Testing multi-field Inflation with the Galaxy Power Spectrum and Bispectrum

New Physics from Galaxy Clustering at GGI
02.10.2025

Dennis Linde

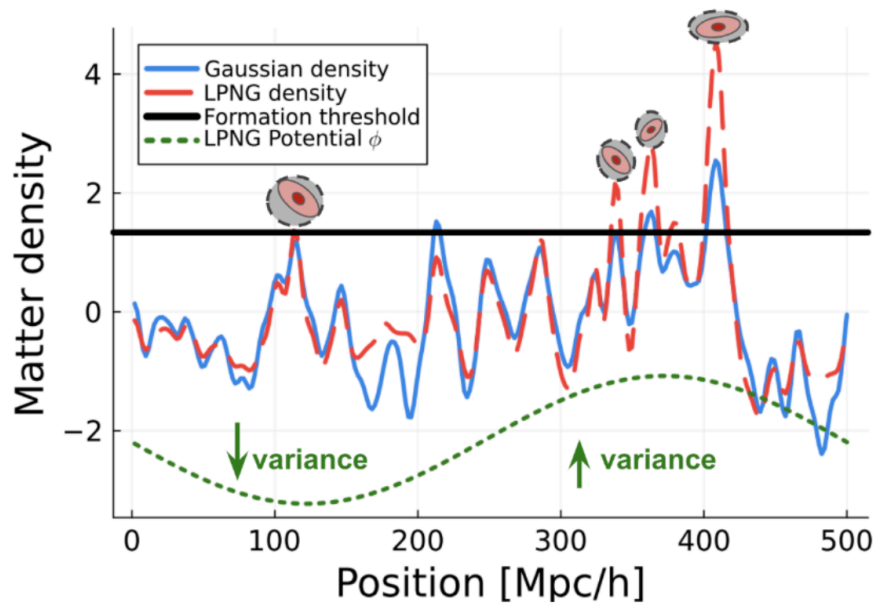
In progress within the **Euclid Collaboration**
with A. Moradinezhad Dizgah, G. Parimbelli, K. Pardede,
M. Cagliari, E. Sefusatti, G. D'Amico, V. Desjaques, A. Eggemeier

UNIVERSITÀ DI PARMA
INFN

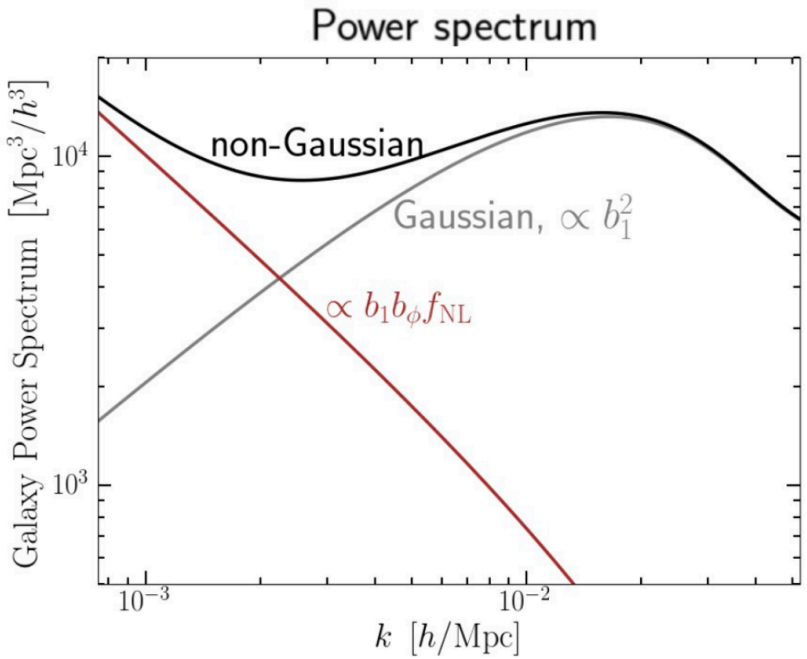
Local Primordial non-Gaussianity

Local non-Gaussian Potential:

$$\phi(\mathbf{x}) = \phi_{\mathrm{G}}(\mathbf{x}) + f_{\mathrm{NL}}^{\mathrm{loc}}(\phi_{\mathrm{G}}^2(\mathbf{x}) - <\phi_{\mathrm{G}}^2(\mathbf{x})>)$$



J. M. Sullivan ++ (2025)



Credits: A. Barreira

Corresponding denisty field:

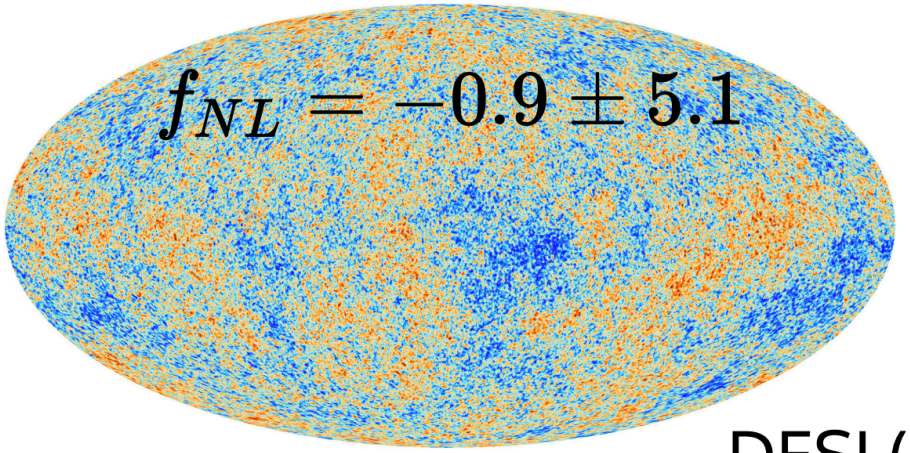
$$\delta_h(\mathbf{x}) = \delta_h^{\mathrm{G}}(\mathbf{x}) + \delta_h^{\mathrm{PNG}}(\mathbf{x})$$

$$\delta_h^{\mathrm{PNG}}(\mathbf{x}) = f_{\mathrm{NL}}[b_\phi \phi(\mathbf{x}) + b_{\phi\delta}\phi(\mathbf{x})\delta(\mathbf{x}) + ...]$$

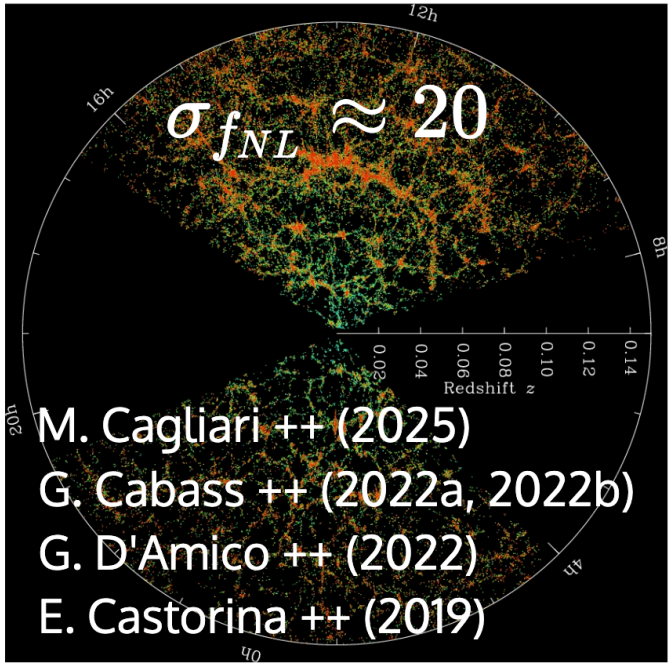
N. Dalal ++ (2008)
A. Slosar ++ (2008)

Previous Constraints

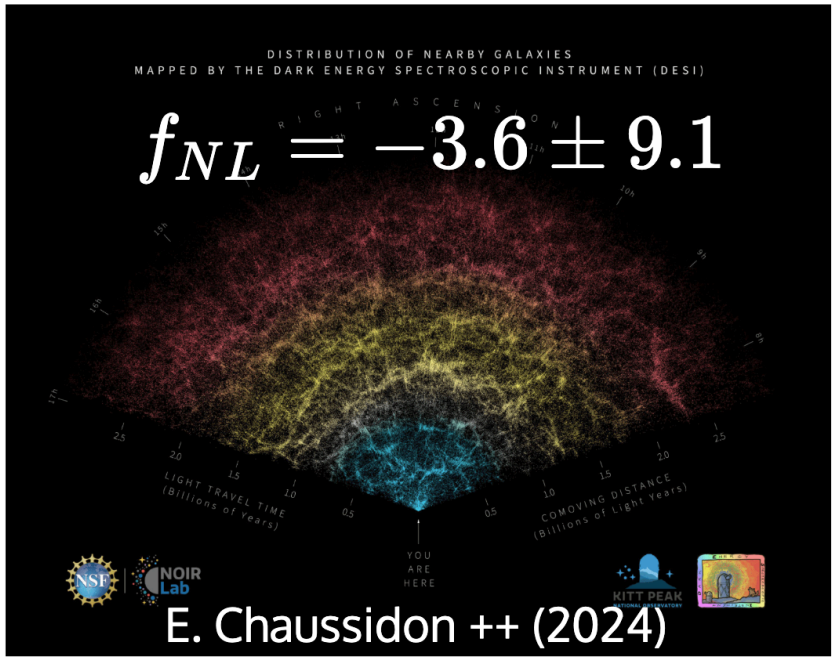
Planck (2018)



SDSS

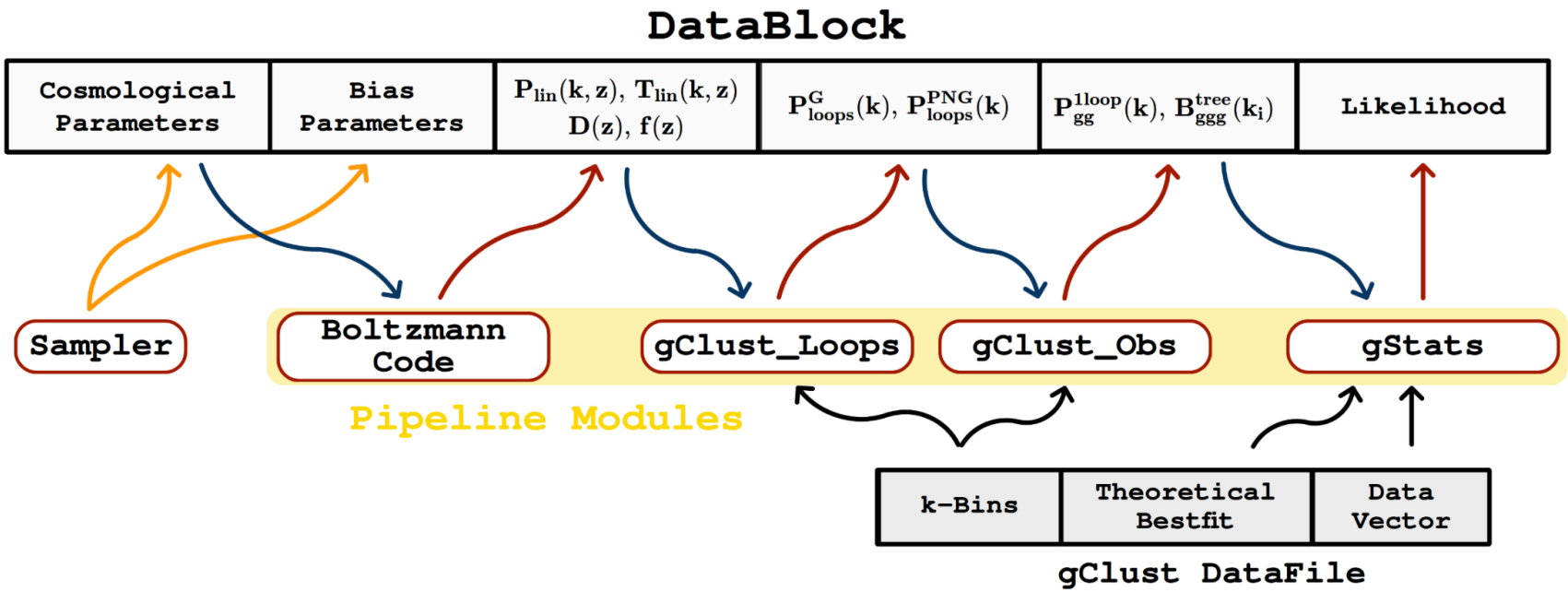


DESI (2024)



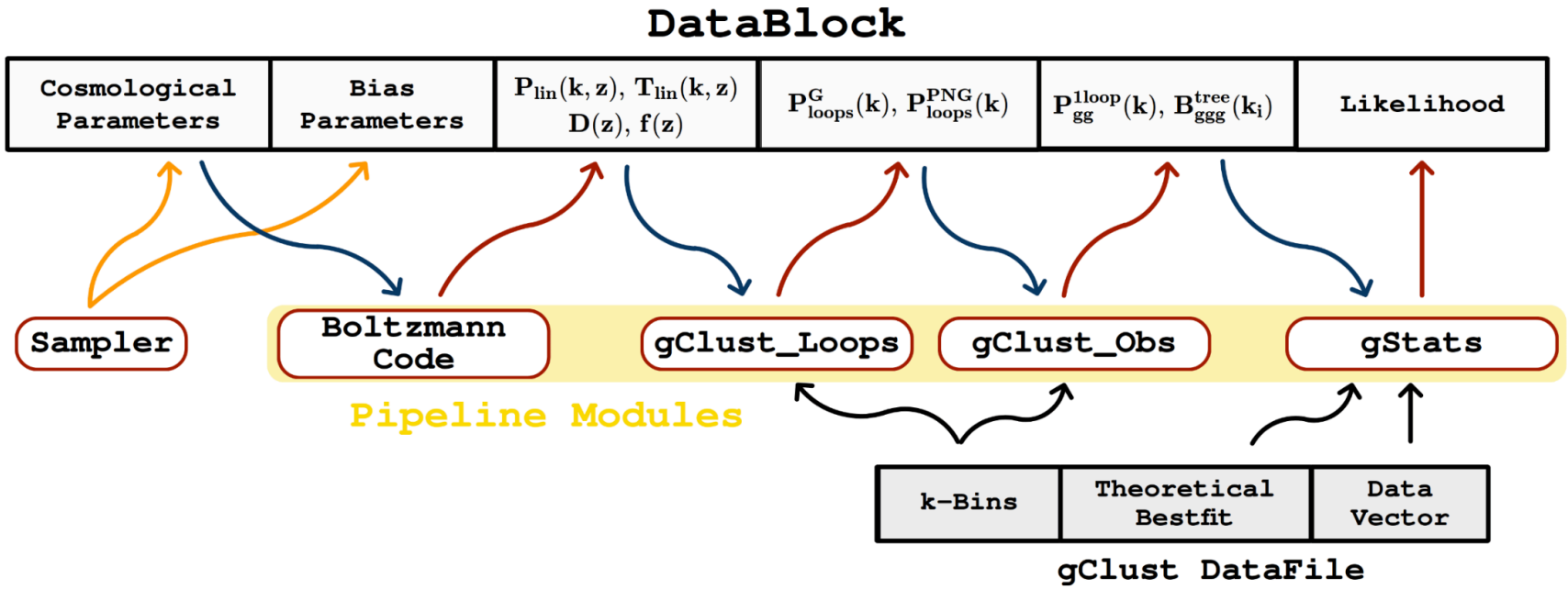
CosmoSIS – gClust and gStats Modules

- Fully integrated into **CosmoSIS** → Modular Structure J. Zuntz ++ (2014)



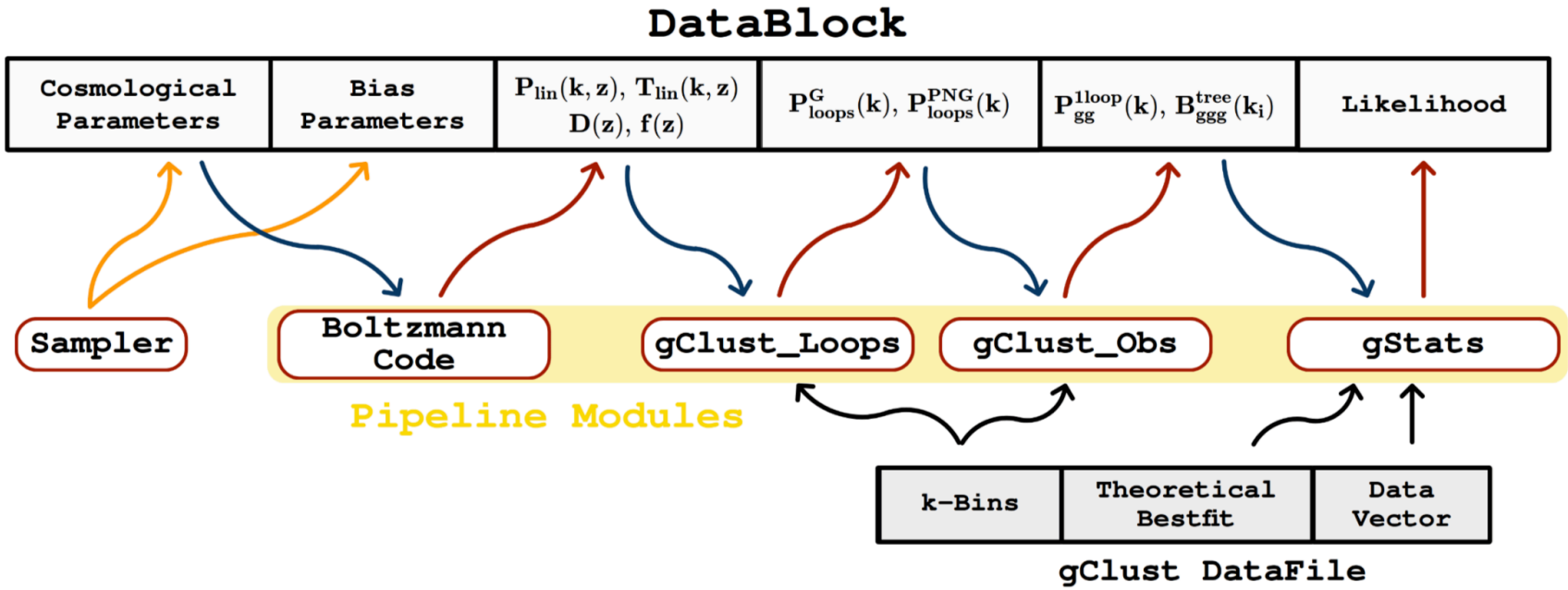
CosmoSIS – gClust and gStats Modules

- Fully integrated into **CosmoSIS** → Modular Structure J. Zuntz ++ (2014)
- **1-Loop Power Spectrum** and **Tree-Level Bispectrum** in Realspace and RSD including **fNL** (including fNL loops and corresponding new **PNG Counter-Terms**)
- **FFTLog matrices** and **Gaussian Covariance** computations on the fly



