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Lrs Bianchi Type Ii Magnetized String Cosmological Model With Bulk Viscous Fluid In Bimetric Theory Of Gravitation

Gaikwad N. P.
Department Of Mathematics, Dharampeth M. P. Deo Memorial Science, College, Nagpur – 440 033 (India)

Abstract
We solved Rosen's bimetric theory of gravitation field equations in order to present the LRS Bianchi type II space-time solution having the magnetic field and with string viscous fluid in this research. The solution was presented using string viscous fluid. It is observed that the magnetic field is with the cosmological origin of the model and it is agreed with Harrison (1973). The small value of the magnetic field originated the universe evolving it with maximum density and ending with zero density. The strong magnetic field ruled out the existence of the universe. The development of the universe has been explored in relation to the model's additional geometrical and physical properties.

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I. Introduction

Cosmic strings are crucial for understanding the early universe. Cosmic strings, with stress energy and are related to the field of gravitational, cause density perturbations that result in the creation of galaxies (Kibble[1] and Zeldovich[2]). Cosmic strings with various features are discussed by Vilenkin[3], Gott[4], and Garfinkle[5]. Latelier[6, 7] and Stachel[8] give the cosmic strings general relativistic formalism.

Eckart[9] and Lifshitz and Landau [10] first suggested the relativistic fluids viscosity theory and the relativistic 2nd order theory has been created by Stewart as well as Israel [11]. The only means to analyze entropy-producing events in the most basic cosmological model is via bulk viscosity. The galaxies'large-scale dispersion in our universe demonstrates that a perfect fluid adequately describes the distribution of matter. However, in the cosmos' initial stages, neutrino decoupling caused the matter to behave as a viscous fluid. The phase transition and string formation in the grand unification theory (GUT) are related to bulk viscosity. Many researchers [12-17] have studied bulk viscosity. Gron[18] researched models of the inflationary Bianchi type that included bulk viscosity & shear.

In addition, the existence of a magnetic field on a galactic scale is a fact that is well-developed in the modern era, and models of anisotropic magnetic fields have a substantial contribution to make in the stellar objects &galaxies evolution. Harrison [19] has put out the idea that magnetic field origin could be found in the cosmos. According to what Melvin [20] has explained, at the universe evolution process time, the matter is in a greatly ionized condition, and as a result of smooth coupling bythe field, it creates a neutral matter as a consequence of the cosmos expansion. The adiabatic compression that occurs in galaxy clusters can give rise to the formation of powerful magnetic fields. An anisotropic structure can be attributed to the large-scale magnetic fields existence in the universe. As a result, the idea that an anisotropic string universe could have a magnetic field is not completely unbelievable. Asseo and Sol [21] stressed how significant it was that the Bianchi Type II universe existed. In their research, Roy and Banerjee[22], Pradhan et al.[23]], and Bali [24] looked at the LRS Bianchi type II cosmological models that represented clouds as well as large strings.

Rosen's [25,26] gravitation bimetric theory is a gravitation theory on the basis of 2 metrics. "1st is the important metric tensor represented as g_{ij} that explains the gravitational potential represents the curved space-time geometry and the 2nd metric γ_{ij} referred to the flatspace–time and explains the inertial forces"in relation to the frame of reference acceleration. This theory is consistent by the currently available observational findings that pertain to general relativity. The Bimetric Theory of Gravitation does not contain any of the singularities which is present in General Relativity and that were observed in cosmological models during the Big Bang. As a result, the Bimetric Theory of Gravitation several parts have already been investigated in detail by several researchers [27-38] in relation to the Bianchi Type of Cosmological Models that are contained within it.

LRS ("Locally Rotationally Symmetric") Bianchi Type II Magnetized String Cosmological Model with Bulk Viscous Fluid have been studied by Atul Tyagi et al.[39] in Einstein's general relativity and we plan to extendtheeffort in Rosen's bimetric theory of gravitation to observe the model's physical &geometrical behavior. It has been seen that this LRS Bianchi type II space-time having a magnetic field and the string viscous fluid by solving theRosen's bimetric theory of gravitation field equations. It is observed the magnetic field could have the cosmological origin of the model and it is agreed with Harrison (1973). The magnetic field originated small value in the universe and starts evolving with maximum density and ending with zero density. The strong magnetic field ruled out the universe existence. The development of the cosmos has been explored in relation to the model's additional geometrical and physical properties.

