Minkowski Functionals in Joint Galaxy Clustering & Weak Lensing Analyses

Cosmology from Home 2022

Nisha Grewal

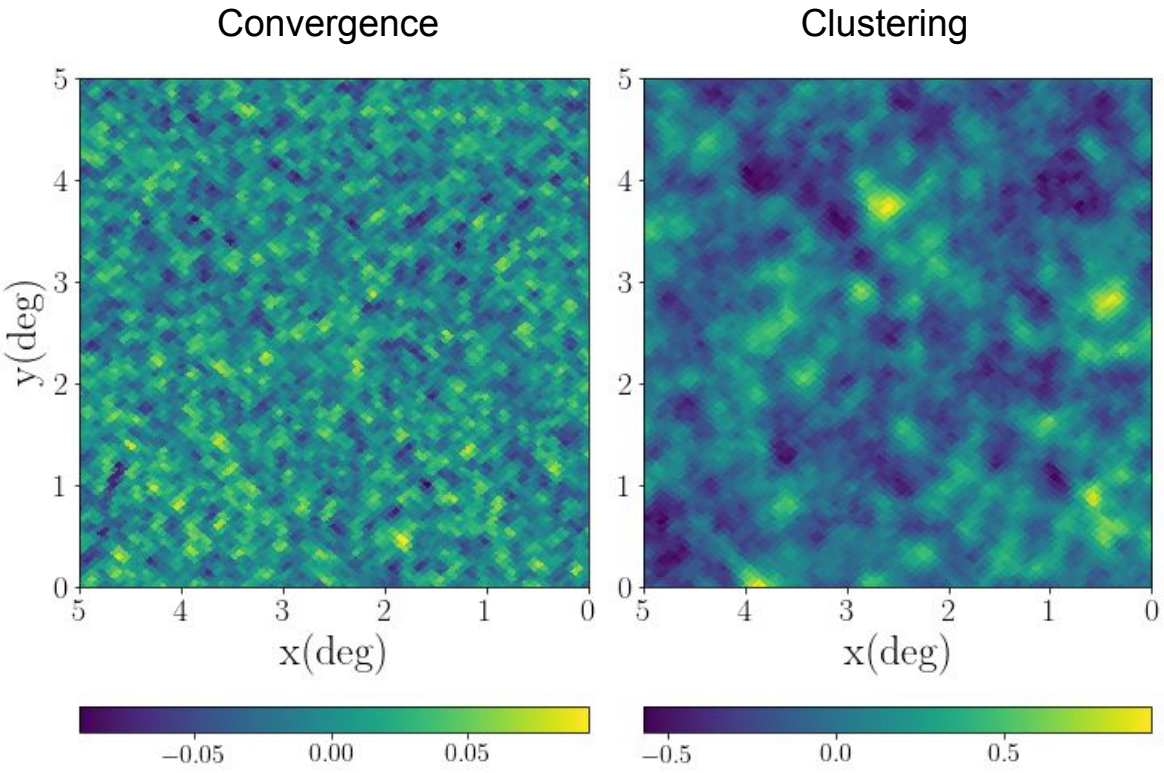
Grewal et al arXiv 2206.03877

Motivation

- Power spectra measured from convergence and clustering maps have high constraining power
- Minkowski functionals measured from convergence maps have high constraining power