CosmoSIS – gClust and gStats Modules

- **Analytical Marginalization** and **Reconstruction**
- **Boltzmann Emulators** and **Fast Samplers**
- **2-4 hours** wall time for high-resolution PNG runs (**MPI** + **OpenMP** parallelized)
- **2 minutes** for Power Spectrum with PNG fixed Cosmology runs



Setup for the Runs

Data:

- **Abacus Summit** including fNL B. Hadzhiyska ++ (2024)

  → $V = (2\ \mathrm{Gpc}/h)^3$ → $M_{\mathrm{particles}} = 1.01 \times 10^{10} M_\odot/h$

  → 2 Realisations

- **Euclid-like Hα Galaxies** adjusted to the Flagship of Euclid

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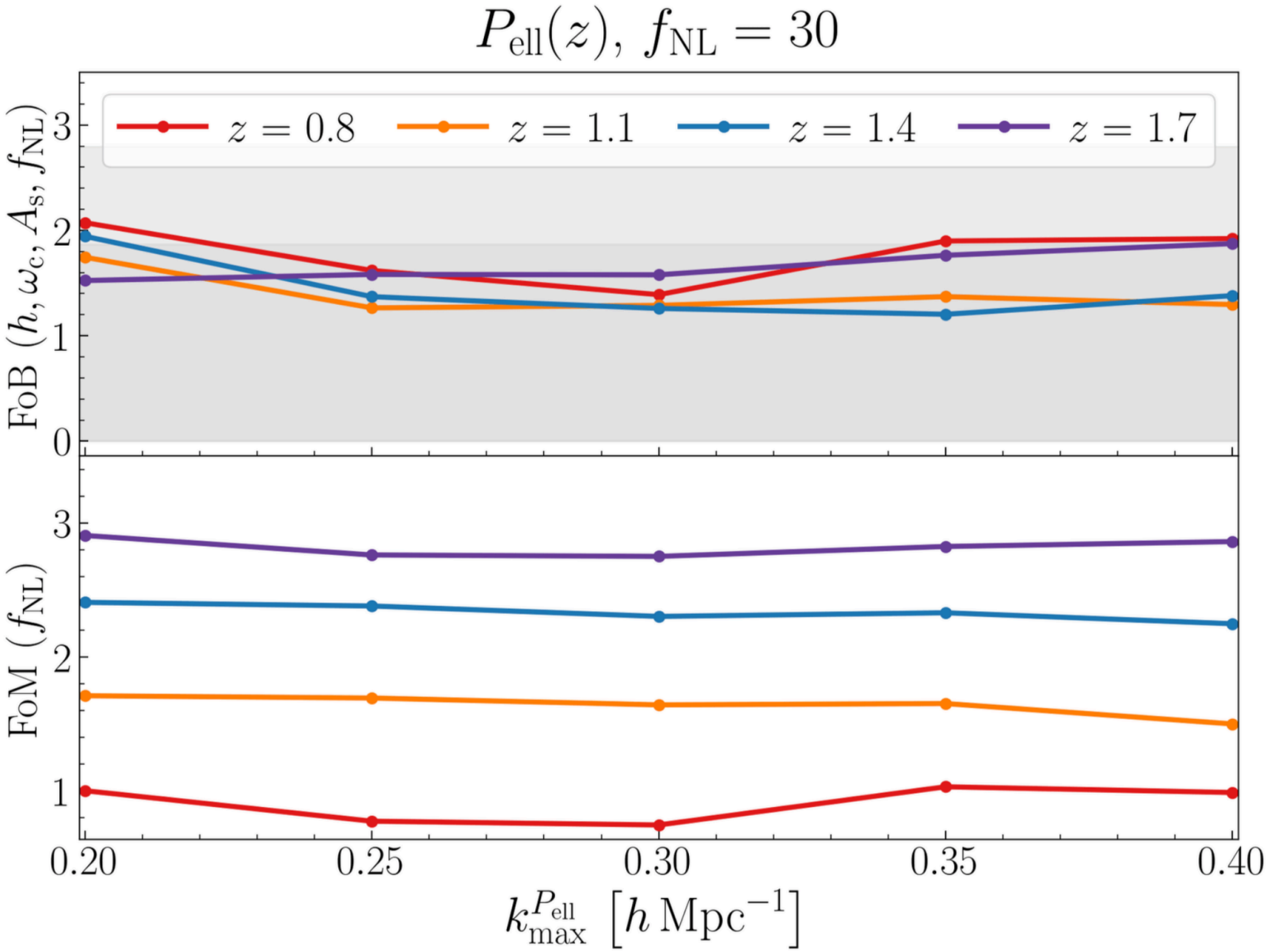
Pipeline:

- Theoretical **Gaussian Covariance**
- **Varied Cosmology** together with fNL
- **Fixing $\mathbf{b}_{\phi\delta}$** to UHMF and using **physical prior-choice** for $\mathbf{b}_\phi$

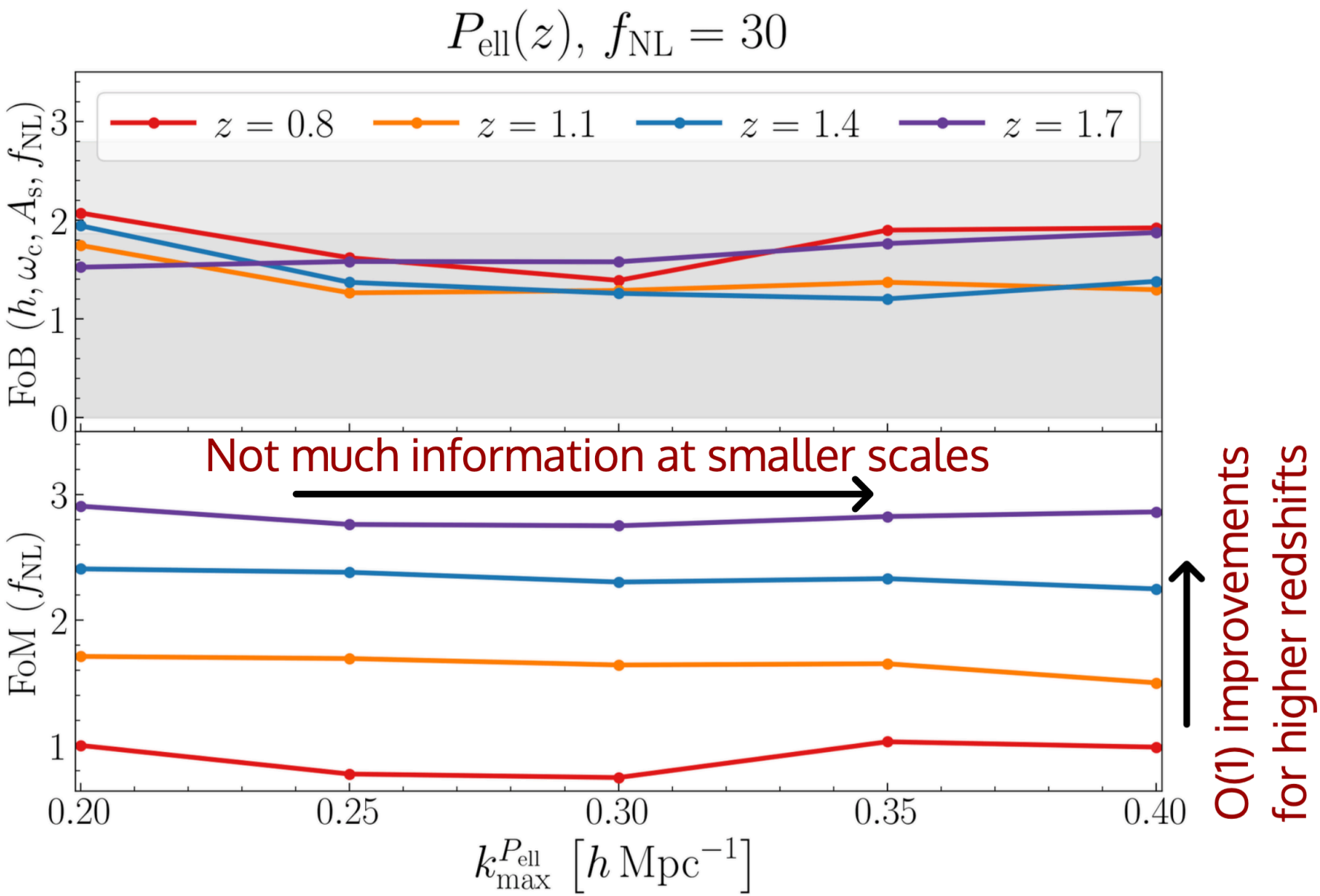
$$b_\phi = 2\delta_c(b_1 - p_{b_\phi}) \qquad \mathcal{P}(p_{b_\phi}) = \mathcal{N}(0.75, 0.25^2)$$

