Imprints of cosmic voids in the CMB lensing maps

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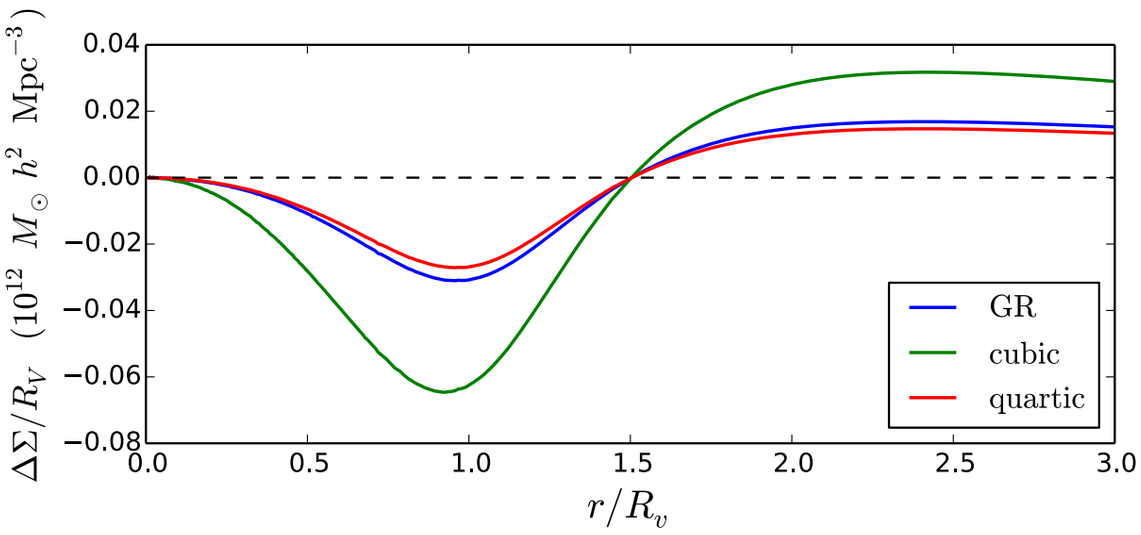
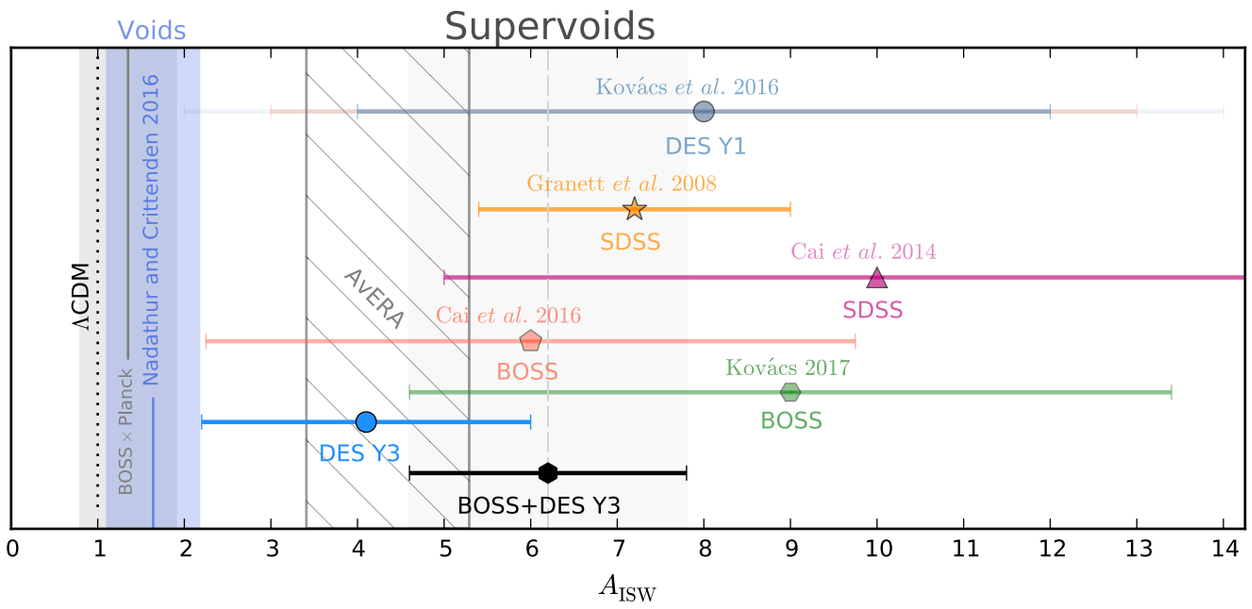
Motivations

Voids are good candidates to study Dark Energy and modified gravity models

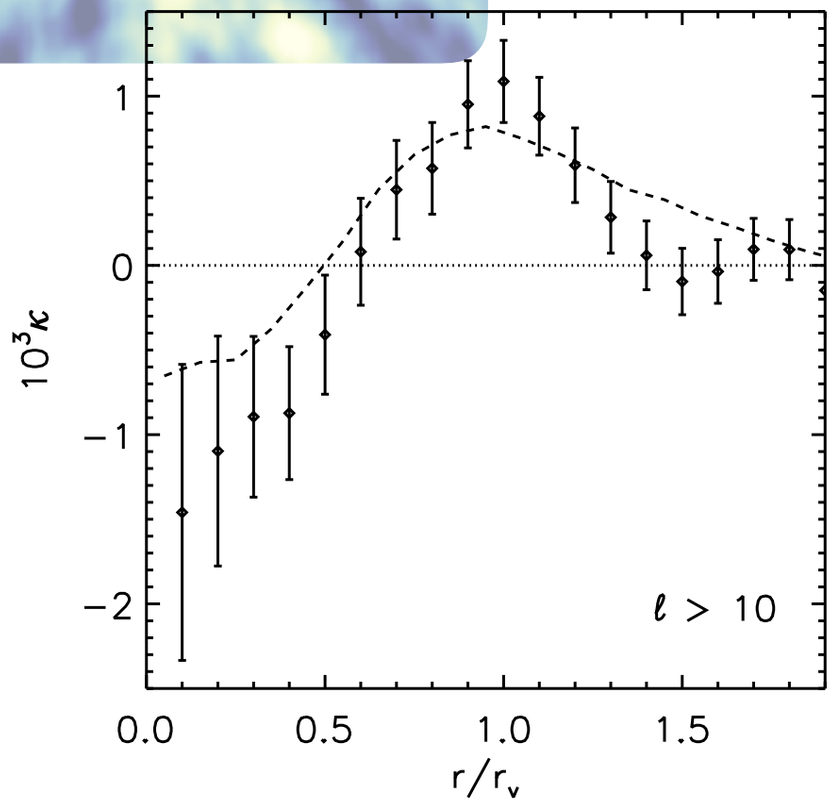


Excess imprint of cosmic voids in CMB temperature maps observed (ISW effect)



