Quantum Model for Bio-Superconductivity: I

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Contents

Abstract

The model for generalized EEG relates very closely to the general model of high T_c super-conductivity. This motivates a separate discussion of the vision about bio-super-conductivity in TGD Universe.

1. General mechanisms of bio-superconductivity

The many-sheeted space-time concepts suggested a very general mechanism of superconductivity based on the "dropping" of charged particles from atomic space-time sheets to larger space-time sheets. The first guess was that larger space-time sheets are very dry, cool and silent so that the necessary conditions for the formation of high T_c macroscopic quantum phases are met. The criticism against "dropping" is that particle can topologically condense on several space-time sheets which therefore are not separate worlds: this is indeed assumed in the recent view about GRT and QFT limit of TGD. Dropping could therefore occur only at larger space-time sheet at the boundary of the smaller one. The expansion of the space-time sheet (flux tube) in p-adic phase transition liberates also zero point kinetic energy (cyclotron energy).

The possibility of large $\hbar$ quantum coherent phases makes the assumption about thermal isolation between space-time sheets un-necessary. The establishment of thermal equilibrium would rely on the phase transitions transforming ordinary to dark matter and vice versa. Biophotons could be produced from dark photons in this manner. The flow from a flux tube portion with larger value of h_{eff} to that with a smaller value liberates cyclotron energy.

A crucial element is quantum criticality predicting a new kind of superconductivity explaining the strange features of high T_c super-conductivity. This led to the proposal that there are two kinds of Cooper pairs, exotic Cooper pairs with spin $S = 1$ and counterparts of ordinary BCS type Cooper pairs with spin $S = 0$. Both correspond to a large value of Planck constant. Exotic Cooper pairs are quantum critical meaning that they can decay to ordinary electrons. Below temperature $T_{c_1} > T_c$ only exotic Cooper pairs with spin are present and their finite lifetime implies that super-conductivity is broken to ordinary conductivity satisfying scaling laws characteristic for criticality. At T_c spinless BCS type Cooper pairs become stable and exotic Cooper pairs can decay to them and vice versa. An open question is whether the BCS type Cooper pairs can be present also in the interior of cell.

These two superconducting phases would compete in certain narrow interval around critical temperature for which body temperature of endotherms is a good candidate in the case of living matter. Also high T_c superfluidity of bosonic atoms dropped to space-time sheets of electronic Cooper pairs becomes possible besides ionic super conductivity. Even dark neutrino superconductivity can be considered below the weak length scale of scaled down weak bosons.

Magnetic flux tubes would be carriers of dark particles and magnetic fields would be crucial for super-conductivity. Two parallel flux tubes carrying magnetic fluxes in opposite directions is the simplest candidate for super-conducting system. This conforms with the observation that antiferromagnetism is somehow crucial for high temperature super-conductivity. The spin interaction energy is proportional to Planck constant and can be above thermal energy: if the hypothesis that dark cyclotron energy spectrum is universal is accepted, then the energies would be in bio-photon range and high temperature super-conductivity is obtained. If fluxes are parallel spin $S = 1$ Cooper pairs are stable. $L = 2$ states are in question since the members of the pair are at different flux tubes. These two kinds of Cooper pairs could correspond to BCS type and exotic Cooper pairs.

The fact that the critical magnetic fields can be very weak or large values of $\hbar$ is in accordance with the idea that various almost topological quantum numbers characterizing induced magnetic fields provide a storage mechanism of bio-information.

This mechanism is extremely general and in principle works for electrons, protons, ions, charged molecules and even exotic neutrinos and an entire zoo of high T_c bio-superconductors, super-fluids and Bose-Einstein condensates is predicted. Of course, there are restrictions due to the thermal stability it room temperature and it seems that only electron, neutrino, and proton Cooper pairs are possible at room temperature besides Bose-Einstein condensates of all bosonic ions and their exotic counterparts resulting when some nuclear color bonds become charged.

2. Hierarchies of preferred p-adic length scales and values of Planck constant

TGD inspired quantum biology and number theoretical considerations suggest preferred values for $r = \hbar/\hbar_0$. For the most general option the values of $\hbar$ are products and ratios of two integers n_a and n_b. Ruler and compass integers defined by the products of distinct Fermat

primes and power of two are number theoretically favored values for these integers because the phases $exp(i2\pi/n_i)$, $i \in \{a,b\}$, in this case are number theoretically very simple and should have emerged first in the number theoretical evolution via algebraic extensions of p-adics and of rationals. p-Adic length scale hypothesis favors powers of two as values of r.

The hypothesis that Mersenne primes $M_k = 2^k - 1$, $k \in \{89, 107, 127\}$, and Gaussian Mersennes $M_{G,k} = (1+i)k - 1$, $k \in \{113, 151, 157, 163, 167, 239, 241..\}$ (the number theoretical miracle is that all the four p-adic length scales sith $k \in \{151, 157, 163, 167\}$ are in the biologically highly interesting range 10 nm-2.5 μm) define scaled up copies of electro-weak and QCD type physics with ordinary value of $\hbar$ and that these physics are induced by dark variants of corresponding lower level physics leads to a prediction for the preferred values of $r = 2^{k_d}$, $k_d = k_i - k_j$, and the resulting picture finds support from the ensuing models for biological evolution and for EEG. This hypothesis - to be referred to as Mersenne hypothesis - replaces the earlier rather ad hoc proposal $r = \hbar/\hbar_0 = 2^{11k}$ for the preferred values of Planck constant.

3. Fractal hierarchy of magnetic flux sheets and the hierarchy of genomes

The notion of magnetic body is central in the TGD inspired theory of living matter. Every system possesses magnetic body and there are strong reasons to believe that the magnetic body associated with human body is of order Earth size and that there could be an entire hierarchy of these bodies with even much larger sizes. Therefore the question arises what one can assume about these magnetic bodies. The quantization of magnetic flux suggests an answer to this question.

1. The quantization condition for magnetic flux reads in the most general form as $\oint (p - eA) \cdot dl = n\hbar$. If supra currents flowing at the boundaries of the flux tube are absent one obtains $e \int B \cdot dS = n\hbar$, which requires that the scaling of the Planck constant scales up the flux tube thickness by r^2 and scaling of B by $1/r$. If one assumes that the radii of flux tubes do not depend on the value of r, magnetic flux is compensated by the contribution of the supra current flowing around the flux tube: $\oint (p - eA) \cdot dl = 0$. The supra currents would be present inside living organism but in the faraway region where flux quanta from organism fuse together, the quantization conditions $e \int B \cdot dS = n\hbar$ would be satisfied.

2. From the point of view of EEG especially interesting are the flux sheets which have thickness $L(151) = 10$ nm (the thickness of cell membrane) carrying magnetic field having strength of endogenous magnetic field. In absence of supra currents these flux sheets have very large total transversal length proportional to r^2. The condition that the values of cycloctron energies are above thermal energy implies that the value of r is of order 2^{k_d}, $k_d = 44$. Strongly folded flux sheets of this thickness might be associated with living matter and connect their DNAs to single coherent structure. One can of course assume the presence of supra currents but outside the organism the flux sheet should fuse to form very long flux sheets.

3. Suppose that the magnetic flux flows in head to tail direction so that the magnetic flux arrives to the human body through a layer of cortical neurons. Assume that the flux sheets traverse through the uppermost layer of neurons and also lower layers and that DNA of each neuronal nuclei define a transversal sections organized along flux sheet like text lines of a book page. The total length of DNA in single human cell is about one meter. It seems that single organism cannot provide the needed total length of DNA if DNA dominates the contribution. This if of course not at all necessarily since supra currents are possible and outside the organism the flux sheets can fuse together. This implies however correlations between genomes of different cells and even different organisms.

These observations inspire the notion of super- and hyper genes. As a matter fact, entire hierarchy of genomes is predicted. Super genes consist of genes in different cell nuclei arranged to threads along magnetic flux sheets like text lines on the page of book whereas hyper genes traverse through genomes of different organisms. Super and hyper genes provide an enormous representative capacity and together with the dark matter hierarchy allows to resolve the paradox created by the observation that human genome does not differ appreciably in size from that of wheat.

1 Introduction

The model for EEG and its varints and nerve pulse relies on a general model of high T_c superconductivity [K1, K2]. In this chapter the general vision behind model of cell membrane as superconductor inspired by the identification of dark matter in terms of hierarchy of Planck constants and the notion of magnetic body is discussed.

1.1 General Mechanism Of Bio-Superconductivity

The ideas about high temperature super-conductivity have evolved gradually as a reaction to experimental input and evelution in the understanding of TGD.

1. The many-sheeted space-time concept suggests a very general mechanism of superconductivity based on the "dropping" of charged particles from atomic space-time sheets to larger space-time sheets. The first guess was that larger space-time sheets are very dry, cool and silent so that the necessary conditions for the formation of high T_c macroscopic quantum phases are met. The criticism against this model is that particles topologically condensed to all space-time sheets having non-empty Minkowski space projection to the region where the particle is.

2. The possibility of large $\hbar$ quantum coherent phases makes the assumption about thermal isolation between space-time sheets un-necessary. At larger space-time sheet the interactions of the charged particles with classical em fields generated by various wormhole contacts feeding gauge fluxes to and from the space-time sheet in question give rise to the necessary gap energy. The simplest model for Cooper pair is space-time sheet containing charged particles having attractive Coulombic interaction with the quarks and antiquarks associated with the throats of the wormhole contacts.

3. It became clear quantum criticality predicting a new kind of superconductivity explaining the strange features of high T_c super-conductivity is essential. There are two kinds of Cooper pairs, exotic Cooper pairs and counterparts of ordinary BCS type Cooper pairs. Both correspond to a large value of Planck constant. Exotic Cooper pairs are quantum critical meaning that they can decay to ordinary electrons. Below temperature $T_{c_1} > T_c$ only exotic Cooper pairs with spin are present and their finite lifetime implies that super-conductivity is broken to ordinary conductivity satisfying scaling laws characteristic for criticality. At T_c spinless BCS type Cooper pairs become stable and exotic Cooper pairs can decay to them and vice versa. An open question is whether the BCS type Cooper pairs can be present also in the interior of cell.

   These two superconducting phases compete in certain narrow interval around critical temperature for which body temperature of endotherms is a good candidate in the case of living matter. Also high T_c superfluidity of bosonic atoms dropped to space-time sheets of electronic Cooper pairs becomes possible besides ionic super conductivity. Even dark neutrino superconductivity can be considered below the weak length scale of scaled down weak bosons.

4. Magnetic flux tubes would be carriers of dark particles and according to the findings about high temperature super-conductivity magnetic fields are indeed crucial for super-conductivity. Two parallel flux tubes carrying magnetic fluxes in opposite directions is the simplest candidate for super-conducting system. This conforms with the observation that antiferromagnetism is somehow crucial for high temperature super-conductivity. The spin interaction energy is proportional to Planck constant and can be above thermal energy: if the hypothesis that dark cyclotron energy spectrum is universal is accepted, then the energies would be in bio-photon range and high temperature super-conductivity is obtained. If fluxes are parallel spin $S = 1$ Cooper pairs are stable. $L = 2$ states are in question since the members of the pair are at different flux tubes. These two kinds of Cooper pairs could correspond to BCS type and exotic Cooper pairs.

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This mechanism is extremely general and in principle works for electrons, protons, ions, charged molecules and even exotic neutrinos and an entire zoo of high T$_c$ bio-superconductors, super-fluids and Bose-Einstein condensates is predicted. Of course, there are restrictions due to the thermal stability it room temperature and it seems that only electron, neutrino, and proton Cooper pairs are possible at room temperature besides Bose-Einstein condensates of all bosonic ions and their exotic counterparts resulting when some nuclear color bonds become charged.

5. This mechanism of high temperature super-conductivity is extremely general and in principle works for electrons, protons, ions, charged molecules and even exotic neutrinos and an entire zoo of high T$_c$ bio-superconductors, super-fluids and Bose-Einstein condensates is predicted. Of course, there are restrictions due to the thermal stability it room temperature. If h_{eff} is proportional to the particle mass, the binding energy of Cooper pairs identifiable as spin-spin interaction energy and does not depend on the mass of the Cooper pair. The bindng energy is proportional to h_{eff} and in visible and UV range if bio-photons result when dark photon transforms to ordinary photon. The hypothesis that gravitational Planck constant and h_{eff} are identical ($h_{eff} = h_{gr}$) in microscopic domain, implies the universality.

1.2 Hierarchies Of Preferred P-Adic Length Scales And Values Of Planck Constant

All p-adic length scales above electron length scale $L_e(127)$ were identified erratically in all writings about TGD before 2014. This deserves some clarifying comments.

1. The wrong identification was $L(151) \simeq 10$ nm implying wrong identification of other scales above $L(127)$ since I have calculated them by scaling $L(151)$ by an appropriate power of two. What I have denoted by $L(151)$ is actually obtained by scaling the Compton length $L_e(127) = \hbar/m_e$ by $2^{(151-127)/2}$ and therefore electrons Compton scale if it would correspond to $k = 151$. Since the mass of electron from p-adic mass calculations is given by $m_e = \sqrt{5+X}\hbar/L(127)$, the correct identification of $L(151)$ would be

$$L(151) = 2^{(151-127)/2}L(127) = 2^{(151-127)/2}L_e(151)/\sqrt{5+X} = 10/\sqrt{5+X} \ \ nm \ \ , \ \ 0 \leq X \leq 1 \ .$$

   Here X denotes the unknown second order contribution of form $X = n/M_{127}$, n integer, to the electron mass, and in the first approximation one can take $X = 0$ - the approximation is excellent unless n is very large. In the sequel I will try to use the shorthand $L_e(k) = \sqrt{5}L(k)$ but cannot guarantee that the subscript "e" is always present when needed: it is rather difficult to identify all places where the earlier erratic definition appears. I can only apologise for possible confusions.

2. This mistake has no fatal consequences for TGD inspired quantum biology. Its detection however provides a further support for the speculated central role of electron in living matter. Since the scales obtained by scaling the electron Compton scale seem to be important biologically (scaled up Comton scale $\sqrt{5}L(151)$ corresponds to cell membrane thickness), the conclusion is that electrons - or perhaps their Cooper pairs - play a fundamental role in living matter. The correct value of $L(151)$ is $L(151) = 4.5$ nm, which is slightly below the p-adic length scale $L_e(149) = 5$ nm assigned with the lipid layer of cell membrane.

3. I have also assigned to electron the time scale $T = .1$ seconds defining a fundamental biorhythm as a secondary p-adic time scale $T_2(127) = \sqrt{M_{127}}T(127)$. The correct assignment of $T = .1$ seconds is as the secondary Compton time $T_{2,e}(127) = \sqrt{M_{127}}T_e(127)$ of electron: secondary p-adic time scale is $T_2(127) = \sqrt{M_{127}}T(127)$ and corresponds to $T_{2,e}(127)/\sqrt{5} = .045$ seconds and to $f(127) = 22.4$ Hz.

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2. From the point of view of EEG especially interesting are the flux sheets which have thickness $L = 10$ nm (the thickness of cell membrane) carrying magnetic field having strength of endogenous magnetic field. $L = 10$ nm corresponds to p-adically scaled electron Compton length $L_e(151)$. In absence of supra currents these flux sheets have very large total transversal length proportional to r^2. The condition that the values of cycloctron energies are above thermal energy implies that the value of r is of order 2^{k_d}, $k_d = 44$. Strongly folded flux sheets of this thickness might be associated with living matter and connect their DNAs to single coherent structure. One can of course assume the presence of supra currents but outside the organism the flux sheet should fuse to form very long flux sheets.

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1.4 Bose-Einstein Condensates At Magnetic Flux Quanta In Astrophysical Length Scales

The model for the topological condensation at magnetic flux quanta of endogenous magnetic field $B_{end} = .2$ Gauss is based on the dark matter hierarchy with levels characterized by the values of Planck constant. The hypothesis for the preferred values of Planck constans allows to build quantitative model for the Bose-Einstein condensation at magnetic flux quanta assuming that the value of B_{end} scales like $1/\hbar$. A justification for this hypothesis comes form flux quantization conditions and from the similar scaling of Josephson frequencies [K5].

1. There are several levels of dynamics. In topological condensation the internal dynamics of ions is unaffected and $\hbar$ has the ordinary value. For instance, the formation of Cooper pairs involves dynamics at $k_d = 24 = 151 - 127$ level of dark matter hierarchy if one assumes that electrons and Cooper pairs have size given by the cell membrane thickess equal to $L_e(151)$. Also the dynamics of ionic Cooper pairs remains unaffected in the topological condensation to magnetic flux quanta obeying $k_d > 24$ dynamics.

2. Cyclotron energies scale as as $\hbar$ so that for a sufficiently high value of k_d thermal stability of cyclotron states at room temperature is achieved for a fixed value of B. Same applies to spin flip transitions in the recent scenario. The model for EEG based on dark matter hierarchy [K5] involves the hypothesis that EEG quanta correspond to Josephson radiation with energies in the visible and UV range and that they produce in the decay to ordinary photons either bunches of EEG photons or visible/UV photons. This identification allows to deduce the value of k_d when the frequency of the dark photon is fixed. The Mersenne hypothesis for the preferred p-adic length scales and values of Planck constants leads to very precise predictions.

3. Cyclotron energies $E = (\hbar/2\pi) \times ZeB/Am_p$ are scaled up by a factor $r = 2^{k_d}$ from their ordinary values and for 10 Hz cyclotron frequency are in the range of energies of visible light for $k_d = 46$.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. There are concept maps about topics related to the contents of the chapter prepared using CMAP realized as html files. Links to all CMAP files can be found at `http://tgdtheory.fi/cmaphtml.html` [L3]. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L4].

- Quantum biology [L7]
- Magnetic body [L6]
- Basic Mechanisms associated with magnetic body [L2]
- High temperature superconductivity [L5]

2 General TGD Based View About Super-Conductivity

Today super-conductivity includes besides the traditional low temperature super-conductors many other non-orthodox ones [D33]. These unorthodox super-conductors carry various attributes such as cuprate, organic, dichalcogenide, heavy fermion, bismute oxide, ruthenate, antiferromagnetic and ferromagnetic. Mario Rabinowitz has proposed a simple phenomenological theory of superfluidity and super-conductivity which helps non-specialist to get a rough quantitative overall view about super-conductivity [D33].

2.1 Basic Phenomenology Of Super-Conductivity

The following provides the first attempt by a non-professional to form an overall view about super-conductivity.

2.1.1 Basic phenomenology of super-conductivity

The transition to super-conductivity occurs at critical temperature T_c and involves a complete loss of electrical resistance. Super-conductors expel magnetic fields (Meissner effect) and when the external magnetic field exceeds a critical value H_c super-conductivity is lost either completely or partially. In the transition to super-conductivity specific heat has singularity. For long time magnetism and super-conductivity were regarded as mutually exclusive phenomena but the discovery of ferromagnetic super-conductors [D26, D9] has demonstrated that reality is much more subtle.

The BCS theory developed by Bardeen, Cooper, and Schrieffer in 1957 provides a satisfactory model for low T_c super-conductivity in terms of Cooper pairs. The interactions of electrons with the crystal lattice induce electron-electron interaction binding electrons to Cooper pairs at sufficiently low temperatures. The electrons of Cooper pair are at the top of Fermi sphere (otherwise they cannot interact to form bound states) and have opposite center of mass momenta and spins. The binding creates energy gap E_g determining the critical temperature T_c. The singularity of the specific heat in the transition to super-conductivity can be understood as being due to the loss of thermally excitable degrees of freedom at critical temperature so that heat capacity is reduced exponentially. BCS theory has been successful in explaining the properties of low temperature super conductors but the high temperature super-conductors discovered in 1986 and other non-orthodox superconductors discovered later remain a challenge for theorists.

The reasons why magnetic fields tend to destroy super-conductivity is easy to understand. Lorentz force induces opposite forces to the electrons of Cooper pair since the momenta are opposite. Magnetic field tends also to turn the spins in the same direction. The super-conductivity is destroyed in fields for which the interaction energy of magnetic moment of electron with field is of the same order of magnitude as gap energy $E_g \sim T_c$: $e\hbar H_c/2m \sim T_c$.

If spins are parallel, the situation changes since only Lorentz force tends to destroy the Cooper pair. In high T_c super-conductors this is indeed the case: electrons are in spin triplet state ($S = 1$) and the net orbital angular momentum of Cooper pair is $L = 2$. The fact that orbital state is not $L = 0$ state makes high T_c super-conductors much more fragile to the destructive effect of impurities than conventional super-conductors (due to the magnetic exchange force between electrons responsible for magnetism). Also the Cooper pairs of ^3He superfluid are in spin triplet state but have $S = 0$.

The observation that spin triplet Cooper pairs might be possible in ferro-magnets stimulates the question whether ferromagnetism and super-conductivity might tolerate each other after all, and the answer is affirmative [D9]. The article [D26] provides an enjoyable summary of experimental discoveries.

2.1.2 Basic parameters of super-conductors from universality?

Super conductors are characterized by certain basic parameters such as critical temperature T_c and critical magnetic field H_c, densities n_c and n of Cooper pairs and conduction electrons, gap energy E_g, correlation length ξ and magnetic penetration length λ. The super-conductors are highly complex systems and calculation of these parameters from BCS theory is either difficult or impossible.

It has been suggested [D33] that these parameters might be more or less universal so that they would not depend on the specific properties of the interaction responsible for the formation of Cooper pairs. The motivation comes from the fact that the properties of ordinary Bose-Einstein condensates do not depend on the details of interactions. This raises the hope that these parameters might be expressible in terms of some basic parameters such as T_c and the density of conduction electrons allowing to deduce Fermi energy E_F and Fermi momentum k_F if Fermi surface is sphere. In [D33] formulas for the basic parameters are indeed suggested based on this of argumentation assuming that Cooper pairs form a Bose-Einstein condensate.

1. The most important parameters are critical temperature T_c and critical magnetic field H_c in principle expressible in terms of gap energy. In [D33] the expression for T_c is deduced from the condition that the de Broglie wavelength λ must satisfy in supra phase the condition

$$\lambda \geq 2d = 2(\frac{n_c}{g})^{-1/D} \tag{2.1}$$

guaranteeing the quantum overlap of Cooper pairs. Here n_c is the density of Bose-Einstein condensate of Cooper pairs and g is the number of spin states and D the dimension of the condensate. This condition follows also from the requirement that the number of particles per energy level is larger than one (Bose-Einstein condensation).

Identifying this expression with the de Broglie wavelength $\lambda = \hbar/\sqrt{2mE}$ at thermal energy $E = (D/2)T_c$, where D is the number of degrees of freedom, one obtains

$$T_c \leq \frac{h^2}{4Dm}(\frac{n_c}{g})^{2/D} . \tag{2.2}$$

m denotes the effective mass of super current carrier and for electron it can be even 100 times the bare mass of electron. The reason is that the electron moves is somewhat like a person trying to move in a dense crowd of people, and is accompanied by a cloud of charge carriers increasing its effective inertia. In this equation one can consider the possibility that Planck constant is not the ordinary one. This obviously increases the critical temperature unless n_c is scaled down in same proportion in the phase transition to large $\hbar$ phase.

2. The density of n_c Cooper pairs can be estimated as the number of fermions in Fermi shell at E_F having width Δk deducible from kT_c. For $D = 3$-dimensional spherical Fermi surface one has

$$\begin{aligned} n_c &= \frac{1}{2}\frac{4\pi k_F^2 \Delta k}{\frac{4}{3}\pi k_F^3} n \ , \\ kT_c &= E_F - E(k_F - \Delta k) \simeq \frac{h^2 k_F \Delta k}{m} \ . \end{aligned} \tag{2.3}$$

Analogous expressions can be deduced in $D = 2$- and $D = 1$-dimensional cases and one has

$$n_c(D) = \frac{D}{2}\frac{T_c}{E_F} n(D) . \tag{2.4}$$

The dimensionless coefficient is expressible solely in terms of n and effective mass m. In [D33] it is demonstrated that the inequality 2.2 replaced with equality when combined with 2.4 gives a satisfactory fit for 16 super-conductors used as a sample.

Note that the Planck constant appearing in E_F and T_c in Eq. 2.4 must correspond to ordinary Planck constant $\hbar_0$. This implies that equations 2.2 and 2.4 are consistent within orders of magnitudes. For $D = 2$, which corresponds to high T_c superconductivity, the substitution of n_c from Eq. 2.4 to Eq. 2.2 gives a consistency condition from which n_c disappears completely. The condition reads as

$$n\lambda_F^2 = \pi = 4g .$$

Obviously the equation is not completely consistent.

3. The magnetic penetration length λ is expressible in terms of density n_c of Cooper pairs as

$$\lambda^{-2} = \frac{4\pi e^2 n_c}{m_e} . \tag{2.5}$$

The ratio $\kappa \equiv \frac{\lambda}{\xi}$ determines the type of the super conductor. For $\kappa < \frac{1}{\sqrt{2}}$ one has type I super conductor with defects having negative surface energy. For $\kappa \geq \frac{1}{\sqrt{2}}$ one has type II super conductor and defects have positive surface energy. Super-conductors of type I this results in complex stripe like flux patterns maximizing their area near criticality. The super-conductors of type II have $\kappa > 1/\sqrt{2}$ and the surface energy is positive so that the flux penetrates as flux quanta minimizing their area at lower critical value H_{c_1} of magnetic field and completely at higher critical value H_{c_2} of magnetic field. The flux quanta contain a core of size ξ carrying quantized magnetic flux.

4. Quantum coherence length ξ can be roughly interpreted as the size of the Cooper pair or as the size of the region where it is sensible to speak about the phase of wave function of Cooper pair. For larger separations the phases of wave functions are un-correlated. The values of ξ vary in the range $10^3 - 10^4$ Angstrom for low T_c super-conductors and in the range $5-20$ Angstrom for high T_c super-conductors (assuming that they correspond to ordinary $\hbar$!) the ratio of these coherence lengths varies in the range $[50-2000]$, with upper bound corresponding to $n_F = 2^{11}$ for $\hbar$. This would give range $1-2$ microns for the coherence lengths of high T_c super-conductors with lowest values of coherence lengths corresponding to the highest values of coherence lengths for low temperatures super conductors.

Uncertainty Principle $\delta E\delta t = \hbar/2$ using $\delta E = E_g \equiv 2\Delta$, $\delta t = \xi/v_F$, gives an order of magnitude estimate for ξ differing only by a numerical factor from the result of a rigorous calculation given by

$$\xi = \frac{4\hbar v_F}{E_g} . \qquad (2.6)$$

E_g is apart from a numerical constant equal to T_c: $E_g = nT_c$. Using the expression for v_F and T_c in terms of the density of electrons, one can express also ξ in terms of density of electrons.

