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Higher Dimensional Bianchi Type I Universe in Creation-field Cosmology

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Abstract We have studied the Hoyle-Narlikar C-field cosmology with Bianchi type-I space-time in higher dimensions. Using methods of Narlikar and Padmanabhan (Phys. Rev. D 32:1928, 1985), the solutions have been studied when the creation field C is a function of time t only. The geometrical and physical aspects for model are also studied.

Keywords Bianchi type-I space-time · Creation field cosmology · Cosmological model of universe · Higher dimensions

1 Introduction

The study of higher dimensional physics is important because of several prominent results obtained in the development of the super-string theory. In the latest study of superstrings and super-gravity theories, Weinberg [19] studied the unification of the fundamental forces with gravity, which reveals that the space-time should be different from four. Since the concept of higher dimensions is not unphysical, the string theories are discussed in 10-dimensions or 26-dimensions of space-time. Because of this, studies in higher dimensions inspired many researchers to enter into such a field of study to explore the hidden knowledge of the universe. Chodos and Detweller [5], Lorentz-Petzold [13], Ibanez and Verdaguer [11], Gleiser and Diaz [6], Banerjee and Bhui [2], Reddy and Venkateswara [16], Khadekar and Gaikwad [12], Adhav et al. [1] have studied the multi-dimensional cosmological models in general relativity and in other alternative theories of gravitation.

The three important observations in astronomy viz., the phenomenon of expanding universe, primordial nucleon-synthesis and the observed isotropy of cosmic microwave background radiation (CMBR) were supposed to be successfully explained by big-bang cosmology based on Einstein's field equations. However, Smoot et al. [18] revealed that the earlier predictions of the Friedman-Robertson-Walker type of models do not always exactly meet

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our expectations. Some puzzling results regarding the red shifts from the extra galactic objects continue to contradict the theoretical explanations given from the big bang type of the model. Also, CMBR discovery did not prove it to be a out come of big bang theory. Infact, Narlikar et al. [14] have proved the possibility of non-relic interpretation of CMBR. To explain such phenomenon, many alternative theories have been proposed from time to time. Hoyle [10], Bondi and Gold [3] proposed steady state theory in which the universe does not have singular beginning nor an end on the cosmic time scale. Moreover, they have shown that the statistical properties of the large scale features of the universe do not change. Further, the constancy of the mass density has been accounted by continuous creation of matter going on in contrast to the one time infinite and explosive creation of matter at $t = 0$ as in the earlier standard model. But the principle of conservation of matter was violated in this formalism. To overcome this difficulty Hoyle and Narlikar [9] adopted a field theoretic approach by introducing a massless and chargeless scalar field C in the Einstein-Hilbert action to account for the matter creation. In the C-field theory introduced by Hoyle and Narlikar there is no big bag type of singularity as in the steady state theory of Bondi and Gold [10]. A solution of Einstein's field equations admitting radiation with negative energy massless scalar creation fields C was obtained by Narlikar and Padmanabhan [15]. The study of Hoyle and Narlikar theory [7–9] to the space-time of dimensions more than four was carried out by Chatterjee and Banerjee [4]. The solutions of Einstein's field equations in the presence of creation field have been obtained for Bianchi type-I universe in four dimensions by Singh and Chaubey [17].

Here, we have considered a spatially homogeneous and anisotropic Bianchi type-I cosmological model in Hoyle and Narlikar C-field cosmology with five dimensions. We have assumed that the creation field C is a function of time t only i.e. $C(x,t) = C(t)$.

This study is important because of the fact that the resulting cosmological model is considered to be amenable to the model obtained by Singh and Chaubey [17].

2 Hoyle and Narlikar *C*-field Cosmology

Introducing a massless scalar field called as creation field viz. C-field, Einstein's field equations are modified. Hoyle and Narlikar [7–9] field equations are

$$R_{ij} - \frac{1}{2} g_{ij} R = -8\pi ({}^{m}T_{ij} + {}^{c}T_{ij}), \tag{2.1}$$

where ${}^{m}T_{ij}$ is matter tensor of Einstein theory and ${}^{c}T_{ij}$ is matter tensor due to the C-field which is given by

$${}^{c}T_{ij} = -f\left(C_i C_j - \frac{1}{2} g_{ij} C^k C_k\right), \tag{2.2}$$

where $f > 0$ and $C_i = \frac{\partial C}{\partial x^i}$.