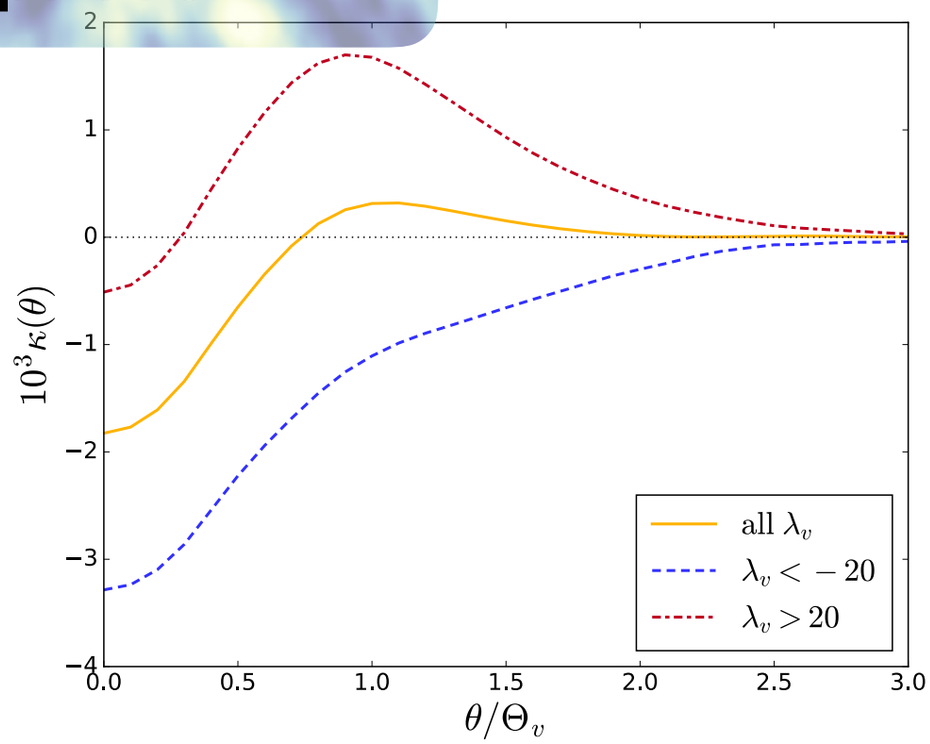
Motivations

One detection using BOSS data



Cai et al. 2017, MNRAS, 466, 3364

The signal depends on the void population



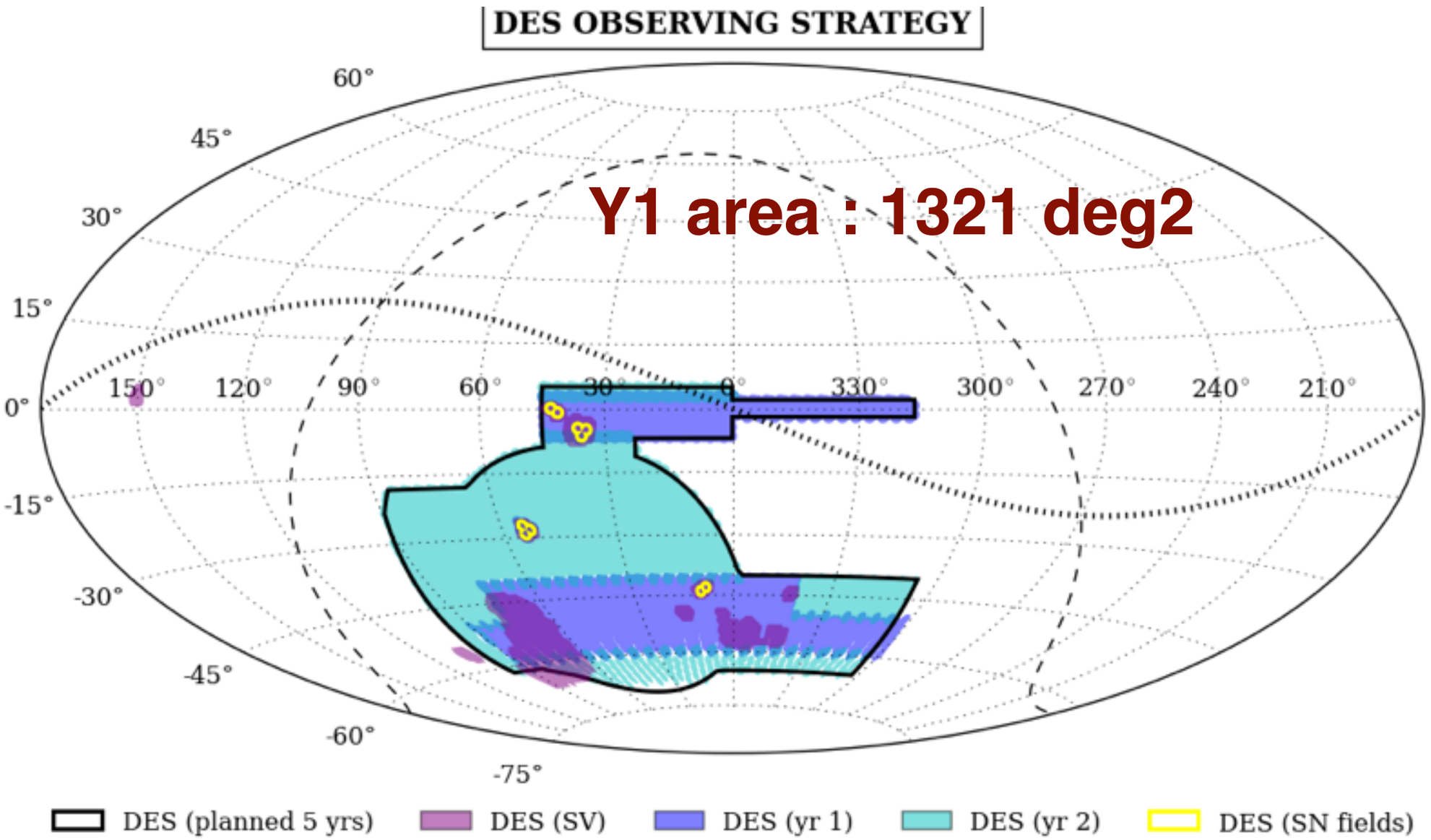
Nadathur et al. 2017, MNRAS, 467, 4067

Using simulations can help to prune our void catalog to optimize our detection

The Dark Energy Survey

Survey characteristics :

- **Imaging galaxy survey.**
- **5000 sq. deg. after 6 years (2013-2018)**
- **570-Megapixel digital camera, DECam, mounted on the Blanco 4-meter telescope at Cerro Tololo Inter-American Observatory (Chile).**
- **Five filters are used (grizY) with a nominal limiting magnitude $i_{AB} \simeq 24$ and with 10 passes with a typical exposure time of 90 sec for griz and 45 sec for Y**


DES OBSERVING STRATEGY
Y1 area : 1321 deg2
60°
45°
30°
15°
0°
-15°
-30°
-45°
-60°
-75°
150°
120°
90°
60°
30°
0°
330°
300°
270°
240°
210°
DES (planned 5 yrs)
DES (SV)
DES (yr 1)
DES (yr 2)
DES (SN fields)

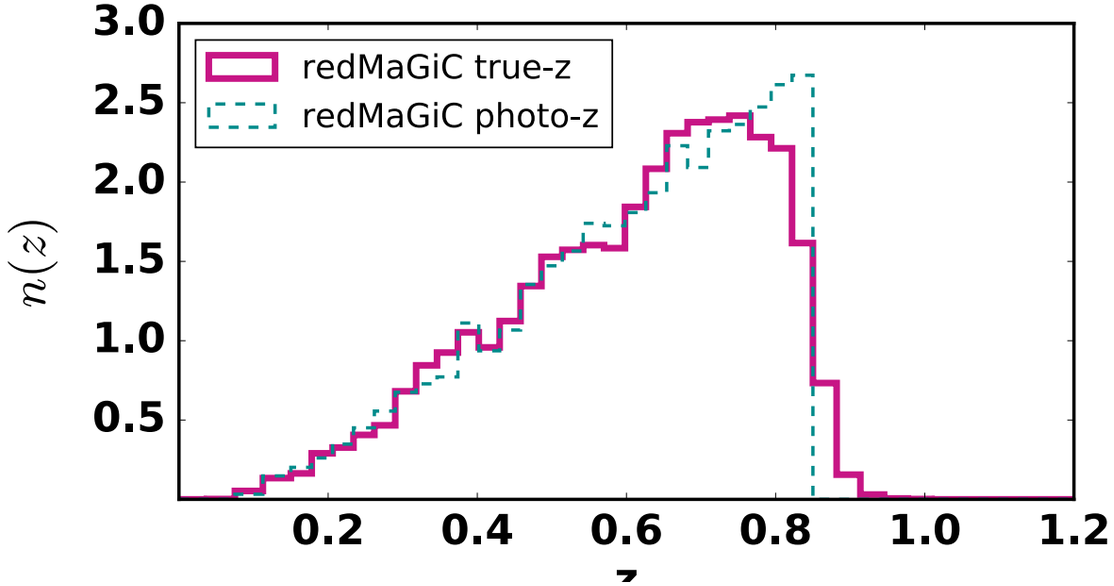
Reference : redMaGiC sample

redMaGiC algorithm is designed to select galaxies with high quality photometric redshift estimates

Rozo et al. 2016

Two tracers :

- **RedMagiC High-luminosity sample**
- **RedMagiC High-density sample**



The void finder

- **Divide the sample in redshift slices. 100*Mpc/h* slices are shown to be a good compromise considering *redMaGiC* redshift accuracy.**

- **Compute the density field for each slice by counting the galaxy number in each pixel and smoothing the field with a Gaussian with a predefined smoothing scale.**

- **Select the most underdense pixel and grow around it the void until it reaches the mean density.**

- **Save the void, erase it from the density map and iterate the process with the following underdense pixel.**

Sánchez et al. (DES Collaboration), MNRAS 465, 746, 2017.

