Bio-Systems as Super-Conductors: Part I

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Abstract

In this chapter various TGD based ideas related to the role of super-conductivity in bio-systems are studied. TGD inspired theory of consciousnses provides several motivations for this.

1. Quantum criticality, hierarchy of dark matters, and dynamical $\hbar$

Quantum criticality is the basic characteristic of TGD Universe and quantum critical superconductors provide an excellent test bed to develop the ideas related to quantum criticality into a more concrete form.

The hypothesis that Planck constants in M^4 and CP_2 degrees of freedom are dynamical possessing quantized spectrum given as integer multiples of minimum value of Planck constant adds further content to the notion of quantum criticality. Number theoretic considerations favor the hypothesis that the integers corresponding to Fermat polygons constructible using only ruler and compass and given as products $n_F = 2^k \prod_s F_s$, where $F_s = 2^{2^s} + 1$ are distinct Fermat primes, are favored. The reason would be that quantum phase $q = exp(i\pi/n)$ is in this case expressible using only iterated square root operation by starting from rationals. The known Fermat primes correspond to $s = 0, 1, 2, 3, 4$ so that the hypothesis is very strong and predicts that p-adic length scales have satellite length scales given as multiples of n_F of fundamental p-adic length scale. $n_F = 2^{11}$ corresponds in TGD framework to a fundamental constant expressible as a combination of Kähler coupling strength, CP_2 radius and Planck length appearing in the expression for the tension of cosmic strings, and seems to be especially favored in living matter.

Phases with different values of M^4 and CP_2 Planck constants behave like dark matter with respect to each other in the sense that they do not have direct interactions except at criticality corresponding to a leakage between different sectors of imbedding space glued together along M^4 or CP_2 factors. In large $\hbar(M^4)$ phases various quantum time and length scales are scaled up which means macroscopic and macro-temporal quantum coherence.

The only coupling constant strength of theory is Kähler coupling constant g_K^2 which appears in the definition of the Kähler function K characterizing the geometry of the configuration space of 3-surfaces (the "world of classical worlds"). The exponent of K defines vacuum functional analogous to the exponent of Hamiltonian in thermodynamics. The allowed value(s) of g_K^2, which is (are) analogous to critical temperature(s), is (are) determined by quantum criticality requirement. Contrary to the original hypothesis inspired by the requirement that gravitational coupling is renormalization group invariant, α_K does not seem to depend on p-adic prime whereas gravitational constant is proportional to L_p^2. The situation is saved by the assumption that gravitons correspond to the largest non-super-astrophysical Mersenne prime M_{127} so that gravitational coupling is effectively RG invariant in p-adic coupling constant evolution.

$\hbar(M^4)$ and $\hbar(CP_2)$ appear in the commutation and anticommutation relations of various superconformal algebras. Only the ratio of M^4 and CP_2 Planck constants appears in Kähler action and is due to the fact that the M^4 and CP_2 metrics of the imbedding space sector with given values of Planck constants are proportional to the corresponding Planck constants. This implies that Kähler function codes for radiative corrections to the classical action, which makes possible to consider the possibility that higher order radiative corrections to functional integral vanish as one might expect at quantum criticality. For a given p-adic length scale space-time sheets with all allowed values of Planck constants are possible. Hence the spectrum of quantum critical fluctuations could in the ideal case correspond to the spectrum of $\hbar$ coding for the scaled up values of Compton lengths and other quantal lengths and times. If so, large $\hbar$ phases could be crucial for understanding of quantum critical superconductors, in particular high T_c superconductors.

A further great idea is that the transition to large $\hbar$ phase occurs when perturbation theory based on the expansion in terms of gauge coupling constant ceases to converge: Mother Nature would take care of the problems of theoretician. The transition to large $\hbar$ phase obviously reduces gauge coupling strength α so that higher orders in perturbation theory are reduced whereas the lowest order "classical" predictions remain unchanged. A possible

quantitative formulation of the criterion is that maximal 2-particle gauge interaction strength parameterized as $Q_1Q_2\alpha$ satisfies the condition $Q_1Q_2\alpha \simeq 1$.

TGD actually predicts an infinite hierarchy of phases behaving like dark or partially dark matter with respect to the ordinary matter and the value of $\hbar$ is only one characterizer of these phases. These phases, especially so large $\hbar$ phase, seem to be essential for the understanding of even ordinary hadronic, nuclear and condensed matter physics. This strengthens the motivations for finding whether dark matter might be involved with quantum critical super-conductivity.

Cusp catastrophe serves as a metaphor for criticality. In the recent case temperature and doping are control variables and the tip of cusp is at maximum value of T_c. Critical region correspond to the cusp catastrophe. Quantum criticality suggests the generalization of the cusp to a fractal cusp. Inside the critical lines of cusp there are further cusps which corresponds to higher levels in the hierarchy of dark matters labelled by increasing values of $\hbar$ and they correspond to a hierarchy of subtle quantum coherent dark matter phases in increasing length scales. The proposed model for high T_c super-conductivity involves only single value of Planck constant but it might be that the full description involves very many values of them.

2. Many-sheeted space-time concept and ideas about macroscopic quantum phases

Many-sheeted space-time leads to obvious ideas concerning the realization of macroscopic quantum phases.

a) The dropping of particles to larger space-time sheets is a highly attractive mechanism of super-conductivity. If space-time sheets are thermally isolated, the larger space-time sheets could be at extremely low temperature and super-conducting.

b) The possibility of large $\hbar$ phases allows to give up the assumption that space-time sheets characterized by different p-adic length scales are thermally isolated. The scaled up versions of a given space-time sheet corresponding to a hierarchy of values of $\hbar$ are possible such that the scale of kinetic energy and magnetic interaction energy remain same for all these space-time sheets. For instance, for scaled up variants of space-time sheet having size scale characterized by $L(151) = 10$ nm (cell membrane thickness) the critical temperature for superconductivity could be higher than room temperature.

c) The existence of wormhole contacts have been one of the most exotic predictions of TGD. The realization that wormhole contacts can be regarded as parton-antiparton pairs with parton and antiparton assignable to the light-like causal horizons accompanying wormhole contacts, and that Higgs particle corresponds to wormhole contact, opens the doors for more concrete models of also super-conductivity involving massivation of photons.

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 antifermion 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. A further questionable feature is that a quantum superposition of many-particle states with widely different masses would be in question. The interpretational problems could be resolved elegantly in zero energy ontology 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.

Rather remarkably, 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.

d) Quantum classical correspondence has turned out be a very powerful idea generator. For instance, one can ask what are the space-time correlates for various notions of condensed matter such as phonons, BCS Cooper pairs, holes, etc... For instance, TGD predicts the existence of negative energy space-time sheets so that ordinary particles can and must exist in negative energy states (in cosmological scales the density of inertial energy is predicted to vanish. The question is whether holes could have quite concrete representation as negative energy space-time sheets carrying negative energy particles and whether the notion of Cooper pair of holes could have this kind of space-time correlate.

3. Model for high T_c superconductivity

The model for high T_c super-conductivity relies on the notions of quantum criticality, dynamical Planck constant, and many-sheeted space-time.

These ideas lead to a concrete model for high T_c superconductors as quantum critical superconductors allowing to understand the characteristic spectral lines as characteristics of interior and boundary Cooper pairs bound together by phonon and color interaction respectively. The model for quantum critical electronic Cooper pairs generalizes to Cooper pairs of fermionic ions and for sufficiently large $\hbar$ stability criteria, in particular thermal stability conditions, can be satisfied in a given length scale. Also high T_c superfluidity based on dropping of bosonic atoms to Cooper pair space-time sheets where they form Bose-Einstein condensate is possible.

At qualitative level the model explains various strange features of high T_c superconductors. One can understand the high value of T_c and ambivalent character of high T_c super conductors suggesting both BCS type Cooper pairs and exotic Cooper pairs with non-vanishing spin, the existence of pseudogap and scalings laws for observables above T_c, the role of stripes and doping and the existence of a critical doping, etc... An unexpected prediction is that coherence length is actually $\hbar/\hbar_0 = 2^{11}$ times longer than the coherence length predicted by conventional theory so that type I super-conductor would be in question with stripes serving as duals for the defects of type I super-conductor in nearly critical magnetic field replaced now by ferromagnetic phase.

At quantitative level the model predicts correctly the four poorly understood photon absorption lines and the critical doping ratio from basic principles. The current carrying structures have structure locally similar to that of axon including the double layered structure of cell membrane and also the size scales are predicted to be same so that the idea that axons are high T_c superconductors is highly suggestive.

4. Empirical evidence for high T_c superconductivity in bio-systems

The evidence for super-conductivity in bio-systems. DNA should be insulator but under some circumstances it becomes conductor and perhaps even high T_c quantum critical superconductor. Also evidence for Josephson effect has been reported. The so called ORMEs patented by Hudson are claimed to behave like superconductors: unfortunately the academic world has not taken these claims seriously enough to test them. The claimed properties of ORMEs conform with high quantum critical T_c super-conductivity and superfluidity. The strange findings about the strange quantal behavior of ionic currents through cell membranes suggest the presence of ionic supra currents.

1 Introduction

In this chapter various TGD based ideas related to the role of super-conductivity in bio-systems are studied. TGD inspired theory of consciousnses provides several motivations for this.

1. Supra currents and Josephson currents provide excellent tools of bio-control allowing large space-time sheets to control the smaller space-time sheets. The predicted hierarchy of dark matter phases characterized by a large value of $\hbar$ and thus possessing scaled up Compton and de Broglie wavelengths allows to have quantum control of short scales by long scales utilizing

de-coherence phase transition. Quantum criticality is the basic property of TGD Universe and quantum critical super-conductivity is therefore especially natural in TGD framework. The competing phases could be ordinary and large $\hbar$ phases and supra currents would flow along the boundary between the two phases.

2. It is possible to make a tentative identification of the quantum correlates of the sensory qualia quantum number increments associated with the quantum phase transitions of various macroscopic quantum systems [K3] and various kind of Bose-Einstein condensates and super-conductors are the most relevant ones in this respect.

3. The state basis for the fermionic Fock space spanned by N creation operators can be regarded as a Boolean algebra consisting of statements about N basic statements. Hence fermionic degreees of freedom could correspond to the Boolean mind whereas bosonic degrees of freedom would correspond to sensory experiencing and emotions. The integer valued magnetic quantum numbers (a purely TGD based effect) associated with the defect regions of super conductors of type I provide a very robust information storage mechanism and in defect regions fermionic Fock basis is natural. Hence not only fermionic super-conductors but also their defects are biologically interesting [L1, M6].

1.1 General ideas about super-conductivity in many-sheeted space-time

The notion of many-sheeted space-time alone provides a strong motivation for developing TGD based view about superconductivity and I have developed various ideas about high T_c super-conductivity [42] in parallel with ideas about living matter as a macroscopic quantum system. A further motivation and a hope for more quantitative modelling comes from the discovery of various non-orthodox super-conductors including high T_c superconductors [42, 41, 40], heavy fermion super-conductors and ferromagnetic superconductors [34, 36, 35]. The standard BCS theory does not work for these super-conductors and the mechanism for the formation of Cooper pairs is not understood. There is experimental evidence that quantum criticality [33] is a key feature of many non-orthodox super-conductors. TGD provides a conceptual framework and bundle of ideas making it possible to develop models for non-orthodox superconductors.

1.1.1 Quantum criticality, hierarchy of dark matters, and dynamical $\hbar$

Quantum criticality is the basic characteristic of TGD Universe and quantum critical superconductors provide an excellent test bed to develop the ideas related to quantum criticality into a more concrete form.

The hypothesis that Planck constants in M^4 and CP_2 degrees of freedom are dynamical possessing quantized spectrum given as integer multiples of minimum value of Planck constant [A9] adds further content to the notion of quantum criticality.

Phases with different values of M^4 and CP_2 Planck constants given by $\hbar(M^4) = n_a\hbar_0$ and $\hbar(CP_2) = n_b\hbar_0$ behave like dark matter with respect to each other in the sense that they do not have direct interactions except at criticality corresponding to a leakage between different sectors of imbedding space glued together along M^4 or CP_2 factors. The scalings of M^4 and CP_2 covariant metrics are from anyonic arguments given by $(n_b/n_a)^2$ and 1 so that the value of effective $\hbar$ appearing in Schrödinger equation is given by $\hbar/\hbar_0 = n_a/n_b$ and in principle can have all positive rational values. In large $\hbar(M^4)$ phases various quantum time and length scales are scaled up which means macroscopic and macro-temporal quantum coherence.

Number theoretic considerations favor the hypothesis that the integers corresponding to Fermat polygons constructible using only ruler and compass and given as products $n_F = 2^k \prod_s F_s$, where $F_s = 2^{2^s} + 1$ are distinct Fermat primes, are favored. The reason would be that quantum phase $q = exp(i\pi/n)$ is in this case expressible using only iterated square root operation by starting from rationals. The known Fermat primes correspond to $s = 0, 1, 2, 3, 4$ so that the hypothesis is very strong and predicts that p-adic length scales have satellite length scales given as multiples of n_F of fundamental p-adic length scale. $n_F = 2^{11}$ corresponds in TGD framework to a fundamental constant expressible as a combination of Kähler coupling strength, CP_2 radius and Planck length appearing in the expression for the tension of cosmic strings, and seems to be especially favored in living matter [M3].

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$\hbar(M^4)$ and $\hbar(CP_2)$ appear in the commutation and anticommutation relations of various superconformal algebras. Only the ratio $\hbar/\hbar_0 = n_a/n_b$ of M^4 and CP_2 Planck constants appears in Kähler action and is due to the fact that the M^4 and CP_2 metrics of the imbedding space sector with given values of Planck constants are proportional to the corresponding Planck constants [A9]. This implies that Kähler function codes for radiative corrections to the classical action, which makes possible to consider the possibility that higher order radiative corrections to functional integral vanish as one might expect at quantum criticality. For a given p-adic length scale space-time sheets with all allowed values of Planck constants are possible. Hence the spectrum of quantum critical fluctuations could in the ideal case correspond to the spectrum of Planck constants coding for the scaled up values of Compton lengths and other quantal lengths and times. If so, large $\hbar$ phases could be crucial for understanding of quantum critical superconductors, in particular high T_c superconductors. For a fixed value of n_a/n_b one obtains zoomed up versions of particles with size scaled up by n_a.

A further great idea is that the transition to large $\hbar$ phase occurs when perturbation theory based on the expansion in terms of gauge coupling constant ceases to converge: Mother Nature would take care of the problems of theoretician. The transition to large $\hbar$ phase obviously reduces gauge coupling strength α so that higher orders in perturbation theory are reduced whereas the lowest order "classical" predictions remain unchanged. A possible quantitative formulation of the criterion is that maximal 2-particle gauge interaction strength parameterized as $Q_1Q_2\alpha$ satisfies the condition $Q_1Q_2\alpha \simeq 1$.

TGD actually predicts an infinite hierarchy of phases behaving like dark or partially dark matter with respect to the ordinary matter [F6] and the value of $\hbar$ is only one characterizer of these phases. These phases, especially so large $\hbar$ phase, seem to be essential for the understanding of even ordinary hadronic, nuclear and condensed matter physics [F6, F8, F9]. This strengthens the motivations for finding whether dark matter might be involved with quantum critical superconductivity.

Cusp catastrophe serves as a metaphor for criticality. In the recent case temperature and doping are control variables and the tip of cusp is at maximum value of T_c. Critical region correspond to the cusp catastrophe. Quantum criticality suggests the generalization of the cusp to a fractal cusp. Inside the critical lines of cusp there are further cusps which corresponds to higher levels in the hierarchy of dark matters labelled by increasing values of $\hbar$ and they correspond to a hierarchy of subtle quantum coherent dark matter phases in increasing length scales. The proposed model for high T_c super-conductivity involves only single value of Planck constant but it might be that the full description involves very many values of them.

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1. The dropping of particles to larger space-time sheets is a highly attractive mechanism of super-conductivity. If space-time sheets are thermally isolated, the larger space-time sheets could be at extremely low temperature and super-conducting.

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3. The idea that wormhole contacts can form macroscopic quantum phases and that the interaction of ordinary charge carriers with the wormhole contacts feeding their gauge fluxes to larger space-time sheets could be responsible for the formation of Cooper pairs, have been around for a decade [J5]. The rather recent realization that wormhole contacts can be actually regarded as space-time correlates for Higgs particles leads also to a new view about the photon massivation in super-conductivity.

