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Bianchi Type V Universe With Wet Dark Fluid In Scalar-Tensor Theory of Gravitation

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Abstract

Using Bianchi type V space-time, field equations in presence of wet dark fluid in Saez-ballaster theory are obtained. A new equation of state for the dark energy component of the universe has been used, which is modeled on the equation of state $p = \gamma(\rho - \rho_*)$ that can describe a liquid such as water. The exact solutions are obtained. The solutions for constant deceleration parameter have been investigated in detail for both power – law and exponential forms, also $\gamma = \frac{1}{3}$ (Disordered radiation) case has been discussed. The physical and geometrical features of the model are also studied.

INTRODUCTION

Recent observational data suggest that the universe is dominated by two dark components containing dark matter and dark energy. Major development in cosmology is that our universe is making a transition from a decelerating phase to an accelerating. This was confirmed by anisotropies in the cosmic microwave background radiation as seen in the data from satellite and large scale structure. Astrophysical observations indicate that accelerated expansion of universe is driven by exotic energy with large negative pressure which is known as dark energy. Dark matter is used to explain galactic curves and large scale structure formation. Origin of dark energy dark matter and their natures are challenging problems in modern cosmology.

The nature of the dark energy component of the universe (Riess A. G.,et al. [1], perimutter, S. et al [2], Sahani, V [3]) remains one of the deepest mysteries of cosmology. There is certainly (Ratra, B. et al. [4], Caldwell, R ,R. et al [5], Barrieiro. T., et al [6]), k-essence (Armendartz-Picon. C., et al [7]), Armendartz-Picon. C., et al [8], Gonzalez [9]), phantom energy (Caldwell, R ,R. [10], Carroll S.M. et al [11], Elizalde, E., et al [12]). Modifications of the Friedmann Equation (Freese, K. et al [13]., Freese, K. [14], Gondolo, P. et al [15]) as well as what might be derived from brane cosmology (Deffayet,C., et al [16], Dvali, G., et al [17], Dvali, G., et al [18]) have also been used to explain the acceleration of the universe. Also there are interacting DE models like Chaplygin gas (Kamenshchik et al. [19], Bento et al [20]), holographic models (Cohen, A., et al [21], Horava, P., et al [22], Thomas, S.et al [23]) etc. have been proposed but none of these models are entirely convicing so far. A particular case of linear equation of state has used in the cosmological context by X-anthopuolos [24] orthogonal space-times with two hypersurface orthogonal, space-like, commutting killing fields.

Recently there has been an immense interest in scalar – tensor theories of gravitation proposed by Brans and Dicke (1961 [25]), Nordvedt (1970 [26]), and saez and ballester (1986 [27]). Among them Brans-Dicke and Saez-Ballester scalar-tensor theories are considered to be viable alternatives to general relativity. Brans-Dicke theory includes a long range scalar field interacting equally with all forms of matter (with the exception of electromagnetism) while in Saez-Ballester scalar – tensor theory metric is coupled with a dimensionless scalar field in a simple manner. A brief review of Saez-Ballester theory is given by Reddy et al. (2006 [28]). The field equations of Saez-Ballester scalar tensor theory for the combined scalar and tensor fields are

$$G_{ij} - \omega\phi^n\left(\phi_{,i}\phi_{,j} - \frac{1}{2}g_{ij}\phi_{,k}\phi^{,k}\right) = -kT_{ij} \tag{1}$$

and the scalar field ϕ satisfies the equation

$$2\phi^n\phi^i_{;i} + n\phi^{n-1}\phi_{,k}\phi^{,k} = 0 \tag{2}$$

Where $G_{ij} = R_{ij} - \frac{1}{2}g_{ij}R$ is the Einstein tensor, R the scalar curvature, ω and n are constants, T_{ij} is the stress tensor of matter and comma and semicolon denote partial and covariant differentiation respectively.

In this work, we used that Wet Dark Fluid (WDF) as a model for the dark energy physically motivated equation of state is offered with properties relevant for the dark energy problem. Here the motivation stems from an empirical equation of state proposed by Tait [29] and Hayword [30] to treat water and aqueous solution. The equation of state for WDF is very simple and given as

$$p_{WDF} = \gamma(\rho_{WDF} - \rho_*) \tag{3}$$

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 : $0 \le \gamma \le 1$.

