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Dynamics of Non-static Plane Symmetric Isotropic Universe with Special Form of Deceleration Parameter in Barber's Second Self Creation Theory

D. R. Manekar[1], S. R. Bhoyar[2,*] and Hemant Kumar[3]

1 Research Scholar, Shri Jagdishprasad Jhabarmal Tibrewala University, Vidyanagri, Jhunjhunu, Rajasthan, India.

2 Department of Mathematics, Phulsing Naik Mahavidyalaya, Pusad, Maharashtra, India.

3 Department of Mathematics, Shri Jagdishprasad Jhabarmal Tibrewala University, Vidyanagri, Jhunjhunu, Rajasthan, India.

Abstract: In this context we have study the dynamics of non-static plane symmetric cosmological model with special form of deceleration parameter by utilizing Barber's Second Self Creation Theory. Also we have discussed some kinematical and geometrical parameters of the models.

MSC: 83C56.

Keywords: Non-static Plane Symmetric Universe, Special Form of Deceleration Parameter, Barber's Second Self Creation Theory.

1. Introduction

Dark energy (DE) is the name given to the astounding force that is making the speed of expansion of our universe accelerates as time goes on, rather than ease off. That is contrary to what one may anticipate from a universe that started in a Big Bang. Cosmologists in the 20^{th} century took in the universe is developing. They calculated the expansion may continue ceaselessly or finally if the universe had adequate mass and in this manner enough self-gravity banter and cause a Big Crunch. By and by, in mid-21^{st} century cosmology, that idea has created. The universe is seen as developing faster today than billions of years earlier. What could be making the speed of expansion increase? Stargazers as of now and again examine a shocking force as a likely strategy to get it. Lately, a couple of observational affirmations have shut the primary sureness that the universe experiences an early growing similarly as late-time accelerated augmentation [1–3]. It has been said that this is achieved by the presence of some confounding force containing horrible gravitational effects which is alluded to as DE. There are primarily two different ways to manage deal with this odd nature of DE and infinite speeding up issues. One technique prompts change of action standard in GR known as adjusted theories of gravity which are considered as elective approaches to manage combine DE. In the other philosophy, to appreciate the possibility of DE, a couple of dynamical DE candidates are introduced [4, 5]. The most un-complex comprehension for this DE is the introduction of a cosmological consistent identifying with state of state limit $\omega_\Lambda = -1$. Moreover, in the gathered works disseminated from the cosmological solid there are different applicants of DE which is identified with the energy thickness of a dynamical scalar field, for example,

* *E-mail: drsrb2014@gmail.com*

substance ($\omega_\Lambda > -1$) [6, 7]. Spirit field ($\omega_\Lambda < -1$) [8, 9] and Quinton (that can inverse apparition locale to center district) [10, 11]; Chaplygin gas [12], k-essence [13–16], Tachyon field, Holographic and Age realistic DE.

