DEMNUni : The imprint of massive neutrinos on the cross-correlation between cosmic voids and CMB lensing

Pauline Vielzeuf

Windows on the Universe

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ICISE, Quy Nhon (Vietnam) , August 6 - 12, 2023

Institut Physique de l'Univers
Aix-Marseille Université
Centre de Physique des Particules de Marseille CPPM

Rencontres du Vietnam
icise Quy Nhon Vietnam

Outline

- DEMNUni :
- The imprint of massive neutrinos
- on the cross-correlation between cosmic voids
- and CMB lensing

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DEMNUni: The imprint of massive neutrinos on the cross-correlation between cosmic voids and CMB lensing

arXiv:2303.10048

Pauline Vielzeuf[a] Matteo Calabrese[b] Carmelita Carbone[c] Giulio Fabbian[d,e] and Carlo Baccigalupi[f,g,h]

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DEMNUni simulations

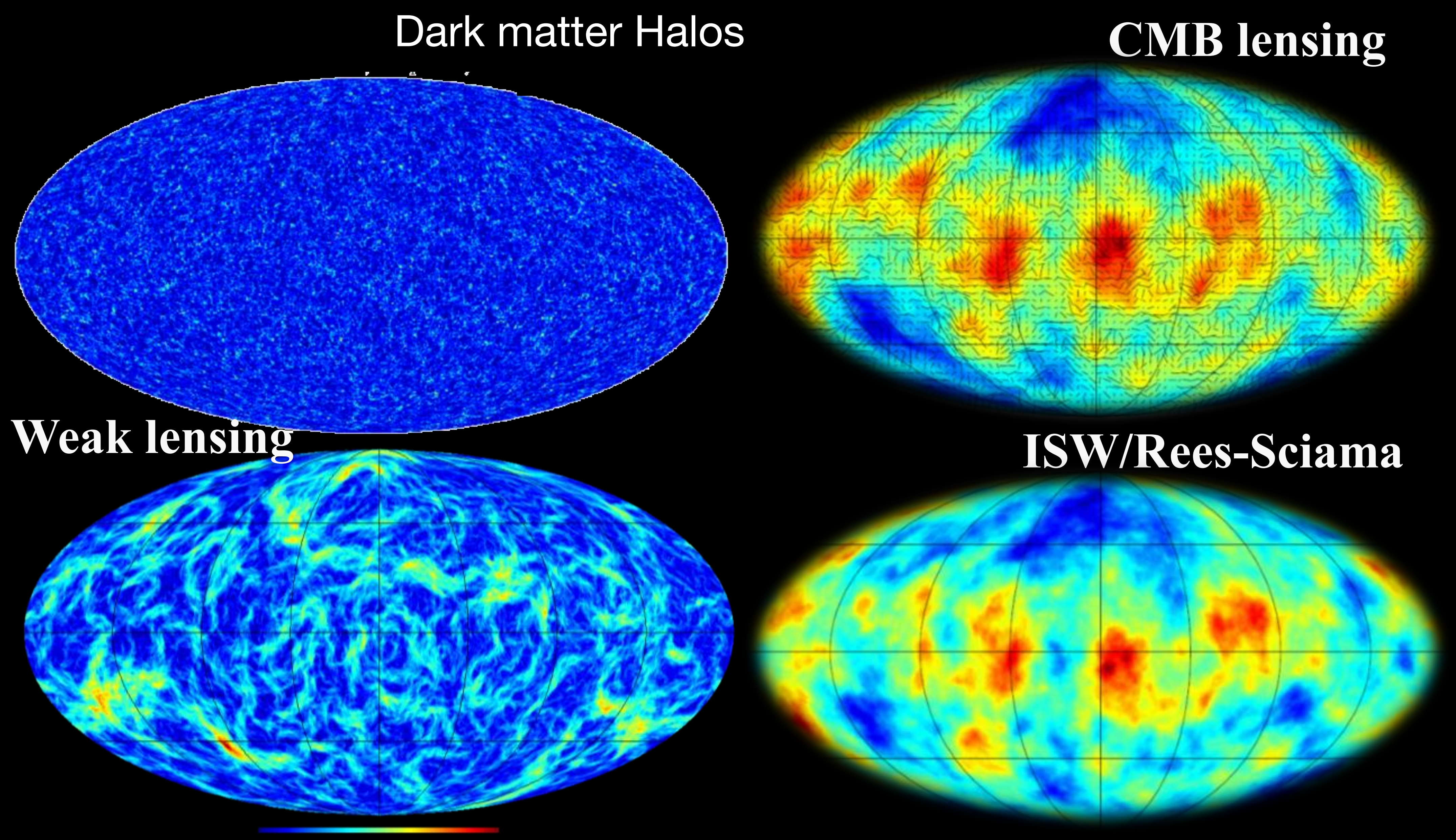
Carbone, 2016 (1605.02024)

14 cosmological simulations with volume: $(2\ \mathrm{Gpc}/h)^3$, N_{part}: 2×2048^3 (CDM+)
baseline Planck-13 cosmology

+

M=0, 0.17, 0.3, 0.53 eV (DEMNUni-I)

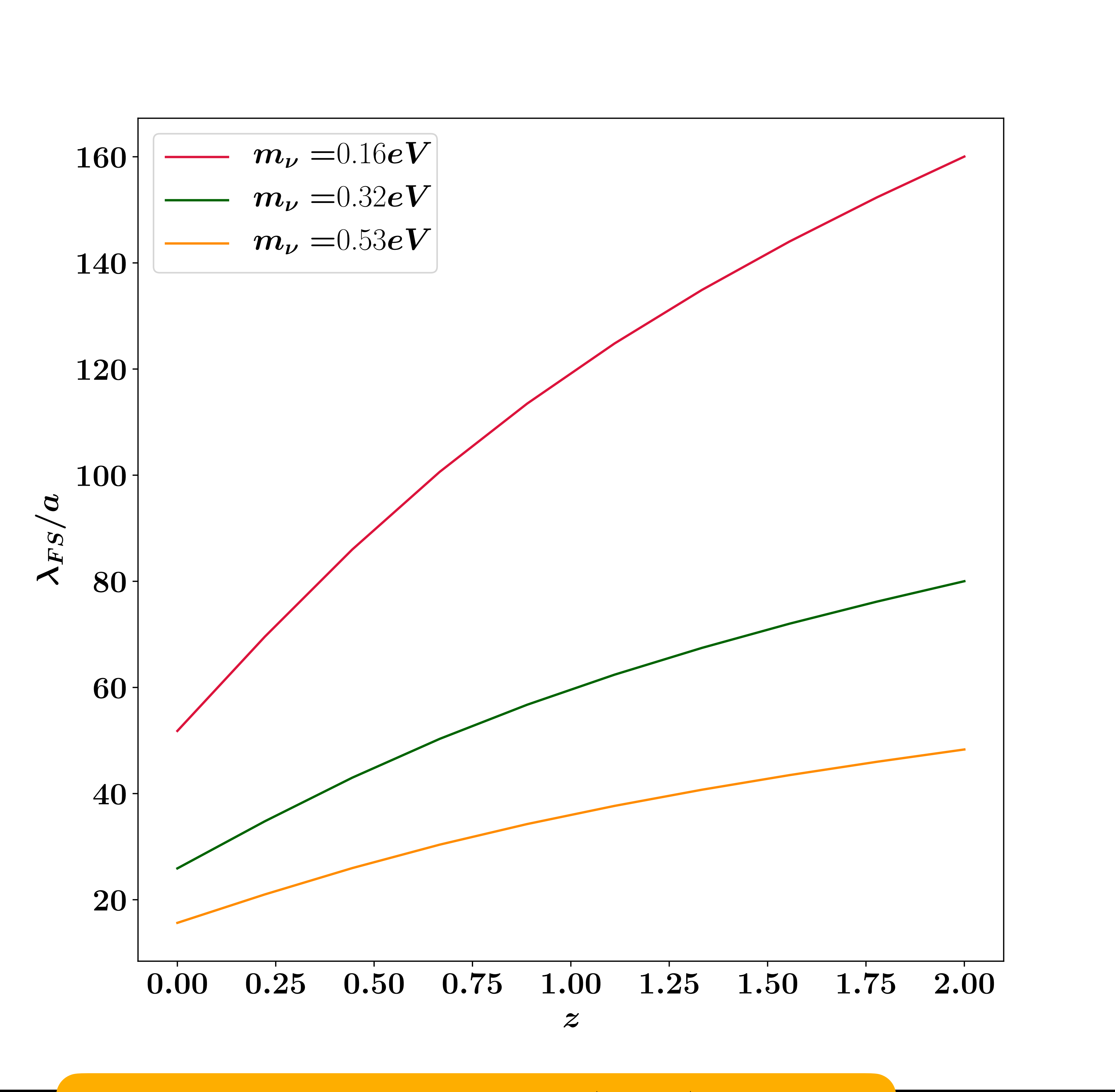
5 snaps per sim stored between z=0-2,
all the halo/subhalo catalogs stored from z<2



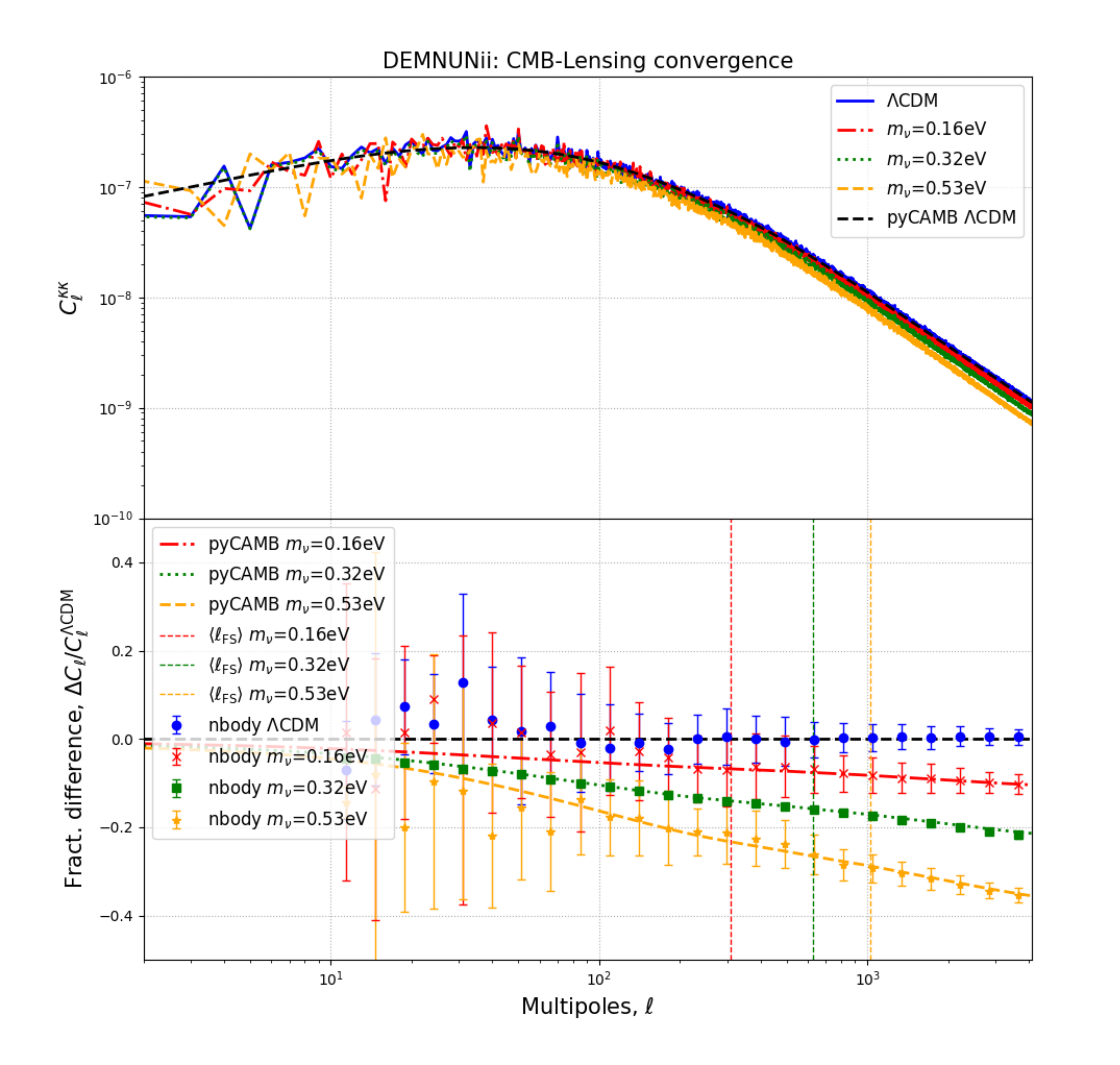
- CMB lensing map for each catalog,
- CMB lensing separate effect from DM and Mnu for 0.53
- diluted DM particles catalog

Massive neutrinos in cosmology

At small scales, due to their non-zero velocity, massive neutrinos will travel across **density fluctuations and thus smooth them.**

