

# Can quantum biology really do without new physics?

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### Abstract

Quantum biology is now taken rather seriously. Photosynthesis and avian navigation are two key applications of quantum biology. The basic problem in both cases is posed by the fact that the magnetic interaction energy in Earth's magnetic field is roughly million times smaller than thermal energy. The so called radical-pair mechanism (RPM) was proposed already at 60's as a possible solution to the problem posed by anomalously large effect in EPR and NMR experiments. According to RPM, a radical pair is accompanied by electron pair, which is in a superposition of spin triplet and singlet states and behaves as quantum coherent system for a time sufficiently long to induce chemical effects. The hyperfine interaction of the members of the electron pair with the nuclei of radicals would amplify the effect. The neutralization of radical pair puts an end to the coherence interaction period.

The proposal is that RPM gives rise to chemical compass making possible avian navigation. There is however a problem. RPM has been observed in laboratory only for magnetic fields in the range 1 mT- 10 T. Earth's magnetic field is only 2 per cent of the lower bound so that it is quite possible that RPM is not at work.

This opens up the door for new quantum physics proposed by TGD based model of quantum biology. In this approach magnetic body acts as intentional agent using biological body as a sensory receptor and motor instrument. Macroscopic quantum coherence is made possible by dark matter realized as a hierarchy of  $h_{eff} = n \times h$  phases.

In this chapter RMP is summarized and compared with the TGD based vision. Also the possible connection between avian navigation and circadian clock suggested by the fact that both involve photoreceptor known as cryptochrome and a possible connection with gravitaxis are considered in TGD framework.

## 1 Introduction

I was recently 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.

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 as radical-pair mechanism (RPM) [I2, I5, I6] 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  $h_{eff} = n \times h$  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* [I4] (see <http://tinyurl.com/zv1mzp6>). Cryptochrome (CRY) (see <http://>

[//tinyurl.com/create.php](http://tinyurl.com/create.php)) has been proposed to be the photoreceptor being involved with both circadian rhythms and magnetosensitivity. In response to light CRY slows down the circadian clock and eventually leads to an arrhythmic 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 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 [I3] (see <http://tinyurl.com/j4vnr8c>) 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 magnetoreception in birds: The radical pair mechanism* by Rodgers and Hore [I2] (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* [I5] (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 [I6] (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 [?] 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 could use the same mechanism - RPM would be this mechanism if standard quantum theory is enough to understand these phenomena.

1. Magneto-sensitivity and circadian clock seem to be related: light-activated photoreceptors - 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 necessary for the *chemical* magnetoreception and the establishment of circadian rhythm with period of order 24 hours. This is an important hint but leaves much open. 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?

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.

It has been also found (see <http://tinyurl.com/zv1mzp6>) 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 suggest that the clock in question does not use only the amount of blue light as a cue.

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 Geometro-dynamics (TGD), Strong form of Holography (SH), Zero Energy Ontology (ZEO), Causal Diamond (CD), Magnetic Body (MB), Biological Body (BB).

## 2 How to understand circadian clock, magneto-sensing and gravitaxis in TGD framework?

That photoreceptors responsible for circadian rhythms are involved with magnetoreception and the presence of blue light is necessary for magnetoreception are the basic challenges for any model. In RPM model this would follow from the assumption that blue light generates radical-pairs interacting with magnetic field but why just RPM should be crucial for photoreception? Why not some "easier" mechanism? Could bio-rhythms be due to some deeper quantum mechanism involving magnetic fields in an essential manner? Of course, RPM could still be involved but with non-standard value of Planck constant if TGD view is correct. Non-standard value of Planck constant could be involved even with the original anomalies associated with EPR and NMR.

I have described briefly what TGD is in the Appendix and recommend it for the reader before continuing.

### 2.1 Basic problems and basic principles

In Appendix I summarize what TGD and TGD inspired theory of quantum biology and quantum consciousness are. Here I just list the basic ideas relevant to the model considered. The basic elements of this model are MB following from the many-sheeted view about space-time and distinguishing between TGD and Maxwell's theory and the hierarchy of Planck constants  $h_{eff} = n \times h$  possibly satisfying the additional constraint  $h_{eff} = h_{gr}$  giving connection with quantum gravity which would allow macroscopic quantum phases in arbitrarily long length scales in TGD Universe.

The key principles and mechanism should be same as in TGD based model of quantum biology.

1. Magnetic body (MB) of living organism has a fractal structure corresponding to body parts labelled by corresponding cyclotron frequency scales. MB serves as an intentional agent receiving sensory data from biological body (BB) and controlling it. BB and MB must communicate and dark photons would make this possible. EEG would be one example of this communication and MB would receive by sensory data from cell membrane as dark generalized Josephson photons and control BB by dark cyclotron photons with the mediary of genome (at least) [K2, K13, K12]. EEG would generalize to other frequency ranges and generalized EEG rhythms could emerge in this manner. Dark phases of matter emerge at quantum criticality which is central element of the model. As a matter fact, TGD Universe is in well-defined sense quantum critical.
2. One cannot avoid the following questions. Is the avian navigation an automatic process. Could MB control it? Is conscious intelligence and volition involved so that the mechanism in question would be only a tool. Is the MB in question that of species or does the bird decide whether to follow the flux tubes of the personal MB connecting the bird to where it was born or in the horizontal direction defined by the MB of Earth? One must leave these questions open although the idea that the bird follows the horizontal flux tubes connecting it to the birth place (and assignable to the species?) is very attractive and would not favor the flux tubes of Earth which are not horizontal.