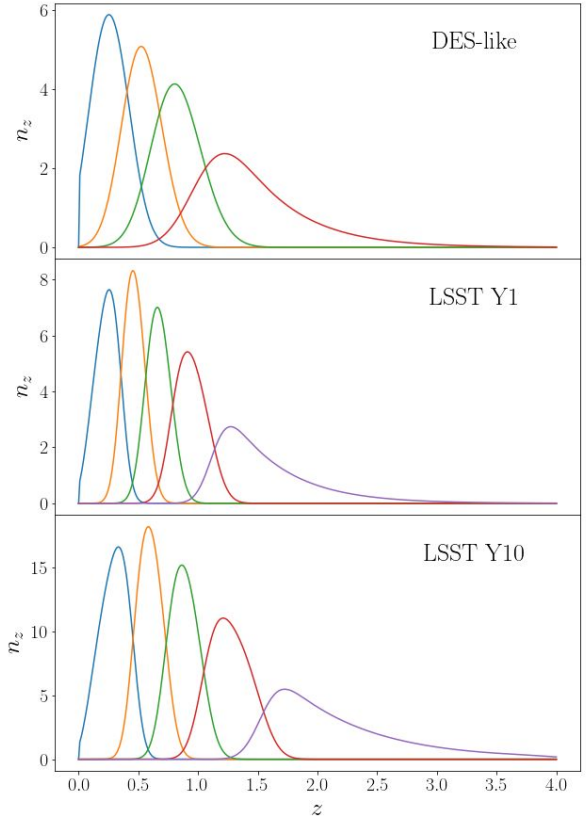
Goal: Investigate the constraining power of the higher order statistics Minkowski functionals measured from density clustering maps

