

Source clustering impact on weak lensing high-order statistics

17.06.2026 / The Non-Gaussian Universe

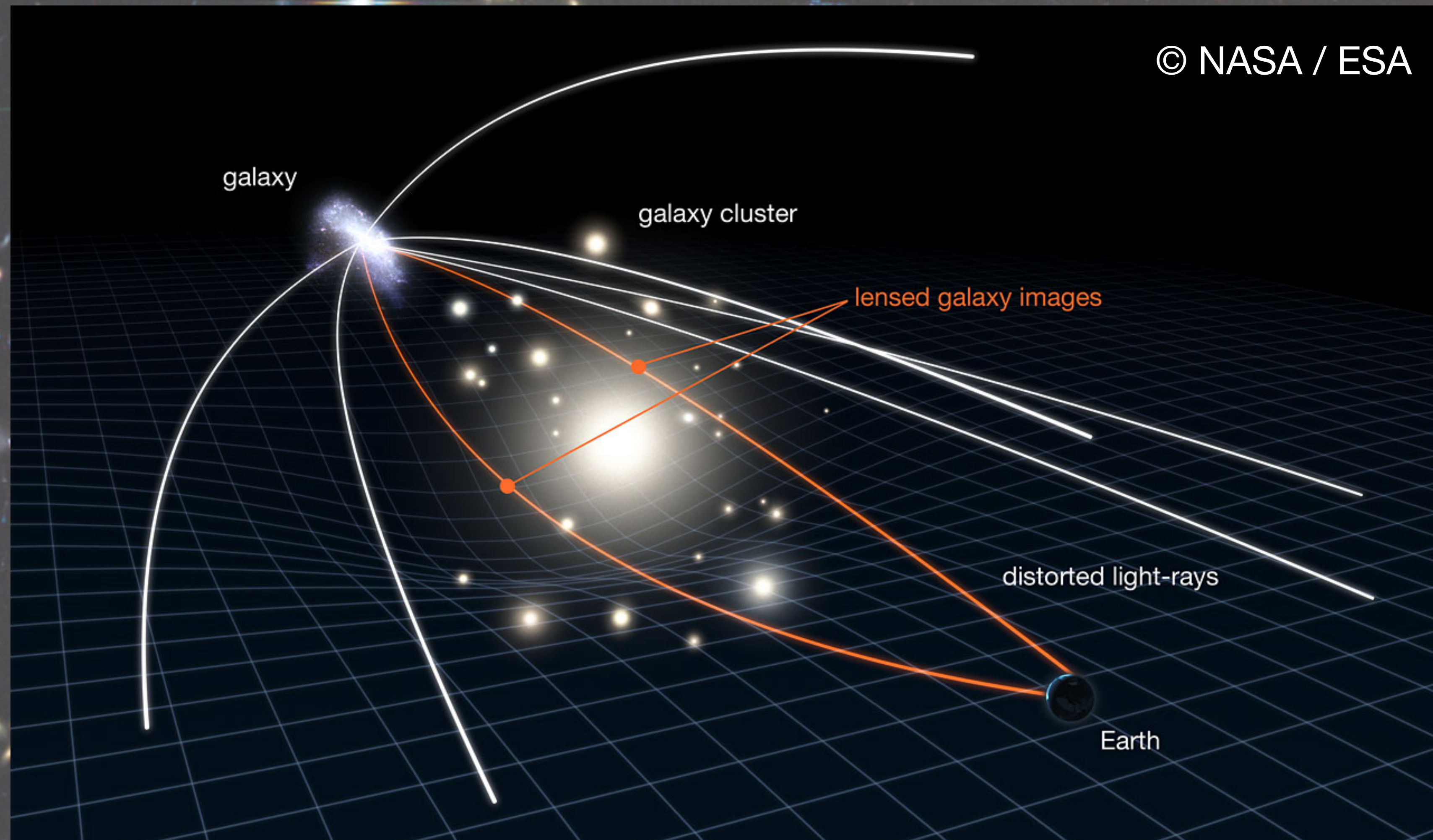
Seung-gyu Hwang / Natalia Porqueres, Jean-Luc Starck



Weak gravitational lensing

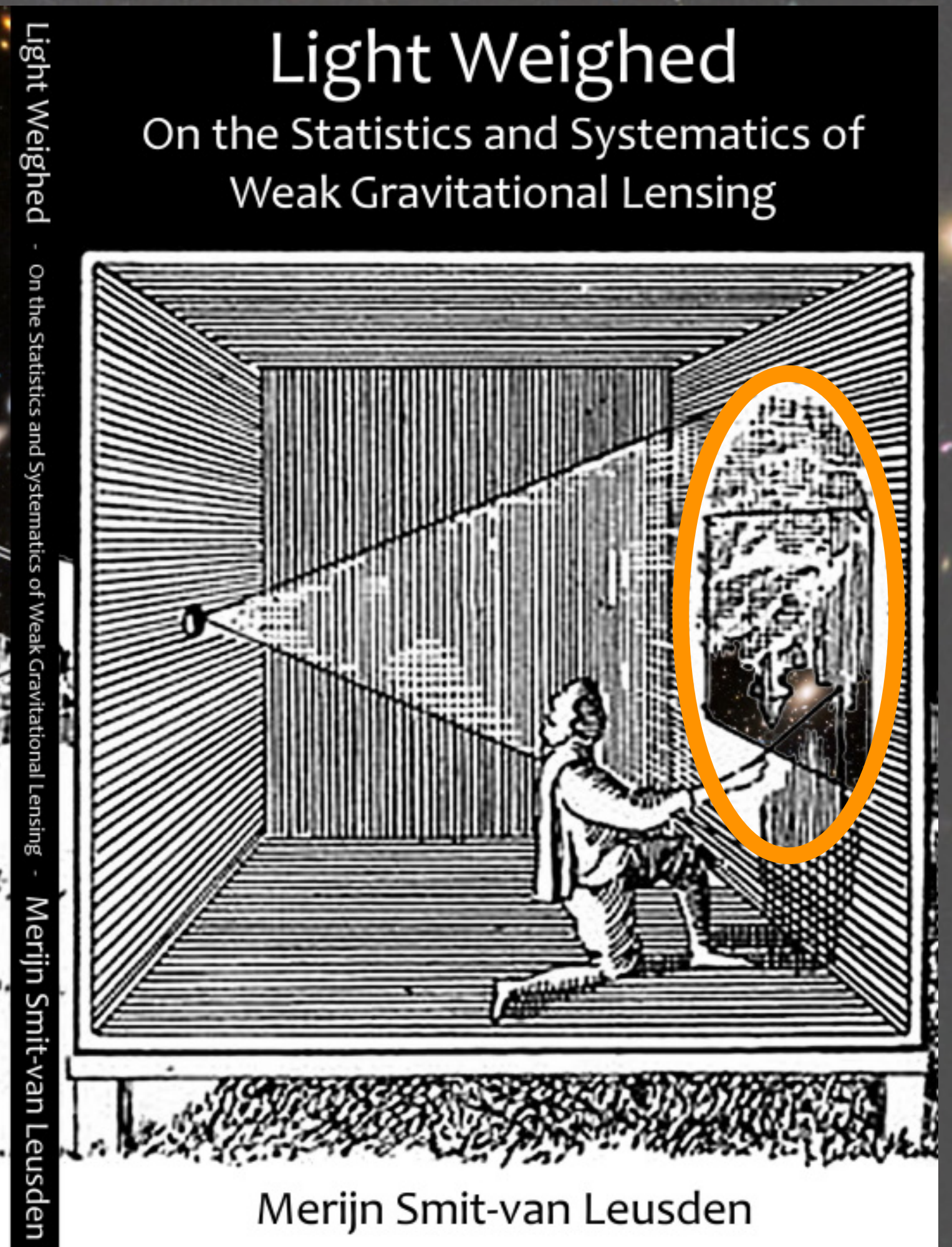
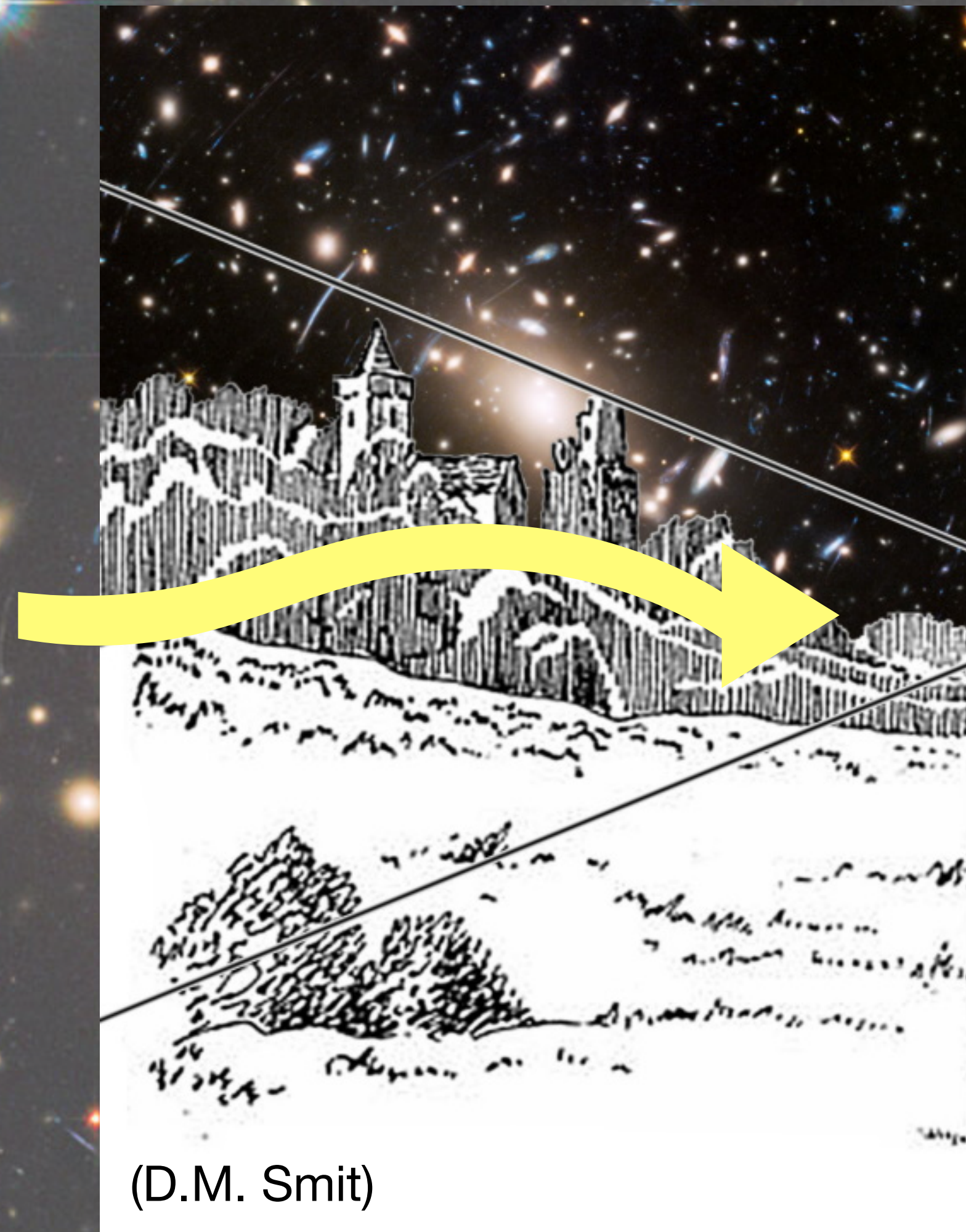