Ananda and Bruni [1] investigated Cosmo-elements and dull energy with non-straight condition of express: a quadratic model. Bhoyar and Chirde [2] examined Bianchi type-III and Kantowski Sachs cosmological model containing attractive field with variable cosmological steady in everyday hypothesis of relativity. The overall arrangements of the Einstein's field conditions for the cosmological models they had acquired under the suspicion of against solid liquid. Borgade et al. [3] committed to oneself impelling examination of elements of mass gooey string in LRS Bianchi type-I cosmological model inside the condition of elective hypothesis of gravity with Langrangian be the indiscreet perform of gravity hypothesis. Coley [4] studied dynamics of cosmological model in Bran-World scenario. Demianski et al. [5] examined the elements of a 11-dimensional homogeneous cosmological model. They accepted that the t = const. hyper surfaces are results of a 3-dimensional Bianchi type-IX space and a 7-dimensional torus. Li [7] inspected the elements of two-scalar-field cosmological models. Not at all like in the circumstances of remarkable potential, had they found that there are late-time attractors in which one scalar field rules the energy thickness of universe and the other one rot. They had additionally talked about the chance of various attractors model which is valuable to acknowledge the evolution of the universe from a scaling period to late speed increase time. Pavluchenko [11] studied Dynamics of the cosmological models with perfect fluid in Einstein–Gauss–Bonnet gravity: low-dimensional case. Pawar and Shahare [12] researched elements of shifted Bianchi type-III cosmological model in gravity hypothesis. Reddy et al. [14] researched a dull energy model within the sight of mass less scalar field in the edge work of locally rotationally symmetric (LRS) Bianchi type-II space-time. To track down a deterministic model of the universe they had utilized the half and half development law to settle Einstein's field conditions. They had additionally, utilize a connection between metric potential for this reason. Singh and Sonia [15] studied dynamical System Perspective of Cosmological Models Minimally Combined with Scalar Field. Tandon [16] investigated, a model in the presence of general relativity for the setting of Bianchi structure I cosmological models. For finding a deterministic model of the universe and to get the specific arrangements of the field conditions of Einstein, they guessed Hubble boundary which gives the fixed worth of deceleration boundary that gains the necessary aftereffects of the field conditions of Einstein. Vinutha and Kavya [17] examined dynamics of cosmological model. Zhuravlev and Chervon [18] introduced a subjective examination of chiral cosmological model (CCM) elements with two scalar fields in the spatially level Friedman-Robertson-Walker Universe. The asymptotic conduct of chiral models they explored dependent on the qualities of the basic places of the self-collaboration potential and zeros of the metric segments of the chiral space. The grouping of basic marks of CCMs they proposed. The part of zeros of the metric segments of the chiral space in the asymptotic elements they dissected. They had shown that such zeros lead to new basic marks of the relating dynamical frameworks.

For studying the accelerating expansion of the Universe several authors utilized the Barber's Second self-creation Theory of gravitation. Chirde and Rahate [26] investigated FRW Cosmological Solution in Self Creation Theory. Hatkar and Katore [28] explored anisotropic mass gooey string cosmological models with heat motion in Barber'S hypothesis. Katore and Shaikh [30] contemplated Einstein Rosen String Cosmological Model in Barber's Second Self-Creation Theory. Mohanty et al. [31] tackled the field conditions of Barber's second self-creation hypothesis with an ideal liquid in an inhomogeneous anisotropic locally rotationally symmetric Bianchi type I space-time. Rathore and Mandawat [33] examined Five Dimensional Perfect Fluid Cosmological Models in Barber's Second Self-Creation Theory.

Spurred by the above examinations and conversation, in this work, we consider Non-Static Plane Symmetric Cosmological Models with dynamics of fluid in Barber's Theory of Gravitation. The work in this paper is designed as follows: In the section of 'Model and The Field Equations', we have considered a Non-Static Plane Symmetric cosmological model in the framework of Barber's Theory of Gravitation with Dynamics of Fluid and derived the field equations. In the section of

'Solution of the Field Equations', we have consider the special form of Deceleration Parameter Proposed by Berman of the scale factor. Section 'Kinematical Parameters' described the behaviors of different aspects of kinematical parameters with some graphical nature. The outcomes are summed up with ends in the last segment.

2. Model and the Field Equations

Let us consider a non-static plane symmetric space-time of the form

$$ds^2 = e^{2h}\left(dt^2 - dr^2 - r^2 d\theta^2 - s^2 dz^2\right), \tag{1}$$

Where, h and s are the functions of cosmic time t and r, θ, z are the general cylindrical co-ordinates. The field equations in Barber's second self-creation theory of gravitation are:

$$R_i^j - \frac{1}{2}R = \psi^{-1}T_i^j \tag{2}$$

The Scalar Field is defined as,

$$\begin{aligned} \psi &= \psi^k_{;k} \quad \text{and} \\ \psi^k_{;k} &= \frac{8\pi}{3}\mu T, \end{aligned} \tag{3}$$

