The problem of time and the TGD counterpart of $F = ma$

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Abstract

An innocent looking question "What $F = ma$ means in TGD?", posed by Lawrence B. Crowell in a FB discussion, can be abstracted to the question how the transfers of conserved isometry charges of $H = M^4 \times CP_2$ are realized at the level of fundamental interactions. At this level, the question is about how the conserved charges associated with the initial state particles are redistributed between the final state particles.

Somewhat surprisingly, TGD based quantum ontology implies that quantum non-determinism is an essential part of the answer to the question. Equally surprisingly, also a connection with the theory of consciousness and cognition emerges at the fundamental elementary particle level.

In the TGD view, the weak violation of the classical non-determinism in holography = holomorphy vision of TGD leads to the identification of self as a sequence of "small" state function reductions (SSFRs) identified as TGD counterparts of repeated measurements of the same observables: now however the observables related to the non-determinism are measured in SSFRs and give rise to the correlates of cognition. By quantum criticality, a "big" state function reduction (BSFR) as the TGD counterpart of what occurs in quantum measurement, can take place. BSFR means the death of self and its reincarnation with an opposite arrow of time.

Quantum criticality of the TGD Universe, realized in terms of holography = holomorphy principle, would be essential for this. For instance, particle decay involving topological changes could correspond to this process and all particle interactions would basically be due to the quantum criticality so that instead of SSFR, BSFR takes place. Intention is transformed to action at fundamental level. Cognition is dangerous in the TGD Universe!

1 Introduction

This contribution was inspired by a posting of Lawrence B. Crowell related to one particular problem related to the notion of time in general relativity: the general coordinate invariance implies interpretational problems since it is difficult to identify any preferred time coordinates used by observers. The identification of spatial coordinates is problematic for the same reason.

There are also other deep problems. In curved space-time classical conservation laws are lost. Einstein's equations are formulated in terms of energy momentum tensor but Newton's equations ($F = ma$) expressing the conservation of momentum and energy cannot be formulated in a general coordinate invariant way since the notions of energy and momentum fluxes are lost.

TGD view of the problem of time inspired Lawrence B. Crowell to ask about the TGD counterpart of $F = ma$. This question can be abstracted to the question about how the transfers of conserved isometry charges of $H = M^4 \times CP_2$ are realized at the level of fundamental interactions. At this level the question is about how the conserved charges associated with the initial state particles are redistributed between the final state particles.

Somewhat surprisingly, TGD based quantum ontology [L2, L7] implies that quantum non-determinism is an essential part of the answer to the question. Equally surprisingly, also a connection with the theory of consciousness and cognition emerges at the fundamental elementary particle level as also realized in [L11].

A detailed consideration of the question of Crowell led to a considerable clarification of the previous views. In the TGD view, the weak violation of the classical non-determinism in holography = holomorphy vision of TGD leads to the identification of self as a sequence of "small" state function reductions (SSFRs) identified as TGD counterparts of repeated measurements of the same observables: now however the observables related to the non-determinism are measured in SSFRs and give rise to the correlates of cognition. By quantum criticality, a "big" state function reduction (BSFR) as the TGD counterpart of what occurs in quantum measurement, can take place. BSFR means the death of self and its reincarnation with an opposite arrow of time.

Quantum criticality of the TGD Universe, realized in terms of holography = holomorphy principle, would be essential for this. For instance, particle decay could correspond to this process and all particle interactions would basically be due to the quantum criticality so that instead of SSFR, BSFR takes place. Intention is transformed to action. Thinking is dangerous in the TGD Universe!

2 From the problem of time in general relativity to the TGD counterpart of $F = ma$ as a general view of particle reactions

In the sequel the arguments inspired by the discussion about time and the TGD counterpart of $F = ma$ with Lawrence B. Crowell are summarized. What is new from the point of view of TGD is that the role of quantum criticality in quantum measurement is considerably clarified. Also the very close relationship of fundamental physics with cognition and intentionality in the TGD Universe becomes concrete: also particle reactions can be see as intentions transformed to actions.

2.1 The 3 problems related to the notion of time

It is good to beging with my first comment to the posting of Lawrence B. Crowell.