3. Quantum criticality allows several values of Planck constant are possible. The interpretation is in terms of long range as quantum fluctuations and quantum coherence in various length scales would have a universal explanation. Quantum criticality would be a general property of living matter and crucial also now.
4. The most economic assumption is that the mechanism is same as in the case of cell membrane identified as generalized Josephson junction coding nerve pulse sequences and membrane oscillations to EEG and in this manner sending sensory information to MB of the brain. I have indeed proposed long time ago that also biomolecules act as Josephson junctions. In fact, the cell membrane identified as generalized Josephson junction reduces microscopically to an array of generalized Josephson junctions defined by membrane proteins. For generalized Josephson junction Josephson energy  $2eV$  for Cooper pair is replaced with its sum with the difference of cyclotron energies at different sides of the cell membrane. Electronic Cooper pairs would be naturally involved but also bosonic ions and Cooper pairs of fermionic ions can be considered for large values of  $h_{eff}$  and are indeed in crucial role in TGD based model of cell membrane.

One of the first applications of TGD inspired biology was the explanation of so called Comorosan effect [I7, I1] in terms of bio-molecular Josephson junctions [K17]. The model assuming generalized Josephson junctions applies in the case of general biomolecules and suggests that there is universal 5 second Josephson time involved. This would require rather large value of  $h_{eff}$  (Josephson frequency is inversely proportional to  $1/h_{eff}$ ) since the voltage involved is expected to be rather high in molecular length scales.

5. The basic assumption would be that blue light kicks the photoreceptor CRY to an excited state, which is quantum critical and generates large  $h_{eff}$  phases possibly satisfying also the  $h_{eff} = h_{gr}$  condition with several values of  $h_{eff}$  at the flux tubes. Note that each flux tube carries only one kind of charged particle if it corresponds to a unique value of Planck constant. Dark charged particles are like books on shelves and the situation is just the opposite for the random dense soup of bio-molecules assumed in standard biochemistry.

The basic prediction would be the dependence of the effect on strength of magnetic field as in case of RPM. The slowing down of the rhythm in presence of external  $B_E$  could be understood if the cyclotron energy difference in  $B_E$  between ground state and excited state changes so that the energy difference becomes smaller and flux tube in question has smaller value of  $B_{gal}$ : this could be due to the change of the net charge of the molecule.

One should explain several phenomena using the same model.

1. Navigation involving perception of Earth's magnetic field, which possibly weakens to endogenous magnetic field which is 2/5 of it inside brain. A constraint to  $h_{eff}$  emerges from the condition that cyclotron frequency is in visible-UV range.

If one demands  $h_{eff} = h_{gr} = GM_D m / v_0$  one finds that dark mass  $M_D$  is of order  $10^{-4} M_E$  and that it would correspond to a spherical layer of dark mass at distance of Moon. Skeptic of course begins to talk about Occam's razor. This layer is however natural in the model of dark matter. One could of course just speak about  $h_{eff}$  and forget  $h_{gr} = h_{eff}$ . The important point is that the notions introduced are not ad hoc notions but follow naturally from the very general assumptions of TGD as unification of fundamental interactions (see Appendix).

2. The challenge is to understand circadian rhythm with period about 24 hours. There is some evidence for the importance of the galactic magnetic fields for living matter. One such piece of evidence is the observation that the occurrence of tinnitus seems to appear rhythmically but with respect to galactic time. Galactic magnetic field of strength of about 1 nT could provide explanation. There is also earlier rather mysterious observation that precognition events seem to occur near galactic midday [J4]: this observation is of course not taken seriously by skeptics but deserves to be noticed. A possible test for the TGD based model is that the bio-clock actually measures sidereal rather than circadian time.

The galactic cyclotron time for  $h_{gr}$  associated with Earth mass  $M_E$  is very natural if flux tubes carry Earth's gravitational field - is very near to 12 hours for galactic magnetic field a

fraction of nT. Cyclotron frequency would generate the biorhythm in manner analogous to that happening in the case of EEG. Only frequency scale would be much longer.

More precisely, according to the estimate of [?] the cyclotron time of DNA in  $B_{end}$  equal to 1 s is scaled up to 11.7 hours in  $B_{gal}=.63$  nT. This estimate is obtained by accepting the  $h_{eff} = h_{gr} = GMm/v_0$  hypothesis by identifying  $M$  as Earth's mass, and by assuming that the parameter  $r = v_0/v_{rot,M}$  for Earth has the same value as for Sun. One has  $v_0 \simeq 2^{-11}$  for Sun from the Bohr orbit model for the orbits of the 4 inner planets originally proposed by Nottale and  $v_{rot}$  is the rotational velocity of Sun.

It is needless to emphasize that this estimate involves uncertainties and that the value of  $B_{gal}$  assignable to the flux tubes has a distribution, which could be as wide as that for the energies of bio-photons. There are however good hopes of obtaining the circadian (or possibly sidereal) rhythm with natural choice of parameters.

3. The TGD description of gravitaxis should involve the flux tubes carrying gravitational flux of Earth. The same mechanism might be behind ordinary sensing of the gravitational acceleration. A good guess is that this magnetic field has same strength as galactic magnetic field  $B_{gal}$  to which Earth's mass would be associated via  $h_{gr}$ . The  $h_{eff}$  should be correspondingly higher to guarantee that dark cyclotron energy is in visible-UV range. The energy of blue light is good candidate now for exciting the quantum critical state in which this value of  $h_{eff}$  is realized.

Gravitaxis would require the detection of the strength of Earth's gravitational field coded into the density of flux tubes parallel to it. The system should be able to detect the density of the flux tubes and this would occur naturally at quantum criticality via reconnections with these flux tubes and involving dark photons with energies in visible-UV range.

