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Barotropic Cosmological Models with Varying Gravitational Constant in Hoyle Narlikar's Creation Field Theory of Gravitation

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Abstract

Plane symmetric and LRS Bianchi type – V cosmological models have been studied with varying gravitational constant G in Hoyle Narlikar's creation field theory of gravitation for the barotropic fluid distribution. The solution of the field equations have been obtained by assuming that $G=B^m$, where B is scale factor and m is a constant, Also, the physical properties of the model are studied.

Keywords: creation field theory, varying gravitational constant, plane symmetric, LRS Bianchi Type-V.

1. Introduction

For early development of the Universe, the most prevailing cosmological model is given by Big Bang theory Called Big Bang Model of universe, which is based on Albert Einstein's General Relativity [1]. According to this model, universe is continuously expanding from an extremely hot and dense state. This theory offers an extensive explanation for a broad range of observed phenomena, including cosmic microwave background, large scale structure, abundance of light element and Hubble's law. Also big bang theory helps to simplify assumptions such as homogeneity and isotropy of space. But the state of universe is poorly understood in the earliest instants of big bang expansion. This theory fails to provide the explanation for initial condition of universe.

Three outstanding problems are generally considered with big bang theory: The horizon problem, flatness problem and magnetic monopole problem. After that alternative theories were proposed from time to time, the well-known theory was steady state theory given by Bondi and Gold [2]. According to steady state theory, universe has no beginning nor end in time. Steady state theory is a view that a universe is always expanding but with this a constant average density has maintained. But again it is now rejected as the observations shown clearly the big bang type cosmology and fine age universe and contradicts to fundamental laws of physics which states that matter and energy are interchangeable but the total amount of energy and matter in this

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universe remains constant. But steady state theory requires the continuous creation of matter in violation of this law. For maintenance of uniformity of the mass density, they visualized the very slow but continuous creation at $t = 0$, however it suffers from serious drawback of not giving any physical justification for continuous creation of matter.

Hoyle and Narlikar [3-5] introduced the C-field theory which admits the possibility of an ever existing expanding universe with constant density of matter. In this theory due the presence of an appropriate creation field with negative energy the constancy of matter density is possible. Narlikar [6] also investigated that matter creation is accomplished at the expense of negative energy C-field. And that introduction of negative energy field has solved the problem of horizon and flatness faced by big bang model. Bali and Tikekar [7] investigated C field cosmological model for dust distribution with variable gravitational constant in framework of flat FRW space time. Solutions of Einstein field equation admitting radiation with a negative energy massless scalar field C have been obtained by Narlikar and Padmnabhan [8]. Chatterjee and Bannerjee [9] have studied C- field cosmology in higher dimensions. Singh and Chaubey [10] have investigated Bianchi type I, III, V, VI and Kantowski Sach universes in creation field cosmology. Adhav *et al.* [11] have obtained Kasner and Axially symmetric universes in C field theory of gravitation. Adhav *et al.* [12] investigated stiff domain walls in creation field cosmology. Bali and Saraf [13] have investigated C-field cosmological model for dust distribution with varying λ. Recently Ghate *et al.* [14-16]have studied the cosmological models in creation field theory of gravitation with different contexts.

The cosmological constant λ and the gravitational constant G are two parameters present in Einstein's field equations. In cosmological point of view, Dirac [17] was the first cosmologist to draw the attention of scientific community towards the possibility of a time dependent gravitational constant. The Newtonian constant of gravitation G plays the role of coupling constant between gravitation and matter. In Einstein's field equations to achieve the possible unification of gravitation and elementary particle physics (or to incorporate Mach's principle in general relativity) numerous modifications are made in general relativity where G varies with time. The implications of time varying G are important only at early stages of evolution of universe.

