Quantum criticality and dark matter: part II

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Abstract

Quantum criticality is one of the corner stone assumptions of TGD. The value of Kähler coupling strength fixes quantum TGD and is analogous to critical temperature. TGD Universe would be quantum critical. What does this mean is however far from obvious and I have pondered the notion repeatedly both from the point of view of mathematical description and phenomenology. Dark matter as a hierarchy of phases of ordinary matter labelled by the value of effective Planck constant h_{eff} following as prediction of adelic physics suggests a general approach to quantum criticality. In the second part of the chapter about quantum criticality condensed matter applications are discussed.

1 Introduction

Quantum criticality is one of the corner stone assumptions of TGD. The value of Kähler coupling strength fixes quantum TGD and is analogous to critical temperature. TGD Universe would be quantum critical. What does this mean is however far from obvious and I have pondered the notion repeatedly both from the point of view of mathematical description and phenomenology [K6, K19].

1. Criticality is characterized by long range correlations and sensitivity to external perturbations and living systems define an excellent example of critical systems - even in the scale of populations since without sensitivity and long range correlations cultural evolution and society would not be possible. For a physicist with the conceptual tools of existing theoretical physics the recent information society in which the actions of people at different side of globe are highly correlated, should look like a miracle.

2. The hierarchy of Planck constants with dark matter identified as phases of ordinary matter with non-standard value $h_{eff} = n \times h$ of Planck constant is one of the "almost-predictions" of TGD is definitely something essentially new physics. The phase transition transforming ordinary matter to dark matter in this sense generates long range quantal correlations and even macroscopic quantum coherence.

   Finding of a universal mechanism generating dark matter have been a key challenge during last ten years. Could it be that criticality is always accompanied by the generation of dark matter? If this is the case, the recipe would be stupifuingly simple: create a critical system! Dark matter would be everywhere and we would have observed its effects for centuries! Magnetic flux tubes (possibly carrying monopole flux) define the space-time correlates for long range correlations at criticality and would carry the dark matter. They are indeed key players in TGD inspired quantum biology.

3. Change of symmetry is assigned with criticality as also conformal symmetry (in 2-D case). In TGD framework conformal symmetry is extended and infinite hierarchy of breakings of conformal symmetry so that a sub-algebras of various conformal algebras with conformal weights coming as integer multiples of integer n defining h_{eff} would occur.

4. Phase separation is what typically occurs at criticality and one should understand also this. The strengthening of this hypothesis with the assumption $h_{eff} = h_{gr}$, where $h_{gr} = GMm/v_0$ is is the gravitational Planck constant originally introduced by Nottale. In the formula v_0 has dimensions of velocity, and will be proposed to be determined by a condition relating the size of the system with mass M to the radius within which the wave function of particle m with $h_{eff} = h_{gr}$ is localized in the gravitational field of M.

5. The condition $h_{eff} = h_{gr}$ implies that the integer n in h_{eff} is proportional to the mass of particle. The implication is that particles with different masses reside at flux tubes with different Planck constant and separation of phases indeed occurs.

6. What is remarkable is that neither gravitational Compton length nor cyclotron energy spectrum depends on the mass of the particle. This universality could play key role in living matter. One can assign Planck constant also to other interactions such as electromagnetic interaction so that one would have $h_{em} = Z_1 Z_2 e^2/v_0$. The phase transition could take place when the perturbation series based on the coupling strength $\alpha = Z_1 Z_2 e^2/\hbar$ ceases to converge. In the new phase perturbation series would converge since the coupling strength is

proportional to $1/h_{eff}$. Hence criticality and separation into phases serve as criteria as one tries to see whether the earlier proposals for the mechanisms giving rise to large h_{eff} phases make sense. One can also check whether the systems to which large h_{eff} has been assigned are indeed critical.

The motivation for this work came from super-fluidity. Superfluids exhibit rather mysterious looking effects such as fountain effect and what looks like quantum coherence of superfluid containers, which should be classically isolated. These findings serve as a motivation for the proposal that genuine superfluid portion of superfluid corresponds to a large h_{eff} phase near criticality at least and that also in other phase transition like phenomena a phase transition to dark phase occurs near the vicinity.

1.1 Some applications to condensed matter physics

In the second part of the chapter the applications to condensed matter physics are discussed. By its nature condensed matter physics provides rich repertoire of critical phenomena.

1. Different phases of same substance, say water, can be in phase equilibrium at criticality and dark matter. There are critical regions of parameter space -critical lines and critical points, in which the transitions between different phases are possible. Long range thermodynamical correlations are associated with these systems and the association with dark matter would suggest that dark matter could appear in these critical systems.

2. Different substances can form mixtures (`http://tinyurl.com/286nqx`). For instance, oil can mix to water in some parameter regions. This kind of systems are good candidates for critical systems. There is actually rich spectrum of mixtures. Solutions (`http://tinyurl.com/yz3hvq`), colloids (`http://tinyurl.com/yabljt8l`), dispersions (`http://tinyurl.com/bq3vm2m`) and the substances can be also in different phases (gas, liquid, solid) so that very rich spectrum of possibilities emerges. Is the generation of dark matter involved only with the phase transitions between different types of mixed phases or between mixed and non-mixed phase? Are some phases like gel inherently critical?

3. One example about criticality is phase transition to super-fluidity or super-conductivity. In the transition from super-conducitivity the value of specific hearts diverges having the shape of greek letter λ: hence the name lambda point. This suggests that in transition point the specific heat behaves like N^2 due to the quantum coherence instead of proportionality to N as usually. The strange properties of super-fluid, in particular fountain effect, could be understood in terms of $h_{eff} = h_{gr}$ hypothesis as will be discussed.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L2].

2 Liquids, superconductivity and superfluidity

2.1 Mysterious Action At Distance Between Liquid Containers

This section as also the consideration of the idea that criticality could involve a phase transition transforming ordinary matter to dark matter was inspired by a link sent by Ulla. The link was to a popular article (`http://tinyurl.com/yaaqnebp`) telling about mysterious looking action at a distance between liquid containers.

For several years it has been that superfluid helium in reservoirs next to each other with distance of few micrometers acts collectively, even when the channels connecting them are so thin and long that substantial flow of matter between them is not possible. The article mentions a theoretical model [B1] developed by a team of scientists include those from the Instute of Physical Chemistry of the Polish Academy of Sciences in Warzaw (IPCPACW). According to the article the model reveals that the phenomenon is much more general than previously thought and could take place also systems which are usually regarded as classical (what this actually means in quantum world

is not quite clear!). The reading of the abstract of the article (http://tinyurl.com/y7pmbw2k) shows that only Monte Carlo studies are done so that "predicts" is more appropriate than "reveals".

According to the article, the first report about "action at a distance" was between superfluid reservoirs was published in 2010 in Nature Physics [D16] (http://tinyurl.com/y7pfc9a9). The team from the University of Buffalo and the State University of New York created an array of tens of millions of cubical reservoirs containing liquid healiium on a silicon plate. The centres of reservoirs had distance of 6 μ and the reservoirs had edge length of 2 μm so that the width of the horizontal gap between reservours was 4 μm. The reservoirs were covered with another silicon plate with a very thin gap above the reservoirs allowing to fill them with liquid helium. The thickness of this vertical gap was $d = 32$ nm - in TGD language this is $d = 3.2L(151)$, where the p-adic length scale $L(151) = 10$ nm defines the thickness of cell membrane The gap was so thin that it did not allow a significant flow of liquid helium between the different reservoirs.

Remark: To be precise, $L(151)$ should be called the Compton length of electron if it would correspond to Gaussian Mersenne $MG, k = 151 = (1+i)^k - 1$ and is $L_e(151) = \sqrt{5} \times L(151)$, where $L(151)$ would be the genuine p-adic length scale. For brevity I often call L_e just p-adic length scale and drop the subscript "e".

The expectation was that different reservoirs would behave like independent systems without interactions. In particular, the specific heat of the whole system would be sum over the specific heats of individual systems, which were identical. This was not the case. An excess of specific heat was observed in the system. The super-fluid helium was acting as a physical whole.

The natural explanation would be in terms of the superfluid character of the systems. Still the absence of the direct contact - say thin "threads" connecting the reservoirs - makes one to wonder whether the situation can be understood in the framework of conventional quantum physics.

In co-operation with Prof. Douglas Abraham from Oxford University, Dr. Maciolek from (IPC-PACW) has developed a theory to exlain the observations [B1] (http://tinyurl.com/y7pmbw2k). The new theory predicts that the effect of "action at a distance" does not require quantum physics and can also occur in classical one-component fluids, as well as its mixtures. The article says that this theory is confirmed by computer simulations carried out by Oleg Vasilyev from the Max-Planck Insitute für Intelligente Systeme. I would be here a little bit skeptical: experiments conform, computer simulations only allow to calculate!

The theory makes certain predictions.

1. Super-fluidity is not a necessary condition. The phenomenon can occur if the system is near criticality and thus involves at least two different phases of matter. Therefore low temperatures a not necessary. For instance, water and lutidine - a model mixture of water and oil - mix only in certain temperature range and "action at a distance" appears only in this range. On basis of the popular article it remains clear whether this is a prediction or an experimental fact.

2. The dimensions of the reservoins and the connecting channels are also important. The phenomenon ceas the distances are significantly larger than the size of human cells.

Some comments from TGD based view about criticality already summarize are in order.

1. The notion of "classical" can be misleading. One can model physical phenomena classically - thermodynamical phase transitions are basic example of this but the microscopic - and also non-microscopic physics of long range correlations - can be actually quantal. Basically all physics is quantal and during last years people have begun to learn that even macroscopic physical can behave non-classically. In TGD framework however quantum physics as classical space-time correlates and this brings a new element.

2. The key question is what makes the superfluids closed in the reservoirs to behave like single quantum coherent system in the first experiment. TGD based view about space-time correlates of criticality and long range correlations associated with suggests that magnetic flux tubes or sheets connecting the superfluid reservoirs are essential. Even more, these flux quanta - possible carrying monople fluxes - would be universal space-time correlates of any critical phenomenon. In separate section I will discuss a model for the fountain effect exhibited by ^4He based on the notion of flux quantum carrying the genuine super fluid (normal and super-fluid component are involved) having non-standard value of Planck constant,

which is rather large so that the gravitational Compton length is macroscopic length and the effects of gravitation the wave function are very small and the super-fluid apparently defies gravitational force.

3. Second question is why cell length scale of few microns would serve as a prerequisite for the phenomenon. The length scale range 10 nm-2.5 μm involves as many as four p-adic length scales labelled by Gaussian Mersennes ($k = 151, 157, 163, 167$ and corresponds to length scale range between thickness of cell membrane and cell nucleus size. TGD suggests strongly dark variants of weak with $h_{eff} = n \times h$ and also strong physics with corresponding gauge bosons being effective as massless particles below these length scales. The exchange of these massless bosons would generate long range correlations at criticality. Also p-adic variants of these physics with mass scales of weak bosons reduced to a range varying in 1-100 eV range would be involved if TGD vision is correct. Hence criticality would involve quantum physics and even dark matter!

4. Phase separation - be it separation of particles in mixture or phases of say water - is very relevant of criticality. How this happens. The TGD answer already considered relies on the notion of hierarchy of Planck constants $h_{eff} = n \times h$ and universality of cyclotron frequencies associated with magnetic flux tubes and due to the identification $\hbar_{eff} = \hbar_{gr} = GMm/v_0$ already discussed. The large mass M is the mass of the dark fraction of the Earth's mass. This implies that Planck constant characterizes particle and also that the gravitational Compton length is same for all particles and the energy spectrum of cyclotron radiation is universal and in the range of visible and UV energies associated with bio-photons.

   All these predictions conform nicely with the universality of criticality. The prediction is that bio-photons would accompany any Earthly critical system. What of course raises the eyebrows of skeptics is the proposed dependence of critical phenomena on the dark gravitational mass of the planet or system which the system is part of.

2.2 The Behavior Of Superfluids In Gravitational Field

Superfluids apparently defy gravitational force as so called fountain effect (`http://tinyurl.com/kx3t52r`) demonstrates. In the following TGD inspire model based on the hypothesis that the genuine superfluid part of superfluid at least near criticality corresponds to large h_{eff} phase is considered.

2.2.1 Fountain effect

In an arrangement involving a vessel of superfluid inside another one such that the levels of superfluids are different in the two vessels, the superfluid flows spontaneously along the walls of the vessels as a superfluid film. The flow is from the vessel in which the level of superfluid is higher until the heights are equal or *all* fluid has left the other container. For illustrations see the pictures of the article (see `http://tinyurl.com/h66hydb`) [D17] "Why does superfluid helium leak out of an open container?".

What is strange that all the fluid flows from the vessel to another one it the height of vessel is high enough. According to the prevailing wisdom super-fluid actually consists of ordinary fluid and genuine superfluid. The fluid flows from the vessel as a genuine superfluid so that the process must involve a phase transition transforming the ordinary fluid component present in the fluid to superfluid keeping superfluid fraction constant. A further strange feature is that the superfluid flows as a film covering the inner (and also outer) surface of entire container so that return flow is not possible. This suggests interpretation as a macroscopic quantum phenomenon

According to the article of Golovko the existing wisdom about flow is that it corresponds to wetting. This would however predict that the phenomenon takes place also above the critical point (λ point) for the ordinary fluid. This is not the case. Secondly, the force responsible for the sucking the superfluid from the container would act only at the boundary of the film. As the film covers both the interior and exterior walls of the container the boundary vanishes, and therefore also the force so that the flow of the superfluid to another container should stop. The amount of the superfluid leaving the container should be small and equal to the amount of super-fluid in the film: this is not the case. Hence the conventional explanation does not seem to work.

2.2.2 TGD inspired model for the fountain effect

What could be the TGD explanation for fountain effect?

Macroscopic quantum coherence in the scale of the film is suggestive and hierarchy of Planck constants $h_{eff} = n \times h$ and magnetic flux quanta suggest themselves. Whether this notion is relevant also for the description of the super-fluid itself is not of course obvious and one might argue that standard description is enough. Just for fun, we can however for a moment assume that the super-fluid fraction could correspond to a dark phase of 4^He located at flux quanta. The natural candidates for the flux quanta is a flux sheet connecting the vessel to the external world or smaller vessel and larger vessel to each other. The flux sheet would accompany the film covering the inside and outside walls. The fact that the flow seems to defy gravitational force suggests that macroscopic quantum coherence is involved in these degrees of freedom and that one should describe the situation in terms of wave function for super-fluid particles in the gravitational potential of Earth. For ordinary value of Planck constant one cannot of course expect macroscopic quantum coherence since coherence length is not expected to be much larger than Compton length. TGD predicts that h_{eff} characterizes Kähler magnetic flux tubes at which the dark Bose-Einstein condensate resides. There can consider several identifications of h_{eff} corresponding to gravitational interaction, electromagnetism, or long range Z^0 interaction possible in TGD and originally associated with super-fluidity interpreted as Z^0 superconductivity.

3. (a) For gravitational interaction, the identification is $h_{eff} = h_{gr}$, where h_{gr} is what I call gravitational Planck constant of Nottale [?]

$$\hbar_{gr} = \frac{GMm}{v_0} = \frac{r_S m}{2\beta_0} \quad , \quad \beta_0 = \frac{v_0}{c} \tag{2.1}$$

In the expression of h_{gr} M is the "large" mass - naturally Earth's mass M_E. m would be the mass of ^4He atom. $r_S = 2GM/c$ denotes Schwartschild radius of Earth, which from $M_E = 3 \times 10^{-6} M_{Sun}$ and from $r_S(Sun) = 3$ km is 4.5 mm. v_0 could be some characteristic velocity for Earth-super fluid system and the rotation velocity $v_0 = 465.1$ m/s of Earth is the first guess. However, the model for cyclotron frequencies of dark ions favor rather large value of v_0, say $v_0/c = 1/2$.

The gravitational Compton length $\lambda_{gr} = h_{gr}/m$ does not depend on the mass of the particle and equals to $\lambda_{gr} = GM/v_0 \simeq 645$ meters for $v_0 = 465.1$ m/s. The scale of the superfluid system would be much smaller than the minimum coherence length, which does not look plausible.

(b) The generalization of Nottale's formula to the electromagnetic case would be $\hbar_{em} = Q_{em} e^2/v_0 > \hbar$. Q_{em} should refer to the em charge of super-fluid but this is essentially zero so that this option is not feasible.

(c) According to the standard model, the nuclear Z^0 charges are indeed non-vanishing in the standard model, where Z^0 quanta are massive. In TGD framework, one can however argue that they are actually screened above weak boson Compton length. For $\hbar_{eff} = \hbar_Z$ the intermediate boson Compton length could be scaled up by the factor $\hbar_Z/\hbar$ so that Z^0 quanta would be effectively massless below this screening scale.

The generalization of the Nottale's formula would read as $\hbar_Z = Q_Z g_Z^2/v_0$, where ZQ_Z refers to the total Z^0 charge of the super-fluid phase. Cell scale would require $h_Z/h \sim 10^{11}$. Screening scale is atomic for $h_Z/h \sim 10^7$: this value turns out to be too large. A value of order 2^8 is required. If the screening of nuclear charges in the scale of ^4He nuclei, one would have $h_Z/h \sim 100$. This value of h_Z/h is however not consistent with the Nottale's hypothesis and with the idea about scaled up weak boson Compton length.

A possible way to solve this problem is to assume that weak bosons can also appear at electroweak p-adic scales which differ from intermediate boson length scale [K7]

and have scaled down masses. If this scale corresponds to the atomic p-adic length scale $L(k = 137)$ as the size scale of Cooper pairs suggests, then $h_Z \simeq 2^8$ would correspond to the p-adic length scale $L(153)$ ($L(151) \simeq 10$ nm corresponds to cell membrane thickness).

A simple model for the situation discussed would rely on Schrödinger equation at the flux quantum which is locally a thin hollow cylinder turning around at the top of the wall of the container.

(a) One obtains 1-dimensional Schrödinger equation

$$(-\frac{\hbar_{eff}^2\partial_z^2}{2m} + mg_{eff}z)\Psi = E\Psi \quad , \quad h_{eff} = nh_0 = \frac{nh}{6} \quad . \tag{2.2}$$

It is easy to see that the energy spectrum is invariant under the scaling $h \to h_{eff} = xh$ and $z \to z/x$. One has $\Psi_{xh,g_{eff}=g/x}(z) = \Psi_{h,g}(z/x)$ so that simple scaling of the argument z in question. The energy of the solution is same. If the ordinary solution has size scale L, the scaled up solution has size scale xL.

