PNG from eBOSS DR16

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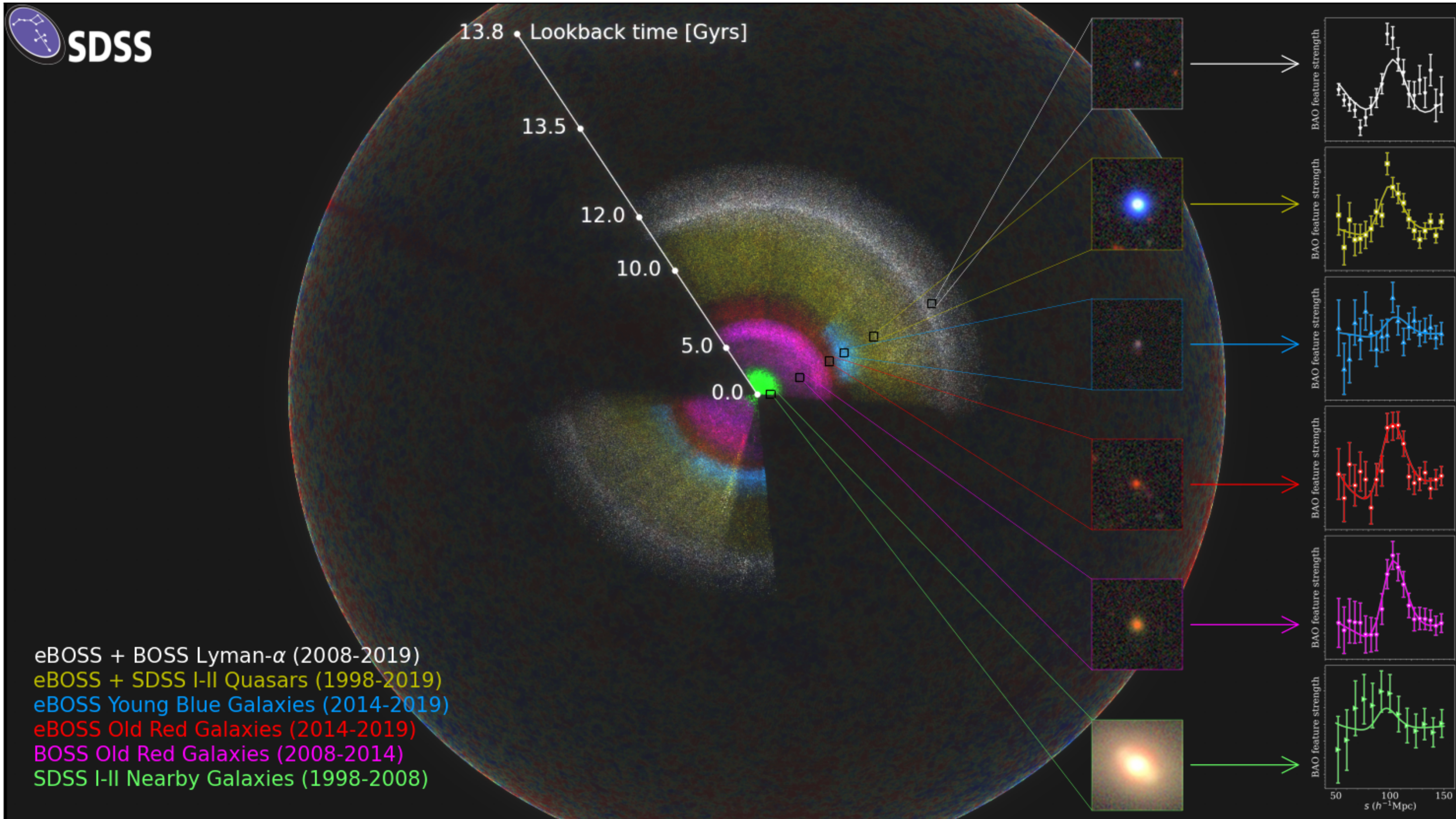
Mueller et al. 2021 arXiv:2106.13725
Rezaie et al. 2021 arXiv:2106.13724

In collaboration with Mehdi Rezaie, Ashley Ross, Hee-Jong Seo, Will Percival

Overview

- eBOSS DR16 QSO data set
- Scale dependent halo bias
- Results
- Methods
- Challenges
- More challenges
- Comments

20 years of SDSS redshift surveys



Anand Raichoor (EPFL), Ashley Ross (Ohio State University) and the SDSS Collaboration.

Sloan Digital Sky Survey Telescope

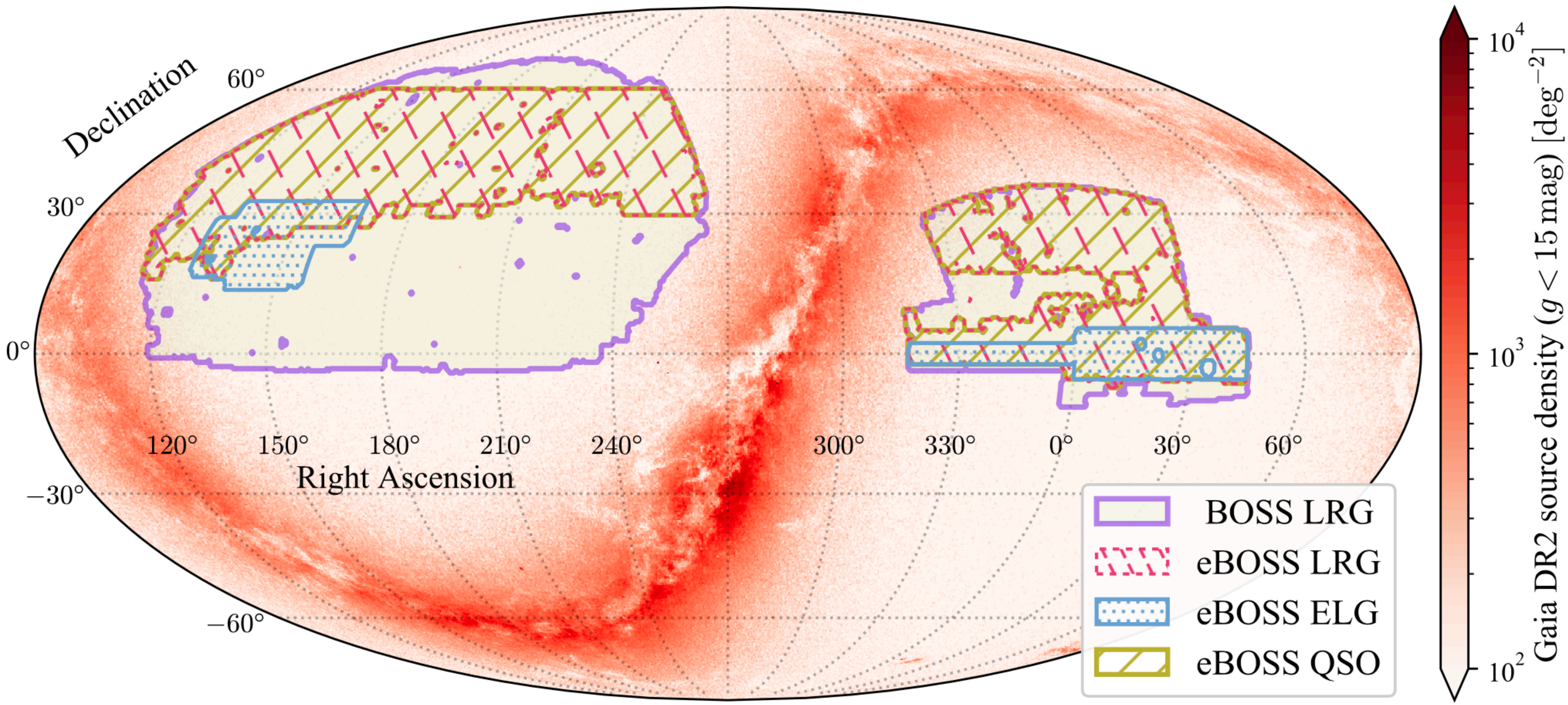
Apache Point Observatory, New Mexico, USA

(e)BOSS

(extended) Baryon Oscillation Spectroscopic Survey

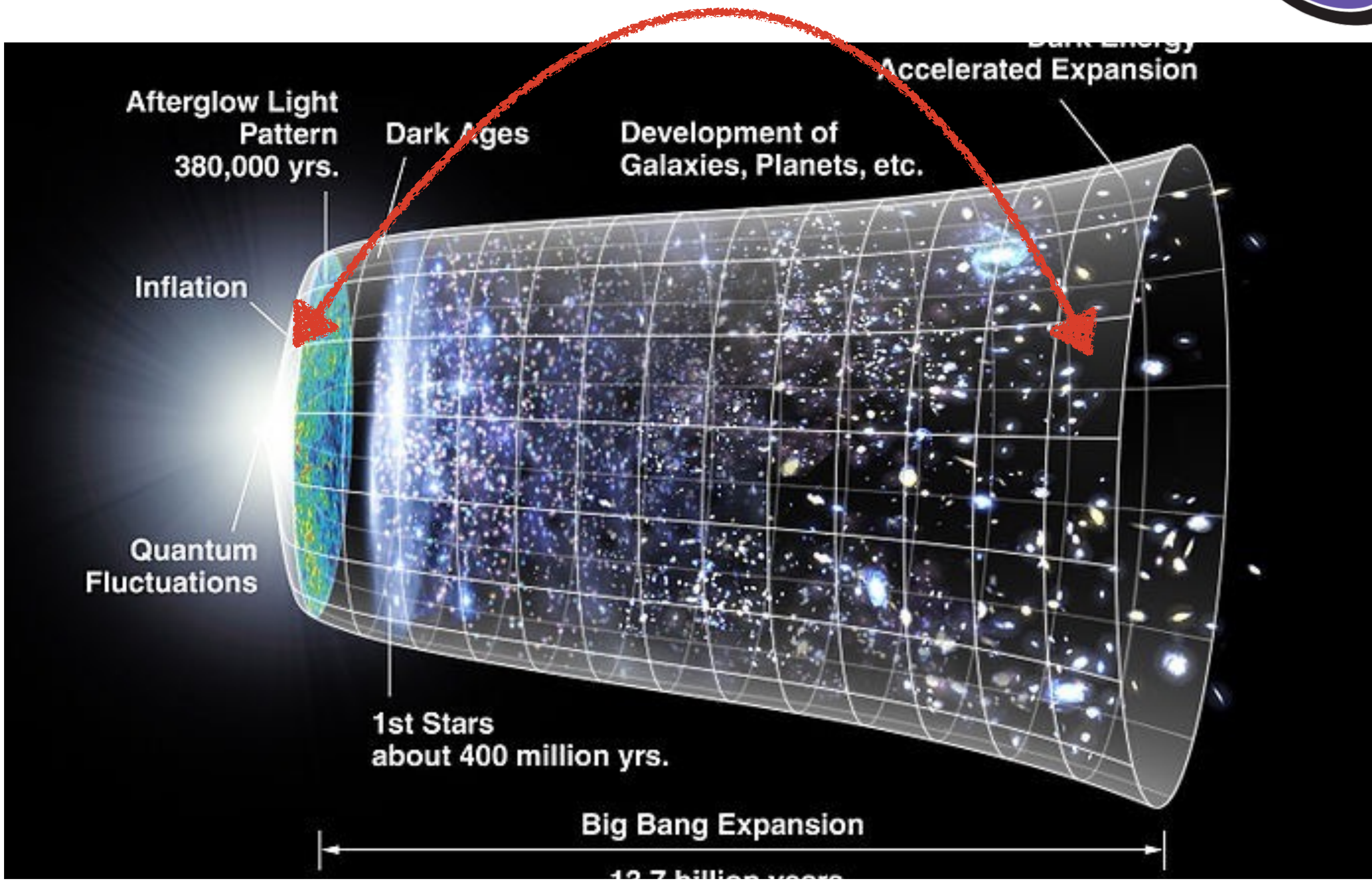
Dawson et al. 2016

eBOSS Footprint



(Figure from C. Zhao et al. 2020)

Window to the early universe



More than BAO and RSD….

Primordial Non-Gaussianity (PNG) can distinguish between physically distinct models of inflation.

Primordial non-Gaussianity

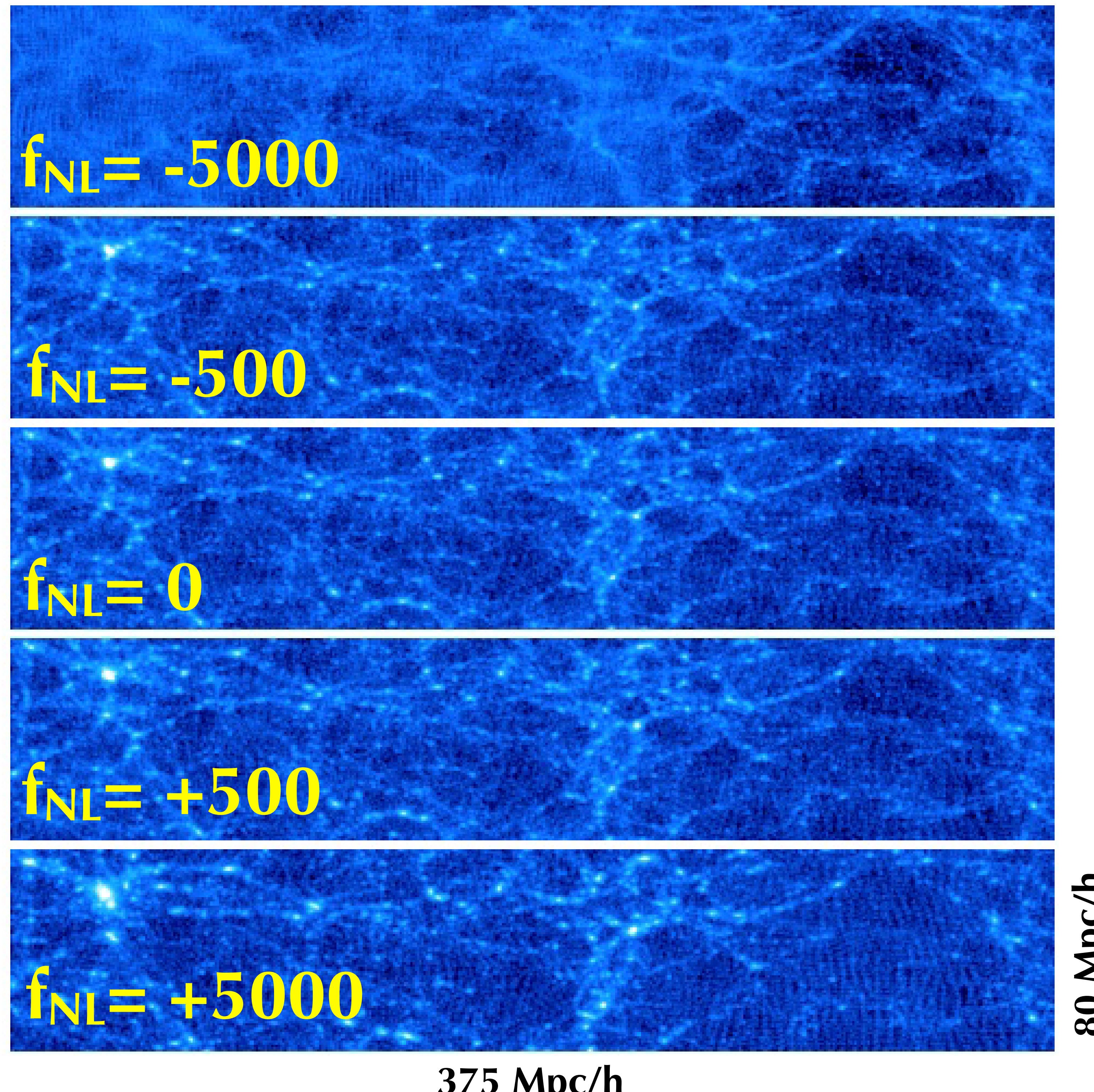
Dalal et al, 2008

Primordial non-Gaussianity: predicted in multi-field inflationary models (+ ones with interactions)

