

Quantum Model for Nerve Pulse and EEG

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Abstract

In this article a unified model of nerve pulse and EEG is discussed.

1. In TGD Universe the function of EEG and its variants is to make possible communications from the cell membrane to the magnetic body and the control of the biological body by the magnetic body via magnetic flux sheets traversing DNA by inducing gene expression. This leads to the notions of super- and hyper-genome predicting coherent gene expression at level of organs and population.
2. The assignment the predicted ranged classical weak and color gauge fields to dark matter hierarchy was a crucial step in the evolution of the model, and led among other things to a model of high T_c superconductivity predicting the basic scales of cell, and also to a generalization of EXG to a hierarchy of ZXGs, WXGs, and GXGs corresponding to Z^0 , W bosons and gluons.
3. Dark matter hierarchy and the associated hierarchy of Planck constants plays a key role in the model. For instance, in the case of EEG Planck constant must be so large that the energies of dark EEG photons are above thermal energy at physiological temperatures. The assumption that a considerable fraction of the ionic currents through the cell membrane are dark currents flowing along the magnetic flux tubes explains the strange findings about ionic currents through cell membrane. Concerning the model of nerve pulse generation, the newest input comes from the model of DNA as a topological quantum computer and experimental findings challenging Hodgkin-Huxley model as even approximate description of the situation.
4. The identification of the cell interior as gel phase containing most of water as structured water around cytoskeleton - rather than water containing bio-molecules as solutes as assumed in Hodgkin-Huxley model - allows to understand many of the anomalous behaviors associated with the cell membrane and also the different densities of ions in the interior and exterior of cell at qualitative level. The proposal of Pollack that basic biological functions involve phase transitions of gel phase generalizes in TGD framework to a proposal that these phase transitions are induced by quantum phase transitions changing the value of Planck constant. In particular, gel-sol phase transition for the peripheral cytoskeleton induced by the primary wave would accompany nerve pulse propagation. This view about nerve pulse is not consistent with Hodgkin-Huxley model.

The model leads to the following picture about nerve pulse and EEG.

1. The system would consist of two superconductors- microtubule space-time sheet and the space-time sheet in cell exterior- connected by Josephson junctions represented by magnetic flux tubes defining also braiding in the model of tqc. The phase difference between two super-conductors would obey Sine-Gordon equation allowing both standing and propagating solitonic solutions. A sequence of rotating gravitational penduli coupled to each other would be the mechanical analog for the system. Soliton sequences having as a mechanical analog penduli rotating with constant velocity but with a constant phase difference between them would generate moving kHz synchronous oscillation. Periodic boundary conditions at the ends of the axon rather than chemistry determine the propagation velocities of kHz waves and kHz synchrony is an automatic consequence since the times taken by the pulses to travel along the axon are multiples of same time unit. Also moving oscillations in EEG range can be considered and would require larger value of Planck constant in accordance with vision about evolution as gradual increase of Planck constant.
2. During nerve pulse one pendulum would be kicked so that it would start to oscillate instead of rotating and this oscillation pattern would move with the velocity of kHz soliton sequence. The velocity of kHz wave and nerve pulse is fixed by periodic boundary

conditions at the ends of the axon implying that the time spent by the nerve pulse in traveling along axon is always a multiple of the same unit: this implies kHz synchrony. The model predicts the value of Planck constant for the magnetic flux tubes associated with Josephson junctions and the predicted force caused by the ionic Josephson currents is of correct order of magnitude for reasonable values of the densities of ions. The model predicts kHz em radiation as Josephson radiation generated by moving soliton sequences. EEG would also correspond to Josephson radiation: it could be generated either by moving or standing soliton sequences (latter are naturally assignable to neuronal cell bodies for which \hbar should be correspondingly larger): synchrony is predicted also now.

Keywords: Topological Geometroynamics, quantum theories of consciousness, nerve pulse, EEG.

1 Introduction

The general vision about living system as a conscious hologram and the view about how "topological light rays" (massless extremals, MEs) serve as remote entanglers and induce self-organization via the leakage of ionic currents between various space-time sheets implies that several space-time sheet pairs are involved with the bio-control. Perhaps the most radical deviation from the standard neuroscience thinking came with the realization that in TGD Universe every physical system has also magnetic/field body of size much larger than the material body and that material bodies can be seen as motor and sensor organs of the personal magnetic body. This counter intuitive conclusion is unavoidable if one accepts many-sheeted macroscopic quantum coherence, Uncertainty Principle and topological field quantization. p-Adic physics as physics of intention and cognition provides an additional support for this view: the smaller the space-time sheet is p-adically, the larger it is in the real sense so that cognition and intentionality are predicted to be astrophysical phenomena and evolve from long to short length and time scales just as it indeed occurs when motor activity is learned.

The TGD based view about dark matter hierarchy involving a hierarchy of values of Planck constant provides a justification for this picture. Dark matter hierarchy corresponds to the hierarchy of moments of consciousness with increasingly long duration with respect to geometric time and defines a hierarchy of conscious entities and reflective levels of consciousness.

Dark matter hierarchy provides a mechanism for the formation of macroscopic and macro-temporal quantum phases in all length scales. The earlier assumption about thermal isolation of space-time sheets corresponding to different p-adic length scales can be given up and thermal stability condition becomes an additional strong constraint allowing to eliminate various options very effectively. Since cyclotron energies scale like \hbar , thermal stability is possible to achieve for them.

The basic idea behind the model of nerve pulse is that some kind of quantum jump reduces the magnitude of membrane potential below the threshold leading to the generation of nerve pulse. Several identifications of this quantum jump have been discussed during years but no really convincing option has been found. The evolution of ideas about dark matter hierarchy and associated hierarchy of Planck constants led to a breakthrough in several sectors. The assignment the predicted ranged classical weak and color gauge fields to dark matter hierarchy was the crucial step and led among other things to a model of high T_c superconductivity predicting the basic scales of cell, to a generalization of the genetic code to a hierarchy of genetic codes, and also to a generalization of EEG to a hierarchy of EEGs, ZEGs, and WEGs and of the colored variant of EEG. The newest input comes from the model of DNA as topological quantum computer and experimental findings challenging Hodgkin-Huxley model as even approximate description of the situation.

1.1 A model for nerve pulse generation and EEG

The model of nerve pulse has developed through several tortuous twists reflecting the development of the basic ideas of TGD inspired theory of consciousness and of bio-systems as macroscopic quantum systems. The chapters about EEG and ZEG provide a necessary background for the model of nerve pulse. The chapters [M4, M5] of [12] written before dark matter revolution provide a detailed discussion of basic aspects of EEG. The newest chapter [M3] related to EEG provides a very general vision about the hierarchy of EEGs based on dark matter hierarchy and about its generalization to ZXG, WXG, and GXG (Z , W , and G denote for dark Z^0 and W bosons and gluons with interaction range which can be arbitrary long at higher levels of dark matter hierarchy). This model relates closely to the model of bio-superconductivity as quantum critical high T_c super-conductivity [J1, J2, J3].

The basic hypothesis has been that quantum jump takes the resting potential below the threshold for the generation of nerve pulse. One can imagine several manners for how this could happen.

Quite recently I learned that nerve pulse propagation seems to be an adiabatic process and thus does not dissipate [46, 47]: the authors propose that 2-D acoustic soliton is in question. Adiabaticity is what one expects if the ionic currents are dark currents (large \hbar and low dissipation) or even supra currents. Furthermore, Josephson currents are oscillatory so that no pumping would be needed. Combining this input with the model of DNA as topological quantum computer (tqc) [19] leads to a rather precise model for the generation of nerve pulse.

1. The system would consist of two superconductors- micro-tubule space-time sheet and the space-time sheet in cell exterior- connected by Josephson junctions represented by magnetic flux tubes defining also braiding in the model of tqc. The phase difference between two super-conductors would obey Sine-Gordon equation allowing both standing and propagating solitonic solutions. A sequence of rotating gravitational penduli coupled to each other would be the mechanical analog for the system. Soliton sequences having as a mechanical analog penduli rotating with constant velocity but with a constant phase difference between nearest neighbors would generate moving kHz synchronous oscillation. Also moving oscillations in EEG range can be considered and would require larger value of Planck constant in accordance with vision about evolution as gradual increase of Planck constant.
2. During nerve pulse one pendulum would be kicked so that it would start to oscillate instead of rotating and this oscillation pattern would move with the velocity of kHz soliton sequence. The velocity of kHz wave and nerve pulse is fixed by periodic boundary conditions at the ends of the axon implying that the time spent by the nerve pulse in traveling along axon is always a multiple of the same unit: this implies kHz synchrony. The model predicts the value of Planck constant for the magnetic flux tubes associated with Josephson junctions and the predicted force caused by the ionic Josephson currents is of correct order of magnitude for reasonable values of the densities of ions. The model predicts kHz em radiation as Josephson radiation generated by moving soliton sequences. EEG would also correspond to Josephson radiation: it could be generated either by moving or standing soliton sequences (latter are naturally assignable to neuronal cell bodies for which \hbar should be correspondingly larger): synchrony is predicted also now.
3. The previous view about micro-tubules in nerve pulse conduction can be sharpened. Micro-tubular electric field (always in the same direction) could explain why kHz and EEG waves and nerve pulse propagate always in same direction and might also feed energy to system so that solitonic velocity could be interpreted as drift velocity. This also inspires a generalization of the model of DNA as tqc since also micro-tubule-cell membrane systems are good candidates for performers of tqc. Cell replication during which DNA is out of game

seems to require this and micro-tubule-cell membrane tqc would represent higher level tqc distinguishing between multi-cellulars and mono-cellulars.

4. New physics would enter in several manners. Ions should form Bose-Einstein cyclotron condensates. The new nuclear physics predicted by TGD predicts that ordinary fermionic ions (such as K^+ , Na^+ , Cl^-) have bosonic chemical equivalents with slightly differing mass number. Anomalies of nuclear physics and cold fusion provide experimental support for the predicted new nuclear physics. Electronic supra current pulse from micro-tubules could induce the kick of pendulum inducing nerve pulse and induce a small heating and expansion of the axon. The return flux of ionic Josephson currents could induce convective cooling of the axonal membrane. A small transfer of small positive charge into the inner lipid layer could induce electronic supra current by attractive Coulomb interaction. The exchange of exotic W bosons which are scaled up variants of ordinary W^\pm bosons is a possible manner to achieve this if new nuclear physics is indeed present.

2. The function of neural transmitters

TGD leads to a general view about the functions of membrane oscillations, nerve pulse and neural transmitters. Electromagnetic membrane oscillations induced might provide a realization of the genetic and even memetic code (chapter *Genes and Memes* of [11]) as a fundamental cognitive code. The binding of various information molecules to the corresponding receptors gives rise to neuronal qualia analogous to tastes and odors but providing information about external world whereas ordinary receptors give information about nearby environment. At our level of hierarchy these qualia could correspond to emotions in consistency with the finding that neurotransmitters can be identified as information molecules. Information molecules might be also seen as classifying the character of information transferred in quantum web in which magnetic flux tubes defined links between sender and receiver: a concrete realization of idea is discussed in [22].

1.2 A model for a hierarchy of EEGs

There are three contributions to EEG besides neural noise: Schumann frequencies, cyclotron frequencies, and the frequencies associated with Josephson junctions determined by the sum of the constant voltage and voltage perturbation determined by the superposition of cyclotron frequencies. Cyclotron contribution can be interpreted as a control signal from a magnetic body in question and affects both the ions at the flux sheets traversing DNA and the Josephson junction. The coherent state of photons generated by Josephson current corresponds to a reaction to this signal received by the magnetic body as a feedback. Schumann frequencies can be assigned to the control by magnetic body of Earth and correlate with the collective aspects of consciousness.

