About some unclear issues of TGD

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April 1, 2017

Abstract

TGD has been in the middle of palace revolution during last two years and it is almost impossible to keep the chapters of the books updated. Adelic vision and twistor lift of TGD are the newest developments and there are still many details to be understood and errors to be corrected. The description of fermions in TGD framework has contained some unclear issues. Hence the motivation for the brief comments.

1 Introduction

TGD has been in the middle of palace revolution during last two years and it is almost impossible to keep the chapters of the books updated. Adelic vision and twistor lift of TGD are the newest developments and there are still many details to be understood and errors to be corrected. The description of fermions in TGD framework has contained some unclear issues. Hence the motivation for the following brief comments.

There questions about the adelic vision about symmetries. Do the cognitive representations implying number theoretic disretization of the space-time surface lead to the breaking of the basic symmetries and are preferred imbedding space coordinates actually necessary?

In the fermionic sector there are many questions deserving clarification. How quantum classical correspondence (QCC) is realized for fermions? How is SH realized for fermions and how does it lead to the reduction of dimension $D = 4$ to $D = 2$ (apart from number theoretical discretization)? Can scattering amplitudes be really formulated by using only the data at the boundaries of string sheets and what does this mean from the point of view of the modified Dirac equation? Are the spinors at light-like boundaries limiting values or sources? A long-standing issue concerns the fermionic anti-commutation relations: what motivated this article was the solution of this problem. There is also the general problem about whether statistical entanglement is "real".

2 Comments

2.1 Adelic vision and symmetries

In the adelic TGD strong form of holography (SH) stating that 2-D surfaces code for the data about quantum states and preferred extremals of Kähler action is weakened. Also the points of the space-time surface having imbedding space coordinates in an extension of rationals (cognitive representation) are needed so that data are not precisely 2-D. I have believed hitherto that one must use preferred coordinates for the imbedding space H - a subset of these coordinates would define space-time coordinates. These coordinates are determined apart from isometries. Does the number theoretic discretization imply loss of general coordinate invariance and also other symmetries?

The reduction of symmetry groups to their subgroups (not only algebraic since powers of e define finite-dimensional extension of p-adic numbers since e^p is ordinary p-adic number) is genuine loss of symmetry and reflects finite cognitive resolution. The physics itself has the symmetries of real physics.

The assumption about preferred imbedding space coordinates is actually not necessary. Different choices of H-coordinates means only different and non-equivalent cognitive representations. Spherical and linear coordinates in finite accuracy do not provide equivalent representations.

2.2 Quantum-classical correspondence for fermions

Quantum-classical correspondence (QCC) for fermions is rather well-understood but deserves to be mentioned also here.

QCC for fermions means that the space-time surface as preferred extremal should depend on fermionic quantum numbers. This is indeed the case if one requires QCC in the sense that the fermionic representations of Noether charges in the Cartan algebras of symmetry algebras are equal to those to the classical Noether charges for preferred extremals.

Second aspect of QCC becomes visible in the representation of fermionic states as point like particles moving along the light-like curves at the light-like orbits of the partonic 2-surfaces (curve at the orbit can be locally only light-like or space-like). The number of fermions and antifermions dictates the number of string world sheets carrying the data needed to fix the preferred extremal by SH. The complexity of the space-time surface increases as the number of fermions increases.

2.3 Strong form of holography for fermions

It seems that scattering amplitudes can be formulated by assigning fermions with the boundaries of strings defining the lines of twistor diagrams [K1, K2]. This information theoretic dimensional reduction from $D = 4$ to $D = 2$ for the scattering amplitudes can be partially understood in terms of strong form of holography (SH): one can construct the theory by using the data at string worlds sheets and/or partonic 2-surfaces at the ends of the space-time surface at the opposite boundaries of causal diamond (CD).

4-D modified Dirac action would appear at fundamental level as supersymmetry demands but would be reduced for preferred extremals to its 2-D stringy variant serving as effective action. Also the value of the 4-D action determining the space-time dynamics would reduce to effective stringy action containing area term, 2-D Kähler action, and topological Kähler magnetic flux term. This reduction would be due to the huge gauge symmetries of preferred extremals. Sub-algebra of super-symplectic algebra with conformal weigths coming as n-multiples of those for the entire algebra and the commutators of this algebra with the entire algebra would annihilate the physical states, and thecorresponding classical Noether charges would vanish.

One still has the question why not the data at the entire string world sheets is not needed to construct scattering amplitudes. Scattering amplitudes of course need not code for the entire physics. QCC is indeed motivated by the fact that quantum experiments are always interpreted in terms of classical physics, which in TGD framework reduces to that for space-time surface.

2.4 The relationship between spinors in space-time interior and at boundaries between Euclidian and Minkoskian regions

Space-time surface decomposes to interiors of Minkowskian and Euclidian regions. At light-like 3-surfaces at which the four-metric changes, the 4-metric is degenerate. These metrically singular 3-surfaces - partonic orbits- carry the boundaries of string world sheets identified as carriers of fermionic quantum numbers. The boundaries define fermion lines in the twistor lift of TGD citeallbdiagrams,twistquestions. The relationship between fermions at the partonic orbits and interior of the space-time surface has however remained somewhat enigmatic.