Planck constrains PNG supremely well ($f_{NL} = -0.9 \pm 5.1$)

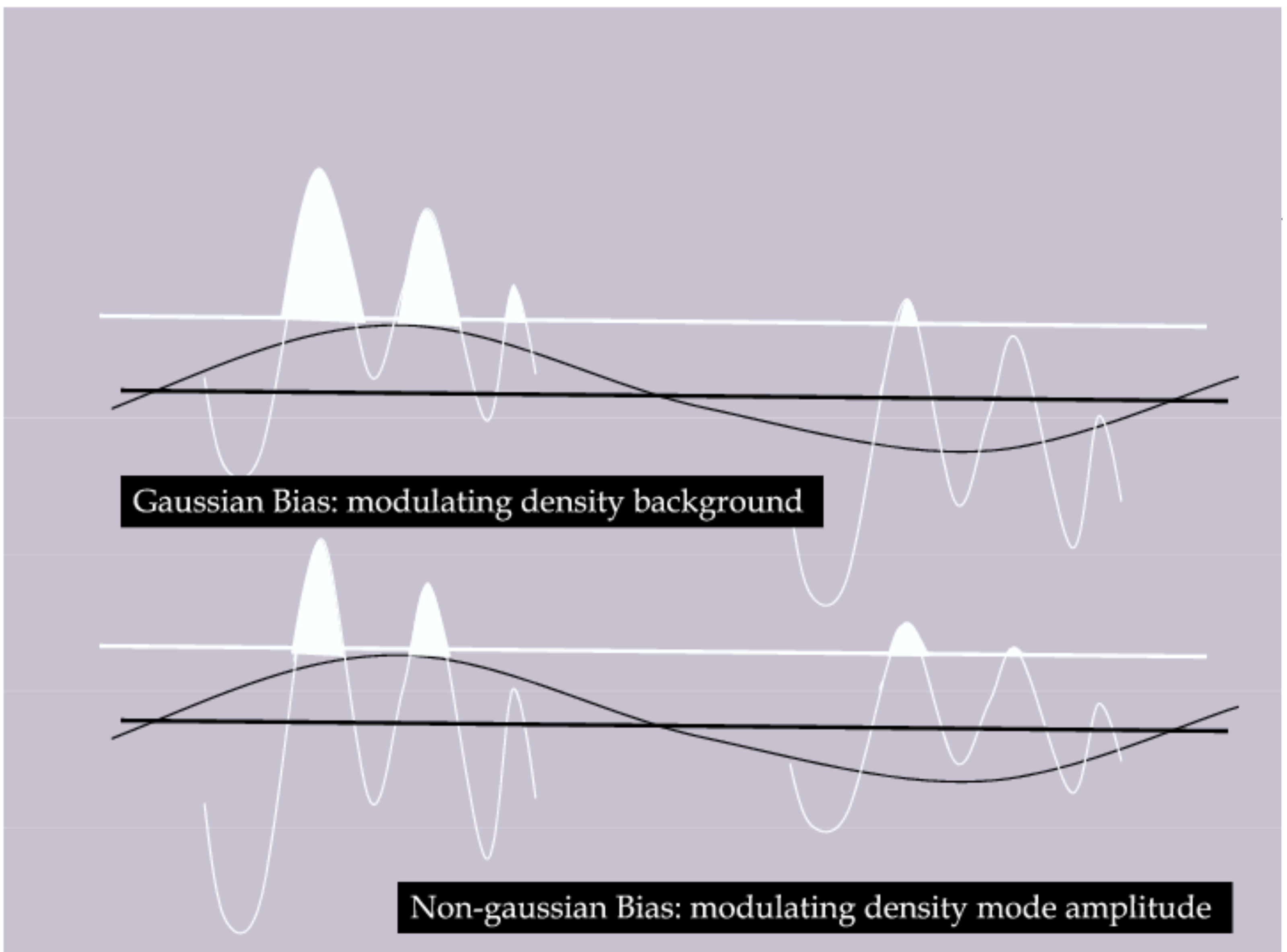
Future improvement will come from galaxy LSS

$$\Phi = \phi + f_{\rm NL}\phi^2$$



Scale dependent bias

Primordial non-Gaussianity leads to mode coupling



$$\text{bias} = \frac{\text{clustering of galaxies}}{\text{clustering of dark matter}}$$

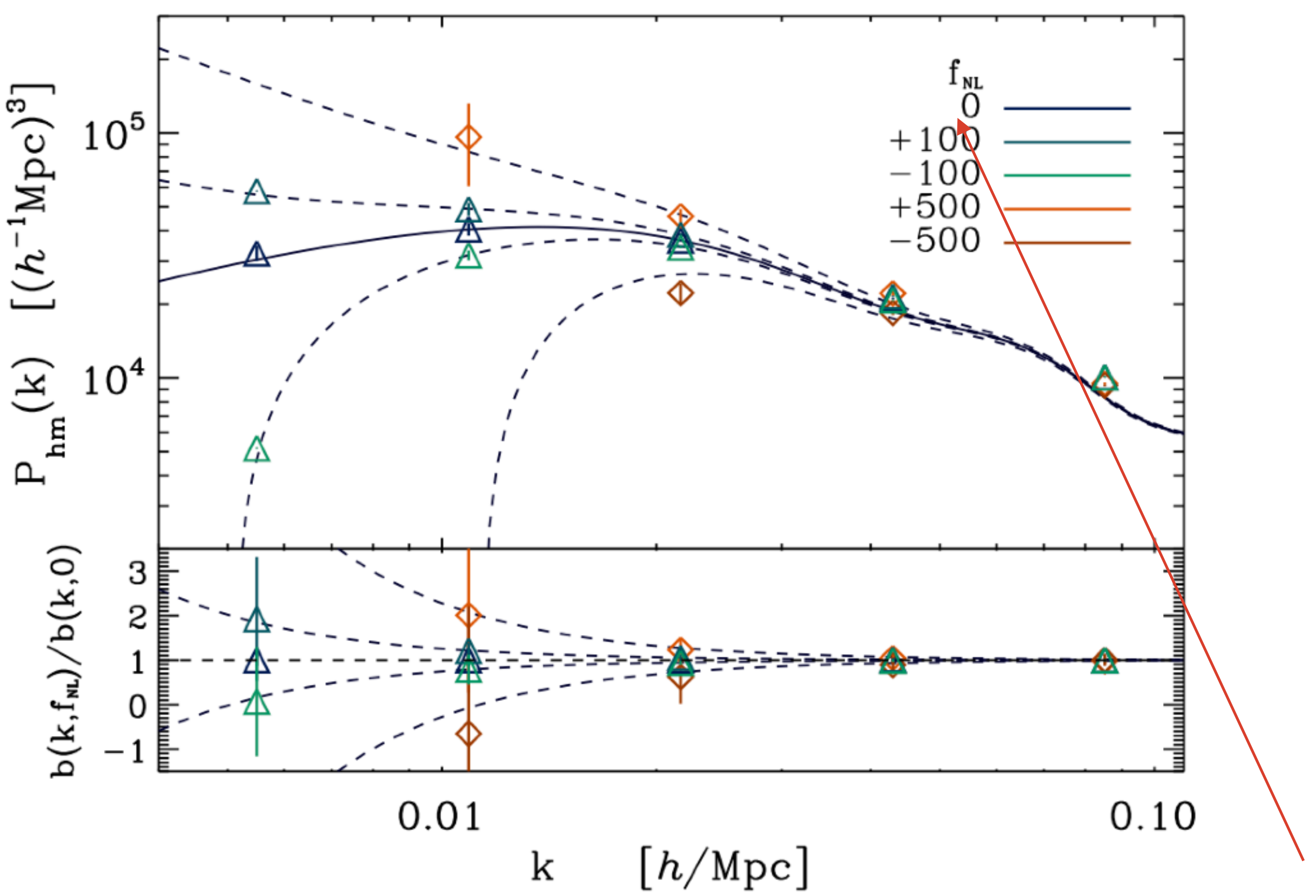
$$\Delta b(k) \propto \frac{f_{NL}}{k^2}$$

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

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

Primordial non-Gaussianity

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



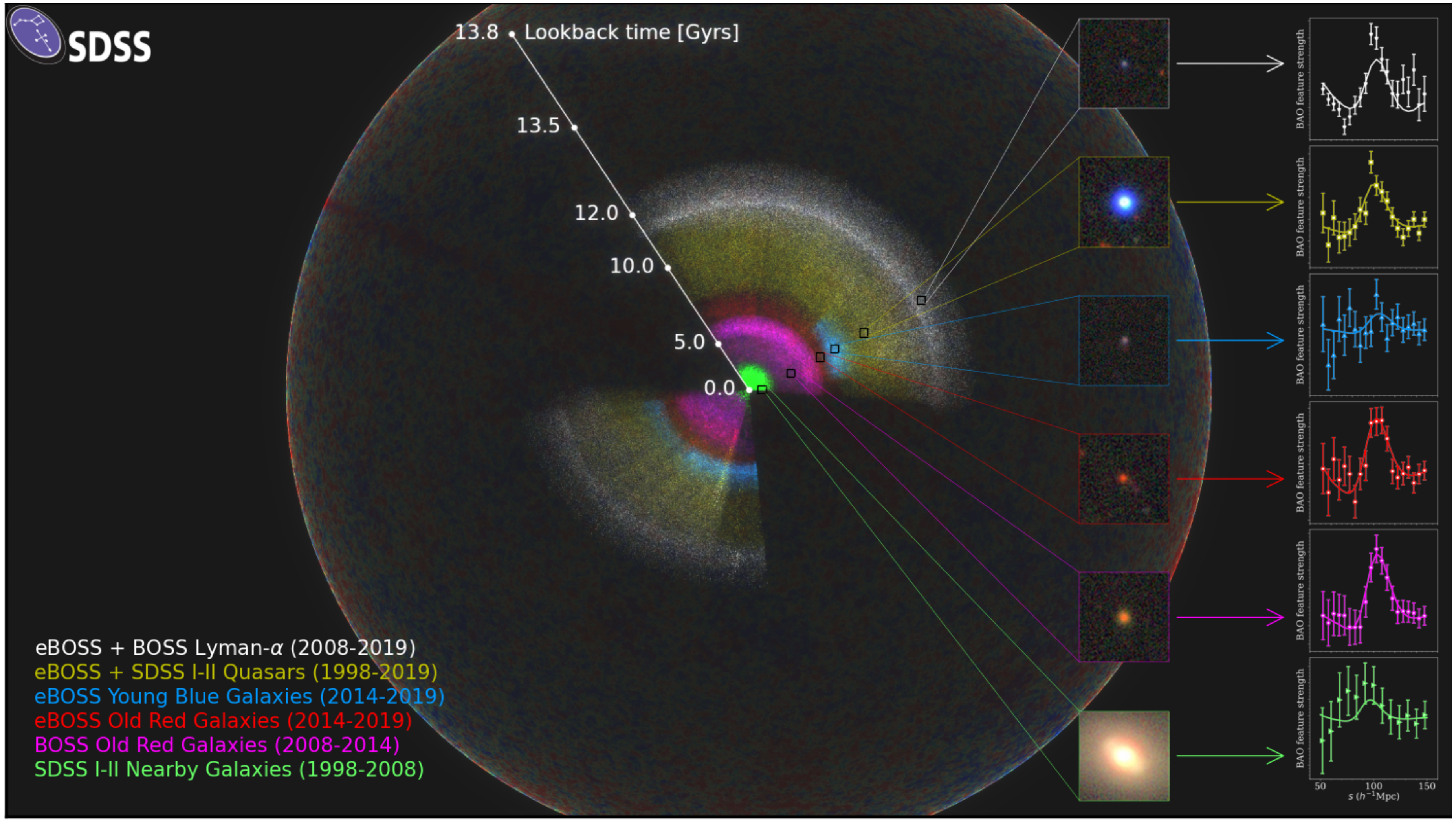
- Very sensitive at large scales
- Constrain Inflation by measuring the galaxy power spectrum at large scales