For instance, BCS theory predicts $n = 3.52$ for metallic super-conductors and $n = 8$ holds true for cuprates [D33]. For cuprates one obtains $\xi = 2n^{-1/3}$ [D33]. This expression can be criticized since cuprates are Mott insulators and it is not at all clear whether a description as Fermi gas makes sense. The fact that high T_c super-conductivity involves breakdown of anti-ferromagnetic order might justify the use of Fermi gas description for conducting holes resulting in the doping.

For large $\hbar$ the value of ξ would scale up dramatically if deduced theoretically from experimental data using this kind of expression. If the estimates for ξ are deduced from v_F and T_c purely calculationally as seems to be the case, the actual coherence lengths would be scaled up by a factor $\hbar/\hbar_0 = n_F$ if high T_c super-conductors correspond to large $\hbar$ phase. As also found that this would also allow to understand the high critical temperature.

2.2 Universality Of The Parameters In TGD Framework

Universality idea conforms with quantum criticality of TGD Universe. The possibility to express everything in terms of density of critical temperature coding for the dynamics of Cooper pair formation and the density charge carriers would make it also easy to understand how p-adic scalings and transitions to large $\hbar$ phase affect the basic parameters. The possible problem is that the replacement of inequality of Eq. 2.2 with equality need not be sensible for large $\hbar$ phases. It will be found that in many-sheeted space-time T_c does not directly correspond to the gap energy and the universality of the critical temperature follows from the p-adic length scale hypothesis.

2.2.1 The effect of p-adic scaling on the parameters of super-conductors

p-Adic fractality expresses as $n \propto 1/L^3(k)$ would allow to deduce the behavior of the various parameters as function of the p-adic length scale and naive scaling laws would result. For instance, E_g and T_c would scale as $1/L^2(k)$ if one assumes that the density n of particles at larger space-time sheets scales p-adically as $1/L^3(k)$. The basic implication would be that the density of Cooper pairs and thus also T_c would be reduced very rapidly as a function of the p-adic length scale. Without thermal isolation between these space-time sheets and hight temperature space-time sheets there would not be much hopes about high T_c super-conductivity.

In the scaling of Planck constant basic length scales scale up and the overlap criterion for super-conductivity becomes easy to satisfy unless the density of electrons is reduced too dramatically. As found, also the critical temperature scales up so that there are excellent hopes of obtain high

T_c super-conductor in this manner. The claimed short correlation lengths are not a problem since they are calculational quantities.

It is of interest to study the behavior of the various parameters in the transition to the possibly existing large $\hbar$ variant of super-conducting electrons. Also small scalings of $\hbar$ are possible and the considerations to follow generalize trivially to this case. Under what conditions the behavior of the various parameters in the transition to large $\hbar$ phase is dictated by simple scaling laws?

1. Scaling of T_c and E_g

T_c and E_g remain invariant if E_g corresponds to a purely classical interaction energy remaining invariant under the scaling of $\hbar$. This is not the case for BCS super-conductors for which the gap energy E_g has the following expression.

$$\begin{aligned} E_g &= \hbar\omega_c exp(-1/X) \ , \\ X &= n(E_F)U_0 = \frac{3}{2}N(E_F)\frac{U_0}{E_F} \ , \\ n(E_F) &= \frac{3}{2}\frac{N(E_F)}{E_F} \ . \\ \omega_c &= \omega_D = (6\pi^2)^{1/3}c_s n_n^{1/3} \ . \end{aligned} \tag{2.7}$$

Here ω_c is the width of energy region near E_F for which "phonon" exchange interaction is effective. n_n denotes the density of nuclei and c_s denotes sound velocity.

$N(E_F)$ is the total number of electrons at the super-conducting space-time sheet. U_0 would be the parameter characterizing the interaction strength of of electrons of Cooper pair and should not depend on $\hbar$. For a structure of size $L \sim 1$ μ m one would have $X \sim n_a 10^{12}\frac{U_0}{E_F}$, n_a being the number of exotic electrons per atom, so that rather weak interaction energy U_0 can give rise to $E_g \sim \omega_c$.

The expression of ω_c reduces to Debye frequency ω_D in BCS theory of ordinary super conductivity. If c_s is proportional to thermal velocity $\sqrt{T_c/m}$ at criticality and if n_n remains invariant in the scaling of $\hbar$, Debye energy scales up as $\hbar$. This can imply that $E_g > E_F$ condition making scaling non-sensible unless one has $E_g \ll E_F$ holding true for low T_c super-conductors. This kind of situation would *not* require large $\hbar$ phase for electrons. What would be needed that nuclei and phonon space-time sheets correspond to large $\hbar$ phase.

What one can hope is that E_g scales as $\hbar$ so that high T_c superconductor would result and the scaled up T_c would be above room temperature for $T_c > .15$ K. If electron is in ordinary phase X is automatically invariant in the scaling of $\hbar$. If not, the invariance reduces to the invariance of U_0 and E_F under the scaling of $\hbar$. If n scales like $1/\hbar^D$, E_F and thus X remain invariant. U_0 as a simplified parameterization for the interaction potential expressible as a tree level Feynman diagram is expected to be in a good approximation independent of $\hbar$.

It will be found that in high T_c super-conductors, which seem to be quantum critical, a high T_c variant of phonon mediated superconductivity and exotic superconductivity could be competing. This would suggest that the phonon mediated superconductivity corresponds to a large $\hbar$ phase for nuclei scaling ω_D and T_c by a factor $r = \hbar/\hbar_0$.

Since the total number $N(E_F)$ of electrons at larger space-time sheet behaves as $N(E_F) \propto E_F^{D/2}$, where D is the effective dimension of the system, the quantity $1/X \propto E_F/n(E_F)$ appearing in the expressions of the gap energy behaves as $1/X \propto E_F^{-D/2+1}$. This means that at the limit of vanishing electron density $D = 3$ gap energy goes exponentially to zero, for $D = 2$ it is constant, and for $D = 1$ it goes zero at the limit of small electron number so that the formula for gap energy reduces to $E_g \simeq \omega_c$. These observations suggests that the super-conductivity in question should be 2- or 1-dimensional phenomenon as in case of magnetic walls and flux tubes.

2. Scaling of ξ and λ

If n_c for high T_c super-conductor scales as $1/\hbar^D$ one would have $\lambda \propto \hbar^{D/2}$. High T_c property however suggests that the scaling is weaker. ξ would scale as $\hbar$ for given v_F and T_c. For $D = 2$ case the this would suggest that high T_c super-conductors are of type I rather than type II as they would be for ordinary $\hbar$. This conforms with the quantum criticality which would be counterpart of critical behavior of super-conductors of type I in nearly critical magnetic field.

3. Scaling of H_c and B

The critical magnetization is given by

$$H_c(T) = \frac{\Phi_0}{\sqrt{8}\pi\xi(T)\lambda(T)} , \tag{2.8}$$

where Φ_0 is the flux quantum of magnetic field proportional to $\hbar$. For $D = 2$ and $n_c \propto \hbar^{-2}$ $H_c(T)$ would not depend on the value of $\hbar$. For the more physical dependence $n_c \propto \hbar^{-2+\epsilon}$ one would have $H_c(T) \propto \hbar^{-\epsilon}$. Hence the strength of the critical magnetization would be reduced by a factor $2^{-11\epsilon}$ in the transition to the large $\hbar$ phase with $n_F = 2^{-11}$.

Magnetic flux quantization condition is replaced by

$$\int 2eBdS = n\hbar 2\pi . \tag{2.9}$$

B denotes the magnetic field inside super-conductor different from its value outside the super-conductor. By the quantization of flux for the non-super-conducting core of radius ξ in the case of super-conductors of type II $eB = \hbar/\xi^2$ holds true so that B would become very strong since the thickness of flux tube would remain unchanged in the scaling.

2.3 Quantum Criticality And Super-Conductivity

The notion of quantum criticality has been already discussed in introduction. An interesting prediction of the quantum criticality of entire Universe also gives naturally rise to a hierarchy of macroscopic quantum phases since the quantum fluctuations at criticality at a given level can give rise to higher level macroscopic quantum phases at the next level. A metaphor for this is a fractal cusp catastrophe for which the lines corresponding to the boundaries of cusp region reveal new cusp catastrophes corresponding to quantum critical systems characterized by an increasing length scale of quantum fluctuations.

Dark matter hierarchy could correspond to this kind of hierarchy of phases and long ranged quantum slow fluctuations would correspond to space-time sheets with increasing values of $\hbar$ and size. Evolution as the emergence of modules from which higher structures serving as modules at the next level would correspond to this hierarchy. Mandelbrot fractal with inversion analogous to a transformation permuting the interior and exterior of sphere with zooming revealing new worlds in Mandelbrot fractal replaced with its inverse would be a good metaphor for what quantum criticality would mean in TGD framework.

2.3.1 How the quantum criticality of superconductors relates to TGD quantum criticality

There is empirical support that super-conductivity in high T_c super-conductors and ferromagnetic systems [D26, D17] is made possible by quantum criticality [D35]. In the experimental situation quantum criticality means that at sufficiently low temperatures quantum rather than thermal fluctuations are able to induce phase transitions. Quantum criticality manifests itself as fractality and simple scaling laws for various physical observables like resistance in a finite temperature range and also above the critical temperature. This distinguishes sharply between quantum critical super conductivity from BCS type super-conductivity. Quantum critical super-conductivity also exists in a finite temperature range and involves the competition between two phases.

The absolute quantum criticality of the TGD Universe maps to the quantum criticality of subsystems, which is broken by finite temperature effects bringing dissipation and freezing of quantum fluctuations above length and time scales determined by the temperature so that scaling laws hold true only in a finite temperature range.

Reader has probably already asked what quantum criticality precisely means. What are the phases which compete? An interesting hypothesis is that quantum criticality actually corresponds to criticality with respect to the phase transition changing the value of Planck constant so that the competing phases would correspond to different values of $\hbar$. In the case of high T_c super-conductors (anti-ferromagnets) the fluctuations can be assigned to the magnetic flux tubes of the dipole field patterns generated by rows of holes with same spin direction assignable to the stripes. Below T_c fluctuations induce reconnections of the flux tubes and a formation of very long flux tubes and make possible for the supra currents to flow in long length scales below T_c. Percolation type phenomenon is in question. The fluctuations of the flux tubes below $T_{c1} > T_c$ induce transversal phonons generating the energy gap for $S = 1$ Cooper pairs. $S = 0$ Cooper pairs are predicted to stabilize below T_c.

2.3.2 Scaling up of de Broglie wave lengths and criterion for quantum overlap

Compton lengths and de Broglie wavelengths are scaled up by an integer n, whose preferred values correspond to $n_F = 2^k \prod_s F_s$, where $F_s = 2^{2^s} + 1$ are distinct Fermat primes. In particular, $n_F = 2^{k11}$ seem to be favored in living matter. The scaling up means that the overlap condition $\lambda \geq 2d$ for the formation of Bose-Einstein condensate can be satisfied and the formation of Cooper pairs becomes possible. Thus a hierarchy of large $\hbar$ super-conductivities would be associated with to the dark variants of ordinary particles having essentially same masses as the ordinary particles.

Unless one assumes fractionization, the invariance of $E_F \propto \hbar_{eff}^2 n^{2/3}$ in $\hbar$ increasing transition would require that the density of Cooper pairs in large $\hbar$ phase is scaled down by an appropriate factor. This means that supra current intensities, which are certainly measurable quantities, are also scaled down. Of course, it could happen that E_F is scaled up and this would conform with the scaling of the gap energy.

2.3.3 Quantum critical super-conductors in TGD framework

For quantum critical super-conductivity in heavy fermions systems, a small variation of pressure near quantum criticality can destroy ferromagnetic (anti-ferromagnetic) order so that Curie (Neel) temperature goes to zero. The prevailing spin fluctuation theory [D7] assumes that these transitions are induced by long ranged and slow spin fluctuations at critical pressure P_c. These fluctuations make and break Cooper pairs so that the idea of super-conductivity restricted around critical point is indeed conceivable.

Heavy fermion systems, such as cerium-indium alloy $CeIn_3$ are very sensitive to pressures and a tiny variation of density can drastically modify the low temperature properties of the systems. Also other systems of this kind, such as $CeCu_2Ge_2$, $CeIn_3$, $CePd_2Si_2$ are known [D26, D9]. In these cases super-conductivity appears around anti-ferromagnetic quantum critical point.

The last experimental breakthrough in quantum critical super-conductivity was made in Grenoble [D17]. URhGe alloy becomes super-conducting at $T_c = .280$ K, loses its super-conductivity at $H_c = 2$ Tesla, and becomes again super-conducting at $H_c = 12$ Tesla and loses its super-conductivity again at $H = 13$ Tesla. The interpretation is in terms of a phase transition changing the magnetic order inducing the long range spin fluctuations.

TGD based models of atomic nucleus [K19] and condensed matter [K6] assume that weak gauge bosons with Compton length of order atomic radius play an essential role in the nuclear and condensed matter physics. The assumption that condensed matter nuclei possess anomalous weak charges explains the repulsive core of potential in van der Waals equation and the very low compressibility of condensed matter phase as well as various anomalous properties of water phase, provide a mechanism of cold fusion and sono-fusion, etc. [K6, K4]. The pressure sensitivity of these systems would directly reflect the physics of exotic quarks and electro-weak gauge bosons. A possible mechanism behind the phase transition to super-conductivity could be the scaling up of the sizes of the space-time sheets of nuclei.

Also the electrons of Cooper pair (and only these) could make a transition to large $\hbar$ phase. This transition would induce quantum overlap having geometric overlap as a space-time correlate. The formation of flux tubes between neighboring atoms would be part of the mechanism. For instance, the criticality condition $4n^2\alpha = 1$ for BE condensate of n Cooper pairs would give $n = 6$ for the size of a higher level quantum unit possibly formed formed from Cooper pairs. If one does not assume invariance of energies obtained by fractionization of principal quantum number, this transition has dramatic effects on the spectrum of atomic binding energies scaling as $1/\hbar^2$ and practically universal spectrum of atomic energies would result [K4] not depending much on nuclear charge. It seems that this prediction is non-physical.

Quantum critical super-conductors resemble superconductors of type I with $\lambda \ll \xi$ for which defects near thermodynamical criticality are complex structures looking locally like stripes of thickness λ. These structures are however dynamical in super-conducting phase. Quite generally, long range quantum fluctuations due to the presence of two competing phases would manifest as complex dynamical structures consisting of stripes and their boundaries. These patterns are dynamical rather than static as in the case of ordinary spin glass phase so that quantum spin glass or 4-D spin glass is a more appropriate term. The breaking of classical non-determinism for vacuum extremals indeed makes possible space-time correlates for quantum non-determinism and this makes TGD Universe a 4-dimensional quantum spin glass.

2.3.4 Could quantum criticality make possible new kinds of high T_c super-conductors?

The transition to large $\hbar = r\hbar_0$ phase increases various length scales by r and makes possible long range correlations even at high temperatures. Hence the question is whether large $\hbar$ phase could correspond to ordinary high T_c super-conductivity. If this were the case in the case of ordinary high T_c super-conductors, the actual value of coherence length ξ would vary in the range $5-20$ Angstrom scaled up by a factor r. For effectively D-dimensional super-conductor The density of Cooper pairs would be scaled down by an immensely small factor $1/r^D$ from its value deduced from Fermi energy.

Large $\hbar$ phase for some nuclei might be involved and make possible large space-time sheets of size at least of order of ξ at which conduction electrons forming Cooper pairs would topologically condense like quarks around hadronic space-time sheets (in [K6] a model of water as a partially dark matter with one fourth of hydrogen ions in large $\hbar$ phase is developed).

Consider for a moment the science fictive possibility that super conducting electrons for some quantum critical super-conductors to be discovered or already discovered correspond to large $\hbar$ phase with $\hbar = r\hbar_0$ keeping in mind that this affects only quantum corrections in perturbative approach but not the lowest order classical predictions of quantum theory. For $r \simeq n2^{k11}$ with $(n,k) = (1,1)$ the size of magnetic body would be $L(149) = 5$ nm, the thickness of the lipid layer of cell membrane. For $(n,k) = (1,2)$ the size would be $L(171) = 10$ μm, cell size. If the density of Cooper pairs is of same order of magnitude as in case of ordinary super conductors, the critical temperature is scaled up by 2^{k11}. Already for $k = 1$ the critical temperature of 1 K would be scaled up to $4n^2 \times 10^6$ K if n_c is not changed. This assumption is not consistent with the assumption that Fermi energy remains non-relativistic. For $n = 1$ $T_c = 400$ K would be achieved for $n_c \to 10^{-6}n_c$, which looks rather reasonable since Fermi energy transforms as $E_F \to 8 \times 10^3 E_F$ and remains non-relativistic. H_c would scale down as $1/\hbar$ and for $H_c = .1$ Tesla the scaled down critical field would be $H_c = .5 \times 10^{-4}$ Tesla, which corresponds to the nominal value of the Earth's magnetic field.

Quantum critical super-conductors become especially interesting if one accepts the identification of living matter as ordinary matter quantum controlled by macroscopically quantum coherent dark matter. One of the basic hypothesis of TGD inspired theory of living matter is that the magnetic flux tubes of the Earth's magnetic field carry a super-conducting phase and the spin triplet Cooper pairs of electrons in large $\hbar$ phase might realize this dream. That the value of Earth's magnetic field is near to its critical value could have also biological implications.

2.4 Space-Time Description Of The Mechanisms OfSuper-Conductivity

The application of ideas about dark matter to nuclear physics and condensed matter suggests that dark color and weak forces should be an essential element of the chemistry and condensed matter physics. The continual discovery of new super-conductors, in particular of quantum critical superconductors, suggests that super-conductivity is not well understood. Hence super-conductivity provides an obvious test for these ideas. In particular, the idea that wormhole contacts regarded as parton pairs living at two space-time sheets simultaneously, provides an attractive universal mechanism for the formation of Cooper pairs and is not so far-fetched as it might sound first.

2.4.1 Leading questions

It is good to begin with a series of leading questions. The first group of questions is inspired by experimental facts about super-conductors combined with TGD context.

1. The work of Rabinowitch [D33] suggests that that the basic parameters of super-conductors might be rather universal and depend on T_c and conduction electron density only and be to a high degree independent of the mechanism of super-conductivity. This is in a sharp contrast to the complexity of even BCS model with its somewhat misty description of the phonon exchange mechanism.
Questions: Could there exist a simple universal description of various kinds of super-conductivities?

2. The new super-conductors possess relatively complex chemistry and lattice structure.
Questions: Could it be that complex chemistry and lattice structure makes possible something very simple describable in terms of quantum criticality. Could it be that the transversal oscillations magnetic flux tubes allow to understand the formation of Cooper pairs at T_{c1} and their reconnections generating very long flux tubes the emergence of supra currents at T_c?

3. The effective masses of electrons in ferromagnetic super-conductors are in the range of 10-100 electron masses [D26] and this forces to question the idea that ordinary Cooper pairs are current carriers.
Questions: Can one consider the possibility that the p-adic length scale of say electron can vary so that the actual mass of electron could be large in condensed matter systems? For quarks and neutrinos this seems to be the case [K12, K13]. Could it be that the Gaussian Mersennes $(1+i)^k-1$, $k = 151, 157, 163, 167$ spanning the p-adic lengthscale range 10 nm-2.5 μm very relevant from the point of view of biology correspond to p-adic length especially relevant for super-conductivity?

Second group of questions is inspired by quantum classical correspondence.

1. Quantum classical correspondence in its strongest form requires that bound state formation involves the generation of flux tubes between bound particles. The weaker form of the principle requires that the particles are topologically condensed at same space-time sheet. In the case of Cooper pairs in ordinary superconductors the length of join along boundaries bonds between electrons should be of order $10^3 - 10^4$ Angstroms. This looks rather strange and it seems that the latter option is more sensible.
Questions: Could quantum classical correspondence help to identify the mechanism giving rise to Cooper pairs?

2. Quantum classical correspondence forces to ask for the space-time correlates for the existing quantum description of phonons.
Questions: Can one assign space-time sheets with phonons or should one identify them as oscillations of say space-time sheets at which atoms are condensed? Or should the microscopic description of phonons in atomic length scales rely on the oscillations of wormhole contacts connecting atomic space-time sheets to these larger space-time sheets? The identification of phonons as wormhole contacts would be completely analogous to the similar identification of gauge bosons except that phonons would appear at higher levels of the hierarchy of space-time sheets and would be emergent in this sense. As a matter fact, even gauge bosons as pairs of fermion and anti-fermion are emergent structures in TGD framework and this plays fundamental role in the construction of QFT limit of TGD in which bosonic part of action is generated radiatively so that all coupling constants follow as predictions [K14, K8]. Could Bose-Einstein condensates of wormhole contacts be relevant for the description of super-conductors or more general macroscopic quantum phases?

The third group of questions is inspired by the new physics predicted or by TGD.

1. TGD predicts a hierarchy of macroscopic quantum phases with large Planck constant.
Questions: Could large values of Planck constant make possible exotic electronic super-conductivities? Could even nuclei possess large $\hbar$ (super-fluidity)?

2. TGD predicts that classical color force and its quantal counterpart are present in all length scales.
Questions: Could color force, say color magnetic force which play some role in the formation

of Cooper pair. The simplest model of pair is as a space-time sheet with size of order ξ so that the electrons could be "outside" the background space-time. Could the Coulomb interaction energy of electrons with positively charged wormhole throats carrying parton numbers and feeding em gauge flux to the large space-time sheet be responsible for the gap energy? Could wormhole throats carry also quark quantum numbers. In the case of single electron condensed to single space-time sheet the em flux could be indeed fed by a pair of $u\overline{u}$ and $\overline{d}d$ type wormhole contacts to a larger space-time sheet. Could the wormhole contacts have a net color? Could the electron space-time sheets of the Cooper pair be connected by long color flux tubes to give color singlets so that dark color force would be ultimately responsible for the stability of Cooper pair?

3. Suppose that one takes seriously the ideas about the possibility of dark weak interactions with the Compton scale of weak bosons scaled up to say atomic length scale so that weak bosons are effectively massless below this length scale [K6].
   Questions: Could the dark weak length scale which is of order atomic size replace lattice constant in the expression of sound velocity? What is the space-time correlate for sound velocity?

2.4.2 Photon massivation, coherent states of Cooper pairs, and wormhole contacts

The existence of wormhole contacts is one of the most stunning predictions of TGD. First I realized that wormhole contacts can be regarded as parton-antiparton pairs with parton and antiparton assignable to the light-like causal horizons accompanying wormhole contacts. Then came the idea that Higgs particle could be identified as a wormhole contact. It was soon followed by the identification all bosonic states as wormhole contacts [K10]. Finally I understood that this applies also to their super-symmetric partners, which can be also fermion [K8]. Fermions and their super-partners would in turn correspond to wormhole throats resulting in the topological condensation of small deformations of CP_2 type vacuum extremals with Euclidian signature of metric to the background space-time sheet. This framework opens the doors for more concrete models of also super-conductivity involving the effective massivation of photons as one important aspect in the case of ordinary super-conductors.

There are two types of wormhole contacts. Those of first type correspond to elementary bosons. Wormhole contacts of second kind are generated in the topological condensation of space-time sheets carrying matter and form a hierarchy. Classical radiation fields realized in TGD framework as oscillations of space-time sheets would generate wormhole contacts as the oscillating space-time sheet develops contacts with parallel space-time sheets (recall that the distance between space-time sheets is of order CP_2 size). This realizes the correspondence between fields and quanta geometrically. Phonons could also correspond to wormhole contacts of this kind since they mediate acoustic oscillations between space-time sheets and the description of the phonon mediated interaction between electrons in terms of wormhole contacts might be useful also in the case of super-conductivity. Bose-Einstein condensates of wormhole contacts might be highly relevant for the formation of macroscopic quantum phases. The formation of a coherent state of wormhole contacts would be the counterpart for the vacuum expectation value of Higgs.

The notions of coherent states of Cooper pairs and of charged Higgs challenge the conservation of electromagnetic charge. The following argument however suggests that coherent states of wormhole contacts form only a part of the description of ordinary super-conductivity. The basic observation is that wormhole contacts with vanishing fermion number define space-time correlates for Higgs type particle with fermion and anti-fermion numbers at light-like throats of the contact.

The ideas that a genuine Higgs type photon massivation is involved with super-conductivity and that coherent states of Cooper pairs really make sense are somewhat questionable since the conservation of charge and fermion number is lost for coherent states. A further questionable feature is that a quantum superposition of many-particle states with widely different masses would be in question. These interpretational problems can be resolved elegantly in zero energy ontology [K3] in which the total conserved quantum numbers of quantum state are vanishing. In this picture the energy, fermion number, and total charge of any positive energy state are compensated by opposite quantum numbers of the negative energy state in geometric future. This makes possible to speak about superpositions of Cooper pairs and charged Higgs bosons separately in positive energy sector.

If this picture is taken seriously, super-conductivity can be seen as providing a direct support for both the hierarchy of scaled variants of standard model physics and for the zero energy ontology.

2.4.3 Space-time correlate for quantum critical superconductivity

The explicit model for high T_c super-conductivity relies on quantum criticality involving long ranged quantum fluctuations inducing reconnection of flux tubes of local (color) magnetic fields associated with parallel spins associated with stripes to form long flux tubes serving as wires along which Cooper pairs flow. Essentially [D3] [D3] type phenomenon would be in question. The role of the doping by holes is to make room for Cooper pairs to propagate by the reconnection mechanism: otherwise Fermi statistics would prevent the propagation. Too much doping reduces the number of current carriers, too little doping leaves too little room so that there exists some optimal doping. In the case of high T_c super-conductors quantum criticality corresponds to a quite wide temperature range, which provides support for the quantum criticality of TGD Universe. The probability $p(T)$ for the formation of reconnections is what matters and exceeds the critical value at T_c.

2.5 Super-Conductivity At Magnetic Flux Tubes

Super-conductivity at the magnetic flux tubes of magnetic flux quanta is one the basic hypothesis of the TGD based model of living matter. There is also evidence for magnetically mediated super-conductivity in extremely pure samples [D19]. The magnetic coupling was only observed at lattice densities close to the critical density at which long-range magnetic order is suppressed. Quantum criticality that long flux tubes serve as pathways along which Cooper pairs can propagate. In anti-ferromagnetic phase these pathways are short-circuited to closed flux tubes of local magnetic fields.

Almost the same model as in the case of high T_c and quantum critical super-conductivity applies to the magnetic flux tubes. Now the flux quantum contains BE condensate of exotic Cooper pairs interacting with wormhole contacts feeding the gauge flux of Cooper pairs from the magnetic flux quantum to a larger space-time sheet. The interaction of spin 1 Cooper pairs with the magnetic field of flux quantum orients their spins in the same direction. Large value of $\hbar$ guarantees thermal stability even in the case that different space-time sheets are not thermally isolated.

The understanding of gap energy is not obvious. The transversal oscillations of magnetic flux tubes generated by spin flips of electrons define the most plausible candidate for the counterpart of phonons. In this framework phonon like states identified as wormhole contacts would be created by the oscillations of flux tubes and would be a secondary phenomenon.

