Criticality and dark matter

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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. 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 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 [K16, K12, K33].

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.

One can find a summary about basic concepts of TGD with illustrations at `http://tgdtheory.fi/public_html/pdfpool/append.pdf`. There are concept maps about topics related to the contents of the chapter prepared using CMAP realized as html files. Links to all CMAP files can be found at `http://tgdtheory.fi/cmaphtml.html` [L1]. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L2]. The topics relevant to this chapter are given by the following list.

- TGD as infinite-dimensional geometry [L10]
- Symmetries of WCW [L9]
- KD equation [L5]
- Kaehler-Dirac action [L4]
- Hierarchy of Planck constants [L3]
- Quantum criticality [L8]

2 Criticality In TGD Framework

In the following the proposal that quantum criticality or even criticality (with thermodynamical criticality included) could in TGD framework correspond to phase transition generating dark matter identified as phases of the ordinary matter with non-standard value $h_{eff} = n \times h$ of Planck constant and residing at dark magnetic flux tubes is discussed.

The precise meaning of quantum criticality has remained frustratingly fuzzy since the long range fluctuations and possible quanta associated with them do not correspond to any of the co-existing phases naturally but rather to transitions between them. Here Zero Energy Ontology (ZEO) in which basic objects are time evolutions suggests an elegant description: the ends of space-time surfaces at opposite boundaries of CD correspond to different values of h_{eff}. This would also give a connection with inclusions of hyper-finite factors: the integer m characterizing the inclusion equals to the radion $m = h_{eff}(f)/h_{eff}(i)$ of Planck constants for final and initial phases.

2.1 Mathematical Approach To Criticality

Concerning the understanding of criticality one can proceed purely mathematically. Consider first 2-dimensional systems and 4-D conformal invariance of Yang-Mills theories.

1. In 2-dimensional case the behavior of the system at criticality is universal and the dependence of various parameters on temperature and possible other critical parameters can be expressed in terms of critical exponents predicted in the case of effectively 2-dimensional systems by conformal field theory discovered by Russian theoreticians Zamolodchikov, Polyakov and Belavin [B2]. To my opinion, besides twistor approach this is one of the few really significant steps in theoretical physics during last forty years.

2. Twistors discovered by Penrose relate closely to 4-D conformal invariance generalized to Yangian symmetry [**?**] [B5, B3, B4] in the approach developed by Nima Arkani-Hamed and collaborators recently. 2-dimensional conformal field theories are relatively well-understood and classified. String models apply the notions and formalism of conformal field theories.

3. The notion of conformal symmetry breaking emerges from basic mathematics and is much deeper than its variant based on Higgs mechanism able to only reproduce the mass spectrum but not to predict it: in p-adic thermodynamics based on super-conformal invariance prediction becomes possible [K35].

2.1.1 Basic Building Bricks Of TGD Vision

The big vision is that 2-D conformal invariance generalizes to 4-D context [K7, K16, K12] and the conjecture is that it can be extended to Yangian symmetry assignable - not to finite-D conformal algebra of Minkowski space - but to the infinite-D generalization of 2-D conformal algebra to 4-D context. The details of this generalization are not understood but the building bricks have been identified.

1. One building brick is the infinite-D group of symplectic symmetries of $\delta M^4_- \times CP_2$ having the structure of conformal algebra but the radial light-like coordinate r_M of δM^4_+ replacing complex coordinate z: r_M presumably allows a continuation to a hyper-complex analog of complex coordinate. One can say that finite-D Lie algebra defining Kac-Moody algebrais replaced with an infinite-D symplectic algebra of $S^2 \times CP_2$ and made local with respect to r_M

2. Second building brick is defined by the conformal symmetries of S^2 depending parametrically on r_M and are due to metric 2-dimensionality of δM^4_+. These symmetries are possible only in 4-D Minkowski space. The isometry algebra of δM^4_+ is isomorphic with that of ordinary conformal transformations (local radial scaling compensates the local conformal scaling).

3. Light-like orbits of the partonic 2-surfaces have also the analog of the extended conformal transformations as conformal symmetries and respect light-likeness.

4. At least in space-time regions with Minkowskian signature of the induced metric spinor modes are localized to string 2-D world sheets from the condition that electric charge is well-defined for the modes. This guarantees that weak gauge potentials are pure gauge at string world sheets and eliminates coupling of fermions to classical weak fields which would be a strong arguments against the notion of induced gauge field. Whether string world sheets and partonic 2-surfaces are actually dual as far as quantum TGD is considered, is still an open question.

The great challenge is to combine these building bricks to single coherent mathematical whole. Yangian algebra, which is multi-local with locus generalized from a point to partonic 2-surface would be the outcome. Twistors would be part of this vision: M^4 and CP_2 are indeed the unique 4-D manifolds allowing twistor space with Kähler structure. Number theoretic vision involving classical number fields would be part of this vision. 4-dimensionality of space-time surfaces would follow from associativity condition stating that space-time surfaces have associative tangent - or normal space as surfaces in 8-D imbedding space endowed with octonionic tangent space structure. 2-dimensionality of the basic dynamical objects would follow from the condition that fundamental objects have commutative tangent - or normal space. String world sheets/partonic 2-surfaces would be commutative/co-commutative or vice versa.

2.1.2 Hierarchy Of Criticalities And Hierarchy Breakings Of Conformal Invariance

The TGD picture about quantum criticality connects it to the failure of classical non-determinism for Kähler action defining the space-time dynamics. A connection with the hierarchy of Planck constants [K11] and therefore dark matter in TGD sense emerges: the number n of conformal equivalence classes for space-time surfaces with fixed ends at the boundaries of causal diamond corresponds to the integer n appearing in the definition of Planck constant $h_{eff} = n \times h$.

A more detailed description for the breaking of conformal invariance is as follows. The statement that sub-algebra V_n of full conformal algebra annihilates physical states means that the generators L_{kn}, $k > 0$, $n > 0$ fixed, annihilate physical states. The generators L_{-kn}, $k > 0$, create zero norm states. Virasoro generators can be of course replaced with generators of Kac-Moody algebra and even those of the symplectic algebra defined above.

Since the action of generators L_m on the algebra spanned by generators $Ln + m$, $m > 0$, does not lead out from this algebra (ideal is in question), one can pose a stronger condition that all generators with conformal weight $k \geq n$ annihilate the physical states and the space of physical states would be generated by generators L_k, $0 < k < n$. Similar picture would hold for also for Kac-Moody algebras and symplectic algebra of $\delta M_+^4 \times CP_2$ with light-like radial coordinate of δM_+^4 taking the role of z. Since conformal charge comes as n-multiples of $\hbar$, one could say that one has $h_{eff} = n \times h$.

The breaking of conformal invariance would transform finite number of gauge degrees to discrete physical degrees of freedom at criticality. The long range fluctuations associated with criticality are potentially present as gauge degrees of freedom, and at criticality the breaking of conformal invariance takes place and these gauge degrees of freedom are transformed to genuine degrees of freedom inducing the long range correlations at criticality.

Changes of symmetry are assigned with criticality since Landau. Could one say that the conformal subalgebra defining the genuine conformal symmetries changes at criticality and this makes the gauge degrees of freedom visible at criticality?

2.1.3 Emergence Of The Covering Spaces Associated With The Hierarchy Of Planck Constants

The original vision was that the hierarchy of Planck constants corresponds to a hierarchy of n-fold singular coverings of the imbedding space - or more precisely given causal diamond (CD) forming a book-like structure with pages labelled by the effective value of Planck constant $h_{eff}/h = n$. This view allowed to understand the basic aspects of the hierarchy: in particular, the relative darkness of phases associated with different values of n. The generalization of imbedding space is however un-necessary. The non-determinism of Kähler action allows to replace singular coverings of imbedding space with the identification of space-time surfaces with their singular coverings. Space-like 3-surfaces at the opposite boundaries of CD are connected by a multi-sheeted covering with sheets co-inciding at the ends.

How does this picture relate to the breaking of conformal symmetry? The idea is simple. One goes to n-fold covering space by replacing z coordinate by $w = z^{1/n}$. With respect to the new variable w one has just the ordinary conformal algebra with integer conformal weights but in n-fold singular covering of complex plane or sphere. Singularity of the generators explains why $L_k(w)$, $k < n$, do not annihilate physical states anymore. Sub-algebra would consist of non-singular generators and would act as symmetries and also the stronger condition that Lk, $k \geq n$, annihilates the physical states could be satisfied. Classically this would mean that the corresponding classical Noether charges for Kähler action are non-vanishing.

Another manner to look the same situation is to use z coordinate. Now conformal weight is fractionized as integer multiples of $1/n$ and since the generators with fractional conformal weight are singular at origin, one cannot assume that they annihilate the physical states: fractional conformal invariance is broken. Quantally the above conditions on physical states would be satisfied. Sphere - perhaps the sphere assigned with the light-cone boundary or geodesic sphere of CP_2 - would be effectively replaced with its n-fold covering space, and due to conformal invariance one would have n additional discrete degrees of freedom.

These discrete degrees of freedom would define n-dimensional Hilbert space space by the n fractional conformal generators. One can also second quantize by assigning oscillator operators to these discrete degrees of freedom. In this picture the effective quantization of Planck constant would result from the condition that conformal weights for the physical states are integers.

2.1.4 Other Connections

The values of effective Planck constants seems to have profound connections to several key ideas of TGD.

1. As already found, the connection with the hierarchy of broken conformal symmetries is highly suggestive. The integer $h_{eff}/h = n$ would characterize the sub-algebra of gauge conformal symmetries.

2. There seems to be a connection with negentropic entanglement [K19] associated with the density matrix of the state resulting in state function reduction, which is proportional to unit matrix - projector to an eigen space of density matrix. Negentropic entanglement would occur in the new discrete degrees of freedom most naturally. In the special 2-particle case negentropic entanglement corresponds to unitary entanglement encountered in quantum computation: large h_{eff} makes possible long-lived entanglement and its negentropic character implies that Negentropy Maximization Principle [K19] favors its generation. An interesting hypothesis to be killed is that the p-adic prime characterizing the space-time sheet string world sheet or partonic 2-surface divides n.

3. The realization of number theoretic univarsality in terms of strong form holography assumes that string world sheets and partonic 2-surfaces serve as "space-time genes" allowing continuation to preferred extremals. These 2-surfaces are characterized by parameters, which belong to an extension of rationals inducing extensions of p-adic number fields. One has a hierarchy of extensions of increasing complexity. Given extension is characterized by preferred primes known as ramified primes with the property that they are products of powers of primes of extension containing higher powers. The product n of ramified rational primes characterizes the extension and is an integer. The preferred p-adic primes could correspond to the prime factors of n and NMP implies a generalization of p-adic length scale hypothesis stating that primes near but below powers of prime are physically favored and thus selected in number theoretic evolution.

   The identification of the of $h_{eff}/h = n$ with the index characterizing ramification is highly suggestive and would lead to a direct connection with the number theoretic view about evolution. Note also that ramification is highly analogous to criticality so that the connection is natural.

2.2 Phenomenological Approach To Criticality

These statements do not have any obvious content for an experimentalist. One should have also a more concrete view about criticality. Theoretician would call this phenomenology.

1. Phase transitions and criticality are essential piece of being alive. Criticality means high sensitivity to signals and makes sensory perception possible. Criticality implies also long range correlations making us coherent units. The long range correlations between people who have never seen each other, like most of us, make possibly society, and demonstrate that the criticality appears also at collective levels of life and consciousness: usually biologists dismiss this. For physicist - at least me - the correlation between behaviors of him and his cat looks like a miracle!

2. Self-organization takes place by phase transitions and criticality with long range correlations. In zero energy ontology (ZEO) self-organisation is however self-organisation for entire temporal patters of space-time dynamics characterised by the 3-surfaces at the ends of causal diamond so that behaviours rather than states emerge. Also the synergy is made possible by criticality.

3. Criticality appears only in a very narrow range of control parameters and is therefore difficult to produce critical systems tend to fall off from criticality: good example is our society which is all the time at the verge of some kind of catastrophe.

One can build refined and highly predictive conformal field theory models but they do not tell what are the microscopic mechanisms behind criticality.

1. What are the space-time correlates for criticality and long range correlations? Something must quite concretely connect the sub-systems, bind them to single coherent unit at criticality. Magnetic flux tubes is of course the TGD based answer! But this is not enough. The

long range correlations must be quantal and this requires that Planck constant is large: $h_{eff} = n/times; h$! Dark matter! The emergence of dark matter phase makes system critical! TGD Universe is critical at fundamental level and this implies that this dark matter is present at all length scales.

2. Long range interactions certainly define a basic characteristic of criticality. How do they emerge? Does some universal mechanism exist? $h_{eff} = n \times h$ hypothesis and p-adic length cale hypothesis allow to understand this. Weak bosons are effectively massless below weak boson Compton length - about 10^{-17} meters. When h_{eff} is scaled up by n, this Compton length is scaled up by n too. Weak interactions would become long ranged below much longer length scale, say even cellular scale and among other things explain chiral selection of biomolecules. Similar argument can be carried out for gluons and dark/p-adically scaled down) quarks and gluons would also appear in living matter.

3. Phase separation is key feature of criticality. How does this separation take place? Is there a universal mechanism as suggested by the fact that at criticality everything is universal. The answer relies on the notion of many-sheeted space-time, $h_{eff} = n \times h$ hierarchy, and the notion of gravitational Planck constant $h_{gr} = GMm/v_0$ introduced originally by Nottale [**?**]. The additional hypothesis [K26]

$$h_{eff} = h_{gr}$$

brings in gravitational interaction: the gravitational Planck constant is assigned with gravitation mediated by magnetic flux tubes connecting the two dark systems. The hypothesis predicts that h_{eff} is proportional to particle mass. This means each particle type is at its own dark flux tube/quantum nicely separated from each other. This would explain the phase separation at criticality even if the phase transformed after criticality to ordinary $h_{eff} = h$ phase. Pollack's exclusion zones (EZs) [L7] show the effect too: charge separation occurs and impurities in EZ get put of it. $h_{eff} = h_{gr}$ hypothesis implies that the scaled up Compton length becomes $\lambda_{gr} = GM/v_0$ and does not depend on particle mass at all: and ideal outcome concerning collective quantum coherence. In living matter with dynamics characterized by phase transitions this phase separation of different biologically important molecules would be in crucial role. The cell would not be anymore a random soup of huge number of different biomolecules but nicely arranged archive.

Critical reader - and even me after 9 ears of work! - can of course ask what the mass M appearing in the formula for h_{gr} really is. The logical answer is that it is the portion of matter that is dark: to this dark particles couple. In the Nottale's original model M and in TGD generalization of this model M corresponds to the entire mass of say Sun. This makes sense only if the approximate Bohr orbits in solar system reflect the situation when most of the matter in solar system was dark. Nowadays this is not the case anymore. For Earth the portion of dark matter in TGD sense should be something like 4×10^{-4} as becomes clear by just looking the values of the energies associated with dark cyclotron photons and requiring that they are in the range of bio-photon energies (dark photons would transforming to ordinary photons produce bio-photons). Without this assumption the range of bio-photon energies would be above 40 keV.

Besides dark matter also p-adically scaled up variants of weak interaction physics are possible: now weak bosons would be light but not massless above the Compton length which would be scaled up. In the TGD based model of living matter both dark matter and p-adically scaled up variants of particles appear and both are crucial for understanding metabolism. Both kind of phases could appear universally in critical systems. Dark matter would be a critical phenomenon and appear also in thermodynamical phase transitions, not only in quantum phase transitions.

Also so called free energy phenomena, cold fusion, remote mental interactions, etc are critical phenomena and therefore very difficult to replicate unless one knows this so that it is very easy to label researchers of these phenomena crackpots. The researchers in these fields could be seen as victims of the phenomenon they are studying! Life of course is also a critical phenomenon but even the vulgar skeptics are living and conscious beings and usually do not try to deny this!

2.3 Do The Magnetic Flux Quanta Associated With Criticality Carry Monopole Flux?

TGD allows the possibility that the magnetic flux quanta associated with criticality carry monopole flux. In Maxwellian electrodynamics this is not possible. These flux tubes are associated with elementary particles: in this case they have open string like portions at parallel space-time sheets connected at their ends by wormhole contacts to form a closed two-sheeted loop. Since the magnetic monopole flux is conserved along the flux tube, one has full reason to wonder whether these closed magnetic flux tubes can be created from vacuum.

One can imagine two manners to create flux loops: in a continuous energy conserving manner classically or by quantum jump in which quantum sub-Universe associated with given causal diamond (CD) is re-created (recall that causal diamonds define the observable Universes and they have finite size as intersections of future and past directed light-ones)

Consider for simplicity flux tubes which are circular. How the flux tubes can be generated?

1. One possibility is that an existing circular flux tube splits into two. This would take place by self-reconnection: circular flux tubes evolves first a figure eight shape, and after that self-reconnects and splits to two circular flux tubes. Figure eight shape is necessary because the direction of the conserved magnetic flux defines orientation and flux tube portions with opposite orientations cannot join. This mechanism allows replication of flux tubes and could be behind the $1 \to 2$ decays of elementary particles and the reverse reactions. It could be also behind biological replication at both DNA and cell level, and even higher levels. The reconnection of U-shaped flux tubes for two systems so that they become connected by a pair of flux tubes is the reverse of this process and is proposed to define fundamental mechanism of directed attention.

2. Can one imagine a purely classical mechanism in which flux tubes would be generated from nothing? An idealization as a closed string allows to imagine a closed string which begins from point and expands: in string models this kind of closed strings indeed pop up from vacuum. Energy conservation however forbids the classical occurrence of this process. Therefore this process is possible only in path integral formalism which allows processes, which are classically impossible.

   In TGD framework space-time surfaces appearing in the functional integral are extremals of Kähler action and conserve energy so that this kind of process is impossible. It is difficult to say what happens when the string is replaced with a flux tube having a a finite thickness: could this make it possible an energy conserving process in which initial state would not contain flux tubes but final would contain flux tubes? At elementary particle level this would mean generation of a particle or a pair from vacuum but this does not take place. Note that the development of Higgs expectation can be interpreted as generation of new vacuum state which contains Higgs bosons: TGD counterpart of the ground state would be a superposition of states containing various numbers of flux loops.

3. One can however consider a *quantum jump* generating flux tube from nothing. The sequence of quantum jumps consist of sub-sequences consisting of state function reductions to a fixed boundary of CD ("upper" or "lower"). A sub-sequence defining self corresponds to a sequence of repeated quantum measurements having no effect on the state in ordinary quantum measurement theory. In TGD state function reduction has effect on the second boundary. Or to be precise, on the wave function in the moduli space associated with the second boundary with moduli characterising among other things the temporal distance from the fixed boundary. This effect gives rise to the experienced flow of time as increase of the average temporal distance between the tips of CD and also to its arrow.

   These state function sequences do not last for ever (self has finite lifetime!): Negentropy Maximization Principle (NMP) eventually forces state function reduction at the opposite boundary of CD. The new state can contain flux loops which did not exist in the initial state. These flux loops could exists also outside the CD but this is not relevant for the physics experienced by the conscious observer associated with given CD.

   The generation of this kind of monopole flux loops from nothing could be seen as a direct proof for macroscopic quantum jumps re-creating the Universe. Penrose proposed something

similar in Shadows of Mind: quasicrystals are non-periodic lattices which look like lattices but - unlike ordinary crystals - cannot be generated by gradual lattice growth but must pop up in quantal manner to existence.

3 What's New In TGD Inspired View About Phase Transitions?

The comment of Ulla mentioned Kosterlitz-Thouless phases transition and its infinite order. I am not a condensed matter physicist so that my knowledge and understanding are rather rudimentary and I had to go to to Wikipedia (see `https://en.wikipedia.org/wiki/Phase_transition`). I realized that I have not payed attention to the classification of types of phase transitions, while speaking of quantum criticality [K36]. Also the relationship of ZEO inspired description of phase transitions to that of standard positive energy ontology has remained poorly understood. In the following I try to represent various TGD inspired visions about phase transitions and criticality in organized manner and relate them to the standard description.

3.1 About Thermal And Quantum Phase Transitions

It is good to beging with something concrete. Wikipedia article lists examples about different types of phase transitions. These phase transitions are thermodynamical.

