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Massive String Cosmological Model for Ferfect Fluid Distribution with Cosmological Term Λ In Bimetric Theory of Gravitation

S. S. Charjan
Department of Mathematics, K. Z. S. Science College, Bramhani, Kalmeshwar, Dist. Nagpur, Maharashtra, India

ABSTRACT : Massive string magnetized cosmological model for perfect fluid distribution with cosmological term Λ is deduced by solving Rosen's field equations. To deduce a determinate solution, the condition $A = B^n$(where,$n > 0$ real constants), between the metric potentials is used. It is seen that Massive string Bianchi Type I magnetized cosmological model (36) in bimetric theory of gravitation exists. It never goes to vacuum model . When$u \to -\infty$, then $\theta \to -\infty$, $\sigma \to -\infty$ and when $u \to \infty$, then $\theta \to \infty$, $\sigma \to \infty$. This confirms that the model is expanding as well as shearing. The expansion and the shear in the model increases as cosmic time u increases. Further when $u \to \infty$, then $\in = \lambda \to \infty$, $p \to \infty$. When $u \to -\infty$ then $\in = \lambda \to 0$ and $p \to 0$, which shows that our model goes over to vacuum model, when the cosmic time u is minus infinity. In the special case, in the absence of magnetic field i.e., $K = 0$, it is seen that, our model (36) exists. Also the expansion and shear in the model increases, as the cosmic time u increases.

Keywords: Bimetric Gravitational Theory, Electromagnetic Field, Cosmology
Mathematics Subject Classification 2010: 83-XX, 83C50, 83F05

I. INTRODUCTION

Several new theories of gravitation have been formulated which are considered to be alternatives to Einstein's theory of gravitation. The most important among them is Rosen's bimetric theory of gravitation [1 - 2]. The Rosen's bimetric theory is the theory of gravitation based on two metrics. One is the fundamental metric tensor g_{ij} describes the gravitational potential and the second metric γ_{ij} refers to the flat space–time and describes the inertial forces associated with the acceleration of the frame of reference. The metric tensor g_{ij}determine the Riemannian geometry of the curved space time which plays the same role as given in Einstein's general relativity and it interacts with matter. The background dmetric γ_{ij} refers to the geometry of the empty universe (no matter but gravitation is there) and describe the inertial forces. The metric tensor γ_{ij} has no direct physical significance but appears in the field equations. Therefore it interacts with g_{ij} but not directly with matter. One can regard γ_{ij} as giving the geometry that would exists if there were no matter. In the absence of matter one would have g_{ij}=γ_{ij}. Moreover, the bimetric theory also satisfied the covariance and equivalence principles; the formation of general relativity. This theory agrees with the present observational facts pertaining to general relativity [3 – 4]. Thus at every point of space–time in Rosen's bimetric theory of gravitation, there are two metrics

$$ds^2 = g_{ij}dx^i dx^j \quad (1)$$

$$d\eta^2 = \gamma_{ij}dx^i dx^j \quad (2)$$

The field equations of Rosen's bimetric theory of gravitation are

$$N_i^j - \frac{1}{2} N \delta_i^j = -8\pi k T_i^j \quad (3)$$

where $N_i^j = \frac{1}{2}\gamma^{pr}\left(g^{sj} g_{si|p}\right)_{|r}$, $N = N_i^i$, $k = \sqrt{\frac{g}{\gamma}}$ with $g = det(g_{ij})$ and $\gamma = det(\gamma_{ij})$. Here the vertical bar (|) stands forγ -covariant differentiation and T_i^j is the energy-momentum tensor of matter fields. Cosmic string arises during the phase transition after the big – bang explosion in the evolution of early stage of universe and formation of Galaxies. The general treatment of the string was initiated by Letelier and Stachel [5 - 7]. The cosmic strings have stress energy and couple to the gravitational field and give rise to density perturbations. The magnetic field is present in galactic and intergalactic system and therefore the magnetic field with energy density and string tension density of the cosmic string have been taken in the formation of our model in bimetric theory of gravitation.

In the context of general relativity cosmic strings do not occur in Bianchi Type models (see K. D. Krori et al.) [8]. In it, some Bianchi Type cosmological models – two in four and one in higher dimensions– are studied by Krori et al. They have shown that the cosmic strings do not occur in Bianchi Type V cosmology. Bali and Dave [9], Bali and Upadhaya [10], Bali and Singh [11], Bali and Pareek [12] have investigated Bianchi Type IX, I and V string cosmological models under different physical conditions in general relativity.

