

The Galaxy Bispectrum as a Probe of Primordial non-Gaussianity

Tobias Baldauf

with Leonardo Senatore and Uroš Seljak

Institute for Theoretical Physics
University of Zurich

Cosmology in Northern California
22/10/2010



1 Introduction

2 Perturbation Theory and Diagrammatics

3 The Galaxy Bispectrum

4 Summary

Motivation to Study LSS Effects of non-Gaussianity

Goals

- learn about the dynamics of the inflaton field
- LSS provides constraints independent of CMB constraints

Approach

- bispectrum as a measure of interactions between short and long modes
- perturbation theory to derive shape and scale dependence
- additional difficulties: non-linear clustering, biased tracers

Motivation to Study LSS Effects of non-Gaussianity

Goals

- learn about the dynamics of the inflaton field
- LSS provides constraints independent of CMB constraints

Approach

- bispectrum as a measure of interactions between short and long modes
- perturbation theory to derive shape and scale dependence
- additional difficulties: non-linear clustering, biased tracers

Primordial non-Gaussianity from Inflation

Models of Inflation

- slow-roll single-field Inflation - small non-Gaussianity
- non-standard single-field Inflation - equilateral and orthogonal non-Gaussianity
- multifield Inflation - local non-Gaussianity

Local non-Gaussianity

$$\Phi_{\text{nG}}(\mathbf{x}) = \varphi(\mathbf{x}) + f_{\text{NL}} (\varphi^2(\mathbf{x}) - \langle \varphi^2 \rangle) + g_{\text{NL}} \varphi(\mathbf{x})^3$$

Primordial non-Gaussianity from Inflation

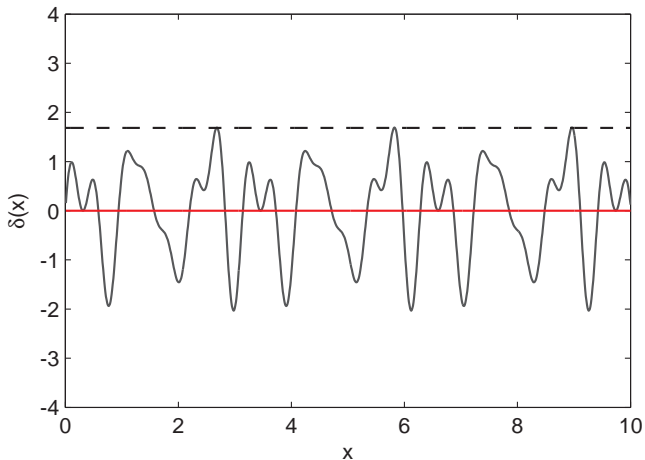
Models of Inflation

- slow-roll single-field Inflation - small non-Gaussianity
- non-standard single-field Inflation - equilateral and orthogonal non-Gaussianity
- multifield Inflation - local non-Gaussianity

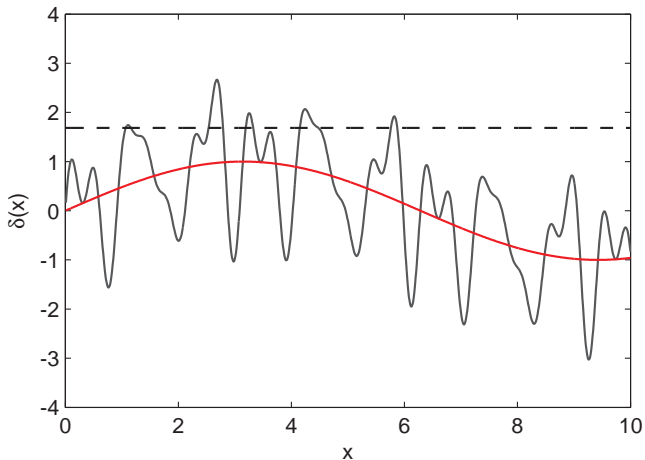
Local non-Gaussianity

$$\Phi_{\text{nG}}(\mathbf{x}) = \varphi(\mathbf{x}) + f_{\text{NL}} (\varphi^2(\mathbf{x}) - \langle \varphi^2 \rangle) + g_{\text{NL}} \varphi(\mathbf{x})^3$$