1. In first order phase thermodynamical phase transitions heat is absorbed and phases appear as mixed. Melting of ice and boiling of water represent the basic examples. Breaking of continuous translation symmetry occurs in crystallization and symmetry is smaller at low temperature. One speaks of spontaneous symmetry breaking: thermodynamical fluctuations are not able to destroy the configuration breaking the symmetry.

2. Second order phase transitions are also called continuous and they also break continuous symmetries. Susceptility diverges, correlation range is infinite, and power-law behaviour applies to correlations. Ferromagnetic, super-conducting, and superfluid transitions are examples. Conformal field theory predics power-law behavior and infinite correlation length. Infinite susceptility means that system is very sensitive to external perturbations. First order phase transition becomes second order transition at critical point. Here the reduction by strong form of holography might make sense for high Tc superconductors at least (they are effectively 2-D).

3. Infinite order phase transitions are also possible. Kosterlitz-Thouless phase transition occurring in 2-D systems allowing conformal symmetries represents this kind of transition. These phase transitions are continuous but do not break continuous symmetries as usually.

4. There are also liquid-glass phase transitions. Their existence is hypothetical. The final state depends on the history of transition. Glass state itself is more like an on going phase transition rather than phase.

These phase transitions are thermal and driven by thermal fluctuations. Also quantum phase transitions (see `https://en.wikipedia.org/wiki/Quantum_phase_transition`) are possible.

1. According to the standard definition they are possible only at zero temperature and driven by quantum fluctuations. For instance, gauge coupling strength would be analogous to quantum temperature. This is a natural definition in standard ontology, in which thermodynamics and quantum theory are descriptions at different levels.

   Quantum TGD can be seen as a square root of thermodynamics in a well-defined sense and it makes possible to speak about quantum phase transitions also at finite temperature if one can identify the temperature like parameter characterizing single particle states as a kind of holographic representations of the ordinary temperature.

2. The traces of quantum phase transitions are argued to be visible also at finite temperatures if the energy gap is larger than the thermal energy: $\hbar\omega >\geq T$. In TGD framework Planck constant has a spectrum $h_{eff}/h = n$ and allows very large values. This allows quantum phase transitions even at room temperature and TGD inspired quantum biology relies crucially on this. What is of special interest that also ordinary thermal phase transitions might be accompanied by quantum phase transitions occurring at the level of magnetic body and perhaps even inducing the ordinary thermal phase transition.

3. Quantum critical phase transitions occur at critical point and are second order phase transitions so that susceptibility diverges and system is highly sensitive to perturbations and so in wide range around critical temperature (zero in standard theory). Long range fluctuations are generated and this conforms with the TGD vision about the role of large h_{eff} phases and generalized conformal symmetry: which also implies that the region around criticality is wide (exponentially decaying correlations replaced with power law correlations).

3.2 Some Examples Of Quantum Phase Transitions In TGD Framework

TGD suggests some examples of quantum phase transition like phenomena.

1. Bose-Einstein (BE) condensate consisting of bosons in same state would represent a typical quantum phase. I have been talking a lot about cyclotron BE condensates at dark magnetic flux tubes [K18, K23, K24]. The bosonic particles would be in the same cyclotron state. One can consider also the analogs of Cooper pairs with members at flux tubes of a pair of parallel flux tubes with magnetic fields in same or opposite direction. One member at each tube having spin 1 or zero. This would give rise to high T_c superconductivity.

2. One natural mechanism of quantum phase transition would be BE condensation to a new single particle state. The rate for an additions of new particle to condensate is proportional to $N + 1$ and disappearance of particle from it to N, where N is the number of particles in condensate. The net rate for BE condensation is difference of these and non-vanishing.

   Quantum fluctuations induce phase transition between states of this condensate at criticality. For instance, cyclotron condensate could make a spontaneous phase transition to a lower energy state by a change of cyclotron energy state and energy would be emitted as a dark cyclotron radiation. This kind of dark photon radiation could in turn induce cyclotron transition to a higher cyclotron state at some other flux tube. If NMP holds true it could pose restrictions for the occurrence of transitions since one expects that negentropy is reduced. The transitions should involve negentropy transfer from the system.

   The irradiation of cyclotron BE condensate with some cyclotron frequency could explain cyclotron phase transition increasing the energy of the cyclotron state. This kind of transition could explain the effecs of ELF em fields on vertebrate brain [J2] in terms of cyclotron phase transition and perhaps serving as a universal communication and control mechanism in the communications of the magnetic body with biological body and other magnetic bodies [K9]. The perturbation of microtubules by an oscillating voltage [J1] (see `https://www.youtube.com/watch?v=VQngptkPYE8`) has been reported by the group of Bandyonophyay [J3] to induce what I have interpreted as quantum phase transition [L13] (see `http://tgdtheory.fi/public_html/articles/anesthetes.pdf`).

   External energy feed is essential and dark cyclotron radiation or generalized Josephson radiation from cell membrane acting as generalized Josephson junction and propagating along flux tubes could provide it. Cyclotron energy is scaled up by h_{eff}/h and would be of the order of biophoton energy in TGD inspired model of living matter and considerably above thermal energy at physiological temperature.

3. Also quantum phase transitions affecting the value of h_{eff} are possible [K32] When h_{eff} is reduced and frequency is not changed, energy is liberated and the transition proceeds without external energy feed (NMP might pose restrictions). Another option is increase of h_{eff} and reduce the frequency in such a manner that that single particle energies are not changed. One can imagine many other possibilities since also p-adic length scale leading to a change of

mass scale could change. A possible biological application is to the problem of understanding how biomolecules find each other in the molecular soup inside cell so that catalytic reactions can proceed. Magnetic flux tubes pairs connecting the biomolecules would be generated in the reconnection of U-shaped tentacle like flux tubes associated with the reactants, and the reduction of h_{eff} for the flux tube pair would contract it and force the biomolecules near each other.

4. The model for cold fusion in TGD Universe relies on a process, which is analogous to quantum phase transition [L11] [**?**]. Protons from the exclusion zones (EZs) of Pollack [L7] [L7] are transferred to dark protons at magnetic flux tubes outside EZ and part of dark protons sequences transform by dark weak decays and dark weak boson exchanges to neutrons so that beta stable dark nuclei are obtained with binding energy much smaller than nuclear binding energy. This could be seen as dark nuclear fusion and quantum analog of the ordinary thermal nuclear fusion. The transformation of dark nuclei to ordinary nuclei by h_{eff} reducing phase transition would liberate huge energy if allowed by NMP [K19] and explain the reported biofusion.

5. Energetics is clearly an important factor (in ordinary phase transitions for open system thermal energy feed is present). The above considerations assume that ordinary positive energy ontology effectively applies. ZEO [K19] allows to consider a more science fictive possibility. In ZEO energy is conserved when one considers single zero energy state as a time evolution of positive energy state. If single particle realizes square root of thermodynamics, one has superposition of zero energy states for which single particle states appear as pairs of positive and negative energy states with various energies: each state in superposition respects energy conservation. In this kind of situation one can consider the possibility that temperature increases and average single particle energy increases. In positive energy ontology this is impossible without energy feed but in ZEO it is not excluded. I do not understand the situation well enough to decide whether some condition could prevent this. Note however that in TGD inspired cosmology energy conservation holds only in given scale (given CD) and apparent energy non-conservation would result by this kind of mechanism.

3.3 ZEO Inspired View About Phase Transitions

This section begins with questions related to TGD based description of phase transitions, discusses the TGD view about the role of symmetries in phase transitions, and asks what new ZEO can give to the description of phase transitions.

3.3.1 Question related to TGD inspired description of phase transitions

The natural questions are for instance following ones.

1. The general classification of thermodynamical phase transitions is in terms of order: the order of the lowest discontinuous derivative of the free energy with respect to some of its arguments. In catastrophe theoretic description one has a hierarchy of criticalities of free energy as function of control variables (also other behavior variables than free energy are possible) and phase transitions with phase transitions corresponding to catastrophe containing catastrophe.... such that the order increases. For intance, for cusp catatrophe one has lambda-shaped critical line and critical point at its tip. Thom's catastrophe theory description is mathematically very attractive but I think that it has problems at experimental side. It indeed applies to flow dynamics defined by a gradient of potential and thermodynamics is something different.

   In TGD framework the sum of Kähler function defined by real Kähler action in Euclidian space-time regions and imaginy Kähler action from Minkowskian space-time regions defining a complex quanty replaced free energy. This is in accordance with the vision that quantum TGD can be seen as a complex square root of thermodynamics. Situation is now infinite-dimensional and catastrophe set would be also infinite-D. The hierarchy of isomorphic superconformal algebras defines an infinite hierarchy of criticalities with levels labelled by Planck constants and catastrophe theoretic description seems to generalize.

Does this general description of phase transitions at the level of dark magnetic body (field body is more general notion but I will talk about magnetic body (MB) in the sequel) allow to understand also thermodynamical phase transitions as being induced from those for dark matter at MB?

2. Quantum TGD can be formally regarded as a square root of thermodynamics. Does this imply "thermal holography" meaning that single particle states can represent ensemble state as square root of the thermal state of ensemble. Could one unify the notions of thermal and quantum phase transition and include also the phase transitions changing h_{eff}? Could MB make this possible?

3. How does the TGD description relate to the standard description? TGD predicts that conformal gauge symmetries correspond to a fractal hierarchy of isomorphic conformal sub-algebras. Only the lowest level with maximal conformal symmetry matters in standard theory. Are the higher "dark" levels something totally new or do they appear in the description of also ordinary phase transitions? What is the precise role of symmetries and symmetry changes in TGD description and is this consistent with standard description. Here the notion of field body is highly suggestive: the dynamics of field body could induce the dynamics of ordinary matter also in phase transitions.

There is a long list of questions related to various aspects of TGD based description of phase transitions.

1. In TGD framework NMP applying to single system replaces second law applying to ensemble as fundamental description. Second law follows from the randomness of the state function reduction for ordinary matter and in long length and time scales from the ultimate occurrence of state function reductions to opposite boundary of CD in ensemble. How does this affect the description of phase transitions? NMP has non-trivial implications only for dark matter at MB since it NMP does favor preservation and even generation of negentropic entanlement (NE). Does NMP imply that MB plays a key role in all phase transitions?

2. Does strong form of holography of TGD reduce all transitions in some sense to this kind of 2-D quantum critical phase transitions at fundamental level? Note that partonic 2-surfaces can be seen as carriers of effective magnetic charges and string world sheets carrying spinor modes accompany magnetic flux tubes. Could underlying conformal gauge symmetry and its change have practical implications for the description of all phase transitions, even 3-D and thermodynamical phase transitions?

3. Could many-sheetedness of space-time - in particular the associated p-adic length scale hierarchy - be important and could one identify the space-time sheets whose dynamics controls the transition? Could the fundamental description in terms of quantum phase transitions relying on strong form of holography apply to all phase transitions? Could dark phases at MB be the key to the description of also ordinary thermodynamical phase transitions? Could one see dark MB as master and ordinary matter as slave and redue the description of all phase transitions to dark matter level.

   Could the change of h_{eff} for dark matter at field body accompany any phase transition - even thermodynamical - or only quantum critical phase transition at some level in the hierarchy of space-time sheets? Or are also phase transitions involving no change of h_{eff} possible? Do ordinary phase transitions correspond to these. What is the role of h_{eff} changing "transitons" and their dynamical symmetries?

4. The huge vacuum degeneracy of Kähler action implies that any space-time surface with CP_2 projection that is Lagrangian manifold and has therefore dimension not larger than two, is vacuum extremal. The small deformations of these vacuum extremals define preferred extremals. One expects that this vacuum degeneracy implies infinite number of ground states as in the case of spin glass (magnetized system consisting of regions with different direction of magnetization). One can speak of 4-D spin glass. It would seem that the hierarchy of Planck constants labelling different quantum phases and the phase transitions between these

phases can be interpreted in terms of 4-D spin glass property? Besides phases one would have also phase transitions having "transitons" as building bricks.

It seems that one cannot assign 4-D spin glass dynamics to MB. If magnetic flux tubes are carriers of monopole flux, they cannot be small local deformations of vacuum extremals for which Kähler form vanishes. Hence 4-D spin glass property can be assigned to flux tubes carrying vanishing magnetic flux. Early cosmology suggests that cosmic strings as infinitely flux tubes having 2-DCP_2 projection and carrying monopole flux are deformed to magnetic flux tubes and suffer topological condensation around vacuum extremals and deform them during the TGD counterpart of inflationary period.

Remark: Glass state looks like a transition rather than state and ZEO and 4-D spin glass description would seem to fit naturally to his situation: glass would be a 4-D variant of spin glass. The time scale of transition is long and one might think that h_{eff} at the space-time sheet "controlling" transition is rather large and also the change of h_{eff} is large.

3.3.2 Symmetries and phase transitions

The notion of symmetry is considerably more complex in TGD framework than in standard picture based on positive energy ontology. There are dynamical symmetries of dark matter states located at the boundaries of CD. For space-time sheets describing phase transitions there are also dynamical symmetries but they are different. In standard physics one has just states and their symmetries. Conformal gauge symmetries forming a hierarchy: conformal field theories this symmetry is maximal and the hierarchy is absent.

1. There is importance and very delicate difference between thermal and thermodynamical symmetries. Thermal symmetries are due to thermal equilibrium implying symmetries in *statistical sense*. Quantal symmetries correspond to representations of symmetry group and are possible if thermal fluctuations do not transform the states of the representations the states of other representation.

   Dark dynamical symmetries are quantum symmetries. The breaking of thermal translational symmetry of liquid leads to discrete translational symmetry of crystal having interpretation as quantum symmetry. The generation of continuous thermal translational symmetry from discrete quantum symmetry means loss of quantum symmetry. To my opinion, standard thinking is sloppy here.

2. For thermodynamical phase transitions temperature reduction induces spontaneous breaking of symmetry: consider only liquid-to-crystal transition. Analogously, in gauge theories the reduction gauge coupling strength leads to spontaneous symmetry breaking: quantum fluctuations combine representation of sub-group to a representation of larger group. It would seem that spontaneous symmetry breaking actually brings in a symmetry and the ubroken symmetry is "thermal" or pure gauge symmetry. QCD serves as an example: as strong coupling strength (analogous to temperature) becomes large confinement occurs and color symmetry becomes pure gauge symmetry.

3. In TGD the new feature is that there are two kinds of symmetries for dark conformal hierarchies. Symmetries are either pure gauge symmetries or genuine dynamical symmetries affecting the dark state at field body physically. As h_{eff} increases, the conformal pure gauge symmetry is reduced (the conformal gauge algebra annilating the states becomes smaller) but dynamical symmetry associated with the degrees of freedom above measurement resolution increases. In ordinary conformal theories pure gauge conformal symmetry is always maximal so that this phenomenon does not occur.

   The intuitive picture is that the increase of dynamical symmetry induced by the reduction of pure gauge conformal symmetry occurs as temperature is lowered and quantum coherence in longer scales becomes possible. This conforms with the thermodynamical and gauge theory views if pure gauge symmetry is identified as counterpart of symmetry as it is understood in thermodynamics and gauge theories.

   The dynamical symmetry of dark matter however increases. This symmetry is something new and would be genuine quantum symmetry in the sense that quantum fluctuations respect

the representations of this group. The increase of h_{eff} indeed implies reduction of Kähler coupling strength analogous to reduction of temperature so that these quantum symmetries can emerge.

4. There is also a dynamical symmetry associated with phase transitions $h_{eff}(f) = m \times h_{eff}(i)$ such that m would define the rank of ADE Lie group G classifying states of "transitons". Lie groups with ranks $n_{eff}(i)$ and $n_{eff}(f)$ would be ranks for the Lie group G in the initial and final states. G would correspond to either gauge (not pure gauge) or Kac-Moody symmetry as also for corresponding dynamical symmetry groups associated with phases.

5. An interesting question relates to Kosterlitz-Thouless Thouless phase transition (see `https://en.wikipedia.org/wiki/KosterlitzThouless_transition`), which is 2-D and for which symmetry is not changed. Could one interpret it as a phase transition changing h_{eff} for MB: symmetry group as abstract group would not change although the scale in which acts would change: this is like taking zoom. The dynamical symmetry group assignable to dark matter at flux tubes would however change but remain hidden.

To sum up, the notion of magnetic (field) body might apply even to the ordinary phase transitions. Dark symmetries - also discrete translational and rotational symmetries - would be assigned with dark MB possibly present also in ordinary phases. The dynamical symmetries of MB would bring a new element to the description. Ordinary phase transitions would be induced by those of MB. This would generalize the vision that MB controls biological body central for TGD view about living matter. In the spirit of slaving hierarchy and TGD inspired vision about quantum biology, ordinary matter would be slave and MB the master and the description of the phase transitions in terms of dynamics of master could be much more simpler than the standard description. This would be a little bit like understanding technical instrument from the knowledge of its function and from control level rather than from the mere physical structure.

3.3.3 What ZEO can give to the description of criticality?

One should clarify what quantum criticality exactly means in TGD framework. In positive energy ontology the notion of state becomes fuzzy at criticality. It is difficult to assign long range fluctuations and associated quanta with any of the phases co-existent at criticality since they are most naturally associated with the phase change. Hence Zero Energy Ontology (ZEO) might show its power in the description of (quantum) critical phase transitions.

1. Quantum criticality could correspond to zero energy states for which the value of h_{eff} differs at the opposite boundaries of causal diamond (CD). The space-time surface between boundaries of CD would describe the transition classically. If so, then quanta for long range fluctuations would be genuinely 4-D objects - "transitons" - allowing proper description only in ZEO. This could apply quite generally to the excitations associated with quantum criticality. Living matter is key example of quantum criticality and here "transitons" could be seen as building bricks of behavioral patterns. Maybe it makes sense to speak even about Bose-Einstein condensates of "transitons".

2. Quantum criticality would be associated with the transition increasing $n_{eff} = h_{eff}/h$ by integer factor m or its reversal. Large h_{eff} phases as such would not be quantum critical as I have sloppily stated in several contexts earlier. $n_{eff}(f) = m \times n_{eff}(i)$ would correspond to a phase having longer long range correlations as the initial phase. Maybe one could say that at the side of criticality (say the "lower" end of CD) the $n_{eff}(f) = m \times n_{eff}(i)$ excitations are pure gauge excitations and thus "below measurement resolution" but become real at the other side of criticality (the "upper" end of CD)? The integer m would have clear geometric interpretation: each sheet of n_i-fold coverings defining space-time surface with sheets co-inciding at the other end of CD would be replaced with its m-fold covering. Several replications of this kind or their reversals would be possible.

3. The formation of m-fold covering could be also interpreted in terms of an inclusion of hyperfinite factors labelled by integer m. This suggests a deep connection with symmetries of dark matter. Generalizing the McKay correspondence between finite subgroups of SU(2)

characterizing the inclusions and ADE type Lie groups, the Lie group G characterizing the dynamical gauge group or Kac-Moody group for the inclusion of HFFs characterized by m would have rank given by m (the dimension of Cartan algebra of G).

These groups are expected to be closely related to the inclusions for the fractal hierarchy of isomorphic sub-algebras of super-symplectic subalgebra. $h_{eff}/h = n$ could label the sub-algebras: the conformal weights of sub-algebra are n-multiples of those of the entire algebra. If the sub-algebra with larger value of n_{eff} annihilates the states, it effectively acts as normal subgroup and one can say that the coset space of the two super-conformal groups acts either as gauge group or (perhaps more naturally) Kac-Moody group. The inclusion hierarchy would allow to realize all ADE groups as dynamical gauge groups or more plausibly, as Kac-Moody type symmetry groups associated with dark matter and characterizing the degrees of freedom allowed by finite measurement resolution.

4. If would be natural to assign "transitons" with light-like 3-surfaces representing parton orbits between boundaries of CD. I have indeed proposed that Kac-Moody algebras are associated with parton orbits where super-symplectic algebra and conformal algebra of light-one boundary is associated with the space-like 3-surfaces at the boundaries of CD. This picture would provide a rather detailed view about symmetries of quantum TGD.

The number-theoretic structure of h_{eff} reducing transitions is of special interest.

1. A phase characterized by $h_{eff}/h = n_{eff}(i)$ can make a phase transition only to a phase for which $n_{eff}(f)$ divides $n_{eff}(i)$. This in principle allows purely physics based method of finding the divisors of very large integers (gravitational Planck constant $h_{gr} = GMm/v_0 = h_{eff} = n \times h$ defines huge integer).

