I J R B A T, Issue (VIII), Vol. I, Jan 2020: 161-165 e-ISSN 2347 – 517X

A Double Blind Peer Reviewed Journal

OPEN ACCESS

Original Article

Reg. No.: MH-NGP/00016

INTERNATIONAL JOURNAL OF RESEARCHES IN BIOSCIENCES, AGRICULTURE AND TECHNOLOGY

COSMIC STRING COSMOLOGICAL MODEL IN SCALE COVARIANT THEORY OF GRAVITATION

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Communicated : 29.12.19	Revision :14.01.2020 Accepted : 27.01.2020	Published: 30.01.2020

ABSTRACT:

Ruban's space time deal with sting source in the scale covariant theory of gravitation suggested by Canuto *et al.* [4] by using special law of variation for the Hubble's parameter given by Bermann [3]. In this theory a cosmological model with a negative constant deceleration parameter is obtained and some physical properties of the model are also investigated.

Key words: -*Cosmic string, scale covariant theory of gravitation, Ruban's space time.*

INTRODUCTION:

As predicted by Grand Unified Theories (GUT), the origin of galaxies and formation of other astronomically immense scale structures of the Universe are based upon the symmetry breaking phase transitions after the big bang explosion, when the temperature falls below some critical temperature. The creation of topologically stable defects such as Cosmic strings, monopoles, vacuum domain walls, textures and other 'hybrid' creatures are such type of transitions leads. One of the most outstanding problems of cosmology is to study the effects of cosmic strings as the vacuum strings to generate density perturbations which are strong enough for the creation of galaxies. The gravitational effects that arise from the coupling between their stress-energy and gravitational field are also produce from these strings. Moreover, the immense scale network of strings of the early universe does not contradict the present-day observations. Letelier [7] was introduced the general relativistic treatment of strings and suggested the energy momentum tensor for classical massive strings while some cosmological solutions of massive strings in Bianchi type I and Kantowski-Sachs space-times are represented by Letelier [7]. The cloud of strings is described as massive strings and a geometrical string with particles attached to its extension formed each massive string. Therefore, the generalization of Takabayasi's relativistic model of strings (termed as p-strings) is the cloud forming strings, where strings and particles are together. Khadekar *et al.* [6], Adhav [1], Reddy *et al.*[14], Pund *et al.*[12], Mete *et al.*[9], Nimkar *et al.*[11] and Vinutha *et al.*[19] are some of the authors who have studied several aspects of the cosmic string.

The scale covariant theory of gravitation which is formulated by Canuto *et al.* [4] also admits a variable G and which is a viable alternative to general relativity. The cosmological constant Λ appears as a variable parameter in the frame work of the scale-covariant theory. Einstein's

General Relativity Theory on the other hand does not admit the possibility of variable G or variable Λ.

The field equations with zero cosmological constant in scale –covariant theory are

$$R_{ij}-\frac{1}{2}Rg_{ij}+f_{ij}(\phi)=-8\pi G(\phi)T_{ij} \quad (1)$$

and

$$\phi^2 f_{ij}=2\phi\phi_{i;j}-4\phi_i\phi_j-g_{ij}\left(\phi\phi^k_{;k}-\phi^k\phi_k\right) \quad (2)$$

In which ϕ is the scale function satisfying $0\prec\phi\prec\infty$ and other symbols have their usual meanings as in Riemannian geometry.

Where, R is the Ricci scalar , R_{ij} is the Ricci tensor, G the gravitational constant and T_{ij} is the energy momentum tensor. A semicolon denotes covariant derivative and ϕ_i denotes ordinary derivative with respect to x^i. A special feature of this theory is that no independent equation for ϕ exists.

The possibilities for guage functions ϕ that have been considered as

$$\phi(t)=\left(\frac{t_0}{t}\right)^{\varepsilon}, \quad \varepsilon=\pm 1,\pm\frac{1}{2},$$

Where t_0 is the constant. The form $\phi\approx t^{\frac{1}{2}}$ is the one most favored to fit observations.

A detailed discussion of scale covariant theory is contained in the work of Canuto *et al.* [4], Hafizur Rahman *et al.*[5], Reddy and Venkateswarlu [15], Reddy *et al.*[16], Mishra, [10], Singh N. Ibotombi *et al.*[18], Belinchon [2], Raju *et al.*[13]. Also Reddy. *et al.*[17] have investigated a cosmological model with a negative constant deceleration parameter in scale –covariant theory of gravitation.

In this paper, we study Ruban's cosmological model with a negative constant deceleration parameter by using the Hubble's special law of variation suggested by Bermann [3].

