Quantitative model of high T_c super-conductivity and bio-super-conductivity

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Abstract

In this article the earlier flux tube model for high T_c super-conductivity and bio-super-conductivity is formulated in more precise manner. The model leads to highly non-trivial and testable predictions.

1. Also in the case of ordinary high T_c super-conductivity large value of $h_{eff} = n \times h$ is required.
2. In the case of high T_c super-conductivity two kinds of Cooper pairs, which belong to spin triplet representation in good approximation, are predicted. The average spin of the states vanishes for antiparallel flux tubes. Also super-conductivity associated with parallel flux tubes is predicted and could mean that ferromagnetic systems could become super-conducting.
3. One ends up to the prediction that there should be a third critical temperature T^{**} not lower than $T^{**}_{min} = 2T^*/3$, where T^* is the higher critical temperature at which Cooper pairs identifiable as mixtures of $S_z = \pm 1$ pairs emerge. At the lower temperature $S_z = 0$ states, which are mixtures of spin triplet and spin singlet state emerge. At temperature T_c the flux tubes carrying the two kinds of pairs become thermally stable by a percolation type process involving re-connection of U-shaped flux tubes to longer flux tube pairs and supra-currents can run in long length scales.
4. The model applies also in TGD inspired model of living matter. Now however the ratio of critical temperatures for the phase transition in which long flux tubes stabilize is roughly by a factor 1/50 lower than that in which stable Cooper pairs emerge and corresponds to thermal energy at physiological temperatures which corresponds also the cell membrane potential. The higher energy corresponds to the scale of bio-photon energies (visible and UV range).

1 Introduction

I have developed already earlier [K1, K2, K4, K5] a rough model for high T_c super conductivity [D3, D4, D5, D2, D1, D6]. The members of Cooper pairs are assigned with parallel flux tubes carrying fluxes which have either same or opposite directions. The essential element of the model is hierarchy of Planck constants defining a hierarchy of dark matters.

1. In the case of ordinary high T_c super-conductivity bound states of charge carriers at parallel short flux tubes become stable as spin-spin interaction energy becomes higher than thermal energy.

   The transition to super-conductivity is known to occur in two steps: as if two competing mechanisms were at work. A possible interpretation is that at higher critical temperature Cooper pairs become stable but that the flux tubes are stable only below rather short scale: perhaps because the spin-flux interaction energy for current carriers is below thermal energy. At the lower critical temperature the stability would is achieved and supra-currents can flow in long length scales.

2. The phase transition to super-conductivity is analogous to a percolation process in which flux tube pairs fuse by a reconnection to form longer super-conducting pairs at the lower critical temperature. This requires that flux tubes carry anti-parallel fluxes: this is in accordance with the anti-ferro-magnetic character of high T_c super conductivity. The stability of flux tubes very probably correlates with the stability of Cooper pairs: coherence length could dictate the typical length of the flux tube.

3. A non-standard value of h_{eff} for the current carrying magnetic flux tubes is necessary since otherwise the interaction energy of spin with the magnetic field associated with the flux tube is much below the thermal energy.

There are two energies involved.

1. The spin-spin-interaction energy should give rise to the formation of Cooper pairs with members at parallel flux tubes at higher critical temperature. Both spin triplet and spin singlet pairs are possible and also their mixture is possible.

2. The interaction energy of spins with magnetic fluxes, which can be parallel or antiparallel contributes also to the gap energy of Cooper pair and gives rise to mixing of spin singlet and spin triplet. In TGD based model of quantum biology antiparallel fluxes are of special importance since U-shaped flux tubes serve as kind of tentacles allow magnetic bodies form pairs of antiparallel flux tubes connecting them and carrying supra-currents. The possibility of parallel fluxes suggests that also ferro-magnetic systems could allow super-conductivity.

   One can wonder whether the interaction of spins with magnetic field of flux tube could give rise to a dark magnetization and generate analogs of spin currents known to be coherent in long length scales and used for this reason in spintronics (`http://en.wikipedia.org/wiki/Spintronics`). One can also ask whether the spin current carrying flux tubes could become stable at the lower critical temperature and make super-conductivity possible via the formation of Cooper pairs. This option does not seem to be realistic.

In the following the earlier flux tube model for high T_c super-conductivity and bio-super-conductivity is formulated in more precise manner. The model leads to highly non-trivial and testable predictions.

