DES X CMB
Voids X CMB lensing (DES)
Voids X CMB (DEMNUNii)

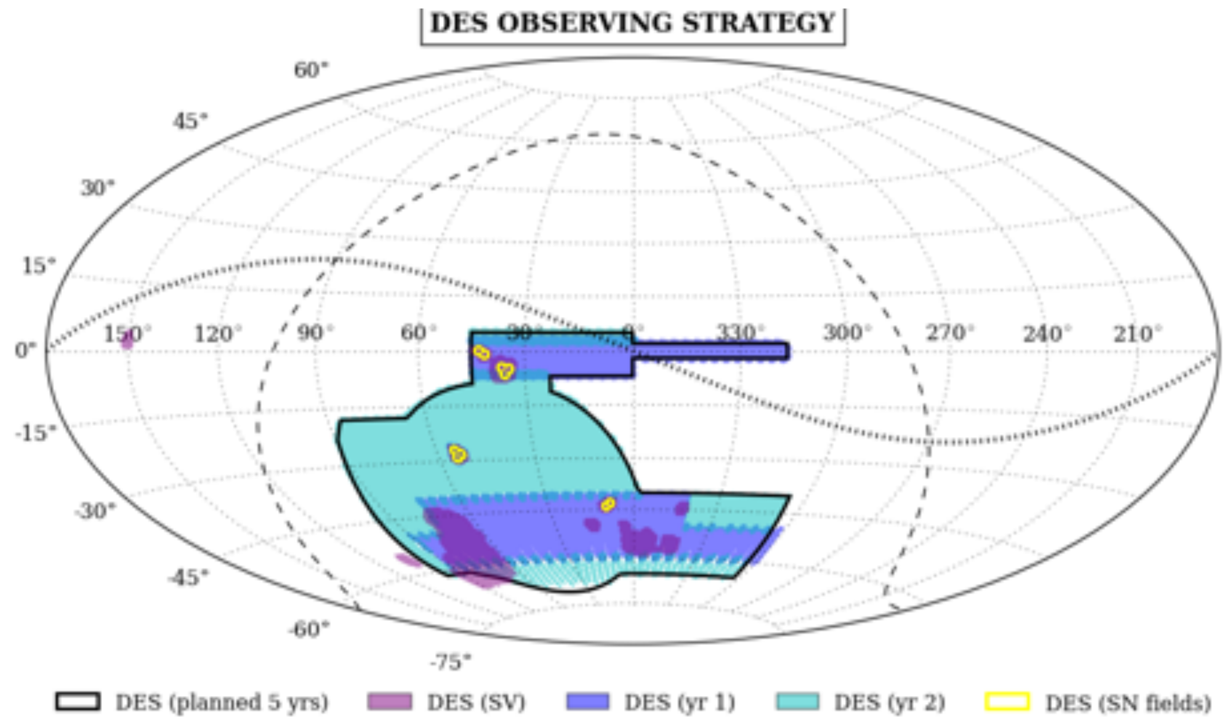
EuclidXCMB meeting, Bologna, November 5th

Pauline Vielzeuf + a lot of collaborators

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



DESxCMB

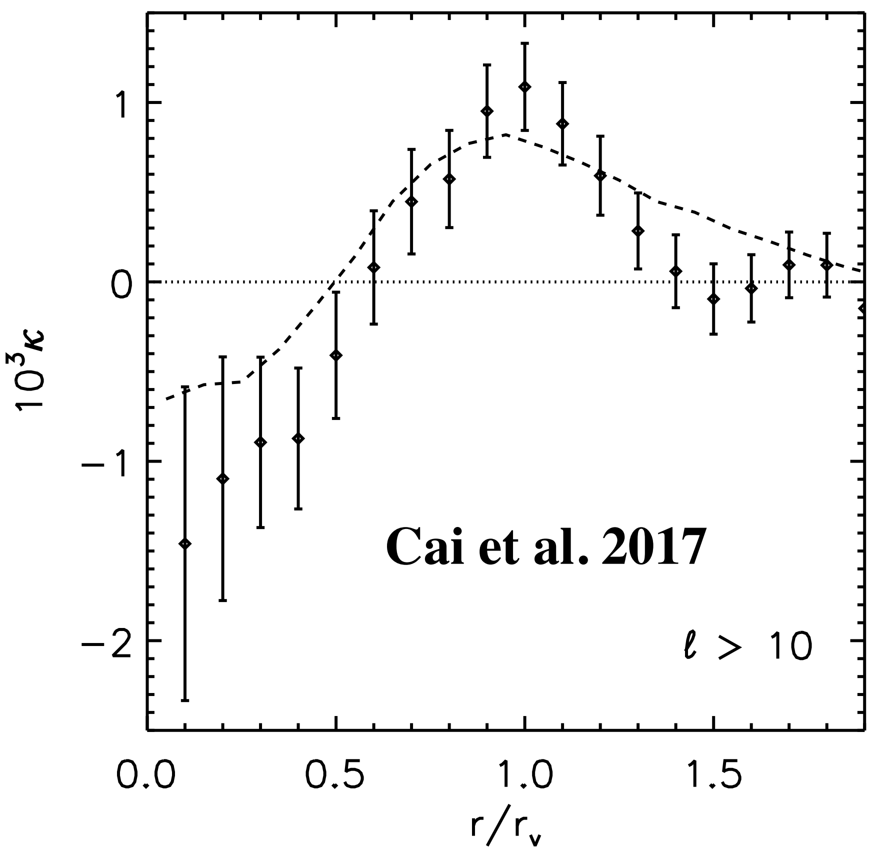
Paper	Title	Tracer (LSS)	CMB map	estimator	detection level/science
Giannantonio et al 2016	CMB lensing tomography with the DES Science Verification galaxies	Benchmark sample SV Crocce et al 2016	SPT convergence Planck convergence	$\omega^{\kappa g}$	6σ
Baxter et al 2016	Joint Measurement of Lensing-Galaxy Correlations Using SPT and DES SV Data	Benchmark sample SV Crocce et al 2016	SPT convergence	$\omega^{\kappa g} + \omega^{\gamma_t g}$	combined analysis cosmological parameter estimation
Kovács et al 2016	Imprint of DES super-structures on the Cosmic Microwave Background	Voids identified in DESY1 redMaGic galaxies	Planck (SMICA) CMB temperature map +Jubilee simulation	stacking	2σ tension with ΛCDM simulations
Baxter et al 2018	A Measurement of CMB Cluster Lensing with SPT and DES Year 1 Data	redMaPPer cluster catalog from DESY1	convergence SPT reconstructed	stacking	8.1σ detection constrain the amplitude of the relation between cluster mass and optical richness to roughly 17% precision
Omori et al 2018 (a)	Dark Energy Survey Year 1 Results: tomographic cross-correlations between DES galaxies and CMB lensing from SPT+Planck	redMaGiC sample DESY1	SPT + Planck lensing	$\omega^{\kappa g}$	combined analysis cosmological parameter estimation
Omori et al 2018 (b)	Dark Energy Survey Year 1 Results: Cross-correlation between DES Y1 galaxy weak lensing and SPT+Planck CMB weak lensing	shear catalog from DESY1	SPT + Planck lensing	$\omega^{\gamma_t g}$	combined analysis cosmological parameter estimation
Baxter et al 2019	Dark Energy Survey Year 1 Results: Methodology and Projections for Joint Analysis of Galaxy Clustering, Galaxy Lensing, and CMB Lensing Two-point Functions	redMaGiC sampleDESY1 +shear catalog from DESY1	SPT + Planck lensing	$\omega^{\kappa g} + \omega^{\gamma_t g}$	**METHODOLOGY PAPER: combined analysis cosmological parameter estimation**
DES & SPT Collaborations 2018	Dark Energy Survey Year 1 Results: Joint Analysis of Galaxy Clustering, Galaxy Lensing, and CMB Lensing Two-point Functions	redMaGiC sampleDESY1+ shear catalog from DESY1	SPT + Planck lensing	$\omega^{\kappa g} + \omega^{\gamma_t g}$	combined analysis cosmological parameter estimation
Kovács et al 2019	More out of less: an excess integrated Sachs-Wolfe signal from supervoids mapped out by the Dark Energy Survey	Voids identified in DESY3 redMaGic galaxies	Planck (SMICA) CMB temperature map +Jubilee simulation	stacking	2.6σ tension with ΛCDM simulations
Vielzeuf et al (coming soon)	Dark Energy Survey Year 1 Results: the lensing imprint of cosmic voids on the Cosmic Microwave Background	Voids identified in DESY1 redMaGic galaxies	Planck convergence	stacking	3σ detection for various analysis choices

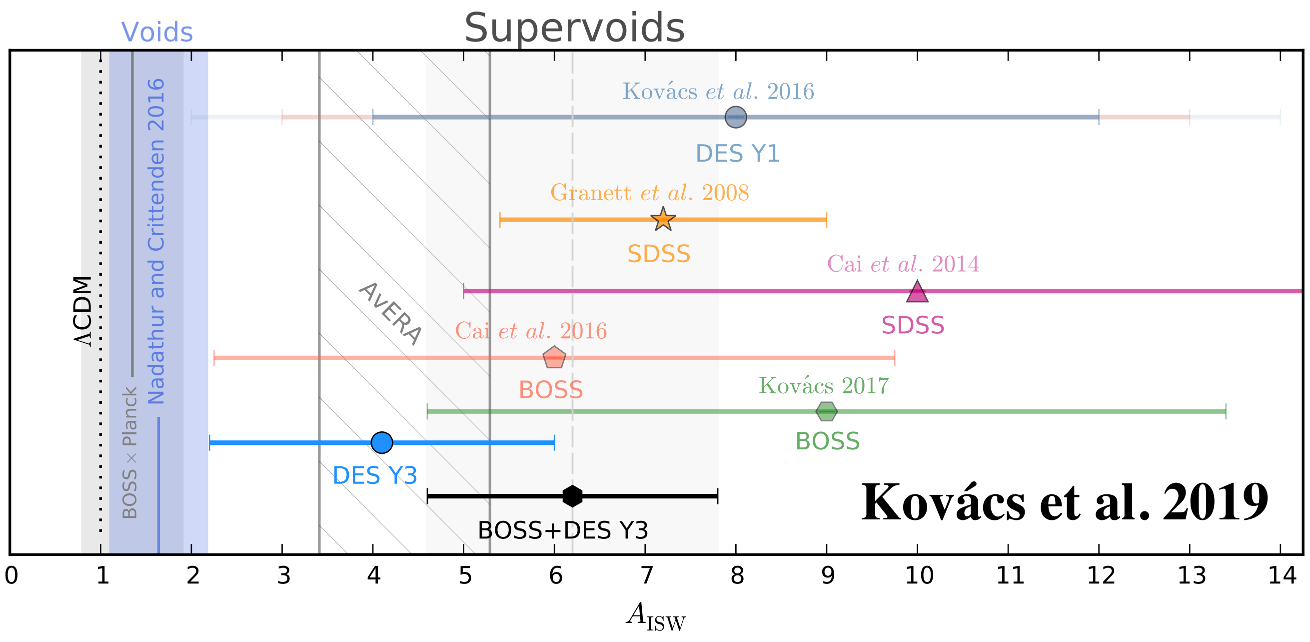
+ Prat et al 2019 : shear ratio SPT+ Planck -> cosmological parameter

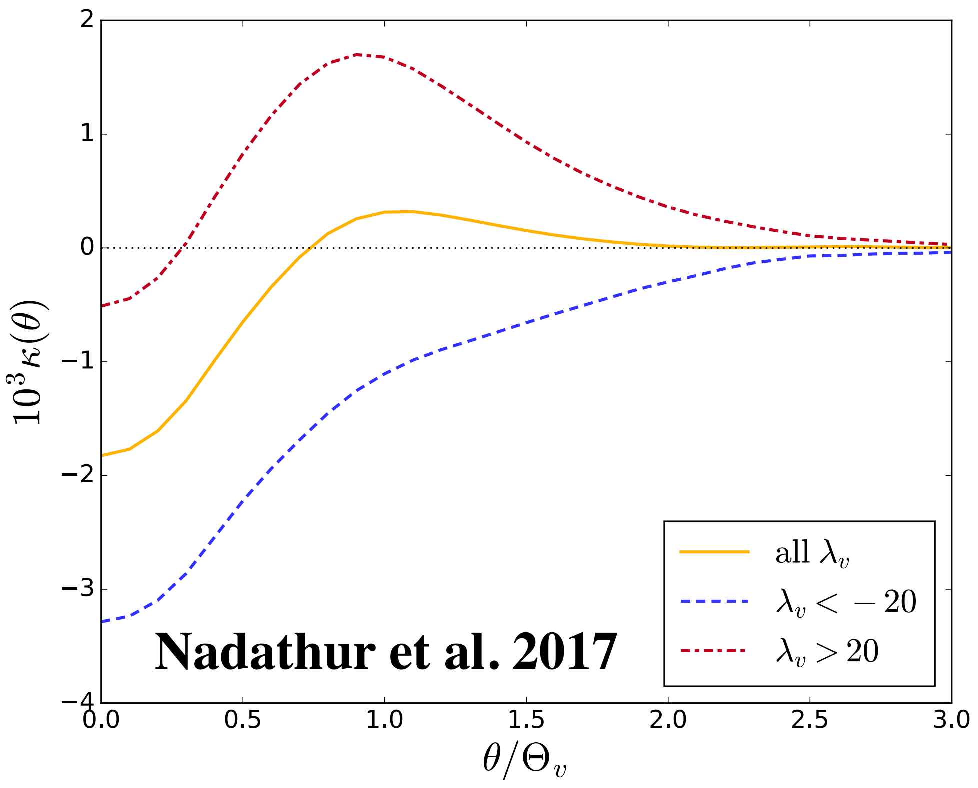
DESxCMB

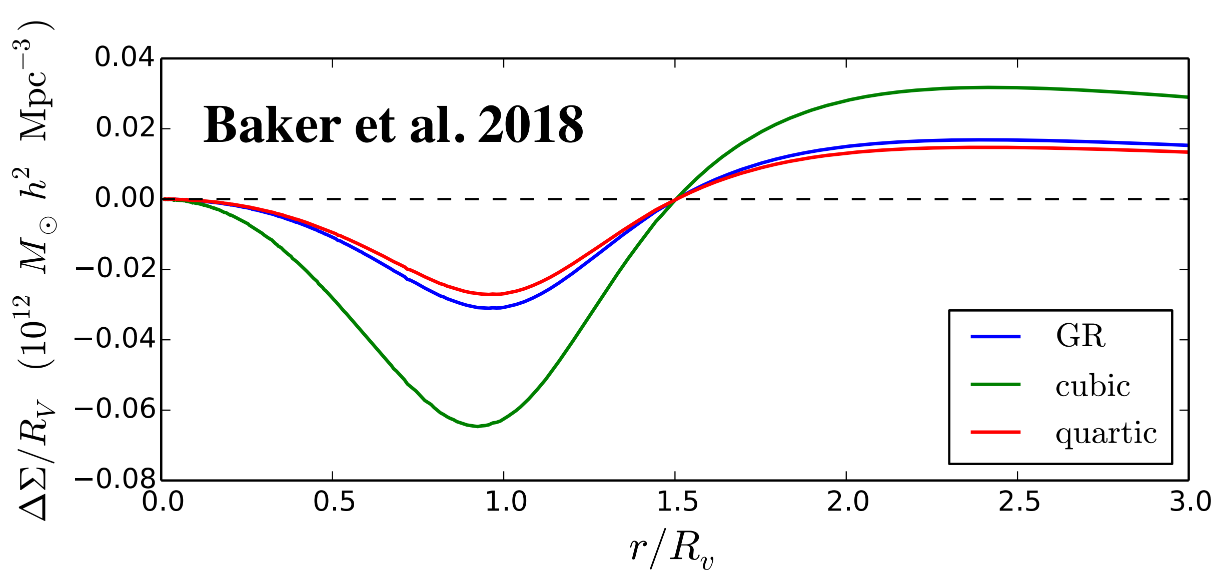
Paper	Title	Tracer (LSS)	CMB map	estimator	detection level/science
Giannantonio et al 2016	CMB lensing tomography with the DES Science Verification galaxies	Benchmark sample SV Crocce et al 2016	SPT convergence Planck convergence	$\omega^{\kappa g}$	6σ
Baxter et al 2016	Joint Measurement of Lensing-Galaxy Correlations Using SPT and DES SV Data	Benchmark sample SV Crocce et al 2016	SPT convergence	$\omega^{\kappa g} + \omega^{\gamma_t g}$	combined analysis cosmological parameter estimation
Kovács et al 2016	Imprint of DES super-structures on the Cosmic Microwave Background	Voids identified in DESY1 redMaGic galaxies	Planck (SMICA) CMB temperature map +Jubilee simulation	stacking	2σ tension with ΛCDM simulations
Baxter et al 2018	A Measurement of CMB Cluster Lensing with SPT and DES Year 1 Data	redMaPPer cluster catalog from DESY1	convergence SPT reconstructed	stacking	8.1σ detection constrain the amplitude of the relation between cluster mass and optical richness to roughly 17% precision
Omori et al 2018 (a)	Dark Energy Survey Year 1 Results: tomographic cross-correlations between DES galaxies and CMB lensing from SPT+Planck	redMaGiC sample DESY1	SPT + Planck lensing	$\omega^{\kappa g}$	combined analysis cosmological parameter estimation
Omori et al 2018 (b)	Dark Energy Survey Year 1 Results: Cross-correlation between DES Y1 galaxy weak lensing and SPT+Planck CMB weak lensing	shear catalog from DESY1	SPT + Planck lensing	$\omega^{\gamma_t g}$	combined analysis cosmological parameter estimation
Baxter et al 2019	Dark Energy Survey Year 1 Results: Methodology and Projections for Joint Analysis of Galaxy Clustering, Galaxy Lensing, and CMB Lensing Two-point Functions	redMaGiC sampleDESY1 +shear catalog from DESY1	SPT + Planck lensing	$\omega^{\kappa g} + \omega^{\gamma_t g}$	**METHODOLOGY PAPER: combined analysis cosmological parameter estimation**
DES & SPT Collaborations 2018	Dark Energy Survey Year 1 Results: Joint Analysis of Galaxy Clustering, Galaxy Lensing, and CMB Lensing Two-point Functions	redMaGiC sampleDESY1+ shear catalog from DESY1	SPT + Planck lensing	$\omega^{\kappa g} + \omega^{\gamma_t g}$	combined analysis cosmological parameter estimation
Kovács et al 2019	More out of less: an excess integrated Sachs-Wolfe signal from supervoids mapped out by the Dark Energy Survey	Voids identified in DESY3 redMaGic galaxies	Planck (SMICA) CMB temperature map +Jubilee simulation	stacking	2.6σ tension with ΛCDM simulations
Vielzeuf et al (coming soon)	Dark Energy Survey Year 1 Results: the lensing imprint of cosmic voids on the Cosmic Microwave Background	Voids identified in DESY1 redMaGic galaxies	Planck convergence	stacking	3σ detection for various analysis choices

