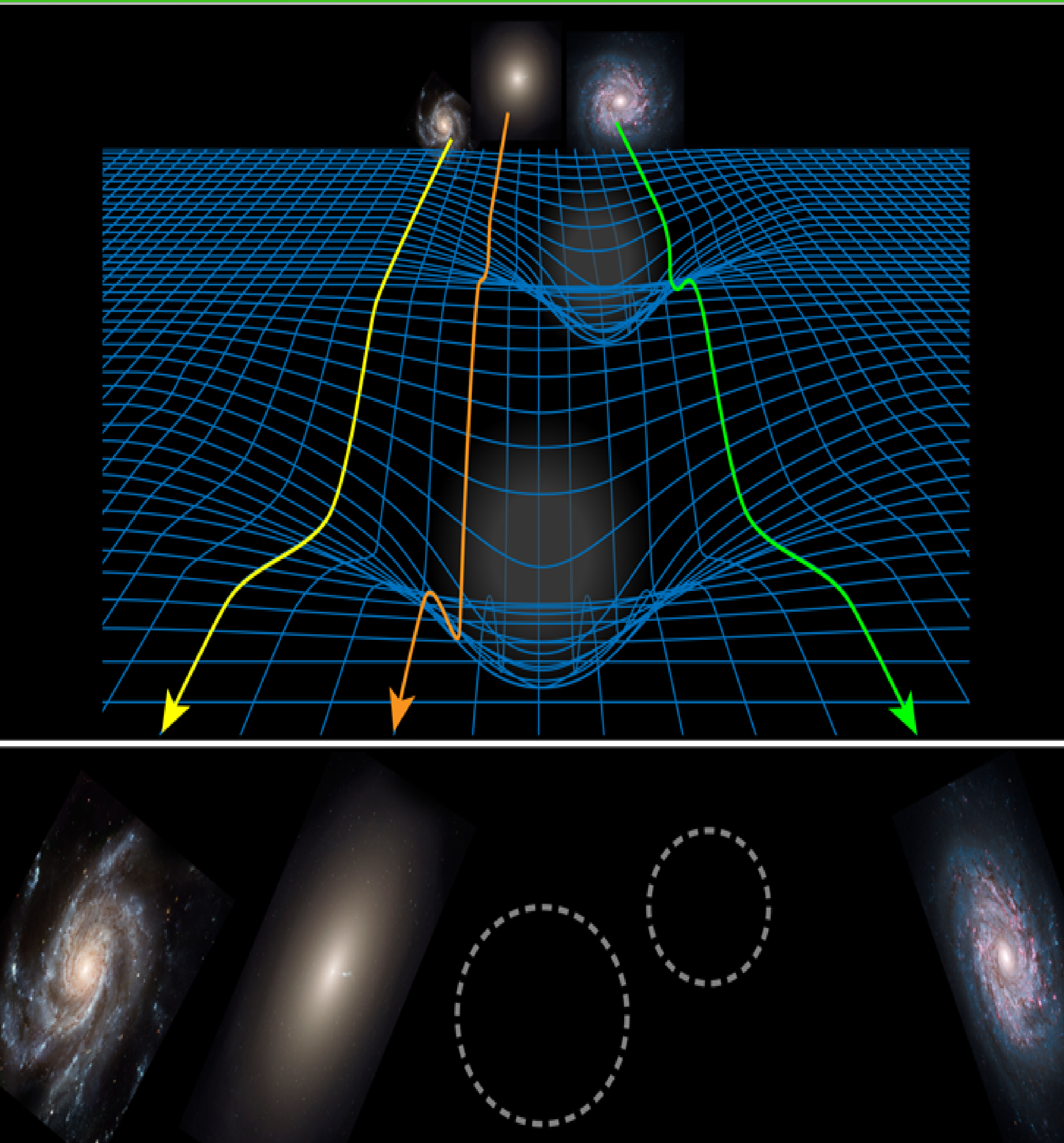
Weak Lensing By Voids In Weak Lensing Maps