Weak gravitational lensing

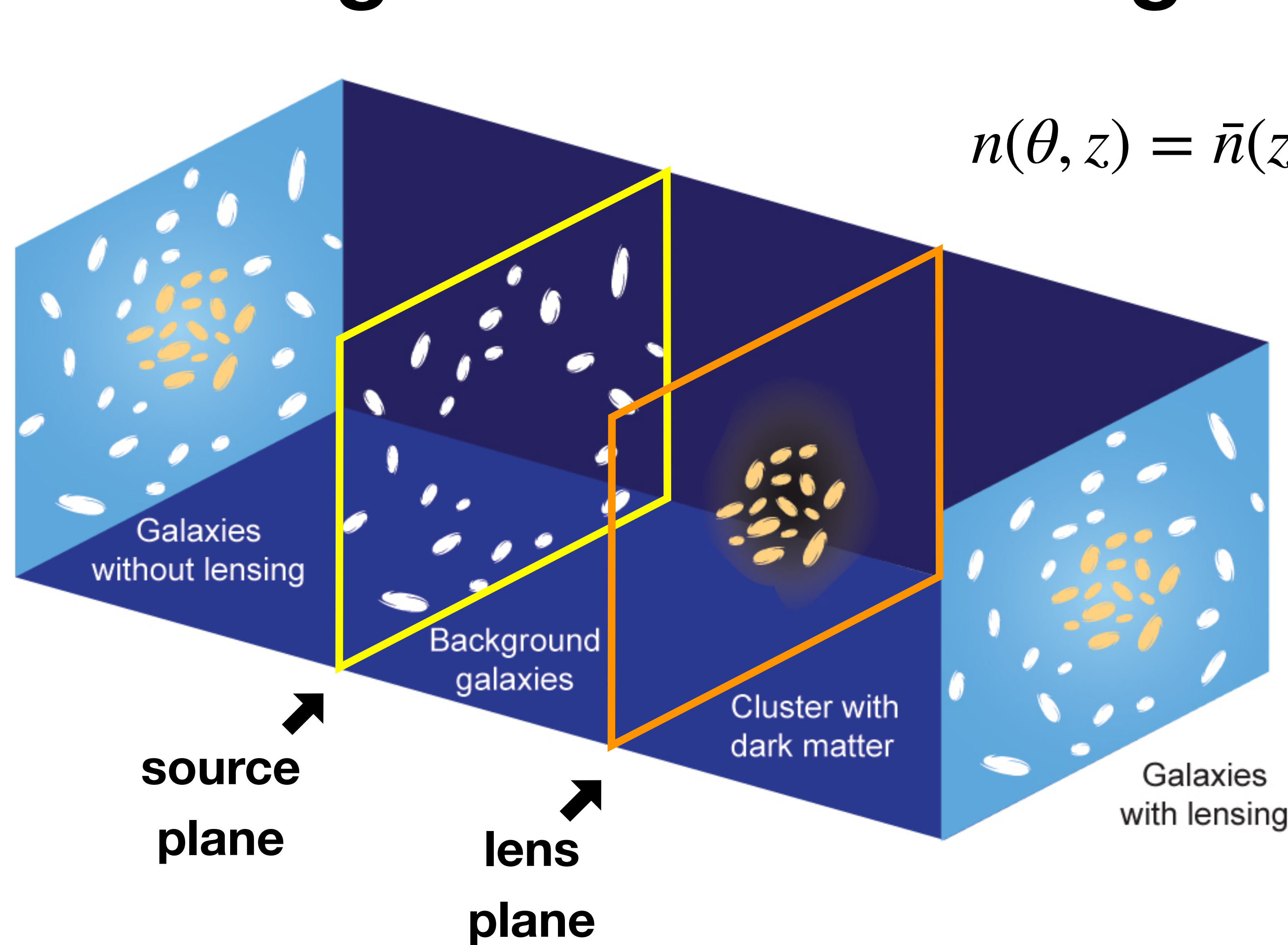


Weak gravitational lensing

- **Systematics**
 - Intrinsic alignment
 - **Source clustering**
 - Magnification
 - etc...