Motivations





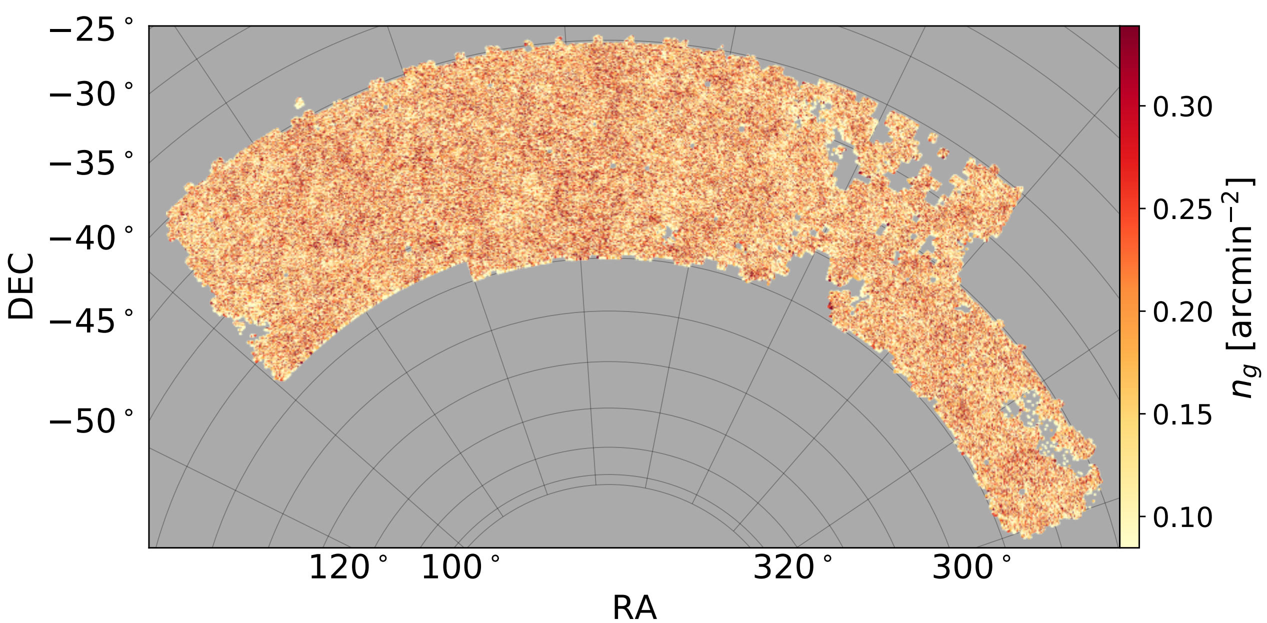


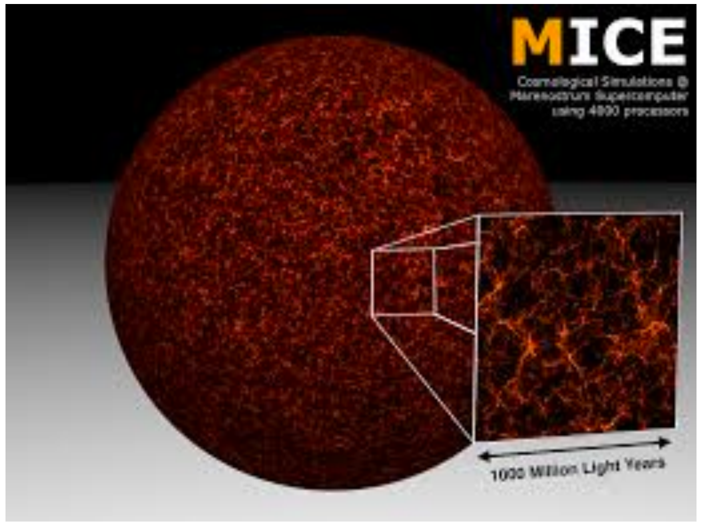


DES Y1 xPlanck

Dark Energy Survey Year 1 Results: the lensing imprint of cosmic voids on the Cosmic Microwave Background

P. Vielzeuf[1,2,3]⋆ A. Kovács[1,4,5]†, U. Demirbozan[1], P. Fosalba[6,7], E. Baxter[8], N. Hamaus[9], D. Huterer[10], R. Miquel[11,1], S. Nadathur[12], G. Pollina[9], C. Sánchez[8], L. Whiteway[13], T. M. C. Abbott[14], S. Allam[15], J. Annis[15], S. Avila[16], D. Brooks[13], D. L. Burke[17,18], A. Carnero Rosell[19,20], M. Carrasco Kind[21,22], J. Carretero[1], R. Cawthon[23], M. Costanzi[24,25], L. N. da Costa[20,26], J. De Vicente[19], S. Desai[27], H. T. Diehl[15], P. Doel[13], T. F. Eifler[28,29], S. Everett[30], B. Flaugher[15], J. Frieman[15,31], J. García-Bellido[16], E. Gaztanaga[6,7], D. W. Gerdes[32,10], D. Gruen[33,17,18], R. A. Gruendl[21,22], J. Gschwend[20,26], G. Gutierrez[15], W. G. Hartley[13,34], D. L. Hollowood[30], K. Honscheid[35,36], D. J. James[37], K. Kuehn[38,39], N. Kuropatkin[15], O. Lahav[13], M. Lima[40,20], M. A. G. Maia[20,26], M. March[8], J. L. Marshall[41], P. Melchior[42], F. Menanteau[21,22], A. Palmese[15,31], F. Paz-Chinchón[21,22], A. A. Plazas[42], E. Sanchez[19], V. Scarpine[15], S. Serrano[6,7], I. Sevilla-Noarbe[19], M. Smith[43], E. Suchyta[44], G. Tarle[10], D. Thomas[12], J. Weller[45,46,9], J. Zuntz[47]

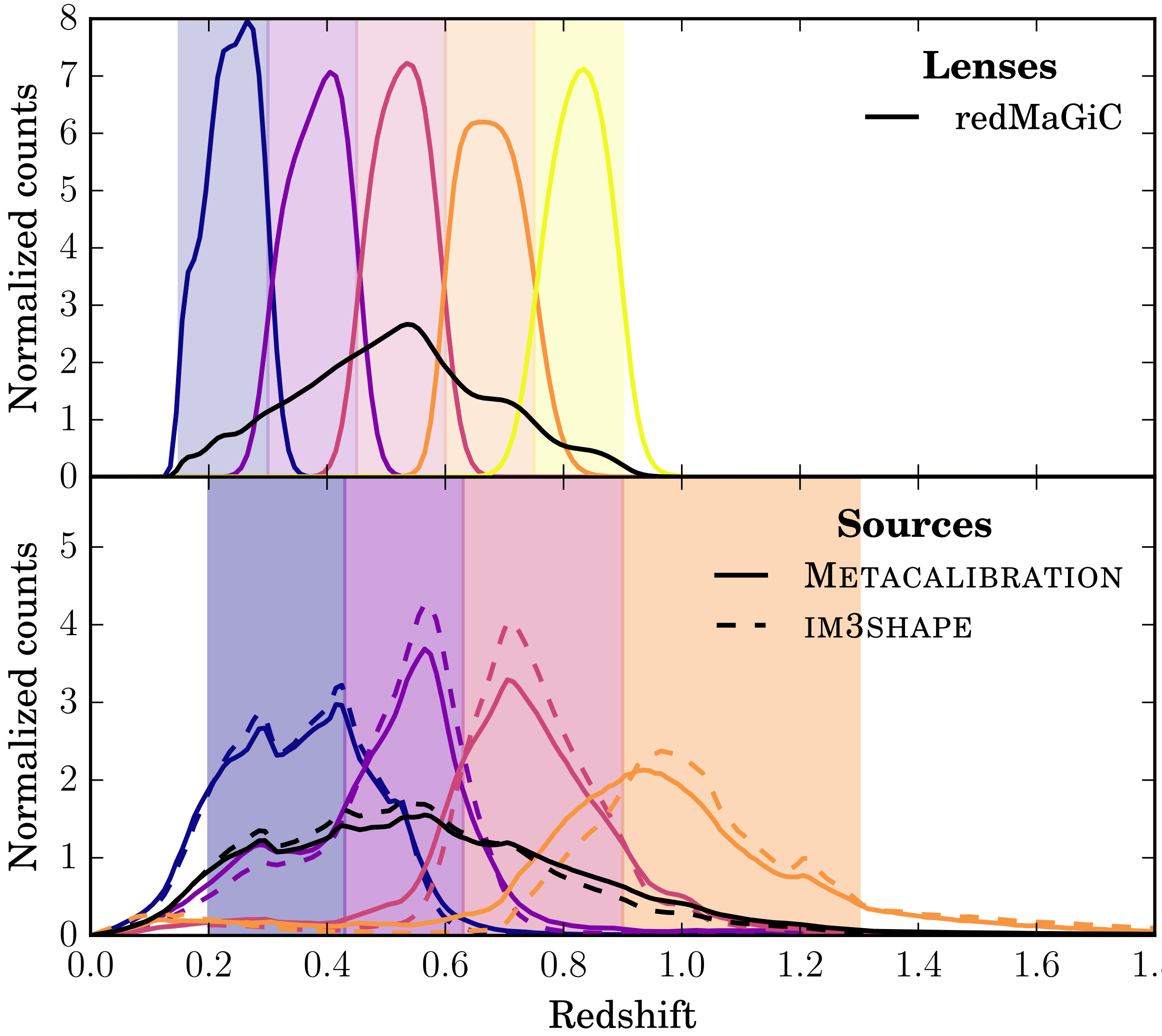




Tracing the density field with good photometry

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

Rozo et al. 2016



z range	$L_{\rm min}/L_*$	$n_{\rm gal}$ (arcmin^{-2})	$N_{\rm gal}$
$0.15 < z < 0.3$	0.5	0.0134	63719
$0.3 < z < 0.45$	0.5	0.0344	163446
$0.45 < z < 0.6$	0.5	0.0511	240727
$0.6 < z < 0.75$	1.0	0.0303	143524
$0.75 < z < 0.9$	1.5	0.0089	42275

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.**

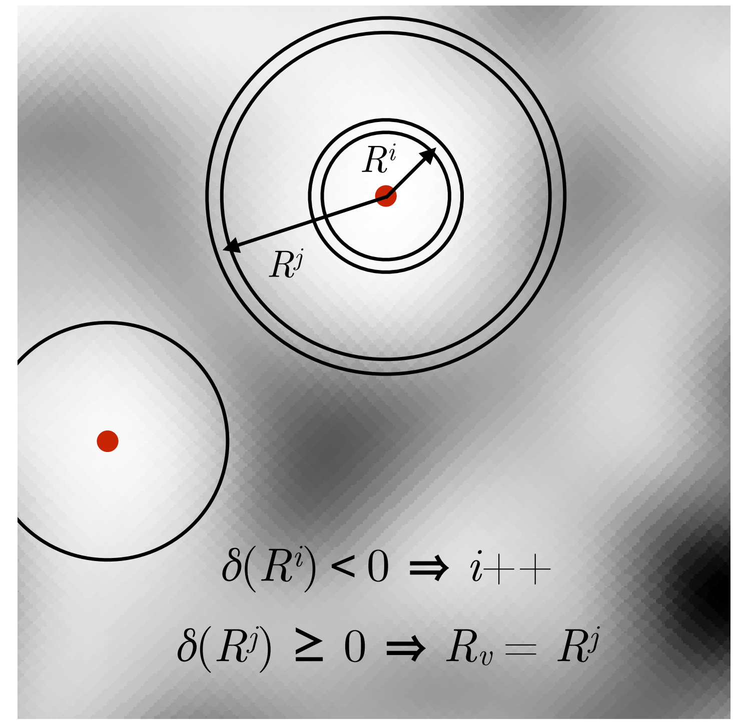


Figure 1. Graphical description of the void-finding algorithm presented in this paper. The background gray-scaled field is the smoothed galaxy field ($\sigma = 10$ Mpc$/h$) in a redshift slice used by the void-finder. The two solid (red) dots show two void centers. For the upper void, we show a circular shell or radius R^i. Since the density contrast $\delta(R^i) < 0$, the algorithm checks larger shells, up to radius R^j such that $\delta(R^j) \geqslant 0$. The void radius is then defined as $R_v = R^j$.

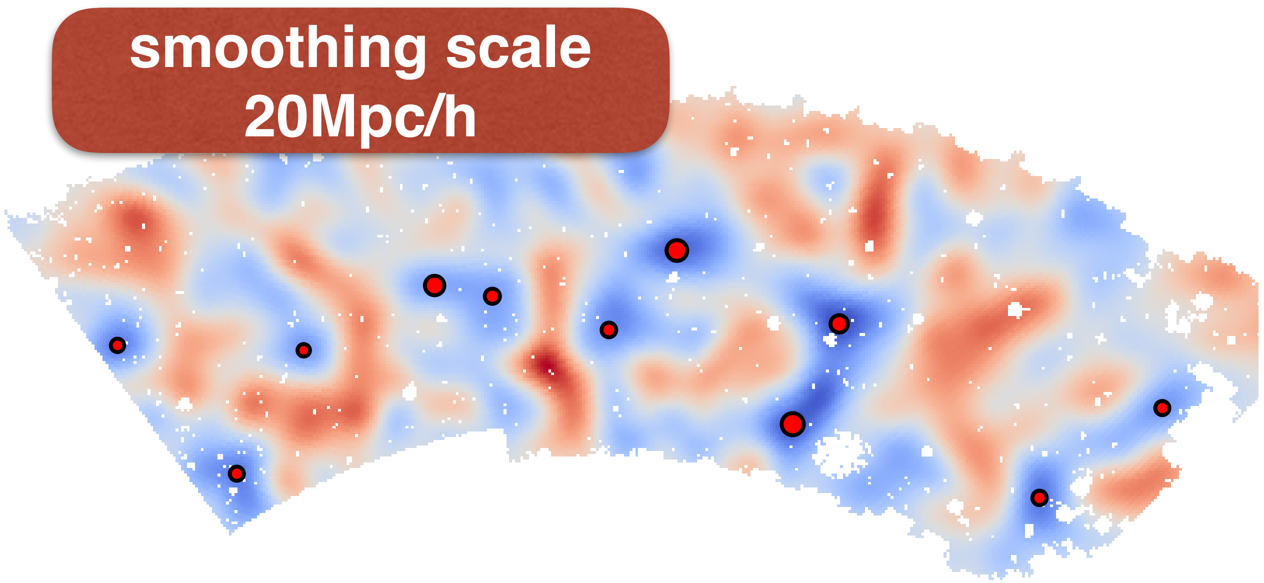
Sánchez et al. (DES Collaboration), MNRAS 465, 746, 2017.