Large values of $\hbar$ allow to consider not only the Cooper pairs of electrons but also of protons and fermionic ions. Since the critical temperature for the formation of Cooper pairs is inversely proportional to the mass of the charge carrier, the replacement of electron with proton or ion would require a scaling of $\hbar$. If T_{c1} is proportional to $\hbar^2$, this requires scaling by $(m_p/m_e)^{1/2}$. For $T_{c1} \propto \hbar$ scaling by $m_p/m_e \simeq 2^{11}$ is required. This inspired idea that powers of 2^{11} could define favored values of $\hbar/\hbar_0$. This hypothesis is however rather ad hoc and turned out to be too restrictive.

Besides Cooper pairs also Bose-Einstein condensates of bosonic ions are possible in large $\hbar$ phase and would give rise to super-conductivity. TGD inspired nuclear physics predicts the existence of exotic bosonic counterparts of fermionic nuclei with given (A, Z) [L1], [L1].

2.5.1 Superconductors at the flux quanta of the Earth's magnetic field

Magnetic flux tubes and magnetic walls are the most natural candidates for super-conducting structures with spin triplet Cooper pairs. Indeed, experimental evidence relating to the interaction of ELF em radiation with living matter suggests that bio-super-conductors are effectively 1- or 2-dimensional. $D \leq 2$-dimensionality is guaranteed by the presence of the flux tubes or flux walls of, say, the magnetic field of Earth in which charge carries form bound states and the system is equivalent with a harmonic oscillator in transversal degrees of freedom.

The effect of Earth's magnetic field is completely negligible at the atomic space-time sheets and cannot make super conductor 1-dimensional. At cellular sized space-time sheets magnetic field makes possible transversal the confinement of the electron Cooper pairs in harmonic oscillator states but does not explain energy gap which should be at the top of 1-D Fermi surface. The critical temperature extremely low for ordinary value of $\hbar$ and either thermal isolation between space-time sheets or large value of $\hbar$ can save the situation.

An essential element of the picture is that topological quantization of the magnetic flux tubes occurs. In fact, the flux tubes of Earth's magnetic field have thickness of order cell size from the quantization of magnetic flux. The observations about the effects of ELF em fields on bio-matter [J5] suggest that similar mechanism is at work also for ions and in fact give very strong support for bio-super conductivity based on the proposed mechanism.

2.5.2 Energy gaps for superconducting magnetic flux tubes and walls

Besides the formation of Cooper pairs also the Bose-Einstein condensation of charge carriers to the ground state is needed in order to have a supra current. The stability of Bose-Einstein condensate requires an energy gap $E_{g,BE}$ which must be larger than the temperature at the magnetic flux tube.

Several energies must be considered in order to understand $E_{g,BE}$.

1. The Coulombic binding energy of Cooper pairs with the wormhole contacts feeding the em flux from magnetic flux tube to a larger space-time sheet defines an energy gap which is expected to be of order $E_{g,BE} = \alpha/L(k)$ giving $E_g \sim 10^{-3}$ eV for $L(167) = 2.5\ \mu$m giving a rough estimate for the thickness of the magnetic flux tube of the Earth's magnetic field $B = .5 \times 10^{-4}$ Tesla.

2. In longitudinal degrees of freedom of the flux tube Cooper pairs can be described as particles in a one-dimensional box and the gap is characterized by the length L of the magnetic flux tube and the value of $\hbar$. In longitudinal degrees of freedom the difference between $n = 2$ and $n = 1$ states is given by $E_0(k_2) = 3h^2/4m_eL^2(k_2)$. Translational energy gap $E_g = 3E_0(k_2) = 3h^2/4m_eL^2(k_2)$ is smaller than the effective energy gap $E_0(k_1) - E_0(k_2) = h^2/4m_eL^2(k_1) - h^2/4m_eL^2(k_2)$ for $k_1 > k_2+2$ and identical with it for $k_1 = k_2+2$. For $L(k_2 = 151)$ the zero point kinetic energy is given by $E_0(151) = 20.8$ meV so that $E_{g,BE}$ corresponds roughly to a temperature of 180 K. For magnetic walls the corresponding temperature would be scaled by a factor of two to 360 K and is above room temperature.

3. Second troublesome energy gap relates to the interaction energy with the magnetic field. The magnetic interaction energy E_m of Cooper pair with the magnetic field consists of cyclotron term $E_c = n\hbar eB/m_e$ and spin-interaction term which is present only for spin triplet case and is given by $E_s = \pm\hbar eB/m_e$ depending on the orientation of the net spin with magnetic field. In the magnetic field $B_{end} = 2B_E/5 = .2$ Gauss ($B_E = .5$ Gauss is the nominal value of the Earth's magnetic field) explaining the effects of ELF em fields on vertebrate brain, this energy scale is $\sim 10^{-9}$ eV for $\hbar_0$ and $\sim 1.6 \times 10^{-5}$ eV for $\hbar = 2^{14} \times \hbar_0$.

The smallness of translational and magnetic energy gaps in the case of Cooper pairs at Earth's magnetic field could be seen as a serious obstacle.

1. Thermal isolation between different space-time sheets provides one possible resolution of the problem. The stability of the Bose-Einstein condensation is guaranteed by the thermal isolation of space-time if the temperature at the magnetic flux tube is below E_m. This can be achieved in all length scales if the temperature scales as the zero point kinetic energy in transversal degrees of freedom since it scales in the same manner as magnetic interaction energy.

2. The transition to large $\hbar$ phase could provide a more elegant way out of the difficulty. The criterion for a sequence of transitions to a large $\hbar$ phase could be easily satisfied if there is a large number of charge Cooper pairs at the magnetic flux tube. Kinetic energy gap remains invariant if the length of the flux tube scales as $\hbar$. If the magnetic flux is quantized as a multiple of $\hbar$ and flux tube thickness scales as $\hbar^2$, B must scale as $1/\hbar$ so that also magnetic energy remains invariant under the scaling. This would allow to have stability without assuming low temperature at magnetic flux tubes.

3 TGD Based Model For High T_c Super Conductors

High T_c superconductors are quantum critical and involve in an essential magnetic structures, they provide an attractive application of the general vision for the model of super-conductivity based on magnetic flux tubes.

3.1 Some Properties Of High T_c Super Conductors

Quite generally, high T_c super-conductors are cuprates with CuO layers carrying the supra current. The highest known critical temperature for high T_c superconductors is 164 K and is achieved under huge pressure of 3.1×10^5 atm for LaBaCuO. High T_c super-conductors are known to be super conductors of type II.

This is however a theoretical deduction following from the assumption that the value of Planck constant is ordinary. For $\hbar = 2^{14}\hbar_0$ (say) ξ would be scaled up accordingly and type I super-conductor would be in question. These super-conductors are characterized by very complex patterns of penetrating magnetic field near criticality since the surface area of the magnetic defects is maximized. For high T_c super-conductors the ferromagnetic phase could be regarded as an analogous to defect and would indeed have very complex structure. Since quantum criticality would be in question the stripe structure would fluctuate with time too in accordance with 4-D spin glass character.

The mechanism of high T_c super conductivity is still poorly understood [D28, D30].

1. It is agreed that electronic Cooper pairs are charge carriers. It is widely accepted that electrons are in relative d-wave state rather than in s-wave (see [D25] and the references mentioned in [D28]). Cooper pairs are believed to be in spin triplet state and electrons combine to form $L = 2$ angular momentum state. The usual phonon exchange mechanism does not generate the attractive interaction between the members of the Cooper pair having spin. There is also a considerable evidence for BCS type Cooper pairs and two kinds of Cooper pairs could be present.

2. High T_c super conductors have spin glass like character [D27]. High T_c superconductors have anomalous properties also above T_c suggesting quantum criticality implying fractal scaling of various observable quantities such as resistivity. At high temperatures cuprates are anti-ferromagnets and Mott insulators meaning freezing of the electrons. Superconductivity and conductivity are believed to occur along dynamical stripes which are antiferromagnetic defects.

3. These findings encourage to consider the interpretation in terms of quantum criticality in which some new form of super conductivity which is not based on quasiparticles is involved. This super-conductivity would be assignable with the quantum fluctuations destroying antiferromagnetic order and replacing it with magnetically disordered phase possibly allowing phonon induced super-conductivity.

4. The doping of the super-conductor with electron holes is essential for high T_c superconductivity, and there is a critical doping fraction $p = .14$ at which T_c is highest. The interpretation is that holes make possible for the Cooper pairs to propagate. There is considerable evidence that holes gather on one-dimensional stripes with thickness of order few atom sizes and lengths in the range 1-10 nm [D30], which are fluctuating in time scale of 10^{-12} seconds. These stripes are also present in non-superconducting state but in this case they do not fluctuate appreciably. The most plausible TGD based interpretation is in terms of fluctuations of magnetic flux tubes allowing for the formation of long connected flux tubes making super-conductivity possible. The fact that the fluctuations would be oscillations analogous to acoustic wave and might explain the BCS type aspects of high T_c super-conductivity.

5. T_c is inversely proportional to the distance L between the stripes. A possible interpretation would be that full super-conductivity requires de-localization of electrons also with respect to stripes so that T_c would be proportional to the hopping probability of electron between neighboring stripes expected to be proportional to $1/L$ [D30].

3.1.1 From free fermion gas to Fermi liquids to quantum critical systems

The article of Jan Zaanen [D29] gives an excellent non-technical discussion of various features of high T_c super-conductors distinguishing them from BCS super-conductors. After having constructed a color flux tube model of Cooper pairs I found it especially amusing to learn that the analogy of high T_c super-conductivity as a quantum critical phenomenon involving formation of dynamical stripes to QCD in the vicinity of the transition to the confined phase leading to the generation of string like hadronic objects was emphasized also by Zaanen.

BCS super-conductor behaves in a good approximation like quantum gas of non-interacting electrons. This approximation works well for long ranged interactions and the reason is Fermi statistics plus the fact that Fermi energy is much larger than Coulomb interaction energy at atomic length scales.

For strongly interacting fermions the description as Fermi liquid (a notion introduced by Landau) has been dominating phenomenological approach. ^{3}He provides a basic example of Fermi liquid and already here a paradox is encountered since low temperature collective physics is that of Fermi gas without interactions with effective masses of atoms about 6 times heavier than those of real atoms whereas short distance physics is that of a classical fluid at high temperatures meaning a highly correlated collective behavior.

It should be noticed that many-sheeted space-time provides a possible explanation of the paradox. Space-time sheets containing join along boundaries blocks of ^3He atoms behave like gas whereas the ^3He atoms inside these blocks form a liquid. An interesting question is whether the ^3He atoms combine to form larger units with same spin as ^3He atom or whether the increase of effective mass by a factor of order six means that $\hbar$ as a unit of spin is increased by this factor forcing the basic units to consist of Bose-Einstein condensate of 3 Cooper pairs.

High T_c super conductors are neither Fermi gases nor Fermi liquids. Cuprate superconductors correspond at high temperatures to doped Mott insulators for which Coulomb interactions dominate meaning that electrons are localized and frozen. Electron spin can however move and the system can be regarded as an anti-ferromagnet. CuO planes are separated by highly oxidic layers and become super-conducting when doped. The charge transfer between the two kinds of layers is what controls the degree of doping. Doping induces somehow a de-localization of charge carriers accompanied by a local melting of anti-ferromagnet.

Collective behavior emerges for high enough doping. Highest T_c results with 15 per cent doping by holes. Current flows along electron stripes. Stripes themselves are dynamical and this is essential for both conductivity and superconductivity. For completely static stripes super-conductivity disappears and quasi-insulating electron crystal results.

Dynamical stripes appear in mesoscopic time and length scales corresponding to 1-10 nm length scale and picosecond time scale. The stripes are in a well-defined sense dual to the magnetized stripe like structures in type I super-conductor near criticality, which suggests analog of type I super-conductivity. The stripes are anti-ferromagnetic defects at which neighboring spins fail to be antiparallel. It has been found that stripes are a very general phenomenon appearing in insulators, metals, and super-conducting compounds [D8].

3.1.2 Quantum criticality is present also above T_c

Also the physics of Mott insulators above T_c reflects quantum criticality. Typically scaling laws hold true for observables. In particular, resistivity increases linearly rather than transforming from T^2 behavior to constant as would be implied by quasi-particles as current carriers. The appearance of so called pseudo-gap [D32] at $T_{c1} > T_c$ conforms with this interpretation. In particular, the pseudo-gap is non-vanishing already at T_{c_1} and stays constant rather than starting from zero as for quasi-particles.

3.1.3 Results from optical measurements and neutron scattering

Optical measurements and neutron scattering have provided especially valuable microscopic information about high T_c superconductors allowing to fix the details of TGD based quantitative model.

Optical measurements of copper oxides in non-super-conducting state have demonstrated that optical conductivity $\sigma(\omega)$ is surprisingly featureless as a function of photon frequency. Below the critical temperature there is however a sharp absorption onset at energy of about 50 meV [D21]. The origin of this special feature has been a longstanding puzzle. It has been proposed that this absorption onset corresponds to a direct generation of an electron-hole pair. Momentum conservation implies that the threshold for this process is $E_g + E$, where E is the energy of the "gluon" which binds electrons of Cooper pair together. In the case of ordinary super-conductivity E would be phonon energy.

Soon after measurements, it was proposed that in absence of lattice excitations photon must generate two electron-hole pairs such that electrons possess opposite momenta [D21]. Hence the energy of the photon would be $2E_g$. Calculations however predicted soft rather than sharp onset of absorption since pairs of electron-hole pairs have continuous energy spectrum. There is something wrong with this picture.

Second peculiar characteristic [D23, D20, D13] of high T_c super conductors is resonant neutron scattering at excitation energy $E_w = 41$ meV of super conductor. This scattering occurs only below the critical temperature, in spin-flip channel and for a favored momentum exchange $(\pi/a, \pi/a))$, where a denotes the size of the lattice cube [D23, D20, D13]. The transferred energy is concentrated in a remarkably narrow range around E_w rather than forming a continuum.

In [D6] is is suggested that e-e resonance with spin one gives rise to this excitation. This resonance is assumed to play the same role as phonon in the ordinary super conductivity and e-e resonance is treated like phonon. It is found that one can understand the dependence of the second derivative of the photon conductivity $\sigma(\omega)$ on frequency and that consistency with neutron scattering data is achieved. The second derivative of $\sigma(\omega)$ peaks near 68 meV and assuming $E = E_g + E_w$ they found nearly perfect match using $E_g = 27$ meV. This would suggest that the energy of the excitations generating the binding between the members of the Cooper pair is indeed 41 meV, that two electron-hole pairs and excitation of the super conductor are generated in photon absorption above threshold, and that the gap energy of the Cooper pair is 27 meV. Of course, the theory of Carbotte *et al* does not force the "gluon" to be triplet excitation of electron pair. Also other possibilities can be considered. What comes in mind are spin flip waves of the spin lattice associated with stripe behaving as spin 1 waves.

In TGD framework more exotic options become possible. The transversal fluctuations of stripes- or rather of the magnetic flux tubes associated with the stripes- could define spin 1 excitations analogous to the excitations of a string like objects. Gauge bosons are identified as wormhole contacts in quantum TGD and massive gauge boson like state containing electron-positron pair or quark-antiquark pair could be considered.

3.2 TGD Inspired Vision About High T_c Superconductivity

The following general view about high T_c super-conductivity as quantum critical phenomenon suggests itself. It must be emphasized that this option is one of the many that one can imagine and distinguished only by the fact that it is the minimal option.

3.2.1 The interpretation of critical temperatures

The two critical temperatures T_c and $T_{c_1} > T_c$ are interpreted as critical temperatures. The recent observation that there exists a spectroscopic signature of high T_c super-conductivity, which prevails up to T_{c_1} [D4], supports the interpretation that Cooper pairs exist already below T_{c1} but that for some reason they cannot form a coherent super-conducting state.

One can imagine several alternative TGD based models but for the minimal option is the following one.

1. T_{c_1} would be the temperature for the formation of two-phase system consisting of ordinary electrons and of Cooper pairs with a large value of Planck constant explaining the high critical temperature.

2. Magnetic flux tubes are assumed to be carriers of supra currents. These flux tubes are very short in in anti-ferromagnetic phase. The holes form stripes making them positively charged so that they attract electrons. If the spins of holes tend to form parallel sequences along stripes, they generate dipole magnetic fields in scales of order stripe length at least. The corresponding magnetic flux tubes are assumed to be carriers of electrons and Cooper pairs.

The flux tube structures would be closed so that the supra currents associated with these flux tubes would be trapped in closed loops above T_c.

3. Below T_{c1} transversal fluctuations of the flux tubes structures occur and can induce reconnections giving rise to longer flux tubes. Reconnection can occur in two manners. Recall that upwards going outer flux tubes of the dipole field turn downwards and eventually fuse with the dipole core. If the two dipoles have opposite directions the outer flux tube of the first (second) dipole can reconnect with the inward going part of the flux tube of second (first) dipole. If the dipoles have same direction, the outer flux tubes of the dipoles reconnect with each other. Same applies to the inwards going parts of the flux tubes and the dipoles fuse to a single deformed dipole if all flux tubes reconnect. This alternative looks more plausible. The reconnection process is in general only partial since dipole field consists of several flux tubes.

4. The reconnections for the flux tubes of neighboring almost dipole fields occur with some probability $p(T)$ and make possible finite conductivity. At T_c the system the fluctuations of the flux tubes become large and also $p(T, L)$, where L is the distance between stripes, becomes large and the reconnection leads to a formation of long flux tubes of length of order coherence length at least and macroscopic supra currents can flow. One also expects that the reconnection occurs for practically all flux tubes of the dipole field. Essentially a percolation type phenomenon [D3] would be in question. Scaling invariance suggests $p_c(T, L) = p_c(TL/\hbar)$, where L is the distance between stripes, and would predict the observed $T_c \propto \hbar/L$ behavior. Large value of $\hbar$ would explain the high value of T_c.

This model relates in an interesting manner to the vision of Zaanen [D31] expressed in terms of the highway metaphor visualizing stripes as quantum highways along which Cooper pairs can move. In antiferromagnetic phase the traffic is completely jammed. The doping inducing electron holes allows to circumvent traffic jam due to the Fermi statistics generates stripes along which the traffic flows in the sense of ordinary conductivity. In TGD framework highways are replaced with flux tubes and the topology of the network of highways fluctuates due to the possibility of reconnections. At quantum criticality the reconnections create long flux tubes making possible the flow of supra currents.

3.2.2 The interpretation of fluctuating stripes in terms of 1-D phonons

In TGD framework the phase transition to high T_c super-conductivity would have as a correlate fluctuating stripes to which supra currents are assigned. Note that the fluctuations occur also for $T > T_c$ but their amplitude is smaller. Stripes would be parallel to the dark magnetic flux tubes along which dark electron current flows above T_c. The fluctuations of magnetic flux tubes whose amplitude increases as T_c is approached induce transverse oscillations of the atoms of stripes representing 1-D transverse phonons.

The transverse fluctuations of stripes have naturally spin one character in accordance with the experimental facts. They allow identification as the excitations having 41 meV energy and would propagate in the preferred diagonal direction $(\pi/a, \pi/a)$. Dark Cooper pairs would have a gap energy of 27 meV. Neutron scattering resonance could be understood as a generation of these 1-D phonons and photon absorption a creation of this kind of phonon and breaking of dark Cooper pair. The transverse oscillations could give rise to the gap energy of the Cooper pair below T_{c1} and for the formation of long flux tubes below T_c but one can consider also other mechanisms based on the new physics predicted by TGD.

Various lattice effects such as superconductivity-induced phonon shifts and broadenings, possible isotope effects in T_c (questionable), the penetration depth, infrared and photoemission spectra have been observed in the cuprates [D2]. A possible interpretation is that ordinary phonons are replaced by 1-D phonons defined by the transversal excitations of stripes but do not give rise to the binding of the electrons of the Cooper pair but to to reconnection of flux tubes. An alternative proposal which seems to gain experimental support is that spin waves appearing near antiferromagnetic phase transitions replace phonons.

3.2.3 More precise view about high T_c superconductivity taking into account recent experimental results

There are more recent results allowing to formulate more precisely the idea about transition to high T_c super-conductivity as a percolation type phenomenon. Let us first summarize the recent picture about high T_c superconductors.

1. 2-dimensional phenomenon is in question. Supra current flows along preferred lattice planes and type II super-conductivity in question. Proper sizes of Cooper pairs (coherence lengths) are ξ =1-3 nm. Magnetic length λ is longer than $\xi/\sqrt{2}$.

2. Mechanism for the formation of Cooper pairs is the same water bed effect as in the case of ordinary superconductivity. Phonons are only replaced with spin-density waves for electrons with periodicity in general not that of the underlying lattice. Spin density waves relate closely to the underlying antiferromagnetic order. Spin density waves appear near phase transition to antiferromagnetism.

3. The relative orbital angular mentum of Cooper pair is L=2 ($x^2 - y^2$ wave), and vanishes at origin unlike for ordinary s wave SCs. The spin of the Cooper pair vanishes.

Consider now the translation of this picture to TGD language. Basic notions are following.

1. Magnetic flux tubes and possibly also dark electrons forming Cooper pairs.

2. The appearence of spin waves means sequences of electrons with opposite spins. The magnetic field associated with them can form closed flux tube containing both spins. Assume that spins-are orthogonal to the lattice plane in which supracurrent flows. Assume that the flux tube branches associated with electron with given spin branches so that it is shared with both neighboring electrons.

3. Electrons of opposite spins at the two portions of the closed flux tube have magnetic interaction energy. The total energy is minimal when the spins are in opposite directions. Thus the closed flux tube tends to favor formation of Cooper pairs.

4. Since magnetic interaction energy is proportional to $h_{eff} = n \times h$, it is expected stabilize the Cooper pairs at high temperatures. For ordinary super-conducti- vity magnetic fields tends to de-stabilize the pairs by trying to force the spins of spin singlet pair to the same direction.

5. This does not yet give super-conductivity. The closed flux tubes associated with paired spins can however reconnect so that longer flux closed flux tubes are formed. If this occurs for entire sequences, one obtains two flux tubes containing electrons with opposite spins forming Cooper pairs: this would be the "highway" and percolation would corresponds to this process. The pairs would form supracurrents in longer scales.

6. The phase phase transitions generating the reconnections could be percolation type phase transition.

This picture might apply also in TGD based model of bio-superconductivity.

1. The stability of dark Cooper pairs assume to reside at magnetic flux tubes is a problem also now. Fermi statistics favors opposite spins but this means that magnetic field tends to spit the pairs if the members of the pair are at the same flux tube.

2. If the members of the pair are at different flux tubes, the situation changes. One can have $L = 1$ and $S = 1$ with parallel spins (ferromagnetism like situation) or $L = 2$ and $S = 0$ state (anti-ferromagnetism like situation). $L > 0$ is necessary since electrons must reside at separate flux tubes.

3.2.4 Nematics and high T_c superconductors

Waterloo physicists discover new properties of superconductivity is the title of article (see `http://tinyurl.com/jfz3l45`) popularizing the work of David Hawthorn, Canada Research Chair Michel Gingras, doctoral student Andrew Achkar and post-doctoral student Zhihao Hao published in Science [D14] (see `http://tinyurl.com/zycahrx`). There is a dose of hype involved. As a matter of fact, it has been known for years that electrons flow along stripes, kind of highways in high T_c superconductors.

This effect is known as nematicity and means that electron orbitals break lattice symmetries and align themselves like a series of rods. Nematicity in long length scales occurs a temperatures below the critical point for super-conductivity. In the above mentioned work cuprate CuO_2 is studied. For non-optimal doping the critical temperature for transition to macroscopic superconductivity is below the maximal critical temperature. Long length scale nematicity is observed in these phases.

In the article by Rosenthal et al [D22] (see `http://tinyurl.com/h34347f`) it is however reported that nematicity is in fact preserved above critical temperature as a local order -at least up to the upper critical temperature, which is not easy to understand in the BCS theory of superconductivity. One can say that the stripes are short and short-lived so that genuine super-conductivity cannot take place.

These two observations lend further support for the TGD inspired model of high T_c superconductivity and bio-superconductivity. It is known that antiferromagnetism is essential for the phase transition to superconductivity but Maxwellian view about electromagnetism and standard quantum theory do not make it easy to understand how. Magnetic flux tube is the first basic new notion provided by TGD. Flux tubes carry dark electrons with scaled up Planck constant $h_{eff} = n \times h$: this is second new notion. This implies scaling up of quantal length scales and in this manner makes also super-conductivity possible.

Magnetic flux tubes in antiferromagnetic materials form short loops. At the upper critical point they however reconnect with some probability to form loops with look locally like parallel flux tubes carrying magnetic fields in opposite directions. The probability of reverse phase transition is so large than there is a competion. The members of Cooper pairs are at parallel flux tubes and have opposite spins so that the net spin of pair vanishes: $S = 0$. At the first critical temperature the average length and lifetime of flux tube highways are too short for macroscopic super-conductivity. At lower critical temperature all flux tubes re-connect permantently average length of pathways becomes long enough.

This phase transition is mathematically analogous to percolation in which water seeping through sand layer wets it completely. The competion between the phases between these two temperatures corresponds to quantum criticality in which phase transitions $h_{eff}/h = n_1 \leftrightarrow n_2$ take place in both directions ($n_1 = 1$ is the most plausible first guess). Earlier I did not fully realize that Zero Energy Ontology provides an elegant description for the situation [L11] [K22]. The reason was that I thought that quantum criticality occurs at single critical temperature rather than temperature interval. Nematicity is indeed detected locally below upper critical temperature and in long length scales below lower critical temperature.

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3.2.5 Explanation for the spectral signatures of high T_c superconductor

The model should explain various spectral signatures of high T_c super-conductors. It seems that this is possible at qualitative level at least.

1. Below the critical temperature there is a sharp absorption onset at energy of about $E_a = 50$ meV.

2. Second characteristic [D23, D20, D13] of high T_c super conductors is resonant neutron scattering at excitation energy $E_w = 41$ meV of super conductor also visible only below the critical temperature.

3. The second derivative of $\sigma(\omega)$ peaks near 68 meV and assuming $E = E_g + E_w$ they found nearly perfect match using $E_g = 27$ meV for the energy gap.

$E_g = 27$ meV has a natural interpretation as energy gap of spin 1 Cooper pair. $E_w = 41$ meV can be assigned to the transversal oscillations of magnetic flux tubes inducing 1-D transversal photons which possibly give rise to the energy gap. $E_a = 50$ meV can be understood if also $S = 0$ Cooper pair for which electrons of the pair reside dominantly at the "outer" dipole flux tube and inner dipole core. The presence of this pair might explain the BCS type aspects of high T_c super-conductivity. This identification would predict the gap energy of $S = 0$ Cooper pair to be $E_g(S = 0) = 9$ meV. Since the critical absorption onset is observed only below T_c these Cooper pairs would become thermally stable at T_c and the formation of long flux tubes should somehow stabilize them. For very long flux tubes the distance of a point of "outer" flux tube from the nearby point "inner" flux tube becomes very long along dipole flux tube. Hence the transformation of $S = 0$ pairs to $S = 1$ pairs is not possible anymore and $S = 0$ pairs are stabilized.