The theory of an expanding universe also supports the idea of time dependent gravitational constant [18]. After the emergence of superstring theory Marciano [19] had considered the gravitational constant G as a dynamical quantity. Goldman [20] had shown that the scale dependent G can represent dark matter. Stefancic [21] had investigated a phantom energy model with time varying G. Variability of G was also supported by the results coming up from type Ia supernova observations [22]. Recently Ray and Mukhopadhyay [23] have obtained dark energy models with time dependent gravitational constant. Bali and Kumawat [24] have studied cosmological model with variable G in C-field theory.

In this paper, Plane symmetric and LRS Bianchi type-V cosmological models have been studied in Hoyle Narlika's creation field theory of gravitation. The source of energy momentum tensor is the barotropic fluid with varying gravitational constant. The solution of the field equations have been obtained by assuming that $G = B^m$, where B is scale factor and m is a constant. The physical properties of the model are studied.

2. Hoyle-Narlikar Theory

The Einstein field equations are modified by Hoyle and Narlikar [3-5] through the introduction of a massless scalar field usually called Creation field *viz*. *C*-field. The modified field equations are

$$R_i^j - \frac{1}{2} R g_i^j = -8\pi G \left[\underset{(m)}{T_i^j} + \underset{(c)}{T_i^j} \right], \tag{2.1}$$

where $\underset{(m)}{T_i^j}$ is a matter tensor for perfect fluid of Einstein's theory given by

$$\underset{(m)}{T_i^j} = (\rho + p) v_i v^j - p g_i^j \tag{2.2}$$

and $\underset{(c)}{T_i^j}$ is a matter tensor due to C-field given by

$$\underset{(c)}{T_i^j} = -f\left(C_i C^j - \frac{1}{2} g_i^j C^\alpha C_\alpha \right), \tag{2.3}$$

Here ρ is the energy density of massive particles and p is the pressure. v_i are co- moving four velocities which obeys the relation $v_i v^j = 1, v_\alpha = 0$, $\alpha = 1, 2, 3$. $f > 0$ is the coupling constant between matter and creation field and $C_i = \frac{dC}{dx^i}$.

As T^{00} has negative value (i.e. $T^{00} < 0$), the *C*-field has negative energy density producing repulsive gravitational field which causes the expansion of the universe. Thus the energy conservation law reduces to

$$^{(m)}T^{ij}{}_{;j} = -{}^{(c)}T^{ij}{}_{;j} = f C^i C^j{}_{;j}, \tag{2.4}$$

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

The above equation is identical with

$$mg_{ij}\frac{dx^i}{ds}-C_j=0, \tag{2.5}$$

which gives the 4-momentum of the created particle is compensated by 4-momentum of the C-field. In order to maintain the balance the C-field must have negative energy.

Further, the C-field satisfies the source equation

$$fC^i{}_{;i}=J^i{}_{;i} \quad \text{and} \quad J^i=\rho\frac{dx^i}{ds}=\rho v^i, \tag{2.6}$$

where ρ is the homogeneous mass density.

The conservation equation for C-field is given by

$$\left(8\pi G T_i^{\,j}\right)_{;j}=0. \tag{2.7}$$

The physical quantities in cosmology are the expansion scalar θ, the mean anisotropy parameter Δ, the shear scalar σ^2 and the deceleration parameter q are defined as

$$\theta=3H, \tag{2.8}$$

$$\Delta=\frac{1}{3}\sum_{i=1}^{3}\left(\frac{H_i-H}{H}\right)^2, \tag{2.9}$$

$$\sigma^2=\frac{1}{2}\left(\sum H_i^{\,2}-3H^2\right)=\frac{3}{2}\Delta H^2, \tag{2.10}$$

$$q=-\frac{\ddot{R}/R}{\dot{R}^2/R^2}, \tag{2.11}$$

where H is a Hubble parameter.

3. Plane Symmetric Universe

Plane symmetric metric is considered in the form,

$$ds^2=dt^2-A^2(dx^2+dy^2)-B^2dz^2, \tag{3.1}$$

where $A,\ B$ are scale factors and are functions of cosmic time t.