1. In the materialistic ontology subjective and geometric time are identified and this leads to deep problems.

   In TGD zero energy ontology [L2, L6] allows both times and solves both the measurement problem and the problem of free will. Subjective time corresponds to a sequence of "small" state function reductions (SSFRs) replacing the Zeno effect, in which nothing happens, with the notion of self.

Zero energy ontology replaces space-time surfaces as analogs of Bohr orbits for 3-surfaces having an interpretation as a geometric representation of particles. The classical dynamics is slightly non-deterministic although field equations are satisfied. This has crucial implications for the description of fundamental interactions [L10, L12]. This non-determinism also makes possible the description of physical correlates of cognition.

2. The second problem relates to the geometric time. General coordinate invariance allows an endless number of identifications of the time coordinate. In TGD, space-times are 4-surfaces in $H = M^4 \times CP_2$ and M^4 provides linear Minkowskian time or light-cone proper time (cosmic time) as a preferred time coordinate for the space-time surfaces.

3. The loss of Poincare invariance in General Relativity is the third problem and led to TGD. In TGD one obtains classical conservation laws due to the Poincare invariance of M^4 factor of H.

2.2 What does $F = ma$ mean in TGD?

Lawrence B. Crowell asked about how the counterpart of $F = ma$ emerges in TGD. At the general level the answer is as follows.

1. $F = ma$ states momentum conservation for a particle plus its environment by characterizing the momentum is exchanged between the particle and environment. In TGD, momentum conservation generalizes to field equations for the space-time surfaces as analogs of Bohr orbits of particles identified as 3-surfaces. The field equations state the conservation of Poincare and color charges classically.

   Unlike in General Relativity, Newton's equations at the fundamental level are therefore not given up in TGD and their generalization defines the dynamics of space-time surfaces [K1]. Therefore TGD is formally like hydrodynamics.

   Einstein's equations follow naturally at the QFT limit as a remnant of Poincare invariance when the sheets of the many-sheeted space-time are replaced with a slightly curved region of M^4 carrying the sum of induced gauge fields and gravitational fields defined as deviation from M^4 metric.

2. This can be made much more precise. Holography = holomorphy (H-H) hypothesis [L10, L8, L14] reduces the field equations to local algebraic equations in terms of generalized holomorphy irrespective of action as long as it general coordinate invariant and expressible in terms of the induced geometry. This generalizes the role of holomorphy in string models.

   In conformal field theories, holomorphy serves as a correlate for 2-D criticality. In TGD it would be a correlate for quantum criticality in the 4-D sense. This principle is extremely powerful since various dynamical parameters are analogous to a critical temperature.

   Space-time surfaces as minimal surfaces become analogs of Bohr orbits. Minimal surface equations generalize massless field equations and the TGD counterparts of field equations of gauge theories follow automatically.

3. Holomorphy is violated as 3-D surfaces, which are analogous to the singularities of analytic functions. This can be seen as a generalization of the fact that analytic functions can be expressed in terms of the holographic data given at poles and cuts.

4. What is crucial is that there is a slight failure of determinism (but not of field equations). This occurs also for soap films, modellable as 2-D minimal surfaces: the frames do not uniquely determine the soap film. In TGD, the identification of this non-determinism as a p-adic non-determinism is attractive and leads to a generalization of the notion of p-adic number field to a function field [L10, L13].

   H-H vision leads to a long-sought-for understanding of the origin of p-adic length scales hypothesis which for 30 years ago led to a surprisingly successful particle mass calculations based on p-adic thermodynamics [K3, K2] [L4]. The most recent article is about the application to the calculation of the mass spectrum of quarks and hadrons [L11]. The p-adic non-determinism and p-adic length scale hypothesis would have origin in the iterations of polynomials defining dynamical symmetries in H-H vision and also giving a connection to the Mandelbrot fractals and Julia sets becomes possible.

2.3 Geometric and fermionic counterparts of $F = ma$ in TGD

The next question concerns the counterpart of $F = ma$ at geometric and fermionic levels respectively.

$F = ma$ is a simple model for interactions. How are the interactions of two space-time surfaces A and B as analogs of Bohr orbits described geometrically?

