Article

Some String Cosmological Universes Containing Dark Energy

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Abstract

Here we have investigated on string cosmological model universe coupled with electromagnetic field to study the evolution of the universe, it is found that such a model contains dark energy which implies that dark energy is there in the universe from the very beginning of its evolution when the particles exhibits in the form of strings. Moreover there is possibility that dark energy dominated universe can contain in it highly contracted cosmic string. Using suitable physical assumptions for different cases, the field equations are solved exactly. The physical and kinematical features of the models and the effects of electromagnetic field with many novel and interesting consequences are revealed through this work and discussed in some details. Here the bulk viscosity and electromagnetic field are found to play great roles in the evolution of universe which will be beneficial in further research works.

Keywords: String universe, viscosity, electromagnetic field, dark energy.

Introduction

Different investigators studied about the existence of the dark energy to explain the accelerated expansion of the universe in the frame work of general relativity. From the critical study of our present universe it is found that dark energy, and of course, dark matter is there in the universe from the beginning of its evolution manifesting in one form or the other. The different forms contained in our model universe are found to be generalized Chaplygin gas, quintessence and phantom energy; of course, the generalized Chaplygin gas can explain the origin of dark energy as well as dark matter in our universe which are the major candidates for the accelerated expansion of the universe instead of slowing down as predicted by the Big Bang theory [1]. Differentevidences and confirmationsfor accelerated expansion in the universe have been suggested from the theoretical and observational facts like cosmic microwave background radiation (CMBR) ,Type SNeIa supernova, CMB anisotropies, the large scale galaxy structures of the universe and Sachs Wolf effects etc. as suggested by[2-10].

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On the other hand the study of string cosmological models is widely done by many authors in recent time because of their prime role in the description of the evolution of the early phase of the universe. One dimensional string is believed to occur as a topological stable defect during the initial phase of the universe. The physical basis of the string lies in the fact that the density perturbation which arise from the cosmic strings leads to the formation of large scale structures like galaxies [11]. Since the universe is filled with lots of large-scale structures like galaxies, string cosmology can greatly help in the view of the primordial phase of evolution of the universe. Moreover, Grand Unified Theories (GUT) predicts the presence of strings in the initial epoch. Many good authors have investigated about different aspects of the string cosmological models either in the framework of Einstein, Relativity (ER) or in modified theories of gravity using various space times. Besides the pioneering works of [12-22], Tripathy et al. The authors [23-24] have studied string cloud cosmology and [25-28] have been studiedstring cosmologies with bulk viscosity. Also, the gravitational effects of cosmic strings have extensively discussed by Vilenkin [29] and Gott [30] in general relativity. Some string cosmological models were studied by different authors like [31-59]. Manihar Singh and his co-authors [60-63] also investigated some interesting models of cosmic string universes and got some stimulating results. The existence of large-scale network of strings in the early universe is not a contradiction with the present day observation of universe. In the present epoch, for a physically meaningful string model, it is desirable that either strings disappear at a certain epoch of cosmic evolution, or it has a particle-dominated future asymptote with undetectable strings.

In the description of the energy distribution in the universe, we know that magnetic field plays an important role as it contains highly ionized matter. The strong magnetic field may be treated due to adiabatic compression in cluster of galaxies. Cosmic anisotropies may also be attributed to the large scale magnetic fields. Also,[64,65] have studied the behavior of string cosmological models in the presence of electromagnetic fields. The necessity of electromagnetic field, along with the topological defects in the form of cosmic string has already been established and the need of viscosity in describing the evolution of the properties of the universe has been justified by [66]. Some authors consider the string tension, density λ to be proportional to energy density ρ, the proportionality constant being a constant for the whole range of cosmic time. In fact, both λ and ρ should evolve with time and in turn the proportionality relation should be disturbed in the course of growth of the cosmic time.

Here in this paper, we discuss about a string cosmological model universe containing dark energy coupled with an electromagnetic field by considering the LRS Bianchi type-I metric. The basic field equations for this metric and their solutions have been derived. The physical and kinematic properties of the solutions obtained by considering three different cases are discussed in some details. Also, we have studied the effects of bulk viscosity and magnetic field in the evolution of the universe. We found that in this model universe, with the increase of cosmic time, string tension density is found to decrease whereas the particle energy density is found to increase showing that this model universe will ultimately become a fluid containing only of particles and not strings. Our model is also seen to be a universe with accelerated expansion, and moreover the pressure is found to be negative, which are all characteristicsfor this model universe to be a dark energy universe.

