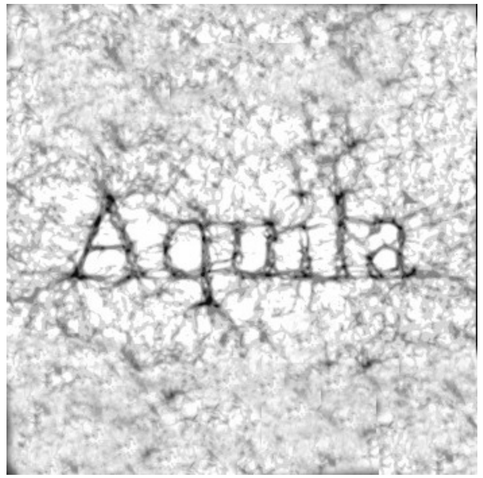
Field-level inference of local primordial non-Gaussianity with next-generation galaxy surveys

Adam Andrews
w. J. Jasche, F. Finelli, G. Lavaux, F. Schmidt



Parma, 2024
New Physics from Galaxy Clustering

arxiv: 2203.08838

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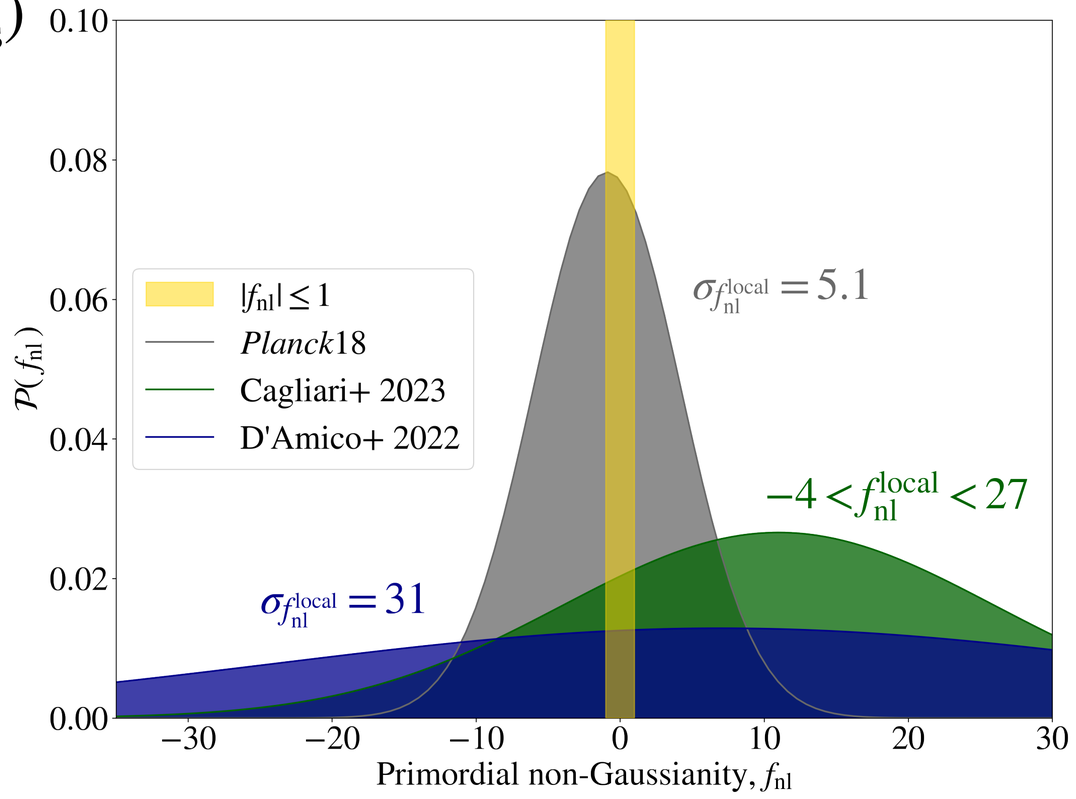

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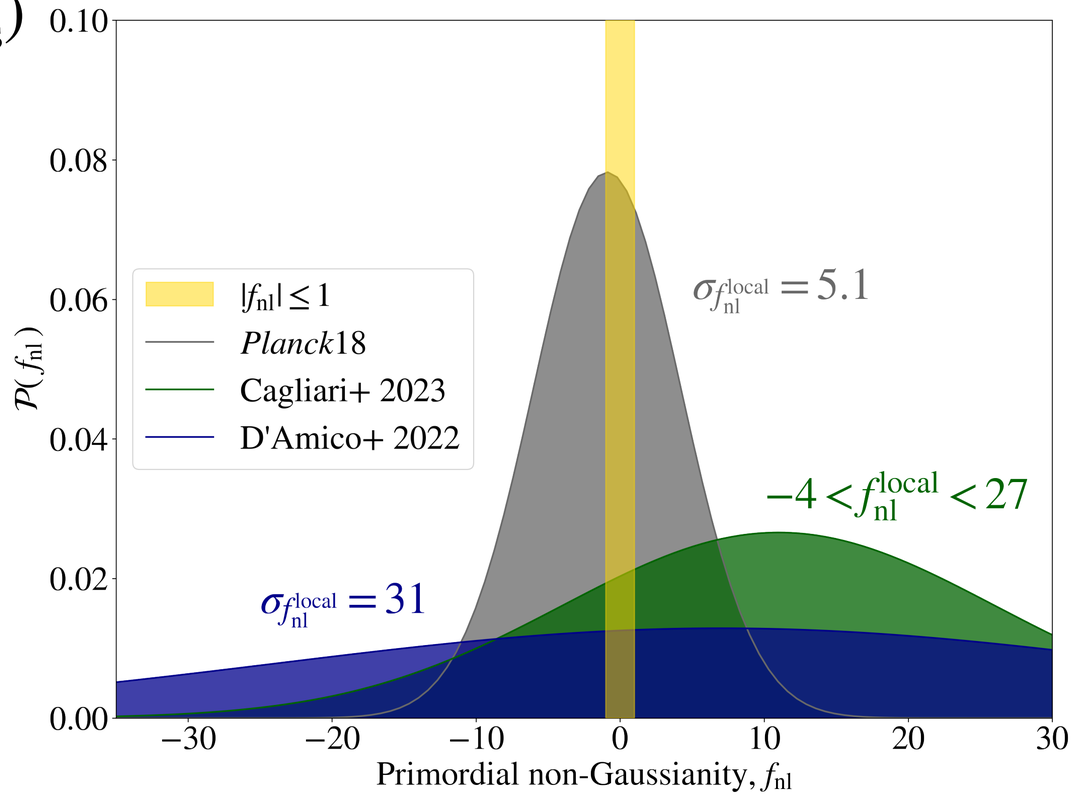

*Planck 2018

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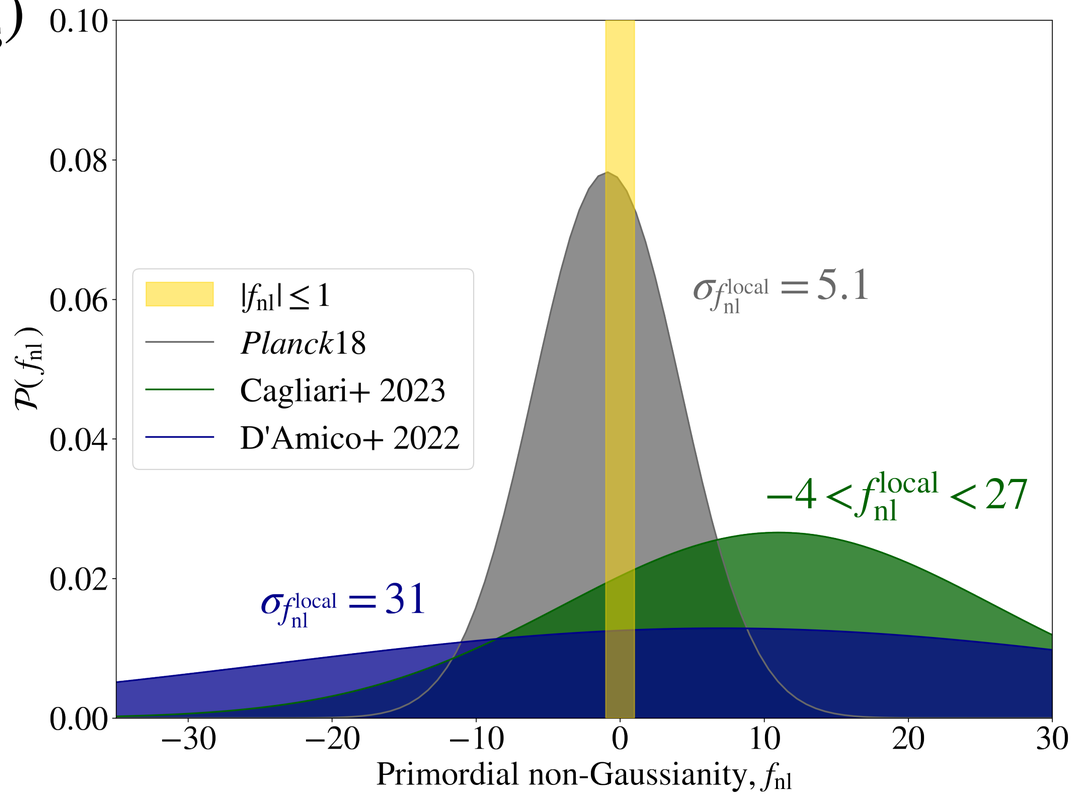

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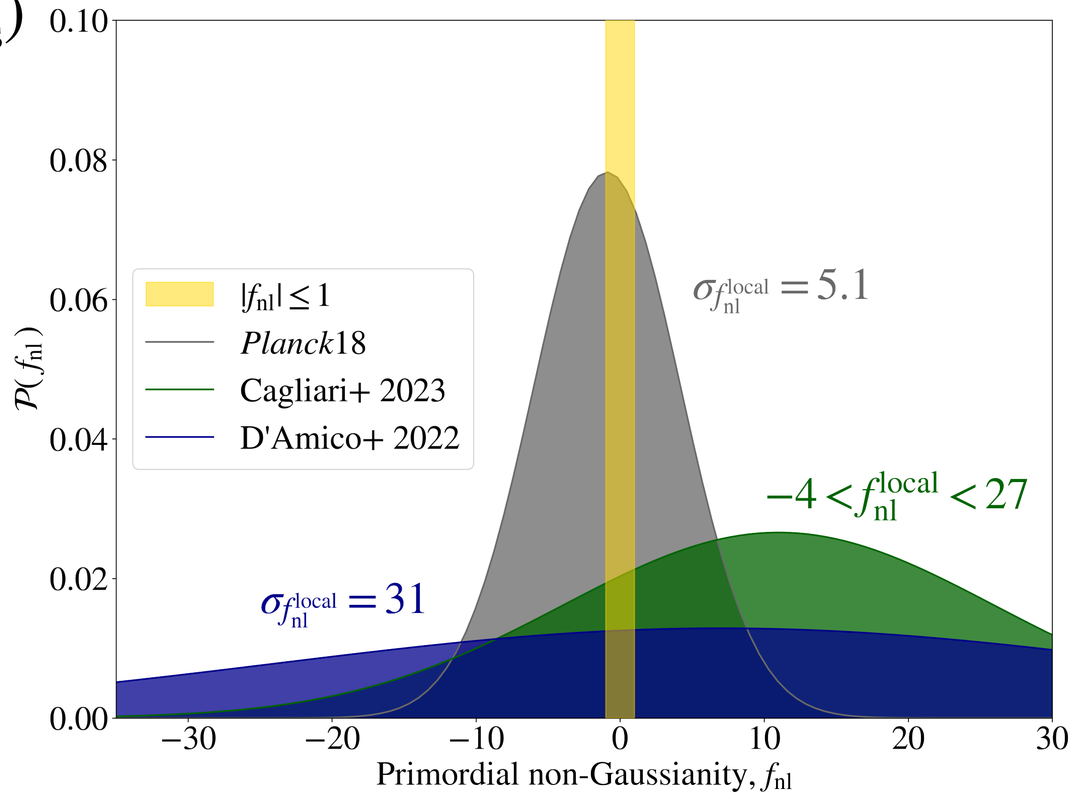

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(Bispectrum + Power spectrum)***:

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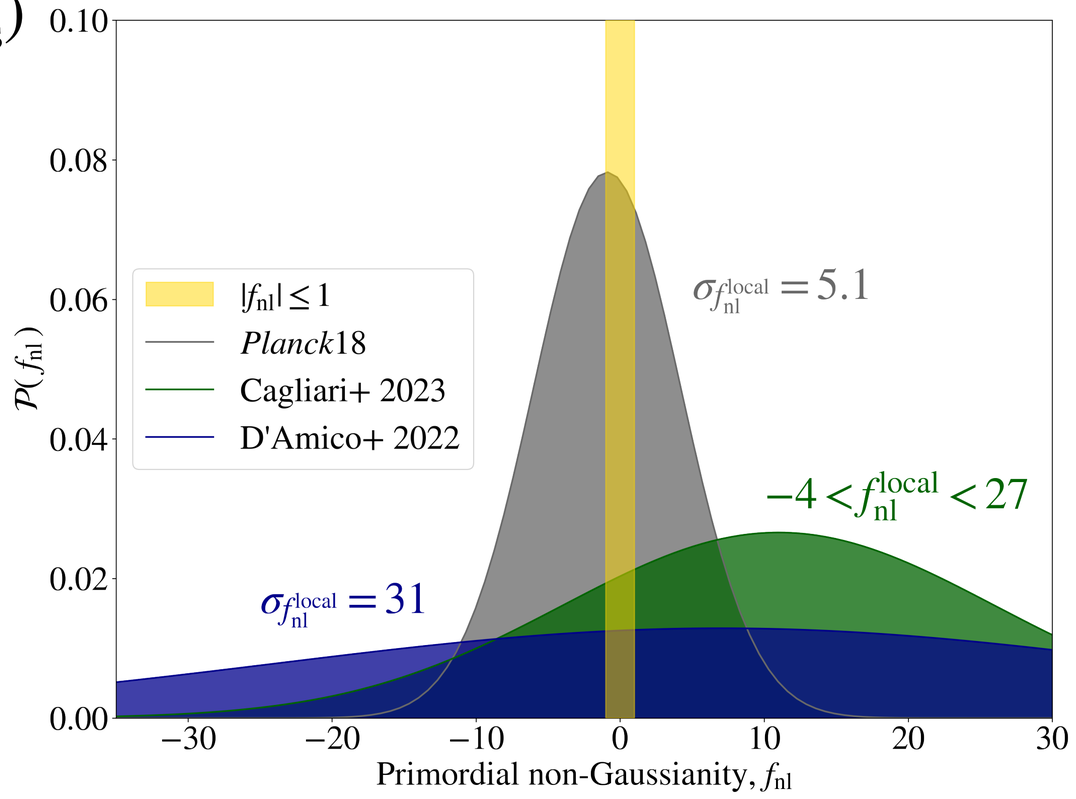

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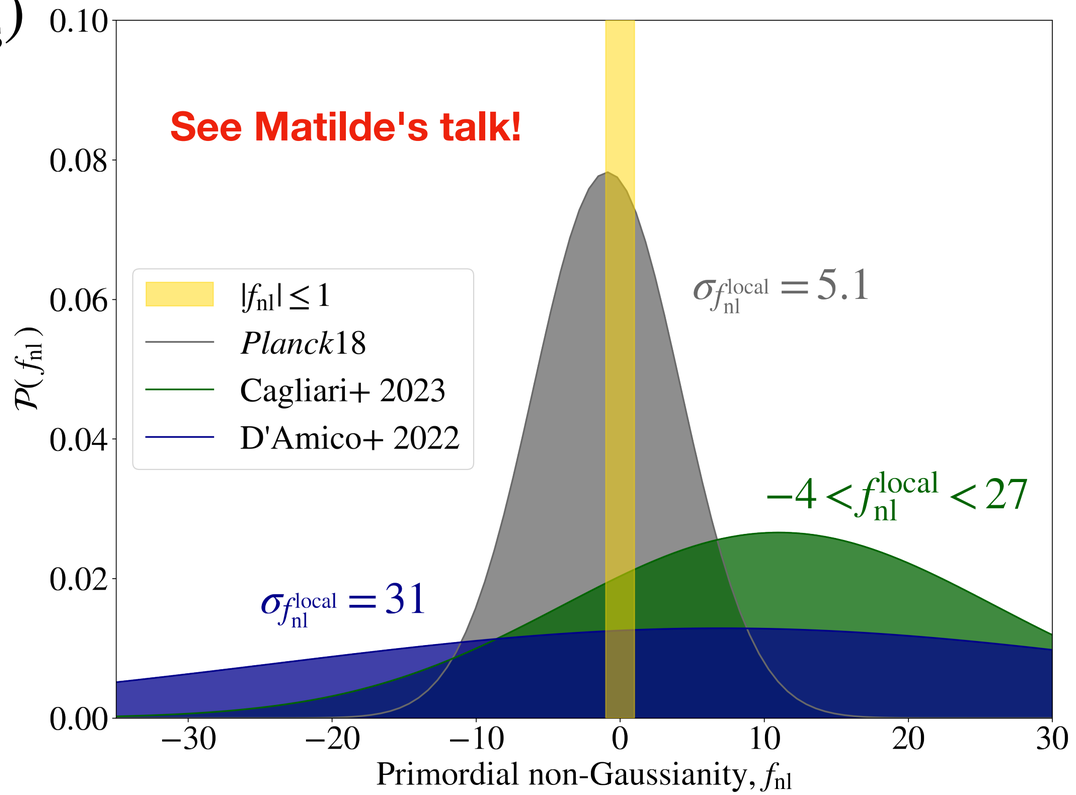

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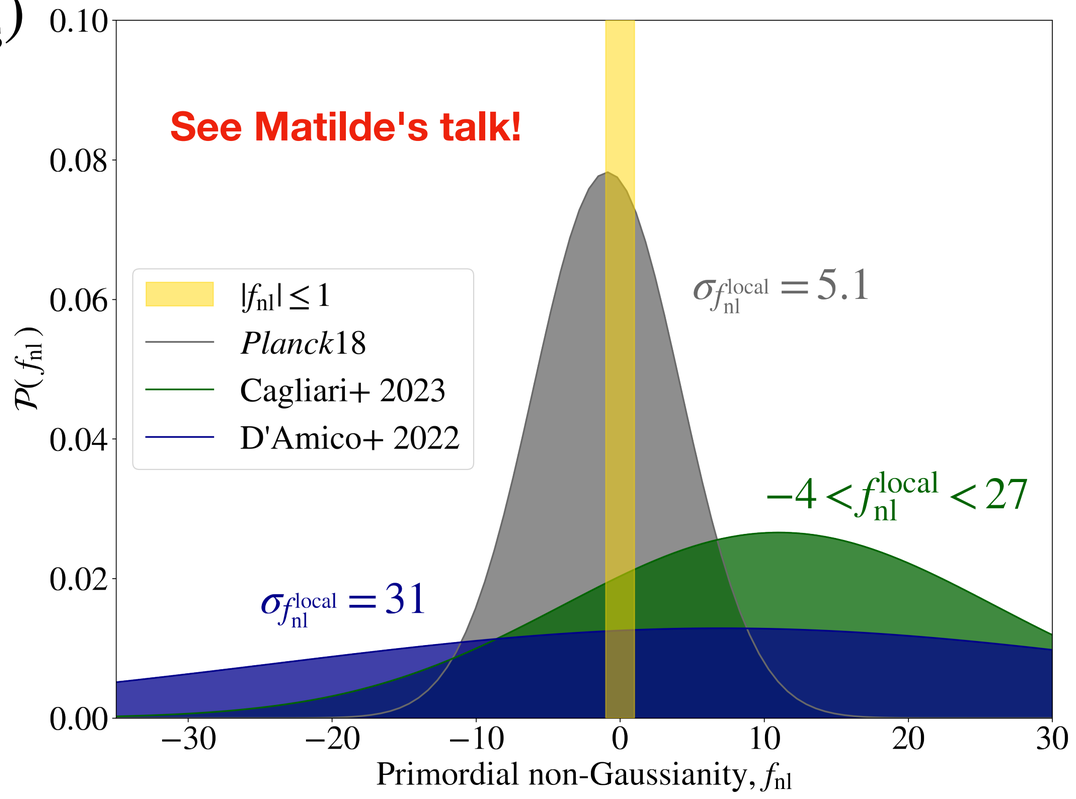
Can we do better?
Can we use the full field?



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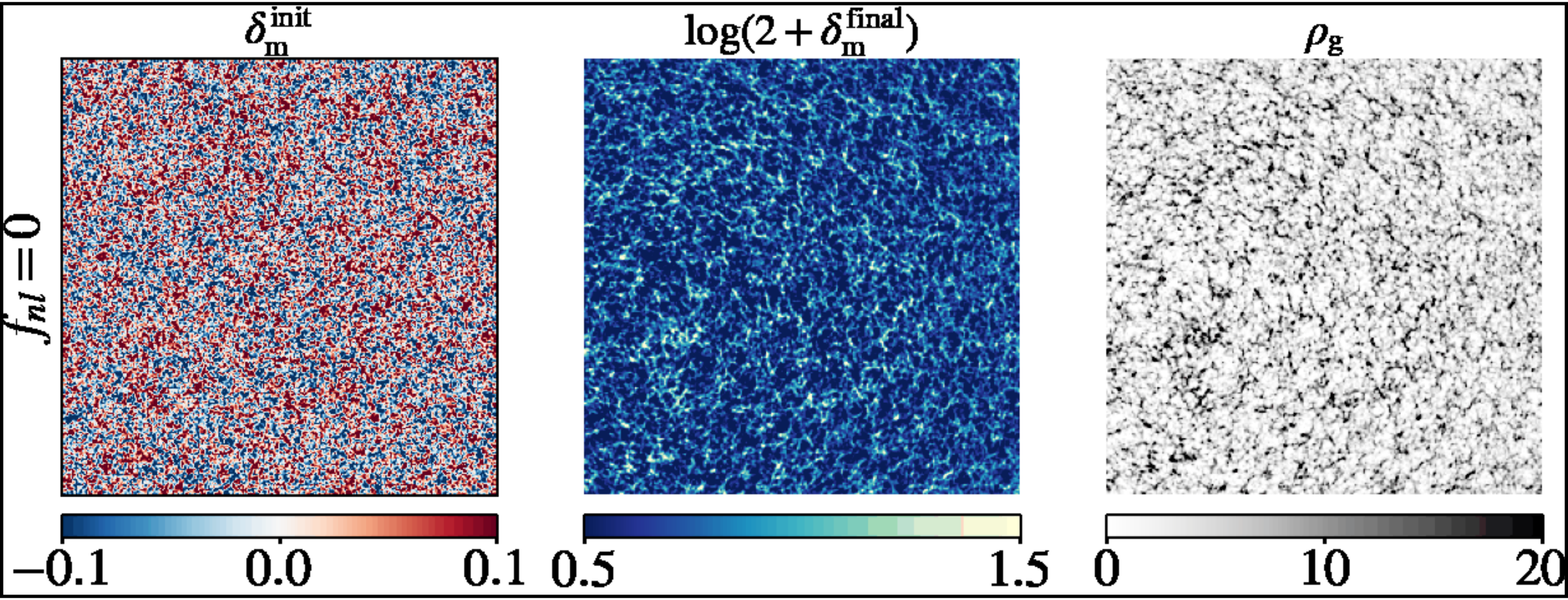

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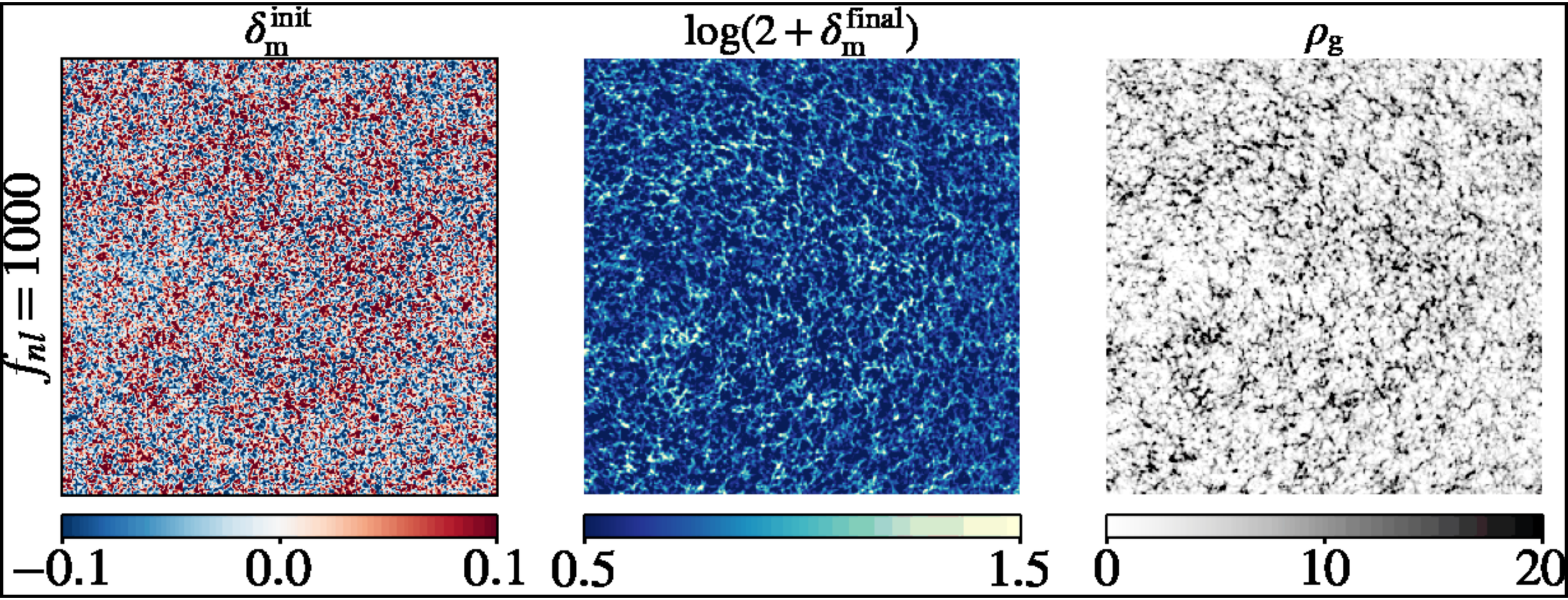