1. Also in the case of ordinary high T_c super-conductivity large value of $h_{eff} = n \times h$ is required.

2. In the case of high T_c super-conductivity two kinds of Cooper pairs, which belong to spin triplet representation in good approximation, are predicted. The average spin of the states vanishes for antiparallel flux tubes. Also super-conductivity associated with parallel flux tubes is predicted and could mean that ferromagnetic systems could become super-conducting.

3. One ends up to the prediction that there should be a third critical temperature T^{**} not lower than $T^{**}_{min} = 2T^*/3$, where T^* is the higher critical temperature at which Cooper pairs identifiable as mixtures of $S_z = \pm 1$ pairs emerge. At the lower temperature $S_z = 0$ states, which are mixtures of spin triplet and spin singlet state emerge. At temperature T_c the flux tubes carrying the two kinds of pairs become thermally stable by a percolation type process involving re-connection of U-shaped flux tubes to longer flux tube pairs and supra-currents can run in long length scales.

4. The model applies also in TGD inspired model of living matter. Now however the ratio of critical temperatures for the phase transition in which long flux tubes stabilize is roughly by a factor 1/50 lower than that in which stable Cooper pairs emerge and corresponds to thermal energy at physiological temperatures which corresponds also the cell membrane potential. The higher energy corresponds to the scale of bio-photon energies (visible and UV range).

2 A more detailed flux tube model for super-conductivity

The following little calculations support the above vision and lead to quite predictive model.

2.1 Simple quantitative model

It is best to proceed by building a quantitative model for the situation.

1. Spin-spin interaction energy for electron pair with members de-localized at parallel magnetic flux tubes must be deduced from the standard expression for the magnetic field created by the second charge and from the expression for the magnetic interaction energy of magnetic moment with external magnetic field.

   The magnetic field created by dipole μ outside the dipole is given by

$$B = \frac{\mu_0}{4\pi a^3} \times (3nn\cdot\mu - \mu) \ . \tag{2.1}$$

   The factor $\frac{\mu_0}{4\pi}$ can be taken equal to $1/4\pi$ as unity in the units in which $\mu_0 = \epsilon_0 = c = 1$ holds true. n is direction vector associated with the relative position vector a.

   The magnetic interaction energy reads as $E = -\mu \cdot B$ and in the case of identical magnetic moments reads as

$$E = \frac{1}{4\pi a^3} \times (-3\mu_1\cdot n\mu_2\cdot n + \mu_1\cdot\mu_2) \ . \tag{2.2}$$

2. The magnetic dipole moment of electron is $\mu = -(ge/2m)S$, $S = \hbar/2$, $g \simeq 2$. For proton analogous expression holds with Lande factor $g = 5.585694713(46)$.

A simple model is obtained by assuming that the distance between the members of Cooper pair is minimal so that the relative position vector is orthogonal to the flux tubes.

1. This gives for the spin-spin interaction Hamiltonian the expression

$$H_{s-s} = \frac{1}{4\pi a^3} \times (\frac{ge\hbar}{2m})^2 \times O \ \ , \quad O = -3(m_1)_x(m_2)_x + m_1\cdot m_2 \ . \tag{2.3}$$

   m_i refers to spin in units of $\hbar$. x referes to the direction in the plane defined by flux tubes and orthogonal to them. m_x can be expressed in terms of spin raising and lowering operators as $m_x = (1/2)(m_+ + m_-)$, $m_\pm = m_x \pm im_y$. This gives

$$(m_1)_x(m_2)_x = \frac{1}{4}\sum_{i=\pm,j=\pm}(m_i)_1(m_j)_2 \ . \tag{2.4}$$

   $m_1\cdot m_2$ can be expressed as $(1/2)\times[(m_1+m_2)^2 - m_1^2 - m_2^2]$. In the case of spin 1/2 particles one can have spin singlet and spin triplet and the value of $m_1\cdot m_2$ is in these cases given by $m_1\cdot m_2(singlet) = -3/4$ and $m_1\cdot m_2(triplet) = 1/4$

   The outcome is an expression for the spin-spin interaction Hamiltonian

$$
\begin{aligned}
&H_{s-s} = E_{s-s} \times O \ , && E_{s-s} = \tfrac{1}{4\pi a^3} \times (ge\hbar/2m)^2 \times O \ , \\
&O = O_1 + O_2(S) \ , && O_1 = -\tfrac{3}{4}\sum_{i=\pm,j=\pm}(m_i)_1(m_j)_2 \ , \\
&O_2(singlet) = -\tfrac{3}{4} \ , && O_2(triplet) = \tfrac{1}{4} \ .
\end{aligned}
\tag{2.5}
$$

