Comparison of Orch-OR hypothesis with the TGD point of view

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Abstract

Penrose-Hameroff (P-H) model and its variants such as Diosi-Penrose (D-P) model have been leading candidates for a quantum theory of consciousness. In light of recent experiments and theoretical arguments, the D-P model looks highly implausible. The key problem is energy conservation, which is actually the central problem of general relativity and caused by loss of Poincare invariance. The basic idea of Penrose about quantum gravitational superposition is almost a must but in the framework of general relativity its mathematical realization is not possible.

TGD provides an alternative view based on the identification of space-times as 4-surfaces in $M^4 \times CP_2$ related by $M^8 - H$ duality to 4-surfaces in M^8. In this approach Poincare invariance is exact. In the TGD framework the hierarchy of Planck constants $h_{eff} = nh_0$ includes also gravitational Planck constant $h_{gr} = GMm/v_0$ introduced first by Nottale. This makes it possible to realize quantum coherence (in particular, gravitational one) in arbitrarily long spatial and temporal scales.

In this article P-H and P-P models are compared with the TGD point of view. In TGD, the generation of quantum gravitational binding energy liberates energy and provides the basic mechanism of metabolism and a direct connection with quantum biochemistry emerges. The gravitational magnetic bodies (MBs) of Earth and Sun are in an essential role. Could one invent a mechanism involving only self-gravitational interaction energies of the living body itself? The large gravitational Compton length $\Lambda_{gr} = GM/v_0$ requires the presence of a large mass, say star, which would serve as basic metabolic energy source but the presence of a planet is not necessary in the prebiotic stage.

There are strong indications that water is a quantum critical system at the physiological temperature range. This suggests that scaled variants of magnetic bodies of water blobs as candidates for proto cells appear in quantum superposition with values of the parameter v_0. This would induce large density fluctuations at the level of the ordinary biomatter. State function reduction would induce a phase transition to a scaled-up state in the presence of energy feed. The return to the original state would liberate the gravitational energy as metabolic energy. Note that there are also indications for the quantum (gravitational) criticality of microtubules so that they would be very special from the point of view of life and neuron level consciousness.

The gravitational self-interaction energy for water blobs with Planck mass corresponds to an energy scale of 3.5 meV identifiable as the energy difference between two opposite membrane potentials. Could gravitational metabolic energy make possible the action potential of proto cells observed even for monocellulars?

1 Introduction

Diosi-Penrose variant of the Orch-Or [J4] model constrains the range of the separation parameter R, also called the resolution scale of matter density, and predicts that weak em radiation accompanies Orc-OR, which are not predicted by the original Penrose model [J8]. Two years ago experiments by Donadi et al carried out in Gran Sasso underground laboratory failed to detect the predicted radiation [D1] (see `https://cutt.ly/JJ569SI` or arXiv version `https://cutt.ly/ZJ56482`).

These conclusions have been strengthened in a theoretical article by Diosi et al [J3] (`https://cutt.ly/8J6qdD8`) inspired by these experimental findings. The authors represented theoretical arguments leading to the conclusion that D-P theory theory is highly implausible with reasonable values of the scale parameter R.

According to the abstract of [J3], partial separation, applying at the microtubular (MT) level, requires the brain to maintain coherent superpositions of tubulin of such mass, duration, and size that vastly exceed any of the coherent superposition states that have been achieved with state-of-the-art optomechanics and macromolecular interference experiments. The conclusion is that none of the scenarios discussed in the article (with a possible exception to the case of partial separation of tubulins) are plausible. There is also a popular article (`https://cutt.ly/KJ6qrPp`) briefly summarizing these conclusions.

In the sequel Penrose view about gravitational state function collapse, Penrose-Hameroff (P-H) model (P-H model) and Diosi-Penrose (D-P) model are discussed from the TGD point of view.

1.1 Penrose theory

It is appropriate to briefly summarize the assumptions of the original Penrose theory [J8] for quantum gravitationally induced state function collapse.

1. Quantum superpositions for masses in different configurations have different gravitational energies. Also gravitational fields must appear in quantum superposition. However, since a theory of quantum gravitation is lacking, it is not clear how to mathematically formulate this intuition.

   The description of the two states with different self-interaction energies relies on a classical non-relativistic description of gravitation. When two configurations in the superposition are known, it is in principle straightforward to calculate the difference E_g of self-interaction energies.

   The basic hypothesis is that the superpositions of gravitational fields of different configurations are unstable against collapse. For simplicity a superposition of two configurations is assumed.

2. An intuitive estimate for the duration of the state ending with collapse is based on Uncertainty Principle:

   $$\tau \sim \frac{\hbar}{E_g} \quad .$$

   τ inversely proportional to E_g. τ is suggested to correspond to a typical time scale of human consciousness via the formula $\tau = \hbar/E_g$. The value of E_g is extremely small, which makes gravitational quantum coherence extremely vulnerable.

3. One must somehow characterize the states appearing in the superposition. The notion of separation distance R characterizes ΔE_g. The value of R must be guessed. This is not easy since the very definition of R remains unclear, at least to me. One could take R only as a phenomenological parameter characterizing the resolution scale.

   Alternative identification would be as a separation distance. Separation would mean creation of a superposition of two classical configurations for which internal gravitational energies differ. As if the distance between nucleons of nuclei or between nuclei of atoms had changed by length R. For nuclei (atoms) R would correspond to the nucleon (nuclear) size scale.

Coherence is required in the sense that the change of gravitational energies tends to be of the same sign for all particles. Otherwise the change E_g of the gravitational self-interaction energy is expected to be vanishingly small to give short enough $\tau \simeq \hbar/E_g$.

4. Since the change of gravitational interaction energy for all particle pairs must be of the same sign, the replacement of R as a scaling parameter comes into mind: different configurations would differ by a scaling.

1.2 Penrose-Hameroff theory of consciousness

Penrose's view about gravitational state function reduction [J8] is part of the Orch-OR proposal of Penrose and Hameroff [J7, J5, J6]. The duration of the quantum gravitational coherence must last long enough, of the order of the typical time scale of conscious experience or possibly time between two conscious experiences. Perturbations should not induce a too fast decorence: in standard quantum theory this looks unavoidable.

1. Microtubule (MT) hypothesis states that MTs are systems able to appear in quantum gravitational superpositions. Why this should be the case, remains unclear to me.

2. Superpositions of MT configurations must last long enough. τ could correspond either to the duration of conscious experience or time between two moments of consciousness. τ should be long enough and is estimated to be in the range 5 sec- 10^{-2} seconds. $\tau = \hbar/E_g$ gives an estimate for E_g, which is extremely small, of order 10^{-13} eV for $\tau = .1$ seconds corresponding to 10 Hz frequency in alpha band. Extremely small energies (in comparison to metabolic energy quantum of about .5 eV) are involved and one can argue that electromagnetic interactions unavoidably spoil the gravitational quantum coherence in standard quantum physics framework.