A. Barreira ++ (2020)

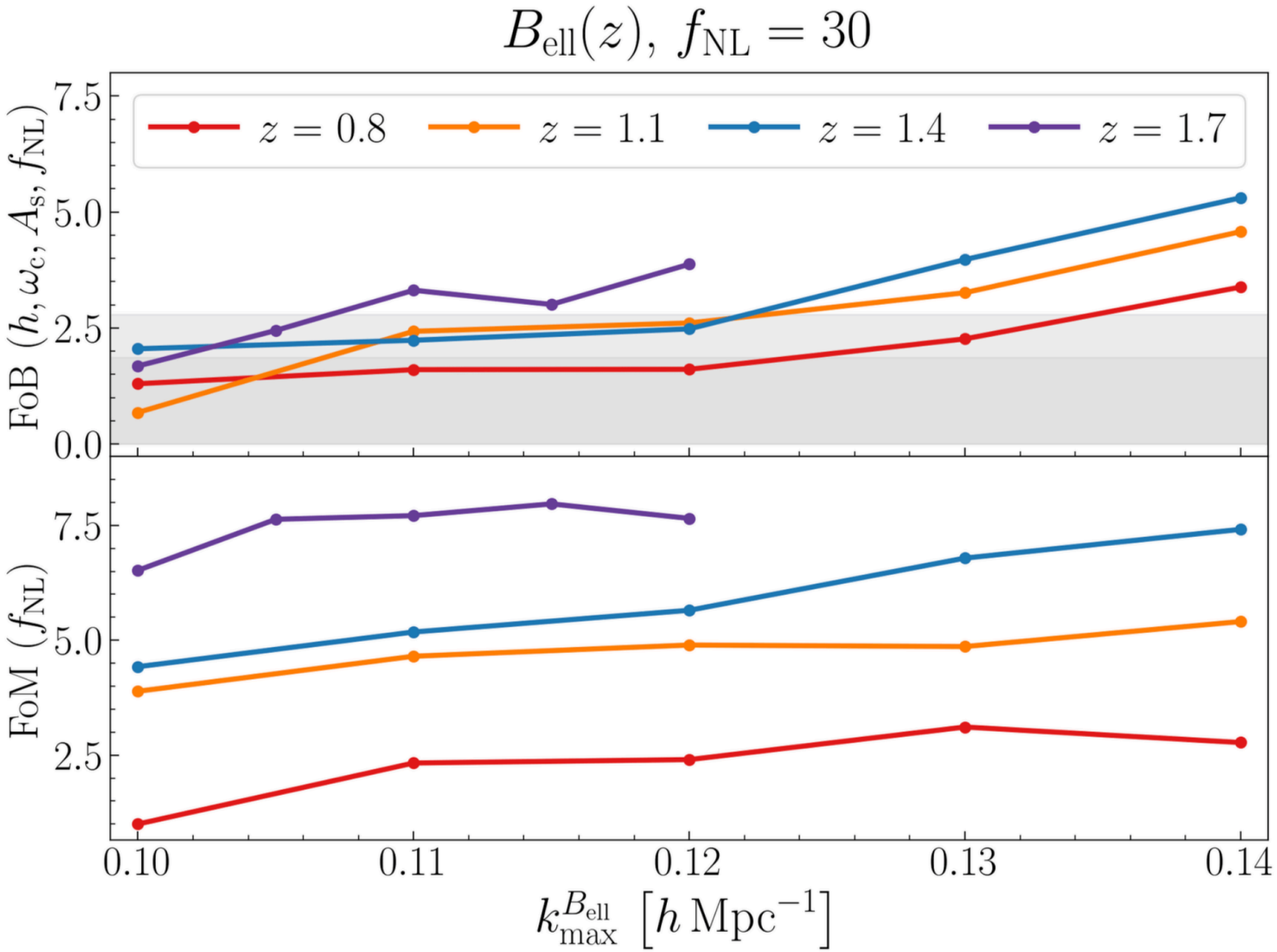
Scale-Cuts within the Power Spectrum



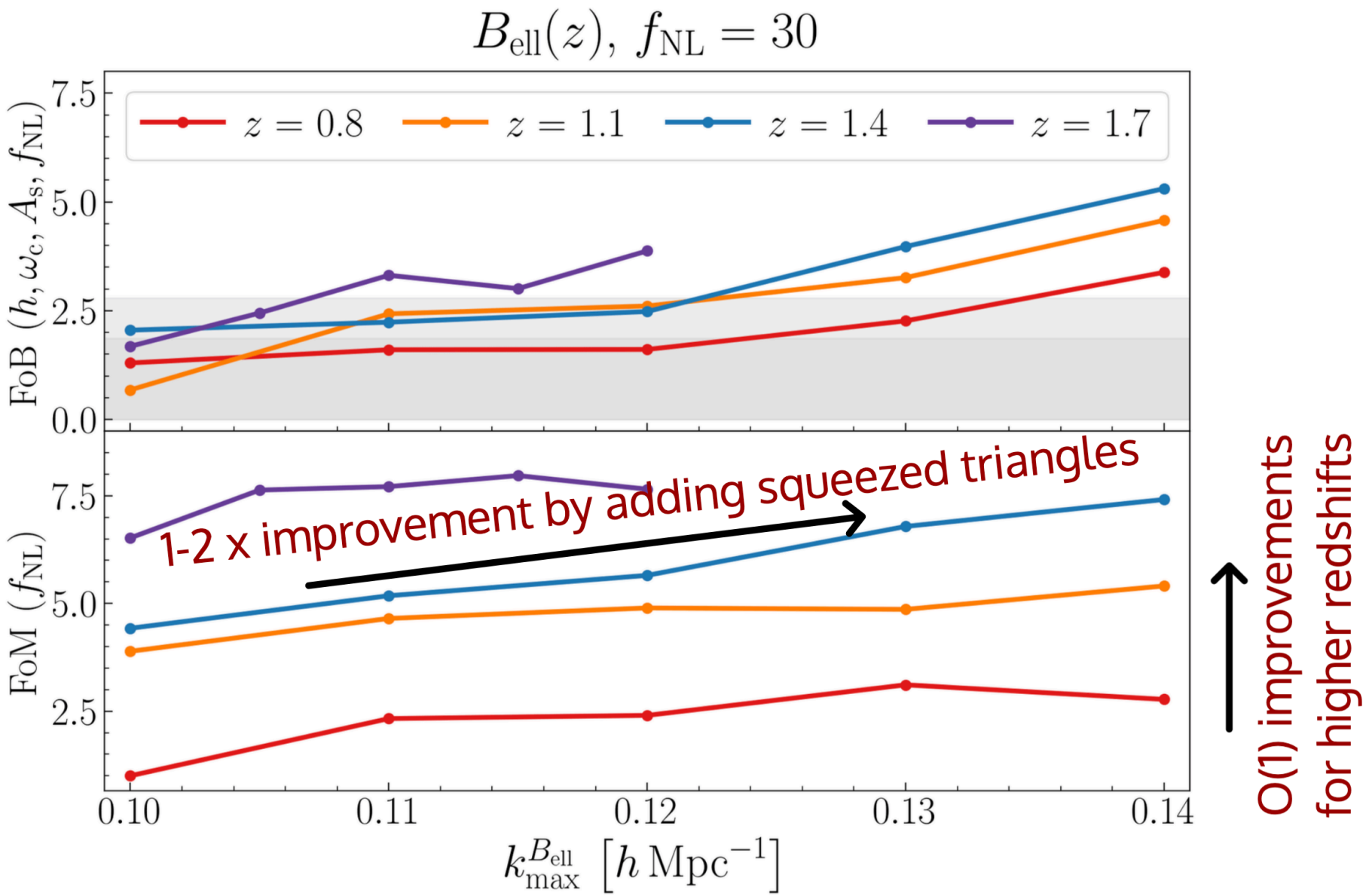
Scale-Cuts within the Power Spectrum



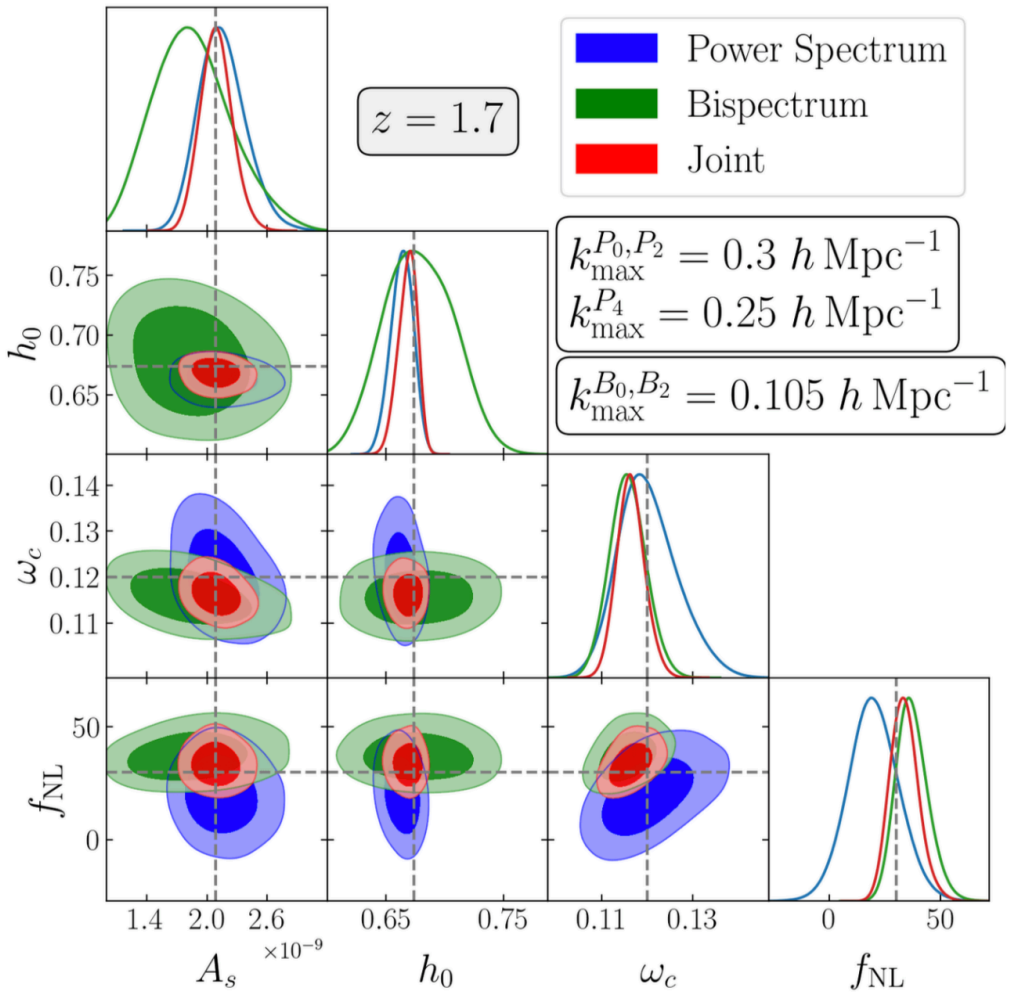
Scale-Cuts within the Bispectrum

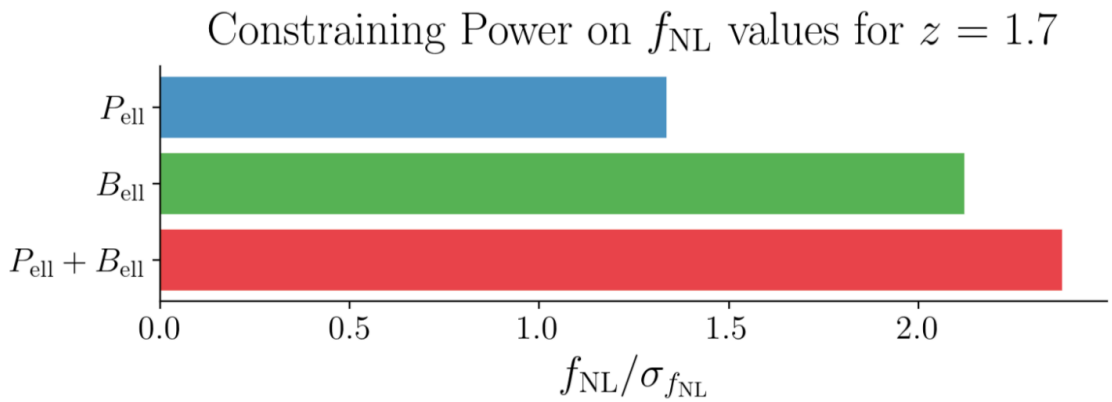


Scale-Cuts within the Bispectrum



fNL Constraints for the P, B and P+B





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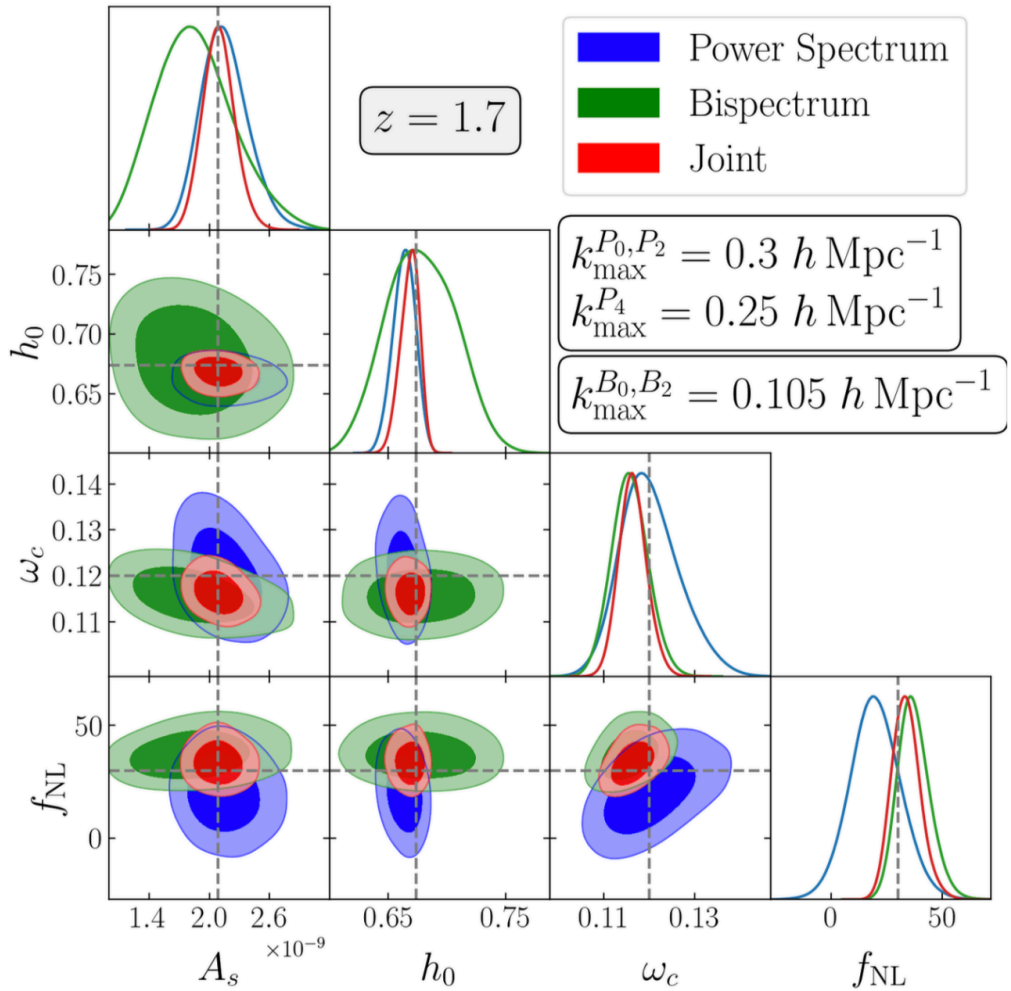
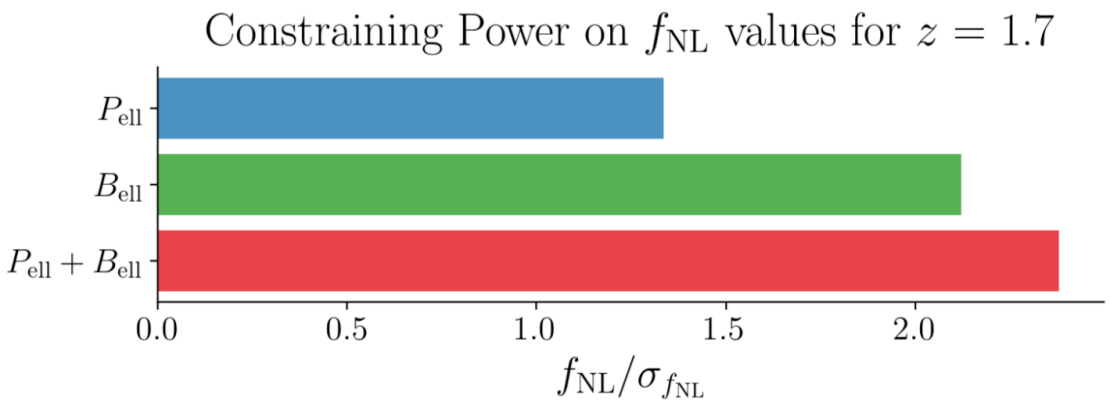
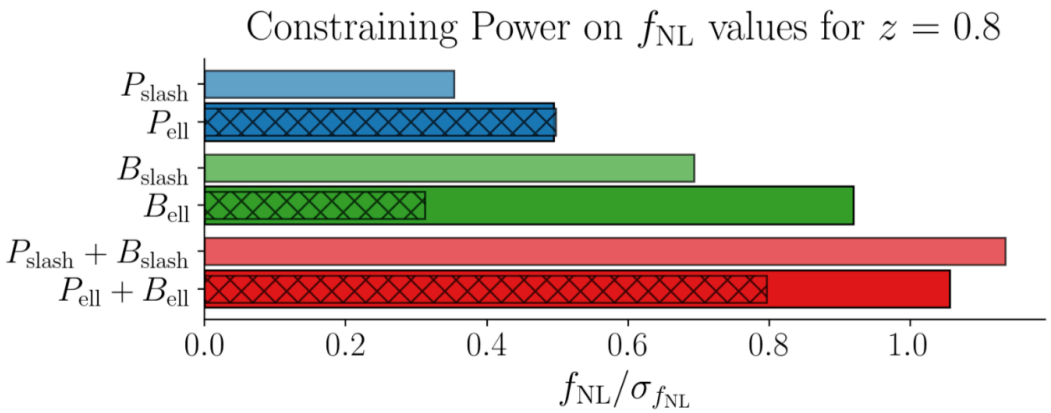
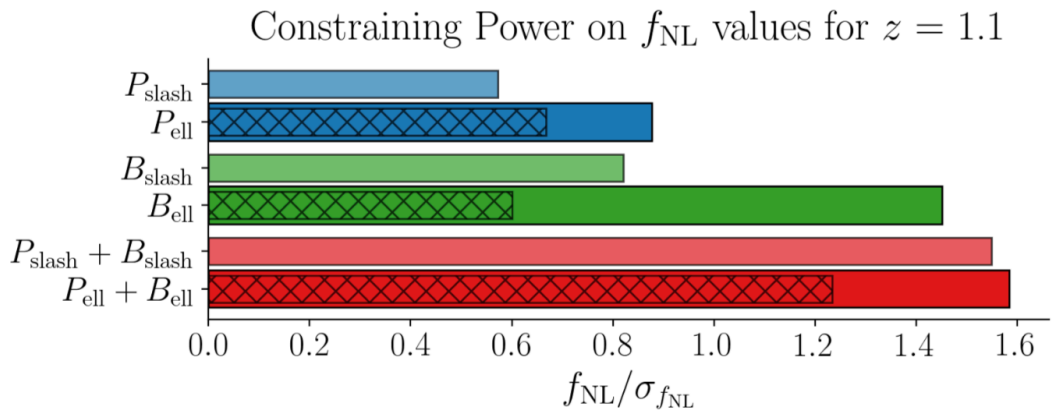


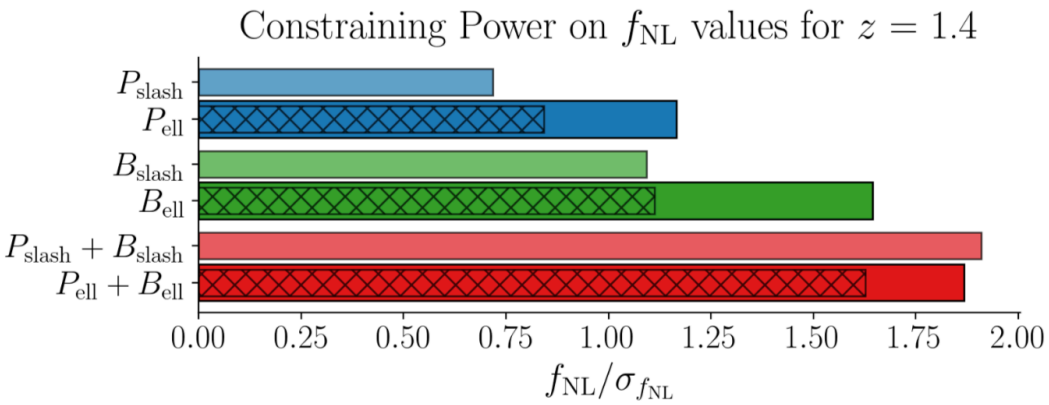


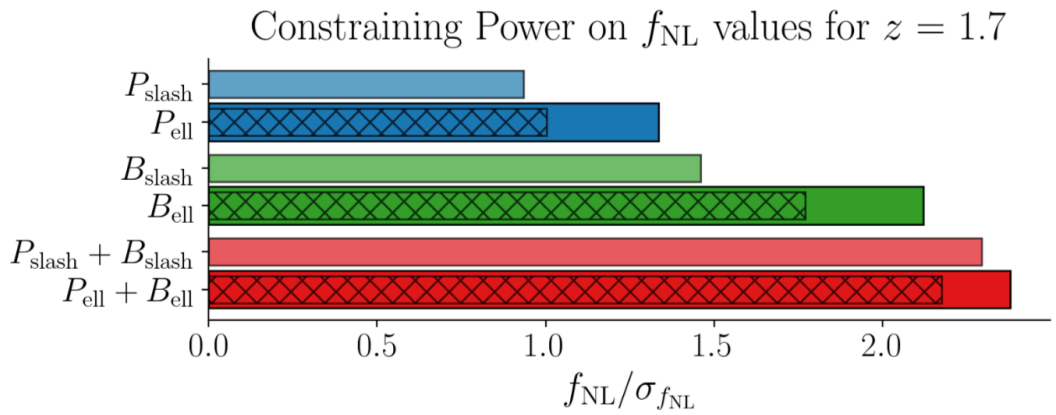
→ **Significant** and **unbiased** detection of **fNL** within the **Joint** driven by the Bispectrum

Constraining Power on fNL









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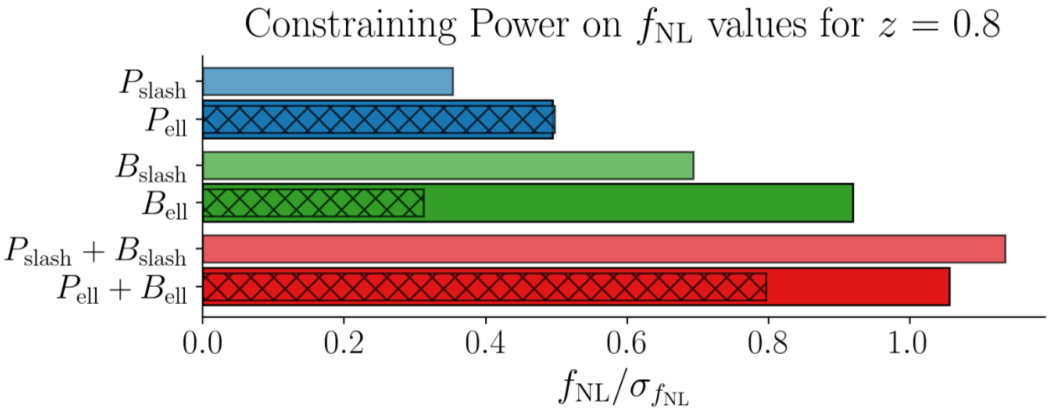
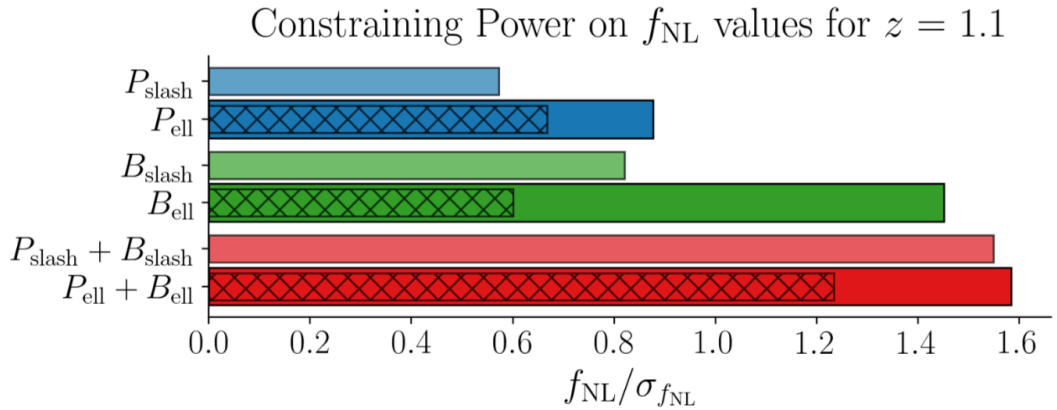
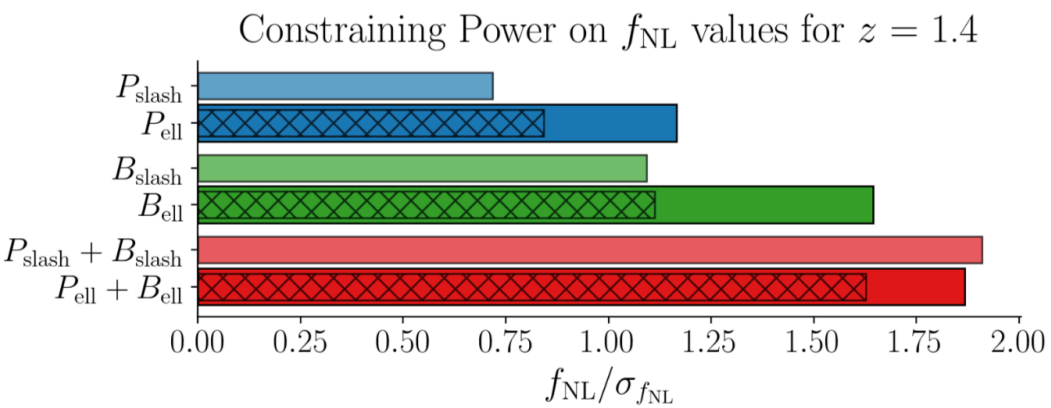
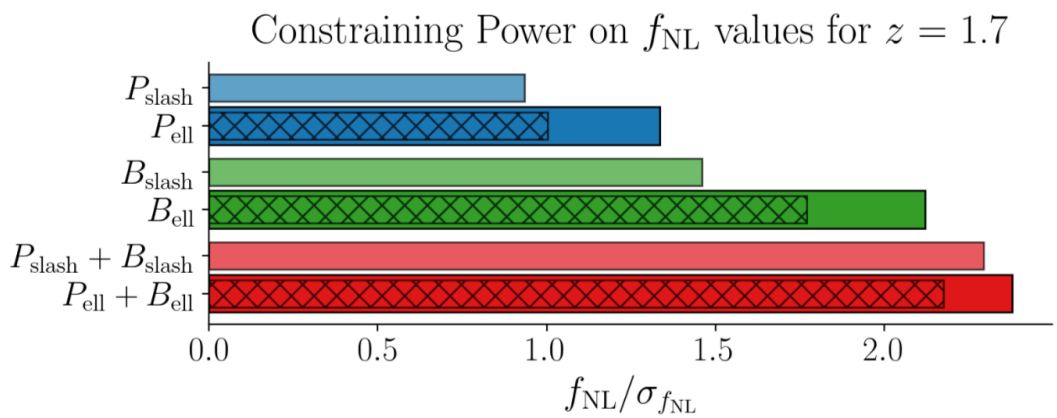