2. In TGD inspired theory of consciousness a possible application is to a model for how people known as idiot savants unable to understand what the notion of prime means are able to decompose large integers to prime factors [K25]. I have proposed that the division to prime factors is a spontaneous process analogous to the splitting of a periodic wave characterized by wave length $\lambda/\lambda_0 = n_i$ to a wave with wavelength $\lambda/\lambda_0 = n_{eff}(f)$ with $n_{eff}(f)$ a divisor of $n_{eff}(i)$. This process might be completely spontaneous sequence of phase transitions reducing the value of n_{eff} realized geometrically as the number of sheets of the singular covering defining the space-time sheet and somehow giving rise to a direct sensory percept.

4 Applications of quantum criticality

During years I have proposed several examples about systems to which I have assigned non-standard value of Planck constant $h_{eff} = n \times h$. If the hypothesis about the connection with criticality is correct they should exhibit criticality and if $h_{eff} = h_{gr}$ hypothesis is true, also phase separation. Also the proposed mechanisms to generate dark matter should involve generation of criticality.

4.1 Particle Physics

In particle physics there are some possible applications for the new view about dark matter.

1. The perturbative expansion of scattering amplitudes in terms of gauge coupling strength or gravitational coupling strength ceases to converge at some critical value of the coupling parameter. This can be regarded as a critical phenomenon since a transition to strongly coupled phase with different properties takes place. For instance, in gauge theories according to the electric-magnetic duality the magnetic monopoles replaces charged particles as natural basic entities. The original proposal indeed was that the transition to large h_{eff} phase takes place when the perturbation theory in terms of say electromagnetic coupling strength $Z_1 Z_2 e^2/\hbar c$ ceases to converge. By replacing h with $h_{em} = Z_1 Z_2/e^2 h_{eff}$ the convergence is achieved and v_0/c replaces gauge coupling strength as coupling constant. A stronger hypothesis is that $h_{eff} = h \times h = h_{em}$ would connect this hypothesis with generalized conformal invariance and its breaking.

2. One of the earliest applications of TGD notion of color (associated not only with quarks and gluons but also leptons through color partial waves) was to to explain anomalous production of electron-positron pairs in heavy ion collisions just above the Coulomb wall [C5, C3, C4, C6]. The TGD inspired hypothesis [K29] was that the electron positron pairs result from the decays of leptopions, which are pion-like color singlet bound states of color octet excitations of electron and positron but one could consider also other options. The identification as positronium is excluded since in this case direct decays would not be kinematically possible. The objection against postulating new elementary light particles is that they should make themselves visible in the decay widths of weak bosons.

   One manner to escape the problem is that spartners are heavy so that the decays of weak bosons to spartner pairs are not possible. Another explanation could be that the exotic particles involved correspond to non-standard value of Planck constant. As a matter fact, these particles could be very massive but due to the large value of h_{eff} would appear as effectively massless particles below the scaled-up Compton length.

   One can consider also other identifications for the new particles possibly involved. TGD predicts that right handed covariantly constant neutrino generates $\mathcal{N} = 2$ supersymmetry. An elegant universal explanation for the absence of spartners would be that they are heavy but can make themselves visible as dark variants in scales below scaled up Compton length. Maybe the lepto-electrons are selectrons possibly moving in color octet partial wave!

   This explanation would apply to all elementary elementary particles and predict that these particles can be produced only in critical systems. This would solve the puzzle created by the non-observation of standard $\mathcal{N} = 1$ SUSY and at LHC. Leptopion production indeed takes place at criticality: just above the Coulomb wall, when the incoming nucleus becomes able to collide directly with the target. It should be noticed that there is experimental evidence also for the leptopions associated with muon and tau [K29].

3. RHIC and later LHC found that the de-confinement phase transition (criticality is obviously involved!) supposed to lead to QCD plasma produced something different. The phase in question has long range correlations and exhibits the presence of string like structures decaying to ordinary hadrons. There is also evidence for strong parity breaking in the system and it is involved with the magnetic fields present [C1]. TGD interpretation could be in terms of a criticality in which long range correlations are generated as dark matter is created. Since strong parity breaking is involved, it seems that the dark particles must be associated with the weak length scale characterized by Mersenne prime M_{89}, which characterizes also the "almost-predicted"! scaled up copy of ordinary hadron physics characterize by Mersenne prime M_{107}. The mass scale is 512 times higher than for ordinary hadrons. Due to darkness the Compton scales of M_{89} hadrons and also weak bosons would be scaled up to about M_{107} p-adic scale if $h_{eff}/h = 2^9$ holds true.

4.2 Condensed Matter Physics

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 the association with dark matter would suggest that dark matter could appear in these critical systems.

2. Different substances can form mixtures (`http://en.wikipedia.org/wiki/Mixture`). 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://en.wikipedia.org/wiki/Solution`), colloids (`http://en.wikipedia.org/wiki/Colloid`), dispersions (`http://en.wikipedia.org/wiki/Dispersion`) 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.

4.3 Living Matter

Biology is full of critical systems and criticality makes living matter highly sensitive to the external perturbations, gives maximal richness of structure, and makes them quantum coherent in macroscopic scales. Therefore it is not difficult to invent examples. The basic problem is whether the criticality is associated only with the transitions between different systems or with the systems themselves.

1. Sols and gels are very important in biology. Sol is definition a micture solid grains and liquid (say blood of cell liquid). Gel involves fixed solid structure and liquid. Sol-gel phase transition of the cell fluid takes place when nerve pulse travels along axon leading to the expansion of the cell. Is the dark phase generated with the sol-gel transition or does it characterized sol. Perhaps the most logical interpretation is that it is involved with the phase transition.

2. Pollack's fourth phase of water resembles gel [L7]. Charge separation implying that the exclusion zones are negatively charged takes place. Charging takes place because part of protons goes to outside of EZ. TGD proposal is that protons go to magnetic flux tubes outside the region or to flux tubes which are considerably larger than EZ that most of their wave functions is located outside the EZ. Is fourth phase is permanently quantum critical? Or is the quantum criticality associated only with the transition so that magnetic flux tubes would carry protons but they would not be dark after the phase transition. EZs have a strange property that impurities flow out of them. Could the presence of dark flux tubes and $h_{eff} = h_{gr}$ forces the separation of particles with different masses?

3. The chirality selection of bio-molecules is a mystery from the point of view of standard physics. Large h_{eff} phase with so large value of Planck constant that the Compton length of weak bosons defines nanoscale, could explain this: weak bosons would be effectively massless and mediate long range interactions below the scaled up Compton scale. This phase transition could also force phases separation if $h_{gr} = h_{eff}$ holds true. If the masses of biomolecules with different handedness are slightly different also the values of h_{gr} would differ and the molecules would go to flux tubes with different value of h_{eff} - at least in the phase transition. The value of $h_{gr} = GMm/v_0$ is in the range $10^{10} - 10^{11}$ for biomolecules so that the $\Delta n/n \simeq \Delta m/m \simeq 10^{-10} - 10^{-11}$ would be needed: this would correspond to an energy of eV which corresponds to the energy scale of bio-photons and visible light.

4. Neuronal membrane could be permanently a critical system since the membrane potential is slightly above the threshold for nerve pulse generation. Criticality might give rise to the dark magnetic flux tubes connecting lipids to the DNA nucleotides or codons assumed in the model of DNA as topological quantum computer. The braiding of the flux tubes would represent the effect of the nerve pulse patterns and would be generated by the 2-D flow of the lipids of the membrane forming a liquid crystal.

4.4 Fringe Physics

If one wants the label of crackpot it is enough to study critical phenomena. Those who try to replicate (or usually, to non-replicate) the claimed findings fail (or rather manage) easily since criticality implies careful tuning of the external parameters to demonstrate the phenomenon. Therefore the tragedy of fringe physicist is to become a victim of the phenomenon that he is studying.

1. Cold fusion involves bombarding of target consisting of Palladium target doped with deuterium using hydrogen atoms as projectiles. Cold fusion is reported to occur in a critical range of doping fraction. This suggests quantum criticality and large h_{eff} phase. One of the TGD based models generalizes the model of Widom and Larsen [C2]. The model assumes that weak interactions involving emission of W boson neutralizing the incoming proton makes possible to overcome the Coulomb wall. What would make the system critical? Does criticality make Palladium a good catalyst? Could the Palladium and with a large surface area define nano-scale variant of partonic 2-surface and large area which quite generally would make it effective as catalyst? Certainly this could hold true for bio-catalysts. Could Pd target be permanently in critical state? Effectiveness of catalyst might mean quantum coherence making chemical reaction rates proportional to N^2 instead of N, which could be the number of reactants of particular kind.

2. Di-electric breakdown in given medium occurs when the electric field strength is just above the critical value. A lot of strange claims have been assigned to these systems by non-professionals: in academic environment these phenomena are kind of taboo. Tesla studied them and was convinced that these phenomena involve new physics [K34]. The basic finding was that that charges appeared everywhere: this certainly conforms with long range fluctuations and emergence of flux tubes carrying charged particles as dark matter to the environment. Unfortunately, recent day physicist regards Tesla's demonstrations as a mere entertainment and does not bother to ponder whether Maxwell's theory really explains what happens. It is tragic that the greatest intellectual achievements stop thinking for centuries. $h_{gr} = h_{eff}$ hypothesis allows even to estimate the length scales range in which these phenomena should appear.

   Ball lightning (`http://en.wikipedia.org/wiki/Ball_lightning`) is also a good candidate for an analogous phenomenon and has been admitted to be a real phenomenon after sixties even by skeptics.

   C. Seward has discovered that di-electric breakdowns generate rather stable torus-like magnetic flux tubes around the breakdown current [H1] (`http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6748850`), which he calls ESTSs (Electron Spiral Toroid Spheromak) and proposed that ball lightnings might correspond to rotating ESTSs.

   In TGD framework the stability might be understood if the toroid corresponds to a magnetic flux tube carrying monopole flux. This would allow to understand stability of the configuration and of ball lightning. Monopole flux tubes could also provide a solution to the plasma confinement problem plaguing hot fusion. Also ordinary lightnings involve poorly understood aspect such as gamma and X-ray bursts and high energy electrons. The common mystery is how the dissipation in atmosphere could allow this phenomena. A possible explanation would be in terms of dark flux tubes generated near criticality to the generation of lightning.

3. So called free energy systems [H3] (for TGD inspired view see the book [K27] include many phenomena claimed to involve a liberation of surplus energy. To my opinion, it is quite possible that over-unity energy production is a transient phenomenon and the dreams about final solution of energy problems will not be fulfilled. What makes these phenomena so interesting to me is that they might involve new physics predicted or at least allowed by TGD.

   The splitting of water represents besides magnetic motors (to be discussed below) a key example of free energy phenomena. In the splitting of water to oxygen and hydrogen the formation of Brown gas [H3] (Wikipedia article about Brown gas `http://en.wikipedia.org/wiki/Oxyhydrogen` provides an amusing example full of "fringe science"s about how skeptic writes about something inducing cognitive dissonance in skeptic's mind) with strange properties was reported long time ago. For instance, Brown gas is reported to melt metals whose melting temperature is thousands of degrees although the Brown gas itself has temperature of order 100 degrees Celsius.

   I have proposed an interpretation as large h_{eff} phase containing dark proton sequences at magnetic flux tubes and responsible for the liberation of energy as this phase transforms to ordinary one. Brown's gas could be essentially the fourth phase of water containing

exclusion zones (EZs) discovered by Pollack [L7]. The TGD inspired model for them [L7] involves magnetic flux tubes at which part of protons in EZ is transferred and forms dark proton sequences- essentially dark protons. There a many manners to generate Brown's gas: for instance, cavitation due to the mechanical agitation and application of electric fields could do it. The expanding and compressing bubble created by acoustic wave in sono-luminescence and reported to have a very high temperature and maybe even allowing nuclear fusion, could be also EZ.

4. Water memory [I5, I6, I1] is one of the curse words of skeptic and related to scientific attempts to understand the claimed effects of homeopathy, which defines even stronger curse word in the vocabulary of skeptic - of equal strength as "remote mental interaction". The simple idea that the mere presence of original molecules could be replaced by electromagnetic representation of relevant properties of the molecule is utterly impossible for a skeptic to grasp - despite that also skeptic lives in information society. I have developed a model for water memory explaining also claimed homeopathic effects [K15] and this process has been extremely useful for the development of the model of living matter. Same mechanisms that apply to the model of living matter based on the notion of magnetic body, apply also to water memory and remote mental interactions.

   The key idea is that low energy frequency spectrum provides a representation for the bio-active molecules. The spectrum could be identified as cyclotron frequency spectrum associated with the magnetic bodies of EZs and allow them to mimic the bio-active molecule as far as the effects on living matter are considered. The mechanical agitation of the homeopathic remedy could generate EZs just as it generates cavitation. The model for dark proton sequences yields counterparts of DNA, RNA, amino-acids and even tRNA and genetic code based primitive life would be realized at fundamental particle level with biological realization serving as a higher level representation.

The above sections only list examples about systems where dark matter in TGD sense could appear. A lot of details remain to be understood. The basic question whether some of these systems are permanently near critical state or only in phase transitions between different phases.

4.5 Proposed Mechanisms For Generating Large h_{eff} Phase

I have proposed several mechanisms, which might generate large h_{eff} phase, and an interesting question is whether these mechanisms generate criticality.

1. Generation of strong electric fields near criticality for the di-electric breakdown is consistent with criticality and living matter would provide a key example in this respect. Teslas's strange findings support the view about presence of dark matter phases.

2. The findings of Cyril Smith [I3] suggesting a pairing between low and high em frequencies such that low frequency irradiation of bio-matter creates regions to which one can assign high frequency and corresponding wavelength as a size scale. TGD explanation would be that the ratio f_h/f_l of high and low frequencies equals to the $h_{eff}/h = n$, and there is a criticality in the sense that for integer values of this frequency ratio a phase transition transforming dark low energy photons to high frequency of same energy or vice versa can take place. The reverse transition might be interpreted as an analog of Bose-Einstein condensation for low frequency photons (recall the n-fold covering property). The criticality would thus be associated with the formation of the analog of Bose-Einstein condensate.

3. I have proposed that rotating systems could in certain circumstances make a transition to a critical state in which large h_{eff} phase is generated.

   (a) First motivation comes from a model for the findings reported by Russian experimentalists Roschin and Godin [H4] who studied a rotating magnetic system probably inspired by the work of british inventor Searl. The experimenters claim several unexpected effects near criticality for mechanical breakdown of the system. For instance, cylindrical magnetic walls of thickness of few centimeters with distance of order.5 meters are

formed. The system starts to accelerate spontaneously. Cooling of the nearby environment is reported. Also visible light probably due to di-electric breakdown - another critical phenomenon - are reported.

One of the proposed TGD inspired explanations [K2] suggests that there is energy and angular momentum transfer from the magnetic walls which could contain dark matter. Dark photons at cyclotron frequencies but possessing energies of visible photons could make the energy transfer very effective. One possibility is the change of direction for spontaneous dark magnetization emitting large amount of energy. Also collective cyclotron transitions reducing the angular momentum of Bose-Einstein condensate like state can be considered.

(b) Second motivation comes from the magnetic motor of Turkish inventor Yildiz [H2, H5], which run for hours in a public demonstration. I have developed a model of magnetic motor, which might contain the essential elements of the motor of Yildiz.

The key idea is that radial permanent magnets generate magnetic monopole flux tubes emanating radially through the stator and rotor returning back along z-axis. Monopole character implies that no current to preserve the magnetic field. This I think is essential.

If the rotor consist of magnets tangential to a circle, a constant torque is generated. Angular momentum and energy conservation of course requires a feed of energy and angular momentum. If dark matter phase is generated, it could come from some magnetic body containing charged particles with spontaneous magnetization and carrying both spin and energy. Also angular momentum of cyclotron Bose-Einstein condensate can be considered. One possibility is that the dark matter associated with Earth estimated later to be a fraction of about $.2 \times 10 \times -4$ of Earth's mass is the provider of angular momentum and energy. The system is certainly critical in the sense that it is near the mechanical breakdown and in some demonstrations the breakdown has also occurred. This of course raises the possibility that the energy feed comes from mechanical tensions.

(c) Third motivation comes from a model of a rotating system to which constant torque is applied. This situation can be described in terms of potential function $V = \tau\phi$ and modelled using Schrödinger equation [K17]. Since V is not periodic function of ϕ, the solution cannot be periodic if τ lasts forever. It is however possible to have a situation in which the duration T of τ is finite. In this case one can consider the possibility that the phase space which is in the simplest situation circle is replaced with its n-fold covering and solutions are periodic with period $n \times 2\pi$ during the period T and before it energy eigenstates for a free system. The average energy for the final state would be differ from that for the initial state and the difference would be the energy fed to the system equal to $\Delta E = \tau\Delta\phi$ classically. During energy feed the systems wave functions have $1/n$-fractional angular momenta unless one assumes $h_{eff} = n \times h$ phase.

What is intriguing that also stationary solutions are obtained: the equation reduces to that for Airy functions in this case. These solutions do not however satisfy periodicity condition for any finite n. Solutions located in a finite covering of circle cannot be energy eigenstates. Could the constancy of energy mean that no dissipation takes place and no energy is feed to the system.

This description brings in mind the general view about large h_{eff} phases as being associated with the breaking of conformal invariance. n could characterize the number of sheets of the covering of S^2. What does criticality correspond to now? Why should angular momentum and energy feed require or imply criticality? There is also a criticality associated with the change of n as the minimum number of periods that τ lasts. If this is the correct identification, the value of n would increase after every turn in positive energy ontology. In ZEO it would be pre-determined and determined by the duration of τ.

The motivation for the model comes from the ATPase molecule (`http://en.wikipedia.org/wiki/ATPase`), which is a basic tool in energy metabolism. ATPase can be regarded as a molecular motor taking its energy from the change of the energy of protons

as they flow through the cell membrane. Three ADPs are transformed to ATP during single turn by giving them phosphate molecule. What could make the system critical? The system in question is not neuronal membrane but there is tendency to consider the possibility that also the mitochondrial membrane potential is near to breakdown value and the flow of protons through it is the counterpart for nerve pulse.

4. TGD inspired model [L6] for the recent findings about microtubules by the group of the group of Bandyonopadhyay. [J1, J3] is based on the assumption that the oscillatory em perturbation of the system induces generation of A type microtubules not present in Nature by a phase transition from B type microtubules. This phenomenon would take for a critical frequency and $f_h/f_l = n$ condition is suggestive. The proposal is that large h_{eff} phase is generated and gives rise to long range correlations at the level of microtubule so that 13-tubulin units combine to form longer units and the broken helical symmetry becomes un-broken symmetry. Quite recently also an observation of short lasting (nanoseconds) super-conductivity at room temperature (`http://www.sciencealert.com/physicists-achieve-superconductivity-at-room-temperature`) induced by irradiation of high temperature super conductor with infrared light. The mechanism could be similar and involve $f_h/f_l = n$ condition.

5 Applications To Condensed Matter

5.1 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://www.eurekalert.org/pub_releases/2014-11/iopc-tm112614.php`) telling about mysterious looking action at a distance between liquid containers.

For several years it has been that 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://journals.aps.org/prl/abstract/10.1103/PhysRevLett.113.077204`) 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 [D5] (`http://www.nature.com/nphys/journal/v6/n7/full/nphys1671.html`). 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 (IPCPACW) has developed a theory to exlain the observations [B1] (`http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.113.077204`). 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 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 $h_{eff} = h_{gr} = GMm/v_0$

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.

5.2 The Behavior Of Superfluids In Gravitational Field

Superfluids apparently defy gravitational force as so called fountain effect (`http://en.wikipedia.org/wiki/Superfluid_helium-4`) 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.

5.2.1 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 [D6] "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.

5.2.2 TGD inspired model for the fountain effect

What could be the TGD explanation for fountain effect?

1. 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 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 dark phase of $4^H e$ located at flux quanta. The natural candidates for the flux quanta is flux sheet connecting the vessel to the external world or smaller vessel and larger vessel to each other. Flux sheet sheet would accompany the film covering the inside and outside walls.

