АСТРОФИЗИКА

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PLANE SYMMETRIC ANISOTROPIC DARK ENERGY COSMOLOGICAL MODEL IN BIMETRIC THEORY OF GRAVITATION

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The plane symmetric space-times with anisotropic dark energy and with constant deceleration parameter have been derived by solving the Rosen's field equations in Bimetric theory of gravitation. We explored both models in power law as well as in exponential law. In power law, the model attains both phases accelerating as well as decelerating in the expansion with anisotropic fluid which is in the form of dark energy and there is no chance of real matter in this power law. In exponential law, the model is dust, isotropize in nature with constant acceleration in the expansion. Further, other geometrical and physical aspects of the models are also studied.

Key words: *cosmology: dark energy: modified theories of gravity*

1. *Introduction*. The most remarkable advancement in cosmology is its observational evidence which says that our universe is in an accelerating expansion phase. Supernova Ia data [1-4] gave the first indication of the accelerated expansion of the universe. This was also confirmed by the observations of anisotropies in the cosmic microwave background (CMB) radiation as seen in the data from satellite such as WMAP [5,6] and large scale structure [7-10]. These cosmological observations suggest that our universe is (approximately) spatially flat and its cosmic inflation is due to the matter field (dark energy) having negative pressure (violating energy conditions), with composition of the universe density in the following way: 74% dark energy (DE), 22% dark matter and 4% ordinary matter. The cosmological constant, Λ is the most theoretical candidate of DE which has the equation of state (EoS) $\omega = -1$. Astronomical observations indicate that the cosmological constant is many orders of magnitude smaller than estimated in modern theories of elementary particles [11]. Stabell and Refsdal [12] discussed the evolution of Friedmann-Lemaitre Robertson and Walker (FLRW) dust models in the presence of positive cosmological constant. These results are given in a more generalized form in [13,14] using the general EoS. Though there is compelling evidence that expansion of the universe is accelerating, yet the nature of dark energy have been under consideration with different candidates of DE like Chaplygin gas, phantoms, quintessence, cosmological constant etc since the last

decade [15-19]. Rodrigues [20] proposed Bianchi I with a non-dynamical DE component which yields anisotropic vacuum pressure in two ways: (i) by considering the anisotropic vacuum consistent with energy-momentum conservation; (ii) by implementing a Poisson structure deformations between canonical momenta such that re-scaling of scale factors is not violated. Koivisto and Mota [21] have investigated a cosmological model containing the DE fluid with nondynamical anisotropic EoS and interacts with perfect fluid and they suggested that if the DE EoS is anisotropic, the expansion rate of the universe becomes direction dependent at late times and cosmological models with anisotropic EoS can explain some of the observed anomalies in CMB.

According to recent cosmological observations of WMAP [5-6] and Plank results [7-9] and [22-33], the universe is homogeneous and isotropic in nature, but no one knows that the universe has particular type OR definite type of nature and therefore cosmologists have been exposing the universe, right from many decades, by assuming an isotropic as well as anisotropic models in their research in order to get different types of secrets of the nature. Anisotropic cosmological models are studied in recent times with the advent of more precise data from measurements of cosmic microwave background temperatures anisotropy. Further, the analysis of the large-scale CMB fluctuations confirms that our present day physical universe is isotropic, homogeneous and expanding and it is well represented by FRW model but isotropic models are unstable near the origin and fail to describe the early universe and anisotropy plays a significant role in the models near origin. Analysis of WMAP datasets shows us that the universe could have a preferred direction. Hence, the studies of the anisotropic Bianchi models are important [34].

