Optimising primordial non-Gaussianity measurements from galaxy surveys

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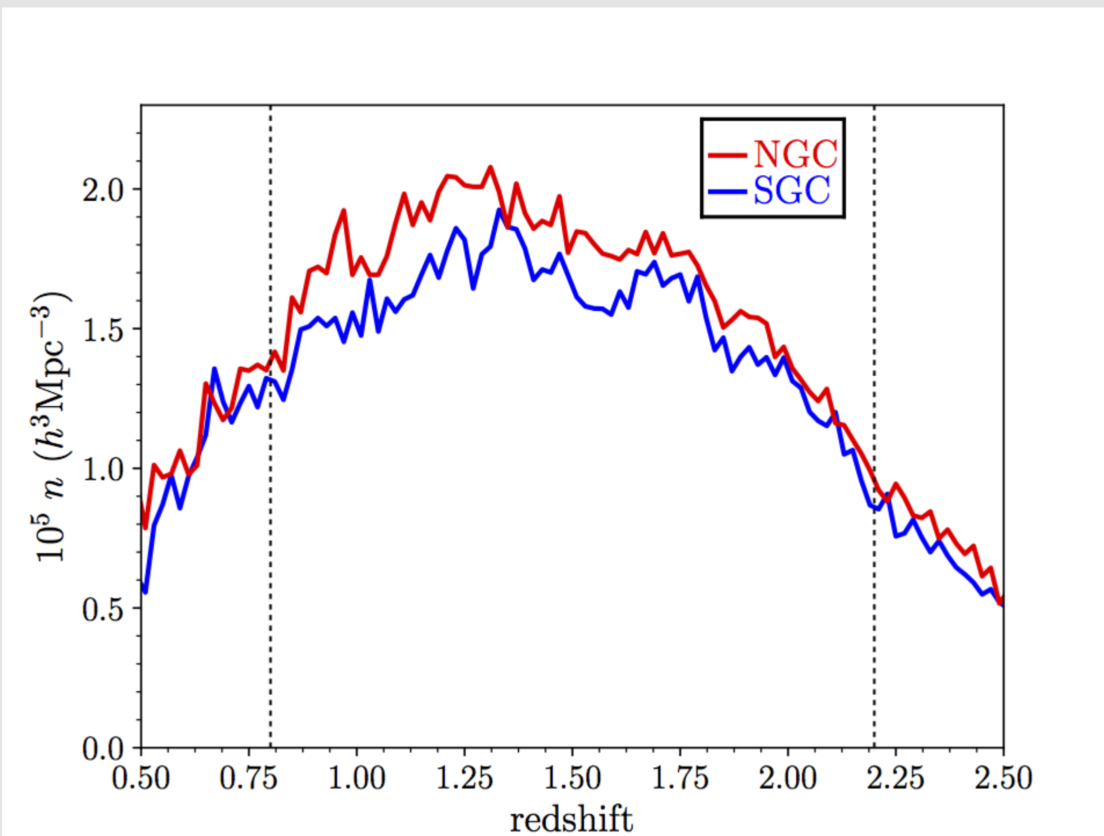
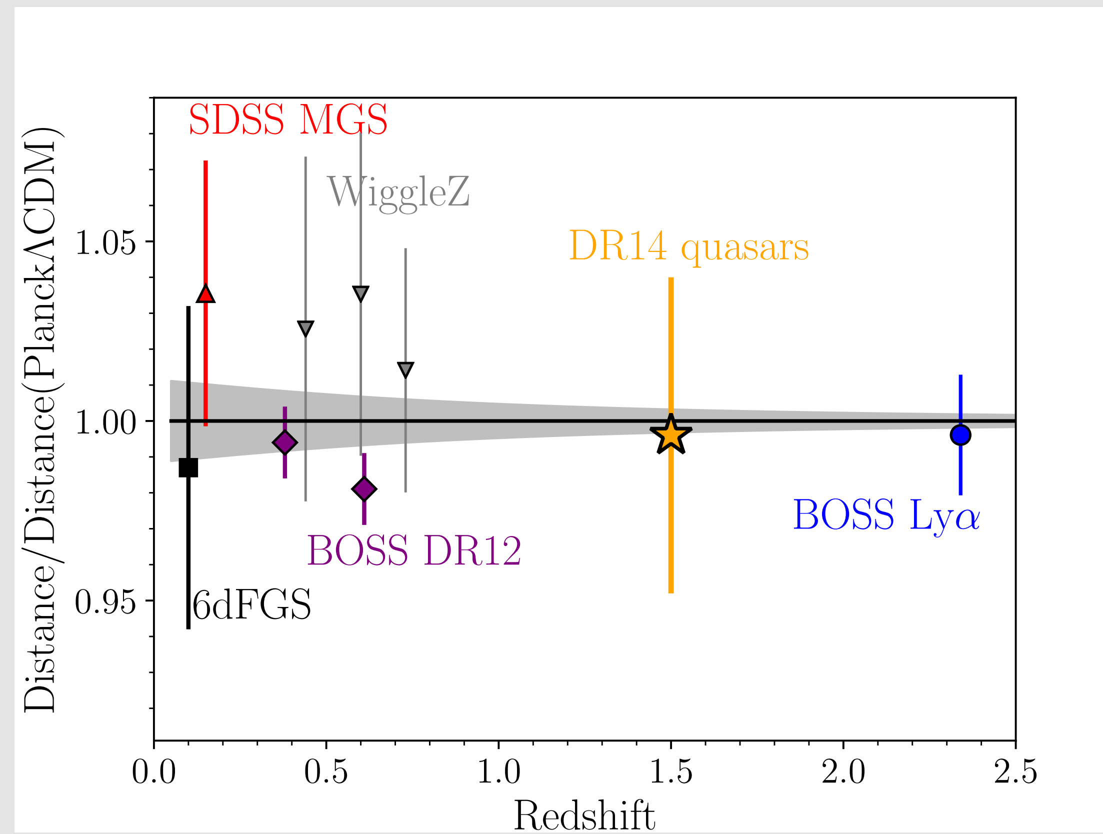
Outline