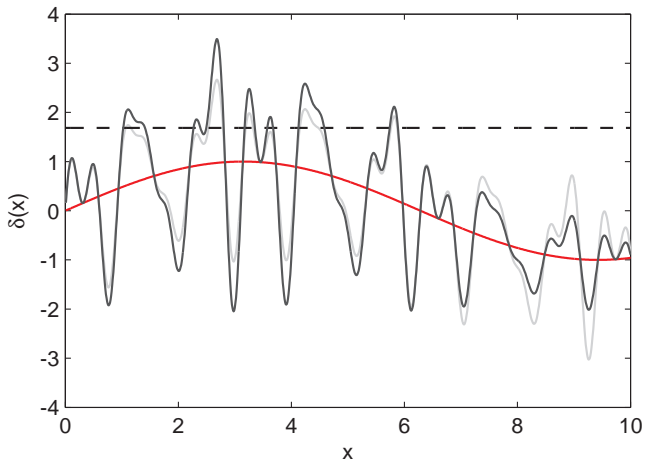
Clustering with local non-Gaussianity



Clustering with local non-Gaussianity



Clustering with local non-Gaussianity



1 Introduction

2 Perturbation Theory and Diagrammatics

3 The Galaxy Bispectrum

4 Summary

Ingredients

- galaxy/halo density field δ_g
- matter density field δ_m
- primordial gravitational potential φ
- power spectrum $P_{\delta\delta}(k) = \alpha(k)P_{\delta\varphi}(k) = \alpha^2(k)P_{\varphi\varphi}$

○ φ

◐ δ_g

● δ_m

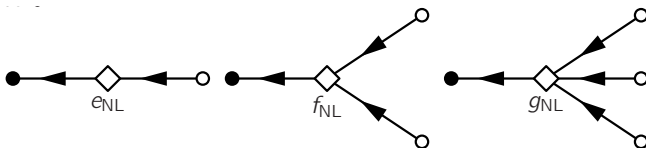
⊗ P_φ

Local non-Gaussianity

$$\Phi_{\text{nG}}(\mathbf{x}) = \varphi(\mathbf{x}) + f_{\text{NL}} (\varphi^2(\mathbf{x}) - \langle \varphi^2 \rangle) + g_{\text{NL}} \varphi(\mathbf{x})^3,$$

$$\delta(\mathbf{k}) = \alpha(k) \Phi_{\text{nG}}(\mathbf{k})$$

$$= \alpha(k) \varphi(\mathbf{k}) + \alpha(k) f_{\text{NL}} \int d^3 q \delta^{(D)}(\mathbf{k} - \mathbf{q}_1 - \mathbf{q}_2) \varphi(\mathbf{q}_1) \varphi(\mathbf{q}_2) + \dots$$



Non-linear Clustering

Fluid equations

$$\frac{\partial \delta(\mathbf{x}, \tau)}{\partial \tau} + \theta(\mathbf{x}, \tau) = 0$$

$$\frac{\partial \theta(\mathbf{x}, \tau)}{\partial \tau} + \mathcal{H}(\tau)\theta(\mathbf{x}, \tau) + \frac{3}{2}\Omega_m \mathcal{H}^2(\tau)\delta(\mathbf{x}, \tau) = 0$$

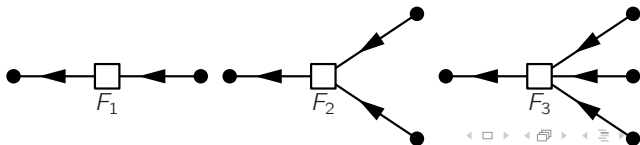
Non-linear Clustering

Fluid equations

$$\frac{\partial \delta(\mathbf{x}, \tau)}{\partial \tau} + \theta(\mathbf{x}, \tau) = 0$$

$$\frac{\partial \theta(\mathbf{x}, \tau)}{\partial \tau} + \mathcal{H}(\tau)\theta(\mathbf{x}, \tau) + \frac{3}{2}\Omega_m \mathcal{H}^2(\tau)\delta(\mathbf{x}, \tau) = 0$$

