Quantum Relativity Unification

Estelle Asmodelle*

Relative Cosmos, 47 Narooma Rd, NSW, 2250, Australia.
e.asmodelle@relativecosmos.com

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Abstract

A conceptual approach to the unification of quantum mechanics and general relativity is outlined using Bohmian Mechanics as a preferred quantum mechanical interpretation. It is suggested that the Copenhagen Interpretation of quantum mechanics violates symmetry and is inconsistent; therefore is not suitable as a unification candidate. The idea of a 5th informational dimension is proposed; referred to as the property of *Spacetime Diaphaneity* for information. This Spacetime Diaphaneity allows information to be independent of spacetime, yet information can reside spatially or temporally within spacetime. This concept explains entanglement and hints at a resolution to the black hole information paradox. Moreover, this idea may also allow Bohmian mechanics to become background-independent and produce a new definition of time that is more viable for unification with gravity.

An open problem

The focus of this paper is the unification of quantum mechanics and the general theory of relativity. The content here is largely about quantum information rather than gravity but it is essential to revise certain ideas in order to have an appropriate foundation for unification with general relativity.

In my humble opinion, I believe Quantum Mechanics [QM] is incomplete, which is a product of misunderstood concepts and a misguided interpretation. I would like to introduce a new concept that may modify a specific interpretation of quantum mechanics in such a way as to be suitably prepared for unification with gravity. The main new concept is *Spacetime Diaphaneity*. Firstly, I would like to examine some incompatibilities with unification.

The general theory of relativity [GR] has passed every test [1] and is a robust geometric theory of gravity while only several solutions to the field equations are known. On the other hand, quantum mechanics has been hugely successful and enabled the technology of the modern world. However, quantum mechanics [QM] is not a theory but rather a collection of postulates that are based on experimental observations, yet for simplicity, I will refer to it as a theory. The issues explored here is not the quantum mechanical nature of reality but its accepted interpretation. Many alternative interpretations have emerged during the subsequent decades, and most agree empirically with quantum mechanics but differ only in their philosophical and ontological interpretation.

The most important issue with the incompatibilities of QM and GR are rooted in the way both theories treat time; known as the problem of time. The latter treats time and space as dimensions that are collectively called spacetime, while the former via the time dependent Schrödinger equation treats time and space as separate entities. This shown in Equation 1, with the wavefunction being

*http://www.relativecosmos.com/

Ψ and V being a potential. Further, QM takes a Newtonian stance of absolute time and absolute space, while time is taken as a parameter and not an observable.

$$i\hbar\frac{\partial\Psi}{\partial t} = -\frac{\hbar^2}{2m}\frac{\partial^2\Psi}{\partial x^2} + V(x)\Psi \tag{1}$$

There are other fundamental differences, GR is fully deterministic, while QM, or rather the Copenhagen Interpretation, is probabilistic or stochastic. Then there is the issue of background independence, which means equations of a theory are independent of the shape of the spacetime. In GR background independence is essentially the property that the spacetime metric is the direct solution of dynamical evolution. However, in QM there is no background independence. It would be impossible to unify two theories that treat the background, and hence coordinate systems, differently.

The Copenhagen Interpretation also presents us with the measurement problem or the collapse of the probability amplitudes of the wavefunction into an observable quantity. This concept demands that reality does not exist until it is measured. This was institutionalised by Bohr and is still believed today and its interpretation is clearly evident in Wheeler's delayed-choice Gedankenexperiment [7]. In fact, this interpretation literally means quantum behaviour does not exist without an observer to bring it into existence, as Jordan [2] stated, "Observations not only disturb what has to be measured, they produce it!" This illustrates the absurdity of the Copenhagen Interpretation for in the very early universe, in particular the quantum fluctuations of the big bang, there was no observer present yet the entire universe began at the quantum level. In essence, this antecedent causality disproves this Copenhagen premise.

Next is the difference in which both theories consider causality. GR is classically deterministic and so causality is maintained in a progressive cause and effect nature. In regards to the Copenhagen Interpretation, Brukner [3] sums it up with the following, "... the causal order of events is not always fixed, but is subject to quantum uncertainty." Moreover, the quantum world can also allow retrocausality as suggested by Leifer and Pusey [4].

Quantum Mechanics ensures conservation of information and time-reversal symmetry, because of the conservation of probability. This comes from the time-dependent Schrödinger Equation. However, the Copenhagen Interpretation does not preserve conservation of quantum information, breaking time-reversible symmetry as stated by Glattfelder [5].

If one applies the principle of parsimony, better known as Occam's razor, to the concept of a quantum mechanical interpretation, then clearly the interpretation with the least number of assumptions should be the correct one. Hence an ontological quantum mechanical description seems the best approach with any unification.

