

PROBING THE EARLY UNIVERSE USING LARGE SCALE STRUCTURE

Nishant Agarwal

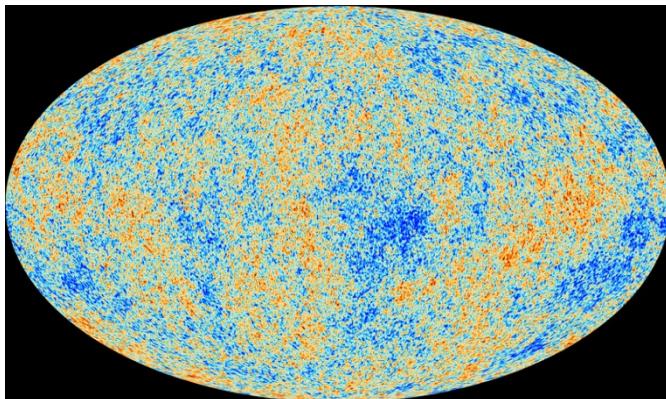
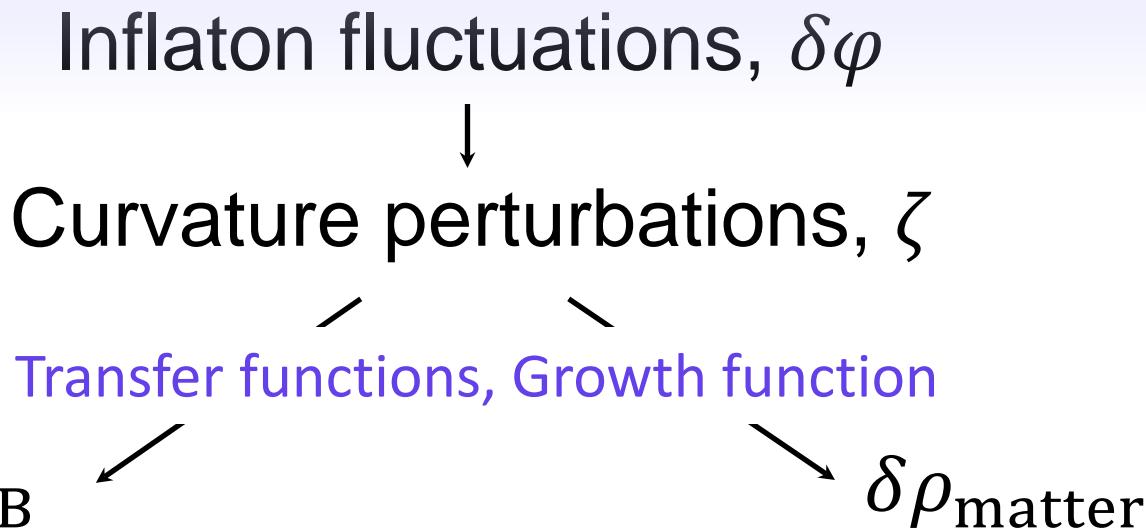
*McWilliams Center for Cosmology
Carnegie Mellon University*

In collaboration with – Shirley Ho, Sarah Shandera, Adam Myers, Hee-Jong Seo, Ashley Ross, Richard Lyons, Ashley Disbrow, Daniel Eisenstein, Christopher Hirata, Nikhil Padmanabhan, Nicholas Ross, David Schlegel, Anze Slosar, Michael Strauss, David Weinberg, et al. + SDSS-III collaboration

