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ORIGINAL ARTICLE

A five dimensional Kaluza-Klein bulk viscous string cosmological model in Brans-Dicke scalar-tensor theory of gravitation

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Abstract In this paper, we have investigated a five dimensional Kaluza-Klein space-time in the frame work of Brans-Dicke (Phys. Rev. 124:925, 1961) scalar-tensor theory of gravitation when the source of energy momentum tensor is a bulk viscous fluid containing one dimensional cosmic strings. We have obtained a determinate solution of the field equations using the special law of variation for Hubble's parameter proposed by Bermann (Nuovo Cimento B 74:182, 1983) We have also used a barotropic equation of state for the pressure and density. Some physical properties of the model are also discussed.

Keywords Kaluza-Klein model · Bulk viscosity · Cosmic strings · Brans-Dicke theory

1 Introduction

There has been a considerable interest in constructing cosmological models in alternative theories of gravity during past decades. The study of cosmological models in Brans and Dicke (1961) and Saez and Ballester (1986) scalar-tensor theories of gravitation is quite important in view of the fact that scalar fields play a vital role in inflationary cosmology. Brans-Dicke theory introduces a long range scalar field φ interacting equally with all forms matter (with the exception of electromagnetism) besides the metric tensor g_{ij} and a dimensionless coupling constant ω. In Saez-Ballester scalar-tensor theory the metric is coupled with a dimensionless scalar field in a simple manner. This theory suggests a possible way to solve missing matter problem in non-flat FRW cosmologies. The field equations given by Brans and Dicke for the combined scalar and tensor fields are

$$\Box\varphi = \varphi_{;k}^{\ ,k} = \frac{8\pi}{3+2\omega}T \tag{1}$$

$$, R_{ij} - \frac{1}{2}g_{ij}R = -\frac{8\pi}{\varphi}T_{ij} - \frac{\omega}{\varphi^2}\left(\varphi_{,i}\varphi_{,j} - \frac{1}{2}\varphi_{,k}\varphi^{,k}\right) - \frac{1}{\varphi}(\varphi_{;ij} - g_{ij}\Box\varphi) \tag{2}$$

where φ is the scalar field, ω is the dimensionless coupling constant (this should be constrained as $\omega \geq 40{,}000$ for its consistency with solar system bounds, Bertotti et al. 2003; Felice et al. 2006), T_{ij} is the energy momentum tensor and R_{ij} and R have their usual meaning. Also,

$$T^{ij}_{;j} = 0 \tag{3}$$

is a consequence of the field equations (1) and (2). Here semicolon indicates covariant derivative and comma denotes ordinary derivative with respect to x^k.

Brans-Dicke (BD) theory of gravity is one of the most important scalar-tensor theories due to its vast cosmological implications (Bertolami and Martins 2000; Banerjee and Pavon 2001). Several aspects of BD cosmology have been investigated by many authors. Singh and Rai (1983) presented a nice review of work done in BD theory. It is well known that spatially homogeneous and anisotropic

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