To find the WDF energy density, we use the energy conservation equation

$$\dot{\rho}_{WDF} + 3H(P_{WDF} + \rho_{WDF}) = 0 \tag{4}$$

Using the equation of state for WDF, Eqn. (3), and relation $3H = \frac{\dot{V}}{V}$ in the above Eqn. (4),

we get

$$\rho_{WDF} = \frac{\gamma}{1+\gamma}\rho_* + \frac{C}{V^{(1+\gamma)}} \tag{5}$$

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

WDF includes two components, 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, $p = \gamma\rho$.

We can easily show that if C >0, this fluid will not violate the strong energy condition, $p + \rho \ge 0$. Thus we get

$$p_{WDF} + \rho_{WDF} = (1+\gamma)\rho_{WDF} - \gamma\rho_* = (1+\gamma)\frac{C}{V^{(1+\gamma)}} \ge 0 \tag{6}$$

Different cosmological models in the framework of scalar-tensor theories have investigated by many authors. Several aspects of the cosmological models in Saez-Ballaster scalar-tensor theory have discussed by Reddy, D.R.K.et. al. [31], Rao, V.U.M. et. al.[32, 33, 34]. Recently Chirde et al. [35] and Katore S.D. et. al. [37] studied dark energy in cosmological model in this Scalar - tensor theory.The wet dark fluid has been used as dark energy in the homogeneous isotropic FRW model by Holman and Naidu [37]. Singh and Chaubey [38], studied the Bianchi type-1 universe filled with dark energy from a wet dark fluid in general relativity. The Bianchi type-V universe filled with dark energy from a wet dark fluid has been studied by Chaubey [39]**.** Adhav et al.[40] investigated Biancy type-III cosmological models with dark energy in the form of Wet Dark energy in the presence and absence of magnetic field. Katore et al. [41] studied the behavior of plane symmetric metric with wet dark fluid in general relativity. Very recently, Chirde et al. [42] studied Bianchi Type I universe with wet dark fluid in Scalar - tensor theory of gravitational.

In this paper, we have studied Bianchi type V universe with wet dark fluid in Scalar - tensor theory of gravitational. Some physical and kinematical properties of the model are also discussed.

2. The Metric and Field Equations

We Consider Bianchi type V space-time in the form

$$ds^2 = dt^2 - A^2dx^2 - B^2e^{-2x}dy^2 - C^2e^{-2x}dz^2 \tag{7}$$

Where A, B, C are the functions of cosmic time t only.

The Einstein field equations for the metric (7) are written in the form

$$\frac{\ddot{B}}{B}+\frac{\ddot{C}}{C}+\frac{\dot{B}}{B}\frac{\dot{C}}{C}-\frac{1}{A^2}-\frac{\omega}{2}\phi^n\dot{\phi}^2=kT_1^1 \tag{8}$$

$$\frac{\ddot{A}}{A}+\frac{\ddot{C}}{C}+\frac{\dot{A}}{A}\frac{\dot{C}}{C}-\frac{1}{A^2}-\frac{\omega}{2}\phi^n\dot{\phi}^2=kT_2^2 \tag{9}$$

$$\frac{\ddot{A}}{A}+\frac{\ddot{B}}{B}+\frac{\dot{A}}{A}\frac{\dot{B}}{B}-\frac{1}{A^2}-\frac{\omega}{2}\phi^n\dot{\phi}^2=kT_3^3 \tag{10}$$

$$\frac{\dot{A}}{A}\frac{\dot{B}}{B}+\frac{\dot{A}}{A}\frac{\dot{C}}{C}+\frac{\dot{B}}{B}\frac{\dot{C}}{C}-\frac{3}{A^2}+\frac{\omega}{2}\phi^n\dot{\phi}^2=kT_4^4 \tag{11}$$

$$2\frac{\dot{A}}{A}-\frac{\dot{B}}{B}-\frac{\dot{C}}{C}=kT_1^4 \tag{12}$$

$$\ddot{\phi}+\dot{\phi}\left(\frac{\dot{A}}{A}+\frac{\dot{B}}{B}+\frac{\dot{C}}{C}\right)+\frac{n}{2}\frac{\dot{\phi}^2}{\phi}=0 \tag{13}$$

Here k is the gravitational constant and dot (.) over letter denotes differentiation with respect to t.
The energy- momentum tensor of the source is given by

$$T_i^j=(\rho_{WDF}+P_{WDF})u_iu^j-p_{WDF}\delta_i^j \tag{14}$$

Where, u^i is the flow vector satisfying

$$g_{ij}u^iu^j=1 \tag{15}$$

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

In a co- moving system of coordinates, from Eqn. (4) we find

$$T_1^1=T_2^2=T_3^3=-p_{WDF},\quad T_4^4=\rho_{WDF}\ \text{ and }\ T_1^4=0 \tag{16}$$

