Non-Gaussianity in rapid-turn multi-field inflation

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1. Introduction

Primordial non-Gaussianity is a powerful tool to **discriminate between models of inflation** by probing the dynamics and field content of the very early Universe. We show that theories of inflation with multiple, rapidly turning fields can generate a bispectrum with several potentially large contributions that are not necessarily of the local shape. We derive a novel, analytical formula for bispectrum generated from multi-field mixing on super-horizon scales for a general theory with two fields, an arbitrary field-space metric, and a potential that supports sustained, rapidly turning field trajectories. **Detection of local non-Gaussianity with an amplitude $f_{\rm NL}^{\rm loc} \sim \mathcal{O}(1)$ would rule out all attractor models of single-field inflation.**

2. Primordial bispectrum

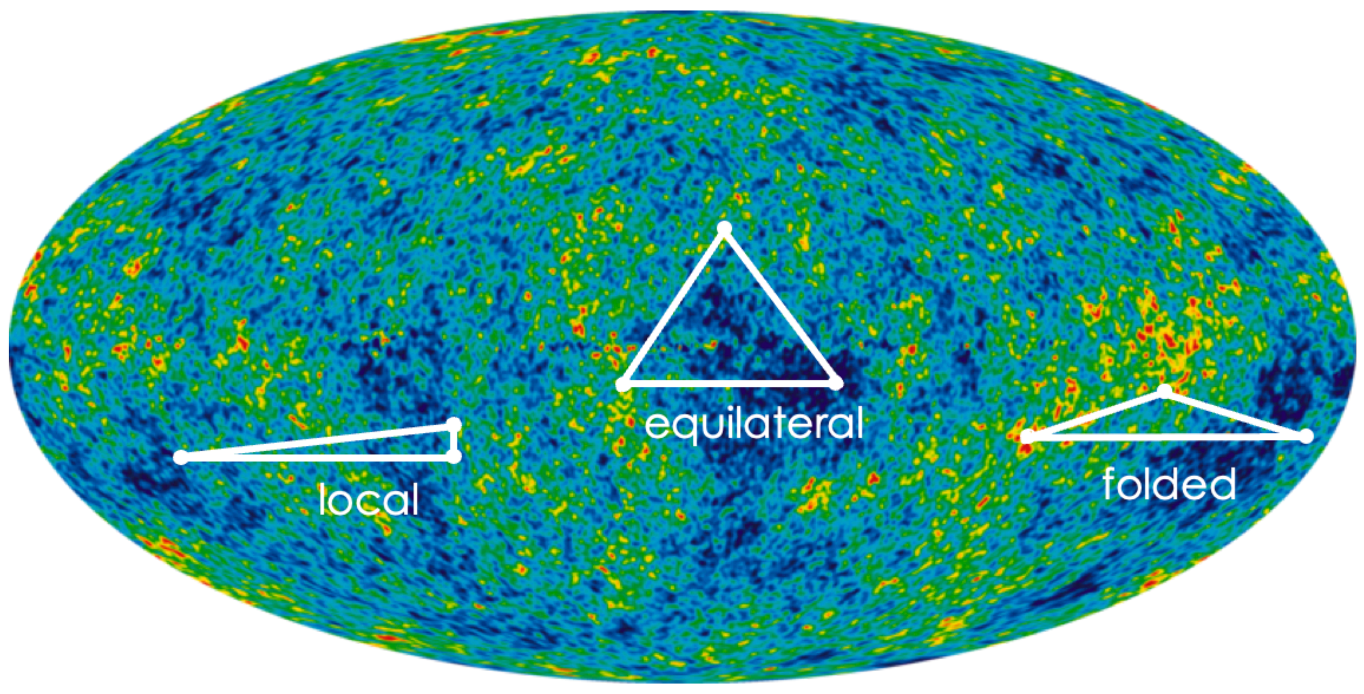
The primordial bispectrum is the three-point correlation function of curvature perturbation

$$\left\langle \mathcal{R}_{\vec{k}_1}\mathcal{R}_{\vec{k}_2}\mathcal{R}_{\vec{k}_3}\right\rangle = (2\pi)^3\delta^{(3)}(\vec{k}_1+\vec{k}_2+\vec{k}_3)B_{\mathcal{R}}(k_1,k_2,k_3)\ ,$$

$$B_{\mathcal{R}}(k_1,k_2,k_3) \propto \sum_{\rm shape} f_{\rm NL}^{\rm shape} S_{\rm shape}(k_1,k_2,k_3).$$

The amount of non-Gaussianity is quantified by the parameter

$$-\frac{6}{5}f_{\rm NL}(k_1,k_2,k_3) = \frac{B_{\mathcal{R}}(k_1,k_2,k_3)}{P_{\mathcal{R}}(k_1)P_{\mathcal{R}}(k_2)+(\vec{k}\ \text{cyclic perms})}\ .$$