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

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

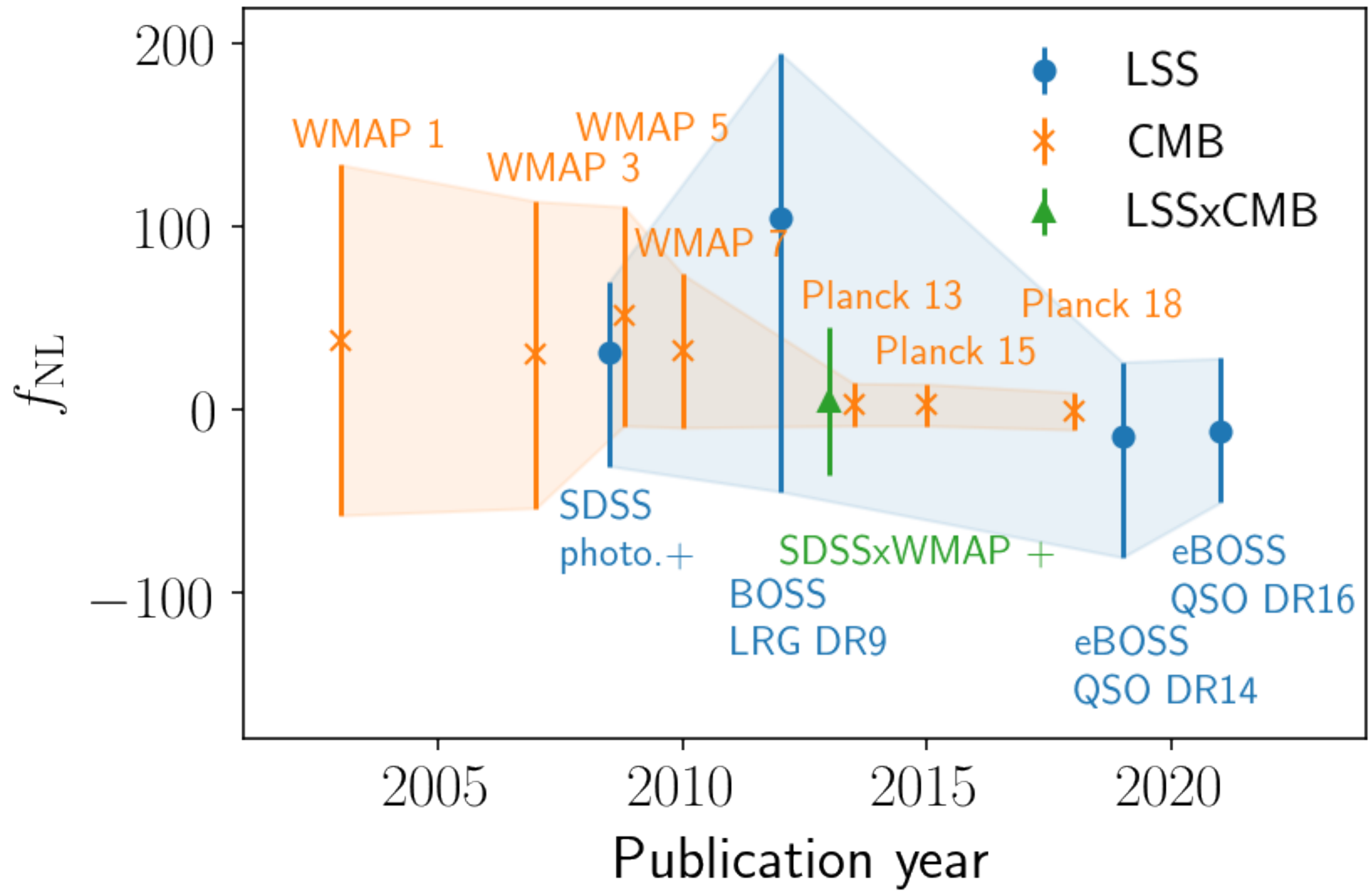
fNL: Parameter to quantity amplitude of primordial non-Gaussianity

Why eBOSS QSO?



$$b_{\text{total}} = b + \Delta b$$
$$\Delta b(k) \propto \frac{f_{NL}}{k^2}$$

- Large redshift range 0.8<z<2.2
- Largest volume survey with spectroscopic redshifts
- Best S/N at the larges scales

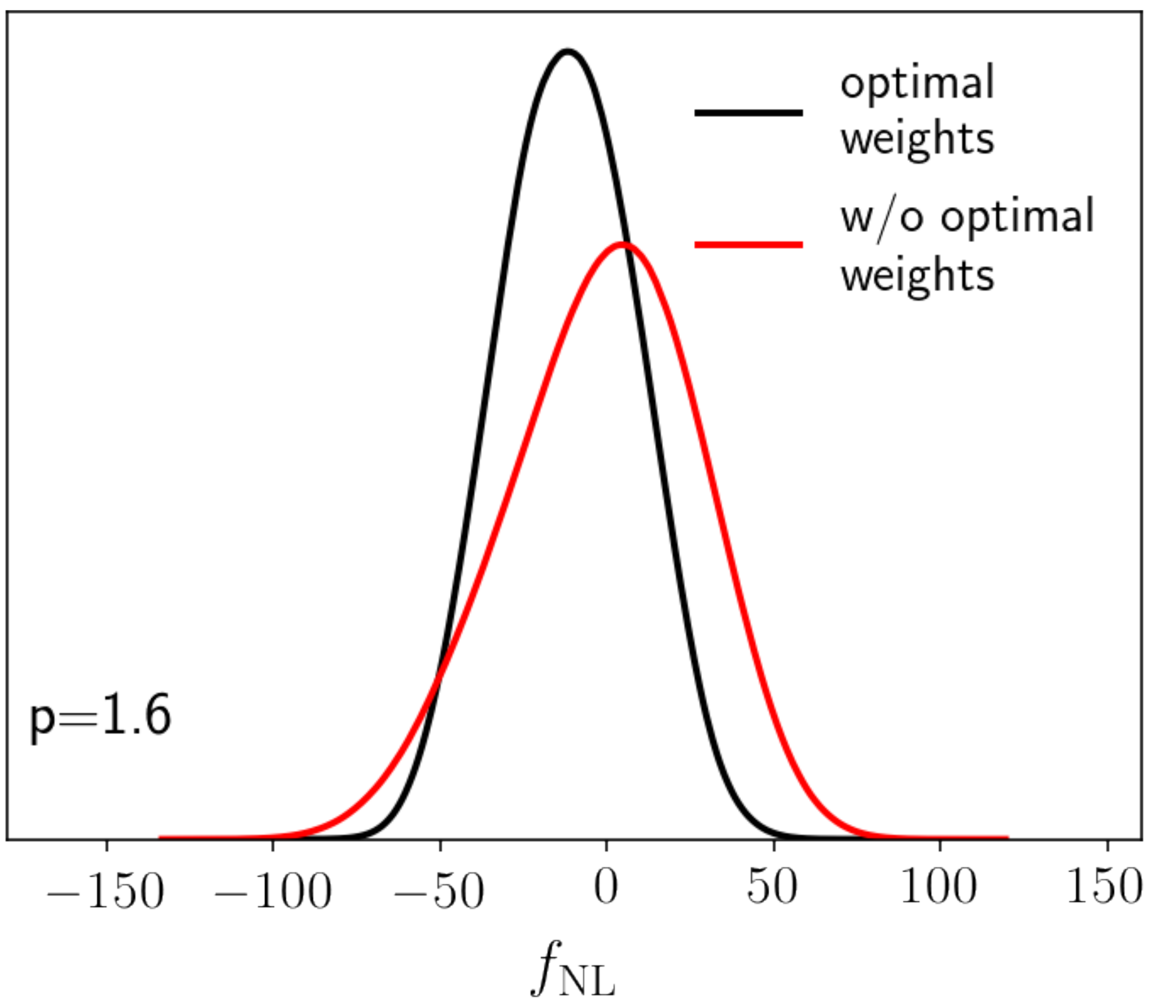


$$f_{\rm NL} = -12 \pm 21$$ Mueller et al 2021

Tightest constraints from LSS so far

Results I

Neural Network systematic treatment



Mueller et al 2021

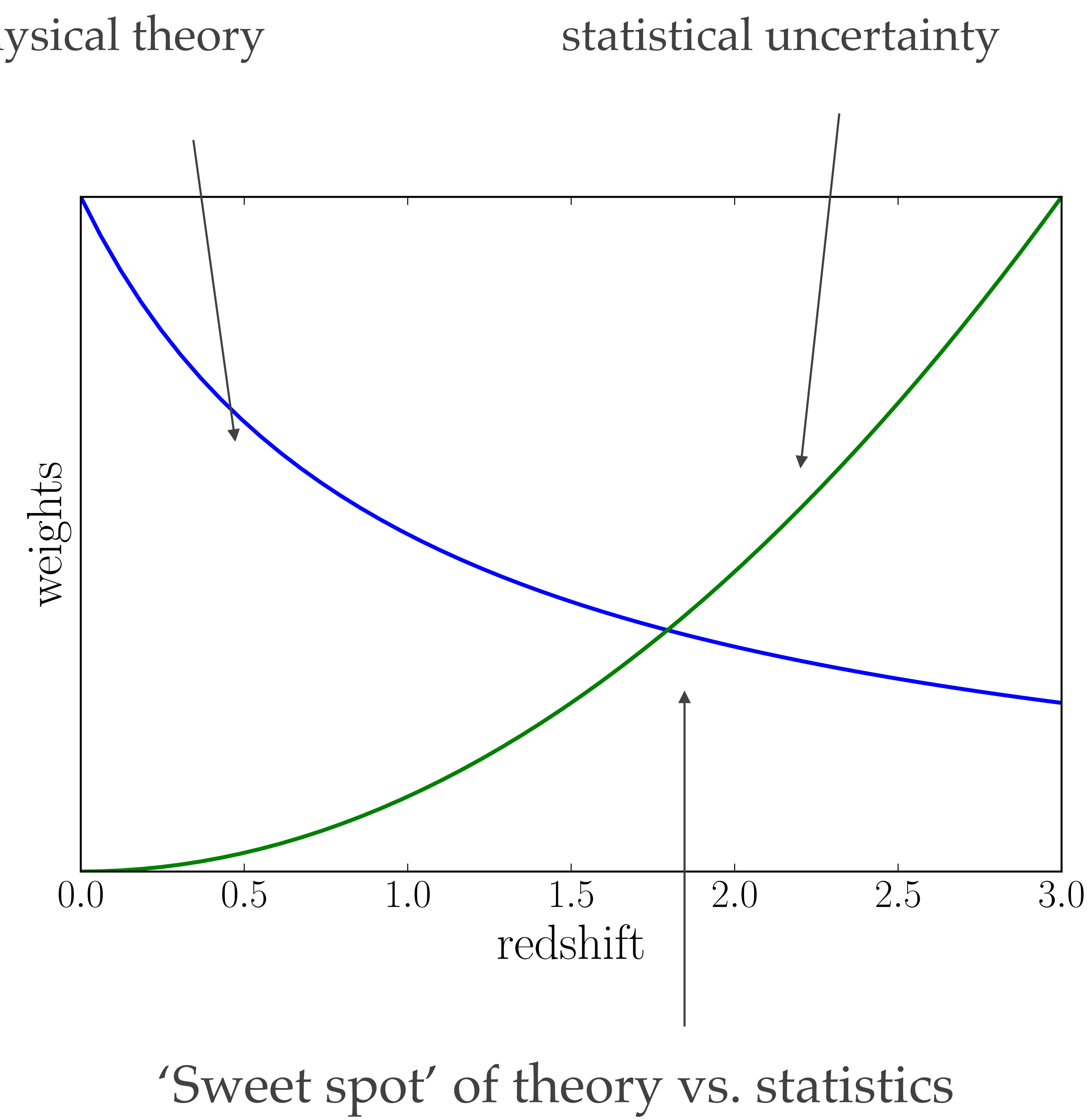
$$f_{\rm NL} = -12 \pm 21$$

$$(f_{\rm NL} = -1^{+32}_{-26})$$

Optimise galaxy clustering analysis

Redshift weighting

- The underlying physical theory is evolving with redshift
- Redshift weights optimally balance the statistical uncertainty (n(z)) and redshift evolution of the theory you want to constrain
- Reduce uncertainty on measured cosmological parameters



$$w_{\text{tot}} = w_{\text{FKP}} \times w_z$$

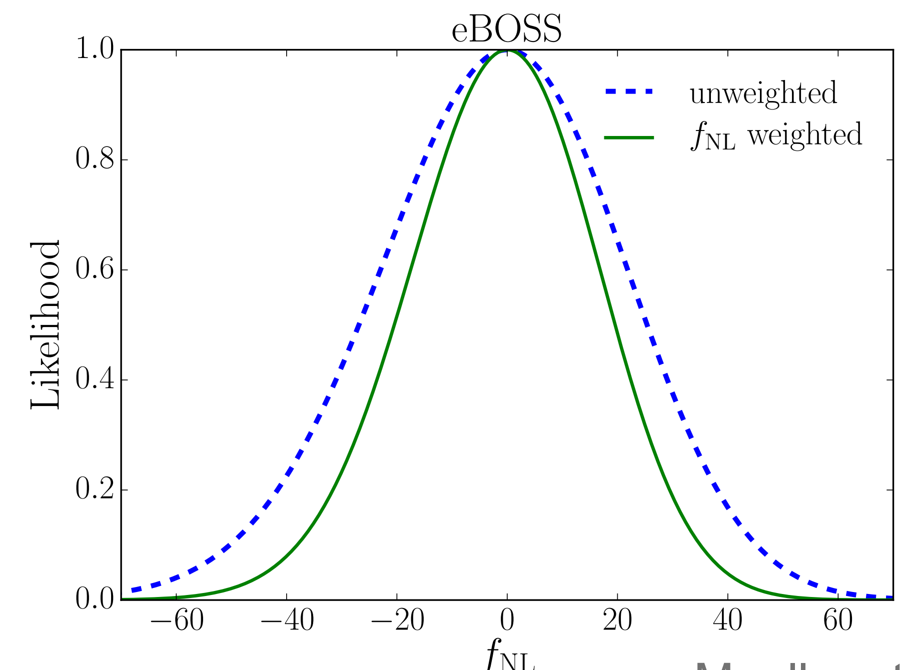
It works!

Forecasts

Measurement improvements

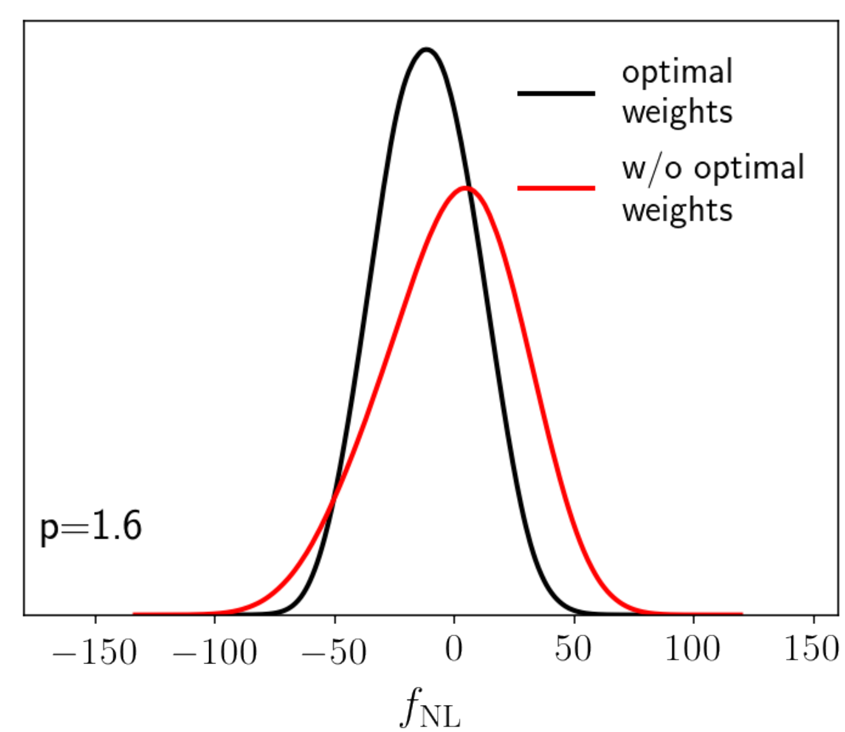
- ~30% improvement on fNL constraints
- Improvement depends on redshift range and bias model
- Computationally more feasible for large data sets
- Weights are model dependent, i.e. optimal for a certain theory to be measured

Forecasts:



Mueller et al. 2017

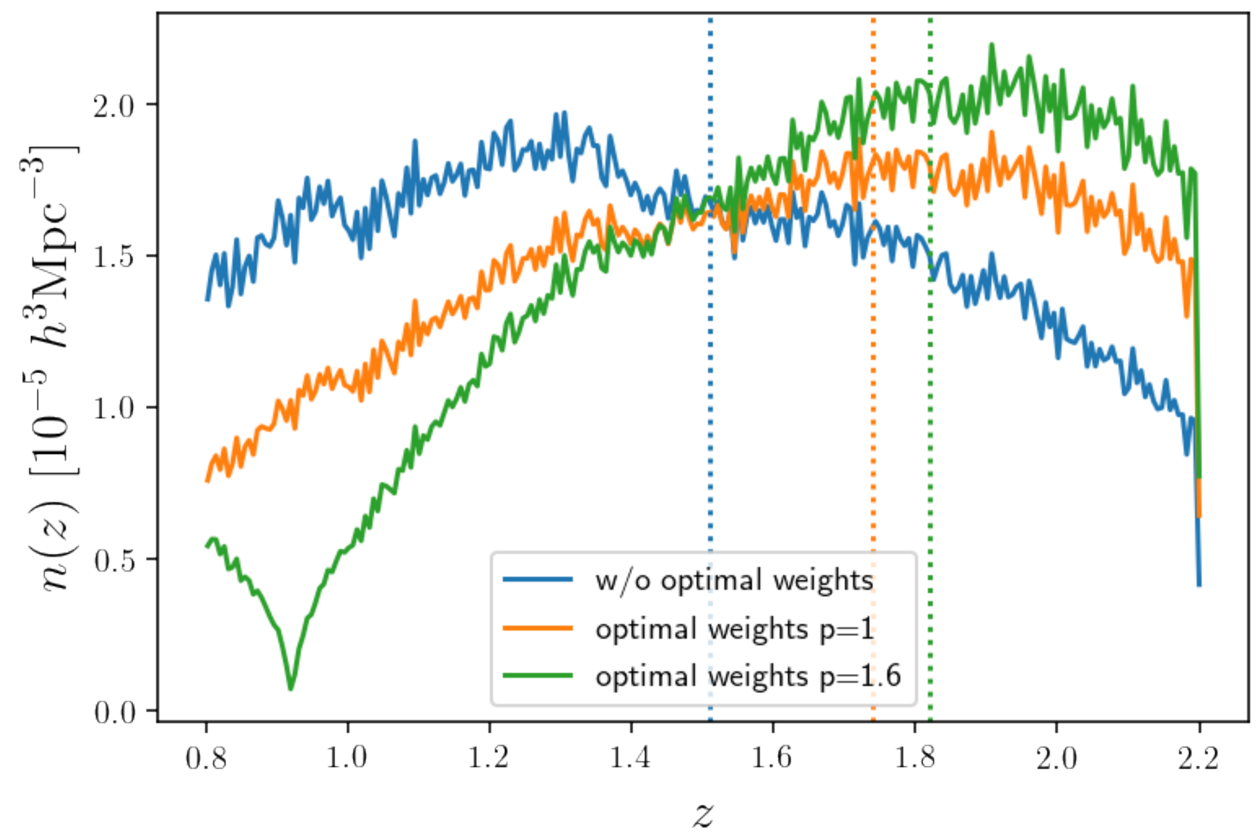
Data:



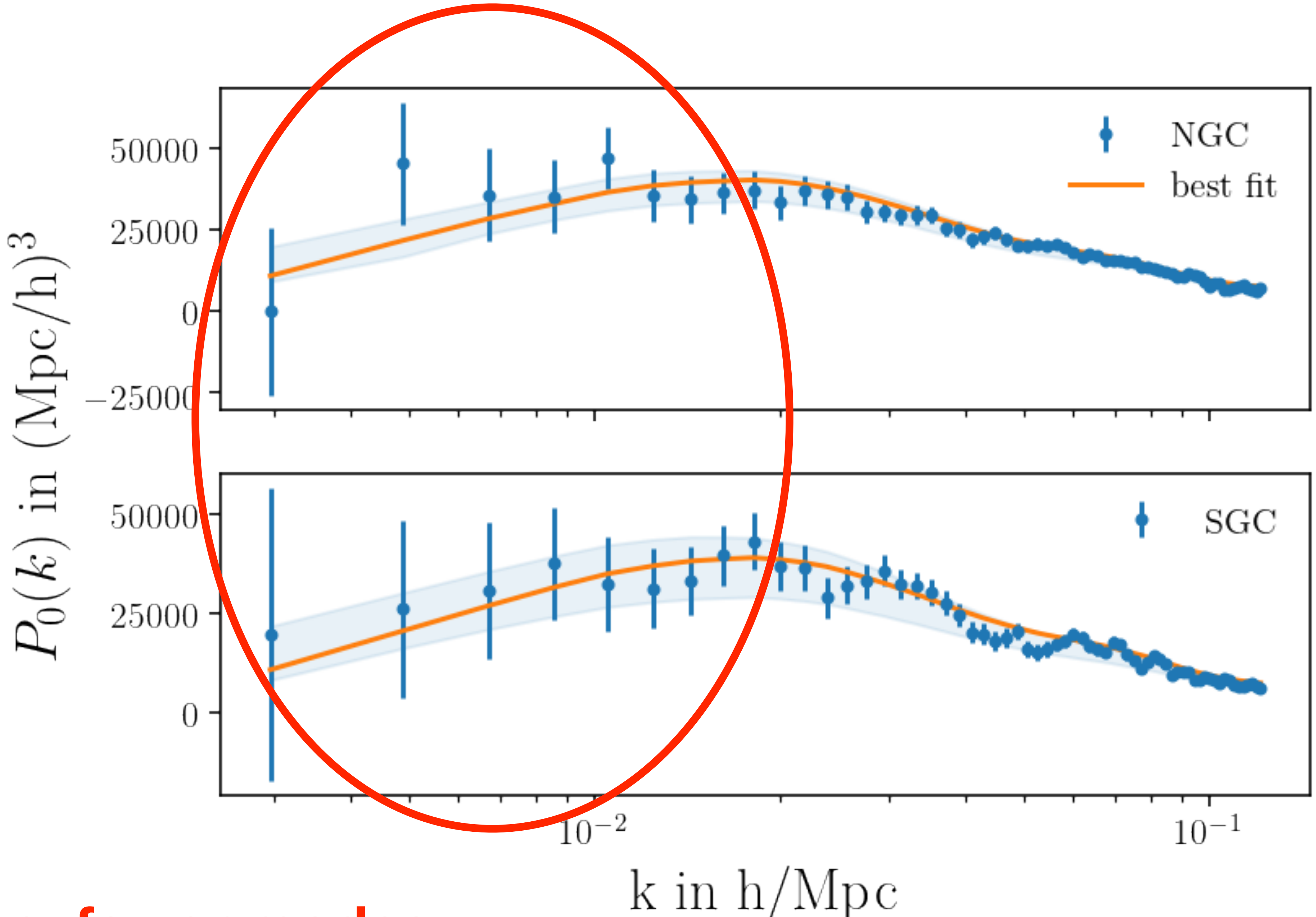
Redshift distribution

Optimal Weights

The optimal weights shift the effective redshift from
z=1.51 to z=1.82 (p=1.6) and z=1.74 (p=1.0)

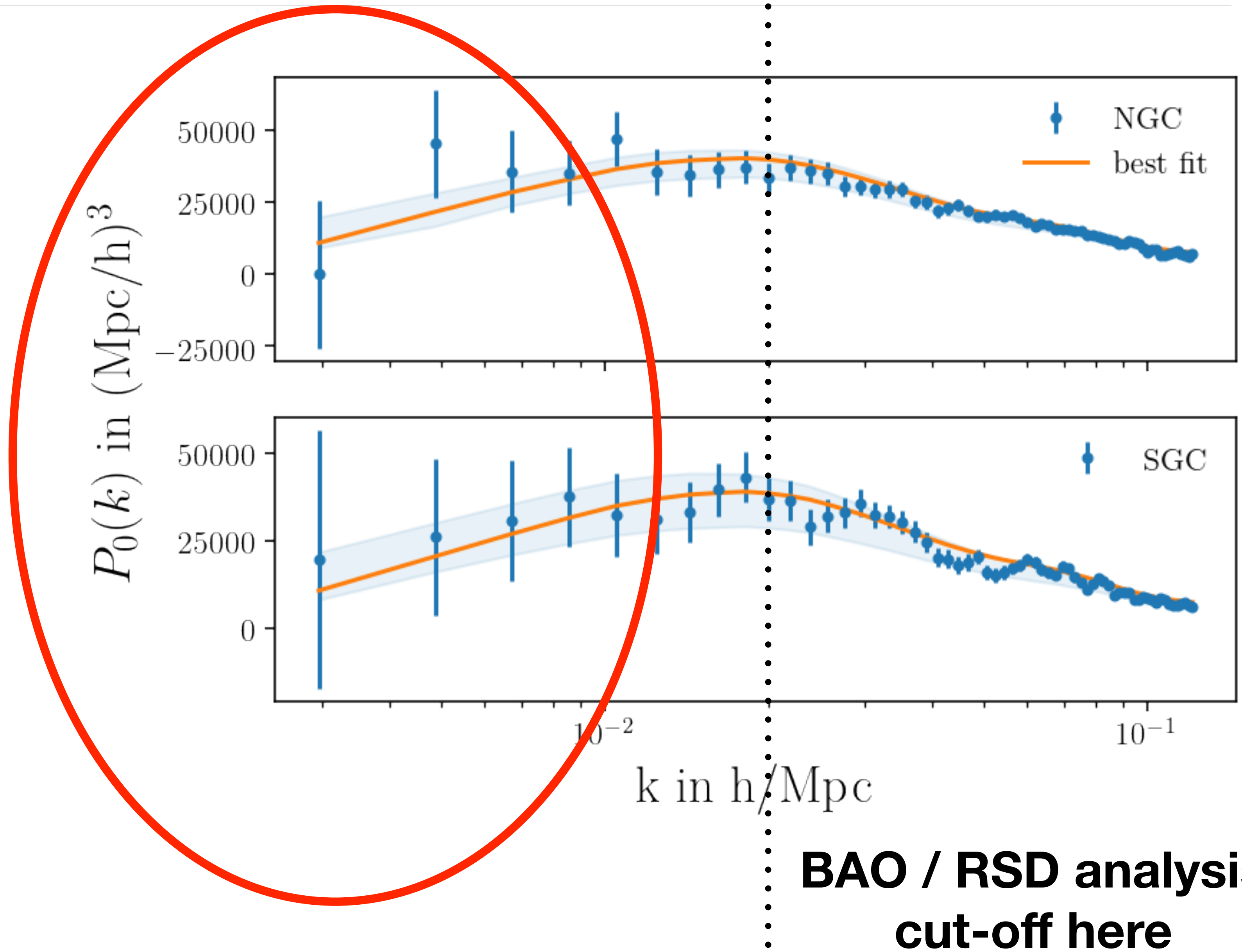


Challenge I: Systematics



A lot of noise, fewer modes

Challenge I: Systematics



BAO / RSD analysis cut-off here

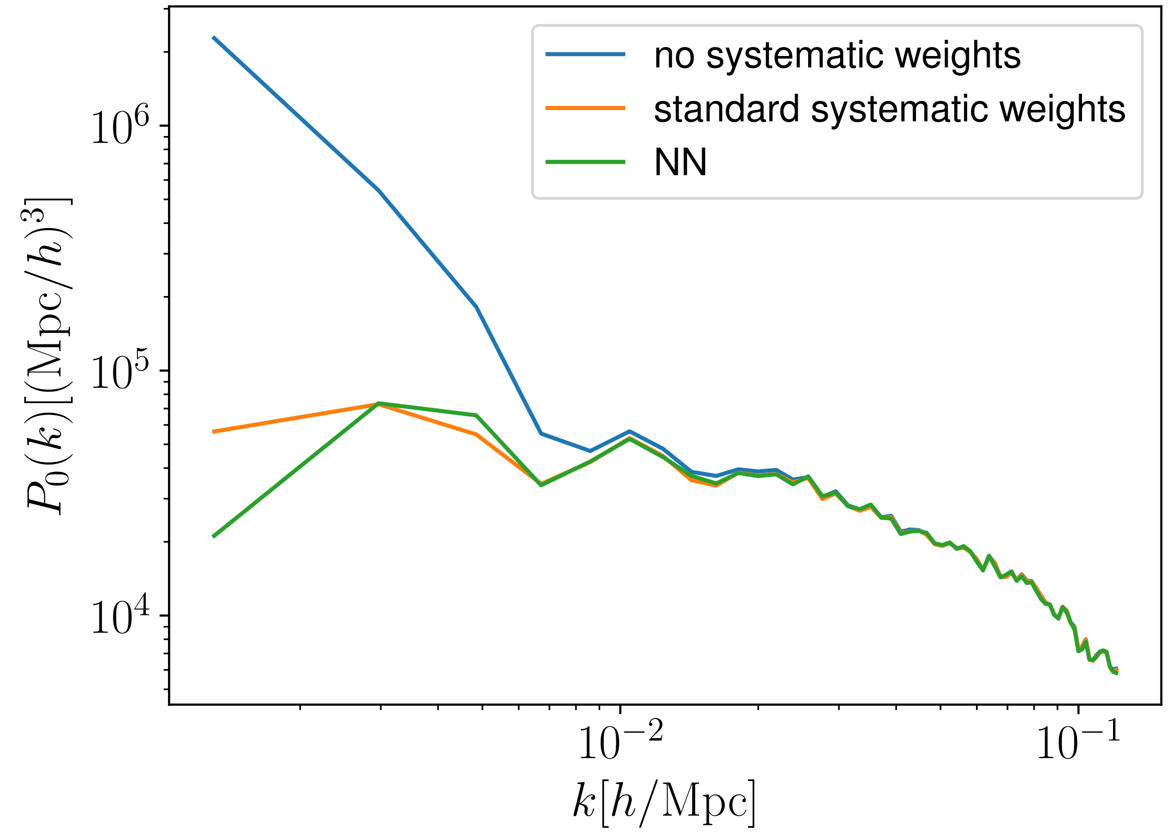
Side note:

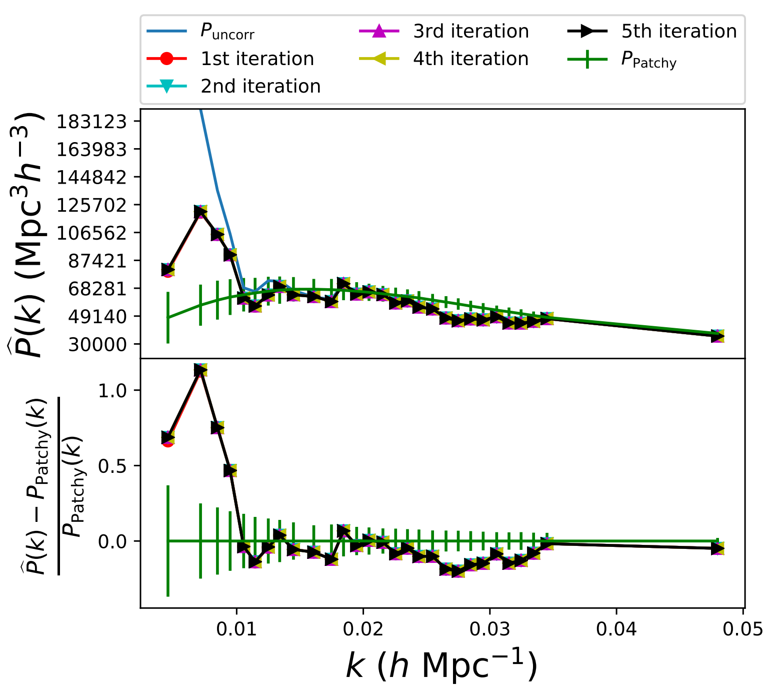
Largest scales ever used in any LSS analysis