4. Two magnetic fields  $B_{end}$  and  $B_{gal}$  would be involved as also two values of Planck constant but cyclotron energies would be same and in bio-photon energy range. The two MBs should be able to communicate and one can consider the possibility that the spectrum of ionic cyclotron frequencies for  $B_{end} = .2$  Gauss in EEG range corresponds to electronic cyclotron frequencies for a spectrum of values of  $G_{gal}$ . This assumption would fix the parameters of the model to very high degree. Interestingly, according to TGD based quantum model for hearing [K11], the audible frequencies would be coded by the thickness of flux tubes (or equivalently by the value of the magnetic field) and galactic flux tubes would give rise to a similar coding. Could hearing actually use the flux tubes of  $B_{gal}$ ?

If so, the ranges for audible frequencies and for bio-photon energies measured as number of octaves would be same. The range of frequencies audible for humans is about 10 octaves beginning from 20 Hz. Hence the spectrum of bio-photons should extend from say 1 eV to 10 keV. Dark IR photons are also predicted as a Josephson radiation from cell membrane with energies of photons of order  $2eV \sim .1$  eV (Coulomb energy of Cooper pair assignable to cell membrane Josephson junction and roughly twice the thermal energy  $E_{th} = 3T/2 \simeq .5$  eV at physiological temperature 330 K). I do not know whether IR energies are excluded as bio-photon energies and therefore whether the range of bio-photon frequencies could actually begin from .1 eV. If so, bio-photon energies would extend up to 1 keV.

It is important to notice that the MB involved with navigation could be Earth's MB or galactic MB if its flux tubes correspond to personal MB of the organism connecting it to its birth place. It is quite possible that both MBs are be involved. One can imagine endless variety of models and the proposed model can be defended by the fact that it is based on the same mechanism as the quantum model for communications between BB and MB giving as special case the model of cell membrane.

## 2.2 Could circadian rhythms be analogous to EEG rhythms in TGD Universe?

In TGD Universe it is natural to think that the circadian rhythms and in fact all biorhythms - are basically analogous to EEG rhythms.

1. In TGD EEG frequencies would correspond basically to cyclotron frequencies in and endogenous magnetic field of .2 Gauss which is 2/5:th of Earth's magnetic field carrying dark particles (in TGD sense) having non-standard value  $h_{eff} = n \times$ .
2. The energies of cyclotron photons, which would be extremely small and much below thermal energy for the ordinary value of Planck constant, are scaled up by factor  $n$  by  $E = h_{eff} \times f$  formula and can have non-trivial biological effects.
3. A further proposal is that the formulate  $h_{eff} = h_{gr} = GMm/v_0$  holds true - at least for large values of  $h_{eff}$ . Here  $h_{gr}$  is gravitational Planck constant assignable to magnetic flux tubes mediating gravitational interaction,  $v_0$  is a parameter with dimensions of velocity,  $m$  is the mass of the dark charged particle at the flux tubes, and  $M$  is some large mass.

This formula guarantees that cyclotron energies proportional to  $h_{gr}eB/m$  do not depend on the mass  $m$  of the charged particle for given charge. This in turn implies that dark cyclotron energy spectrum is universal. The hypothesis is that the transformation of dark photons to ordinary photons produces ordinary photons identifiable as bio-photons. If so the energies would be in visible-UV range and would dark photons could induce transitions of biomolecules and could serve as a biochemical control tool of the MB. If one accepts  $h_{gr} = h_{eff}$  hypothesis for EEG, the value of the mass  $M$  should be around  $M = M_D \sim 10^{-4}M_E$  for EEG. Using some additional cues given by TGD based view about how planets were condensed around dark matter blobs forming spherical cells or tubes around Sun or actually any astrophysical object, I have proposed a possible identification of  $M_D$  as a mass of spherical shell of dark matter assignable to Earth at the distance of Moon [?, K6]. Here skeptic of course has an excellent opportunity to introduce Occam's razor and I am of course ready to consider also the option that  $h_{eff} = h_{gr}$  does not hold true at the flux tubes of  $B_{end}$ .

What about the identification of circadian rhythms as cyclotron frequencies?

1. The general idea is that the flux tubes of both Earth's magnetic field and of galactic magnetic field can locally self-organize into complex braided structures serving defining the MBs of organisms, which would therefore be parts of much bigger organism. The flux tubes could connect living systems to each other and for instance, birds and fishes to their birth places.
2. The cyclotron time is much longer than for EEG rhythms and the natural guess is that the flux tubes of interstellar (galactic) magnetic field with field strength varying around the mean value  $B_{gal} \sim 1$  nT are involved. The spectrum of cyclotron times would be of correct order of magnitude.  $h_{gr} = h_{eff}$  hypothesis essential for the coupling of MB to biochemistry would be satisfied for  $M = M_E$  in  $h_{gr} = GMm/v_0$  so that one cannot assume that only dark mass contributes to the large mass in  $h_{gr}$ .

### 2.3 Trying to figure out the general mechanism

The details of the mechanism could be fixed by empirical input and using second assumption above as a guideline.

1. To my best understanding the role of RPM for avian chemical compass is speculative. RPM has been indeed observed only for magnetic fields stronger than 10 Gauss. Therefore it can be challenged. Even the notion of chemical compass is speculative.
2. The large cyclotron energies of dark charged particles would solve the problem caused by the extreme smallness of the electronic cyclotron energies - this could be the case even for ions. Radical pairs and electron pairs assigned with them could of course be present also in TGD inspired model. Even pairs of ions and bosonic ions.
3. In TGD context one could assume only spin singlet or triplet Cooper pairs with large value of  $h_{eff} = h_{gr}$  in  $B_{end} = 0.2$  Gauss. The existence of superconducting phase would require that Cooper pairs assignable to several CRY molecules reside at same flux tube pairs. This would make the process quantum coherent in longer scale.