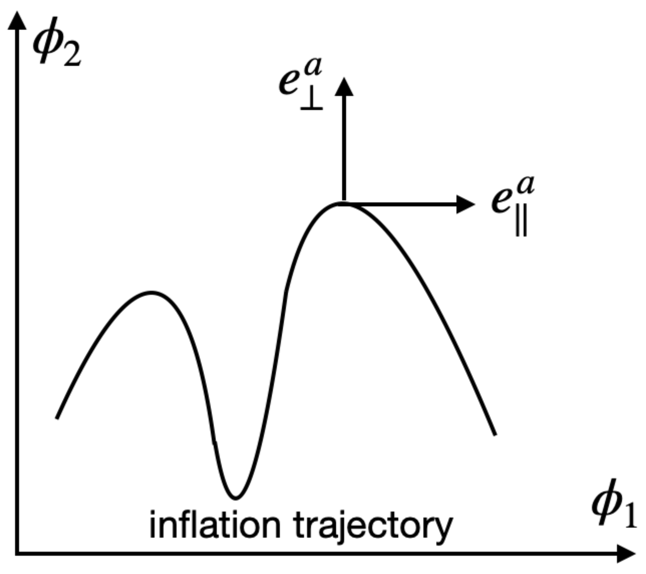


3. Multi-field inflation

$$S = \int d^4x\sqrt{-g}\left[\frac{M_{\rm pl}^2}{2}R - \frac{1}{2}g^{\mu\nu}G_{ab}(\phi)\partial_\mu\phi^a\partial_\nu\phi^b - V(\phi^a)\right].$$

Trajectory turns **couple** the fluctuations and modify their dispersion relations and correlators

$$\begin{cases}\dot{\mathcal{R}} & \simeq 2\eta_\perp H\mathcal{S},\\ \dot{\mathcal{S}} & \simeq (-2\epsilon - \frac{\mathcal{M}_{\perp\perp}}{V} + \frac{\mathcal{M}_{\parallel\parallel}}{V} - \frac{4}{3}(\eta_\perp)^2)H\mathcal{S}.\end{cases}$$



$$D_N e^a_\parallel = \eta_\perp e^a_\perp$$

Power spectrum of **curvature perturbations**, **cross-correlation** and **isocurvature perturbations**

$$\langle\mathcal{R}_{\vec{k}_1}\mathcal{R}_{\vec{k}_2}\rangle = \frac{1}{2\epsilon}\langle\delta\phi_{\parallel\vec{k}_1}\delta\phi_{\parallel\vec{k}_2}\rangle \ \Rightarrow\ P_{\mathcal{R}},$$

$$\langle\mathcal{R}_{\vec{k}_1}\mathcal{S}_{\vec{k}_2}\rangle = \frac{1}{2\epsilon}\langle\delta\phi_{\parallel\vec{k}_1}\delta\phi_{\perp\vec{k}_2}\rangle \ \Rightarrow\ C_{\mathcal{RS}},$$

$$\langle\mathcal{S}_{\vec{k}_1}\mathcal{S}_{\vec{k}_2}\rangle = \frac{1}{2\epsilon}\langle\delta\phi_{\perp\vec{k}_1}\delta\phi_{\perp\vec{k}_2}\rangle \ \Rightarrow\ P_{\mathcal{S}}.$$

$$\mathcal{M}^a{}_b = G^{ac}\nabla_b\nabla_c V - R^a_{dfb}\dot{\phi}^d\dot{\phi}^f.$$

General form of the non-Gaussianity parameter with a scale and shape dependence

$$-\frac{6}{5}f_{\rm NL}^{\rm loc}(k_1,k_2,k_3) = \sum_{I,J=\mathcal{R},\mathcal{C}} f_{\rm NL}^{IJ}\frac{\tilde{\mathcal{P}}^I(k_1)\tilde{\mathcal{P}}^J(k_2)+(\vec{k}\ \text{cyclic perms})}{P_{\mathcal{R}}(k_1)P_{\mathcal{R}}(k_2)+(\vec{k}\ \text{cyclic perms})}$$

4. Single-field inflation

$$f_{\rm NL}^{\rm type} \simeq \mathcal{O}(\epsilon,\eta), \qquad [1]$$

$$f_{\rm NL}^{\rm loc} = 0. \qquad [2,\ 3]$$

Current observational bound:

$$f_{\rm NL}^{\rm loc} = -0.9 \pm 5.1.$$

5. Slow-turn vs rapid-turn

Slow-turn: $\eta_\perp \ll 1$ [4]