Recently, Borkar et al. have developed the models like Bianchi Type I string dust cosmological model with magnetic field in bimetric relativity [13] , LRS Bianchi Type I string dust magnetized cosmological models in bimetric theory of relativity [14] ,The charged perfect fluid distribution in bimetric theory of relativity [15] , Bianchi Type I bulk viscous fluid string dust cosmological model with magnetic field in bimetric relativity[16] and Bianchi Type I magnetized cosmological model in bimetric theory of gravitation [17]. Sahoo et al. [18] have investigated Bianchi Types V and VI_0 cosmic strings coupled with Maxwell fields in bimetric theory of gravitation. Gaikwad et al. [19] have developed Bianchi Type I massive string barotropic perfect fluid cosmological model in the bimetric theory of gravitation.

In this paper Massive string magnetized cosmological model for perfect fluid distribution with cosmological term Λ is deduced by solving Rosen's field equations. To deduce a determinate solution, the condition $A = B^n$(where,$n > 0$ real constants), between the metric potentials is used.

It is seen that Massive string Bianchi Type I magnetized cosmological model (36) in bimetric theory of gravitation exists. It never goes to vacuum model . When$u \to -\infty$, then $\theta \to -\infty$, $\sigma \to -\infty$ and when $u \to \infty$, then $\theta \to \infty$, $\sigma \to \infty$. This confirms that the model is expanding as well as shearing. The expansion and the shear in the model increases as cosmic time u increases. Further when $u \to \infty$, then $\in = \lambda \to \infty$, $p \to \infty$. When $u \to -\infty$ then $\in = \lambda \to 0$ and $p \to 0$, which shows that our model goes over to vacuum model, when the cosmic time u is minus infinity. In the special case, in the absence of magnetic field i.e., $K = 0$, , it is seen that, our model (36) exists. Also the expansion and shear in the model increases, as the cosmic time u increases.

II. SOLUTION OF ROSEN'S FIELD EQUATIONS

We consider an LRS Bianchi Type I metric is in the form

$$ds^2 = - dt^2 + A^2 dx^2 + B^2 (dy^2 + dz^2) \quad (4)$$

where A and B are functions of t alone.

The flat metric corresponding to metric (4) is

$$d\square\square^2 = \square\, dt^2 + dx^2 + dy^2 + dz^2 \quad (5)$$

The energy momentum tensor for the string dust with magnetic field is taken as

$$T_i^j = (\rho + p)\, \upsilon_i \upsilon^j + p\, g_i^j - \lambda\, x_i\, x^j + E_j^i \quad (6)$$

with $\quad v^i v_i = -x^i x_i = -1 \quad (7)$

and $\quad v^i x_i = 0 \quad (8)$

In this model, ρ and □ denote the proper energy density and the string tension density, x^i is the unit space like vector specifying the direction of string and v^i is the unit time like vector .

The co-moving coordinate system is chosen as v^i= (0,0,0,1) ; x^i= ($\frac{1}{A}$,0,0,0)

If ρ_p is the particle density of configuration, then

$$\rho = \rho_p + \lambda$$

of the system of strings respectively. The electromagnetic field E_{ij} is given by Lichnerowicz (1967)

$$E_{ij} = \bar{\mu}\left[|h|^2\left(v_i v_j + \frac{1}{2} g_{ij}\right) - h_i h_j\right] \quad (9)$$

The four velocity vector v_i is given by

$$g_{ij}\, v^i v^j = \square 1 \quad (10)$$

and $\bar{\mu}$ is the magnetic permeability and h_i the magnetic flux vector defined by

$$h_i = \frac{\sqrt{-g}}{2\bar{\mu}} \varepsilon_{ijkl} F^{kl} v^j \quad (11)$$

where F_{kl} is the electromagnetic field tensor and $\square_{ijkl}$ is the Levicivita tensor density.

Assume the comoving co-ordinates and so we have $v^1 = v^2 = v^3 = 0, v^4 = 1$. Further the magnetic field taken along x-axis so that

$$h_1 \neq 0, h_2 = h_3 = h_4 = 0$$

yield

F_{23} = constant = H (*say*) (10)

Due to the assumption of infinite electrical conductivity, we have

$$F_{14} = F_{24} = F_{34} = 0^{\cdot}$$

The only non–vanishing component of F_{ij} is F_{23}.

