Quantum asymmetry between space and time: Phenomenological emergence of Lorentz invariance

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Symmetries and their violations play essential roles in modern physics. Lorentz invariance and the combined symmetry of charge conjugation (C), spatial inversion (P), and time reversal (T) have survived repeated experimental testing [1] and remain exact symmetries in the Standard Model of particle physics. In contrast, violations of the separate symmetries of P, CP and T are found in particle decays involving the weak interaction and have been widely studied over the past half a century [2-5].

The violation of time reversal symmetry (T violation) is associated with two versions of the Hamiltonian, one for each direction of time evolution. A recently introduced Quantum Theory of Time (QTT) [6-8] uses a sum-over-paths approach to explicitly take into account the distinction between the two versions. The new theory predicts quantum effects that are analogous to the time dilation and length contraction in special relativity but associated with spatial variations in the amount of T violation rather than relative velocities. Here, we show that a Galilean transformation of a spatially uniform background T violating field corresponds to a Lorentz transformation of the dynamics associated with different inertial reference frames. Hence, without manually introducing it, we show that Lorentz invariance emerges phenomenologically in the new theory in a natural way, i.e. due to the Galilean transformation of the background T violating field.

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