Bianchi Type V Cosmological Model with Wet Dark Fluid in Brans-Dicke Theory of Gravitation

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Abstract

In this article, we investigate the role of wet dark fluid (WDF) in Bianchi type V space – time in scalar – tensor theory of gravitation proposed by Brans – Dicke. In this theory, we solved the field equation for the case where. Various physical features of the models are also discussed.
Keywords: Wet Dark Fluid, Negative Constant Deceleration Parameter, Brans-Dicke Theory, Bianchi Type V Space Time

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I. INTRODUCTION

In recent years number of theories of gravitation has been proposed as alternatives for Einstein's theory. Although Einstein's theory of relativity is an excellent theory to explain the gravitational effects, it is unable to describe the present cosmic acceleration and reality of dark energy. Scalar-tensor theories of gravitation formulated by Jordan [1955], Brans and Dicke [1961], Nordtvedt [1970], Ross [1972], Saez-Ballester [1985] are most important. Brans-Dicke theory of gravitation is well known competitor of Einstein's theory of general relativity. In Brans-Dicke gravitational constant (G) is not presumed to be constant but its inverse is replace by scalar field which has the physical effects of changing the effective gravitational constant from place *to* place and with time. It admits more solutions such as exact solution, null dust solution in an important class of space-time. Brans-Dicke theory is a special case of scalar- tensor theories, is one of most viable theories. The gravitational coupling constant, being the inverse of space time scalar field is one of feature of this theory.

Brans-Dicke theory introduced a scalar tensor theory of gravitation involving a scalar function in addition to the familiar general relativistic metric tensor. In this theory the scalar field has the dimension of inverse of gravitational constant and its role is confined to its effects on gravitational field equations.

Brans – Dicke (1961) field equations for combined scalar and tensor fields are

$$G_{ij} = -8\pi\phi^{-1}T_{ij} - \omega\phi^{-2}(\phi_{,i}\,\phi_{,j} - \frac{1}{2}g_{ij}\phi_{,k}\,\phi^{,k}) - \phi^{-1}(\phi_{i;j} - g_{ij}\phi_{;k}^{,k}) \quad (1.1)$$

and

$$\phi_{;k}^{,k} = 8\pi(3+2\omega)^{-1}T \quad (1.2)$$

Where

$G_{ij} = R_{ij} - \frac{1}{2}Rg_{ij}$ is the Einstein tensor, T_{ij} is the stress energy tensor of matter and ω is the dimension less coupling constant, comma and semicolon denotes partial and co-variant differentiation respectively.

The equation of motion

$$T^{ij}_{;j} = 0 \quad (1.3)$$

are consequence of the field equations (1.1) and (1.2).

Singh and Chaubey [1988] investigated the Bianchi type-1 universe filled with dark energy from a wet dark fluid. The cosmological models with deceleration parameter have been studied by Maharaj and Naidu [1993]. Bianchi type I cosmological model with deceleration parameter in scalar tensor theories proposed by Brans-Dicke have been studied by Reddy and Venkateswara [2001]. By Using a special law of variations of Hubble's parameter, some cosmological model in Lyra geometry has been studied by Rehman et al;. [2004]. Holman and Naidu [2005] investigated that their model is consistent with the most recent SNIa data, the WMAP results as well as the constraints coming from measurements of the power spectrum. A Cosmological Model with Negative Constant Deceleration Parameter in A Scalar-Tensor Theory has been investigated by Reddy, D.R.K. and Rao, M.V.S. [2006]. Chaubey [2009] studied the Bianchi type-V universe filled with dark energy from a wet dark fluid in general relativity. Bianchi type-III cosmological models with dark energy in the form of Wet Dark energy in the presence and absence of magnetic field have been investigated by Adhav et al.[2011]. The behavior of plane symmetric metric with wet dark fluid in general relativity has been studied by Katore et al. [2012]. Axially symmetric non-static wet dark fluid in Brans-Dicke theory of gravitation has been investigated by Nimkar [2012]. Chirde and Kadam [2013] studied Six dimensional Bianchi Type-I universe with wet dark fluid in general relativity. Chirde and Rahate [2013] investigated Bianchi Type I universe with wet dark fluid in scalar tensor theory of gravitation. Exact Kantowski-Sachs anisotropic dark energy cosmological models in Brans-Dicke theory of gravitation with constant deceleration parameter have been investigated by Pawar and Solanke [2014]. Recently, Bhoyar, Chirde and shekh [2014] studied Non-static plane symmetrical cosmological model with magnetized anisotropic dark energy by hybrid expansion law in $f(R,T)$ gravity. Very recently Sahoo et. al. (2014) investigated Bianchi type VI_{h}, II and III cosmological model with WDF in scale invariant theory of gravity and Tade et al. [2016] constructed Bianchi type III cosmological model in Bimetric theory of gravity.

