

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 [26, 24, 31].

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 quantum 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 stupifungly 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.

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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 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://www.tgdtheory.fi/cmaphtml.html>[33]. Pdf representation of same files serving as a kind of glossary can be found at <http://www.tgdtheory.fi/tgdglossary.pdf> [34]. The topics relevant to this chapter are given by the following list.

- TGD as infinite-dimensional geometry [42]
- Symmetries of WCW [41]
- KD equation [37]
- Kaehler-Dirac action [36]
- Hierarchy of Planck constants [35]
- Quantum criticality [40]

2 Criticality in TGD framework

In the following the proposal that criticality cold 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.

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 [1]. 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 [?, ?, ?, ?, ?] 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 [?]padphys.

2.2 Basic building bricks of TGD vision

The big vision is that 2-D conformal invariance generalizes to 4-D context [22, 26, 24] 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 algebras 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.

2.3 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 [23] 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 L_{n+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?

2.4 Emergence of covering spaces associated with the hierarchy of Planck constants

Another picture about hierarchy of Planck constants is based on n -fold covering space bringing in n discrete degrees of freedom. 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 L_k , $k \geq n$, 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.

2.5 Negentropic entanglement and hierarchy of Planck constants

Also a connection with negentropic entanglement [28] associated with density matrix, which is proportional to unit matrix or direct sum of matrices proportional to unit matrices of various dimensions is natural in dark matter phase, emerges. Negentropic entanglement would occur in the new discrete degrees of freedom most naturally. In special 2-particle case negentropic entanglement corresponds to unitary entanglement encountered in quantum computation: large h_{eff} of course makes possible long-lived entanglement and its negentropic character implies that Negentropy Maximization Principle [28] favors its generation. An interesting hypothesis to be killed is that the p -adic prime characterizing the space-time sheet divides n .

2.6 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 patterns 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 scale 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 [?]Nottale. The additional hypothesis [29]

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

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) [39] 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!

2.7 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 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 $1 \rightarrow 2$ 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 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 exist 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 Test cases for the hypothesis that dark matter is generated at 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.

3.1 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 explain anomalous production of electron-positron pairs in heavy ion collisions just above the Coulomb wall [6, 7, 8, 5]. The TGD inspired hypothesis [30] 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 [30].

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 [3]. 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.

3.2 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-conductivity the value of specific heats 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.

3.3 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 mixture 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 [?]. 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.

3.4 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 [4]. 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 [32]. 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 [13] (<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 [11] (for TGD inspired view see the book [?]) 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 [11] (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 [39]. The TGD inspired model for them [39] 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 [16, 17, 14] 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 [25] 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.

3.5 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 [18] 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 [12] 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 [21] 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 [10, 9], 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 $.2 \times 10^{-4}$ 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 [27]. 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 zero energy ontology 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 [38] for the recent findings about microtubules by the group of the group of Bandyonopadhyay. [19, 20] 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.

4 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 [2] developed by a team of scientists include those from the Institute of Physical Chemistry of the Polish Academy of Sciences in Warsaw (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 [?]superfluidaction (<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 helium on a silicon plate. The centres of reservoirs had distance of 6μ and the reservoirs had edge length of $2 \mu\text{m}$ so that the width of the horizontal gap between reservoirs was $4 \mu\text{m}$. 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 $d = 32 \text{ nm}$ - in TGD language this is $d = 3.2L(151)$, where the p-adic length scale $L(151) = 10 \text{ nm}$ 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 explain the observations [?] (<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 Institute 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 reservoirs and the connecting channels are also important. The phenomenon ceases when the distances are significantly larger than the size of human cells.

Some comments from TGD based view about criticality already summarized 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 monopole 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 ${}^4\text{He}$ 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 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 inspired model based on the hypothesis that the genuine superfluid part of superfluid at least near criticality corresponds to large h_{eff} phase is considered.

5.1 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 [?]superfluidflow "Why does superfluid helium leak out of an open container?".

What is strange that all the fluid flows from the vessel to another one if the height of vessel is high enough. According to the prevailing wisdom superfluid 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 superfluid in the film: this is not the case. Hence the conventional explanation does not seem to work.

5.2 TGD inspired model for the fountain effect

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

$$\left(-\frac{\hbar^2 \partial_z^2}{2m} + mgz\right)\Psi = E\Psi.$$

2. By introducing dimensionless variable

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

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

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

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:

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

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.

5.3 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, if 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 condition $R = z_0$ to fix the value of v_0 . This would give the formula

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

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.

6 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 $E = h_{eff} e B_{end} / 2\pi m$ in few eV range for the value of n in question?

6.1 Some background

First some background.

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

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

makes the model quantitative. 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 Schwarzschild 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 $5.65 \times 10^{-4}c$ 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.

6.2 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 n in $h_{eff} = n \times h$ equals to the ratio of gravitational and ordinary Compton lengths

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

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.

6.3 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.

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