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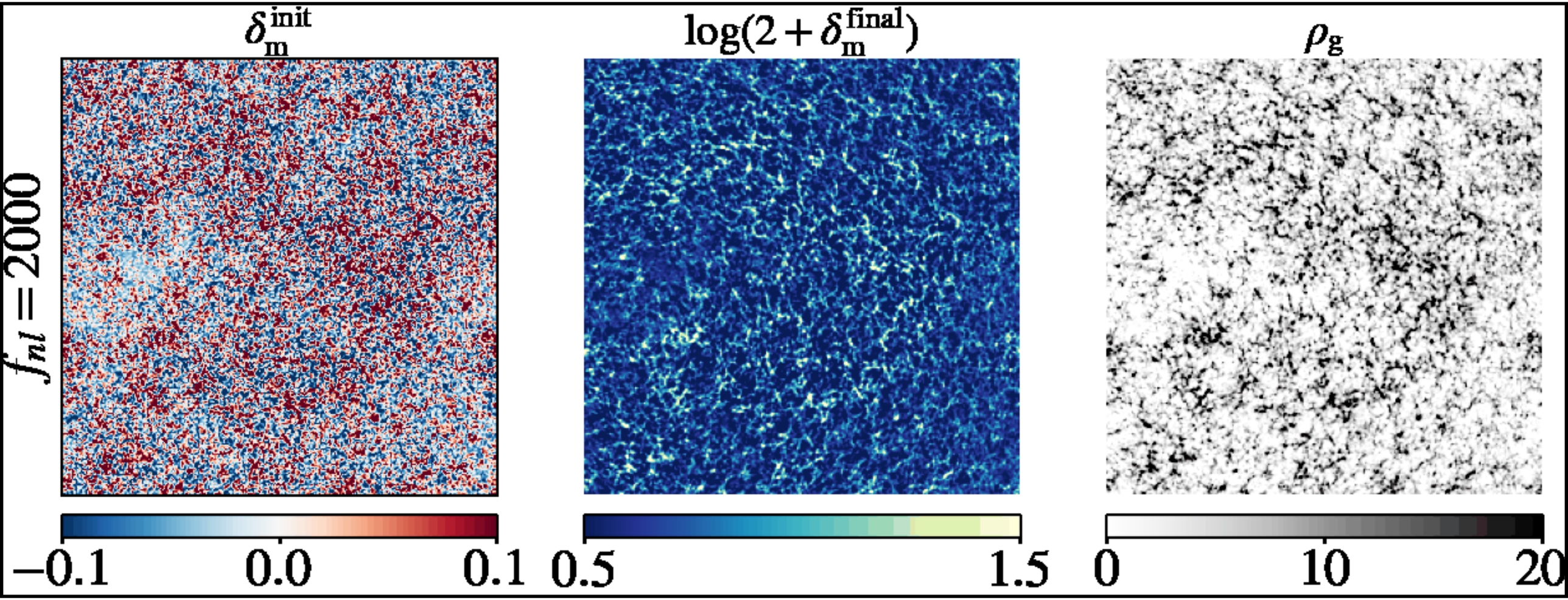

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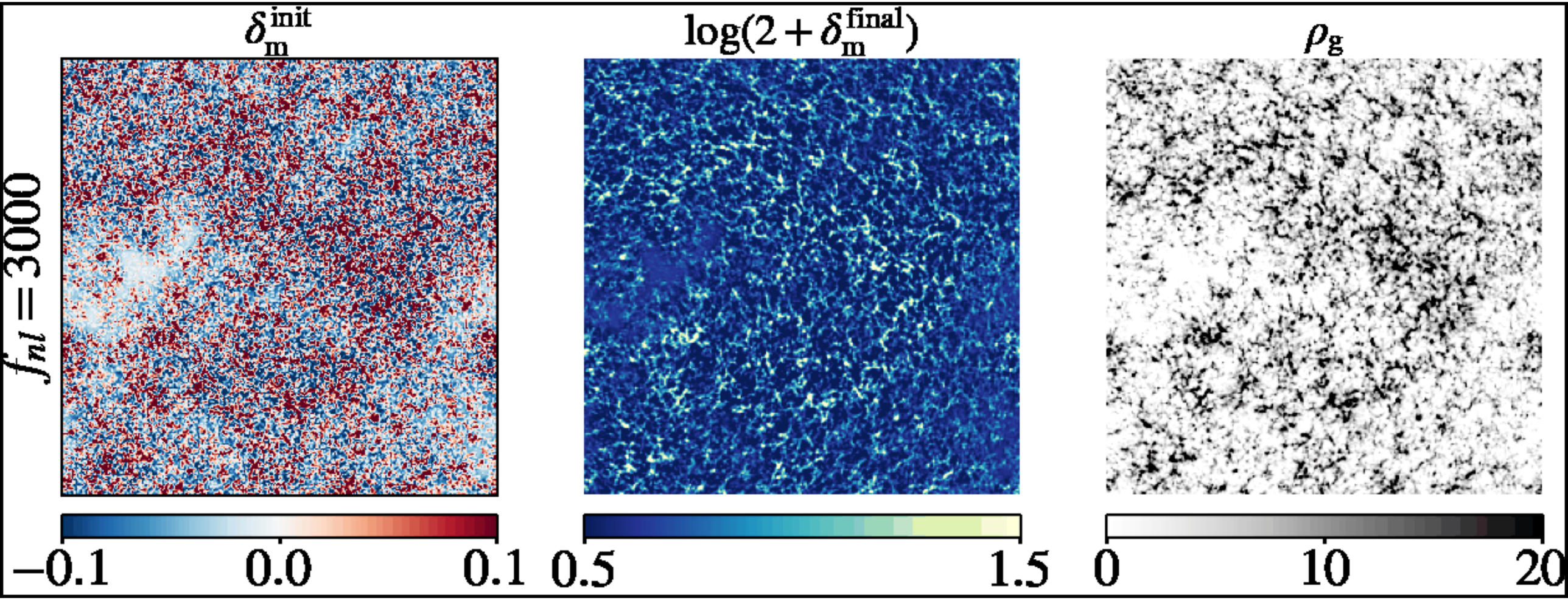

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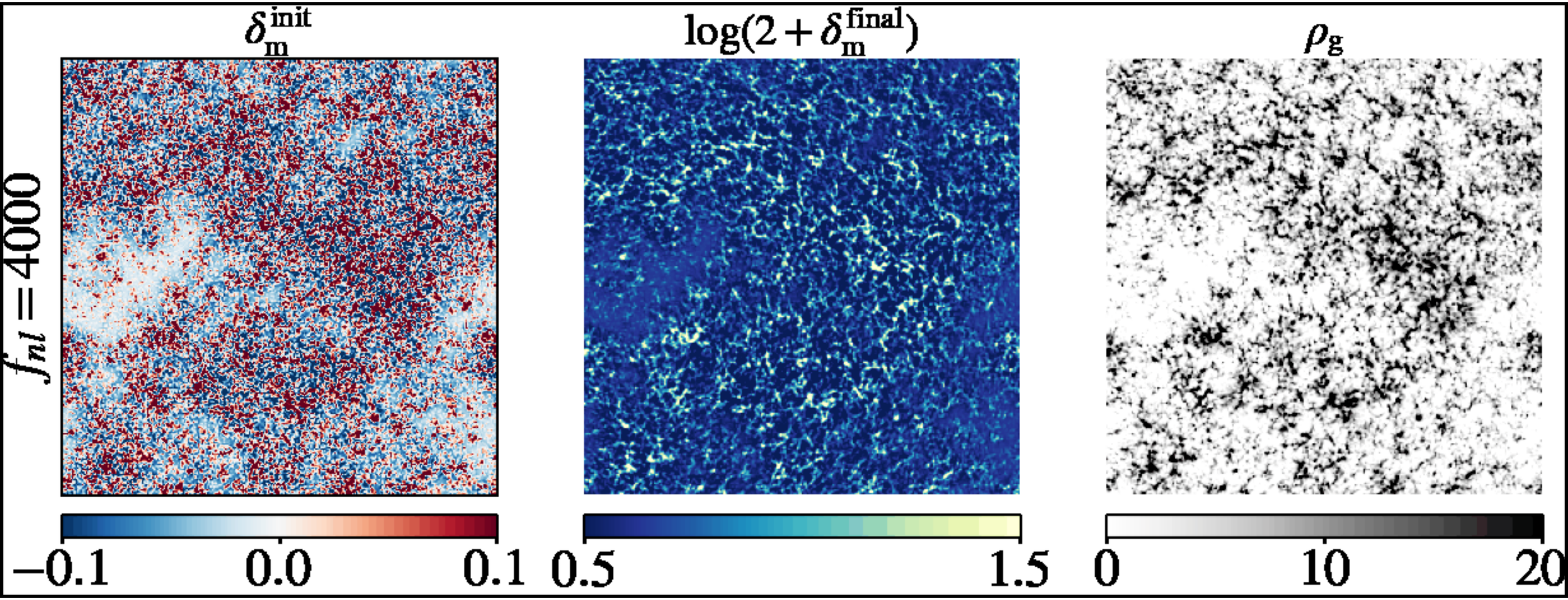

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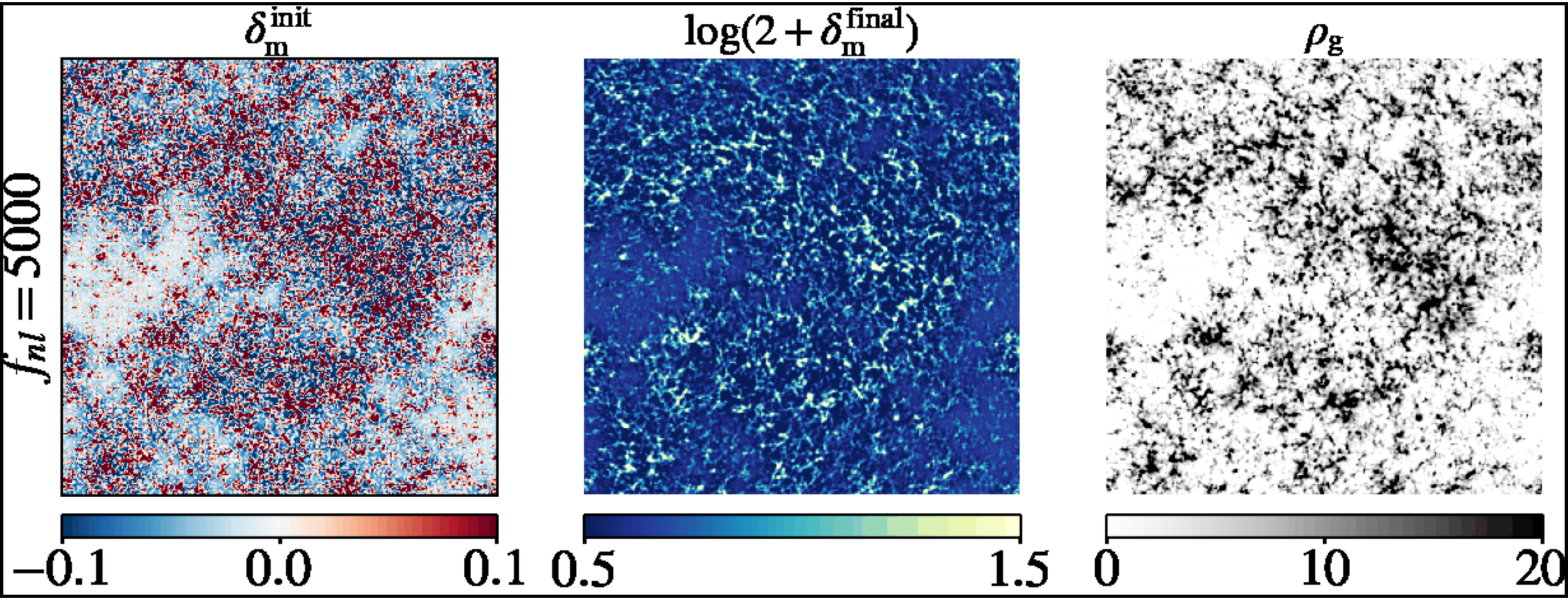

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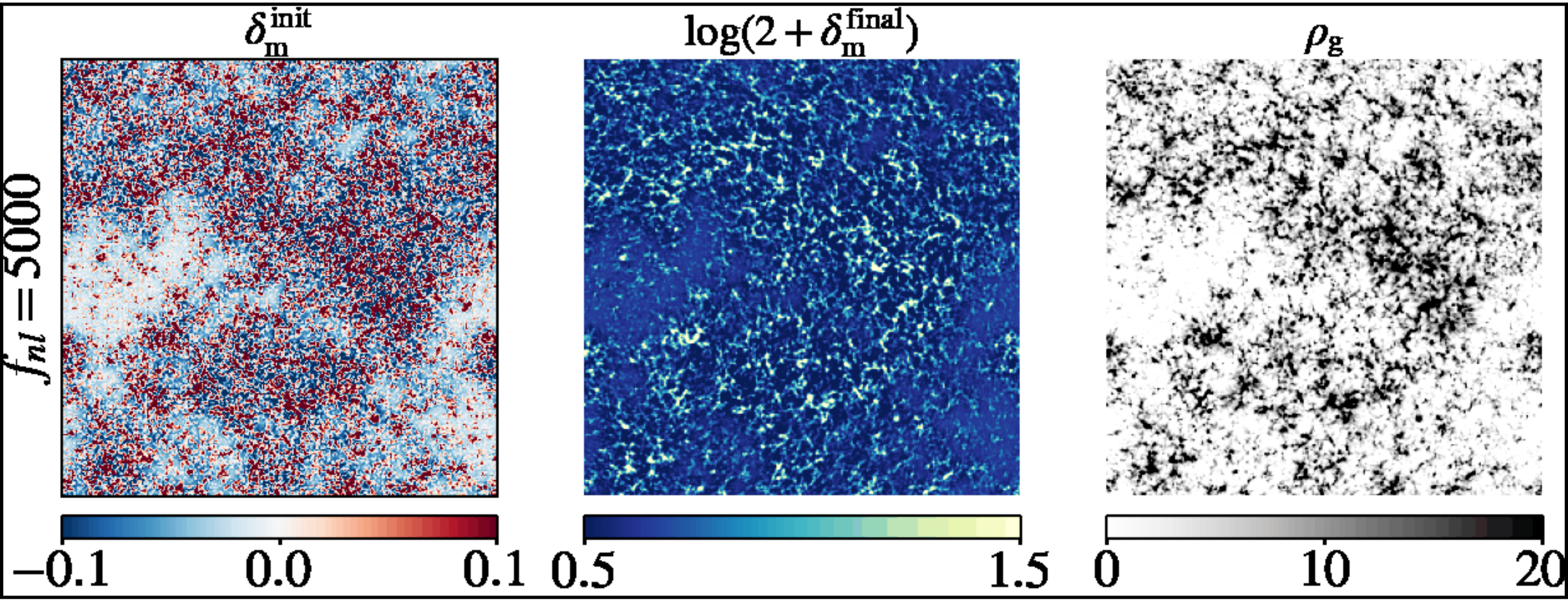

~~Summary statistics:~~

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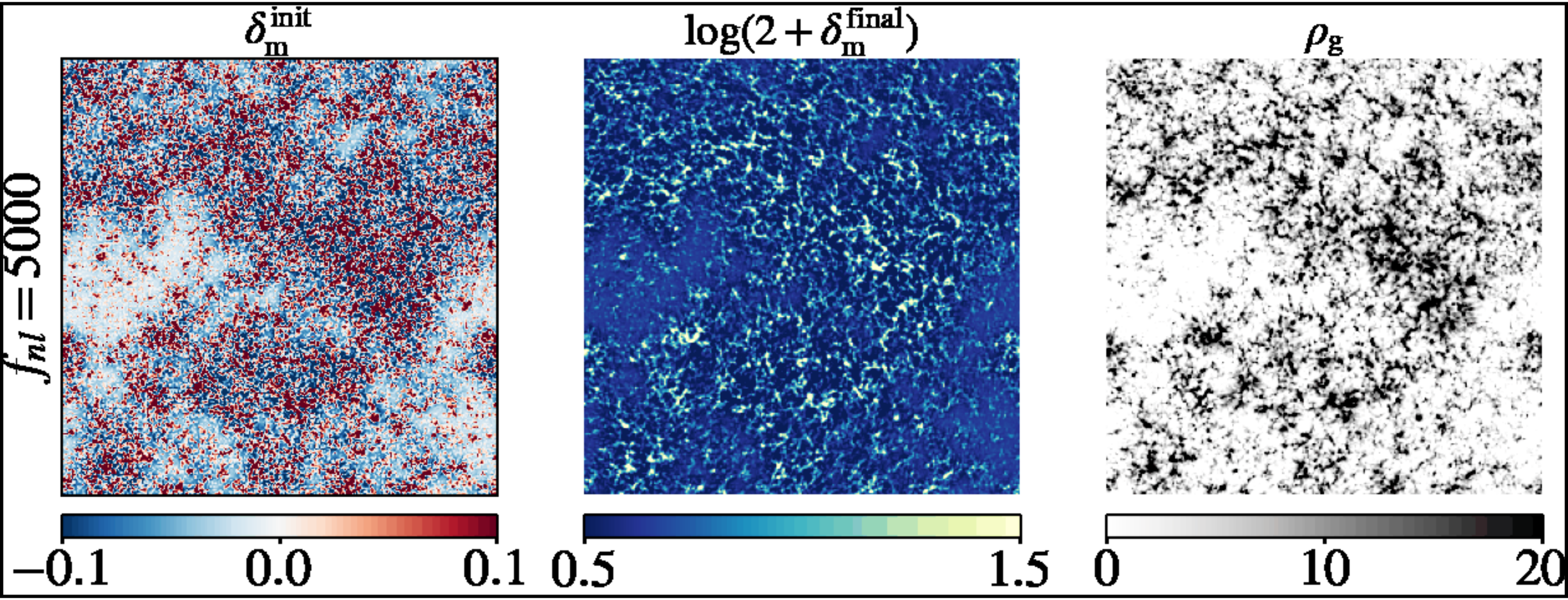

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Goal: ***Fit the full cosmic field***

Bayesian field-level inference

Bayesian Origin Reconstruction from Galaxies
https://www.aquila-consortium.org/

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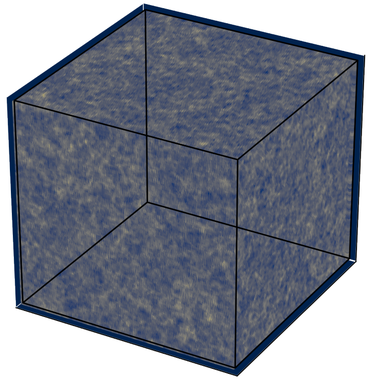

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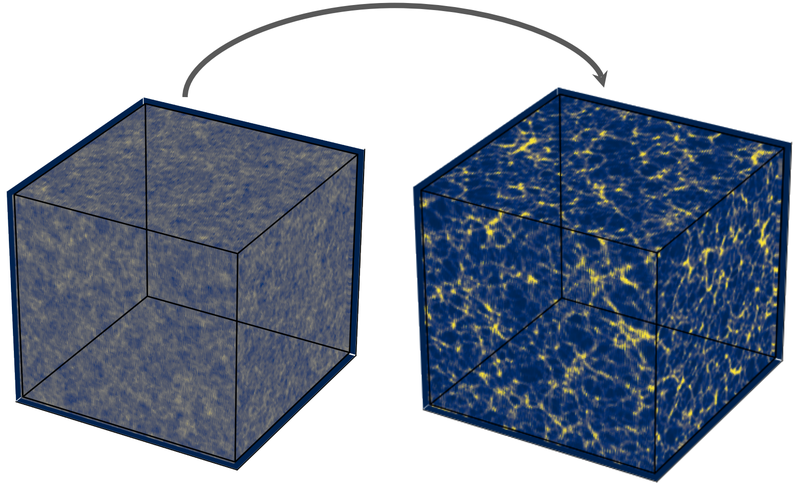

Initial conditions with f_{NL}

Structure formation (LPT, 2LPT)

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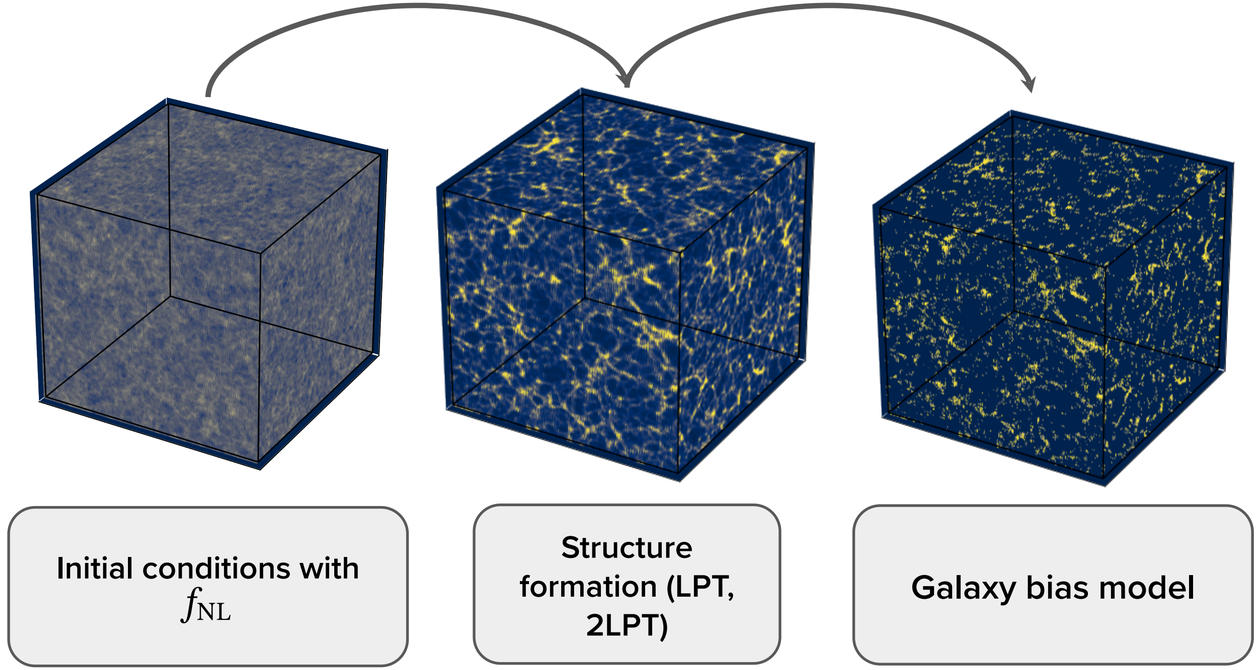