- Increased Constraining Power at **higher redshifts**
- **RSD helps** within P and B

- **> 1-sigma detection** within each Joint run
- Joint is on **equal terms with and without RSD**





Conclusion and Future Prospects

- Fast **CosmoSIS pipeline** for **Power Spectrum** plus **Bispectrum** used for the PNG analysis within Euclid
- **Full-Scope analysis** of the **Abacus-Suite** with **Euclid-like Galaxies**
- **Unbiased** and **significant detection** of **non-zero fNL** throughout all redshifts

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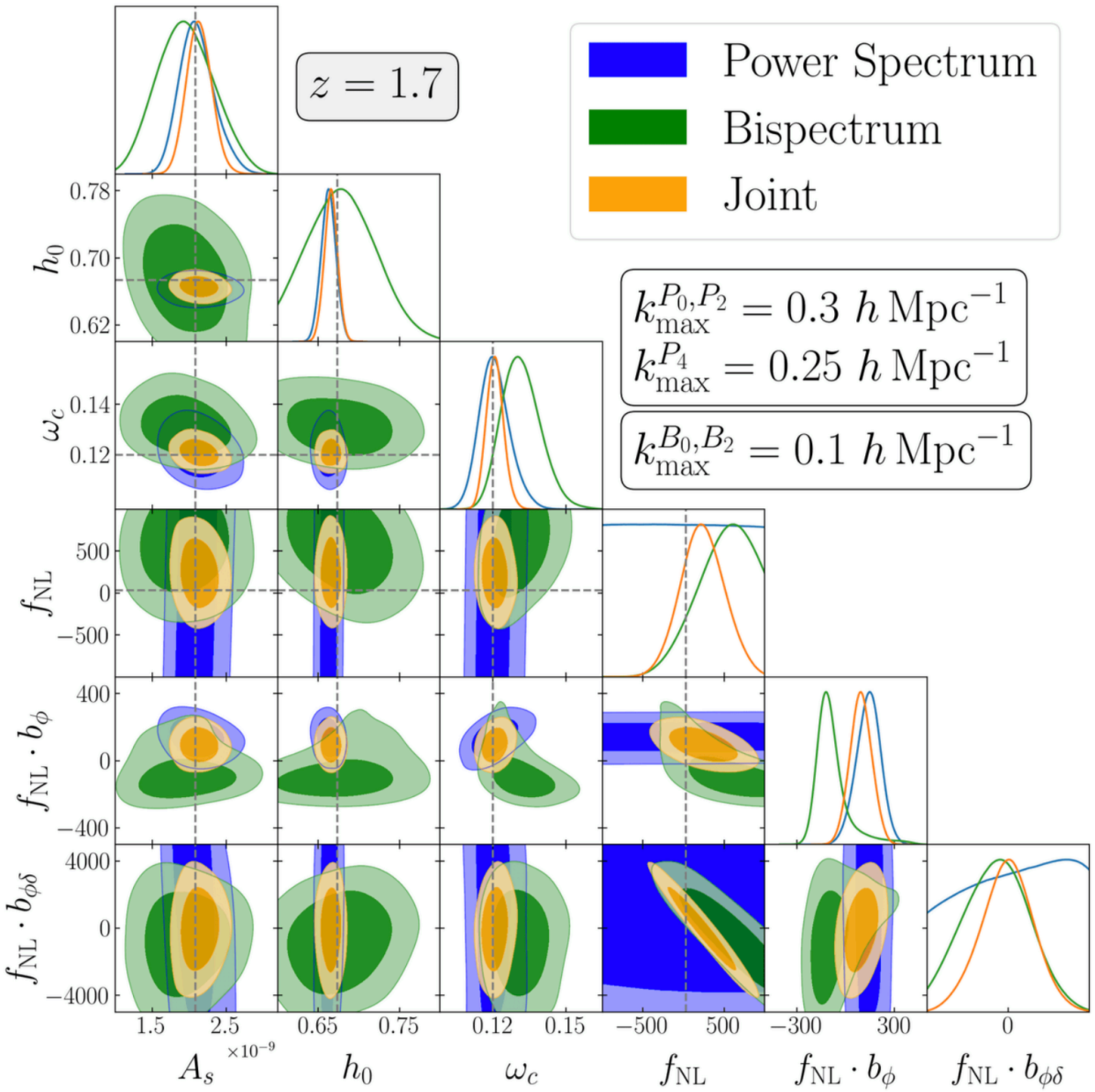
Upcoming:

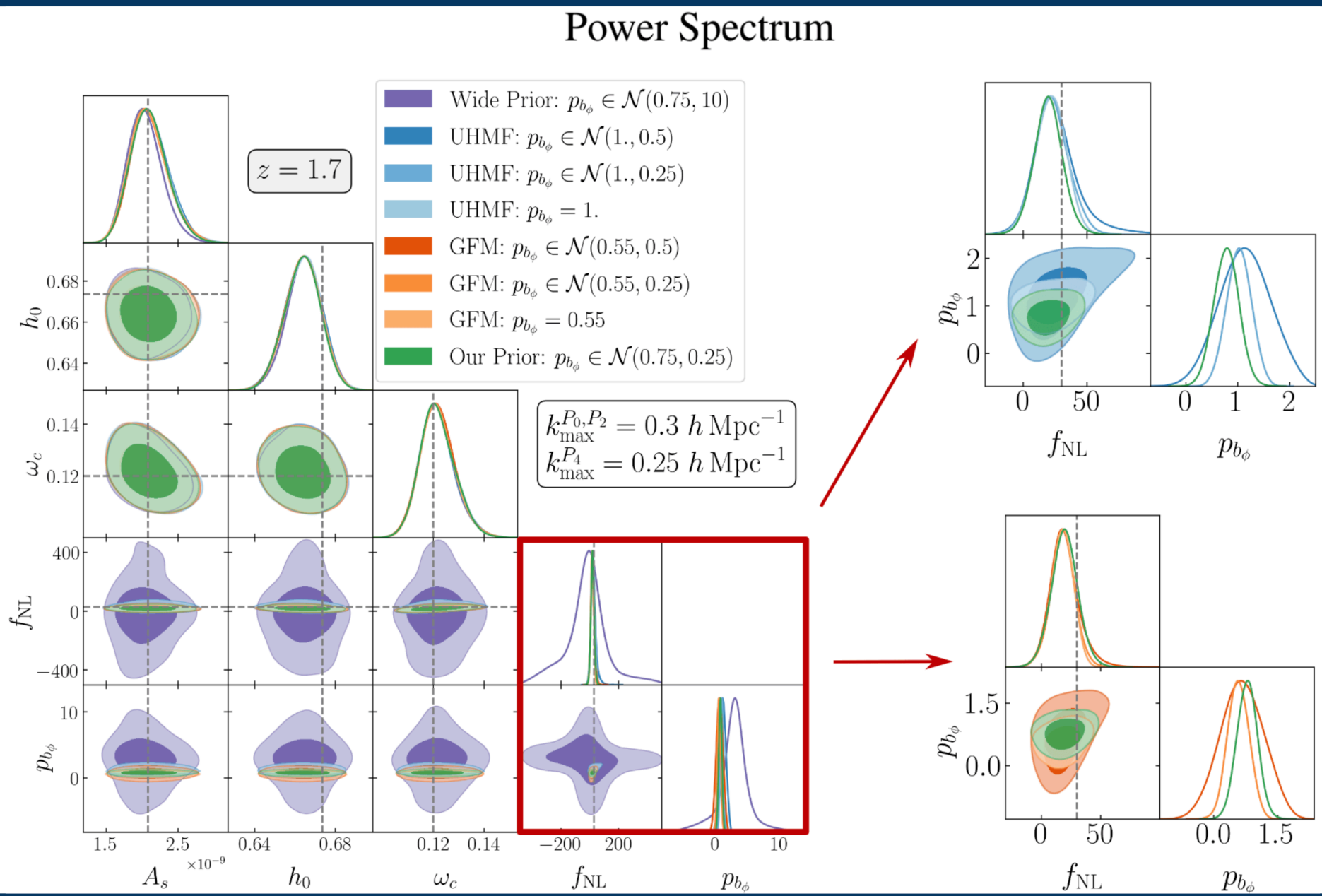
- **Adding Systematics** and **Survey Specifications** as additional modules within the pipeline
- Applying the pipeline to **Euclid DR1 - DR5**
- Including **other PNG shapes** (equilateral, orthogonal) at 1-loop order (in collab. with D. Karagiannis and M. Ballardini)


That's all folks!
Grazie per l'attenzione!

Constraining Power on the PNG Parameters



Physical Prior Choices



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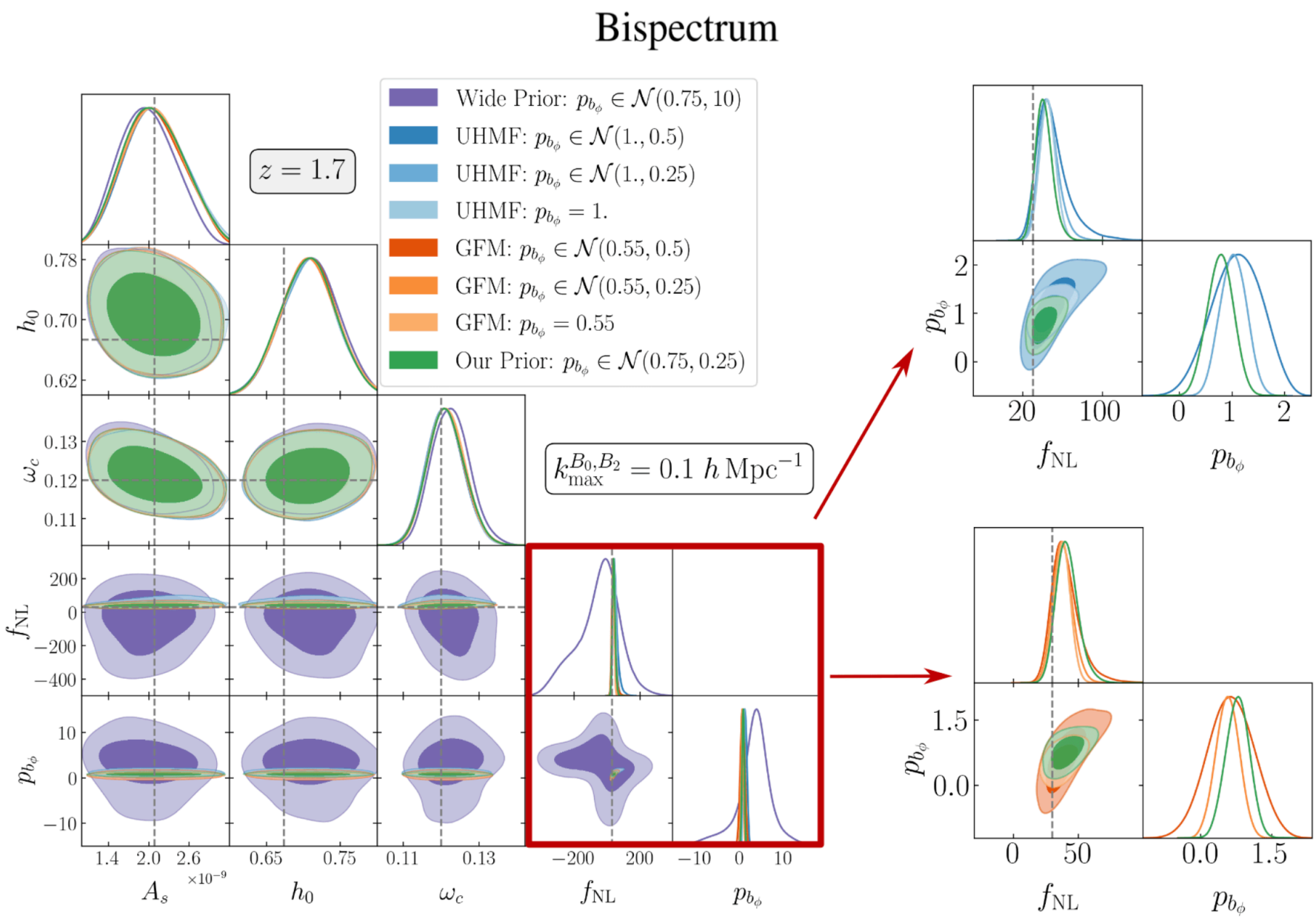
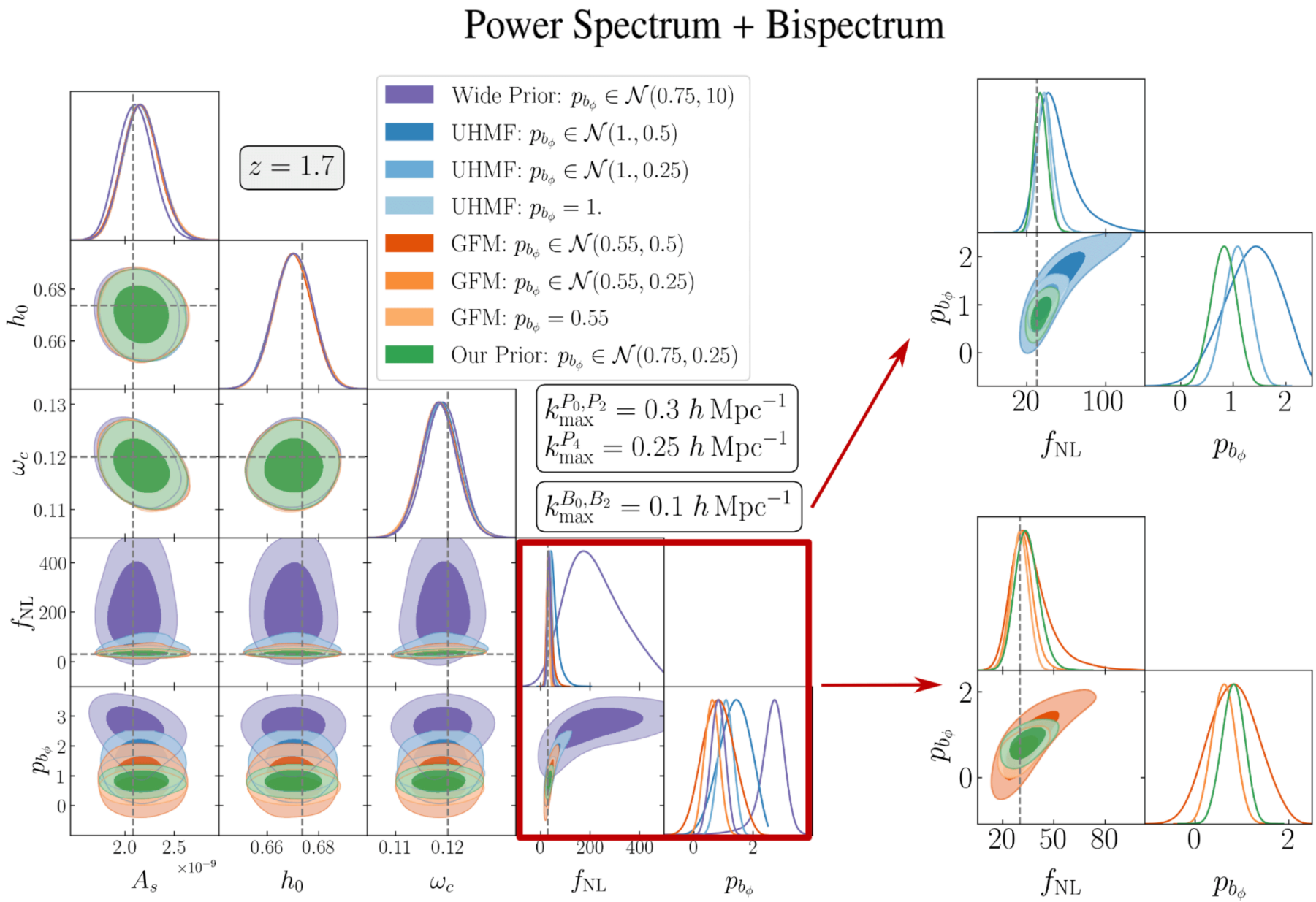
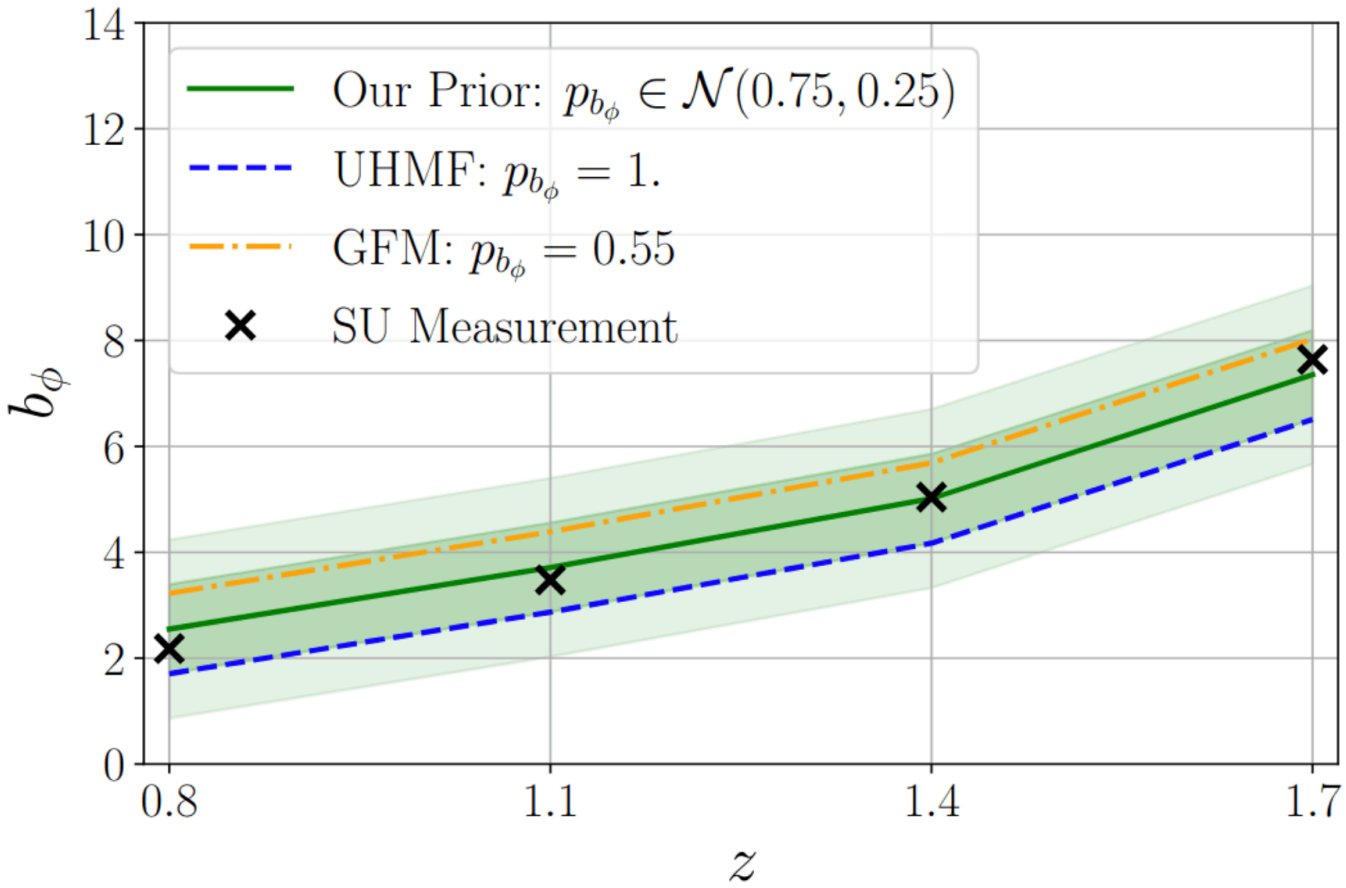


