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

M. Pitkänen,

February 2, 2024
Email: matpitka6@gmail.com.
http://tgdtheory.com/public_html/.
Postal address: Rinnekatu 2-4 A 8, 03620, Karkkila, Finland. ORCID: 0000-0002-8051-4364.

Contents

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 [D2] (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 [L14]. 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 [L12].

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 [L12] 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 [D2] (`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 [D2], 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 [L12, L13] 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 [L12, L13]. 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 [K2, K3, K4, K5]. 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 [K8, K1] [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 [L12, L13].

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 [L12].

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 [L12].

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 penduli as a mechanical analog [K9]. 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 [L12], 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 [L13, L15].

2.1.1 Dark-electron hole pairs as a signature of gravitational metabolism

An intriguing resemblance between the physics of electron-hole pair Bose-Einstein condensates at very low temperatures and photosynthesis have been discovered. The findings are described in a popular article at (`https://rb.gy/fnv3j`). The original article of Schouten et al [I5] can be found at `https://rb.gy/b982c`. It has been observed that electron-hole pairs as quasiparticles form Bose-Einstein condensates at very low temperatures. They behave very similarly as in living matter where temperature is much higher and these Bose-Einstein condensates should not exist.

1. TGD predicts dark matter as phases of ordinary matter with effective Planck constant $h_{eff} = nh_0$ (n integer, $h_0 < h$) residing at field body (in particular, at the monopole flux tubes of the magnetic body (MB)) defining the TGD counterpart for classical em fields in TGD as collection of space-time sheets carrying classical fields.

   The large value of h_{eff} makes these phases macroscopically quantum coherent and analogous to Bose-Einstein condensates. This leads to a variety of predictions. In particular, the magnetic body (MB) would be in a key role in living matter controlling the ordinary biomatter and forcing it to behave coherently. The very large value of gravitational Planck constant $h_{eff} = h_{gr} = GMm/\beta_0$, $\beta_0 = v_0/c \leq 1$, makes possible gravitational quantum coherence at the gravitational MB and the classical gravitational fields of Sun and Earth play a key role in quantum biology: this is reflected by many magic numerical co-incidences [L10].

2. The strange effects in the brain (the quantal effects of ELF em fields in the brain) originally led to the TGD view of dark matter, which is also predicted by the number theoretical vision of TGD. For instance, superconductivity and analogous phenomena are possible at room temperatures at MB of the system. The TGD based model of high Tc superconductivity relies on them [**?**, **?**, L4].

3. One interesting structure is a pair of a dark electron and the hole created as the electron becomes a dark electron at MB. The quantum numbers of holes and dark electrons are in

1-1 correspondence, and this could make possible a kind of quantum holography mapping the state of holes to that of dark electrons. This would provide representations of biological body (BB) at MB as kinds of sensory perceptions about the state of BB [L16].

4. The transfer of electrons to dark electrons can cause electronic charge fluctuations in ordinary matter due to the transfer of electrons to dark electrons at MB. For strange metals, these fluctuations have been observed: it is difficult to understand them as being caused by the attachment of electrons to atoms of strange metal since the time scale is too long (`https://rb.gy/ws51f`).

The reported experimental findings about a connection between electron-hole pair BE-condensates at low temperatures and photosynthesis can be seen as a support for the TGD view of dark matter and living systems. In particular, the TGD view would be important for understanding photosynthesis and other proposals for how quantum physics could be relevant for biology. For instance, the model for the ability of birds to navigate by utilizing the magnetic field of Earth suffers from a problem that the ordinary Planck constant is too small by a factor of order 1/100.

1. The TGD explanation of the new findings is in terms of the hierarchy of Planck constants labelling dark matter as phases of ordinary matter. Gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$, $\beta_0 \leq 1$, labels a levels of hierarchy, which are of special importance in the TGD based model of living matter.

2. In TGD, one could have Bose-Einstein condensates of hole-dark electron pairs. Dark electrons would reside in a very long gravitational flux tube and would be kicked to height of order Earth radius by solar photons during photosynthesis. They would serve as a metabolic energy resource: gravitational batteries would be loaded in photosynthesis. When dark electrons drop down and transform to ordinary ones, they liberate energy which can be stored or used. ATP-ADP process could involve this dropping down.

   Also dark protons could be transferred to magnetic fux tubes. This would take place in Pollack effect in which irradation of water in the presence of gel phase leads to the formation negatively charged regions with effective stoichiometry $H_{1.5}O$. Part of protons goes somewhere and one possible place could be gravitational MB but also much shorter flux tubes for which dark proton corresponds to the size scale of DNA nucleotide are possible and would be important for the reaization of dark genetic codon. Perhaps the most plausible option is that triplets of dark protons and electrons are involved in the case of metabolic energy storage.

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 [L12], 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 [L12] 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 [L12] 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 [L12]). 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 [L12], 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 [K7] [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, K6]. $M^8 - H$ 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, I6, 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 [L12, L13].