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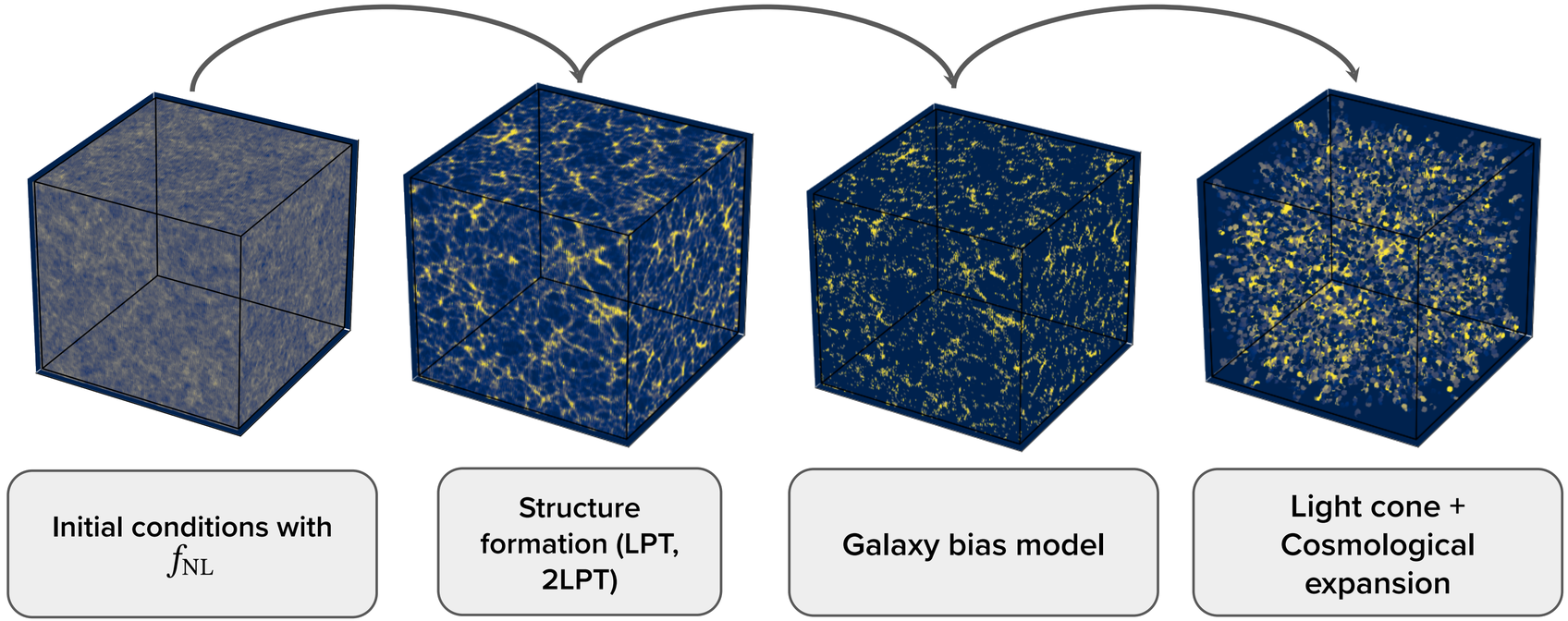

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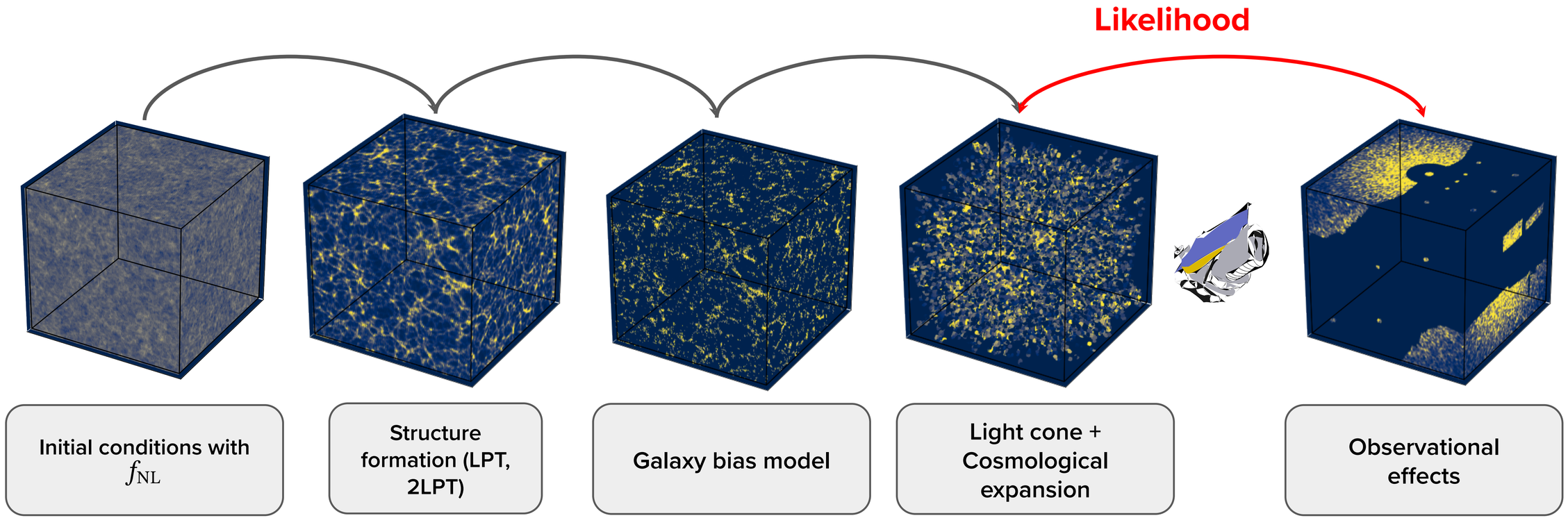

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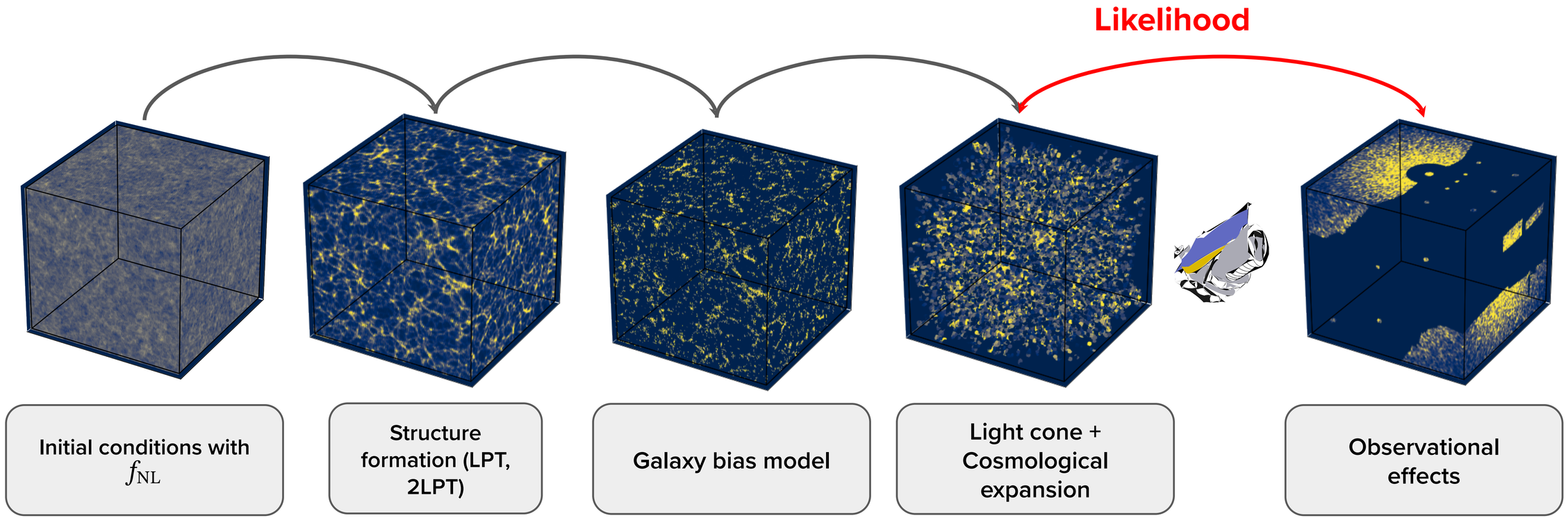

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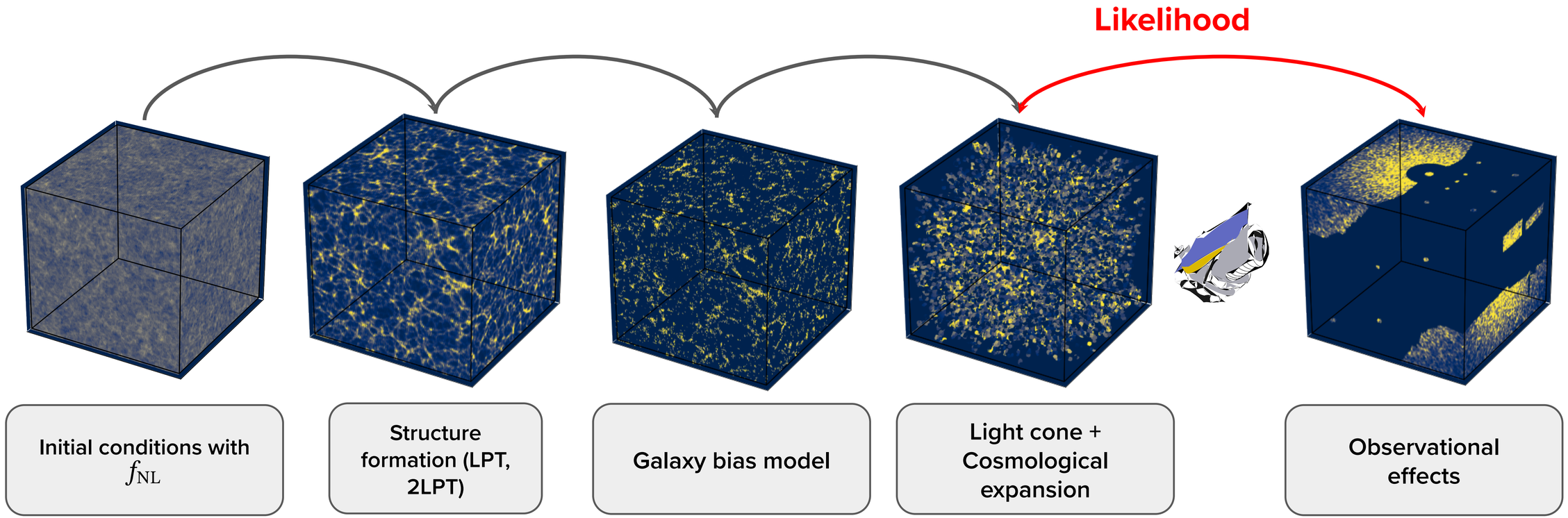

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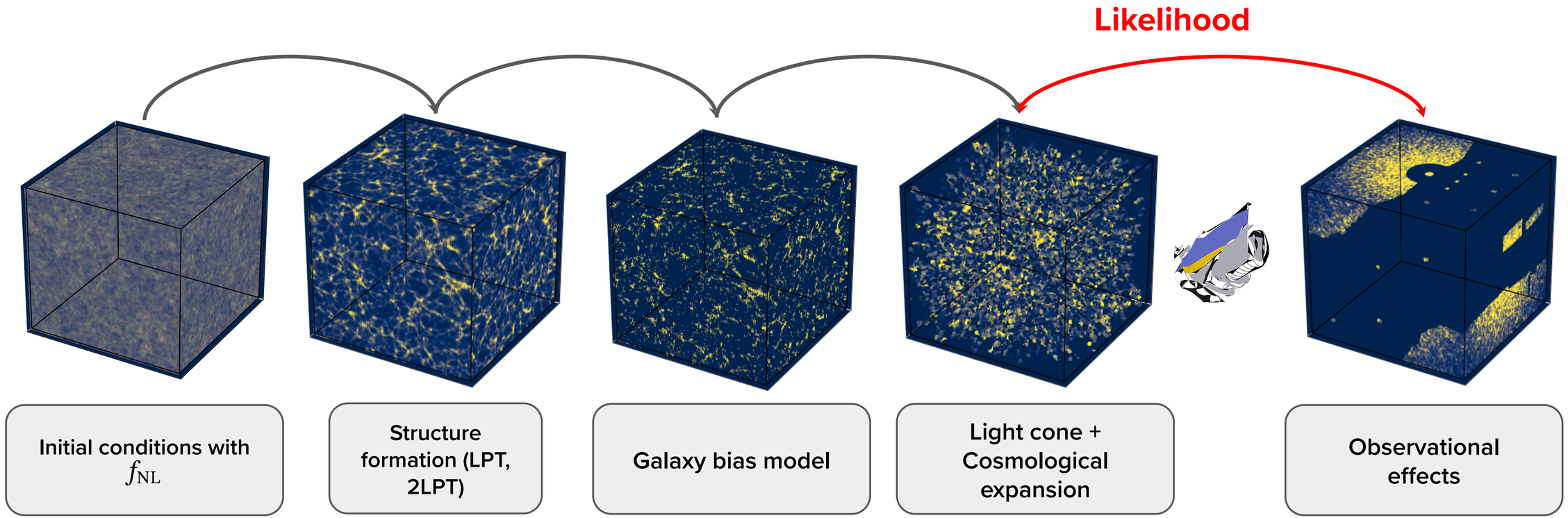

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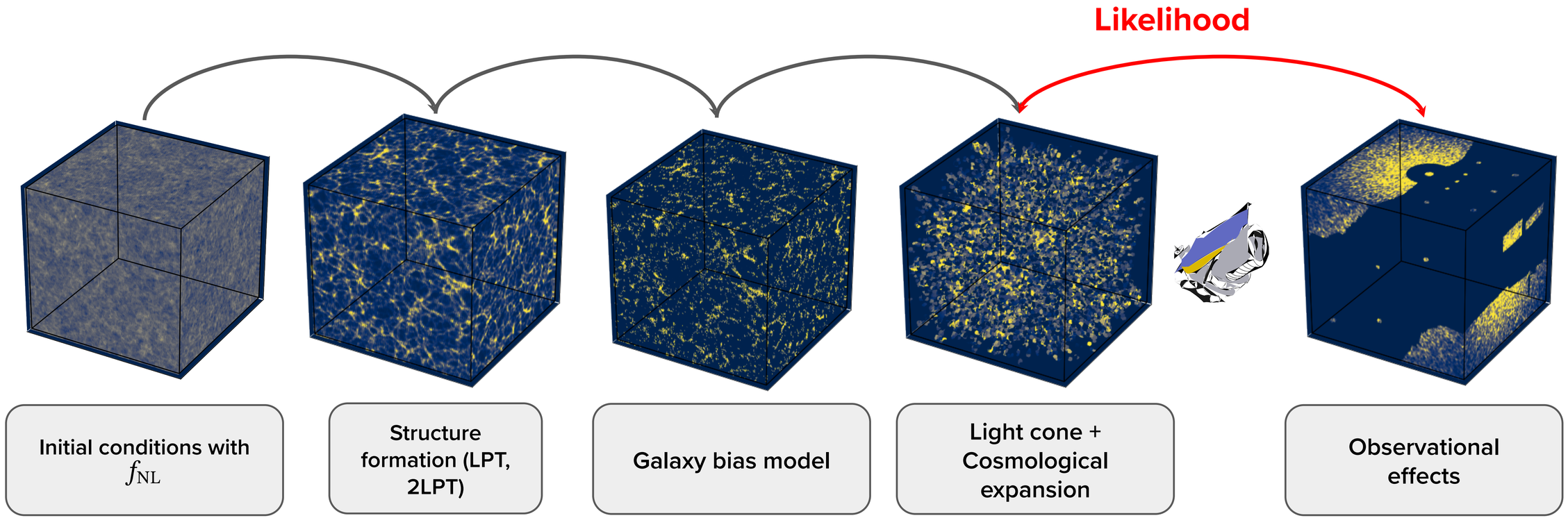

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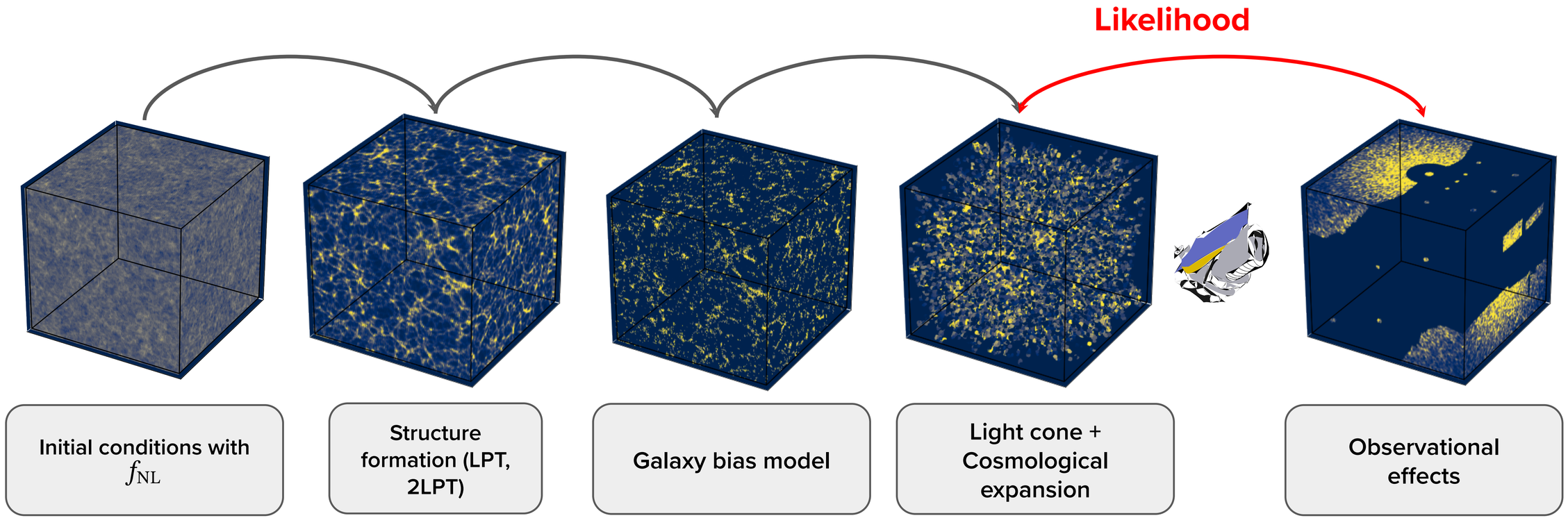

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See Beatriz's talk on *LEFT*-field!

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arxiv: 2203.08838

Proof-of-concept

SDSS3

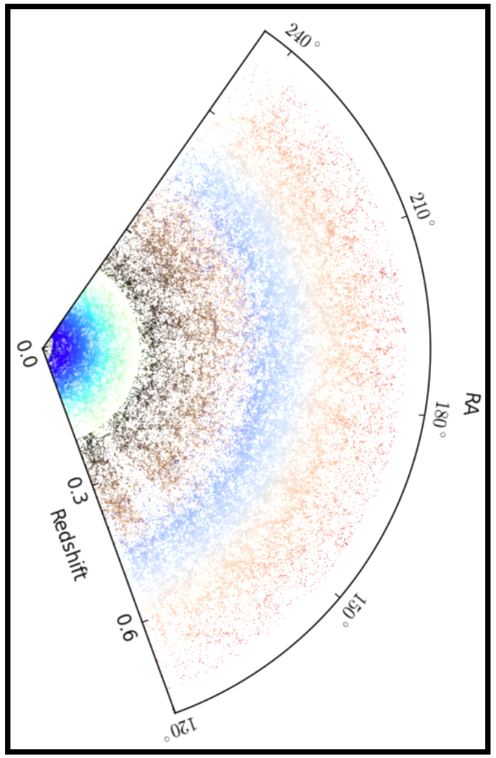

Figure Credit: Guilhem Lavaux

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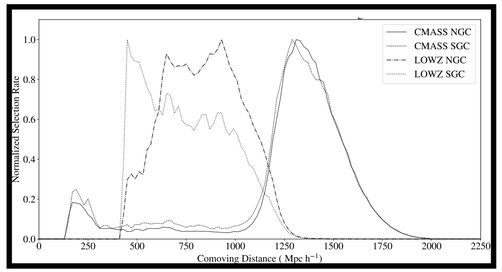

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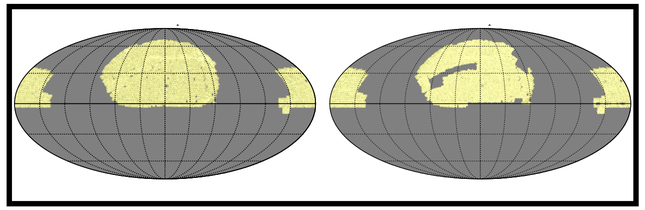

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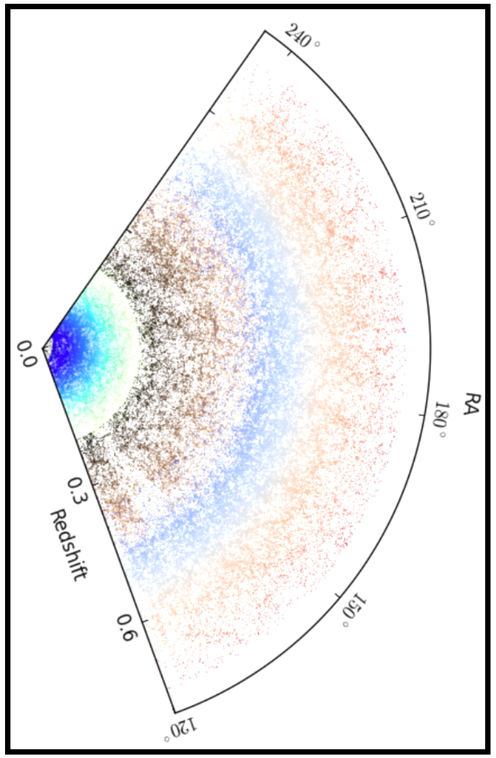

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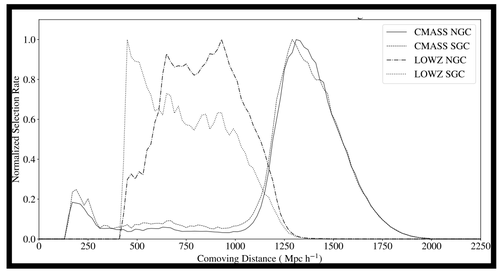

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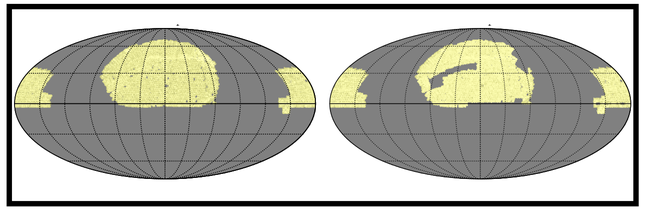
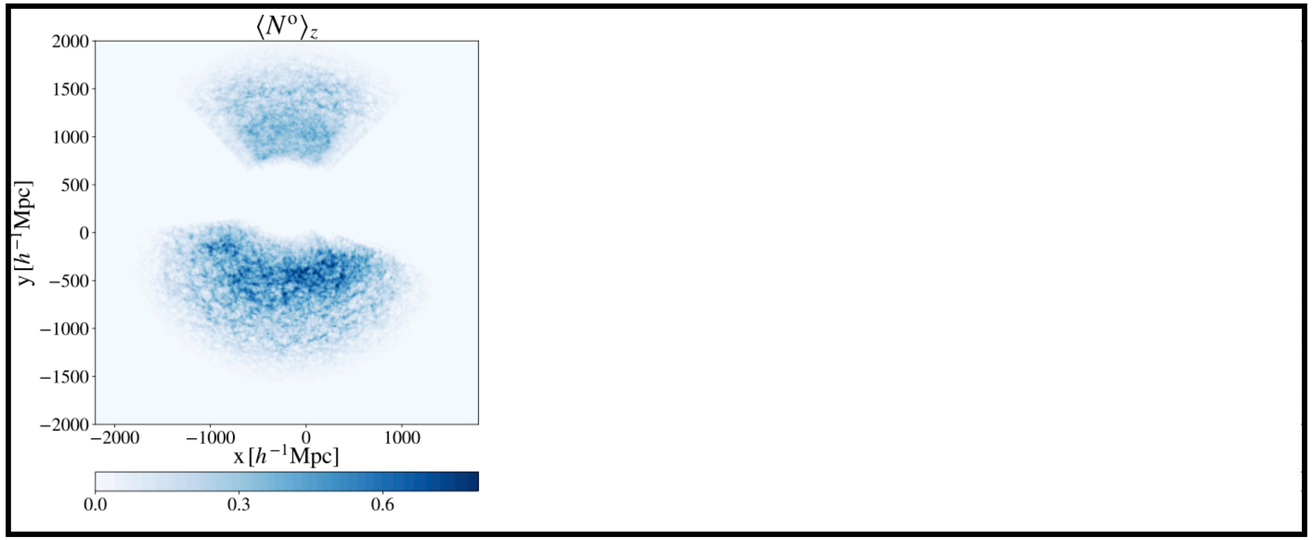


Mock Data



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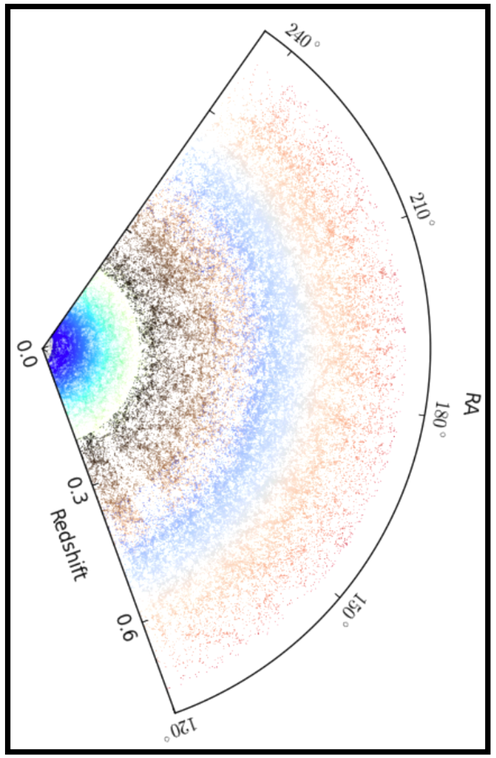

