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ORIGINAL ARTICLE

Accelerating and decelerating cosmology from spinor and scalar fields non-minimally coupled with $f(R)$ gravity

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Abstract In this paper we investigate the accelerating and decelerating cosmological models with non-linear spinor fields and non-minimal interaction of $f(R)$ gravity with a scalar field. We combine two different approaches to the description of dark energy: modified gravity theory and introduction of the additional fields. Solutions for the FRW universe with power-law scale factor are reconstructed for the model under consideration with specific choice for scalar and spinor potentials. It is explained the role of scalar and spinor potentials as well as $f(R)$ function for emergence of accelerating or decelerating cosmology.

Keywords Dark energy · Spinor fields · Scalar fields · Non-minimal interaction

1 Introduction

The problem of the dark energy and dark matter is one of the main challenges of modern cosmology. Astrophysical data indicate that the observed universe is in an accelerated phase (Riess et al. 1998; Perlmutter et al. 1998; Hicken et al. 2009; Dunkley et al. 2009; Percival et al. 2010). This acceleration could be induced by the so-called dark energy (see Bamba et al. 2012 for a recent review). On the other hand, astrophysical observations provide evidence (Clowe et al. 2006; Bertone et al. 2005) for the existence of a non-baryonic, non-interacting and pressure-less component of the Universe, dubbed dark matter. This leads us to the need to revise the standard cosmology.

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The cosmological constant models are the simplest candidates for the solution of the problem of the universe acceleration. However, these models have still problems with the consistent description of the different evolution stages of the Universe. Scalar theory is most popular to describe the current accelerating expansion and early-time inflation. However, to describe the dark matter we have to introduce additional fields. One can consider a model with two scalar fields (Elizalde et al. 2004) (or scalar field and Lagrange multiplier(s) Lim et al. 2010; Capozziello et al. 2010, 2013a, 2013b; Saez-Gomez 2012; Cid and Labrana 2012), or, for example, models with additional spinor field to describe dark energy and dark matter.

The study of spinor fields in curved spacetime has a long history. The Dirac equation was investigated for massless spinor fields in curved space-time more than 50 years ago (Brill and Wheeler 1957). Spinor fields can be used to describe the primordial inflation (Armendariz-Picon and Greene 2003) and current expansion (Ribas et al. 2005). However, the exact solutions in the presence of the spinor field is difficult to build (for example, see Makarenko and Obukhov 2012).

A significant number of attempts have been made to construct the cosmological models with a spinor field for description of dark energy, where a non-canonical kinetic term was considered, such as k-inflation and k-essence models (Rakhi et al. 2010; Boehmer et al. 2010; Watanabe 2009; Wang et al. 2010; Cai and Wang 2008). In Inagaki and Rybalov (2011), Osetrin and Rybalov (2013), the properties of one of the foregoing models with self-interacting spinor with the noncanonical kinetic term were studied.

It should be noted that the models involving the squared classical Dirac Lagrangian can be considered as a special case of the k-essence model (Ribas et al. 2008; Chimento et al. 2008; Myrzakulov 2010). The scalar invariant con-