Chris Davies
Supervisors: Baojiu Li & Marius Cautun
Durham University

Motivations

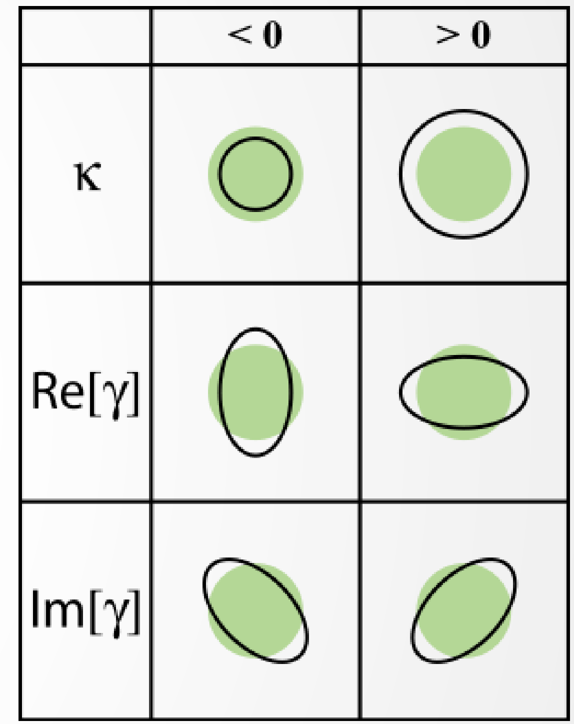
- Most void studies focus on galaxy voids, which are biased tracers
- Voids are understood as matter underdensities, so can we identify such underdensities in observations?
- Weak lensing directly probes the (projected) mass distribution
- so what are properties of voids in weak lensing maps?
- Ultimately we are interested in the potential of weak lensing voids as new cosmological probes

Gravitational Lensing



Convergence

Shear

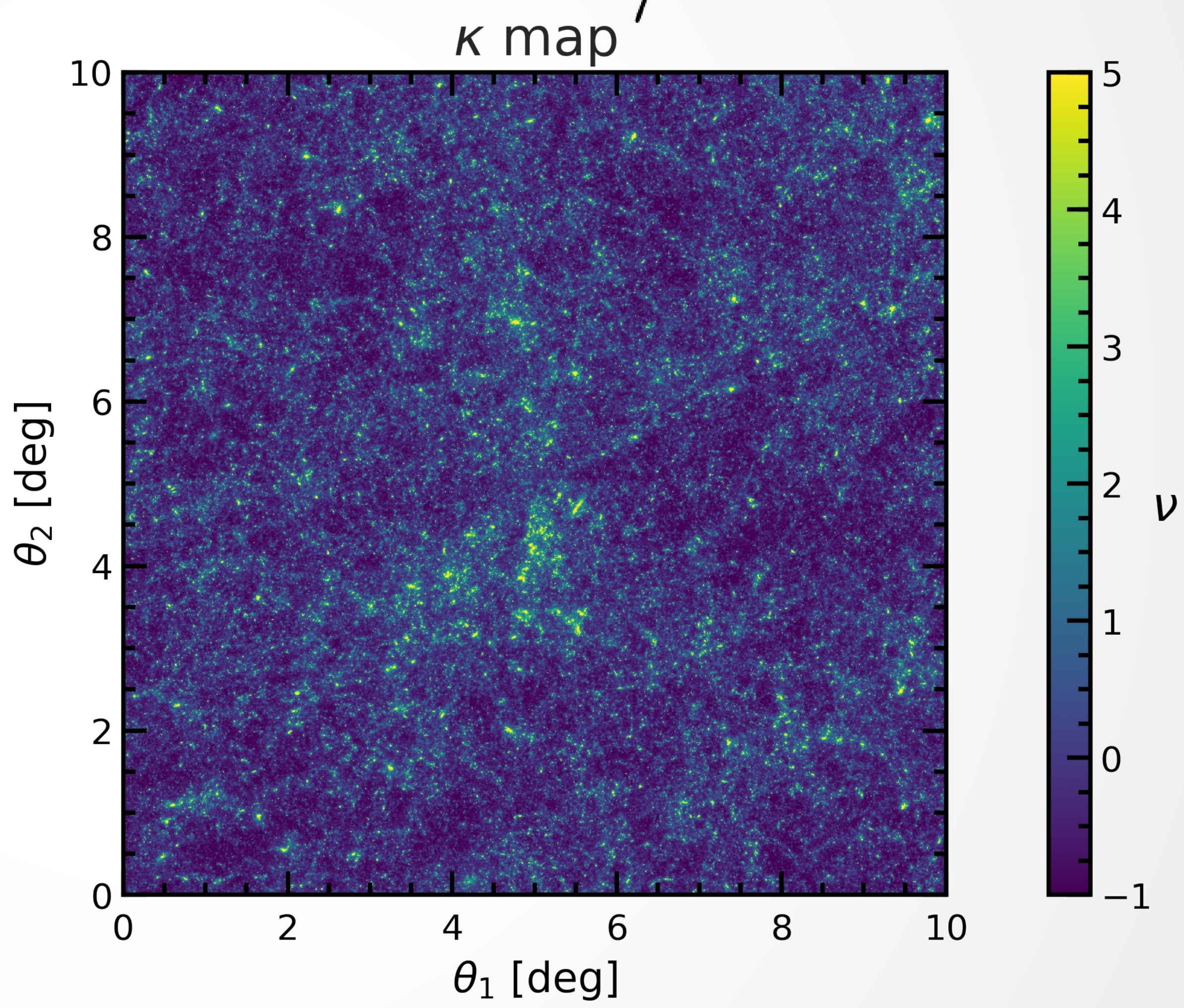


$$\gamma_t = \overline{\kappa}(< r) - \kappa(r)$$

Convergence Map

- Projected density weighted by lensing kernel
- Generated using on the fly ray – tracing
- high ν = high density
- Mean κ = 0