3.2.6 Model for Cooper pairs

The TGD inspired model for Cooper pairs of high T_c super-conductor involves several new physics aspects: large $\hbar$ phases, the notion of magnetic flux tubes. One can also consider the possibility that color force predicted by TGD to be present in all length scales is present.

1. One can consider two options for the topological quantization of the dipole field. It could decompose to a flux tube pattern with a discrete rotational symmetry Z_n around dipole axis or to flux sheets identified as walls of finite thickness invariant under rotations around dipole axis. Besides this there is also inner the flux tube corresponding to the dipole core. For the flux sheet option one can speak about eigenstates of L_z. For flux tube option the representations of Z_n define the counterparts of the angular momentum eigenstates with a cutoff in L_z analogous to a momentum cutoff in lattice. The discretized counterparts of spherical harmonics make sense. The counterparts of the relative angular momentum eigenstates for Cooper pair must be defined in terms of tensor products of these rather than using spherical harmonics assignable with the relative coordinate $r_1 - r_2$. The reconnection mechanism makes sense only for the flux tube option so that it is the only possibility in the recent context.

2. Exotic Cooper pair is modeled as a pair of large $\hbar$ electrons with zoomed up size at space-time representing the dipole field pattern associated with a sequence of holes with same spin. If the members of the pair are at diametrically opposite flux tubes or at the "inner" flux tube (dipole core) magnetic fluxes flow in same direction for electrons and spin 1 Cooper pair is favored. If they reside at the "inner" flux tube and outer flux tube, spin zero state is favored. This raises the question whether also $S = 0$ variant of the Cooper pair could be present.

3. Large $\hbar$ is needed to explain high critical temperature. By the general argument the transition to large $\hbar$ phase occurs in order to reduce the value of the gauge coupling strength - now fine structure constant- and thus guarantee the convergence of the perturbation theory. The generation or positive net charge along stripes indeed means strong electromagnetic interactions at stripe.

Color force in condensed matter length scales is a new physics aspect which cannot be excluded in the case that transverse oscillations of flux tubes do not bind the electrons to form a Cooper pair. Classically color forces accompany any non-vacuum extremal of Kähler action since a non-vanishing induced Kähler field is accompanied by a classical color gauge field with Abelian holonomy. Induced Kähler field is always non-vanishing when the dimension of the CP_2 projection of the space-time surface is higher than 2. One can imagine too alternative scenarios.

1. Electromagnetic flux tubes for which induced Kähler field is non-vanishing carry also classical color fields. Cooper pairs could be color singlet bound states of color octet excitations of electrons (more generally leptons) predicted by TGD and explaining quite impressive number of anomalies [K20]. These states are necessarily dark since the decay widths of gauge bosons do not allow new light fermions coupling to them. The size of these states is of order electron size scale $L(127)$ for the standard value of Planck constant. For the non-standard value of Planck constant it would be scaled up correspondingly. For $r = \hbar/\hbar_0 = 2^{14}$ the size would

be around 3.3 Angströms and for $r = 2^{24}$ of order 10 nm. Color binding could be responsible for the formation of the energy gap in this case and would distinguish between ordinary two-electron states and Cooper pair. The state with minimum color magnetic energy corresponds to spin triplet state for two color octed fermions whereas for colored fermion and anti-fermion it corresponds to spin singlet (pion like state in hadron physics).

2. A more complex variant of this picture served as the original model for Cooper pairs. Electrons at given space-time sheet feed their gauge flux to large space-time sheet via wormhole contacts. If the wormhole throats carry quantum numbers of quark and antiquark one can say that in the simplest situation the electron space-time sheet is color singlet state formed by quark and antiquark associated with the upper throats of the wormhole contacts carrying quantum numbers of u quark and $\overline{d}$ quark. It can also happen that the electronic space-time sheets are not color singlet but color octet in which case the situation is analogous to that above. Color force would bind the two electronic space-time sheets to form a Cooper pair. The neighboring electrons in stripe possess parallel spins and could form a pair transforming to a large $\hbar$ Cooper pair bound by color force. The Coulombic binding energy of the charged particles with the quarks and antiquarks assignable to the two wormhole throats feeding the em gauge flux to Y^4 and color interaction would be responsible for the energy gap.

3.2.7 Estimate for the gap energy

If transverse oscillations are responsible for the binding of the Cooper pairs, one expects similar expression for the gap energy as in the case of BCS type super conductors. The 3-D formula for the gap energy reads as

$$\begin{aligned} E_g &= \hbar\omega_D exp(-1/X) \ , \\ \omega_D &= (6\pi^2)^{1/3} c_s n^{1/3} \\ X &= n(E_F)U_0 = \frac{3}{2}N(E_F)\frac{U_0}{E_F} \ , \\ n(E_F) &= \frac{3}{2}\frac{N(E_F)}{E_F} \ . \end{aligned} \tag{3.1}$$

X depends on the details of the binding mechanism for Cooper pairs and U_0 parameterizes these details.

Since only stripes contribute to high T_c super-conductivity it is natural to replace 3-dimensional formula for Debye frequency in 1-dimensional case with

$$\begin{aligned} E_g &= \hbar\omega exp(-1/X) \ , \\ \omega &= kc_s n \ . \end{aligned} \tag{3.2}$$

where n is the 1-dimensional density of Cooper pairs and k a numerical constant. X would now correspond to the binding dynamics at the surface of 1-D counterpart of Fermi sphere associated with the stripe.

There is objection against this formula. The large number of holes for stripes suggests that the counterpart of Fermi sphere need not make sense, and one can wonder whether it could be more advantageous to talk about the counterpart of Fermi sphere for holes and treat Cooper pair as a pair of vacancies for this "Fermi sphere". High T_c super conductivity would be 1-D conventional super-conductivity for bound states of vacancies. This would require the replacement of n with the linear density of holes along stripes, which is essentially that of nuclei.

From the known data one can make a rough estimate for the parameter X. If $E_w = hf = 41$ meV is assigned with transverse oscillations the standard value of Planck constant would give $f = f_0 = 9.8 \times 10^{12}$ Hz. In the general case one has $f = f_0/r$. If one takes the 10^{-12} second length scale of the transversal fluctuations at a face value one obtains $r = 10$ as a first guess. $E_g = 27$ meV gives the estimate

$$exp(-1/X) = \frac{E_g}{E_w} \tag{3.3}$$

giving $X = 2.39$.

The interpretation in terms of transversal oscillations suggests the dispersion relation

$$f = \frac{c_s}{L} \ .$$

L is the length of the approximately straight portion of the flux tube. The length of the "outer" flux tube of the dipole field is expected be longer than that of stripe. For $L = x$ nm and $f_D \sim 10^{12}$ Hz one would obtain $c_s = 10^3 x$ m/s.

3.2.8 Estimate for the critical temperatures and for $\hbar$

One can obtain a rough estimate for the critical temperature T_{c1} by following simple argument.

1. The formula for the critical temperature proposed in the previous section generalize in 1-dimensional case to the following formula

$$T_{c1} \leq \frac{\hbar^2}{8m_e}(\frac{n_c}{g})^2 \ . \tag{3.4}$$

   g is the number of spin degrees of freedom for Cooper pair and n_c the 1-D density of Cooper pairs. The effective one-dimensionality allows only single $L = 2$ state localized along the stripe.The $g = 3$ holds true for $S = 1$.

2. By parameterizing n_c as $n_c = (1 - p_h)/a$, $a = x$ Angstrom, and substituting the values of various parameters, one obtains

$$T_{c1} \simeq \frac{r^2(1-p_h)^2}{9x^2} \times 6.3 \ meV \ . \tag{3.5}$$

3. An estimate for p_h follows from the doping fraction p_d and the fraction p_s of parallel atomic rows giving rise to stripes one can deduce the fraction of holes for a given stripe as

$$p_h = \frac{p_d}{p_s} \ . \tag{3.6}$$

   One must of course have $p_d \leq p_s$. For instance, for $p_s = 1/5$ and $p_d = 15$ per cent one obtains $p_h = 75$ per cent so that a length of four atomic units along row contains one Cooper pair on the average. For $T_{c1} = 23$ meV (230 K) this would give the rough estimate $r = 23.3$: $r = 24$ satisfies the Fermat polygon constraint. Contrary to the first guess inspired by the model of bio-superconductivity the value of $\hbar$ would not be very much higher than its standard value. Notice however that the proportionality $T_c \propto r^2$ makes it difficult to explain T_{c1} using the standard value of $\hbar$.

4. One $p_h \propto 1/L$ whereas scale invariance for reconnection probability ($p = p(x = TL/\hbar)$) predicts $T_c = x_c\hbar/L = x_c p_s \hbar/a$. This implies

$$\frac{T_c}{T_{c1}} = 32\pi^2\frac{m_e a}{\hbar_0}x^2 g^2 \frac{p_s}{(1-(p_d/p_s)^2)^2}\frac{x_c}{r} \ . \tag{3.7}$$

   This prediction allows to test the proposed admittedly somewhat ad hoc formula. For $p_d << p_s$ T_c/T_{c1} does behaves as $1/L$. One can deduce the value of x_c from the empirical data.

5. Note that if the reconnection probability p is a universal function of x as quantum criticality suggests and thus also x_c is universal, a rather modest increase of $\hbar$ could allow to raise T_c to room temperature range.

The value of $\hbar$ is predicted to be inversely proportional to the density of the Cooper pairs at the flux tube. The large value of $\hbar$ needed in the modelling of living system as magnetic flux tube super-conductor could be interpreted in terms of phase transitions which scale up both the length of flux tubes and the distance between the Cooper pairs so that the ratio rn_c remains unchanged.

3.2.9 Coherence lengths

The coherence length for high T_c super conductors is reported to be 5-20 Angstroms. The naive interpretation would be as the size of Cooper pair. There is however a loophole involved. The estimate for coherence length in terms of gap energy is given by $\xi = \frac{4\hbar v_F}{E_g}$. If the coherence length is estimated from the gap energy, as it seems to be the case, then the scaling up of the Planck constant would increase coherence length by a factor $r = \hbar/\hbar_0$. $r = 24$ would give coherence lengths in the range $12 - 48$ nm.

The interpretation of the coherence length would be in terms of the length of the connected flux tube structure associated with the row of holes with the same spin direction which can be considerably longer than the row itself. As a matter fact r would characterize the ratio of size scales of the "magnetic body" of the row and of row itself. The coherence lengths could relate to the p-adic length scales $L(k)$ in the range $k = 151, 152, .., 155$ varying in the range $(10, 40])$ nm. $k = 151$ correspond to thickness cell membrane.

3.2.10 Why copper and what about other elements?

The properties of copper are somehow crucial for high T_c superconductivity since cuprates are the only known high T_c superconductors. Copper corresponds to $3d^{10}4s$ ground state configuration with one valence electron. This encourages the question whether the doping by holes needed to achieve superconductivity induces the phase transition transforming the electrons to dark Cooper pairs.

More generally, elements having one electron in s state plus full electronic shells are good candidates for doped high T_c superconductors. If the atom in question is also a boson the formation of atomic Bose-Einstein condensates at Cooper pair space-time sheets is favored. Superfluid would be in question. Thus elements with odd value of A and Z possessing full shells plus single s wave valence electron are of special interest. The six stable elements satisfying these conditions are ^{5}Li, ^{39}K, ^{63}Cu, ^{85}Rb, ^{133}Cs, and ^{197}Au.

3.2.11 A new phase of matter in the temperature range between pseudo gap temperature and T_c?

Kram sent a link to a Science Daily popular article titled High-Temperature Superconductor Spills Secret: A New Phase of Matter? (see alsothis). For more details see the article in Science [D15].

Zhi-Xun Shen of the Stanford Institute for Materials and Energy Science (SIMES), a joint institute of the Department of Energy's SLAC National Accelerator Laboratory and Stanford University, led the team of researchers, which discovered that in the temperature region between the pseudo gap temperature and genuine temperature for the transition to super-conducting phase there exists a new phase of matter. The new phase would not be super-conducting but would be characterized by an order of its own which remains to be understood. This phase would be present also in the super-conducting phase.

The announcement does not come as a complete surprise for me. A new phase of matter is what TGD inspired model of high T_c superconductivity indeed predicts. This phase would consist of Cooper pairs of electrons with a large value of Planck constant but associated with magnetic flux tubes with short length so that no macroscopic supra currents would be possible.

The transition to super-conducting phase involves long range fluctuations at quantum criticality and the analog of a phenomenon known as percolation [D3]. For instance, the phenomenon occurs for the filtering of fluids through porous materials. At critical threshold the entire filter suddenly wets as fluid gets through the filter. Now this phenomenon would occur for magnetic flux tubes carrying the Cooper pairs. At criticality the short magnetic flux tubes fuse by reconnection to form long ones so that supra currents in macroscopic scales become possible.

It is not clear whether this prediction is consistent with the finding of Shen and others. The simultaneous presence of short and long flux tubes in macroscopically super-conducting phase is certainly consistent with TGD prediction. The situation depends on what one means with super-conductivity. Is super-conductivity super-conductivity in macroscopic scales only or should one call also short scale super-conductivity not giving rise to macroscopic super currents as super-conductivity. In other words: do the findings of Shen's team prove that the electrons above gap temperature do not form Cooper pairs or only that there are no macroscopic supra currents?

Whether the model works as such or not is not a life and death question for the TGD based model. One can quite well imagine that the first phase transition increasing $\hbar$ does not yet produce electron Compton lengths long enough to guarantee that the overlap criterion for the formation of Cooper pairs is satisfied. The second phase transition increasing $\hbar$ would do this and also scale up the lengths of magnetic flux tubes making possible the flow of supra currents as such even without reconnections. Also reconnections making possible the formation of very long flux tubes could be involved and would be made possible by the increase in the length of flux tubes.

3.3 Speculations

3.3.1 21-Micrometer mystery

21 micrometer radiation from certain red giant stars have perplexed astronomers for more than a decade [D5]. Emission forms a wide band (with width about 4 micrometers) in the infrared spectrum, which suggests that it comes form a large complex molecule or a solid or simple molecules found around starts. Small molecules are ruled out since they produce narrow emission lines. The feature can be only observed in very precise evolutionary state, in the transition between red giant phase and planetary nebular state, in which star blows off dust that is rich in carbon compounds. There is no generally accepted explanation for 21-micrometer radiation.

One can consider several explanations based on p-adic length scale hypothesis and some explanations might relate to the wormhole based super-conductivity.

1. 21 micrometers corresponds to the photon energy of 59 meV which is quite near to the zero point point kinetic energy 61.5 meV of proton Cooper pair at $k = 139$ space-time sheet estimated from the formula

$$\Delta E(2m_p, 139) = \frac{1}{2}\frac{\pi^2}{(2m_p)L_e(139)^2} = \frac{1}{8}\Delta E(m_p, 137) \simeq 61.5\ meV \quad .$$

   Here the binding energy of the Cooper pair tending to reduce this estimate is neglected, and this estimate makes sense only apart from a numerical factor of order unity. This energy is liberated when a Cooper pair of protons at $k = 139$ space-time sheet drops to the magnetic flux tube of Earth's magnetic field (or some other sufficiently large space-time sheet). This energy is rather near to the threshold value about 55 meV of the membrane potential.

2. 21 micrometer radiation could also result when electrons at $k = 151$ space-time sheet drop to a large enough space-time sheet and liberate their zero point kinetic energy. Scaling argument gives for the zero point kinetic energy of electron at $k = 151$ space-time sheet the value $\Delta(e, 151) \simeq 57.5$ meV which is also quite near to the observed value. If electron is bound to wormhole with quantum numbers of $\overline{d}$ Coulombic binding energy changes the situation.

3. A possible explanation is as a radiation associated with the transition to high T_c super conducting phase. There are two sources of photons. Radiation could perhaps result from the de-excitations of wormhole BE condensate by photon emission. $\lambda = 20.5$ micrometers is precisely what one expects if the space-time sheet corresponds to $p \simeq 2^k$, $k = 173$ and assumes that excitation energies are given as multiples of $E_w(k) = 2\pi/L_e(k)$. This predicts excitation energy $E_w(173) \simeq 61.5$ meV. Unfortunately, this radiation should correspond to a sharp emission line and cannot explain the wide spectrum.

3.3.2 Are living systems high T_c superconductors?

The idea about cells and axons as superconductors has been one of the main driving forces in development of the vision about many-sheeted space-time. Despite this the realization that the supra currents in high T_c superconductors flow along structure similar to axon and having same crucial length scales came as a surprise. Axonal radius which is typically of order $r = .5$ μm. $r = 151 - 127 = 24$ favored by Mersenne hypothesis would predict $r = .4$ μm. The fact that water is liquid could explain why the radius differs from that predicted in case of high T_c superconductors.

Interestingly, Cu is one of the biologically most important trace elements [D1]. For instance, copper is found in a variety of enzymes, including the copper centers of cytochrome c-oxidase, the Cu-Zn containing enzyme superoxide dismutase, and copper is the central metal in the oxygen carrying pigment hemocyanin. The blood of the horseshoe crab, Limulus polyphemus uses copper rather than iron for oxygen transport. Hence there are excellent reasons to ask whether living matter might be able to build high T_c superconductors based on copper oxide.

3.3.3 Neuronal axon as a geometric model for current carrying "rivers"

Neuronal axons, which are bounded by cell membranes of thickness $L_e(151)$ consisting of two lipid layers of thickness $L_e(149)$ are good candidates for high T_c superconductors in living matter.

These flux tubes with radius .4 μm would define "rivers" along which conduction electrons and various kinds of Cooper pairs flow. Scaled up electrons have size $L_e(k_{eff} = 151)$ corresponding to 10 nm, the thickness of the lipid layer of cell membrane. Also the quantum fluctuating stripes of length 1-10 nm observed in high T_c super conductors might relate to the scaled up electrons with Compton length 10 nm, perhaps actually representing zoomed up electrons!

The original assumption that exotic *resp.* BCS type Cooper pairs reside at boundaries *resp.* interior of the super-conducting rivulet. It would however seem that the most natural option is that the hollow cylindrical shells carry all supra currents and there are no Cooper pairs in the interior. If exotic Cooper pairs reside only at the boundary of the rivulet or the Cooper pairs at boundary remain critical against exotic-BCS transition also below T_c, the time dependent fluctuations of the shapes of stripes accompanying high T_c super-conductivity can be understood as being induced by the fluctuations of membrane like structures. Quantum criticality at some part of the boundary is necessary in order to transform ordinary electron currents to super currents at the ends of rivulets. In biology this quantum criticality would correspond to that of cell membrane.

4 Models For Ionic Superconductivity

In this section the model for ionic superconductivity is constructed as a straightforward generalization of the model of high T_c electronic superconductivity. There is however a loophole involved. TGD based model of atomic nucleus predicts that fermionic ions can have bosonic chemical equivalents for which one of the color bonds connecting nucleons to nuclear string is charged. Dark fermionic ions like Na^+, K^+, and Cl^- could be actually exotic ions of this kind having different mass number and be able to form Bose-Einstein condensates. This is required by the recent model for nerve pulse [K18]. The prediction can be tested.

The new model for the topological condensation at magnetic flux quanta of endogenous magnetic field differs radically from the earlier model and allows to understand that effects of ELF em fields on brain. Bose-Einstein condensates of bosonic ions are predicted to be of special importance for the functioning of living systems. Also a quantitative understanding of the effects of Schumann resonances and EEG emerges.

4.1 Model For Ionic Superconductivity

Exactly the same mechanisms are expected to work also in the case of ions and the only differences come from the different mass and charge of ion.

1. Magnetic flux tubes are carriers of supra currents and magnetic fields favor the formation of spin 1 Cooper pairs which are parallel and have also spins parallel to the flux tubes. In living matter the flux tubes could be dark magnetic flux tubes connecting different biomolecules.

For instance, DNA as topological quantum computer model [K7] assumes that flux tubes connect nucleotides of DNA with the lipid layers of nuclear or cell membrane.

2. Mersenne hypothesis discussed in the introduction is assumed and makes possible precise quantitative predictions using scaling arguments. With the motivation coming from the model of cell membrane as Josephson junction it is also assumed that magnetic field scales as $1/\hbar$ and that the supra currents at the boundaries of flux tubes guarantee that the quantization condition $\oint (p - eA) \cdot dl = 0$ is satisfied. This allows the flux tubes to have a fixed transversal size (cell membrane thickness) irrespective of the value of Planck constant. An attractive hypothesis is that the $B_{end} = 0.2$ Gauss and its $1/\hbar$ scaled variants define preferred values of magnetic field.

3. In the case of ionic super-conductivity there is no antiferromagnetic lattice present. Therefore there is no obvious reason for having higher critical temperature $T_{c,1}$. Percolation type mechanism is possible if a recombination of shorter magnetic flux tubes to form longer ones takes place at critical temperature. According to the model of DNA as topological quantum computer recombination of the flux tubes is a basic mechanism of information processing mechanism in living matter so that percolation type criticality might be present.

4. For large values of $\hbar$ the gap for magnetic cyclotron energies implies that proton Cooper pairs condense to the ground state in the degrees of freedom transversal to the flux tube in which harmonic oscillator states provide a good approximate model. In the longitudinal degrees of freedom one has effectively particle in box. The corresponding energy gap $E = \pi^2\hbar^2/2m_pL^2$ is below thermal energy at room temperature for flux tube lengths L of order $L(139)$ for ordinary value of $\hbar$. For electron this length scale is by a factor $m_p/m_e \simeq 2^{11}$ longer and corresponds to about 100 nm. The value of flux tube length however scales as $\hbar$ if one assumes that energy does not change in the scaling of $\hbar$. Hence arbitrarily long flux tube lengths are possible. For ion with mass number A the minimnum value of $\hbar$ allowing given flux tube length L scales as $\hbar \propto AL$.

5. In the case of bosonic ions there is no need for Cooper pairs and super-conductivity would be due to the Bose-Eizntein condensation of ions. TGD based nuclear physics also predicts exotic ions, which are chemically like their fermionic counterparts but are actually bosons. This is made possible by the possibility of the color flux tubes connecting nucleons to nuclear string to carry charges $1, 0, -1$.

6. Whether the Cooper pairs of fermionic ions can be thermally stable is far from obvious. The model for electronic super-conductivity would suggest transversal fluctuations of the flux tube as the mediator of the attractive interaction winning Coulomb repulsion and making possible the formation of the Cooper pairs.

   One might hope that the ions are trapped to the neighboring nodes of the transversal standing wave type oscillations and in this manner form correlated pairs. The size of the Cooper pairs would correspond to a multiple of wavelength for the transversal oscillations in this case. The approximation of the magnetic flux tube as string would suggest that waves are of form $sin(\omega t)sin(kz)$, $k = \omega$. The frequencies $\omega = n\pi/L$ would be allowed for a flux tube of length L.

   Perhaps it would be more appropriate to say that one has Bose-Einstein condensate of transverse phonons making possible the Bose-Einstein condensate of Cooper pairs. It is quite possible that metabolic energy must be pumped to the Bose-Einstein condensate of transverse oscillations in order to not lose the ionic super-conductivity.

4.2 Super Conductors Of Exotic Bosonic Counterparts Of Fermionic Ions

If ion is boson, no Cooper pairs is needed in order to have a super conductor, and Ca^{++} and Mg^{++} ions at dark magnetic flux tubes with large value of Planck constant could give rise to high T_c super-conductors in this manner. Fermionic ions (Na^+, K^+, Cl^-, ..) would not define supra currents. The explanation of the effects of ELF em fields on vertebrate brain however suggests

Table 1: The modification of cyclotron frequencies of most important ions are modified by simplest replacements with exotic ions

$$\begin{array}{llll} Ion & f_c/Hz & Pseudo-ion & f_c/Hz \\ ^{23}Na^+ & 13.1 & ^{19}Ne_+ & 15.7 \\ ^{23}Na^+ & 13.1 & ^{24}Mg_-^{++} & 12.5 \\ ^{39}K^+ & 7.7 & ^{40}A_+ & 7.5 \\ ^{39}K^+ & 7.7 & ^{40}Ca_-^{++} & 7.5 \\ ^{35}Cl^- & 8.6 & ^{40}A_- & 7.5 \end{array} \tag{4.1}$$

Table 2: The first columns give the cyclotron frequencies and cyclotron energies for biologically relevant bosonic ions in $B_{end} = .2 \times 10^{-4}$ Tesla. The third column gives cyclotron energy.

Ion	f_1/Hz	E_1/eV
$^6Li^+$	50.1	3.3
$^{24}Mg^{2+}$	25.0	1.65
$^{16}O^{2-}$	37.6	2.48
$^{32}S^{2-}$	18.8	1.24
$^{40}Ca^{2+}$	15.0	.99
$^{55}Mn^{2+}$	11.4	.75
$^{56}Fe^{2+}$	10.8	.71
$^{59}Co^{2+}$	10.0	.66
$^{64}Zn^{2+}$	9.4	.62
$^{80}Se^{2-}$	7.6	.5

cyclotron Bose-Einstein condensates of also ions behaving chemically like fermionic ions. Also the model of nerve pulse requires Josephson currents of ions which are chemical equivalents of fermionic ions.

TGD based nuclear physics [L1] allows this kind of ions. The model indeed predicts the possibility of exotic nuclei for which one or more color bonds connecting nucleons to the nuclear string are charged. These exotic nuclei with electronic states identical to those of genuine ions could save the situation. The **Table 1** describes how cyclotron frequencies for $B = .2$ Gauss of the most important ions are modified in the simplest replacements with exotic ions. For instance, the notation Mg_-^{++} tells that there is double electronic ionization and electron shell of Argon as usual but that one color bond is negatively charged.

$f_c(K+)$ and $f_c(Cl^-)$ are replaced with the frequency 7.5 Hz and one can do only using the cyclotron frequencies $f(Ca^{++})/2 = 7.5$ Hz, $f_c(Mg^{++}) = 12.5$ Hz, and $f(Ca^{++}) = 15$ Hz. The nominal values of the lowest Schumann frequencies are 7.8 Hz and 14.3 Hz. All ions with relevance for nerve pulse and EEG could be bosonic ions or bosonic pseudo-ions. I do not know how well the needed ionization mechanisms are understood in the standard framework.

4.3 More Quantitative Picture About Bose-Einstein Condensates

Cyclotron frequencies of biologically important ions in the endogenous magnetic field $B_{end} = 0.2$ Gauss are involved with the effects of ELF em fields on vertebrate brain and are also central in the model of EEG [K5]. This motivates a more detailed study of these frequencies. Also the cyclotron frequencies of biologically important molecules are interesting.