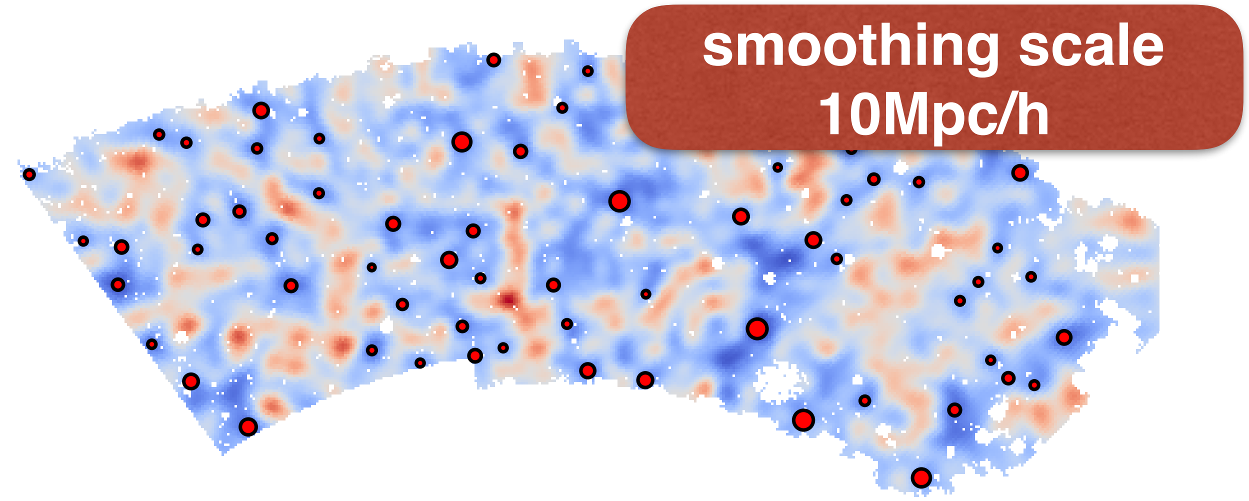
Catalogs

Two tracers :
- RedMagiC High-luminosity sample
- RedMagiC High-density sample

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

4 void catalogs





+ 2VIDES catalogs as cross-check

Catalogs

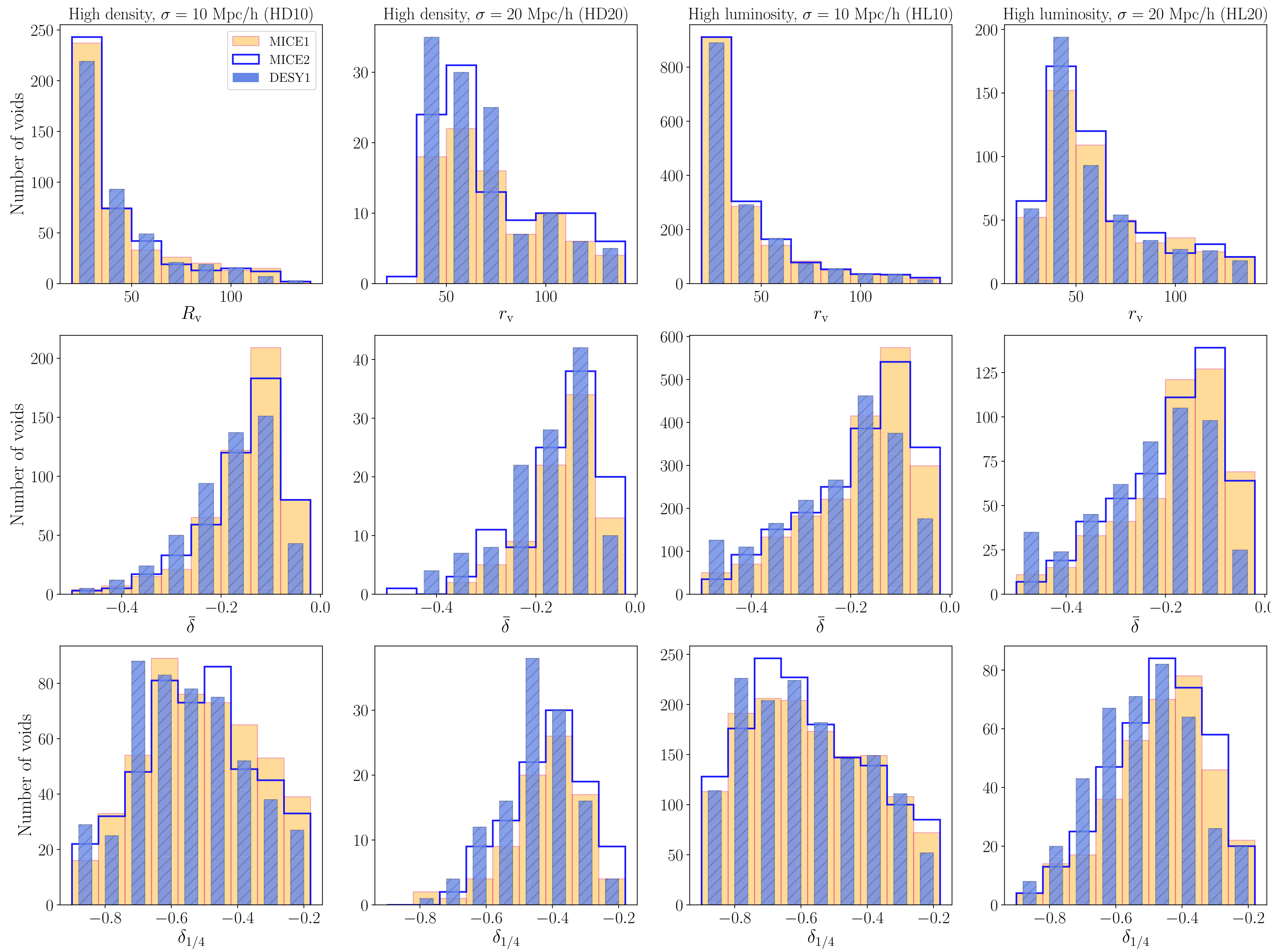
High luminosity (HL)

Smoothing	DES Y1	MICE 1	MICE 2
10 Mpc/h	1218	1158	1219
20 Mpc/h	411	364	400

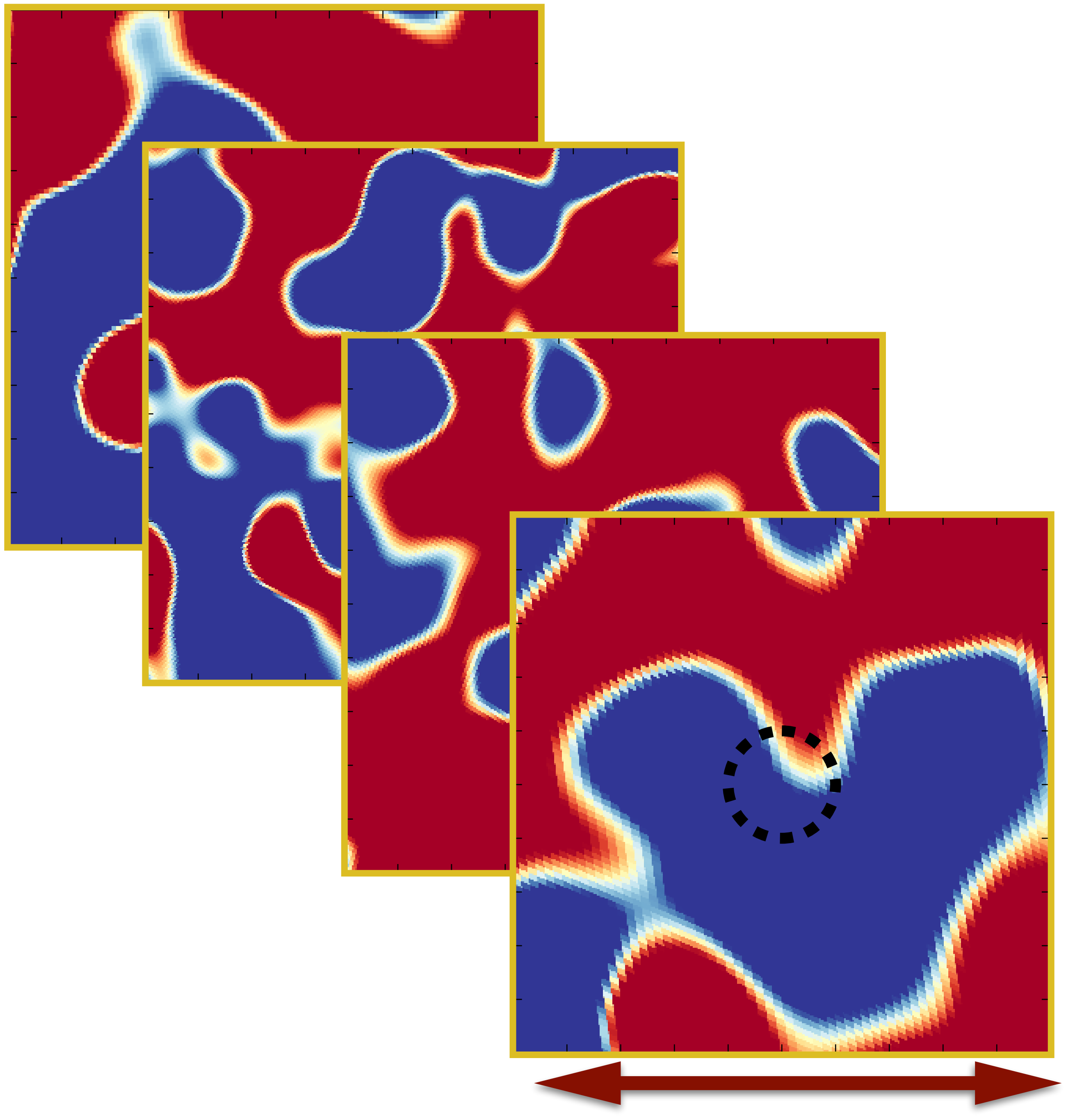
High density (HD)

Smoothing	DES Y1	MICE 1	MICE 2
10 Mpc/h	518	521	495
20 Mpc/h	122	85	106

`VIDE`	DES Y1	MICE
All	7383	36115
Pruned	239	1687



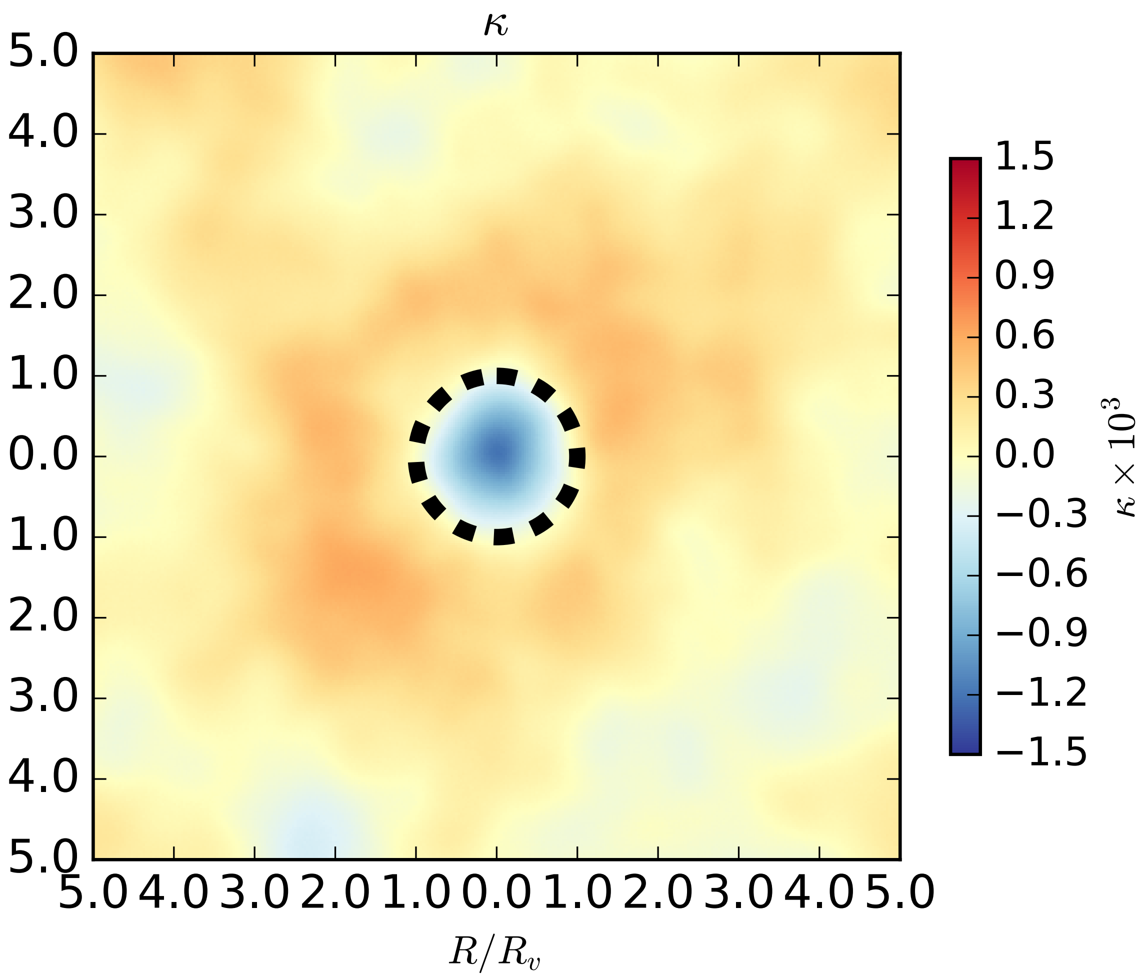
Stacking methodology

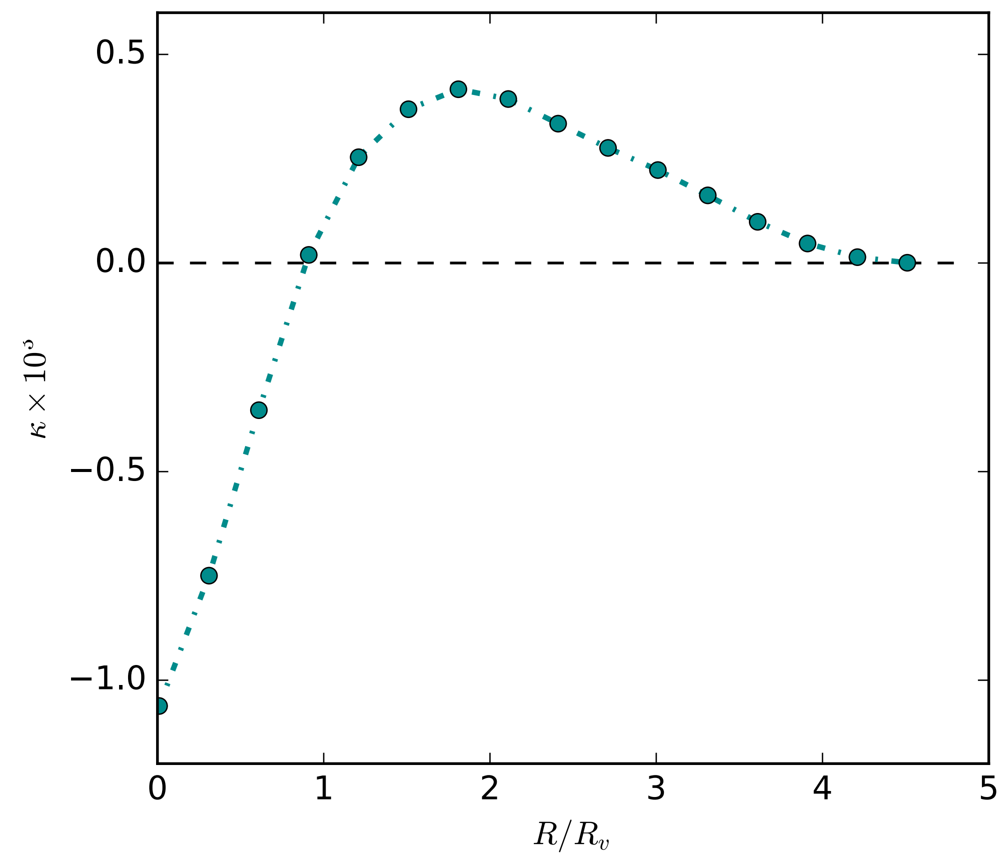


- Cutting out patches of the CMB convergence map centered at the void center position using healpix tools (Górski et al., 2005);
- Re-scaling the patches given the angular size of voids;
- Stacking all patches and measure the average signal in different concentric radius bins around the void center.