II. The Metric And Field Equations

By considering that LRS Bianchi Type-II metric in the form,

$$ds^2 = -dt^2 + A^2(dx^2 + dy^2) + B^2(dy - xdz)^2, \quad (1)$$

where A&$B$are "functions of the cosmic time as t only.

The flat metric corresponding to metric (1)" is

$$ds^2 = -dt^2 + (dx^2 + dy^2) + (dy - dz)^2. \quad (2)$$

The T_i^j denoted as the energy-momentum tensor for the strings cloud having abulk viscous fluid and E_i^j denoted as the electromagnetic field isshown by:

$$T_i^j = \rho v_i v^j - \lambda x_i x^j - \xi\theta\left(v_i v^j - g_i^j\right) + E_i^j, \quad (3)$$

where ρrepresented by thecloud strings rest energy density, ξ represented as the bulk viscosity coefficient, λrepresented by the string tension density, θrepresented as the expansion scalar, $v^i = (0,0,0,1)$is represented as the space-like four-velocity vector, and the string direction x^i is choosing $x^i = (1/A, 0,0,0)$, the time-like vector such that

$$v_i v^j = -x_i x^j = -1, \quad (4)$$

$$v^i x_j = 0, \quad (5)$$

and electromagnetic field E_i^j is

$$E_i^j = \bar{\mu}\left[|h|^2\left(v_i v^j + \frac{1}{2}g_i^j\right)\right]. \quad (6)$$

The vector of the magnetic flux is represented by:

$$h_i = \frac{\sqrt{-g}}{2b}\epsilon_{ijk}F^{kl}v^i, \quad (7)$$

where $\bar{\mu}$denoted as the magnetic permeability, F^{kl}denoted as "the electromagnetic field tensor, ϵ_{ijk} denoted as the Levi Civita tensor and a magnetic field is along x-direction, $F_{23}$is the only non-vanishing component of F^{sp} and $h_1 \neq 0, h_2 = h_3 = h_4 = 0$. Because" of the infinite electrical conductivity assumption, which is$F_{14} = F_{24} = F_{34} = 0$ and $F_{23} \neq 0$.

The article is loaded on the string and its density ρ_p is defined by

$$\rho_p = \rho - \lambda. \quad (8)$$

Scalar expansion denoted as theθ is expressed as $\theta = v^l_{|l}$and having a value

$$\theta = 2\frac{\dot{A}}{A} + \frac{\dot{B}}{B}. \quad (9)$$

From Maxwell's equation, $F_{[ij,k]}$, we write

$$F_{23} = -F_{32} = H = \text{constant}. \quad (10)$$

Then, equation (7) is

$$h_1 = \frac{H}{\bar{\mu}B}. \quad (11)$$

By utilizing the equation (10), equation (6) yield

$$E_1^1 = -\frac{H^2}{2\bar{\mu}B^2A^2} = -E_2^2 = -E_3^3 = E_4^4. \quad (12)$$

With this equation (12), equation (3) yield the component of an energy-momentum tensor T_i^j "as

$$T_1^1 = -\lambda - \xi\theta - \frac{H^2}{2\bar{\mu}B^2A^2}, \quad T_2^2 = T_3^3 = -\xi\theta - \frac{H^2}{2\bar{\mu}B^2A^2}, \quad T_4^4 = -\rho - \frac{H^2}{2\bar{\mu}B^2A^2}. \quad (13)$$

Rosen's field"equ. for the metric (1) & (2) having the components of T_i^j, (equation (13)) becomes

$$\frac{\ddot{B}}{B} - \frac{\dot{B}^2}{B} = 16\pi A^2 B\left(\lambda + \xi\theta + \frac{H^2}{2\bar{\mu}B^2A^2}\right), \quad (14)$$

$$2\frac{\ddot{A}}{A} - \frac{\ddot{B}}{B} - 2\frac{\dot{A}^2}{A^2} + \frac{\dot{B}^2}{B^2} - \frac{B^2}{A^2} = 16\pi A^2 B\left(\xi\theta - \frac{H^2}{2\bar{\mu}B^2A^2}\right), \quad (15)$$

$$\frac{\ddot{B}}{B} - \frac{\dot{B}^2}{B} + \frac{B^2}{A^2} = 16\pi A^2 B\left(\xi\theta - \frac{H^2}{2\bar{\mu}B^2A^2}\right), \quad (16)$$

$$2\frac{\ddot{A}}{A} + \frac{\ddot{B}}{B} - 2\frac{\dot{A}^2}{A^2} - \frac{\dot{B}^2}{B^2} = 16\pi A^2 B\left(\rho + \frac{H^2}{2\bar{\mu}B^2A^2}\right). \quad (17)$$

