phi j_I$, $j_I = \epsilon^{\alpha\beta\gamma\delta} A_\beta J_{\gamma\delta}$ so that $j \cdot A$ vanishes identically. Conservation of the Kähler current requires that the proportional factor $\Phi$ must satisfy $d\Phi \cdot j_I + \Phi I = 0$ where $I$ is instanton density. $d\Phi$ is either orthogonal to $j_I$ or both $d\Phi$ and $j_I$ are light-like and have same direction.

   This kind of proportionality might hold true also for other isometry currents and would mean "topologicalization" of conserved currents in accordance with the idea about almost topological QFT.

One also ends up with the proposal that preferred extremals are such that the flow lines of isometry currents integrate to coordinate lines globally. This kind of flow is known as Beltrami flow. This would mean that they define the analog of hydrodynamic flow in which the orbits of particles do not cross each other and there are no collisions. The analog of quantum flow (no collisions - no dissipation) would be in question and one could assign to the flow an order parameter of a supra phase varying only along the flow lines. The basic condition for a flow $J$ to define Beltrami flow read as $J \wedge dJ = 0$, where $J$ is the 1-form defined by the current (covariant form of current depending on induced metric).

### 4.6.2 Reduction to Chern-Simons term by the weak form of electric-magnetic duality

The proportionality of Kähler current to instanton current implies the reduction of action to 3-D terms but not yet a reduction to Chern-Simons terms implying almost topological QFT property.

1. This is guaranteed if one assumed what I have called weak form of electric-magnetic duality. This duality generalizes the Montonen-Olive electric-magnetic duality and would hold at wormhole throats and space-like 3-surfaces at the ends of space-time sheets but not necessarily elsewhere. It would imply that Kähler flux equals to magnetic flux so that Kähler electric charge is quantized. There are good reasons to assume that this charge corresponds to fermion number so that all wormhole throats carrying fermion number would be magnetic monopoles carrying Kähler magnetic charge equal to fermion number. Physical particles would correspond to multi-monopole states with vanishing total Kähler magnetic charge.

2. It is important to notice that the weak form of electric-magnetic duality at the space-like 3-surfaces and wormhole throats involves the induced metric of the space-time sheet so that metric does not disappear from the theory although Kähler action reduces to Chern-Simons term. This gives a precise content to the attribute "almost". The reduction to Chern-Simons terms would mean enormous calculational simplification of the theory and raises the hope that the theory could be calculable.

3. This also fixes to a high degree the view about leptons and hadrons. For instance, leptons should be string like objects formed by Kähler magnetically charged wormhole throats connected by magnetic flux tubes. Analogous picture applies to gauge bosons consisting of wormhole contacts with throats carrying fermion and antifermion numbers respectively. Hadrons could correspond multimonopole states.

### 4.6.3 Morse, Kähler, and me

First year physics student would immediately say that $\sqrt{g_4}$ is imaginary in the space-time regions with Minkowskian signature of the induced metric and real otherwise. For me it took 33 years to finally accept this trivial fact as a fact but finally I had to give up! This simple fact implies that Minkowskian regions give imaginary exponent of Chern-Simons term and Euclidian regions real exponent of Chern-Simons term [37]. Under rather natural assumptions the two Chern-Simons terms are identical and would be obtained as an exponent of Chern-Simons term multiplied by complex number.

The imaginary exponent gives rise to interference effects typical for gauge theories and defining the core mechanism of quantum field theories and implies that stationary phase approximation makes sense. Stationary phase approximation is important also in topological QFTs and Chern-Simons term plays the role of Morse function in topological QFTs classifying the topological of 4-manifolds. The real exponent defines Kähler function and guarantees the convergence of the functional integral and guarantees that it exists as a genuine mathematical object.