Now using the eqn. (8)-(13) and eqns. (16), we have

$$\frac{\ddot{B}}{B}+\frac{\ddot{C}}{C}+\frac{\dot{B}}{B}\frac{\dot{C}}{C}-\frac{1}{A^2}-\frac{\omega}{2}\phi^n\dot{\phi}^2=-kp_{WDF} \tag{17}$$

$$\frac{\ddot{A}}{A}+\frac{\ddot{C}}{C}+\frac{\dot{A}}{A}\frac{\dot{C}}{C}-\frac{1}{A^2}-\frac{\omega}{2}\phi^n\dot{\phi}^2=-kp_{WDF} \tag{18}$$

$$\frac{\ddot{A}}{A}+\frac{\ddot{B}}{B}+\frac{\dot{A}}{A}\frac{\dot{B}}{B}-\frac{1}{A^2}-\frac{\omega}{2}\phi^n\dot{\phi}^2=-kp_{WDF} \tag{19}$$

$$\frac{\dot{A}}{A}\frac{\dot{B}}{B}+\frac{\dot{A}}{A}\frac{\dot{C}}{C}+\frac{\dot{B}}{B}\frac{\dot{C}}{C}-\frac{3}{A^2}+\frac{\omega}{2}\phi^n\dot{\phi}^2=K\rho_{WDF} \tag{20}$$

$$2\frac{\dot{A}}{A}-\frac{\dot{B}}{B}-\frac{\dot{C}}{C}=0 \tag{21}$$

$$\ddot{\phi}+\dot{\phi}\left(\frac{\dot{A}}{A}+\frac{\dot{B}}{B}+\frac{\dot{C}}{C}\right)+\frac{n}{2}\frac{\dot{\phi}^2}{\phi}=0 \tag{22}$$

Using Eqns.(17) and (18), we get

$$\frac{d}{dt}\left[\frac{\dot{A}}{A}-\frac{\dot{B}}{B}\right]+\left[\frac{\dot{A}}{A}-\frac{\dot{B}}{B}\right]\left[\frac{\dot{A}}{A}+\frac{\dot{B}}{B}+\frac{\dot{C}}{C}\right]=0 \tag{23}$$

Let V be the function of t defined by

$$V = ABC \tag{24}$$

From Eqns. (23) and (24), we get

$$\frac{d}{dt}\left[\frac{\dot{A}}{A}-\frac{\dot{B}}{B}\right]+\left[\frac{\dot{A}}{A}-\frac{\dot{B}}{B}\right]\frac{\dot{V}}{V}=0$$

Integrating above Eqn. We get

$$\frac{A}{B}=d_1\exp\left(x_1\int\frac{dt}{V}\right) \tag{25}$$

$$\frac{B}{C}=d_2\exp\left(x_2\int\frac{dt}{V}\right) \tag{26}$$

$$\frac{A}{C}=d_3\exp\left(x_3\int\frac{dt}{V}\right) \tag{27}$$

Where $d_1, d_2, d_3 and, x_1, x_2, x_3$ are integration constants.

From equation (21), we get

$$A^2 = BC \tag{28}$$

In the view of, $V = ABC$, we write A,B,C In the explicit form

$$A(t) = V^{\frac{1}{3}} \tag{29}$$

$$B(t) = DV^{\frac{1}{3}}\exp\left(X\int\frac{dt}{V}\right) \tag{30}$$

$$C(t) = D^{-1}V^{\frac{1}{3}}\exp\left(-X\int\frac{dt}{V}\right) \tag{31}$$

Where D and X are constants.

Using equations (17) - (20), we get

$$\left(\frac{\ddot{A}}{A}+\frac{\ddot{B}}{B}+\frac{\ddot{C}}{C}\right)+2\left[\frac{\dot{A}}{A}\frac{\dot{B}}{B}+\frac{\dot{A}}{A}\frac{\dot{C}}{C}+\frac{\dot{B}}{B}\frac{\dot{C}}{C}\right]-\frac{6}{A^2}=\frac{3k}{2}[\rho_{WDF}-p_{WDF}] \tag{32}$$

From the equation (24) , we have

$$\frac{\ddot{V}}{V}=\left(\frac{\ddot{A}}{A}+\frac{\ddot{B}}{B}+\frac{\ddot{C}}{C}\right)+2\left[\frac{\dot{A}}{A}\frac{\dot{B}}{B}+\frac{\dot{B}}{B}\frac{\dot{C}}{C}+\frac{\dot{A}}{A}\frac{\dot{C}}{C}\right] \tag{33}$$