It is assumed that creation field C is a function of time only i.e. $C(x,t)=C(t)$ and $\underset{(m)}{T_i^{\,j}}=(\rho,-p,-p,-p)$.

The field equations (2.1) for metric (3.1), with the help of equations (2.2) and (2.3) are given by

$$\frac{\dot{A}^2}{A^2}+2\frac{\dot{A}\dot{B}}{AB}=8\pi G(t)\left(\rho-\frac{1}{2}f\dot{C}^2\right), \tag{3.2}$$

$$\frac{\ddot{A}}{A}+\frac{\ddot{B}}{B}+\frac{\dot{A}\dot{B}}{AB}=8\pi G(t)\left(\frac{1}{2}f\dot{C}^2-p\right), \tag{3.3}$$

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

where over dot $\left(\cdot\right)$ denotes the partial differentiation w. r. to t

The conservation equation (2.7) for the metric (3.1) is

$$8\pi\dot{G}(\rho-\frac{1}{2}f\dot{C}^2)+8\pi G\left[\dot{\rho}-f\dot{C}\ddot{C}+\rho\left(2\frac{\dot{A}}{A}+\frac{\dot{B}}{B}\right)+\left(f\dot{C}^2-p\right)\left(2\frac{\dot{A}}{A}+\frac{\dot{B}}{B}\right)\right]=0, \tag{3.5}$$

Solutions of the Field Equations

The field equations (3.2-3.4) are three independent equations which contain five unknowns $A,\ B, G,\ \rho$ and p. Hence two additional conditions may be used to obtain the solution.

We assume that the expansion θ in the model is proportional to σ. This condition leads to

$$B=A^n, \tag{3.6}$$

where n is the proportionality constant.

The motive behind assuming condition is explained with reference to Thorne [25].

Observations of the velocity red-shift relation for extra galactic sources suggest that Hubble expansion of the universe is isotropic today within ≈ 30 percent [26, 27]. To put more precisely, red shift place the limit $\frac{\sigma}{\theta}\leq 0.3$ on the ratio of shear σ to Hubble constant H in the neighborhood of our galaxy today. Collin *et al.* [28] have pointed that for spatially homogeneous metric, the normal congruence to the homogeneous expansion satisfies that the condition $\frac{\sigma}{\theta}$ is constant.

Using equation (3.6), field equations (3.2-3.5)take the form

$$\left(2n+1\right)\frac{\dot{A}^2}{A^2}=8\pi G\left(\rho-\frac{1}{2}f\dot{C}^2\right), \tag{3.7}$$

$$2\frac{\ddot{A}}{A}+\frac{\dot{A}^2}{A^2}=8\pi G\left(\frac{1}{2}f\dot{C}^2-p\right). \tag{3.8}$$

$$8\pi\dot{G}(\rho-\frac{1}{2}f\dot{C}^2)+8\pi G\left[\dot{\rho}-f\dot{C}\ddot{C}+(n+2)\rho\frac{\dot{A}}{A}-(n+2)f\dot{C}^2\frac{\dot{A}}{A}+(n+2)p\frac{\dot{A}}{A}\right]=0. \tag{3.9}$$

Following Hoyle and Narlikar, the source equation of C-field: $C^i_{;i}=0$ leads to $C=t$ for large r. Thus $\dot{C}=1$.

Using $\dot{C}=1$, equation (3.7) leads to

$$8\pi G\rho=(2n+1)\frac{\dot{A}^2}{A}+4\pi Gf\ . \tag{3.10}$$

Using $\dot{C}=1$ and barotropic condition $p=\gamma\rho$ in (3.8), we have

$$2\frac{\ddot{A}}{A}+\frac{\dot{A}^2}{A^2}=4\pi Gf-8\pi G\gamma\rho, \tag{3.11}$$

where $0\le\gamma\le1$.

