Some new aspects of the TGD inspired model of the nerve pulse

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Abstract

In this article various aspects of the TGD inspired model of nerve pulses are discussed.

1. Nerve pulses relate closely to the communications from the cell membranes to the magnetic body (MB) of the system using dark, frequency modulated Josephson radiation inducing at MB a sequence of cyclotron resonances serving as control signals and eventually giving rise to nerve pulse patterns. This would generalize the "right brain signs-left brain talks" metaphor. Also the model of meV spikes appearing in preneural systems is discussed.
2. Quantum gravitation in the TGD sense a can assign the needed huge values of h_{eff} to the gravitational magnetic bodies. Quantum gravitational flux tubes assignable to the Sun, Earth, and perhaps also other planets and even the Moon could be highly relevant for the living cell and the brain.
3. The connection with microtubular level is considered and the transfer of charged particles between microtubules and very long gravitational flux tubes assignable to them allows to induce membrane oscillations and even nerve pulse.
4. Zero Energy Ontology (ZEO) and Negentropy Maximization Principle (NMP) could allow computers to become effectively living intelligent systems able to reach goals by an analog of trial and error process. This requires the failure of quantum statistical determinism. This is the case if the gravitational Compton time defining a lower bound for the gravitational quantum coherence time is longer than the clock period of the computer. MB would play a key role also in the case of living computers and dark Josephson radiation could serve as a communication tool. Superconducting computers have Josephson junctions as basic active elements and are more promising than transistor based computers.
5. Also the recent finding that the neuronal system is in a certain sense 11-dimensional is discussed in the TGD framework. The basic observation is that the 12-neutron system, with neurons assignable to the 12 vertices of icosahedron and defining 11-D simplex, could be involved. Icosahedron and tetrahedron appear also with the TGD based model of bioharmony serving also as a model of the genetic code.

Contents

1 Introduction

For about two decades ago I ended up with idea about the cell membrane as Josephson junction, which then led to a quantum view [K11, K4, K12] [L15, L16] about cell membrane as a generalized Josephson junction consisting of Josephson junctions defined by membrane proteins and to the proposal that a soliton sequence analogous to a sequence of rotating pendulum with a constant phase difference defines the ground state of the neuronal membrane. The perturbation in which the penduli associated to some penduli change their direction of rotation provides a possible model of nerve pulse.

An alternative model, inspired by the superconductor model of computers, is that the presence/absence of magnetic flux through the Josephson junction induces nerve pulse. In this framework, ordinary cell membranes could correspond to sequences of vibrating penduli, which do not allow nerve pulse in this sense. However, the recent findings suggest that also in this case spikes with voltage difference in meV scale can give rise to analogs of nerve pulse patterns [L22].

The basic problem was that the frequency of the Josephson radiation would have a scale of 5 THz and is much higher than EEG frequencies. which are in the 10 Hz scale. The TGD view of dark matter as phases of ordinary matter with non-standard value of Planck constant, which are much larger than h, solves the problem. Josephson radiation would consist of dark photons. Later it turned out that this hierarchy is predicted by the number theoretical vision of TGD.

In this article various aspects of the TGD inspired model of nerve pulse are discussed.

1. The key assumption is that nerve pulses relate closely to the communications from the cell membranes to the magnetic body (MB) of the system using dark, frequency modulated Josephson radiation inducing a sequence of cyclotron resonances serving as control signals and eventually giving rise to nerve pulse patterns. This could generalize the "right brain signs-left brain talks" metaphor. Also the model of meV spikes appearing in preneural systems, considered in detail in [L22], is briefly discussed.

2. The basic question concerns the identification of the origin of the huge value of h_{eff}. This brings in quantum gravitation in the TGD sense, which assigns huge values of h_{eff} to the gravitational magnetic bodies giving rise to even astrophysical scales of quantum coherence. Quantum gravitational flux tubes assignable to the Sun, Earth, and perhaps also other planets and even the Moon could be highly relevant for the living cell and the brain.

3. Also the connection with microtubular level is considered [L22, L19] and the transfer of charged particles between microtubules and very long gravitational flux tubes assignable to them allows to induce membrane oscillations and even nerve pulse.

4. Recently I have considered the question whether ordinary computers under some conditions could in the TGD framework behave like living systems [L28, L27]. The condition is that quantum statistical determinism fails. Zero Energy Ontology (ZEO) [K13] and Negentropy Maximization Principle (NMP) [L30, L18], which are behind the TGD view of quantum measurement theory, could allow these systems to become effectively living intelligent systems in the sense that they are able to reach goals by an analog of trial and error process.

   This is the case if the gravitational Compton time defining a lower bound for the gravitational quantum coherence time is longer than the clock period of the computer. MB would play a key role also in the case of living computers and dark Josephson radiation could serve as a communication tool. Superconducting computers have Josephson junctions as basic active elements and are more promising than transistor transistor based computers in this respect.

5. Also the recent finding that the neuronal system is in a certain sense 11-dimensional is discussed in the TGD framework. The basic observation is that the 12-neutron system, with neurons assignable to the 12 vertices of icosahedron and defining 11-D simplex, could be involved. Icosahedron and tetrahedron appear also in the TGD based model of biohar-mony [L3] [L14, L17, L25], which also serves as a model of the genetic code. This model involves so-called icosa-tetrahedral tessellation of the hyperbolic space H^3 having highly unique properties.

2 Magnetic body a "boss" of biological body

2.1 The notion of magnetic body

Magnetic body (MB) carrying dark matter would serve as the boss controlling ordinary matter at flux tubes.

1. MB has as building bricks magnetic flux quanta, which look locally either flux tubes or flux sheets. It consists of two kinds of flux quanta. Flux can be vanishing, which corresponds to the Maxwellian case. The flux can be also non-vanishing and quantized and corresponds to a monopole flux. In a monopole case the magnetic field requires no current to create it. This option is not possible in the Maxwellian world. These flux tubes play a key role in the TGD Universe in all scales.

2. Also Earth's magnetic field with nominal value $B_E = .5$ Gauss would have these two parts. Monopole part corresponds to the "endogenous" magnetic field $B_{end} = .2$ Gauss explaining strange effects of ELF em radiation to the physiology and behavior of vertebrates [J1]. The presence of this part identifiable as monopole flux explains why Earth has a magnetic field [L4]: this field should have decayed a long time ago in Maxwellian world since it requires currents to generate it and they disappear. Magnetic fields of permanent magnets could have a monopole part consisting of flux quanta. Electromagnets would not have it.

3. MB would carry dark matter as $h_{eff} = ntimes; h_0$ phases and act as a "boss" controlling ordinary matter [L9]. Communication to and control of the biological body (ordinary matter) would be based on dark photons, which can transform to ordinary photons and vice versa. Molecular transitions would be one form of control.

   One can assign dark charges with protons and positive ions Na^+, K^+, Ca^{++}, Mg^{++},... The valence electron could be dark in the sense that it is transferred to the MB, most plausibly to the gravitational MB. This interpretation does not make sense for the negatively charged ions such as Cl^- and P^{3-} since the additional electron is localized to the partially filled atomic shell. Electrons could be however transferred to dark electrons at these MBs.

4. Dark photons with large h_{eff} serve as communication and control tools. Josephson frequencies would be involved with the communication of sensory data to MB and cyclotron frequencies with control by MB. Dark photons are assumed to transform to bio-photons [L1, L2] with energies covering visible and UV associated with the transitions of biomolecules. The control by MB, having layers with size even larger than the size of the Earth, means that remote mental interactions would be routine in living matter. EEG would be a particular example of these communications: without MB it is difficult to understand why the brain would use such a large amount of energy to send signals to outer space.

5. It was the experiments of Blackman [J1] and others that led to the notion of h_{eff} hierarchy. The large effects of radiation at ELF frequencies could be understood in terms of cyclotron transitions in $B_{end} = .2$ Gauss if the value of h in $E = hf$ is replaced with h_{eff}, which would be rather large and possibly assignable to gravitational flux tubes with $\hbar_{eff} = \hbar_{gr} = GMm/v_0$.

   MB would control BB by cyclotron radiation - possibly via genome accompanied by dark genome at flux tubes parallel to the DNA strands. Cyclotron Bose-Einstein condensates of bosonic ions, Cooper pairs of fermionic ions, and Cooper pairs of protons and electrons would appear in living matter and $h_{eff} = h_{gr}$ hypothesis predicts universal energy spectrum in the range of bio-photon energies.

   Cell membrane could act as a generalized Josephson junction generating dark Jophson radiation with energies given by the sum for ordinary Josephson energy and of the difference of cyclotron energies for flux tubes at the two sides of the membrane. The variation of the membrane potential would induce variation of the Josephson frequency and code the sensory information at cell membrane to a dark photon signal sent to MB.

6. In zero energy ontology (ZEO) [K13] field body and MB correspond to 4-D rather than 3-D field patterns. Quantum states are replaced by quantum counterparts of behaviors and biological functions. The basic mechanism used by MB would be generation of conscious holograms by using dark photon reference beams from MB and their reading. In ZEO also the time reversals of these processes are possible and make it possible to understand memory as communications with geometric past. Sensory perception and memory recall would be time reversals of each other and correspond to sequences of SSRs. Motor action would correspond to BSRs.

2.2 Dark cyclotron radiation

The cyclotron frequencies associated with the gravitational MB of the Earth [K7] [L22, L19] should play a key role in TGD inspired quantum biology and relate to the feedback from MB to the living matter. This could be the situation also in the case of computers. The first guess, inspired by the model for the findings of Blackman [J1] and others on effects of ELF em fields on brain, is that monopole flux tubes associated with the MB of Earth correspond to the endogenous magnetic field of $B_{end} = 2B_E/5$ ($B_E = .5$ Gauss is the nominal value of the Earth's magnetic field).

This value is only the average value since frequency modulation is the way to code information and is achieved by varying the flux tube thickness in turn affecting the value of B_{end}. Probably there exists an entire hierarchy of values of the dark magnetic field strength perhaps coming as powers of 2. For cyclotron frequencies associated with the gravitational MB, h_{eff} would correspond to the gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$ for Earth. Note that, in

accordance with the Equivalence Principle, the cyclotron energy $E_c = \hbar_{gr}eB/m = GMeB/\beta_0$ does not depend on m.

The huge value of $\hbar_{gr}/h_0$ would corresponds to the number sheets of a many-sheeted structure defined by a multi-sheeted covering of CP_2 by parallel monopole flux tubes so the the roles of M^4 as space-time and CP_2 as field space would change. This would allow us to understand how the basic formula $E = \hbar_{gr}f$ scales the extremely small cyclotron energy to an energy which is at least the thermal energy. Cyclotron transition would be a quantum phase transition.

