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Extra dimensions, Entropy Violation and Primordial Fluctuations

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ABSTRACT

We explore an alternate approach to the origin of primordial fluctuations using extra dimensions. A non-inflationary cosmology is considered, with the evolution of 4 + d dimensions from the initial singularity. The extra dimensions evolve more rapidly than the ordinary space and reach their maximum volume in a short interval of time, at the end of which they get stabilized. Due to random interactions between the bulk and the brane, the entropy may be sucked from the normal space. These interactions occur only for a short interval of time and hence only a small amount of entropy is consumed. An approximate equation which describes the decrease in entropy, in a region of normal space, is constructed. Finally, this violation of law of entropy is related to the increase in density of that region of space by simple thermodynamic considerations. This process occurs randomly in different regions of normal space generating the primordial fluctuations in density, which grow over time and eventually become the universe we see today.

1. Introduction

Our universe consists of many galaxies, stars and other different structures. But on large scales it is homogeneous and isotropic [7]. The early universe had tiny fluctuations in density in the order of 10^{-5} (i.e., one part in 100000) [9] which evolved with time and became the planets, stars and galaxies we see today. The growth of the density fluctuations is proportional to the scale factor of the universe.

$$\delta \sim a(t) \quad (1)$$

$$\delta \sim (1+Z)^{-1} \quad (2)$$

where a(t) is the scale factor and Z is the redshift in radiation that decreases with time. The growth of primordial fluctuations is usually explained by the inflationary model [1]. The inflationary epoch which occurs 10^{-35}s after the Big Bang, causes a region smaller than the size of a photon to expand into cosmological scales. The primordial fluctuations in the early universe are a result of the fluctuations in the inflaton field that grow exponentially soon after the Big Bang and eventually become the universe we see today. In this paper an alternate approach to the origin of primordial fluctuations is explored using extra dimensions.

The idea of extra dimensions dates back a long time. But it came under serious recognition when Theodor Kaluza tried to unify gravitation and electromagnetism using extra dimensions in 1921, now popularly known as Kaluza-Klein theory. Later, the extra space became an important tool in string theory to unify all the fundamental forces of nature. Also, many authors have tried to solve some of the cosmological problems like the horizon problem, the flatness problem etc., using extra dimensions [2][3][4].

In this paper, a non-inflationary scenario with the evolution of extra dimensions from initial singularity along with the normal space is considered [2]. The evolution of universe is considered as illustrated in Friedmann-Robertson-Walker model, along with the evolution of extra dimensions, which are taken to be compact hyperbolic manifold. As argued in [2], the evolution of extra dimensions takes some time, at the end of which they get stabilized. The extra space then contracts rapidly, thereby, squeezing out its entropy into the normal three dimensions. In this paper, these extra dimensions are thought to evolve more rapidly, compared to the normal space. Also, the extra space attains its maximum volume before it is stabilized. During its rapid evolution, entropy in the normal dimensions may be sucked or consumed, due to the huge difference in the expansion rates between the normal space and extra space. This consumption of entropy occurs "randomly" in different regions of the normal space for a very short time i.e. "almost instantaneous". This decrease in entropy in different regions of space causes the density in that region to increase by a very small amount, thereby, leading to primordial fluctuations. It is to be noted that the consumption of entropy occurs only during the evolution of extra dimensions and before they are stabilized, whereas after the stabilization of extra dimensions the universe may be explained as in model [2].

This paper is organized as follows: in section 2, an approximate equation which describes the decrease in entropy in a particular region in normal three dimensions is constructed; in section 3, the decrease in entropy and change in density are related by simple thermodynamic considerations; finally in section 4, we summarize and conclude.