4. Quantum criticality is needed and could be associated with the emergence of high  $T_c$  superconductivity [K9, K10] and would correspond to the transversal oscillations of magnetic flux tubes analogous to phonons assumed in ordinary superconductivity and also in RPM. They would lead to a transitions between flux tube pair with shape of flattened square and pair of pairs flux tubes of similar shaped induced by reconnection somewhere along flux tube pair. In transition to superconductivity long flattened square would stabilize. Above transition temperature shorter flattened square shapes would be stable and one would have super-conductivity but in short scale only.
5. Electron pairs would be analogous to Cooper pairs and if there is many of them in the system one would speak of super-conductivity. In TGD inspired quantum biology the electron pairs might be Cooper pairs with members at flux tubes, which are either parallel or antiparallel. Spin singlet and triplet Cooper pairs would correspond to flux tubes with opposite and parallel fluxes. The quantum coherent fluctuation between them assumed in the model does not look possible in TGD framework and is not needed.
6. Spin singlet Cooper pairs would result for closed flux tubes with the shape of flattened square. If one has pairs of this kind of flux tubes in parallel and close enough to each other, the second member of the Cooper pair could hop to second flux tube of the other flux tube pair so that members of the pair would be at flux tubes with parallel magnetic fields and form triplet. This kind of hopping could gives rise to the coherent quantum transitions between spin singlet and triplets and the ratio of singlets and triplets would be different from one in the final state and depend on the value of magnetic field and cause a chemical effect. This assumption need not be necessary for the model to work. The control by MB could be much more direct and take place at bio-photon energies.
7. Dark photons are somehow emitted and go to the flux tubes of  $B_{gal}$  in the case of circadian rhythm and gravitaxis. In the case of avian navigation the flux tubes could be those of  $B_{end}$  ( $B_E$  could be equal to  $B_{end}$  inside brain) or those of  $B_{gal}$ .

The model of cell membrane as generalized Josephson junction with membrane proteins (channels and pumps) suggests a model in which the emission of dark photons could be generalized Josephson radiation with energy determined as difference of cyclotron energies plus ordinary Josephson energy. Dark Josephson photons going to the flux tubes of Earth equal to  $B_{end} = 2B_E/5$  inside organism. from Blackman's experiments. This would give rise to magneto-detection of  $B_E$ . The mechanism would be exactly like the mechanism communicating sensory data to MB from cell membrane and allowing MB to control cell via genome using dark cyclotron photons. One can however consider also the replacement of  $B_{end}$  with  $B_{gal}$ .

One can imagine also the analog of RPM mechanism. In this case the dark electron pairs would fluctuate quantum coherently between spin singlet and triplet state and also interact with nuclear spins of the radical pair. The fusion of radical pair to a neutral state would destroy the quantum coherence. By a generalization of Uncertainty Principle cyclotron time would define the natural time scale and would be much longer than the time scale of coherence for RPM model. Maybe this could allow to test  $h_{eff}$  hypothesis.

## 2.4 More concrete model for the mechanism of magnetoreception and circadian rhythms

It is could to list some basic facts first.

1. Photopigment CRY must be excited by blue light needed to perceive magnetic field.
2. CRY interacts with magnetic field to establish the biorhythm.
3. External magnetic fields around 3 Gauss in presence of blue light slowed down the speed of the circadian clock.

What is the mechanism giving rise to the circadian clock? The naïve guess is that circadian rhythm corresponds to the periodic variation of the sensitivity to the external magnetic field determined by the amount of solar light. This certainly serves as a cue for the behavior and affects directly neuronal level but need not give rise to the fundamental biorhythm.

The simplest model does not explain why the circadian clock slows down (leading eventually to the loss of circadian rhythm) in external magnetic fields  $B_{ext}$  not too far from 3 Gauss- about 6 times the value of Earth's magnetic field? Hence it seems that the amount of blue light alone is not behind the clock mechanism but something more delicate is involved. The cyclotron frequencies assignable to weak external magnetic field (say  $B_{gal}$  whose flux tubes mediate gravitational interaction) as primary sources of circadian rhythms and controlled by  $B_{ext}$  somehow are suggested by the TGD inspired model of EEG.

The following picture suggests itself in TGD framework, where MB containing dark matter as large  $h_{eff} = h_{gr}$  phases of ordinary matter controls biochemistry in quantum coherent manner in scales of even entire organism.

1. Basic entities are CRY molecule and its MB carrying some internal magnetic field  $B_{end}$  (to be not confused with  $B_{end} \simeq .2$  Gauss) and having large  $h_{eff}$ . MB of galactic magnetic field  $B_{gal}$ : this in order to obtain cyclotron frequencies of order 24 hours for protons and ions. Magnetic flux tubes of galactic MB carrying cyclotron Bose-Einstein condensates for electrons, protons, ions each of them with  $h_{eff} = h_{gr}$  proportional to the mass of charged particle in question. Different charged particles at their own flux tubes like books in the shelves of library.
2. Photons of blue light excite CRY. Excited CRY gradually returns to the ground state. This should lead to emission of dark cyclotron photons with cyclotron frequency of magnetic field involved for some charged particles at flux tubes? Transformation to dark cyclotron photons increasing  $\hbar$  to  $\hbar_{eff} = n \times \hbar$  takes place only at quantum criticality for the emitted photons. This might select the transitions corresponding to blue light.
3. The two MBs should interact by dark radiation at cyclotron frequencies. The excitations of CRY molecule by blue light would decay to ground state and emit dark photons with energy of blue light but with the cyclotron frequency for protons/ions of or order 24 hours. Magnetic field with the strength not too far from 1 nT, the strength of galactic magnetic field seems to be the most natural possibility.
4. CRY's MB must reconnect with that of galactic MB. Reconnection makes possible resonant interaction at multiples of cyclotron frequency. Large  $h_{eff}$  and biophoton hypothesis require that the energies involved are in visible-UV range. Blue light is in this range.
5. The resonant interaction would give rise to the perception of Earth's MB and make possible navigation: bird would fly to in the direction, where it perceives the flux tubes of Earth's MB.
6. Circadian rhythm would correspond to the galactic cyclotron frequency which would be same for all charged particles with the same charge by  $h_{gr} = h_{eff}$  hypothesis implying that dark cyclotron photons have universal energy spectrum in the range of biophoton energies.