where T is the trace of the energy momentum tensor that describes all non-gravitational and non-scalar field theory. μ is a coupling constant. The early universe would be altogether different with unexpected sort of actual properties in comparison to the current day universe. We need to think about all prospects of issue dispersion. We will manage a few subtleties of these actual appropriations which we accept assumed a critical part in the construction arrangement of the universe. With this discussion let us consider the dynamics of fluid energy momentum tensor as:

$$T_i^j = (p+\rho)\,u_i u_j - p g_{ij}, \tag{4}$$

where p is the pressure of the universe and ρ is the energy density of the matter. With respect to energy momentum tensor (4) and from the equations (1)-(3) we get the field equations as:

$$e^{-2h}\left[2\ddot{h} + \dot{h}^2 + \frac{2\dot{h}\dot{s}}{s} + \frac{\ddot{s}}{s}\right] = -\psi^{-1}p \tag{5}$$

$$e^{-2h}\left[2\ddot{h} + \dot{h}^2\right] = -\psi^{-1}p \tag{6}$$

$$e^{-2h}\left[\frac{2\dot{h}\dot{s}}{s} + 3\dot{h}^2\right] = \psi^{-1}\rho \tag{7}$$

3. Solution of the Field Equations

The arrangement of Equation (5) to (7) is having with three directly autonomous conditions with five unknowns h, s, ψ, p and ρ. In order to obtain its solution, we consider special form of deceleration parameter which has a significant importance in cosmology since it elegantly illustrates different cosmic evolutionary phases given by the following equations.

To find the solution we consider the relation between scalar field and scale factor

$$\psi = a^{\gamma}; \quad \gamma \text{ be any constant} \tag{8}$$

The obtained scalar field is,

$$\psi = \left(e^{\alpha k t} - 1\right)^{\frac{\gamma}{\alpha}} \tag{9}$$

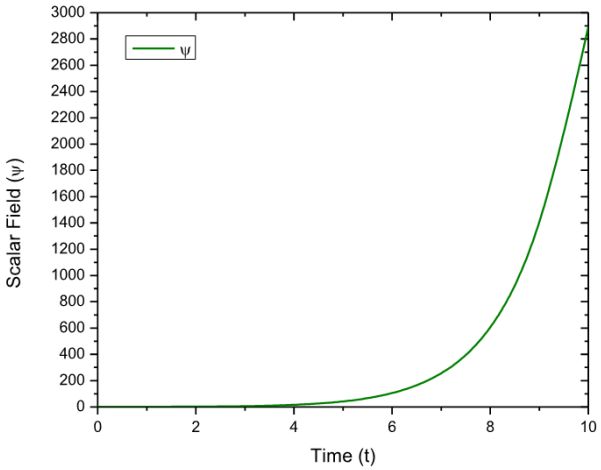

Figure 1. **Nature of Scalar Field Vs Time with suitable constants** $\alpha = 0.23, k = 1.52$ **and** $\gamma = 0.53$**.**

While observing the nature as specified in the above **Figure 1** we can say that the scalar field of the universe or the model of dynamics of fluid experiencing an exponential nature at it then singular at $t = 0$. For getting the values of metric potentials; we assume that the relation between the metric potentials as:

$$e^h = s^n; n > 1 \tag{10}$$

Hence with this the metric potentials are found out to be,

$$s = \left(\frac{1}{\alpha}\right)^{\frac{1}{4n+1}} \left(e^{\alpha k t} - 1\right)^{\frac{3}{\alpha(4n+1)}} \tag{11}$$

$$e^h = \left(\frac{1}{\alpha}\right)^{\frac{n}{4n+1}} \left(e^{\alpha k t} - 1\right)^{\frac{3n}{\alpha(4n+1)}} \tag{12}$$

Utilizing the metric potentials (11) and (12) the resulting pressure of the Universe is found out to be,

$$p = \alpha_1 e^{\alpha k t} \left(e^{\alpha k t} - 1\right)^{\frac{\gamma}{\alpha} - \frac{6n}{\alpha(4n+1)} - 1} \left[6n\alpha - \frac{9n^2}{(4n+1)\left(1 - e^{-\alpha k t}\right)}\right] \tag{13}$$