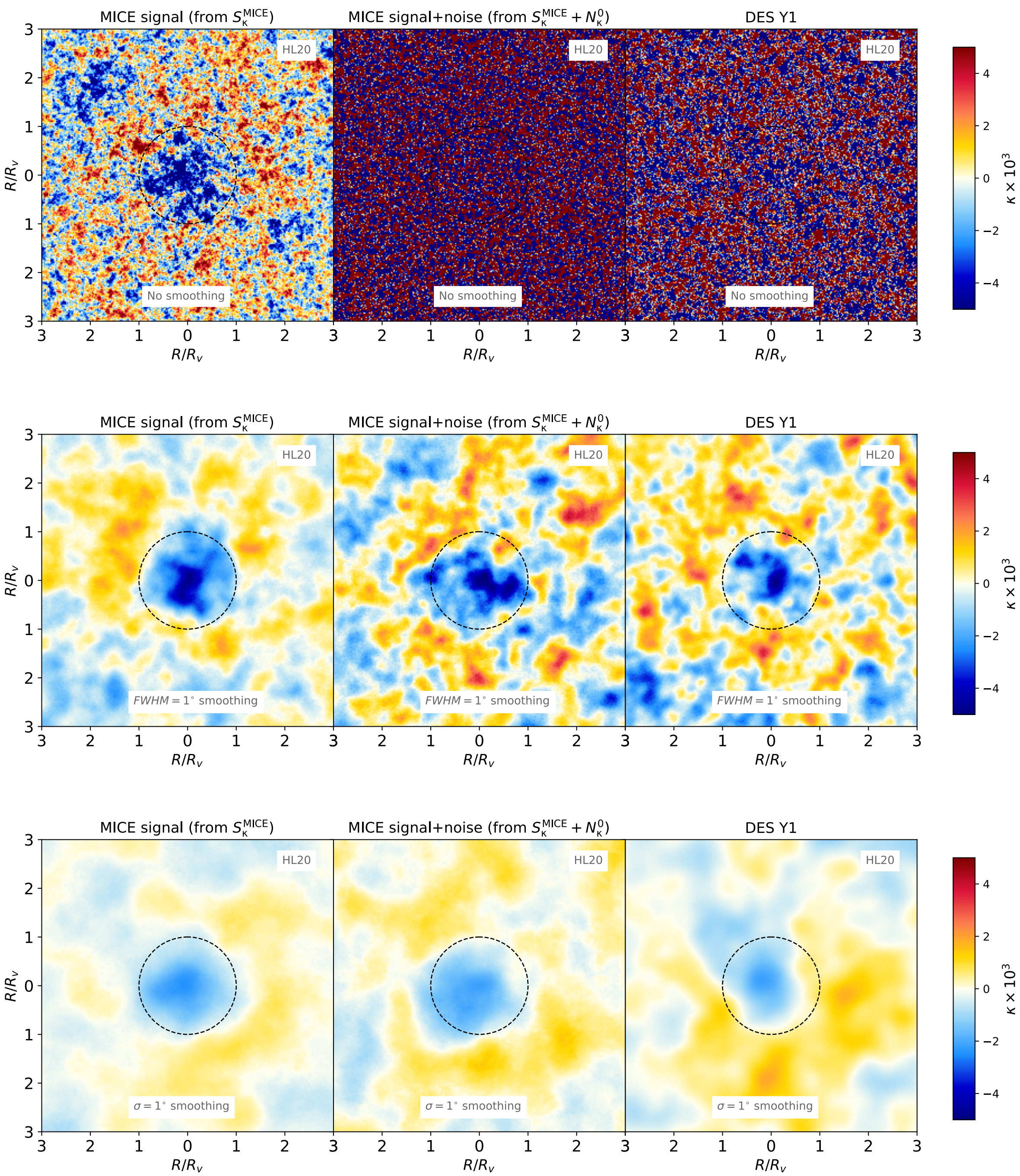
Stacking methodology

Stacked Healpix image → **CMB convergence profile**

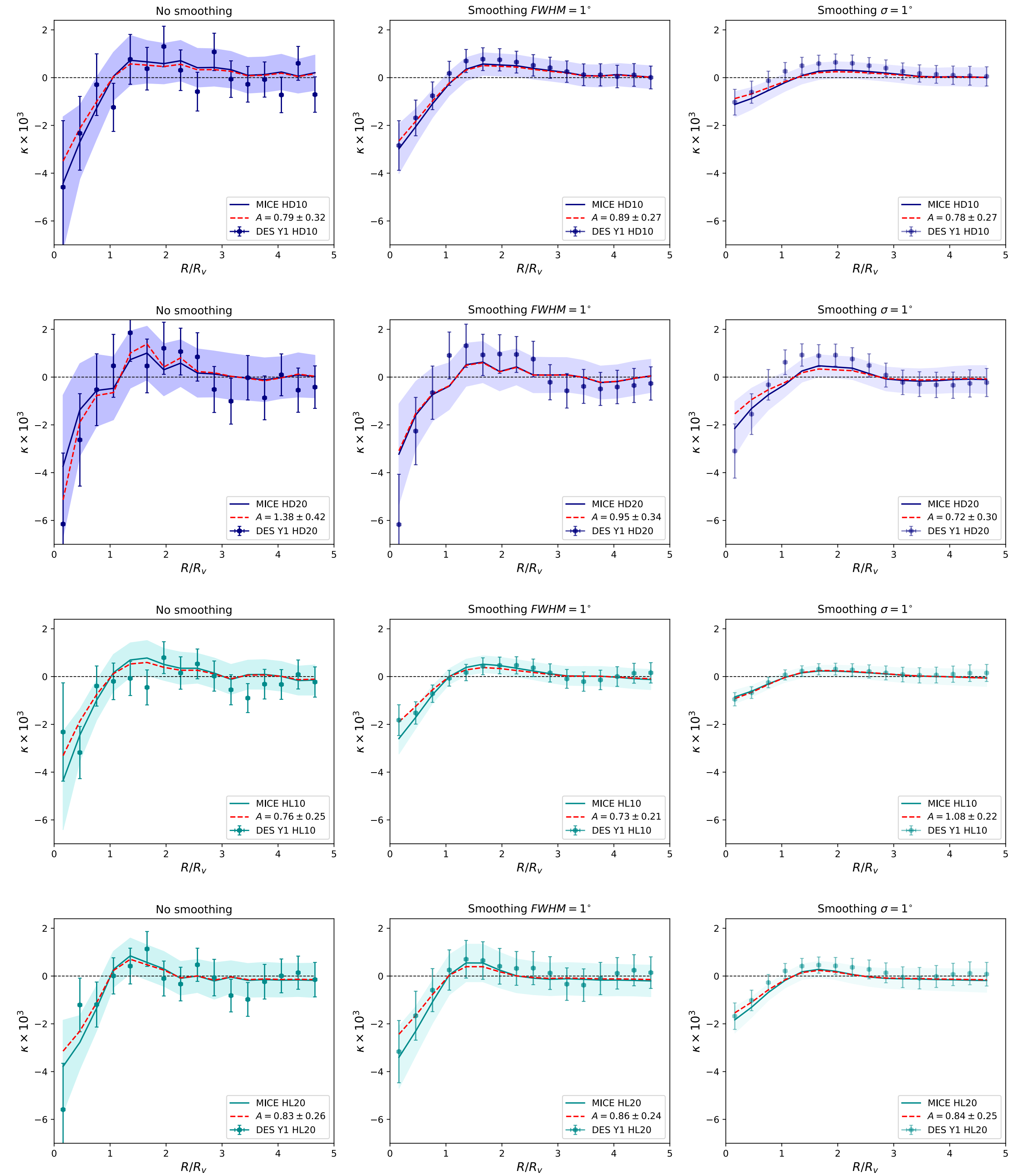




Results

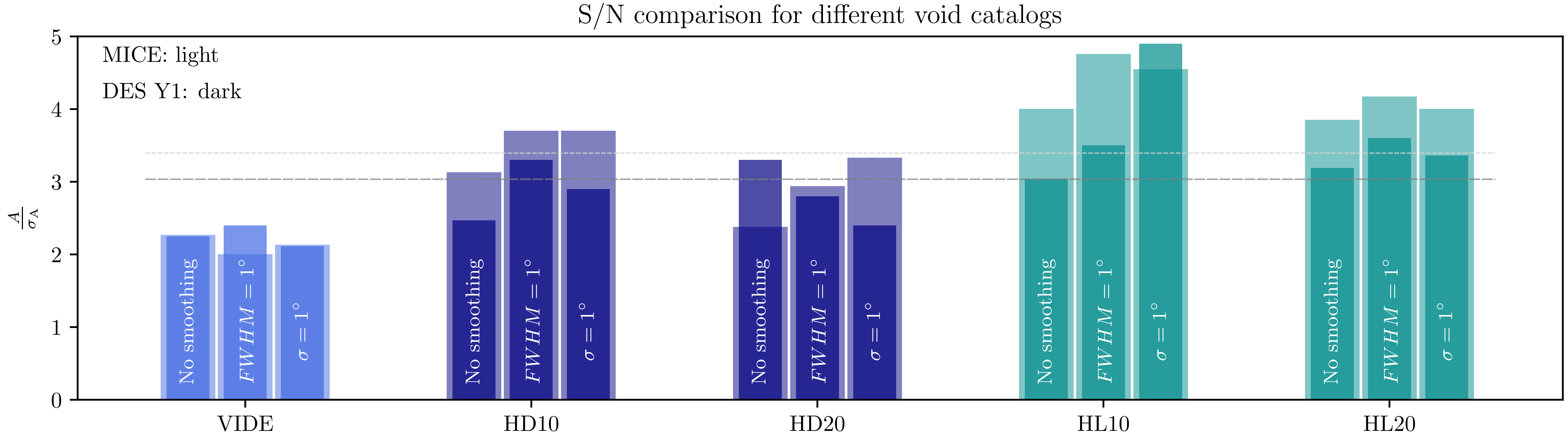


MICE signal (from $S_\kappa^{\rm MICE}$)
MICE signal+noise (from $S_\kappa^{\rm MICE} + N_\kappa^0$)
DES Y1
HL20
No smoothing
$FWHM = 1^\circ$ smoothing
$\sigma = 1^\circ$ smoothing
R/R_v
$\kappa \times 10^3$



No smoothing
Smoothing $FWHM = 1^\circ$
Smoothing $\sigma = 1^\circ$
R/R_v
$\kappa \times 10^3$
MICE HD10
$A = 0.79 \pm 0.32$
DES Y1 HD10
MICE HD10
$A = 0.89 \pm 0.27$
DES Y1 HD10
MICE HD10
$A = 0.78 \pm 0.27$
DES Y1 HD10
MICE HD20
$A = 1.38 \pm 0.42$
DES Y1 HD20
MICE HD20
$A = 0.95 \pm 0.34$
DES Y1 HD20
MICE HD20
$A = 0.72 \pm 0.30$
DES Y1 HD20
MICE HL10
$A = 0.76 \pm 0.25$
DES Y1 HL10
MICE HL10
$A = 0.73 \pm 0.21$
DES Y1 HL10
MICE HL10
$A = 1.08 \pm 0.22$
DES Y1 HL10
MICE HL20
$A = 0.83 \pm 0.26$
DES Y1 HL20
MICE HL20
$A = 0.86 \pm 0.24$
DES Y1 HL20
MICE HL20
$A = 0.84 \pm 0.25$
DES Y1 HL20

Results



No smoothing

Catalogue	VIDE	HD10	HD20	HL10	HL20
MICE	2.27	3.13	2.38	4.00	3.85
DES Y1	2.25	2.47	3.29	3.04	3.36

***FWHM*= 1° smoothing**

Catalogue	VIDE	HD10	HD20	HL10	HL20
MICE	2.00	3.70	2.94	4.76	4.17
DES Y1	2.42	3.30	2.79	3.48	3.58

σ = 1° smoothing

Catalogue	VIDE	HD10	HD20	HL10	HL20
MICE	2.13	3.70	3.33	4.55	4.00
DES Y1	2.11	2.89	2.40	4.91	3.19

Quick Conclusions

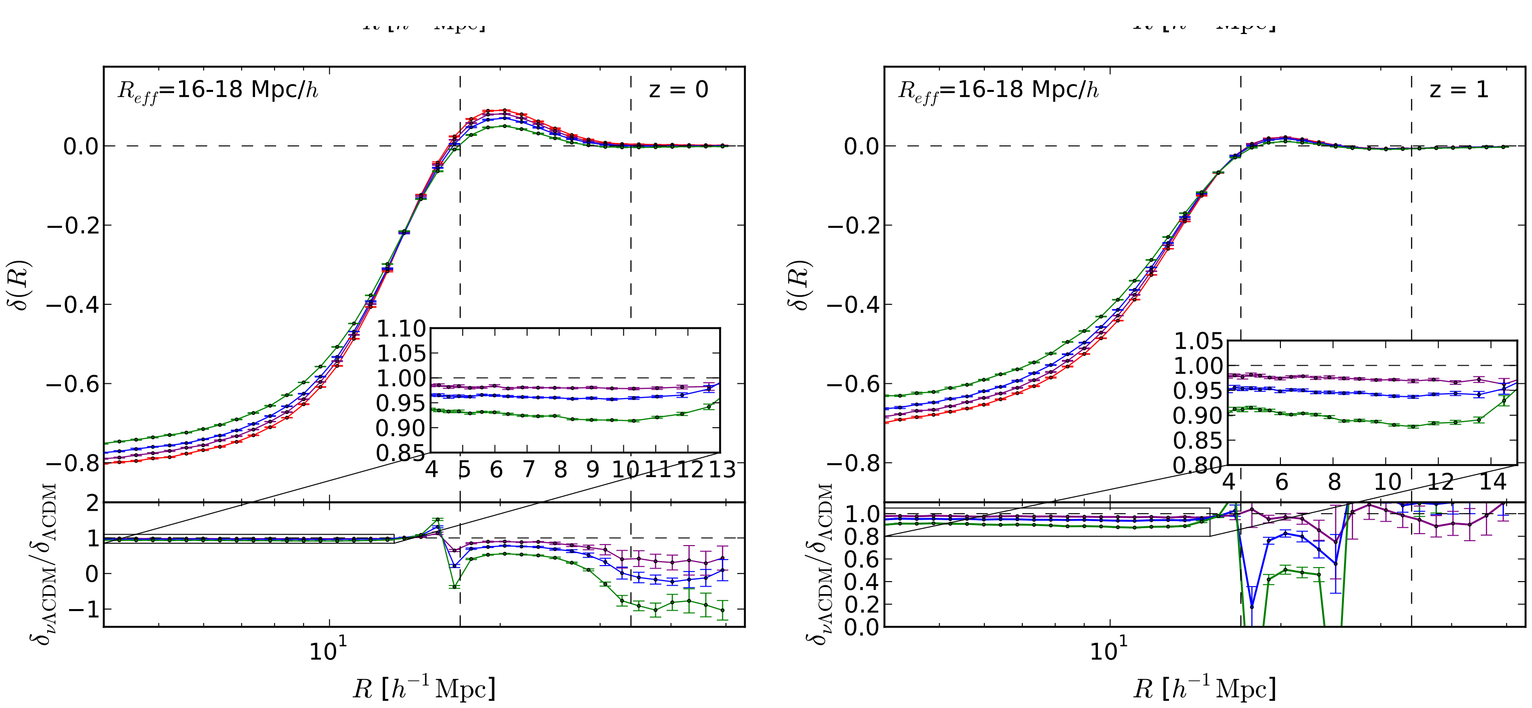
- We study cosmic voids identified in Dark Energy Survey galaxy samples, culled from the first year of observations. We relied on the *redMaGiC* sample of lu- minous red galaxies of exquisite photometric redshift accuracy to robustly identify cosmic voids in photometric data. We then aimed to cross-correlate these cosmic voids with lensing maps of the Cosmic Microwave Background using a stacking methodology.
- We then comprehensively searched for the best combination of parameters that guarantees the best chance to detect a signal with observed DES data. We concluded that the lower tracer density of the higher luminosity *redMaGiC* galaxy catalogue is preferable to achieve a higher signal-to-noise for both 10 Mpc/h and 20 Mpc/h initial Gaussian smoothing.
- We robustly detected imprints at the 3σ significance level with most of our analysis choices, reaching $S/N \approx 4$ in the best predicted measurement configurations using DES Y1 high luminosity *redMaGiC* data.