Close to big bang singularity, the assumption of spherically symmetric and isotropy cannot be strictly valid and therefore we consider plane-symmetric, which is less restrictive than spherical symmetry and can provide an avenue to study inhomogeneities in early universe. Thus the plane-symmetric space-times are physically important. In the literature, many authors consider plane symmetry and provide an avenue to study inhomogeneities. Da Silva and Wang [35], Anguige [36], Nouri- Zonoz and Tavanfar [37], Pradhan et al. [38,39] and Yadav [40] have studied the plane symmetric and inhomogeneous cosmological models in different physical context. Recently, Akarsu and Kilinc [41] investigated anisotropic Bianchi type I models in the presence of perfect fluid and minimally interacting DE with anisotropic EoS parameter and found that an anisotropy of the DE did not always promote anisotropy of the expansion.The anisotropic fluid may support isotropization of the expansion for relatively earlier times in the universe. Further Akarsu et al. [42] have worked on the Bianchi type III model in the presence of single imperfect fluid with dynamical anisotropic EoS parameter and dynamical energy density and observed that anisotropy of the expansion vanished and hence the universe approached isotropy for late times of the universe in accelerating models.

Though the Einstein theory of relativity (GR) is one of the successful theory of gravitation and is consistent with experimental data and observations, it has some lacunas that it is not free from singularities which were appearing in big-bang in cosmological models and therefore several theories of gravitation have been proposed as the alternative to the theory of GR. The most important one amongst them is Rosen's (1973, 1975) bimetric theory of gravitation (BTG).This BTG obeys the principles of covariance and equivalence of GR and it is free from singularities and also it is fit with observations of GR.This theory is based on two matrices viz: the fundamental metric tensor g_{ij} and flat metric γ_{ij} which are

$$ds^2 = g_{ij} dx^i dx^j \tag{1}$$

and

$$d\eta^2 = \gamma_{ij}\, dx^i dx^j\,. \tag{2}$$

Rosen (1973, 1975) developed the field equations of his BTG as

$$N_i^j - \frac{1}{2} N \delta_i^j = -T_i^j \tag{3}$$

where

$$N_i^j = \frac{1}{2}\gamma^{pr}\left(g^{sj} g_{si}\big|_p\right)\Big|_r \tag{4}$$

is the Rosen's Ricci tensor and $N = g^{ij} N_{ij}$ is the Rosen scalar. Here and hereafter the vertical bar (|) stands for γ-covariant differentiation where $g = \det(g_{ij})$ and $\gamma = \det(\gamma_{ij})$.

Right from Rosen (1973, 1975), many researchers have been developing the cosmological models of the universe in BTG and trying to evaluate geometrical and physical properties of the universe. We would like to quote some of them as Rosen [43-45], Karade [46], Isrelit [47], Yilmaz [48], Reddy and Rao [49], Katore and Rane [50], Khadekar and Tade [51], Borkar et al. [52-62], Gaikwad et al. [63] etc.

The plane symmetric space-times is physically important, since it is less restrictive than spherical symmetry and can provide an avenue to study inhomogeneties in early universe. Therefore, in this article, we take-up the study of plane symmetric space-times with anisotropic dark energy and with constant deceleration parameter in bimetric theory of gravitation. We explored both power law and exponential law models of plane symmetric space-times. It is realized that in power law, the model attains both phases accelerating as well as decelerating in the expansion with anisotropic fluid which is in the form of dark energy and there is no chance of real matter in this power law. In exponential law, the model is dust, isotropize in nature with accelerating phase in the expansion. Other geometrical and physical aspects of the models are also studied.

2. *Metric and field equations.* We consider the plane symmetric metric in the form

$$ds^2 = A^2\left(dx^2 - dt^2\right) + B^2 dy^2 + C^2 dz^2 , \tag{5}$$

where the A, B and C are the functions of cosmic time t alone.