Utilizing the metric potentials (11) and (12) the resulting energy density of the Universe is found out to be,

$$\rho = 9\alpha_1 n\,(3n+2) \left(\frac{1}{1 - e^{-\alpha k t}}\right)^2 \left(e^{\alpha k t} - 1\right)^{\frac{\gamma}{\alpha} - \frac{6n}{\alpha(4n+1)}} \tag{14}$$

Utilizing the metric potentials (11) and (12) in the model (1) the resulting Cosmological model of the Universe is found out to be,

$$ds^2 = \left[\left(\frac{1}{\alpha}\right)^{\frac{2n}{4n+1}} \left(e^{\alpha k t} - 1\right)^{\frac{6n}{\alpha(4n+1)}}\right] \left(dt^2 - dr^2 - r^2 d\theta^2 - \left[\left(\frac{1}{\alpha}\right)^{\frac{2}{4n+1}} \left(e^{\alpha k t} - 1\right)^{\frac{6}{\alpha(4n+1)}}\right] dz^2\right), \tag{15}$$

The above model (15) of the universe is the special form of deceleration parameter cosmological model and we got the potential functions of this model in terms of special form. At $t = 0$ the model shows singularity and model turn into constant. In the similar manner the potential functions (11) & (12) are also vanishes for $t = 0$.

4. Kinematical Parameters of the Model

The kinematical parameters of the model of the universe with respect to special form of deceleration parameter found out and its graphical behavior is shown in the following domain of this section.

The spatial volume with respect to the average scale factor which is nothing but the special form of deceleration parameter is found out to be,

$$V = \left(e^{\alpha kt} - 1\right)^{3/\alpha} \tag{16}$$

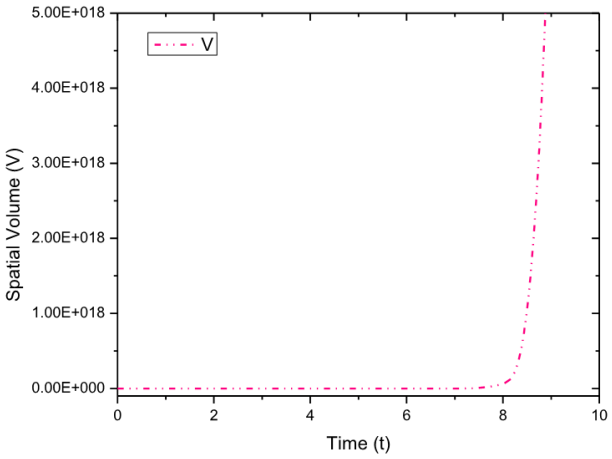

Figure 2. **Nature of Spatial Volume (V) Vs Time with suitable constants** $\alpha = 0.23$ **and** $k = 1.52$**.**

The average scale factor with respect to the special form of deceleration parameter proposed by Berman is:

$$a = \left(e^{\alpha kt} - 1\right)^{1/\alpha} \tag{17}$$

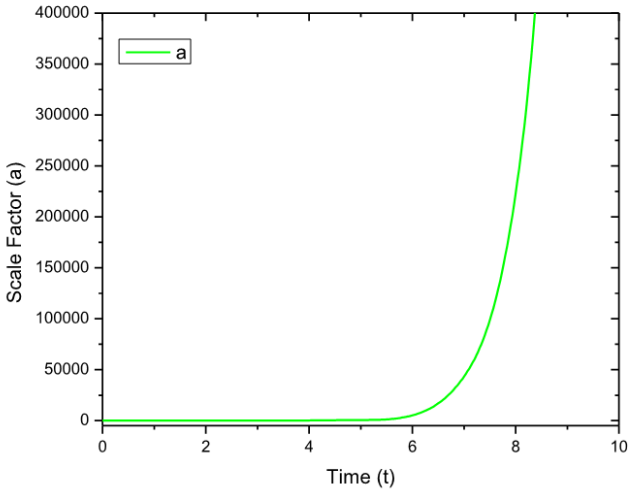

Figure 3. **Nature of Scale Factor (a) Vs Time with suitable constants** $\alpha = 0.23$ **and** $k = 1.52$**.**