The height for a trajectory in gravitational field of Earth is scaled up for a given initial vertical velocity v_i is scaled as $h \to xh$ so quantum behavior corresponds to the classical behavior and de-localization scale is scaled up. Could this happen at various layers of magnetic body for dark particles so that they would be naturally at much higher heights. Cell scale would be scaled to Earth size scale of even larger sizes for the values of $\hbar_{eff}/h = n$ involved.

For classical solution with initial initial vertical velocity $v_i = 1$ m/s the height of the upwards trajectory is $h = v_i^2/2g$ 5 cm. Quantum classical correspondence would be given by $E = mv_i^2/2$ and this allows to look the delocalization scale of a solution.

(b) One can introduce the dimensionless variable u (note that one has $g_{eff}/g = 1/x$, $x = h/h_{eff}$) as

$$u = \frac{z - \frac{E}{mg_{eff}}}{z_0} \quad , \qquad z_0 = \left[\frac{2m^2g_{eff}}{\hbar_{eff}^2}\right]^{-1/3} = \frac{h_{eff}}{h}(\frac{m}{m_p})^{2/3} \times (\frac{g}{L_p^2})^{-1/3} \simeq \frac{h_{eff}}{h} \times (\frac{m}{m_p})^{2/3} \times 2.4$$

$$L_p = \frac{\hbar c}{m_p} = \simeq 2.1 \times 10^{-16} \text{ m} \quad ,$$

(2.3)

Here m_p denotes proton mass and L_p proton Compton length. z_0 scales as $\hbar_{eff}$ as one might expect. z_0 characterizes roughly the scale of the s lution. From the scale of the fountain effect about 1 meter, one can conclude that one should have $h_{eff}/h \sim 2^8$.

This allows to cast the equation to the standard form of the equation for Airy functions encountered in WKB approximation

$$-\frac{d^2\Psi}{du^2} + u\Psi = 0 \quad . \tag{2.4}$$

Remark: Note that the classical solution depends on m. In central force problem with $1/r$ and $h_{eff} = GMm/v_0$ the binding energy spectrum $E = E_0/n^2$ has scale $E_0 = v_0^2m$ and is universal.

(c) The interesting solutions correspond to Airy functions $Ai(u)$ which approach rapidly zero for the values of $u > 1$ and oscillate for negative values of u. These functions $Ai(u + u_1)$ are orthogonal for different values of u_1. The values of u_1 correspond to different initial kinetic energies for the motion in vertical direction. In the recent situation these energies correspond to the initial vertical velocities of the super-fluid in the film. $u = u_0 = 1$ defines a convenient estimate for the value of z coordinate above which wave function approaches rapidly to zero.

For classical solution with initial initial vertical velocity $v_i = 1$ m/s the height of the upwards trajectory is $h = v_i^2/2g$ 5 cm. Quantum classical correspondence would be given by $E = mv_i^2/2 = E$ and this allows to look the delocalization scale of a solution.

The Airy function $Ai(u)$ approaches rapidly to zero (see the graph of `https://en.wikipedia.org/wiki/Airy_function`) and one can say that above $u_0 = 3$ the function vanishes. Already at $u_0 = 1$ wave function is rather small as compared with its value at $u = 0$. This condition translates to a condition for z as

$$z_0 = z_{cl} + u_0 z_0 \quad , \quad z_{cl} = \frac{E}{mg_{eff}} \quad , \quad z_0 = \frac{h_{eff}}{h}\left[\frac{\hbar^2}{2m^2 g}\right]^{1/3} \quad . \tag{2.5}$$

The condition is consistent with the classical picture and the classical height z_{cl} scales like h_{eff}/h. The parameter $u_0 z_0$ defines the de-localization scale consistent with the expectations. Below z_{cl} the wave function oscillates which intuitively corresponds to the sum of waves in upwards and downwards directions.

What can one conclude about the value of $x = h_{eff}/h_0$ in the case of super-fluidity?

i. Using the previous formula, the condition that z_0 is of order 1 meter fixes its value to $h_{eff}/h_0 \sim 2^8$. Could super-fluidity correspond to the value of $h_{eff} = h_{em} > h$ assignable to electromagnetic flux tubes? The generalization $h_{em} = Ze^2/v_0$ of the Nottale's formula would require that the super fluid phase has a large total em charge Z. The Cooper pairs are however neutral. This leaves under consideration only the old idea that super-fluidity corresponds to Z^0 super-conductivity inspired by the idea that TGD predicts long range Z^0 fields and by the fact that nuclei carry indeed carry non-vanishing Z^0 charge mostly due to neurons.

ii. Both $\hbar_{eff}(gr)/\hbar \simeq 2^{24}$ and $\hbar_{gr} = GMm/v_0$ given by Nottale's hypothesis give quite too large value of z_0.

The gravitational Compton length λ_{gr} is given by $\lambda_{gr} = GM_e/v_0 = r_S/2v_0$ and - in accordance with the Equivalence Principle - does not depend on m. The Schwartschild radius of Earth is $r_S = .9$ cm. One could argue that λ_{gr} is a reasonable lower bound for z_0 if h_{gr} appears in the gravitational Schrödinger equation. For $v_0/c = 2^{-11}$ required by the Bohr orbit model for the 4 inner planets, this would give $\lambda_{gr} = 9$ m. The energy scale of dark cyclotron states comes out correctly if one has $v_0/c = 1/2$ giving the lower bound $z_0 \geq r_S = .9$ cm.

However, the proportionality of z_0 to h_{eff}/h implies that the z_0 is scaled by a factor of order $2GM_E m_p/v_0 \sim 10^{14}$ from its value $z_0 = .2$ mm and would be gigantic. It seems that this option indeed fails.

iii. Could the fountain effect be due to the reduction of g in principle possible if G is prediction and CP_2 length replaces Planck length as fundamental scale? If one assumes $h_{eff} = h$ and scaled down value of g corresponding to $G_{eff} = R^2/\hbar_{gr}$ such that $\hbar_{gr}$ is scaled from its normal value: $\hbar_{gr} \to y\hbar_{gr}$, $G_{eff} \to G_{eff}/y$. This would give the scaling of $z_0 \propto g^{-1/3}$ as $z_0 \to y^{1/3} z_0$ giving $z_0 \simeq .2$ mm should be scaled up to about 1 mm which would give $y \sim 10^9$. This would mean a huge breaking of Equivalence Principle.

2.2.3 Superfluids dissipate!

People in Aalto University - located in Finland by the way - are doing excellent work: there is full reason to be proud! I learned from the most recent experimental discovery by people working in Aalto University from Karl Stonjek. The title of the popular article (see `http://tinyurl.com/yagsttw7`) is "*Friction found where there should be none—in superfluids near absolute zero*".

In rotating superfluid one has vortices and they should not dissipate. The researchers of Aalto University however observed dissipation: the finding by J Mäkinen *et al* is

published in in Phys Rev B [D15] (see http://tinyurl.com/y7dtsdys). Dissipation means that they lose energy to environment. How could one explain this?

What comes in mind for an inhabitant of TGD Universe, is the hierarchy of Planck constants $h_{eff} = n \times h$ labelling a hierarchy of dark matters as phases of ordinary matter. The reduction of Planck constant h_{eff} liberates energy in a phase transition like manner giving rise to dissipation. This kind of burst like liberation of energy is mentioned in the popular article "glitches" in neutron stars). I have already earlier proposed an explanation of fountain effect of superfluidity in which superfluid flow seems to defy gravity. The explanation is in terms of large value of h_{eff} implying delocalization of superfluid particles in long length scale [**?**] (see http://tinyurl.com/y8xhvwt2).

Remark: Quite generally, binding energies are reduced as function of $h_{eff}/h = n$. One has $1/n^2$ proportionality for atomic binding energies so that atomic energies defined as rest energy minus binding energy indeed increase with n. Interestingly, dimension 3 of space is unique in this respect. Harmonic oscillator energy and cyclotron energies are in turn proportional to n. The value of n for molecular valence bonds depends on n and the binding energies of valence bonds decrease as the valence of the atom with larger valence increases. One can say that the valence bonds involving atom at the right end of the row of the periodic table carry metabolic energy. This is indeed the case as one finds by looking the chemistry of nutrient molecules.

The burst of energy would correspond to a reduction of n at the flux tubes associated with the superfluid. Could the vortices decompose to smaller vortices with a smaller radius, maybe proportional to n? I have proposed similar mechanism of dissipation in ordinary fluids for more than two decades ago. Could also ordinary fluids involve hierarchy of Planck constants and could they dissipate in the same manner?

In biology liberation of metabolic energy - say in motor action - would take place in this kind of "glitches". It would reduce h_{eff} resources and thus the ability to generate negentropy: this leads to smaller negentropy resources and one gets tired and thinking becomes fuzzy.

2.2.4 An improvement of the flux tube picture

The above arguments related to fountain effect cry for a more precise formulation of the rather loose ideas about how gravitational interaction is mediated by flux tubes.

It has been assumed that $\hbar_{gr} = GMm/v_0$ characterizes the flux tubes connecting mass M - say solar mass - to a smaller mass m. This assumption cannot be correct as such.

i. The assumption treats the two masses asymmetrically.

ii. A huge number of flux tubes is needed since every particle pair $M-m$ would involve a flux tube. It would be also difficult to understand the fact that one can think the total gravitational interaction in Newtonian framework as sum over interactions with the composite particles of M. In principle M can be decomposed into parts in many ways - elementary particles and their composites and larger structures formed from them: there must be some subtle difference between these different compositions - all need not be possible - not seen in Newtonian and GRT space-time but maybe having representation in many-sheeted space-time and involving h_{gr}.

iii. Flux tube picture in the original form seems to lead to problems with the basic properties of the gravitational interaction: namely superposition of gravitational fields and absence or at least smallness of screening by masses between M and m. One should assume that the ends of the flux tubes associated with the pair pair $M - m$ move as m moves with respect to M. This looks too complex.

Linear superposition and absence of screening can be understood in the picture in which particles form topological sum contacts with the flux tubes mediating gravitational interaction. This picture is used to deduce QFT-GRT limit of TGD. Note that also other space-time sheets can mediate the interaction and pairs of MEs

and flux tubes emanating from M but not ending to m are one possible option. In the following I however talk about flux tubes.

These problems find a solution if h_{gr} characterizes the *magnetic body* (MB) of a particle with mass m topologically condensed to a flux tube carrying total flux M. m can also correspond to a mass larger than elementary particle mass. This makes the situation completely symmetric with respect to M and m. The essential point is that the interaction takes place via touching of MB of m with flux tubes from M.

i. In accordance with the fractality of the many-sheeted space-time, the elementary particle fluxes from a larger mass M can combine to a sum of fluxes corresponding to masses $M_i < M$ with $\sum M_i = M$ at larger flux tubes with $\hbar_{gr} = GMM_i/v_{0,i} \geq \hbar$. This can take place in many ways, and in many-sheeted space-time gives rise to different physical situations.

   Due to the large value of h_{gr} it is possible to have macroscopic quantum phases at these sheets with a universal gravitational Compton length $L_{gr} = GM_i m/v_0$. Here m can be also a mass larger than elementary particle mass. In fact, the convergence of perturbation theory indeed makes the macroscopic quantum phases possible. This picture holds true also for the other interactions. Clearly, many-sheeted space-time brings in something new, and there are excellent reasons to believe that this new relates to the emergence of complexity - say via many-sheeted tensor networks [L6].

ii. This picture implies that fountain effect is a kind of antigravity effect for dark matter - maybe even for non-microscopic masses m - since the larger size of MB implies larger average distance from the source of the gravitational flux. This might have technological applications some day.

This picture is a considerable improvement but there are still problems to ponder. In particular, one should understand why the integer $n = h_{eff}/h = h_{gr}/h$ interpreted as a number of sheets of the singular covering space of MB of m emerges topologically. The large value of h_{gr} implies a huge number of sheets.

Could the flux sheet covering associated with M_i code the value of M_i using as unit Planck mass as the number of sheets of this covering? One would have $N = M/M_{Pl}$ sheeted structure with each sheet carrying Planckian flux. The fluxes experienced by the MB of m in turn would consist of sheets carrying fusion $n_m = M_{Pl}v_0/m$ Planckian fluxes so that the total number of sheets would be reduced to $n = N/m = GMm/v_0$ sheets.

Why this kind of fusion of Planck fluxes to larger fluxes should happen? Could quantum information theory provide clues here? And why v_0 is involved?

2.2.5 What about Sun?

Just for interest one can also look what one obtains in the case of Sun: this also leads to a guess for a general formula for the parameter v_0.

i. The replacement of Earth-particle system with particle-Sun system requires scaling r_S by a factor $10^6/3$, the scaling of R_E by factor about 110, and scaling of v_0/c by factor 4.3 if v_0 is identified as solar rotation velocity. The resulting value of z_0 is 1.7×10^{10} m whereas the distance of Earth from Sun is $R = 1.5 \times 10^{11}$ m, roughly 10 times larger than z_0.

ii. On the other hand, of one uses the value $v_0/c \simeq 2^{-11}$ needed in the model of inner planetary orbits as Bohr orbits, one obtains $z_0 = 7.3 \times 10^8$ m to be compared with the value of solar radius $R_S = 6.96 \times 10^8$ meters. For this value of v_0 the gravitational Compton length is $\lambda_{gr} = 6 \times 10^6$ meters, which happens to be rather near to the Earth's radius.

iii. The challenge is to predict the value of the parameter v_0. The above observation suggests that one could pose the consistency consistency condition $R = z_0$ to fix the value of v_0. This would give the formula

$$\beta_0 = (\frac{r_s}{4\pi R})^{1/2} \quad .$$

This scales up β_0 from 1.6×10^{-6} to 2.3×10^{-6} by a factor $1.41 \simeq \sqrt{2}$. For Sun one obtains $\beta_0 = 5.85 \times 10^{-4}$ consistent with the value required by Bohr quantization.

2.2.6 Evidence for macroscopic quantum coherence of fluid flow at criticality

Evidence for the hierarchy of Planck constants implying macroscopic quantum coherence in quantum critical systems is rapidly accumulating. Also people having the courage to refer to TGD in their articles are gradually emerging. A series of fluid dynamics experiments (`http://tinyurl.com/jpf5f5j`) providing this kind of evidence is performed by Yves Couder and Emmanuel Fort (see for instance [D3]). Mathematician John W. M. Bush has commented [D13] (`http://tinyurl.com/jskythl`) these findings in the Proceedings of National Academy of Sciences and the article provides references to a series of papers by Couder and collaborators.

The system studied consist of a tray containing water at a surface, which is oscillating. The intensity of vibration is just below the critical value inducing so called Faraday waves (`http://tinyurl.com/hwuloet`) at the surface of water. Although the water surface is calm, water droplet begins to bounce and generates waves propagating along the water surface - "walkers". Walkers behave like classical particles at Bohr orbits. As they pass through a pair of slits they behave they choose random slit but several experiments produce interference pattern. Walkers exhibit an effect analogous to quantum tunneling and even the analogs of quantum mechanical bound states of walkers realized as circular orbits emerge as the water tray rotates!

The proposed interpretation of the findings is in terms of Bohm theory (`http://tinyurl.com/homasgz`). Personally I find it very difficult to believe in this since Bohm's theory has profound mathematical difficulties. Bohm's theory was inspired by Einstein's belief on classical determinism and the idea that quantum non-determinism is not actual but reduces to the presence of hidden variables. Unfortunately, this idea led to no progress.

TGD is analogous to Bohm's theory in that classical theory is exact but quantum theory is now only an exact classical correlate: there is no attempt to eliminate quantum non-determinism. Quantum jumps are between superpositions of entire classical time evolutions rather than their time=constant snapshots: this solves the basic paradox of Copenhagen interpretation. A more refined formulation is in terms of zero energy ontology, which in turn forces to generalize quantum measurement theory to a theory of consciousness.

Macroscopic quantum coherence associated with the behavior of droplets bouncing on the surface of water is suggested by the experiments. For instance, quantum measurement theory seems to apply to the behavior of single droplet as it passes through slit. In TGD the prerequisite for macroscopic quantum coherence would be quantum criticality at which large $h_{eff} = n \times h$ is possible. There indeed is an external oscillation of the tray containing water with an amplitude just below the criticality for the generation of Faraday waves at the surface of water. Quantum classical correspondence states that the quantum behavior should have a classical correlate. The basic structure of classical TGD is that of hydrodynamics in the sense that dynamics reduces to conservation laws plus conditions expressing the vanishing of an infinite number of so called supersymplectic charges - the conditions guarantee strong form of holography and express quantum criticality. The generic solution of classical field equations could reduce to Frobenius integrability conditions guaranteeing that the conserved isometry currents are integrable and thus define global coordinates varying along the flow lines [K16].

The correlate for quantum criticality would be classical criticality and criticalities for various hydrodynamical stabilities would serve as excellent candidates for the situation in which large h_{eff} should become manifest.

One should of course be very cautious. For ordinary Schrödinger equation the system is closed. Now the system is open. This is not a problem if the only function of external vibration is to induce quantum criticality. The experiment brings in mind the old vision of Frölich about external vibrations as induced of what looks like quantum coherence. In TGD framework this coherence would be forced coherence at the level of visible matter but the oscillation itself would correspond to genuine macroscopic quantum coherence and large value of h_{eff} [K9]. A standard example is provided by penduli, which gradually start to oscillate in unisono in presence of weak synchronizing signal. In brain neurons would start to oscillator synchronously by the presence of dark photons with large h_{eff}.

2.3 New findings related to high Tc super-conductivity

I learned simultaneously about two findings related to high Tc super-conductivity. The first finding [D14] provides further evidence for high Tc superconductivity at room temperature and pressure. Skinner has made a strange observation about magnetic susceptibility as a function of temperature for two values of external magnetic field [D1] (see `http://tinyurl.com/yaxtjjp5`). What looks like noise is essentially same for the curves at the level of detail. Unless only pseudonoise is in question, the finding forces to ask whether the data are manipulated. TGD inspired explanation involving so called de Haas-van Alphen effect allows to understand how pseudo noise for certain pairs of value of external magnetic field could have same shape.

