Impact of Baryonic Feedback on Cosmological Constraints from Weak Lensing

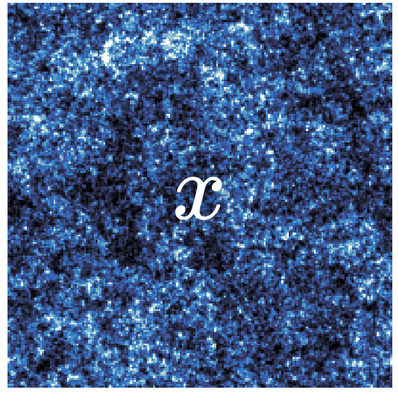
Andreas Tersenov

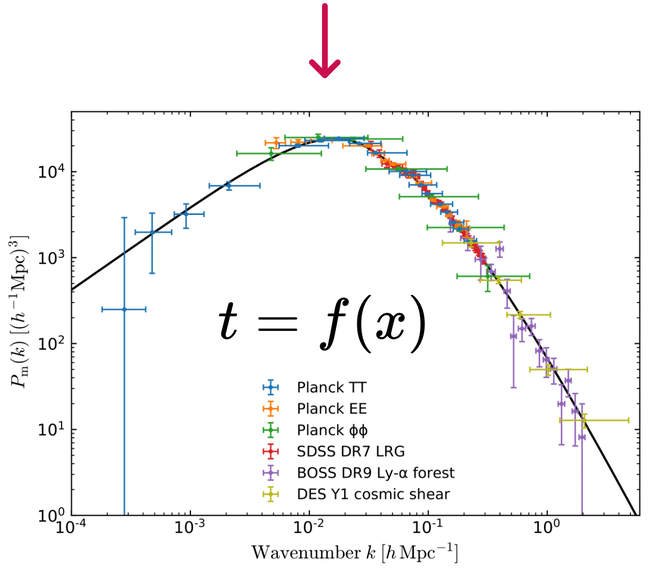
Deep CosmoStat Days, Feb 12, 2026

FORTH

CosmoStat

How to constrain cosmological parameters?





For which we have / assume an analytical likelihood function

$$p\left(t = t_0 \mid \theta\right)$$

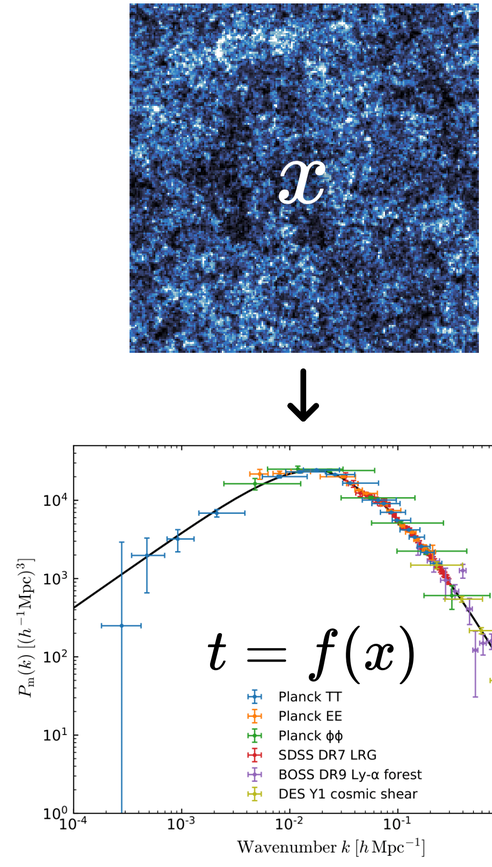
Likelihood → connects our compressed observations to the cosmological parameters

$$\underbrace{p\left(\theta \mid t = t_0\right)}_{\text{posterior}} \propto \underbrace{p\left(t = t_0 \mid \theta\right)}_{\text{likelihood}} \underbrace{p(\theta)}_{\text{prior}}$$

Credit: Justine Zeghal

2pt vs higher-order statistics

Using Power Spectra for constraining cosmological parameters misses the non-Gaussian information in the field.



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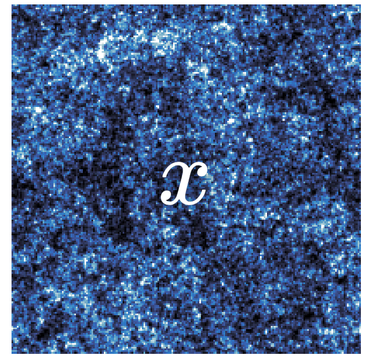
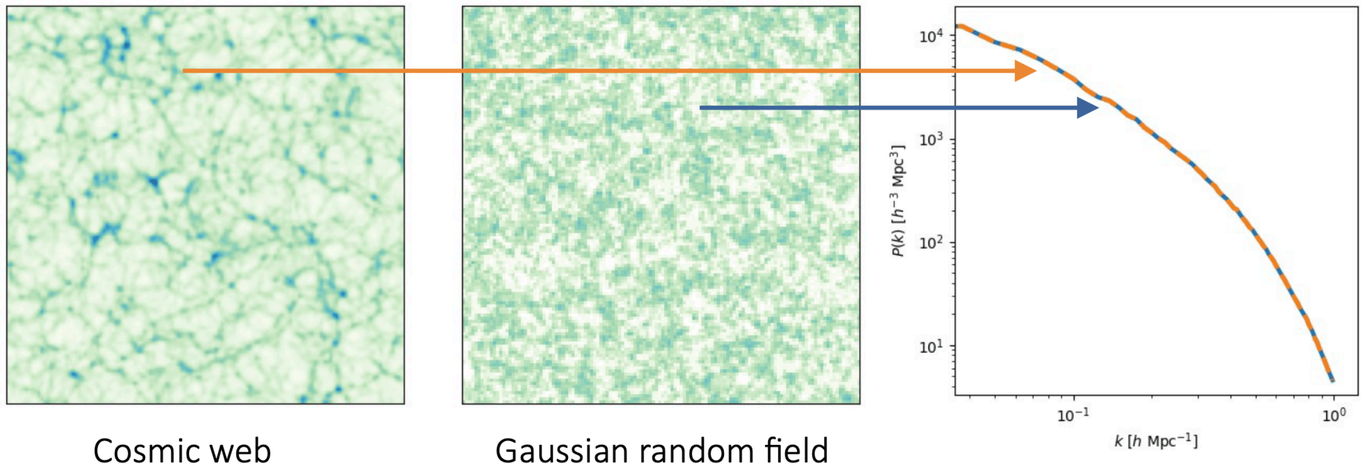
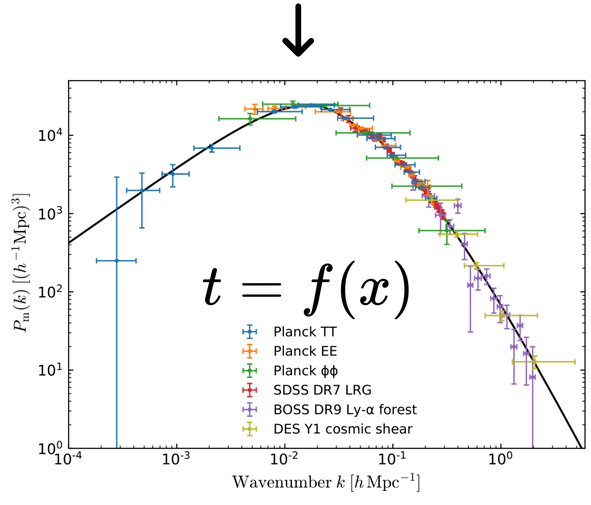




Cosmic web

Gaussian random field



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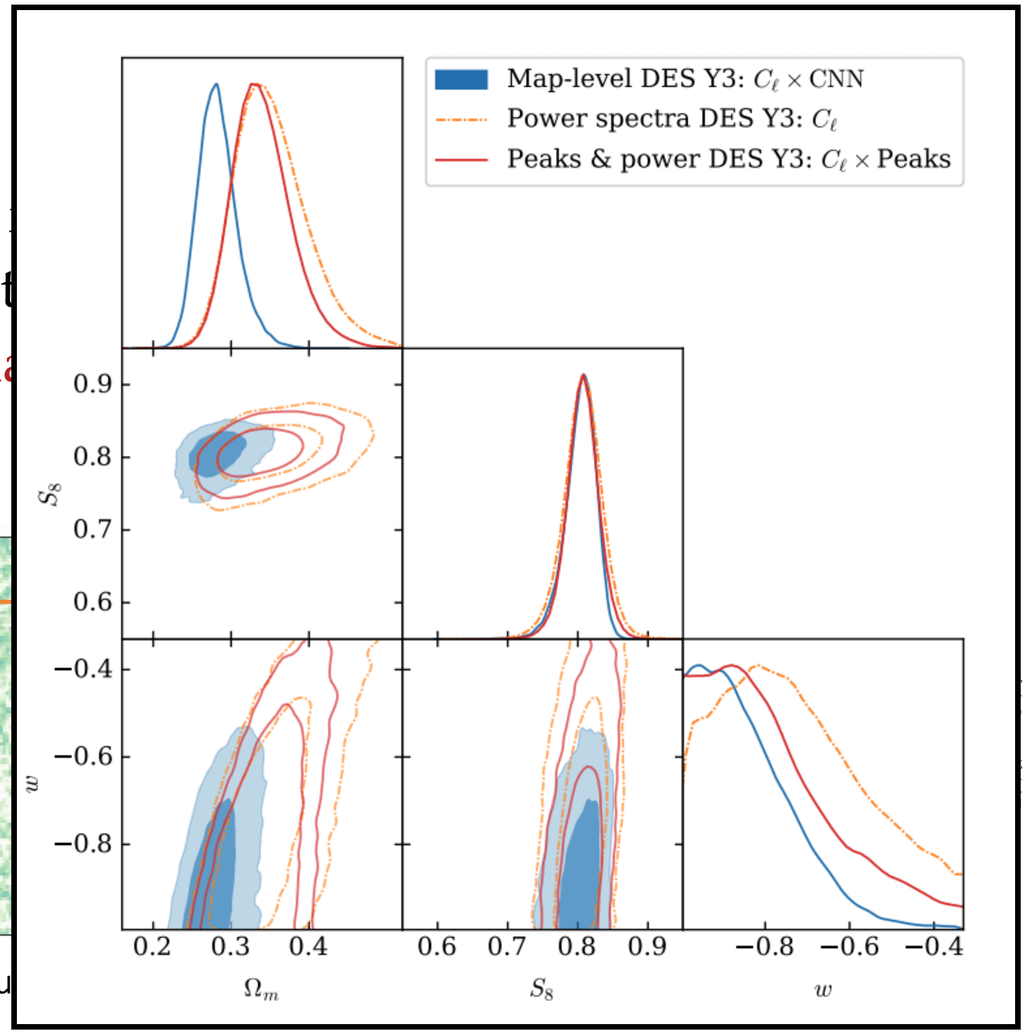
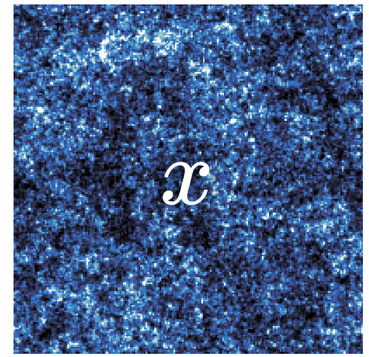
Using Power Spectra
cosmological paramet
non-Gaussian informa

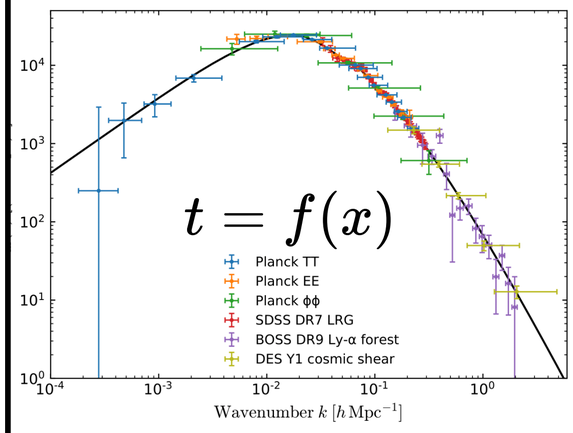
Cosmic web

Gau



DES Y3 Results





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Baryonic effects

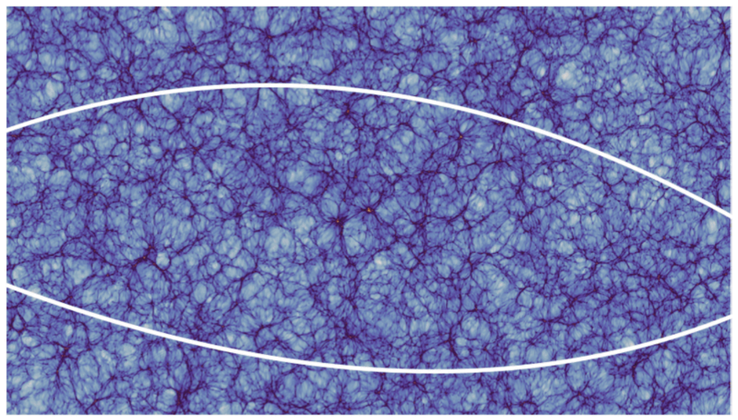
- Effects that stem from astrophysical processes involving **ordinary matter** (gas cooling, star formation, AGN feedback)
- They modify the matter distribution by redistributing gas and stars within halos.

- Suppress matter clustering on small scales
- Depend on the cosmic baryon fraction and cosmological parameters.
- Must be cut/modeled/marginalized over to avoid biases in cosmological inferences from WL.

0:00

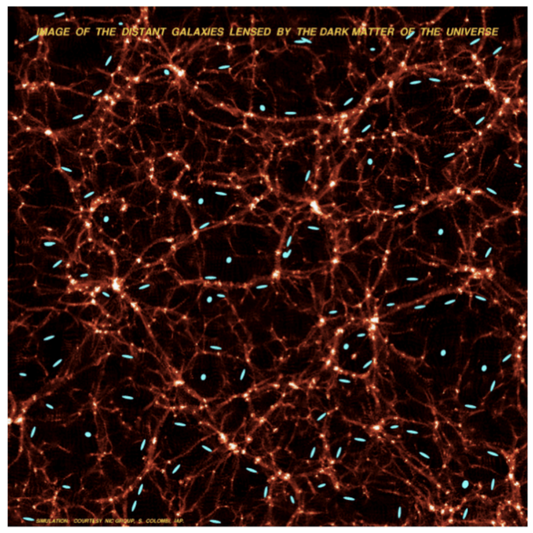
Baryonic impact on LSS statistics

Far galaxies



Large Scale Structure: DM + baryons

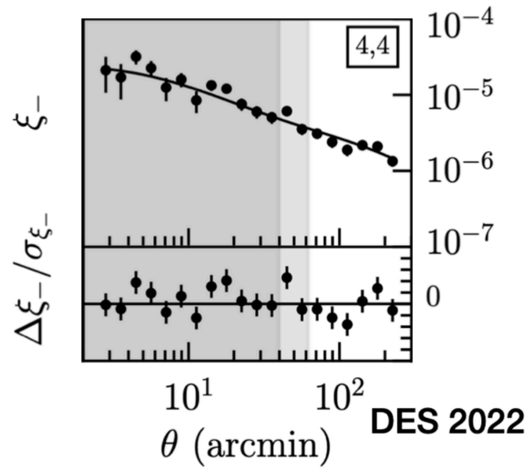
Observer



Courtesy of NYC group, S.Colombi

Correlation of galaxy shapes due to LSS gravity

$$C_{\gamma_i\gamma_j}(\ell) = \int_0^{\chi_H} \frac{g_i(\chi) g_j(\chi)}{\chi^2} P\left(\frac{\ell}{\chi}, z(\chi)\right) d\chi$$