- Overview: extended BOSS survey (eBOSS)
- Constraining primordial non-Gaussianity with LSS
- Redshift weighting techniques
- Accounting for systematics effects

eBOSS: First results

eBOSS collaboration: Ata et al. (2017)





147,000 quasars from the extended Baryon Oscillation Spectroscopic Survey (eBOSS)

Good agreement with Planck LCDM

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Primordial Non-Gaussianity

- Simple form: Local type

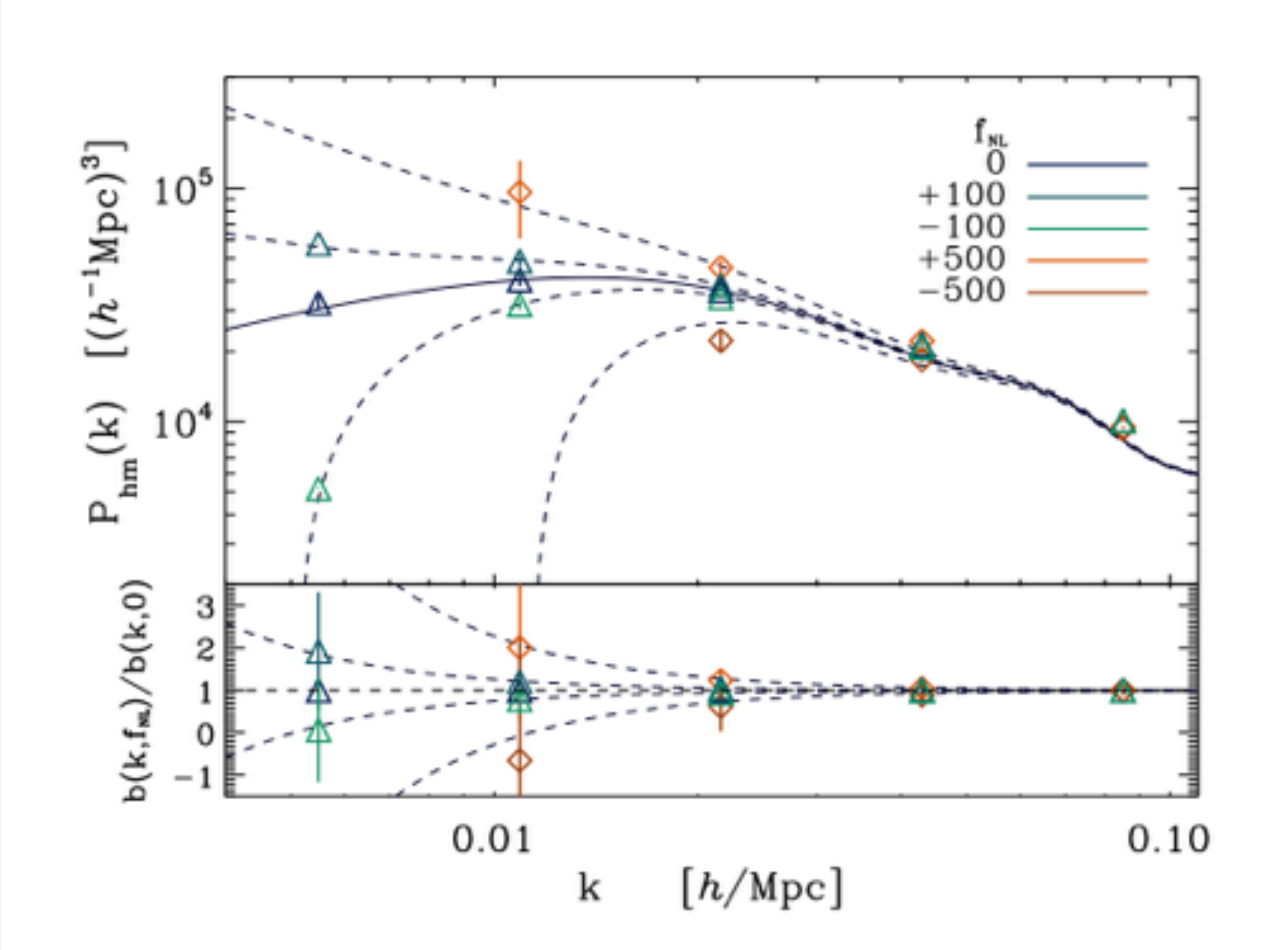
$$\Phi(x) = \phi(x) + f_{NL}^{loc}(\phi^2(x) - \langle\phi^2(x)\rangle)$$

- Induces scale dependent halo bias due to “mode coupling”

e.g.de Putter

Primordial non-Gaussianity from LSS

Scale dependent halo bias



$$b_{\text{total}} = b + \Delta b$$

$$\Delta b(k) \propto \frac{f_{NL}}{k^2}$$

Very sensitive at large scales

e.g. Dalal et. al 2008, Slosar et. al 2008

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Constraints from LSS

Current, e.g.:

Ross et al. (2012) : SDSS DR9 BOSS data

$$-45 < f_{\rm NL}^{\rm local} < 195$$

Giannantonio et al. (2014): Correlations between CMB lensing and large-scale structure

$$f_{\rm NL} = 12 \pm 21(1\sigma)$$

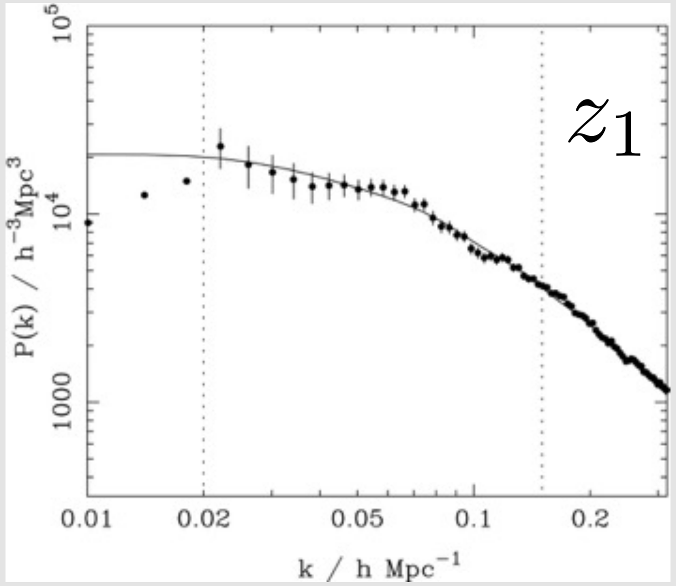
Upcoming, e.g.:

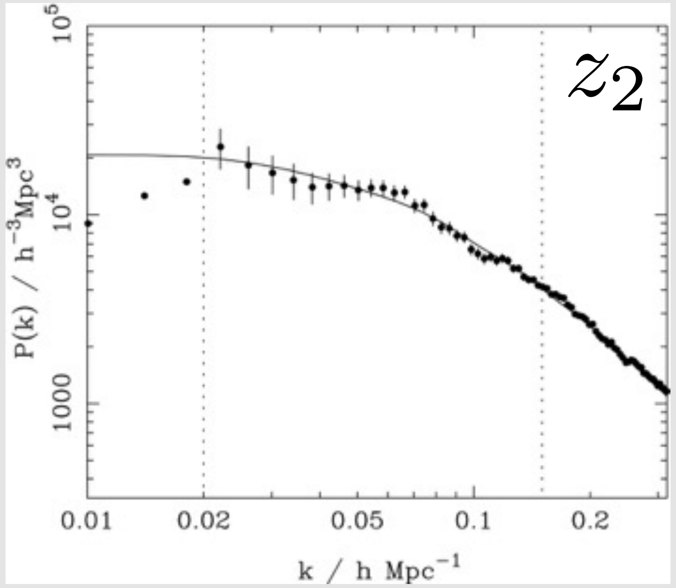
DESI, Euclid : error on fNL ~ few

Further improvement with SPHEREx: error on fNL~1

Optimising LSS analysis

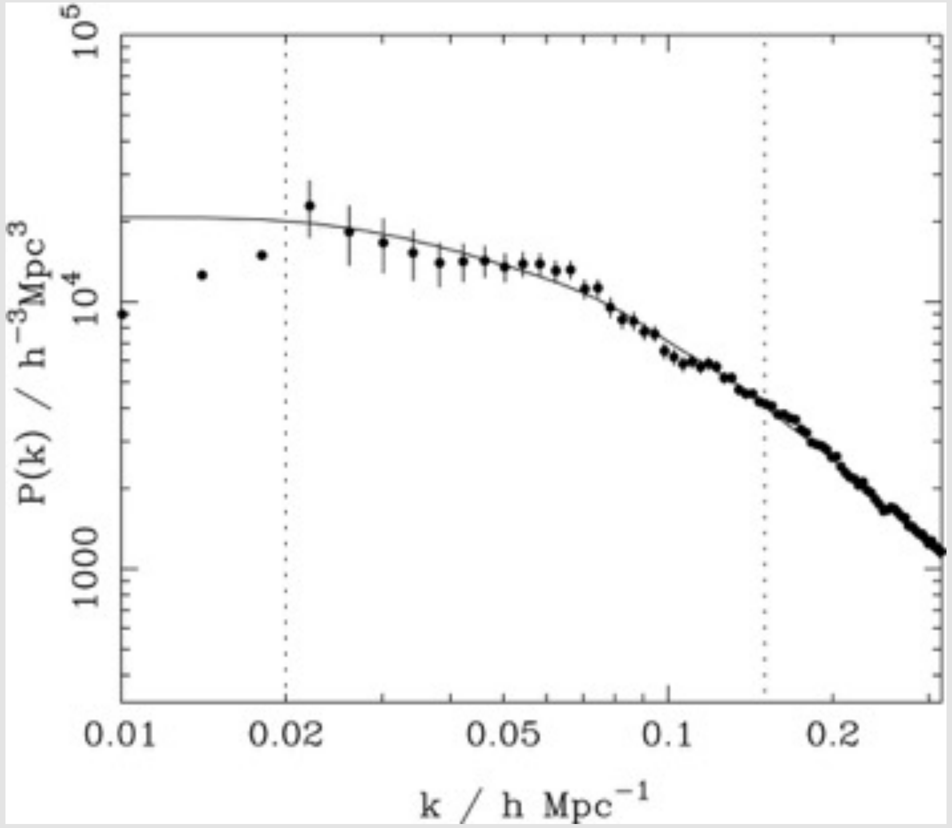
Idea: No binning in redshift





$z_3, z_4, z_5, z_6, \ldots$

Apply redshift weights



Redshift weighted power spectrum

Redshift Weighting

Idea: No binning in redshift

Motivation:

- Fisher predictions ~20% better than actual results
- Reduce edge effects due to binning
- Decrease computational effort for large data sets
- Splitting the survey volume decreases S/N at large scales at which non-Gaussianity has the biggest impact

FKP weights

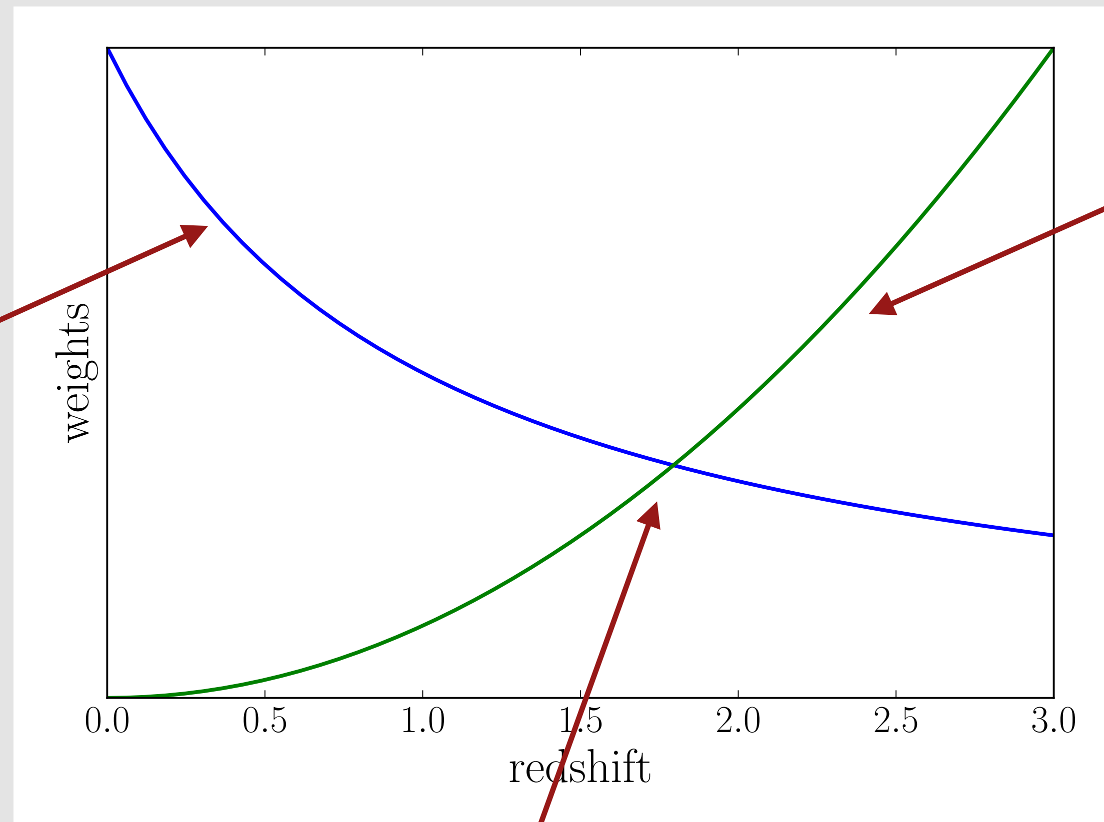
Feldman, Kaiser, Peacock (1994)