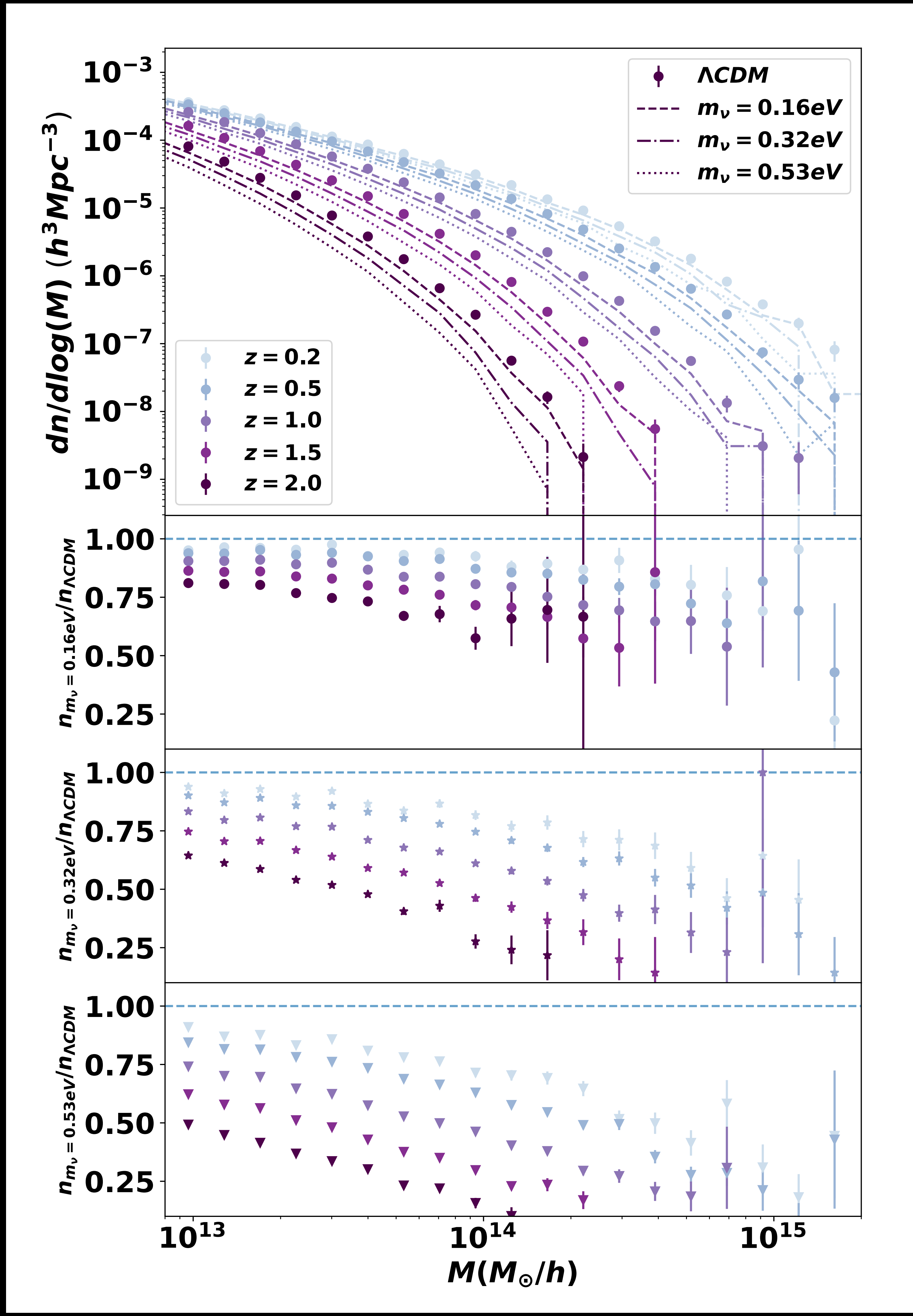


$$\lambda_{\rm FS}(m_\nu, z) \sim 8.1 \frac{H_0(1+z)}{H(z)} \left(\frac{1eV}{m_\nu}\right) h^{-1}{\rm Mpc},$$



Massive neutrinos in cosmology

The Halo Mass function -> Consequence on the halo population



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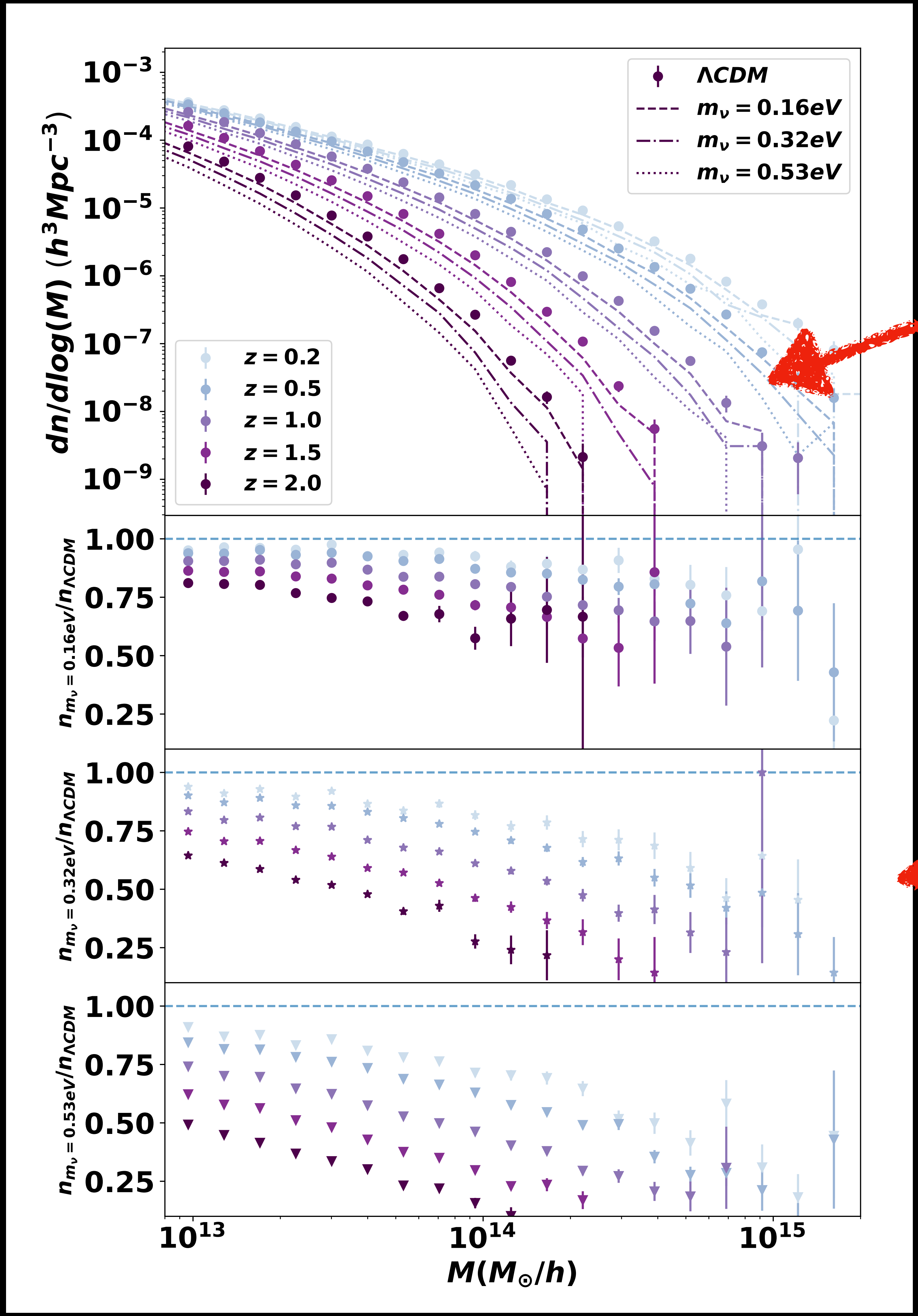
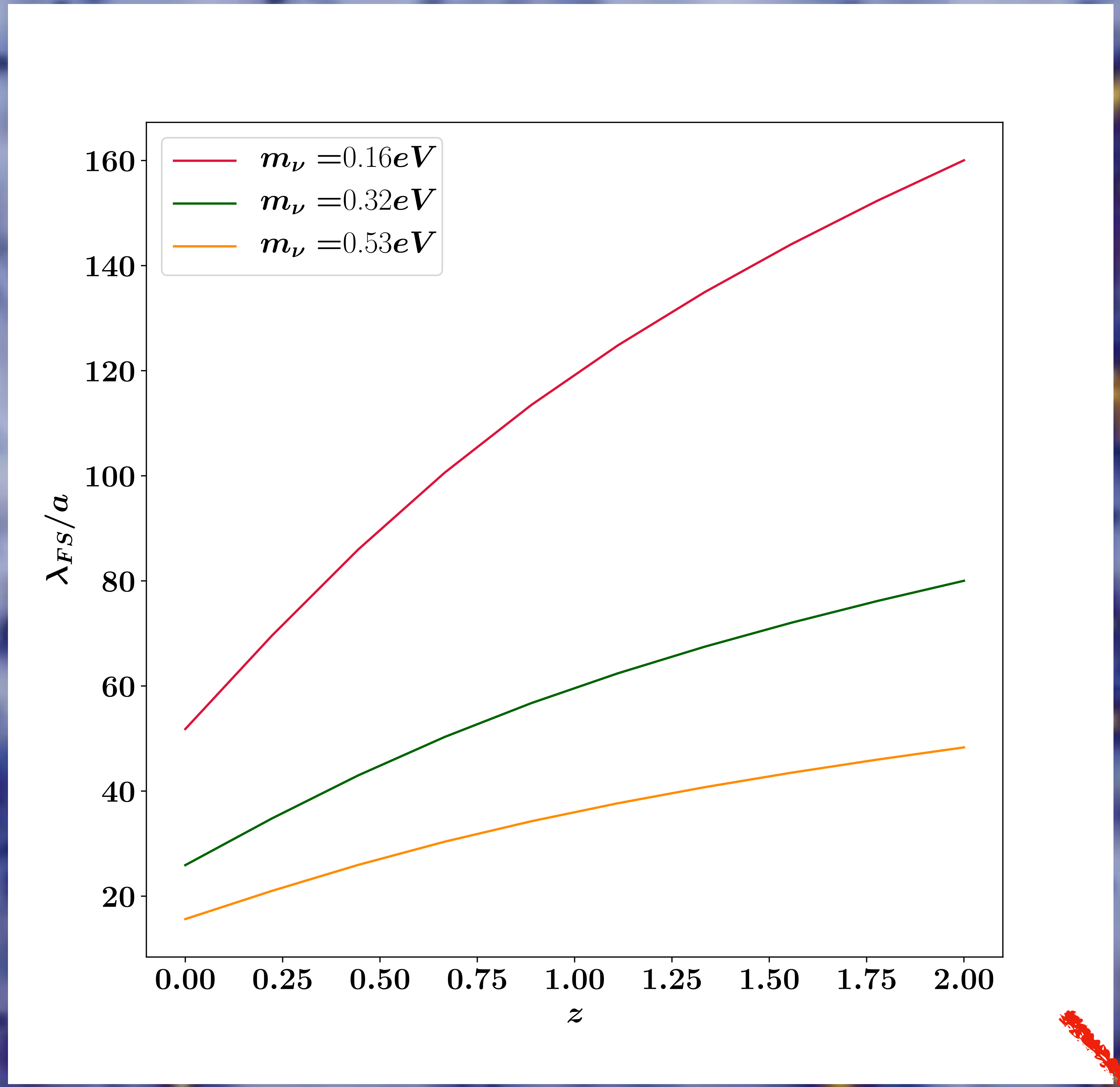


Massive neutrinos smooth the matter field decreasing thus the number of identified structures

Higher the mass of Neutrinos, higher its effect will be

Cosmic voids

Cosmic voids



filaments

voids

At **scales comparable to cosmic voids**, massive neutrinos will **fall in the potential wells**.

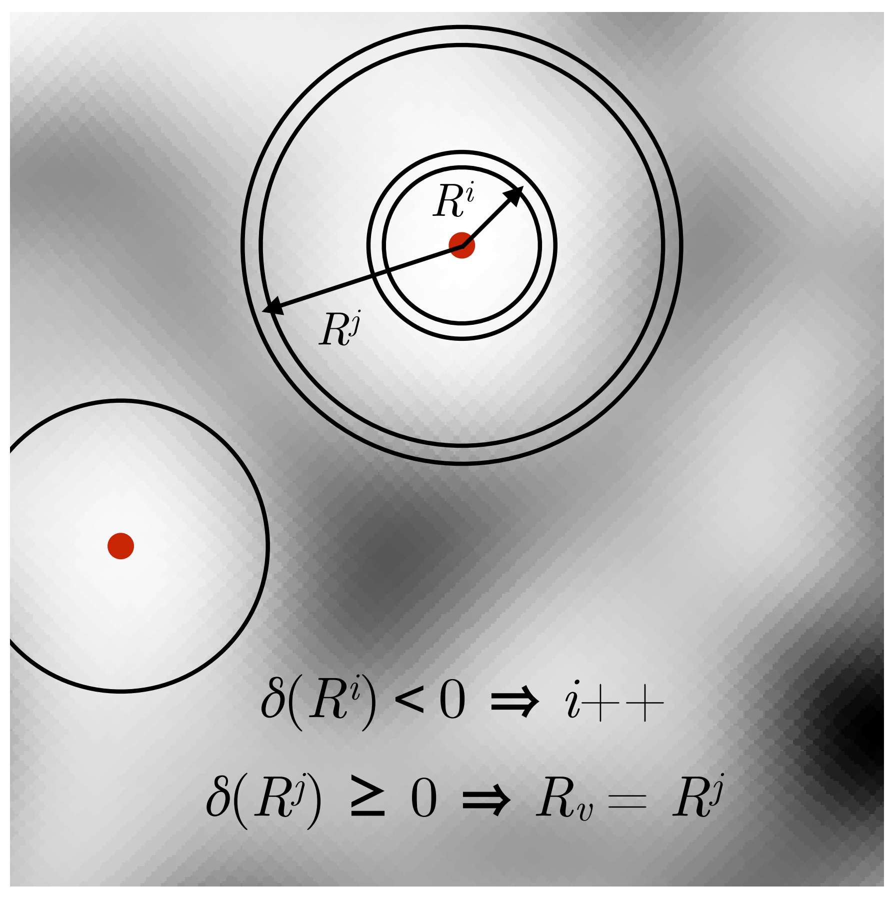
cosmic voids might be particularly affected by the presence of massive neutrino, due to the fact that the typical size of voids (10 to 100s of h^{-1}Mpc)