### 4.6.4 Could Kähler action reduce to a 2-D integral?

Effective 2-dimensionality suggests a further dimensional reduction in the sense that Chern-Simons terms might allow expression as 2-dimensional integrals. If this idea is accepted, the only natural option is a reduction to a sum of areas of string world sheets with dynamical string tension. I have indeed developed a detailed proposal concerning the identification of this string world sheet [35]. String world sheets indeed emerge naturally in quantum TGD and have as their boundary the space-like braid strands at the ends of space-time surfaces and light-like braid strands at the light-like 3-surfaces. Knotting of string world sheets is possible in 4-D space-time whereas braid strands link and knot at 3-surfaces so that quantum TGD would provide a theory of ordinary knots and 2-knots. This adds additional aspect to the statement that TGD is almost topological QFT.

## 4.7 Twistor revolution and TGD

During last decade so called twistor revolution has revived theoretical physics and has also had strong impact on TGD.

### 4.7.1 Twistor revolution

There are classical papers by several authors such as Witten and Nima Arkani-Hamed who is one of the leading theoreticians driving the twistor revolution [3, 5, 4, 2] .

1. The notion of twistor is due to Penrose and is very convenient notion in theories describing massless particles and therefore possessing conformal invariance extending Poincare symmetries by the inclusion of scalings and so called special conformal transformation which is analogous to reflections in spherical mirror.

2. Twistor kinematics means that one can express massless four-momentum and helicity in terms of two massless spinors combining to a twistor living in 4-D complex space which reduces to $CP_3$ because of projective invariance of the description. The beauty of the twistor kinematics is that non-linear action of special conformal transformations linearizes in $CP_3$. What one does is to replace light-like geodesic in Minkowski space with points in the twistor space $CP_3$ whereas the complex lines of $CP_3$ correspond to points of Minkowski space. To be honest, complexified Minkowski space is in question and this is one of the technical difficulties involved.

3. Gauge theories without fermions and scalar fields are such theories and the applications of twistorial methods to $\mathcal{N} = 4$ super-symmetric Yang-Mills theory has produced amazingly strong results demonstrating that Feynman diagrams sum up to stunningly single twistorial expressions. The key idea is that four-dimensional integrals over loop momenta are interpreted as residue integrals in the complexified space of four-momenta so that they reduce to residues from poles. The surprising discovery is that using Yangian invariants one can express the planar loop amplitudes for given number of external states with given helicities and momenta in terms of on mass shell amplitudes for smaller number of particles and with smaller number of loops by using recursion formulas.

4. Twistor revolution has led to a discovery of what is known as dual twistors. The massless momenta associated with incoming states of twistor diagram and expressible in terms of ordinary twistors, can be also expressed as differences of so called region momenta propagating in the edges of polygon characterizing twistor diagram. The massless momenta correspond to intersections of complex lines in what is called momentum twistor space so that one diagram has interpretation also as a diagram in momentum twistor space. The theory possesses conformal invariance also in the momentum twistor space and the two conformal symmetries combine to form a large infinite-dimensional symmetry known as Yangian symmetry [1] associated with the conformal group of Minkowski space.

5. The work of Nima Arkani-Hamed and others [2] has revealed that the integrands for the twistor amplitudes for planar diagrams can be expressed as residue integrals over Grassmannians $G(n, k)$ where $n$ is the number of massless external particles (gluons or gluinos) and $k$ is the number of negative (say) helicities. The integrands appearing in these integrals are Yangian invariants and there are recipes for their construction. The generalization of BCFW formula gives a recursion formula allowing to deduce the l-loop construction to the scattering of n particles with k negative helicities. The vision of Arkani-Hamed is that this approach allows to get rid of space-time altogether.

### 4.7.2 The impact of twistor approach on TGD

Twistor revolution has had also a strong impact on TGD [33, 35, 36].

1. The study of the modified Dirac equations for induced spinors [8] motivated the proposal that the fermions associated with the braid strands accompanying wormhole throats are massless and on mass shell always - even for the internal lines of generalized Feynman diagrams. Since the sign of the energy of internal line can be also negative, wormhole contacts identified as building

bricks of virtual bosons can carry space-like virtual momentum. The condition that all wormhole throats appearing in the loops of generalized Feynman diagrams are on mass shell and massless poses enormously strong constraints on loops and with additional restrictions coming from the geometric picture and Uncertainty Principle one can expect that only finite number of diagrams contributes to a given scattering amplitude so that the diagrammatics should be extremely simple, perhaps much simpler than in twistorial diagrammatics involving infinite number of diagrams labelled by the number of loops.

