TGD inspired model for magneto-reception and circadian rhythm

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December 27, 2019

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Abstract

One of the proposals of quantum biology is a quantum mechanism for the mysterious looking ability of birds and fishes to find back to the place, where they were born. It is believed that navigation involves detection of the inclination of the local magnetic field of Earth but not its direction as in the ordinary ordinary compass. The alternative option states that birds have an analog of compass in their brain. The challenge is to understand what is the mechanism making possible to get the information about magnetic field and how this information is transformed to a chemical signal and eventually to a pattern of nerve pulses. In TGD framework one can challenge the assumption that the magnetic field of Earth is what makes possible the navigation and even what the navigation means.

Quantum biologists try to solve the problem using standard quantum physics. The formidable looking problem is that the energy scale for magnetic energies is extremely small. In the magnetic field of Earth the magnetic interaction cyclotron energy for electron is by factor of order one million below the thermal energy. If one believes of quantum physics in its standard form, one should understand how it is possible to generate a signal making possible non-trivial chemical effects. The proposal that has gained widest acceptance is known has as radical-pair mechanism (RPM) and has raised hopes about circumvent this problem.

The answer to the question whether RPM works is very important from the point of view of TGD based explanation for macroscopic quantum effects in living matter since TGD based model involves new quantum physics via the hypothesis that dark matter corresponds to $h_{eff} = n \times h_0$ phases located at flux tubes of "magnetic body" (MB). If RPM fails, TGD based quantum biology would be the next natural trial (if science proceeded by trying first all options that fail).

I have already earlier proposed a TGD based model for the findings related to magnetoreception and pace-keeper mechanism. The model discussed also photo-taxis and gravi-taxis. The improved model discussed here relies on essentially the same elements but does not assume RPM as the mechanism producing nuclear spin polarization as an analog of compass.

1 Introduction

For few years ago I was contacted by a friend with whom we have had several interesting discussions about consciousness and neuroscience. She sent several links related to certain aspects of quantum biology about which I had not been aware and these links inspired this article.

1.1 Background

One of the proposals of quantum biology is a quantum mechanism for the mysterious looking ability of birds and fishes to find back to the place, where they were born. It is believed that navigation involves detection of the inclination of the local magnetic field of Earth but not its direction as in the ordinary ordinary compass. The alternative option states that birds have an analog of compass in their brain. The challenge is to understand what is the mechanism making possible to get the information about magnetic field and how this information is transformed to a chemical signal and eventually to a pattern of nerve pulses. In TGD framework one can challenge the assumption that the magnetic field of Earth is what makes possible the navigation and even what the navigation means.

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The answer to the question whether RPM works is very important from the point of view of TGD based explanation for macroscopic quantum effects in living matter since TGD based model involves new quantum physics via the hypothesis that dark matter corresponds to $h_{eff} = n \times h_0$ phases located at flux tubes of "magnetic body" (MB). If RPM fails, TGD based quantum biology would be the next natural trial (if science proceeded by trying first all options that fail).

I received links to several articles and list them here to help the interested reader. The following list is about phenomena involved.

- *Cryptochrome Mediates Light-Dependent Magnetosensitivity of Drosophila's Circadian Clock* by Yoshii et al [I3] (see `http://tinyurl.com/zvlmxp6`). Cryptochrome (CRY) (see `http://tinyurl.com/create.php`) has been proposed to be the photo-receptor being involved with both circadian rhythms and magneto-sensitivity. In response to light CRY slows down the circadian clock and eventually leads to an arhythmic behavior.

  The response to magnetic fields in the range around 3 Gauss (6 times the strength of $B_E = .5$ Gauss) was found to be slowing down of the circadian clock. Clock response to magnetic field was present in the presence of blue light (photon energy in the range 2.64-2.75 eV) but absent in red-light illumination. This suggests that the blue light is necessary for any response at all and that magnetic field affects the response.

  This response could be understood as the effect as the activation of CRY by the external field but one can consider also more complex mechanisms. This finding is taken as a support for RPM, which predicts that the response depends on wave-length and strength of magnetic field.

- *Circadian and Geotactic Behaviors: Genetic Pleiotropy in Drosophila Melanogaster* by Clayton [I2] (see `http://tinyurl.com/j4vmr8c`) tells about correlation between circadian rhythms and gravitaxis (geotaxis). The following excerpt from the abstract gives some idea about the findings.

  > *Two of these genes, cryptochrome (CRY) and Pigment-dispersing-factor (PDF) are integral to the function of biological clocks. PDF plays a crucial role in maintaining free-running circadian periods. The CRY gene alters blue-light (< 420 nm) phototransduction which affects biological clocks, spatial orientation and taxis relative to gravity, magnetic fields, solar, lunar, and celestial radiation in several species. The CRY gene is involved in phase resetting (entrainment) of the circadian clock by blue light (< 420 nm).*

The following articles are about radical-pair mechanism.

- *Chemical magneto-reception in birds: The radical pair mechanism* by Rodgers and Hore [I1] (see `http://tinyurl.com/zsg4b95`).

  The abstract of the article is too long to be attached here but very informative and honestly tells the situation in the field. Abstract describes the basic problem that RPM must solve: the magnetic interaction energy of electron with the Earth's magnetic field is by 6 orders of magnitude too low. The abstract also mentions that with few exceptions RPM has been observed only in magnetic field intensities 10 Gauss- 10 Tesla. The exception would be avian compass and photosynthesis! The strength of 10 Gauss field is 50 times higher than the strength of Earth's magnetic field of $B_E \sim .5$ Gauss so that it is far from proven that RPM could be behind the avian chemical compass and unreasonable effectiveness of photosynthesis. Quantum biology might require new physics!