The Void finder

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

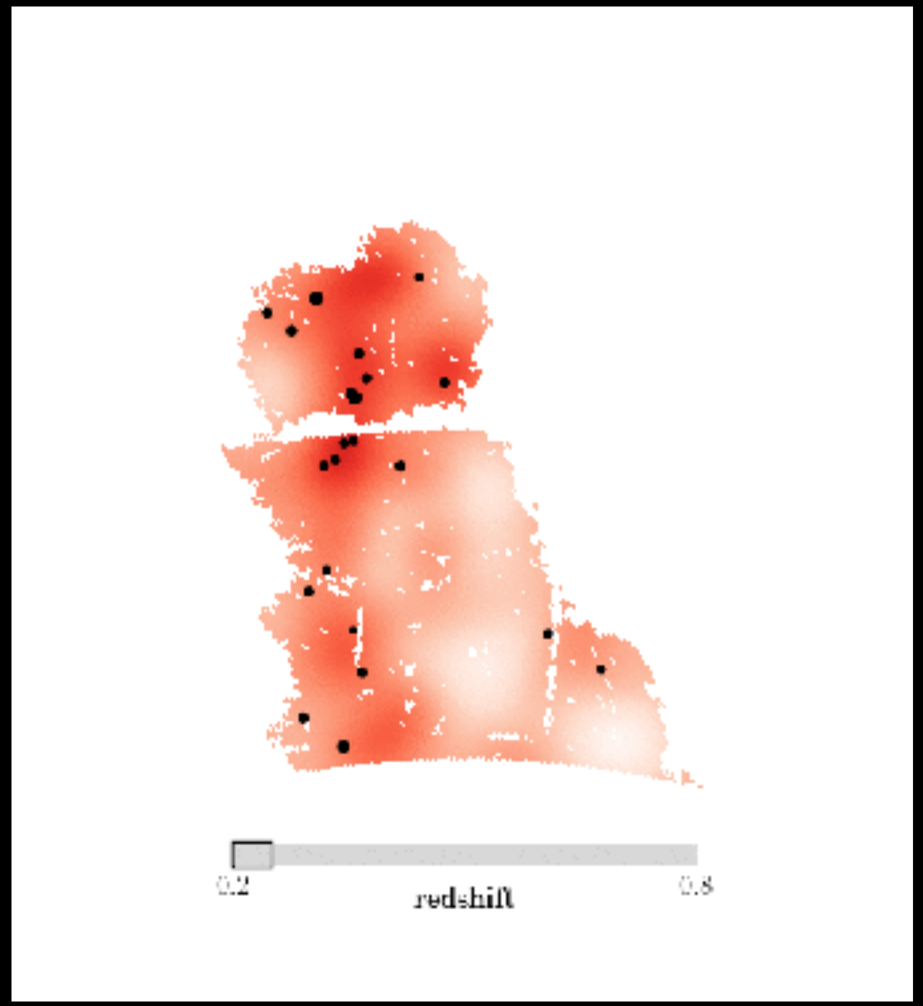
- Divide the sample in redshift slices. Here 100*Mpc/h*

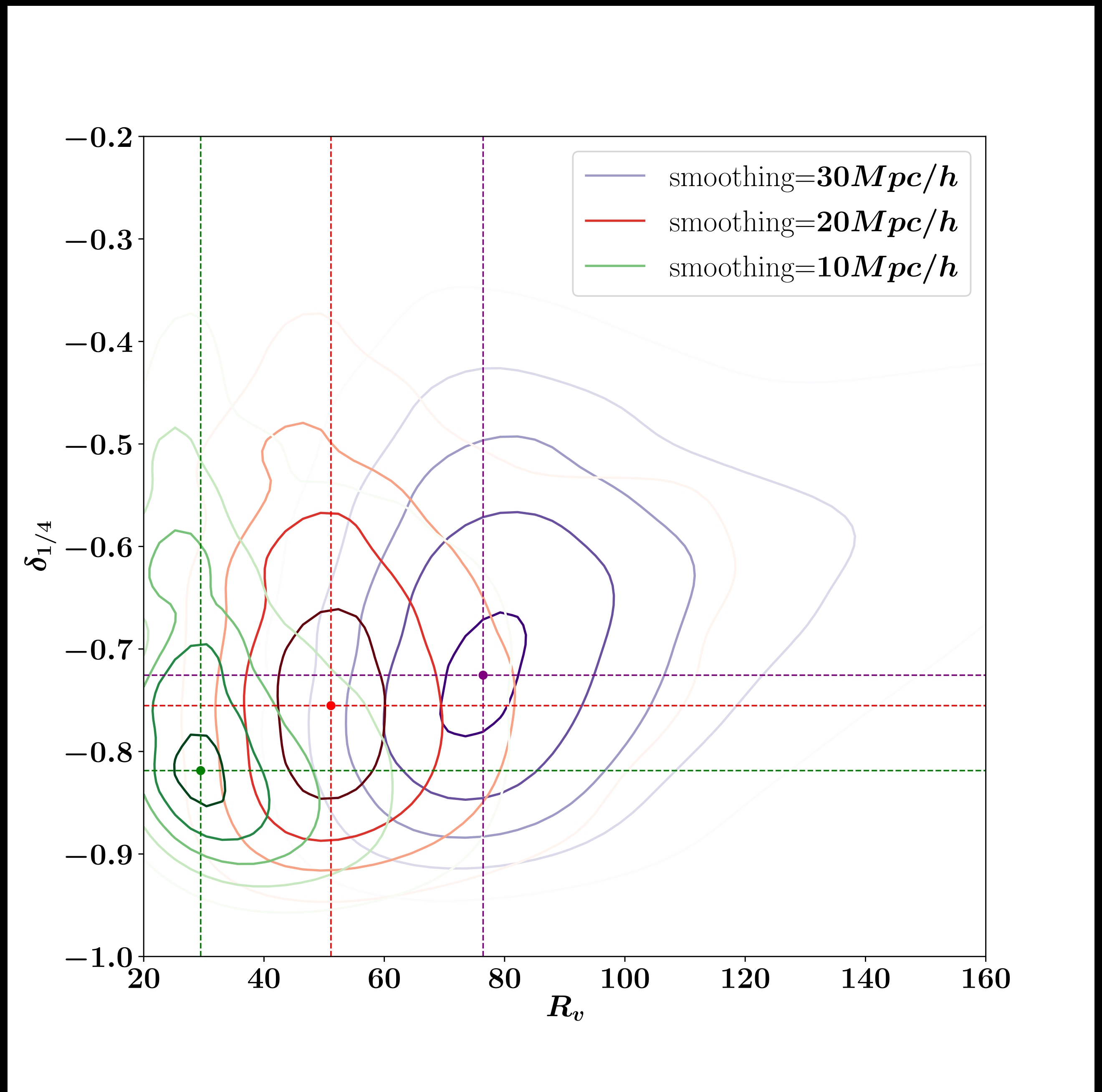
- Compute the density field for each slice by counting the galaxy number in each pixel and smoothing the field with a Gaussian with a predefined smoothing scale.



- 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.





smoothing scale	$10h^{-1}$ Mpc	$20h^{-1}$ Mpc	$30h^{-1}$ Mpc
$n_{\Lambda\mathrm{CDM}}$	144,594	68,221	30,055
$n_{\Lambda\mathrm{CDM}+m_\nu=0.16\mathrm{eV}}$	129,957	65,563	30,767
$n_{\Lambda\mathrm{CDM}+m_\nu=0.32\mathrm{eV}}$	114,046	61,945	30,986
$n_{\Lambda\mathrm{CDM}+m_\nu=0.53\mathrm{eV}}$	98,658	58,016	30,814

increase neutrino mass -> decrease number of voids

increase smoothing scale -> decrease the difference

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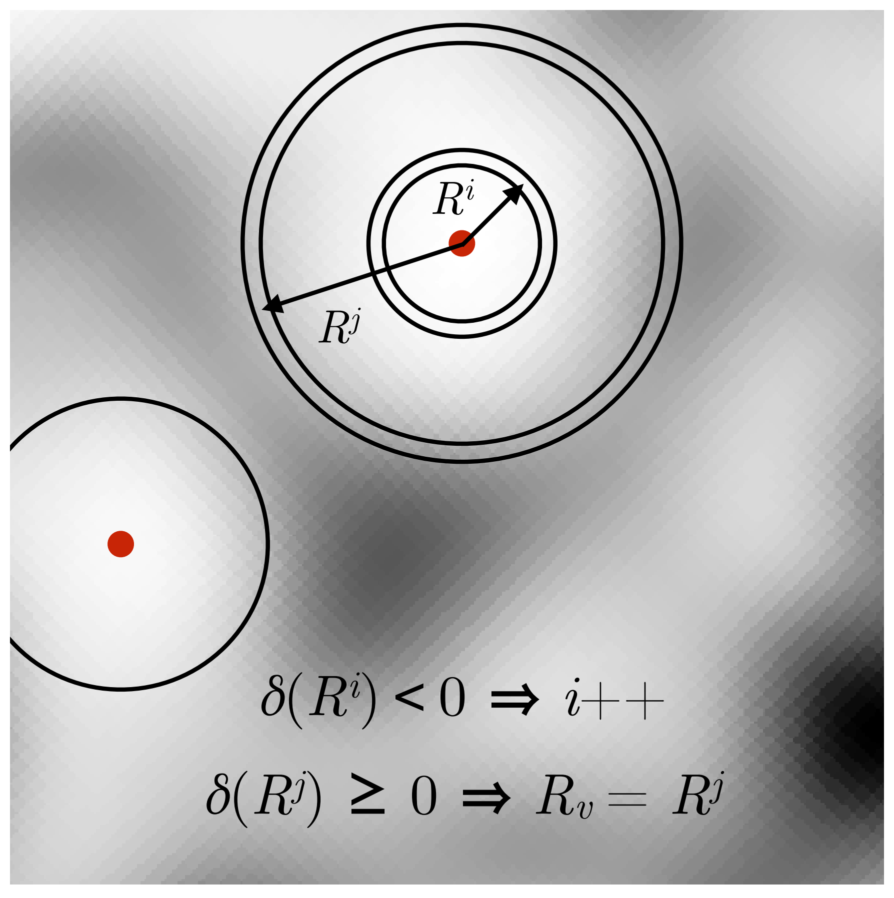

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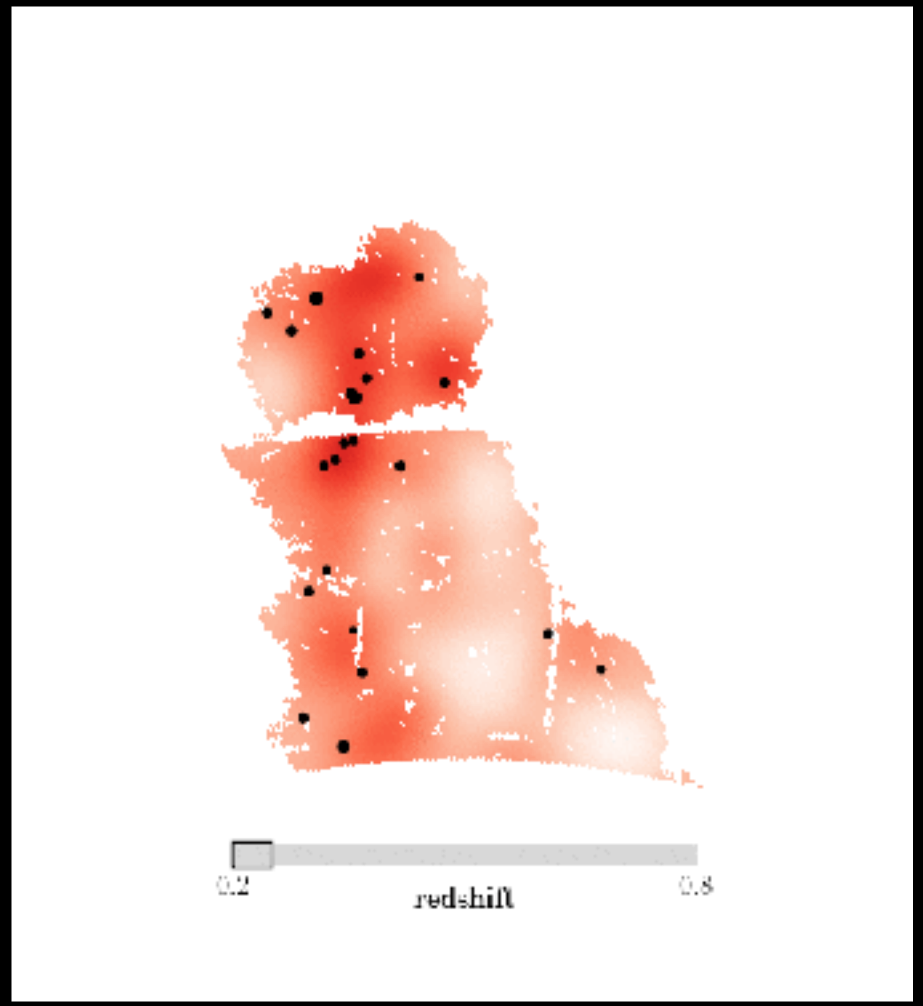