Weak lensing: Source clustering



$$n(\theta, z) = \bar{n}(z) \left[1 + f(\delta(\theta, z)) \right]$$

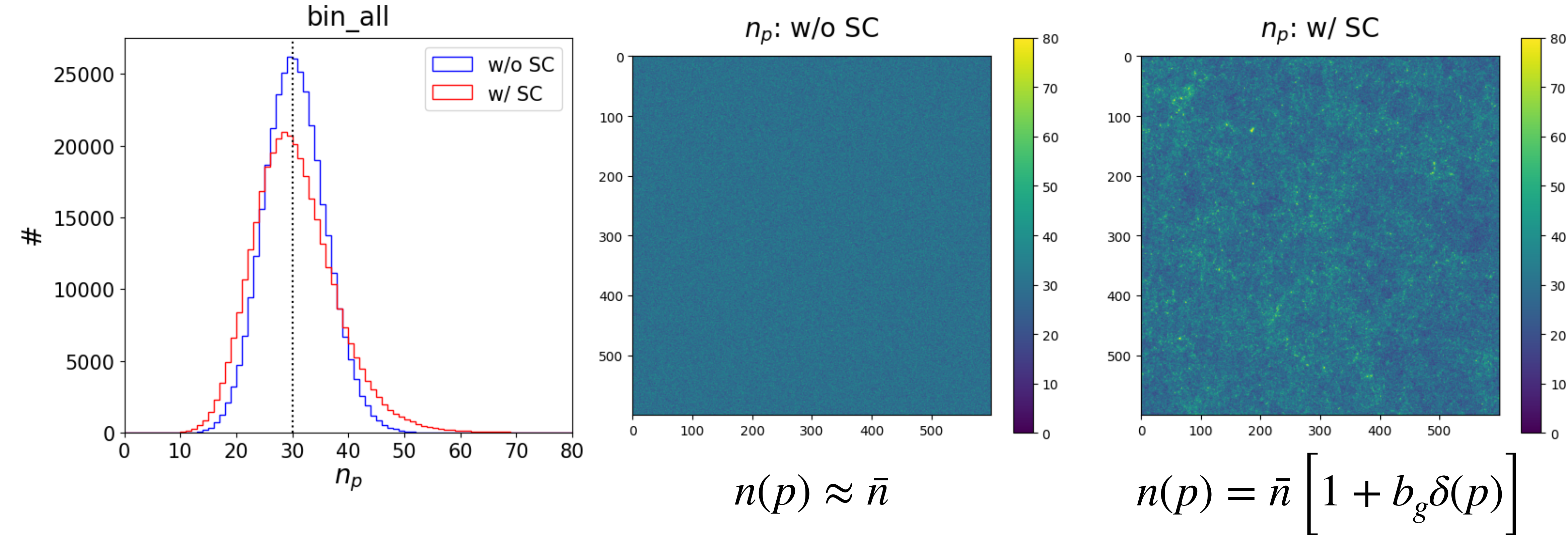
$\Rightarrow \gamma, \kappa$



Weak lensing: Source clustering

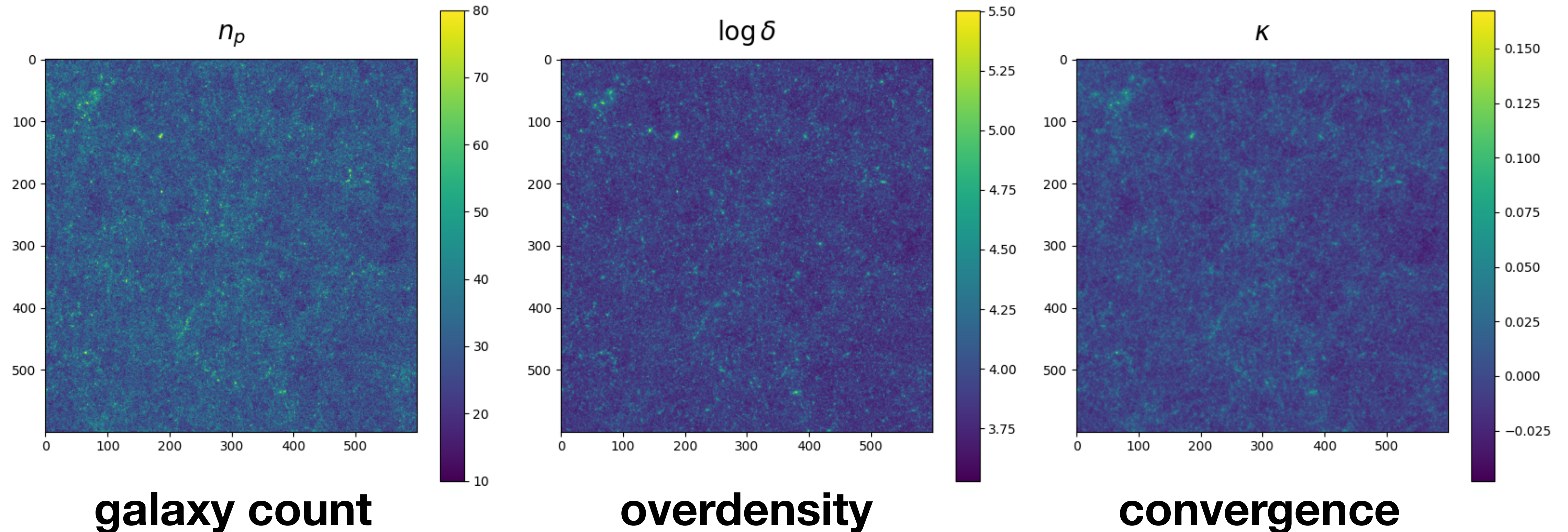
e.g. cosmo-SLICS

galaxy count



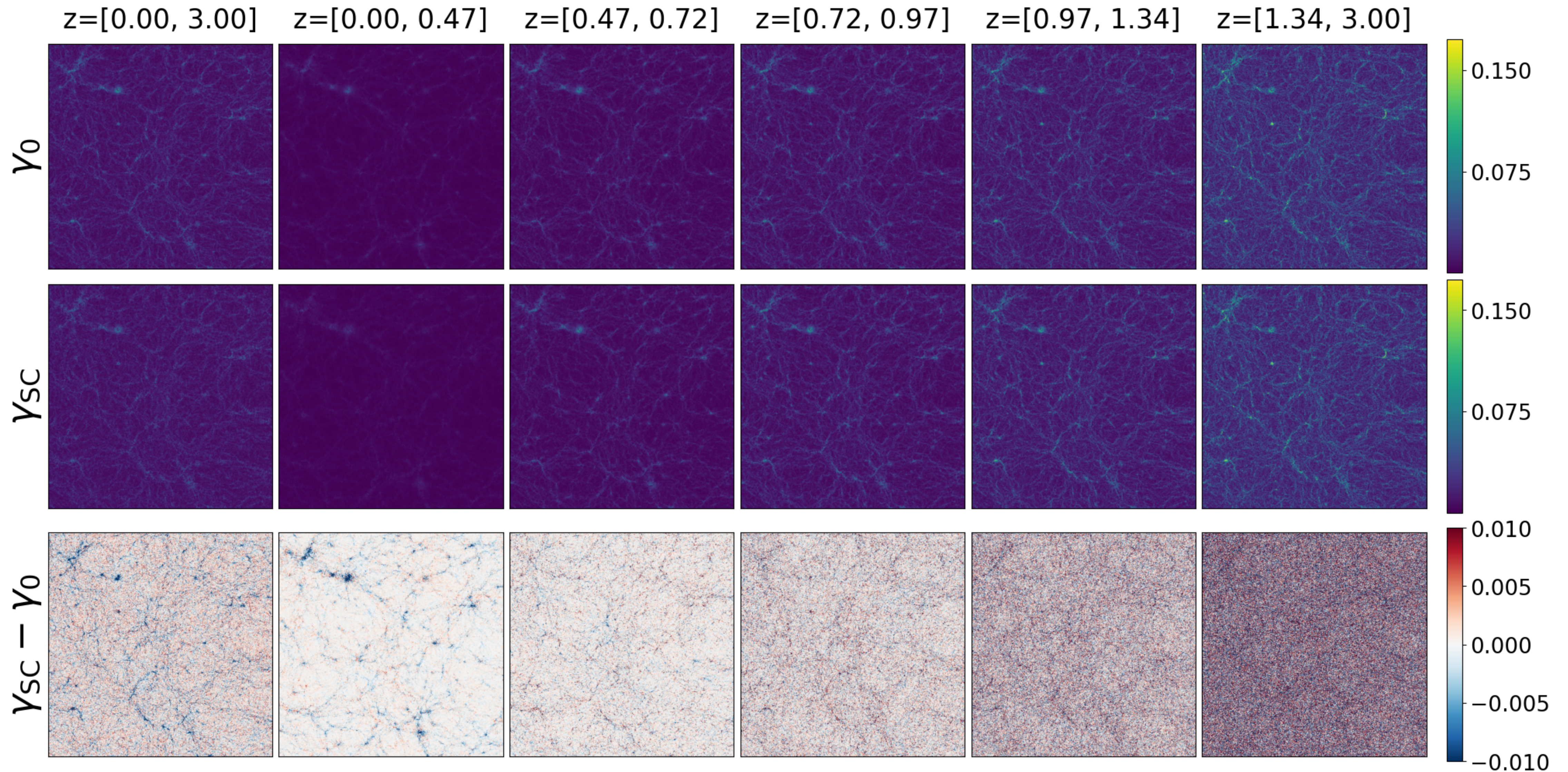
Weak lensing: Source clustering

e.g. cosmo-SLICS: **with source clustering**



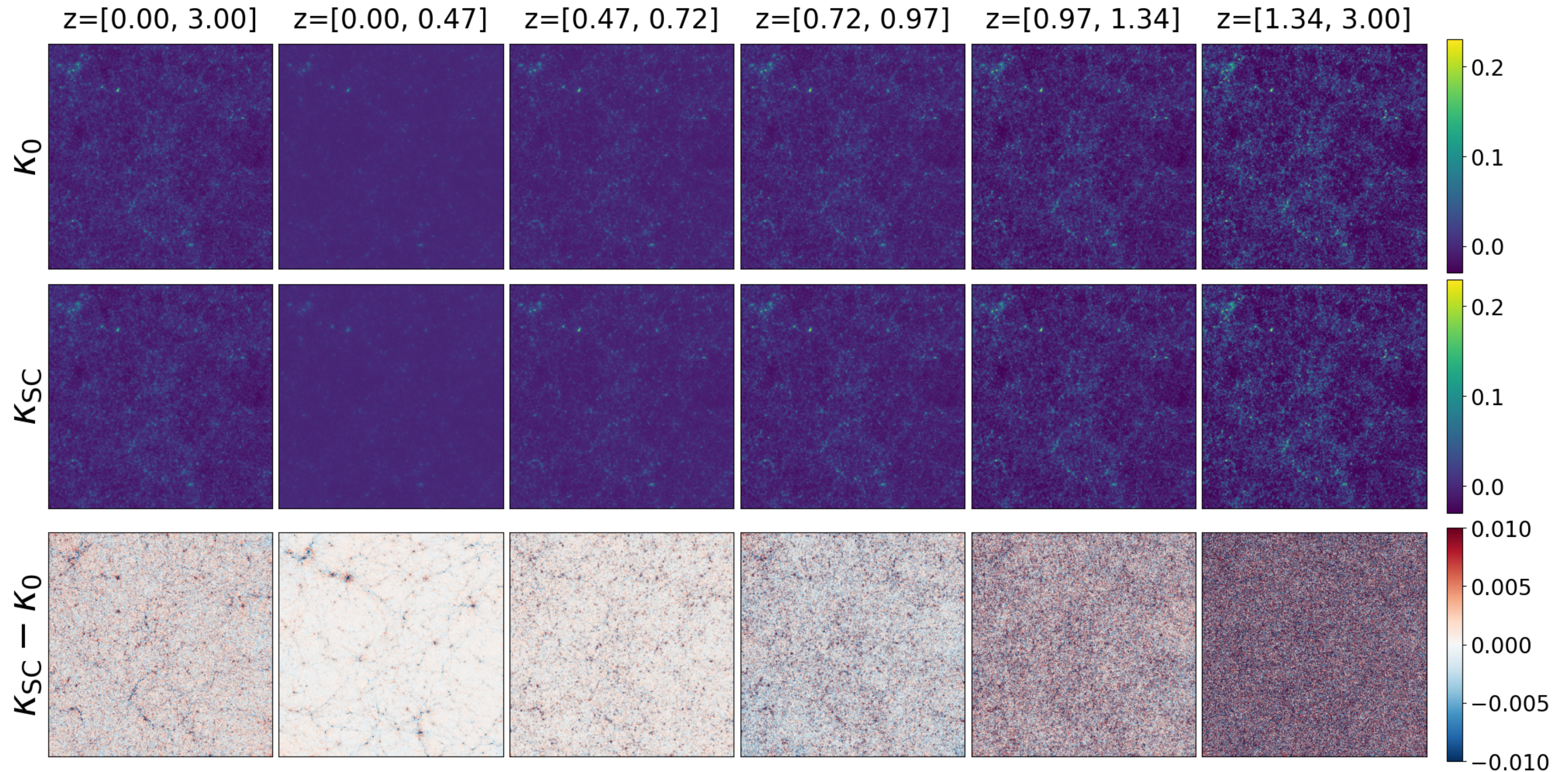
Weak lensing: Source clustering

N.B. noiseless



Weak lensing: Source clustering

N.B. noiseless



Weak lensing: Source clustering

- **Source clustering implementation** (Gatti+2024)

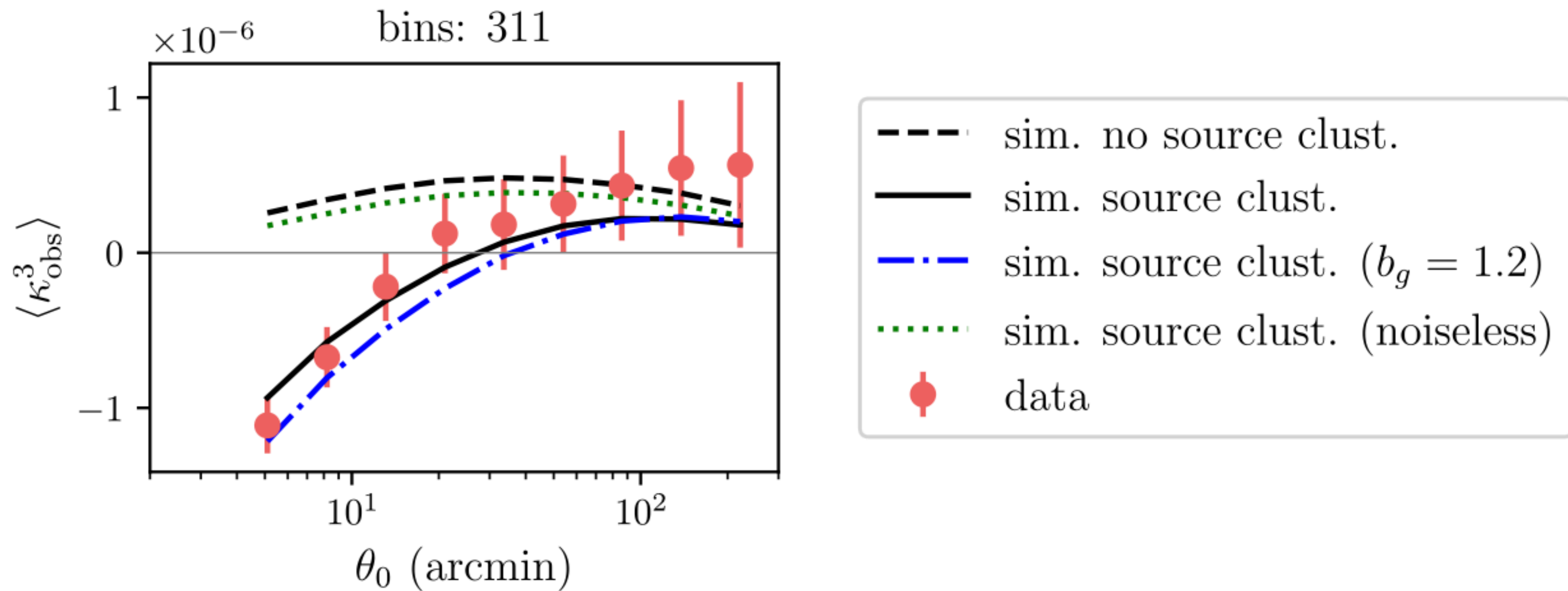
$$\gamma(p) = \frac{\sum_s \bar{n}(s) \gamma(p, s)}{\sum_s \bar{n}(s)} + \frac{\sum_g w_g e_g}{\sum_g w_g}$$

$$\gamma_{\text{sc}}(p) = \frac{\sum_s \bar{n}(s) [1 + b_g \delta(p, s)] \gamma(p, s)}{\sum_s \bar{n}(s) [1 + b_g \delta(p, s)]} + \underbrace{\left(\frac{\sum_s \bar{n}(s)}{\sum_s \bar{n}(s) [1 + b_g \delta(p, s)]} \right)^{1/2}}_{\text{Noise}} F(p) \frac{\sum_g w_g e_g}{\sum_g w_g}$$