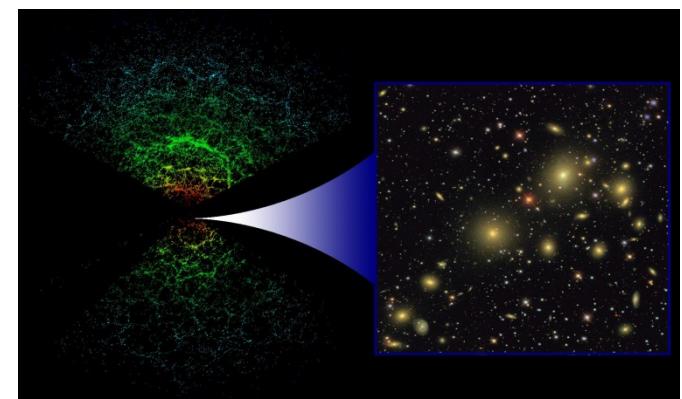
LSST-DESC Collaboration Meeting, December 04, 2013

Introduction

- Introduction
- Scale-dependent bias
- Constraints and systematics
- Conclusions



Planck



SDSS

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Statistics of ζ

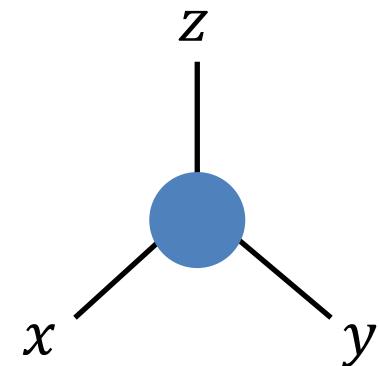
- Gaussian perturbations
(2-point function)

$\langle \zeta(\vec{x})\zeta(\vec{y}) \rangle(t)$ – Power spectrum



- Non-Gaussian perturbations
(n -point functions)

$\langle \zeta(\vec{x})\zeta(\vec{y})\zeta(\vec{z}) \rangle(t)$ – Bispectrum



Introduction

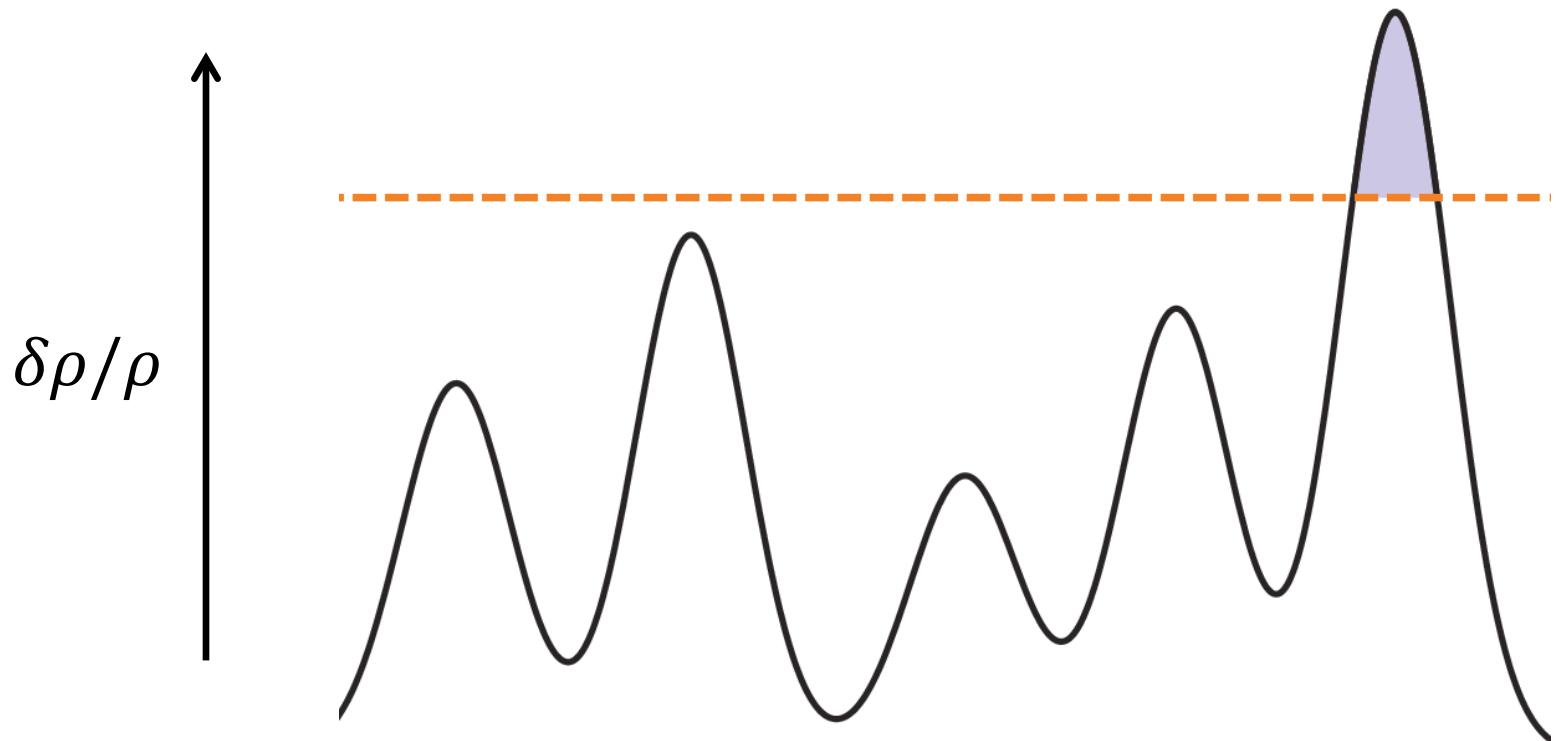
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- The 3-point function (or any n -point function in general) of ζ will leave observable effects in both, the CMB and LSS
- Additionally, the *squeezed bispectrum* gives rise to a mode coupling that affects the abundance and clustering of virialized objects – hence it *leaves signatures in the power spectrum* of dark matter halos