Credit: Giovanni Aricò

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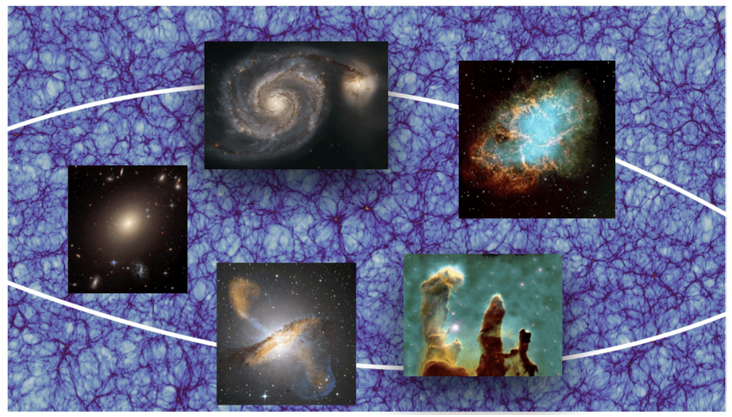

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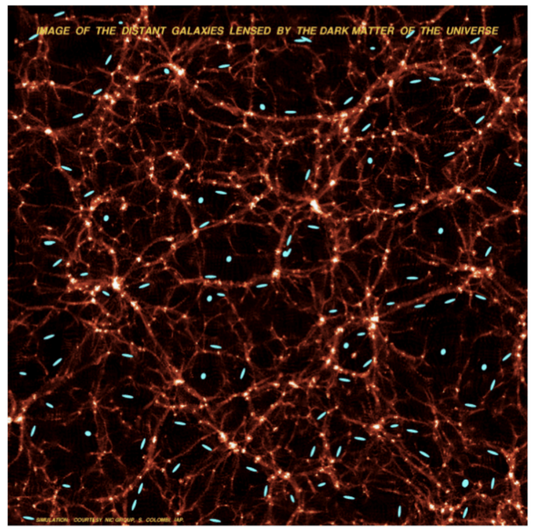

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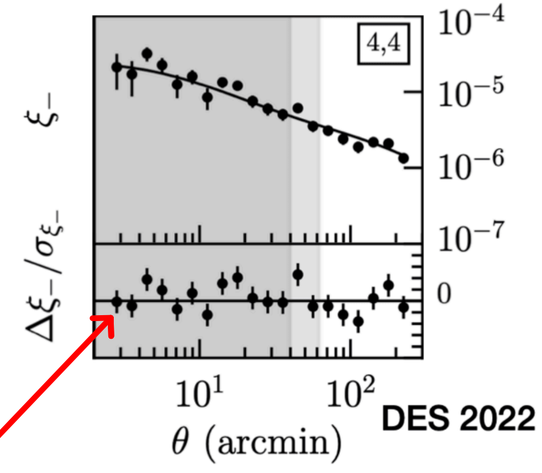


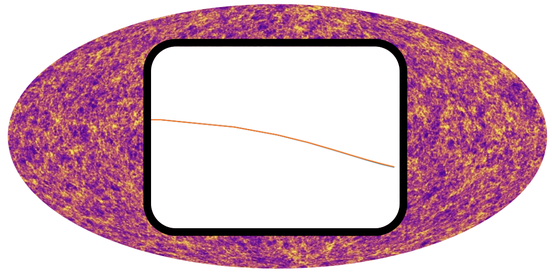
baryonic effects in *P(k)*

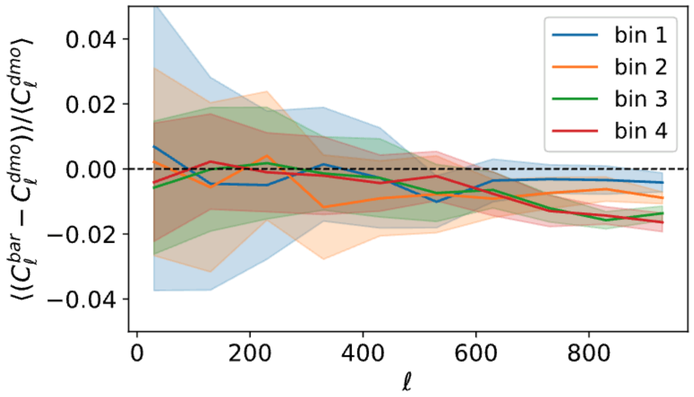
Credit: Giovanni Aricò

cosmoGRID:

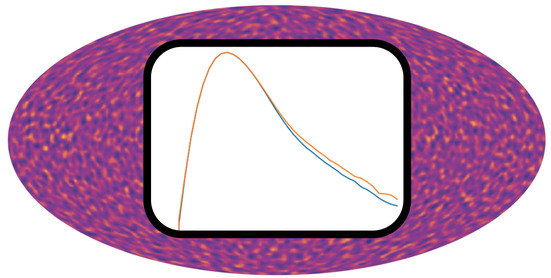
N-body sims, providing DMO & baryonified full-sky κ-maps.
Baryonic effects are incorporated using a shell-based Baryon Correction Model.

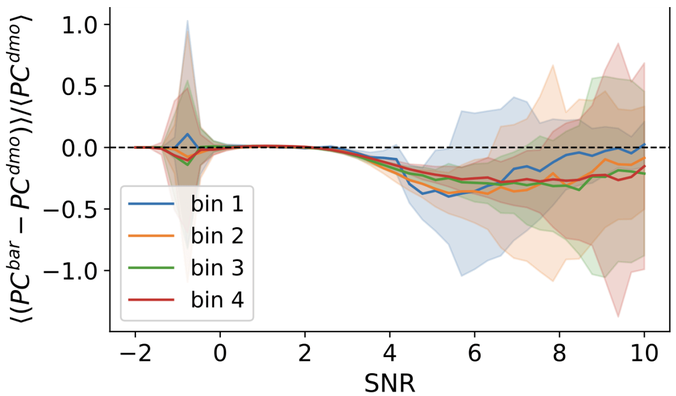
Power Spectrum →



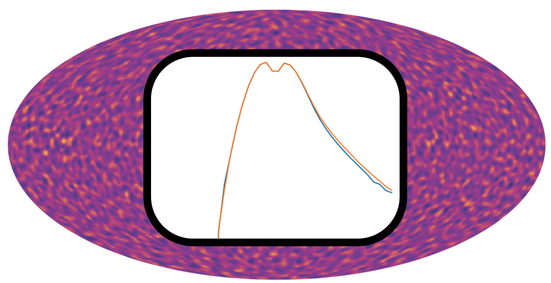


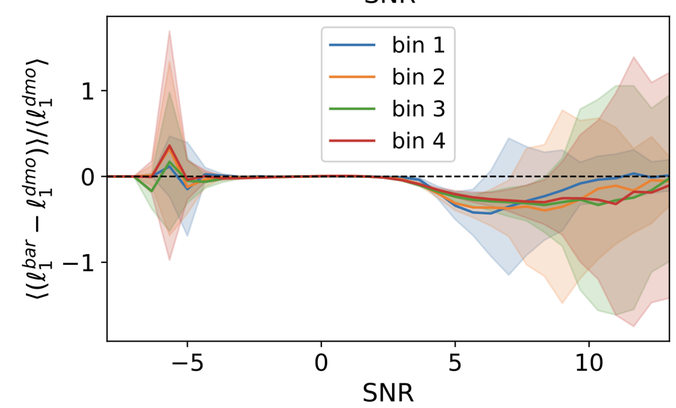
Wavelet peaks: local maxima of wavelet coefficient maps →





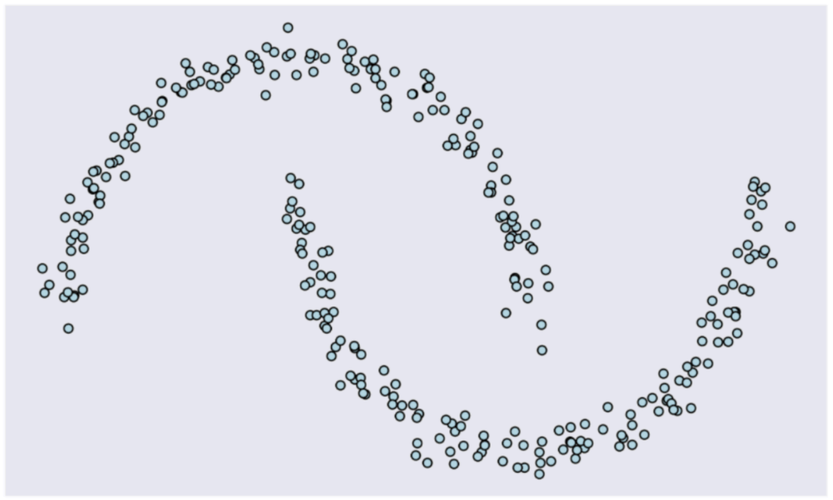
Wavelet l1-norm: sum of wavelet coefficients within specific amplitude ranges across different wavelet scales →



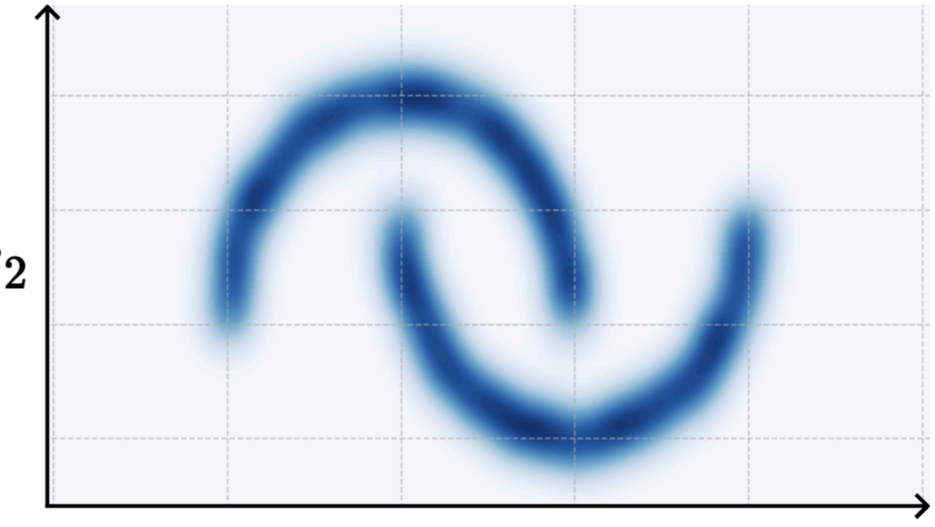


Density Estimation

Training Samples x_{train}



Model $p_\phi(x)$



Maximize the likelihood of the training samples

$$\hat{\phi} = \arg\max \left[\log p_\phi(x_{\text{train}})\right]$$

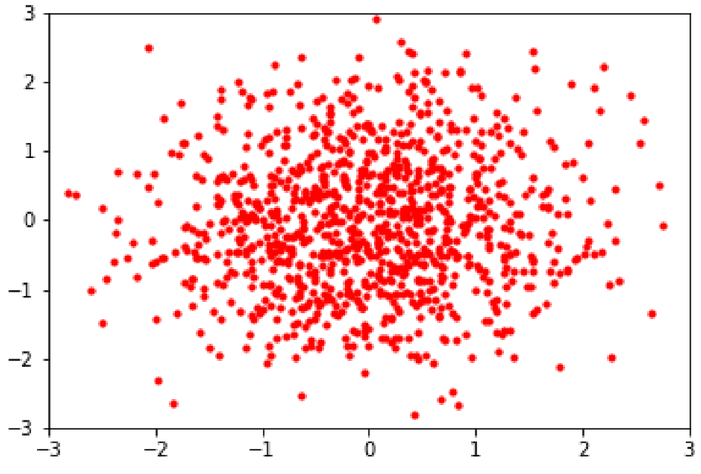
Normalizing Flows for Density Estimation

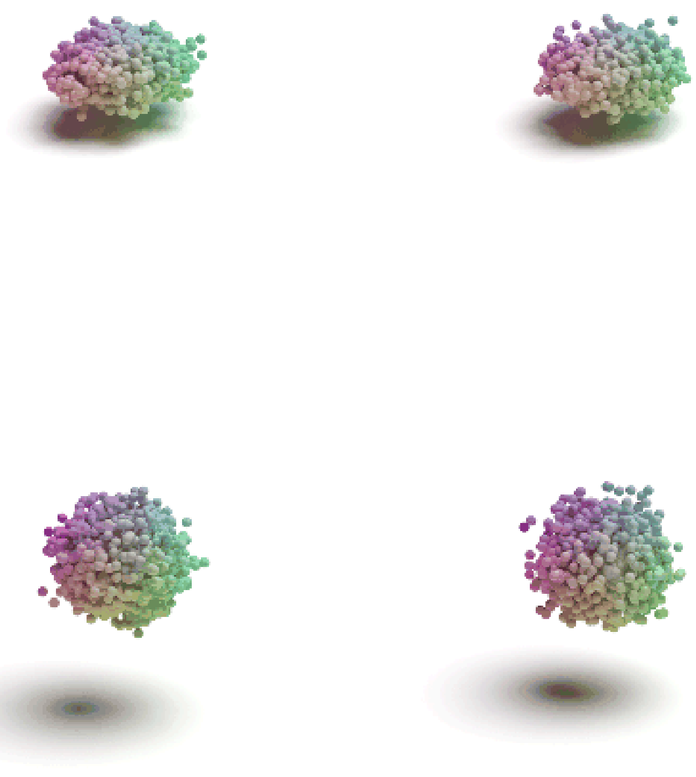
Normalizing Flows (NF) are based on mapping functions $f : \mathbb{R}^n \to \mathbb{R}^n$

Those functions enable us to map a latent variable $z \sim p_z(z)$ to a variable $x \sim p_x(x)$.

We can approximate distributions with NFs by *learning* this function

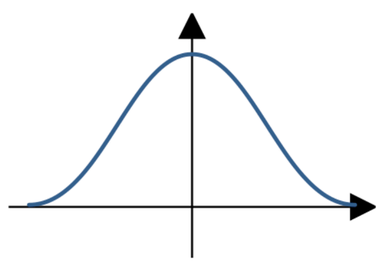
(discretize the problem into learning the parameters of a series of bijections)



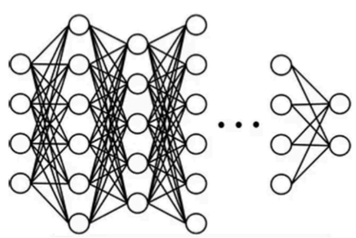


Inference method: SBI

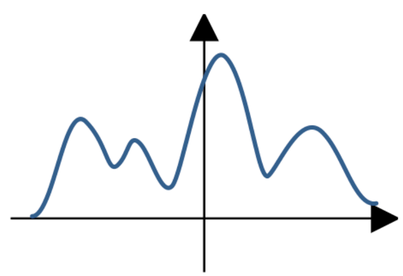
Gaussian
$\mathcal{N}(\mathbf{0},\mathbf{1})$



Density estimator
(Conditional MAF)



