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On the possibility of blue tensor spectrum within single field inflation

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Abstract

We present a series of theoretical constraints on the potentially viable inflation models that might yield a blue spectrum for primordial tensor perturbations. By performing a detailed dynamical analysis we show that, while there exists such possibility, the corresponding phase space is strongly bounded. Our result implies that, in order to achieve a blue tilt for inflationary tensor perturbations, one may either construct a non-canonical inflation model delicately, or study the generation of primordial tensor modes beyond the standard scenario of single slow-roll field.

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1. Introduction

In recent years, the measurements of the cosmic microwave background (CMB) temperature anisotropies verified a nearly scale-invariant power spectrum of the primordial curvature perturbation to high precision [1]. This observational fact is highly consistent with the predictions from the perturbation theory of inflationary cosmology [2]. Therefore, inflation, which originally appeared in early 80's [3] (see also [4]), has become the most prevailing paradigm of describing the very early universe. Furthermore, inflationary cosmology also predicts a nearly scale-invariant power spectrum of the primordial gravitational waves, of which the magnitude is relatively smaller than that of the primordial curvature perturbation [5]. If these primordial tensor fluctuations exist, they could lead to the B-mode polarization signals in the CMB [6] and hence are expected to be observed in cosmological surveys.

So far there is no observational evidence that indicates existence of the primordial tensor fluctuations [7–9]. However, as was pointed out in [10], a suppression of power in the B-mode angular power spectrum at large scales might exist, which implies that a spectrum of primordial gravitational waves could have a blue tilt. Thus, from the perspective of theoretical interpretations, it is interesting to investigate whether a power spectrum of primordial gravitational waves with a blue tilt can be achieved in the framework of inflationary cosmology.

This question has already drawn the attention of cosmologists in the literature, and a couple of different mechanisms were put forward, namely the beyond-slow-roll inflation [11], the matter-bounce inflation [12], inflation with non-Bunch–Davis vacuum [13], the non-commutative field inflation [14], the variable gravity quintessential inflation [15], the string gas cosmology [16], or the Hawking radiation during inflation [17]. Therefore, a careful characterization of the power spectrum of the primordial B-mode polarization is very important to falsify the paradigms of very early universe (see [18] for the characterization of the primordial gravitational waves within various very early universe models).

In the present work we make a remark on the potential challenge of regular inflation models to generate a blue tilt for the primordial gravitational waves. We restrict ourselves within the standard general relativity and present a potential resolution to this challenge by proposing to extend the parameter space of inflation models by including non-canonical operators. In particular, we phenomenologically consider a class of inflation models with the Horndeski operator being involved. Such models were considered in inflationary cosmology for the purpose of circumventing the paradigm of Higgs inflation [19], and are dubbed as "G-inflation" [20] (see for example [21] for generalized analyses and see [22] for a counter-claim from the stability viewpoint). In our construction, differing from the application of the Galilean symmetry, inflation is driven by a scalar field with a Horndeski operator which could be achieved either by the kinetic term or the potential energy. We investigate the dynamics of this cosmological system by performing a detailed phase space analysis. We find that in general the generation of a blue tilt of the primordial gravitational waves in a viable inflation model is difficult since the expected trajectories are not stable in the phase space. However, a short period of super-inflationary phase might be possible and thus would circumvent the above theoretical challenges.

The article is organized as follows. In Section 2, we briefly review the standard picture of predictions made by regular inflation models on the primordial curvature and tensor perturbations. We can see that it is forbidden to produce a power spectrum of the primordial tensor modes with a blue tilt in a wide class of inflation models. Then, in Section 3 we present a class of extended inflation models by including a parameterized Horndeski operator. By selecting several typical inflation potentials, we perform the dynamical analyses in details and derive their attractor solu-