4.3.1 Bose-Einstein condensates of bosonic ionized atoms

The number of elements for which ions are bosons is not very large. **Table 2** lists the cyclotron frequencies of bosonic ions which are biologically important for $B_{end} = .2 \times 10^{-4}$ Tesla.

Table 2 inspires some comments.

1. For Li^+ the dominating isotope $^7Li^+$ is fermion. $^6Li^+$ is boson and its abundance is 5 per cent. Li^+ ions are used as medications in mania and represents mood stabilizer [J1]. A possible explanation is that the cyclotron oscillations of Bose-Einstein condensate of $^6Li^+$ ions serve as a biological clock helping to stabilize the mood. The cyclotron frequency is however 50 Hz and higher than thalamocortical resonance frequency having nominal value 40 Hz.

   An alternative explanation for the effect of Li^+ is based on the observation that $^7Li_+$ has cyclotron frequency equal to 42.9 Hz for $B_{end} = .2\times 10^{-4}$ Tesla, which is at the upper limit of the 40 Hz resonance band. The presence of lithium ions or their Cooper pairs could enhance thalamocortical resonance.

   These hypothesis could be tested by looking whether the use of pure $A = 6$ ($A = 7$) isotope of Li^+ amplifies the beneficial effect and the use of $A = 7$ ($A = 6$) isotope nullifies it.

2. For Mg^{2+} cyclotron energy corresponds to the energy of photon of green light. Chlorophyll is not able to convert nutrients to sugar without magnesium, which suggests that cyclotron transitions of Mg BE condensate are at least partially responsible for the green color of plants. Mg BE condensate could control the coherent occurrence of photosynthesis in the size scale of plant.

3. For oxygen ion the cyclotron frequency is 37.6 Hz and rather near to ~ 40 Hz thalamocortical resonance frequency, which suggests that the cyclotron transitions of oxygen ions might play key role in inducing coherent firing of neurons at this frequency. This would mean that oxygen would be much more than a mere provider of metabolic energy. Note also that $\Delta n = 3$ cyclotron transition of Na^+ ion corresponds to frequency 39 Hz and might be involved with the synchronous firing.

4. Ca^{2+} ions play a unique role in the functioning of living matter. In particular, calcium waves appearing in a wide range of time scales are known to serve a crucial role in nervous system [J11]. Ca^{2+} corresponds to.99 eV cyclotron energy scale, which is twice the energy of metabolic energy quantum. Hence one can ask whether the cyclotron transitions of Ca^{2+} BE condensate could induce a collective emission of metabolic energy quanta and in this manner induce coherent metabolic activity in the scale of entire body.

5. The cyclotron frequencies Mn, Fe, Co, Cu, and Zn are in alpha band and corresponding cyclotron energies are somewhat above metabolic energy quantum. These energy quanta could drive protons from larger space-time sheet to $k = 137$ atomic space-time sheet. 10 Hz frequency is known to define an important biological clock and Co ions could be essential for the functioning of this clock. $n = 3$ multiple of Co^{2+} cyclotron frequency corresponds to the 30 Hz threshold of gamma band known to be important for cognition. Also $3f_c(Fe^{2+}) = 32.2$ Hz and $3f_c(Mn^{2+}) = 34.2$ belong to gamma band. The presence of Bose-Einstein condensates of these ions in length scale of $5L(212) = 141$ km could mean that these bio-rhythms are shared by different organisms inside regions of this size.

6. The fact that the cyclotron frequency of Se^{2-} ion, which is known to be a biologically important trace element, corresponds to the nominal value of the metabolic energy quantum, raises the question whether Selenium BE condensate might act as a metabolic synchronizer.

4.3.2 Cyclotron frequencies and Schumann frequencies

Even in the case that Cooper pairs of fermionic ions are not thermally stable, the cyclotron transitions of fermionic ions like K^+, Cl^-, and Na^+ are expected to be important. In **Table 3** cyclotron frequencies and energies of some fermionic ions are given. Notice that the cyclotron energy of K^+ ion corresponds to metabolic energy quantum. Quite generally fermionic ions cannot be involved with the generation of Josephson part of EEG.

The first thing to notice is the close relationship of cyclotron frequencies with the lowest resonance frequencies in the spectrum of geo-electromagnetic field starting from 5 Hz, so called Schumann frequencies [F1], are $7.8, 14, 20, 26, 33, 39$ and 45 Hz. 5 Hz corresponds roughly to the

Table 3: The first columns give cyclotron frequencies and corresponding cyclotron energies for some ions in $B_{end} = .2 \times 10^{-4}$ Tesla for some fermionic ions.

Ion	f/Hz	E_c/eV
$^7Li_+$	42.9	
F^-	15.8	1.04
Na^+	13	.86
Al^+	11.1	.73
Cl^-	8.5	.56
K^+	7.5	.50
Cu^+	4.8	333.9
Ag^+	2.8	.18
I^+	2.4	.16
Au^+	1.5	.10

threshold 4 Hz of theta frequency range below which EEG spectrum lies during sleep which suggests that wake-up state involves the coupling of brain with geo-electro-magnetic activity. 7.8 Hz corresponds to the threshold for alpha waves associated with wake-up state without cognition; 14 Hz corresponds to threshold of 13 Hz for beta waves accompanying cognitive activities, and 33 Hz is quite near to the threshold 30 Hz for gamma waves known to be important in the temporal coding of sensory data.

Consider now examples of cyclotron frequencies keeping in mind that Schumann frequencies vary typically within 1 Hz interval around their mean values [F1].

1. As already noticed, the frequencies, which are multiples of 15 Hz can be assigned to Ca^{2+} ion. The excitations $n = 3, 5, 7, ..$ correspond to the frequencies $45, 75, 105, ...$ Hz. All these frequencies have been observed. The two lowest frequencies correspond to Schumann frequencies 14 and 45 Hz with accuracy of 1 Hz.

2. Na_+ has $A = 23$ and gives $f = 13$ Hz. This is the lower bound for the frequency of beta EEG waves which are associated with conscious cognition. This would suggest that the presence of em field of 13 Hz frequency correlates with large fluxes of Na_+ ions through the axonal cell membrane during nerve pulse generation. This could result from increased amplitude of Na_+ Josephson current facilitating the emission of nerve pulses at the second half of the EEG cycle. Silencing of mind by meditation or closing eyes reduces amplitudes associated with EEG frequencies below 13 Hz and conscious cognition disappears.

   $n = 3$ excitation of Na_+ corresponds to 39 Hz, which is one of the Schumann frequencies and quite near to the 40 Hz resonant frequency associated with the thalamocortical circuit. This could correspond to jumping of Na_+ ions from ground state to $n = 3$ state or vice versa. $n = 5$ quantum jumps correspond to 65 Hz which is average EEG frequency during REM sleep! Thus 13, 39 and 65 Hz frequencies correspond to the basic signatures of conscious cognition. The two lowest transition frequencies correspond to Schumann frequencies 14 and 45 Hz within accuracy of 1 Hz.

3. K_+ has $A = 39$ and gives $f = 7.5$ Hz, which is theta frequency rather near to the lowest Schumann resonance frequency 7.8 Hz. K_+ ion flux could correlate with em fields in the range of the alpha frequencies creating cyclotron resonance. Theta activity dominates during sleep and Adey's observations [J5] demonstrate that 7 Hz ELF field increases reaction times. Second and third transition frequencies are within 1.5 Hz Schumann frequencies 20 and 37.5 Hz.

4. Cl_- ion has $A = 35$ and gives $f = 8.5$ Hz. Chloride ion has inhibitory effect. $n = 3, 7, ..$ excitations correspond to 25.5, 42.5 Hz, ... Rather interestingly, frequencies rather near to 40 Hz associated with thalamo-cortical loops appear as excitations for all ions relevant to nerve pulse activity. Note that 39 Hz is also Schumann frequency. Two lowest transition frequencies of Cl_- are quite near to Schumann frequencies 7.8 and 25 Hz.

5. Fe^{2+} has $A = 56$ and corresponds to 10.7 Hz. $3f_c(Fe^{2+}) = 32.2$ Hz is rather near to Schumann frequency 33 Hz whereas Co^{2+} corresponds to 10 Hz in excellent accuracy. Co has especially large nuclear magnetic moment and serves as a natural magnet. Fe^{2+} and/or Co^{2+} could be present in magnetic sensory organ possessed also by humans making it possible to navigate using magnetic fields. Yarrow suggests that Co makes B_{12} magnetic vitamin [J5] so that it can serve as fundamental biological clock at frequency very precisely equal to 10 Hz. Co is carried by B_{12} vitamin and is known to be important for normal consciousness: among other things the lack of B_{12} causes fatigue, blurred vision and cognitive problems.

6. Mg^{2+} has A=24 and $f = 25$ Hz which is near to Schumann frequency: $n = 3$ corresponds 75 Hz. Charged polypeptides could also form BE condensates and be involved with cyclotron mechanism: they are rather heavy and their cyclotron frequencies are in Hz range. Negatively charged organic molecules are indeed known to be present in neurons.

To sum up, surprisingly many magnetic transition frequencies are near to Schumann frequencies which suggests strong resonant interaction between brain and geo-electromagnetic fields.

4.3.3 What about proton's cyclotron frequency?

There are good reasons to expect that the cyclotron frequency of proton and its odd harmonics play an important role in brain functioning. The cyclotron frequency of proton in $B_{end} = .2$ Gauss is $f(p) = 300$ Hz. The frequency associated with $n = 3$ transition would be $3f(p) = 900$ Hz. Third harmonics of cyclotron frequencies of many ions with f_c in alpha band belong to gamma band known to relate to cognition. Perhaps this is true also in the case of proton.

The duration of single bit of the memetic codeword consisting of 127 bits and having total duration defined by the p-adic timescale $T^{(2)}_{M_{127}} = .1$ seconds corresponds to the frequency $f_m =$ 1027 Hz. This frequency is by 10 per cent higher than the cyclotron frequency of proton for $B_{end} = .2$ Gauss. If magnetic homeostasis is realized, as will be discussed later, and if it allows 10 per cent variation of the strength of magnetic field as the width 1 Hz of alpha band suggests, it is possible to realize this frequency as proton's cyclotron transition frequency.

The frequency of neuronal synchronization, which is obviously associated with cognitive processing, is $\simeq 1$ kHz and might well be identifiable with f_m. The maximum rate of neuronal firing is slightly below kHz: this rate however corresponds to the rate of quantum jumps rather than oscillation frequency at space-time level.

4.3.4 Bose-Einstein condensates of bosonic molecular ions

Also biologically relevant bosonic molecular ions such SO_4^{2-}, CO_3^{2-}, NO_3^-, NO_2^- could form Bose-Einstein condensates. The cyclotron frequencies for bosonic molecular ions satisfying the thermal stability condition $A \leq 233 \times Z$ at room temperature are typically in theta and delta band and above $f_{min} = 1.29$ Hz.

DNA is negatively charged and an interesting question is whether DNA satisfies the stability condition. The molecular weights of DNA nucleotides A, T, C, G are 132, 126, 96, 149. The molecular weight of deoxyribose sugar attached to the nucleotide is 100 and that of phosphate group PO_4^{2-} is 95. Altogether this makes molecular weights 327, 321, 291, 344. Since phosphate group is doubly charged this structure has cyclotron energy which is higher than thermal energy. Also DNA sequences satisfy the thermal stability condition. The presence of DNA Bose-Einstein condensates at magnetic flux quanta could mean that DNA can be transferred between different organisms along these space-time sheets and that DNAs of different organisms of same species could form quantum coherent systems inside regions where magnetic field can be regarded as a constant.

5 About high T_c superconductivity and other exotic conductivities

During years I have been developing a model for high T_c superconductivity (see `https://en.wikipedia.org/wiki/High-temperature_superconductivity`). The recent view is already rather detailed but the fact that I am not a condensed matter physicist implies that professional might regard the model as rather lopsided. Quite recently I read several popular articles related to superconductivity and various types of other exotic conductivities: one can say that condensed matter physics has experienced an inflation of poorly understood conductivities. This of course is an fascinating challenge for TGD. In fact, super string theorist Subir Sachdev has taken the same challenge (see `http://tinyurl.com/hu4a27f`).

In particular, the article about superconductivity (see `http://tinyurl.com/h59yqn4`) provides a rather general sketch about the phase diagram for a typical high T_c super conductor and discusses experimental support for the idea quantum criticality in standard sense and thus defined only at zero temperature could be crucial for the understanding of high T_c super conductivity.

The cuprates doped with holes by adding atoms binding some fraction of conduction electrons are very rich structured. The transition from antiferromagnetic insulator to ordinary metal involves several steps described by a 2-D phase diagram in the plane defined by temperature and doping fraction. Besides high T_c super conducting region the phases include pseudogap region, a region allowing charge oscillations, strange metal region, and metal region.

In the following I consider the general vision based on magnetic flux tubes carrying the dark $h_{eff}/n = n$ variants of electrons as Cooper pairs or as free electrons allowing to understand not only high T_c super-conductivity and various accompanying phases but also exotic variants of conductivity associated with strange and bad metals, charge density waves and spin density waves. One could also understand the anomalous conductivity of SmB_6 [L8], and the fact that electron currents in graphene behave more like viscous liquid current than ohmic current (see `http://tinyurl.com/jlgd2we`).

The TGD inspired model for the anomalous conductivity of SmB_6 as flux tube conductivity developed during last year [L8] forms an essential element of the mode. This model implies that Fermi energy controlled by the doping fraction would serve as a control variable whose value determines whether electrons can be transferred to magnetic flux tubes to form cyclotron orbits at the surface of the tube. Also the metals (such as graphene) for which current behaves more like a viscous flow rather than Ohmic current can be understood in this framework: the liquid flow character comes from magnetic field which is mathematically like incompressible liquid flow.

5.1 The phase diagram and observation

The popular article "The Quantum Secret to Superconductivity" (see `http://tinyurl.com/h59yqn4`) tells about an article published in Nature [D10] (see `http://tinyurl.com/go9k8cs`) about the work of a group o researchers at the National Laboratory for Intense Magnetic Fields (LNCMI) in Toulouse, France led by Cyril Proust and Louis Taillefer.

The popular article contains a phase diagram, which gives a bird's eye of view about high T_c superconductors and provided the stimulus for this article. The diagram describes the phases of a doped cuprate (now yttrium barium copper oxide superconductor $YBa_2Cu_3O_7$, see `https://en.wikipedia.org/wiki/Cuprate`). Doping means an addition of impurities, which bind electrons and lead to the formation of holes. Also electron doping is possible. The diagrams contains several regions representing phases of the system.

The diagram (see **Fig. 1**), which probably should not be taken too literally, can be seen as a qualitative representation of the phase transition sequence leading from an antiferromagnetic insulator to a conducting metal. It is considerably more complex than the corresponding diagram for the ordinary insulator metal transition. One starts from un-doped antiferromagnetic insulator and increases the doping fraction and ends up with metal. The holistic strategy is to try to understand all transitions and phases appearing in the entire diagram using same basic model rather than the mere transition to super-conductivity.

1. Above temperature dependent critical doping around $d = .05$ (meaning addition of impurities) a transition to so called pseudogap phase occurs. At a higher temperature dependent critical doping ratio varying in the range $(.05, .14)$ emerges a hill representing high T_c superconductivity.

2. There is also a parabola shaped region bounded at the top of super-conducting hill in which charge density wave define the ground state. In his phase kind of jerkwise conductivity

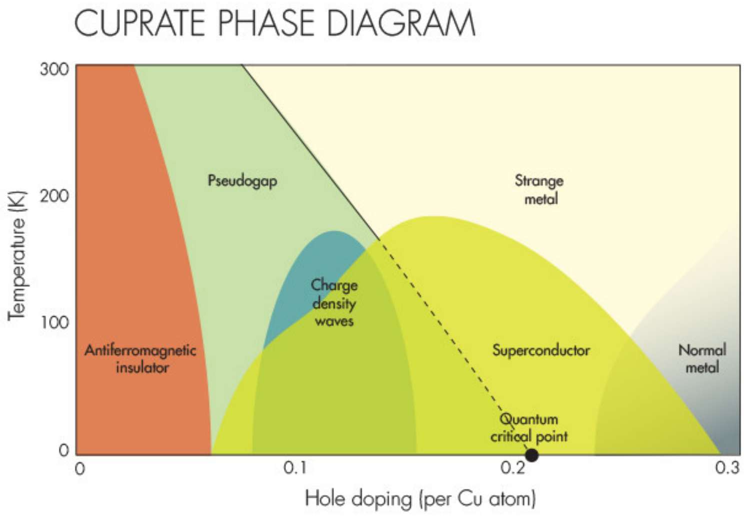

Figure 1: The phase diagram of typical high T_c superconductor

but not yet superconductivity occurs. The piece of parabola is contained in doping fraction interval between $(.08, .13)$ (reader might disagree, I apologize for my bad eye sight).

3. At temperature above 170 K and for temperature depending doping ratio decreasing with temperature linearly pseudogap is transformed to a strange metal bounded by superconductor hill below. Farthest to the right is the ordinary metal phase bounded by superconducting hill and strange metal region. Critical doping fraction for the transition from superconductivity to ordinary conductivity decreases with temperature and is in the range $(.26, .29)$.

The challenge is to understand what these regions correspond physically and what happens in the transitions between them. The crucial observation is following. The researchers realized that the line representing the boundary between pseudogap and strange metal seems to continue below the super-conducting regions. Could one destroy the superdonducting region to see whether it meets the $T = 0$ axis at the bottom and could at this point quantum phase transition occur at critical value of doping?

This was done by putting the system to a strong magnetic field of 90 Tesla destroying the superconducting phase by making Cooper pair unstable. It was indeed observed that the number of holes per Cu atom - called charge carrier density (perhaps misleadingly) - increased by a factor 6 at this critical point - actually in its vicinity since $T = 0$ is not reachable exactly. The researchers think that this might be crucial guideline in attempts to understand high T_c superconductivity and I share their belief. The understanding of what really happens in the transition to super-conductivity or rather in the transition from the pseudogap state to super-conductivity is the problem.

5.2 Alternative proposals for the mechanism of superconductivity

What has been observed is quantum critical point at $T = 0$ at which the density of holes per atom increases by a factor of 6. This does not mean that the superconducting charge carriers are Cooper pairs of holes. The phenomenon might have nothing to do with superconductivity in superconducting phase. The phenomenon is observed by using strong magnetic fields preventing superconductivity so that one in principles does not study the same system anymore.

Several hypothesis for the mechanism of super conductivity have been proposed and some of them are mentioned in the popular article (see `http://tinyurl.com/h59yqn4`) .

1. Spin density waves (mentioned in Wikipedia article but not discussed in the popular article) would take the role of phonons and induce the formation of Cooper pairs by a kind of water

bed effect. These waves do not appear in the phase diagram. Now the Coulomb repulsion forces the members of Cooper pair to reside at different lattice sites and the outcome would be d-wave Cooper pair having a note at origin. In TGD the members of Cooper pair at parallel flux tubes so that also now d-wave is obtained for spin singlet state and p-wave for spin triplet.

2. Charge density wave fluctuations would somehow be involved with the formation of Cooper pairs. Phase diagram for charge density fluctuations does not support this picture since the superconducting regions is much larger. Transitions to superconductivity can happen from 4 regions: pseudo gap region, the regions with fluctuating charge density, strange conductor, and ordinary conductor. Also spin density wave fluctuations could have similar role.

3. A phase transition occurring to the anti-ferromagnetic phase is suggested to somehow induce the formation of Cooper pairs. The called Merlin-Wagner theorem stating the absence of breakdown of continuous symmetry in two-dimensional models of statistical physics at non-zero temperatures does not support this hypothesis. One could circumvent this problem by assuming that only patches forming kind of checkerboard consisting of super-conducting and non-superconducting regions can develop in 2-D. No checkerboards have been observed. Note that there is however an objection against Merlin-Wagner theorem. Antiferromagnetic order has been detected in undoped cuprates with the same 2-D structure.

Subir Sachdev is a super string theoretician, who has been developing superstring inspired methods - in particular AdS/CFT correspondence - to study quantum critical phenomena. Sachev and collaborators have developed methods for studying "strange metals". These systems are exceptional in that they do not have any quasiparticle excitations. Sachev has correctly predicted charge density fluctuations in high T_c superconductors and also proposed that the precursor for high T_c superconductivity would be what he calls fractionized Fermi liquid meaning fractional spin and charge. One would have something like ordinary conductivity but with fractional charges. This phase could correspond to strange metal.

5.3 TGD proposal for the mechanism of high T_c superconductivity

The challenge for TGD inspired qualitative model is to understand these phases in terms of magnetic flux tubes and dark electrons possibly forming Cooper pairs at them.

5.3.1 Formulation of the model

The starting point is the model developed hitherto.

1. Consider first Merlin-Wagner theorem as an objection against breaking of 2-D continuous symmetries. TGD suggests however a mechanism allowing a breakdown of 2-D continuous symmetries (by strong form of holography TGD space-time is almost 2-D as far as scattering amplitudes are considered: string world sheets and partonic 2-surfaces). The continuous symmetries in question include supersymplectic transformations having conformal structure meaning that the generators are labelled by conformal weights which come as integer multiples of generating weights. This symmetry breaking would lead from the original symmetry algebra to its sub-algebra isomorphic with the original. Just a zoom up of the original symmetry would be the outcome! Maybe Merlin and Wagner could tolerate this!

   Now one would have something different from a checkerboard of patches. There would be quantum critical phase in which a phase containing Cooper pairs at short flux tubes with Planck constant $h_{eff}/h = n_1$ and phase containing long flux tubes with $n_2 > n_1$ but no Cooper pairs at them. There would be fluctuationS between these phases. Fluctuation would have in ZEO as correlate space-time surface connecting three surfaces at opposite boundaries of CD such that the values of n would be different at them [L11] (see `http://tgdtheory.fi/public_html/articles/phasetransitions.pdf`).

2. The earlier model [L9] (see `http://tgdtheory.fi/public_html/articles/newsupercond.pdf`) identifies the pseudogap as quantum fluctuating phase in which there isA competition

between short and long flux tubes pairs related by re-connections for short flux tubes containing Cooper pairs such that their members are at parallel flux tubes of pair carrying magnetic fields in opposite direction. Long flux tubes canot carry Cooper pairs and this together with fluctuations spoils macroscopic super-conductivity in pseudogap phase and makes it a poor conductor.

Pseudogap is present in the density of states since part of electrons goes to the short flux tubes. The transition to superconducting phase identified in terms long flux tubes carrying Cooper pairs would occur when Cooper pairs go also to the long flux tubes and would be analogous to the percolation phase transition in which water begins to dribble through a sand layer. Pseudogap phase is quantum critical: zero energy ontology (ZEO), which allows to see quantum theory as a square root of thermodynamics at single particle level indeed allows quantum criticality also at non-vanishing temperatures.

3. Strange metal phase can be identified as a phase in which only short super-conducting flux tubes are present and carry supra currents but in short scales only. Since Cooper pairs have spin zero, the charged currents do not carry spin: this conforms with the observation that the resistance for spin currents has different temperature dependence than for charged currents. Therefore the generalization to 2-D case of the charge-spin separation possible in 1-D case (but also in this case non gauge-invariant notion, (see `http://tinyurl.com/znsver8`) is not needed. Quite generally, the possibility of short scale $S = 0$ super conductivity could explain the charge-spin separation.

   The fact that scattering leads from dark phase at flux tubes to ordinary phase could explain the linear temperature dependence of the resistance of strange metals. In ordinary metals the dependence is quadratic: the reason is that the number of initial and final state electrons is proportional to T. If the number of dark Cooper pair at flux tubes does not depend on temperature one obtains linear dependence.

   The absence of quasiparticle excitations in strange metal would be due to the fact that Cooper pairs are dark and at magnetic flux tubes. Both n_1 and $n_2 > n_1$ phase would be present below critical doping fraction in the experiment discussed and would correspond to a situation in which there is fluctuation between the short length scale superconductivity and long length scale flux tubes not containing Cooper pairs. The strong magnetic field used in the experiment would not destroy the long flus tubes and the quantum critical phase would survive.

4. The quantum critical phase transition discussed in the article at zero temperature and critical doping fraction increases the number of holes per copper atom by a factor 6. Also this can be understood qualitatively. The transfer of electrons to dark Cooper pairs generates holes. In pseudogap region the long flux tubes do not carry Cooper pairs. As the phase transition occurs, only short flux tubes remain and accept pairs maximal number so that the number of holes per copper atom increases. Also the properties of pseudogap can be understood. Pseudo gap means a low density of states at certain points of Fermi surface (the point defines a preferred direction of current) and is known to be only in direction parallel to CuO bonds: this can be understood if flux tubes are parallel to them.

5.3.2 Charge density waves and spin density waves and their fluctuations

Can TGD say something interesting about charge density waves (see `https://en.wikipedia.org/wiki/Charge_density_wave`) and spin density waves (see `https://en.wikipedia.org/wiki/Spin_density_wave`)?

1. Charge density wave defines a ground state of the system having lower energy than the state with constant density of electrons. These waves are periodic standing waves with wavelength $\lambda = \hbar/k_F$. Wavelength does not in general correspond to a multiple of lattice constant. In presence of these waves conduction occurs in random jerkwise fashion like the water dribbling from faucet. The standard explanation for the jerkwise current is that the charge density wave is in a potential well caused by defect and when the electric field exceeds the critical value it is released and slides generating an ohmic current. Below the threshold the system would behave as an insulator.

2. Spin density waves are very similar to charge density waves: instead of charge, the direction of spin varies in oscillatory manner with wavelength defined by Fermi wave vector in ground state. Also now a current is formed in direction of the magnetic field above critical value of magnetic field. Sliding mechanism is proposed also now as the underlying mechanism of conductivity.

3. The key question is where a spatially varying fraction of charge/spin goes as charge/spin density wave is formed. In TGD Universe the answer would be rather obvious: "To flux tubes!". Both charge density wave and spin density could involve a sequence of magnetic flux loops with a period defined by k_F so that supra currents could flow below this length scale. Charge density wave could result from a transfer of electrons to flux tubes producing oscillator charge density at the flux tube inducing corresponding charge density oscillation in lattice. In the case of spin density wave the spin directions would be correlated at flux tubes and induce corresponding correlation in the lattice.

4. The conductivity associated with charge density wave above critical electric field could correspond to a kind of premature and temporary phase transition to super-conducting phase in which long flux tubes contain Cooper pairs but are still unstable. In the transition to superconductivity a reconnecting to long flux loop looking like long and thin rectangle would be formed by reconnections. One would have a system fluctuating between short and long scale superconductivities. One could of course consider also sliding of the flux tubes but this does not seem so plausible option in TGD framework.