2. The masslessness of all fermionic braid strands appearing in the diagram makes twistorial approach extremely natural. The problem is only the treatment of massive external particles expressible as bound states of massless fermions and antifermions at wormhole throats. The idea is that the vertices of generalized Feynman diagrams can be interpreted as 3-gons of twistorial diagrams with region momenta describing momentum exchanges between the throats of wormhole contacts. This picture allows to consider the possibility that 3-vertices could be expressible using the same general formulas as used in Grassmannian approach to $\mathcal{N} = 4$ SYM. Kinematical constraints would imply that only a finite number of diagrams would contribute to a give reaction meaning also upper bound on the number of loops.

3. One might of course argue that the massless propagators on mass shell braid strands make the amplitudes infinite. This is not the case since the momentum appearing in the propagators is $M^2$ projection of the momentum for a preferred $M^2 \subset M^4$.

   Generalized Feynman diagrammatics - or rather given $CD$ - involve however a selection of preferred $M^2 \subset M^4$. $M^2$ is forced by number theoretical vision as complex and thus commutative subspace of octonions. Physically $M^2$ is forced by the construction of massless states as the sub-space containing non-physical polarizations. $M^2$ fixes the quantization axes of energy and spin. In generalized Feynman diagrams the propagators for on mass shell states contain only the $M^2$ projection of four-momentum so that the propagators are finite. The modification of gauge conditions to statement that $M^2$ projection of momentum is orthogonal to polarization vector allows massive states for gauge bosons. Lorentz invariance is not broken since one must integrate over all the choices of $M^2$.

### 4.7.3 Could TGD circumvent the difficulties of twistor approach?

The twistor approach has also some problems and TGD allows also to consider solutions to the difficulties of twistorial approach.

1. Twistor approach to $\mathcal{N} = 4$ SYM applies only to planar Feynman diagrams containing no intersecting lines and this restriction interpreted as approximation becomes exact only at the limit when the gauge group becomes infinite-dimensional. One could argue that in TGD string like objects defined by the Kähler magnetic flux tubes are the basic objects and the stringy character makes planar approximation exact. One could also argue that infinite-dimensional symplectic group takes the role of gauge group in TGD. A more convincing argument is that non-planar diagrams are possible but that generalized Feynman diagrams can be regarded as generalizations of knot diagrams. The crossings of the lines are the problem and for knot diagrams there is a recipe for removing the crossings gradually completely and in this manner obtain an expression for knot invariant. Similar un-knotting procedure could make sense also in TGD framework.

2. $\mathcal{N} = 4$ SYM is believed to be ultraviolet finite but twistor approach does not remove the infrared divergences. In TGD framework external particles are bound states of massless particles and this brings in IR cutoff naturally. The upper bound for the size for CDs brings this cutoff in the case of photons, gluons, and gravitons. One implication is that Higgs like states are not needed in TGD framework.

   The recent considerations [36] suggest a more refined view about particle masses. It seem that it is $M^2$ mass squared which is given by stringy mass formula fixed by conformal invariance. If so, p-adic thermodynamics allows to calculate thermal $M^2$ mass squared and this mass squared wold defining the observed mass of the elementary fermion. Fermionic braid strands would be massless in $M^4$ sense. The situation is obviously tricky and the understanding of the role of $M^2$ in TGD framework is one of the basic challenges of the theory.

3. In twistor approach there are also problems with the understanding of renormalization group, which involves momentum scale: this is understandable since conformal invariance does not allow a preferred scale. One should be able to to bring in massive particles without losing the conformal invariance. The fractal hierarchy of CDs within CDs with quantized size scales leads to a detailed proposal for how the vision about p-adic coupling constant evolution is realized for generalized Feynman diagrams [36].

