Certain hypothesis related to the Nature of Dark Energy and Dark Matter in Cosmological Phase Transitions on the Evolution of the Universe

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Abstract: In this paper we investigate the nature of dark forces and extend their effects to analyses the various cosmological phase transitions that occurred whose evidence can be found in the chronology of the Universe, along with the observational evidence and study the Big Bang Cosmological Models which signifies the existence of Dark Energy and Dark Matter, in addition to various scalar field models such as cosmological inflation, quintessence, and other elements. We study the present-case scenario about the evolution of the Universe with respect to the Friedmann Equations, governing the expansion of space in homogeneous and isotropic models of the Universe within the context of general relativity.

Key words: Scale Factor, Einstein's Cosmological Constant, Cosmic Microwave Background Radiation, Lambda-CDM Model, and De-Sitter Universe.

I. INTRODUCTION:

Recently the small value of the cosmological constant and its ability to accelerate the expansion of the Universe is of great interest. We discuss the possibility of forming of anisotropic compact stars from this cosmological constant as one of the competent candidates of dark energy. For this purpose we consider the analytical solution of Krori and Barua metric. We take the radial dependence of cosmological constant and check all the regularity conditions, TOV equations, stability and surface redshift of the compact stars.

Cosmology is the branch of science concerned with the study of the entire. In the early 1990s, one thing was fairly certain about the expansion of the universe. It might have enough energy density to stop its expansion, it might have so little energy density that it would never stop expanding, but gravity was certain to slow the expansion as time went on. The universe is full of matter and the attractive force of gravity pulls all matter together. So the expansion of the universe has not been slowing due to gravity, as everyone thought, it has been accelerating. No one expected this, no one knew how to explain it. But something was causing it. Eventually theorists came up with three sorts of explanations. Maybe it was a result of a long-discarded version of Einstein's theory of gravity, one that contained what was called a "cosmological constant. Theorists still don't know what the correct explanation is, but they have given the solution a name. It is called dark energy. More is unknown than is known. We know how much dark energy there, other than that, it is a complete mystery. But it is an important mystery. Some theorists have named this "quintessence", but, if quintessence is the answer, we still don't know what it is like what it interacts with, or why it exists. So the mystery continues.

In recent years, there has been a striking and yet significant evidence for the detection of Einstein's cosmological constant (Λ) is one of the most important and residual problem in cosmology. The observational study of Type Ia supernovae presented possible evidence that the Universe is speeding up. The discovery of cosmic acceleration, was undoubtedly one of the most important finding in modern cosmology.

The origin of cosmic acceleration still remains a deep mystery. In context to General Relativity, if the Universe is filled with ordinary matter or radiation, gravity should lead to a slowing rate of expansion, the expansion set by the powerful explosion, known to many as "Big Bang". But, if we observe the chronology of the Universe, after the advent of cosmic inflation, the Universe still expands in an accelerating rate. Hence, the term "Dark Energy" comes into play and tied to Einstein's cosmological constant, explaining the unrealistic expansion of the Universe. Therefore, a hypothetical form of matter, known as "Dark Matter" was introduced. Hence, the origin of dark forces from the present epoch of the Big Bang was known.

Until about forty years ago, astronomers thought that the Universe is composed entirely of "Baryonic Matter". However, in the recent years, there has been some evidence accumulating that suggests that there is something in our Universe which we cannot see, perhaps some new form of matter (or) energy. If we assume the standard model of cosmology proposed to be correct, the best current measurements indicate that dark energy contributes 68.3% (approx. 70%) of the total energy in the present-day observable universe. The mass-energy of dark matter and ordinary (baryonic) matter contribute 26.8% (approx. 25%) and 4.9% (approx. 5%) respectively. These values were determined by making accurate measurements of the cosmic microwave background fluctuations, by NASA's WMAP (Wilkinson's Microwave Anisotropy Probe).

In the current accepted model in modern cosmology, the Universe is spatially flat ($\Omega_{total} = \Omega_{mass} + \Omega_{relativistic} + \Omega_{\Lambda} = 0.315 \pm 0.018 + 9.24 \times 10^{-5} + 0.6817 \pm 0.0018 = 1.00 \pm 0.02$) and accelerating, composed of normal mass (baryonic matter and dark matter), relativistic particles (photons and neutrinos) and dark energy or the cosmological constant.

Therefore, the fate and face of the Universe is always tied to the nature and role of dark energy and dark matter. They must have played a significant role in the chronology of the Universe in certain dominations, leading the Universe to the present state.