Posterior
$p(\theta \mid x)$



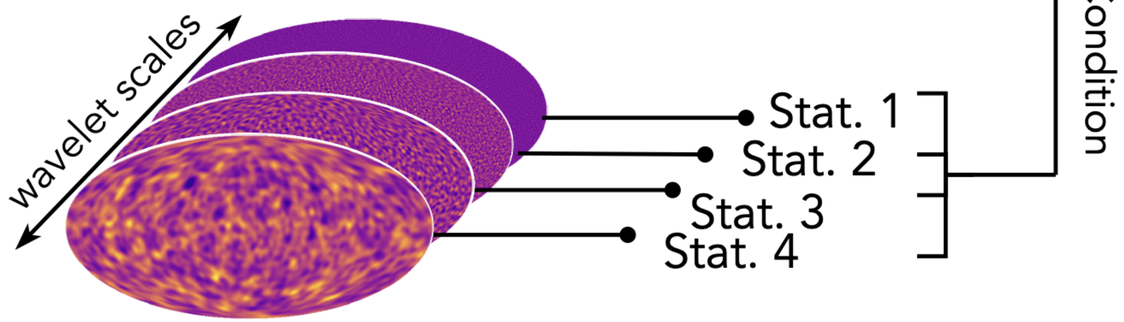
Training objective

$$\mathcal{L} = -\log p_\phi(\theta|x)$$

cosmoGRID
κ-maps

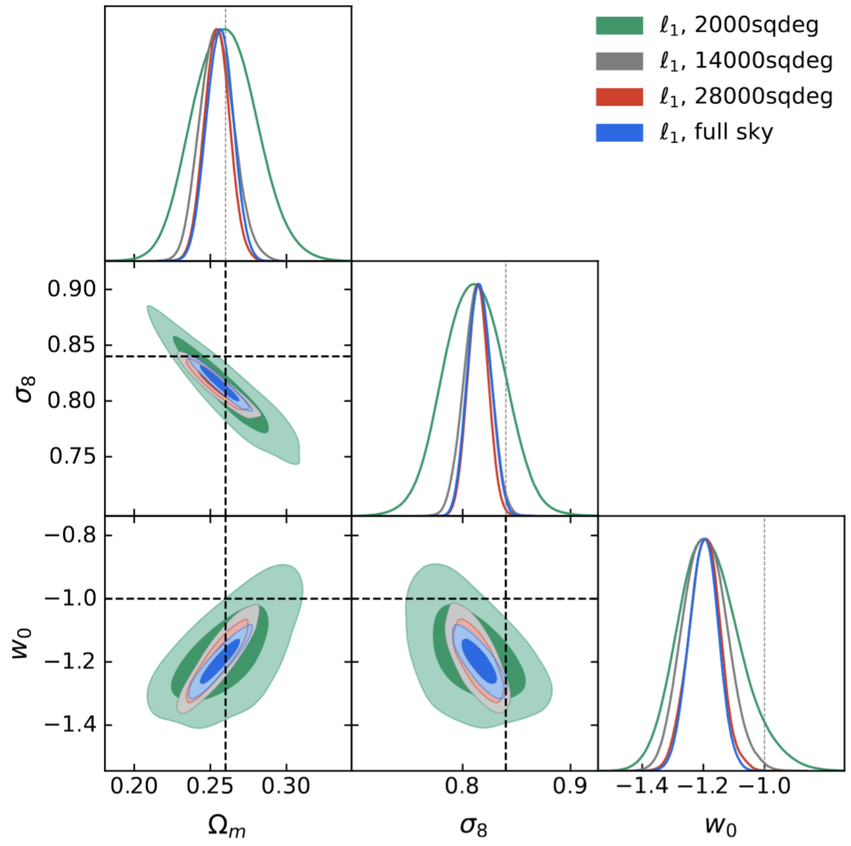
+ noise

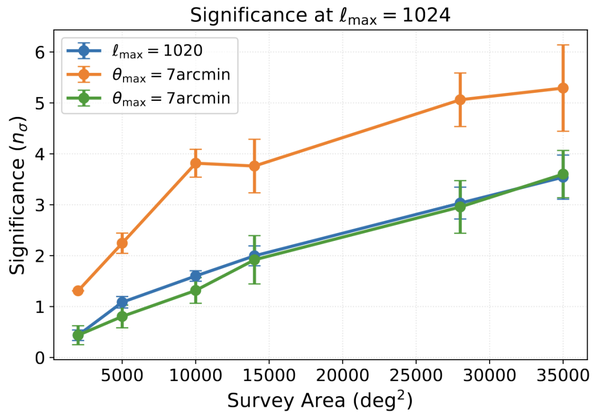
wavelet
transform

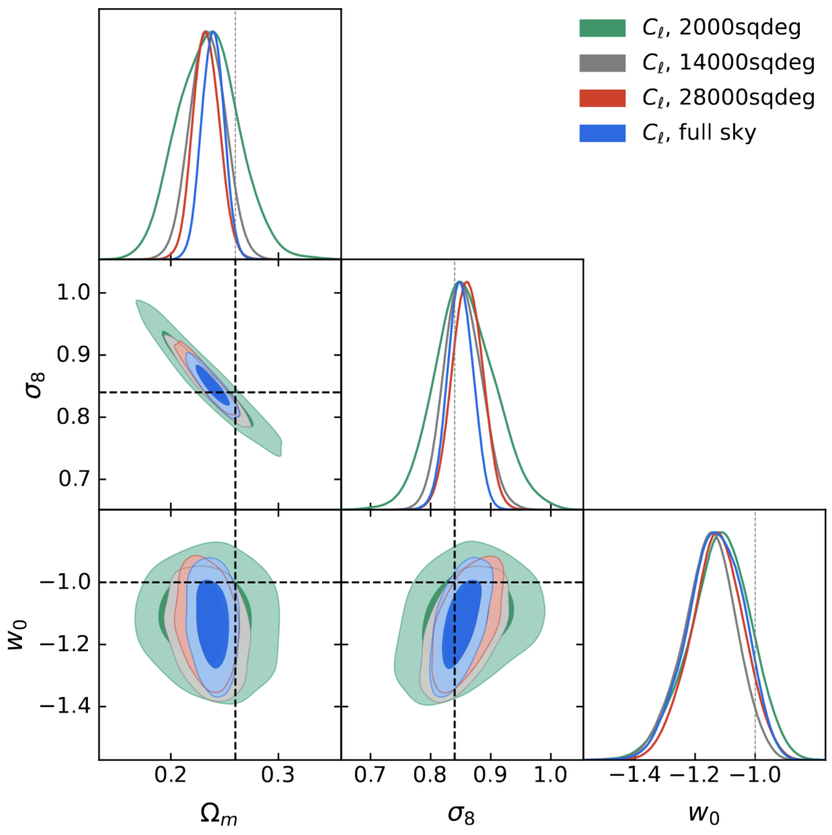


* https://github.com/sachaguer/jaxili

The Scaling of Baryonic Bias with Survey Area



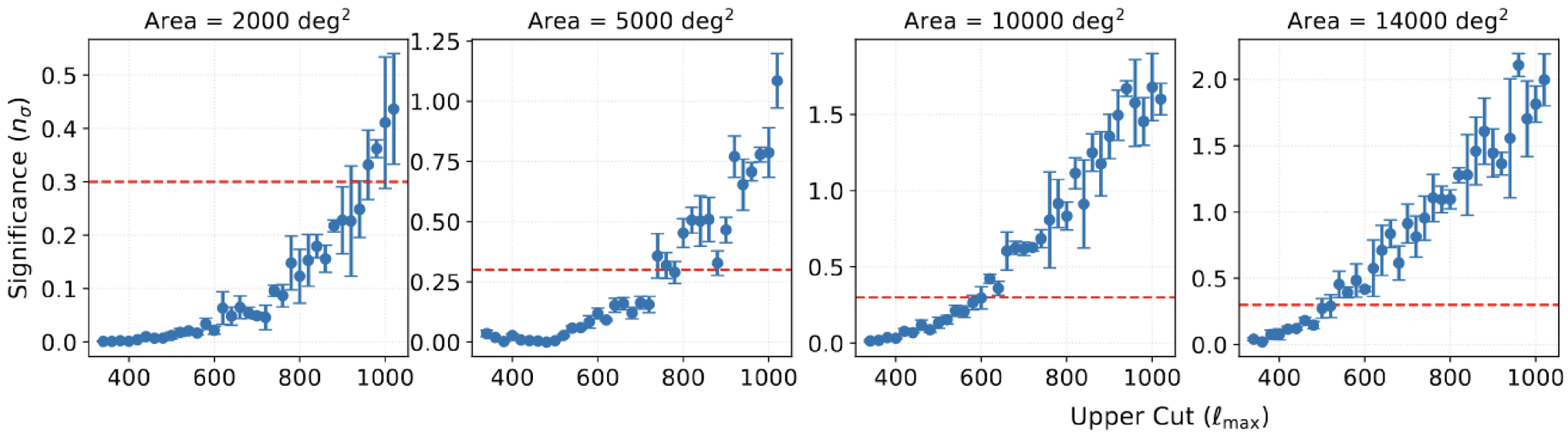




Results

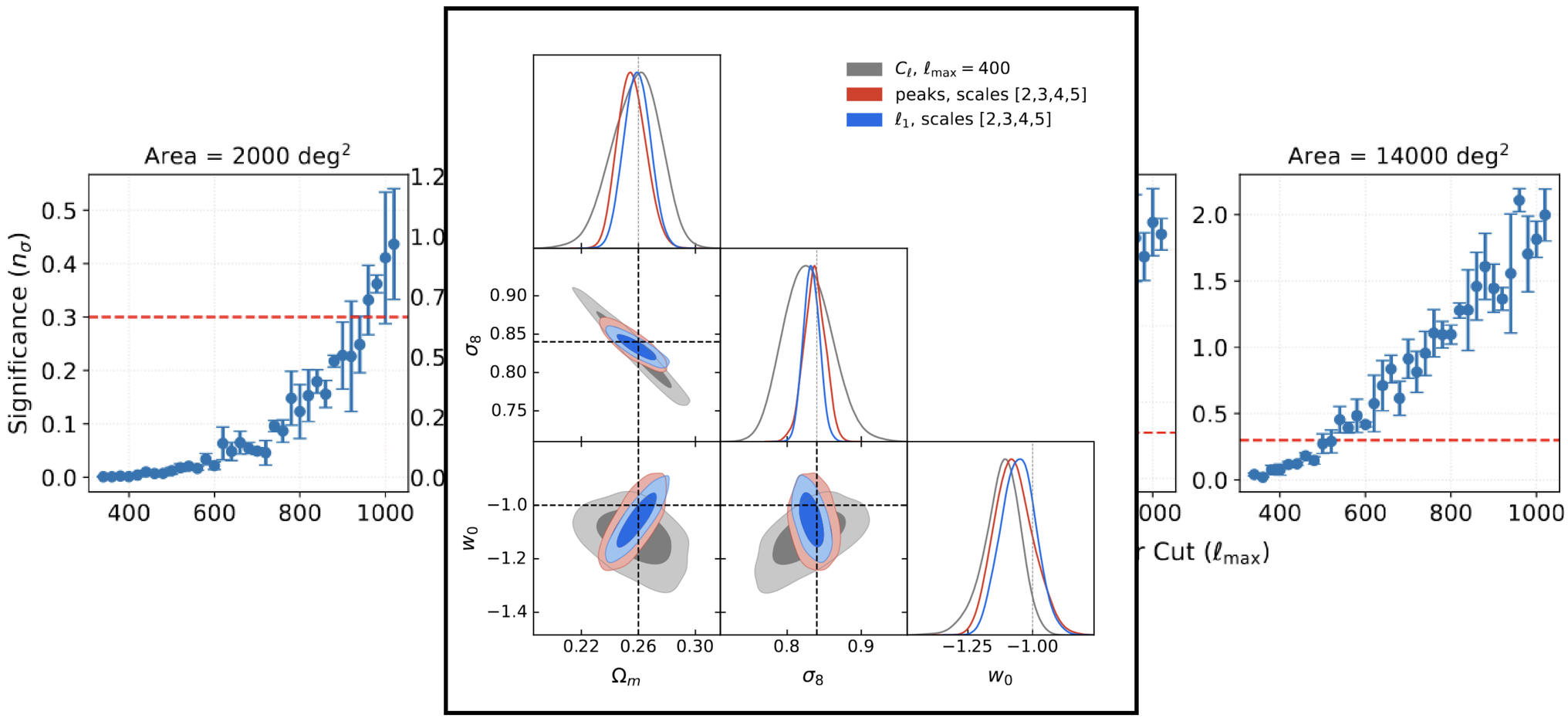
Results

Determining Robust Scale Cuts

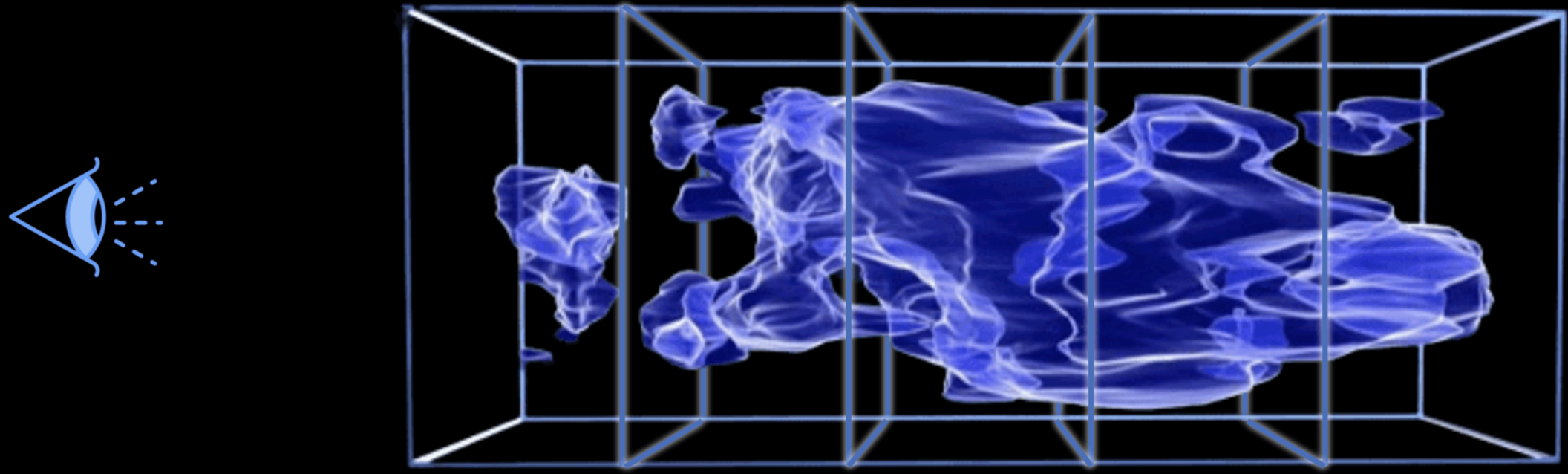


Results

Information Content at Large Scales



Weak lensing tomography



Credit: Justine Zeghal

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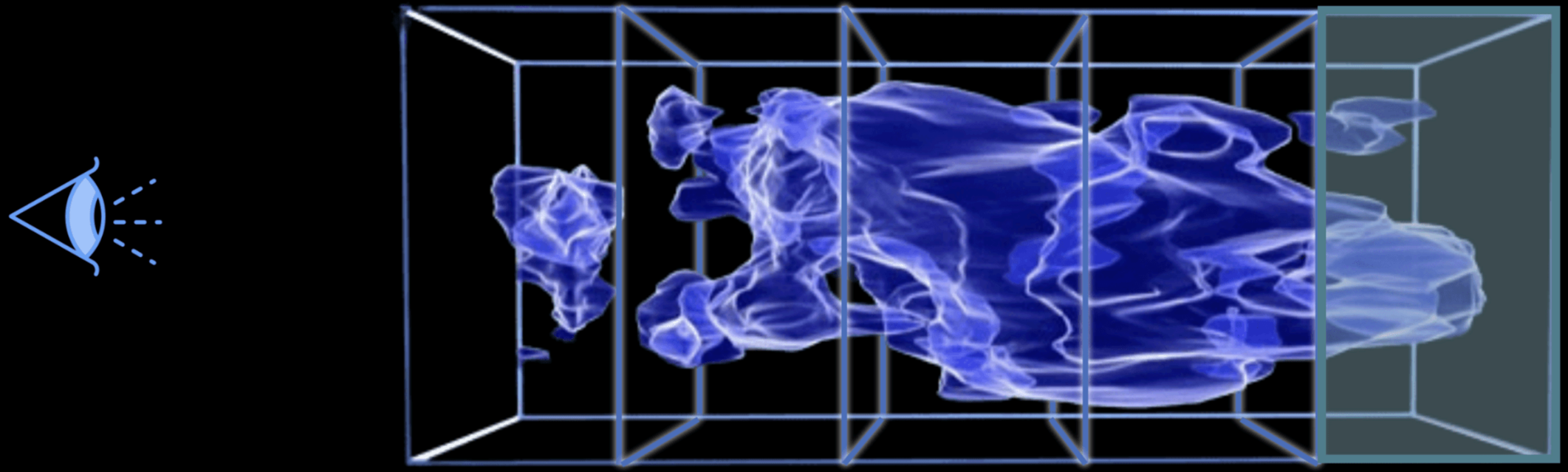

