What's new in TGD inspired view about phase transitions?

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Abstract

The article tries to represent various TGD inspired visions about (quantum) phase transitions and (quantum) criticality in an organized manner and relate them to the more standard description of phase transitions. The new concepts are quantum theory as square root thermodynamics, Zero Energy Ontology (ZEO), and dark matter as phases with varying value of Planck constant $h_{eff} = n \times h$ labelling the fractal hierarchies of isomorphic sub-algebras of various super-conformal algebras generalizing those of standard physics, and the notion of magnetic body. The cautious proposal is that magnetic body as a controller and inducer of dynamics in living matter might generalize. Even thermodynamical phase transitions might be induced by dark quantum phase transitions. Symmetries are crucial in the description of phase transitions and TGD suggests a slightly different interpretation for their role than standard physics based picture lacking the notion of magnetic body.

1 Introduction

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 [K9]. 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.

1.1 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).

1.2 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 [K2, K4, K5]. 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 [K1]. 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 [L3] (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 [K7] 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 [L2] [K8]. Protons from the exclusion zones (EZs) of Pollack [L1] [L1] 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 [K3] 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 [K3] 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.

2 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.

2.1 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 super-conformal 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.

2.2 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.

2.3 Quantum phase transitions and 4-D spin glass energy landscape

TGD has led to two descriptions for quantum criticality. The first one relies on the notion of 4-D spin glass degeneracy and emerged already around 1990 when I discovered the unique properties of Kähler action. Second description relies on quantum phases and quantum phase transitions and I have tried to explain my understanding about it above. The attempt to understand how these two approaches relate to each other might provide additional insights.

1. Vacuum degeneracy of Kähler action is certainly a key feature of TGD and distinguishes it from all classical field theories. Small deformations of the vacua probably induced by gluing of magnetic flux tubes (primordially cosmic strings) to these vacuum space-time sheets deforms them slightly and would give rise to TGD Universe analogous to 4-D spin glass. The challenge is to relate this description to the vision provided by quantum phases and quantum phase transitions.

2. In condensed matter physics one speaks of fractal spin glass energy landscape with free energy minima inside free energy minima. This landscape obeys ultrametric topology: p-adic topologies are ultra metric and this was one of the original motivations for the idea that p-adic physics might be relevant for TGD. Free energy is replaced with the sum of Kähler function - Kähler action of Euclidian space-time regions and imaginary Kähler action from Minkowskian space-time regions.

3. In the fractal spin glass energy landscape there is an infinite number of minima of free energy. The presence of several degenerate minima leads to what is known as frustration. In TGD framework all the vacuum extremals have the same vanishing action so that there is infinite degeneracy and infinite frustration (also created by the attempt to understand what this might imply physically!). The diffeomorphisms of M^4 and symplectic transformations of CP_2 map vacuum extremals to each other and acts therefore as gauge symmetries. Symplectic transformations indeed act as U(1) gauge transformations. Besides this each Lagrangian sub-manifold of CP_2 defines its own space of vacuum-extremals as orbit of this symplectic group.

   As one deforms vacuum extremals slightly to non-vacuum extremals, classical gravitational energy becomes non-vanishing and Kähler action does not vanish anymore and the above gauge symmetries become dynamical symmetries. This picture serves as a useful guideline in the attempts to physically interpret. In TGD inspired quantum biology gravitation plays indeed fundamental role (gravitational Planck constant h_{gr}).

4. Can one identify a quantum counterpart of the degeneracy of extremals? The notion of negentropic entanglement (NE) is cornerstone of TGD. In particular, for maximal negentropic entanglement density matrix is proportional to unit matrix so that states are degenerate in the same sense as the states with same energy in thermodynamics. Energy has Kähler function as analogy now: hence the degeneracy of density matrix could correspond to that for Kähler function. More general NE corresponds to algebraic entanglement probabilities and allows to identify unique basis of eigenstates of density matrix. NE is favored by NMP and serves key element of TGD inspired theory of consciousness.

   In standard physics degeneracy of density matrix is extremely rare phenomenon as is also entanglement with algebraic entanglement probabilities. These properties are also extremely unstable. TGD must be somehow special. The vacuum degeneracy of Kähler action indeed distinguishes TGD from quantum field theories, and an attractive idea is that the degeneracy associated with NE relates to that for extremals of Kähler action. This is not enough however: NMP is needed to stabilize NE and this occurs only for dark matter ($h_{eff}/h > 1$ equals to the dimension of density matrix defining NE).

   The strong form of holography takes this idea further: 2-D string world sheets and partonic 2-surfaces are labelled by parameters, which belong to algebraic extension of rationals. This replaces effectively infinite-D WCW with discrete spaces characterized by these extensions and allows to unify real and p-adic physics to adelic physics. This hierarchy of algebraic extensions would be behind various hierarchies of quantum TGD, also the hierarchy of deformations of vacuum extremals.

5. In 3-D spin glass different phases assignable to the bottoms of potential wells in the fractal spin energy landscape compete. In 4-D spin glass energy of TGD also time evolutions compete, and degeneracy and frustration chacterize also time evolutions. In biology the notions of function and behavior corresponds to temporal patterns: functions and behaviors are fighting for survival rather than only organisms.

   At quantum level the temporal patterns would correspond to phase transitions perhaps induced by quantum phase transitions for dark matter at the level of magnetic bodies. Phase transitions changing the value of h_{eff} would define correlates for "behaviors" and the above proposed description could apply to them.

6. Conformal symmetries (the shorthand "conformal" is understood in very general sense here) allow to understand not only quantum phases but also quantum phase transitions at fundamental level and "transitons" transforming according to representations of Kac-Moody group or gauge group assignable to the inclusion of hyperfinite factors characterized by the integer m in $h_{eff}(f) = m \times h_{eff}(i)$ could allow precise quantitative description. Fractal symmetry breaking leads to conformal sub-algebra isomorphic with the original one

   What could this symmetry breaking correspond in spin energy landscape? The phase transition increasing the dynamical symmetry leads to a bottom of a smaller well in spin energy landscape. The conformal gauge symmetry is reduced and dynamical symmetry increased, and the system becomes more critical. Indeed, the smaller the potential well, the more prone the system is for being kicked outside the well by quantum fluctuations. The smaller the well, the large the value of h_{eff}. At space-time level this corresponds to a longer scale. At the level of WCW (4-D spin energy landscape) this corresponds to a shorter scale.

2.4 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 hyper-finite 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 $\hbar_{gr} = GMm/v_0 = \hbar_{eff} = n \times \hbar$ 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 [K6]. 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.

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