The objective of a variable gravitational constant G has been offered by [1] in the structure of general relativity. [2] offered a variation connecting the deviation of G among that of Λ who has been functioning in the structure of general relativity. This variation permits us to use Einstein's field equations form, that is not changed as deviation in Λ is escorted by a deviation of G. Using this approach, Bianchi models and Friedman-Robertson-Walker (FRW) models have been explored by numerous authors. In the Bianchi type-I model, the cosmological term is proportional to the Hubble parameter with variable G and Λ. FRW model has been discovered by [3],[4],[5],[6],[7],[8],[9],[10],[11] and [12]. The codification of the FRW universe has considered by [13] along with a perfect fluid in the equation of state and a cosmological constant. The matter distribution is isotropic and homogeneous because we know that universe being spherically symmetric. Gravitational constant G and cosmological constant lambda plays a significant role in Einstein theory of gravitation. [1] was the first one who considers the probability of variable G.[14] has done several amendment of general relativity to permit a variable G. But these assumptions were not accepted worldwide. Lambda and G like coupling variables of general relativity are considered in Einstein's field equations, proposed by [2],[15],[3] and [5]. The possibility of varying of probably increase of G has been discussed by many other researchers [16],[17],[15],[18]. The vast difference between cosmological constant and vacuum energy density has been complex problem in quantum field theory discussed by [19],[20],[21],[22],[23],[24]. It was opinion by various researchers [25],[26] that universe had non zero cosmological constant. Time dependent G and lambda were obtained by [27]. Number of authors [15],[28],[6],[7],[11],[29],[11],[30], [31], [32],[33] has considered homogeneous isotropic cosmological model with variable G and lambda in space times.

We have claimed about the conduct of the anisotropy of the dark energy and the geometrical characteristics of the models. To get this objective, we also apply an association between metric potential. It is noticed that these anisotropic and isotropic dark energy cosmological models constantly signifies an accelerated universe and are fixed with the current interpretations.

The Prime purpose of proposed work is to explored in this paper we explore, a dark energy model in the existence of general relativity for the context of Bianchi form-V cosmological models.

The manuscript leads by the series of sections as mentioned: In section 2, the basic definitions of anisotropic models are mentioned. In the division 3, field equation's results are obtained in the existence of general relativity for the context of Bianchi form-V cosmological models, in section 4, the conclusion drawn from the results.

II. MODEL AND FIELD EQUATIONS

The form of Bianchi type-V metric is considered as

$$ds^2 = -dt^2 + A^2(t)dx^2 + e^{2x}\left(B^2(t)dy^2 + C^2(t)\, dz^2\right) \tag{1}$$

The functions of t are $A^2(t), B^2(t), C^2(t)$. The energy momentum (T_i^j)tensor in an imperfect Bulk viscous fluid is specified by

$$T_i^j = (\rho + \bar{p})\, \upsilon_i \upsilon_j + \bar{p} g_{i_j} \tag{2}$$

We have relations satisfying following conditions where ρ is the energy density, the four-velocity vector of the element is υ_i, θ is the scalar expansion ε is coefficient of bulk viscosity, $\bar{p}$ is dissipative pressure and p is equilibrium pressure.

$$v_i\, v_j = -1 \tag{3}$$

$$\bar{p} = p - \varepsilon\, \theta \tag{4}$$

$$p = \omega\rho\,, \quad 0 \le \omega \le 1. \tag{5}$$

The Einstein's field equations with cosmological constant lambda and time dependent gravitational G when $R_{ij} - \frac{1}{2} R_1^1 g_{i_j} = -8\pi\, G(t) T_{i_j} + \Lambda(t) g_{i_j}$ (6)

Where the Ricci scalar is R. In commoving co-ordinate system, by substituting the value of energy momentum tensor (2) we get the field equation (6).