In this work, we used that Wet Dark Fluid (WDF) as a model for the dark energy physically motivated equation of state proposed by Hayward [1965] and Tait [1988] is offered with properties relevant for the dark energy problem. This model is in the spirit of Chaplygin gas as model for dark energy investigated by Gorini et al. [2004]. The equation of state for WDF is very simple and given as

$$p_{WDF} = \gamma(\rho_{WDF} - \rho_*) \tag{1.4}$$

Where p_{WDF} and ρ_{WDF} represents pressure and energy density of Wet Dark Fluid.

It is motivated by the fact that it is a good approximation for many fluids, including water, in which internal attraction of the molecules makes negative pressure possible.

The parameters γ and ρ_* are taken to be positive and we restrict ourselves to values : $0 \le \gamma \le 1$ .If C_s denote adiabatic sound speed in WDF, then $\gamma = C_s^{\ 2}$ by Babichev et al.[2004]

To find the WDF energy density, we use the energy conservation equation together with the equation (1.4)

$$\rho_{WDF} = \frac{\gamma}{1+\gamma}\rho_* + \frac{C}{V^{(1+\gamma)}} \tag{1.5}$$

Where, C is the constant of integration and V is the volume expansion.

A piece that behaves as a cosmological constant as well as a piece whose red shift as a standard fluid with an equation of state , $p = \gamma\rho$, these two components are naturally included in WDF .We can show that if we take C >0, this fluid will not violate the strong energy condition $p + \rho \ge 0$.

$$p_{WDF} + \rho_{WDF} = (1+\gamma)\rho_{WDF} - \gamma\rho^* = (1+\gamma)\frac{C}{V^{(1+\gamma)}} \ge 0 \tag{1.6}$$

In this paper, we have studied Bianchi type-V cosmological model with negative constant deceleration parameter in the scalar tensor theory of gravitation proposed by Brans – Dicke in presence of wet dark fluid. Some physical and kinematical properties of the model are also discussed.

II. FIELD EQUATION AND SOLUTIONS

The Bianchi type V space – time is considered in the form

$$ds^2 = dt^2 - A^2dx^2 - B^2e^{-2x}dy^2 - C^2e^{-2x}dz^2 \tag{2.1}$$

Where a is non-zero constant and A, B, C are the functions of t only.

The field equations for the metric (2.1) are written in the form

$$\frac{B_{44}}{B} + \frac{C_{44}}{C} + \frac{B_4}{B}\frac{C_4}{C} - \frac{1}{A^2} + \frac{\omega}{2}(\frac{\phi_4}{\phi})^2 + \frac{\phi_4}{\phi}\left(\frac{B_4}{B} + \frac{C_4}{C}\right) + \frac{\phi_{44}}{\phi} = 8\pi\phi^{-1}T_1^1 \tag{2.2}$$

$$\frac{A_{44}}{A} + \frac{C_{44}}{C} + \frac{A_4}{A}\frac{C_4}{C} - \frac{1}{A^2} + \frac{\omega}{2}(\frac{\phi_4}{\phi})^2 + \frac{\phi_4}{\phi}\left(\frac{A_4}{A} + \frac{C_4}{C}\right) + \frac{\phi_{44}}{\phi} = 8\pi\phi^{-1}T_2^2 \tag{2.3}$$

$$\frac{A_{44}}{A} + \frac{B_{44}}{B} + \frac{A_4}{A}\frac{B_4}{B} - \frac{1}{A^2} + \frac{\omega}{2}(\frac{\phi_4}{\phi})^2 + \frac{\phi_4}{\phi}\left(\frac{A_4}{A} + \frac{B_4}{B}\right) + \frac{\phi_{44}}{\phi} = 8\pi\phi^{-1}T_3^3 \tag{2.4}$$