Why the external magnetic field with strength of order 3 Gauss has the slowing down effect? CRY should be able to couple to magnetic fields of this order of magnitude. The coupling should reduce the frequency of the emitted dark photons. It would seem that the frequency of dark photons emitted by CRY is reduced. This requires that the energy difference for its excited and ground states is reduced. If the ground state and excited state have different the difference of total energies contains the difference of cyclotron frequencies proportional to charge difference and magnetic field. If this difference is negative, its magnitude increases with  $B_{ext}$  so that the frequency of emitted photons reduced. Hence the CRY couples to flux tubes with weaker galactic magnetic field. This slows down the clock.

One can of course adopt a conservative attitude and consider a minimal modification of RPM by assuming quantum criticality and by replacing the Planck constant with  $h_{eff} = n \times h$  eit  $n \geq 50$ . The excitation of CRY molecule responsible for the phenomena described could indeed

involve generation of radical pair in presence of blue light. The decay of RPM to neutral pair could produce photons transforming to dark photons at flux tubes? If so, the decoherence produced by the decay of RP would be compensated by coherence at the level of dark matter: negentropy maximization principle (NMP) [K4] would suggest this.

## 2.5 Gravitaxis and $h_{eff} = h_{gr}$ hypothesis

Gravitaxis might relate to the basic hypothesis about dark matter in TGD Universe as large  $h_{eff}$  phases: one would have  $h_{eff} = h_{gr} = GMm/v_0$ ,  $v_0$  is velocity parameter,  $m$  is some large mass, now presumably Earth's mass. This hypothesis is originally due to Nottale and plays key role in TGD inspired quantum biology.

What sensing a gradient in gravitational field could mean from the point of view of this hypothesis?

1. The simplest model assumes that the flux tubes along with gravitational interaction is mediated, are magnetic flux tubes with vanishing Kähler magnetic field but non-vanishing electromagnetic and  $Z^0$  magnetic fields. These flux tubes would be vacuum extremals in absence of volume term in action. The volume term is proportional to cosmological constant and induced by the twistor lift of TGD [K3]. The flux tubes carrying magnetic monopole flux would be assigned to non-gravitational interactions: this distinction looks natural but does not seem to be necessary.
2. The density of the gravitational magnetic flux tubes must correlate with the average intensity of gravitational field at GRT limit of TGD. At fundamental level of many-sheeted space-time the detection of gravitational field strength would reduce to the detection of the density of these flux tubes. This detection would reduce to the same mechanism which makes possible magneto-sensitivity making possible avian navigation, biological clocks, and basic step of photosynthesis.

The overall conclusion is that TGD based quantum biology neatly unifies the description of several phenomena suggesting quantum biology in terms of magnetic body and dark matter as large  $h_{eff}$  phases. TGD based model is also needed since RPM proposal predicts effect which is at most 2 per cent of that needed to explain the observations.

## 3 TGD view about magneto-reception and circadian rhythm: few years later

Above is described the TGD based model for the findings related to magnetoreception and pace-keeper mechanism [L3] as it was for few years ago. The model discussed also photo-taxis and gravi-taxis. The improved model discussed below relies on essentially the same elements but does not assume RPM as the mechanism producing nuclear spin polarization as an analog of compass.

### 3.1 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 then 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.

### 3.2 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  $\Theta$  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  $\Theta$  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.

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

A more complex model could rely on cell membrane as GJJ [K12] [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

$$\Delta E_c(h_{eff}) = \frac{\hbar_{eff}}{\hbar} \times \Delta E_c(\hbar) \quad (3.1)$$

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

$$f_{J,G} = \frac{\Delta E_{J,G}}{\hbar_{eff}} = \Delta E_c(\hbar) + \frac{f_J}{\hbar_{eff}} \quad (3.2)$$

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  $\Omega$  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  $\Omega$  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 naïve expectation is that the difference  $\Delta f_c$  of cyclotron frequencies would correspond to the dominating part of  $\Omega$  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  $T_{G,J} \geq T_{12}$ . 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  $\hbar_{gr}$  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

$$n_1 B_1 = n_2 B_2 \tag{3.3}$$

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  $B_i \rightarrow B_i + B$  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

$$f_{G,J} = (n_1 - n_2)f_c(B) + \frac{ZeV}{\hbar_{gr}} \quad , \quad M = M_D \quad \text{or} \quad M = M_E \quad . \tag{3.4}$$

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  $\mu$  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 [K12] [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.

### 3.4 Quantitative formulation of the model

Consider next the quantitative formulation of the model.