Scale-dependent bias

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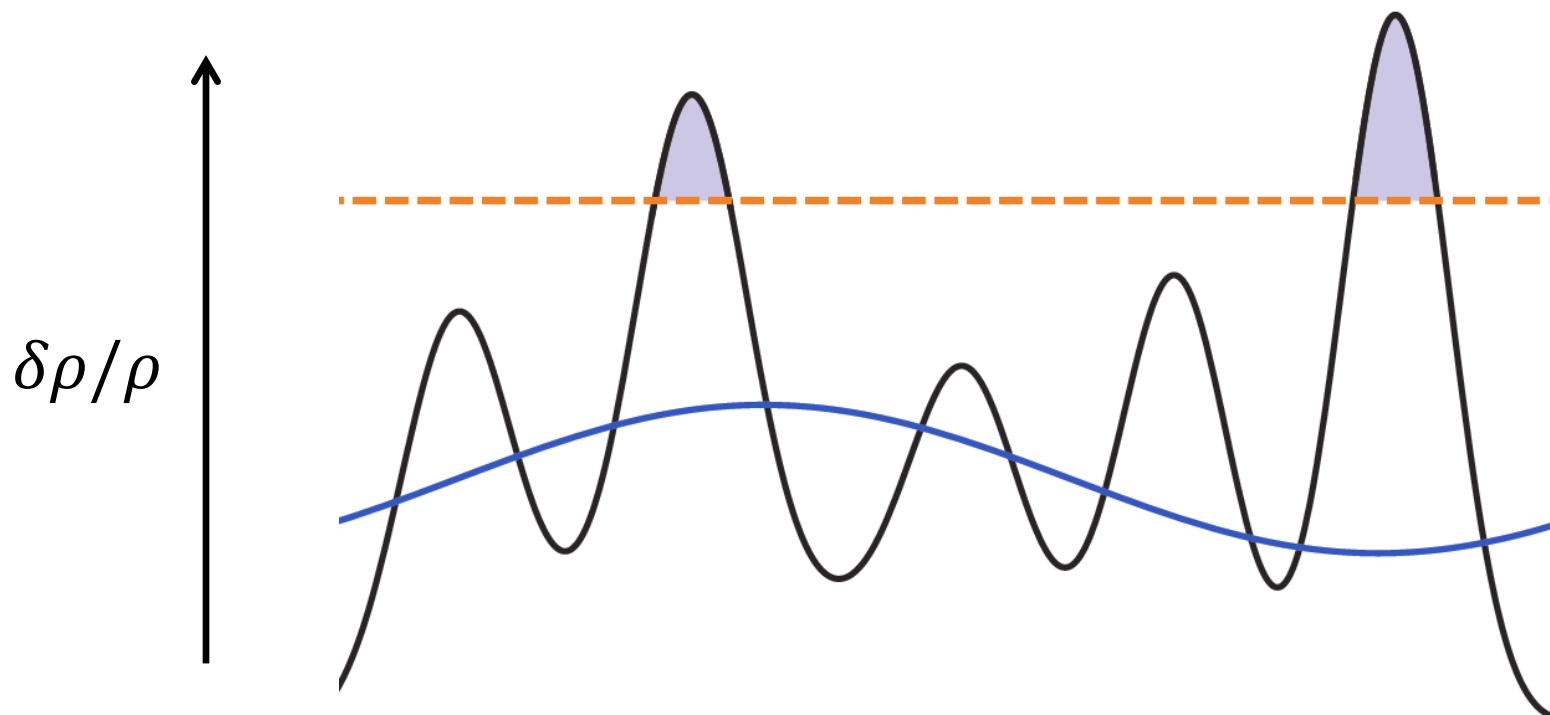
In the absence of local f_{NL}