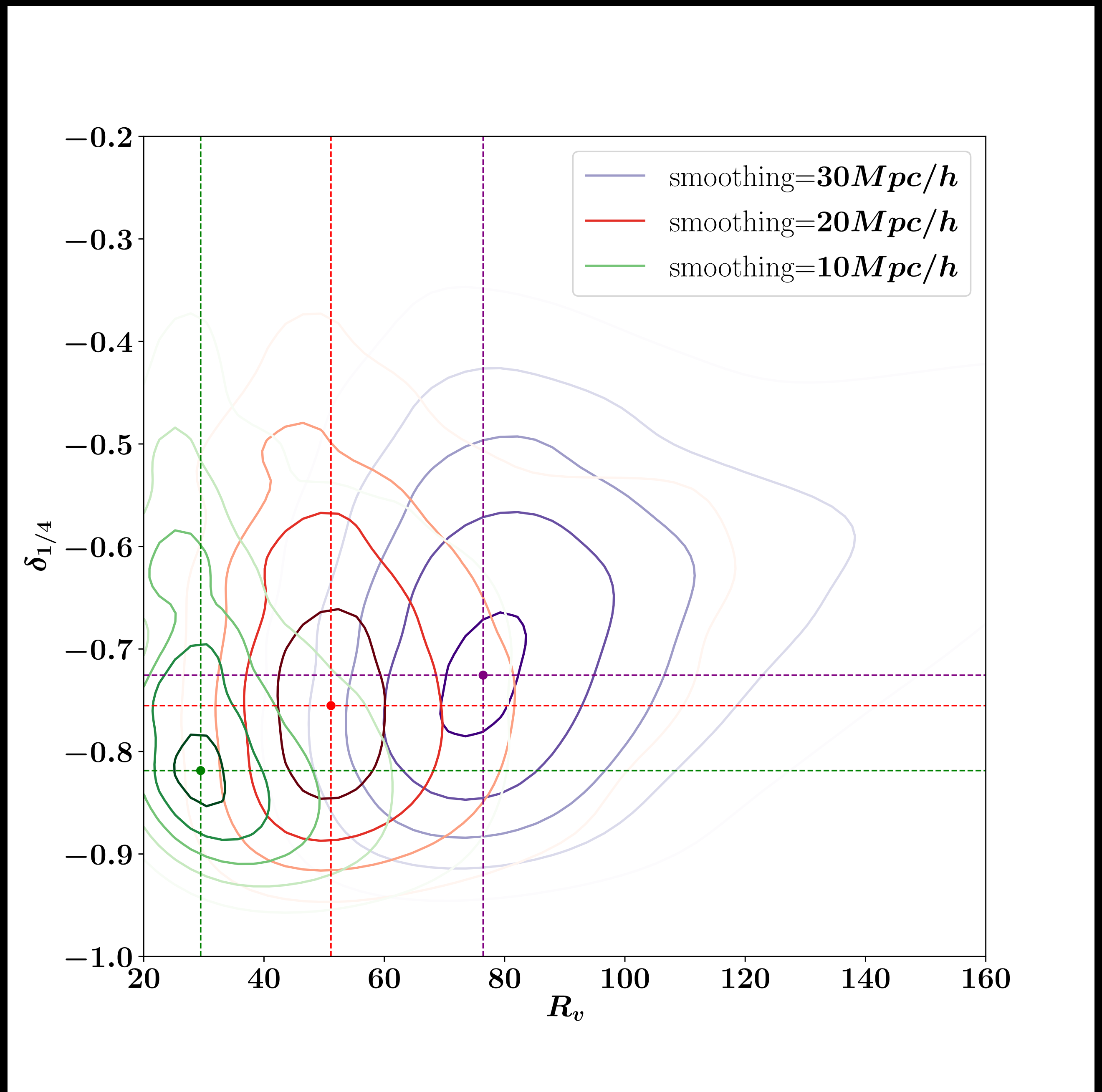

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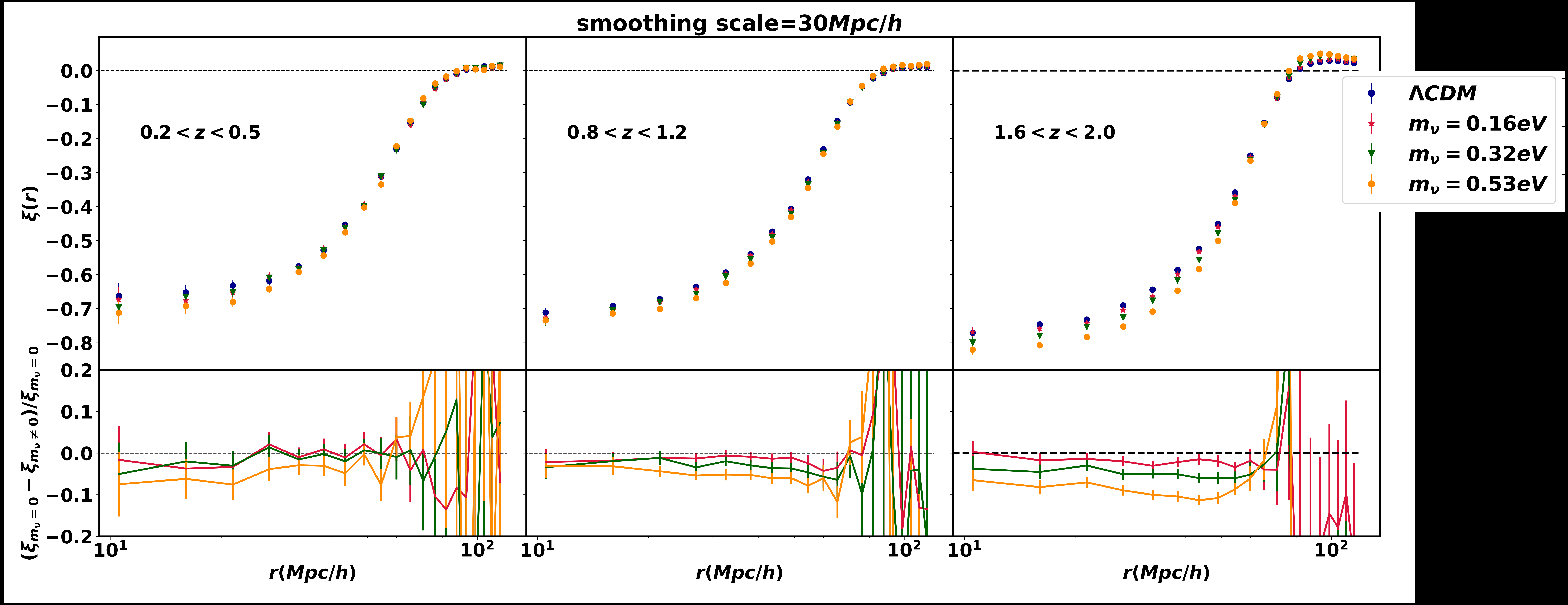
Massive neutrinos in cosmology

Void density profile



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Voids in massive neutrino cosmologies seem to be slightly deeper than in the massless case

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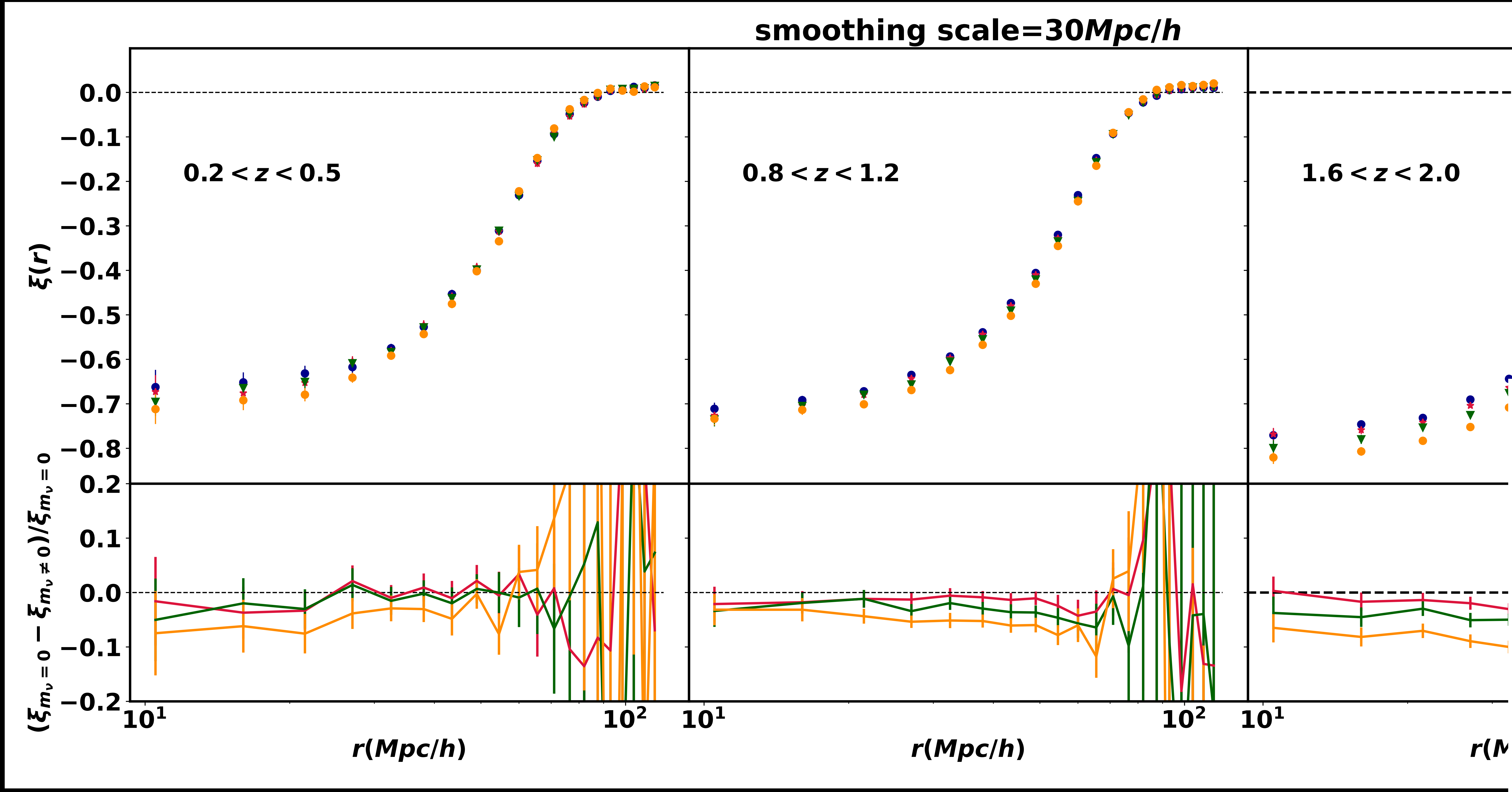

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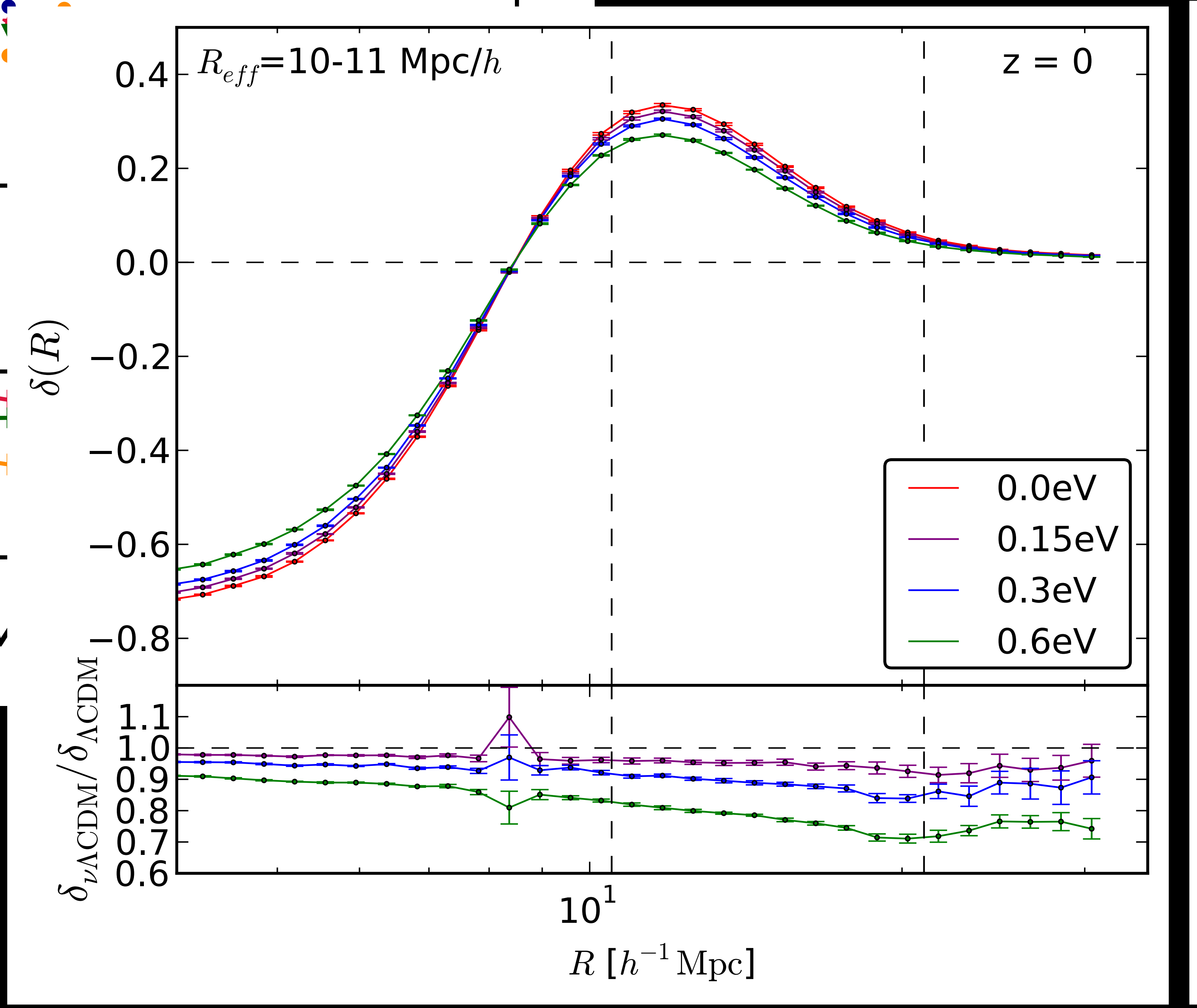
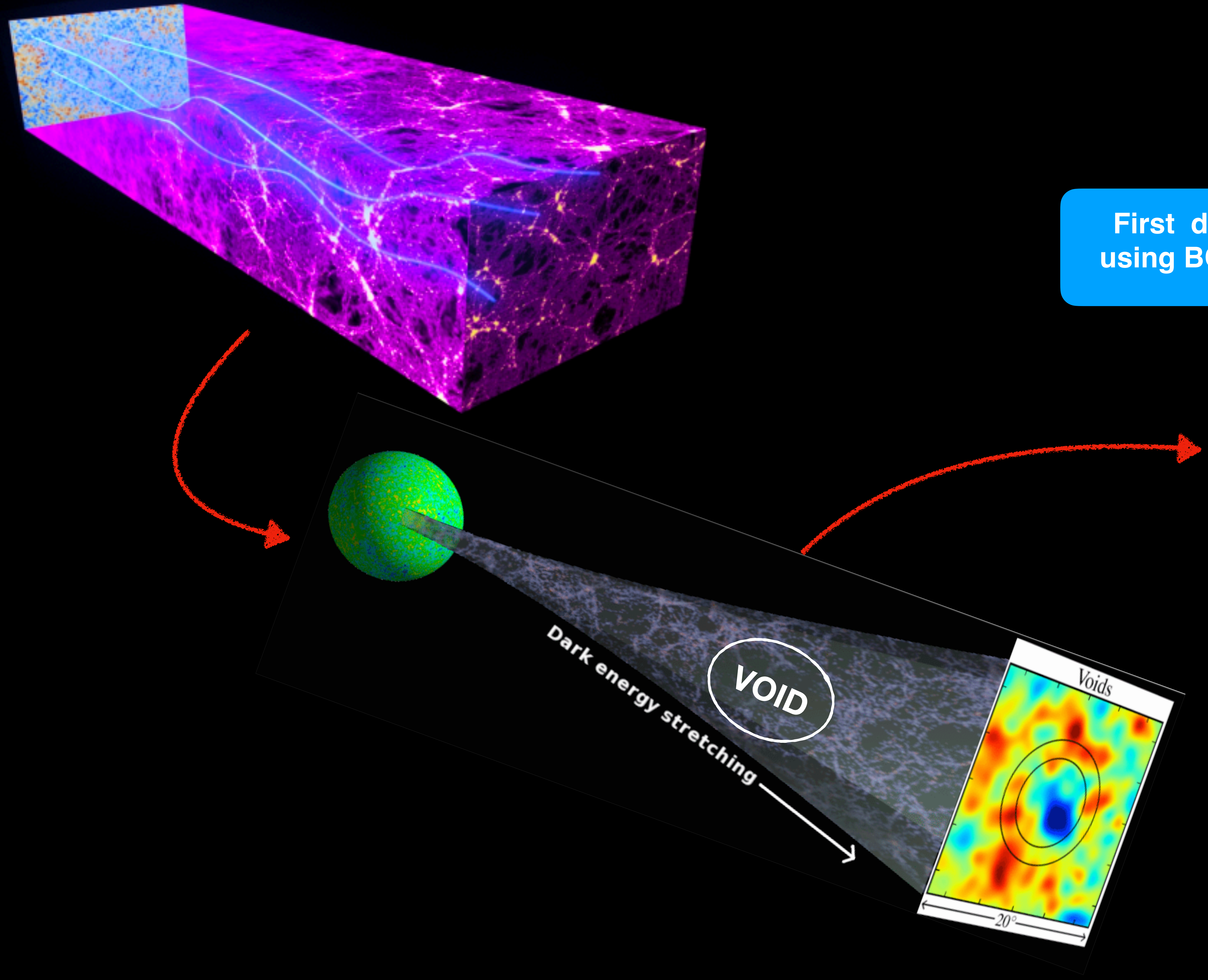