2. Entropy Suction by Extra Dimensions

As explained already, the evolution of extra dimensions occurs rapidly and reaches its maximum volume before the KK modes are stabilized. During this process, it is possible that there exist random interactions between the bulk and the brane in different points in space that are not stabilized and are short-lived. Hence, a small amount of entropy may be sucked from normal space due to the rapid expansion of extra space. Here we formulate an approximate equation that describes the decrease in entropy of a region in normal space. The metric is taken as in the model of [5],

$$ds^2 = - dt^2 + a(t)^2\, dx^\mu dx_\mu + b(t)^2\, dy^i dy_i \quad (3)$$

where μ = 0,1,2,3 and i= 1 – d, where d is the number of extra dimensions. Here a(t) and b(t) are the scale factors of normal

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three dimensions and extra dimensions, respectively. Both these scale factors evolve from initial singularity. As explained already, the extra dimensions evolve more rapidly than the ordinary space and reach their maximum volume in a short interval of time,

$$\dot{b}(t) \gg \dot{a}(t) \qquad (4)$$

Consider a region of volume V_1 in normal space during this evolution period. This region loses its entropy due to the rapid expansion of extra space for a very small interval of time $\Delta t = t_f - t_i$, such that this process is "almost instantaneous". Let the region expand to a volume V_2 in this time interval. It is reasonable to assume that the decrease in entropy in a given volume is proportional to the ratio of scale factors of normal space to extra space. Also, the consumption of entropy from our normal space is very small; otherwise the universe would have been completely different today. Let,

$$K(t) = \frac{\dot{a}(t)}{\dot{b}(t)} \qquad (5)$$

$$\frac{S_f}{S_i}(t) \propto e^{-k(t)} \qquad (6)$$

$$\frac{S_f}{S_i}(t) = Ce^{-k(t)} \qquad (7)$$

where S_i and S_f are initial and final entropy during the expansion process for a time Δt. Here the ratio of final entropy to initial entropy is considered as a function of time because the differential of the scale factors, $\dot{b}(t)$ and $\dot{a}(t)$ changes with time (accelerating expansion). Thus to get the net decrease in entropy we need to integrate equation (7),

$$\int_{t_i}^{t_f} \frac{S_f}{S_i}\, dt = \int_{t_i}^{t_f} C\, e^{-k(t)} dt \qquad (8)$$

where C is a constant that is yet to be determined. By using equations (4) and (8), it is found that decrease in entropy, $\Delta S = S_i - S_f \approx 10^{-5}$(by neglecting the contribution of C). Therefore the entropy is not conserved in this region of space.

3. Density Fluctuations

In this section, we relate the change in entropy and change in density by classical thermodynamic considerations. The decrease in entropy in a particular region of space results in proportional increase in density in that region. The primordial soup in the early universe is generally assumed to be a "perfect fluid", with equation of state,

$$P = \rho_m RT \qquad (9)$$

where ρ_m is the mass density and R is a particular gas constant. Also non-relativistic equations are generally preferred in calculations. The universe is expanding adiabatically with many irreversible processes. We consider a small region in normal space of volume V_1, which undergoes irreversible adiabatic expansion under a constant pressure P from state 1 to state 2. As explained already, this region loses its entropy for a short interval of time Δt. As entropy is a state function, the change in entropy between initial and final states can be calculated by considering the combination of different equilibrium processes. To get a simple mathematical relation between change in entropy and density, we consider the combination of a reversible isothermal process till an intermediate state 3 and an isentropic expansion from state 3 to state 2. The general representation of the combination of these two processes is shown in figure 1.

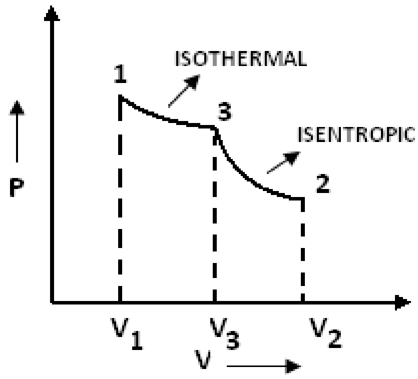

Figure 1

The net change in entropy between state 1 and state 2 is given by,

$$\Delta S = \Delta S_{1\text{-}3} + \Delta S_{3\text{-}2} \qquad (10)$$

As entropy is conserved in an isentropic process,

$$\Delta S_{3\text{-}2} = 0 \qquad (11)$$

The change in entropy between initial and final states,

$$\Delta S = \Delta S_{1\text{-}3} = nk \ln \left(\frac{V_3}{V_1}\right) \qquad (12)$$

where n is the number of particles, k is the Boltzmann constant and V_3 is the volume of the intermediate state, till which the process is assumed to be reversibly isothermal.