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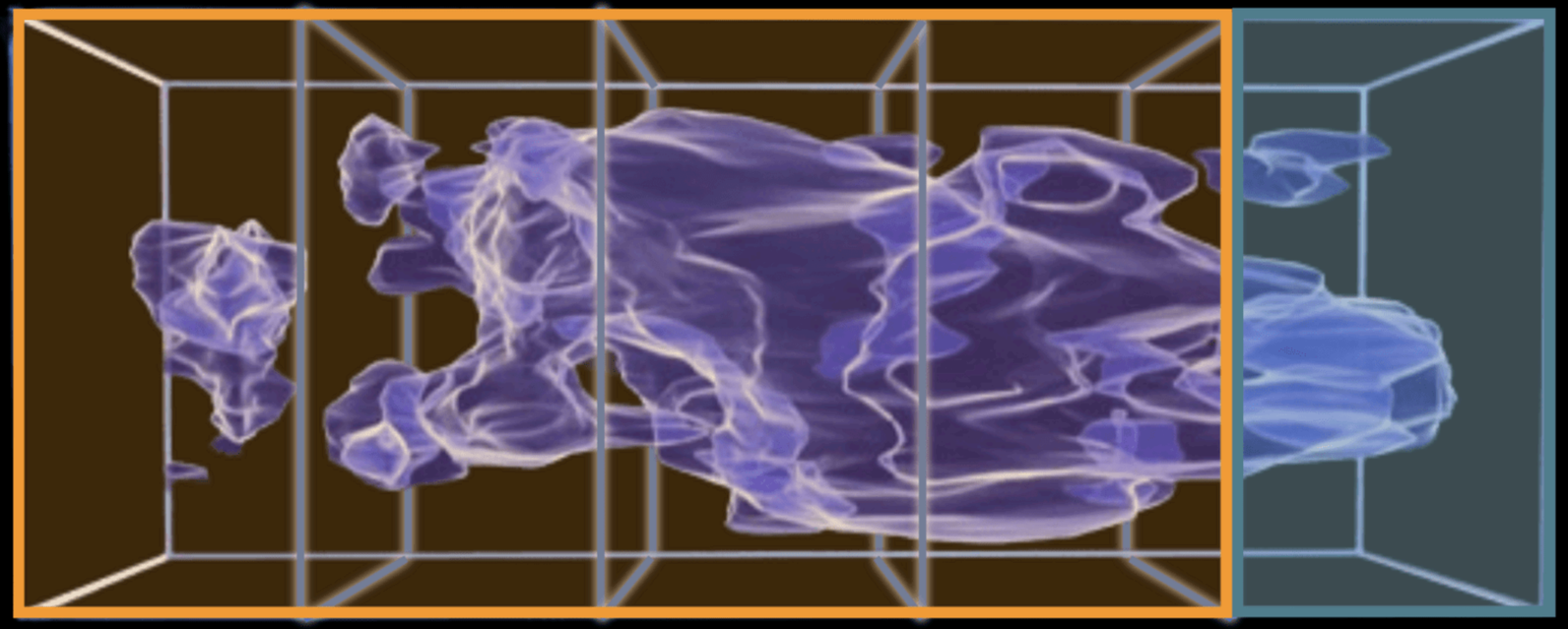

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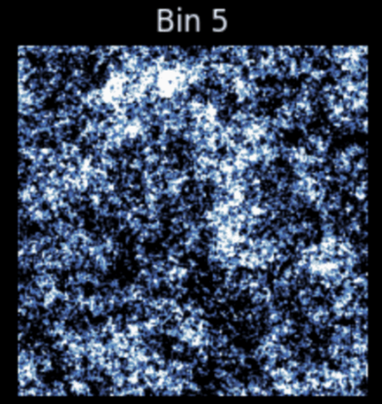

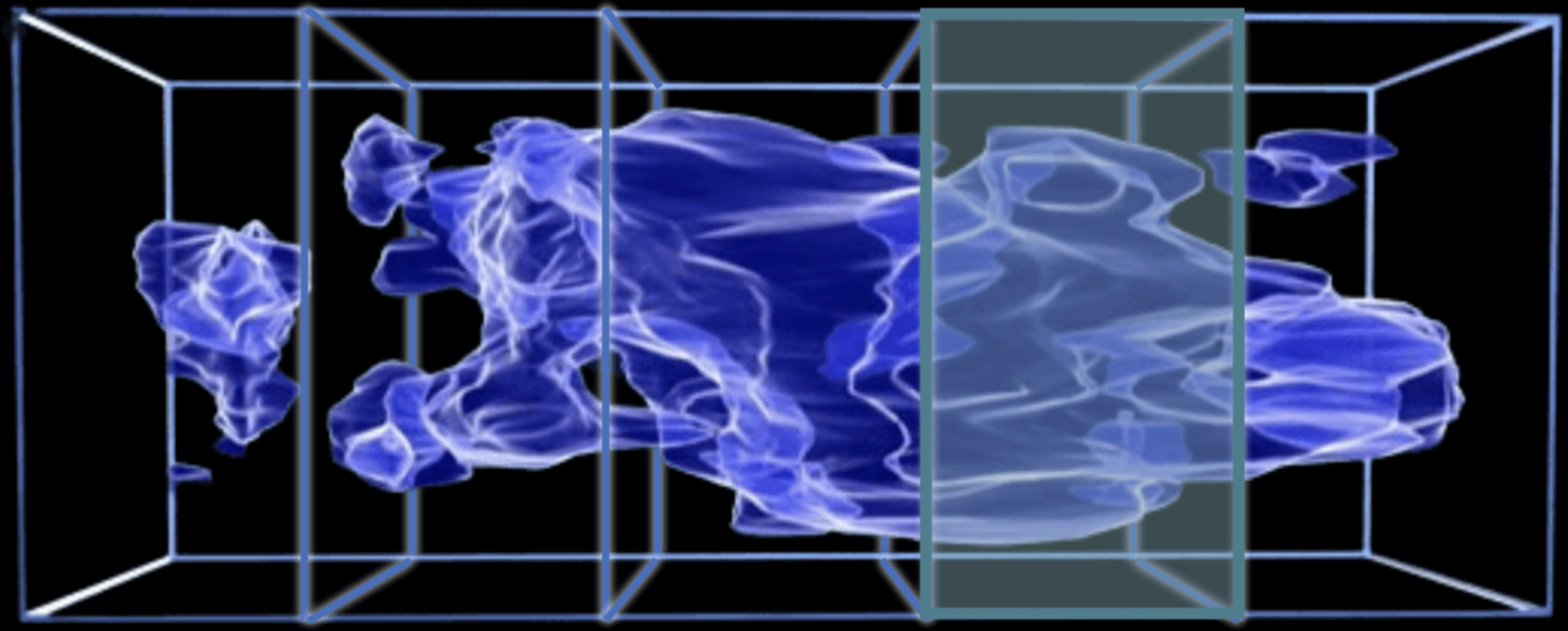

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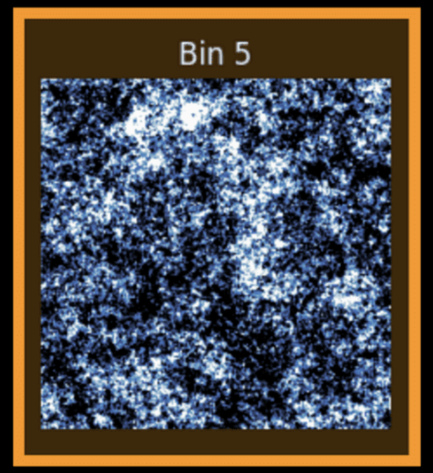

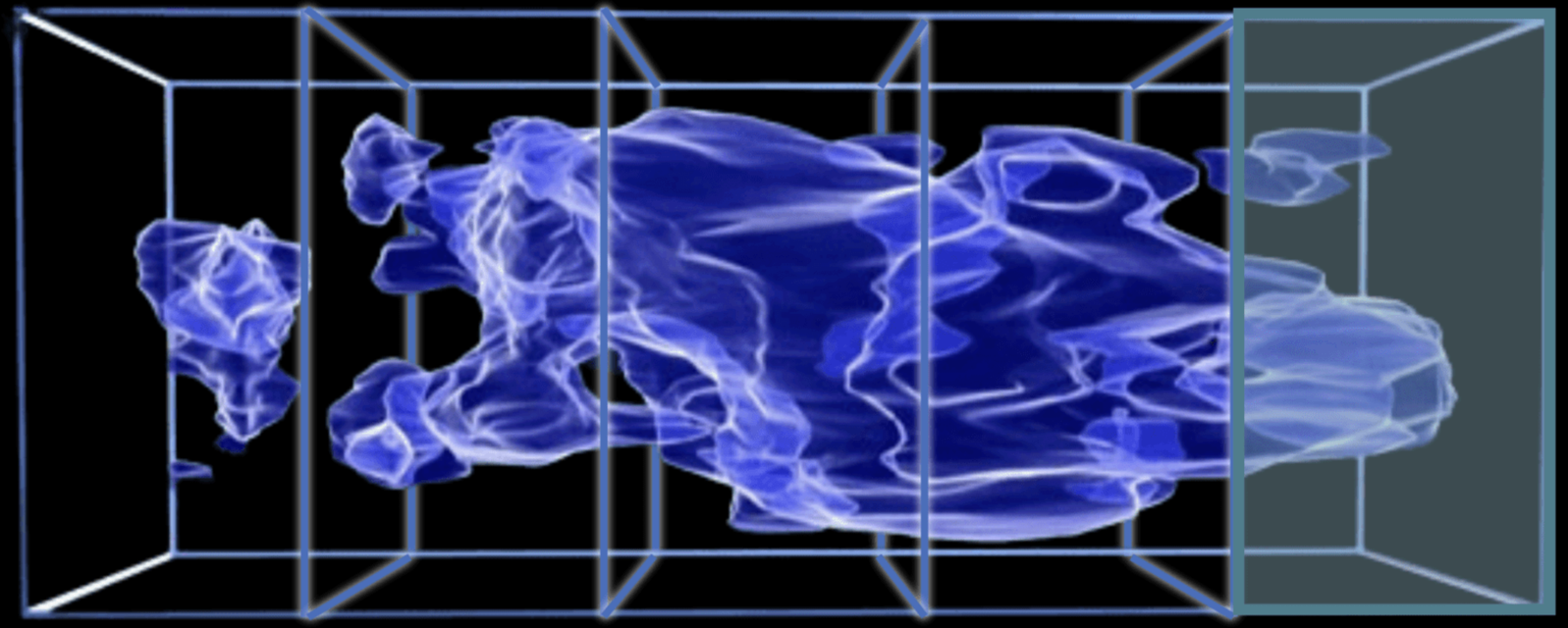

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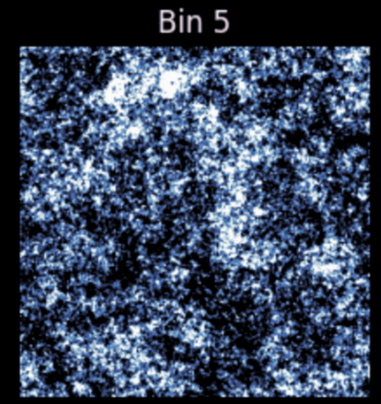

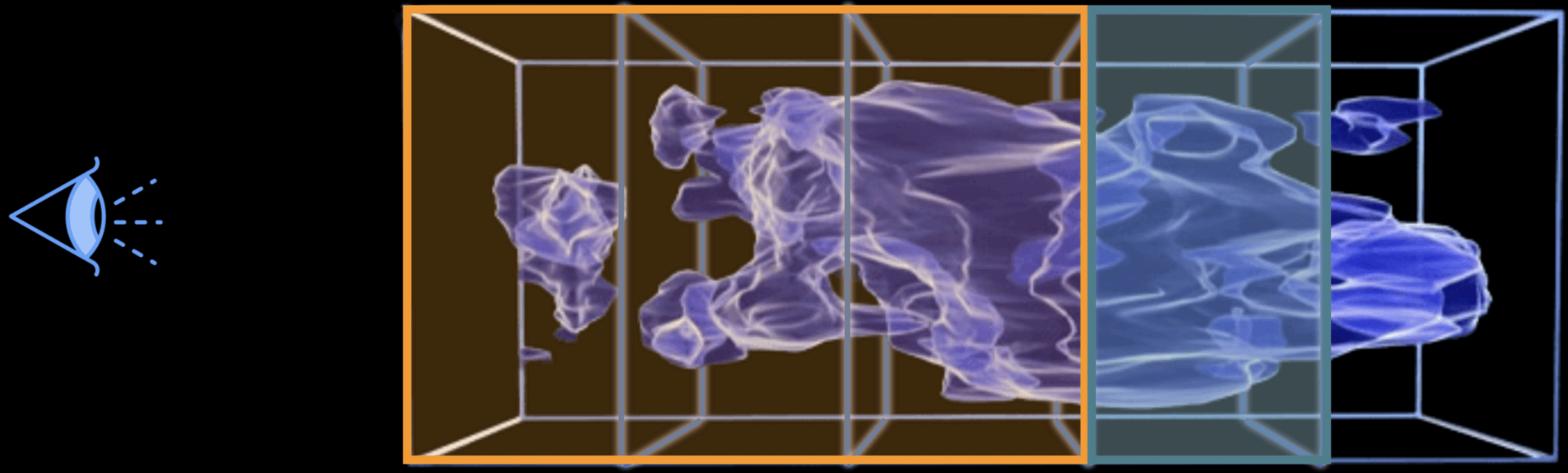

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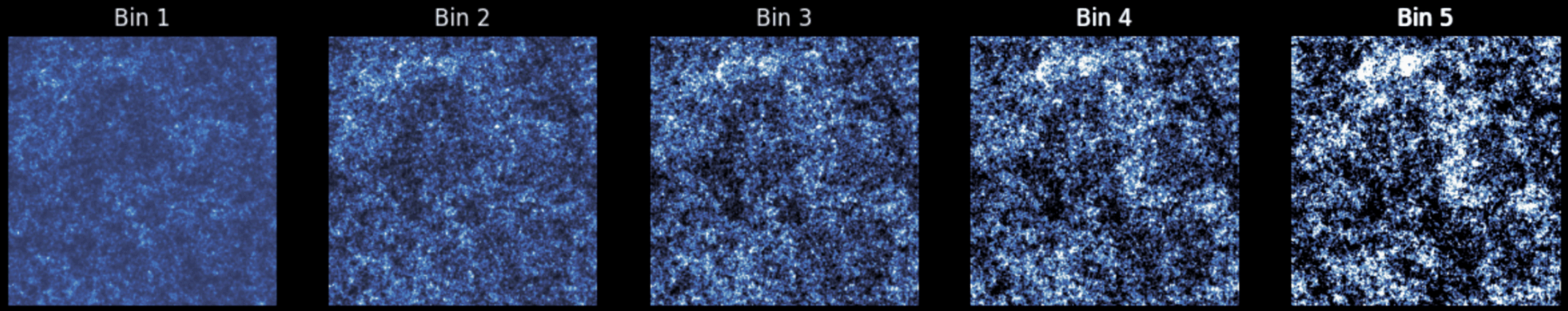

