Can we really measure fnl from the galaxy power spectrum?

Nina Roth, Cristiano Porciani
MNRAS Letters 2012, 425, 81-85

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Argelander-Institut für Astronomie

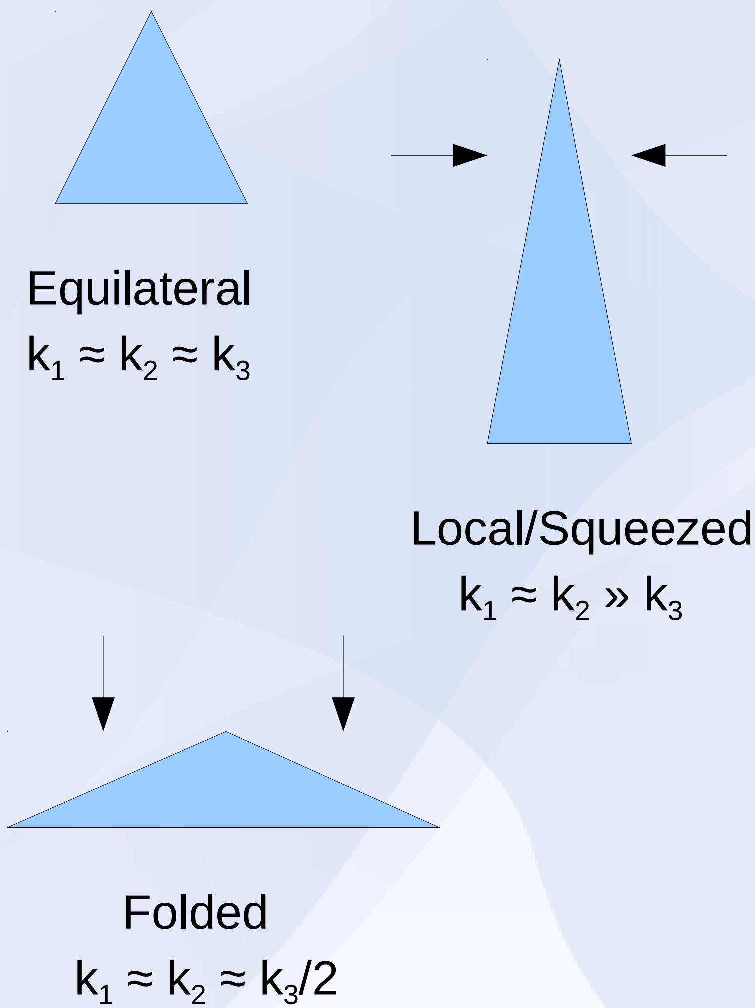
universitätbonn
Rheinische Friedrich-Wilhelms-Universität Bonn

What is Primordial non-Gaussianity?

- “Primordial”
  - Refers to initial density/potential perturbations
  - Different from NG introduced by non-linear structure formation at late times
- Describes a wide class of effects with different physical origin
  - Signal determined by specific model of Inflation
  - Standard slow-roll: deviations undetectable
- Leads to non-zero n-point correlation functions for n>2 (or equivalently: Bispectrum, Trispectrum, …)

➔ A detection would imply new physics!

Different types



- Bispectrum “templates” defined by triangle configurations which maximize the signal in the 3-point function
- Most common: local type

$$\Phi(\mathbf{x}) = \phi(\mathbf{x}) + f_{\rm NL}^{\rm loc}\phi^2(\mathbf{x}) + g_{\rm NL}^{\rm loc}\phi^3(\mathbf{x})$$