4. Quantum classical correspondence has turned out be a very powerful idea generator. For instance, one can ask what are the space-time correlates for various notions of condensed matter such as phonons, BCS Cooper pairs, holes, etc... For instance, TGD predicts the existence of negative energy space-time sheets so that ordinary particles can and must exist in negative energy states (in cosmological scales the density of inertial energy is predicted to vanish [D5]). The question is whether holes could have quite concrete representation as negative energy space-time sheets carrying negative energy particles and whether the notion of Cooper pair of holes could have this kind of space-time correlate.

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1.3 Empirical evidence for high T_c superconductivity in bio-systems

The evidence for super-conductivity in bio-systems. DNA should be insulator but under some circumstances it becomes conductor [68] and perhaps even high T_c quantum critical super-conductor. Also evidence for Josephson effect has been reported [59]. The so called ORMEs patented by Hudson [128] are claimed to behave like superconductors: unfortunately the academic world has not taken these claims seriously enough to test them. The claimed properties of ORMEs conform with high quantum critical T_c super-conductivity and superfluidity. The strange findings about the strange quantal behavior of ionic currents through cell membranes [72] suggest the presence of ionic supra currents. This evidence is discussed in the next chapter [J2].

2 General TGD based view about super-conductivity

Today super-conductivity includes besides the traditional low temperature super-conductors many other non-orthodox ones [32]. These unorthodox super-conductors carry various attributes such 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 [32].

2.1 Basic phenomenology of super-conductivity

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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 [34, 36] 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_{gap} 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 $E_{gap} \sim T_c$: $e\hbar H_c/2m \sim T_c$.

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 [36]. The article [34] 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_{gap}, 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 [32] 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 [32] 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 [32] the expression for T_c is deduced from the condition that the de Broglie wavelength λ must satisfy in supra phase the condition

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

guaranteing 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

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

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

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

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

$$n_c(D) = \frac{D}{2}\frac{T_c}{E_F} n(D) \ . \tag{4}$$

The dimensionless coefficient is expressible solely in terms of n and effective mass m. In [32] it is demonstrated that the inequality 2 replaced with equality when combined with 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. 4 must correspond to ordinary Planck constant $\hbar_0$. This implies that equations 2 and 4 are consistent within orders of magnitudes. For $D = 2$, which corresponds to high T_c superconductivity, the substitution of n_c from Eq. 4 to Eq. 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

$$\lambda^{-2} = \frac{4\pi e^2 n_c}{m_e} \ . \tag{5}$$

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 $\delta E = E_{gap} \equiv 2\Delta$, $\delta t = \xi/v_F$, gives an order of magnitude estimate for ξ differing only by a numerical factor from the result of a rigorous calculation given by

$$\xi = \frac{4\hbar v_F}{E_{gap}} . \tag{6}$$

E_{gap} is apart from a numerical constant equal to T_c: $E_{gap} = nT_c$. 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 [32]. For cuprates one obtains $\xi = 2n^{-1/3}$ [32]. 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 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 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 critical temperature follows from the p-adic length scale hypothesis.

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

1. The behavior of the basic parameters under p-adic scaling and scaling of Planck constant

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_{gap} 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. As a matter fact, the

2. Could gap energies be universal?

Suppose that the super-conducting electrons are at a space-time sheet corresponding to some p-adic length scale. They can leak to either larger or smaller space-time sheets via the formation of join along boundaries bonds. The energy E_J associated with the formation of a join along boundaries bond connecting two space-time sheets characterized by k_1 and k_2 mediating transfer of Cooper pair to smaller space-time sheet defines a potential barrier so that for thermal energies below this energy no join along boundaries bonds are formed to smaller space-time sheets. The gap energy deduced from T_c would not necessarily correspond in this case to the binding energy of Cooper pair but to the energy $E_J > E_{gap}$ of the join along boundaries bond.

One can imagine two options for E_J in the approximation that the interaction energy of Cooper pair with surroundings is neglected.

Option I: The formation of JAB is a process completely independent from the flow of Cooper pair through it and thermal photons are responsible for it. In this case the order of magnitude for E_J would naturally correspond to $\hbar/L(k_1)$. Cell size $L(167) = 2.5$ μm would correspond to $E_J \sim .4$ eV which does not make sense.

Option II: One cannot separate the flow of the Cooper pair through the JAB from its formation involving the localization to smaller space-time sheet requiring thermal photon to provide the difference of zero point kinetic energies. E_J would naturally correspond to the difference $\Delta E_0 = E_0(k_1) - E_0(k_2)$ of zero point kinetic energies $E_0(k) = D\pi^2\hbar^2/4mL^2(k)$ of the Cooper pair, where D is the effective dimensionality of the sheets. The reason why JABs inducing the flow $k_1 \rightarrow k_2$ of charge carriers are not formed spontaneously must be that charge carriers at k_1 space-time sheet are in a potential well. This option seems to work although it is certainly oversimplified since it neglects the interaction energy of Cooper pairs with other particles and wormhole throats behaving effectively like particles.

If E_J given as difference of zero point kinetic energies, determines the critical temperature rather than E_{gap}, universality of the critical temperature as a difference of zero point kinetic energies is predicted. In this kind of situation the mechanism binding electrons to Cooper pairs is not relevant for what is observed as long as it produces binding energy and energy gap between ground state and first excited state larger than the thermal energy at the space-time sheet in question. This temperature is expected to scale as zero point kinetic energy. As already found, the work of Rabinowitz [32] seems to support this kind of scaling law.

3. Critical temperatures for low and high T_c super conductors

Consider now critical temperatures for low and high T_c electronic super-conductors for option II assuming $D = 3$.

1. For low T_c super conductors and for the transition $k_2 = 167 \rightarrow k_1 = 163$ this would give $\Delta E_0 = E_0(163) \sim 6 \times 10^{-6}$ eV, which corresponds to $T_c \sim .06$ K. For $k_2 = 163 \rightarrow 157$ this would give $\Delta E \sim 1.9 \times 10^{-4}$ eV corresponding to 1.9 K. These orders of magnitude look rather reasonable since the coherence length ξ expected to satisfy $\xi \leq L(k_2)$, varies in the range $.1 - 1$ μm for low T_c super conductors.

2. For high T_c super-conductors with ξ in the range $5 - 20$ Angstrom, $E_J \sim 10^{-2}$ eV would give $k_1 = 149$, which would suggest that high T_c super-conductors correspond to $k = 151$ and $\xi \ll L(k_2 = 151) = 10$ nm (cell membrane thickness). In this case $\Delta << E_J$ is quite

possible so that high T_c super-conductivity would be due to thermal isolation rather than a large value of energy gap. This provides a considerable flexibility concerning the modelling of mechanisms of Cooper pair formation.

4. $E_J < E_{gap}$ case as a transition to partial super-conductivity

For $E_J < E_{gap}$ the transition at $T_c \simeq E_J$ does not imply complete loss of resistivity since the Cooper pairs can flow to smaller space-time sheets and back without being destroyed and this is expected to induce dissipative effects. Some super-conductors such as $ZrZn_2$ ferromagnet do not lose their resistivity completely and the anomaly of specific heat is absent [34]. The mundane explanation is that super-conductivity exists only in clusters.

2.2.2 The effect of the scaling of $\hbar$ to the parameters of BCS super-conductor

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_{gap}

T_c and E_{gap} remain invariant if E_{gap} 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 Δ has the following expression.

$$\begin{aligned}
\Delta &= \hbar\omega_c exp(-1/X) \ , \\
X &= n(E_F)U_0 = \frac{3}{2}N(E_F)\frac{U_0}{E_F} \ , \\
n(E_F) &= \frac{3}{2}\frac{N(E_F)}{E_F} \ . \\
\omega_c &= \omega_D = (6\pi^2)^{1/3}c_s n_n^{1/3} \ .
\end{aligned} \tag{7}$$

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 $L \sim 1\ \mu$ 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 $\Delta \sim \omega_c$.

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 $\Delta > E_F$ condition making scaling non-sensible unless one has $\Delta \ll E_F$ 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 Δ 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 parametrization 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 high 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 $\simeq 2^{11}$.

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 $\Delta \simeq \omega_c$. 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

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

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

$$\int 2eBdS = n\hbar 2\pi \ . \tag{9}$$

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 [34, 35] is made possible by quantum criticality [33]. 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 $\hbar$. This hypothesis seems to work in the case of high T_c super-conductivity. The prediction is that quantum criticality sets on at some critical temperature $T_{c_1} > T_c$ meaning the emergence of exotic Cooper pairs which are however unstable against decay to ordinary electrons so that the super-conductivity in question gives rise to ordinary conductivity in time scales longer than the lifetime of exotic Cooper pair dictated by temperature. These exotic Cooper pairs can also transform to BCS type Cooper pairs which are stable 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. 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 Possible implications of charge and spin fractionization

Masses as given by representations of super conformal algebras and p-adic thermodynamics are invariant under changes of the Planck constants. The original assumption that Poincare quantum numbers are invariant in Planck constant changing quantum transition is however too strong and conflicts with the model explaining quantization of planetary orbits in terms of gigantic value of $\hbar$ [D6, J6]. What happens is spin fractionization with unit of spin replaced with n_a/n_b and fractionization of color and presumably of also electro-weak charges with unit given by n_b/n_a. For instance, n_a/n_b fractionization would happen for angular momentum quantum number m, for the integer n characterizing the Bohr orbits of atom, harmonic oscillator, and integers labelling the states of particle in box.

The fractionization can be understood in terms of multiple covering of M^4 by symmetry related CP_2 points formed in the phase transition increasing $\hbar$ [A9]. The covering is characterized by $G_b \subset SU(2) \subset SU(3)$ and fixed points correspond to orbifold points. The copies of imbedding space with different G are glued with each other along M^4 factors at orbifold point, representing origin of CP_2.

An interesting implication of spin fractionization is that for n_a and $n_b = 1$ the unit of spin would become n_a standard units. This might be interpreted by saying that minimum size of a Bose Einstein condensate consisting of spin 1 Cooper pairs is $n_b/2$ Cooper pairs with spin 1. On the other hand charge could be fractionized to e/n_b in this case. A possible interpretation is that electron is delocalized to n_a separate G_a related sheets of the M^4 covering of CP_2 projection such that each of them carries a fractional charge e/n_a. Geometrically this would correspond to a ring consisting of n_a discrete points.

2.3.4 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 [37] 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 [34, 36]. 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 [35]. 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 [F8] and condensed matter [F9] 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. [F9, J6]. 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 join along boundaries bonds 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 [J6] 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 structure 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. The model for high T_c super-conductors leads to the conclusion that the boundaries between the two phases are the carriers of the supra currents. Wormhole contacts appear naturally at boundaries and the mere assumption that $q\bar{q}$ type wormhole contacts feed the em gauge flux of electrons from the space-time sheet of Cooper pair to a larger space-time sheet predicts correctly the properties of high T_c Cooper pairs.

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

The transition to large $\hbar$ phase increases various length scales by n/v_0 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 n/v_0 to $n-40n$ μm to be compared with the range $.2-2$ μm for low T_c super-conductors. The density of Cooper pairs would be scaled down by an immensely small factor $2^{-33}/n^3$ from its value deduced from Fermi energy so that neither high T_c nor ordinary super-conductors can correspond to larger $\hbar$ phase for electrons.

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 [F9] 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 $\hbar(k) = n_F\hbar_0$ keeping in mind that this affects only quantum corrections in perturbative approach but not the lowest order classical predictions of quantum theory. For $n_F = n/v_0 \simeq n2^{k11}$ with $k=1, n=1$ the size of magnetic body would be $L(149) = 5$ nm, the thickness of the lipid layer of cell membrane. For $k=2, n=1$ 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 $n_c \rightarrow 10^{-6}n_c$, which looks rather reasonable since Fermi energy transforms as $E_F \rightarrow 8\times 10^3 E_F$ 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 of super-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 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.

1. The work of Rabinowitch [32] 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 this mean that there exists a simple universal description of various kinds of super-conductivities? Could this mechanism involve large $\hbar$ phase for nuclei in case of quantum critical super-conductivity? Could wormhole contacts or their Bose-Einstein condensate play some role. Are the Cooper pairs of quantum critical super-conductors at the boundaries of the competing phases?

2. The effective masses of electrons in ferromagnetic super-conductors are in the range of 10-100 electron masses [34] and this forces to question the idea that ordinary Cooper pairs are current carriers. Quantum classical correspondence requires that bound states involve formation of join along boundaries bonds between bound particles. 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.
   Questions: Could quantum classical correspondence help to identify the mechanism giving rise to Cooper pairs? The simplest model of pair is as a space-time sheet with size of order ξ so that the electrons are "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 and form color singlet like structures connected by long color flux tubes so that color force would be ultimately responsible for the stability of Cooper pair? In case of single electron condensed to single space-time sheet the em flux could be indeed feeded by u and $\overline{d}$ type wormhole contacts to larger space-time sheet. Or could electrons be free-travellers bound to structures involving also other particles?

3. Quantum classical correspondence forces to ask for the space-time correlates for the existing quantum description of phonons.
   Questions: What are the space-time sheets associated with phonons? Could the microscopic description of phonons in atomic length scales rely on the oscillations of wormhole contact Bose-Einstein condensates at the boundaries of nucleon space-time sheets with size scale of order atom size? 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?

4. 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 which is a transition to dark nuclear phase so that size of dark quarks involved would be scaled up to $L(k \rightarrow k+22 \rightarrow k+44)$, say $k = 113 \rightarrow 135 \rightarrow 157$), and the size of hadronic space-time sheets would be scaled up as $k = 107 \rightarrow 129 \rightarrow 151$? Could it be that also other p-adic primes are possible as suggested by the p-adic mass calculations of hadron masses predicting that hadronic quarks can correspond to several values of k? Could it be that the Gaussian Mersennes $(1+i)^k - 1$, $k = 151, 157, 163, 167$ spanning the p-adic length scale range 10 nm-2.5 μm correspond to p-adic length especially relevant for super-conductivity.

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

The existence of wormhole contacts have been one of the most exotic predictions of TGD. The realization that wormhole contacts can be regarded as parton-antiparton pairs with parton and antiparton assignable to the light-like causal horizons accompanying wormhole contacts, and that Higgs particle corresponds to wormhole contact [F2], opens the doors for more concrete models of also super-conductivity involving massivation of photons.

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 antifermion 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. A further questionable feature is that a quantum superposition of many-particle states with widely different masses would be in question. The interpretational problems could be resolved elegantly in zero energy ontology [C2] 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.

Rather remarkably, 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 Phonon exchange mechanism

Sound waves correspond to density variations of condensed matter. If dark gluons and exotic weak bosons with weak scale of order atomic radius explain the low compressibility of condensed matter [F9] then these forces should be essential for the description of what happens for sound waves below the atomic length scale. In particular, the lattice length appearing in Debye frequency should be expressible in terms of dark weak length scale.

Quantum classical correspondence requires that phonons should have identification as space-time sheets and that sound velocity is coded in the geometry of the space-time sheet. This interpretation of course makes sense only if the space-time sheet of phonon is in contact with atoms so that atomic oscillations induce oscillations of the induced gauge fields inside it.

The obvious objection against this picture is that one can imagine the possibility of free phonons analogous to photons connecting nuclei with say distance of micrometer and having no contact with the nuclei in between. One can of course turn the situation around and ask whether free phonons are the hen and lattice oscillations the egg. Could free photons exist and induce resonant oscillations of atomic nuclei if their velocity is consistent with the sound velocity deducible from the lattice constant and elastic constant for the interactions between atoms?

The existence of warped vacuum extremals, and in general the huge vacuum degeneracy of field equations, suggest how this space-time representation of phonons might occur. The simplest warped extremal corresponds to the mapping $M^4 \rightarrow CP_2$ defined as $\Phi = \omega m^0$, where Φ is coordinate of the geodesic circle of CP_2 with other coordinates being constant. The induced metric is $g_{m^0m^0} = 1 - R^2\omega^2/4$, $g_{ij} = -\delta_{ij}$. Light velocity with respect to M^4 coordinates, which are physically preferred coordinates, is reduced to $v = \sqrt{1 - R^2\omega^2/4}$. The crazy guess would be that the reduced signal velocity could have interpretation as sound velocity with the previous prerequisites.