$$\nu = \kappa / \sigma$$



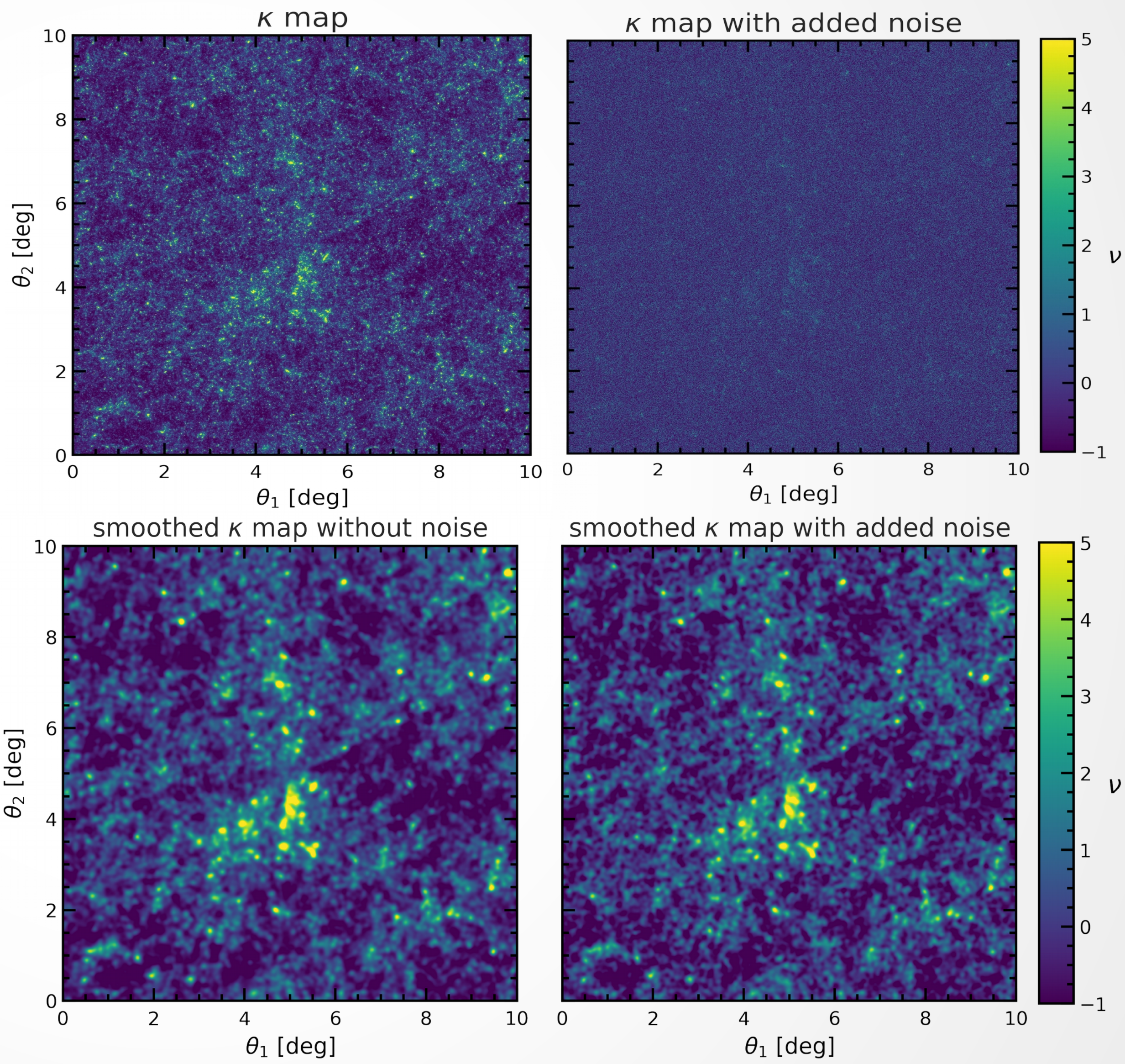
Galaxy Shape Noise

Adding Galaxy Shape Noise:

- Noise map generated to match LSST specifications
- $\sigma_{int} = 0.4$, $n_{gal} = 40$ arcmin^{-2}
- Signal is suppressed when adding noise

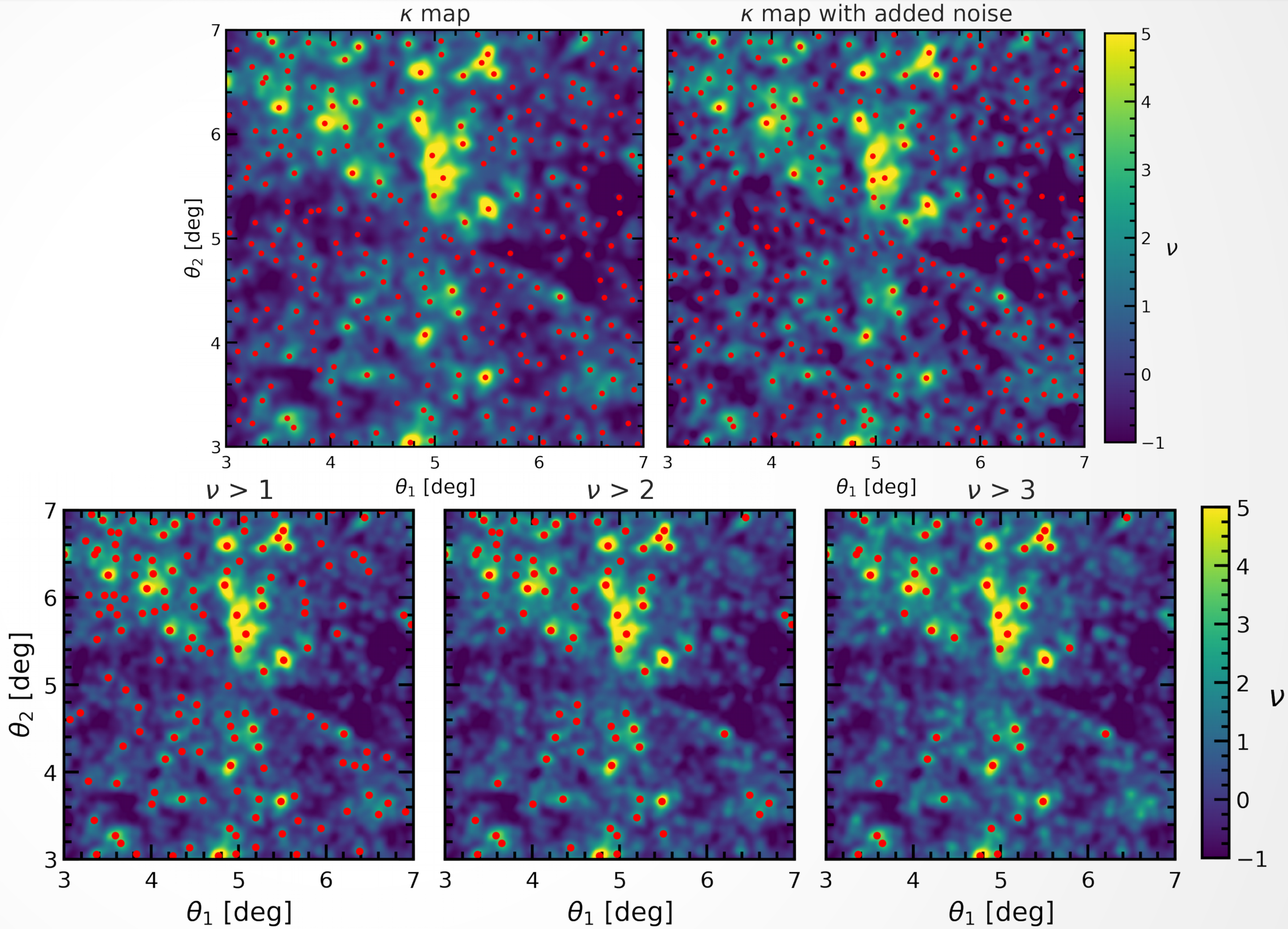
Recovering the signal:

- Smooth over 2.5 arcmin
- Smoothing length has been tuned to minimise impact of noise, without over smoothing



Weak Lensing Peaks

- A peak is a pixel at a local maximum (red)
- Galaxy shape noise adds some spurious peaks
- Produce different peak catalogues by trimming away peaks with low signal to noise ratio