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Scale-dependent bias

In the presence of local f_{NL} : $\zeta = \zeta_G + \frac{3}{5} f_{\text{NL}} \zeta_G^2$



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- The power spectrum of dark matter halos is given by

$$P_{\text{halo}}(M, k, z, f_{\text{NL}}) = [b_1(M, z) + \Delta b(M, k, z, f_{\text{NL}})]^2 P_{\text{matter}}(k, z)$$

with $\Delta b_{\text{non-Gaussian}} \propto f_{\text{NL}} \frac{(b_1(M, z) - p)}{k^2}$

N. Dalal, O. Dore, D. Huterer, and A. Shirokov, 2008; S. Matarrese and L. Verde, 2008; A. Slosar, C. Hirata, U. Seljak, S. Ho, and N. Padmanabhan, 2008

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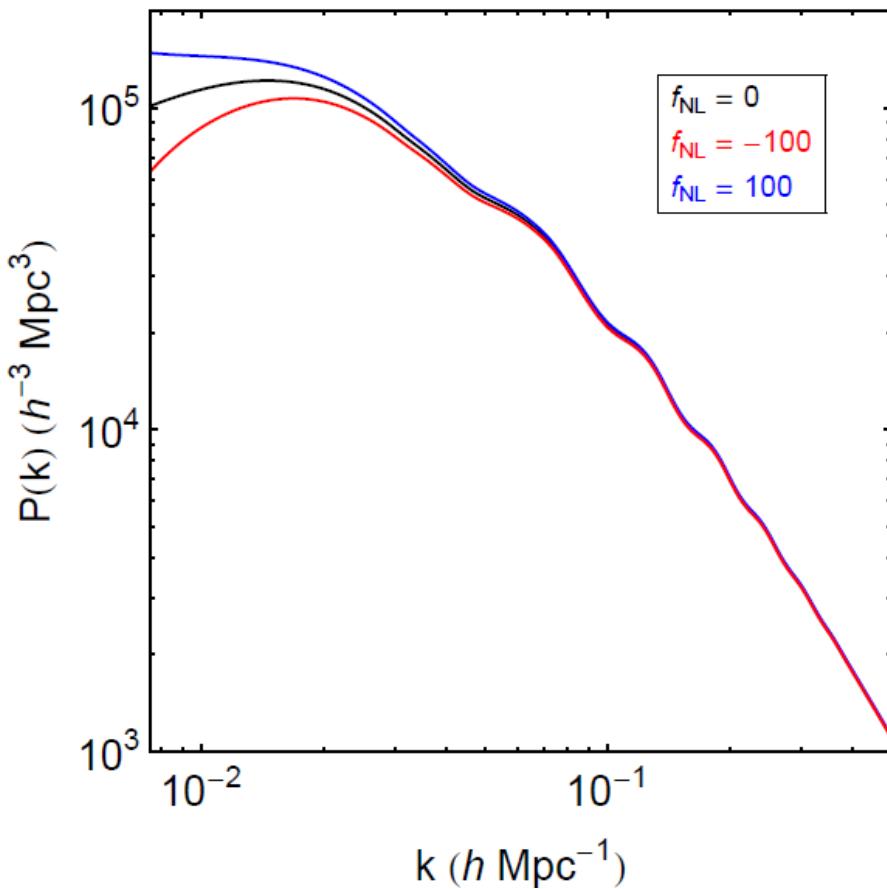
- In general $\Delta b_{\text{non-Gaussian}} \propto \mathcal{A}_{\text{NL}}(b_1(M, z)) \frac{(b_1(M, z) - p)}{k^\alpha}$