Voids X CMB (DEMNUNii)

(The SISSA/Milano/Aosta/Sussex collaboration)

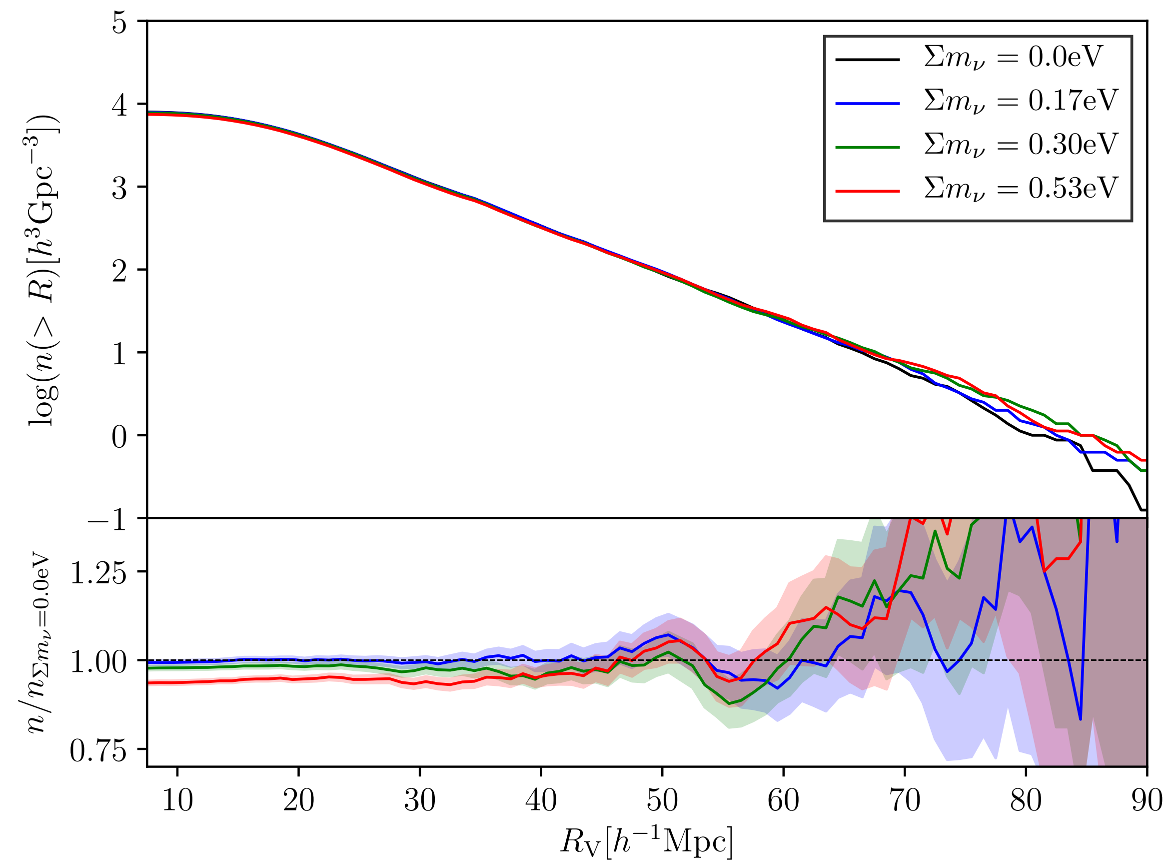
Pauline Vielzeuf, Carmelita Carbone, Matteo Calabrese, Giulio Fabbian, Silvia Miati, Carlo Baccigalupi

Motivation: Massive Neutrinos and voids

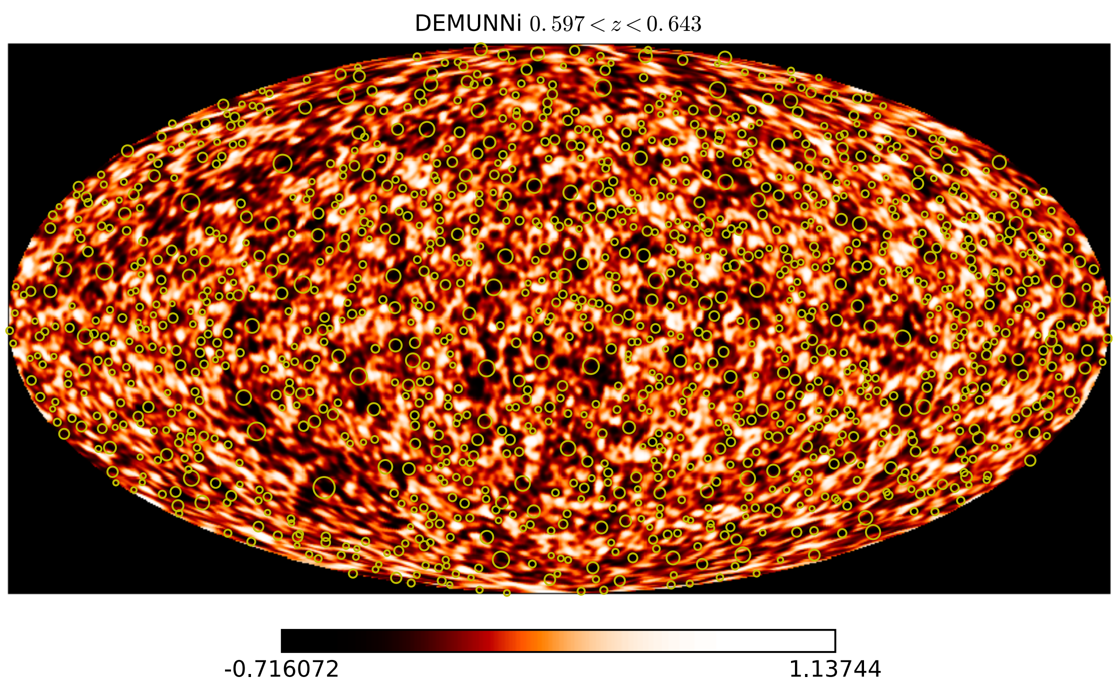


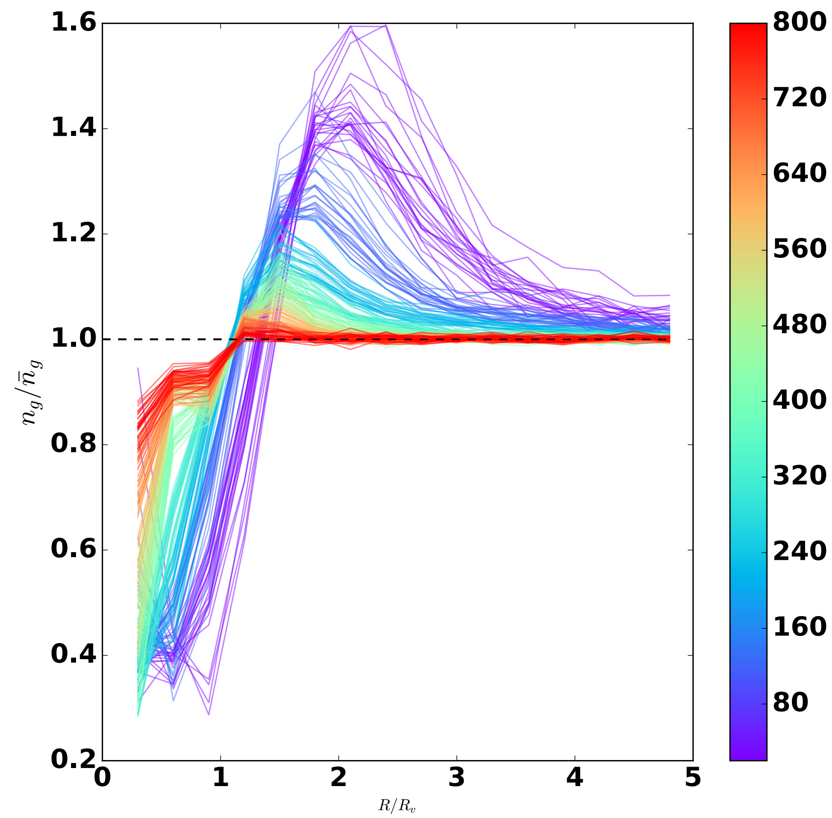
Massara et al. 2015

Kreisch, 2019



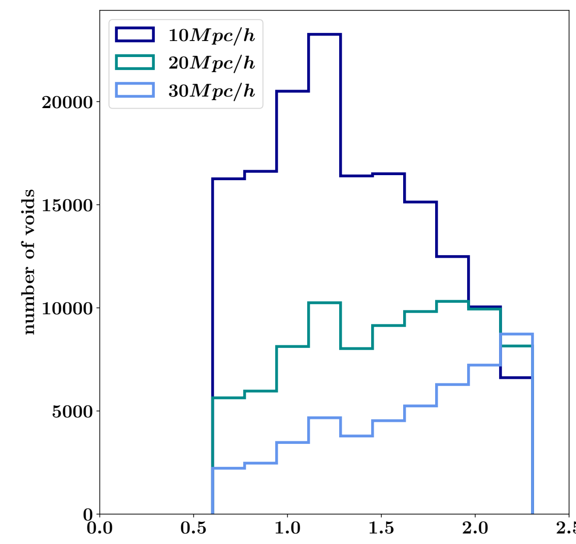
Step 1 : building the catalog(s) and validate them

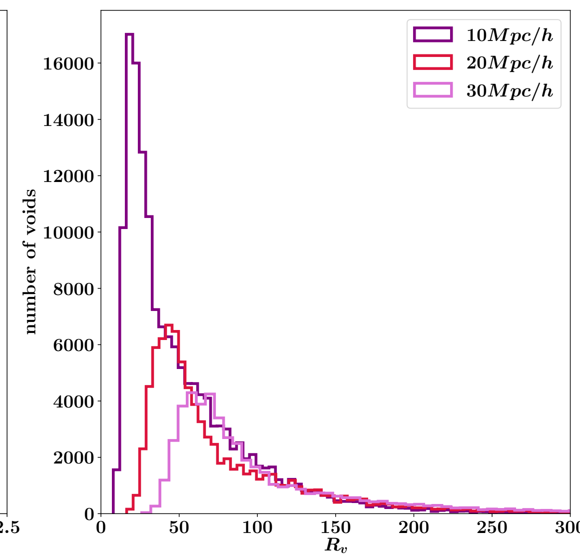




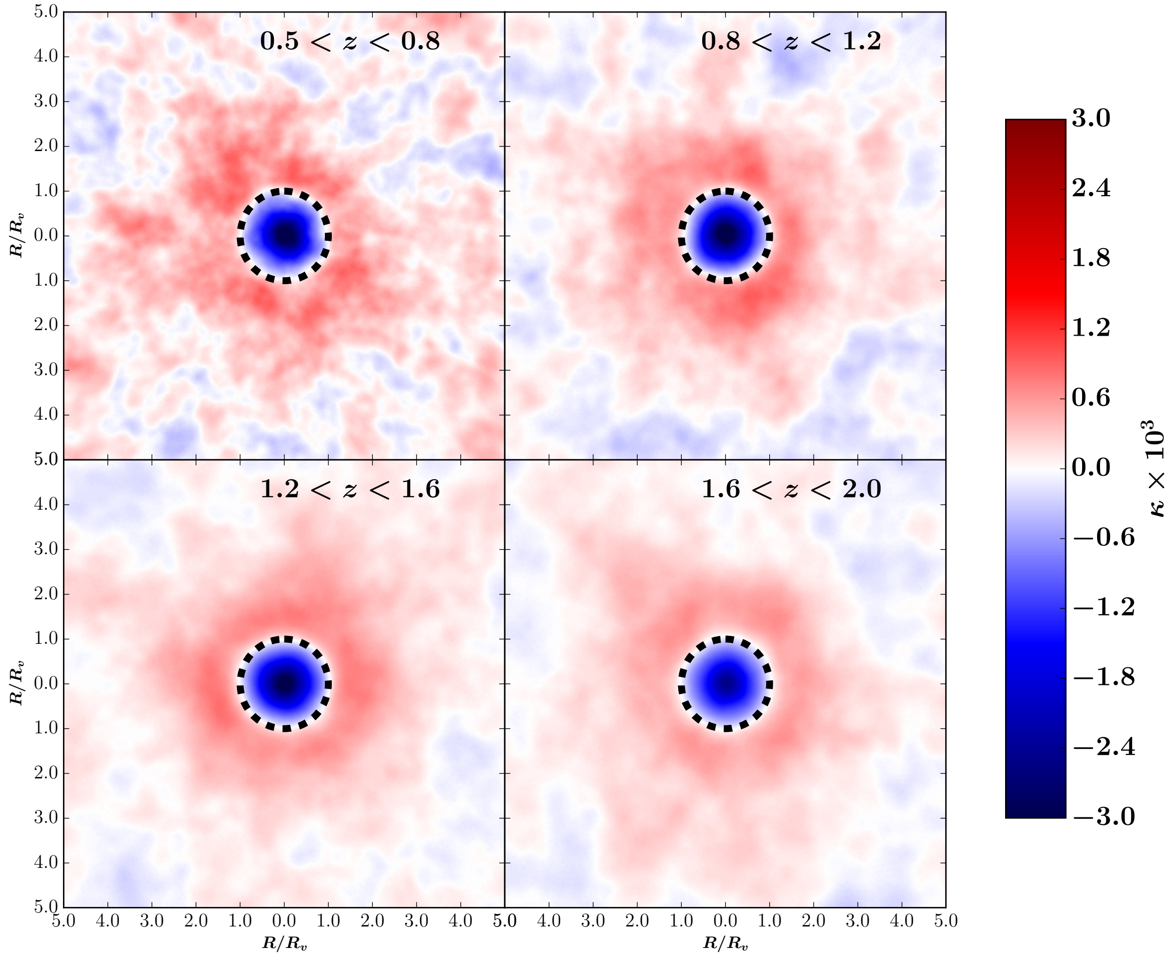
We use DM Halos as tracer

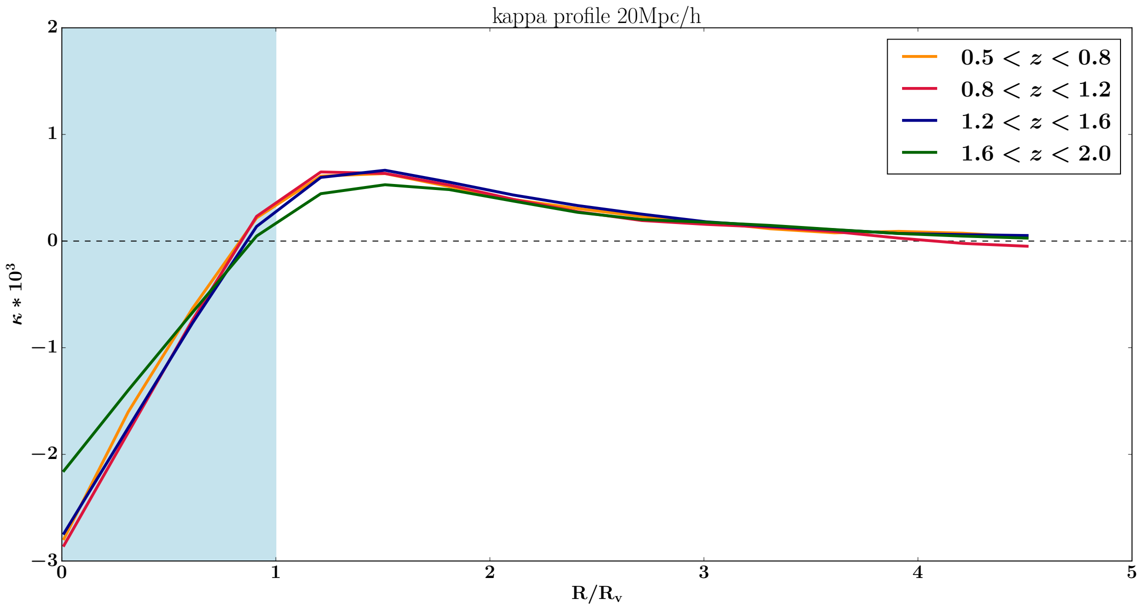
- $10 Mpc/h$, 153830 voids
- $20 Mpc/h$, 85386 voids
- $30 Mpc/h$, 48648 voids