For small perturbations of vacuum extremals the term coming from the variation with respect to the induced metric vanishes, and the only contribution comes from the variation of the induced Kähler form. As a consequence, the field equations reduce to empty space Maxwell's equations $j^\alpha_K = 0$ for the induced Kähler form in the induced metric of determined by vacuum extremal in the lowest non-trivial order. This means that the maximal signal velocity is in general reduced and the reduction can be very large as the case of warped vacuum extremals demonstrates. The longitudinal Kähler electric field associated with phonons would serve as a correlate for the longitudinal sound waves.

In higher orders the solution develops a non-vanishing Kähler current j^α_K and this relates naturally to the fact that the phonon exchange involves dissipation. In the case of the simplest warped vacuum extremals the relevant parameter for the perturbation theory is ωR which is near to unity so that perturbative effects can be quite sizable if the phonons are representable in the proposed manner. The non-vanishing of the vacuum Lorentz force $j^\alpha_K J_{\alpha\beta}$ serves as a space-time correlate for the presence of dissipative effects. For the known solutions of field equations the Lorentz force vanishes and the interpretation is that they represent asymptotic self-organization patters. Phonons would be different and represent transient phenomena.

If this interpretation is correct, the phonon mechanism for the formation of Cooper pairs could have a description in terms of the topological condensation of electrons at space-time sheets representing phonons connecting atomic nuclei. The essential point would be that electrons of Cooper pair would be outside the space-time in well-defined sense. Also now wormhole contacts would be involved but the Coulomb interaction energy of delocalized electrons with charged wormhole throats would be negligible as compared to the interaction energy with nuclei.

2.4.4 Space-time correlate for quantum critical superconductivity

The series of leading questions has probably given reader a hunch about what the mechanism of super-conductivity could be in the quantum critical case.

1. Exotic Cooper pair as a pair of space-time sheets of scaled up electrons feeding their gauge fluxes to a larger space-time sheet via $q\overline{q}$ type wormhole contacts

Quantum critical electronic super-conductivity requires new kind of Cooper pairs which are responsible for supra currents in the temperature range $[T_c, T_{c_1}]$ inside stripe like regions (flux tubes). These Cooper pairs are quantum critical against decay to ordinary electrons so that in time scale characterizing quantum criticality so that super-conductivity is reduced to conductivity whose temperature dependence is characterized by scaling laws. Below T_c large $\hbar$ variants of BCS Cooper pairs are good candidates for supra current carriers and would result from exotic Cooper pairs. A model for the exotic Cooper pairs is considered in the sequel. Boundary plays an essential role in that the Cooper pairs at boundary must be in quantum critical phase also below T_c since otherwise the transformation of ordinary electrons to large $\hbar$ BCS type Cooper pairs and vice versa is not possible.

If wormhole contact for large $\hbar$ electron corresponds to e^+e^- pairs, one ends up with a stability problem since the annihilation of electron and e^+ at wormhole throat can lead to the disappearance of the space-time sheet. If there are two wormhole contacts corresponding to quark anti-quark pairs the situation changes. The requirement that the net charge of wormhole throats is +2e implies $u\overline{d}$ configuration for upper wormhole throats and its conjugate for the lower wormhole throats. If the wormhole throats of each electron carry net color quantum numbers the binding of electrons by color confining force would guarantee the stability of the exotic Cooper pair. This would require that wormhole throats form a color singlet not reducible to product of pion type $u\overline{d}$ type color singlets.

BCS type Cooper pair results when both electrons end up at same space-time sheet of exotic Cooper pair via a join along boundaries bond. This hopping would also drag the wormhole contacts with it and the second space-time sheet could contract. These Cooper pairs can in principle transform to pairs involving only two join along boundaries contacts carrying e^+e^- pairs at their throats. For these Cooper pairs case the binding of electrons would be due to phonon mechanism.

2. General comments

Some general comments about the model are in order.

1. High T_c super conductors are Mott insulators and antiferromagnets in their ground state, which would suggest that the notion of non-interacting Fermi gas crucial for BCS type description is not useful. Situation is however not so simple if antiferromagnetic phase and magnetically disordered phase with large $\hbar$ for nuclei compete at quantum criticality. Large $\hbar$ makes possible high T_c variant of BCS type superconductivity in magnetically disordered phase in interior of rivulets but it is possible to get to this phase only via a phase consisting of exotic Cooper pairs and this is possible only in finite temperature range below T_c.

2. For both exotic and phonon mediated super-conductivity Cooper pair can be said to be outside the space-time sheet containing matter. Assuming a complete delocalization in the exotic case, the interaction energy is the expectation value of the sum of kinetic and Coulombic interaction energies between electrons and between electrons and wormhole throats. In the case of phonon space-time sheets situation is different due to the much larger size of Cooper pair space-time sheet so that Coulomb interaction with wormhole throats provides the dominating contribution to the binding energy.

3. The explicit model for high T_c super-conductivity relies on quantum criticality involving long ranged quantum fluctuations. The mechanism seems could apply in all cases where quantum critical fluctuations can be said to be carriers of supra currents and exotic super-conductivity vanishes when either phase dominates completely. 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.

2.5 Super-conductivity at magnetic flux tubes

Super-conductivity at 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 [38]. The magnetic coupling was only observed at lattice densities close to the critical density at which long-range magnetic order is suppressed. Quantum criticality suggests that the super-conductivity appears at the boundaries of two competing phases and that Cooper pairs correspond to space-time sheets feeding their em gauge charge via $q\overline{q}$ type wormhole contacts to larger space-time sheet.

Almost the same model as in the case of high T_c and quantum critical super-conductivity applies to 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.

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 the confinement of the electron Cooper pairs in harmonic oscillator states. The critical temperature is however 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 [117, 105] 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 Bose-Einstein condensation to the ground state occurs and the stability of Bose-Einstein condensate requires an energy gap which must be larger than the temperature at the magnetic flux tube.

There are several energies to be considered.

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 $E_g = \alpha/L(k)$ giving $E_g \sim 10^{-3}$ eV for $L(167) = 2.5$ μm 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 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 ordinary value of $\hbar$ and $\sim 2n \times 10^{-6}$ eV for $\hbar = n2^{11} \times \hbar(1)$. At the next level of dark hierarchy the energy would be $4n^2 \times 10^{-3}$ eV and would still correspond to a temperature $4n^2$ K.

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 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

The model of exotic Cooper pairs has been already described and since high T_c superconductors are quantum critical, they provide an attractive application of the model.

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 $\hbar = 2^{11}\hbar_0$ 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 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 [57, 46]. 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 [47] and the references mentioned in [57]). 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.

High T_c super conductors have spin glass like character [56]. 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 is known to occur along dynamical stripes which are antiferromagnetic defects.

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 is assignable with the quantum fluctuations destroying antiferromagnetic order and replacing it with magnetically disordered phase possibly allowing phonon induced super-conductivity.

The doping of the super-conductor with electron holes is essential for high T_c superconductivity and the there is a critical doping fraction $p = .14$ at which T_c is highest. 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 [46], which are fluctuating in time scale of 10^{-12} seconds. These stripes are also present in non-conductong and non-superconducting state but in this case they do not fluctuate. One interpretation for the fluctuations is as oscillations analogous to acoustic wave and essential for the binding of Cooper pairs. Quantum criticality suggests an alternative interpretation.

T_c is inversely proportional to the distance L between the stripes. One interpretation is in terms of generalization of the Debye frequency to 2-dimensional case. One could also consider phonons with wavelength equal to the distance between the stripes. A further interpretation would be that full super-conductivity requires delocalization 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 $1/L$ [46]. Later a TGD based interpretation will be discussed.

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

The article of Jan Zaanen [40] 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.

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 Tc 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 delocalization 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 superconductivity 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 stipe like structures in type I super-conductor near criticality, which suggests type I super-conductivity: as found large $\hbar$ Cooper pairs would make it possible. 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 superconducting compounds [45].

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 [39] at $T_{c1} > T_c$ conforms with this interpretation. In particular, the fact pseudo-gap is non-vanishing already at T_{c_1} and stays constant rather than starting from zero as for quasi-particles conforms with the flux tube interpretation.

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 [58]. 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 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 [58]. 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 [54, 55, 51] 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 for favored momentum exchange $(\pi/a, \pi/a))$, where a denotes the size of the lattice cube [54, 55, 51]. The transferred energy is concentrated in a remarkably narrow range around E_w rather than forming a continuum.

In [43] 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 ordinary super conductivity and ee 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.

3.2 Vision about high T_c superconductivity

The following general view about high T_c super-conductivity as quantum critical phenomenon suggests itself.

3.2.1 Interpretation of critical temperatures

The two critical temperatures T_c and $T_{c_1} > T_c$ are interpreted as critical temperatures. T_{c_1} is the temperature for the formation of a quantum critical phase consisting of ordinary electrons and exotic Cooper pairs with large value of Planck constant. Quantum criticality of exotic Cooper pairs prevails for temperatures below T_{c_1} in the case that one has conductivity. For completely static stripes there is no conductivity. The absence of fluctuations suggests the loss of quantum criticality. One interpretation could be that exotic Cooper pairs are there but there can be no conductivity since the necessary transition of incoming ordinary electrons to large $\hbar$ dark electrons and back is not possible. T_c is the temperature at which BCS type Cooper pairs with large Planck constant become possible and exotic Cooper pairs can decay to the ordinary Cooper pairs.

3.2.2 Model for exotic and BCS type Cooper pairs

Exotic Cooper pair is modelled as a pair of large $\hbar$ electrons with zoomed up size at space-time sheets X^4_c topologically condensed to the background space-time sheet Y^4 of condensed matter system. The Coulombic binding energy of charged particles with the quarks and antiquarks assignable to the two wormhole throats feeding the em gauge flux to Y^4 could be responsible for the energy gap. Color force would bind the two space-time sheets to exotic Cooper pair.

Electrons of exotic Cooper pair can also end up a to same space-time sheet and possibly but not necessarily feed their em fluxes via two wormhole contacts carrying electron-positron pairs. In this case they are bound by the usual phonon interaction and form ordinary Cooper pair with large value of Planck constant.

The origin of the large $\hbar$ electrons must somehow relate to the breaking of antiferromagnetic phase by stripes. The neighboring electrons in stripe possess parallel spins and could therefore form a pair transforming to a large $\hbar$ Cooper pair bound by color force. This mechanism would be the TGD counterpart for the mechanism allowing the superconducting phases at different stripes to fuse to a single super-conducting phase at longer length scales.

Various lattice effects such as superconductivity-induced phonon shifts and broadenings, isotope effects in T_c, the penetration depth, infrared and photoemission spectra have been observed in the cuprates [41]. This would support the view that quantum criticality involves the competition between exotic and large $\hbar$ variant of BCS type super-conductivity and the proposed mechanism transforming exotic Cooper pair to BCS type pairs. The loss of antiferromagnetic order for higher dopings would make possible BCS type phonon induced super-conductivity with spin singlet Cooper pairs.

3.2.3 What is the value of $\hbar$?

The observed stripes would carry large $\hbar$ electrons attracted to them by hole charge. The basic question concerns the value of $\hbar$ which in the general case is given by $\hbar = n_a/n_b$ where n_i is the order of the maximal cyclic subgroup of G_i.

1. The thickness of stripes is few atomic sizes and the first guess is that scaled up electrons have atomic size. The requirement that the integer n_a defining the value of M^4 Planck constant correspond to a n-polygon constructible using only ruler and compass gives strong constraints. An even stronger requirement would be that subgroup $G_a \subset SU(2)$ characterizes the Jones inclusion involved and thus the covering of CP_2 by M^4 points, corresponds to exceptional group via McKay correspondence, leaves only one possibility: $N(G_b) = 120$ which corresponds to E_8 Dynkin diagram having Z_5 as maximal cyclic subgroup and involving Golden Mean. The p-adic length scale of electron would be scaled up: $L(127) \rightarrow 5L(127) \simeq L(127+12) = L(139) \simeq 1.6$ Angstrom. This picture is not consistent with the model involving cell membrane length scale and the appearance of 50 meV energy scale which can be interpreted in terms of Josephson energy for cell membrane at criticality for nerve pulse generation is too intriguing signal to be dismissed.

2. The length of stripes is in the range 1-10 nm and defines second length scale in the system. If the Compton wavelength of scaled up electron corresponds to this length then $n_a = n_F = 2^{11}$ whose powers are encountered in the quantum model of living matter would suggest itself, and would predict the effective p-adic length scale electron to be $L(127+22) = L(149) = 5$ nm, the thickness of the lipid layer of the cell membrane which brings in mind cell membrane and bio-superconductivity. It will be found that simple stability arguments favor this size scale for scaled up electrons and size $L(151)$ for the exotic Cooper pairs. The minimum option is that only the exotic Cooper pairs making possible super-conductivity above T_c and broken by quantum criticality against transition to ordinary electron need have size of order $L(151) = 10$ nm.

3. The coherence length for high T_c super conductors is reported to 5-20 Angstroms. The naive interpretation would be as the size of BCS type Cooper pair which would suggest that scaled up electrons have at most atomic size. There is however a loophole involved. The estimate for coherence length in terms of gap energy is given by $\xi = \frac{4\hbar v_F}{E_{gap}}$. If coherence length is estimated from the gap energy, as it seems to be the case, then the scaling up of Planck constant would increase coherence length by a factor n_F and give coherence length in the range $1-4$ μm.

4. The dependence $T_c \propto 1/L$, where L is the distance between stripes is a challenge for the model since it would seem to suggest that stripe-stripe interaction is important for the energy gap of BCS type Cooper pairs. One can however understand this formula solely in terms of 2-dimensional character of high T_c super-conductors. To see this, consider generalization of the 3-D formula

$$\begin{aligned} E_{gap} &= \hbar\omega_c exp(-1/X) \\ \omega_D &= (6\pi^2)^{1/3} c_s n_n^{1/3} \end{aligned}$$

for the gap energy to 2-dimensional case. Since only the nuclei inside stripes contribute to high T_c super-conductivity it is natural to replace 3-dimensional formula for Debye frequency in 2-dimensional case with

$$\omega_D = kc_s n_h^{1/2} \quad ,$$

where n_h is the 2-dimensional density of holes and k a numerical constant. Since one has $n_h \propto 1/L^2$ this indeed predicts $E_{gap} \propto 1/L$.

3.2.4 Quantum criticality below T_{c_1}

Exotic Cooper pairs would be present below the higher critical temperature T_{c_1} associated with high T_c super-conductors and start to transform to BCS type Cooper pairs at T_c. Also the reverse process occurs. In the intermediate temperature range they would be unstable against transition changing the value of Planck constant to ordinary ones and this instability would break the exotic super-conductivity to ordinary conductivity with resistance obeying scaling law as a function of temperature typical for quantum critical systems. The complete stability of stripes would indicate that the exotic Cooper pairs are present but conductivity is not possible since ordinary electrons entering to the system cannot transformed to exotic Cooper pairs.

3.2.5 Why doping by holes is necessary?

In high T_c super-conductivity doping by holes plays a crucial role. What is known that holes gather to the stripes and that there is a critical doping at which T_c is maximum. Cusp catastrophe as a general model for phase transition suggests that that super-conductivity is possible only in finite range for the hole concentration. This is indeed the case.

The holes form a positive charge density and this inspires the idea that Coulomb attraction between exotic Cooper pairs of electrons and holes leads to the formation of stripes. Stripes provide also electrons with parallel spins which can transform to exotic large $\hbar$ Cooper pairs at quantum criticality with respect to $\hbar$.

One should also understand the upper limit for the hole concentration.

1. The first explanation is that super-conductivity is not preserved above critical hole concentration due to the loss of fractal stripe structure. Part of the explanation could be that beyond critical hole concentrations it is not possible to arrange the stripes to a fractal lattice formed by a lattice of "super-stripes" which are lattices of stripes of thickness $L(151)$ containing the observed stripes such that super-stripes have separation $d \geq L(151)$. Doping fraction p gives an estimate for the distance d between super-stripes as $d = xL(151)$, $x = r/p - 1$, where r is the fraction of atoms belonging to stripe inside super-stripe and p is doping fraction. $x = 2/5$ and $p = .15$ gives $d = 5L(151)/3$. Note that ideal fractality would require $x/(1+x) = r$ giving $r \simeq p/2$.

2. One could also consider the possibility that large $\hbar$ BCS super-conductivity is not lost above critical hole concentration but is useless since the transformation of ordinary current carrying electrons to large $\hbar$ exotic Cooper pairs would not be possible. Thus a quantum critical interface allowing to transform ordinary current to supra current is necessary.