$$w_{\rm FKP}(z) = 1/\left[1 + n(z)P_0\right]$$

- Inverse variance weight $$C \propto \left(P + \frac{1}{\bar{n}}\right)^2 \frac{1}{dV}$$
- Balances shot noise and cosmic variance
- Improves signal to noise of 2-point statistics

“Sweet Spot”: Theory vs. Statistics

FKP: Balance comic variance and shot noise



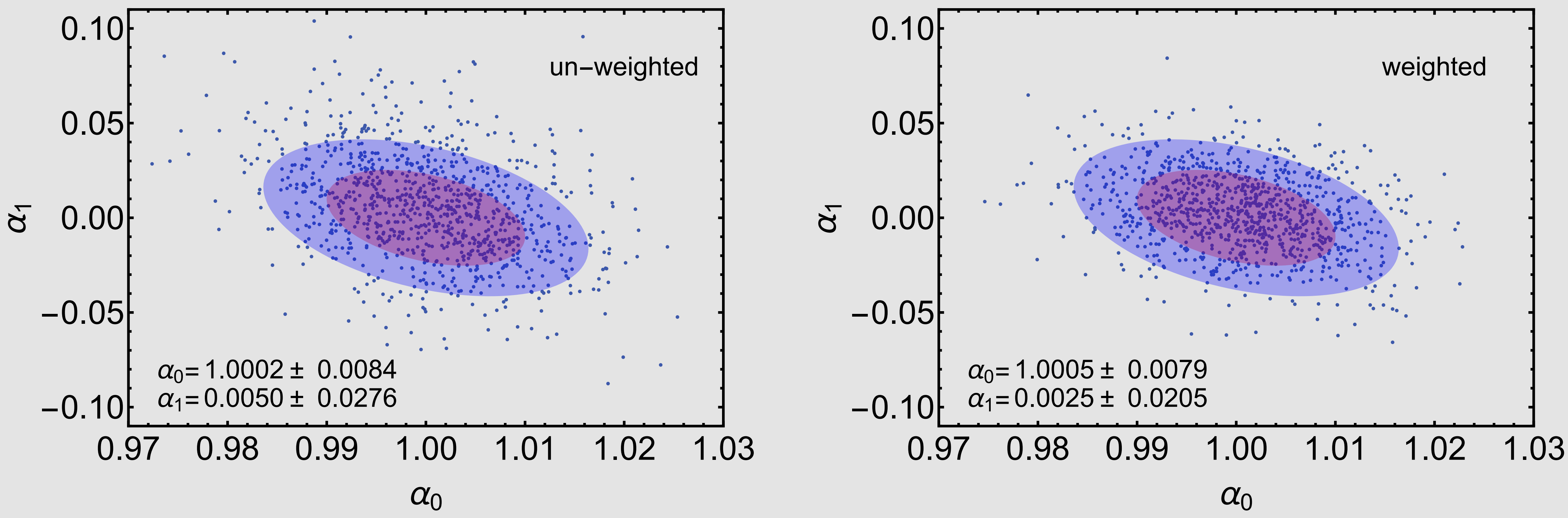
Physical theory

$$\mathbf{w} = w_{l,f_{\rm NL}} dW$$

Weights optimally balance statistical uncertainty and underlying redshift evolution of the theory

Redshift weights for BAO

Zhu et al. (2014, 2016)



Redshift weights improve BAO constraints

Redshift weights do NOT bias the results

Methodology

Minimise Fisher information

Mueller et al. (2017), Ruggeri et al. (2016), Zhu et al. (2014, 2016)

$$F_{ij} \equiv \left\langle \frac{\partial^2 \mathcal{L}}{\partial\theta_i \partial\theta_j} \right\rangle$$