The flat metric corresponding to metric (5) is

$$d\eta^2 = -dt^2 + dx^2 + dy^2 + dz^2 . \tag{6}$$

The energy momentum tensor T_i^j of the perfect fluid is given by

$$T_i^j = (\rho + p)v_i v^j + p g_i^j , \tag{7}$$

where ρ and p are the proper energy density and pressure of the matter respectively and v^i is the 4-velocity vector with magnitude

$$g_{ij} v^i v^j = -1. \tag{8}$$

We assume the co-moving co-ordinates system, so that

$$v^1 = v^2 = v^3 = 0 , \quad v^4 = 1. \tag{9}$$

The anisotropic fluid is characterized by equation of state parameter $p = \omega\rho$, where ω is not necessarily constant (Carroll et al. [64]), equation (7) of energy momentum tensor yields its surviving components

$$\begin{aligned} T_1^1 &= p_x = \omega_x\rho = (\omega + \delta)\rho , \\ T_2^2 &= p_y = \omega_y\rho = (\omega + \gamma)\rho , \\ T_3^3 &= p_z = \omega_z\rho = \omega\rho , \\ T_4^4 &= -\rho , \end{aligned} \tag{10}$$

where p_x, p_y, p_z and ω_x, ω_y and ω_z are the pressures and directional EoS parameters along x, y and z axes respectively, ω is the deviation free EoS parameter of the fluid, δ and γ are the skewness parameters and they are deviations of ω along x and y axes respectively.

We write the Rosen's field equations (3) and (4) for the metrics (5) and (6) with the help of (10) as

$$\frac{B_{44}}{B} + \frac{C_{44}}{C} - \frac{B_4^2}{B^2} - \frac{C_4^2}{C^2} = (\omega + \delta)\rho , \tag{11}$$

$$2\frac{A_{44}}{A} - \frac{B_{44}}{B} + \frac{C_{44}}{C} - 2\frac{A_4^2}{A^2} + \frac{B_4^2}{B^2} - \frac{C_4^2}{C^2} = (\omega + \gamma)\rho , \tag{12}$$

$$2\frac{A_{44}}{A} + \frac{B_{44}}{B} - \frac{C_{44}}{C} - 2\frac{A_4^2}{A^2} - \frac{B_4^2}{B^2} + \frac{C_4^2}{C^2} = \omega\rho , \tag{13}$$

$$\frac{B_{44}}{B}+\frac{C_{44}}{C}-\frac{B_4^2}{B^2}-\frac{C_4^2}{C^2}=\rho, \tag{14}$$

where

$$A_4=\frac{dA}{dt}, \quad A_{44}=\frac{d^2A}{dt^2} \quad \text{etc}.$$

3. *Solutions of the field equations*. We are trying to find the solutions of the field equations (11-14) which are four in seven unknowns A, B, C, ρ, ω, δ and γ. Therefore, to get a determinate solution, one has to assume three extra conditions. In order to have the linear relation between the metric potentials, we assume that the scalar expansion is proportional to shear (Collin et al. [65]).This assumption leads two relations

$$B=\mu C \tag{15}$$

and

$$A=B^m, \tag{16}$$

where μ and m are positive constants.

With the condition (15), equations (11-14) reduce to

$$2\frac{B_{44}}{B}-2\frac{B_4^2}{B^2}=(\omega+\delta)\rho, \tag{17}$$

$$2\frac{A_{44}}{A}-2\frac{A_4^2}{A^2}=(\omega+\gamma)\rho, \tag{18}$$

$$2\frac{A_{44}}{A}-2\frac{A_4^2}{A^2}=\omega\rho, \tag{19}$$

$$2\frac{B_{44}}{B}-2\frac{B_4^2}{B^2}=-\rho. \tag{20}$$

Equations (18) and (19) provide the value of γ as

$$\gamma=0. \tag{21}$$

With this value $\gamma=0$ (equation (21)), the above equations (17-20) further reduce to

