On the Foundational Conflict of Quantum Theory and Classical Gravity

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Abstract

We compile a short list of reasons explaining why Quantum Theory (QT) and General Relativity (GR) cannot be trivially reconciled. Our opinion reflects a personal viewpoint and is likely to stand at odds with mainstream beliefs on Quantum Gravity, Black Hole phenomenology and related foundational topics.

Key words: Foundational Physics, Quantum Theory, General Relativity, Unification.

There are clear indications today that developing a coherent synthesis of QT and GR is still confronted by theoretical challenges. Despite an impressive volume of research carried out over the years (see [1-2] for two randomly picked examples), limitations persist in consistently combining the two frameworks. To make progress, model building efforts often resort to either semi-classical approximations, simplifying symmetry assumptions, convenient metric choices or extensions beyond the standard formalism of QT or GR. It is our belief that the root cause of these limitations is that QT and GR are inherently built on *incompatible premises*. Three arguments supporting this viewpoint are listed below:

1) *Gravitational decoherence* induces transition to classical behavior [3-4]. Likewise, the quantum superposition of a pair of massive particles - spatially separated and placed in the gravitational field of a third particle - is either prone to transition to chaos and non-integrable dynamics *or* be analytically intractable (the 3-body problem) [5, 10].

2) The operational definition and behavior of “time” are different in QT than in GR [6]

3) Quantum Field Theory is Lorentz invariant, GR is not (excluding special cases). In particular,

3.a) In curved spacetime, momentum vectors defined at different points cannot be trivially added. Two momentum vectors are said to be parallel if they are compared at the same point by means of parallel transport. But there is no way of adding up parallel momentum vectors that is *independent* of the curve along which the parallel transport takes place. If, however, one limits the discussion to systems whose spatial extent is bounded (isolated systems), it turns out that a total energy and momentum can be precisely defined: in particular, if all components of the metric tensor are coordinate-independent, the four-momentum of a test particle is a conserved quantity along its trajectory [7].

3.b) A general gravitational field *cannot be stationary* in any reference frame, implying that no conserved energy can be defined. This is to say that is generally no coordinate system which renders a given metric time independent [8].

3.c) In general, conserved quantities in GR can only be built in *nearly flat spacetime* and, away from the linearized theory, the time-dependence of the metric prohibits an unambiguous definition of locally defined conserved quantities. In particular, the flux of energy carried away by gravitational waves can be shown to be conserved *only to lowest order* in the metric deviations from the flat spacetime metric [9].

References

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