3. The separation scale R appearing as a basic parameter must be estimated or rather, guessed. The problem is that the definition of R does not have clear geometric meaning. Atomic separation of order nuclear or nucleon size scale for Carbon atoms is assumed as a working hypothesis. The rate for a collapse in the case of a single Carbon atom can be estimated from the dimensional estimate for the change of the gravitational energy as $E_g \simeq Gm^2/R$. The change is assumed to have the same sign for all Carbon atoms so that this estimate is multiplied by the number of Carbon atoms. $\tau = 25$ ms is assumed from a 40 Hz synchrony time scale. The gravitational quantum coherence of $N \sim 10^{11}$ tubulins is required with this assumption.

   Tubulin has a mass of 50 kDa, and Da corresponds to proton mass. This makes a mass of $5 \times 10^{16} m_p = 3.9 \times 10^{-4}$ Planck masses. The length of a structure containing 10^{11} tubulins forming a cylinder of parallel 13 MTs, each consisting of 13 tubulin units of length about 10 nm, would be of order 15 m so that a single axon cannot satisfy the constraints. Empirical inputs restrict the value of R. Shifts of the nuclei would be measured in femtometers:$R = 2.5fm$. 1 nm scale separations for electrons would be required.

The following items summarize what I found difficult to understand.

1. The changes of gravitational interaction energies should have the same sign in order to guarantee that τ is not too large. Scalings would satisfy this constraint. The notion of separation scale does not code for this intuition.

2. What about the changes of electromagnetic energies induced by the separation? Can they be the same for the states of superposition so that only gravitational energy would be liberated in Orch-OR?

3. Why would microtubules be so special? Why not for instance axonal membranes or DNA?

4. The idea that consciousness consists of moments identifiable as quantum jumps is attractive but in conflict with the idea that conscious experience has a duration. This has been a decades-long headache also in the TGD framework. Could the quantum jump be the beginning of a conscious experience and the next quantum jump the end of it? Could one have a

kind of holography of consciousness with quantum jump as analog of the 3-D boundary of space-time coding the information determining the contents of conscious experience: this is the most recent TGD view [L13]. Also self hierarchy as analog of various geometric hierarchies of TGD would conform with the idea that the structures for the physical world and conscious experience reflect each other. A category theorist might speak of a functor between physics and consciousness.

1.3 Diosi-Penrose theory

Diosi-Penrose (D-P) theory involves the additional prediction that Orch-OR involves also weak emission of electromagnetic radiation. This emission is argued to take care of energy conservation, which both Penrose and Diosi, regard as an unphysical feature.

It must be emphasized, the loss of classical conservation laws defines the basic problem of general relativity since the isometries of Minkowski space-time are lost and Noether's theorem cannot be used to derive the existence of energy, momentum and angular momentum. It was just this problem, which led to TGD.

I must confess that I really do not understand the mechanism of energy liberation proposed by Diosi. The following is only my humble attempt to understand.

1. One would have a superposition of two states with different gravitational self-interaction energies. In a non-relativistic Newtonian mechanics, one can in principle assign well-defined energies to them. Also changes of electromagnetic interaction energies and kinetic energies of particles must be taken into account. The changes of both gravitational and electromagnetic interaction energies and changes of particle energies can be computed classically if the two configurations are specified precisely.

   This is because the separation scale R, whatever it might mean, does not induce only a change of gravitational energy but also of electromagnetic interaction energies and kinetic energies. Stationarity assumption simplifies the situation.

   In short scales, the changes of electromagnetic interaction energies have a completely different order of magnitude than gravitational interactional energies and this does not add to the plausibility of quantum gravitational coherence. In longer scales electromagnetic interaction energies are expected to compensate each other. Since gravitation is not screened, the situation can be and, in the case of MTs, should be different for gravitation.

   A solution of the objections might be based on a precisely defined notion of scale hierarchy allowing to separate gravitational and electromagnetic interactions.

2. The predictions depend on the resolution scale R of mass density identified also as a separation distance R. R can correspond a) to tubulin protein scale (partial separation), b) atomic nuclei ($R \sim 2.5$ Fermi for Carbon atoms), or c) its nucleons. By estimates, R should be of order nuclear size scale or even of nucleon size (b) and c)).

   The interpretation of the R has remained unclear for me. The illustrations of popular talks suggest an interpretation as a distance between copies of the system at different positions self-interaction energies for two configurations differing by a shift are the same.

   If the shift occurs in the relative radial coordinates for the parts of the system and if one stays in the framework of general relativity, it is difficult to avoid the interpretation as scaling. Both local and global scalings could be considered. It however turns out that TGD allows a more elegant view [L11].

3. What about the total energies of the superposed configurations? If the state with a higher energy is less probable, the collapse tends to lead to a less energetic state and the collapse liberates energy.

   The amount E_g of liberated gravitational binding energy liberated would be extremely small for $\tau = \hbar/E_g \sim .5 - 10^2$ sec, which corresponds to energy $E_g \simeq 10^{-12}$ eV. Here $E_g = N \times e$ refers to the total liberated energy. The total liberated energy would be proportional to the number of basic units in quantum coherence. For $R = \hbar/m_p$ and proton as a basic unit, this would give $e = Gm_p^3 \sim 10^{-38} m_p$. Roughly $N = 10^9$ protons would be required.

It would seem that in the Diosi-Penrose model the liberated energy must be be essentially electromagnetic and kinetic energy. It is difficult to make any estimates without a detailed model. In any case, the electromagnetic energy would dominate at least in short enough scales.

4. The collapse is assumed to be a Poisson process: this reduces its description to a single particle level corresponding in scale R. Momentum changes should be random so that only dissipation visible as an increase of temperature should result. Temperature change is the measured observable.

5. Despite the incoherence for em interactions, the changes of gravitational self-interaction energies at single particle level should add up coherently. It is not easy to understand how gravitational coherence in long scales is possible if everything reduces to a single particle level and electromagnetic energy dominates. The existence of length scale hierarchy suggests a possible solution to this problem. The separation of electromagnetic and gravitational degrees of freedom however requires new physics.

To sum up, if the superposed states differ by scaling instead of R, the changes of both gravitational and em interaction energies could be estimated in the general relativistic framework from their scaling behavior and one obtains simple expressions. The estimate for the changes of kinetic energies requires some assumptions.

