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ORIGINAL ARTICLE

Cosmic evolution in a modified Brans-Dicke theory

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Abstract We consider Brans-Dicke theory with a self-interacting potential in Einstein conformal frame. We introduce a class of solutions in which an accelerating expansion is possible in a spatially flat universe for positive and large values of the Brans-Dicke parameter consistent with local gravity experiments. In this Einstein frame formulation, the theory appears as an interacting quintessence model in which the interaction term is given by the conformal transformation. In such an interacting model, we shall show that the solutions lead simultaneously to a constant ratio of energy densities of matter and the scalar field.

Keywords Cosmology · Theory · Dark energy

1 Introduction

Cosmological observations on expansion history of the universe indicate that the universe is in a phase of accelerated expansion (Riess et al. 1998; Perlmutter et al. 1997a, 1997b). This phenomenon may be interpreted as evidence either for existence of some exotic matter components or for modification of the gravitational theory. In the first route of interpretation one can take a mysterious cosmic fluid with sufficiently large and negative pressure, dubbed dark energy. This viewpoint also includes quintessence models (Ratra and Peebles 1988; Caldwell et al. 1998; Steinhardt et al. 1999; Macorra and Piccinelli 2000; Gonzalez-Diaz 2000; Bludman and Roos 2002; Cai et al. 2010), which invokes a scalar field minimally coupled to gravity. The scalar field takes negative pressure during its evolution by rolling down a proper potential. In the second route, however, one attributes the accelerating expansion to a modification of general relativity. This includes scalar-tensor theories, scalar fields non-minimally coupled to gravity (Faraoni et al. 1999; Faraoni 2004).

Here we shall consider a self-interacting Brans-Dicke (BD) theory (Brans and Dicke 1961) as a prototype of scalar-tensor theories. The original motivation of the BD theory was the search for a theory containing Mach's principle which has found a limited expression in general relativity. As the simplest and best-studied generalization of general relativity, it is natural to think about the BD scalar field as a possible candidate for producing cosmic acceleration without invoking a quintessence field or exotic matter systems (Setare 2007; Setare and Jamil 2010). In fact, there have been many attempts to show that BD model can potentially explain the cosmic acceleration. It is shown that this theory can actually produce a non-decelerating expansion for low negative values of the BD parameter ω (Banerjee and Pavon 2001). This conflicts with the lower bound imposed on this parameter by solar system experiments (Will 1993; Will 2005). Some authors propose modifications of the BD model such as introducing some potential functions for the scalar field (Bertolami and Martins 2000; Mak and Harko 2002), or considering a field-dependent BD parameter (Chakraborty and Debnath 2008), without resolving this problem.

All the works in this context use Jordan frame representation of BD theory. It is however well-known that this theory, like any other scalar-tensor theories, can be represented in the so-called Einstein frame by using a conformal transformation (Faraoni et al. 1999; Faraoni 2004). Although these two conformal frames are mathematically equivalent there are some debates on their physical equivalence. Here there

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