Because of the negative value of T^{00} ($T^{00} < 0$), the C-field has negative energy density producing repulsive gravitational field which causes the expansion of the universe. Hence, the energy conservation equation reduces to

$${}^{m}T^{ij}{}_{;j} = -{}^{c}T^{ij}{}_{;j} = f C^i C^j{}_{;j} \tag{2.3}$$

i.e. matter creation through non-zero left hand side is possible while conserving the over all energy and momentum.

Above equation is similar to

$$mg_{ij}\frac{dx^i}{ds} - C_j = 0, \tag{2.4}$$

which implies that the 4-momentum of the created particle is compensated by the 4-momentum of the C-field. In order to maintain the balance, the C-field must have negative energy. Further, the C-field satisfy the source equation $fC^i{}_{;i} = J^i{}_{;i}$ and $J^i = \rho\frac{dx^i}{ds} = \rho v^i$, where ρ is homogeneous mass density.

3 Metric and Field Equations

The five-dimensional Bianchi-Type-I line element can be written as

$$ds^2 = dt^2 - a_1^2 dx^2 - a_2^2 dy^2 - a_3^2 dz^2 - a_4^2 du^2, \tag{3.1}$$

where a_1, a_2, a_3 and a_4 are functions of t only.

Here the extra coordinate is taken to be space like.

We have assumed that creation field C is function of time t only i.e.

$$C(x,t) = C(t) \quad \text{and} \quad {}^mT^i_j = \operatorname{diag}(\rho, -p, -p, -p, -p). \tag{3.2}$$

We have assumed that velocity of light and gravitational constant are equal to one unit.

Now, the Hoyle-Narlikar field equations (2.1) for metric (3.1) with the help of (2.2), (2.3), and (3.2) can be written as

$$\frac{\dot a_1 \dot a_2}{a_1 a_2} + \frac{\dot a_1 \dot a_3}{a_1 a_3} + \frac{\dot a_1 \dot a_4}{a_1 a_4} + \frac{\dot a_2 \dot a_3}{a_2 a_3} + \frac{\dot a_2 \dot a_4}{a_2 a_4} + \frac{\dot a_3 \dot a_4}{a_3 a_4} = 8\pi\left(\rho - \frac{1}{2}f\dot C^2\right), \tag{3.3}$$

$$\frac{\ddot a_2}{a_2} + \frac{\ddot a_3}{a_3} + \frac{\ddot a_4}{a_4} + \frac{\dot a_2 \dot a_3}{a_2 a_3} + \frac{\dot a_2 \dot a_4}{a_2 a_4} + \frac{\dot a_3 \dot a_4}{a_3 a_4} = 8\pi\left(-p + \frac{1}{2}f\dot C^2\right), \tag{3.4}$$

$$\frac{\ddot a_1}{a_1} + \frac{\ddot a_3}{a_3} + \frac{\ddot a_4}{a_4} + \frac{\dot a_1 \dot a_3}{a_1 a_3} + \frac{\dot a_1 \dot a_4}{a_1 a_4} + \frac{\dot a_3 \dot a_4}{a_3 a_4} = 8\pi\left(-p + \frac{1}{2}f\dot C^2\right), \tag{3.5}$$

$$\frac{\ddot a_1}{a_1} + \frac{\ddot a_2}{a_2} + \frac{\ddot a_4}{a_4} + \frac{\dot a_1 \dot a_2}{a_1 a_2} + \frac{\dot a_1 \dot a_4}{a_1 a_4} + \frac{\dot a_2 \dot a_4}{a_2 a_4} = 8\pi\left(-p + \frac{1}{2}f\dot C^2\right), \tag{3.6}$$

