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BIANCHI TYPE V UNIVERSE WITH TIME VARYING COSMOLOGICAL CONSTANT AND QUADRATIC EQUATION OF STATE IN $f(R,T)$ THEORY OF GRAVITY[†]

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In recent years, modified theories of gravity have been extensively studied because of the discovery and confirmation of the current phase of accelerated expansion of the universe. The $f(R,T)$ theory of gravity is one such theory, proposed by Harko *et al*. in 2011, in which R is the Ricci scalar and T is the trace of the stress-energy tensor. In this paper, we study Bianchi type V universe in $f(R,T)$ theory of gravity with time varying cosmological constant and a quadratic equation of state $p = \alpha\rho^2 - \rho$, where $\alpha \neq 0$ is a constant. We obtain exact solutions of the field equations for two cases: one with a volumetric expansion law and the other with an exponential expansion law. The physical features of the two models are discussed by examining the behavior of some important cosmological parameters such as the Hubble parameter, the deceleration parameter etc. We find that the models have initial singularity and the physical parameters diverge at the initial epoch. The model 1, corresponding to the volumetric expansion law does not resemble ΛCDM model while the model 2, corresponding to the exponential expansion law, resembles ΛCDM model. The energy conditions of the models are also examined and found to be consistent with recent cosmological observations.
Keywords: *Bianchi type V universe; $f(R,T)$ theory of gravity; Equation of state; ΛCDM model*
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1. INTRODUCTION

Various astrophysical and cosmological observations like type Ia supernovae [1-3], Cosmic Microwave Background (CMB) [4, 5], Large Scale Structure (LSS) [6, 7] and other improved measurements of supernovae conforms the discovery of the late-time cosmic acceleration although it is yet to be ascertained what led to the start of this acceleration. According to the recent Planck collaboration results [8], it is found that about 95% of the total constituent of the universe is mysterious. Within the framework of General Relativity, the observed cosmic acceleration can be attributed to an exotic component of the universe with large negative pressure which contributes nearly 68% of the total energy content of the universe. This unknown energy fluid, supposed to be responsible for the late-time cosmic acceleration, is given the name dark energy. In literature, several dark energy candidates like quintessence [9,10], k-essence [11], tachyon [12], phantom [13], Chaplygin gas [14], Holographic dark energy [15] etc. have been proposed and studied in various cosmological background. It is seen that even though the hypothetical dark energy can smoothly explain the accelerated expansion of the universe, many dark energy models encounter with problems when tested by some old red-shift objects [16, 17]. Therefore, the other way considered to explain the cosmic acceleration is modifications of Einstein's theory of gravitation. Some of the most studied modifications of Einstein's General theory of Relativity are the $f(R)$ theory of gravity [18, 19], $f(\mathrm{T})$ gravity [20], $f(R,T)$ theory of gravity [21], $f(G)$ gravity [22] etc. In the $f(R,T)$ theory of gravity, the gravitational Lagrangian in the Einstein-Hilbert action is modified by replacing the Ricci scalar R by an arbitrary function $f(R,T)$ of R and the trace T of the stress-energy tensor. Harko *et al*. [21] have derived the gravitational field equations of this theory in the metric formalism, as well as the equations of motion for test particles, which follow from the covariant divergence of the stress-energy tensor. They have also presented the field equations corresponding to the homogeneous and isotropic FRW metric and provided a number of specific cosmological models that correspond to some explicit forms of the function $f(R,T)$ such as $f(R,T) = R + 2f(T)$, $f(R,T) = f_1(R) + f_2(T)$, $f(R,T) = f_1(R) + f_2(R)f_3(T)$. Since then many researchers have studied various isotropic and anisotropic cosmological models in different contexts within this framework of modified theory of gravity.

In literature, various homogeneous and anisotropic cosmological models such as the Bianchi type models are studied in the context of dark energy as well as in alternative or modified theories of gravity. Homogeneous and anisotropic models of the universe are becoming more and more popular because of the anomalies found in the observations like Cosmic Microwave Background (CMB) and Large-Scale Structure [23, 24]. Also, models that are spatially homogeneous and anisotropic are helpful in describing the evolution of the early stages of the universe. Bianchi type V models are significant because they include the space of constant negative curvature as a special case.

In this paper, we study a spatially homogeneous and anisotropic Bianchi type V universe with a time dependent cosmological constant Λ and a quadratic equation of state $p = \alpha\rho^2 - \rho$ [25], where $\alpha \neq 0$ is a constant within the

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