#### 3.4.1 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.

##### 1. The parameters appearing in dark cyclotron energy

The condition  $h_{eff} = h_{gr}$  would be satisfied.  $h_{gr} = GMm/v_0$  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 [?]. 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] [K14, K5, K6].
3. For the 4 inner planets of Sun one has  $\beta_0 = v_0/c \simeq 2^{-11}$  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  $\beta_0$  could depend on the  $M_D$  but also a restricted universality can be considered. I have considered a model for  $\beta_0$  [L5] [K1].

##### 2. Strengths 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 correspond 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 have 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.

### 3.4.2 Quantitative tests

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

#### 1. The values of the velocity parameters

1. Just as a blind guess I assumed first  $\beta_0 \simeq 2^{-11}$  assigned to the 4 inner planets of Sun by Nottale [E1] [K14, ?] (the assignment was based on the idea about near universality of  $\beta_0$ ) 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  $v = \sqrt{GM}r$  for circular orbit of radius  $r$ . At the surface of Earth with  $r = R$  the rotational velocity of Earth

$$\beta_{0,E} \simeq \beta_{rot,R} 1.5 \times 10^{-6} = 3 \times 10^{-3} \beta_{0,Sun} \quad (3.5)$$

would be first order of magnitude guess.

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

$$\beta_{0,D} = \sqrt{R_E r} \times 2\beta_{0,E} \simeq 0.8 \times \beta_0 \quad (3.6)$$

This is surprisingly near to  $\beta_0$ , 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  $\beta$  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  $\beta_0$  comes in powers of 2 and corresponds to the spectrum of preferred p-adic length scales.

#### 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

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

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

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

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

$$E_c = \hbar \frac{ZeB}{m_{eff}} , \quad (3.7)$$

where one has

$$m_{eff} = \frac{\hbar\beta_{0,D}}{GM_D} = \frac{2\hbar\beta_{0,D}}{r_S} = \beta_{0,D} \times 1.24 \text{ eV} . \quad (3.8)$$

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

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

$$E_c \simeq 2 \text{ eV} ,$$

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  $f_c = 1 \text{ Hz}$ ). One has for  $f_c(e, p, Fe^{++}) = (6 \times 10^5, 300, 10) \text{ Hz}$  and  $f_J(e, p, Fe^{++}) = (18 \times 10^3, 9, .3) \text{ Hz}$ .

2. For  $(B_{gal}, M = M_E, \beta_{0,E} = 3 \times 10^{-3} \beta_0)$  mode one has  $E_c = .13 \text{ eV}$ , 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  $h_{gr}$  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

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

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  $B_{gal} = .5 \text{ nT}$  and equal to  $f_c = 4 \times 10^4 \text{ s}$  to be compared to  $T_{12} = 4.3 \times 10^4 \text{ s}$ .
2. For  $h \rightarrow h_{gr}$  the situation changes.  $f_{J,G}$  would behave like  $a + b/N$ ,  $N$  the number of nucleotides.  $E_{J,G}$  would behave like  $aN + b$



### 3.4.3 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.

#### 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  $L(169) = 5 \mu\text{m}$ . 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

$$f_{G,J} = 2^{169-k} f_c(\text{ion}, B_{end}) + f_J(\hbar) \frac{\hbar}{h_{gr}} . \quad (3.9)$$

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.

#### 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 [K11] 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  $f = r f_0$ ,  $1 \leq r \leq 2$ , 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  $r f_0$  associated with rational  $1 \leq r = p/q \leq 2$  would be  $f_{G,J} = r f_0 = \frac{1}{m_{eff}} Z e B_{end}(r) + f_J(\hbar_{gr})$  giving

$$e B_{end}(r) = \frac{m_{eff}}{Z} \times (r f_0 - f_J(\hbar) \frac{m_{eff}}{m}) , \quad m_{eff} = \frac{\hbar v_0}{GM} = \frac{2\hbar v_0}{r_s} . \quad (3.10)$$

The appearance of Schwarzschild 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. 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  $\mu\text{m}$  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/ybjmkykb>) is 2-layered structure with thickness of cell size scale.

1. The layers have thickness 2  $\mu\text{m}$  and having 1  $\mu\text{m}$  empty region between. The total thickness is 5  $\mu\text{m}$ , 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  $n_1 B_1 = n_2 B_2$  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  $6 \times 10^5$  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  $\text{Ca}^{++}$  ion in  $B_{end} = .2$  Gauss. Could there be a communication between these two levels at the cyclotron frequencies of  $\text{Ca}^{++}$ ? 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  $\text{Ca}^{++}$  ions in biology (see <http://tinyurl.com/w9o29xa>)?

The objection is that the dark photon energies are different for  $B_{end}$  and  $B_{gal}$ :  $\sim 2$  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.

## 4 Appendix: What TGD is?

Since the purpose is to see the representations through TGD lense it is polite to first to tell to the reader what TGD is. The reader interested in details can find them for instance in [K16].

## 4.1 Why TGD?

The first question is “Why TGD?”. The attempt to answer this question requires overall view about the recent state of theoretical physics.

Obviously standard physics plagued by some problems. These problems are deeply rooted in basic philosophical - one might even say ideological - assumptions which boil down to -isms like reductionism, materialism, determinism, and locality.

Thermodynamics, special relativity, and general relativity involve also postulates, which can be questioned. In thermodynamics second law in its recent form and the assumption about fixed arrow of thermodynamical time can be questions since it is hard to understand biological evolution in this framework. Clearly, the relationship between the geometric time of physics and experienced time is poorly understood. In general relativity the beautiful symmetries of special relativity are in principle lost and by Noether’s theorem this means also the loss of classical conservation laws, even the definitions of energy and momentum are in principle lost. In quantum physics the basic problem is that the non-determinism of quantum measurement theory is in conflict with the determinism of Schrödinger equation.