Using equations (28), (32) and (33), we have

$$\frac{\ddot{V}}{V}-\frac{6}{V^{\frac{2}{3}}}=\frac{3k}{2}[\rho_{WDF}-p_{WDF}] \tag{34}$$

The law of conservation for energy- momentum tensor gives

$$\dot{\rho}_{WDF}=-\frac{\dot{V}}{V}(\rho_{WDF}+p_{WDF}) \tag{35}$$

From equations (33) and (34), we have

$$\dot{V}=\pm\sqrt{[C_1+3kV^2\rho_{WDF}+9V^{\frac{4}{3}}]} \tag{36}$$

Where C_1, is a constant of integration..

Rewriting (35) in the form

$$\frac{\dot{\rho}_{WDF}}{(\rho_{WDF}-p_{WDF})}=-\frac{\dot{V}}{V} \tag{37}$$

And taking into account that the pressure and the energy density obeying an equation of state of type $p_{WDF}=f(\rho_{WDF})$, we conclude that ρ_{WDF} and p_{WDF} are the function of V. Hence the right – hand side of equation (34) is function of V only.

$$\ddot{V}=\frac{3k}{2}(\rho_{WDF}-p_{WDF})V+6V^{\frac{1}{3}}=F(V) \tag{38}$$

From the mechanical point of view, equation (38) can be interpreted as equation of motion of a single particle with unit mass under the force $F(V)$. Then

$$\dot{V}=\sqrt{2[\in-U(V)]} \tag{39}$$

Here $\in$ can be viewed as energy and U (V) as the potential of the force F.

Comparing equations (38) and (39) we find $\in=\frac{C_1}{2}$ and

$$U(V)=-\left[\frac{3k}{2}V^2\rho_{WDF}+\frac{9}{2}V^{\frac{4}{3}}\right] \tag{40}$$

Finally, we write the solution to the equation (36) in quadrature form

$$\int\frac{dV}{\sqrt{2\left\{C_1+\frac{3k}{2}\rho_{WDF}V^2\right\}}}=t+t_0 \tag{41}$$

Where , the integration constant t_o can be taken to be zero, since it only gives a shift in time.

From equations (5) and (41) we obtained

$$\int\frac{dV}{\sqrt{\left\{\frac{3k\gamma\rho_*}{(1+\gamma)}V^2+3kCV^{(1-\gamma)}+9V^{\frac{4}{3}}+C_1\right\}}}=t \tag{42}$$

From equations (22), we yield

$$\phi=\left[\alpha\left(\frac{n+2}{2}\right)\int\frac{1}{V}dt\right]^{\frac{2}{n+2}} \tag{43}$$

3. Some particular Cases

Case I : $\gamma=\frac{1}{3}$ (Disordered radiation)

For C_1=0, Equation (42) reduces to

$$\int\frac{dV}{\sqrt{\frac{3k\rho_*V^2}{4}+3kCV^{\frac{2}{3}}+9V^{\frac{4}{3}}}}=t \tag{44}$$

Case I (a): when $\rho_*=\frac{1}{K^2C}$

$$V=\left[e^{\sqrt{\frac{k\rho_*}{3}}t}-\frac{6}{k\rho_*}\right]^{\frac{3}{2}} \tag{45}$$

Using equations (29),(30), (31) & (45), we get

$$A(t)=\left[e^{C_2 t}-C_3\right]^{\frac{1}{2}} \tag{46}$$

$$B(t)=D\left[e^{C_2 t}-6C_3\right]^{\frac{1}{2}}\exp\left\{\frac{2X}{C_2C_3}\left[\frac{1}{\sqrt{C_3}}\tan^{-1}\left(\sqrt{\frac{C_3}{e^{C_2 t}-C_3}}\right)-\frac{1}{\sqrt{e^{C_2 t}-C_3}}\right]\right\} \tag{47}$$

$$C(t)=D^{-1}\left[e^{C_2 t}-C_3\right]^{\frac{1}{2}}\exp\left\{\frac{-2X}{C_2C_3}\left[\frac{1}{\sqrt{C_3}}\tan^{-1}\left(\sqrt{\frac{C_3}{e^{C_2 t}-C_3}}\right)-\frac{1}{\sqrt{e^{C_2 t}-C_3}}\right]\right\} \tag{48}$$

Where $C_2=\sqrt{\frac{k\rho_*}{3}}$ and $C_3=\frac{6}{k\rho_*}$.

