IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Anisotropic Bianchi Type-Vi Cosmological Model Containing Dark Energy In Presence Of Electromagnetic Field

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Abstract

Cosmology is a discipline to understand the nature of origin, evolution, large Scale Structure, and ultimate fate of the universe. It is perhaps the oldest discipline of the world. Cosmological models which are spatially homogeneous but anisotropic have significant role in the description of the universe at its early stages of evolution. The cosmological and astronomical data obtained from the supernovae Ia (SNeIa), the CMB radiation anisotropies, The Large Scale Structure (LSS) and X-ray experiments support the discovery of accelerated expansion of the present day universe [1-8].

Keywords: Anisotropic; Bianchi Type-vi; Cosmological; Model; Dark Energy; Electromagnetic; Field

1. Introduction

When we study the Bianchi type models, we observe that the models contain isotropic special cases and they permit arbitrarily small anisotropic levels at some instant of cosmic times. Bianchi type cosmological models are important in the sense that this models are homogenous and anisotropic, from which the process of isotropization of the universe is studied through the passage of time. Moreover, from the theoretical point of view, anisotropic universe has a greater generality than isotropic models. The simplicity of the field equation made Bianchi space time useful in construction models of spatially homogenous and anisotropic cosmologies.

Considerable work has been done for constructing various Bianchi type cosmological models. Bianchi type VI spaces are of particular interest since they are sufficiently complex. In Einstein's general relativity, in order to have such acceleration, one needs to introduce a component to the matter distribution of the universe with a large negative pressure. This component is usually referred as dark energy [DE]. Astronomical observations indicate that our universe is flat and currently consists of approximately 2/3 dark energy and 1/3 dark matter. The nature of dark energy as well as dark matter is unknown, and many radically different models have been proposed, such as a tiny positive cosmological constant.

Bianchi type VI models of the universe give a better explanation of some of the cosmological problems such as primordial helium abundance and they also isotropize in a special sense. Ellis and MacCallum [9] obtained solutions of Einstein's field equations for a Bianchi type VI space-time in the case of a stiff-fluid. Collins [10] and Ruban [11] have also presented some exact solutions of Bianchi type VI for perfect fluid distributions satisfying specific equations of state.

Dunn and Tupper [12] investigated a class of Bianchi type VI perfect fluid cosmological models associated with electromagnetic field. Roy and Singh [13] studied some Bianchi VI cosmological models with free gravitational field of the magnetic type. Ribeiro and Sanyal [14] investigated Bianchi-VI viscous fluid cosmology with magnetic field. Patel and Koppar [15] obtained some Bianchi type VI viscous fluid cosmological models. Bali, Pradhan and Hassan [16] studied Bianchi type VI magnetized barotropic bulk viscous fluid massive string universe in General Relativity Bali, Banerjee and Banerjee [17] obtained Bianchi type VI bulk viscous massive string cosmological models in General Relativity. Bali, Banerjee and Banerjee [18] studied some LRS Bianchi type VI cosmological models with special free Gravitational fields. Pradhan and Bali [19] presented magnetized Bianchi type VI barotropic massive string universe with decaying vacuum energy density. Recently, a new class of LRS Bianchi type VI universe with free gravitational field and decaying vacuum energy is obtained by Pradhan [20]. Weinberg[21] gravitation and cosmology. Abdel-Megied and Hezagy [22] obtained Bianchi Type VI cosmological model with electromagnetic field in Lyra’s Geometry. Katore and Kapse [23] studied dynamics of Bianchi Type VI holographic Dark Energy models in General Relativity and Lyra’s Geometry. Madsen [24] studied magnetic Field, in cosmology. Mathur, Singh and Tyagi [25] obtained Bianchi Type 1 viscous fluid cosmological model with electromagnetic field. Bianchi Type V electromagnetic string dust cosmological model is obtained by Deo, Gopalkrushna’s, Punwatkar, and Patil [27]. Solanke and Karade [28] studied Bianchi Type V universe filled with combination of perfect fluid and scalar field couple with electromagnetic flux in f (R, T) theory of gravity.