3.2.6 Zeros of Riemann ζ and quantum critical super conductors

A long standing heuristic hypothesis has been that the radial conformal weights Δ assignable to the functions $(r_M/r_0)^\Delta$ of the radial lightlike coordinate r_M of $\delta M^4_+/-$ of lightcone boundary in super-canonical algebra consisting of functions in $\delta M^4_\pm \times CP_2$ are expressible as linear combinations of zeros of Riemann Zeta. Quantum classical correspondence in turn inspires the hypothesis that these conformal weights can be mapped to the points of a geodesic sphere of CP_2 playing the role of conformal heavenly sphere.

The arguments of [C1] suggest that radial conformal weight Δ in fact depends on the point of geodesic sphere S^2 in CP_2 and is given in terms of the inverse $\zeta^{-1}(z)$ of Riemann ζ having the natural complex coordinate z of S^2 as argument. This implies a mapping of the radial conformal weights to the points of the geodesic sphere CP_2. Linear combinations of zeros correspond to algebraic points in the intersections of real and p-adic space-time sheets and are thus in a unique role from the point of view of p-adicization. This if one believes the basic conjecture that the numbers p^s, p prime and s zero of Riemann Zeta are algebraic numbers.

Zeros of Riemann Zeta have been for long time speculated to closely relate to fractal and critical systems. If the proposed general ansatz for super-canonical radial conformal weights holds true, these speculations find a mathematical justification.

Geometrically the transition changing the value of $\hbar(M^4)$ correspond to a leakage of partonic 2-surfaces between different copies of $M^4 \times CP_2$ with same CP_2 factor and thus same value of $\hbar(CP_2)$ but different scaling factor of CP_2 metric. M^4 metrics have the same scaling factor given by n_b^2.

Critical 2-surfaces can be regarded as belonging to either factor which means that points of critical 2-surfaces must correspond to the CP_2 orbifold points, in particular, $z = \xi^1/\xi^2 = 0$ and $z = \xi^1/\xi^2 = \infty$ remaining invariant under the group $G \subset SU(2) \subset SU(3)$ defining the Jones inclusion, that is the north and south poles of homologically non-trivial geodesic sphere $S^2 \subset CP_2$ playing the role of heavenly sphere for super-canonical conformal weights. If the hypothesis $\Delta = \zeta^{-1}(z)$ is accepted, the radial conformal weight corresponds to a zero of Riemann Zeta: $\Delta = s_k$ at quantum criticality.

At quantum level a necessary prerequisite for the transition to occur is that radial conformal weights, which are conserved quantum numbers for the partonic time evolution, satisfy the constraint $\Delta = s_k$. The partonic 2-surfaces appearing in the vertices defining S-matrix elements for the phase transitions in question need not be of the required kind. It is enough that $\Delta = s_k$ condition allows their evolution to any sector of H in question. An analogous argument applies also to the phase transitions changing CP_2 Planck constant: in this case however leakage occurs through a partonic 2-surface having single point as M^4 projection (the tip of $M^4_\pm$).

Quantum criticality for high temperature super-conductivity could provide an application for this vision. The super conducting stripe like regions are assumed to carry Cooper pairs with a large value of M^4 Planck constant corresponding to $n_a = 2^{11}$. The boundary region of the stripe is assumed to carry Cooper pairs in critical phase so that super-canonical conformal weights of electrons should satisfy $\Delta = s_k$ in this region. If the members of Cooper pair have conjugate conformal weights, the reality of super-canonical conformal weight is guaranteed. The model predicts that the critical region has thickness $L(151)$ whereas scaled electron with $n = 2^{11}$ effectively correspond to $L(127+22) = L(149)$, the thickness of the lipid layer of cell membrane. This picture would suggests that the formation and stability of the critical region is essential for the formation of phase characterized by high T_c super-conductivity with large value of Planck constant and forces temperature to a finite critical interval. In this framework surface super-conductivity would be critical and interior super-conductivity stable.

These observations in turn lead to the hypothesis that cell interior corresponds to a phase with large M^4 Planck constant $\hbar(M^4) = 2^{11}\hbar_0$ and cell membrane to a quantum critical region where the above mentioned condition $\Delta = s_k$ is satisfied. Thus it would seem that the possibility of ordinary electron pairs to transform to large $\hbar$ Cooper pairs is essential in living matter and that the transition takes place as the electron pairs traverse cell membrane. The quantum criticality of cell membrane might prevail only in a narrow temperature range around T=37 C. Note that critical temperature range can also depend on the group G having C_n, $n = 2^{11}$ cyclic group as maximal cyclic group (C_n and D_n are the options).

3.3 A detailed model for the exotic Cooper pair

3.3.1 Qualitative aspects of the model

High T_c superconductivity suggests that the Cooper pairs are stripe like structures of length 1-10 nm. The length of color magnetic flux tube is characterized by the p-adic length scale in question and $L(151) = nm$ is highly suggestive for high T_c superconductors.

These observations inspire the following model.

1. The space-time sheet of the exotic Cooper pair is obtained in the following manner. Take two cylindrical space-time sheets which have radius of order $L(149)$. One could of course argue that flux tubes can have this radius only along CuO plane and must flattened in the direction orthogonal to the super-conducting plane with thickness of few atomic units in this direction. The assumption about flattening leads however to a very large electronic zero point kinetic energy. Furthermore, in the absence of flattening supra phases belonging to different CuO planes combine to form single quantum coherent phase so that coherence length can be longer than the thickness of CuO layer also in orthogonal direction.

2. Assume that the cylinders they contain electrons with u wormhole throat at top and $\overline{d}$ wormhole throat at bottom feeding the em gauge flux to the larger space-time sheet. Connect these parallel flux tubes with color magnetic bonds. If the $u\overline{d}$ states associated with the flux tubes are not in color singlet states, color confinement between wormhole quarks binds the electronic space-time sheets together and electrons are "free-travellers". These exotic Cooper pairs are energy minima for electrons are in large $\hbar$ phase if the electron kinetic energy remains invariant in $\hbar$ changing phase transition. This is achieved by fractionization of quantum numbers characterizing the kinetic energy of electron.

3. If the flux tubes carry magnetic flux electron spins are parallel to the magnetic field in minimum energy state. If the magnetic flux rotates around the resulting singlet sheeted structure the spin directions of electrons are opposite and only $S = 0$ state is possible as a minimum energy state since putting electrons to the same flux tube would give rise to a repulsive Coulomb interaction and also Fermi statistics would tend to increase the energy.

4. The homological magnetic monopoles made possible by the topology of CP_2 allows the electrons to feed their magnetic fluxes to a larger space-time sheet via u throat where it returns back via $\overline{d}$ throat. A 2-sheeted monopole field is in question. The directions of the magnetic fluxes for the two electrons are independent. By connecting the flux tubes by color bonds one obtains color bound electrons. In this kind of situation it is possible to have $S = 1$ state even when electrons are at different flux tubes portions so that energies are degenerate in various cases. The resulting four combinations give $S_z = \pm 1$ states and two $S_z = 0$ states which means spin triplet and singlet. Interestingly, the first 23 year old model of color confinement was based on the identification of color hyper charge as homological charge. In the recent conceptual framework the space-time correlate for color hyper charge Y of quark could be homological magnetic charge $Q_m = 3Y$ so that color confinement for quarks would have purely homological interpretation at space-time level.

5. One can also understand how electrons of Cooper pair can have angular momentum ($L = 2$ in case of high T_c Cooper pairs and $L = 0$ in case of ^{3}He Cooper pairs) as well as correlation between angular momentum and spin. The generation of radial color electric field determined by the mechanical equilibrium condition $E + v \times B = 0$ inside give portion of flux tube implies that electrons rotate in same direction with velocity v. A non-vanishing radial vacuum E requires that flux tube portion contains cylindrical hole inside it. Without hole only $v = 0$ is possible. Assume that the directions of radial E and thus v can be freely chosen inside the

vertical portions of flux tube. Assume that also $v = 0$ is possible in either or both portions. This allows to realize L_z values corresponding to $L = 0, 1, 2$ states.

6. Since quarks in this model appear only as parton pairs associated with wormhole contacts, one expects that the corresponding p-adic mass scale is automatically determined by the relevant p-adic length scale, which would be $L(151)$ in case of high T_c superconductors. This would mean that the mass scale of inertial mass of wormhole contact would be 10^2 eV even in the case that p-adic temperature is $T_p = 1$. For $T_p = 2$ the masses would be extremely small. The fact that the effective masses of electrons can be as high as $100m_e$ [34] means that the mass of wormhole contact does not pose strong constraints on the effective mass of the Cooper pair.

7. The decay of Cooper pair results if electrons are thrown out from 2e space-time sheet. The gap energy would be simply the net binding energy of the system. This assumption can make sense for high T_c super-conductors but does not conform with the proportionality of the gap energy to Debye frequency $\omega_D = v_s/a$ in the case of ordinary super-conductors for which phonon space-time sheets should replace color flux tubes.

8. Both the assumption that electrons condensed at $k = 149$ space-time sheets result from scaled up large $\hbar$ electrons and minimization of energy imply the scales $L(149)$ and $L(151)$ for the space-time sheets involved so that there is remarkable internal consistency. The model explains the spins of the exotic Cooper pairs and their angular momenta. The dark BSC type Cooper pairs are expected to have $S = 0$ and $L = 0$.

3.3.2 Quantitative definition of the model

There are several poorly understood energies involved with high T_c super-conductors below T_c. These are $E_g = 27$ meV, $E_1 = 50$ meV, $E_w = 41$ meV, and $E_2 = 68$ meV. These numbers allow to fix the wormholy model for quantum critical super-conductors to a high degree.

Consider now a quantitative definition of the model.

1. p-Adic length scale hypothesis combined with the ideas about high T_c super-conductivity in living matter plus the fact that the stripe like defects in high T_c superconductors have lengths 1-10 nm suggests that the length scales $L(151) = 10$ nm corresponding to cell membrane thickness and $L(149) = 5$ nm corresponding to the thickness of its lipid layer are the most important p-adic length scales. Of course, also $L(145 = 5\times29) = 1.25$ nm could be important. $L(151)$ would be associated with the structure consisting of two flux tubes connected by color bonds.

2. The kicking of electrons from $k = 151$ to $k = 149$ space-time sheet should define one possible excitation of the system. For wormhole contacts kicking of electron to smaller space-time sheet is accompanied by the kicking of wormhole contacts from the pair $(151, 157)$ to a pair $(149, 151)$ of smaller space-time sheets. This can be achieved via a flow along JABs $157 \rightarrow 151$ and $151 \rightarrow 149$. Also the dropping of electrons from color flux tube to larger space-time sheet defines a possible transition.

3. Assume that given electrons reside inside electronic flux tubes connected having u and $\overline{d}$ at their ends and connected by color bonds. Assume that electrons are completely delocalized and consider also the configuration in which both electrons are in the same electronic flux tube. The total energy of the system is the sum of zero point kinetic energies of electrons plus attractive Coulomb interaction energies with u and $\overline{d}$ plus a repulsive interaction energy between electrons which contributes only when electrons are in the same flux tube. Minimum energy state is obviously the one in which electrons are at different flux tubes.

By effective one-dimensionality the Coulomb potential can be written as $V(z) = \alpha Qz/S$, where S is the thickness of the flux tube. It is assumed that S scales $L(k)^2/y$, $y > 1$, so that Coulomb potential scales as $1/L(k)$. The average values of Coulomb potential for electron quark interaction ($Q(u) = 2/3$ and $Q(\overline{d}) = 1/3$) and ee interaction are

$$\begin{aligned} V_{eq} &= \frac{y}{2}V(k) \ , \\ V_{ee} &= \frac{y}{3}V(k) \ , \\ V(k) &= \frac{\alpha}{L(k)} \ . \end{aligned} \tag{10}$$

One can introduce a multiplicative parameter x to zero point kinetic energy to take into account the possibility that electrons are not in the minimum of kinetic energy. The color interactions of wormhole throats can of course affect the situation.

With these assumptions the estimate for the energy of the 2e space-time sheet is

$$\begin{aligned} E_{2e}(k) &= 2xT(k) - 2V_{eq} + \epsilon V_{ee} = 2xT(k) - y(1-\frac{\epsilon}{3})V(k) \ , \\ T(k) &= \frac{D}{2}\frac{\pi^2}{2m_eL^2(k)} \ , \\ V(k) &= \frac{\alpha}{L(k)} \ . \end{aligned} \tag{11}$$

Here $\epsilon = 1/0$ corresponds to the situation in which electrons are/are not in the same flux tube. One has $x \geq 1$ and $x = 1$ corresponds to the minimum of electron's kinetic energy. If the maximum area of the tube is $\pi L(151)^2$, one should have $y \leq \pi$. The effective dimension is $D = 1$ for flux tube. $k = 151$ and $k = 149$ define the most interesting p-adic length scales now.

4. By p-adic scaling one has

$$E_{2e}(k) = 2^{151-k} \times 2xT(151) - 2^{(151-k)/2} \times y(1-\frac{\epsilon}{3})V(151) \ . \tag{12}$$

The general form of the binding energy implies that it has maximum for some value of k and the maximum turns out to correspond to $k = 151$ with a rather reasonable choice of parameters x and y.

One could also require a stability against the transition $151 \to 149$. Here a difficulty is posed by the fact that color interaction energy of wormhole contacts probably also changes. One can however neglect this difficulty and look what one obtains. In this approximation stability condition reads as

$$E_{2e}(149) - E_{2e}(151) = 6xT(151) - y(1-\frac{\epsilon}{3})V(151) > 0 \ . \tag{13}$$

One obtains

$$\frac{y}{x} \leq \frac{6T(151)}{V(151)} = \frac{6}{\alpha}\frac{\pi^2}{2m_eL(151)} \simeq 3.54 \ . \tag{14}$$

For $k > 151$ the binding energy decreases so fast that maximum of the binding energies at $k = 151$ might be guaranteed by rather reasonable conditions on parameters.

5. The general formula λ is expected to make sense and gives rather large λ. The BCS formula for ξ need not make sense since the notion of free electron gas does not apply. A good guess is that longitudinal ξ is given by the height $L(151) = 10$ nm of the stripe. Transversal ξ, which is in the range 4-20 Angstroms, would correspond to the thickness of the color magnetic flux tube containing electrons. Hence the scale for ξ should be smaller than the thickness of the stripe.

3.3.3 Estimation of the parameters of the model

It turns out to be possible to understand the energies E_2, E_1, E_w and E_g in terms of transitions possible for wormhole contact option. The values of the parameters x and y can be fitted from the following conditions.

1. The largest energy $E_2 = 68$ meV is identified as the binding energy in the situation in which electrons are at different flux tubes. Hence one has $E_{2e}(\epsilon = 0) = -E_2$ giving

$$-2xT(151) + yV(151) = E_2 \ . \tag{15}$$

The peak in photo-absorption cross section would correspond to the dropping of both electrons from the flux tube to a much larger space-time sheet.

2. The energy $E_g = 27$ meV is identified as the binding energy in the situation that electrons are at the same flux tube so that E_g represents the energy needed to kick electrons to a much larger space-time sheet. This gives

$$-2xT(151) + \frac{2}{3}yV(151) = E_g \ . \tag{16}$$

3. E_w corresponds to the difference $E_2 - E_g$ and has an interpretation as the energy needed to induce a transition from state with $\epsilon = 0$ (electrons at different flux tubes) to the state with $\epsilon = 1$ (electrons at the same flux tube).

$$E_{2e}(151, \epsilon = 1) - E(2e)(151, \epsilon = 0) = \frac{y}{3}V(151) = E_w \ . \tag{17}$$

This condition allows to fix the value of the parameter y as

$$y = \frac{3E_w}{V(151)} \ . \tag{18}$$

Condition 1) fixes the value of the parameter x as

$$x = \frac{E_w}{T(151)} . \tag{19}$$

Using $V(151) \simeq 144$ meV and $T(151) = 20.8$ meV this gives $y = .8539 < \pi$ and $x = 1.97$. The area of the color flux tube is .27 per cent about $S_{max} = \pi L^2(151)$ so that its radius equals in a good approximation $L(149)$, which looks rather large as compared to the estimated thickness of the visible stripe. $x = 1.97$ means that the electron's kinetic energy is roughly twice the minimal one. $y/x = .43$ satisfies the bound $y/x < 6T(151)/V(151) = .87$ guaranteing that the binding energy is maximum for $k = 151$. This result is rather remarkable.