From figure 1, it is seen that $V_3 = xV_2$, where $x < 1$. Therefore,

$$\Delta S = nk \ln \left(x \frac{V_2}{V_1}\right) \qquad (13)$$

By assuming the number of particles n to be constant,

$$\Delta S = nk \ln \left(x \frac{\rho_1}{\rho_2}\right) \qquad (14)$$

Here ρ_1 and ρ_2 are the density of the region at time t_i and t_f, respectively. Neglecting the contribution of the terms n, k and x,

$$\Delta S \sim \ln \left(\frac{\rho_1}{\rho_2}\right) \qquad (15)$$

But the entropy decreases during the expansion process as explained already. Thus the density (ρ_2) at time t_f is greater than the density (ρ_1) at time t_i. As decrease in entropy is in the range of 10^{-5}, the increase in density in the region considered is also very small. As this process is almost instantaneous, the density of rest of the homogeneous universe has not changed much in the time Δt, such that the density fluctuation in normal space is,

$$\delta = \frac{\rho_f - \rho_i}{\rho_f} \approx 10^{-5} \qquad (16)$$

This fluctuation occurs randomly in different regions of normal space, before the extra dimensions are stabilized, such that the modern day universe is evolved.

4. Conclusion

In this paper we have demonstrated that the primordial fluctuations may arise due to the rapid evolution of extra dimensions, before they get stabilized. The entropy is sucked into the extra space from different regions of normal space, randomly, due to short lived interactions between the bulk and the brane. We have also demonstrated that this decrease in entropy leads to fluctuation in density by using simple thermodynamic considerations. Once the extra dimensions are stabilized, the entropy will be squeezed out from extra dimensions, as explained in model [2], resulting in the large entropy of the universe ($\approx 10^{88}$) [8]. Here, though the exact mechanism by which the entropy is sucked by extra dimensions is not explored, an alternative explanation for the origin of primordial fluctuation has been explained. Also it is to be noted that as a result of decrease in entropy, fluctuations in dark matter density may also occur. These fluctuations are stabilized by gravity and grow over time to become the universe we see today. As the evolution of extra dimensions is associated with decrease in entropy, it can be postulated that to open and travel through extra dimensions (faster than light scenarios), entropy of the normal space should be made to decrease.

References

[1] A. H. Guth, Phys. Rev. D23, 347 (1981); A. D. Linde, Phys. Lett. B 108, 389 (1982); A. Albrecht and P.J. Steinhardt, Phys. Rev. Lett. 48, 1220 (1982).

[2] Glenn D. Starkman, Dejan Stojkovic and Mark Trodden, "Large Extra Dimensions and Cosmological Problems", arXiv:hep-th/0012226.

[3] Daniel J. H. Chung and Katherine Freese, "Can Geodesics in Extra Dimension Solve the Cosmological Horizon Problem?", arXiv:hep-ph/9910235..

[4] C. P. Burgees, "Extra Dimensions and Cosmological Constant Problem", arXiv:0708.0911 [hep-ph].

[5] E.W. Kolb, D. Lindley and D. Seckel, Phys. Rev. D30, 1205 (1984).

[6] Bradley W. Caroll, "An Introduction to Modern Astrophysics, 2nd edition"

[7] Jeremy Goodman, "Geocentrism re-examined", arXiv:astro-ph/9506068.

[8] Paul H. Frampton , Stephen D. H. Hsu, David Reeb and Thomas W. Kephart, "What is the entropy of the universe?", arXiv:0801.1847 [hep-th].

[9] Eric Gawiser and Joseph Silk, "Extracting Primordial Density Fluctuations", arXiv:astro-ph/9806197.