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Vacuum restructuring and scalar particle production in a closed isotropic universe

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We study scalar particle production in a closed isotropic universe within the extended phase space approach. Unlike the treatments in which the gravitational field is treated classically, we quantize the coupled gravitational and matter degrees of freedom and derive the Schrodinger equation for the wave function of the Universe, including perturbative contributions associated with a slight deviation from conformal coupling. We start from the effective action for scalar and spinor fields interacting with gravity, with the spinor field introduced to cancel vacuum divergences arising in the theory. The gravitational degree of freedom is described in the coordinate representation, while the matter modes are treated in the holomorphic representation. We then analyze particle-production processes as perturbative transitions between quantum states. Unlike the usual path-integral treatment, where perturbations are assumed to be independent of velocities, the perturbative interaction in our model depends on the time derivative of the scale factor. We compare this description with the conventional canonical approach based on Bogoliubov transformations and discuss the relation between the two formulations.

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