The analysis of the Josephson current leads to the conclusion that the frequencies in the coherent state of photons are in general sums and differences of Josephson frequency and harmonics of cyclotron frequencies. For small amplitudes this implies that alpha band to which the cyclotron frequencies most biologically important bosonic ions has as satellites theta and beta bands. Higher harmonics correspond to gamma and higher bands having also satellites. For large amplitudes EEG becomes chaotic which is indeed the property of beta band during say intense concentration or anxiety. The findings of Nunez about narrow 1-2 Hz wide bands at 3,5,7 Hz and 13,15,17 Hz confirm with the prediction of satellite bands and fix the Josephson frequency to 5 Hz. This picture explains the general characteristics of EEG in wake-up state qualitatively and quantitatively.

In order to understand the characteristics during various stages of deep sleep one must assume that the cyclotron frequency scale of ions is scaled down by a factor of $1/2$. One explanation is that right *resp.* left brain hemisphere corresponds to $Z = 2$ *resp.* $Z = 1$ quantization condition $Z \int B dS = n\hbar$ for the magnetic flux. $Z = 2$ case allows only doubly charged bosonic ions at

magnetic flux sheets. $Z = 1$ case also also singly charged ions be their bosons or fermions and for this option magnetic field is scaled down by a factor of $1/2$. The alternative explanation is that during sleep only Bose-Einstein condensates of singly charged exotic ions resulting when color bond inside nucleus becomes charged are present. This reduces the scale of cyclotron frequencies by a factor $1/2$ and leaves only theta and delta bands. During stage 4 sleep only DNA cyclotron frequencies in delta band are around 1 Hz and just above the thermal threshold are predicted to be present. In the simplified model one has $\hbar/\hbar_0 = 2^{11k_d}$. For $k_d = 3$ and magnetic field scaled up by 2^{11} and flux tube area scaled down by $^{-22}$ DNA frequencies are scaled up to kHz for $Z = 2$ flux quantization and might define neuronal synchronization frequencies.

The generalization of the model for EXG hierarchy to the case of ZXG, WXG, and GXG corresponding to Z^0 boson, W boson, and gluons is straightforward and cyclotron frequency spectrum is essentially the same. Z^0 ions are obtained when nuclear color bonds become charged and the combination of ordinary and exotic ionization can produce also em neutral Z^0 ions. Any atom, almost always boson, has an exotically charged counterpart with same statistics so that very rich spectrum of Bose-Einstein condensates results.

2 Exotic charge transfer between cell interior and exterior as fundamental control mechanism

The notions of ionic channels and pumps associated with the cell membrane are central for the standard cell biology [36]. There are however puzzling observations challenging this dogma and suggesting that the currents between cell interior and exterior have quantum nature and are universal in the sense that they not depend on the cell membrane at all [31, 32, 39, 37, 30]. One of the pioneers in the field has been Gilbert Ling [31], who has devoted for more than three decades to the problem, developed ingenious experiments, and written several books about the topic. The introduction of the book [35]) gives an excellent layman summary about the paradoxical experimental results.

It was a pleasant surprise to find that these experimental findings give direct support for the existence of an exotic charge transfer between cell interior and exterior.

Ionic supra currents and Josephson currents or the exchange of exotic W bosons could be in question. For the first option, the experimental data led to a model for cell homeostasis as a flow equilibrium in which very small densities of super-conducting ions (also molecular ions) and ionic supercurrents at cellular and other super-conducting space-time sheets dictate the corresponding densities at the atomic space-time sheets.

This control mechanism need not be the only one. Magnetic flux tubes serving as colored braid strands connecting different bio-molecules in highly selective manner and phase transitions reducing or increasing \hbar could explain the mysterious precision of bio-catalysis as how the prebiotic evolution has led to the known biology [L7]. Magnetic flux tubes could also act as Josephson junctions between widely separated structures.

2.1 Strange behavior of the intracellular water

The basic strange feature of cellular interior is related to its gelatinous nature and is in fact familiar for everyone. Although 80 percent of hamburger is water, it is extremely difficult to extract this water out. Ling [32] has demonstrated this at cellular level by using a centrifuge and cells for which cell membrane is cut open: centrifugal accelerations as high as 1000 g fail to induce the separation of the intracellular water.

The assumption that cytoplasm behaves like gel explains these findings. Egg is very familiar example of gel phase so that this proposal could have been made already by the pioneers. The

dipolar nature of bio-molecules and induced polarization are basis prerequisites for the formation of gels. Ling raises the cohesion between water and protein molecules caused by electric dipole forces as a fundamental principle and calls this principle association-induction hypothesis [31]. This cohesion gives rise to liquid crystal [40] like structure of water implying among other things layered structures and internal electric fields orthogonal to the plane of the layers [31, 28, 29]. For instance, cell membranes can be understood as resulting from the self-organization of liquid crystals [13]. The fundamental importance of electret nature of biomatter was also realized by Fröhlich [27] and led him to suggest that macroscopic quantum phases of electric dipoles might be possible. This concept, which is in central role in many theories of quantum consciousness, has not been established empirically.

The introduction of (wormhole) magnetic flux tubes with large Planck constant mean of course a considerable generalization of this framework. The flux tubes would provide the mechanism of cohesion not reducible to electromagnetic forces predicted by standard quantum mechanics.

2.2 Are channels and pumps really there?

Standard neurophysiology relies strongly on the concepts of what might be called hydro-electro-chemistry. The development of the theory has occurred through gradual improvements saving the existing theory.

The development began from the basic observation that cells are stable gelatinous entities not mixing with the surrounding water. This led to the hypothesis that cell membrane takes care that the contents of the cell do not mix with the cell exterior. It was however soon found that cell membrane allows some ions to flow through. The interaction between theory and experiment led gradually to the notions of ion channel and ion pump, which are still central for the standard paradigm of the cell [36]. Note that also 'electric pump' taking care that membrane potential is preserved, is needed.

These notions developed gradually during the period when cell was seen as a bag containing water and a mixture of various biochemicals. If cell biology would have started to develop during the latter half of this century and after the discovery of DNA, cell as a computer metaphor might have led to a quite different conceptualization for what happens in the vicinity of the cell membrane. Also the notion of liquid crystals [40] would have probably led to different ideas about how homeostasis between cell interior and exterior is realized [31, 28, 29].

For me it was quite a surprise to find that pump-channel paradigm is not at all so well-established as I had believed as an innocent and ignorant outsider. The first chapter of the book "Cells, Gels and the Engines of Life" of Gerald Pollack [35] provides a summary about the experimental paradoxes (the interested reader can find the first chapter of this book from web).

The standard theoretical picture about cell is based on the observation that cell exterior and interior are in a relative non-equilibrium. The measured concentrations of various atomic ions and organic molecules are in general different in the interior and exterior and cell membrane seems to behave like a semi-permeable membrane. There is also a very strong electric field over the cell membrane. In standard approach, which emerged around 1940, one can understand the situation by assuming that there are cell membrane pumps pumping ions from cell interior to exterior or vice versa and channels through which the ions can leak back. Quite a many candidates for proteins which seem to function like pump and channel proteins have been identified: even a pump protein for water [35]! This does not however prove that pumping and channeling is the main function of these proteins or that they have anything to do with how ionic and molecular concentrations in the interior and exterior of the cell are determined. It could quite well be that pump and channel proteins are receptors involved with the transfer of information rather than charges and only effectively act as pumps and channels.

There are several serious objections of principle against the vision of cell as a bag of water

containing a mixture of chemicals. Even worse, the hypothesis seems to be in conflict with experimental data.

2.2.1 Selectivity problem

Cell membrane is extremely selective and this leads to an inflation in the complexity of channels and pumps. The problem might be christened as a dog-door problem: the door for dog allows also cat go through it. Channels cannot be simple sieves: it is known that channels which let some ions through do not let much smaller ions through. There must be more complicated criteria than geometric size for whether the channel lets the ion go through. Quite generally, channels must be highly selective and this seems to require complicated information processing to decide which ion goes through and which not. As a consequence, the models for channels inflate in their complexity.

2.2.2 Inflation in the number of pumps and channels

Channels and pumps for atomic ions and channels and pumps for an astronomical number of organic molecules are needed. The first question is where to put all those channels and pumps? Of course, one could think that pumps and channels are constructed by the cell only when they are needed. But how does the cell know when a new pump is needed if the cell as never met the molecule in question: for instance, antibiotic or curare molecule?

To realize how weird the picture based on channels and pumps is, it is useful to imagine a hotel in which there is a door for every possible client letting only that client through but no one else. This strange hotel would have separate door for every five point five milliard humans. Alternatively, the building would be in a continual state of renovation, new doors being built and old being blocked.

There is however an TGD based objection against this slightly arrogant argument. In TGD framework cell is a self-organizing structure and it might be that there is some mechanism which forces the cell to produce these pumps and channels by self-organization. Perhaps the basic characteristic of quantum control in many-sheeted space-time is that it somehow forces this kind of miracles to occur.

2.2.3 Why pumping does not stop when metabolism stops?

One can also wonder how metabolism is able to provide the needed energy to this continual construction of pumps and channels and also do the pumping. For instance, sodium pump alone is estimated to take 45-50 per cent of the cell's metabolic energy supply. Ling has studied the viability of the notion of the ionic pump experimentally [31] by exposing cell to a cocktail of metabolic poisons and depriving it from oxygen: this should stop the metabolic activities of the cell and stop also the pumping. Rather remarkably, nothing happened to the concentration gradients! Presumably this is the case also for the membrane potential so that also the notion of metabolically driven electrostatic pumps seems to fail. Of course, some metabolism is needed to keep the equilibrium but the mechanism does not seem to be a molecular mechanism and somehow manages to use extremely small amount of metabolic energy.

2.2.4 How it is possible that ionic currents through silicon rubber membrane are similar to those through cell membrane?

A crucial verification of the channel concept was thought to come in the experiment of Neher and Sakmann [38] (which led to a Nobel prize). The ingenious experimental arrangement was following. A patch of membrane is sucked from the cell and remains stuck on the micropipet orifice. A steady voltage is applied over the patch of the membrane and the resulting current is measured. It was found that the current consists of discrete pulses in consistency with the

assumption that a genuine quantum level current is in question. The observation was taken as a direct evidence for the postulate that the ionic currents through the cell membrane flow through ionic channels.

The later experiments of Fred Sachs [37] however yielded a complete surprise. Sachs found that when the patch of the cell membrane was replaced by a patch of silicon rubber, the discrete currents did not disappear: they remained essentially indistinguishable from cell membrane currents! Even more surprisingly, the silicon rubber membrane showed ion-selectivity features, which were essentially same as those of the cell membrane! Also the currents through synthetic polymer filters [30] were found to have essentially similar properties: as if ion selectivity, reversal potential, and ionic gating would not depend at all on the structure of the membrane and were more or less universal properties. Also experiments with pure lipid-layer membranes [39] containing no channel proteins demonstrated that the basic features – including step conductance changes, flickering, ion selectivity, and in-activation– characterized also cell membranes containing no ionic channels.

The in-escapable conclusion forced by these results seems to be that the existing 60-year old paradigm is somehow wrong. Ionic currents and their properties seem to be universal and depend only on very weakly on the properties of the membrane.

2.3 Cytoplasm as gel

The solution to the above described anomalies proposed by Pollack is that cytoplasm is gel phase [35]. Pollack describes in detail various aspects of cytoplasm as a gel phase and here only short summary can be given.

1. Cytoplasm can be regarded as a network consisting of cross-linked negatively charged proteins. Water is condensed around the proteins to form structured water. If protein is hydrophilic, water self-organizes around it as a multilayered structure: the number of molecular layers can as high as 600 and the thickness of the layered structure is a considerable fraction of micrometer. If the protein is hydrophobic, water forms another structured phase known as clathrate water: in this case the number of hydrogen bonds between water atoms is large. These phases can be regarded as intermediate between ice and water. Also ordinary ions have this kind of layered structure around them. Chemical cross-links tend to be stable with heat, pH, and solvent composition whereas physical cross-links formed by intermolecular interactions are sensitive to environmental interactions and are of special interest from the point of view of phase transitions.
2. Pollack proposes that the formation of polymers takes place in an environment containing layered water for the simple reason that monomers cannot diffuse to the layered water so that the probability of association with the end of the growing polymer increases.
3. Cell interior is populated by micro-tubules, various filamentary structures, and the so called micro-trabecular matrix. Micro-trabecular network divides cell into a compartments in such a manner that the typical distance between two proteins in water is about 5 nm: this corresponds to the p-adic length scale $L(149)$, the thickness of the lipid layer of cell membrane. This is probably not an accident and the micro-trabecular network might be closely involved with the highly folded network of intracellular membranes. There would be a layer of thickness of about 6 water molecules per given protein surface so that a dominating portion of intracellular water could be structured.
4. The layered water has several tell-tale signatures that have been observed in gels. It freezes at much lower temperature than ordinary water; various relaxation times are shorter since the energy transfer to the water lattice occurs faster than to non-structure water; the diffusion rates of particles into the structured water are much slower than to ordinary water by entropy

argument; a simple geometric argument tells that the larger the size of the hydrated ion the lower the diffusion rate; strong gradients of ionic concentrations can form in gel phase as has been observed.

