Global Journal of Science Frontier Research
Physics and Space Science
Volume 13 Issue 3 Version 1.0 Year 2013
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

FRW Viscous Fluid Cosmological Model in F(R,T) Gravity

By R.L.Naidu, K. Dasu Naidu, T. Ramprasad & D.R.K.Reddy
MVGR College of Engineering, Vizianagaram A.P, India

Abstract - Friedmann-Robertson-Walker (FRW) space time is considered in f(R,T) gravity proposed by Harko et al. (Phys.Rev.D 84, 024020, 2011) when the source for energy momentum tensor is a bulk viscous fluid. A barotropic equation of state for the pressure and energy density is assumed to get a determinate solution of the field equations. Also the bulk viscous pressure is assumed to be proportional to energy density. A physical discussion of the model is also presented.

Keywords : *FRW model - f (R,T) gravity-viscous fluid.*

GJSFR-A Classification : *FOR Code: 260201*

FRW VISCOUS FLUID COSMOLOGICAL MODEL INFR,TGRAVITY

Strictly as per the compliance and regulations of :

FRW Viscous Fluid Cosmological Model in F(R,T) Gravity

R.L.Naidu [α], K. Dasu Naidu [σ], T. Ramprasad [ρ] & D.R.K.Reddy [ω]

Abstract - Friedmann-Robertson-Walker (FRW) space time is considered in f(R,T) gravity proposed by Harko et al. (Phys.Rev.D 84, 024020, 2011) when the source for energy momentum tensor is a bulk viscous fluid. A barotropic equation of state for the pressure and energy density is assumed to get a determinate solution of the field equations. Also the bulk viscous pressure is assumed to be proportional to energy density. A physical discussion of the model is also presented.

Keywords : FRW model - f (R,T) gravity - viscous fluid.

I. Introduction

Modified theories of gravitation have been extensively studied in connection with their cosmological implications. Noteworthy among them are the scalar-tensor theories of gravitation formulated by Brans and Dicke (1961), Nordtvedt (1970), Sen(1957) ,Sen and Dunn(1971) and Saez and Ballester (1986). In recent years there has been an increasing interest in modified theories of gravity in view of the direct evidence of late time acceleration of the universe and existence of the dark matter and dark energy (Reiss et al. 1998; Perlmutter et al.1999; Bennet et al;2003). In particular, f(R) theory of gravity formulated by Nojiri and Odintsov (2003a) and f(R,T) theory of gravity proposed by Harko et al.(2011) are attracting more and more attention. It has been suggested that cosmic acceleration can be achieved by replacing Einstein-Hilbert action of general relativity with a general function f(R) (R being the Ricci scalar curvature). A comprehensive review of modified f(R) gravity is given by Copeland et al.(2006) while a detailed discussion of f(R,T) gravity is given by Harko et al.(2011).Also, Caroll et al.(2004), Nojiri and Odintsov(2003b,2004,2007) and Chiba et al. (2007) are some of the authors who have investigated several aspects of f(R) gravity. Very recently, Adhav (2012) has obtained Bianchi type-I cosmological model in f(R, T) gravity. Reddy et al. (2012a, b) have discussed Bianchi type-III and Kaluza-Klein cosmological models in f(R,T) gravity while Reddy and Shantikumar (2012, 2013) studied some anisotropic cosmological models and Bianchi type-III dark energy model, respectively, in f(R,T) gravity.

Author α σ ρ : Department of Basic Science and Humanities, GMR Institute of technology. E-mail : lakshunnaidu.reddi@gmail.com
Author ω : Department of Science and Humanities M. V. G. R. College of Engineering, Vizainagaram, Andhra Pradesh.
E-mail : reddy_einstein@yahoo.com

It is well known that viscosity plays an important role in cosmology (Singh and Devi 2011; Singh and Kale 2011; Setare and Sheykhi 2010 and Misner 1969). Also, bulk viscosity appears as the only dissipative phenomenon occurring in FRW models and has a significant role in getting accelerated expansion of the universe popularly known as inflationary space. Bulk viscosity contributes negative pressure term giving rise to an effective total negative pressure stimulating repulsive gravity. The repulsive gravity overcomes attractive gravity of matter and gives an impetus for rapid expansion of the universe hence cosmological models with bulk viscosity have gained importance in recent years. Barrow (1986), Pavon et al. (1991), Martens (1995), Lima et al. (1993), and Mohanty and Pradhan (1992) are some of the authors who have investigated bulk viscous cosmological models in general relativity. Johri and Sudharsan (1989), Pimental (1994), Banerjee and Beesham (1996), Singh et al.(1997), Rao et al.(2011,2012), Naidu et al. (2012) and Reddy et al.(2012) have studied bulk viscous cosmological models in Brans-Dicke and other modified theories of gravity.

Motivated by the above investigations we study, in this paper, FRW bulk viscous cosmological model in the modified f(R, T) gravity proposed by Harko et al. (2011). Also these models play a vital role in the study of evolution of the universe and the accelerated expansion of the universe.