Second finding provides evidence for positive feedback in the transition to high Tc superconductivity. This inspires a proposal of a general TGD based mechanism of bio-control in which small signal can serve as a control knob inducing phase transition producing macroscopically quantum coherent large h_{eff} phases in living matter.

I have added to the text the discovery of BCS type super-conductivity in lantanium hydroxide at temperature of 250 K towards the end of 2018 together with TGD based explanation in terms of $h_{eff} = n \times h_0$ hypothesis.

2.3.1 High Tc superconductivity at room temperature and pressure

Indian physicists Kumar Thapa and Anshu Pandey have found evidence for superconductivity at ambient (room) temperature and pressure in nanostructures [D14] (see `http://tinyurl.com/ybqybvap`). There are also earlier claims about room temperature superconductivity that I have discussed in my writings [K2, K14, K15].

1. The effect and its TGD explanation

Here is part of the abstract of the article of Kumar Thapa and Anshu Pandey.

We report the observation of superconductivity at ambient temperature and pressure conditions in films and pellets of a nanostructured material that is composed of silver particles embedded into a gold matrix. Specifically, we observe that upon cooling below 236 K at ambient pressures, the resistance of sample films drops below 10^{-4} *Ohm, being limited by instrument sensitivity. Further, below the transition temperature, samples BCSome strongly diamagnetic, with volume susceptibilities as low as -0.056. We further describe methods to tune the transition to temperatures higher than room temperature.*

During years I have developed a TGD based model of high Tc superconductivity and of bio-superconductivity [K2, K14, K15] (see `http://tinyurl.com/yazy5kwt` and `http://tinyurl.com/y7dd4f9m`).

Dark matter is identified as phases of ordinary matter with non-standard value $h_{eff}/h = n$ of Planck constant [**?**, K12] ($h = 6h_0$ is the most plausible option [L7, L13]). Charge carriers are $h_{eff}/h_0 = n$ dark macroscopically quantum coherent phases of ordinary charge carriers at magnetic flux tubes along which the supra current can flow. The only

source of dissipation relates to the transfer of ordinary particles to flux tubes involving also phase transition changing the value of h_{eff}.

This superconductivity is essential also for microtubules exhibit signatures for the generation of this kind of phase at critical frequencies of AC voltages serving as a metabolic energy feed providing for charged particles the needed energy that they have in $h_{eff}/h_0 = n$ phase [L3].

Large h_{eff} phases with same parameters than ordinary phase have typically energies large than ordinary phase. For instance. Atomic binding energies scale like $1/h_{eff}^2$ and cyclotron energies and harmonic oscillator energies quite generally like h_{eff}. Free particle in box is however quantum critical in the sense that the energy scale $E = \hbar_{eff}^2/2mL^2$ does not depend on the h_{eff} if one has $L \propto h_{eff}$. At space-time level this is true quite generally for external (free) particles identified as minimal 4-surfaces. Quantum criticality means independence on various coupling parameters.

What is interesting is that Ag and Au have single valence electron. The obvious guess would be that valence electrons BCSome dark and form Cooper pairs in the transition to superconductivity. What is interesting that the basic claim of a layman researcher David Hudson is that ORMEs or mono-atomic elements as he calls them include also Gold [H1]. These claims are not of course taken seriously by academic researchers. In the language of quantum physics the claim is that ORMEs behave like macroscopic quantum systems. I decided to play with the thought that the claims are correct and this hypothesis served later one of the motivations for the hypothesis about dark matter as large h_{eff} phases [K2, K4]: this hypothesis follows from adelic physics [L11, L12] (see `http://tinyurl.com/ycbhse5c`, which is a number theoretical generalization of ordinary real number based physics.

TGD explanation of high Tc superconductivity and its biological applications strongly suggest that a feed of "metabolic" energy is a prerequisite of high Tc superconductivity quite generally. The natural question is whether experimenters might have found something suggesting that the external energy feed - usually seen as a prerequisite for self-organization - is involved with high T_c superconductivity. During same day I got FB link to another interesting finding related to high Tc superconductivity in cuprates and suggesting positive answer to this question!

2. The strange observation of Brian Skinner about the effect

After writing the above comments I learned from a popular article (see `http://tinyurl.com/ybm8perx`) about and objection (see `http://tinyurl.com/yaxtjjp5`) by Brian Skinner [D1] challenging the claimed discovery [D14] (see `http://tinyurl.com/ybqybvap`). The claimed finding received a lot of attention and physicist Brian Skinner in MIT decided to test the claims. At first the findings look quite convincing to him. He however decided to look for the noise in the measured value of volume susceptibility χ_V. χ_V relates the magnetic field B in superconductor to the external magnetic field B_{ext} via the formulate $B = (1 + \chi_V)B_{ext}$ (in units with $\mu_0 = 1$ one has $B_{ext} = H$, where H is used usually).

For diamagnetic materials χ_V is negative since they tend to repel external magnetic fields. For superconductors one has $\chi_V = -1$ in the ideal situation. The situation is not however ideal and stepwise change of χ_V from $\chi_V = 0$ to χ_V to some negative value but satisfying $|\mu_V| < 1$ serves as a signature of high Tc superconductivity. Both superconducting and ordinary phase would be present in the sample.

Figure 3a of the article of authors gives χ_V as function of temperature for some values of B_{ext} with the color of the curve indicating the value of B_{ext}. Note that μ_V depends on B_{ext}, whereas in strictly linear situation it would not do so. There is indeed transition at critical temperature $T_c = 225$ K reducing $\chi_V = 0$ to negative value in the range $\chi_V \in [-0.05, -.06]$ having no visible temperature dependence but decreasing somewhat with B_{ext}.

The problem is that the fluctuations of χ_V for green curve ($B_{ext} = 1$ Tesla) and blue curve ($B_{ext} = 0.1$ Tesla) have the same shape. With blue curve only only shifted downward relative to the green one (shifting corresponds to somewhat larger dia-magnetism

for lower value of B_{ext}). If I have understood correctly, the finding applies only to these two curves and for one sample corresponding to $Tc = 256$ K. The article reports superconductivity with Tc varying in the range [145,400] K.

The pessimistic interpretation is that this part of data is fabricated. Second possibility is that human error is involved. The third interpretation would be that the random looking variation with temperature is not a fluctuation but represents genuine temperature dependence: this possibility looks infeasible but can be tested by repeating the measurements or simply looking whether it is present for the other measurements.

3. TGD explanation of the effect found by Skinner

One should understand why the effect occurs only for certain pairs of magnetic fields strengths B_{ext} and why the shape of pseudo fluctuations is the same in these situations.

Suppose that B_{ext} is realized as flux tubes of fixed radius. The magnetization is due to the penetration of magnetic field to the ordinary fraction of the sample as flux tubes. Suppose that the superconducting flux tubes assignable 2-D surfaces as in high Tc superconductivity. Could the fraction of super-conducting flux tubes with non-standard value of h_{eff} - depends on magnetic field and temperature in predictable manner?

The pseudo fluctuation should have same shape as a function temperature for the two values of magnetic fields involved but not for other pairs of magnetic field strengths.

i. Concerning the selection of only preferred pairs of magnetic fields de Haas-van Alphen effect gives a clue. As the intensity of magnetic field is varied, one observes so called de de Haas-van Alphen effect (`http://tinyurl.com/hoywcnq`) used to deduce the shape of the Fermi sphere: magnetization and some other observables vary periodically as function of $1/B$ (for a model for the quantum critical variant of the effect see [D12]). In particular, this is true for χ_V.

   The value of P is

$$P_{H-A} \equiv \frac{1}{B_{H-A}} = \frac{2\pi e}{\hbar S_e} \ , \tag{2.6}$$

   where S_e is the extremum Fermi surface cross-sectional area in the plane perpendicular to the magnetic field and can be interpreted as area of electron orbit in momentum space (for illustration see `http://tinyurl.com/y9zxhu9o`).

   De Haas-van Alphen effect can be understood in the following manner. As B increases, cyclotron orbits contract. For certain increments of $1/B$ $n+1$:th orbit is contracted to n:th orbit so that the sets of the orbits are identical for the values of $1/B$, which appear periodically. This causes the periodic oscillation of say magnetization. From this one learns that the electrons rotating at magnetic flux tubes of B_{ext} are responsible for magnetization.

ii. One can get a more detailed theoretical view about de Haas-van Alphen effect from the article of Lifschitz and Mosevich (see `http://tinyurl.com/yay3pg9b`). In a reasonable approximation one can write

$$\begin{aligned} P = \frac{e\hbar}{m_e E_F} = \frac{4\alpha}{3^{2/3}\pi^{1/3}} \times \frac{1}{B_e} \ , \quad B_e \equiv \frac{e}{a_e}^2 = \frac{1}{x^2} \times 16 \text{ Tesla} \ , \\ a_e = (\frac{V}{N})^{1/3} = xa \ , \qquad\qquad a = 10^{-10} \text{ m} \ . \end{aligned} \tag{2.7}$$

   Here N/V corresponds to valence electron density assumed to form free Fermi gas with Fermi energy $E_F = \hbar^2(3pi^2N/V)^{2/3}/2m_e$. $a = 10^{-10}$ m corresponds to atomic length scale. $\alpha \simeq 1/137$ is fine structure constant. For P one obtains the approximate expression

$$P \simeq .15x^2 \text{ Tesla}^{-1} \ .$$

If the difference of $\Delta(1/B_{ext})$ for $B_{ext} = 1$ Tesla and $B_{ext} = .1$ Tesla correspond to a k-multiple of P, one obtains the condition

$$kx^2 \simeq 60 \ .$$

iii. Suppose that $B_{ext,1} = 1$ Tesla and $B_{ext,1} = .1$ Tesla differ by a period P of de Haas-van Alphen effect. This would predict same value of χ_V for the two field strengths, which is not true. The formula used for χ_V however holds true only inside given flux tube: call this value $\chi_{V,H-A}$.

The fraction f of flux tubes penetrating into the superconductor can depend on the value of B_{ext} and this could explain the deviation. f can depend also on temperature. The simplest guess is that two effects separate:

$$\chi_V = \chi_{V,H-A}(\frac{B_{H-A}}{B_{ext}}) \times f(B_{ext}, T) \ . \tag{2.8}$$

Here $\chi_{V,H-A}$ has period P_{H-A} as function of $1/B_{ext}$ and f characterizes the fraction of penetrated flux tubes.

iv. What could one say about the function $f(B_{ext}, T)$? $B_{H-A} = 1/P_{H-A}$ has dimensions of magnetic field and depends on $1/B_{ext}$ periodically. The dimensionless ratio $E_{c,H-A}/T$ of cyclotron energy $E_{c,H-A} = \hbar eB_{H-A}/m_e$ and thermal energy T and B_{ext} could serve as arguments of $f(B_{ext}, T)$ so that one would have

$$f(B_{ext}, T) = f_1(B_{ext})f_2(x) \quad , \quad x = \frac{T}{E_{H-A}(B_{ext}))} \ . \tag{2.9}$$

One can consider also the possibility that $E_{c,H-A}$ is cyclotron energy with $\hbar_{eff} = nh_0$ and larger than otherwise. For $h_{eff} = h$ and $B_{ext} = 1$ Tesla one would have $E_c = .8$ K, which is same order of magnitude as variation length for the pseudo fluctuation. For instance, periodicity as a function of x might be considered.

If $B_{ext,1} = 1$ Tesla and $B_{ext,1} = .1$ Tesla differ by a period P one would have

$$\frac{\chi_V(B_{ext,1}, T)}{\chi_V(B_{ext,2}, T)} = \frac{f_1(B_{ext,1})}{f_1(B_{ext,2})} \tag{2.10}$$

independently of T. For arbitrary pairs of magnetic fields this does not hold true. This property and also the predicted periodicity are testable.

2.3.2 Transition to high Tc superconductivity involves positive feedback

The discovery of positive feedback in the transition to hight Tc superconductivity is described in the popular article "*Physicists find clues to the origins of high-temperature superconductivity*" (see `http://tinyurl.com/ybo89asd`). Haoxian Li *et al* at the University of Colorado at Boulder and the Ecole Polytechnique Federale de Lausanne have published a paper [D6] on their experimental results obtained by using ARPES (Angle Resolved Photoemission Spectroscopy) in Nature Communications (see `http://tinyurl.com/y7z2lbh7`).

The article reports the discovery of a positive feedback loop that greatly enhances the superconductivity of cupra superconductors. The abstract of the article is here.

> *Strong diffusive or incoherent electronic correlations are the signature of the strange-metal normal state of the cuprate superconductors, with these correlations considered to be undressed or removed in the superconducting state. A critical question is if these correlations are responsible for the high-temperature*

superconductivity. Here, utilizing a development in the analysis of angle-resolved photoemission data, we show that the strange-metal correlations don't simply disappear in the superconducting state, but are instead converted into a strongly renormalized coherent state, with stronger normal state correlations leading to stronger superconducting state renormalization. This conversion begins well above Tc at the onset of superconducting fluctuations and it greatly increases the number of states that can pair. Therefore, there is positive feedback––the superconductive pairing creates the conversion that in turn strengthens the pairing. Although such positive feedback should enhance a conventional pairing mechanism, it could potentially also sustain an electronic pairing mechanism.

The explanation of the positive feedback in TGD TGD framework could be following. The formation of dark electrons requires "metabolic" energy. The combination of dark electrons to Cooper pairs however liberates energy. If the liberated energy is larger than the energy needed to transform electron to its dark variant it can transform more electrons to dark state so that one obtains a spontaneous transition to high Tc superconductivity. The condition for positive feedback could serve as a criterion in the search for materials allowing high Tc superconductivity.

The mechanism could be fundamental in TGD inspired quantum biology. The spontaneous occurrence of the transition would make possible to induce large scale phase transitions by using a very small signal acting therefore as a kind of control knob. For instance, it could apply to bio-superconductivity in TGD sense, and also in the transition of protons to dark proton sequences giving rise to dark analogs of nuclei with a scaled down nuclear binding energy at magnetic flux tubes explaining Pollack effect [L4] [L4]. This transition could be also essential in TGD based model of "cold fusion" [L8] based also on the analog of Pollack effect. It could be also involved with the TGD based model for the finding of macroscopic quantum phase of microtubules induced by AC voltage at critical frequencies [L3] (see `http://tinyurl.com/y6vxplt3`).

2.3.3 BCS super conductivity at almost room temperature

Towards the end of year 2018 I learned about the discovery of BCS type (ordinary) superconductivity at temperature warmer than that at North Pole (see `http://tinyurl.com/ybgphjmd`). The compound in question was Lantanium hydride LaH_{10}. Mihail Eremets and his colleagues found that it BCSame superconducting at temperature -23 C and high pressure 170 GPa about 1.6 million times the atmospheric pressure [D5].

The popular article proposed an intuitive explanation of BCS superconductivity, which was new to me and deserves to be summarized here. Cooper pairs would surf on sound waves. The position would correspond to a constant phase for the wave and the velocity of motion would be the phase velocity of the sound wave. The intensity of sound wave would be either maximum or minimum corresponding to a vanishing force on Cooper pair. One would have equilibrium position changing adiabatically, which would conform with the absence of dissipation.

This picture would conform with the general TGD based vision inspired by Sheldrakes's findings and claims related to morphic resonance [L5] , and by the conjectured general properties of preferred extremals of the variational principle implied by twistor lift of TGD [L15]. The experimental discovery is of course in flagrant conflict with the predictions of the BCS theory. As the popular article tells, before the work of Eremets *et al* the maximum critical temperature was thought to be something like 40 K corresponding to -233 °C.

The TGD based view is that Cooper pairs have members (electrons) at parallel flux tubes with opposite directions of magnetic flux and spin and have non-standard value of Planck constant $h_{eff} = n \times h_0 = n \times h/6$ [L7, L13], which is higher than the ordinary value, so that Cooper pairs can be stable at higher temperatures. The flux tubes would have contacts with the atoms of the lattice so that they would experience the lattice oscillations and electrons could surf at the flux tubes.

The mechanism binding electrons to a Cooper pair should be a variant of that in BCS model. The exchange of phonons generates an attractive interaction between electrons leading to the formation of the Cooper pair. The intuitive picture is that the electrons of the Cooper pair can be thought of lying on a mattress and creating a dip towards which the other electron tends to move. The interaction of the flux tubes with the lattice oscillations inducing magnetic oscillations should generate this kind of interaction between electrons at flux tubes and induce a formation of a Cooper pair.

Isotope effect is the crucial test: the gap energy and therefore critical temperature are proportional the oscillation frequency ω_D of the lattice (Debye frequency) proportional to $1/\sqrt{M}$ of the mass M of the molecule in question and decreases with the mass of the molecule. One has lantanium-hydroxide, and can use an isotope of hydrogen to reduce the Debye frequency. The gap energy was found to change in the expected manner.

Can TGD inspired model explain the isotope effect and the anomalously high value of the gap energy? The naïve order of magnitude estimate for the gap energy is of form $E_{gap} = x\hbar_{eff}\omega_D$, x a numerical factor. The larger the value of $h_{eff} = n \times h_0 = n \times h/6$, the larger the gap energy. Unless the high pressure increases ω_D dramatically, the critical temperature 253 K would require $n/6 \sim T_{cr}/T_{max}(BCS) \sim 250/40 \sim 6$. Note that for this value the cyclotron energy $E_c = h_{eff}f_c$ is much below thermal energy for magnetic fields even in Tesla range so that the binding energy must be due to the interaction with phonons.

The high pressure is needed to keep lattice rigid enough at high temperatures so that indeed oscillates rather than "flowing". I do not see how this could prevent flux tube mechanism from working. Neither do I know, whether high pressure could somehow increase the value of Debye frequency to get the large value of critical temperature. Unfortunately, the high pressure (170 GPa) makes this kind of high Tc superconductors unpractical.

2.4 The mysterious dichloromethane droplet, which refuses to sink in water and begins to spin

I received from Resonance Foundation a link to an interesting article "*Chemists baffled by droplet spiraling to its doom*" (see `http://tinyurl.com/y4f46jh4`) telling about the strange behavior of droplets of dichloromethane (DCM) at the surface of water. DCM is heavier than water and one would expect it to sink down but it doesn't: it floats and starts to spin emitting smaller droplets from its boundary so that it eventually decays compeltely. This is like evaporation process said to resemble the behavior of spiral galaxy.