2. The total interaction Hamiltonian of magnetic moment with the magnetic field of flux tube can be deduced as

$$
\begin{aligned}
H_{s-flux} &= -(\mu_Z)_1 B_1 - (\mu_Z)_2 B_2 = \tfrac{ge}{\hbar 2m}(m_1)_z B_1 + (m_2)_z B_2 \\
&= E_{s-flux} \times ((m_1)_z + \epsilon (m_2)_z) \ , \quad E_{s-flux} = \tfrac{ge\hbar B}{2m} \ .
\end{aligned}
\tag{2.6}
$$

3. For the diagonalization of spin-spin interaction Hamiltonian the eigenbasis of S_z is a natural choice. In this basis the only non-diagonal terms are O_1 and E_{s-flux}. O_1 does not mix representations with different total spin and is diagonal for the singlet representation. Also the $S_z(tot) = 0$ state of triplet representation is diagonal with respect to O_1: this is clear from the explicit representation matrices of spin raising and lowering operators (the non-vanishing elements in spin 1/2 representation are equal to 1). $S_z(tot) = 0$ states are eigenstates of O_1 with eigenvalue $+3/4$ for singlet and $-3/4$ for triplet. For singlet one therefore has eigenvalue $o = 0$ and for triplet eigenvalue $o = -1/2$. Singlet does not allow bound state whereas triplet does.

   $S_z(tot) = 1$ and $S_z(tot) = -1$ states are mixed with each other. In this case the O_1 has non-diagonal matrix elements equal to $O_1(1,-1) = O_1(-1,1) = 1$ so that the matrix representing O is given by

$$
O = \begin{pmatrix} \frac{1}{4} & 1 \\ 1 & \frac{1}{4} \end{pmatrix} \ . \tag{2.7}
$$

   The eigenvalues are $o_+ = 5/4$ and $o_- = -3/4$. Cooper pairs states are linear combinations of $S_z = \pm 1$ states with coefficients with have either same or opposite sign so that a maximal mixing occurs and the average spin of the pair vanishes.

   To sum up, there are two bound states for mere spin-spin interaction corresponding to $o = -1/2$ spin 0 triplet state and $o = -3/4$ state for which spin 1 and spin -1 states are mixed.

4. For spin singlet at parallel flux tubes the spin-flux interaction vanishes: $H(para, singlet) = 0$. Same holds true for $S_z = \pm 1$ states at biologically especially interesting antiparallel flux tubes: $H(anti, S_z = \pm 1) = 0$. For antiparallel flux tubes $S_z = 0$ states in singlet and triplet are mixed by $H(anti, S_z = 0)$. The two resulting states must have negative binding energy so that one obtains 3 bound states altogether and only one state remains unbound. The amount of mixing and thermal stability of possibly slightly perturbed singlet state is determined by the ratio x of the scale parameters of H_{s-flux} and H_{s-s}.

   The explicit form of $H(anti, S_z = 0)$ is

$$
\begin{aligned}
H(anti, S_z = 0) &= -\frac{E_{s-s}}{2}\begin{pmatrix} 1 & x \\ x & 0 \end{pmatrix} \\
x &= -\frac{4E_{s-flux}}{E_{s-s}} = -32\pi\frac{ma^3}{ge\hbar B} \ , \\
E_{s-s} &= \frac{1}{8\pi}\left(\frac{ge\hbar}{2m}\right)^2\frac{1}{a^3} \ .
\end{aligned}
\tag{2.8}
$$

The eigenvalues $H(anti, S_z = 0)$

$$E_{\pm} = -\frac{E_{s-s}}{4}(1 \pm \sqrt{1+4x^2}) \quad . \tag{2.9}$$

What is remarkable is that both parallel antiparallel flux tubes give rise to 2 bound states assignable to spin triplet. Singlet does not allow bound states.

5. The Planck constant appearing in the formulas can be replaced with $\hbar_{eff} = n\hbar$. Note that the value of the parameter x is inversely proportional to h_{eff} so that singlet approximation improves for large values of h_{eff}.

2.2 Fermionic statistics and bosons

What about fermionic statistics and bosons?