The identification of the cytoplasm as a gel has profound implications for the standard views about cell.

1. The original motivation for postulating semipermeable cell membrane, channels, and pumps was the need to hinder the diffusion of various ions between cell interior and exterior taking place if cytoplasm is ordinary water into which molecules are dissolved. If cytoplasm is in gel phase, cell membrane need not perform pumping and channeling anymore except perhaps in situations involving the formation of a local sol phase. This raises the question about the proper functions of the cell membrane.
2. It is possible to drill to cell membrane holes with size of order $1 \mu\text{m}$ without an appreciable effect on the functioning of the cell and also show that these holes remain as such for long periods of time [35]. It is also possible to splice cells into pieces continuing to function for days. That K^+ flux through cell membrane does not change when lipids are partially removed. These findings force to ask whether the assumption about the continuity of the cell membrane might be too strong [35]. Electron micrographs however demonstrate the presence of the bi-layered structure. What is intriguing that this structure is seen even in the absence of lipid layers. In TGD framework this paradoxical finding might be understood in terms of a presence of space-time sheets corresponding to p-adic length scales $L(k)$, $k = 149, 151$ as vacuum structures predicted also by TGD inspired model of high T_c super-conductivity [J1].
3. There is also the strange finding that water flux through cell membrane is much higher than the flux through isolate lipid bi-layer as if some unidentified channels were present. In TGD framework this might be seen as an evidence for the presence of (wormhole) magnetic flux tubes as carriers of water molecules.
4. The fundamental assumptions about ionic equilibrium must be reconsidered, and the Hodgkin-Huxley model for the generation of nerve pulse becomes more or less obsolete. Indeed, it has been found that action potentials can be generated even in absence of Na^+ and K^+ ions playing a key role in Hodgkin-Huxley model. Rather remarkably, the high concentration of K^+ ions and low concentration of Na_+ ions in cytoplasm could be understood on basis of gel property only. Also a new view about cell potential emerges. The standard paradigm states that the resting potential is over the *cell membrane* rather than over a length scale of cell radius. Potentials of same order of magnitude have been however seen in de-membrated cells (50 mV in slight excess of action potential and critical potential), colloidal suspensions, and gels which suggest that larger part of cell than mere cell membrane is involved with the generation of the action potential and one should thus speak of cell potential instead of membrane potential.
5. Pollack suggests that the phase transitions of the gel phase make possible to realize various functions at molecular and cellular level and represents empirical evidence for the phase transition like aspects assigned to these functions including sensitivity to various factors such as pH, temperature, chemical environment, electromagnetic fields, mechanical forces, etc... and the threshold behavior [35]. Also the responses are typical for phase transitions in that they involve dramatic changes in volume, shape, di-electric constant, etc.. With these motivations Pollack discusses phase transition based models for contraction, motility, secretion, transport or molecules, organized flow of particles during cell division, cell locomotion, contraction of muscle, generation of action potentials, etc.. For instance, the transport of bio-molecules

along micro-tubule could involve propagating gel-sol-gel phase transition meaning also propagating melting of the layered water around micro-tubule.

6. Divalent ions, such as Mg^{++} and Ca^{++} can act as cross links between negatively charged proteins binding them to form networks. Monovalent ions cannot do this. Peripheral cytoskeleton is this kind of network consisting of micro-tubules and actin molecules cross-linked - according to Pollack- by Ca^{++} ions. On the other hand, it is known that Mg^{++} (Ca^{++}) ions dominate in the cell interior (exterior) and that the presence of Ca^{++} ions in the cell exterior is crucial for the generation of nerve pulse. The influx of Na^+ ions having higher affinity to proteins can induce a phase transition to sol-like phase. Pollack suggests a model of nerve pulse based on this mechanism of gel-sol phase transition for peripheral cytoskeleton: this model does not actually explain why Ca^{++} ions in the exterior of axon are necessary.

2.4 TGD based vision inspired by the findings

The vision about dark matter and the model of nerve pulse formulated in terms of Josephson currents brings an additional perspective to the role of pumps and channels and allows to avoid harmony with the standard views about their role.

1. In long length scales visible matter forms roughly 5 per cent of the total amount of matter. In TGD Universe the dark matter would correspond to matter with large Planck constant including dark variants of ordinary elementary particles. In living matter situation could be the same and visible matter could form only a small part of the living matter. Dark matter would be however visible in the sense that it would interact with visible matter via classical electromagnetic fields and photon exchanges with photons suffering Planck constant changing phase transition. Hence one can consider the possibility that most of the biologically important ions and perhaps even molecules reside at the magnetic flux quanta in large \hbar phase.
2. Bosonic ions could form Bose-Einstein condensates at the flux tubes in which case supra currents flowing without any dissipation would be possible. The model for high T_c superconductivity suggests that only electronic and protonic superconductivity are possible at room temperature. If so, Cooper pairs of fermionic ions are excluded. New nuclear physics predicted by TGD could however come in rescue here. The TGD based model for atomic nucleus assumes that nuclei are strings of nucleons connected by color bonds having quark and antiquark at their ends. Also charged color bonds are possible and this means the existence of nuclei with anomalous charge. This makes possible bosonic variants of fermionic ions with different mass number and it would be interesting to check whether biological important ions like Na^+ , Cl^- , and K^+ might actually correspond to this kind of exotic ions.

This leads to the following TGD inspired vision about cell as a gel.

1. DNA as tqc hypothesis and cell membrane as sensory receptor provide possible candidates for the actual functions of the cell membrane and ionic channels and pumps could act as kind of receptors. That standard physics is able to describe gel phase is of course a mere belief and (wormhole) magnetic flux tubes connecting various molecules (DNA, RNA, amino-acids, biologically important ions) would be "new physics" cross-links could explain the strong correlations between distant molecules of the gel phase.
2. Dark ionic currents are quantal currents. If the dark ions flow along magnetic or wormhole magnetic flux tubes connecting cell interior and exterior, their currents through cell membrane would be same as through an artificial membrane.

3. Pumps and channels could serve the role of sensory receptors by allowing to take samples about the chemical environment. Proteins could act as pumps and channels in sol phase if magnetic flux tubes are absent in this phase since also in TGD Universe homeostasis and its control at the level of visible matter in sol phase might requires them. The metabolic energy needed for this purpose would be however dramatically smaller and a reliable estimate for this would allow an estimate of the portion of dark matter in living systems.
4. Quantum criticality suggests that the phase transitions for the gel phase are induced by quantum phase transitions changing the value of Planck constant for magnetic flux tubes and inducing the change of the length of the flux tube. Macroscopic quantum coherence would explain the observed co-operativity aspect of the phase transitions. Concerning locomotion and transport mountain climbing using pickaxe and rope inspires a guess for a general mechanism. For instance, a packet of molecules moving along actin molecule or a molecule carrying a cargo along micro-tubule could repeat a simple basic step in which a magnetic flux tube with large \hbar is shot along the direction of the electric field along micro-tubule and stuck to a ratchet followed by a phase transition reducing the value of \hbar and shortening the flux tube and forcing the cargo to move forward. The metabolic energy might be provided by the micro-tubule rather than molecular motor.
5. The reconnection of flux tubes would be a second phase transition of this kind. This phase transition could lead from a phase in phase proteins are unfolded with flux tubes connecting amino-acids to water molecules and thus possessing a large volume of layered water around them to a phase in which they become folded and flux tubes connect amino-acids to each other in the interior of protein. The phase transition could be associated with the contraction of connecting filaments of muscle cell. The phase transitions are also seen in "artificial protein" gels used for drug delivery applications, and are built from polymers arranged in alpha helices, beta sheets and common protein motifs [35]. If wormhole magnetic flux are taken as a basic prerequisite of life, one must ask whether these "artificial proteins" represent artificial life.
6. The fact that cytoskeleton rather than only cell membrane is involved with the generation of action potential conforms with the idea that nerve pulse propagating along axon involves also axonal micro-tubules and that Josephson currents between axon and micro-tubules are involved in the process.
7. Di-valent ions (Ca^{++} ions according to Pollack) serve as cross links in the peripheral cytoskeleton. The influx of monovalent ions from the exterior of the axon induces gel-sol phase transition replacing di-valent ions with monovalent ions and the disappearance of cross links. \hbar changing phase transitions and reconnection of flux tube are the basic candidates for the mechanisms involved. Assume that n-valency means that n flux tubes can enter to or leave the ion.
 - i) \hbar increasing phase transition would allow the flow of the monovalent ions like Na^+ from the cell exterior along the magnetic flux tubes connecting axonal interior and exterior. Suppose that in the original situation the flux tubes end to the axonal membrane (this is not the only possibility, they could also end to Ca^{++} ions in cell interior). The flux tubes extending to the axonal exterior could result by \hbar increasing phase transition increasing the length of the flux tubes connecting peripheral cytoskeleton to the axonal membrane. In this model the very slow diffusion rate of the ions to gel phase would have explanation in terms of new physics involving dark matter and (wormhole) magnetic flux tubes.
 - ii) Cross-linking divalent ions such as Ca^{++} or Mg^{++} would be connected by two flux tubes to amino-acids of two negatively charged proteins whereas monovalent biological ions like Na^+ would have only single flux tube of this kind and could not serve as cross links. In the phase

transitions removing the cross links the replacement of divalent ion with two monovalent positively charged ions would take place. The removal of amino-acid Ca^{++} cross links would involve reconnection process in which amino-acid- Ca^{++} flux tubes would reconnect with flux tubes ending to Na^+ ions.

8. The increase of the Planck constant would induce the expansion of the peripheral cytoskeleton making possible the inflow of Na^+ ions, and divalent ions binding negatively charged actin molecules to a network would be replaced with inflowing Na^+ ions. After this a reverse phase transition would occur. Both phase transitions could be induced by a quantal control signal (Josephson current) inducing quantum criticality and a change of Planck constant.
9. A propagating Ca^{++} wave inducing the gel-sol-gel phase transition of peripheral cytoskeleton would accompany nerve pulse. Quite generally, Ca^{++} waves are known to play a fundamental role in living matter as kind of biological rhythms. Irrespective of whether one believes option i) or ii), this might relate to the cross-linking by flux tubes and gel-sol-gel phase transitions induce by phase transitions increasing Planck constant temporarily. The velocities and oscillation periods of Ca^{++} waves vary in an extremely wide range: this can be understood if the flux tubes involved correspond to a very wide spectrum of Planck constant.

To sum up, the strange discoveries about the behavior of cell membrane provide direct experimental evidence for the presence of dark matter in living systems, for the prediction that it interacts with ordinary matter via classical electromagnetic fields, and for the assumption that it does not dissipate appreciably and could therefore have large value of \hbar and form macroscopic quantum phases.

3 TGD based model of nerve pulse and EEG

The model of nerve pulse described below can be motivated by the observed adiabaticity of the nerve pulse and by the strange findings about ionic currents associated with the cell membrane and by the model of Danish researchers for the nerve pulse [56, 46, 47]. The model involves also a fusion of various ideas of earlier models. In particular, Josephson currents and solitons are in a key role in the model but with the necessary flexibility brought in by the hierarchy of Planck constants. The model of nerve pulse by Pollack [35] discussed at the end of previous section allows to understand the behavior of ionic currents quantitatively.