2.3 The possible role of quantum gravitation in quantum biology

The basic question is how to achieve quantum coherence in macroscopic scales. During late years, the TGD view of quantum gravitation has developed dramatically and provides a beautiful vision of living matter as being controlled by dark matter at the gravitational monopole flux tubes forming dark MBs with onion-like structure consisting of shells formed from tangential monopole flux tubes and connected by radial flux tubes along which graviton mediating the gravitational interaction propagate [L19, L22, L31, L32].

Why the role of quantum gravitation could be so decisive is that it has infinite range and is not screened. In TGD, gravitational quantum coherence in even astrophysical scales becomes possible. The basic quantification tool is gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$ originally introduced by Nottale [E1]. In accordance with the Equivalence Principle, the gravitational Compton length $\Lambda_{gr} = GM/\beta_0 = r_S/2\beta_0$ is independent of the small mass m. The most amazing and crazy sounding consequence is that the gravitational MBs of the Sun, Earth, and possibly also of other planets, even the Moon, could be highly relevant for quantum biology. Astrologists would not have been totally wrong.

2.3.1 Gravitational Compton frequencies

Suppose that one has a particle with mass m with Compton length $r_c(m) = \hbar/m$ and the ordinary Compton frequency $f_c = m/\hbar$. The gravitational Compton frequencies $f_{gr}(M, \beta_0) = m/\hbar_{gr}(M, \beta_0) = 2\beta_0/r_s$, which do not depend on m.

Gravitational Compton frequencies could be important in biology. Consider first the Earth's gravitational Compton frequency. The value of the gravitational Compton length $\Lambda_{gr}(M_E, \beta_0 = 1) = GM/\beta_0 = 0.45$ cm, which is also independent of m, defines a lower bound for the gravitational quantum coherence length. Λ_{gr} corresponds to a gravitational Compton frequency $f_{gr} = 6.7times; 10^{10}$ Hz $\simeq 67$ GHz.

The frequencies in the GHz scale are found to be important also in living matter. As a matter of fact, there is experimental support for a fractal hierarchy of frequency scale come as powers $f = 10^{3k}$ Hz, $k = 0, 1, ..,$, that is 1 Hz, kHz, MHz,GHz, and THz assignable to microtubules [J3] (`https://rb.gy/9rvpr`). For these reasons it is interesting to look at 1 GHz as an example.

Also the gravitational Compton frequency f_{gr} associated with the gravitational MB of the Sun, having $\beta_0 \simeq 2^{-11}$, could be important. For the Sun, gravitational Compton length is rather near to $R_E/2$ where $R_E = 6378$ km is Earth radius. The corresponding Compton frequency $f_{gr}(M_S, \beta_{Sun} = 2^{-11}) \simeq \beta_{Sun}/GM_S$ is about 100 Hz and corresponds to the upper bound for EEG, which conforms with the fact that quantum gravitational coherence time should not be smaller than Λ_{gr}. Note that the cyclotron frequency Lithium in the endogenous magnetic field $B_{end} = .2$ Gauss assignable to the Earth's gravitational flux tubes is 50 Hz. For the lightest ion, which is tritium, the cyclotron frequency is about 100 Hz and maximal.

1. The lower cyclotron frequencies of the heavier ions in $B_{end,E} = .2$ Gauss assignable to Earth belong also to EEG range and correspond to longer solar quantum coherence lengths. DNA would correspond to 1 Hz and perhaps to the largest quantum gravitational coherence length in the EEG range. The cyclotron frequencies above 100 Hz would correspond to solar gravitational quantum coherence lengths below R_E.

2. The cyclotron frequencies above 100 Hz would correspond to solar gravitational quantum coherence lengths below R_E: this does not look feasible. For protons and electrons the cyclotron frequencies are indeed above $f_{gr,S}$. For protons (electrons) the cyclotron frequency f_c in $B_{end,E} = .2$ Gauss is 300 Hz ($6times; 10^5$ Hz). It is important to notice that for

$\hbar_{gr}(M,m)$ cyclotron energy does not depend on mass and is the same for electrons and protons.

Could the value of β_0 for protons and electrons at the flux tubes of $B_{end,E}$ ($B_{end,S}$) be $\beta_0 = 1/3$ ($\beta_0 = 2^{-11}/3$)? Could one say that electrons and protons are slightly more advanced than other ions in the evolutionary sense?

3. For the Sun, one has $\beta_0 \simeq 2^{-11} \simeq m_e/m_p$ instead of $\beta_0 = 1$. The value of B_{end} for the Sun cannot be the same as for Earth. A good estimate is obtained from the value range for B in the outer magnetosphere, where the solar magnetic field should dominate. The order of magnitude is $B_{end,S} \simeq 10nT = 2^{11}B_{end,E}$. For this value, the cyclotron energy would be the same as for Sun and Earth and energy resonance would be possible! This observation was made already in [K7].

4. The replacement of $\hbar_{gr}(M_E,m) \to \hbar_{gr}(M_{Sun},m)$ means multiplication of say EEG period by a factor $r = (M_{Sun}/M_E)\beta_{0,E}/\beta_{0,Sun} \simeq 2.2times;10^8$ so that alpha period .1 seconds corresponds to $2.2times;10^7$ seconds. Intriguingly, one year corresponds to $3.25times;10^7$ seconds and defines a fundamental biorhythm, which would correspond to a 6.7 Hz rhythm for EEG not far from the lowest Schumann resonance frequency.

5. The energies $E = h_{gr}(M,m,\beta_0)f_{gr}(Sun)$ assignable to the gravitational Compton frequency of Sun are proportional to m and since nucleon mass dominates over electron mass they are in good approximation proportional to the mass number of the molecules. This suggests a multi-resonance in which each electron, proton and even nucleon absorbs boson, maybe dark gravitons, with frequency f_{gr}. For electrons, the energy is about 1 meV, which could relate to the miniature potentials for neurons. For protons the energy would be about 2 eV, which corresponds to red light. Large scale quantum coherence could make the rate of gravitational multi-resonance.

2.3.2 Could also the gravitational magnetic bodies of the Moon and other planets be involved?

If one accepts that the gravitational MBs of Earth and Sun are important, one cannot avoid the question whether also the other planets could be important for quantum biology.

1. The value of h_{eff} deduced from the original findings of Blackman [J1] and others was very large since the energy of the dark photon had to belong to the range between thermal energies at physiological temperature and UV photons. The identification $\hbar_{eff} = \hbar_{gr}(M_E,\beta_0)$ is suggestive. Assuming that the dark Josephson radiation from the cell membrane being received resonantly at the MB of Earth would suggest the simplest option as $h_{eff,J} = h_{gr}(M_E,\beta_0 = 1)$? Would the condition $Z_J eV_C = E_c = GM_E ZeB/\beta_0$, where $eV_C = .05$ eV values for voltage for dark gravitational flux tubes in a communicating Josephson junction and the value of the magnetic field with a MB flux tube?

2. The experiments of Blackman provided evidence for the existence of an "endogenous" magnetic field $B_{end} = .2$ Gauss. In TGD, B_{end} was identified as the monopole part of the Earth's magnetic field. Assuming $B = B_{end} = .2$ Gauss and $Z_J = Z$, we get $eV_C = 13.5$ eV which is slightly lower than the ionization energy of hydrogen atom 13.6 eV and much higher than $eV_C = .05$ eV. The interpretation as a Josephson junction is not meaningful.

   Could the interpretation be that the transition to very long flux tubes effectively nearly ionizes the hydrogen atom? Could hydrogen atom ionization produce dark UV photons with monopole flux tubes on Earth?

3. The monopole flux tubes of MBs can adjust their flux tube thickness, which controls the strength of the magnetic field, so that frequency modulation becomes possible and they can receive information also from the transition of atoms and molecules by tuning to cyclotron resonance and control them by the same mechanism!

   I have indeed proposed in the context of the model of bioharmony [L14] that the value of B_{end} has a discrete spectrum. In particular, the visible range of photons could correspond

to frequencies forming an analog of a 12-note system and the spectrum of B_{end} could realize this system. Note also that the parameter $\beta_0 \leq 1$ could allow us to realize a spectrum of energies for a fixed frequency.

4. One should obtain also the energy range of biophotons (energy range for visible light) as energies of dark Josephson photons. What if we replace the mass of the Earth with the mass of the moon $M_M = .012M_E$ giving $\Lambda_{gr} = .54times; 10^{-4}$ meters, the size scale of a large neuron (water blob of size 10^{-4} m has Planck mass), and keep B_{end} and β_0 the same? For $Z_J = Z$, the value of eV_C decreases to $1.2times; 13.5/100eV = .16$ eV, which is in infrared and in a reasonable approximation 2 times the membrane potential. This is smaller than the typical energy of biophotons which is in visible range. If the values of B define a 12-note spectrum or something more general, this would give rise to biophoton energies above IR.

   It is important to notice that the experiments of Blackman and others fix only the value of B_{end} to .2 Gauss, identifiable as monopole part of the Earth's magnetic field, but require only that the cyclotron energy is above the thermal energy so that the Moon could solve the problem!

5. In the case of Moon, the Josephson energy for the cell membrane given by $E_J = .055$ eV is obtained for $Z_J = 2$ and $Z = 1$ having natural interpretation for cyclotron transitions. This value could relate to the Pollack phase transition occurring at the physiological temperature range [I1, I6, I11]!

6. If one has introduced Sun, Earth and Moon to quantum biology, there is not much respectability to be lost anymore, and one can ask whether other planets could be of significance. Could the horoscope builders have been right in some sense?

   The mass of Mars is roughly 11 percent of Earth mass and would give $E_c = 1.8$ eV for $B_{end} = .2$ Gauss. This is in the visible biophoton range. The interpretation of the frequencies f_{gr} as upper end points of the spectrum so that lower frequencies would correspond to smaller values of B_{end}. I have proposed that the values of B_{end} correspond to 12-note scale with inspiration coming from the model of bioharmony [L3] [L14].

2.3.3 Moon and neuroscience

Quantum gravitation favors the communications between cell membranes as dark Josephson junction and corresponding MBs carrying dark charged particles. The variations of the membrane voltage induce the modulation of the Josephson frequency and resonant receival induces a sequence of pulses coding the variations of the membrane potential to a sequence of pulses.

1. The cyclotron energies

$$E_c = \hbar_{gr}\frac{ZeB}{m} = \frac{GMZeB}{\beta_0} = \frac{r_s}{2l_B^2\beta_0}$$

   do not depend on the mass m of the charged particle and are therefore universal. Same is true for the gravitational Compton length $L_{gr} = r_s/2\beta_0$ of the particle.