Simulations

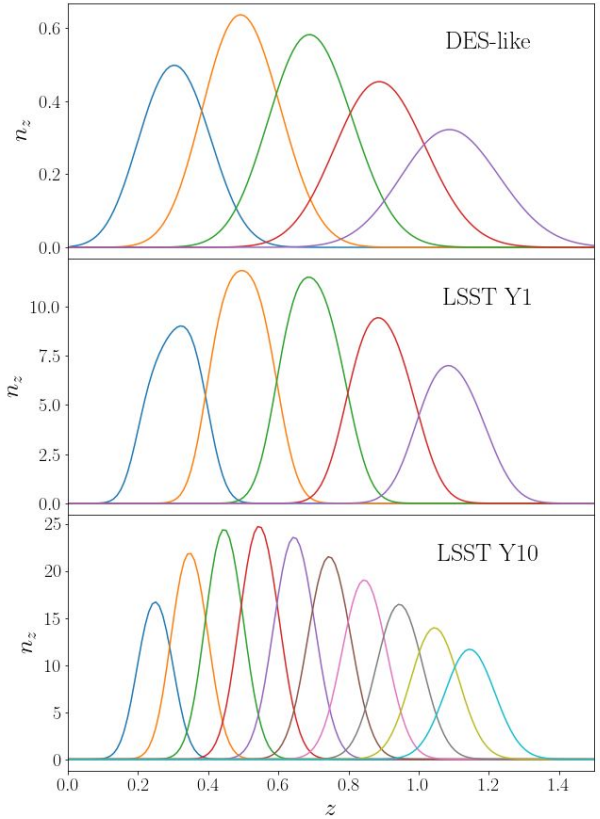


Redshift Distributions

Convergence

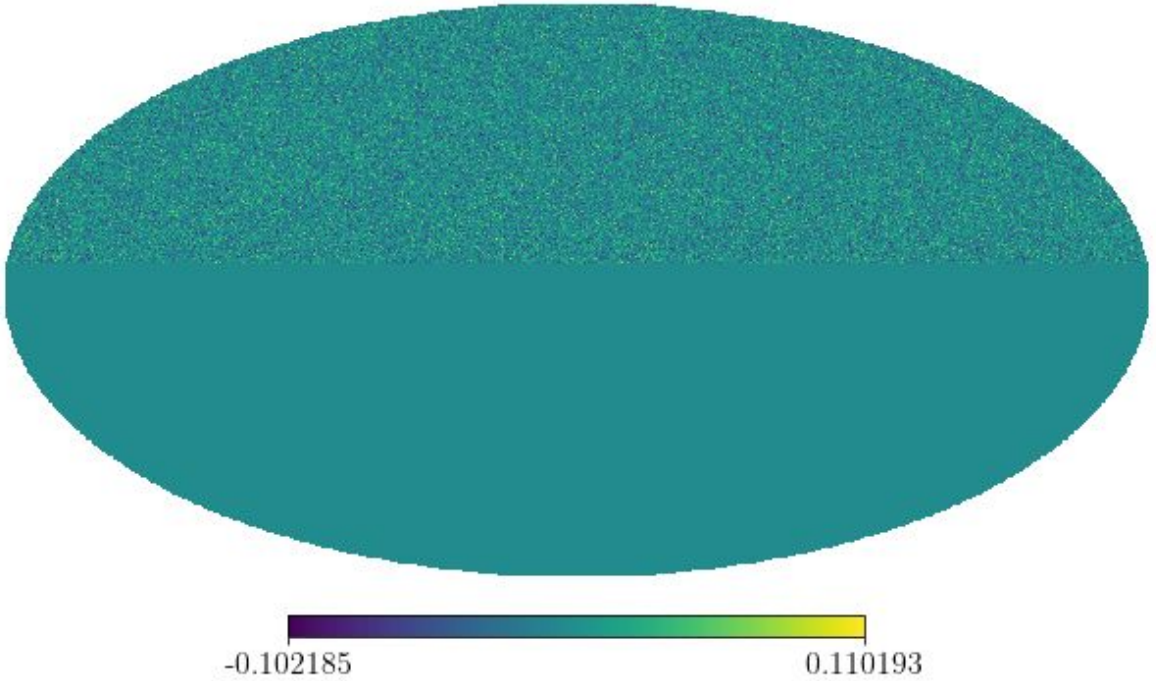


Clustering

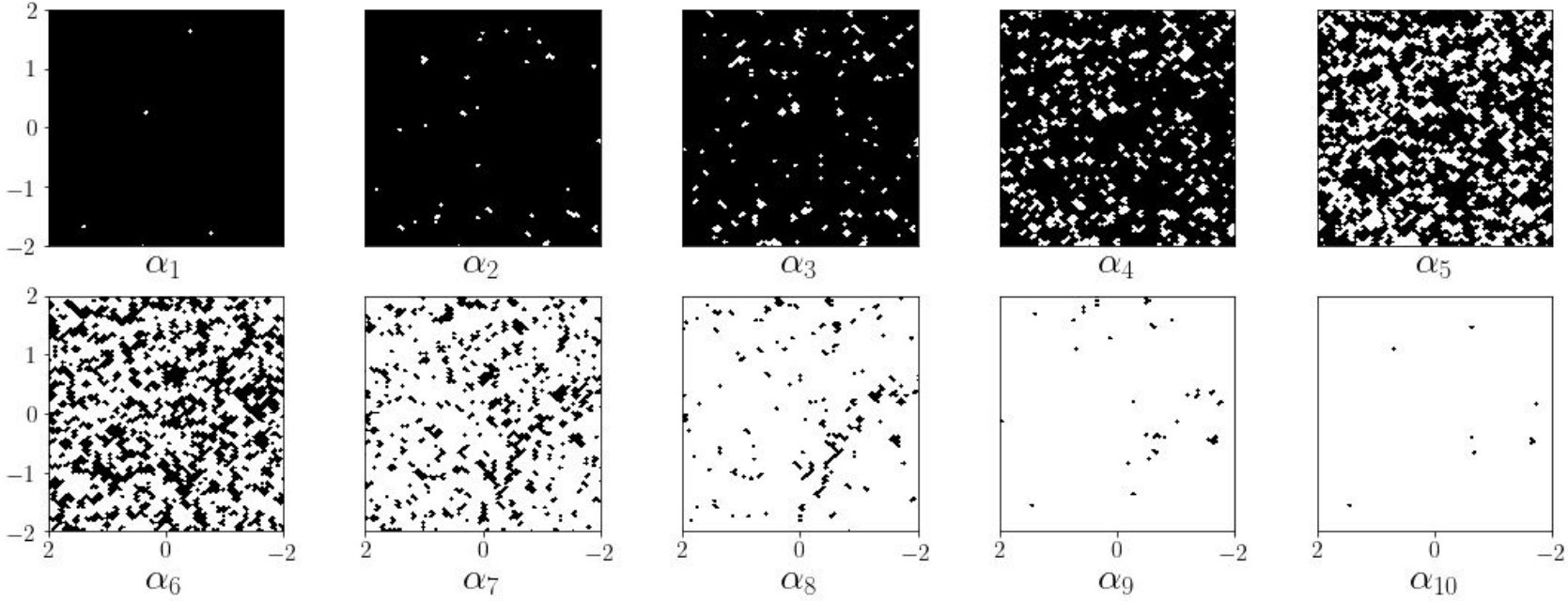


Zhang et al
arxiv 2111.04917

Simplified Sky Masking



Excursion Sets



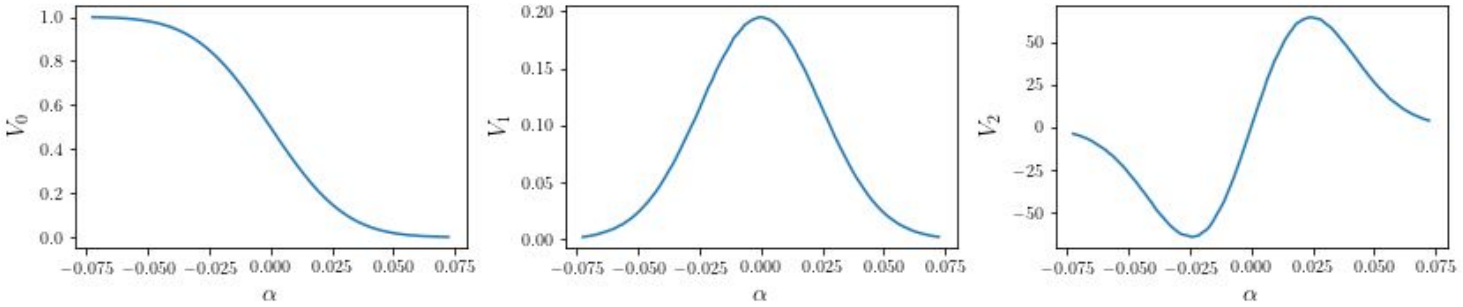
Minkowski Functionals (MF)

$$V_0(\nu) = \frac{1}{A}\int_A \Theta(\alpha(\mathbf{x}) - \nu) d\phi d\theta$$

$$V_1(\nu) = \frac{1}{4A}\int_A \delta(\alpha(\mathbf{x}) - \nu)\sqrt{\alpha_\phi^2 + \alpha_\theta^2} d\phi d\theta$$

$$V_2(\nu) = \frac{1}{2\pi A}\int_A \delta(\alpha(\mathbf{x}) - \nu)\frac{2\alpha_\phi \alpha_\theta \alpha_{\phi\theta} - \alpha_\phi^2 \alpha_{\theta\theta} - \alpha_\theta^2 \alpha_{\phi\phi}}{\alpha_\phi^2 + \alpha_\theta^2} d\phi d\theta$$