   The conductivity induced by critical magnetic field could be understood if the magnetic field induced a phase transition reconnections transforming the periodic short flux tube structure to a pair of long flux tubes. Why the magnetic field would induce this, is not clear. Same question of course applies in the case of the critical electric field inducing the generation of current in charge density wave.

5.3.3 The role of doping fraction

Can one understand the role of doping fraction?

1. The number of holes per copper atom depends on the doping fraction. The holes would be created when dark Cooper pairs are generated. If the density of dark Cooper pairs increases dramatically at critical doping fraction, the density of holes must increase. Somehow the over-critical doping fraction would favor the formation and stability of short dark flux tubes. Maybe it becomes energetically more favorable for electrons to go to flux tubes. This might relate to cyclotron energy proportional to h_{eff} at flux tubes and Fermi energy E_F: a kind of resonant transfer suggests itself.

   For some time ago I constructed a model for the anomalous conductivity of SmB_6 in external field in terms of Haas-van-Alphen effect for non-standard value of h_{eff} [L8] (see `http://tgdtheory.fi/public_html/articles/SmB6.pdf`). A resonant transfer of electrons to flux tubes occurs if the energy energy at the surface of the Fermi sphere corresponds to energy for a cyclotron orbit at the surface of the flux tube. The largest orbit at Fermi sphere would be at the surface of the flux tube. This implies the occurrence of Haas van Alphen as a periodic dependence of magnetization on the value of external magnetic field $1/B$ and also explains also the anomalous conductivity of SmB_6 as flux tube conductivity occurring when the resonance condition is satisfied.

   A rather natural expectation is that same happens now. The doping fraction would control the value of Fermi energy, and this in turn would control the rate for the leakage of electrons to Cooper pairs at flux tubes by resonance condition. If the dependence of the Fermi energy on doping fraction is slow this could allow to understand why an entire range of doping fractions is possible. That the electrons must have Fermi energy must correlate with the wave length of of charge and spin density waves. The length of the short flux tube loop corresponds to Fermi wave vector.

   There is also a feedback effect involved. When electrons become Cooper pairs at short flux tubes, their density in lattice is reduced and this reduces Fermi energy so that resonance condition might fail to be satisfied. If flux tubes carry monopole flux, flux is quantized and the value of the magnetic field depends on the thickness of the flux tube, which could also be dynamical.

2. Below critical doping fraction long flux tubes would be possible but would be unstable and unable to carry stable Cooper pairs. The reason could be that the resonance condition for the transfer fails to be satisfied (the thickness of long flux tubes would not satisfy the resonance condition). Superconductivity and strange metal property would disappear above certain temperature dependent value of the doping fraction. Also this could be understood in terms the failure of the resonance condition for both short and long flux tubes. In the charge density wave region the resonance condition would be satisfied for the long flux tubes.

5.3.4 Connection with Sachdev's ideas

Sachdev's ideas mentioned above have correspondences in TGD. AdS/CFT is central in Sachev's approach and it has been also proposed as a solution of so called sign problem (see http://tinyurl.com/h9ogjjd) plaguing QFT models and statistical physics models in dimension $D \geq 3$. Sign problem gives one additional good reason for the localization of the induced spinor fields at 2-D string world sheets in TGD framewwork [K21].

1. AdS/CFT relies on conformal symmetry: in TGD framework the conformal symmetry is generalized to super-symplectic symmetry and other symmetries having conformal structure and assignable to the boundary of light-cone and to the light-like orbits of partonic 2-surfaces at which the induced metric changes its signature from Minkowskian to Euclidian.
2. TGD Universe is quantum critical so that also this aspect is shared. AdS/CFT correspondence relies on holography: in TGD framework one has strong form of holography and one can say that the 10-D bulk is replaced with 4-D space-time surface in $M^4 \times CP_2$.
3. Charge and spin fractionization are plausible also in TGD: the unit would be scaled down by $1/n$ ($h_{eff}/h = n$) and in twistorial approach [K23] this is understood quite satisfactorily.
4. Also in TGD the precursor would be strange metal. I have already explained how charge spin separation reflecting itself as different temperature dependences of resistances for charged and spin currents and the linear dependence of resistivity on temperature can be understood.

There are also differences. In TGD framework strange conductor would be flux tube superconductor in short length scales with $h_{eff}/h = n_1 < n_2$ rather than fractional ordinary conductor.

5.3.5 Bad and strange metals and metals behaving like water

Besides high T_c superconductors there are also other exotic conductors such as strange and so called bad metals http://tinyurl.com/zzzyenp) difficult to understand using the ideas of existing condensed matter physics.

In the case of bad metals (see http://tinyurl.com/k54k9oa) the conductivity is low but is preserved to too high temperatures. The problem is that if the electrons scatter as usual the time τ between collisions becomes too small and at higher temperatures Uncertainty Principle requiring $T \times \tau \geq h$ fails to be satisfied. Quite recent proposal [D16] is that current carrying electrons somehow disappear and this fluctuation is not only responsible for low but on-vanishing conductivity. These fluctuations could be due to the quantum critical fluctuations transforming electrons to Cooper pairs at short flux tubes. Bad metal would be unable to decide whether to be an insulator or strange metal.

Also graphene behaves in a strange manner (see http://tinyurl.com/hffdl8s) in the sense that currents behave more like viscous liquid flow rather than ohmic currents. The presence of vortices is a basic signal about this. A model assuming a negative resistance allowing electrons to move in "wring direction" in electric field is considered as an explanation. To me this option looks tricky.

Liquid like behavior might be understood if the currents flow at magnetic flux tubes. Magnetic field is mathematically analogous to an incompressible liquid flow. Flux tubes would be like water pipes forming a network and the topology of the ohmic currents would reflect the topology of this loopy magnetic network. The direction of the electric field inside flux tube space-time sheet would be parallel to the flux tube so that negative resistance would not be required: electric field would change direction locally rather than resistance its sign. In long scales at the space-time sheets assignable to the ordinary matter the direction of electric field would be constant. The phenomenon would reflect many-sheetedness of space-time lost in the gauge theory limit of TGD. Note that if currents are supra currents along flux tube pairs in short scales, there would be no resistivity in these scales.

To sum up, the notions of magnetic flux tube and dark matter hierarchy suggest common mechanisms for all the exotic conductivities. From this it is of course a long way to quantitative models.

5.4 New findings about high-temperature super-conductors

Bozovic et al have reported rather interesting new findings about high T_c super-conductivity: for over-critical doping the critical temperature is proportional to the density of what is identified as Cooper pairs of electronic super-fluid. Combined with the earlier findings that super-conductivity is lost - not by splitting of Cooper pairs - but by reduction of the scale of quantum coherence, and that below minimal doping fraction critical temperature goes abruptly to zero, allows to add details to the earlier TGD inspired model of high T_c super-conductivity. The super-conductivity would be indeed lost by the reconnection of flattened square shaped long flux loops to shorter loops of pseudogap phase. Quantum coherence would be reduced to smaller scale as h_{eff} is reduced. Transversal flux tube “sound waves” would induce the reconnections. Electrons at flux loops would stabilize them by contributing to the energy density and thus to the inertia increasing the string tension so that the average amplitude squared of oscillations is reduced and critical temperature increases with electron density.

5.4.1 Results

A popular article in Phys.org (see `http://tinyurl.com/htr2qjj`) tells about new interesting results about high T_c superconductivity. Bozovic et al have published in Nature an article titled “*Dependence of the critical temperature in overdoped copper oxides on superfluid density*” (see `http://tinyurl.com/gqo9j67`) [D12]. The abstract of the article gives first glimpse about the work.

> *The physics of underdoped copper oxide superconductors, including the pseudogap, spin and charge ordering and their relation to superconductivity is intensely debated. The overdoped copper oxides are perceived as simpler, with strongly correlated fermion physics evolving smoothly into the conventional BardeenCooperSchrieffer behaviour. Pioneering studies on a few overdoped samples indicated that the superfluid density was much lower than expected, but this was attributed to pair-breaking, disorder and phase separation. Here we report the way in which the magnetic penetration depth and the phase stiffness depend on temperature and doping by investigating the entire overdoped side of the La2xSrxCuO4 phase diagram. We measured the absolute values of the magnetic penetration depth and the phase stiffness to an accuracy of one per cent in thousands of samples; the large statistics reveal clear trends and intrinsic properties. The films are homogeneous; variations in the critical superconducting temperature within a film are very small (less than one kelvin). At every level of doping the phase stiffness decreases linearly with temperature. The dependence of the zero-temperature phase stiffness on the critical superconducting temperature is generally linear, but with an offset; however, close to the origin this dependence becomes parabolic. This scaling law is incompatible with the standard BardeenCooperSchrieffer description.*

I do my best in order to understand what this says. The Wikipedia article (see `http://tinyurl.com/b25sucr`) helps to get overall view about high T_c superconductivity. The Phys.org article (see `http://tinyurl.com/htr2qjj`) gives first clues in attempts to understand what the abstract says. The earlier article of Bozovic et al (see `http://tinyurl.com/hk88h5w`) [D11] stating that the loss of super-conductivity does not mean splitting of Cooper pairs but loss of quantum coherence or rather its reduction to shorter length scale gives additional insights.

In the following I proceed by self-Socratean method by making questions and bringing in the TGD view based on quantum criticality and magnetic flux tube pairs as carriers of members of Cooper pairs responsible for the supra current.

5.4.2 Basic notions

I try first to understand the notions of doping and phase stiffness.

1. In the work under discussion [D12] overdoped cuprate superconductors were studied. Doping by holes and electrons is possible. Underdoped superconductors are studied and are not well-understood. Superconductivity appears in some range for the values of the doping fraction: the minimal doping is typically something like .05 for holes and .2 for electrons from the diagram of Wikipedia article.

   "Overdoping" is achieved by the addition of strontium atoms as impurities. It had been already known that overdoping induces a reduction of the density of electron pairs and that critical temperature is reduced as a consequence. In the experiments discussed the critical temperature was found to depend linearly on the density of what was identified as super-fluid electron pairs linearly and going to zero as the doping fraction increases. In TGD pairs would correspond to small scale super-conductivity.

   There is also the notion of self-doping, see the popular article titled "*Self-doping may be the key to superconductivity in room temperature*" at `http://tinyurl.com/jxrdagm` telling about the article of Magnuson et al [D18] (see `http://tinyurl.com/zvfhqu2`). There are mysterious chains between the lattice planes of cuprate carrying negative charge. Self doping means that the system itself generates them and controls the charge density at them. Could these chains be associated with the flux tube pairs carrying the Cooper pairs in TGD framework?

2. Phase stiffness refers to the phase of a complex order parameter (see the article "*Weak phase stiffness and nature of the quantum critical point in underdoped cuprates*" of Yildrim and Ku at `http://arxiv.org/abs/1302.7317`), which might correspond to that assignable to the short range super-conductivity (or superfluidity as authors identify it). One poses twisted boundary conditions forcing the phase to vary spatially. How this is done, I do not understand.

   The phase stiffness corresponds to energy density forced by these boundary conditions. In lowest order approximation energy density is proportional to the square of the gradient of the phase and coefficient is analogous to string tension. This parameter is proportional the density of Cooper pairs theoretically. The strange thing is that phase stiffness goes to zero below the minimal doping rather than going to zero smoothly. In overdoped region the phase stiffness at zero temperature limit was found to depend linearly on the critical temperature.

5.4.3 TGD based model for the findings

TGD inspired model for high T_c superconductivity and bio-superconductvity have been developed gradually during two decades [**?**, K1, K2, K15, K16] [L9, L10]. The new results allow to add new details to this model, in particular to the understanding of what happens when the superconductivity is lost.

1. The popular article says that the critical temperature is controlled by the 2-dimensional density of electron pairs identified as super-fluid Cooper pairs. They would correspond to the so called pseudogap phase. An important point is that super conductivity is not lost due to the breaking of Cooper pairs as in the ordinary super-conductivity but due to too small value of the density of electron pairs: this is also the TGD view. In an earlier work to which Bojovic also contributed it is claimed that super-conductivity is lost due to the loss of quantum coherence rather than splitting of Cooper pairs [D11] (see `http://tinyurl.com/zmbeynz`).

Both these findings conform with the TGD view that transition to super-conductivity means a phase transition increasing the value of h_{eff} increasing the range of quantum coherence scaling like h_{eff}. Cooper pairs exist also in pseudogap phase and can have non-standard value of h_{eff} but the closed flattened square shaped flux loops along which the members of pairs flow are too short to give rise to super-conductivity in macroscopic scales. in TGD framework the electron super-fluid about which the article talks would correspond to short scale superconductivity.

The density of Cooper pairs for small value of h_{eff} identified by authors as super-fluid carriers would be the critical quantity: for some range of this parameter the h_{eff} increasing phase transition would take place. This range would in turn correspond to a range for the energy assignable to the pair if the energy is proportional to 2-D Fermi energy.

2. This allows to consider TGD based model of high T_c super-conductivity in which Cooper pairs have their members at parallel magnetic flux tubes closing to a loop and carrying magnetic fluxes in opposite direction in the case of antiferromagnet. In pseudogap phase the pairs would have their members at the flux tubes with opposite spin directions. In the phase transition to superconductivity the value of h_{eff} would increase and the flux tubes would reconnect to much longer flux tubes and macroscopic super current would flow.

3. What happens in the phase transition increasing h_{eff} giving rise to superconductivity in macroscale? The lengths of closed flux loops are scaled up in reconnection. Longitudinal energy is not affected. It seems that the transversal distances between flux tubes cannot change.

   What happens to the strength of magnetic field? Is should be reduced to keep cyclotron energy proportional to $h_{eff}B$ constant? For monopole flux, flux conservation requires that magnetic flux BS does not change so that the area S of the flux tube would scale like h_{eff}. That cyclotron energy is not changed at all would conform with the intuition about quantum criticality.

4. Why the phase trasition to larger h_{eff} phase occurs only above the critical temperature? Why these flux loops are unstable against reconnection above critical temperature? Cooper pairs do not split but reconnection splitting long closed flux loop to a sequence of shorter ones takes place.

   Some energy assignable to large h_{eff} flux tubes is reduced below the thermal energy above critical temperature and a transition to small h_{eff} phase. In reconnection process the parallel flux tubes with opposite fluxes touch each other. This touching occurs if there are oscillations of flux tubes in transversal direction analogous to transversal sound waves.

   Does the average amplitude of transversal "sound waves" become so large above critical temperature that reconnections occur? This brings in mind ordinary BSC superconductivity in which phonon-electron interaction makes possible formation of Cooper pairs as bound states. Phonons for the ordinary super-conductvity however corresponds to lattice oscillations and make superconductivity possible. Now just the opposite happens.

5. What the proportionality of T_c to the density of small Cooper pairs could mean? The energy of transversal phonon is proportional to its amplitude squared. If the amplitude and thus energy is above critical value the reconnection occurs.

   Why the critical thermal energy increases with the density of small Cooper pairs? Does the presence of Cooper pairs stabilize the flux tubes: for too small density flux tubes are not stable since their string tension is too low and they are too soft and have large amplitude of thermal fluctuations.

   Does the presence of Cooper pairs increase the inertia of flux tubes and therefore their string tension? The hermal energy of stringy sound waves proportional to critical temperature becomes proportional to electron density if the electron density dominates in string tension. This would explain also the lower critical value for the doping fraction. Below it flux tubes become so soft that reconnection occurs too fast to allow super-conductivity at all. Above pseudogap temperature even the short loops would become unstable.

What we have obtained? In TGD framework the super-conductivity is not spoiled by the splitting of Cooper pairs but by the reconnection of flattened square shaped long flux loops. Super-conductivity is lost by the reconnection of flattened square shaped long flux loops to shorter loops of pseudogap phase, which is super-conducting but in smaller scale. Transversal flux tube “sound waves” induce the reconnections. Electrons at flux tubes stabilize them by contributing to the energy density and thus to the inertia increasing the string tension so that the average amplitude squared of oscillations is reduced and critical temperature increases with electron density.

6 Self Hierarchy And Hierarchy Of Weakly Coupled Super Conductors

The realization that bio-systems are full of macroscopic quantum phases led to the general idea about the dynamical realization of the self-hierarchy as a master-slave hierarchy formed by weakly coupled super conductors. It is now clear that mere Josephson currents are not enough: the breaking of super-conductivity due to leakage of supra currents from the super-conducting space-time sheets might also be an essential part of bio-control. A possible general conclusion is that Josephson currents are responsible for coordination whereas dissipative currents are related with the control aspect. The idea about charge entanglement made possible by W MEs and generating the dissipative currents makes this vision more precise.

One of the great ideas was that soliton sequences associated with the Josephson currents underly nerve pulse sequences. This idea turned out be be wrong as such: as a matter, soliton sequences correspond to various bio-rhythms such as kHz resonance frequency and various EEG rhythms in the recent model and nerve pulses could be understood as a perturbation of this sequences when rotational motion of some pendulum in the sequence of penduli becomes oscillatory. Since home-ostasis as a many-sheeted ionic flow equilibrium involves also Josephson currents in an essential manner, it would be however light hearted to assume that Josephson currents and the dynamics at the level of cell membrane were totally uncorrelated. The model for sol-gel phase transition indeed demonstrates that Josephson currents generate Josephson photons crucial for stabilizing gel phase.

The hierarchy of favored Planck constants predicted by the Mersenne hierarchy implies a hierarchy of Josephson junctions defined by cell membranes and the value of Planck constants defines the evolutionary level of cell. As already noticed, EEG radiation and its fractal generalization and bio-photons can be identified as decay products of dark Josephson radiation in the case that the cell membrane space-time sheet is almost vacuum extremal. The frequency of the possible Josephson currents associated with the atomic space-time sheets of the cell membrane (or some larger space-time sheets with the same potential difference by the average many-sheeted ir-rotationality of the cell membrane electric field) corresponds in the resting potential of about -70 mV. For almost vacuum extremal option the Josephson currents could define bio-rhythms in extremely wide range from 10^{-15} s time scale to time scales comparable to the duration of life cycle.

Also hierarchies with levels characterized by the size scale of the membrane like structure involved can be considered but experimentally the situation remains open. Potential differences are in any case limited by the condition that Josephson energies are above thermal threshold. One possibility is that pairs or parallel super-conducting magnetic flux tubes form Josephson junctions. Indeed, at the higher levels of dark matter hierarchy one obtains both time-like and space-like soliton sequences and their Lorentz boosts.

What remained open in the earlier picture was the relationship between Josephson current circuitry and EEG, and nerve pulse generation and the possible analogs of EEG, ZEG (and WEG) and nerve pulse generation in various other frequency scales. The possibiity of generalized EEG hierarchy associated with dark matter hierarchy lead to a general quantitative picture in this respect and allows to interpret the components of generalized EEG in terms of cyclotron radiation and Josephson radiation as a response to cyclotron radiation. The general manner to code information about sensory input and motor actions is in terms of frequency modulation of the EEG frequencies defining EEG rhyths. A fascinating possibility is that scaled up variants of nerve pulses with typical time scale of about 2 seconds instead of millisecond associated with say neuronal bi-layers are realized in higher vertebrates. At the next level the “nerve pulses” would have duration of order 1.1 hours.

Supra currents running parallel to the axon suggest an important additional piece to the picture about of quantum control. Constructive interference of supra currents leads to a large net Josephson current and various biological clocks could rely on this mechanism. When reference supra current representing the expected sensory input and a current representing real sensory input and flowing in parallel manner in weakly coupled super conductors, are sufficiently near to each other, constructive interference of the Josephson currents occurs and can give rise to a synchronous firing. This makes possible conscious comparison circuits. Conscious novelty detectors can be build easily from comparison circuits using inhibitory and excitatory synaptic connections.

It must be emphasized that detailed models cannot be taken too seriously. There are simply quite too many new physic mechanisms to be considered. The following considerations actually represent the first general vision about the role of super conductivity in living matter, and also this is a good reason for not taking them too literally. As in the case of other similar sections, I have made the decision to keep it as such since the general vision might apply also in the recent framework although it failed in the original model of nerve pulse and EEG. The replacement of the representation of Josephson junction by magnetic flux tubes carrying dark variants of electrons and ions might provide a general realization of the vision. For instance, standing wave solitons associated with the Josephson currents between cytoskeletal microtubules and regions of the cell membrane could be involved with DNA - cell membrane TQC. These currents - at least in the case of axons- might be also responsible for ordinary EEG (note that a hierarchy of fractal variants of EEG are predicted [K5].

6.1 Simple Model For Weakly Coupled Super Conductors

Several kinds of Josephson currents between cell interior and exterior are possible. Solitons represent quantized Josephson currents which are large and able to facilitate the generation of nerve pulse in the case of Na_+ and Ca_{++}. Soliton sequences are the simplest solutions of Sine-Gordon equation for the Josephson junctions associated with a linear structure such as axon idealized as an infinitely long and thin cylindrical surface and are mathematically equivalent with a rotating gravitational pendulum.

The most general formulation starts from the Klein-Gordon equation for the order parameters Ψ_i, $i = 1,2$ for the super-conductors coupled linearly to each other in the junction

$$\begin{aligned} D\Psi_1 &= m^2\Psi_1 + m_{12}^2\Psi_2 \ , \\ D\Psi_2 &= m^2\Psi_2 + m_{12}^2\Psi_1 \ , \\ D &= (\partial_\mu + iZeA_\mu)(\partial_\mu - iZeA_\mu) \end{aligned} \tag{6.1}$$

Here m denotes the charge of the super-conducting particle (say Cooper pair) and m_{12}^2 is real parameter characterizing the coupling between the super conductors. A_μ denotes electromagnetic vector potential associated with the super conductors. D denotes d'Alembert operator $\partial_t^2 - \nabla^2$.

Weakly coupled super conductors are assumed to possess cylindrical symmetry and can regarded as inner and out cylinder with Josephson junctions idealized with smooth distribution of them. If ME acts as Josephson junctions this assumption is exact. Weak coupling means that that the densities of charge carriers are same at the two sides of the junction in a good approximation:

$$\Psi_i = \sqrt{n}exp(i\Phi_i) \ , \ i = 1,2 \ . \tag{6.2}$$

Under these assumptions one obtains for the phase difference $\Phi \equiv \Phi_1 - \Phi_2$ the Sine-Gordon equation with a coupling to the vector potential

$$\partial^\mu \left[\partial_\mu \Phi - q\Delta A_\mu\right] = m_{12}^2 sin(\Phi) \tag{6.3}$$

ΔA_μ denotes the difference of the vector potential over the junction. q denotes the charge of the super-conducting charge carrier.

Note that Lorentz gauge condition

$$\partial_\mu A^\mu = 0 \tag{6.4}$$

does not trivialize the coupling to the vector potential since the equation holds true only in 3-dimensional surface defining the junction and the contribution from the direction of the normal is not present.

Josephson current J_J can be identified as the divergence of the 4-current $j_\mu = Ze\rho = Ze\Psi^*(\partial_\mu^{\rightarrow} - \partial_\mu^{\leftarrow})\Psi$ at the either side of the junction.

$$J_J = \partial_\mu J^\mu = Ze \times \frac{n}{m} \times m_{12}^2 sin(\Phi) \ . \tag{6.5}$$

The Josephson current per unit length of axonal membrane of radius R and thickness d is given by

$$J = Ze \times \frac{n2\pi Rd}{m} \times m_{12}^2 sin(\Phi) \ . \tag{6.6}$$

The parameter m_{12}^2 is analogous to the inverse of the magnetic penetration length squared ($\hbar = c = 1$) for the super-conductors involved.

$$m_{12}^2 = \frac{1}{\Lambda^2} \ . \tag{6.7}$$

If one can regard the Josephson junction region as a defect in a super-conductor, Λ is apart from a numerical constant of order unity equal to the thickness of the Josephson junction. In the case of the cell membrane this would mean that the small oscillations associated with the Josephson junction have frequencies of order 10^{16} Hz and correspond to quanta with energies of order 100 eV.

The covariant constancy conditions

$$\begin{aligned} \partial_t\Phi &= ZeV(t,z) \ , \\ \partial_z\Phi &= ZeA_z(t,z) \ . \end{aligned} \tag{6.8}$$

are mutually consistent only if the electric field in the axial direction vanishes. They are not however consistent with the right hand side of the equation and only one of the conditions can be satisfied. The condition effectively reduces the equation to an ordinary differential equation. Of course, one cannot assume the condition for general solutions.

For a constant potential difference V_0 the Josephson current is sinusoidal for $\partial_t\Phi = ZeV_0$ ansatz with the basic frequency given by $\omega = eV_0$. An exact treatment replaces the sinusoidal time dependence of Φ with the time dependence of the angle coordinate of gravitational pendulum so that higher harmonics are involved. In the case of cell membrane $V(t)$ is typically a sum of constant part and time dependent part giving rise to frequency modulation of the basic Josephson current:

$$\omega(t) = eV = eV_0 + eV_1(t) \ .$$

Entire hierarchy of frequency modulations is possible since also eV_1 can be frequency modulated by Josephson currents.

6.2 Simplest Solutions Of Sine-Gordon Equation

Free Sine-Gordon equation resulting, when the coupling to the em field can be neglected, gives a good view about the solutions of full equation. In cylindrical geometry Sine-Gordon equation becomes effectively 2-dimensional under rather natural conditions. This is rather nice since two-dimensional Sine-Gordon equation is completely integrable and thus allows an infinite number of conserved charges [?].

Sine-Gordon equation allows two kinds of vacua. The vacua of first type correspond to $\Phi = 2n\pi$ ground state configuration and vacua second type to $\Phi = (2n+1)\pi$. The small perturbations around these vacua correspond to massive 1+2 dimensional free field theory with field equations

$$\begin{aligned}
D\Phi &= \epsilon\frac{1}{\Lambda^2}\Phi \ ; \\
D &= \partial_t^2 - \nabla^2 \ , \\
\epsilon &= -1 \ \text{for} \ \Phi = n2\pi \ , \\
\epsilon &= 1 \ \text{for} \ \Phi = (2n+1)\pi \ .
\end{aligned} \tag{6.9}$$

In the language of quantum field theory, the small perturbations around $\Phi = n2\pi$ describe particle with mass squared $m^2 = \frac{1}{\Lambda^2}$ whereas the small perturbations of the $\Phi = (2n+1)\pi$ vacuum describe tachyons with negative mass squared $m^2 = -\frac{1}{\Lambda^2}$. Therefore these vacua will be referred to as time like and space-like respectively.

One might argue that the space-like vacua are un-stable in the case that the continuous sheet of the Josephson junctions consists actually of discrete Josephson junctions, whose dynamics is given by the differential equation

$$\frac{d^2\Phi}{dt^2} = -\frac{sin(\Phi)}{\Lambda^2}$$

allowing only $\Phi = n2\pi$ as stable ground state. For MEs acting as Josephson junction the situation is different. On the other hand, the ground state at which soliton generation is possible should be quantum critical and hence very sensitive to external perturbations. Note that time like and space-like sectors in axonal portion of neuron are permuted by a duality transformation $z \leftrightarrow vt$ (v=c=1), $\Phi \rightarrow \Phi + \pi$, which is exact symmetry of the 1+1-dimensional Sine-Gordon equation.