   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 Strange coincidences related to gravitational Planck constant, basic biorhythms, membrane potential and metabolic energy currency

It is becoming clear that the gravitational quantum coherence is central for life on Earth. The hierarchy of Planck constants $h_{eff} = nh_0$ involves special values, in particular gravitational Planck constants $\hbar_{eff} = \hbar_{gr} = GMm/\beta_0$, where M is a large mass (say mass of Sun or Earth) and m is small mass (say mass of electron or proton) and $\beta_0 = v_0/c \leq 1$ is velocity parameter, are of key importance for living matter. Particles with a different value of $\hbar_{gr}$ correspond to different gravitational flux tubes and the value of β_0 can depend on the particle.

There are several amazing numerical co-incidences supporting this view.

1. For Sun one has $\beta_0 \simeq 2^{-11}$ which happens to be rather near to the electron proton mass ratio m_e/m_p. The condition $\hbar_{gr}(M_S, m_p, \beta_0(Sun) \simeq m_e/m_p) = \hbar_{gr}(M_S, m_e, \beta_0 = 1)$ would guarantee resonance between dark photons generated by the solar gravitational flux tubes assignable to protons and electrons.

2. In accordance with Equivalence Principle, the gravitational Compton length $\hbar_{gr}(M_S, \beta_0)/m = GM/\beta_0 = r_S/2\beta_0$ is independent of m for Sun $GM_S/\beta_0(Sun)$ is rather near to Earth radius. For Earth one has $GM_S/\beta_0(Earth) \simeq .45$ cm which corresponds to the size scale of the somewhat mysterious snowflake analogous to a zoom-up of a basic hexagonal unit cell of ice crystal. There is evidence for $\beta_0(Earth) = 1$ in hydrodynamics, in particular from the TGD based model [L7] for the observed hydrodynamical quantum analogs described in an article of Bush et al [D1] (see `https://cutt.ly/nEk5OLA` and `https://cutt.ly/xEk5Api`)

3. The gravitational Compton length of the galactic blackhole corresponds rather precisely to the $n = 1$ Bohr orbit associated with the Sun. This suggests gravitational quantum coherence in the scale of the galaxy.

In the following some additional strange coincidences are discussed. It would be very natural if the basic biorhythms defined by the duration $T_d = 24$ hours of day and the duration of year $T_y = 365$ days would correspond to energies of dark photons $E = \hbar_{gr} f$, which are biologically significant energies. The potential energy $eV_c \simeq .05$ eV associated with the cell membrane defines Josephson energy in the TGD inspired model of cell membrane. Metabolic energy currency with the nominal value of .5 eV is second important energy. Could the periods of fundamental biorhythms, fundamental biological energies, and the gravitational Planck constants for Sun and Earth correlate?

The above assumptions imply that one has $\beta_0(Sun)/\beta_0(Earth) \simeq m_e/m_p$ and $h_{gr}(Sun, me)/h_{gr}(Earth, m_p) \simeq M(Sun)/M(Earth)$. The value of Sun-Earth mass ratio is $M_S/M_E \simeq 6 \times 10^5$.

1. The corresponding frequency corresponding to the basic biorhythm $T_d = 24$ is $f_d = 1/G_d = 1/24hours = [1/(2.4 * 3.6)]10^{-6} \simeq 1.1^{-6}$ s. The corresponding Josephson energy would be $E(\hbar_{gr}(Sun, m_e), f_d) \simeq .06eV = E_J$. This is very near to the Josephson energy E_J for cell membrane potential!

2. For $T_y = 1$ year $= 365$ days one has $E(\hbar_{gr}(Sun, m_p), f = 1/T_y) \simeq (m_p/m_e) * (24\, hours/year) \times E_J \simeq (2^{11}/365)E_J \simeq .33eV$. This is not far from the value of the metabolic energy currency near to .5 eV.

2.5.4 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 [L12], 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 [L12] 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.

2.5.5 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 [L11].

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.

3 Appendix: Quantum gravitational decoherence as a way to test the Diosi-Penrose model

The approach of Donati et al [D2] to test the Penrose-Diosi variant of the Orch-Or [J4] model yielded a null result. In the sequel, the Diosi-Penrose model is discussed from the point of view of standard quantum theory predicting the negative outcome and the experiment of Donati is summarized. Also the TGD view of the situation is briefly described.

3.1 Brief summary and criticism of Penrose-Diosi model

A natural starting point idea would be that ordinary quantum coherence induces quantum gravitational coherence.

1. Quantum superposition of 3-geometries dictated by mass distributions of particles defined by particle wave functions. The wave function of the many-particle system is a superposition over configurations with localized particles and each configuration corresponds to a superposition of gravitational potentials defining gravitational self-energy.

2. In general relativity, this superposition corresponds to a point in the space of 3-geometries, the superspace of Wheeler consisting of 3-geometries. Therefore quantum gravitation is unavoidable and quantum coherence for matter dictates that for the gravitation. Therefore ordinary quantum theory forces quantum gravitation in the counterpart of the superspace.

   In this view, the rate of quantum gravitational dehorence corresponds to the rate of ordinary quantum coherence: this conforms with Einstein's equations and Equivalence Principle.

3. It is essential that one has a many-particle system. For a single particle system the gravitational self-energy is the same for all positions of the particle and does not depend on the wave function at all. Even for many particle systems, the superposition of shifted systems have the same gravitational binding energy.

