New Law of Physics Could Explain Quantum Mysteries

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The Invariant Set Postulate differentiates between reality and unreality, suggesting the existence of a state space, within which a smaller subset of state space (reality) is embedded. Image is from the Christus-Pavilion in Volkenroda, Germany. Credit: Wikimedia Commons.

(PhysOrg.com) -- Since the early days of quantum mechanics, scientists have been trying to understand the many strange implications of the theory: superpositions, wave-particle duality, and the observer's role in measurements, to name a few. Now, a new proposed law of physics that describes the geometry of physical reality on the cosmological scale might help answer some of these questions. Plus, the new law could give some clues about the role of gravity in quantum physics, possibly pointing the way to a unified theory of physics.

Tim Palmer, a weather and climate researcher at the European Centre for Medium-Range Weather Forecasts in Reading, UK, has been interested in the idea of a new geometric framework for quantum theory for a long time. Palmer's doctoral thesis was in general relativity theory at Oxford University in the late 1970s. His studies convinced him that a successful quantum theory of gravity requires some geometric generalization of quantum theory, but at the time he was unsure what specific form this generalization should take. Over the years, Palmer's professional research moved away from this area of theoretical physics, and he is now one of the world's experts on the predictability of climate, a subject which has considerable input from nonlinear dynamical systems theory. In a return to his original quest for a realistic geometric quantum theory, Palmer has applied geometric thinking inspired by such dynamical systems theory to propose the new law, called the Invariant Set Postulate, described in a recent issue of the *Proceedings of the Royal Society A*.

As Palmer explained to *PhysOrg.com*, the Invariant Set Postulate is proposed as a new geometric framework for understanding the basic foundations of quantum physics. "Crucially, the framework allows a differentiation between states of physical reality and physical 'unreality,'" he said.

The theory suggests the existence of a state space (the set of all possible states of the universe), within which a smaller (fractal) subset of state space is embedded. This subset is dynamically invariant in the sense that states which belong on this subset will always belong to it, and have always belonged to it. States of physical reality are those, and only those, which belong to this invariant subset of state space; all other points in state space are considered "unreal." Such points of unreality might correspond to states of the universe in which counterfactual measurements are performed in order to answer questions such as "what would the spin of the electron have been, had my measuring apparatus been oriented this way, instead of that way?" Because of the Invariant Set Postulate, such questions have no definite answer, consistent with the earlier and rather mysterious notion of "complementarity" introduced by Niels Bohr.

According to Palmer, quantum mechanics is not itself sufficiently complete to determine whether a point in state space lies on the invariant set, and indeed neither is any algorithmic extension to quantum theory. As Palmer explains, in quantum theory, states associated with these points of unreality can only be described by abstract mathematical expressions which have the algebraic form of probability but without any underlying sample space. It is this which gives quantum theory its rather abstract mathematical form.

As well as being able to provide an understanding of the notion of complementarity, the two-fold ontological nature of state space can also be used to explain one of the long-standing mysteries of quantum theory: superpositions. According to the Invariant Set Postulate, the reason that Schrodinger's cat seems to be both alive and dead simultaneously is not because it is, in reality, in two states at once, but rather because quantum mechanics is ignorant of the intricate structure of the invariant set which determines the notion of reality. Whichever point (alive or dead) lies on the invariant set, that one is real. The notion of quantum coherence, which is reflected in the concept of superposition, is, rather, carried by the self-similar geometry of the invariant set.

With superposition seemingly resolved from the perspective of the Invariant Set Postulate, other aspects of quantum mechanics can also be explained. For instance, if states are not in superpositions, then making a measurement on the quantum system does not "collapse the state" of the system. By contrast, in Palmer's framework, a measurement merely describes a specific quasi-stationary aspect of the geometry of the invariant set, which in turn also informs us humans about the invariant set.

The Invariant Set Postulate appears to reconcile Einstein's view that quantum mechanics is incomplete, with the Copenhagen interpretation that the observer plays a vital role in defining the very concept of reality. Hence, consistent with Einstein's view, quantum theory is incomplete since it is blind to the intricate structure of the invariant set. Yet consistent with the Copenhagen interpretation, the invariant set is in part characterized by the experiments that humans perform on it, which is to say that experimenters do indeed play a key role in defining states of physical reality.

Yet another quantum mechanical concept that the Invariant Set Postulate may resolve is wave-particle duality. In the two-slit experiment, a world where particles travel to areas of destructive interference simply does not lie on the invariant set, and therefore does not correspond to a state of physical reality.

Among the remaining mysteries of quantum mechanics that the Invariant Set Postulate might help explain is the role of gravity in quantum physics. As Palmer notes, gravity has sometimes been considered as an objective mechanism for the collapse of a superposed state. However, since the Invariant Set Postulate does not require superposed states, it does not require a collapse mechanism. Rather, Palmer suggests that gravity plays a key role in defining the state space geometry of the invariant set. This idea fits with Einstein's view that gravity is a manifestation of geometry. As such, Palmer suggests, unifying the concepts of non-Euclidean causal space-time geometry and the fractal atemporal geometry of state space could lead to the long-sought theory of "quantum gravity." Such a theory would be very different from previous approaches, which attempt to quantize gravity within the framework of standard quantum theory.

Palmer's paper is an exploratory analysis of this Invariant Set Postulate, and he now hopes to develop his ideas into a rigorous physical theory. Just as global space-time geometric methods transformed our understanding of classical gravitational physics in the 1960s, Palmer hopes that the introduction of global state space geometric methods could give scientists a deeper understanding of quantum gravitational physics. And, as suggested above, combining these two types of geometry might help lead to the long-sought unified theory of physics.

More information: T.N. Palmer. "The Invariant Set Postulate: a new geometric framework for the foundations of quantum theory and the role played by gravity." Proceedings of the Royal Society *A*. doi:10.1098/rspa.2009.0080