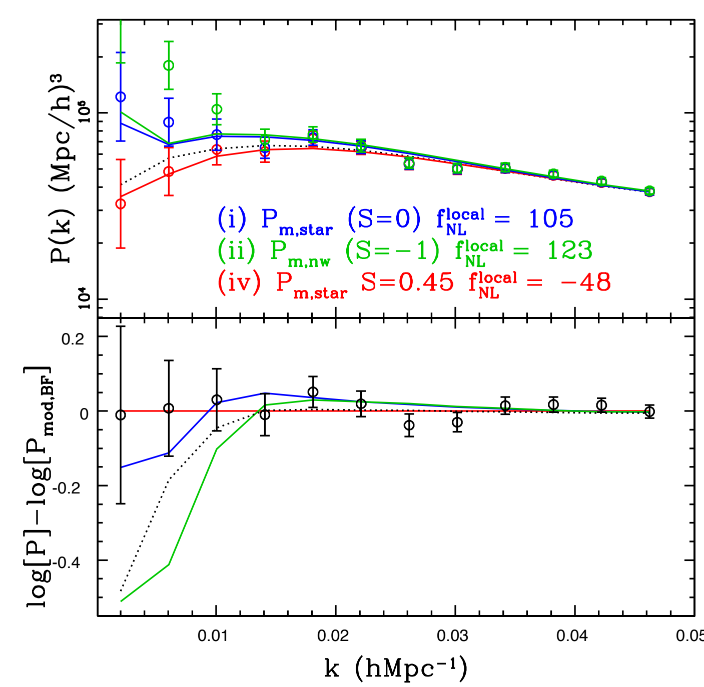
Imaging systematics

Large scales are dominated by systematics

eBOSS QSO







BOSS DR12 LRGs see Kalus et al. 2018

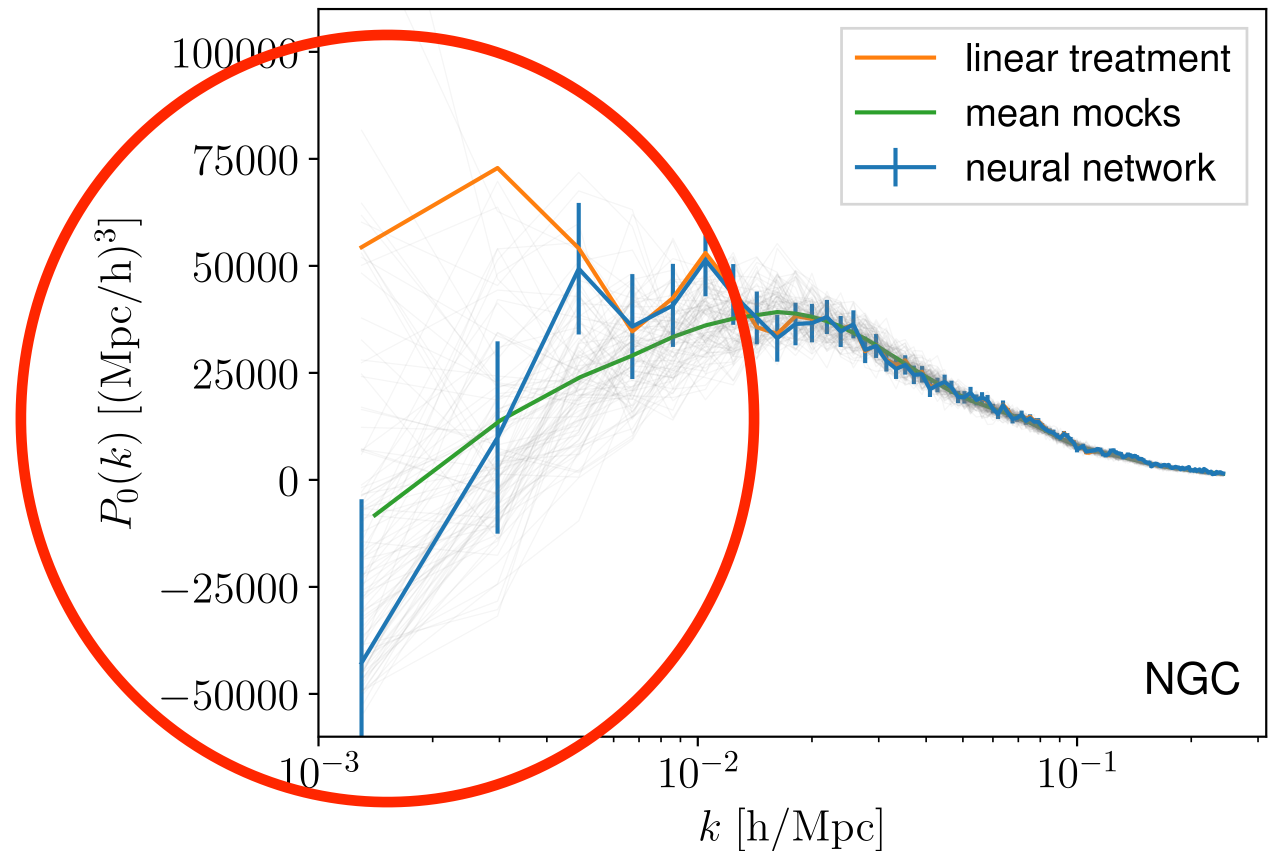
BOSS DR9 LRGs see Ross et al. 2012

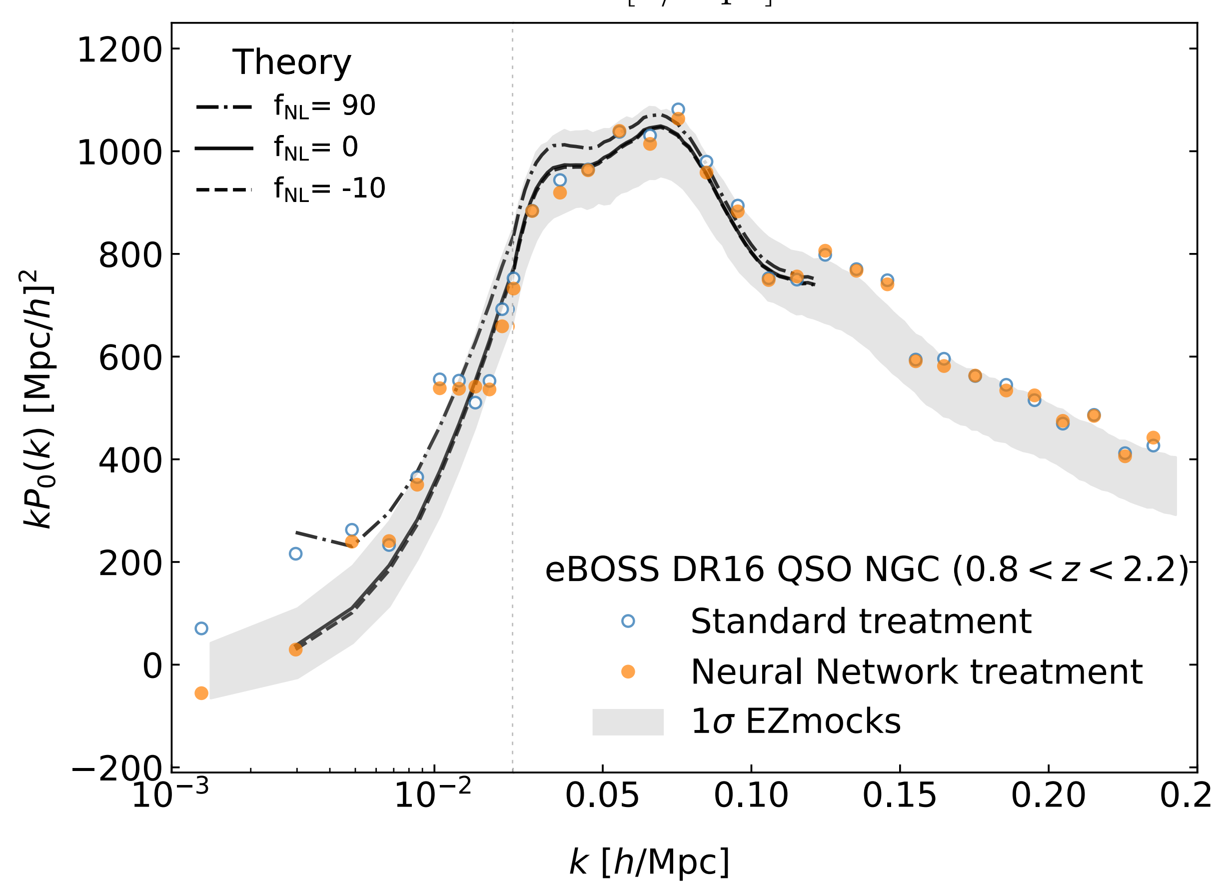
Imaging systematics

Systematic Treatment

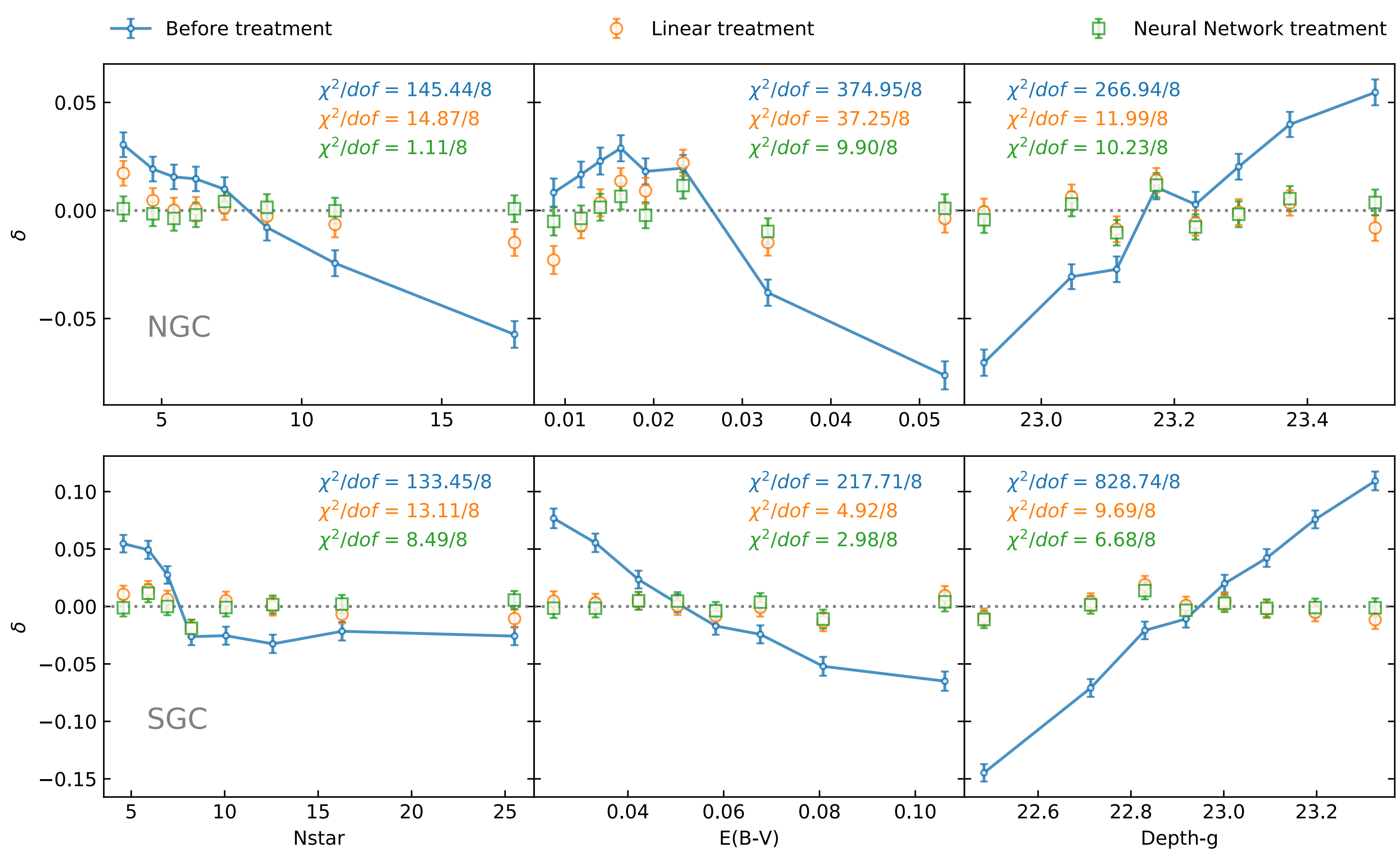
-> better, new catalog for eBOSS DR16 QSO