2. Josephson frequencies are given by $ZeV/2\pi\hbar_{gr}$ and is inversely proportional to the mass of the charged particle. In the case of ions this means the $1/A$-proportionality and ordering of Josephson frequency scales as subharmonics.

3. The frequency resonance condition $f_J = E_J/h_{gr} = f_c = ZeB/m$ is equivalent to the energy resonance condition

$$E_J = ZeV_{mem} = \hbar_{gr}f_c = \frac{r_s}{2l_B^2\beta_0} = \frac{r_S}{2\beta_0}\frac{eB}{\hbar}.$$

   This condition fixes the relation between the voltage of the Josephson junction and the strength B of the magnetic field. $\frac{eB}{\hbar} = ZeV_{mem}\frac{2Z\beta_0}{r_S}$

For $V_{mem} = .05$ V,$Z = 2$, $r_S = r_{S,E} = 1$ cm and $\beta_0 = 1$, and using the fact that $B = 1$ Tesla corresponds to magnetic length $l_B = \sqrt{\hbar/eB} = 64$ nm, this gives $B = 184\ nT$.

It came as a surprise that this field strength is about $2.3times; 10^{-3}$ weaker than the endogenous magnetic field $.2times; 10^{-4}$ Tesla at the surface of Earth. The strengths of the magnetic fields outside the inner magnetosphere are of order nTesla. Does this mean that the EEG signals from the cell membrane are received by charged particles at the flux tubes of the magnetosphere for which the field is much weaker than at the surface of Earth. This is indeed proposed in the model of EEG.

How could one get rid of the problem?

(a) The expression for B is proportional to $\beta_0 \leq 1$ and to $1/r_S$. For the Moon the mass is $.01M_E$ so that the value of the B would be scale by factor 100 so that it would be by factor .92 weaker than B_{end}. As proposed already earlier, the gravitational MB of Moon could be involved with the dynamics of the cell membrane and the endogenous magnetic field of Blackman could be assignable to Moon!

(b) The proportionality of B to eV_{mem} allows us to consider the possibility that also DNA involves Josephson junctions. In fact, the TGD inspired model for the Comorosan effect assumes that biomolecules quite generally involve them. By a naive dimensional argument one expects that the value of ZeV is scaled up by factor of order 100 as one scales the membrane thickness 10 nm to 1 Angstrom. This would give B_{end} for the gravitational flux tubes of the Earth.

The possibility of simultaneous frequency and energy resonance means universal cyclotron resonance irrespective of the mass of the charged particle. Josephson frequencies are however inversely proportional to the mass of the charged particle appearing both in the cell membrane and the receiving flux tube. The resonance mechanism therefore makes it possible to use the same information for receivers with different masses. Each of them generates a different sequence of pulses at times for which modulated Josephson frequency equals the cyclotron frequency defining a specific kind of information characterized by the scale defined by Josephson period. Electron mass, proton mass and ion masses define characteristic frequency scales. For B_{end}, the cyclotron frequencies are in EEG range for ions which also favours the Moon option.

2.4 The models of genetic code in terms of dark protons dark photons

The TGD inspired view of genetic code has evolved during decades.

(a) The first model of the genetic code was based on the so-called Combinatorial Hierarchy [K5] [L17] and predicted what I called memetic code realized as sequences of 21 DNA codons. Surprisingly, this model made a comeback as I prepared this article.

(b) After several stray paths I ended up from a model of music harmony [L3] [L5, L8, L14] based on Hamiltonian cycles at the icosahedron to a model of genetic code also involving the tetrahedral Hamiltonian cycle.

The basic observation was that the 12-note scale could correspond to a Hamiltonian cycle of icosahedron such that the steps of the cycle define a quint cycle. The 12-note scale is obtained from the quint by octave equivalence. There are 3-types of icosahedral Hamiltonian cycles and each cycle defines 20 3-chords assignable to the triangular faces of the icosahedron and defines a musical harmony.

One obtains 20+20+20 chords for the 3 different harmonies with symmetry groups Z_6, Z_4 and Z_2. The orbits of these groups define sets of 3-chords. The surprising finding was that if these sets are identified as amino acids, the numbers of the chords are the same as the numbers of DNAs coding for a given amino acid. By adding a tetrahedral Hamiltonian cycle one obtains 64 3-chords. At the level of molecules the music would be "music of light". Since music expresses and generates emotions,

the idea that emotions appear already at the molecular level was natural. Different combinations of 3 Hamiltonian cycles with symmetries Z_6, Z_4 and Z_2 would correspond to different moods at bio-molecular level (why just 3?)

The model made almost correct predictions for the numbers of mRNA codons coding for amino-acids. I have discussed a considerable number of its variants during years and even considered the replacement of icosahedron and tetrahedron with some other geometric object. The basic problem was that gluing the tetrahedron and icosahedron together looked ugly and would have allowed only 63 codons. At that time I did not yet realize that an icosahedron and tetrahedron could be parts of a bigger structure.

(c) Second model was based on the realization of codons as dark proton triplets assumed to reside at the monopole flux tubes parallel to DNA strands [L5, L8]. Dark proton triplets would neutralize the constant negative charge of -3 units per codon. The model suggested that it might be possible to understand the numbers of DNA, RNA, tRNA and amino acids in terms of entangled states of dark proton triplets representing codons. The model had also problems: in particular, one had to assume an additional binary degree of freedom to get the number DNA and mRNA codons correctly and the proposed identifications of this new degree of freedom did not look quite realistic.

(d) Icosa-tetrahedral realization [L17] of the code in terms of icosa-tetrahedral honeycomb of H^3 was the next step in the evolution of ideas. It was made possible only by the dramatic development of understanding of TGD itself, in particular of its number theoretical aspects related to $M^8 - H$ duality [L11, L12].

The tessellations of the hyperbolic 3-space H^3 represented as possibly complex mass shell in $M^4_c \subset M^8_c$ and as light-cone proper time = constant hyperboloids in $M^4 \subset M^4 times; CP_2$ are central in the the realization of holography in TGD. Icosa-tetrahedral honeycomb is a completely unique tessellation involving only Platonic solids and all possible platonic solids, tetrahedron, icosahedron, and octahedron are present. Kind of quantum Platonic holy trinity would be in question.

This led to a proposal of the genetic code in terms of icosa-tetrahedral honeycomb induced to the 3-surface by restriction. This realization could be assignable to the magnetic body of the system involving dark matter in the TGD sense. The realization would be universal and would not be restricted to mere biology. Counterparts of codons and genes can be realized also for higher-dimensional objects, say cell membrane and even brain.

Icosa-tetrahedral realization led to a proposal that the realizations of the code in terms of dark photon triplets and in terms of dark proton triplets are closely related. I did not however really understand the properties of the icosa-tetrahedral honeycomb when I published the first article about it [L17]. The article [L25] represents a considerably more precise view of the very special role of the icosa-tetrahedral tessellation and applies it to develop a model of DNA.

Sequences of N dark cyclotron photon triplets as representations of genes consisting of N dark proton triplets would make possible communications between dark genes by 3N-resonance. Genes would serve as addresses, much like in LISP, and the message would be coded by the modulation of the frequency scale. The details of this picture that were not discussed at that time create problems that are solved by the model based on icosahedral honeycomb.

2.5 The interpretational problems associated with the hierarchy of Planck constants

The idea of a hierarchy for Planck's constants was originally inspired by the observations of Blackman [J1] and other pioneers of bioelectromagnetism. It was found that ELF frequency radiation or ELF frequency modulated electromagnetic radiation (ELF frequencies include EEG frequencies) has quantum-like effects on the behavior and neurophysiology of mammals. A typical example is 15 Hz and its harmonic multiples. As if the radiation would induce cyclotron transitions in a magnetic field, which is about 2/5 of the Earth's magnetic field.

The energies of $E = hf$ associated with these frequencies are extremely small, an order of 10^{-13} eV, about 11 orders of magnitude smaller than the thermal energy at physiological temperatures. Therefore no quantum effects are allowed by standard quantum mechanics and also thermal effects are impossible. Therefore these effects were "forgotten".

This led to the idea of a hierarchy of Planck's constants.

(a) At least h_{eff}/h of the order 10^{11} would be needed to cross the thermal threshold. If the effects correspond to visible light (biophotons), then h_{eff}/h is of order 10^{13}. Number theoretical vision led to the proposal that one has $h_{eff} = nh_0$, where $h_0 < h$ is the minimum value of h_{eff}. The integer n could correspond to a dimension of an extension of rationals. There are empirical indications that $h_{eff} < h$ is possible,

(b) I have developed arguments supporting the proposal that the value of h/h_0 corresponds to the scale the ratio $R^2/l_P^2 \simeq 10^7$, where R is CP_2 size scale and l_P is Planck length length scale. l_P would correspond to the real size scale of CP_2 and R would correspond to the size scale of the dark space-time sheet assignable to CP_2 type extremal. R determined from the formula $R^2 = (h/h_0)l_P^2$. The proportionality to $\sqrt{h/h_0}$ rather than h/h_0 motivated by the formula $l_P = \sqrt{\hbar G}$. The assignment to the CP_2 radius R the same M^4 scale is somewhat questionable.

(c) The Gravitational Planck's constant $\hbar_{gr} = GMm/v_0$, which Nottale introduced, would be a special case and its huge value would reflect the infinite range of the unscreened gravitational interaction. $\hbar_{gr}$ has huge values and could explain the findings of Blackman.

(d) There is however a problem. How can one interpret the huge scaling $E_c = hf \to (\hbar_{gr}/\hbar)E_c$ of the cyclotron energy at space-time level? Blackman's observations can be explained in terms of the gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$ of Earth predicting gravitational Compton length $\Lambda_{gr} = GM/\beta_0 = r_S/2\beta_0$. For $\beta_0 = v_0/c = 1$ (favored value for the Earth) this gives $\Lambda_{gr} = r_S/2 = .5$ cm. For ion with mass number A one has $N_{gr} = \hbar_{gr}\hbar = r_S/2l_c(A) = Ar_S/2\beta_0 l_c(p)$, $l_c(p) = 1.32$ fm sheets with each containing a charged particle and forming a connected quantum coherent structure. For Ca with $A = 40$ this would give about $1.5 times; 10^{14}$ sheets.

What looks obvious is that h_{gr}/h, as the dimension n of an extension of rationals, must correspond to a number of basic units producing the ordinary cyclotron energy $E_c = hf$. What are these units?

Blackman's findings can be explained if the strength of the endogenous magnetic field is roughly 2/5 of the strength of the Earth's magnetic field $B_E = .5$ Gauss. The interpretation would be as a monopole flux tube part of B_E. The natural interpretation of the gravitational flux tubes would be as flux tubes of the endogenous magnetic field of Blackman. They would form a connected structure defining a region of quantum coherence. The first interpretation is that there is only single flux tube with quantized flux of $\hbar_{eff}/\hbar$ units: one would have covering of M^4. The second interpretation is that there $\hbar_{eff}/\hbar$ flux tubes with standard flux quantum: one would have covering of CP_2 by parallel flux tubes.

