Quantum gravitation and quantum biology in TGD Universe

February 19, 2026

Matti Pitkänen

orcid:0000-0002-8051-4364.
email: matpitka6@gmail.com,
url: http://tgdtheory.com/public_html/,
address: Valtatie 8, as. 2, 03600, Karkkila, Finland.

Contents

1 Introduction **4**
1.1 The role of quantum gravitation in TGD inspired quantum biology 4
1.2 TGD based view of nerve pulse 5

2 Update of the general ideas of TGD inspired quantum biology **6**
2.1 Basic motion patterns as analogs of Bohr orbits 6
2.2 Quantum criticality 7
2.3 Excitable systems in zero energy ontology 7
2.4 The notions of magnetic and electric body 8
2.5 The notion of gravitational magnetic body 9
2.5.1 Gravitational magnetic body as a controlling agent and the prediction of two metabolic energy quanta 9
2.5.2 The role of solar gravitational field in metabolism 11
2.5.3 Metabolic energy depends on gravitational environment 12
2.5.4 Do Moon travellers survive in TGD Universe? 13
2.5.5 Dark gravitational bonds and high energy phosphate bond 13
2.6 Gravitational magnetic body and the model of dark DNA 14
2.6.1 Original model of DDNA 14
2.6.2 The revised model of DDNA 15
2.6.3 Could the HBs associated with the base pairs of DNA become gravitationally dark? 15
2.6.4 A quantum gravitational mechanism for the splitting of HBs associated with base pairs 16
2.6.5 Quantum gravitational explanation for the different chemistries in vivo and in vitro 16
2.6.6 Dark proteins and quantum gravitation 17
2.7 Living systems as analogs of topological quantum computers 17
2.7.1 Basic distinctions from the standard view 18
2.7.2 TQC in the TGD framework 18

3 Update of the TGD based view of nervous system 20
3.1 The recent TGD based view of nervous system . . . 21
3.2 Clarification of some basic concepts . . . 22
3.2.1 About the notion of dark ion . . . 22
3.2.2 About the notion of electric flux quantum . . . 22
3.3 Gravitationally dark effective ions . . . 23
3.3.1 Signatures of dark effective ions . . . 23
3.3.2 Some facts about Calcium ions . . . 24
3.3.3 Ca^{++} waves . . . 24
3.4 About the model for the nerve pulse . . . 24
3.5 Microtubular level . . . 26
3.5.1 Could the metabolism of cilia and flagella rely on gravitationally dark electrons? 26
3.5.2 TGD based view about axonal and cellular microtubules . . . 28
3.5.3 Delayed luminescence for microtubules,quantum gravitation, and the mechanism of anesthesia . . . 28

4 How multicellular without a nervous system can behave as if it had a nervous system? 31
4.1 Animals without the brain behave as if they had the brain . . . 31
4.1.1 Findings of Prakash et al . . . 31
4.1.2 Popular summary of the experimental findings . . . 32
4.1.3 The model for the cilium and ciliary motor actions . . . 33
4.2 Ciliary flocking and emergent instabilities enable collective agility in a non-neuromuscular animal . . . 34
4.3 The analog of the nervous system at the level of multi-ciliary system . . . 35
4.4 TGD based intepretation of the findings of Prakash *et al* . . . 36
4.4.1 Homeostasis in the TGD Universe . . . 36
4.4.2 Cilium as a quantum gravitational pendulum . . . 36
4.4.3 Correlation between the height of the tissue and membrane potential of cilium 37
4.4.4 What happens in the adhesion and de-adhesion? . . . 37
4.4.5 Adhesion energy and de-adhesion as precedessor of nerve pulse generation . 38
4.4.6 Do 'spikes' correspond to real spikes? . . . 38
4.4.7 The generation of propagating waves . . . 39
4.4.8 Flocking as a generation of quantum gravitational coherence . . . 40
4.4.9 How could a living system direct its attention? . . . 40
4.5 Possible implications of the notion of pre-CNS . . . 41
4.5.1 Can organisms without CNS learn? . . . 41
4.5.2 Also plants have senses and motor actions . . . 41
4.5.3 Talking fungi . . . 42

5 Are space-time boundaries possible in the TGD framework? 43
5.1 Light-like 3-surfaces from $det(g_4) = 0$ condition . . . 43
5.2 Can one allow macroscopic Euclidean space-time regions . . . 44
5.3 But are the normal components of isometry currents finite? . . . 45
5.4 $det(g_4) = 0$ condition as a realization of quantum criticality . . . 46

6 Krebs cycle from TGD point of view 47
6.1 Lane's view of the role of Krebs cycle in the emergence of life . . . 47
6.1.1 Krebs cycle . . . 47
6.1.2 Reverse Krebs cycle . . . 48
6.1.3 The importance of charge separation . . . 48
6.1.4 The proposal for the evolution of life . . . 49
6.2 TGD view of Krebs cycle and early life . . . 51
6.2.1 Some basic ideas of TGD inspired quantum biology . . . 52
6.2.2 Expanding Earth hypothesis, Cambrian explosion, and emergence of oxygen rich oceans . . . 54
6.3 Appendix: A Corrected physical interpretation of the parameter β_0 . . . 58

7 About the mechanism of the energy transfer in photosynthesis 58
7.1 Some facts . . . 58
7.2 The TGD based model . . . 59
7.2.1 Basic questions . . . 59
7.2.2 Quantitative data . . . 59
7.2.3 How could the electrons be transferred to the reaction center as dark electrons? 60
7.2.4 Is this picture consistent with the quantum gravitational storage of metabolic energy? . . . 62

8 Could life have emerged when the universe was at room temperature? 63
8.1 Does standard Big Bang cosmology allow emergence of life at matter temperature $T \sim 300$ K? . . . 63
8.2 TGD view of cosmological evolution and biology . . . 65
8.2.1 Key ideas of the TGD inspired biology . . . 67
8.2.2 Basic ingredients of life found in conditions prevailing in the early universe 70

9 Appendix: Basic facts about cilia and flagella 72
9.1 Structure and function of cilia . . . 72
9.2 Beating waves . . . 73

Abstract

In this article the quantum gravitational aspects of quantum biology are discussed in the TGD framework. 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.

Gravitational MB of Earth, which consists of very long loop-like flux tubes with gravitational Planck constant introduced by Nottale explains the findings of Blackman and others, 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.

A correct order of magnitude estimate for the upper bound metabolic energy quantum as the energy liberated as a dark proton hydrogen bond becomes ordinary is obtained. 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. 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.

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.

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.

The quantum gravitational view about metabolism leads also to a modification of the views about nerve pulse conduction. In the earlier 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. One unsolved problem is the conduction of neural signals through the myelinated portions of the axons where nerve pulse is impossible. The formation of dark hydrogen- and valence bonds leads to effective ionization which takes membrane potential below critical value for the generation of nerve pulse, which is generated in unmyelinated portions.

The delocalization of protons and possibly also electrons to gravitational bonds provides a concrete realization of the Josephson junction model in which the ground state of the axon corresponds to a soliton sequence, which has a sequence of rotating gravitational pendulums as a mechanical analog. Action potential corresponds to a soliton (or several solitons) with opposite direction of rotation.

The critical dynamics of microtubules (MTs) involves variation of MT length relying on GDP→ GTP transition, which involves the change of HB to gravitational HB 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.

A model of the pre-neural system, based on the gravitational MB and the predicted electronic metabolic energy quantum, is developed in order to explain how animals without 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.

1 Introduction

This article summarizes the recent understanding about the biological role of quantum gravitation in the TGD Universe.

1.1 The role of quantum gravitation in TGD inspired quantum biology

In this article several new ideas related to quantum gravitation in the sense of TGD are introduced. The notion of quantum gravitational magnetic body (MB) leads to a considerably sharpening of the existing picture and provides an improved understanding of the real nature and role of biologically important dark ions.

1. The notion of magnetic body (MB) carrying ordinary matter as phases with effective Planck constant $h_{eff} = nh_0$ suggests that MB acts as a master and ordinary matter is at the bottom of the slaving hierarchy. There are reasons to believe that gravitational flux tubes with very large value $h_{eff} = h_{gr}GMm/v_0$ of gravitational Planck constant [E1] [**?**, K26] [L37, L29] are of special importance and correspond to the very high level in the hierarchy and to scales of order Earth scale. One could say that quantum gravity would transform chemistry to biochemistry and distinguish between the chemistries in *vivo* and in *vitro*.

2. Gravitational MB, which consists of very long loop-like flux tubes with gravitational Planck constant introduced by Nottale [E1] explains the findings of Blackman and others [J1], 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). Due to delocalization of the proton, hydrogen would be effectively negatively ionized.

   Gravitationally dark electrons or their Cooper pairs would in turn accompany gravitationally dark valence bonds (VBs) 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.

   A correct order of magnitude estimate for the upper bound metabolic energy quantum as the energy liberated as a dark proton HB becomes ordinary is obtained. 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. 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.

3. One obtains a correct order of magnitude estimate for the upper bound metabolic energy quantum as the energy liberated as a dark proton HB becomes ordinary. 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 about .4 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.

4. 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 a metabolic energy storage. Remarkably, the photosphere has temperature in thermal energy in the range [.4,.6] eV which corresponds to metabolic energy quantum.

5. This picture about dark HB leads to a rather detailed model of the role of phosphate in metabolism. Electronic metabolism could solve the problem due the lack of ATP machinery inside cilium and near it. Spikes having the same scale as miniature potentials observed in neurons could also appear in plants. For the recently observed spike sequences in fungi, the voltage spike has an amplitude with order of magnitude roughly consistent with the electronic metabolic energy quantum [I2].

6. A detailed model for the pairing of DNA and dark DNA (DDNA) emerges and forces to modify the earlier model somewhat. The HBs associated with base pairs could transform to gravitational HBs either by reconnecting directly with gravitational flux tubes or by double reconnection with gravitational HBs assignable to phosphate of the DNA nucleotide. This process could make possible the splitting of these HBs occurring in the replication and transcription. The very weak dependence of DNA properties on various salt concentrations in vivo is in sharp contrast to the strong dependence in vitro. This difference can be understood.

1.2 TGD based view of nerve pulse

The proposed model starts from the existing TGD based view about nerve pulse but the new quantum gravitational view about metabolism leads to a sharpening of the understanding of the role of biologically important ions in nerve pulse conduction.

1. TGD leads to a quantum view [K28, K16, K29] [L27, L29] about cell membrane as a generalized Josephson junction consisting of Josephson junctions defined by membrane proteins and to the proposal that soliton sequences analogous to a sequence of rotating penduli with phase difference increasing along the axon, define the resting states of the membrane.

   Nerve pulse would be induced by a perturbation transforming rotation to vibration locally, this propagating perturbation could be called pre-nerve pulse. Also the variant, in which rotation is replaced by oscillation - one would have an "oscillon" sequence - so that perturbation would generate a propagating soliton, can be considered. Note however that one cannot associate a definite rotation direction to an oscillon. The criticality against the generation of nerve pulse has remained poorly understood.

2. TGD also leads to a speculative view about the function of nerve pulse patterns. Usually they are considered to serve as signals inside the brain. An alternative view [L27] is that they make signalling by dark photons propagating along flux tubes parallel to axons or massless extremals parallel to flux flux tubes. The synaptic vesicles containing neurotransmitters would temporarily fuse the pre- and postsynaptic neurons and also connect flux tubes to a single flux tube acting as a wave guide so that dark photon messages could propagate.

   This would make possible very rapid communications between the brain (or even MB) and sensory organs and the building of standardized sensory inputs and standardized mental images by using a virtual sensory input from the brain or MB. Essentially pattern completion and recognition would be in question. Sensory perception would be an artwork rather than photograph. Nerve pulses could also send sensory information from the neuronal membrane to MB.

3. Could the meridian system serve as a precedessor of the nervous system such that gap junctions could define permanent flux tube connections between cells? In the nervous system the connections would be dynamical and used only when needed.

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

1. In the earlier quantum model, the cell membrane acts as a generalized Josephson junction for biologically important dark metal ions. The ground state of the axon corresponds to a soliton sequence, which has a sequence of rotating gravitational pendulums as a mechanical analog. Action potential corresponds to a soliton (or several solitons) with opposite direction of rotation.

2. In the updated model, the dark ions are identified as gravitationally dark effective ions with gravitationally delocalized Cooper pairs of dark electrons. Also gravitationally dark protons assignable to HBs are involved. The delocalization of protons and possibly also electrons to gravitational bonds provides a concrete realization for the variation of the membrane potential in the myelinated portions of the axons, where ion currents are not possible.

3. One unsolved problem of the Hodgkin-Huxley model is the conduction of neural signals through the myelinated portions of the axons, where nerve pulse is impossible. The formation of dark hydrogen- and valence bonds induces an effective ionization, which takes membrane potential below the critical value for the generation of nerve pulse, which is generated in unmyelinated portions.

4. Microtubules (MTs) are believed to be important in many quantum biological approaches and deserve a separate discussion. In the TGD framework, the quantum antenna hypothesis was one of the first proposals in this direction [K24]. Their precise role has however remained unclear hitherto.

   MTs appear in several variants. Cilia and flagella, which are analogous to axons, contain stationary MTs whereas axonal MTs are highly dynamical. The critical dynamics of axonal MTs involves a variation of MT length relying on GDP$\rightarrow$ GTP transition, which involves the change of HB to gravitational HB and vice versa changing the local membrane potential. Therefore MT dynamics makes possible the propagation of the perturbation of the membrane potential in unmyelinated portions of the axon. The effect of anesthetics can be understood in terms of a reduced density of HBs preventing the formation of gravitational HBs so that MTs and the axonal potential freeze.

The findings about multicellular animals of Prakash et al [I15, I13, I14], which have no nervous system but behave as if they had brain, provide valuable hints in attempts to understand the role of MTs. A model of the pre-neural system, based on the gravitational MB and the predicted electronic metabolic energy quantum, is developed in order to explain how these animals control their cilia. Cilia have no mitochondria inside them or in their vicinity and the electronic metabolism could replace the usual metabolism.

2 Update of the general ideas of TGD inspired quantum biology

In the sequel I develop a TGD based interpretation of findings in the conceptualization provided by TGD. I will proceed from general to specific and use cilia as example to illustrate the general ideas.

2.1 Basic motion patterns as analogs of Bohr orbits

Prakash *et al* identify a small number of basic motion patterns of cilium [I15, I13, I14]. More complex motion patterns of cell can be constructed as combinations of from these using simple rules.

For a general mechanical determiministic system 3-D initial values for generalized positions and velocities determine the time evolution and huge number of different time evolutions are possible. A chaotic behavior is much more plausible than the highly organized behavior analogous to that for organisms possessing central nervous system.

These findings resonate with the general TGD based classical description of classical physics in terms of the topology of space-time surfaces $X^4 \subset M^4 \times CP_2$ as preferred extermals (PEs) of the basic action principle [L35].

1. In the TGD framework, space-time as a 4-surface in $H = M^4 \times CP_2$ is topologically non-trivial in all scales and various shapes of matter, usually assigned to matter in almost flat and topologically trivial space-time of general relativity, correspond directly to the topology of the space-time surface.

2. From the general coordinate invariance, space-time surface is a preferred extremal (PE) of a general coordinate invariance action principle, which realizes holography in the sense that 3-surface as boundary values determines almost completely the 4-surface, which is therefore analogous to Bohr orbit. There is however a small failure of determinism localizable at the singularities where minimal surface property fails. PEs are minimal surfaces with singularities analogous to frames of ordinary soap films [L39].

3. The space-time counterparts of all biological and neurological functions (this includes the development of mechanical and electromagnetic patterns such as nerve pulse patters) correspond to PEs. PEs are also analogous to the modules of computer programs. A small failure of quantum determinism corresponds to a selection of sub-modules in branching points and correspond to the non-determinism of soap films with frames.

4. Zero energy ontology of TGD which predicts that quantum states of a system are superpositions of space-time surfaces as preferred extremals (PEs) of action. "Small" state function reductions (SSFRs) as the TGD counterparts of "weak" measurements would select between different variants of space-time surface with same singularities (frames of soap film) and BSFRs would correspond to big changes.

   The small repertoire of different motion patterns would correspond to a collection of PEs. From these patterns for cilia more complex patterns would be constructed for the motion patterns for a cell would emerge. From the patterns for cell motion the patterns for a multi-cellular system would emerge. There would be a hierarchy of complexity reducing to a hierarchy of extensions of rationals at fundamental level.

2.2 Quantum criticality

Also cilium and a ciliary system could be near quantum criticality and this could be essential for the changes of the state of the motion of cilia.

The motions of microtubules inside cilia force the bending of cilia. The beating waves with frequency 4-10 Hz propagating along cilia and having constant phase along a 1-D section curve of the 2-D transverse section of transversal plane of cilium are known to induce the motions of a single cilium. In multicilium system these motions are in the same phase and induce coherent motion

When the height h, the orientation of cilium, and the beating frequency f are near criticality, a BSFR would occur and induce a sudden change in the motion of cilium. The criticality of the beating frequency could mean resonance between the microtubuli inside cilium and BSFR would induce the shortening of the flux tube pair connecting them. This would induce the bending of the flux tube.

The presence of 3 parameters suggests a catastrophe theoretic description using Thom's catastrophe theory based on a butterfly catastrophe with 3 control parameters.

2.3 Excitable systems in zero energy ontology

In the TGD framework, the idea that excitable systems as systems making "big" state function reductions (BSFRs) as counterparts of ordinary SFRs in macroscopic spatial and temporal scales

is suggestive. In BSFR the arrow of time changes and after BSFR the dissipative development occurs in reverse time direction and looks to the observer with the standard arrow of time like self-organization and generation of patterns. This BSFR is followed by second BSFR re-establishing the original arrow of time.

In quantum critical systems, the value of h_{eff} would be fluctuating and the change of h_{eff} could happen in BSFR. The dynamics of microtubules (MTs) could be quantum critical since it involves continual growth and decay of MTs, which would correspond to a sequence of BSFRS. During mitosis (cell replication) the expansion and contraction of MTs involving change of h_{eff} and BSFR would play a key role role.

Bio-catalysis is another example [L79]. The reactants would be brought near each other by a contraction of the flux tube pairs connecting them. The flux tubes pairs would be formed by a reconnection of U-shaped flux tubes of reactants acting as tentacles if there is cyclotron frequency resonance (the thicknesses of the U-shape flux tubes are identicals). The BSFR involving a contraction due to the reduction of h_{eff}. After reaction h_{eff} could reduce to its original value in second BSFR.

2.4 The notions of magnetic and electric body

The notions of magnetic body and electric body are central in TGD inspired quantum biology but their precise definition has been far from clear. The intuitive notion is that MB consists of U-shaped monopole flux tubes extending from the system considered and serving as kinds of tentacles. These flux tubes for two systems can reconnectand form a pair of flux tubes connecting the system if the cyclotron frequencies of the tubes are the same so that cyclotron resonance becomes possible.

MB is characterized by the value of the effective Planck constant $h_{eff} = nh_0$, where n corresponds to the dimension of the extension of rationals assignable to the space-time regions by $M^8 - H$ duality [L22, L23]. One can assign MB to flux tubes mediating electromagnetic, gravitational and even weak and color interactions, and the scale of MB correlates with the screening length of these interactions. For gravitation there is no screening and the values of $h_{eff} = h_{gr}$ can be very large. The large value of $h_{gr} = GMm/v_0$ [E1] implies that the dark cyclotron radiation in the EEG range would correspond to visible and UV energies.

In the TGD framework magnetic body (MB) would serve as the controlling agent receiving sensory information as a frequency modulated dark Josephson radiation and controlling the cell by using dark cyclotron radiation coming as pulses corresponding to resonant receival of Josephson radiation.

What could be the electric counterpart of the magnetic body? Magnetic flux tubes can also be dynamical and locally orthogonal helical magnetic and electric fields are possible. Electric body should be something different. Various membrane-like structures populate the Universe and they could correspond to electric bodies.

1. The 4-surfaces X^4 with 1-D CP_2 projection and 3-D M^4 projection having 2-D membrane as E^3 projection are good candidates for various membrane objects in TGD Universe [L39]. The E^3 projection is not a minimal surface although X^4 is, and this possible if the 1-D CP_2 projection is dynamical. The flux tubes of MB should be assignable to kind of membrane-like surface.

2. The gravitational MB, it it exist, could be a layered structure containing the Bohr orbits with Bohr radii $r_n \propto n^2$ of particles in the gravitational field of Earth. Particles with different masses would concentrate at the same orbits. One would have the shell structure of the ordinary atom. This notion generalizes also to other interactions and for them the values of h_{eff} would be much smaller.

3. Flux sheets with a cylindrical rotational symmetry containing the orbits can be considered. These surfaces should be realized as preferred extremals of the action and should be minimal surfaces in $H = M^4 \times CP_2$. As closed surfaces they cannot define minimal surfaces of the Euclidean 3-space E^3. Indeed, soap bubbles are not minimal surfaces but require a constant pressure difference between interior and exterior.

The analog of the pressure difference would be non-trivial and dynamic 1-D projection of 4-D surface to CP_2 [L39]. The liberation of metabolic energy quantum would be analogous to a transition of hydrogen atom to a lower energy state.

2.5 The notion of gravitational magnetic body

The notion of gravitational MB turns out to be crucial for the understanding of the role of quantum gravitation in TGD inspired quantum biology.

2.5.1 Gravitational magnetic body as a controlling agent and the prediction of two metabolic energy quanta

In the TGD framework magnetic body (MB) would serve as the controlling agent receiving sensory information as a frequency modulated dark Josephson radiation and controlling the cell by using dark cyclotron radiation coming as pulses corresponding to resonant receival of Josephson radiation.

The large value of $h_{eff} = h_{gr} = GMm/v_0$ [E1] implies that the dark cyclotron radiation in the EEG range would correspond to visible and UV energies.

The intuitive notion is that MB consists of U-shaped monopole flux tubes extending from the system considered and serving as kinds of tentacles. These flux tubes for two systems can reconnect and form a pair of flux tubes connecting the system if the cyclotron frequencies of the tubes are the same so that cyclotron resonance becomes possible.

In [L43], the question of what the notion of gravitational MB does mean, was considered.

1. The dark flux tube would be "gravitational" with $h_{eff} = h_{gr}$. Gravitational flux tubes carry Kähler monopole flux but no gravitational flux. This would be in conflict with the irrotational nature of gravitational field at Newtonian limit. The monopole flux could however have interpretation as gravimagnetic flux. The attribute "gravitational" is motivated by the assumption that one has $h_{eff} = h_{gr}$. The ordinary, short, MB reconnects atoms A and B.

   Gravitational flux tubes have lengths, which can be of the order of Earth size scale and the radii of gravitational Bohr orbits define a natural scale form them. Gravitational flux tubes are closed flux tubes with the shape of a highly flattened triangle with a long side in the vertical direction and having length of order Earth size scale and short side of order interatomic distance for the atoms A and B connected by HB.

   This inspires a rather concrete vision about the structure of gravitational MB as a forest of gravitational flux tubes analogous to trees. This applies also to non- gravitational flux tubes with smaller values of h_{eff}. One would have a full magnetic flora. The larger the value of h_{eff}, the more complex the magnetic plant would be. MB would be like a fractally scaled-up variant of the ordinary forest. Reconnections would make possible transfer of gravitational flux tubes so that also magnetic fauna would be present.

2. One obtains gravitationally dark hydrogen bond (HB) from an ordinary HB when a HB from A to B reconnects with a pre-existing long gravitational flux tube to create a very long gravitational flux tube from A to B. Proton is delocalized as a gravitationally dark proton and its gravitational potential energy is reduced so that the flux tube stores metabolic energy. In the reverse process a reverse reconnection takes place and this metabolic energy is liberated.

   The reconnection process requires a feed of energy: for instance solar radiation can provide it in photosynthesis. A similar description applies in the case of valence bonds (VBs). Note that the transformation of an ordinary, short HB to a long gravitational HB is not a realistic option since this would require a lot of energy since magnetic energy would be created.

3. The elongated gravitational flux tubes could correspond to either hydrogen bonds (HBs) or valence bonds (VBs). The loop-like bond could connect nearby atoms just like the ordinary bond. The delocalization of the charge to the flux tube leads to an effectively ionized donor atom.

4. All values of h_{eff} are possible. For electromagnetic flux tubes the values of h_{eff}/h are not very large. This picture leads to a view about hydrogen and VBs as bonds having

$h_{eff}/h > 1$ [L11]. Also gravitational variants of hydrogen and VBs are possible. In this case, the proton or electron would be vertically delocalized in the Earth scale so that the donor atom would be effectively ionized. For instance, a phosphate ion could be an effective ion having a gravitational hydrogen bond with the hydrogen of a water molecule.

5. A gravitational VB, connecting a metal atom with an atom with an opposite valence, would lead to effective ionization of the metal atom. For instance, biologically important bosonic ions such as Ca^{++}, Mg^{++}, Fe^{++} and Zn^{++} associated with their oxides could correspond to effective ions like this.

   The signature would be a pairing with a neutral oxygen atom by a gravitational VB. I have introduced the notion of dark ion to explain the findings of Blackman [J1] and others and dark ion could correspond to this kind of pair. Note that the original variant of the model assumed that the entire ion is dark, the later version assumed that the valence electron of free atom is dark, and the model considered here assumes that darkness is a property of bond.

6. The effective ionization requires energy ΔE to compensate the increment of the gravitational potential energy given by $\Delta E_{gr} = (\langle V_{gr}(R)\rangle - V_{gr}(R_E))$. Here $E_{gr}(R)$ is gravitational potential energy proton or electron, and R_E denotes the radius of Earth, and R is the distance of the point of flux tube from the center of Earth.

   Classical energy conservation suggests that the value of vertical kinetic energy at the surface of Earth is equal to the increment of the gravitational potential energy at the top of the loop. From energy conservation one can estimate the metabolic energy quantum as a liberated kinetic energy in the normal direction equal to the increase of gravitational potential energy. Hence the naive guess could be correct.

7. The maximal value for ΔE_{max} for electron Cooper pair (dark Cooper pair is at infinite distance) corresponds to $V_{gr}(R_E) = .36$ meV to be compared with the energy scale .3 meV defined by the temperature of 3 K microwave background and to the value .4 meV of the miniature potential. This suggests that, in the case of the electron, the reduction of kinetic energy contributes more than 10 per cent to the ΔE.

   For a single dark proton one has $V_{gr}(R_E) \simeq .34$ eV, which is below the nominal value of the metabolic energy currency about .5 eV.

8. The condition that the end of the vertical gravitational loop travels along a stationary orbit parallel to the plane of rotation of Earth such that the normal velocity of the dark particle vanishes at the top, implies for the tangential velocity v_T the condition $v_T^2 = \omega^2 R^2 = GM/R$ allowing to determine the radius of the orbit as

$$\frac{R}{R_E} = (\frac{r_{s,E}c^2}{2\omega^2})^{1/3} \times \frac{1}{R_E} \simeq 3.1 \quad .$$

   The change of the gravitational potential energy in the transition to an ordinary proton would be $\Delta E = \Delta E_{gr} = .68 \times V_{gr}(R_E)$, which would give $\Delta E = .18$ eV. In the dark genetic codons hydrogen bonds appear as triplets. 3 dark protons would give metabolic energy quantum .55 eV. Interestingly, a translocation of 3 protons fuels synthesis of ATP!

9. For an electron Cooper pair the upper bound for the metabolic energy quantum would be $\Delta E_{max} = .33$ meV, which is below the miniature potential .4 meV. For the stationary flux tubes one obtains $\Delta E = .17$ meV. Later the evidence for the 'spikes' in fungi [I2] discovered by Adamatsky will be discussed: their amplitude is reported to be in the range .03-2.1 meV which contains ΔE.

   For an electron Cooper pair triplet one would have $\Delta E = .51$ meV consistent with the miniature potential .4 meV. Should one take this seriously? Could also dark electron Cooper pairs organize into triplets like dark protons would do and in this manner define dark genetic code? TGD predicts that genetic code is universal: could also dark electron Cooper pairs define a dark variant of the genetic code?

Posner molecules $[(PO_4)^{-3})]_6Ca_9^{+2}$, to be discussed in the sequel, consists of 3 $[(PO_4)^{-3})]_2Ca_3^{+2}$ acting as a basic unit. This unit could contain 3 electronic Cooper pairs with electronic metabolic energy quantum $\Delta E = .51$ meV. In principle, Cooper pairs can have spin 1 or spin state giving 4 states altogether. Could these states define letters of a dark genetic codon so that the basic unit would define a genetic codon and Posner molecule could correspond to a triplet of genetic codons?

The TGD view about formation of bound states as Galois singlets [L48] allows us to consider this possibility. For an extension of extensions of ... the Galois group would decompose to a hierarchy of Galois groups actings as normal subgroups. Codons as triplets would be Z_3 singlets in both the ordinary and the electronic genetic code. Genes would correspond to larger Galois groups decomposing to normal subgroups. Codon doublets of DNA double strands would be Z_2 singlets and triplets of triplets of Posner molecules would be Z_3 singlets.

10. A proper treatment of the situation would require Schrödinger equation for the dark particle at the flux loop. The situation is analogous to a quantum model of the fountain effect of super-fluidity discussed in [K10, K11, K12, **?**] in a situation when the gravitational potential can be linearized (WKB approximation).

    One can consider Schödinger equation for h_{gr} idealizing the loop with a 1-D box with gravitational potential GMm/r. The Schrödinger equation reduces in dimensionless variable $u = (m/\hbar_{gr})z = 2\beta_0(z/r_s)$, $r_s = 2GM$ to

$$(-\frac{\partial_u^2}{2} - \frac{\beta_0}{u})\Psi = \frac{E}{m}\Psi \equiv \epsilon\Psi \quad .$$

    A possible condition is that the vertical derivative $\partial_z\Psi$ vanishes at the top of the loop. The metabolic energy quantum equals $(GM/R_E - \epsilon(v))m$ and is quantized. The height of the loop could be quantized using the condition that the loop end is stationary with respect to Earth.

If this speculative picture makes sense, quantum gravitation would play a key role in metabolism and genetic code.

1. The transformation of electrons and protons between ordinary and gravitationally dark states would be a key process of metabolism and biocatalysis. This conforms with the fact that proton and electron exchanges play a key role in biology. For instance, phosphorylation means that the receiving molecule gains phosphate, which can form gravitationally a dark hydrogen bond so that the system becomes metabolically active. This would correspond to the activation in bio-catalysis.

2. In the same way, in a redox reaction, the electron donor is oxidized and the electron receiver is reduced. Reduced molecule gains the ability to have a gravitationally dark electron, and therefore becomes metabolically active in the electronic sense. Redox reaction would be the electronic counterpart for phosphorylation.

2.5.2 The role of solar gravitational field in metabolism

Also the gravitational field of the Sun could be important in metabolism.

1. At the distance of 1 AU of the Earth, the counterpart of single proton metabolic energy quantum .18 eV would be 2.6 eV, which is in the visible range. For a proton triplet, the energy would be 7.8 eV and in the UV range. This quantum would be realized as a long flux tube directed away from the Sun in the plane of the Earth's orbit and orthogonal to the orbit.

2. Could the visible solar radiation kick protons to solar gravitational flux tubes and the radiation of photosphere having energy range [.4,.6] eV to the gravitational flux tubes of Earth in photosynthesis? Could the solar part of dark gravitational energy for protons be transformed to ordinary metabolic quanta in metabolism? Note that the feed of the solar radiation energy to flux tubes suggests a modification of the proposed simple model involving only gravitation.

3. This picture would be true for all Sun-like stars and for planets at the distance of Earth and supports the view that Earth-like planets for Sun-like stars are favourable for life.

2.5.3 Metabolic energy depends on gravitational environment

According to the proposed simple model, bio-chemistry would strongly depend on the local gravitational environment.

1. For an object with mass M and radius R, the estimated maximal gravitational metabolic energy quantum E_{max} is scaled up by factor is scaled up by a factor $z = (M/M_E) \times (R_E/R)$. The values of z for Mercury, Venus, Mars, and Moon are (.2,.14,.86,.04). For Venus, which is called the sister planet of Earth, z is not too far from unity.

   For the stationary orbits around an object with radius R_1, mass M_1, and rotation frequency ω_1 the ratio $\Delta E_1/\Delta E_E$ of metabolic energy quantum to that for Earth satisfies the scaling formula

$$\begin{array}{lll} \frac{\Delta E_1}{\Delta E_E} = \frac{R_E}{R_1} \times (1 - x_1 x_2 x_3) & & , \\ x_1 = (\frac{M_1}{M_E})^{1/3} \; per, & x_2 = \times (\frac{\omega_E}{\omega_1})^{2/3} \;\; , & x_3 = \frac{R_E}{R_1} \end{array}$$

2. In the case of the Moon, E_{max} would be by a factor $z = R_E/R_{Moon} = .017$ smaller than at the surface of Earth. The stationarity condition would require a flux tube orbit radius smaller than the Moon radius. In the case of Venus, the sidereal rotation period is -243.0 days (retrograde): also now the orbit of stationary radius would be smaller than the radius of Venus. This suggests that only the metabolism utilizing the solar gravitational field photosynthesis is possible and would be essentially the same as at the surface of Earth.