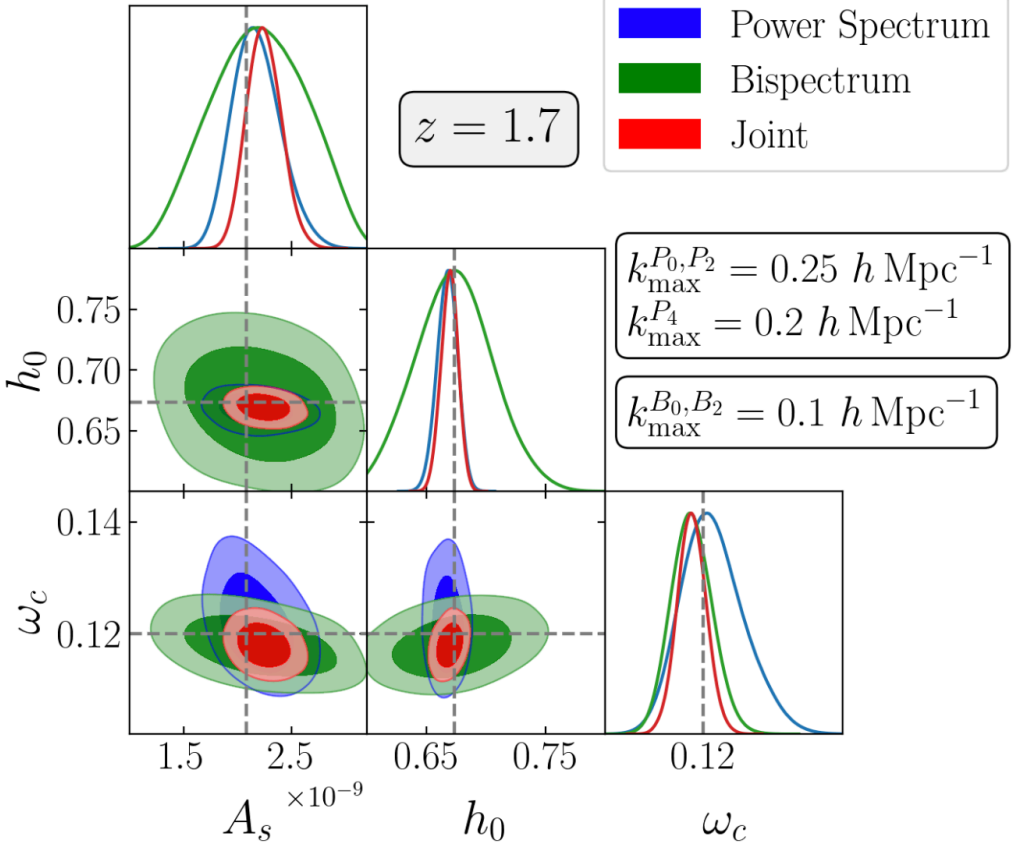
Physical Prior Choices

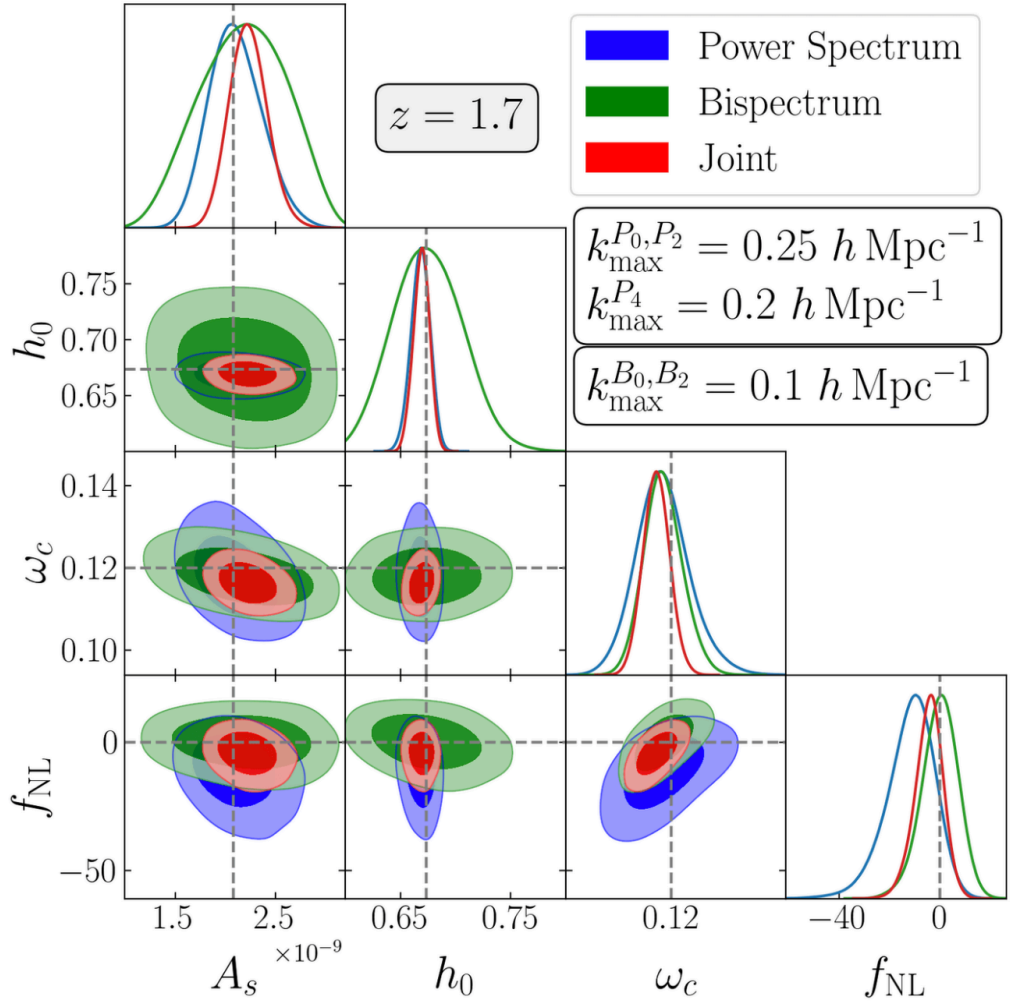


Physical Prior Choice vs. SU Measurement

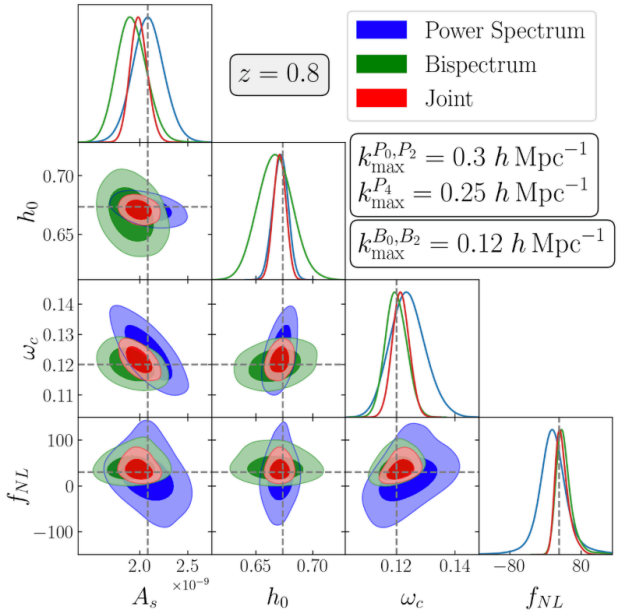


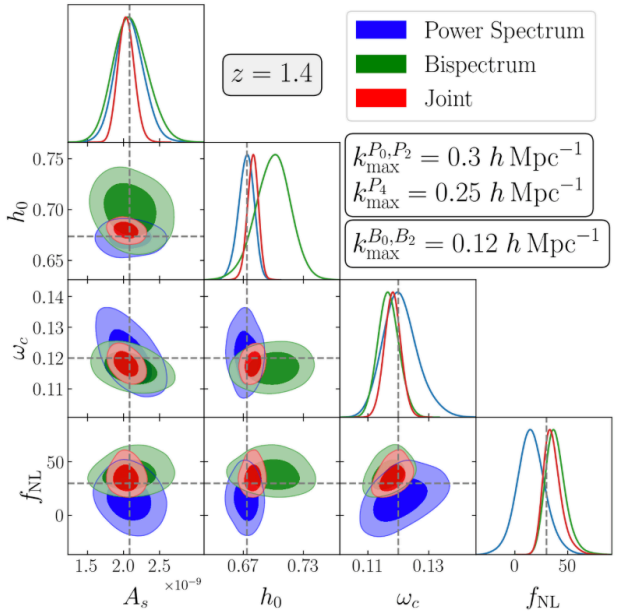
Null-Test on the Gaussian Simulations

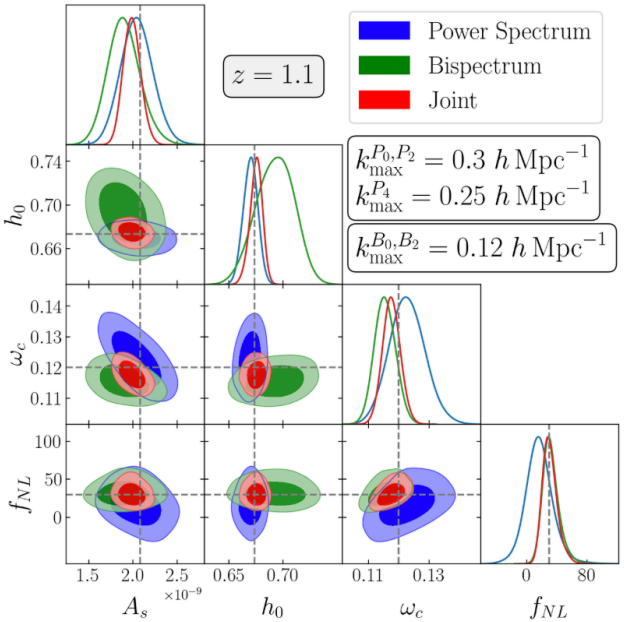


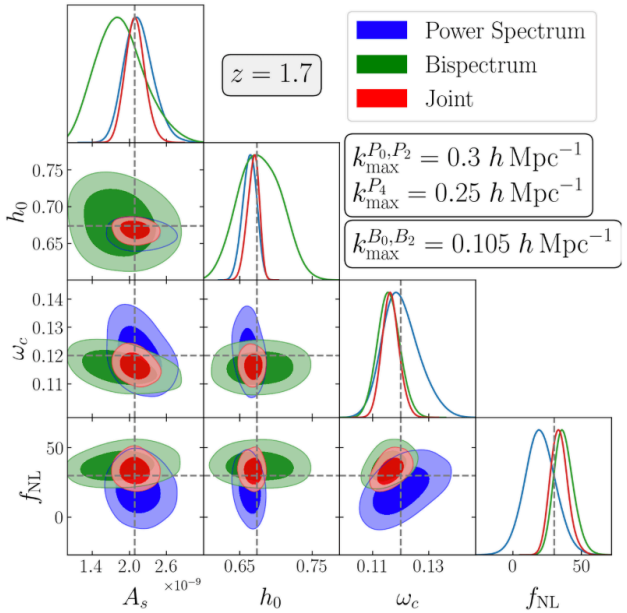


Posteriors of all redshifts



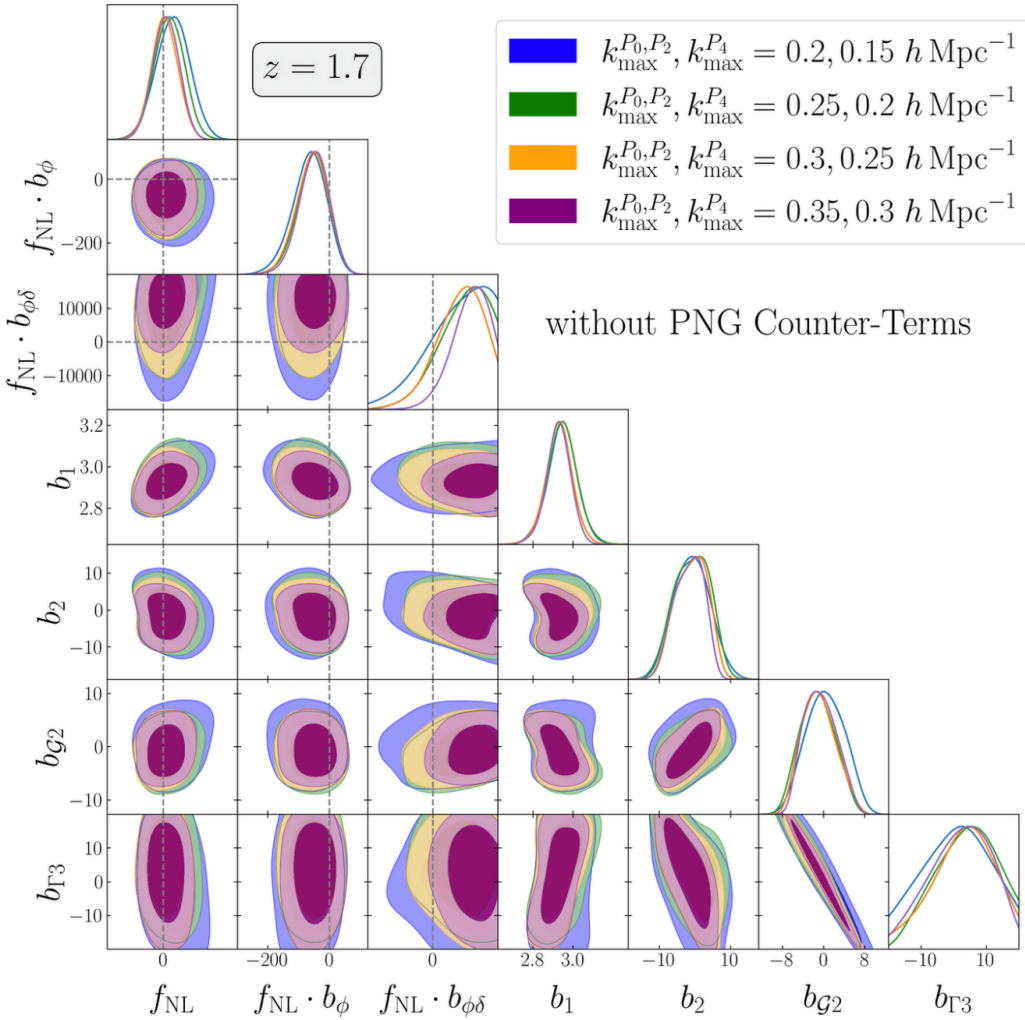


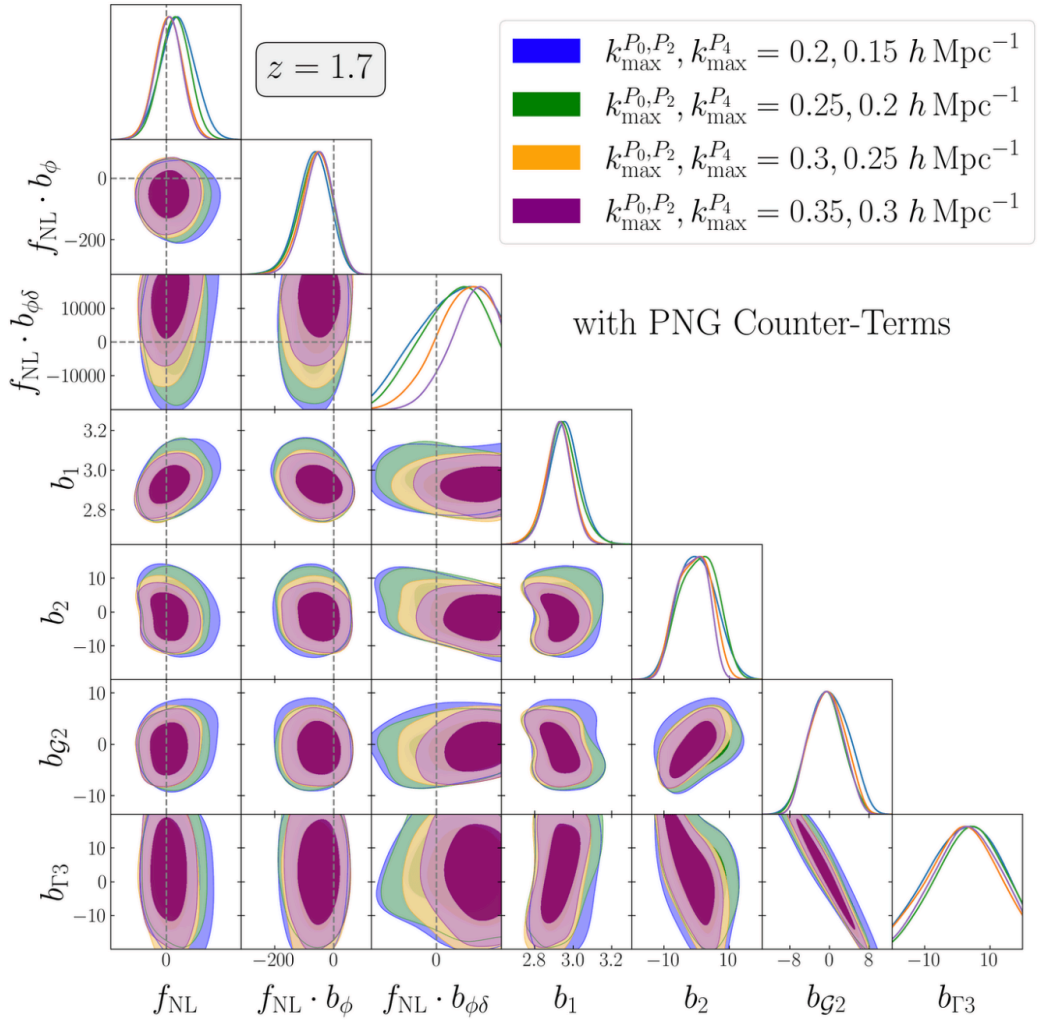




