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Slow-roll inflation with a Gauss-Bonnet correction

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We consider slow-roll inflation for a single scalar field with an arbitrary potential and an arbitrary nonminimal coupling to the Gauss-Bonnet term. By introducing a combined hierarchy of Hubble and Gauss-Bonnet flow functions, we analytically derive the power spectra of scalar and tensor perturbations. The standard consistency relation between the tensor-to-scalar ratio and the spectral index of tensor perturbations is broken. We apply this formalism to a specific model with a monomial potential and an inverse monomial Gauss-Bonnet coupling and constrain it by the 7-year Wilkinson Microwave Anisotropy Probe data. The Gauss-Bonnet term with a positive (or negative) coupling may lead to a reduction (or enhancement) of the tensor-to-scalar ratio and hence may revive the quartic potential ruled out by recent cosmological data.

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I. INTRODUCTION

Inflation in the early Universe has become the standard model for the generation of cosmological perturbations in the Universe, the seeds for large-scale structure and temperature anisotropies of the cosmic microwave background. The simplest scenario of cosmological inflation is based upon a single, minimally coupled scalar field with a flat potential. Quantum fluctuations of this inflaton field give rise to an almost scale-invariant power spectrum of isentropic perturbations (see Refs. [1, 2] for reviews).

String theory is often regarded as the leading candidate for unifying gravity with the other fundamental forces and for a quantum theory of gravity. It is known that the effective supergravity action from superstrings induces correction terms of higher order in the curvature, which may play a significant role in the early Universe. The simplest such correction is the Gauss-Bonnet (GB) term in the low-energy effective action of the heterotic string [3]. Such a term provides the possibility of avoiding the initial singularity of the Universe [4]. In the presence of an exponential potential for the modulus field, nonsingular cosmological solutions were found which begin in an asymptotically flat region, undergo superexponential inflation and end with a graceful exit to a phase with decreasing Hubble radius [5].

There are many works discussing accelerating cosmology with the GB correction in four and higher dimensions [6–9]. Recently it has been shown that the GB term might give rise to violent instabilities of tensor perturbations [10]. A model in which inflation is driven by the GB term and a higher-order kinetic energy term was studied. When the GB term dominates the dynamics of the background, tensor perturbations exhibit violent negative instabilities around a de Sitter background on small scales, in spite of the fact that scale-invariant scalar perturbations can be achieved [10]. Besides the kinetic and GB terms, a scalar potential arises naturally from supersymmetry breaking or other nonperturbative effects.

In a previous work, we investigated inflationary solutions and resulting cosmological perturbations for the special case of power-law inflation when both the GB correction and the scalar potential are present [11]. Power-law inflation happens when both the potential and the GB coupling take an exponential form. In this model instabilities of either scalar or tensor perturbations show up on small scales for GB-dominated inflation. The GB correction with a positive (or negative) coupling may lead to a reduction (or enhancement) of the tensor-to-scalar ratio in the potential-dominated case. This effect leads to tight constraints on the magnitude of the GB correction from the Wilkinson Microwave Anisotropy Probe (WMAP) 5-year analysis [12].

Here we generalize our previous work to the more general case of slow-roll inflation with an arbitrary potential and an arbitrary coupling. Making use of a combined hierarchy (ϵ_i, δ_i) of Hubble and GB flow functions (as defined below) with $|\epsilon_i| \ll 1$ and $|\delta_i| \ll 1$, analogous to the standard slow-roll approximation, we derive the power spectra of scalar and tensor perturbations. In this scenario the spectral index of scalar perturbations contains not only the Hubble flow parameters but also the GB flow parameters. Moreover, the standard consistency relation of single-field slow-roll inflation is modified. In order to impose observational constraints on such models, we focus on a specific model with a monomial potential and an inverse monomial GB coupling. We analyze the influence of the GB term on the scalar spectral index $n_{\mathcal{R}}$ and the tensor-to-scalar ratio r.

This paper is organized as follows. In Sec. II we define the Hubble and GB flow functions. Then by using the background equations of motion, we demonstrate that the slow-roll solution exists and is stable under asymptotic conditions. In Sec. III we calculate the power spec-

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