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Noether symmetry approach in the cosmological alpha-attractors

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Abstract

In cosmological framework, Noether symmetry technique has revealed a useful tool in order to examine exact solutions. In this work, we first introduce the Jordan-frame Lagrangian and apply the conformal transformation in order to obtain the Lagrangian equivalent to Einstein-frame form. We then analyze the dynamics of the field in the cosmological alpha-attractors using the Noether symmetry approach by focusing on the single field scenario in the Einstein-frame form. We show that with a Noether symmetry the corresponding dynamical system can be completely integrated and the potential exhibited by the symmetry can be exactly obtained. With the proper choice of parameters, the behavior of the scale factor displays an exponential (de Sitter) behavior at the present epoch. Moreover, we discover that the Hubble parameters strongly depends on the initial values of parameters exhibited by the Noether symmetry. Interestingly, it can retardedly evolve and becomes a constant in the present epoch in all cases.

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1. Introduction

In modern cosmology, the mechanism of cosmic inflation seems conceivable. Inflation marks nowadays an inevitable ingredient when studying very early evolution of the universe. The reason stems from the fact that it solves most of the puzzles that plague the standard Big Bang theory, and simultaneously is consistent with recent observational data. In other words, it not only gives sensible explanations for the horizon, flatness, and relic abundant problems, but also provides us primordial density perturbation as seeds of the formation for a large-scale structure in the universe.

Despite all its success, however, the underlying mechanism of the inflationary physics is still unknown. Recent observational data much flavors large field inflationary models with plateau-like inflaton potentials. However, there are several different ways of constructing successful inflationary models. In the supergravity context, a model with plateau potentials was proposed by the authors of Refs. [1,2]. Here it describes a potential which is exponentially approaching a positive constant for super-Planckian values of the inflaton field. Later on, a theory with a similar potential was realized as the Starobinsky model [3], and then the Higgs inflation model with a similar potential was developed [4,5]. It is worth noting that these models lead to nearly identical predictions, providing the best fit to the latest Planck data [6,7]. Moreover, recent investigation shows the inflaton field can emerge as a composite state of a new strongly interacting gauge theory [8,9]. More recently, a broad class of inflationary models, dubbed cosmological attractors [10–16], yields very similar inflationary predictions.

Interestingly, the cosmological α-attractors incorporate most of the existing inflationary models with plateau-like potentials including the Starobinsky model and some generalized versions of the Higgs inflation. Regarding the α-attractors, the flatness of the inflaton potential is implemented and protected by the existence of a pole in the kinetic term of the scalar field. Moreover, at large-field values, any non-singular inflaton potential acquires a universal plateau-like form when performing the (conformal) transformation. Regarding the hyperbolic geometry and the flatness of the Kahler potential in the supergravity context, the universal behaviors of these theories make very similar cosmological predictions preserving good match to the latest cosmological observations [17–20]. The successful extensions of these models can also describe dark energy/cosmological constant and supersymmetry breaking [21–29].

The purpose of the present study is to analyze the dynamics of the field in the cosmological α-attractors through the Noether symmetry technique. Here we concentrate on the single field scenario. It is worth noting that this approach proved to be very useful not only to fix physically viable cosmological models with respect to the conserved quantities, e.g., couplings and potentials, but also to reduce dynamics and achieve exact solutions. Moreover, the existence of Noether symmetries plays crucial roles when studying quantum cosmology [30].

In the present paper, we consider the single-field model of cosmological α-attractors. The structure of the paper is as follows: In Sec. 2, we introduce the model in the Jordan frame (JF) and transform the original action into the equivalent Einstein frame (EF) by applying the conformal transformation. In Sec. 3, we adopt the Noether symmetry approach to study the related dynamical systems obtained from a point-like Lagrangian. Here we can determine the form of the undefined potential of the action by imposing the Noether symmetry. We also compute the general solutions with the helps of the new coordinate system. Moreover, we compute the Hubble parameter and display plot as a function of time for some specific cases. Finally, we conclude our findings in the last section.