Undecidability and the problem of outcomes in quantum measurements

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Abstract

We argue that it is fundamentally impossible to recover information about quantum superpositions when a quantum system has interacted with a sufficiently large number of degrees of freedom of the environment. This is due to the fact that gravity imposes fundamental limitations on how accurate measurements can be. This leads to the notion of undecidability: there is no way to tell, due to fundamental limitations, if a quantum system evolved unitarily or suffered wavefunction collapse. This in turn provides a solution to the problem of outcomes in quantum measurement by providing a sharp criterion for defining when an event has taken place. We analyze in detail in examples two situations in which in principle one could recover information about quantum coherence: a) “revivals” of coherence in the interaction of a system with the measurement apparatus and the environment and b) the measurement of global observables of the system plus apparatus plus environment. We show in the examples that the fundamental limitations due to gravity and quantum mechanics in measurement prevent both revivals from occurring and the measurement of global observables. It can therefore be argued that the emerging picture provides a complete resolution to the measurement problem in quantum mechanics.

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