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Oscillating Theory of the Universe

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Abstract- We propose here a new theory of the cosmic evolution of the universe, giving its name as the "oscillating theory of the universe". In this theory we have an endless universe having different epochs in its continuing endless process, an epoch being equal to one complete oscillation starting from a big bang like event and undergoing through different phases until it arrives at a pseudo crunch to be followed by another big bang like event, of course, after a bounce. This moment of time is the end of an epoch and the beginning of another new epoch, which happens after a complete oscillation. In this oscillating theory the length of an epoch need not be equal to the length of another epoch. And interestingly, it is found that there exists the significance of negative time at some point during the cosmic evolution of the universe.

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Oscillating Theory of the Universe

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I. Introduction

There have been some theories and models of the universe, namely, standard big bang theory and inflationary models [Guth(1981), Albrecht and Steinhardt(1982), Linde (1982)], steady state theory [Hoyle and Narlikar (1964)], Brans-Dicke theory [Brans and Dicke (1961)], Dirac cosmology [Dirac (1973)], pre-big bang model [Gasperini and Veneziano (1993), Gasperini et al.(1997), Gasperini and Veneziano (2003)], ekpyrotic model [Khoury et al. (2001), Khoury et al. (2002a), Khoury et al. (2002b)], Horava-Witten heterotic M-theory [Horava and Witten (1996), Lukas et al. (1999a), Lukas et al. (1999b)], cyclic theory of the universe [Steinhardt and Turok (2002a), Steinhardt and Turok (2002b)], and the new ekpyrotic model [Buchbinder et al.(2007a), Buchbinder et al. (2007b), Buchbinder et al.(2008), Creminelli and Senatore (2007)]. In this paper, we attempt to introduce another new theory of the universe in which the universe undergoes an endless series of oscillations forming different epochs, and we name it as the "oscillating theory of the universe". Our model differs from oscillatory model introduced earlier based on a closed universe; rather our universe is flat and infinite. Our universe no longer passes through a singularity in which the energy and the temperature diverge, rather the density and the temperature remain finite at the transition. Tolman (1934) pointed out that entropy produced during one cycle would be added to the entropy produced in the next, causing each cycle to be longer than the one before it. But his assumption is not necessarily true in our case. One oscillation may be longer or shorter than the next one as in our case the accelerated expansion, caused by the dark energy, is already diluting almost all the entropy, black holes and other debris accompanied with our universe which was produced in the previous epoch.

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II. A Brief Sketch of the Oscillating Theory

In the proposed oscillating theory of the universe we consider the evolution of a scalar field ϕ coupled to our universe with gravity. In this theory one epoch begins with a big bang, after which the inflationary phase comes with a high rate of expansion. After a short period a stage is reached when the scalar field ϕ becomes nearly fixed during which the universe undergoes radiation-dominated and matter-dominated phases. Next during this process the universe reaches a stage when the potential energy of the scalar field begins to dominate giving a period of accelerated expansion which is the present age of the universe. During this period of accelerated expansion, the black holes, matter, radiation, all debris, neutron stars, neutrinos will be diluted away making the universe empty, smooth and flat. During this period the slope of the potential $V(\phi)$ causes the scalar field ϕ to roll down in the negative direction and the accelerated expansion will continue during which the potential energy almost drops to zero. At this point the universe will be dominated by the kinetic energy of the scalar field ϕ. But again, this kinetic energy will be damped away by the expansion of the universe. Then the moment comes when the total energy consisting of the kinetic energy and negative potential energy almost becomes zero at which moment the universe seems to be static momentarily. Then the scalar field starts to roll back towards $-\infty$ and the universe begins to contract. Now the kinetic energy of ϕ grows which means that the gravitational energy is being converted to the kinetic energy of ϕ. Thus the kinetic energy becomes increasingly dominant and the scalar field diverges as the radius of the universe tends to zero. Then a bounce follows and radiation is produced and the universe is beginning to expand. Though, for some time, the kinetic energy density of the scalar field continues to dominate over the radiation, soon after the universe becomes radiation-dominated, and it undergoes a radiation-dominated phase, and then followed by a matter-dominated phase. During this phase the motion of the scalar field is rapidly damping, and it remains with almost reaching its maximum value. Then after a period of some billion years the potential energy of the scalar field begins to dominate, still ϕ rolling towards $-\infty$. As the scalar field rolls towards $-\infty$ the expansion of the universe begins diluting all the debris, the black holes, neutron stars etc. and flattening and making smooth the universe again. Then when all the energy of the scalar field is used up the universe seems to have a momentary pause, after which it (the universe) starts contracting leading to a pseudo crunch. Then after a bounce it goes for a big bang starting anew the process of evolution in the positive direction again. Thus the universe goes on in an endless continuing process, where there is the significance of negative time in the evolution process of the universe, at least during the period when $\phi \to -\infty$. Here the periods of oscillation may not be necessarily equal.