I could understand why the droplet floats - by creating a film acting as a boat - and Marangoni effect causing the droplet to decay by emitting smaller droplets (being due to the reduction of string tension at droplet water interface causing radial outwards directed tangential force).

But I could not understand how droplet could start to rotate? Where is the opposite angular momentum. Does water below the droplet rotate in opposite direction?

One strategy in TGD framework is to proceed in general manner.

i. Self-organization process is in question and the rotation could have interpretation as generation long length scale motion requiring long range correlations. Also the build-up of a "boat" as liquid layer coming from droplet allowing the rest of droplet to float instead of sinking to the water would be part of this process.

ii. Energy feed is always involved with all self-organization processes. In TGD Universe one can ask whether self-organizing systems are analogous to living systems (see `http://tinyurl.com/y3xbkokb`). For living systems in TGD Universe the metabolic energy feed is needed to keep the distribution of subsystems with Planck constant $h_{eff} = nh_0$ larger than its standard value and responsible for long range quantum correlations. This because the larger the value of h_{eff} characterizing the phase of ordinary matter is, the larger the energy of the system is, and because

h_{eff} tends to decrease spontaneouly. Phase of ordinary mattter with nonstandard value of h_{eff} has interpretation as dark matter.

Quantum scales are typically proportional to h_{eff} and large value means long scale of quantum coherence at the level of magnetic body which serves as a "boss" of ordinary matter in master slave hierarchy. If so, dark matter in TGD Universe would be visible through self-organization processes: quantum coherence in long lengths cales would force self-organization and generation of long range correlations.

iii. This picture would suggestthat also now magnetic body carrying dark matter phases is present. Could the angular momentum opposite to that of the rotating droplet be assigned with the rotating dark matter at magnetic body? I have proposed analogous explanation for the spontaneous accelerration rotation in rottatin magnetic systems reported by Godin and Roschin: (see `http://tinyurl.com/yyzld5ml`) . It should be easy to kill this hypothesis: the alternative standard physics option is that it is in the liquid below the droplet so that it would rotate in opposite direction.

iv. Where does the needed "metabolic" energy feed come from. The decay of the droplet means that its surface tension is reduced. Surface tension measures the surface energy density so that surface energy must be lost. Could part of this energy go to the self-organization as "metabolic" energy for magnetic body and for rotational. Part of energy would go to the radial motion of smaller droplets emanating from the droplet.

v. Surface tension is thought to be due to cohesive forces. In case of water and some other liquids hydrogen bonds would be responsible for them. London forces would be attractive interactions between dipoles of polarizable molecules and would contribute for polar molecules. Surface tension characterizes surface energy density and thus energy could come from this as the droplet decays to smaller ones. But does this make sense?

One can argue that this decay to smaller droplets increases surface area so that the process would not liberate energy but require it. The droplet is believedto float by reducing its density (Arhimedes law). This must increases its volume. Could the emitted droplets have the original original density so that their volume would be smaller and surface area too. Could this reduce the total surface energy in the process? The rest would go to rotation?

In FB Wes Johnson suggested that water droplet could act as a propeller. The droplet indeed looks like a propeller. Probably you mean that propeller property causes lift so that buoynancy would not be needed? This looks like a good idea. There would be two models. Propellor model and buoynancy model.

i. For the buoynancy model the expansion of the droplet could provide the needed buoyancy: the density of the droplet should become smaller than that of water. Droplet would generate a membrane serving as a boat. The droplet would expand and this expansion would store energy, which would be liberated. Where do the energy and angular momentum come from?

ii. Both options lead to the same question. Were do energy angular momentum come? Could the energy and angular momentum come from water or from the flux tubes/sheets of the magnetic body of water as h_{eff} decreases and liberates energy? Flux tubes in water accompany hydrogen bonds and even long flux tubes could correspond to hydrogen bonds. Magnetic body of water would save the droplet from drowning!

iii. This argument involves only energy. Entropy is also involved. I just wrote a little article about application of minimization of Gibbs energy G to water in TGD sense. One has $\Delta G = \Delta H - T\Delta S \leq 0$, H is enthalpy, the heat used or liberated. It is safest to have $\Delta S > 0$. If flux tubes in water shorten, long range order reduced to that in shorter length scale so that entropy is generated. This liberates also energy if long dark flux tubes behave like hydrogen bonds.

3 Deviations from Maxwell's electrodynamics

3.1 Does The Physics Of SmB_6 Make The Fundamental Dynamics Of TGD Directly Visible?

The group of Suchitra Sebastian has discovered very unconventional condensed matter system, which seems to be simultaneously both insulator and conductor of electricity but only in presence of magnetic field. Science article is entitled "Unconventional Fermi surface in an insulating state" [D10] (see `http://tinyurl.com/y79qo7lp`). There is also a popular article with title "Paradoxical Crystal Baffles Physicists" in Quanta Magazine summarizing the findings (see `http://tinyurl.com/qhwdmxj`). I learned about the finding first from the blog posting of Lubos Motl (see `http://tinyurl.com/yacm6bj7`).

3.1.1 Observations

The crystal studied at superlow temperatures was Samarium hexaboride - briefly SmB_6. The high resistance implies that electron cannot move more that one atom's width in any direction. Sebastian et al however observed electrons traversing over a distance of millions of atoms- a distance of orde 10^{-4} m, the size of a large neuron. So high mobility is expected only in conductors. SmB_6 is neither metal or insulator or is both of them! The finding is described by Sebastian as a "big schock" and as a "magnificent paradox" by condensed matter theorists Jan Zaanen. Theoreticians have started to make guesses about what might be involved but accorrding to Zaanen there is no even remotely credible hypothesis has appeared yet.

On basis of its electronic structure SmB_6 should be a conductor of electricity and it indeed is at room temperature: the average number conduction electrons per SmB_6 is one half. At low temperatures situation however changes. At low temperatures electrons behave collectivily. In superconductors resistance drops to zero as a consequence. In SmB_6 just the opposite happens. Each Sm nucleus has the average 5.5 electrons bound to it at tight orbits. Below 223 degrees of Celsius the conduction electrons of SmB_6 are thought to "hybridize" around samarium nuclei so that the system becomes an insulator. Various signatures demonstrate that SmB_6 indeed behaves like an insulator.

During last five years it has been learned that SmB_6 is not only an insulator but also so called topological insulator. The interior of SmB_6 is insulator but the surface acts as a conductor. In their experiments Sebastian *et al* hoped to find additional evidence for the topological insulator property and attempted to measure quantum oscillations in the electrical resistance of their crystal sample. The variation of quantum oscillations as sample is rotated can be used to map out the Fermi surface of the crystal. No quantum oscillations were seen. The next step was to add magnetic field and just see whether something interesting happens and could save the project. Suddenly the expected signal was there! It was possible to detect quantum oscillations deep in the interior of the sample and map the Fermi surface! The electrons in the interior travelled 1 million times faster than the electrical resistance would suggest. Fermi surface was like that in copper, silver or gold. A further surprise was that the growth of the amplitude of quantum oscillations as temperature was decreased, was very different from the predictions of the universal Lifshitz-Kosevich formula for the conventional metals.

3.1.2 Could TGD help to understand the strange behavior of SmB_6?

There are several indications that the paradoxical effect might reveal the underlying dynamics of quantum TGD. The mechanism of conduction must represent new physics and magnetic field must play a key role by making conductivity possible by somehow providing the "current wires". How? The TGD based answer is completely obvious: magnetic flux tubes - one of the basic distinctions between electrodynamics of Maxwell and its TGD variant! Also the failure of Lischitz-Kosevich formulas should be understood.

1. Single sheet of many-sheeted space-time resembles topological insulator

One should also understand topological insulator property at deeper level, that is the conduction along the boundaries of topological insulator. One should understand why the current runs along 2-D surfaces. In fact, many exotic condensed matter systems are 2-dimensional in good approximation. In the models of integer and fractional quantum Hall effect electrons form a 2-D system with braid statistics possible only in 2-D system. High temperature super-conductivity is also an effectively 2-D phenomenon. By strong form of holography these aspects are also key aspects of quantum TGD at the fundamental level of single space-time sheet when the approximation replacing many-sheeted space-time with that of GRT and standard model does not mask the simplicity of the fundamental dynamics.

i. Many-sheeted space-time is second fundamental prediction TGD. The dynamics of single sheet of many-sheeted space-time should be very simple by the strong form of holography implyhing effective 2-dimensionality. The standard model description of this dynamics masks this simplicity since the sheets of many-sheeted space-time are replaced with single region of slightly curved Minkowski space with gauge potentials sums of induced gauge potentials for sheets and deviation of metric from Minkowski metric by the sum of corresponding deviations for space-time sheets. Could the dynamics of exotic condensed matter systems give a glimpse about the dynamics of single sheet? Could topological insulator and anyonic systems [K13] provide examples of this kind of systems?

ii. Second basic prediction of TGD is strong form of holography: string world sheets and partonic 2-surfaces serve as kind of "space-time genes" and the dynamics of fermions is 2-D at fundamental level. It must be however made clear that at QFT limit the spinor fields of embedding space replace these fundamental spinor fields localized at 2-surface. One might argue that the fundamental spinor fields do not make them directly visible in condensed matter physics. Nothing however prevents from asking whether in some circumstances the fundamental level could make itself visible.

In particular, for large h_{eff} dark matter systems (, whose existence can be deduced from the quantum criticality of quantum TGD) the partonic 2-surfaces with CP_2 size could be scaled up to nano-scopic and even longer size scales. I have proposed this kind of surfaces as carriers of electrons with non-standard value of h_{eff} in QHE and FQHE [K13].

The long range quantum fluctuations associated with large, $h_{eff} = n \times h$ phase would be quantum fluctuations rather than thermal ones. In the case of ordinary conductivity thermal energy makes it possible for electrons to jump between atoms and conductivity becomes very small at low temperatures. In the case of large scale quantum coherence just the opposite happens as observed. One therefore expects that Lifshitz-Kosevich formula for the temperature dependence of the amplitude does not hold true.

The generalization of Lifschitz-Kosevich formula to quantum critical case deduced from quantum holographic correspondence by Hartnoll and Hofman [D12] (`http://tinyurl.com/ybednd85` is expected to hold true qualitatively also for quantum criticality in TGD sense. The first guess is that by underlying super-conformal invariance scaling laws typical for critical systems hold true. In the proposed formula the dependence on temperature is via a power of dimensionless parameter $x = T/mu$;, where μ is chemical potential for electron system. As a matter fact, exponent of power of x appears and reduces to first for Lifshitz-Konsevich formula. Since magnetic field is important, one also expects that the ratio of cyclotron energy scale $E_c \propto \hbar_{eff} eB/m_e$ to Fermi energy appears in the formula. One can even make an order of magnitude guess for the value of $h_{eff}/h \sim 10^6$ from the facts that the scale of conduction and conduction velocity were millions times higher than expected.

Strings are 1-D systems and strong form of holography implies that fermionic strings connecting partonic 2-surfaces and accompanied by magnetic flux tubes are fundamental. At light-like 3-surfaces fermion lines can give rise to braids. In TGD framework AdS/CFT correspondence generalizes since the conformal symmetries are extended. This is possible only in 4-D space-time and for the embedding space $H = M^4 \times CP_2$ making possible to generalize twistor approach [K17].

iii. Topological insulator property means from the perspective of modelling that the action reduces to a non-abelian Chern-Simons term. The quantum dynamics of TGD at space-time level is dictated by Kähler action. Space-time surfaces are preferred extremals of Kähler action and for them Kähler action reduces to Chern-Simons terms associated with the ends of space-time surface opposite boundaries of causal diamond and possibly to the 3-D light-like orbits of partonic 2-surfaces. Now the Chern-Simons term is Abelian but the induced gauge fields are non-Abelian. One might say that single sheeted physics resembles that of topological insulator.

iv. The effect appears only in magnetic field. I have been talking a lot about magnetic flux tubes carrying dark matter identified as large h_{eff} phases: topological quantization distinguishes TGD from Maxwell's theory: any system can be said to possess "magnetic body", whose flux tubes can serve as current wires. I have predicted the possibility of high temperature super-conductivity based on pairs of parallel magnetic flux tubes with the members of Cooper pairs at the neighboring flux tubes forming spin singlet or triplet depending on whether the fluxes are have same or opposite direction.

Also spin and electric currents assignable to the analogs of spontaneously magnetized states at single flux tube are possible. The obvious guess is that the conductivity in question is along the flux tubes of the external magnetic field. Could this kind of conductivity explains the strange behavior of SmB_6. The critical temperature would be that in which the parallel flux tubes are stable. The interaction energy of spin with the magnetic field serves as a possible criterion for the stability if the presence of dark electrons stabilizes the flux tubes.

2. Magnetic flux tubes as dark current carriers in quantum criticality

The following represents an extremely childish attempt of a non-specialist to understand how the conductivity might be understood. The current carrying electrons at flux tubes near the top of Fermi surface are current carriers. $h_{eff} = n \times h$ and magnetic flux tubes as current wires bring in the new elements. Also in the standard situation one considers cylinder symmetric solutions of Schrödinger equation in external magnetic field and introduces maximal radius for the orbits so that formally the two situations seem to be rather near to each other. Physically the large h_{eff} and associated many-sheeted covering of space-time surface providing the current wire makes the situation different since the collisions of electrons could be absent in good approximation so that the velocity of charge carriers could be much higher than expected as experiments indeed demonstrate.

Quantum criticality is the crucial aspect and corresponds to the situation in which the magnetic field attains a value for which a new orbit emerges/disappears at the surface of the flux tube: in this situation dark electron phase with non-standard value of h_{eff} can be generated. This mechanism is expected to apply also in bio-superconductivity and to provide a general control tool for magnetic body.

i. Let us assume that flux tubes cover the whole transversal area of the crystal and there is no overlap. Assume also that the total number of conduction electrons is fixed, and depending on the value of h_{eff} is shared differently between transversal and longitudinal degrees of freedom. Large value of h_{eff} squeezes the electrons from transversal to longitudinal flux tube degrees of freedom and gives rise to conductivity.

ii. Consider first Schrödinger equation. In radial direction one has harmonic oscillator and the orbits are Landau orbits. The cross sectional area behaves like $\pi R^2 =$

$n_T h_{eff}/2m\omega_c$ giving $n_T \propto 1/h_{eff}$. Increase of the Planck constant scales up the radii of the orbits so that the number of states in cylinder of given radius is reduced. Angular momentum degeneracy implies that the number of transversal states is $N_T = n_T^2 \propto 1/h_{eff}^2$. In longitudinal direction one has free motion in a box of length L with states labelled by integer n_L. The number of states is given by the maximum value N_L of n_L.

iii. If the total number of states is fixed to $N = N_L N_T$ is fixed and thus does not depend on h_{eff}, one has $N_L \propto h_{eff}^2$. Quanta from transversal degrees of freedom are squeezed to longitudinal degrees of freedom, which makes possible conductivity.

iv. The conducting electrons are at the surface of the 1-D "Fermi-sphere", and the number of conduction electrons is $N_{cond} \simeq dN/d\epsilon \times \delta\epsilon \simeq dN/d\epsilon T = NT/2\epsilon_F \propto 1/h_{eff}^4$. The dependence on h_{eff} does not favor too large values of h_{eff}. On the other hand, if scattering of electrons at flux tubes could be absent. The assumption $L \propto h_{eff}$ increases the range over which current can flow.

v. To get a non-vanishing net current one must assume that only the electrons at the second end of the 1-D Fermi sphere are current carriers. The situation would resemble that in semiconductor. The direction of electric field would induce symmetry breaking at the level of quantum states. The situation would be like that for a mass in Earth's gravitational field treated quantally and electrons would accelerate freely. Schrödinger equation would give rise to Airy functions as its solution.

3. Quantum critical quantum oscillations

What about quantum oscillations in TGD framework?

i. Quantum oscillation refers to de Haas-van Alphen effect (`http://tinyurl.com/yaaljv9j`) - an oscillation of the induced magnetic moment as a function of $1/B$ with period $\tau = 2\pi e/\hbar A$, where A is the area of the extremal orbit of the Fermi surface, in the direction of the applied field. The effect is explained to be due to the Landau quantization of the electron energy. I failed to really understand the explanation of this source and in my humble opinion the following arguments provide a clearer view about what happens.

ii. If external magnetic field corresponds to flux tubes, Fermi surface decomposes into cylinders parallel to the magnetic field since the motion in transversal degrees of freedom is along circles. In the above thought experiment also a quantization in the longitudinal direction occurs if the flux tube has finite length so that Fermi surface in longitudinal direction has finite length. One expects on basis of Uncertainty Principle that the area S of the cross section of Fermi cylinder in momentum space is given by $S \propto h_{eff}^2/\pi R^2$. This follows also from the equation of motion of electron in magnetic field. As the external magnetic field B is increased, the radii of the orbits decrease inside the flux tube, and in momentum space the radii increase.

iii. Why does the induced magnetic moment (magnetization) and other observables oscillate?

   A. The simplest manner to understand this is to look at the situation at space-time level. Classical orbits are harmonic oscillator orbits in radial degree of freedom. Suppose that the area of flux tube is fixed and B is increased. The orbits have radius $r_n^2 = (n + 1/2) \times \hbar/eB$ and shrink. For certain field values the flux $eBA = n\hbar$ corresponds to an integer multiple of the elementary flux quantum . of a new orbit at the boundary of the flux tube emerges if the new orbit is near the boundary of Fermi sphere providing the electrons. This is clearly a critical situation.

   B. In de Haas- van Alphen effect the orbit $n+1$ for B has same radius as the orbit n for $1/B + \Delta(1/B)$: $r_{n+1}(1/B) = r_n(1/B + \Delta(1/B))$. This gives approximate differential equation with respect to n and one obtains $(1/B)(n) = (n+1/2) \times \Delta(1/B)$. $\Delta(1/B)$ is fixed from the condition the flux quantization. When

largest orbit is at the surface of the flux, tube the orbits are same for $B(n)$ and $B(n+1)$, and this gives rise to the de Haas - van Alphen effect.

