Effect of Bulk Viscosity on Interacting Modified Chaplygin Gas in Kaluza–Klein Cosmology

*Sweeti B. Rokde Vidya Thakare
*Priyadarshini College of Engineering, Nagpur
Shri Shivaji Science College, Amravati
Corresponding author: sweety.3.r@gmail.com

Article Info
Page Number: 1008 – 1021
Publication Issue:
Vol. 71 No. 3s2 (2022)

Article History
Article Received: *28 April 2022*
Revised: *15 May 2022*
Accepted: *20 June 2022*
Publication: *21 July 2022*

Abstract
This work deals with bulk viscous Kaluza - Klein cosmological model with" Modified Chaplygin Gas (MCG)" for describing consolidation of Dark matter and Dark energy which interrelated with matter sign-changeable form.Further, cosmological parameters such as scale factor, energy density, Hubble, and deceleration parameter are generated and evaluated through graphical representation.

Keywords: Energy density, Dark energy (DE), Dark matter (DM), bulk viscosity, Modified Chaplygin gas.

1. Introduction

As per the latest discoveries of many cosmologists and cosmological observations, it shows that expansion of universe is accelerating [30, 33, 20, 6, 44, 29, 32, 2, 43]. New area of research in cosmology has provided. As it is generally known to all of us that 25% portion of the universe is fill up with DM, 70% portion with DE and only 5% part of the universe is visible. For this reason, DE is one of the unsolved enigmas of cosmology.

Now, mostly question arises about the nature of dark energy, whose solution has not still found as model for the same. For getting the solutions of these problems, numbers of quintessence models recommended [11, 7]such as cosmological constant [24], K-essence [1], tachyonic [40], phantom [8], holographic dark energy [18], and extra dimension. These quintessence models are considered as possible candidate for the Dark Energy (DE) to accommodate a huge energy density. Chaplygin Gas is one such candidate [47, 27, 26] which caught the attention of many workers.

As per the references [43, 42, 41, 21] the bulk viscosity provides various interesting facts in the homogeneous dynamics cosmological models. Zhai et al. [48] firstly initiated the concept of CG with viscosity and thereafter, it got expanded by research [46, 34, 31, 35].
Many researchers [3, 28, 19, 22] stated that bulk viscous cosmological models are widely discussed in GR. As per the studied of Santhi and Reddy [39], Kaluza-Klein (KK) cosmological model having extent viscosity in relation of Barbers second self-creation cosmology has been prepared. After examined by Samanta and Bishi [38],the universe geometry is purported by Kaluza Klein extent viscous cosmology with "Modified Cosmic Chaplygin Gas" is in GR. Khadekar and Gharad [16]studied Big Rip singularity in (4 +1)

dimension viscous cosmology.RecentlyAlmada and Miguel [13]studied a hybrid model thatconstructed through a generalized Chaplygingas with bulk viscosity.

Kaluza-Klein (KK) [14, 17] was the first one to introduce the idea of extra dimensional model. As per the theory of Kaluza and Klein, space-time is extended by the addition of an extra dimension from the four used in Einstein's general relativity. After the continuous research, many cosmologists have found that, deep knowledge to understand the interaction of particle can be provided by the higher dimensional gravity theories and it isplaying a vital role to clear the concept regarding the problem of DE.

Many authors have studied various Dark Energy and Dark Matter, Kaluza-Klein cosmological models [12, 25, 36, 5, 15, 4]. Hence, the development of CG in Kaluza- Klein cosmology would be quite interesting. Hence, the development of Chaplygin Gas model in Kaluza-Klein universe would be considered to be one of the interesting CG models. Chayan et al. [10] has deliberated character of variable "modified Chaplygin gas" (VMCG) in anistropic universe. Salti al. [37], discussed "Variable Chaplygin gas (VCG)" in framework of KK universe. Saadat [34] also discussed the interconnection between MCCG and pressure less matter which is actually in the existence of bothshear and bulk viscosities in FRW cosmology.

As per the motivational factor of above statement in Kaluza-Klein cosmology, we generalized the result of Naji et al. [23] and constructed Modified Chaplygin gas MCG by introducing bulk viscosity to formulate in Kaluza and Klein cosmology.

The present paper has discussed the following sections: In 2^nd^sec., we have introduced different CG models. Coming to the 3^rd^ sec., we considered FRW cosmology and solved field equation. Now, we would like to consider small visible matter and relationship between "Modified Chaplygin Gas" and matter that includes bulk viscosity. In addition, we have reviewed different CG models and then got equation for energy density in form of scale factor. In same way in 4^th^ sec., we considered the interrelation of "Modified Chaplygin Gas" with reaction of fluid viscosity on cosmological parameters, for special and general cases. Eventually, in last section concluding remark are given.

As per the practical view, it can be stated that, the modified Chaplygin gas provides an interesting candidate for the present accelerated expansion of the universe. Here we obtained modified Freidmann equation, deceleration parameter and the age of the universe in the scenario and show that they are consistent with the present observational data.

2. Chaplygin Gas as a Model of Dark Energy

An interesting model to describe DE is CG, in whichthe matter is taken to be a fluid obeying an exotic equation of state [9],

$$p_d = -B/\rho_d \qquad (1)$$

Here p_d is pressure and ρ_d is energy density, whereasBpositive constant. The "Chaplygin Gas" is not consistent with observational data; subsequently the equation (1) generalized,

$$p_d = -B/\rho_d^{\alpha}\ , \quad 0 < \alpha \leq 1 \qquad (2)$$

which is known as Generalized Chaplygin Gas (GCG). From equation (2.2), when energy density is high, GCG represents $p_d = 0$ (at early time) which never in agreement with present universe.
For that reason, "Modified Chaplygin Gas (MCG)" was proposed EoS of the form,

$$p_d = \gamma\rho_d - B/\rho_d^{\alpha}, \quad \gamma \text{ positive constant.} \quad (3)$$

The MCG is more suitable to have high pressure at high energy density and constant negative pressure at low energy density.