Multipling equation (3.10) by γ and adding (3.11) gives

$$2\frac{\ddot{A}}{A}+[(2n+1)\gamma+1]\frac{\dot{A}^2}{A^2}=(1-\gamma)4\pi Gf\ . \tag{3.12}$$

To obtain the deterministic solution, we assume

$$G=A^m, \tag{3.13}$$

where m is a constant and A is the scale factor.

Using equation (3.13) in equation (3.12), we get

$$2\ddot{A}+\left[(2n+1)\gamma+1\right]\frac{\dot{A}^2}{A}=(1-\gamma)4\pi fA^{m+1}. \tag{3.14}$$

Let us assume that $\dot{A}=F(A)$

This leads to $\ddot{A}=FF'$ with $F'=\frac{dF}{dA}$.

Using this in equation (3.14) it reduces to

$$\frac{dF^2}{dA}+\left[(2n+1)\gamma+1\right]\frac{\dot{A}^2}{A}=(1-\gamma)4\pi fA^{1+m}, \tag{3.15}$$

which on simplification gives

$$F^2 = \frac{(1-\gamma)4\pi f}{m+(2n+1)\gamma+3} A^{m+2}. \tag{3.16}$$

The integration constant has been taken zero for simplicity.

Equation (3.16) leads to

$$\frac{dA}{\sqrt{A^{m+2}}} = \sqrt{\frac{4\pi f(1-\gamma)}{(2n+1)\gamma+m+3}} dt. \tag{3.17}$$

To obtain the determinate value of A in terms of cosmic time t, we consider $m=-1$

Putting $m=-1$ in (3.17), we have

$$\frac{dA}{\sqrt{A}} = \sqrt{\frac{4\pi f(1-\gamma)}{(2n+1)\gamma+2}} dt. \tag{3.18}$$

On integration equation (3.18) gives

$$A = (at+b)^2, \tag{3.19}$$

where

$$a = \frac{1}{2}\sqrt{\frac{4\pi f(1-\gamma)}{(2n+1)\gamma+2}} \tag{3.20}$$

and $$b = \frac{N}{2}. \tag{3.21}$$

Here N is a constant of integration.

Thus we have

$$G = A^{-1} = (at+b)^{-2}. \tag{3.22}$$

Using equations (3.19) and (3.22), equation (3.10) simplifies to

$$8\pi\rho = 4a^2(2n+1) + 4\pi f \tag{3.23}$$

With the help of equation (3.19), the metric (3.1) leads to

$$ds^2 = dt^2 - (at+b)^4(dx^2+dy^2) - (at+b)^{4n} dz^2. \tag{3.24}$$

Using $p=\gamma\rho$ in equation (3.9) we get

$$8\pi(G\dot{\rho}+\dot{G}\rho)-4\pi\dot{G}f\dot{C}^2-8\pi Gf\dot{C}\ddot{C}-8\pi G(n+2)f\dot{C}^2\frac{\dot{A}}{A}+8\pi G(n+2)\rho\frac{\dot{A}}{A}(1+\gamma)=0 \tag{3.25}$$

Using equations (3.19) and (3.22) in equation (3.25) we get

$$\frac{d\dot{C}^2}{dt}+(2n+3)\frac{\dot{A}}{A}\dot{C}=2\frac{\dot{\rho}}{f}+\left[(n+1)+(n+2)\gamma\right]\frac{\dot{A}}{A}\frac{\rho}{f} \tag{3.26}$$

To reach the deterministic value of $\dot{C}$, we assume $a=1$ and $b=0$.

