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Holographic Origin of High Cosmological Constant Related to Large Mass Defect in Semiclosed Friedman Universe

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Abstract- An extremely high value of Einstein's cosmological constant $\Lambda \sim 10^{122}$ in quantum cosmology compared to astronomical observations, $0 \leq \Lambda \leq 1$, is related to the extremely large general relativistic mass defect of massive semiclosed universe.

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I. Introduction

Inflationary cosmology succeeded in explaining the origin of the large-scale structure of observed universe evolving from a singular Big Bang or large quantum fluctuations of pre-existing spacetime metric in causally related small region, answering why the present universe appeares flat, homogeneous and isotropic.Yet, apart from problems of the fine tuning of initial conditions and the unitarity of the expansion history,[1,2] there have been continued interpretational controversies regarding the extremely high quantum vacuum energy density to support inflation. We here show that about 120 order of magnitude supression of calculated quantum vacuum density to observed values can be understood as a general relativistic mass defect of an expanding and supermassive semiclosed universe.

II. Dimensional Cosmological Constant

Hubble parameter H was originally used to represent Hubble law, $v = Hd$, relating the relative velocity v of the extragalactic objects at a distance d receding away from the Earth. In the Friedman universe H is defined as $H(t) = (da(t)/dt)/a(t)$, where $a(t)$ is a scale factor normalized to a = 1 at the present epoch t = t_0 ~ 14Gyr, and obeys the equation[2]

$$H(t)^2 = 8\pi G/3[\rho_{m0}/a(t)^3 + \rho_{r0}/a(t)^4 + \rho_{\Lambda 0}/a(t)^{3(\omega+1)}]. \qquad (1)$$

Here ρ_{m0} is the nonrelativistic matter (dark and luminous) densitiy, ρ_{r0} the relativistic radiation density, and $\rho_{\Lambda 0}$ the dark energy density at $t = t_0$ where $\omega = p_\Lambda/\rho_\Lambda c^2 < -1$ is the equation of state relating ρ_Λ and pressure ρ_Λ in inflationary cosmology. The most direct evidence of dark energy comes from obsevations of supernpovae with uniform energy density.

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In the Friedman-Lemaître cosmology the expansion history is determined by a set of dimensionless parameters at present epoch whose sum is normalized to uinity. As the observed energy density in the cosmic background radiation shows a minor contribution $\Omega_r \sim 1 \times 10^{-4}$ to H_0^2 the following numerical relations between dimensionless density parameters $\Omega_{\Lambda,m}$ and the critical densities $\rho_{c\Lambda,m}$ are considered significant:

$$\Omega_\Lambda = 8\pi\rho_\Lambda G/3H_0^2 = \rho_{\Lambda 0}/\rho_{c\Lambda 0} = 0.72, \qquad (2)$$

$$\Omega_m = 8\pi\rho_m G/3H_0^2 = \rho_{m0}/\rho_{cm0} = 0.28 \qquad (3)$$

Only from dimensional cosideration, we put $\Lambda = c^5/\hbar G = c^2/l_{pl}^2 \sim 10^{88}\mathrm{sec}^{-2}$, where $l_{pl} = c^2/\hbar G = 10^{-33}$ cm is the Planck length, $m_{pl} = \hbar/cl_{pl} \sim 10^{-5}$ g the planck mass. Using the Planck constant $\hbar = 1.026 \times 10^{-27}$ erg・sec and the cosmological unit h defined in H_0 = 100 hkm/sec Mpc, we get $\Lambda \sim 10^{122} h^{-2}$.