Standard model is believed to summarize the recent understanding of physics. The attempts to extrapolate physics beyond standard model are based on naïve length scale reductionism and have products Grand Unified Theories (GUTs), supersymmetric gauge theories (SUSYs). The attempts to include gravitation under same theoretical umbrella with electroweak and strong interactions has led to super-string models and M-theory. These programs have not been successful, and the recent dead end culminating in the landscape problem of super string theories and M-theory could have its origins in the basic ontological assumptions about the nature of space-time and quantum.

## 4.2 TGD and GRT

The new view about space-time as 4-D surface in certain fixed 8-D space-time is the starting point motivated by the above mentioned energy problem of general relativity and means in certain sense fusion of the basic ideas of special and general relativities.

The higher-dimensional space-time is 8-D  $H = M^4 \times CP_2$ : empty Minkowski space  $M^4$  of special relativity with points replaced by 4-D  $CP_2$  (complex projective space of 4 real dimensions). The symmetries of special relativity are preserved but lifted to the level of  $H$  so that classical conserved quantities like energy exist.  $CP_2$  in turns codes in its geometry the standard model symmetries and quantum numbers and its spinor connection codes for classical electroweak gauge fields. Their projections to space-time surface are dynamical. Also classical color fields can be understood. These geometrized fields are expressible only in terms of four  $CP_2$  coordinates and cannot as such directly correspond to those of standard model. How standard model emerges as a limit of TGD will discussed below.

Rather recently [K3] I have discussed twistor lift of TGD replacing space-times with the twistor spaces and  $H$  with the product of twistor spaces of  $M^4$  and  $CP_2$ , which are unique as 4-D spaces in the sense that they have twistor spaces with Kähler structure making possible to lift the Kähler action to 6-D one. The theory dimensionally reduced to a 4-D theory containing cosmological constant and gravitational constant as additional constants besides  $CP_2$  radius and Kähler coupling strength.

## 4.3 TGD and string models

TGD can be also seen as a generalization of hadronic string model or of superstring models by replacing strings with 3-D surfaces and 10-D space-time with 8-D  $M^4 \times CP_2$ . 3-space as we experience it corresponds to a large 3-surface to which smaller 3-surfaces are glued by wormhole contacts. These smaller 3-surfaces we would interpret as physical objects with shape and size and when they are really small, we call them elementary particles. We would directly see this extremely complex space-time geometry. This geometry has fractal hierarchical structure: 3-surfaces glued to larger 3-surfaces glued to....

As a matter fact, string world sheets and what I call partonic 2-surfaces in 4-D space-time regarded as space-time surface turn out to be fundamental objects of also TGD forced by very general principles such as well-definedness of em charge and strong form of holography (SH) implied

by strong form of general coordinate invariance [K15]. SH states that information given at these 2-surfaces allows to deduce information about quantum states and classical dynamics: effective 2-dimensionality in the sense of information theory would be in question.

#### 4.4 TGD based ontology

TGD forces to dramatically generalize the ontology of standard model and GRT.

1. The new view about space-time differs radically from that of GRT. Space-time surfaces are topologically non-trivial in all scales. They have typically finite size and obey size scale hierarchy. One can glue space-time sheets to larger space-time sheets to get a fractal scale hierarchy with sheets glued to larger sheets by wormhole contacts and having interpretation as correlates for physical objects.

Second key difference is that space-time surfaces can have also regions with Euclidian signature of the induced metric - time and space are geometrically in the same role. Wormhole contacts are this kind of regions and serve as building bricks of elementary particles and are identifiable as lines of generalized scattering diagrams.

2. A new view about classical fields emerges distinguishing TGD from Maxwell's theory. One can say that each physical object has field identity - field body consisting of space-time sheets. The notion of magnetic body (MB) turns out to be central in TGD inspired biology and adds MB to the pair organism-environment as a third member. The communications from BB involve classical radiation fields: EEG is one example of this communication from the brain to the MB of brain. The size scale of MB is typically considerably larger than that of BB: even of order Earth size scale or even larger. MB makes possible remote mental interactions and could be behind the morphic fields of Sheldrake.
3. How TGD relates to GRT and standard model? The basic idea is that the sheets of many-sheeted space-time obeying extremely simple physics (only 4 analogs of field variables plus SH realized by preferred extremal property implying effective 2-dimensionality of dynamics) are lumped together and identified as GRT space-time differing slightly from flat  $M^4$ .

The deviation comes in the following manner. The deviations of the induced metric for space-time sheets from  $M^4$  metric (empty space metric) are summed up to give GRT gravitational field as deviation from  $M^4$  metric. Induced gauge potentials known once space-time surface is known are summed up in the same manner to give the gauge potentials of standard model. This because test particle experiences the sums of various induced fields associated with space-time sheets. Ordinary linear superposition is replaced at fundamental level with the set theoretic union for space-time sheets.

4. The hierarchy of Planck constants  $h_{eff} = n \times h$  was originally motivated by certain strange findings in neuroscience about effects of ELF em fields on vertebrate brain [K8, K7]. First it was postulated that dark matter corresponds to phases of ordinary matter with  $h_{eff} = n \times h$  having certain special kind of space-time surfaces (singular  $n$ -sheeted covering spaces) as correlates. Later it turned that these phases are actually predicted by basic TGD: in TGD framework Planck constants is for single space-time sheet  $h$  and only effectively  $h_{eff} = n \times h$  but at QFT limit one can say that  $h_{eff} = n \times h$  is strictly true.