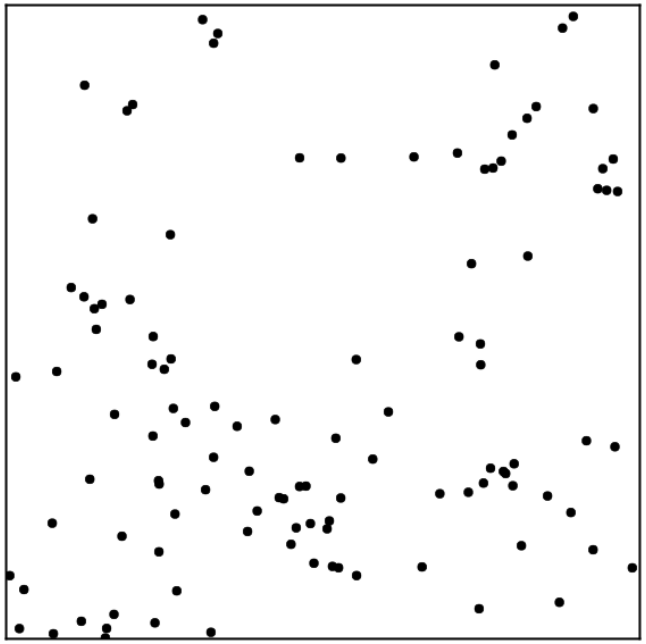


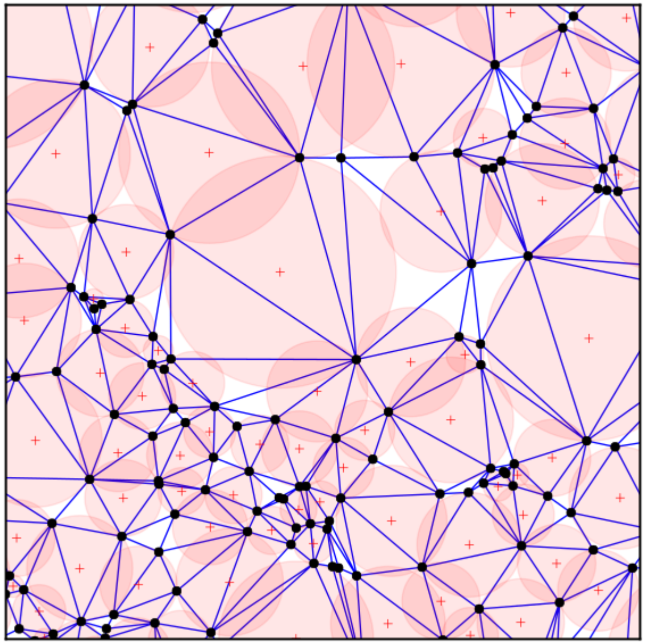
No galaxy shape noise case

Void Finding Algorithm

- In principle most void finding algorithms can be applied to the convergence map
- We use the Tunnel algorithm (Cautun et al 2018) – this gives us the largest circles that are empty of tracers
- We take WL peaks as our void tracer population

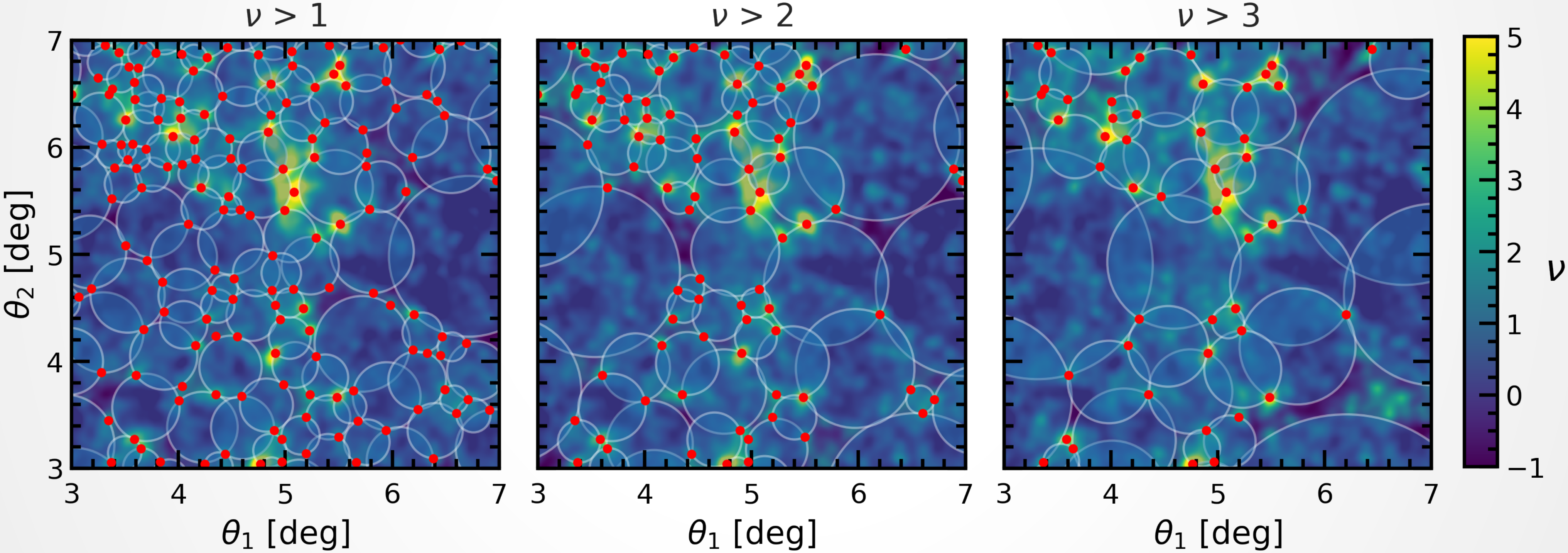
- The algorithm:
  - Build a delaunay tessellation with weak lensing peaks as vertices
  - Construct circumcircles out of tessellated triangles