The Hubble parameter for model (1) is found out to be,

$$H = \frac{\dot{a}}{a} = \frac{ke^{\alpha kt}}{(e^{\alpha kt} - 1)} \tag{18}$$

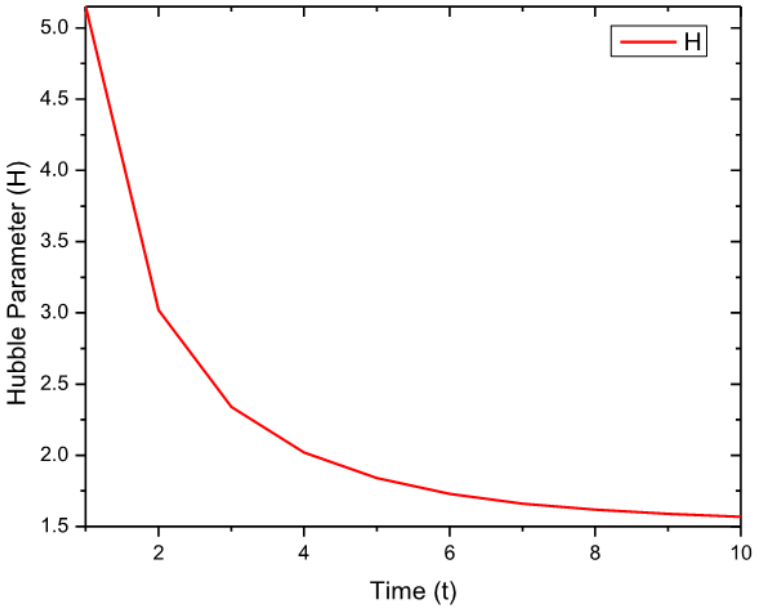

Figure 4. **Nature of Hubble Parameter (H) Vs Time with suitable constants $\alpha = 0.23$ and $k = 1.52$.**

The obtained expansion scalar θ is

$$\theta = 3H = \frac{3ke^{\alpha kt}}{(e^{\alpha kt} - 1)} \tag{19}$$

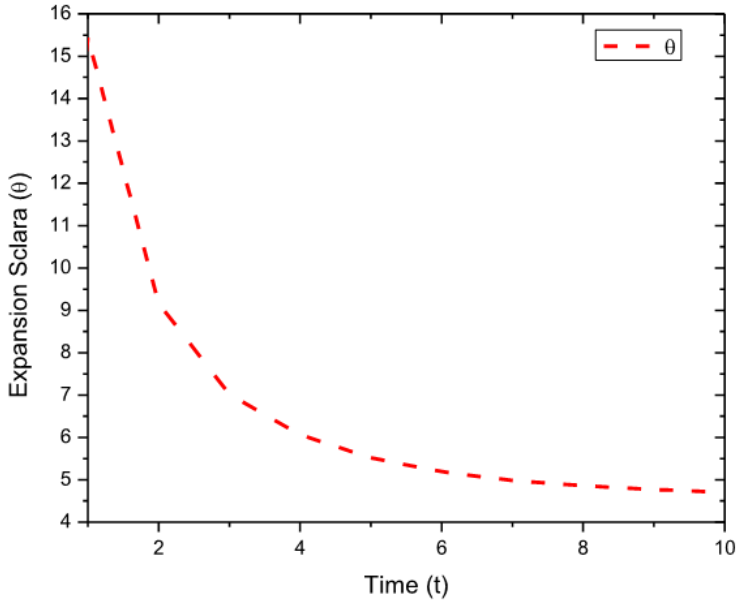

Figure 5. **Nature of Expansion Scalar Vs Time with suitable constants $\alpha = 0.23$ and $k = 1.52$.**