$\Rightarrow$ The higher the overdensity, the larger the S/N

Higher-order weak lensing statistics

- **Source clustering impact on HOS** (Gatti+2024)

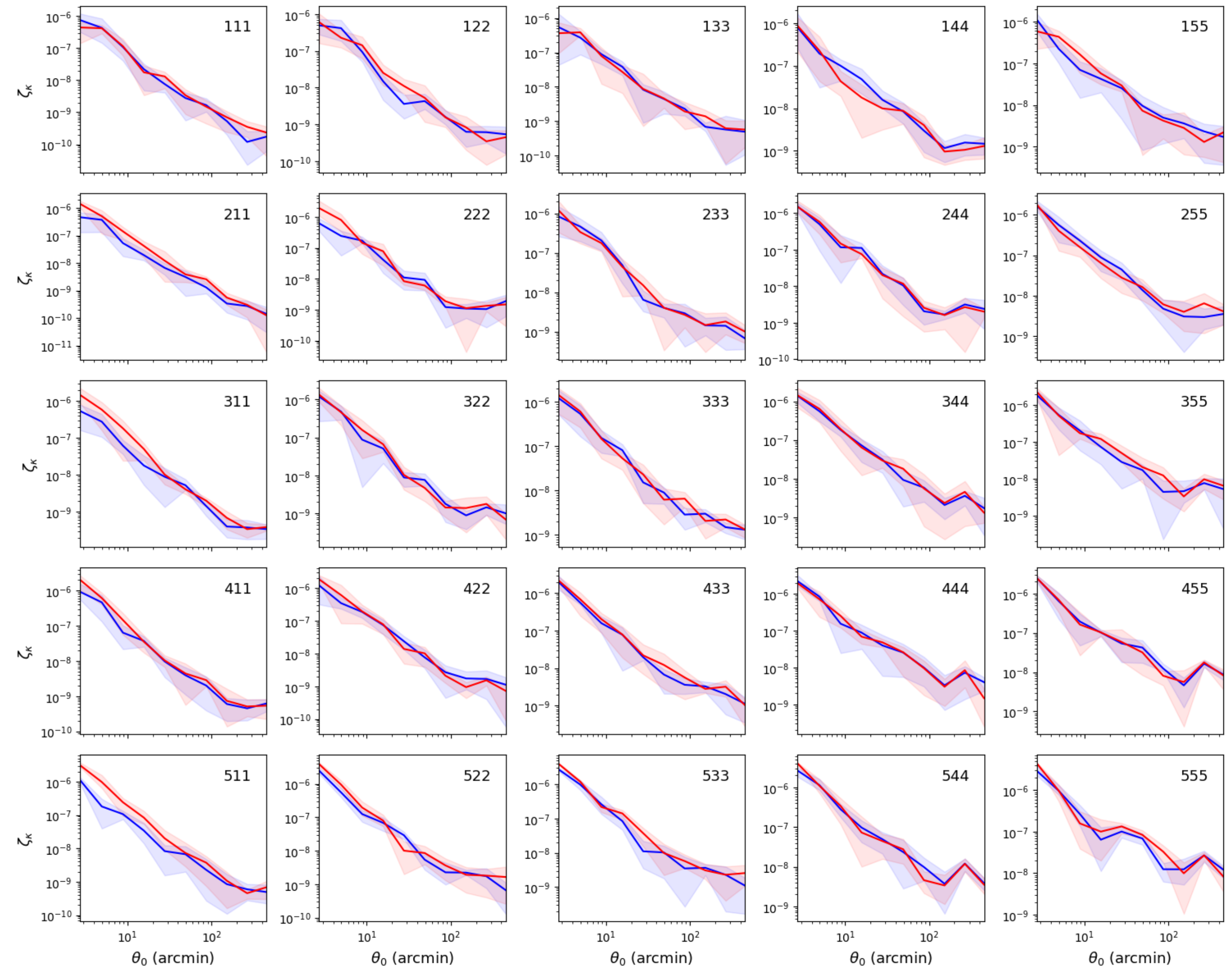
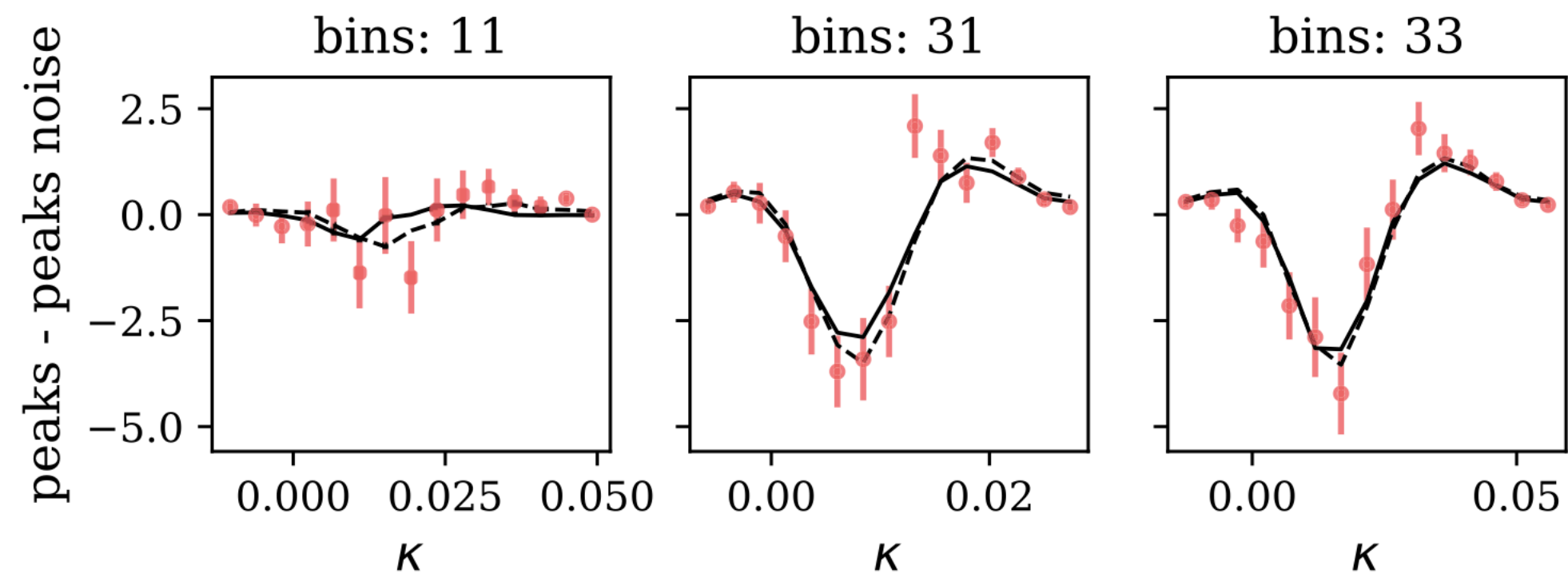


• Source clustering impact on HOS (Gatti+2024)

— sims. source clust. — sims. no source clust.

κ -3PCF

Peak counts



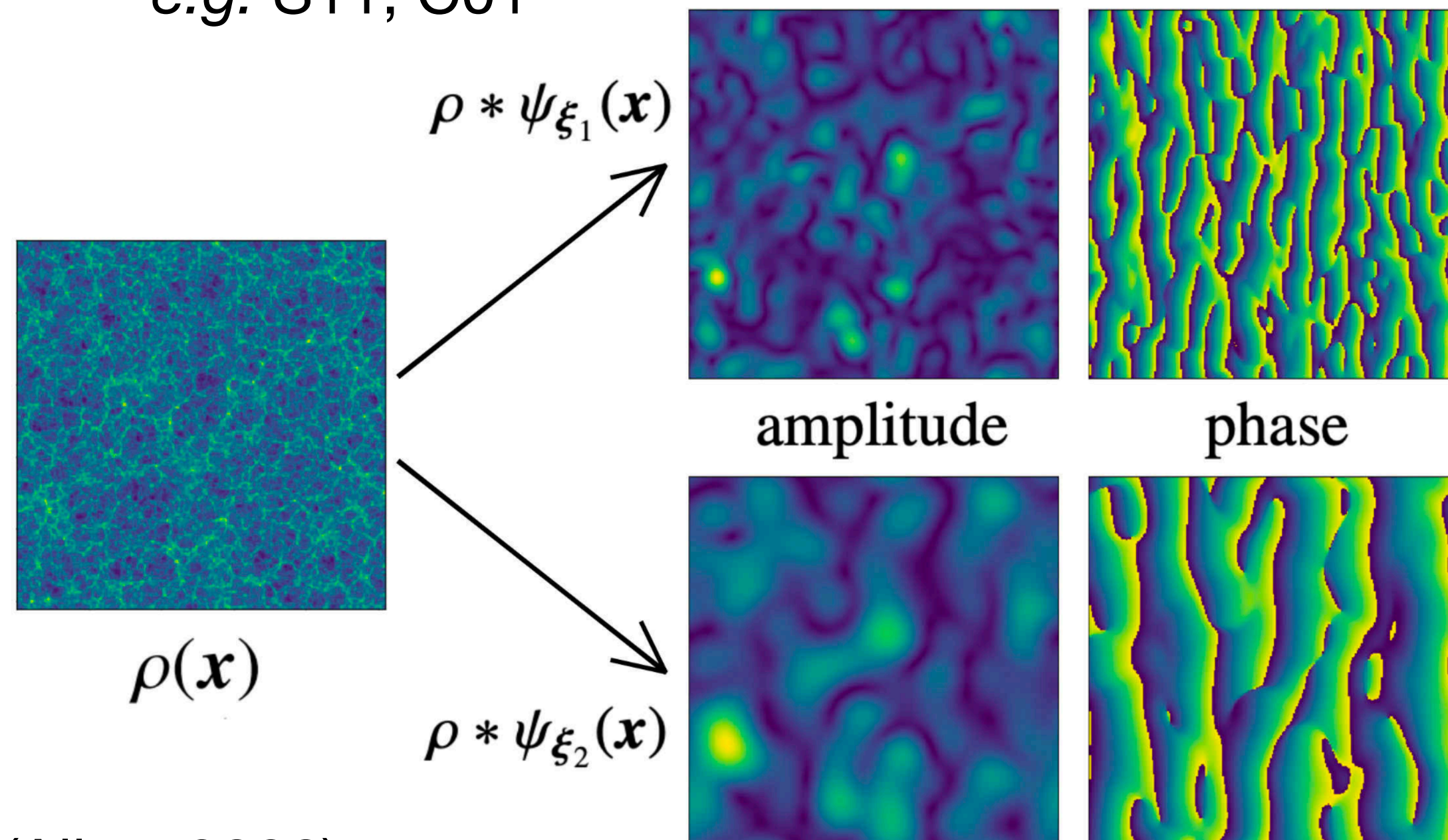
Higher-order weak lensing statistics

Statistics	Observable	Note
γ -2PCF	$\xi_{\pm}$	<i>treecorr</i>
κ -2PCF, κ -3PCF	$\xi_{\kappa}, \zeta_{\kappa}$	<i>treecorr</i>
κ -1PDF	$P(\kappa)$	
Moments of κ	$\langle \kappa^2 \rangle, \langle \kappa^3 \rangle$	central moment
Wavelet phase harmonics	S00, S11, S01 / C01	<i>pywph</i>
Wavelet peak counts	count	<i>wl_stats_torch</i>
Wavelet /1-norm	/1-norm	<i>wl_stats_torch</i>