3. FRW Cosmology inBulk Viscous

Kaluza-Klein metric given by

$$ds^2 = -dt^2 + a(t)^2\left[\frac{dr^2}{1-kr^2} + r^2\left(d\theta^2 + \sin^2\theta\, d\phi^2\right) + \left(1-kr^2\right)d\varphi^2\right] \quad (4)$$

where $a(t)$ is the scale factor and k = 0, ± 1 is the curvature factor. Here considers k = 0.
The Einstein field equations are

$$R_\nu^\mu - \frac{1}{2}Rg_\nu^\mu = T_\nu^\mu \quad (5)$$

The energy momentum tensor corresponding to the bulk viscous fluid is given by,

$$T_\nu^\mu = (p+\rho)\delta_0^\mu\delta_\nu^0 - p\delta_\nu^\mu \quad (6)$$

$u^0 = 0$, $u^1 = u^2 = u^3 = u^4 = 0$ with $g^{\mu\nu}u_\mu u_\nu = 1$.
From equation (5) and (6), yield

$$\frac{\dot{a}^2}{a^2} = \frac{\rho}{6}, \quad (7)$$

$$\frac{\ddot{a}}{a} + \frac{\dot{a}^2}{a^2} = \frac{-p}{3} \quad (8)$$

The energy–momentum conservation equation in (4+1)-dimensional spacetime is given by

$$\dot{\rho} + 4H(\rho + p) = 0. \quad (9)$$

where $H = \dot{a}/a$ is Hubble expansion parameter. Also

$$\rho = [\rho_d + \rho_m] \quad (10)$$

The pressure p in equation (9) is to be sure DE pressure together viscous contributions,

$$p = p_d - 4H[\xi_0 + \xi_1 H] \quad (11)$$

where ξ_0 and ξ_1 is viscous coefficients.
Using EoS (1) in equation (9) we get following energy density

$$\rho_{CG} = \left(B + \frac{C}{a^8}\right)^{1/2} \quad (12)$$

where C is integrating constant.
From equations (2) and (9), we get

$$\rho_{GCG} = \left(B + \frac{C}{a^{4(1+\alpha)}} \right)^{\frac{1}{1+\alpha}} \qquad (13)$$

Now, using MCG equation of state in conservation equation (10) we obtained,

$$\rho_{MCG} = \left(\frac{B}{(1+\gamma)} + \frac{C}{(1+\gamma)} a^{-4(1+\gamma)(1+\alpha)} \right)^{\frac{1}{1+\alpha}} \qquad (14)$$

4. Interacting Dark Energy

For describing consolidation of Dark fluid i.e. MCG which interrelated with matter sign-changeable form. To introduce this, we mathematically separate the energy momentum conservation equation (10) in two relations:

$$\dot{\rho}_m + 4H\rho_m = Q \qquad (15)$$

$$\dot{\rho}_d + 4H(\rho_d + p) = Q \qquad (16)$$

Pressure p_d is given in equation (11).

Interacting term Q usually defined as $Q = 4Hb\rho_m$, $Q = 4Hb\rho_d$ or $Q = 4Hb\rho$.

Consider a sign-changeable interaction form as,

$$Q = 4Hb\rho_d \qquad (17)$$

here b is dimensionless parameter.

Deceleration Parameter defined as

$$q = -1 - \frac{\dot{H}}{H^2} \qquad (18)$$

While universe transform fromdeceleration $q > 0$ to accelerationq < 0then the above interaction sign can also gets changed.

4.1 Special case

Assume $k = 0$, $\Lambda = \beta_1 \rho$, $8\pi G = 1$and also consider emergent model of scale factor,

$$a = a_0 \left(B + e^{kt} \right)^m, \; a_0 > 0, k > 0, \; B > 0, \; m > 1 \qquad (19)$$

By using equations (17) and (19) in equation (16), these yields

$$\dot{\rho}_d \frac{\left(B + e^{kt}\right)}{mk} + \rho_d \left[4mk(1+\gamma) - 4mkb - 4mkB\right] e^{kt} - \frac{12mke^{2kt}}{\left(B + e^{kt}\right)} \xi_0 + \frac{12m^2k^2e^{3kt}}{\left(B + e^{kt}\right)^2} \xi_1 = 0$$

(20)

We get an unphysical solution from the above equation, for $\alpha = -1$

$$\rho_d = 12m \left\{ \xi_0 \left[\frac{k}{S} - \frac{Bk}{(S-k)\left(B + e^{kt}\right)} \right] - \xi_1 mk \left[\frac{\left(B + e^{kt}\right)k}{(S+k)} - 2kB + \frac{B^2 k}{(S-k)\left(B + e^{kt}\right)} \right] \right\} + C\left(B + e^{kt}\right)^{S/k}$$

(21)

where $S = \left[4mk(1+\gamma) - 4mkb - 4mkB\right]$and C is an integrating constant.