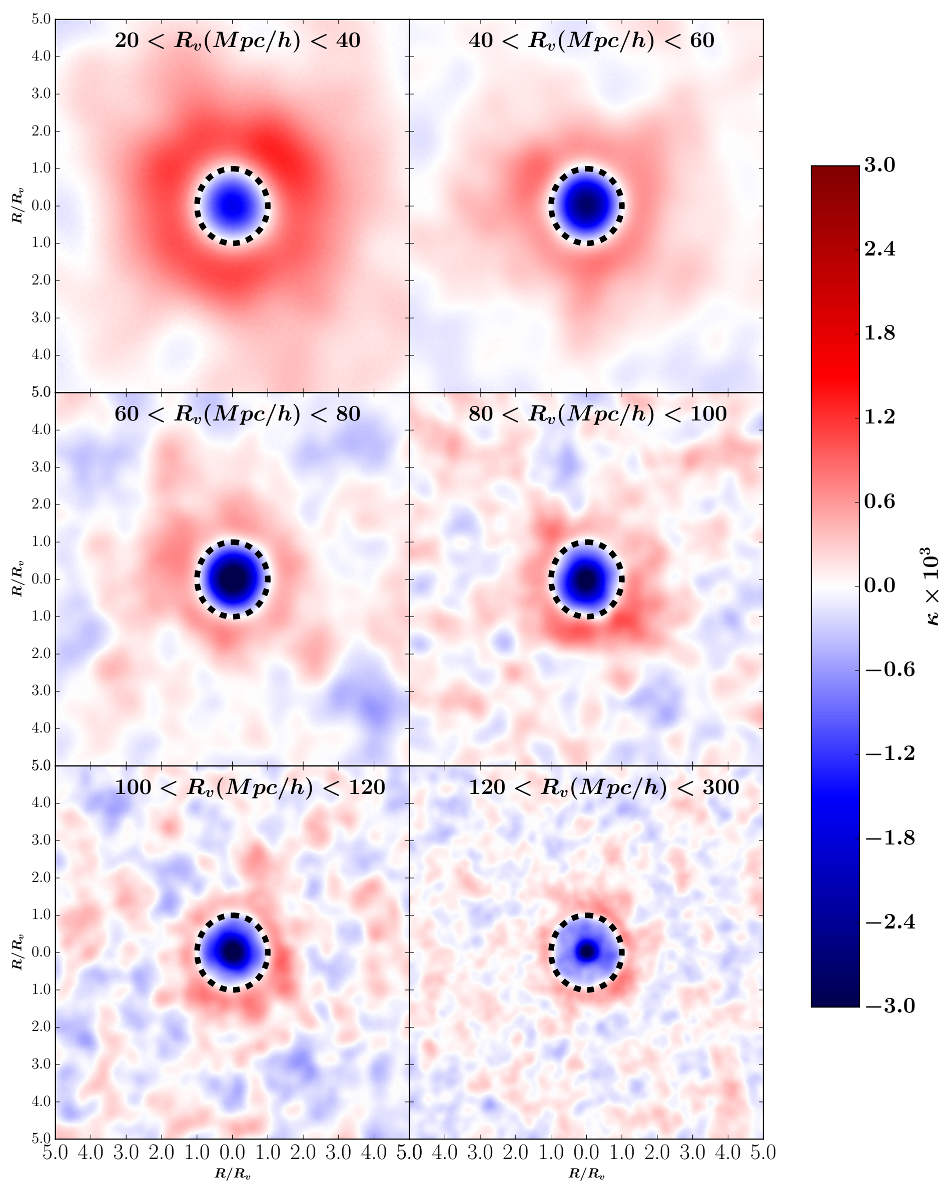


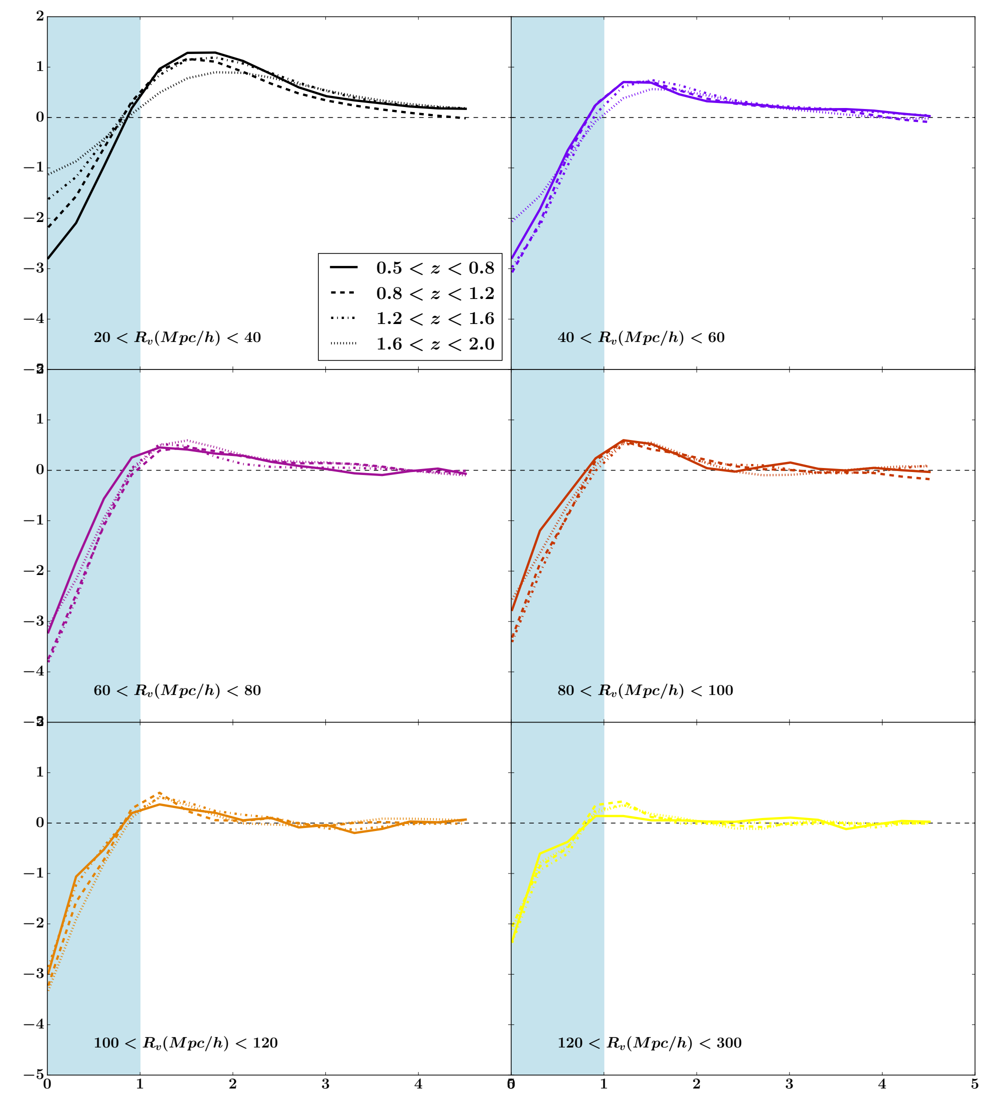
Step 2 : Cross-correlate with CMB and look for a signal





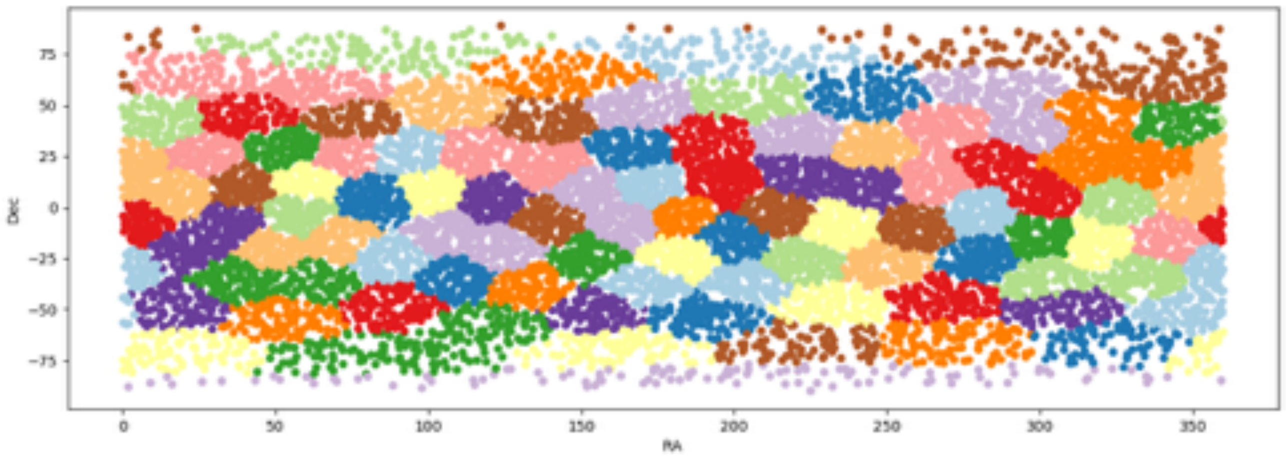
Step 3 : Study subpopulation lensing profiles to improve our S/N

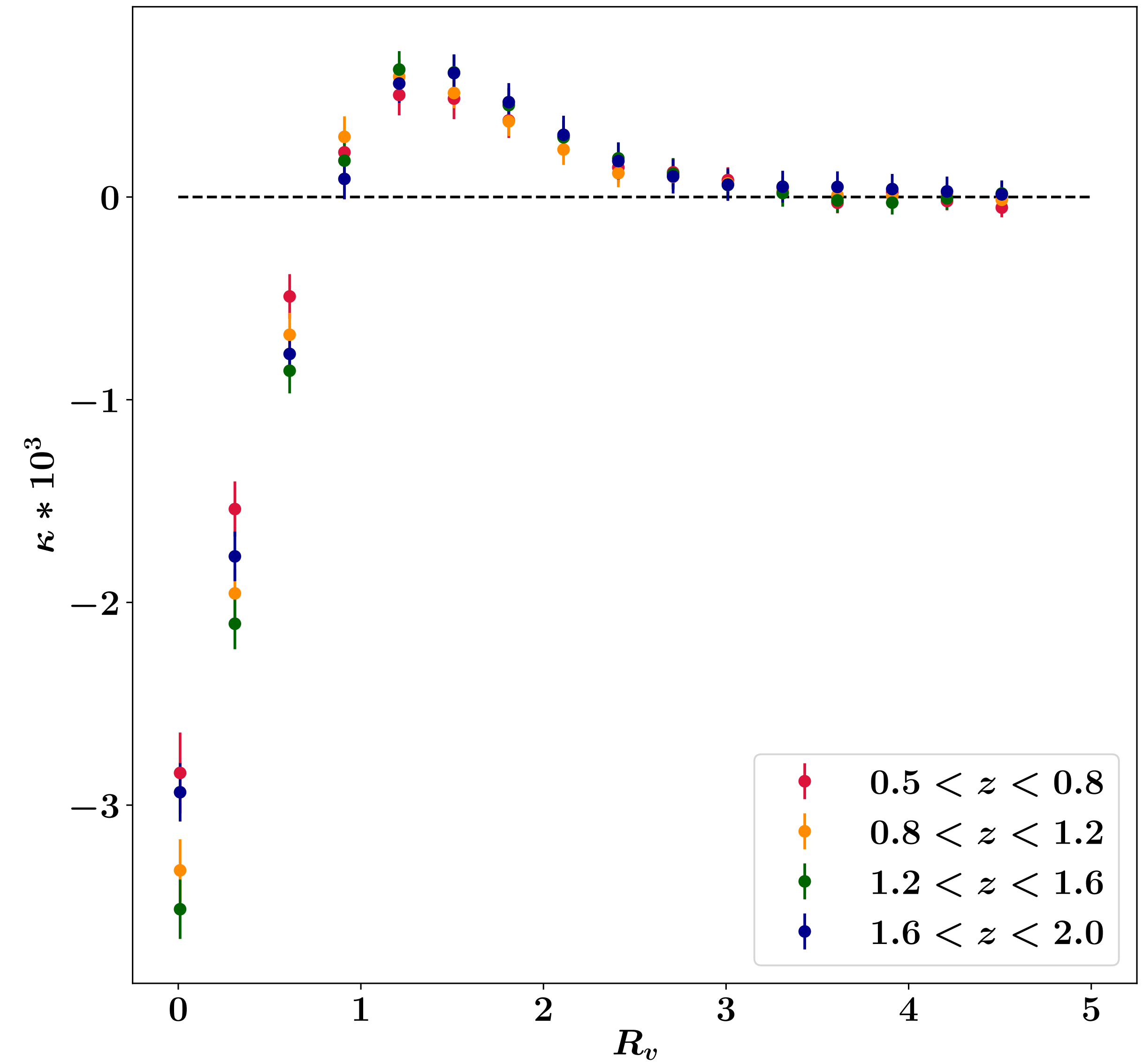




Step 3 : errors estimation

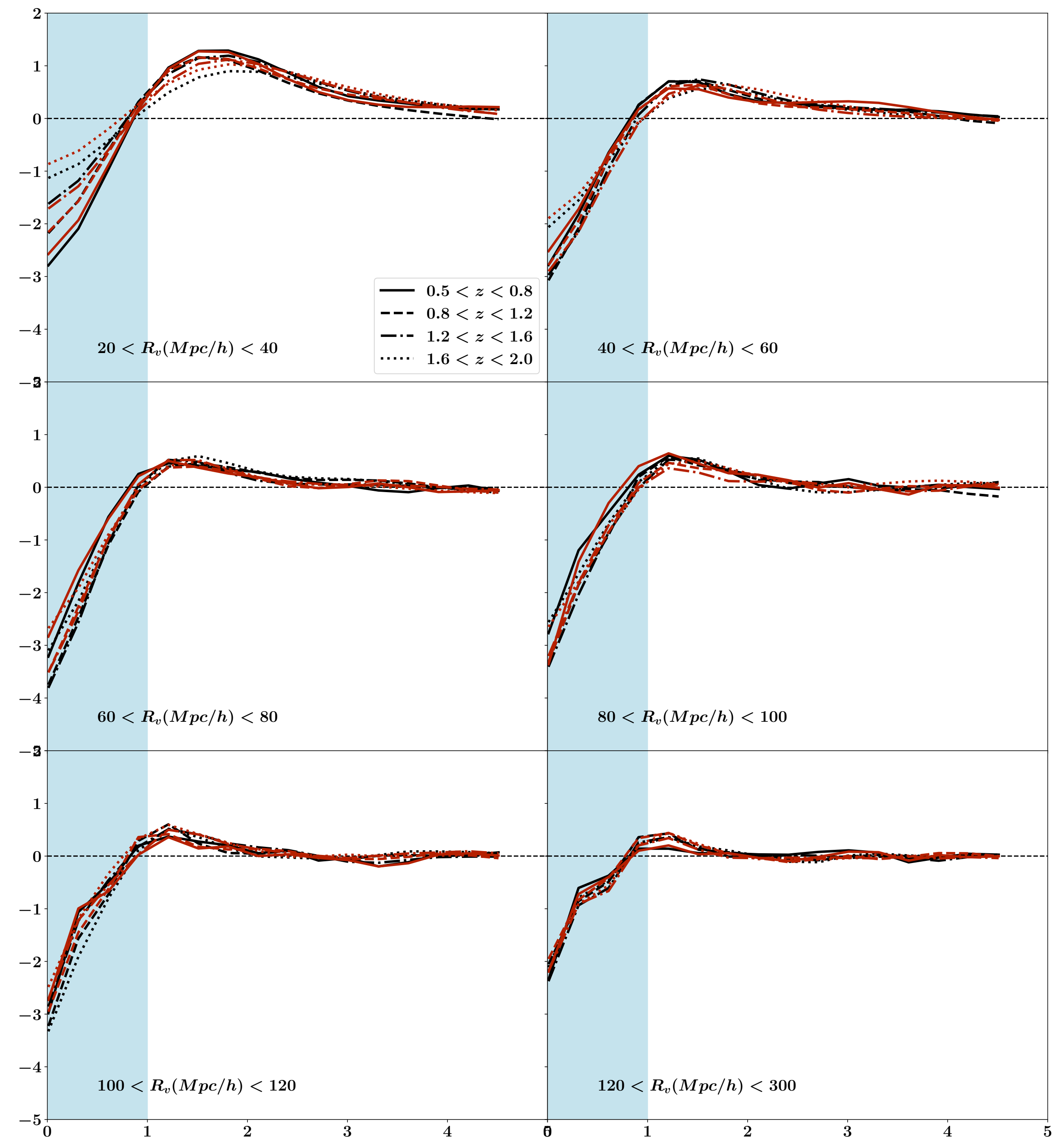
$$C_{JK}(p_i, p_j) = \frac{(N_{JK} - 1)}{N_{JK}} \sum_{n=1}^{N_{JK}} (p_i^n - \bar{p_i})(p_j^n - \bar{p_j})$$



