Scale-dependent primordial trispectrum and cosmological parameter constraints

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Motivation: *tensions* in ΛCDM cosmological parameters

- Hubble H_0 tension between CMB and local distance-ladder measurements at ~ 3.5 σ
- Mild differences in constraints from large-angle and small-angle CMB data
  - Planck lowl vs highl
  - SPT vs Planck

- Precision cosmological parameters are mostly derived from two-point functions of density fluctuations
  - CMB power spectrum
  - Weak lensing power spectrum
- Solutions generally modify the shape of the power spectrum!

ΛCDM+?

Change the physical law

- modify gravity

The composition of "stuff" in the universe

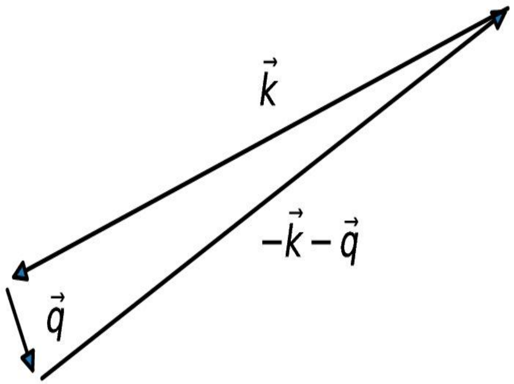
- ΛCDM + N_{eff}
- Λ?DM
- ...

Statistics of primordial fluctuations

- Change the primordial power spectrum (2-point)
- non-Gaussian mode coupling (higher-order)

“Squeezed-configuration” bispectrum

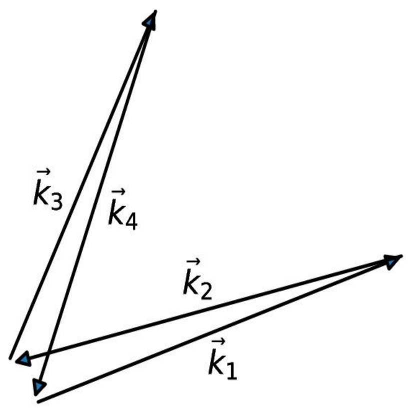
$$\langle \Phi(\mathbf{k}_1)\Phi(\mathbf{k}_2)\Phi(\mathbf{k}_3)\rangle_c$$



- Tight constraint from Planck satellite for scale-independent local type, $f_{NL} \sim 0.8 \pm 5$
- Detection points to inflationary dynamics beyond single-field slow roll (SFSR)

“Collapsed-configuration” trispectrum

$$\langle \Phi(\mathbf{k}_1)\Phi(\mathbf{k}_2)\Phi(\mathbf{k}_3)\Phi(\mathbf{k}_4)\rangle_c$$



- Modulation of small-scale modes by a large-scale mode
- Leads to dipole and higher-order modulation of CMB fluctuations
- Points to inflationary dynamics beyond single-field slow roll (SFSR)