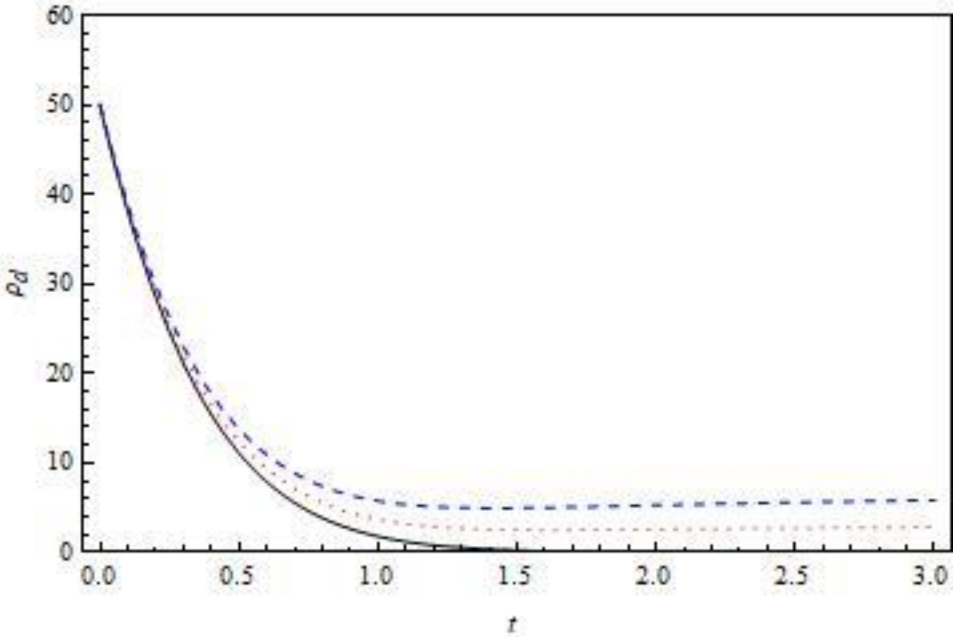

Fig.1: For
$B = 1.1, b = 0.5, \xi_1 = 0.1, \gamma = 2, m = 1, k = 1, \xi_0 = 0.1\ (Bold), \xi_0 = 1.5\ (Dotted), \xi_0 = 3\ (Dashed)$.

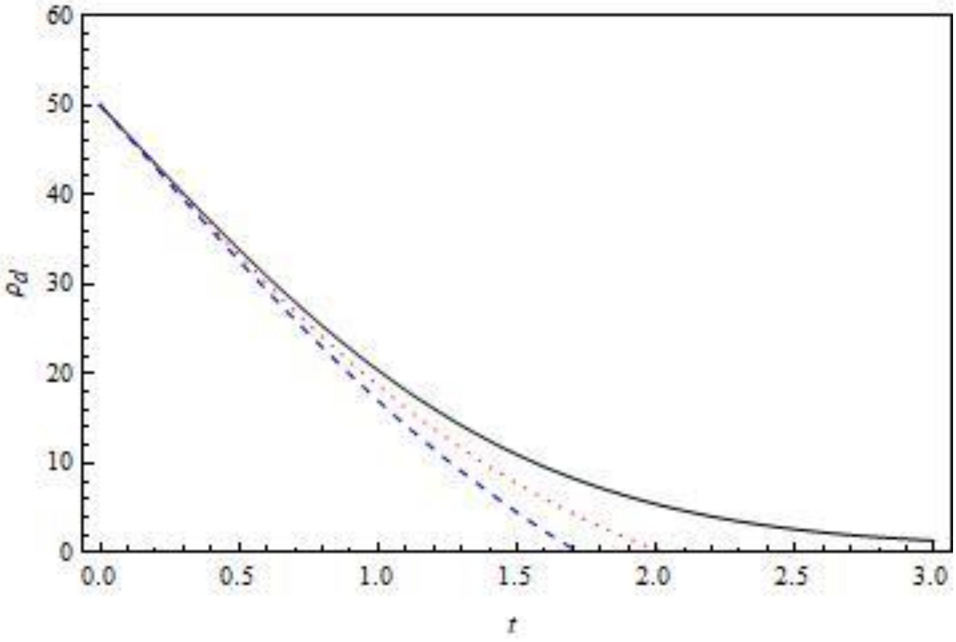

Fig.2: For
$B = 2, b = 0.5, \xi_1 = 0.1, \gamma = 2, m = 1, k = 1, \xi_1 = 0.01\ (Bold), \xi_1 = 2\ (Dotted), \xi_1 = 4\ (Dashed)$.

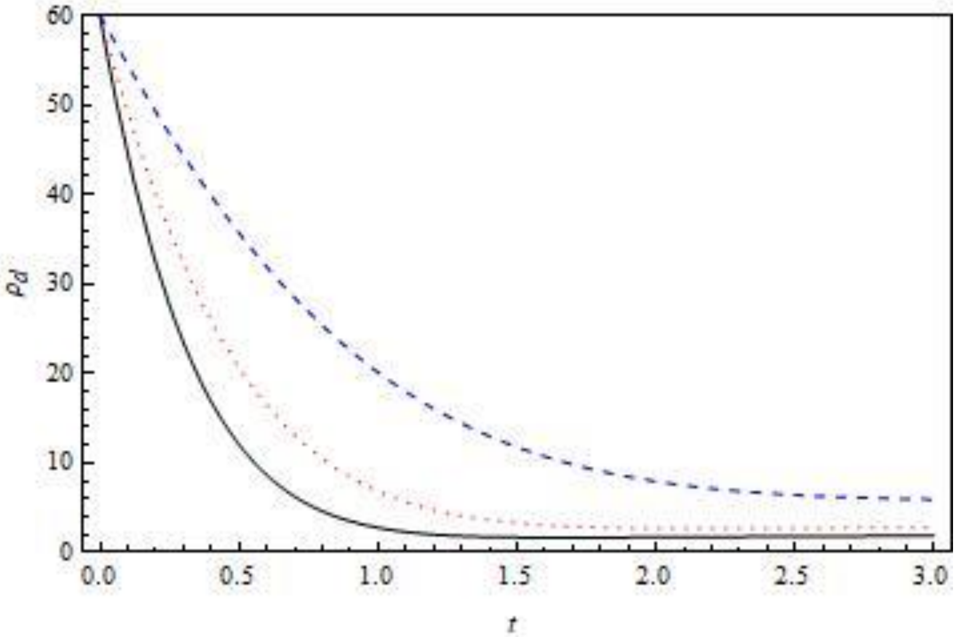

Fig.3: For
$B=1, \xi_0=1, \xi_1=0.01, \gamma=2, m=1, k=1, b=0.5\ (Bold), b=1\ (Dotted), b=1.5\ (Dashed)$.