Void Identification

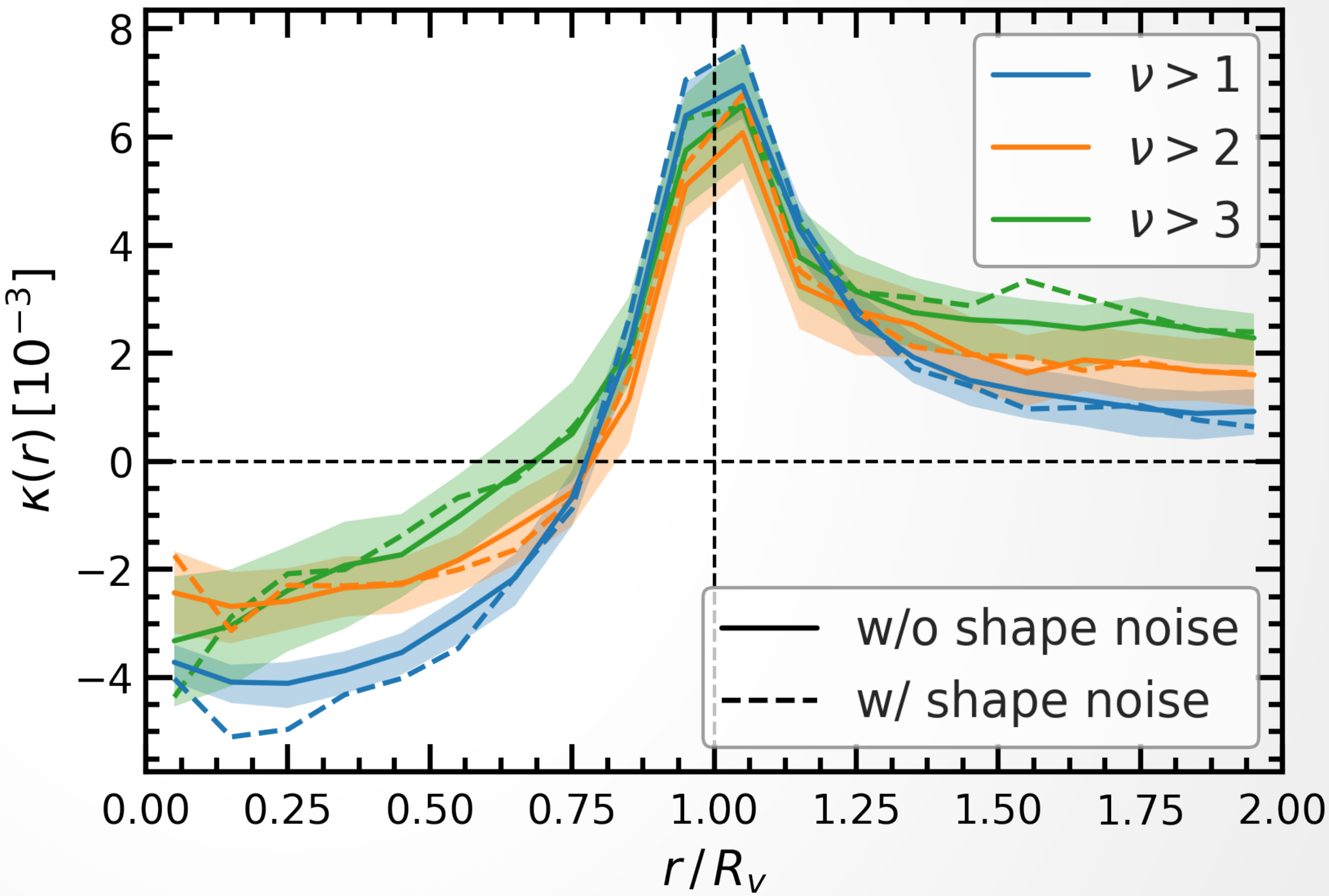
- These are our VOLEs (VOids from LEnsing)
- The 3 peak catalogues gives 3 void catalogues



