Some comments related to quantum measurement theory according to TGD

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Abstract

In the sequel I represent some comments on quantum measurement theory inspired by FB discussions. The TGD view about time is involved because measurement theory in TGD relies crucially on zero energy ontology (ZEO). One particular topic is the finding of Afshar challenging Copenhagen interpretation but providing direct support for ZEO.

1 Does the analog of repeated second quantization take place at the level of WCW?

The world of classical worlds (WCW) is the basic structure of quantum TGD. It can be said to be the space of 3-surfaces consisting of pairs of (not necessarily connected 3-surfaces) at the boundaries of causal diamond (CD) and connected by a not necessarily connected 4-surface. 4- surface defines the interaction between the states associated with the 3-surfaces. The state associated with given 3-surface correspond to WCW spinor and one has modes of WCW spinor fields. WCW decomposes to sub-WCWs assignable to CDs and effectively the universe reduces to CD.

The key idea is that the WCW spinor fields are purely classical spinor fields. No second quantization is performed for them. Second quantization of induced spinor fields at space-time level is however carried out and gamma matrices of WCW anticommuting to its Kähler metric are linear combinations of fermionic oscillator operators.

The classicality of WCW spinor fields looks somewhat problematic.

1. The classicality of WCW spinor fields has implications for quantum measurement theory. State function reduction involves reduction of entanglement between systems at different points of space-time and therefore also many-particle states and second quantization are involved. However, second quantization does not take place at the level of WCW and it seems that entanglement between two 3-surfaces is not possible. Therefore measurements at WCW level should correspond to localizations not involving a reduction of entanglement. Measurements could not be interpreted as measurements of the universal observable defined by density matrix of subsystem. This looks problematic.

2. At the space-time level second quantization is a counterpart for the formation of many-particle states. Particles are pointlike and one of the outcomes is entanglement between point like particles. Since the point of WCW is essentially point-like particle extended to 3-surface, one would expect that second quantization in some sense takes place at the level of WCW although the theory is formally purely classical.

3. Also the hierarchy of infinite primes suggests an infinite hierarchy of second quantizations. Could it have counterpart at the level of WCW: can WCW spinor field be second quantized and classical simultaneously?

Could the counterpart for the hierarchy of infinite primes and second quantization be realized automatically at WCW level? One can indeed interpret the measurements at WCW as either localizations or as reductions of entanglement between states associated with different points of WCW. The point is that the disjoint union of 3-surfaces X^3 and Y^3 can be regarded either as a pair (X^3, Y^3) of 3-surfaces in $WCW \times WCW$ or as a 3-surface $Z^3 = X^3 \cup Y^3 \subset WCW$. The general identity behind this duality $WCW = WCW \times WCW = ... = WCW^n = ...$

One could think the situation in terms of $(X^3, Y^3) \in WCW \times WCW$ in which case one can speak of entanglement between WCW spinor modes associated with X^3 and Y^3 reduced by the measurement of density matrix. Second interpretation as a localization of wave function of $Z^3 = X^3 \cup Y^3 \in WCW$.

2 About quantum measurement theory in ZEO

Below some questions raised in the discussions about quantum measurement theory are discussed.

2.1 About the notion of observable

In ordinary quantum theory observables are hermitian operators and their eigenvalues representing the values of observables are real.

In the twistor lift of TGD using $M^4 \times CP_2$ picture [K2, K3] the gauge coupling strengths are complex and therefore also classical Noether charges are complex. This should be the case also for quantum observables. Total quantum numbers could be still real but single particle quantum numbers complex. I have proposed that this is true for conformal weights and talked about conformal confinement.

Also in the ordinary twistor approach virtual particles are on mass shell and thus massless but complex. Same is expected in TGD for 8-momenta so that one obtains particles massive in 4-D sense but massless in 8-D sense: this is absolutely crucial for the generalization of twistor approach to 8-D context. Virtual momenta could be massless in 8-D sense but complex but *total* momenta would be real. This would apply to all quantal charges, which for Cartan algebra are identical with classical Noether charges.

I learned also a very interesting fact about normal operators for which operator and its hermitian conjugate commute. As the author mentions, this trivial fact has remained unknown even for professionals. One can assign to a normal operator real and imaginary parts, which are commuting as hermitian operators so that - according to the standrd quantum measurement theory - they can be measured simultaneously.