In the physical case, equation (20) can be used and find the nature of dark energy density. Fig. (1) and Fig. (2) shows nature of energy density in contrary to time for varying bulk viscosity coefficient ξ_0 and ξ_1 accordingly. Fig. (1) displays energy density is increasing mode and Fig. (2) shows that energy density is in decreasing mode with increasing values of ξ_1. Fig. (3) exhibitsillustration of energy density contradicting to time for different values of interaction parameter and appeared that as the value of b increases energy density also increases.

4.2 General Case

Using equations (7), (11) and (17) in equation (16), we get general solution and found the following nonlinear differential equation

$$\dot{\rho}_d+\left[\frac{4(1+\beta_1)^{1/2}}{6^{1/2}}(1+\gamma)-\frac{3(1+\beta_1)^{3/2}}{6^{1/2}}\xi_1-\frac{4b(1+\beta_1)^{1/2}}{6^{1/2}}\right]\rho_d^{3/2}-\frac{4B(1+\beta_1)^{1/2}}{6^{1/2}}\rho_d^{1/2-\alpha}-3(1+\beta_1)\rho_d\xi_0=0 \quad (22)$$

We can’t solve equation (22) because it is highly nonlinear. Therefore, any kind of easier calculation we can take only two stages named as early time universe [t << 1] and late time universe [t >> 1] as stated below:

4.2.1 Early time universe [t << 1]

First term of the equation (22) can be neglected at t << 1 having large energy density. To get the reaction of viscosity, take $B = 0$ and $\alpha = \frac{1}{2}$.

Thus equation (22) becomes

$$\dot{\rho}_d + \frac{(1+\beta_1)^{1/2}}{6^{1/2}}\left[4(1+\gamma) - 3\xi_1(1+\beta_1) - 4b\right]\rho_d^{3/2} - 3(1+\beta_1)\xi_0\rho_d = 0 \qquad (23)$$

Solving equation (23), we get

$$\rho_d = \left\{\frac{-(1+\beta_1)^{-1/2}}{3\sqrt{6}\xi_0}\left[4(1+\gamma) - 3\xi_1(1+\beta_1) - 4b\right] + C\exp\left[-3(1+\beta_1)\xi_0 t\right]\right\}^{-2} \qquad (24)$$

where C is an integrating constant.

Using equation (24) in equation (7) we obtained Hubble expansion parameter

$$H = \frac{(1+\beta_1)^{1/2}}{6^{1/2}}\left\{\frac{-(1+\beta_1)^{-1/2}}{3\sqrt{6}\xi_0}\left[4(1+\gamma) - 3\xi_1(1+\beta_1) - 4b\right] + C\exp\left[-3(1+\beta_1)\xi_0 t\right]\right\}^{-1} \qquad (25)$$

Using equation (25) in equation (18) we obtained deceleration parameter as,

$$q = -1 - 18(1+\beta_1)^{1/2}\xi_0\, C\exp[-3(1+\beta_1)\xi_0 t] \qquad (26)$$

With the aim of real Hubble expansion that leads to a constant eventually we get the conditions:

$$4(1+\gamma) - 3\xi_1(1+\beta_1) - 4b > 0 \qquad (27)$$

$$\xi_0 > 0$$

In above status we have analyzed at early universe, the nature of Hubble and deceleration expansion.

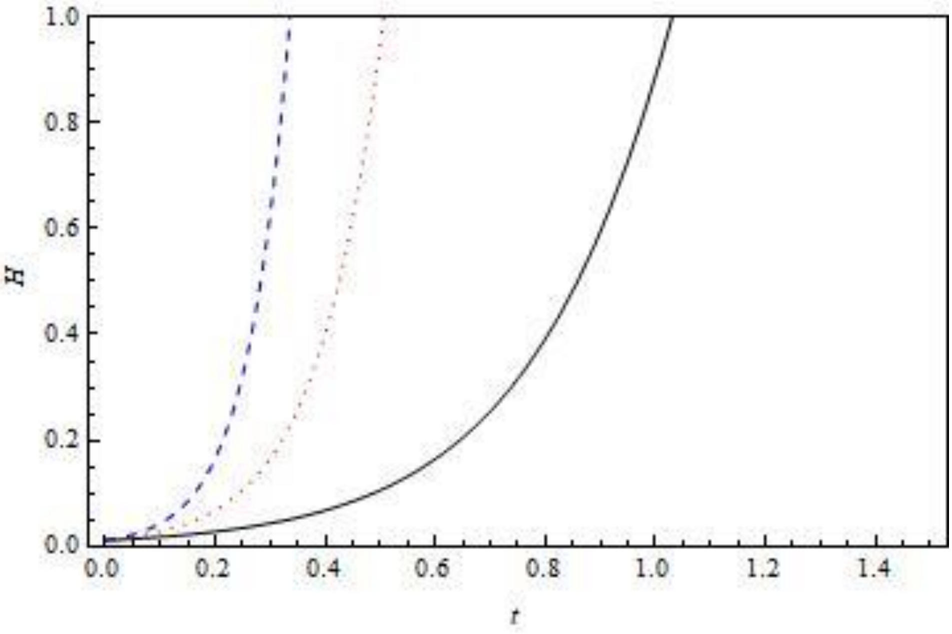

Fig. 4: For
$b = 2, \xi_1 = 0.1, C = 44, \gamma = 1, \beta = 0.5, \xi_0 = 1\ (Bold), \xi_0 = 2\ (Dotted), \xi_0 = 3(Dashed)$