So that

$$h_1 = \frac{AH}{\bar{\mu} B^2}$$

and

$$|h|^2 = \frac{H^2}{\bar{\mu}^2 B^4}$$

The components of electromagnetic field E_i^j are given by

$$E_1^1 = -E_2^2 = -E_3^3 = E_4^4 = -\frac{H^2}{2\bar{\mu} B^4}$$

$$T_1^1 = \left(p - \lambda - \frac{H^2}{2\bar{\mu} B^4}\right), T_2^2 = T_3^3 = \left(p + \frac{H^2}{2\bar{\mu} B^4}\right), T_4^4 = \left(-\rho - \frac{H^2}{2\bar{\mu} B^4}\right) \quad (12)$$

Rosen's Field Equations becomes

$$\frac{-A_{44}}{A}+\frac{2B_{44}}{B}+\frac{A_4^{\ 2}}{A^2}-\frac{2B_4^{\ 2}}{B^2}=16\pi AB^2\left(-p+\lambda+\frac{H^2}{2\bar{\mu}B^4}\right)-2\Lambda \tag{14}$$

$$\frac{A_{44}}{A}-\frac{A_4^{\ 2}}{A^2}=16\pi AB^2\left(-p-\frac{H^2}{2\bar{\mu}B^4}\right)-2\Lambda \tag{15}$$

$$\frac{A_{44}}{A}+\frac{2B_{44}}{B}-\frac{A_4^{\ 2}}{A^2}-\frac{2B_4^{\ 2}}{B^2}=16\pi AB^2\left(\rho+\frac{H^2}{2\bar{\mu}B^4}\right)-2\Lambda \tag{16}$$

III. SOLUTION OF FIELD EQUATIONS

The field equation (14) (15) and (16) are the arrangement of three equations with six unknowns A, B,Λ, λ, $\rho$and$p$ ⥂⥂⥂⥂.Thus initially the system is undetermined, so we need three more equations to attain the complete solution of the system. Therefore we supposed that expansion θ is proportional to share σ.

$$\mathrm{A}=\mathrm{B}^n \quad \text{and} \quad \Lambda=\frac{\alpha}{AB^2} \tag{17}$$

We assume the above conditions under two cases : (i)$\rho+\lambda=0$ and (ii) $\rho-\lambda=0$ (18)

Case I : $\rho+\lambda=0$

On adding equations (14) and (16) we get

$$\frac{4B_{44}}{B}-\frac{4B_4^{\ 2}}{B^2}=16\pi AB^2\left(-p+\lambda+\rho+\frac{H^2}{\bar{\mu}B^4}\right)-4\Lambda \tag{19}$$

$$\frac{B_{44}}{B}-\frac{B_4^{\ 2}}{B^2}=\frac{48\pi \mathrm{K}\mathrm{B}^{n-2}}{4-n}-\frac{2\alpha}{(4-n)\mathrm{B}^{n+2}} \tag{20}$$

On putting $B_4=f(B)$ and $B_{44}=ff'$ in equation (20) we obtain

$$\frac{df^2}{dB}-\frac{2f^2}{B}=\frac{96\pi \mathrm{K}B^{n-1}}{4-n}-\frac{4\alpha}{(4-n)B^{n+1}} \tag{21}$$

On integration, equation (21) leads to

$$f^2=\frac{96\pi KB^n}{(4-n)(n-2)}+\frac{4\alpha}{(4-n)(n+2)B^n}+MB^2 \tag{22}$$

Here M is the constant of integration.

From equation (22), we get

$$\int\frac{dB}{\sqrt{\frac{96\pi KB^n}{(4-n)(n-2)}+\frac{4\alpha}{(4-n)(n+2)B^n}+MB^2}}=t+V \tag{23}$$

Here V is the constant of integration. Value of B can be obtained from equation (23).
Putting B=T , x=X , y=Y and z=Z metric (1) becomes

$$ds^2 = -\frac{dT^2}{\left[\frac{96\pi K T^n}{(4-n)(n-2)} + \frac{4\alpha}{(4-n)(n+2)T^n} + MT^2\right]} + T^{2n} dX^2 + T^2(dY^2 + dZ^2) \tag{24}$$

Case II : $\rho - \lambda = 0$

On subtracting equations (14) from (16) we get,

$$2\left[\frac{A_{44}}{A} - \frac{A_4^2}{A^2}\right] = 16\pi A B^2 P \tag{25}$$

(25)