Importance of the PNG Counter-Terms

$$P^{\rm PNG}_{ct,\Phi}(k,\mu) = -\,k^2\,\mathcal{M}^{-1}(k)\,P(k)\,\left(C_0^{\Phi} + C_2^{\Phi}\,\mu^2 + C_4^{\Phi}\,\mu^4\right)$$
$$P^{\rm PNG}_{ct,12}(k,\mu) = -\,k^2\,\mathcal{M}(k)\,\left(C_0^{12} + C_2^{12}\,\mu^2 + C_4^{12}\,\mu^4\right)$$





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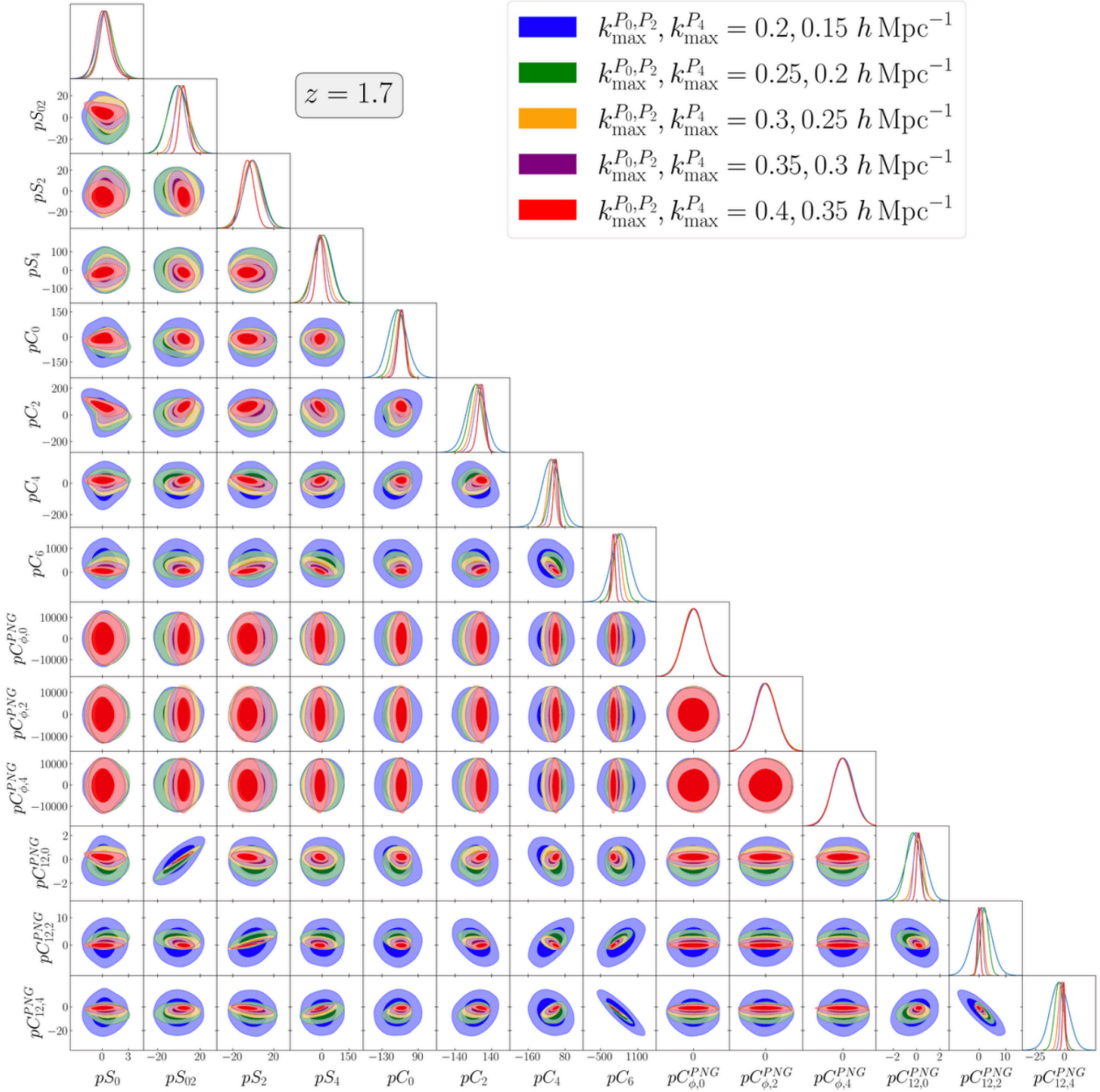
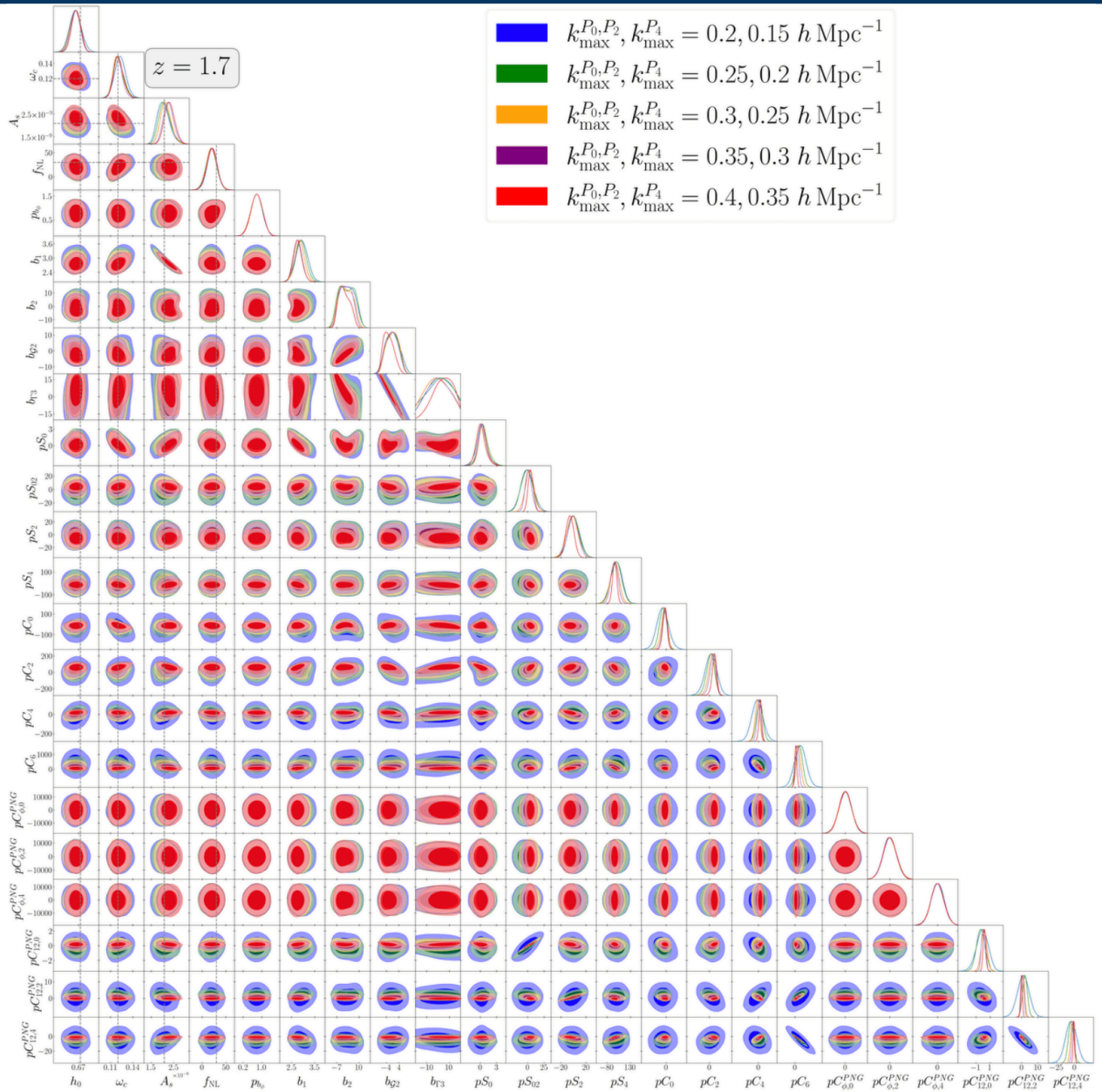
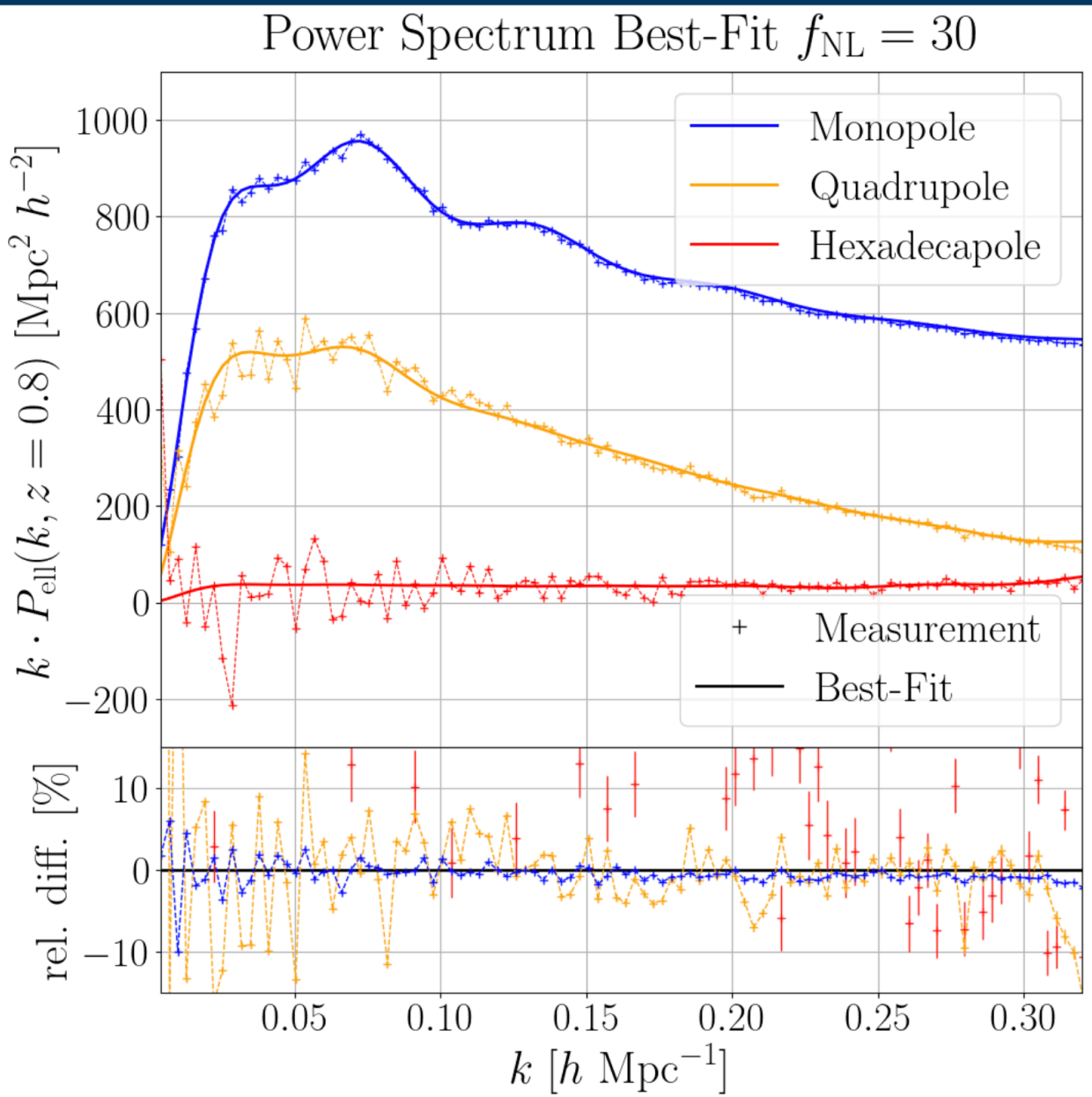