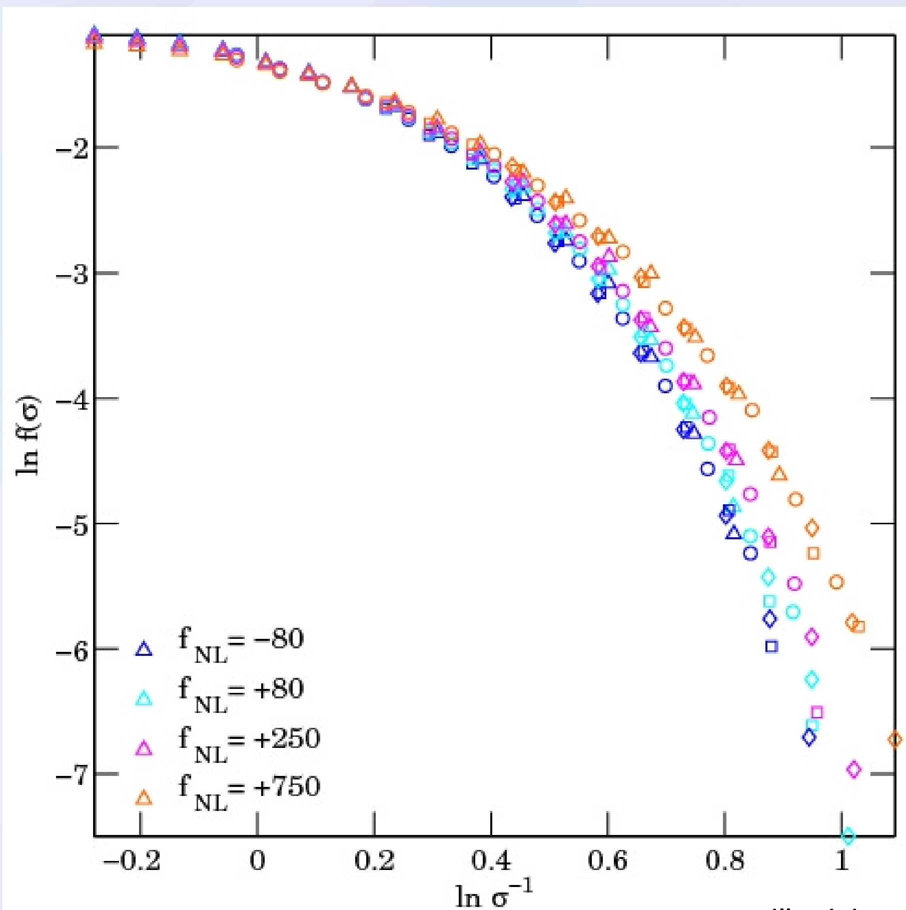
$$B_\Phi^{\rm loc}(\mathbf{k}_1, \mathbf{k}_2, \mathbf{k}_3) = 2 f_{\rm NL}^{\rm loc}\left[P_\phi(k_1)P_\phi(k_2) + ({\rm cyc.})\right]$$

✔ Many signals are maximal for local model

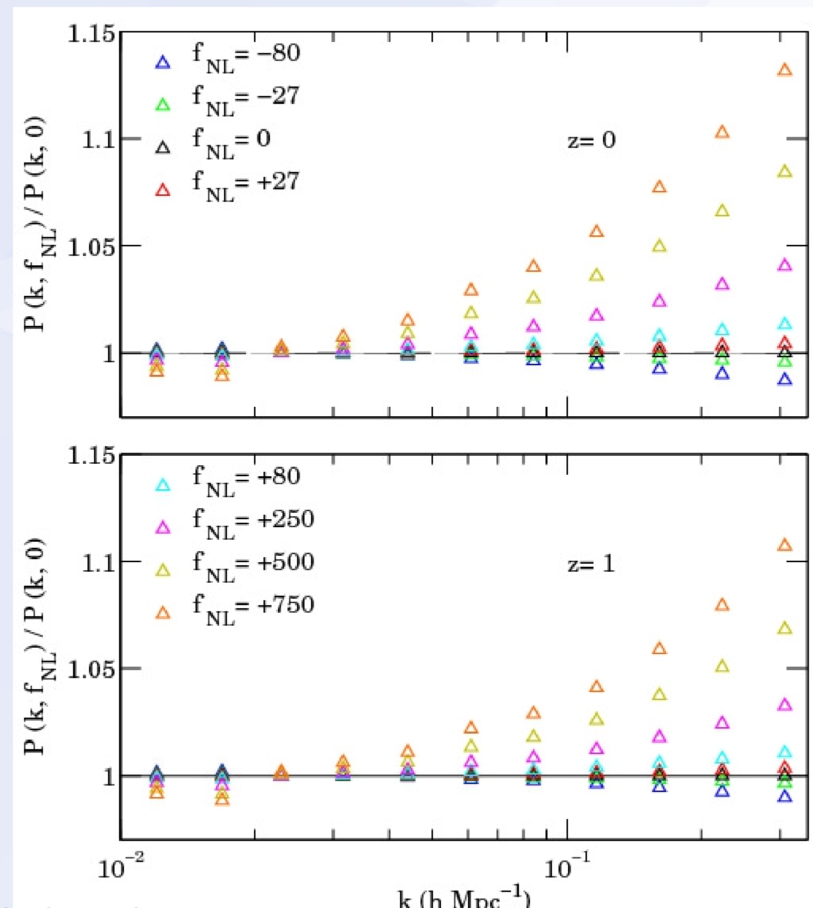
✗ Other types have to be approximated or calculated numerically