C. It is not necessary to assume finite radius for the flux tube, and the exact value of the radius of the flux tube does not play and important role. The value of flux tube radius can be estimated from the ratio of the Fermi energy of electron to the cyclotron energy. Fermi energy about .1 eV depending only on the density of electrons in the lowest approximation and only very weakly on temperature. For a magnetic field of 1 Tesla cyclotron energy is .1 meV. The number of cylinders defined by orbits is about $n = 10^4$.

iv. What happens in TGD Universe in which the areas of flux tubes identifiable as space-time quanta are finite? Could quantum criticality of the transition in which a new orbit emerges at the boundary of flux tube lead to a large h_{eff} dark electron phase at flux tubes giving rise to conduction?

A. The above argument makes sense also in TGD Universe for the ordinary value of Planck constant. What about non-standard values of Planck constant? For $h_{eff}/h = n$ the value of flux quantum is n-fold so that the period of the oscillation in de Haas - van Alphen effect becomes n times shorter. The values of the magnetic field for which the orbit is at the surface of the flux tube are however critical since new orbit emerges assuming that the cyclotron energy corresponds is near Fermi energy. This quantum criticality could give rise to a phase transition generating non-standard value of Planck constant.
What about the period $\Delta(1/B)$ For $h_{eff}/h = n$? Modified flux quantization for extremal orbits implies that the area of flux quantum is scaled up by n. The flux changes by n units for the same increment of $\Delta(1/B)$ as for ordinary Planck constant so that de Haas -van Alphen effect does not detect the phase transition.

B. If the size scale of the orbits is scaled up by $\sqrt{n}$ as the semiclassical formula suggests the number of classical orbits is reduced by a factor $1/n$ if the radius of the flux tube is not changed in the transition $h \to h_{eff}$ to dark phase. n-sheetedness of the covering however compensates this reduction.

C. What about possible values of h_{eff}/h? The total value of flux seems to give the upper bound of $h_{eff}/h = n_{max}$, where n_{max} is the value of magnetic flux for ordinary value of Planck constant. For electron and magnetic field for $B = 10$ Tesla and has $n \leq 10^5$. This value is of the same order as the rough estimate from the length scale for which anomalous conduction occurs.

Clearly, the mechanism leading to anomalously high conductivity might be the transformation of the flux tubes to dark ones so that they carry dark electrons currents. The observed effect would be dark, quantum critical variant of de Haas-van Alphen effect!

Also bio-superconductivity is quantum critical phenomenon and this observation would suggests sharpening of the existing TGD based model of bio-super-conductivity. Super-conductivity would occur for critical magnetic fields for which largest cyclotron orbit is at the surface of the flux tube so that the system is quantum critical. Quantization of magnetic fluxes would quantify the quantum criticality. The variation of magnetic field strength would serve as control tool generating or eliminating supra currents. This conforms with the general vision about the role of dark magnetic fields in living matter.

To sum up, a breakthrough of TGD is continuing. I have written about thirty articles during this year - more than one article per week. There is huge garden there and trees contain fruits hanging low! It is very easy to pick them: just shatter and let them drop to the basket! New experimental anomalies having a nice explanation using TGD based concepts appear on weekly basis and the mathematical and physical understanding of TGD is taking place with great leaps. It is a pity that I must do all alone. I would like to share. I can only hope that colleagues could take the difficult step: admit what has happened and make a fresh start.

3.2 Are monopoles found?

LNC scientist report of having discovered magnetic monopoles (see `http://tinyurl.com/ppquxyy` and `http://tinyurl.com/y95zbuew`). The claim that free monopoles are discvoered are discovered is to my opinion too strong.

TGD allows monopole fluxes but no free monopoles. Wormhole throats however behave effectively like monopoles when looked at either space-time sheet, A or B. The first TGD explanation that comes in mind is in terms of 2-sheeted structures with wormhole contacts at the ends and monopole flux tubes connecting the wormhole throats at A and B so that closed monopole flux is the outcome. All elementary particles are predicted to be this kind of structures in the scale of Compton length. First wormhole carries throat carries the elementary particle quantum numbers and second throat neutrino pair neutralizing the weak isospin so that weak interaction is finite ranged. Compton length scales like h_{eff} and can be nano-scopic or even large for large values of h_{eff}. Also for abnormally large p-adic length scale implying different mass scale for the particle, the size scale increases.

How to explain the observations? Throats with opposite apparent quantized magnetic charges at given space-time sheet should move effectively like independent particles (although connected by flux tube) in opposite directions to give rise to an effective monopole current accompanied by an opposite current at the other space-time sheet. This is like having balls at the ends of very soft strings at the two sheets. One must assume that only the current only at single sheet is detected. It is mentioned that ohmic component corresponds to effectively free monopoles (already having long flux tubes connecting throats with small magnetic string tension). In strong magnetic fields shorter pairs of monopoles are reported to become "ionized" and give rise to a current increasing exponentially as function of square root of external magnetic field strength. This could correspond to a phase transition increasing h_{eff} with no change in particle mass. This would increase the length of monopole flux tube and the throats would be effectively free magnetic charges in much longer Compton scale.

The analog of color de-confinement comes in mind and one cannot exclude color force since non-vanishing Kähler field is necessarily accompanied by non-vanishing classical color gauge fields. Effectively free motion below the length scale of wormhole contact would correspond to asymtotic freedom. Amusingly, one would have zoomed up representation of dynamics of colored objects! One can also consider interpretation in terms of Kähler monopoles: induced Kähler form corresponds to classical electroweak U(1) field coupling to weak hypercharge but asymptotic freedom need not fit with this interpretation. Induced gauge fields are however strongly constrained: the components of color gauge fields are proportional to Hamiltonians of color rotation and induced Kähler form. Hence it is difficult to draw any conclusions.

3.3 Badly behaving photons and space-time as 4-surface

There was an interesting popular article with title *Light Behaving Badly: Strange Beams Reveal Hitch in Quantum Mechanics* (see `http://tinyurl.com/hefhdad`). The article told about a discovery made by a group of physicists at Trinity College Dublin in Ireland in the study of helical light-beams with conical geometry. These light beams are hollow and have the axis of helix as a symmetry axis. The surprising finding was that according to various experimental criteria one can say that photons have spin $S = \pm 1/2$ with respect to the rotations around the axis of the helix [D2] (see `http://tinyurl.com/zoro4gz`).

The first guess would be that this is due to the fact that rotational symmetry for the spiral conical beam is broken to axial rotational symmetry around the beam axis. This makes the situation 2-dimensional. In $D = 2$ one can have braid statistics allowing fractional angular momentum for the rotations around a hole - now the hollow interior of the beam. One can however counter argue that photons with half odd integer braid spin should obey Fermi statistics. This would mean that only one photon with fixed

spin is possible in the beam. Something seems to go wrong with the naïve argument. It would seem that the exchange of photons does not seem to correspond to 2π rotation as a homotopy would be the topological manner to state the problem.

The authors of the article suggest that besides the ordinary conserved angular momentum one can identify also second conserved angular momentum like operator.

i. The conserved angular momentum is obtained as the replacement

$$J = L + S \to J_\gamma = L + \gamma S \quad . \tag{3.1}$$

ii. The eigenvalue equation for j_γ for a superposition of right and left polarizations with $S = \pm 1$

$$a_1 \times e_R exp(il_1\theta) + a_2 \times e_L exp(il_2\theta) \quad , \tag{3.2}$$

where l_i and also $s_z = \pm 1$ are integers, makes sense for

$$\gamma = \frac{(l_1 - l_2)}{2} \quad , \tag{3.3}$$

and gives eigenvalue

$$j_\gamma = \frac{l_1 + l_2}{2} \quad . \tag{3.4}$$

Since l_1 and l_2 are integers by the continuity of the wave function at 2π (even this can be questioned in hollow conical geometry) $(l_1 + l_2)/2$ and $(l_1 - l_2)/2$ are either integers or half integers. For $l_1 - l_2 = 1$ the one has $J_\gamma = J_{1/2} = L + S/2$, which is half odd integer. The stronger statement would be that 2-D $S_\gamma = S/2$ is half-odd integer.

There is an objection against this interpretation. The dependence of the angular momentum operator on the state of photon implied by $\gamma = (l_1 - l_2)/2$ is a highly questionable feature. Operators should not depend on states but define them as their eigenstates. Could one understand the experimental findings in some different manner? Could the additional angular momentum operator allow some natural interpretation? If it really generates rotations, where does it act?

In TGD framework this question relates interestingly to the assumption that space-time is 4-surface in $M^4 \times CP_2$. Could X^4 and M^4 correspond to the two loci for the action of rotations? One can indeed have two kinds of photons. Photons can correspond to space-time sheets in $M^4 \times CP_2$ or they can correspond to space-time sheets topologically condensed to space-time surface $X^4 \subset M^4 \times CP_2$. For the first option one would have ordinary quantization of angular momentum in M^4. For the second option quantization in X^4 angular momentum, which using the units of M^4 angular momentum could correspond to half-integer or even more general quantization.

i. For the first (photons in M^4) option angular momentum $J(M^4) = L(M^4) + S(M^4)$ acts at point-like limit on a wave function of photon in M^4. $J(M^4)$ acts as a generator of rotations in M^4 should have the standard properties: in particular photon spin is $S = +/-1$.

ii. For topologically condensed photons at helix the angular momentum operator $J(X^4) = L(X^4) + S(X^4)$ generates at point-like limit rotations in X^4. If M^4 coordinates - in particular angle coordinate ϕ around helical axis - are used for X^4, the identifications

$$J(X^4) = kJ(M^4) \quad , \quad L(X^4) = kL(M^4) \quad , \quad S(X^4) = kS(M^4) \quad . \tag{3.5}$$

are possible.

iii. In the recent case X^4 corresponds to effectively a helical conical path of photon beam, which is effectively 2-D system with axial $SO(2)$ symmetry. The space-time surface associated with the helical beam is analogous to a covering space of plane defined by Riemann surface for $z^{1/n}$ with origin excluded (hollowness of the spiral beam is essential since at z-axis various angles ϕ correspond to the same point and one would obtain discontinuity). It takes n full turns before one gets to the original point. This implies that $L(X^4) = kL(M^4)$ can be fractional with unit $\hbar/n$ meaning $k = 1/n$ when the angle coordinate of M^4 serves as angle coordinate of X^4.

iv. For $n = 2$ one has $k = 1/2$ and 4π rotations in Minkowski space interpreted as shadows of rotations at X^4 must give a phase equal to unity. This would allow half integer quantization for $J(X^4), L(X^4)$ and $S(X^4)$ of photon in M^4 units. $S(X^4)$ corresponds to a local rotation in tangent space of X^4. The braid rotation defined by a path around the helical axis corresponds to a spin rotation and by $k = 1/2$ to $S(X^4) = S(M^4)/2 = 1/2$. Hence one has effectively $S(M^4) = \pm 1/2$ for the two circular polarizations and thus $\gamma = \pm 1/2$ independently of l_i: in the above model $\gamma = (l_1 - l_2)/2$ can have also other values. Now also other values of n besides $n = 2$ are predicted.

   l_i can be both integer and half odd integer valued. One can reproduce the experimental findings for integer valued l_1 and l_2. One has $j = l_1 + 1/2 = l_2 - 1/2$ from condition that superpositions of both right and left-handed spiral photons are possible. If j is half-odd integer, $l_1 + l_2 = 2j$ is odd integer. For instance, $S(X^4) = 1/2$ gives $l_1 - l_2 = -1$ consistent with integer/half-odd integer property of both l_1 and l_2. For $j = 1/2$ one has $l_1 + l_2 = 1$ and $l_1 - l_2 = -1$ giving $(l_1, l_2) == (0, 1)$.

v. Is there something special in $n = 2$. In TGD elementary particles have wormhole contacts connecting two space-time sheets as building bricks. If the sheets form a covering of M^4 singular along plane M^2 one has $n = 2$ naturally.

One can worry about many-sheeted statistics. The intuitive view is that one just adds bosons/fermions at different sheets and each sheet corresponds to a discrete degree of freedom.

i. Statistics is not changed to Fermi statistics if the exchange interpreted at X^4 corresponds to $n \times 2\pi$ rotation. For $n = 2$ a possible modification of the anti-commutation relations would be doubling of oscillator operators assigning $a_k(i)$, $i = 1, 2$ to the 2 sheets and formulating braid anti-commutativity as

$$\begin{array}{lll} \{a_k(1), a_l(2)\} = 0 \ , & \{a_k^\dagger(1), a_l^\dagger(2)\} = 0 \ , & \{a_k^\dagger(1), a_l(2)\} = 0 \ . \\ [a_k(i), a_l(i)] = 0 & \left[a_k^\dagger(i), a_l^\dagger(i)\right] = 0 & \left[a_k^\dagger(i), a_l(i)\right] = \delta_{k,l} \ . \end{array} \tag{3.6}$$

   This would be consistent with Bose-Einstein statistics. For n-sheeted case the formula replacing pair $(1, 2)$ with any pair $(i, j \neq i)$ applies. One would have two sets of mutually commuting (creation) operators and these sets would anti-commute and Bose-Einstein condensates seem to be possible.

ii. One can worry about the connection with the hierarchy of Planck constants $h_{eff} = n \times h$, which is assigned with singular n-sheeted covering space. The 3-D surfaces defining ends of the covering at the boundaries of causal diamond (CD) would in this case co-incide. This might be the case now since the photon beam is assumed to be conical helix. Space-time surface would be analogous to n 3-D paths, which co-incide at their ends at past and future boundaries of CD.

   Does the scaling of Planck constant by n compensate for the fractionization so that the only effect would be doubled Bose-Einstein condensate. It woud seem that these condensates need not have same numbers of photons. The scaling of cyclotron energies by n is central in the application of $h_{eff} = nh$ idea. It could be interpreted by saying that single boson state is replaced with n-boson state with the same cyclotron frequency but n-fold energy.

iii. In the fermionic case on obtain n additional degrees of freedom and ordinary single fermion state would be replaced with a set of states containing up to n fermions. This would lead to a kind of breakdown of fermion statistics possibly having interpretation in terms of braid statistics. And old question is whether one could understand quark color as $h_{eff}/h = n = 3$ braid statistics for leptons. At the level of CP_2 spinors em charge corresponds to sum of vectorial isospin and of anomalous color hypercharge which is for leptons $n = 3$ multiple of that for quarks. This could be perhaps interpreted in terms of scaling in hypercharge degree of freedom due to 3-sheeted covering. This picture does not seem however to work.

To sum up, also M^4 angular momentum and spin make sense and are integer valued but for the system identifiable as topological condensed photon plus helix rather than topological condensed photon at helix. Many-sheeted space-time can in principle rise to several angular momenta of this kind. Symmetry breaking go $SO(2)$ subgroup is however involved. The general prediction is $1/n$ fractionization.

Remark: I encountered a popular article (see `http://tinyurl.com/ybovyxd3`)about strange halving of photon angular momentum unit two years after writing the above comments. The immediate reaction was that the finding could be seen as a direct proof for $h_{eff} = nh_0$ hierarchy, where h_0 is the minimal value of Planck constants, which need not be ordinary Planck constant h as I have often assumed in previous writings.

Various arguments indeed support for $h = 6h_0$. This hypothesis would explain the strange findings about hydrogen atom having what Mills calls hydrino states having larger binding energy than normal hydrogen atom [L7] (see `http://tinyurl.com/goruuzm`): the increase of the binding energy would follow from the proportionality of the binding energy to $1/h_{eff}^2$. For $n_0 = 6 \to n < 6$ the binding energy is scale up as $(n/6)^2$. The values of $n = 1, 2, 3$ dividing n are preferred. Second argument supporting $h = 6h_0$ comes from the model for the color vision [L13] (see `http://tinyurl.com/y9jxyjns`).

What is the interpretation of the ordinary photon angular momentum for $n = n_0 = 6$? Quantization for angular momentum as multiples of $\hbar_0$ reads as $l = l_0\hbar_0 = (l_0/6)\hbar$, $l_0 = 1, 2...$ so that fractional angular momenta are possible. $l_0 = 6$ gives the ordinary quantization for which the wave function has same value for all 6 sheets of the covering. $l_0 = 3$ gives the claimed half-quantization.

3.4 Non-local production of photon pairs as support for $h_{eff}/h = n$ hypothesis

Again a new anomaly! Photon pairs have been created by a new mechanism. Photons emerge at different points (see `http://tinyurl.com/lseqyrq`).

Could this give support for the TGD based general model for elementary particle as a string like object (flux tube) with first end (wormhole contact) carrying the quantum numbers - in the case of gauge boson fermion and antifermion at opposite throats of the contact. Second end would carry neutrino-right-handed neutrino pair neutralizing the possible weak isospin. This would give only local decays. Also emissions of photons from charged particle would be local.

Could the bosonic particle be a mixture of two states. For the first state flux tube would have fermion and antifermion at the same end of the fluxtube: only local decays. For the second state fermion and antifermion would reside at the ends of the flux tubes residing at throats associated with different wormhole contacts. This state in state would give rise to non-local two-photon emissions. Mesons of hadron physics would correspond to this kind of states and in old-fashioned hadron physics one speaks about photon-vector meson mixing in the description of the photon-hadron interactions. If the Planck constant $h_{eff}/h = n$ of the emitting particle is large, the distance between photon emissions would be long. The non-local days could make the visible both exotic decay and allow to deduce the value of n! This would how require the transformation of emitted dark photon to ordinary (same would happen when dark photons transform to biophotons)

Can one say anything about the length of fux tube? Magnetic flux tube contains fermionic string. The length of this string is of order Compton length and of the order of p-adic length scale.

What about photon itself - could it have non-local fermion-antifermion decays based on the same mechanism? What the length of photonic string is is not clear. Photon is massless, no scales! One identification of length would be as wavelength defining also the p-adic length scale.

To sum up: the nonlocal decays and emissions could lend strong support for both flux tube identification of particles and for hierarchy of Planck constants. It might be possible to even measure the value of n associated with quantum critical state by detecting decays of this kind.

4 Thermodynamical surprises

4.1 Quantization of thermal conductance and quantum thermodynamics

The finnish research group led by Mikko Möttönen working at Aalto University has made several highly interesting contributions to condensed matter physics during last years (see `http://tinyurl.com/yartleg2` about condensed matter magnetic monopoles and `http://tinyurl.com/jd26rhy` about tying quantum knots: both contributions are interesting also from TGD point of view). This morning I read about a new contribution published in Nature [D8] (see `http://tinyurl.com/y7bfzsnh`). One can find also a popular article telling about the finding (see `http://tinyurl.com/yba239d7`).