In the TGD framework scaling hypothesis is not necessary and for the already proposed mechanism of metabolism [L11] the space-time surfaces in the superposition do not differ by a scaling. However, it turns out that scaling induced density fluctuations could play an important role also in the TGD based view about quantum gravitation.

1.4 Empirical test of Diosi-Penrose theory

D-P model has been empirically tested by Donade et al [D1] (`https://cutt.ly/qKszmNC`). Authors estimate the rate for the emission of radiation predicted by the D-P model, which is faint but detectable. Also a dedicated experiment at the Gran Sasso underground laboratory to measure the emission rate is reported. The null result sets a lower bound on the effective size of the mass density of nuclei, which is about three orders of magnitude larger than previous bounds. This rules out the natural parameter-free version of the Diosi-Penrose model.

1. The weak radiation would relate to the change of electromagnetic energy induced by the change of gravitational self-interaction energy of charged particles. The radiation is assumed to be a single particle phenomenon occurring spontaneously as a Poisson process in short scales even without the quantum coherent superposition of gravitational fields. Therefore it is argued that a gravitational long length scale quantum coherence need not be present and non-biological systems can be used in the test. As explained, this hypothesis remains rather unclear to me since no detailed mechanism is proposed: only the existence of the radiation is proposed.

   One must consider a system exhibiting quantum coherence in a long enough scale. This quantum coherence is assigned with conduction electrons. A shielded germanium detector is used.

2. The mathematical treatment, discussed in the Appendix of [D1], is based on the evolution equation for the density matrix containing operator terms representing matter Hamiltonian and gravitational self-interactions. The collapses at single particle level give rise to diffusion as charged particles liberate energy in gravitational collapse.

3. No emission was detected within the wavelength range corresponding to nuclear-atomic length scale range and therefore photon energies in the range $10-10^5$ eV. Note that the large energy scales suggested by Uncertainty Principle suggest that something is badly wrong with the model. If quantum gravitational coherence in biological scale is involved , this is not expected.

   The separation scale R should be longer than atomic scale but this is excluded theoretically because the rate of spontaneous collapse would be quite too slow so that decoherence caused by other interactions would prevent long enough coherence time τ for Orch-OR.

In the sequel TGD based view of how quantum gravitation is present in quantum biology [L11, L12] is briefly summarized and compared with the ideas and models of Penrose, Hameroff and Diosi.

2 Comparison with TGD based approach

Quite recently, the role of quantum gravitation in the biology of the TGD Universe has been considerably clarified [L11, L12]. This includes quantum gravitational models of metabolism, biocatalysis, and the analog of topological quantum computation.

The TGD view about quantum gravitation differs in many aspects dramatically from that of Penrose. What is common is the vision about quantum coherent superpositions of space-times, now space-time surfaces, as also the proposal that MTs might have a special role as also water. The reason would be quantum criticality making possible long length scale quantum fluctuations, which can be described in terms of the effective Planck constant h_{eff} labelling phase of ordinary matter behaving like dark matter [K4, K5, K6, K7]. By its huge value, $h_{eff} = h_g r = GMm/v_0$, introduced originally by Nottale [E1], would be most important for biology and consciousness at brain level [K9, K3] [L8, L7].

For these reasons, it is interesting to find how the TGD view relates to P-H and D-P models.

2.1 TGD inspired quantum gravitational view about metabolism and nerve pulse conduction

A considerable progress in the understanding of quantum gravitational aspects of quantum biology in the TGD framework has taken place recently [L11, L12].

1. The TGD based view about cell and neuronal membrane, nerve pulse and EEG assumes pre-neural level, which is quantal. In this view, cell membranes act as Josephson junctions and communicate sensory input to the magnetic body (MB) of the system as dark Josephson radiation. MB in turn controls the cell by dark cyclotron radiation produced as pulses as MB receives frequency modulated Josephson radiation resonantly.

   Number theoretic vision implies the notion of Galois confinement [L5], which inspires the notion of a dark N-particle, which consists of N dark particles as an analog of the color confined state of quarks. Dark 3N-protons and dark 3N-protons as fundamental representations of genetic code are central for the TGD inspired quantum biology [L3, L6]. Cyclotron 3N-resonance for dark 3N-photons makes possible targeted communications and control with gene defining the address of the receiver like in LISP and frequency scale modulation defining the signal transformed to N-cyclotron resonance peaks.

2. Gravitational MB of Earth, which consists of very long U-shaped tentacle like flux tube loops with a scale of the Earth radius with gravitational Planck constant $\hbar_{gr}$ introduced by Nottale [E1] explains the findings of Blackman [J2] and others about physiological and behavioral effects of ELF radiation in EEG rane, is of special interest and assumed to play a key role in metabolism. Gravitationally dark protons would be associated with very long gravitationally dark hydrogen bonds (HBs) so that hydrogen is effectively negatively ionized.

   Gravitationally dark electrons or their Cooper pairs would in turn accompany gravitationally dark valence bonds connecting metal atoms or their Cooper pairs with molecules of opposite valence (hydrogen peroxide H_2O_2). Also the metal atom is effectively ionized. This provides a more accurate view of dark metal ions assumed to play a central role in the TGD inspired quantum biology.

3. The estimate for the upper bound metabolic energy quantum as the energy liberated as a dark proton HB becomes ordinary is of a correct order of magnitude. A more precise model predicts correctly the nominal value of metabolic energy quantum for proton triplets which appear also in the generation of ATP.

   For triplets of electron Cooper pairs, the same mechanism predicts an upper bound of the electronic metabolic energy quantum, which corresponds to the so-called miniature potential

of few meV. This raises the question whether the letters of genetic code could be realized by the 4 states of electron Cooper pairs and whether the Posner molecule could realize it [L11].

4. Electronic metabolism would solve the problem due the lack of ATP machinery inside cilium and near it. This picture leads to a rather detailed model of the role of phosphate in metabolism and also to a detailed model for the pairing of DNA and dark DNA (DDNA) and forces to modify the earlier model somewhat.

5. Also the gravitational MB of Sun could be involved, and the prediction is that the energy range for the metabolic energy quanta corresponds to the range of visible energies so that photosynthesis could use photon energy to kick dark protons and dark electrons to the gravitational MBs of Earth and Sun to serve as metabolic energy storage.

The quantum gravitational view about metabolism leads also to a modification of the views about nerve pulse conduction [L11].

1. In the quantum model, the cell membrane acts as a *generalized* Josephson junction for biologically important dark metal ions. These ions are identified as gravitationally dark effective ions with gravitationally delocalized electron Cooper pairs.