$$\frac{A_4}{A}\frac{B_4}{B} + \frac{A_4}{A}\frac{C_4}{C} + \frac{B_4}{B}\frac{C_4}{C} - \frac{3}{A^2} - \frac{\omega}{2}(\frac{\phi_4}{\phi})^2 + \frac{\phi_4}{\phi}\left(\frac{A_4}{A} + \frac{B_4}{B} + \frac{C_4}{C}\right) = 8\pi\phi^{-1}T_4^4 \tag{2.5}$$

$$\frac{2A_4}{A} = \frac{B_4}{B} + \frac{C_4}{C} \tag{2.6}$$

$$\phi_{44} + \phi_4\left(\frac{A_4}{A} + \frac{B_4}{B} + \frac{C_4}{C}\right) = \frac{8\pi T}{(3+2\omega)} \tag{2.7}$$

The equation of motion (1.3) takes form

$$(\rho_{WDF})_4 + (\rho_{WDF} + P_{WDF})\left(\frac{A_4}{A} + \frac{B_4}{B} + \frac{C_4}{C}\right) = 0 \tag{2.8}$$

Where suffix 4 after unknowns and function denote partial differentiation with respect to t.

The stress energy-momentum tensor of source is given by

$$T_i^j = (\rho_{WDF} + P_{WDF})u_iu^j - p_{WDF}\delta_i^j \tag{2.9}$$

Where, u^i is the flow vector, together with

$$g_{ij}u^i u^j = 1 \quad (2.10)$$

Here, ρ_{WDF} is the total energy density of a perfect fluid and/or dark energy, while p is the corresponding pressure, and ρ_{WDF} and p_{WDF} are related by an equation of state.

From Eqn. (2.1), (2.9) and (2.10), the components of $T_i^{\ j}$, using a co - moving coordinates system, can be obtained as,

$$T_1^1 = T_2^2 = T_3^3 = -p_{WDF}, \quad T_4^4 = \rho_{WDF} \text{ and } T_1^4 = 0 \quad (2.11)$$

Now using the eqn. (2.2)-(2.8) and eqns. (2.11), we have

$$\frac{B_{44}}{B} + \frac{C_{44}}{C} + \frac{B_4}{B}\frac{C_4}{C} - \frac{1}{A^2} + \frac{\omega}{2}\left(\frac{\phi_4}{\phi}\right)^2 + \frac{\phi_4}{\phi}\left(\frac{B_4}{B} + \frac{C_4}{C}\right) + \frac{\phi_{44}}{\phi} = -8\pi\phi^{-1}p_{WDF} \quad (2.12)$$

$$\frac{A_{44}}{A} + \frac{C_{44}}{C} + \frac{A_4}{A}\frac{C_4}{C} - \frac{1}{A^2} + \frac{\omega}{2}\left(\frac{\phi_4}{\phi}\right)^2 + \frac{\phi_4}{\phi}\left(\frac{A_4}{A} + \frac{C_4}{C}\right) + \frac{\phi_{44}}{\phi} = -8\pi\phi^{-1}p_{WDF} \quad (2.13)$$

$$\frac{A_{44}}{A} + \frac{B_{44}}{B} + \frac{A_4}{A}\frac{B_4}{B} - \frac{1}{A^2} + \frac{\omega}{2}\left(\frac{\phi_4}{\phi}\right)^2 + \frac{\phi_4}{\phi}\left(\frac{A_4}{A} + \frac{B_4}{B}\right) + \frac{\phi_{44}}{\phi} = -8\pi\phi^{-1}p_{WDF} \quad (2.14)$$

$$\frac{A_4}{A}\frac{B_4}{B} + \frac{A_4}{A}\frac{C_4}{C} + \frac{B_4}{B}\frac{C_4}{C} - \frac{3}{A^2} - \frac{\omega}{2}\left(\frac{\phi_4}{\phi}\right)^2 + \frac{\phi_4}{\phi}\left(\frac{A_4}{A} + \frac{B_4}{B} + \frac{C_4}{C}\right) = 8\pi\phi^{-1}\rho_{WDF} \quad (2.15)$$

$$\frac{2A_4}{A} = \frac{B_4}{B} + \frac{C_4}{C} \quad (2.16)$$

$$\phi_{44} + \phi_4\left(\frac{A_4}{A} + \frac{B_4}{B} + \frac{C_4}{C}\right) = \frac{8\pi(\rho_{WDF} - 3P_{WDF})}{(3+2\omega)} \quad (2.17)$$

$$(\rho_{WDF})_4 + (\rho_{WDF} + P_{WDF})\left(\frac{A_4}{A} + \frac{B_4}{B} + \frac{C_4}{C}\right) = 0 \quad (2.18)$$