$$\frac{1}{A^2} - \frac{\ddot{B}}{B} - \frac{\ddot{C}}{C} - \frac{\dot{B}\dot{C}}{BC} = 8\pi G\bar{p} - \Lambda \tag{7}$$

$$\frac{1}{A^2} - \frac{\ddot{A}}{A} - \frac{\ddot{C}}{C} - \frac{\dot{A}\dot{C}}{AC} = 8\pi G\bar{p} - \Lambda \tag{8}$$

$$\frac{1}{A^2} - \frac{\ddot{B}}{B} - \frac{\ddot{A}}{A} - \frac{\dot{A}\dot{B}}{AB} = 8\pi G\bar{p} - \Lambda \tag{9}$$

$$-\frac{1}{A^2} + \frac{\dot{B}\dot{C}}{BC} + \frac{\dot{A}\dot{B}}{AB} + \frac{\dot{A}\dot{C}}{AC} = 8\pi G\rho + \Lambda \tag{10}$$

$$2\frac{\dot{A}}{A} - \frac{\dot{B}}{B} - \frac{\dot{C}}{C} = 0 \tag{11}$$

Wherever derivatives of A, B, C are denoted by dots with respect to "t". In prospect of disappearing of the divergence of Einstein tensor, we get

$$8\pi G \left[\dot{\rho} + (\rho + \bar{p}\,) \left[\frac{\dot{A}}{A} + \frac{\dot{B}}{B} + \frac{\dot{C}}{C}\right]\right] + 8\pi\rho\dot{G} + \dot{\Lambda} = 0 \tag{12}$$

$T_{i,j}^{j} = 0$, the usual energy conservation equation gives

$$\dot{\rho} + (\rho + \bar{p}\,) \left[\frac{\dot{A}}{A} + \frac{\dot{B}}{B} + \frac{\dot{C}}{C}\right] = 0 \tag{13}$$

$$8\pi\rho\dot{G} + \dot{\Lambda} = 0 \tag{14}$$

From the equation (14) we conclude that for non -zero energy density, G is constant and lambda is zero or constant. For Bianchi $-V$ space time the Average scale factor R is $[ABC]^{1/3}$.

By considering the equation (7) to (9) and (11) we acquire

$$\frac{\dot{A}}{A} = \frac{\dot{R}}{R} \tag{15}$$

$$\frac{\dot{B}}{B} = \frac{\dot{R}}{R} - \frac{K}{R^3} \tag{16}$$

$$\frac{\dot{C}}{C} = \frac{\dot{R}}{R} - \frac{K}{R^3} \tag{17}$$

Wherever K is constant by integrating equation (15) - (17)

$$A = K_1 R \tag{18}$$

$$B = K_2 R\ e^{\left[\left(-K \int \frac{dt}{R^3}\right]\right.} \tag{19}$$

$$C = K_3 R\ e^{\left[\left(-K \int \frac{dt}{R^3}\right]\right.} \tag{20}$$

Integrating constants are K_1, K_2, K_3., Scalar expansion is $\theta = 3H$ (21)

Shear tensor is $\sigma = \frac{K}{R^3}$ (22)

In this model we consider the spatial volume by taking $V = ABC$ (23)

In the model the Hubble parameter and deceleration parameter is described as

$$H = \frac{\dot{R}}{R} = \frac{1}{3}\left[\frac{\dot{A}}{A} + \frac{\dot{B}}{B} + \frac{\dot{C}}{C}\right] \tag{24}$$

$$q = -1 - \frac{\dot{H}}{H^2} \tag{25}$$

Wherever $H_1 = \frac{\dot{A}}{A}$, $H_2 = \frac{\dot{B}}{B}$, $H_3 = \frac{\dot{C}}{C}$

In direction of x, y *and* z here H_1, H_2, H_3 are the directional Hubble factors respectively.

In the Einstein's field equations from (7) to (10) shear scalar σ, deceleration parameter q and Hubble parameter H can also be written as

$$H^2(2q-1) - \sigma^2 + \frac{1}{R^2} = 8\pi G \bar{p} - \Lambda \tag{26}$$

$$3H^2 - \sigma^2 - \frac{3}{R^2} = 8\pi G\rho + \Lambda \tag{27}$$

$$\dot{\rho} + 3(\rho + \bar{p}) H = 0 \tag{28}$$

It was recognized that the energy density of the universe is infinity huge and average scale factor R is near to zero while expansion of universe that is as R increases the density decreases and when R is infinity the density becomes zero. From equation (27) we get $\frac{\rho_v}{\rho_c} \to 1$ where

$\rho_v = \frac{\Lambda}{8\Pi G}$, $\rho_c = \frac{3H^2}{8\pi G}$. For $\Lambda \geq 0$, $\rho < \rho_c$

Also from equation (27) we get $0 < \frac{\sigma^2}{\theta^2} < \frac{1}{3}$ and $0 < \frac{8\Pi \rho G}{\theta^2} < \frac{1}{3}$