For the first interpretation the CP_2 coordinates would be multivalued functions of M^4 coordinates.

(a) To explain Blackman's findings, at least 10^{11} sheets parallel to M^4 would be needed: the sheets would be extremely near to each other in CP_2, which looks strange. Maybe this option is meaningful only for sufficiently small values of h_{eff} and the scaling could mean that each sheet of the covering carries a charged particle with the ordinary value of Planck constant so that the sum of ordinary cyclotron energies equals to $E_c = ntimes; hf$, where n is the number of sheets. Cyclotron transition would be quantum phase transition.

(b) The idea of a pile of charged particles located on top of each other looks unrealistic except possibly for small values of n appearing for other than gravitational interactions. But is this really the case: the point is that the Compton length of the charged particle

is scaled up by factor h_{eff}/h and corresponds to the geometric size of the particle. If one one has $N_{eff} = h_{eff}/h$ particles on top of each other in M^4, this means that there N particles per Compton volume, - area, or -length, depending whether the structure $k = 3-$, $k = 2-$, or $k = 1$-dimensional. The mass density is $Nm/\lambda_c^k N^k = N^{1-k}m/\lambda_c^k$, where λ_c is the ordinary Compton length and is rather small for large values of h_{eff} for $k > 1$. For $k = 1$, the density is one particle per ordinary Compton length. In atomic nuclei this is possible for nuclear strings.

(c) One can look whether this really works for the findings of Blackman. The flux quantization generalizes: the flux quantum corresponds to $\hbar_{eff}$. The condition for the flux quantization reads $\int eBdS = n\hbar$ in the standard situation and quantization condition for a disk of radius R gives $R = \sqrt{n}\sqrt{\hbar_{eff}/\hbar}l_B/\sqrt{\pi}$, where $l_B = \sqrt{\hbar/eB}$ is the magnetic length.

(d) For the monopole flux tubes, the flux quantization condition is replaced with $\oint JdS = n\hbar_{eff}$, where Kähler magnetic fields as induced Käher J forms part of ordinary magnetic field eB and in long scales is equal to eB apart from a numerical constant k: $J = keB$. The integration is over sphere with area $4\pi R^2$. This gives

$$R = \sqrt{n/4\pi k}\sqrt{N}l_B = \sqrt{1/4\pi k}\sqrt{nN}l_B,$$

where $N_{eff} = \sqrt{\hbar_{eff}/\hbar}$. The value of k is $k = 1/3$ [L34].

(e) In the experiments of Blackman, $h_{eff} = \hbar_{gr,Earth}$ is a reasonable guess. As already found, this gives $N(A) = (A/40)times; 1.5times; 10^{14}$, where $A = 40$ corresponds to Ca ion. $B = 1$ Tesla corresponds to magnetic length of $l_B = \sqrt{\hbar/eB} = 64$ nm defining the radius of flux quantum and for the endogenous magnetic field $B_{end} = .2times; 10^{-4}$ Tesla this would correspond to the magnetic length $l_B = 1.43times; 10^{-5}$ m. The value of R given by the previous formula gives $R = \sqrt{3n}times; 85.6$ m. This looks suspiciously large.

The number of Ca ions per flux tube of this area would be $N(A)$ and the number density density of Ca ions per area would be $R = N/\pi R^2 = \sqrt{4\pi/3n}/l_B^2$. For $n = 1$, the number of Ca ions would be of order one 2.05 per area of ordinary flux quantum which corresponds to the size scale of cell. The flux tube is expected to be longer than R so that the density of dark Ca ions would be smaller than $N/\pi R^3$. This makes sense if the Ca ions have wave functions localized to this volume.

(f) The choice $n = 1$ for the number of flux quanta is the simplest option but the large radius of the flux tube could be critized. The second and more realistic looking option, consistent with Equivalence Principle, is that the flux tube radius corresponds to the gravitational Compton length $\Lambda_{gr} = r_s/2\beta_0$ and would not therefore depend on the mass of the charged particle. The number of flux quanta for $\hbar_{gr}$ would be increase from $n = 1$ to

$$n = \frac{R^2}{\Lambda_{gr}^2} = \frac{2\beta_0 l_B^2}{r_S l_c(A)} = 2\beta_0 \frac{l_B^2 A}{r_S l_c(p)}.$$

For $\beta_0 = 1$, $B = B_{end} = .2$ Gauss, and $A = 40$ this gives the estimate $n = 2.13times; 10^8$. This would increase the number of Ca ions per transversal area of the ordinary flux tube to about $4times; 10^8$, which corresponds to roughly 1 Ca ion per volume defined by $L(151) = 10$ nm defining the thickness of the cell membrane.

One can also consider the possibility that single flux represents n-fold covering of M^4 by $n \sim 4times; 10^8$ space-time sheets and N_{gr}/n-fold covering of CP_2 by flux tubes.

Second option is in terms of a collective cyclotron transition of ions at parallel flux tubes in M^4.

(a) The parallel flux tubes would form a quantum coherent structure, which is a multi-sheeted covering of CP_2, in the sense that M^4 coordinates can be considered multi-valued "fields" in CP_2. The change of the roles of the Minkowski space-time and field space is possible only in TGD.

(b) The ions at the flux tubes would make a simultaneous cyclotron transition and the result of this quantum phase transition would be a scaling of the cyclotron energy by a factor of 10^{11} at least. I have proposed the attribute multi-sheeted for coherent structures defining single connected space-time surface as quantum coherence region and many-sheeted for structure consisting of disjoint space-time sheets.

(c) As far as numbers are considered, the calculations in this case do not differ from the calculations in the first case. The number of parallel flux tube in the flux tube bundles replaces the number of sheets of the flux tube with radius R, which now becomes the radius of the flux tube bundle. Also now the Λ_{gr} can be considered as the radius of the flux tube bundle.

3 A model of nerve pulse

The model of nerve pulse started to develop roughly two decades ago [K11]. The basic idea was that the cell membrane is a Josephson junction formed by a pair of superconductors assignable to the lipid layers of the cell membrane. The Josephson frequencies assignable to the .05 eV scale are about 5 THz and much higher than EEG frequencies. This led to the proposal that the large value of effective Planck constant h_{eff} explaining the findings of Blackman [J1] and others could reduce the frequency scale ($f_J = E_J/h_{eff} = ZeV/h_{eff}$).

Later the number theoretic interpretation of h_{eff} led to the idea that there could be an entire fractal hierarchy of Planck constants and that it corresponds to frequency scales realizing long range correlations assignable to quantum criticality expected to characterize the cell membrane. This fractal hierarchy could be also interpreted in terms of holography, which is a central principle of TGD. Holography means not only that 3-D data (3-surface) code for 4-D space-time surface but that a small piece of the system represents a good approximation for the entire system. This is nothing but fractality. This view would concretized the vision about holography of consciousness [K2], which is one of the first TGD inspired ideas related to consciousness.

3.1 Interpretation of the axon as a series of Josephson junctions

The TGD based model for an axon [K11] is as a series of Josephson junctions with a large value of h_{eff}, perhaps $h_{eff} = h_{gr}$, where $\hbar_{gr} = GMm/\beta_0$ (the velocity parameter satisfies $\beta_0/c \leq 1$), is the gravitational Planck constant introduced by Nottale [E1]. The model is mathematically equivalent to a series of gravitational penduli defining a discretized version of the Sine-Gordon system [**?**]. Josephson junctions would correspond to membrane proteins.

(a) One can consider two different identifications of the ground state of the system.

   i. The ground state could be the state in which all oscillators oscillate in synchrony with the same amplitude. There would be constant phase difference between neighboring oscillations, which would give rise to a propagating phase wave.

   ii. Another option is that all penduli all rotate in the ground state with a constant phase difference. This would give rise to a travelling soliton chain. Also the direction of rotation matters. It would correlate with the arrow of time and the sign of the membrane potential if the nerve pulse corresponds to a pair of BSFRs.

   iii. One should understand what distinguishes between ordinary cells and neurons. An attractive interpretation is that ordinary cells are in a collective oscillation mode and neurons are in a collective rotation mode. The need for metabolic energy is expected to be lower in the collective oscillation phase. This would conform with the fact that neurons consume more metabolic energy than ordinary cells.

One can imagine several versions for nerve pulse generation.

   i. The first option is that one pendulum moves from oscillation to temporary rotation and induces as a chain reaction a propagating transition for a few penduli at time. This option does not explain the difference between neurons and ordinary cells.

ii. The second option is that the ground state corresponds to a collective rotation with an associated traveling wave as the phase of the rotation, and that bit corresponds to the direction of rotation. The local change of the direction of rotation would correspond to the nerve pulse.
ZEO suggests that the arrow of time changes when the nerve pulse begins and ends and is therefore correlated with the direction of rotation. The ground state would change to a nerve pulse lasting for time of the order of 1 ms corresponding to the duration of nerve pulse associated with the distance of the order 1 μm, between neighboring neurons or between the myelin sheets.
Time reversal would be advantageous from the point of view of metabolism, because dissipation would occur in a direction opposite to the standard direction of time. From the point of view of the outsider, the system would be extracting energy from the environment.

iii. The proposed identifications of the bit are not the only possible ones that one can imagine. In the Josephson junction model of superconducting computer, the presence/absence of a magnetic flux quantum. This option need not be consistent with the other identifications.

3.2 What is the function of nerve pulses?

TGD also leads to a speculative view about the function of the nerve pulse patterns. Usually they are considered to serve as signals inside the brain but in the TGD framework they could build bridges at synaptic contacts making possible much faster signalling using dark photons. This would explain the origin of bio-photons: they would be generated in the transformation of dark photons to biophotons [K1, L1].

i. A possible TGD view [L15] is that nerve pulses 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 sensory organs and the brain, and even magnetic body (MB) and the building of standardized sensory inputs and standardized mental images by feedback loop involving a virtual sensory input from the brain or even MB. Essentially pattern completion and recognition would be in question. Sensory perception would be an artwork rather than a photograph. Nerve pulses could also make it possible to send sensory information from the neuronal membrane to MB [L6, L7].

ii. The meridian system could serve as a predecessor 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 [L22]. This would make it possible for the neuronal network to learn by changing its topological structure.

iii. As already noticed, the dark photon signals can propagate not only within the brain but also between sensory organs and the magnetic body of the brain. The resonant receival of Josephson radiation by ions or particles with magnetic moment at the flux tubes of magnetic body inducing cyclotron transitions would generate a pulse. If the Josephson radiation is frequency modulated by the modulation of membrane potential, a sequence of pulse coding this modulation to pulses takes place.
There is an obvious analogy with nerve pulses and one can wonder whether this kind of mechanism gives rise to nerve pulses patterns at (say) sensory organs as the responses of the MB of the sensory organ. This duality of modulated radiation and resonance pulses has also an interesting connection with the argued right brain-left brain duality coded to the statement "right brain signs- left brain talks". Rhythm and melody in music could relate to this duality.