4. The model should explain also the energy $E_1 \simeq 50$ meV at which sharp photon absorption sets on. The basic observation is that for neuronal membrane 50 mV corresponds to the critical voltage for the generation of nerve pulse. In super-conductor model of cell membrane 50 meV is identified as the energy of Josephson photon emitted or absorbed when Cooper pair moves from cell interior to exterior of vice versa. Thus 50 meV energy *might* correspond to the energy of Josephson photon and kick BCS type Cooper pair between the two layers of the double-layered super stripe.

   Note that 50 meV corresponds to a thermal energy of 3-D system at T= 333 K (60 C). This is not far from 37 C, which would also suggest that high T_c super-conductivity is possible at room temperatures. In the case of cell membrane quantum criticality could among other things make possible the kicking of the large $\hbar$ BCS type Cooper pairs between lipid layers of cell membrane. If so, neurons would be quantum critical only during nerve pulse generation.

   One can consider also alternative explanation. 50 meV is not much higher than 41 meV so that it could relate to the $\epsilon = 0 \rightarrow 1$ transition. Recoil effects are negligible. Perhaps $m = 1$ rotational excitation of electron of 2e system residing at the same flux tube and having energy $E = 9$ meV is in question. This excitation would receive the spin of photon. The energy scale of electronic rotational excitations is $\hbar^2/2m_eL^2(149) \sim 8.4$ meV if the radius of the flux tube is $L(149)$.

To sum up, the model allows to understand the four energies assuming natural values for adjustable parameters and predicts that $k = 151$ corresponds to stable Cooper pairs. It seems that the model could apply to a large class of quantum critical super-conductors and scaled up electrons might be involved with all condensed matter phenomena involving stripes.

3.3.4 Model for the resonance in neutron scattering

The resonance in neutron scattering is usually understood as a resonance in the scattering from the modification of the lattice induced by the formation of stripes and this scattering gives the crucial information about cross-like structure of Fermi surface of holes suggesting crossed stripes. One can also consider the possibility that the scattering is on exotic Cooper pairs which could always accompany stripes but as such need not give rise to super-conductivity or not even conductivity unless they are in quantum critical state.

Consider now the TGD based model for neutron scattering based on the proposed model for Cooper pairs.

1. Neutrons couple naturally to the magnetic field accompanying color magnetic field at the space-time sheet of Cooper pair by magnetic moment coupling. As found, $E_w = 41$ meV can be interpreted as the energy needed to induce the $\epsilon = 0 \rightarrow 1$ transition. Spin flip necessarily occurs if the electron is kicked between the vertical flux tubes.

2. Resonance would result from the coherent coupling to the wormhole BE condensate making scattering rate proportional to N^2, where N denotes the number of wormhole contacts, which is actually identical with the total number of super conducting electrons. Therefore the prediction of the TGD based model is very similar to the prediction of [43]. The absence of the resonance above critical temperature suggests that exotic Cooper pairs are not present above T_c. The presence of quantum criticality also above T_c suggests that Cooper pairs decay to wormholy space-time sheets containing single electron plus wormholy pion $u\bar{d}$ responsible for the ordinary conductivity. The transition is possible also for these space-time sheets but they do not form Bose-Einstein condensate so that the resonance in neutron scattering is predicted to be much weaker for temperatures above the critical temperature. For overcritical doping the resonance should be absent if exotic Cooper pairs are possible only at the boundaries of two phases disappearing at critical doping.

3. The momentum transfer associated with the resonance is located around the momentum $(\pi/a, \pi/a)$ in resiprocal lattice [53], where a denotes the length for the side of the lattice cell. The only possible conclusion is that in the scattering neutron momentum is transferred to the lattice whereas the remaining small momentum is transferred to the momentum of wormhole BE condensate. Thus the situation is analogous to that occurring in Mössbauer effect.

3.3.5 What is the origin of picosecond time scale

The model should also predict correctly the picosecond and 1-10 nm length scales. Quantum criticality suggests that picosecond time scale relates directly to the 10 nm length scale via p-adic length scale hypothesis. $L(151) = 10$ nm defining the size for color flux tubes containing electrons of Cooper pair and lower limit for the distance between predicted super-stripes would correspond to a p-adic time scale $T(151) \sim 10^{-16}/3$ seconds for ordinary Planck constant. For $\hbar = 2^{22}\hbar_0$ this time scale would be scaled up to about $.15n$ picoseconds. This kind of length scale corresponds for electron to $n_F = 2^{22}$ rather than $n_F = 2^{11}$. One could however argue that by the very definition of quantum quantum criticality several values of n_F must be involved. The quantum model of EEG indeed assumes this kind of hierarchy [M3]. Note that $n_F = 3 \times 2^{12}$ would give picosecond scale as also (157).

Just for fun one can also consider the possibility that this time scale is due to the large $\hbar$ phase for nuclei and hadrons. Large $\hbar$ for nuclei and quarks would means gigantic Compton lengths and makes possible macroscopic quantum phase competing with ordinary phase. If one accepts TGD based model for atomic nuclei where $k = 129$ corresponds to the size of the magnetic body of ordinary nuclei [F8], the super-stripes could involve also the color magnetic bodies of dark hadrons. The size of color magnetic body for ordinary hadrons is $L(k_{eff} = 107 + 22 = 129)$ and therefore $L(k_{eff} = 129 + 22 = 151)$ for dark hadrons. This of course forces the question whether the nuclei along stripes correspond to dark nuclei. Large $\hbar$ phase for hadrons means also scaling up of the basic purely hadronic time scales. Notice that neutral pion lifetime $\sim 2 \times 10^{-16}$ seconds would be scaled up by a factor 2^{11} to .2 picoseconds.

3.3.6 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 to think that the doping by holes needed to achieve superconductivity induces the dropping of these electrons to $k = 151$ space-time sheets and gives rise to 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. Partially dark Au for which dark nuclei form a superfluid could correspond to what Hudson calls White Gold [128] and the model for high T_c superconductivity indeed explains the properties of White Gold.

3.4 Speculations

3.4.1 21-Micrometer mystery

21 micrometer radiation from certain red giant stars have perplexed astronomers for more than a decade. 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

$$\Delta E(2m_p, 139) = \frac{1}{2}\frac{\pi^2}{(2m_p)L(169)^2} = \frac{1}{8}\Delta E(m_p, 137) \simeq 61.5 \ meV \ \ .$$

   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. This observation and the presence of the carbon compounds leads to ask whether bio-superconductors and perhaps even some primitive forms of life might be involved.

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 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. $\lambda = 20.48$ 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 $E_w(k) = 2\pi/L(k)$. 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.

3.4.2 Ionic high T_c superconductivity and high T_c super-fluidity

The model of electronic superconductivity generalizes to the case of fermionic ions in almost trivial manner. The stability condition determining the p-adic length scale in question is obtained by replacing electron mass with the mass Am_p of ion and electron charge with the charge Ze of the ion. The expression of binding energy as sum of kinetic energy and Coulombic interaction energy has the general form

$$T_e + V_{ee} + V_{eq} \quad = \quad \frac{a_e}{L^2(k)} - \frac{b_e}{L(k)} \ , \tag{20}$$

and gives maximum binding energy for

$$L \quad = \quad \frac{2a_e}{b_e} \simeq L(151) \ . \tag{21}$$

The replacement of electrons with ions of charge Z induces the replacements

$$\begin{aligned} a_e &\rightarrow \frac{m_e}{Am_p} a_e \ , \\ b_e &\rightarrow Z^2 b_e \ , \\ L &\rightarrow \frac{m_e}{AZ^2 m_p} L_e \simeq \frac{1}{AZ^2} L(129) \ . \end{aligned} \tag{22}$$

This scale would be too short for ordinary value of $\hbar$ but if the nuclei are in large $\hbar$ phase, L is scaled up by a factor $\simeq n \times 2^{11}$ to $L(k_{eff}) = nL(k+22)$. This gives

$$L(k) \quad \simeq \quad \frac{n}{AZ^2} L(151) \ . \tag{23}$$

This length scale is above $L(137)$ for $AZ^2 < 2^7 n = 128n$: $n = 3$ allows all physical values of A. If $L(135)$ is taken as lower bound, one has $AZ^2 < 2^9 n$ and $n = 1$ is enough.

Second constraint comes from the requirement that the gap temperature defined by the stability against transition $k \rightarrow k-2$ is above room temperature.

$$3 \times \frac{\pi^2 \hbar^2}{2Am_p L^2(k)} \simeq 2^{-k+137} \frac{.5}{A} \quad \text{eV} \geq T_{room} \simeq .03 \quad \text{eV} \ . \tag{24}$$

Since the critical temperature scales as zero point kinetic energy, it is scaled down by a factor m_e/Am_p. $k \geq 137$ would give $A \leq 16$, $k = 135$ would give $A \leq 64$, and $k = 131$ allows all values of A.

The Bose-Einstein condensates of bosonic atoms giving rise to high T_c super fluidity are also possible in principle. The mechanism would be the dropping of atoms to the space-time sheets of electronic Cooper pairs. Thermal stability is achieved if nuclei are in doubly dark nuclear phase and electrons correspond to large $\hbar$ phase. Electronic Cooper pairs would correspond to $k_{eff} = 151 + 22 = 173$ space-time sheets with size about 20 μm. This is also the size scale of the Bohr radius of dark atoms [J6]. The claimed properties of so called ORMEs [128] make them a possible candidate for this kind of phase.

3.4.3 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. $\lambda = 2^{11}$ would predict $r = .2$ 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 [60]. 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.

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

Neuronal axons, which are bounded by cell membranes of thickness $L(151)$ consisting of two lipid layers of thickness $L(149)$ are high T_c superconductors (this was not the starting point but something which popped out naturally). The interior of this structure is in large $\hbar$ nuclear phase, which is partially dark. Since the thickness of the tube should be smaller than the quantum size of the dark nuclei, a lower limit for the radius r of the corresponding nuclear space-time sheets is obtained by scaling up the weak length scale $L_w(113) = 2^{(11-89)/2}L_w(89)$ defined by W boson Compton length by a factor 2^{22} to doubly dark weak length scale $L_w = 2^{22}L_w(113) = .2$ μm.

These flux tubes with radius $r > L_w$ define "rivers" along which conduction electrons and various kinds of Cooper pairs flow. Scaled up electrons have size $L(k_{eff} = 149)$ corresponding to 5 nm, the thickness of the lipid layer of cell membrane. The observed quantum fluctuating stripes of length 1-10 nm might relate very closely to scaled up electrons with Compton length 5 nm, perhaps actually representing zoomed up electrons!

According to the model of dark Cooper pairs the $k = 149$ flux tubes at which electrons are condensed should be hollow. What comes in mind first is that a cylinder with radius $L(149)$ is in question having a hollow interior with say atomic radius.

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 Exotic atoms, wormhole super conductivity and wormhole magnetic fields

Exotic atom, wormhole super conductivity and wormhole magnetic fields are purely TGD based concepts and it seems that these concepts might be involved with the transition from organic chemistry to biochemistry. There is certainly much more involved, in particular the long range color and weak forces discussed in [F9].

4.1 Exotic atoms

For ordinary atoms all electrons are condensed on the "atomic" condensation level. One could however think the possibility that some electrons, most probably some valence electrons with high value of principal quantum number n, condense to the lower condensation level, at which atom itself is condensed. This process would give rise to exotic atoms. The exotic counterpart of atom with charge Z would behave chemically as element with $Z - n(val)$, where $n(val)$ is the number of exotic valence electrons. The energy levels of electron at the exotic condensate level should depend only very weakly on the nuclear charge of the parent atom: only the number of valence electrons is what matters. In particular, "electronic" alchemy becomes in principle possible by dropping some electrons on the lower condensate level. One can consider two options depending on whether the dropped electrons are ordinary or dark.

1. Dropped electrons are not dark

The model to be represented is the first version about exotic super-conductivity which was based on the idea about wormhole contact as a counterpart of phonon. Much later it became obvious that charged wormhole contacts can be in fact be identified as counterparts for charged Higgs field making photons massive. This aspect is not discussed below.

The exotic electrons see the Coulomb field of nucleus with effective charge $n(val)$. This charge and gravitational flux flows from the atomic condensate level via the tiny wormhole contacts located near the boundaries of atomic condensate level. If the electric flux of the wormhole is quantized with proton charge as unit there are $n(val)$ wormhole contacts, with each wormhole carrying one unit of electric charge. Note that the minimal unit of flux is naturally 1/3 of elementary charge and the detection of electric flux of this size would be a triumph of the theory. In order to be able to evaluate the energy levels of this pseudo hydrogen atom one must know something about the mass of the wormhole contacts. The following physical considerations give estimate for the mass.

p-Adic length scale hypothesis states that physically most interesting length/mass scales are in one-one- correspondence with p-adic primes p near prime powers of two ($p \simeq 2^k$, k prime) and p-adic mass scale is given by $m \sim 1/L(p)$, where $L(p)$ is p-adic length scale expressible in terms of Planck length as $L(p) \simeq 10^4\sqrt{p}\sqrt{G}$. The representation of wormhole contact as parton pair suggests that apart from effects related to the binding of wormhole throats to single unit, the inertial mass is just the sum of contributions of parton and antiparton associated with the throats carrying opposite gauge quantum numbers. If the time orientations of the space-time sheets involved are opposite, the energies can sum up to zero and the wormhole contact carries no mass. Otherwise the mass is sum of the two masses and the dominant contribution to their mass is determined by the length scale associated with the smaller space-time sheet and thus proportional to $1/\sqrt{p_1}$. In atomic length scales this would give mass of order 10^4 eV and in the length scale corresponding to room temperature mass would be of order 10^{-2} eV. Atoms ($k = 137$) can feed they electromagnetic gauge fluxes directly to "lower" p-adic condensate levels (such as $k = 149$) rather than $k = 139$ to minimize the contribution of wormhole masses to energy.

The small mass of wormhole implies that for atoms with sufficiently high Z it could be energetically favorable to drop electrons to the lower condensate level. Very light wormhole contacts are described by d'Alembertian operator associated with the induced metric of the 3-dimensional surface describing the boundary of atomic surface and having one time like direction.

Wormhole contacts are free to move along the boundary of the atomic 3-surface. If wormhole contacts are very light but not exactly massless, it is clear that wormhole contacts behave as bosons restricted to this surface and that state they condense on ground state. For very light but not massless wormhole contacts the lowest state has energy equal to rest mass of the wormhole and next state has energy of order $\pi/a \sim 10^4\ eV$, where a is the radius of atom. Therefore very light wormhole contacts BE condense on the ground state and give rise to a constant charge distribution on the spherical shell surrounding atom. For exactly massless wormhole contacts the zero energy state is not possible and localization of massless wormhole contacts on surface of atomic size would require energy of order $10^4\ eV$. In the interior of this shell electrons are free and in exterior they move in the field of this charge distribution and form bound states. The energies of the electrons at "lower" space-time sheet depend only weakly on the value of Z (only via the dependence of the size of atomic 3-surface on Z) so that the spectral lines associated with the exotic atoms should be in certain sense universal.

The dropping of electrons of heavy atoms, such as Gold or Pb, to the lower space-time sheet, might be energetically favorable or require only a small energy and be induced by, say, absorption of a visible light. Once single electron is dropped it becomes more favorable for second electron to drop since the potential well in the final state is now deeper. The fact, that wormhole contacts form BE Einstein condensate, gives transition probability proportional to N^2 instead of N, N being the number of wormhole contacts already present. In this manner even cascade like process could become possible leading to drop of all valence electrons to the lower space-time sheet. One could even end up from heavy metal such as lead to pseudo-Xenon noble gas evaporating instantaneously!

2. Could exotic valence electrons be dark?

The basic objection against the proposed model is that the proposed wormhole mechanism has no experimental support. If temperature is same at the space-time sheets carrying the dropped electrons, it is not possible to have high T_c super-conductivity for conventional mechanisms.

The valence electrons could however be also dark, which would mean that at some radius atomic electric gauge fluxes flow to a dark space-time sheet and is shared to n_b sub-fluxes so that the each sheet carries flux n_{val}/n_b. For $n_a/n_b > 1$ the fractionization of the radial electric gauge flux could make the states of valence electrons thermally unstable. $n_a/n_b > 1$ would however favor the formation of Cooper pairs and thus high T_c variant of conventional super-conductivity with critical temperature scaled up by n_a^2.

