Physical signatures of the quantum nature of time

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I recently introduced [1,2] a new sum-over-paths formalism that accounts for the quantum nature of time. It treats time and space on the same footing at a fundamental level. The representation of the state of an object is given in terms of virtual quantum paths for which translations in time are generated by the Hamiltonian, and translations in space by the momentum operator. If the Hamiltonian respects time reversal symmetry then an object can be localised in both time and space. In this case there is no time evolution and no conservation laws. However, if the Hamiltonian violates time reversal symmetry (T violation), the same construction exhibits destructive interference in the paths over time, which results in time evolution that obeys conservation laws. The formalism is then analogous to the 5 dimensional "proper time" formalism introduced by Feynman [3] and extended by Nambu [4] in the 1950's and explored more recently as "parametrized relativistic quantum theories" [5].

The important point is that time evolution and conservation laws are not built into the formalism but rather they emerge *phenomenologically* from T violation. The formalism, therefore, potentially offers an explanation of the origin of dynamics and also new insight into the problem of the arrow of time.

Work has now progressed to checking for physical signatures of the new formalism. Local variations in T violation are found to induce corresponding variations in local clock time and this manifests as a quantum version of relativistic time dilation. Nuclear reactors provide sources of local variation in T violation and the prospect for detecting a predicted quantum time dilation in their vicinity will be discussed.

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[3] R. P. Feynman, Mathematical Formulation of the Quantum Theory of Electromagnetic Interaction, *Phys. Rev.* **80**, 440-457 (1950), Appendix A. http://dx.doi.org/10.1103/PhysRev.80.440

[4] Y. Nambu, The Use of the Proper Time in Quantum Electrodynamics I, *Prog. Theor. Phys.* **5**, 82 (1950). http://dx.doi.org/10.1143/ptp/5.1.82

[5] J. R. Fanchi, Review of invariant time formulations of relativistic quantum theories, *Found. Phys.* **23**, 487-548 (1993). http://dx.doi.org/10.1007/BF01883726