   In the Penrose-Diosi model, it is however proposed that the above argument works for single particle and gravitational interaction energy is estimated by assigning to wave function an effective 2-particle system.

   The underlying reason for this assumption is the idea that the notion of wave function and therefore also wave function collapse somehow reduces to classical gravitation.

This argument predicts a null result in any experiment trying to demonstrate gravitational quantum coherence in the sense of Penrose-Diosi.

3.2 Could one measure the rate of gravitational quantum decoherence in the Penrose-Diosi model?

In the Penrose-Diosi model [J4], the quantum gravitational coherence can in principle be detected by measuring the rate for gravitational quantum decoherence.

1. Quantum gravitational decoherence for a wave function representing a superposition of mass distribution and a shifted mass distribution is considered.

   The idea is gravitational quantum coherence could be detected if the corresponding quantum decoherence occurs faster than other forms of decoherence. The basic objection is that the Equivalence Principle states that the two decoherences are one and the same thing.

If the gravitational coherence time is short enough but not too short, this might be possible. Limits for the decoherence time τ_{gr} are proposed and are between millisecond and second: these are biologically relevant time scales.

2. Gravitational quantum decoherence time τ_{gr} is estimated by applying Uncertainty Principle: $\tau_{gr} = \hbar/\Delta E_{gr}$. ΔE_{gr} is the difference between the gravitational self-energy for a system and a shifted system.

   One has actually a superposition of different classical configurations each inducing a classical gravitational field. Wave functions for particles of *many-particle state* define the gravitational superposition. Gravitational superposition coded by a wave function for a large number of particles. In this case, gravitational binding energies E_{gr} ΔE_{gr} between 2 different quantum states are well-defined.

   One could take atomic physics as a role model in the calculation of the change of the gravitational potential energy. Coulomb energy would be replaced with gravitational potential energy.

3. With a motivation coming from the notion of gravitational wave function collapse, one however considers *single particle* states obtained as a superposition of $\Psi(r)$ and its shift $\Psi(r+d)$. In this case, the gravitational interaction energy is not well-defined unless one defines it as a gravitational self-interaction energy, which however does not depend on the position of the particle at all and is same for local state and the bilocal state.

   Penrose suggests that the difference between gravitational interaction energies makes sense and can be estimated *classically* using effective mass densities $m|\Psi^2|(r)$ and $m|\Psi(r+d)|^2$ instead of $\Psi(r)$ and $\Psi(r+d)^*$. One seems to think that one has effectively a two-particle system and calculates the gravitational interaction energy for it. To me this looks like treating a delocalized single-particle state as a two-particle state.

4. The situation could be simplified for a superposition of a macroscopic quantum state, say B-E condensate, and its shift. One could try to detect decoherence time τ for this situation. Now however the fact that B-E condensate is effectively a single particle, suggests that the change of the gravitational self-interaction energy vanishes.

5. It turns out that it is not possible to find parameter values which would allow a test in the framework of recent technology.

   The intuitive idea is that the gravitational SFRs localizing the wave functions effectively induce instantaneous shifts of particles. For charged particles this induces accelerated motion and emission of radiation. This radiation might be detectable. The implicit assumption is however that a single particle state effectively behaves like a 2-particle state as far as gravitation is considered.

   No evidence for this radiation and therefore for gravitational SFRs is found.

One can represent several critical arguments against the Penrose-Diosi model besides the argument represented in the beginning.

1. The reduction to a single particle case does not make sense in standard quantum physics (Penrose suggests something different). The gravitational self-interaction energy is the same for both shifted single particle states for any single particle wave function. For many-particle states the situation would change.

2. The radiation should have wavelength λ of order of the shift parameter d. d is expected to correspond to atom size or nuclear or nucleon size in the case of atoms. The energies for photons would be above 10^4 eV. These energies are suspiciously large. Much larger shifts would be required but these are not plausible for the proposed mechanism.

3. Why shifted mass distributions are assumed? Even in the case of many-particle systems the gravitational self-interaction energy does not depend on wave function if the system is only shifted. The reason is that the relative positions of particles are not changed in the shift.

If one uses many-particle states, a superposition of scaled mass distributions would be more natural in the standard quantum physics framework. A coherent, easy-to-calculate, change of the gravitational interaction energy. A possible connection with density changing phase transitions, such as melting and boiling, emerges. Water is a key substance in living systems!

3.3 The approach of Donadi et al

The model proposed by Donadi et al is as follows.

1. A many-particle state with delocalized single particle wave functions induces superposition of 3-geometries shifted with respect to each other. Now a superposition of a quantum coherent state and its spatial shift is considered.

2. The estimation for the gravitational decoherence time τ for Orch-OR from Uncertainty Principle: $\tau \sim \hbar/\Delta E_{gr}$. ΔE_{gr} is quantum uncertainty of the gravitational binding energy. Change in the gravitational self-interaction energy in the formation of superposition of shifted configurations.

3. One must calculate the average value of the binding energy for a single particle state effectively regarded as 2-particle state. The outcome is finite. ΔE_{gr} is assumed to be effectively the change of classical self-interaction energy for a mass density $\rho = m|\Psi|^2$, m the mass of the particle. Ψ can be solved from Schrödinger Newton equation. Point-like particle is replaced with the wave function of the particle defining a mass density.