3. In the case of Mars one has $\omega_1/\omega_E \simeq 1$, $M_1/M_E = .1$, $R_1/R_E = .533$. This gives $\Delta E = .24\Delta E_E$, which for the proton Cooper pair would give .13 eV. Could the solar gravitational field save the space traveller in case of Moon and Mars? The largest distance from Earth is about 1.7 AU and at this distance the maximal value of the solar metabolic energy quantum is scaled down by a factor .59.

Jupiter's (`https://cutt.ly/CF8bteR`) moon Europa (`https://cutt.ly/HF8buAp`) is one of the most promising candidates for a seat of life since it contains water in the form of ice. Is quantum gravitational metabolism based on the solar and Jovian gravitational fields consistent with Earth-like metabolism?

For the Jupiter's gravitational field, the gravitational potential energy at the surface of Europa is $V_{gr} = GM_J m/R_{Eu}$ and defines the maximal value ΔE_{max} of the metabolic energy quantum for a flux loop defining dark gravitational HB oriented radially outwards along A line connecting Europa and Jupiter. The mean distance d_{Eu} from Jupiter is $d_{Eu} = 105.3 \times R_E$ to be compared with the radius $R_J = 10.97 R_E$ of Jupiter. The mass of Jupiter is $M_J = 317.8 M_E$. This gives $\Delta E_{max,Eu}/\Delta E_{max,E} = V_{gr,J}/V_{gr,E} = (M_J/M_E) \times (R_E/d_{Eu}) \simeq 3.0$.

For a single gravitationally dark proton, the maximal metabolic energy gain would be .99 eV, which is twice the metabolic energy quantum. Standard metabolic energy quantum .5 eV corresponds to a radially oriented loop with height $h = d_{Eu}$. If a proton triplet defines the metabolic energy quantum, one would have $h = (1/5)R_{Eu}$.

Solar radiation should provide metabolic energy. The average distance d_J of Jupiter from Sun varies between 5.0AU and 5.4AU so that the gravitational metabolic energy quantum has upper bound $\Delta E_{gr,Sun,J} \leq \Delta E_{gr,Sun,E}/5 \simeq .5$ eV, which corresponds to metabolic energy quantum. Photosphere produces IR radiation with energies in the range .4-.6 eV. Therefore Europa seems to satisfy the conditions from quantum gravitational metabolism.

Just for fun, one can also look at the situation at the surface of Sun.

1. At the surface of the Sun, one has $z \simeq 3.0 \times 10^2$ and the metabolic energy quantum .55 eV for dark proton triplet scales to $\Delta E_{Sun} \sim .16$ keV: this is below the threshold for the nuclear fusion and below the temperature of $\sim .23$ keV of the solar corona. An interesting question is whether the X-ray radiation arriving to Earth could have some, perhaps even biological, function. TGD indeed predicts that nuclei have excitations in the keV range [K23].

2. For a dark electron Cooper at solar surface, the upper bound is .08 eV. The temperature of the photosphere corresponds to photon energy of .4-.6 eV, which corresponds to the metabolic energy quantum associated with the Earth's gravitational flux tubes. Could the IR thermal radiation from the photosphere serve as a metabolic energy source?

How does this model relate to the TGD inspired model for Cambrian Explosion [L15] [L38] ?

1. The TGD explanation for the sudden emergence of new phyla in Cambrian Explosion is that the radius of Earth doubled in CE in rather short time. If the end of flux tube moves along stationary orbit, the scaling formula gives for the metabolic energy quantum before the transition for the dark proton triplet the value $\Delta E_{gr} = .38 \times \Delta E_{gr,max}$, which gives $\Delta E_{gr} = .3$ eV. This is considerably smaller than .55 eV.

2. According to Stephen Gould (see the book "Wonderful life" about Burgess Shale Fauna [I18]), a large number of the phyla suddenly disappeared. Could this mean that they were not able to adapt to the transition increasing the value of the metabolic energy quantum? On the other hand, a rapid evolution started. Could this relate to the increased sizes of the protonic and electronic metabolic energy quanta? Solar metabolic energy quanta would not have changed.

2.5.4 Do Moon travellers survive in TGD Universe?

3 dark protons give the nominal value of metabolic quantum. If the naive estimates are taken seriously, terrestrial life might not be possible on Mars and Moon. Humans have however successfully visited the Moon and it is not clear whether the solar gravitational field comes to rescue.

Rather than giving up the idea, it is better to ask what goes wrong with the simplest model. The quasiclassical estimate assumes that the dark charge at the top and bottom of the gravitational flux tube has the same kinetic energy. If the kinetic energy at the top is higher, the value of the metabolic energy quantum increases. This inspires the question whether the reduction of the kinetic energy in the metabolic energy quantum can be neglected.

1. The simplest model for the particle at gravitational VB is as a particle in a box with kinetic energies given by $E_n = n^2\hbar_{eff}^2/mL^2$, L the length of the loop. If L scales like h_{eff}, the kinetic energy does not depend on h_{eff}. Therefore the scale of kinetic contribution can be estimated in a molecular length scale.

2. Could the system adapt to a reduction of the maximal gravitational potential at the surface of the Moon, Mars, or Venus by increasing the average value of n in the superposition of the standing waves having maximum at the top of the valence loop? The system would adapt by increasing the localization of the dark charge at the top of the loop. The reduction of the bond length would mean reduction of the superposition to $n = 0$ wave so that the kinetic energy would be indeed liberated.

2.5.5 Dark gravitational bonds and high energy phosphate bond

How could the somewhat mysterious high energy phosphate bond (HEPB) associated with di-phospates (DP) and tri-phosphates (TP) relate to the gravitationally dark hydrogen bonds (HBs)?

1. HEPB (`https://cutt.ly/2FcLFJY`) is identified as the bond ... $- -O - -$... connecting two P atoms in ATP or ADP (`https://cutt.ly/HFcLKyk`). Hydrolysis involves also one H_2O molecule. The $-O - P$ bond splits inducing the splitting of ATP to ADP and P_1. One cannot assign HEPBs to the monophosphates (MPs) associated with DNA so that the splitting of the O-P bond must play an essential role..

2. It is best to start by listing the facts about $ATP \rightarrow ADP + P_i + 2H^+$ reaction for which the Wikipedia article (see `https://cutt.ly/xFbuDet`) gives both graphical representation and the overall formula for the reaction.

   In the initial state 4 O-atoms of ATP have a visible negative charge. The simplest assumption is that all ions O^- actually correspond to gravitationally hydrogen bonded $O...H$ pairs

with a delocalized proton charge so one should use the notation $O^{"-"}$. O^- would be replaced with $O...H-O-H$ such that the HB carries a gravitationally dark proton delocalized in even astrophysical scale. The negative charge would be only effective and associated with $OH^{"-"}$ rather than being a real negative charge of O^-. The same assumption is natural also for ADP and AMP. This would define the meaning of organic phosphates. In the final state both P_i and ADP have visible charge -3 to give a total visible charge -6.

$2H^+$ in the final state guarantees the conservation of the visible charge in the reaction.

3. The $P(O^{"-"})_2$ of the third phosphate transforms to an inorganic phosphate P_i. A natural interpretation is that the gravitationally dark protons become ordinary ones. This explains $2H^+$ in the final state. This reaction would liberate part of the metabolic energy.

4. One H_2O molecule is used in the reaction. The natural assumption is that one hydrogen of H_2O has a dark gravitational HB with the oxygen appearing in $O-P$ of $(O_2^{"-"}P=O)-O-P...$ so that it one has $O^{"-"}$ visible charge -1. The bond $...P-O-...H$ becomes the effective oxygen ion of $...P-O^{"-"}$ of P_i so that P_i would not be completely inorganic. The remaining OH of the water molecule becomes one $O^{"-"}$ of P of ADP. Also this reaction can liberate metabolic energy.

2.6 Gravitational magnetic body and the model of dark DNA

Dark DNA (DDNA) is identified in terms of dark proton triplets assigned with flux tubes parallel to DNA. Codons correspond in the original model to smaller circular flux tubes carrying the dark proton triplets. This model is modified by replacing the circular flux tubes with long U-shaped gravitational HBs. In order to avoid confusion, one must make clear that this realization of DDNA differs from that discussed in [L48] and one must check whether they are consistent and what new predictions follow from the recent, much more specific, model.

2.6.1 Original model of DDNA

The original proposal for DDNA was that the dark proton charge screens the negative charge of phosphates so that the charge associated with the DDNA codon would be +3. If one has dark nucleons (proton and neutron), also other charges than +3 are possible in the proposed model and would be needed for amino acid polymers (AAs) [L48].

The most recent model discussed in [L48] made the following assumptions.

1. Dark nucleotides correspond to closed loops containing a dark nucleon: both dark protons and possibly effectively dark neutrons are possible so that dark nucleon has spin and strong isopin corresponding to 4 letters of the genetic code. A dark neutron could be only effectively a neutron and could be formed from a dark proton, which has transferred its charge to a flux tube connecting it with the neighboring dark proton.

   The total charge is that for dark protons as required by the condition dark DNA charge is neutralized. This conforms with the model for the formation of dark protons by Pollack effect [I8, L4, I21, I16] as transfer of ordinary protons to dark protons at flux tubes possibly forming dark codons as dark proton triplets [L4].

   The flux tube could be regarded as analogous to dark π^0/π^- or dark Z^0/W^-. These two options could be dual descriptions as the conserved vector current and partially axial current hypothesis of old fashioned hadron physics suggest.

2. The loop carries angular momentum and the angular momenta of dark protons and dark nuclei sum up. The tensor product decomposition of the states obtained in this manner gives DDNA, DRNA, DtRNA, and DAA therefore unifying the counterparts of the basic biomolecules at the dark level.

3. A natural expectation is that $h_{eff}=nh$ forms the unit of angular momentum, in particular spin. This gives a very strong condition and strongly suggests that dark particle corresponds to n-particle as analog of Bose-Einstein condensate: dark 3N-protons and dark 3N-photons as representations of genes with N-codons have been indeed suggested to play a key role in

TGD inspired quantum biology. Dark photons with energy of $E = h_{eff}f$ would correspond to $n_{eff} = h_{eff}/h$ dark photons forming an analog of BE-condensate.

Dark space-time sheets X^4 correspond to n-sheeted structures with Galois group of n-D extension of rationals. Many-sheetedness could correspond to many-valuedness of X^4 as a map $M^4 \to CP_2$ or vice versa and one can have also have n_1- and n_2 valuedness with $n = n_1 n_2$. In fact, one has a natural factorization of the order of the Galois group to a product of integers corresponding to its decomposition to normal subgroups so that $n = n_1 n_2 ... n_k$ is the general proposal. n_{gr} (assigned to h_{gr}), n_{em} , n_{weak}, n_{color} can have further decompositions. n-sheetedness with respect to CP_2 would correspond to n copies of a space-time sheet in M^4, for instance parallel flux tubes forming a quantum coherent structure. For $\hbar_{gr}$ this would be the natural option and for $n_{gr} = \hbar_{gr}/\hbar = n_{gr} \sim 10^{14}$. In this case, N-codon interpretation is not appropriate not natural, rather n_{gr} gravitationally dark DNA flux tubes could integrate to a quantum coherent parallel structure with a size about 1 mm.

2.6.2 The revised model of DDNA

In the model of DDNA-DNA considered here gravitationally dark HBs would define the dark codons.

1. The earlier model is modified by replacing the closed flux tubes associated with the dark nucleons with gravitationally dark HBs.

2. There is no screening now, and the negative charge of phosphates is only effective and assignable to water molecules surrounding DNA rather than phosphates directly so that DNA stability would be achieved also now.

3. Dark DNA has still effective charge -1 per codon and the dark proton charge would be delocalized at the dark gravitational flux tubes and thus invisible. DDNAs would be connected by quantum numbers of loopy flux tube pairs with quantum numbers π^0 or π^- connecting dark nucleons of dark DNA. A dark proton at the strong flux tubes would transform to an effective dark neutron in the case of π^-. The value of h_{eff} for these would most naturally correspond to h_{color}.

   I have proposed that even the nucleons of ordinary nuclei can have dark flux tubes, which emanate from nuclei of nuclei and carry quantum numbers of pions and having size of even atomic scale. This could relate to the observed discrepancy of the radius of protons. As a matter of fact, this would mean the counterpart of dark HBs at the level of strong interactions.

4. What is new as compared to the earlier model is that there would be a composite of n_{gr} more or less parallel DNA flux tubes assignable to a volume of order 1 mm and each having a length proportional to $\hbar_{gr}$. Also single flux tube visiting through all the DNAs can be considered. One would have a flux tube spaghetti also assumed to be generated in the formation of astrophysical objects [L18, L20, L36].

2.6.3 Could the HBs associated with the base pairs of DNA become gravitationally dark?

DNA base pairs are connected by 2 (A-T) or 3 (G-C) HBs: what could this mean from the point of view of DNA energy metabolism?

1. If these strands can appear as dark gravitational strands, the maximum of 2 (3) metabolic quanta could be liberated in A-T (G-C) pairs via a transformation to ordinary HBs. Could this serve as a yet-unidentified source of metabolic energy in the replication and transcription?

2. Could the dark/organic mono-phosphates of the double DNA strand serve as a source of metabolic energy for DNA transferred to the HBs connecting base pairs?

3. Suppose that the DDNA parallel to DNA corresponds to a sequence of gravitational HBs B_{gr} as loops associated with the organic phosphates. Codon would correspond to a bound state of dark protons associated with three dark gravitational HBs.

   Consider an ordinary HB A_o associated with a base pair and B_{gr} associated with the corresponding dark/organic phosphate. Can one transform A_o to A_{gr} to achieve the transfer of metabolic energy?

   Two reconnections for a HB pair (A_o, B_{gr}) can transform the pair to (A_{gr}, B_o). The gravitationally dark proton and metabolic energy would be transferred to basepair from the organic phosphate, which itself would become an organic phosphate ion P_1^-.

   Note: Also the phospholipids of the cell membrane are accompanied by a monophosphate group. Also microtubules are accompanied by GMPs. Could they serve as metabolic energy sources in the cell membrane using the above described mechanism?

2.6.4 A quantum gravitational mechanism for the splitting of HBs associated with base pairs

The splitting of HBs associated with base pairs [**?**]`https://cutt.ly/9FmJywe`) plays a fundamental role in DNA opening necessary for DNA replication and transcription. These HBs must split during replication and transcription and many other processes such as selective recognition of DNA by proteins, regulation of RNA cleavage by site-specific mutations, and intermolecular interaction of proteins with their target DNA or RNA. Could the notion of gravitational HB provide insights about the process?

1. As the figures of (`https://cutt.ly/PFmJaFr`) illustrate, the base pairs of the double DNA/RNA strand have 2 or 3 HBs. HBs of type $N-H...O$ and $H-N...O$ and $N-H...N$ (called imino HB) are possible. Imino HB appears for both A-T with 2 HBs and G-C with 3 HBs.

   Since the hydrogen of $X-H...Y$ is nearer to Y than X, the splitting is expected to give $X+H-Y$, $X, Y \in \{N, O\}$. This is indeed the case when X and Y are different. However, the imino HB $N-H...N$ actually splits to $N-H+N$ rather than the expected $N+H-N$. An exchange of a hydrogen atom is said to occur.

2. The temporary formation of a gravitationally dark HB could explain how this is possible. The gravitationally dark proton is at a large distance from the N atoms so that they are in a symmetric position and both outcomes for the splitting are equally probable so that the exchange rate increases.

3. This requires a temporary transformation of $N-H...N$ HB to a gravitationally dark HB. Could double reconnection transform the pair $(A_o, B_{gr}$ formed by $N-H...N$ HB and dark HB of phosphate bond to (A_{gr}, B_o), which then splits?

2.6.5 Quantum gravitational explanation for the different chemistries in vivo and in vitro

If gravitationally dark hydrogen and VBs are relevant to biology, their effects should distinguish between matter in vivo, gel phase and matter in vitro. The difference should be especially clear at physiological temperatures. Is there any empirical evidence for the deviations from what is inspected on the basis of the standard biochemical intuition?

The interactions between DNA metal ions present living matter could serve as a test for the proposal. In the TGD framework, both metal ions and DNA could be gravitationally dark (in vivo or gel phase) or ordinary (in vitro phase).

1. For the DNA and metal ions as they are usually understood, the phosphate ions $(PO_4)^-$ of DNA should have interactions with metal ions and the concentrations should affect the properties of DNA. This should be true both in vivo and in vitro.

2. In the TGD framework, DNA strand in vivo and in gel phase would be accompanied by a dark DNA strand. The phosphate ions $(PO_4)^-$ would be actually pseudo-ion $(PO_4)^{"-"}$, in the sense that the ion O^- would be replaced with a gravitationally hydrogen bonded structure $O...H-O-H$ such that the HB carries a gravitationally dark proton delocalized in a very long scale. The effective negative charge would be associated with $OH^{"-"}$ pseudo ion rather than being a real negative charge assignable to O.

   Outside the physiological temperature range and in vitro, the oxygen ion would be real and the situation would be as in the standard chemistry apart from the possible effects of darkness of metal ions. The simplest assumption is that both metal ions and DNA are dark at the same temperature range only.

3. (Gravitationally) dark metal ions of type X^{++} would also have a dark valence electron at flux tube. One can speak of dark salt since flux tube bonds would connect X with H_2O_2. Same applies to Cooper pairs of dark ions X^+.

   The phosphate of DDNA-DNA pair has Coulomb interaction with neither ordinary nor dark ions but the metal ion would interact with $OH^{"-"}$. This suggests that the presence of metal ions does, and ions in general, has no strong effect on the DNA properties in vivo. Besides realizing genetic code, dark DNA would shield the system from the perturbations caused by various ions.

4. Experimentally this seems to be the case. Most interactions between DNA and ions are modelled and studied experimentally in dilute water solutions. According to [I6] (`https://cutt.ly/bFQ1Gla`), under these conditions the DNA interaction with charged ligands, the helix-coil transition temperature, and other DNA properties are strongly dependent on the low-molecular-weight salt concentration, see [I6] and references therein. However, for condensed DNA states (fibers, gels) or in vivo, similar characteristics are often independent of or only slightly dependent on the ionic composition of the solvent.

What about amino-acids (AAs)? The proposal is that also DAA-AA pairing realizes dark genetic code. If this code is realized in terms of gravitationally dark HBs, one expects that the same should be true for AAs.

2.6.6 Dark proteins and quantum gravitation

What about dark proteins in the recent situation?

1. In the case of AA of a protein, the effective charge is assignable to the donor atom, which could be either atom of peptide backbone or of water molecule. Can one assign to a given amino acid (AA) of protein (`https://cutt.ly/sFRYlWA`) 3 gravitational HBs carrying a dark proton each?

2. In the formation of AA sequence, peptide bonding occurs, which means that $(C=0)-(OH)$ is replaced with C=O and NH_2 is replaced with $N-H$. $(N-H)-(C-H)-(C=O)$ is the unit of peptide backbone (`https://cutt.ly/nFRYnu4`).

   The H atom of $N-H$ could form a gravitationally dark HB to O atom of water molecule, which would give $N^{"-"}$. Also N could form HB with H of water molecule: this would give $OH^{"-"}$. $C=O$ could form a dark HB with the H of the water molecule so that $OH^{"-"}$ is generated but $=O$ remains neutral. As in the case of DDNA-DNA pair, an effective negative charge of -3 units would be generated if one counts also the $COH^{"-"}$ as part of the peptide backbone.

2.7 Living systems as analogs of topological quantum computers

Topological quantum computation (TQC) has in the TGD framework a realization in terms of braids realized as magnetic flux tubes connecting subsystems [K2, K1, K32]. The flux tubes carry $h_{eff} = nh_0$ phases of ordinary matter behaving in many respects like dark matter. In living matter TQC-like activities would be realized in several scales associated with the hierarchy defined by the levels of MB and one can even speculate that TGD is the basic function of living matter. This motivates a brief comparison of TGD based view about quantum computation (QC) and TQC with the standard view.

2.7.1 Basic distinctions from the standard view

The TGD based view about quantum computation (QC) [K2, K1, K32] differs in several aspects from the standard view.

1. The hierarchy of Planck constants makes it possible scal the time and spatial scales of QC by realizing it using dark matter as $h_{eff} = nh_0$ as phases for ordinary matter. This is possible at quantum criticality in which long range correlations associated with quantum fluctuations are realized as $h_{eff} = nh_0$ phases, which play a crucial role in the living matter. What is favorable for QC is that for large values of h_{eff} dissipation rate is small.

2. The fragility of quantum entanglement is a basic problem of standard QCD. Partially it is due to the smallness of Planck constant. Number theoretic vision predicts that one can assign to quantum entanglement ordinary entanglement entropy and also p-adic entanglement entropy which is possible if entanglement probabilities belong to the extension of rationals assigned to the space-time region considered. $h_{eff}/h_0 = n$ corresponds to the dimension of extension associated with the space-time surface and is determined by the degree of the polynomial determining it at the level of $M^9 8$ ($M^8 - H$ duality). Negentropy Maximization Principle (NMP) is the basic principle of TGD inspired theory of consciousness as a generalization of quantum measurement theory based on zero energy ontology (ZEO).

   The prediction is that the quantum entanglement associated with entanglement with positive p-adic entanglement negentropies is very stable and the negentropy of the entire system tends to increase. This implies evolution as an increase of algebraic complexity accompanied by the increase of h_{eff} and quantum coherence scales.

3. Negentropic quantum entanglement favored by NMP satisfies strong constraints. In particular, the entanglement probabilities are rational numbers. Therefore this kind of entanglement is very rare. This solves a second basic problem of QC: there are quite too many possible quantum entanglements so that combinatorial explosion is unavoidable.

4. ZEO [L21, L33] [K34] allows also QCs in both time directions. In "big" state function reduction (BSFR) the computation halts and the arrow of time is changed and QC in the opposite time direction begins. At the human level the wake-sleep cycle corresponds to the periods separated by BSFRs. The saying that problems are solved, by sleeping over night, makes sense at a deeper level. During this period dissipation looks like self-organization and regeneration of structures, healing, and biological systems would apply this mechanism in all scales in order to fight against second law. One can also ask whether QC forth-and-back in time could make QC much faster.

2.7.2 TQC in the TGD framework

TQC is a very natural option in the TGD framework [K2, K1, K32]. The basic notions are magnetic body (MB) having magnetic flux tubes and flux sheets as body parts and dark matter residing at MB.

1. ZEO replaces 3-D quantum states with superpositions of deterministic time evolutions as preferred extremals (PEs) of the basic action principle, and are analogous to Bohr orbits and realize almost ideal holography - required by the realization of general coordinate invariance, in the sense that 3-D data fix the entire 4-surface. PEs are analogous to biological functions,

behavior patterns in neuroscience, and computer programs in computer science. SFRs as acts of free will replaced these programs with new ones.

PEs would be 4-D minimal surfaces with singularities of lower dimension. PE is analogous to soap film spanned by frames defining the singularities. As in the case of soap films, the frames give rise to a finite failure of strict determinism and ideal holography. This failure would be a classical space-time correlate for quantum non-determinism, or at least what I have called cognitive non-determinism as a correlate for imagination.

In purely classical physics holography is not realized. It is easy to understand this by thinking in terms of a point-like particle (for which 3-surface is a generalization). A particle at a given point can go in any direction with any velocity. By ideal holography only single direction and unique velocity is allowed.

2. Magnetic flux tubes connecting 3-surfaces give rise to networks. 3-surfaces appear as nodes of this network. An interesting possibility is that these 3-surfaces have as a good approximation 2-D projection to 3-space and therefore define membrane-like objects. All membrane like objects, such as cell membrane could be associated with this kind of 4-surfaces.

   The flux tube connections are a new element not present in the standard physics. The flux tubes can be idealized as string-like entities. In 3-D space the flux tubes can get knotted and linked with each other and define in this way braids - or rather, generalizations of braids. They would define the topological space-time correlate for a TQC program,

3. Fermionic degrees of freedom (quarks at fundamental level giving rise to all elementary particles including bosons and also leptons as the bound states) define the fermionic part of TQC. Fermionic states reside at the ends of braids at the nodes of the network and more generally at the 3-surfaces from which the flux tubes begin.

   An important delicacy, forced by the fact that flux tubes carry monopole flux, is that flux tubes associated with a 3-surface are tentacle-like U-shaped flux loops, and their reconnection builds flux tube pairs connecting 3-surfaces.

4. Reconnection for U-shaped flux tubes for a pair A,B of nodes forms a flux tube pair connecting A and B. The reversal of this process destroys the flux tube connection. If all flux tube connections from subsystem A to the environment disappear, A de-entangles. Thus it seems that the presence of flux tube pairs makes possible entanglement. The change of entanglement in turn has braiding as a space-time correlate.

   The halting of TQC assignable to subsystems could correspond to the de-reconnection process for a subsystem. Partial de-reconnection is also possible and the notion of partial halting might make sense.

   The braids are effectively 1-D and their time evolution defines effectively 2-D surfaces inside a 4-D space-time surface. They can form 2-knots as a generalization of ordinary knots which are 1-knots. The reconnection processes define the topology of these 2-knots. For higher-D space-time surface 2-knotting is not possible so that from the point of view of TQC, the dimension D=4 for the space-time is completely unique as also the dimension D=3 for 3-space.

5. Dance metaphor [K2, K1, K32] is a highly useful way to see TQC in the TGD framework. One can think that the nodes of the network are like dances connected to each other by thin threads. Dancers change their partners and define a complex pattern on the dance floor. At the space-time level this defines braiding of the time-lines of the dancers. One can speak of a time-like braid.

   Also the threads connecting the dancers are braided and form space-like braind determined completely by the time-like braiding once the initial state of the space-like braid is fixed. This is not quite the case if reconnections splitting or creating threads between dancers take place. One can say that the space-like braiding records the history of the dance hall as analog of akashic records. One can also speak of topological memory.

6. The evolution of the entire TGD Universe can be regarded as a fractal hierarchy of TQCs based on the fractal hierarchy of magnetic flux tubes characterized by algebraic extensions of rationals to which one can assign p-adic primes as maximal ramified primes. These in term define p-adic length scales assignable to the flux tubes. The braiding of flux tubes takes place in all scales. For instance, while moving around, we contribute to a generation of this kind of braids defining analogs of TQCs.

Biochemistry could represent especially refined analog of TQC. The basic notions of biochemistry interpreted in TGD framework correspond to those of TQC according to TGD as described above but also some new elements emerge.

1. Consider the TGD inspired view about bio-catalysis [L79]. Reconnection is the basic mechanism of bio-catalysis. According to the TGD based view about bio-catalysis, reactants find each other by using as tentacles U-shaped flux tubes and resonance mechanism.

   Flux tubes can touch but this is not enough. There must be a resonance. This occurs if the cyclotron frequencies associated with the flux tubes are identical. This is possible if the flux tubes have the same radius and therefore identical magnetic field strengths and cyclotron frequencies.

   If the value of h_{eff} associated with the flux tubes is reduced, the pair is shortened and forces the reactants near each other. The reduction of h_{eff} liberates energy, which in turn makes it possible to overcome the potential wall, which otherwise prevents the reaction from occurring. After the reaction the energy needed to overcome the wall is liberated and can bring U-shaped flux tubes to its original size. Note that the values of h_{eff} tend to be reduced and metabolic energy feed is to provide the energy needed to preserve the distribution of h_{eff} values.

   Since reconnection takes place and reaction can produce new nodes, biochemical reactions do not reduce to the notion of gate in the generalized view of TQC.

2. Besides reconnection, the notion of tuning is also fundamental and brings a new element to TQC according to TGD. The change of the thickness of the flux tube as the basic motor action of the flux tube (besides reconnection and contraction) changes the cyclotron frequency. The frequency modulation makes it possible for flux tubes to search whether some objects are present in the environment. This would be the basic operation of the immune system at quantum level [K19] [L47]. The tuning of the flux tubes of MBs of the water clusters makes it possible for them to mimic the cyclotron spectrum of invader molecules and this ability explains water memory.

3. Bioharmony [L2] [L26, L31, L48] is a further TGD based notion. The proposal is that genetic code has two quantum realizations. The first one is based on dark nucleon sequences with a dark codon realized as a nucleon triplet. For the second realization codon corresponds to dark photon triplet. These triplets behave like quantum coherent units and are analogous to quarks as 3-quark bound states.

   The binding mechanism is purely number theoretic and universal. Also genes can be regarded as dark 3N-nucleons or 3N-photons. The states of dark proton triplets correspond to all basic biomolecules DNA- ,RNA-, and tRNA-codons, as wella s amino acids (AAs).

   Bioharmony defines the dark photon realization of genetic code. Communications occur by using 3-chords (or possibly even 3N-chords). The ordinary resonance between participants with the same value of h_{eff} is replaced with 3N-resonance. The allowed 64 3-chords define bio-harmony as a collection of allowed 3-chords. Music expresses and creates emotions and the natural interpretation is that bioharmony is assigned to variants of genetic code which correspond to different molecular moods. Also the energy resonant communications between dark and ordinary variants of codons must be possible and this poses extremely stringent conditions on the basic bio-molecules.

   Bioharmony realizes genetic code and would become the basic code of TQC. Codons or even their sequences would serve as addresses. The signal is a sequence of these 3-chords, analog for a piece of music, and is received by resonance mechanism only by receivers which correspond

to a sequence of dark nucleon triplets defining the same codons. Note that also partial resonance is possible in which case the number of possible receivers is higher. The principle is the same as in LISP. The message can be coded to the modulation of the frequency scale of chords. The cyclotron resonance peaks define a sequence of pulses making it possible to interpret the message. Nerve pulse pattern could be induced by this kind of pulse sequence.

3 Update of the TGD based view of nervous system

The existing TGD based view of the nervous system will be summarized first. After that the basic notions and the ideas about what happens in nerve pulse conduction are sharpened by using the quantum gravitational view about metabolism. Also the relationship between biochemistry and TGD view about quantum biology will be discussed and lead to highly non-trivial insights about the role of the basic biomolecules.

3.1 The recent TGD based view of nervous system

The proposal [K28, K16, K29, L27] is that the cell membrane possesses a pre-NS based on cell membranes acting as generalized Josephson junctions.

1. The oscillations of membrane potential induce Josephson oscillations as soliton sequences, which represent the ground state of the axon, and possibly also of cilium. A sequence of rotating mathematical penduli in different phases giving rise to a wave is a good analogy. Pre-nerve pulse would correspond to a perturbation of the soliton sequence in which some penduli oscillate instead of rotating, which propagates with the same velocity as the soliton sequence.

   One can also consider an alternative scenario in which the roles of rotation and oscillation are changed. The soliton sequence requires more metabolic energy than its oscillatory counterpart and one might argue that the latter is more favored for this reason.

2. Generalized Josephson radiation gives rise to sensory communications from the cell membrane to its MB using frequency modulated generalized Josephson radiation with generalized Josephson frequencies $f_J = E_c/h_{eff}$ (and their multiples), which correspond to the energies $E_J = \Delta E_c + ZeV$, where ΔE_c is the difference of cyclotron energies for flux tubes at different side of membrane, and ZeV is the usual Josephson energy. Z denotes the charge of a Cooper pair or bosonic ion. For $h_{eff} = h_{gr}$ the generalized frequencies are in EEG range and nerve pulses appear as frequency modulations of the generalized Josephson frequencies.

3. The frequency modulated generalized Josephson radiation is received at MB and induces pulse by cyclotron resonance defining the response of MB as a dark cyclotron radiation. The response of MB corresponds to a sequence of resonance peaks, which induce pre-nerve pulses as propagating perturbations of the soliton sequence. The perturbation would change the rotating motion of the effective gravitational pendulum to an oscillating motion.

   The pre-nerve pulse induces a nerve pulse if a quantum criticality condition stating that the magnitude of the resting potential is above the critical value is satisfied. Synaptic transmission builds a contact between pre- and postsynaptic cells and connects U-shaped flux tubes parallel to the dendrites and axon to a pair of flux tubes.

Which part of the neuron could receive the response of MB?

1. The original proposal [K28] was that the response of MB occurs directly at the level of the genome. This would require a network of flux tubes connecting cell nucleus and cell membrane transmitting the response from genome to cell membrane. This flux tube network would also make topological quantum computation-like processes possible [K1, K32].

2. One can also imagine a simpler scenario. The response would be received by the cell membrane and generate second messenger molecules, which carry a chemical signal to the cell nucleus. The response could be seen as a sensory communication with a reversed arrow of

time. The objection is that sensory and motor systems are different for vertebrates. One can however argue that the time reversal is for the combined system. If sensory and motor sub-systems have opposite arrows of time, only either of them contributes to "our" conscious experience at once.

Interestingly,in human EEG there is a clear division into quasi-stationary periods with a duration of about .3 seconds [J2] discussed from the TGD point of view in [L1]. The first half of the period looks ordered and the second half chaotic. I have proposed that these pieces are separated by BSFR at MB as a response of MB and correspond to different arrows of time.

Synaptic transmission is second key part of neural activity.

1. Synaptic transmission involves the transmission of a bag of neural transmitters implying that the pre- and post-synaptic cell membranes touch and fuse to a singly entity temporarily. This would imply also the fusion of the magnetic flux tubes assignable to pre- and postsynaptic axons to a single flux tube and make possible both the transfer of quantum coherence and the propagation of dark photon signals assignable to magnetic flux tubes acting as wave guides. The flux tubes could be called pre-axons.

2. The deeper function of neurotransmitters remains a mystery in the framework of the standard neuroscience but terms like reward and punishment are routinely used. In the TGD framework, these terms could be more than convenient metaphors.