- *The Radical Pair Mechanism and the Avian Chemical Compass: Quantum Coherence and Entanglement* by Zhang et al [I4] (see `http://tinyurl.com/zvcguuz`).

  The abstract gives brief summary of the radical pair mechanism.

  > *We review the spin radical pair mechanism which is a promising explanation of avian navigation. This mechanism is based on the dependence of product yields on 1) the hyperfine interaction involving electron spins and neighboring nuclear spins and 2) the intensity and orientation of the geomagnetic field. This review describes the general scheme of chemical reactions involving radical pairs generated from singlet and triplet precursors; the spin dynamics of the radical pairs; and the magnetic field dependence of product yields caused by the radical pair mechanism. The main part of the review includes a description of the chemical compass in birds. We review: the general properties of the avian compass; the basic scheme of the radical pair mechanism; the reaction kinetics in cryptochrome; quantum coherence and entanglement in the avian compass; and the effects of noise. We believe that the quantum avian compass can play an important role in avian navigation and can also provide the foundation for a new generation of sensitive and selective magnetic-sensing nano-devices.*

  The basic idea of RPM is that the creation of electron pairs in states, which are quantum coherent superpositions of spin singlet and triplet states of two electrons, have hyperfine magnetic interactions with nuclear spins giving rise to anomalously large EPR and NMR signals. The small mass of electron is essential but still the problem in the case of avian compass and photosynthesis is to understand how quantum coherence time can be long enough for large enough effect to result before the neutralization of the radical pair.

- *The radical-pair mechanism as a paradigm for the emerging science of quantum biology* by Kominis [I5] (see `http://tinyurl.com/glegn3u`).

  > *The radical-pair mechanism was introduced in the 1960's to explain anomalously large EPR and NMR signals in chemical reactions of organic molecules. It has*

> *evolved to the cornerstone of spin chemistry, the study of the effect electron and nuclear spins have on chemical reactions, with the avian magnetic compass mechanism and the photosynthetic reaction center dynamics being prominent biophysical manifestations of such effects. In recent years the RPM was shown to be an ideal biological system where the conceptual tools of quantum information science can be fruitfully applied. We will here review recent work making the case that the RPM is indeed a major driving force of the emerging field of quantum biology.*

The claim RPM as a new paradigm could be motivated by the observation that radical pairs are formed also in the photosynthesis. As already found, the problem is that the magnetic field of Earth is only two percent of the minimal value of the magnetic field needed for RPM according to the laboratory experiments.

It is worth of emphasizing that RPM was introduced as early as 1960's to explain anomalously large EPR and NMR signals in chemical reactions of organic molecules. In TGD I ended up to the hypothesis h_{eff} hypothesis [K5] and stronger $h_{eff} = h_{gr}$ hypothesis [K6] through the attempt to understand the observation of the pioneers of bio-electromagnetism (see for instance [J1, J2, J3] that ELF radiation in EEG frequency range has quantal looking effects on living matter at harmonics of cyclotron frequencies of biologically important ions in endogenous magnetic field $B_{end} = .2$ Gauss, which might correspond to the field strength at the flux tubes of Earth's magnetic field inside organism tuned to give rise to cyclotron frequencies ideal for biology. Cyclotron energies for ions are ridiculously small as compared to thermal energy and large h_{eff} seemed to be the only possible explanation. Could large h_{eff} effects been observed already around 1960's without realizing that new quantum physics is in question?

1.2 Some hints

It seems that several biological phenomena involve the same mechanism - RPM would be this mechanism. Even magneto-reception could use RPM if standard quantum theory is enough to understand these phenomena. In TGD framework one can however give up this assumption.

1. Magneto-sensitivity and circadian clock seem to be related: light-activated photo-receptors - cryptochromes (CRYs) serve also as magnetic sensors and the external magnetic fields slow down circadian rhythm.

2. Also gravitaxis that is the ability to move in direction parallel or opposite to the gradient of local gravitational field could relate to this mechanism. This requires that organism is able to perceive the gradient for the strength of the local gravitational field.

Blue light is also an important factor involved.

1. Blue light seems to be necessary for the *chemical* magneto-reception. It is not clear whether it is necessary for establishment of circadian rhythm with period of order 24 hours or does not only interfere with it.

   What about pace-maker mechanism'? Is just the presence of blue light enough for establishing to put the circadian clock ticking or does the periodic variant of the amount of blue light give rise to internal clock? Or does blue light in the case of magneto-reception interfere with the pace-keeper mechanism?

2. Blue light seems to have health effects. For instance, exposure to blue light at night time could be harmful to health (see `http://tinyurl.com/mggpafe`). In particular, too much blue light at night time could affect the circadian clock and too much blue light could lead to sleep disorders and various negative health effects such as several types of cancer (breast, prostate), diabetes, heart disease, and obesity. It is known that the amount of blue light correlates with melatonin secretion. Could the periodic variation of the intensity of blue light give rise to internal clock? Of course, there are very probably several cues used by internal clock (for instance, birds are not dead matter behaving as robots!) and the variation of the intensity of blue light could be only one of them.

3. It has been also found (see http://tinyurl.com/zvlmxp6) that the presence of external magnetic fields in the range around 3 Gauss (Earth's magnetic field has nominal value .5 Gauss so that this field is 6 times stronger) tends to increase the period of the circadian clock. This would suggests that the clock in question does not use only the amount of blue light as a cue.