2. The delocalization of protons and possibly also electrons to gravitational bonds provides a concrete realization of the Josephson junction model in which the ground state of the axon corresponds to a soliton sequence, which has a sequence of rotating gravitational pendulums as a mechanical analog [K1]. Action potential would correspond to a soliton (or several solitons) with an opposite direction of rotation. One cannot exclude the option that the ground state corresponds to a propagating wave of small oscillation and the nerve pulse to a soliton or several solitons.

3. The conduction of neural signals through the myelinated portions of the axons, where nerve pulse is impossible, remains a still unsolved problem of neuroscience. The formation of dark hydrogen- and valence bonds leads to an effective ionization, which takes membrane potential below critical value for the generation of nerve pulse, which is generated in the unmyelinated sections.

   The critical dynamics of microtubules (MTs) involves variation of MT length relying on GDP $\rightarrow$ GTP transition, which involves the change of MB to gravitational MB and vice versa changing the local membrane potential. Therefore MT dynamics makes possible the propagation of the action potential. The effect of anesthetics can be understood in terms of reduced density of HBs preventing the formation of gravitational HBs so that MTs and the axonal potential freeze.

4. A model of the pre-neural system [L11], based on the gravitational MB and the predicted electronic metabolic energy quantum, is developed in order to explain how animals without a nervous system behave as if they had the brain. These animals move using cilia/flagella, which have no mitochondria inside them or in their vicinity. This suggests that the electronic metabolism could replace the usual metabolism.

Quantum gravitation in the TGD sense also provides insights about bio-catalysis and topological quantum computation-like processes [L12, L14].

2.2 The P-H theory and TGD

One could end up with the analog of Orch-OR in the TGD framework via the following arguments.

1. Gravitation is an unscreened long range interaction. Therefore it is plausible that it should allow quantum coherence in arbitrarily long scales. The first guess for the coherence scale in the presence of a large mass is as Schwartschild radius $r_s = 2GM$: the analog of the quantum gravitational Compton length is indeed proportional to it. This however requires large values of Planck constants and leads to the TGD view of dark matter as $h_{eff} = nh_0$ phases of ordinary matter.

Note that in the P-H model the gravitational self-interaction energy was in a crucial role. In the proposed TGD based model for metabolism, for genetic code, and for the role MTs in the propagation of action potential, the interaction of dark electrons and protons with gravitational fields of Earth and Sun is in a key role. This suggests a strong dependence of life on the planetary environment [L11], which is not a good news for space travellers. The metabolic mechanisms relying on self-interactions would avoid this dependence.

2. One can indeed generalize the notion of gravitational metabolism to gravitational self-interactions for quantum critical systems of which MTs and water at physiological temperature range provide basic candidates. At quantum gravitational criticality these systems would define quantum superpositions of gravitational MBs with different values of $\hbar_{gr} = GMm/v_0$ and gravitational Compton length $\Lambda_{gr} = GM/\beta_0$, $\beta_0 = v_0/c$. β_0 is expected to have a discrete spectrum by number theoretic constraints and $\beta_0 = 1/n$ is the simplest option.

   Also now the presence of a large mass M (planet, star or both) is needed in order to have large enough value of gravitational Compton length Λ_{gr}, which defines a lower bound for the quantum gravitational coherence scale.

3. The crucial finding is that binding energy of protons in the Earth's gravitational field is of order of the metabolic energy quantum .5 eV. A more precise model [L11] leads to the conclusion that metabolic energy quantum corresponds to 3 protons: the transfer of 3 protons through the cell membrane indeed takes place in ATP-ADP process. Also electrons give rise to metabolic energy quantum. Also the solar gravitational field gives rise to metabolic energy currency and this currency would be important in photosynthesis.

4. Intriguingly, the mass of a water blob of radius 17 μm, the size of a neuron, equals the Planck mass. This suggests that Planck mass, rather than Planck length, is important in biology. The estimate for the gravitational energy of this water blob gives energy which is of the same order of magnitude as Coulomb energy $ZeV = 0.05Z$ eV associated with the membrane potential. Could a cell define a gravitationally quantum coherent structure and could the changes of the gravitational self-interaction energy serve as metabolic energy quanta? The changes seem to be too small if they correspond to scalings.

   Furthermore, in the case Earth, the Schwartschild radius is .9 cm, which is a biological length scale and one has $\Lambda_{gr} = r_s/cv_0 = GM/v_0 = .45cm(c/v_0)$. One has $\beta_0 = v_0/c \simeq 1$ in a good approximation.

5. There are indications that β_0 is quantized to rational values. The space-time surfaces in the superposition would correspond to different values of β_0 and Λ_{gr}

   Could different space-time surfaces assignable to MBs in the superposition correspond to different values of β_0? $\beta_0 = 1/n$? For $n = 2$, Λ_{gr} would be scaled up by factor 2. This need not imply scaling at the level of ordinary matter but could imply it at the level of MB. $\beta_0 = 1 - 1/n$ would allow arbitrarily small scalings of Λ_{gr}.

   In the TGD framework, the space-time surfaces in the superposition need not be scaled variants of the ground state space-time surface. The gravitational binding energy of long gravitational flux tubes accompanying the gravitational HBs and VBs is reduced and would serve as a local metabolic energy resource. Could the number of potential metabolic energy quanta as the number of these bonds to the integer n appearing in v_0?

P-H hypothesis involves the assumption that MTs are quantum systems.

1. There is indeed evidence for MTs as quantum coherent systems [J1, J5] discussed from the TGD point of view in [L1]. In TGD the quantum coherence would be due to metabolic energy feed taking care that dark particles decaying back to ordinary ones can be re-created [L4]. Quantal flow equilibrium would be in question.

   In TGD, a related crucial element is the hierarchy of dark matters labelled by $h_{eff} = nh_0$. The gravitational Planck constant GMm/v_0 would correspond to the top of this hierarchy and make possible gravitational quantum coherence in long scales.

2. In the TGD framework, one expects that MTs define an important level in the hierarchy of consciousness. The criticality of axonal MTs in the sense that their lengths are continually changing could be actually quantum criticality at the level of the MB of MT. This could make MTs special since quantum criticality makes a system an ideal sensory receptor and controller. The increase of h_{eff} in turn increases the cognitive resources of the system since algebraic complexity increases.

3. The transfer of protons from MTs to dark protons at its MB can indeed explain why the conduction of action potentials through the myelinated sections of the axon is possible. The charge of the MT region changes and this changes membrane potential and gives rise to action potential.

4. The inclusion of self-gravitation could add the ability of water to serve as a metabolic energy source gravitational self-interaction energy as a metabolic energy. One might hope that this allows us to overcome the dependence of metabolism on planetary gravitational fields. In fact, only water is able to do this.

Could the following picture make sense?