1. The total wave function must be antisymmetric and the manner to achieve this for spin triplet state is anti-symmetrization in longitudinal degrees of freedom. In 3-D model for Cooper pairs spatial antis-ymmetrization implies $L = 1$ spatial wave function in the relative coordinate and one obtains $J = 0$ and $J = 2$ states. Now the state could be antisymmetric under the exchange of longitudinal momenta of fermions. Longitudinal momenta cannot be identical and Fermi sphere is replaced by its 1-dimensional variant. In 3-D model for Cooper pairs spatial anti-symmetrization implies $L = 1$ spatial wave function in the relative coordinate. Antisymmetry with respect to longitudinal momenta would be the analog for the odd parity of this wave function. Ordinary super-conductivity is located at the boundary of Fermi sphere in a narrow layer with thickness defined by the binding energy. The situation is same now and the thickness should correspond now to the spin-flux interaction energy.

2. Second possibility is more exotic and could be based on antisymmetric entanglement in discrete dark degrees of freedom defined by the sheets of the singular covering assignable to the integer $n = h_{eff}/h$. For $n = 2m$ one can decompose the n discrete degrees of freedom to the discrete analogs of m spatial coordinates q_i and m canonical momenta p_i and assume that the unitary entanglement matrix (negentropic entanglement) is proportional to the standard antisymmetric matrix defining symplectic structure and expressible as a direct sum of 2×2 permutation symbols ϵ_{ij}. $J_{p_i,q_i} = -J_{q_i p_i} = 1/\sqrt{2m}$. This matrix is antisymmetric and unitary in standard sense and quaternionic sense.

3. What about bosons? I have proposed that bosonic ions (such as Ca^{++}) associated with single flux tube form cyclotron Bose Einstein condensates giving rise to spontaneous dark magnetization. Bosonic supra currents can indeed run independently along single flux tube as spin currents. Also now the thermal stability of cyclotron states require large h_{eff}. The supra-currents (spin currents) of bosonic ions could be associated with flux tubes and fermionic supra-currents with their pairs. Even dark photons could give rise to spin currents.

   At the formal level the model applies in the case of bosons too. Symmetrization/anti-symmetrization for spin singlets/triplets would be replaced with anti-symmetrization/symmetrization. The analog of Fermi sphere would be obtained for spin singlet states requiring anti-symmetrization in longitudinal degrees of freedom.

2.3 Interpretation in the case of high T_c super-conductivity

It is interesting to try to interpret the results in terms of high T_c super-conductivity (`http://en.wikipedia.org/wiki/High-temperature_superconductivity`).

1. The four eigen values of total Hamiltonian are

$$E = E_{s-s} \times \lambda \quad ,$$

$$\lambda \in \{\frac{5}{4}, -\frac{3}{4}, -\frac{1}{4}(1 \pm \sqrt{1+4x^2})\} \quad . \tag{2.10}$$

Two bound states with different binding energies are obtained which should be an empirically testable prediction in the case of the ordinary high T_c superconductivity since it predicts two critical temperatures. Cooper pairs are apart from possible small mixing with singlet state triplet states. The average spin is however vanishing also for $S_z = \pm 1$ states-

2. Two phase transitions giving rise to Cooper pairs are predicted. The simplest interpretation would be that super-conductivity in short scales is already present below the higher critical temperature and corresponds to the currents carries forming a mixture of $S_z = \pm 1$ states. These supra currents would stabilize flux tubes below some rather short scale. At the lower critical temperature the super-conductivity assignable to $S_z = 0$ spin triplets slightly mixed with singlet would become possible and the scale in which supra-currents can run would increase due to the occurrence of the percolation phenomenon. Below the lower critical temperature the interaction with flux tubes is indeed involved in an essential manner as a mixing of singlet and triplet states. One could perhaps say that $S_z = 0$ states stabilize the flux tube pair.

3. The critical temperatures for the stability of Cooper pairs are predicted to be in ratio $3/1 + \sqrt{1+4x^2}$ roughly equal the upper bound $3/2$ for small x. The critical temperatures are identical for $x = \sqrt{63/4} \simeq 4$. In the ordinary high T_c super-conductivity in cuprates the two critical temperatures are around $T^* = 300$K and $T_c = 80K$. The ratio $T^*/T_c = 3.75$ fails to be consistent with the upper bound $3/2$.

4. If one takes the model deadly seriously despite its strong simplifying assumptions one is forced to consider a more complex interpretation. What comes in mind is that both kind of Cooper pairs appear first and super-conductivity becomes possible at T_c. T^* would correspond to the emergence of $S_z = \pm 1$ mixtures. The critical temperature T^{**} for the emergence $S_z = 0$ pairs would not be lower than $T^{**}_{min} = (2/3) \times 300 = 200$ K. At temperature T_c the flux tubes carrying the two kinds of pairs become thermally stable by a percolation type process involving re-connection of U-shaped flux tubes to longer flux tube pairs and supra-currents can run in long length scales. This model conforms with the interpretation of pseudo-gap in terms o pre-formed Cooper pairs not able to form coherent supra-currents (`http://en.wikipedia.org/wiki/Pseudogap`).