1.3 Improved TGD inpired model

I have already earlier proposed a TGD based model for the findings related to magnetoreception and pace-keeper mechanism [L3]. The model discussed also photo-taxis and gravi-taxis. The improved model discussed here relies on essentially the same elements but does not assume RPM as the mechanism producing nuclear spin polarization as an analog of compass.

Magnetic flux tubes are key objects of TGD based quantum biology able to act as sending and receiving antennas and if they contain cyclotron Bose-Einstein condensates they can act also as quantum compasses communicating the orientation of the external magnetic field by emission of Larmor radiation at cyclotron frequencies f_c. This radiation is received by other flux tubes at resonance and the modulation of f_c produces resonances as ticks of the clock. The energies involved must be above thermal energy and $h_{eff} = h_{gr}$ hypothesis guarantees this.

Pace-maker function requires cell membrane as a generalized Josephson junction (GJJ) emitting generalized Josephson radiation with energy $E_{G,J}$, which is sum of Josephson energy $E_J = ZeV$ and difference $\Delta E_c(\hbar_{gr})$ of cyclotron energies at the two sides of membrane. The TGD view about metabolic energy as manner to increase $h_{eff} = h_{gr}$ allows to interpret irradiation by blue light as metabolic energy feed, and explains the slowing down of the circadian period as a reduction of ordinary Josephson frequency $f_J = ZeV/\hbar_{gr}$. Also the loss of rhythm can be understood as a transition in which the analog of GJJ n as a gravitational pendulum makes a transition from rotational to vibrational motion. Photo-receptors such as cytochrome appear as absorbers of dark photons transformed to bio-photons and transform dark photon information to chemical information.

Before continuing it is good to list some abbreviations. Electromagnetic (em), Exclusion Zone (EZ), radical-pairing mechanism (RPM) are standard notions. At least for TGD inspired notions appear in the sequel: Topological Geometrodynamics (TGD), Strong form of Holography (SH), Zero Energy Ontology (ZEO), Causal Diamond (CD), Magnetic Body (MB), Biological Body (BB).

2 Guidelines for the TGD based model

One can ask whether RPM is the primary part of magneto-reception. In TGD the basic structures would be dark magnetic flux tubes serving as both antennas and senders of dark photons. This might allow to separate the chemical photo-reception completely from the magneto-reception and RPM would not be needed to generate nuclear spin polarization.

2.1 Magneto-receptor as quantum compass

Magneto-reception could rely on quantum analog of compass consisting of flux tube containing dark cyclotron Bose-Einstein condensates. In the presence of external magnetic field - larger flux tube - Larmor radiation would be generated at cyclotron frequencies and energies scaled up by h_{eff}/h. These dark photons would transform to photons of blue light and be received by photo-receptors such as cryptochromes. The signal would be transformed to a chemical signal using the same basic mechanism as in photosynthesis without need to generate nuclear spin polarization. The same signal could also induce cyclotron transition of cyclotron Bose-Einstein condensates at magnetic flux tubes.

Why would blue light be needed?

1. The first explanation for the necessity of blue light could be that it kicks the cyclotron Bose-Einstein condensate from the ground state to excited state which them return to ground state by Larmor radiation. Blue light could induce transition between genuine transversal cyclotron degrees of freedom or between longitudinal "particle-in-box" degrees of freedom.

One can however argue that also in ground state spin reversing transition are possible if the particle has magnetic moment (for Cooper pair this is not the case).

2. Second explanation would be that blue light serves as metabolic energy needed to increase the value of h_{eff} [L6, L8]. If one assumes $\hbar_{eff} = \hbar_{gr} = GMm/v_0$ it is not clear whether the increase of h_{eff} is possible at gravitational flux tubes. Should one assume that the increase of h_{gr} means increase of the mass m of charged particles attached (by wormhole contacts, that is touching) with the gravitational flux tubes? m could correspond to mass of electron or biologically important ion - an integer valued spectrum $\hbar_{gr}$ in multiples of GMm_p/v_0 would result for ions.

2.2 The simplest pace-keeper mechanism does not explain the slowing down of the circadian rhythm

The simplest pace-keeper mechanism at fundamental level would correspond to a flux tube for which the orientation angle Θ of the external magnetic field with respect to the flux tube direction varies. Flux tube direction defines preferred quantization axis. The projection of the external magnetic field B to the direction of flux tube would vary and cause the cyclotron frequency scale to vary: one would have frequency modulation. The orthogonal component of B induces Larmor precession manifesting itself as cyclotron transitions at quantum level.

If there is a dark system with same value of h_{eff} receiving radiation with frequency near the cyclotron frequency, it develops a frequency resonance periodically if Θ varies periodically. Also the variation of the intensity of external magnetic field could be detected in this manner. Each resonance would correspond to a tick of the clock. The receiver could be also ordinary atom and in this case the tick would correspond to energy resonance. At magnetic side frequency resonance would be involved an at chemical side one would energy resonance.

What is important is that the period detected would directly correspond to the physical period.

There is however a problem involved. Why the irradiation by blue light would interfere with the pace-keeper mechanism? Why the clock would slow down and eventually cease to work?

1. Could the excitation of magnetic state make impossible the pace-keeper mechanism. If blue light increases the value of h_{eff}, energy resonance associated with the chemical aspect of pace-keeper function could be lost. The fraction of flux tubes for which this has happened would gradually increase during irradiation and this could spoil chemical pace-keeper mechanism.

2. But how to understand the slowing down of the clock? Why would the cyclotron period depending only the variation of external magnetic field increase? This is very difficult - if not impossible - to understand in a model assuming that the pace-maker rhythm equals to a rhythm assignable to the variation of external magnetic field if the measuring flux tube remains stationary.