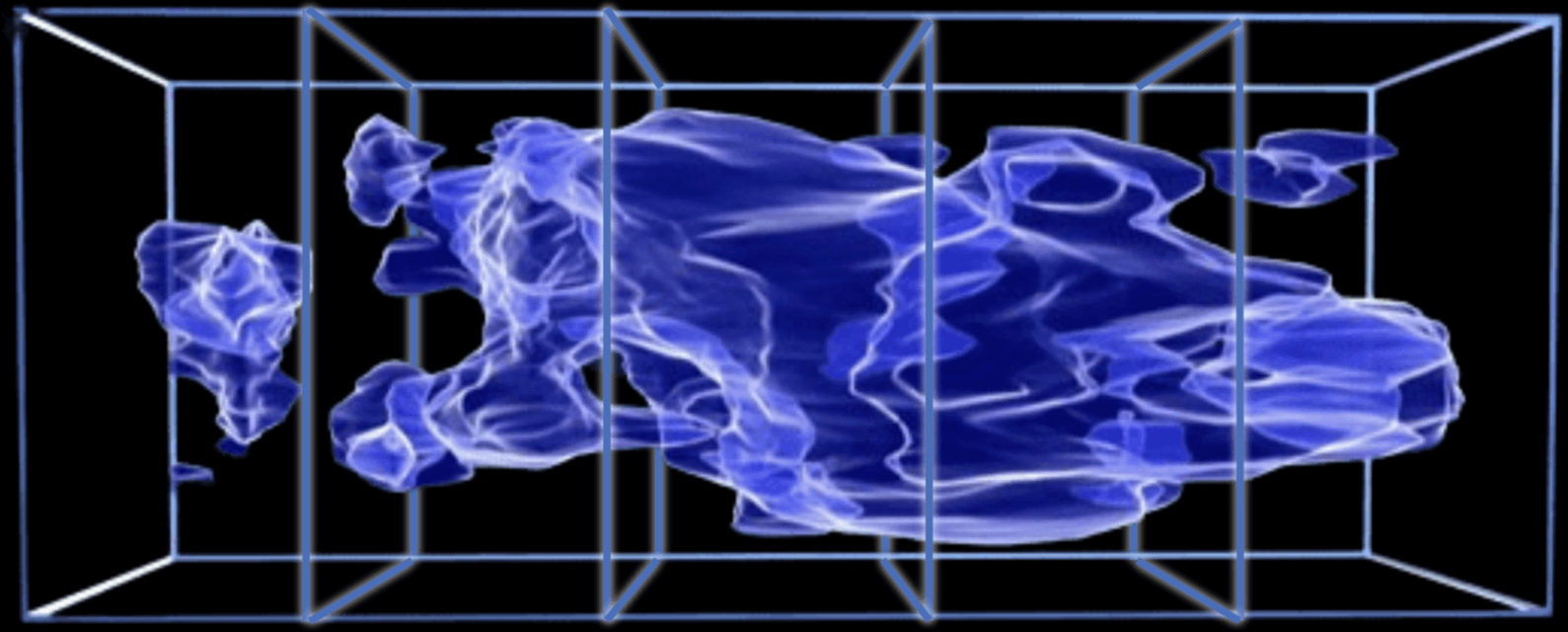

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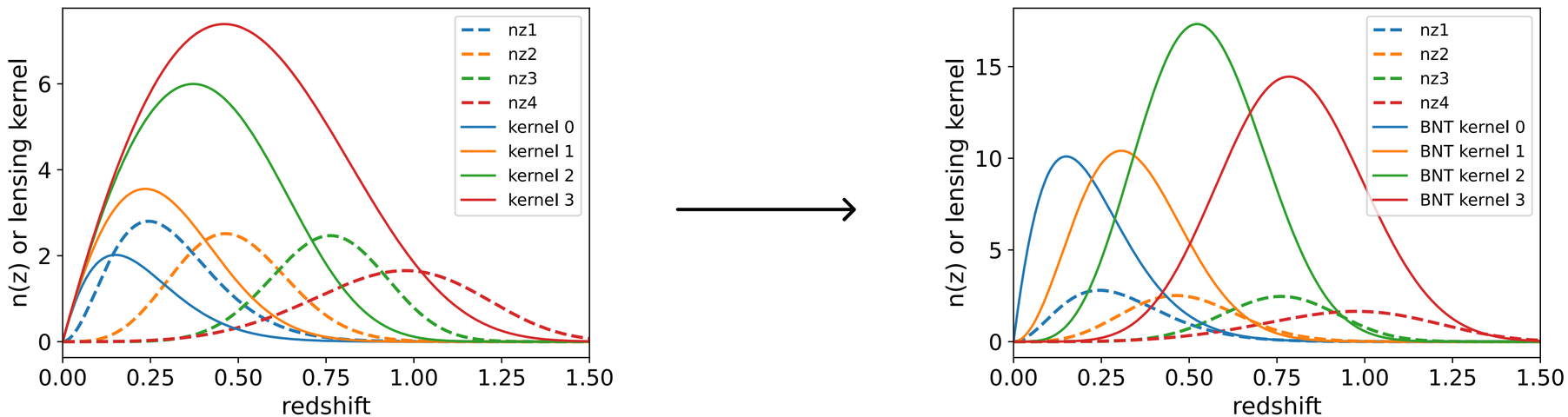
BNT transform

- When we observe shear, contributions come from mass at different redshifts.
- **BNT Transform**: method to "null" contributions from unwanted redshift ranges.
- It reorganizes weak-lensing data so that only specific redshift ranges contribute to the signal.
- BNT aligns angular (ℓ) and physical (k) scales.
- This could help mitigate baryonic effects by optimally removing sensitivity to poorly modeled small scales and controlling scale leakage.



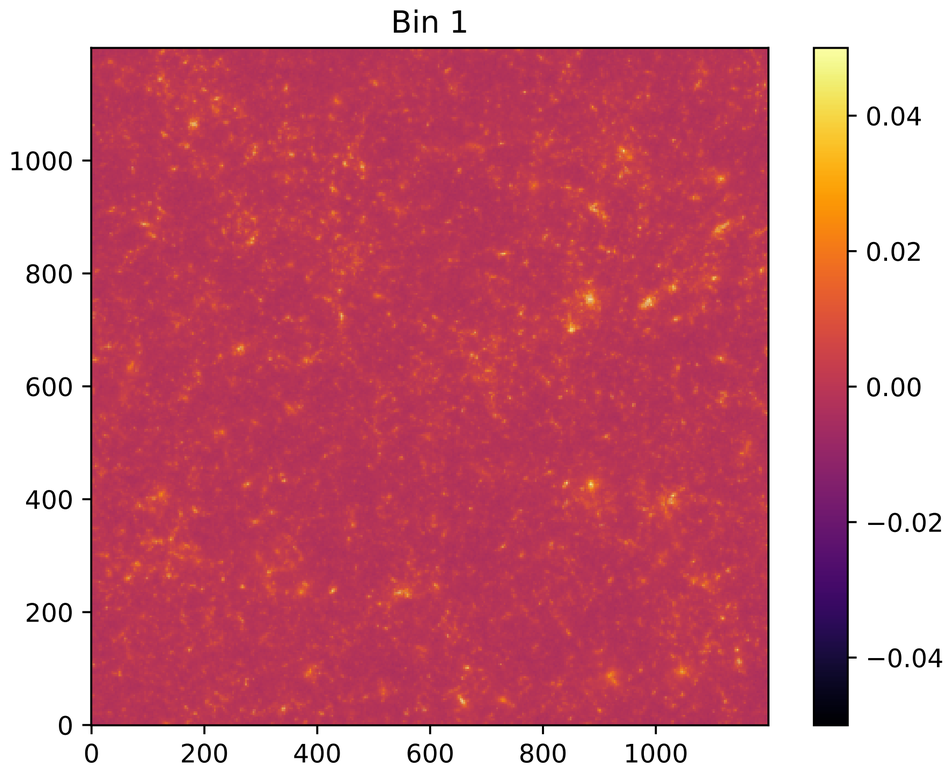
BNT maps

no BNT

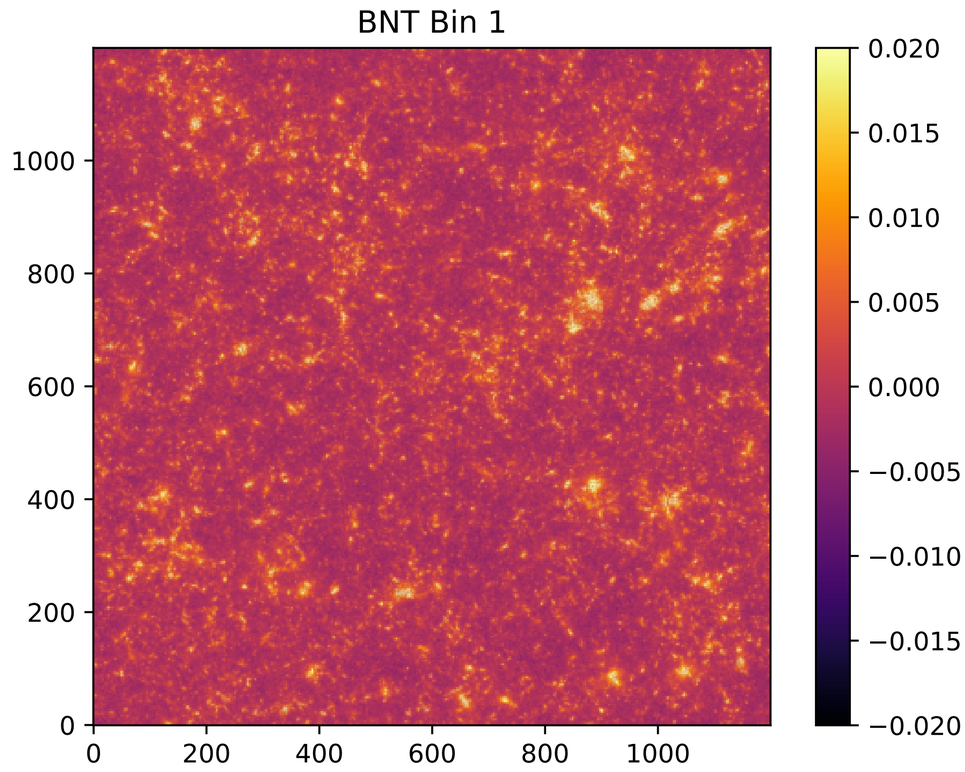
BNT

BNT maps

no BNT

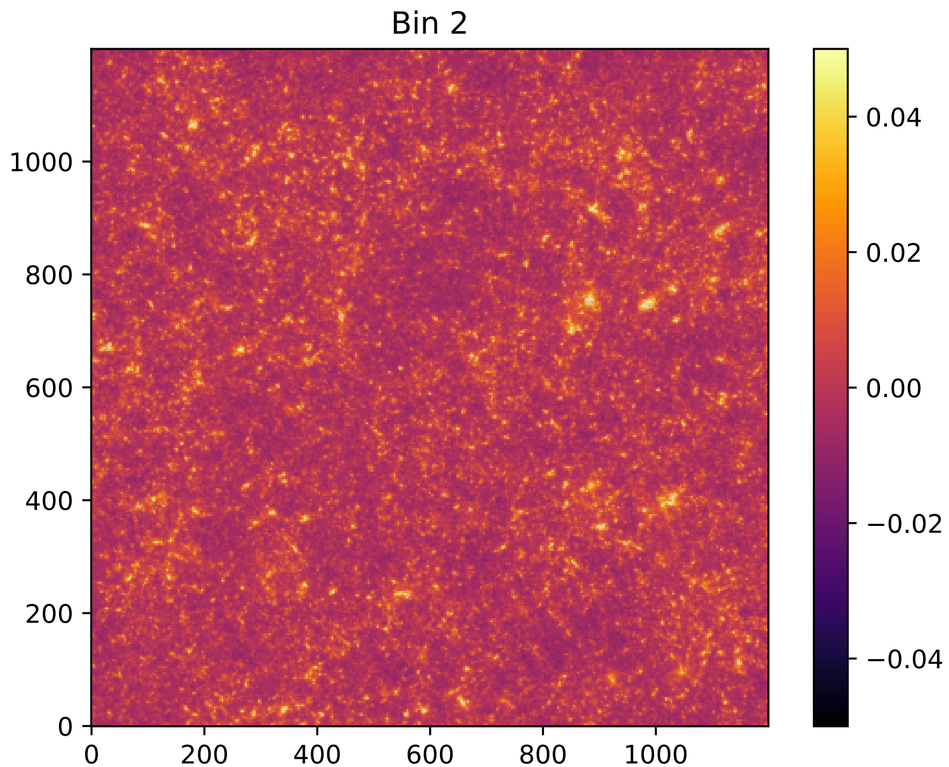


BNT



BNT maps

no BNT



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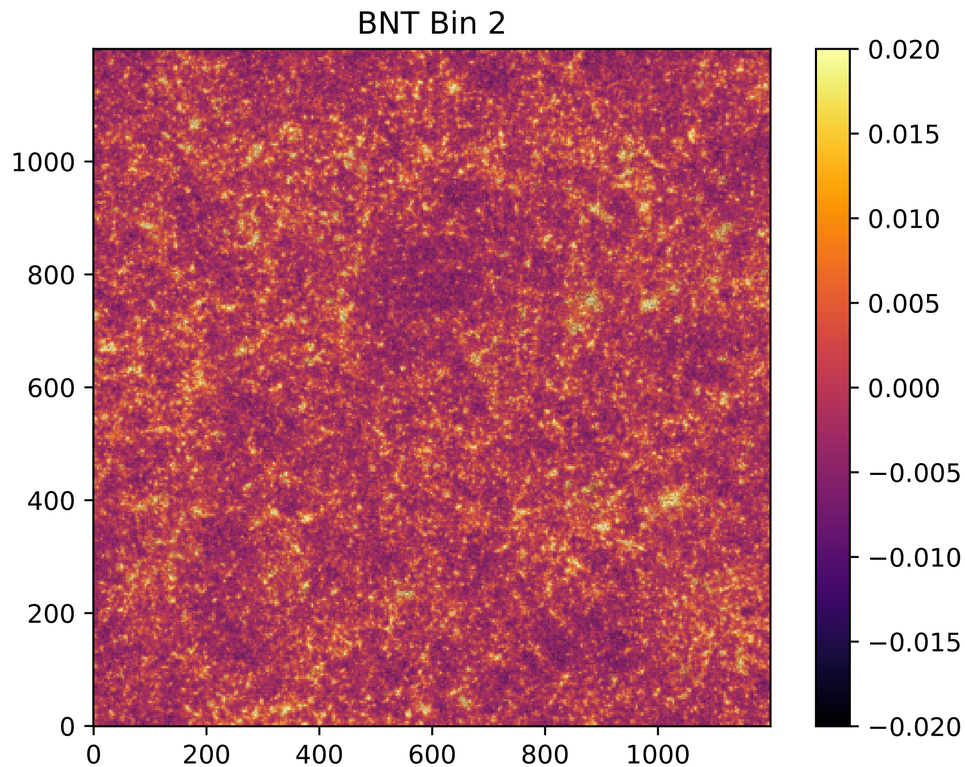