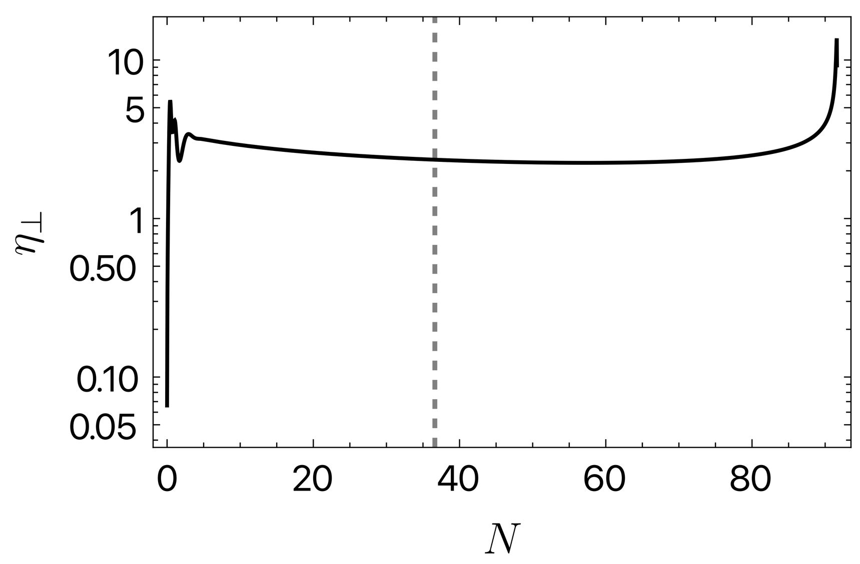
$$f_{\rm NL}^{\rm loc} \supset \frac{5}{6}\sqrt{\frac{r}{8}}\left(\frac{T_{\mathcal{RS}}}{\sqrt{1+T_{\mathcal{RS}}^2}}\right)^3 \partial_{\perp *}\ln T_{\mathcal{RS}}$$

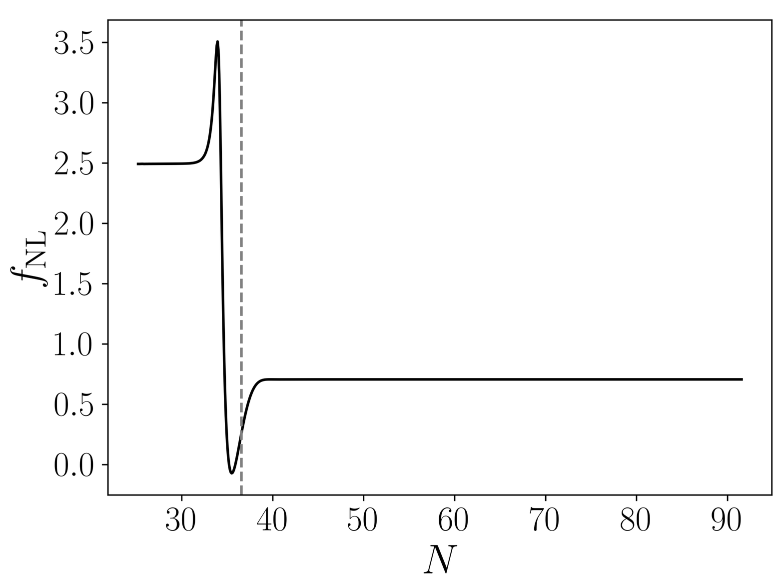
Rapid-turn: $\eta_\perp \gg 1$ [5]

$$f_{\rm NL}^{\rm loc} \supset \eta_{\perp *}\, I_4 + \tilde{M}_{\perp\perp *}\, I_5 + \tilde{M}_{\perp\parallel *}\, I_6$$

6. Example: Angular inflation

$$G_{ab} = \frac{6\tilde{\alpha}}{(1-\phi^2-\chi^2)^2}\delta_{ab}, \quad V(\phi,\chi) = \frac{\tilde{\alpha}}{2}\left(m_\phi^2\phi^2 + m_\chi^2\chi^2\right) \quad [6]$$





$$f_{\rm NL}^{\rm loc} = -\frac{5}{6}\left(0.006\, I_{1*} + 1.89\, I_{2*} + 0.004\, I_{3*} - 2.35\, I_{4*} - 0.015\, I_{5*} + 2.3\, I_{6*}\right) \quad [5]$$

$$f_{\rm NL}^{\rm loc} = 0.705 \simeq \mathcal{O}(1)$$

7. Conclusions

1. **Extended** the δN-formalism to rapid-turn inflation.
2. Identified new **model-independent** potentially large contributions to the non-Gaussianity parameter.
3. The resulting bispectrum in general is **not of the local shape**.
4. Detection of $f_{\rm NL}^{\rm loc} \sim \mathcal{O}(1)$ would signal:
   - **New particles:** inflation with more than one field, curved field-space, steep potentials, UV competions...
   - Or **non-inflationary** perturbations?

8. References

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