The law for the conservation of energy-momentum tensor

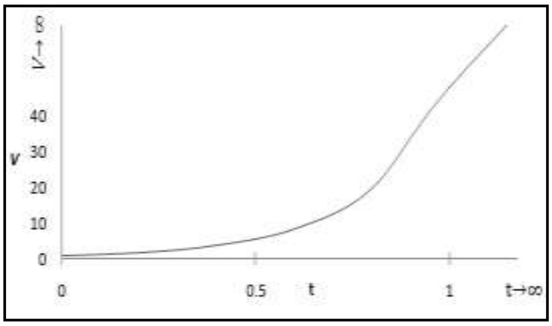
$T^{ij}_{|j} = 0,$
yield
$$\dot{\rho} = \lambda\left(2\frac{\dot{A}}{A}\right) - (\rho - \xi\theta)\left(2\frac{\dot{A}}{A} + 2\frac{\dot{B}}{B}\right), \qquad (18)$$
where $\dot{A} = \frac{\partial A}{\partial t}, \dot{B} = \frac{\partial B}{\partial t}, \ddot{A} = \frac{\partial^2 A}{\partial t^2}, \ddot{B} = \frac{\partial^2 B}{\partial t^2}$.

III. Field Equations With Physical ParametersSolution

Equations (14-18) are five differential equations in five unknowns $A, B, \rho, \lambda,$ and ξ, (as θ is in terms of A and B). Therefore, this system of five differential equations (14-18) determines a unique solution.
After solving equations (15) and (16), we get,
$$\frac{d}{dt}\left(\frac{\dot{A}}{A}\right) - \frac{d}{dt}\left(\frac{\dot{B}}{B}\right) = \frac{B^2}{A^2}, \qquad (19)$$
and from equations (14) - (17), we write,
$$-2\frac{d}{dt}\left(\frac{\dot{A}}{A}\right) = 16\pi A^2 B(\lambda + \xi\theta - \rho). \qquad (20)$$
With this equation (20), the differential equations (14), (16), and (17) yield
$$\frac{d}{dt}\left(\frac{\dot{A}}{A}\right) = \frac{B^2}{A^2}. \qquad (21)$$
From equations (19) and (21), we get
$$\frac{d}{dt}\left(\frac{\dot{B}}{B}\right) = 0, \qquad (22)$$
which yield
$$B = e^{(lt+m)}, \qquad (23)$$
where $l(> 0)$ and m are integration constants.
Using this given value (equ. (23)) of B, from equation (21), after straightforward calculations, we write the value of A as
$$A = \frac{1}{2}\left[e^{(lt+2m-t-c_2)} + e^{(lt+t+c_2)}\right], \qquad (24)$$
where $c_1, c_2,$and $m$are constants.
For simplicity, we assume $c_2 = m$. So that,
$$A = e^{(lt+m)}\cosh t. \qquad (25)$$
Hence metric (1) reduces to
$$ds^2 = -dt^2 + e^{2(lt+m)}[\cosh^2 t\,(dx^2 + dy^2) + (dy - xdz)^2]. \qquad (26)$$
This is the required metric that represents the LRS Bianchi type-II magnetized string cosmological model having a bulk viscous fluid in the gravitation bimetric theory, and it is free from a singularity. It is to be noted that the behavior of our model is reflected by hyperbolic geometric functions and a magnetic field.
The model's spatial volume denoted as V is determined by
$$V = e^{(lt+m)}(\cosh t)^2. \qquad (27)$$
After substituting the value of A A and$B$ from equations (25) and (23) in equ. (17), we have computed the energy density ρ as
$$\rho = \left(\frac{1-\tanh^2 t}{e^{3(lt+m)}}\right)\left[\frac{1-\tanh^2 t}{8\pi} - \frac{H^2}{2\bar{\mu}e^{(lt+m)}}\right]. \qquad (28)$$
Scalar expansion is denoted as θ is represented by equ. (9), and having a value,
$$\theta = (2\tanh t + 3l). \qquad (29)$$
From equation (16), the bulk viscosity ξ can be written as
$$\xi = \left(\frac{1-\tanh^2 t}{(2\tanh\ t+3l)e^{3(lt+m)}}\right)\left[\frac{1-\tanh^2 t}{16\pi} + \frac{H^2}{2\bar{\mu}e^{(lt+m)}}\right]. \qquad (30)$$
Substituting the values of the scalar expansion θ (from equation (29)) and bulk viscosity ξ (from equation (30)) in equation (14), we write the string tension density λ as
$$\lambda = \left(\frac{\tanh^2 t-1}{e^{3(lt+m)}}\right)\left[\frac{(1-\tanh^2 t)}{8\pi} + \frac{H^2}{2\bar{\mu}e^{(lt+m)}}\right]. \qquad (31)$$
Using equations (28) and (31), we obtain the particle density ρ_p from equation (8), and it is as
$$\rho_p = \left(\frac{1-\tanh^2 t}{e^{3(lt+m)}}\right)\left[\frac{3(1-\tanh^2 t)}{16\pi} + \frac{H^2}{2\bar{\mu}e^{(lt+m)}}\right]. \qquad (32)$$
The components σ_i^j of the shear tensor are defined as
$$\sigma_i^j = \frac{1}{2}\left(v^j_{|i} + v^i_{|j}\right) - \frac{1}{2}\left(v^j v_i + v^i v_j\right) - \frac{\theta}{3}\left(g_i^j + v^j v_i\right),$$
and the magnitude σ of shear is $\sigma^2 = 1/2\left(\sigma_{ij}\sigma^{ij,}\right)$ and in this model, its value is
$$\sigma = \left[\frac{1}{\sqrt{3}}\left((2\tanh t + 3l)\right)^{1/2}\right]. \qquad (33)$$
The parameter of the decelerationis denoted as q for the model (27) and is represented by,