So: What is the precise relationship between induced spinors Ψ_B at light-like partonic 3-surfaces and Ψ_I in the interior of Minkowskian and Euclidian regions? Same question can be made for the spinors Ψ_B at the boundaries of string world sheets and Ψ_I in interior of the string world sheets. There are two options to consider:

- Option I: Ψ_B is the limiting value of Ψ_I .
- Option II: Ψ_B serves as a source of Ψ_I .

For the Option I it is difficult to understand the preferred role of Ψ_B.

I have considered Option II already years ago but have not been able to decide.

1. That scattering amplitudes could be formulated only in terms of sources only, would fit nicely with SH, twistorial amplitude construction, and also with the idea that scattering amplitudes in gauge theories can be formulated in terms of sources of boson fields assignable to vertices and propagators. Now the sources would become fermionic.

2. One can take gauge theory as a guideline. One adds to free Dirac equation source term $_k\Psi$. Therefore the natural boundary term in the action would be of the form (forgetting overall scale factor)

$$S_B = \overline{\Psi}_I \Gamma^\alpha (C-S) A_\alpha \Psi_B + c.c \ .$$

   Here the modified gamma matrix is $\Gamma^\alpha(C-S)$ (contravariant form is natural for light-like 3-surfaces) is most naturally defined by the boundary part of the action - naturally Chern-Simons term for Kähler action. A denotes the Kähler gauge potential.

3. The variation with respect to Ψ_B gives

$$G^\alpha (C-S) A_\alpha \Psi_I = 0$$

   at the boundary so that the C-S term and interaction term vanish. This does not however imply vanishing of the source term! This condition can be seen as a boundary condition.

The same argument applies also to string world sheets.

2.5 About second quantization of the induced spinor fields

The anti-commutation relations for the induced spinors have been a long-standing issue and during years I have considered several options. The solution of the problem looks however stupifuingly simple. The conserved fermion currents are accompanied by super-currents obtained by replacing Ψ with a mode of the induced spinor field to get $\overline{u}_n \Gamma^\alpha \Psi$ or $\overline{\Psi}\Gamma^\alpha u_n$ with the conjugate of the mode. One obtains infinite number of conserved super currents. One can also replace both Ψ and $\overline{\Psi}$ in this manner to get purely bosonic conserved currents $\overline{u}_m \Gamma^\alpha u_n$ to which one can assign a conserved bosonic charges Q_{mn}.

I noticed this years ago but did not realize that these bosonic charges define naturally anti-commutators of fermionic creation and annihilation operators! The ordinary anti-commutators of quantum field theory follow as a special case! By a suitable unitary transformation of the spinor basis one can diagonalize the hermitian matrix defined by Q_{mn} and by performing suitable scalings one can transform anti-commutation relations to the standard form. An interesting question is whether the diagonalization is needed, and whether the deviation of the diagonal elements from unity could have some meaning and possibly relate to the hierarchy $h_{eff} = n \times h$ of Planck constants - probably not.

2.6 Is statistical entanglement "real" entanglement?

The question about the "reality" of statistical entanglement has bothered me for years. This entanglement is maximal and it cannot be reduced by measurement so that one can argue that it is not "real". Quite recently I learned that there has been a longstanding debate about the statistical entanglement and that the issue still remains unresolved.

The idea that all electrons of the Universe are maximally entangled looks crazy. TGD provides several variants for solutions of this problem. It could be that only the fermionic oscillator operators at partonic 2-surfaces associated with the space-time surface (or its connected component) inside given CD anti-commute and the fermions are thus indistinguishable. The extremist option is that the fermionic oscillator operators belonging to a network of partonic 2-surfaces connected by string world sheets anti-commute: only the oscillator operators assignable to the same scattering diagram would anti-commute.

What about QCC in the case of entanglement. ER-EPR correspondence introduced by Maldacena and Susskind for 4 years ago proposes that blackholes (maybe even elementary particles) are connected by wormholes. In TGD the analogous statement emerged for more than decade ago - magnetic flux tubes take the role of wormholes in TGD. Magnetic flux tubes were assumed to be accompanied by string world sheets. I did not consider the question whether string world sheets are always accompanied by flux tubes.

What could be the criterion for entanglement to be "real"? "Reality" of entanglement demands some space-time correlate. Could the presence of the flux tubes make the entanglement "real"? If statistical entanglement is accompanied by string connections without magnetic flux tubes, it would not be "real": only the presence of flux tubes would make it "real". Or is the presence of strings enough to make the statistical entanglement "real". In both cases the fermions associated with disjoint space-time surfaces or with disjoint CDs would not be indistinguishable. This looks rather sensible.

The space-time correlate for the reduction of entanglement would be the splitting of a flux tube and fermionic strings inside it. The fermionic strings associated with flux tubes carrying monopole flux are closed and the return flux comes back along parallel space-time sheet. Also fermionic string has similar structure. Reconnection of this flux tube with shape of very long flattened square splitting it to two pieces would be the correlate for the state function reduction reducing the entanglement with other fermions and would indeed decouple the fermion from the network.

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