$$\frac{\ddot a_1}{a_1} + \frac{\ddot a_2}{a_2} + \frac{\ddot a_3}{a_3} + \frac{\dot a_1 \dot a_2}{a_1 a_2} + \frac{\dot a_1 \dot a_3}{a_1 a_3} + \frac{\dot a_2 \dot a_3}{a_2 a_3} = 8\pi\left(-p + \frac{1}{2}f\dot C^2\right), \tag{3.7}$$

$$\dot\rho + \left(\frac{\dot a_1}{a_1} + \frac{\dot a_2}{a_2} + \frac{\dot a_3}{a_3} + \frac{\dot a_4}{a_4}\right)(\rho + p) = f\dot C\left[\ddot C + \left(\frac{\dot a_1}{a_1} + \frac{\dot a_2}{a_2} + \frac{\dot a_3}{a_3} + \frac{\dot a_4}{a_4}\right)\dot C\right], \tag{3.8}$$

where dot $(\cdot)$ indicates the derivative with respect to t.

Assuming

$$V = a_1 a_2 a_3 a_4 \tag{3.9}$$

above (3.8) can be written in the form

$$\frac{d}{dV}(V\rho) + p = f\dot C(V)\frac{d}{dV}[V\dot C(V)]. \tag{3.10}$$

In order to obtain a unique solution, one has to specify the rate of creation of matter-energy (at the expense of the negative energy of the C-field). Without loss of generality, we assume that the rate of creation of matter energy density is proportional to the strength of the existing C-field energy-density, i.e. the rate of creation of matter energy density per unit proper-volume is given by

$$\frac{d}{dV}(V\rho) + p = \alpha^2 \dot{C}^2 \equiv \alpha^2 g^2(V), \tag{3.11}$$

where α is proportionality constant and we have defined $\dot{C}(V) \equiv g(V)$.

Substituting it in (3.10), we get

$$\frac{d}{dV}(V\rho) + p = f g(V) \frac{d}{dV}(Vg). \tag{3.12}$$

Comparing right hand sides of (3.11) and (3.12), we get

$$g(V)\frac{d}{dV}(gV) = \frac{\alpha^2}{f} g^2(V). \tag{3.13}$$

Integrating, which gives

$$g(V) = BV^{(\frac{\alpha^2}{f}-1)}, \tag{3.14}$$

where B is arbitrary constant of integration.

We consider the equation of state of matter as

$$p = \gamma\rho. \tag{3.15}$$

Substituting (3.14) and (3.15) in (3.11), we get

$$\frac{d}{dV}(V\rho) + \gamma\rho = \alpha^2 B^2 V^{2(\frac{\alpha^2}{f}-1)}. \tag{3.16}$$

Which further yields

$$\rho = \frac{\alpha^2 B^2}{(2\frac{\alpha^2}{f} - 1 + \gamma)} V^{2(\frac{\alpha^2}{f}-1)}. \tag{3.17}$$

Subtracting (3.4) from (3.5), we get

$$\frac{d}{dt}\left(\frac{\dot{a}_1}{a_1} - \frac{\dot{a}_2}{a_2}\right) + \left(\frac{\dot{a}_1}{a_1} - \frac{\dot{a}_2}{a_2}\right)\left(\frac{\dot{a}_1}{a_1} + \frac{\dot{a}_2}{a_2} + \frac{\dot{a}_3}{a_3} + \frac{\dot{a}_4}{a_4}\right) = 0. \tag{3.18}$$

Now, from (3.9) and (3.18), we get

$$\frac{d}{dt}\left(\frac{\dot{a}_1}{a_1} - \frac{\dot{a}_2}{a_2}\right) + \left(\frac{\dot{a}_1}{a_1} - \frac{\dot{a}_2}{a_2}\right)\frac{\dot{V}}{V} = 0.$$

Integrating, which gives

$$\frac{a_1}{a_2} = d_1 \exp\left(x_1 \int \frac{dt}{V}\right), \quad d_1 = \text{constant}, \ x_1 = \text{constant}. \tag{3.19}$$

Subtracting (3.5) from (3.6), we get

$$\frac{d}{dt}\left(\frac{\dot{a}_2}{a_2}-\frac{\dot{a}_3}{a_3}\right)+\left(\frac{\dot{a}_2}{a_2}-\frac{\dot{a}_3}{a_3}\right)\frac{\dot{V}}{V}=0.$$