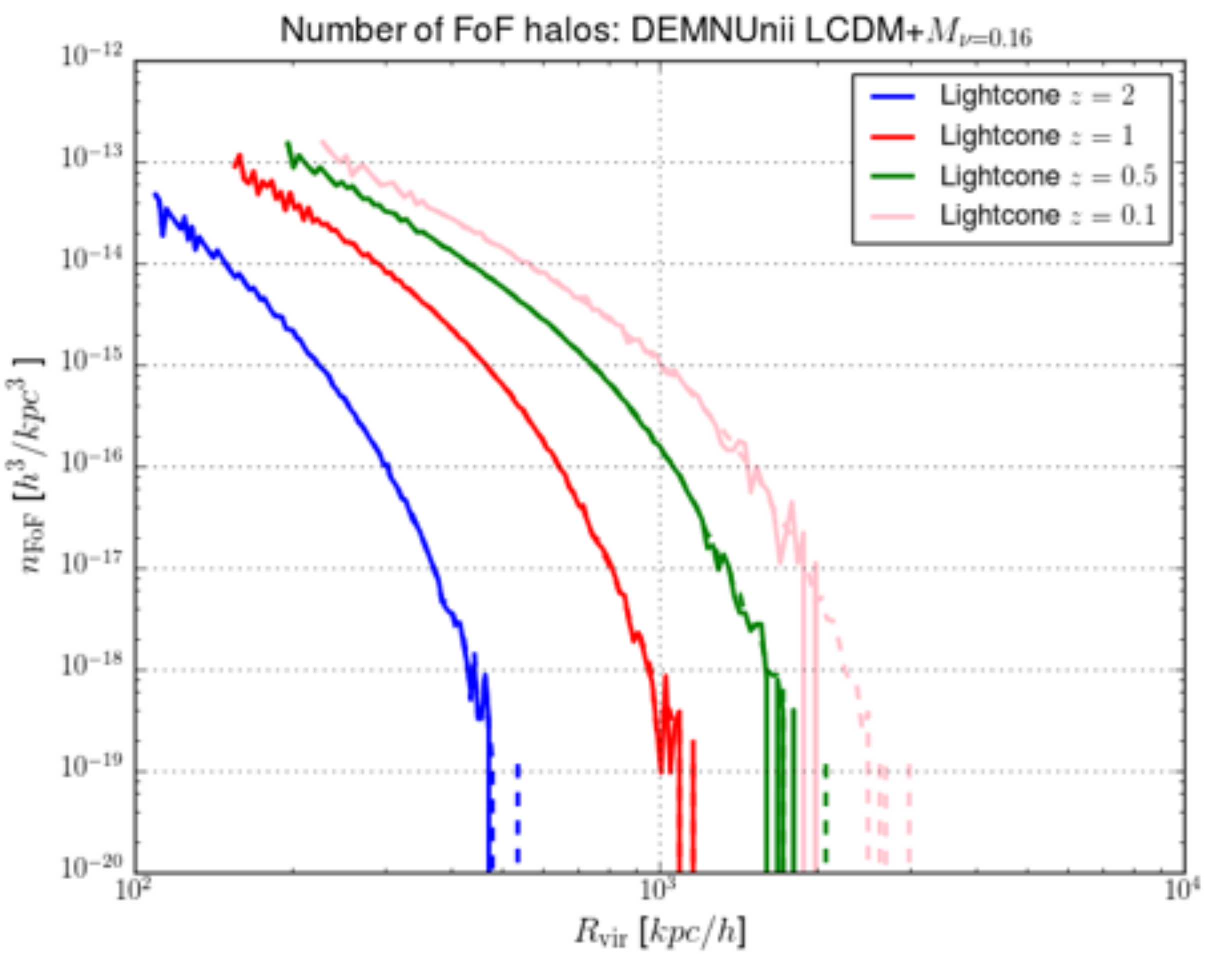


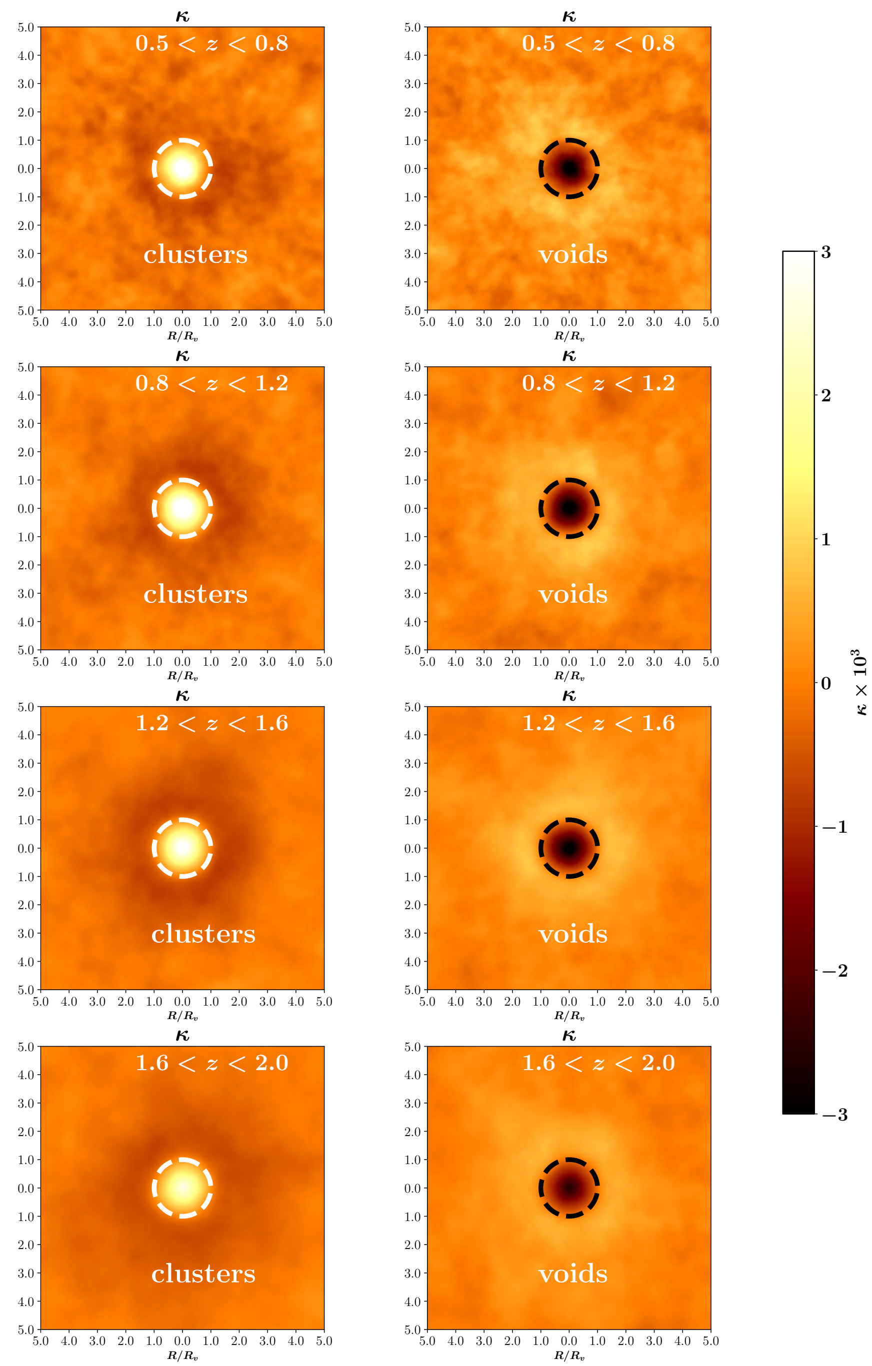
Note : We are thinking on the feasibility to evaluate the covariance from various realisations

Step 4 : Reproduce the analysis with massive neutrinos



Going Further: Voids VS Clusters





Going Further: Voids VS ISW

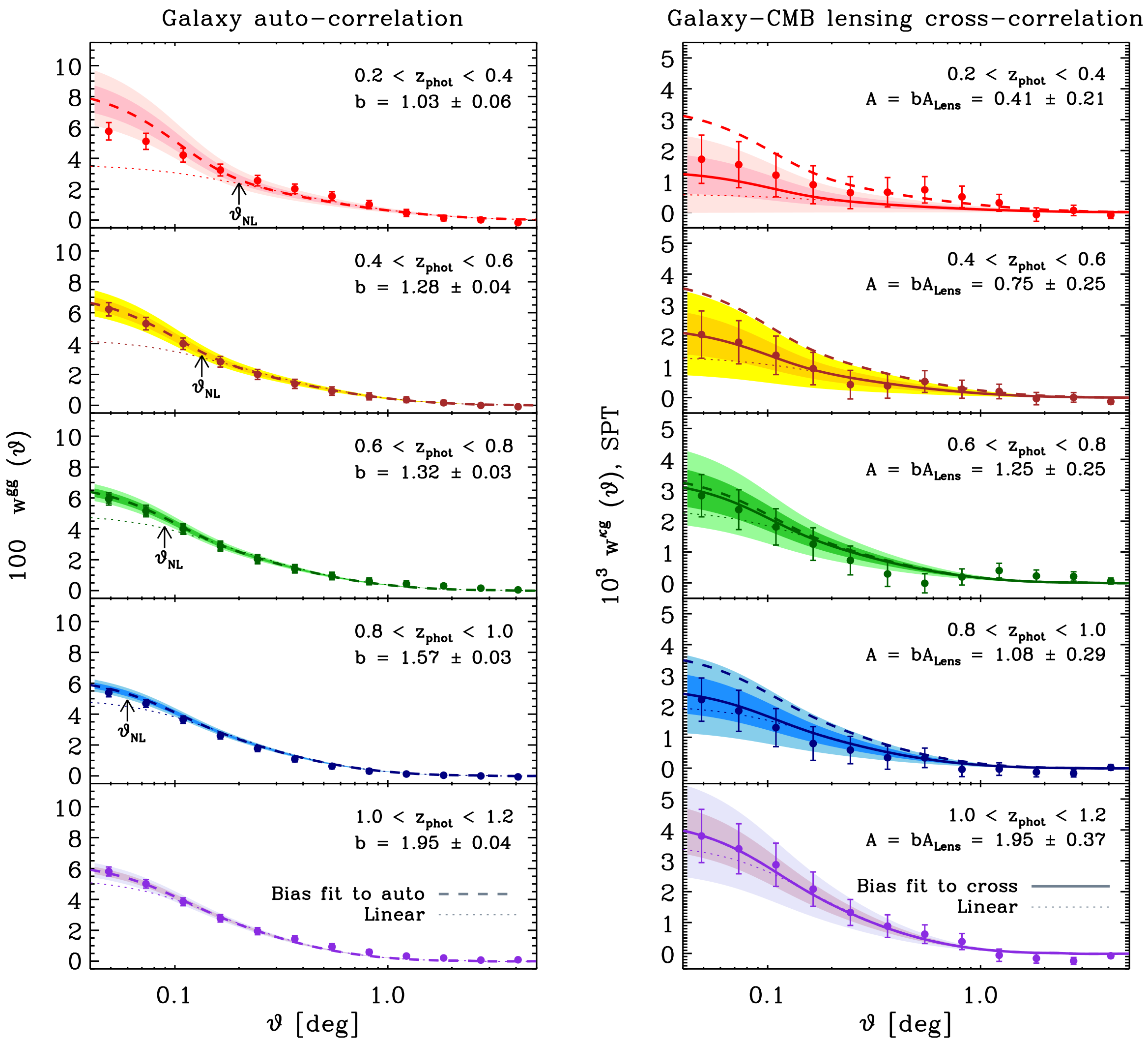
by Silvia Miati (Milano)

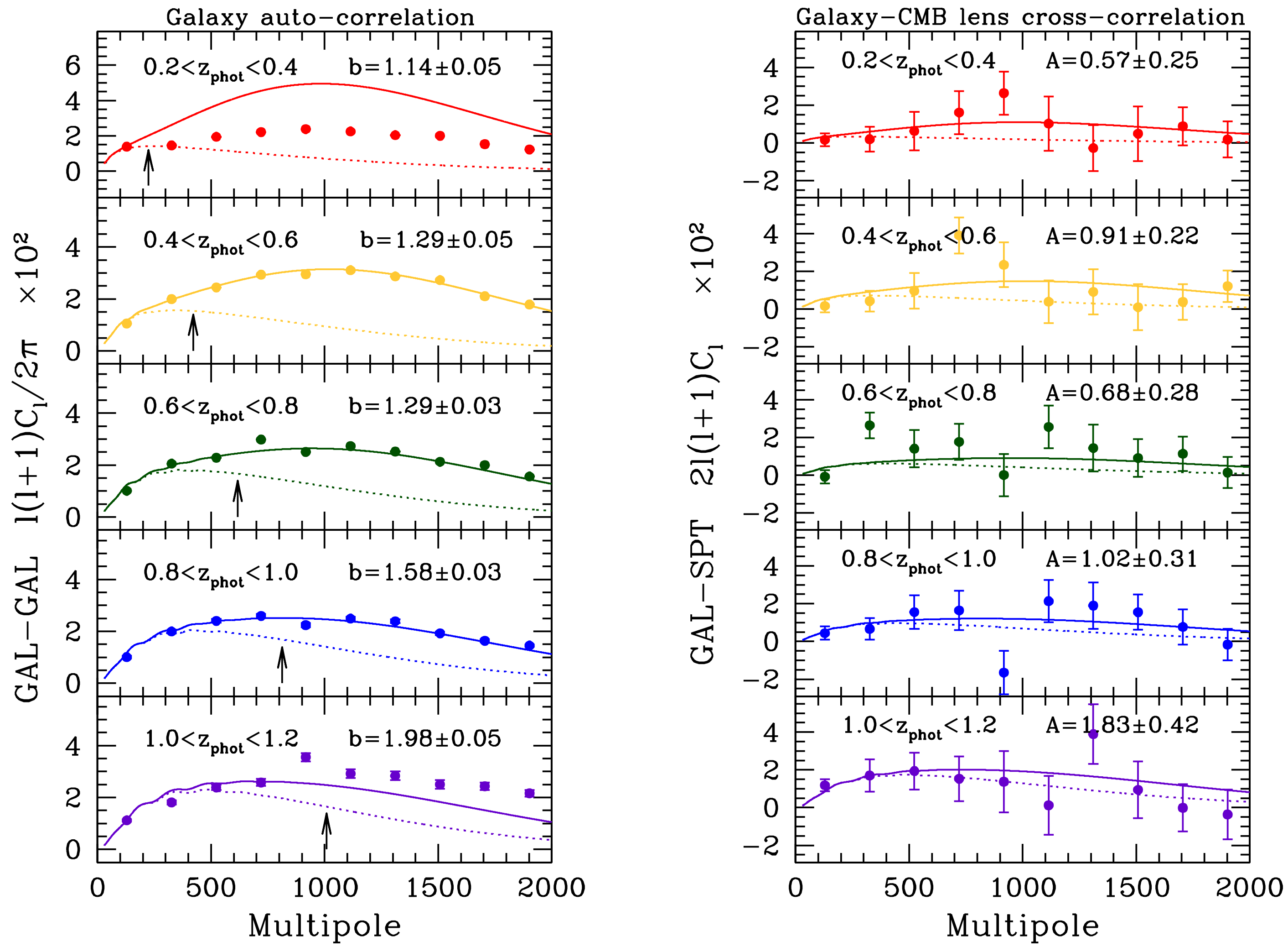
Going even more far away (TO DO LIST)

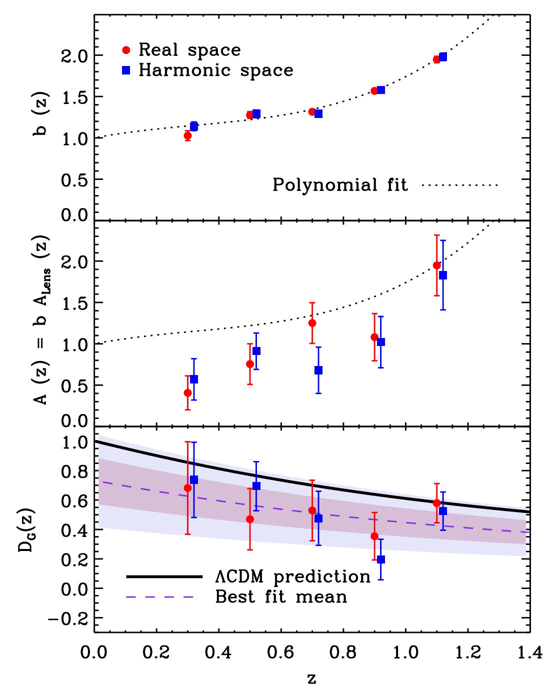
- Compare the signal going beyond Born approximation for the CMB lensing reconstructed map
- Vary matter field tracer (Galaxies, clusters,filaments…)
- Try other simulations (Flagship, DUSTGRAIN)
- Try other void definitions (3D voids?)