How could one test the model? There are two approaches.

3.3.1 Direct measurement of gravitational decoherence time τ_{gr} is not possible

Gravitational decoherence should be faster than ordinary so that ordinary causes of decoherence are not yet active. Could one find such a system and be able to measure τ_{gr}.

1. A direct test of the equation of τ requires creating a large superposition of a massive system, to guarantee that τ_{gr} is short enough for the collapse to become effective before any kind of external noise disrupts the measurement.

2. Penrose and collaborators suggested a setup for creating a spatial superposition of a mirror of mass 10^{-12} Kg that has a decay time of order $\tau_{gr} \sim 0.002 - 0.013$ s, which is competitive with standard decoherence times.

3. The major difficulty in implementing this and similar proposals consists in creating a superposition of a relatively large mass and keeping it stable for times comparable to τ_{gr}.

   (a) To give some examples, the largest spatial superposition so far achieved is of about 0.5 m, but the systems involved are Rb atoms (mass $m = 1.42 \times 10^{-25}$ Kg), which are quite too light.

   (b) In matter-wave interferometry with macromolecules states are delocalized over distances of hundreds nm, and masses beyond 25 kDa (10^{-23} Kg), still not enough. Mass too small!

   (c) By manipulating *phononic* states, collective superpositions of estimated 10^{16} carbon atoms (mass $\sim 10^{-10}$ Kg) are created over distances of 10^{11} m, coherence scale is about 10^{-5} meters, neuron size. The life-time of phonons is of order 10^{-12} s, which is too short. 2 ms is the lower bound for τ.

   What does this mean? A superposition of wave functions with mean positions differing by 10^{-11} m define mass densities? Coherence scale 10^{-5} m.

These numbers show that keeping the measurement of τ is beyond the reach of recent technologies.

3.3.2 Could Brownian-like diffusion as a side effect allow the detection of gravitational wave function collapses?

The assumptions of the model of Donadi et al [D2]) are as follows.

1. Penrose-Diosi model is assumed and single particle states are considered. Gravitational wave function collapse is Poissonian: collapses occur independently.

2. Lindblad dynamics for the density matrix ρ of the system is assumed. Gravitational decoherence implies non-unitary dynamics. The form of the decoherence term is dictated by the difference between gravitational self-interaction energies. $Tr(\rho p^2)$ increases with time. Diffusion would heat the system. The size scale range $R_0 = 10^{-14} - 10^{-15}$ m for the system experiencing gravitational collapse is excluded experimentally.

3. This leaves however dissipative effects. One can argue that the collapse induces an emission of radiation by charged particles since effectively the charged particle is in instantaneous motion during the collapse. In collapses particles are randomly moved and radiate. The wavelength λ of the radiation is smaller than charged particle size: atom size or even nuclear or nucleon size.

   The first criticism is that one has a single particle state and according to the standard view gravitational self-energy does not depend on the wave function. The second criticism is that the scale of energies of photons is huge as compared to intuitive expectations for gravitational interaction energies.

4. The intensity of the radiation can be estimated. The predicted radiation intensity is weak but detectable. The wavelength of the radiation emitted in gravitational collapse should be of the order d. For d in the range of proton wavelength and atomic size scale, the energy would have a lower bound 10^4 eV. This looks unrealistic.

5. The radiation was not detected. No evidence for the proposed kind of collapse was observed in the expected range between atomic scale and proton Compton length.

3.4 Comparison with the TGD view

A brief comparison with the TGD view is useful.

3.4.1 Some suggestive observations

There are some suggestive observations which might be used to end up with a TGD based view of the role of quantum gravitation in living matter.

1. The gravitational binding energy of protons in the Earth's gravitational field is about .5 eV. For electrons one has .25 meV. These are biologically relevant energy scales!

2. Could quantum gravitation be quantum coherent in long, even astrophysical scales? For a macroscopic system GMm is the counterpart of coupling strength. If the entire system $M + m$ behaves like a quantum coherent system, the perturbation series is with respect to gravitational fine structure constant $\alpha_g r = GMm/hbar \gg 1$ and does not converge.

3. Nottale hypothesis introduces gravitational Planck constant $\hbar_{gr} = GMm/beta_0$, $\beta_0 = v_0/ \leq 1$. Gravitational Compton length $\Lambda_{gr} = GM/beta_0 = r_s/2\beta_0$ ($r_s = 2GM$ is Schwartschild radius) of order Earth radius for M=M(Sun) and about .45 cm for $M = M(Earth)$ the size of snowflake. α_{gr} is replaced in the quantum phase transition $\hbar \to \hbar_{gr}$ with a universal coupling strength $\alpha_{gr} = beta_0/4\pi < 1/4\pi$: the perturbation series converges!!

3.4.2 What kind of quantum superpositions should one consider?

Gravitational fields have infinite range and are not screened. This suggests that long range quantum coherence induced by them is possible.

1. The notion of MB carrying dark matter in the TGD sense is an essential notion. Scaled versions of magnetic bodies carrying quantum coherent dark matter with $\hbar_{eff}$. For gravitational quantum coherence one has $\hbar_{eff} = \hbar_{gr}$. Quantum coherence of MB would induce the coherence of ordinary matter forcing its quantum gravitational coherence.