Later the view about dark matter as evolved and according to the recent view dark matter would emerge at quantum criticality (perhaps even at ordinary criticality) and would be a correlate for long range quantum fluctuations and long range quantum coherence. Various quantal length scales are indeed typically scaled up by  $n$ . This suggests that biosystems are quantum coherent and quantum critical because MB contains dark matter.

MB containing dark matter would serve as intentional agent receiving sensory data from BB and controlling BB. EEG and its generalizations to various frequency ranges based on dark photons would be the tool for this. The dark cyclotron photons assignable to given charged particle would have very specific value of  $h_{eff}$  guaranteeing that cyclotron energy scale does not depend on particle mass and would be in the range of biophoton energies (visible and

UV). Biophotons would result in the phase transition  $h_{eff} \rightarrow h$ . Also dark photons in IR range (Josephson photons assignable to cell membranes) are predicted.

Biochemistry would not be enough to understand the biology. MB and its “motor actions” would be crucial for understanding bio-catalysis, in particular the miraculous property of biomolecules to find each other in the molecular crowd.

5. Zero energy ontology (ZEO) is a further new piece of TGD ontology. In standard ontology the state of system at fixed value of time characterize the time evolution of the system. Classically the state is typically characterized by particle positions and velocities and by values of say Maxwellian fields and their time derivatives. Field equations in principle allow to deduce the time evolution from these.

In ZEO one introduces causal diamond (CD). CD is intersection of future and past directed light-cones (Penrose diagram) with points replaced by  $CP_2$ . CDs are assumed to form a fractal scale hierarchy. CD has two light-like boundaries: “future” and “past” boundary. Light-likeness means that 3-D  $M^4$  projection of given boundary correspond to a sphere expanding with light-velocity.

Physical states are replaced with zero energy states analogous to physical events consisting of initial and final states. Initial/final state can be assigned to 3-D intersections of space-time surfaces with the “future”/“past” boundary of CD. ZEO is consistent with the crossing symmetry of quantum field theories and with the conservation laws. It is however extremely flexible since any zero energy state is in principle achievable by a sequence of quantum jumps. The analog of ordinary positive energy can be assigned with either “future” or “past” boundary and the arrow of time is different for these states. ZEO leads to a quantum measurement theory allowing to circumvent the basic problem of standard quantum measurement theory due to the non-determinism of state function reduction contra determinism of unitary time evolution.

6. p-Adic and adelic physics are further new ontological elements of TGD. p-Adic numbers are generalizations of real numbers, and there are infinite number of p-adic number fields for each prime  $p = 2, 3, 5, \dots$ . I ended up with p-adic physics almost accidentally by playing with p-adic generalization of thermodynamics and finding that p-adic thermodynamics can reproduce elementary particle masses with minimal assumptions and thus replaced Higgs mechanism with more fundamental theory. The properties of p-adic number led soon to the proposal that p-adic number fields are correlates for cognition and imagination. Much later this led to the unification of real physics and various p-adic physics in terms of adelic physics fusing all these number fields to a bigger structure.

Why p-adic physics is so nice that one can talk about p-adic embedding space and space-time surfaces as kind of cognitive representations of real space-time surfaces. In particular, SH allows to assign p-adic space-time surface to given set of string world sheets and partonic 2-surfaces as preferred extremal but no necessary to real one. All imaginations cannot be realized!

Also p-adic generalization of Shannon entropy makes sense but it can be negative. One can say that entanglement carries negative p-adic entropy - positive negentropy - although real entropy is non-negative. The interpretation is in terms of conscious information naturally assignable to cognition.

## 4.5 TGD, quantum measurement theory, and consciousness

TGD inspired theory of consciousness can be seen as quantum measurement theory in ZEO. Observer as an outsider becomes a part of physical system. Observer does not cause state function reductions but as a conscious entity is a sequence of state functions on same boundary of CD - generalized Zeno effect.

1. The maximization of negentropy gain in state function reduction becomes the basic variational principle of consciousness theory consistent with second law which applies at the level of ensembles and is closely related to the growth of real entanglement entropy. I refer to this principle as Negentropy Maximization Principle (NMP).

2. In ZEO state function reduction can take place to either boundary of CD. In a sequence of reductions to a fixed boundary the boundary itself remains fixed as also the states at it - possibly entangled with those at the opposite boundary. This boundary is referred to as “passive”. The second - “active” - boundary drifts farther away from the passive boundary and the states at it change. Each step can be regarded as time localization localizing the active boundary of CD.

Self corresponds to this sequence of state function reductions. The permanent part of self - “soul” - corresponds to the unchanging part of self and changing part corresponds to consciousness determined by sensory input. In particular, the experience about flow of time corresponds to the drift of the active boundary of CD farther away. Self is a generalized Zeno effect.

3. Eventually NMP forces the first reduction to the opposite boundary to occur. This is the counterpart of the usual large and non-deterministic quantum jump assignable to quantum measurement. Self dies and re-incarnates as time reversed self since the CD starts to increase in size in opposite time direction. This prediction has rather radical implications.

Some of the implications deserve to be noticed.

1. One ends up with a new view about time. Geometric time as fourth space-time coordinate (or time coordinate as distance between the tips of CD) is not same as subjective time defined by a sequence of state function reductions. The consciousness experience associated with each reduction has the changing components with contents coming from the active boundary so that subjective time is mapped to discrete clock time.
2. Selves having hierarchy of CDs as embedding space correlate form a hierarchy. Subself is assumed to be experienced as mental image and subsubelves as kind of average sub-subself so that self is not drowned to microscopic information. Subconscious corresponds to conscious sub-sub-... -selves. We are ourselves mental images of some higher level self and the hierarchy continues ad infinitum with entire Universe at the top.

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