Integrating, we get

$$\frac{a_2}{a_3}=d_2\exp\left(x_2\int\frac{dt}{V}\right),\qquad d_2=\text{constant},\ x_2=\text{constant}. \tag{3.20}$$

Subtracting (3.6) from (3.7), we get

$$\frac{d}{dt}\left(\frac{\dot{a}_3}{a_3}-\frac{\dot{a}_4}{a_4}\right)+\left(\frac{\dot{a}_3}{a_3}-\frac{\dot{a}_4}{a_4}\right)\frac{\dot{V}}{V}=0.$$

Which on integration gives

$$\frac{a_3}{a_4}=d_3\exp\left(x_3\int\frac{dt}{V}\right),\qquad d_3=\text{constant},\ x_3=\text{constant}. \tag{3.21}$$

Subtracting (3.4) from (3.7), we get

$$\frac{d}{dt}\left(\frac{\dot{a}_1}{a_1}-\frac{\dot{a}_4}{a_4}\right)+\left(\frac{\dot{a}_1}{a_1}-\frac{\dot{a}_4}{a_4}\right)\frac{\dot{V}}{V}=0.$$

Integrating, we get

$$\frac{a_1}{a_4}=d_4\exp\left(x_4\int\frac{dt}{V}\right),\qquad d_4=\text{constant},\ x_4=\text{constant}, \tag{3.22}$$

where $d_4=d_1d_2d_3$, $x_4=x_1+x_2+x_3$ and $V=a_1a_2a_3a_4$.

Using (3.19), (3.20), (3.21), and (3.22), the values of $a_1(t)$, $a_2(t)$, $a_3(t)$, and $a_4(t)$ can be written explicitly as

$$a_1(t)=D_1V^{1/4}\exp\left(X_1\int\frac{dt}{V}\right), \tag{3.23a}$$

$$a_2(t)=D_2V^{1/4}\exp\left(X_2\int\frac{dt}{V}\right), \tag{3.23b}$$

$$a_3(t)=D_3V^{1/4}\exp\left(X_3\int\frac{dt}{V}\right), \tag{3.23c}$$

$$a_4(t)=D_4V^{1/4}\exp\left(X_4\int\frac{dt}{V}\right), \tag{3.23d}$$

where the relations $D_1D_2D_3D_4=1$ and $X_1+X_2+X_3+X_4=0$ are satisfied by D_i $(i=1,2,3,4)$ and X_i $(i=1,2,3,4)$.

Adding (3.4), (3.5), (3.6), (3.7) and 4 times (3.3), we get

$$\left(\frac{\ddot{a}_1}{a_1}+\frac{\ddot{a}_2}{a_2}+\frac{\ddot{a}_3}{a_3}+\frac{\ddot{a}_4}{a_4}\right)+2\left(\frac{\dot{a}_1\dot{a}_2}{a_1a_2}+\frac{\dot{a}_2\dot{a}_3}{a_2a_3}+\frac{\dot{a}_3\dot{a}_1}{a_3a_1}+\frac{\dot{a}_1\dot{a}_4}{a_1a_4}+\frac{\dot{a}_2\dot{a}_4}{a_2a_4}+\frac{\dot{a}_3\dot{a}_4}{a_3a_4}\right)$$
$$=\frac{32}{3}\pi(\rho-p). \tag{3.24}$$

From (3.9) we have

$$\frac{\ddot{V}}{V}=\left(\frac{\ddot{a}_1}{a_1}+\frac{\ddot{a}_2}{a_2}+\frac{\ddot{a}_3}{a_3}+\frac{\ddot{a}_4}{a_4}\right)+2\left(\frac{\dot{a}_1\dot{a}_2}{a_1a_2}+\frac{\dot{a}_2\dot{a}_3}{a_2a_3}+\frac{\dot{a}_3\dot{a}_1}{a_3a_1}+\frac{\dot{a}_1\dot{a}_4}{a_1a_4}+\frac{\dot{a}_2\dot{a}_4}{a_2a_4}+\frac{\dot{a}_3\dot{a}_4}{a_3a_4}\right). \tag{3.25}$$