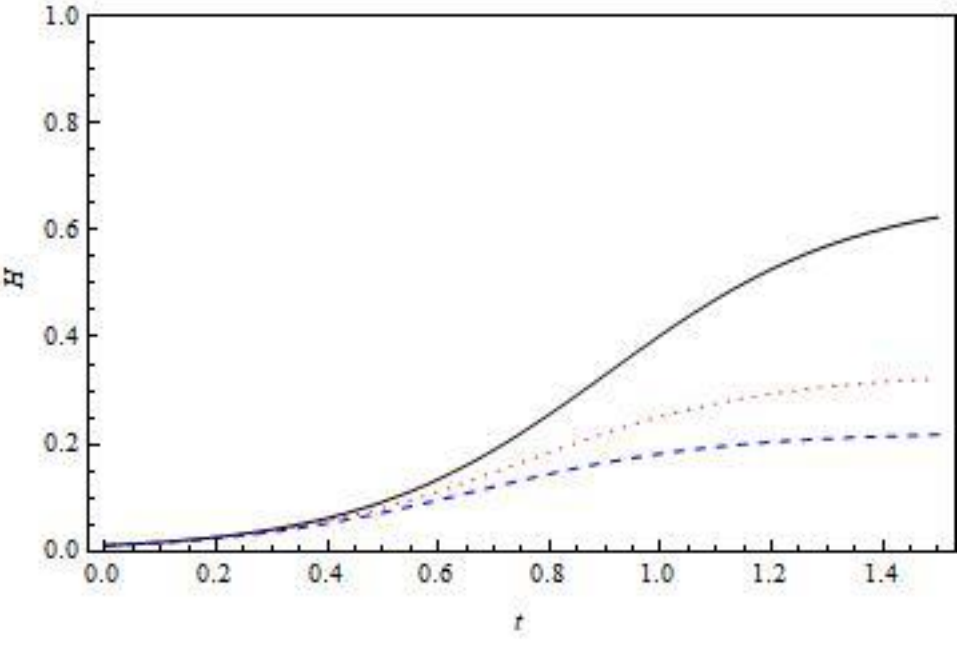

Fig. 5: For
$b = 2, \xi_0 = 1, C = 44, \gamma = 1, \beta = 0.5, \xi_1 = 1\ (Bold), \xi_2 = 2\ (Dotted), \xi_3 = 3(Dashed)$

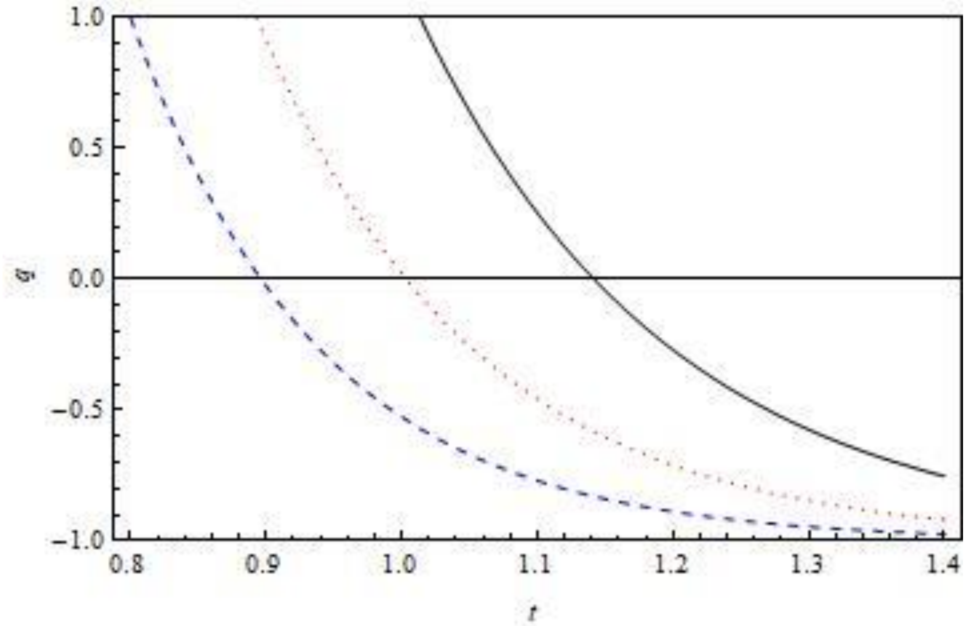

Fig. 6: For
$b = 2, \xi_1 = 0.1, C = 44, \gamma = 2, \beta = 0.5, \xi_0 = 1.2\ (Bold), \xi_0 = 1.4\ (Dotted), \xi_0 = 1.6 (Dashed)$

Figs. (4) and (5) shows graphical representation of Hubble parameter. The thing observed that Hubble expansion increases with increasing value of ξ_0 and gets decreased with the consistent increasing value of ξ_1. In Fig. (6), bulk viscosity coefficients ξ_0 effect has been shown on q deceleration parameter and seen that q decreases with increasing ξ_0 .
Further it is having discernedobserved that the model which we obtain undergoes decelerated phase of expansion and transition from deceleration to an acceleration.