From equations (5) and (44), we get

$$\rho_{WDF}=\frac{\rho_*}{4}+\left[e^{C_2 t}-C_3\right]^{-2} \tag{49}$$

And from equations (3) and (49), we get

$$p_{WDF}=\frac{-\rho_*}{4}+\frac{C}{3}\left[e^{C_2 t}-C_3\right]^{-2} \tag{50}$$

Using equation (43),we get

$$\phi=\left\{\frac{(n+2)\alpha}{C_2C_3}\left[\frac{1}{\sqrt{C_3}}\tan^{-1}\left(\sqrt{\frac{C_3}{e^{C_2 t}-C_3}}\right)-\frac{1}{\sqrt{e^{C_2 t}-C_3}}\right]\right\}^{\frac{2}{n+2}} \tag{51}$$

The physical quantities of observational interest in cosmology are the expansion scalar θ ,the mean anisotropy parameter A, the shear scalar σ^2, and the deceleration parameter q. They are defined as

$$\theta=3H \tag{52}$$

$$A=\frac{1}{3}\sum_{1}^{4}\left(\frac{\Delta H_i}{H}\right)^2 \tag{53}$$

$$\sigma^2=\frac{1}{2}\left(\sum_{i=1}^{3}H_i^2-3H^2\right)=\frac{3}{2}AH^2 \tag{54}$$

$$q=\frac{d}{dt}\left(\frac{1}{H}\right)-1 \tag{55}$$

By using equations (52) - (55), we can express the physical quantities as

$$\theta=\frac{3}{2}\sqrt{\frac{k\rho_*}{3}}\frac{e^{\sqrt{\frac{k\rho_*}{3}}t}}{\left[e^{\sqrt{\frac{k\rho_*}{3}}t}-\frac{6}{k\rho_*}\right]} \tag{56}$$

$$A=\frac{8X^2}{k\rho_* e^{2\sqrt{\frac{k\rho_*}{3}}t}\left[e^{\sqrt{\frac{k\rho_*}{3}}t}-\frac{6}{k\rho_*}\right]} \tag{57}$$

$$\sigma^2 = \frac{X^2}{\left[e^{\sqrt{\frac{k\rho_*}{3}}t} - \frac{6}{k\rho_*}\right]^3} \tag{58}$$

$$q = -1 + \frac{12}{k\rho_*} e^{-\sqrt{\frac{k\rho_*}{3}}t} \tag{59}$$

Here the model has a future singularity in finite time.

Case I (b): when $\rho_* > \frac{1}{K^2 C}$

Equation (44) yields to

$$V = \left[\left(\frac{4C}{\rho_*} - \frac{36}{k^2\rho_*^2}\right)^{\frac{1}{2}} \sinh\left(\sqrt{\frac{k\rho_*}{3}}t\right) - \frac{6}{k\rho_*}\right]^{\frac{3}{2}} \tag{60}$$

Then for small value of t (i.e. near singularity t=0)

$$\sinh\left(\sqrt{\frac{k\rho_*}{3}}t\right) \approx \sqrt{\frac{k\rho_*}{3}}t \tag{61}$$

Therefore equation (60) reduces to

$$V = \left[\sqrt{\frac{k\rho_*}{3}}\left(\frac{4C}{\rho_*} - \frac{36}{k^2\rho_*^2}\right)^{\frac{1}{2}} t - \frac{6}{k\rho_*}\right]^{\frac{3}{2}} \tag{62}$$

Then from equations (29),(30),(31) and (62), we get

$$A(t) = (C_4 t - C_5)^{\frac{1}{2}} \tag{63}$$

$$B(t) = D(C_4 t - C_5)^{\frac{1}{2}} e^{\frac{3X}{C_4\sqrt{C_4 t - C_5}}} \tag{64}$$

$$C(t) = D^{-1}(C_4 t - C_5)^{\frac{1}{2}} e^{\frac{-3X}{C_4\sqrt{C_4 t - C_5}}} \tag{65}$$

Where $c_4 = \sqrt{\frac{k\rho_*}{3}}\left(\frac{4C}{\rho_*} - \frac{36}{k^2\rho_*^2}\right)^{\frac{1}{2}}$ and $C_5 = \frac{6}{k\rho_*}$

From equation (5) and (62), we get

$$\rho_{WDF} = \frac{\rho_*}{4} + C[C_4 t - C_5]^{-2} \tag{66}$$

And from equations (3) and (66), we get

$$p_{WDF} = \frac{-\rho_*}{4} + \frac{C}{3}[C_4 t - C_5]^{-2} \tag{67}$$

Using equation (43),we get

$$\phi = \left\{\frac{-3(n+2)\alpha}{2C_4\sqrt{C_4 t - C_5}}\right\}^{\frac{2}{n+2}} \tag{68}$$