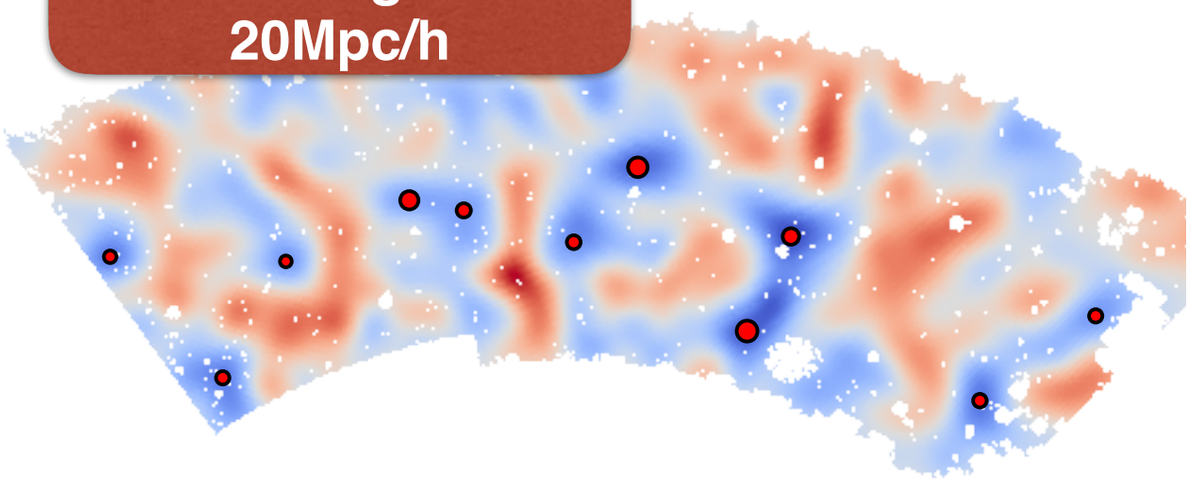
Two tracers :