3.1 Soliton model of nerve pulse

Let us first briefly summarize soliton model of nerve pulse proposed by Danish researchers [56, 46, 47, 44].

1. The temperature of the axon is slightly above the critical temperature T_c for the phase transition leading from crystal like state of the lipid layers to a liquid crystal state. Near criticality the elastic constants and heat capacity of the membrane vary strongly and have maxima at criticality so that also sound velocity varies strongly near criticality. Also the relaxation times are long. There is also dispersion present meaning that the frequency of sound wave depends nonlinearly on wave vector. Non-linearity and dispersion are prerequisites for the presence of solitons which by definition do not dissipate energy.
2. Variations of temperature, volume, area, and thickness and also other mechanical effects are known to accompany nerve pulse propagation. It is also known that the heat density and temperature of the cell membrane increases slightly first and is then reduced. This

suggests adiabaticity in average sense. These findings motivate the assumption that nerve pulse actually corresponds to acoustic soliton [46, 47].

3. Soliton model reproduces correctly the velocity of nerve pulse inside myelin sheaths but it is not clear to me how well the much lower conduction velocity in non-myelin sheathed regions is reproduced. It is not clear how the lower values of the conduction velocity and its proportionality to the axonal radius in non-myelinated regions can be understood. Intuitively it however seems clear that the lower velocity is due to the feedback from the interaction of ions with the region exterior to cell membrane. In the case of myelin sheaths the conduction of nerve pulse is usually believed to take place via saltation [55]: the depolarization induced at Ranvier node is believed to be enough to take the membrane potential below critical value in the next node so that nerve pulse hops between the nodes. Insulation would improve the insulation and make this process possible. The reversible heat transfer process is however known to be present also in the myelinated portions of axon so that there must be a pulse propagating also in these regions [47]. It is not clear how the myelin sheet can increase the velocity in the soliton model but the reduction of the feedback inducing friction suggests itself.
4. Soliton property predicts adiabaticity. Ordinary ionic currents however dissipate so that adiabaticity assumption is questionable in standard physics context. The model does not predict the growth of entropy followed by its reduction. This behavior is consistent with adiabaticity in a time resolution of order millisecond.
5. The estimate for the capacitor energy density during the nerve pulse is considerably smaller than the energy density is many times magnitude smaller than that of the acoustic wave. This might allow to demonstrate that Hodgkin-Huxley model is not a complete description of the situation.
6. Authors notice [46, 47] that the shapes of the curves representing solitonic energy density and the capacitor energy density as a function of time are essentially identical. Same applies to the experimentally deduced heat change release curve and capacitor energy density for garfish axon. Also heat release and the deviation of the membrane potential from its resting value are in exact phase. These similarities could reflect a control signal responsible for the nerve pulse originating somewhere else, perhaps at micro-tubules. This could explain why secondary nerve pulse is not generated immediately after the first one although the temperature is slightly lower after the pulse than before it. This could of course be also due to the exhaustion of the metabolic resources.

3.2 Consistency with the absence of dissipative currents through the axonal membrane

The basic inputs of the TGD based model are following.

1. The presence of acoustic soliton or density pulse proposed by Danish researchers [47] looks plausible but a more fundamental quantum control mechanism inducing the acoustic soliton cannot be excluded. Among other things this should explain why acoustic solitons propagate always in the same direction. In particular, one can consider a soliton like excitation (say breather for Sine-Gordon equation) associated with the electronic or ionic Josephson currents running along magnetic flux tubes. The strange effects associated with the ionic currents through the cell membrane suggest quite generally that at least weak ionic currents through normal cell membrane are non-dissipative quantal currents. The adiabaticity of the nerve pulse suggests that also strong ionic currents are quantal.

2. Strong ionic currents generating nerve pulse through axonal membrane are absent in the resting state. The naive explanation is simple: the life time of the magnetic flux tubes connecting the axonal interior to the exterior is short or the flux tubes are altogether absent. The observation that Josephson currents in constant voltage are automatically periodic suggests a less naive explanation allowing the flux tubes to be present all the time. The presence of ionic Josephson currents predicts a small amplitude oscillation of membrane potential for which 1 kHz synchronous oscillation is a natural identification. Josephson oscillation correspond naturally to propagating soliton sequences for Sine-Gordon equation. The dynamics of the simplest modes is equivalent to the rotational motion of gravitational pendulum: the oscillation of membrane potential corresponds to the variation of $d\Phi/dt \propto V$. Note that if axon is above the melting temperature, the lipid layer is in gel phase and fluid motion is impossible. The surface density of lipids is dramatically reduced at criticality so that lipid layers behave like fluids [47]. This means that tqc is not possible by the braiding of lipids.
3. Nerve pulse is generated when the magnitude of the negative membrane potential is reduced below the critical value. Generation of the nerve pulse is like a kick to a rotating gravitational pendulum changing the sign of $\Omega = d\Phi/dt$ so that rotational motion is transformed to oscillatory motion lasting for about the period of rotation. An opposite but slightly stronger kick must reduce the situation to the original one but with a slightly higher value of Ω . These kicks could correspond to voltage pulse between micro-tubules and inner lipid layer of cell membrane induced by the addition of small positive (negative) charge on lipid layer. This pulse would induce electronic DC Josephson current inducing the kick and thus reducing V . The exchange of scaled variants of W bosons (assignable to W MEs) could mediate the transfer of charge through the cell membrane and reduce the membrane potential below the critical value but one can consider also other mechanisms.
4. The conservative option would be that ordinary ionic currents take care of the rest and Hogkin-Huxley model applies. This was assumed in the earliest model in which soliton sequence for Josephson current was assumed to induce nerve pulse sequence: in the recent model this assumption does not make sense. The findings of Danish researchers do not however support the conservative option [47]. Nerve pulse could be due to dark ionic (possibly supra -) currents with large \hbar with a low dissipation rate. Their flow would be made possible by the presence of magnetic flux tubes connecting cell interior and exterior.

3.3 The relation to the model of Pollack

In the model of Pollack [35] for the action potential gel-sol-gel phase transition for the peripheral cytoskeleton accompanies the generation of the action potential. The model allows to understand reasonably well the behavior and the physical role of the ionic currents and explains various anomalies. Using pendulum analogy, the kick to the rotating pendulum representing Josephson junction would force it to an oscillatory motion inducing a gel-sol-gel phase transition propagating along the peripheral cytoskeleton.

The challenge is to understand how quantum criticality making possible the phase transition is induced.

1. The primary Josephson currents from the micro-tubuli to the axonal membrane would reduce the magnitude of the cell potential below the critical value (slowing down of the pendulum rotation). This should somehow take the peripheral cytoskeleton near to quantum criticality and induce the increase of Planck constant for the flux tubes connecting peripheral cytoskeleton to the axonal membrane and increasing their length so that they would extend to axonal exterior. This would make possible the flow of monovalent dark ions (say Na^+) from the axonal exterior replacing Ca^{++} acting as cross links between negatively charged proteins and

in this manner induce gel-sol phase transition. The reverse phase transition would reduce Planck constant. If ionic currents are non-dissipative they flow back automatically much like oscillating Josephson currents.

2. There are two forms of quantum criticality corresponding to critical sub-manifolds $M^2 \times CP_2$ and $M^4 \times S^2$, where $M^2 \subset M^4$ has interpretation as plane of non-physical polarizations and $S^2 \subset CP_2$ is a homologically trivial geodesic sphere of CP_2 with vanishing induced Kähler form (see the Appendix of [L7]). The latter kind of quantum criticality corresponds to very weak induced Kähler fields and thus to almost vacuum extremals. Given electromagnetic field can be imbedded as a 4-surface in many manners: as a vacuum extremal, as a non-vacuum extremal maximizing Kähler electric energy, or something between them.
3. Quantum criticality suggests that em fields in the cell interior correspond to nearly vanishing induced Kähler fields and that in the resting state the em fields at cell membrane and peripheral cytoskeleton correspond to strong Kähler fields. The magnitude of the cell potential in the absence of the membrane is about .05 V and slightly below the magnitude of the critical potential [35]. Hence the reduction of the magnitude of Kähler voltage between the inner boundary of the peripheral cytoskeleton and cell exterior to a small enough value but increasing em voltage could induce quantum criticality making possible \hbar increasing phase transition for the magnetic flux tubes connecting peripheral cytoskeleton to the axonal membrane. This framework also allows to understand the paradoxical fact that a reduction of the magnitude of the cell potential induces the action potential rather than its increase as the naive idea about di-electric breakdown would suggest.
4. The energy of the Josephson photon associated with cell membrane Josephson junction is about .05 eV at criticality for the generation of action potential. This is not too far from the value of the metabolic energy quantum liberated in the dropping of proton Cooper pair from $k = 139$ atomic space-time sheet or of electron Cooper pair from $k = 151$ cell membrane space-time sheet to a much larger space-time sheet. This leads to the idea that phase conjugate IR photons of Josephson radiation couple resonantly to the gel defined by the peripheral cytoskeleton and induce fast dropping of protons to larger space-time sheets and that this in turn induces the increase of Planck constant for magnetic flux tubes inducing gel-to-sol phase transition. This idea has been discussed already earlier and will be reconsidered in the section where the relationship of the model with microtubular level is discussed.
5. A comment relating this picture to DNA as tqc model is in order. The basic difference between TGD and standard model is that color rotations leave invariant the induced Kähler field but affect electro-weak gauge fields. In particular, color rotations change the intensity of em field by transforming em and Z^0 fluxes to each other. The most elegant variant of the model of DNA as tqc replaces qubit with qutrit (true/false/undefined) presented as color triplet of quarks associated with the (wormhole) magnetic flux tubes connecting nucleotides with lipids [L7]. Hence the color rotations representing basic 1-gates would not affect induced Kähler fields and cannot induce phase transitions although they would affect cell potential. For 2-gate represented by the basic braiding operation permuting the ends of the neighboring strands the situation is different. Quantum criticality would make possible the generation of braiding by taking cell membrane to liquid state. The discussion about the effects of anesthetics in the sequel forces however to conclude that in the liquid crystal state action potentials are not possible. Propagating action potentials could however represent tqc programs as time-like braidings if it is microtubular surface that suffers a gel-sol-gel transition during the nerve pulse.

3.4 Could Hodgkin-Huxley model provide a phenomenological description?

The physics behind Hodgkin-Huxley model is not consistent with the physics behind the TGD based model of nerve pulse. The cell as gel hypothesis excludes Hodgkin-Huxley model even without any TGD based physics. If ionic currents were ordinary Ohmic currents as in the case of soliton model and Pollack's model, Hodgkin-Huxley model might be interpreted as a phenomenological description. In TGD framework the dark currents do not dissipate and the model can serve only a recipe to mimic the time evolution of the ionic currents by a judicious tailoring of the time dependence of ionic conductances.

The current associated with a given ion would be proportional to the sum of the electric forces experienced by the particle:

$$I_X = g_X [Q_X e (V_{em} - V_X)] .$$

In the catastrophe theoretic variant of the Hodgkin-Huxley model [25], which assumes a wave (Ca^{++} now) triggering the nerve pulse, the values of the ionic conductivities g_{Na} , g_{Cl} and g_K at resting state are $g_{Na} = 0$, $g_{Cl} = .15 \text{ mmho/cm}^2$ and $g_K = .24 \text{ mmho/cm}^2$. The values of V_X are $V_K = -77$, $v_{Na} = +50$, $v_{Cl} = -46$, when millivolt is used as unit. The value of the resting potential is $v_R = -65 \text{ mV}$. The vanishing of g_{Na} at the resting value and down to the point, when nerve pulse is triggered, is assumed in Hodgkin-Huxley model and in the catastrophe theoretic model of the nerve pulse [25]. The vanishing of g_{Na} codes for the absence of magnetic flux tubes in TGD framework.

3.5 What the replacement of Ohmic ionic currents with quantal currents means?

Before the replacement of Hodgkin-Huxley model with a genuinely quantal model can be taken seriously, one must answer many difficult questions which also Hodgkin and Huxley must have faced as they developed their own model.

3.5.1 Questions about resting potential

Q: In the resting state membrane potential is negative and cell has a negative net charge. What stabilizes the cell against the leakage of the negative charge if pumps and channels are not responsible for this?

