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General $f(R)$ and conformal inflation from minimal supergravity plus matter

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Abstract

We embed general $f(R)$ inflationary models in minimal supergravity plus matter, a single chiral superfield Φ, with or without another superfield S, via a Jordan frame Einstein+scalar description. In particular, inflationary models like a generalized Starobinsky one are analyzed and constraints on them are found. We also embed the related models of conformal inflation, also described as Jordan frame Einstein+scalar models, in particular the conformal inflation from the Higgs model, and analyze the inflationary constraints on them.

1. Introduction

Inflation is the leading cosmological model for the initial stages of the evolution of our Universe. On the other hand, one of the best models for particle physics at higher energies than the ones we currently probe at accelerators involves supersymmetry. Including gravity in the picture, we expect that physics at high energies has as an effective theory given by supergravity. So it is natural to look for inflation in supergravity, and yet obtaining good supergravity models of inflation is notoriously difficult, and generally involves some type of fine-tuning. For instance, until recently there were various negative results ("no-go theorems") for the simplest set-up, for minimal ($\mathcal{N} = 1$) supergravity coupled to matter in the form of a single chiral superfield, see e.g. [1,2].

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Recently however, models embedding rather general potentials within $\mathcal{N} = 1$ supergravity with one chiral superfield were proposed [3,4], as well as ways to embed general potentials within $\mathcal{N} = 1$ supergravity with one chiral superfield (Φ), plus another one (S) stabilized at zero [2]. Also, a special class of models that has been called α-attractors can be embedded in $\mathcal{N} = 1$ supergravity with one chiral superfield [5,6].

In this paper we are interested in the embedding in minimal supergravity plus matter of Jordan frame Einstein+scalar models, which can be written as Einstein+scalar with a potential. One such class of models are the $f(R)$ models. We will show that a generic $f(R)$ model can be written as a Einstein+scalar model, and reversely, any Einstein+scalar with potential model can be written in $f(R)$ form. In particular, we will analyze several inflationary potentials from the point of view of $f(R)$ and of the minimal supergravity embedding. In the constraints, we will use the results of the Planck [7] and WMAP [8] experiments, but not the value of the tensor to scalar ratio r from BICEP2 [9], since there is uncertainty surrounding it [10,11] and recently the joint Planck and BICEP2 paper drastically modified the result [12].

We will also consider another class of Jordan frame Einstein+scalar models that goes under the name of conformal inflation. These are models with two scalar fields and local Weyl symmetry, found in [13,14], following earlier work by [15–20]. These models generically give rise to the same predictions as the Starobinsky model [21], since the asymptotic Einstein-frame scalar potential in the inflationary region is the same. In [22] it was considered the possibility that the inflaton is also the Higgs, since by now the Higgs is the only discovered scalar [23,24], and moreover it was found that with some rather unusual choices for an arbitrary function we can get a generalized type of Starobinsky model in the inflationary region (the idea of Higgs inflation has a long history; for the present discussion we note that the Bezrukov–Shaposhnikov model [25] admits a Weyl-symmetric formulation [26]). In this paper we will see that we can actually get any potential of the "new inflation" type, and we will investigate the embedding in supergravity of these conformal Higgs inflation models, and their relation to $f(R)$ models. Note that the generalized Starobinsky model was considered before, for instance in [27,28], and in the context of supergravity with two chiral superfields in [29–31]. After the paper first appeared on arXiv, I became aware of other papers dealing with issues related to the ones described in this paper: in [32] it was considered a supersymmetrization of $R + R^n$ Starobinsky-like models, in [33] it was shown that the α-attractors later embedded in supergravity in [5,6] can also be related to $f(R)$ models coupled to an auxiliary vector field, and in [34] it was analyzed the relation between $f(R)$ models and generalized versions of the Starobinsky model.

The paper is organized as follows. In section 2 we will first show that a general $f(R)$ action can be obtained from Einstein–Hilbert plus a dynamical scalar, and then embed them in minimal supergravity. In section 3 we will focus on examples relevant for inflation and consider inflationary constraints on them. In section 4 we change the focus to conformal inflation models, and show how to embed them in minimal supergravity. In section 5 we consider the set-up of conformal inflation coming from the Higgs, inflationary models related to it, and inflationary constraints on them, and in section 6 we conclude.

2. General $f(R)$ from minimal supergravity

2.1. $f(R)$ actions as EH plus dynamical scalar

There is a general procedure for writing an $f(R)$ action as a usual Einstein–Hilbert one plus a dynamical scalar field. For instance, in the case of a monomial correction to the Einstein–Hilbert