2. In TGD gravitationally quantum coherent states would not be superpositions of shifted 3-geometries. Coherent and large change of the self-interaction energy takes place in the scaling. Therefore superpositions of scaled versions of 3-D surfaces are more natural.

3. Ordinary phase transitions such as melting and evaporation involve density fluctuations, which would be induced by scalings. Quantum superposition of states with different densities at thermal criticality induced by quantum criticality.

4. Water as a liquid has a very special role: it has hundreds of thermodynamic anomalies. The strongest ones are in the physiological temperature range. There is evidence that several phases are simultaneously present. Could this reflect the presence of several dark phases at the MB.

This argument predicts a null result in any experiment trying to demonstrate gravitational quantum coherence in the sense of Penrose-Diosi.

3.5 Could one measure the rate of gravitational quantum decoherence in the Penrose-Diosi model?

In the Penrose-Diosi model, the quantum gravitational coherence can in principle be detected by measuring the rate for gravitational quantum decoherence.

1. Quantum gravitational decoherence for a wave function representing a superposition of mass distribution and a shifted mass distribution is considered.

   The idea is gravitational quantum coherence could be detected if the corresponding quantum decoherence occurs faster than other forms of decoherence. The basic objection is that the Equivalence Principle states that the two decoherences are one and the same thing.

   If the gravitational coherence time is short enough but not too short, this might be possible. Limits for the decoherence time τ_{gr} are proposed and are between millisecond and second: these are biologically relevant time scales.

2. Gravitational quantum decoherence time τ_{gr} is estimated by applying Uncertainty Principle: $\tau_{gr} = \hbar/\Delta E_{gr}$. ΔE_{gr} is the difference between the gravitational self-energy for a system and a shifted system.

   One has actually a superposition of different classical configurations each inducing a classical gravitational field. Wave functions for particles of *many-particle state* define the gravitational superposition. Gravitational superposition coded by a wave function for a large number of particles. In this case, gravitational binding energies E_{gr} ΔE_{gr} between 2 different quantum states are well-defined.

   One could take atomic physics as a role model in the calculation of the change of the gravitational potential energy. Coulomb energy would be replaced with gravitational potential energy.

3. With a motivation coming from the notion of gravitational wave function collapse, one however considers *single particle* states obtained as a superposition of $\Psi(r)$ and its shift $\Psi(r+d)$. In this case, the gravitational interaction energy is not well-defined unless one defines it as a gravitational self-interaction energy, which however does not depend on the position of the particle at all and is same for local state and the bilocal state.

   Penrose suggests that the difference between gravitational interaction energies makes sense and can be estimated *classically* using effective mass densities $m|\Psi^2|(r)$ and $m|\Psi(r+d)|^2$ instead of $\Psi(r)$ and $\Psi(r+d)^*$. One seems to think that one has effectively a two-particle system and calculates the gravitational interaction energy for it. To me this looks like treating a delocalized single-particle state as a two-particle state.

4. The situation could be simplified for a superposition of a macroscopic quantum state, say B-E condensate, and its shift. One could try to detect decoherence time τ for this situation. However, the fact that B-E condensate is effectively a single particle, suggests that the change of the gravitational self-interaction energy vanishes.

5. It turns out that it is not possible to find parameter values which would allow a test in the framework of recent technology.

   The intuitive idea is that the gravitational SFRs localizing the wave functions effectively induce instantaneous shifts of particles. For charged particles this induces accelerated motion and emission of radiation. This radiation might be detectable. The implicit assumption is however that a single particle state effectively behaves like a 2-particle state as far as gravitation is considered.

   No evidence for this radiation and therefore for gravitational SFRs is found.

One can represent several critical arguments against the approach besides the argument represented in the beginning.

1. The reduction to a single particle case does not make sense. The gravitational self-interaction energy is the same for both shifted single particle states for any single particle wave function. For many-particle states the situation would change.

2. The radiation should have wavelength λ of order of the shift parameter d. d is expected to correspond to atom size or nuclear or nucleon size in the case of atoms. The energies for photons would be above 10^4 eV. These energies are suspiciously large. Much larger shifts would be required but these are not plausible for the proposed mechanism.

3. Why shifted mass distributions are assumed? Even in the case of many-particle systems the gravitational self-interaction energy does not depend on wave function if the system is only shifted. The reason is that the relative positions of particles are not changed in the shift.

   If one uses many-particle states, a superposition of scaled mass distributions would be more natural. A coherent, easy-to-calculate, change of the gravitational interaction energy. A possible connection with density changing phase transitions, such as melting and boiling, emerges. Water is a key substance in living systems!

3.6 The approach of Donadi et al

The model considered by Donadi et al is as follows.

1. A many-particle state with delocalized single particle wave functions induces superposition of 3-geometries shifted with respect to each other. Now a superposition of a quantum coherent state and its spatial shift is considered.

2. The estimation for the gravitational decoherence time τ for Orch-OR from Uncertainty Principle: $\tau \sim \hbar/\Delta E_{gr}$. ΔE_{gr} is quantum uncertainty of the gravitational binding energy. Change in the gravitational self-interaction energy in the formation of superposition of shifted configurations.