2. Some important terms

2.1 Cosmological Model

Cosmological model of the universe is the model of the universe with which we try to see to what extent this model resembles with the actual universe. One of the principal goals of the cosmological model is to describe the different phases of evolution of the universe. The first epoch is that of rapid expansion of the Universe, also known as inflationary period. Most of the theories describe this phase by means of a scalar field related to the hypothetic inflation. The next phase corresponds to the deceleration when the matter and radiation dominate over the scalar field. The present era is characterized by the accelerated mode of expansion where dark matter and dark energy play the dominating role. By this acceleration we understand the acceleration that we observed at present time.

2.2 Spatially homogenous and anisotropic models

Experimental studies of the isotropy of the cosmic microwave background radiation and reflection of the amount of helium formed in the initial stages of the evolution of the universe, stimulated theoretical study of anisotropic cosmological model. At present stage of evolution, the universe is spherically symmetric and the distribution of matter in it is generally isotropic and homogenous. But in the early stages of evolution, the picture might not be as smooth as near the Big Bang singularity, the assumption of spherical symmetry, as well as that of isotropy could not be strictly valid. The anisotropy of the cosmic expansion, which is supposed to disappear with time, is a very important quantity. Recent experimental data as well as theoretical arguments support the existence of anisotropy expansion of phase, which evolves into an isotropic one. This very fact forces one to study evolution of the universe with the assumption of the universe with the anisotropic background.

Cosmologists use the term to describe the uneven temperature distribution of the cosmic microwave background radiation. There is evidence for the so-called Axis of Evil in the early Universe that is at odds with the currently favored theory of rapid expansion after the Big

Bang. Cosmic anisotropy has also been seen in the alignment of the galaxies rotation axes and polarization angles of quasars.

2.3 Dark Energy

A hypothetical form of Energy, it is supposed, is spread uniformly throughout the space (and time) and has anti gravitational properties. It represents a possible mechanism for the Cosmological constant, and thus is one of the possible explanations for the current accelerating rate of expansion of the universe. And it is estimated to account for about 74 percent of the mass-energy of the universe. In the early 20^{th} century the common world-view held that the Universe is static-more or less the same throughout eternity. Even Albert Einstein supported this long-standing idea, and in order to get the steady state Universe he introduced cosmological constant in his famous system. So, when in 1922 the Russian meteorologist and mathematician Alexander Friedman had published a set of possible mathematical solutions that gave a non static Universe, Einstein rejected it nothing that this model was indeed a mathematically possible solution to the field equations. This model has gained big popularity only after the works of Robertson and Walker and became known as FRW model. This model describes a homogeneous and isotropy Universe. By homogeneity we mean that space has the same metric properties (measure) in all points, whereas by isotropy we mean that the space has the same measure in all directions. This idea of expanding Universe suggested the presence of an initial singularity, which means the finiteness of time. Though the idea of an expanding Universe was supported both theoretically and experimentally, it was strongly believed that the Universe is expanding with deceleration. So, in 1998, when it was found that the Universe is expanding with acceleration, it comes like a bolt from the blue. The observation of type Ia supernova (SNeIa) in 1998 established that our Universe is currently accelerating and recent observation of SNeIa of high confidence level have further confirmed this.

In addition, measurements of the cosmic microwave background (CMB) and large scale structure (LSS) strongly indicate that our Universe is dominated by a component with negative pressure, dubbed as dark energy.

2.4 Cosmic Microwave Background

The cosmic microwave background (CMB) is the thermal radiation left over from the time of recombination in Big Bang cosmology. In older literature, the CMB is also variously known as cosmic microwave background radiation (CMBR) or "relic radiation". The CMB is a cosmic background radiation that is fundamental to observational cosmology because it is the oldest light in the universe, dating to the epoch of recombination. With a traditional optical telescope, the space between stars and galaxies (the background) is completely dark. However, a sufficiently sensitive radio telescope shows a faint background glow, almost isotropic, that is not associated with any star, galaxy, or other object. This low is strongest in the microwave region of the radio spectrum. The accidental discovery of the CMB in 1964 by the American radio astronomers Arno Penzias and Robert Wilson was the culmination of work initiated in the 1940s, and earned the discoverer the 1978 Nobel Prize.