2. The identification $h_{eff} = h_{gr}$, where h_{gr} is what I call gravitational Planck constant

$$h_{gr} = \frac{GMm}{v_0} = \frac{r_S m}{2\beta_0} \quad , \quad \beta_0 = \frac{v_0}{c} \tag{5.1}$$

makes the model quantitive. 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 would be some characteristic velocity for Earth-superfluid system and the rotation velocity $v_0 = 465.1$ m/s of Earth is a good candidate in this respect. Also the radius of Earth $R_E = 6.38 \times 10^6$ meters will be needed.

3. In TGD inspired biology the hypothesis $h_{gr} = h_{eff} = n \times h$. One of the basic implications is that the energies of cyclotron photons associated with magnetic flux tubes have universal energy spectrum since the dependence on the mass of the charged particle disappears. Also the gravitational Compton length. 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 in the recent case. The scale of the superfluid system is thus much smaller than the coherence length.

4. 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. Now the coherence length of 645 meters justifies the application of Schrödinger equation.

A simple model for the situation would be based 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.

1. One obtains 1-dimensional Schrödinger equation

$$(-\frac{\hbar^2 \partial_z^2}{2m} + mgz)\Psi = E\Psi \quad . \tag{5.2}$$

2. By introducing dimensionless variable

$$u = \frac{z - \frac{E}{mg}}{z_0} \quad , \quad z_0 = \left[\frac{2m^2 g}{\hbar^2}\right]^{-1/3} \quad . \tag{5.3}$$

One can cast the equation to the standard form of the equation for Airy functions encountered in WKB approximation

$$-\frac{d^2\Psi}{du^2} + u\Psi = 0 \quad . \tag{5.4}$$

3. 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. The corresponding value of z is just the length z_0 already defined:

$$z_0 = \left[\frac{r_S(E) R_E^2}{4\pi\beta_0^2}\right]^{1/3} \quad . \tag{5.5}$$

4. By feeding in the values of various parameters one obtains $z = 2.85 \times 10^7$ meters. This corresponds to a time scale of.1 seconds in good approximation and this in turn defines a fundamental bio-rhythm and secondary p-adic time scale for electron. The value of z is somewhat smaller than the circumference of Earth which corresponds to Schumann resonance 7.8 Hz. This co-incidence is not trivial and together with many other similar "co-incidences" provides further support for the deep interconnections between gravitation and biology suggested by TGD.

   From the large value of z_0 it is clear that the quantum motion of the ^4He is essentially free motion in the scales considered so that one can understand why it apparently defies gravitation.

5.2.3 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.

1. 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.

2. 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.

3. 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.

5.2.4 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://phys.org/news/2010-10-fluid-dynamics-insights-quantum-mechanics.html`) providing this kind of evidence is performed by Yves Couder and Emmanuel Fort (see for instance [D1]). Mathematician John W. M. Bush has commented [D4] (`http://www.pnas.org/content/107/41/17455.full`) 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 (`https://en.wikipedia.org/wiki/Faraday_wave`) 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 Bom theory (`https://en.wikipedia.org/wiki/De_BroglieBohm_theory`). 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 super-symplectic 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 [K38]. 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} [K40]. 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}.

5.3 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" [L12] (`http://www.sciencemag.org/content/early/2015/07/01/science.aaa7974`). There is also a popular article with title "Paradoxical Crystal Baffles Physicists" in Quanta Magazine summarizing the findings (`https://www.quantamagazine.org/20150702-paradoxical-crystal-baffles-physicis`
I learned about the finding first from the blog posting of Lubos Motl.

5.3.1 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.

5.3.2 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.

1. 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 [K22] provide examples of this kind of systems?

2. 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 imbedding 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 [K22].

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 [D3] (`http://journals.aps.org/prb/abstract/10.1103/PhysRevB.81.155125` 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 imbedding space $H = M^4 \times CP_2$ making possible to generalize twistor approach [K28].

3. 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.

4. 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.

1. 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.

2. 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.

3. 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.

4. 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.

5. 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?

1. Quantum oscillation refers to de Haas-van Alphen effect (`http://phy.ntnu.edu.tw/~changmc/Teach/SS/SSG_note/grad_chap14.pdf`) - 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.

2. 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.

3. 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 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 $n = 10^4$.

4. 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.

6 Biological Applications

6.1 Worrying About The Consistency With The TGD Inspired Quantum Biology

The life of theoretician trying to be worth of his salt is full of worrying: it is always necessary to make internal consistency checks. One of the worries is whether the hypothesis $h_{eff} = h \times h = h_{gr} = GMm/v_0$ is really consistent with TGD inspired quantum biology or has wishful thinking made its way to the arguments? More precisely, does the nominal value $B_{end} = .2 \times 10^{-4}$ Tesla of "endogenous" magnetic field suggested by the effects of ELF em fields on brain give electron cyclotron energy $E = h_{eff}eB_{end}/2\pi m$ in few eV range for the value of n in question?

6.1.1 Some background

First some background.

1. The identification $h_{eff} = h_{gr}$, where h_{gr} is what I call gravitational Planck constant

$$h_{gr} = \frac{GMm}{v_0} = \frac{r_S m}{2\beta_0} \quad , \quad \beta_0 = \frac{v_0}{c} \tag{6.1}$$

makes the model quantitive. 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 would be some characteristic velocity for Earth-superfluid system and the rotation velocity $v_0 = 465.1$ m/s of Earth is a good candidate in this respect. Also the radius of Earth $R_E = 6.38 \times 10^6$ meters will be needed.

2. One could fix the value of v_0 in the following manner. Consider the Schrödinger equation for particle in gravitational field of a massive object at vertical flux tubes carrying the gravitational interaction. The solutions are Airy functions which decay very fast above some critical distance z_0. Require that z_0 is apart from a numerical factor equal to Earth radius. This condition predicts the value of v_0 which is consistent in the case of Earth and Sun with earlier hypothesis about their values. For Sun v_0 would be 5.65×10^{-4}c and for Earth orbital rotation velocity β_0 scaled up from 1.6×10^{-6} to 2.3×10^{-6} by a factor $1.41 \simeq \sqrt{2}$.

3. In TGD inspired biology the hypothesis $h_{gr} = h_{eff} = n \times h$ plays a key role. One of the basic implications is that the energies of cyclotron photons associated with magnetic flux tubes have universal energy spectrum since the dependence on the mass of the charged particle disappears. Also the gravitational Compton length. 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 in the recent case. The scale of the superfluid system is thus much smaller than the coherence length.

4. Note that the nominal value of B_{end} is definitely not the only value in the spectrum of B_{end}. Already the model of hearing forces to allowing spectrum of about 10 octaves (3 orders of magnitude) corresponding the spectrum of audible frequencies. Also the geometric model of harmony correlating music and genetic code requires this.

6.1.2 Does $h_{gr} = h_{eff}$ hypothesis predict that the energy range of dark photons is that of biophotons?

Consider now the question whether the predicted value of n is consistent with the assumption that dark cyclotron photons have energies in visible and and UV range.

1. The value of integer $ninh_{eff} = n \times n$ equals to the ratio of gravitational and ordinary Compton lengths

$$n = \frac{h_{eff}}{h} = \frac{\lambda_{gr}}{\lambda_c} \quad .$$

   For electron one obtains $n = .6 \times 10^{15}$. In the case of proton the frequency the ratio would be by a factor about 2×10^3 higher.

   The value of n is much higher than the lower bound $10^9/6$ given as the ratio of visible photon frequency about 10^{14} Hz and cyclotron frequency $f = 6 \times 10^5$ Hz of electron in the magnetic field having the nominal value $B_{end} = .2$ Gauss of endogenous magnetic field. The discrepancy is six orders of magnitude. Desired value would be correspond to magnetic field strengths of order B_{end} in $B_{gal} = 1$ nT range which corresponds to the order of magnitude for galactic magnetic fields.

   The value of n would give for B_{end} and an ion with 10 Hz cyclotron frequency (say Fe^{++} ion) energy of visible photon. The condition $\frac{h_{eff}}{h}$ predicts a value which is at least by a factor $m_p/m_e \simeq 2^{11}$ higher and one must also now assume galactic magnetic field strength to obtain a sensible result.

2. The naive expectation was that $B_{end} = .2 \times 10^{-4}$ Tesla should give energy in few eV range. Something goes definitely wrong since the magnetic fields in this value range should be in key role. Either the hypothesis $h_{eff} = h_{gr}$ is wrong or the model is somehow wrong.

6.1.3 How to modify the $h_{gr} = h_{eff}$ hypothesis?

It seems that one should modify the hypothesis $h_{gr} = h_{eff}$ somehow.

1. A formal generalization of form $h_{gr} = kh_{eff}$, $k$integer could be imagined. It should guarantee that the cyclotron energies in $B_{end} = .2$ Gauss are in bio-photon range. This would be satisfied for $k \sim B_{end}/B_{gal} \sim 2 \times 10^4$: the Compton wave length λ_{eff} would be a k-multiple of λ_{gr}. This kind of modification is of course completely adhoc unless one is able to find some physical and mathematical justification for it.

2. Could one justify the replacement of the velocity v_0 with a velocity which differs by factor k from the rotation velocity of Earth? This would give $v_0/c \simeq 3 \times 10^{-2}$. It is however difficult to find justification why the rotation velocity around Earth would be so large.

3. Could $1/k$ characterize the dark matter portion of Earth? This would require $M_{dark,E}/M_E \sim 5 \times 10^{-5}$ if one does not change the value of v_0 constant. One might justify this hypothesis by saying that it is indeed dark matter to which the gravitational flux tubes with large value of Planck constant connect biomatter.

The hypothesis that only a fraction of dark matter is involved seems to be rather feasible one. Is the modification consistent with the existing picture.

1. Can the model for the planetary system based on Bohr orbits tolerate this modification? This is the case only if the recent state of the planetary system reflects the past state, when most of the matter was dark. During the evolution of Sun and planets the dark matter would have gradually transformed to ordinary matter. This picture is consistent with the proposal that dark magnetic flux tube carry dark energy as magnetic energy and dark matter has large h_{eff} phases. It also explains the (only) 10 percent accuracy of predictions necessity to assume different v_0 for inner and outer planets ($v_{outer} = v_{inner}/5$ but for Earth having principal quantum number $n = 5$ both identifications are possible).

2. The model explaining the apparent ability of superliquids to defy gravity leads to a Schrödinger equation in gravitational field but h replaced with h_{gr}. The value of the height parameter z_0 associated with gravitational Schrödinger equation telling the height above which Schrödinger amplitude decays rapidly to zero is given by

$$z_0 = \left[\frac{r_S(E)R_E^2}{4\pi\beta_0^2}\right]^{1/3}$$

   is reduced by a factor $k^{-1/3} \simeq .06$ from value 2.85×10^7 km, which is about circumference of Earth to about 17 km, which corresponds to the size scale of atmosphere so that nothing catastrophic occurs. The corresponding time scale corresponds to 170 Hz frequency.

3. The value of the gravitational Compton length in case of Earth is scaled down by factor $1/k \sim 2 \times 10^{-4}$ to give $\Lambda_{gr} \sim 12.9$ cm. This corresponds to the length scale of brain hemisphere - and excellent candidate for macroscopically quantum coherent system - so that TGD inspired biology seems to tolerate the reduction.

To summarize, the hypothesis $h_{gr} = h_{eff}$ predicts universal dark cyclotron photon spectrum in bio-photon range only if the dark magnetic flux tubes couple biomatter to dark part of Earth, which should carry a portion of order 2×10^{-4} of the Earth's mass. This means a correction to the earlier picture, which however does not change the overall picture in any manner.

6.2 A New Control Mechanism Of TGD Inspired Quantum Biology

The idea that TGD Universe is quantum critical, is the corner stone of quantum TGD and fixes the theory more or less uniquely since the only coupling constant parameter of the theory - Kähler coupling strength - is analogous to critical temperature. Also more than one basic parameters are in principle possible - maximal quantum criticality fixes the values of all of them - but it seems that only Kähler coupling strength is needed. TGD Universe is a quantum critical fractal: like a ball at the top of hill at the top of hill at.... Quantum criticality allows to avoid the fine tuning problems plaguing as a rule various unified theories.

6.2.1 Quantum criticality

The meaning of quantum criticality at the level of dynamics has become only gradually clearer. The development of several apparently independent ideas generated for about decade ago have led to the realization that quantum criticality is behind all of them. Behind quantum criticality are in turn number theoretic vision and strong forms of general coordinate invariance and holography.

1. The hierarchy of Planck constants defining hierarchy of dark phases of ordinary matter corresponds to a hierarchy of quantum criticalities assignable to a fractal hierarchy of sub-algebras of super-symplectic algebra for which conformal weights are n-ples of those for the entire algebra, n corresponds to the value of effective Planck constant $h_{eff}/h = n$. These algebras are isomorphic to the full algebra and act as gauge conformal algebras so that a broken super-conformal invariance is in question.

2. Quantum criticality in turn reduces to the number theoretic vision about strong form of holography. String world sheets carrying fermions and partonic 2-surfaces are the basic objects as far as pure quantum description is considered. Also space-time picture is needed in order to test the theory since quantum measurements always involve also the classical physics, which in TGD is an exact part of quantum theory.

   Space-time surfaces are continuations of collections of string world sheets and partonic 2-surfaces to preferred extremals of Kähler action for which Noether charges in the sub-algebra of super-symplectic algebra vanish. This condition is the counterpart for the reduction of the 2-D criticality to conformal invariance. This eliminates huge number of degrees of freedom and makes the strong form of holography possible.

3. The hierarchy of algebraic extensions of rationals defines the values of the parameters characterizing the 2-surfaces, and one obtains a number theoretical realization of an evolutionary hierarchy. One can also algebraically continue the space-time surfaces to various number fields - reals and the algebraic extensions of p-adic number fields. Physics becomes adelic. p-Adic sectors serve as correlates for cognition and imagination. One can indeed have string world sheets and partonic 2-surfaces, which can be algebraically continued to preferred extremals in p-adic sectors by utilizing p-adic pseudo constants giving huge flexibility. If this is not possible in the real sector, figment of imagination is in question! It can also happen that only part of real space-time surface can be generated: this might relate to the fact that imaginations can be seen as partially realized motor actions and sensory perceptions.

6.2.2 Quantum criticality and TGD inspired quantum biology

In TGD inspired quantum biology quantum criticality is in crucial role. First some background.

1. Quantum measurement theory as a theory of consciousness is formulated in zero energy ontology (ZEO) and defines an important aspect of quantum criticality. Strong form of NMP states that the negentropy gain in the state function reduction at either boundary of causal diamond (CD) is maximal. Weak form of NMP allows also quantum jumps for which negentropic entanglement is not generated: this makes possible ethics (good and evil) and morally responsible free will: good means basically increase of negentropy resources.

2. Self corresponds to a sequence state function reductions to the same boundary of CD and h_{eff} does not change during that period. The increase of h_{eff} (and thus evolution!) tends to occur spontaneously, and can be assigned to the state function reduction to the opposite boundary of CD in zero energy ontology (ZEO). The reduction to the opposite boundary means death of self and living matter is fighting in order to avoid this even. To me the only manner to make sense about basic myth of Christianity is that death of self generates negentropy.

3. Metabolism provides negentropy resources for self and hopefully prevents NMP to force the fatal reduction to the opposite boundary of CD. Also homeostasis does the same. In this process self makes possible evolution of sub-selves (mental images dying and re-incarnating) state function by state function reduction so that the negentropic resources of the Universe increase.

6.2.3 A new mechanism of quantum criticality

Consider now the mechanisms of quantum criticality. The TGD based model [L12] [K36] (`http://tgdtheory.fi/public_html/articles/SmB6.pdf`) for the recent paradoxical looking finding [L12] (`http://www.sciencemag.org/content/early/2015/07/01/science.aaa7974`) that topological insulators can behave like conductors in external magnetic field led to a discovery of a highly interesting mechanism of criticality, which could play a key role in living matter.

1. The key observation is that magnetic field is present. In TGD framework the obvious guess is that its flux tubes carry dark electrons giving rise to anomalous currents running in about million times longer time scales and with velocity, which is about million times higher than expected. Also supra-currents can be considered.

The currents can be formed of the cyclotron energies of electrons are such that they correspond to energies near the surface of the Fermi sphere: recall that Fermi energy for electrons is determined by the density of conduction electrons and is about 1 eV. Interestingly, this energy is at the lower end of bio-photon energy spectrum. In the field of 10 Tesla the cyclotron energy of electron is .1 mV so that the integer characterizing cyclotron orbit must be $n \simeq 10^5$ if conduction electron is to be transferred to the cyclotron orbit.

2. The assumption is that external magnetic field is realized as flux tubes of fixed radius, which correspond to space-time quanta in TGD framework. As the intensity of magnetic field is varied, one observes so called de Haas-van Alphen effect (`https://en.wikipedia.org/wiki/De_Haasvan_Alphen_effect`) 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 [D3]).

   This 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.

3. For some critical values of the magnetic field strength a new orbit emerges at the boundary of the flux tube. If the energy of this orbit is in the vicinity of Fermi surface, an electron can be transferred to the new orbit. This situation is clearly quantum critical.

   If the quantum criticality hypothesis holds true, $h_{eff}/h = n$ dark electron phase can be generated for the critical values of magnetic fields. This would give rise to the anomalous conductivity perhaps involving spin current due to the spontaneous magnetization of the dark electrons at the flux tube. Even super-conductivity based on the formation of parallel flux tube pairs with either opposite or parallel directions of the magnetic flux such that the members of the pair are at parallel flux tubes, can be considered and I have proposed this a mechanism of bio-superconductivity and also high Tc super-conductivity.

6.2.4 A new mechanism of quantum bio-control

The quantum criticality of the process in which new electron orbit emerges near Fermi surface suggests a new mechanism of quantum bio-control by generation of super currents or its reversal.

1. In TGD inspired quantum biology magnetic body uses biological body as motor instrument and sensory receptor and EEG and its fractal variants with dark photons with frequencies in EEG range but energy $E = h_{eff}f$ in the range of bio-photon energies make the necessary signalling possible.

2. Flux tubes can become braided and this makes possible quantum computation like processes [K10]. Also so called 2-braids - defined by knotted 2-surfaces imbedded in 4-D space-time surface - are possible for the string world sheets defined by flux tubes identified to be infinitely thin, are possible. As a matter fact, also genuine string world sheets accompany the flux tubes. 2-braids and knots are purely TGD based phenomenon and not possible in superstring theory or M-theory.

3. It is natural to speak about motor actions of the magnetic body. It is assumed that the flux tubes of the magnetic body connect biomolecules to form a kind of Indra's web explaining the gel like character of living matter. h_{eff} reducing phase transitions contract flux tubes connecting biomolecules so that they can find each other by this process and bio-catalysis becomes possible. This explains the mysterious looking ability of bio-molecules to find each other in the dense molecular soup. In fact the dark matter part is far from being soup! The hierarchy of Planck constants and $h_{eff} = h_{gr}$ hypothesis imply that dark variants of various particles with magnetic moment are neatly at their own flux tubes like books in shelf.

   Reconnection of the U-shaped flux tubes emanating from two subsystems generates a flux tube pair between them and gives rise to supracurrents flowing between them. Also cyclotron radiation propagating along flux tubes and inducing resonant transitions is present. This would be the fundamental mechanism of attention.

4. I have proposed that the variation of the thickness of the flux tubes could serve as a control mechanism since it induces a variation of cyclotron frequencies allowing to get in resonance or out of it. For instance, two molecules could get in flux tube contact when the cyclotron frequencies are identical and this can be achieved if they are able to vary their flux tube thickness. The molecules of immune system are masters in identifying alien molecules and the underlying mechanism could be based on cyclotron frequency spectrum and molecular attention. This would be also the mechanism behind water memory and homeopathy (`http://tgdtheory.fi/public_html/hologram/hologram.html#homeoc` [K15] which still is regarded as a taboo by mainstreamers.

5. Finally comes the promised new mechanism of bio-control. The variation of the magnetic field induced by that of flux tube thickness allows also to control whether there is quantum criticality for the generation of dark electron supra currents of electrons. The Fermi energy of the conduction electrons at the top of Fermi sphere is the key quantity and dictated by the density of these electrons. This allows to estimate the order of magnitude of the integers N characterizing cyclotron energy for ordinary Planck constant and the maximal value of $h_{eff}/h = n$ cannot be larger than N.