$\mathcal{L}$ – Likelihood

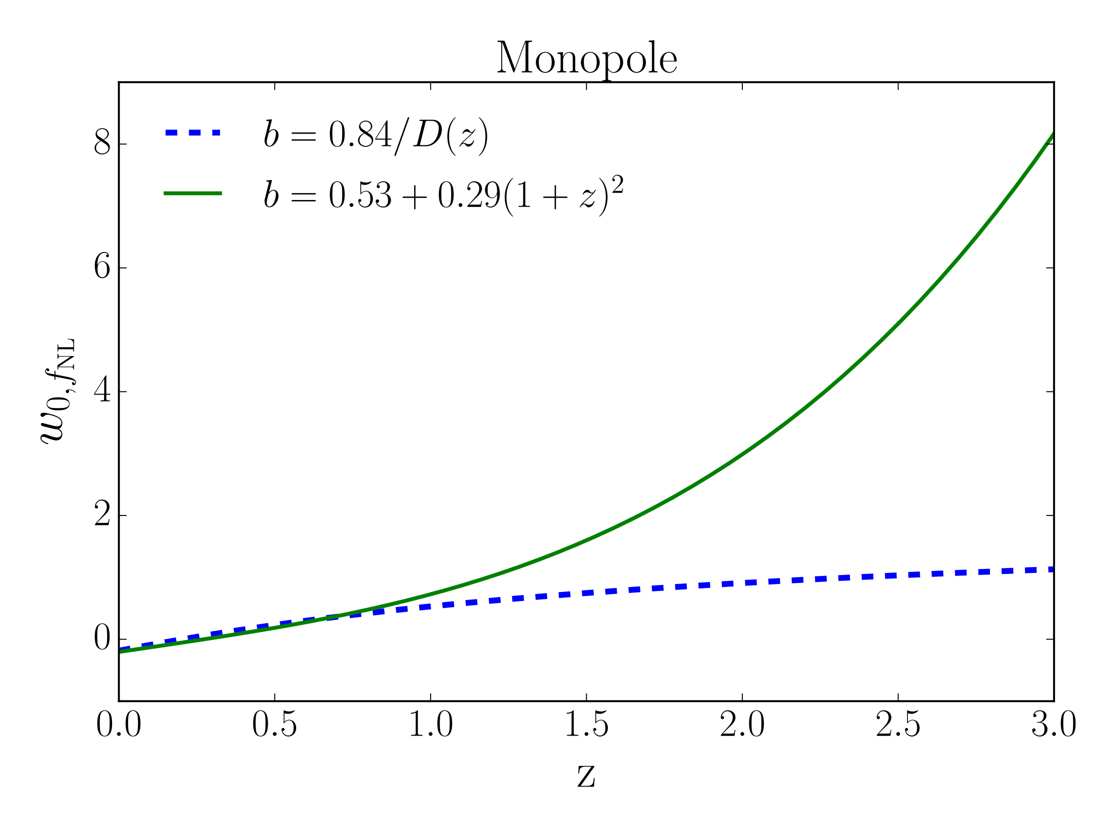
θ_i, θ_j – parameters

Redshift weights:

$$\mathbf{w}^T = C^{-1}\mu_{,i}.$$

Depends on the tracer

More total weight is given to galaxies at high redshifts



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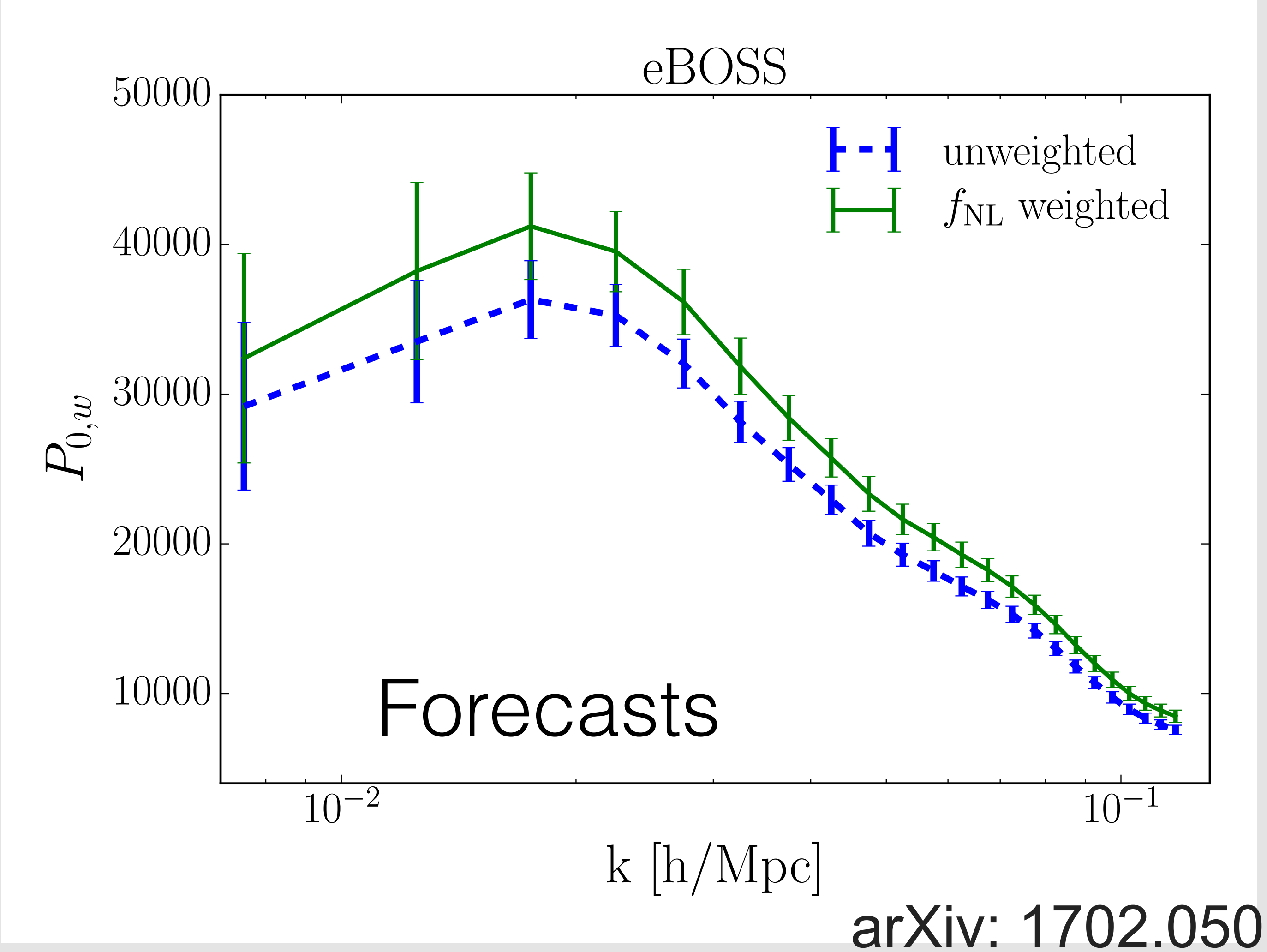
Redshift weighted power spectrum