$$2\frac{B_{44}}{B}-2\frac{B_4^2}{B^2}=(\omega+\delta)\rho, \tag{22}$$

$$2\frac{A_{44}}{A}-2\frac{A_4^2}{A^2}=\omega\rho, \tag{23}$$

$$2\frac{B_{44}}{B}-2\frac{B_4^2}{B^2}=-\rho. \tag{24}$$

With the second relation (16), the above equations (22-24) become

$$2\frac{B_{44}}{B}-2\frac{B_4^2}{B^2}=(\omega+\delta)\rho, \tag{25}$$

$$2m\frac{B_{44}}{B}-2m\frac{B_4^2}{B^2}=\omega\rho, \tag{26}$$

$$2\frac{B_{44}}{B}-2\frac{B_4^2}{B^2}=-\rho. \tag{27}$$

The average scale factor a of an anisotropic model (5) is defined as

$$a=(ABC)^{1/3}. \tag{28}$$

The spatial volume scale factor V is given by

$$V=a^3=ABC. \tag{29}$$

We define the generalized mean Hubble parameter H as

$$H=\left(\frac{a_4}{a}\right)=\frac{1}{3}\left(H_x+H_y+H_z\right), \tag{30}$$

where $H_x=A_4/A$, $H_y=B_4/B$ and $H_z=C_4/C$ are the directionals of Hubble parameter H in the directions of x, y and z, respectively.

The deceleration parameter q is defined by

$$q=-\left(\frac{a\,a_{44}}{a_4^2}\right)=-\left(1+\frac{H_4}{H^2}\right). \tag{31}$$

Next, we assume the special law of variation for the mean Hubble's parameter H proposed by Berman [66] that yields a constant value of deceleration parameter q, and the relation

$$H=ca^{-n}, \tag{32}$$

where c (>0) and n (≥ 0) are constants.

Then equations (30-32) yield a constant value of deceleration parameter q as,

$$q=n-1 \quad \text{for} \quad n\neq 0. \tag{33}$$

The sign of q indicates that whether the model accelerates or not. For $n>1$, the universe shows decelerating behavior while for $n<1$, we have an accelerating universe. The value $n=1$ yields neither accelerating nor decelerating expansion means expansion with constant speed.

From equation (32), we obtain the value of average scale factor 'a' as

$$a=\left(nct+c_1\right)^{1/n} \quad \text{for} \quad n\neq 0, \tag{34}$$

where c_1 is the constant of integration. We have

$$a=c_2e^{ct} \quad \text{for} \quad n=0, \tag{35}$$

where c_2 is the constant of integration. Thus the law of variation of Hubble parameter yields two types of expansion in the universe: power law expansion, equation (34) and exponential law expansion, equation (35).

Power Law Model

We have the value of our average scale factor a, in power law as

$$a=(nct+c_1)^{1/n} \quad \text{for} \quad n\neq 0.$$

From the equation (30) of mean Hubble parameter H with equation (34), we write

$$\frac{a_4}{a}=\frac{c}{(nct+c_1)}.$$

With this value of a_4/a and with the generalized mean Hubble parameter, equation (30), we write

$$\frac{1}{3}\left(\frac{A_4}{A}+\frac{B_4}{B}+\frac{C_4}{C}\right)=\frac{c}{(nct+c_1)}$$

and then using equations (15) and (16), we have calculated the values of scale factors A, B and C as

$$A=\alpha_1(nct+c_1)^{3m/n(m+2)}, \tag{36}$$

$$B=\alpha_2(nct+c_1)^{3/n(m+2)}, \tag{37}$$

$$C=\alpha_3(nct+c_1)^{3/n(m+2)}, \tag{38}$$

where α_1, α_2, α_3, c_1, $c>0$, $m>0$, $n\neq 0$ all are constants.

Thus the required metric is

$$\begin{aligned} ds^2 &= \alpha_1^2(nct+c_1)^{6m/n(m+2)}\left[dx^2-dt^2\right]+\alpha_2^2(nct+c_1)^{6/n(m+2)}dy^2+ \\ &\quad +\alpha_3^2(nct+c_1)^{6/n(m+2)}dz^2. \end{aligned} \tag{39}$$

This is plane symmetric anisotropic dark energy cosmological model with constant deceleration parameter in bimetric theory of gravitation in power law expansion.