   The neurotransmitters arriving in the synaptic contact could induce a change of the local bioharmony and thus a change of the local mood so that the heuristic terminology would be justified. At the level of the basic biomolecules the epigenetic regulation based on methylation could induce similar changes [L48]. The decision making of neurons would rely on emotions created by various synaptic inputs: this is the situation also at our level!

Axonal MTs could make the conduction of nerve pulses through the myelinated portions of the axon possible. Inside myelinated portions the transfer of ions between interior and exterior of the axonal membrane is not possible. The shortening of axonal MTs involves localization of delocalized protons and electrons at gravitational flux tubes and changes the charge of the axonal interior and this in turn can take the membrane potential below the critical value and make the conduction possible. Note however that the drop of electrons and protons would take place at Bohr orbit with Earth radius. A further localization to atomic level would liberate more energy.

3.2 Clarification of some basic concepts

In the following I try to further clarify the basic notions used in order to identify the weaknesses of the scenario.

3.2.1 About the notion of dark ion

The original view was that dark ion as a whole resides at the flux tube. Later this statement became more precices: dark ion is touches the , say gravitational, dark flux tube with $h_{eff} > h$. This applies also to both gravitational, electromagnetic, weak, and color flux tubes and ordinary bonds correspond to electromagnetic flux tubes with $h_{eff} = h_{em}$ [L11].

The entire dark ion touching the flux tube would have wave function in the magnetic field of flux tube having the touching point as argument. Cyclotron states are natural.

The more precise view considered already earlier is that one has effective ion: the dark elecron or Cooper pair resides at gravitational flux tube is not bound to the atom as effective ion. The predictions for dark cyclotron states are same as for the older picture and the predictions related to the dark electron or proton are new.

3.2.2 About the notion of electric flux quantum

What does one mean the flux tube parallel to axon?

1. I have talked assigned to axon a magnetic flux tube parallel to it and accompanied by magnetic flux tubes transversal to it. This would correspond to a 3-D network of flux tubes.

   The problem has been how to describe the membrane structure with electric field and electric flux orthogonal to the flux tube. This situation requires genuine electric flux quanta analogous to magnetic flux quanta and the time dependent deformations of the magnetic flux tube cannot give them. However, magnetic flux tubes allow very simple time dependent deformations allowing longitudinal electric flux along the tube.

2. Could electric flux quanta associated with a pair of lipid layers correspond to a pair of membrane-like objects having 1+2-D rather than 4-D M^4 projection connected by time-dependent deformations of transversal magnetic flux tubes carrying a longitudinal electric field?

3. Unfortunateluy, I did not have any candidate for an explicit solution of field equations describing 2-D membrane-like object such as cell body or axon. For some time ago I finally understood 2-D membrane-like objects in terms of 3+1-D minimal surfaces in $H = M^4 \times CP_2$.

   M^4 projection is 3-D and E^3 projection 2-D membrane. The basic problem is posed by the fact that 2-D closed minimal surfaces are not possible. For soap bubbles a pressure difference over the soap bubble is required and one loses minimal surface property. The solution of the problem was that the 1-D CP_2 projection of the surface is dynamical and allows 4-D minimal surface. The simplest option is that it represents rotating geodesic circle.

4. Therefore one can ask whether lipid bilayer could have pair of electric bodies (EBs) serving for them as a kind of template and connected by transversal elecric flux tubes carrying a longitudinal rather than transversal electric field.

3.3 Gravitationally dark effective ions

Besides organic molecules but also metal ions are fundamental for metabolism and bio-catalysis. This led to the TGD inspired proposal that they give rise to dark ions and the recent work gives further support for the view is that gravitationally dark electrons given them their special role

1. Various bosonic effective metal ions and their Cooper pairs can get paired by gravitational flux tube with atoms of opposite total valence. The distance between paired system can become due the relative motion of the atoms considered. Also reconnections of gravitational flux tubes could cause this.

   Correlations are predicted between the members of pairs. The presence of gravitational hydrogen- and valence bonds (VBs) implying the presence of effectiove ions could distinguish biochemistry from chemistry. Also electrolysis, and therefore organic chemistry in general, involves the ionization of atoms very difficult to understand without the notion of dark gravitational valence- and hydrogen bonds. Also the physics of water is full of thermodynamical anomalies suggesting the presence of these bonds.

2. According to standard chemistry, one has equilibrium $X(OH)_2 \leftrightarrow X^{++} + 2OH^-$ for X$\in$ {Ca, Mg, Fe} in water environment. Gravitational effective ionization effectively breaks charge conservation and one would obtain quantum correlated pairs formed from X^{++} connected by flux tubes H_2O_2. Gravitationally dark electrons would not be visible. This would mean apparent charge non-conservation, which could be tested as deviation of the concentrations from the prediction $n(X^{++}) = 2n(OH^-)$.

   This could happen also for water itself. $H_3O)^+$ and OH^- ions are present. OH is not stable but the pairing $2(H_3O)^+ + 2H_2O_2$ by gravitational hydrogen bonds is possible. Also H_2O + OH^- pairs with one dark gravitational proton are possible. The concentrations of $(H_3O)^+$ and OH^- would be different.

3.3.1 Signatures of dark effective ions

The ions X^{++}, X $\in$ {Ca,Mg, Fe,Z} and X $\in$ {Li, Na, K} would be actually effective ions with gravitationally dark VBs. Dark effective ions have special signatures, which allow to test the TGD view.

1. These effective ions effectively break charge conservation. Is the transformation of $X(OH)_2 \to X^{++} + H_2\,O_2$ rather than $X(OH)_2 \to X^{++} + 2OH^-$ in question as would be if electrons become gravitationally dark. Note that hydrogen peroxide $H_2\,O_2$ is a reactive oxygen species (ROS) (`https://cutt.ly/NFima6X`) playing a very important role in biology. ROS are produced in biological processes, in particular metabolic process such as respiration and photosynthesis. TGD view would mean that ROS are not a nuisance but an essential element of electron based metabolism.

   For X^+, $X \in \{Li, Na, K\}$ the electrons of the Cooper pair are paired with two OHs. Two XOHs forms Cooper pair of X^+:s correlated hydrogen peroxide H_2O_2. This would represent new physics and effective charge non-conservation.

2. Quantum gravitational correlations between H_2O_2 and X^{++}, $X \in \{Ca, Mg, Fe, Zn\}$ and between H_2O_2 and Cooper pars of X^+, $X \in \{Li, Na, K\}$ are predicted and this prediction might be testable.

3.3.2 Some facts about Calcium ions

Basic facts about Ca ions allow to get idea about the implications of new metabolic quantum and the quantum gravitational realization of metabolic energy quanta.

1. Calcium ions (Ca^{++}) contribute to the physiology and biochemistry of organisms' cells. They play an important role in signal transduction pathways, where they act as a second messenger, in neurotransmitter release from neurons, in contraction of all muscle cell types, and in fertilization.

2. Calcium phosphate `https://cutt.ly/4FimgMc` appearing in bones combines effective ions possibly having gravitationally dark protons and electrons (Calcium phosphate is also considered in [L28]). Posner molecule $[(PO_4)^{-3})]_6Ca_9^{+2}$ made of 6 phosphate ions and 9 calcium ions would be the key player and has been proposed to play central role in consciousness theory [J5, J8] (`https://cutt.ly/bFimzit`). I already mentioned Posner molecules and a possible realization of genetic code using dark Cooper pairs of electrons. I have considered Posner molecules from the TGD point of view in [L6].

3. Ca^{++} currents initiate action potentials. Voltage gated Ca^{++} channels emerge first in the maturing of neuron and also in evolution of nervous system (already monocellular eukariotes generate action potentials). Na^+ channels emerge later. The action potentials pulses have a longer dead time for Ca^{++} than for Na^+.

   For instance, Ca^{++} initiates a contraction of muscle and helps to maintain the potential difference over cell membrane, which conforms with the proposed role in electronic metabolism.

4. Ca^{++} appears as a second messanger molecule. The TGD view about second messanger molecules is discussed in [L45]. Cell interior, in particular mitochondria and endoplasmic membranes contain storages of Ca^{++}. Mitochondria would thus involve both forms of metabolism.

3.3.3 Ca^{++} waves

Ca^{++} waves could be effective ions due to gravitationally dark Cooper pairs.

1. Ca^{++} waves are very important in biology and appear in cell interior and between cells. A calcium wave is defined as a localized increase in cytosolic Ca^{++} that is followed by a succession of similar events in a wave-like fashion. Ca^{++} waves can be restricted to one cell (intracellular) or transmitted to neighboring cells (intercellular).

2. Calcium waves are also associated with glial cells. Ca^{++} waves are of special importance in astrocytes and other glial cells [J7]. This should relate to electronic metabolism of the primary cilia associated with both neurons and glial cells.

   Calcium waves and miniature potentials would naturally relate to dark electron metabolism. Both glial cells [J4] and neurons [J3] have primary cilia acting as sensory receptors and since cilia cannot use ATP metabolis, electronic metabolism is natural.

3.4 About the model for the nerve pulse

Could one construct a simplified TGD based model for the nerve pulse [K28] using this kind of picture utilizing holography meaning that one can take the EBs as basic objects to which one can assign densities of various ions atoms and normal components of electric field as charge densities? Can one decompose these densities to various contribution assignable to ions or effective ions?

The basic physical picture would be as follows. The transformation of the pairs of metal atom with atoms with total valence equal to that of metal would generate gravitationally dark metal atoms, which are effective ions which correlate with the paired atoms. The valence charge of the metal atom effectively disappears and implies an effective charge non-conservation. In nerve pulse these effective ions would disappear and would look like charge non-conservation. Also effective ionic currents appear.

1. Josephson currents are assumed to flow along dark flux tubes connecting the two systems and electric field would be along them. Gravitationally dark protons and electrons reside at gravitational flux tubes as very long loops connecting cell interior and exterior. Dark ions are associated with these flux tubes (touch them).

2. What kind of dark Josephson currents could flow along them? If the two atoms are localized at the ends pf the dark gravitational valence- of hydrogen bond at the opposite sites of the membrane, the dark electron and proton Josephson currents can run along gravitational flux tube. Also effective dark ion currents can flow between interior and exterior since the gravitational VB with H_2O_2 can get stretched.

   Gravitational flux tubes assignable to valence and hydrogen would connect systems such as X^{++}, X$\in$ Ca, Mg, Fe and hydrogen peroxide H_2O_2, which is a reactive oxygen species (ROS). The currents would flow between systems containing these dark ions and molecules.

3. More than 100 miniature potentials induced by Ach vesicles are needed to initiate nerve pulse in synaptic contact. The miniature potential corresponds to a liberation gravitational electronic metabolic quantum as a transformation of gravitationally dark electron to ordinary one. This critical reduction of membrane potential would induce the reduction of the membrane potential below the critical value and induce the action potential. Also protonic metabolic quanta are involved and would relate to the ordinary metabolism based on ATP machinery.

The TGD picture challenges the Hodgkin-Huxley model of nerve pulse generation (`https://cutt.ly/FFiWTNA`). The model for the neuronal membrane assumes that ohmic currents flow through the ion channels. What happens when a Ca^{++} initiated action potential is generated?

1. The standard description using Hodgkin-Huxley model is in terms of a rush of Ca^{++} ions to the cell interior along Ca^{++} channels. The process occurs spontaneously since the cell interior is negatively charged and does not require metabolic energy. These currents would be ohmic and dissipative. This description could make sense only in the non-myelinated portions of the axons.

   Since only non-dissipative Josephson currents for dark Ca^{++} ions are possible, the rush of dark Ca^{++} dark ions does not seem plausible in the TGD picture. However, the delocalized electronic charge could end up to the hydrogen peroxide H_2O_2 paired with Ca and a genuine Ca_{++} ions would be created. The same applies to Cooper pairs of other dark metallic ions. In the myelinated portions of axon this kind of mechanism could work so that the Hodgkin-Huxley model would describe the situation.

   Inside the myelinated portions of the axon, the transformation of gravitationally dark protons to ordinary protons would reduce the associated effective negative charge and make membrane potential more positive and take it below the critical value for nerve pulse generation at non-myelinated portions.

   Also pairs of dark Ca^{++} ions and dark H_2O_2 pairs from $Ca(OH)_2$ can be created, perhaps by a double (effective) ionization creating pairs of dark Ca^{++} ions and dark H_2O_2 pairs from $Ca(OH)_2$ in an electric field in the cell interior. Also dark gravitational VBs associated

with Ca would be created in the cell interior and dark electron Josephson currents would be generated. The charge densities inside and/and outside the neuronal membrane would change and affect the membrane potential. This option could be realized in the non-myelinated sections of the axon in the resting state: nerve pulse would involve a transformation of dark ions to ordinary ones.

2. What looks very strange from the TGD point of view is that, although the generation of nerve pulse is spontaneous and is therefore expected to reduce the value h_{gr}, which in turn would liberate energy identified as a metabolic energy, just the opposite occurs. Can one conclude that a BSFR occurs at critical membrane potential and the arrow of time is changed. In this situation the process would be dissipative but in a reversed time direction. Later support for this interpretation will be found.

This raises a question considered from the TGD point of view in [K27]. Do the ion channels and pumps really act as channels for ionic currents or can only electronic, protonic and ionic Josephson currents flow through them?

1. The experimental work of Ling, Sachs and Qin [I10, I17] and other pioneers [I7, I4] challenges the notions of ionic channels and pumps central to the standard cell biology. Ling has demonstrated that the ionic concentrations of a metabolically deprived cell are not changed at all: this challenges the notion of cell membrane ionic pumps.

2. The work of Sachs and Qin and others based on patch-clamp technique shows that the quantal ionic currents through the cell membrane remain essentially as such when the membrane is replaced by a silicon rubber membrane or by a cell membrane purified from channel proteins! This challenges the notion of cell membrane ionic channels. A further puzzling observation is much more mundane: an ordinary hamburger contains roughly 80 per cent of water and is thus like a wet sponge: why is it so difficult to get the water out of it?

Membrane potential changes sign during the nerve pulse. The interpretation as a BSFR changing the arrow of time is suggestive and the above observation suggests the same?

1. If the action potential corresponds to two subsequent BSFRs as a kind of quantum tunneling event, the arrow of time temporarily changes at MB and changes the effective arrow of time at the level of the ordinary biomatter. Gel-sol phase transition in the neuron interior near neuronal membrane signals about the reduction of the quantum coherence scale.

2. The TGD based description for the change of the sign of the membrane potential is in terms of the model of nerve pulse describing the ground state as a soliton/oscillon sequence and mathematically equivalent to a sequence of gravitational penduli rotating/oscillating in synchrony. Can one choose between these options?

   Critical membrane potential would correspond to a situation in which the rotation changes to oscillation or vice versa. The fact that the membrane potential changes sign and has original magnitude, supports the soliton model. The rotation frequency would transform to a vibration frequency, decrease further, change sign and eventually transform to a negative rotation frequency. The arrow of time would have changed. The reverse of this process would correspond to the second BSFR leading to hyperpolarization.

3.5 Microtubular level

TGD predicts two forms of metabolism [L43]. The ordinary metabolism relies on gravitationally dark protons originating from hydrogen bonds. For the new form of metabolism dark protons are replaced with gravitationally dark electrons or their Cooper pairs originating from metal atoms. Both dark electrons and dark electron Cooper reside at gravitational Bohr orbits with the same spectrum of radii. When they transform back to ordinary particles, they become gravitational Bohr orbits at distance defined by Earth radius and therefore liberate energy.

This metabolic mechanism could be associated with cilia and flagella having no mitochondria in their interior and could be also important in the metabolism of axonal MTs.

3.5.1 Could the metabolism of cilia and flagella rely on gravitationally dark electrons?

The recent work in TGD has led to considerable progress in the understanding of metabolism [L43] already discussed in the section 2.5. The TGD based view about metabolism involves in an essential way quantum gravity.

The observation is that the gravitational binding energy of dark protons at Bohr orbits in Earth's gravitational field for $h_{eff} = h_{gr} = Gmm/v_0$ [E1] [K10, K11, K12, K13, K26] [L37, L29] can correspond to metabolic energy quantum in good approximation. The proposal is that the transformation of protons of hydrogen bonds possible for electronegative atoms and occurring at least for phosphate generates gravitationally dark protons. Their transformation would liberate metabolic energy quantum.

The prediction is that besides gravitationally dark protons also similar electrons define a metabolic energy currency relating to standard metabolic currency like cent to dollar. It is proposed that the electronic metabolic currency can be applied to the purely understood metabolism of cilia and flagella (`https://cutt.ly/WDkYZzx`). I attach the proposal below almost as such.

According to [I19] (`https://cutt.ly/EDkW2bu`) the recent measurements in sea urchin sperm (length ~ 50 μm long, diameter 0.2 μm) show that the energy consumed per flagellar beat corresponds to $\simeq 2 \times 10^5$ ATP molecules. There is no GTP inside cilium as in the case of axonal MTs (`https://cutt.ly/5DkYGB2`). It is difficult to understand how ATP machinery could provide the metabolic energy feed.

This motivates the question about whether local ciliary metabolism could rely on the transformation of valence electrons of some biologically important ions to dark electrons at the gravitational MB and vice versa? The reduction of h_{gr} for electrons would provide the metabolic energy related by a factor $m_e/m_p \simeq 2^{-11}$ to the ordinary. According [I19], about 4×10^8 gravitationally dark electrons would transform to ordinary ones in a single stroke of cilium.

Electronic metabolic energy quantum would relate like cent to dollar and make possible a more refined metabolism with fine tuning. Electronic metabolism could also be an essential part of ordinary metabolism.

Consider now the idea more quantitatively.

1. What could be the electronic analog of ATP machinery. All biologically important ions can be considered as effective ions with some valence electrons at gravitational MB. In particular, the bosonic ions Ca^{++}, Mg^{++}, Fe^{++} and Zn^{++} could have Bose-Einstein condensates of gravitationally dark Cooper pairs at the gravitational MB.

   Ca^{++} waves play a key role in cellular biology, Fe^{++} is essential for oxygen based metabolism, and Mg^{++} and Zn^{++} are important in bio-catalysis: for instance, ATP must bind to Mg ions in order to become active.

2. What could be the mechanism transforming valence electrons to dark electrons? This should happen for positively charged biologically important ions, in particular for the bosonic ions Ca^{++}, Mg^{++}, Fe^{++} and Zn^{++}. The consumption of metabolic energy would correspond to a de-ionization of dark ion Ca^{++} and this might make it possible to test the proposal. For instance, Ca^{++} could accompany ciliary waves.

Where could the energy for ionization come from?

1. This question is also encountered in the chemistry of electrolytes [L11]. It is very difficult to understand how the external electromagnetic potentials, which give rise to extremely weak electric fields in atomic scales, could lead to ionization. The acceleration of electrons in the electric field along dark flux tubes involves very small dissipation and can easily give rise to electron energies making ionization possible.

2. MTs have a longitudinal electric field which by the generalization of Maxwell's equations to many-sheeted space-time (in stationary situation potential difference is same for paths along different space-time sheets) gives rise to an electric field along the magnetic flux tubes. These flux tubes need not be gravitational.

   By darkness, the dissipation rate is low. Could the acceleration along flux tubes, in particular MT flux tubes, lead to the ionization? Could the electret property of linear biomolecules

quite generally serve for the purpose of generating electronic metabolic energy storages in this way?

3. Assuming opposite charges $\pm Z_{MT}$ at the ends of dark magnetic flux tube associated with the MT, one obtains a rough estimate. The length of the cilium is $L \leq .5 \times 10^{-4}$ m and its radius is $R \sim 2 \times 10^{-7}$ m. The estimate for the energy gained by a unit charge e as it travels through the ciliary MT is $E \sim Z_{MT} e^2 L/R^2 \simeq Z_{MT} \times 2.85$ eV. The valence electron energy for atomic number Z with principal quantum number n (giving the row of the Periodic Table) is $E \simeq (Z/n)^2 \times 13.6$ eV. The ionization condition would be $Z_{MT} \geq (Z^2/n^2) \times 13.6/2.85$. For the double ionization in the case of Ca^{++} with $Z = 20$ and $n = 3$ this would give $Z_{MT} \geq 212$.

3.5.2 TGD based view about axonal and cellular microtubules

Axonal MTs and also subset of MTs in the cell body are highly dynamical critical systems changing their length continually. It seems that they are essential motor instruments of MB just like the MTs of motor cilia. Could the microtubular structures in cell soma are also analogous to supporting structures which can be rapidly deformed by making them unstable against the change of length.

1. Instability of axonal MTs and nerve pulse conduction

In the TGD framework, axonal MTs could make nerve pulse conduction in the myelinated portions of axons possible. The localization of dark proton charges in the shortening flux tube would change the charge of the MT interior and in this way affect the local membrane potential and bring it to criticality. Time reversal and BSFR could be associated with the change of the growth of the MT length to decrease or vice versa. The lengthening and shortening processes would be the same but have different arrows of time. The propagation of the wave at which arrow of time for MT changes would correlate with the conduction of nerve pulse.

The dynamic instability of the axonal and some cellular MTs (`https://cutt.ly/ADzx3re`) is not well-understood. Power stroke causing the decay of the MT at its end is the basic notion. Whether chemical action precedes the mechanical one or vice versa is not clear. Therefore an obvious question is whether chemistry and mechanics are enough. The following represent a possible TGD based view about the power stroke.

1. Gravitationally dark proton transforms to ordinary proton of a phosphate hydrogen bond in the transformation of GTP to GDP. This liberates metabolic energy quantum, serving as a power stroke. This localizes one unit of proton charge and in this manner affects membrane potential.

2. Assume that MT is associated with a cylindrical membrane, that is 4-D minimal surface with 3-D M^4 projection having no counterpart in GRT. M^4 projection would have the microtubular cylinder as an E^3 projection. Cylinder is not a minimal surface and the cylindrical analog of the soap bubble requires a pressure difference over the cylinder walls.

   In the TGD framework, CP_2 projection as a dynamical 1-D curve, say rotating geodesic line of CP_2 would give rise to the effective pressure difference [L39]. This analog of pressure difference would increase in the power stroke and locally expand the cylinder at the position of GDP. This would push tubulin protein outwards. These kinds of power strokes would force the MT to decay and shorten.

2. Energetics of the axonal transport

The transfer of material along the MT is the basic motor activity of MTs (`https://cutt.ly/TDzOePw`). The transfer of protein cargoes is a very slow process even on human time scales. Therefore these processes could involve electron (Cooper pair) based metabolism in an essential way. Note however that mitochondria are present also inside MTs.

If electronic metabolism is in question, these processes are predicted to be much slower than those induced by protonic metabolic currency since the work $F\Delta x$ done by the force corresponds to metabolic energy quantum and for Δx about tubulin size, F smaller by a factor m_e/m_p than in the case of protonic metabolic quantum.

3.5.3 Delayed luminescence for microtubules,quantum gravitation, and the mechanism of anesthesia

Jack Tuszynksi has reported very interesting findings in Science of Consciousness 2022 (https://cutt.ly/PF6OcxA). The findings are described in a popular article (https://cutt.ly/tF6OhWz).

A delayed luminescence in microtubules (MTs) irradiated by laser light has been observed. This can be seen as a support for the presence of quantum coherence at least in the scale of MTs. Also it was found that the application of anesthetics (such as noble gas Xenon expected to have very weak chemical effects) shortens the delay time. This suggests the reduction of quantum coherence by anesthetics so that quantum coherence in long scales should be crucial for consciousness. One of the challenges is to understand the reason for the reduction of quantum coherence.

Delayed luminescence has been associated with bio-photons a long time ago and DNA is proposed to serve as the seat of the delayed luminescence. In particular, the group involving also Tuszynski has studied the emission of mitochondrial biophotons and their effect on electrical activity of the membrane via MTs [J6] (https://cutt.ly/XF6OqLA). A TGD based view of biophotons as decay products of dark photons is discussed in [K5, K7].

To my opinion, the findings represented by Tuszynski provide support for quantum consciousness but not specifically for Orch-OR, which still remains a rather poorly defined approach since the statement that Planck scale quantum gravity effects are crucial for consciousness has no concrete content.

The TGD based interpretation of findings of Tuszynski would be as follows.

1. The laser beam serves as a metabolic energy feed increasing the value of h_{eff} and therefore the scale of quantum coherence. One can say that this metabolic energy feed creates or wakes up an analog of a conscious living organism: now at the level of microtubule MB. As it "dies" in "big" state function reduction (BSFR) involving the reduction of h_{eff} to a smaller value, not necessarily the normal value $h_{eff} = h$, the loaded metabolic energy is liberated.

   This would not apply only to MTs but quite generally. For instance, biophoton emission from cut leaves, would represent a similar decay process. Biophotons would be ordinary photons resulting as decay products of dark photon BE condensates and dark photons emitted with cyclotron Bose-Einstein condensates decay.

2. The delocalization mechanism associated with the formation of the gravitational variants of hydrogen- and valence bonds allows effective charge densities in short scales and could have dramatic implications for the model of nerve pulse. The nerve pulse need not correspond to a generation of ohmic currents through the membrane but to effective ionization or its reverse process due to the transformation of hydrogen and valence bonds to dark gravitational bonds.

3. MTs could play an important role since they involve GTPs as analogs of ATPs and are thus involved with metabolism. The conduction of nerve pulse in the sense of the Hodgkin-Huxley model through myelinated sections of axons is very difficult to understand. The new view would allow the shortening and lengthening of MTs to change the effective charge density of MTs so that membrane potential would change and nerve pulse conduction in the TGD sense would be possible.

How could one understand the effect of anesthetics? I have considered this problem earlier. First one should try to understand how the critical dynamics of MTs relates to nerve pulse conduction inside myelinated regions of the axon.

1. Certainly the membrane potential should become hyperpolarized to prevent nerve pulse condition so that consciousness would be lost. In myelinated portions of axons there is only propagating perturbation of membrane potential taking it below the threshold for nerve pulse generation so that nerve pulse is generated at unmyelinated portion. In the ground state one has propagating Sine-Gordon soliton (or oscillon sequence) visualizable as a sequence of rotating (oscillating) gravitational penduli.

   In the perturbation some penduli start to rotate in an opposite direction (or oscillation transforms to a rotation). Usually this would require flow of charge through the cell membrane as

Josephson current. Now the variation of the effective charge densities caused by the delocalization of protons inside the axon would induce an effective Josephson current. The effective charge inside the axonal interior becomes less negative and induces at non-myelinated portions of the axon a nerve pulse describable using the Hodgkin-Huxley model.

2. A couple of comments about the arrow of time are in order. Nerve pulse is induced by ~ 200 miniature potentials of amplitude about .4 meV which could be assigned to electron metabolic energy quantum. This corresponds to energy of .8 eV, roughly 2 protonic metabolic energy quanta. This supports an interpretation in terms of a time reversed process in which two metabolic energy quanta decay to ~ 200 miniature potentials. This conforms with the proposal that nerve pulse generation is BSFR inducing time reversal.

   The reconnection transforming HB (VB) to its gravitational variant or vice versa during nerve pulse propagation induces the transfer of proton (electron) to HB. Since the size scale of the gravitational bond is that of Earth, this would take time and could be too slow for protons. The problem disappears if the reconnection corresponds to BSFR changing the arrow of time. The BSFR occurs and the final state is what becomes the causal agent just as in the explanation of Libet's findings about active aspects of consciousness.

3. If the anesthetic induces the transformation of gravitationally dark HBs (VBs) to ordinary ones in the interior of the axon, the effective charge of the axon becomes more (less) negative and the axonal potential becomes more (less) negative. MTs have GTPs near their ends and GDPs in the intermediate region. Negative charges of GTPs and GDPs would naturally correspond to gravitational HBs.

   The variation of MT lengths involves a transformation of GTPs to GDPs and vice versa. This would change the effective charge density of the MTs and affect the membrane potential. If gravitational HBs become ordinary, metabolic energy is liberated and vice versa. Hyperpolarization would require a generation of reconnections and a local change of the MT lengths.

   The variation of the lengths of axonal MTs would induce effective negative charge near the growing end of MT. Could the moving depolarization front of the axonal membrane correspond to an increasing GDP region of an axonal MT?

4. The presence of soliton (oscillon) suggests periodic effective charge density waves in which the protons transform to gravitationally dark protons and vice versa in a periodic manner. Could this mean a periodic variation of the lengths of axonal MTs?

   Also the transformation of metallic valence bonds to their dark variants and vice versa could control the membrane potential. Ca^{++} waves would result in cell interior when valence electron pairs of Ca atoms or their salts become gravitationally dark. Could periodic rotation (oscillation) accompany dark electron metabolism with a much smaller energy cost?

How the presence of noble gas having very weak chemical interactions could affect the nerve pulse conduction inside the axon? One can proceed by making questions.

1. Could the anesthetic freeze the dynamics of MTs so that nerve pulse conduction would become impossible? The presence of an anesthetic should make the axonal interior more negative and induce hyperpolarization.

   Could the presence of the anesthetic stabilize the MTs by minimizing the length of their GDP region? Somehow the growth of MT should be prevented means addition of tubulins and GTPs. This is achieved if the density of tubulin-GTP pairs in axonal water is reduced. The generation of GTP from GDP requires a formation of gravitational HBs from ordinary HBs. The density of ordinary HBs should be reduced.

2. Could the presence of the anesthetic reduce the density of ordinary HBs in the axonal water? HBs are associated with water clusters. How could the presence of anesthetic reduce the rate for the generation of water clusters and therefore HBs in the axonal water?

   In the TGD inspired theory consciousness, the MBs of water clusters can be seen as correlates for mental images of water as a conscious entity [K19] [L47]. The level of consciousness for

water would be reduced. It would be water, which is anesthetized! This would freeze the MTs so that also the axonal membrane freezes electrically.

3. Meyer and Overton observed that the potency of anaesthetic agents correlates with their lipid solubility. Anesthetics also seem to affect specific ion channels and receptors. One can argue that if the anesthetic is solvable to lipids, it can also enter inside the axon and somehow reduce the density of HBs assignable to the water molecule clusters accompanied by gravitational MBs. The effective charge of the axonal interior would become more negative and induce a hyperpolarization if the exterior is not affected.

4. How happens when water is anesthetized? A hint comes from the Pollack effect [L4]. The exclusion zones discovered by Pollack are negatively charged regions at the interfaces of hydrophilic surfaces. The TGD based interpretation could be that part of protons become dark protons at gravitational HBs. It is known that anesthetics diminish the amount of EZ water (`https://pubmed.ncbi.nlm.nih.gov/27054588/`).

5. How could anesthetics prevent the formation of EZs and thus of gravitational HBs? A metabolic energy feed is needed in the Pollack effect and is by photons as also the delayed luminescence for MTs demonstrates. How could the feed of photons needed to produce EZs be prevented by anesthetics? Energy is feeded in resonance. Could the presence of anesthetic change the energy needed to transform HB to dark gravitational HB so that the resonance condition would not be satisfied.

4 How multicellular without a nervous system can behave as if it had a nervous system?

In the TGD framework, the quantum models of cell membrane and nerve pulse rely on the notions of magnetic body and dark matter [K16, K28, K29, L27]. The generalization of this view leads to a notion, which could be christened as pre-neural system (PNS). Also the multi-cellulars without CNS would possess PNS.

4.1 Animals without the brain behave as if they had the brain

The motivations for this article came from the Quantum Magazine article (`https://cutt.ly/IDnfovQ`) telling about the findings of Manu Prakash and Mathew Storm Bull. The work of Prakash and Bull is published as 3 articles [**?**]hat can be found in arXiv.org. In the following I summarize the findings as they are described in the popular article.

4.1.1 Findings of Prakash et al

Trichoplax adhaerens is a marine creature, classified as a placozoan, which has the smallest known genome in the animal kingdom. Trichoplax has thousands to few millions of cells and is between prokaryotes and eukaryotes as far complexity is considered.

Trichoplax (`https://cutt.ly/SD6GGW5`) is a very flat organism formed with diameter about 1 mm and thickness about 25 μm. For cell number N in the range $[10^3, 10^6]$ cells and for a cell approximated as a ball with radius r, this gives r in the range $[2.1, 21]$ μm. Despite the lack of neuronal system and muscles, the motion of trichoplax is extremely well-orchestrated and efficient.

The goal of the project of Manu Prakash and his graduate student Matthew Storm Bull was to understand how the neuromuscular system might have evolved and how the early multicellular creatures without a nervous system managed to move, find food and reproduce. Epithelial sheets formed by Trichoplax cells are studied. Trichoplax cells are monociliated that is they have only a single cilium. This simplifies the experimental study and modelling of Trichoplax.

First some basic facts.

1. Motile cilia and flagella are the analogs of muscles and primary (non-motile) ciliar serve the role of sensory organs at the cellular level. Cilia and flagella have similar structures and only their functions differ. Cilia force liquid to move with respect to the cell. Flagella make it possible for the cell to move with respect to liquid (`https://cutt.ly/TDngqhO`).

2. The force needed for the bending of the cilium is produced by the outer and inner dynein arms of the axonemal MT doublets connected to the central pair of microtubules by radial spokes. Airway cilia have components typical for motile cilia.

3. Beating waves as contraction waves of the axoneme induce bending of the cilium. The frequency of the beating wave is the key parameter in the dynamics of the cilium.

   That the beating frequencies are in the EEG range suggests that in some respects neurons and ordinary cells have much more in common than thought. Beating frequency would take care of synchrony and one can ask whether cilia have an analog of EEG.