From equation (2.16), we get

$$A^2 = BC \quad (2.19)$$

Using equation (2.19), the set of equations (2.12) to (2.18) takes the form

$$\frac{B_{44}}{B} + \frac{C_{44}}{C} + \frac{B_4}{B}\frac{C_4}{C} - \frac{1}{BC} + \frac{\omega}{2}\left(\frac{\phi_4}{\phi}\right)^2 + \frac{\phi_4}{\phi}\left(\frac{B_4}{B} + \frac{C_4}{C}\right) + \frac{\phi_{44}}{\phi} = -8\pi\phi^{-1}p_{WDF} \quad (2.20)$$

$$\frac{B_{44}}{2B} + \frac{3C_{44}}{2C} + \frac{B_4}{B}\frac{C_4}{C} - \frac{1}{4}\left(\frac{B_4}{B}\right)^2 + \frac{1}{4}\left(\frac{C_4}{C}\right)^2 - \frac{1}{BC} + \frac{\omega}{2}\left(\frac{\phi_4}{\phi}\right)^2 + \frac{\phi_4}{2\phi}\left(\frac{B_4}{B} + \frac{3C_4}{C}\right) + \frac{\phi_{44}}{\phi} = -8\pi\phi^{-1}p_{WDF} \quad (2.21)$$

$$\frac{3B_{44}}{2B} + \frac{C_{44}}{2C} + \frac{B_4}{B}\frac{C_4}{C} + \frac{1}{4}\left(\frac{B_4}{B}\right)^2 - \frac{1}{4}\left(\frac{C_4}{C}\right)^2 - \frac{1}{BC} + \frac{\omega}{2}\left(\frac{\phi_4}{\phi}\right)^2 + \frac{\phi_4}{2\phi}\left(\frac{3B_4}{B} + \frac{C_4}{C}\right) + \frac{\phi_{44}}{\phi} = -8\pi\phi^{-1}p_{WDF} \quad (2.22)$$

$$\frac{1}{2}\left(\frac{B_4}{B}\right)^2 + \frac{1}{2}\left(\frac{C_4}{C}\right)^2 + \frac{2B_4}{B}\frac{C_4}{C} - \frac{3}{BC} - \frac{\omega}{2}\left(\frac{\phi_4}{\phi}\right)^2 + \frac{3\phi_4}{2\phi}\left(\frac{B_4}{B} + \frac{C_4}{C}\right) = 8\pi\phi^{-1}\rho_{WDF} \quad (2.23)$$

$$\phi_{44} + \frac{3}{2}\phi_4\left(\frac{B_4}{B} + \frac{C_4}{C}\right) = \frac{8\pi(\rho_{WDF} - 3P_{WDF})}{(3+2\omega)} \quad (2.24)$$

$$(\rho_{WDF})_4 + \frac{3}{2}(\rho_{WDF} + P_{WDF})\left(\frac{B_4}{B} + \frac{C_4}{C}\right) = 0 \quad (2.25)$$

We consider the equation of state in following form,

$$\rho_{WDF} = 3p_{WDF} \quad (2.26)$$

Which represents matter distribution with disordered radiation which is analogous to $\rho = 3p$ in general relativity

With the help of equation (2.26), the set of equations (2.20) to (2.25) reduces to

$$\frac{B_{44}}{B} + \frac{C_{44}}{C} + \frac{B_4}{B}\frac{C_4}{C} - \frac{1}{BC} + \frac{\omega}{2}\left(\frac{\phi_4}{\phi}\right)^2 + \frac{\phi_4}{\phi}\left(\frac{B_4}{B} + \frac{C_4}{C}\right) + \frac{\phi_{44}}{\phi} = -8\pi\phi^{-1}p_{WDF} \quad (2.27)$$