By using equations (52) - (55), we can express the physical quantities as

$$\theta = \frac{3}{2}\frac{\sqrt{\frac{k\rho_*}{3}}\left(\frac{4C}{\rho_*}-\frac{36}{k^2\rho_*^2}\right)^{\frac{1}{2}}}{\left[\sqrt{\frac{k\rho_*}{3}}\left(\frac{4C}{\rho_*}-\frac{36}{k^2\rho_*^2}\right)^{\frac{1}{2}}t-\frac{6}{k\rho_*}\right]} \tag{69}$$

$$A = \frac{18X^2}{k\rho_*\left(\frac{4C}{\rho_*}-\frac{36}{k^2\rho_*^2}\right)\left[\left(\frac{4C}{\rho_*}-\frac{36}{k^2\rho_*^2}\right)^{\frac{1}{2}}t-\frac{6}{k\rho_*}\right]^{\frac{1}{2}}} \tag{70}$$

$$\sigma^2 = \frac{9X^2}{4\left[\left(\frac{4C}{\rho_*}-\frac{36}{k^2\rho_*^2}\right)^{\frac{1}{2}}t-\frac{6}{k\rho_*}\right]^3} \tag{71}$$

$$q = 1 \tag{72}$$

Here the model has a future singularity in finite t.

Case I (c): when $\rho_* < \frac{1}{K^2C}$

Equation (44) yields to

$$V = \left[\left(\frac{36}{k^2\rho_*^2}-\frac{4C}{\rho_*}\right)^{\frac{1}{2}}\cosh\left(\sqrt{\frac{k\rho_*}{3}}t\right)-\frac{6}{k\rho_*}\right]^{\frac{3}{2}} \tag{73}$$

Then for small value of t (i.e. near singularity t=0)

$$\cosh\left(\sqrt{\frac{k\rho_*}{3}}t\right) \approx 1+\frac{k\rho_*}{3}t^2 \tag{74}$$

Therefore from equations (73) and (74) we get

$$V = \left[\left(1-\frac{Ck^2\rho_*}{9}\right)^{\frac{1}{2}}t^2+\left(\frac{36}{k^2\rho_*^2}-\frac{4C}{\rho_*}\right)^{\frac{1}{2}}-\frac{6}{k\rho_*}\right]^{\frac{3}{2}} \tag{75}$$

Then from equations (29),(30),(31) and (75), we get

$$A(t) = \left(C_6t^2+C_7\right)^{\frac{1}{2}} \tag{76}$$

$$B(t) = D\left(C_6t^2+C_7\right)^{\frac{1}{2}} e^{\frac{X}{C_7\sqrt{C_6}}\left(\frac{C_6t^2}{C_6t^2+c_7}\right)^{\frac{1}{2}}} \tag{77}$$

$$C(t) = D^{-1}\left(C_6t^2+C_7\right)^{\frac{1}{2}} e^{\frac{-X}{C_7\sqrt{C_6}}\left(\frac{C_6t^2}{C_6t^2+c_7}\right)^{\frac{1}{2}}} \tag{78}$$

Where $c_6 = \left(1 - \frac{Ck^2\rho_*}{9}\right)^{\frac{1}{2}} - \frac{6}{k\rho_*}$ and $c_7 = \left(\frac{36}{k^2\rho_*^2} - \frac{4C}{\rho_*}\right)^{\frac{1}{2}} - \frac{6}{k\rho_*}$

From equation (5) and (62), we get

$$\rho_{WDF} = \frac{\rho_*}{4} + C\left[C_6 t^2 + C_7\right]^{-2} \tag{79}$$

And from equations (3) and (79), we get

$$p_{WDF} = \frac{-\rho_*}{4} + \frac{C}{3}\left[C_6 t^2 + C_7\right]^{-2} \tag{80}$$

Using equation (43) and (75),we get

$$\phi = \left\{\frac{(n+2)\alpha}{2C_7\sqrt{C_6}}\left(\frac{C_6 t^2}{C_6 t^2 + C_7}\right)^{\frac{1}{2}}\right\}^{\frac{2}{n+2}} \tag{80}$$

By using equations (52) - (55), we can express the physical quantities as

$$\theta = \frac{3C_6 t}{(C_6 t^2 + C_7)} \tag{82}$$

$$A_m = \frac{2X^2}{3C_6{}^2 t^2 (C_6 t^2 + C_7)} \tag{83}$$

$$\sigma^2 = \frac{X^2}{\left[C_6 t^2 + C_7\right]^3} \tag{84}$$

$$q = \frac{-C_7}{C_6 t^2} \tag{85}$$

4. Models with Deceleration Parameter

Case I: The power law

Here we take

$$V = at^b \tag{86}$$

Where a and b are constants.