3. One must calculate the average value of the binding energy for a single particle state effectively regarded as 2-particle state. The outcome is finite. ΔE_{gr} is assumed to be effectively the change of classical self-interaction energy for a mass density $\rho = m|\Psi|^2$, m the mass of the particle. Ψ can be solved from Schrödinger Newton equation. Point-like particle is replaced with the wave function of the particle defining a mass density.

How could one test the model? There are two approaches.

3.6.1 Direct measurement of gravitational decoherence time τ_{gr} is not possible

Gravitational decoherence should be faster than ordinary so that ordinary causes of decoherence are not yet active. Could one find such a system and be able to measure τ_{gr}.

1. A direct test of the equation of τ requires creating a large superposition of a massive system, to guarantee that τ_{gr} is short enough for the collapse to become effective before any kind of external noise disrupts the measurement.

2. Penrose and collaborators suggested a setup for creating a spatial superposition of a mirror of mass 10^{-12} Kg that has a decay time of order $\tau_{gr} \sim 0.002 - 0.013$ s, which is competitive with standard decoherence times.

3. The major difficulty in implementing this and similar proposals consists in creating a superposition of a relatively large mass and keeping it stable for times comparable to τ_{gr}.

   (a) To give some examples, the largest spatial superposition so far achieved is of about 0.5 m, but the systems involved are Rb atoms (mass $m = 1.42 \times 10^{-25}$ Kg), which are quite too light.

   (b) In matter-wave interferometry with macromolecules states are delocalized over distances of hundreds nm, and masses beyond 25 kDa (10^{-23} Kg), still not enough. Mass too small!

   (c) By manipulating *phononic* states, collective superpositions of estimated 10^{16} carbon atoms (mass $\sim 10^{-10}$ Kg) are created over distances of 10^{11} m, coherence scale is about 10^{-5} meters, neuron size. The life-time of phonons is of order 10^{-12} s, which is too short. 2 ms is the lower bound for τ.

   What does this mean? A superposition of wave functions with mean positions differing by 10^{-11} m define mass densities? Coherence scale 10^{-5} m.

   These numbers show that keeping the measurement of τ is beyond the reach of recent technologies.

3.6.2 Could Brownian-like diffusion as a side effect allow the detection of gravitational wave function collapses?

The assumptions of the model of Donadi et al [D2] are as follows.

1. Penrose-Diosi model is assumed and single particle states are considered. Gravitational wave function collapse is Poissonian: collapses occur independently.

2. Lindblad dynamics for the density matrix ρ of the system is assumed. Gravitational decoherence implies non-unitary dynamics. The form of the decoherence term is dictated by the difference between gravitational self-interaction energies. $Tr(\rho p^2)$ increases with time. Diffusion would heat the system. The size scale range $R_0 = 10^{-14} - 10^{-15}$ m for the system experiencing gravitational collapse is excluded experimentally.

3. This leaves however dissipative effects. One can argue that the collapse induces an emission of radiation by charged particles since effectively the charged particle is in instantaneous motion during the collapse. In collapses particles are randomly moved and radiate. The wavelength λ of the radiation is smaller than charged particle size: atom size or even nuclear or nucleon size.

   The first criticism is that one has a single particle state and according to the standard view gravitational self-energy does not depend on the wave function. The second criticism is that the scale of energies of photons is huge as compared to the intuitive expectations for gravitational interaction energies.

4. The intensity of the radiation can be estimated. The predicted radiation intensity is weak but detectable. The wavelength of the radiation emitted in gravitational collapse should be of the order d. For d in the range of proton wavelength and atomic size scale, the energy would have a lower bound 10^4 eV. This looks unrealistic.

5. The radiation was not detected. No evidence for the proposed kind of collapse was observed in the expected range between atomic scale and proton Compton length.

3.7 Comparison with TGD view

A brief comparison with the TGD view is useful.

3.7.1 Some suggestive observations

There are some suggestive observations which might be used to end up with a TGD based view of the role of quantum gravitation in living matter.

1. The gravitational binding energy of protons in the Earth's gravitational field is about .5 eV. For electrons one has .25 meV. These are biologically relevant energy scales!

2. Could quantum gravitation be quantum coherent in long, even astrophysical scales? For a macroscopic system GMm is the counterpart of coupling strength. If the entire system $M + m$ behaves like a quantum coherent system, the perturbation series is with respect to gravitational fine structure constant $\alpha_g r = GMm/hbar \gg 1$ and does not converge.

3. Nottale hypothesis introduces gravitational Planck constant $\hbar_{gr} = GMm/beta_0$, $\beta_0 = v_0/ \leq 1$. Gravitational Compton length $\Lambda_{gr} = GM/beta_0 = r_s/2\beta_0$ ($r_s = 2GM$ is Schwartschild radius) of order Earth radius for M=M(Sun) and about .45 cm for $M = M(Earth)$ the size of snowflake. α_{gr} is replaced in the quantum phase transition $\hbar \to \hbar_{gr}$ with a universal coupling strength $\alpha_{gr} = beta_0/4\pi < 1/4\pi$: the perturbation series converges!!