1. Superpositions of geometries are replaced in TGD with superpositions of space-time surfaces with quantum gravitationally important modifications assignable to the gravitational magnetic body. There would be no problems with energy conservation and the new view about space-time allows us to identify also MTs as and their MBs as space-time surfaces, which are minimal surfaces with singularities analogous to soap films with frames.

2. A lot of new physics emerges: number theoretical physics and geometric physics related by $M^8 - H$ duality, number theoretical h_{eff} hierarchy labelling dark matter as phases of ordinary matter; gravitational Planck constant $\hbar_{gr} = GMm/v_0$ characterizing particle of mass touching gravitational flux tube; and zero energy ontology (ZEO).

3. The crucial point is that the huge value of $\hbar_{gr}$ would allow to avoid the loss of quantum gravitational coherence otherwise caused by the other interactions.

   For $\hbar_{gr} = GMm/v0 > \hbar$ one must replace $\hbar$ with $\hbar_{gr}$ meaning that $GMm > v_0\hbar$. The TGD based quantum gravitation becomes visible for particles of mass m in the gravitational field of large mass M at flux tubes with $GMm/v_0 > \hbar$. The gravitational Compton length $\Lambda_{gr} = GM/v_0 = r_s/2v_0$ does not depend on m and for Earth one has $\Lambda_{gr} = .45\ cm/(v_0/c)$, which is a biological scale. Cyclotron frequencies for a charged particle with mass m are also independent of m. Josephson frequency $f_J = ZeV/\hbar_{gr}$ is dramatically smaller than for ordinary $\hbar$ and corresponds to ELF frequency in the case of cell membrane.

4. Gravitational variants of hydrogen bonds (HBs) and valence bonds (VBs) as long U-shaped flux tubes are part of picture. Liberation of metabolic energy as an increase of gravitational binding energy as very long dark gravitational HB or VB becomes short. Metabolic energy quanta come as protonic and electronic varaints differing by factor m_p/m_e. The masses of Earth and Sun have a central role. Also other masses involved but the proportionality of $\hbar_{gr}$ to M means that these are the most important ones.

5. Gravitational energy difference would be roughly $\Delta GMm/R$ for a long gravitational flux tube associated with dark HB (VB) and short tube and corresponds to metabolic energy associated with the long HB (VB). A rough guess for the metabolic energy would be about .5 eV for proton. This would give time of order 10^{-14} sec corresponding to an energy of IR photon. For electron the metabolic energy in the meV range. A more careful estimates increase the number of protons and electrons to 3.

   This would suggest that the space-time surfaces in the superposition correspond to space-time surfaces with various numbers of potential metabolic energy quanta. These space-time surfaces are *not* scaled versions of the ground state space-time surface as in the GRT picture but analogous to the deformation of the surface of Earth by the presence of biosphere such as plants and trees. By fractaility. this kind of magnetic forests of U-shaped flux tubes would appear in all scales and first emerged in the model of atomic nucleus carring quarks.

In order to get some grasp on the new idea, one can play with numbers.

1. One can consider the analog of the P-H hypothesis $\tau = \hbar/E_g$ as $\tau = \hbar_{gr}/E_g = \hbar/R$ in the case of the gravitational flux tubes of Earth with size scale R determined by Earth radius R_E.

   The time scale corresponding to dark proton flux tube of length of order Earth radius $R_E \sim 6.37 \times 10^6$ m would be $R_E/(v_0/c)$ and would give $\tau = 21$ ms for $\beta_0 = v_0/c = 1$. The time scale of nerve pulses is a few ms.

2. Also gravitational Compton time should have relevance. For $\beta_0 = 1$ one has $\tau = GM/c = r_s/2c$. For Earth this would give $\tau = 1.7 \times 10^{-11}$ s. For ordinary Planck constant this corresponds to an meV energy scale. So called miniature end plate potentials .4 mV (`https://cutt.ly/HSJIn76`) have this scale.

2.3 Could the space-time surfaces in the superposition correspond to different scalings?

The change of gravitational interaction energy should not be random and should be such that the changes of gravitational energy are of the same sign for all particles. The interpretation of the parameter R as a shift does not look plausible.

This does not leave many options in the GRT framework. The change of the gravitational interaction energy could be induced by a scaling also in TGD framework, but most naturally at the level of gravitational MB as scaling of magnetic flux tube thickness, whose thickness is naturally proportional to $\hbar_{gr}/\hbar$. This would conform with the underlying scaling invariance of TGD so that R should be replaced by a dimensionless scaling parameter $\Lambda - 1$.

1. Scalings are indeed natural in the TGD framework, where the analog of time evolution is assigned with scaling rather than time translation and p-adic thermodynamics with conformal weight rather than energy so that a discrete superposition of scaled variants of space-time surface would make sense. One option is that scalings correspond to different p-adic primes , perhaps near to each other. Scalings by say powers of 2 suggested by p-adic length scale hypothesis could make sense at the level of visible matter in critical situation involving large density fluctuations (as in the evaporation). In this case the quantum criticality of MB could induced criticality of the ordinary matter.

   The scaling of flux tube thickness could correspond to that for the universal particle independent gravitational Compton length $\Lambda_{gr} = GM/v_0$ induced by the change of the velocity parameter as $\Delta v_0/v_0 \Delta\Lambda$. Small scalings would be possible and they would be realized for dark particles at gravitational flux tubes. Note that this requires the presence of a heavy astrophysical object such as a star serving also as a metabolic energy source.

2. The scale change would be proportional to the change of the scaling parameter $\Lambda - 1 = \Delta\Lambda$. In the P-H model, the estimates for the separation scale R, whose interpretation seems to be as a shift, vary between nucleon size scale and size scale of tubulin protein (10 nm).

3. A simple estimate shows that for 10^{11} tubulins assignable 10 m long axon containing 13×13 tubulins per length of about 10 nm, the scale of gravitational self-interaction energy is of order 10^{-16} eV so that the interpretation of a reduction of gravitational binding energy for an analog of Orch-OR as a potential metabolic energy is excluded. The mechanism proposed in [L11] is the only possible mechanism involving only MTs (plus the gravitational field of Earth to make Λ_{gr} large enough).

4. For the TGD based quantum gravitational model of metabolism E_g has a scale of metabolic energy quantum and is many orders of magnitude larger than allowed by the constraint if it defines a time scale in a range 5 sec- 10^{-2} sec. For ordinary Planck constant, one would have $\tau \sim 10^{-13}$ sec. In the TGD framework $h_{eff} = \hbar_{gr}$ implies $\tau = h_{gr}/E_g$. For the Earth's mass, the time scale would be the desired one. This supports the hypothesis that cell interiors consisting of ordered water define gravitationally quantum coherent regions and the surfaces in the superposition differ by the number of gravitational HBs and VBs.