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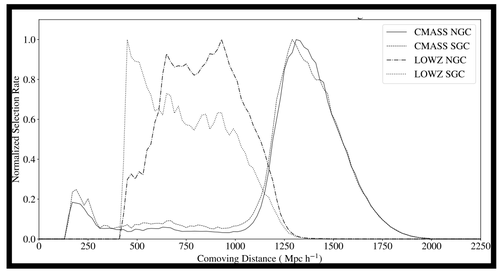

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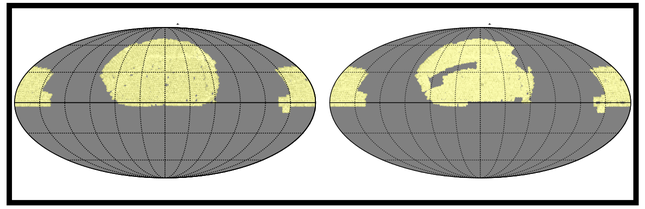
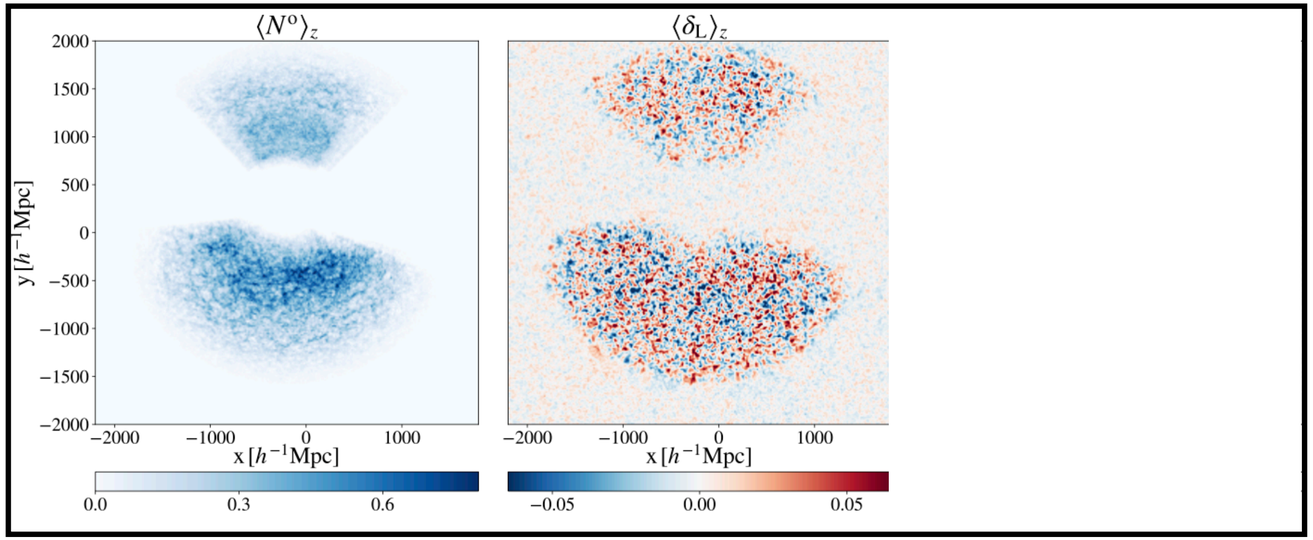


Mock Data

Inferred ICs



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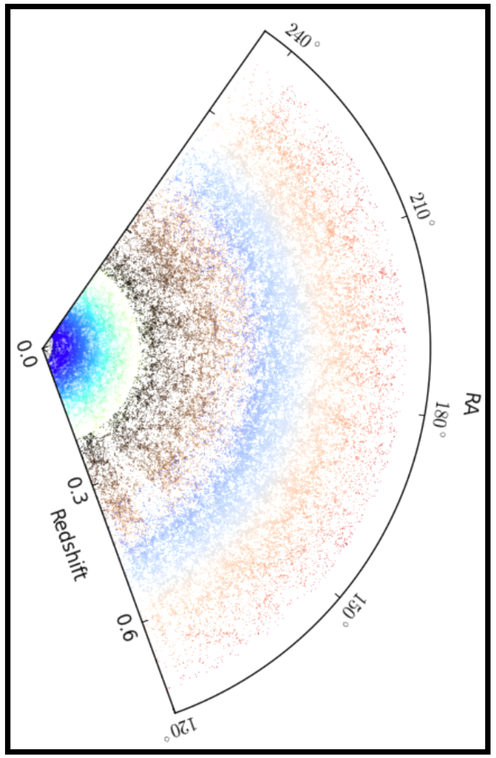

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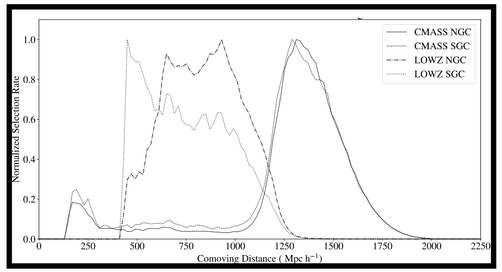

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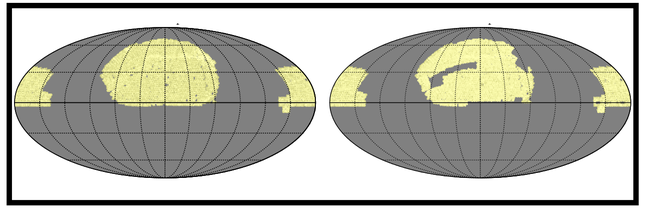

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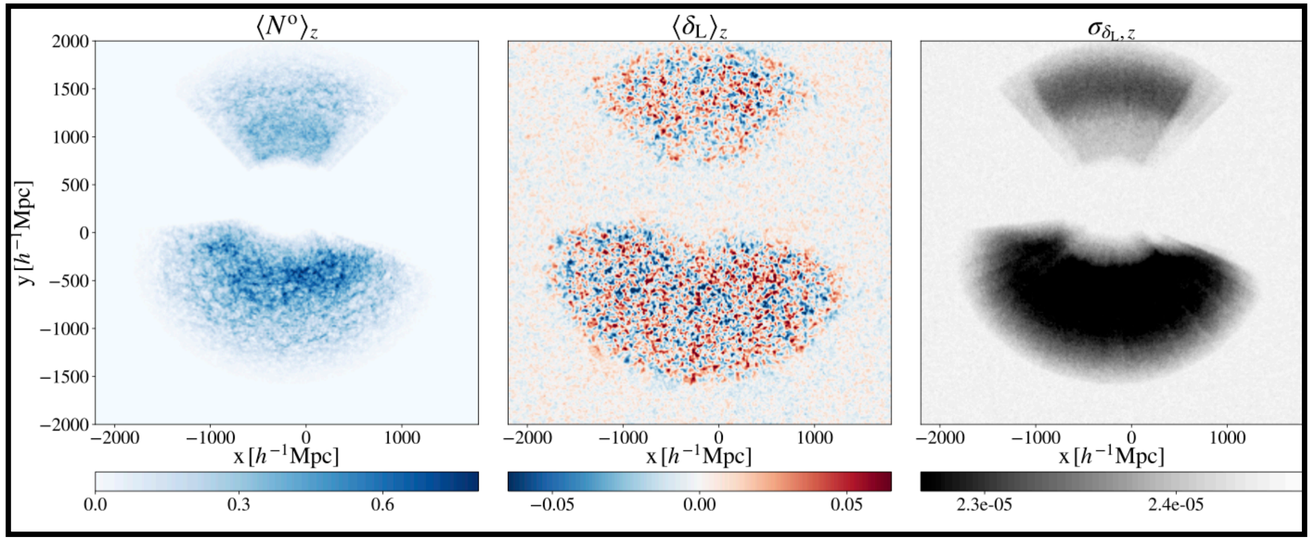
Uncertainty



SDSS3

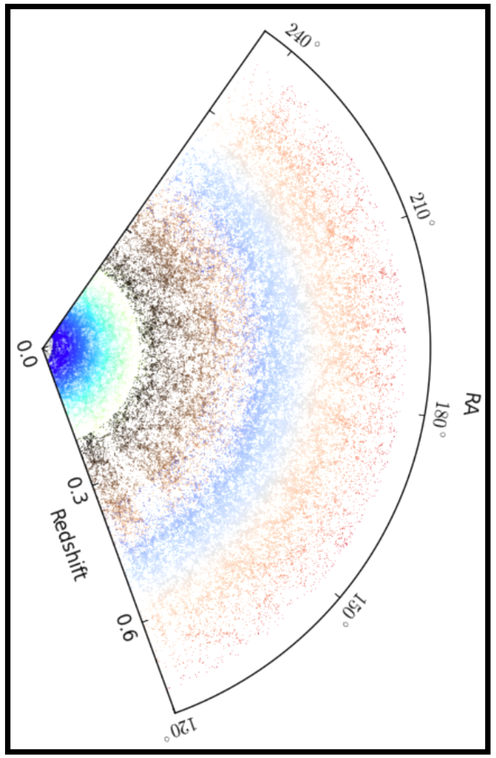
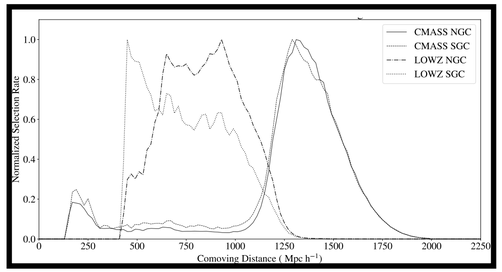


Figure Credit: Guilhem Lavaux

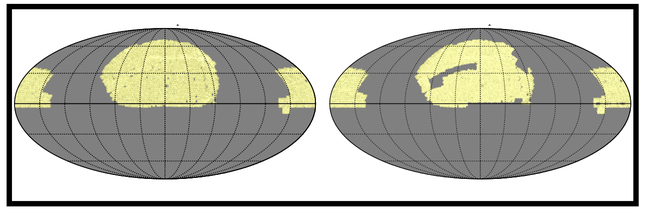
arxiv: 2203.08838

Proof-of-concept

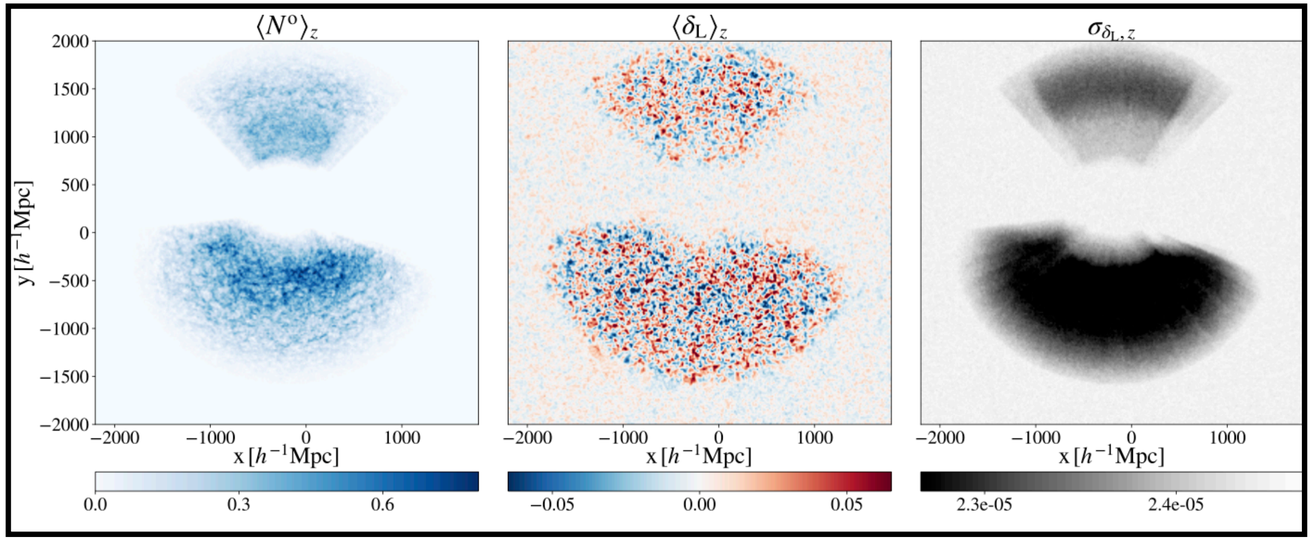
Radial selection function



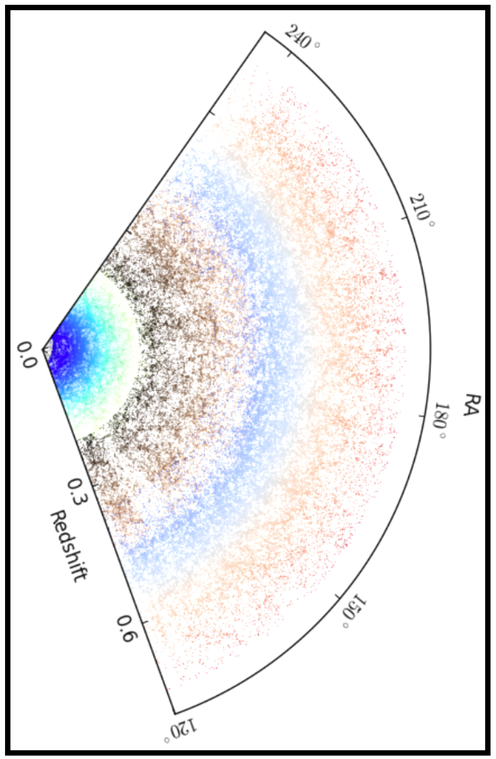
Angular selection function



Mock Data | Inferred ICs | Uncertainty



SDSS3



Bias parameters

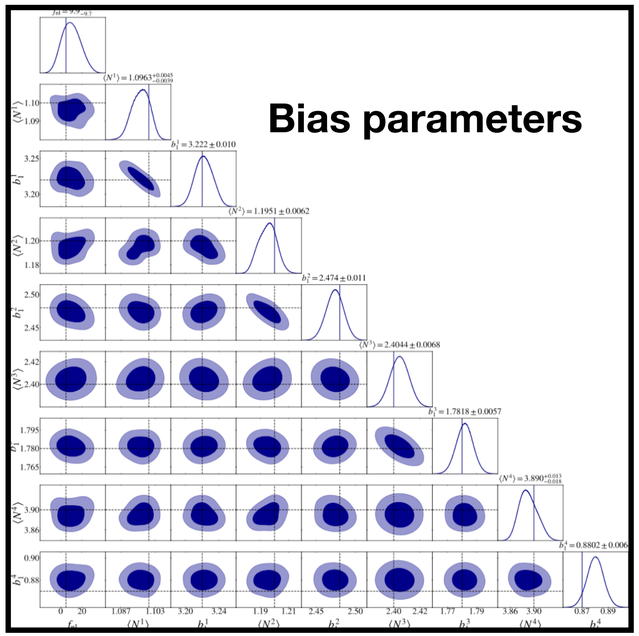


Figure Credit: Guilhem Lavaux

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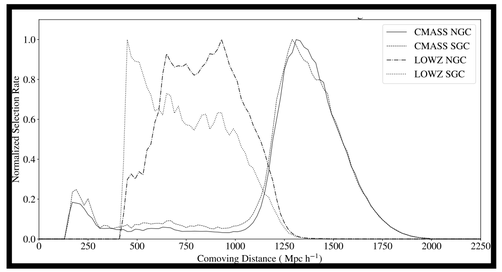
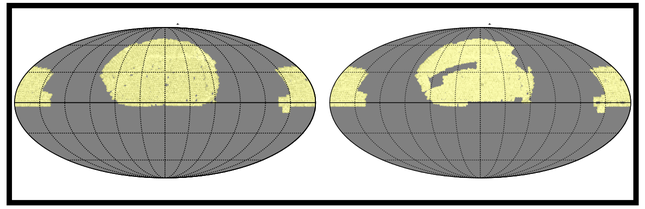
Proof-of-concept

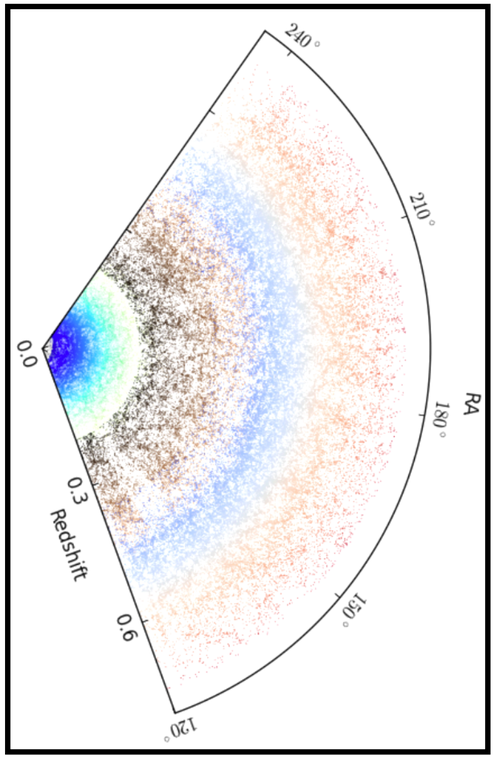
Radial selection function



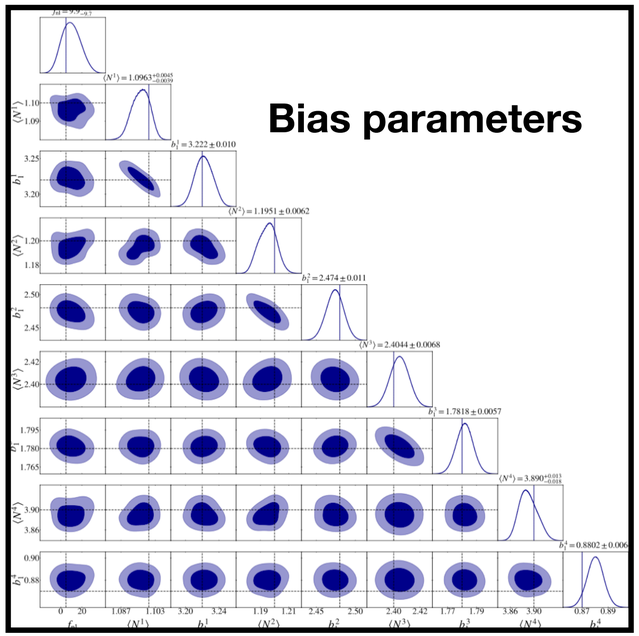
Angular selection function



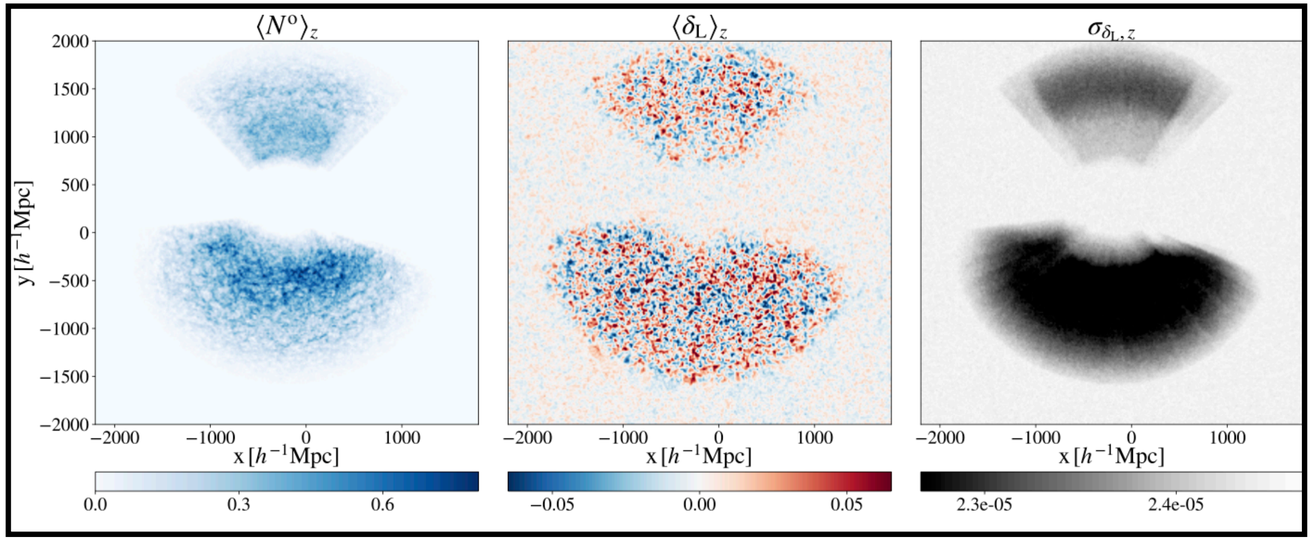
SDSS3

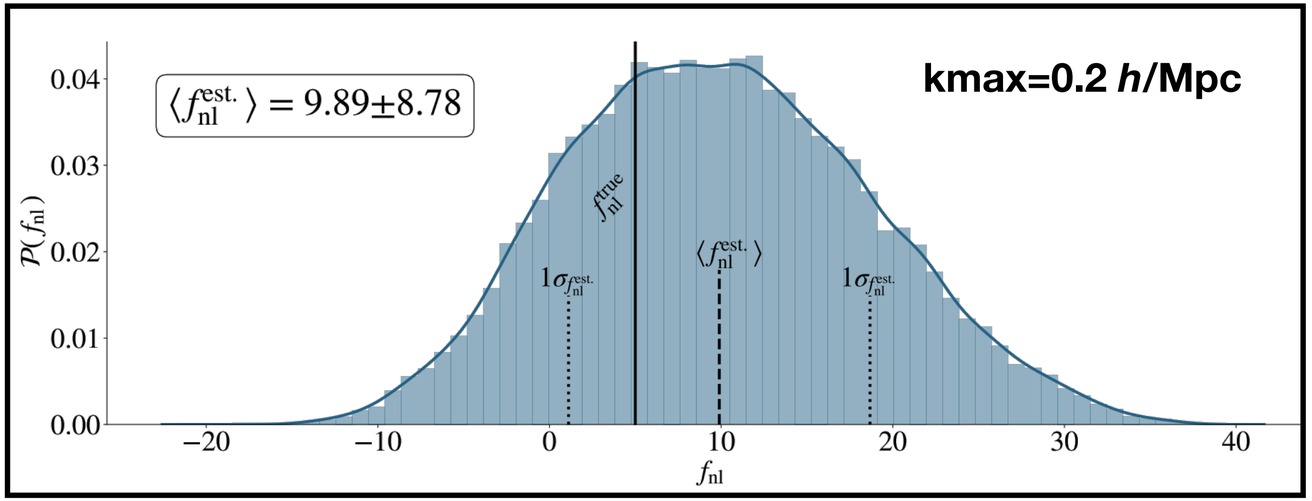


Bias parameters



Mock Data | Inferred ICs | Uncertainty





Posterior distribution

Figure Credit: Guilhem Lavaux

Andrews et al., *TBD*

Quijote-PNG suite analysis

Coulton et al. 2022

Andrews et al., *TBD*

Quijote-PNG suite analysis

Coulton et al. 2022

Necessary developments to the forward model?

Andrews et al., *TBD*

Quijote-PNG suite analysis

Coulton et al. 2022

Necessary developments to the forward model?

How well do we reconstruct the ICs?