Effects on large-scale structure

Halo mass function



Matter power spectrum



Pillepich, Porciani & Hahn
2010, MNRAS, 402, 191

Scale-dependent bias

(e.g. Dalal et al. 2008; Smith, Ferraro & LoVerde 2012)

$$\frac{P_{\rm hm}(k)}{P_{\rm m}(k)} = b_1(f_{\rm NL}, g_{\rm NL}) + \frac{\beta_f f_{\rm NL} + \beta_g g_{\rm NL}}{\alpha(k)}.$$

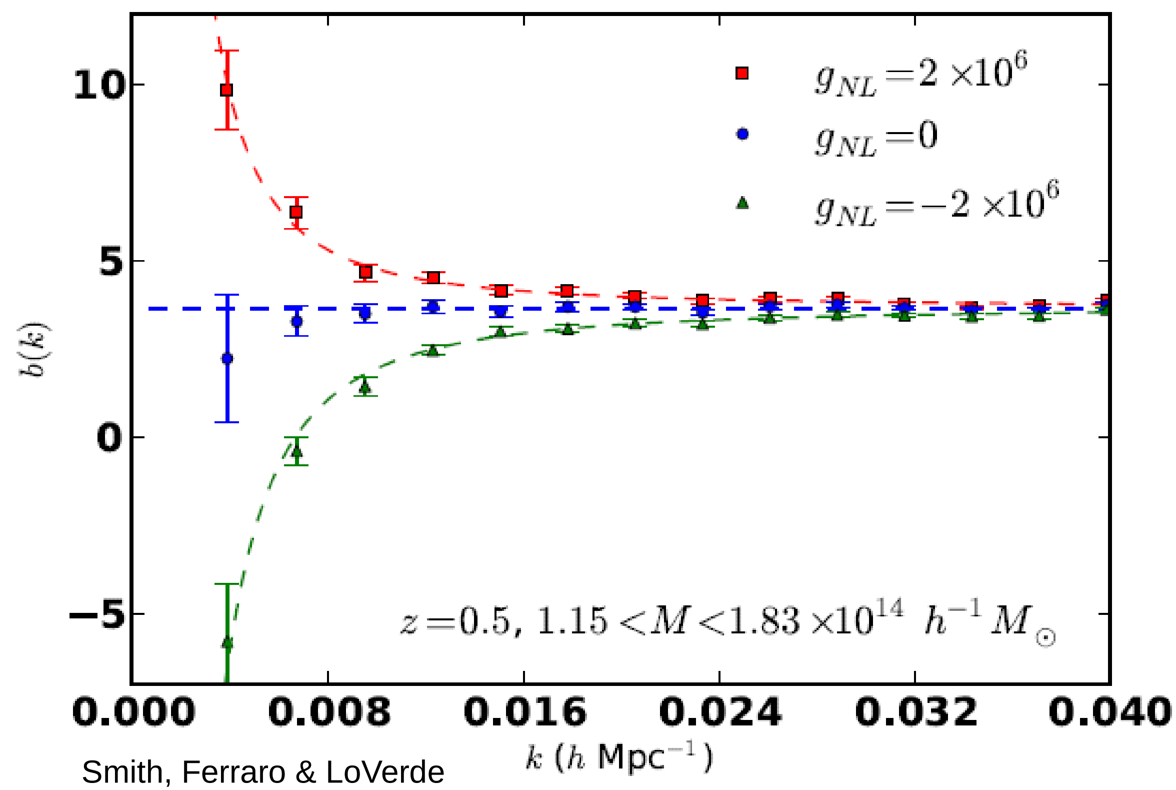
$$\beta_f \quad = \quad 2\nu^2 - 2$$

$$\alpha(k,z) = \frac{2k^2 D(z) T(k)}{3\Omega_{\rm m} H_0^2}$$

$$\nu = [\delta_c(b_1 - 1) + 1]^{1/2} \qquad (\text{where } \delta_c = 1.42)$$

$$\beta_g = \kappa_3 \Big[-0.7 + 1.4(\nu-1)^2 + 0.6(\nu-1)^3 \Big] - \frac{d\kappa_3}{d\log\sigma^{-1}} \left(\frac{\nu - \nu^{-1}}{2} \right)$$