$$q = -\left[1 + \frac{2(1-\tanh^2 t)/3}{\left(2\tanh {t}/{3}+l\right)^2}\right]. \quad (34)$$

All these results of physical parameters are very complicated; therefore, to study the physical &geometrical features of them, we were taking restrictions on constants. For simplicity, we have been assuming that for theconstants particular values $l = 1$&$m = 0$ in the physical parameter to examine the geometrical and physical significance.



Graph-1: VVst

It has been observed that the scale factors A, B,and the volume denoted as V admit constant value one, initially $t = 0$, and they are increasing by the rise of time t and approach infinity while the$t \to \infty$. This suggested that the model with hyperbolic geometry starts evolving with the universe of special relativity and increases, whose volume diverges to the infinity at the site ofthe late epoch of time t (shown in Graph-1). The model has volumetric hyperbolic expansion.

IV. The Model Geometrical And Physical Significance

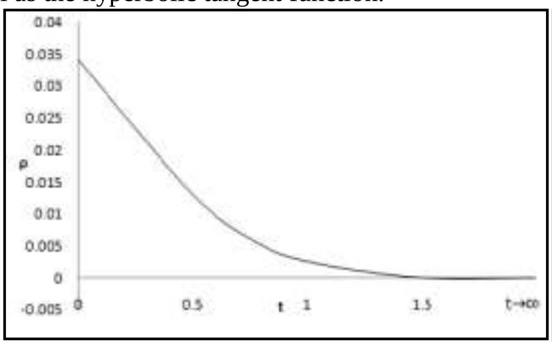
For a suitable choice of constants $l = 1$ and $m = 0$, we re-write the energy ρ, particle density ρ_p, and string tension density λ as

$$\rho = \left(\frac{1-\tanh^2 t}{e^{3t}}\right)\left[\frac{(1-\tanh^2 t)}{8\pi} - \frac{H^2}{2\bar{\mu}e^t}\right], \quad (35)$$