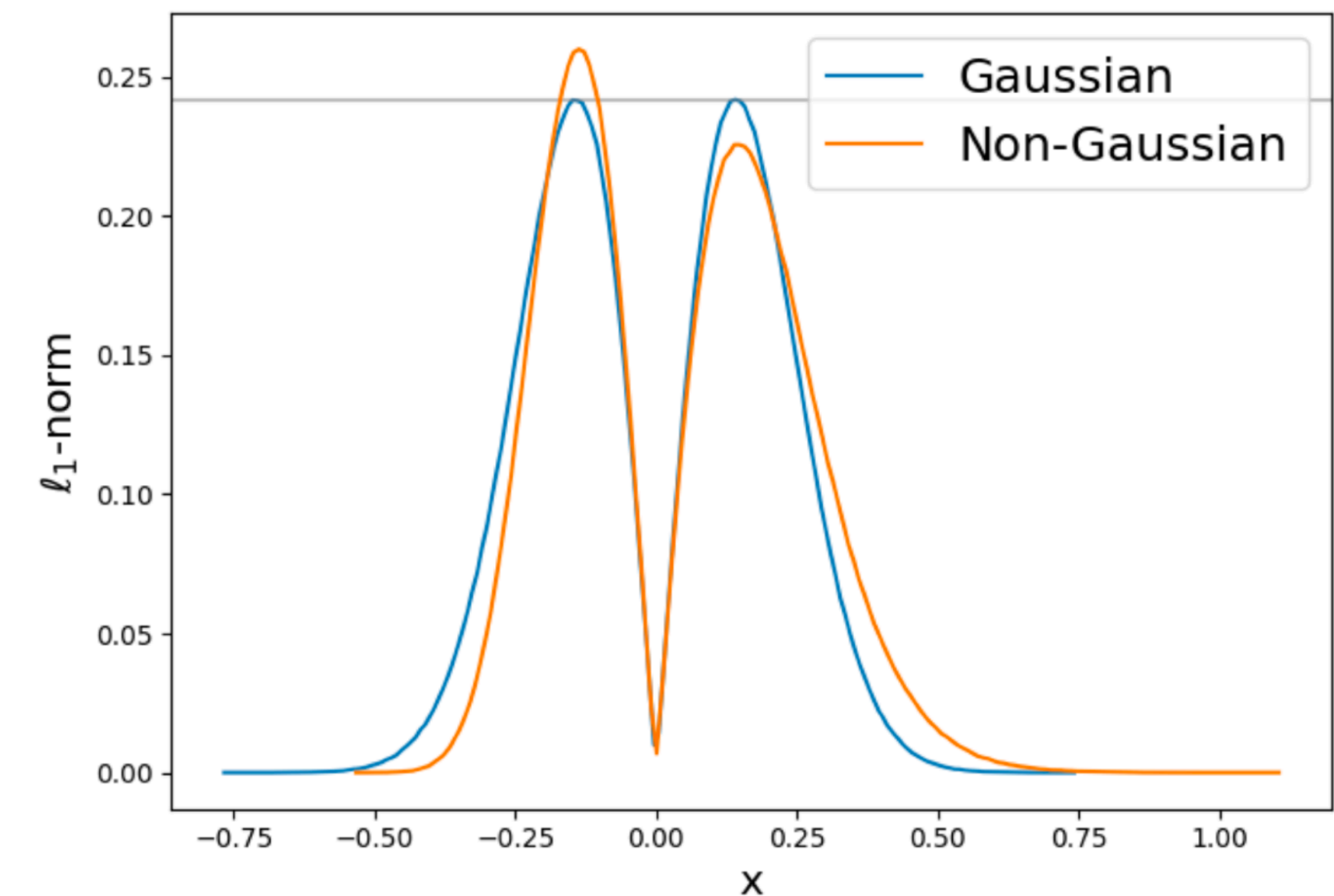
Wavelet summary statistics

- **Wavelet phase harmonics**
 - bump steerable wavelets
 - combinations of scales & phases
- **Wavelet peak counts & /1-norm**
 - Starlet wavelets
 - simultaneous multi-scale

e.g. S11, C01



(Allys+2020)

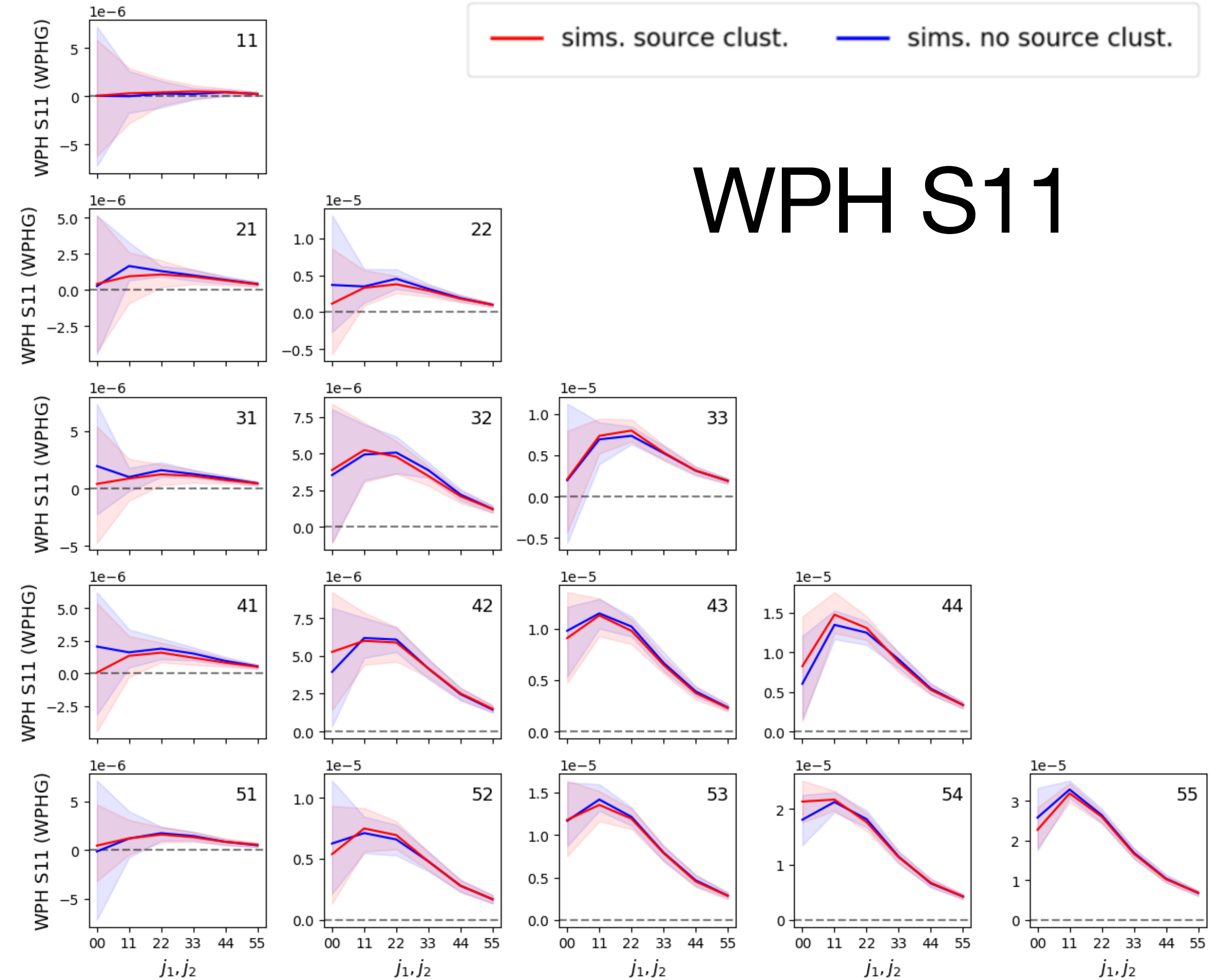
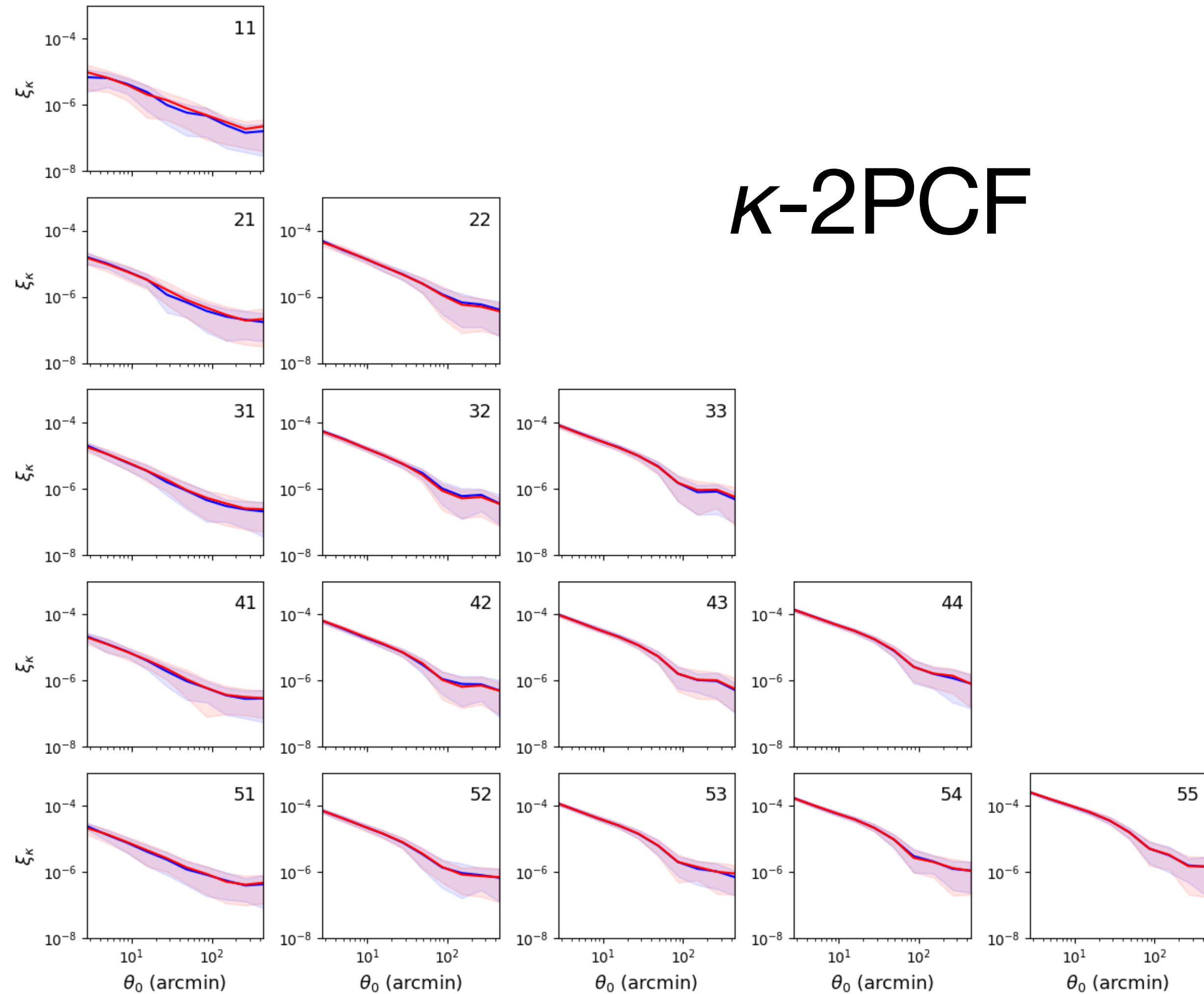