Solutions of Field Equations

The LRS Bianchi type-I metric is taken

$$ds^2 = -dt^2 + A^2dx^2 + B^2(dy^2 + dz^2) \tag{1}$$

Einstein's field equations is given by

$$R_{ij} - \frac{1}{2}g_{ij}R = -T_{ij} \tag{2}$$

Here energy momentum tensor is

$$T_{ij} = \rho u_{ij} + (p - \xi\theta)(u_{ij} + g_{ij}) - \lambda x_i x_j + E_{ij} \tag{3}$$

whereρ and p are respectively the fluid density and pressure, ξ is the coefficient of bulk viscosity, $u^i$are the four-vector velocity of flow, and θ is the expansion factor of the flow lines. λ is the string tension density, x^i is a unit space like vector representing the direction of string. E_{ij} is the energy-momentum tensor for the electromagnetic field. Also u^i and x^i satisfy the relations.

$$g_{ij}u^iu^j = -1 \quad and \quad g_{ij}x^ix^j = 1 \tag{4}$$

Here,

$$E_{23} = E_{32} = H = constant,$$
$$E_{14} = E_{24} = E_{34} = 0,$$
$$E_{44} = \frac{H^2}{8\pi B^4} = \eta$$

Einstein field equations give

$$2\left(\frac{B_4}{B}\right)_4 + 3\left(\frac{B_4}{B}\right)^2 - \xi\left(\frac{A_4}{A} + 2\frac{B_4}{B}\right) = -p + \lambda + \eta \tag{5}$$

$$\left(\frac{A_4}{A}\right)_4 + \left(\frac{B_4}{B}\right)_4 + \left(\frac{A_4}{A}\right)^2 + \left(\frac{B_4}{B}\right)^2 + \left(\frac{A_4}{A}\right)\left(\frac{B_4}{B}\right) - \xi\left(\frac{A_4}{A} + 2\frac{B_4}{B}\right) \quad = -p - \eta \tag{6}$$

$$\left(\frac{B_4}{B}\right)^2 + 2\left(\frac{A_4}{A}\right)\left(\frac{B_4}{B}\right) = \rho + \eta \tag{7}$$

In this problem

$$\theta = u^a{}_{;a} = \frac{A_4}{A} + 2\frac{B_4}{B} \tag{8}$$

and

$$\sigma^2 = \left(\frac{A_4}{A}\right)^2 + 3\left(\frac{B_4}{B}\right)^2 + 2\left(\frac{A_4}{A}\right)\left(\frac{B_4}{B}\right) + 2\left(\frac{A_4}{A} + 2\frac{B_4}{B}\right)^2 \tag{9}$$

Case I: $\rho = \lambda$ and $\rho = 3p$

Then from (5) and (7) we get

$$p = 2\left(\frac{A_4}{A}\right)\left(\frac{B_4}{B}\right) - 2\left(\frac{B_4}{B}\right)^2 - 2\left(\frac{B_4}{B}\right)_4 + \xi\left(\frac{A_4}{A} + 2\frac{B_4}{B}\right) \quad (10)$$

And the equation (6) gives us

$$\eta = \left(\frac{B_4}{B}\right)_4 - \left(\frac{A_4}{A}\right)_4 + \left(\frac{B_4}{B}\right)^2 - \left(\frac{A_4}{A}\right)^2 - 3\left(\frac{A_4}{A}\right)\left(\frac{B_4}{B}\right) \quad (11)$$

From (5) and (6) we get

$$\lambda - 2p = 3\left(\frac{B_4}{B}\right)_4 + \left(\frac{A_4}{A}\right)_4 + \left(\frac{A_4}{A}\right)^2 + 4\left(\frac{B_4}{B}\right)^2 + \left(\frac{A_4}{A}\right)\left(\frac{B_4}{B}\right) - 2\xi\left(\frac{A_4}{A} + 2\frac{B_4}{B}\right) \quad (12)$$

Equations (10) and (12) give

$$\lambda = \left(\frac{A_4}{A}\right)_4 - \left(\frac{B_4}{B}\right)_4 + \left(\frac{A_4}{A}\right)^2 + 5\left(\frac{A_4}{A}\right)\left(\frac{B_4}{B}\right) \quad (13)$$