The presence of Ca, Na and K ions in cells and their importance for the functioning of cell membrane could be also due to the fact that these ions are formed when some of the valence electrons transform to dark electrons and become super-conducting. An alternative explanation is that also the nuclei in question are dark and n_a/n_b is so high that atomic binding energies for valence electrons are below thermal threshold and cold plasma of dark ions is formed. These electrons could form Cooper pairs for large enough n_a/n_b. Magnetic flux sheets are excellent candidates for these space-time sheets. The observed ions would result via a phase transition of these ions to ordinary ones. Chemically the resulting elements would behave like noble gas. This kind of mechanism might be involved also with the formation of high T_c super-conductors.

4.2 Mono-atomic elements as dark matter and high T_c super-conductors?

The ideas related to many-sheeted space-time began to develop for a decade ago. The stimulation came from a contact by Barry Carter who told me about so called mono-atomic elements, typically transition metals (precious metals), including Gold. According to the reports these elements, which are also called ORMEs ("orbitally rearranged monoatomic elements") or ORMUS, have following properties.

1. ORMEs were discovered and patented by David Hudson [128] are peculiar elements belonging to platinum group (platinum, palladium, rhodium, iridium, ruthenium and osmium) and to transition elements (gold, silver, copper, cobalt and nickel).

2. Instead of behaving as metals with valence bonds, ORMEs have ceramic like behavior. Their density is claimed to be much lower than the density of the metallic form.

3. They are chemically inert and poor conductors of heat and electricity. The chemical inertness of these elements have made their chemical identification very difficult.

4. One signature is the infra red line with energy of order .05 eV. There is no text book explanation for this behavior. Hudson also reports that these elements became visible in emission spectroscopy in which elements are posed in strong electric field after time which was 6 times longer than usually.

The pioneering observations of David Hudson [128] - if taken seriously - suggest an interpretation as an exotic super-conductor at room temperature having extremely low critical magnetic fields of order of magnetic field of Earth, which of course is in conflict with the standard wisdom about super-conductivity. After a decade and with an impulse coming from a different contact related to ORMEs, I decided to take a fresh look on Hudson's description for how he discovered ORMEs [128] with dark matter in my mind. From experience I can tell that the model to be proposed is probably not the final one but it is certainly the simplest one.

There are of course endless variety of models one can imagine and one must somehow constrain the choices. The key constraints used are following.

1. Only valence electrons determining the chemical properties appear in dark state and the model must be consistent with the general model of the enhanced conductivity of DNA assumed to be caused by large $\hbar$ valence electrons with $r = \hbar/\hbar_0 = n$, $n = 5, 6$ assignable with aromatic rings. $r = 6$ for valence electrons would explain the report of Hudson about anomalous emission spectroscopy.

2. This model cannot explain all data. If ORMEs are assumed to represent very simple form of living matter also the presence electrons having $\hbar/\hbar_0 = 2^{k11}$, $k = 1$, can be considered and would be associated with high T_c super-conductors whose model predicts structures with thickness of cell membrane. This would explain the claims about very low critical magnetic fields destroying the claimed superconductivity.

Below I reproduce Hudson's own description here in a somewhat shortened form and emphasize that must not forget professional skepticism concerning the claimed findings.

4.2.1 Basic findings of Hudson

Hudson was recovering gold and silver from old mining sources. Hudson had learned that something strange was going on with his samples. In molten lead the gold and silver recovered but when "I held the lead down, I had nothing". Hudson tells that mining community refers to this as "ghost-gold", a non-assayable, non-identifiable form of gold.

Then Hudson decided to study the strange samples using emission spectroscopy. The sample is put between carbon electrodes and arc between them ionizes elements in the sample so that they radiate at specific frequencies serving as their signatures. The analysis lasts 10-15 seconds since for longer times lower electrode is burned away. The sample was identified as Iron, Silicon, and Aluminum. Hudson spent years to eliminate Fe, Si, and Al. Also other methods such as Cummings Microscopy, Diffraction Microscopy, and Fluorescent Microscopy were applied and the final conclusion was that there was nothing left in the sample in spectroscopic sense.

After this Hudson returned to emission spectroscopy but lengthened the time of exposure to electric field by surrounding the lower Carbon electrode with Argon gas so that it could not burn. This allowed to reach exposure times up to 300 s. The sample was silent up to 90 s after which emission lines of Palladium (Pd) appeared; after 110 seconds Platinum (Pt); at 130 seconds Ruthenium (Ru); at about 140-150 seconds Rhodium; at 190 seconds Iridium; and at 220 seconds Osmium appeared. This is known as fractional vaporization.

Hudson reports the boiling temperatures for the metals in the sample having in mind the idea that the emission begins when the temperature of the sample reaches boiling temperature inspired by the observation that elements become visible in the order which is same as that for boiling temperatures.

The boiling temperatures for the elements appearing in the sample are given by the following table.

Element	Ca	Fe	Si	Al	Pd	Rh
$T_B/^oC$	1420	1535	2355	2327	>2200	2500
Element	Ru	Pt	Ir	Os	Ag	Au
$T_B/^oC$	4150	4300	> 4800	> 5300	1950	2600

Table 2. Boiling temperatures of elements appearing in the samples of Hudson.

Hudson experimented also with commercially available samples of precious metals and found that the lines appear within 15 seconds, then follows a silence until lines re-appear after 90 seconds. Note that the ratio of these time scales is 6. The presence of some exotic form of these metals suggests itself: Hudson talks about mono-atomic elements.

Hudson studied specifically what he calls mono-atomic gold and claims that it does not possess metallic properties. Hudson reports that the weight of mono-atomic gold, which appears as a white powder, is 4/9 of the weight of metallic gold. Mono-atomic gold is claimed to behave like super-conductor.

Hudson does not give a convincing justification for why his elements should be mono-atomic so that in following this attribute will be used just because it represents established convention. Hudson also claims that the nuclei of mono-atomic elements are in a high spin state. I do not understand the motivations for this statement.

4.2.2 Claims of Hudson about ORMEs as super conductors

The claims of Hudson that ORMES are super conductors [128] are in conflict with the conventional wisdom about super conductors.

1. The first claim is that ORMEs are super conductors with gap energy about $\Delta = .05$ eV and identifies photons with this energy resulting from the formation of Cooper pairs. This energy happens to correspond one of the absorption lines in high T_c superconductors.

2. ORMEs are claimed to be super conductors of type II with critical fields H_{c1} and H_{c2} of order of Earth's magnetic field having the nominal value $.5\times 10^{-4}$ Tesla [128]. The estimates for the critical parameters for the ordinary super conductors suggests for electronic super conductors critical fields, which are about .1 Tesla and thus by a factor $\sim 2^{11}$ larger than the critical fields claimed by Hudson.

3. It is claimed that ORME particles can levitate even in Earth's magnetic field. The latter claim looks at first completely nonsensical. The point is that the force giving rise to the levitation is roughly the gradient of the would-be magnetic energy in the volume of levitating super conductor. The gradient of average magnetic field of Earth is of order B/R, R the radius of Earth and thus extremely small so that genuine levitation cannot be in question.

4.2.3 Minimal model

Consider now a possible TGD inspired model for these findings assuming for definiteness that the basic Hudson's claims are literally true.

1. In what sense mono-atomic elements could be dark matter?

The simplest option suggested by the applicability of emission spectroscopy and chemical inertness is that mono-atomic elements correspond to ordinary atoms for which valence electrons are dark electrons with large $\hbar/\hbar_0 = n_a/n_b$. Suppose that the emission spectroscopy measures the energies of dark photons from the transitions of dark electrons transforming to ordinary photons before the detection by de-coherence increasing the frequency by the factor $r = \hbar/\hbar_0$. The size of dark electrons and temporal duration of basic processes would be zoomed up by r.

Since the time scale after which emission begins is scaled up by a factor 6, there is a temptation to conclude that $r = n_a/n_b = 6$ holds true. Note that $n = 6$ corresponds to Fermat polygon and is thus preferred number theoretically in TGD based model for preferred values of $\hbar$ [A9]. The simplest possibility is that the group G_b is trivial group and $G_a = A_6$ or D_6 so that ring like structures containing six dark atoms are suggestive.

This brings in mind the model explaining the anomalous conductivity of DNA by large $\hbar$ valence electrons of aromatic rings of DNA. The zooming up of spatial sizes might make possible exotic effects and perhaps even a formation of atomic Bose-Einstein condensates of Cooper pairs. Note however that in case of DNA $r = 6$ not gives only rise to conductivity but not super-conductivity and that $r = 6$ cannot explain the claimed very low critical magnetic field destroying the super-conductivity.

2. Loss of weight

The claimed loss of weight by a factor $p \simeq 4/9$ is a very significant hint if taken seriously. The proposed model implies that the density of the partially dark phase is different from that of the ordinary phase but is not quantitative enough to predict the value of p. The most plausible reason for the loss of weight would be the reduction of density induced by the replacement of ordinary chemistry with $\hbar/\hbar_0 = n_a/n_b = 6$ chemistry for which the Compton length of valence electrons would increase by this factor.

3. Is super-conductivity possible?

The overlap criterion is favorable for super-conductivity since electron Compton lengths would be scaled up by factor $n_a = 6, n_b = 1$. For $\hbar/\hbar_0 = n_a = 6$ Fermi energy would be scaled up by $n_a^2 = 36$ and if the same occurs for the gap energy, T_c would increase by a factor 36 from that predicted by the standard BCS theory. Scaled up conventional super-conductor having $T_c \sim 10$ K would be in question (conventional super-conductors have critical temperatures below 20 K). 20 K upper bound for the critical temperature of these superconductors would allow 660 K critical temperature for their dark variants!

For large enough values of n_a the formation of Cooper pairs could be favored by the thermal instability of valence electrons. The binding energies would behave as $E = (n_b/n_a)^2 Z_{eff}^2 E_0/n^2$, where Z_{eff} is the screened nuclear charge seen by valence electrons, n the principal quantum number for the valence electron, and E_0 the ground state energy of hydrogen atom. This gives binding energy smaller than thermal energy at room temperature for $n_a/n_b > (Z_{eff}/n)\sqrt{2E_0/3T_{room}} \simeq 17.4 \times (Z_{eff}/n)$. For $n = 5$ and $Z_{eff} < 1.7$ this would give thermal instability for $n_a = 6$.

Interestingly, the reported .05 eV infrared line corresponds to the energy assignable to cell membrane voltage at criticality against nerve pulse generation, which suggests a possible connection with high T_c superconductors for which also this line appears and is identified in terms of Josephson energy. .05 eV line appears also in high T_c superconductors. This interpretation does not exclude the interpretation as gap energy. The gap energy of the corresponding BCS super-conductor would be scaled down by $1/n_a^2$ and would correspond to 14 K temperature for $n_a = 6$.

Also high T_c super-conductivity could involve the transformation of nuclei at the stripes containing the holes to dark matter and the formation of Cooper pairs could be due to the thermal instability of valence electrons of Cu atoms (having $n = 4$). The rough extrapolation for the critical temperature for cuprate superconductor would be $T_c(Cu) = (n_{Cu}/n_{Rh})^2 T_c(Rh) = (25/36)T_c(Rh)$. For $T_c(Rh) = 300$ K this would give $T_c(Cu) = 192$ K: accoding to Wikipedia cuprate perovskite has the highest known critical temperature which is 138 K. Note that quantum criticality suggests the possibility of several values of (n_a, n_b) so that several kinds of super-conductivities might be present.

4.2.4 ORMEs as partially dark matter, high T_c super conductors, and high T_c superfluids

The appearance of .05 eV photon line suggest that same phenomena could be associated with ORMEs and high T_c super-conductors. The strongest conclusion would be that ORMEs are T_c super-conductors and that the only difference is that Cu having single valence electron is replaced by a heavier atom with single valence electron. In the following I shall discuss this option rather independently from the minimal model.

1. ORME super-conductivity as quantum critical high T_c superconductivity

ORMEs are claimed to be high T_c superconductors and the identification as quantum critical superconductors seems to make sense.

1. According to the model of high T_c superconductors as quantum critical systems, the properties of Cooper pairs should be more or less universal so that the observed absorption lines discussed in the section about high T_c superconductors should characterize also ORMEs. Indeed, the reported 50 meV photon line corresponds to a poorly understood absorption line in the case of high T_c cuprate super conductors having in TGD framework an interpretation as a transition in which exotic Cooper pair is excited to a higher energy state. Also Copper is a transition metal and is one of the most important trace elements in living systems [60]. Thus the Cooper pairs could be identical in both cases. ORMEs are claimed to be superconductors of type II and quantum critical superconductors are predicted to be of type II under rather general conditions.

2. The claimed extremely low value of H_c is also consistent with the high T_c superconductivity. The supra currents in the interior of flux tubes of radius of order $L_w = .2$ μm are BCS type supra currents with large $\hbar$ so that T_c is by a factor 2^{11} higher than expected and H_c is reduced by a factor $2^{-11/2}$. This indeed predicts correct order of magnitude for the critical magnetic field.

3. $r = \hbar/\hbar_0 = 2^{11}$ is considerably higher that $r = 6$ suggested by the minimum model explaining emission spectroscopic results of Hudson. Of course, several values of $\hbar$ are possible and the values $r \in \{5, 6, 2^{k11}\}$ are indeed assumed in TGD inspired model of living matter and generalize EEG [M3]. Thus internal consistency would be achieved if ORMEs are regarded as a very simple form of living matter.

4. The electronic configurations of Cu and Gold are chemically similar. Gold has electronic configuration $[Xe, 4f^{14}5d^{10}]6s$ with one valence electron in s state whereas Copper corresponds to $3d^{10}4s$ ground state configuration with one valence electron. This encourages to think that the doping by holes needed to achieve superconductivity induces the dropping of these electrons to $k = 151$ space-time sheets and gives rise to exotic Cooper pairs. Also this model assumes the phase transition of some fraction of Cu nuclei to large $\hbar$ phase and that exotic Cooper pairs appear at the boundary of ordinary and large $\hbar$ phase.

   More generally, elements having one electron in s state plus full electronic shells are good candidates for doped high T_c superconductors. Both Cu and Au atoms are bosons. More generally, if the atom in question is boson, the formation of atomic Bose-Einstein condensates at Cooper pair space-time sheets is favored. 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.

2. "Levitation" and loss of weight

The model of high T_c superconductivity predicts that some fraction of Cu atoms drops to the flux tube with radius $L_w = .2\ \mu$m and behaves as a dark matter. This is expected to occur also in the case of other transition metals such as Gold. The atomic nuclei at this space-time sheet have high charges and make phase transition to large $\hbar$ phase and form Bose-Einstein condensate and superfluid behavior results. Electrons in turn form large $\hbar$ variant of BCS type superconductor. These flux tubes are predicted to be negatively charged because of the Bose-Einstein condensate of exotic Cooper pairs at the boundaries of the flux tubes having thickness $L(151)$. The average charge density equals to the doping fraction times the density of Copper atoms.

The first explanation would be in terms of super-fluid behavior completely analogous to the ability of ordinary superfluids to defy gravity. Second explanation is based on the electric field of Earth which causes an upwards directed force on negatively charged BE condensate of exotic Cooper pairs and this force could explain both the apparent levitation and partial loss of weight. The criterion for levitation is $F_e = 2eE/x \geq F_{gr} = Am_pg$, where $g \simeq 10$ m^2/s is gravitational acceleration at the surface of Earth, A is the atomic weight and m_p proton mass, E the strength of electric field, and x is the number of atoms at the space-time sheet of a given Cooper pair. The condition gives $E \geq 5 \times 10{-}10Ax$ V/m to be compared with the strength $E = 10^2 - 10^4$ V/m of the Earths' electric field.

An objection against the explanation for the effective loss of weight is that it depends on the strength of electric field which varies in a wide range whereas Hudson claims that the reduction factor is constant and equal to 4/9. A more mundane explanation would be in terms of a lower density of dark Gold. This explanation is quite plausible since there is no atomic lattice structure since nuclei and electrons form their own large $\hbar$ phases.

4. The effects on biological systems

Some monoatomic elements such as White Gold are claimed to have beneficial effects on living systems [128]. 5 per cent of brain tissue of pig by dry matter weight is claimed to be Rhodium and Iridium. Cancer cells are claimed to be transformed to healthy ones in presence of ORMEs. The model for high T_c super conductivity predicts that the flux tubes along which interior and boundary supra currents flow has same structure as neuronal axons. Even the basic length scales are very precisely the same. On basis of above considerations ORMEs are reasonable candidates for high T_c superconductors and perhaps even super fluids.