A: The findings about the strange behavior of cell membrane inspire TGD based answer. Cell membrane space-time sheet is its own quantum world and the flow of ions occurs only in the presence of magnetic flux tubes connecting it to the external world. These currents are however oscillatory Josephson currents if dissipation is absent. Hence there is no need to cut completely the connections to the external world.

Q: How the resting state can result spontaneously if pumps are absent?

A: If ionic currents are Josephson currents, they are automatically oscillating and the return to the original state is guaranteed. The flux tubes carrying the ionic currents will be assumed to connect axonal micro-tubules to the space-time sheet of the cell interior. Consider first the most obvious objections.

1. Dark ions cannot transform to ordinary ones in the exterior of the cell membrane. This might indeed kill the model.

2. All biologically important ions are not bosons and the model for high T_c super-conductor in its recent form allows only electronic and protonic Cooper pairs at room temperature [J1]. TGD based nuclear physics however predicts the possibility of exotic nuclei for which one or more color bonds connecting nucleons to the nuclear string are charged. These exotic nuclei with electronic states identical to those of genuine ions could save the situation.

The table below describes how cyclotron frequencies for $B = .2$ Gauss of the most important ions are modified in the simplest replacements with exotic ions. For instance, the notation Mg_-^{++} tells that there is double electronic ionization and electron shell of Argon as usual but that one color bond is negatively charged.

<i>Ion</i>	<i>f_c/Hz</i>	<i>Pseudo-ion</i>	<i>f_c/Hz</i>
$^{23}Na^+$	13.1	$^{19}Ne_+$	15.7
$^{23}Na^+$	13.1	$^{24}Mg_-^{++}$	12.5
$^{39}K^+$	7.7	$^{40}A_+$	7.5
$^{39}K^+$	7.7	$^{40}Ca_-^{++}$	7.5
$^{35}Cl^-$	8.6	$^{40}A_-$	7.5

(1)

$f_c(K^+)$ and $f_c(Cl^-)$ are replaced with the frequency 7.5 Hz and one can do only using the cyclotron frequencies $f(Ca^{++})/2 = 7.5$ Hz, $f_c(Mg^{++}) = 12.5$ Hz, and $f(Ca^{++}) = 15$ Hz. The nominal values of the lowest Schumann frequencies are 7.8 Hz and 14.3 Hz. All ions with relevance for nerve pulse and EEG could be bosonic ions or bosonic pseudo-ions. I do not know how well the needed ionization mechanisms are understood in the standard framework.

For small oscillations the maximal charge transfer ΔQ generated by an oscillating ionic Josephson current during the cycle is proportional to $\hbar/f_J \propto \hbar^2$ and $\hbar/\Omega \propto \hbar$ for solitonic situation. ΔQ is very small for the ordinary value of \hbar : also the oscillation period is very small. For large values of \hbar situation changes and large maximal ion transfers are possible. An \hbar increasing phase transition could be involved with the generation of the nerve pulse. Quantum criticality during nerve pulse generation indeed suggest the presence of flux tubes with varying values of \hbar . The lifetimes of the connected flux tubes could be proportional to \hbar at criticality. A fractal hierarchy of pulses and EEG like oscillations of the membrane potential corresponding to various values of \hbar is suggestive.

3.5.2 More quantitative picture

One can construct a model based on Sine-Gordon wave equation for the phase difference Φ between the superconductors connected by Josephson junction sequences defined by magnetic flux tubes and idealizable as a continuous Josephson junction.

1. For a Josephson junction idealizable as a hollow cylinder with radius R and thickness d the expression of the Josephson current reads as

$$J = J_0 \sin(Ze \int V dt / \hbar) .$$

J_0 is in the case of cell membrane given by

$$J_0 = \frac{Ze2\pi dR}{\Lambda^2} \frac{\hbar}{m} ,$$

where R and d would be now the radius and thickness of the axon, Λ is the magnetic penetration length, and m is the mass of the charge carrier. Although this expression does not

hold true as such when Josephson junctions are replaced by magnetic flux tubes connecting micro-tubules and axon, one can safely make some qualitative conclusions. The amplitude of the Josephson current increases with \hbar . For electron the value of the amplitude is by a factor $x \simeq Am_p/m_e \simeq 2^{11}A$ larger than for ion with a mass number A . This gives for electron Cooper pairs a unique role as an initiator of the nerve pulse. Note that the amplitudes of the Josephson currents of electron and ions are quite near to each other if one has $\hbar(\text{ion}) = 2^{11}A\hbar e$: this might explain why the powers of 2^{11} for \hbar seem to be favored.

2. Electronic Josephson current dominates and makes it ideal for the generation of nerve pulse (kick to gravitational pendulum). This is possible if the net amount of electronic charge is so small that it flows out during the generation of flux tubes. For ions this need not occur even if ion densities are of same order of magnitude. Constant voltage V creates an oscillating current and no catastrophic leakage takes place and the resting state results automatically. The ionic Josephson currents assignable to the magnetic flux tubes connecting micro-tubules through the cell membrane to the external world could be responsible for the nerve pulse.
3. The mechanical analog for Sine-Gordon system [26] assignable to Josephson junction is rotating pendulum but one must be cautious in applying this analogy. There are two options concerning the modeling of the situation.
 - i) Membrane potential represents an external voltage $V(t)$ and one has $\Phi_i = Z_i e \int V dt / \hbar$, where Φ is the phase difference between Bose-Einstein condensates.
 - ii) System is autonomous and membrane potential $V(t) = \hbar(d\Phi_i/dt)/Z_i e$ is completely determined by the dynamics of any phase Φ_i . This option is highly predictive and discussed in the sequel.
4. The analogy with gravitational pendulum allows to identify the phase angle Φ as the counterpart of angle Θ characterizing angular position of mathematical pendulum (note that this analogy can be misleading since it implicitly brings in 3-D thinking).
 - i) In this picture rotating pendulum corresponds to a soliton sequence containing infinite number of solitons: both stationary and moving soliton sequences are obtained. The sign of $\Omega = d\Phi/dt$ is fixed and approximately constant for large values of Ω . Resting potential could correspond to this kind of situation and $\Omega \simeq 2\pi$ kHz is suggested by kHz synchrony. A mechanism of this synchrony will be discussed below. For large values of \hbar even values of Ω in EEG range could correspond to membrane potential. For large values of Ω one as $V \simeq \hbar\Omega_i/Z_i e$. If also EEG rhythms correspond to Ω they must correspond to different values of \hbar and $f \propto 1/\hbar$ would hold true. Changes in the dominating EEG rhythm (40 Hz, 10 Hz, 5 Hz,...) could correspond to phase transitions changing \hbar to given value for a large number of axons. The maximal charge transfer during single period is proportional to $\Delta Q \propto 1/\Omega$.
 - ii) Hyperpolarization/polarization would mean fastening/slowing down of the pendulum rotation and slowing down would make the system unstable. Near criticality against the generation of nerve pulse would mean that pendulum is rotating rather slowly ($\Omega \ll f_J$) so that a small kick can transform rotation to oscillation. The sign of $V \propto d\Phi/dt$ would change and large amplitude oscillatory motion would result for single period only after which a kick in opposite direction would lead back to the resting state. Membrane potential varies between the resting potential $V_0 = -75$ V and $V_1 = +40$ V during nerve pulse: $V_1 > |V_0|$ would have killed the model. Note that $V_1 = 40$ V is rather near to the critical potential about $V_1 = 50$ V: ideally these potentials should be identical.
 - iii) The so called breathers -both stationary and moving- correspond to soliton-antisoliton bound state (see the visualization in [26]). Breathers could be identified as large amplitude

oscillations around $\Phi = 0$ ground state. Physical intuition suggests that breathers are possible also for a ground state corresponding to a rotating pendulum (representing moving or stationary waves). They would correspond to kicking of one pendulum in a sequence of pendulums along z-axis rotating in phase at the initial moment. The kick could correspond to a genuine external perturbation generated by a pair electronic supra current pulses of opposite sign giving constant velocity increments $\Delta\Omega$ initiating and halting the nerve pulse just like they would do in the case of tqc but in opposite time order. If the background corresponds to a propagating EEG wave, also nerve pulse is expected to propagate with the same velocity. The propagation direction of EEG wave would also explain why nerve pulses propagate only in single direction.

5. For the ordinary value of \hbar , the frequency Ω of the Josephson current corresponds to that assignable to energy .07 eV being around $f = 1.6 \times 10^{13}$ Hz and quite high. For $x \equiv \hbar/\hbar_0 = 2^{44}$ the frequency would be near to cyclotron frequency of about 1 Hz assignable to DNA strands. For $x = 3 \times 2^{3 \times 13}$ f would be near to the fundamental 10 Hz frequency which is secondary p-adic time scale associated with electron and correspond to the temporal duration of negative energy space-time sheet assignable to electron. For $x = 3 \times 2^{3 \times 11}$ one would obtain a 640 Hz frequency which corresponds to the time scale of nerve pulse. It seems clear that the original hypothesis that only powers of 2^{11} define the spectrum of Planck constant is too restrictive. The requirement that cyclotron frequencies and Josephson frequencies are proportional to each other for small oscillations would guarantee resonant behavior for common strength of the magnetic field would give $\hbar \propto A$. This would require that each ion species lives at its own flux tubes.

3.5.3 Questions about axonal instability

Q: What instabilizes the axon? Why the reduction rather than increase of the magnitude of the membrane potential induces the instability? Why the reduction of the resting potential below the critical value induces nerve pulse?

A: Large enough voltage pulse between micro-tubules and membrane could generate electronic DC supra current. The introduction of a small amount of positive charge to the inner lipid layer and staying there for some time would generate the voltage pulse between micro-tubules and lipid layer so that DC electronic supra current would be induced, and induce the reduction $\Delta V \simeq .02$ eV of the magnitude of the membrane potential. A similar introduction of negative charge would induce hyperpolarization and the direction of the current would be opposite if it is generated at all. The mechanism generating the small positive charge to the inner lipid layer could be based on the exchange of exotic W bosons between pairs of exotic nuclei at opposite sides of the cell membrane so that the negative charge of the inner lipid layer would be reduced.

Q: Can one understand the observed radial force, the increase of the radius of axons and the reduction of its thickness, and heating followed by cooling?

A: The observed outward force acting on a test system might be due to the ionic Josephson currents to which the test system responds. During the second half of the pulse the sign of the ionic force is predicted to change. The pressure caused by the electronic Josephson current pulse might relate to the increase of the radius of the axonal membrane and with the reduction of its thickness as well as the slight increase of its temperature as being due to the electrons which heat the lipid layer as they collide with it. The ions return at the second half of the pulse and could transfer the heat away by convection.

1. This hypothesis gives the estimate for the force f per unit area as

$$\begin{aligned}
f_{2e}(t) &= \frac{dn(\text{lipid})}{da} \times \frac{J(t)}{2e} \times \hbar k \\
&= \frac{dn}{da} \times U \times \frac{\hbar^2 k}{2m_e c} \times \sin(\omega_J(2e)t) , \\
U &= \frac{2\pi A}{\Lambda^2} .
\end{aligned} \tag{2}$$

The parameter A corresponds to the parameter dR in the case that Josephson junctions have the thickness of axonal membrane, and is not relevant for order of magnitude estimate. R corresponds to the distance between micro-tubules and cell exterior space-time sheet to which flux tubes end. $dn(\text{lipid})/da$ is the 2-D density Josephson junctions equal to the density of lipids.

$k \simeq 2\pi/R$ is the wave vector of electron Cooper pair at the magnetic flux tube. The 3-momentum of electron is enormous for the proposed value of \hbar , and the only possible interpretation is that the four-momentum of electron is virtual and space-like and corresponds to exchange of space-like virtual photon describing Coulomb interaction with lipid layer.

