Primordial spectra from sudden turning trajectory†

T. Noumi[*1] and M. Yamaguchi[*2]

Inflation is strongly supported by recent observations of cosmic microwave background (CMB) anisotropies.[1,2] In particular, single field slow-roll inflation predicts almost adiabatic, Gaussian, and scale invariant primordial curvature perturbations, and these predictions well fit the observational results. On the other hand, high energy theories such as supergravity and superstring theory generically predict additional scalar fields other than inflaton. To reconcile such a generic prediction of theories with recent observations, it may be suggested that only one light field plays a role of inflaton while the others are heavy. In fact, effects of such heavy fields are generically suppressed by their mass and the inflationary dynamics can be well approximated by single field inflation.

While such a scenario can explain the current observational results well, it would be quite interesting if we could detect some deviation from single field slow-roll inflation in the current and future observational experiments: such a deviation would be useful as a probe of high energy physics. In this report, we would like to investigate a possibility that heavy fields can affect inflationary dynamics and imprint some features on primordial spectra.

One typical situation heavy fields matter is the case when heavy fields are excited by the sudden turn of the potential and oscillates with high frequency.[3–7] In general, oscillations of heavy fields generate the following two significant effects: the modification of the Hubble parameter and the conversion effect, that is, the mixing between adiabatic and isocurvature (heavy field) modes. We investigate these effects in detail and evaluate the power spectra and bispectra of the primordial curvature perturbations in two-field inflationary models with the canonical kinetic terms and a sudden turning potential.

Suppose that the background trajectory is first along the bottom of the potential (the slow-roll direction). The trajectory starts oscillating at the turning point and such a heavy field oscillation induces a deviation from single field slow-roll inflation. The primordial power spectrum of scalar curvature perturbations can then be calculated as

$$\mathcal{P}_\zeta(k) = \frac{H_{\rm sr}^2}{8\pi^2 M_{\rm sr}^2 \epsilon_{\rm sr}} \left[1 + \mathcal{C}_{\rm Hubble}(k) + \mathcal{C}_{\rm conv}(k)\right], \quad (1)$$

where the first term represents the almost scale-invariant power spectrum in single field slow-roll inflation. The last two terms are the scale-dependent deviation originated from the heavy field oscillations.

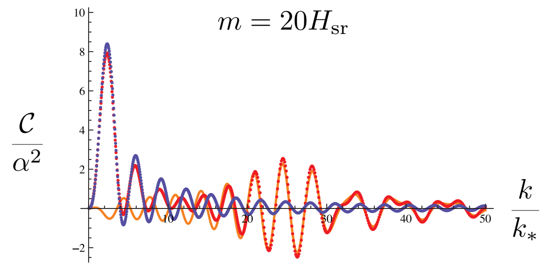

Fig. 1. Deviation in the primordial power spectrum. The orange/red/blue are $-\mathcal{C}_{\rm Hubble}$, $\mathcal{C}_{\rm conv}$, and $\mathcal{C} = \mathcal{C}_{\rm Hubble} + \mathcal{C}_{\rm conv}$, respectively. Free parameters of our model are the heavy field mass m, the turning angular α, and the turning scale k_*. Here we used $m = 20_{\rm sr}$ and assumed that α is small enough, say $\alpha \sim \mathcal{O}(0.1)$.

The deviation $\mathcal{C}_{\rm Hubble}$ is from the Hubble deformation effect and $\mathcal{C}_{\rm conv}$ is from the conversion effect. As depicted in Fig. 1, the parametric resonance amplification occurs from both of the two effects and the peak at the turning scale arises from the conversion effect. It is, however, explicitly shown that resonance effects from the two effects accidentally cancel each other out for the case with the canonical kinetic terms. As a consequence, the peak at the turning scale becomes clear and this feature characterizes this class of models with heavy field oscillations.

We also evaluated primordial bispectra, whose main source comes again from the Hubble deformation effect and the conversion interaction. We find resonance and peak features in the bispectra as in the case of power spectra. Although the size of bispectra is not necessarily large, our results may be useful for probing these effects observationally.

In this work, we discussed two-field models with a sudden turning potential as a phenomenological toy model, and clarified features of heavy field oscillations. It would be interesting to investigate more realistic models with heavy field oscillations e.g. based on string theory. It must be important to discuss their detectability in the current and future observations.

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*1 RIKEN Nishina Center
*2 Department of Physics, Tokyo Institute of Technology

References
1) G. Hinshaw *et al.*: arXiv:1212.5226.
2) P. A. R. Ade *et al.*: arXiv:1303.5082.
3) X. Chen: JCAP **1201**, 038 (2012).
4) G. Shiu and J. Xu: Phys. Rev. D **84**, 103509 (2011).
5) S. Cespedes, V. Atal and G. A. Palma: JCAP **1205**, 008 (2012).
6) A. Achucarro, J. -O. Gong, S. Hardeman, G. A. Palma and S. P. Patil: JHEP **1205**, 066 (2012).
7) X. Gao, D. Langlois and S. Mizuno: JCAP **1210**, 40 (2012).