Using (17), (18), and (15) in equation (25), we get

$$B_{44} - \frac{B_4^2}{B} = -\frac{16\pi K}{3n} B^{n-1} - \frac{2\alpha}{3n\, B^{(n+1)}} \tag{26}$$

On putting $B_4 = f(B)$ and $B_{44} = ff'$ in equation (26) we obtain

$$\frac{df^2}{dB} - \frac{2f^2}{B} = \frac{-32\pi K B^{n-1}}{3n} - \frac{4\alpha}{3n B^{n+1}} \tag{27}$$

(27)

On integrating equation (27) we get,

$$f^2 = \frac{-32\pi K B^n}{3n(n-2)} + \frac{4\alpha}{3n(n+2)B^n} + NB^2 \tag{28}$$

Here N is the constant of integration.

$$\int \frac{dB}{\sqrt{\frac{-32\pi K B^n}{3n(n-2)} + \frac{4\alpha}{3n(n+2)B^n} + NB^2}} = t + U \tag{29}$$

Where U is the constant of integration. Value of B can be obtained from equation (29).
Hence, by appropriate transformation of coordinates
B=T , x=X , y=Y and z=Z metric (1) becomes

$$ds^2 = -\frac{dT^2}{\left[\frac{-32\pi K T^n}{3n(n-2)} + \frac{4\alpha}{3n(n+2)T^n} + N\,T^2\right]} + T^{2n} dX^2 + T^2(dY^2 + dZ^2)$$

Now choosing the cosmic time $u = \pm\, log\, T$. For convenience, we can select$u = -\, log\, T$, then the model (24) goes over to

$$ds^2 = -\frac{du^2}{\left[M - \frac{32\pi l}{(4-n)(n-2)}K(e^{-u})^{n-2} + \frac{4\alpha}{n}\right]} + (e^{-u})^2[(e^{-u})^{2n-2}dX^2 + dY^2 + dZ^2 \tag{30}$$

IV. PHYSICAL AND GEOMETRICAL CHARACTERISTICS

For the model (24), energy density(ρ), string tension density(λ), particle energy density(ρ_p), pressure(P), expansion(θ), share (σ) are given by

$$\rho = -\lambda = \frac{K(4n+2)}{(4-n)}()^{-4} \quad - \frac{\alpha(n-1)}{4\pi(4-n)})^{-2(n+2)} \tag{31}$$

$$\rho_p = \frac{2K(4n+2)}{(4-n)}(e^{-u})^{-4} - \frac{\alpha(n-1)}{2\pi(4-n)}(e^{-u})^{-2(n+2)} \tag{32}$$

$$P = \frac{-(2n+4)K}{(4-n)}(e^{-u})^{-4} + \frac{\alpha(n-2)}{4\pi(4-n)}(e^{-u})^{-2(n+2)} \tag{33}$$

$$\theta = (n+2)\left[\frac{96\pi K()^{n-2}}{(4-n)(n-2)} + \frac{4\alpha}{(4-n)(n+2)})^{-2(n+2)} \quad + M\right]^{\frac{1}{2}} \tag{34}$$

$$\sigma = \frac{(n-1)}{\sqrt{3}}\left[\frac{96\pi K()^{n-2}}{(4-n)(n-2)} + \frac{4\alpha}{(4-n)(n+2)})^{-2(n+2)} \quad + M\right]^{\frac{1}{2}} \tag{35}$$

For the model (30), energy density(ρ), string tension density (λ), particle energy density (ρ_p), pressure (P), expansion (θ), share (σ) are given by

$$\rho = \lambda = \frac{\alpha(n-1)}{12\pi\ n}(e^{-u})^{2(n+2)-} - \frac{2K(2n+1)}{3n\ (e^{-u})^4} \tag{36}$$

$$\rho_p = 0 \tag{37}$$

$$P = -\frac{\alpha}{12\pi T^{2(n+2)}}(e^{-u})^{2(n+2)-} - \frac{2K}{3(e^{-u})^4} \tag{38}$$

$$\theta = (n+2)\left[\frac{4\alpha}{3n(n+2)()^{2(n+2)}} - \frac{32\pi K T^{n-2}}{3n(n-2)} + N\right]^{\frac{1}{2}} \tag{39}$$

$$\sigma = \frac{(n-1)}{\sqrt{3}}\left[\frac{4\alpha}{3n(n+2)(e^{-u})^{2(n+2)}} - \frac{32\pi K(e^{-u})^{(n-2)}}{3n(n-2)} + N\right]^{\frac{1}{2}} \tag{40}$$