From (3.24), (3.25) and (3.15), we get

$$\frac{\ddot{V}}{V}=\frac{32}{3}\pi(1-\gamma)\rho. \tag{3.26}$$

Substituting (3.17) in (3.26), we get

$$\frac{\ddot{V}}{V}=\frac{32}{3}\frac{\pi(1-\gamma)\alpha^2B^2}{(2\frac{\alpha^2}{f}-1+\gamma)}V^{2(\frac{\alpha^2}{f}-1)}. \tag{3.27}$$

Which further gives

$$V=\left\{B(f-\alpha^2)\left[\frac{32(1-\gamma)}{3(2\alpha^2-f+\gamma f)}\right]^{1/2}\right\}^{\frac{f}{f-\alpha^2}}t^{\frac{f}{f-\alpha^2}}. \tag{3.28}$$

Substituting (3.28) in (3.14), we get

$$g=\frac{1}{(f-\alpha^2)}\left[\frac{32\pi(1-\gamma)}{3(2\alpha^2-f+\gamma f)}\right]^{-1/2}\frac{1}{t}. \tag{3.29}$$

Also, from equation $\dot{C}(V)=g(V)$, we get

$$C=\frac{1}{(f-\alpha^2)}\left[\frac{32\pi(1-\gamma)}{3(2\alpha^2-f+\gamma f)}\right]^{-1/2}\log t. \tag{3.30}$$

Substituting (3.28) in (3.17), the homogeneous mass density becomes

$$\rho=\frac{3\alpha^2 f}{32\pi(1-\gamma)(f-\alpha^2)^2}\frac{1}{t^2}. \tag{3.31}$$

Using (3.15), pressure becomes

$$p=\frac{3\alpha^2\gamma f}{32\pi(1-\gamma)(f-\alpha^2)^2}\frac{1}{t^2}. \tag{3.32}$$

From (3.31) and (3.32), it is observed that

(i) When time $t\to\infty$, we get, density and pressure tending to zero i.e. the model reduces to vacuum.

(ii) When $f=\alpha^2$, there is singularity in density and pressure.
(iii) There is also singularity in density and pressure for $\gamma=1$.

Using (3.28) in (3.23a), (3.23b), (3.23c), and (3.23d), we get

$$a_1(t)=D_1K^{1/4}t^{\frac{f}{4(f-\alpha^2)}}\exp\left[\frac{X_1}{K}\left(1-\frac{f}{\alpha^2}\right)t^{\frac{\alpha^2}{\alpha^2-f}}\right], \tag{3.33a}$$

$$a_2(t)=D_2K^{1/4}t^{\frac{f}{4(f-\alpha^2)}}\exp\left[\frac{X_2}{K}\left(1-\frac{f}{\alpha^2}\right)t^{\frac{\alpha^2}{\alpha^2-f}}\right], \tag{3.33b}$$

$$a_3(t)=D_3K^{1/4}t^{\frac{f}{4(f-\alpha^2)}}\exp\left[\frac{X_3}{K}\left(1-\frac{f}{\alpha^2}\right)t^{\frac{\alpha^2}{\alpha^2-f}}\right], \tag{3.33c}$$

$$a_4(t)=D_4K^{1/4}t^{\frac{f}{4(f-\alpha^2)}}\exp\left[\frac{X_4}{K}\left(1-\frac{f}{\alpha^2}\right)t^{\frac{\alpha^2}{\alpha^2-f}}\right], \tag{3.33d}$$

where

$$K=\left\{B(f-\alpha^2)\left[\frac{32\pi(1-\gamma)}{3(2\alpha^2-f+\gamma f)}\right]^{1/2}\right\}^{\frac{f}{f-\alpha^2}}$$

and D_1, D_2, D_3, D_4 andX_1, X_2, X_3, X_4 are constants of integration, satisfying the relations $D_1D_2D_3D_4=1$ and $X_1+X_2+X_3+X_4=0$.