The CMB is a snapshot of the oldest light in our Universe, imprinted on the sky when the Universe was just 380,000 years old. It shows tiny temperature fluctuations that correspond to regions of slightly different densities, representing the seeds of all the future structure: the stars and galaxies of the development of the universe, and its discovery is considered a landmark test of the Big Bang model of the universe.

2.5 Big Bang

The Big Bang theory is the prevailing cosmological model for the universes from earliest known periods through its subsequent large-scale evolution. The model accounts for the fact that the universe expanded from a very high density and high temperature state, and offers a comprehensive explanation for the broad range of phenomena, including the abundance of light elements, the cosmic microwave background, large scale structure and Hubble's Law.

2.6 Dark Matter

Dark matter is a hypothetical type of matter composing the approximately 27- percent of the mass and energy in the observable universe that is not accounted for by dark energy, baryonic matter, and neutrinos. The name refers to the fact that it does not emit or interact with electromagnetic radiation, such as light, and is thus invisible to the entire electromagnetic spectrum. Although dark matter cannot be directly observed with conventional electromagnetic telescope, its existence and properties are inferred from its various gravitational effects such as the motions of visible matter, via gravitational lensing, its influence on the universe's large-scale structure, and its effects in the cosmic microwave background. Dark matter is transparent to electromagnetic radiation and/or is so dense and small that it fails to absorb or emit enough radiation to be detectable with current imaging technology.

3. Cosmological constant

In the context of cosmological constant is a homogenous energy density that causes the expansion of the Universe to accelerate. Originally proposed early in the development of general relativity in order to allow a static universe solution it was subsequently abandoned when the Universe was found to be expanding. Now the cosmological constant is invoked to explain the observed acceleration of the expansion of the Universe. The cosmological constant is the simplest realization of dark energy, which the more generic name is given to the unknown cause of the acceleration of the Universe.

4. Line Element

A formula which express the distance between adjacent points is called a metric or line element. For example $ds^2 = dx^2 + dy^2 + dz^2$ is a line element. It expresses the distance between adjacent points (x, y, z) and (x+dx, y+dy, z+dz). More generally curvilinear co-ordinates u, v, w

$$ds^2 = adu^2 + bdv^2 + cdw^2 + 2fdvdw + 2gdwdu + 2hdudv$$

Where a, b, c……. h are functions of co-ordinates u, v, and w.

This idea was generalized and extended to a space of n dimensions by Riemann who defined the infinitesimal distance ds between adjacent points whose co-ordinates in a system are $x^i$and$x^i + dx^i$ by the formula

$ds^2 = g_{ij}dx^i dx^j$ (Where i, j =1, 2,….., n)

Where the co-efficient g_{ij} are functions of co-ordinatesx^i.

5. Ricci Tensor

In relativity theory, the Ricci tensor is the part of the curvature of space-time that determines the degree to which will tend to converge or diverge in time. It is related to the matter content of the universe by means of the Einstein field equation. In differential geometry, lower bounds on the Ricci tensor on a Riemannian manifold allow one to extract global geometric and topological information by comparison with the geometry of a constant curvature space form. If the Ricci tensor satisfies the vacuum Einstein equation, then the manifold is an Einstein manifold, which has been extensively studied. In this connection, the Ricci flow equation governs the evolution of a given metric to an Einstein metric; the precise manner in which this occurs ultimately leads to the solution of the Poincare conjecture.

The Ricci tensor is defined as the contraction of the Riemann tensor in the following manner $R_{ij} = g^{\alpha\beta}R_{\alpha ij\beta} = R^{\beta}_{ij\beta}$.

6. Deceleration parameter

The deceleration parameter q in cosmology is a dimensionless measure of the cosmic acceleration of the expansion of space in a Robertson-Walker universe.