Λ^2 satisfies in the first approximation the formula

$$\Lambda^{-2} = \frac{4\pi e^2 n_e}{m_e} + \sum_I \frac{4\pi e^2 n_I}{A m_I} = \alpha_{em} 16\pi^2 \times \left[\frac{\hbar_0 n_e}{m_e} + \sum_I \frac{\hbar_0 n_I}{A_I m_I} \right] . \tag{3}$$

Note that there is no real dependence on \hbar . Above critical voltage electrons could dominate in the expression but during nerve pulse ions should give the dominating contributions. U cannot be too far from unity.

2. From this one can integrate the total momentum of Cooper pairs transferred to the lipid layer before the flux tubes fuse together if one knows the value of time t when this happens. $F \propto \hbar^2/m_e^2$ proportionality implies that for the required large value of $\hbar/\hbar_0 \simeq 3 \times 2^{33}$ the force is by a factor 6×10^{20} stronger than for \hbar_0 .
3. The force caused by ionic Josephson currents on piston is given by

$$f(t) = \sum_I \frac{2me}{m_I} \frac{2}{Z_I} \times f_{2e}\left(\frac{Z_I}{2} \frac{\Omega}{\omega_J} t\right) . \tag{4}$$

The comparison with the observed force gives estimate for the value of magnetic penetration length and thus density of electrons at the flux tube.

4. According to [47] in one particular experiment the force on piston of area $S = .01 \text{ cm}^2$ at the maximum of voltage ($t = 2\pi/\Omega$) is $F = 2 \text{ nN}$. This gives a killer test for the model. One obtains an estimate for the parameter $U = \frac{\Lambda^2}{2\pi A}$ as

$$U \equiv \frac{\Lambda^2}{2\pi A} = \frac{dn}{da} S \times \frac{\hbar^2 k}{m_p c F} \times \sum_I \frac{2}{A_I Z_I} . \tag{5}$$

The value of U should not deviate too much from unity. One can use the estimates

$$\frac{\hbar}{\hbar_0} = 3 \times 2^{33} , \quad k = \frac{2\pi}{R} .$$

Note that the experimental arrangement forces to use this value of k . The actual value in normal situation could be smaller and depends on the distance of the boundary of cell exterior space-time sheet on micro-tubules. Using the values $d = 10$ nm and $R = 5$ μ m this gives

$$U \simeq \sum_I \frac{2}{A_I Z_I} \times X ,$$

$$X = 9 \times 2^{66} \times \frac{\hbar_0^2 2\pi}{m_p c F R} \times \frac{S}{S(\text{lipid})} . \quad (6)$$

The factor $X = .9267$ is of order unity! Taking into account that \hbar/\hbar_0 is enormously large number it is difficult to believe that the result could be mere accident. Hence U does not deviate too much from unity and there are good hopes that the model works.

For $n_I = x_I/a^3$, $a = 10^{-10}$ m, and $A = dR$ one obtains a direct estimate which combined with above estimate gives two conditions which should be consistent with each other:

$$U = 76.1 \times \sum_I \frac{x_I}{A_I} ,$$

$$U = .93 \times \sum_I \frac{x_I}{A_I Z_I} . \quad (7)$$

These estimates are consistent for $x_I \sim 10^{-2}$, which makes sense.

3.5.4 Questions about primary wave and EEG

Q: Where the primary wave propagates: along axon or along micro-tubules?

A: This question need not make sense if micro-tubules and axon are connected by magnetic flux tubes to form single quantum coherent system. That axonal micro-tubules have constant electric field which is always in same direction could explain why the background soliton sequences and nerve pulses propagate always in the same direction and suggests that the primary wave propagates along micro-tubules. On the other hand, if W exchange between cell exterior and exterior reduces the negative charge of the inner lipid layer then axon could be seen as initiator. This could induce conformational or gel-sol phase transition propagating along micro-tubule and inducing the pair of voltage pulses in turn inducing the fusion of flux tubes at cell membrane which in turn would induce criticality of the axonal membrane. For this option axonal soliton would be a shadow of the micro-tubular soliton rather than completely independent dynamical process.

Q: How nerve pulse velocities are determined?

A: At first glance it seems nerve pulse velocity v could be determined by boundary conditions guaranteing synchronization of neuronal activity rather than by dissipation as in Hodgkin-Huxley model. As a matter fact, dissipation turns out to affect also v just because it is determined by boundary conditions!

1. Hodgkin-Huxley model would suggest that nerve pulse velocity is dictated by frictional effects as an analog of a drift velocity. The rough order of magnitude estimates for the velocities of conformational waves along micro-tubuli are consistent with the velocities of nerve pulses. The proportionality $v \propto d$ of nerve pulse velocity to nerve axonal radius might be understood

as resulting on the dependence on the length of flux tubes connecting axon and micro-tubules and mediating a frictional feedback interaction from axon. Feedback would be naturally reduced as d increases. Feedback interaction could explain also the sensitivity of the thermal parameters of the axonal membrane to the proteins in its vicinity. If the frictional feedback is due to the environmental noise at the axon amplified at quantum criticality this is what one expects. Quite generally, quantum criticality would explain the high sensitivity of the thermal parameters on noise. Saltation cannot be responsible for the higher conduction velocity in myelin sheathed portions of axon. The insulation would reduce the environmental noise at the level of axons and thus reduce the frictional feedback from axon to the micro-tubules.

2. The introduction of friction is however problematic in the recent situation. In absence of boundary conditions Sine-Gordon equation predicts for the propagating soliton sequences a continuous velocity spectrum and friction should affect Ω and V rather than phase velocity v but it is not clear whether it can affect v .

i) In this framework the boundary boundary conditions at the ends of the axon or some sub-unit of axon would dictate the values of v : $\gamma\Omega L/v = n2\pi$ corresponds to periodic boundary conditions (note that $\gamma = \sqrt{1 - (v/c)^2} \simeq 1$ holds true). $v = \Omega L/n2\pi$ implies that friction indeed affects also v .

ii) The relationship states that the time taken by the nerve pulse propagate through the axon is always $T = L/v = n2\pi/\Omega$: this would synchronize neurons and $\Omega \simeq 2\pi$ kHz is suggested by the well-known 1 kHz synchrony difficult to understand in the standard framework where v would be determined by chemistry rather than geometry. Myelin shielding could in this picture guarantee that coherent wave propagation is possible over the entire axon so that boundary conditions can be applied.

iii) This would give $v \simeq \Omega L/n2\pi < \Omega L/2\pi$. $\Omega = 2\pi$ kHz and $n = 1$ would give for $L \in [1 \text{ cm} - 10 \text{ cm}]$ $v \in 10 \text{ m/s} - 100 \text{ m/s}$ corresponding roughly to the observed range of values. For short axons velocity would be lower: for $L = 10 \mu\text{m}$ one would have $v = .01 \text{ m/s}$. For longer axons the value of n could be higher or the axon would decompose into structural units for which periodic boundary conditions are satisfied. The sections between Ranvier nodes have length measured in millimeters as are also the lengths of axonal micro-tubules and 1 mm would correspond to a velocity of 1 m/s. The actual velocity for the myelinated sections varies between 18-100 m/s so that basic structural units should be longer. The proportionality of v to the radius of axon would follow from the proportionality of the length of the axon or its basic sub-unit (not longer than $\sim 10 \text{ cm}$) to its radius: the simplest geometric explanation for this would be in terms of scaling invariance of the axonal geometry consistent with fractality of TGD Universe. In the standard framework this proportionality would be explained by the minimization of dissipative losses in the case of long axons: one cannot exclude some variant of this explanation also now since friction indeed reduces v .

iv) There is an electric field associated with micro-tubules (always in same direction). Could this electric field play the role of external force feeding energy and momentum to the moving soliton sequence to compensate dissipation so that v would have interpretation as a drift velocity?

Q: Can one understand EEG in this framework?

A: Just like kHz waves also EEG generating waves could correspond to propagating soliton sequences. Since V is not affected, the value of \hbar must be much larger and one must have $\hbar \propto f$, where f defines the EEG rhythm. It is known that EEG amplitudes associated with EEG rhythms behave roughly like $1/f$. This can be understood. By Maxwell's equation the divergence of electromagnetic field tensor is proportional to 4-current implying the amplitude of EEG identified

as Josephson radiation is proportional J_0/Ω and therefore to \hbar . The propagation velocity $v = \Omega L/2\pi n$ of EEG generating waves is rather slow as compared to kHz waves: for $f = 10$ Hz one would have 10 cm long axon $v = 1$ m /s. Synchronization results automatically from periodic boundary conditions at the ends of the axons.

Nerve pulses during EEG rhythms would have much slower velocity of propagation and the duration of nerve pulse would be much longer. The maximal charge transfer would be proportional to $1/\hbar$. It would thus seem that EEG and nerve pulse activity should exclude each other for a given axon. Ω is however smaller so that the generation of nerve pulse is easier unless also ion densities are lower so that J_0 (analogous to gravitational acceleration g in pendulum analogy) is reduced. Perhaps this takes place. The consistency with the propagation velocity of micro-tubular conformational (or even gel-sol-gel) waves might pose additional constraints on v and thus on frequencies Ω for which nerve pulses are possible. That ordinary EEG is not associated with ordinary cells might be due to the fact that \hbar is much smaller: the fractal analog of EEG generating waves could be present but these EEG waves would correspond to faster oscillations in accordance with the view about evolution as an increase of \hbar .

3.6 Model for anesthetic action

The molecular mechanism of the anesthetic action is a fascinating unsolved problem of neuro-physiology. Noble gases have very weak chemical interactions. Despite this many noble gas such as Xe, Kr, Ar but to my best knowledge not Ne and He, act as anaesthetics. Also chemically non-inert molecules have quite similar narcotic effect so that chemistry does not seem to matter as Hodgkin-Huxley model would predict.

It is known that the narcotic efficiency of anesthetics correlates with their solubility in lipids [34]. Anesthetics also reduce the melting temperature of the lipid layer. Strong pressure increases the melting temperature and it is known that high pressure brings consciousness back. Thus anesthetic molecules dissolved into the lipid membrane should hinder the generation of the nerve pulse somehow and liquid state of the axonal membrane could be the reason for this. The explanation of the soliton model for the anesthetic action [44, 47] is that the metabolic energy needed to generate an acoustic soliton becomes too high when axon is too high above the critical temperature.

To get a useful perspective note that also the problem why ordinary cell and neuronal soma outside axonal hillock do not allow action potentials is poorly understood. The obvious idea is that anesthetized axonal membrane (or at least axonal hillock) is just like the ordinary cell membrane. The model for DNA-cell membrane system as a topological quantum computer requires the liquid-crystal property of the lipid layers of the ordinary cell membrane and neuronal membrane outside axonal hillock. If this is the case, then liquid phase for axonal membrane implied by the anesthetic action would indeed make it more or less equivalent with the ordinary cell membrane. Therefore the question is why the liquid-crystal property of the ordinary cell membrane prevents the generation of the action potential.

1. Pollack's model [35] suggests that anesthetics could hinder the occurrence of the gel-sol phase transition for the peripheral cytoskeleton. Suppose that \hbar increasing phase transition for the magnetic flux tubes connecting peripheral cytoskeleton to the axon extends them to the axonal exterior and makes possible the influx of monovalent ions inducing gel-sol phase transition.
2. Suppose that the phase transition increasing \hbar is induced by the reduction of the voltage over the axonal membrane (assume to be much smaller than cell potential) inducing almost vacuum property and quantum criticality. Somehow the presence of anesthetics would prevent this. Either the voltage over the membrane is increased in magnitude so that the flow of dark ionic currents to the membrane is not enough to induce quantum criticality or

the flow of dark currents is completely prevented. The first option is more economical and could be tested by finding whether the voltage over the axonal membrane (membrane in a solid state) is considerably smaller than that over the ordinary cell membrane (membrane in liquid-crystal state). The first option also predicts that during sleep the increase of cell potential (hyperpolarization) actually corresponds to the increase of the membrane potential.