The propagating waves are of form $sin(u)$, where one has

$$\begin{aligned}
u &= \gamma_P(t - \frac{v_P z}{v^2}) \ , \ \text{time like case} \\
u &= \gamma_P(z - v_P t) \ , \ \text{space-like case} \\
\gamma_P &= \sqrt{\frac{1}{1-(\frac{v_P}{v})^2}} \ .
\end{aligned} \tag{6.10}$$

Here v_P is the velocity parameter characterizing the boost. The frequency of these small propagating oscillations (plane waves) is in two cases given by

$$\begin{aligned}
\Omega &= \frac{\gamma_P v}{\Lambda} \ , \ \text{time like case} \ , \\
\Omega &= \frac{\gamma_P v_P}{\Lambda} \ , \ \text{space-like case} \ .
\end{aligned} \tag{6.11}$$

The frequency is very high for time like waves, of order 10^{10} Hz and therefore a typical time scale for the conformational dynamics of proteins. In space-like case the phase velocity of the propagating waves is $v_P < v$ and frequencies are small and one could consider the possibility of identifying these oscillations as propagating EEG waves. For the time like excitations phase velocity is $v_p = v^2/v_P > v$ and larger than light velocity. For ordinary elementary particles the situation is same but since phase velocity is in question, there are no interpretational problems.

One-dimensional solutions of the Sine-Gordon equation give quite satisfactory picture about the situation as far as the physical interpretation is considered. The simplest solutions of this type correspond to solutions depending on time or spatial coordinates only. For time like vacua one-dimensional solutions depend on time only: note that these solutions are possible for arbitrary geometry of the Josephson junction. For space-like like vacua one-dimensional solutions are possible in the axonal portions of the neuron: the simplest one-dimensional solutions depend on the axonal coordinate z only.

Field equations reduce to the equations of motion for gravitational pendulum:

$$\frac{d^2\Phi}{du^2} = -\frac{1}{\Lambda^2}sin(\Phi) \ . \quad (6.12)$$

$u = vt$ holds true in time like case ($v = c \equiv 1$ is good approximation). $u = z$ holds true in space-like case (in this case equation makes sense for axonal portions only). Energy conservation for the gravitational pendulum gives

$$\frac{1}{2}v^2(\frac{d\Phi}{du})^2 + \frac{v^2}{\Lambda^2}\left[1 - cos(\Phi)\right] = K\frac{2v^2}{\Lambda^2} \ , \quad (6.13)$$

where K is dimensionless constant analogous to energy. There are two kinds of solutions: oscillating solutions ($K < 1$) and rotating solutions ($K > 1$): single soliton solution corresponds to $K = 1$.

One can integrate the conservation law for energy to give the time/spatial period of oscillation or rotation (T/λ). For oscillating solutions one has

$$T = \frac{\lambda}{v} = \frac{\Lambda}{v}\int_{-\Phi_0}^{+\Phi_0} d\Phi \frac{1}{\sqrt{2\left[-cos(\Phi_0) + cos(\Phi)\right]}} \ . \quad (6.14)$$

Here Φ_0 is maximum value of the phase angle for oscillating solution. For the rotation period one obtains

$$T = \frac{\lambda}{v} = \frac{\Lambda}{v}\int_{0}^{2\pi} d\Phi \frac{1}{\sqrt{(\frac{d\Phi}{dt})^2(\Phi = \pi) + 2\left[1 - cos(\Phi)\right]}} \ . \quad (6.15)$$

By Lorentz-boosting space-like axonal solutions to move with velocity v_p one obtains propagating soliton sequences.

Sine-Gordon equation is completely integrable and thus allows an infinite number of conserved charges. In quantum theory the eigenvalues of mutually commuting charges characterize the quantum state and these charges are basic quantum observables. Does it make sense to quantize Sine-Gordon and could one characterize the state of the axonal membrane in terms of these charges? Here one must point out the similarity to the ideas of Nanopoulos [J6], who speculates with the possibility that certain 2-dimensional conformal field theory characterizes the state of micro-tubule and the infinite number of conserve charges characterize the information content of the micro-tubule. It is perhaps also worth of mentioning that the quantum group $SU(2)$ appears in the quantization of the Sine-Gordon equation [**?**]: could quantum groups have important applications in biology?

6.3 Are Both Time Like And Space-Like Soliton Sequences Possible Ground States?

The model for the Josephson junction predicts the existence of both time like and space-like soliton sequences. Mathematician would expect that both ground states of coupled super conductors are realized in brain. The presence of space-like and time like modes could provide general insights to brain functioning and could relate to the fundamental dichotomies of brain consciousness.

Time like soliton sequences do not in general propagate and if they propagate, the phase velocity exceeds light velocity (due to $t - vx/c^2$ dependence). The size of coherence region in the case of gap junction connected neurons can be rather large. Also micro-tubuli could form large coherent regions.

The time scales involved with the time like soliton sequence are however very fast, much faster that the time scales of EEG. This suggests that soliton sequences and oscillations are responsible for a synchronization in various scales defined by p-adic and dark matter hierarchies. One cannot exclude the possibility that the appearance of time like soliton sequences correlates with the emergence of standing EEG waves and synchronous firing whereas propagating space-like soliton sequences could accompany nerve pulse conduction. Since non-propagating collective firing does not occur, standing soliton sequences could be associated with glial cells and propagating soliton sequences with neuronal axons.

Soliton sequences could provide a general realization of biological clocks and facilitate the generation of macroscopic quantum systems. Also the gap junction connected neuron groups associated with primary sensory organs, various organs and brain could correspond to time like solitons.

For ordinary value of $\hbar$ the small oscillations for time like ground state have period of order 10^{-10} seconds: this follows solely from the spatial extension of nerve pulse of order $\Lambda \sim 10^{-2}$ meters and involves no assumptions about the detailed properties of the super conductor. These oscillations could coordinate protein dynamics. I do not know whether endoplasma membranes inside cells have resting potential: if not, they are good candidates for the carriers of time like ground states with oscillating voltage.

For cell membrane situation is different and the only possible interpretation is that the resting potential for ordinary value of Planck constant and for far-from-vacuum ground state corresponds to the 10^{-13} second time scale determined by the membrane voltage and the mechanical analog is very rapidly rotating gravitational pendulum. Almost vacuum extremal property and large values of Planck constant change the situation and $k_d = 47$ level would correspond to 5 Hz oscillation frequency. Note that the hypothesis is $h_{eff} = nh$, where n is product of distinct Fermat primes and power 2^{k_d}. These time-like soliton sequences could indeed be interpreted as standing EEG waves whereas space-like soliton sequences would correspond to propagating EEG waves. The presence of perturbations appearing at multiples of cyclotron frequencies of biologically important ions means that standing and moving waves at other frequencies are possible. Nerve pulse patterns induces frequency modulations of the corresponding Josephson currents and Josephson radiation.

Glial cells [I2] form a considerable fraction of cell population of brain are glial cells and are connected to each other by gap junctions, which can serve as Josephson junctions. In glial cells large amplitude oscillations with longer oscillation period could be present. The ciliar beating of monocellular animals [I2] could be coordinated to coherent motion (making possible swimming of the monocellular organism) by the "EEG" waves.

Gap junctions between the nerve cells are not common but are encountered in the large coherently firing groups of nerve cells in the brain, in the sensory organs and other organs such as heart. The value of the parameter K is only slightly larger than the critical value $K = 1$ for EEG since the period of EEG oscillations is typically by a factor of order 10^8 longer than the period of small oscillations. The problem disappears when higher levels of dark matter hierarchy are allowed. Of course, if the potential difference in question corresponds to the membrane potential, one must have $K \gg 1$. One can wonder whether the criticality might have some deeper significance: perhaps phase transitions between EEG: s corresponding to rotating and oscillating gravitational penduli are possible.

6.4 Quantum Tools For Bio-Control And -Coordination

Coordination and control are the two fundamental aspects in the functioning of the living matter. TGD suggests that at quantum level deterministic unitary time evolution of Dirac equation corresponds to coordination whereas time evolution by quantum jumps corresponds to quantum control. More precisely, the non-dissipative Josephson currents associated with weakly coupled super conductors would be the key element in coordination whereas resonant dissipative currents between weakly coupled super conductors would make possible quantum control.

This view allows to consider more detailed mechanisms. What is certainly needed in the coordination of the grown up organism are biological clocks, which are oscillators coupled to the biological activity of the organ. Good examples are the clocks coordinating the brain activity, respiration and heart beat [I5]. For example, in the heart beat the muscle contractions in various parts of heart occur in synchronized manner with a well defined phase differences. Various functional disorders, say heart fibrillation, result from the loss of this spatial coherence. For a control also biological alarm clocks are needed. An alarm clock is needed to tell when the time is ripe for the cell to replicate during morphogenesis. Some signal must tell that is time to begin differentiation to substructures during morphogenesis: for example, in the case of the vertebrates the generation of somites is a very regular process starting at certain phase of development and proceeding with a clockwise precision.

6.4.1 Homeostasis as many-sheeted ionic flow equilibrium

The experimental work of Ling, Sachs and Qin [I4, I6] and other pioneers [I3, I1] challenges the notions of ionic channels and pumps central to the standard cell biology. Ling has demonstrated that the ionic concentrations of a metabolically deprived cell are not changed at all: this challenges the notion of cell membrane ionic pumps. The work of Sachs and Qin and others based on patch-clamp technique shows that the quantal ionic currents through cell membrane remain essentially as such when the membrane is replaced by a silicon rubber membrane or by a cell membrane purified from channel proteins! this challenges the notion of cell membrane ionic channels. A further puzzling observation is much more mundane: ordinary hamburger contains roughly 80 per cent of water and is thus like a wet sponge: why it is so difficult to get the water out of it?

These puzzling observations can be understood if the homeostasis of cell and its exterior is regarded as an ionic flow equilibrium in the many-sheeted space-time. Ionic super currents from super-conducting controlling space-time sheets flow to controlled atomic space-time sheets and back. Currents are of course ohmic at the atomic space-time sheets. One can understand how extremely small ionic densities and super currents at cellular space-time sheets can control ionic currents and much higher ionic densities at atomic space-time sheets. Immense savings in metabolic energy are achieved if the ohmic currents at the atomic space-time sheets flow through the cell membrane region containing the strong electric field along super-conducting cell membrane space-time sheet (rather than atomic space-time sheets) as a non-dissipative supra current. This clever energy saving trick makes also the notion of ionic channels obsolete for weak ionic currents at least.

Super-conducting space-time sheets contain a plan of the bio-system coded to ion densities and magnetic quantum numbers characterizing the super currents. Bio-control by em fields affects these super currents and one can understand the effects of ELF em fields on bio-system in this framework. The model relies crucially on the liquid crystal property of bio-matter (hamburger mystery!) making possible ohmic current circuitry at the atomic space-time sheets as a part of the many-sheeted control circuitry. There is a considerable evidence for this current circuitry, Becker is one of the pioneers in the field [J4]: among other things the circuitry could explain how acupuncture works.

6.4.2 Quantum model for pattern recognition

Time translation invariant pattern recognition circuit can be realized by using two coupled super-conductors. The first super-conductor contains the reference supra current and second super-conductor contains the supra current determined by the sensory input. Supra currents are assumed to have same spatially and temporally constant intensity. If the supra currents have spatially constant phase difference, also Josephson currents are in the same phase and sum up to a large current facilitating synchronous firing. The temporal phase difference of supra currents does not matter since it affects only the overall phase of the Josephson current. Therefore patterns differing by time translations are treated as equivalent. Quite generally, the requirement of time translational invariance, favors the coding of the sensory qualia to transition frequencies.

The destructive interference of supra currents provides an tool of pattern cognition in situations when the precise timing is important. The pattern to be recognized can be represented as a reference current pattern in some neuronal circuit. Input pattern determined by sensory input in turn is represented by supra current interfering with the reference current. If interference is destructive, synchronous generation of nerve pulses in the circuit occurs and leads to a conscious pattern recognition. Obviously the loss of time translation invariance makes this mechanism undesirable in the situations in which the precise timing of the sensory input does not matter. One can however imagine situations when timing is important: for instance, the deduction of the direction of the object of the auditory field from the phase difference associated with signals entering into right and left ears could correspond to this kind of situation.

In both cases one can worry about the regeneration of reference currents. The paradigm of four-dimensional quantum brain suggests that sensory input leads by self-organization to a stationary spatial patterns of supra-currents and this process depends only very mildly on initial values. Thus self-organization would generate automatically pattern recognizers.

6.4.3 General mechanism making possible biological clocks and alarm clocks, comparison circuits and novelty detectors

Weakly coupled super conductors and quantum self-organization make possible very general models of biological clocks and alarm clocks as well as comparison circuits and novelty detectors.

The Josephson junction between two super-conductors provides a manner to realize a biological clock. Josephson current can be written in the form [D36]

$$\begin{aligned} J &= J_0 sin(\Delta\Phi) = J_0 sin(\Omega t) \ , \\ \Omega &= ZeV \ , \end{aligned} \tag{6.16}$$

where Ω is proportional to the potential difference over the Josephson junction. Josephson current flows without dissipation.

In BCS theory of super-conductivity the value of the current J_0 can be expressed in terms of the energy gap Δ of the super conductor and the ordinary conductivity of the junction. When the temperature is much smaller than critical temperature, the current density for a junction is given by the expression [D36]

$$J_0 = \frac{\pi}{2e}\frac{\sigma_s \Delta}{d} \ . \tag{6.17}$$

Here σ_s is the conductivity of the junction in the normal state assuming that all conduction electrons can become carriers of the supra current. d is the distance between the super conductors. The current in turn implies a position independent(!) oscillation of the Cooper pair density inside the two super conductors. By the previous arguments the density of the Cooper pairs is an ideal tool of bio-control and a rhythmic change in biological activity expected to result in general. Josephson junctions are therefore good candidates for pacemakers not only in brain but also in heart and in respiratory system.

In the presence of several parallel Josephson junctions quantum interference effects become possible if supra currents flow in the super conductors. Supra current is proportional to the gradient of the phase angle associated with the order parameter, so that the phase angle Φ is not same for the Josephson junctions anymore and the total Josephson current reads as

$$J = \sum_n J_0(n) sin(\Omega t + \Delta\Phi(n)) \ . \tag{6.18}$$

It is clear that destructive interference takes place. The degree of the destructive interference depends on the magnitude of the supra currents and on the number of Josephson junctions.

There are several options depending on whether both super conductors carry parallel supra currents or whether only second super conductor carries supra current.

1. If both super conductors carry supra currents of same magnitude but different velocity, the phases associated with the currents have different spatial dependence and destructive interference occurs unless the currents propagate with similar velocity. This mechanism makes possible comparison circuit serving as a feature detector. What is needed is to represent the feature to be detected by a fixed supra current in the second super conductor and the input as supra current with same charge density but difference velocity. The problem is how the system is able to generate and preserve the reference current. If case that feature detector "wakes-up" into self state when feature detection occurs, the subsequent quantum self-organization should lead to the generation of the reference current representing the feature to be detected.

2. If only second super conductor carries supra current and of this supra current for some reason decreases or becomes zero, constructive interference occurs for individual Josephson currents and net Josephson current increases: current causes large gradients of Cooper pair density and can lead to the un-stability of the structure. When the supra current in the circuit dissipates below a critical value, un-stability emerges. This provides a general mechanism of biological alarm clock.

   Assume that the second super conductor carriers a supra current. As the time passes the reference current dissipates by phase slippages [D34, D36]. If the reference current is large enough, the dissipation takes place with a constant rate. This in turn means that the Josephson current increases in the course of time. When the amplitude of the Josephson current becomes large enough, the density gradients of the charge carriers implied by it lead to a un-stability of the controlled system: the clock rings. Since the dissipation of (a sufficiently large) Josephson current takes place at constant rate this alarm clock can be quite accurate. It will be found that a variant of this mechanism might be at work even in the replication of DNA. The un-stability itself can regenerate the reference current to the clock. If the alarm clock actually "wakes-up" the alarm clock to self state, self-organization by quantum jumps must lead to an asymptotic self-organization pattern in which the supra current in the circuit is the original one. Actually this should occur since asymptotic self-organization pattern depends only weakly on the initial values.

3. Novelty detector can be build by feeding the outputs of the feature detectors to an alarm clock circuit. In alarm clock circuit only the second super conductor carries supra current, which represents the sum of the outputs of the feature detectors. Since the output of a feature detector is non-vanishing only provided the input corresponds to the feature to be detected, the Josephson current in additional circuit becomes large only when the input does not correspond to any familiar pattern.

6.4.4 How MEs could generate soliton sequences?

MEs could as bio-controllers using the same general mechanism which underlies remote mental interactions and this aspect of bio-control could be seen as endogenous remote mental interactions between cells and other parts of organism. Pairs of low and high frequency MEs are involved. Low frequency MEs, say EEG MEs, serve as correlates for quantum entanglement between body parts: already this is enough for remote viewing regarded as sharing of mental images by fusion of mental images. The psychokinesis aspect is possible by high frequency MEs propagating like massless particles inside low frequency MEs. These MEs induce bridges and thus leakage of ions between various space-time sheets at the receiving end. This means self-organization by dissipation.

MEs can also act as Josephson junctions connecting super-conducting space-time sheet characterized by p-adic primes which can be different. This kind of Josephson junction contains the em field associated with ME as an external field and the mathematical description of this coupling follows from the model for the coupling of electromagnetic field to super conducting order parameters. In Minkowski coordinates the modification of the Sine-Gordon equation is simple:

$$\partial^{\mu}\left[\partial_{\mu}\Phi - Ze\Delta A_{\mu}\right] = m_{12}^2 sin(\Phi) \ . \tag{6.19}$$

Here Φ denotes the phase difference over the Josephson junction, which is idealized with a continuous Josephson junction, and actually is a continuous Josephson junction in the case of ME. ΔA_{μ} denotes the difference of the vector potential over the junction.

The coupling to the vector potential can in the lowest order described by the condition

$$\partial_{\mu}\Phi_0 = Ze\Delta A_{\mu}$$

assumed to hold for a maximal number of components of vector potential. Here of course integrability conditions pose restrictions. One can develop perturbation series for Φ by substituting Φ_0 to the right hand side and calculating Φ_1 using the right hand side as a source term, and so on.

If the transversal em field associated with ME contains time independent radial electric field this gives rise to a constant potential term giving rise to a generation of soliton sequences. The period

Ω of rotation for the soliton satisfies $\Omega = eV$, where eV corresponds to the potential difference defined by the constant part of the electric field of ME. It can also happen that ME contains only the oscillatory electromagnetic field: if the frequency is same as the frequency associated with small oscillations of the Sine-Gordon pendulum a resonant coupling is expected to result. In this case the frequency is in radio frequency range.

Also noise is present and it is quite possible that the noise provides the energy needed to amplify the weak periodic signal provided by ME to a soliton sequence by stochastic resonance. The mechanism is discussed in detail in the chapter "Quantum model for EEG and nerve pulse". This suggests that MEs could basically control small very fast oscillations of the membrane potential.

7 Model For The Hierarchy Of Josephson Junctions

As far as hierarchy of EEGs and its generalizations is considered the hierarchy of Josephson junctions assignable to cell membrane itself is relevant. Dark matter hierarchy and p-adic fractality allow to imagine a fractal hierarchy of structures analogous to cell membrane with arbitrarily large thickness. One can even imagine scaled up variants of cell membrane with different p-adic length scale and value of Planck constant but possessing same membrane potential as ordinary cell membrane. The generalization of the imbedding space helps to understand what is involved and is discussed in Appendix.

7.1 The Most Recent Model For The Generation Of Nerve Pulse

For some time ago I learned [J2, J3, J8, J9, J10] (thanks to Ulla Mattfolk) that nerve pulse propagation seems to be an adiabatic process and thus does not dissipate: the authors propose that 2-D acoustic soliton is in question. Adiabaticity is what one expects if the ionic currents are dark currents (large $\hbar$ and low dissipation) or even supra currents. Furthermore, Josephson currents are oscillatory so that no pumping is needed. Combining this input with the model of DNA as topological quantum computer (TQC) [K7] leads to a rather precise model for the generation of nerve pulse.

1. The system would consist of two superconductors- microtubule space-time sheet and the space-time sheet in cell exterior- connected by Josephson junctions represented by magnetic flux tubes defining also braiding in the model of TQC. The phase difference between two super-conductors would obey Sine-Gordon equation allowing both standing and propagating soliton solutions. A sequence of rotating gravitational penduli coupled to each other would be the mechanical analog for the system. Soliton sequences having as a mechanical analog penduli rotating with constant velocity but with a constant phase difference between them would generate moving kHz synchronous oscillation. Periodic boundary conditions at the ends of the axon rather than chemistry determine the propagation velocities of kHz waves and kHz synchrony is an automatic consequence since the times taken by the pulses to travel along the axon are multiples of same time unit. Also moving oscillations in EEG range can be considered and would require larger value of Planck constant in accordance with vision about evolution as gradual increase of Planck constant.

2. During nerve pulse one pendulum would be kicked so that it would start to oscillate instead of rotating and this oscillation pattern would move with the velocity of kHz soliton sequence. The velocity of kHz wave and nerve pulse is fixed by periodic boundary conditions at the ends of the axon implying that the time spent by the nerve pulse in traveling along axon is always a multiple of the same unit: this implies kHz synchrony. The model predicts the value of Planck constant for the magnetic flux tubes associated with Josephson junctions and the predicted force caused by the ionic Josephson currents is of correct order of magnitude for reasonable values of the densities of ions. The model predicts kHz em radiation as Josephson radiation generated by moving soliton sequences. EEG would also correspond to Josephson radiation: it could be generated either by moving or standing soliton sequences (latter are naturally assignable to neuronal cell bodies for which $\hbar$ should be correspondingly larger): synchrony is predicted also now.

3. The previous view about microtubules in nerve pulse conduction can be sharpened. Microtubular electric field (always in the same direction) could explain why kHz and EEG waves and nerve pulse propagate always in same direction and might also feed energy to system so that soliton velocity could be interpreted as drift velocity. This also inspires a generalization of the model of DNA as TQC sine also microtubule-cell membrane systems are good candidates for performers of TQC. Cell replication during which DNA is out of game seems to require this and microtubule-cell membrane TQC would represent higher level TQC distinguishing between multi-cellulars and mono-cellulars.

4. New physics would enter in several manners. Ions should form Bose-Einstein cyclotron condensates. The new nuclear physics predicted by TGD [L1], [L1] predicts that ordinary fermionic ions (such as K^+, Na^+, Cl^-) have bosonic chemical equivalents with slightly differing mass number obtained by replacing one or more neutral color flux tubes connecting nucleons of neutral atom with a charged one. Anomalies of nuclear physics and cold fusion provide experimental support for the predicted new nuclear physics. Electronic supra current pulse from microtubules could induce the kick of pendulum inducing nerve pulse and induce a small heating and expansion of the axon. The return flux of ionic Josephson currents would induce convective cooling of the axonal membrane. A small transfer of small positive charge into the inner lipid layer could induce electronic supra current by attractive Coulomb interaction. The exchange of exotic W bosons which are scaled up variants of ordinary $W^{\pm}$ bosons is a natural manner to achieve this if new nuclear physics is indeed present.

7.2 Quantum Model For Sensory Receptor

This original model of nerve pulse and EEG was still based on the implicit assumption that the space-time sheet carrying the Josephson currents is far from vacuum. The model for sensory receptor and sensory qualia however led to a the proposal that the space-time sheet in question is near vacuum extremal [K9, K17]. Near vacuum extremal property does not affect the general structure of the model in an essential manner.

1. The only change [K17, K18] is the replacement of charges ± 1 of ions with effective charges given as

$$Q_{eff} = -\frac{Z-N}{2p} + 2Z + q_{em} \ . \tag{7.1}$$

Z and N denote nuclear charge and neutron number. $p = sin^(\theta_W)$ corresponds to Weinberg angle. For K^+, Cl^-, Na^+, Ca^{++} one has $Z = (19, 17, 11, 20)$, $Z - N = (-1, -1, -1, 0)$, and $q_{em} = (1, -1, 1, 2)$. **Table 4** gives the values of Josephson energies for some values of resting potential for $p = sin^(\theta_W) = .0295$ reproducing the frequencies of peak sensitivity for photoreceptors. Rather remarkably, they are in IR or visible range.

2. The energies are in UV and visible range. Hence one can consider also Josephson junctions with considerably lower membrane potentials of order mV are possibly without losing the thermal stability. For instance, one could consider $k = 151, 157, 163, 167$ Josephson junctions with a membrane potential scaling as $1/L(k)$. For $k = 167$ the energies would be scaled down by a factor $2^{-(167-151)/2} = 2^{-8}$ giving for $V_{eff} = .09$ V a photon energy somewhat below the thermal energy at room temperature. On the other hand, the fact that Josephson junctions with a vanishing Z^0 field are at the verge of thermal instability suggests that also they might be present in living matter.

3. From **Table 4** one can evaluate the value of Planck constant for a given Josephson frequency for various ions. For $f_J = 5$ Hz giving a first estimate for neuronal Josephson frequency and V=-55 mV corresponding to the critical voltage for the generation of action potential one obtains the values $r = \hbar/\hbar_0 = (1.51, 1.89, 2.11, 1.59) \times 2^{46}$ for $(Na^+, Cl^-, K^+, Ca^{++})$. For V=-70 mV corresponding to the resting potential of neuron and same Josephson frequency one obtains $r = (0.961.201.341.01) \times 2^{47}$. For Ca^{++} ion r is very near to a power of 2. A good

Table 4: Table gives the prediction of the model of photoreceptor for the Josephson energies for typical values of the membrane potential. For comparison purposes the energies E_{max} corresponding to peak sensitivities of rods and cones, and absorption ranges for rods are also given. R, G, B, W refers to red, green, blue, white. The values of Weinberg angle parameter $p = sin^2(\theta_W)$ are assumed to be .23 and.0295. The latter value is forced by the fit of Josephson energies to the known peak energies.