2. Metric and Field Equation:

We consider Ruban's space time Lima [8] in the form

$$ds^2=dt^2-A^2(x,t)dx^2-B^2(t)(dy^2+h^2dz^2), \quad (3)$$

$$h(y)=\frac{\sin\sqrt{k}}{\sqrt{k}}y=\sin y \quad if \ k=1$$
$$=y \quad if \ k=0$$
$$=\sinh y \quad if \ k=-1$$

The Letelier [7] given the energy momentum tensor for cosmic strings is

$$T_i^j=\rho\, u_i u^j-\lambda\, x_i x^j, \quad (4)$$

where ρ is the rest energy density of cloud of strings with particles attached to them, $\rho=\rho_p+\lambda$, , ρ_p being the rest energy density of particles attached to the strings and λ *be* the tension density of the system of strings. As pointed out by Letelier [7], λ may be positive or negative, x^i represents a direction of anisotropy, i.e. the direction of the strings and u^i represent the system four-velocity.

We have

$$u^i u_i=-x^i x_i=1, \text{ and } u^i x_i=0 \quad (5)$$

We consider

$$\rho=\rho_p+\lambda \quad (6)$$

Here negative, ρ and λ are the functions of t only.

Where ρ_p is the rest energy density of the particles attached to the string.

Using the co-moving coordinate system, T_j^i can be obtained as

$$T_1^1 = 0 \quad ,T_2^2 = 0, T_3^3 = \lambda, T_4^4 = \rho \tag{7}$$

The field equations (1) and (2) for the metric (3) with the help of (5) to (7) can be written as

$$2\frac{\ddot{B}}{B} + \left(\frac{\dot{B}}{B}\right)^2 + \frac{k}{B^2} - \frac{\dot{A}}{A}\frac{\dot{\phi}}{\phi} + 2\frac{\dot{B}}{B}\frac{\dot{\phi}}{\phi} + \frac{\ddot{\phi}}{\phi} - \left(\frac{\dot{\phi}}{\phi}\right)^2 = 0 \tag{8}$$

$$\frac{\dot{B}}{B}\frac{\dot{A}}{A} + \frac{\ddot{B}}{B} + \frac{\ddot{A}}{A} + \frac{\dot{A}}{A}\frac{\dot{\phi}}{\phi} + \frac{\ddot{\phi}}{\phi} - \left(\frac{\dot{\phi}}{\phi}\right)^2 = 0 \tag{9}$$

$$\frac{\dot{B}}{B}\frac{\dot{A}}{A} + \frac{\ddot{B}}{B} + \frac{\ddot{A}}{A} + \frac{\dot{A}}{A}\frac{\dot{\phi}}{\phi} + \frac{\ddot{\phi}}{\phi} - \left(\frac{\dot{\phi}}{\phi}\right)^2 = 8\pi\lambda \tag{10}$$

$$2\frac{\dot{B}}{B}\frac{\dot{A}}{A} + \frac{\dot{B}^2}{B^2} + \frac{k}{B^2} - \frac{\ddot{\phi}}{\phi} + 3\left(\frac{\dot{\phi}}{\phi}\right)^2 + \frac{\dot{A}}{A}\frac{\dot{\phi}}{\phi} + 2\frac{\dot{B}}{B}\frac{\dot{\phi}}{\phi} = 8\pi\rho \tag{11}$$

For a cosmological model corresponding to string in scale covariant theory with the help of special law of variation by using Hubble's parameter proposed by Berman [3] that give constant deceleration parameter models of the universe. We consider only constant deceleration parameter model defined by

$$q = -\left[\frac{B\ddot{B}}{\left(\dot{B}\right)^2}\right] = constant \tag{12}$$

Where B is the overall scale factor and the constant is taken to be negative. The solution of (12) is

$$, \quad B = (at+b)^{\frac{1}{1+q}} \tag{13}$$

Where $a \neq 0$ and b are constants of integration. This equation implies that the condition of the expansion is $1+q \succ 0$ (because the scale factor B cannot be negative as well as we know that if $q \succ 0$ then $\frac{dB}{dt}$ is slowing down and if $q \prec 0$ then $\frac{dB}{dt}$ is speeding up).

Also the equations being highly non-linear we assume a relation between metric coefficients given by $A = x^n B^n$. Now with the help of (12),the field equations of Scale Covariant theory admit an exact solution given by

$$B = M(at+b)^N \text{ ,where } \quad M = \left(\frac{1}{x^n h}\right) \tag{14}$$

$$A = M_1 (at+b)^{N_1} \text{ ,where } N_1 = nN \tag{15}$$

$$N = \frac{3}{(1+q)(n+2)}$$

Using (14) and (15), the line element (3) become

$$ds^2 = dt^2 - M_1^{\,2}(at+b)^{2N_1}dx^2 - M^2(at+b)^{2N}(dy^2 + h^2dz^2) \tag{16}$$

In equation (4) the quantities ρ and λ are the functions of t only. When we take the string source is along z-axis we get $\lambda = 0$ from equation (9) & (10).In the literature Letelier [7], we have the equations of state for string model as

$\rho = \lambda$ (geometric String)

$\rho = (1+\omega)\lambda$ (p-string or Takabayasi String)

$\rho + \lambda = 0$ (Reddy string)

Using above equations ,we get $\rho = 0$,which shows that in scale covariant theory neither geometric string nor p-string nor the Reddy string survive. Hence we observe that the geometric strings, p-strings and Reddy strings do not exist in the scale covariant theory of gravitation.