4.1.2 Popular summary of the experimental findings

I add to the summary my own comments in order to give a hint about TGD based interpretation of the findings.

1. The claim is that behavior of Trichoplax can be described entirely using the language of physics and dynamical systems.

   Comment: To my understanding, a description in this sense means mathematical modelling using formalism of physics and identifying simple basic mechanical functions serving a role analogous to program modules of the software.

   The nature of the living systems is very difficult to understand using only recent day physics and it is very difficult to believe that purely mechanistic description could be possible. However, the possibility to construct such a simple model is in itself a strong guideline in attempts to really understand how the motor actions of Trichoplax are possible.

2. Cilia are typically seen in the context of fluids: propelling bacteria or other organisms through water, or moving mucus or cerebrospinal fluids in a body. Therefore the expectation was that the cilia to glide over surfaces, with a thin layer of fluid separating animal and substrate. But when the researchers looked through their microscopes, they saw that the cilia seemed to walk, not swim.

   The claim is that instead of hydrodynamic description, it is possible to have much simpler description in terms mechanics involving notions like friction and adhesion.

   Comment: I understand that these conclusions hold true for the motion along the surface and one can wonder whether the conclusions hold true for swimming.

3. The characterization of the cilia's walking gait was taken as a goal. Only three types of basic motions:slipping, during which the cilia barely grazed the surface; walking, when the cilia adhered to the surface briefly before popping off; and stalling, when the cilia got stuck against the surface.

   Comment: What is really surprising is that the motion consists of such simple basic modules somewhat like a computer program. For instance, in a general Hamiltonian system one expects Hamiltonian chaos. Bohr orbits are what comes into the quantum mind.

Mechanical models for the walking activity were developed by the authors [I15, I13, I14].

1. In the models the walking activity emerged naturally from the interplay between the internal driving forces of the cilia and the effective energy of their adhesion to the surface. The right balance between those two parameters (calculated from experimental measurements of the cilia's orientation, height from the surface and beat frequency in the EEG ranfe in the situation considered) resulted in regular locomotion, with each cilium sticking and then lifting away, like a leg. The wrong balance produced the slipping or stalled phases.

   Comment: My understanding is that the driving force of the cilium serves as an input analogous to external force and chosen so that a model for a particular motion is obtained. The model is therefore not fully deterministic and autonomous. On the other hand, the reduction of hydrodynamical description to mechanical description is highly non-trivial and suggests that some new physics is involved.

2. The walking cilium can be modeled as an excitable system. In an excitable system, the signals spread and get amplified rather than progressively damping out and coming to a stop. A neuron is a classic example of an excitable system. Small voltage perturbations can cause it to fire suddenly, and above some threshold, the new stimulated state propagates to the rest of the system.

   The same phenomenon seems to occur in the cilia. In the experiments and simulations, small perturbations in the height of cilium from the surface, rather than voltage, led to relatively large changes in the activity of nearby cilia. They could suddenly change their orientation, and even switch from a stalled state to a walking one.

   Comment: Excitability, and self-organization in general, is in conflict with the expectations based on second law of thermodynamics. The metabolic energy feed is the way to understand the situation in non-equilibrium thermodynamics.

   This behavior requires an highly non-linear mechanical system at criticality. This does not however explain why so few modes, in fact analogous to Bohr orbits, are possible. A quantum biologist could ask whether quantum criticality is involved. At classical level catastrophic theoretic description in terms of phase transitions is suggestive.

   The similarities with neuronal behaviors inspire the question whether the ciliary system defines some kind of pre-neuronal system preceding the nervous system in evolution and shared by it as the fact that sensory receptors are cells with cilia.

3. It was measured how the mechanical gait of each cilium led to small, local fluctuations in the height h of the tissue. Equations for how this would 'tug' at nearby cells to affect their behavior were deduced, even as the cilia on those cells cycled through movements of their own. A convenient analogy is a network of springs tied together by tiny oscillating motors.

   When the researchers modeled this dance between elasticity and activity, as they called it, they found that the mechanical interactions of cilia pushing against a substrate and cells tugging at each other transmitted information rapidly across the organism.

   Stimulating one region led to waves of synchronized cilia orientation that moved through the tissue. This elasticity and strain in the physics of a walking cilium, now multiplied by millions of them in a sheet, gives rise to coherent motile behavior.

   Comment: Here it is difficult to avoid the question whether the 'tug' as touching of cells (or cilia of different cells) is analogous to synaptic transmission in the neural system.

4. The synchronized orientation patterns could be complex. Sometimes the activity of the system produced vortices, with the cilia oriented around a single point. In other cases, the cilia reoriented in fractions of a second, first pointing one way and then another flocking as a group of starlings or a school of fish might, and resulting in an agility that made it possible for the animal to sometimes change direction on a dime.

   Comment: Courageous quantum biologists might associate with the agility a quantum jump in multi-cellular scale.

5. It was found that the information transmission was selective. After certain stimuli, the energy injected into the system by the cilia just dissipated instead of spreading and changing the organism's behavior. As if the organism would direct its attention to particular parts of the perceptive field and react only to the changes in these parts.

   Comment: Brain is able to direct its attention to particular objects of the perceptive field. Is the ciliary system able to direct its attention?

4.1.3 The model for the cilium and ciliary motor actions

The model starts from the model of nerve pulse and generalizes it to the case of cilium.

Concerning the understanding of the findings about the motor actions of multi-cellulars without a nervous system, this vision raises obvious questions.

1. MB should serve as the "boss" also for the multi-cellulars without a nervous system. The general quantal sensory communication and control mechanism should be the same as for organisms with a nervous system. Frequency modulated dark Josephson radiation should mediate sensory data to MB and dark cyclotron radiation would mediate the control commands from MB as pulse patterns as a response to sensory input.

2. Could the beating wave, which has frequency in EEG range, be analogous to EEG wave, membrane oscillation, and possibly perturbed oscillon/soliton sequence, which defines the ground state of ciliary membrane?

3. Cilia are analogous to axons. Could ciliary membrane act as a Josephson junction communicating sensory data to MB? The MTs of the motile cilia play a role analogous to that of axonal MTs as motor organs of MB. Could one consider analogs of nerve pulses for cilia inducing ciliary motor actions rather than nerve pulse patterns? No nerve pulse is involved. Could the analogs of nerve pulses be pre-nerve pulses analogous to miniature potentials of .4 meV generated in synaptic contacts for instance by acetylcholine containing vesicles (`hhttps://cutt.ly/JD1ONEu`) and induce beating waves inducing ciliary bending? 100-200 hundred miniature potentials are needed to generate a nerve pulse.

4. Here the poorly understood origin of the ATP needed by ciliary motor activities [I19] serves as a guideline. Cilia and flagella cannot have mitochondria as ATP sources inside them and the diffusion of ATP from nearby mitochondria is strongly limited. The proposal discussed in [I19] is that a local generation of ATP using mechanisms, which depend on nutrients could solve the problem. It is difficult to avoid the feeling that something strange is involved with the ciliary metabolism.

   TGD leads to the proposal that the standard metabolic energy quantum of about .5 eV corresponds to the change of gravitational binding energy as a proton of HB is transferred to a dark proton at at the gravitational flux tube around its Bohr orbit in the gravitational field of Earth with gravitational Planck constant $h_{eff} = h_{gr} = GMm/v_0$. Dark electrons would correspond to gravitational binding energy for a valence electron or a pair of valence electrons (Cooper pair) transferred to a gravitational flux tube.

   The energy of the single electron metabolic energy quantum would be by a factor $m_e/m_p \sim 2^{-11}$ smaller than the standard metabolic quantum about .25 meV and relate to the standard metabolic energy quantum like cent to dollar. For an electron Cooper pair it would be 2 times larger and about .5 meV. Intriguingly, this energy is rather near to the Coulomb energy change assignable to the miniature potentials .4 meV (`https://cutt.ly/vDRysfU`)! Could the analog of nerve pulse be a propagating miniature potential induced by the dropping of an electron Cooper pair of say Ca^{++} ion from the gravitational Bohr orbit back to Rydberg state with very small binding energy.

5. Cilium is modelled as a 2-D quantum gravitational pendulum with gravitational Planck constant controlled by MB using electronic metabolic energy quanta and the resulting model for the motion is in many respects similar to the model of nerve pulse. In the resting state ciliary penduli oscillate or rotate with constant phase difference so that a wave-like motion results.

6. The analog of nerve pulse transmission can be identified. Temporary fusion of pre- and postsynaptic cells takes place in nerve pulse transmission. The tugs would correspond to the adhesion of their cilia and make possible the transfer of quantum coherence and synchrony between the neighboring cells and in this way generate quantum coherence in multi-cell scale? The adhesion of cilium to the plane in which it moves is also possible.

   Both kinds of adhesions spoil the synchronous oscillation of neighboring penduli. The adhesion followed by de-adhesion changes the relative phase and a further 'tug' is plausible. This leads a domino effect to an analog of nerve pulse conduction. In this process, the U-shaped flux tubes assignable to the cilia of the neighboring cells fuse to form a larger quantum coherent unit. Same would happen in the case of ordinary nerve pulse transmission [L27]. The system is quantum critical in the sense that when the cilia oscillate/rotate with a phase

difference below some critical value, no touchings occur and no nerve pulses are generated. Perturbations change the situation.

4.2 Ciliary flocking and emergent instabilities enable collective agility in a non-neuromuscular animal

It is useful to start with a more technical summary of the work of Prakash *et al* provided by the abstract of the article "*Ciliary flocking and emergent instabilities enable collective agility in a non-neuromuscular animal*" [I15] by Mathew Bull, Vivek Prakash, and Manu Prakas as such.

Effective organismal behavior responds appropriately to changes in the surrounding environment. Attaining this delicate balance of sensitivity and stability is a hallmark of the animal kingdom. By studying the locomotory behavior of a simple animal (Trichoplax adhaerens) without muscles or neurons, here, we demonstrate how monociliated epithelial cells work collectively to give rise to an agile non-neuromuscular organism.

Via direct visualization of large ciliary arrays, we report the discovery of subsecond ciliary reorientations under a rotational torque that is mediated by connective tissue mechanics and the adhesion of cilia to the underlying substrate. In a toy model, we show a mapping of this system onto an "active-elastic resonator". This framework explains how perturbations propagate information in this array as linear speed traveling waves in response to mechanical stimulus.

Next, we explore the implications of parametric driving in this active-elastic resonator and show that such driving can excite mechanical 'spikes'. These 'spikes' in collective mode amplitudes are consistent with a system driven by parametric amplification and a saturating nonlinearity.

We conduct extensive numerical experiments to corroborate these findings within a polarized active-elastic sheet. These results indicate that periodic and stochastic forcing are valuable for increasing the sensitivity of collective ciliary flocking. We support these theoretical predictions via direct experimental observation of linear speed traveling waves which arise from the hybridization of spin and overdamped density waves. We map how these ciliary flocking dynamics result in agile motility via coupling between an amplified resonator and a tuning (Goldstone-like) mode of the system. This sets the stage for how activity and elasticity can self-organize into behavior which benefits the organism as a whole.

4.3 The analog of the nervous system at the level of multi-ciliary system

The TGD based model for nerve pulse and EEG generalizes in a rather straightforward manner to cilia.

1. Ciliary membranes define pre-neural system. The membranes act as generalized Josephson junctions. The modulations of the oscillation frequency of dark Josephson radiation code for the sensory input to MB. Beating waves have frequencies in EEG range and define the analogs of EEG waves as propagating oscillation patterns of the membrane potential.

2. The first guess is that non-motile cilia serve as sensory receptors mediating sensory input to MB as dark Josephson radiation and motile cilia as motor instruments of MB and analogs of muscle. Trichoplax has only a single cilium, which acts as a motor organ. Does it also act as a sensory receptor, or does the remaining cell membrane serve in this role?

3. Pre-nerve pulses at the level of animal would correspond to perturbations of the soliton sequences or their oscillatory variants: either one rotating/oscillating pendulum starts to oscillate/rotate. This transition would be induced by the response of MB and cyclotron resonance pulse. Nerve pulse/action potential would be replaced by propagating miniature potential.

4. The ciliary counterparts of action potentials would be analogs of miniature potentials and induced by the electronic metabolic energy quantum. They would represent the response of

MB at cilia, propagate to the basal body and proceed as chemical communications to the cell nucleus using second messangers and induce gene expression as a response.

5. The ciliary MBs of cells organize to a larger MB controlling the motion of cell and the MBs of cells in turn organize to even larger MB controlling the collective motion.

6. Synaptic transmission would be replaced with 'tug, that is the touch of neighboring cells, making possible the transfer of the beating waves between the cells. If the touch reduces to the touch of the cilia, the connection with the model of nerve pulse transmission would be even closer. Note however that there is only one flagellum per Trichoplax cell. The orbits of straight ciliar define cones, which correspond to 2-D space-times in 4-D space-time.

   The intersection of these surfaces consist of discrete points in the generic case. If the neighboring cilia rotate with the same frequency and are in the same phase so that the minimal distance between ciliar remains constant, they cannot touch. Above some critical phase difference touching can take place and the touching can occur and the neighboring cilia drop from the phase synchrony.

7. The quantum coherence extended in the fusion of the ciliary MBs generated in the touching of cells or individual cilia. Does also the transfer of local bioharmony take place in the touch. Are the analogs of transmitters involved and affect the bioharmony of the MB of the receiving cell just like nerve transmitters are proposed to do?

4.4 TGD based intepretation of the findings of Prakash *et al*

The findings described in the articles [I15, I13, I14] have made it possible to develop a TGD based picture about the situation.

4.4.1 Homeostasis in the TGD Universe

In biology the balance between sensitivity and stability modelled by Prakash *et al* is known as homeostasis. In biological view, homeostasis is based on a complex many-layered control hierarchies analogous to those used in computation as if a master programmer had written these programs. But can these kinds of control hierarchies really emerge in standard physics?

The proposal of the model of Prakash *et al* is that the 'active-elastic' resonator as a relatively simple mechanical system can at least mimic homeostasis. The model for the epithelial sheet of the animal as a set of oscillators representing cilia coupled by strings. The direction of the cilium defines an effective spin. A resonant coupling of this spin to an external torque represents the control of the motion and parametric resonance allows energy cascades creating collective responses.

In the TGD framework, homeostasis emerges spontaneously via the second law of thermodynamics in reverse time direction.

1. In zero energy ontology (ZEO), biological self-organization and homeostasis involve in an essential manner the possibility of time reversal occurring in "big" (ordinary) state function reduction (BSFR) occuring in long length scales. Time reversal changes repellers to attractors so that homeostasis as an ability of the system to stay near the critical point becomes possible by performing BSFRs.

2. Dissipation of energy is a process in which the coherence scales of excitation decreases. Time reversed periods mean dissipation with a reversed arrow of time and in the model of Prakash *et al* they would correspond to energy cascades proceeding from short to long length scales.

Parametric amplification and a saturating nonlinearity can be seen as the mathematical model for the BSFR inducing time reversal.

1. 'Spikes' mean amplification and in ZEO they could correspond to BSFR changing the arrow of time at the level of MB so that the amplification process would reduce to dissipation with a reversed arrow of time.

2. I have proposed that the interpretation of nerve pulse as a pair of BSFRs temporarily changing the sign of resting potential. An analogous interpretation could make sense now.

4.4.2 Cilium as a quantum gravitational pendulum

The findings of Prakash *et al* makes it possible to consider a concrete TGD inspired model for a single cilium and its dynamics.

1. The observed sub-second time scale for the ciliary reorientations conforms with the interpretation of beating waves are analogs of EEG waves transformed to mechanical waves as longitudinal contraction waves of cilium causing the bending. These waves would be induced by the membrane potential waves of ciliary membrane and in TGD corresponds to waves associated with the Josephson junction defined by the membrane communicating data to the MB of the system characterized by $h_{eff} = h_{gr} = GMm/v_0$.

2. In the first approximation, one can idealize the cilium/flagellum as a rigid linear object of radius $r = .2$ μm, length $l = 100$ μm, and with a density not far from the density of water of 10^3 kg/m^3. The presence of gravitational Planck constant suggests that one can model cilium as a gravitational pendulum with a mass independent oscillation period $T = 2\pi\sqrt{l/g}$, which corresponds to a sub-second time scale $T \simeq .2$ s for $l = 100$ μm.

   The values of l vary in a wide range. For $l = 20$ μm mentioned as an upper bound for the length of flagellum, one has $T \sim .1$ corresponding to 10 Hz EEG resonance frequency. The range $l = 2 - 4$ μm was mentioned in [I3] as a lower bound for the length of beating cilium, corresponds to 25-36 Hz frequency range. In the same source, 10-12 μm was reported as normal cilium length: it corresponds to pendulum frequency 15.8 Hz. Furthermore, the beating frequency was reported to depend only weakly on l so that the beating frequency and pendulum frequency cannot be identified.

   The estimates for the period of the cilium as gravitational pendulum correspond to EEG frequencies as also in the frequency range of beating waves. For $h_{eff} = \hbar_{gr} = GMm/v_0$ and m equal to proton mass, the corresponding transition energies are in the eV scale of biophotons for protons. What puts the bells ringing is that for electrons the energy scale is the same as that of the electronic metabolic energy quantum.

3. As a 2-D gravitational pendulum cilium can also rotate. Angular momentum is quantized as units $h_{eff} = h_{gr}$. Electronic metabolic energy quanta can induce transitions between the harmonic oscillator states of the cilium. The transitions between the states of the quantum gravitational pendulum changing angular momentum would serve as the quantum counterpart for the torque in the models of Prakash *et al*. They would represent the quantum control by MB by using the transformation of gravitationally dark electrons to ordinary electrons.

4.4.3 Correlation between the height of the tissue and membrane potential of cilium

The height h of the tissue is interpreted as a parameter analogous to membrane potential.

1. TGD suggests that the membrane potential of cilium is proportional to the h. The critical height h_{cr} would correspond to a critical value V_{cr} of the ciliary membrane potential for the generation of miniature potential reducing V_{cr}.

2. Cilium as a gravitational pendulum is free when its distance from the surface is larger than the pendulum length l so that $h_{cr} = l$ is a natural identification. When the adhesion occurs MB induces a burst of miniature potentials $\Delta V = .5$ meV feeding electronic metabolic energy quanta to the cilium to achieve de-adhesion.

4.4.4 What happens in the adhesion and de-adhesion?

The key step of the process is the adhesion of cilia to the substrate and its reversal. The probability for the adhesion depends on the tissue height h and obviously vanishes for $h > l$, l the length of cilium. For very small h the cilium sticks on the surface. Part of the cilium would stick to the

surface horizontally. Effective adhesion energy is assumed to be in a crucial role. The control action of the cell (animal) is modelled as an external torque on cilium.

Adhesion can also mean that two neighboring cilia moving in opposite direction stick together.

1. In the TGD framework, the de-adhesion could be induced by a transformation of a suitable number of electronic metabolic energy quanta about $E_c = .25$ meV associated with single electron (cilia do not have mitochondria) to the kinetic energy of the cilium as a gravitational pendulum.

   One can estimate the velocity v if the de-adhesion induced by a receival of single metabolic energy quantum E_c from $mv^2/2 = E_c$. This gives $v \simeq 60$ μ m/s. The estimate looks rather reasonable. For the standard metabolic energy quantum .5 eV, one would be $v \simeq 2.7$ mm/s.

2. If momentum is conserved, the change of the horizontal momentum component for the cilia as a pendulum is compensated by the recoil momentum of the entire cell. This gives an estimate for the change ΔV of the velocity of the cell as $\Delta V \sim (m_c/M) \times v$.

4.4.5 Adhesion energy and de-adhesion as precedessor of nerve pulse generation

What the notion of effective adhesion energy could mean in the TGD Universe (note that adhesion energy as a term is misleading since it actually corresponds to adhesion energy per surface area).

1. A very naive order of magnitude estimate used in the modelling of wetting of a surface by water approximates adhesion energy density with the surface tension σ_W for water: $\sigma_w \simeq 7210^{-3} kg/s^2$. This corresponds to an energy density per unit area $\epsilon = .5 \times 10^{-11}$ eV/(μ m)^2. For the cilium with radius $r = .2$ μ m attached vertically this would give $W = sigma_W \pi r^2 \simeq .7 \times 10^{-12}$ eV. This is extremely small energy and looks unrealistic.

2. For instance, if chemical or other kinds of bonds are formed with the surface, the adhesion energy can be even in the eV range. TGD suggests the formation of flux tube bonds between cilia and surface is what comes into mind and the adhesion energy would correspond to the reduction of energy when the bond is formed and shortens by the reduction of h_{eff} as in the basic step of bio-catalysis.

3. The thermal stability of adhesion would suggest that the adhesion energy is of the order of thermal energy, which is of the order .05 eV, which is about 10 percent of the standard metabolic energy quantum. If this is the case, the size of .5 meV for the metabolic energy quantum of electron Cooper pairs implies that at least 100 dark gravitational electrons must transform to ordinary ones to liberate the cilium, which has stuck vertically. Recall that cilia can also stick to each other and the same estimate holds also now as a lower bound coming from the thermal stability of adhesion.

4. Intriguingly, the number of miniature potentials generated by acetylcholine vesicles needed to generate action potential is 100-200 (`hhttps://cutt.ly/JD1ONEu`)! This suggests that the de-adhesion process is a precedessor for the generation of nerve pulse in the postsynaptic neuron. This conforms with the view that the ciliary membrane is a precedessor of axon.

5. Nerve pulse transmission connects the pre- and postsynaptic flux tubes to longer flux tubes and generates larger quantum coherent units. 100-200 miniature potentials generate an action potential after the connection has formed. What could be the counterpart of this at the level of cilia?

   Intriguingly, the de-adhesion from the surface requires at least 100 miniature potentials in the model of cilium as a gravitational pendulum. Also the cilia of the neighboring cells can stick together if they move in opposite directions. De-adhesion would require roughly the same energy. Both mechanisms would generate the analog of nerve pulse.

   Could the preneural system have transformed to a neural system by the evolution of single flagellum to axon? Could primary cilia have evolved to dendrites? Did flagella having even rather long lengths start to form permanent almost-contacts with the primary cilia of the neighboring cell or even more distant cells, which then developed to synaptic contacts. This

would have required the evolution of cilia with radius below .5 μ to axon with radius about 2.5 μm, and containing axonal MTs instead of axonemal MTs. ATP based metabolism in the interior would have emerged besides electron based metabolism, and besides miniature potentials also action potentials and critical membrane potential would have emerged.

4.4.6 Do 'spikes' correspond to real spikes?

Spikes induced by a driving of an 'active-elastic' resonator define a key notion in the models of Prakash *et al*. The intuitive picture of the resonator is as a collection of cilia as motors connected by strings. The 'spikes' would be analogs of nerve pulses. 'Spikes' correspond to tugs inducing flocking and in neuroscience induce formation of larger coherent units of neurons.

In the TGD based model for nerve pulse, spike corresponds to a perturbation coming from MB and transforming the motion of a single pendulum from rotation to oscillation or vice versa. Same should be true now if the cilium is the precedessor of the axon.

1. The active-elastic resonator could correspond to cilia as quantum gravitational penduli and the temporary formation of flux tube connections between the MBs of the penduli could be a counterpart for the formation of strings.

2. A direct touch of cells is not necessary for a 'tug'. The touching of neighboring cilia might be enough and could be regarded as one particular case of adhesion and would be analogous to touch of pre- and postsynaptic cells mediated by the neurotransmitter vesicle. Since the distances between cells are measured in micrometers and if the ciliar lengths are about 100 μ, this is possible.

   In the TGD framework, one can consider the option that cilia do not even touch. Since quantum coherence is at the level of MBs, and what is needed in the TGD framework, is a reconnection of the U-shaped flux tubes associated with the cells: this is assumed to take place also in the synaptic contact in which neurons fused temporarily.

3. The probability for the reconnection of flux tubes (for the touching of cilia) increases as the cells approach each other and could lead to a fusion of several cellular MBs to a larger MB inducing a flock behavior controlled by the larger MB. This would take place when two neighboring ciliary gravitational penduli are in opposite phase with large enough amplitude so that they approach each other.

4. The propagation of nerve pulse would be a domino effect in which the adhesion of neighboring cells or adhesion of cell to surface followed by de-adhesion, which spoils synchronous motion locally and inducies new adhesion. A multiple collision generating quantum coherent at the flux tube level would be in question.

5. In the collective mode the metabolic quanta E_c from cells would arrive in synchrony (but with time lapse to give rise to a wave) so that the cells would walk in synchrony. The rotation of the cilia as gravitational penduli with a constant phase difference gives rise to a wave. In this macroscopic gravitational quantum state Trichoplax would walk. Walking involves gravitation in an essential manner so that the appearance of quantum gravitation is not surprising.

4.4.7 The generation of propagating waves

The model for the generation of propagating waves is very much analogous to the model of axonal membrane as Josephson junction [K28, K16, K29] [L27, L29]. The oscillating waves for the phase differences of the Cooper pair wave function over Josephson junction define a dynamics analogous to that to a sequence of gravitational penduli. This model could apply as such at the level of ciliary membrane serving as a pre-axon.

The local motion could correspond to oscillation or rotation and the analog of nerve pulse would mean local transformation of oscillation to rotation or vice versa generating soliton or defect of soliton sequence locally.

Also waves that propagate at the level of the entire animal are involved and can be associated with a system of genuine gravitational penduli forming a planar structure. There would also be a propagating wave at the larger MB induced by the temporary fusion of MBs of cilia.

1. The local oscillation of the cilium takes place with the frequency $f = \sqrt{g/l}/2\pi$ of the gravitational pendulum. For the propagating wave $u = \omega t$ is replaced with $\omega(t - x/V)$. The rotation of the pendulum in a vertical rotation plane does not make sense but there are also modes in which the pendulum rotates in plane and have angular momentum which is large since one has $h_{eff} = h_{gr}$ serves as the unit of angular momentum. These modes would be crucial for the control of the motion.

   The speed V of the wave would be analogous to a conduction velocity of nerve pulse. The first guess for the velocity would be as the velocity $V \sim (m_c/M) \times v$, where v is the horizontal velocity gained by the cilium de-attachment already estimated, and m_c and M are the masses of cilium and cell.

2. If one or more metabolic energy quanta E_c feed energy to a single pendulum, the pendulum ceases to be in phase with its neighbors. If the same takes place for MBs, they might reconnect. Could a phase transition initiated by a seed at the level of MBs generate a larger quantum coherent unit analogous to a moving vortex? Energy cascade would correspond to BSFR with time reversal.

4.4.8 Flocking as a generation of quantum gravitational coherence

What could the formation of collective modes, flocking, mean in the TGD framework?

1. The modes of a single cilium correspond to a sticking to the plane without motion, rotation around a roughly elliptical orbit in plane, and rotation without motion. If a single cilium behaves as a solid body, one has a vortex- like structure rotating like a rigid body. Note however that Trichoplax can be very far from a rigid body: it can even split into two parts.

2. The quantal description of the cilia as a quantum gravitational pendulum combined with the conservation of angular momentum suggests that the angular momentum for the center of mass motion of the Trichoplax and the total angular momentum of the ciliary oscillators sum up to zero. This would explain the nearly circular motions. Linear motion of Trichoplax would correspond to a common vertical rotation plane without rotation.

   In fact, both momentum and angular momentum generation could rely on conservation laws and reduce to exchanges of these conserved quantities between MB and system. This seems to be the only option since metabolic energy quanta with $h_{eff} = h$ cannot create forces and torques in the scale of an organism.

   It deserves to be mentioned that the generation of angular momentum of astrophysical objects such as galaxies is poorly understood in the general relativistic framework and the TGD proposal is that the angular momentum of visible matter is accompanied by opposite angular momentum of dark matter and magnetic bodies of astrophysical objects [L18].

3. This model would realize the fractal aspect of holography: the ciliary motion would correspond to the motion of the entire animal. Second aspect of holography is that 3-D data fix the time evolution in the sense that the orbits are analogous to Bohr orbits. In TGD, this is forced by the realization of the general coordinate invariance, and means that the 3-D surface of $H = M^4 \times CP_2$ is almost uniquely determined by a 3-D surface without any data about its 4-D tangent space. Also this aspect of holography is realized and could explain why such an extremely simple model can describe the motion of Trichoplax.

4. Moving vortex-like defects could correspond to the formation of quantum coherent states in which cilia as gravitational penduli are in the same quantum state with non-vanishing angular momentum and non-trivial center-of-mass motion. There is also an analogy with the decomposition of the rotational motion to vortices in super-fluidity.

4.4.9 How could a living system direct its attention?

Prakash *et al* [I15, I13, I14] also found that Trichoplax can also react in a selective manner to perturbations as if it could direct its attention.

According to the TGD inspired theory of consciousness, a metabolic energy feed to the target of attention serves as a correlate for the directed attention. The target corresponds to a mental image of the MB of the system. Mental images have correlates at the level of the space-time surfaces. Space-time surfaces are minimal surfaces with singularities analogous to soap films with frames [L39]. At the frames the dynamics fail to be completely deterministic so that they naturally serve as space-time correlates of mental images. The non-determinism is also finite.

This mental image 'wakes up' in a BSFR separating it from the environment and the superposition of 4-D soap films is reduced so that a single alternative from a finite number of time evolutions is selected. This explains the mysterious looking discovery that during intensive discussion almost anything can happen in the background and remain unnoticed. Sensory input does not lead to a wake up of mental image. The behaviour of the Trichoplax is completely analogous to the behaviour of higher life forms.

4.5 Possible implications of the notion of pre-CNS

The notion of pre-CNS is very general and it is interesting to consider the most obvious implications.

4.5.1 Can organisms without CNS learn?

In [I11] the question whether learning without the nervous system is impossible is considered. Computers are left out of consideration and this restricts the discussion to organic matter. One can consider several definitions for learning. If the change in behaviour is taken as a signature of learning, one ends up to the conclusion that there are large classes of organisms without nervous systems, which are able to learn: paramecia, bacteria and plants are three large classes of this kind of organisms.

There is evidence that multi-cellulars have evolved from the colonies of mono-cellulars, and it is known that colonies of bacteria learn [I12] (`https://cutt.ly/zDOvhuN`). For instance, E. Choli colonies can anticipate changes in the environment by associating higher temperatures with a lack of oxygen. This is the basic type of learning in neural systems and interpreted in terms of changes of synaptic strengths.

Animals with ciliary systems have pre-CNS in the proposed sense, and could learn by essentially the same mechanisms as neuronal networks. Associative learning involves a strengthening of synaptic contacts increasing the probability for the formation of transmitter vesicles. Now this would mean the increase of the probability for the formation of a 'tug' contact and this would lead to the analogs of sub-neural networks.

The model of genetic code based on bioharmony [L2, L26, L31, L48] leads to the proposal that the basic mechanism of learning emerge already at the level of basic biomolecules DNA, RNA, tRNA, and amino acids (AA). Bioharmonies define different moods and the learning by conditioning involves in an essential manner moods affected by the stimulus already at the molecular level. The basic moods would be realized already at the level of basic biomolecules X=DNA, RNA, tRNA, AAs, or rather, the pairings DX-X where DX is the dark analog of X identified as dark nucleon sequence [L48]. Epigenetic mechanisms could stabilize the bioharmonies as correlates for the moods.

There is experimental evidence for this kind of learning (`https://cutt.ly/6SuLNqk`). When the RNA of an animal, which has learned a conditioned behavior, is scattered on the neurons of the animal that has not learned the behavior, the neurons so the signatures of learned behavior. Somehow the RNA transmits the conditioning based on negative or positive emotions generated by the stimulus. The explanation terms of DRNA-RNA pairing carrying the mood infecting the neurons with the conditioned behavior is discussed in the TGD framework in [L16, L19].

4.5.2 Also plants have senses and motor actions

Also plants have senses (`https://cutt.ly/mDOA9Zo`) and motor actions (for instance, sun flower orients itself towards Sun) and can learn (`https://cutt.ly/sDOPUZo`).

Can the proposed general model for pre-CNS explain these findings?

1. Microtubules are essential for cilia and axons. In general, plant cells do not have centriole or flagella: the motile, freely swimming sperm cells of some plants are an exception.

   Plants however have root hair (`https://cutt.ly/JDOA7rc`) consisting of epidermal cells having lateral tubular extensions resembling cilia. Their radius varies between 17-17 μm and the length varies between 80-1,500 μm so that their scale is roughly 100 times larger than that of cilia. The basic function of root-hair cells is to collect water and nutrients from the soil.

2. The MBs of root-hair cells controlling them must be able to receive sensory input from root-hair cells and control their activities. Essentially the same general model seems to work as in the case of axons and cilia.

   The membranes of root-hair cells could serve as sensory receptors using Josephson radiation to communicate the sensory input to MB. Root hair cells do not contain chloroplasts nor do they perform photosynthesis, which suggests that also now the electronic variant of metabolism is involved. The miniature potentials would appear as analogs of nerve pulses.

   Some parts in the stem of the plant can be surrounded by hairy extensions which consist of a single cell or are multicellular structures. Also these could serve as sensory receptors. Note that the hairy geometry would maximize the sensory area.

3. What about the counterpart of the neuron network? Although plant cells are covered by cell walls composed of cellulose, hemicelluloses and pectin, they are not completely isolated. Plasmodesma (`https://cutt.ly/9DOSraf`) are gap junction-like connections between neighboring plant cells, which allow the transfer of molecules. Plasmodesma could also act as analogs of permanent synaptic contacts, something which brings in mind a meridian system. Note that plasmodesma also have MTs as components.