III. Holographic Cosmological Constant

Holographic principle in string theory states that the description of events in a volume of spacetime can be encoded on the boundary to the region like a gravitational horizon. The principle suggests that the entire universe can be seen as a two-dimensional information structure on the cosmological horizon with possible quantum fluctuations. From the observed cosmic background microwave temperature T = 3 K the entropy density s of the universe at $t = t_0$ is estimted by $s \sim gT^3$. Using g = 2 for photon we have $s_\gamma(t_0) \sim 1.5$ A volume estimate $V = (4\pi/3)R^3$ with R = 10^{28}cm gives a total radiation entropy $S_\gamma \sim 6.3 \times 10^{87}$. The entropy contribution frombaryons is smaller than S_γ. Inclusion of neutrino contribution increases S_γ to $S_{\gamma+\nu} \sim 10^{88}$. This is well below the holographic bound of the present universe dictated by the area in terms of the Planck units l_{pl} giving

$$S_{holog}(t_0) \sim (R/l_{pl})^2 \sim 10^{122}. \qquad (4)$$

It is suggested that 34 orders of magnitde difference may come from supermassive black holes.[3] In the following we attribute the difference to the mass defect of the semiclosed Friedman universe.

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IV. Semiclosed Universe and Mass Defect

The possibility of joining-on of the dust-filled semi-closed Friedman universe to an asymptotically flat space through Schwarzschid throat was first pointed out by Tolman[4] and used by Oppenheimer and Snyder[5] in their study of the dust motion in massive steller objects, followed by Milne,[6] Zel'dovich[7] and Novikov[8] independently in the form extendible to the electrically charged universe joined onto asymptotically flat outer space through double-valued Reissner-Nordström (RN) bottle-neck prevented from gravitatinal pinch-off by the gauge field lines of force extending to infinity or to an oppostely charged anti-universe.[9]

We here consider the embedding of the Planck length l_{pl} in the line element ds of de-Sitter universe:

$$ds^2 = g_{tt}c^2dt^2 - g_{rr}\,dr^2,$$
$$g_{rr} = g_{tt}^{-1} = (1 - \Lambda c^2r^2 + l_{pl}^2/r^2). \qquad (5)$$

We find that the light velocity $dr/dt = c\sqrt{g_{tt}/g_{rr}} = c\,(1 - \Lambda r^2 + l_{pl}^2/r^2) < c$, determined from $ds^2 = 0$, is super-luminal at $r = l_{pl} \sim 10^{-33}$cm and decreases with the increase of r until dr/dt = c is reached at $r = (l_{pl}/c)^{1/2} \sim 10^{-22}\,\Lambda^{-1/2}$cm. From there the light velocity decreases to dr/dt = c = 0 at r = $(c\Lambda^{1/2})^{-1} \sim 10^{-11}\Lambda^{-1/2}$cm. In the inflationary universe the radius of the causally related small region expands from $r = l_{pl} \sim 10^{-33}$cm to r = $l_{infll} \sim 10^{-35}$ cm followed by a bief interlude of heating.

The semiclosed Friedman universe is a spherical but unisotropic universe joined onto an asymptotically flat space, and expands with increasing proper time $\tau = \int g_{tt} d\tau$ and radius $R = \int g_{rr} dr$ until the maximum radius R_{max} is reached with the proper volume $V_p = 2\pi\int r^2 g_{rr} dr$ and mass $M_p = \rho V_p$ filling the lower hemisphere of the closed universe with $\Omega_\Lambda = 0.5$. With further increase of r from $r = R_{max}$, R_p begins to decrease towards $R_p \sim l_P$, forming a Planck scale gravitational semiclosure with $\Omega_\Lambda = 1$. In quantum cosmlogy it is likely that the gavitational semiclosure develop black holes at $r = R_p = 0$ evaporating a dark energy[1] until the semiclosed universe reaches Ω_Λ = 0.5, liberating the half of the total mass energy M_pc^2 with holographic information content $(R_{max}/l_{pl})^2$.

V. Conclusion

We have seen that the extremely high value of the cosmological constant $\Lambda \sim 10^{122}$ in quantum cosmology compared to astronomical observations, $0 \leq \Lambda \leq 1$, can be related to the extremely large general reltivistic mass defect of the semiclosed universe with $0.5 \leq \Omega_\Lambda \leq 1$.

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