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ORIGINAL ARTICLE

Kaluza-Klein universe with cosmic strings and bulk viscosity in $f(R,T)$ gravity

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Abstract A five dimensional Kaluza-Klein cosmological model is considered in the frame work of $f(R,T)$ gravity proposed by Harko et al. (Phys. Rev. D 84:024020, 2011) when the source for energy momentum tensor is a bulk viscous fluid containing one dimensional cosmic strings. A barotropic equation of state is assumed to get a determinate solution of the field equations. Also, the bulk viscous pressure is assumed to be proportional to the energy density. The physical behavior of the model is also discussed.

Keywords Kaluza-Klein universe · Cosmic strings · Bulk viscosity · $f(R,T)$ gravity

1 Introduction

It is well known that the discovery of the accelerated expansion of the universe has revolutionized modern cosmology (Riess et al. 1998; Perlmutter et al. 1999; Bennet et al. 2003). Astrophysical observations indicate that this cosmic acceleration is driven by exotic energy with a large negative pressure which is known as dark energy (for a general complete review see Nojiri and Odintsov 2007). In recent years modified theories of gravity are attracting much attention to explore the dark energy and late time acceleration of the universe. Among the various modifications of general relativity, $f(R)$ theory of gravity has gained importance during the last decade since it provides a natural gravitational alternative to dark energy. It has been suggested that cosmic acceleration can be achieved by replacing the Einstein-Hilbert action of general relativity with a general function $f(R)$ of Ricci scalar R. The explanation of cosmic acceleration is obtained just by introducing the term $1/R$ which is essential at small curvatures. The useful aspects of $f(R)$ gravity are that it gives an easy unification of early time inflation and late time acceleration. It also describes the transition phase of the universe from deceleration to acceleration (Nojiri and Odintsov 2007). Capozziello et al. (2007, 2008), Multamaki and Vilja (2006, 2007), Sharif (2010). Azadi et al. (2008), Caroll et al. (2004), Nojiri and Odintsov (2003, 2004, 2007) and Chiba et al. (2007) are some of the authors who have investigated several aspects of $f(R)$ gravity. Copeland et al. (2006) have given a comprehensive review of $f(R)$ gravity.

Recently, Harko et al. (2011) proposed another modification of Einstein's theory of gravitation which is known as $f(R,T)$ theory of gravity wherein the gravitational Lagrangian is given by an arbitrary function of the Ricci scalar R and of the trace T of the stress energy tensor T_{ij}. They have derived the field equations of $f(R,T)$ gravity from Hilbert-Einstein type variational principle by taking the action

$$S=\frac{1}{16\pi}\int\left[f(R,T)+L_m\right]\sqrt{-g}d^4(x) \tag{1}$$

where $f(R,T)$ is an arbitrary function of the Ricci scalar R, T is the trace of energy tensor of the matter T_{ij} and L_m is the matter Lagrangian density. By varying the action S of the gravitational field with respect to the metric tensor components g^{ij}, they have obtained the field equations of

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