Scale-dependent bias

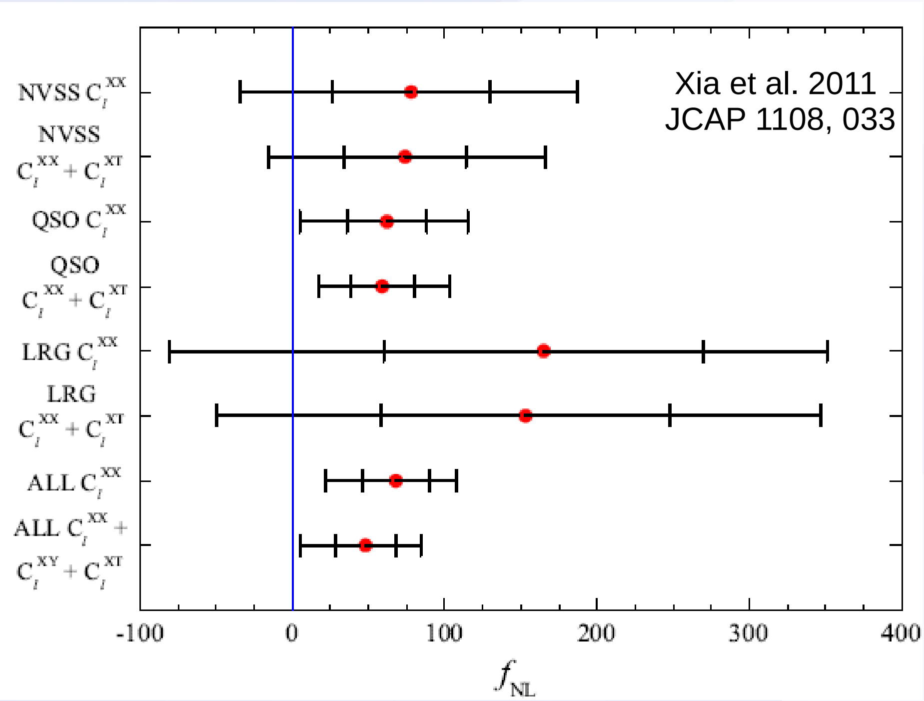


Smith, Ferraro & LoVerde
2012, JCAP 03, 032

A detection of fnl > 0?

(Xia et al. 2011)

- Analysis of angular power spectra of radio sources (NVSS), SDSS QSOs, MegaZ-LRGs (SDSS II) & cross-correlation with CMB temperature map
- No indication for non-local type of PNG
- No indication for (local) gnl ≠ 0
- Some indication of local-type PNG with fnl ≈ 40 ± 20



Critical assumption: The underlying model has either fnl ≠ 0 **or** gnl ≠ 0.

Simulations

- WMAP 5 cosmology, comoving 1.2 Gpc/h box
- {fnl, gnl} = {50, ±5e5} (within current limits from CMB), 4 realizations each
- Mass range: 10^{13} - 10^{15} $M_{\odot}$/h (at redshift 0)
- "Current sample": z = {0.5, 1, 1.5} and b_1= 1.8 - 2.9
- "Future sample": z = {0, 0.5, 1, 1.5, 2} and b_1= 1.8 - 5.9