BNT maps

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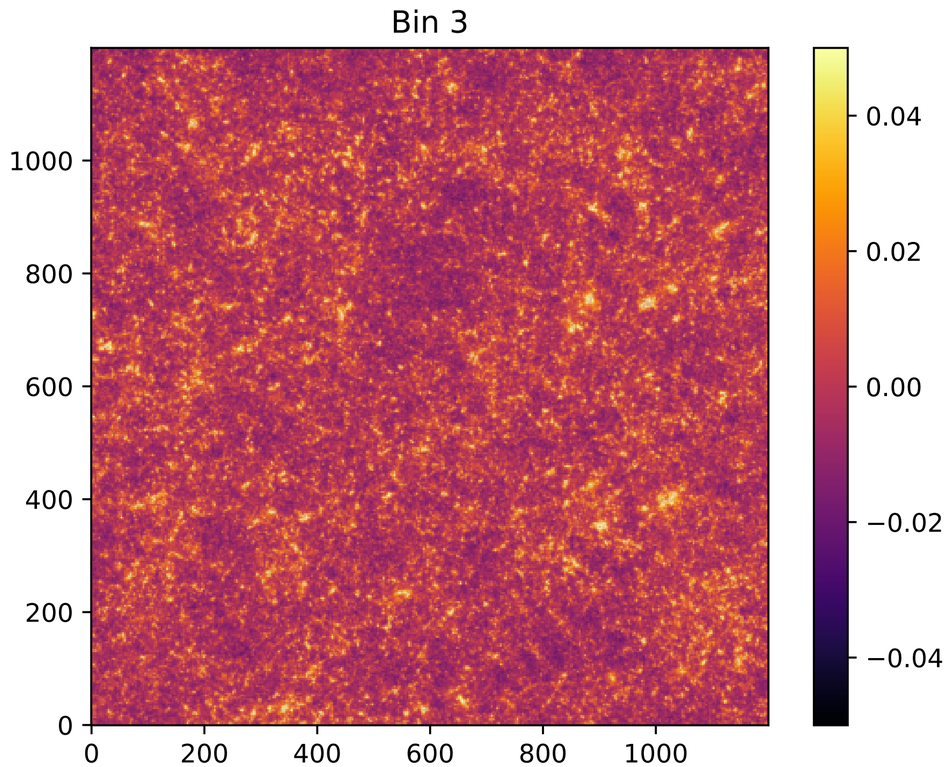
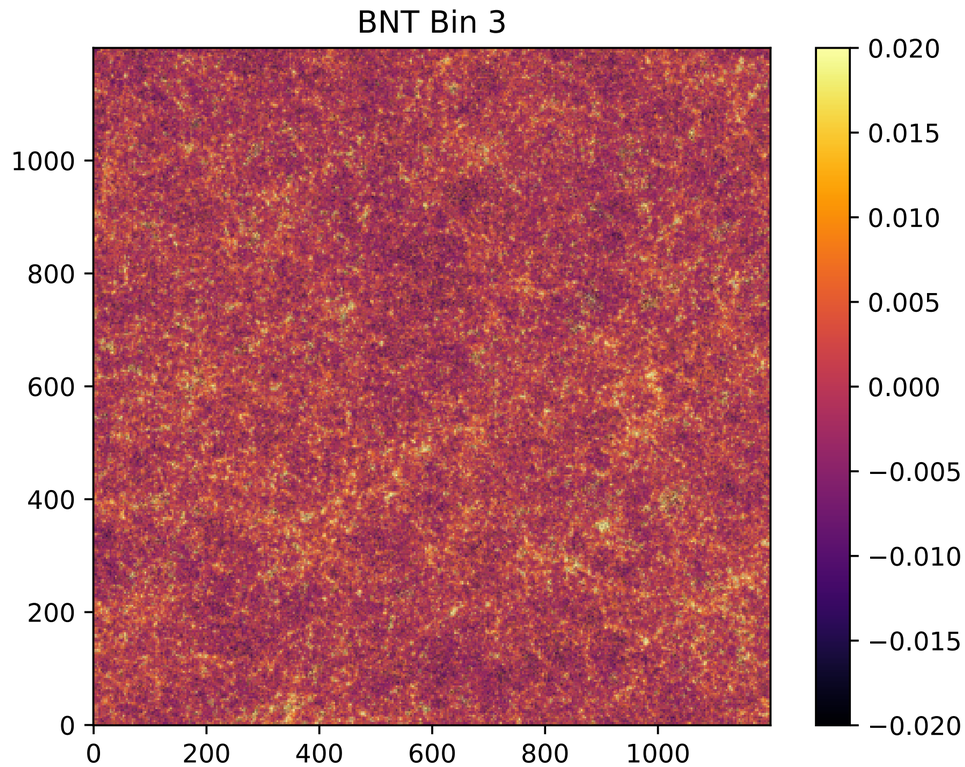
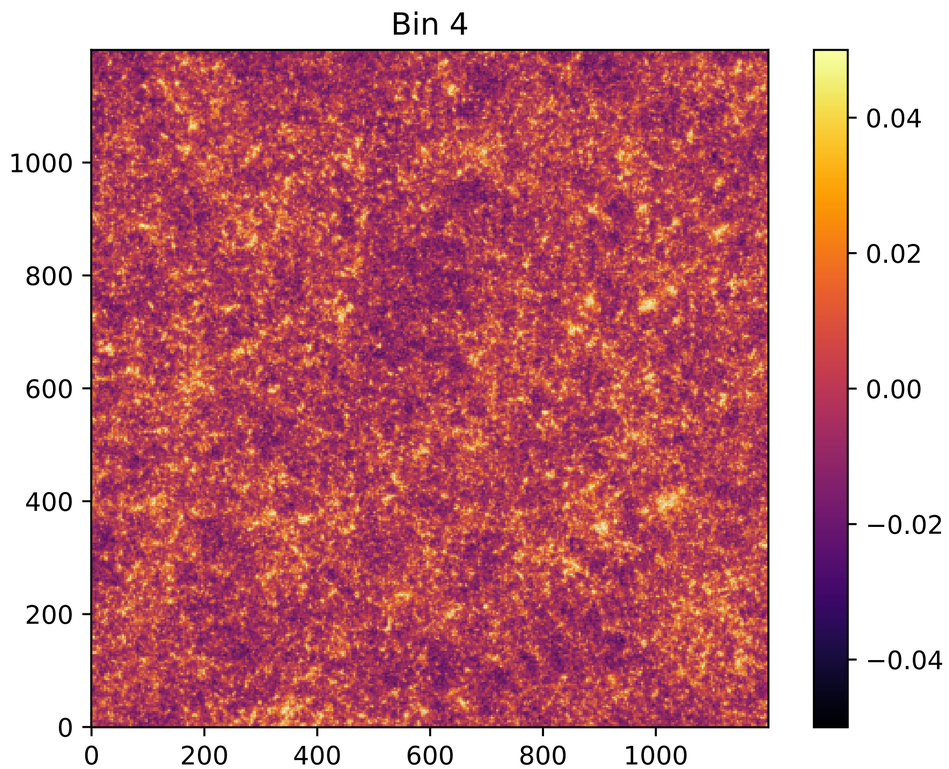


BNT

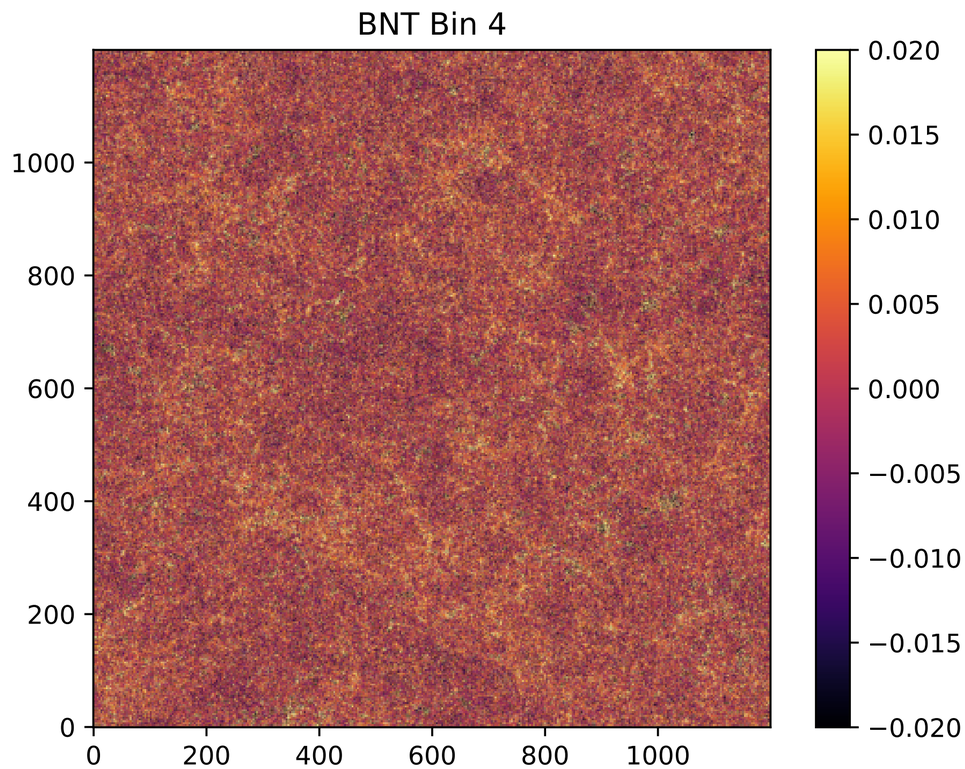


BNT maps

no BNT

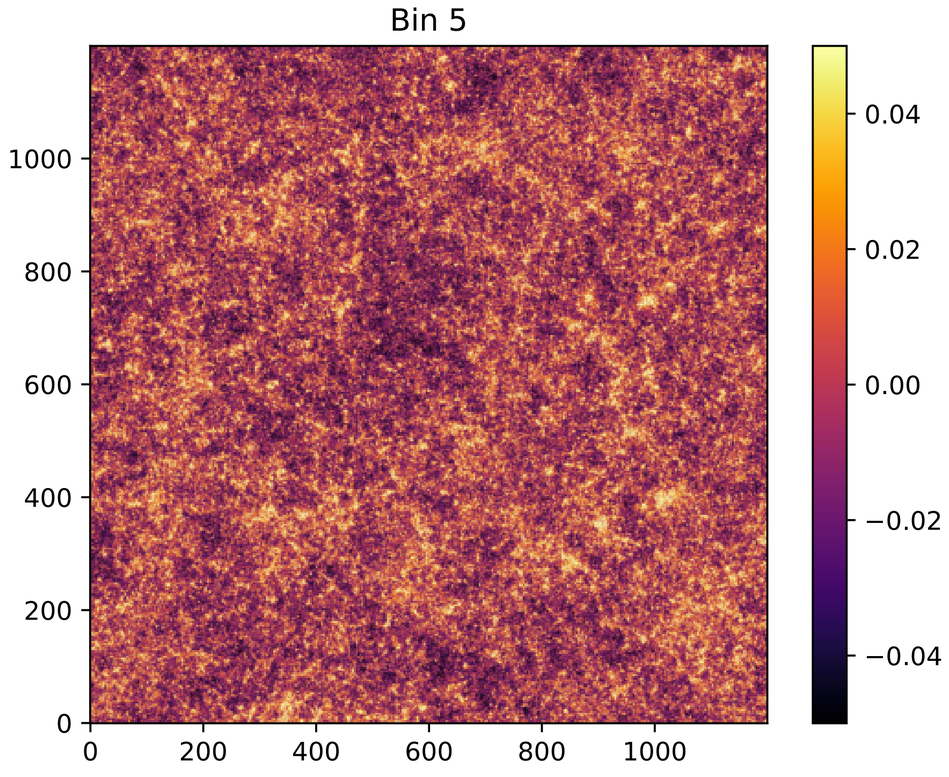


BNT

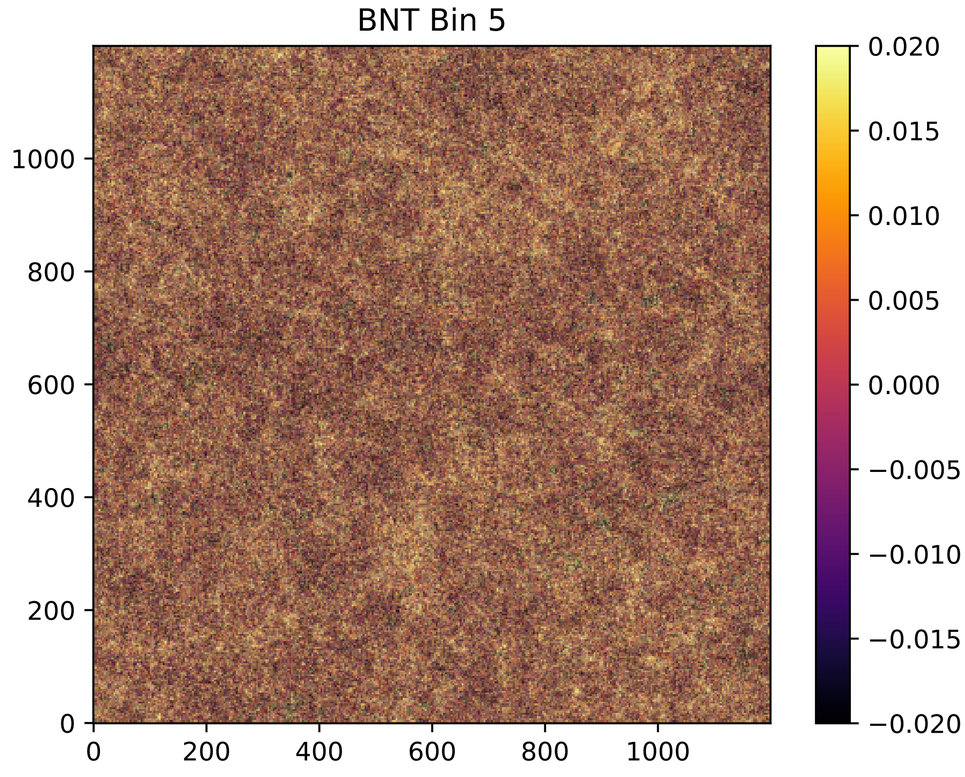


BNT maps

no BNT



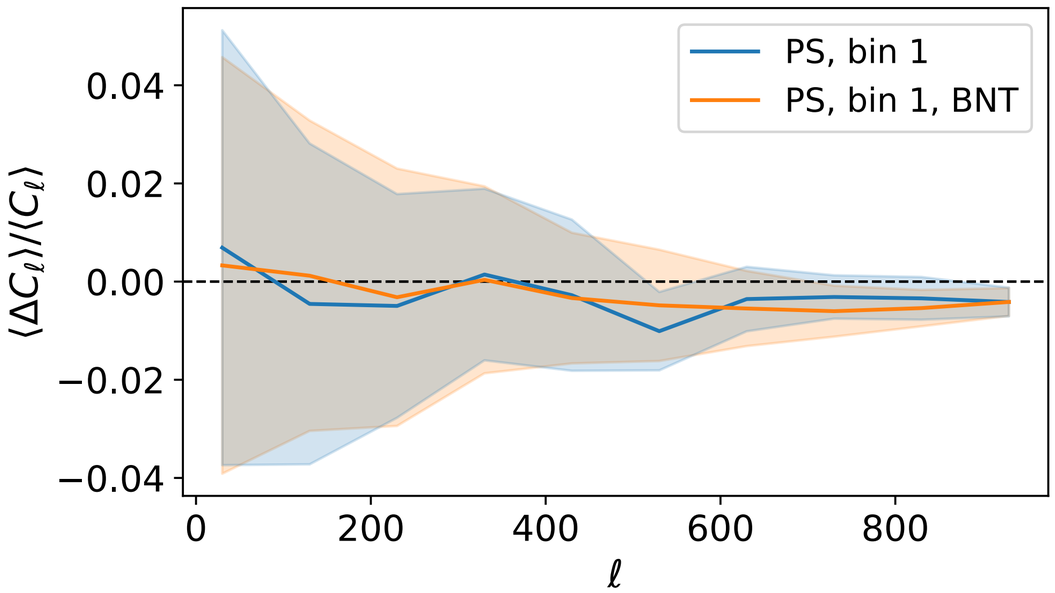
BNT



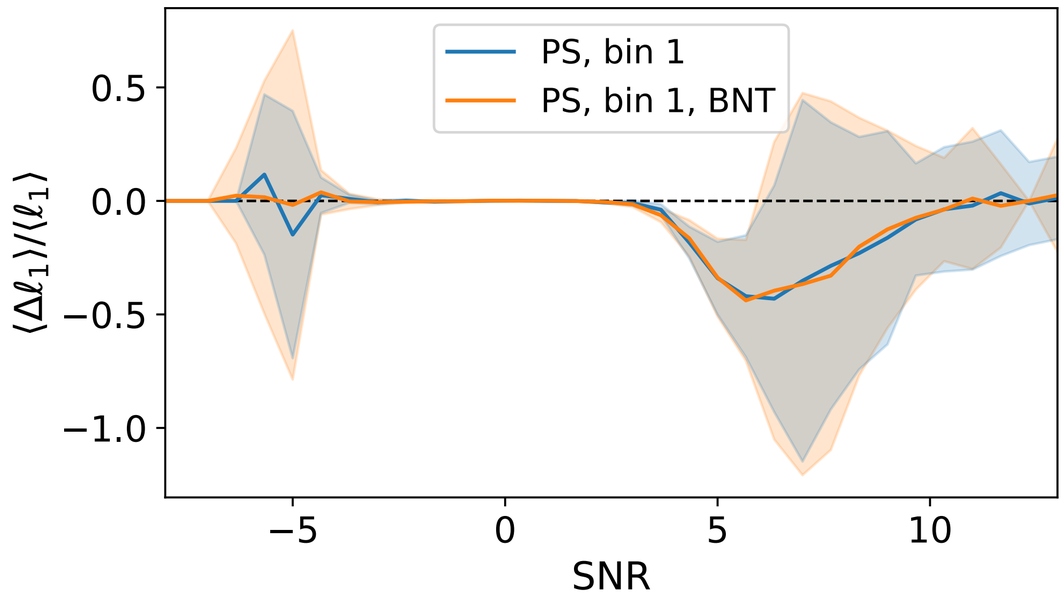
How are statistics impacted?