2.3 A model based on cell membrane as a generalized Josephson junction (GJJ)

A more complex model could rely on cell membrane as GJJ [K3] [L1]. Now one would give up the simplest pace-maker mechanism and replace the bio-rhythm with generalized Josephson energy $E_{J,G}$ given as the sum $E_{J,G} = E_J + \Delta E_c(\hbar_{gr})$ of the ordinary Josephson energy $E_J = ZeV$ and the difference of cyclotron energies

$$\Delta E_c(h_{eff}) = \frac{\hbar_{eff}}{\hbar} \times \Delta E_c(\hbar) \tag{2.1}$$

associated with the flux tubes at the two sides of the membrane and orthogonal to it. Generalized Josephson frequency $f_{G,J}$ would be given by

$$f_{J,G} = \frac{\Delta E_{J,G}}{\hbar_{eff}} = \Delta E_c(h) + \frac{f_J}{h_{eff}} \quad . \tag{2.2}$$

1. The pace-maker rhythm could correspond to $f_{J,G}$ or its constant part coupling to dark flux tube by cyclotron resonance. This part should be rather slow (say 12 hours) and here one might consider specialized cells. In an analogy model as rotating gravitational pendulum $f_{J,G}$ would correspond to the rotation frequency Ω of the pendulum, perhaps near the critical value at which rotation transforms to oscillation. This transition could explain the loss of bio-rhythm. Irradiation by blue light should lead to a gradual reduction of Ω causing slowing down of the rotation. Same would happen also in the generation of nerve pulse.

   Note that for the Josephson radiation received at flux tubes of dark magnetic body carrying galactic magnetic field - the model for pace-make rhythm already discussed would apply. This clock would tick when the modulated generalized Josephson period $T_{J,G}$ has the value T_{12} about 12 hours.

2. $f_J = ZeV/\hbar_{gr}$ would be reduced by irradiation by blue light feeding metabolic energy inducing a phase transition increasing $\hbar_{gr}$. The naive expectation is that the difference Δf_c of cyclotron frequencies would correspond to the dominating part of Ω about $T_{12} \sim 12$ hours.

   (a) For B_{end} option this turns out to be a good guess.

   (b) For B_{gal} option the cyclotron frequency would correspond to a cyclotron period about T_{12}. In this case the two contributions to $f_{G,J}$ should of the same same order determined by $1/T_{12}$. The cyclotron contribution depends on the sign of $n_1 - n_2$ so that Josephson and cyclotron contributions can have opposite signs and almost cancel: this could give rise to a period $T_{G,J} \geq\geq T_{12}$. Negative sign might be needed to fine-tune $T_{J,G}$ to T_{12}. Note that Josephson contribution behaves like $1/\hbar_{gr}$ so that the effect of blue light could be understood. Note also that below a critical value of $T_{G,J}$ the rotation of analog gravitational pendulum changes to vibration and the clock-function is lost. This is indeed observed after long enough irradiation.

3. There is still one objection. The flux tubes associated with cell membrane Josephson junctions should have radius of order $L(151) \sim 10$ nm. For acceptable values of h_{gr} this would however give huge cyclotron energy scale of order keV. The only option seems to be that one has slightly different values of $B = B_i$, $i = 1, 2$, at the flux tubes at the opposite sides of membrane. One would have

$$n_1 B_1 = n_2 B_2 \tag{2.3}$$

   in the ground state, where n_1 and n_2 are cyclotron quantum numbers so that the contribution of the difference of cyclotron energies to Josephson energy would vanish in ground state giving $E_{J,G} = ZeV/\hbar_{gr}$.

   In the replacement $B_i \to B_i + B$ with $B = B_{end}$ or $B = B_{gal}$, the cyclotron energy difference becomes $\Delta E_J = (n_1 - n_2)\hbar_{gr}(M_D)eB/m$ or $(n_1 - n_2)\hbar_{gr}(M_E)eB_{gal}/m$, where one has $M_D = 2 \times 10^{-4} M_E$. One has

$$f_{G,J} = (n_1 - n_2) f_c(B) + \frac{ZeV}{h_{gr}} \quad , \quad M = M_D \ \text{ or } \ M = M_E \ . \tag{2.4}$$

4. If the charged particle has magnetic moment, the difference between cyclotron energies involves spin contribution proportional to $\mu(B_1 - B_2)/m = \hbar_{gr}\mu B_1(n_2 - n_1)/n_2)$. This contribution is small if n_i is large and $n_2 - n_1$ is small. Second option is that magnetic moment μ vanishes: this is the case if one as Cooper pairs with vanishing spin.

The increase of $\hbar_{gr}$ locally induced by metabolic energy feed could induce also nerve pulse [K3] [L1].

1. The ground state of axons would correspond to a propagating soliton sequence nano-scopically analogous to a sequence of rotational gravitational penduli with constant phase difference. The local increase of $\hbar_{gr}$ would transform some rotating penduli to an oscillating mode and generate a local propagating perturbation identifiable as nerve pulse.

2. The increase of h_{gr} would correspond to a replacement of ions attached to gravitational flux tubes with heavier ones. This could relate to the flows of ions through cell membrane during nerve pulse. For instance, the replacement of electron with proton would reduce f_J by factor m_e/m_p. Nerve pulse would correspond to replacement of ions assignable to gravitational flux tubes with heavier ones.

3 Quantitative formulation of the model

Consider next the quantitative formulation of the model.