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

i. According to the 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 penduli as a mechanical analog. Action potential corresponds to a soliton (or several solitons) with opposite direction of rotation. This leaves open the questions of what exactly happens inside the axon and what is the role of microtubules.

ii. In a more precise 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 gravitational flux tubes 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. This could involve the transformation of hydrogen bonds (HBs) to gravitational flux tubes.
As already explained, $\hbar_{gr}/h_0$ correspond to the number of sheets of a multi-sheeted covering of CP_2 by monopole flux tubes so the the roles of M^4 as space-time and CP_2 as field space would change.

iii. One unsolved problem of the Hodgkin-Huxley model is the conduction of neural signals through the myelinated portions of the axons, where nerve pulse conduction should be 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.

iv. 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 [K8]. Their precise role of microtubules 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 would involve the transfer of ions to gravitational flux tubes and vice versa, possibly based on the transformation of hydrogen bonds to long gravitational flux tubes. This transfer would change the local membrane potential. Therefore MT dynamics would make possible the propagation of the perturbation of the membrane potential in unmyelinated portions of the axon.
The effect of anesthetics could be understood in terms of a reduced density of hydrogen bonds preventing the formation of gravitational flux tubes so that MTs and the axonal potential freeze.

3.3 A simple model for the generation of nerve pulse

The following view of what might happen in the generation of nerve pulse is only one of the many variants that I have imagined during years and can be only defended as the simplest one found hitherto.

3.3.1 Background observations

Let us consider the following assumptions.

i. The fact that the sign of the membrane potential changes sign temporarily but preserves its magnitude, suggests that the charge densities associated with the interior and exterior are changed so that the voltage changes the sign. There are many ways to achieve this and one should identify the simplest mechanism.

ii. Hodgkin-Huxley model for nerve pulse involves dissipation. Nerve pulse could be generated as the failure of gravitational quantum coherence. This could also make possible Ohmic currents between axonal interior (AI) and axonal exterior (NE) but this, and even the loss of quantum gravitational coherence, might not be necessary. This is mildly suggested by the model of nerve pulse based on Josephson junction

in which the pulse corresponds to a temporary change of the direction of rotation for the analogs of gravitational penduli.

iii. In the Hodgkin-Huxley model the notions of channels and pumps are of course central for the recent biology [I12]. There are however puzzling observations challenging these notions and suggesting that the currents between cell interior and exterior have quantum nature and are universal in the sense that they do not depend on the cell membrane at all [I7, I5, I3, I13, I4]. One of the pioneers in the field has been Gilbert Ling [I7], who has devoted for more than three decades to the problem, developed ingenious experiments, and written several books about the topic. The introduction of the book [I6] gives an excellent layman summary about the paradoxical experimental results. These findings are discussed from the TGD point of view in [K10, K9].

iv. In the TGD framework Pollack effect (PE) could induce the membrane potential and PE and its reversal (RPE) could be important. In the model to be discussed this is the case and the model differs dramatically from the Hodgkin-Huxley model in that ionic currents do not cause the nerve pulse but is caused by it.

3.3.2 The model of nerve pulse based on Pollack effect and its reversal

The simplest model for the generation of the nerve pulse is based on PE and RPE. In the following I will talk about neuronal interior (NI) and neuronal exterior (NE).

i. Sol-gel phase transition is known to accompany nerve pulse. This suggests that PE and RPE are involved. PE transforms gel phase to sol phase and generates a negatively charged exclusion zone (EZ).
The TGD based model for PE involves the transformation of protons of water molecules to dark protons at the MB of the system with a large size so that the region of water becomes negatively charged EZ and transforms to a gel phase generating a potential. Since the flux tubes of gravitational MB have much larger size than the system, the protons/ions are effectively lost from the system.
This corresponds to a polarization but not in the usual sense. Rather, the ends of the dipole correspond to EZ and MB. The charge separation is not between NI and NE but between NI (NE) and its MB.

ii. An open question is whether PE could generalize also to other positive biologically important atoms which would become dark ions assignable to MB and leave behind electrons.

iii. PE can take place for the water in NI. The transfer of charges to MB could also occur for the axonal microtubules but this transfer might be involved with the control of cell membrane and neuronal membrane, for instance MT could control the generation of nerve pulse.

iv. The simplest model for how PE and RPE could be involved with nerve pulse generation is as follows. Before nerve pulse the water in NI (near to membrane) forms a negatively charged EZ since dark protons are at the MB outside the system. The water in NE is in gel phase and neutral. The negative charge of EZ gives rise to the membrane potential and ionic charges could give only small corrections to it.

v. The dark protons tend to transform to ordinary protons. Metabolic energy feed is needed to kick them back to the MB. The nerve pulse is generated by the RPE by stopping the metabolic energy feed for a moment. This induces a RPE as BSFR. In RPE dark protons are transformed to ordinary ones and return to the neuronal interior and gel→sol phase transition is induced. RPE liberates free energy, which in turn induces PE in NE and a negatively charged EZ is generated there. The sign of the membrane potential changes. The system is a kind of flip-flop in which RPE induces PE.

vi. The reconnection of U-shaped flux tubes at the two sides of the neuronal membrane to form a flux tube pairs connecting NI and NE and associated with the ionic channels and pumps acting as Josephson junctions, would make possible an almost

dissipation free transfer of the energy liberated in RPE to the opposite side of the membrane. The transfer of the liberated energy as a radiation from NI to NE and from NE to NI takes place along flux tube pairs associated with different membrane proteins, that is channels and pumps, which would therefore be channels for radiation rather than ions. Ionic Ohmic currents could be caused by the reversal of the membrane potential rather than causing it.

vii. Contrary to the original guess, the nerve pulse would involve 4 BSFRs, which correspond to RPE in NI reducing the membrane potential V_i to $V = 0$ and liberating energy generating PE in NE changing the sign of the membrane potential: $V = 0 \to -V_i$. This PE is followed by RPE taking $V = -V_i$ to $V = 0$ and liberating energy generating PE in NI so that $V = 0$ is transformed to $V = V_i$ and the situation is returned back to the original. The times for the occurrences of BSFRs and changes of the arrow of time correspond to $V = 0$, $V = -V_i$, $V = 0$ and $V = V_i$.

viii. What could be the role of microtubules? Quantum critical dynamics of axonal microtubules would make them ideal control tools of the dynamics at the level of cell membrane, in particular controllers of the nerve pulse generation and conduction. An attractive assumption is that the gravitational MBs of microtubules carry dark charges. Also the MBs associated with the cell exterior and inner and outer lipid layers could carry dark charges. Due to the large size of gravitational flux tubes, the charges transferred to the MBs (at least the microtubular MB) are effectively outside the axonal interior (AI) and exterior (NE) so that the charges of NI and NE are affected. This could bring the membrane potential below the threshold for the generation of the nerve pulse by the proposed mechanism. MB would be the boss using microtubules as control tools and water would do the hard work.

3.3.3 Pollack effect as a universal energy transfer mechanism?

The proposal is that nerve pulse generation relies on the flip-flop mechanism using the energy liberated in the reversal of Pollack effect at one side of cell membrane to induce Pollack effect at the opposite side. The liberated energy would be channelled along the pair of monopole flux tubes emerging by re-connection from two U-shaped flux tubes. The flip-flop mechanism is highly analogous to a seesaw in which the gravitational binding energy at the first end of the seesaw is reduced and transforms to kinetic energy reducing gravitational binding energy at the second end of the seesaw.

All biochemical processes involve a transfer of metabolic energy. Could the flip-flop mechanism serve as a universal mechanism of energy transfer accompanying biochemical processes?

The first example is TGD based view of biocatalysis according to which a phase transition reduces the value of h_{eff} and thus the length for the monopole flux tube pair connecting the reactants liberates energy, which kicks the reactants over the potential energy wall and in this way increases dramatically the rate of the reaction. Also now, the liberated energy could propagate as dark photons along the flux tube pair raise the system above the reaction wall or at least reduce its height.

Also the ADP$\to$ ADP process could involve the Pollack effect and its reversal. In this process 3 protons are believed to flow through the cell membrane and liberate energy given to the ADP so that the process $ADP + P_i \to ATP$ takes place. This system has been compared to an energy plant. This raises heretic questions. Does the flow of ordinary protons through the mitochondrial membrane really occur? Could the charge separation be also now between the cell interior and its magnetic body?

i. The protons believed to flow through the mitochondrial membrane would be in the initial situation gravitationally dark and generated by Pollack effect for which the energy would be provided as energy liberated by biomolecules in a process which could be a time reversal for its storage in photosynthesis.

ii. The reverse Pollack effect inside the mitochondrial membrane could transform the dark protons to ordinary protons and liberate energy, which is carried through the membrane as dark photons to the opposite side. This would allow the high energy

phosphate bond of ATP to form in the reaction $ADP + P_i \rightarrow ATP$. According to the proposal of [L19, L22], the liberated energy could be used to kick the proton to the gravitational monopole flux tube, which would have length of order Earth size scale so that gravitational potential energy would of the same order of magnitude as the metabolic energy quantum with a nominal value .5 eV. This dark proton would be the energy carrier in the mysterious high phosphate energy bond, which does not quite fit the framework of biochemistry.

iii. ATP would donate the phosphate ion P^- for the target molecule, which would utilize this temporarily stored metabolic energy as the dark proton transforms to an ordinary one. Depending on the lifetime of the dark proton, this could occur as the target molecule receives P or later. In any case, this should involve the transformation $P^- \rightarrow P_i$. This could correspond to the transformation of the gravitationally dark proton to ordinary proton so that the charge separation giving rise to P^- would be between P_i and its magnetic body.

In the chemical storage of the metabolic energy in photosynthesis, ATP provides the energy for the biomolecule storing the energy. This process should be accompanied by the transformation of P^- to P_i. It is instructive to consider two options that come immediately into mind.