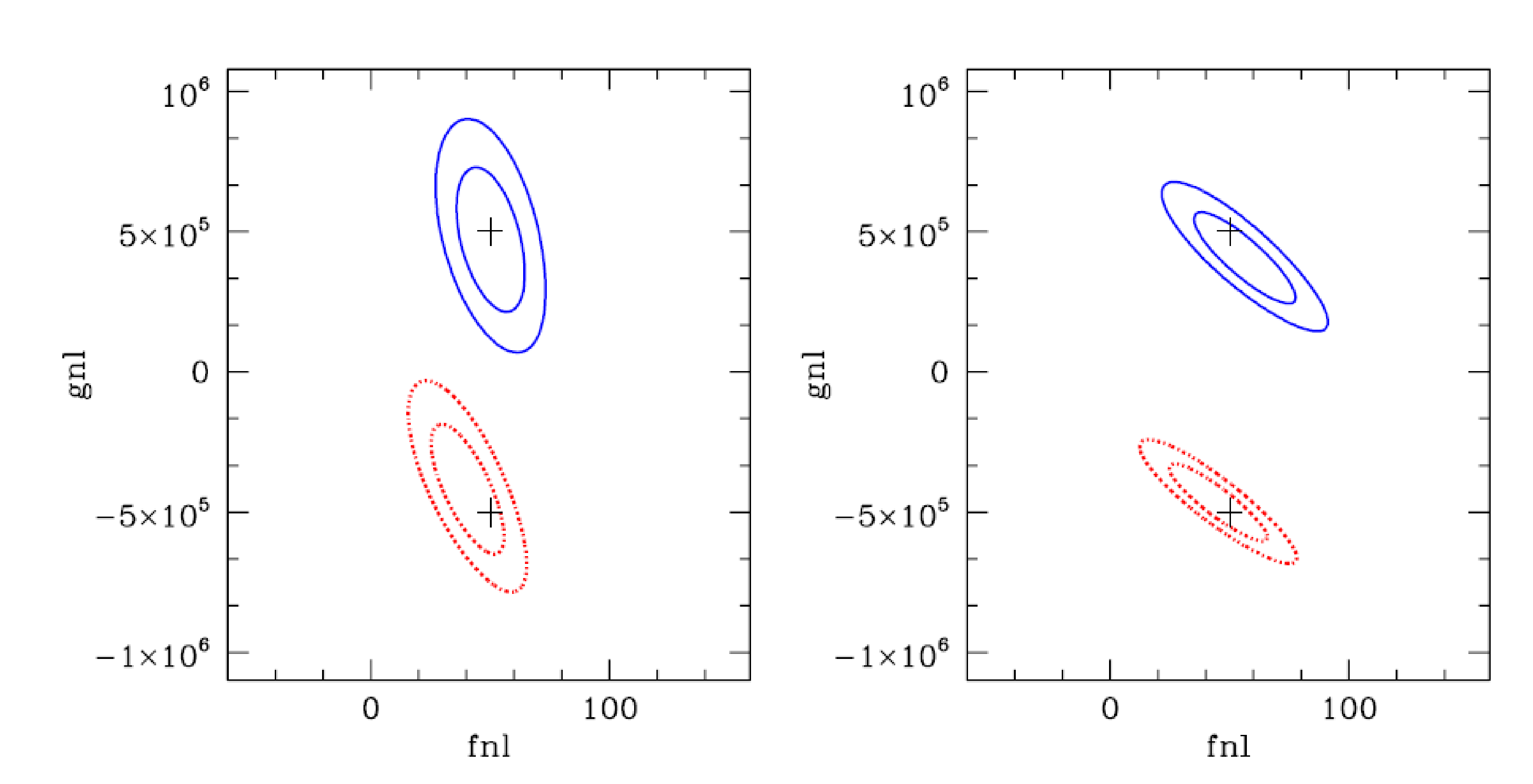
$$\frac{P_{\mathrm{hm}}(k)}{P_{\mathrm{m}}(k)} = b_1(f_{\mathrm{NL}}, g_{\mathrm{NL}}) + \frac{\beta_f f_{\mathrm{NL}} + \beta_g g_{\mathrm{NL}}}{\alpha(k)}.$$

1) Calculate P_{hm} and P_{mm} (average over realizations)