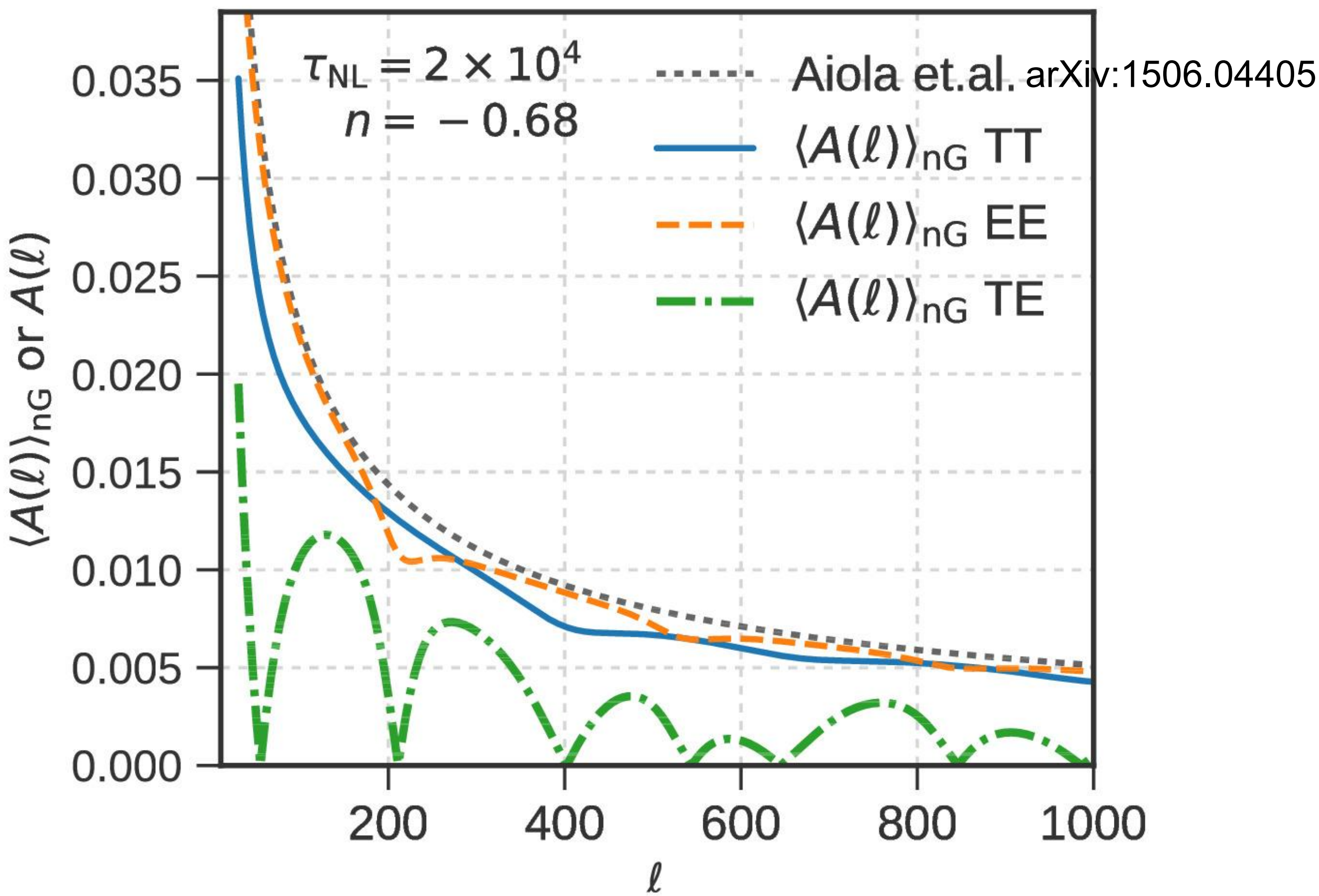
Scale-dependent local-type trispectrum

$$T(\mathbf{k}_1, \mathbf{k}_2, \mathbf{k}_3, \mathbf{k}_4) = \tau_{\rm NL} \left(\frac{k_2 k_4}{k_p^2} \right)^n P(k_1) P(k_3) P(|\mathbf{k}_1 - \mathbf{k}_2|) + \text{permutations} \quad (13)$$

Byrnes et al.
arXiv:1007.4277

- Global isotropy is preserved i.e. $\langle A_x \rangle = \langle A_y \rangle = \langle A_z \rangle = 0$
- But, the expected (cosmic) variance of the *hemispherical power asymmetry* increases due to the presence of the trispectrum
- Only constraint on $\tau_{\rm NL}$ with n=0 currently exists from Planck data
  $\tau_{\rm NL} < 28000$ (95 % c.l.)

$$\Delta \hat{X}_0^{wx}(\ell) = \frac{1}{(2\ell+1)\sqrt{C_\ell^{ww} C_{\ell+1}^{xx}}} \sum_{m=-\ell}^{\ell} a_{\ell m}^{w*} a_{\ell+1,m}^{x}$$



Our original motivation to study the scale-dependent local-type trispectrum: as a simple model to produce **scale-dependent hemispherical power asymmetry**.