4. Plants communicate with each other [I5] (`https://cutt.ly/PDOSies`), for instance via their roots send signals to each other under the soil by using chemical secretions.

   In the TGD Universe, the communications mediated by dark photon signalling via the layers of MB could make indirect communications possible. Plants form communities (`https://cutt.ly/eDOSf0F`). One can even ask whether for instance a crop field or wood resembling a ciliary community covering a cell membrane could give rise to a higher level nervous system of some kind.

4.5.3 Talking fungi

After having written this article I learned of a fascinating discovery of Andrew Adamatsky [I2], who has studied sponges and found that they show electrical activity sequences of analogs of action potentials ('spikes').

The abstract of the article gives an overview about the findings.

Fungi exhibit oscillations of extracellular electrical potential recorded via differential electrodes inserted into a substrate colonised by mycelium or directly into sporocarps. We analysed electrical activity of ghost fungi (Omphalotus ni- diformis), Enoki fungi (Flammulina velutipes), split gill fungi (Schizophyllum commune) and caterpillar fungi (Cordyceps militari). The spiking characteristics are species specific: a spike duration varies from one to 21 hours and an amplitude from 0.03 mV to 2.1mV.

We found that spikes are often clustered into trains. Assuming that spikes of electrical activity are used by fungi to communicate and process information in mycelium networks, we group spikes into words and provide a linguistic and information complexity analysis of the fun- gal spiking activity. We demonstrate that distributions of fungal word lengths match that of human languages. We also construct algorithmic and Liz-Zempel complexity hierarchies of fungal sentences and show that species S. commune generate most complex sentences

The amplitude of spikes varies in the range .03- 2.1 meV. The analogs of miniature potentials correspond to energy .4 meV. The prediction of the TGD based model for the metabolic energy

quantum for electron triplet is .51 meV. The solar gravitational metabolism associated with photosynthesis would correspond to the upper bound of 2.5 meV for the metabolic energy. The natural question is whether this kind of communication is specific to fungi or occurs also in preunoral and neuronal systems in general.

The language hypothesis conforms with the TGD based view that the dark variants of genetic code realized using as codons dark photon triplets analogous to 3-chords defining what I call bioharmony serving as a correlate for emotional state and fundamental level [L31, L48]. Dark 3N-photons as representation of for instance genes, define analogs of music pieces. For the TGD based view of the emergence of human language see [K35]. Genetic code would have number theoretic and geometric origin and would be universal. It would have several realizations and be realized also in other than biological systems.

Dark 3N-photons are analogous to Bose-Einstein condensate of 3N-photons and correspond to so-called Galois singlets, whose formation would rely on a universal number theoretical mechanism for the formation of bound states. The sequence of dark codons selects the receiver, which must possess the same sequence of dark nucleon triplets to achieve resonance. If the frequency scale is modulated, the reception generates a sequence of 3N-pulses analogous to nerve pulse sequence and in this way transforms information coded to frequency modulation to a pulse sequence.

5 Are space-time boundaries possible in the TGD framework?

One of the key ideas of TGD from the very beginning was that the space-time surface has boundaries and we see them directly as boundaries of physical objects.

It however turned out that it is not at all clear whether the boundary conditions stating that no isometry currents flow out of the boundary, can be satisfied. Therefore the cautious conclusion was that perhaps the boundaries are only apparent. For instance, the space-time regions correspond to maps $M^4 \to CP_2$, which are many-valued and have as turning points, which have 3-D projections to M^4. The boundary surfaces between regions with Minkowskian and Euclidean signatures of the induced metric seem to be unavoidable, at least those assignable to deformations of CP_2 type extremals assignable to wormhole contacts.

There are good reasons to expect that the possible boundaries are light-like and possibly also satisfy the $det(g_4) = 0$ condition and I have considered the boundary conditions but have not been able to make definite conclusions about how they could be realized.

1. The action principle defining space-times as 4-surfaces in $H = M^4 \times CP_2$ as preferred extremals contains a 4-D volume term and the Kähler action plus possible boundary term if boundaries are possible at all. This action would give rise to a boundary term representing a normal flow of isometry currents through the boundary. These currents should vanish.

2. There could also be a 3-D boundary part in the action but if the boundary is light-like, it cannot depend on the induced metric. The Chern-Simons term for the Kähler action is the natural choice. Twistor lift suggests that it is present also in M^4 degrees of freedom. Topological field theories utilizing Chern-Simons type actions are standard in condensed matter physics, in particular in the description of anyonic systems, so that the proposal is not so radical as one might think. One might even argue that in anyonic systems, the fundamental dynamics of the space-time surface is not masked by the information loss caused by the approximations leading to the field theory limit of TGD.

   Boundary conditions would state that the normal components of the isometry currents are equal to the divergences of Chern-Simons currents and in this way guarantee conservation laws. In CP_2 degrees of freedom the conditions would be for color currents and in M^4 degrees of freedom for 4-momentum currents.

3. This picture would conform with the general view of TGD. In zero energy ontology (ZEO) [L21, L33] phase transitions would be induced by macroscopic quantum jumps at the level of the magnetic body (MB) of the system. In ZEO, they would have as geometric correlates classical deterministic time evolutions of space-time surface leading from the initial to the final state [L17]. The findings of Minev et al provide [L17] lend support for this picture.

5.1 Light-like 3-surfaces from $det(g_4) = 0$ condition

How the light-like 3- surfaces could be realized?

1. A very general condition considered already earlier is the condition $det(g_4) = 0$ at the light-like 4-surface. This condition means that the tangent space of X^4 becomes metrically 3-D and the tangent space of X^3 becomes metrically 2-D. In the local light-like coordinates, $(u, v, W, \overline{W})$ $guv = g_{vu}$) would vanish (g_{uu} and g_{vv} vanish by definition.

   Could $det(g_4) = 0$ and $det(g_3) = 0$ condition implied by it allow a universal solution of the boundary conditions? Could the vanishing of these dimensional quantities be enough for the extended conformal invariance?

2. 3-surfaces with $det(g_4) = 0$ could represent boundaries between space-time regions with Minkowskian and Euclidean signatures or genuine boundaries of Minkowskian regions.

   A highly attractive option is that what we identify the boundaries of physical objects are indeed genuine space-time boundaries so that we would directly see the space-time topology. This was the original vision. Later I became cautious with this interpretation since it seemed difficult to realize, or rather to understand, the boundary conditions.

   The proposal that the outer boundaries of different phases and even molecules make sense and correspond to 3-D membrane like entities [L39], served as a partial inspiration for this article but this proposal is not equivalent with the proposal that light-like boundaries defining genuine space-time boundaries can carry isometry charges and fermions.

3. How does this relate to $M^8 - H$ duality [L22, L23]? At the level of rational polynomials P determined 4-surfaces at the level of M^8 as their "roots" and the roots are mass shells. The points of M^4 have interpretation as momenta and would have values, which are algebraic integers in the extension of rationals defined by P.

   Nothing prevents from posing the additional condition that the region of $H^3 \subset M^4 \subset M^8$ is finite and has a boundary. For instance, fundamental regions of tessellations defining hyperbolic manifolds (one of them appears in the model of the genetic code [L31]) could be considered. $M^8 - H$ duality would give rise to holography associating to these 3-surfaces space-time surfaces in H as minimal surfaces with singularities as 4-D analogies to soap films with frames.

   The generalization of the Fermi torus and its boundary (usually called Fermi sphere) as the counterpart of unit cell for a condensed matter cubic lattice to a fundamental region of a tessellation of hyperbolic space H^3 acting is discussed is discussed in [L40]. The number of tessellations is infinite and the properties of the hyperbolic manifolds of the "unit cells" are fascinating. For instance, their volumes define topological invariants and hyperbolic volumes for knot complements serve as knot invariants.

This picture resonates with an old guiding vision about TGD as an almost topological quantum field theory (QFT) [K20, K4, K33], which I have even regarded as a third strand in the 3-braid formed by the basic ideas of TGD based on geometry-number theory-topology trinity.

1. Kähler Chern-Simons form, also identifiable as a boundary term to which the instanton density of Kähler form reduces, defines an analog of topological QFT.

2. In the recent case the metric is however present via boundary conditions and in the dynamics in the interior of the space-time surface. However, the preferred extremal property essential for geometry-number theory duality transforms geometric invariants to topological invariants. Minimal surface property means that the dynamics of volume and Kähler action decouple outside the singularities, where minimal surface property fails. Coupling constants are present in the dynamics only at these lower-D singularities defining the analogs of frames of a 4-D soap film.

   Singularities also include string worlds sheets and partonic 2-surfaces. Partonic two-surfaces play the role of topological vertices and string world sheets couple partonic 2-orbits to a network. It is indeed known that the volume of a minimal surface can be regarded as a homological invariant.

3. If the 3-surfaces assignable to the mass shells H^3 define unit cells of hyperbolic tessellations and therefore hyperbolic manifolds, they also define topological invariants. Whether also string world sheets could define topological invariants is an interesting question.

5.2 Can one allow macroscopic Euclidean space-time regions

Euclidean space-time regions are not allowed in General Relativity. Can one allow them in TGD?

1. CP_2 extremals with a Euclidean induced metric and serving as correlates of elementary particles are basic pieces of TGD vision. The quantum numbers of fundamental fermions would reside at the light-like orbit of 2-D wormhole throat forming a boundary between Minkowskian space-time sheet and Euclidean wormhole contact- parton as I have called it. More precisely, fermionic quantum numbers would flow at the 1-D ends of 2-D string world sheets connecting the orbits of partonic 2-surfaces. The signature of the 4-metric would change at it.

2. It is difficult to invent any mathematical reason for excluding even macroscopic surfaces with Euclidean signature or even deformations of CP_2 type extremals with a macroscopic size. The simplest deformation of Minkowski space is to a flat Euclidean space as a warping of the canonical embedding $M^4 \subset M^4 \times S^1$ changing its signature.

3. I have wondered whether space-time sheets with an Euclidean signature could give rise to black-hole like entities. One possibility is that the TGD variants of blackhole-like objects have a space-time sheet which has, besides the counterpart of the ordinary horizon, an additional inner horizon at which the signature changes to the Euclidean one. This could take place already at Schwarzschild radius if g_{rr} component of the metric does not change its sign.

5.3 But are the normal components of isometry currents finite?

Whether this scenario works depends on whether the normal components for the isometry currents are finite.

1. $det(g_4) = 0$ condition gives boundaries of Euclidean and Minkowskian regions as 3-D light-like minimal surfaces. There would be no scales in accordance with generalized conformal invariance. g_{uv} in light-cone coordinates for M^2 vanishes and implies the vanishing of $det(g_4)$ and light-likeness of the 3-surface.

   What is important is that the formation of these regions would be unavoidable and they would be stable against perturbations.

2. $g^{uv}\sqrt{|g_4|}$ is finite if $det(g_4) = 0$ condition is satisfied, otherwise it diverges. The terms $g^{ui}\partial_i h^k \sqrt{|g_4|}$ must be finite. $g^{ui} = cof(g_{iu})/det(g_4)$ is finite since $g_{uv}g_{vu}$ in the cofactor cancels it from the determinant in the expression of g^{ui}. The presence of $\sqrt{|g_4|}$ implies that the these contributions to the boundary conditions vanish. Therefore only the condition boundary condition for g^{uv} remains.

3. If also Kähler action is present, the conditions are modified by replacing $T^{uk} = g^{u\alpha}\partial_\alpha h^k \sqrt{|g_4|}$ with a more general expression containing also the contribution of Kähler action. I have discussed the details of the variational problem in [K6, K4].

   The Kähler contribution involves the analogy of Maxwell's energy momentum tensor, which comes from the variation of the induced metric and involves sum of terms proportional to $J_{\alpha\mu}J_\mu^{beta}$ and $g^{\alpha\beta}J^{\mu\nu}J_{\mu\nu}$.

   In the first term, the dangerous index raisings by g^{uv} appear 3 times. The most dangerous term is given by $J^{uv}J^v_v\sqrt{|g|} = g^{u\mu}g^{v\nu}J_{\alpha\beta}g^{vu}J_{vu}\sqrt{|g|}$. The divergent part is $g^{uv}g^{vu}J_{uv}g^{vu}J_{vu}\sqrt{|g|}$. The diverging g^{uv} appears 3 times and $J_{uv} = 0$ condition eliminates two of these. $g^{vu}\sqrt{|g|}$ is finite by $\sqrt{|g|} = 0$ condition. $J_{uv} = 0$ guarantees also the finiteness of the most dangerous part in $g^{\alpha\beta}J^{\mu\nu}J_{\mu\nu}\sqrt{|g|}$.

There is also an additional term coming from the variation of the induced Kähler form. This to the normal component of the isometry current is proportional to the quantity $J^{n\alpha}J^k_l\partial_\beta h^l\sqrt{|g|}$. Also now, the most singular term in $J^{u\beta} = g^{u\mu}g^{\beta\nu}J_{\mu\nu}$ corresponds to J^{uv} giving $g^{uv}g^{vu}J^{uv}\sqrt{|g|}$. This term is finite by $J_{uv} = 0$ condition.

Therefore the boundary conditions are well-defined but only because $det(g_4) = 0$ condition is assumed.

4. Twistor lift strongly suggests that the assignment of the analogy of Kähler action also to M^4 and also this would contribute. All terms are finite if $det(g_4) = 0$ condition is satisfied.

5. The isometry currents in the normal direction must be equal to the divergences of the corresponding currents assignable to the Chern-Simons action at the boundary so that the flow of isometry charges to the boundary would go to the Chern-Simons isometry charges at the boundary.

   If the Chern-Simons term is absent, one expects that the boundary condition reduces to $\partial_v h^k = 0$. This would make X^3 2-dimensional so that Chern-Simons term is necessary. Note that light-likeness does not force the M^4 projection to be light-like so that the expansion of X^2 need not take with light-velocity. If CP_2 complex coordinates are holomorphic functions of W depending also on $U = v$ as a parameter, extended conformal invariance is obtained.

5.4 $det(g_4) = 0$ condition as a realization of quantum criticality

Quantum criticality is the basic dynamical principle of quantum TGD. What led to its discovery was the question "How to make TGD unique?". TGD has a single coupling constant, Kähler couplings strength, which is analogous to a critical temperature. The idea was obvious: require quantum criticality. This predicts a spectrum of critical values for the Kähler coupling strength. Quantum criticality would make the TGD Universe maximally complex. Concerning living matter, quantum critical dynamics is ideal since it makes the system maximally sensitive and maximallt reactive.

Concerning the realization of quantum criticality, it became gradually clear that the conformal invariance accompanying 2-D criticality, must be generalized. This led to the proposal that super symplectic symmetries, extended isometries and conformal symmetries of the metrically 2-D boundary of lightcone of M^4, and the extension of the Kac-Moody symmetries associated with the light-like boundaries of deformed CP_2 type extremals should act as symmetries of TGD extending the conformal symmetries of 2-D conformal symmetries. These huge infinite-D symmetries are also required by the existence of the Kähler geometry of WCW [K20, K8, K30] [L35, L49].

However, the question whether light-like boundaries of 3-surfaces with scale larger than CP_2 are possible, remained an open question. On the basis of preceding arguments, the answer seems to be affirmative and one can ask for the implications.

1. At M^8 level, the concrete realization of holography would involve two ingredients. The intersections of the space-time surface with the mass shells H^3 with mass squared value determined as the roots of polynomials P and the tlight-like 3-surfaces as $det(g_4) = 0$ surfaces as boundaries (genuine or between Minkowskian and Euclidean regions) associated by $M^8 - H$ duality to 4-surface of M^8 having associative normal space, which contains commutative 2-D subspace at each point. This would make possible both holography and $M^8 - H$ duality.

   Note that the identification of the algebraic geometric characteristics of the counterpart of $det(g_4) = 0$ surface at the level of H remains still open.

   Since holography determines the dynamics in the interior of the space-time surface from the boundary conditions, the classical dynamics can be said to be critical also in the interior.

2. Quantum criticality means ability to self-organize. Number theoretical evolution allows us to identify evolution as an increase of the algebraic complexity. The increase of the degree n of polynomial P serves as a measure for this. $n = h_{eff}/h_0$ also serves as a measure for the scale of quantum coherence, and dark matter as phases of matter would be characterized by the value of n.

3. The 3-D boundaries would be places where quantum criticality prevails. Therefore they would be ideal seats for the development of life. The proposal that the phase boundaries between water and ice serve as seats for the evolution of prebiotic life, is discussed from the point of TGD based view of quantum gravitation involving huge value of gravitational Planck constant $\hbar_{eff} = \hbar_{gr} = GMm/v_0$ making possible quantum coherence in astrophysical scales [L42]. Density fluctuations would play an essential role, and this would mean that the volume enclosed by the 2-D M^4 projection of the space-time boundary would fluctuate. Note that these fluctuations are possible also at the level of the field body and magnetic body.

4. It has been said that boundaries, where the nervous system is located, distinguishes living systems from inanimate ones. One might even say that holography based on $det(g_4) = 0$ condition realizes nervous systems in a universal manner.

5. I have considered several variants for the holography in the TGD framework, in particular strong form of holography (SH). SH would mean that either the light-like 3-surfaces or the 3-surfaces at the ends of the causal diamond (CD) determine the space-time surface so that the 2-D intersections of the 3-D ends of the space-time surface with its light-like boundaries would determine the physics.

   This condition is perhaps too strong but a fascinating, weaker, possibility is that the internal consistency requires that the intersections of the 3-surface with the mass shells H^3 are identifiable as fundamental domains for the coset spaces $SO(1,3)/\Gamma$ defining tessellations of H^3 and hyperbolic manifolds. This would conform nicely with the TGD inspired model of genetic code [L31].

6 Krebs cycle from TGD point of view

This section was inspired by the YouTube video (`https://cutt.ly/7XTY1Cc`) in which biologist Nick Lane talked of Krebs cycle, also known as citric acid cycle, (`https://cutt.ly/kXTY9B5`). The title of the video was "How the Krebs cycle powers life and death?". I am grateful for Marko Manninen for the link.

6.1 Lane's view of the role of Krebs cycle in the emergence of life

Lane's talk starts with a picture about the network of metabolic reaction pathways of an animal cell. Its complexity is absolutely stunning. In the network nodes correspond to various biochemical compounds and edges between them to reactions catalyzed by biocatalyst.

This huge complexity shows how magnificent work biochemists have done but also forces, at least me, to ask whether there should exist a description relying on deeper principles and involving something beyond chemistry.

Before continuing, I can of course reveal the cards already now and tell that I have been working for roughly two decades with what I could call TGD (Topological Geometrodynamics) [L35] inspired quantum biology. Quantum gravitation in the TGD sense and phases of ordinary matter, which can be quantum coherent in arbitrarily long length scales and behave in many respects like dark matter, play a crucial role in this model. The model challenges the vision of life as nothing but biochemistry.

6.1.1 Krebs cycle

In the middle of the illustration of the metabolic network stands the Krebs cycle. There is in fact also another cycle found by Krebs: readers can try to identify it from the picture of the video.

1. The input of the cycle is glucose C_6H_{12} produced in previous reactions splitting carbohydrates, proteins and lipids. Glucose is first split into pyruvate involving 2 carbon atoms. This produces carbon dioxide CO_2, which can be said to be a waste product. Second output of the cycle is water H_2O.

2. The Krebs cycle has two basic functions. The first function is to build precursors of various biomolecules like amino acids, nucleotides, and lipids for further processing in the other parts of the reaction pathway network.

   Second function is to liberate the metabolic energy of the pyruvate. Mitochondria, where Krebs cycle takes place are both power stations and molecular factories of the cell building the basic building blocks constructed in other parts of the cell.

3. Although CO_2 and H_2O can be said to be the outputs of the aerobic Krebs cycle, Lane prefers to talk about $2H$ as the output. The pairs $2H$ react with NAD^+ to give $NADH + H^+$. The reaction liberates energy kicking the proton H^+ over the potential wall defined by the membrane voltage.

   Eventually the proton falls back and gains energy by acceleration in the electric field: the energy of the proton makes possible the energization of ADP by phosphorylation: $ADP \to ATP$ adding one phosphate P_i to ADP. $ATP \to ADP$ in turn takes care of the further distribution of the metabolic energy. One can say that ATP serves as a basic metabolic currency and all biological processes use this standard coin. Note that Krebs cycle has both aerobic and anaerobic variants and only the last step involves oxidative phosphorylation.

   NADH , which has taken hydrogen and one electron e^- of 2H carries the electron to electron chain in which electrons are transferred in a stepwise manner along the mitochondrial membrane and gradually gives up its energy and end up to oxygen and ADP.

4. Krebs cycle is indeed a cycle. At the first step it transforms pyruvate involving two C atoms to a compound with 6 C atoms and and at the first half of the cycle it is transformed to a compound with 4 C atoms going through 4 steps being eventually transformed to the compound with 6 C atoms.

6.1.2 Reverse Krebs cycle

In the reverse Krebs cycle (`https://cutt.ly/HXTY5RR`, CO_2 and $2H$ and energy are the inputs and pyruvate is the output. Also reactions like $NAD^+2H \to NaDH + H^+$ are reverted so that a time reversal at some level is suggestive. Instead of production of ATP, ATP is used to get energy in absence of some other energy source such as solar radiation. The symmetry between the two halves of the Krebs cycle allows the production of the precursors of various biomolecules also in the reverse Krebs cycle.

1. Reverse Krebs cycle is obviously a natural predecessor of the Krebs cycle, which appears when animals use the energy stored chemically by photosynthesizing organisms. Instead of photons, the reverse Krebs cycle can also use biochemical energy. Even electron energy can be used.

2. Photosynthesis relies on the reverse Krebs cycle used by plants and some other photosynthesizing organisms (algae living in oceans). Energy comes from photons of solar radiation and is stored in various biomolecules and ATP produced in the reverse Krebs cycle. The biomolecules storing energy are then used by animals using the Krebs cycle.

3. In the archaea and bacteria H_2O as input of reverse Krebs cycle can be replaced with H_2S. This can occur even in mammalian mitochondria under stress conditions, when oxygen supply is reduced (`https://cutt.ly/qXTUe4j`)

4. The Krebs cycle can be reversed under some conditions such as cancer. Lane argues that the reverted Krebs cycle is favourable for cancer cells since it produces basic precursors of the basic biomolecules. But also the Krebs cycle does this: maybe the reverse Krebs cycle does this more effectively. In any case, the reverse Krebs cycle does not liberate metabolic energy so that it has disastrous effects.

5. Some primitive life forms can use both Krebs cycle and reverse Krebs cycle, be animal- or plant-like, one might say.

6.1.3 The importance of charge separation

Lane emphasized the importance of charge separation. The interior of the cell is negatively charged and the outside positively charged. This charge separation is very common in living matter. For instance, DNA is negatively charged: one unit of negative charge per nucleotide associated with phosphate. Earth's interior is negatively charged and exterior positively charged.

Pollack effect [I8, I9, L4, I16, I21] generates negatively charge regions of water, exclusion zones with effective stoichiometry H_2O and layer like hexagonal structure consisting of hexagons. Clearly, the Pollack effect produces OH^- from H_2O molecules.

Pollack effect is induced by the irradiation of water in a presence of gel at visible or IR wavelengths and induces charge separation. This effect is poorly understood in the standard chemistry framework and its explanation involving new physics is a central element in the TGD based view of living matter [L4].

Krebs cycle takes care of the charge separation requiring energy feed metabolic energy storage in the pyruvate.

6.1.4 The proposal for the evolution of life

Lane also discusses evolution of life starting from the idea that the primitive form of reverse Krebs cycle preceded the recent forms of life. It was discovered in 1966 that photosynthetic bacteria living in anaerobic environments use the reverse Krebs cycle to produce basic biomolecules and to store energy.

1. Margaret Dayhoff was the mother of bioinformatics. On the basis of the evolution of the present day form of enzyme ferredoxin, which has simple inorganic active site and has a key role in photon energy utilization, Dayhoff suggested that its prototype was incorporated into metabolism very early in biological evolution, even before genetic code existed(!). Ferredoxin was evolved by a doubling of a shorter protein, which would have evolved only 8 the simplest amino acids. This shorter ancestor in turn involves only amino acids alanine, proline, serine, and glycine.

   For instance, methanogens (archaea) and acetogens (bacteria) use a simple analog of Krebs cycle to grow from H_2 and CO_2 by using a so-called COA pathway.

   Reverse Krebs cycle is associated with anaerobic photosynthetic bacteria and since photosynthesis makes chemical energy storage possible, reverse Krebs cycle must have appeared first. Its analog can also use chemical energy of inorganic molecules.

2. Bill Martin proposed that so-called LUCA living in hydrothermal vents is the ancestor of bacteria and archaea (`https://cutt.ly/hXTUoZ6`). LUCA would have lived 4 billion years ago. LUCA was autotrophic and made all its biomolecules from the inorganic molecules of the environment containing hydrogen, CO_2 and nitrogen turning them to organic compounds like ammonia. It lived in the dark and there was no oxygen so that it would have obtained its metabolic energy from some other source than recent plants and animals.

   It would have used the primitive version of the reverse Krebs cycle with H_2S and CO_2 as inputs to build basic biomolecules. This process is an analog of photosynthesis storing energy as chemical energy. Inorganic molecules would have replaced photons as the source of metabolic energy.

   The genes of LUCA would have been very simple. The first naive guess is that the genes of LUCA are shared by archaea, prokaryotes, and eukaryotes and this gives constraints on the speculations concerning their genome. This gives however quite too high a number of candidates. The lateral transfer of genes must be taken into account. It implies that the common genes need not be possessed by LUCA. The outcome was a proposal involving 355 genes for LUCA. For instance, the genes responsible for the synthesis of nucleic acids and amino acids were missing. Also the genes needed to code complete ribosomes were missing.

3. Deborah Kelley discovered alkaline hydrothermal vents with charge separation between interior containing. They are rich in hydrogen gas. Hydrothermal vents were predicted by geologist Mike Russel based on the study of what looked like fossilized mineral sponges. The

pores of this inorganic structure would have had OH^- ions in the interior and protons in the exterior. The walls would have contained FeS.

Lane suggests that inorganic pores inside the hydrothermal vents represent a candidate for a proto cell.

1. Lane emphasized the importance of the charge separation. The interior of both proto cell and its modern version must have been negatively charged (alkaline) whereas the exterior was positively charged. Lane notices that a similar charge separation also characterizes Earth interior and exterior: the electric field of Earth is made possible by this charge separation. What is amusing and thought provoking is that the strength of the electric field in lightning is the same as through the cell membrane! Could one see Earth itself as a giant cell? Did life proceed from long scales to short scales or vice versa?

2. A primitive predecessor of reverse Krebs cycle using perhaps H_2S and CO_2 instead of water would have generated the building bricks of chemical life. Oxidation of inorganic compounds such as iron ions could have served as the source of the metabolic energy.

3. Lane discusses a proposal for the steps leading to pyruvate from which the Krebs cycle starts from. Bound methanol from CO_2. From this to pyruvate containing two carbons. This is realized in the lab. Also lipids would have been generated leading to the emergence of cell membranes.

   It should be noticed in passing that in the experiments producing the basic biomolecules UV light is often needed: this is understandable since the scale of molecular energies is in visible and UV. The problem is that the recent life forms do not however utilize UV light.

4. These life forms would have lived in hydrothermal vents and would have disappeared as life based on photosynthesis generating oxygen emerged. All plant-like life forms not using photosynthesis would have disappeared in CE if they existed at all.

   Oxygen based life would have been the winner since reverse Krebs cycle for photosynthesis is much more effective than for the variant of Krebs cycle using chemical energy. Also aerobic Krebs cycle is much more effective than that based on fermentation. The monocellular life forms, possibly using H_2S based metabolism, would have disappeared in CE when the oxygen levels in oceans would have increased dramatically.

5. Note that the same proposal for the proto cell could work if H_2O replaces H_2S if it is available. One can also make "What if?" question. Can on imagine that photons and oxygen were in some mysterious way available from the beginning.

6. The next revolution according to Lane would have been the emergence of photosynthesis as analog of reverse Krebs. H_2O would have replaced H_2S from water. $CO_2 + H_2 \to CH_2O + O_2$ became the basic reaction making possible the storage of metabolic energy to carbon compounds and producing the basic building blocks of biomolecules.

   The Great oxidation event (GOE) , estimated to have occurred for 2.4-2.2 billion years before the Cambrian explosion (CE), would have initiated a very slow oxidation of oceans and amplified in CE dramatically. This would explain why the fossils of life forms utilizing oxygen based photosynthesis are absent before CE.

The scenario however has problems.

1. The proposal is that metabolism came first. However, metabolism requires biocatalysts and their generation requires genes. If metabolism was miraculously possible without genes, how genes emerged from metabolism? All nothing-but-chemistry based views of the origin of life have hen-egg problems. Did the cell membrane emerge first? Did proteins or genes emerge first? Did proteins, DNA or RNA emerge first?

   All these need each other in recent life, which leads to asking whether something much deeper emerged first or was present from the beginning at the level of fundamental physics. Could this something relate to the difference between in-organic and organic matter and to the incredible efficiency and precision of bio-catalysis? Does biophysics involve something totally new, not yet identified?

2. Did the GOE really happen? What is known of fossils suggests that it occurred in CE but how is this possible? Did oxygen rich oceans appear out of nowhere just like the complex multicellulars. Could one think that this somehow occurred and multicellular cells replaced the possibly existing life forms in hydrothermal vents at the surface of Earth using chemical energy as metabolic energy?

3. As Lane emphasizes, charge separation is crucial. Pollack effect induces it. We do not understand the Pollack effect in the standard biochemistry framework.

These objections give a good motivation for developing a TGD based view about Krebs cycle. This view is based on some basic ideas of TGD inspired quantum biology, quantum gravitational views of metabolism [L44] and evolution of life [L42], the TGD inspired view about how Pollack effect induces charge separations leading also to a view of genetic code realized in terms of both dark proton and dark photon triplets, the TGD proposal for what happened in Cambrian explosion in which oxygenated oceans and highly developed multicellulars emerged apparently out of nowhere [L15, L38, L30].

6.2 TGD view of Krebs cycle and early life

The TGD based view of life could have emerged from the problems of the view of Lane.

1. Brief overview of quantum TGD

TGD and TGD inspired theories of consciousness and quantum biology rely on a new view of space-time and quantum theory [L35].

1. In the original form TGD was proposed to be a geometrization of classical physics: the gauge fields of standard model and gravitational fields are geometrized in terms of the geometry of 8-D space $H = M^4 \times CP_2$ in which space-times are 4-D surfaces.

   The new view of space-time leads to notions like topological field quantization. Maxwellian fields are replaced by topological field quanta such as magnetic flux quanta (tubes and sheets) and electric flux quanta which correspond to space-time surfaces of finite spatial size in H.

2. Later the geometrization program was extended to include entire quantum physics and was based on the notion of the "world of classical worlds" (WCW) consisting of 4-D surfaces identified as space-time surfaces in H, which are preferred extremals of action principle analogous to Bohr orbits.

   Preferred extremal/Bohr orbit property leads naturally to holography which is not quite exact, which has important implications for quantum biology and understanding of cognition. This in turn leads to zero energy ontology (ZEO). Quantum states are not superpositions of 3-D surfaces but of 4-surfaces.

   They are therefore quantum variants for analogs of deterministic time evolutions: functions, behaviors of computer programs. The notion of function is central in biology and neuroscience and would be also a central notion in fundamental quantum physics.

   ZEO leads to a TGD inspired theory of consciousness as a generalization of quantum measurement theory solving its basic problem due to the conflict of the determinism of unitary time evolution with non-determinism of state function reduction. Quantum jump replaces the entire superposition of space-time surfaces with a new one rather than violating the deterministic time evolution of a given space-time surface. There are two causalities: this solves the basic problem of quantum measurement theory. There are also two times: the geometric time of a physicist and the subjective time as a sequence of quantum jumps.

   This in turn leads to a new view about state function reductions (SFR): in ordinary "big" SFR the arrow of time changes whereas in "small" SFR as an analog of weak measurement it is not changed. The findings of Minev et al [L17] provide direct support for ZEO [L17]. Also the views about thermodynamics must be modified since the arrow of time can change. The implications are especially profound in biology.

3. Later came a generalization of the physics based on real numbers to what I call adelic physics [L12, L13]. Adeles are fusion of reals and p-adic number fields identified as correlates of cognition and intention. p-Adic number fields are completions of rationals just like real numbers. They allow an infinite number of extensions induced by algebraic extensions of rationals.

   It is natural to interpret the hierarchies of extensions of rationals as evolutionary hierarchies and one can assign to extensions the value of effective Planck constant $h_{eff} = nh_0$ determined by their dimension. Also biological evolution reduces to the increase of algebraic complexity in a sequence of quantum jumps replacing zero energy state with a new one.

   This framework led to $M^8 - H$ duality, which generalizes the momentum-position duality of wave mechanics. This duality provides two views of physics. The complexification M^8_c of M^8, as analog of complexified8-D momentum space, has an interpretation as complexified octonions. At the level of M^8 the counterparts of 4-surfaces are determined by the roots of monomial polynomials P of a real argument and having integer coefficients. The roots of P correspond to, in general complex, mass squared values defining mass shells H^3 (hyperbolic spaces) in momentum space $M^4_c \subset M^8_c$. The roots are algebraic numbers in an extension of rationals defined by P and the Galois group of P acts as symmetries of the theory.