4. The beauty of Feynman graphs is their ability to code unitarity in an elegant manner by using analyticity. Unitarity conditions are obtained simply by considering the discontinuities of the amplitude at cuts associated with on mass shell configurations of momenta. These discontinuities are expressible by putting internal lines on mass shell so that integral over intermediate on mass shell states is obtained. Unitarity is however not manifest in twistor approach.

   The situation is more complex in TGD framework. M-matrices are not unitary and S-matrix is analogous to the phase of a complex number where as the hermitian square root of the density matrix is analogous to its modulus. Therefore unitary is not required at this level. Different M-matrices (allowing also integer powers of $S$) must form an infinite-dimensional Kac Moody type algebra and this gives strong constraints on the amplitudes. How to take into account these constraints should be understood.

5. Locality is not manifest in twistor approach. In other words, for Grassmannian amplitudes the poles do not correspond to single particle propagator poles associated with internal lines as they do in Feynman graphs. TGD is manifestly non-local theory since zero energy states involve partonic 2-surfaces at both light-like boundaries of CD. Also partonic 2-surfaces and braids are non-local objects. Yangian symmetry is manifestly non-local since the generators are multilocal objects and in TGD framework this multilocality generalized since the n points of multilocal generator of Yangian algebra are replaced by n partonic 2-surfaces. Also this aspect should be understand in detail.

Twistor approach combined with the requirement of number theoretic universality realized in terms of quantum arithmetics leads to a rather detailed view about generalized Feynman diagrams [36].

1. One can understand how p-adic length scale hypothesis (stating that primes near powers of two are physically preferred) emerges. This has been one of the main challenges of quantum TGD since 1995 when I performed p-adic mass calculations for the first time.

2. A deep connection with adeles used in Langlands program emerges since the amplitudes can be understood as having values in the tensor product of quantum rationals corresponding to various values of p-adic prime and real amplitudes are obtained by using canonical identification mapping powers of $p$ with their inverses.

3. One implication is that for large primes assignable to elementary particles the convergence in powers of $p$ is extremely fast (one has $p = M_{127} = 2^{127} - 1$ for electron and $p = M_{89}$ for weak gauge bosons!).

## 4.8 Particle physics applications

The attempts to connect TGD to phenomenology involve a lot of guess work since the calculational machinery is not available and the detailed interpretations involve a lot of guess work. Despite these difficulties TGD makes already now an impressive list of new physics predictions [16, 17]. What helps considerably is the strong connection with standard model symmetries. At quantitative level p-adic length scale hypothesis is extremely valuable. The progress at LHC and also in Fermilab has given strong boost to TGD at the level of concrete predictions. The recent discovery of the super-luminal neutrinos gives direct support for the sub-manifold gravity at the level of kinematics [20], which is the most primary level.

There are several basic questions to be answered and answers might emerge in the near future.

### 4.8.1 Does Higgs exist?

Do Higgs or Higgs like particles exist or not and if not what replaces this kind of particles in TGD framework? The situation is not settled here but the simplest scenario supported by ZEO and generalized Feynman diagrammatics is that there are no Higgs like particles and that even photons, gluons, and gravitons have a small mass. Instead of Higgs entire new hadron physics characterized by Mersenne prime $M_{89}$ should become visible at TeV length scale and the recent signal interpreted usually in terms of Higgs particle would correspond to pions of $M_{89}$ physics. There is also other evidence for new meson like states of the new hadron physics [16].

TGD predicts also other analogs of hadron physics: in particular lepto-hadron physics associated with colored excitations of leptons [31]. Also for these empirical support has been accumulating since seventies but has been put under the rug. These states would be necessarily dark matter in the sense that they would correspond to non-standard value of Planck constant.

### 4.8.2 What about SUSY in TGD sense?

What SUSY in TGD sense means and are there any experimental indications for it? TGD predicts super-conformal invariance but it is far from clear whether TGD predicts the counterpart of space-time super-symmetry.