Andrews et al., *TBD*

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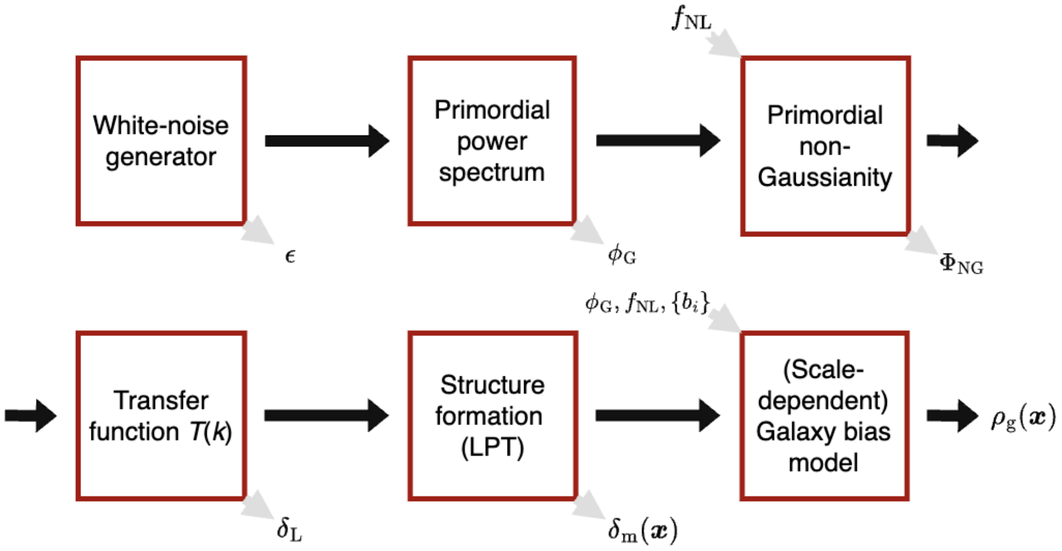


Andrews et al., *TBD*

Quijote-PNG suite analysis

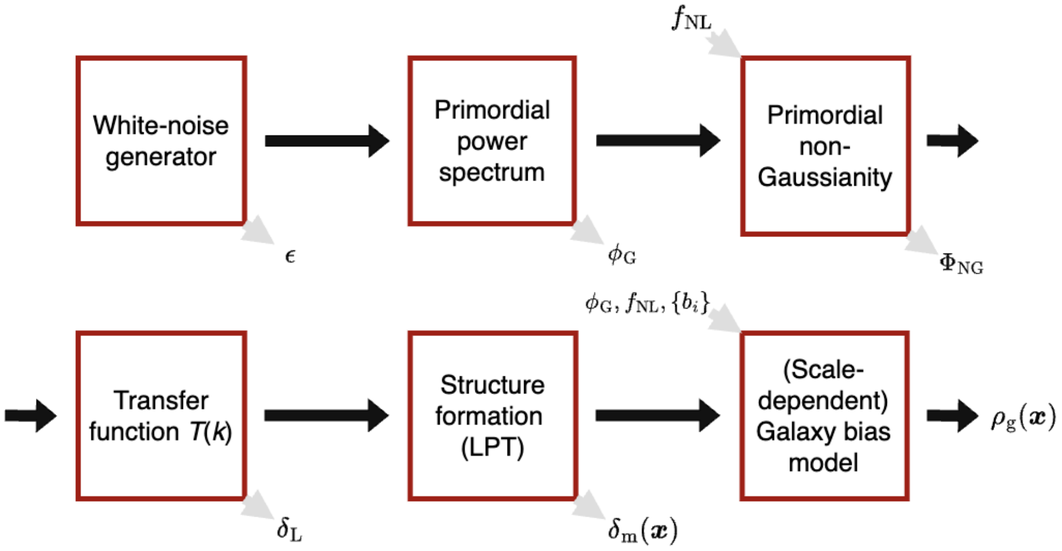
Coulton et al. 2022

$$\rho_{\rm g}(\vec{x}) = \langle N_{\rm g}^{\rm O} \rangle \, [1 + b_1 \, \delta_{\rm m}(\vec{x}) + \frac{b_2}{2} \delta_{\rm m}^2(\vec{x}) + b_{\rm K} \, K^2(\vec{x}) \; + b_\nabla \, \nabla^2 \delta_{\rm m}(\vec{x}) + \; b_\phi \, f_{\rm nl} \, \phi_{\rm g}(\vec{q}) + b_{\phi,\delta} \, f_{\rm nl} \, \delta_{\rm m}(\vec{x}) \, \phi_{\rm g}(\vec{q})]$$

Necessary developments to the forward model?

How well do we reconstruct the ICs?

Comparison to other methods?



Andrews et al., *TBD*

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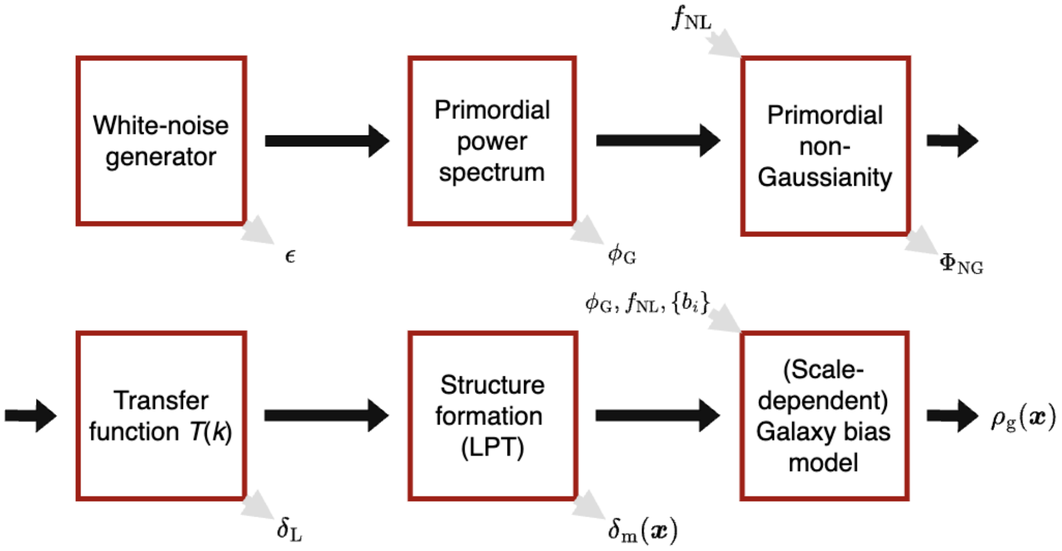
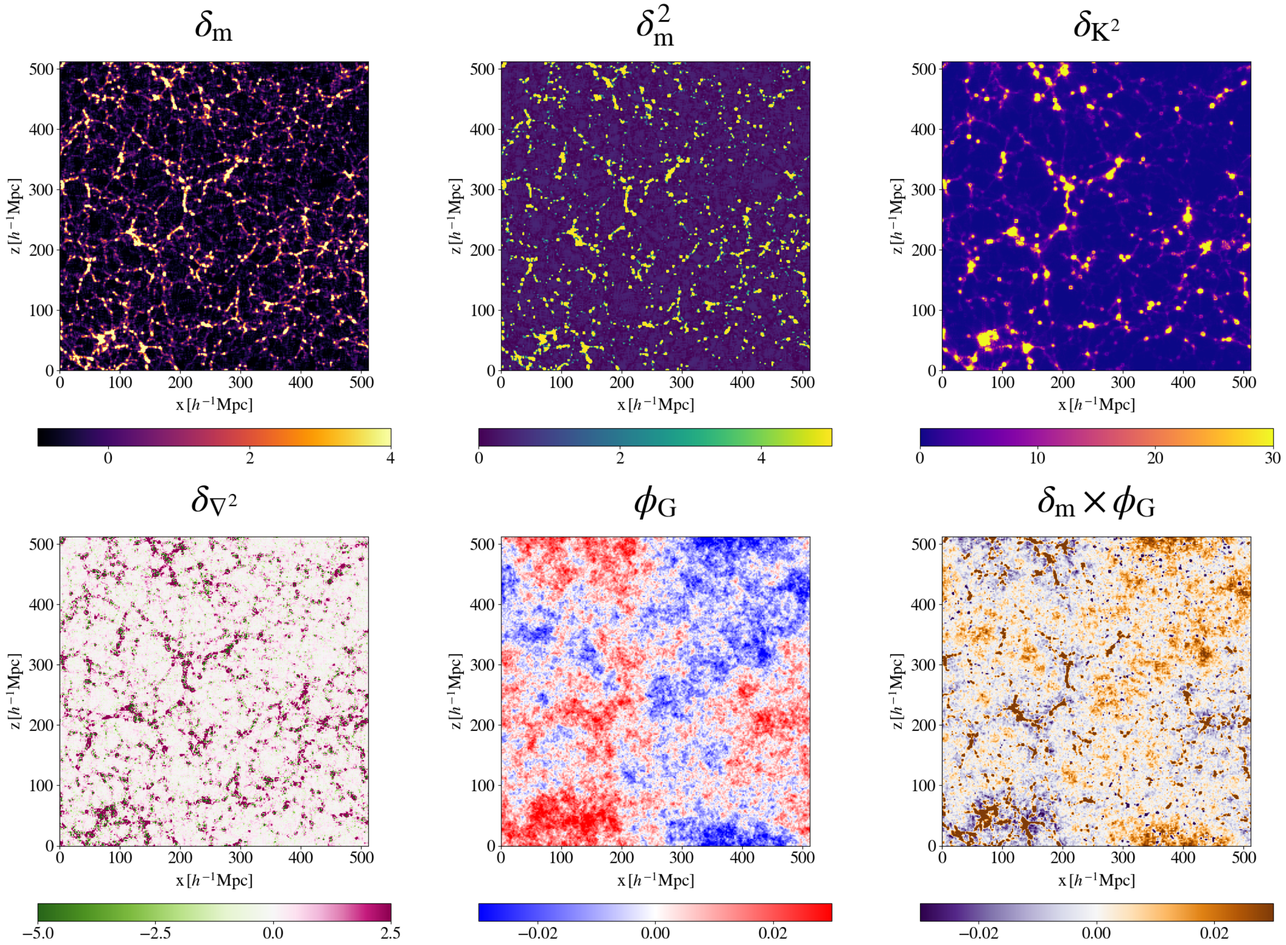
Necessary developments to the forward model?

How well do we reconstruct the ICs?

Comparison to other methods?





Andrews et al., *TBD*

Quijote-PNG suite analysis

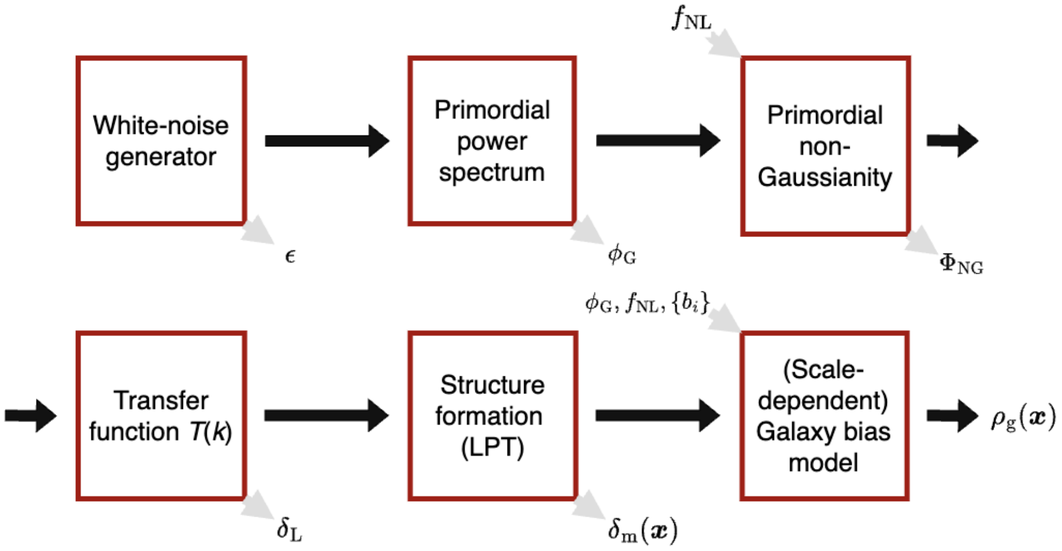
Coulton et al. 2022

$$\rho_g(\vec{x}) = \langle N_g^O \rangle \left[1 + b_1\,\delta_m(\vec{x}) + \frac{b_2}{2}\delta_m^2(\vec{x}) + b_K\,K^2(\vec{x}) + b_\nabla\,\nabla^2\delta_m(\vec{x}) + b_\phi\,f_{nl}\,\phi_g(\vec{q}) + b_{\phi,\delta}\,f_{nl}\,\delta_m(\vec{x})\,\phi_g(\vec{q})\right]$$

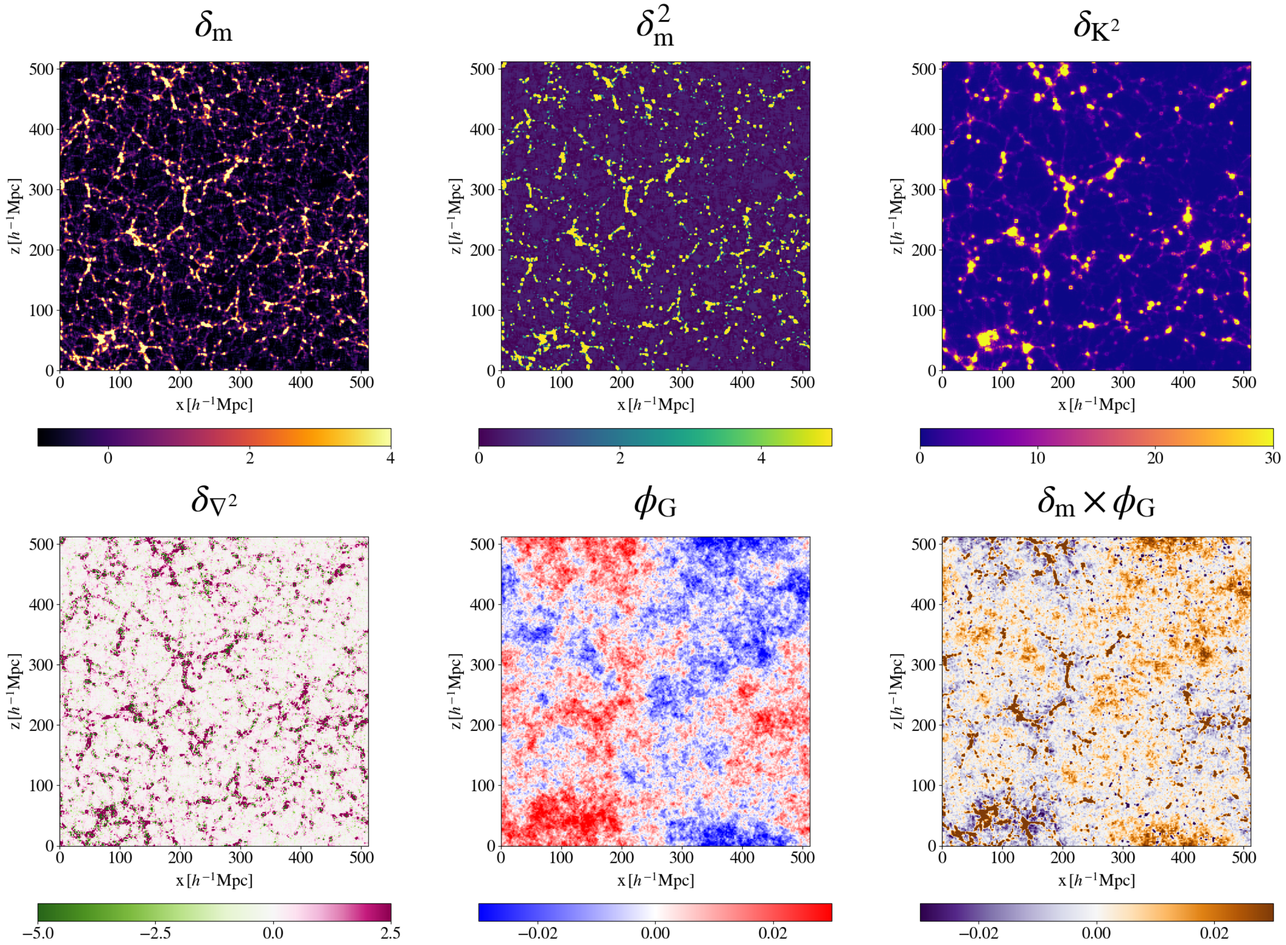
Necessary developments to the forward model?

How well do we reconstruct the ICs?

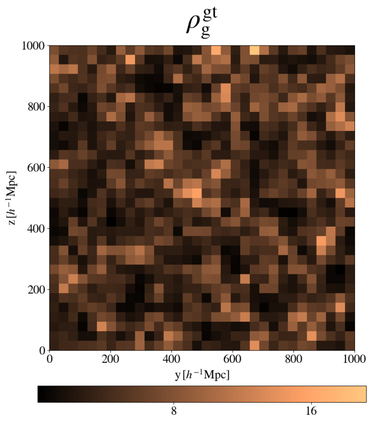
Comparison to other methods?



See Jamie's talk+paper on bphi!

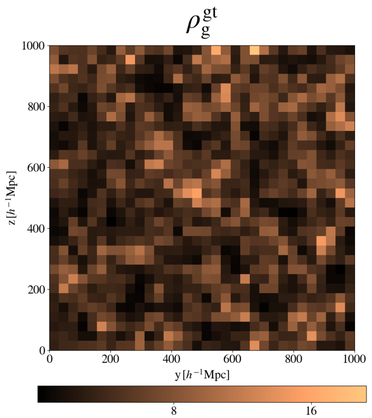


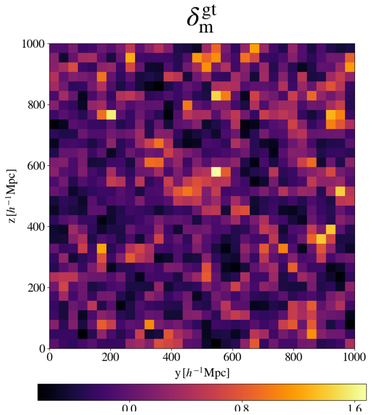
Preliminary results: Posterior-predictions



kmax = 0.1 *h*/Mpc, p=1

Preliminary results: Posterior-predictions





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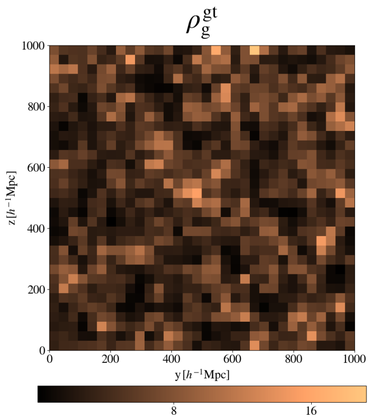

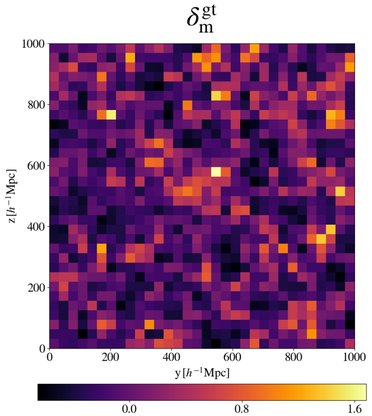

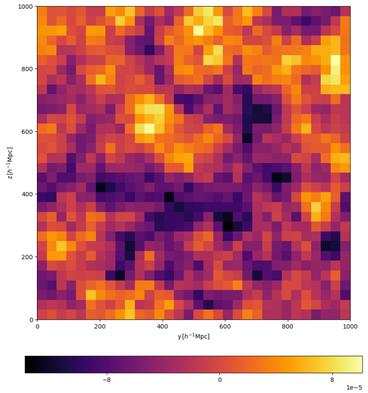

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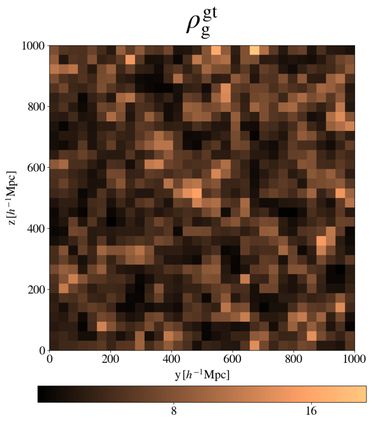
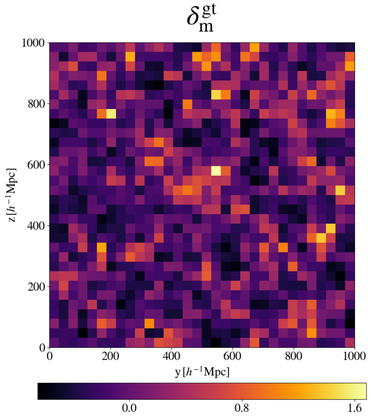
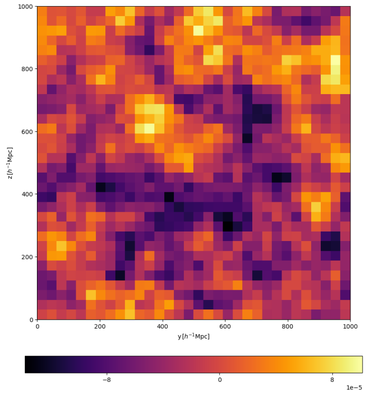
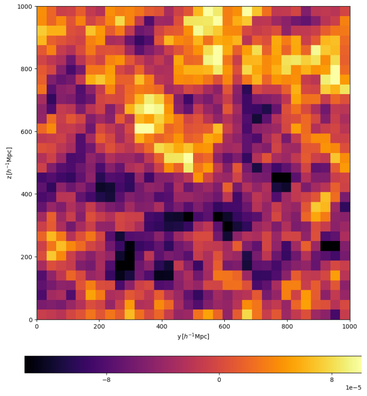
Preliminary results: Posterior-predictions









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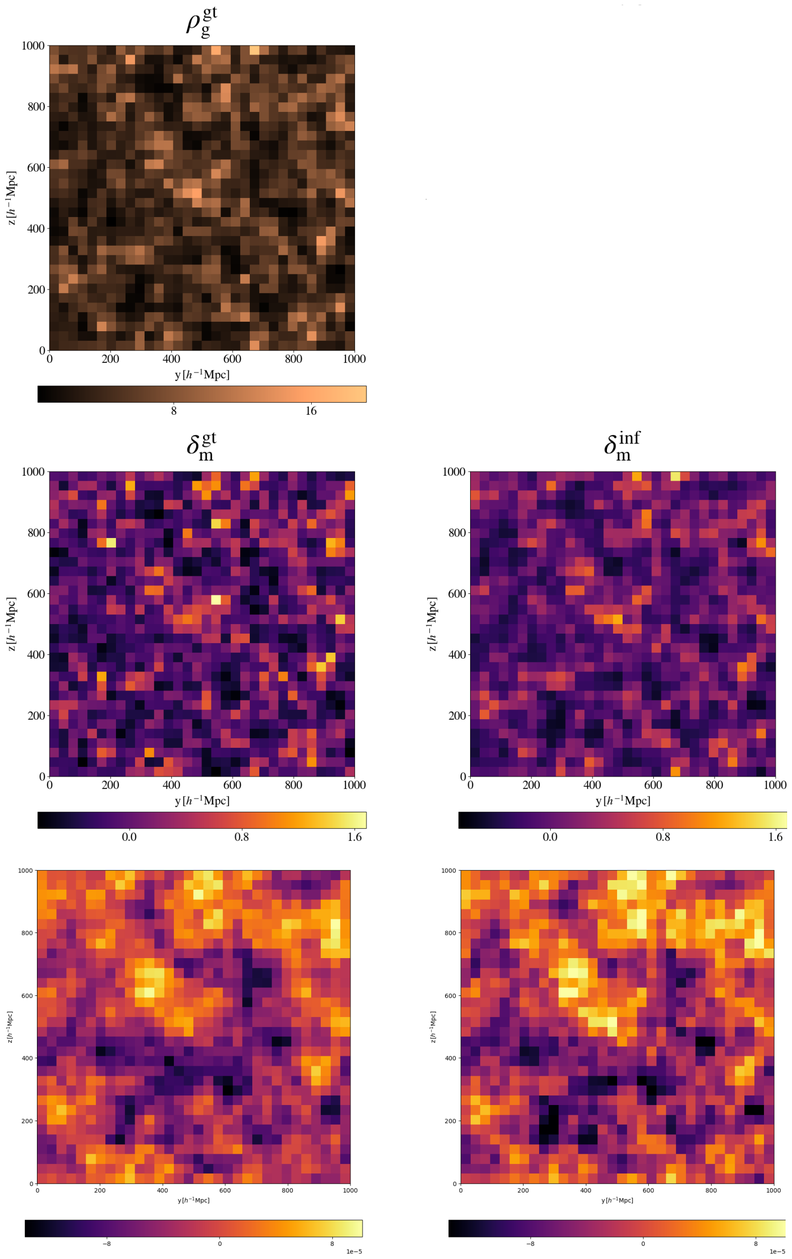
Preliminary results: Posterior-predictions



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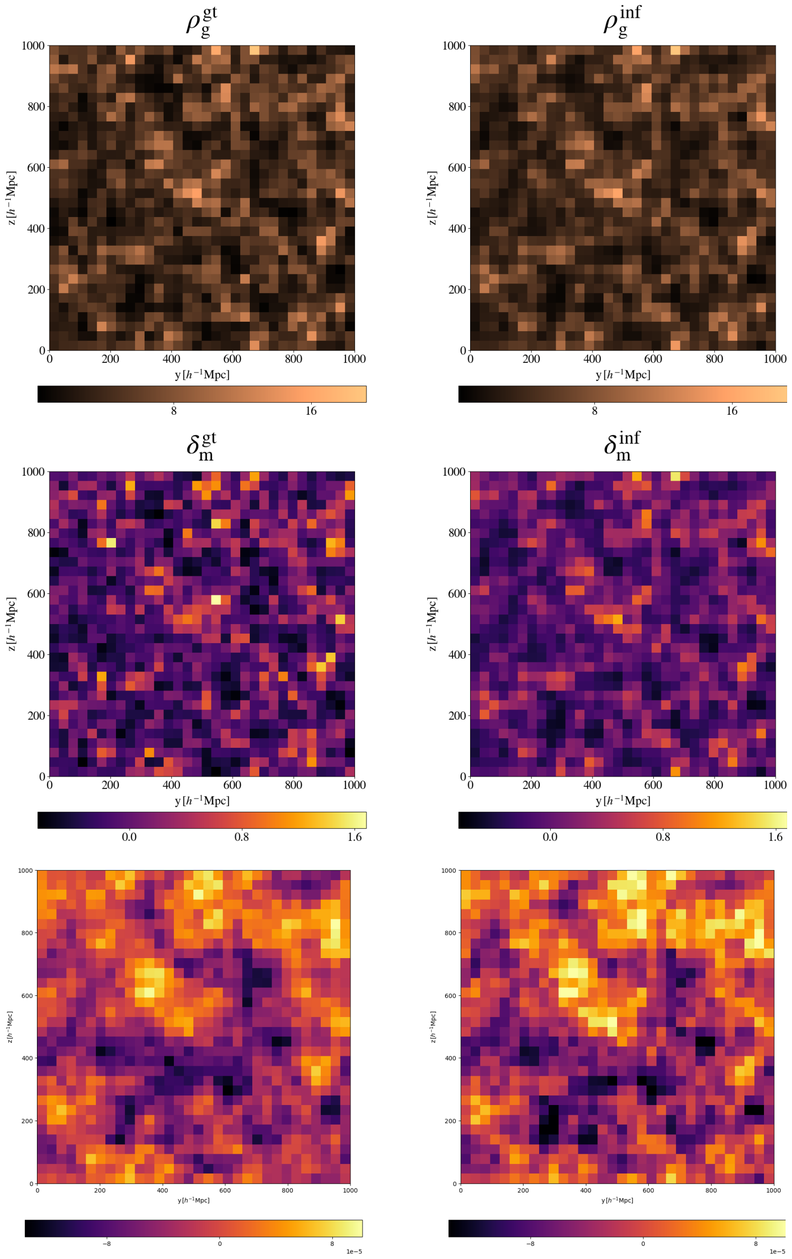
Preliminary results: Posterior-predictions