One ends up to the prediction that there should be a third critical temperature T^{**} not lower than $T^{**}_{min} = 2T^*/3$, where T^* is the higher critical temperature at which Cooper pairs identifiable as mixtures of $S_z = \pm 1$ pairs emerge. At the lower temperature $S_z = 0$ states, which are mixtures of spin triplet and spin singlet state emerge.

2.4 Quantitative estimates in the case of TGD inspired quantum biology

Using the formulas obtained above one can make rough quantitative estimates and get grasp about bio-super-conductivity as predicted by the model.

1. To get grasp to the situation it is good to consider as starting point electron with nanometer scale $a = a_0 = 1$ nm taken as the distance between flux tubes. For $h_{eff} = n \times h$ value of Planck constant one obtains $E_{s-s} = n^2 (a/a_0)^3 \times E_0$. $E_0 = 1.7 \times 10^{-7}$ eV.

   Taking $B = 1$ Tesla one obtains for E_{s-flux} $E_{s-flux} = n \times E_{s-flux,0}$, $E_{s-flux,0} = 6.2 \times 10^{-7}$ eV. For $B = B_{end} = .2$ Gauss suggested as an important value of dark endogenous magnetic field one obtains $E_{s-flux,0} = 2.5 \times 10^{-11}$ eV.

2. It seems reasonable to require that the two interaction energies are of same order of magnitude. Spin-flux interaction energy is rather small. For instance, for B=1 Tesla its magnitude for electron is about $E_{s-flux,0} = 6.2 \times 10^{-7}$ eV so that a large value of h_{eff} seems to be necessary.

3. The hypothesis that bio-photons result in the transformations of dark photons to ordinary photons suggests that the energy scale is in the range of visible and UV photons and therefore above eV. This suggests for electron $h_{eff}/h = n \geq 10^7$. The condition that the value of E_{s-s} is also in the same range requires that a scales like $n^{1/3}$. This would give scaling, which is

larger than $10^{7/3} \simeq 215$: this would mean $a \geq 2 \times 10^{-7}$ m which belongs to the range of biologically most important length scales between cell membrane thickness and nucleus size.

4. The hypothesis $\hbar_{eff} = n \times \hbar = \hbar_{gr} = GMm/v_0$ [K9, K8] implies that cyclotron energy spectrum is universal (no dependence on the mass of the charged particle. Same would hold true for the spin-flux interaction energy. Spin spin interaction energy is proportional to h_{eff}^2/m^2a^3, where a is minimum distance between members of the Cooper pair. It is invariant under the simultaneous scaling of h_{eff} and m so that all charged particles can form Cooper pairs and spin currents for flux tubes with same distance and same magnetic field strength. This would correspond to the universality of the bio-photons [K7]. This would be also consistent with the earlier explanation for the finding of Hu and Wu [J1] that proton spin-spin interaction frequency for the distance defined by cell membrane thickness is in ELF frequency scale. The proposal was that dark proton sequences are involved at both sides of the membrane.

   Universality of Cooper pair binding energies implies universality of super-conductivity all fermionic ions can form superconducting Cooper pairs as has been assumed in the models for strange effects of ELF em fields on vertebrate brain, for cell membrane as Josephson junction, and for EEG [K3], and in the modelf for nerve pulse [K6]. As found, Bose-Einstein condensates of bosonic ions could give rise to spontaneous dark magnetization and spin currents along single flux tube so that bosons would be associated with flux tubes and fermions with pairs of them.

   The value of h_{eff} for proton would satisfy $n \geq 2 \times 10^{10}$. This would guarantee that proton cyclotron frequency for $B = B_{end}$ corresponds to thermal energy 2.5×10^{-2} eV at room temperature.

   Note that I have considered also the option that the valies of h_{eff} are such that the universal cyclotron energy scale in magnetic field of $B \simeq .2$ Gauss is in the range of bio-photon energies so that h_{eff} would be by a factor of order 50 higher than in the estimate coming from spin temperature.

5. This observation raises the question whether there are two widely different energy scales present in living matter. The first scale would be associated with spin-spin interaction and would correspond to the energy scale of bio-photons. Second scale would be associated with spin-flux interaction and correspond to the energy scale of resting potential just above the thermal energy at physiological temperatures.