3.1 Basic parameters of the model

There are several parameters characterizing the new physics predicted by TGD and the model provides an excellent opportunity to get grasp on these parameters. In particular, the gravitational Planck constant $h_{gr} = GMm/V_0$ involves dark mass M and velocity parameter v_0 as parameters. The notion of magnetic field in TGD framework differs from its Maxwellian counterpart and magnetic field B_E of Earth can be decomposed to dark and ordinary part. Dark part consisting of monopole flux tubes could correspond to the endogenous magnetic field $B_{end} \simeq .2$ Gauss satisfying $B_{end} = 2B_E/5$ for $B_E = .5$ Gauss.

3.1.1 The parameters appearing in dark cyclotron energy

The condition $h_{eff} = h_{gr}$ would be satisfied. $\hbar_{gr} = GMm/v_0$ contains 3 parameters.

1. M denotes the dark mass expected to differ from M_E. There are several estimates for M.

   (a) $M = M_D = 2 \times 10^4$ was suggested by the model of fountain effect in super-fluidity [K5]. While writing this article I learned that the "inner inner" core of Earth has mass $M_D/2 = 10^{-4}M_E$ if its density is the average density of Sun. The density of the inner core is certainly higher.

   (b) I have associated to Earth also a spherical layer with mass $M = .5\times 10^{-4}M_E$ at distance of Moon. This mass has effect only at distances larger than distance of Moon but if one accepts the notion of magnetic body the effect could be real.

2. One can ask whether also the masses of various parts of Sun such as the mass of inner core with mass of inner inner core subtracted, mass of outer core, and mass of entire Sun could define dark masses with different value of v_0. Also sums of the masses could be involved. It turns out that the model requires masses $M = M_D$ for detection of B_{end} and $M = M_E$ for pace-keeper mode as dark masses. In the model of Nottale for planets as analogs of Bohr orbits one has $M = M_{Sun}$ [E1] [K4, K1, K6].

3. For the inner planets of Sun one has $\beta_0 = v_0/c \simeq 2^{-11}$ for inner planets and $\beta_0 = 2^{-11}/5$ for outer planets: $\beta_0 = 2^{-11}$ is the first guess also for Earth to be taken very cautiously. The value of β_0 could depend on the M_D but also a restricted universality can be considere. I have considered a model for β_0 [L5] [K7].

3.1.2 Strenghts of the magnetic fields

In TGD Universe Earth's magnetic field contains a monopole flux tube part - perhaps identifiable as the endogenous magnetic field $B_{end} = 2B_E/5$ - and non-monopole part.

1. B_E or part of it is measured. B_E has two parts in TGD Universe. Monopole part and non-monopole part. $B_{end} = 2B_E/5 = .2$ Gauss is suggested by the findings of Blackman and others and could corresponds to the monopole flux part of B_E. The nominal value of the Earth's magnetic field $B_E = .5$ Gauss.

2. B_{end} corresponds to a flux tube radius of about $L(169)$ then the minimal radius for flux tube would be about $L(163) \sim .640$ nm. The energies would be of the order of energies defined by membrane potential V. This looks natural at least because axonal radius is of order micrometer so that flux tubes with roughly half of the axonal radius could make sense.

   Monopole flux tube with a stronger magnetic field detecting B_E or B_{end} would be naturally associated with the magneto-receptor. This flux tube should has naturally radius 5 nm or 10 nm corresponding to $L(k)$, $k = 147$ or $k = 151$.

3. The estimate for the value of B_{gal} assigned with the pace-keeper mechanism is in the range $.5 - 1.9$ nT. For $B_{gal} = .5$ nT one has $B_{gal} = 2.5 \times 10^{-5} B_{end}$.

Remark: Could either monopole or non-monopole part be parallel to rotation axis of Earth? Non-monopole part would be naturally parallel to rotation axis since it is generated by the rotation of outer core. Monopole part could correspond to the magnetic axis. The change of the direction of B_E would be induced by the change of the direction of the monopole part and induce currents changing the non-monopole part. Monopole part together with this refreshing mechanism would explain the maintenance B_E [L2]. The magnetic North pole is recently moving rather rapidly towards Siberia and the strength of B_E has been decreasing suggesting that the refreshing operation has been activated.

3.2 Quantitative tests

Does the proposed picture work quantitatively? Or is even the qualitative model correct as such.

3.2.1 The values of the velocity parameters

1. Just as a blind guess I assumed first $\beta_0 \simeq 2^{-11}$ assigned to the inner planets of Sun by Nottale [E1] [K4, K5] (the assignment was based on the idea about near universality of β_0) and to the identification of dark mass as $M = M_D = 2 \times 10^{-4} M_E$ - the mass estimate for the "inner inner" core. This assignment gave a reasonable value for the universal cyclotron energy scale.

2. A possible justification for the guess comes from the behavior of the rotation velocity of particle in gravitational field of Earth behaving as $v = \sqrt{GMr}$ for circular orbit of radius r. At the surface of Earth with $r = R$ the rotational velocity of Earth

$$\beta_{0,E} \simeq \beta_{rot,R} 1.5 \times 10^{-6} = 3 \times 10^{-3} \beta_{0,Sun} \tag{3.1}$$

   would be first order of magnitude guess.

3. At the radius $r = 300$ km assignable to "inner inner" core one would have by scaling

$$\beta_{0,D} = \sqrt{R_E r} \times 2\beta_{0,E} \simeq 0.8 \times \beta_0 \quad . \tag{3.2}$$

   This is surprisingly near to β_0, which suggests that this parameter might be universal. One can test this hypothesis by looking what one obtains from this ansatz for the pace-maker model with $M = M_E$ and it turns out that nearly same value of β is needed.

4. One must bear in mind that also the value $\beta_{0,D} = \beta_0 = 2^{-11}$ is number theoretical favoured.

   Remark: The model for stars as analogs of blackhole like objects [L7] supports the view that the spectrum of β_0 comes in powers of 2 and corresponds to the spectrum of preferred p-adic length scales.