Here we consider the case of radiating fluid

$$\rho = 3p \quad (14)$$

Using equation (10), (13) and the relation $\rho = \lambda$ in equation (14) we get

$$5\left(\frac{B_4}{B}\right)_4 + \left(\frac{A_4}{A}\right)_4 + \left(\frac{A_4}{A}\right)^2 + 6\left(\frac{B_4}{B}\right)^2 - \left(\frac{A_4}{A}\right)\left(\frac{B_4}{B}\right) - 3\xi\left(\frac{A_4}{A} + 2\frac{B_4}{B}\right) = 0 \quad (15)$$

Conveniently a set of solution of the equation (15) may be taken as

$$A = k_3\left[1 - e^{\left(\frac{k_1}{k_0}t - k_2\right)}\right]^{-\frac{k_0}{k_1}} \quad (16)$$

$$B = k_4\left[1 - e^{\left(\frac{k_1}{k_0}t - k_2\right)}\right]^{-n\frac{k_0}{k_1}} \quad (17)$$

$$\xi = \frac{1}{3(2n+1)}\left(1 - e^{\left(\frac{k_1}{k_0}t - k_2\right)}\right)^{-1}\left[(5n+1)\frac{k_1}{k_0} + (6n^2 - n + 1)e^{\left(\frac{k_1}{k_0}t - k_2\right)}\right] \quad (18)$$

where k_0, k_1, k_2, k_3, k_4 and n are arbitrary constants.

Therefore we have from equations (8)-(13) we have

$$p = \frac{\frac{1}{3}e^{\left(\frac{k_1}{k_0}t - k_2\right)}}{\left[1 - e^{\left(\frac{k_1}{k_0}t - k_2\right)}\right]^2}\left[(5n+1)e^{\left(\frac{k_1}{k_0}t - k_2\right)} + (1-n)\frac{k_1}{k_0}\right] \quad (19)$$

$$\rho = \lambda = \frac{e^{\left(\frac{k_1}{k_0}t - k_2\right)}}{\left[1 - e^{\left(\frac{k_1}{k_0}t - k_2\right)}\right]^2}\left[(5n+1)e^{\left(\frac{k_1}{k_0}t - k_2\right)} + (1-n)\frac{k_1}{k_0}\right] \quad (20)$$

$$\eta = \frac{e^{\left(\frac{k_1}{k_0}t-k_2\right)}}{\left[1-e^{\left(\frac{k_1}{k_0}t-k_2\right)}\right]^2}\left[(n^2-3n-1)e^{\left(\frac{k_1}{k_0}t-k_2\right)}+(n-1)\frac{k_1}{k_0}\right] \tag{21}$$

$$\theta = (2n+1)e^{\left(\frac{k_1}{k_0}t-k_2\right)}\left(1-e^{\left(\frac{k_1}{k_0}t-k_2\right)}\right)^{-1} = (2n+1)\left(e^{\left(-\frac{k_1}{k_0}t+k_2\right)}-1\right)^{-1} \tag{22}$$

$$\sigma = (9n+3)^{\frac{1}{2}}e^{\left(\frac{k_1}{k_0}t-k_2\right)}\left(1-e^{\left(\frac{k_1}{k_0}t-k_2\right)}\right)^{-1} = (9n+3)^{\frac{1}{2}}\left(e^{\left(-\frac{k_1}{k_0}t+k_2\right)}-1\right)^{-1} \tag{23}$$

Therefore the volume V and deceleration parameter q are obtained as

$$V = k_3{k_4}^2\left[1-e^{\left(\frac{k_1}{k_0}t-k_2\right)}\right]^{-(2n+1)\frac{k_1}{k_0}} \tag{24}$$

$$q = -\frac{k_1\left(e^{\left(\frac{k_1}{k_0}t-k_2\right)}-1\right)}{(2n+1)k_0e^{\left(\frac{k_1}{k_0}t-k_2\right)}} - \frac{k_1}{(2n+1)k_0} - 1 \tag{25}$$

Again from (22) and (23) we get

$$\frac{\sigma}{\theta} = [3(3n+1)]^{\frac{1}{2}}(2n+1)^{-1} \tag{26}$$

Case II: In this case we take $\rho = -\lambda$ and $\rho = \frac{3p}{2}$

The equations (5) and (6) give

$$\left(\frac{B_4}{B}\right)_4 - \left(\frac{A_4}{A}\right)_4 + 2\left(\frac{B_4}{B}\right)^2 - \left(\frac{A_4}{A}\right)^2 - \left(\frac{A_4}{A}\right)\left(\frac{B_4}{B}\right) = \lambda + 2\eta \tag{27}$$