1. Geo H^k metric vision suggests that a generalization of a contact interaction is in question. The intersection of A and B defines the contact points. Without additional assumptions the intersection of A and B would be a discrete set of points. One can argue that this is not enough.

2. The intuitive idea is that there must exist additional prerequisites for the formation of a quantum coherent structure, at least in the interaction region. The proposal is that A and B share a common generalized complex structure, which I call Hamilton-Jacobi structure [L5] so that the conformal moduli defining the H-J structure would identical.

   The common H-J coordinates involve hypercomplex coordinate pair u, v with light-like coordinate curves, common complex M^4 coordinate w and common complex CP_2 coordinates. The analytic functions defining A and B as their root must be generalized analytic functions of the same H-J coordinates.

3. The solution of field equations in Minkowskian space-time regions implies that either u or v is a passive coordinate since it cannot appear in the generalized analytic functions (the real hypercomplex coordinates u and v are analogous to z and $\overline{z}$). The 2-D surfaces at which u and v vary, are generalizations of straight strings of M^4 and dynamically very simple. Vibrational string degrees of freedom are frozen but the string ends at the partonic orbits are dynamical and can carry fermion numbers.

   In this case, the intersection of A and B consists of 2-D string world sheets connecting light-like partonic orbits. This gives a connection with string model type description.

4. Self-interactions of the space-time surface correspond to self-intersections consisting of string world sheets. For instance, the description of the internal dynamics of hadrons [L12, L11] is realized in terms of self-intersections.

In the fermionic sector modified/induced Dirac equation at the space-time level holds true for the induced spinor fields and can be solved exactly by the holomorphy just as in the case of string models. At the level of scattering amplitudes the dynamics reduces to the fermionic N-point functions.

Propagators are free propagators in H and the hard problem is to understand how fermion pair creation is possible when fermions are free in H. The notion of exotic smooth structure, possible only for 4-D space-time surfaces, solves the problem.

3 How to translate $F = ma$ to a view about the transfer of isometry charges between initial and final state particles?

Let us return to the original question. How can one understand the generalization of $F = ma$ in terms of a transfer of isometry charges of A (momenta color charges) from the initial state particles A and B to the final state particles? The classical field equations state the local conservation of isometry currents. How can this give rise to a transfer of total charges?

1. In the interaction region the Hamilton-Jacobi structures for A and B must be identical. Intersection consists of string world sheets. The interacting state therefore differs from the non-interacting state. Intuitively it is clear that the incoming states in the distant geometric past approach disjoint Bohr orbits. This is true also in the remote future except that the scattering need not be elastic and the particles identifiable bremsstrahlung can be emitted in the interactions. The interaction can also induce the decay of A and B. What happens in hadronic reactions gives a good idea of what happens.

2. The key notion is the mild failure of classical determinism for the Bohr orbits, which also characterizes criticality. The minimal surfaces describing the space-time surfaces have 3-D loci of non-determinism at which the classical determinism fails. These loci are analogous to the 1-D frames spanning 2-D soap films, which are also slightly non-deterministic minimal surfaces. There are several soap films spanned by the same collection of frames. The non-determinism gives rise to a sequence of small state function reductions (SFRs) generalizing the Zeno effect of standard quantum mechanics.

3.1 The description of the scattering in space-time degrees of freedom

Consider first the situation for a single particle as a 4-D Bohr orbit.

1. The non-determinism gives rise to internal interactions assignable to the self intersection as string world sheets. In the TGD inspired theory of consciousness, they can be identified in terms of geometric correlates of cognition.

2. Thinking is however dangerous also at the elementary particle level! The non-determinism is associated with quantum criticality and can lead to the decay of a partonic orbit to two or even more pieces. It can also change the topology of the partonic 2-surface characterized by genus g (CKM mixing). The partonic decay can in turn induce the decay of the space-time surface itself. The outcome would be a particle decay.

   This also leads to an emission of virtual particles as Bohr orbits, which appear as exchanges in 2-particle interactions. Massless extremals/topological light rays [K4] as counterparts of massless modes of gauge fields can be emitted. Closed 2-sheeted monopole flux tubes as geometric particles can be created by a splitting of a single monopole flux pair by a reconnection: this would be involved with a particle decay and emission of a virtual particle.