Exponential Law Model

We have the value of an average scale factor a, in exponential law as

$$a=c_2e^{ct}, \quad \text{for} \quad n=0.$$

From the equation (30) of mean Hubble parameter H with relations (15) and (16), we have obtained the values of scale factors A, B and C as

$$A=\beta_1\, e^{3mct/(m+2)}, \tag{40}$$

$$B=\beta_2\, e^{3ct/(m+2)}, \tag{41}$$

$$C=\beta_3\, e^{3ct/(m+2)}, \tag{42}$$

where β_1, β_2, β_3, $c>0$, $m>0$ all are constants.

Thus the required metric in exponential law is

$$ds^2=\beta_1^2\, e^{6mct/(m+2)}\left(dx^2-dt^2\right)+\beta_2^2\, e^{6ct/(m+2)}dy^2+\beta_3^2\, e^{6ct/(m+2)}dz^2 \tag{43}$$

represents plane symmetric anisotropic dark energy cosmological model with constant deceleration parameter in bimetric theory of gravitation.

4. *Geometrical and Physical Significance of Power Law Model.* The power law model (39) having the scale factors which are increasing with time. Initially, they admit the constant values increasing with time and admit infinite values finally. Thus in the beginning stage, the model becomes flat whose scale factors diverge to infinity at later stage.

The physical quantities that are important in cosmology are spatial volume V, mean Hubble parameter H and the scalar of expansion θ and in this power law model (39), these take the values

$$V = L(nct + c_1)^{3/n}, \tag{44}$$

where L is a constant,

$$H = \frac{c}{(nct + c_1)}, \tag{45}$$

$$\theta = 3H = \frac{3c}{(nct + c_1)}. \tag{46}$$

The volume of the model is an increasing function of time t. Model starts with constant volume ($c_1 \neq 0$) and volume is continuously increasing and diverges to infinity in the later stage of the model. The Hubble parameter H obeys its law that it is inversely proportional to Hubble time t. Initially, it attains the maximum constant (non-zero) value ($c_1 \neq 0$) and decreasing with increase in time t and vanishes finally. The scalar expansion θ follows the same nature as that of H that it is very very high in the beginning stage and it is slowing down continuously and attains minimum position in the ending stage.

The matter energy density ρ, an anisotropy parameter A_m and the shear σ have been calculated as

$$\rho = \frac{6nc^2}{(m+2)(nct + c_1)^2}, \tag{47}$$

$$A_m = \frac{1}{3}\sum_{i=1}^{3}\left(\frac{\Delta H_i}{H}\right)^2 = 2\frac{(m-1)^2}{(m+2)^2}, \tag{48}$$

$$\sigma^2 = \frac{3}{2}A_m H^2 = \frac{3c^2(m-1)^2}{(m+2)^2(nct + c_1)^2}. \tag{49}$$

The ratio σ/θ admits the value

$$\sigma/\theta = (m-1)/\sqrt{3}(m+2). \tag{50}$$

It is seen that the energy density of matter is also decreasing function of time

t. Initially, it attains the maximum value and goes on decreasing continuously with increase in time t and attains minimum value finally. This shows that the model starts with a very high density anisotropic fluid and density is slowing down and vanishes finally. Anisotropic parameter A_m is independent of time t and attains the non-zero constant value and thus the model is in anisotropic in nature.

In particular, for $m = 1$, an anisotropic parameter A_m is zero and the model becomes isotropic. The model has shear and it is decreasing function of time t. Initially, it admits a non-zero constant value and it is continuously decreasing and goes over to zero finally.Thus the model has shear which is continuously decreasing and model is shearless at final stage. In particular for $m = 1$, the magnitude of the shear σ^2 is zero and thus the model becomes shearless in particular for $m = 1$. The ratio σ/θ is zero for $m = 1$ that also supports the isotropic nature of the model for $m = 1$.

The equation of state parameter ω in the power law model admits the value

$$\omega = -m, \quad (m > 0). \tag{51}$$

The deviations δ and γ of equation of state parameter ω along x and y axes are

$$\delta = (m-1), \tag{52}$$

$$\gamma = 0, \tag{53}$$

respectively.