   These 3-D objects are continued by holography to 4-surfaces. The holographic dynamics is dictated by the condition that the normal space of the 4-surface is associative, that is quaternionic. The second condition is that the normal space contains commutative space (analogous to complex numbers). This guarantees that the normal space corresponds to a point of CP_2 and makes it possible to map these associative 4-surfaces to space-time surfaces in H.

6.2.1 Some basic ideas of TGD inspired quantum biology

Consider now some aspect of TGD inspired quantum biology relevant for what follows.

1. Dark matter and quantum biology

Basic prediction of the number theoretic vision of TGD is a hierarchy of dark matter phases labelled by $h_{eff} = nh_0$, where n is the dimension associated with the extension of rationals.

1. Dark matter in the TGD sense residing at monopole flux tubes is central for the TGD view of life. Also the electric flux quanta, which correspond to deformations of minimal surfaces of H with 2-D membrane-like projection to E^3 are expected to be important and accompany for instance, the lipid layers of cell membrane and boundaries between two phases. For instance, molecules could be accompanied by these kinds of membranes involving $h_{eff} > h$ phases. Dark variants of protons and electrons and perhaps also ions reside at the field equanta.

2. Large value of h_{eff}/h would mean high algebraic complexity and high "IQ" so that the magnetic body (MB) would naturally use the biological body as a motor instrument and sensory receptor.

3. There are reasons to believe that the value of h_{eff} correlates with the interactions mediated by the flux tubes. Gravitational Planck constant $\hbar_{hr}/ = GMm/\beta_0$, where $\beta_0 = v_0/c \leq 1$ defines a quantize velocity parameter, M corresponds to either Earth's or solar mass and m is mass of a particle, is determined by Equivalence Principle and would characterize gravitational flux tubes. $\hbar_{gr}$ must be used in the condition $\hbar_{gr}/\hbar \geq 1$ is satisfied. This notion was originally introduced by Nottale [E1] and discussed from the TGD point in [K31, K25, K26].

   This proposal generalizes to other interactions. The gravitational Compton length $\Lambda_{gr} = \hbar_{gr}/m = GM/v_0 = r_S/2\beta_0$, where r_S is Scwartshild radius. For Earth this gives $\Lambda_{gr} = .45$ cm. This should be a fundamental biological and also hydrodynamical length scale [L42, L34] besides the corresponding length scale associated with the Sun.

4. Large values of h_{eff}, in particular $\hbar_{gr}$, mean the presence of long range quantum fluctuations serving as correlations for quantum criticality, which in the TGD Universe would accompany

ordinary criticality. In living matter these fluctuations would be associated with the criticality with respect to melting/freezing and boiling/condensing.

There would also be criticality around physiological temperature especially relevant to biological life [L42]. In these transitions, large density fluctuations take place and this leads to the TGD view about the role of quantum gravitation in biology and theory of conscious experience. Quantum gravitation would not be relevant in Planck scale but for Planck mass scale and appear in macroscopic scales longer than Λ_{gr} and even in the scale of Earth and even Sun.

5. One ends up with a quantum gravitational view of metabolism [L44] based on the proposal that both hydrogen bonds and valence bonds are accompanied by magnetic flux tubes and be characterized by even $\hbar_{gr}$ and therefore can have very long lengths giving rise to quantum coherence in long scales. The delocalization of dark protons at gravitational flux tubes by the absorption of dark solar photons would be a central element and one can say that the gravitational flux tubes serve as gravitational batteries with the metabolic energy stored in the reduction of the gravitational binding energy. One also ends up with a vision of how the neural system evolved [L44].

6. Pollack effect [I8, I9, L4, I16, I21] is a central element in the TGD view of living matter [L4, L9, L24, L7]. What would happen is that in the presence of a gel phase, the irradiation by visible or IR light would generate the negatively charged exclusion zone (EZ) by kicking protons of H_2O to the flux tubes of the MB of water where they could form sequences of dark protons.

   Pollack effect would thus explain charge separation occurring for cell and DNA and even for Earth and would be absolutely central for TGD. A feed of metabolic energy would be necessary to preserve the charge separation requiring dark protons. An alternative interpretation is that preservation of high level of cognitive consciousness, measured by the value distribution of h_{eff} as analog of IQ, requires metabolic energy feed

7. Dark proton triplets or dark nucleon triplets [L48] at monopole flux tubes would provide a realization of the genetic code, and give rise to dark variants of DNA, RNA, tRNA and amino acids already at the level of water. Since also metabolism is involved.

8. The realization of the genetic code in terms of dark photon triplets would be essential for communications. The biochemical realization would be a secondary realization of the genetic code and would emerge later.

9. Number theoretic vision leads to a proposal that genetic code is universal [L31, L48]. Even the cell membrane could realize the genetic code. The key notion would be so-called icosatetrahedral tessellation at the hyperbolic space H^3 (mass shell and its counterpart in H) allowing realization of genetic code which would induce realizations at the space-time level. Also higher than 1-D realizations, such as realization at the level of cell membrane.

This picture would solve the hen-egg problems of the nothing-but-chemistry approach [L43]. All the basic building blocks necessitating each other emerge simultaneously. The TGD based view of space-time also strongly suggests that membrane-like structures are universal at the space-time level [L39] and are associated with cell membranes and various boundary layers.

2. Zero energy ontology

Zero energy ontology (ZEO) [L21, L33, L41] [K34] is also important for the TGD view of life.

1. "Big" or ordinary SFRs (BSFRs), would reverse the arrow of time and the interpretation of BSFR could be interpreted as a universal counterpart of death. BSFR would however mean reincarnation with an opposite arrow of time.

2. Sleep-awake cycle could be due to BSFRs at some level of MB. At the level of bio-molecules analogous cycles are also present. During the sleep period, dissipation occurs with a reverse arrow of time and this looks like healing when looked from the opposite time direction.

Since MB controls biological matter with f $h_{eff} = h$, the change of the arrow of time in BSFRs at the level of the magnetic/field body would induce effective time reversal at the level of the ordinary biomatter. The arrow of time for ordinary matter would change in a very short time scale since BSFRs would occur with a high rate.

An attractive conjecture is that Krebs cycle and its reversal are time reversals of each other at some level of MB. If so, the appropriate levels of MBs of animals and plants tend to live in opposite time directions. As noticed, the Krebs cycle can change to its reversal, say in cancer, and the interpretation would be that the analog of cell death followed by a reincarnation with an opposite arrow of time occurs.

6.2.2 Expanding Earth hypothesis, Cambrian explosion, and emergence of oxygen rich oceans

The TGD proposal is that life and photosynthesis and higher chemical life emerged in underground oceans. Oxygen is needed and oxidation of the underground oceans would have taken place by photosynthesis by reverse Krebs cycle and been based on water instead of H_2S.

1. Evolution of life in underground oceans

Consider now the TGD picture.

1. Life would have evolved in underground oceans shielded from meteoritic bombardment and cosmic rays. The radius of Earth increased rapidly by a factor of about 2 during the Cambrian explosion (CE). The multicellular life utilizing photosynthesis bursted to the surface of Earth and formed recent oceans.

   There would have been no oceans before the CE. Hydrothermal vents could have existed. The possible lifeforms were very simple bacteria, which photosynthesized using H_2S since there was now water and oxygen.

   Earth was like Mars now: Mars has no oceans and no oxygen. There are indications of underground reservoirs of water and signs of simple life forms.

2. Cosmic expansion in GRT predicts astrophysical objects to expand smoothly. This does not happen. In the TGD Universe, the expansion would be a quantum phenomenon and take place in rapid jerks and such a jerk would have induced CE.

   I got interested in the Expanding Earth hypothesis after watching a video [**?**] by Neal Adams. The video is very impressive artwork but in the lack of references skeptics probably cannot avoid the feeling that Neal Adams might use his highly developed animation skills to cheat the reader. I found also a polemic article [**?**] of Adams but the references were lacking. The basic argument was that the Wegener hypothesis generalizes. If the radius of the Earth were 1/2 of the recent radius, the whole Earth would be covered by continents fitting together along their boundaries.

2. Expanding Earth hypothesis

This leads to Expanding Earth Hypothesis (EEH) [L15, L38, L30].

1. EEH stating that the radius of Earth increased rather rapidly by a factor of about two in Cambrian Explosion and underground oceans serving as seats for highly evolved photosynthesizing life bursted to the surface and forming oceans.

2. Highly developed multicellular animals and photosynthesizing algae bursted to the surface. Note that algae are responsible for the production of most oxygen also in the recent oceans. If hydrothermal vents contained sulphur based life it disappeared because the generation of the basic building blocks of biomolecules was too slow.

   Interestingly, the radius of Mars is roughly 1/2 of that for Earth. Could Mars have underground oceans teeming with life? When does the radius increase by factor two?

3. There is however a problem. How is photosynthesis possible underground? It is dark there! The basic proposal is that solar photons with energies in the visible and possibly infrared range arrive as dark photons along monopole flux tubes, which extend above the Earth and carry dark matter. The strength of the magnetic field would be about .2 Gauss and fraction 2/5 of the nominal value of the Earth's total magnetic field involving also a non-monopole part.

4. Also dark photons from the interior of Earth propagating along the flux tubes or associated with them could have served as an energy source. The temperature in the Earth's inner core (with radius about 20 percent of the Earth's radius) corresponds to about 5,500 K, which corresponds to a thermal energy scale of about .55 eV, which corresponds to the nominal value of the metabolic energy quantum.

   The energy at the maximum of the energy distribution is roughly 3 times larger than this energy and would be around 1.65 eV. The energy at the maximum wavelength of thermal energy distribution is 5 times higher and about 2.75 eV, which is the upper bound for the energy range 2-2.75 eV of visible photons.

   If the temperature of the inner core before CE has not differed appreciably from that now, which could hold true if the inner core was already before CE in the expanded state as also water containing regions, the idea about dark photons from the inner core as a metabolic energy source, which would make possible the evolution of photosynthesis in underground oceans, makes sense.

3. A model for the growth of the Earth radius by factor 2

The idea about relatively fast growth of the Earth radius by factor 2 raises the eyebrows of standard physicists. How can such a large change of density make sense? It seems safe to exclude the possibility that the mass of Earth has increased roughly by a factor of 8 (mass should have arrived from dark magnetic flux tube structure to which the core of Earth is associated as a tangle).

Monopole flux tube spaghetti should determine the structure of the ordinary condensed matter making Earth. One can consider several possibilities by allowing a fractal behaviour of the matter density induced by the structure of the flux tube spaghetti if it does not fill the entire volume [L38, L30].

The increase of the radius of Earth by factor about 2 means that the average density decreases by a factor 1/8. I have considered several options for what this could mean.

1. Quantum gravitation plays a key role in the TGD view of the emergence of life [L42] and brings in a completely new element. Density fluctuations at quantum criticality associated with the density changing phase transitions, such as freezing and evaporation, affect gravitational binding energy dramatically in long scales. This leads to a view how life could have evolved from this kind of quantum criticality. If the density fluctuations correspond to local scalings, they affecte all gravitational binding energies in the same manner by reducing them.

   Quantum gravitational Compton length $\Lambda_{gr}GM/\beta_0$ using the definition $\hbar_{gr} = GMm/\beta_0$ defines the key parameter. This suggests a considerable flexibility since the transition could be induced from the level of quantum gravitational flux tubes and leave the details for what happens in scales below Λ_{gr} open.

2. Both the necessity of local scalings and energy conservation in the transition give further constraints. In the scaling of the radius of Earth by factor 2 induced by local scalings, the gravitational binding energy is reduced dramatically. There must be a way to compensate for the increase of the energy. Energy must be liberated in some degrees of freedom and condensed matter degrees of freedom in atomic scales are a natural candidate here.

   For protons the gravitational binding energy is below .5 eV and for nucleus with mass number A it is below $.5A$ eV. The reduction of the gravitational binding energy per particle in the phase transition would be of this order of magnitude. Encouragingly, this energy corresponds to a typical energy scale for the interactions energies between atoms.

3. The electronic size of an atom is inversely proportional to $n^2h_{eff}^2/Z^2$, where n is the principal quantum number for valence electrons and Z is the charge of the atomic nucleus. The electronic binding energies are proportional to Z^2n^2/h_{eff}^2 so that the transition would require energy feed if scaling occurs in electronic degrees of freedom. Energy is not liberated. Furthermore, the electronic size of the atom cannot be affected in the transition.

   Note however that the experiments of Randell Mills [**?**] provide support for the possibility of h_{eff} smaller than h for valence electrons [L8]. The TGD inspired model for chemical bonds [L11] suggests that the value of h_{eff} characterizes valence bonds.

4. Second possibility is that the energy is liberated in atomic size scales defined in terms of the size lattice constant a defining the unit cell of the atomic lattice, which is rather constant. The atomic p-adic length scale defining a would increases by factor 2 or the value of h_{eff} assignable to the atomic p-adic length scale (the p-adic length scale $L(137)$ is a good guess) increases by a factor 2 from $h/2$ to h. Note that before the transition the value of h_{eff} assignable to a cannot be the same as the value assignable to the atomic electrons, since the latter cannot change in the transition.

   The reduction of the gravitational binding energy should correspond to the liberated interatomic interaction energy depending on a which would increase by a factor 2. If this interaction energy can be regarded as positive interaction energy of positively charged atoms without conduction electrons, it is positive, and would decrease in the transition and could compensate for the reduction of the gravitational binding energy.

5. The phase transition would have been local and occurred gradually. The regions of water containing the photosynthesizing life forms and multicellular animals would have been in the recent phase already before CD. Water atoms behaved like dark matter since h_{eff} was twice its value for other atoms (as unit cells).

   The same could apply also to the inner core serving as a source of dark photons providing the metabolic energy. Indeed, the radius of the inner core is roughly 1/5 of the radius of Earth, so that the possibility that also the inner core was in the ordinary phase looks realistic: the doubling of the Earth radius would be replaced with a scaling by factor 10/6.

   Only the mantle would have been in the exotic phase. Of course, also the uppermost layers could have been also in the ordinary phase as the recent situation on Mars would suggest. The phase transition would have gradually proceeded in the mantle during the period when the radius of Earth was doubled.

6. The arguments of [L30] based on the idea that CP_2 length scale corresponds actually to Planck length scaled by factor $\sqrt{h/h_0}$ led to a speculation that $h_{eff} = h$ could be proportional to integer $n_0 = (7!)^2$ defining the order of Galois group for the number theoretic ground state in the length scales of atomic physics [L32]. 7! would correspond to the order of the permutation group S_7 and $S_7 \times S_7$ would define the Galois group of the ground state corresponding to $h_{eff} = h$.

   This suggests that the order of the Galois group was given by $n = n_0/2 = 7!^2/2$ before CE and was replaced with $n_0 = (7!)^2$) in CE. The Galois group would have been $S_7 \times A_7$, where A_7 is an alternating group, which is simple. Z_2 is the only normal subgroup of S_7.

Can one imagine any evidence for an analog of the exotic phase in the framework of known physics? In the case of water, superionic ice [**?**] (`https://cutt.ly/uXUIkUQ` and `https://cutt.ly/3XUIWhX`) existing at extreme pressures is a possible candidate for the exotic phase of water. Superionic ice is proposed to appear in the mantles of giant planets such as Uranus and Neptune and in [L38, L30] the possibility that it could occuring the Earth's mantle was considered. The density of superionic ice is slightly less than 4 times the density of ordinary ice. The reduction of h_{eff} with factor 2 ($n = n_0/2 = (7!)^2/2$) would given a density, which is 8 times the density of ordinary ice. The increase of the density by factor 2 would require effective 2-dimensionality but superionic ice is 3-D.

4. Quantum gravitational metabolism

Consider first the quantum gravitational metabolism at Earth in the recent situation. In [L44], I discussed the following vision.

1. The long gravitational monopole flux tubes with $\hbar_{eff} = \hbar_{gr} = GM_E m/\beta_0$, $\beta_0 = v_0/c \leq 1$, have lengths much longer than gravitational Compton length $\Lambda_{gr} = \hbar_{gr}/m = GM/\beta_0$ does not depend on the mass m of charged particle, now proton at the dark hydrogen bond. Λ_{gr} is about .45 cm for $\beta \simeq 1$ using $\hbar_{gr} = GMm/\beta_0$. There are several pieces of evidence suggesting that Λ_{gr} is a fundamental scale of hydrodynamics [L34, L42].

   The length of long dark hydrogen bond flux tubes should be of order Earth size scale. For the recent life forms they would extend from the surface of Earth to the atmosphere.

   The dark photons of sunlight are absorbed by these flux tubes and this would increase the length if the energy reduces the gravitational binding energy. These flux tubes would serve as quantum gravitational batteries just like cell membranes as electromagnetic batteries.

2. Skeptics can of course wonder how it is possible that extremely weak gravitational interaction of gravitation and photons allows the transfer of dark photon energy to gravitational degrees of freedom. As a matter fact, quantum coherence means that gravitational interaction is actually extremely strong!

   In ordinary quantum theory one should use $\alpha_{gr} = GMm/\hbar$ as a coupling strength. It is larger than unity for Mm larger than Planck mass squared and the perturbation series fails! The introduction of $\hbar_{gr}$ saves the perturbation theory! As a matter of fact, the original motivation for h_{eff} was that the Universe is theoretician friendly and the increase of $\hbar$ means a phase transition making perturbation theory possible.

   One can characterize dark gravitational interaction by a dimensionless coupling parameter $\alpha_{gr} = GMm/4\pi\hbar_{gr} = \beta_0/4\pi$, which depends on β_0 only and is $1/4\pi$ for $\beta_0 = 1$ and therefore by a factor $1/e^2$ larger than fine structure constant and still of the same size as strong coupling strength α_s!

3. The upper bound for the gravitational binding energy of a proton in the Earth's gravitational field is of the order of . 5 eV metabolic energy quantum. If the dark proton at the long flux tube is localized at the surface of Earth, its gravitational binding energy increases and energy is liberated as metabolic energy. The flux tube can be given the original length by the absorption of a dark photon of solar radiation. The order of magnitude of energy is around metabolic energy quantum if 3 protons are localized simultaneously [L44]. ATP machinery indeed involves 3 protons which could have formed dark 3-proton.

4. The model also predicts a new metabolic energy currency associated with electrons. It is by the ratio $m_e/m_p \simeq 2^{-11}$ smaller than the standard metabolic energy quantum with the nominal value .5 eV.

5. The situation before CE

Consider now the situation before CE, when oceans were underground. One can imagine several options depending on whether dark solar radiation, dark photons from the Earth's core, or both provide the metabolic energy in the primordial photosynthesis.

1. For the simplest option involving only dark photons from the Earth's core, the dark flux gravitational flux tubes extending downwards to the interior of Earth would be spontaneously formed and their formation would have liberated metabolic energy given by the increase of the gravitational potential. If the flux tube extends down to the surface of the inner core with radius of $2R_E/5$, the metabolic energy released for the hydrogen bond would be about 1.5 eV to be compared with metabolic energy quantum of .5 eV. The absorption of a dark photon with energy of 2 eV would leave .5 eV of metabolic energy.

   One can ask whether the ADP molecule could have contained this kind of long dark hydrogen bond and whether it could have shortened in ADP $\rightarrow$ ATP transition by absorption of a dark photon before CE.

One can also imagine that the dark cyclotron state of the dark proton was excited by the dark solar photon and was liberated as the metabolic energy in the interior as the dark proton was localized.

2. Could the dark photons from the Earth's core be involved with the metabolism of recent life forms? Say those living underground? Could the increase of the radius of Earth by a factor of 2 have reduced the rate for the increase of the length of dark hydrogen bonds so that this mechanism became insignificant? Could one imagine that the Earth's mantle still contains life forms utilizing the core of Earth as a metabolic energy source? I have suggested this half-jokingly for more than 2 decades ago [K14, K15].

The next question concerns the identification of the primordial photosynthesizers.

1. They would have been the underground counterparts of the recent plants. Dark magnetic flux tubes emanating from them would have formed a kind of magnetic forest.

2. They did not have roots, leaves, nor flowers and lived in underground oceans and did photosynthesis. Algae `https://cutt.ly/9XTBTEO`) living in oceans satisfy these conditions. They include cyanobacteria (red and green algae) and glaucofytes. They or their predecessors (at least cyanobacteria) should have lived in the underground oceans and have evolved to the recent algae and plants after CE. Interestingly, algae produce most of the oxygen of Earth also in the recent biosphere. Cyanobacteria living in endosymbiosis with algae are the first known organisms that have produced oxygen.

3. This picture also solves the problem of how the oceans were oxygenated. They were oxygenated from the beginning and only bursted to the surface of Earth in CE.

4. This picture also conforms with the proposal of Lane that Earth and cell are very much analogous and makes this idea very concrete. The TGD variant of this proposal suggests that lightnings are actually analogs of action potentials possible even for unicellular organisms.

6.3 Appendix: A Corrected physical interpretation of the parameter β_0

Writing of this article led to an observation an apparent paradox, which resulted from a wrong interpretation of the parameter β_0 in Nottale's formula.

1. As already discussed, the quantum gravitational phase transition reducing the value of β_0 by factor 2 was involved with CE and led to the increase of the radius of Earth by factor 2.

   There are indications that the recent value β_0 is $\beta_0 \simeq 1$ and thus near to the maximal value [L34, L42]. This however leads to the conclusion that $\beta_0 = 2$ was true before CE. This leads to a contradiction if one assumes that $\beta_0 = v_0/c$ is consistent with special relativity.

2. The resolution of the apparent contradiction is based on the fact that the definition of the parameter β_0 in the Nottale's formula is actually not unique and determined only by scaling without further inputs such as the condition $\beta_0 \leq 1$. Therefore one can replace the formula $\hbar_{gr} = GMm/\beta$ with the formula $\hbar_{gr} = GMm/2\beta_{0,ph}$ if one defines $\beta_{0,ph} = \beta_0/2$. For this option, the value of $\beta_{0,ph}$ would have decreased from $\beta_{0,ph} = 1$ to $\beta_{0,ph} = 1/2$ in CE. The value of Λ_{gr} after CE would be $\Lambda_{gr} = GM/2\beta_{0,ph} = r_s/2$ just as proposed earlier [L34, L42].

7 About the mechanism of the energy transfer in photosynthesis

I learned about very interesting results related to photosynthesis. A popular article on the BigThink page (`https://rb.gy/phb4c`) tells about an article published in the journal PNAS [I20] (`rb.gy/9zppa`).

The basic mystery of photosynthesis is extreme energy efficiency. Up to 95% of the photon's energy is transmitted in a medium that would seem to be as inhospitable as possible for energy transmission with almost no dissipation. The use of very low temperatures, the shooting of monochromatic photons into a lattice, and superconductivity are out of the question. The incoming photons also have a wavelength distribution, which does not facilitate the energy transfer either.

7.1 Some facts

Consider first a summary of the basic findings and conclusions.

1. Chlorophyll is the basic structure involved with photosynthesis. Its basic function is to gather solar energy and transfer it to the reaction center where the energy is stored to various biomolecules. There are 2 wavelength bands, corresponding to 430 nm in blue and 662 nm in red, where the absorption is especially strong. The so-called LH2 proteins act as antennas absorbing photons. In the reaction center LH1 proteins perform photosynthesis by building biomolecules to which the solar energy is stored.

2. It has been observed that the lower limit of the size of the so-called light-absorbing LH2 antenna proteins is 2.5 nm. It is also the minimum distance between LH2 proteins. The proposal is that the LH2 antenna network could somehow make the transfer of energy almost without dissipation.

   It is believed that the disorganization of the proteins might explain this. However, in the popular article there was no intuitive argument as to why this is so. The claim is made on the basis of computational models and empirical facts gained by studying the transfer process. I find it difficult to imagine how the irregular positions of proteins could promote the process.

3. The proposed interpretation of the findings is as follows. A photon enters and excites the electron of the LH2 protein. When the electron is de-excited, one or more photons are generated which in turn excite the electrons of the next LH2 proteins. Finally, the generated photons excite the electrons of the reaction center and these electrons are used in the photosynthetic process to produce sugar molecules.

7.2 The TGD based model

The findings seem to resonate with two key views of the TGD inspired quantum biology.

1. Photosynthesis involves at least a temporary storage of solar energy to quantum gravitational energy batteries [L44, L42].

2. There is dark variant of the genetic code and realization of dark DNA double strand base on the icosahedral tessellation [L51] of the hyperbolic 3-space H^3, which is realized both as a mass shell in $M^4 \subset M^8$ and light-cone proper time=constant 3-surface in $M^4 \subset M^4 \times CP_2$.

   Icosa-tetrahedral and possible other hyperbolic tessellations would be associated, not with the biological body, but with the magnetic body (MB) of the biosystem carrying dark matter identified as phases of the ordinary matter with effective Planck constant $h_{eff} = nh_0$. The location of dark matter at the field body would explain why dark matter has not been found in various searches.

7.2.1 Basic questions

What are the questions waiting for an answer?

1. Why would the dissipation be so low? Quantum coherence in a scale of at least the order of tens of nanometers could guarantee this. Dark matter as phases with a large value of h_{eff} indeed implies a long quantum coherence scale. Also a regular crystal structure is a natural prerequisite for a low dissipation. The dissipation is minimized if the energy, or possibly the electrons, are transferred through the hyperbolic tessellation of the MB carrying dark matter.

2. The minimum distance between LH2 proteins is about 2.5-4 nanometers, which corresponds to the DNA codon size scale. In the TGD based model for genetic code, the dark realization of the genetic code and the DNA double helix are connected to an icosa-tetrahedral honeycomb in hyperbolic 3-space H^3 assigned with the MB [L51]. Could the crystalline structure be realized by using the same icosa-tetrahedral tessellation as associated with the dark DNA and dark genome controlling the ordinary genome.

If the transfer of energy to the reaction center occur at the MB as a transfer of dark electrons, the dissipation could be very small since there would be no direct interaction of the dark electrons with the ordinary matter if the interaction vertices can involve only particles with the same value of h_{eff}, as seems natural.

7.2.2 Quantitative data

Consider next the quantitative data.

1. The distance between LH2 proteins is in the range 2.5-3.1 nm. This scale corresponds to the DNA codon size scale and to the cell size of the fundamental region of the icosa-tetrahedral tessellation, which has Platonic solids as cells [L51]. There are 12 icosahedrons, 20 tetrahedrons and 30 octahedrons forming a region of size 10 nm, which corresponds to the p-adic length scale $L(151)$ (associated with a p-adic prime $p \simeq 2^k$, $k = 151$) appearing as a characteristic length scale in bomatter. This region corresponds to 10 DNA codons for which the total twist along the DNA strand is 6π that is 3 full turns.

2. The size of the structure involved with the photosynthesis would be naturally cell size scale? The wavelength of the red light gives a length scale of order .5 μm and serves a natural lower bound. Note that cell nucleus size is about 1 μm.

3. The time τ required for the energy transfer between adjacent antenna proteins varies from 5.7 to 14 ps. In time τ, the distance traveled by the light is $L = 1.71 - 4.2$ mm. Interestingly, for Earth the gravitational Compton wavelength $\Lambda_{gr}(E) = GM_E/\beta_0(E)$ is for $\beta_0(E) = v_0/c = 1$ equal to $\Lambda_{gr}(E) = 4.5$ mm. Gravitational Compton frequency is $f_{gr}(E) = 67$ GHz and corresponds to a time of about $T_{gr}(E) = 15$ ps, the upper limit for the estimated time.

   f_{gr} corresponds to a photon energy of $E_{gr} = .27$ meV. The electronic metabolic energy quantum in the case of the Earth would be related by a factor m_e/m_p the protonic metabolic energy quantum identifiable as standard metabolic energy currency. The model for the findings of Andrew Adamatsky [I2] suggests that sponges have a language based on membrane potential oscillations with membrane potential variations of order mV. The TGD based model suggests the existence of metabolic energy quantum of this order of magnitude [L44]! meV is also the energy associated with the miniature membrane potentials. Could τ be identifiable as the gravitational Compton time T_{gr} at which the dark matter at the MB would oscillate?

7.2.3 How could the electrons be transferred to the reaction center as dark electrons?

Could the process at the level of LH2 antenna proteins correspond to the propagation of the dark electron and the hole associated with it? The dark electron would hop between the sites of the tessellation perhaps by quantum tunneling, which in TGD Universe corresponds to a pair of "big" (ordinary) state function reductions (BSFRs) changing the arrow of time temporarily. The dark electron current would be analogous to super current and the system "hole + dark electron" would be analogous to a Cooper pair.

1. The duration τ of a single step should correspond to the oscillation period $\tau \sim T_{gr}$. If so, the oscillation would play the role of EEG resonance oscillation coordinating the transfer by induces the pairs of BSFRs.

2. The first guess is that electrons are converted to dark electrons with a large value of the gravitational Planck's constant $\hbar_{eff} = \hbar_{gr} = GMm/\beta_0(M)$ [E1] located at the gravitational MB of the Earth or Sun. They would be transferred to the U-shaped monopole flux tubes and the reduction of the binding energy of the electron would be equal to the energy of the incoming photon absorbed by it.

   The reduction of the binding energy cannot be however purely gravitational. For electrons, the maximal gravitational binding energy in the case of the Earth is about $E_{gr}(Earth, e) =$ .25 meV whereas the incoming photon has energy $E \simeq x \times .5$ eV, where x is in the range 4 to 6 in the wavelength range considered. For the Sun the maximal binding energy E_{gr} is reduced by the ratio $[M(Earth)/M(Sun)] \times [R(Sun)/R(Earth) = .071$. In the case of protons with

$E_{gr}(Earth, p) = .5$ eV this gives to $E_{gr}(Sun, p) = .14$ eV, which happens to be roughly twice the energy assignable to membrane potential. For electrons this gives $E_{gr}(Sun, e) = 1.8$ μeV.

For the energy transfer in photosynthesis, the energy of the solar photon cannot therefore correspond to the change of gravitational binding energy in the case of electrons. Rather, the energy must be identified as the change of electromagnetic binding energy as an atom is effectively ionized when an electron becomes a dark electron at the MB. This MB need not be gravitational and could also correspond to a relatively small $h_{eff} > h$.

3. What comes to mind are dark unpaired valence electron states of atoms in which the h_{eff} of an unpaired electron increases so that binding energy is scaled down by $1/h_{eff}^2$. The binding energy spectrum of the dark electron states is obtained by scaling the ordinary binding energy spectrum and these states are analogous Rydgerg states in that the radius of Bohr orbits is scaled up by h_{eff}^2. If the valence electron becomes gravitationally dark ($h_{eff} = h_{gr}$), the atom effectively suffers ionization to a state with vanishing energy and positive charge. Dark ions could correspond to this kind of states.

4. How could the energy transfer to the reaction center take place? The simplest mechanism could be the following. One can charge the solar energy batteries by transforming ordinary electrons to dark electrons at the MB of the Sun. At the reaction center the dark electrons drop back and transform to ordinary electrons and are available for the photosynthesis proper, storing the energy to biomolecules.

   The experimental findings could be consistent with the assumption that the pairs formed by a dark electron and hole move to the reaction center, and the movement of the dark electron is analogous to a conduction in a lattice by hopping. The lattice could correspond to the tetra-icosahedral tessellation assignable also with DNA and genetic code. The time for one transition would correspond to $T_{gr}(Earth) \sim 15ns$. This supports the view that the MB of the Earth is present.

5. Why would the dropping down to Earth take place in the reaction center? The holes have an effective positive charge because the dark electrons have a large distance to the surface of Earth. If the reaction center has a negative charge, it attracts the positively charged holes. The holes move towards the reaction center and the dark electrons and gravitational monopole flux tubes and dark electrons follow. The electrons transform to normal ones and holes disappear. The predicted negative charge of the reaction center serves as a test for the proposal.

6. How this negatively charged region in the reaction center could be generated? Pollack effect [I8, L4, I21, I16], discussed from the TGD point of view in [L4], is caused by (say) IR radiation in the presence of gel phase, and indeed generates negatively charged exclusion zones. The exclusion zones could be due the transfer of protons of water molecules to dark protons at the flux tubes of the MB,which is however not gravitational. Both cells and DNA represent examples of negatively charged objects. Pollack effect is indeed a key element of the TGD inspired view of living matter. There it is natural to assume that the exclusion zone is present also in the reaction center.

If the energies of dark electrons and holes are separately conserved, they can annihilate to the ordinary electron in the reaction center. Can this be true?

1. Why would the energy of the dark electron be conserved in the hopping along the tessellation? Single step would correspond to a motion under the magnetic Lorentz force, which conserves energy since force is orthogonal to the velocity.

2. What about the dark electron-hole interaction? This interaction is present if the flux tube follows the motion of the hole-dark electron pair. This pair would form a bound state analogous to the Cooper pair and its energy would be conserved if its scattering would reduce to the magnetic scattering of the dark electron. The situation would be very much like in the case of superconductivity.

3. If the hole corresponds to a transition of an unpaired valence electron to a large h_{eff} analog of a Rydberg state with a very large size, the binding energy and energy of the state is very near to zero. The ionization energy scale for valence electrons is measured in electron volts just like for the photons from the Sun.