Rezaie et al. 2021
arXiv:2106.13724





Systematic treatments

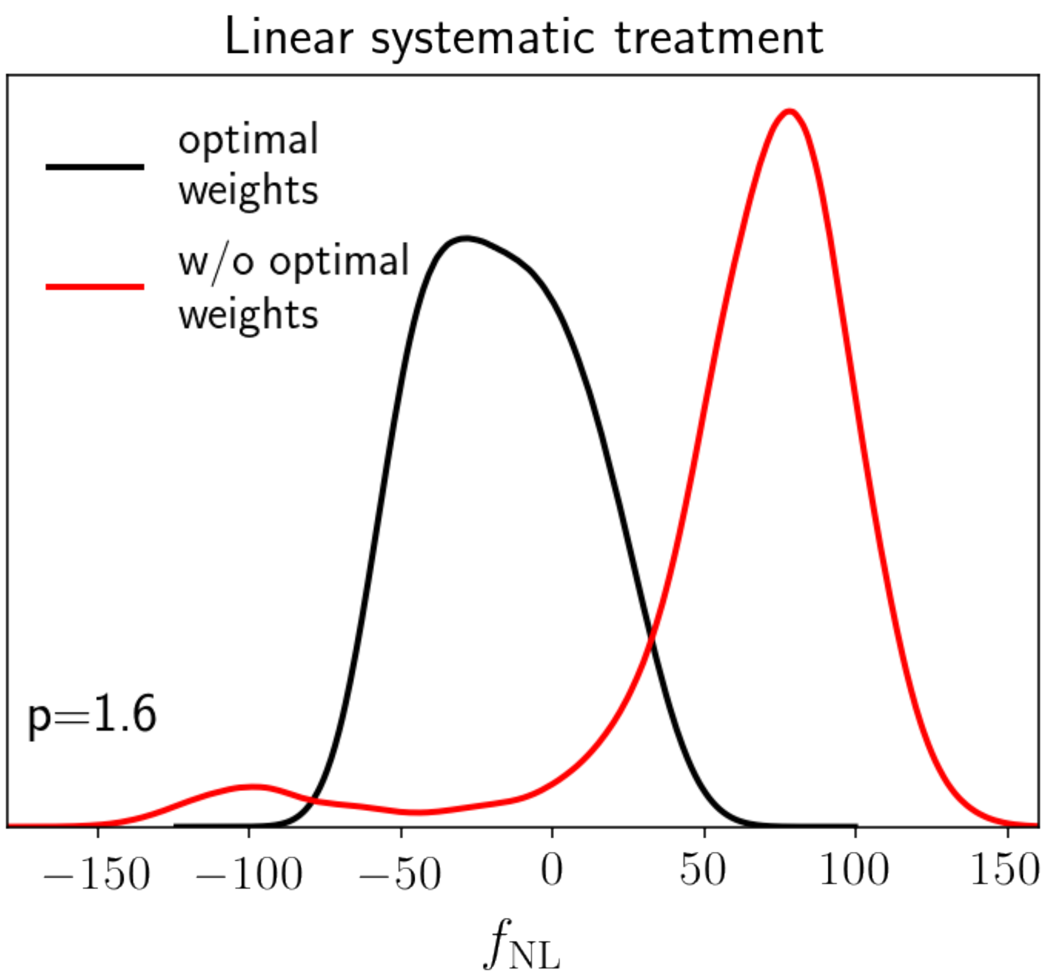


- Need to correct for stellar density
- Neural Network can account for non-linear systematic effects

Rezaie et al. 2021 arXiv:2106.13724

See also Ashley Ross' talk tomorrow for more details on systematic treatment

Results for linear treatment



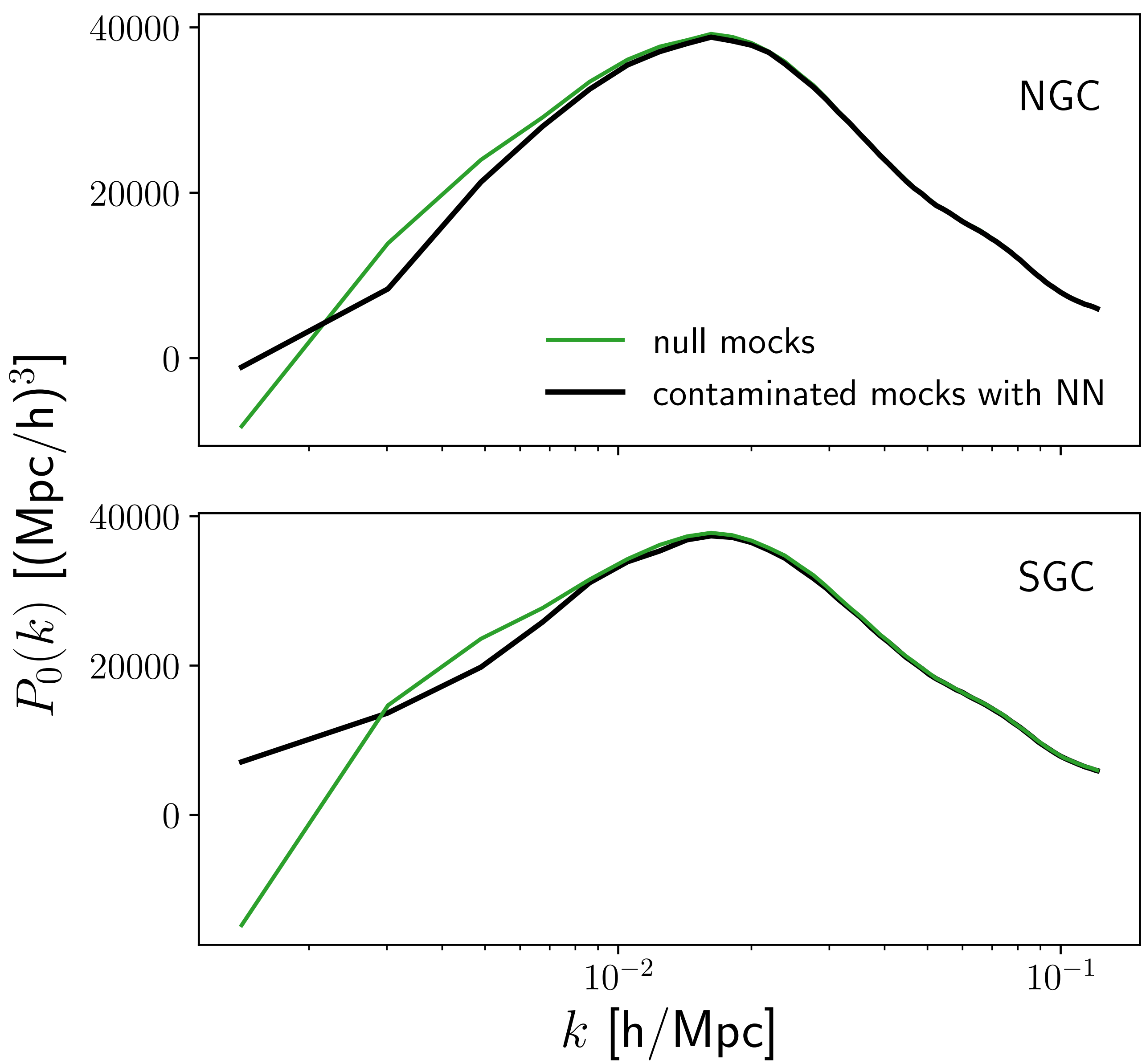
Problem II: Systematics

Does the systematic treatment bias the result?

Problem II: Systematics

Yes!

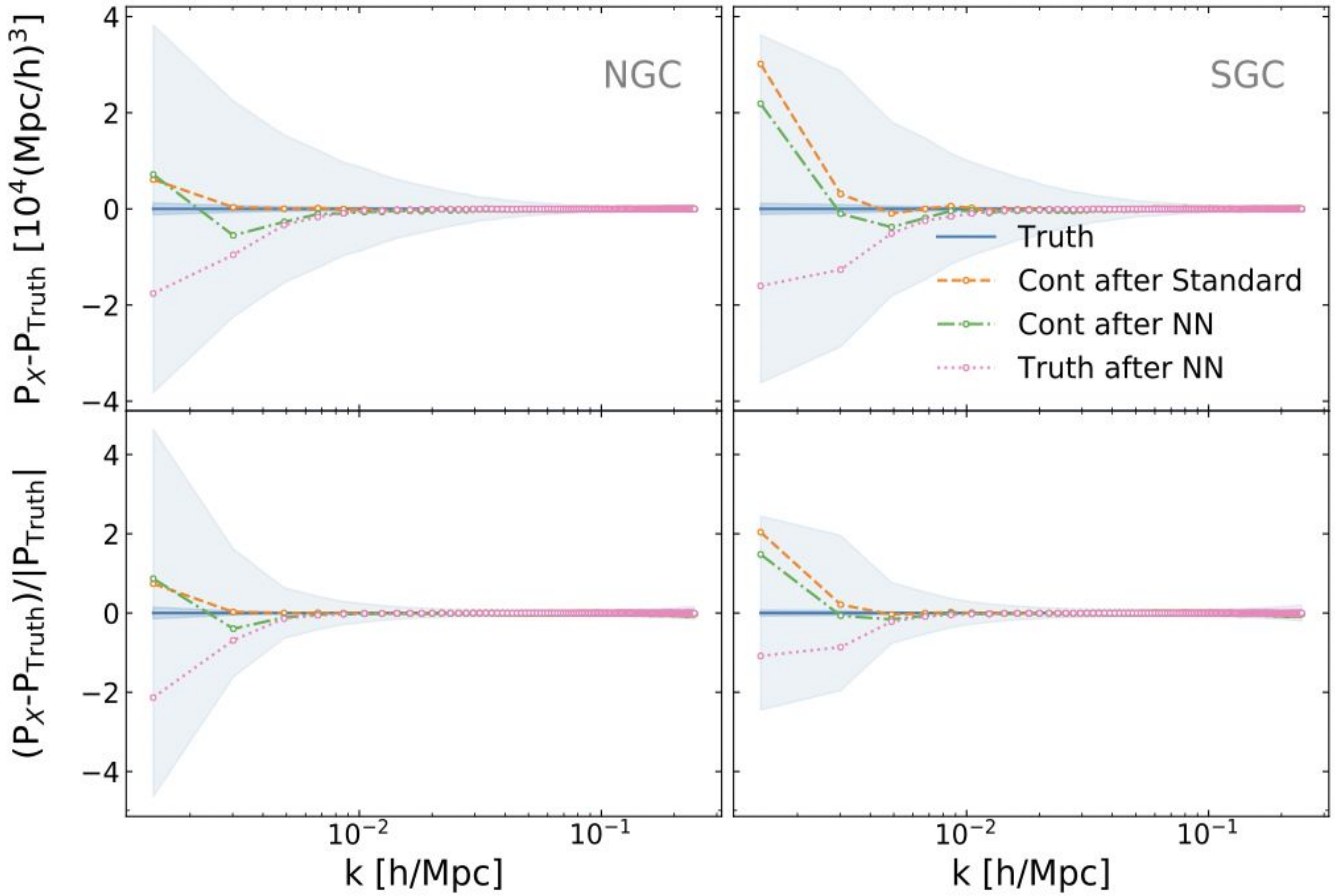
Problem II: Systematics



Modes are removed!

Problem II: Systematics

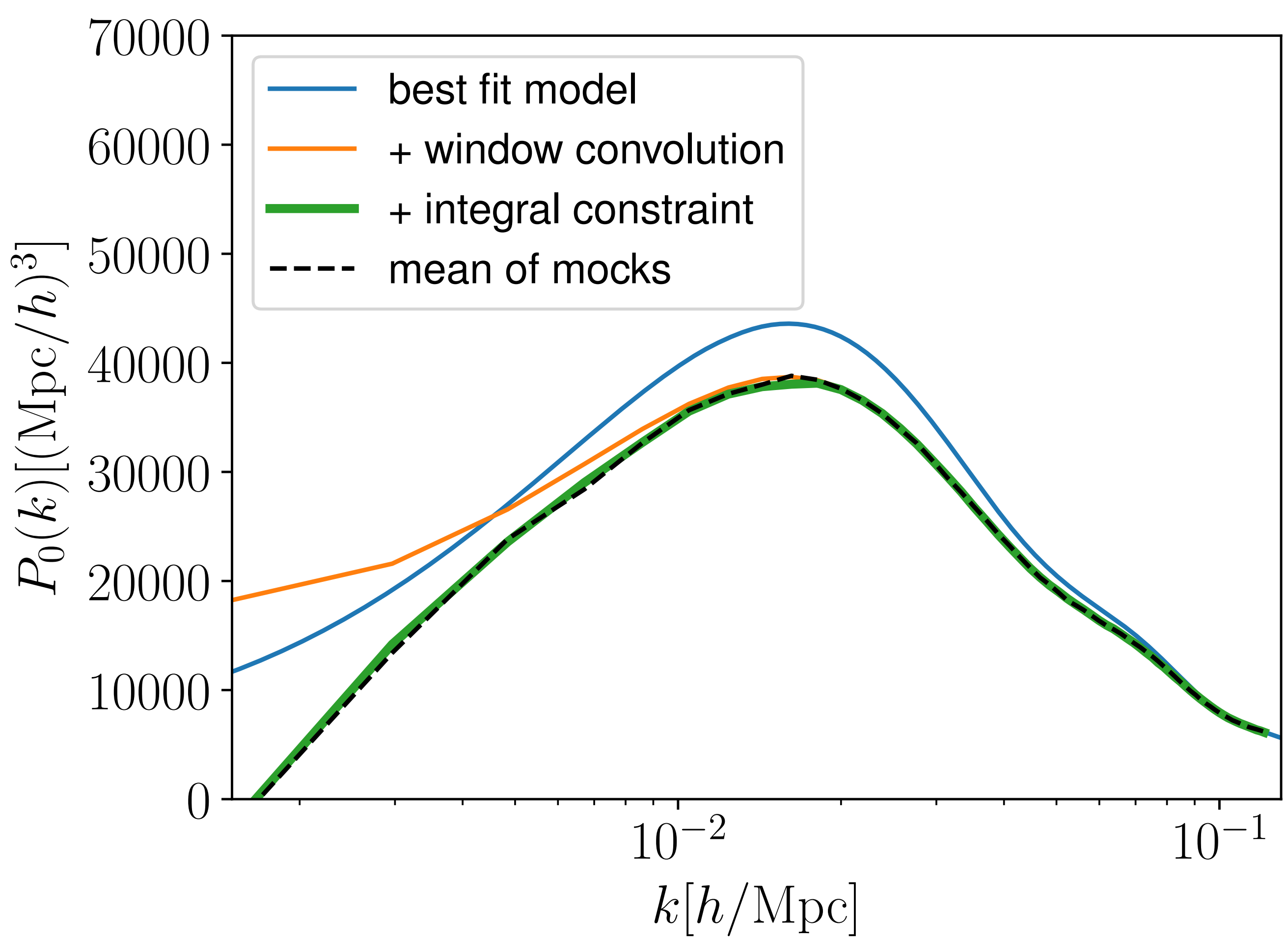
Rezaie et al. arXiv:2106.13724



Mitigation bias. The template-based imaging treatment removes some of the true clustering signal (*Rezaie et al '21*). A more flexible model will remove more of the true clustering. *Conservative Approach:* Reduce the flexibility of the model at the expense of leaving behind some systematics (see, *Rezaie et al '20*).