(Sreekanth+2024)

Data and method

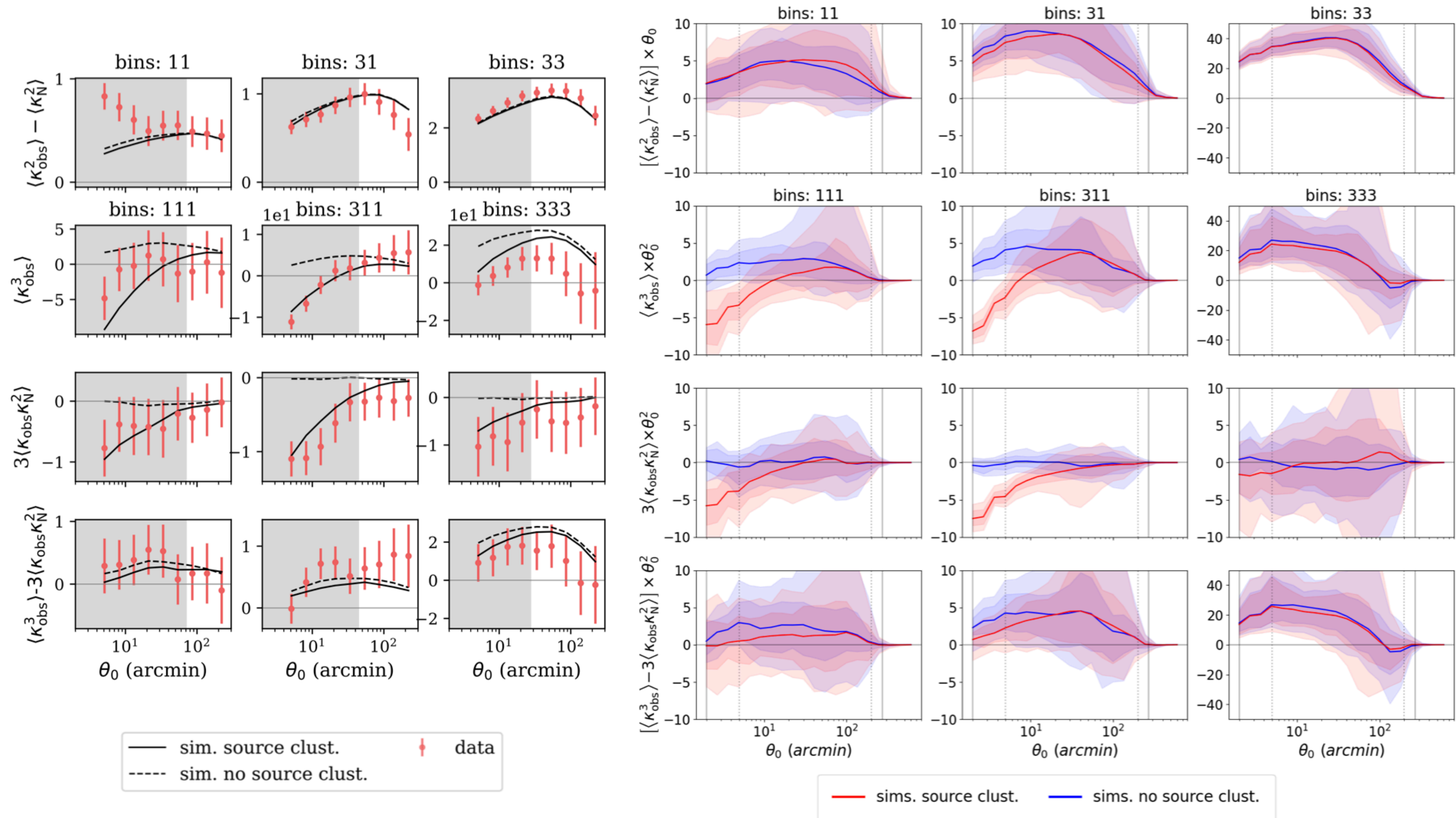
- ***Cosmo-SLICS*** (Harnois-Déraps+2019)
 - 1 cosmology $\times$ 10 light cones $\times$ 10 noises = 100 realizations
 - without source clustering / with source clustering
- **Summary statistics**
 - Gaussian statistics: $\langle k^2 \rangle$, k -2PCF, WPH S11
 - non-Gaussian statistics: $\langle k^3 \rangle$, WPH C01 *c.f.* Gatti+2024
 - **wavelet peak counts, wavelet /1-norm**