CONCLUSION

We have simulations, we have cross-correlation signal, we still have plenty of test to do but things are moving forward


Galaxy auto-correlation
Galaxy-CMB lensing cross-correlation
0.2 < z_phot < 0.4 b = 1.03 ± 0.06
0.4 < z_phot < 0.6 b = 1.28 ± 0.04
0.6 < z_phot < 0.8 b = 1.32 ± 0.03
0.8 < z_phot < 1.0 b = 1.57 ± 0.03
1.0 < z_phot < 1.2 b = 1.95 ± 0.04
Bias fit to auto
Linear
0.2 < z_phot < 0.4 A = bA_Lens = 0.41 ± 0.21
0.4 < z_phot < 0.6 A = bA_Lens = 0.75 ± 0.25
0.6 < z_phot < 0.8 A = bA_Lens = 1.25 ± 0.25
0.8 < z_phot < 1.0 A = bA_Lens = 1.08 ± 0.29
1.0 < z_phot < 1.2 A = bA_Lens = 1.95 ± 0.37
Bias fit to cross
Linear
ϑ_NL
100 w^gg (ϑ)
10^3 w^κg (ϑ), SPT
ϑ [deg]


Galaxy auto-correlation
Galaxy-CMB lens cross-correlation
0.2<z_phot<0.4 b=1.14±0.05
0.4<z_phot<0.6 b=1.29±0.05
0.6<z_phot<0.8 b=1.29±0.03
0.8<z_phot<1.0 b=1.58±0.03
1.0<z_phot<1.2 b=1.98±0.05
0.2<z_phot<0.4 A=0.57±0.25
0.4<z_phot<0.6 A=0.91±0.22
0.6<z_phot<0.8 A=0.68±0.28
0.8<z_phot<1.0 A=1.02±0.31
1.0<z_phot<1.2 A=1.83±0.42
GAL-GAL l(l+1)C_l/2π ×10^2
GAL-SPT 2l(l+1)C_l ×10^2
Multipole


Real space
Harmonic space
Polynomial fit
b (z)
A (z) = b A_Lens (z)
D_G(z)
ΛCDM prediction
Best fit mean
z

$$w^{\delta_g \delta_g}(\theta_\alpha) = \frac{DD(\theta_\alpha) - 2DR(\theta_\alpha) + RR(\theta_\alpha)}{RR(\theta_\alpha)},$$

$$DD(\theta_\alpha) = \frac{1}{N^{DD}_{\theta_\alpha}} \sum_{i=1}^{N_{\rm gal}} \sum_{j=1}^{N_{\rm gal}} \eta_i^D \eta_j^D \Theta_\alpha(\hat{\theta}^i - \hat{\theta}^j),$$

$$DR(\theta_\alpha) = \frac{1}{N^{DR}_{\theta_\alpha}} \sum_{i=1}^{N_{\rm gal}} \sum_{j=1}^{N_{\rm rand}} \eta_i^D \eta_j^R \Theta_\alpha(\hat{\theta}^i - \hat{\theta}^j),$$

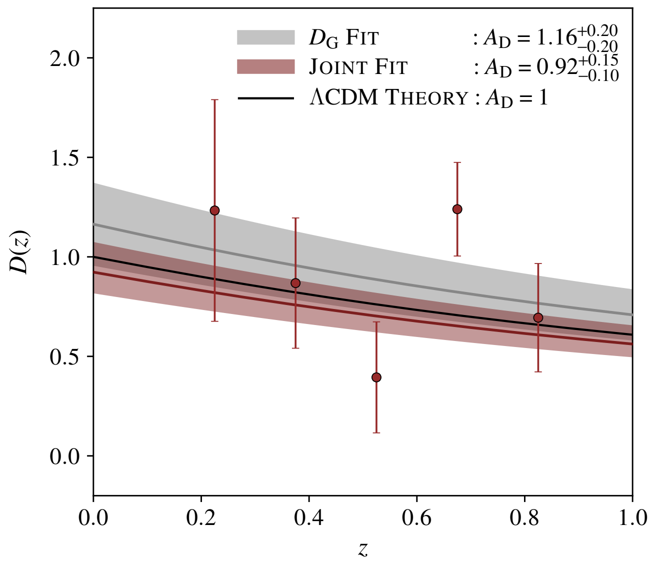
$$RR(\theta_\alpha) = \frac{1}{N^{RR}_{\theta_\alpha}} \sum_{i=1}^{N_{\rm rand}} \sum_{j=1}^{N_{\rm rand}} \eta_i^R \eta_j^R \Theta_\alpha(\hat{\theta}^i - \hat{\theta}^j),$$

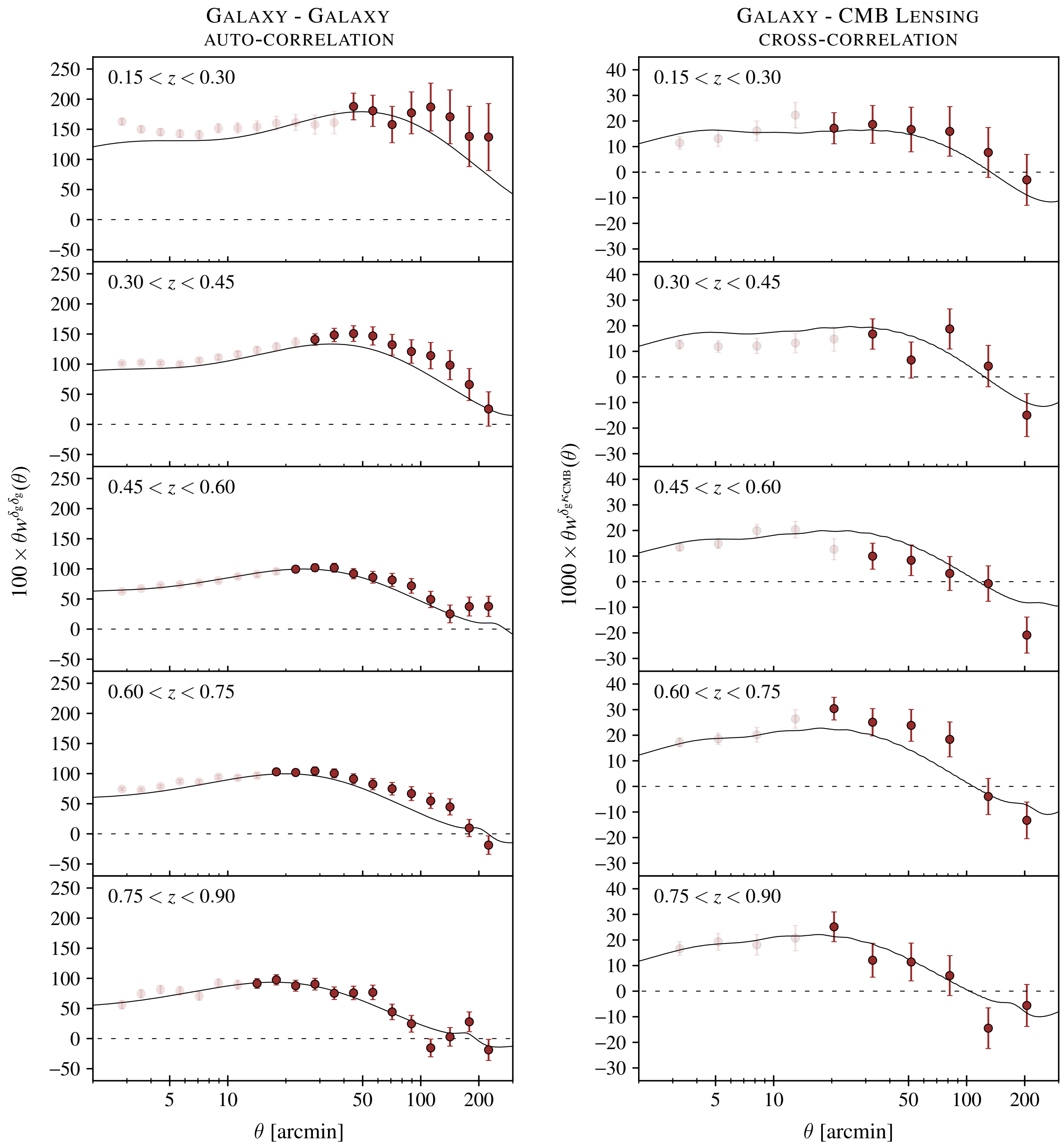
$$w^{\delta_g \kappa_{\rm CMB}}(\theta_\alpha) = D\kappa_{\rm CMB}(\theta_\alpha) - R\kappa_{\rm CMB}(\theta_\alpha),$$

with

$$D\kappa_{\rm CMB}(\theta_\alpha) = \frac{1}{N^{D\kappa_{\rm CMB}}_{\theta_\alpha}} \sum_{i=1}^{N_{\rm gal}} \sum_{j=1}^{N_{\rm pix}} \eta_i^D \eta_j^{\kappa_{\rm CMB}} \kappa_{{\rm CMB},j} \Theta_\alpha(\hat{\theta}^i - \hat{\theta}^j)$$

$$R\kappa_{\rm CMB}(\theta_\alpha) = \frac{1}{N^{R\kappa_{\rm CMB}}_{\theta_\alpha}} \sum_{i=1}^{N_{\rm rand}} \sum_{j=1}^{N_{\rm pix}} \eta_i^R \eta_j^{\kappa_{\rm CMB}} \kappa_{{\rm CMB},j} \Theta_\alpha(\hat{\theta}^i - \hat{\theta}^j)$$



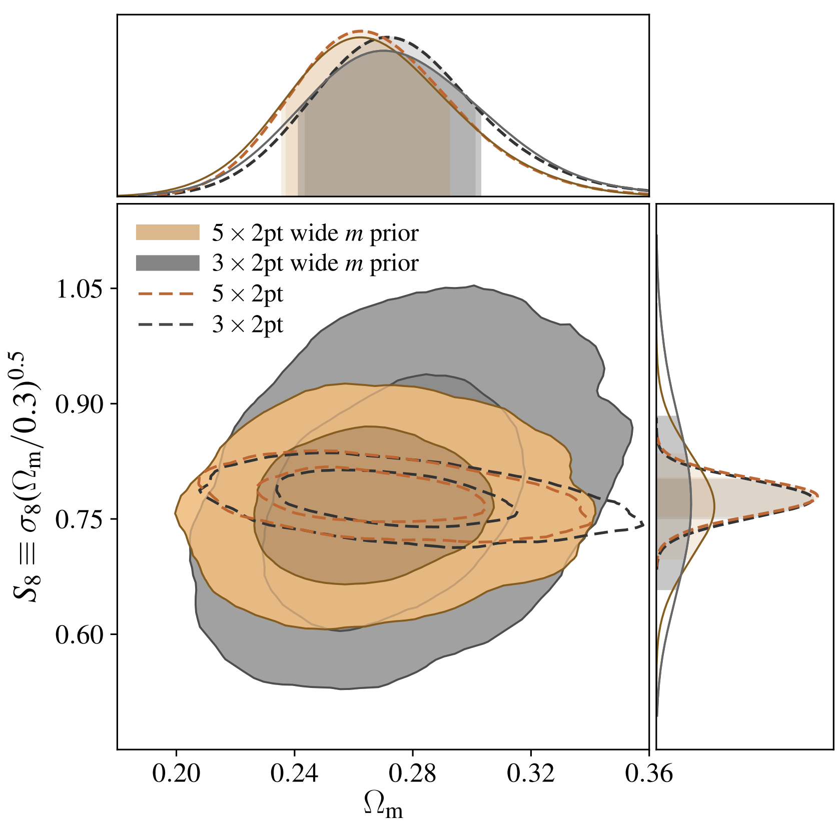


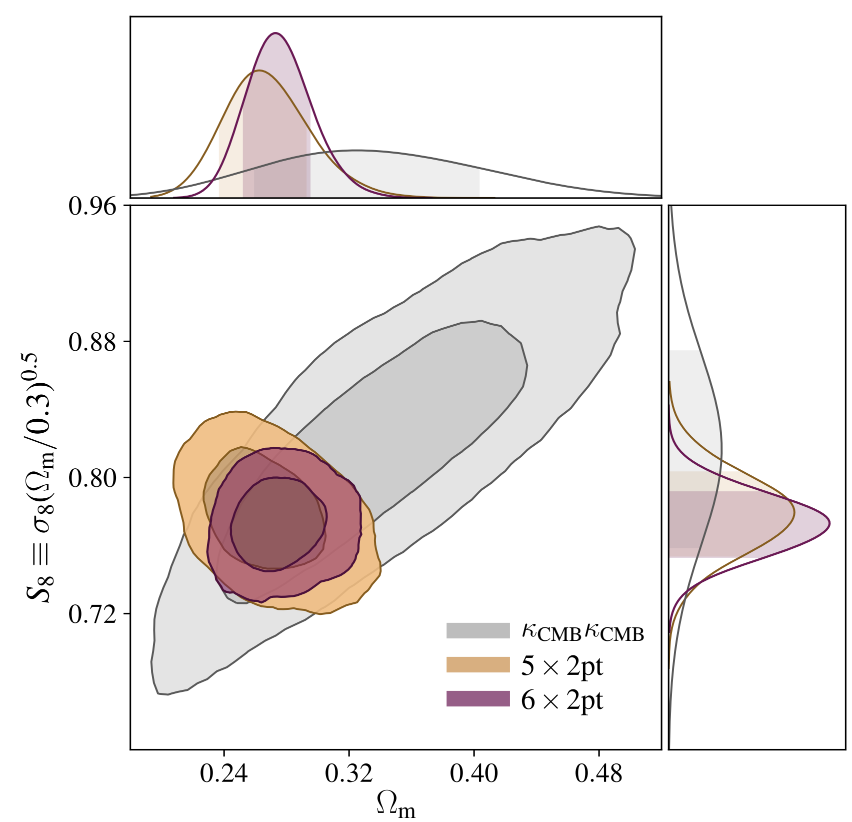
$\delta_g\delta_g$	$\delta_g\gamma$	$\delta_g\kappa_{\mathrm{CMB}}$
Elvin-Poole et al. (2018)	**Prat et al. (2018)**	**Omori et al. (2018a)**
	$\gamma\gamma$	$\gamma\kappa_{\mathrm{CMB}}$
	Troxel et al. (2018)	**Omori et al. (2018b)**
		$\kappa_{\mathrm{CMB}}\kappa_{\mathrm{CMB}}$
		Planck (2015)

3x2pt
Methodology:
Krause et al. (2018)
Simulation:
MacCrann et al. (2018)
Results:
DES et al. (2018)

5x2pt
Methodology:
Baxter et al. (2018)
Results:
This work

6x2pt
Results:
This work





ma per seguir virtute e canoscenza
SISSA
Scuola Internazionale Superiore
di Studi Avanzati

Osservatorio Astronomico
della Regione Autonoma
Valle d'Aosta
Planetario di Lignan

Observatoire Astronomique
de la Région Autonome
Vallée d'Aoste
Planétarium de Lignan

INSTITUTO DE ASTROFISICA DE CANARIAS · IAC

INAF
ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

Euclid consortium

IFAE
Institut de Física d'Altes Energies

ifpU

UNIVERSITAS STUDIORUM MEDIOLANENSIS

US
UNIVERSITY OF SUSSEX

MICE