Ion	Na^+	Cl^-	K^+	Ca^{+2}
$E_J(.04\ \ mV, p = .23)/eV$	1.01	1.40	1.51	1.76
$E_J(.065\ \ V, p = .23)/eV$	1.64	2.29	2.69	2.73
$E_J(40\ \ mV, p = .0295)/eV$	1.60	2.00	2.23	1.68
$E_J(50\ \ mV, p = .0295)/eV$	2.00	2.49	2.79	2.10
$E_J(55\ \ mV, p = .0295)/eV$	2.20	2.74	3.07	2.31
$E_J(65\ \ mV, p = .0295)/eV$	2.60	3.25	3.64	2.73
$E_J(70\ \ mV, p = .0295)/eV$	2.80	3.50	3.92	2.94
$E_J(75\ \ mV, p = .0295)/eV$	3.00	3.75	4.20	3.15
$E_J(80\ \ mV, p = .0295)/eV$	3.20	4.00	4.48	3.36
$E_J(90\ \ mV, p = .0295)/eV$	3.60	4.50	5.04	3.78
$E_J(95\ \ mV, p = .0295)/eV$	3.80	4.75	5.32	3.99
Color	R	G	B	W
E_{max}	2.19	2.32	3.06	2.49
energy-interval/eV	1.77-2.48	1.97-2.76	2.48-3.10	

mnemonic is that the Josephson energies of biologically important ions vary in an interval, which is in a reasonable approximation half octave ($E_J(K^+)/E_J(Na^+) = 1.3958 \simeq \sqrt{2} \simeq 1.4142$).

It interesting to try to interpret the resting potentials of various cells in this framework in terms of the Josephson frequencies of various ions. **Table 4** gives the values of Josephson frequencies of basic biological ions for typical values of the membrane potential.

1. The maximum value of the action potential during nerve pulse is +40 mV so that Josephson frequencies are same as for the resting state of photoreceptor. Note that the time scale for nerve pulse is so slow as compared to the frequency of visible photons that one can consider that the neuronal membrane is in a state analogous to that of a photoreceptor.

2. For neurons the value of the resting potential is -70 mV. Na^+ and Ca^{++} Josephson energies 2.80 eV and 2.94 eV are in the visible range in this case and correspond to blue light. This does not mean that Ca^{++} Josephson currents are present and generate sensation of blue at neuronal level: the quale possibly generated should depend on sensory pathway. During the hyper-polarization period with -75 mV the situation is not considerably different.

3. The value of the resting potential is -95 mV for skeletal muscle cells. In this case Ca^{++} Josephson frequency corresponds to 4 eV metabolic energy quantum.

4. For smooth muscle cells the value of resting potential is -50 mV. In this case Na^+ Josephson frequency corresponds to 2 eV metabolic energy quantum.

5. For astroglia the value of the resting potential is -80/-90 mV for astroglia. For -80 mV the resting potential for Cl^- corresponds to 4 eV metabolic energy quantum. This suggests that glial cells could also provide metabolic energy as Josephson radiation to neurons.

6. For all other neurons except photo-receptors and red blood cells Josephson photons are in visible and UV range and the natural interpretation would be as bio-photons. The bio-photons detected outside body could represent sensory leakage. An interesting question is whether the IR Josephson frequencies could make possible some kind of IR vision.

Table 5: Cyclotron frequencies of quarks and electron in magnetic field $B_{end} = .2$ Gauss for standard vacuum with very small Z^0 field and nearly vacuum extremal.

fermion	$f_c(e)/MHz$	$f_c(u)/MHz$	$f_c(d)/MHz$
standard	.564	.094	.019
nearly vacuum extremal	8.996	2.275	.947

7.3 The Role Of Josephson Currents

The general vision is that Josephson currents of various ions generate Josephson photons having dual interpretations as bio-photons and EEG photons. Josephson photons can in principle regenerate the quale in the neurons of the sensory pathway. In the case of motor pathways the function would be different and the transfer of metabolic energy by quantum credit card mechanism using phase conjugate photons is suggested by the observation that basic metabolic quanta 2 eV *resp.* 4 eV are associated with smooth muscle cells *resp.* skeletal muscle cells.

As already found in the previous section, the energies of Josephson photons associated with the biologically important ions are in general in visible or UV range except when resting potential has the value of -40 mV which it has for photoreceptors. In this case also IR photons are present. Also the turning point value of membrane potential is +40 mV so that one expects the emission of IR photons.

Josephson photons could be used to communicate the qualia to the magnetic body.

1. If Josephson currents are present during the entire action potential, the entire range of Josephson photons down to frequencies of order 2 kHz range is emitted for the standard value of $\hbar$. The reason is that lower frequencies corresponds to cycles longer than the duration of the action potential. The continuum of Josephson frequencies during nerve pulse makes it possible to induce cyclotron transitions at the magnetic body of neuron or large structure. This would make possible to communicate information about spatial and temporal behavior of the nerve pulse pattern to the magnetic body and build by quantum entanglement a sensory map.

2. The frequencies below 2 kHz could be communicated as nerve pulse patterns. When the pulse rate is above $f = 28.57$ Hz the sequence of pulses is experienced as a continuous sound with pitch f. f defines the minimum frequency for which nerve pulses could represent the pitch and there remains a 9 Hz long range to be covered by some other communication method.

3. The cyclotron frequencies of quarks and possibly also of electron would make possible a selective reception of the frequencies emitted during nerve pulse. Same applies also to the Josephson frequencies of hair cell (, which does not fire). If the value of Planck constant is large this makes possible to communicate the entire range of audible frequencies to the magnetic body. Frequency would be coded by the magnetic field strength of the flux tube. Two options are available corresponding to the standard ground state for which Z^0 field is very weak and to almost vacuum extremals. For the first option one as ordinary cyclotron frequencies. The cyclotron frequency scales for them differ by a factor

$$r(q) = \frac{Q_{eff}(q)}{Q_{em}(q)} = \frac{\epsilon(q)}{2pQ_{em}(q)} + 1 \ , \ \ \epsilon(u) = -1 \ \ , \epsilon(d) = 1 \tag{7.2}$$

from the standard one. For $p = .0295$ one obtains $(r(u), r(d), r(e) = (24.42, 49.85, 15.95)$. The cyclotron frequencies for quarks and electron with masses m(u)=2 MeV, m(d)=5 MeV, and m(e)=.5 MeV are given by **Table 5** for the two options. If one assumes that B_{end} defines the upper bound for field strength then he standard option would require both d quark and electron. Gor $d$quark with kHz CD the upper bound for cyclotron frequencies would be 20 kHz which corresponds to the upper limit of audible frequencies.

4. Besides cyclotron frequencies also the harmonics of the fundamental frequencies assignable to quark and electron CDs could be used and in case of musical sounds this looks a highly attractive option. In this case it is now however possible to select single harmonics as in the case of cyclotron transitions so that only the rate of nerve pulses can communicate single frequency. Lorentz transform sub-CD scales up the frequency scale from the secondary p-adic time scale coming as octave of 10 Hz frequency. Also the scaling of $\hbar$ scales this frequency scale.

7.4 What Is The Role Of The Magnetic Body?

The basic vision is that magnetic body receives sensory data from the biological body- basically from cell membranes and possibly via genome - and controls biological body via genome. This leaves a huge amount of details open and the almost impossible challenge of theoretician is to guess the correct realization practically without any experimental input. The following considerations try to clarify what is involved.

7.4.1 Is magnetic body really needed?

Libet's findings and the model of memory based on time mirror (see **Fig.** `http://tgdtheory.fi/appfigures/timemirror.jpg` or **Fig. ??** in the appendix of this book) hypothesis suggests that magnetic body is indeed needed. What is the real function of magnetic body? Is it just a sensory canvas? The previous considerations suggest that it is also the seat of geometric qualia, in particular the pitch of sound should be coded by it. It would be relatively easy to understand magnetic body as a relatively passive sensory perceiver defining sensory map. If one assumes that motor action is like time reversed sensory perception then sensory and motor pathways would be just sensory pathways proceeding in opposite time directions from receptors to the various layers of the magnetic body. Brain would perform the information processing.

Certainly there must exist a region in which the motor and sensory parts of the magnetic body interact. What comes in mind is that these space-time sheets (or actually pairs of space-time sheets) are parallel and generate wormhole contacts between them. This interaction would be assignable to the region of the magnetic body could receive positive energy signals from associative sensory areas and send negative energy signals to motor motor neurons at the ends of motor pathways wherefrom they would propagate to premotor cortex, supplementary motor cortex and to frontal lobes where the abstract plans about motor actions are generated.

7.4.2 Is motor action time reversal of sensory perception in zero energy ontology?

One could argue that the free will aspect of motor actions does not conform with the interpretation as sensory perception in reversed direction of time. On the other hand, also percepts are selected -say in binocular rivalry [J7]. Only single alternative percept need to be realized in a given branch of the multiverse. This makes possible metabolic economy: for instance, the synchronous firing at kHz frequency serving as a correlate for the conscious percept requires a lot of energy since dark photons at kHz frequency have energies above thermal threshold. Similar selection of percepts could occur also at the level of sensory receptors but quantum statistical determinism would guarantee reliable perception. The passivity of sensory perception and activity of motor activity would reflect the breaking of the arrow of time if this interpretation is correct.

7.4.3 What magnetic body looks like?

What magnetic body looks like has been a question that I have intentionally avoided as a question making sense only when more general questions have been answered. This question seems however unavoidable now. Some of the related questions are following. The magnetic flux lines along various parts of magnetic body must close: how does this happen? Magnetic body must have parts of size at least that defined by EEG wavelengths: how do these parts form closed structures? How the magnetic bodies assignable to biomolecules relate to the Earth sized parts of the magnetic body? How the personal magnetic body relates to the magnetic body of Earth?

1. The vision about genome as the brain of cell would suggest that active and passive DNA strands are analogous to motor and sensor areas of brain. This would suggests that sensory data should be communicated from the cell membrane along the passive DNA strand. The simplest hypotesis is that there is a pair of flux sheet going through the DNA strands. The flux sheet through the passive strand would be specialized to communicate sensory information to the magnetic body and the flux sheet through the active strand would generate motor action as DNA expression with transcription of RNA defining only one particular aspect of gene expression. Topological quantum computation assignable to introns and also electromagnetic gene expression would be possible.

2. The model for sensory receptor in terms of Josephson radiation suggests however that flux tubes assignable to axonal membranes carry Josephson radiation. Maybe the flux tube structures assigned to DNA define the magnetic analog of motor areas and flux tubes assigned with the axons that of sensory areas.

3. A complex structure of flux tubes and sheets is suggestive at the cellular level. The flux tubes assignable to the axons would be parallel to the sensory and motor pathways. Also microtubules would be accompanied by magnetic flux tubes. DNA as topological quantum computer model assumes and the proposed model of sensory perception and cell membrane level suggests transversal flux tubes between lipids and nucleotides. The general vision about DNA as brain of cell suggest flux sheets through DNA strands.

   During sensory perception of cell and nerve pulse the wormhole flux tube connecting the passive DNA strand of the first cell to the inner lipid layer would recombine with the flux tube connecting outer lipid layer to some other cell to form single flux tube connecting two cells. In the case of sensory organs these other cells would be naturally other sensory receptors. This would give rise to a dynamical network of flux tubes and sheets and axonal sequences of genomes would be like lines of text at the page of book. This structure could have a fractal generalization and would give rise to an integration of genome to super-genome at the level of organelles, organs and organism and even hypergenome at the level of population. This would make possible a coherent gene expression.

4. This vision gives some idea about magnetic body in the scale of cell but does not say much about it in longer scales. The CDs of electrons and quarks could provide insights about the size scale for the most relevant parts of the magnetic body. Certainly the flux tubes should close even when they have the length scale defined by the size of Earth.

Additional ideas about the structure follow follow if one assumes that magnetic body acts a sensory canvas and that motor action can be regarded as time reversed sensory perception.

1. If the external world is represented at part of the magnetic body which is stationary, the rotation of head or body would not affect the sensory representation. This part of the magnetic body would be obviously analogous to the outer magnetosphere, which does not rotate with Earth.

2. The part of the magnetic body at which the sensory data about body (posture, head orientations and position, positions of body parts) is represented, should be fixed to body and change its orientation with it so that bodily motions would be represented as motions of the magnetic , which would be therefore analogous to the inner magnetosphere of rotating Earth.

3. The outer part of the personal magnetic body is fixed to the inner magnetosphere, which defines the reference frame. The outer part might be even identifiable as the inner magnetosphere receiving sensory input from the biosphere. This magnetic super-organism would have various life forms as its sensory receptors and muscle neurons. This would give quantitative ideas about cyclotron frequencies involved. The wavelengths assignable to the frequencies above 10 Hz would correspond to the size scale of the inner magnetosphere and those below to the outer magnetosphere. During sleep only the EEG communications with outer magnetic body would remain intact.

4. Flux quantization for large value of $\hbar$ poses an additional constraint on the model.

(a) If Josephson photons are transformed to a bunch of ordinary small $\hbar$ photons magnetic flux tubes can correspond to the ordinary value of Planck constant. If one assumes the quantization of the magnetic flux in the form

$$\int BdA = n\hbar$$

used in super-conductivity, the radius of the flux tube must increase as $\sqrt{\hbar}$ and if the Josephson frequency is reduced to the sound frequency, the value of $\hbar$ codes for the sound frequency. This leads to problems since the transversal thickness of flux tubes becomes too large. This does not however mean that the condition might not make sense: for instance, in the case of flux sheets going through DNA strands the condition might apply.

(b) The quantization of magnetic flux could be replaced by a more general condition

$$\oint (p - ZeA)dl = n\hbar \ , \tag{7.3}$$

where p represents momentum of particle of super-conducting phase at the boundary of flux tube. In this case also $n = 0$ is possible and poses no conditions on the thickness of the flux tube as a function of $\hbar$. This option looks reasonable since the charged particles at the boundary of flux tube would act as sources of the magnetic field.

(c) Together with the Maxwell's equation giving $B = ZeNv$ in the case that there is only one kind of charge carrier this gives the expression

$$N = \frac{2m}{RZ^2e^2} \tag{7.4}$$

for the surface density N of charge carrier with charge Z. R denotes the radius of the flux tube. If several charge carriers are present one has $B = \sum_k N_k Z_k e v_k$, and the condition generalizes to

$$N_i = \frac{2m_i v_i}{RZ_i \sum_k Z_k v_k e^2} \ . \tag{7.5}$$

It seems that this condition is the most realistic one for the large $\hbar$ flux sheets at which Josephson radiation induces cyclotron transitions.

7.4.4 What are the roles of Josephson and cyclotron photons?

The dual interpretation of Josephson radiation in terms of bio-photons and EEG photons seems to be very natural and also the role of Josephson radiation seems now relatively clear. The role of cyclotron radiation and its interaction with Josephson radiation are not so well understood.

1. At least cell membrane defines a Josephson junction (actually a collection of them idealizable as single junctions). DNA double strand could define a series of Josephson junctions possibly assignable with hydrogen bonds. This however requires that the strands carry some non-standard charge densities and currents- I do not know whether this possibility is excluded experimentally. Quarks and antiquarks assignable to the nucleotide and its conjugate have opposite charges at the two sheets of the wormhole flux tube connective nucleotide to a lipid. Hence one could consider the possibility that a connection generated between them by reconnection mechanism could create Josephson junction.

2. The model for the photoreceptors leads to the identification of bio-photons as Josephson radiation and suggests that Josephson radiation propagates along flux tubes assignable to the cell membranes along sensory pathways up to sensory cortex and from there to motor cortex and back to the muscles and regenerates induced neuronal sensory experiences.

3. Josephson radiation could be used quite generally to communicate sensory data to/along the magnetic body: this would occur in the case of cell membrane magnetic body at least. The different resting voltages for various kinds of cells would select specific Josephson frequencies as communication channels.

4. If motor action indeed involves negative energy signals backwards in geometric time as Libet's findings suggest, then motor action would be very much like sensory perception in time reversed direction. The membrane resting potentials are different for various types of neurons and cells so that one could speak about pathways characterized by Josephson frequencies determined by the membrane potential. Each ion would have its own Josephson frequency characteristizing the sensory or motor pathway.

The basic questions concern the function of cyclotron radiation and whether Josephson radiation induces resonantly cyclotron radiation or vice versa.

1. Cyclotron radiation would be naturally associated with the flux sheets and flux tubes. The simplest hypothesis is that at least the magnetic field $B_{end} = .2$ Gauss can be assigned with the some magnetic flux quanta at least. The model for hearing suggests that B_{end} is in this case quantized so that cyclotron frequencies provide a magnetic representation for audible frequencies. Flux quantization does not pose any conditions on the magnetic field strength if the above discussed general flux quantization condition involving charged currents at the boundary of the flux quantum are assumed. If these currents are not present, $1/\hbar$ scaling of B_{end} for flux tubes follows.

2. The assumption that cyclotron radiation is associated with the motor control via genome is not consistent with the vision that motor action is time reversed sensory perception. It would also create the unpleasant question about information processing of the magnetic body performed between the receival of sensory data and motor action.

3. The notion of magnetic sensory canvas suggests a different picture. Josephson radiation induces resonant cyclotron transitions at the magnetic body and induces entanglement of the mental images in brain with the points of the magnetic body and in this manner creates sensory maps giving a third person perspective about the biological body. There would be two kind of sensory maps. Those assignable to the external world and those assignable to the body itself. The Josephson radiation would propagate along the flux tubes to the magnetic body.

4. There could be also flux tube connections to the outer magnetosphere of Earth. It would seem that the reconnections could be flux tubes traversing through inner magnetosphere to poles and from there to the outer magnetosphere. These could correspond to rather low cyclotron frequencies. Especially interesting structure in this respect is the magnetic flux sheet at the Equator.

7.5 Dark Matter Hierarchies Of Josephson Junctions

The hierarchy of Josephson junctions assignable to cell membrane and characterized by values of Planck constant provides a rather nice model for cell membrane but one can consider also more general dark hierarchies of Josephson junctions. This model conforms with the general vision that living matter processes information by locating it to various pages of the "Big Book".

7.5.1 Maximization of Planck constant in quantum control and communication in living matter

The sectors of the imbedding space for which CD and CP_2 are replaced with their n_a- *resp.* n_b-fold coverings define the most promising candidates concerning the understanding of living matter, at least the quantum control of living matter. The reason is that the value of the Planck constant is maximized and given by $r = \hbar/\hbar_0 = n_a n_b$. Also the number of pages with same Planck constant would be finite unlike for the more general option allowing rational values of Planck constant. In particular, infinite number of pages with the standard value of Planck constant would be possible and this might lead to mathematical difficulties.

Experimental constraints allow to consider also the possibility that only covering spaces are possible. One must be however very cautious in making hasty conclusions. If also factor spaces are allowed one can have G_a or G_b as discrete and exact symmetry groups at the level of dark matter and these symmetries would be manifested as approximate symmetries of the visible matter topologically condensed around the dark matter.

1. In M^4 degrees of freedom since the restriction to the orbifold $\hat{M}^4/G_a$ is equivalent to the exact G_a-invariance of dark matter quantum states. Molecular rotational symmetries correspond typically to small groups G_a and might relate to this symmetry. Small values of n_a would not affect dramatically the value of Planck constant if n_b is large.

2. $G_a = Z_n$, $n = 5, 6$ are favored for molecules containing aromatic cycles. Also genuinely 3-dimensional tetrahedral, octahedral, and icosahedral symmetries appear in living matter.

In the sequel only integer values of Planck constant will be considered. An especially interesting hierarchy corresponds to ruler and compass integers expressible as a product of power of two and distinct Fermat primes (see Appendix). The reason is that these integers correspond to number theoretically very simple quantum phases. This hierarchy includes as a special case powers of two and one can imagined a resonant interaction between p-adic length scale hierarchy and hierarchy of Planck constants.

7.5.2 Dark hierarchy of Josephson junctions with a constant thickness

The model for EEG relies on fractal hierarchy of cell membrane like structures with a fixed thickness and membrane potential. Therefore cell membrane thickness is not scaled by $\hbar$ as one might naively expect. Same applies to magnetic flux tubes: this is possible since the condition for the quantization of magnetic flux can be replaced with a more general one if one allows charged currents at the boundaries of flux quanta [K17]. In this model the value of $\hbar$ becomes a measure for the evolutionary level of cell and neurons in hippocampus, associative regions of cortex and their motor counterparts, and frontal lobes are expected to correspond to the largest values of $\hbar$ measuring also the time scale of long term memory and planned action. Note that cell membrane corresponds to twin primes $k = 149$ and $k = 151$ with $k = 151$ defining a Gaussian Mersenne so that it is indeed very special.

Page of a book is rather precise metaphor for the magnetic flux sheet going through a linear array of strings of nuclei and also for a collection flux tubes parallel to axons. This raises several questions. Do the lines of the text of this book correspond to axons in neural circuits? Do the pages correspond to larger structures formed by the axons?

The quantum model for qualia [K17] implies that Josephson radiation travels through flux tubes parallel to sensory pathways and there could be also a horizontal organization of the neurons- at least at the level of sensory receptors in the sense that magnetic flux tubes connecting DNA nucleotides to lipids of cell membrane fuse to form longer flux tubes between DNA nucleotides of different cells when sensory receptor is active. Axons could thus be seen as the analogs of text lines which however can interact with each other. Similar organization would appear at the level of flux sheets traversing through DNA strands.

Books are made for reading and one can thus ask whether the book metaphor extends. Could the observed moving brain waves scanning cortex relate to the “reading” of the information associated with these sheets of book by the magnetic body and does our internal speech correspond to this “reading” ? One is also forced to ask whether these brain waves are induced by waves propagating along magnetic flux quanta of the magnetic body of Earth or personal magnetic body in the case that it has components other than magnetic flux sheets serving as Josephson junctions.

7.5.3 An objection against a fractal hierarchy of Josephson junctions with thickness scaling as $\hbar$

One can consider also a hierarchy of Josephson junctions with a scaled up thickness proportional to $\hbar$ instead of constant thickness. If these junctions have same voltage at all levels of the hierarchy a resonant interaction between various levels of the hierarchy would become possible.

Table 6: Twin primes define especially interesting candidates for double membrane like structures defining Josephson junctions. Also included the pair $(137, 13^2 = 169)$ although $k = 169$ is not prime. The two largest scales could relate to structures appearing in brain.

$(k, k+2)$	$(137, 139)$	$(149, 151)$	$(167, 169 = 13^2)$	$(179, 181)$
$L_e(k)$	$.78\ A$	$5\ nm$	$2.5\mu m$	$.32\ mm$
$(k, k+2)$	$(191, 193)$,	$(197, 199)$		
$L_e(k)$	$1\ cm$	$8\ cm$		

One can represent common sense objections against this idea. The electric field involved with the higher levels of Josephson junction hierarchy is very weak: something like 10^{-7} V/m for lito-ionospheric Josephson junctions (of thickness about 176 km from the scaling of the cell membrane thickness by $\lambda^4 = 2^{44}$) which might be responsible for EEG. The electric field of the Earth at space-time sheets corresponding to ordinary matter is much stronger: about $10^2 - 10^4$ V/m at the surface of Earth but decreasing rapidly as ionosphere is approached being about.3 V/m at 30 km height. The estimate for the voltage between ionosphere and Earth surface is about 200 kV [F2].

The many-sheeted variant of Faraday law implies that on order to have a voltage of order.08 V over lito-ionospheric Josephson junction at dark matter space-time sheet, the voltage over ionospheric cavity must be almost completely compensated by an opposite voltage over litosphere so that lito-ionospheric double layer could be seen as a pair of capacitor plates in a radial electric field of order 10^{-7} V/m generated by the charge density in sub-litospheric part of Earth. This condition requires fine-tuning and therefore looks unrealistic.

A natural distance scale in which the electric field is reduced would correspond to 10-20 km thick layer in which whether phenomena are present. The mirror image of this layer would be Earth's crust. The cell membrane counterpart would be a dipole layer like charge density between the lipid layers of the cell membrane. Note that the electric field at dark matter space-time can be constant. However, as far as Josephson junction is considered, it is only the net voltage what matters.

7.6 P-Adic Fractal Hierarchy Of Josephson Junctions

p-Adic length scale hypothesis allows to imagine a hierarchy of Josephson junctions at least in length scales regarded usually as biologically relevant. The voltage through the junction need not however be same as for the ordinary cell membrane anymore. Twin primes are especially interesting since they would naturally correspond to pairs of structures analogous to a pair of lipid layers defining cell membrane.

In particular, twin primes abundant in the p-adic length scale range assignable to living matter could define double layered structures acting as Josephson junctions.

Also Gaussian Mersennes define highly interesting p-adic length scales and the length scale range between cell membrane thickness and the size of cell contains as many as four Gaussian Mersennes corresponding to $k = 151, 157, 163, 167$. Only the smallest one is associated with a twin prime but p-adic length scale hypothesis allows also non-prime values of k.

7.6.1 The possibility of a p-adic hierarchy of membrane like structures accompanied by Josephson junctions

One can imagine the existence of fractally scaled up variants of cell membrane defining hierarchy of Josephson junctions possibly realized as magnetic flux tubes. The possible existence of this hierarchy is however not relevant for the model of EEG in its recent form.

The first hierarchy correspond to the p-adic length scales varying in the range of biologically relevant p-adic length scales $L(k)$ involving membrane like structures. Twin primes $(k, k+2)$ are good candidates here (Table 3). Second hierarchy corresponds to dark matter hierarchy for which length scales come as $\sqrt{r}L(k))$, $r = \hbar/\hbar_0$. Later the question which values of r are favored will be discussed.

The size of cell nucleus varies in the range $(L(169) = 5\,\mu m, 2L(169) = 10\,\mu m)$. This is consistent with the assumption that cell nucleus provides the fundamental representation for this block. This would mean that at least the multiply coiled magnetic flux quantum structures associated with DNA appear as fractally scaled up copies.

Each dark matter level corresponds to a block of p-adic length scales $L(k)$, $k = 151, ..., 169$. Also new length scales emerge at given level and correspond to $L(k)$, $k > 169$. The dark copies of all these length scales are also present. Hence something genuinely new would emerge at each level.

7.6.2 Fractal hierarchy of magnetic bodies assignable to cell

Second hierarchy corresponds to a dark matter hierarchy involving values of Planck constant. The original hypothesis was that the values of Planck constant comes as $r \equiv \hbar/\hbar_0 = 2^{11k}$ of given p-adic length scale assignable to biological membrane like structure. A possible justification for the hypothesis is that the ratio of electron and proton masses is rather near to 2^{11} and that this number appears in quantum TGD in the role of fundamental constant. This hypothesis is however un-necessarily restrictive and it is better to consider at least the values of r given as products of two ruler and compass integers n_F expressible as a product of distinct Fermat primes and some power of two. The justification comes from the number theoretic vision about evolution and number theoretical simplicity of the phases $q = exp(i2\pi/n_F)$ (Appendix).

The emergence of a genuinely new structure or function in evolution would correspond to the emergence of new level in this fractal hierarchy. Quantum criticality would be essential: phases corresponding different values of Planck constant would compete at quantum criticality.

The flux sheet or tubes through cell membranes should integrate to larger structures at the higher levels of dark matter hierarchy implying the integration of sensory inputs from a large number of cells to single coherent input at higher levels of dark matter hierarchy. One can think two options: the sensory inputs from cell membranes are communicated directly to the magnetic body or via the DNA. The second option would require that the flux sheets or tubes starting from cell membrane traverse also the DNA.

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