- RedMagiC High-luminosity sample
- RedMagiC High-density sample

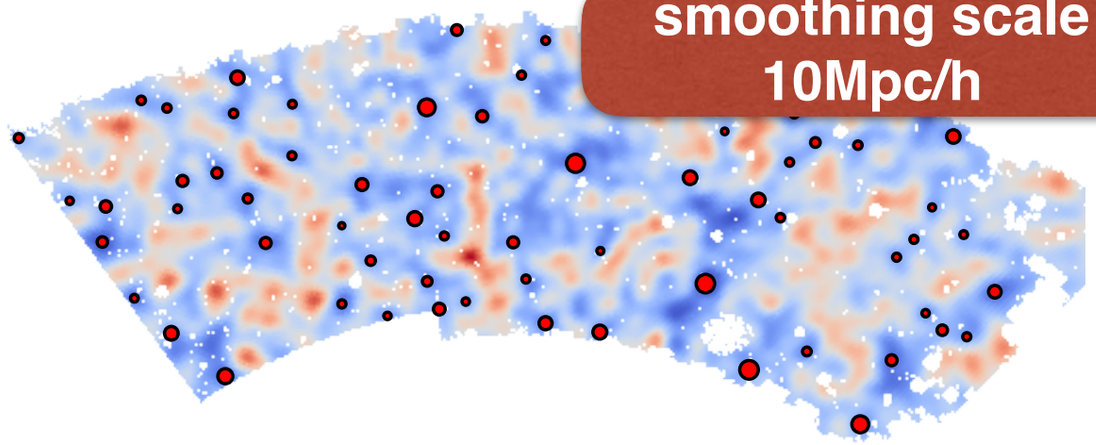
Two smoothing scales:
10 Mpc/h
20 Mpc/h

4 void catalogs

smoothing scale
20Mpc/h

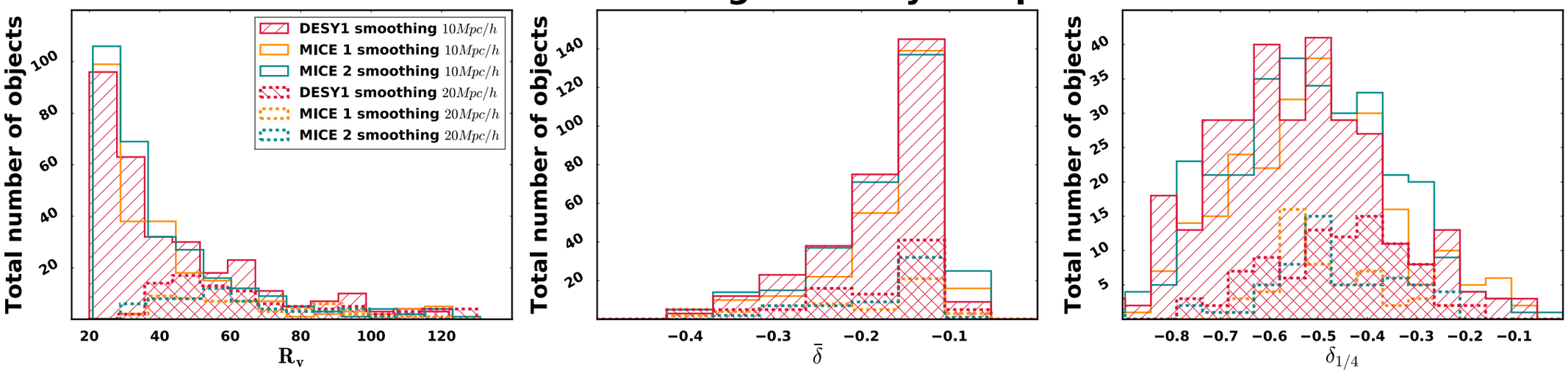


smoothing scale
10Mpc/h

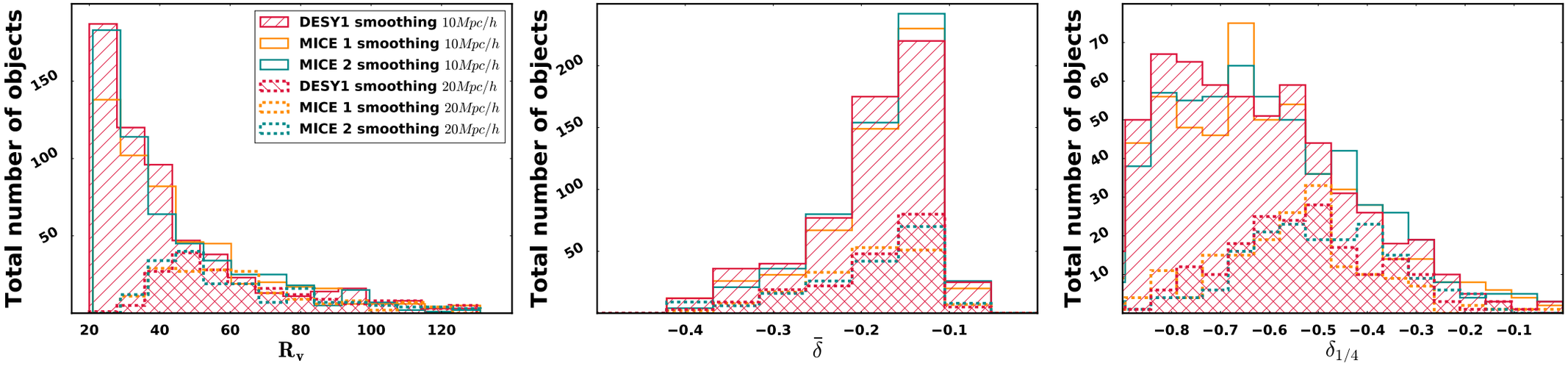


Catalog comparison

redMaGiC High-density sample

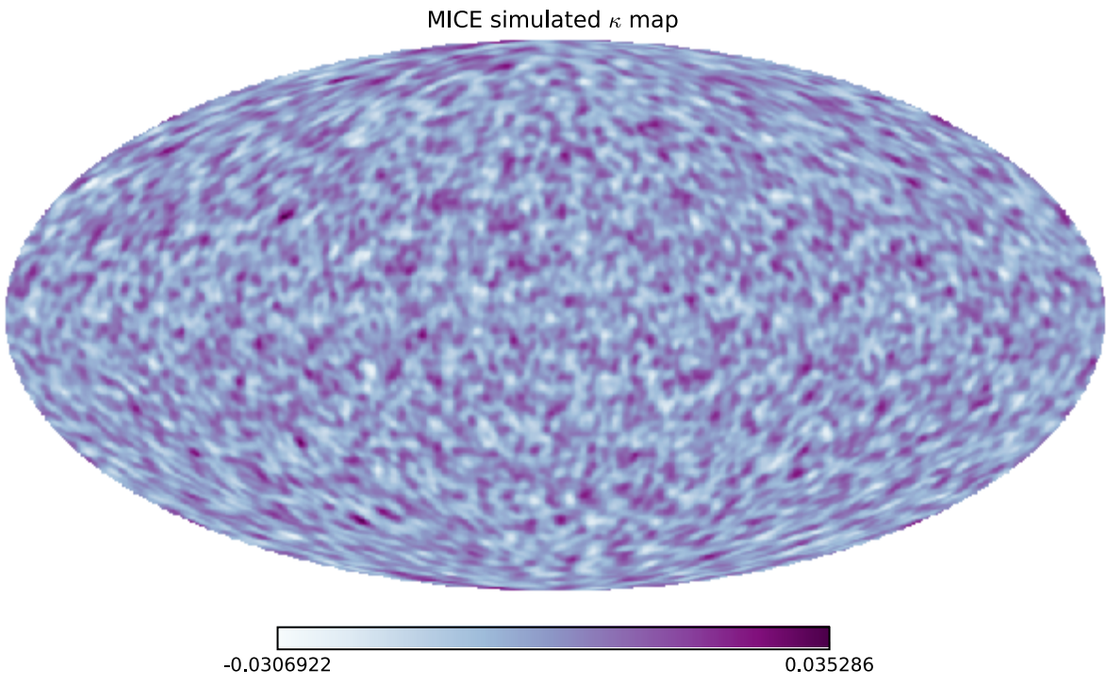


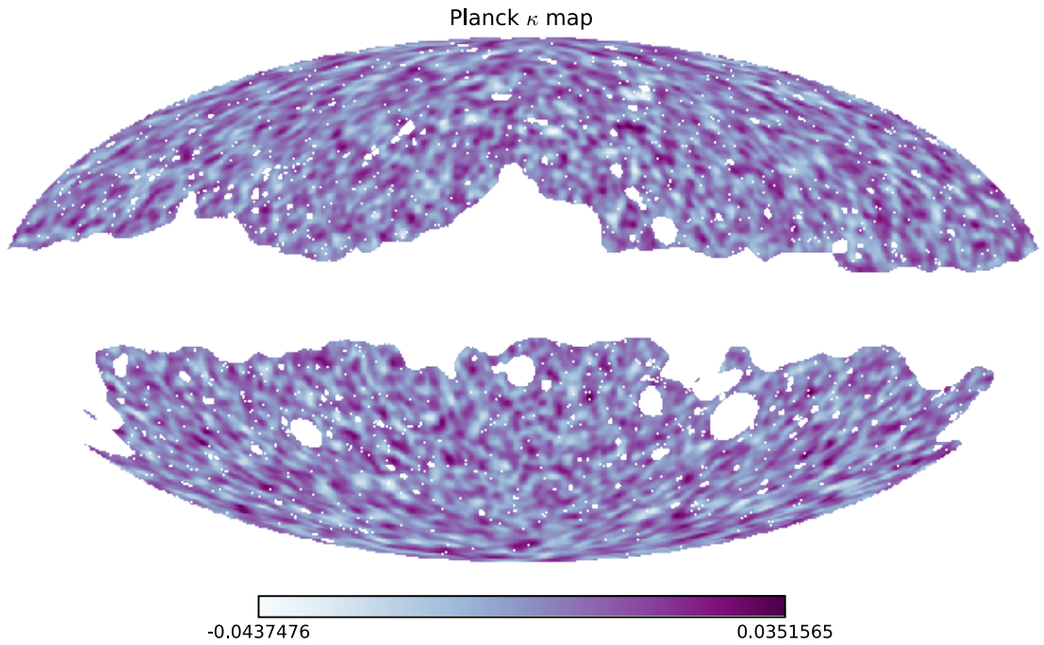
redMaGiC High-luminosity sample



High density			
Smoothing	DES Y1	MICE 1	MICE 2
10 Mpc/h	303	262	294
20 Mpc/h	89	64	64
High luminosity			
Smoothing	DES Y1	MICE 1	MICE 2
10 Mpc/h	579	524	564
20 Mpc/h	195	180	181

The CMB convergence maps





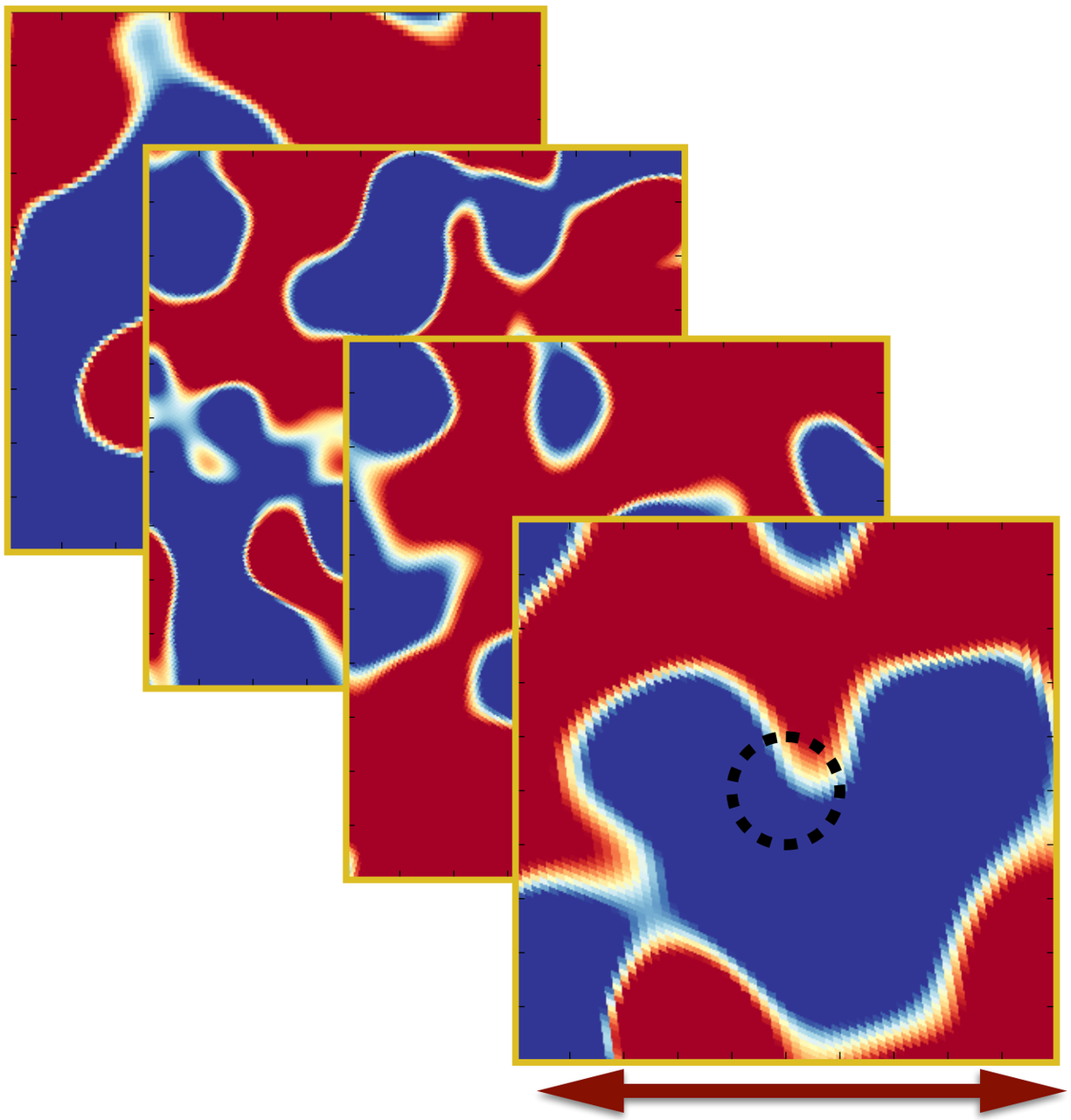
flat standard ΛCDM

$\Omega_m = 0.25, \Omega_\Lambda = 0.75, \Omega_b = 0.044,$

$\sigma_8 = 0.8$ and $h = 0.7$

Planck 2015 results. XV. (2016)