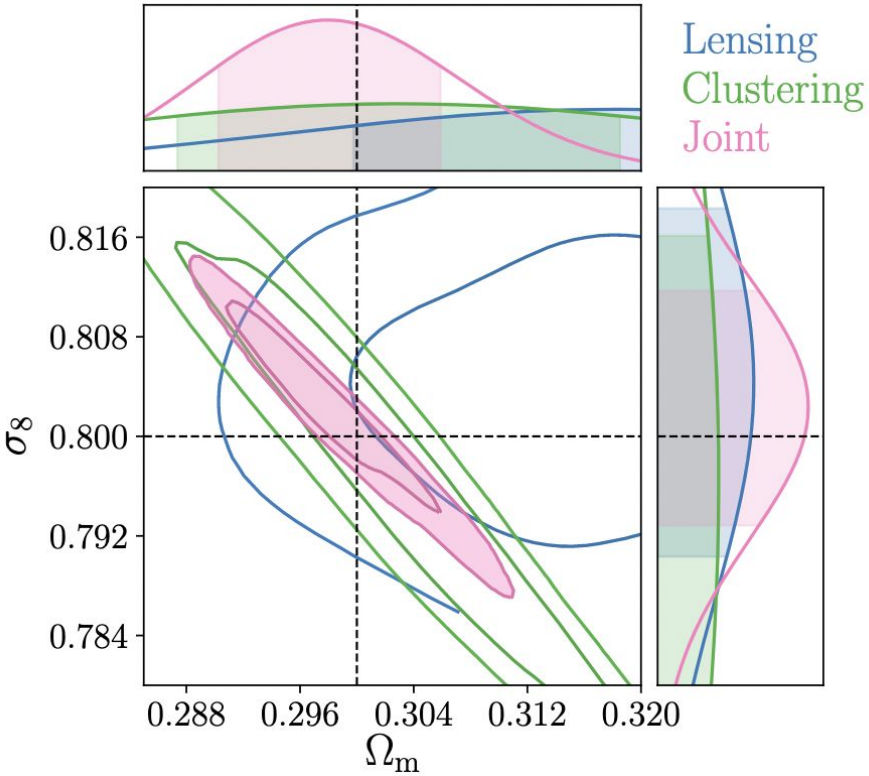
Area **Perimeter** **Curvature**

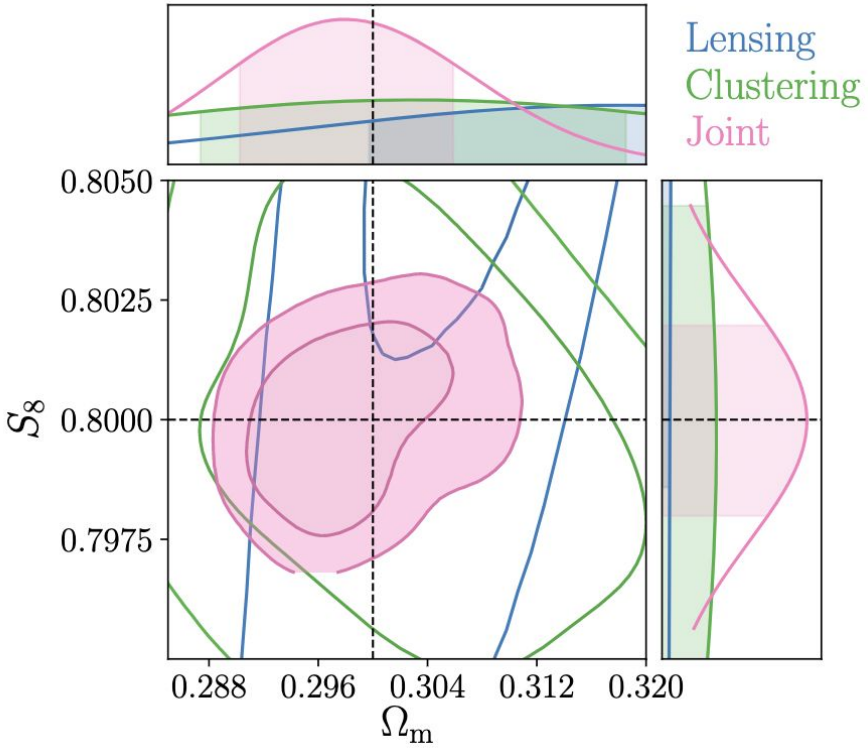


Method

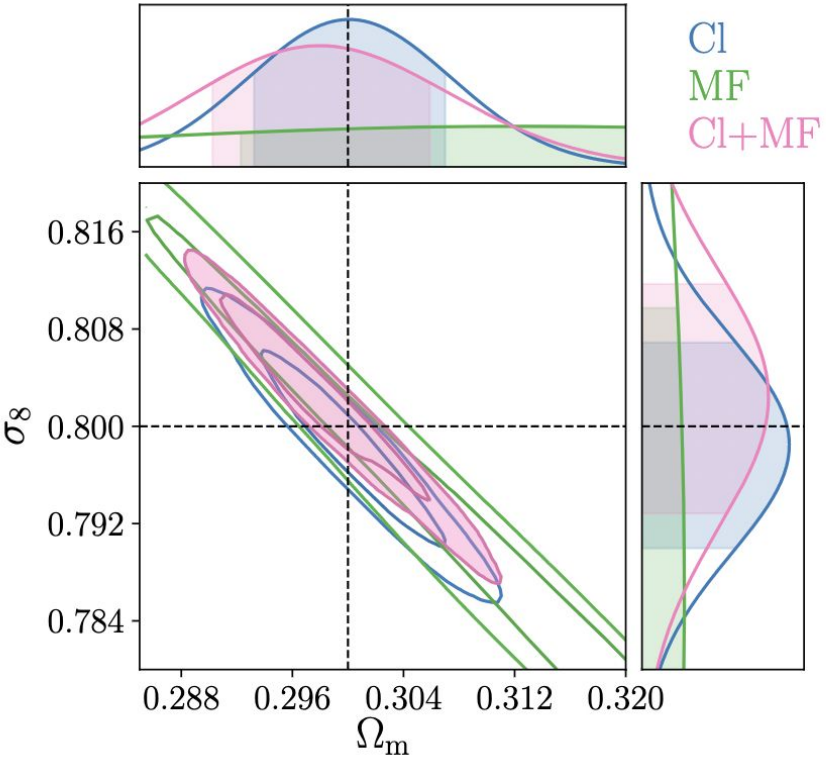
1. Generate simulated convergence and clustering maps
2. Calculate observables (MFs and/or power spectra Cls)
3. Calculate likelihood
    - Get covariance and mean from a set of simulations at fixed cosmology
4. Use Emcee via CosmoSIS to explore the parameter space