It is defined by:

$$q = -\frac{\ddot{a}a}{\dot{a}^2}$$

Where a is the scale factor of the universe and the dots indicate derivatives by proper time. The expansion of the universe is said to be accelerating if $\ddot{a}$ is positive (recent measurement suggest it is), and in this case the deceleration parameter will be negative.

7. Hubble's Law

Hubble's law is the name observation in physical cosmology that:

1. Object observed in deep space (extragalactic space, 10 mega par sec (Mpc or more) are found to have a Doppler shift interpretable as relative velocity away from Earth.
2. This Doppler-shift measured velocity, of various galaxies receding from the Earth, is approximately proportional to their distance from the Earth for galaxies up to a few hundred mega per sec away.

   Hubble's law is considered the first observational basis for the expansion of the universe and today serves as one of the pieces of evidence most often cited in support of Big Bang model.

8. Metric and field equations

We consider Bianchi type- VI metric in the form

$ds^2 = -dt^2 + A^2dx^2 + B^2e^{-2ax}dy^2 + c^2e^{2ax}dz^2$(2.1)

Where, A, B and C are function of cosmic time t and m is a constant parameter.

Here $x^1 = x, x^2 = y, x^3 = z, x^4 = t$(2.2)

Now, for the metric (1) the components are

$$g_{11} = A^2, g_{22} = B^2e^{-2ax}, g_{33} = c^2e^{2ax}, g_{44} = -1$$

We know that

$$g^{ij} = \frac{1}{g_{ij}}$$

Now,

$$g^{11} = \frac{1}{A^2}, g^{22} = \frac{1}{B^2e^{-2ax}}, g^{33} = \frac{1}{C^2e^{2ax}}, g^{44} = -1$$

Also, we have,

$$g = |g_{ij}| = \begin{vmatrix} g_{11} & g_{12} & g_{13} & g_{14} \\ g_{21} & g_{22} & g_{23} & g_{24} \\ g_{31} & g_{32} & g_{33} & g_{34} \\ g_{41} & g_{42} & g_{43} & g_{44} \end{vmatrix}$$

$$g = \begin{vmatrix} A^2 & 0 & 0 & 0 \\ 0 & B^2e^{-2ax} & 0 & 0 \\ 0 & 0 & C^2e^{2ax} & 0 \\ 0 & 0 & 0 & -1 \end{vmatrix}$$

$$= -A^2B^2C^2$$

$$\Rightarrow -g = A^2B^2C^2$$

$$\Rightarrow \sqrt{-g} = ABC$$

$$\Rightarrow \log\sqrt{-g} = \log(ABC)$$

$$\Rightarrow \log\sqrt{-g} = \log A + \log B + \log C$$

$$\frac{\partial}{\partial x}\left(\log\sqrt{-g}\right) = 0$$

$$\frac{\partial}{\partial y}\left(\log\sqrt{-g}\right) = 0$$

$$\frac{\partial}{\partial z}\left(\log\sqrt{-g}\right) = 0$$

$$\frac{\partial}{\partial t}\left(\log\sqrt{-g}\right) = \frac{\dot{A}}{A} + \frac{\dot{B}}{B} + \frac{\dot{C}}{C}$$

$$\Rightarrow \frac{\partial^2}{\partial t^2}\left(\log\sqrt{-g}\right) = \frac{\ddot{A}}{A} + \frac{\ddot{B}}{B} + \frac{\ddot{C}}{C} - \frac{\dot{A}^2}{A^2} - \frac{\dot{B}^2}{B^2} - \frac{\dot{C}^2}{C^2}$$

The Christoffel's symbol of first kind is defined as

$$\Gamma_{ij,k} = \frac{1}{2}\left\{\frac{\partial g_{ik}}{\partial x^j} + \frac{\partial g_{jk}}{\partial x^i} - \frac{\partial g_{ij}}{\partial x^k}\right\}$$