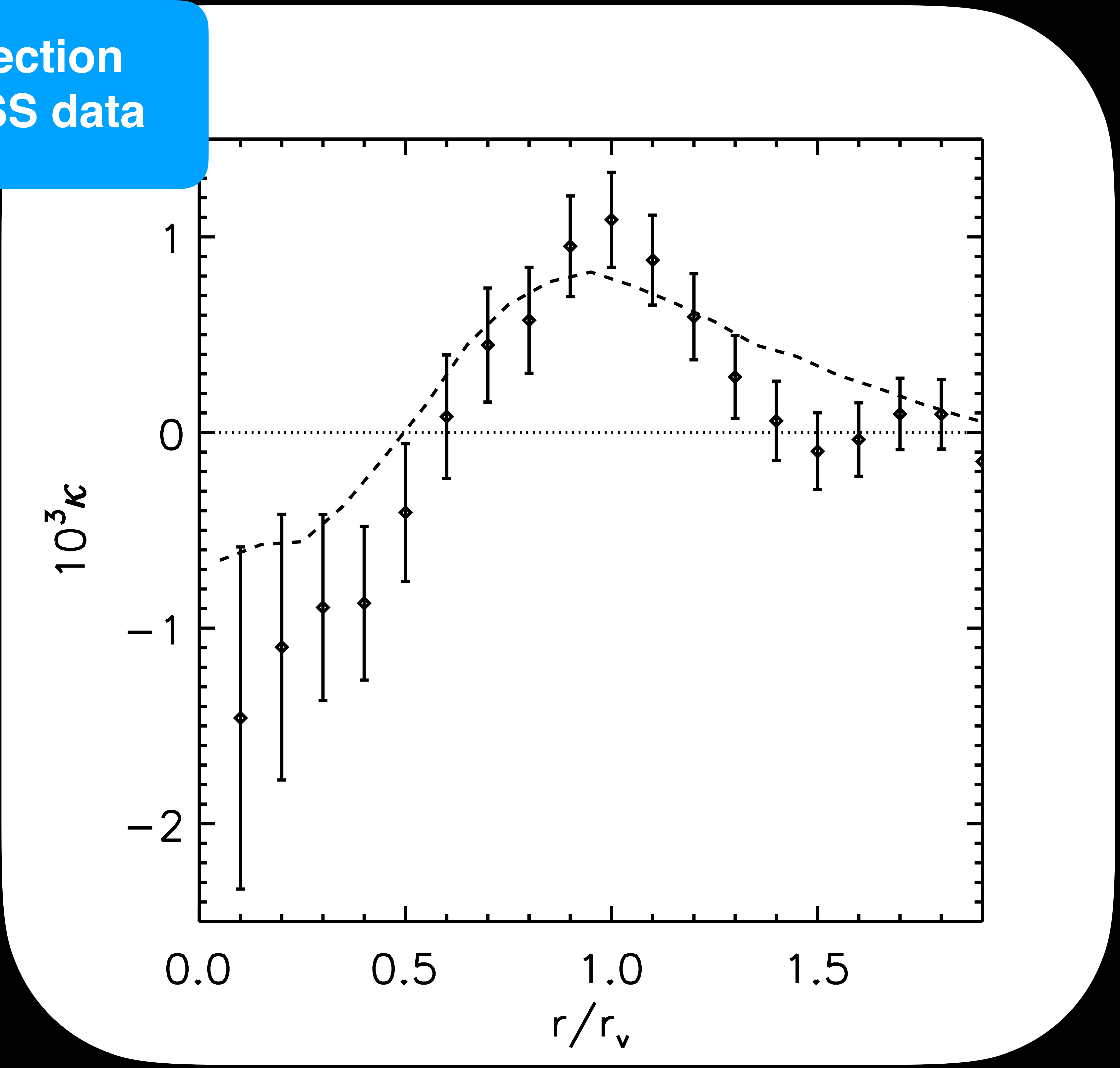
Voids in massive neutrino cosmologies seem to be slightly deeper than in the massless case

Massara (2015)

CMB lensing X voids

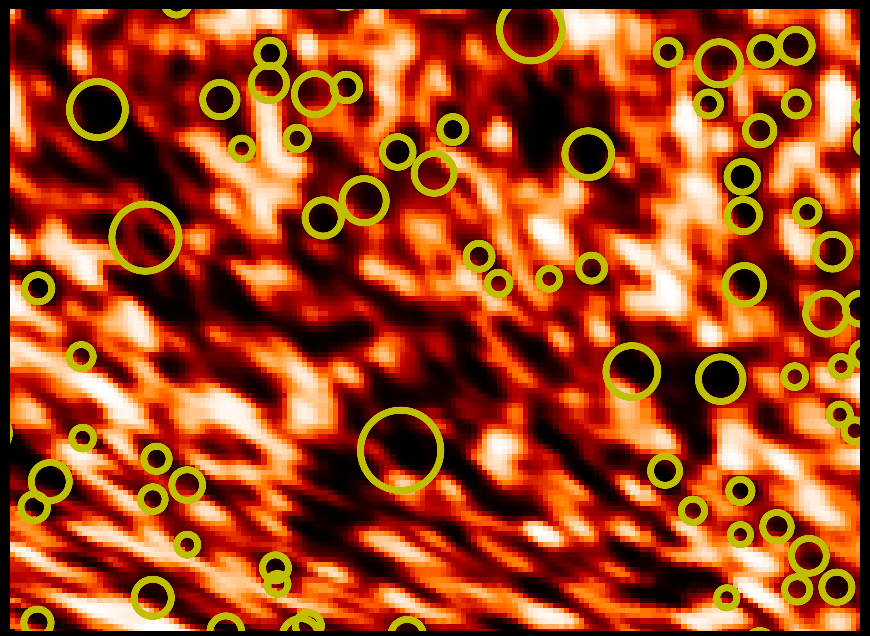


First detection using BOSS data



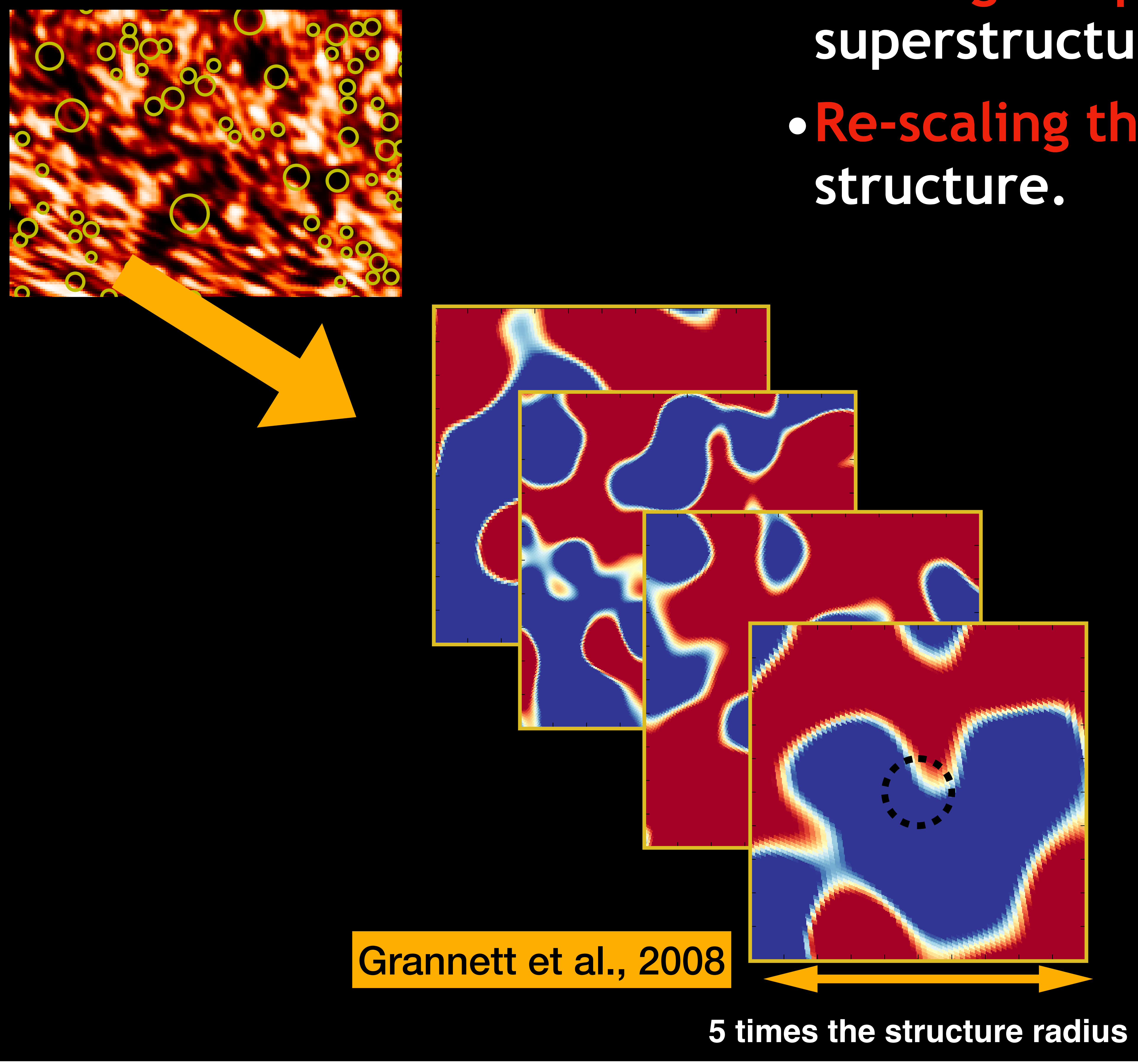
Cai et al. 2017, MNRAS, 466, 3364

methodology



methodology

- Cutting out patches of the CMB map centered at superstructure position using healpix (Górski et al., 2005).
- Re-scaling the patches given the angular size of the structure.