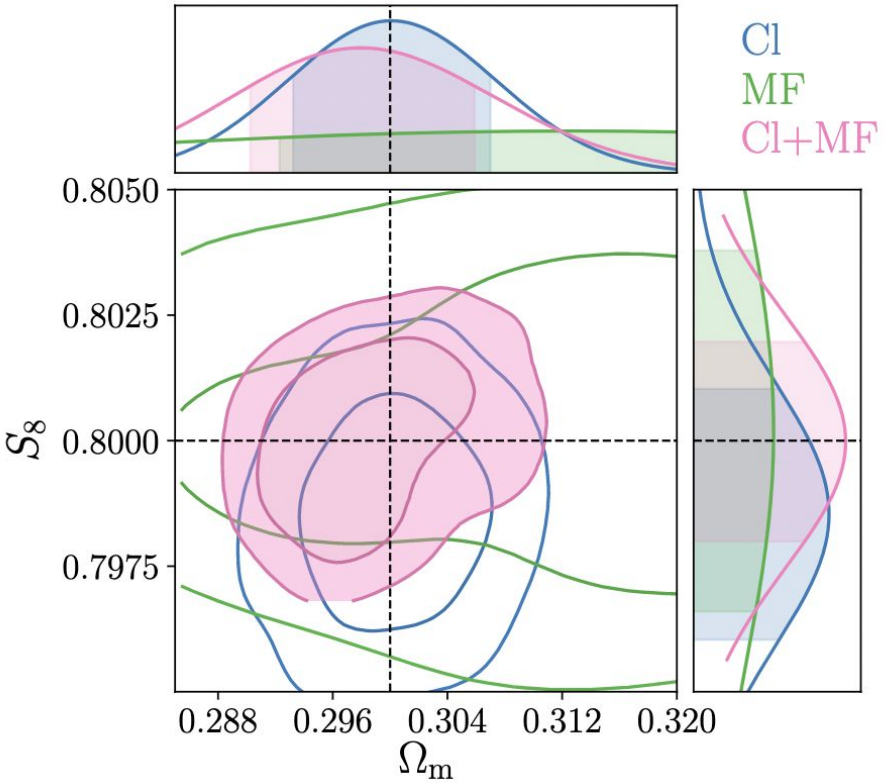
Results - Map Type (with MF+Cl)





Results - Observables (with lens+clust)





Conclusion

- For a simplified model with both convergence and clustering, MFs don't add information not already contained by Cls

- Adding clustering to the analysis has a significant improvement on the constraints in an joint Minkowski and power spectra analysis, just as in the standard 3x2pt approach

- The S_8 degeneracy direction from MF measurements is the same as for power spectrum measurements
  - Compared to other parameters, it is a more useful diagnostic of constraining power with analysis type and map type

Future Work

- To get stronger constraints from MF calculations, one must study small-scale non-linear regimes with baryonic effects

- Speed up the slow likelihood calculations. Examples:
  - emulator
  - neural network

- Likelihood-free inference

- Other potential applications for MFs:
  - measuring them from shear maps instead of convergence maps
  - doing a cross correlation analysis

Thank you