Thus equation (3.26) leads to

$$\frac{d\dot{C}^2}{dt}+\frac{2(2n+3)}{t}\dot{C}^2=2\left[(n+1)+(n+2)\gamma\right]\left[\frac{2n+1}{\pi f}+1\right]\frac{1}{t}. \tag{3.27}$$

On integration equation (3.27) gives

$$\dot{C}^2t^{4n+6}=2\left[(n+1)+(n+2)\gamma\right]\left[\frac{2n+1}{\pi f}+1\right]\int\frac{1}{t}t^{4n+6}dt. \tag{3.28}$$

Simplifying equation (3.28), we get

$$\dot{C}=\sqrt{\frac{(n+1)+(n+2)\gamma}{2n+3}\left[\frac{2n+1}{\pi f}+1\right]}, \tag{3.29}$$

which on integration gives

$$C=\sqrt{\frac{(n+1)+(n+2)\gamma}{2n+3}\left[\frac{2n+1}{\pi f}+1\right]}\ t. \tag{3.30}$$

Taking $\pi f=\frac{(n+1)(1+\gamma)+\gamma}{(n+2)(1-\gamma)(2n+1)}$, we find $\dot{C}=1$, which agrees in the values used in the source equation. Thus creation field C is proportional to time t and the metric (3.1) for the constraints mentioned above, leads to

$$ds^2=dt^2-t^4dx^2-t^{4n}(dy^2+dz^2). \tag{3.31}$$

The physical parameters for the model (3.31) obtained are as follows:
Energy density (ρ),

$$8\pi\rho=4(2n+1)+4\left[\frac{(n+1)(1+\gamma)+\gamma}{(n+2)(1+\gamma)(2n+1)}\right], \tag{3.32}$$

Gravitational constant G,

$$G = t^{-2}, \tag{3.33}$$

Scale factor A ,

$$A = t^2, \tag{3.34}$$

Deceleration parameter (q) ,

$$q = -\frac{1}{2}, \tag{3.35}$$

Expansion Scalar (θ) ,

$$\theta = \frac{2(n+2)}{t}, \tag{3.36}$$

Anisotropic parameter (Δ) ,

$$\Delta = \frac{2(1-n)^2}{(n+2)^2} = cons\tan t\,(\neq 0\ for\ n \neq 1), \tag{3.37}$$

Shear Scalar (σ) ,

$$\sigma^2 = \frac{2(1-n)^2}{3t^2}, \tag{3.38}$$

4. LRS –Bianchi Type -V Model

LRS Bianchi type-V metric is considered in the form,

$$ds^2 = dt^2 - A^2 dx^2 - B^2 e^{-2kx}(dy^2 + dz^2), \tag{4.1}$$

where A, B are scale factors and are functions of cosmic time t.

It is assumed that creation field C is a function of time only

i.e. $C(x,t) = C(t)$ and $\underset{(m)}{T_i^j} = (\rho, -p, -p, -p)$.

The field equations (2.1), for metric (4.1), with the help of equations (2.2) and (2.3) are given by

$$\frac{\dot{A}^2}{A^2} + 2\frac{\dot{A}\dot{B}}{AB} - 3\frac{k^2}{A^2} = 8\pi G(t)\left(\rho - \frac{1}{2} f\dot{C}^2\right), \tag{4.2}$$

$$2\frac{\dot{B}^2}{B} + \frac{\dot{B}^2}{B^2} - \frac{k^2}{A^2} = 8\pi G(t)\left(\frac{1}{2} f\dot{C}^2 - p\right), \tag{4.3}$$

$$\frac{\dot{A}}{A} + \frac{\ddot{B}}{B} + \frac{\dot{A}\dot{B}}{AB} - \frac{k^2}{A^2} = 8\pi G(t)\left(\frac{1}{2} f\dot{C}^2 - p\right), \tag{4.4}$$

$$\frac{\dot{A}}{A}=\frac{\dot{B}}{B}. \tag{4.5}$$

where the over dot $\left(\dot{}\right)$ represents the derivative with respect to t.