4 Physical Properties

The expansion scalar θ is given by

$$\begin{aligned}\theta&=4H,\\ \theta&=\left(\frac{f}{f-\alpha^2}\right)\frac{1}{t}.\end{aligned} \tag{4.1}$$

The mean anisotropy parameter is given by

$$\begin{aligned}A&=\frac{1}{4}\sum_{i=1}^{4}\left(\frac{\Delta H_i}{H}\right)^2,\\ A&=\frac{4X^2}{K^2}\left(\frac{f-\alpha^2}{f}\right)^2t^{2(\frac{\alpha^2}{\alpha^2-f})}.\end{aligned} \tag{4.2}$$

The shear scalar σ^2 is given by

$$\begin{aligned}\sigma^2&=\frac{1}{2}\left(\sum_{i=1}^{4}H_i^2-4H^2\right)=\frac{4}{2}AH^2,\\ \sigma^2&=\frac{X^2}{2K^2}t^{2(\frac{f}{\alpha^2-f})}.\end{aligned} \tag{4.3}$$

The deceleration parameter q is given by

$$q = \frac{d}{dt}\left(\frac{1}{H}\right) - 1,$$
$$q = 3 - \frac{4\alpha^2}{f}, \tag{4.4}$$

where $\Delta H_i = H_i - H$.

Here H is Hubble parameter and

$$X^2 = X_1^2 + X_2^2 + X_3^2 + X_4^2.$$

If $f > \alpha^2$ then for large t, the model tends to isotropic case.

Case I: $\gamma = 0$ (Dust):

In this case, we obtain the values of various parameters as

$$g = \frac{1}{f-\alpha^2}\left[\frac{3(2\alpha^2 - f)}{32\pi}\right]^{1/2}\frac{1}{t},$$
$$C = \frac{1}{f-\alpha^2}\left[\frac{3(2\alpha^2 - f)}{32\pi}\right]^{1/2}\log t,$$
$$\rho = \frac{3\alpha^2 f}{32\pi(f-\alpha^2)^2}\frac{1}{t^2},$$
$$a_1(t) = D_1 K_1^{1/4} t^{\frac{f}{4(f-\alpha^2)}} \exp\left[\frac{X_1}{K_1}\left(1 - \frac{f}{\alpha^2}\right)t^{\frac{\alpha^2}{\alpha^2 - f}}\right],$$
$$a_2(t) = D_2 K_1^{1/4} t^{\frac{f}{4(f-\alpha^2)}} \exp\left[\frac{X_2}{K_1}\left(1 - \frac{f}{\alpha^2}\right)t^{\frac{\alpha^2}{\alpha^2 - f}}\right],$$
$$a_3(t) = D_3 K_1^{1/4} t^{\frac{f}{4(f-\alpha^2)}} \exp\left[\frac{X_3}{K_1}\left(1 - \frac{f}{\alpha^2}\right)t^{\frac{\alpha^2}{\alpha^2 - f}}\right],$$
$$a_4(t) = D_4 K_1^{1/4} t^{\frac{f}{4(f-\alpha^2)}} \exp\left[\frac{X_4}{K_1}\left(1 - \frac{f}{\alpha^2}\right)t^{\frac{\alpha^2}{\alpha^2 - f}}\right],$$

where

$$K_1 = \left\{B(f-\alpha^2)\left[\frac{32\pi}{3(2\alpha^2 - f)}\right]^{1/2}\right\}^{\frac{f}{f-\alpha^2}}.$$

Here D_1, D_2, D_3, D_4 and X_1, X_2, X_3, X_4 are constants of integration, satisfying the relations $D_1 D_2 D_3 D_4 = 1$ and $X_1 + X_2 + X_3 + X_4 = 0$.