II. Metric and Field Equations

Assuming the universe to be homogeneous and isotropic, FRW metric can be written as

$$ds^2 = -dt^2 + a^2(t)\left[\frac{dr^2}{1-kr^2} + r^2(d\theta^2 + sin^2\theta d\phi^2)\right] \quad (1)$$

Where a (t) is the scale factor of the universe and k= -1, 0, +1, respectively, for open, flat and closed models.

The field equations of f(R, T) gravity are derived from Hilbert-Einstein type variational principle by taking the action.

$$S = \frac{1}{16\pi}\left[\int\{f(R,T) + L_m\}\sqrt{-g}\ d^4x\right] \quad (2)$$

Where f(R, T) is an arbitrary function of the Ricci scalar R, T is the trace of energy tensor of the matter T_{ij} and L_m is the matter Lagrangian density.

Global Journal of Science Frontier Research (A) Volume XIII Issue III Version I Year 2013

Now, by varying the action S of the gravitational field with respect to the metric tensor components g^{ij}, we obtain the field equations of f(R, T) gravity, with the special choice of f(R,T) (Harko et al.2011) given by

$$F(R,T)=R+2f(T) \quad (3)$$

as (for a detailed derivation of the field equations one can refer to Harko et al. 2011)

$$R_{ij}-\frac{1}{2}Rg_{ij} = 8\pi T_{ij} + 2f'(t)T_{ij} + [2pf'(T)+f(T)]g_{ij} \quad (4)$$

Where the overhead prime indicates derivative with respect to the argument.

We consider the energy momentum tensor for a bulk viscous fluid as

$$T_{ij} = (\rho+\bar{p})u_i u_j + \bar{p}g_{ij} \quad (5)$$

And

$$\bar{p} = p-3\zeta H \quad (6)$$

Where ρ is the rest energy density of the system, ζ (t) is the coefficient of bulk viscosity, 3ζH is usually known as bulk viscous pressure and H is Hubble's parameter.

Also, $u^i = \delta_4^i$ is a four-velocity vector which satisfies.

$$g_{ij}u^i u_j = -1 \quad (7)$$

Here we also consider ρ and $\bar{p}$ as functions of time t only.

Using co moving coordinates and a particular choice of the function given by (Harko et al.2011).

$$f(T) = \mu T, \mu \text{ is a constant} \quad (8)$$

The field equations (4) for the metric (1) with the help of equations (5) and (7) yield the following independent equations

$$2a\frac{a_{44}}{a^2}+\frac{{a_4}^2}{a^2}+\frac{k}{a^2} = (8\pi+\mu)\bar{p}+\mu\rho \quad (9)$$

$$\frac{3}{a^2}(a_4^2 + k) = (8\pi + 3\mu)\rho - \mu\bar{p} \quad (10)$$

where a suffix 4 indicates differentiation with respect to t.

III. Solutions and the Model

From the two independent field equations (9) and (10) we have to determine the unknowns a, ρ, p and ζ. Also the field equations are highly non-linear in nature and therefore we use the following plausible physical conditions:

i. For a baratropic fluid the combined effect of the proper pressure and the barotropic bulk viscous pressure can be expressed as

$$\bar{p} = p-3\zeta H = \varepsilon\rho \quad (11)$$

where $p = \varepsilon_0\rho$, $0 \le \varepsilon_0 \le 1$

ii. We use the variation of Hubble's parameter proposed by Berman (1983) that yields constant deceleration parameter models of the universe defined by

$$q = -a\frac{a_{44}}{a_4^2} = \text{constant} \quad (12)$$

which yields the solution

$$a = (ct+d)^{\frac{1}{1+q}} \quad (13)$$

Where $c \neq 0$ and d are constants of integration. This equation implies that the condition for accelerated expansion of the universe is $1+q>0.$

Now solving the field equations (9) and (10) with the help of (11) and (13), we obtain FRW viscous fluid model, through a proper choice of coordinates (I e., c=1 and d=0) as

$$ds^2 = -dt^2 + t^{\frac{2}{1+q}}\left[\frac{dr^2}{1-kr^2} + r^2\{d\theta^2 + \sin^2\theta d\phi^2\}\right] \quad (14)$$

With the following physical quantities in the model

Energy density:

$$\rho = \frac{1}{4\pi+4\varepsilon+\mu}\left[\frac{2-q}{(1+q)^2t^2} + \frac{2k}{t^{\frac{1}{(1+q)}}}\right] \quad (15)$$

Pressure:

$$p = \frac{\varepsilon_0}{4\pi+4\varepsilon+\mu}\left[\frac{2-q}{(1+q)^2t^2} + \frac{2k}{t^{\frac{1}{(1+q)}}}\right] \quad (16)$$

Coefficient of bulk viscosity:

$$\zeta = \frac{1}{3}\left(\frac{\varepsilon_0-\varepsilon}{4\pi+4\varepsilon+\mu}\right)\left[\frac{2-q}{(1+q)t} + \frac{2k}{t^{\frac{1-q}{(1+q)}}}\right] \quad (17)$$

Hubble's parameter

$$\boldsymbol{H = \frac{a_4}{a} = \frac{1}{(1+q)t}} \quad (18)$$

Bulk viscous pressure

$$\bar{p} = \frac{\varepsilon}{4\pi+4\varepsilon+\mu}\left[\frac{2-q}{(1+q)^2t^2} + \frac{2k}{t^{\frac{1}{(1+q)}}}\right] \quad (19)$$

IV. Physical Discussion and Conclusions

Model given by the Eq.(14) represents FRW viscous fluid cosmological model in f(R,T) gravity. The model represents expanding model. It can be observed that for large t there is accelerated expansion in accordance with recent observational data. Physical quantities ρ, p, ζ H, and $\bar{p}$ vanish for large t while at the initial epoch, i.e. at t=0 they all diverge.