3. Some Physical and Kinematical properties for the model:

In this section we discuss some physical and kinematical properties of Ruban's cosmic string models. The cosmic string models scale covariant theories are given by (16). The physical quantities that are important in cosmology are special volume *V*. The expansion scalar θ ,shear scalar σ^2 and the Hubble's parameter H and have the following expression for the model given by (16):

Spatial Volume : $V = (T)^{\frac{1}{1+q}}$ (17)

Scalar Expansion: $\theta = \frac{1}{3}U^{i}_{;i} = \frac{N_2}{T}$, (18)

Where, $N_2 = a(N_1 + 2N)$

Shear Scalar : $\sigma^2 = \frac{1}{2}\sigma_{ij}\sigma^{ij} = \frac{N_3}{T^2}$ (19)

Where, $N_3 = \frac{N_2^2}{6}$

Hubble Parameter : $H = \frac{aN}{T}$ (20)

It may be observed that at initial moment, when $T = 0$, the spatial volume will be zero while the energy density diverges. when $T \to 0$,then expansion scalar θ ,shear scalar σ^2 and the Hubble's parameter H tends to ∞.

Also, Since $\lim_{T\to\infty}\left(\frac{\sigma}{\theta}\right) \neq 0$ and hence the model does not approach isotropy for large values of *T*. The scalar field ϕ increases indefinitely as time $T \to \infty$ and is free from initial singularity.

CONCLUSION:

In this paper we have studied the field equations of scale covariant theory of gravitation suggested by Canuto *et al.*[4] for Ruban's space time. The field equations being highly non-linear, we have obtained a cosmological model with the help of special law of variation proposed by Bermann [3].Also in Ruban space time, cosmic strings model which represent Geometric string, p-string and Reddy string do not survive in scale covariant theory of gravitation given by Canuto *et al.* [4].

REFERENCES:

1.Adhav,K.S.: Canadian Journal of Physics, **90**,2,119-123(2012).

2.Belinchon,J.A.:Chin.Phys.Lett.,**29**,5,050401(1-4)(2012).

3.Bermann,M.S.: Nuovo Cimeto, **74B**,182(1983).

Canu 4.Canuto,V and S.H.Hsieh.: Physical Review letters,**39**,8(1977).

5.Hafizur Rahman and Banerji, S.: Astrophysics and space Science,**113**,405- 412 (1985).

6.Khadekar, G.S. and Tade, S.D.: Astrophysics and space Science, **310,**1-2,45- 51(2007).

7.Letelier, P. S.: Phys. Rev. D., 2414 (1983).

8.Lima J.A.S., Nobre M.A.S.: Class. Quantum Grav.,**7,** 399-409 (1990).

9.Mete,V.G.,Elkar,V.D.and Nimkar,A.S.: International Journal of Mathematical Archive, **6**,12,95-99 (2015).

10.Mishra B.: Bulg.J.Phys., **30,**113-116(2003).

11.Nimkar,A.S.andPund,A.M.:International Refereed Journal of Engineering and Science, 7,2,8-11(2018).

12.Pund,A.M.andNimkar,A.S.:International Journal of Mathematical Archive,**6**,9,18-21(2015).

13.Raju, P.,Sobhan Babu, K.and Reddy,D.R.K.: Astrophysicsand spaceScience, **361**,34(2016).

14.Reddy, D.R.K., Naidu, R. L.,Naidu, K.D. and Prasad,T.R.: Astrophysics and Space Science, **346,**1,261-265(2013).

15.Reddy,D.R.K.andVenkateswarlu,R.:Astrop

Space Science., **136,**191(1987).
16.Reddy,D.R.K.,Patrudu,R,B.M.and Venkateswrlu,R.:Astrophysics and space Science, **204,**155-160(1993).
17.Reddy,D.R.K.,Naidu,R.L.andAdhav,K.S..: Astrophysics and paceScience,**307**,365-367(2007).
18.Singh,N.Ibotombi and Sorokhaibam,A.: Astrophysics and space Science, DOI10.1007/s10509-007-9512-x (2007).
19.Vinutha,T.,Rao,V.U.M.,Getaneh,B.and Mengesha,M.:Astrophysics and Space Science **363** ,188 (2018).