The conservation equation (2.7) for the metric (4.1) is

$$8\pi\dot{G}(\rho-\frac{1}{2}f\dot{C}^2)+8\pi G\left(\dot{\rho}-f\dot{C}\ddot{C}+(\rho+p)\left(\frac{\dot{A}}{A}+2\frac{\dot{B}}{B}\right)-f\dot{C}^2\left(\frac{\dot{A}}{A}+2\frac{\dot{B}}{B}\right)\right)=0. \tag{4.6}$$

Solution of the field equations:

Solving equation (4.5) we get

$$B=KA, \tag{4.7}$$

where K is integration constant.

With the help of (5.7), field equations (4.2-4.4) and the conservation equation (4.6) take the form

$$3\frac{\dot{A}^2}{A^2}-3\frac{k^2}{A^2}=8\pi G(t)\left(\rho-\frac{1}{2}f\dot{C}^2\right), \tag{4.8}$$

$$2\frac{\ddot{A}}{A}+\frac{\dot{A}^2}{A^2}-\frac{k^2}{A^2}=8\pi G(t)\left(\frac{1}{2}f\dot{C}^2-p\right). \tag{4.9}$$

and

$$8\pi\dot{G}(\rho-\frac{1}{2}f\dot{C}^2)+8\pi G\left(\dot{\rho}-f\dot{C}\ddot{C}+3\rho\frac{\dot{a}_1}{a_1}-3f\dot{C}^2\frac{\dot{a}_1}{a_1}+3p\frac{\dot{a}_1}{a_1}\right)=0 . \tag{4.10}$$

Following Hoyle and Narlikar, the source equation of C-field: $C^i_{;i}=0$ leads to $C=t$ for large r.

Thus $\dot{C}=1$

Using $\dot{C}=1$, equation (4.10) leads to

$$8\pi G\rho=3\frac{\dot{A}^2}{A^2}-3\frac{k^2}{A^2}+4\pi Gf. \tag{4.11}$$

Using $\dot{C}=1$ and barotropic condition $p=\gamma\rho$ in equation (4.11), we have

$$2\frac{\ddot{A}}{A}+\frac{\dot{A}^2}{A^2}-\frac{k^2}{A^2}=4\pi Gf-8\pi G\rho, \tag{4.12}$$

where $0\le\gamma\le 1$.

Multiplying equation (4.11) by γ and adding (4.12) gives

$$2\frac{\ddot{A}}{A}+(1+3\gamma)\frac{\dot{A}^2}{A^2}=(1-\gamma)4\pi Gf+(1+3\gamma)\frac{k^2}{A^2}, \quad (4.13)$$

To obtain the deterministic solution, we assume

$$G=A^m, \quad (4.14)$$

where n is a constant and A is the scale factor.

Using equation (4.14) in equation (4.13), we get

$$2\ddot{A}+(1+3\gamma)\frac{\dot{A}^2}{A}=(1-\gamma)4\pi fA^{m+1}+(1+3\gamma)\frac{k^2}{A}. \quad (4.15)$$

Let $\dot{A}=F(A)$, Thus $\ddot{A}=FF'$ with $F=\frac{dF}{dA}$.

Using this in equation (4.15), it reduces to

$$\frac{dF^2}{dA}+\frac{(1+3\gamma)}{A}F^2=(1-\gamma)4\pi fA^{m+1}+(1+3\gamma)\frac{k^2}{A}, \quad (4.16)$$

which on simplification gives

$$F^2=\frac{(1-\gamma)4\pi f}{(n+3\gamma+3)}A^{m+2}+k^2. \quad (4.17)$$

The integration constant has been taken zero for simplicity.