The metabolic mechanism based on gravitational HBs and VBs imply the dependence of life on planetary gravitational fields. However, metabolic autonomy could be of high relevance for the life on other planets and also for space travel (this is discussed from the TGD point of view in [L11]). Also the possible proto cells in interplanetary space could use a metabolism based on gravitational self-energy. The presence of a nearby star seems however necessary to guarantee that the quantum gravitational coherence scale $\Lambda_{gr} = GM/v_0$ is long enough. For biological systems, such as cells, it is extremely small.

Could the gravitational self-interaction energy of water serve as a source of metabolic energy and allow to circumvent this dependence?

1. Consider first the cell scale. Water blob of Planck mass $M_{Pl} = 2.2 \times 10^{-8}$ kg has size $R \simeq 1.74 \times 10^{-4}$ m, which corresponds to the size of a large neuron. In this case, one has $E_g = \Delta E = [\lambda - 1)/lambda]E_g$, $E_g \simeq GM^2/R \sim 7$ meV. Maximum energy gain is 3.5 meV, which is roughly 10 times the energy scale of miniature potentials and is by a factor of 10 smaller than the Coulomb energy scale $\sim .05$ eV assignable to the membrane potential. The energy scale corresponds however to the difference of Coulomb energies of cell membrane for opposite values of membrane potential.

   If the system is critical so that large density fluctuations inducing the scaling of R and preserving M are possible, the scaling parameter $\Delta\Lambda$ characterizing the possible changes of water volume can be large. In this case, one could consider the possibility that some kind of metabolic energy needs could be satisfied.

2. Could larger water blobs, say those assignable to muscles, which indeed experience scale changes, help? For the entire body of mass of 50 kg and size scale of $R = 1$ m, the estimate for gravitational self-interaction energy is of order 6.4×10^{12} eV, which is about 10^{-6} J: lifting a weight of 1 kg to a height of 1 m requires 10 J. This option does not look realistic. Note also that the liberated metabolic energy feed cannot be targeted in a precise way.

3. Just for fun, one could also consider the entire biological body with (say) size $R = 1$ m and mass $M = 50$ kg and regard cells with mass of order Planck mass m_{Pl} as the dark particles at the flux tubes of its MB. The flux tubes connecting cells to each other would be stretched to gravitational flux tubes of length of roughly body size R. This option would allow a targeting of the metabolic energy by transforming the dark cell back localized to the biological body.

   The estimate for the order of magnitude of a metabolic energy quantum $E = GMM_{Pl}/R$ for MB flux tubes of size R would be $E \sim .25$ eV, one half of the value of the metabolic energy quantum. As will be found, the change of the sign of the membrane potential involved with an action potential requires energy of 3.5 meV and this energy could be generated already by a mass $M \sim .5$ kg.

2.4 Could the TGD analog of Orch-OR make possible an action potential for protocells?

The idea about gravitational superpositions of space-time surfaces related by scalings looks interesting since the scalings could relate to the scaling of the parameter β_0 in $\hbar_{gr} = GMm/v_0$ and in Λ_{gr} in the case that the flux tubes correspond to the mass of Earth or Sun.

For the masses M of say living organisms Λ_{gr} is extremely small. The presence of a stellar object, having a gravitational field characterized by $\hbar_{gr} = GMm/v_0$ and $\Lambda_{gr} = GM/v_0$, is needed in order to have quantum gravitational coherence in biologically interesting scales.

2.4.1 Quantum gravitational phase transitions of water blobs as the TGD counterpart of Orch-OR?

Instead of Orch-OR, quantum gravitational phase transitions are suggestive in the TGD framework. The quantum gravitational superpositions would be associated with quantum phase transitions changing Λ_{gr} and perhaps also inducing a scaling of the system consisting of ordinary matter. This scaling would mean large density fluctuations affecting the gravitational self-interaction energy.

1. Ordered water forming a gel-like phase in the presence of biomolecules is a natural guess for what gravitationally quantum coherent phase could be. A membrane-like object separating proto-cell from environment is needed to create a volume of water with quantum gravitational coherence.

   2-D membrane-like objects with 1+2-D M^4 projection, possibly pairs of them forming double membranes, appearing in these scales could serve as templates for membrane-like objects, which could have preceded cell membrane and also for the recent cell membrane. Their presence could have led to the emergence of lipid layers, which involve only hydrocarbons. These membrane-like objects form a fractal hierarchy and could accompany both galactic and planetary planes as walls and also the biosphere at the surface of Earth serving as analog of the cell membrane.

2. p-Adic length scale hypothesis and the number-theoretically miraculous appearance of 4 Gaussian Mersenne primes $L(k) \simeq 2^k$, $k = 151, 157, 163, 167$, between the cell membrane length scale and cell nucleus scale suggests that gravitational quantum coherence in these scales is involved.

3. Protocell as a pair of 2 membrane-like objects and as a template of cell membrane could define electric flux quantum as a counterpart of magnetic flux quantum. It would have carried an electric field as an analog of capacitor plates.

   If the electric voltage is absent, only mechanical work is possible. The energy scale in mechanical thermodynamic degrees of freedom is however huge as compared to the energy scale in gravitational self-interaction energy degrees of freedom so that the change of gravitational self-interaction energy to mechanical work in the cellular scale is not possible.

   Pollack effect [I1] caused by the stellar radiation could have generated the negative charge to the interior of the inner membrane. In principle, this requires the presence of only water.

4. One can imagine that the value of $\hbar_{gr}$ characterized by the value of β_0 and associated with the stellar gravitational flux tubes, fluctuates locally and generates scaled variants of gravitational flux tubes in turn inducing density fluctuations and the thermodynamical criticality of water. Fluctuations would produce water regions with a reduced density analogous to a vapour phase.

5. The liberated self-interaction energy would be $E_{gr} \simeq (\lambda - 1)GM^2/R$, where R is the size of the water blob, and scales like R^5. λ is the scaling inducing also the scaling of $\Lambda_{gr} = GM/v_0 \to \lambda\Lambda_{gr}$.

   At quantum criticality, assumed to induce thermodynamic criticality, the change of the free energy would be very small for the values of scalings in the superposition. The first guess is that by the quantization of $\beta_0 = 1/n$, one has $\lambda = n$. $n = 2$ gives 2-adic scaling and p-adic length scale hypothesis favoring $p \simeq 2^k$ could relate to these phase transitions. This picture makes sense if the criticality is analogous to that of boiling water.

   For a water blob of Planck mass with $\beta_0 = 1/n$, the gravitational metabolic energy gain is below 3.5 meV, which corresponds to the miniature potential.