A negative lambda will increase the anisotropy. While for $\Lambda \geq 0$ implies positive lambda which obstructs the upper limit of anisotropy. By taking the equation (26) and (27) we get

$$\frac{d\theta}{dt} = \Lambda + 12\pi G\theta\varepsilon - 4\pi G(\rho + 3p) - \frac{\theta^2}{3} - 2\sigma^2 \tag{29}$$

III. SOLUTION OF THE FIELD EQUATIONS

A relation between average scale factor R and Hubble parameter H was assumed as

$$H = a(R^{-n} + 1) \tag{30}$$

On integrating we get $R^n = e^{na(t+t_0)} - 1$ (31)

By taking the big bang condition that is at $t = 0, R = 0$, we obtained $t_0 = 0$ .Thus equation (31) is

$$R^n = e^{nat} - 1 \tag{32}$$

Use equations (31) in (18)-(20) $A = K_1[e^{nat} - 1]^{\frac{1}{n}}$ (33)

$$B = K_2[e^{nat} - 1]^{\frac{1}{n}} \exp\left(-K \int \frac{dt}{R^3}\right) \tag{34}$$

$$C = K_3[e^{nat} - 1]^{\frac{1}{n}} \exp\left(-K \int \frac{dt}{R^3}\right) \tag{35}$$

To determine the coefficient of bulk viscosity we assume

$\xi(t) = \xi_0\, \rho^m$ where ξ_0 , m are constants. (36)

by [43],[45],[44],[46]

Use equation (36) in equation (28) we get

$$\rho = \frac{l[1-e^{-nat}]^{\frac{9a\epsilon_0}{n}}}{[e^{nat}-1]^{\frac{3(1+w)}{n}}} \exp\left[9a\xi_0\left[-at + \frac{1}{n(1-e^{-nat})}\right]\right] \tag{37}$$

From equation (26)-(27) we get

$$\Lambda = \frac{1}{[(1+w)(e^{nat}-1)-3a\xi_0\, e^{nat}]}\left[\left[\frac{a^2\, e^{nat}}{[e^{nat}-1]^2}[3(1+w)e^{nat}(e^{nat}-1) - 9a\xi_0\, e^{nat} - 2n\,(e^{nat}-1)]\right] + \frac{K^2}{[e^{nat}-1]^{\frac{6}{n}}}[(1-w)(e^{nat}-1) + 3a\,\xi_0\, e^{nat}] - \frac{1}{[e^{nat}-1]^{\frac{2}{n}}}[(1+3w)(e^{nat}-1) - 9a\xi_0\, e^{nat}]\right]$$

(38)

From equation (27)

$$G = \frac{[e^{nat}-1]^{\frac{3(1+w)}{n}}}{8\pi l[(1+w)(e^{nat}-1)-3a\xi_0\, e^{nat}]} \times \frac{\left[3a^2(1+w)e^{2nat} - \frac{2K^2}{[e^{nat}-1]^{\frac{6-n}{n}}} - \frac{2}{[e^{nat}-1]^{\frac{2-n}{n}}}\right]}{[1-e^{-nat}]^{\frac{9a\epsilon_0}{n}} \exp\left[9a\xi_0\left[-at + \frac{1}{n(1-e^{-nat})}\right]\right]} \qquad (39)$$

MODEL FOR n=0

$$H = 2a \qquad (40)$$

$$R = e^{2at} \qquad (41)$$

$$A = K_1 e^{2at} \qquad (42)$$

$$B = K_2 \exp\left[2at + \frac{k\, e^{-6at}}{6a}\right] \qquad (43)$$

$$C = K_3 \exp\left[2at - \frac{k\, e^{-6at}}{6a}\right] \qquad (44)$$

$$\rho = K_4 \exp\,[6at(3\xi_0 - (1+w)] \qquad (45)$$

$$\sigma = K\, e^{-6at} \qquad (46)$$

$$\theta = 6a \qquad (47)$$

$$q = -1 \qquad (48)$$

$$\Lambda = 12a^2 + \frac{K^2\, e^{-12at}}{[(1+w)-6a\xi_0]}[1 - w + 6a\xi_0] - e^{-4at}\frac{[3(w-6a\xi_0)+1]}{[(1+w)-6a\xi_0]} \qquad (49)$$

$$G = \frac{-[1+K^2 e^{-8at}]}{4\pi K_4[1+w-6a\xi_0]\exp[2at[9\xi_0-1-3w]]} \qquad (50)$$

The model does not have initial singularity. Throughout the growth of cosmos, the scalar expansion is constant. The model observes constant extension. The model is accelerating at constant rate which displays the exponential growth of the cosmos for the solution for negative value of deceleration parameter $q = -1$. Initially when $t = 0$, scale factor, shear scalar, viscosity, density, gravitational constant and cosmological constant are all constant. Throughout the evolution, the rate of expansion of the universe is constant. Also gravitational constant and lambda becomes infinity for the huge value of "t".