3. The scattering of two interacting particles A and B reduces to self interaction in the interaction region behaving like a single particle. The slight non-determinism makes possible a geometric generalization of the Feynman diagram type description. Now however all would be discrete and finite. There would be no path integral and therefore no divergences.

   The outcome would be a classical description and the generalization of $F = ma$ would code for the transfers of isometry charges from A and B to the final state particles generated in the scattering. The slight classical non-determinism would make this possible.

3.2 The description of the scattering in fermionic degrees of freedom

The description of the scattering in fermionic degrees of freedom involves highly non-trivial aspects.

1. In the fermionic degrees of freedom, the fermionic propagators between points of the singular 3-surfaces defining the interaction vertices as ends of string world sheets of the intersection would describe the situation.

2. The crucial point is the possibility of fermion pair creation only for 4-D space-time surfaces due to the existence of the exotic smooth structures [A2, A3, A1] discussed from the TGD point of view in [L9, L3, L8, L3, L9, L1]. In other space-time dimensions the fermions would be free.

3. Fermion pair creation corresponds intuitively to the turning of a fermion line in time direction. At the 3-D holomorphic singularities X^3 (analogous to cuts of analytic functions) the minimal surface equations fail and the additional pieces of the classical action, in particular 4-volume

as the analog of cosmological constant term, become relevant. The twistor lift of TGD [K6, K5] implies that the action is sum of Kähler action and volume term.

4. X^3 represents a defect of the standard smooth structure and the turning of a fermion line at X^3 at which standard smoothness fails corresponds to the transformation of u-type coordinate curve to a v-type coordinate curve takes place in the pair creations. u and v are associated with the parallel Minkowskian space-time sheets of the 2-sheeted space-time region. The creation of fermion occurs at the boundaries of two string world sheets at different monopole flux tubes so that a decay of monopole flux tube to a pair of them occurs.

   The pair creation would take place in the interaction regions and lead to the generation of final state fermions as the decay to 3-surfaces takes place. Closed 2-sheeted monopole flux tubes carrying fermion lines at their ends defined by Euclidean wormhole contacts connecting two sheets are generated.

5. At the 3-D defects minimal surface property fails and the trace of the second fundamental form, call it H^k, which vanishes almost everywhere, has a delta function singularity. By its group theoretical properties H^k has an interpretation as a generalized Higgs field. What is new is its M^4 part, which has an interpretation as a local acceleration for a 4-D Bohr orbit. The same interpretation applies to the TGD counterpart of the ordinary Higgs.

6. The vertices at 3-D singularities are analogous to points at which the direction of the motion for a Brownian particle changes. Conformal invariance suggests that the 8-D Higgs vector H^k is light-like so that one has $H_kH^k = 0$. Higgs has the dimension of $\hbar$/length and its vanishing gives rise to the analog of 8-D massless fixing M^4 mass squared in terms of CP_2 mass squared. A reasonable guess is that the square of M^4 part of H^k is proportional to particle mass squared. This would give rise to quantum-classical correspondence.

3.3 Possible implications for the TGD inspired theory of consciousness

In TGD, consciousness and cognition are assigned with the internal degrees of freedom (IDF) assignable with the classical non-determinism. Ordinary SFRs (BSFRs) are assigned with the ordinary degrees of freedom (ODF) assignable to the entire Bohr orbits and measured in the ordinary quantum measurements. Several questions related to the relationship of IDF and ODF) come to mind.

Consider two systems A and B.

1. The IDF of A need not entangle with the ODF of A although the ODF of A and B can entangle. Could this relate to sensory perception?

2. The IDF of A can entangle with the ODF B. Could this make possible psychokinesis and hypnosis?

3. The IDF of A and B can entangle. Could this relate to telepathy?

4. Entanglement can also occur between the IDF and ODF of A. Could this relate to the realization of intentions in motor degrees of freedom?

The precise role of quantum criticality should be understood. Conservation laws pose strong restrictions here: a stable particle like proton or electron serves as an example. The intuitive idea is that a perturbation is needed to trigger a BSFR, which transforms intention realized as entanglement to a motor action or to an action affecting the external world. Is the quantum entanglement of IDF with its ODF enough to trigger a BSFR of the system: a spontaneous decay of an unstable particle would be an example now.

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