Using equations (29),(30), and (86), we get

$$A(t) = a^{\frac{1}{3}} t^{\frac{b}{3}} \tag{87}$$

$$B(t) = Da^{\frac{1}{3}} t^{\frac{b}{3}} \exp\left\{\frac{Xt^{1-b}}{a(1-b)}\right\} \tag{88}$$

$$C(t) = D^{-1} a^{\frac{1}{3}} t^{\frac{b}{3}} \exp\left\{\frac{-Xt^{1-b}}{a(1-b)}\right\} \tag{89}$$

Where X and D are constants.

From equation (5) and (86), we have

$$\rho_{WDF} = \frac{\gamma}{1+\gamma}\rho_* + \frac{C}{a^{(1+\gamma)}} t^{-(1+\gamma)b} \tag{90}$$

And from (5) and (90), we get

$$p_{WDF} = \gamma\left[\frac{-1}{1+\gamma}\rho_* + \frac{C}{a^{(1+\gamma)}}t^{-(1+\gamma)b}\right] \quad (91)$$

Using equation (43) and (86) we get

$$\phi = \left\{\frac{(n+2)\alpha}{2a(1-b)}t^{(1-b)}\right\}^{\frac{2}{n+2}} \quad (92)$$

By using (52) - (55), we can express the physical quantities as

$$\theta = \frac{b}{t} \quad (93)$$

$$A_m = \frac{6X^2}{a^2b^2t^{2(b-1)}} \quad (94)$$

$$\sigma^2 = \frac{X^2}{a^2t^{2b}} \quad (95)$$

$$q = \frac{3}{b} - 1 \quad (96)$$

where X is constant.
For large t, the model tends to be isotropic when $b > 1$
Case II: The exponential type
Here we take

$$V = \alpha_1 e^{\beta t} \quad (97)$$

Where α_1 and β are constants
Using equations (29), (30), (31) and (97) we get

$$A(t) = \alpha_1^{\frac{1}{3}} e^{\frac{\beta t}{3}} \quad (98)$$

$$B(t) = D\alpha_1^{\frac{1}{3}} \exp\left\{\frac{\beta t}{3} - \frac{Xe^{-\beta t}}{\alpha_1\beta}\right\} \quad (99)$$

$$C(t) = D^{-1}\alpha_1^{\frac{1}{3}} \exp\left\{\frac{\beta t}{3} + \frac{X_2e^{-\beta t}}{\alpha_1\beta}\right\} \quad (100)$$

Where X and D are constants.

From equation (5) and (97), we have

$$\rho_{WDF} = \frac{\gamma}{1+\gamma}\rho_* + \frac{C}{\alpha_1^{(1+\gamma)}}e^{-(1+\gamma)\beta t} \quad (101)$$

And from (3) and (101), we get

$$p_{WDF} = \gamma\left[\frac{-1}{1+\gamma}\rho_* + \frac{C}{\alpha_1^{(1+\gamma)}}e^{-(1+\gamma)\beta t}\right] \quad (102)$$

Using equation (43) and (97) we get

$$\phi = \left\{\frac{-(n+2)\alpha}{2\alpha_1\beta}e^{-\beta t}\right\}^{\frac{2}{n+2}} \quad (103)$$

By using (52) - (55), and (97) we can express the physical quantities as

$$\theta = \beta \quad (104)$$

$$A_m = \frac{6X^2 e^{-2\beta t}}{\alpha_1^2 \beta^2} \tag{105}$$

$$\sigma^2 = \frac{X^2 e^{-2\beta t}}{\alpha_1{}^2} \tag{106}$$

$$q = -1 \tag{107}$$

where X is constant.

For large t, the model tends to be isotropic.

Conclusion

A Bianchi type V universe with wet dark fluid has been investigated in Saez – Ballester scalar- tensor theory of gravitation**.** A Bianchi type V universe has been considered for a new equation of state for the dark energy component of the universe. Two cases of models with constant deceleration parameter have been discussed in detail. Also some physical and geometrical features have been studied. It is interesting that when $\phi \to 0$ our results analogues with the results obtained by R. Chaubey et al. [39].