Equation (4.17) leads to

$$\frac{dA}{\sqrt{4\pi f(1-\gamma)A^{m+2}+k^2(m+3\gamma+3)}}=\frac{dt}{\sqrt{m+3\gamma+3}}. \quad (4.18)$$

To obtain the determinate value of A in terms of cosmic time t, we consider $m=-1$
Putting $m=-1$ in (5.18), we have

$$\frac{dA}{\sqrt{A+\frac{k^2(3\gamma+2)}{4\pi f(1-\gamma)}}}=\sqrt{\frac{4\pi f(1-\gamma)}{3\gamma+2}}dt. \quad (4.19)$$

On integration equation (4.19) gives

$$A=(at+b)^2-\frac{k^2(3\gamma+2)}{4\pi f(1-\gamma)}, \quad (4.20)$$

where

$$a=\frac{1}{2}\sqrt{\frac{4\pi f(1-\gamma)}{3\gamma+2}} \tag{4.21}$$

and $$b=\frac{N}{2}\ . \tag{4.22}$$

Here N is a constant of integration. Thus we have

$$G=A^{-1}=(at+b)^{-2}\ . \tag{4.23}$$

From equations (4.11), (4.20) and (4.23) we have

$$8\pi\rho=\frac{12a^2(at+b)-3k^2}{\left[(at+b)^2-\frac{k^2(3\gamma+2)}{4\pi f(1-\gamma)}\right]}+4\pi f\ . \tag{4.24}$$

With the help of (4.10) the metric (4.1) leads to

$$ds^2=dt^2-\left[(at+b)^2-\frac{k^2(3\gamma+2)}{4\pi f(1-\gamma)}\right]\left[dx^2+e^{-2kx}(dy^2+dz^2)\right]. \tag{4.25}$$

Using $p=\gamma\rho$, equation (2.11) leads to

$$8\pi(G\dot{\rho}+\dot{G}\rho)-4\pi\dot{G}f\dot{C}^2-8\pi Gf\dot{C}\ddot{C}-24\pi Gf\dot{C}^2\frac{\dot{A}}{A}+24\pi G\rho(1+\gamma)\frac{\dot{A}}{A}=0\ . \tag{4.26}$$

With the help of equations (4.20) and (4.22), equation (4.24) leads to

$$\frac{d\dot{C}^2}{dt}+\frac{10a(at+b)}{\left[(at+b)-\frac{k^2(3\gamma+2)}{4\pi f(1-\gamma)}\right]}\dot{C}^2=$$

$$\left[\frac{6a^3(at+b)(3\gamma+2)-\frac{3}{2}k^2a(at+b)(3\gamma+1)-\frac{6a^3(at+b)k^2(3\gamma+2)}{4\pi f(1-\gamma)}}{\pi f\left[(at+b)^2-\frac{k^2(3\gamma+2)}{4\pi f(1-\gamma)}\right]^2}\right] \tag{4.27}$$

$$+\frac{2\pi ft(3\gamma+2)}{\pi f\left[t^2-\frac{k^2(3\gamma+2)}{4\pi f(1-\gamma)}\right]}$$

To reach the deterministic value of $\dot{C}$, we assume $a=1$ and $b=0$

Thus equation (4.27) leads to

$$\frac{d\dot{C}^2}{dt}+\frac{10t}{\left[t^2-\frac{k^2(3\gamma+2)}{4\pi f(1-\gamma)}\right]}\dot{C}^2=$$

$$\frac{2\pi f t(3\gamma+2)}{\pi f\left[t^2-\frac{k^2(3\gamma+2)}{4\pi f(1-\gamma)}\right]^2}-\frac{6t^3(3\gamma+2)-\frac{3}{2}k^2t(3\gamma+1)-\frac{6k^2t(3\gamma+2)}{4\pi f(1-\gamma)}}{\pi f\left[t^2-\frac{k^2(3\gamma+2)}{4\pi f(1-\gamma)}\right]^2} \tag{4.28}$$

