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IR finite correlation functions in de Sitter space, a smooth massless limit, and an autonomous equation

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We consider a theory of a massive scalar field in de Sitter spacetime. Through the Yang-Feldman-type equation, the one-, two-, and three-loop quantum corrections for the long-wavelength modes' two-point and four-point correlation functions have been calculated. The corresponding massive perturbative series being summed rids of secular effects. In contrast to the standard theory of a massive scalar field based on the de Sitter-invariant vacuum, we developed vacuum-independent reasoning that may not possess de Sitter invariance but results in a smooth massless limit of the correlation function's infrared part (with the expected secular growth in that case). The main "building block" of the elaborated approach is the free massive field's correlation function, which coincides with the Ornstein-Uhlenbeck process's one and has a clear physical interpretation. Our outcomes correspond to the Schwinger-Keldysh technique's results at the late-time limit and were also compared with those obtained in the framework of the stochastic approach and with the Hartree-Fock approximation. At last, we have constructed an autonomous equation for the two-point function. Integrating its approximate version, one can obtain a non-analytic expression with respect to the self-interaction coupling constant λ. Our result almost coincides with the stochastic one in the whole interval of a new dimensionless parameter.

Primary authors: KAMENSHCHIK, Alexander (Istituto Nazionale di Fisica Nucleare); PETRIAKOVA, Polina (Istituto Nazionale di Fisica Nucleare)

Presenter: PETRIAKOVA, Polina (Istituto Nazionale di Fisica Nucleare)