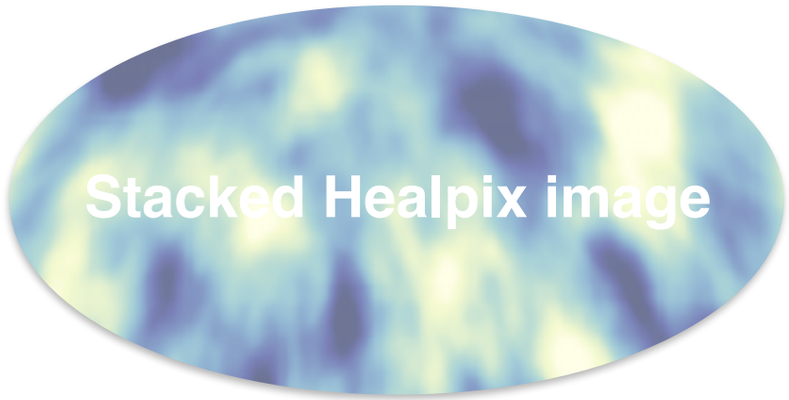
Stacking methodology

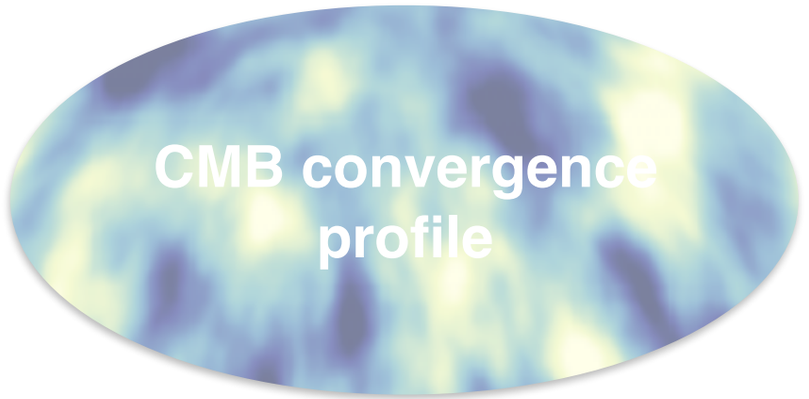


5 times the void radius

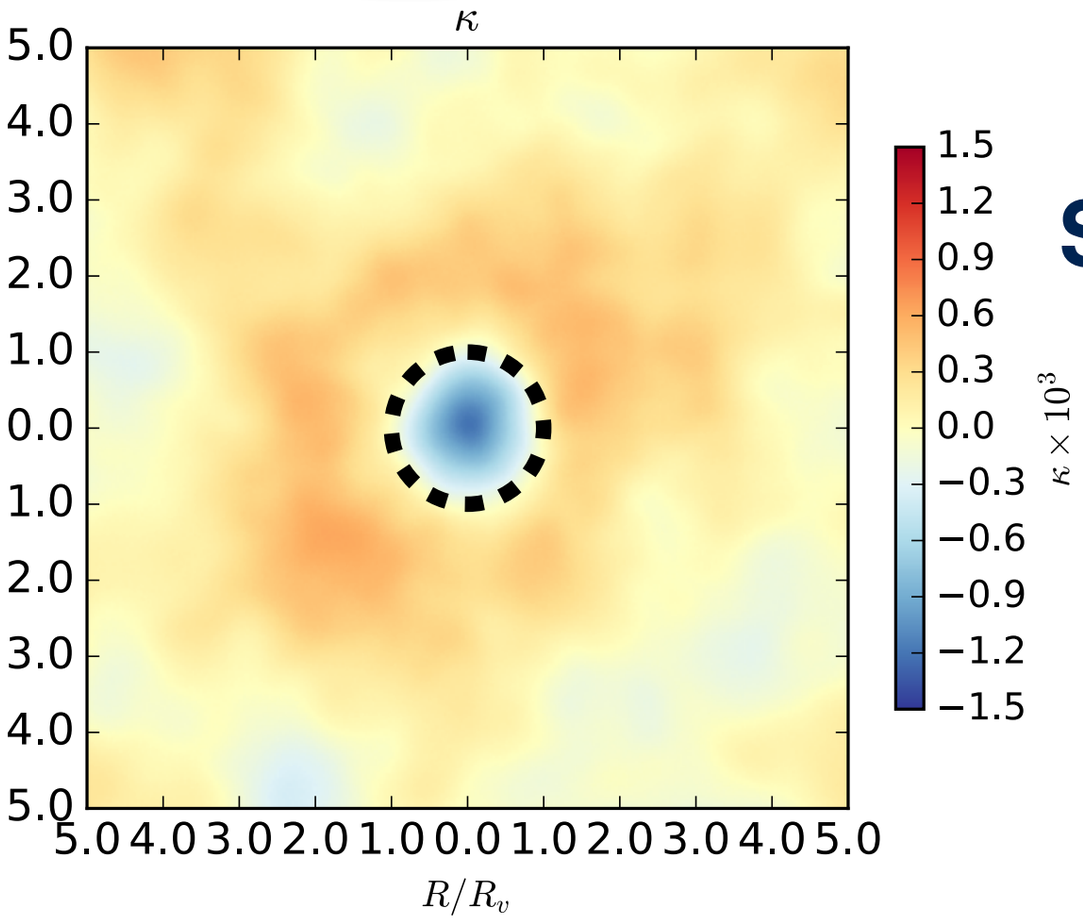
- Cutting out patches of the CMB convergence map centered at the void center position using healpix (Górski et al., 2005).
- Re-scaling the patches given the angular size of voids.
- Stacking all patches and measuring the average signal in different concentric radius bins around the void center.