V. SOLUTION IN THE ABSENCE OF MAGNETIC FIELD

Case I : $\rho + \lambda = 0$

In the absence of magnetic field equation (24) becomes

$$ds^2 = -\frac{dT^2}{\left[\frac{4\alpha}{(4-n)(n+2)T^n} + MT^2\right]} + T^{2n}dX^2 + T^2(dY^2 + dZ^2)$$

Now choosing the cosmic time $u = \pm\, log\, T$. For convenience, we can select $u = -\, log\, T$, then above model goes over to

$$ds^2 = -\frac{du^2}{\left[M\rightleftarrows\rightleftarrows + \frac{4\alpha}{(4-n)(n+2)}\right]} +)^2 \quad [(e^{-u})^{2n-2}dX^2 + dY^2 + dZ^2 \qquad (41)$$

For the model (41), energy density(ρ), string tension density (λ), particle energy density (ρ_p), pressure (P), expansion (θ), share (σ) are given by

$$\rho = -\lambda = -\frac{\alpha(n-1)}{4\pi(4-n)()^{2(n+2)}} \qquad (42)$$

$$\rho_p = -\frac{\alpha(n-1)}{2\pi(4-n)(e^{-u})^{2(n+2)}} \qquad (43)$$

$$P = \frac{\alpha(n-2)}{4\pi(4-n)(e^{-u})^{2(n+2)}} \qquad (44)$$

$$\theta = (n+2)\left[\frac{4\alpha}{(4-n)(n+2)()^{2(n+2)}} + M\right]^{\frac{1}{2}} \qquad (45)$$

$$\sigma = \frac{(n-1)}{\sqrt{3}}\left[\frac{4\alpha}{(4-n)(n+2)()^{2(n+2)}} + M\right]^{\frac{1}{2}} \qquad (46)$$

Case II : $\rho - \lambda = 0$

In the absence of magnetic field equation (30) becomes

$$ds^2 = -\frac{dT^2}{\left[\frac{4\alpha}{3n(n+2)T^n} + NT^2\right]} + T^{2n}dX^2 + T^2(dY^2 + dZ^2)$$

Now choosing the cosmic time $u = \pm\, log\, T$. For convenience, we can select $u = -\, log\, T$, then the above model goes over to

$$ds^2 = -\frac{du^2}{\left[N\rightleftarrows\rightleftarrows + \frac{4\alpha}{3n(n+2)}\right]} + (e^{-u})^{2n}dX^2\,)^{2n} \quad (dY^2 + dZ^2)\ (47) \qquad (47)$$

For the model (47), energy density(ρ), string tension density (λ), particle energy density (ρ_p), pressure (P), expansion (θ), share (σ) are given by

$$\rho = \lambda = \frac{\alpha(n-1)}{12\pi n()^{2(n+2)}} \qquad (48)$$

$$\rho_p = 0$$

(49)

$$P = -\frac{\alpha}{12\pi(e^{-u})^{2(n+2)}} \qquad (50)$$

$$\theta = (n+2)\left[\frac{4\alpha}{3n(n+2)()^{2(n+2)}} + N\right]^{\frac{1}{2}} \qquad (51)$$

$$\sigma = \frac{(n-1)}{\sqrt{3}}\left[\frac{4\alpha}{3n(n+2)(e^{-u})^{2(n+2)}} + N\right]^{\frac{1}{2}} \tag{52}$$

VI. CONCLUSION

There is no big-bang and big crunch singularities in our model (30). From the equations (32), (33) and (34), it is seen that the such a Bianchi Type I magnetized cosmological model (36) in bimetric theory of gravitation exists. It never goes to vacuum model . When$u \to -\infty$, then $\theta \to -\infty$, $\sigma \to -\infty$ and when $u \to \infty$, then $\theta \to \infty$, $\sigma \to \infty$. This confirms that the model is expanding as well as shearing. The expansion and the shear in the model increases as cosmic time u increases. Further when $u \to \infty$, then $\in = \lambda \to \infty$, $p \to \infty$. When $u \to -\infty$ then $\in = \lambda \to 0$ and $p \to 0$, which shows that our model goes over to vacuum model, when the cosmic time u is minus infinity. In the special case, in the absence of magnetic field i.e., $K = 0$,, it is seen that, our model (36) exists. Also the expansion and shear in the model increases, as the cosmic time u increases.

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