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Asymptotic Freedom in de Sitter Space

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We investigate infrared dynamics of four-dimensional Einstein gravity in de Sitter space. With the accelerated expansion of the universe, conformal zero modes accumulate at the horizon. The inflaton reresent the characteristic scale of the zero mode distribution. Furthermore, the introduction of an inflaton in the low energy effective theory is necessary to preserve Lorentz symmetry. We observe and postulate a duality between quantum effects in Einstein gravity and classical evolutions in inflation/quintessence models. The duality implies the effective action of Einstein gravity can be constructed as inflation/quintessence models with manifest general covariance. We show that $g = G_N H^2/\pi$: the only dimensionless coupling of H^2 (Hubble parameter) and G_N (Newton's coupling) in Einstein gravity is screened by the infrared logarithmic fluctuations of the conformal mode. We evaluate the one-loop β function of g with respect to the cosmic time $\log Ht$ as $\beta(g) = -(1/2)g^2$, i.e., g is asymptotically free toward future. We have identified de Sitter entropy $1/g$ with von Neumann entropy of the conformal zero modes. The former evolves according to the β function and Gibbons-Hawking formula. The latter is found to increase by diffusion in the stochastic process at the horizon in a consistent way. Our Universe is located very close to the fixed point $g = 0$ with a large entropy. We discuss possible physical implications of our results such as logarithmic decay of dark energy.

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