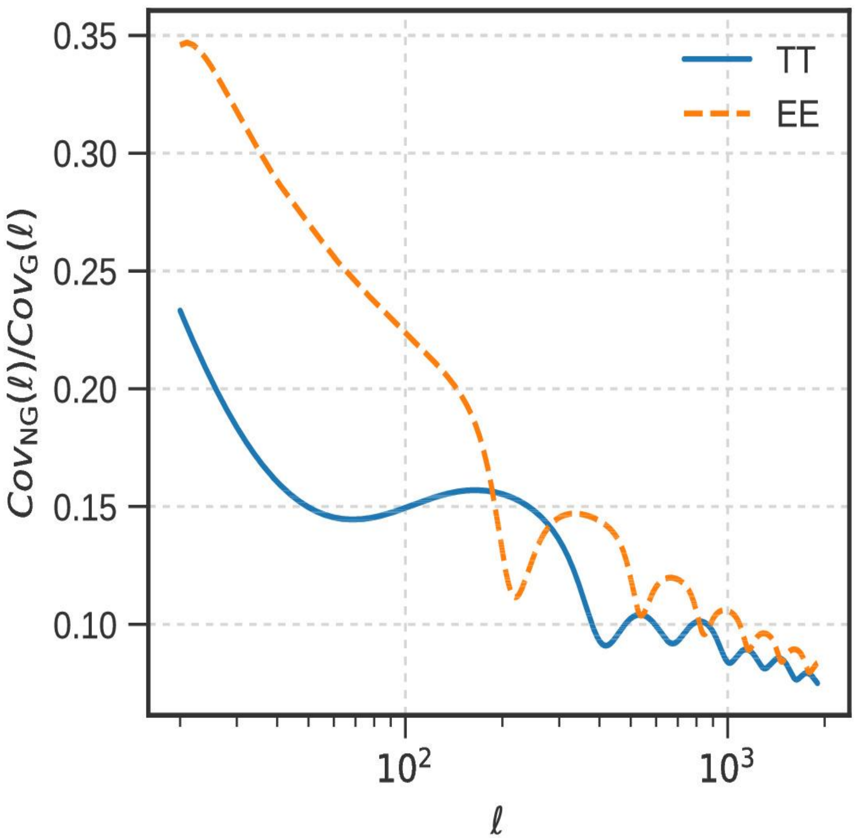
Non-Gaussian C_ℓ covariance

$$\mathbf{C}(\hat{C}_\ell, \hat{C}_{\ell'}) = \frac{2C_\ell^2}{2\ell+1}\delta_{\ell,\ell'} + \frac{1}{(2\ell+1)(2\ell'+1)} \sum_{m,m'} \left\langle a_{\ell m} a_{\ell,-m} a_{\ell',m'} a_{\ell',-m'} \right\rangle_c$$

where,

$$\hat{C}_\ell = \frac{1}{2\ell+1} \sum_{m=-\ell}^{\ell} a_{\ell m}^* a_{\ell m}.$$