The common mechanism for high T_c, ORME- and bio- super-conductivities could explain the biological effects of ORMEs.

1. In unhealthy state superconductivity might fail at the level of cell membrane, at the level of DNA or in some longer length scales and would mean that cancer cells are not anymore able to communicate. A possible reason for a lost super conductivity or anomalously weak super conductivity is that the fraction of ORME atoms is for some reason too small in unhealthy tissue.

2. The presence of ORMEs could enhance the electronic bio- superconductivity which for some reason is not fully intact. For instance, if the lipid layers of cell membrane are, not only wormhole-, but also electronic super conductors and cancer involves the loss of electronic super-conductivity then the effect of ORMEs would be to increase the number density of Cooper pairs and make the cell membrane super conductor again. Similar mechanism might work at DNA level if DNA:s are super conductors in "active" state.

5. Is ORME super-conductivity associated with the magnetic flux tubes of dark magnetic field $B_d = 0.2$ Gauss?

The general model for the ionic super-conductivity in living matter, which has developed gradually during the last few years and will be discussed in detail later, is based on the assumption that super-conducting particles reside at the super-conducting magnetic flux tubes of Earth's magnetic field with nominal value $B_E = .5$ Gauss. It later became clear that the explanation of ELF em fields on vertebrate brain requires $B_d = .2$ Gauss rather than B_E as was erratically assumed in the original model. The interpretation was as dark magnetic field $B_d = .2$ Gauss.

The predicted radius $L_w = .2$ μm is consistent with the radius of neuronal axons. For $\hbar \rightarrow n \times 2^{11}\hbar$, $n = 3$, the radius is 1.2 μm and still smaller than the radius d of flux tube of B_E of order $d = 5$ μm and scales up as $d \rightarrow \sqrt{B_d/B_E}\sqrt{r}d = \sqrt{5r/2}d$ in the replacement $\hbar/\hbar_0 \rightarrow r$, $B_E \rightarrow B_d$. Consistency is achieved even for $r = 1$ and for $r = 6$ the radius corresponds to the size of large neuron. The most natural interpretation would be that these flux tubes topologically condense at the flux tubes of B_d or B_E. Both bosonic ions and the Cooper pairs of electrons or of fermionic ions can act as charge carriers so that actually a whole zoo of super-conductors is predicted. There is even some support for the view that even molecules and macromolecules can drop to the magnetic flux tubes [K6].

4.2.5 Nuclear physics anomalies and ORMEs

At the homepage of Joe Champion [129] information about claimed nuclear physics anomalies can be found.

1) The first anomaly is the claimed low temperature cold fusion mentioned at the homepage of Joe Champion [129]. For instance, Champion claims that Mercury (Z=80), decays by emission of proton and neutrons to Gold with Z=79 in the electrochemical arrangement described in [129].

2) Champion mentions also the anomalous production of Cadmium isotopes electrochemically in presence of Palladium reported by Tadahiko Mizuno.

The simplest explanation of the anomalies would be based on genuine nuclear reactions. The interaction of dark nuclei with ordinary nuclei at the boundary between the two phases would make possible genuine nuclear transmutations since the Coulomb wall hindering usually cold fusion and nuclear transmutations would be absent (Trojan horse mechanism). Both cold fusion and reported nuclear transmutations in living matter could rely on this mechanism as suggested in [F8, F10, F9, J6].

4.2.6 Possible implications

The existence of exotic atoms could have far reaching consequences for the understanding of bio-systems. If Hudson's claims about super-conductor like behavior are correct, the formation of exotic atoms in bio-systems could provide the needed mechanism of electronic super-conductivity. One could even argue that the formation of exotic atoms is the magic step transforming chemical evolution to biological evolution.

Equally exciting are the technological prospects. If the concept works it could be possible to manufacture exotic atoms and build room temperature super conductors and perhaps even artificial life some day. It is very probable that the process of dropping electron to the larger space-time sheet requires energy and external energy feed is necessary for the creation of artificial life. Otherwise the Earth and other planets probably have developed silicon based life for long time ago. Ca, K and Na ions have central position in the electrochemistry of cell membranes. They could actually correspond to exotic ions obtained by dropping some valence electrons from $k = 137$ atomic space-time sheet to larger space-time sheets. For instance, the $k = 149$ space-time sheet of lipid layers could be in question.

The status of ORMEs is far from certain and their explanation in terms of exotic atomic concept need not be correct. The fact is however that TGD predicts exotic atoms: if they are not observed TGD approach faces the challenge of finding a good explanation for their non-observability.

4.3 Wormholes and super-conductors

4.3.1 Charged wormhole contacts behave like super conductor

Wormhole contacts are bosons and suffer Bose-Einstein condensation to the ground state at sufficiently low temperatures. Their masses are very small and they are mobile in the directions tangential to the surface of atom. Very light but not exactly massless wormhole contacts look therefore ideal candidates for super conducting charge carriers. The em current of wormhole contacts at the "lower" space-time sheet however corresponds to opposite current on the atomic space-time sheet so that actually motion of dipoles is in question (dipole moment is extremely small). Kind of "apparent" super conductivity is in question, which looks real, when one restricts attention to either space-time sheet only. It should be noticed that the dropping of electrons to lower space-time sheets is not absolutely necessarily for wormhole super conductivity since wormhole contacts can appear as genuine particles. For instance, magnetic fields created by rotating wormhole contacts on the boundaries of magnetic flux tubes are possible.

What is required for macroscopic wormhole super conductivity is the formation of a join along boundaries condensate at the atomic space-time sheet. This implies that wormhole contacts move freely in the outer surfaces defined by this condensate. Wormhole contacts condense on ground state since there is large energy gap: for very light wormholes and join along boundaries condensate of size L the order of magnitude for the gap is about π/L. Wormhole contacts can appear as super conducting "charge carriers" also at lower condensate levels. The energy gap allows objects with size of order $10^{-5} - 10^{-4}$ meters in room temperature: later it will be suggested that the largest macroscopic quantum systems in brain are of this size. If the thermalization time for between degrees of freedom associated with different space-time sheets is long, wormhole contacts can form metastable BE condensates also in longer length scales.

It has recently become clear that wormhole contacts can be seen as space-time counterparts for Higgs type particles [F2] so that nothing genuinely new would be involved. Coherent states of wormhole contacts could appear also in the description of the ordinary super-conductivity in terms of coherent states of Cooper pairs and charged Higgs type particles making sense in the zero energy ontology [C2]. Mathematically the coherent states of wormholes and Cooper pairs are very similar so that one can indeed speak about wormhole super-conductivity. For instance, both states are described by a complex order parameter. One can of course ask whether charged wormhole contacts and Cooper pairs could be seen as dual descriptions of super-conductivity. This need not be the case since standard Higgs mechanism provides an example of a presence of only wormhole contact Bose-Einstein condensate.

4.3.2 Wormhole magnetic fields as templates for bio-structures?

Wormhole magnetic fields are structures consisting of two space-time sheets connected by wormhole contacts (a more detailed treatment will be found in later chapters). The space-time sheets do not contain ordinary matter and the rotating wormhole contacts near the boundaries of the space-time sheets create magnetic fields of same strength but of opposite sign at the two space-time sheets involved. An attractive possibility is that not only ordinary but also wormhole magnetic fields could correspond to defects in bio super conductors and that they serve as templates for the formation of living matter. DNA and the hollow microtubular surfaces consisting of tubulin molecules are excellent examples of structures formed around defects of type II super conductor. The stripe like regions associated with the defects of superconductor could in turn correspond to wormhole magnetic or Z^0 magnetic fields serving as templates for the formation of cell membranes, epithelial cell sheets and larger structures of same kind.

Super conducting space-time sheets indeed form p-adic hierarchy and same holds true for the sizes of defects characterized by the coherence length ξ in case of super conductors of type II and by the magnetic penetration depth λ in case of super conductors of type I. The assumption that defects correspond to wormhole magnetic fields means that defect is a two-sheeted structure with wormhole magnetic field at larger sheet k cancelling the original magnetic field in the region of defect whereas the upper sheet contains the field as such. If upper sheet k_1 is super-conductor and the penetrating field is below the critical field $B_c(k)$, the field can penetrate only to the sheet k in the region near boundaries of the higher level space-time sheet such that the field strength is so large (by flux conservation) that it exceeds the critical value. This is achieved by the presence of supra currents near the boundaries of the smaller space-time sheet k.

In the case of super conductor of type II penetration occurs as flux tubes in the entire space-time sheet k_1, when the field strength is in the critical range (H_{c_1}, H_{c_2}). This hierarchical penetration in principle continues up to atomic length scales and once can say that defects decompose into smaller defects like Russian doll. It might well be that the fractal structure of defects is a basic architectural principle in bio-systems. Also the amplification of magnetic flux can take place: in this case two sheets contain magnetic fields having opposite directions.

Also defects formed by genuine wormhole magnetic fields are possible: in this case no external field is needed to create the defect. This kind of defects are especially interesting since their 3-space projections need not be closed flux tubes. Topologically these defects are closed as required by the conservation of magnetic flux since the magnetic flux flows from space-time sheet to another one at the ends of the defect behaving like magnetic monopoles.

In the case that the space-time sheets of wormhole magnetic field have opposite time orientations, the particles at the two space-time sheets have opposite inertial energies and it is in principle possible to generate these kind of states from vacuum. A possible interpretation for negative energy particles at the second sheet of the field quantum of wormhole magnetic field is as space-time correlates for holes.

An interesting working hypothesis is that wormhole magnetic fields serve as templates for the formation of bio-structures. The motivations are that defect regions could be regarded as realization for the reflective level of consciousness in terms of fermionic Fock state basis and that the surrounding 3-surface is in super conducting state so that also primitive sensory experiencing becomes possible. One could even say that defects formed by wormhole flux tubes are the simplest intelligent and living systems; that the type of super conductor (I or II) gives the simplest classification of living systems and that systems of type I are at higher level in evolution than systems of type II. A possible example of defects of type II are all linear bio-structures such as DNA, proteins, lipids in the cell membrane, microtubules, etc... Examples of defects of type I would be provided by cell membranes, epithelial sheets and the bilayered structures in the cortex.

4.3.3 How magnetic field penetrates in super conductor?

There are motivations for finding a mechanism for the amplification of magnetic fields although the original motivation coming from attempt to explain the claimed levitation of ORMEs in the Earth's magnetic field has disappeared.

1. Magnetic flux is channelled to flux tubes when it penetrates to super-conductors of type II and the strength of the magnetic field is scaled up roughly as λ/ξ in this process.

2. Cells are known to be sensitive for very weak magnetic fields.

3. TGD proposal for the information storage in terms of topological integers related to magnetic fields also requires that the weak magnetic macroscopic fields prevailing inside brain are

somehow amplified to stronger fields in microscopic length scales.

The basic mechanism for the amplification is the current of wormhole contacts induced by external magnetic field at given condensate level, which in turn serves as a source for a secondary magnetic field at higher level. Since the mass of the wormhole contact is very small the resulting current of wormhole contacts and thus the induced secondary magnetic field is strong.

1. The relevant portion of the many sheeted space-time consists of "our" space-time sheet and many sheets above it and at the top is the atomic space-time sheet. At "our" space-time sheet external magnetic field induces em surface current of wormhole contacts at this level. This current is concentrated on 2-dimensional surfaces, which corresponds to the boundaries of 3-surfaces at the previous level of the hierarchy. The interaction of wormhole contacts with the magnetic field is via the vector potential associated with the external magnetic field on "our" sheet. To get rid of unessential technicalities it is useful to assume cylindrical geometry at each space-time sheet: cylindrical surfaces with axis in same direction are considered and the radii of these surfaces get smaller in the higher levels of the topological condensate.

2. Let us study what happens to the wormhole contacts on the cylindrical surface in constant magnetic field in the direction of the cylinder of radius R, when the magnitude of the magnetic field increases gradually. One has to solve d'Alembert type wave equation for the scalar field (describing wormhole contacts on cylinder in the vector potential associated with the external magnetic field, which is constant on the cylinder and in direction of the atzimutal coordinate ϕ: $A_\phi = BR/2$. Ground states correspond to the with minimum energy solutions. Vector potential gives just constant contribution to the d'Alembert equation and for small enough values of B the constant, nonrotating solution remains energy minimum. When the condition $eA_\phi = m$, $m = 1, 2, ...$ is satisfied one however gets rotating solution with angular momentum $L_z = m$ with same energy as the original vacuum solution! This implies that at the critical values

$$B_{cr,m} = \frac{(2m+1)}{eR^2} , \tag{25}$$

   the solution with $L_z = m$ becomes unstable and is replaced with $L_z = m + 1$ to achieve energy minimum.

3. At the higher condensation level the current of wormhole contacts generate a surface current

$$\begin{aligned} K &= n(\#)ev , \\ v &= \frac{m}{RE} , \end{aligned} \tag{26}$$

   where $n(\#)$ is surface density of the wormhole contacts and $v = R\omega$ is the velocity of rotating wormhole contacts: v is quantized from the quantization of angular momentum. E is the energy of rotating wormhole. This surface current gives rise to axial magnetic field $B = n(\#)ev$ in the interior of the cylinder at the higher condensate level.

4. The magnetic field can penetrate also to the higher levels of the hierarchy via exactly the same mechanism. At higher levels the requirement that magnetic flux is quantized implies relativistic energies for wormhole contacts and therefore one has $K = n(\#)ev \simeq n(\#)e$. The magnetic fields at various levels have quantized values not depending much on the original magnetic field!

5. In non-relativistic situation one has $v \simeq eBR/m(\#)$ and the relationship $B(higher) = K$ following from Maxwell equations gives

$$
\begin{aligned}
B(higher) &= \mu_R(p_1,p_2)B(lower) \ , \\
\mu_R(p_1,p_2) &= \frac{e^2 n(\#)R}{m(\#)} \ .
\end{aligned} \quad (27)
$$

Nonrelativistic wormhole contacts amplify the magnetic field at the larger space-time sheet by a factor $\mu_R(p_1,p_2)$. $\mu_R(p_1,p_2) \sim 10^6$ is required to explain Hudson's claims if penetration takes place in single step: of course multistep process is also possible. It is useful to express the parameters m and R and $n(\#)$ at given p-adic condensation level in terms of the p-adic length scale $L(p)$ as

$$
\begin{aligned}
m(\#) &= \frac{m_0}{L(p)} \ \ m_0 << 1 \ , \\
R &= R_0 L(p) \ , \\
v &= \frac{m}{m_0 R_0} << 1 \ , \\
n(\#) &= \frac{n_0}{L^2(p)} \ .
\end{aligned} \quad (28)
$$

By fractality the dimensioness numbers m_0, R_0, n_0. should not depend strongly on p-adic condensation level. The expression for the amplification factor $\mu_R(p_1,p_2)$ in non-relativistic case reads as

$$
\mu_R(p_1,p_2) = \frac{e^2 n_0 R_0}{m_0} \ . \quad (29)
$$

Situation of course becomes relativistic for suitably large values of integer m.

5 Evidence for electronic super conductivity in bio-systems

There exists some evidence for super-conductivity in bio-systems. DNA should be insulator but under some circumstances it becomes conductor [68] and perhaps even high T_c super-conductor. Also evidence for Josephson effect has been reported [59].

5.1 DNA as a conductor?

Barton *et al* [68] have done several experiments between 1993-1997 related to the conductivity properties of DNA double helix. The conclusion is that DNA double helix has the ability to do chemistry at distance: *"A DNA molecule with a chemical group artificially tethered to one end appears to mediate a chemical change far down the helix, causing a patch of damaged DNA to be mended."*.

What seems to occur is flow of electron current along DNA with very small resistance. Typically the experiments involve electron donator and acceptor separated by a long distance along DNA. When acceptor is radiated it goes to excited state and an electron current flows from donator to acceptor as a consequence. Standard wisdom tells that this should not be possible. The current should flow by quantum tunnelling between adjacent building units of DNA and it should diminish exponentially with distance. For proteins this is known to be the case. In experiments however no distance dependence was observed. Irradiation with visible light was also involved.

