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A local diagnostic program for unitary evolution in general space-times

We present a local framework for investigating non-unitary evolution groups pertinent to effective field theories in general semi-classical spacetimes. Our approach is based on a rigorous local stability analysis of the algebra of observables and solely employs geometric concepts in the functional representation of quantum field theory. In this representation, it is possible to construct infinitely many self-adjoint extensions of the canonical momentum field at the kinematic level, and by the usual functional calculus arguments this holds for the Hamiltonian, as well. However, these self-adjoint domains have only the trivial wave functional in common with the solution space of the functional Schrödinger equation. This is related to the existence of boundaries in configuration field space which can be penetrated by the probability flux, causing probability to leak into regions in configuration field space that require a more fundamental description. As a consequence the evolution admits no unitary representation. Instead, in the absence of ghosts, the evolution is represented by contractive semi-groups in the semiclassical approximation. This allows to quantify the unitarity loss and, in turn, to assess the quality of the semi-classical approximation. We perform numerical experiments based on our formal investigations to determine regions in cosmological spacetimes where the semiclassical approximation breaks down for free quantum fields.

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