Cosmological constant Problem and Holographic Principle in 2-D

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Abstract – The holographic principle is extended to deal with a two dimensional universe. Applying it to a spherical shell, which radius is related to the cosmological constant, we find a characteristic time comparable to the age of the observable universe.

1- Introduction

The cosmological constant problem has been the subject of a plenty of studies in the last times [1 to 5]. In reference [6] the time evolution of the universe world line, was compared with the growing of a polymer chain.

In four dimensions, Flory's free energy [7,8] adapted to model an evolving universe reads

$$F_4 = (N^2 \lambda^4)/R^4 + R^2/(N \lambda^2). \qquad (1)$$

In (1) the first term corresponds to the monomer-monomer repulsion energy, and the second one gives the entropy contribution [9] with a temperature of the order of the unit. Besides this N is the number of monomers in the chain and λ is the Planck length given by

$$\lambda = \hbar/(M_{Pl}\, c) = (\hbar\, G/c^3)^{1/2}. \qquad (2)$$

Taking the minimum of F_4 relative to R, we get the radius of gyration R_Λ which is related to the cosmological constant problem [6]

$$R_\Lambda = N^{1/2}\,\lambda. \qquad (3)$$

We also can write

$$R_\Lambda^{\,2} = (N\lambda)\,\lambda = L\,\lambda. \qquad (4)$$

In (4), L is the chain length which we identify with the radius of the observable universe. We must notice that, in obtaining (3) we have neglected a constant that we suppose to be of the order of the unit.

2- Holographic Principle (HP) in two dimensions (2-D)

The HP is usually thought as the content of information present in a certain volume being represented by certain number of unit cells tiling (covering) its boundary. But in this work we want to extend the HP to a universe in two dimensions. Therefore let us consider a spherical surface of radius R_Λ, a bubble wall related to the cosmological constant problem. In order to apply the HP to this problem, we need to enumerate its basic statements, namely

. The total information content of a 2-D universe, in this case a spherical surface of radius R_Λ, can be registered in the perimeter of its maximum circle.

.. The boundary of this spherical surface, here the perimeter of its maximum circle, contains at most a single degree of freedom per Planck length.

These two postulates were adapted for the 2-D case, following McMahon [10].

We fix interest in the surface of a sphere with radius R_Λ. According equation (3) this radius grows with $\sqrt{N}$, and we look at an isothermal process described by a stationary variation of the free energy F. We have

$$\Delta F = \Delta U - T\Delta S = 0. \quad (5)$$

Putting

$$\Delta U = hc/(2R_\Lambda), \quad (6A)$$

$$\Delta S = ½ (P/P_0) = (\pi R_\Lambda)/\lambda, \quad (6B)$$

$$h\upsilon = h/\tau = 2T, \quad (k_B = 1). \quad (6C)$$

In (6A), ΔU and ΔS are variations of the internal energy and entropy, and P is the perimeter of the maximum circle. (6C) stems for the energy equipartition of a harmonic oscillator in 2-D.

Inserting (6A), (6B) and (6C) in (5) and solving for τ, we obtain

$$\tau = \pi R_\Lambda^2/(c\lambda) = \pi N(\lambda/c). \quad (7)$$

We can also write

$$\tau = \pi L/c = \pi/H_0. \quad (8)$$

In order to obtain the second equality of (7) and (8), we have used relation (4). Besides this we notice that in (8) H_0 is the Hubble's constant and τ is the age of the observable universe. From (7) we also see that it is equal to $N\pi$ times the Planck time.

Finally we notice that, as can be verified in (6C), the “isothermal process” corresponds here to equal-time points at the surface of the “cosmological bubble” of radius R_Λ.

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