The non-vanishing Christoffel's symbol of first kind are given by

$$\Gamma_{11}^4 = -A\dot{A} \ , \Gamma_{12}^2 = -B^2ae^{-2ax}, \quad \Gamma_{13}^3 = C^2ae^{2ax}, \quad \Gamma_{14}^1 = A\dot{A},$$

$$\Gamma_{22}^1 = B^2ae^{-2ax}, \quad \Gamma_{22}^4 = -B\dot{B}e^{-2ax}, \quad \Gamma_{24}^2 = B\dot{B}e^{-2ax}, \Gamma_{33}^1 = -C^2ae^{2ax},$$

$$\Gamma_{33}^4 = -C\dot{C}e^{2ax}, \quad \Gamma_{34}^3 = C\dot{C}e^{2ax}$$

The Christoffel's symbols of second kind is defined as

$$\Gamma_{jk}^i = g^{i\alpha}\Gamma_{jk,\alpha}$$

The non-vanishing Christoffel's symbol of second kind are given by

$$\Gamma_{11}^4 = A\dot{A}, \quad \Gamma_{12}^2 = -a, \quad \Gamma_{13}^3 = a,$$

$$\Gamma_{14}^1 = \frac{\dot{A}}{a}, \quad \Gamma_{22}^1 = \frac{B^2ae^{-2ax}}{A^2}, \quad \Gamma_{22}^4 = B\dot{B}e^{-2ax}, \quad \Gamma_{24}^2 = \frac{\dot{B}}{B}, \quad \Gamma_{33}^1 = -\frac{C^2ae^{2ax}}{A^2} \quad ,$$

$$\Gamma^4_{33} = C\dot{C}e^{2ax}, \qquad \Gamma^3_{34} = \frac{\dot{C}}{C}$$

Ricci tensor is given by

$$R_{\mu\vartheta} = \frac{\partial^2 \log\sqrt{-g}}{\partial x^\mu \, \partial x^\vartheta} - \frac{\partial \Gamma^a_{\mu\upsilon}}{\partial x^a} + \Gamma^b_{\mu a}\Gamma^a_{b\vartheta} - \Gamma^b_{\mu\vartheta}\frac{\partial \log\sqrt{-g}}{\partial x^b}$$

The non-vanishing Ricci tensors are given by

$R_{11} = \left[-\frac{1}{BC}\left(2a^2BC - A\dot{A}\dot{C}B - A\dot{A}\dot{B}C - A\ddot{A}BC\right)\right]$(2.3)

$R_{22} = \frac{1}{AC}Be^{-2ax}\left(\ddot{B}AC + \dot{B}\dot{A}C + \dot{B}\dot{C}A\right)$ (2.4)

$R_{33} = \frac{1}{AB}Ce^{2ax}\left(\ddot{C}AB + \dot{A}\dot{C}B + A\dot{B}\dot{C}\right)$(2.5)

$R_{44} = -\frac{\ddot{A}BC+\ddot{B}AC+\ddot{C}AB}{ABC}$ (2.6)

Ricci scalar is given by,

$R = g^{ii}R_{ii} = \sum_i^4 g^{ii}\, R_{ii}$ $\qquad \Rightarrow R = g^{11}R_{11} + g^{22}R_{22} + g^{33}R_{33} + g^{44}R_{44}$

$\therefore R = 2\left[-\frac{a^2}{A^2} + \frac{\ddot{A}}{A} + \frac{\dot{A}\dot{C}}{AC} + \frac{\dot{A}\dot{B}}{AB} + \frac{\ddot{B}}{B} + \frac{\dot{C}\dot{B}}{CB} + \frac{\ddot{C}}{C}\right]$ (2.7)

Einstein tensor is given by,

$G_{ij} = R_{ij} - \frac{1}{2}g_{ij}R$ (2.8)

Using equation (2.3),(2.4),(2.5),(2.6),(2.7)and values of g^{11}, g^{22}, g^{33}andg^{44} in equation (2.8) we get,

$G_{11} = a^2 + \frac{\ddot{B}}{B} + \frac{\dot{B}\dot{C}}{BC} + \frac{\ddot{C}}{C}$ (2.9)