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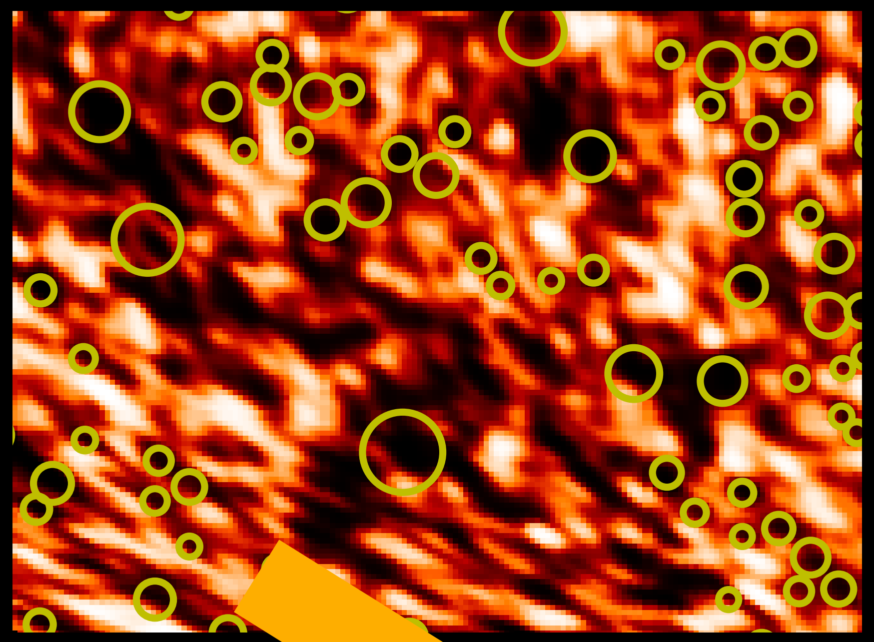
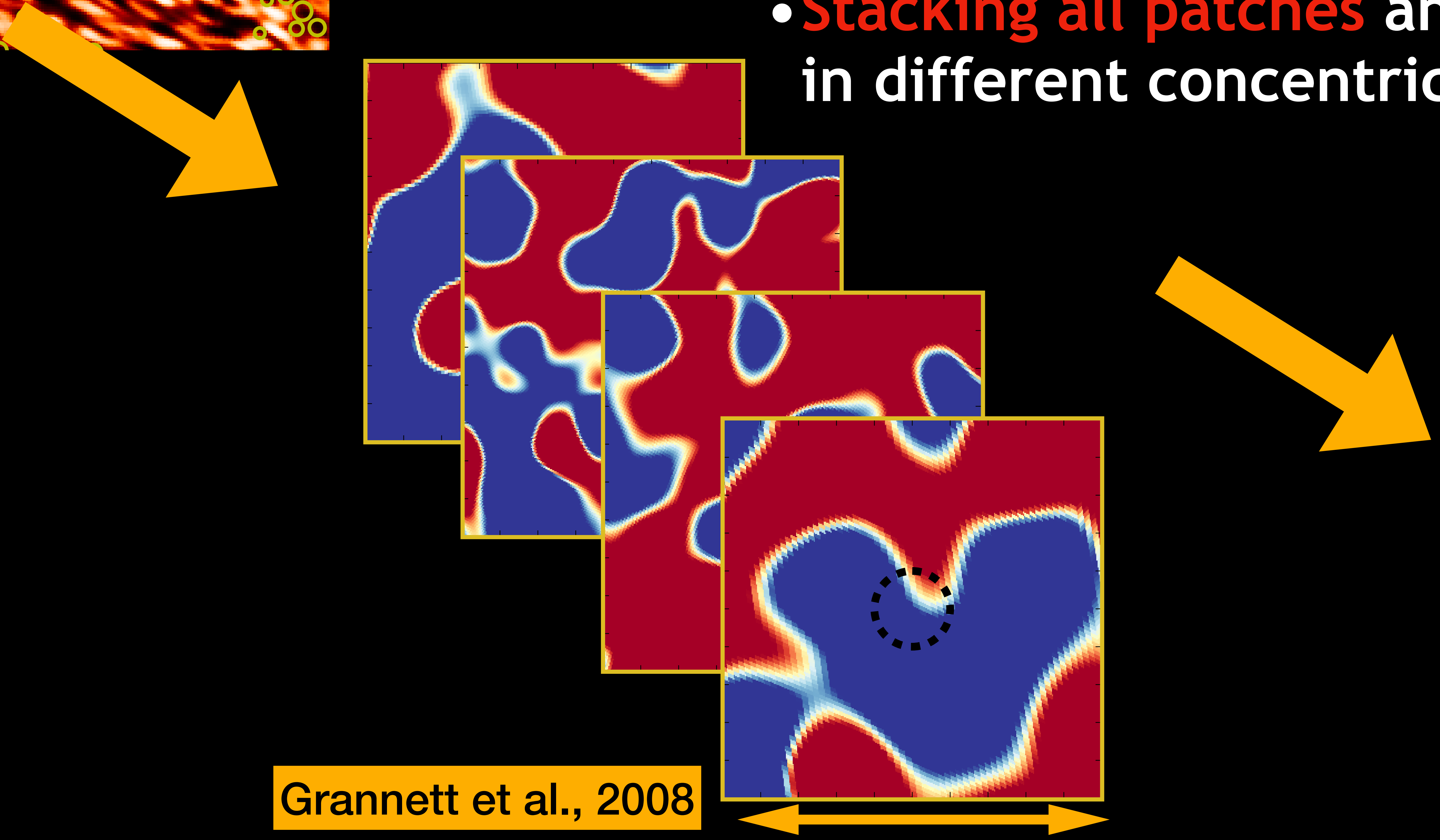


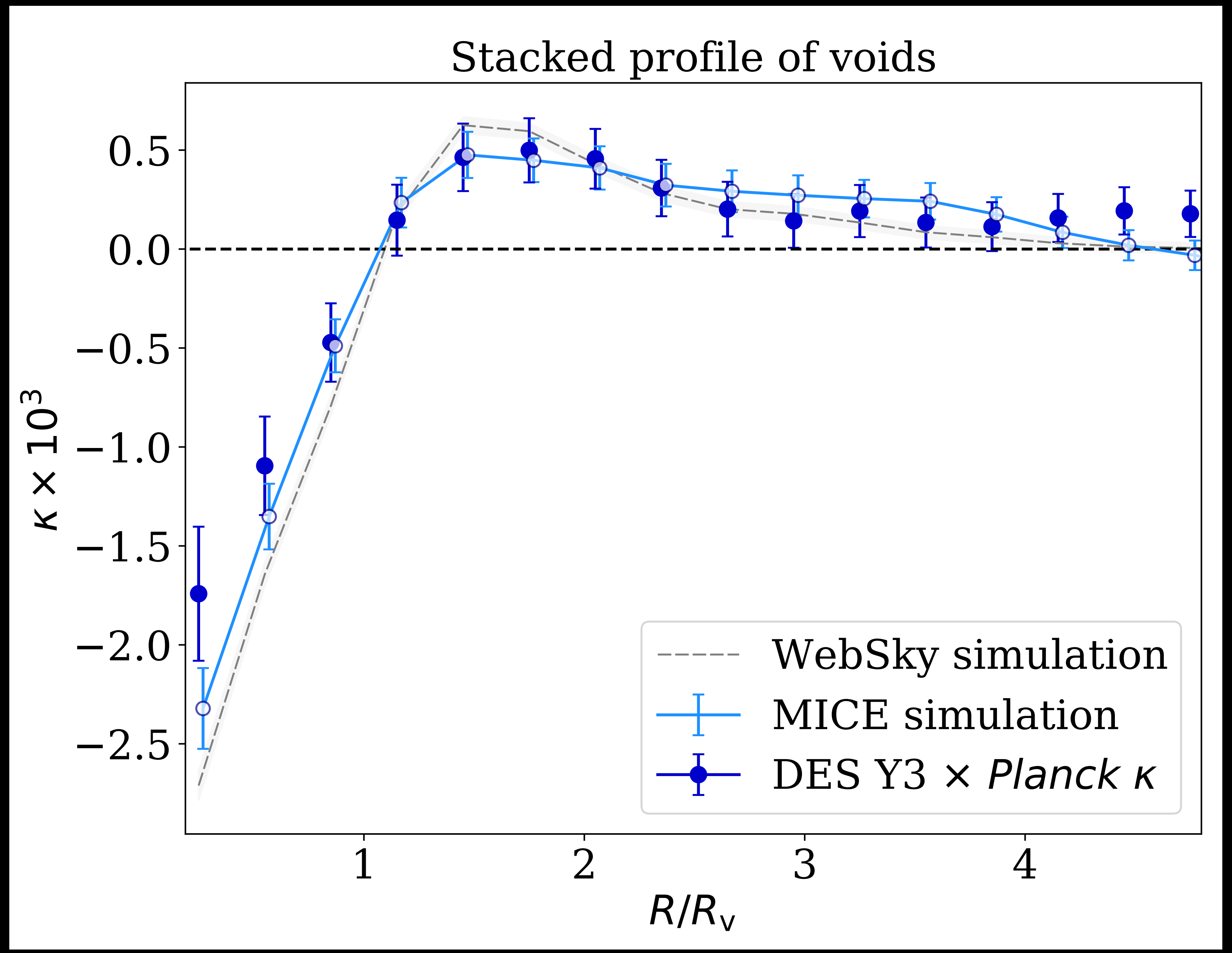
- **Cutting out patches** of the CMB map centered at superstructure position using healpix (Górski et al., 2005).
- **Re-scaling the patches** given the angular size of the structure.
- **Stacking all patches** and measuring the average signal in different concentric radius bins around the center.

Kovacs (2022)