6.3 Are Bacteria Able To Induce Super-Fluidity?

Nature News tells that a team led by Auradou et al reports in the article "Turning Bacteria Suspensions into Superfluids" [I4] published in Phys Rev Letters that bacterium swimming in fluid do not only reduce its viscosity associated with shear stress (viscous force parallel to the surface) but makes it to behave in super-fluid like manner above a critical concentration of bacteria.

As the number of bacteria (E. coli) was increased, the viscosity associated with shear stress (the viscous force parallel to the surface) dropped: this in accordance with theoretical expectations. Adding about 6 billion cells (the fluid volume is not mentioned but it seems that the effect occurs above critical density of bacteria), the apparent viscosity dropped to zero - or more precisely, below the experimental resolution. The super-fluid like behavior was preserved above the critical concentration. What is important that this did not happen for dead bacteria: bacteria play an active role in the reduction of viscosity.

Researchers are not able to identify the mechanism leading to the superfluid-like behavior but some kind of collective effect is believed to be in question. The findings suggest that the flagellae - kind of spinning hairs used by the bacteria to propel themselves - should play an essential part in the phenomenon. As bacteria swim, they fight against current, decreasing the local forces between molecules that determine the fluid's viscosity. Above critical density the local effects would somehow become global.

Cates et al have proposed this kind of phenomenon: see the article "Shearing Active Gels Close to the Isotropic-Nematic Transition" [I7]. The authors speak in the abstract about zero apparent viscosity.

1. The title of the article of Cates et al tells that the phenomenon occurs near isotropic-nematic transition. Nematic is defined as a liquid crystal for which the molecules are thread-like and parallel. I dare guess that in the recent case the approximately parallel flagellae would be modelled as liquid crystal like 2-D phase at the surface of bacterium. In the isotropic phase the orientations of the flagellae would be uncorrelated and long range orientational correlations would emerge in the phase transition to nematic phase.

2. Also the notions of contractile and extensile gels are introduced. Contraction and extension of gels are though to occur through molecular motors. The transformation of the fluid to apparent superfluid would require energy to run the molecular motors using metabolic energy and ordinary superfluidity would not be in question.

3. The model predicts divergence of viscosity for contractile gels. For extensile gels a zero of apparent viscosity is predicted. There is a hydrodynamical argument for how this would occur but I did not understand it. The active behavior of the bacteria would means that the gel like surface phase (nematic liquid crystal) formed by the flagellae extends to reduce viscosity. If I have understood correctly, this applies only to the behavior of single bacterium and is about the reduction of viscosity in the immediate vicinity of cell.

My deep ignorance about rheology allows me freedom to speculate freely about the situation in TGD framework.

1. In TGD inspired biology gel phase corresponds to a phase, which involves flux tube connections between basic units. Flux tubes contain dark matter with non-standard value $h_{eff} = n \times h$. The h_{eff} changing phase transitions scaling the lengths of flux tubes proportional to h_{eff} are responsible for the contractions and extensions of gel.

   The extension of the gel should lead to a reduction of viscosity since one expects that dissipative effects are reduced as h_{eff} increases and quantum coherence is established in longer scales. Large h_{eff} phases are associated with criticality. Now the criticality would be associated with isotropic-nematic phase transition. The parallelization of flagellae would be due to the quantum coherence assignable with the flagellae.

   Note that the mechanism used by bacteria to control the liquid flow would be different since now molecular motors are replaced by h_{eff} changing phase transitions playing key role in TGD inspired view about biochemistry. For instance, reacting biomolecules find each other by h_{eff} reducing phase transition contracting the flux tubes connecting them.

2. This model does not yet explain the reduction of apparent viscosity to zero in the entire fluid occurring above a critical density of bacteria. What could happen could be analogous to the emergence of high T_c superconductivity according to TGD [K24] (`http://tgdtheory.fi/public_html/tgdeeg/tgdeeg.thml#biosupercond`). Below pseudo gap temperature the emergence of magnetic flux tube pairs makes possible super-conductivity in short scales. At critical temperature a phase transition in which flux tubes reconnect to form larger thermodynamically stable networks occurs. One can speak about quantum percolation.

   The reduction of viscosity for a single bacterium could be based on the phase transition of liquid molecules to dark molecules flowing along the resulting flux tubes with very small friction (large $heff$) but only below certain scale smaller than the typical distance between bacteria. This would be the analog for what happens below pseudo gap. Above critical density he magnetic flux tubes associated with bacteria would reconnect and forming a net of connected flux tube paths at scale longer than inter-bacterial distances. This would be the counterpart for the emergence of superconductivity by percolation in long scales.

7 TGD Inspired View About Blackholes And Hawking Radiation

The most recent revelation of Hawking was in Hawking radiation conference held in KTH Royal Institute of Technology in Stockholm. The title of the posting of Bee (`http://backreaction.blogspot.fi/2015/08/hawking-proposes-new-idea-for-how.html`) telling about what might have been revealed is "Hawking proposes new idea for how information might escape from black holes". Also Lubos (`http://motls.blogspot.fi/2015/08/stephen-hawking-solves-information-loss.html`) has - a rather aggressive - blog post about the talk. A collaboration of Hawking, Andrew Strominger and Malcom Perry is behind the claim and the work should be published within few months.

This inspired a fresh discussion of the notions of blackhole and Hawking radiation in TGD framework. The intention is to demonstrate that a pseudo problem following from the failure of General Relativity below black hole horizon is in question. There are several new elements involved but concerning black holes the most relevant new element is the assignment of Euclidian space-time regions as lines of generalized Feynman diagrams implying that also blackhole interiors correspond to this kind of regions. Negentropy Maximization Principle is also an important element and predicts that number theoretically defined black hole negentropy can only increase. The real surprise was that the temperature of the variant of Hawking radiation at the flux tubes of proton Sun system is room temperature! Could TGD variant of Hawking radiation be a key player in quantum biology?

7.1 Is Information Lost Or Not In Blackhole Collapse?

The basic problem is that classically the collapse to blackhole seems to destroy all information about the matter collapsing to the blackhole. The outcome is just infinitely dense mass point. There is also a theorem of classical GRT stating that blackhole has no hair: blachole is characterized only by few conserved charges.

Hawking has predicted that blackhole loses its mass by generating radiation, which looks like thermal. As blackhole radiates its mass away, all information about the material which entered to the blackhole seems to be lost. If one believes in standard quantum theory and unitary evolution preserving the information, and also forgets the standard quantum theory's prediction that state function reductions destroy information, one has a problem. Does the information really disappear? Or is the GRT description incapable to cope with the situation? Could information find a new representation?

Superstring models and AdS/CFT correspondence have inspired the proposal that a hologram results at the horizon and this hologram somehow catches the information by defining the hair of the blackhole. Since the radius of horizon is proportional to the mass of blackhole, one can however wonder what happens to this information as the radius shrinks to zero when all mass is Hawking radiated out.

What Hawking suggests is that a new kind of symmetry known as super-translations - a notion originally introduced by Bondi and Metzner - could somehow save the situation. Andrew Strominger has recently discussed the notion [B7] (`http://arxiv.org/abs/1401.7026`). The information would be "stored to super-translations". Unfortunately this statement says nothing to me nor did not say to Bee and New Scientist reporter. The idea however seems to be that the information carried by Hawking radiation emanating from the blackhole interior would be caught by the hologram defined by the blackhole horizon.

Super-translation symmetry acts at the surface of a sphere with infinite radius in asymptotically flat space-times looking like empty Minkowski space in very distant regions. The action would be translations along sphere plus Poincare transformations.

What comes in mind in TGD framework is conformal transformations of the boundary of 4-D lightcone, which act as scalings of the radius of sphere and conformal transformations of the sphere. Translations however translate the tip of the light-cone and Lorentz transformations transform the sphere to an ellipsoid so that one should restrict to rotation subgroup of Lorentz group. Besides this TGD allows huge group of symplectic transformations of $\delta CD \times CP_2$ acting as isometries of WCW and having structure of conformal algebra with generators labelled by conformal weights.

7.2 What Are The Problems?

My fate is to be an aggressive dissident listened by no-one, and I find it natural to continue in the role of angry old man. Be cautious, I am arrogant, I can bite, and my bite is poisonous!

1. With all due respect to Big Guys, to me the problem looks like a pseudo problem caused basically by the breakdown of classical GRT. Irrespective of whether Hawking radiation is generated, the information about matter (apart from mass, and some charges) is lost if the matter indeed collapses to single infinitely dense point. This is of course very unrealistic and the question should be: how should we proceed from GRT.

   Blackhole is simply too strong an idealization and it is no wonder that Hawking's calculation using blackhole metric as a background gives rise to blackbody radiation. One might hope that Hawking radiation is genuine physical phenomenon, and might somehow carry the information by being not genuinely thermal radiation. Here a theory of quantum gravitation might help. But we do not have it!

2. What do we know about blackholes? We know that there are objects, which can be well described by the exterior Schwartschild metric. Galactic centers are regarded as candidates for giant blackholes. Binary systems for which another member is invisible are candidates for stellar blackholes. One can however ask wether these candidates actually consist of dark matter rather than being blackholes. Unfortunately, we do not understand what dark matter is!

3. Hawking radiation is extremely weak and there is no experimental evidence pro or con. Its existence assumes the existence of blackhole, which presumably represents the failure of classical GRT. Therefore we might be seeing a lot of trouble and inspired heated debates about something, which does not exist at all! This includes both blackholes, Hawking radiation and various problems such as firewall paradox.

There are also profound theoretical problems.

1. Contrary to the intensive media hype during last three decades, we still do not have a generally accepted theory of quantum gravity. Super string models and M-theory failed to predict anything at fundamental level, and just postulate effective quantum field theory limit, which assumes the analog of GRT at the level of 10-D or 11-D target space to define the spontaneous compactification as a solution of this GRT type theory. Not much is gained.

   AdS/CFT correspondence is an attempt to do something in absence of this kind of theory but involves 10- or 11- D blackholes and does not help much. Reality looks much simpler to an innocent non-academic outsider like me. Effective field theorizing allows intellectual laziness and many problems of recent day physics will be probably seen in future as being caused by this lazy approach avoiding attempts to build explicit bridges between physics at different scales. Something very similar has occurred in hadron physics and nuclear physics and one has kind of stable of Aigeias to clean up before one can proceed.

2. A mathematically well-defined notion of information is lacking. We can talk about thermodynamical entropy - single particle observable - and also about entanglement entropy - basically a 2-particle observable. We do not have genuine notion of information and second law predicts that the best that one can achieve is no information at all!

   Could it be that our view about information as single particle characteristic is wrong? Could information be associated with entanglement and be 2-particle characteristic? Could information reside in the relationship of object with the external world, in the communication line? Not inside blackhole, not at horizon but in the entanglement of blackhole with the external world?

3. We do not have a theory of quantum measurement. The deterministic unitary time evolution of Schrödinger equation and non-deterministic state function reduction are in blatant conflict. Copenhagen interpretation escapes the problem by saying that no objective reality/realities exist. Easy trick once again! A closely related Pandora's box is that experienced time and geometric time are very different but we pretend that this is not the case.

   The only way out is to bring observer part of quantum physics: this requires nothing less than quantum theory of consciousness. But the gurus of theoretical physics have shown no interest to consciousness. It is much easier and much more impressive to apply mechanical algorithms to produce complex formulas. If one takes consciousness seriously, one ends up with the question about the variational principle of consciousness. Yes, your guess was correct! Negentropy Maximization Principle! Conscious experience tends to maximize conscious information gain. But how information is represented?

7.3 TGD View About Black Holes And Hawking Radiation

My own basic strategy is to not assume anything not necessitated by experiment or not implied by general theoretical assumptions - these of course represent the subjective element.

7.3.1 The basic ideas of TGD relevant for blackhole concept

The basic assumptions/predictions of TGD relevant for the recent discussion are following.

1. Space-times are 4-surfaces in $H = M^4 \times CP_2$ and ordinary space-time is replaced with many-sheeted space-time. This solves what I call energy problem of GRT by lifting gravitationally broken Poincare invariance to an exact symmetry at the level of imbedding space H.

GRT type description is an approximation obtained by lumping together the space-time sheets to single region of M^4, with various fields as sums of induced fields at space-time surface geometrized in terms of geometry of H.

Space-time surface has both Minkowskian and Euclidian regions. Euclidian regions are identified in terms of what I call generalized Feynman/twistor diagrams. The 3-D boundaries between Euclidian and Minkowskina regions have degenerate induced 4-metric and I call them light-like orbits of partonic 2-surfaces or light-like wormhole throats analogous to blackhole horizons and actually replacing them. The interiors of blackholes are replaced with the Euclidian regions and every physical system is characterized by this kind of region.

Euclidian regions are identified as slightly deformed pieces of CP_2 connecting two Minkowskian space-time regions. Partonic 2-surfaces defining their boundaries are connected to each other by magnetic flux tubes carrying monopole flux.

Wormhole contacts connect two Minkowskian space-time sheets already at elementary particle level, and appear in pairs by the conservation of the monopole flux. Flux tube can be visualized as a highly flattened square traversing along and between the space-time sheets involved. Flux tubes are accompanied by fermionic strings carrying fermion number. Fermionic strings give rise to string world sheets carrying vanishing induced em charged weak fields (otherwise em charge would not be well-defined for spinor modes). String theory in space-time surface becomes part of TGD. Fermions at the ends of strings can get entangled and entanglement can carry information.

2. Strong form of General Coordinate Invariance (GCI) states that light-like orbits of partonic 2-surfaces on one hand and space-like 3-surfaces at the ends of causal diamonds on the other hand provide equivalent descriptions of physics. The outcome is that partonic 2-surfaces and string world sheets at the ends of CD can be regarded as basic dynamical objects.

   Strong form of holography states the correspondence between quantum description based on these 2-surfaces and 4-D classical space-time description, and generalizes AdS/CFT correspondence. Conformal invariance is extended to the huge super-symplectic symmetry algebra acting as isometries of WCW and having conformal structure. This explains why 10-D space-time can be replaced with ordinary space-time and 4-D Minkowski space can be replaced with partonic 2-surfaces and string world sheets. This holography looks very much like the one we are accustomed with!

3. Quantum criticality of TGD Universe fixing the value(s) of the only coupling strength of TGD (Kähler coupling strength) as analog of critical temperature. Quantum criticality is realized in terms of infinite hierarchy of sub-algebras of super-symplectic algebra actings as isometries of WCW, the "world of classical worlds" consisting of 3-surfaces or by holography preferred extremals associated with them.

   Given sub-algebra is isomorphic to the entire algebra and its conformal weights are $n \geq 1$-multiples of those for the entire algebra. This algebra acts as conformal gauge transformations whereas the generators with conformal weights $m < n$ act as dynamical symmetries defining an infinite hierarchy of simply laced Lie groups with rank $n-1$ acting as dynamical symmetry groups defined by Mac-Kay correspondence so that the number of degrees of freedom becomes finite. This relates very closely to the inclusions of hyper-finite factors - WCW spinors provide a canonical representation for them.

   This hierarchy corresponds to a hierarchy of effective Planck constants $h_{eff} = n \times h$ defining an infinite number of phases identified as dark matter. For these phases Compton length and time are scale up by n so that they give rise to macroscopic quantum phases. Superconductivity is one example of this kind of phase - charge carriers could be dark variants of ordinary electrons. Dark matter appears at quantum criticality and this serves as an experimental manner to produce dark matter. In living matter dark matter identified in this manner would play a central role. Magnetic bodies carrying dark matter at their flux tubes would control ordinary matter and carry information.

4. I started the work with the hierarchy of Planck constants from the proposal of Nottale stating that it makes sense to talk about gravitational Planck constant $h_{gr} = GMm/v_0$, $v_0/c \leq 1$

(the interpretation of symbols should be obvious). Nottale found that the orbits of inner and outer planets could be modelled reasonably well by applying Bohr quantization to planetary orbits with tge value of velocity parameter differing by a factor 1/5. In TGD framework h_{gr} would be associated with magnetic flux tubes mediating gravitational interaction between Sun with mass M and planet or any object, say elementary particle, with mass m. The matter at the flux tubes would be dark as also gravitons involved. The Compton length of particle would be given by GM/v_0 and would not depend on the mass of particle at all.

The identification $h_{gr} = h_{eff}$ is an additional hypothesis motivated by quantum biology, in particular the identification of biophotons as decay products of dark photons satisfying this condition. As a matter fact, one can talk also about h_{em} assignable to electromagnetic interactions: its values are much lower. The hypothesis is that when the perturbative expansion for two particle system does not converge anymore, a phase transition increasing the value of the Planck constant occurs and guarantees that coupling strength proportional to $1/h_{eff}$ increases. This is one possible interpretation for quantum criticality. TGD provides a detailed geometric interpretation for the space-time correlates of quantum criticality.

Macroscopic gravitational bound states not possible in TGD without the assumption that effective string tension associated with fermionic strings and dictated by strong form of holography is proportional to $1/h_{eff}^2$. The bound states would have size scale of order Planck length since for longer systems string energy would be huge. $h_{eff} = h_{gr}$ makes astroscopic quantum coherence unavoidable. Ordinary matter is condensed around dark matter. The counterparts of black holes would be systems consisting of only dark matter.

5. Zero energy ontology (ZEO) is central element of TGD. There are many motivations for it. For instance, Poincare invariance in standard sense cannot make sense since in standard cosmology energy is not conserved. The interpretation is that various conserved quantum numbers are length scale dependent notions.

   Physical states are zero energy states with positive and negative energy parts assigned to ends of space-time surfaces at the light-like boundaries of causal diamonds (CDs). CD is defined as Cartesian products of CP_2 with the intersection of future and past directed lightcones of M^4. CDs form a fractal length scale hierarchy. CD defines the region about which single conscious entity can have conscious information, kind of 4-D perceptive field. There is a hierarchy of WCWs associated with CDs. Consciously experienced physics is always in the scale of given CD.

   Zero energy states identified as formally purely classical WCW spinor fields replace positive energy states and are analogous to pairs of initial and final, states and the crossing symmetry of quantum field theories gives the mathematical motivation for their introduction.

6. Quantum measurement theory can be seen as a theory of consciousness in ZEO. Conscious observer or self as a conscious entity becomes part of physics. ZEO gives up the assumption about unique universe of classical physics and restricts it to the perceptive field defined by CD.

   In each quantum jump a re-creation of Universe occurs. Subjective experience time corresponds to state function reductions at fixed, passive bounary of CD leaving it invariant as well as state at it. The state at the opposite, active boundary changes and also its position changes so that CD increases state function by state function reduction doing nothing to the passive boundary. This gives rise to the experienced flow of geometric time since the distance between the tips of CD increases and the size of space-time surfaces in the quantum superposition increases. This sequence of state function reductions is counterpart for the unitary time evolution in ordinary quantum theory.

   Self "dies" as the first state function reduction to the opposite boundary of CD meaning re-incarnation of self at it and a reversal of the arrow of geometric time occurs: CD size increases now in opposite time direction as the opposite boundary of CD recedes to the geometric past reduction by reduction.

   Negentropy Maximization Principle (NMP) defines the variational principle of state function reduction. Density matrix of the subsystem is the universal observable and the state function reduction leads to its eigenspaces. Eigenspaces, not only eigenstates as usually.

Number theoretic entropy makes sense for the algebraic extensions of rationals and can be negative unlike ordinary entanglement entropy. NMP can therefore lead to a generation of NE if the entanglement correspond to a matrix proportional to a unitary matrix so that the density matrix of the final state is higher-D unit matrix. Another possibility is that entanglement matrix is algebraic but that its diagonalization in the algebraic extension of rationals used is not possible. This is expected to reduce the rate for the reduction since a phase transition increasing the size of extension is needed.

The weak form of NMP does not demand that the negentropy gain is maximum: this allow the conscious entity responsible for reduction to decide whether to increase maximally NE resources of the Universe or not. It can also allow larger NE increase than otherwise. This freedom brings the quantum correlates of ethics, moral, and good and evil. p-Adic length scale hypothesis and the existence of preferred p-adic primes follow from weak form of NMP and one ends up naturally to adelic physics.

7.3.2 Could electric-magnetic duality allow to understand $1/h_{eff}^2$ dependence of the effective string tension?

Electric-magnetic duality (possibly the TGD counterpart of AdS/CFT duality) might allow to understand the proportionality of effective string tension to $1/h_{eff}^2$.