S. Shandera, N. Dalal, and D. Huterer, 2011; J. Ganc and E. Komatsu, 2012; I. Agullo and S. Shandera, 2012

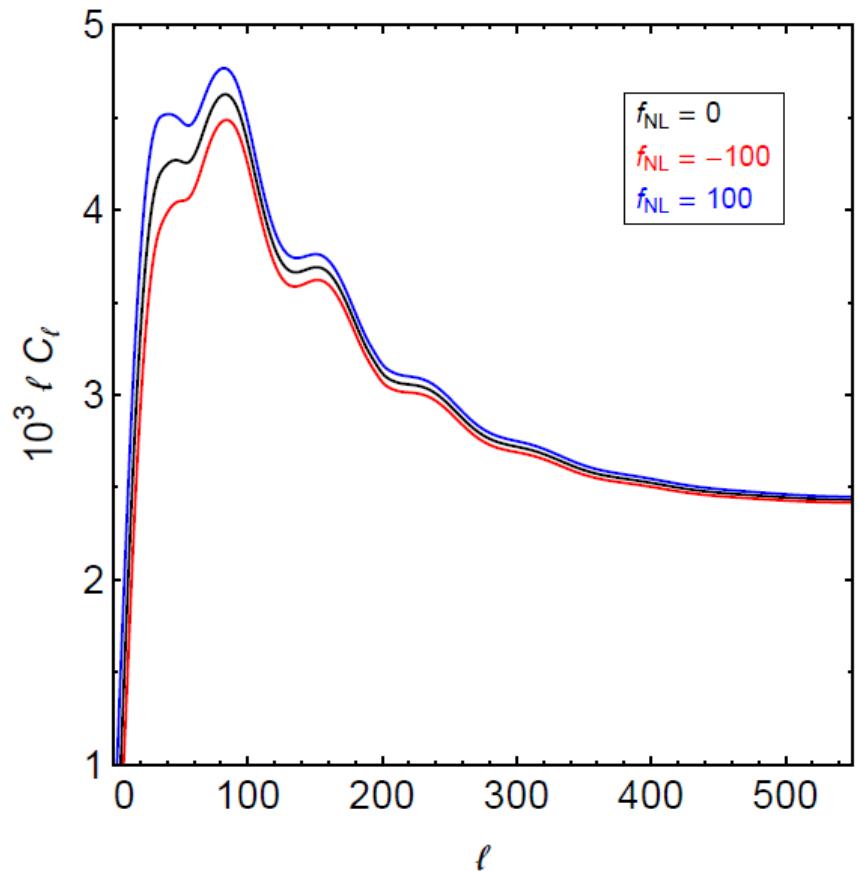
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Power spectrum