As $t \to \infty$, so $\frac{\sigma}{\theta} \to 0$, hence the model inclines to isotropy for a large value of "t".

IV. DISCUSSION AND CONCLUSION

With the advancement in astrophysical studies and latest technologies, there is lot more to be observed, analysed and learned in our never-ending universe. According to multiverse theory, there can be possibilities of many alternative universes with different timelines, different laws of physics, never-ending possibilities, and new concepts. Therefore, this is still a puzzle unsolved by our dedicated scientists of the world, far from the ultimate understanding of what the universe has to offer. There is a possibility that we may come across various other cosmological phenomena's which will further enhance our understanding on the universe.

Dark energy and dark matter definitely proved to be a valuable asset in determining the face of the universe. But, to determine the fate, we should have a clear understanding of what's beyond the limit we can see. By the discoveries and headwork of many scientists, we come to a conclusion that dark energy and dark matter played a significant role from the present epoch of the universe. And definitely, the quest to unravel more secrets of the cosmos shall never come to an end. Hence, we should always keep over minds open to observe, admire and appreciate the wonders of cosmos, and move on to develop a better understanding of our universe in which the greatest minds ever lived.

In this paper we investigate the nature of dark forces and extend their effects to analyse the various cosmological phase transitions that occurred whose evidence can be found in the chronology of the Universe, along with the observational evidence and study the Big Bang Cosmological Models which signifies the existence of Dark Energy and Dark Matter, in addition to various scalar field models such as cosmological inflation, quintessence, and other elements. We study the present-case scenario about the evolution of the Universe with respect to the Friedmann Equations, governing the expansion of space in homogeneous and isotropic models of the Universe within the context of general relativity, in order to obtain a clear and crisp picture towards which the Universe is heading with time.

It has been observed that the presence of dark matter and dark energy in the big bang universe can be traced back to inflationary universe. It has been observed that when inflation ends, inferred inertial mass of a portion of the virtual matter convert into inertial mass of real particles. The proposition re-quires that the inertial of the visible matter be in space time accelerating frame of reference, which is responsible for the late-time accelerating expansion of the universe. It has been observed that mass is free fall in the inflation any universe and when inflation end it converts into the dark matter in the universe. Therefore, it is observed that nothing in the universe that drives the accelerating expansion of the universe

With the advancement in astrophysical studies and latest technologies, there is lot more to be observed, analysed and learned in our never-ending universe. According to multiverse theory, there can be possibilities of many alternative universes with different timelines, different laws of physics, never-ending possibilities, and new concepts. Therefore, this is still a puzzle unsolved by our dedicated scientists of the world, far from the ultimate understanding of what the universe has to offer. There is a possibility that we may come across various other cosmological phenomena's which will further enhance our understanding on the universe.

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In this paper we examined a cosmological development in the background of homogeneous, anisotropic Bianchi type V space-time which offered a variation law for Hubble parameter H that includes viscous fluid matter distribution. The model isotropizes asymptotically and the isotropization is accelerated by the existence of shear viscosity.

This paper deals study the present-case scenario about the evolution of the Universe with respect to the Friedmann Equations, governing the expansion of space in homogeneous and isotropic models of the Universe within the context of general relativity. The field equation's results are obtained in the existence of general relativity for the context of Bianchi form-V cosmological models by assuming $\xi(t) = \xi_0\, p^m$, [35]-[39], where ξ_0, m are constants. It has also been assumed a variation law for Hubble parameter is constant when $H(R) = a\,(R^{-n} + 1)$, where a >0, n>1.

One universe model has been acquired and their physical behavior has been discussed. The universe follows a non-singular state when $n = 0$. Presences of bulk viscosity increase matter density's value. As $\frac{\sigma}{\theta} \to 0\,, t \to \infty$ the models approaches isotropy for large values of "t".

When $n = 0$, at constant rate, the model is accelerating as $q = -1$. A suitable depiction of the growth of cosmos could be provided by the solutions obtained in the present paper. In brief , the law of variation of Hubble parameter offered by [3] to Bianchi type $-V$ space-time to discover particular solutions of Einstein's field equations has been extended.

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