   The energy scale for icosa-tetrahedral honeycomb scaling like $\hbar_{eff}^2/(2m_eL^2)$, L the size of the fundamental region, gives an estimate for the unit of energy quantization, which does not depend on $\hbar_{eff}$. The energy scale is 10^2 eV for $L = L(151) = 10$ nm. This scale is expected to be very large as compared to the energy gap so that transitions are not possible. The situation would be like in superconductivity and superfluidity.

4. What about energy conservation in the motion of the localized valence hole? Valence electron hole can be replaced with the valence electron of a neighboring atom and this makes possible its movement towards the negatively charged reaction center. The energy of the valence hole in the center of mass system of the atom is not changed but the ionized atom or the molecule containing it would experience the Coulomb force assumed to be associated with the reaction center and its center of mass energy can change.

   How is it possible that the attractive Coulomb field between the hole and the reaction center does not affect the energy of the valence hole? The question is well-motivated The Coulomb energy between the hole and the reaction center is expected to be much larger than the energy gap. For instance, for distance of 1 μm the Coulomb energy between unit charges is of order 10^{-2} eV.

   What prevents the valence hole from accelerating and getting more energetic? The U-shaped gravitational magnetic flux tube has a string tension and the lengthening of the flux tube could compensate for the Coulomb force. The Coulomb energy would be transformed to elastic energy of the flux tube. In the reaction center the flux tube would contract and the dark electron could fuse with the hole having the same energy.

7.2.4 Is this picture consistent with the quantum gravitational storage of metabolic energy?

Is this picture consistent with the earlier proposal for the metabolic energy storage, which is based on the notion of gravitationally dark protons [L44] and also predicts electronic metabolic energy currency of about .25 meV for which there is some evidence [I2]?

1. The motivation for the proposal is that the gravitational potential energy of a proton at the surface of Earth is .5 eV: this happens to be the nominal value of metabolic energy quantum. Of course, since the electromagnetic binding energies in molecular scale are measured using eV as units, this might be a pure accident. The weaker optimistic interpretation is that this coincidence makes possible interaction between quantum gravitational and quantum electromagnetic degrees of freedom.

   When the distance from the surface of Earth in the direction of the Sun, the gravitational forces of Sun and Earth are identical. This condition gives an upper bound for the distance $r(Earth)$ of the particle from the Earth in the direction of Sun as $r(Earth)/AU - r(Earth) = \sqrt{M(Earth)/M(Sun)}$ giving $r(Earth) \simeq 100R(Earth)$ to be compared to the distance of Moon about $r(Moon) \simeq 60R(Earth)$. The value of the gravitational potential difference as is 99% of the maximal one.

   The proposal [L44] is that the transformation of protons of water molecules to gravitationally dark protons could serve as a mechanism for the storage of metabolic energy.

   If the metabolic energy quantum is determined *solely* by the gravitation of Earth, this mechanism does not work at large distances from the surface of Earth. The fact that Moon travellers have survived does not favor a purely gravitational mechanism but the fact that molecular binding energies are of the same order, might save the mechanism. A more imaginative option is that the gravitational MB of the Moon traveller is still associated with Earth and makes it possible to store metabolic energy to the gravitational MB of Earth.

2. Dark protons triplets could serve as a storage of metabolic energy in the case of ATP (high energy phosphate bond) and maybe even in the case of biomolecules. This is supported by the appearance of 3 protons as a kind of basic unit in ATP→ ADP metabolic machinery.

3. In the Pollack effect, IR radiation effectively ionizes water molecules and produces effective stoichiometry $H_{1.5}O$ inside a negatively charged exclusion zone. The decrease of the electronic binding energy per water molecule in the Pollack effect could be naturally given by the energy of the IR photon and would be rather small. If the Coulomb binding energy of the dark proton triplets with the exclusion zone is equal the metabolic energy quantum $E = .5$ eV, the reduction of the gravitational binding energy in the transfer of dark proton triplet to the gravitational MB would be given by E and would lead to a zero energy state. Could one the build-up the energy carrying bio-molecules by transferring dark proton triplet to the gravitational magnetic bodies of the biomolecules by using the energy liberated by dark electrons as they drop down and transform to ordinary electrons in the reaction center?

8 Could life have emerged when the universe was at room temperature?

This article was inspired by the popular article *" Ask Ethan: Did life begin when the Universe was room temperature?* of Ethan Siegel (see this).

One can consider this question in both standard cosmology and in the TGD inspired cosmology. For both options, if one identifies life as chemical life, the building brick atoms of various important biomolecules should have been present at this stage of cosmological evolution.

Cosmic microwave background (CMB) was decoupled from matter at temperature 3,000 K, below which only light neutral atoms, but no molecules, were present. After that CMB temperatures decreased and at some moment it was equal to $T \sim 300$ K. The identification of the temperature T for the emergence of life as temperature of the cosmic microwave background (CMB) is excluded since no basic bio-molecules were present at that time, only simplest atoms were present. Therefore the temperature $T \sim 300$ K for matter should have emerged during the gravitational heating.

If the heating led to the ordinary nuclear fusion, it is difficult to understand how the biomolecules could have survived. In the standard cosmology this does not look plausible. Therefore the answer to the question is negative.

In TGD inspired cosmology, the temperature T would naturally correspond to the quantum critical temperature $T_P \sim 300$ K for the Pollack effect [I8, L4, I21, I16]. In TGD it would be involved with the transformation of protons to their dark counterparts at magnetic flux tubes (see [L4, L9, L57, L24, L58, L52]). Dark nuclei would have transformed to ordinary nuclei liberating almost all nuclear binding energy. The temperature T_P would have been reached by gravitational heating and Pollack effect would make possible the generation of nuclei by dark fusion [L5, L25, L10, L67] in turn forming the needed biomolecules.

One can argue that the liberated energy heats the matter to even higher temperatures and the ordinary fusion is ignited. However, the infinite number of degrees of freedom for the monopole flux tubes implies that there is a limiting temperature T_H [K21, K22], analogous to the Hagedorn temperature [**?**] discovered in string models and nuclei could be generated solely by "cold fusion" without not ignition of ordinary fusion. Note that there is an entire hierarchy of Hagedorn temperatures corresponding to preferred p-adic length scales characterizing the flux tubes.

The biomolecules would have survived if T_P was slightly below the Hagedorn temperature T_H for the monopole flux tubes serving as an upper bound for the temperature of flux tubes and therefore of the temperature of matter. Dark fusion could have generated planets [L55] and perhaps even part of the matter of the Sun [L65], the physics of which could be dramatically different from that in the standard model. If so, the ordinary nuclear fusion could be replaced with dark fusion in TGD. Life could have emerged much earlier than in the standard cosmology.

In the sequel I will discuss the question "Could life have emerged when the universe was at room temperature?" in more detail from the point of views of the standard cosmology and TGD.

8.1 Does standard Big Bang cosmology allow emergence of life at matter temperature $T \sim 300$ K?

One can pose a long list of questions related to the notion of life. Is life Universal? Is chemical life the only possible form of life and what kinds of non-chemical lifeforms can be imagined? TGD leads to proposals for some exotic forms of life such as plasmoid life for which NASA has found empirical indications in the ionosphere [L52]. Water as such could be a primitive life form [L47, L42]. TGD also allows us to consider conscious and living computers [L64, L74] and quartz life can be imagined. Gallium based living computers could even have motor activities [L73]. These life forms would b based on the same basic mechanisms as the ordinary life.

Even if one restricts consideration to biochemical life, there is a long list of conditions to be satisfied. Sufficiently complex molecules should exist; the counterparts of DNA and other information molecules seem necessary; the analog of genetic code is desirable; the cell membrane should exist; the ability to replicate seems to be necessary; metabolism and metabolic energy sources are needed. The reason is that biochemical life requires complex chemistry made possible by stars and planets.

The Panspermia hypothesis allowing life to develop in interstellar space could be correct as also the notion of plasma life [L52, L58] suggests but does not solve the problem about the origin of biochemical life.

According to the standard cosmology, CMB decoupled from matter at $T_{CMB} \sim 3{,}000$ K. What did standard cosmology look like at $T_{CMB} \sim 300$ K? Were galaxies, stars and planets present at time? What is the CMB temperature for the most distant parts of the Universe studied now by JWST?

To answer these questions, some basic facts about standard cosmology are in order.

1. In Robertson-Walker type cosmology, there are two alternative natural time coordinates. Cosmic proper time t and the scale parameter a (which in TGD corresponds to light-cone proper time). Their relation depends on whether the cosmology is matter or radiation dominated or possibly string dominated. Matter dominated cosmology corresponds to $a \propto t^{2/3}$ and radiation dominated cosmology to $a \propto t^{1/2}$. In matter dominated cosmology, this gives for the CMB temperature the dependence

$$T_{CMB} \propto a_{now}/a \propto (t_{now}/t)^{-2/3} \quad , \quad t_{now} \sim 14Gy \quad .$$

2. Redshift-distance relation is a second useful relation.

$$1 + z = a_{now}/a(t) = T_{CMB}(t)/T_{CMB}(now) \quad .$$

   allowing to translate redshift to temperature. $T_{CMB} = 300$ K would correspond to $1+z = 100$ and $t_{now}/t = (a_{now}/a)^{3/2} = 10^3$.

   T_{CMB} does correspond to the temperature of matter, which must have been considerably lower to make possible gravitational instabilities generating gravitational condensation leading to the formation of stars and galaxies. The reason is that high temperature means high pressure gradients preventing the gravitational condensation.

3. JWST gives information about most earliest times and largest distances $z = 14.3$ is highest redshift observed by JWST (see this). This redshift corresponds to T_{CMB}= 42 K, a distance of $d = 33.8$ billion light-years, and an age of 286 million years.

   By the way, it is surprising how little we actually know about early cosmology. This gives a lot of degrees of freedom for the speculations about the earlier cosmology.

At the temperature $T_{CMB} \simeq 300$ K no molecules were present. This leaves only the option that $T \simeq 300$ K corresponds to the temperature of matter. In the standard model, stars and galaxies and planets are formed by gravitational condensation induced by gravitational instability. This requires low enough pressure and therefore a sufficiently low temperature and large enough matter clump (see this). Neutrality after decoupling makes possible the low temperature. Gravitational condensation increased the temperature and eventually ignited fusion. Could this have occurred early enough to allow $T = 300$ K as the matter temperature?

1. The ignition of ordinary fusion requires formation of stable H_2 and DH molecules. The rate for the formation of these molecules is expected to decrease with temperature since there a potential wall must be overcome. This would give a bound on the rate of temperature decrease. It is now argued on the basis of experimental data that this is not the case [E3]: the rate does not decrease with decreasing temperature. An interesting possibility is that this requires new physics [L72].

2. For chemical life to be present already at $T = 300$ K, much more complex molecules are required and the stars and even planets should have existed already at that time. This looks highly implausible. This temperature should have also occurred during the gravitational heating preceding the ignition of the nuclear fusion and it is difficult to understand how the biomolecules could have survived this heating. Bochemical life should have emerged later.

8.2 TGD view of cosmological evolution and biology

Could life in some form emerge at matter temperature $T = 300$ K in TGD inspired cosmology? TGD inspired views about cosmology, galaxies, stars and planets as well as about life differ dramatically from the standard views and it is not obvious what the answer to the question is.

1. TGD view of cosmology and formation of galaxies and stars

The TGD view of cosmology and astrophysics is described in [L62].

1. TGD provides a new view of spacetime. Space-time is identified as a 4-surface in $H = M^4 \times CP_2$ obeying almost deterministic holography realized by holomorphic reducing Riemannian geometry to algebraic geometry [L60, L66, L75]. This leads to a view in which cosmic strings, monopole flux tubes, and field bodies become new central notions of cosmology.

2. Also the hierarchy of Planck constants labelling phases of ordinary matter behaving like dark matter is an essential piece of the picture. Zero energy ontology as a new ontology of quantum theory is also a central piece having implications even in astrophysical and cosmological scales.

3. The TGD view of the formation of galaxies and stars differs from the standard view. Gravitational condensation is replaced with the TGD analog of inflation [L63, L62]. Flux tube tangles from cosmic strings decay partially to ordinary matter.

   Galaxies and stars would not have formed by gravitational condensation but by the generation of thickened tangles of cosmic strings liberating energy and generating the ordinary matter as liberated matter. These tangles could have also emerged in the intersections of cosmic strings and this option looks natural for spiral galaxies.

2. What one can say about TGD based cosmology before the formation of galaxies and stars?

Assuming TGD inspired cosmology, how much can one say about cosmology before the formation of galaxies and stars?

1. The primordial period was dominated by cosmic strings for which string world sheets had 2-dimensional M^4 projection [L62]. Einsteinian space-time emerged locally when the M^4 projection of cosmic strings increased to $D = 4$ in the formation of monopole flux tubes. In this process energy of the cosmic string was transformed to ordinary matter and it involved a serious phase transition. This process is analogous to inflation.

2. If this process indeed led to the formation of galaxies preceded by the formation of quasars, one is forced to ask whether there was any plasma period such that plasma consisting of protons and light nuclei formed by cosmic nucleosynthesis? Was there any period in which plasma consisted of free quarks and leptons? Was there any counterpart of cosmic nucleosynthesis? Was there any counterpart for the formation of neutral atoms leading to the generation of CMB?

3. TGD view of standard model physics

TGD predicts the symmetries of the standard model but the recent TGD based view of standard model physics relies on a very different view of color than the standard model.

1. This view suggests a hierarchy of hadron physics labelled by certain p-adic length scales with increasing mass scales [L50]. Could it be that the transition from cosmic string dominated phase took place as a sequence of phase transitions eventually leading to the ordinary hadron physics [L71].

2. TGD predicts only quarks and leptons and an infinite number of color partial waves in CP_2. This hierarchy of the representations of color groups give rise to an infinite hierarchy of standard model physics with an increasing mass scale [L69, L68]. There were two different phases generalizing the notions of hadronic phase and quark-gluon plasma applying to both leptons and quarks.

   One can speak of the analog of hadronic phase in which fundamental particles as external states of interactions correspond to color partial waves of fundamental fermions (quarks and leptons) in $H = M^4 \times CP_2$. The only light states are color singlets and this prediction follows from the Dirac equation in H [L68]. Colored states had masses of order CP_2 mass (10^{-4} times Planck mass).

   There was also the analog of quark gluon plasma as a phase in which quarks and leptons are massless but there are no gluons. This phase appears in particle interactions which occur as the corresponding Bohr orbit-like space-time surfaces intersect along 2-D string world sheets. String model type description applies to these interactions.

3. This forces us to ask whether cosmic evolution took place as a sequence of phase transitions in which the hadron physics with a given p-adic mass scale made a phase transition to a hadron physics with a lower p-adic mass scale. The conjecture is that preferred p-adic mass scales could correspond to Mersenne primes and the Gaussian counterparts. This process led to the ordinary hadron physics labelled by M_{107}.

   So: was there any cosmic nucleosynthesis? Does the plasma of massless leptons and quarks correspond to the plasma of quarks, gluons and leptons in the standard cosmology? Or do monopole flux tubes replace the plasma in the TGD inspired cosmology? Should one give up the narrative about the first 3 minutes altogether?

vm *4. A new view of stars*

TGD also leads to a new view of stars as monopole flux tube tangles leading to identification of blackhole-like objects as volume filling flux tubes and predicting an entire hierarchy of blackhole-like objects.

1. Solar physics involves a large number of anomalies [L65] serving as a motivation for the new vision inspired by the TGD view of star formation and cosmic evolution. For instance, there is evidence that the surface of the Sun is solid rather than plasma and that the Sun contains water. Could dark variants of ordinary atoms and molecules be in question?

2. The rather radical proposal is that a transition from M_{89} physics to M_{127} would take place in the surface layers of the star and produce solar wind and radiation [L65]. This would be a part of the process which started as a transformation of cosmic strings to monopole flux tubs and continued as a sequence of transitions in which part the energy of the monopole flux tubes transforms to ordinary matter as they thicken the p-adic characterizing them thickens. The classical energy of the flux tube could first transform to M_{89} hadrons which then decay to ordinary hadrons by a p-adic cooling [K21] transforming the p-adic prime $M_{89} = 2^{127} - 1$ to $M_{89} = 2^{127} - 1$ characterizing ordinary hadrons.

3. Second proposal is that energy could be fed as dark energy or as M_{89} hadrons along monopole flux tubes connecting the star, say the Sun, to the galactic center or blackhole. In this picture there is no need to assume that the solar core is a seat of ordinary nuclear fusion.

4. Stars could be metabolizing systems analogous to living systems from a network connected by monopole flux tubes. Metabolic energy feed would make large h_{eff} phases inside stars which would make the number theoretically very complex and perhaps a living, conscious system, an analog of a living cell. Also dark fusion could take place both at the surface and the interior of the Sun.

5.A new view of the formation of planets

TGD suggests a new view of the formation of planets. In the TGD Universe, planets need not to be formed via the gravitational condensation of the planetary disk. The strange fact that Vega has a planetary disk but no planets [L70] gives some support for this guess.

1. The proposal is that mini Big Bangs [L55, L56] exploded layers of the star which then suffered gravitational condensation to planets. Here the dark fusion as TGD counter of "cold fusion" [L5, L25, L67] could have played a key role and generated heavier elements. Dark fusion could have occurred also at the surface of the Sun and created dark variants of the heavier elements. After a mini Big Bang giving rise to the planet, the dark nuclei would have transformed to ordinary nuclei and liberated a lot of energy.

2. If the first 3 minutes narrative is given up, one must challenge also the view about the origin of CMB. One can even imagine that there was no cosmic nucleosynthesis creating a plasma of light charged nuclei in turn forming neutral atoms leading to a decoupling of CMB.

   Nucleons could of course be present. Their density could be determined by thermodynamic considerations. If the chemical potentials vanished, standard model prediction for the densities is true. If the density of nucleons is lower than this density, chemical potentials would also characterize the situation. If the density of nucleons was much smaller than predicted by the standard cosmology, the origin of CMB is far from certain? Could the heavier nuclei have emerged in the formation of galaxies and stars as dark stellar wind transformed nuclei to ordinary nuclei?

3. Recently it was indeed proposed [E3] that CMB could contain a considerable contribution from the period when galaxies and stars formed and radiation decoupled from thermal equilibrium. A second proposal [L65] is that galactic nuclear and stars are enough for nucleosynthesis by a totally different mechanism.

   TGD could explain this contribution [L70]. $t = 500$ My is a very rough estimate for this decoupling time assignable to the formation of galaxies and stars. At that time CMB temperature would have been $T_{CMB} \sim 27$ K. Unfortunately, JWST cannot see at this distance. t could be smaller than the above estimate. The already mentioned JWST observation of the most distant object corresponds to $T_{CMB} = 42$ K, which corresponds to 286 My.

8.2.1 Key ideas of the TGD inspired biology

TGD inspired biology involves several new ideas such as the notion of magnetic/field body, Hagedorn temperature as limiting temperature at flux tubes, dark fusion based on Pollack effect, universal realization of the genetic code, expanding Earth hypothesis suggesting that life evolved in underground oceans [L15] [L54, L53] and plasma life [L52].

X. Hagedorn temperature

Was dark life possible before T=300 K? Did chemical life emerge at this temperature? As already explained, the requirement that basic biomolecules exist excludes the interpretation as CMB temperature $T_{CMB} \sim$ 300 K. This leaves two interpretations. The first interpretation is as Pollack temperature T_P around which Pollack effect [I8, L4, I21, I16] takes place and the second interpretation is as a Hagedorn temperature T_H [**?**] associated with monopole flux tubes.

1. $T \sim 300$ K could correspond to the Hagedorn temperature T_H of the monopole flux tubes. T_H has a profound role in the TGD cosmology [L62] and TGD inspired quantum biology [L78, L80], where the aging could mean the emergence of a thermal equilibrium between the field body and the biological body.

2. At the Pollack temperature T_P, somewhat below T_H, the system is quantum critical against the occurrence of the Pollack effect. T_P could correspond also to the energy difference for the systems -OH and O^-+dark protons at magnetic flux tubes defining the analog of qubit [L64, L73]. Pollack temperature plays a key role in the TGD inspired quantum biology [L4, L9, L57, L24, L58, L52].

T_P could be slightly below T_H as the maximal temperature to which dark fusion as TGD counterpart of "cold fusion" [L10, L5, L25, L67] could raise the temperature of the monopole flux tubes involved. The cyclotron transition energy scale at the field body could also naturally correspond to this energy scale. Indeed, in the TGD view of dark information molecules quantum communications could involve multi-cyclotron resonances [L59]. The identification $T_P \sim T_H \sim 300$ K does not lead to any obvious conflicts and looks physically more plausible.

"Dark life" could have emerged as the planets emerged or could have emerged even in the Sun if the TGD proposal for the physics of the Sun is accepted [L65]. The dark variant of the genetic code, DNA, and proteins at the field body could exist already before this and one could consider plasma life [L52] at the field body of the Sun even before planets existed. Even the field body of the galaxy can be considered as a seat of plasma life.

This suggests that field bodies couple with biological bodies near the Hagedorn temperature T_H slightly above T_P. The coupling would involve cyclotron resonance. At the level of the cell membrane Josephson radiation modulated by the varying membrane potential would give rise to the signals coding biological information [L59].

1. Is the quantum coherence length scale determined by T_H? For $T_H \sim 300$ K, this corresponds to an IR length scale of order cell size. Does $T \leq 300$ K make possible the emergence of cell membrane like structures, Josephson junctions and Pollack effect. Is the ordinary coherence of biomatter forced by quantum coherence at the field body? The size scale of the field body would be determined by T_H. Is the quantum coherence length at the field body obtained from the coherence length at the biological body by scaling it with h_{eff}/h?

2. One can argue that the coupling of field bodies with biological bodies eventually leads to thermal equilibrium and that this means a loss of quantum coherence and death. This would occur very slowly if the temperature T at which this occurs corresponds to Hagedorn temperature. The TGD based model for aging [L80] relies on this.

7. The notions of field body and large h_{eff} phases of ordinary matter as analog of dark matter

The notion of field body distinguishes between TGD and Maxwellian (and also gauge theory view) of classical fields.

1. Field bodies can be both gravitational [L42] and electric [L52] and long range gravitational and electric fields play a key role in the TGD inspired quantum biology. Monopole flux tubes appearing as building bricks of field bodies are very special by their topological stability and exist in all scales. There exists a multitude of miracle-like numerical coincidences supporting the assumption that gravitational field bodies of the Earth, Sun and even galaxy are of special importance. Note that the gravitational field body of the Earth does not exist before the formation of Earth.

   Cells, DNA and the Earth are negatively charged and one can assign electric field bodies to these systems [L52, L61, L3] and they are expected to be very relevant for life in the TGD Universe.

2. Dark matter-like $h_{eff} \geq h$ phases are not the same thing as the galactic dark matter identifiable as TGD analog of dark energy. h_{eff} characterizes the algebraic complexity assignable to polynomials, and even rational and analytic functions with Taylor coefficients in an extension of rationals [L60, L66, L74]. The hierarchy of these extensions gives rise to an evolutionary hierarchy.

This raises interesting questions.

1. Could some field bodies have carried dark life before the emergence of chemical life at the Earth and even the emergence of the Earth? Could the gravitational magnetic body of the Sun have carried dark ions and served as a seat of prebiotic life? Could plasma life at the field body of the Sun take the role of panspermia? There is also the galactic wind: could this make possible prebiotic plasmoid lifeforms in the interstellar space?

2. The notion of plasma life [L52] is inspired by the universal genetic code in terms of hyperbolic 3-geometry [L51]. It involves in an essential way plasma phases consisting of dark ions, at least dark protons.

   TGD suggests a universal mechanism making this kind of system analogous to a hybrid of quantum computer and classical computer and providing a realization of a dark variant of the genetic code [L51, L64]. TGD inspired quantum biology indeed assumes that the dark counterpart of the basic information molecules DNA, RNA, proteins, mRNA are realized at the level of the bodies of the Sun and Earth.

8. Dark fusion

The existence of stars and planets seems to be a prerequisite for the existence of ordinary biochemical life. Dark fusion, as a counterpart of "cold fusion", claimed to occur at room temperature, could have been an essential prerequisite for their formation. This kills $Y = T_{CMB} \sim 300$ K hypothesis. One can also consider alternative, more reasonable hypotheses.

The gravitational condensation leading to the formation of planets would heat the system and could have led to temperature $T \sim 300$ K. This in turn could have led to a formation of dark matter at monopole flux tubes. If the flux tubes with infinite number of degrees of freedom had Hagedron temperature $T_H = 300$ K could be seen as Hagedorn temperature. This could have led to a dark fusion explaining "cold fusion" [L67] and producing various elements and ordinary fusion would not be needed. This could have led also to the formation of living systems via the formation of dark matter transforming them to ordinary matter.

Dark fusion could have occurred even at the surface or interior of the Sun. Dark matter at this temperature could have been generated even in the solar interior and could have made it a living system.

vm *9. Universal realization of genetic code and $h_{eff} \geq h$ phases at field bodies as life forms*

TGD suggests an Universal genetic code realized in terms of the highly unique icosa tetrahedral tessellation of hyperbolic 3-space defined by the light-cone proper time hyperboloid [L51, L31, L14]. This picture leads to a very general communication and control mechanism involving what I call N-resonance involving N simultaneous cyclotron resonances for N-photons analogous to Bose-Einstein condensates. Genetic codons would use to communications 3-resonances and genes 3N-resonances.

Could one imagine a dark counterpart of biochemistry at the field bodies?

1. I have indeed proposed that the fundamental realization of genetic code is in terms of dark counterparts of basic information molecules DNA, RNA, amino acids, and tRNA [L14]. Dark DNA/RNA codon would correspond to entangled dark proton triplet at monopole flux tubes parallel to ordinary DNA/RNA strand. Dark codons could fuse to dark genes as quantum coherent systems.

2. They could communicate with each other by sending the dark photon counterparts of the genes as 3N-photons consisting of dark photon triplets with energies defined as cyclotron transition energies. Also the communication with ordinary information molecules could be possible.

   The receiver characterized by the similar N-codon would receive the message as resonance. The signal would be coded to modulations of the frequency scale and the signal would be coded to a sequence of pulses in the receival.

3. The basic question is whether the field bodies emerged before or after the emergence of biomatter. Long range gravitational and electric fields are needed. This would suggest that the answer is "after". Prebiotic life could have emerged before the emergence of planets at the field body of the Sun and even before the emergence of the Sun at the field body of the galaxy.

10 .Expanding Earth hypothesis, Pollack effect, and plasma life

Pollack effect, the notion of plasma life, and Expanding Earth hypothesis are key elements of the TGD based view of living systems.

1. Pollack effect.

   Pollack effect and its reversal make it possible to transfer matter between biological and field bodies.

   Pollack effect [I8, L4, I21, I16] and its reversal are in a key role in the TGD inspired quantum biology [L9, L57, L24, L58, L52]. For the basic form of the Pollack effect both the Earth and the Sun and the presence of ordinary water are necessary. Pollack effect does not make sense in absence of stars and planets. As proposed, Pollack temperature could be near the Hagedorn temperature for gravitational monopole flux tubes. At the level of chemistry, the Pollack effect would naturally correspond to the flip of a topological qubit having as its bit values OH and O^- + dark proton [L64] and this means that it has many generalizations.

2. Plasma life as a predecessor of the chemical life.

   The findings of NASA [**?**] (see this) inspire the proposal that plasma life obeying a dark variant of genetic code evolved in the ionosphere of the Earth [L52, L58] and migrated to the Earth.

   There are several interesting questions to be answered. Did the plasma life emerge at the field body of the Sun already before the formation of the Earth and transform to ordinary life after the mini Big Bang creating the Earth? Also the notion of quartz life could make sense [L64, L58]: how could it relate to plasma life in the ionosphere and to biological life?

3. Expanding Earth hypothesis.

   TGD also leads to a proposal that the chemical life evolved in the underground oceans [L54, L53]. Did biolife emerge after the emergence of planets or before this in the interstellar plasma? There is a long list of questions to be answered.

   (a) Were the dark protons and ions formed by dark fusion already at the surface of the Sun and gave rise to plasma life at the field body of the Sun. Was the Earth formed in a mini Big Bang for the Sun throwing out a layer which gravitationally condensed to form the Earth?

   (b) How Expanding Earth hypothesis and plasma life hypothesis could relate? How the plasma life in the monopole flux tubes was transformed to life in underground oceans? Did the dark ions end up in the Earth's interior along monopole flux tubes?

8.2.2 Basic ingredients of life found in conditions prevailing in the early universe

Using the James Webb Space Telescope, astronomers have detected complex organic molecules frozen in ice around a baby star called ST6, located in the Large Magellanic Cloud, a neighboring galaxy about 160,000 light-years away (see). There is an article [E2] about the finding by Sewilo M. et al, with title "Protostars at Subsolar Metallicity: First Detection of Large Solid-State Complex Organic Molecules in the Large Magellanic Cloud", published in Astrophysical Journal Letters (see this).

Molecules like methanol, ethanol, acetaldehyde, methyl formate, and even acetic acid the key ingredient of vinegar were locked inside cosmic ice. These chemicals belong to the molecules that help kick-start chemistry needed for life. Until now, finding them in solid ice was incredibly rare, even inside our own galaxy.

The Large Magellanic Cloud is a harsh place. It has fewer heavy elements and stronger radiation conditions similar to the early universe, long before planets like Earth existed. Despite this complex organic chemistry is possible there. Does this mean that the ingredients for life don t need perfect conditions or that there is new physics involved? Even more, is this new physics universal.

It is very difficult to imagine how a complex biochemistry (biochemistry as we understand it) could have prevailed much before planets like Earth did exist. New physics seems to be required and TGD predicts it. The notion of a field body (field-/magnetic body) carrying large h_{eff} phases of ordinary matter [L44, L77, L42, L52, L76] could explain how the organic molecules crucial for life could have formed in these circumstances.

1. Water is a key element of life in TGD inspired quantum biology. Therefore the fact that the molecules were inside ice is a valuable hint. Pollack effect [L76] occurs when water is irradiated with, say, infrared photons arriving from the Sun or some other source now the protostar. Pollack effect generates negatively charged regions, Exclusion Zones (EZs) with rather strange properties such as the ability to kick out impurities, which seems to be in conflict with the second law of thermodynamics.

   Protons must go somewhere from the EZ and the TGD inspired proposal is that they go to the magnetic body of the system and form a large h_{eff} phase, in many cases behaving like dark matter. These phases are not however identifiable as galactic dark matter. h_{eff} serves as a measure for the algebraic complexity of the space-time surface and also for the level of conscious intelligence, a kind of universal IQ. The magnetic body naturally controls the physics of ordinary matter.

   What matters is the energy needed to kick ordinary protons to the magnetic body: the needed energy corresponds to the energy difference between $-OH$ and O^- + dark protons in the magnetic body. These two states of proton are proposed to define what might be regarded as a universal topological qubit [L42, L52, L64]). Also the formation of organic molecules as bound states liberates binding energy and can induce the generalized Pollack effect.

2. The formation of dark protons at the magnetic body of water could represent one of the first steps in the evolution of life and already at this stage the dark analogs of the basic information molecules, genetic code and metabolism could have emerged. The chemical realization of the genetic code would have emerged later.

Could the Pollack effect and the notion of magnetic body allow us to understand the formation of the basic molecules of life found to exist in the Magellanic Cloud. -OH group, appearing also in water molecules, is essential for the standard form of Pollack effect so that it could be important also now. Pollack effect has also a generalization [L52, L46, L64] in which the formation of bound state of atoms would involve the emission of the binding energy as visible or UV photons, which could kick protons or even alkali ions to the magnetic body and generate negatively charged EZs. The wildest dream is that the generalized Pollack effect gives rise to the basic organic molecules of life.

Consider next the possible role of the ordinary Pollack effect.

1. Complex alcohols can contain more than one -OH group bound to a saturated Carbon atom. Simple alcohols (see this) obey the formula $H-(CH_2)_n-OH$. Both methanol $(CH_3)-OH$ and ethanol $(CH_3)-(CH_2)-OH$ contain the -OH group so that Pollack effect is possible for them and could explain the special effects of alcohol on consciousness. Note that methane CH_4 emerges from the decompositions of organic materials.

2. Acetaldehyde $(CH_3)-(H-C=O)$ can be formed by a partial oxidation of ethanol in an exothermic reaction at temperatures 500-650 C. The reaction equation for the condensation of acetaldehyde and O_2 is $2\ (CH_3)-(CH_2)-OH+O_2 \rightarrow 2(CH_3)-(H-C=O)+2H_2O$.

   One can imagine the following sketch for what might happen. At the first step the protons of $-OH$ groups of ethanols are kicked to dark protons at the magnetic body. This would induce the transformation of $C-O$ bonds to $C=O$ bonds, forcing C to give up the second H atom of CH_2. The dark protons would drop back to ordinary protons and together with electrons and the two H atoms and oxygens of O_2 would form 2 water molecules.

3. Methyl formate $(CH_3)-(O=C-OH)$ can be produced in the condensation reaction $(CH_3)-OH+H-(O=C-OH) \rightarrow CH_3)-(O=C-OH)+H_2O$ of methanol $(CH_3)-OH$ and formic acid $H-(O=C-OH)$. Dehydration is involved.

   OH group must be replaced with $O=C-OH$ in the reaction. One can imagine that the proton of $-OH$ is temporarily transformed to a dark proton at the magnetic body and facilitates the replacement. After that the dark proton, O^- and $H-$ of $H-(O=C-OH)$ combine to form the water molecule.