Full Power Spectrum Parameter Space



Best-Fit for fNL = 30



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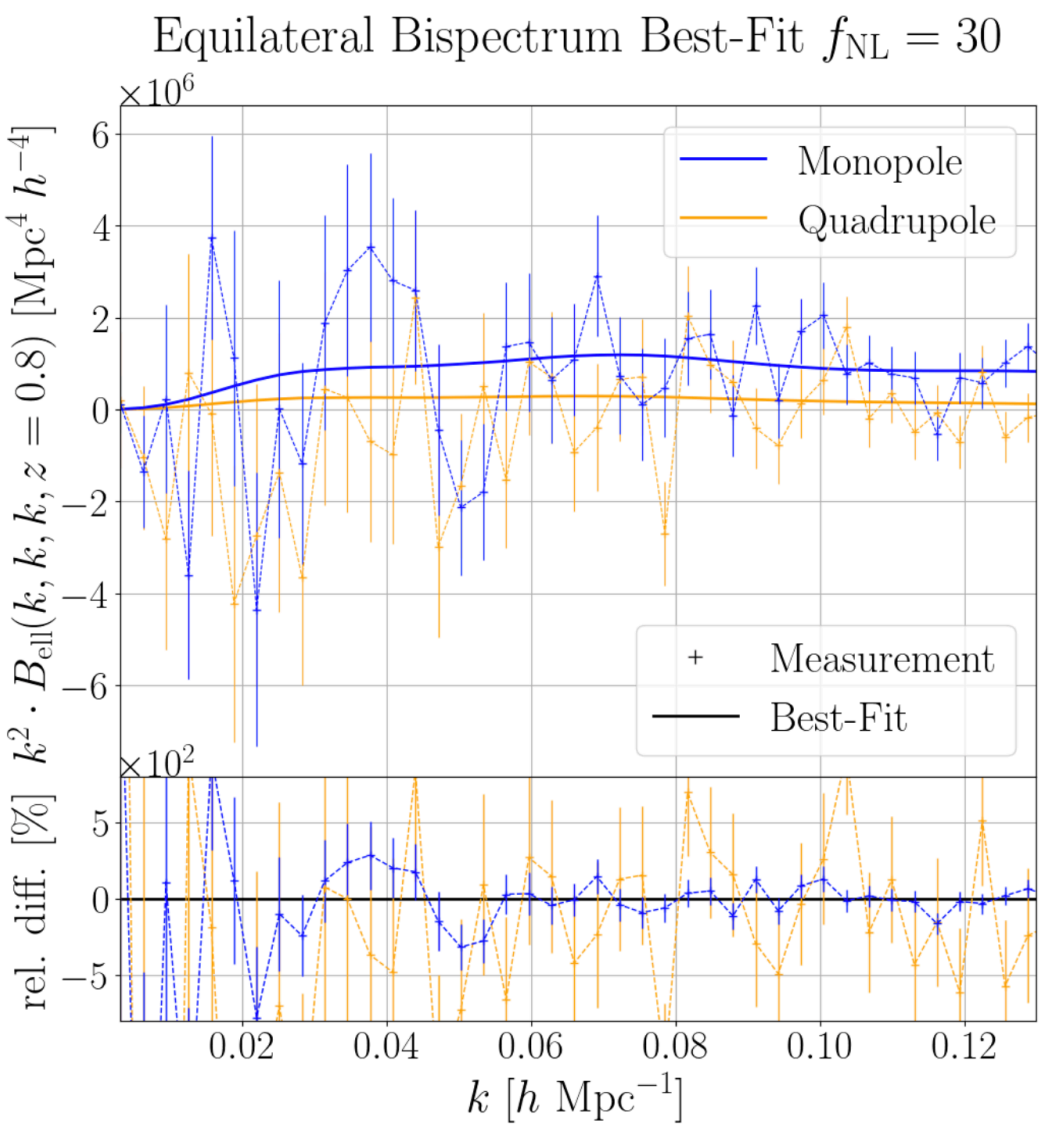
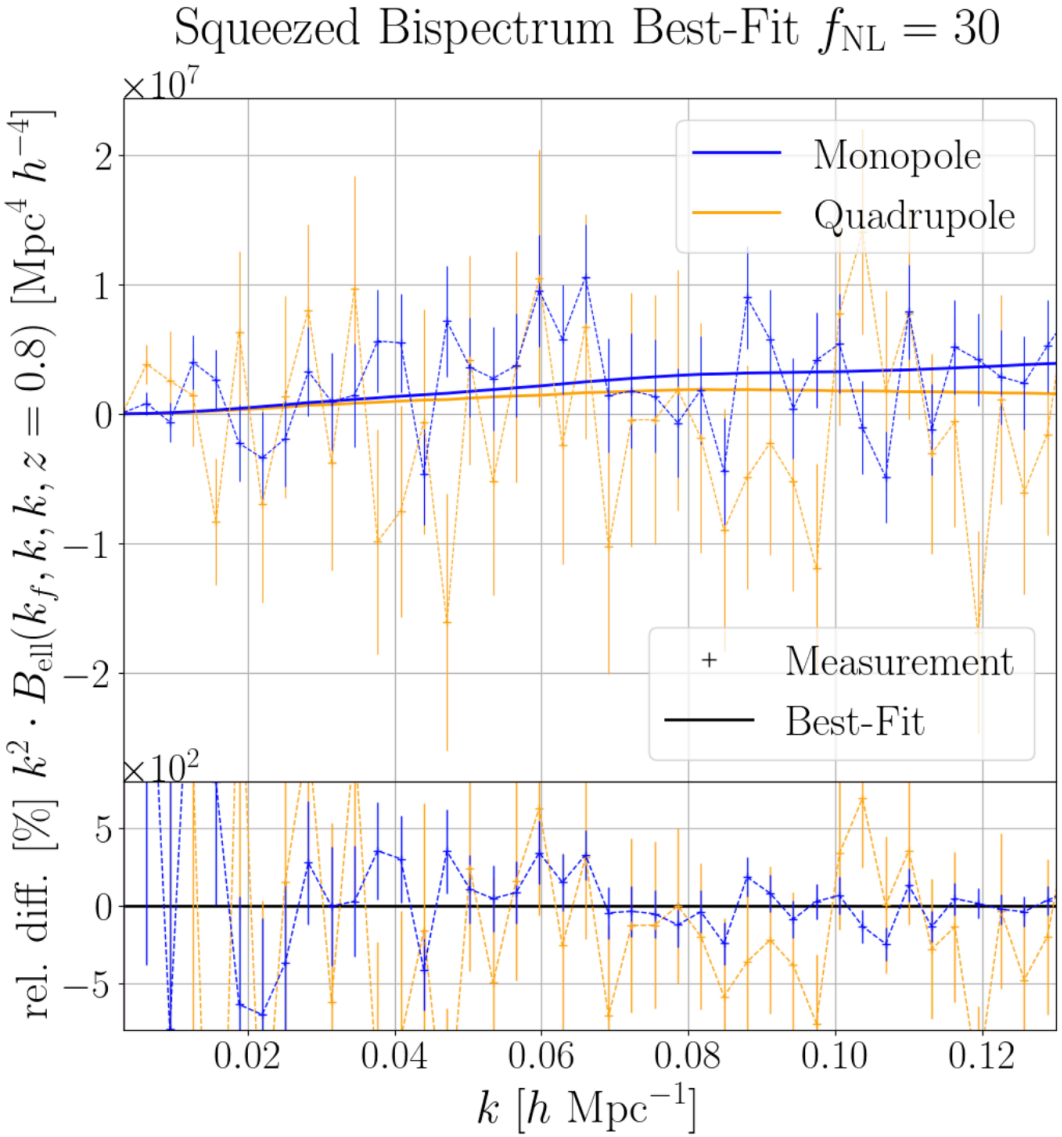
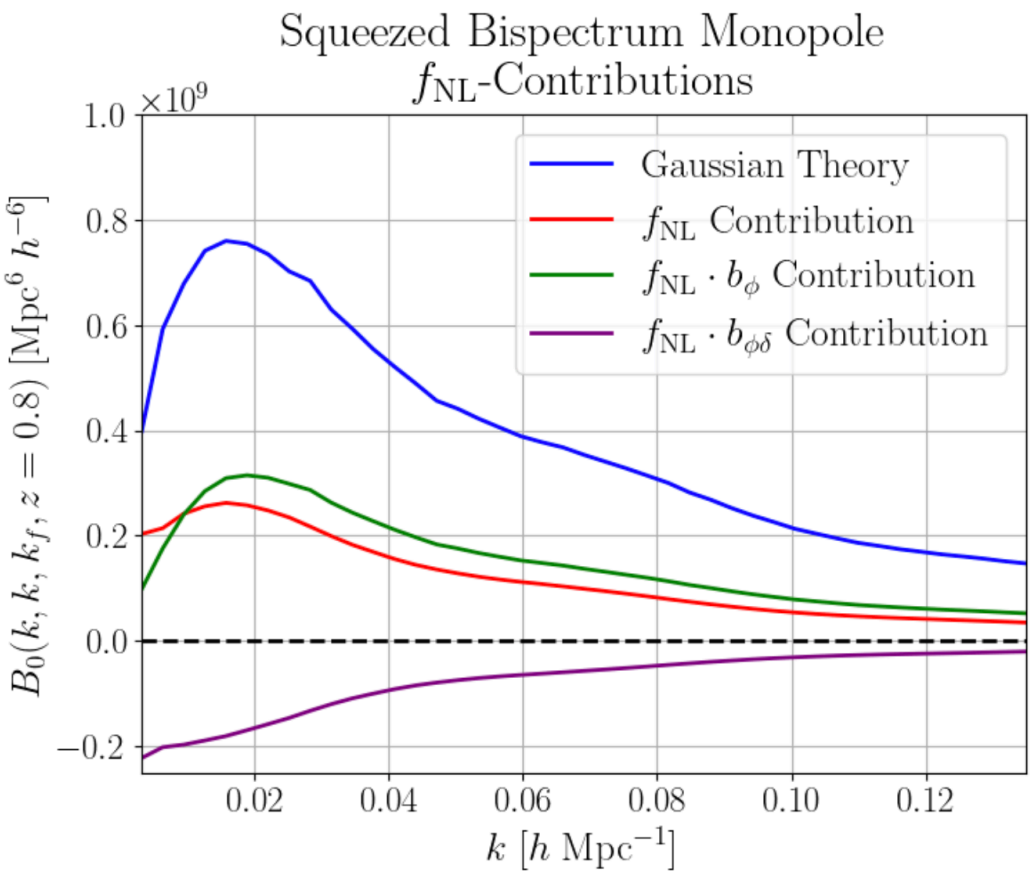
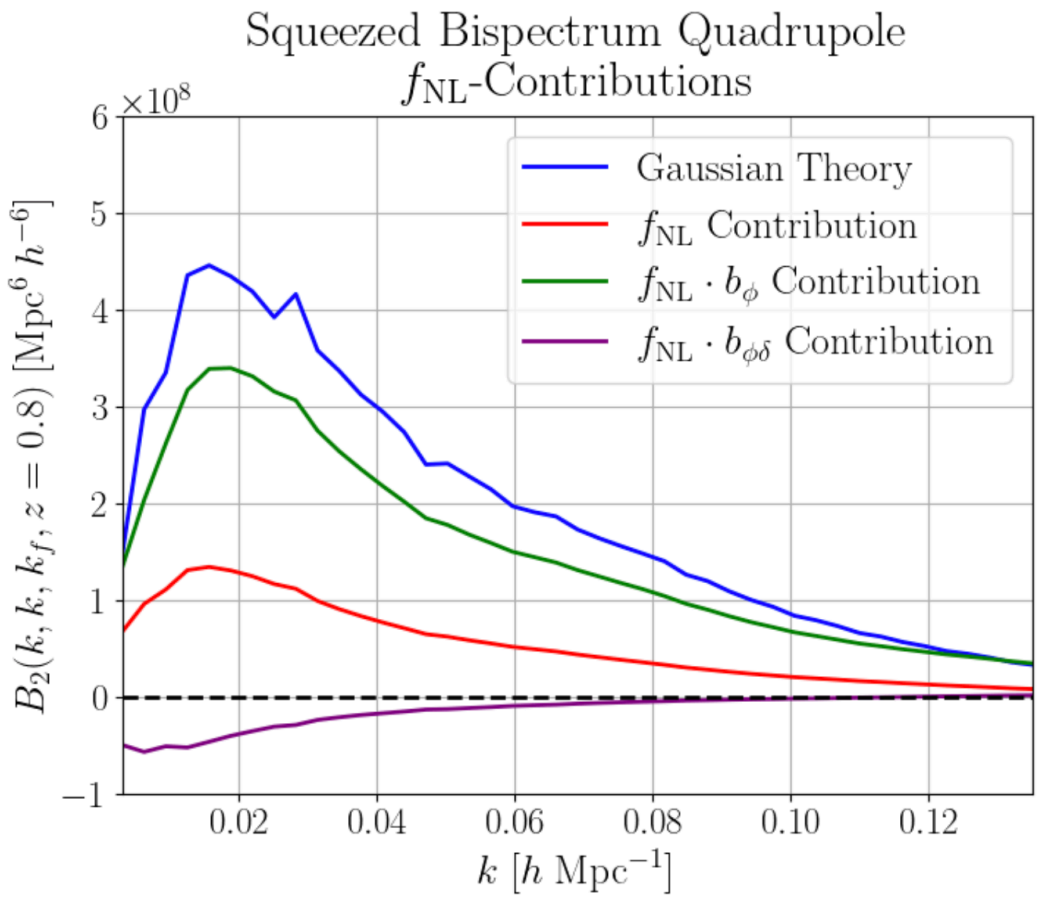


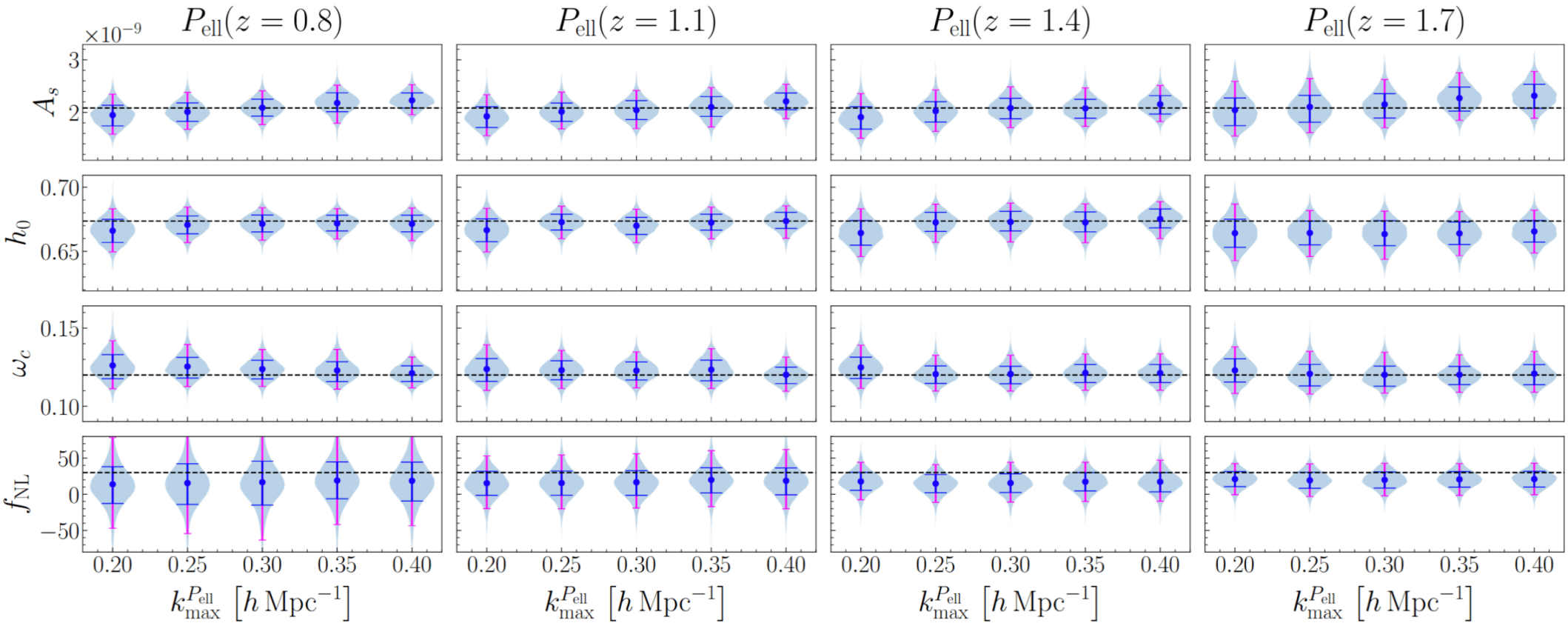


PNG Effect on the Bispectrum





Scale-Cut Analysis Power Spectrum



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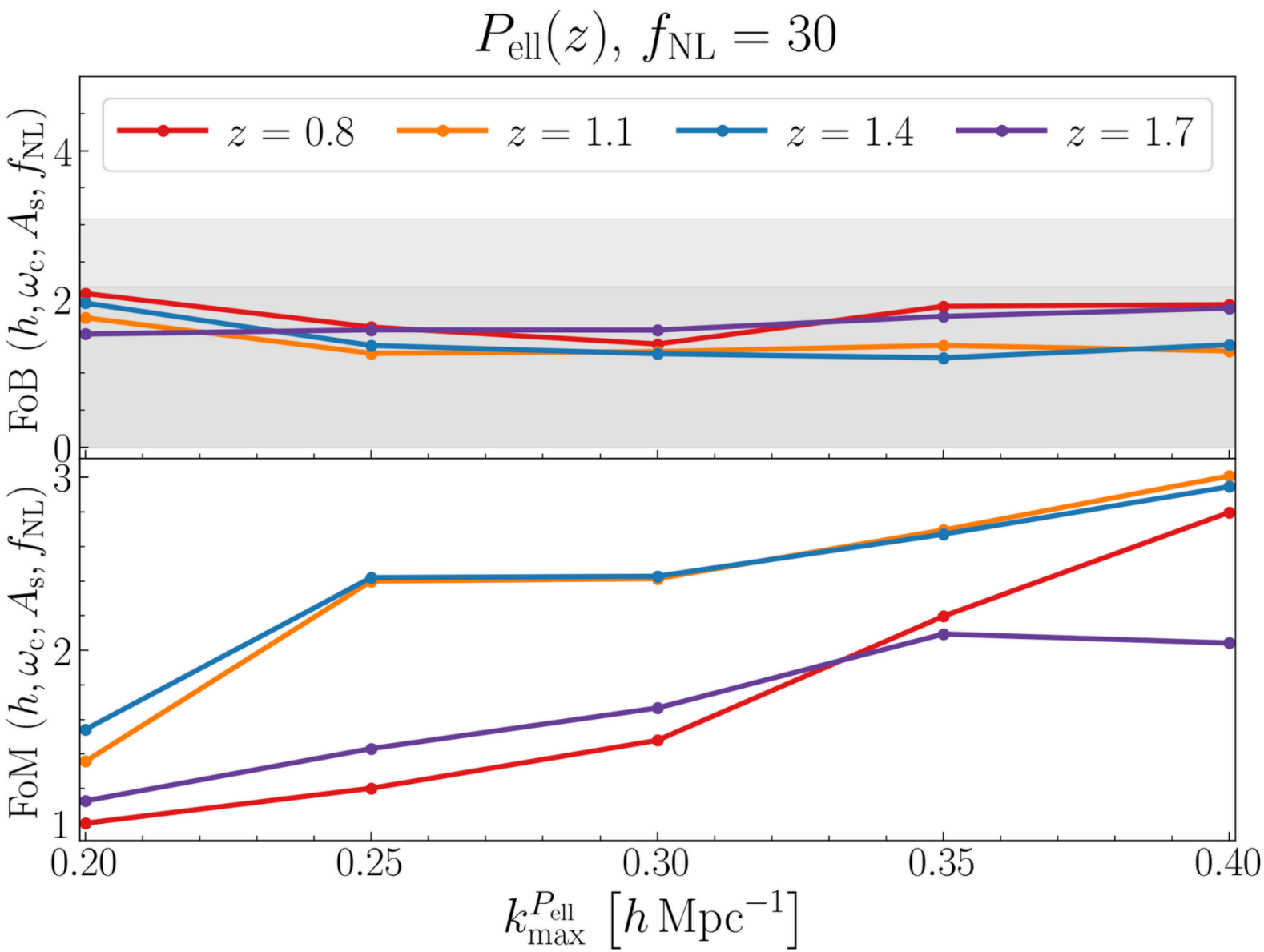
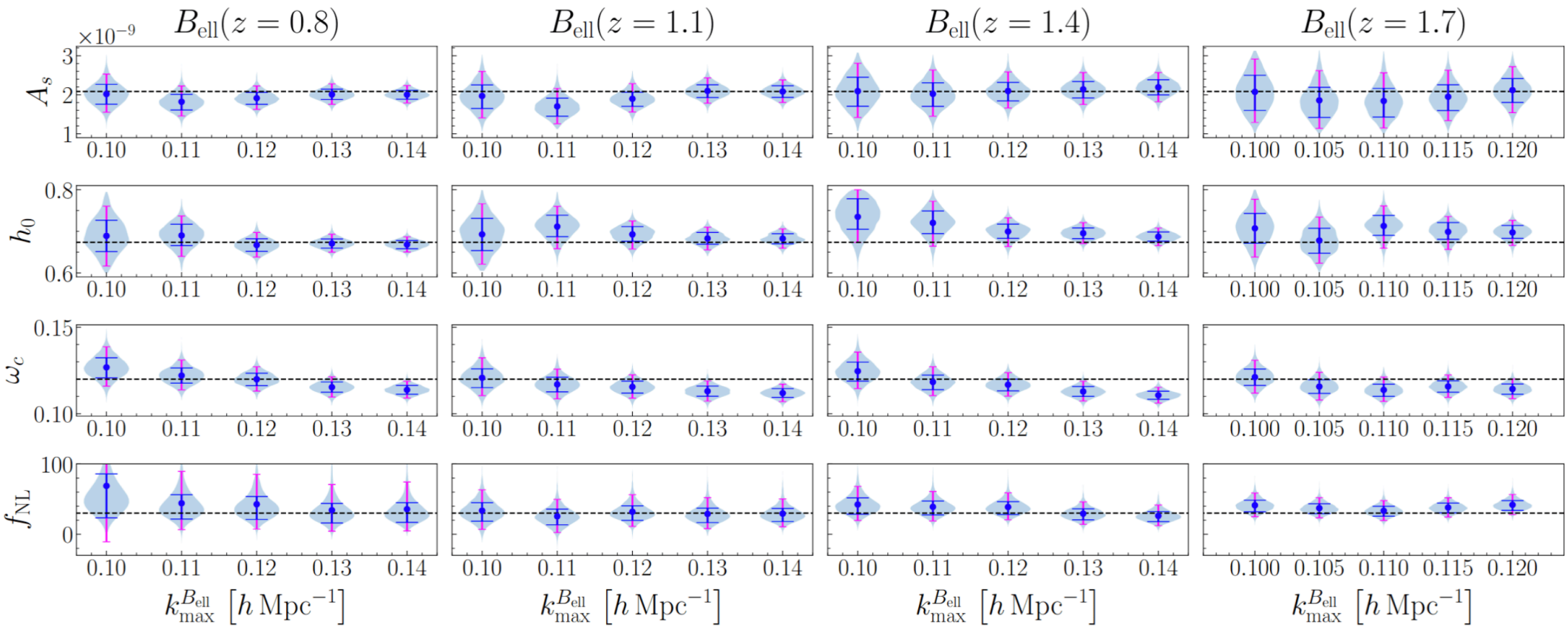