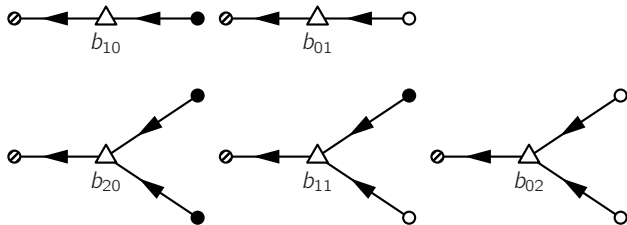
$$\delta_n(\mathbf{k}) = \int d^3 q_1 \dots \int d^3 q_n \delta^{(D)}\left(\mathbf{k} - \sum_s \mathbf{q}_s\right) F_n(\mathbf{q}_1, \dots, \mathbf{q}_n) \delta_0(\mathbf{q}_1) \dots \delta_0(\mathbf{q}_n)$$



Multivariate Biasing¹

$$\delta_{\mathbf{g}}(\mathbf{x}) = \sum_{i,j} b_{ij} \delta^i(\mathbf{x}) \varphi^j(\mathbf{x})$$

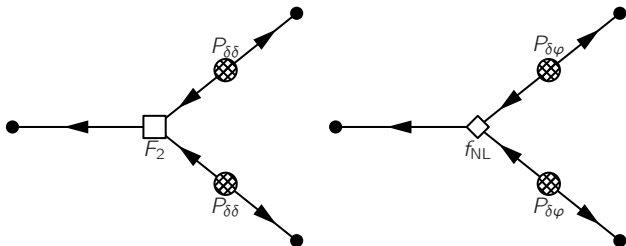
$$\delta_{\mathbf{g},ij}(\mathbf{k}) = b_{ij} \int d^3 q_1 \dots \int d^3 q_{i+j} \delta^{(D)}\left(\mathbf{k} - \sum_s \mathbf{q}_s\right) \delta_1(\mathbf{q}_1) \dots \varphi_j(\mathbf{q}_{i+j})$$



¹[Giannantonio & Porciani 2010]

Example: Matter Bispectrum

$$\begin{aligned}
 B_{\text{mmm}}(\mathbf{k}_1, \mathbf{k}_2, \mathbf{k}_3) &= \left(2P(k_1)P(k_2)F_2(\mathbf{k}_1, \mathbf{k}_2) + 2 \text{ cyc.} \right) + \\
 &\quad \left(2f_{\text{NL}} \frac{P(k_1)P(k_2)\alpha(k_3)}{\alpha(k_1)\alpha(k_2)} + 2 \text{ cyc.} \right) \\
 &= B_{F_2}(\mathbf{k}_1, \mathbf{k}_2, \mathbf{k}_3) + B_{f_{\text{NL}}}(\mathbf{k}_1, \mathbf{k}_2, \mathbf{k}_3)
 \end{aligned}$$