The equation of state parameter ω has very important physical significance in the dark energy model that it is always negative. In a power law model (39), it is noticed that this equation of state parameter ω is appeared with value $\omega = -m$ $(m > 0)$ which is negative always. This clearly shows that the model containing an anisotropic perfect fluid which is in dark energy form and there is no chance of real baryonic matter in this power law model. The deviation δ of equation of state parameter ω along x-axis is found to be $(m - 1)$ and the deviation γ along y-axis comes out to be $\gamma = 0$. From this, it is opined that the fluid having anisotropic nature along x-axis and isotropic nature along y-axis. In particular for $m = 1$, the deviations δ and γ of ω, both are zero and hence the model approaches to isotropize in nature for $m = 1$.

In this power law model $(n \neq 0)$ the model attains both phases accelerating as well as decelerating in the expansion with anisotropic fluid which is in the form of dark energy. In view of the observations such as Type Ia supernovae (SNe Ia), Wilkinson Microwave Anisotropic probe (WMAP) and Cosmic Microwave Background (CMB), Sloan Digital Sky Survey (SDSS) and Large Scale Structure (LSS) and Chandra X-ray Observatory which strongly suggested that the universe is spatially flat and dominated by an exotic component with large negative pressure, referred to as dark energy, we focused our attention on flat universe with matter energy density Ω_M and dark energy density Ω_Λ with the relation

$$\Omega_M + \Omega_\Lambda = 1, \tag{54}$$

where $\Omega_M = \rho/3H^2$ and $\Omega_\Lambda = \Lambda/3H^2$.

This equation (54), yields

$$\frac{\rho}{3H^2} + \frac{\Lambda}{3H^2} = 1,$$

or

$$\Lambda = 3H^2 - \rho. \tag{55}$$

Using the values of Hubble parameter H and energy density ρ given by equations (45) and (47), respectively, in equation (55), we get

$$\Lambda = \frac{3(m-2n+2)c^2}{(m+2)(nct+c_1)^2} > 0, \quad m > 2(n-1). \tag{56}$$

In regards with flat universe the value of cosmological constant Λ have been found and it is given by equation (56) which is dominated by time t. This derived value of cosmological constant Λ is a positive decreasing function of time t and approaches a small positive value at late times. Such type of behavior of cosmological constant corresponds to repulsion with cosmic acceleration which is in good agreement with recent supernovae observations and confirmed by recent supernovae Ia observations [1-4] and [67].

5. *Geometrical and Physical Significance of Exponential Law Model.* For $n = 0$, we have the exponential law (35) for an average scale factor 'a'. In this exponential law, the required metric is given by model (43) and we are analyzing the geometrical and physical significance of this exponential law model (43) in this article. Its spatial volume V, Hubble parameter H and scalar expansion θ have been derived as

$$V = Me^{3ct}, \tag{57}$$

where M is a constant.

$$3H = \theta = 3c, \tag{58}$$

where $(c > 0)$ is constant.

It is seen that the scale factors A, B and C and volume V of the model in exponential law are exponentially increasing with time. Initially, they are admitting non-zero constant values and they diverge to infinity finally. Thus, the exponential law model starts with non-zero constant scale factors and non-zero constant volume and its scale factors and volume are exponentially increasing and diverges to infinity in the evolution of the model. The Hubble parameter H and scalar expansion θ are the time independent quantities and attain the constant values which shows that the rate of expansion in the model is constant.

The matter energy density ρ, an anisotropy parameter A_m and the shear σ have been calculated as

$$\rho=0, \tag{59}$$

$$A_m=2\frac{(m-1)^2}{(m+2)^2}, \tag{60}$$

$$\sigma^2=\frac{3(m-1)^2 c^2}{(m+2)^2}, \tag{61}$$

and

$$\sigma/\theta=(m-1)/\sqrt{3}\,(m+2). \tag{62}$$

It is noticed that the matter energy density of an anisotropic fluid is found to be zero suggested the dust model in this exponential law. An anisotropic parameter A_m and shear σ both are independent of time t and admit the constant value shows the anisotropic nature of the model with constant shear. It is also clear that particularly for $m=1$, A_m attains zero value and shear σ also admits zero value which suggested that this exponential law model approaches to isotropy in nature and it is shearless for $m=1$.