Grannett et al., 2008

5 times the structure radius

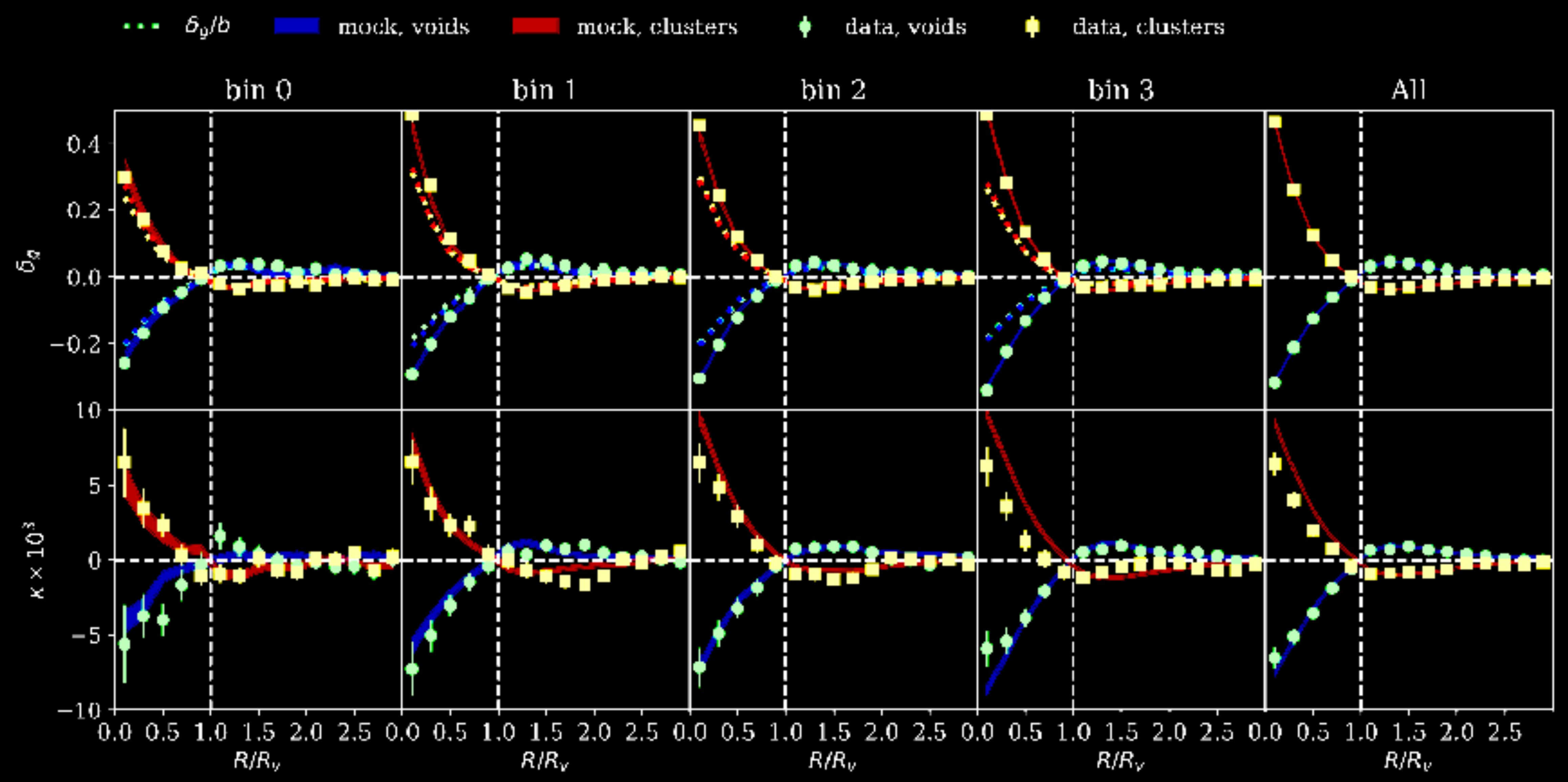


6.6σ detection of negative CMB convergence

State of the art and motivations

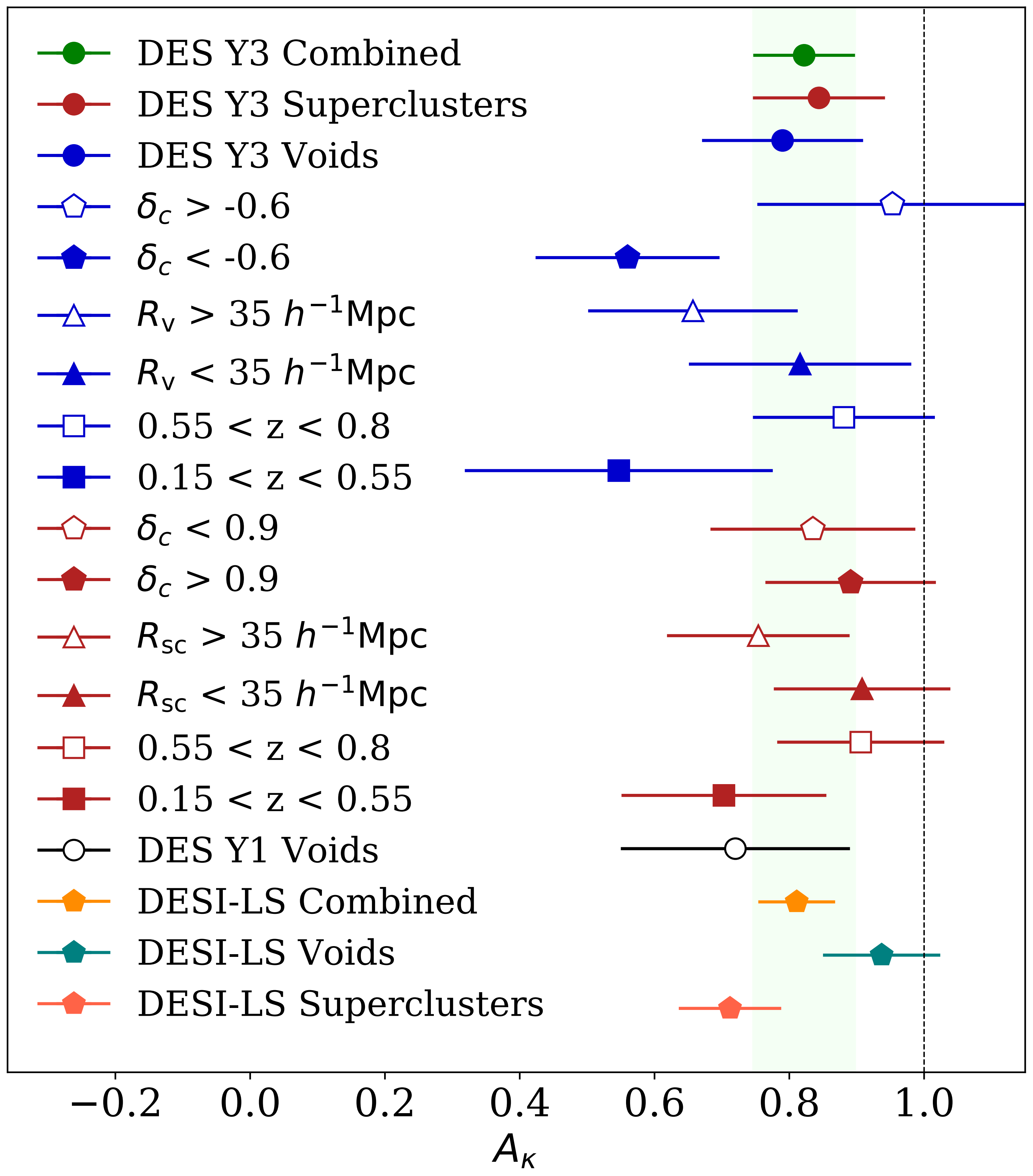
DESI

DESI Legacy Survey analysis
https://arxiv.org/abs/2105.11936



Summary : consistency parameter

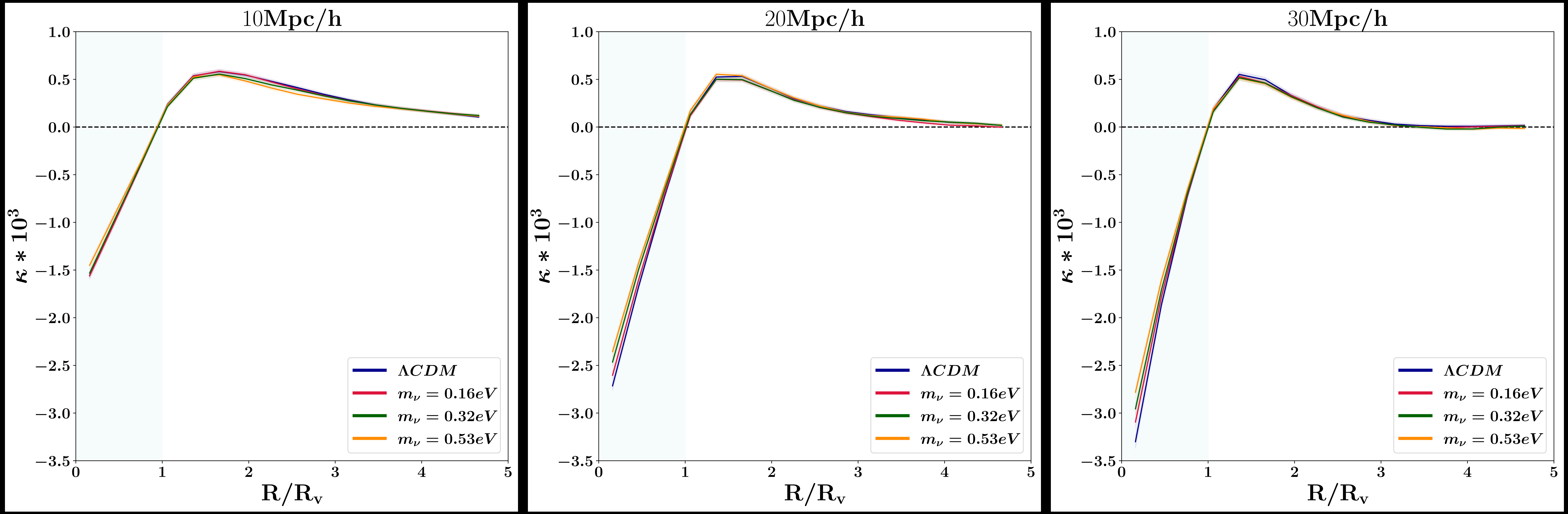
$A_\kappa = \kappa_{DES} / \kappa_{sim}$ ~2.3σ tension



CMB lensing X voids

Correlation signal in DEMNUni

The increase in the smoothing scale in the void finder results in a boost of the intensity of the correlation signal



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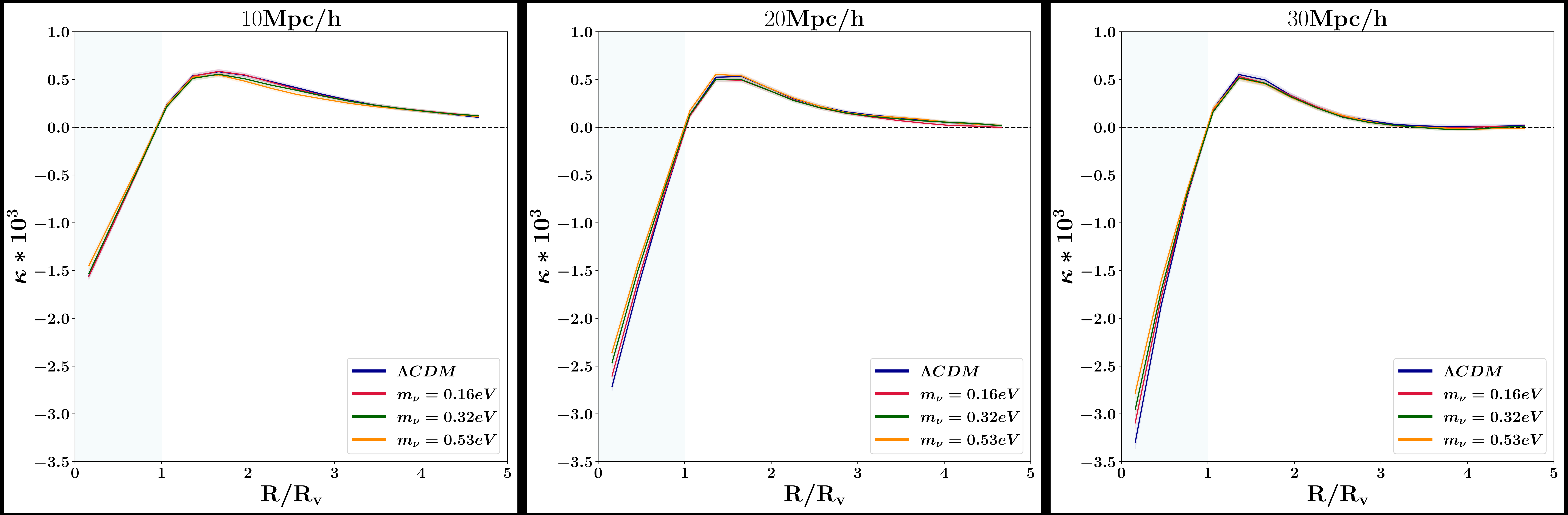

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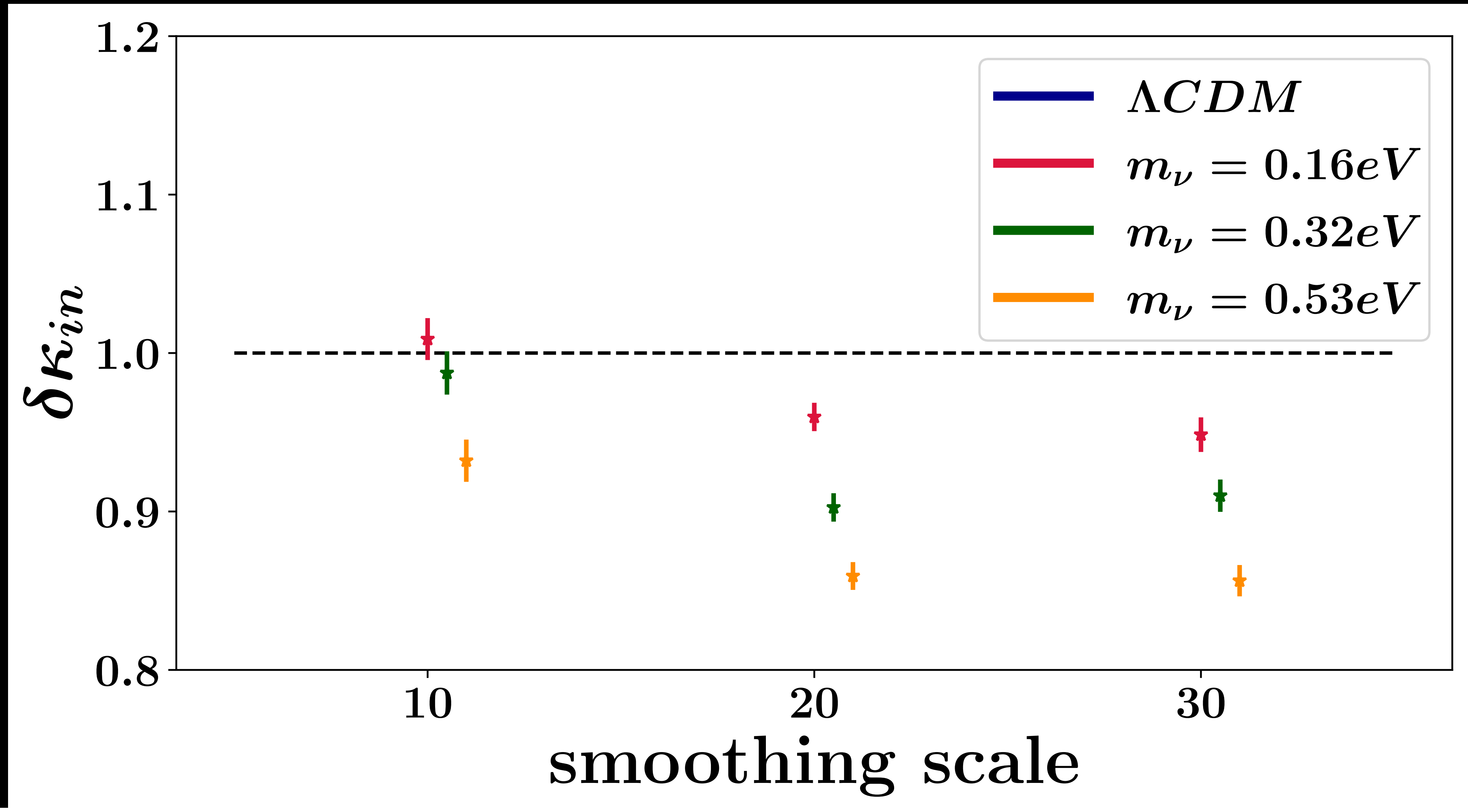
sensitivity parameter

$$\delta\kappa_{in} = \frac{\sum_0^{r<R_v/2} \kappa_{m_\nu=0.16\mathrm{eV},0.32\mathrm{eV},0.53\mathrm{eV}}}{\sum_0^{r<R_v/2} \kappa_{m_\nu=0}},$$