3.7 Could micro-tubule-axon system perform topological quantum computation?

The proposed picture is consistent with the model of DNA as a topological quantum computer [L7] and with the idea that also micro-tubules could be involved with tqc. The model of DNA as tqc in its basic form assumes that DNA is connected to the nuclear membrane and cell membranes associated with the cell body by magnetic flux tubes such that each nucleotide is connected to single lipid. Tqc programs are coded to the temporal braiding patterns of lipids. This requires that lipid layer is liquid crystal and thus below the critical temperature. The flux tube connecting DNA to inner lipid layer and that beginning from outer lipid layer can form single flux tube or be split. If they form single flux tube braiding and tqc are not possible. During tqc the braid strands going through cell membrane are split and the dance of lipids induced by water flow defining time like braiding (hydrophilic lipid ends are anchored to the cellular water) induces braiding of the magnetic flux tubes which write the tqc program to memory. Furthermore, the lifetimes of flux tubes in the connected state must be short enough to prevent the generation of a nerve pulse. This is the case if the temperature is sufficiently below the critical temperature. The ionic supra currents are identifiable as the observed quantal non-dissipative currents flowing through the cell membrane when tqc is not on.

Centrioles have their own genetic code realized in terms of RNA and they play key role during gene replication when DNA is out of the game. This encourages to think that micro-tubules make possible an independent tqc like process. The question is how micro-tubule-axon system could perform tqc assuming that the recent picture about DNA as tqc [L7] is roughly correct. The assumptions of the model relevant for the recent situation are following.

1. Flux tubes consists of pieces between standard plugs represented by hydrogen bond acceptors ($O =$, aromatic rings,...). For instance, XYP molecules, $X = A, T, C, G$, $Y = M, D, T$ would represent standard plugs and that the transformation $XTP \rightarrow XDP + P_i$ represents the splitting of the flux tube and thus of braid strand. The XMPs associated with DNA would represent the ends of the braid strands. The formation of hydrogen bond between water molecule and $O =$ associated with phosphates at the hydrophilic ends of phospholipids would initiate tqc [L7].
2. In the model for protein folding [22] free amino-acid corresponds to a codon XYZ in the sense of wobble base pairing meaning that the third nucleotide corresponds to a quantum superposition of colors of nucleotides coding for the same amino-acid. Hydrogen bonds correspond flux tubes also and hydrogen bonds between $N - H$ and $O =$ groups in alpha helices and beta sheets mean a shortcut making it impossible to continue the flux tube from $O =$ further. Only the continuation of the flux tube through non-hydrogen bonded $O =$ acting as a plug is possible. $Y = Z$ rule holds true for the $O = -N - H$ hydrogen bonds and defines folding code. This however requires quantum generalization of the wobble base pairing (before the formation of hydrogen bond the flux tube ending to $N - H$ corresponds to a quantum superposition of third nucleotides appearing in the codons coding for the amino-acid) since otherwise amino-acid sequence for alpha helix would fix completely the DNA sequence coding for the helix. Inside proteins amino-acids correspond to code YZ part of the codon XYZ and inside alpha helices and beta sheets the flux tubes from DNA would

end to amino-acids and for them one could have only braiding between DNA and tubulins. Only in the case of non-hydrogen bonded amino-acids the flux tube connection from DNA could continue to the lipid layer and only in this case one could have the generalization of DNA tqc with flux tubes connecting DNA via tubulins to the axonal lipid layer.

Taking this picture as a starting point one can consider several options. For two first options tubulins are basic units. For the third one DNA nucleotides and amino-acids would have this role.

Option I: Tubulins could be connected to the lipid layer of the axonal membrane by flux tubes and the melting of the axonal membrane would induce braiding during the propagation of nerve pulse. α tubulins are accompanied by stable GTPs analogous to single DNA nucleotide so that α tubulin could take the role of DNA nucleotide with braid strands to lipids having only single color. Compared to DNA tqc this computation would represent much rougher resolution. β tubulins are accompanied by unstable GTPs able to suffer a hydrolysis to GDP. Also this process would correspond to the splitting of flux tube but the connection to tqc remains unclear. One can imagine one/two connected flux tubes to lipid layer represents bit.

Option II: For some years ago I considered the possibility of a gel-sol-gel phase transition proceeding along the surface of the micro-tubuli, accompanying nerve pulse, perhaps inducing nerve pulse, and coding for long term sensory memories in terms of 13 13-bit sequences defined by the tubulin helices with bit represented as a conformation of micro-tubule. This hypothesis might be easily shown to be wrong on basis of the available experimental facts already now. Suppose however that this phase transition happens and that the braid strands do not continue from the micro-tubular surface to the cell nucleus. In this case the braiding could be induced by a gel-sol-gel transition accompanying and perhaps generating the nerve pulse at the micro-tubular level and inducing the disassembly of the microtubule to tubulins followed by re-assembly inducing the braiding. Also this braiding would contribute to tqc like process or at least to a memory storage by braiding and options I and II would provide the complete story.

Option III: What about the variant of DNA-membrane tqc for axons? In the model of DNA as tqc these flux tubes continue back to the nucleus or another nucleus: the flux tubes must be split at cell membrane during tqc and this splitting induces the required isolation from the external world during tqc. During nerve pulse the situation would be different and the flow of lipids in liquid phase could induce DNA-lipid layer braiding: the isolation could however fail now. Tqc would explain why the axon melts during nerve pulse.

There are objections against this option.

i) By previous argument only Y-codons of DNA and only non-hydrogen bonded O =s of amino-acids would contribute to the braid strands. This does not look nice.

ii) The idea about magnetic flux tubes emanating from DNA and flowing along micro-tubules interiors and radiating to the axonal membrane looks also ugly: in any case, this would not affect tqc and nerve pulse could be seen as a direct gene expression not conforming with the idea that microtubules define an independent computational system.

iii) One can wonder why also the magnetic flux tubes from DNA could not end to the space-time sheet of the cell exterior if they do so in the case of axon. The justification for 'No' (besides isolation) could be that also cell soma would possess standing soliton sequence like waves and standing nerve pulses in this kind of situation.

The following considerations do not depend on the option used.

1. What comes first in mind is that the braiding codes memories, with memories understood in TGD sense using the notion of 4-D brain: that is in terms of communications between brain geometrically now and brain in the geometric past. In standard neuroscience framework braiding of course cannot code for memories since it changes continually. Nerve pulse sequences would code for long term sensory memories in a time scale longer than millisecond and micro-tubular phase transition could have a fine structure coding for sensory data in time

scales shorter than nerve pulse duration. The fact is that we are able to distinguish from each other stimuli whose temporal distance is much shorter than millisecond and this kind of coding could make this possible. Also the direct communication of the auditory (sensory) input using photons propagating along MEs parallel to axon could also explain this.

2. In the model of DNA as tqc nucleotides A, T, C, G are coded into a 4-color of braid strand represented in terms of quarks u, d and their antiquarks. An analogous coding need not be present also now: rather, all braid strands could have same color represented by G of GTP . Tubulins could be seen as higher level modules consisting of order hundred 500 amino-acids. This corresponds to a DNA strand with length of about $.5 \mu\text{m}$ corresponding to the p-adic length scale $L(163)$ which is one of the four magic p-adic length scales ($k = 151, 157, 163, 167$) which correspond to Gaussian Mersennes. This higher level language character of micro-tubular tqc programs would conform with the fact that only eukaryotes possess them.
3. Cellular cytoskeleton consists of micro-tubules. Could micro-tubular tqc -in either of the proposed forms- take place also at the cell soma level? Could DNA-nuclear membrane system define the primordial tqc and micro-tubular cytoskeleton-cell membrane system a higher level tqc that emerged together with the advent of the multicellulars? Is only the latter tqc performed at the multicellular level? The notions of super- and hypergenome encourage to think that both tqc's are performed in all length scales. One can imagine that ordinary cell membrane decomposes into regions above and below the critical point (the value of the critical temperature can be controlled. Those below it would be connected to DNA by flux tube bundles flowing inside the micro-tubular cylinders. Micro-tubular surfaces would in turn be connected to the regions above the critical point. One should also understand the role of $M_{13} = 2^{13} - 1$ 12-bit higher level "genetic code" assignable naturally to micro-tubules. For instance, could the bit of this code tell whether the module defined by the tubulin dimer strand bundle participates tqc or not?

4 Model for a hierarchy of EEGs

The effects of ELF em fields on vertebrate brain have gradually led to the recent model for EEG and its generalization.

4.1 Summary about effects of ELF em fields on vertebrate brain

The work by pioneers of bio-electromagnetism (Wertheimer, Milham, Marino, Becker, Adey, Blackman and many others) which began already at sixties led to amazing discoveries about ELF fields on vertebrate brain (for a review see [59]). The publications of Blackman and collaborators [42] provide a detailed summary of these developments. The results of the work of Bawin, Adey, Blackman and others can be summarized by saying that radio frequency em fields amplitude modulated by ELF frequencies affect in certain frequency and amplitude windows brain tissue [41, 42]. The function of the radio frequency carrier wave is to facilitate the penetration of em field into tissue and its frequency is not essential for the occurrence of the effect. Presumably nonlinear effects give rise to a secondary wave with modulation frequency which is the primary source of effects.

4.1.1 Basic effects

The effects of ELF em fields on brain include chemical, physiological and behavioral changes within windows in frequency and field intensity. It is essential that the effects have been observed only in vertebrates which thus possess EEG. A good summary is the online review article of Cherry [59].

The well documented and established non-thermal biological effects of EMR include significant alteration of cellular calcium ion homeostasis, reduction of melatonin, and the detection of Schumann resonances [54] by human and avian brains. A key effect is change in Ca^{2+} homeostasis: Ca^{2+} it is involved with both pre- and postsynaptic steps of nerve pulse transmission and also with intracellular communication. For instance, Ca^{2+} is involved with gene expression, the development and plasticity of nervous system, modulation of synaptic strengths, and with $Ca^{2+} - cAMP$ signal transduction process.

Change in Ca^{2+} homeostasis has harmful effects in central nervous system, endocrine system and immune system. At the level of CNS this means changes of reaction time and behavioral alternations. At the level of neuro-endocrine system a good example is the reduction of the melatonin production in pineal gland having wide variety of harmful effects since melatonin serves as effective scavenger of free radicals: among the effects are DNA strand breakage, chromosome aberrations and problems with gap junction communications. Melatonin is also crucial for healthy sleep and for the reduction of cholesterol and blood pressure. In case of immune system an example is provided by the change of functioning of lymphocytes in turn reducing the competence of immune system making the subject more vulnerable to allergens, toxins and viruses.

4.1.2 Amplitude windows

Two main amplitude windows have been seen. For the first window ELF em fields have values of electric field in tissue around 10^{-7} V/m. The effects are high level effects and associated with navigation and prey detection in marine vertebrates and with the control of human biological rhythms. For ELF modulated radio frequency fields (RF) and microwaves (MW) the intensities are around 1 – 10 V/m. In this case the effects are neurophysiological effects are lower level effects at the level of the brain tissue. In the case of brain tissue maximal sensitivity to electromagnetic fields occurs between 6 and 20 Hz.

In order to get grasp about orders of magnitude, it is good to notice that cell membrane electric field has a strength about 10^7 V/m whereas EEG electric fields in the range 5 – 10 V/m. The fact that the second intensity window corresponds to 1 – 10 V/m suggests that the em field simulates the em field associated with EEG: a valuable guideline in attempts to understand what is involved. For Schumann resonances electric field is of order .6 mV/m. For sferics (em perturbations associated with lightnings) magnetic field strength is not above nTesla: this corresponds to electric field strength 10 V/m associated also with EEG waves [53]. Field strength of V/m corresponds roughly to energy flux $\mu W/m^2$.

The presence of windows and weak intensities implies that the effects cannot be thermal. A good metaphor is the effect of radio noise on radio receiver: it occurs at definite frequency and destroys the information content of the original transmission.

4.1.3 The effects occur at harmonics of cyclotron resonance frequencies

Blackman also discovered that odd multiples 15, 45, 75, 105... of 15 Hz had much stronger effect on tissue than even multiples 30, 60, 90... Hz and realized a possible role of Earth's magnetic field [42]: it must be however emphasized that the value of magnetic field in question is $B_{end} = .2$ Gauss and smaller than $B_E = .5$ Gauss. A possible interpretation is that harmonics of cyclotron frequencies might be the information carrying frequencies in EEG.