3.2.2 Cyclotron and Josephson energy scales and corresponding frequencies

Cyclotron and Josephson energy/frequency scales will be considered for three cases.

- Magneto-receptor mode

$$(B_{end}, M_D = 2 \times 10^{-4} M_E, \beta_{0,D} = \beta_0) \quad , \quad .$$

- First variant of pace-keeper mode

$$(B_{gal}, M_E, \beta_{0,E}) \quad ,$$

  where $\beta_{0,E} \simeq 3 \times 10^{-3} \beta_0$ is the rotational velocity at the surface of Earth.

- Second variant of pace-keeper mode

$$(B_{gal}, M_E, \beta_0) \quad .$$

Universal cyclotron energy is given as a multiple $E_n = nE_c$, $E_c = ZeB/m_{eff}$. For $h_{eff} = h_{gr}$ cyclotron energies are universal having no dependence on the mass of the charged particle. The interpretation is in terms of Equivalence Principle. One has

$$E_c = \hbar \frac{ZeB}{m_{eff}} \quad , \tag{3.3}$$

where one has

$$m_{eff} = \frac{\hbar \beta_{0,D}}{GM_D} = \frac{2\hbar\beta_{0,D}}{r_S} = \beta_{0,D} \times 1.24 \ \ eV \quad . \tag{3.4}$$

Note that this value is for $M_D = 2 \times 10^{-4} M_E$. For $M_D \to M_E$ m_{eff} scales to $m_{eff} = .5 \times 10^{-4} m_{eff} = \beta_{0,D} \times 2.48 \times 10^{-4}$ eV for $M_D \to M_E$ applying for B_{gal}.

1. For $(B_{end}, M = M_D, \beta_{0,D} = \beta_0 = 2^{-11})$ mode this gives the estimate

$$E_c \simeq 2 \ \ eV \quad ,$$

   Note that E_c scale is considerably higher than E_J scale about .06 eV in magneto-receptor mode. One has $f_J/f_c = E_J/E_c = .03$.

   Cyclotron frequencies of biologically important ions in B_{end} are in EEG range 1-100 Hz (DNA has on the average $f_c = 1$ Hz). One has for $f_c(e, p, Fe^{++}) = (6 \times 10^5, 300, 10)$ Hz and $f_J(e, p, Fe^{++})$= $(18 \times 10^3, 9, .3)$ Hz.

2. For $(B_{gal}, M = M_E, \beta_{0,E} = 3 \times 10^{-3} \beta_0$ mode one has $E_c = .13$ eV, which is above thermal threshold and roughly the energy $2eV$ of Cooper pair for cell membrane with voltage $.06eV$. One has $f_J/f_c = E_J/E_c \simeq .06/.13 \simeq .46 \leq 1$ and $T_J/T_c \simeq 2.2$.

   This option looks rather reasonable. In particular the effect of blue light increases $\hbar_{gr}$ and reduces f_J slowing down the circadian rhythm and can also cause the transition in which the $f_{G,J}$ becomes critical and the rotation of the analog pendulum transforms to oscillation and circadian rhythm is lost.

3. For $(B_{gal}, M = M_E, \beta_0)$ mode one would obtain

$$E_c = 4 \times 10^{-4} \ \ eV \quad ,$$

   which is below thermal threshold. $E_{G,J}$ would be however above thermal threshold. One has $f_J/f_c = E_J/E_c \simeq 150$ and $T_J/T_c = 1/150$. This option is not attractive.

A comment about the special role of DNA molecules is in order. DNA molecules are charged carrying charge of -1 units per nucleotide and -2 units per nucleotide pair of double strand.

1. For B_{end} the cyclotron frequency of DNA nucleotide would be about 1 Hz on the average and for fixed h_{eff} would not depend much on the length of DNA since DNA has constant Z/m ratio. Also cyclotron energy would be constant for fixed h_{eff}. For single nucleotide the cyclotron frequency would be same as for any ion for $B_{gal} = .5$ nT and equal to $f_c = 4 \times 10^4$ s to be compared to $T_{12} = 4.3 \times 10^4$ s.

2. For $h \to h_{gr}$ the situation changes. $f_{J,G}$ would behave like $a + b/N$, N the number of nucleotides. $E_{J,G}$ would behave like $aN + b$

3.3 Trying to build a more general view

The proposed picture is rather general and there is a temptation to generalize it further. The question whether there might be other dark masses besides M_E and M_D perhaps assignable to structures of Earth was already briefly considered. One can also ask about the spectrum of magnetic fields and whether also other structures bounded by double membrane (as a matter of fact, also single layered membrane might allow GJJs) could be possible.

3.3.1 What about p-adically scaled variants of magnetic fields?

The model discussed involves only 2 magnetic fields: B_{end} and B_{gal}, and one can expect that also other magnetic field strengths might be important. p-Adic length scale hypothesis suggests scale hierarchy of magnetic field strengths.