4.2.2 Late time universe [t >>1]
At late time, energy density has small value; we can obtain equation (22),
Consider $\alpha = 1/2$, we get,

$$\rho_d = \frac{4B}{3\xi_0 6^{1/2}} + C \exp\{-3(1+\beta_1)\xi_0 t\} \qquad (27)$$

So, Hubble expansion parameter as,

$$H = \frac{(1+\beta_1)^{1/2}}{6^{1/2}} \sqrt{\frac{4B}{3\xi_0 6^{1/2}} + C \exp\{-3(1+\beta_1)\xi_0 t\}}$$

5. Conclusion

In the present work, we have acknowledged Modified Chaplygin Gas with bulk viscosity in Kaluza-Klein cosmology as a candidate for merger of dark matter and dark energy which combines with ordinary matter sign-changeable form. We examined time-dependent density both numerically and analytically and acquired behavior of time dependent density in particular case and general case. In particular case we assumed $k = 0$ (flat universe), $\Lambda = \beta_1 \rho$ and $8\pi G = 1$ and also consider emergent model of scale factor to explain analytical and numerical analysis of energy density from conservation law equation. In Figs. (1) and (3) we have produced nature of energy density with time for changing bulk viscosity coefficients ξ_0, ξ_1 and collaborating parameter and resulted as energy density is decreasing function of time. Nonetheless, it is clear that from Figs. (1) and (3) ρ_d increases with increasing ξ_0, ξ_1 and b (interaction parameter).

In general case, we found highly non-linear differential equation which is very complicated to solved, therefore for simplicity calculation we got two stages name as early time and late time. In early time energy density is high whereas in late time energy density very low, with this consideration simplified equation (21) and found the expression for energy density ρ_d and Hubble expansion parameter$H$. In Figs. (4) – Fig. (6) we have displayed the change of Hubble parameter and deceleration parameter with time for varying viscosity coefficients and interaction parameter. It is observed that$H$increases with increasing value of $\xi_0$and decreases with increasing value ofξ_1 and q decreases with increasingξ_0 respectively. It is observed that the viscous parameters help to get solution that is in agreement with observational data.

Moreover, it is detected that model which we obtained, undergo decelerated expansion to an accelerated expansion and graphical shownthat the physical behavior of the studied model to explore the accelerated expansion of the universe.

References:

1. Armendariz-Picon, Christian, V. Mukhanov, and Paul J. Steinhardt. "Dynamical solution to the problem of a small cosmological constant and late-time cosmic acceleration." Physical Review Letters 85, no. 21 (2000): 4438. https://doi.org/10.1103/PhysRevLett.85.4438
2. Bahcall, Neta A., Jeremiah P. Ostriker, Saul Perlmutter, and Paul J. Steinhardt. "The cosmic triangle: Revealing the state of the universe." science 284, no. 5419 (1999): 1481-1488.DOI: 10.1126/science.284.5419.1481
3. Barrow, John D. "The deflationary universe: instability of the de Sitter universe." Physics Letters B 180, no. 4 (1986): 335-339.https://doi.org/10.1016/0370-2693(86)91198-6
4. Bento, M. C., Orfeu Bertolami, and Anjan A. Sen. "Generalized Chaplygin gas, accelerated expansion, and dark-energy-matter unification." Physical Review D 66, no. 4 (2002): 043507.https://doi.org/10.1103/PhysRevD.66.043507
5. Deepak Mathur, N. K. V. . (2022). Analysis & Prediction of Road Accident Data for NH-19/44. International Journal on Recent Technologies in Mechanical and Electrical Engineering, 9(2), 13–33. https://doi.org/10.17762/ijrmee.v9i2.366
6. Bertone, Gianfranco, Geraldine Servant, and Guenter Sigl. "Indirect detection of Kaluza-Klein dark matter." Physical Review D 68, no. 4 (2003): 044008.DOI: 10.1103/PhysRevD.68.044008
7. Bridle, Sarah L., Ofer Lahav, Jeremiah P. Ostriker, and Paul J. Steinhardt. "Precision cosmology? Not just yet..." Science 299, no. 5612 (2003): 1532-1533.https://www.jstor.org/stable/i371103
8. Caldwell, Robert R., Rahul Dave, and Paul J. Steinhardt. "Cosmological imprint of an energy component with general equation of state." Physical Review Letters 80, no. 8 (1998): 1582. https://doi.org/10.1103/PhysRevLett.80.1582