2) Get b(k) from ratio

3) Find best fnl, gnl (likelihood) after marginalization over b_1

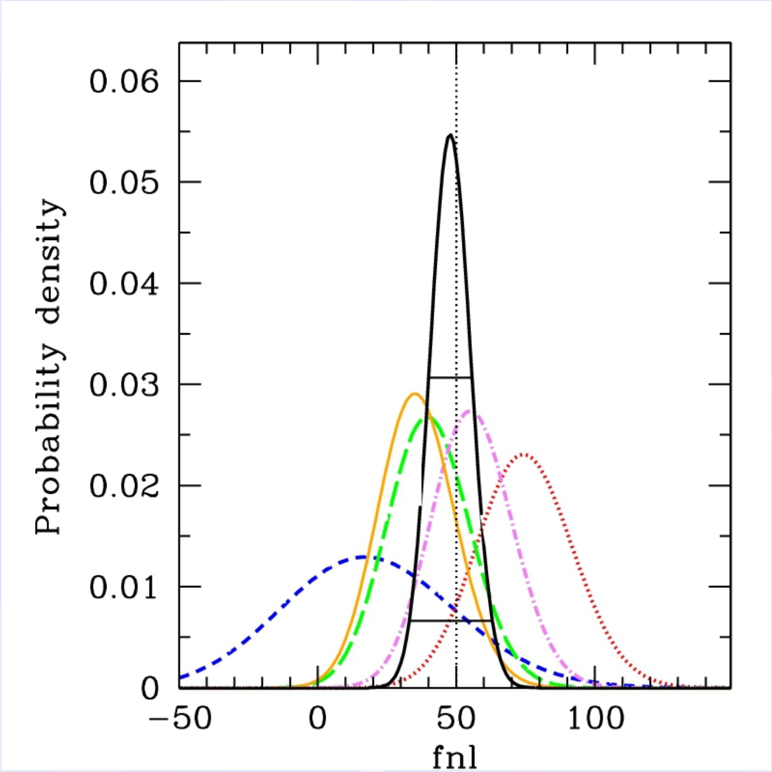
Degeneracy



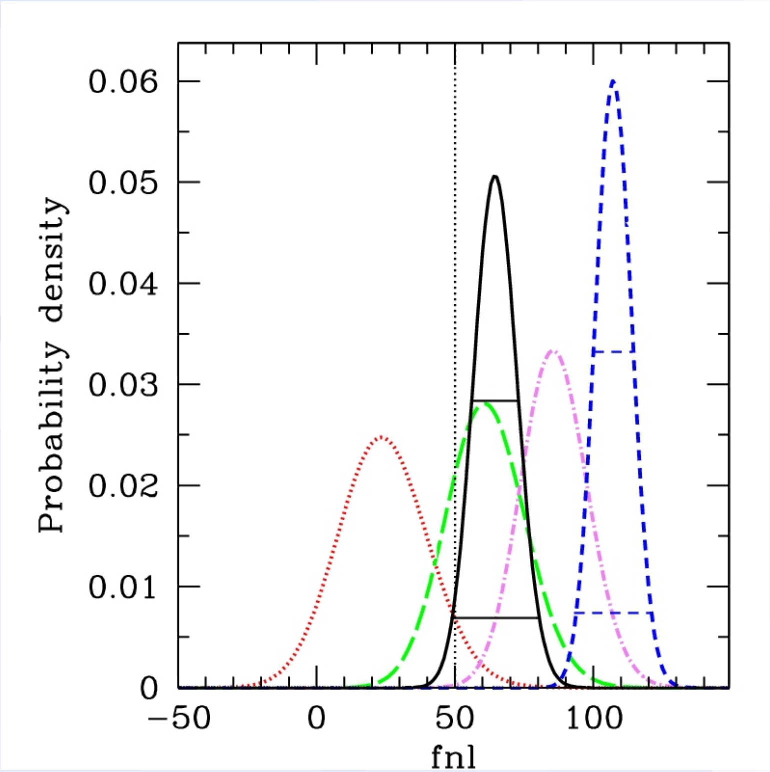
"Current sample"
(3 bins, up to z=1.5)

"Future sample"
(5 bins, up to z=2)

One-parameter model (fnl)