Angular power spectrum



Constraints and systematics

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- **Data:** SDSS photometric luminous red galaxies (900,000) and quasars (1.6 million)
- **Method:**
 - Determine redshift distributions, angular power spectra
 - Correct angular power spectrum data for systematics
 - MCMC analysis to constrain \mathcal{A}_{NL} and α

S. Ho et al, 2012; S. Ho, N. Agarwal, et al, arXiv:1311.2597; N. Agarwal et al, arXiv:1309.2954

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- Common sources of systematics (for photometric surveys) –
 - Stars
 - Sky
 - Seeing variations
 - Dust extinction
 - Color offsets
 - Magnitude errors

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- Common sources of systematics (for photometric surveys) –
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 - **Unknowns?**

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- Consider a linear relationship between systematics and the observed density field,

$$\delta_{g,\text{obs}}^{\alpha}(\ell, m) = \delta_{g,\text{true}}^{\alpha}(\ell, m) + \sum_{i=1}^{N_{\text{sys}}} \epsilon_i^{\alpha}(\ell) \delta_i(\ell, m)$$

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Unknown systematics

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- Define an unknown contamination coefficient

$$\mathcal{U}_\ell^{\alpha,\beta} = \frac{(U_\ell^{\alpha,\beta})^2}{C_{\ell,\text{obs}}^{\alpha,\alpha} C_{\ell,\text{obs}}^{\beta,\beta}}, \quad \alpha \neq \beta$$

and compare this with

$$n^2 \frac{\sigma(C_{\ell,\text{obs}}^{\alpha,\alpha}) \sigma(C_{\ell,\text{obs}}^{\beta,\beta})}{C_{\ell,\text{obs}}^{\alpha,\alpha} C_{\ell,\text{obs}}^{\beta,\beta}}$$

