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FRW COSMOLOGICAL MODELS WITH CONSTANT DECELERATION PARAMETER

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ABSTRACT

This paper deals with FRW-Cosmological model of the universe for conharmonically flat space time. Einstein field equations with bulk viscosity are solved by using a constant deceleration parameter. A new class of exact solution of the field equation has been obtained in which cosmological term decreases with cosmic time. A detailed study of physical and kinematical properties of the model is also discussed.

Key words: Cosmology, FW Model, Constant Deceleration Parameter, Bulk Viscosity.

INTRODUCTION :

The cosmological principle, which states that there is no privileged position in the universe and it is as such spatially homogeneous and isotropic, is the backbone of any cosmological model of the universe. FRW line element fits best with the cosmological principle. The FRW model, in the background of a bulk viscous fluid distribution of matter, represents an expanding and decelerating universe. However, the latest findings on observational grounds during the last three decades by various cosmological missions like observations on type-la Supernovae (Sne la) [1-5], CMBR fluctuations [6, 7], large scale structure (LSS) analysis [8, 9], SDSS Collaboration [10, 11], WMAP Collaboration [12], Chand X-ray observatory [13], Hubble space telescope cluster supernova survey V [14], BOSS Collaboration [15], WiggleZ dark energy survey [16] and latest Planck Collaboration results [17] all confirm that our universe is undergoing an accelerating expansion.

In general relativity, the energy conservation equation provides a linear relationship amongst the rate of expansion, pressure, density, bulk viscosity and temperature. DE negative pressure and density are also included in it. Many cosmologists have been studied the problem of the equation of state for baryonic matter by providing the phases of the Universe like stiff matter, radiation-dominated and the present dust dominated universe, but the determination of the EoS for DE is an important problem in observational cosmology at present.

In this paper, we have studied FRW cosmological model with constant deceleration parameter in the presence of bulk viscosity in the scale covariant theory of gravitation.

METRIC AND FIELD EQUATION :

We consider homogeneous and isotropic spatially flat Rabertson-Walker line element of the form

$$ds^2 = dt^2 + S^2(t)(dx^2 + dy^2 + dz^2) \qquad \text{... (1)}$$

where S(t) is the scale factor.

The energy momentum tensor for bulk viscous fluid is taken as

$$T_{ij} = (\rho + p)\, v_i v_j + \bar{p} g_{ij} \qquad \text{... (2)}$$

where ρ is proper energy density and $\bar{p}$ is the effective pressure given by

$$\bar{p} = p - \xi v^i_{;i} \qquad \text{... (3)}$$

satisfying equation of state

$$p = (\omega - 1)\rho;\ 1 \le \omega \le 2\ . \qquad \text{... (4)}$$

In the above equation p is the isotropic pressure and v^i is the four velocity vector satisfying $v^i v_i = -1$.

The Einstein field equations (in gravitational units 8 π G = C = 1) and varying cosmological constant Λ (t), in comoving system of coordinates lead to

$$\bar{p} - \Lambda = (2q - 1)H^2, \qquad \text{... (5)}$$

$$\rho + \Lambda = 3H^2\ . \qquad \text{... (6)}$$

In the above equation, H is the Hubble parameter and q is the deceleration parameter defined as

$$H = \frac{\dot{S}}{S}\ , \qquad \text{... (7)}$$

$$q = -1 - \frac{\dot{H}}{H^2} = \frac{-S\ddot{S}}{\dot{S}^2} \qquad \text{... (8)}$$

where an overhead dot (.) represents ordinary derivative with respect to t. The vanishing divergence of Einstein tensor gives rise to

$$\dot{\rho} + 3(\rho + \overline{p})H + \dot{\Lambda} = 0 \qquad \text{... (9)}$$

SOLUTION OF FIELD EQUATION :

The field equations (4) – (6) are system of three equation with five unknown parameter S, ρ, p, Λ and ξ.

Thus, two more relation connecting these variables are needed to solve these equations.

First, we consider the deceleration parameter to be constant and set

$$q = \frac{-S\ddot{S}}{\dot{S}^2} = \text{constant (n)} \qquad \text{... (10)}$$

yields

$$S = [S_0(t + t_0)]^{\frac{1}{1+n}}$$

$$= (S_0 T)^{\frac{1}{1+n}} \qquad \text{... (11)}$$

where S_0 and t_0 are constant of integration and set $T = t + t_0$.

Secondly, we assume

$$\xi = \xi_0 + \xi_1 H;\ \xi_0, \xi_1 > 0 \qquad \text{... (12)}$$

From equation (1) and (11), we obtain

$$ds^2 = -dt^2 + (S_0 T)^{\frac{2}{1+n}}(dx^2 + dy^2 + dz^2) \qquad \text{... (13)}$$

Expansion scalar θ, matter density ρ, cosmological term Λ, coefficient of bulk viscosity ξ, for the model (13) is given by

$$\theta = \frac{3}{(1+n)T}$$

$$\rho = \frac{1}{(w-1)}\left[\frac{3\xi_0}{(n+1)T} + \frac{(3\xi_1 + 2n - 1)}{(n+1)^2 T^2}\right]$$

$$\Lambda = \frac{3w - 3\xi_1 - 2n - 2}{(w-1)(n+1)^2 T^2} - \frac{3\xi_0}{(n+1)T}$$

$$\xi = \xi_0 + \frac{\xi_1}{(1+n)T}$$

We observe that model has singularity at T = 0. The model starts with a big-bang at T = 0 and the expansion in the model decreases as time increases. Expansion of model stop at T = ∞. At T = 0, θ, ρ, Λ, ξ are all diverge whereas ρ / θ^2 is constant. In the limit of large time i.e. $T \rightarrow \infty$, θ, ρ and Λ are zero whereas ξ is constant and ρ / θ^2 is constant and ρ / θ^2 is infinite. Thus, the matter density is comparable with vacuum energy density and expansion throughout the evaluation. In the presence of bulk viscosity is to increase the value of matter density ρ and to decrease the value of cosmological term Λ.

CONCLUSION :

In this paper, we have studied homogeneous and isotropic spatially flat FRW cosmological models with constant deceleration parameter in the contest of general relativity. For n > 0, the model represents a decelerating universe throughout the evaluation. If n = 0, we get H = 1 / T and q = 0, so that every galaxy moves with constant speed. The exact solution presented in this paper are and may be useful for better understanding of evaluation of the universe.

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