3.7.2 What kind of quantum superpositions should one consider?

Gravitational fields have infinite range and are not screened. This suggests that long range quantum coherence induced by them is possible.

1. The notion of MB carrying dark matter in the TGD sense is essential. Scaled versions of magnetic bodies carrying quantum coherent dark matter with $\hbar_{eff}$. For gravitational quantum coherence one has $\hbar_{eff} = \hbar_{gr}$. Quantum coherence of MB would induce the coherence of ordinary matter forcing its quantum gravitational coherence.

2. In TGD gravitationally quantum coherent states would not be superpositions of shifted 3-geometries. Coherent and large change of the self-interaction energy takes place in the scaling. Therefore superpositions of scaled versions of 3-D surfaces are more natural.

3. Ordinary phase transitions such as melting and evaporation involve density fluctuations, which would be induced by scalings. Quantum superposition of states with different densities at thermal criticality induced by quantum criticality.

4. Water as a liquid has a very special role: it has hundreds of thermodynamic anomalies. The strongest ones are in the physiological temperature range. There is evidence that several phases are simultaneously present. Could this reflect the presence of several dark phases at the MB.

REFERENCES

Condensed Matter Physics

[D1] Bush JWM et al. Wavelike statistics from pilot wave dynamics in circular corral. *Phys Rev E*, 88(011001(R)), 2013. Available at: `https://journals.aps.org/pre/abstract/10.1103/PhysRevE.88.011001`.

[D2] Donadi S et al. Underground test of gravity-related wave function collapse. *Nature*, 17:74–78, 2021. Available at: `https://www.nature.com/articles/s41567-020-1008-4`.

Cosmology and Astro-Physics

[E1] Nottale L Da Rocha D. Gravitational Structure Formation in Scale Relativity, 2003. Available at: https://arxiv.org/abs/astro-ph/0310036.

Biology

[I1] The Fourth Phase of Water: Dr. Gerald Pollack at TEDxGuelphU, 2014. Available at: https://www.youtube.com/watch?v=i-T7tCMUDXU.

[I2] Pollack G. *Cells, Gels and the Engines of Life*. Ebner and Sons, 2000. Available at: https://www.cellsandgels.com/.

[I3] Emoto M. *Crystal Clear – Messages from Water*. Beyond Worlds, 2005. Available at: https://www.libristo.eu/en/book/hidden-messages-in-water_09269861.

[I4] Zhao Q Pollack GH, Figueroa X. Molecules, water, and radiant energy: new clues for the origin of life. *Int J Mol Sci*, 10:1419–1429, 2009. Available at: https://tinyurl.com/ntkfhlc.

[I5] Mazziotti DA Schouten A. Sager-Smith LM. Exciton-Condensate-Like Amplification of Energy Transport in Light Harvesting. *PRX Energy*, 2(023002), 2023. Available at: https://journals.aps.org/prxenergy/abstract/10.1103/PRXEnergy.2.023002.

[I6] Pollack GH Zheng J-M. Long-range forces extending from polymer-gel surfaces. *Phys Rev E*, 68:031408–, 2003. Available at: https://tinyurl.com/ntkfhlc.

Neuroscience and Consciousness

[J1] Bandyopadhyay A. Experimental Studies on a Single Microtubule (Google Workshop on Quantum Biology), 2011. Available at: https://www.youtube.com/watch?v=VQngptkPYE8.

[J2] Blackman CF. *Effect of Electrical and Magnetic Fields on the Nervous System*, pages 331–355. Plenum, New York, 1994.

[J3] Derakshani M et al. At the crossroad of the search for spontaneous radiation and the Orch OR consciousness theory. *Physis of Life Reviews*, 42(4), 2022. Available at: https://www.researchgate.net/publication/360675065_At_the_crossroad_of_the_search_for_spontaneous_radiation_and_the_Orch_OR_consciousness_theory. .

[J4] Kassi A et al. Models of wave-function collapse, underlying theories, and experimental tests. *Rev Mod Phys*, 85:471–527, 2013.

[J5] Bandyopadhyay A Ghosh G, Sahu S. Evidence of massive global synchronization and the consciousness: Comment on "Consciousness in the universe: A review of the 'Orch OR' theory" by Hameroff and Penrose. *Phys Life Rev*, 11:83–84, 2014.

[J6] Penrose R Hameroff S. Reply to criticism of the Orch OR qubit Orchestrated objective reduction is scientifically justified. *ScienceDirect*, 2013. Available at: https://www.sciencedirect.com.

[J7] Penrose R Hameroff SR. *Orchestrated reduction of quantum coherence in brain micro-tubules: A model for consciousness*, pages 507–540. MIT Press, Cambridge, 1996.

[J8] Penrose R. On gravity's role in quantum state reduction. *Gen Relat Gravit*, 28:581–600, 1996.

Books related to TGD

[K1] Pitkänen M. About the Nottale's formula for h_{gr} and the possibility that Planck length l_P and CP_2 length R are related. In *Dark Matter and TGD: https://tgdtheory.fi/tgdhtml/Bdark.html*. Available at: https://tgdtheory.fi/pdfpool/vzerovariableG.pdf, 2023.

