Primordial fluctuations in bulk inflaton model

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Abstract

An inflationary brane model driven by a bulk inflaton with exponential potential is proposed. We find a family of exact solutions that describe power-law inflation on the brane. These solutions enable us to derive exact solutions for metric perturbations analytically. By calculating scalar and tensor perturbations, we obtain a spectrum of primordial fluctuations at the end of the inflation. The amplitudes of scalar and tensor perturbations are enhanced in the same way if the energy scale of the inflation is sufficiently higher than the tension of the brane. Then the relative amplitude of scalar and tensor perturbations is not suppressed even for high-energy inflation. This is a distinguishable feature from the inflation model driven by inflaton on the brane where tensor perturbations are suppressed for high-energy inflation. We also point out that massive Kaluza-Klein modes are not negligible at high-frequencies on 3-space of our brane.

Higher dimensional formulation is necessary for theories such as superstring and M theory. All these theories are confronted with a problem that our universe seems to be four-dimensional, which is conventionally coped with compactifications of the extra dimensions. Braneworld model where our universe is a four-dimensional subspace in a higher dimensional spacetime, is an epoch-making scenario because it broke the conventional idea that the extra dimensions must be compact and small. In this scenario, ordinary matter fields are confined on the brane, while graviton can propagate through the extra dimensions. Thus higher-dimensional feature of spacetime must emerge in the nature of gravity.

In the early universe, inflation can amplify vacuum fluctuation of Kalzua Klein modes as well as a massless mode. Thus inflation is a powerful tool to probe the extra dimensions. Inflation can occur by the dynamics of inflaton either on the brane or in the bulk.

In this contribution we proposed an inflationary brane model driven by a bulk inflaton with exponential potential.

$$S = \int d^5x\sqrt{-g_5}\left(\frac{1}{2\kappa^2}R - \frac{1}{2}\partial_\mu\phi\partial^\mu\phi - \Lambda(\phi)\right) - \int d^4x\sqrt{-g_4}\lambda(\phi), \tag{1}$$

$$\kappa^2\Lambda(\phi) = \left(\frac{\Delta}{8}+\delta\right)\lambda_0^2 e^{-2\sqrt{2}b\kappa\phi}, \quad \kappa^2\lambda(\phi) = \sqrt{2}\lambda_0 e^{-\sqrt{2}b\kappa\phi}. \tag{2}$$

A family of exact solutions that describe power-law inflation on the brane was obtained, where the scalar field has non-trivial time dependence. We calculated the primordial fluctuations in this model. Tensor and scalar perturbations were shown to be described by 5D massless scalar field. Then the quantization of the 5D massless field in this background was done. Using this result, the specturm of the primordial fluctuations were calculated.

$$\langle\varphi^2\rangle_0 \quad \longrightarrow \quad C_0^2\lambda_0\left(\frac{H}{2\pi}\right)^2\left(\frac{p}{H}\right)^{\frac{3\Delta+8}{\Delta+2}}, \tag{3}$$

$$\langle\varphi^2\rangle_m \quad \longrightarrow \quad C_m^2\lambda_0\left(\frac{H}{2\pi}\right)^2\left.\left(\frac{pe^{\alpha(\eta)}}{H}\right)^3\right|_{\rm end}, \tag{4}$$

In order to connect our result with observations accurately, we should know the subsequent evolution of the perturbations. It has been shown that at large scales $\mathcal{R}_c$ remains constant if we can neglect the dark radiation. Thus the evolution of $\mathcal{R}_c$ is very simple and our results can be directly used at the horizon re-enter. However, in order to know the CMB anisotropy, we should know not only the curvature perturbations $\mathcal{R}_c$ but also the anisotropic stress induced by bulk gravitational fields which is measured by the difference between Φ and Ψ. The evolution of this anisotropic stress is still uncertain. The evolution of the gravitational waves inside the horizon is also unknown. These issues deserve further investigations. For details of this study, see [1]

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References

[1] K. Koyama and K. Takahashi, hep-th/0301165.