On integration equation (4.28) leads to

$$\dot{C}^2=\frac{(3\gamma+2)}{5}[\frac{3}{\pi f}+1]. \tag{4.29}$$

Simplifying equation (4.29), we get

$$\dot{C}=\sqrt{\frac{(3\gamma+2)}{5}[\frac{3}{\pi f}+1]} \tag{4.30}$$

On integration (4.30), we get

$$C=\sqrt{\frac{(3\gamma+2)}{5}[\frac{3}{\pi f}+1]}\times t \tag{4.31}$$

Taking $\pi f=\left(\frac{3\gamma+2}{1-\gamma}\right)$, we find that $\dot{C}=1$ which agrees with the value used in the source equation.

$$ds^2=dt^2-\left(t^2-\frac{k^2}{4}\right)\left[dx^2+e^{-2kx}\left(dy^2+dz^2\right)\right]. \tag{4.32}$$

The physical parameters for the model (4.32) obtained are as follows:
Energy density (ρ),

$$8\pi\rho=4\left[3+\frac{(3\gamma+2)}{(1-\gamma)}\right], \tag{4.33}$$

Gravitational constant G,

$$G=\left(t^2-\frac{k^2}{4}\right)^{-1}, \tag{4.34}$$

Scale factor A,

$$A=\left(t^2-\frac{k^2}{4}\right), \tag{4.35}$$

Deceleration Parameter (q),

$$q=-\frac{1}{8}\left(\frac{k^2}{t^2}+4\right), \tag{4.36}$$

Expansion Scalar (θ),

$$\theta=\frac{6t}{\left(t^2-\frac{k^2}{4}\right)}, \tag{4.37}$$

Shear Scalar (σ),

$$\sigma^2=0, \tag{4.38}$$

Anisotropic parameter (Δ),

$$\Delta=0, \tag{4.39}$$

5. Physical Behavior of the Model

(i) Spatial Volume (V)

Plane symmetric cosmological model starts evolving with big bang singularity when $t=0$ and expands infinitely with the increase in cosmic time t. LRS Bianchi type-V cosmological model starts evolving with finite volume at $t=0$ and expands infinitely with the increase in cosmic time *t*. Hence all the models are expanding throughout the evolution.

(ii) Energy density (ρ) :

We observed that in both the models the density remains constant from the big bang with the increase in cosmic time t. This indicates to the steady state cosmological models of the universe which implies the matter is supposed to move along the geodesic normal to the surface $t = constant$. As the matter moves further apart, it is assumed that more mass is continuously created to maintain the matter density its constant value [5, 29].

(iii) Gravitational constant (G) :

We observed that in both the models the gravitational constant G is initially infinite. The Gravitational constant G is a decreasing function of time and approaches to zero for large values of t. In most variable G cosmologies, G is a decreasing function of time [30, 31], but the possibility of an increasing G has also been suggested by several authors [32-36].

(iv) Deceleration parameter (q) :

For Plane symmetric cosmological models the deceleration parameter (q) is constant $\left(q = -\frac{1}{2}\right)$ throughout the evolution of the universe indicating that the models are accelerating throughout the evolution. For LRS Bianchi type – V model the deceleration parameter is constant $\left(q = -\frac{1}{2}\right)$, when $m = 0$ indicating that the model is accelerating. When $m \neq 0$, the value of deceleration parameter (q) is negative and finite for $t = 0$ and tends to $-\infty$, for large values of t .

It is also observed that, for both the cosmological models, the mean anisotropy parameter (Δ) is constant. Hence both the models are anisotropic throughout the evolution of the universe except at $n = 1$ (*i.e.* the model does not approach isotropy).

6. Conclusion

Plane symmetric and LRS Bianchi type – V cosmological models have been investigated in Hoyle Narlikar's creation field theory of gravitation. The source for energy momentum tensor is barotropic fluid with varying gravitational constant. All the models are accelerating throughout the evolution which matches with recent SNe Ia observations. The gravitational constant G are decreasing functions of t. In most variable G cosmologies, G is a decreasing function of time.

In both the models, it is observed that the creation field C increases with cosmic time t which matches with the results obtained by Hoyle and Narlikar.

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