$$P_{l,w}(k) \equiv \frac{1}{N_i} \int d\mathcal{W}(z) w_{l,i}(z) P_l(k,z)$$



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Feldman, Kaiser & Peacock:

$$d\mathcal{W} \equiv C^{-1} = \left(\frac{\bar{n}}{\bar{n}P+1}\right)^2 dV$$

Normalisation:

$$N_i = \int w_i \; d\mathcal{W}$$

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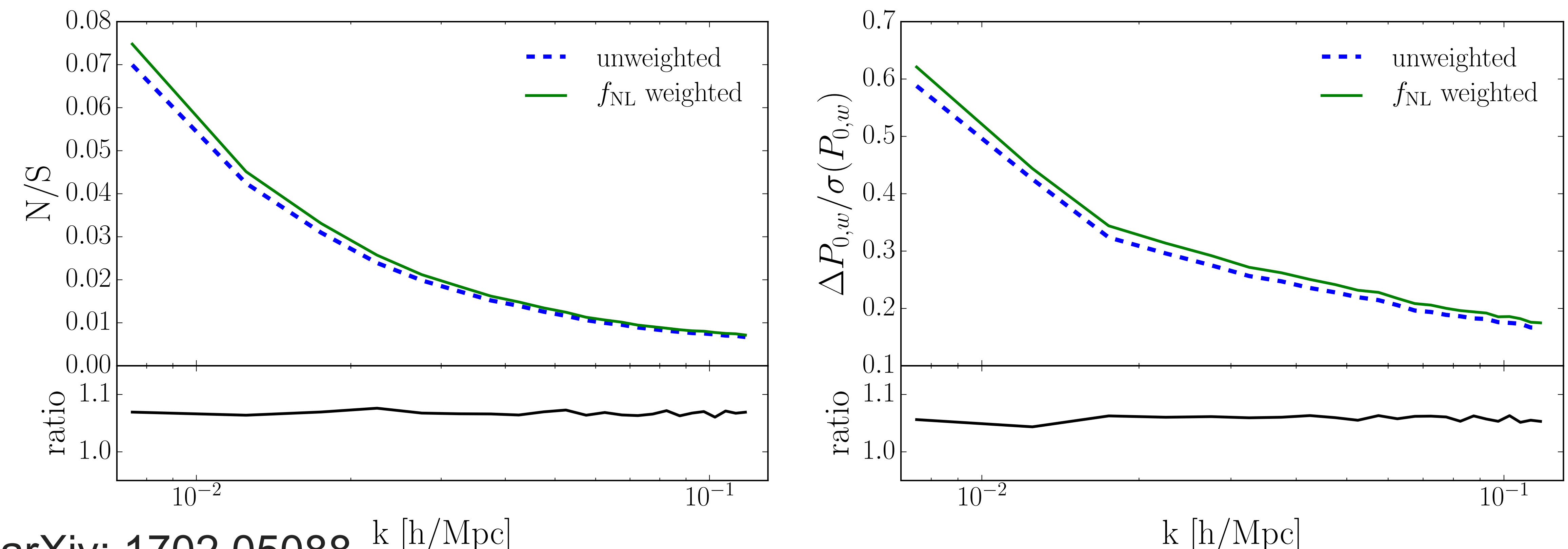
“Sweet Spot”: Theory vs. Statistics



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Statistical noise on the weighted power spectrum is larger

But: It is more sensitive to f_NL, i.e more capable to constrain PNG

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Measurement improvement

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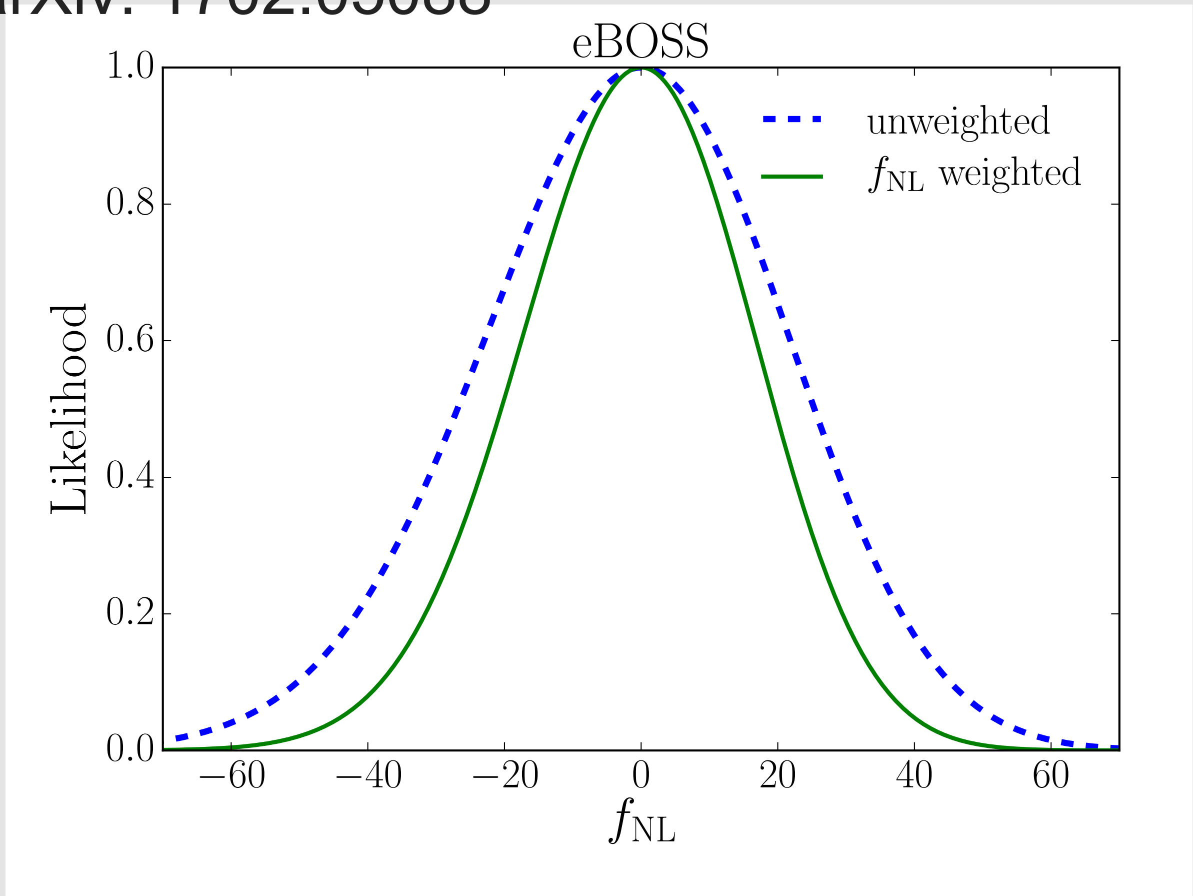