What has been shown in the recent work is that quantal thermal conductivity is possible for wires of 1 meter when the heat is transferred by photons. This length is by a factor 10^4 longer than in the earlier experiments. The improvement is amazing and the popular article tells that it could mean a revolution in quantum computations since heat spoling the quantum coherence can be carried out very effectively and in controlled manner from the computer (see `http://tinyurl.com/yba239d7`). Quantal thermal conductivity means that the transfer of energy along wire takes place without dissipation.

To understand what is involved consider first some basic definitions. Thermal conductivity k is defined by the formula $j = k\nabla T$, where j is the energy current per unit area and T the temperature. In practice it is convenient to use thermal power obtained by integrating the heat current over the transversal area of the wire to get the heat current dQ/dt as analog of electric current I. The thermal conductance g for a wire allowing approximation as 1-D structure is given by conductivity divided by the length of the wire: the power transmitted is $P = g\Delta T$, $g = k/L$.

One can deduce a formula for the conductance at the limit when the wire is ballistic meaning that no dissipation occurs. For instance, superconducting wire is a good candidate for this kind of channel and is used in the measurement. The conductance at the limit of quantum limited heat conduction (see `http://tinyurl.com/y7dtfrvt`) is an integer multiple of conductance quantum $g_0 = k_B^2\pi^2 T/3h$: $g = ng_0$. Here the sum is over parallel channels. What is remarkable is quantization and independence on the length of the wire. Once the heat carriers are in wire, the heat is transferred since dissipation is not present.

A completely analogous formula holds true for electric conductance along ballistic wire (see `http://tinyurl.com/y8gheqw6`): now g would be integer multiple of $g_0 = \sigma/L = 2e^2/h$. Note that in 2-D system quantum Hall conductance (not conductivity) is integer (more generally some rational) multiple of $\sigma_0 = e^2/h$. The formula in the case of conductance can be "derived" heuristically from Uncertainty Principle $\Delta E\Delta t = h$ plus putting $\Delta E = e\Delta V$ as difference of Coulomb energy and $\Delta t = q/I = qL/\Delta V = e/g_0$.

The essential prerequisite for quantal conduction is that the length of the wire is much shorter than the wavelength assignable to the carrier of heat or of thermal energy:

$\lambda \gg L$. It is interesting to find how well this condition is satisfied in the recent case.

The wavelength of the photons involved with the transfer should be much longer than 1 meter. An order of magnitude for the energy of photons involve and thus for the frequency and wavelength can be deduced from the thermal energy of photons in the system. The electron temperatures considered are in the range of 10-100 mK roughly. Kelvin corresponds to 10^{-4} eV (this is more or less all that I learned in thermodynamics course in student days) and eV corresponds to 1.24 microns. This temperature range roughly corresponds to energy range of $10^{-6} - 10^{-5}$ eV. The wave wavelength corresponding to maximal intensity of blackbody radiation is in the range of 2.3-23 centimeters. One can of course ask whether the condition $\lambda \gg L = 1$ m is consistent with this. A specialist would be needed to answer this question. Note that the gap energy .45 meV of superconductor defines energy scale for Josephson radiation generated by super-conductor: this energy would correspond to about 2 mm wavelength much below one 1 meter. This energy does not correspond to the energy scale of thermal photons.

I am of course unable to say anything interesting about the experiment itself but cannot avoid mentioning the hierarchy of Planck constants. If one has $E = h_{eff}f$, $h_{eff} = n \times h$ instead of $E = hf$, the condition $\lambda \gg L$ can be easily satisfied. For superconducting wire this would be true for superconducting magnetic flux tubes in TGD Universe and maybe it could be true also for photons, if they are dark and travel along them. One can even consider the possibility that quantal heat conductivity is possible over much longer wire lengths than 1 m. Showing this to be the case, would provide strong support for the hierarchy of Planck constants.

There are several interesting questions to be pondered in TGD framework. Could one identify classical space-time correlates for the quantization of conductance? Could one understand how classical thermodynamics differs from quantum thermodynamics? What quantum thermodynamics could actually mean? There are several rather obvious ideas.

i. Space-time surfaces are preferred extremals of Kähler action satisfying extremely powerful conditions boiling down to strong form of holography stating that string world sheets and partonic 2-surfaces basically dictate the classical space-time dynamics [K1, K19, K16]. Fermions are localized to string world sheets from the condition that electromagnetic charge is well-defined for spinor modes (classical W fields must vanish at the support of spinor modes).

   This picture is blurred as one goes to GRT-standard model limit of TGD and space-time sheets are lumped together to form a region of Minkowski space with metric which deviates from Minkowski metric by the sum of the deviations of the induced metrics from Minkowski metric. Also gauge potentials are defined as sums of induced gauge potentials. Classical thermodynamics would naturally correspond to this limit. Obviously the extreme simplicity of single sheeted dynamics is lost.

ii. Magnetic flux tubes to which one can assign space-like fermionic strings connecting partonic 2-surfaces are excellent candidates for the space-time correlates of wires and at the fundamental level the 1-dimensionality of wires is exact notion at the level of fermions. The quantization of conductance would be universal phenomenon blurred by the GRT-QFT approximation.

   The conductance for single magnetic flux tube would be the conductance quantum determined by preferred extremal property, by the boundary conditions coded by the electric voltage for electric conduction and by the temperatures for heat conduction. The quantization of conductances could be understood in terms of preferred extremal property. m-multiple of conductance would correspond to m flux tubes defining parallel wires. One should check whether also fractional conductances coming as rational m/n are possible as in the case of fractional quantum Hall effect and assignable to the hierarchy of Planck constants $h_{eff} = n \times h$ as the proportionality of quantum of conductance to $1/h$ suggests.

iii. One can go even further and ask whether the notion of temperature could make sense at quantum level. Quantum TGD can be regarded formally as a "complex

square root" of thermodynamics. Single particle wave functions in Zero Energy Ontology (ZEO) can be regarded formally as "complex square roots" of thermodynamical partition functions and the analog of thermodynamical ensemble is realized by modulus squared of single particle wave function.

In particular, p-adic thermodynamics used for mass calculations can be replaced with its "complex square root" and the p-adic temperature associated with mass squared (rather than energy) is quantized and has spectrum $T_p = log(p)/n$ using suitable unit for mass squared [K8].

Whether also ordinary thermodynamical ensembles have square roots at single particle level (this would mean thermodynamical holography with members of ensemble representing ensemble!) is not clear. I have considered the possibility that cell membrane as generalized Josephson junction is describable using square root of thermodynamics [L4]. In ZEO this would allow to describe as zero energy states transitions in which initial and final states of event corresponding to zero energy state have different temperatures.

Square root of thermodynamics might also allow to make sense about the idea of entropic gravity, which as such is in conflict with experimental facts [K18] .

4.2 Deviation from the prediction of standard quantum theory for radiative energy transfer in faraway region

I encountered in FB a highly interesting finding discussed in two popular articles (see `http://tinyurl.com/yc64fmoo` and `http://tinyurl.com/yc9fwvnh`). The original article (see `http://tinyurl.com/y9kafhme`) is behind paywall but one can find the crucial figure 5 online (see `http://tinyurl.com/ybr87h7u`) . It seems that experimental physics is in the middle of a revolution of century and theoretical physicists straying in superstring landscape do not have a slightest idea about what is happening.

The size scale of objects studied - membranes in temperature of order room temperature 300 Kfor instance - is about 1/2 micrometers: cell length scale range is in question. They produce radiation and other similar object is heated if there is temperature difference between the objects. The heat flow is proportional to the temperature difference and radiative conductance G_{rad} characterizes the situation. Planck's black body radiation law, which initiated the development of quantum theory for more than century ago, predicts G_{rad} at large enough distances.

i. The radiative transfer is larger than predicted by Planck's radiation law at *small distances* (nearby region) of order average wavelength of thermal radiation deducible from its temperature. This is not a news.

ii. The surprise was that radiative conductance is 100 times larger than expected from Planck's law at *large distances* (faraway region) for small objects with size of order .5 micron. This is a really big news.

The obvious explanation in TGD framework is provided by the hierarchy of Planck constants. Part of radiation has Planck constant $h_{eff} = n \times h_0$, which is larger than the standard value of $h = 6h_0$ (a good guess for atoms [L7, L13, L14]). This scales up the wavelengths and the size of nearby region scales like n. Faraway region can become effectively nearby region and conductance increases.

My guess is that this unavoidably means beginning of the second quantum revolution brought by the hierarchy of Planck constants. These experimental findings cannot be put under the rug anymore.

4.3 Time crystals, macroscopic quantum coherence, and adelic physics

Time crystals were (see `http://tinyurl.com/jbj5j68` were proposed by Frank Wilzek in 2012. The idea is that there is a periodic collective motion so that one can see the

system as analog of 3-D crystal with time appearing as fourth lattice dimension. One can learn more about real life time crystals at http://tinyurl.com/zy73t6r.

The first crystal was created by Moore *et al* (see http://tinyurl.com/js2h6b4) and involved magnetization. By adding a periodic driving force it was possible to generate spin flips inducing collective spin flip as a kind of domino effect. The surprise was that the period was twice the original period and small changes of the driving frequency did not affect the period. One had something more than forced oscillation - a genuine time crystal. The period of the driving force - Floquet period- was 74-75 μs and the system is measured for N=100 Floquet periods or about 7.4-7.5 milliseconds (1 ms happens to be of same order of magnitude as the duration of nerve pulse). I failed to find a comment about the size of the system. With quantum biological intuition I would guess something like the size of large neuron: about 100 micrometers.

Second law does not favor time crystals. The time in which single particle motions are thermalized is expected to be rather short. In the case of condensed matter systems the time scale would not be much larger than that for a typical rate of typical atomic transition. The rate for 2P $\rightarrow$ 1S transition of hydrogen atom estimated at http://tinyurl.com/jtze3kg gives a general idea. The decay rate is proportional to $\omega^3 d^2$, where $\omega = \Delta E/\hbar$ is the frequency difference corresponding to the energy difference between the states, d is dipole moment proportional to αa_0, a_0 Bohr radius and $\alpha \sim 1/137$ fine structure constant. Average lifetime as inverse of the decay rate would be 1.6 ns and is expected to give a general order of magnitude estimate.

The proposal is that the systems in question emerge in non-equilibrium thermodynamics, which indeed predicts a master-slave hierarchy of time and length scales with masters providing the slowly changing background in which slaves are forced to move. I am not a specialist enough to express any strong opinions about thermodynamical explanation.

4.3.1 First TGD based impressions

What does TGD say about the situation?

i. So called Anderson localization (see http://tinyurl.com/z9ems4o) is believed to accompany time crystal. In TGD framework this translates to the fusion of 3-surfaces corresponding to particles to single large 3-surface consisting of particle 3-surfaces glued together by magnetic flux tubes. On can say that a relative localization of particles occurs and they more or less lose the relative translation degrees of freedom. This effect occurs always when bound states are formed and would happen already for hydrogen atom.

   TGD vision would actually solve a fundamental problem of QED caused by the assumption that proton and electron behave as independent point like particles: QED predicts a lot of non-existing quantum states since Bethe-Salpeter equation assumes degrees of freedom, which do not actually exist. Single particle descriptions (Schrödinger equation and Dirac equation) treating proton and electron effectively as single particle geometrically (rather than independent particles) having reduced mass gives excellent description whereas QED, which was thought to be something more precise, fails. Quite generally, bound states are not properly understood in QFTs. Color confinement problem is second example about this: usually it is believed that the failure is solely due to the fact that color interaction is strong but the real reason might be much deeper.

ii. In TGD Universe time crystals would be many-particle systems having collection of 3-surfaces connected by magnetic flux tubes (tensor network in terms of condensed matter complexity theory). Magnetic flux tubes would carry dark matter in TGD sense having $h_{eff}/h = n$ increasing the quantal scales - both spatial and temporal - so that one could have time crystals in long scales.

   Biology could provide basic examples. For instance, EEG resonance frequency could be associated with time crystals assignable to the magnetic body of brain carrying dark matter with large $h_{eff}/h = n$ - so large that dark photon energy

$E = h_{eff}f$ would correspond to an energy above thermal energy. If bio-photons result from phase transitions $h_{eff}/h = n \to 1$, the energy would be in visible-UV energy range. These frequencies would in turn drive the visible matter in brain and force it to oscillate coherently.

iii. The time crystals claimed by Monroe and Lurkin to be created in laboratory demand a feed of energy (see `http://tinyurl.com/zm4m5v9`) unlike the time crystals proposed by Wilzek. The finding is consistent with the TGD based model. In TGD the generation of large h_{eff} phase demands energy. The reason is that the energies of states increase with h_{eff}. For instance, atomic binding energies decrease as $1/h_{eff}^2$. In quantum biology this requires feeding of metabolic energy. Also now interpretation would be analogous to this.

iv. Standard physics view would rely in non-equilibrium thermodynamics whereas TGD view about time crystals would rely on dark matter and hierarchy of Planck constants in turn implied by adelic physics suggested to provide a coherent description fusing real physics as physics of matter and various p-adic physics as physics of cognition.

Number theoretical universality (NTU) leads to the notion of adelic space-time surface (monadic manifold) involving a discretization in an extension of rationals defining particular level in the hierarchy of adeles defining evolutionary hierarchy. $h_{eff}/h = n$ has been identified from the beginning as the dimension of poly-sheeted covering assignable to space-time surface. The action of the Galois group of extensions indeed gives rise to covering space. The number n of sheets would be the dimension of the extension implying $h_{eff}/h = n$, which is bound to increase during evolution so that the complexity increases.

Indeed, since n is positive integer evolution is analogous to a diffusion in half-line and n unavoidably increases in the long run just as the particle diffuses farther away from origin (by looking what gradually happens near paper basket one understands what this means). The increase of n implies the increase of maximal negentropy and thus of negentropy. Negentropy Maximization Principle (NMP) follows from adelic physics alone and there is no need to postulate it separately. Things get better in the long run although we do not live in the best possible world as Leibniz who first proposed the notion of monad proposed!

4.3.2 Second look a couple of years later

4.3.3 Further comments on time crystals

Google has reported about a realization of a time crystal as a spin system. A rather hypish layman article (`https://cutt.ly/5QWZLWk`) creates the impression that perpetuum mobile has been discovered. Also the Quanta Magazine article (`https://cutt.ly/6QWZXfT`) creates this impression. The original research article [D7] (`https://cutt.ly/RQWZCSR`) provides a realistic description.

It is interesting to look at the situation in the TGD framework. From the abstract of the article also from the Wikipedia article about time crystals one learns that the system has periodic energy feed and is therefore not closed so that the finding is not in conflict with the second law and perpetuum mobile is not in question.

What is time crystal? The notion of time crystal (`https://cutt.ly/2n65xOk`) is a temporal analog of ordinary crystals in the sense that there is temporal periodicity, was proposed by Frank Wilczeck in 2012. Experimental realization was demonstrated in 2016-2017 but not in the way theorized by Wilczek. Soon also a no-go theorem against the original form of the time crystal emerged and motivated generalizations of Wilzeck's proposal.

The findings reported by Google are however extremely interesting. Very concisely, researchers study a spin system, which has two directions of magnetization and the external laser beam induces the system to oscillate between the two magnetization directions with a period, which is a multiple of the period of the laser beam. It is

interesting to consider the system in TGD framework and I have actually discussed time crystals briefly in a recent article [L26].

i. Space-time surfaces as periodic minimal surfaces as counterparts of time crystals In TGD, classical physics is an exact part of quantum theory and quantum classical correspondence holds true. Hence it is interesting to consider first the situation at the classical space-time level. In TGD time crystals have as classical correlates space-time surfaces which are periodic minimal surfaces. It is possible to have analogs of time-crystals and also more general structures built as piles of lego like basic pieces in time direction bringing in mind sentences of language and DNA, which is quasi-periodic structure and more general than crystal.

ii. What about thermodynamics of time crystals? Could the time crystal be possible also in thermodynamic sense and even for thermodynamically closed systems? In the TGD framewoork, Negentropy Maximization Principle (NMP) [L24] and zero energy ontology (ZEO) [L17, L25] forces to generalize thermodynamics to allow both time arrows. ZEO is forced by TGD inspired theory of consciousness and solves the basic paradox of quantum measurement theory. The arrow of time would change in ordinary ("big") state function reduction (BSFR) and would remain unaffected in "small" SFR (SSFR). Second law holds true at the level of real physics but in the cognitive sector information increases and NMP holds true.

Also new quantum theory might be needed to explain why the period is multiple of the driving period. The first possibly needed new element is hierarchy of effective Planck constants $h_{eff} = n \times h_0$ having number theoretical interpretation. h_{eff} measures the scale of quantum coherence and has also interpretation as the order of Galois group for a polynomial defining the space-time surface in M^8 mapped to $M^4 \times CP_2$ by $M^8 - H$ duality [L18, L19, L23].

The replacement of $h_{eff} \to kh_{eff}$ scales the periods by k and keeps energies unchanged. In TGD inspired biology h_{eff} hierarchy is in a crucial role and its levels behave relative to each other like dark matter.

In the recent case, the magnetic body (MB)of the spin system controlling its behavior would have $h_{eff} = nh_0$. Each period would be initiated by BSFR at the level of MB and change the arrow of time and induce effective change of it also at the level of the ordinary matter.

In ZEO, time crystal-like entities, which live in cycle by extracting back part of the energy that they have dissipated in a time reversed mode, are in principle possible. System "breathes". Various bio-rhythms could correspond to time crystals. The biological analogy is obvious and we know that life requires a metabolic energy feed: in TGD Universe it prevents the decrease of h_{eff} [L27].

For a thermodynamically open system, part of the dissipated energy leaks into the external world during each half cycle. Same happens in the time reversed mode and would mean that the system apparently receives positive energy also from the external world. Could this energy feed compensate for the energy loss to the external world by dissipation so that no external energy feed would be needed? Perhaps this might be the case in the ideal situation. One would have almost a perpetuum mobile! Periodic driving feeding energy to the system would be needed to take care that h_{eff} is not reduced.

5 Some condensed matter anomalies

5.1 Exciton-polariton Bose-Einstein condensate at room temperature and h_{eff} hierarchy

Ulla gave in my blog (see `https://goo.gl/Yo3zQG`) a link to a very interesting work about Bose-Einstein condensation of quasi-particles known as exciton-polaritons. The

goo.gl/eKg13Spopular article tells about a research article [D9] (see https://goo.gl/bZ6LFs) published in Nature by IBM scientists.