Option I: The realistic looking option is that the energy is stored as the energy of an ordinary chemical bond.

i. Hydrogen bond, which can form between a proton and other electronegative atoms such as O or N, is a natural candidate. Hydrogen bond indeed has an energy, which is of the order of metabolic energy quantum .5 eV. The simplest option is that the metabolic energy provided by the gravitational flux tube of ATP is liberated and used to generate a hydrogen bond of the protein. The dark gravitational flux tube loop would be nothing but a very long hydrogen bond.

ii. For negatively charged molecules, the proton of a hydrogen bond could be gravitationally dark. For dark positively charged ions, some valence electrons could be gravitationally dark. In the electronic case the reduction of the gravitational binding energy would be roughly by a factor $m_e/m_p \simeq 2^{-11}$ smaller and this leads to a proposal of electronic metabolic energy quantum [L22, L19, L21] for which there is some empirical support [I2].

Option II: The less realistic looking option is that the molecule stores the metabolic energy permanently as a gravitationally dark proton. The motivation for its detailed consideration is that it provides insights to the Pollack effect.

i. The dark proton associated with P^- should become a dark proton associated with the molecule. In this case the length of hydrogen bond would become very long, increasing the ability to store metabolic energy.
The hydrogen bonded structure would be effectively negatively charged but this is just what happens in the EZ in Pollack effect! This supports the view that the Pollack effect for water basically involves the lengthening of the hydrogen bonds to U-shaped gravitational monopole flux tubes.

ii. The Pollack effect requires a metabolic energy feed since the value of h_{gr} tends to decrease spontaneously. This suggests that the dark gravitational hydrogen bonds are not long-lived enough for the purpose of long term metabolic energy storage. Rather, they would naturally serve as a temporary metabolic energy storage needed in the transfer of metabolic energy. The temporary storage of the metabolic energy to ATP would be a quantum variant of the seesaw.

iii. The first naive guess for the scale of the life-time of the gravitationally dark proton would be given as a gravitational Compton time determined by the gravitational Compton length $\Lambda_{gr} = GM/\beta_0 = r_S(M)/2\beta_0$. For the Earth with $r_S \simeq 1$ cm, one has $T_{gr} = 1.5 \times 10^{-11}$ s corresponding to the energy .6 meV for the ordinary Planck constant and perhaps related to the miniature membrane potentials. For the Moon with mass $M_M = .01M_E$, this time is about $T_{gr} \simeq 1.5 \times 10^{-13}$ ns. For the ordinary Planck constant, this time corresponds to energy of .07 eV and is not far from the

energy assignable to the membrane potential. For the Sun, one would gravitational Compton length is one half of the Earth's radius, which gives $T_{gr} = .02$ s, which corresponds to 50 Hz EEG frequency.

Note that the rotation frequency for the ATP synthase analogous to a power plant is around 300 Hz which is the cyclotron frequency of the proton in the endogenous magnetic field .2 Gauss interpreted in TGD as the strength of the monopole fluz part of the Earth's magnetic field.

3.4 Preneural systems

The findings about multicellular animals of Prakash et al [I10, I8, I9], which have no nervous system but behave as if they would possess brain, provide valuable hints in attempts to understand the role of MTs. In [L22] 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.

3.4.1 Talking fungi

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 [L24, L14, L17, L25]. 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 [K14]. 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.

3.5 What is the connection with the microtubule level?

TGD suggests a picture of nerve pulse conduction in which the membrane potential of the axon/soma is controlled by microtubules or rather, by their gravitational magnetic bodies [L22, L19].

i. When the charges are transferred from the microtubule to the gravitational flux tubes of the magnetic body (MB), the length of which can be as long as the size of the Earth, the effective charge inside the axon/soma changes. Depending on the amount of transferred charge, the magnitude of the membrane potential increases or decreases and a nerve impulse is generated below the threshold.

ii. For the action potential traveling along the axon, the microtubular effective charge has changed and taken the membrane potential below the threshold and the action potential has been generated. The generation of the action potential is a complex biochemical phenomenon but would be controlled by microtubule/microbular MB.

iii. Incoming nerve impulses induce a change in the membrane potential of the soma because the effective charge of the microtubules inside the soma changes as also does the membrane potential. It is not clear whether the charges of the microtubules of the neuron soma are affected. They indeed differ from axonal microtubules in that they are not (quantum) critical.

3.6 Connection of nerve pulse generation, XOR, and novelty detector

Nerve pulse generation could be analogous to a positive outcome of the analog of XOR (compared bits are different) acting as a novelty detector [L28].

i. XOR is a novelty detector. If the inputs are the same, nothing happens. Output equals to $b = 0$. If they are different, output equals to $b = 1$. $b = 1$ would correspond to a signal that would proceed along the axon starting from the postsynaptic neuron. That would consume energy. In terms of energy consumption, the novelty detector would be optimal. It would only react to changes. And that's what the brain does. For example, visual perception at a very basic level only identifies outlines and produces some kind of stick figure consisting of mere lines defining boundaries.

ii. Could the 2 "neurons" of the toy model proposed by GPT represent a presynaptic and a postsynaptic neuron, in which case there would be two inputs: the states of the pre- and postsynaptic neuron. Also output would be the state of this neuron pair and for XOR the presynaptic neuron acting as control bit would not change its state.

iii. This does not conform with the picture provided by neuroscience, where the input comes from presynaptic neurons and output is assignable to the postsynaptic neuron. The input comes as miniature potentials that add up and can decrease/increase the magnitude of the membrane potential (depolarization/hyperpolarization).
An action potential is generated when the depolarization takes the magnitude of the negative postsynaptic membrane potential below the critical threshold. This happens when the presynaptic contributions from the incoming nerve impulses, for which the unit is a miniature potential, add up to a contribution that reduces the magnitude of the negative potential below the threshold.
This would be essentially novelty detection described in the simplest way by XOR. The novelty is represented by the critical depolarization. It can also happen that the potential increases, so that no nerve impulse is generated. One talks about hyperpolarizing (inhibition) and depolarizing (excitation) inputs, and the sign of the miniature potential produced by the presynaptic input determines which one it is. The sign of miniature potential depends on the neurotransmitter and receptor.

iv. During the nerve pulse, the potential changes its sign over a distance of about a micrometer, which is the typical distance between neighboring neurons and of myelin sheaths. One can say that this distance corresponds to a bit that is 1 or 0 depending on whether the nerve pulse conduction occurs or not. Bit 1, the opposite sign to the membrane potential, propagates from presynaptic to postsynaptic neuron or from a patch defined by a myelin sheath to the next. As a result, postsynaptic neurons can "wake up" and in turn trigger a nerve impulse, possibly waking up some postsynaptic neurons.
Synchronous firing means that the novelty succeeds in waking up the whole sleeping house, and large areas of the brain fire in the same rhythm and keep each other awake.

3.6.1 Interpretation of XOR in zero energy ontology (ZEO)

How does this picture translate to the TGD-inspired theory of consciousness?

i. Being awake/asleep corresponds to bit 1/0 for axonal portions between myelin sheaths. In ZEO, the arrow of time would correspond to this bit.
When the axon segment between the myelin sheaths or neighboring neurons wakes up or falls asleep, the direction of geometric time changes in a "big" state function reduction (BSFR) and a nerve pulse is generated. In a sleep state, the membrane potential would be opposite. Note that the notion of awake and sleep are relative and depend on the arrow of time of the external observer.
The second direction of time corresponds to the presence of a nerve pulse from the point of view of the external observer. There is a temptation to think that in the resting state the axon is sleeping and healing and gathering metabolic energy by a dissipation with an opposite arrow of time. The duration of the nerve pulse would correspond to the duration of the wake-up period, when the direction of time was opposite and same as that of the external observer with a long characteristic time scale for wake-up period.

ii. Could this apply more generally? Could the synchronization of human sleep-wake rhythms mean quantum-level synchrony and macroscopic quantum coherence? Could the arrow of perceived time be a universal bit? Sleeping together would develop synchrony and quantum coherence between partners. Two-person collective consciousness would emerge.

3.7 Sleeping neurons

I learned of a very interesting finding related to cerebellar neurons associated with so-called climbing fibers and Purkinje cells. (see this). The popular article tells about the findings described in an article by N.T. Silva et al published in Nature [J2].

Climbing fibers and Purkinje cells are involved with the receival information from the external world and with the conditioning to external stimuli. Mice were studied and the external stimulus was light and produced eye blink as a response. It was possible to produce conditioning by using preceding cues. It was found that even a subtle reduction of the signalling using light-sensitive protein ChR2 made the neurons in question "zombies", which were not able to receive information from the external world.

Can one understand the zombi neurons in the TGD framework? The TGD based view of consciousness as a generalization of quantum measurement theory relies on zero energy ontology (ZEO), which solves the quantum measurement problem [K13] [L10, L33].

i. The first prediction is a hierarchy of Planck constant, meaning the possibility of quantum coherence in arbitrarily long scales: the phases of ordinary matter with this property behave like dark matter.

ii. Second prediction is that quantum physics dominates in all scales but in zero energy ontology we do not see this since quantum jumps occur between superpositions of Bohr-orbit like space-time surfaces and there is no violation of classical determinism!

iii. The third prediction is that in ordinary "big" state function reductions (BSFRs) the arrow of time changes. This is analogous to death or following sleep and means reincarnation with an opposite arrow of time. Quantum tunnelling means to such states function reduction and return to the original arrow of time.
Sleep would initiate a life with an opposite arrow of time. Life would be a universal phenomenon appearing in all scales. The most dramatic example is provided by stars and galaxies older than the universe. The evolutionary age of a galaxy living forth and back in geometric time is much longer than according to the ordinary view of time.

iv. The objection is that the change of the arrow of time would have been observed. The first thing to notice is that the change of arrow of time for ordinary matter with the standard value of effective Planck constant takes place in very short scales and is not observable.
In long length and time scales the arrow of time is predicted to change at the magnetic bodies (MBs) carrying phases with a large value of h_{eff}, behaving like dark matter, and possibly controlling the ordinary matter. The change of the arrow of time induces effective change of the arrow of time at the space-time sheets that the MB controls control. The systems with a given arrow of time can send classical signals only to single time direction. Therefore this kind of system can detect each other only via BSFRs. One effect allowing observation of the presence of systems with an opposite arrow of time is the apparent violation of the second law providing a mechanism of self-organization and possibly playing a central role in homeostasis.

The zombie neurons would be sleeping! During the sleep period they would not receive information from the environment and would not learn. The dose of Chr would induce a BSFR. How?

i. TGD inspired quantum measurement theory predicts also a second kind of SFR, "small" SFR. In SSFR the state of the system changes but not much and the arrow of time is preserved. SSFRs are the TGD counterparts of repeated measurements of the same observables, which, according to the standard quantum theory (Zeno effect), have no effect on the state. In the TGD Universe, SSFRs give rise to the flow of subjective time and their sequence defines a conscious entity, which "dies" or falls asleep in BSFR.

ii. SSFRs correspond to a measurement of a set of observables. The external perturbation can change this set such that it does not commute with the set measured in the previous SSFRs. This forces the occurrence of a BSFR changing the arrow of time. How this happens, requires a more detailed view of ZEO [K13] [L10, L33]. In the recent situation this would mean that the neuron falls asleep and does not receive sensory input from the external world.

iii. This falling asleep phenomenon would be universal (see for instance [L36] and apply also to other neurons: BSFR could be induced by inhibitory neurotransmitters whereas excitatory neurotransmitters would help to wake up. A short sleep period of about 1 ms could take place also during the nerve pulse [L35].