In this case, the expansion scalar θ is given by

$$\theta = \left(\frac{f}{f-\alpha^2}\right)\frac{1}{t}.$$

The mean anisotropy parameter is given by

$$A = \frac{4X^2}{K_1^2}\left(\frac{f-\alpha^2}{f}\right)^2 t^{2(\frac{\alpha^2}{\alpha^2-f})}.$$

The shear scalar σ^2 is given by

$$\sigma^2 = \frac{X^2}{2K_1^2} t^{2(\frac{f}{\alpha^2-f})}.$$

The deceleration parameter q is given by

$$q = 3 - \frac{4\alpha^2}{f},$$

where $X^2 = X_1^2 + X_2^2 + X_3^2 + X_4^2$.

If $f > \alpha^2$, this model also tends to isotropy for large t.

Case II: $\gamma = \frac{1}{3}$ (Disordered Radiation):

In this case, we obtain the values of various parameter as

$$g = \frac{1}{f-\alpha^2}\left[\frac{3(3\alpha^2-f)}{32\pi}\right]^{1/2}\frac{1}{t},$$

$$C = \frac{1}{f-\alpha^2}\left[\frac{3(3\alpha^2-f)}{32\pi}\right]^{1/2}\log t,$$

$$\rho = \frac{9\alpha^2 f}{64\pi(f-\alpha^2)^2}\frac{1}{t^2},$$

$$p = \frac{3\alpha^2 f}{64\pi(f-\alpha^2)^2}\frac{1}{t^2},$$

$$a_1(t) = D_1 K_2^{1/4} t^{\frac{f}{4(f-\alpha^2)}} \exp\left[\frac{X_1}{K_1}\left(1-\frac{f}{\alpha^2}\right)t^{\frac{\alpha^2}{\alpha^2-f}}\right],$$

$$a_2(t) = D_2 K_2^{1/4} t^{\frac{f}{4(f-\alpha^2)}} \exp\left[\frac{X_2}{K_1}\left(1-\frac{f}{\alpha^2}\right)t^{\frac{\alpha^2}{\alpha^2-f}}\right],$$

$$a_3(t) = D_3 K_2^{1/4} t^{\frac{f}{4(f-\alpha^2)}} \exp\left[\frac{X_3}{K_1}\left(1-\frac{f}{\alpha^2}\right)t^{\frac{\alpha^2}{\alpha^2-f}}\right],$$

$$a_4(t) = D_4 K_2^{1/4} t^{\frac{f}{4(f-\alpha^2)}} \exp\left[\frac{X_4}{K_1}\left(1-\frac{f}{\alpha^2}\right)t^{\frac{\alpha^2}{\alpha^2-f}}\right],$$

where

$$K_2 = \left\{B(f-\alpha^2)\left[\frac{32\pi}{3(3\alpha^2-f)}\right]^{1/2}\right\}^{\frac{f}{f-\alpha^2}}.$$

Here D_1, D_2, D_3, D_4 and X_1, X_2, X_3, X_4 are constants of integration, satisfying the relations $D_1D_2D_3D_4 = 1$ and $X_1 + X_2 + X_3 + X_4 = 0$.

In this case, the expansion scalar θ is given by

$$\theta = \left(\frac{f}{f-\alpha^2}\right)\frac{1}{t}.$$

The mean anisotropy parameter is given by

$$A = \frac{4X^2}{K_2^2}\left(\frac{f-\alpha^2}{f}\right)^2 t^{2(\frac{\alpha^2}{\alpha^2-f})}.$$

The shear scalar σ^2 is given by

$$\sigma^2 = \frac{X^2}{2K_2^2} t^{2(\frac{f}{\alpha^2-f})}.$$

The deceleration parameter q is given by

$$q = 3 - \frac{4\alpha^2}{f}$$

where $X^2 = X_1^2 + X_2^2 + X_3^2 + X_4^2$.

For $f > \alpha^2$, this model also tends to isotropy for large t.

5 Conclusion

In this paper we have considered the space-time geometry corresponding to Bianchi type-I in Hoyle-Narlikar [7–9] creation field theory of gravitation with five dimensions. Bianchi type-I universe in creation-field cosmology has been investigated by Singh and Chaubey [17] whose work has been extended and studied in five dimensions. An attempt has been made to retain Singh and Chaubey's [17] forms of the various quantities. We have noted that all the results of Singh and Chaubey [17] can be obtained from our results by assigning appropriate values to the functions concerned.

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