Equations (7) and (27) yields

$$\eta = \left(\frac{B_4}{B}\right)_4 - \left(\frac{A_4}{A}\right)_4 + \left(\frac{B_4}{B}\right)^2 - \left(\frac{A_4}{A}\right)^2 - 3\left(\frac{A_4}{A}\right)\left(\frac{B_4}{B}\right) \tag{28}$$

Again equations (5) and (28) implies

$$2\left(\frac{B_4}{B}\right)_4 + 2\left(\frac{B_4}{B}\right)^2 - 2\left(\frac{A_4}{A}\right)\left(\frac{B_4}{B}\right) - \xi\left(\frac{A_4}{A} + 2\frac{B_4}{B}\right) = -p \tag{29}$$

and from equations (7) and (28), we get

$$\rho = \left(\frac{B_4}{B}\right)_4 - \left(\frac{A_4}{A}\right)_4 - \left(\frac{A_4}{A}\right)^2 - 5\left(\frac{A_4}{A}\right)\left(\frac{B_4}{B}\right) \tag{30}$$

Here we consider string dust distribution in internabular space so that

$$\rho = \frac{3p}{2} \tag{31}$$

So equations (29),(30) and (31) give

$$\left(\frac{A_4}{A}\right)_4 - 4\left(\frac{B_4}{B}\right)_4 + \left(\frac{A_4}{A}\right)^2 - 3\left(\frac{B_4}{B}\right)^2 + 8\left(\frac{A_4}{A}\right)\left(\frac{B_4}{B}\right) + \frac{3}{2}\xi\left(\frac{A_4}{A}\right) + 3\xi\left(\frac{B_4}{B}\right) = 0 \tag{32}$$

Therefore,

$$A = \left[1 - k_0 k_2 e^{\frac{k_1 t}{4+k}}\right]^{-\left(\frac{4+k}{k_0}\right)k k_3} \tag{33}$$

$$B = \left[1 - k_0 k_2 e^{\frac{k_1 t}{4+k}}\right]^{\left(\frac{4+k}{k_0}\right)k_3} \tag{34}$$

$$\xi = \frac{2}{3(2-k)}\left[k_1 + (k^2 - 8k - 3)k_1 k_2 k_3 e^{\frac{k_1 t}{4+k}}\right]\left[1 - k_0 k_2 e^{\frac{k_1 t}{4+k}}\right] \tag{35}$$

where k_0 , k_1 , k_2 , k_3 , k_4 and n are arbitrary constants, and are a set of solution of equation (32).

Hence from equations (28)-(30) we obtain

$$\eta = \left(\frac{{k_1}^2 k_2 k_3}{4+k}\right) e^{\frac{k_1 t}{4+k}}\left(1 - k_0 k_2 e^{\frac{k_1 t}{4+k}}\right)^{-2} \times \left[k_2 k_3 (4+k)(k^2 + 3k + 1)e^{\frac{k_1 t}{4+k}} - k - 1\right] \tag{36}$$

$$p = \frac{2}{3}\left(1 - k_0 k_2 e^{\frac{k_1 t}{4+k}}\right)^{-2} e^{\frac{k_1 t}{4+k}}\left[(5k - k^2)k_1^2 k_2^2 k_3^2 e^{\frac{k_1 t}{4+k}} - \frac{k+1}{4+k}{k_1}^2 k_2 k_3\right] \tag{37}$$

$$-\lambda = \rho = \left(1 - k_0 k_2 e^{\frac{k_1 t}{4+k}}\right)^{-2} e^{\frac{k_1 t}{4+k}}\left[(5k - k^2)k_1^2 k_2^2 k_3^2 e^{\frac{k_1 t}{4+k}} - \frac{k+1}{4+k}{k_1}^2 k_2 k_3\right] \tag{38}$$

Also from equations (9) and (8), we got the values of shear scalar σ and expansion factor θas

$$\sigma = k_1 k_2 k_3 (3k^2 - 10k + 11)^{\frac{1}{2}}\left(1 - k_0 k_2 e^{\frac{k_1 t}{4+k}}\right)^{-1} e^{\frac{k_1 t}{4+k}} \tag{39}$$

$$\theta = k_1 k_2 k_3 (2-k)\left(1 - k_0 k_2 e^{\frac{k_1 t}{4+k}}\right)^{-1} e^{\frac{k_1 t}{4+k}} \tag{40}$$

