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ORIGINAL ARTICLE

Cosmic expansion driven by real scalar field for different forms of potential

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Abstract We discuss the expansion of the universe in the FRLW model assuming that the source of dark energy is either tachyonic scalar field or quintessence. The tachyonic scalar field with exponential and power-law potential (function of homogeneous scalar field ϕ) both gives exponential expansion of the universe. It is found that this behaviour is not distinguishable from the quintessence with respect to these potentials.

Keywords Dark energy · Tachyonic scalar field · Quintessence

1 Introduction

The recently observed accelerated expansion of the universe is understood by different dark energy models. A class of scalar fields is one of the promising candidate of dark energy (Ratra and Peebles 1988; Caldwell et al. 1998; Liddle and Scherrer 1998; Padmanabhan 2003). The dark energy is often treated as scalar field (tachyonic or quintessence), while among itself, the tachyonic scalar field arising from string theory (Sen 2002) (for different reasons in our context) has been widely used in literature (Padmanabhan and Roy Choudhury 2002; Bagla et al. 2003; Padmanabhan 2002; Sadeghi et al. 2009; Setare 2007; Setare et al. 2008, 2009).

The relativistic Lagrangian proposed (Sen 2002) for the tachyonic scalar field ϕ gives the action as

$$\mathcal{A} = \int d^4x\sqrt{-g}\left(\frac{R}{16\pi G} - V(\phi)\sqrt{1-\partial^i\phi\partial_i\phi}\right) \tag{1}$$

with tachyonic scalar field Lagrangian

$$L_{tach} = -V(\phi)\sqrt{1-\partial_i\phi\partial^i\phi} \tag{2}$$

and the corresponding energy momentum tensor

$$T^{ik} = \frac{\partial L}{\partial(\partial_i\phi)}\partial^k\phi - g^{ik}L \tag{3}$$

gives the energy density and pressure as

$$\rho = \frac{V(\phi)}{\sqrt{1-\partial_i\phi\partial^i\phi}}; \qquad P = -V(\phi)\sqrt{1-\partial_i\phi\partial^i\phi} \tag{4}$$

respectively. The spatially homogeneous approximation of the field leads to the following forms of the above expressions

$$\rho = \frac{V(\phi)}{\sqrt{1-\dot{\phi}^2}}; \qquad P = -V(\phi)\sqrt{1-\dot{\phi}^2}, \tag{5}$$

where an overdot denotes the derivative with respect to time (as in the rest of this paper). The equation for conservation of energy of this field is

$$\frac{\dot{\rho}_\phi}{\rho_\phi} = -3H\dot{\phi}^2, \tag{6}$$

where H represents the Hubble parameter.

The Friedmann equation for single component dominated by scalar field can be written for the flat spatial geometry as

$$H^2 = \frac{1}{3M_p^2}\frac{V(\phi)}{\sqrt{1-\dot{\phi}^2}}, \tag{7}$$

where $M_p^2 = \frac{1}{8\pi G}$. The equation of motion of tachyonic scalar field could be found by varying the action (1) as

$$\frac{\ddot{\phi}}{\dot{\phi}} + \frac{(1-\dot{\phi}^2)V'(\phi)}{\dot{\phi}V(\phi)} + 3H\left(1-\dot{\phi}^2\right) = 0, \tag{8}$$

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