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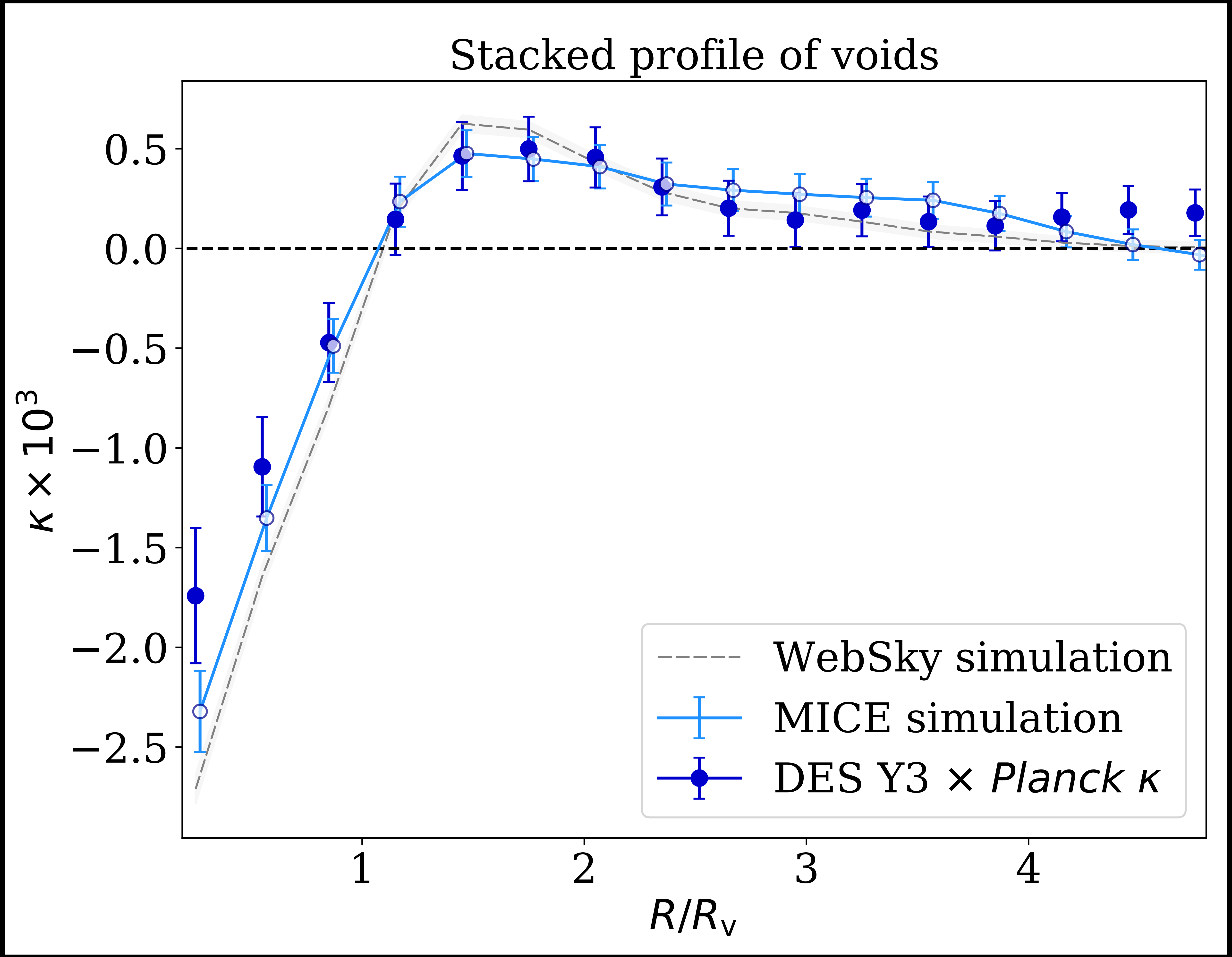
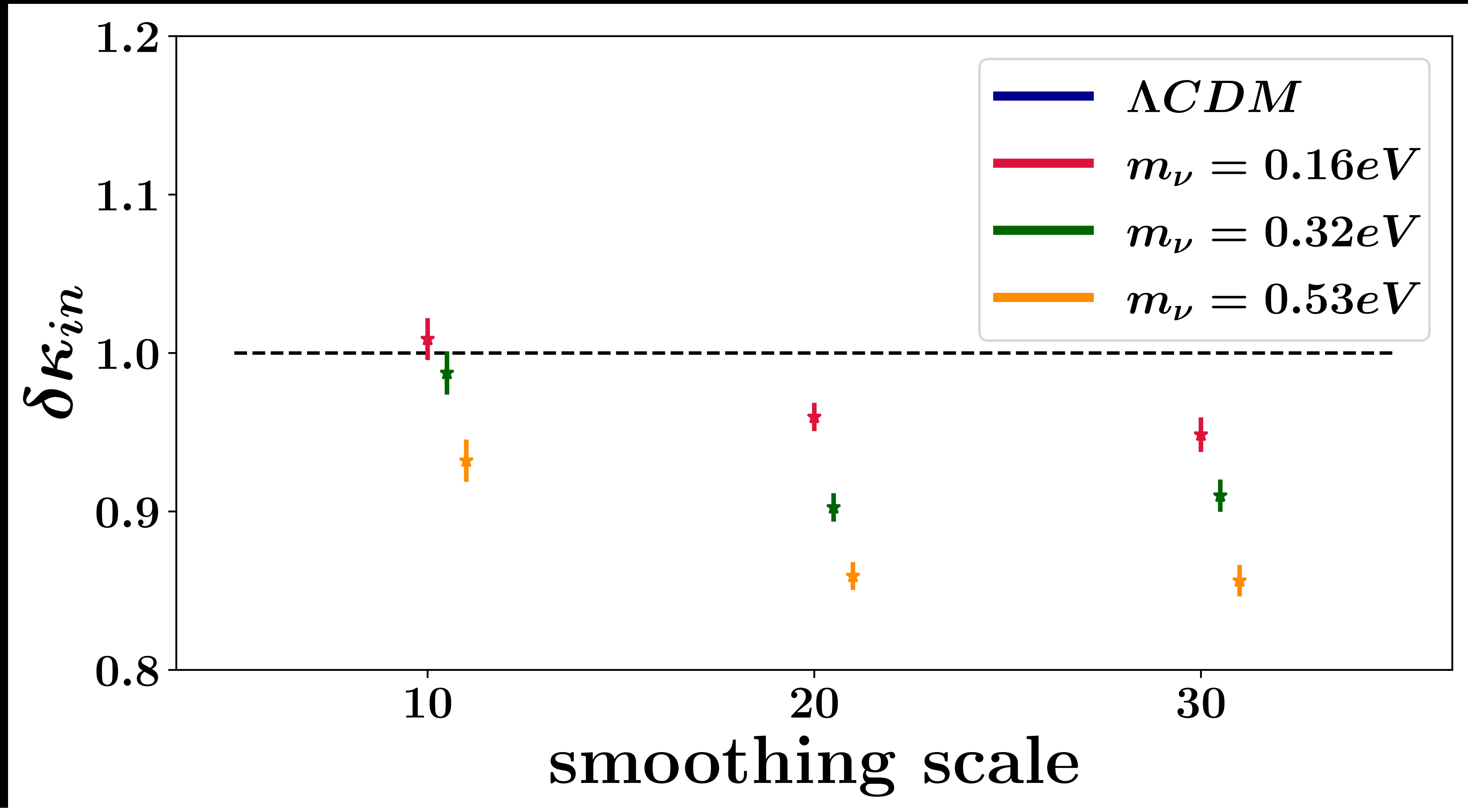




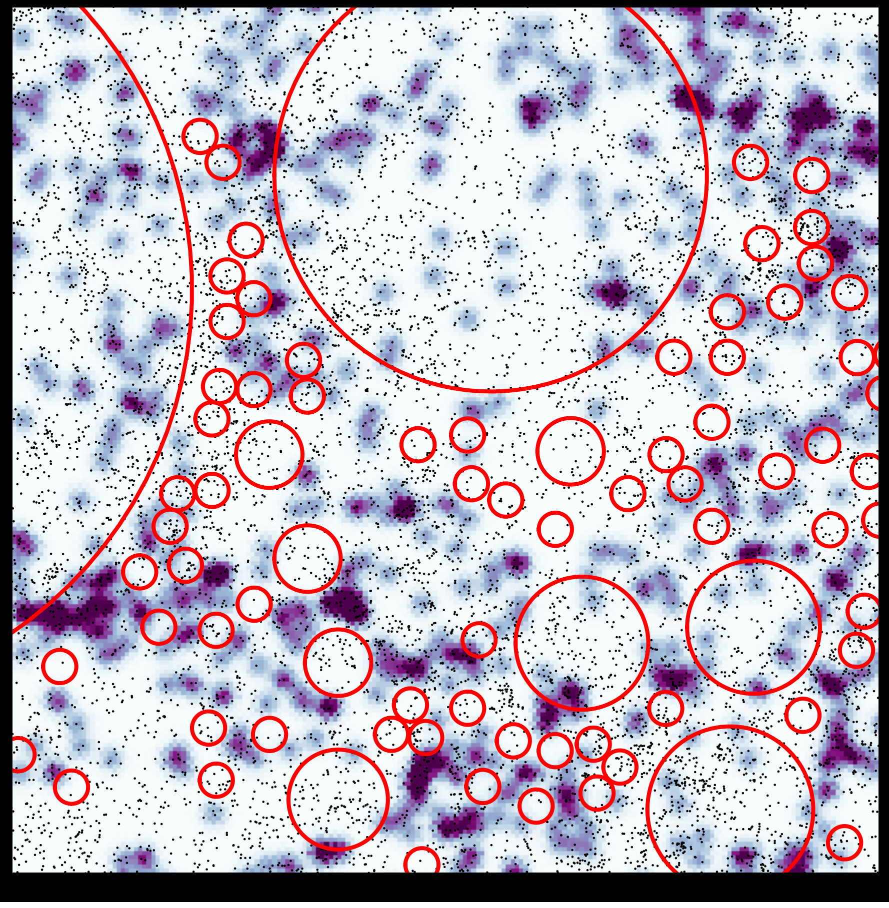
Conclusions

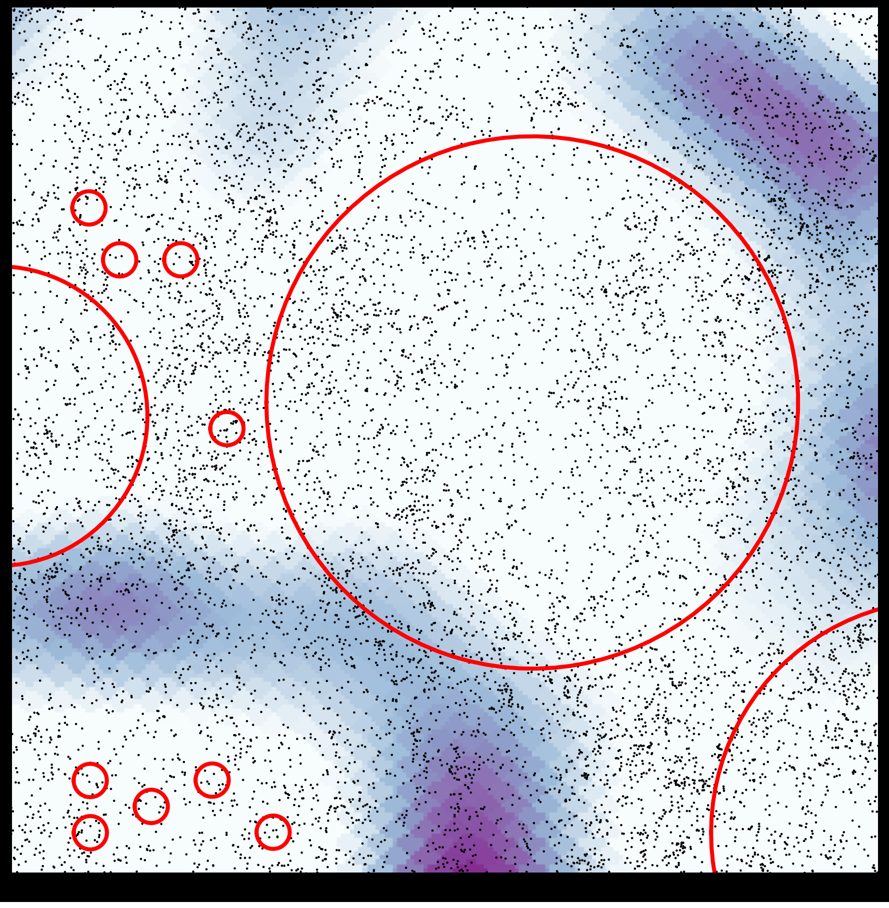
Cosmic voids are promising tool for cosmology and massive neutrino cosmology, in particular using their correlation signal with CMB maps

We note that the presence of massive neutrinos in our simulation tends to decrease the void-CMB lensing signal, and this effect is more enhanced as one increases neutrino mass, and for larger smoothing scales in the void identification process. This suggest that more the neutrinos are massive, less empty will be the voids (lower de-lensing signal implying more matter inside the voids).

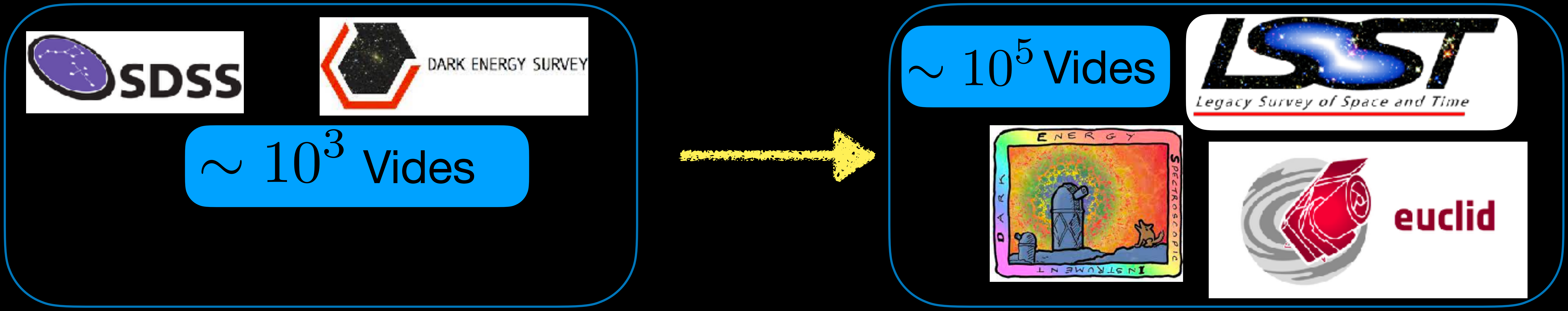
The measure of the reduction in the lensing signal inside cosmic voids due to the presence of massive neutrinos is in particular interesting as it is consistent with the tensions in the same lensing signal with massless neutrinos and ΛCDM simulation

The presence of massive neutrinos will depend on the scales and redshift considered





And now ?



Thank you!