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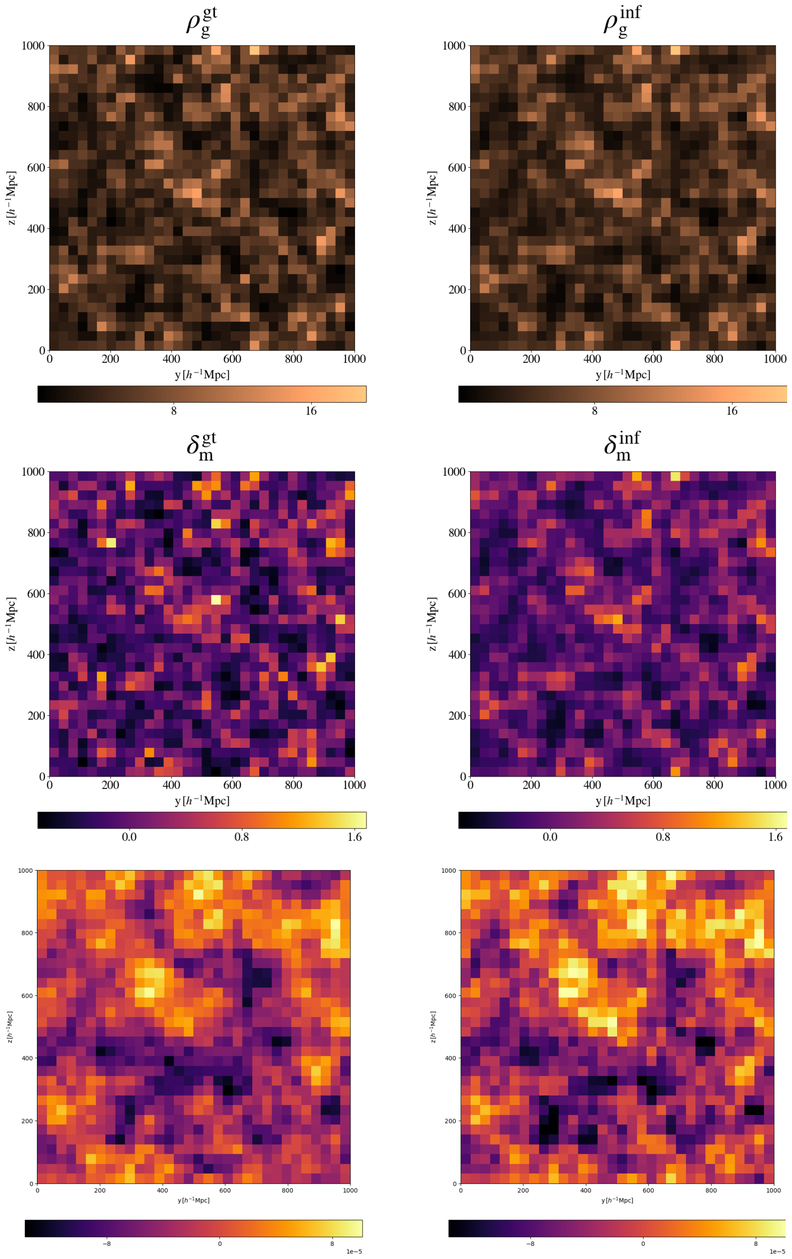

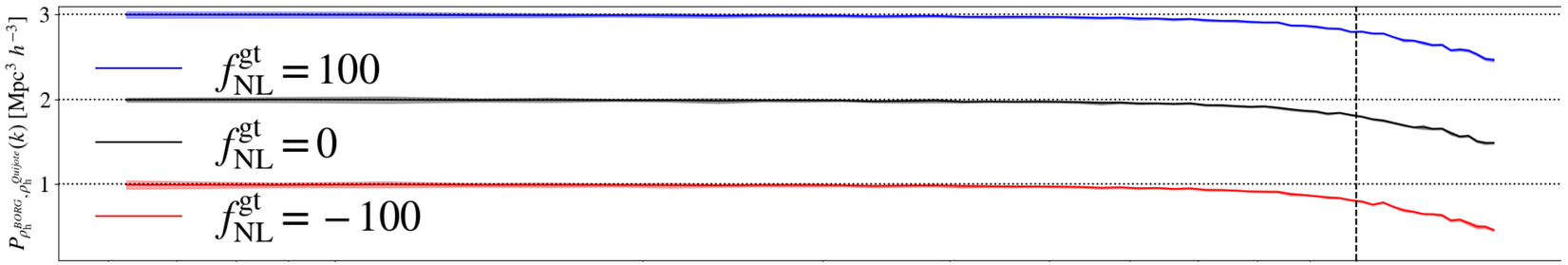

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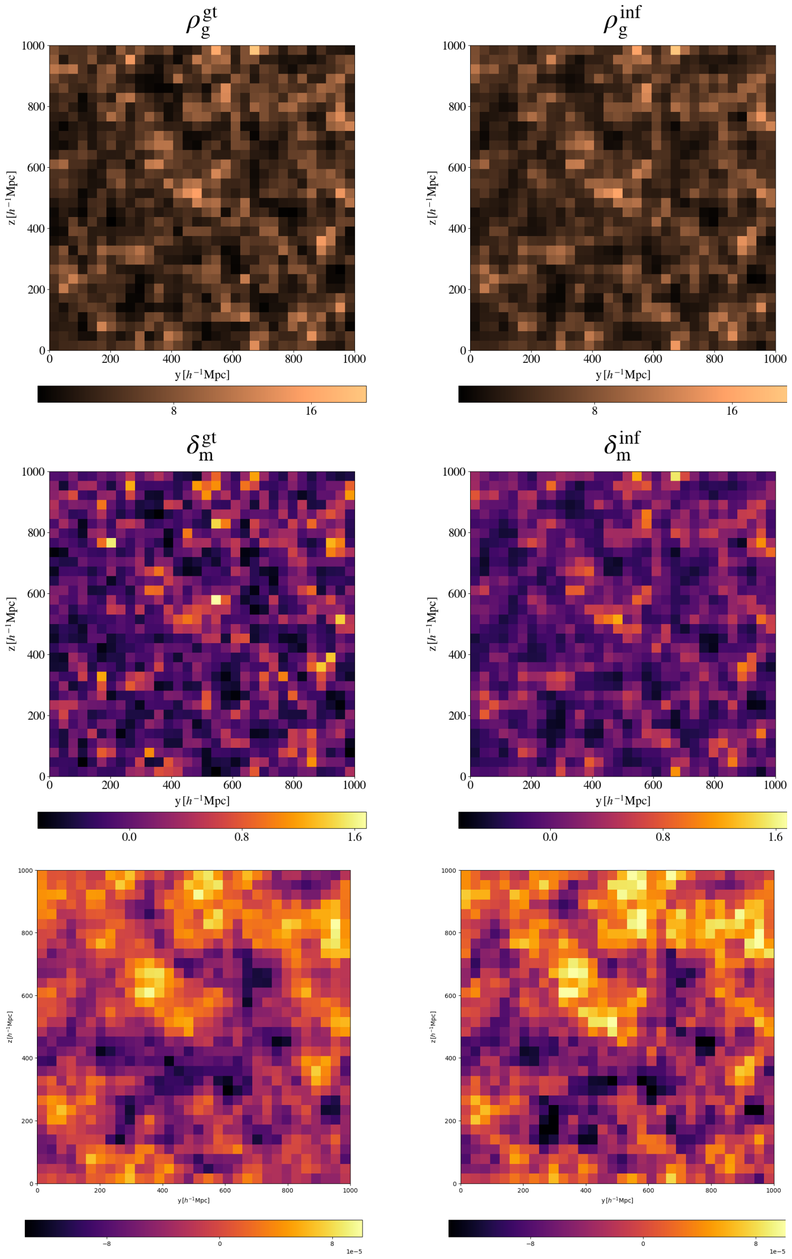

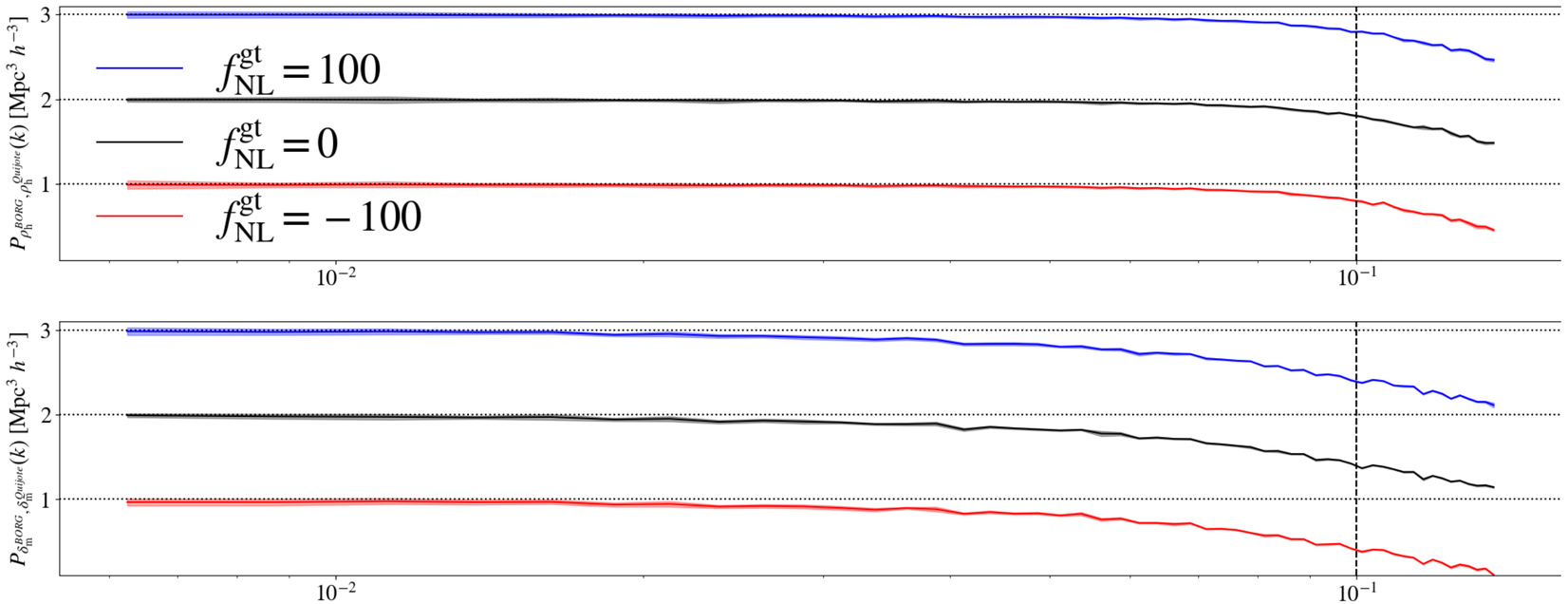

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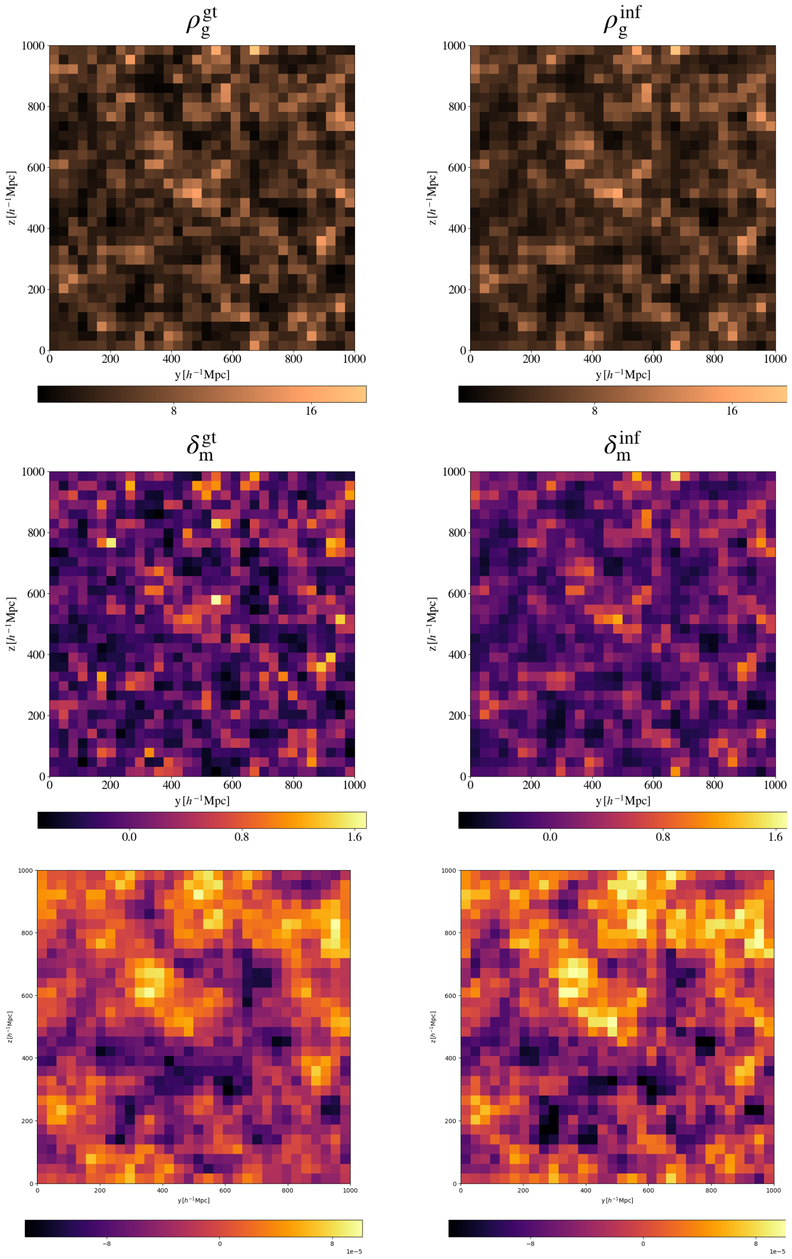

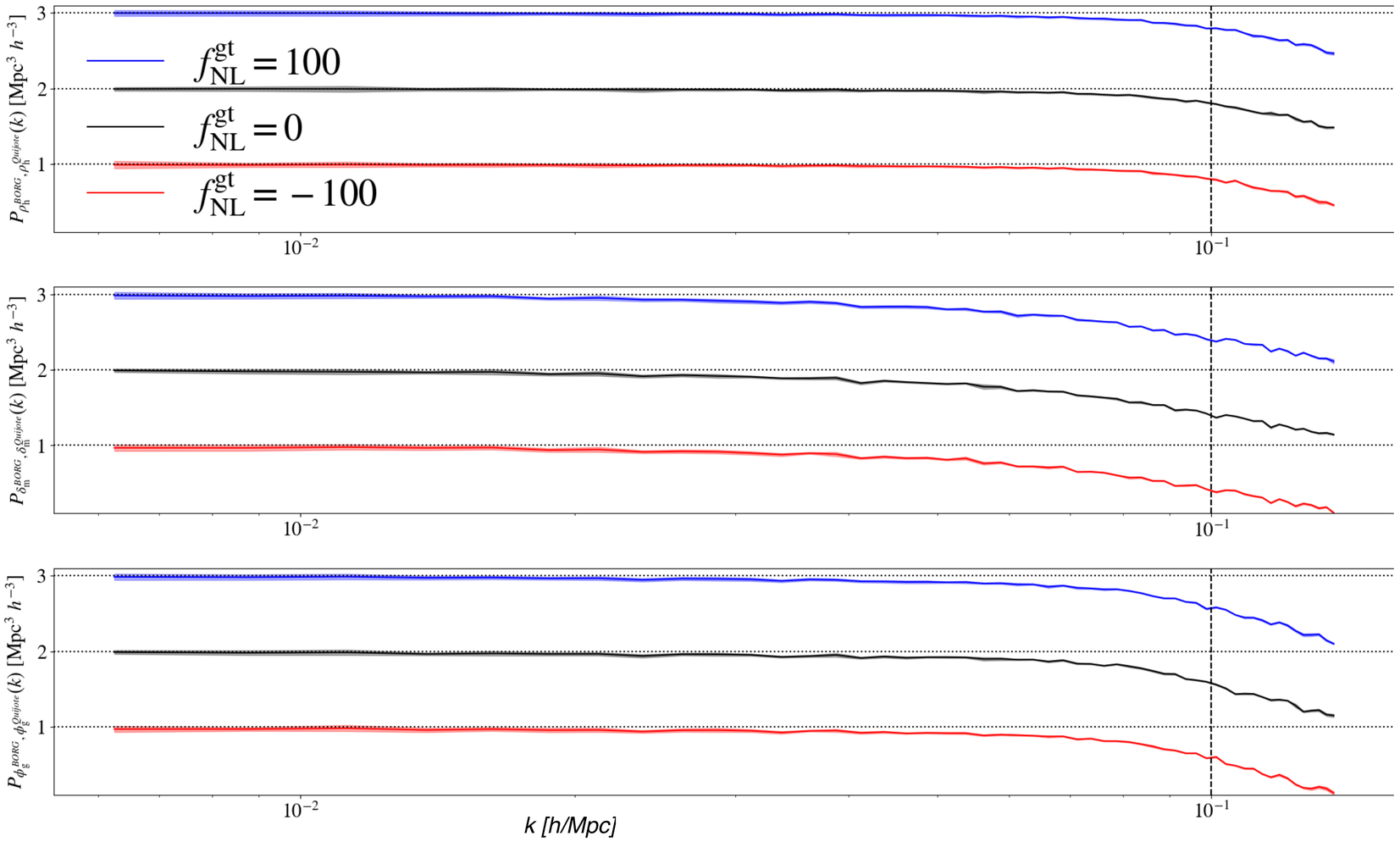

kmax = 0.1 *h*/Mpc, p=1

Preliminary results: Inferring $f_{\rm nl}$, bias and ICs

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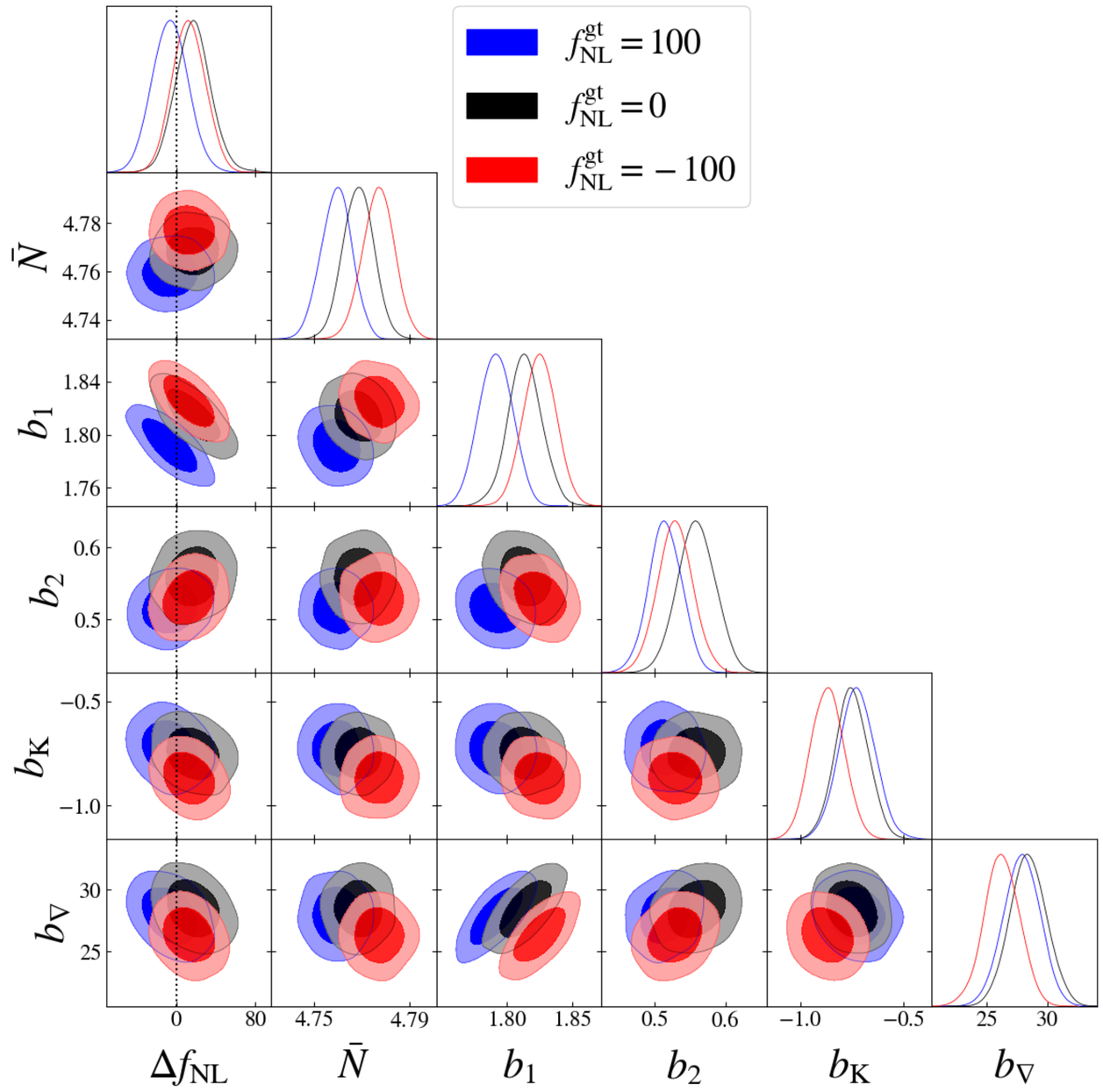

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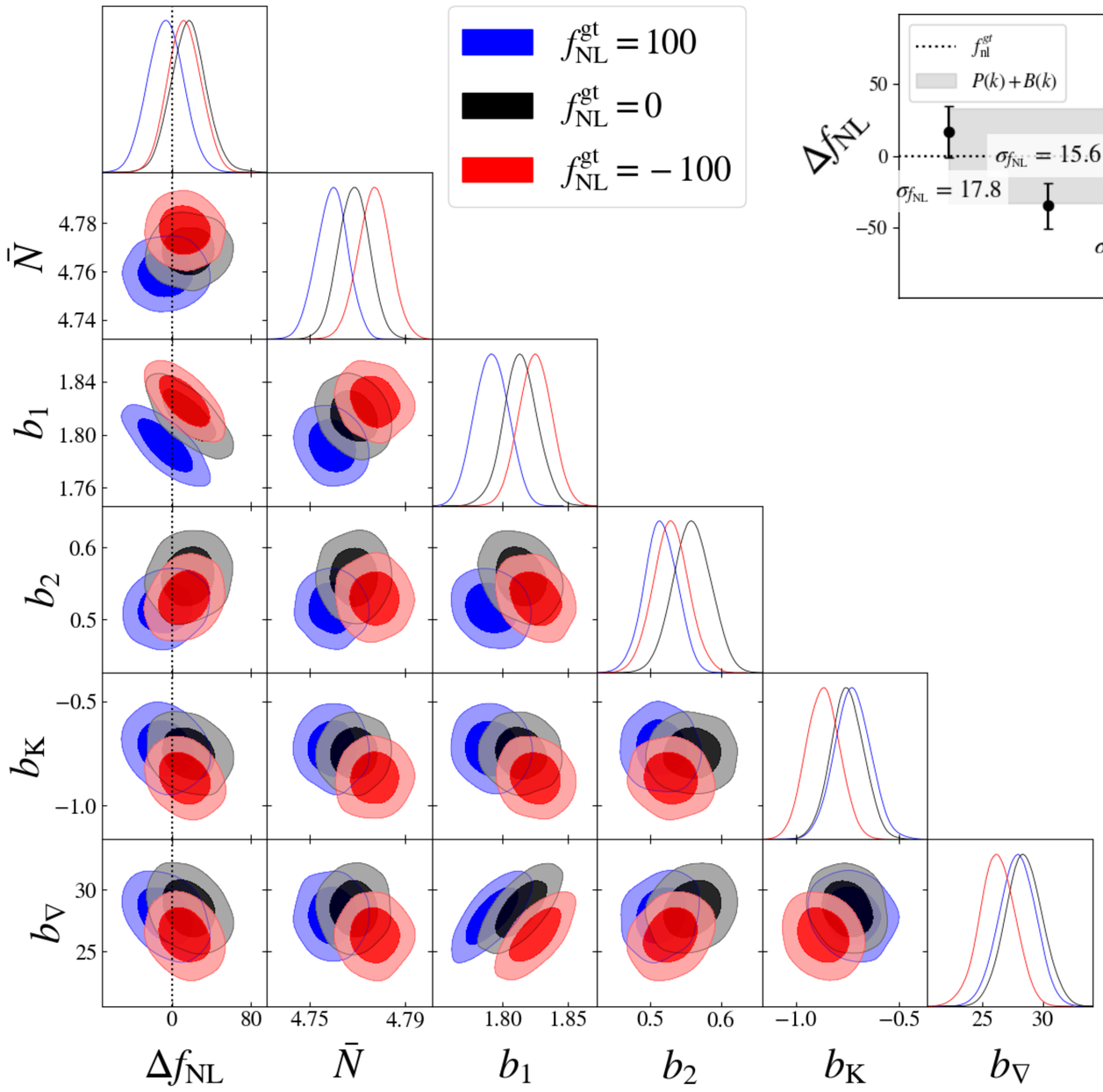