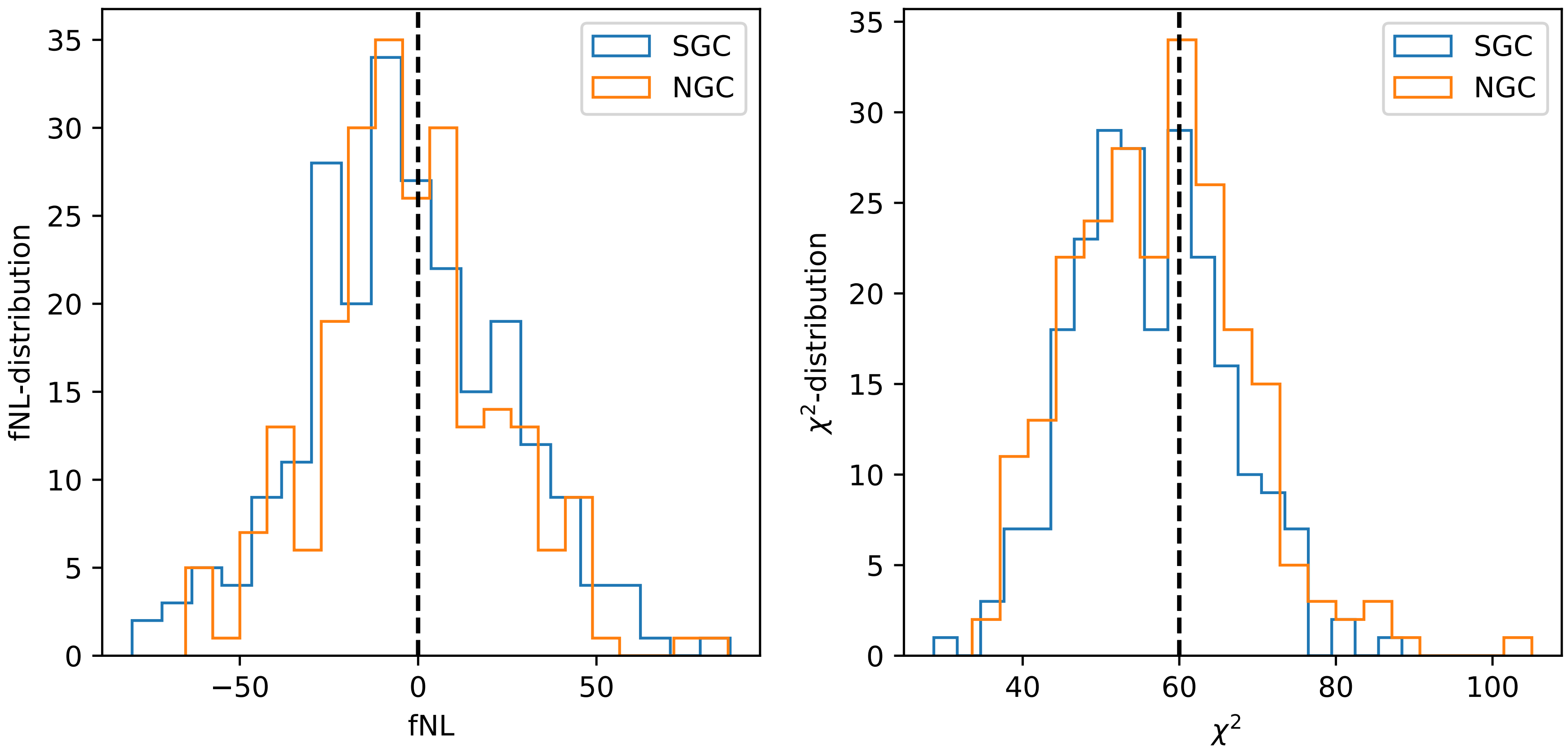
Test with mocks!

Challenge III: Model



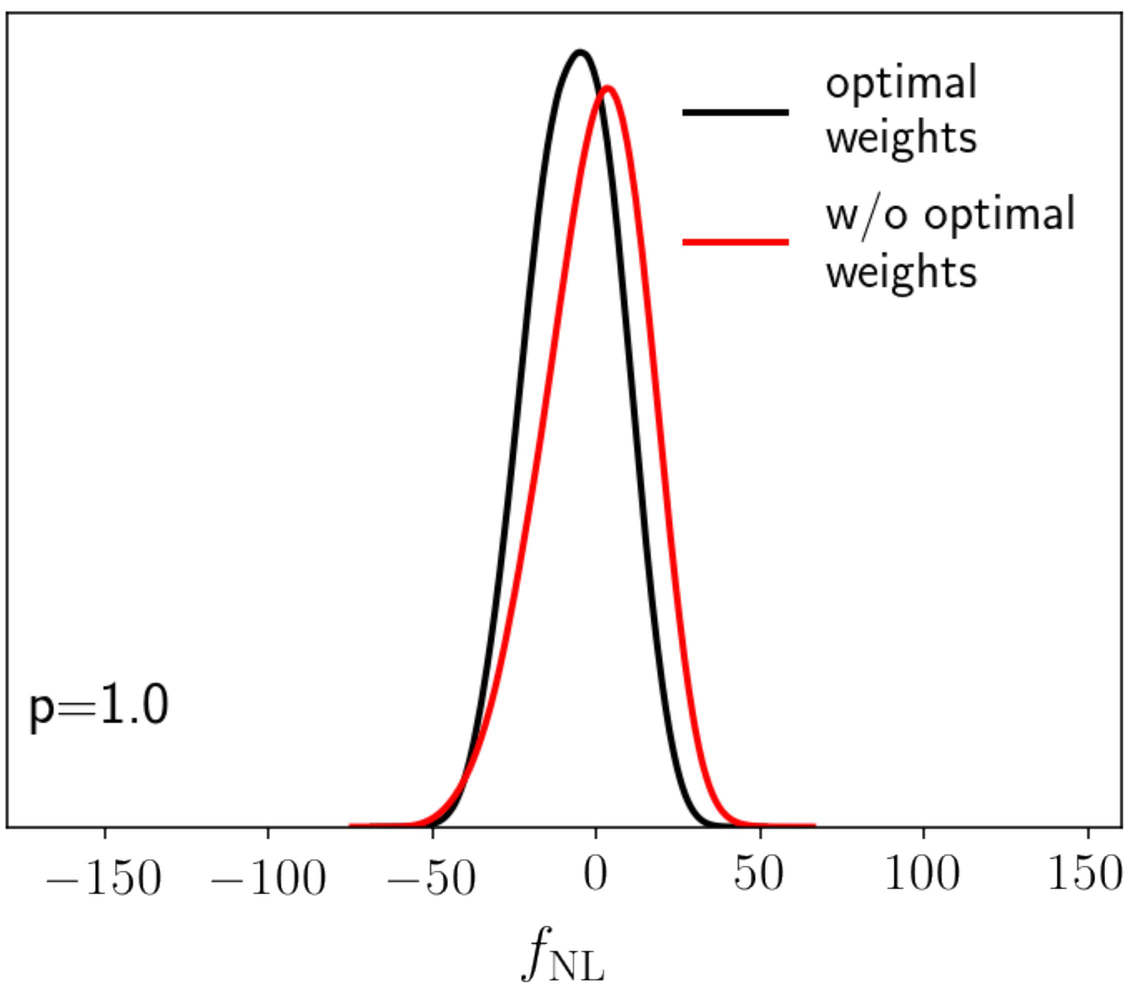
No survey is perfect….

Need mocks!



SGC
NGC
fNL-distribution
fNL
−50
0
50
SGC
NGC
χ^2-distribution
χ^2
40
60
80
100

Challenge III: Model



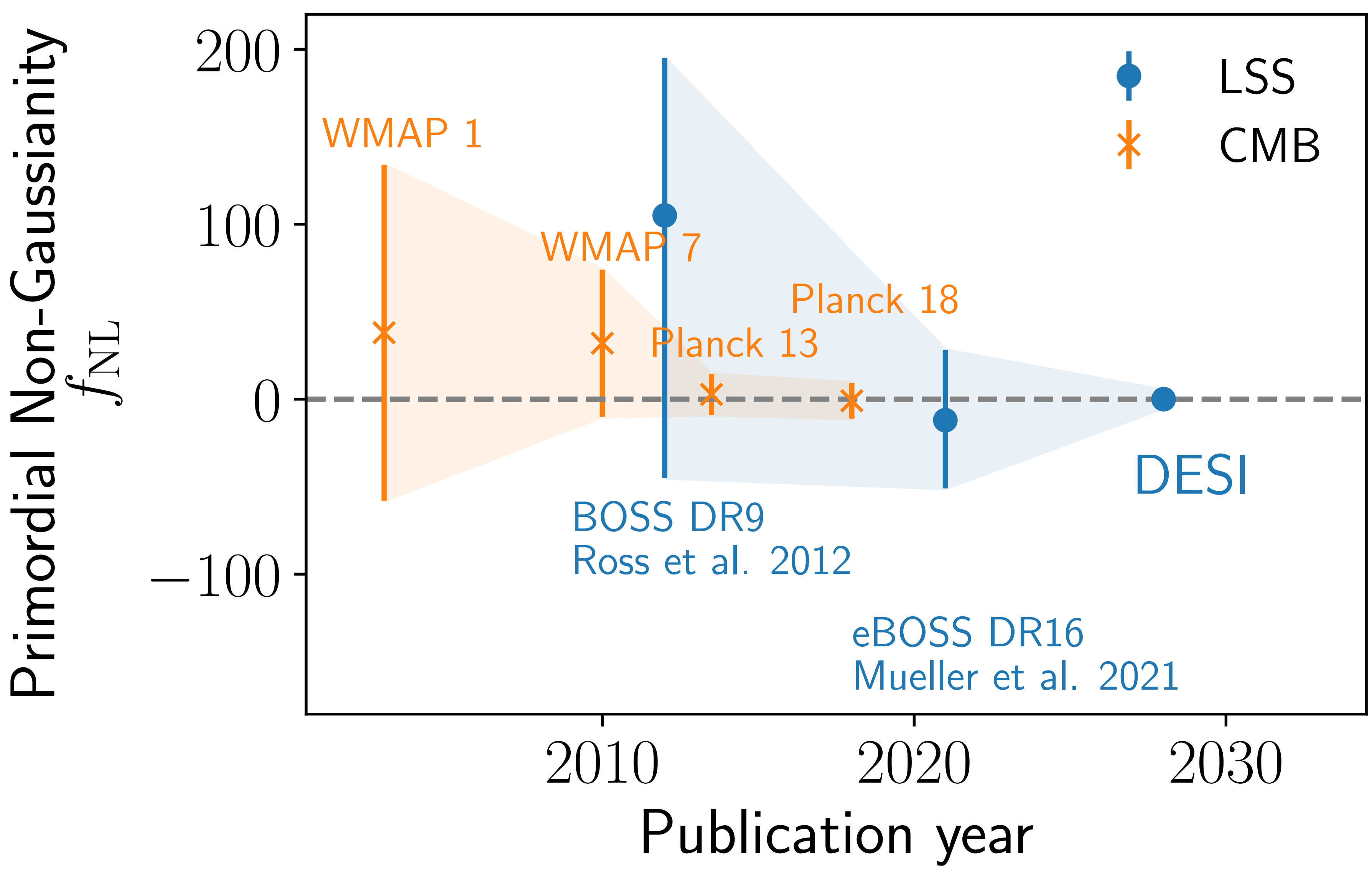
$$\Delta b(k) = 2(b-p) f_{\rm NL} \frac{\delta_{\rm crit}}{\alpha(k)}$$

$$f_{\rm NL} = -7 \pm 14$$

Merger rate
p=1 : no recent mergers
p=1.6 for objects that populate only recently merged halos

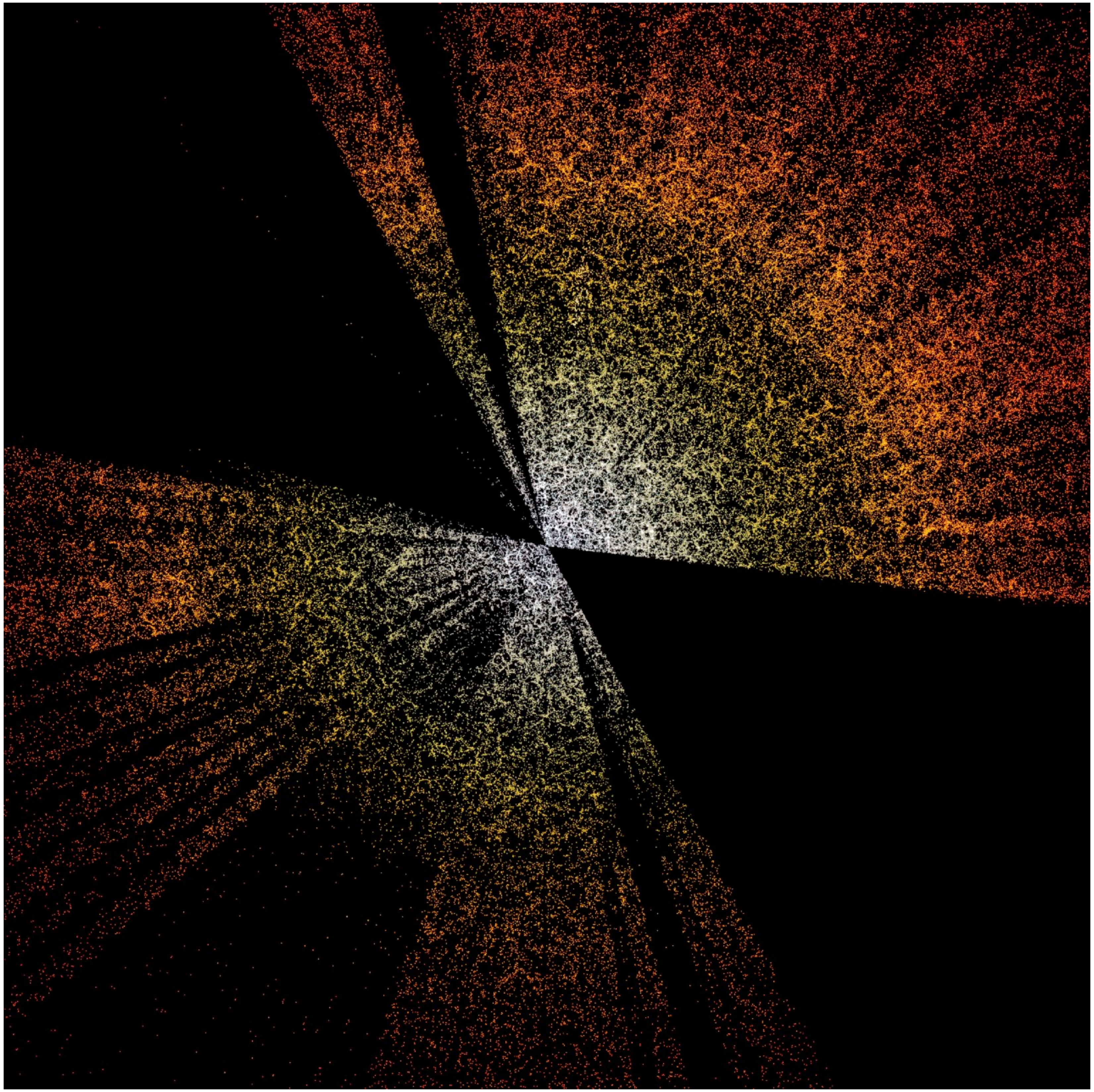
See also Alex Barreira's talk yesterday

DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science



Factor ~ 5 gain in precision

~~Future~~ Present: Dark Energy Spectroscopic Instrument (DESI)