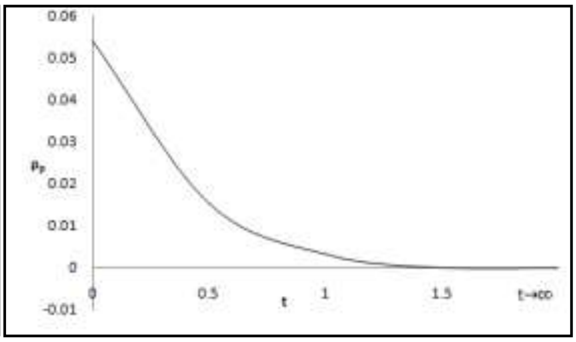
$$\rho_p = \left(\frac{1-\tanh^2 t}{e^{3t}}\right)\left[\frac{3(1-\tanh^2 t)}{16\pi} + \frac{H^2}{2\bar{\mu}e^t}\right], \quad (36)$$

$$\lambda = \left(\frac{\tanh^2 t-1}{e^{3t}}\right)\left[\frac{(1-\tanh^2 t)}{16\pi} + \frac{H^2}{2\bar{\mu}e^t}\right], \quad (37)$$

These physical variables are decreasing functions of time and are controlled by the magnetic field H as well as the hyperbolic tangent function.

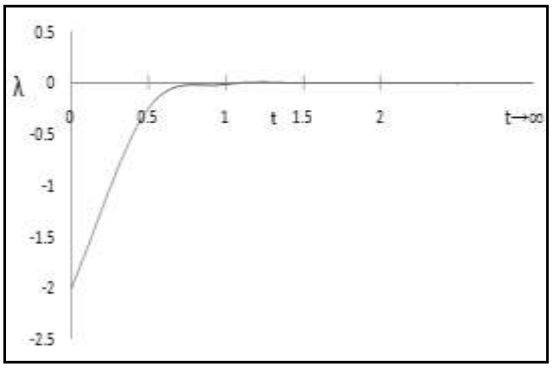


Graph-2: ρVst



Graph-3: ρ_pVst

Initially, when $t \to 0$, we have three different types of nature of energy density depending upon the nature of the magnetic field $(H^2/2\bar{\mu})$ ($\rho > 0$ for $(H^2/2\bar{\mu}) < 0.0398$, $\rho = 0$ for $(H^2/2\bar{\mu}) = 0.0398$ and $\rho < 0$ for $(H^2/2\bar{\mu}) > 0.0398$) and when $t \to \infty$, $\rho \to 0$. Thus the magnetic field could have the cosmological origin of the model, and it has small values $(H^2/2\bar{\mu}) \leq 0.0398$, in the early universe with matter density $\rho \geq 0$ and a strong magnetic field $(H^2/2\bar{\mu}) > 0.0398$, giving rise non-existence of the model, since $\rho < 0$. Hence the small value of the magnetic field $(H^2/2\bar{\mu}) < 0.0398$ originated the model and starts evolving it whose energy den attains maximum value, initially attains zero value, and finally, it is shown in Graph-2. Thus, under the magnetic field impact, the model begins to evolveby the high-density matter whose density slows down, and the model is converted to a vacuum at the final stage. If the magnetic field is growing, then the model will be destroyed, OR the model will die, i.e., the model does not exist. The particle density ρ_p is always positive under the influence of a magnetic field$(H^2/2\bar{\mu},)$ and it attains maximum value, initially when $t \to 0$ and the zero value, and finally when $t \to \infty$ and the magnetic field do not disturb the behavior of particle density ρ_p whose nature is shown in Graph-3.



Graph-4: $\lambda \text{V}st$

The magnetic field also doesn't disturb the λ denoted as the string tension density nature. Initially, when $t \to 0$, string tension density λ attains a negative value, and its valuerises with the time t and it attains 0 value finally when $t \to \infty$. Thus, the string tension density is found to be non-positive in the evolution of the model, and therefore, phases of the string in the universe have disappeared OR switched off without affecting the magnetic field.

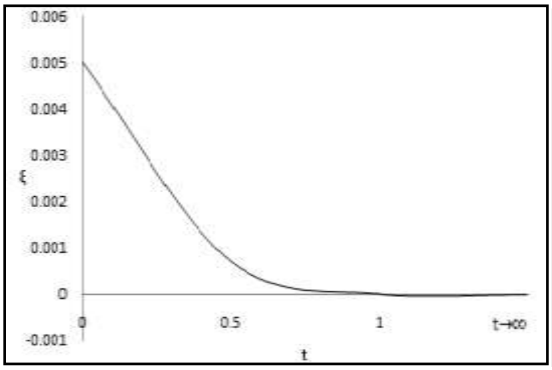
The bulk viscosity coefficient is denoted as ξ, the shear tensoris denoted as σ, the scalar expansion is denoted as θ, and the deceleration parameter q can be re-written for $l = 1$and $m = 0$ as

$$\xi = \left(\frac{1-\tanh^2 t}{(2\tanh t+3l)e^{3(lt+m)}}\right)\left[\frac{(1-\tanh^2 t)}{16\pi} + \frac{H^2}{2\bar{\mu}e^t}\right], \quad (38)$$