Scale-Cut Analysis Bispectrum



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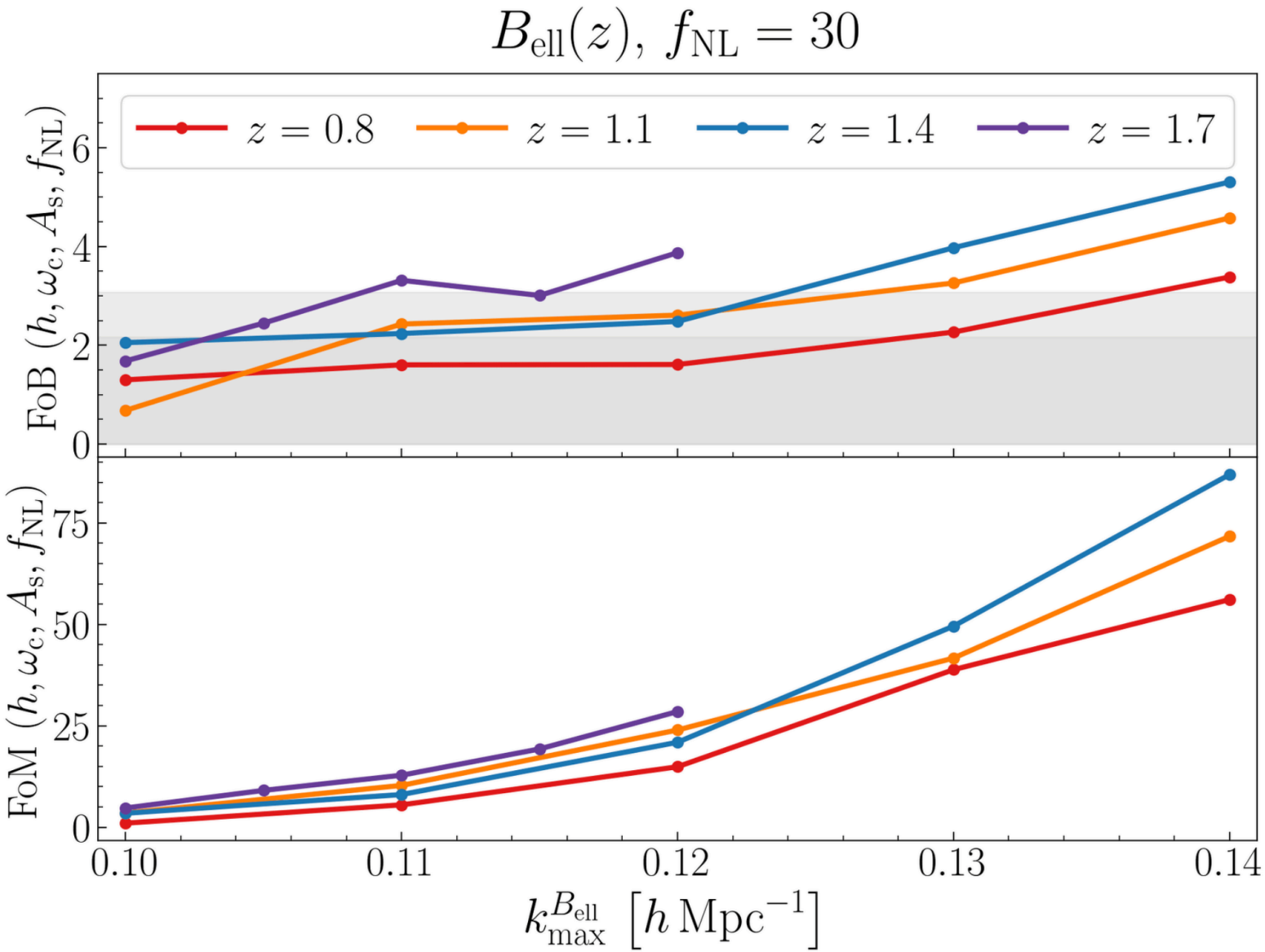
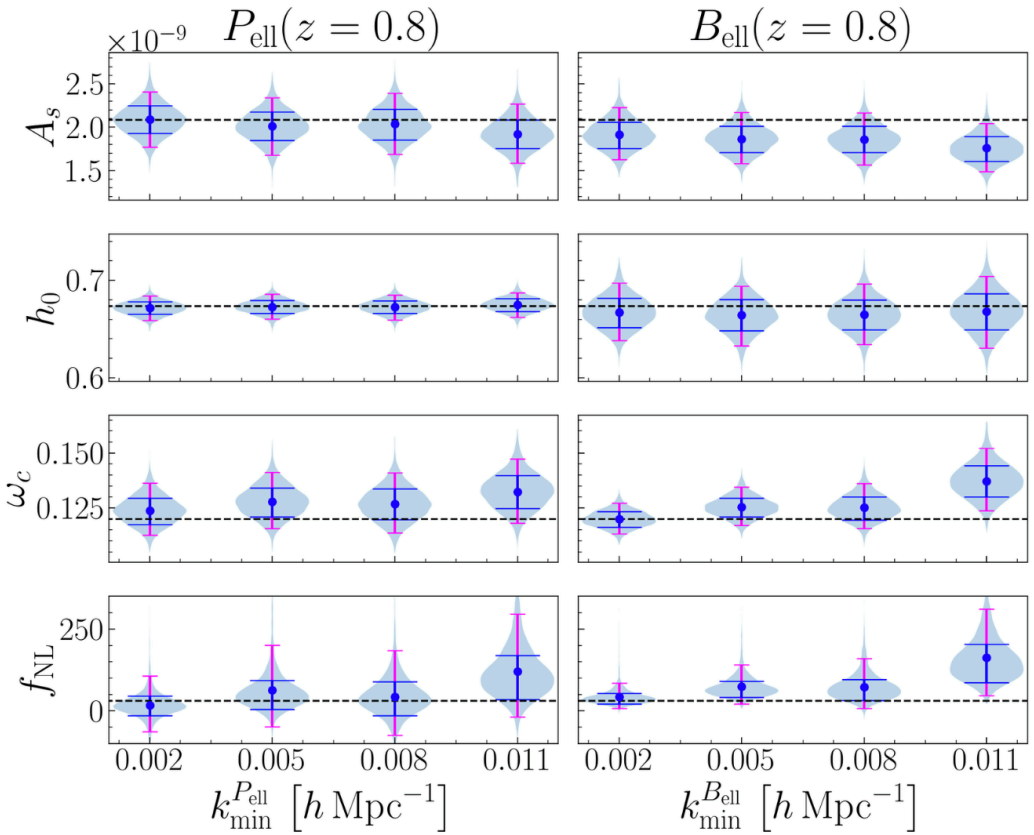
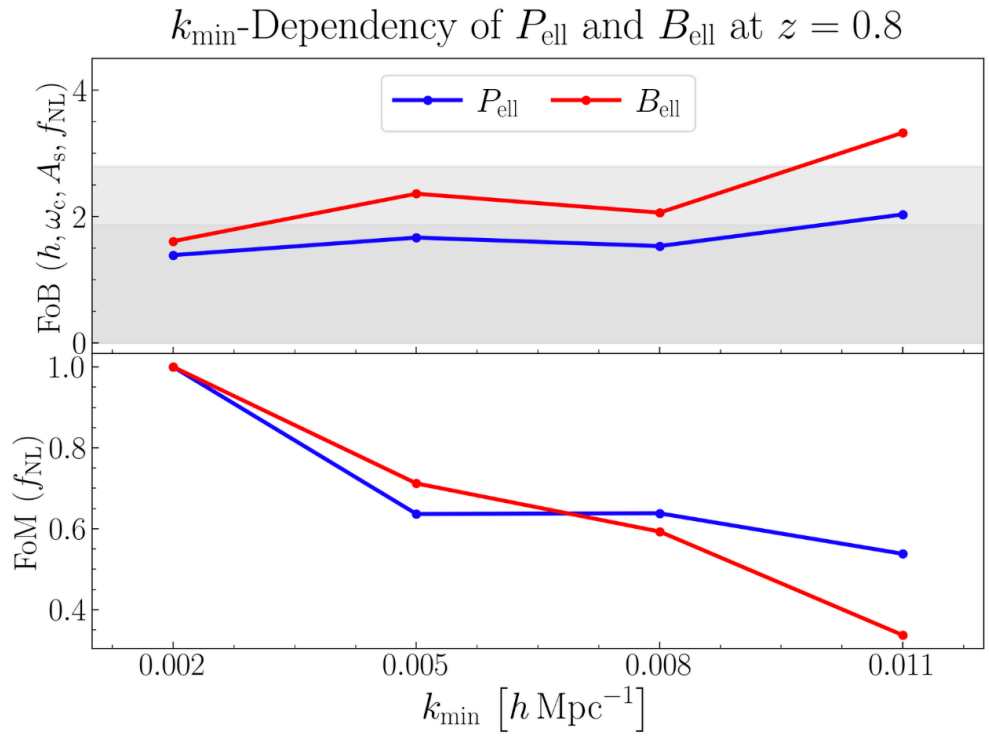
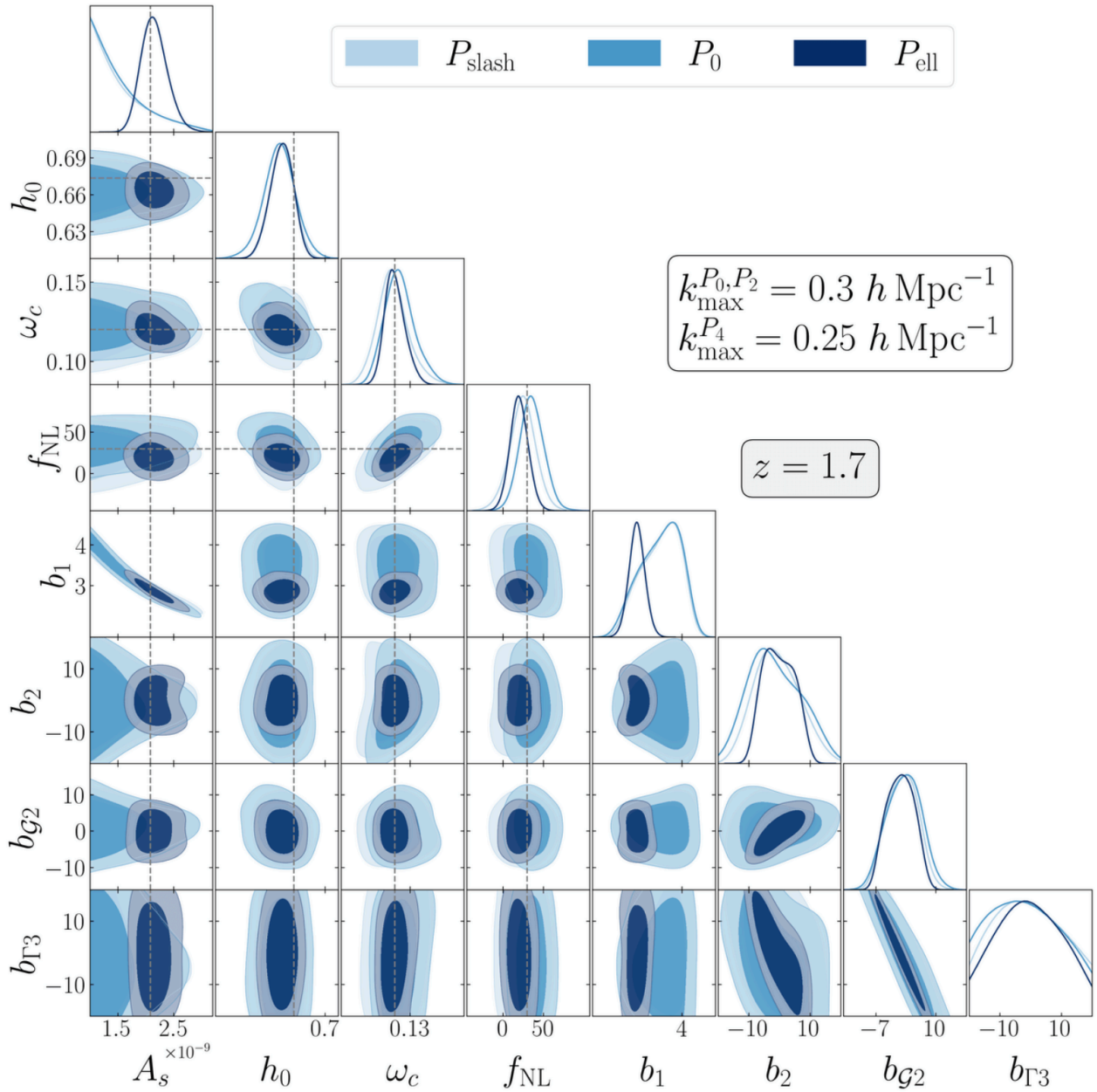


Constraints from Largest Scales

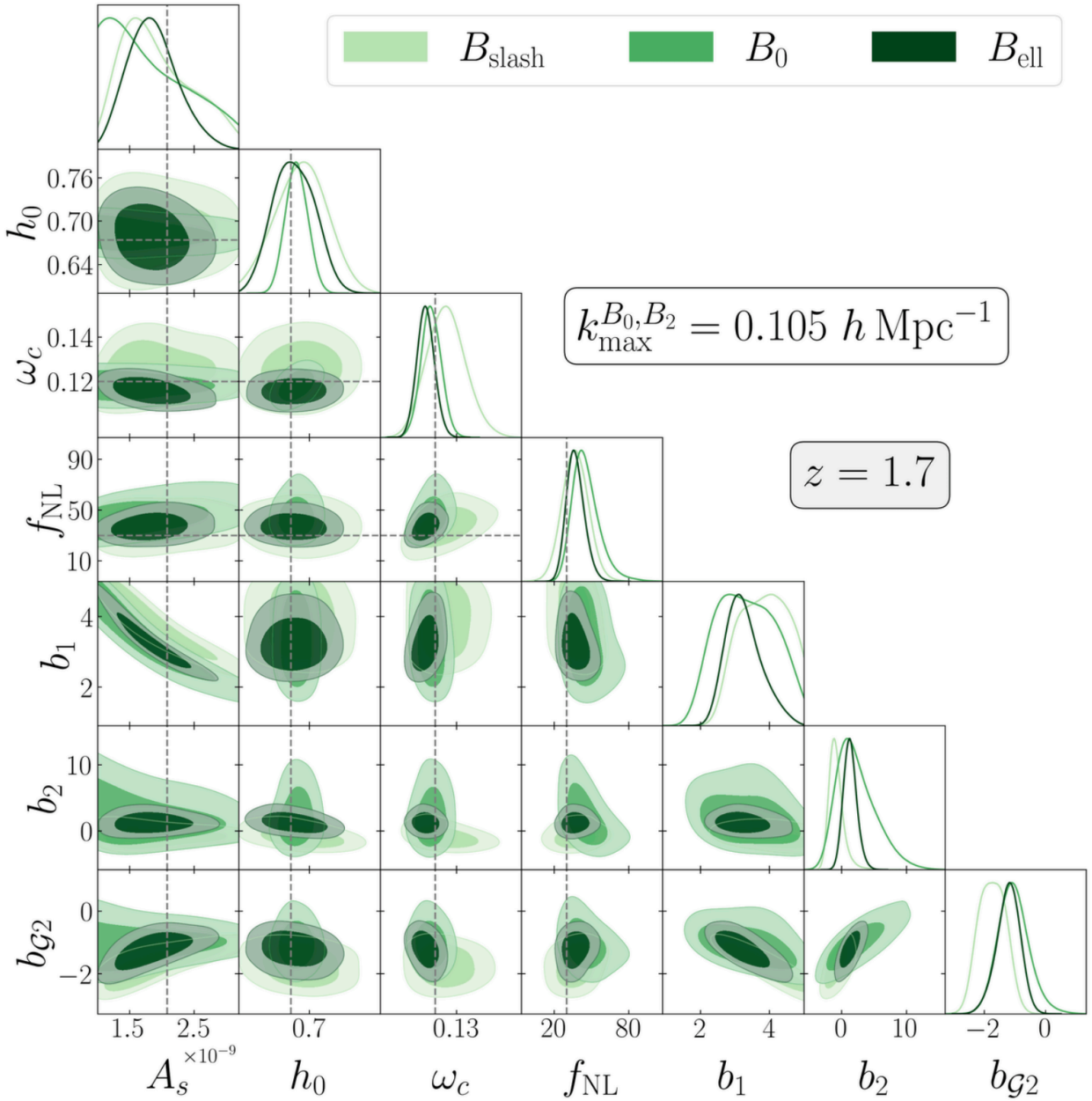




Multipoles vs. Slash Posteriors



Multipoles vs. Slash Posteriors



Multipoles vs. Slash Posteriors