$$\frac{B_{44}}{2B} + \frac{3C_{44}}{2C} + \frac{B_4}{B}\frac{C_4}{C} - \frac{1}{4}\left(\frac{B_4}{B}\right)^2 + \frac{1}{4}\left(\frac{C_4}{C}\right)^2 - \frac{1}{BC} + \frac{\omega}{2}\left(\frac{\phi_4}{\phi}\right)^2 + \frac{\phi_4}{2\phi}\left(\frac{B_4}{B} + \frac{3C_4}{2C}\right) + \frac{\phi_{44}}{\phi} = -8\pi\phi^{-1}p_{WDF} \quad (2.28)$$

$$\frac{3B_{44}}{2B} + \frac{C_{44}}{2C} + \frac{B_4}{B}\frac{C_4}{C} + \frac{1}{4}\left(\frac{B_4}{B}\right)^2 - \frac{1}{4}\left(\frac{C_4}{C}\right)^2 - \frac{1}{BC} + \frac{\omega}{2}\left(\frac{\phi_4}{\phi}\right)^2 + \frac{\phi_4}{2\phi}\left(\frac{3B_4}{2B} + \frac{C_4}{C}\right) + \frac{\phi_{44}}{\phi} = -8\pi\phi^{-1}p_{WDF} \quad (2.29)$$

$$\frac{1}{2}\left(\frac{B_4}{B}\right)^2 + \frac{1}{2}\left(\frac{C_4}{C}\right)^2 + \frac{2B_4}{B}\frac{C_4}{C} - \frac{3}{BC} - \frac{\omega}{2}\left(\frac{\phi_4}{\phi}\right)^2 + \frac{3\phi_4}{2\phi}\left(\frac{B_4}{B} + \frac{C_4}{C}\right) = 8\pi\phi^{-1}\rho_{WDF} \quad (2.30)$$

$$\phi_{44}+\frac{3}{2}\phi_4\left(\frac{B_4}{B}+\frac{C_4}{C}\right)=0 \qquad (2.31)$$

$$(\rho_{WDF})_4+2\rho_{WDF}\left(\frac{B_4}{B}+\frac{C_4}{C}\right)=0 \qquad (2.32)$$

On adding equations (2.28) and (2.29), we get

$$\frac{B_{44}}{B}+\frac{C_{44}}{C}+\frac{B_4}{B}\frac{C_4}{C}-\frac{1}{BC}+\frac{\omega}{2}\left(\frac{\phi_4}{\phi}\right)^2+\frac{\phi_4}{\phi}\left(\frac{B_4}{B}+\frac{C_4}{C}\right)+\frac{\phi_{44}}{\phi}=-8\pi\phi^{-1}p_{WDF}$$

Therefore above set of equations (2.27) – (2.32) reduces to

$$\frac{B_{44}}{B}+\frac{C_{44}}{C}+\frac{B_4}{B}\frac{C_4}{C}-\frac{1}{BC}+\frac{\omega}{2}\left(\frac{\phi_4}{\phi}\right)^2+\frac{\phi_4}{\phi}\left(\frac{B_4}{B}+\frac{C_4}{C}\right)+\frac{\phi_{44}}{\phi}=-8\pi\phi^{-1}p_{WDF} \qquad (2.33)$$

$$\frac{1}{2}\left(\frac{B_4}{B}\right)^2+\frac{1}{2}\left(\frac{C_4}{C}\right)^2+\frac{2B_4}{B}\frac{C_4}{C}-\frac{3}{BC}-\frac{\omega}{2}\left(\frac{\phi_4}{\phi}\right)^2+\frac{3\phi_4}{2\phi}\left(\frac{B_4}{B}+\frac{C_4}{C}\right)=8\pi\phi^{-1}\rho_{WDF} \qquad (2.34)$$

$$\phi_{44}+\frac{3}{2}\phi_4\left(\frac{B_4}{B}+\frac{C_4}{C}\right)=0 \qquad (2.35)$$

$$(\rho_{WDF})_4+2\rho_{WDF}\left(\frac{B_4}{B}+\frac{C_4}{C}\right)=0 \qquad (2.36)$$

Hence we have obtained field equations with five unknown $B, C, \rho_{WDF}, P_{WDF}$ and ϕ. To get a exact solution one extra condition is required, we consider the physical condition that the Shear scalar is σ proportional to Scalar expansion θ, which leads to the relationship between the metric potentials *B* and *C.*
i.e.

$$B=C^n \qquad (2.37)$$

Where n is an arbitrary constant.