How are statistics impacted?

Power Spectrum

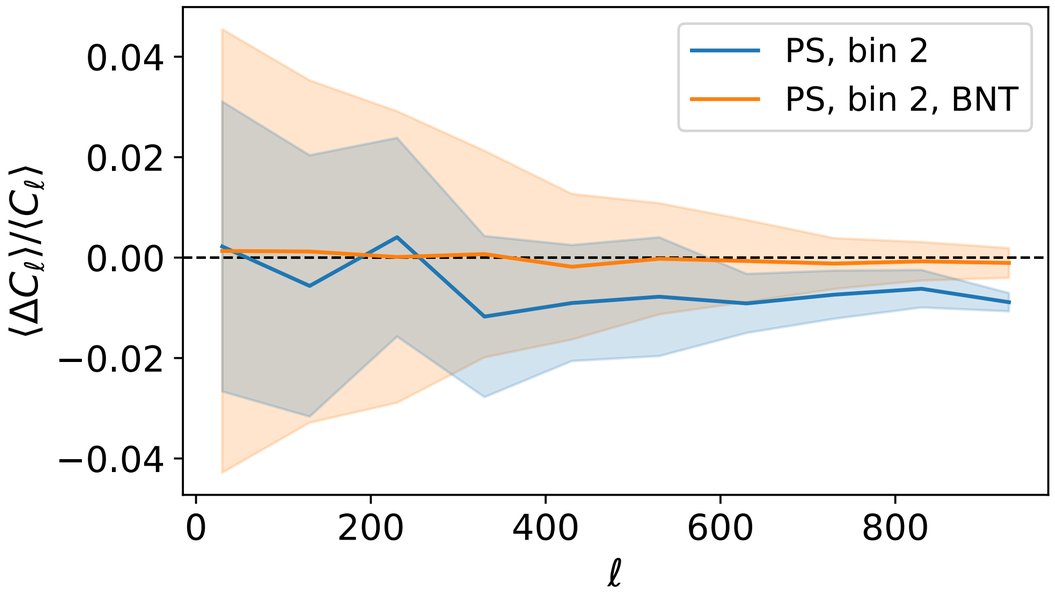


l1-norm



How are statistics impacted?

Power Spectrum



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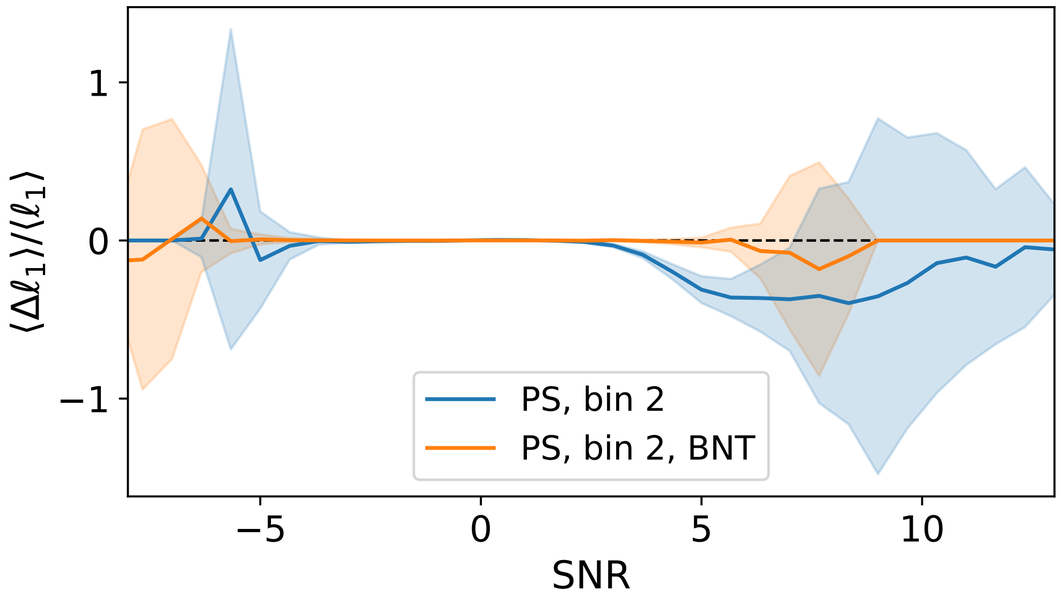
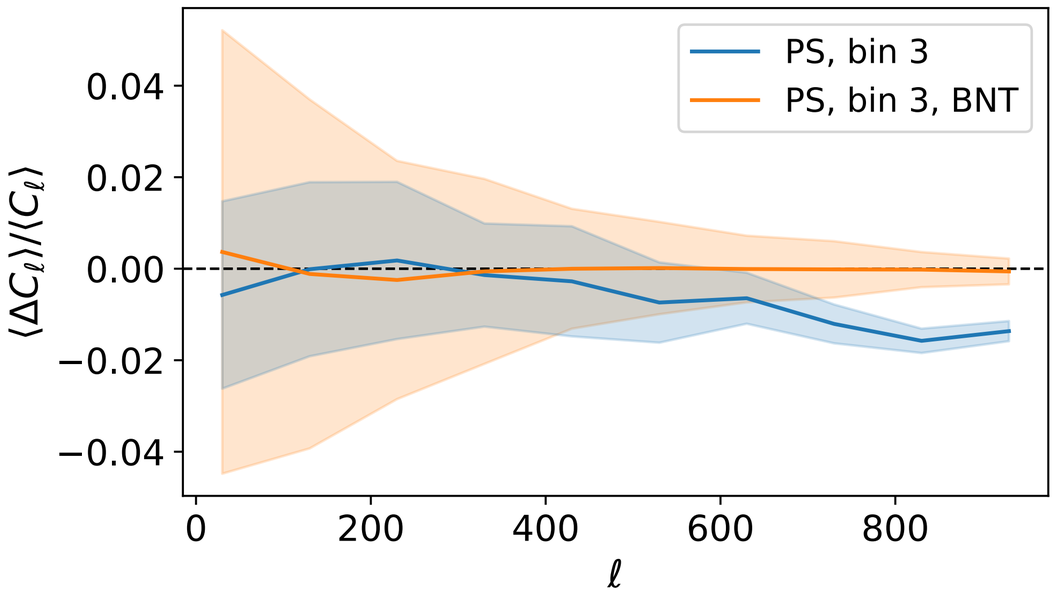


How are statistics impacted?

Power Spectrum



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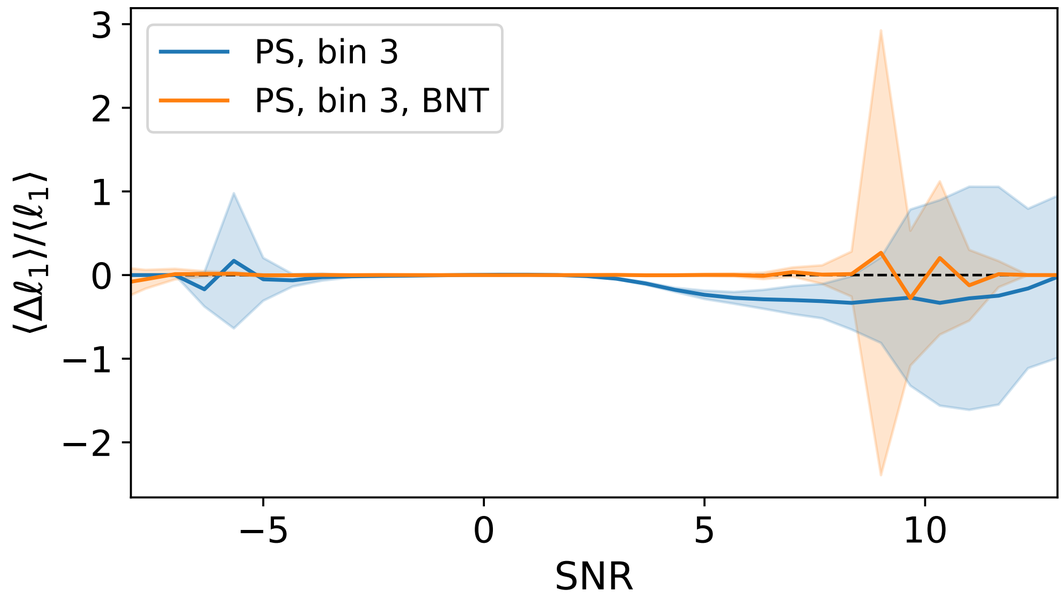
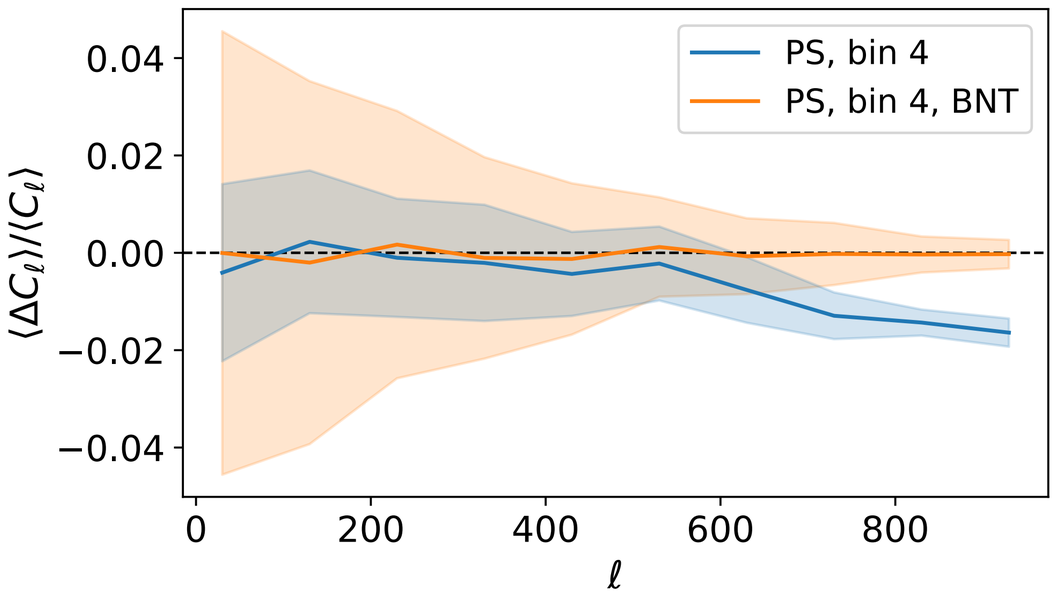


How are statistics impacted?

Power Spectrum



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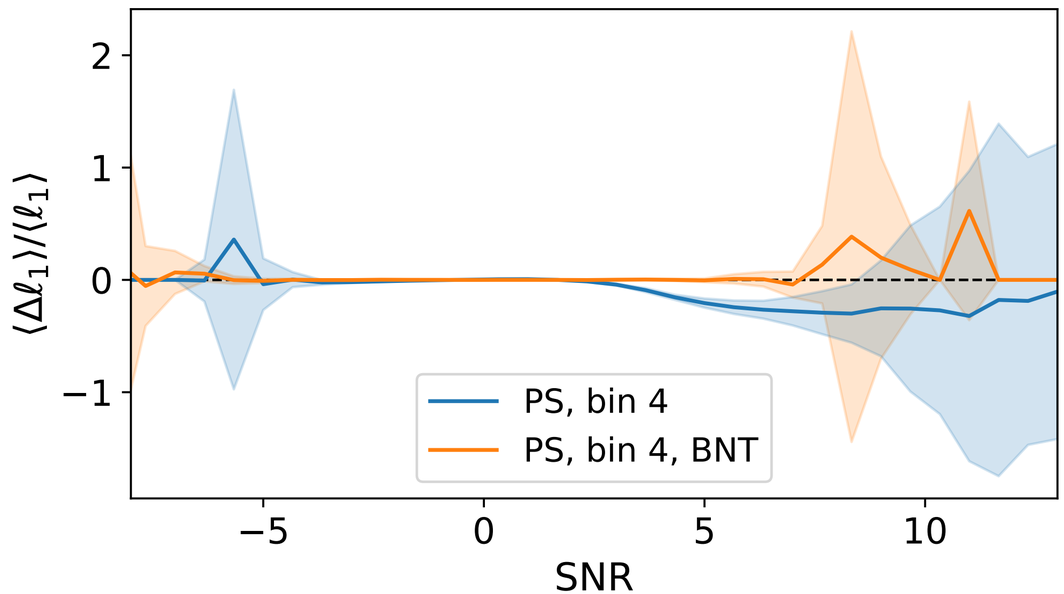
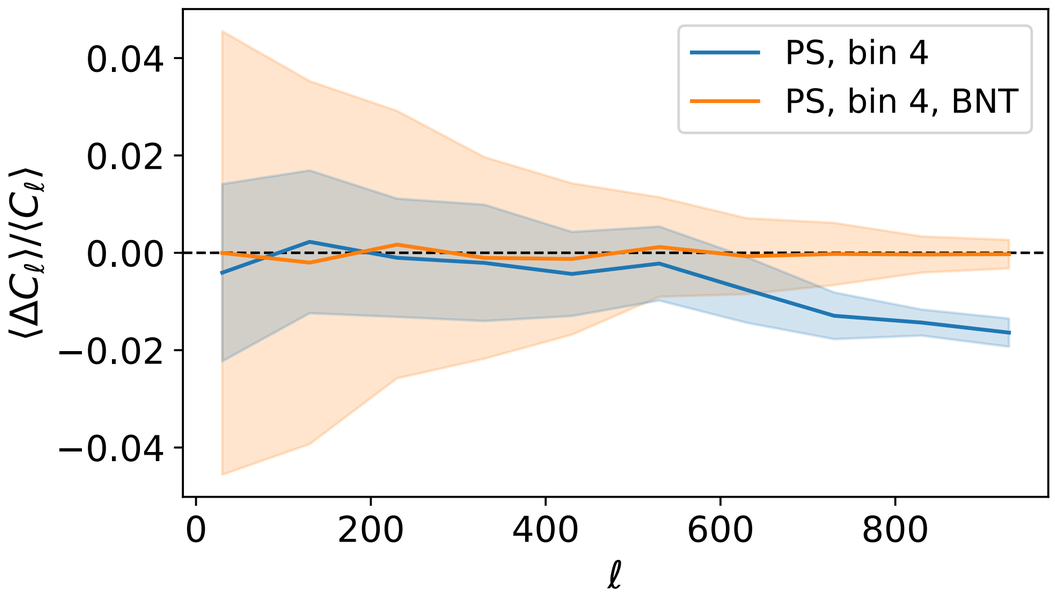


How are statistics impacted?