30-40% improvement for eBOSS

Depends on

Redshift range

Bias evolution

+ Improved constraints

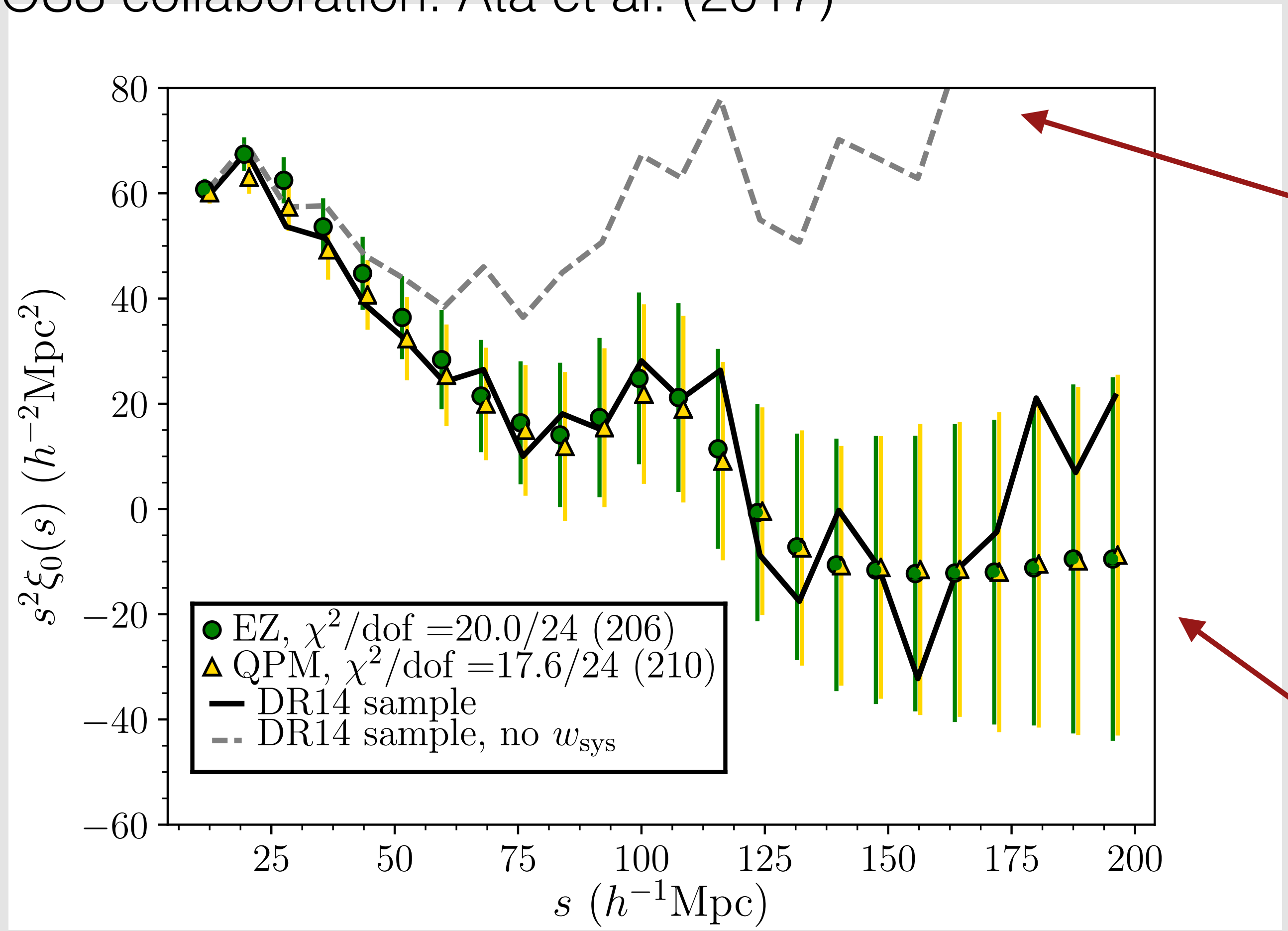
+ Computationally more feasible for large data sets

— Weights are model dependent

— Loss of generality

Problem: Systematics

eBOSS collaboration: Ata et al. (2017)