for an $n\sigma$ -cut

Constraints and systematics

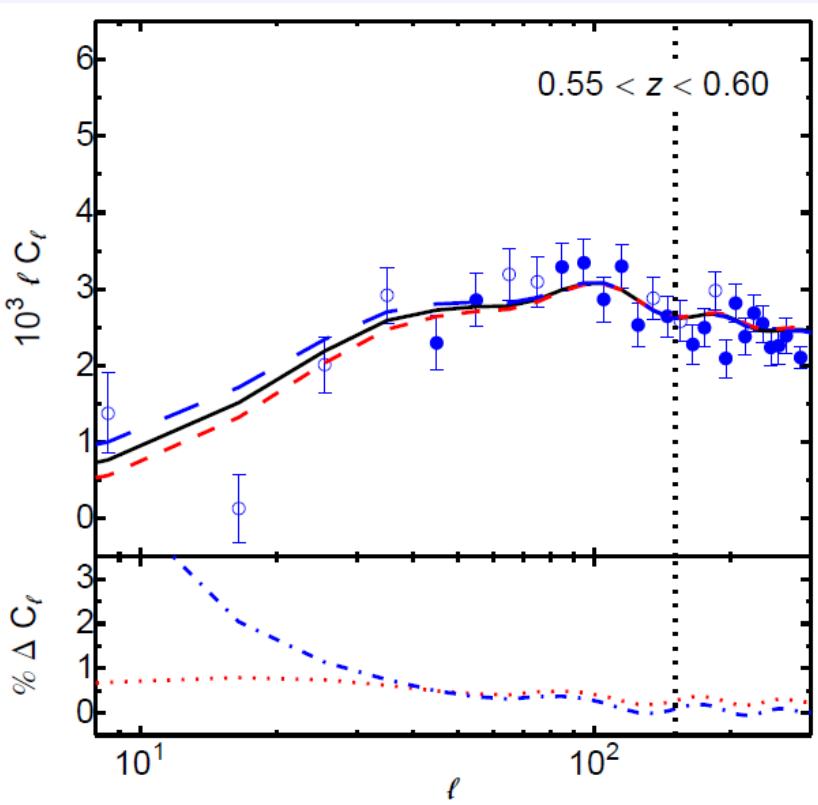
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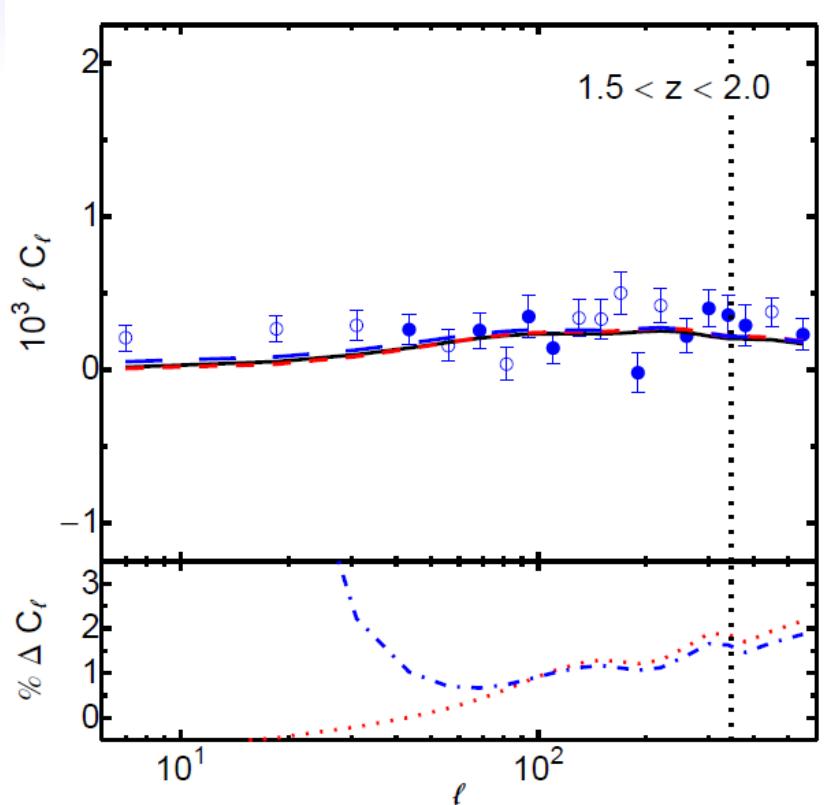
$$\Delta b_{\text{non-Gaussian}} \propto \mathcal{A}_{\text{NL}}(b_1(M, z)) \frac{(b_1(M, z) - p)}{k^\alpha}$$

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LRGs

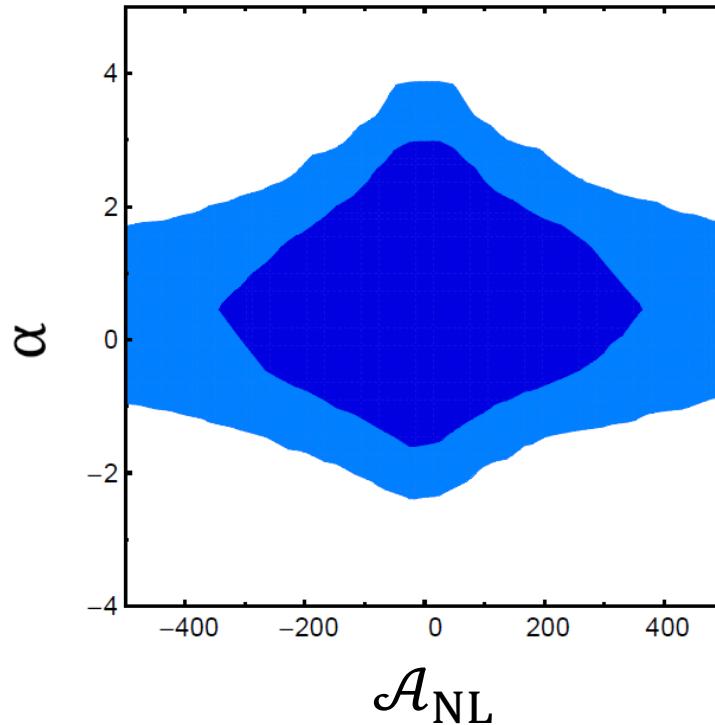


Quasars

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- Constraints on \mathcal{A}_{NL} and α – LSS data

