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Quantum field theories with quantum causal structure

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We study quantum gravity induced quantum causal structure in the context of quantum field theories. We argue both conceptually and numerically that when spacetime is treated quantumly, (1) exact microcausality condition, (2) exact causal boundaries, and (3) the distinction between particles and antiparticles cannot be maintained. These suggest possibilities of “time travel” and “tunneling out of black holes”, but to examine whether such possibilities can be realized, concrete calculations are needed. We present a method to conduct calculations for quantum field theories on quantum spacetime based on the expansion of Feynman diagrams into worldline diagrams. As a first application, we show that quantum causal structure regularizes matter field UV singularities. This result reinforces previous suggestions from analyzing entanglement in the presence of quantum causality.

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