Non-Gaussianities of primordial perturbations and tensor sound speed[†]

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Inflation is now widely accepted as a paradigm of early Universe to explain the origin of the primordial perturbations as well as to solve the horizon and the flatness problems of the standard big-bang cosmology. The current observational data such as the cosmic microwave background (CMB) anisotropies support almost scale-invariant, adiabatic, and Gaussian primordial curvature fluctuations as predicted by inflation. While the paradigm itself is well established and widely accepted, its detailed dynamics, e.g. the identification of an inflaton, its kinetic and potential structure, and its gravitational coupling, are still unknown.

The non-Gaussianities of primordial curvature perturbations are powerful tools to give such informations. For example, it is well-known that the equilateral type of bispectrum of primordial curvature perturbations is enhanced by the inverse of their sound speed squared [1,2]. The null observation of the equilateral type by the Planck satellite, characterized as $f_{\rm NL}^{\rm equil} = 42 \pm 75$ (68% CL)[3], yields stringent constraints on the sound speed of the curvature perturbations as $c_s \geq 0.02$ (95% CL)[3].

Inflation generates not only primordial curvature perturbations but also primordial tensor perturbations [4]. Very recently, it was reported that primordial tensor perturbations have been found and the tensor-to-scalar ratio r is given by $r = 0.20^{+0.07}_{-0.05}$ (68% CL)[5], though it is constrained as $r < 0.11$(95% CL) in the Planck results[6]. Their amplitude directly determines the energy scale of inflation, so it is estimated as $V^{1/4} \simeq 2.2 \times 10^{16}$ GeV given $r \simeq 0.2$[5] and $P_\zeta \simeq 2.2 \times 10^{-9}$[6]. If we go beyond the powerspectrum, it is known that the bispectra of primordial tensor perturbations enable us to probe the gravitational coupling of the inflaton field[7]. Such a non-trivial gravitational coupling easily modifies the sound speed of primordial tensor perturbations, c_γ, and it can significantly deviate from unity[8]. Then, one may wonder if the small sound velocity of primordial tensor perturbations can enhance their non-Gaussianities as in the case of the curvature perturbations. In this work, we addressed this issue.

The relation between the sound speed and the non-Gaussianities of primordial curvature perturbations can be clearly understood by use of the effective field theory (EFT) approach to inflation[9]. Inflation can be characterized by the breakdown of time-diffeomorphism invariance due to the time-dependent cosmological background and the general action for inflation can be constructed based on this symmetry breaking structure. The primordial curvature perturbation can be identified with the Goldstone mode π associated with the breaking of time-diffeomorphism invariance. The symmetry arguments require that modification of the sound speed c_s induces non-negligible cubic interactions of the Goldstone mode π, and hence the sound speed and the bispectrum of the curvature perturbations are directly related.

In this work, we investigated the relation between the sound speed of tensor perturbations and the bispectrum of primordial perturbations, based on the EFT approach. We first identified what kind of operators can modify the tensor sound speed. Then, we clarify which type of non-Gaussianity arises associated with the modification and can be used as a probe for the tensor sound speed. We found that the tensor sound speed is not directly related to tensor bispectra, in contrast to the scalar sound speed case. We also discussed primordial trispectra as a possible probe of tensor sound speed.

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