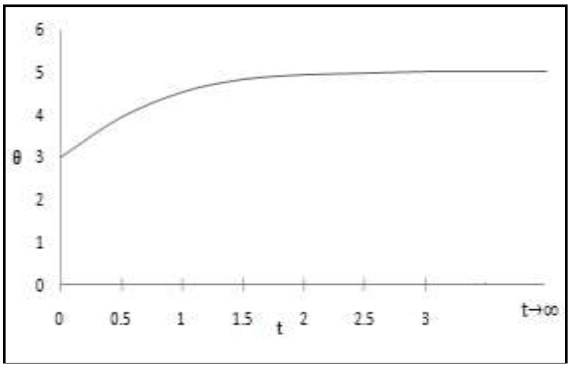
$$\theta = (2\tanh t + 3l), \quad (39)$$

$$\sigma = \left[\frac{1}{\sqrt{3}}\left((2\tanh t + 3)\right)^{1/2}\right], \quad (40)$$

$$q = -\left[1 + \frac{2(1-\tanh^2 t)/3}{\left(2\tanh t/_3 + 1\right)^2}\right]. \quad (41)$$



Graph-5: $\xi \text{V}st$



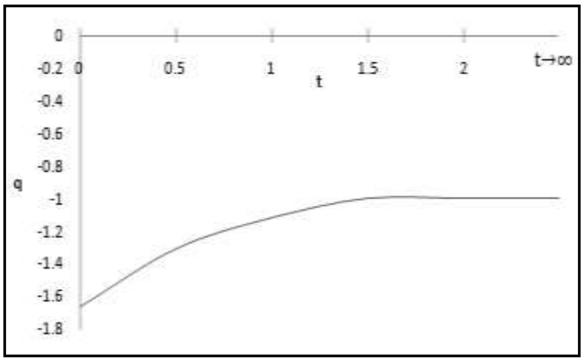
Graph-6: $\theta \text{V}st$

The nature of the bulk viscosity coefficient denoted asξ (decreasing time function as$t$), the scalar expansion denoted asθ, and the shear$\sigma$are not affected by a magnetic field. Initially, when $t \to 0$, ξadmits maximum value and its intensity is slowing down and admits a negligible value at the final stage. This shows that there is a maximum intensity of viscosity in the beginning, and this viscosity decreasescontinuously and goes over to the value zero at themodel end. Therefore, the model beginsby havinga high viscosity of the fluid and ends with viscous less fluid (shown in Graph5). The θ represents the scalar expansion that has a nature in the hyperbolic tangent function, and it is independent of the magnetic field. Primarily, when $t \to 0$, it achieves a constant value forever, and then it increases with the rise of time t and again attains a constant value when

$t \to \infty$. So that the model begins with uniform expansion as well as it ends with uniform expansion. In the meanwhile, there is an accelerating sense in the expansion in the beginning period, shown in Graph-6. This scalar expansion θ dominates the nature of viscosity ξ.
We can develop the relations among the energy density ρ, particle density ρ_p, θ, and ξ as
$\rho = 2\xi\theta - 3(1 - \tanh^2 t)H^2/2\bar{\mu}e^{4t}$,
$\rho_p = 3\xi\theta - (1 - \tanh^2 t)H^2/\bar{\mu}e^{4t}$.

From this, we can put the nature of energy density ρ in terms of the energy density ρ is less than $(2\xi\theta)$ by an amount $(3H^2/2\bar{\mu})$, initially and finally it is $(2\xi\theta)$, and goes over to zero, since ξ is zero, at the final stage. Also, in regards to particle density ρ_p, it is less than $(3\xi\theta)$ by an amount $(H^2/\bar{\mu})$, initially and finally, it is $(3\xi\theta)$, and it vanishes, since $\xi$is 0, at the last stage.

The shear σ is independent of the magnetic field, and it behaved in thesame way as of θ denoted as the scalar expansion. Therefore, the model has uniform shear in the beginning as well as in the ending.