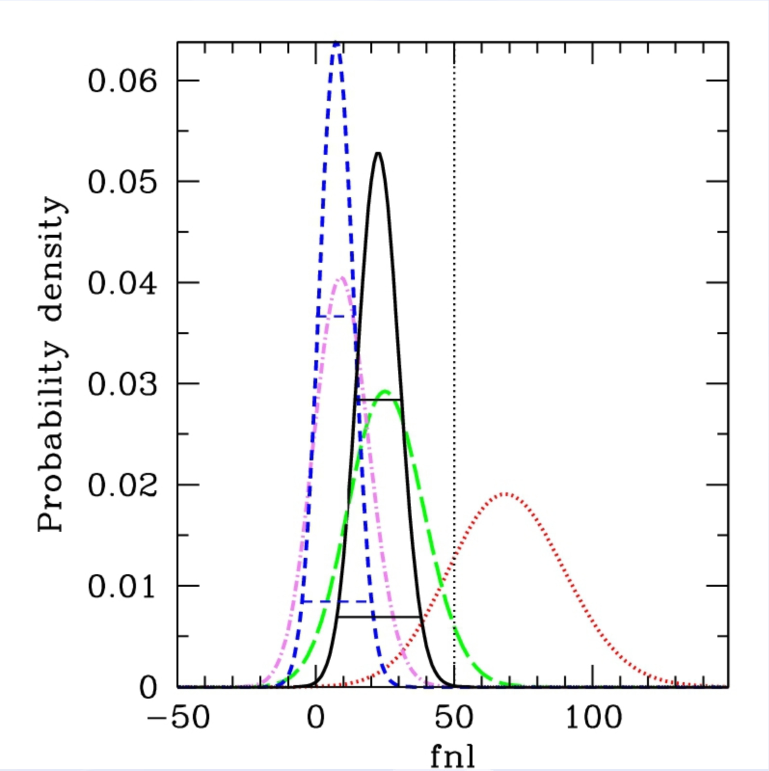


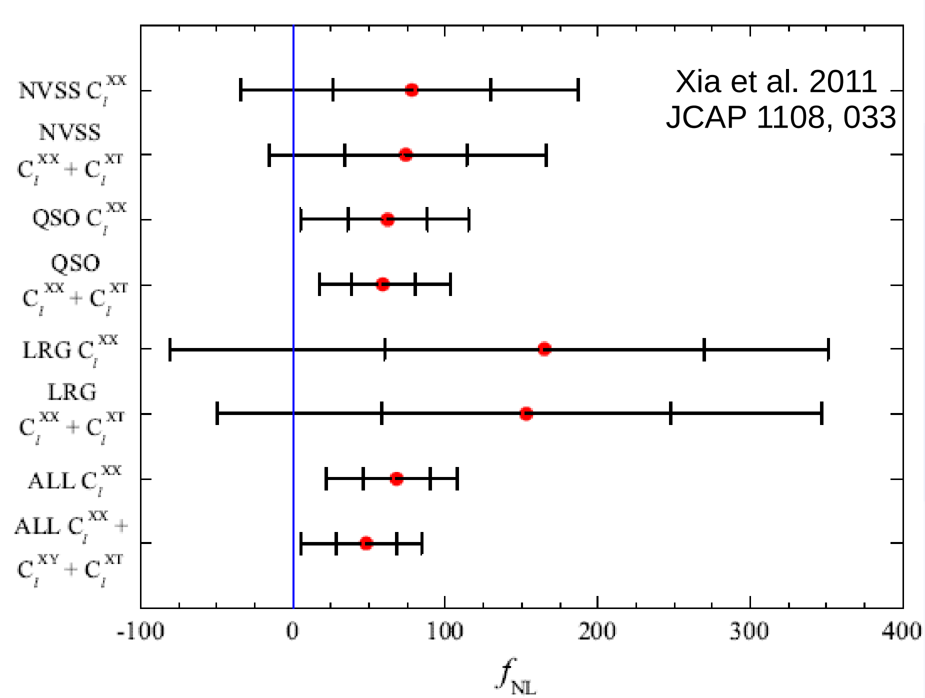
Simulation: fnl = 50, gnl = +5e5
Model: **gnl = +5e5, fnl fitted**, “future sample”



Simulation: fnl = 50, gnl = +5e5
Model: **gnl = 0, fnl fitted**, both samples

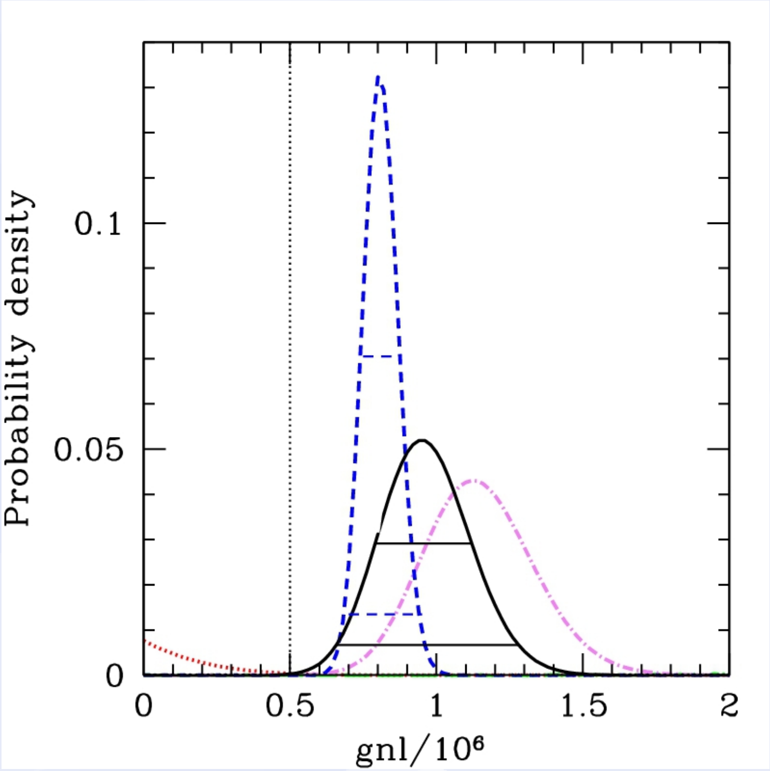
Redshift dependence?



