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Constant ratio of cosmological constant and energy density in FRW bulk viscous cosmological models

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Abstract.*We have investigated Constant Ratio of Cosmological Constant and Energy Density in FRW Bulk Viscous Cosmological Models in general relativity. The deceleration parameter is assumed to be constant. This should aid resolution of several difficult problems of astronomy such as the best value for the Hubble parameter, energy density isotropic pressure and cosmological constant at present and at recombination. A detailed study of physical and kinematical behavior of the model is also discussed. The model is found to be compatible with the results of recent cosmological observations.*
Key words.*FRW Model, Deceleration Parameter, Bulk Viscosity, Hubble parameter.*

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I. INTRODUCTION:

The results coming from the analysis of type-Ia supernovae surveys, large scale structure and cosmic microwave background anisotropy spectrum strongly indicate that our Universe is spatially flat and has a phase transition from decelerating to accelerating [1-4]. The proposals that have been put forward to explain this observed phenomenon can basically be classified into two categories. One is to assume that in the framework of Einstein's general relativity, an exotic component with negative pressure called mysterious energy or dark energy is necessary to explain this observed phenomenon, for a good review of the dynamics of different dark energy models[5-8].

Ruban and Finkelstein [9], Barker [10], Banerjee and Santos [11, 12] and Santhi& Rao [13, 14] have investigated several aspects of Nordtvedt general scalar-tensor theory. Rao and Kumari [15] studied a cosmological model with negative constant deceleration parameter in this theory. Rao *et al*. [16] have investigated Kaluza-Klein radiating model in a general scalar-tensor theory of gravitation. Rao et al. [17] have obtained Kantowski-Sachs string cosmological model with bulk viscosity in general scalar-tensor theory of gravitation. Rao and Neelima [18] have discussed Bianchi type-V I0 space time with strange quark matter attached to string cloud in general scalar-tensor theory. Recently, Rao *et al*. [19] have studied Kantowski-Sachs dark energy cosmological model in general scalar-tensor theory of gravitation.

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

II. 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

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

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

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

satisfying equation of state.

In the above equation p is the isotropic pressure and ν^i is the four-velocity vector satisfying $\nu^i \nu_i = -1$. The Einstein field equations (in gravitational units 8 π G = c = 1) and varying cosmological constant Λ (t), in comoving system of coordinates to

$$\bar{p} - \Lambda = (2q - 1)H^2\,, \qquad \text{... (4)}$$

$$\rho + \Lambda = 3H^2 \quad \text{... (5)}$$

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

$$H = \frac{\dot{S}}{S} \quad \text{... (6)}$$

$$q = -1 - \frac{\dot{H}}{H^2} = -\frac{S\ddot{S}}{\dot{S}^2} \quad \text{... (7)}$$

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

$$\dot{\rho} + 3(\rho + \bar{p})H + \dot{\Lambda} = 0 \quad \text{... (8)}$$

III. SOLUTION AND DISCUSSION:

The equations (4) and (5) are two equation in five unknown parameter S, ρ, Λ, p and ξ. Thus, three more equation connecting these variables are needed to solve these equations.
First, we choose

$$q = -1 - \frac{\dot{H}}{H^2} = -\frac{S\ddot{S}}{\dot{S}^2} = n \ \text{(constant)} \quad \text{... (9)}$$

After calculation, we get

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

$$= (S_0 T)^{\frac{1}{1+n}} \quad \text{... (10)}$$

So and to being constant of integration and set T = t_0 + t.
Secondly, we assume

$$\xi = \xi_0\theta, \quad \text{... (11)}$$

where $\xi_0 > 0$ is constant.
Next, we consider $\Lambda = \Lambda_0\rho$, ... (12)
where $\Lambda_0 > 0$ is constant.
Using equation (11) in equation (1), we get

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

Expansion scalar θ, matter density ρ, cosmological parameter Λ, the ratio Ω = Λ / ρ and isotropic pressure p for the model (13) are given by

$$\theta = \frac{3}{(1+n)T} \quad \text{... (14)}$$

$$(1+\Lambda_0)\rho = \frac{3}{(1+n)^2 T^2} \quad \text{... (15)}$$

$$\Lambda = \frac{3\Lambda_0}{(1+\Lambda_0)T^2(1+n)^2} \quad \text{... (16)}$$

$$\Omega = \Lambda_0 \quad \text{... (17)}$$

$$p = \frac{(2n-1)}{(n+1)^2 T^2} + \frac{9\xi_0}{(n+1)^2 T^2} + \frac{3\Lambda_0}{(1+\Lambda_0)(1+n)^2 T^2} \quad \text{... (18)}$$

We notice that the models with big-bang at T = 0. At T = 0, all physical parameter θ, ρ, Λ and p are infinite. For the large value of T, θ, ρ, Λ and p become zero. We observe that ρ / θ^2 and Ω are constant throughout the evaluation of the universe. Initially cosmological term Λ is very large and becomes zero at late times.

IV. CONCLUSION:

In this paper, we have considered FRW bulk viscous cosmological models with constant ratio of matter energy density and vacuum energy density and constant deceleration parameter . For n > 0, the model describes a decelerating universe throughout the evaluation of the universe. Let n = 0, we obtain $H = T^{-1}$ and q = 0, so that galaxy moves with constant speed. The exact solution of field equation described for better understanding of origin and evolution of the universe.

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