We solve the set of above non-linear equations with the help of special law of variation of Hubble's parameter, proposed by Bermann (1983) that yields constant deceleration parameter model of the universe.

We consider only constant deceleration parameter model defined by

$$q=-\left[\frac{RR_{44}}{(R_4)^2}\right]=cons\tan t \qquad (2.38)$$

Where $R=\left(A^3e^{-2x}\right)^{\frac{1}{3}}$ is the overall scale factor. The solution of equation (2.38) is given by

$$R=(\alpha t+\beta)^{\frac{1}{1+q}} \qquad (2.39)$$

Where $\alpha\neq 0$ and β are constants of integration. This equation implies that condition of expansion is $1+q>0$.
After solving above equations, exact solutions are given by

$$A=e^{\frac{2x}{3}}(\alpha t+\beta)^{\frac{1}{1+q}} \qquad (2.40)$$

$$B=e^{\frac{4xn}{3(n+1)}}(\alpha t+\beta)^{\frac{2n}{(1+q)(1+n)}} \qquad (2.41)$$

$$C=e^{\frac{4x}{3(n+1)}}(\alpha t+\beta)^{\frac{2}{(1+q)(1+n)}} \qquad (2.42)$$

Using equations (2.40), (2.41), & (2.42), the line element (2.1) becomes

$$ds^2=dt^2-e^{\frac{4x}{3}}(\alpha t+\beta)^{\frac{2}{1+q}}dx^2-e^{\frac{2x(n-3)}{3(n+1)}}(\alpha t+\beta)^{\frac{4n}{(1+q)(1+n)}}dy^2-e^{\frac{2x(1-3n)}{3(n+1)}}(\alpha t+\beta)^{\frac{4}{(1+q)(1+n)}}dz^2 \qquad (2.43)$$

Through a proper choice of coordinates and constants of integration, the equation (2.43) reduces to

$$ds^2=\frac{dT^2}{\alpha^2}-e^{\frac{4x}{3}}T^{\frac{2}{1+q}}dX^2-e^{\frac{2x(n-3)}{3(n+1)}}T^{\frac{4n}{(1+q)(1+n)}}dY^2-e^{\frac{2x(1-3n)}{3(n+1)}}T^{\frac{4}{(1+q)(1+n)}}dZ^2 \qquad (2.44)$$

III. SOME PHYSICAL PROPERTIES

In the frame – work of Brans – Dicke scalar – tensor theory of gravitation, the model given by (2.44) represent an exact radiating cosmological model with a negative constant deceleration parameter (i.e. it is an accelerating universe).

The volume element of model (2.44) is given by

$$V=\sqrt{-g}=T^{\frac{3}{1+q}} \qquad (3.1)$$

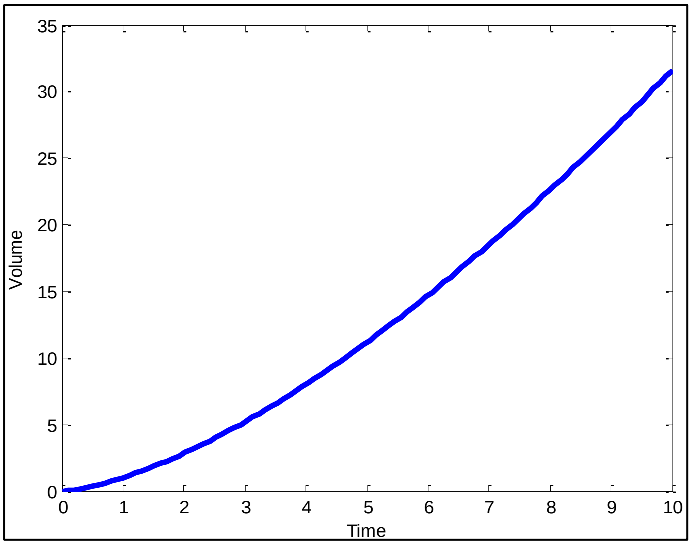

Fig. 1: Volume element of model

Here we have observed that at the initial point $T = 0$, the proper volume becomes zero and it becomes infinitely large.
The average Hubble parameter H, scalar expansion θ and shear scalar σ are defined as