Graph-7: qVst

The deceleration parameteris the increasing time function t. Firstly, when $t \to 0$, it has the least value $(-5/3,)$ and it is (-1) finally when $t \to \infty$. Thus the deceleration parameter q always appeared with a negative value in the increasing sense, that displays the model has expansion with slowing down acceleration.

In the magnetic field absence, that means for $H = 0$, all the physical parameters $\rho_p, \lambda, \xi. \theta, \sigma$, and q behaves in a same way as the behavior in the magnetic field existence. In regards to energy density ρ of matter, it is 0.0398 , initially, and it is zero, finally, in the magnetic field absence. So that the model goes over to vacuum if the magnetic field is removed from it.

In the ξ denoted as the bulk viscosity absence, i.e., $\xi = 0$, the physical parameters ρ, ρ_p, λ, and q all are zero, and the scalar expansion θ and also the shear σ admit the constant values. This displayed the vacuum model with uniform expansion and uniform shear in the bulk viscosity coefficient ξ absence.

V. Summary

1. "We have examined theLRS Bianchi Type II space-time having a magnetic field and string bulk viscous fluid by solving Rosen's bimetric theory of gravitation field equations and" studying its nature.
2. It is observed that the magnetic field has the cosmological origin of the model and agrees with Harrison (1973). In the early universe, the magnetic field has a smaller value $(H^2/2\bar{\mu}) \le 0.0398$, with matter density $\rho \ge 0$, and a greater magnetic field $(H^2/2\bar{\mu}) > 0.0398$ gives rise non-existence model, since $\rho < 0$. Thus the small value of the magnetic field originated the model and started evolving it whose energy density attains maximum value initially and attains minimum value finally. This shows the model started evolving with high-density matter and converted to vacuum at the end, because of the magnetic field effect.
3. The particle density ρ_p is always positive and is not affected by a magnetic field. Initially, it attains maximum value, and finally, it attains zero value.
4. In the process of the development of the universe, the string tension density λ has been seen to have a negative value, and it has not been affected by the magnetic field. This demonstrates that the string phases that were present in the cosmos either stopped existing or vanished without being affected by a magnetic field.
5. The ξbulk viscosity coefficient is a reducing function of time t. It is highest in the beginning and has a negligible value at the model end. Therefore, the model beginsby having a high viscosity of the fluid and ends with viscous less fluid.

6. The model starts to evolve with uniform expansion and also ends with uniform expansion. In the meanwhile, there is an accelerating sense of expansion in the beginning period.
7. One can observe the nature of energy density ρ and particle density ρ_p in terms of ξ and θ. Initially, energy density ρ is less than $(2\xi\theta)$ by an amount of $(3H^2/2\bar{\mu},)$ and finally, it is $(2\xi\theta)$ and goes over to zero since $\xi = 0$ at the final stage. Similarly, the particle density ρ_p is less than $(3\xi\theta)$ by an amount $(H^2/2\bar{\mu})$, initially and finally, it is $(3\xi\theta,)$ and it vanishes since ξ is 0, at the last stage.
8. The model has a uniform shear at the beginning and the ending.
9. The deceleration parameter q is an increasing time function t. Firstly, while the $t \to 0$, it has the least value of $(-5/3)$, and it has a value of (-1), and finally, when $t \to \infty$. The deceleration parameter q appears to have a negative value, which displays the model has expansion with slowing down acceleration.
10. In the magnetic field absence, all physical parameters work in a similar way as that of the behavior in the magnetic field existence. Thus magnetic fields do not disturb the character of physical parameters, except the matter density ρ. Thus, ρ is negligible, and therefore the model converts into a vacuum in the magnetic field absence.
11. In the absence of the coefficient of bulk viscosityξ, our non-vacuum model converted to vacuum, but there is uniform expansion and uniform shear.
12. The ratio $\sigma/_{\theta} \neq 0$, while,$t \to \infty$, displayed that the model is not isotropic.

VI. Conclusion

We have deduced LRS Bianchi type II space-time having a magnetic field and with string viscous fluid by solving the Rosen's bimetric theory of gravitation field equations. It has been observed that the magnetic field could have the model's cosmological origin, which agrees with Harrison (1973). The magnetic field'ssmall value originated in the universe and started evolving with maximum density and ending with zero density. The strong magnetic field ruled out the universe existence. Other physical &geometrical behaviors of the model were researched in the universe evolution.

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