1. Certainly TGD SUSY cannot be $\mathcal{N} = 1$ SUSY of the minimal super-symmetric extension of the standard model since Majorana spinors are not possible in TGD framework since they would break the separate conservation laws for baryon and lepton number. The most general vision is that the fermionic oscillator operators at partonic 2-surfaces act as SUSY generators so that the value of $\mathcal{N}$ is quite high but SUSY is badly broken [16]. For covariantly constant right handed neutrino and antineutrino the breaking of SUSY would be small because these neutrinos do not have electroweak interactions. This would correspond to $\mathcal{N} = 2$ SUSY. The smallest breaking is obtained when one considers only $\mathcal{N} = 1$ multiplets.

2. A rather radical proposal is that the super-partners of fermions have same mass scale as fermions [16]. This makes sense if the super-partners are in non-trivial color partial waves. This is true if the super conformal generators creating them from fermions correspond to color octet representations. This would be a dramatic support for the prediction that color is analogous to orbital angular momentum rather than spin in TGD framework. This would also require squarks to be dark in TGD sense. The strongest support for the non-existence of SUSY in standard sense is the absence of the missing energy singatures at LHC. If spartners are colored, their absence as missing energy can be understood as being due to color confinement forcing the to shadronize and decay eventually to hadrons.

   The mysterious X and Y mesons could be understood in terms of smesons formed from spartners of charged quarks [16]. There is also evidence for exotic satellites of pions and some of them might allow interpretation as spions. The colored leptons giving rise to leptohadrons could be actually colored sleptons. If this interpretation is correct, SUSY would have been observed already at seventies!

### 4.8.3 Is QCD really the final theory of strong interactions?

The common belief is that QCD is *the* theory of strong interactions. But is this really so? The fact is however that non-perturbative QCD remain poorly understood.

1. TGD suggests that color magnetic flux tubes assignable to magnetically charged quarks are necessary to understand low energy hadron physics and one ends up with rather detailed vision about jets, hadronization and fragmentation in terms of flux tubes [36]. These processes assumed in perturbative QCD - or better to say jet-QCD - do not have a real mathematical justification.

2. Also the assumption of preferred plane $M^2$ defining longitudinal momenta of partons is an ad-hoc assumption which in TGD framework is part of the fundamental theory.

3. TGD suggests also an explanation for the already mentioned satellites of pion in terms of excitations of the color magnetic flux tubes as a low energy signature clearly distinguishing between TGD and QCD [16].

4. The quark gluon plasma discovered already in heavy ion collisions at RHIC has been rediscovered heavy ion collisions at LHC and - somewhat surprisingly - also inproton-proton collisions. This phase does not heave like a gas of partons without no long range correlations as QCD would suggest but like a perfect liquid with very small viscosity to entropy density ratio $\eta/s$. It has been thought that this ratio equals to its lower bound deduced by assuming AdS/CFT correspondence. AdS/CFT approach ha however turned out to work poorly as a model for the quark gluon plasma whereas the approach based on Lund string model works well. In TGD framework the picture based on magnetic flux tubes (string like objects) would explain perfect liquid property in terms of long range correlations due to the magnetic flux tubes and also suggests and also the low value of $\eta/s$ ratio. TGD actually allows values which are even smaller than the lower bound from AdS/CFT [16].

#### 4.8.4 Other new physics predictions

It has become clear that TGD makes many other new physics predictions - or safer to say - almost predictions [16]. Some examples.

1. Scaled versions of hadron physics are possible also in non-microscopic length scales. The biologically most interesting length scale range from 10 nm to 5 $\mu$m contains as many as four Gaussian Mersennes which could correspond to scaled up variants of hadron physics so that quark could play key role in the physics of life.

2. There is also evidence for the prediction that fermions can appear in several p-adic length scales: in particular, the masses of low energy hadrons could be understood if quarks appear in several p-adic mass scales. Also neutrinos could appear in several p-adic mass scales.

3. TGD based explanation of family replication phenomenon predicts combinatorial SU(3) symmetry associated with three families so that there should exist gauge boson octet having interpretation as a representation of this symmetry.

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