$G_{22} = B^2e^{-2ax}\left(\frac{a^2}{A^2} - \frac{\ddot{A}}{A} - \frac{\dot{A}\dot{C}}{AC} - \frac{\ddot{C}}{C}\right)$ (2.10)

$G_{33} = C^2e^{2ax}\left(\frac{a^2}{A^2} - \frac{\ddot{A}}{A} - \frac{\dot{A}\dot{B}}{AB} - \frac{\ddot{B}}{B}\right)$(2.11)

$G_{44} = -\frac{a^2}{A^2} + \frac{\dot{A}\dot{C}}{AC} + \frac{\dot{C}\dot{B}}{BC} + \frac{\dot{A}\dot{B}}{AB}$ (2.12)

Einstein field equation is given by

$R_{ij} - \frac{1}{2}g_{ij}R = -8\pi T_{ij}$ (2.13)

Where,T_{ij} is energy-momentum tensor.

Now the energy momentum tensor for perfect fluid is given by,

$T_{ij} = (\rho + p)u_iu_j + pg_{ij} + E_{ij}$(2.14)

Where $E_{ij} = -F_{il}F^l{}_j + \frac{1}{4}g_{ij}\, F_{lm}F^{lm}$

Here ρ and p denote density and pressure respectively. And $u_i$is the four velocity vector satisfying$g^{ij}u_iu_j = 1$.

The non-vanishing components of the electromagnetic energy –momentum tensor ${E^i}_j$ are obtained as

$$E_1^1 = -E_2^2 = -E_3^3 = E_4^4 = -\frac{1}{2}g^{11}g^{44}F_{14}^2 = \frac{4\pi}{A^2}F_{14}^2$$

Now using equation (2.9)-(2.14), the Einstein field equations for the matric (2.1) reduces to following set of equations

$$\frac{\ddot{B}}{B} + \frac{\dot{B}\dot{C}}{BC} + \frac{\ddot{C}}{C} + \frac{a^2}{A^2} = -8\pi p - \frac{4\pi}{A^2}F_{14}^2 \quad (2.15)$$

$$\frac{\ddot{A}}{A} + \frac{\ddot{C}}{C} + \frac{\dot{A}\dot{C}}{AC} - \frac{a^2}{A^2} = -8\pi p + \frac{4\pi}{A^2}F_{14}^2 \quad (2.16)$$

$$\frac{\ddot{A}}{A} + \frac{\ddot{B}}{B} + \frac{\dot{A}\dot{B}}{AB} - \frac{a^2}{A^2} = -8\pi p + \frac{4\pi}{A^2}F_{14}^2 \quad (2.17)$$

$$\frac{\dot{A}\dot{B}}{AB} + \frac{\dot{A}\dot{C}}{AC} + \frac{\dot{B}\dot{C}}{BC} - \frac{a^2}{A^2} = 8\pi\rho + \frac{4\pi}{A^2}F_{14}^2 \quad (2.18)$$

$$\left(\frac{\dot{B}}{B} - \frac{\dot{C}}{C}\right) = 0 \quad (2.19)$$

The spatial volume V and average scale factor S for Bianchi type-VISpace time is defined as

$$V = S^3 = ABC \quad (2.20)$$

The generalized mean Hubble parameter H is given by

$$H = \frac{1}{3}(H_1 + H_2 + H_3) \quad (2.21)$$

Where,

$$H_1 = \frac{\dot{A}}{A}, H_2 = \frac{\dot{B}}{B}, H_3 = \frac{\dot{C}}{C}$$

Are directional Hubble parameters in x , y , z direction respectively.

The scalar expansion is defined by

$$\Theta = 3H \quad (2.22)$$

Shear scalar defined by

$$\sigma^2 = \frac{1}{2}\left(\sum_{i=1}^{3} H_i^2 - 3H^2\right) \quad (2.23)$$

The anisotropy parameter defined by

$$\Delta = \frac{1}{3}\sum_{i=1}^{3}\left(\frac{H_i - H}{H}\right)^2 \quad (2.24)$$

The declaration parameter q is defined as

$$q = -\frac{S\ddot{S}}{\dot{S}^2} \quad (2.25)$$

The sign of q indicates whether this model inflates or not.