The mean anisotropy parameter for the given expansion of the model (1) is found out to be,

$$A_m = \frac{(e^{\alpha kt} - 1)}{ke^{\alpha kt}} \tag{20}$$

The resulting shear scalar of the given model is,

$$\sigma^2 = \frac{3ke^{\alpha kt}}{2\,(e^{\alpha kt} - 1)} \tag{21}$$

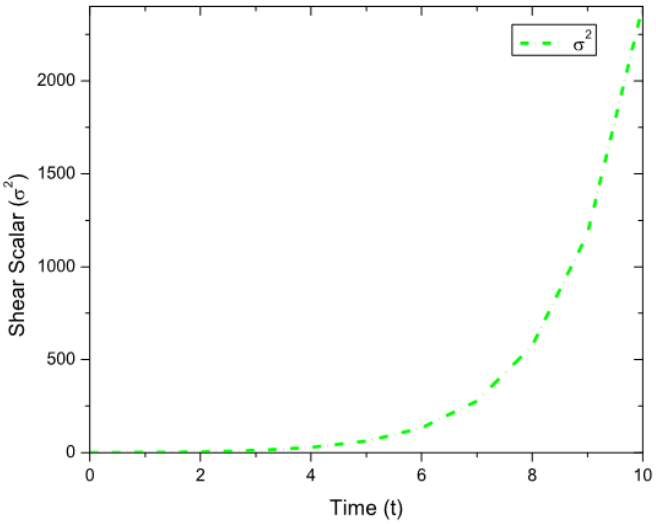

Figure 6. **Nature of Shear Scalar Vs Time with suitable constants** $\alpha = 0.23$ **and** $k = 1.52$**.**

The deceleration parameter is found out to be,

$$q = \frac{\alpha}{e^{\alpha k t}} - 1 \tag{22}$$

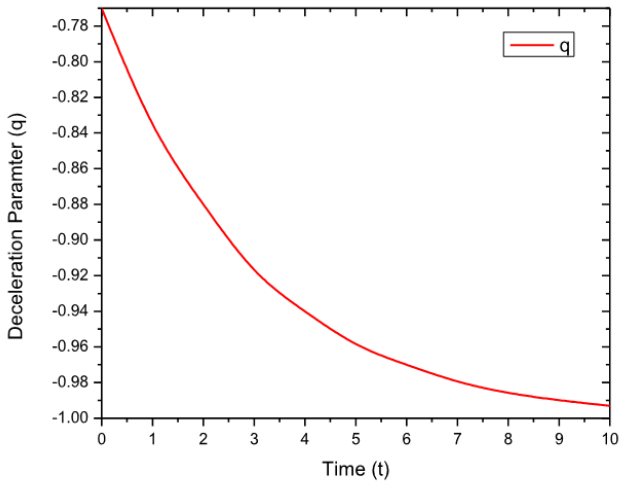

Figure 7. **Nature of Deceleration Parameter (q) Vs Time with suitable constants** $\alpha = 0.23$ **and** $k = 1.52$**.**

The nature of deceleration parameter of the model is as shown in the above graphical representation. While observing above Figure 7 it can be concluded that the values of deceleration parameter are lies in between $-0.78 \leq q \leq -1$ and by the recent observation we can say that the universe shows the decelerated expansion of the universe.

5. Conclusions

In this present article, we have explored the dynamics of non-static plane symmetric cosmological models in the frame work of Barber's second self-creation theory of gravitation.For finding the solutions of field equations we have consider the special form of deceleration parameter. The metric potentials found for this model are the exponential function of cosmic time t. The resulting cosmological model having a singularity at, $t = 0$ and also the model is in exponent form. The parameters p, ρ

& ψ is having the singular point at $t = 0$. The deceleration parameter is lies in between $-0.78 \leq q \leq -1$ and by the recent observation we can conclude that the universe shows the decelerated expansion of the universe. Hence these all findings show that our current universe is experiencing an accelerated expansion. Some physical and kinematical parameters of the models have been graphically described.

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