Bose-Einstein condensation happens for exciton-polaritons at room temperature, this temperature is four orders of magnitude higher than the corresponding temperature for crystals. This puts bells ringing. Could $h_{eff}/h = n$ be involved?

One learns from Wikipedia (see https://goo.gl/jLU7QG) that exciton-polaritons are electron hole pairs- photons kick electron to higher energy state and exciton is created.These quasiparticles would form a Bose-Einstein condensate with large number of particles in ground state. The critical temperature corresponds to the divergence of Boltzmann factor given by Bose-Einstein statistics.

i. The energy of excitons must be of order thermal energy at room temperature: IR photons are in question. Membrane potential happens to corresponds to this energy. That the material is organic, might be of relevance. Living matter involves various Bose-Einstein condensate and one can consider also excitons.

   As noticed the critical temperature is surprisingly high. For crystal BECs it is of order .01 K. Now by a factor 30,000 times higher!

ii. Does the large value of $h_{eff} = n \times h$ visible make the critical temperature so high?

   Here I must look at same Wikipedia article for BEC of quasiparticles. Unfortunately the formula for the density of quasiparticle density dn/dV at criticality is copied from source and contains several errors. Dimensions are completely wrong. The formulas should read

$$(\frac{dn}{dV})^{1/3} = \frac{(m_{eff}T_{cr})^{1/2}}{\hbar} \quad .$$

   (One can put Boltzmann constant $k_B = 1$ by using for temperature same units as for energy).

iii. The correct formula for the critical temperature T_{cr} reads as

$$T_{cr} = \frac{\hbar^2(\frac{dn}{dV})^{2/3}}{m_{eff}} \quad .$$

iv. In TGD one can generalize by replacing $\hbar$ with $\hbar_{eff} = n \times \hbar$ so that one has

$$T_{cr} \to n^2 T_{cr}.$$

   Critical temperature would be proportional to n^2 and the high critical temperature (room temperature) could be understood. In crystals the critical temperature is very low but in organic matter a large value of $n \sim 100$ could change the situation. $n \sim 100$ would scale up the atomic scale of 1 Angstrom as a coherence length of valence electron orbitals to cell membrane thickness about 10 nm. There would be one dark electron-hole pair per volume taken by dark valence electron: this would look reasonable.

One must consider also the conservative option $n = 1$. T_{cr} is also proportional to $(dn/dV)^2$, where dn/dV is the density of excitons and to the inverse of the effective mass m_{eff}. m_{eff} must be of order electron mass so that the density dn/dV or n is the critical parameter. In standard physics so high a critical temperature would require either large density dn/dV about factor 10^6 higher than in crystals.

Is this possible?

i. Fermi energy E_F is given by almost identical formula but with factor $1/2$ appearing on the right hand side. Using the density dn_e/dV for electrons instead of dn/dV gives an upper bound for $T_{cr} \leq 2E_F$. E_F varies in the range 2-10 eV. The actual values of T_{cr} in crystals is of order 10^{-6} eV so that the density of quasi particles must be very small for crystals: $dn_{cryst}/dV \simeq 10^{-9} dn_e/dV$.

ii. For crystal the size scale L_{cryst} of the volume taken by quasiparticle would be 10^{-3} times larger than that taken by electron, which varies in the range $10^{1/3} - 10^{2/3}$ Angstroms giving the range $(220 - 460)$ nm for L_{cryst}.

iii. On the other hand, the thickness of the plastic layer is $L_{layer} = 35$ nm, roughly 10 times smaller than L_{cryst}. One can argue that $L_{plast} \simeq L_{layer}$ is a natural order of magnitude for L_{cryst} for quasiparticle in plastic layer. If so, the density of quasiparticles is roughly 10^3 times higher than for crystals. The $(dn/dV)^2$-proportionality of T_{cr} would give the factor $T_{cr,plast} \simeq 10^6 T_{cr,cryst}$ so that there would be no need for non-standard value of h_{eff}!

But is the assumption $L_{plast} \simeq L_{layer}$ really justified in standard physics framework? Why this would be the case? What would make the dirty plastic different from super pure crystal?

The question which option is correct remains open: conservative would of course argue that the now-new-physics option is correct and might be right.

5.2 Quantum scarring from TGD point of view

I learned about very interesting phenomenon serving as a challenge for TGD. In quantum scarring the system does not thermalize as one might expect as the popular article "*Quantum scarring appears to defy universe's push for disorder*" describes (see `http://tinyurl.com/y2bo8r8y`). The experimental article by Bernien *et al* with title *Probing many-body dynamics on a 51-atom quantum simulator* [D4] (see `http://tinyurl.com/yykagmeu`) has the following abstract.

> *Controllable, coherent many-body systems can provide insights into the fundamental properties of quantum matter, enable the realization of new quantum phases and could ultimately lead to computational systems that outperform existing computers based on classical approaches. Here we demonstrate a method for creating controlled many-body quantum matter that combines deterministically prepared, reconfigurable arrays of individually trapped cold atoms with strong, coherent interactions enabled by excitation to Rydberg states. We realize a programmable Ising-type quantum spin model with tunable interactions and system sizes of up to 51 qubits. Within this model, we observe phase transitions into spatially ordered states that break various discrete symmetries, verify the high-fidelity preparation of these states and investigate the dynamics across the phase transition in large arrays of atoms. In particular, we observe robust many-body dynamics corresponding to persistent oscillations of the order after a rapid quantum quench that results from a sudden transition across the phase boundary. Our method provides a way of exploring many-body phenomena on a programmable quantum simulator and could enable realizations of new quantum algorithms.*

There are many theoretical articles about MBQS. As an example I include the abstract of the article "*Quantum scarred eigenstates in a Rydberg atom chain: entanglement, breakdown of thermalization, and stability to perturbations*" by Turner *et al* [D11] (see `http://tinyurl.com/y54unclz`) serving as basis of TGD inspired considerations.

> *Recent realization of a kinetically constrained chain of Rydberg atoms by Bernien et al., [Nature (London) 551, 579 (2017)] resulted in the observation of unusual revivals in the many-body quantum dynamics. In our previous work [C. J. Turner et al., Nat. Phys. 14, 745 (2018)], such dynamics was attributed to the existence of "quantum scarred" eigenstates in the many-body spectrum of the experimentally realized model. Here, we present a detailed study of the eigenstate properties of the same model.*
> *We find that the majority of the eigenstates exhibit anomalous thermalization: the observable expectation values converge to their Gibbs ensemble values, but*

parametrically slower compared to the predictions of the eigenstate thermalization hypothesis (ETH). Amidst the thermalizing spectrum, we identify non-ergodic eigenstates that strongly violate the ETH, whose number grows polynomially with system size. Previously, the same eigenstates were identified via large overlaps with certain product states, and were used to explain the revivals observed in experiment.
Here, we find that these eigenstates, in addition to highly atypical expectation values of local observables, also exhibit sub-thermal entanglement entropy that scales logarithmically with the system size. Moreover, we identify an additional class of quantum scarred eigenstates, and discuss their manifestations in the dynamics starting from initial product states.
We use forward scattering approximation to describe the structure and physical properties of quantum scarred eigenstates. Finally, we discuss the stability of quantum scars to various perturbations. We observe that quantum scars remain robust when the introduced perturbation is compatible with the forward scattering approximation. In contrast, the perturbations which most efficiently destroy quantum scars also lead to the restoration of "canonical" thermalization.

The systems exhibiting quantum scarring (QS) thermalize very slowly or do not thermalize at all. Instead, the system returns to its original state periodically. This behavior does not conform with ergodicity stating that the system goes through all possible state during time evolution.

There are a lot of systems, which fail to be ergodic.

i. In integrable systems - for which TGD is an excellent candidate - all states starting from energy eigenstate have this recurrence property as isolated systems if the energies are commeasurate (rational multiples of same unit of energy). In the recent case only preferred states have this recurrence property.

   In the experimental situation one considers a quenched system: the initial state can be modelled as energy eigenstate of some Hamiltonian H_0 which is replaced with $H = H_0 + H_1$ so that the state is not energy eigenstate anymore. Periodic behavior requires that the state is superposition of finite number of state with commensurate energies in the resolution considered. In the ideal situation the eigenstates of H are integer spaced so that they have the period of the ground state as common periodicity. Period increases if there are states with energies close to each other since states E and $E + \Delta E$ must satisfy $ET = n \times 2\pi$ and $\Delta E \times T = m \times 2\pi$ giving $T = m2\pi/\Delta E = (m/n) \times (E/\Delta E$.

ii. For spin glass [B2] the energy landscape is a fractal with valleys inside valleys, and the system ends down to some valley as it dissipates. The mountains of the energy landscape force the localization and the thermalization is prevented.

   Some kind of dynamical localization is expected place in the situations in which only preferred states give rise to a quantum scar. Dynamical localization could due to genuinely quantal state repulsive exchange forces depending on the relative direction of spins of valence electrons of Rydberg atoms.

One can distinguish between quantum scarring (QS) and quantum many-body scarring (MBQS).

i. In QS the wave function of the particle concentrates along unstable periodic classical orbit. The less unstable the orbit is, the stronger the scarring is. The classical orbit makes itself visible as a quantum scar.

ii. In MBQS scarring is a generalization of quantum scarring and the state of many-particle system returns to the original one. In principle one can describe many-particle system wave-mechanically as single particle state in a higher-D configuration space so that in principle this does not bring anything new. MBQS has been observed in a 1-D lattice formed by Rydberg atoms and ordinary atoms so that

configuration space is effectively discrete. Some atoms of this system at very low temperature are excited to what are believed to be Rydberg atoms with large value of principal quantum number n_P and therefore large radius. This requires energy because bound states energies are proportional to $1/n_P^2\hbar^2$.

Remark: "Believed to be" sounds strange but in TGD framework atoms for which valence electrons have nonstandard value of Planck constant $h_{eff} = nh_0$ can look like Rydberg atoms. For $h = 6h_0$ suggested by experiments of Randell Mills [L7] one would have $h_{eff} = nh/6$ so that one could have one can have fractional principal quantum number $n_{P,eff} = (nn_P)/6$: this provides a test for h_{eff} hypothesis using irradiation with corresponding frequencies. For $n = 6n_1$ one might fail to distinguish these states from Rydberg states since the radii of the states scale like $n_{P,eff}^2$. Large value of h_{eff} would make possible quantum coherence in long length scales and this could be highly relevant for integrability.

Eigenstate thermalization (EST) is an important notion. Eigenstate thermalization takes place by unitary time evolution, which usually generates a superposition of large number of states with same total quantum numbers, in particular energy. Single particle states have however varying energies and in the superposition single particle states get entangled. For sub-systems the density matrix is assumed to develop to a thermal density matrix. In particular, entanglement entropy is identified as thermal entropy. For QS and MBQS EST would occur very slowly or not at all.

In TGD framework one can consider two approaches to MBQS and QS. The general approach starting from the key ideas of TGD and the approach starting directly from the special properties of Rydberg atoms and their possible analogs with non-standard value of $h_{eff} > h$. The key question is whether MBQS is analogous to the periodicity in integrable systems with commeasurate energies.

5.2.1 General TGD based considerations

In the sequel I will briefly discuss some aspects of the basic principles of TGD with some associations to MBQS. Reader can however skip directly to the concrete proposal if this looks easier.

1. TGD as generalization of Wheeler's superspace approach and as geometrization of quantum physics

One could see TGD as a generalization of Wheeler's superspace approach and generalization of Einstein's geometrization program for physics. Integrability, quantum criticality, quantum classical correspondence, zero energy ontology, and hierarchy of Planck constants are the aspects of TGD, which seem to be relevant for MBQS.

i. There are excellent reasons to believe that TGD Universe is integrable and quantum critical system [K16, **?**] in very general sense. Also MBQS are conjectured to possess these properties. Quantum criticality would be responsible for the ground state degeneracy characterizing the model Hamiltonian of Turner *et al* [D11].

ii. TGD generalizes Einstein's vision about the geometrization of physics to the level of quantum physics. The basic geometric object is the "world of classical worlds" (WCW) consisting of pairs of 3-surfaces with members at opposite boundaries of a causal diamond (CD) and connected by preferred extremal of the action which for the twistor lift of TGD decomposes to a sum of so called Kähler action analogous to Maxwell action and a volume term, whose coefficient corresponds to cosmological constant.

   General Coordinate invariance implies holography in the sense that the these pairs of 3-surfaces as analogs of Bohr orbits are equivalent with the 4-D preferred extremals connecting them. Classical theory is an exact part of quantum TGD. Preferred extremals are minimal surfaces which fail to be such only at 2-D singular surfaces having identification as string world sheets and representing orbits of folds of a 3-surface [L15, L16].

In zero energy ontology (ZEO) quantum state - called zero energy state - is a superposition of deterministic preferred extremals. Simplest zero energy states are superpositions with same eigenvalues of observables and total quantum numbers are conserved.

Remark: Wave functions concentrated along periodic unstable classical orbits is central to QS. Superposition should be along unstable classical orbit. One could imagine that the state is superposition of 3-surfaces along classical orbit defined as slices obtained by intersecting with translate of either boundary of CD.

iii. Zero modes are a key element of TGD and correspond to the degrees of freedom, which do not contribute to WCW metric, which is thus degenerate. There would be states with the same total quantum numbers but different values of zero modes so that ground state degeneracy of the model of Turner *et al* [D11] could correspond to wave function in zero modes.

Also fermionic degrees of freedom are geometrized.

i. Fermions are geometrized in terms of WCW spinor structure [K19] with WCW gamma matrices expressible as linear combinations of fermionic oscillator operators for second quantized induced spinor fields. Many-fermion states correspond to the modes of WCW spinor field. This implies what I call super-symplectic symmetry as an extension of the symplectic symmetry acting as isometries of WCW necessary for the existence of Riemann connection in infinite-D context [K3, **?**] (for loop spaces this was shown by Freed [A1]). Formally many-fermion states are just modes of classical spinor field in WCW.

ii. Quantum-classical correspondence (QCC) implies that classical conserved Cartan charges and total fermionic charges are identical. Each particle in many-particle state corresponds near the boundaries of CD to "free particle" having single particle preferred extremal as correlate. One would have superposition of the collections of preferred extremals in the initial state. Superposition in entangled many-fermion state would correspond to a superposition of unions of corresponding 3-surfaces differing by translation and by properties correlating with other single particle quantum numbers.

Quantum state with given total quantum numbers such as energy as for (ETH) is superposition of several many-particle states in general since total quantum numbers are sums of those with varying single particle quantum numbers. At fundamental level this would hold true in fermionic degrees of freedom (bosons are composites of fermions and antifermions in TGD Universe). For MBQS there would be only 2 different orbits corresponding to ground state of atom and Rydberg atom: the electronic Bohr orbits as pieces of space-time surface would be different for these. Therefore the situation would be rather simple classically.

iii. The space-time surface - as opposed to 3-surfaces at the ends of CD - associated with many-particle system would be connected as analog of connected Feynman diagram and correspond to a formation of magnetic flux tubes between atoms as correlates of entanglement. The periodicity of the entanglement would correspond to periodic generation and disappearance of entanglement and flux tube - kind of breathing consisting of phase transitions between gas phase and liquid phase. Somewhat similar situation is encountered in simple systems consisting of plastic balls exhibiting basic aspects of life [L10].

2. Number theoretical vision

Number theoretical vision is second thread of TGD besides the vision about geometrization of physics.

i. p-Adic physics and their fusion to form a hierarchy of adelic physics characterized by a hierarchy of extensions of rational numbers inducing in turn extensions of

various p-adic number fields [L12, L11]. Classical number fields represent second key aspect of number theoretical vision [L9].

Adelic physics predicts a hierarchy $h_{eff} = nh_0$ ($h = 6h_0$ is a good guess [L7]) of effective values of Planck constant assumed to label a hierarchy of phases behaving like dark matter and having an interpretation as a dimension for extension of rationals.

ii. One can ask whether non-standard value of h_{eff} guaranteeing quantum coherence in scales longer than expected is involved with MBQS. One can ask whether Rydberg atoms be actually atoms with valence electrons, which are dark for some value of h_{eff} and have scaled orbits with scaling factor $(h_{eff}/h)^2 = (n/6)^2$. If n is not a multiple of 6, one can speak of fractional principal quantum number $n_P = n/6$ and this might allow to test the hypothesis. For $h_{eff} > h$ pseudo Rydberg electrons could form a nanoscopic quantum system.

MBQS is observed in very low temperatures and one can argue that the ordinary value of Planck constant is enough. One can however wonder whether MBQS is possible at higher temperatures for non-standard value of h_{eff} just like high Tc superconductivity if it is due to large h_{eff}.

iii. If the presence of flux tube connections is necessary for large scale quantum coherence in the scale of the entire system needed and serves also as a correlate for entanglement, one can argue $h_{eff} > h$ is needed. Otherwise one expects thermalization to occur since the system decomposes to smaller quantum-coherent systems.

3. ZEO and generalization of quantum measurement theory

ZEO forces to generalize quantum measurement theory. One could also say that the need to solve the basic paradox of quantum measurement theory forces ZEO.

i. In ZEO state function reduction is replaced with the counterpart of ordinary state function reduction- "big state function reduction" (BSR) and the counterpart of weak measurement - "small state function reduction" (SSR) . The unitary evolution of state corresponds in TGD sequence of unitary evolutions followed by SSR affecting only the states at the active boundary of CD and also de-localizing the active boundary whereas passive boundary and members of state pairs at it would remain unaffected.

SSR would localize the active boundary so that one has only single CD in superposition and mean also time measurement with time defined as the distance between the tips of CD. BSRs would change the roles of passive and active boundaries of CD and change the arrow of time assignable to the state by passive-active characterization.

ii. Are SSRs or BSRs associated with the reduction of entanglement and return to the initial state in MBQS? SSR looks a more plausible interpretation. BSR would reduce the entanglement at the active boundary making it passive and change the arrow of time and next BSR would bring back the original arrow of time and CD boundary would be slightly shifted towards future. It is not clear whether the entanglement is small in the beginning of sequence of SSRs.