6. As already found, the gravitational self-interaction energy cannot be used to perform mechanical work in practice. Since the energy gains are in the meV range, a more promising option is that the energy goes to a creation of a pre-neuronal action potential. By the arguments of [L11], the metabolic energy quantum for electron based metabolism is of order .25 meV and miniature potentials about .4 meV. Action potentials are possible already for mono-cellulars and one can ask whether even a proto-cell could generate the analog of an action potential without the ATP-ADP machinery.

   The scaling of the volume as a phase transition at quantum criticality could be present also in recent biology and one can wonder if the swelling of cells during infection could relate to this process.

2.4.2 Could the generation of gravitational self-interaction energy give rise to action potential?

The generation of gravitational self-interaction energy of a water blob with Planck mass liberates energy. Could it have given rise to an analog of action potential?

1. The gravitational self-interaction energy is of order $E_{gr} = GM^2/R$ and as a function of R scales like R^5 so that it is rather sensitive to the value of R. Already the scaling of R from 10^{-4} m by factor 3.1 transforms metabolic energy quantum of 3.5 meV to .5 eV.

   For a fixed M, E_{gr} scales as $1/R$. The analog of Orch-OR would be following. A superposition of different scalings of a water blob would be created much like in evaporation. After that a phase transition leading to a less dense state with definite scaling would take place. This requires metabolic energy provided by a near enough star. The phase transition back to the original situation takes place and liberates the metabolic energy.

2. When an action potential is generated, the membrane potential changes sign. In ZEO this could correspond to two BSFRs, each of which changes the arrow of time. The change for the arrow of time corresponds naturally to the sign change of V.

   The change of energy in this process is $2QV = 2e^2V^2S/d$, eV corresponds to the Coulomb energy of membrane potential, $Q = ES = VS/d$ is the charged assumed to be conserved in the transition, $S = 4\pi R^2$ corresponds to the area of cell membrane. Charge conservation gives $V = d/S$. The natural scaling is $d \to \lambda d$ and $S \to \lambda^2 d$, which gives $V \to V/\lambda$.

   For $R = 10^{-4}$ m corresponding to Planck mass (large neuron size), $d = 10$ nm, and $V = .05$ V, the change of Coulomb energy of the membrane would be $\Delta E \simeq 6.3$ meV. The upper bound for the change of the gravitation binding energy was 3.5 meV corresponding to a scaling of 2. It would seem that the gravitational phase transition as a 2-fold scaling and its reverse could induce a proto version of the action potential.

2.5 How water blobs could have evolved into living organisms?

Quantum gravitational criticality could be assigned to water blobs. In interstellar space the possible metabolism would not depend on the planetary gravitational flux tubes but would depend on the mass M of the nearest stellar object. Stellar gravitational fields are indeed necessary for large enough gravitational Compton length GM/v_0.

2.5.1 Important facts about water

Consider a water blob of radius R. The phase diagram of water (`https://cutt.ly/EKx9nGX`) allows to understand how thermodynamic criticality under normal conditions and during the prebiotic period could differ. There are two different situations to consider. When the pressure is above tricritical pressure P_{cr}, water allows liquid phase. Below P_{cr}, only solid and vapour phases are possible.

1. The normal physiological situation with normal pressure $P_{phys} = 1$ atm (101.325 kPa) in the vicinity of physiological temperature around $T_{phys} = 37$ C, which is between the freezing point and evaporation point. This kind of criticality could have been present for pressures above the tricritical pressure along a critical line.

   The numerous thermodynamic anomalies of water suggest that it is quantum critical at the physiological temperature range between solid-liquid phase transition and liquid-gas phase transition. The temperature for this range is above $T = 0$ C. Quantum criticality would give rise to superposition of phases with different density and differing by scaling above the tricritical point.

   Solid-liquid critical curve would naturally correspond to quantum criticality. Could some kind of life forms be associated with this criticality?

2. Below the tricritical point, the liquid water phase is absent so that the counterpart of the physiological quantum criticality is not possible. If the pressure is below $P_{cr} = 611.657$ Pa

$\simeq .006P_{phys}$ and temperature below $T_{cr} = 0.01$ C, only solid and vapour phase are possible and criticality would be associated with the curve at which sublimation of ice takes place.

In particular, the situation with $T \simeq 30$ K would correspond to a very early prebiotic phase, when the age of the Universe was about 1 Gy and the cosmic temperature was about 30 K. In this situation, quantum criticality could relate to the sublimation and the density fluctuations associated with it and would involve a superposition of scaled variants of H_0^2 blob.

2.5.2 Snow flakes, Emoto effect, and Pollack effect: life at quantum criticality?

Suppose that solid-liquid solid-vapour critical curves correspond to quantum criticality. Could some kind of life forms be associated with these quantum criticalities?

1. Snowflakes (`https://cutt.ly/sKJclSy`) are amazingly ordered structures and appear in freezing and direct solidification of water vapour. Snow flakes do not have metabolism. Could snowflakes be "corpses" of life forms emerging at quantum criticality?

   The experiments of Masaru Emoto [L2], discussed from the TGD point of view in [L2], demonstrate that if water at freezing point is subject to sound signals, it generates freezing patterns, which can be extremely beautiful or ugly depending on the emotional content than human would associate to the signal. Emoto suggests an interpretation in terms of expression of emotions generated by the sounds.

2. In the TGD framework, a model of harmony leads to a model of genetic code [K2] [L3]. Genetic codons would consist of 6-bit codons realized also as 3-chords represented by 3 dark photons and by dark 3-proton states. The harmony is defined by 3 icosahedral Hamiltonian cycles, each representing a 12-note scale, plus the unique tetrahedral Hamiltonian cycle. The 3-chords define a bioharmony with 64-chords realized as dark photon triplets. Since ordinary harmony of music induces and expresses emotions, the proposal is that a given bioharmony defines an analog of mood already at the level of basic information molecules.

3. Could a dark realization of the genetic code be involved with the criticality of water and explain the high information content of snowflakes and the findings of Emoto? Snowflake has a locally violated 6-fold rotational symmetry and looks like a planar tree with branches emanating from the center. That one cannot find two identical snowflakes, can be understood in terms of criticality during their formation.

   Icosahedron and tetrahedron correspond to an icosahedral symmetry group with 60 elements and hexagon to Z_6. All these groups belong to an infinite hierarchy of discrete and finite subgroups of $SU(2)$ associated with the inclusions of von Neumann algebras known as hyperfinite factors of type II_1 [K10, K8]. $M^8 - H$ duality allows us to interpret $SU(2)$ as a covering group of the automorphism group of quaternions.