B_{end} corresponds to $k = 169$ defining p-adic length scale $L(169) = 5$ μm. This size scale is by factor 2 longer than the scale $L(167)$ assignable with cell nucleus. DNA is coiled and there is temptation to assign with the coiling the Gaussian Mersenne primes $M_{G,k} = 2^k - 1$. $k = 151, 157, 163, 167$: the existence of this Gaussian Mersennes is a number-theoretical miracle. Magnetic fields

The natural scaling for B_{end} assignable to the flux tubes with radius $L(k)$ would be $B_{end}(k) = 2^{169-k} B_{end}$. cyclotron frequencies for B_{end} correspond to cyclotron frequencies in the EEG and the additional p-adic length scales would give rise to scaled up variants of EEG possibly assignable to these smaller structures. Also larger flux tubes can be considered. $B_{gal} \simeq B_{end}(185)$ would also give rise to the counterpart of EEG which scaled up variants of resonance frequencies

$$f_{G,J} = 2^{169-k} f_c(ion, B_{end}) + f_J(\hbar) \frac{\hbar}{h_{gr}} \quad . \tag{3.5}$$

Could different values of B_{end} correspond to different modes for GJJ and cell? For $B_{end}(169)$ $f_{J,G}$ corresponds to EEG spectrum assigned to vertebrates having nervous system and nerve pulse activity having in TGD framework interpretation as manner to connect flux tubes assignable to axons to communication channels along which dark photons can propagate and mediate the message. Nerve pulse patterns would also generate generalized Josephson radiation communicating information to MB.

Could $B_{end}(k)$, $k \leq 169$, correspond to scaled up variants of EEG spectrum assignable to invertebrates? In this case the nerve pulse propagation would be missing but Josephson but localized analogs of nerve pulses involving the transformation of rotational motion to vibrational motion for the pendulum analog of Josephson junction would be possible.

3.3.2 Music and magnetic fields

The assumption that the values of B_{end} come in octaves is of course too strong. TGD based model for hearing and music experience [K2] leads to the proposal that the notes of scale correspond to cyclotron frequencies assignable to specific values of B_{end} and that each p-adic length scale would define its own octave.

Specific note of the scale identifiable as a rational multiple $f = rf_0$, $1 \leq r \leq 2$, of the fundamental frequency f_0 of the octave would correspond to a specific strength $B_{end}(r, k)$. This assumption

is reasonable since in the adelic vision [L4] rationals correspond to the lowest evolutionary level. For GJJ the formula for $B_{end}(r)$ characterizing the note rf_0 associated with rational $1 \leq r = p/q \leq 2$ would be $fG, J = rf_0 = \frac{1}{m_{eff}} ZeB_{end}(r) + f_J(\hbar_{gr})$ giving

$$eB_{end}(r) = \frac{m_{eff}}{Z} \times (rf_0 - f_J[\hbar)\frac{m_{eff}}{m}] \quad , \quad m_{eff} = \frac{\hbar v_0}{GM} = \frac{2\hbar v_0}{r_S} \quad . \tag{3.6}$$

The appearance of Schwartschild radius in formula relate to music is not something that one might expect! Note that $m \propto A$ holds true for ions. The condition $f_0 \geq f_J(\hbar)\frac{m_{eff}}{m}$ seems necessary.

3.3.3 Other membrane bounded structures

Quite generally, bio-structures with sizes between cell membrane thickness and cell size could be characterized by the scales $L(k)$, $k \in \{151, 157, 163, 167\}$ equal to $[10, 80, 640, 2500]$ nm. Could there exist besides cell and nuclear membrane also other membrane structures giving rise to GJJs?

Most viruses have radius varying from 10 to 125-200 nm and could correspond to $k = 151, 157$ and possibly other values of $k \in \{151, 159\}$. The largest viruses have radius 250 nm and length about 350-500 nm. Filoviruses have diameter about 80 nm (radius would correspond to $L(155)$) and length of 1400 nm. Viruses are contained by capsides consisting of identical proteins and can have lipid envelope derived from the host membrane. Maybe viruses utilize the GJJs of the host membrane.

Chloroplasts (`http://tinyurl.com/ycthk562`) and mitochondria (`http://tinyurl.com/oh5qrob`) are structures surrounded by double cell membrane: the inter-membrane space (`http://tinyurl.com/ums7uyx`) is 10-20 nm thick suggesting total thickness 20-30 nm. This could correspond to $L(152)$. Could chloroplasts and mitochondria define GJJs in scale $L(152)$.

Remark: Nucleolus (see `http://tinyurl.com/yavahwzt`) inside cell nucleus has diameter 2.5 μm corresponding to $L(167)$ but is not surrounded by membrane. It is however possible that flux tubes of $B_{end}(167)$ accompany it.

Endoplasmic reticulum (ER) (`http://tinyurl.com/ybjmjykb`) is 2-layered structure with thickness of cell size scale.

1. The layers have thickness 2 μm and having 1 μm empty region between. The total thickness is 5 μm, which corresponds to $L(169)$ assignable to B_{end}. One of the first proposals inspired by p-adic length scale hypothesis in biology was that ER could give rise to the analog of cell membrane. This structure would be naturally accompanied by flux sheet of $B_{end}(169) \equiv B_{end}$ (cell membrane would be accompanied by cylindrical flux sheet of $B_{end}(169) \equiv B_{end}$).

2. Could one assign transversal flux tubes of thickness $L(169)$ with ER possibly measuring the value of magnetic field. Could the measured magnetic field be $B_{end}(169)$ associated with the flux sheet? This would allow to get rid of the condition $n_1B_1 = n_2B_2$ for the magnetic fields at the two sides of cell membrane with order of magnitude $B_{end}(151)$. The problem is that intuitively compass needle should carry magnetic field stronger than the detected field.

3. B_{gal} is a more natural candidate for the magnetic field detected by ER. B_{gal} would correspond to rather slow cyclotron rhythms. The cyclotron frequency for electron would be scaled down by B_{gal}/B_{end} from 6×10^5 Hz to 15 Hz. ER would live slow life as compared to cell membranes - maybe it corresponds to our conscious life.