   If this is the case, the parameter x would be of order $x \simeq 10^{-2}$ and spin-spin interaction energy would dominate. The somewhat paradoxical earlier prediction was that Cooper pairs in bio-super-conductivity would be stable at temperatures corresponding to energy of eV or even higher but organisms do not survive above physiological temperatures. The critical temperature for living matter could be however understood in terms of the temperature sensitivity of the dark magnetization at magnetic flux tubes. Although the binding energies of Cooper pairs are in bio-photon energy range this does not help since the quantum wires along, which they can propagate are unstable above room temperatures.

6. From the estimate of order 10^{-7} eV for energy scales for $a = 1$ nm and $B = 1$ Tesla and from the binding energy of Cooper pairs of order 10^{-2} eV it is clear that ordinary high T_c super-conductivity cannot correspond to the standard value of Planck constant: $h_{eff}/h \simeq 10^5$ is required. The interpretation would be that at the higher critical temperature Cooper pairs become stable but flux tubes are not stable. At the lower critical temperature also flux tubes become stable. This would correspond to the percolation model that I have proposed earlier.

   These two energy scales would be the biological counterparts of the two much lower energy scales in the ordinary high T_c super-conductivity. There ratio of these scales would be roughly 50.

REFERENCES

Condensed Matter Physics

[D1] Scientists Detect 'Fingerprint' of High-temperature Superconductivity Above Transition Temperature. *Science Daily.* Available at: http://www.sciencedaily.com/releases/2009/08/090827141338.htm, 2009.

[D2] Tranquada JM Emery VJ, Kivelson SA. Stripe phases in high-temperature superconductors. *Perspective.* Available at: http://www.pnas.org/cgi/reprint/96/16/8814.pdf, 96(16), August 1999.

[D3] Zaanen J. Why high Tc is exciting? Available at: http://www.lorentz.leidenuniv.nl/research/jan_hitc.pdf, 2005.

[D4] Zaanen J. Superconductivity: Quantum Stripe Search. *Nature* . Available at: http://www.lorentz.leidenuniv.nl/~jan/nature03/qustripes06.pdf, April 2006.

[D5] Zaanen J. Watching Rush Hour in the World of Electrons. *Science.* Available at: http://www.ilorentz.org/~jan/perspstripes.pdf, 2007.

[D6] Buchanan M. Mind the pseudogap. *Nature*, 409:8–11, January 2001.

Neuroscience and Consciousness

[J1] Wu M Hu H. Action Potential Modulation of Neural Spin Networks Suggests Possible Role of Spin. *NeuroQuantology* . Available at: http://cogprints.org/3458/1/SpinRole.pdf, 4:309–317, 2004.

Books related to TGD

[K1] Pitkänen M. Bio-Systems as Super-Conductors: part I. In *Quantum Hardware of Living Matter.* Online book. Available at: http://www.tgdtheory.fi/tgdhtml/bioware.html#superc1, 2006.

[K2] Pitkänen M. Bio-Systems as Super-Conductors: part II. In *Quantum Hardware of Living Matter.* Online book. Available at: http://www.tgdtheory.fi/tgdhtml/bioware.html#superc2, 2006.

[K3] Pitkänen M. Dark Matter Hierarchy and Hierarchy of EEGs. In *TGD and EEG.* Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdeeg.html#eegdark, 2006.

[K4] Pitkänen M. Quantum Model for Bio-Superconductivity: I. In *TGD and EEG.* Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdeeg.html#biosupercondI, 2006.

[K5] Pitkänen M. Quantum Model for Bio-Superconductivity: II. In *TGD and EEG.* Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdeeg.html#biosupercondII, 2006.

[K6] Pitkänen M. Quantum Model for Nerve Pulse. In *TGD and EEG.* Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdeeg.html#pulse, 2006.

[K7] Pitkänen M. Are dark photons behind biophotons? In *TGD based view about living matter and remote mental interactions.* Online book. Available at: http://www.tgdtheory.fi/tgdhtml/tgdlian.html#biophotonslian, 2013.

[K8] Pitkänen M. Criticality and dark matter. In *Hyper-finite Factors and Dark Matter Hierarchy.* Online book. Available at: http://www.tgdtheory.fi/tgdhtml/neuplanck.html#qcritdark, 2014.

[K9] Pitkänen M. Quantum gravity, dark matter, and prebiotic evolution. In *Genes and Memes*. Online book. Available at: `http://www.tgdtheory.fi/tgdhtml/genememe.html#hgrprebio`, 2014.