No galaxy shape noise case

Convergence Profiles

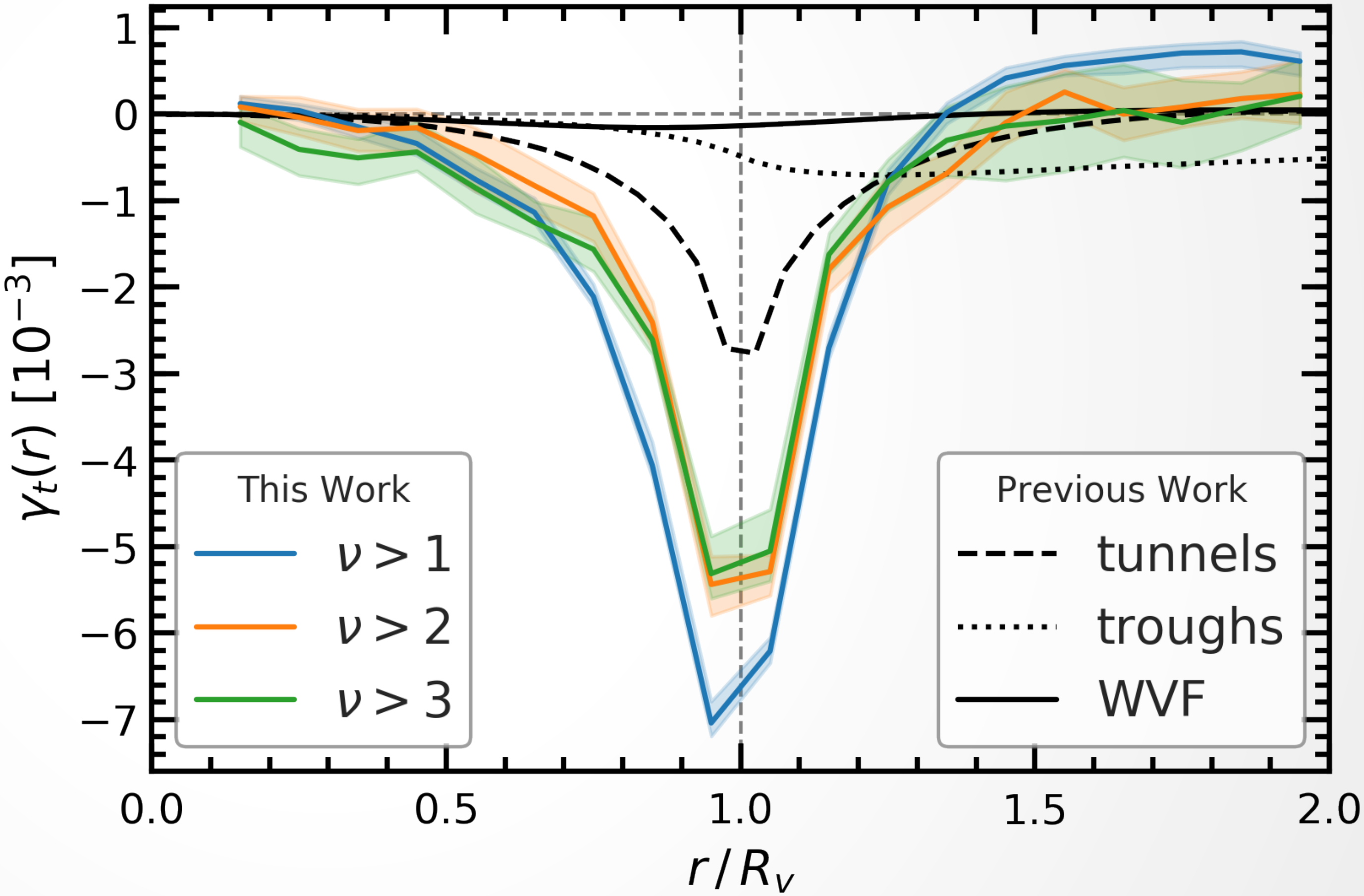
- Underdense at $r/R_v < 0.75$
- Smaller voids are more underdense
- Peak at $r/R_v = 1$
- Return to background at $r/R_v >> 1$



Comparison to Previous Works

- Negative shear => concave lens (diverging)
- Smaller errors than kappa profiles
- Signal is 2 to 25 times stronger than voids identified in the galaxy distribution
- Stronger signal is due to probing the underlying density field directly.