1. The *effective* string tension assignable to fermionic strings accompanying magnetic flux tubes and allowing to express Minkowskian Kähler as stringy action must be inversely proportional to $1/h_{eff}^2$ in order to obtain gravitationally bound states in macroscopic length scales identified as structure for which partonic 2-surfaces are connected by strings accompanying flux tubes. This requirement is not easy to prove since $1/\alpha_K$ is proportional to h_{eff}. Could electric-magnetic duality imply this formula with the interpretation that the effective string tension corresponds to Kähler action for string like object?

2. The Dirac condition would give

$$\frac{g_m g_K}{2\pi} = z \in Z$$

giving

$$\frac{1}{\alpha_m} = \frac{4\alpha_K}{z^2} = \frac{\pi}{2qz^2} \quad .$$

if one accepts the argument of [K39] requiring that Kähler action for CP_2 type vacuum extremal is rational number $q = m/n$ guaranteeing that the exponent of Kähler action for Euclidian space-time regions of preferred extremals belongs to an a finite-dimensional extension of p-adic numbers generated by a root of e (note that e is adelically completely unique). This argument implies $\alpha_K = \pi/8q$ (note that this result is in conflict with earlier ideas about the algebraic structure of α_K [K1] based on much more ad hoc argumens).

This would give

$$\frac{1}{2g_m^2} = \frac{1}{16qz^2} \quad .$$

The contribution of the action from Minkowskian regions would be proportional to π and in case of string like objects string area A should be a rational number. The value of string tension would be reduced by a factor

$$\frac{g_K^2}{g_m^2} = \frac{4\alpha_K^2}{z^2} \quad .$$

This is inconsistent with the model of cosmic strings [K8] predicting much larger tension (consistency would require $g_m = g_K$), and would lead to problems in the model of galactic dark matter assuming that galactic strings are like pearls in necklace around single cosmic string. The duality can thus hold only for M^4 type regions of space-time surface.

3. The formula $g_K^2/g_m^2 = 4\alpha_K^2/z^2$ implies $1/h_{eff}^2$ proportionality for the effective string tension if the formula $h_{eff} = z \times h$ makes sense. z would correspond to the number of sheets for the magnetic flux tubes defining covering of M^4.

7.3.3 The analogs of blackholes in TGD

Could blackholes have any analog in TGD? What about Hawking radiation? The following speculations are inspired by the above general vision.

1. Ordinary blackhole solutions are not appropriate in TGD. Interior space-time sheet of *any* physical object is replaced with an Euclidian space-time region. Also that of blackhole by perturbation argument based on the observation that if one requires that the radial component of blackhole metric is finite, the horizon becomes light-like 3-surface analogous to the light-like orbit of partonic 2-surface and the metric in the interior becomes Euclidian.

2. The analog of blackhole can be seen as a limiting case for ordinary astrophysical object, which already has blackhole like properties due to the presence of $h_{eff} = n \times h$ dark matter particles, which cannot appear in the same vertices with visible manner. Ideal analog of blackhole consist of dark matter only, and is assumed to satisfy the $h_{gr} = h_{eff}$ already discussed. It corresponds to region with a radius equal to Compton length for arbitrary particle $R = GM/v_0 = r_S/2v_0$, where r_S is Schwartschild radius. Macroscopic quantum phase is in question since the Compton radius of particle does not depend on its mass. Blackhole limit would correspond to $v_0/c \to 1$ and dark matter dominance. This would give $R = r_S/2$. Naive expectation would be $R = r_S$ (maybe factor of two is missing somewhere: blame me!).

3. NMP implies that information cannot be lost in the formation of blackhole like state but tends to increase. Matter becomes totally dark and the NE with the partonic surfaces of external world is preserved or increases. The ingoing matter does not fall to a mass point but resides at the partonic 2-surface which can have arbitrarily large surface. It can have also wormholes connecting different regions of a spherical surface and in this manner increase its genus. NMP, negentropy , negentropic entanglement between $h_{eff} = n \times h$ dark matter systems would become the basic notions instead of second law and entropy.

4. There is now a popular article (`https://www.sciencenews.org/article/hawking-proposes-solution-bl` explaining the intuitive picture behind Hawking's proposal. The blackhole horizon would involve tangential flow of light and particles of the infalling matter would induce supertranslations on the pattern of this light thus coding information about their properties to this light. After that this light would be radiated away as analog of Hawking radiation and carry out this information.

   The objection would be that in GRT horizon is no way special - it is just a coordinate singularity. Curvature tensor does not diverge either and Einstein tensor and Ricci scalar vanish. This argument has been used in the firewall debates to claim that nothing special should occur as horizon is traversed. So: why light would rotate around it? No reason for this!

   The answer in TGD would be obvious: horizon is replaced for TGD analog of blackhole with a light-like 3-surface at which the induced metric becomes Euclidian. Horizon becomes analogous to light front carrying not only photons but all kinds of elementary particles. Particles do not fall inside this surface but remain at it!

   The objection now is that photons of light front should propagate in direction normal to it, not parallel. The point is however that this light-like 3-surface is the surface at which induced 4-metric becomes degenerate: hence massless particles live on it.

5. The replacement of second law with NMP leads to ask whether a generalization of blackhole thermodynamics (`https://en.wikipedia.org/wiki/Black_hole_thermodynamics`) does make sense. Since blackhole thermodynamics characterizes Hawking radiation, the generalization could make sense at least if there exist analog for the Hawking radiation (`https:`

//en.wikipedia.org/wiki/Hawking_radiation). Note that also geometric variant of second law makes sense.

Could the analog of Hawking radiation be generated in the first state function reduction to the opposite boundary, and be perhaps be assigned with the sudden increase of radius of the partonic 2-surface defining the horizon? Could this burst of energy release the energy compensating the generation of gravitational binding energy? This burst would however have totally different interpretation: even gamma ray bursts from quasars could be considered as candidates for it and temperature would be totally different from the extremely low general relativistic Hawking temperature of order

$$T_{GR} = \frac{\hbar}{8\pi GM} \quad ,$$

which corresponds to an energy assignable to wavelength equal to 4π times Schwartschild radius. For Sun with Schwartschild radius $r_S = 2GM = 3$ km one has $T_{GR} = 3.2 \times 10^{-11}$ eV.

One can of course have fun with formulas to see whether the generalizaton assuming the replacement $h \to h_{gr}$ could make sense physically. Also the replacement $r_S \to R$, where R is the real radius of the star will be made.

1. Blackhole temperature can be formally identified as surface gravity

$$T = \frac{\hbar_{gr}}{\hbar}\frac{\hbar GM}{2\pi R^2} = \frac{m}{8\pi v_0}\frac{r_S^2}{R^2} \quad .$$

For Sun with radius $R = 6.96 \times 10^5$ km one has $T/m = 3.2 \times 10^{-11}$ giving about 3×10^{-2} eV for proton. This is by 9 orders higher than ordinary Hawking temperature. Amazingly, this temperature equals to room temperature! Is this a mere accident? If one takes seriously TGD inspired quantum biology in which quantum gravity plays a key role [K37], this does not seem to be the case. Note that for electron the temperature would correspond to energy $3/2 \times 10^{-5}$ eV which corresponds to 4.5 GHz frequency for ordinary Planck constant.

It must be however made clear that the value of v_0 for dark matter could differ from that deduced assuming that entire gravitational mass is dark. For $M \to M_D = kM$ and $v_0 \to \sqrt{k}v_0$ the orbital radii remain unchanged but the velocity of dark matter object at the orbit scales to $\sqrt{k}v_0$. This kind of scaling is suggested by the fact that the value of h_{gr} seems to be too large as compared by the identification of biophotons as decay results of dark photons with $h_{eff} = h_{gr}$ (some arguments suggest the value $k \simeq 2 \times 10^{-4}$) [K36].

Note that for the radius $R = r_S/2\sqrt{v_0\pi}$ the thermal energy exceeds the rest mass of the particle. For neutron stars this limit might be achieved.

2. Blackhole entropy

$$S_{GR} = \frac{A}{4\hbar G} = 4\pi\frac{GM^2}{\hbar} = 4\pi\frac{M^2}{M_{Pl}^2}$$

would be replaced with the negentropy for dark matter making sense also for systems containing both dark and ordinary matter. The negentropy $N(m)$ associated with a flux tube of given type would be a fraction h/h_{gr} from the total area of the horizon using Planck area as a unit:

$$N(m) = \frac{h}{h_{gr}} \times \frac{A}{4\hbar G} = \frac{h}{h_{gr}} \times \frac{R^2}{r_S^2} S_{GR} = v_0 \frac{M}{m}\frac{R^2}{r_S^2} \quad .$$

The dependence on m makes sense since a given flux tube type characterized by mass m determining the corresponding value of h_{gr} has its own negentropy and the total negentropy is the sum over the particle species. The negentropy of Sun is numerically much smaller that corresponding blackhole entropy.

3. Horizon area is proportional to $(GM/v_0)^2 \propto h_{eff}^2$ and should increase in discrete jumps by scalings of integer and be proportional to n^2.

How does the analog of blackhole evolve in time? The evolution consists of sequences of repeated state function reductions at the passive boundary of CD followed by the first reduction to the opposite boundary of CD followed by a similar sequence. These sequences are analogs of unitary time evolutions. This defines the analog of blackhole state as a repeatedly re-incarnating conscious entity and having CD, whose size increases gradually. During given sequence of state function reductions the passive boundary has constant size. About active boundary one cannot say this since it corresponds to a superposition of quantum states.

The reduction sequences consist of life cycles at fixed boundary and the size of blackhole like state as of any state is expected to increase in discrete steps if it participates to cosmic expansion in average sense. This requires that the mass of blackhole like object gradually increases. The interpretation is that ordinary matter gradually transforms to dark matter and increases dark mass $M = R/G$.

Cosmic expansion is not observed for the sizes of individual astrophysical objects, which only co-move. The solution of the paradox is that they suddenly increase their size in state function reductions. This hypothesis allows to realize Expanding Earth hypothesis in TGD framework [K13]. Number theoretically preferred scalings of blackhole radius come as powers of 2 and this would be the scaling associated with Expanding Earth hypothesis.

7.4 More About BMS Supertranslations

Bee (see `http://tinyurl.com/z4p9h7l`) had a blog posting about the new proposal of Hawking, Perry and Strominger (HPS, see `http://arxiv.org/abs/1601.00921`) [**?**] to solve the blackhole information loss problem. In the article Maxwellian electrodynamics is taken as a simpler toy example.

1. One can assign to gauge transformations conserved charges. Gauge invariance tells that these charges vanish for all gauge transformations, which approach trivial transformation at infinity. Now however it is assumed that this need not happen. The assumption that action is invariant under these gauge transformations requires that the radial derivative of the function Φ defining gauge transformation approaches zero at infinity but gauge transformation can be non-trivial in the angle coordinates of sphere S^2 at infinity. The allowance of these gauge transformations implies infinite number of conserved charges and QED is modified. The conserved gauge charges are generalizations of ordinary electric charged defined as electric fluxes (defining zero energy photons too) and reduce to electric gauge fluxes with electric field multiplied by Φ.

2. For Maxwell's theory the ordinary electric charged defined as gauge flux must vanish. The coupling to say spinor fields changes the situation and due to the coupling the charge as flux is expressible in terms of fermionic oscillator operators and those of U(1) gauge field . For non-constant gauge transformations the charges are at least formally non-trivial even in absence of the coupling to fermions and linear in quantized U(1) gauge field.

3. Since these charges are constants of motion and linear in bosonic oscillator operators, they create or annihilate gauge bosons states with vanishing energy: hence the term soft hair. Holographists would certainly be happy since the charges could be interpreted as representing pure information. If one considers only the part of charge involving annhilation operators one can consider the possibility that in quantum theory physical states are eigenstates of these "half charges" and thus coherent states which are the quantum analogs of classical states. Infinite vacuum degeneracy would be obtained since one would have infinite number of coherent states labelled by the values of the annihilation operator parts of the charges. A situation analogous to conformal invariance in string models is obtained if all these operators either annihilate the vacuum state or create zero energy state.

4. If these U(1) gauge charges create new ground states they could carry information about matter falling into blackhole. Particle physicist might protest this assumption but one cannot

exclude it. It would mean generalization of gauge invariance to allow gauge symmetries of the proposed kind. What distinguishes U(1) gauge symmetry from non-Abelian one is that fluxes are well-defined in this case.

5. In the gravitational case the conformal transformations of the sphere at infinity replace U(1) gauge transformations. Usually conformal invariance would requite that almost all conformal charges vanish but now one would not assume this. Now physical states would be eigentates of annihilation operator parts of Virasoro generators L_n and analogous to coherent states and code for information about the ground state. In 4-D context interpretation as strong form of holography would make sense.The critical question is why should one give up conformal invariance as gauge symmetry in the case of blackholes.

It is is interesting to look TGD analogy for BMS supertranslation symmetries. Not for solving problems related to blackholes - TGD is not plagued by these problems - but because the analogs of these symmetries are very important in TGD framework.

1. In TGD framework conformal transformations of boundary of causal diamond (CD) correspond to the analogs of BMS transformations. Actually conformal transformations of not only sphere (with constant value of radial coordinate labeling points of light rays emerging from the tip of the light-cone boundary) but also in radial degrees of freedom so that conformal symmetries generalize. This happens only in case of 4-D Minkowski space and also for the light-like 3-surfaces defining the orbits of partonic 2-surfaces. One actually obtains a huge generalization of conformal symmetries. As a matter of fact, Bee wondered whether the information related to radial degrees of freedom is lost: one might argue that holography eliminates them.

2. Amusingly, one obtains also the analogs of U(1) gauge transformations in TGD! In TGD framework symplectic transformations of light-cone boundary times CP_2 act like U(1) gauge transformations but are not gauge symmetries for Kähler action except for vacuum extremals! This is assumed in the argument of the article to give blackhole its soft hair but without any reasonable justification. One can assign with these symmetries infinite number of non-trivial conserved charges: super-symplectic algebra plays a fundamental role in the construction of the geometry of "World of Classical Worlds" (WCW).

   At imbedding space level the counterpart for the sphere at infinity in TGD with the sphere at which the lightcone-boundaries defining the boundary of causal diamond (CD) intersect. At the level of space-time surfaces the light-like orbits of partonic 2-surfaces at which the signature of the induced metric changes are the natural counterparts of the 3-surface at infinity.

   In TGD framework Noether charges vanish for some subalgebra of the entire algebra isomorphic to it and one obtains a hierarchy of quantum states (infinite number of hierarchies actually) labelled by an integer identifiable in terms of Planck constant $h_{eff}/h = n$. If colleagues managed to realize that BMS has a huge generalization in the situation when space-times are surface in $H = M^4 \times CP_2$, floodgates would be open.

   One obtains a hierarchy of breakings of superconformal invariance, which for some reason has remained un-discovered by string theorists. The natural next discovery would be that one indeed obtains this kind of hierarchy by demanding that conformal gauge charges still vanish for a sub-algebra isomorphic with the original one. Interesting to see who will make the discovery. String theorists have failed to realize also the completely unique aspects of generalized conformal invariance at 3-D light-cone boundary raising dimension $D = 4$ to a completely unique role. To say nothing about the fact that M^4 and CP_2 are twistorially completely unique. I would continue the list but it seems that the emergence super string elite has made independent thinking impossible, or at least the communications of the outcomes of independent thinking.

Does one obtain the analogs of generalized gauge fluxes for Kähler action in TGD framework?

1. The first thing to notice is that Kähler gauge potentials are not the primary dynamical variables. This role is taken by the imbedding space coordinates. The symplectic transformations of CP_2 act like gauge transformations mathematically but affect the induced metric

so that Kähler action does not remain invariant. The breaking is small due to the weakness of the classical gravitation. Indeed, if symplectic transformations are to define isometries of WCW, they cannot leave Kähler action invariant since the Kähler metric would be trivial! One can deduce symplectic charges as Noether charges and they might serve as analogs fo the somewhat questionable generalized gauge charges in HPS proposal.

2. If the counterparts of the gauge fluxes make sense they must be associated with partonic 2-surfaces serving as basic building bricks of elementary particles. Field equations do not follow from independent variations of Kähler gauge potential but from that of imbedding space coordinates. Hence identically conserved Kähler current does not vanish for all extremals. Indeed, so called massless extremals (MEs) [K3] can carry a non-vanishing light-like Kähler current, whose direction in the general case varies. MEs are analogous to laser beams and if the current is Kähler charged it means that one has massless charged particle.

3. Since Kähler action is invariant also under ordinary gauge transformations one can formally derive the analog of conserved gauge charge for non-constant gauge transformation Φ. The question is whether this current has any physical meaning.

   One obtains current as contraction of Kähler form and gradient of Φ:

$$j_\Phi^\alpha = J^{\alpha\beta}\partial_\beta\Phi \ , \tag{7.1}$$

   which is conserved only if Kähler current vanishes so that Maxwell's equations are true or if the contraction of Kähler current with gradient of Φ vanishes:

$$j_\Phi^\alpha\partial_\alpha\Phi = 0 \ . \tag{7.2}$$

   The construction of preferred extremals leads to the proposal that the flow lines of Kähler current are integrable in the sense that one can assign a global coordinate Ψ with them. This means that Kähler current is proportional to gradient of scalar function Ψ:

$$j_\Phi^\alpha = g^{\alpha\beta}\partial_\beta\Psi \ . \tag{7.3}$$

   This implies that the gradients of Φ and Ψ are orthogonal. If Kähler current is light-like as it is for the known extremals, Φ is superposition of light-like gradient of Ψ and of two gradients in a sub-space of tangent space analogous to space of two physical polarizations. Essentially the local variant of the polarization-wave vector geometry of the modes of radiative solutions of Maxwell's equations is obtained. What is however important that superposition is possible only for modes with the same local direction of wave vector ($\nabla\Psi$) and local polarization.

   Kähler current would be scalar function k times gradient of Ψ :

$$j_\Phi^\alpha = kg^{\alpha\beta}\partial_\beta\Psi \ . \tag{7.4}$$

   The proposal for preferred extremals generalizing at least MEs leads to the proposal that the extremals define two light-like coordinates and two transversal coordinates.

4. The conserved current decomposes to a sum of interior and boundary terms. Consider first the boundary term. The boundary contributions to the generalized gauge charge is given by the generalized fluxes

$$Q_{\delta,\Phi} = \oint J^{tn}\Phi g^{1/2} \tag{7.5}$$

over partonic 2-surfaces at which the signature of the induced metric changes from Euclidian to Minkowskian. These contributions come from both sides of partonic 2-surface corresponding to Euclidian and Minkowskian metric and they differ by a imaginary unit coming from $g^{1/2}$ at the Minkoskian side. $Q_{\delta,\Phi}$ could vanish since $g^{1/2}$ approaches zero because the signature of the induced metric changes at the orbit of the partonic 2-surfaces. What happens depends on how singular the electric component of gauge potential is allow to be. Weak form of electric magnetic duality proposed as boundary condition implies that the electric flux reduces to magnetic flux in which case the result would be magnetic flux weighted by Φ.

5. Besides this there is interior contribution, which is Kähler current multiplied by -Φ:

$$Q_{int,\Phi} = \int j^t \Phi g^{1/2} \quad . \tag{7.6}$$

This contribution is present for MEs.

6. Could one interpret these charges as genuine Noether charges? Maybe! The charges seem to have physical meaning and they depend on extremals. The functions Φ could even have some natural physical interpretation. The modes of the induced spinor fields are localized at string world sheets by strong form of holography and by the condition that electric charge is well defined notion for them. The modes correspond to complex scalar functions analogous to powers z^n associated with the modes of conformal fields. Maybe the scalar functions could be assigned to the second quantized fermions. Note that one cannot interpret these contributions in terms of oscillator operators since the second quantization of the induced gauge fields does not make sense. This would conform with strong form of holography which in TGD framework sense that the descriptions in terms of fundamental fermions and in terms of classical dynamics of Kähler action are dual. This duality suggest that the quantal variants of generalized Kähler charges are expressible in terms of fermionic oscillator operators generating also bosonic states as analogs of bound states. The generalized charge eigenstates might be also seen as analogs of coherent states.