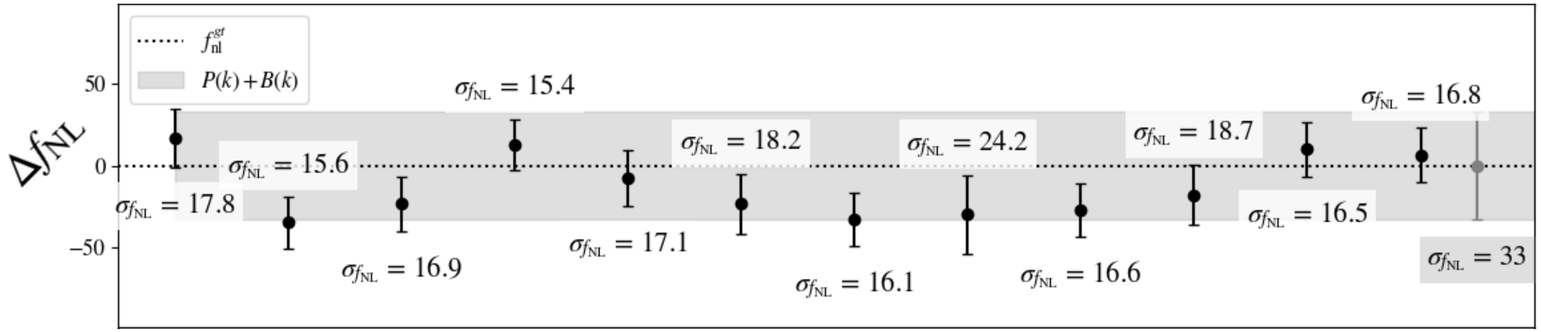

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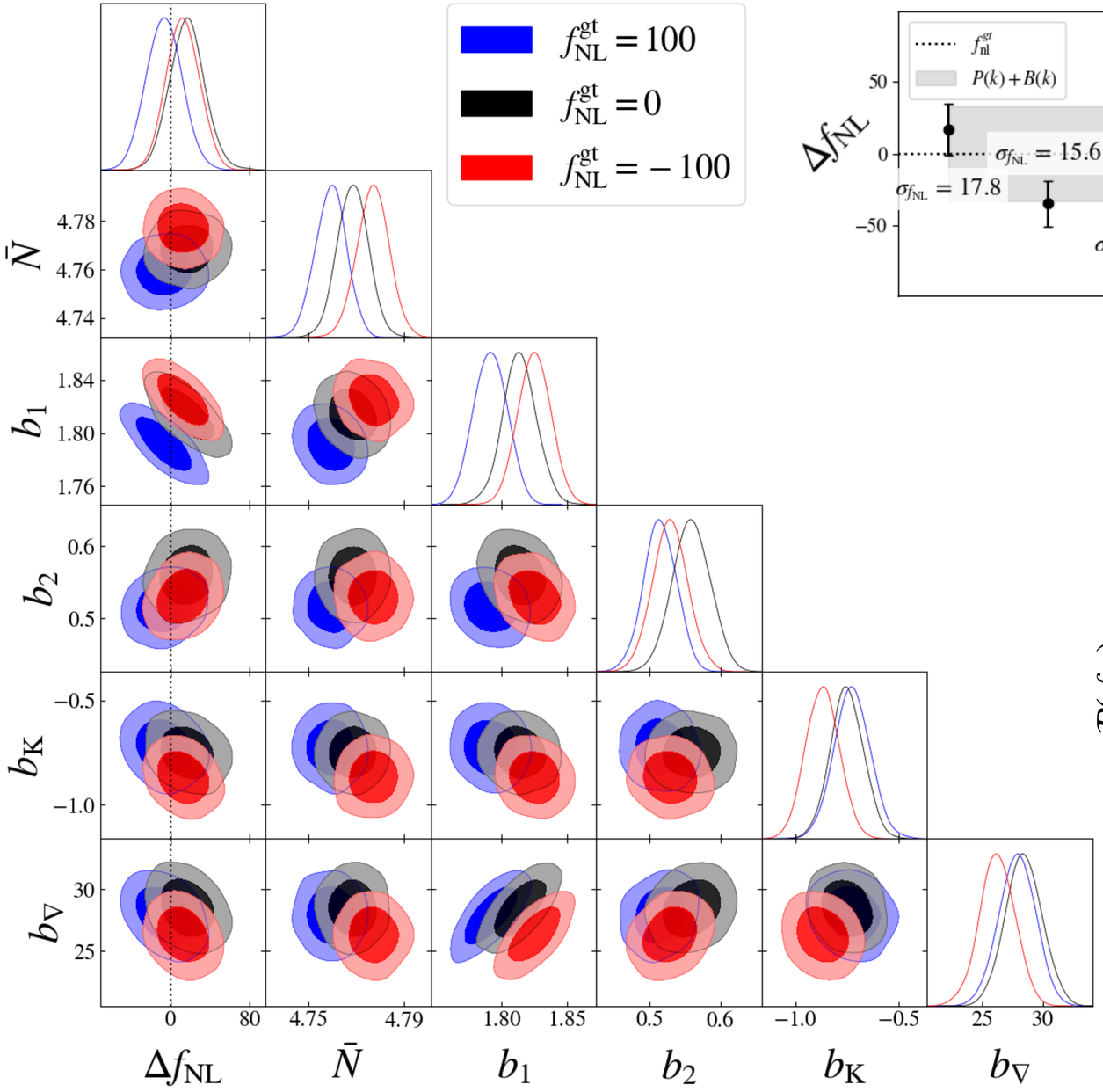

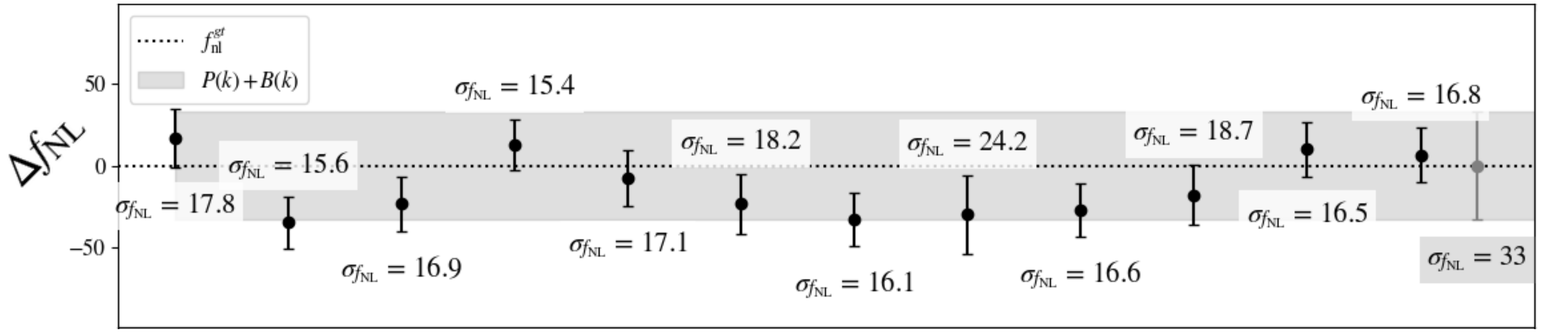

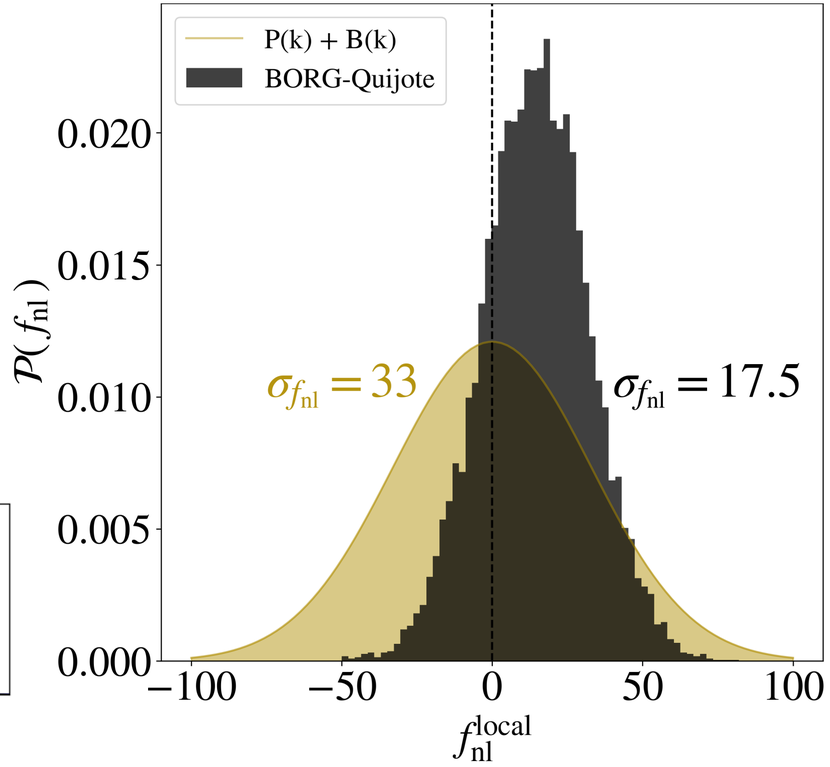

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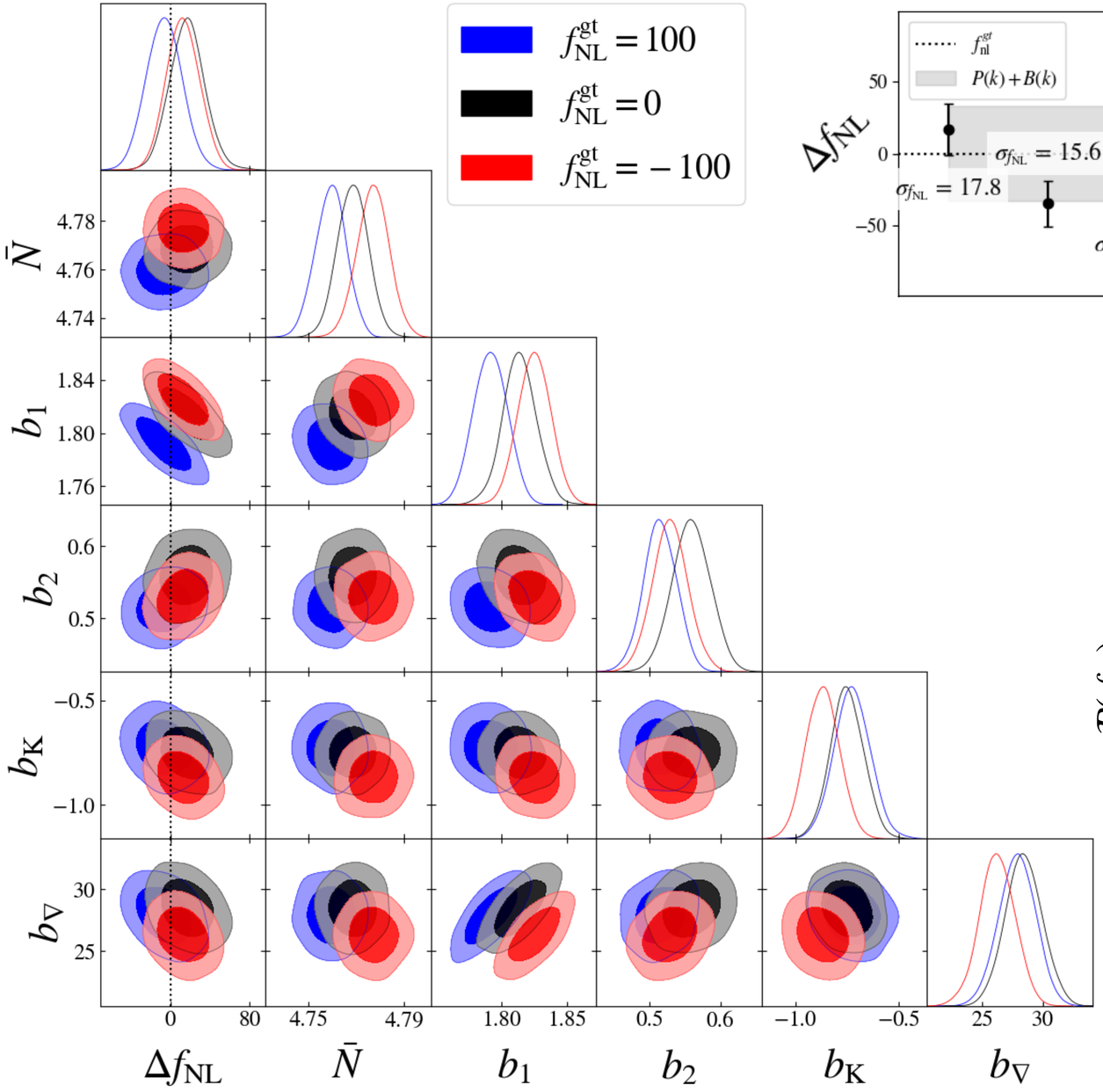
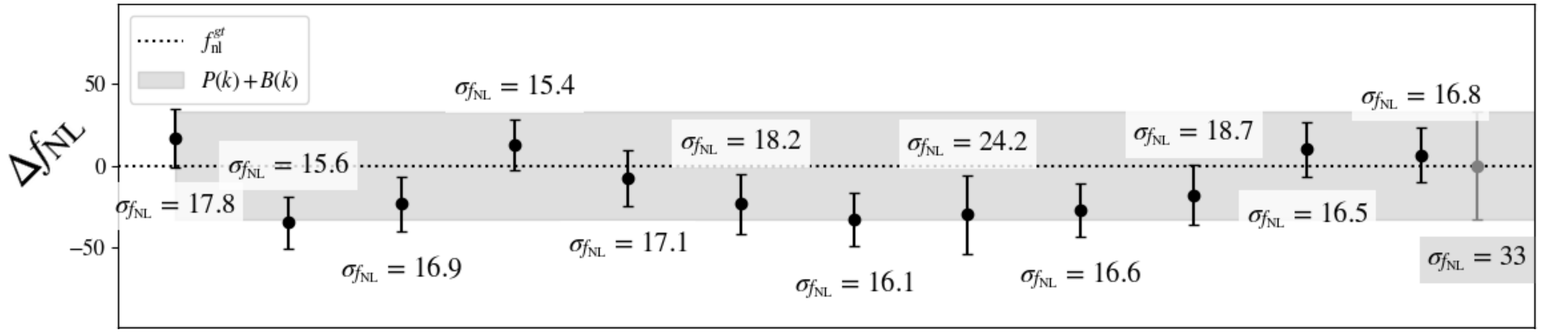
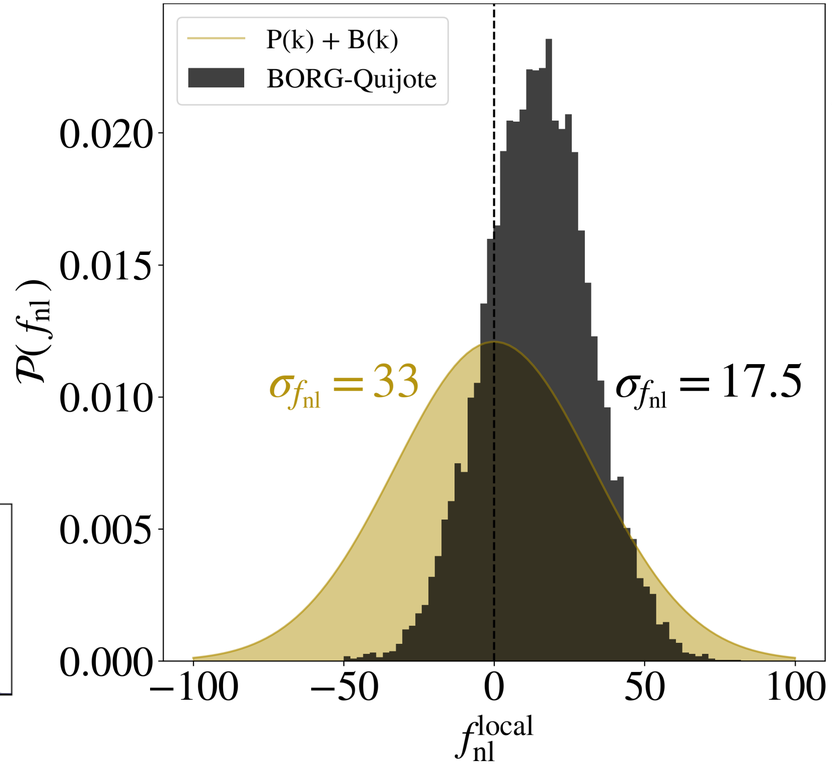