Result: 1. Gaussian: κ -2PCF & WPH S11



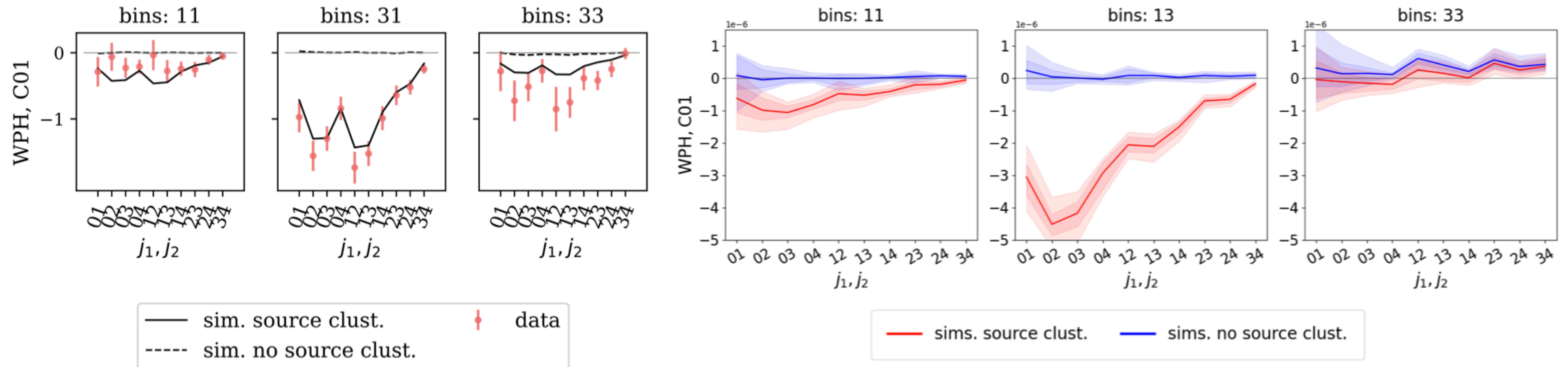
Result: 2. Moments of convergence

c.f. Gatti+2024



Result: 3. Wavelet phase harmonics

c.f. Gatti+2024

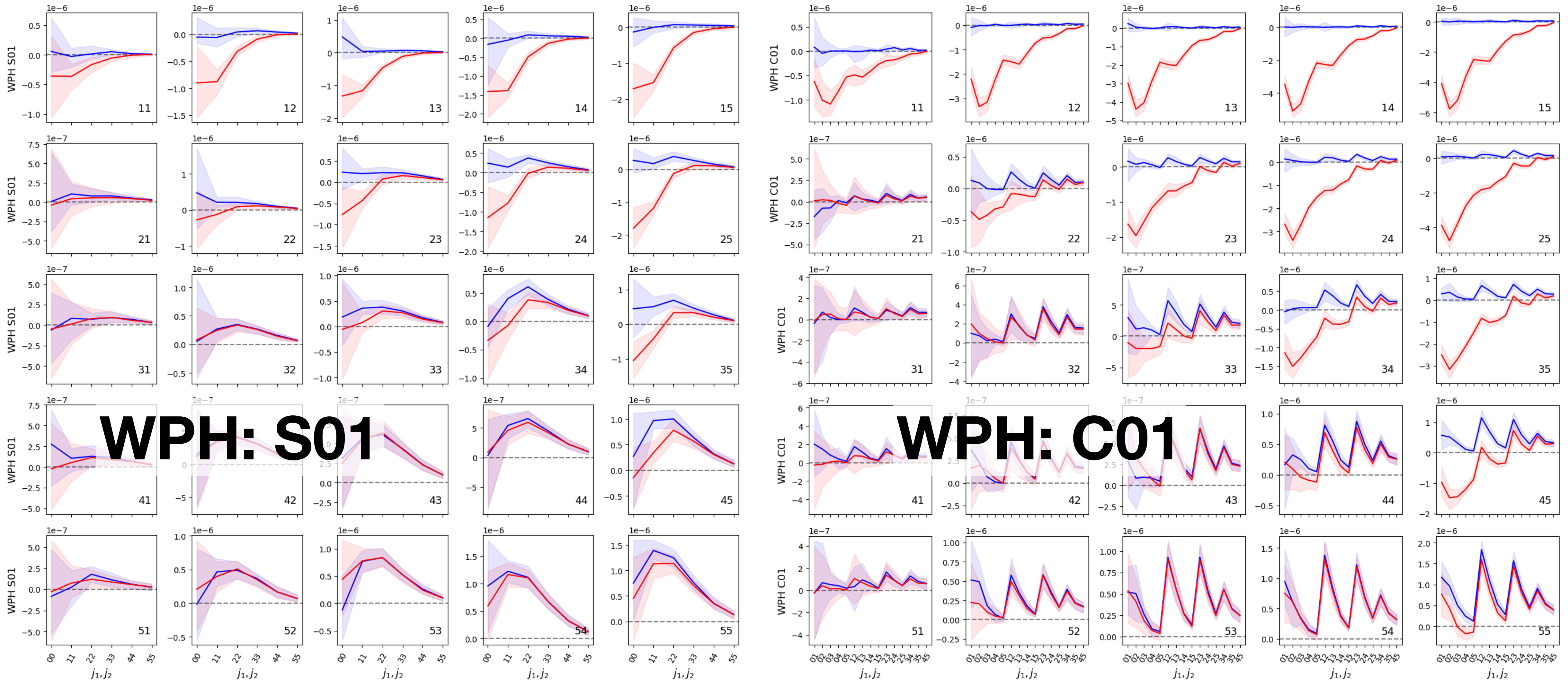


→ different simulations, but consistent results

PKDGRAV3 / *cosmo*-SLICS

Result: 3. Wavelet phase harmonics

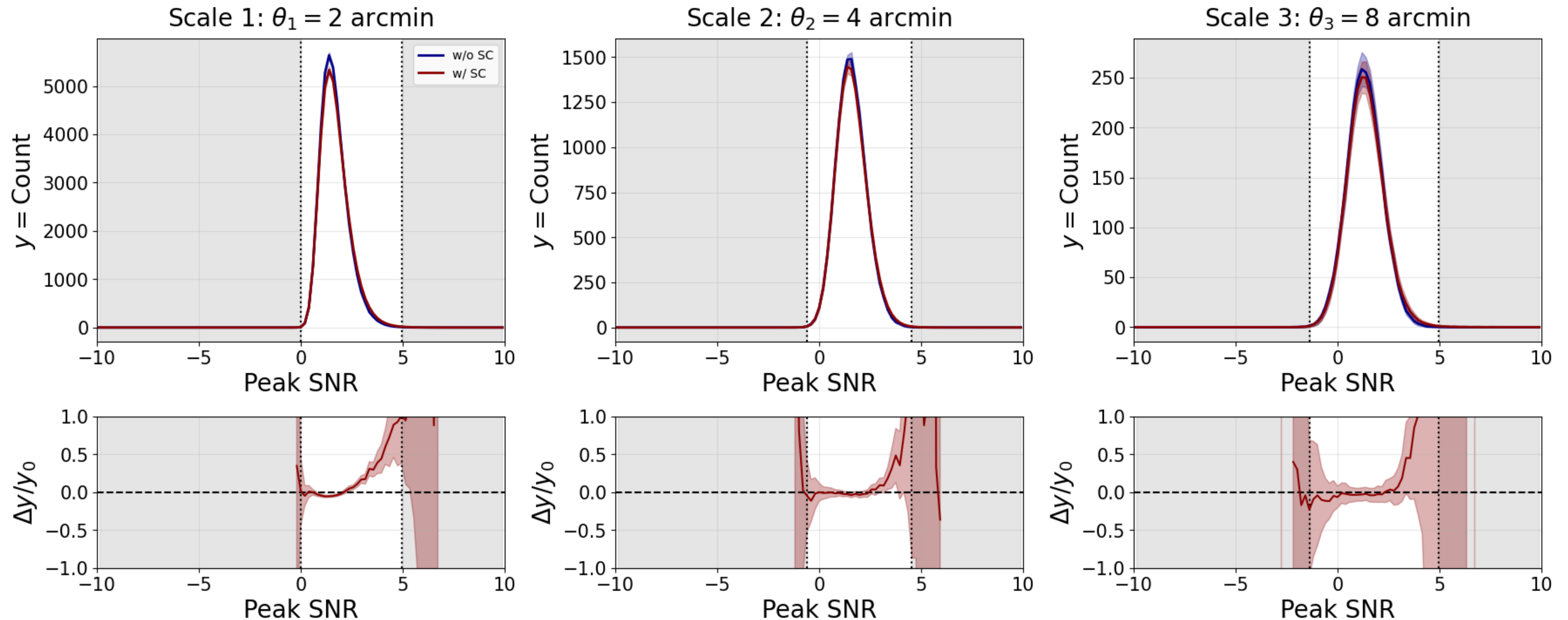
— sims. source clust. — sims. no source clust.



Result: 4. Wavelet peak counts

Wavelet peak counts: bin1 / $z = [0.00, 0.47]$

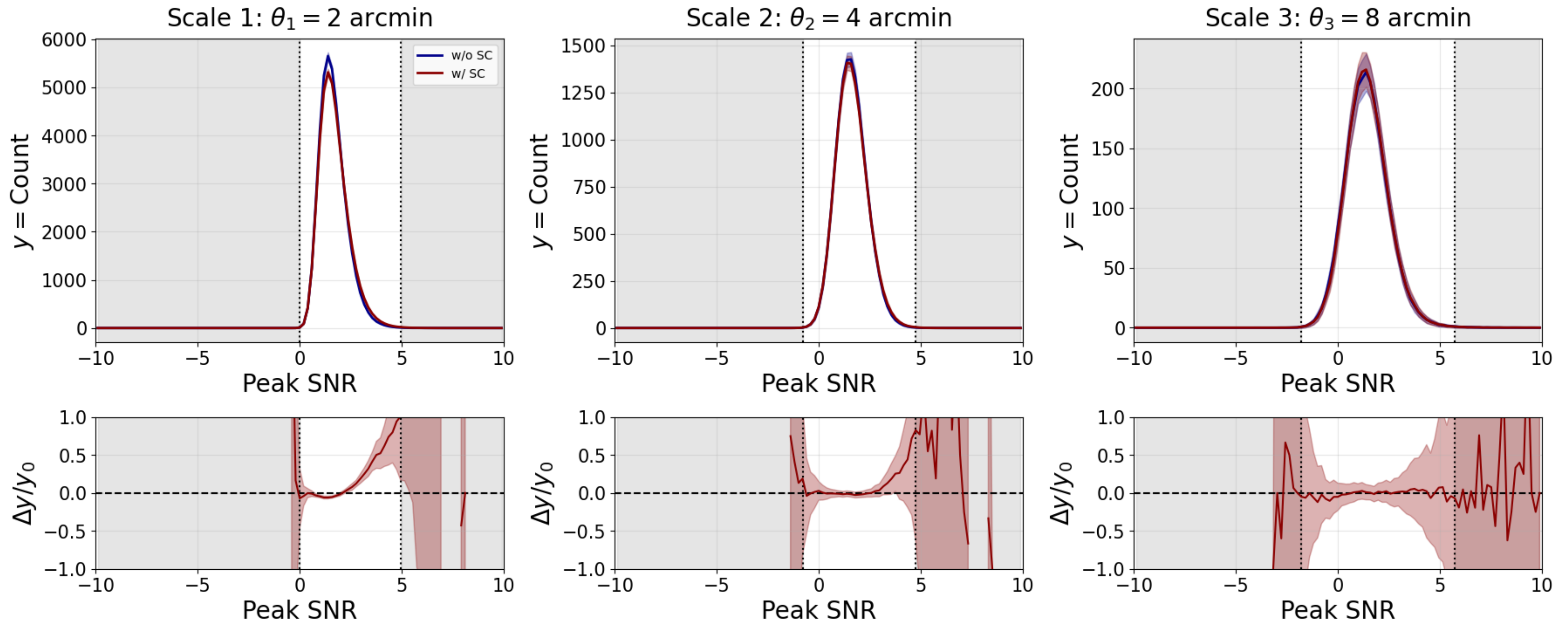
Scale cut: $y_{\text{SC}}(x)/y_{\text{SC,max}} < 0.005$



Result: 4. Wavelet peak counts

Wavelet peak counts: bin3 / $z = [0.72, 0.97]$

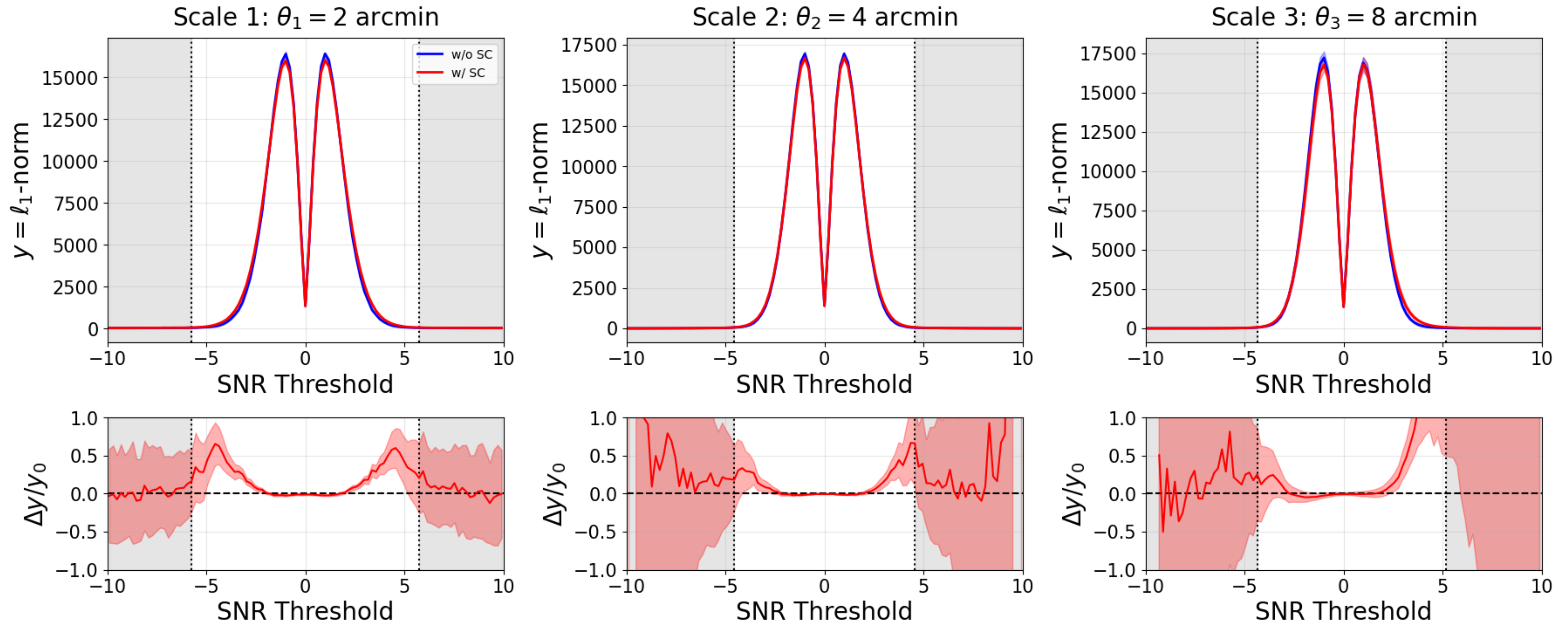
Scale cut: $y_{\text{SC}}(x)/y_{\text{SC,max}} < 0.005$