DARK ENERGY
SPECTROSCOPIC
INSTRUMENT
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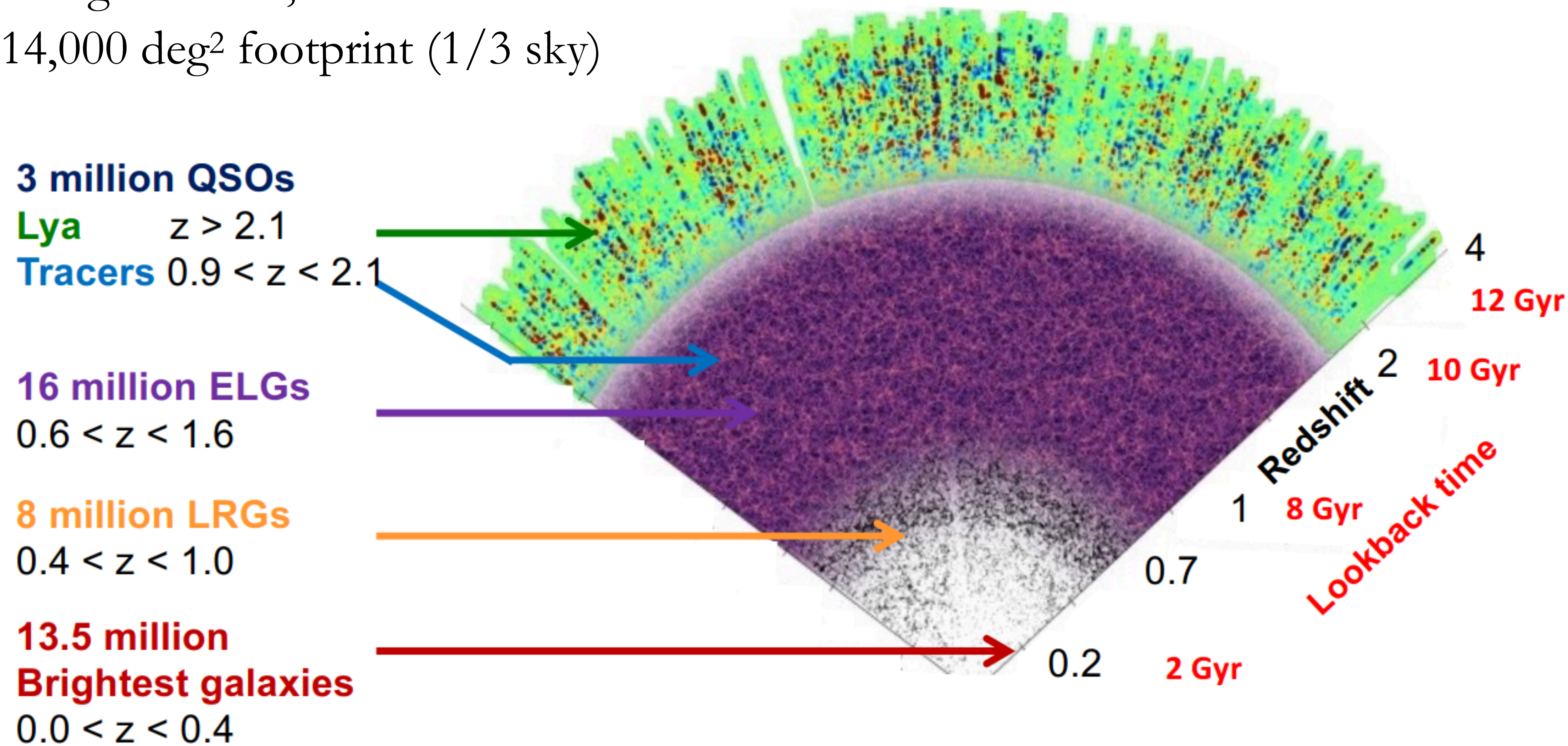
Largest 3D map of the Universe !

DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

DESI ~~will produce~~ is producing the most detailed 3D map of the universe, ever.

- 5-year survey (2021-2026)
- 5 target classes, ~40M redshifts
- 14,000 deg^2 footprint (1/3 sky)



DESI Collaboration et al. 2016

Beyond DESI

And beyond that?

- Can we push $\sigma(f_{\rm NL}) < 1$ with LSS?
- What kind of a survey do we need?

Beyond Euclid?

Answers:

“I am retired by then…”

“I might not be in academia by then…”

“I do theory…”

Beyond Euclid?

1. Options: Join US effort

Schlegel, Ferraro et al 2022 arXiv:2209.03585

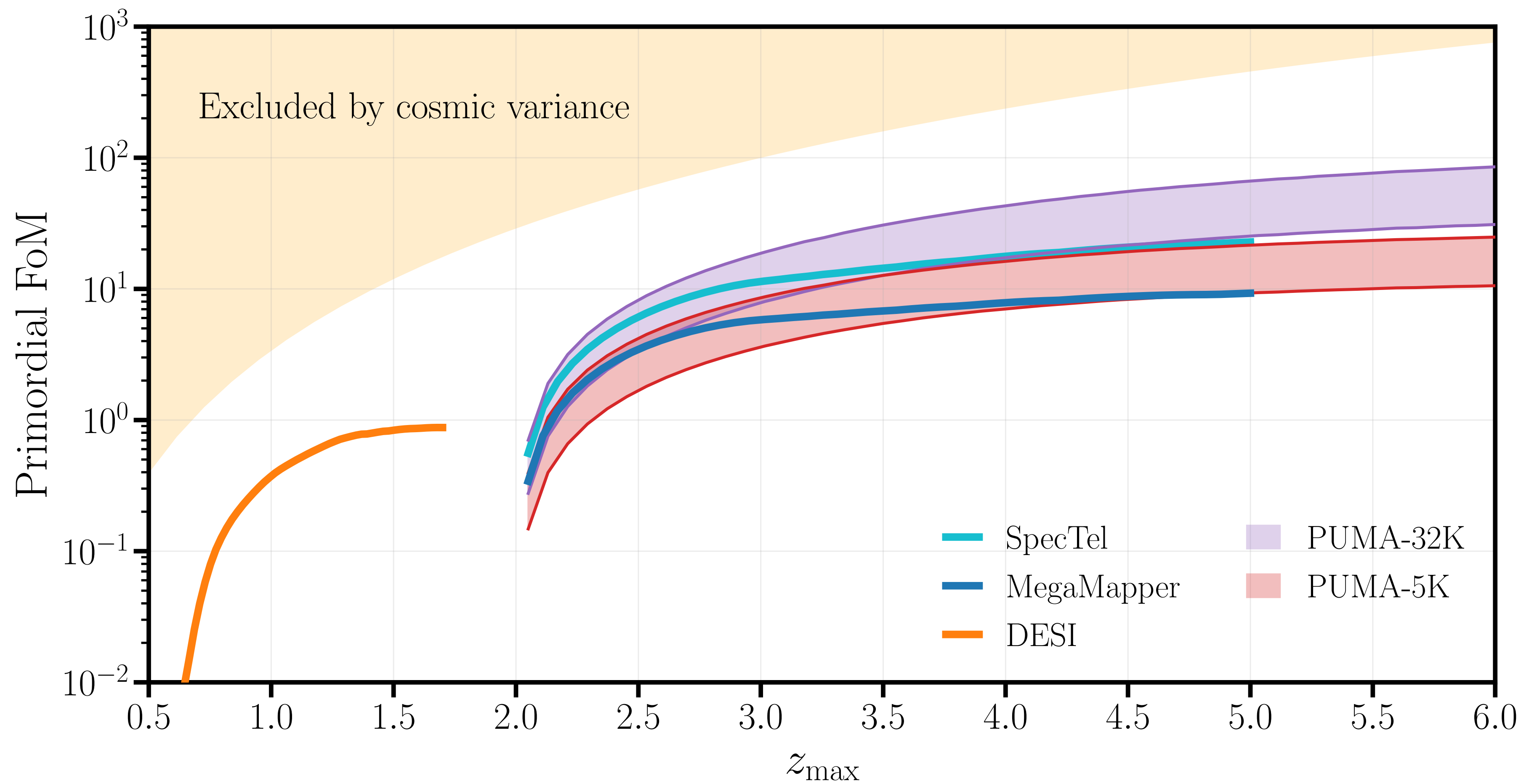


Figure 2: "Figure of Merit" FoM $\equiv 10^{-6}\, N_{\rm modes}$, representing the effective number of "linear" modes observable as a function of $z_{\rm max}$ for DESI, PUMA (-5K and -32K), and MegaMapper and SpecTel, two examples of Stage-5 spectroscopic surveys. For DESI we include only the

Beyond Euclid?

1. Option: Join US effort

2. Option: Stage 5 European Mission after Euclid?

Beyond Euclid?

1. Option: Join US effort

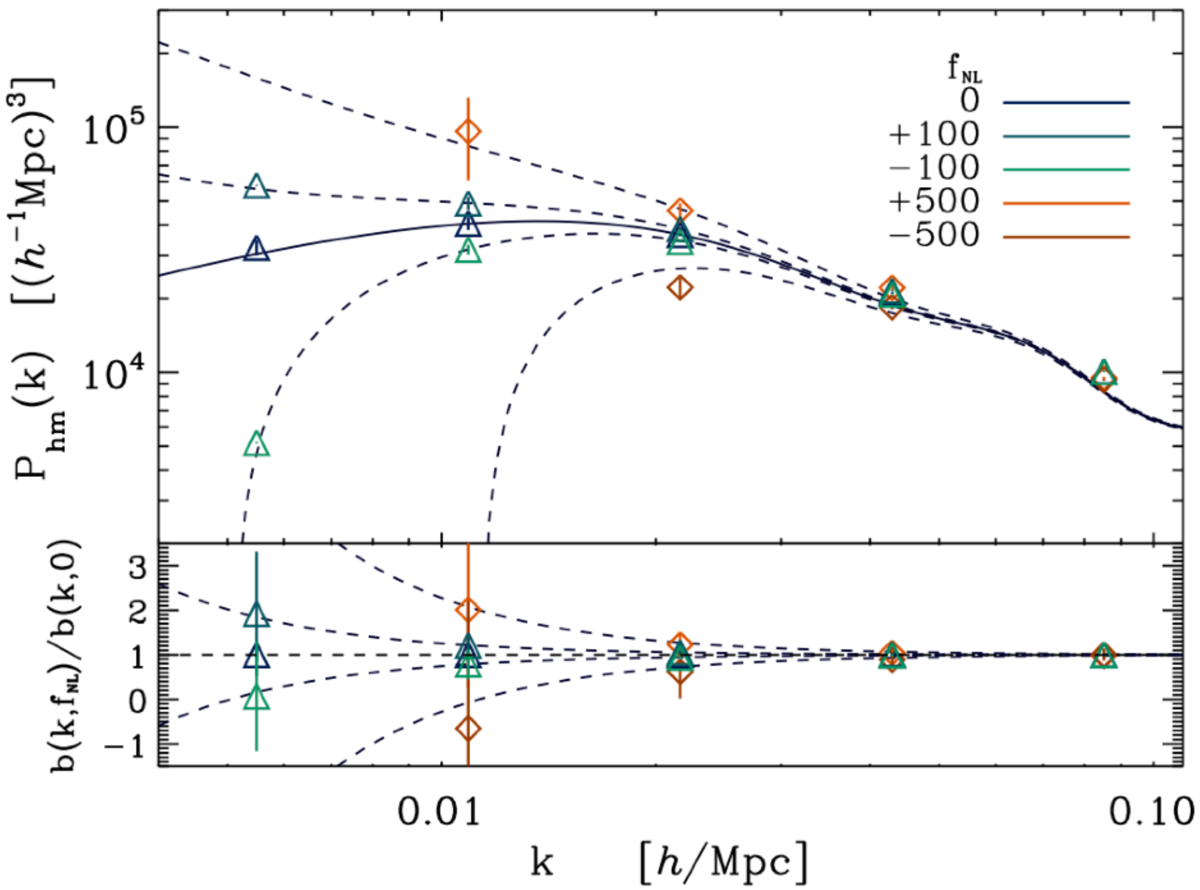
2. Option: Stage 5 European Mission after Euclid

3. Option: Nothing

Same take-away points

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

- LSS can be used to constrain primordial non-Gaussianity through the scale dependent halo bias



Same take-away points

- This measurement needs a large volume survey

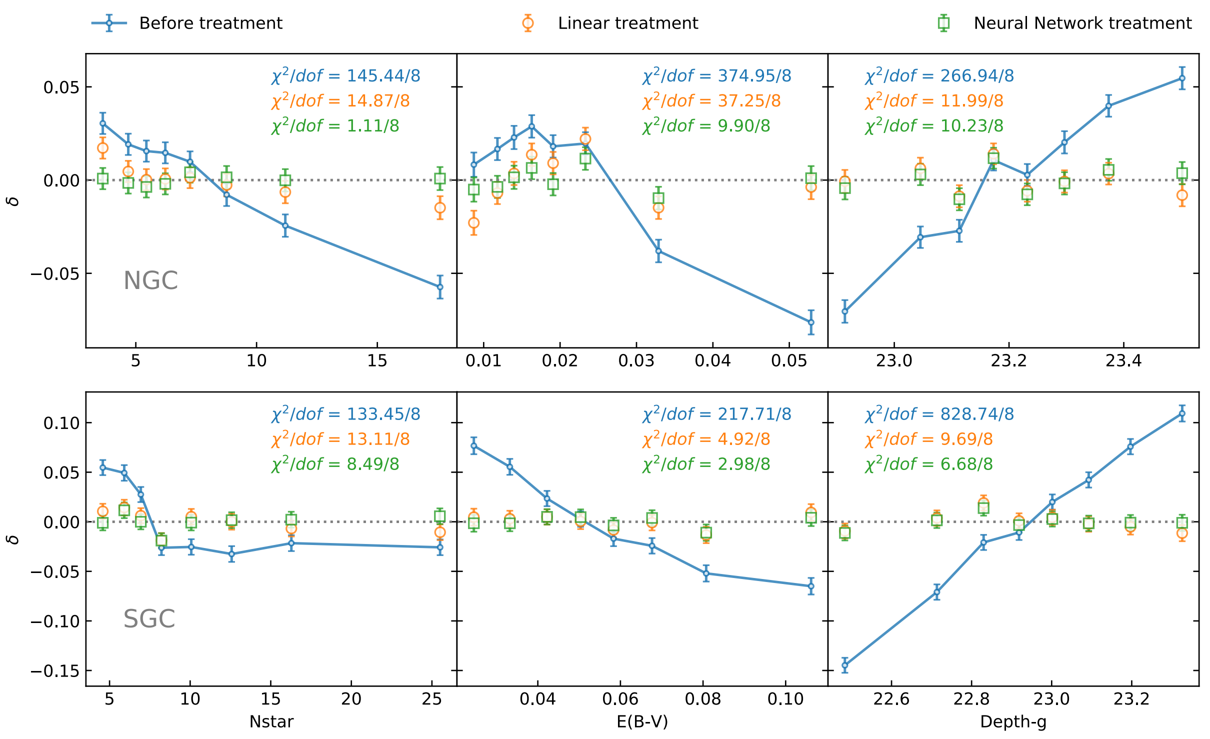
  -> large redshift range

  -> large sky coverage

Same take-away points

- Understanding the observational systematics is crucial

- Might need new catalogs for your analysis!



Same take-away points

- Don’t put too much trust into Fisher forecasts
- Many challenges ahead

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- LSS can be used to constrain primordial non-Gaussianity through the scale dependent halo bias

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