Bohmian Mechanics [BM] is deterministic and is considered an ontic classical theory. This theory provides the simplest description of what is happening in the double-slit experiment. Namely, there is a guiding wave pushing a particle in a particular trajectory. The guiding wave undergoes interference and so the particle is pushed along non-linear trajectories which experimentally match those of standard QM without the need for the Copenhagen mythology. The theory preserves the law of conservation of quantum information and is time-reversible. BM is a no-collapse theory that resolves the measurement problem from the outset, for it is a theory without observers. Of all possible interpretations, BM is the simplest with the fewest assumptions and also preserves the principle of complementarity. A Bohmian guiding equation which represents the velocity for a single particle in $\mathbb{R}^3$ within a potential V and where $\mathbf{Q}$ represents a the particle position, is shown in Equation 2.

$$\frac{d\mathbf{Q}}{dt}(t) = \frac{\hbar}{m}\mathrm{Im}\left(\frac{\bigtriangledown\Psi}{\Psi}\right)(\mathbf{Q},t) \tag{2}$$

The standard objection to BM is that it is not Lorenz invariant, but neither is standard QM. In fact, relativistic quantum mechanics suffer from many problems and is certainly not covariant. These problems led to the development of Quantum Field Theory [QFT], which according to Noldus [6] is "ultra weakly covariant with respect to the background spacetime." In spite of QFT's success it has not produced a suitable unification framework either.

I believe a paradigm shift is required to prepare a quantum mechanical interpretation ready for unification.

Information

In 1991 Rolf Landauer [8] claimed that, "Information is Physical!" Additionally, Landauer [9] also stated that "Information is inevitably tied to a physical representation." The implications were huge for Information Theory and this premise spawned Quantum Information Science, and physicists embraced this catchphrase literally. Since that time, Quantum Information and also Relativistic Quantum Information [RQI] consider this concept to be *a priori*, while some refer to it as the *Landauer principle*. The concept was derived in reference to computational information but has generally been adopted in quantum physics.

Spacetime Diaphaneity

It is my assertion that information is *real* but nonphysical and exists independently of any physical carrier or instrument. Moreover, because of the non-physical nature of information, spacetime possesses a diaphanous, or translucent, property for information. This means information is able to exist in spacetime but is not bound to it. It is not bound spatially nor temporally but can be represented in spacetime. Moreover, it can be correlated in time or space. It follows that our 4-D spacetime exists in a higher dimensional 5th dimension that is non-physical but purely informational. It could be viewed as an information background dimension. This is very different from existing 5-D models, and is an infinite non-metric space that is neither compactified nor curled up but permeates all of spacetime.

The property of entanglement provides the motivation that information possesses Spacetime Diaphaneity, through the sharing of entangled information without violating faster-than-light transmission and therefore preserving special relativity. In fact, nonlocality generally can be described with this informational dimension. Also, instant correlations remove the issue of retrocausality in QM, which would pose a huge problem for unification. The principle can be stated in the following manner.

Spacetime Diaphaneity allows information to be independent of spacetime.

Taking BM as a preferred interpretation, and allowing information to be independent of spacetime could permit a new mathematical derivation which is background independent and presumably, possesses a modified representation of time. From a GR perspective, the spacetime interval remains unchanged as shown in Equation 3 with x_4 being the informational dimension.

$$(\triangle s)^2 = (\triangle x_0)^2 + (\triangle x_1)^2 + (\triangle x_2)^2 - (\triangle x_3)^2 \equiv (\triangle x_0)^2 + (\triangle x_1)^2 + (\triangle x_2)^2 - (\triangle x_3)^2 + \left[(\triangle x_4)^2\right] \quad (3)$$

Spacetime Diaphaneity also has huge implications for the general theory of relativity as well. Most notably the Information Paradox in black holes. Essentially, it means that information that enters a black hole can exist independently of its physical manifestation. The information always exists in the 5th informational dimension but could also be correlated elsewhere. However, the information in a black hole may be spatially entangled, or correlated, with another part of our universe or time entangled with another time. At the very least the information is not lost, exactly where it can actually be located is an open question.

The addition of an informational dimension may allow sharing of information between QM and GR in a unique manner and have additional consequences related to gravity which are not obvious.

Conclusion

It seems since 1927 mainstream physicists have been seduced by the philosophical aspects of the Copenhagen Interpretation and chose to shut-up and calculate. I suggest that Bohmian Mechanics is a more suitable candidate as an interpretation, together with incorporating spacetime diaphaneity.

This is not a research paper and so only the concepts are explored but these ideas could be the basis for a new mathematical framework that resolves the problem of time and background independence. Ideally, such ideas would produce a Relativistic Bohmian Mechanics that is covariant and sharing commonalities with gravity.

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