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ORIGINAL ARTICLE

Emergent universe with scalar (or tachyonic) field in higher derivative theory

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Abstract We consider a spatially homogeneous and isotropic flat Robertson-Walker model filled with a scalar (or tachyonic) field minimally coupled to gravity in the framework of higher derivative theory. We discuss the possibility of the emergent universe with normal and phantom scalar fields (or normal and phantom tachynoic fields) in higher derivative theory. We find the exact solution of field equations in normal and phantom scalar fields and observe that the emergent universe is not possible in normal scalar field as the kinetic term is negative. However, the emergent universe exists in phantom scalar field in which the model has no time-like singularity at infinite past. The model evolves into an inflationary stage and finally admits an accelerating phase at late time. The equation of state parameter is found to be less than -1 in early time and tends to -1 in late time of the evolution. The scalar potential increases from zero at infinite past to a flat potential in late time. More precisely, we discuss the particular case for phantom field in detail. We also carry out a similar analysis in case of normal and phantom tachyonic field and observe that only phantom tachyonic field solution represents an emergent universe. We find that the coupling parameter of higher order correction affects the evolution of the emergent universe. The stability of solutions and their physical behaviors are discussed in detail.

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1 Introduction

Harrison (1967) described a model of closed universe filled with radiation in the presence of a cosmological constant, which asymptotically coincides with Einstein static model in infinite past. Ellis and Maartens (2004) considered the possibility of a similar cosmological solution in which there is no big-bang singularity and the universe effectively avoids a quantum regime for the space-time by staying large at all times. An interesting example of this scenario were given by Ellis et al. (2004) for a closed universe with a minimally coupled scalar field ϕ, which has a special form of interacting potential $V(\phi)$ and possibly the same ordinary matter with equation of state $p = \omega\rho$, where $-\frac{1}{3} \leq \omega \leq 1$. However, exact analytic solution was not presented in this model. A viable cosmological model should accommodate an inflationary phase in the early universe with a suitable accelerating phase at late time. In this way the search of singularity free inflationary model in the context of classical general relativity has recently led to the development of emergent universe (EU).

An emergent universe is a model of the universe in which there is no time-like singularity and having almost static behavior in the infinite past. The EU model eventually evolves from a static phase in the infinite past into an inflationary stage and finally it admits an accelerating phase at late time. In fact EU scenario can said to be a modern version and extension of the original Lamaitre-Eddington universe. In EU scenario, it is assumed that the initial conditions are specified such that the static configuration represents the past eternal state of the universe, out of which the universe slowly