9. Caldwell, Robert R. "A phantom menace? Cosmological consequences of a dark energy component with super-negative equation of state." Physics Letters B 545, no. 1-2 (2002): 23-29.https://doi.org/10.48550/arXiv.astro-ph/9908168
10. Chaplygin, S. "On gas jets, Sci. Mem. Moscow Univ. Math." (1904).
11. Chayan, Shuvendu Chakraborty, and Ujjal Debnath. "Variable modified Chaplygin gas in anisotropic universe with Kaluza-Klein metric." International Journal of Theoretical Physics 52, no. 3 (2013): 862-876.https://doi.org/10.1007/s10773-012-1395-0
12. Chiba, Takeshi, Naoshi Sugiyama, and Takashi Nakamura. "Cosmology with x-matter." Monthly Notices of the Royal Astronomical Society 289, no. 2 (1997): L5-L9. https://doi.org/10.1093/mnras/289.2.L5
13. Gorini, Vittorio, Alexander Kamenshchik, and Ugo Moschella. "Can the Chaplygin gas be a plausible model for dark energy?." Physical Review D 67, no. 6 (2003): 063509.https://doi.org/10.1103/PhysRevD.67.063509
14. Hernández-Almada, A., Miguel A. García-Aspeitia, M. A. Rodríguez-Meza, and V. Motta. "A hybrid model of viscous and Chaplygin gas to tackle the Universe acceleration." The European Physical Journal C 81, no. 4 (2021): 1-9.https://doi.org/10.1140/epjc/s10052-021-09104-w
15. Kaluza, T., Sitz. Press. Akad. Wiss. phys. math.k, 1, 966 (1921).
16. Malla, S., M. J. . Meena, O. . Reddy. R, V. . Mahalakshmi, and A. . Balobaid. “A Study on Fish Classification Techniques Using Convolutional Neural Networks on Highly Challenged Underwater Images”. International Journal on Recent and Innovation Trends in Computing and Communication, vol. 10, no. 4, Apr. 2022, pp. 01-09, doi:10.17762/ijritcc.v10i4.5524.
17. Kamenshchik, Alexander, Ugo Moschella, and Vincent Pasquier. "An alternative to quintessence." Physics Letters B 511, no. 2-4 (2001): 265-268.https://doi.org/10.1016/S0370-2693(01)00571-8
18. Khadekar, G. S., and N. V. Gharad. "Big Rip Singularity in 5D Viscous Cosmology." The Open Astronomy Journal 7, no. 1 (2014).DOI: 10.2174/1874381101407010007
19. Klein, Oskar. "Quantentheorie und fünfdimensionale Relativitätstheorie." Zeitschrift für Physik 37, no. 12 (1926): 895-906.https://doi.org/10.1007/BF01397481
20. Li, Miao. "A model of holographic dark energy." Physics Letters B 603, no. 1-2 (2004): 1-5.https://doi.org/10.1016/j.physletb.2004.10.014
21. Kadhim, R. R., and M. Y. Kamil. “Evaluation of Machine Learning Models for Breast Cancer Diagnosis Via Histogram of Oriented Gradients Method and Histopathology Images”. International Journal on Recent and Innovation Trends in Computing and Communication, vol. 10, no. 4, Apr. 2022, pp. 36-42, doi:10.17762/ijritcc.v10i4.5532.
22. Lima, J. A. S., A. S. M. Germano, and L. R. W. Abramo. "FRW-type cosmologies with adiabatic matter creation." Physical Review D 53, no. 8 (1996): 4287.https://doi.org/10.1103/PhysRevD.53.4287
23. Miller, Andre D., R. Caldwell, Mark Joseph Devlin, W. B. Dorwart, T. Herbig, M. R. Nolta, L. A. Page, J. Puchalla, E. Torbet, and H. T. Tran. "A Measurement of the Angular Power Spectrum of the Cosmic Microwave Background from l= 100 to 400." The Astrophysical Journal 524, no. 1 (1999): L1.https://doi.org/10.1086/312293
24. Misner, Charles W. "The isotropy of the universe." The Astrophysical Journal 151 (1968): 431.

25. Mohanty, G., and B. D. Pradhan. "Cosmological mesonic viscous fluid model." International Journal of Theoretical Physics 31, no. 1 (1992): 151-160.https://doi.org/10.1007/BF00674348
26. Naji, J., B. Pourhassan, and Ali R. Amani. "Effect of shear and bulk viscosities on interacting modified Chaplygin gas cosmology." International Journal of Modern Physics D 23, no. 02 (2014): 1450020.https://doi.org/10.1142/S0218271814500205
27. Nobbenhuis, Stefan. "Categorizing different approaches to the cosmological constant problem." Foundations of Physics 36, no. 5 (2006): 613-680.https://doi.org/10.1007/s10701-005-9042-8
28. Nojiri, Shin'ichi, and Sergei D. Odintsov. "Final state and thermodynamics of a dark energy universe." Physical Review D 70, no. 10 (2004): 103522.https://doi.org/10.1103/PhysRevD.70.103522
29. Arellano-Zubiate, J. ., J. . Izquierdo-Calongos, A. . Delgado, and E. L. . Huamaní. “Vehicle Anti-Theft Back-Up System Using RFID Implant Technology”. International Journal on Recent and Innovation Trends in Computing and Communication, vol. 10, no. 5, May 2022, pp. 36-40, doi:10.17762/ijritcc.v10i5.5551.
30. Panigrahi, D., and S. Chatterjee. "FRW type of cosmology with a Chaplygin gas." International Journal of Modern Physics D 21, no. 10 (2012): 1250079.https://doi.org/10.1142/S0218271812500794
31. Panigrahi, D., and S. Chatterjee. "Spherically symmetric inhomogeneous model with Chaplygin gas." Journal of Cosmology and Astroparticle Physics 2011, no. 10 (2011): 002.https://doi.org/10.1088/1475-7516/2011/10/002
32. Gupta, D. J. . (2022). A Study on Various Cloud Computing Technologies, Implementation Process, Categories and Application Use in Organisation. International Journal on Future Revolution in Computer Science &Amp; Communication Engineering, 8(1), 09–12. https://doi.org/10.17762/ijfrcsce.v8i1.2064
33. Pavon, D., J. Bafaluy, and David Jou. "Causal friedmann-robertson-walker cosmology." Classical and Quantum gravity 8, no. 2 (1991): 347.https://doi.org/10.1088/0264-9381/8/2/014
34. Perlmutter, Saul, Goldhaber Aldering, Gerson Goldhaber, R. A. Knop, Peter Nugent, Patricia G. Castro, Susana Deustua et al. "Measurements of Ω and Λ from 42 high-redshift supernovae." The Astrophysical Journal 517, no. 2 (1999): 565.https://doi.org/10.1086/307221
35. Perlmutter, Saul, G. Aldering, M. Della Valle, S. Deustua, R. S. Ellis, S. Fabbro, A. Fruchter et al. "Discovery of a supernova explosion at half the age of the Universe." Nature 391, no. 6662 (1998): 51-54.https://doi.org/10.1038/34124
36. Pourhassan, Behnam. "Viscous modified cosmic Chaplygin gas cosmology." International Journal of Modern Physics D 22, no. 09 (2013): 1350061.https://doi.org/10.1142/S0218271813500612
37. Riess, Adam G., Alexei V. Filippenko, Peter Challis, Alejandro Clocchiatti, Alan Diercks, Peter M. Garnavich, Ron L. Gilliland et al. "Observational evidence from supernovae for an accelerating universe and a cosmological constant." The Astronomical Journal 116, no. 3 (1998): 1009.https://doi.org/10.1086/300499