It is well known that the present day universe is better, described by FRW model. Also, Harko et al.

(2011) have proposed modified f(R,T) gravity to explain the accelerated expansion of the universe. Here we have investigated a spatially homogeneous and isotropic FRW viscous fluid cosmological model in f(R,T) gravity. It is observed that the model is expanding. The model obtained, here, will be useful to study the role of bulk viscosity in the expansion and evolution of the universe.

References Références Referencias

1. Adhav, K. S.:Astrophys. Space. Sci. **339**, 365 (2012).
2. Banerjee, N., Beesham, A.:Aust. J. Phys. **49**, 899 (1996).
3. Barrow, J. D.: Phys. Lett. **B180**, 335(1986).
4. Bennett, C. L., et al.:Astrophys. J. Suppl. Ser. **148**, 1(2003).
5. Berman, M.S.:Nuovo Cimento **B74**, 182 (1983).
6. Brans, C. H., Dicke, R. H.: Phys. Rev. **124,** 925 (1961).
7. Caroll, S. M., et al.: Phy. Rev. **D 70,** 043528 (2004).
8. Chiba, T., Smith, L., Erickcek, A. L.:Phys. Rev. **D75,** 124014(2007).
9. Copeland, E. J. et al.:Int. J. Mod. Phys. **D15** 1753 (2006)
10. Harko, T., et al.: Phy.Rev. **D84,** 024020 (2011).
11. Johri, V. B., Sudharsan, R.: Aust. J. Phys. **42**, 215 (1989).
12. Lima, J. A. S., et al.: Phy. Rev. **D53**, 4287 (1993).
13. Martens, R.: Class. Quantum Gravity **12,** 1455(1995)
14. Misner, C. V.: Astrophys. J. **151,** 431 (1969).
15. Mohanty, G., Pradhan, B. D.: Int. J. Theor. Phys. **31**, 151(1992).
16. Naidu R. L., et al:Astrophys. Space. Sci. **338,** 351 (2012)
17. Nojiri, S.,Odintsov, S. D.:Phys. Rev. **D68**, 123512 (2003a).
18. Nojiri, S., Odintsov, S. D.:Int. J. Geom. Method. Mod. Phys. **4**, 115 (2007).
19. Nojiri, S., Odintsov, S. D.:Phys. Lett. **A19**, 627(2004).
20. Nojiri, S., Odintsov, S. D.:Phys. Lett. **B562**, 147 (2003b).
21. Nordtvedt, K. Jr.: Astrophys. J. **161**, 1059 (1970).
22. Pavon, D. et al.:Class. Quantum Gravity **8**, 347 (1991).
23. Perlmutter, S., et al.:Astrophys. J. **517**, 567 (1999)
24. Pimental, L. O.: Int. J. Theor. Phys. **33**, 1335 (1994).
25. Rao, V. U. M. et al.:Astrophys. Space Sci. **335**, 635(2011).
26. Rao, V. U. M. et al.: Int. J. Theor. Phys. **51**, 3303 (2012).
27. Reddy, D. R. K., et al.: Astrophys. Space Sci. **342**, 249 (2012a).
28. Reddy, D. R. K. et al.:Int. J. Theor. Phys. DOI:10. 1007/s 100773-012-1437-7.
29. Reddy, D. R. K., et al.: Int. J. Theor. Phys. **51**, 3222 (2012b).
30. Reddy, D. R. K., et al.: Astrophy. Space Sci. DOI:10. 1007/s10509-0121158-7 (2013).
31. Reddy, D. R. K., Santhi kumar, R.: Astrophys. Space Sci. DOI:10. 1007/s 10509-012-1304-2(2012).
32. Reiss, A., et al.:Astron. J. **116**, 1009 (1998).
33. Saez, D., Ballester, V. J.:Phys. Lett. **A113**, 467 (1986)
34. Sen, D. K., Dunn, K.: J. Math Phy. **12**, 578 (1971).
35. Sen, D. K.: Z. Phys. **149**, 311 (1957)
36. Setare, M. R., Sheyki, A.:Int. J. Mod. Phys. **D19**, 171 (2010).
37. Singh, G. P., Kale, A. Y.: Astrphys. Space Sci. **331**, 207 (2011).
38. Singh, J. P. et al.: Aust. J. Phys. **50**, 1(1997)
39. Singh, N. I., Devi, S. R.: Astrophys. Space Sci. **334**, 231 (2011).