For instance, complex values of various charge predicted by twistor lift of TGD would therefore in principle be allowed even without the assumption that the total charges are real (*total* charges as hermitian operators). Combining the two ideas one would have that single particle charges are complex and represented by normal operators and total charges are real and represented by hermitian operators.

2.2 What does amplification process in quantum measurement mean?

Quantum measurement involves an amplification process amplifying the outcome of state function reduction at single particle level to a macroscopic effect. This aspect of quantum measurement theory is poorly understood at fundamental level and is usually though to be unessential concerning the calculation of the predictions of quantum theory.

The intuitive expectation is that the amplification is made possible by criticality - I would suggest quantum criticality - and involves the analog of a phase transition generated by seed. This is like the change for a direction of single spin in magnet at criticality inducing change of the magnetization direction.

Quantum criticality [K1] involves long range fluctuations and correlations for which $h_{eff}/h = n$ serves as a mathematical description in terms of adelic physics in TGD framework. Long range correlations would make possible the classical macroscopic state characterizing the pointer. This large $h_{eff}/h = n$ aspect would naturally correspond to the presence of intelligent observer: h_{eff} indeed closely relates to the description of not only sensory but also cognitive aspects of existence and has number theoretic interpretation as a measure for what might be called IQ of the system.

If this is tge case, one cannot build proper quantum measurement theory in the framework of standard quantum mechanics, which is unable to say anything interesting about cognition and observer. A theory of consciousness is required for this and ZEO based quantum measurement theory is also a theory of consciousness.

2.3 Zero energy ontology and Afshar experiment

Afshar experiment [D1] challenges Copenhagen and many-universe interpretations (see `http://tinyurl.com/ycsttpb9`) and it is interesting to look how it can be understood in ZEO.

Consider first the experimental arrangement of Afshar.

1. A modification of double slit experiment is in question. One replaces the screen with a lense, which reflects from slit 1 to detector 1' and from slit 2 to detector 2'. Lense thus selects the photon path that is the slit through which the photon came.

   The detected pattern of clicks at detectors consists of two peaks: this means particle behavior. One can say that at single photon level either detector/path/slit is selected.

2. One adds a grid of obstacles to the nodes (zeros) of the interference pattern at imagined screen behind the lense. The photons entering the points of grid are absorbed. Since grid is at nodes of the interference pattern this does not affect the detected pattern, when both slits are open but affects the pattern when either slit is closed (grids points are not nodes anymore). This in turn means wave like behavior. This conflicts with principle of complementary stating that either of these behaviors is realized but not both.

Consider the analysis of the situation both in the usual positive energy ontology (PEO) and in ZEO assuming that state function reduction occurs at the detectors.

1. In PEO photon wave function Ψ in the region between slits and lense is superposition of two parts: $\Psi = \Psi_1 + \Psi_2$ with Ψ_i assignable to slit $i = 1, 2$. The lense guides Ψ_1 to detector 1 and Ψ_2 to detector 2. State function reduction occurs and Ψ is projected to Ψ_1 or Ψ_2. Either detector 1 or 2 fires and photon path is selected.

   It however seems that state function reduction - choice of the path/slit - can occur only in the region in front of the grid. In the region between slits and grid one should still have $\Psi 1 + \Psi_2$ since for Ψ_i the grid would have effect to the outcome. This effect is however absent. This does not fit with Copenhagen interpretation demanding that the path of photon is selected also behind the grid. This is the problem.

2. What about the interpretation in ZEO? After state function reduction - detection at detector 1 say - the time evolution between opposite boundaries of CD is relaced with a time reversed one. To explain the observations of Afshar (no deterioration of the pattern at detector caused by grid), one must have time evolution in which the photons coming from the detectors in reversed time direction have wave functions which vanish at the points of grid. This determines the "initial" values for the reversed time evolution: they are most naturally at grid so that grid corresponds naturally to a surface at boundary of CD in question. This is of course not the only choice since one can use the determinism of classical field equations to choose the intersection with CD differently. If time reversal symmetry holds true, the final state in geometric past corresponds to a signal coming from slit 1 (in the case considered as example). There would be no problem! Afshar experiment would be the first laboratory experiment selecting between Copenhagen interpretation and ZEO based quantum measurement theory.

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