Therefore the volume V and deceleration parameter q are obtained as

$$V = \left(1 - k_0 k_2 e^{\frac{k_1 t}{4+k}}\right)^{\frac{1}{k_0}(4+k)(2-k)k_3} \tag{41}$$

$$q = \frac{1}{(4+k)(2-k)k_2 k_3} e^{\frac{-k_1 t}{4+k}}\left[1 - k_0 k_2 e^{\frac{k_1 t}{4+k}}\right] - 1 + \frac{k_0}{(4+k)(2-k)k_3} \tag{42}$$

Therefore from equations (39) and (40) we get

$$\frac{\sigma}{\theta} = \frac{(3k^2 - 10k + 11)^{\frac{1}{2}}}{2-k} \tag{43}$$

Case III: Here we take up the case $p+\rho=0$ and $\xi=l_0\theta^l$

Then from equations (5) and (7) we get the relation

$$\lambda+\xi\left(\frac{A_4}{A}+2\frac{B_4}{B}\right)=2\left(\frac{B_4}{B}\right)_4+2\left(\frac{B_4}{B}\right)^2-2\left(\frac{A_4}{A}\right)\left(\frac{B_4}{B}\right) \tag{44}$$

A set of solutions of equation (44) may be conveniently taken as

$$A=e^{\left(\frac{c_0}{m+1}t^{m+1}+c_1t+c_2\right)} \tag{45}$$

$$B=e^{\left(\frac{d_0}{n+1}t^{n+1}+d_1t+d_2\right)} \tag{46}$$

$$\lambda=2d_0nt^{n-1}+2(d_0t^n+d_1)^2-2(c_0t^m+c_1)\times(d_0t^n+d_1)-l_0(c_0t^m+2d_0t^n+c_1+2d_1)^{l+1} \tag{47}$$

and

$$\xi=l_0(c_0t^m+2d_0t^n+c_1+2d_1)^l \tag{48}$$

wherec_0, c_1, c_2, d_0, d_1, d_2, m and n are arbitrary constants.

From equations (5) and (6) we get

$$\eta=l_0(c_0t^m+2d_0t^n+c_1+2d_1)^{l+1}+(c_0t^m+c_1)(d_0t^n+d_1)-c_0mt^{m-1}-d_0nt^{n-1}-(c_0t+c_1)^2 \tag{49}$$

And equation (7) gives

$$\rho=(d_0t^n+d_1)^2+\frac{1}{2}(c_0t^m+c_1)^2+\frac{3}{2}(c_0t^m+c_1)(d_0t^n+d_1)+\frac{l_0}{2}(c_0t^m+2d_0t^n+c_1+2d_1)^{l+1}+\frac{1}{2}c_0mt^{m-1}-\frac{1}{2}d_0nt^{n-1} \tag{50}$$

Therefore the volume V, expansion scalar θ, shear scalar σ, deceleration parameter q and pressure p are given by

$$V=e^t\left(\frac{c_0}{m+1}t^m+\frac{2d_0}{n+1}t^n\right)+(c_1+2d_1)t+c_2+2d_2 \tag{51}$$

$$\theta=(c_0t^m+c_1)+2(d_0t^n+d_1) \tag{52}$$

$$\sigma^2=3(c_0t^m+c_1)^2+11(d_0t^n+d_1)^2+10(c_0t^m+c_1)(d_0t^n+d_1) \tag{53}$$

$$q=-1-\frac{mc_0t^{m-1}+2d_0nt^{n-1}}{(c_0t^m+2d_0t^n+c_1+2d_1)^2} \tag{54}$$

$$p = \frac{l_0}{2}(c_0 t^m + 2d_0 t^n + c_1 + 2d_1)^{l+1} + \frac{1}{2}(c_0 t^m + c_1)^2 + \frac{1}{2}c_0 m t^{m-1} + \frac{7}{2}(c_0 t^m + c_1 + d_0) - (d_0 t^n + d_1)^2 - \frac{3}{2}d_0 n t^{n-1} \quad (55)$$

3. Physical Interpretations of the Solutions

In the first case we see that as $t \to 0$, η takes a finite value but when $t \to \infty$ it is found that $\eta \to 0$ showing that the effect of the electromagnetic field on the model gradually vanishes until it attains a constant value as the cosmic time increases. Again as $t \to \infty$, we find that $\lambda < 0$ implying that particles dominate the universe as time increases. Thus we see that the electromagnetic field has considerable influence on the characteristic and properties of the model. Here in this model the ratio $\frac{\rho}{\lambda} = 1$ is a constant gravity for the whole range of time and for the model here the expansion rate increases with the increase of the cosmic time,thus reminding of the present dark energy model these since $\frac{\sigma}{\theta} \neq 0$ for all real values of λ , we see that our model is found to be anisotropic through the ages.