Result: 5. Wavelet ℓ_1 -norm

Wavelet ℓ_1 -norm: bin1 / $z = [0.00, 0.47]$

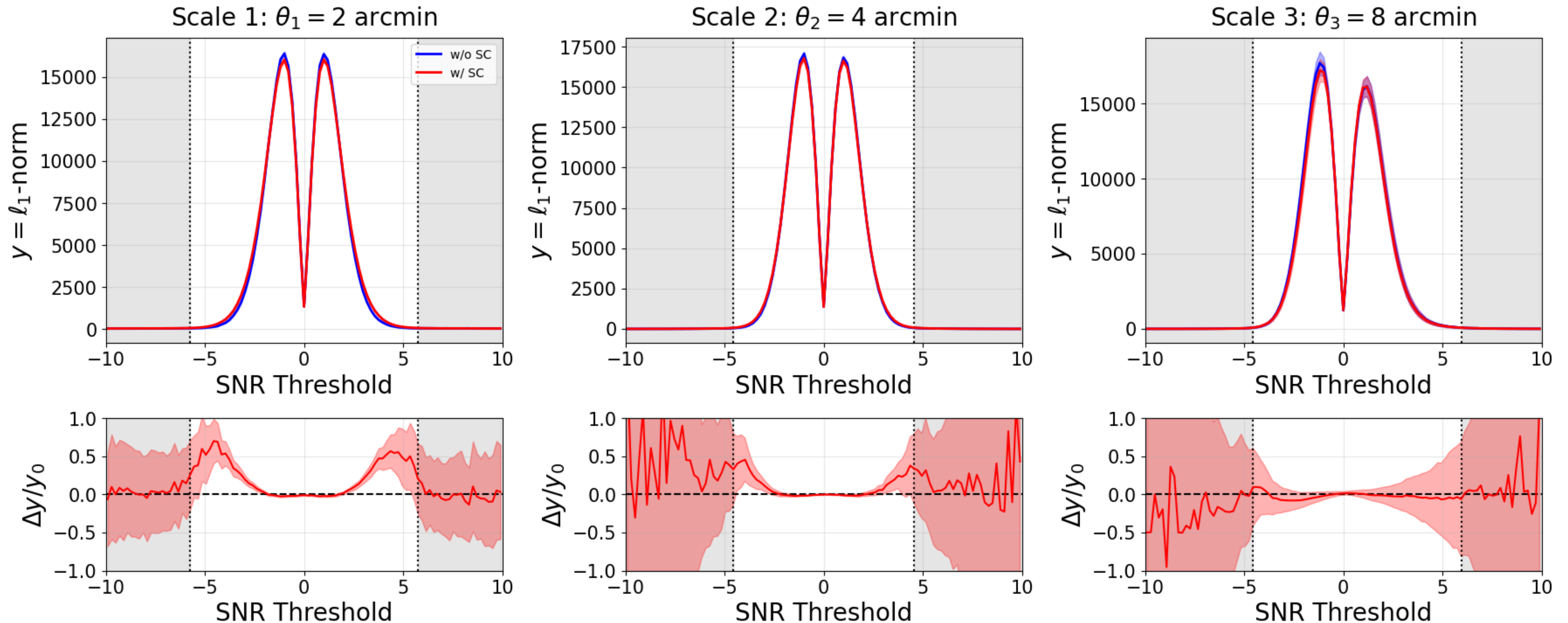
Scale cut: $y_{\text{SC}}(x)/y_{\text{SC,max}} < 0.005$



Result: 5. Wavelet ℓ_1 -norm

Wavelet ℓ_1 -norm: bin3 / $z = [0.72, 0.97]$

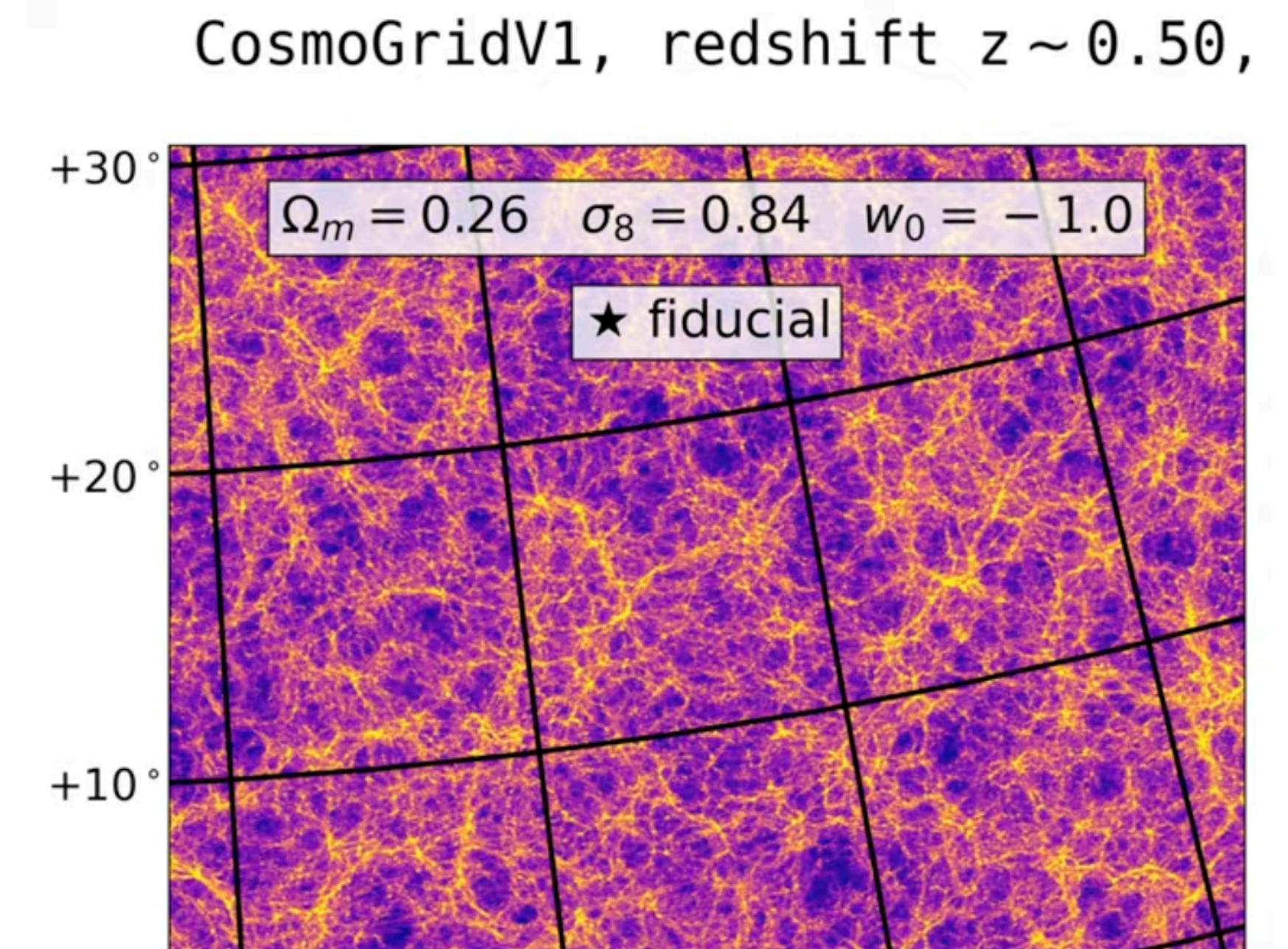
Scale cut: $y_{\text{SC}}(x)/y_{\text{SC,max}} < 0.005$



Future plan

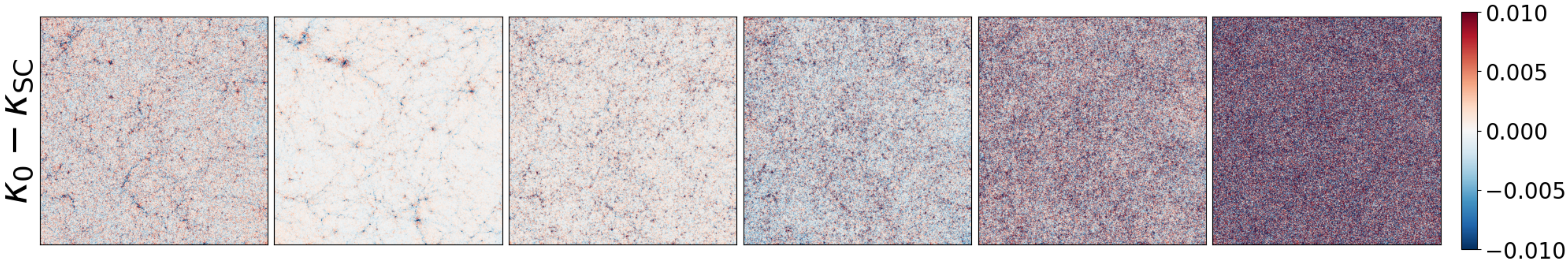
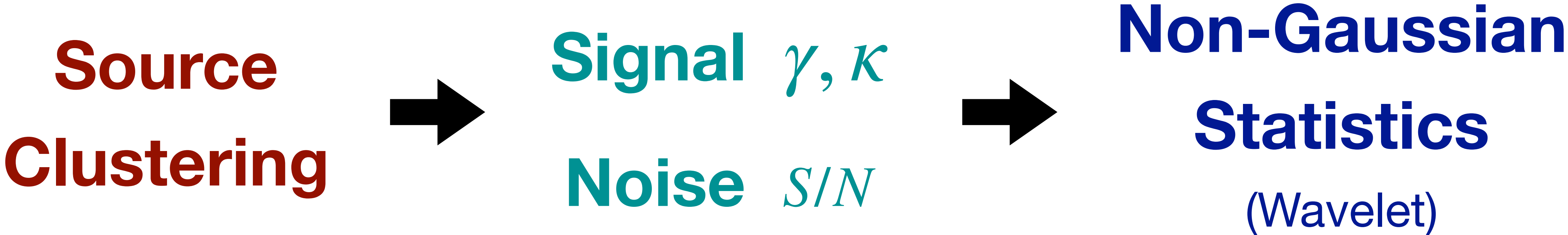
- **Quantify the bias in cosmological inference**

- **Simulation-based inference**
- **Data:** *CosmoGridV1* or *Gower St.*
 1. Train the model **without SC**
 2. Validate and quantify the bias **with SC**



c.f. Gatti+2024, 2025

Summary



Appendix. Cosmological inference