8 Topological Order And Quantum TGD

There was a very interesting link in Thinking allowed original to an article telling about the category theoretical description of topological order [B9] (`http://arxiv.org/abs/1507.04673`). The description of non-Abelian Quantum Hall in terms of patters of zeros of multi-electron wave function and using so called Z_n current algebra states is considered in [B6].

Topological order means emergence of discrete degrees of freedom implying ground state degeneracy and long range correlations, even long range entanglement. Topological order appears in 2+1-D systems. Braiding and braid statistics characterized by R-matrix are central elements. There is also a connection with integrable 2-D quantum field theories. The generalization of R-matrix defines 2-particle S-matrix defining the building brick of N-particle S-matrix in 2-D integrable quantum field theories: the basic interaction is passing-by inducing a phase lag. For braids the exchange is a continuous homotopy and braiding dynamics could make possible topological quantum computation [K10].

One cannot avoid the feeling that topological order is exactly the mathematical tool needed in quantum TGD. On basis of what I have learned recently [L12, **?**] (see this and this), condensed matter physicists might be discovering many-sheeted space-time and exotic effects predicted by quantum TGD without realizing what they are doing! I have believed hitherto that this would be something for elementary particle physicists but they are sunken into the multiverse muds of M-theory landscape.

There are several reasons to believe that the notion of topological order in TGD could be very useful in more concrete formulation of quantum TGD.

1. TGD can be seen as almost topological QFT. 3-D surfaces are by holography equivalent with 4-D space-time surfaces and by strong form of holography equivalent with string world sheets

and partonic 2-surfaces. What make this duality possible is super-symplectic symmetry [K7, K6] realizing strong form of holography and quantum criticality realized in terms of hierarchy of Planck constants characterizing hierarchy of phases of ordinary matter identified as dark matter. This hierarchy is accompanied by a fractal hierarchy of sub-algebras of supersymplectic algebra isomorphic to the entire algebra [K39]: Wheeler would talk about symmetry breaking without symmetry breaking.

2. $h_{eff} = n \times h$ hierarchy corresponds to n-fold singular covering of space-time surface for which the sheets of the covering co-incide at the boundaries of the causal diamond (CD), and the n sheets together with superconformal invariance give rise n additional discrete topological degreees of freedom - one has particles in space with n points. Kähler action for preferred extremals reduces to Abelian Chern-Simons terms characterizing topological QFT. Furthermore, the simplest example of topological order - point like particles, which can be connected by links - translates immediately to the collections of partonic 2-surfaces and strings connecting them.

3. There is also braiding of fermion lines/magnetic flux tubes and Yangian product and co-product defining fundamental vertices, quantum groups associated with finite measurement resolution and described in terms of inclusions of hyper-finite factors [K30] .

Number theoretic vision [K39] - in particular adelic physics - is an additional building brick in TGD. It would be nice to see what comes out from the combination of topological order with the hierarchy of algebraic extensions of rationals and associated extensions of p-adic number fields by extending the physics to adelic physics. The existence of this extension must pose powerful constraints on physics.

In this article topological order and its category theoretical description are considered from TGD point of view - category theoretical notions are indeed very natural in TGD framework. The basic finding is that the concepts developed in condensed matter physics (topological order, rough description of states as tangles (graphs imbedded in 3-D space), ground state degeneracy, surface states protected by symmetry or topology) fit very nicely to TGD framework and has interpretation in terms of the new space-time concept. This promises applications also in the conventional areas of condensed matter physics such as more precise description of solid, liquid, and gas phases.

The following considerations can be blamed to be "just philosophy" since I am not a condensed matter physics and do not try to pretend being computational virtuoso. What I dare argue that TGD allows much more wider perpective than is possible inside the boundaries posed by specialization. My hope is that the reader would realize that TGD provides fascinating challenges and inspiration for theoretical physicist - even those working in condensed matter physics.

8.1 What Does Topological Order Mean?

Topological order is something not describable by local order parameters allowing to characterize different phases by their different symmetries using Landau theory. Fractional Quantum Hall effective is simplest example of this: all phases have the same symmetries. One signature is the existence of several degenerate ground states.

As already noticed, in the fractal Universe of TGD one has a hierarchy of quantum criticalities with levels labelled by $h_{eff} = n \times h$ giving rise to "symmetry breaking without symmetry breaking" in terms of an inclusion hierarchy of isomorphic mutually isomorphic subalgebras of super-symplectic algebra. Could this hierarchy lurk behind the existence of phases with identical symmetries? This hierarchy makes sense also for the ordinary conformal invariance, which is much smaller symmetry than super-symplectic one and replaces AdS/CFT duality with more physical looking duality defined by strong form of holography.

For some reason colleagues have not noticed the possibility of this kind of conformal symmetry breaking. This is not the only rather trivial fact that has escaped the attention of hasty colleagues during last decades. The completely unique role of 4-D space-time, the twistorial uniqueness of $M^4 \times CP_2$ [K28], and the fact that CP_2 codes for standard model symmetries, have also remained un-noticed.

The article *Detecting topological order in a ground state wave function* by Levin and Wen [B8] gives an idea about what topological order is. The simplest situation in which topological order is

encountered, is when one has a set of objects such that each pair can be connected by link. The pair can be characterized by "spin" telling whether its members are connected or not. In condensed matter physics one could have lattice like structure with link between given neighboring points or not. This is very special situation. In principle all possible configurations involving links between objects are possible. One could of course pose additional conditions such as as imbedding of the vertices as lattice, restriction of the links to nearest neighbour links, allowance of only single link between members of pair, and some maximum number of links emanating from given object.

What does topological order mean in quantum theory?

1. In topological quantum computation each braid topology defines unitary S-matrix and one has only single braid topology. Topology is still classical and fixed although the dynamics in this fixed topology is quantal.

2. There is however no deep reason to assume localization into a single topology. This mixing could occur already in particle physics. The TGD based explanation of family replication phenomenon [K5] assumes that quantum superpositions of the topologies of partonic 2-surfaces characterized by genus and that CKM matrix reflects different topological mixings for U and D type quarks [K21]. Ground state wave function would be quantum superposition of graph topologies. Even more: for given graph one would have also a superposition of different imbeddings to 3-space as tangles characterized by knotting and linking.

One can formally describe the topology in terms of "topological spins".

1. For a quantum graph each topological configuration of the system is quantum superposition of graphs with some pairs of vertices connected by link or not. What is fixed are the vertices. One can assign to each pair "spin" -1/1 telling whether the connecting link is present or not. One could assume that each vertex is connected to at least one vertex to exclude lonely vertices. This gives a large number of graphs and ground state is quantum superposition of these graphs. This brings in the long range quantum entanglement between pairs. Some kind of reference configuration could be a graph in which all objects are connected to every other object once.

2. The imbedding of graph to 3-D space gives tangle. Tangle consists of several groups of vertices from which connecting links emerge. By fractality one can also tangles within tangles. Tangle can be characterized by its projection to a suitably chosen plane. In the projection two tangle strands cross and there are two different crossings depending which strand is above which. This defines second spin like variable characterizing tangles.

3. In TGD space-time also 2-braiding is possible. 2-braid can be thought of as an evolution of ordinary knot giving rise to 2-D surface in 4-D space-time. One an have un-knotting or its reversal of knots by a violent manner: the braid strands go simply through each other. Knot invariants are actually constructed by performing this violent un-knotting step by step. A spin like variable telling whether this occurs for a pair of braid strands appearing in 2-knot is needed.

The article considers a lattice in which links are possible between neighboring lattices points. The ground state is a superposition over all link paths as a state with long range entanglement: the product of spins equals to 1 for all closed loops crossing a given curve since the loops intersect the curve always even number of times (this is where topology shows itself!) Could this kind quantum superposition be the first principle approach when one wants to describe many particle system? Liquid, gas, and solid phases would be of course hugely simplified descriptions in this picture. The basic unpleasant question is obvious: can long links be really thermally stable in standard physics?

8.2 Topological Order And Category Theory

The article summarizes the proposal to describe topological order in terms of category theory. In reductionistic approach one decomposes the object to smaller and smaller pieces. In particle physics the actions of symmetries on object characterize the object in terms of quantum numbers. In category theoretical approach one describes the system in terms of its relations with other

systems. Relations corresponds to morphisms mathematically and are deduced by studying the interactions with other systems. How particle interacts with the other particles defines what particle is.

At the level of topology the braiding of object with other objects provides this kind of basic morphism. Fusion or stacking with other objects defines second morphism. The integer valued coefficients of fusion telling which quantum objects appear in the stacking of the object with another object provide information about objects via its relations. Fusion has splitting as its reversal. Algebraically product and co-product correspond to these operations and I have proposed that zero energy states as transition amplitudes represents sequences algebraic operations - product and co-product identified essentially as 3-particle vertices - in Yangian algebra closely related to category theoretical approach [K28]. Particle vertices would represent additional morphisms besides braiding.

Category theoretical approach can be made quantitative in terms of integers N_k^{ij} telling the multiplicity for representation k in the fusion of representations i and j and fractionals spins s_i characterizing the braid statistics. The category in question must involve also the counterpart of tensor product since in physics one must engineer more complex systems from simpler ones. One speaks of tensor category.

One can define stacking of topological orders serving as the counterpart for tensor product and making topological orders a monoid. Stacking is not ordinary tensor product since there is some inherent entanglement always present. I dare to guess that a special case of Connes tensor product is in question [K30]. This inherent entanglement eliminates a lot of states from the ordinary tensor product. Stacking is interpreted in condensed matter context as formation of multilayers.

If stacking by a given topological order leaves other topological orders as such, the topological order is trivial. A non-trivial topological order can have an inverse: this is equivalent with having no topological excitations. The inverse of the topological order is obtained by time reversal operation acting as symmetry. Non-invertible topological orders correspond to non-Abelian braid statistics.

The basic result of article does not say at the first glance too much to a non-specialist. *Up to an invertible topological order 2+1-D fermionic/bosonic topological orders with/without symmetry are classified by modular braided fusion categories (BFC) over symmetric BFC, where symmetric BFC describes product state with/without symmetry.*

I understand that symmetric BFC corresponds to invertible topological orders acting via the stacking and not affecting the topological order: this is like multiplying vector with scalar in projective space.

8.3 Category Theoretical Description Of Topological Order In TGD

Much of the philosophy and mathematical building bricks of this vision are shared by quantum TGD. The notions of topological order, stacking, and gapless states represent however something new and are highly interesting concerning the more detailed formulation of quantum TGD. This kind of approach is not all that is needed in TGD but could give the tools needed to build the roughest topological characterization of spinor fields in the "world of classical worlds" (WCW) at many-particle level.

8.3.1 Topological order in TGD

In quantum TGD combinatorial description in terms of graphs would give the roughest topological description of the ground state in terms of partonic 2-surfaces (vertices) and fermionic strings or magnetic flux tubes (links) connecting them. It must be made clear, that topological order in TGD sense means radical deviation from the standard model thinking in which space-time is fixed background. This goes also beyond the descriptive powers of the long length scale limit of string models assuming that space-time serves as arena of dynamics.

There are two basic topological elements besides many-sheetedness: the graph structure characterized by telling which partonic 2-surfaces are connected by strings/flux tubes and the tangle structure present because there exists infinite number of topologically non-equivalent imbeddings of the graph to 3-D space. 4-D space-time thus allows richest possible topological order besides gigantic super-symplectic symmetries.

1. The strings/flux tubes could connect different partonic surfaces and also return back to the same partonic 2-surface but at different point carrying fermion number. Strings and flux tubes get knotted and linked in 2+1 dimensional situation. The outcome is tangle. If there are only two partonic 2-surface no self-entangling one has braid.

2. For partonic 2-surfaces carrying several fermions also self-tangles are possible and one can have quantum superposition of different self-tangles. Flux tubes of dipole magnetic field serve as an illustration.

3. Also the many-sheeted character of space-time gives additional topological degree of freedom in TGD framework. In TGD Universe even elementary particles are structures with at least two space-time sheets since they consist of a pair of wormhole contacts connecting two space-time sheets and wormhole throats at both sheets are connected by flux tubes carrying monopole flux and fermionic strings. For large values of h_{eff} the size of these structure is scaled up so that one could electrons with size scale of cell! As discussed below, many-sheetedness could correspond to what is called stacking of topological orders.

Topological order defined by links is robust and not affected by thermal fluctuations unless the links are thermally unstable. Thermal stability at high temperatures can be argued to be an ad hoc assumption in standard physics. In TGD framework the thermal stability of long links would be due to the hierarchy of Planck constants $h_{eff} = n \times h$. This could make possible long range quantum entanglement between distant topological spins possible in high temperatures.

What about applications? Can one apply the notion of topological order only to low exotic condensed matter systems at low temperature? TGD suggests that applications are possible even at room temperatures.

1. The distinction between liquids and gases is not really well-understood in text book statistical physics missing strings as fundamental objects so that one has only the point particles - partonic 2-surfaces in TGD - and potential function modelling the interactions between them. Topological order replacing potential function with strings/flux tubes should allow an improved understanding the distinction between fluids and gases.

2. The clusters of water molecules are problematic in the standard model description of water, and are crucial in the physics of living matter (consider only the fourth phase of water discovered by Pollack). The existence of strings connecting partonic 2-surfaces would make the clusters of liquid molecules in TGD framework. There is also a connection with $h_{eff} = n \times h$ hypothesis made rigorous by the hierarchy of quantum criticalities explaining dark matter. The longer the flux tubes defining the link needed for clustering are, the larger the value of h_{eff} must be, and the value of h_{eff} characterizes the length scale in which quantum coherence is present.

3. Reductionist finds it convenient to assume that nuclear physics is totally isolated from the condensed matter physics. There are anomalies challenging this hypothesis. For instance, X rays from Sun with energies in the energy scale of transition energies of heavier ions are found to affect the nuclear decay rates so that they vary periodically with period of year [K20]. Could condensed matter transitions do the same trick?

   The claims about cold fusion represents second example [K20] Most main streamers refuse to even consider cold fusion as a possibly real phenomenon. The flux tubes carrying dark quarks with large h_{eff} would bind nucleons to form nuclei and they could be so long as to make possible interactions with condensed matter. They could explain several other anomalies such as the anomalous value of proton radius.

8.3.2 Stacking, time reversal, and gapless states in TGD framework?

Stacking can be seen as a constrained tensor product. It could have several interpretations in TGD framework.

1. Stacking might correspond to a formation of quantum states assignable to many-sheeted structures formed from single sheeted structures? Stacking would occur already as one forms

elementary particles as double-sheeted structures. Could it be involved with the formation of n-sheeted coverings associated with $h_{eff}/h = n$ and quantum criticality?

2. Topological condensation of a smaller space-time sheet to a larger space-time sheet might have interpretation in terms of stacking? Topologically condensed space-time sheet cannot be represented as a tensor factor in TGD framework. Can the situation be described as a pair of included and including factors with included factor defining measurement resolution for the including factor? Connes tensor product is indeed associated with the inclusion?

3. Many-sheeted space-time suggests the rather exotic looking possibility that two disjoint space-time sheets can have topologically condensed smaller space-time sheets (like liquid drops of the wall) connected to each other by thin flux tubes not visible in the scale of bigger space-time sheets - entanglement would be a resolution dependent notion. In the scale of the bigger space-time sheet one would have ordinary tensor product without entanglement. In the scale of smaller space-time sheets one would have entanglement: subsystems of unentangled systems would entangle. This has a direct application in TGD inspired theory of consciousness: sub-selves (mental images) of self can fuse to stereo mental image shared by the selves although selves do not entangle and remained separate conscious entities [K25].

   Could this be described in the formalism based on categories? Is the notion of resolution inherent to this description? The inclusions of hyper-finite factors can be interpreted in terms of finite measurement resolution, and the description of inclusions indeed involves quantum groups as also topological order. The larger space-time sheet seen in the resolution defined by topological condensed space-time sheets would be characterized by quantum space with fractional quantum dimension resulting by modding out the degrees of freedom of topologically condensed space-time sheets.

4. One can imagine a further interpretation for stacking. Negentropic entanglement between states associated with separated space-time sheets could also give rise to a restricted tensor product [K19]. Negentropic entanglement (NE) can be algebraic such that the coefficients belong to the algebraic extension of rationals characterizing the adele but entanglement probabilities are outside this extension, which encourages the hypothesis that diagonalization is not possible and this kind of NE is stable. NE can also correspond to a projector in which case state function reduction need not lead to an eigen ray since the whole sub-space is eigenspace of density matrix.

Time reversal defines inverse topological order provided one can regard it as a symmetry. For instance, time reversal symmetry protects topological insulator. More generally, one can have symmetry protected topological order (SPT), which is actually trivial topological order but without long range entanglement. Symmetry protected states do not lead to emergent fractional charge, fractional statistic, nor emergent gauge gauge theory unlike topological order. In TGD framework the emergent gauge symmetry could be identified as a symmetry associated with the action of included hyperfinite factor, which indeed causes no measurable effects in the resolution used.

Here an interesting delicacy appears. Is its particle physicist's time reversal, which is slightly broken symmetry? Or is it time reversal in the sense of TGD inspired theory of quantum measurement and consciousness bringing in the arrow of time (or thermodynamics)? Time reversal in the latter sense cannot be interpreted as a symmetry. For instance, time reversal in the latter sense involves state function reduction at opposite boundary of CD, which is dynamical and non-deterministic process leading to death of self and its re-incarnation as time reversed self. Note that time reversal is not allowed for non-Abelian braid statistics and although Kähler action is abelian the vierbein group of CP_2 is non-Abelian and can give rise to non-Abelian braiding by electroweak gauge group.

Gapless boundary excitations implying ground state degeneracy are also an important part of picture.

1. In the case of topological order they are robust against all local perturbations and protected by topology. Systems described by topological QFTs provide a basic example about non-trivial topological order. In the case of SPTs one has only robustness against local perturbations that do not break symmetries.

2. Super-symplectic algebra provides a concretization of the situation in TGD context. The sub-algebra of supersymplectic algebra with conformal weights, which are $h_{eff}/h = n$-ples of those for entire algebra act as gauge transformations and are thus perturbations, which do not change the state: one could say that there is symmetry protection. This differs from topological protection since not all deformations of 3-surfaces at the ends of space-time at boundaries of CD act like gauge symmetries. Indeed, the remaining generators of super-symplectic algebra act as genuine dynamical symmetries and if the generators with conformal weights $0 \leq k \leq n-1$ create physical states one indeed has finite degeneracy of states (this if the conformal weights of the super-symplectic algebra are integers). This gives just the n-fold degeneracy corresponding to singular n-sheeted covering property of space-time surface. Of course, the is a huge difference: usually one deals with finite-D or even discrete groups whereas super-symplectic group is really huge.

To test TGD one must be able to see the physics of single space-time sheet. The difficulty is that usually this physics is masked experimentally: usually we see only the superposition of effects from several sheets. It is also masked theoretically in the approximation based on the space-time of General Relativity and standard model since it is obtained by replacing many-sheeted space-time by a slightly curved region of Minkowski space involving replacement of induced gauge potentials resp. gravitational fields of space-time sheets with their sum defining the gauge potentials of standard model resp. gravitational field of GRT, replacing partonic 2-surfaces by point like particles, and describing fermionic strings in terms of interaction potentials. Condensed matter physicists might be already occasionally seeing the physics of single space-time sheet.

8.3.3 Category theory and TGD

Category theoretical thinking is part of TGD [K4].

1. In reductionistic approach particles are fundamental building bricks. The idea about an isolated particle must be given up in TGD. The strings connecting partonic 2-surfaces are present from beginning rather than only the partonic 2-surfaces, which are the counterparts of particles in the reductionistic approach. Note that in string models one has strings but no partonic two-surfaces so that one still remains in the framework of reductionism!

   This has highly non-trivial implications for the understanding of the formation of gravitational bound states and from TGD point of view the failure of superstring models in long length scales is trivial to understand: superstring description of gravitational interactions makes sense only in Planck length scale: the rest is - not history but - wishful thinking eventually leading to landscape and multiverse [K38](`http://matpitka.blogspot.fi/2015/03/is-formation-of-gravitational-bound.html`).

2. Zero Energy Ontology (ZEO) [K31, K19] is very category theoretical approach. One gives up the notion of positive energy state in ZEO. Positive energy states are replaced with zero energy states, which are pairs of positive and negative energy states at opposite boundaries of causal diamond (CD) and have opposite quantum numbers. Zero energy state is analogous to event in standard ontology consisting of initial and final state. Object is replaced with a relation between objects, one might say.