4. Acetic acid $(CH_3)-(O=C-OH)$ is formed by the transformation $H_2 \rightarrow = O$ occurring in the condensation reaction of ethanol and oxygen as $(CH_3)-(CH_2)-OH+O_2 \rightarrow (CH_3)-(O=C-OH)+H_2O$ involving dehydration. Also now the proton of $-OH$ could transform to a dark proton. This should induce replacement $CH_2 \rightarrow C=O$, the splitting of O_2 and the formation of H_2O. The dark proton would drop back and $-OH$ would be regenerated.

Could the detected molecules allow us to conclude anything about the presence of more complex biomolecules such as sugars and riboses crucial for life?

1. Sugars or carbohydrates (see this), involve monosaccharides with formula $C_nH_{2n}O_n$, with n in the range 5 to 7, have a key role in metabolism. They contain a relatively large number of -OH groups associated with an aromatic ring. For $C_6H_{12}O_6$ (fructose, galactose, glucose) have 4 -OH groups. Yeasts break down fructose, galactose and glucose to ethanol in alcoholic fermentation. More generally, alcohols such as mannitol emerge in the reduction of saccharides.

2. TGD suggests that the metabolic energy liberated as sugars burn to alcohols involves the transfer of dark protons to the magnetic bodies of the acceptor molecules followed by their transformation to ordinary protons liberating the metabolic energy. This would occur in the $ADP \rightarrow ATP$ process.

3. Ribose $C_5H_{10}O_5$ (see this), appearing in RNA, contains 4 -OH groups and deoxyribose $C_5H_{10}O_4$ appearing in DNA contains 3 -OH groups. Phosphorylated ribose appears in ADP, ATP, coenzyme A and NADH.

   Biological and chemical reduction and fermentation can produce ribitol $C_5H_{12}O_5$, which is a sugar alcohol. When ribitol is subjected to hydroxyl radicals, $C-C$ bonds are cleavaged and formic acid $((H-C=O)-(OH))$ appears as a decay product. Methanol was detected: could formic acid transform to methanol $((CH_3)-(OH))$ in the presence of water by the reaction $(H-C=O)-(OH)+H_2O \rightarrow (CH_3)-(OH)+O_2$?

To conclude, the temporary transformation of proton to dark proton at the magnetic body by Pollack effect could be involved with all these reactions. The molecules themselves could be generated by a generalized Pollack effect.

9 Appendix: Basic facts about cilia and flagella

Intermediate filaments, actins and microtubules (MTs) are basic structures of cytoskeleton. MTs are associated with centrosome, cell membrane protrusions known as cilia, flagella, and axons (`https://cutt.ly/FDnfEVP`). Axonal MTs and part of MTs in the cell interior are dynamical and have a varying length. Actins are protrusions of the plasma membrane protrusions known as microvilli (`https://cutt.ly/HDRaxxf`) are analogous to cilia.

Cilia, flagella, axons, and microvilli are involved with motor activities of some kind. In the case of MTs and actins, contractions and lengthenings define the basic element of dynamics. Actin dynamics relates to the gross motion of the cell. The dynamics of axonal MTs might also relate to the nerve pulse conduction. Axonal MTs are not organized into regular structures like the other MTs.

Motile cilia and flagella are precedessors of muscles and motor system. Primary cilia function as antennas and act as mechanical, chemical, and thermal sensory organs.

9.1 Structure and function of cilia

Cilia start from the basal body. One can distinguish between primary and motile cilia (`https://cutt.ly/IDnfKAB`). Unlike motile cilia, primary cilia do not beat and dynein arms and other structures needed for motion are missing. These cilia act as antennas and sensory receptors. All sensory cells have cilia playing the same role so that cilia could be seen as cellular sensory and motor organs.

1. Cilium is a cylindrical protuberance of the plasma membrane. Its radius is about .1 μ m to be compared with axonal radius radius about .25 mum. The length of cilium varies in the range 1-30 μm.

2. Inside cilium is its cytoskeleton known as axoneme. For motile cilia the MTs of the axoneme have 9+2 structure and for primary cilia they have 9+0 structure. For the basal bodies the structure consists of a ring of 9 MT triplets without central MTs. Vertebrates can also have other types of cilia.

3. The 9 pairs of the ring are partially overlapping, which makes it possible for them to glide with respect to each other: this induces the bending of the motile cilium. The tubulins of these pairs are horizontally connected by nexin bonds to form a ring-like structure. Radial spokes and outer and inner dynein arms force the gliding motion.

   The pairs or rings consist of two kinds of MTs. The MT of type A has 13 tubulin protofilaments and MT of type B has 10 protofilaments. In motile cilia and flagella, structures essential for motility, such as axonemal dyneins, radial spokes, and the nexin dynein regulatory complex (N-DRC), are arranged on DMTs with a 96-nm repeating unit.

4. The members of the central pair are non-overlapping MTs connected by a bridge. The center MTs are involved with the control of the ciliary motion induced by the gliding.

   Stabilization of cilia MTs is by inner lumen proteins. The structure and protein composition of motile cilia and flagella are well conserved among eukaryotes.

9.2 Beating waves

Cilia and flagella have similar structures and only their functions differ. Cilia force liquid to move with respect to the cell. Flagella make it possible for the cell to move with respect to liquid (`https://cutt.ly/TDngqh0`). The force needed for cilia beating is produced by the outer and inner dynein arms of the axonemal microtubule doublets connected to the central pair of microtubules by radial spokes. Airway cilia have components typical for motile cilia.

1. Motile cilia and flagella beat in a synchronized pattern. This coordination is achieved by metachronal rhythm, in which a wave of simultaneously beating groups of cilia moves from the anterior to the posterior end of the organism. The motions of cilia along the cell surface have different phases so that the motion looks like a wave: mexican wave (`https://cutt.ly/iDRUehV`) is a good example of this. The waves in the crop field induced by wind serve as a good example.

2. The cilia on the same line perpendicular to the direction of the effective stroke are synchronized and thus have the same phase, and adjacent rows of cilia parallel to the direction of the effective stroke beat with a phase difference.

   Beating corresponds to a contraction wave and here the dynein arms are in an essential role. Orientation, beating frequency, wavelength, amplitude parametrize the motion of cilium.

3. Waves begin from cilia rather than the basal body so that the obvious idea that the cell would initiate the motion, need not be correct. Various wave forms such as plane waves and non-symmetric waves cause the bending.

4. The beating frequency varies in EEG range, which need not be an accident. Some sources report beating frequencies in the range 4-10 Hz. Some sources report 20-60 Hz frequency (`https://cutt.ly/uDngfy0`).

REFERENCES

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`.

[E2] Sevilo M et al. Protostars at Subsolar Metallicity: First Detection of Large Solid-state Complex Organic Molecules in the Large Magellanic Cloud. *Astrophysical Journal Letters*, 992(2), 2025. Available at: https://iopscience.iop.org/article/10.3847/2041-8213/ae0ccd.

[E3] Kroupa P Gjergo E. The impact of early massive galaxy formation on the cosmic microwave bckground, 2025. Available at: https://arxiv.org/abs/2505.04687.

Biology

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

[I2] Adamatsky A. Language of fungi derived from electrical spiking activity, 2022. Available at: https://arxiv.org/pdf/2112.09907.pdf.

[I3] Dutcher SK Bayly PV Bottier M, Thomas KA. How Does Cilium Length Affect Beating? *Biophysical Journal*, 116(7), 2019. Available at: https://www.sciencedirect.com/science/article/pii/S0006349519301390.

[I4] Woodbury DJ. Pure lipid vesicles can induce channel-like conductances in planar bilayers., 1989.

[I5] Elhakeem A et al. Aboveground mechanical stimuli affect belowground plant-plant communication. *PLOS ONE*, 2018. Avaiable at: https://doi.org/10.1371/journal.pone.0195646 .

[I6] Korolev N et al. Competitive Binding of Mg2+, Ca2+, Na+, and K+ Ions to DNA in Oriented DNA Fibers: Experimental and Monte Carlo Simulation. *Biophysical Journal*, 77(5):2736–2749, 1999. Available at: https://doi.org/10.1016/S0006-3495(99)77107-9.

[I7] Lev AA et al. Rapid switching of ion current in narrow pores: implications for biological ion channels. *Proc R Soc London. Series B: Biological Sci s*, pages 187–192, 1993.

[I8] Pollack G. *Cells, Gels and the Engines of Life*. Ebner and Sons, 2000. Available at: https://www.cellsandgels.com/.

[I9] Pollack G. *Cells, Gels and the Engines of Life*. Ebner and Sons, 2000. Available at: https://www.cellsandgels.com/.

[I10] Ling GN. *A physical theory of the living state: the association-induction hypothesis; with considerations of the mechanics involved in ionic specificity*. Blaisdell Pub. Co., New York, 1962.

[I11] Burgos JE. Is a nervous system necessary for learning? *Perspect Behav Sci*, 41(2):343–368, 2018. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6701508/.

[I12] Hopkin M. *Nature*, 2008. Available at: https://www.nature.com/articles/news.2007.360.

[I13] Prakash M MS. Mobile defects born from an energy cascade shape the locomotive behavior of a headless animal, 2021. Available at: https://arxiv.org/abs/2107.02940.

[I14] Prakash M MS, Kroo LA. Excitable mechanics embodied in a walking cilium, 2021. Available at: https://arxiv.org/abs/2107.02930.

[I15] Prakash M MS, Prakash VN. Ciliary flocking and emergent instabilities enable collective agility in a non-neuromuscular animal, 2021. Available at: https://arxiv.org/abs/2107.02934.

[I16] 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.

[I17] Qin F Sachs F. Gated, ion-selective channels observed with patch pipettes in the absence of membranes: novel properties of a gigaseal. *Biophys J*, pages 1101–1107, 1993.

[I18] Gould SJ. *Wonderful Life*. Penguin Books, 1991.

[I19] Vergara C Villar PS and Bacigalupo J. Energy sources that fuel metabolic processes in protruding finger-like organelles. *FEBS Journal*, 2020. Available at: https://doi.org/10.1111/febs.15620.

[I20] Harris D Wang D, Fiebig OC and Schlau-Cohen GS. Elucidating interprotein energy transfer dynamics within the antenna network from purple bacteria. *PNAS*, 120((28)e2220477120), 2023. Available at: https://doi.org/10.1073/pnas.222047712. .

[I21] 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] Blackman CF. *Effect of Electrical and Magnetic Fields on the Nervous System*, pages 331–355. Plenum, New York, 1994.

[J2] Fingelkurts A et al. Consciousness as a phenomenon in the operational architectonics of brain organization: Critality and self-organization considerations. *Chaos, Solitons & Fractals*, 2013. Available at: https://dx.doi.org/10.1016/locate/j.chaos.2013.02.007.

[J3] Green JA and Mykytyn K. Neuronal primary cilia: An underappreciated signaling and sensory organelle in the brain. *Neuropsychopharmacology*, 39(1):244–245, 2013. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3857650/.

[J4] Lee JE Ki SM, Jeong HS. Cilia in glial cells: An oasis in the journey to overcoming neurodegenerative diseases. *Diseases Front. Neurosci.*, pages 716–725, 2021. Available at: https://doi.org/10.3389/fnins.2021.736888.

[J5] Fisher MPA. Quantum Cognition: The possibility of processing with nuclear spins in the brain), 2015. Available at: https://arxiv.org/abs/1508.05929.

[J6] Istvan Bokkon I Rahnama M, Tuszynski JA. Emission of Mitochondrial Biophotons and their Effect on Electrical Activity of Membrane via Microtubules. *Journal of Integrative Neuroscience*, 10(1):65–88, 2011. Available at: https://dx.doi.org/10.1142/S0219635211002622.

[J7] Giaume C Scenes E. Astrocyte calcium waves: What they are and what they do? *Glia*, 54(7):716–725, 2006. Available at: https://doi.org/10.1002/glia.20374.

[J8] Fisher MPA Swift MW and Van de Walle CG. Posner molecules: From atomic structure to nuclear spins, 2017. Available at: https://arxiv.org/pdf/1711.05899.pdf.

Books related to TGD

[K1] Pitkänen M. DNA as Topological Quantum Computer. In *Quantum - and Classical Computation in TGD Universe. https://tgdtheory.fi/tgdhtml/Btgdcomp.html*. Available at: https://tgdtheory.fi/pdfpool/dnatqc.pdf, 2015.

[K2] Pitkänen M. Topological Quantum Computation in TGD Universe. In *Quantum - and Classical Computation in TGD Universe. https://tgdtheory.fi/tgdhtml/Btgdcomp.html*. Available at: https://tgdtheory.fi/pdfpool/tqc.pdf, 2015.

[K3] Pitkänen M. About TGD based view of neuron. In *TGD and EEG: Part I. https://tgdtheory.fi/tgdhtml/Btgdeeg1.html*. Available at: https://tgdtheory.fi/pdfpool/TGDneuron.pdf, 2021.

[K4] Pitkänen M. About Preferred Extremals of Kähler Action. In *Physics in Many-Sheeted Space-Time: Part I. https://tgdtheory.fi/tgdhtml/Btgdclass1.html*. Available at: https://tgdtheory.fi/pdfpool/prext.pdf, 2023.

[K5] Pitkänen M. Are dark photons behind biophotons? In *TGD and Quantum Biology: Part I. https://tgdtheory.fi/tgdhtml/Bqbio1.html*. Available at: https://tgdtheory.fi/pdfpool/biophotonslian.pdf, 2023.

[K6] Pitkänen M. Basic Extremals of Kähler Action. In *Physics in Many-Sheeted Space-Time: Part I. https://tgdtheory.fi/tgdhtml/Btgdclass1.html*. Available at: https://tgdtheory.fi/pdfpool/class.pdf, 2023.

[K7] Pitkänen M. Comments on the recent experiments by the group of Michael Persinger. In *TGD and EEG: Part I. https://tgdtheory.fi/tgdhtml/Btgdeeg1.html*. Available at: https://tgdtheory.fi/pdfpool/persconsc.pdf, 2023.

[K8] Pitkänen M. Construction of WCW Kähler Geometry from Symmetry Principles. In *Quantum Physics as Infinite-Dimensional Geometry. https://tgdtheory.fi/tgdhtml/Btgdgeom.html*. Available at: https://tgdtheory.fi/pdfpool/compl1.pdf, 2023.

[K9] Pitkänen M. Cosmic string model for the formation of galaxies and stars. Available at: https://tgdtheory.fi/pdfpool/galaxystars.pdf, 2023.

[K10] 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.

[K11] 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.

[K12] 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.

[K13] 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.

[K14] Pitkänen M. Crop Circles and Life at Parallel Space-Time Sheets. In *Magnetospheric Consciousness. https://tgdtheory.fi/tgdhtml/Bmagnconsc.html*. Available at: https://tgdtheory.fi/pdfpool/crop1.pdf, 2023.

[K15] Pitkänen M. Crop Circles and Life at Parallel Space-Time Sheets. In *Magnetospheric Consciousness. https://tgdtheory.fi/tgdhtml/Bmagnconsc.html*. Available at: https://tgdtheory.fi/pdfpool/crop2.pdf, 2023.

[K16] Pitkänen M. Dark Matter Hierarchy and Hierarchy of EEGs. In *TGD and EEG: Part I. https://tgdtheory.fi/tgdhtml/Btgdeeg1.html*. Available at: https://tgdtheory.fi/pdfpool/eegdark.pdf, 2023.

[K17] Pitkänen M. Expanding Earth Model and Pre-Cambrian Evolution of Continents, Climate, and Life. In *Physics in Many-Sheeted Space-Time: Part I. https://tgdtheory.fi/tgdhtml/Btgdclass1.html*. Available at: https://tgdtheory.fi/pdfpool/expearth.pdf., 2023.

[K18] 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.

[K19] Pitkänen M. Homeopathy in Many-Sheeted Space-Time. In *TGD Universe as a Conscious Hologram. https://tgdtheory.fi/tgdhtml/Bholography.html*. Available at: https://tgdtheory.fi/pdfpool/homeoc.pdf, 2023.

[K20] Pitkänen M. Identification of the WCW Kähler Function. In *Quantum Physics as Infinite-Dimensional Geometry. https://tgdtheory.fi/tgdhtml/Btgdgeom.html*. Available at: https://tgdtheory.fi/pdfpool/kahler.pdf., 2023.

[K21] Pitkänen M. New Physics Predicted by TGD: Part I. In *p-Adic Physics. https://tgdtheory.fi/tgdhtml/Bpadphys.html*. Available at: https://tgdtheory.fi/pdfpool/TGDnewphys1.pdf, 2023.

[K22] Pitkänen M. New Physics Predicted by TGD: Part II. In *p-Adic Physics. https://tgdtheory.fi/tgdhtml/Bpadphys.html*. Available at: https://tgdtheory.fi/pdfpool/TGDnewphys2.pdf, 2023.

[K23] Pitkänen M. Nuclear String Hypothesis. In *TGD and Nuclear Physics. https://tgdtheory.fi/tgdhtml/Bnucl.html*. Available at: https://tgdtheory.fi/pdfpool/nuclstring.pdf, 2023.

[K24] Pitkänen M. Quantum Antenna Hypothesis. In *Bio-Systems as Self-Organizing Quantum Systems. https://tgdtheory.fi/tgdhtml/BbioSO.html*. Available at: https://tgdtheory.fi/pdfpool/tubuc.pdf, 2023.

[K25] Pitkänen M. Quantum Astrophysics. In *Physics in Many-Sheeted Space-Time: Part II. https://tgdtheory.fi/tgdhtml/Btgdclass2.html*. Available at: https://tgdtheory.fi/pdfpool/qastro.pdf, 2023.

[K26] 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.

[K27] Pitkänen M. Quantum Model for Bio-Superconductivity: II. In *TGD and Quantum Biology: Part I. https://tgdtheory.fi/tgdhtml/Bqbio1.html*. Available at: https://tgdtheory.fi/pdfpool/biosupercondII.pdf, 2023.

[K28] 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.

[K29] Pitkänen M. Quantum Model of EEG. In *TGD and EEG: Part I. https://tgdtheory.fi/tgdhtml/Btgdeeg1.html*. Available at: https://tgdtheory.fi/pdfpool/eegII.pdf, 2023.

[K30] Pitkänen M. Recent View about Kähler Geometry and Spin Structure of WCW . In *Quantum Physics as Infinite-Dimensional Geometry. https://tgdtheory.fi/tgdhtml/Btgdgeom.html*. Available at: https://tgdtheory.fi/pdfpool/wcwnew.pdf, 2023.

[K31] Pitkänen M. TGD and Astrophysics. In *Physics in Many-Sheeted Space-Time: Part II. https://tgdtheory.fi/tgdhtml/Btgdclass2.html*. Available at: https://tgdtheory.fi/pdfpool/astro.pdf, 2023.

[K32] Pitkänen M. Three new physics realizations of the genetic code and the role of dark matter in bio-systems. In *Genes and Memes: Part II. https://tgdtheory.fi/tgdhtml/Bgenememe2.html*. Available at: https://tgdtheory.fi/pdfpool/dnatqccodes.pdf, 2023.

[K33] Pitkänen M. Why TGD and What TGD is? In *Topological Geometrodynamics: an Overview. https://tgdtheory.fi/tgdhtml/Btgdview1.html*. Available at: https://tgdtheory.fi/pdfpool/WhyTGD.pdf, 2023.

[K34] Pitkänen M. Zero Energy Ontology. In *Quantum TGD: Part I. https://tgdtheory.fi/tgdhtml/Btgdquantum1.html*. Available at: https://tgdtheory.fi/pdfpool/ZEO.pdf, 2023.

[K35] Pitkänen M. and Rastmanesh R. New Physics View about Language. In *Genes and Memes: Part II. https://tgdtheory.fi/tgdhtml/genememe2.html*. Available at: https://tgdtheory.fi/pdfpool/languageTGD.pdf, 2020.

Articles about TGD

[L1] Pitkänen M. Commentary on "Consciousness as a phenomenon in the operational architectonics of brain organization: Criticality and self-organization considerations" by Adrew A. Fingelkurts, Alexander A. Fingelkurts, and Carlos F. H. Neves. Available at: https://tgdtheory.fi/public_html/articles/Fingelkurts.pdf., 2013.

[L2] Pitkänen M. Geometric theory of harmony. Available at: https://tgdtheory.fi/public_html/articles/harmonytheory.pdf., 2014.

[L3] Pitkänen M. New results about microtubules as quantum systems. Available at: https://tgdtheory.fi/public_html/articles/microtubule.pdf., 2014.

[L4] Pitkänen M. Pollack's Findings about Fourth phase of Water : TGD View. Available at: https://tgdtheory.fi/public_html/articles/PollackYoutube.pdf., 2014.

[L5] Pitkänen M. Cold Fusion Again . Available at: https://tgdtheory.fi/public_html/articles/cfagain.pdf., 2015.

[L6] Pitkänen M. Are lithium, phosphate, and Posner molecule fundamental for quantum biology? Available at: https://tgdtheory.fi/public_html/articles/fisherP.pdf., 2016.

[L7] Pitkänen M. Could Pollack effect make cell membrane a self-loading battery? Available at: https://tgdtheory.fi/public_html/articles/cfbattery.pdf., 2016.

[L8] Pitkänen M. Hydrinos again. Available at: https://tgdtheory.fi/public_html/articles/Millsagain.pdf., 2016.

[L9] Pitkänen M. Pollack's mechanism and photosynthesis. Available at: https://tgdtheory.fi/public_html/articles/pollackphoto.pdf., 2016.

[L10] Pitkänen M. Cold fusion, low energy nuclear reactions, or dark nuclear synthesis? Available at: https://tgdtheory.fi/public_html/articles/krivit.pdf., 2017.

[L11] Pitkänen M. Does valence bond theory relate to the hierarchy of Planck constants? Available at: https://tgdtheory.fi/public_html/articles/valenceheff.pdf., 2017.

[L12] Pitkänen M. Philosophy of Adelic Physics. In *Trends and Mathematical Methods in Interdisciplinary Mathematical Sciences*, pages 241–319. Springer.Available at: https://link.springer.com/chapter/10.1007/978-3-319-55612-3_11, 2017.

[L13] Pitkänen M. Philosophy of Adelic Physics. Available at: https://tgdtheory.fi/public_html/articles/adelephysics.pdf., 2017.

[L14] Pitkänen M. About the Correspondence of Dark Nuclear Genetic Code and Ordinary Genetic Code. Available at: https://tgdtheory.fi/public_html/articles/codedarkcode.pdf., 2018.

[L15] Pitkänen M. Expanding Earth Model and Pre-Cambrian Evolution of Continents, Climate, and Life. Available at: https://tgdtheory.fi/public_html/articles/expearth.pdf., 2018.

[L16] Pitkänen M. Getting philosophical: some comments about the problems of physics, neuroscience, and biology. Available at: https://tgdtheory.fi/public_html/articles/philosophic.pdf., 2018.

[L17] Pitkänen M. Copenhagen interpretation dead: long live ZEO based quantum measurement theory! Available at: https://tgdtheory.fi/public_html/articles/Bohrdead.pdf., 2019.

[L18] Pitkänen M. Cosmic string model for the formation of galaxies and stars. Available at: https://tgdtheory.fi/public_html/articles/galaxystars.pdf., 2019.

[L19] Pitkänen M. Epigenesis, inherited memories and moods lasting over several generations. Available at: https://tgdtheory.fi/public_html/articles/amoebamemory.pdf., 2019.

[L20] Pitkänen M. Solar Metallicity Problem from TGD Perspective. Available at: https://tgdtheory.fi/public_html/articles/darkcore.pdf., 2019.

[L21] Pitkänen M. Some comments related to Zero Energy Ontology (ZEO). Available at: https://tgdtheory.fi/public_html/articles/zeoquestions.pdf., 2019.

[L22] Pitkänen M. A critical re-examination of $M^8 - H$ duality hypothesis: part I. Available at: https://tgdtheory.fi/public_html/articles/M8H1.pdf., 2020.

[L23] Pitkänen M. A critical re-examination of $M^8 - H$ duality hypothesis: part II. Available at: https://tgdtheory.fi/public_html/articles/M8H2.pdf., 2020.

[L24] Pitkänen M. A model of protocell based on Pollack effect. Available at: https://tgdtheory.fi/public_html/articles/pollackoparin.pdf., 2020.

[L25] Pitkänen M. Could TGD provide new solutions to the energy problem? Available at: https://tgdtheory.fi/public_html/articles/proposal.pdf., 2020.

[L26] Pitkänen M. How to compose beautiful music of light in bio-harmony? https://tgdtheory.fi/public_html/articles/bioharmony2020.pdf., 2020.

[L27] Pitkänen M. A TGD based view about neuron. https://tgdtheory.fi/public_html/articles/TGDneuron.pdf., 2021.

[L28] Pitkänen M. Does Consciousness Survive Bodily Death? https://tgdtheory.fi/public_html/articles/BICS.pdf., 2021.

[L29] Pitkänen M. EEG and the structure of magnetosphere. https://tgdtheory.fi/public_html/articles/mseeg.pdf., 2021.

[L30] Pitkänen M. Empirical support for the Expanding Earth Model and TGD view about classical gauge fields. https://tgdtheory.fi/public_html/articles/expearthnewest.pdf., 2021.

[L31] Pitkänen M. Is genetic code part of fundamental physics in TGD framework? Available at: https://tgdtheory.fi/public_html/articles/TIH.pdf., 2021.

[L32] Pitkänen M. Questions about coupling constant evolution. https://tgdtheory.fi/public_html/articles/ccheff.pdf., 2021.

[L33] Pitkänen M. Some questions concerning zero energy ontology. https://tgdtheory.fi/public_html/articles/zeonew.pdf., 2021.

[L34] Pitkänen M. TGD and Quantum Hydrodynamics. https://tgdtheory.fi/public_html/articles/TGDhydro.pdf., 2021.

[L35] Pitkänen M. TGD as it is towards the end of 2021. https://tgdtheory.fi/public_html/articles/TGD2021.pdf., 2021.

[L36] Pitkänen M. TGD view of the engine powering jets from active galactic nuclei. https://tgdtheory.fi/public_html/articles/galjets.pdf., 2021.

[L37] Pitkänen M. Time reversal and the anomalies of rotating magnetic systems. Available at: https://tgdtheory.fi/public_html/articles/freereverse.pdf., 2021.

[L38] Pitkänen M. Updated version of Expanding Earth model. https://tgdtheory.fi/public_html/articles/expearth2021.pdf., 2021.

[L39] Pitkänen M. What could 2-D minimal surfaces teach about TGD? https://tgdtheory.fi/public_html/articles/minimal.pdf., 2021.

[L40] Pitkänen M. About TGD counterparts of twistor amplitudes: part II. https://tgdtheory.fi/public_html/articles/twisttgd2.pdf., 2022.

[L41] Pitkänen M. About the number theoretic aspects of zero energy ontology. https://tgdtheory.fi/public_html/articles/ZEOnumber.pdf., 2022.

[L42] Pitkänen M. Comparison of Orch-OR hypothesis with the TGD point of view. https://tgdtheory.fi/public_html/articles/penrose.pdf., 2022.

[L43] Pitkänen M. Hen and egg problems of biology from TGD point of view. https://tgdtheory.fi/public_html/articles/henegg.pdf., 2022.

[L44] Pitkänen M. How animals without brain can behave as if they had brain. https://tgdtheory.fi/public_html/articles/precns.pdf., 2022.

[L45] Pitkänen M. Molecular signalling from the TGD point of view. https://tgdtheory.fi/public_html/articles/molesign.pdf., 2022.

[L46] Pitkänen M. Mysteries associated with lightnings, ball lightnings and the electrosphere of Earth. https://tgdtheory.fi/public_html/articles/balllight.pdf., 2022.

[L47] Pitkänen M. TGD view about water memory and the notion of morphogenetic field . https://tgdtheory.fi/public_html/articles/watermorpho.pdf., 2022.

[L48] Pitkänen M. The realization of genetic code in terms of dark nucleon and dark photon triplets. https://tgdtheory.fi/public_html/articles/darkcode.pdf., 2022.

[L49] Pitkänen M. Trying to fuse the basic mathematical ideas of quantum TGD to a single coherent whole. https://tgdtheory.fi/public_html/articles/fusionTGD.pdf., 2022.

[L50] Pitkänen M. Two objections against p-adic thermodynamics and their resolution. https://tgdtheory.fi/public_html/articles/padmass2022.pdf., 2022.

[L51] Pitkänen M. About tessellations in hyperbolic 3-space and their relation to the genetic code . https://tgdtheory.fi/public_html/articles/tessellationH3.pdf., 2023.

[L52] Pitkänen M. About long range electromagnetic quantum coherence in TGD Universe. https://tgdtheory.fi/public_html/articles/hem.pdf., 2023.

[L53] Pitkänen M. Empirical Support for Expanding Earth Hypothesis. https://tgdtheory.fi/public_html/articles/preCEagain.pdf., 2023.

[L54] Pitkänen M. Expanding Earth Hypothesis and Pre-Cambrian Earth. https://tgdtheory.fi/public_html/articles/preCE.pdf., 2023.

[L55] Pitkänen M. Magnetic Bubbles in TGD Universe: Part I. https://tgdtheory.fi/public_html/articles/magnbubble1.pdf., 2023.

[L56] Pitkänen M. Magnetic Bubbles in TGD Universe: Part II. https://tgdtheory.fi/public_html/articles/magnbubble2.pdf., 2023.

[L57] Pitkänen M. Pollack Effect and Some Anomalies of Water. https://tgdtheory.fi/public_html/articles/pollackwater.pdf., 2023.

[L58] Pitkänen M. Pollack effect, lightnings and ball lightnings. https://tgdtheory.fi/public_html/articles/balllightning.pdf., 2023.

[L59] Pitkänen M. Some new aspects of the TGD inspired model of the nerve pulse . https://tgdtheory.fi/public_html/articles/np2023.pdf., 2023.

[L60] Pitkänen M. About Langlands correspondence in the TGD framework. https://tgdtheory.fi/public_html/articles/Frenkel.pdf., 2024.

[L61] Pitkänen M. About the Biefeld Brown effect. https://tgdtheory.fi/public_html/articles/BB.pdf., 2024.

[L62] Pitkänen M. About the Recent TGD Based View Concerning Cosmology and Astrophysics. https://tgdtheory.fi/public_html/articles/3pieces.pdf., 2024.

[L63] Pitkänen M. About the TGD counterpart of the inflationary cosmology. https://tgdtheory.fi/public_html/articles/inflatgd2024.pdf., 2024.

[L64] Pitkänen M. Quartz crystals as a life form and ordinary computers as an interface between quartz life and ordinary life? https://tgdtheory.fi/public_html/articles/QCs.pdf., 2024.

[L65] Pitkänen M. Some solar mysteries. https://tgdtheory.fi/public_html/articles/Haramein.pdf., 2024.

[L66] Pitkänen M. A more detailed view about the TGD counterpart of Langlands correspondence. https://tgdtheory.fi/public_html/articles/Langlands2025.pdf., 2025.

[L67] Pitkänen M. A new experimental demonstration for the occurrence of low energy nuclear reactions. https://tgdtheory.fi/public_html/articles/LENRagain.pdf., 2025.

[L68] Pitkänen M. About Dirac equation in $H = M^4 \times CP_2$ assuming Kähler structure for M^4 . https://tgdtheory.fi/public_html/articles/HJdireq.pdf., 2025.

[L69] Pitkänen M. About the structure of Dirac propagator in TGD. https://tgdtheory.fi/public_html/articles/dirprop.pdf., 2025.

[L70] Pitkänen M. ANITA anomaly, JWST observation challenging the interpretation of CMB, and star formation in the remnant of a star. https://tgdtheory.fi/public_html/articles/ANITACMB.pdf., 2025.

[L71] Pitkänen M. Comparing the S-matrix descriptions of fundamental interactions provided by standard model and TGD. https://tgdtheory.fi/public_html/articles/hadroQCDTGD.pdf., 2025.

[L72] Pitkänen M. Comparing the standard view and TGD vision of the formation of astrophysical objects. https://tgdtheory.fi/public_html/articles/starform2025.pdf., 2025.

[L73] Pitkänen M. Could computers be living and move? https://tgdtheory.fi/public_html/articles/liquidmetallife.pdf., 2025.

[L74] Pitkänen M. Gödel,Lawvere and TGD. https://tgdtheory.fi/public_html/articles/Gtgd.pdf., 2025.

[L75] Pitkänen M. Holography= holomorphy vision and a more precise view of partonic orbits . https://tgdtheory.fi/public_html/articles/HHpartons.pdf., 2025.

[L76] Pitkänen M. Some TGD inspired comments about biocatalysis. https://tgdtheory.fi/public_html/articles/pollackbio.pdf., 2025.

[L77] Pitkänen M. About the TGD based models for Cambrian Explosion and the formation of planets and Moon. https://tgdtheory.fi/public_html/articles/CEagain.pdf., 2026.

[L78] Pitkänen M and Rastmanesh R. Homeostasis as self-organized quantum criticality. Available at: https://tgdtheory.fi/public_html/articles/SP.pdf., 2020.

[L79] Pitkänen M and Rastmanesh R. The based view about dark matter at the level of molecular biology. Available at: https://tgdtheory.fi/public_html/articles/darkchemi.pdf., 2020.

[L80] Pitkänen M and Rastmanesh R. Aging from TGD point of view. https://tgdtheory.fi/public_html/articles/aging.pdf., 2021.