III. An Oscillating Model of the Universe

Here, as an illustration, we take up an oscillating universe. The line element considered is that of the flat and homogeneous Robertson-Walker metric

$$ds^2 = -dt^2 + a^2(t)[dr^2 + r^2(d\theta^2 + sin^2\theta d\varphi^2)] \quad (1)$$

where a is the scale factor. And the study of our model is taken up using the action S which describes the gravity, the scalar field ϕ, and the matter and radiation fluids in the form

$$S = \int d^4x\sqrt{-g}\,[\frac{1}{16\pi G}R - \frac{1}{2}(\partial\phi)^2 - V(\phi) + \psi^4(\phi)(\varrho_r + \varrho_m)], \quad (2)$$

where R is the Ricci scalar and $V(\phi)$ is the scalar potential. And it is such that the coupling $\psi^4(\phi)$ between the scalar field ϕ and the radiation (ϱ_r) and the matter (ϱ_m) densities causes the densities to remain finite at the moment of transition from the big crunch to the big bang event.

From (1) and (2) we get the field equations

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\left(\frac{1}{2}\dot{\phi}^2 + V + \psi^4\varrho_r + \psi^4\varrho_m\right) \quad (3)$$

$$\frac{\ddot{a}}{a} = -\frac{8\pi G}{3}\left(\dot{\phi}^2 - V + \psi^4\varrho_r + \frac{1}{2}\psi^4\varrho_m\right) \quad (4)$$

Here the scalar field ϕ satisfies the equation

$$\ddot{\phi} + 3H\dot{\phi} = -\frac{dV}{d\phi} - \frac{d\psi}{d\phi}\psi^3\varrho_m \quad (5)$$

where

$$H = \frac{\dot{a}}{a} \quad (6)$$

is the Hubble constant.

For radiation or matter the equation of fluid motion is given by

$$a_\psi\frac{d\varrho_\alpha}{da_\psi} = a\frac{d\varrho_\alpha}{da} + \frac{\psi}{\frac{d\psi}{d\phi}}\frac{\partial\varrho_\alpha}{\partial\phi_\alpha} = -3(\varrho_\alpha + p_\alpha) \quad (7)$$

where $\alpha = r, m$.

Also, $a_\psi = a\psi(\phi)$, and p_α is the pressure for the portion of the fluid whose energy density is ϱ_α. Here assumption is implicitly made that radiation and matter couple to $\psi^2(\phi)g_{ij}$ (having scale factor a_ψ) rather than the Einstein metric g_{ij} alone (with scale factor a).

In our case we take the potential of the scalar field in the form

$$V(\phi) = V_0(1 - e^{-b\phi})f(\phi), \quad (8)$$

where $f(\phi)$ is a function such that $V(\phi) \to 0$ as $\phi \to -\infty$. With such a choice we can attain a realistic astrophysical situation by taking $b \geq 10$ and making today's dark energy density which is roughly $6 \times 10^{-30}\ gm/cm^3$ equal to V_0.

Regarding the coupling $\psi(\phi)$, we take

$$\psi(\phi) \sim \varrho^{-\phi/\sqrt{6}} \quad as\ \phi \to -\infty \quad (9)$$

Here we choose $\psi(\phi)$ such that a_ψ and the matter and radiation densities are finite at $a = 0$ during the process of evolution. For large b, the potential is such that $\frac{V''}{V} >> 1$ for $\phi_{min} < \phi < 0$. And in this region the constant term is seen to be irrelevant and we may take $-V_0e^{-b\phi}$ for V. Considering the motion of ϕ back and forth across the potential regime we find a solution to study the moments (periods) before and after the bounce. Over this region $-V_0e^{-b\phi}$ can represent potential V, and a corresponding simple scaling solution is

$$a(t) = t^p, \quad (10)$$

$$V = -V_0e^{-b\phi} = \frac{-p(1-3p)}{t^2}, \quad (11)$$

$$p = \frac{2}{c^2}, \quad (12)$$

which corresponds to an expanding or contracting universe according to t is positive or negative. And here $t = 0$ is chosen to correspond to a bounce. Thus at this particular juncture first t is negative which corresponds to a contracting universe leading to a pseudo big

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crunch; then at $t = 0$ there is a bounce and just after that t is positive which corresponds to an expanding universe with a big bang. Thus at $t = 0$ one epoch of oscillation is completed, and from next moment onwards another epoch begins with a big bang.

IV. Conclusion

With the different arguments and reasons given above and observance of the continuity of the universe with such a theory and the results obtained here we have good reason to think of the oscillating theory as a very much viable new theory of the universe. Considering a model universe with a particular scalar field we have successfully shown that our universe can have different epochs of oscillation, one epochs consisting as usual of the radiation-dominated, matter-dominated and dark energy dominated phases. The different phases have been shown explicitly in our model. Finally we arrive at a juncture where an epoch of oscillation ends and after a bounce another epoch begins with a big bang. During each epoch there is a period of time when $\phi \to -\infty$ during which there is an implication for the existence of negative time; and such a similar situation arises also at the transit period from one epoch to another epoch. In this way the evolution of our universe is an endless process containing different epochs, each epoch comprising of a complete oscillation as we proposed.

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