[K2] Pitkänen M. Criticality and dark matter: part I. In *Dark Matter and TGD: https://tgdtheory.fi/tgdhtml/Bdark.html*. Available at: https://tgdtheory.fi/pdfpool/qcritdark1.pdf, 2023.

[K3] Pitkänen M. Criticality and dark matter: part II. In *Dark Matter and TGD: https://tgdtheory.fi/tgdhtml/Bdark.html*. Available at: https://tgdtheory.fi/pdfpool/qcritdark2.pdf, 2023.

[K4] Pitkänen M. Criticality and dark matter: part III. In *Dark Matter and TGD: https://tgdtheory.fi/tgdhtml/Bdark.html*. Available at: https://tgdtheory.fi/pdfpool/qcritdark3.pdf, 2023.

[K5] Pitkänen M. Criticality and dark matter: part IV. In *Dark Matter and TGD: https://tgdtheory.fi/tgdhtml/Bdark.html*. Available at: https://tgdtheory.fi/pdfpool/qcritdark4.pdf, 2023.

[K6] Pitkänen M. Evolution of Ideas about Hyper-finite Factors in TGD. In *Topological Geometrodynamics: Overview: Part II. https://tgdtheory.fi/tgdhtml/Btgdoverview2*. Available at: https://tgdtheory.fi/pdfpool/vNeumannnew, 2023.

[K7] Pitkänen M. Geometric Theory of Bio-Harmony. In *Genes and Memes: Part II. https://tgdtheory.fi/tgdhtml/Bgenememe2.html*. Available at: https://tgdtheory.fi/pdfpool/harmonytheory.pdf, 2023.

[K8] Pitkänen M. Quantum gravity, dark matter, and prebiotic evolution. In *Evolution in TGD Universe. https://tgdtheory.fi/tgdhtml/Btgdevolution.html*. Available at: https://tgdtheory.fi/pdfpool/hgrprebio.pdf, 2023.

[K9] Pitkänen M. Quantum Model for Nerve Pulse. In *TGD and EEG: Part I. https://tgdtheory.fi/tgdhtml/Btgdeeg1.html*. Available at: https://tgdtheory.fi/pdfpool/nervepulse.pdf, 2023.

[K10] Pitkänen M. Was von Neumann Right After All? In *TGD and Hyper-finite Factors. https://tgdtheory.fi/tgdhtml/BHFF.html*. Available at: https://tgdtheory.fi/pdfpool/vNeumann.pdf, 2023.

Articles about TGD

[L1] Pitkänen M. New results about microtubules as quantum systems. Available at: https://tgdtheory.fi/public_html/articles/microtubule.pdf., 2014.

[L2] Pitkänen M. The experiments of Masaru Emoto with emotional imprinting of water. Available at: https://tgdtheory.fi/public_html/articles/Emoto.pdf., 2018.

[L3] Pitkänen M. How to compose beautiful music of light in bio-harmony? https://tgdtheory.fi/public_html/articles/bioharmony2020.pdf., 2020.

[L4] Pitkänen M. Comparing the Berry phase model of super-conductivity with the TGD based model. https://tgdtheory.fi/public_html/articles/SCBerryTGD.pdf., 2021.

[L5] Pitkänen M. Galois code and genes. https://tgdtheory.fi/public_html/articles/Galoiscode.pdf., 2021.

[L6] Pitkänen M. Is genetic code part of fundamental physics in TGD framework? Available at: https://tgdtheory.fi/public_html/articles/TIH.pdf., 2021.

[L7] Pitkänen M. TGD and Quantum Hydrodynamics. https://tgdtheory.fi/public_html/articles/TGDhydro.pdf., 2021.

[L8] Pitkänen M. Three alternative generalizations of Nottale's hypothesis in TGD framework. https://tgdtheory.fi/public_html/articles/MDMdistance.pdf., 2021.

[L9] Pitkänen M. About the number theoretic aspects of zero energy ontology. https://tgdtheory.fi/public_html/articles/ZEOnumber.pdf., 2022.

[L10] Pitkänen M. Comparison of Orch-OR hypothesis with the TGD point of view. https://tgdtheory.fi/public_html/articles/penrose.pdf., 2022.

[L11] Pitkänen M. Hen and egg problems of biology from TGD point of view. https://tgdtheory.fi/public_html/articles/henegg.pdf., 2022.

[L12] Pitkänen M. How animals without brain can behave as if they had brain. https://tgdtheory.fi/public_html/articles/precns.pdf., 2022.

[L13] Pitkänen M. Quantum Gravitation and Topological Quantum Computation. https://tgdtheory.fi/public_html/articles/TQCTGD.pdf., 2022.

[L14] Pitkänen M. Some objections against TGD inspired view of qualia. https://tgdtheory.fi/public_html/articles/qualia2022.pdf., 2022.

[L15] Pitkänen M. The possible role of spin glass phase and p-adic thermodynamics in topological quantum computation: the TGD view. https://tgdtheory.fi/public_html/articles/QCCC.pdf., 2022.

[L16] Pitkänen M. About the TGD based views of family replication phenomenon and color confinement. https://tgdtheory.fi/public_html/articles/emuanomaly.pdf., 2023.