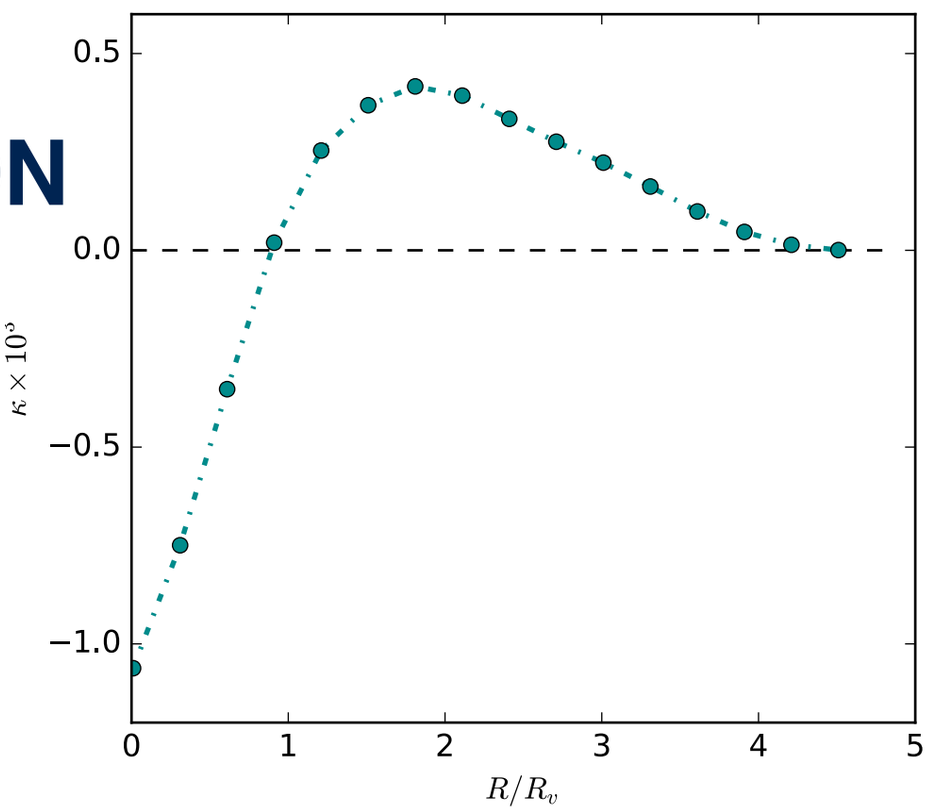
The stacking methodology



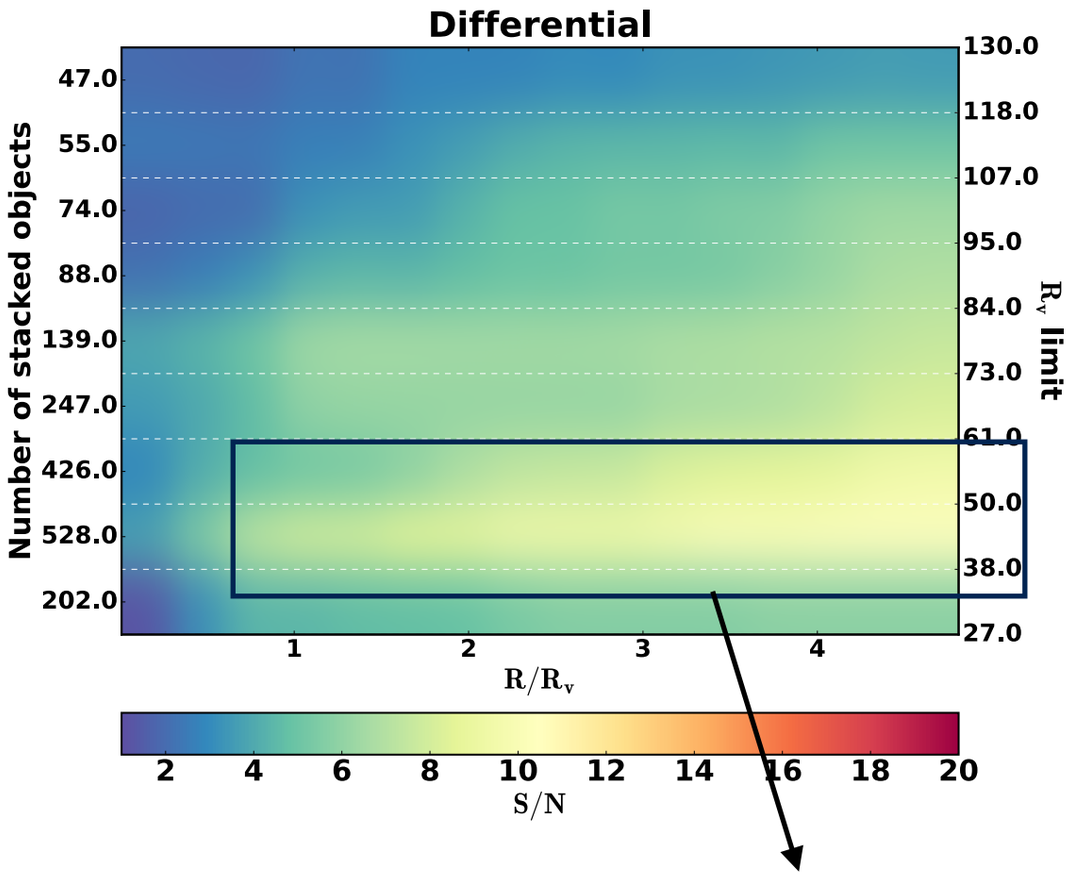


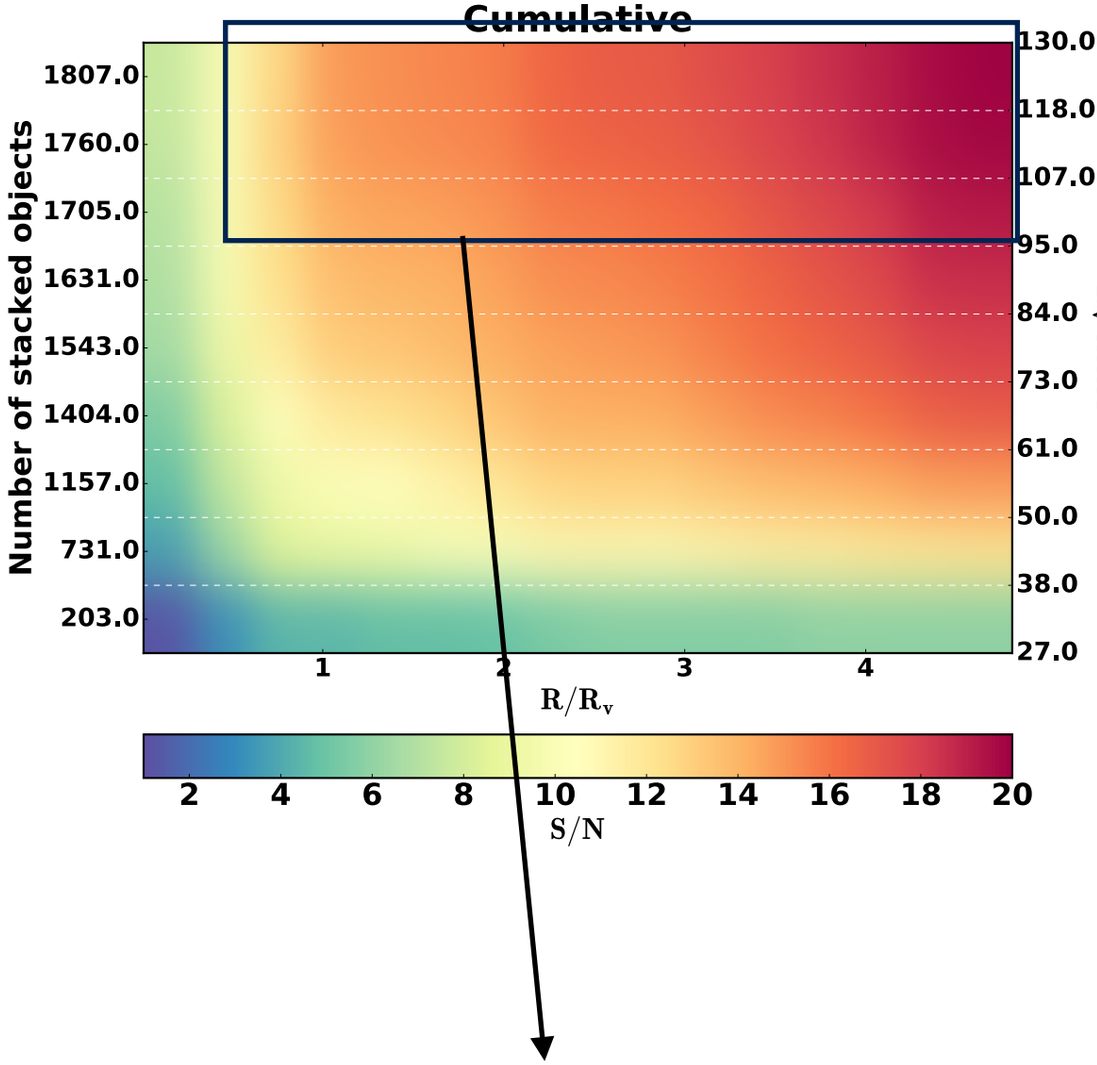
MICE SIMULATION





Optimisation

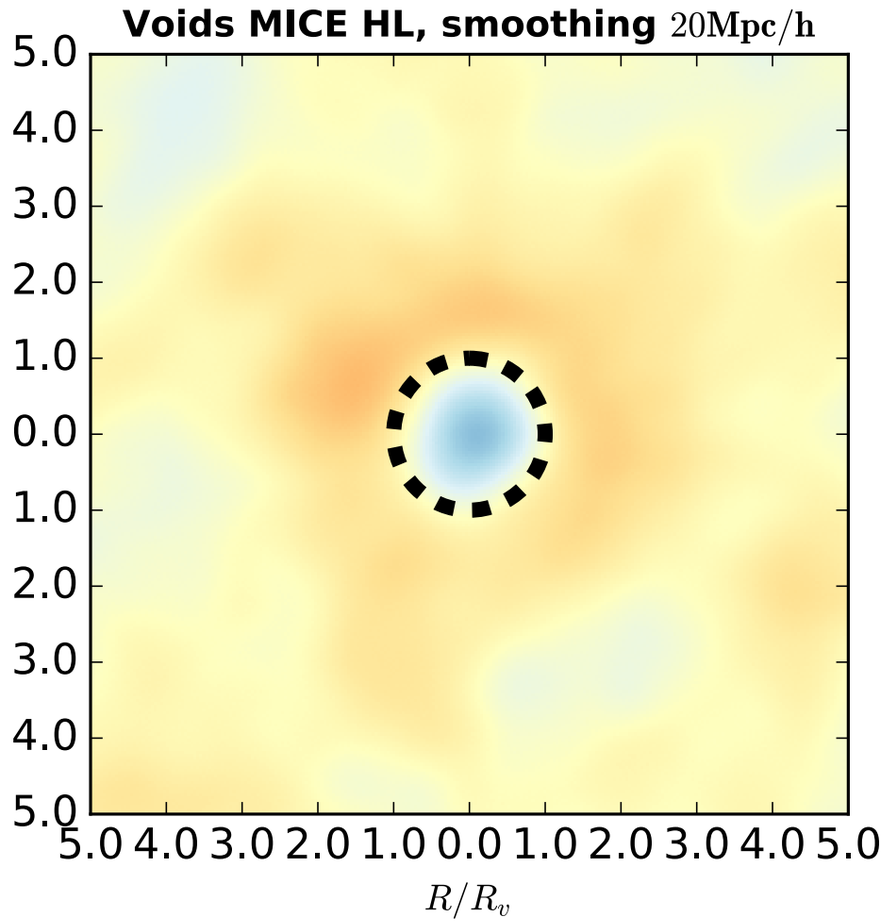


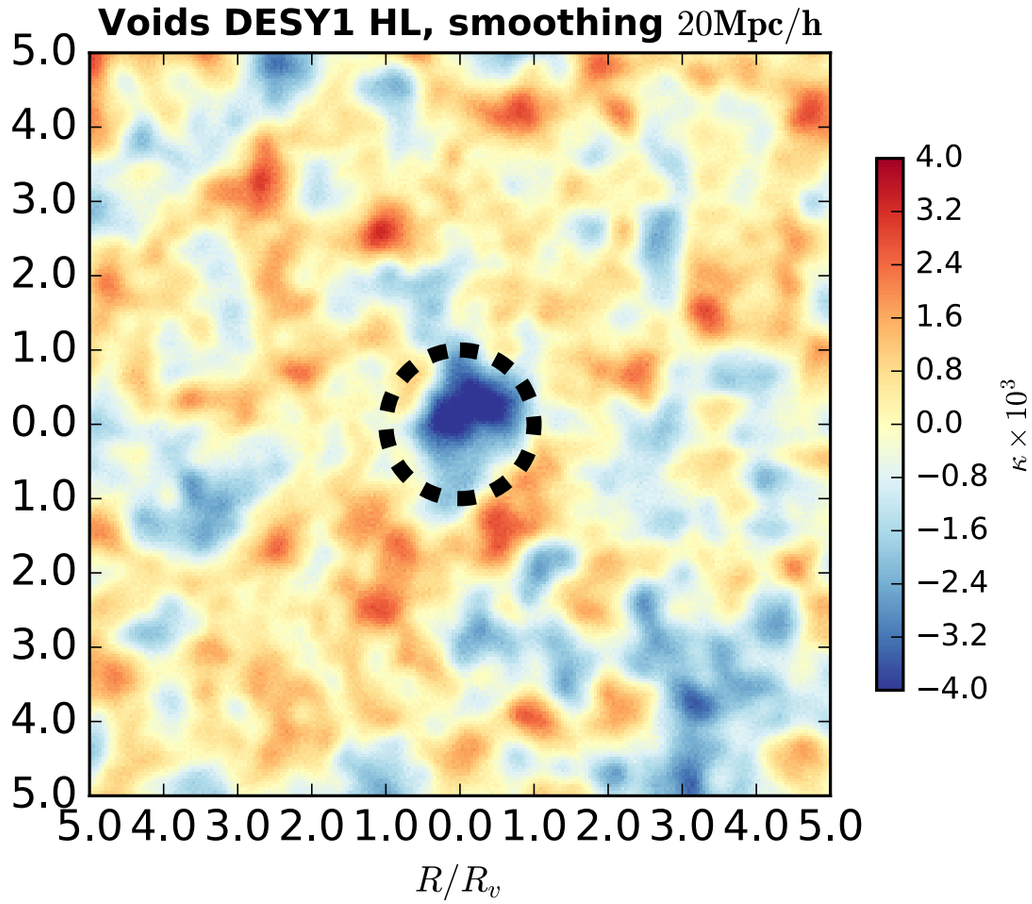


- **The most numerous medium size voids contribute most to the total lensing signal, i.e void with radius in the range 40*Mpc/h* <R_V <80*Mpc/h*.**