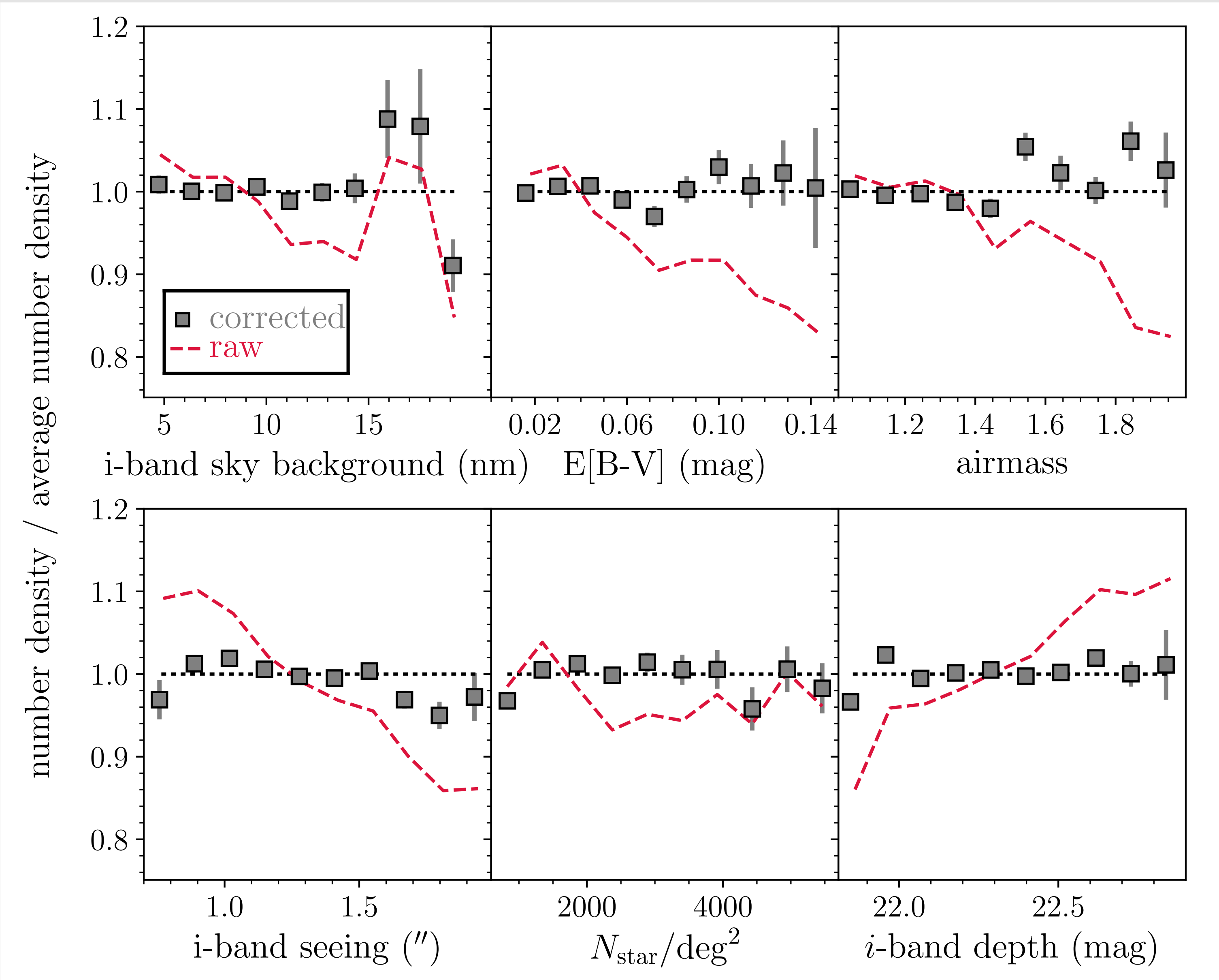
not accounting for systematics

with systematic treatment

Systematic effects are strongly impacting large scales

eBOSS systematics: 'Attack approach'

eBOSS collaboration: Ata et al. (2017)



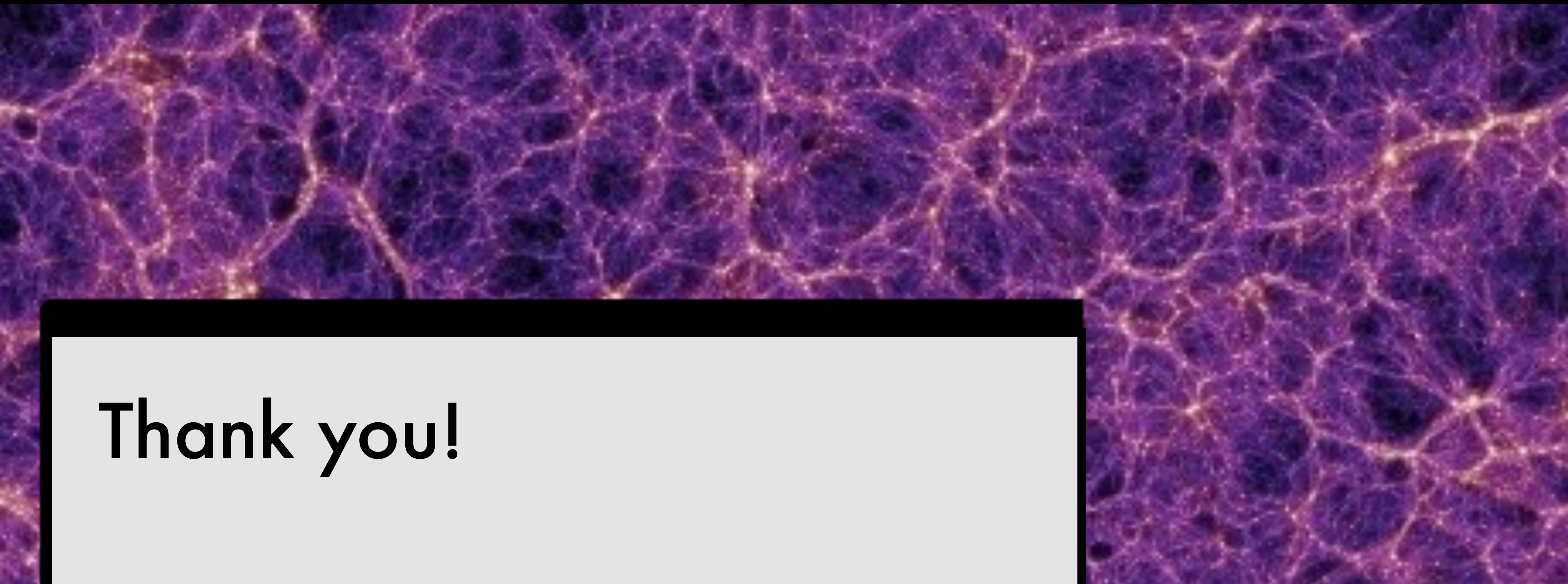
linear fit ~ 1/w

Systematics can have scale dependent effects on large scales

Summary

- First eBOSS results are out!
- Non-Gaussianity can be constrained using the scale dependent halo bias
- Redshift weighting technique: Apply weights to take the underlying theory into consideration
- Systematic effects need to be studied carefully for fNL measurements

Thank you!



Thank you!

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Work in progress…

Non-Gaussianity measurement from eBOSS

Redshift space distortion measurement from eBOSS using redshift weights (Rossana Ruggeri et. al)

Accessing systematic effects using mode projection (Benedict Kalus et. al)