There exist a theory which assumes that the current could flow along the interior of double DNA, that is the region between the bases of strand and complementary strand. The electron would be delocalized in bases rings which would form a stack along DNA. The current would flow by tunnelling also now but the tunnelling probability would be so large that distance dependence would be weak. The critics of Barton argue that this model cannot explain all the experiments of Barton and that the model is not in accordance with basic organic chemistry and biology: ordinary sun light should have rather drastic effects on us. Barton admits that they do not understand the mechanism.

TGD suggests a possible explanation of phenomenon in terms of dark atoms or partially dark atoms for which valence electrons are dark.

1. The bases of DNA contain 5 or 6-cycles: both correspond to Fermat polygons. This symmetry suggests dark phase with $G_a \subset SU(2)$ having maximal cyclic group Z_5 or Z_6 so that one would have $n_a = 5$ or $n_a = 6$ depending on the cycle. This identification would provide first principle explanation for why just these cycles appear in living matter. Most naturally organic atoms would be ordinary but some electrons would reside on dark space-time sheets corresponding to $n_a = 5$ or $n_a = 6$ and $n_b = 1$.

2. The scaled up size of the electronic orbital would be roughly $(n_a n^2/Z_{eff}^2)a_0$ and by a factor n_a^2 larger than the size of ordinary orbital. The large distance of valence electrons suggest $Z_{eff} = 1$ as a first guess, which would imply delocalization of electrons in the length scale $625a_0 \sim 312$ nm for Rb and $900a_0 \sim 45$ nm for Rh. For the estimate $Z_{eff} \sim 10$ deduced below the delocalization would occur in length scales 3 nm and 9 nm which is probably quite enough since there is one DNA triplet per one nanometer if the conduction occurs as a sequence of replacements of a hole with electron analogous to the falling down of domino pieces.

3. The fact that the ratio $6/5 = 1.2$ is rather near to the ratio $45/37 = 1.22$ of nuclear charges of Rh and Rb atoms would guarantee that the binding energy of the valence electron for Rh atom with $n_a = 6$ is reasonably near to that for Rb atom with $n_a = 5$. This encourages to think that the mechanism of conductivity involves the ionization of dark valence electron of acceptor atom so that it can receive the dark valence electron of the donor atom. Delocalization makes this process possible.

4. The DNA environment would induce the phase transition of Rh and Ru atoms to partially dark atoms. The binding energy of the dark valence electron is reduced to $E = (n_b/n_a)^2 Z_{eff}^2 E_0/n^2$, where Z_{eff} is the screened nuclear charge seen by valence electrons, $n = 5$ the principal quantum number for the valence electron in the recent case, and $E_0 = 13.6$ eV the ground state energy of hydrogen atom. $Z_{eff} = 1$ would give .02 eV binding energy which is quite too small. If the binding energy reduces to that of a visible photon parameterized as $E = x$ eV one obtains the condition

$$Z_{eff} = n_a n\sqrt{E/E_0} \simeq 5n_a\sqrt{x/13.6} \ .$$

For Rh $x = 2$ would give $Z_{eff} = 11.5$ and $Z_{eff} = 9.6$ for Rb.

5.2 DNA as a super-conductor?

Also in the model of ORMEs as dark matter led to $n_a = 6, n_b = 1$ in super-conducting phase. This suggests DNA super-conductivity is based on the same mechanism as the explanation of superconductivity assigned with ORMEs. In particular, the energy $E = .05$ eV associated with the critical potential of neuronal membrane could correspond to the gap energy of the DNA super-conductor and this could relate directly to the activation of DNA. As found, the dark variant of a conventional super-conductor with gap energy around 10 K would give rise to a dark superconductor with a gap energy around room temperature. The estimate $E_{gap} = E/n_a^2$ gives 14 K for $n_a = 6$ and 20 K for $n_a = 5$ for the gap energy. DNA carries -2 units of electric charge per single nucleotide and the interpretation could be as one dark Cooper pair per nucleotide. $n_a = 6$ would give the higher critical temperature.

The fact that there is a twist $\pi/10$ per single nucleotide in DNA double strand led to the proposal that DNA pr RNA might serve as a minimal topological quantum computer with computation based on braiding S-matrix and characterized by $n_a = 5$ [E9]. Perhaps dark Cooper pairs having $n_a = 5$ with charge fractionized to five identical fractions along 5-cycles could relate to the topological quantum computation.

DNA strand and its conjugate could form a pair of weakly coupled super-conductors forming kind of a scaled down version for the pairs formed by the inner and outer lipid layers of the axonal membrane or cell interior and exterior. Both DNA strand and double strand corresponds to the secondary p-adic length scale $L(71, 2) \simeq 4.4$ Angstroms. The soliton sequences associated with the phase differences of super-conducting order parameter over the Josephson junctions connecting DNA strands, and idealizable as a continuous one-dimensional Josephson junction, could serve as a quantum control mechanism. Josephson junctions could correspond to MEs which propagate with very low effective phase velocity along the DNA strand. The mathematics would be essentially that of a gravitational pendulum [M2]. Soliton like structures associated with DNA have been proposed also by Peter Gariaev [112].

5.2.1 Aromatic rings and large $\hbar$ phases

Aromatic rings contain odd number of π delocalized electron pairs with atoms in the same plane. The delocalization of π electrons in the ring is used to explain the stability of these compounds [69]. Benzene is the classical example of this kind of structure. Delocalization and DNA conductivity suggest interpretation in terms $n_a = 5$ or $n_a = 6$ phase and raises the question whether the delocalization of electrons could occur also in the orthogonal direction and whether it could give rise to Cooper pairs.

Aromatic rings consisting of 5 or 6 carbons are very common in biology. DNA basis have been already mentioned. Carbohydrates consist of monosaccharide sugars of which most contain aromatic ring (glucose used as metabolic fuel are exception). Monoamine neurotransmitters are neurotransmitters and neuromodulators that contain one amino group that is connected to an aromatic ring by a two-carbon chain (-CH2-CH2-). The neurotransmitters known a monoamines are derived from the four aromatic amino acids phenylalanine, tyrosine, histidine, tryptophan. Also norepinephrine, dopamine, and serotonin involve aromatic rings As a rule psychoactive drugs involve aromatic rings: for instance, LSD contains four rings.

These observations inspire the question whether the compounds containing aromatic rings serve as junctions connecting pre- and postsynaptic neurons and induce Josephson currents between them. If Josephson radiation codes for the mental images communicated to the magnetic body, the psychoactive character of these compounds could be understood. One can also ask whether these compounds induce quantum criticality making possible generation of large $\hbar$ phases?

5.2.2 Graphene as another example of dark electron phase?

The behavior of electrons in graphene, which is two-dimensional hexagonal carbon crystal with a thickness of single atomic layer, is very strange [125]. Electrons behave as massless particles but move with a velocity which is 1/300 of light velocity. Graphene is an excellent conductor. TGD can provide a model for these peculiar properties.

1. One can regard graphene as a giant molecule and the hexagonal ring structure suggests that M^4 Planck constant is scaled up by a factor of 6 and that dark free electron pairs are associated with the ring structures. If also CP_2 Planck is scaled up with the same factor, chemistry is not affected although the size scale of electron wave functions is scaled up by a factor of 6. Just as in the case of DNA, the rings containing delocalized free electron pairs could be responsible for the anomalously high conductivity of graphene. If quantum critical super-conductor is in question, the super-conductivity could become possible in lower temperature.

2. Consider now the explanation for the vanishing of the rest mass. The general mass formula predicted by p-adic thermodynamics [F2] states that particle mass squared is given by the thermal average of the conformal weight and that conformal weight and thus also mass squared is additive in bound states:

$$(\sum_i p_i)^2 = \sum_i m_i^2 \tag{30}$$

   The assumption $p_i^2 = m_i^2$ makes sense only for massless partons moving collinearly. In the QCD based model of hadrons only longitudinal momenta and transverse momentum squared are used as labels of parton states, which would suggest that one has

$$\begin{aligned} p_{i,||}^2 &= m_i^2 \ , \\ -\sum_i p_{i,\perp}^2 + 2\sum_{i,j} p_i \cdot p_j &= 0 \ . \end{aligned} \tag{31}$$

   The masses would be reduced in bound states: $m_i^2 \rightarrow m_i^2 - (p_T^2)_i$. This could explain why massive quarks can behave as nearly massless quarks inside hadrons. In the recent case electrons would become massless if one has hadron like many electron states (free electron pairs?) with $p_T^2 = m_e^2$.

3. TGD also predicts the possibility of anomalous time dilation in the absence of gravitational field implying also reduction of light velocity. The simplest example are vacuum extremals corresponding to the warped imbedding $\phi = \omega t$ to $M^4 \times S^1$,S^1 a geodesic sphere of CP_2, which have induced metric for which time component of metric is $g_{tt} = 1 - R^2\omega^2$ instead of $g_{tt} = 1$. Light velocity defined from the time taken to get from point A to B is reduced by a factor $\sqrt{g_{tt}}$ from its maximal value. If the space-time sheets carrying the electrons have $g_{tt} = 1/300$, one can understand the reduction of light velocity.

5.3 Conducting DNA and metabolism

Besides charge transfer also energy transfer along DNA could be of importance in living systems.

5.3.1 Could metabolism involve electronic visible-dark phase transitions at DNA level?

If the dark valence electron associated with an ordinary atom is transformed to ordinary electron, the binding energy of the electron increases which means a liberation of a considerable amount of energy. This phase transition could liberate a large amount of metabolic energy in a coherent manner and might be involved with metabolism at molecular level.

5.3.2 Could the transfer of electrons along DNA make possible energy transfer?

One important function made possible by the dropping of electrons to larger space-time sheets is the transfer of not only charge but also energy through long distances and metabolism might well use this mechanism. The typical energy liberated when ATP molecule is used is about .5 eV. In the model of ATP [K6] it is suggested that energy metabolism involves the circulation of protons between atomic ($k = 137$) space-time sheets and magnetic flux tubes of Earth. The dropping of proton from $k = 137$ atomic space-time sheet to much larger space-time sheet liberates this energy as zero point kinetic energy and generation of ATP molecule involves kicking of three protons back to the atomic space-time sheets by using metabolic energy.

ATP might provide only the mechanism responsible for the energy transfer over short distances. The dropping of any ion from any space-time sheet to a larger space-time sheet is possible and liberates a definite amount of usable energy. When the smaller space-time sheet corresponds to a super-conducting space-time sheet, the ions or their Cooper pairs can be rapidly transferred as dissipation free supra currents to the region, where the energy is needed. This long distance energy transfer mechanism could be associated with all kinds of linear structures: DNA, proteins, microfilaments, microtubules, axons etc... The magnitude of the energy quantum released would be fixed by the p-adic length scale hypothesis and the mass of the ion or of the Cooper pair. The acceleration in endogenous electric fields provides a mechanism kicking the ions back to the smaller space-time sheets.

Because of their low mass, electrons are exceptional. The dropping of an electronic Cooper pair from $k = 139$ some space-time sheet presumably associated with the hydrogen bonds of length about 3 nm connecting the nucleotides of different DNA strands would liberate a huge energy of about 120 eV. The corresponding UV photon has frequency not far from the miracle frequency associated with $k = 151$ p-adic length scale, which is the first of the four subsequent p-adic miracle length scales corresponding to Gaussian Mersennes. The dropping of electron Cooper pair from the space-time sheet of the DNA strand of thickness of order $4 - 5$ Angstroms, which presumably corresponds to the secondary p-adic length scale $L(71, 2) \simeq 4.4$ Angstroms, liberates energy of about 15 eV, which in turn corresponds to the p-adic miracle length scale $L(157)$. This would mean that all miracle length scales would correspond to some energy unit of energy metabolism [K6]!

An interesting question relates to the possible function of this UV photon. The wavelength $\lambda = L(151)$ corresponds to the thickness of the cell membrane. It is also to the minimal length of DNA sequence (10 DNA triplets) with the property that the net winding is a multiple of 2π $(3\times 2\pi)$. By its reflection symmetry this helical sequence might serve as a subunit of DNA sequence. The ends of this subunit could act as mirrors connected by MEs carrying Bose-Einstein condensed photons propagating back and worth between the mirrors. The energy liberated by the electron as an UV photon could BE condense to this kind of ME.

At least in the case of monocellulars having DNA at cell membrane, the photon could also be reflected between the outer and inner boundary of the cell membrane.

5.4 Some empirical evidence for super conductivity in bio-systems

There is indirect evidence for electronic super conductivity in bio-systems. The basic signatures are photon emission and absorption with energies coming as multiples of the potential difference between two weakly coupled super conductors and voltage-current characteristics of Josephson current. The evidence is related to the tunnelling of electrons between a weakly coupled pair of super conductors.

According to [79], for several biological systems involving nerve or growth processes the square of the activation energy is a linear function of temperature over a moderate range of physiological temperatures. This behavior may be predicted from the hypothesis that the rate of biological process is controlled by single electron tunnelling between micro-regions of super-conductivity. In TGD framework natural candidates for this kind of regions are the lipid layers of cell membranes and cells themselves.

Positive experimental evidence for Josephson effect is reported and discussed in [59]. The evidence is based on the observation of voltage-current characteristic typical to the Josephson current flowing between weakly coupled super conductors, which are identified as neighboring cells. Also the radiation of photons with energies which are multiples of the potential difference between the weakly coupled super conductors is used as an empirical signature. The potential difference is about 15 nV and in competely different range as the potential difference of order .05 V between the lipid layers of the cell membrane. Various species of organisms can detect weak magnetic fields from .1 to 5 gauss and this is in accordance with the existence of Josephson junction in systems, which are super conductors of type II in critical region between H_{c_1} and H_{c_2}. The detection of magnetic fields could be based on the same mechanism as the operation of SQUIDs.

5.5 Microtubular space-time sheets as super conductors?

Microtubules are fashionable candidate for a macroscopic quantum system. Microtubules are the basic structural units of cytoskeleton and it has been suggested that cytoskeleton might play the role of nervous system at single cell level and provide the key element for understanding bio-systems as macroscopic quantum systems [92]. Microtubules are hollow cylindrical tubes with inner and outer radii of 14 nm and 25 nm respectively so that the thickness of the cylinder corresponds roughly to the length scale $\hat{L}(151)$. Microtubules consist of dimers of α and β tubulines having at least two conformations: the position of electron centrally placed in the α-tubulin-β-tubulin juncture probably determines the conformation. Tubulin dimers have size $\sim 8\ nm$ not far from the length scale $\hat{L}(157)$. There are 13 columns of tubulin dimers along the microtubule. The skew hexagonal pattern of microbutules exhibits pattern made up of 5 right handed and 8 left handed helical arrangements.

For left handed arrangement 2π rotation corresponds to a distance $\sim 64\ nm \sim \hat{L}(163)$ along the length of the microtubule [83, 93]. It has been suggested [92] that the electric dipole moments of tubulin dimers form a macroscopic quantum system analogous to a spin system. An alternative possibility is that microtubules might be super conducting. The cylindrical geometry is ideal for the creation of constant magnetic fields inside the tube by helical supracurrents flowing along the surface of the microtubule. The electrons determining the conformation of the tubulin dimer are the most obvious candidates for Cooper pairs. Perhaps the electrons corresponding to a given conformation of tubulin could form delocalized Cooper pairs.

The numbers 5 and 8 correspond to Fermat polygons which suggests that G_a with $n_a = 5 \times 8 = 40$ defining order of maximal cyclic subgroup is involved. $n_a = 40$ was also obtained from the requirement that the 20 aminoacids can be coded by the many-electron states of dark N-hydrogen atom having $n_b = 1$ [F9]. Super-conductivity would correspond to $n_b = 1$ so that by the previous argument the critical temperature would be scaled up by a factor $n_a^2 = 1600$ from that of a conventional super-conductor. The possible problems relate to the thermal stability of light atoms if also nuclei are dark, which is however not expected.

The hypothesis that microtubules are infrared quantum antennas with average length giving rise to .1 eV infrared photon fits nicely with the super conductor idea. The fact that .1 eV is the basic energy scale of wormhole atomic physics explains the average length of microtubules. In case of Cooper pairs there is natural coupling to the Josephson currents related to Josephson junctions between lipid layers of the cell membrane. The coupling of wormhole supra currents to coherent photons contains two contributions. The first contribution is the coupling of the wormhole current to the difference of the gauge potentials describing topologically condensed coherent photons on the two space-time sheets. The second contribution is proportional to the difference of dielectric constants on the two space-time sheets and is non-vanishing even when the topological condensates of coherent photons are identical.

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