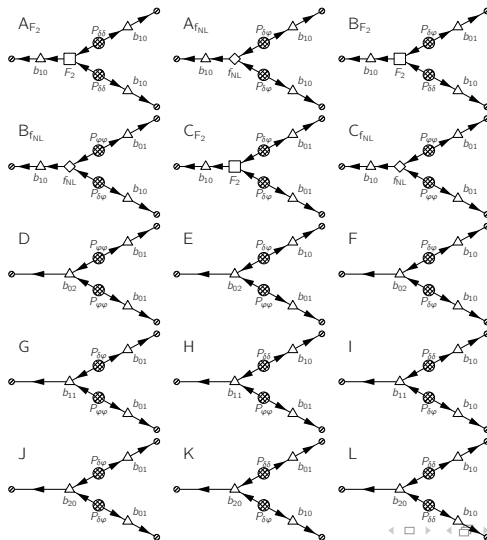
1 Introduction

2 Perturbation Theory and Diagrammatics

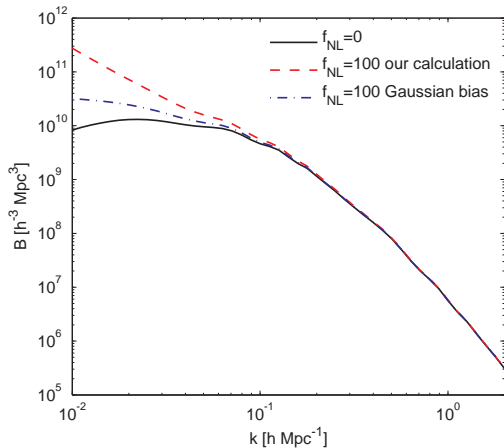
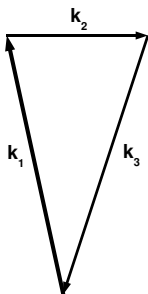
3 The Galaxy Bispectrum

4 Summary

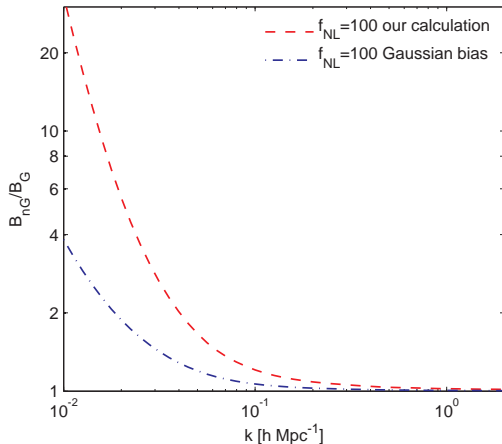
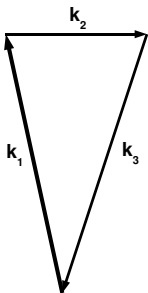
Galaxy Bispectrum



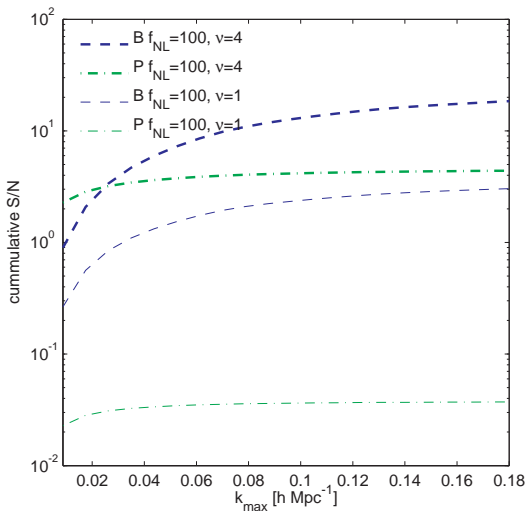
Galaxy Bispectrum - Squeezed Configuration



Galaxy Bispectrum - Squeezed Configuration



Galaxy Bispectrum - Signal-to-Noise



1 Introduction

2 Perturbation Theory and Diagrammatics

3 The Galaxy Bispectrum

4 Summary

Summary

Achievements

- diagrammatic prescription including effects of
 - clustering
 - biasing
 - non-Gaussianity
- corrections to existing calculations at tree level
- bispectrum has more information on nG than power spectrum

Outlook

- resummation and interpretation of loop contributions
- comparison with N-body simulations

Summary

Achievements

- diagrammatic prescription including effects of
 - clustering
 - biasing
 - non-Gaussianity
- corrections to existing calculations at tree level
- bispectrum has more information on nG than power spectrum

Outlook

- resummation and interpretation of loop contributions
- comparison with N-body simulations

Thank you for your attention!