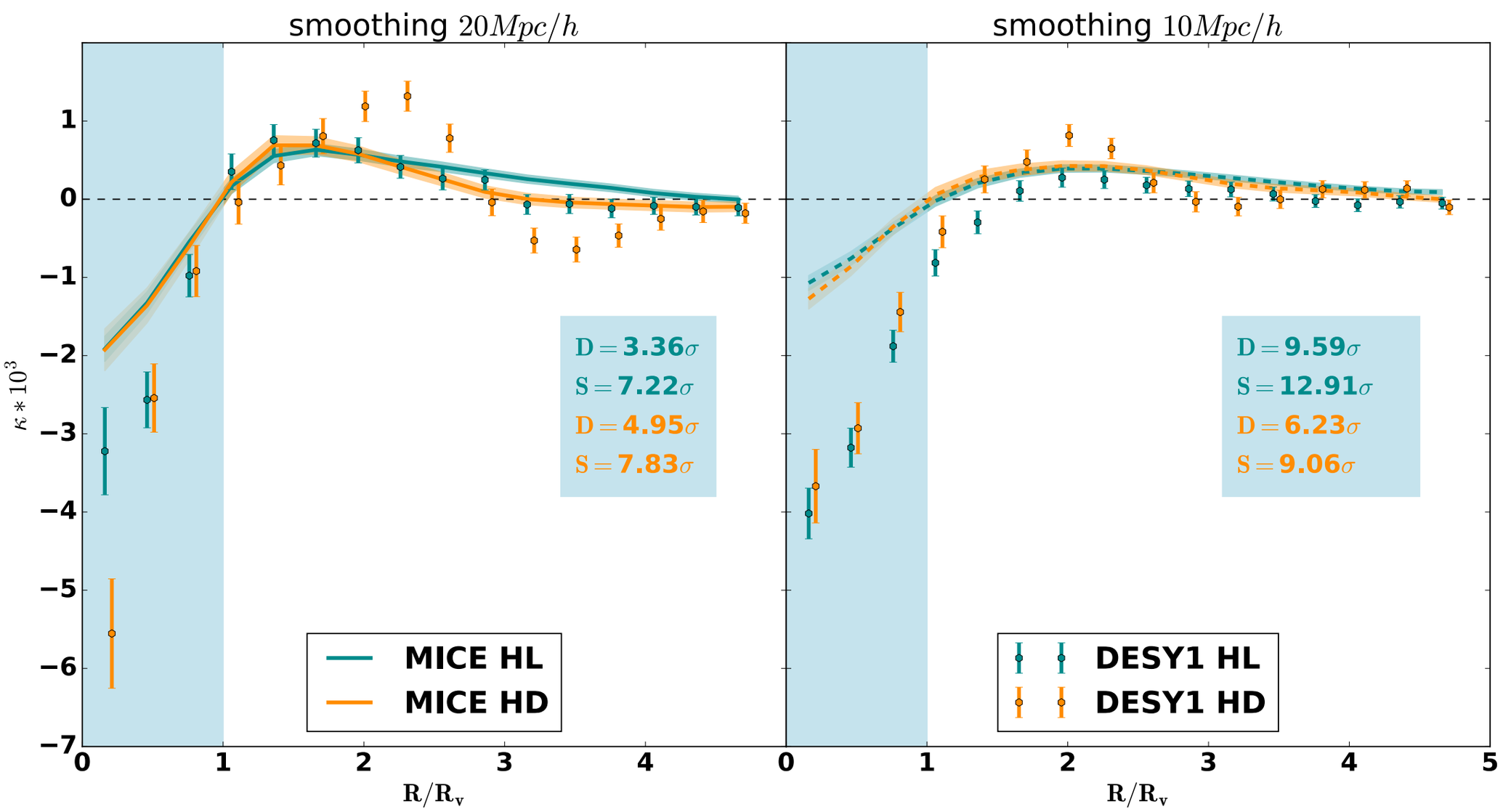
The highest S/N is achieved by stacking all voids, even if some voids are expected to contribute with less pronounced signal and higher noise at small scales.

Application to DESY1 data : Convergence signal comparison





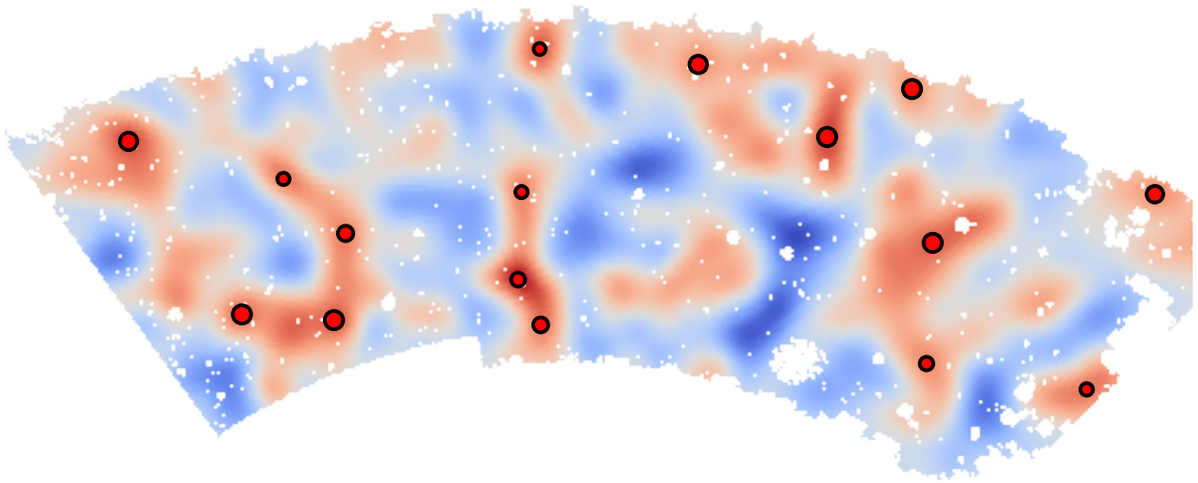
Application to DESY1 data : Convergence signal comparison