38. Riess, Adam G., Louis-Gregory Strolger, John Tonry, Stefano Casertano, Henry C. Ferguson, Bahram Mobasher, Peter Challis et al. "Type Ia supernova discoveries at z> 1 from the Hubble Space Telescope: Evidence for past deceleration and constraints on dark energy evolution." The Astrophysical Journal 607, no. 2 (2004): 665.https://doi.org/10.1086/383612
39. Saadat, H., and B. Pourhassan. "FRW bulk viscous cosmology with modified Chaplygin gas in flat space." Astrophysics and Space Science 343, no. 2 (2013): 783-786.https://doi.org/10.1007/s10509-012-1268-2
40. N. A. Farooqui, A. K. Mishra, and R. Mehra, “IOT based Automated Greenhouse Using Machine Learning Approach”, Int J Intell Syst Appl Eng, vol. 10, no. 2, pp. 226–231, May 2022.
41. Saadat, H., and B. Pourhassan. "FRW bulk viscous cosmology with modified cosmic Chaplygin gas." Astrophysics and Space Science 344, no. 1 (2013): 237-241.https://doi.org/10.1007/s10509-012-1301-5
42. Sahni, Varun, Tarun Deep Saini, Alexei A. Starobinsky, and Ujjaini Alam. "Statefinder—a new geometrical diagnostic of dark energy." Journal of Experimental and Theoretical Physics Letters 77, no. 5 (2003): 201-206.https://doi.org/10.1134/1.1574831
43. Salti, M., O. Aydogdu, A. Tas, K. Sogut, and E. E. Kangal. "Variable Chaplygin gas in Kaluza–Klein framework." Canadian Journal of Physics 97, no. 2 (2019): 117-124.https://doi.org/10.1139/cjp-2017-0873
44. Samanta, G. C., and Binaya K. Bishi. "Universe Described by Kaluza–Klein Space Time with Viscous Modified Cosmic Chaplygin Gas in General Relativity." Iranian Journal of Science and Technology, Transactions A: Science 40, no. 4 (2016): 245-254.https://doi.org/10.1007/s40995-016-0089-5
45. Santhi, and D. R. K. Reddy. "Kaluza-Klein Cosmological Model with Bulk Viscosity in Barber’s Second Self Creation Cosmology." Int. J of Astronomy 4, no. 1 (2015): 1-4.10.5923/j.astronomy.20150401.01
46. Sen, Ashoke. "Remarks on tachyon driven cosmology." In String Theory And Cosmology, pp. 70-75. 2005.https://doi.org/10.1142/9789812701657_0010
47. Setare, M. R., and A. Sheykhi. "Thermodynamics of viscous dark energy in an RSII braneworld." International journal of Modern physics D 19, no. 02 (2010): 171-181.https://doi.org/10.1142/S0218271810016361
48. Singh, G. P., and A. Y. Kale. "Anisotropic bulk viscous cosmological models with particle creation." Astrophysics and Space Science 331, no. 1 (2011): 207-219.https://doi.org/10.1007/s10509-010-0400-4
49. Singh, Kangujam Priyokumar, and Rajshekhar Roy Baruah. "Universe Filled with Generalized Cosmic Chaplygin Gas and Barotropic Fluid." International Journal of Astronomy and Astrophysics 6, no. 1 (2016): 105-110. 10.4236/ijaa.2016.61008
50. Spergel, David N., Licia Verde, Hiranya V. Peiris, Eiichiro Komatsu, M. R. Nolta, Charles L. Bennett, Mark Halpern et al. "First-year Wilkinson Microwave Anisotropy Probe (WMAP)* observations: determination of cosmological parameters." The Astrophysical Journal Supplement Series 148, no. 1 (2003): 175.
51. Tegmark, Max, Michael A. Strauss, Michael R. Blanton, Kevork Abazajian, Scott Dodelson, Havard Sandvik, Xiaomin Wang et al. "Cosmological parameters from SDSS and

WMAP." Physical review D 69, no. 10 (2004): 103501.https://doi.org/10.1103/PhysRevD.69.103501

52. Xu, Y. D., Z. G. Huang, and X. H. Zhai. "Generalized Chaplygin gas model with or without viscosity in the w–w′ plane." Astrophysics and Space Science 337, no. 1 (2012): 493-498.https://doi.org/10.1007/s10509-011-0850-3
53. Yu A., Kamenshchik, Alexander, Ugo Moschella, and Vincent Pasquier. "An alternative to quintessence." Physics Letters B 511, no. 2-4 (2001): 265-268.https://doi.org/10.1016/S0370-2693(01)00571-8
54. Zhai, Xiang-Hua, You-Dong Xu, and Xin-Zhou Li. "Viscous generalized Chaplygin gas." International Journal of Modern Physics D 15, no. 08 (2006): 1151-1161.https://doi.org/10.1142/S0218271806008784