Power Spectrum



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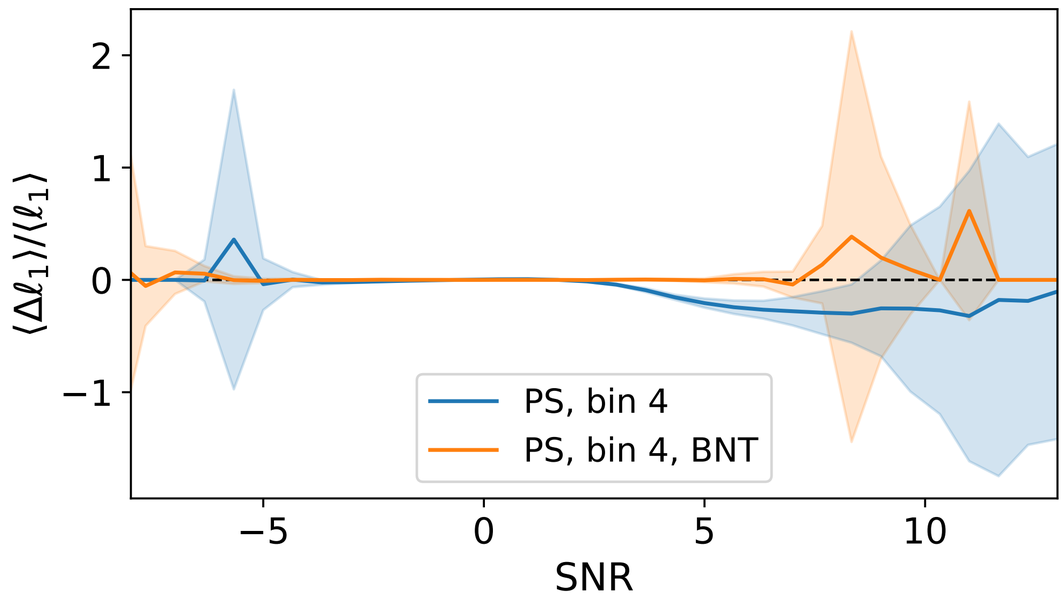
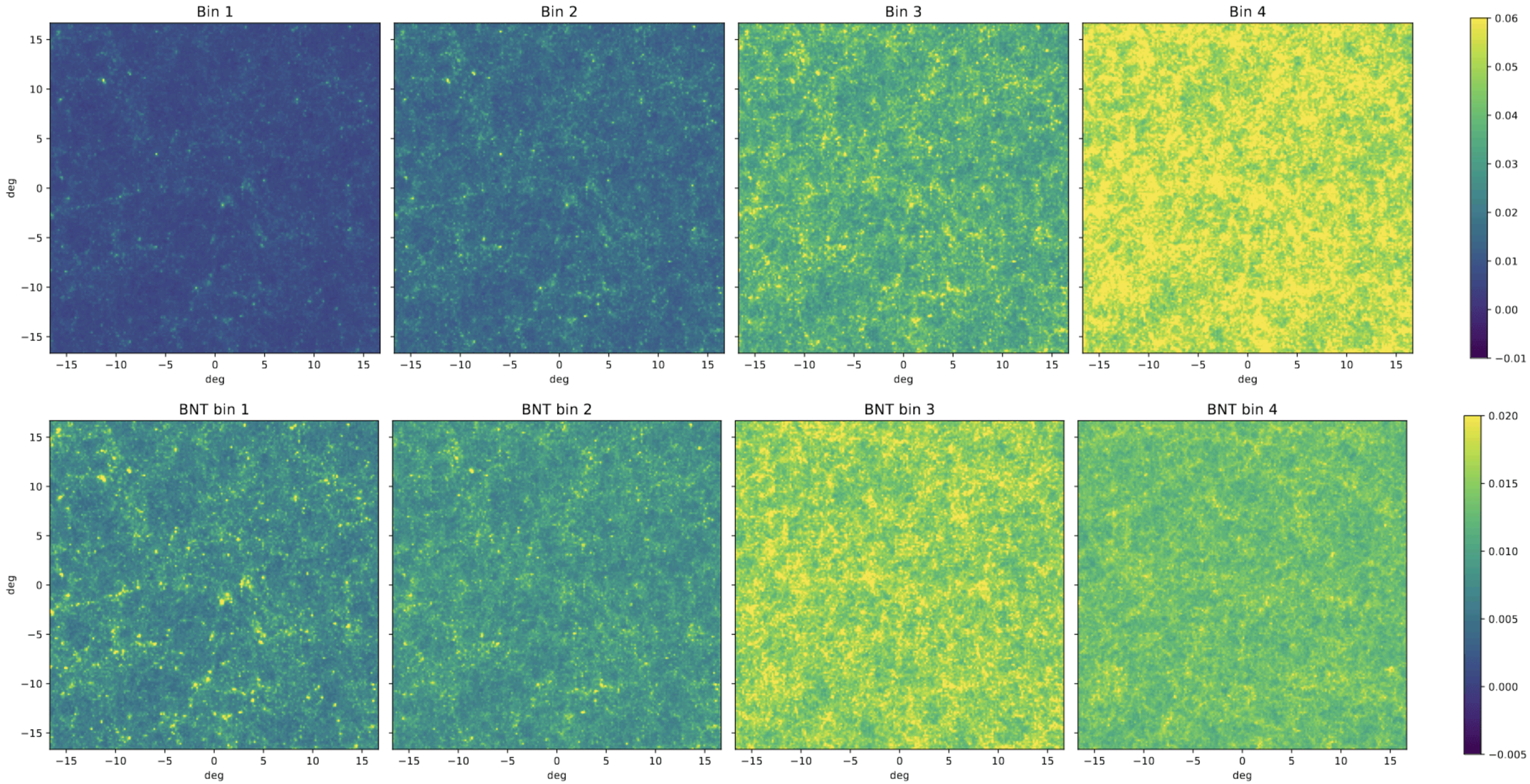
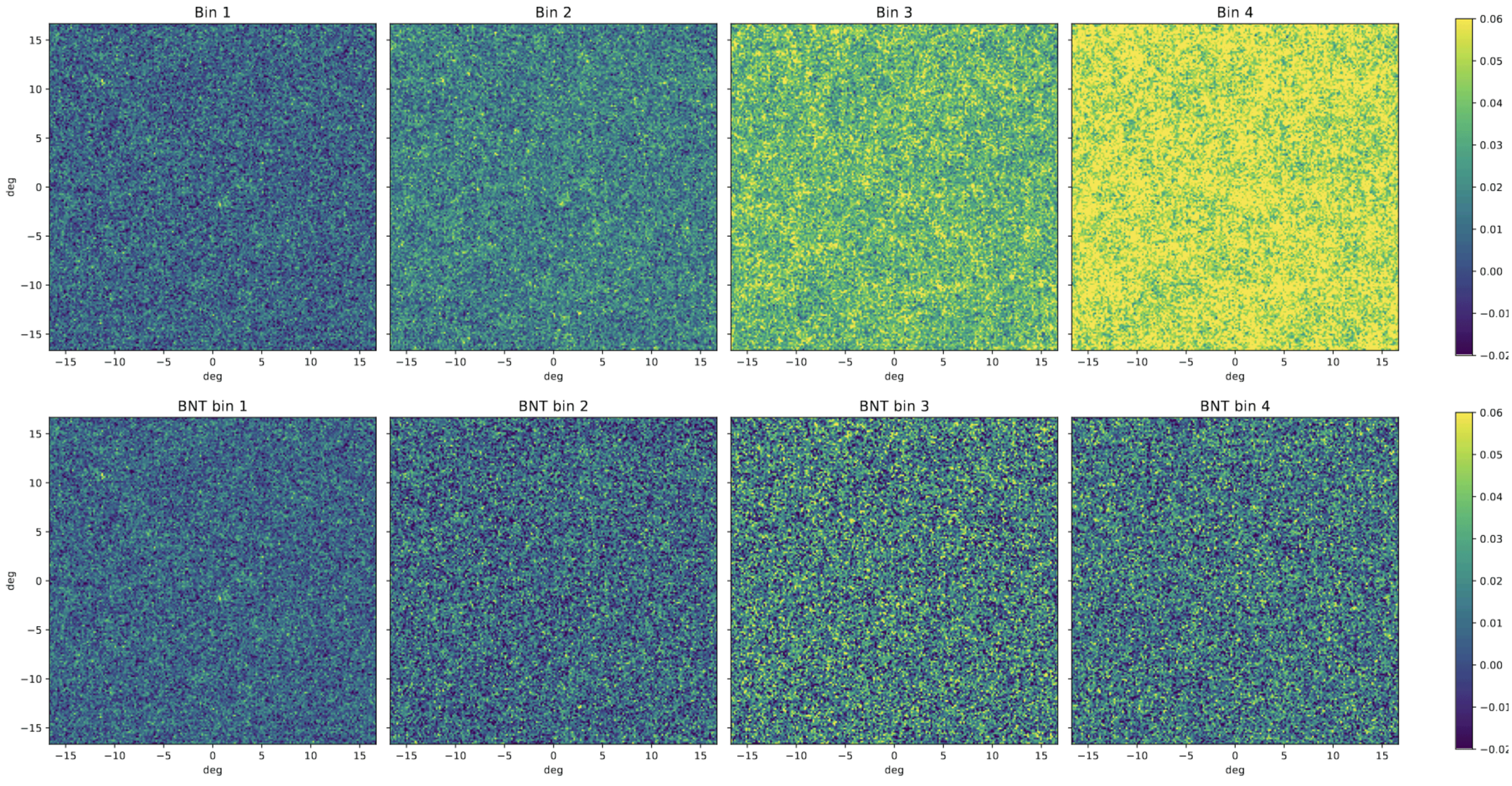


** This could help mitigate baryonic effects by optimally removing sensitivity to poorly modeled small scales and controlling scale leakage?*

Take a look at the maps again..

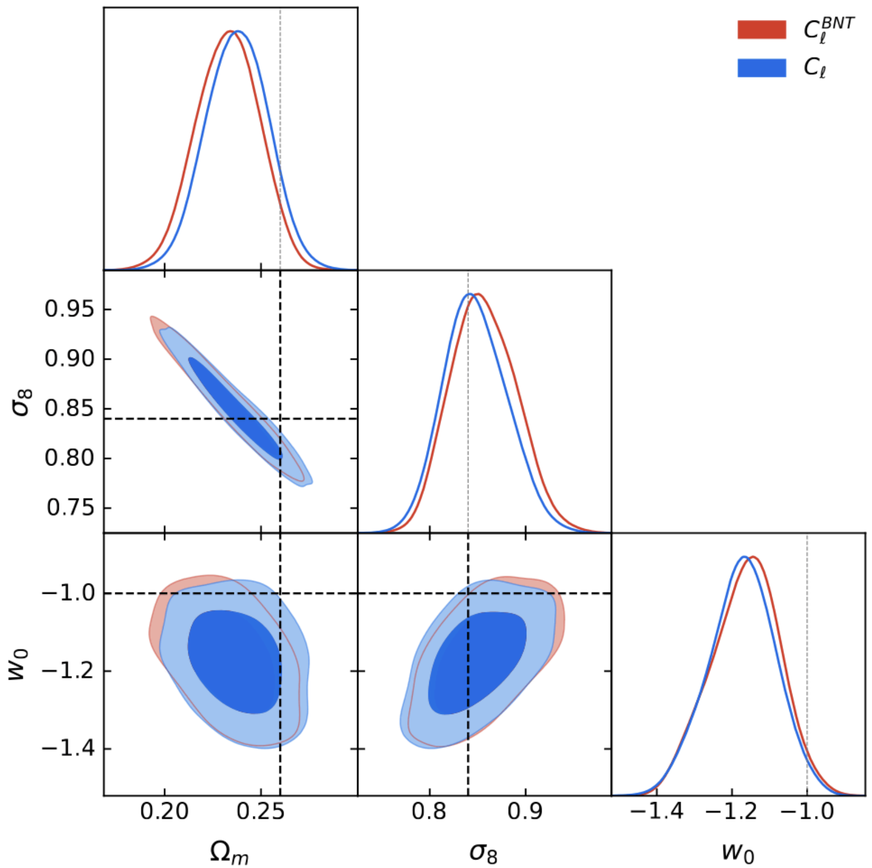


Take a look at the maps again..

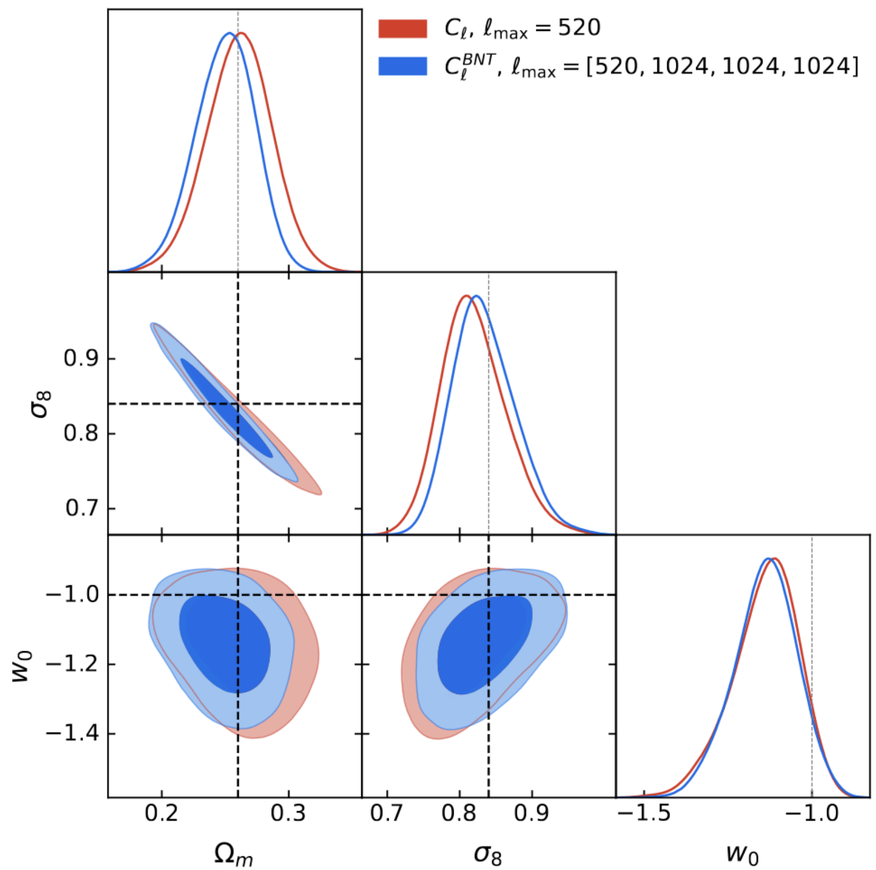


BNT vs Standard contours

PS without scale cuts

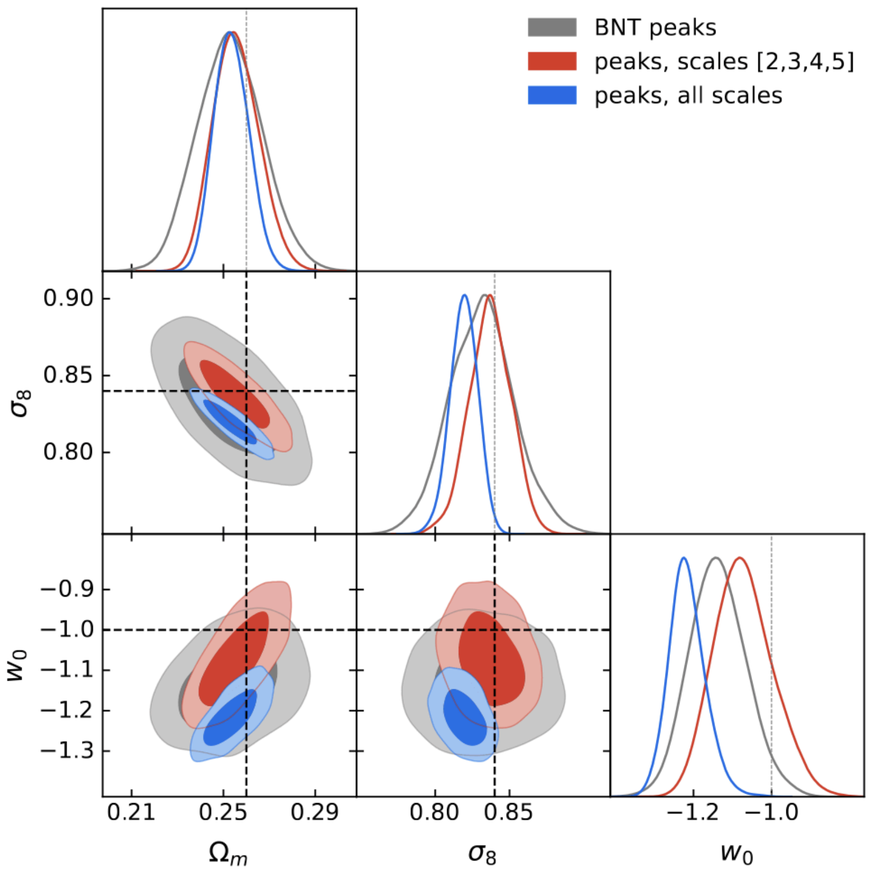


PS with scale cuts



BNT vs Standard contours

Peaks



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