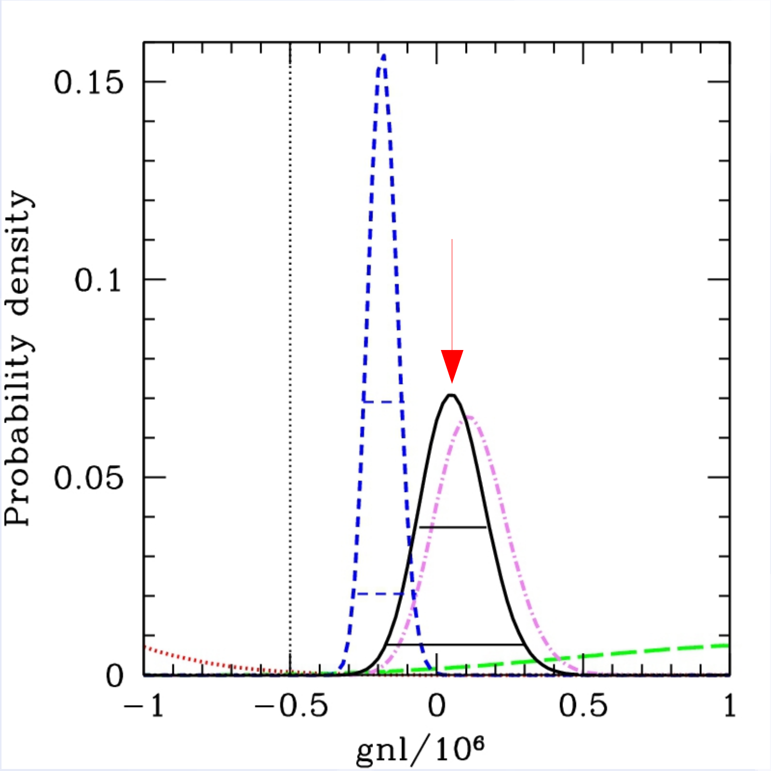


Simulation: fnl = 50, gnl = -5e5
Model: **gnl = 0, fnl fitted**, both samples

One-parameter model (gnl)



Simulation: fnl = 50, gnl = +5e5
Model: **fnl = 0, gnl fitted**, both samples



Simulation with gnl = -5e5

Model selection

- Bayes factor (computed from the likelihood)

$$B_{ab} = \frac{P(D|M_a)}{P(D|M_b)} = \frac{\int \mathcal{L}_a(D|M_a,\theta_a)\,\pi_a(\theta_a)\,\mathrm{d}\theta_\mathrm{a}}{\int \mathcal{L}_b(D|M_b,\theta_b)\,\pi_b(\theta_b)\,\mathrm{d}\theta_\mathrm{b}}$$

✔ Also works for nested models (i.e. fixing one parameter)

- Jeffreys scale (Jeffreys 1961)
  - B_{ab} < 1 favors model 'b'
  - B_{ab} > 30 gives "very strong" evidence to model 'a'

➔ We find that the 2-parameter model is always favored with B_{ab} > 30.

Summary

- Scale-dependent bias effects from fnl and gnl are degenerate
  - Just adding mass/redshift bins does not help
  - Higher-order statistics can break degeneracy
- Purely quadratic model (gnl = 0)
  - Leads to fnl = fnl(z), which depends on the sign of gnl
  - “Best fit” estimates differ significantly from input value
- Purely cubic model (fnl = 0)
  - Effects can cancel out when actual signs are opposite
  - “Best fit” estimates differ significantly from input value
- Model selection techniques
  - Can distinguish between different models
  - Should be applied to observations