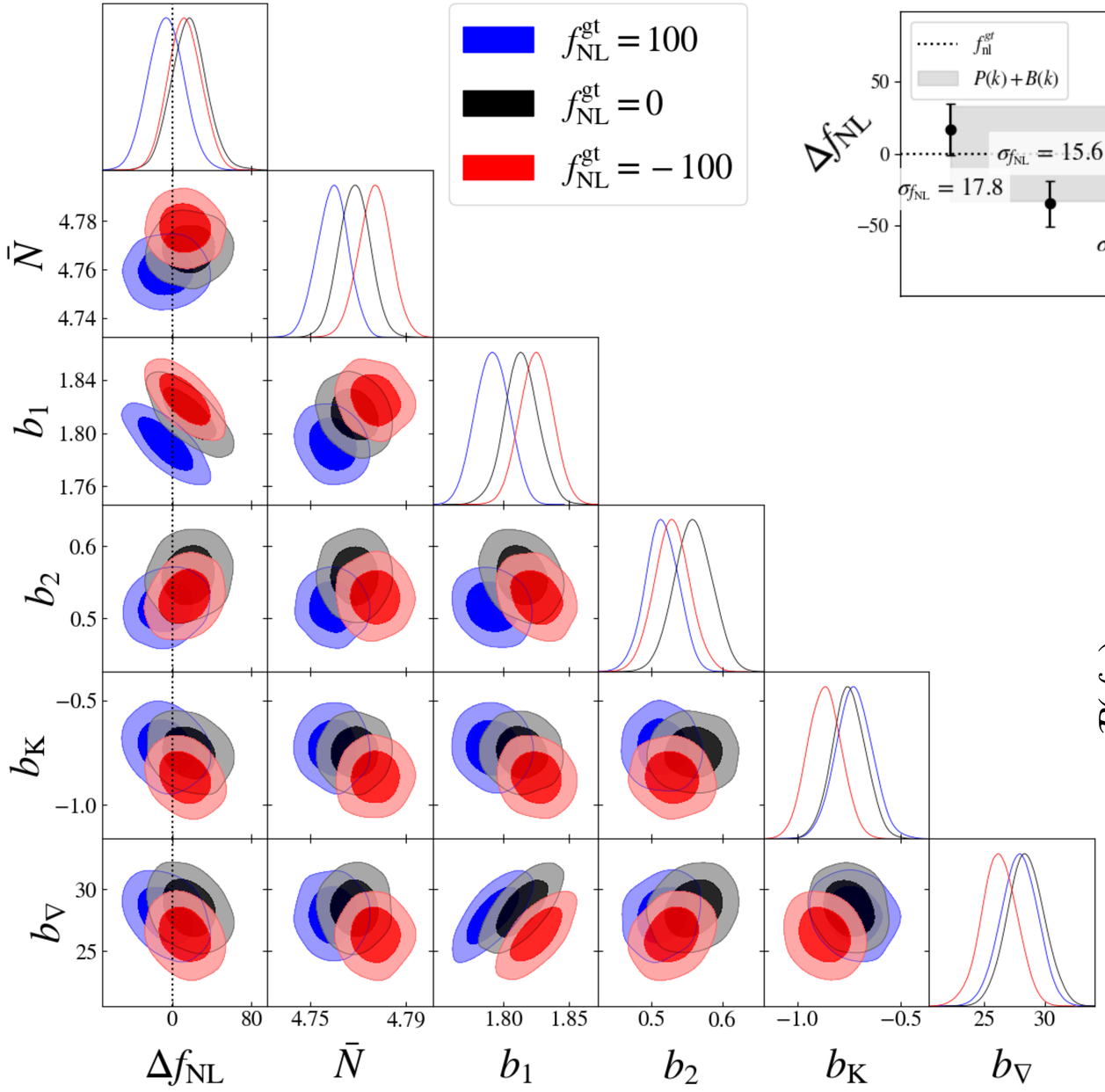


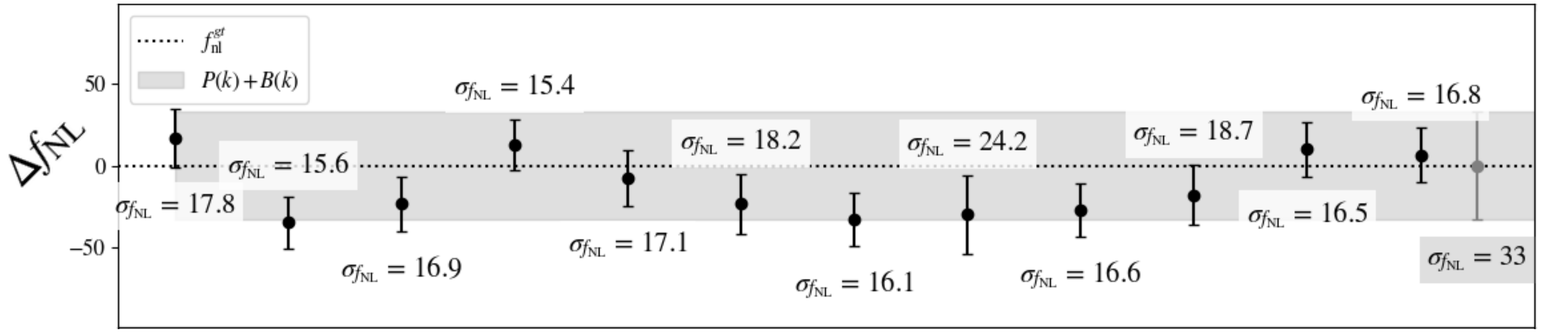


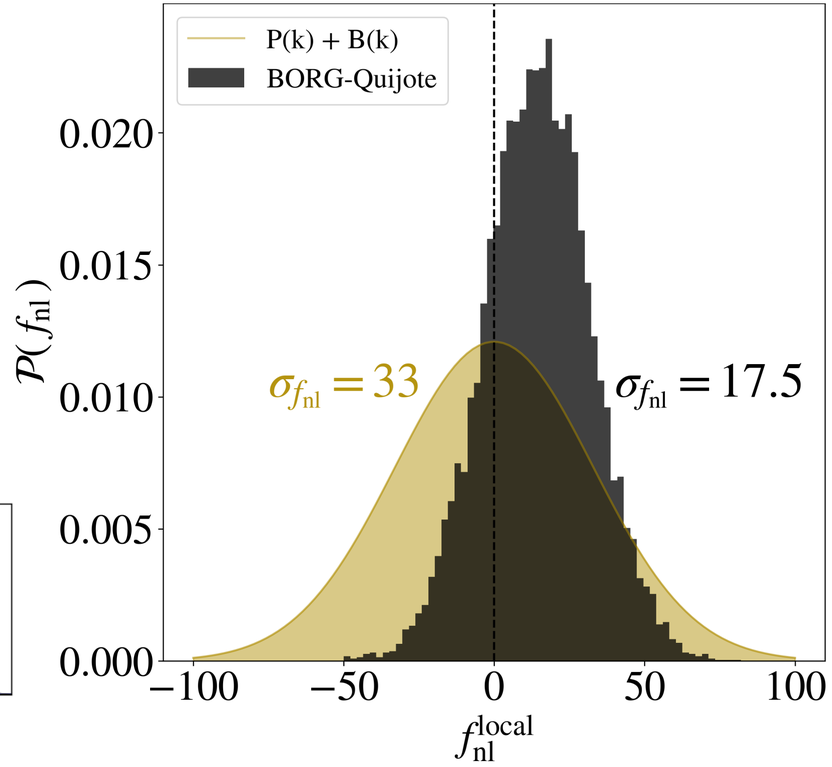
✓ Reconstruct underlying fields

kmax = 0.1 *h*/Mpc, p=1

Preliminary results: Inferring $f_{\rm nl}$, bias and ICs





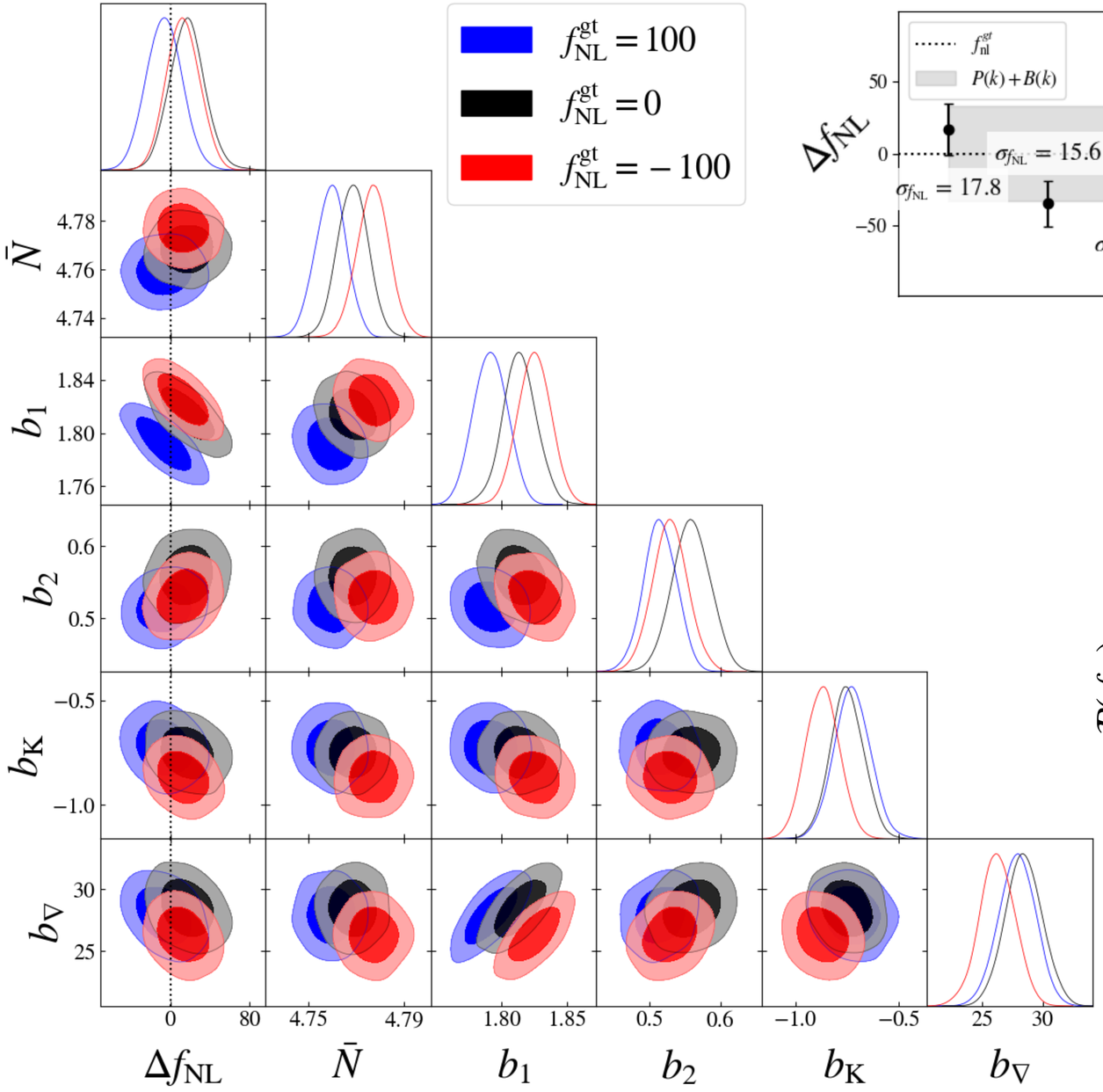


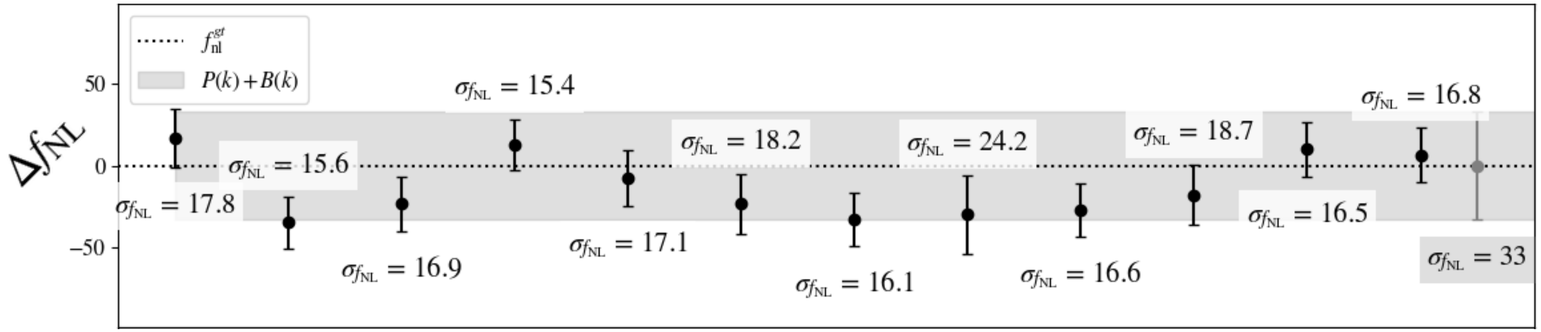
✓ Reconstruct underlying fields

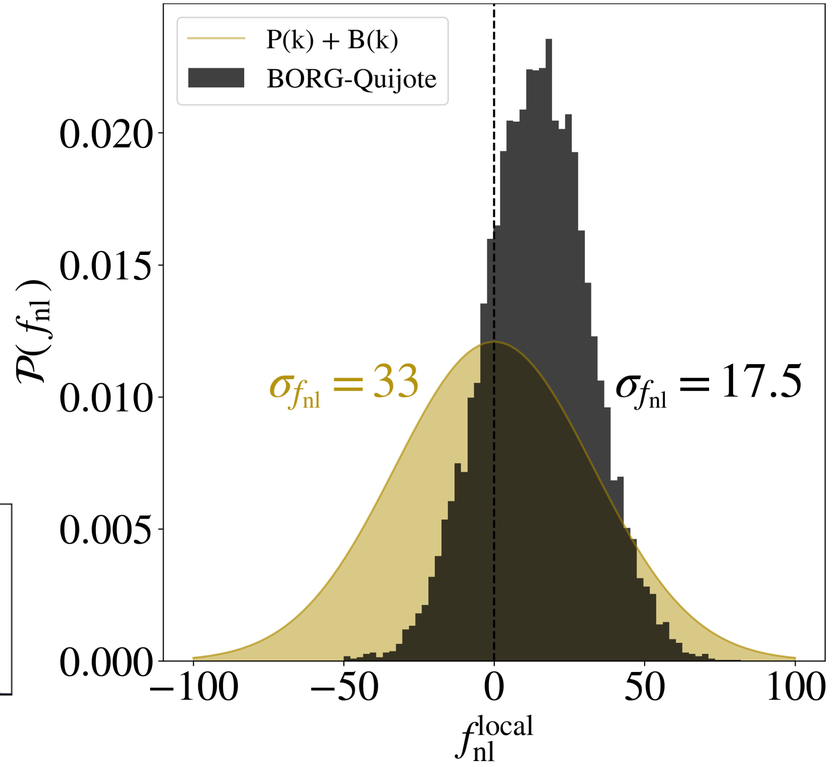
✓ Consistently recover ground truth values

kmax = 0.1 *h*/Mpc, p=1

Preliminary results: Inferring $f_{\rm nl}$, bias and ICs







- ✓ Reconstruct underlying fields
- ✓ Consistently recover ground truth values
- ✓ Outperform traditional summary statistics

kmax = 0.1 *h*/Mpc, p=1

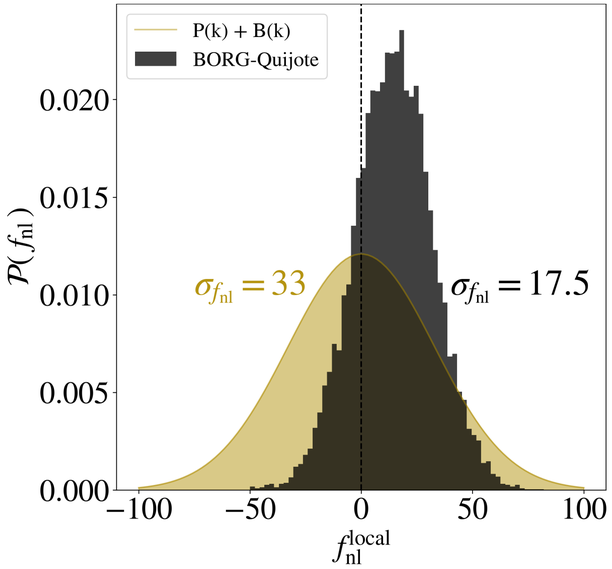
Summary

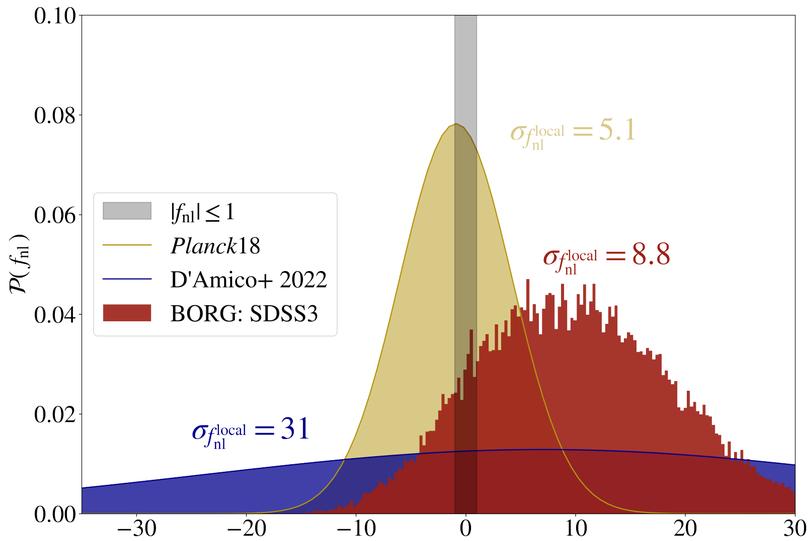
1. Competitive results, incl. forecasts of $\sigma_{f_{\rm nl}} \approx 8.8\ (68\%)$ for SDSS3/BOSS

2. Incorporation of survey geometry effects

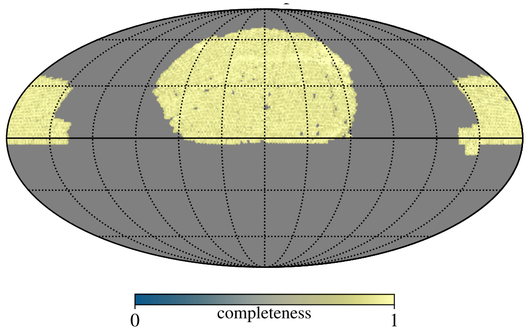
3. Reconstruction of ICs

Posterior distribution of $f_{\rm nl}$

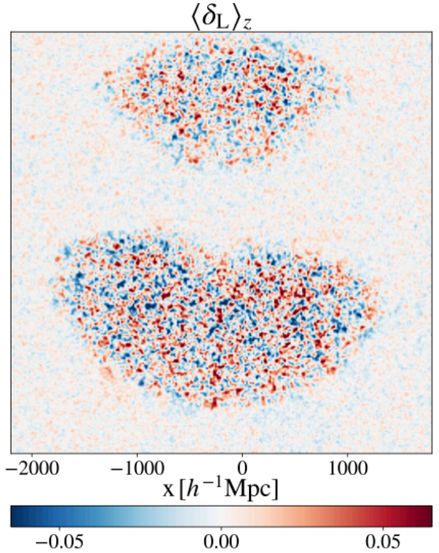




Survey geometry

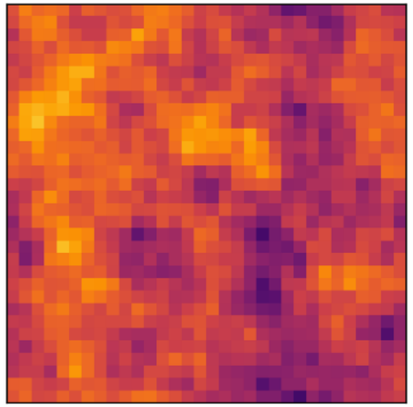


Inferred Initial Conditions

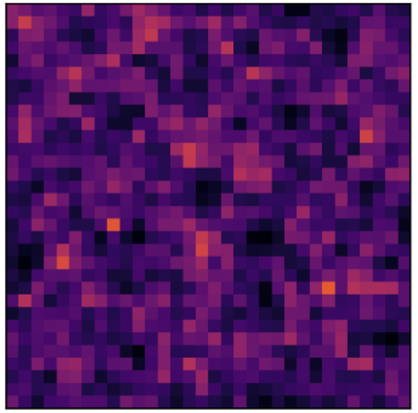


Setting-up: Fixed-phase analysis

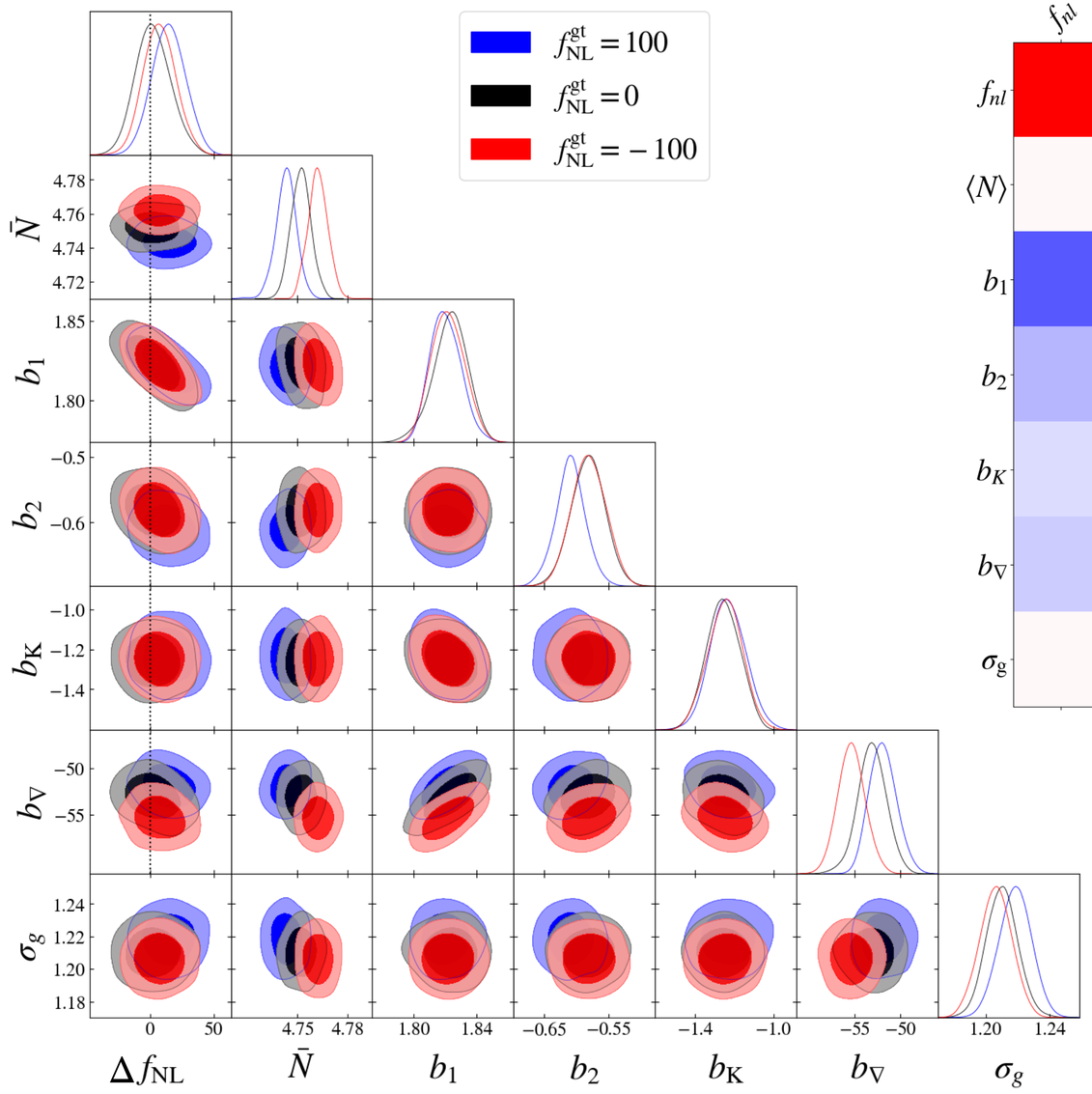
$\phi_g(\vec{q})$

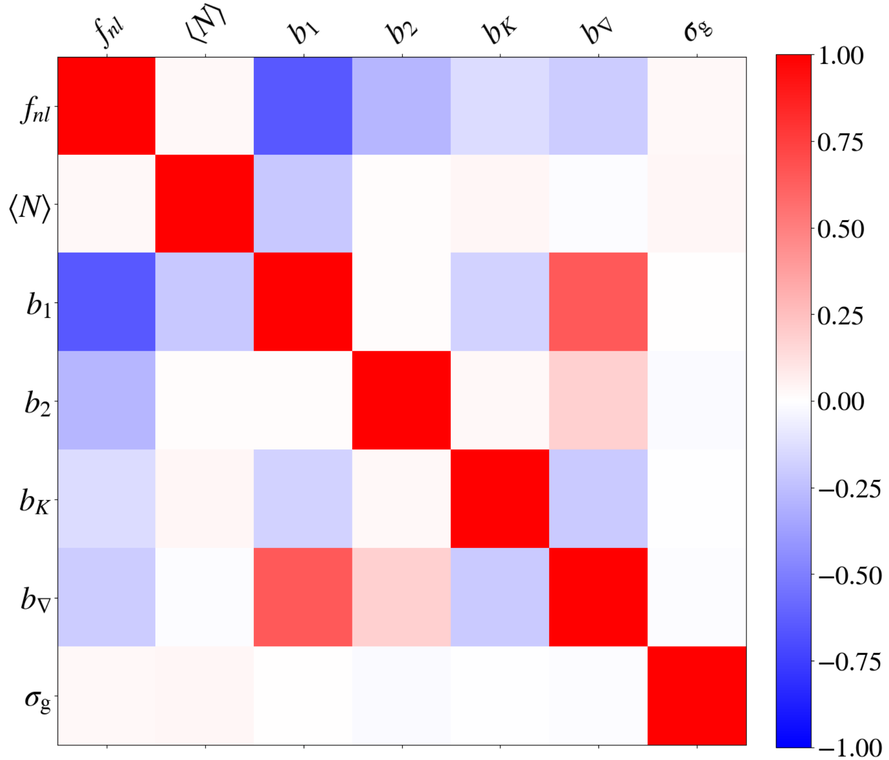


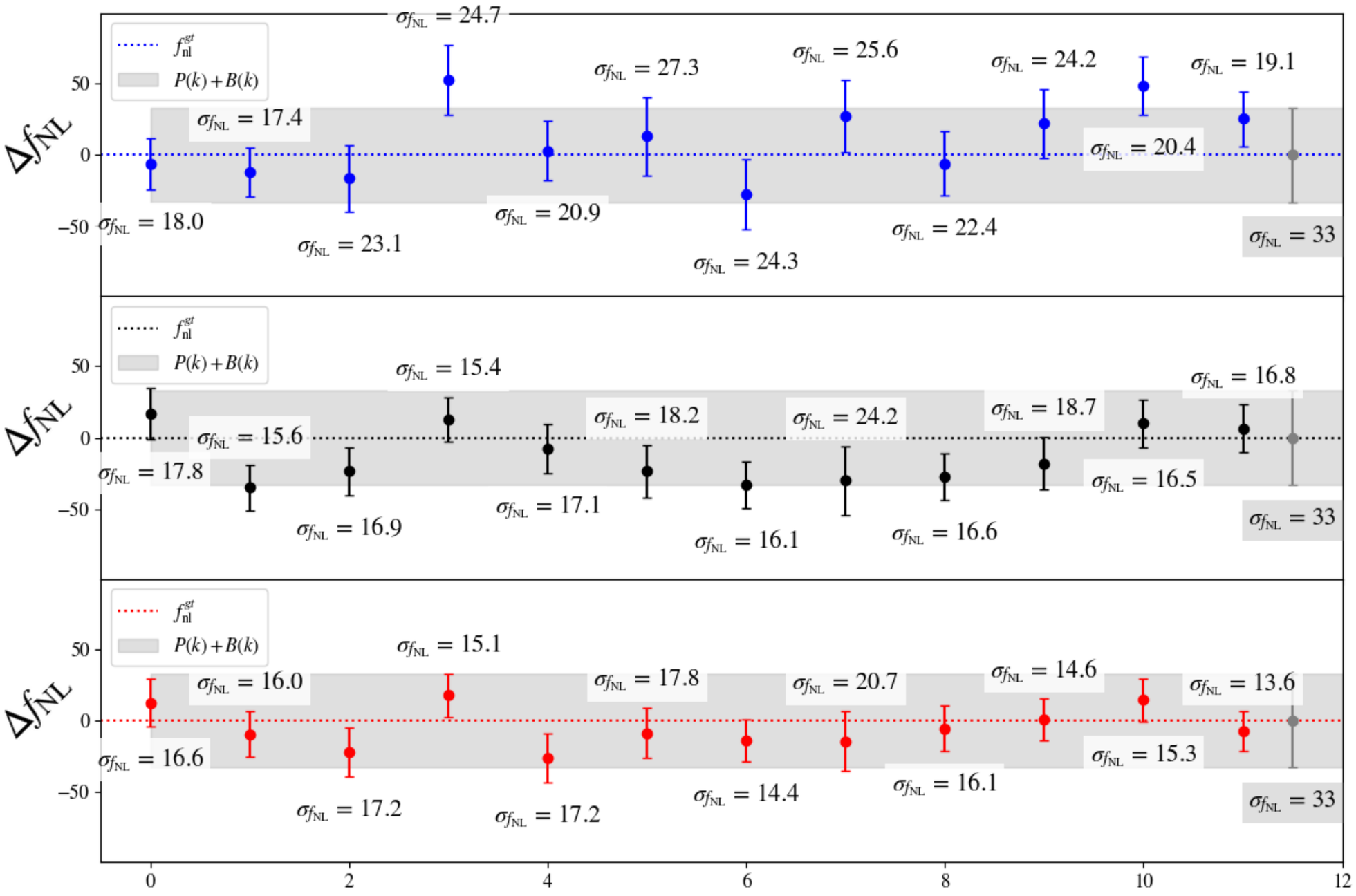
$\rho_h(\vec{x})$



kmax = 0.1 *h*/Mpc, p=1






f_{nl}^{gt}
$P(k)+B(k)$
Δf_{NL}
50
0
−50
$\sigma_{f_{NL}} = 24.7$
$\sigma_{f_{NL}} = 17.4$
$\sigma_{f_{NL}} = 27.3$
$\sigma_{f_{NL}} = 25.6$
$\sigma_{f_{NL}} = 24.2$
$\sigma_{f_{NL}} = 19.1$
$\sigma_{f_{NL}} = 20.4$
$\sigma_{f_{NL}} = 18.0$
$\sigma_{f_{NL}} = 23.1$
$\sigma_{f_{NL}} = 20.9$
$\sigma_{f_{NL}} = 24.3$
$\sigma_{f_{NL}} = 22.4$
$\sigma_{f_{NL}} = 33$
$\sigma_{f_{NL}} = 15.4$
$\sigma_{f_{NL}} = 16.8$
$\sigma_{f_{NL}} = 18.2$
$\sigma_{f_{NL}} = 24.2$
$\sigma_{f_{NL}} = 18.7$
$\sigma_{f_{NL}} = 15.6$
$\sigma_{f_{NL}} = 17.8$
$\sigma_{f_{NL}} = 16.5$
$\sigma_{f_{NL}} = 16.9$
$\sigma_{f_{NL}} = 17.1$
$\sigma_{f_{NL}} = 16.1$
$\sigma_{f_{NL}} = 16.6$
$\sigma_{f_{NL}} = 33$
$\sigma_{f_{NL}} = 15.1$
$\sigma_{f_{NL}} = 16.0$
$\sigma_{f_{NL}} = 17.8$
$\sigma_{f_{NL}} = 20.7$
$\sigma_{f_{NL}} = 14.6$
$\sigma_{f_{NL}} = 13.6$
$\sigma_{f_{NL}} = 16.6$
$\sigma_{f_{NL}} = 15.3$
$\sigma_{f_{NL}} = 17.2$
$\sigma_{f_{NL}} = 17.2$
$\sigma_{f_{NL}} = 14.4$
$\sigma_{f_{NL}} = 16.1$
$\sigma_{f_{NL}} = 33$
0
2
4
6
8
10
12