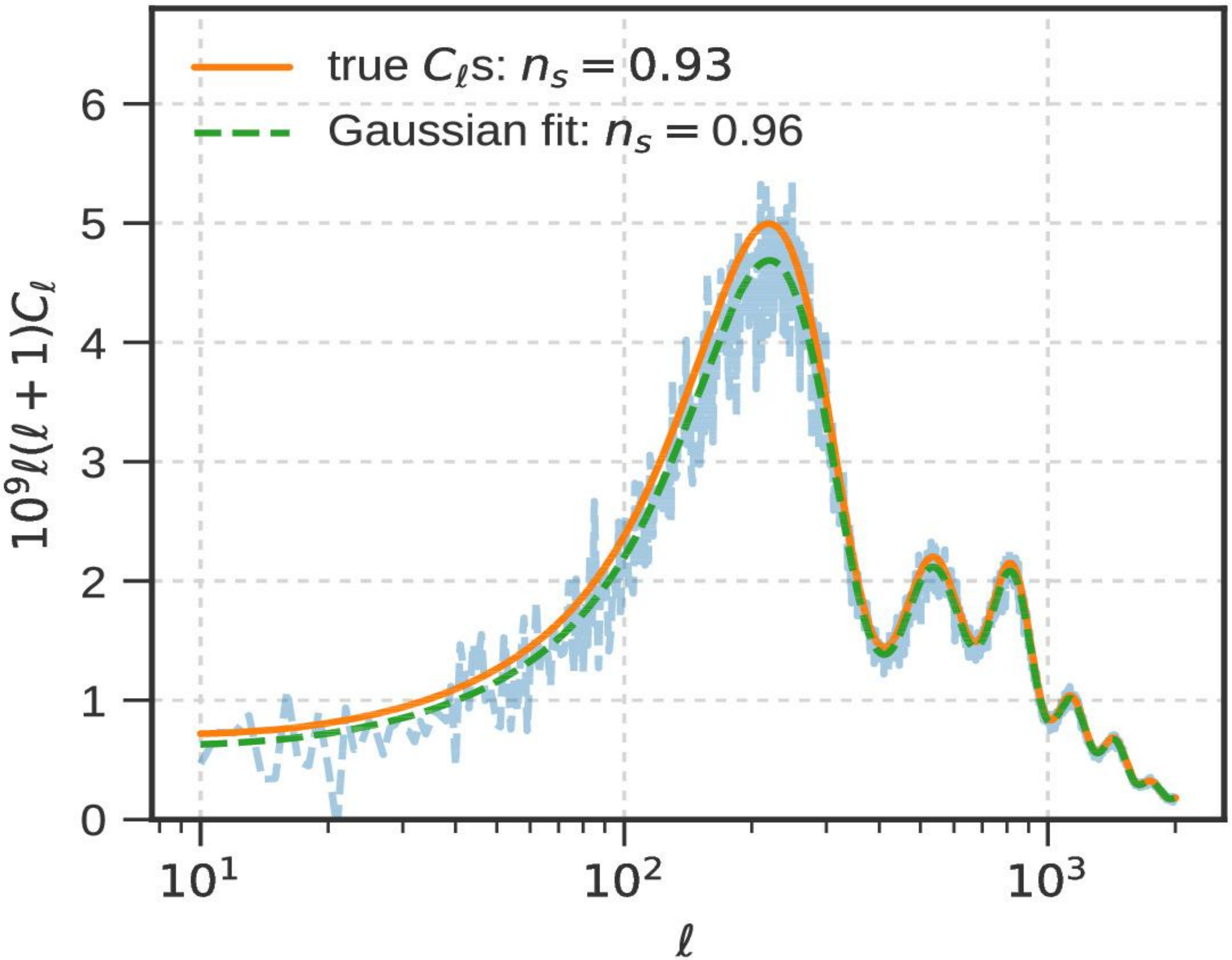
- Function of trispectrum parameters and an infrared-cutoff parameter
- Conceptually similar to the “super-sample covariance” (Takada and Hu, arXiv:1302.6994) in large-scale structure



A simple Monte-Carlo study

- Generate C_l realizations including non-Gaussian covariance
- Fit for cosmological parameters ignoring the non-Gaussian covariance
- This simple exercise shows that the shift in the spectral index can be significantly larger than the precision of current Planck data.

Ratio of non-Gaussian (diagonal) and the Gaussian angular power spectrum covariance term, assuming a fiducial trispectrum amplitude $\tau_{\rm NL}$ and scale dependence **n**.



Example of how the presence of a collapsed-configuration trispectrum can significantly bias the inference of the spectral index, if present but ignored. Fisher error on n_s~0.005

Next step: study the effect on other parameters

- Need to properly account for CMB lensing
  - As the non-primordial parameters like H_0 and Ω_m are sensitive to lensing
- The shift in parameters are realization dependent; so, application to actual Planck data will be more revealing.
- Conservative analysis: marginalize over the non-Gaussian covariance term parameters $\rightarrow$ reduction in precision of cosmological parameters

Summary

- Tight non-Gaussianity constraints from *Planck* satellite must be extended to trispectrum (scale-dependent) as
- It can produce
  - Modulations in the CMB power spectrum and therefore
  - A scale-dependent hemispherical asymmetry of power
  - A large bias in the inferences of spectral index, n_s, and possibly other cosmological parameters