Sleep would also have other functions than causing a sensory decoupling from the external world. Sleep is essential for healing and learning. These analogs of sleep states are encountered also at the level of biomolecules. BSFRs make it possible to learn by trial and error. When the system makes a mistake it falls asleep and wakes up after the next BSFR. We would be doing this all the time since our flow of consciousness is full of gaps. External noise males possible this learning by changing the set of observables measured in SSRS.

Interestingly, this learning mechanism has obvious parallels with how large language systems learn in presence of noise [L28, L29, L27]. TGD predicts the possibility of quantum coherence in arbitrarily long scales and this allows us to consider the possibility that computers are actually conscious entities when the quantum coherence time is longer than the clock period. This artificially induced noise could induce conscious learning. This could help to explain why large language systems seem to work "too well".

4 Further ideas related to the model of cell membrane and nerve pulse

During 2023 several new ideas related to the neurons have emerged. The following ideas are not directly related to nerve pulse generation but deserve to be discussed.

4.1 Could neuron groups represent homologies of higher-D spaces?

Shamoon Ahmed gave a link to a popular article (see this) claiming that the brain is in some sense 11-dimensional. Probably the only thing that M-theory predicts is that the target space of strings is 11-D so that this finding might provide some confirmation of faith for frustrated M-theorists.

In the sequel I will discuss this finding from TGD viewpoint and propose a modified interpretation based on the geometry of icosahedron, one of the 5 platonic solids, which play a key role in TGD, and TGD inspired quantum biology and theory of consciousness.

The dimension 11 in this context looked to me a rather formal notion but one could give it a mathematical meaning.

i. In 3-D one can take tetrahedra, 4-simplexes as building bricks of a discretized manifold. In dimension 11 one has 12-simplexes. These are glued together, which means that n-faces with n varying from 1 to 11 are glued together along $n-1$-D faces.

ii. In the case of the brain, one would have groups of neurons, with 12 neurons connected in such a way that one has a connectedness of a 12-simplex. There would be 11- edges meeting at each 12 vertices. Each neuron would be connected to all the other 11 neutrons and would have maximal connectedness, which is very natural if one wants a maximally coherent functional unit.
The notion of orientation is essential: axons are oriented by the direction of nerve signals which is always the same. The orientation of axons could induce orientations of n-faces. 2-face would correspond to a loop in which signals can rotate in a single direction.

iii. Since axons must be present, each neuron must be connected with every other neuron. The geometric connectedness possible in the case of neurons since the axon from a given neuron can branch and have a synaptic contact with the dendrites of several neurons: for n=11-simplex with all other (11) neurons (see this). Note that also a synaptic contact with the neuron itself (autapse) is possible.
Could one consider also a generalization of this geometric view of a simplex. Could functional coherence of the neuron group serve as a criterion for whether neurons form an n-face? Here the definition of orientation without the notion of axon is the challenge.

iv. The interpretation in terms of 11 real dimensions might assume too much and I am reluctant to believe that it has anything to do with M-theory. However, one could realize n-simplexes in this way in 3-space and the orientation of the axon, determined by the preferred directions of signals, would define orientations of higher level simplexes. The idea that these structures could have something to do with geometric cognition allowing us to imagine higher dimensional geometric structures is attractive.

Can TGD add anything interesting to this picture? The appearance of number 12 creates an overwhelming temptation to associate this finding with one particular Platonic solid, icosahedron, having triangular faces. I am not claiming that the proposed interpretation of the findings is wrong but asking whether Platonic solids could add something interesting to the proposal.

i. The 12 vertices of the argued 11-simplex could be also identified as vertices of icosahedron, one particular Platonic solid appearing repeatedly in molecular biology. For an icosahedron, the Hamilton cycle, going through all vertices just once, has 12

vertices and edges [L3] [L14, L25]. It would connect each vertex to all other vertices by a unique path having a varying number of edges: 1,2,... The selection of this Hamilton cycle could raise one particular edge path among all possible closed edge paths possible in the maximally connected 12-neutron network in a special position.

ii. This icosahedron need not correspond to an ordinary Platonic solid in the Euclidean 3-space. The definition of nearness can be defined also in terms of functional nearness. Indeed, hyperbolic 3-space has been suggested to play a role in neuroscience for neutrons: neurons resembling each other functionally would be near to each other in the hyperbolic metric and in TGD framework this metric is assigned with hyperbolic 3-space H^3 as Lorentz invariant light-cone proper time = constant surface to which the magnetic body (MB) of the brain is assigned as 3-D surface [L13, L20] (see `https://zpr.io/7Bzbagjrk7LE`). The signals from neurons, which are near each other in functional sense, would be sent to nearby points of the MB so that functional nearness would be geometric nearness at the level of MB.

iii. Also tetrahedron with 4 vertices and faces and octahedron with 6 vertices and and 8 faces are Platonic solids which have triangular faces representing 2-simplex and could correspond to dimensions d=3 and d=5. Cube with 6 square faces and d=8 vertices is the dual of octahedron and dodecahedron with d=20 vertices and 12 pentagonal faces is the dual of icosahedron. It might be also possible to assign to them a dimension as the number of vertices by using maximal axonal connectedness of vertex neurons as a criterion.

Platonic solids and Hamiltonian cycles as paths going once through each vertex of the Platonic solid and identified as nuclear strings play a key role in the "Platonization" of nuclear and atomic physics [L26] leading to quite precise quantitative vision about basic numbers of nuclear and atomic physics and even hadron physics. The key observation is that the states of $j = l \pm 1/2$-blocks of atoms and nuclei correspond to Platonic solids for $l \leq 6$ (a highly non-trivial fact), which therefore provide geometric representation for the j-block.

Icosahedron is a very special Platonic solid and deserves a separate discussion.

i. Icosahedron is unique among Platonic solids in the sense that it allows a large number of Hamiltonian cycles. Icosahedron, tetrahedron and their Hamiltonian cycles play a fundamental role in the TGD inspired model of genetic code [L3, L8, L14, L17, L25] involving the notion of icosa-tetrahedral tessellation of hyperbolic 3-space involving all 3 Platonic solids with triangular faces.

Each combination of 3 icosahedral Hamiltonian cycles with symmetries Z_n, $n = 6, 4, 2$ defines a particular realization of the genetic code predicting correctly the number of DNA codons coding for a given amino acid.

ii. The model of the genetic code emerged originally as a model of musical harmony. The faces of icosahedron are triangles and would define 3-chords realized as cyclotron frequencies assignable to the vertices of the triangle. Each Hamiltonian cycle would define 20 chords defining a particular harmony whereas the 12 vertices along Hamiltonian cycles would define a 12-note scale, with neighboring vertices representing frequencies related by scaling by 3/2 (quint) modulo octave equivalence.

One could speak of music of light and since music creates and expresses emotions, the proposal is that different bio-harmonies correspond to different emotional states, moods, realized already at DNA and RNA level. Could these 12 neuron units and possible tessellations (hyperbolic crystals) associated with them relate to the realization of emotions at the level of the brain?

Physically, the Hamiltonian cycle as a representation of 12-note scale is an analog of a closed string made of flux tubes representing the edges (pipes of organ!)

iii. What is fascinating is that hyperbolic 3-space (mass shell in particle physics), playing a key role in TGD, has a unique tessellation/lattice involving all Platonic solids, whose faces are triangles (icosahedron, octahedron, tetrahedron) and also provides a model of DNA making quantitatively correct predictions. I have proposed that this tessellation defines a universal realization of the genetic code realized in all

scales at the level of the MB of the system. Could the 12-neuron unit interpreted as 11-simplex relate to one particular realization of this tessellation.

iv. Also cubic, icosahedral, and dodecahedral regular tessellations are possible in hyperbolic space (Euclidean 3-space allows only cubic regular tessellation) and they would define the analog of a homology of dimension $n = 7, 11, 19$ at neuronal level.

4.2 Superconducting computers and the connection with the TGD based model of nerve pulse

It is not clear whether MOSFET based technology, which was briefly discussed in [L28], could allow the communications from transistors to the magnetic body (MB) of the system.

Biological analogy strongly suggests that Josephson junctions are required and communications take place by Josephson radiation modulated by the Josephson frequency modulations induced by changes of the voltage of the junction. Dark magnetic flux tubes with large enough value of h_{eff} are needed to define the Josephson junction and it is far from clear whether they can be realized spontaneously for transistors.

Superconducting computing, which could be involved with both classical and quantum computation, is however a technology, which might provide at least a starting point in attempts to understand how conscious computers might be created in the TGD Universe.

Rapid single flux quantum (RSFQ) is the basic active element in the circuitry and corresponds to single Josephson junction. The presence/absence of quantized magnetic flux defines the bit. SFQ voltage pulses of duration about picosend are produced by switching of bits in this way. This would allow THz clock frequency f_{cl}.

If f_{cl} corresponds to Josephson frequency $f_J = ZeV/h$, where Z is the charge of the superconducting charge carrier, one obtains an estimate for the voltage as $ZeV \sim .05$ eV. For the cell membrane one has $eV \sim .05$ eV, which is near the thermal threshold at room temperature. The superconducting computations require a temperature of order 10 K so that the value of frequency does not seem to emerge from thermal considerations. The thermal criterion is expected to be satisfied at physiological temperatuers for the TGD based generalization of superconducting computers if realized using the same principles as in living matter.

