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ORIGINAL ARTICLE

Canonical and phantom scalar fields as an interaction of two perfect fluids

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Abstract In this article we investigate and develop specific aspects of Friedmann-Robertson-Walker (FRW) scalar field cosmologies related to the interpretation that canonical and phantom scalar field sources may be interpreted as cosmological configurations with a mixture of two interacting barotropic perfect fluids: a matter component $\rho_1(t)$ with a stiff equation of state ($p_1 = \rho_1$), and an "effective vacuum energy" $\rho_2(t)$ with a cosmological constant equation of state ($p_2 = -\rho_2$). An important characteristic of this alternative equivalent formulation in the framework of interacting cosmologies is that it gives, by choosing a suitable form of the interacting term Q, an approach for obtaining exact and numerical solutions. The choice of Q merely determines a specific scalar field with its potential, thus allowing to generate closed, open and flat FRW scalar field cosmologies.

Keywords Scalar fields cosmologies

1 Introduction

It is well known that scalar fields play an important role in modeling both the early and late stages in the evolution of the Universe (Faraoni 2011; Charters and Mimoso 2010; D'Ambroise 2010; Copeland et al. 2006; Ren and Meng 2006, 2007; Wang and Yang 2006; Capozziello et al. 2009; Giovannini 2007; Williams et al. 2004; Cataldo and del Campo 2000). Inflation is considered an essential part of the description of the early universe (Cardenas 2006, 2007; Nojiri and Odintsov 2003; Zimdahl et al. 1997; Linde 1983, 1994; Kofman et al. 1994). It does solve classical cosmological problems such as flatness, horizon and monopole problems, providing at the same time precise predictions for the primordial density inhomogeneities, which are in good agreement with observational data (Hinshaw et al. 2009). Many different physical fields and mechanisms may be responsible for this accelerating cosmic expansion (Ghosh et al. 2012; Banijamali and Fazlpour 2011, 2012; Chattopadhyay 2011; Brevik et al. 2010, 2011; Chattopadhyay and Debnath 2010a; Avelino and Nucamendi 2009, 2010; Jamil and Farooq 2010; Felippe et al. 2009, 2010; Jamil et al. 2009; Ito and Nojiri 2009; Bamba et al. 2009; Cai and Wang 2008; Cruz et al. 2007; Ren and Meng 2007), however, it has become a common practice to employ scalar fields in order to explain this early accelerated expansion (Bamba et al. 2012). On the other hand, in recent years, several proposals have been made, by using scalar fields, in order to explain the late acceleration of the Universe (Elizalde et al. 2004) and the coincidence problem. In general, due to isotropy and homogeneity of the Universe on cosmological scales, most of the papers consider self-interacting scalar fields in the FRW framework. We shall consider here canonical and phantom scalar fields in the FRW cosmology described by the metric

$$ds^2 = dt^2 - a(t)^2\left(\frac{dr^2}{1-kr^2} + r^2\left(d\theta^2 + \sin^2\theta d\varphi^2\right)\right), \quad (1)$$

minimally coupled to gravity. The evolution of a scalar field cosmology is given by

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