5.2.2 A concrete TGD inspired model for MBQS

The fact that MBQS occurs only for special initial states forces to ask whether it reflects the special properties of the system considered or some general properties such as integrability for a system with commeasurate energies. Or is MBQS something between these two cases: could the property of having energy spectrum with energies coming as rational multiples of a fundamental be dynamically generated (localization)?

i. System could be an integrable system for which the evolution is periodic if energies are commensurate. The spectrum should not differ too much from harmonic oscillator spectrum since small energy differences tend to spoil the periodicity. There

are excellent reasons to expect that TGD is integrable theory but the behavior resembling harmonic oscillator is not obvious.

The system is unstable and should be therefore critical and possess zero modes generating long range quantum fluctuations for which large h_{eff} phases can serve as correlates. This is achieved if ground state has a large degeneracy with respect to energy. Small perturbations can be always described in terms of harmonic oscillators. The frequencies of harmonic oscillators should be expressible as multiples of fundamentals whose ratios are rational numbers.

ii. In TGD framewor the large value of h_{eff} makes possible quantum coherence in longer length scales and commeasurate integrability in such a way that eigenenergies resemble harmonic oscillator spectrum coming as integer multiples of rather few rationally related fundamentals.

iii. Space-time sheet is a natural candidate for a quantum coherent structure and if the space-time sheet decomposes into smaller disjoint sheets also coherence would be lost. Magnetic flux tubes connecting smaller space-time sheets to larger units would be natural correlates of quantum coherence and carry large h_{eff} phases. One could perhaps speak of dynamically generated quantum coherence and integrability with small number of fundamental energies.

iv. Dynamical localization should occur and could be due to interatomic forces. Exchange forces due to the Fermi statistics generate spin-dependent interactions, which are short ranged and repulsive for parallel spins. The exchange forces are excellent candidates for inducing the localization.

Dark valence electrons with large h_{eff} would have stronger exchange forces. This would promote the localization since one could not have effective Rydberg atoms (ERAs) with too small distance between them. If one has a system consisting of ordinary atoms (OAs) plus ERAs, the dark valence electrons could form a macroscopic quantum having MBQS states for this reason.

The physical picture is that states in which ERAs have too small mutual distance are not possible. This gives a constraint to the dynamics. Typically the "spin flip" giving rise to an ERA can occur only for atoms with sufficiently large distances to the nearest ERAs. This constraint dynamics forces localization inducing periodicity.

1. About intermolecular -, van der Waals -, and exchange forces

Intermolecular forces (see `http://tinyurl.com/mmxnctm`) include exchange forces due to Pauli exclusion principle, electrostatic interactions between permanent electric and magnetic multipoles, which can be both attractive and repulsive, and attractive interactions between permanent and induced multipoles - induction -, and between induced multipoles - so called dispersion forces.

In standard QFT van der Waals force-London dispersion force comes from interaction with zero point energy and analogous to Casimir force. London dispersion force is proportional to the product of ionization energies of atoms divided by their sum and product of polarizabilities and therefore proportional to $1/h_{eff}^2$ and would weaken for large h_{eff}.

Lennard-Jones potential (see `http://tinyurl.com/y9bjcxn5`) provides the simplest parameterization of these forces. There is attractive $1/r^6$ term representing dispersion forces and repulsive $1/r^{12}$ term interpreted in terms of exchange forces repulsive/attractive for parallel/opposite spins of electrons. This follows from antisymmetry of the wave function. The dispersion force if proportional to the energy scale of atom and therefore to $1/h_{eff}^2$ so that its scale decreases for large h_{eff}.

The strength of the exchange force is proportional to the inner product of spins and therefore proportional to h_{eff}^2 and increases with h_{eff}^2. This make increase the range of this force and together with the weakening of the dispersion force would make the radius at which the van der Waals force becomes repulsive larger. This would promote dynamical localization.

2. Consistency with the model of MBQS of Turner et al

In the model of MBQS discussed by by Turner *et al* [D11] (see `http://tinyurl.com/y54unclz`) the situation is indeed very much like proposed above. One considers a model Hamiltonian H having decomposition $H = H_0 + H_1$. Ground state and Rydberg state are formally described as two possible states of spin.

The first part in the Hamilton is sum $H_0 = k\sum X_i$ over single particle terms X_i analogous to paramagnetic spin flip term in the interaction of spins with an external magnetic field. It acts on single particle transforming ordinary atom in ground state to Rydberg atom or vice versa.

Second part $H_1 = \sum i \neq j V_{ij} Q^i Q^j$ of the Hamiltonian describes repulsive interatomic forces and is associated with pairs of particles at different sites. Individual terms are proportional to the projectors Q_i and Q_j to Rydberg states at neighboring sites i and j and the parameter V_{ij} describing interaction strength assumed to behave like $1/|i-j|^n$, $n = 6$, at the limit $i \to j$. Lennard-Jones potential would suggest $n = 12$ but this is not essential for the model since one considers an approximation in which only nearest neighbour interactions are considered. This part of the Hamiltonian is the large part non-perturbative and spin-flip term is treated as a small perturbation, which suggests that harmonic oscillator type approximation is good.

In nearest neighbour approximation the large part H_1 is proportional to a sum over terms $V_{i,i+1} Q_i Q_{i+1}$ over nearest neighbour pairs. In the states with minimum energy the positive interaction term (somewhat ironically) vanishes: this is guaranteed if all Rydberg sites have ground states as neighbours. One can introduce to the Hamilton this constraint explicitly, and by a scaling ends up to a Hamiltonian which is just the small paramagnetic spin flip term X_i multiplied from left *resp.* right side by projector P_{i-1} *resp.* P_{i+1} to the subspace satisfying the constraint.

The effect of this Hamiltonian is to induce "spin flips" such that the constraint is respected. The outcome is entangled state and the localization caused by the constraint induces the periodic dynamics and failure of ETH for preferred states.

The entanglement between dark and ordinary states makes sense: $h_{eff} = nh_0$ corresponds at space-time level n-sheeted covering of space-time. One must however assume that the entanglement coefficients are in the extension of rationals associated with the smaller value of n (n_1) belonging to that assignable to the larger value of n (n_2): therefore n_1 divides n_2.

If the effective spin-spin interaction is a sensible model for the situation, the value of h_{eff} affects only the parameters determining the spin-spin interaction. The excitation of ERAs requires energy but so does also the excitation of ordinary Rydberg atoms so that this cannot be used as an objection against the model.

5.3 Three surprising condensed matter findings

I learned about 3 surprising findings related to condensed matter physics and defying standard quantum theory and having a natural explanation in TGD framework.

5.3.1 The strange behavior of light

Light does not behave quite in the manner expected (see `http://tinyurl.com/sjc9rpu`). What was studied was splitting of photons to entangled pairs of photons in the crystal beam entering a crystal. Quantum field theory based on the idea of completely point-like particle predicts that photon pairs should be created at single point. What was observed that members of entangled photon pairs can be also created at separate points. The distances of these points can be about 1/100 microns- which happens to the size scale of cell membrane and fundamental scale in living matter. This length scale is about 100 times the atomic length scale.

Researchers argue that this findings supports new kind of Uncertainty Principle. I do not feel quite easy with this proposal unless it is taken to mean that particle has geometric size to be distinguished from Compton length.

i. In TGD Universe geometric size would be due to the fact that particles are not point-like but correspond to 3-D surfaces whose "orbits" define basic building bricks of space-time as 4-D surface in 8-D space-time $H = M^4 \times CP_2$. Particles can exiss superpositions of their variants with different size scales.

ii. p-Adic physics for various primes p fusing together with real number based physics to what I call adelic physics would provide physical correlates of cognition and sensory experience. The number theoretic vision assigns to each particle extension of rationals characterized by so called ramified primes, which are excellent candidates for defining preferred p-adic length scales. The dimension n of extension defining a measure for algebraic complexity and serving as a kind of universal IQ has interpretation as effective Planck constant $h_{eff}/h_0 = n$ so that a connection with quantum physics - or rather its TGD based generalization - emerges.

iii. p-adic mass calculations rely on p-adic length scale hypothesis stating that primes near powers of 2 are especially interesting physically and massive elementary particles and also hadrons correspond to this kind of primes. p-Adic mass scale would be proportional to $p^{1/2}$.

A lot of new physics is predicted.

i. TGD predicts scaled variants of strong and weak interaction physics corresponding to different values of p and LHC provides handful of bumps having identification as scaled variants of ordinary hadrons and having mass which is 512 higher [K10].

ii. For given particle several mass scales are in principle allowed. Quite generally, particle can correspond to several p-adic primes and therefore can exist in states with different masses differing by power of $2^{1/2}$. The existence of this kind of states in the case of neutrinos would solve some problems related to neutrinos and their masses.

iii. In the case of massless particles different p-adic mass scales do not mean that masses are different (or more precisely, the masses depend on p but are extremely small and below measurement resolution so that mass differences cannot be detected). The p-adic length scale defines the geometric size of the particle as 3-surface to be distinguished from quantum size defined by Compton length. Quantum classical correspondence (QCC) strongly suggests that these two scales are same or at least closely correlated.

The hierarchy of Planck constants $h_{eff} = n \times h_0$ having an interpretation in terms of dark variants of ordinary particles predicts second kind of scale hierarchy.

i. The mass of the dark variant of elementary particle would not differ from the mass of ordinary particle but Compton size for a dark particle is proportional to n - a good guess is that $n = 6$ would correspond to ordinary particle and ordinary value h of h_{eff}.

ii. The scales defined by dark matter hierarchy could relate to p-adic length scales. There could be kind of resonance coupling for massless particles: dark massless particle labelled by n and particle labelled by p-adic prime p could transform to each other with high rate if the p-adic and dark length scales are nearly the same. This could be very relevant for biology.

The experimental findings could be understood if photons can correspond to several p-adic length scales. The length scale 10 nm defining the upper bound for distance between members of entangled photon pair in experiments would correspond to p-adic length scale $L(151)$, which corresponds to Gaussian Mersenne prime $p = (1+i)^{151}-1$. A simple model for photon could be as a closed flux tube like structure of this length. Also $k = 157, 163$, and 167 define Gaussian Mersenne primes, which is a number theoretical miracle. What is fascinating that these scales are fundamental biological length scales assignable to the basic structures of DNA.

5.3.2 New surprises related to super-conductors

So called Anderson's theorem applying to the conventional super-conductors (BCS) states that the addition of non-magnetic impurities does not destroy super-conductivity. It has been however found (see `http://tinyurl.com/vq2do7f`) that this is not the case for iron based high Tc super-conductors. This gives a valuable hints in still-continuing to attempts to understand high Tc super-conductivity.

I have been preaching for fifteen years new kind of super-conductivity explaining high Tc superconductivity making living systems high Tc superconductors [K14, K15].

i. The TGD view about magnetic fields differs from Maxwellian view. The counterparts of Maxwellian magnetic fields are flux quanta, flux tubes or sheets realized as space-time surfaces (or regions of them). Besides counterparts of ordinary magnetic fields there are also monopole flux tubes and they appear in all scales and form the basis of entire TGD view of Universe. They carry dark matter as $h_{eff} = n \times h_0$ phases and for large value of $h_{eff} > h$ there is quantum coherence in long scales making possible super-conductivity along dark magnetic flux tubes. This could explain also high Tc superconductivity in iron based super-conductors.

ii. What was found that the addition of Cobalt atoms destroys the super-conductivity by inducing quantum phase transition. Anderson's theorem for ordinary superconductivity however states that non-magnetic perturbations do not affect superconductivity. In TGD framework the natural interpretation would be that the quantum phase transition reduces the value of $h_{eff}/h_0 = n$ and thus also the quantum coherence length meaning that flux tube length is reduces and superconductivity is possible only in short scales. Note that dark matter is identified as phases with non-standard value of h_{eff} different from h.

iii. Also the nature of so called energy gap assignable to super-conductors was modified as Cobalt atoms were gradually added to destroy super-conductivity. This is not surprising if the value of h_{eff} was reduced. The reduction of h_{eff} in general decreases energies for other parameters kept constant and now it would mean reduction of energy gap and loss of superconductivity.

5.3.3 Conductors of electricity, which are poor conductors of heat

The so called Wiedemann-Franz Law states that good conductors of electricity are also good conductors of heat. The two conductivities are proportional to each other. The metal found 2017 however violates this law (see `http://tinyurl.com/w4t9vdx`) Vanadium dioxide VO_2 transforms from insulator to a conductive metal at 67 degrees Celsius. The experimenters argue that this property could make possible new technologies. For instance, conversion of wasted heat from engines could be transformed to electricity.

Electrons are found to move in coordinated, synchronous manner and this would explain the reduction of heat conductivity to 1/10 of the expected value. There is no superconductivity however. TGD explanation would be in terms of coherence and synchrony induced from the quantum coherence of dark phases of matter having $h_{eff}/h_0 = n$ residing at the magnetic body of the system controlling it.

This forced coherence would be also crucial in living matter: ordinary living matter would not be quantum coherent but the magnetic body carrying dark matter would force the coherence. In fact, all self-organization processes could involve magnetic body and dark matter.

5.4 Fractons and TGD

In Quanta Magazine there was a highly interesting article about entities known as fractons (`https://cutt.ly/kQPph8n`).

There seems to be two different views about fractons as one learns by going to Wikipedia. Fracton can be regarded as a as self-similar particle-like entity (`https://cutt.ly/`

KQPadQL or as "sub-dimensional" particle unable to move in isolation (https://cutt.ly/yQPayJt). I do not understand the motivation for "sub-dimensional". It is also unclear whether the two notions are related. The popular article assigns to the fractons both the fractal character and the inability to move in isolation.

The basic idea shared by both definitions is however that discrete translational symmetry is replaced with a discrete scaling invariance. The analog of lattice which is invariant under discrete translations is fractal invariant under discrete scalings.

One can also consider the possibility that the time evolution operator acts as a scaling rather than translation. At classical level this would produce scaled versions of the system in discrete steps. This is something totally new from quantum field theory (QFT) point of view and it is not clear whether QFT can provide a description of fractons. In QFTs energy corresponds to time translational symmetry and Hamiltonian generates infinitesimal translations. In string models the analog of stringy Hamiltonian is the infinitesimal scaling operator, Virasoro generator L_0. Energy eigenstates would be replaced by scaling eigenstates with energy replaced with conformal weight.

In TGD the extension of physics to adelic physics provides number theoretic and geometric descriptions as dual descriptions of physics [L12, L18, L19, L23]. This approach also provides insights about what fractons as scale invariant (or covariant) entities might be.

i. The extension of conformal invariance to its 4-D analog is key element of TGD and leads to the notion of super-symplectic invariance and to an extension of conformal and Kac-Moody symmetries with two coordinates analogous to the complex coordinate z for ordinary conformal symmetry. Second coordinate is light-like and the fact that light-like 3-surfaces are effectively 2-dimensional is absolutely essential for this approach. The existence of extended conformal symmetries makes the space-time dimension $D = 4$ unique whereas the twistor lift of TGD fixes H to be $H = M^4 \times CP_2$.

ii. The predicted cosmological expansion is not smooth but occurs by discrete scalings as rapid jerks in which the size scale of 3-space as 3-surface increases. Actually they would correspond to discrete quantum jumps but in zero energy ontology (ZEO) in which quantum state are superpositions of space-time surfaces, their classical correlates are smooth time evolutions.

   Scalings by power of 2 are p-adically preferred [K5, **?**]. $M^8 - H$ duality allows us to imagine what this means at M^8-level [L26]. This proposal conforms with the puzzling observation that also astrophysical objects participate in cosmological expansion by comoving with it, they do not expand themselves.

iii. The analog of a unitary time evolution between "small" state function reductions (SSFRs) as the TGD counterparts of weak measurements, is generated by the exponential of the infinitesimal scaling operator, Virasoro generator L_0. One could imagine fractals as states invariant under discrete scalings defined by the exponential of L_0. They could be counterparts of lattices but realized at the level of space-time surfaces having quite concrete fractal structure.

iv. In p-adic mass calculations the p-adic analog of thermodynamics for infinitesimal scaling generator L_0 proportional to mass squared operator M^2 replaces energy. This approach is the counterpart of the Higgs mechanism which allows only to reproduce masses but does not predict them. I carried out the calculations already around 1995 and the predictions were amazingly successful and eventually led to adelic physics fusing real and various p-adic physics [K11].

v. Long range coherence and absence of thermal equilibrium are also mentioned as properties of fractons (at least those of the first kind). Long range coherence could be due to the predicted hierarchy of Planck constants $h_{eff} = n \times h_0$ assigned with dark matter and predicting quantum coherence in arbitrarily long scales and associated with what I called magnetic bodies.

   If translations are replaced by discrete scalings, the analogs of thermodynamic equilibria would be possible for L_0 rather than energy. Fractals would be the analogs

of thermodynamic equilibria. In p-adic thermodynamics, elementary particles are thermodynamic equilibria for L_0 but it is not clear whether the fractal analogy with a plane wave in lattice makes sense.

An attractive identification of the fractal counterpart of an energy eigenstate created in the unitary evolution preceding SSFR is as a scaling eigenstate defined as a superposition of scaled variants of space-time surface obtained by discrete scalings. Energy eigenvalue would be replaced with conformal weight. In zero energy ontology (ZEO), the counterpart of a fractal quantum state could be a superposition over zero energy states located inside the scaled variants of a causal diamond (CD).

The ZEO based proposal is that each unitary evolution preceding SSFR creates a superposition of scaled variants of CD and that the SSFR induces a localization to single CD [L17, L1]. The interpretation would be as a time measurement determined by the scale of the CD.

Second definition assumes that fractons are able to move only in combinations. This need not relate to the scaling invariance. Color confinement comes to mind as an analogy. Quarks are unable to exist as isolated entities, not only to move as in isolated entities.

In the TGD framework, the number theoretical vision leads to the notion of Galois confinement analogous to color confinement [L20]. The Galois group of a given extension of rationals indeed acts as a symmetry at the space-time level. In the TGD inspired biology Galois groups would play a fundamental role [L21]. For instance, dark analogs of genetic codons, codon pairs, and genes would be singlets (invariant) under an appropriate Galois group and therefore behave as a single quantum coherent dynamical and informational unit [L27, L22].

Suppose that one has a system - say a fractal analog of a lattice consisting of Galois singlets. Could fracton be identified as a state which is analogous to quark or gluon and therefore not invariant under the Galois group. The physical states could be formed from these as Galois singlets and are like hadrons.

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