4. The dark proton realization genetic code would be in terms of icosa-tetrahedral tessellation of hyperbolic 3-space H^3 (light-cone proper time constant surface) [L6]. Ordinary ice I_h consists of hexagonal layers (`https://cutt.ly/sKJcveh`): could a hexagonal tessellation at the level of H^3 could be involved. This suggests that if the genetic code is realized at the level of MB, a symmetry breaking leading from an icosa-tetrahedral tessellation to a hexagonal tessellation at the level of ordinary matter takes place in the freezing of water.

5. Intriguingly, the size scale of the snowflake hexagon is of order .45 cm, which happens to be the gravitational Compton length $\Lambda_{gr} = GM_E/v_0$ in the gravitational field of Earth for $v_0 = c$ determined from other arguments [L7]! This scale is huge as compared with the size of order 1 Angström of the ice crystal hexagon. Quantum fluctuations at quantum criticality involve however large values of h_{eff} meaning scaled up sizes for the basic structures. For $h_{eff} = h_{gr}$ the minimum size would naturally be Λ_{gr}! Note that the thickness of human cortex varies in the range .1-.45 cm.

6. The fourth phase of water, as Pollack calls it, is formed in the Pollack effect [I2, I1, I5, I4] and consists of hexagonal layers connected by hydrogen bonds. The effective stoichiometry

is $H_{1.5}O$ so that every fourth proton goes somewhere and a negatively charged exclusion zone (EZ) is formed. In the TGD based model, every fourth proton becomes a dark proton at flux tube so that the stoichiometry becomes $H_{1.5}O$.

Dark protons with $h_{eff} = h_{gr}$ would not be present for snowflakes nor for the crystal-like structures studied by Emoto. However, at the quantum criticality for freezing they could emerge and be associated with quantum gravitational hydrogen bonds (flux tubes) containing dark protons delocalized in the Earth size scale [L11, L12].

The basic claim of Emoto is that water at criticality has emotions and expresses them. If bioharmony determines emotions and is realized in terms of dark proton and dark photon sequences at quantum criticality, the question arises whether a dark realization of the genetic code for snow flakes and whether the MB controls and communicates with water using dark 3-photons. Conditioned learning is based on emotions: could water at criticality be able to learn in this way?

If quantum criticality is the prerequisite of life, one can ask whether snowflakes of the crystal structures of Emoto could be "revived" by bringing the water to criticality.

7. At least for water, silicon, gallium, germanium, bismuth, and plutonium, the density is higher for liquid phase than solid phase above criticality. Could all substances with this property show analogs of Pollack and Emoto effects? Or could these effects appear universally at melting and sublimation curves. What about the analogs of snowflakes with size $\Lambda_{gr} \sim .45$ cm?

2.5.3 Metabolism of the protocell above tri-criticality

Consider first the situation above tricricality, when liquid water and perhaps also the counterpart of physiological quantum criticality was possible.

1. The temperature is above tricritical temperature $T = .01$ C (`https://cutt.ly/EKx9nGX`). The frequency distribution of thermal photons has a maximum at energy .131 eV at this temperature. This energy corresponds to a Josephson energy of a Cooper pair for membrane potential of .066 eV. The membrane potential varies in the range .04-0.08 eV.

   Note that the electronic variant of the gravitational metabolic energy quantum is about .25 meV, which might explain the metabolism of cilia [L11], is of the same order of magnitude as the thermal energy of CMB now.

2. According to the TGD view, biochemistry involves quantum gravitation at the level of dark hydrogen bonds and requires the presence of gravitational fields of both Earth and nearby Sun. In the interstellar space ATP-ADP machinery and its possible electronic counterpart [L11] would have been absent and only gravitational self-interaction energy of the water blob could have served as a metabolic energy source receiving its energy.

   Stellar radiation could feed energy to the quantum gravitational degrees of freedom of the proto cell, in particular in the range of visible energies. The gravitational energy could in turn be feeded to the degrees of freedom of the protocell. Hydrogen bonded structures involving dark HBs could receive this energy as a metabolic energy.

2.5.4 Could cosmic microwave background have served as metabolic energy source for prebiotic life-forms?

In the prebiotic phase at interstellar space the temperature was very low and the water blobs were below tri-criticality so that the liquid phase was absent. Therefore quantum criticality could relate to the sublimation of ice.

Stars are a possible source of metabolic energy but what about the cosmic microwave background as a heat bath providing metabolic energy for water blobs as prebiotic life forms?

1. Energy 3.5 meV assigned with the action potential corresponds to $T \simeq 35K$, which is roughly $T_{phys}/10$, and near to the temperature of the cosmic microwave background in the early Universe with age about 1 Gy. There is evidence that important biomolecules were present

already at this time although chemistry should have been frozen. A TGD based explanation of this finding has been considered in [L10].

2. Could the heat bath defined by the cosmic microwave background (CMB) have served as a source of metabolic energy in the interstellar space during the prebiotic period providing the energy needed to induce action potential? The periodic generation of the action potential as a sequence of pairs of BSFRs would be analogous to breathing or sleep-awake cycle [L9].

   During the sleep period, the water blob would dissipate with a reversed arrow of time and effectively extract thermal energy from the environment. During the wake-up period after BSFR, the blob would dissipate this energy to both internal and external degrees of freedom. The blob would also receive energy from the CMB background serving as a heatbath. The energy dissipated in the internal degrees of freedom would have served as a metabolic energy driving self-organization and gradual chemical evolution in the presence of carbohydrates and atoms needed by the basic organic molecules.

2.6 Could quantum criticality make microtubules very special?

MTs are regarded as very special in P-H theory. Their role at the level of the brain indeed seems to be very special. Why should MTs be so special from the point of view of consciousness?

Quantum criticality is the key feature of the TGD Universe, in particular that of living matter. Quantum criticality makes possible quantum fluctuations and long range correlations at the level of MB realized as a superposition of phases with varying value of $h_{gr} = GMm/v_0$ and and therefore of scaled variants of MBs. Space-time surface in the superposition would correspond to slightly different values of v_0.

MTs are critical systems in the sense that their length fluctuates wildly and their decaying region expands also in transversal directions. This fluctuation could reflect a superposition of quantum critical dark matter at MB with varying values of $h_{eff} = h_{gr}$ and thus different size scales of flux tubes proportional to h_{eff}.

The variation of the flux tube scale would be proportional to $\Delta v_0/v_0$ and, as already proposed, presumably quantized by number theoretical reasons. $\beta_0 = 1/n$ is perhaps the realistic option. The changes of MT lengths could have an interpretation as being induced by the scalings of MB of MT with respect to origin near the passive end of MT so that the scaling would be largest at the active end.

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