In response to the results and speculations of Blackman, Liboff formulated ionic cyclotron resonance (ICR) model [49] based on the realization that the frequencies in question correspond to multiples of the cyclotron frequencies of Ca^{2+} ion in a magnetic field $B_{end} = .2$ Gauss. This model was classical. Later Blanchard and Blackman proposed so called ionic parametric resonance model (IPR) [43]. This phenomenological model combines ICR model with ideas about atomic physics. There are several objections against ICR model; classical orbits of ions in Earth's magnetic field

have radius of order meters; dissipative effects and Brownian forces do not allow cyclotron orbits; charge-to mass ratios appearing in cyclotron frequencies correspond to vacuum rather than water environment characterized by a large value of dielectric constant; it is difficult to understand why odd multiples of cyclotron frequencies give rise to stronger effects [42]. Some of these objections apply also to IPR model.

The pattern of data seems to suggest that the interaction occurs at quantum level. This is in dramatic conflict with the predictions of the standard quantum theory and with the standard view about space-time.

4.1.4 Are quantal effects in question?

The conclusion that the effect of ELF fields on brain represents quantum effects associated with the transitions of ions confined in magnetic field having same strength as Earth's magnetic field, is supported by the following observations.

1. The frequencies 15, 30, 45, 60, 75 Hz having effect on primates are multiples of the same basic frequency $f = 15$ Hz, which turns out to be the cyclotron frequency of Ca^{2+} ion in magnetic field $B_{end} = .2$ Gauss. That these frequencies come in multiples is a direct signature of quantum: in classical world only basic frequency $f = 15$ Hz should have effects (forcing ions to rotational motion around field lines with this frequency).
2. Even multiples of 15 Hz have a weak but non-vanishing effect. Transitions are not possible at all in the lowest order of perturbation theory since the interaction Hamiltonian describing the transitions in question has non-vanishing matrix elements only between states of opposite parities in the dipole approximation applying when the wavelength of the radiation is much larger than the size of the radiating system. Odd and even values of n for cyclotron states have opposite parities so that Δn odd rule results. In higher orders of perturbation theory also transitions for which transition frequency is even multiple of the cyclotron frequency are possible.

There are however also objections.

1. The cyclotron energy scale is about 10^{-14} eV and ridiculously small as compared to the energy scale .086 eV defined by room temperature so that quantal effects should be masked completely by thermal noise.
2. The wave functions of ions in magnetic field are confined in a region of size of order

$$r_n \sim \sqrt{2n/eB} ,$$

which is of the order of cell size: macroscopic quantum state is in question. In fact, the value $.5 \times 10^{-4}$ Tesla for Earth's magnetic fields corresponds to the p-adic length scale $L(169) = 5 \mu\text{m}$ rather precisely for minimal value of the magnetic flux quantized as $ZeBS = n2\pi$ obtained for $n = 1$ (S denotes the area of the flux tube) and $Z = 2$. If one requires quantum classical correspondence, very large values of n are required and cyclotron radii would be much larger than flux tube radius.

A common resolution of all these objections is provided by large \hbar phases and hierarchy of magnetic flux sheets with B scaling like $1/\hbar$ meaning that cyclotron frequencies scale down similarly and cyclotron energies remain invariant. Same applies to spin flip energies scaling in the same manner as cyclotron energies. By the quantization of the magnetic flux, predicted by TGD also classically, the minimal radius of the magnetic flux tube for the magnetic field of Earth of cell size

for ordinary value of \hbar but scales like \hbar if magnetic field remains invariant and flux quantization $BS = n2\pi\hbar$ implying $S \propto \hbar$ holds true. This implies consistency with classical theory for large values of $\hbar = 2^{11k}\hbar_0$, $k = 1, 2, \dots$

4.1.5 A brief summary of the model

Some work is required to end up with the following interpretation based on a model for how the different levels of dark matter hierarchy communicate and control.

1. Ions with charge Z , mass m and spin S in the external magnetic field behave quantum mechanically like harmonic oscillator with energies quantized as

$$E = E_c + E_L \quad , \quad E_c = (n + \frac{1}{2})\hbar\omega_c \quad , \quad E_L = S_z \frac{g\omega_c}{2} \quad , \quad \omega_c = \frac{ZeB}{m} \quad (c = 1) \quad . \quad (8)$$

The first contribution corresponds to cyclotron contribution. For a given value of n the component of angular momentum in the direction of B has $n + 1$ values $n, n - 2, \dots, -n$. E_L denotes spin (Larmor) contribution. g is so called Lande factor which for free elementary fermions equals to $g = 2$. Since S_z is invariant under the scalings of \hbar , Larmor contribution is negligible as compared to cyclotron contribution for large values of \hbar . The contribution to energy coming from the free motion in the direction of magnetic field has not been written.

2. The model for high T_c superconductivity involving competition of two superconductivities, one associated with cell interior and second with cell membrane is the starting point. These phases coexist in a narrow range around critical temperature and 36-37 C range where the effects are observed is a good candidate for this range.
3. Experimental findings suggests strongly that external em field induces resonant transitions between cyclotron states: these transitions are identified as transitions inside the cell/nucleus or its fractally scaled up variant. For $k_d = 4$ level of dark matter hierarchy cyclotron energy scale turns out to be above the thermal energy $2.88T$ of photons at maximum intensity of black body radiation at room temperature for $A \leq 223Z$. Cyclotron radiation can drive charged particles to smaller space-time sheets and this is essential for the metabolism and this process is expected to be part of the interaction of ELF em fields with cell nucleus. The scale of cyclotron energies for $k = 4$ level of dark matter hierarchy is indeed turns out to be consistent with this assumption.
4. The ELF em field used in the experiments have electric fields strengths in two windows: one around 10^{-7} V/m and second corresponding to 1 – 10 V/m. Even in the latter case the field is by a factor of order million weaker than membrane potential: the notion of many-sheeted space-time allows to understand why so weak fields can have effects on biomatter. Amplitude windows are a further mystery related with the interaction of ELF em fields with brain tissue: if ELF em field defines potential difference eV associated with a Josephson junction, one might understand this effect in terms of quantum jumps induced by Josephson current with frequency $f = ZeV/2\pi$.
5. Dark matter hierarchy leads to the hypothesis that there is an entire hierarchy of EEGs generated as coherent photon states by Josephson currents associated with the Josephson junctions whose thickness scales as \hbar and frequency scales as $1/\hbar$ so that cyclotron energy remains invariant and is above the thermal threshold. For each value of \hbar there is also a p-adic hierarchy corresponding to $k = 151, \dots, 169$ with same Josephson frequency: these levels

combine to form single block for dark matter hierarchy formed from the scaled up variants of this block. At least the magnetic flux tube structure of DNA and membrane structure appear as scaled up copies. The lowest level corresponds to cellular or nuclear membrane and ordinary value of \hbar .

6. Josephson current is of form $J \propto \sin(2eVt + 2e \int V_1 dt)$ and its amplitude does not depend on the strength of the perturbation V_1 . V_1 is same for all values of \hbar but scales like $L(k) \simeq 2^{(k-151)/2} \times 10$ nm as a function of p-adic length scale for given value of \hbar . Perturbation is represent as EEG pattern communicated to the magnetic body of fractally scaled up variant of cell or cell nucleus, which reacts appropriately. At the limit when the Josephson frequency $f_J^1 = 2eV_1/2\pi\hbar$ of perturbation satisfies $f_J^1 \gg f_c$, the amplitude of perturbation is coded to frequencies $f_{\pm} = f_J^1 \pm f_J$ in the EEG in a good approximation.
7. The response of the system is that of AND gate. V_1 induces in the neuronal nucleus or its scaled up counterpart cyclotron transitions if the frequency is correct. If this the case, cell nucleus opens up communication line receiving possible control signals from the magnetic body at higher level of hierarchy. V_1 induces in Josephson junctions effects if the amplitude is in the amplitude window guaranteing that the frequencies f_{\pm} belong to EEG resonance bands (or their scaled up variants. In this case magnetic body receives representation of V_1 as coherent photons and responds. If communication line is open the response induces in the cell nucleus gene translation and other activities necessary for the biological response. The model implies that cyclotron frequencies code for the biologically relevant information carried out by classical electric fields so that noise is eliminated very effectively.

4.2 Model for EEG

The effects of ELF em fields on vertebrates lead to a model of EEG [M3] based on the requirement that dark EEG photons have energies $e = \hbar\omega$ above thermal threshold. This is satisfied for fourth level of dark matter hierarchy $\hbar = 2^{k11}$, $k = 1, 2, \dots$. That the effects are observed for vertebrates only, supports the view that the largest value of Planck constant in the "personal" hierarchy of Planck constants determines the evolutionary level as the "slowest" part of personal EEG.

The basic objection of a skeptic against the model of EEG is the assumption that cell membrane has hierarchy of dark scaled up variants acting as Josephson junctions and that the scaled up variant corresponding to EEG corresponds to $\hbar = 2^{44}\hbar_0$ so that the thickness of ionospheric cavity of about 100 km would define the natural length scale! This picture is however consistent with the notion of magnetic body and would conform with the known strong effects of Schumann resonances on consciousness [54]. Of course, the dark scaled up variants of cell membrane need contain only the structures necessary to make them to act as Josephson junctions. The essential assumption is that Josephson energy (and voltage) remain invariant under the scalings whereas Josephson frequency scales down as $1/\hbar$ whereas magnetic field strength and cyclotron frequencies remain invariant so that cyclotron energy scales as \hbar and thus stays above thermal threshold.

The model explains the basic band structure of EEG and predicts correctly the narrow resonances in beta and theta bands [52].

1. Alpha band corresponds to the cyclotron resonances for biologically important dark bosonic ions in dark magnetic field $B_d = 2B_E/5 = .2$ Gauss forming cyclotron condensates on magnetic flux sheets traversing through DNA.
2. Cyclotron radiation gives rise to a perturbation membrane potentials which involves superposition of cyclotron frequencies besides noise. Therefore Josephson radiation contains frequencies $f_{n,\pm} = nf_c \pm f_J$ and these two frequencies correspond for $n = 1$ to theta and beta bands. The predicted satellites of cyclotron frequencies of biologically important ions

correspond to the narrow 1-2 Hz wide resonance bands inside theta and beta bands (narrow bands at 3,5,7 Hz and 13,15,17 Hz) reported by Nunez [52].

The presence of analogs of beta and theta bands is predicted also for higher harmonics of cyclotron frequency at 20, 30, 40, .. Hz. Note that bands $f/Hz = 10 \pm 5Hz, 30 \pm 5, 50 \pm 5$ around odd harmonics are favored. The Josephson frequency $f_J = 5$ Hz is favored by wake up EEG.

3. At the limit of large perturbations $V(t)$ of the membrane voltage due to a noise or large amplitude cyclotron radiation reflecting a state of high arousal the time dependence of Josephson current proportional to $\sin(\omega_J t + \int 2eV dt/\hbar)$ becomes chaotic.
4. The model explains EEG during sleep if the intensity of magnetic field responsible for the dominant part of cyclotron radiation during sleep is halved $B_d \rightarrow B_d/2$ so that alpha band shifts down to 5 Hz. This can be understood if the active neurons (possibly those in some regions of the right hemisphere) are associated with dark magnetic flux sheets with $B_d = .1$ Gauss. Also a model for the phases of sleep emerges.
5. f_J is proportional to membrane voltage and can vary being lowest when membrane potential is near to activation potential. This should shift the position of narrow resonances and model could be tested by comparing membrane voltages and positions of the EEG bands.

Actually an entire hierarchy of scaled variants of EEG is predicted with precise predictions for biorhythms corresponding to narrow resonances of EEG [M3]. This hierarchy starts already from photon frequencies corresponding to the membrane potential $\sim .07$ eV. The biologically most important bosonic ions correspond have cyclotron frequencies in alpha band and its scaled variants and corresponding Josephson radiation generated by Josephson junction interacting with cyclotron radiation gives rise to theta and beta bands. Together with narrow lines corresponding to bosonic ions this is a strong and testable prediction. Also electro-weak and gluonic variants of EEG suggest themselves.

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