8. Solution of the field equations

From equation (2.19) we get $B = \mathrm{m}C$ (3.1)

where m is any constant

Now let us assume, spatial volume as

$V = s^3 = \mathrm{ABC} = e^{3\alpha t^{\beta}}$(3.2)

Where $0 < \beta < 1, \alpha > 0$.

Let us assume

$A = B^n$(3.3)

Thenusing (3.1) and (3.3) in (3.2) we get

$B = m^{\frac{1}{n+2}} e^{\frac{3\alpha}{n+2} t^{\beta}}$ (3.4)

$C = m^{-\frac{n+1}{n+2}} e^{\frac{3\alpha}{n+2} t^{\beta}}$ (3.5)

$A = \mathrm{m}^{\frac{n}{n+2}} e^{\frac{3n\alpha}{n+2} t^{\beta}}$ (3.6)

Adding equation (2.15) and (2.17) and then using equation (3.4)-(3.6),

we get,

$$F_{14}^2 = \frac{9\alpha^2\beta^2 t^{2\beta-1}\left(m^{\frac{n}{n+2}} e^{\frac{3n}{n+2} t^{\beta}}\right)^2}{8\pi(n+2)^2}\left\{(n^2+1) + \frac{3\alpha\beta(\beta-1)}{n+2} t^{\beta-2}(n-1)\right\} - \frac{a^2}{4\pi} \quad (3.7)$$

Adding equation (2.15) and (2.16) and then using equation (3.4)-(3.6),

We get,

$$\mathrm{p} = -\frac{3\alpha\beta}{16\pi(n+2)}\left[\frac{9\alpha\beta}{n+2} t^{2\beta-2} + 3(\beta-1)t^{\beta-2} + \frac{3\alpha\beta}{n+2} t^{2\beta-2}(1+n)\right] \quad (3.8)$$

Using equation (3.7) in equation (2.18), we obtain

$$\rho = \frac{9\alpha^2\beta^2}{8\pi(n+2)^2} t^{2\beta-1}\left[(2n+1) - \frac{1}{2}\left\{(n^2-1) + \frac{3\alpha\beta(\beta-1)}{n+2}(n-1)\right\}\right] + \frac{a^2}{8\pi}\left[\frac{1}{4\pi} - \frac{1}{\left(n^{\frac{n}{n+2}} e^{\frac{3n\alpha}{n+2} t^{\beta}}\right)^2}\right] \quad (3.9)$$

Hubble parameter given by

$\mathrm{H} = \frac{\alpha\beta}{t^{1-\beta}}$(3.10)

Scalar expansion given by

$\Theta = \frac{3\alpha\beta}{t^{1-\beta}}$(3.11)

Shear scalar is obtained as

$\sigma^2 = \frac{3\alpha^2\beta^2(n-1)^2}{(n+2)^2(t^{1-\beta})^2}$(3.12)

Anisotropy parameter is obtained as

$\Delta = \frac{2n^2-4n+2}{(n+2)^2}$(3.13)

Deceleration parameter is obtained as

$q = -1 + \left(\frac{1-\beta}{\alpha\beta}\right)\frac{1}{t^\beta}$(3.14)

9. CONCLUSION

In this project, we have considered scale factor as $R=e^{\alpha t^\beta}$ which is a an exponential function of time t. Again the spatial volume becomes exponential function of time and we can observe that the scale factor as well as spatial volume increases at very high rate as time increases. Hubble's parameter and scalar expansion tend to zero as time tends to infinity. The value of deceleration parameter becomes -1 as time tends to infinity. For $n > 1$ the model is anisotropic and shearing. But the model becomes isotropic and shears free for $n = 1$. In this model universe the electromagnetic component F_{14} is an increasing function of time t and increases as time increases.Lastly the energy density is positive and pressure is negative in this model universe, which gives us a dark energy model with accelerated expansion of the universe.

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