$$\gamma_t = \overline{\kappa}(< r) - \kappa(r)$$

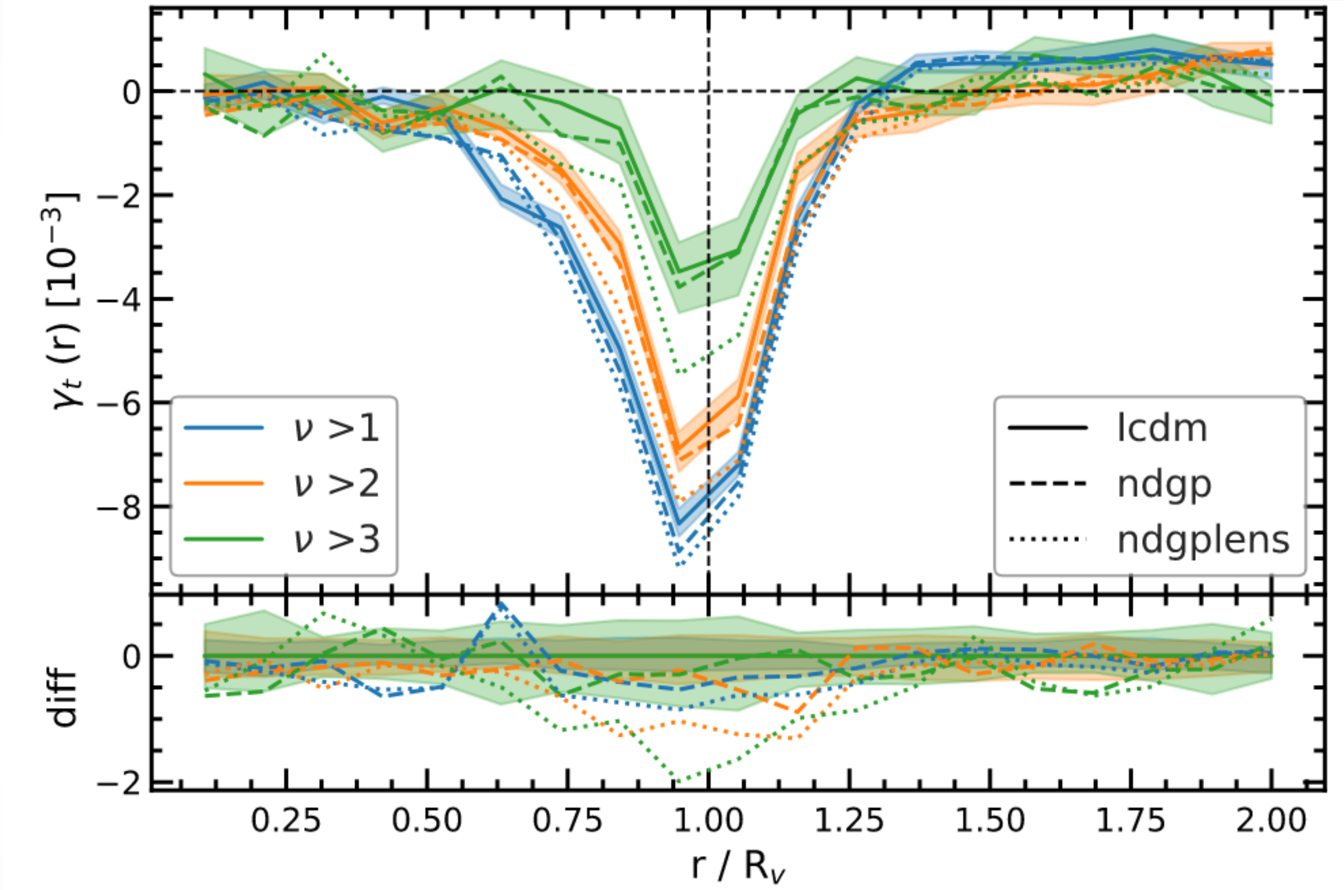


Application to Modified Gravity

- The models: nDGP and nDGP-lens (Barreira et al 2017)
- nDGP: The fifth force affects only the matter profile of voids
- nDGP-lens: Here the fifth force also directly modifies the lensing potential (photon geodesics)

Modified Gravity shear profiles

- Added Galaxy shape noise
- SNR ~8 for 100 deg^2
- LSST forecast SNR ~113 (~ $2x10^4$ deg^2)



Summary

- Void identification in weak lensing maps directly probes matter underdensities
- Here we have identified tunnels in convergence maps, however most void finders can be used on weak lensing maps.
- Weak lensing voids are considerably more underdense (in projection) than galaxy voids
- This method can be used to test alternative cosmological models