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A new formalism to define a vacuum state in curved space-time

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The problem of finding a vacuum definition for a single quantum field in curved spaces is discussed under a new geometrical perspective. The minimum complex structure in phase space necessary to define a vacuum state is mapped to a 2-dimensional hyperbolic space in which distances can be defined. It is shown that well known vacuum prescriptions in the literature correspond to points in this hyperbolic space from which all mapped phase space solutions move on circles around it in the time-independent case, or within thin annular regions in the time-dependent case when the adiabatic approximation is valid. These properties are shown to be equivalent to the stability of the vacuum choice. The analysis is extended to time-dependent cases in which the adiabatic approximation is not valid, in the super-Hubble or low frequency regime. It is shown that stability points or curves can also be found in these situations, and stable quantum vacua can be obtained. This new formalism is applied to two situations: de Sitter space, where the Bunch-Davies vacuum is obtained in a complete different manner through an analysis in the super-Hubble regime, and in the context of cosmological bouncing models in which the contracting phase is dominated by a cosmological
constant in the asymptotic past. A new vacuum state for cosmological perturbations is proposed in this situation.

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