4. Interestingly, the experiments of Blackman [J1] and others involved irradiation of vertebrate brain with harmonics of 15 Hz frequency. The explanation of the findings in terms of cyclotron radiation led to the identification in terms of cyclotron frequencies of Ca^{++} ion in $B_{end} = .2$ Gauss. Could there be a communication between these two levels at the cyclotron frequencies of Ca^{++}? The communication could take place by GJR emitted by dark electron Cooper pairs at endoplasmic reticulum and absorbed GJJs of cell membranes carrying $B_{end}(151)$. Could this explain the very special role of Ca^{++} ions in biology (see `http://tinyurl.com/w9o29xa`)?

   The objection is that the dark photon energies are different for B_{end} and B_{gal}: ~ 2 eV and about $\sim .1$ eV respectively. Energy conservation allows the decay of dark B_{end} photon to a bunch of about 20 dark B_{gal} photons, which are identical. ZEO allows the time reversal of this

process. The bunch of identical 20 dark photons is analogous to a Bose-Einstein condensate behaving like single particle so that one has effectively 2-vertex also now in accordance with the hypothesis that all transformations changing h_{eff} occur at single particle level. I have indeed proposed two processes changing the value of h_{eff}: decaying to a BE condensate would preserve frequency but not energy for single quantum and transformation of say dark photon to bio-photon would preserve energy but not frequency.

REFERENCES

Cosmology and Astro-Physics

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

Biology

[I1] Rodgers CT and Hore PJ. Chemical magnetoreception in birds: The radical pair mechanism. *PNAS*. Available at: http://tinyurl.com/zsg4b95, 106:353–360, 2016.

[I2] Clayton DL. Circadian and geotactic behaviors: Genetic pleiotropy in *drosophila melanogaster*. *Journal of Circadian Rhytms*. Available at: http://dx.doi.org/10.5334/jcr.140, 12(1):1–5, 2016.

[I3] Yoshii T et al. Cryptochrome mediates light-dependent magnetosensitivity of drosophila's circadian clock. *PLoS Biol*. Available at: http://tinyurl.com/zvlmxp6, 7(4), 2009.

[I4] Zhang Y et al. The radical pair mechanism and the avian chemical compass: Quantum coherence and entanglement. arXiv.org. Available at: http://tinyurl.com/zvcguuz, 2015.

[I5] Kominis IK. The radical-pair mechanism as a paradigm for the emerging science of quantum biology. arXiv.org. Available at: https://arxiv.org/abs/1512.00450, 2015.

Neuroscience and Consciousness

[J1] Blackman CF. *Effect of Electrical and Magnetic Fields on the Nervous System*, pages 331–355. Plenum, New York, 1994.

[J2] Blackman CF et al. Effects of ELF fields on calcium-ion efflux from brain tissue, in vitro. *Radiat Res*, 92:510–520, 1982.

[J3] Blackman CF et al. A role for the magnetic field in the radiation-induced efflux of calcium ions from brain tissue, in vitro. *Bioelectromagn*, 6:327–337, 1985.

Books related to TGD

[K1] Pitkänen M. Quantum Astrophysics. In *Physics in Many-Sheeted Space-Time*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdclass.html#qastro, 2006.

[K2] Pitkänen M. Quantum Model for Hearing. In *TGD and EEG*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdeeg.html#hearing, 2006.

[K3] Pitkänen M. Quantum Model for Nerve Pulse. In *TGD and EEG*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdeeg.html#pulse, 2006.

[K4] Pitkänen M. TGD and Astrophysics. In *Physics in Many-Sheeted Space-Time*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdclass.html#astro, 2006.

[K5] Pitkänen M. Criticality and dark matter. In *Hyper-finite Factors and Dark Matter Hierarchy*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/neuplanck.html#qcritdark, 2014.

[K6] Pitkänen M. Quantum gravity, dark matter, and prebiotic evolution. In *Genes and Memes*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/genememe.html#hgrprebio, 2014.

[K7] Pitkänen M. About the Nottale's formula for h_{gr} and the possibility that Planck length l_P and CP_2 length R are identical giving $G = R^2/\hbar_{eff}$. In *Hyper-finite Factors and Dark Matter Hierarchy*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml/neuplanck.html#vzerovariableG, 2018.

Articles about TGD

[L1] Pitkänen M. Quantum Model for Nerve Pulse and EEG. Available at: http://tgdtheory.fi/public_html/articles/pulseeg.pdf, 2008.

[L2] Pitkänen M. Maintenance problem for Earth's magnetic field. Available at: http://tgdtheory.fi/public_html/articles/Bmaintenance.pdf, 2015.

[L3] Pitkänen M. Can quantum biology really do without new physics? Available at: http://tgdtheory.fi/public_html/articles/RPMTGD.pdf, 2016.

[L4] Pitkänen M. Philosophy of Adelic Physics. Available at: http://tgdtheory.fi/public_html/articles/adelephysics.pdf, 2017.

[L5] Pitkänen M. About the physical interpretation of the velocity parameter in the formula for the gravitational Planck constant . Available at: http://tgdtheory.fi/public_html/articles/vzero.pdf, 2018.

[L6] Pitkänen M. Getting philosophical: some comments about the problems of physics, neuroscience, and biology. Available at: http://tgdtheory.fi/public_html/articles/philosophic.pdf, 2018.

[L7] Pitkänen M. Cosmic string model for the formation of galaxies and stars. Available at: http://tgdtheory.fi/public_html/articles/galaxystars.pdf, 2019.

[L8] Pitkänen M. Some applications of TGD inspired quantum biology: bio-chemistry, metabolism, replication. Available at: http://tgdtheory.fi/public_html/articles/bioexamples.pdf, 2019.