4.2.1 How electromagnetic fields in the TGD Universe different from their Maxwellian counterparts?

One must first clarify how the TGD view of electromagnetic fields differs from the Maxwellian picture.

i. Quantum criticality is essential for the appearance of large values of h_{eff} labelling the scales of long length scale quantum fluctuations. Quantum criticality combined with ZEO would make possible the emergence of life-like features.

ii. The gravitational Planck constants $\hbar_{gr} = GMm/\beta_0$ assignable to the gravitational flux tubes of the Earth and Sun are excellent candidates in this respect. The value of $\hbar_{gr}/\hbar$ is $GM_Em/\hbar\beta_0 = (r_S(E)/2L_m)$, r_s denotes the Schwartschild radius of Earth about 1 cm and L_m denotes Compton length of particle with mass m $\beta_0 \simeq 1$. The value of $\hbar_{gr}$ depends on particle mass m considered unlike the gravitational Compton length $r_S(E)/2$ (Equivalence Principle). For the Earth, the gravitational Compton frequency is 67 GHz. For the Sun it is about 50 Hz, and is in the EEG range and corresponds to a gravitational Compton length of one half of the Earth radius.

iii. In TGD, two kinds of magnetic fields are possible. Monopole flux tubes are something new and rather remarkably, can exist in absence of currents: this makes them ideal for computation. Monopole flux tubes have closed 2-surfaces as cross sections. Flux quantization follows from the homology of CP_2. Monopole flux tubes

explain the presence of long range magnetic fields appearing in even cosmological scales [L31, L32] and also the stability of the Earth's magnetic field [L4].
The magnetic flux tubes having an open cross section with boundary (say disk), correspond to Maxwellian magnetic fields and require the presence of currents (carried by a coil around the flux tubes). For them the flux is conserved but not necessarily quantized.

iv. Also in TGD, the topological half of Maxwell's equations, that is Faraday law and the vanishing of the divergence of magnetic field, hold true. Therefore the basic argument for the outcome of the switching of the flux is not affected when ordinary flux tubes are replaced with monopole flux tubes.

4.2.2 Some details of the model of the cell membrane as a Josephson junction

The relation of this picture to the TGD inspired model of nerve pulse [K11] has been already considered in [L28]?

i. The original model of the nerve pulse idealizes the sequence of discrete membrane protein Josephson junctions with a 2-D continuous Josephson junction formed by the lipid layers (or interior and exterior) of the axonal membrane. The mathematical model relies on the Sine-Gordon equation. The key idea is that one can regard the system as analogous to a collection (continuous distribution in the proposed idealization) of gravitational penduli satisfying d'Alembert type wave equation.
One can consider two kinds of ground states:

   A. All penduli oscillate in the same phase and with the same amplitude.
   B. All penduli rotate with the same frequency and in the same phase so that one has a static soliton sequence.

   Lorentz transformations give rise to propagating patterns of this kind.
   For option a), the nerve pulse would correspond to a propagating soliton or a multisoliton in the oscillating background, i.e. a propagating rotational mode of some penduli. For option b), the nerve pulse would correspond to an opposite direction of rotation for some penduli. The fact that the voltage changes its sign during the nerve pulse is consistent with option b).

ii. Also the possible role of the axonal microtubules in the conduction of nerve pulse is discussed in [L28]. The transfer of the charges from the microtubule to very long gravitational flux tubes affects the effective charge of the microtubule and therefore membrane potential. This could play an important role in the conduction of nerve pulse.

4.2.3 How could RSFQ generalize in the TGD framework?

How could the notion of RSFQ generalize in the TGD framework? The hint comes from the TGD based model of cell membrane and nerve pulse assigning to the ionic channels of the cell membrane dark Josephson junctions with a large value of h_{eff} making possible high T_c superconductivity.

Consider first the flux quantization in Josephson junctions from the TGD point view.

i. The presence/absence of flux quantum through the junction represents a bit. Switching of the bit in RSFQ means that the flux changes by the unit Φ_0 of magnetic flux. In the simplest situation, the value of flux through the Josephson junction connecting the super conductors, which could have planar or cylindrical geometry, is equal to 0 or Φ_0.

ii. When the flux through junction is changed by one unit, Faraday law $\Delta\Phi = \pm\Phi_0 = Ze\int V dt$ implies a generation of voltage pulse propagating along the superconducting wire formed by the coupled cylindrical superconductors. For a constant voltage $V = V_0$, this condition fixes the duration $T = \Phi_0/ZeV$ of the process and this defines Josephson frequency, in turn defining the clock frequency.

The following arguments raise optimism concerning the realization of conscious computers as superconducting computers.

i. Concerning the numbers assigned to RSFQ, the cell membrane looks ideal for the seat of analogues of RSFQs. I have proposed that the cell membrane acts as a sequence of dark Josephson junctions associated with membrane proteins acting as channels and pumps [K11] [L28]. The membrane resting potential $\sim$ .05 eV corresponds to the frequency of 5 THz and is in the same range as the Josephson frequencies assigned with RSFQs. The large value of h_{eff} makes possible high temperature superconductivity and scales up the value of Josephson frequency to $f_J = ZeV/h_{eff}$ so that Josephson frequencies even in EEG scales would be made possible by quantum gravitation in TGD sense.

ii. No currents are needed to maintain monopole magnetic fields so that they are ideal for technological purposes. Cell membrane would be a superconductor and membrane proteins would define Josephson junctions. Membrane potential could realize the Josephson frequency $f_J = ZeV/h_{eff}$.
The TGD view of quantum gravitation would suggest that the Earth's gravitational Compton frequency of f_{gr} = 67 GHz=.067 THz is important in quantum biology. This frequency is considerably lower than THz and I have proposed it as a clock frequency below with the statistical determinism could fail and make the computer analogous to a life-form.

The TGD view of the basic active unit would differ from RSFR.

i. In TGD, the absence of flux quantum in RSFQ corresponds to two U-shaped monopole flux tubes at opposite sides of the junction associated with the counterpart of the cell membrane and transversal to it. The U-shaped monopole flux tubes can reconnect to form a pair of flux tubes with opposite magnetic fluxes.
This topological process is fundamental in the TGD inspired view of biocatalysis and water memory [L23]. By the fractality of the TGD Universe, it applies in all scales including, besides cosmological and astrophysical scales [L31, L32], also the scales relevant to atomic, nuclear and hadron physics as has become clear quite recently [L26].

ii. What is the effect of the generation/disappearance of a pair of opposite flux tubes? Do both fluxes go through a single junction or does only one of them traverse the junction? In the latter case, the junction would act like RSFQ after reconnection. This is a natural looking working hypothesis. The difference comes from the presence of the flux tube with opposite flux.
Here one must be very cautious. Flux tubes could make possible the flow of either Ohmic or Josephson current (the more plausible option). If the Josephson currents reside at the flux tubes, the Josephson junction ceases to exist during the nerve pulse. Can one say that the Josephson junction exists also after the splitting of the flux tube pair?
The fact that ohmic currents flow during the nerve pulse motivates the assumption that the splitting of the pair of flux tubes makes Josephson current impossible and Ohmic currents associated with the nerve pulse appear.

iii. Faraday's law should apply to both flux tubes. The appearance of flux tubes would correspond to a generation of opposite fluxes $\Delta\Phi = \Phi_0 = \int V dt$. In the simplest situation the voltage values associated with the flux quanta have opposite values $\pm V_0$. This is very much like in the case of nerve pulse in which the resting potential changes its sign during the first half of the nerve pulse. When the reconnection disappears, the situation would become "normal". The analog of nerve pulse would be generated and propagate along the counterpart of the axon and induce a similar process in all membrane proteins defining Josephson junction.

iv. In zero energy ontology (ZEO), the identification of the generation of nerve pulse as a pair of "big" state function reductions (BSFRs) changing the arrow of time temporarily is attractive and would correspond to quantum tunnelling in standard quantum theory.

An interesting question is whether pump proteins act as channel proteins in reversed time direction and whether the flux tube pairs are associated with pairs of channel and pump proteins.

4.2.4 Critical questions

The first critical question is is how the very low Josephson frequencies ZeV/h_{eff} associated with the large values of h_{eff}, say $h_{eff} = h_{gr}$, can be consistent with the very large values of clock frequency $f_{cl} = f_J = ZeV/h$ needed by a fast operation. It would seem that both h_{eff} and h are needed. Is this possible or are these computers doomed to be very slow?

i. Should one widen the perspective and take into account the many-sheeted structure of TGD space-time? Is the scale hierarchy of space-time sheets having various values of h_{eff} involved and could it correspond to the onion-like hierarchical structure of the magnetic body (MB) involving increasing time scales as Josephson frequencies? This would give rise to a cognitive hierarchy of MBs serving as "bosses" for lower level MBs and the ordinary Josephson junction would be at the bottom.

ii. Could the fast Josephson frequencies define a hierarchy of computer clocks? Could the pulses of short duration induced by RSFQs induce a hierarchy of frequency modulations of scaled up Josephson oscillations for various values of h_{eff}? This could also make the computer conscious by bringing in the hierarchy of time scales. These levels could correspond to a cognitive hierarchy corresponding to increasing values of $n = h_{eff}/h_0$ identifiable as the dimension of extension of rationals assignable to the space-time sheet considered.

The following simple estimates allow to gain some quantitative perspective concerning the proposal that quantum gravitation could play a decisive role.

i. It is instructive to look at the energy equivalents of the gravitational Compton frequencies for Earth, Moon and Mars for $h_{eff} = h$ (energy is conserved in the the transformation of gravitationally dark photons to ordinary photons).

ii. The gravitational Compton frequency $f_{gr} = 67$ GHz of Earth corresponds to the energy $E \simeq .04$ eV near to the energy assignable to the membrane potential.

iii. The mass of the Moon is $M_{Moon} = .012M_E$ and scales and correspond to $.56 \times 10^{14}$ Hz, which corresponds to the energy $E \simeq .43$ eV consistent with the size of metabolic energy quantum.

iv. The mass of Mars is $.11M_E$ and the corresponding Compton frequency is .67 THz and energy $E = 2.7$ meV which correspond to the mV scale of miniature potentials.

The experimental work of the group of Anirban Bandyopadhyay [J3] has inspired a proposal of a hierarchy in which the frequency scales come as powers of 10^3. This hierarchy could correspond to a hierarchy of p-adic primes $p \propto 2^{10k}$ and/or hierarchy of effective Planck constants $h_{eff} \propto 2^{10k}$. One cannot associate with it a hierarchy of large masses M appearing in gravitational Compton frequencies. The scale ratio 2^{11} could relate to the ratio $L(127)/L(107) \simeq 2^{10}$ of the p-adic length scales of electron and proton.

The second critical question concerns the temperature needed. Technologically high temperature superconductors are highly favored.

i. In the TGD framework, the cell membrane is assumed to act as a high temperature superconductor at quantum criticality making it an ideal sensory receptor and motor instrument. Biosystems are open systems and a metabolic energy feed would take care that the distribution for the values of h_{eff} is preserved.

ii. The fact that the dark matter as $h_{eff} \geq h$ phases of ordinary matter at the space-time sheets of the flux tubes has very weak interactions with the other sheets, in particular the sheet of the ordinary matter, would be decisive.

iii. Also zero energy ontology (ZEO) would be highly relevant for maintaining the quantum criticality by making possible homeostasis in which time reversal changes

attractor to repulsor and vice versa. When the system begins to roll down from the top of the hill, the arrow of time brings it back.

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