   Zero energy states are described by M-matrices (M-matrix is expressible as products of square root of density matrix and unitary S-matrix). Dynamics is coded by unitary U-matrix expressible in terms of M-matrices so that states code the dynamics in their representation. ZEO shows its power in TGD inspired theory of consciousness and allows to replace observer as an outsider of the physical world with the notion of self, a conscious entity describable in terms of quantum physics.

9 Deconstruction And Reconstruction In Quantum Physics And Conscious Experience

Deconstruction means roughly putting something into pieces. One could also speak about deconstruction followed by a reconstruction since deconstruction creates the impressions that something

is just destroyed. Often deconstruction is thought to involve the reconstruction. This process is applied in deconstructivistic architecture (https://en.wikipedia.org/wiki/Deconstructivism) as one can learn by going to Wikipedia and also cubism brings in mind this kind of approach. In this process one organizes typical features of given style in new - one might even say "crazy" manner. There can be even a kind of social interaction between buildings: as if they were communicating by exchanging features.

Postmodernism is a closely related movement and claims that truths are socially constructed: great narratives are dead. Nothing could irritate more physicist who has learned how much mistakes and hard work are needed to distill the truth! Everything does not simply go! On the other hand, one can argue the recent sad state of super string theories and frontier theoretical physics in general suggests that postmodernists are right. Superstrings and multiverse are definitely purely social constructs: they were the only games in the town but now American Mathematical Society warns that super string theoreticians are spoiling the public image of science. Multiverse lived only few years. Certainly one great narrative - the story or reductionism and materialism thought to find its final culmination as M-theory - is dead. It is however nonsense to claim that all great narratives are dead. That telling the alternative great narratives in respected journals is impossible does not mean that they are dead!

But is not wise throw the big ideas of deconstruction and reconstruction away. Rather, one can ask whether they could be made part of a new great narrative about physical world and consciousness.

9.1 Deconstruction And Reconstruction In Perception, Condensed Matter Physics And In TGD Inspired Theory Of Consciousness

Deconstruction and reconstruction appear in the construction of percepts, in condensed matter physics, and are also part of TGD inspired theory of consciousness.

9.1.1 Perception

The very idea of deconstruction in architectural sense is highly interesting from the perspective of both quantum physics and consciousness.

The buildup of our perception involves very concretely deconstruction process. First the sensory input is decomposed into features. Edges, corners, positions, motions analyzed to direction and velocity, colors,... Objects are replaced with collections of attributes: position, motion, shape, surface texture, color,.... Deconstruction occurs at lower cortical layers. After this reconstruction takes place: various kinds of features are combined together through a mysterious looking process of binding - and the outcome is a percept.

Reconstruction can occur also in "wrong" manner. This occurs in hallucinations, delusions, and dreams. Humour is based on association of "wrong" things from different categories together. Synesthesia involves association between different sensory modalities: note with a given pitch have characteristic color or numbers correspond to colors or shapes. I remember an article telling about how subject persons in hypnosis can experience what circle with four corners looks like. Some attribute can be lacking from the reconstruction: person can perceive the car as object but not its motion. Car is there now. Moment later it is here. Nothing between.

Also non-standard reconstructions are possible. Could these non-standard reconstructions define a key aspect of creativity. Could reconstruction represent in some lucky situations new idea rather than hallucination or delusion?

For few years ago I listened a radio document about a professional, who builds soundscapes to movies and learned that the construction of soundscape is deconstruction followed by reconstruction. One starts from natural sounds but as such they are not very impressive: driving by car over some-one does not create any dramatic effect- just "splat" - nothing else. Thisit is so non-dramatic that it can be used to create comic. In order to cure the situation the real sounds are analyzed to features and then reconstructed by amplifying some features and by throwing away the unessential ones. The output sounds much more real than the real input. Of course, actors are masters of this technique and this is why videos about ordinary people doing something funny is like looking autistic ghosts. And if you look at the collection of modules of video game you see modules with name "Aargh", "Auch", "Bangggg", etc..

Association is the neuroscientist's key notion and allows to get an idea about what happens in reconstruction. Reconstruction involves association of various features to form the final percepts. First this process occurs for various sensory modalities. Sensory percepts from various sensory modalities are then combined to full percepts in association regions.

But what associations are at deeper level. What features are? Heretic could ask whether they could correspond to conscious experiences not conscious to us but conscious at lower level. Reader probably noticed that reconstruction-deconstruction took place here: the student is not supposed to ask this question since the theories of consciousness for some funny reason - maybe a pure accident - almost as a rule make the assumption that consciousness has no structure- no selves with subselves with sub-selves with... How these features bind to our conscious percepts? Neuroscience alone cannot tell much about this since it is based on physicalism: "hard problem" serves the articulation of this problem.

The following considerations represent deconstructions and reconstructions, and I will not explicitly mention when this happens. I just warn the reader. Do not stop reading however!

9.1.2 Condensed matter physics

One must bring in some basic notions of quantum theory if one wants to reduce deconstruction and reconstruction to quantum physics. The key mathematical fact is that in quantum theory each particle in many-particle state corresponds to a tensor factor. This notion is very difficult to eplain without actually having a lecture series about quantum tneory but I can try.

1. The basic idea is that one can build Hilbert spaces by forming their tensor products of them. If you have Hilbert spaces of dimensions n_1 and n_2, the tensor product has dimension $n_1 \times n_2$. Hilbert spaces represent physical systems: say electron and proton. To describe word consisting of proton and electron you from the tensor product of these Hilbert spaces. This is like playing with legos.

   Now I must be honest, I was cheating a little bit. Life is not quite so simple. One can also form bound states of two systems - say hydrogen atom from proton and electron, and the bound states of hydrogen atom represent only a sub-space of the tensor product. Connes tensor product is more exotic example: it represents only a sub-space of the entire tensor product: only certain kind of entangled states for which the composites are strongly correlated are allowed. As a matter fact, gluing the legos together creates strong correlations between them so that it serves as a good analogy for Connes tensor product and tensor product assignable to bound states.

2. Even elementary particles have several degrees of freedom -say spin and charge - to which one can assign Hilbert spaces decomposing formally into tensor product of Hilbert spaces associated with these degrees of freedom. Sub-space of the full tensor product is allowed, and one can purely formally say that elementary particle is a bound state of even more elementary particles. Somewhat like written word having meaning to us consists of letters, which as such represent nothing to us (but could represent something to lower level conscious entities). Could it be possible to apply deconstruction to elementary particles?

Now comes the surprise: condensed matter physicists have discovered deconstruction long time ago!

1. Electron in the valence band of conductor has three kinds of degrees of freeedom labelled by spin, charge and orbital state- state of electron in atom - characterizing the valence band. One can velocity to both spin, charge and orbital state. The state of electron decomposes in purely formal sense to a bound state of spinon, chargon, and holon. The question is whether one could have a situation deconstructing this bound state to its composites moving with different velocities. One would have effectively three particles and quantally three waves moving with same velocity. For free electrons obeying Dirac equation this is not possible. But this could be (and is!) possible in condensed matter. This deconstruction is mathematically like ionizing an atom: ion and electron are the outcome.

2. Instead of single wave motion there can be three free wave motions occurring with different velocities (wave vectors) corresponding to spinon, chargon and holon. In popular articles this process is called "splitting" of electron. This term is optimal choice if the purpose is to create profound mis-understandings in layman reader associating naturally splitting with a geometric process of putting tiny ball into pieces. As already explained, it is Hilbert space which is decomposed into tensor factors, not a tiny ball. The correlations between factors forced by bound state property are broken in this divorce beteen degrees of freedom.

3. What condensed matter theorist propose is roughly following. The consideration is restricted to effectively one-dimensional systems, call them wires. Atoms along line and electrons at atoms, which can be in conduction bands and give rise to a current. Electron has spin, charge, and orbital degrees of freedom if in conduction band and delocalized and thus shared by the atoms. The spin direction of the electron can vary along wire, and electron can excited to a higher orbital in atom and this exciattion can also vary along wire. These degrees of freedom define tensor factors. Usually these degrees of freedom are bound to single entity free electrons and interacting electrons usually move as a single entity with charge, spin, and orbital excitation.

   The holy trinity of charge, spin, and orbital degrees of freedom can be however split under some circumstances prevailing in condensed matter. The phase of the spinor representing electron can vary along wire and defines wave motion with some velocity/wave vector assignable with the ordinary electric current. The spin of electron can rotate at each point. Also the phase of this rotation can vary along wire so that a wave moving along wire with velocity different from that for charge: this is spin wave having as classical analog the rotation of bicycle pedals. If electron moves in a linear lattice of atoms, the orbital excitation can also vary along the wire and a third wave moving with its own velocity is possible. One has three free particle like entities moving with different velocities! This kind of waves are certainly not possible for the solutions of Dirac equation representing freely moving fermions and particle physicists do not encounter them.

4. These wave motions are different from the wave motions associated with phonons and magnons. For sound it is periodic oscillation for the position of atom, which propagates in sound wave. For magnon it is change of spin direction which propagates and defines a spin 1 collective excitation. Spinon as a quasiparticle has spin 1/2 so that spinon and magnon are different things. Spinon is formal constituent of electron made visible by the condensed matter environment. Magnon is collective excitation of condensed matter system.

   Spin currents provide an example of a situation in which spin and charge currents can flow at different speeds and are becoming important in a new technology known as spintronics. Spin currents have very low resistance and the speculation is that they might relate to high T_c super conductivity.

From the articles that I have seen one might conclude that deconstruction is in practice possible only for effectively 1-dimensional systems. I do not see any obvious mathematical reason why the deconstruction could not occur also in higher-dimensional systems.

It is however true that 1-dimensional systems are very special physically and mathematically ans super string theorists know. Braid statistics replaces ordinary statistics at for them and this brings in a lot of new effects. Furthermore, 2-D integrable gauge theories allow interactions as permutations of quantum numbers and lead to elegant models describing deconstructed degrees of fields as quantum fields in 2-D Minkowski space with interactions reducing to 2-particle interactions describable in terms of R-matrix satisfying the Yang-Baxter equations. It is difficult to say how much the association of deconstruction to 1-D systems is due the fact that they are mathematically easier to handle than higher-D ones.

The rise and fall of superstring models certainly was due to this technical easiness. I learned that the easiest manner to kill the idea that fundamental objects are 3-D was to say that superconformal invariance of super-string models is lost and the theory is not calculable. It took ineeed long time to realize that super-conformal has huge generalization when space-time is 4-D and imbedding space has Minkowski space as its factor. Twistorial considerations fixed the whole scheme uniquely. Theoretician should be patient.

9.1.3 TGD inspired theory of consciousness

The believer in quantum consciousness of course wonders what could be the quantum counterparts of deconstruction and reconstruction. It would seem that analysis and synthesis of the sensory input deconstructs the mental image associated with it to features - simpler fundamental mental images- and reconstruct from these the percept as mental image. What does this correspond at the level of physics?

Before one can really answer one must understand what the quantum physical correlates of mental image are. How mental images die and are born? What features are as mental images? What their binding to sensory percepts does mean physically?

Here I can answer only on my own behalf and to do it I must introduce the basic notions and ideas of TGD inspired theory of consciousness. I will not go to details here because I have done this so many times and just suggest that the reading of some basic stuff about TGD inspired theory of consciousness. Suffice it to list just the basic ideas and notions.

1. Zero energy ontology and causal diamonds and hierarchy of Planck constants assignable to quantum criticality are basic notions. Number theoretic vision is also central. In particular, adelic physics fusing real physics and various p-adic physics as correlates for cognition is also basic building brick.

2. Consciousness theory is generalization of quantum measurement theory constructed to solve the basic problems of ordinary quantum measurement theory: observer becomes self described by physics rather than being outsider of the physical world. Negentropy Maximization Principle (NMP) defines the basic variational principle and state that the negentropy gain in state function reduction is maximal.

   Self hierarchy is the basic notion of TGD inspired theory of consciousness. Self experiences subselves as mental images. Self corresponds to a state function reduction sequence to the same boundary of causal diamond (CD). In standard quantum measurement theory this sequence does not change the state but in TGD framework the state at the opposite boundary of CD and even opposite boundary changes. This gives rise to the experience flow of time having the increases of the temporal distance between the tips of CD as a geometric correlate. Self dies as the first reduction to the opposite boundary takes place and re-incarnates at the opposite boundary as its time reversal. Negentropy Maximization Principle forces it to occur sooner or later. The continual birth and death of mental images supports this view if one accepts the idea about hierarchy. One can also consider identification for what the change of the arrow of time means for mental image.

3. Magnetic bodies carrying dark matter identified as $h_{eff} = n \times h$ phases of ordinary matter define quantum correlates for selves. Magnetic body has hierarchical onion-like structure and it communicates with biological body using dark photons propagating along magnetic flux tubes. EEG and its fractal generalization make both communication from/control of biological body to/by magnetic body. Dark matter hierarchy can be reduced to quantum criticality and this in turn has deep roots in the adelic physics.

What reconstruction could mean in TGD inspired theory of consciousness?

1. The restriction of deconstruction to the degrees of freedom of elementary particle is unnecessary restrictive. One can consider also larger units such a as molecules, cells, etc.. and their representations using tensor products.

2. Besides bound state formation also negentropic entanglement (NE) allows reconstruction of states which are almost stable with respect to NMP. There are two kinds of NE. which can be metastable with respect to NMP. In the first case density matrix is a projector with n identical eigenvalues. This state can result in a state function reduction since it is an eigenstate of the fundamental observable defined by density matrix. It can also happen that the eigenvalues of density matrix having matrix elements in algebraic extension algebraic extension of rationals characterizing the system in the evolutionary hierarchy do not belong to the extension. One can argue that since diagonalization is not possible in the extension,

also state function reduction is impossible without a phase transition extending the extension and identifiable as a kind of evolutionary step.

Both kinds of NEs might be involved. The first option would correspond to a kind of enlightened consciousness since any orthonormal state basis would define eigenstate basis of density matrix. Schrödinger cat would be half alive and half dead or half of X and half of Y, where X and Y are any orthonormal superpositions of alive and dead. For the second option there would be a unique state basis. For instance, cat could be $1/\sqrt{2}$ alive and $1-1/\sqrt{2}$ dead. This could correspond to a state of rational mind discriminating between things. If a phase transition bringing in $\sqrt{2}$ takes place, state function reduction makes cat fully alive or dead.

3. In condensed matter example the velocity of quantal wave motion serves as a criterion allowing to tell whether the degrees of freedom bind or not. Electron velocity is obviously too limited as a signature for binding or its absence. In neuroscience the coherence of EEG is seen as a signature of binding and this suggests that oscillation with same EEG frequency is the signature of binding of mental images to a larger one. In TGD inspired theory of consciousness EEG frequencies correspond to differences of generalized Josephson frequencies that is sums of Josephson frequency for the resting potential and of the difference of cyclotron frequencies for ions at different sides of cell membrane [K9, K23, K24].

4. At the level of magnetic flux tubes binding would correspond to a reconnection of magnetic flux tubes of synchronously firing region to form a larger structure for which the magnetic field strength is same for the composites and therefore also cyclotron frequencies are identical. Reconstruction would have a concrete geometric correlate at the level of magnetic flux tubes as reconnection. Different parts of brain containing quantum states serving as features of mental image would connected by flux tubes of the magnetic body and binding of mental images would take place.

5. In TGD inspired quantum biology dark matter identified as large $h_{eff}=n\times h$ phases give rise to a deconstruction if one accepts the hypothesis $h_{eff}=h_{gr}=GMm/v_0$, where M represents mass of dark matter and m particle mass. Here h_{gr} is assigned with a flux tube connecting masses M and m and v_0 is a velocity parameter characterizing the system. This hypothesis implies that dark cyclotron energy is proportional to $h_{gr}f_c$, where f_c is cyclotron frequency is independent of particle mass: universal cyclotron energy spectrum is the outcome. The dark cyclotron photons can transform to ordinary photons identified as bio-photons.

   What makes this so remarkable is that particles with magnetic dipole moment possessing different masses correspond to different values of h_{eff} and reside at different magnetic flux tubes. This is mass spectroscopy - or deconstruction of charged particles matter by taking the particles with different masses to their own dark worlds! Dark living matter would not be a random soup of particles: each charged particle (also neutral particles with magnetic dipole moment) sits neatly at its own shelf labelled by h_{gr}! In TGD inspired theory of consciousness magnetic flux tubes can be associated with magnetic bodies serving as correlates of selves so that deconstruction for mental images would reduce to this process with each charged particle representing one particular combination and perhaps also a quale [K14].

What about re-construction in this framework?

1. In reconstruction flux tube connections between two subsystems representing sub-selves (experienced by self as mental images) would be formed so that they would fuse to single system characterized by the same cyclotron frequency. Flux tube connection would be formed by the reconnection of U-shaped flux tubes to form single pair of connecting flux tubes connecting the systems. Resonant exchange of dark cyclotron photons and also dark super-conductivity would accompany this process. This process would represent a correlate for directed attention and would take place already at bio-molecular level. For instance, I have proposed that biomolecules with aromatic rings in which circulating electron pair currents generate magnetic bodies are especially important and in some sense fundamental level of the self hierarchy at molecular level. In brain different brain regions could connect to single coherently firing region in this manner.

2. The magnetic bodies associated with brain regions representing features could be connected in this manner to larger sub-selves. Negentropic quantum entanglement - a purely TGD based notion - could define a further correlate for the binding. This entanglement could take place in discrete degrees of freedom related to the hierarchy $h_{eff} = n \times h$ of Planck constants having no correlate in standard physics. The discrete degree of freedom would correspond to n sheets of singular coverings representing space-time surfaces. The sheets would co-incide at the ends of causal diamonds (CDs): on possible interpretation (holography allows many of them) could be that entire closed 3-surfaces formed by space-like 3-surfaces and light-like 3-surface connecting them can be seen as basic objects.

3. Reconstruction by negentropic quantum entanglement and flux tube connections inducing resonance could also lead to non-standard composites. Synesthesia could be understood in this manner and even the sensory experience about circle with four corners could be understood. The binding of left and right brain visual experiences to single one could take place through negentropic entanglement and effectively generate the third dimension. The dimensions would not however simply add: 3-D experience instead of 4-D. Could sensory perception of higher than 3-D objects be possible by a reconstruction fusing several visual percepts - maybe even from different brains - together? Could higher levels of self hierarchy carry out this kind of reconstruction? Could Mother Gaia fuse our experiences to single experience about what it is to be a human kind, species, or bio-sphere?

9.2 Could Condensed Matter Physics And Consciousness Theory Have Something To Share?

Magnetic bodies are present in all scales and one can to ask whether consciousness theory condensed matter physics might have something in common. Could the proposed description apply even at the level of condensed matter? Could construction and reconstruction of mental images identifiable as sub-selves take place already at this level and have interpretation in terms of primitive information processing building standardized primitive mental images?

Deconstruction need not be restricted to electron and velocity could be replaced by oscillation frequency for various fields: at quantum level there is not actually real distinction since in quantum theory velocity defines wave vector. Also more complex objects, atoms, molecules, etc. could be deconstructed and the process could occur at the level of magnetic bodies and involve in essential manner reconnection and other "motor actions" of flux tubes. The notions of quasi-particle and collective excitation would generalized dramatically and the general vision about basic mechanism might help to understand this zoo of exotics.

Future condensed matter theorists might also consider the possibility of reconstruction in new manner giving rise to the analogs of synesthesia. Could features from different objects be recombined to form exotic quasi-objects having parts all around. Could dark matter in TGD sense be involved in essential manner: could cyclotron resonance or its absence serve as a correlate for the binding. The disjoint regions of space would be in well-defined sense near to each other in the reconstructed state. Topology would be different: p-adic topology could provide a natural description for a situation: in p-adic topology systems at infinite distance in real sense can be infinitesimally close to each other p-adically.

One can build many-particle states free many-particle states using tensor products of these primitive tensor factors. Bound states are clearly new kinds of particle like entities. Under additional constraints one obtains bound states. Could deconstruction in physical sense mean the decomposition of this kind of bound states to effectively free many-particle states? Can one see reconstruction the reversal of these process? And is it possible that tensor factors are combined in a totally new manner somewhat like basic geometric features in deconstructivistic architecture?

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