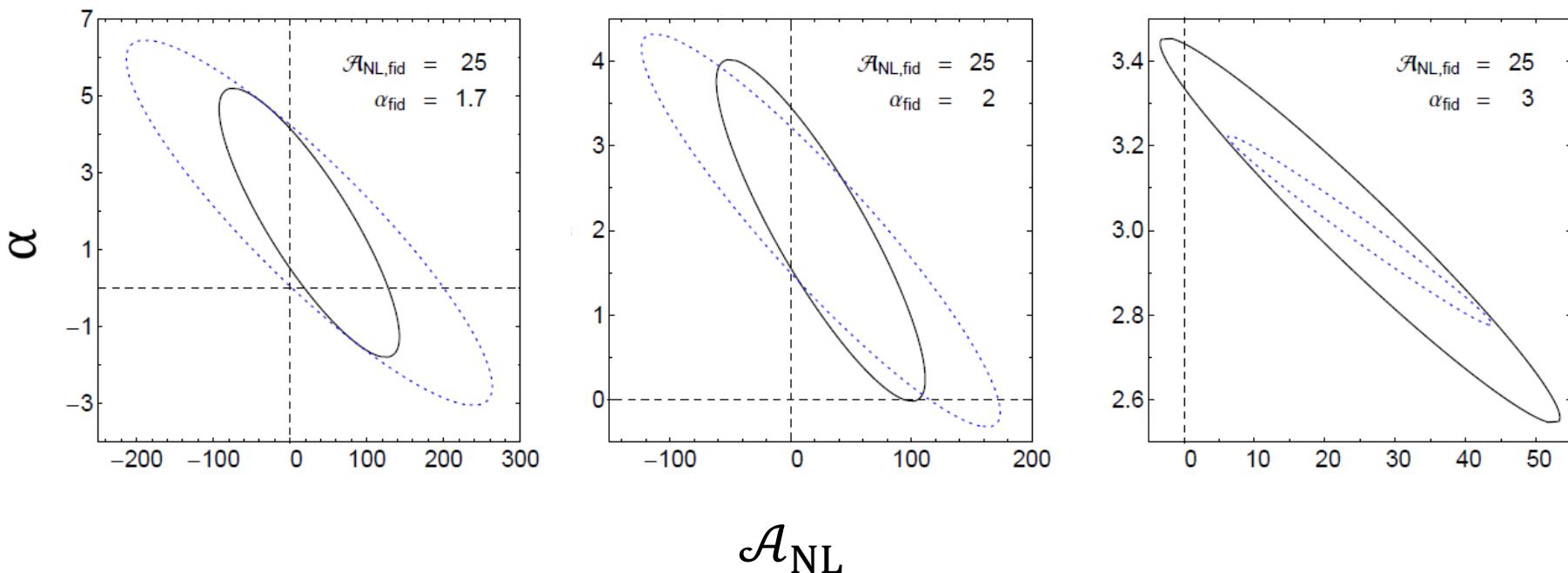


N. Agarwal, S. Ho, and S. Shandera, arXiv:1311.2606; T. Giannantonio et al, 2013

Constraints and systematics

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- Constraints on \mathcal{A}_{NL} and α – Fisher analysis



Conclusions

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- LSS holds immense potential to distinguish between different models of inflation
- It is crucial, however, to understand systematic corrections in order to extract accurate cosmological information from LSS
- This is especially important for future photometric surveys such as LSST