Possibility of Cosmic Time Going Back in Some Dark Energy Model Universe

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Abstract In the course of investigating a universe dominated by phantom dark energy it is found that the idea of negative cosmic time, or in other words, reversing the present arrow of time is valid in such a universe from big rip singularity, thus giving us a realistic universe.

Keywords: *dark energy, reversed arrow of time, phantom energy universe*

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1. Introduction

It is generally assumed that the present accelerated expansion of the universe is mostly due to the presence of an exactly unknown matter, which is generally given the name of dark energy. Many researchers studied possible different forms of dark energy. Among them phantom energy is also one interesting form of dark energy. Different model universes containing phantom dark energy were studied, among others, by [1-28] and Mahanta et al. [29], also studied some kinds of dark energy model universes. Also recently Martin [30] studied about the time arrow in a finite universe.

Here in the study of a universe containing such type of dark energy we get a stimulating result in relation to big rip singularity where such a situation can be saved. According to some researchers there is no possibility of big rip singularity in our universe and rather there is possibility of this universe to be a cyclic one. Very interestingly here in this problem, we find that the big rip singularity in such a universe can be saved if we take the cosmic time to go backward; or in other word, the reversal of the present arrow of time is possible in such an epoch.

2. Solutions of a New Model Universe

In a homogeneous scalar field the energy density and pressure are given by

$$\rho = T_0^0 = \frac{1}{2}\dot{\varphi}^2 + V(\varphi) \tag{1}$$

$$p = -T_1^1 = -T_2^2 = -T_3^3 = \frac{1}{2}\dot{\varphi}^2 - V(\varphi) \tag{2}$$

Thus in a phantom energy dominated universe where the phantom scalar is φ, we have

$$\omega = \frac{\frac{1}{2}\dot{\varphi}^2 - V(\varphi)}{\frac{1}{2}\dot{\varphi}^2 + V(\varphi)} \tag{3}$$

where ω is the equation of state parameter.

Since $\omega < -1$ in the case of phantom energy, from (3) we get

$$\omega = \frac{\frac{1}{2}\dot{\varphi}^2 - V(\varphi)}{\frac{1}{2}\dot{\varphi}^2 + V(\varphi)} < -1 \tag{4}$$

which gives

$$\dot{\varphi}^2 < 0 \tag{5}$$

Thus, showing that there is negative kinetic energy in the case of phantom energy universe. Hence action for phantom may be taken in the form

$$S = \int d^4 x \sqrt{-g}[-\frac{1}{2}g^{ij}\delta_i\varphi\delta_j\varphi - V(\varphi)] \tag{6}$$

Therefore, in the case of the phantom the energy conservation equation takes the form

$$\dot{\rho} + 3H(1+\omega)\rho = 0 \tag{7}$$

With

$$|(1+\omega)| = -(1+\omega) \tag{8}$$

Now from (7), we get

$$\rho = ka^{3|(1+\omega)|} \tag{9}$$

where k being an integration constant.

On the other hand for a spatially flat Friedman Robertson Walker universe metric is

$$ds^2 = dr^2 - a(t)^2[dx^2 + dy^2 + dz^2] \tag{10}$$

From its field equations, we get the relations

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho \tag{11}$$

And

$$\frac{\ddot{a}}{a} = \frac{4\pi G}{3}(\rho + 3p) \tag{12}$$

Now from (9) and (11), we have

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3} k a^{3|(1+\omega)|} \tag{13}$$

which gives

$$a(t) = \left[\frac{3|(1+\omega)|}{2}\sqrt{\frac{8\pi Gk}{3}}(t_b - t)\right]^{-\frac{2}{3}|(1+\omega)|} \tag{14}$$

where

$$t_b = a_0^{-\frac{3}{2}|1+\omega|} + \frac{3|1+\omega|}{2}\sqrt{\frac{8\pi Gk}{3}}t_o \tag{15}$$

$a_0 = a(t_0)$, and t_0 is the present time.

Here we see that, as $t \to t_b$, $a \to \infty$, $\rho \to \infty$ and $p \to \infty$. Thus it predicts big rip singulary at $t = t_b$.

Now if we introduce the concept of negative time, that means the cosmic time going backward, we have, as $t \to t_b$,

$$a(t) = \left[3|(1+\omega)|\sqrt{\frac{8\pi Gk}{3}}t_b\right]^{-\frac{2}{3}|(1+\omega)|} \tag{16}$$

Thus, in this case there will be not be the catastrophic situation where celestial bodies are expected to get smashed to tiny particles.

For this case we have

$$(-\dot{\varphi})^2 < 0 \text{ or } \dot{\varphi} > 0$$

Thus giving

$$\dot{\varphi}^2 > 0 \tag{17}$$

Thereby we have positive kinetic energy when our new time is going back opposite to our present time that is in the negative direction of our usual time thus showing the possibility of reversal of time.

3. Conclusions

Here we study a universe dominated by phantom type dark energy and find that a big rip singularity can be avoided if we consider the time to run in the opposite direction of the present cosmic time. In this way we see that there is possibility of reversing the arrow of time at some practical event of time and place. Since there is no big rip singularity in a realistic universe (so far the present scientific knowledge goes).An interesting conclusion that can be made from the result of our present research is that, if there is universe dominated by phantom type of dark energy then in this universe, in some particular event, the

phenomenon of ageing can be stopped for some particular period of time.

In the cyclic model of the universe [31] the transition from the "big crunch" to the "big bang" occurs as the scalar field $\varphi \to -\infty$ and then rebounds towards positive φ. Motivated by string theory, it is proposed that some small fraction of the $\varphi -$ field kinetic energy is converted to matter and radiation. And the matching rule amounts to

$$\dot{\varphi}e^{\sqrt{3/2\varphi}} \to (1+x)\dot{\varphi}e^{\sqrt{3/2\varphi}} \tag{18}$$

where x is a parameter measuring the efficiency of production of radiation at the bounce. Here, if the concept of negative time is introduced then the expression $\varphi \to -\infty$ has a physical meaning, otherwise imaginary; similarly in the case with the matching rule defined above which is physically possible when a negative arrow of time is introduced.

We also see that, as the universe contracts towards the "big crunch", the scale factor 'a' tends to zero, the scalar field tends to $-\infty$ and the scalar potential becomes negligible [32]. The universe becomes, dominated by the scalar field kinetic energy density since it scales as ,a^{-6} whereas matter and radiation densities scale as a^{-3} and a^{-4} respectively. As scalar kinetic energy domination occurs, the scale factor 'a 'begins to scale as $(-t)^{\frac{1}{3}}$, and the background scale field diverges logarithmically in time.The energy density and Ricci scalar diverge as $(-t)^{-2}$ so that $t = 0$ is a "big crunch" singularity. The relations involved here imply that there exists the negative of time, as otherwise many a thing pertaining to this universe become imaginary which ultimately implies that the universe will be imaginary, which is impossible. Thus for the universe to be realistic one, as it is now, we have to accept the concept the negative time or reversed of our present cosmic time.

Again, if we consider the bounce cosmology in the universe it can be asserted the bounce takes place at $t = t_*$ so that $t_* < 0$ represents the contracting phase whereas $t_* > 0$ can be taken to represent the expanding phase [33]. The bounce time t_* is very small; and the universe has a collapsing era for $t < t_*$, and there after an expanding era begins. Thus, we see that the concept of negative time comes into the picture when we want to describe the time of an event in the contracting phase just before another cycle begins with an expanding era. The negative time is with respect to the frame of reference of time in the expanding phase of a new cycle of the universe or with respect to the present arrow of time. Further research in the direction is being carried on and the results will be reported somewhere.

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