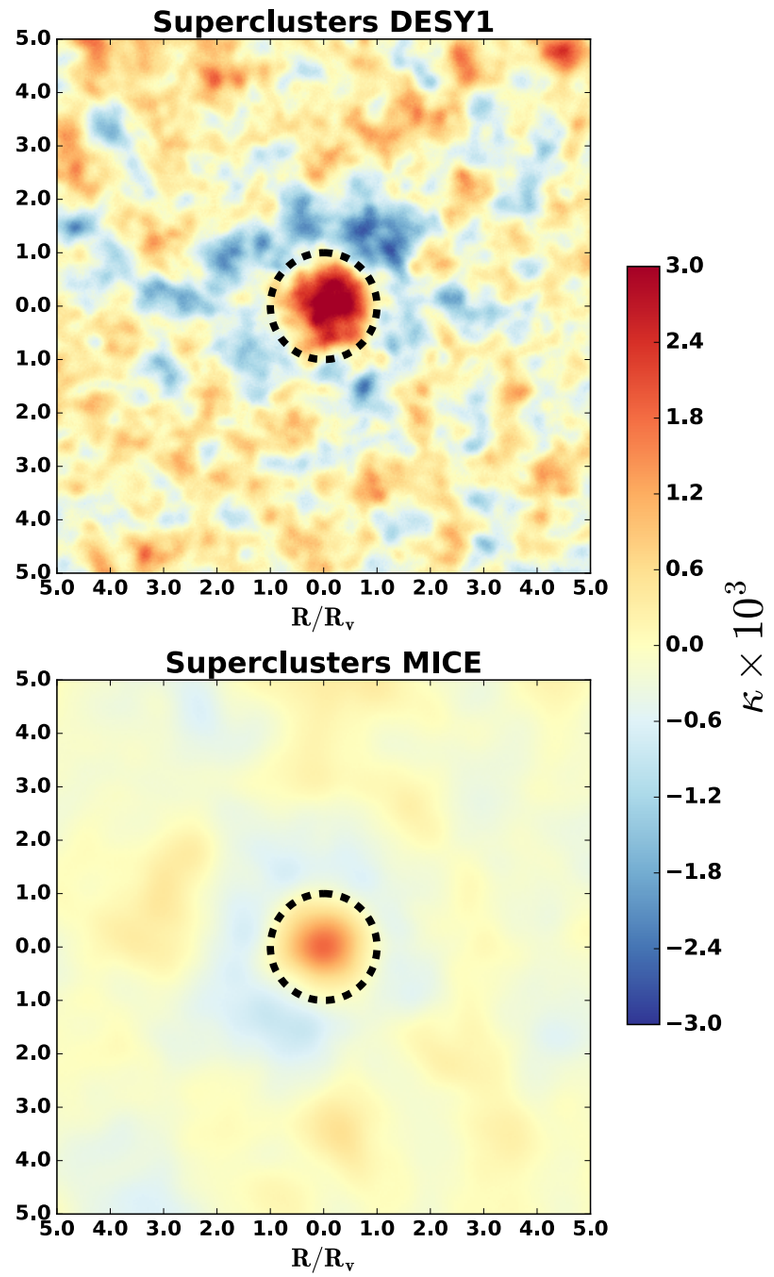


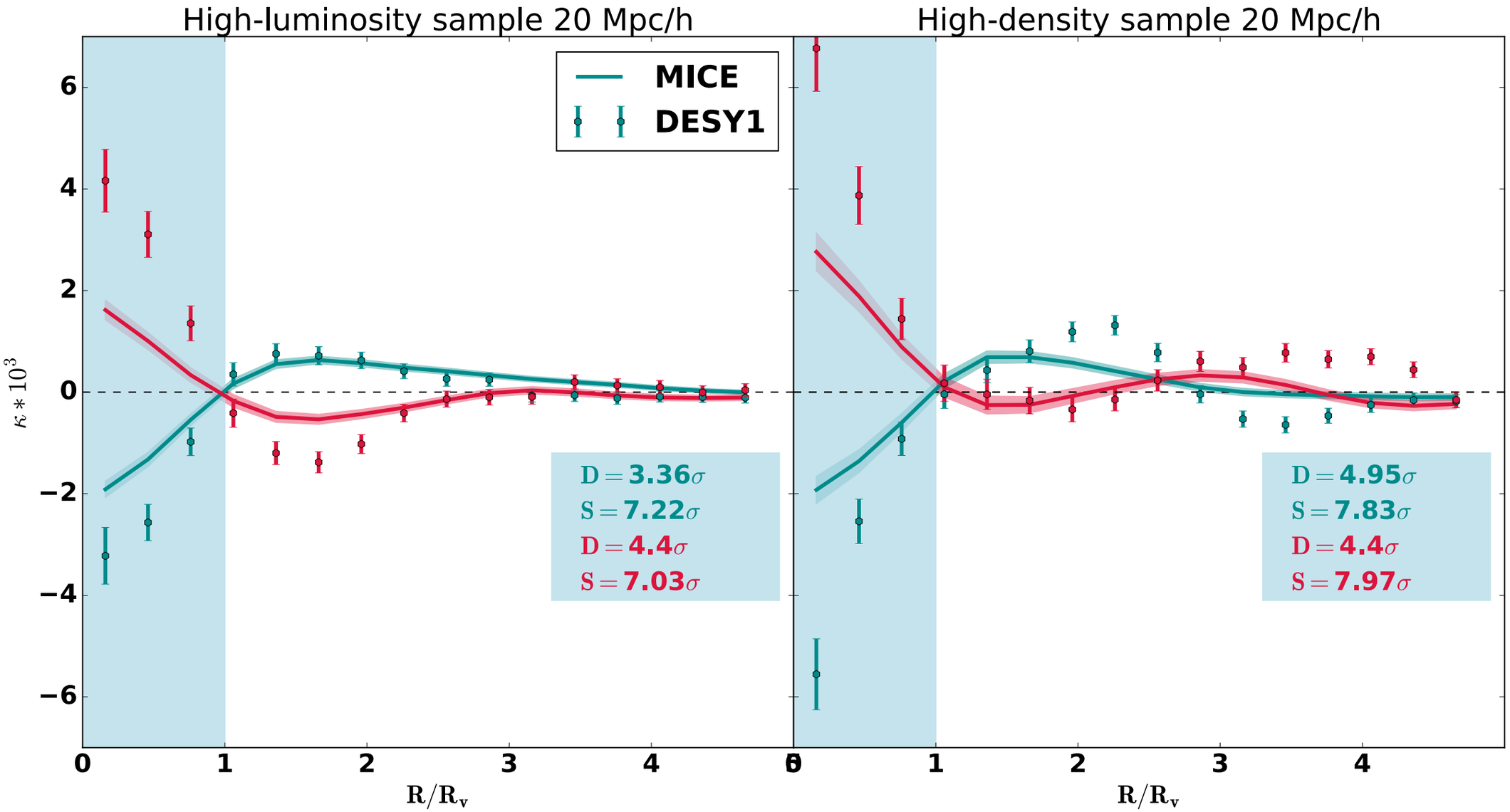
Errors computed using 500 randoms stacked profiles in the CMB convergence maps.

Super-clusters

Inverting the void-finder in order to identify super-clusters in our samples






High-luminosity sample 20 Mpc/h
High-density sample 20 Mpc/h
MICE
DESY1
D = 3.36σ
S = 7.22σ
D = 4.4σ
S = 7.03σ
D = 4.95σ
S = 7.83σ
D = 4.4σ
S = 7.97σ
κ ∗ 10^3
R/R_v
R/R_v

Conclusions and prospects

- Discrepancy have been claimed between observed and simulated imprints of voids in the CMB maps (Temperature and Lensing)

- So far these discrepancy exist only in comparison with LambdaCDM simulations (no theoretical model)

- Euclid will increase our statistical power in the field, and considering the reported discrepancy validation of the simulations will play an important role.

- How the signal behave in MG models?