References

[1] Riess A. G.,et al. Astrophy. J.116, 1009 (1998)
[2] perimutter, S. et al,: Astrophy. J.157,565 (1998)
[3] Sahani, V,: arXiv: astr0-ph/0403324(preprint) (2004)
[4] Ratra, B., Peebles, P.J.E.: Phys. Rev D37, 3406 (1988)
[5] Caldwell, R ,R., Dave. R. Steinhardt. P J.: Phys. Rev. Lett. 80, 1582 (1998)
[6] Barrieiro. T., Copeland. E.J., Nunes N.J.: Phys. Rev D61,127301 (2000)
[7] Armendartz-Picon. C. Damour. T. and Mukhanov. V. Phys. Lett. B 458, 209 (1999).
[8] Armendartz-Picon, C.,Mukhanov. V and Steinhardt. P J.: Phys. Rev. D 63. 103510 (2001)
[9] Gonzalez – Diaz, P.F. Phys. Lett. B 586,1 (2004)
[10] Caldwell, R ,R., Phys. Lett. B 545,23 (2002)
[11] Carroll S.M., Hoffman, M.,Trodden , M.: Phys. Rev D68,023509 (2003)
[12] Elizalde, E., Nojiri,S.,Odintsov,S.D. Phys. Rev D70,043539 (2004)
[13] Freese, K. and Lewis, M.: Phys. Rev B540,1 (2002)
[14] Freese, K.:Nucl. Phys. (Proc.Suppl.) B124, 50 (2003)
[15] Gondolo, P. and Freese, P.: Phys. Rev.D68,063509 (2003)
[16] Deffayet,C.,Dvali,G.R. and Gabadadaze,G.: Phys. Rev.D65,044023 (2002)
[17] Dvali, G., Gabadadaze,G. and Porrati, M. Phys. Lett.B485,208 (2000)
[18] Dvali, G., M.S. Turner.: arXiv:astro-ph/0301510.
[19] Kamenshchik et al.: Phys. Lett.B511,265 (2001)
[20] Bento et al.: Phys. Lett. B 575, 172 (2003)
[21] Cohen, A., Kaplan, D., Nalson,A.: Phys. Rev. Lett. 82, 4971 (1999)
[22] Horava, P., Minic, D.: Phys. Rev. Lett. 85, 1610 (2000).
[23]Thomas, S.: Phys. Rev. Lett. 89, 081301(2002)
[24] X-anthopuolos, B.C.: J.Math. phys. 28, 905 (1987)
[25] Brans,C.,Dicke,R.H.: Phys. Rev.124,925(1961)
[26] Nordtvedt,K. Jr.:Astrophys.J.161.1069 (1970)
[27] Saez,D.Ballester,V.J. Phys. Lett. A113,467 (1986).
[28] Reddy D.R.K. ,Rao,M.V.S.,Rao G.K.:Astrophys. Space Sci.306,171(2006).
[29] P. G. Tait, Voyage of HMS Challanger, 2, 1 (H.M.S.O., London, 1988).
[30] A T J Hayward, *Brit. J. Appl. Phys.* 18, 965 (1967)
[31] Reddy D.R.K. , Naidu R.L..:Astrophys. Space Sci.307,395(2007).
[32] Rao, V.U.M.,Vinutha,T.,Vijaya Shanti, M.: Astrophys. Space Sci.312,189(2007).
[33] Rao, V.U.M., Vijaya Shanti, M Vinutha,T.,.: Astrophys. Space Sci.317,27(2008).
[34] Rao, V.U.M.,Sreedevi Kumari, Neelima, D.:Astrophys. Space Sci.DOI 10.1007/s10509-011-0852-1.
[35] V.R. Chirde & P N Rahate , Prespacetime journal/vol 3/issu 6/pp-609-616 (2012).
[36] Katore S.D. Shaikh A.Y. FIZIKA B 19,3,161-168 (2010).

[37] R. Holman and S. Naidu, arXiv:asroph/ 0408102 (2005).
[38] T. Singh and R. Chaubey, Pramana J. Phys. 71, 447 (2008).
[39] R. Chaubey, Astrophys. Space Sci. 321, 241 (2009).
[40] K.S. Adhav, M.V. Dawande, R.S. Thakare, R.B. Raut.: Int. J. Theo. Phys. 50, 339-348(2011)
[41] S. D. Katore, A. Y. Shaikh, M. M. Sanchetiand S. A. Bhaskar, Prespacetime Jnl. 2, 1 (2011).
[42] V.R. Chirde & P N Rahate , Global Journal of Science Frontier Research (2013).