$$H = \frac{R_4}{R} \quad (3.2)$$

$$\theta = u^i_{;j} \quad (3.3)$$

$$\sigma^2 = \frac{1}{2}\left(\sum_{i=1}^{3} H_i^2 - 3H^2\right) \quad (3.4)$$

The scalar expansion θ, shear scalar σ and average Hubble parameter H are given by

$$H = \frac{\alpha}{(1+q)T} \quad (3.5)$$

$$\sigma^2 = \frac{(n-1)^2\alpha^2}{(n+1)^2(1+q)^2T^2} \quad (3.6)$$

$$\theta = \frac{3\alpha}{(1+q)T} \quad (3.7)$$

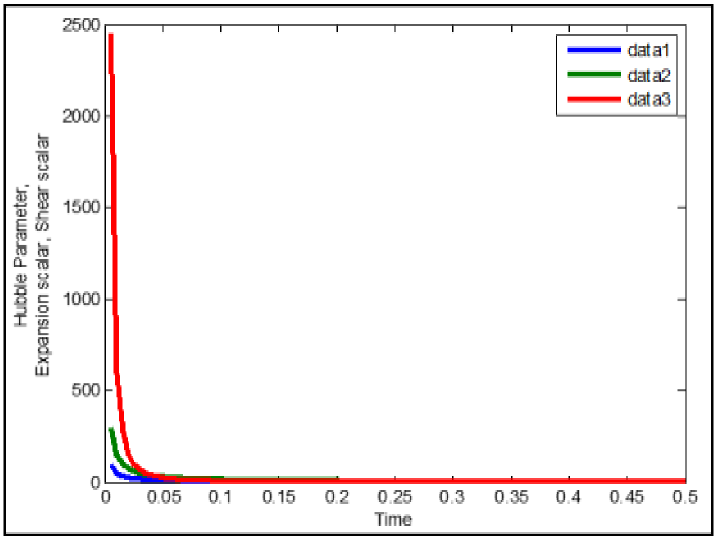

Fig. 2: Hubble parameter

- data 1: Hubble parameter vs time
- data 2: Shear scalar vs time and
- data 3: Scalar expansion vs time

Here, we have observed that Hubble parameter, Scalar expansion diverges initially and Hubble parameter, Scalar expansion tends to zero, for large value of T $(T \to \infty)$. Also we have observed that Shear scalar diverges initially and tends to zero, for large value of T $(T \to \infty)$ except $(n = 1)$. For $(n = 1)$ Shear scalar becomes zero.

The average anisotropy parameter A_m is given by

$$A_h = \frac{2}{3}\left\{\frac{(n-1)^2}{(n+1)^2}\right\} \neq 0, \quad \text{for } n \neq 1, \tag{3.8}$$

The model does not approach isotropy for large value of T, except $(n = 1)$ & model approaches to isotropy for $(n = 1)$.

The overall density parameter Ω_{wdf} is given by

$$\Omega_{wdf} = \frac{K_1(1+q)^2 e^{-\frac{2}{3}x} T^{\frac{1+2q}{1+q}}}{3\alpha^2} \tag{3.9}$$

Also, the expansion Brans – Dicke scalar field ϕ, density and pressure are as follows

$$\phi = K_1 e^{-2x}\left(\frac{1+q}{q-2}\right) T^{\frac{q-2}{q+1}} + \phi_0 \tag{3.10}$$

$$\rho_{WDF} = K_2 e^{-\frac{2}{3}x} T^{\frac{-1}{1+q}} \tag{3.11}$$

$$p_{WDF} = \frac{K_2}{3} e^{-\frac{2}{3}x} T^{\frac{-1}{1+q}} \tag{3.12}$$

From equations (3.6) to (3.8), we can observe that the physical quantities ρ and p diverge at the initial point T = 0, while the Brans-Dicke scalar field ϕ has no initial singularity. Also we can observe that density and pressure tends to zero when $T \to \infty$.

IV. CONCLUSION

Using special law of variation for Hubble's parameter proposed by Bermann (1983), we have obtained the solution of Bianchi type V cosmological model in Brans – Dicke scalar – tensor theory of gravitation in the presence of wet dark fluid. The cosmological model obtained in this case shows a radiating universe in Brans-Dicke theory of gravitation. Physical properties of the model are also discussed.

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