From the nature of the electromagnetic field here we see that the strings co-exist with the electromagnetic field in this model. For this model the deceleration parameter q is found to be negative, which shows that this model inflates. The volume of this model universe is found to increase with time. This model is found to be a shearing one filled with radiating dust particles. There is a bounce at $t = \frac{k_0 k_2}{k_1}$ as there is high expansion at this epoch of time. This model has a constant pressure at $t = 0$, and it decreases gradually as the cosmic time increases.

Also, in the second case as $t \to 0$ we see that η takes a finite value, but when $t \to \infty$ it is found that η tends to a constant quantity showing that the effect of the electromagnetic field on the model gradually vanishes until it attains a constant quantity as the cosmic time increases. Thus the electromagnetic field plays an influential role on the properties of this model universe. From the nature of the electromagnetic field here we see that the string co-exist with the electromagnetic field in this model. Here this model is found to be an expanding as well as a shearing one, the model here expansion rate increases at a rapid state with the increase of time, thus it is interesting to note that our string model may represent a dark energy model. In this model since $\frac{\sigma}{\theta} \neq 0$ for all real values of k, the Universe remains anisotropic throughout the evolution. For this model the decelerations parameter q is seem to be negative, which shows that the model universe here is an inflationary one the volume of this model universe is found to decrease with time .which have a bounce at time given by $k_0 k_2 exp\left(\frac{k_1 t}{4+k}\right) = 1$.

This model has a constant pressure at $t = 0$, it decreases gradually as the cosmic time increases. In this Universe $\lambda < 0$ which implies that particles dominate the Universe as the cosmic time increases. In the string-dominated era, that is, in the early Universe, the strings might produce fluctuations in particle density. As the string vanish and the particles become important, the fluctuations will grow in such a way that finally there will be galaxies and also as strings disappear the Space-time anisotropy introduced by them will disappear in due course. In this model the deceleration parameter is found to be negative. Therefore this model turns out to be of inflationary type. A desirable feature of a meaningful string model is the presence of an inflationary epoch in the very early universe.

The electromagnetic field and bulk viscosity both have greater role in establishing a string phase of the universe as well as in getting an accelerated expansion phase. In order to get an accelerated universe of the Universe, the effective pressure, comprising the proper pressure and bulk viscous pressure has to assumed negative values. A negative pressure simulates a repulsive gravity and inflates the Universe by overwhelming the usual gravitational effects of matter. Since the proper pressure is positive the total pressure can only be negative if we consider a non negative finite bulk viscous pressure in addition to the proper pressure. In other words, bulk viscosity plays an important role in providing inflationary models. However, the bulk viscous driven inflation is strictly associated with the anisotropic nature of this model.

Lastly, in third case also as $t \to 0$ we see that η takes a finite value but when $t \to \infty$it is found that ηtakes another finite value. Thus we see that the electromagnetic field is accompanied with our model universe throughout the ages. Again as $t \to \infty$ we find that λ <0 implying that particles dominate the Universe as time increases. Thus in this case also it is seen that the electromagnetic field has considerable influence on the characteristics and properties of the model Universe.

Here we see that our model Universe rapidly expands with the increase of time reminding this model to be that of dark energy model. Thus we can guess that there may be possibility that strings are there in dark energy model. Here also since $\frac{\sigma}{\theta} \neq 0$, our model Universe is found to be anisotropic one. In this model also the deceleration parameter q is found to be negative which shows that this model inflates. The volume of this model Universe is found to be increased at a very high speed with time.

In this model Universe, with the increase of cosmic time, string tension density is found to decrease whereas the particle energy density is found to increase showing that this model Universe will ultimately become a fluid containing only of particles and not strings. This model also found to be a shearing one. Here the pressure of this model is also found to be negative which is a characteristic of this model Universe to be a dark energy model.

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