An equation of state parameter ω and its deviations δ along x-axis and γ along y-axis have been found as

$$\omega=\delta=\gamma=0. \tag{63}$$

It is observed that the equation of the state parameter ω and its deviations δ and γ along x and y axes, respectively, are not in surviving position in the evolution in exponential law model. Therefore, in the exponential law, the model is dust and isotropize in nature. Further, the deceleration parameter q is found to be $q=-1$ in the exponential law and therefore the model has accelerating phase in the expansion.

6. *Findings.*

1. We have evaluated plane symmetric space-time with anisotropic fluid and with constant deceleration parameter by solving the Rosen's field equations in Bimetric theory of gravitation. We deduced the models in power law expansion as well as in exponential law expansion.

2. In power law expansion, the model starts evolving with non-zero constant volume which increases continuously and diverges to infinity at late times.

3. The Hubble parameter H is inversely proportional to time t and follows its scenario in the evolution in power law model. The scalar expansion θ agreed with the same nature as that of H that there is a very high expansion at the origin and expansion is slowing down at later stage.

4. The matter energy density of dark fluid is very high at the origin of the model and it is also slowing down when the time t increasing.

5. The power law model is in anisotropic in nature but it approaches to isotropic in particular for $m = 1$.

6. The model has shear and the shear in the model vanishes in particular for $m = 1$ in this power law.

7. In this power law, we have found the value of cosmological constant Λ for the flat universe and it is realized that the value of cosmological constant Λ, is in agreement with recent cosmological observations.

8. In power law, the model contains anisotropic fluid in the form of dark energy and there is no chance of real matter in this power law.

9. It is found that our model has both accelerating phase and decelerating phase with anisotropic fluid in the form of dark energy in power law.

10. In exponential law, the model has been examined and it is realized that the model goes over to dust starting with constant volume and volume is exponentially increasing.

11. The model is isotropized in nature always in exponential law.

12. The exponential law model has accelerating phase always in the expansion.

7. *Conclusion*. In this paper, we have investigated plane symmetric anisotropic dark energy cosmological model with constant deceleration parameter by solving the Rosen's field equations in Bimetric theory of gravitation. We have deduced the models in both power law expansion and in exponential law expansion.In power law, the model attains both phases accelerating as well as decelerating in the expansion with anisotropic fluid which is in the form of dark energy and there is no chance of real matter in this power law. In exponential law, the model is dust, isotropize in nature with accelerating phase in the expansion. Other geometrical and physical aspects of the models are also studied.

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ПЛОСКОСИММЕТРИЧНАЯ АНИЗОТРОПНАЯ КОСМОЛОГИЧЕСКАЯ МОДЕЛЬ ТЕМНОЙ ЭНЕРГИИ В РАМКАХ БИМЕТРИЧЕСКОЙ ТЕОРИИ ГРАВИТАЦИИ

М.С.БОРКАР[1], А.АМИН[2]

На основе уравнения поля Розена в биметрической теории гравитации выводится плоскосимметричное пространство-время с анизотропной темной энергией и постоянным параметром замедления. Мы исследовали модели как для степенного, так и для экспоненциального законов. В модели со степенным законом достигаются обе - ускоряющаяся и замедляющаяся фазы анизотропного расширяющегося течения в виде темной энергии, но не реальной материи. При экспоненциальном законе имеем пылевую модель, по природе своей изотропную с постоянным ускоряющимся расширением. Исследуются также другие геометрические и физические аспекты моделей.

Ключевые слова: *космология: темная энергия: модифицированная теория гравитации*

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