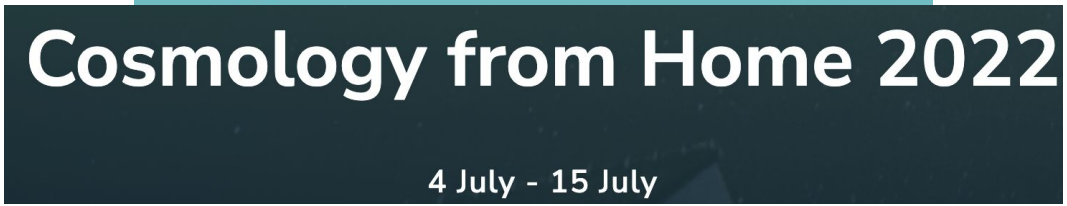
This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 754558

THE CMB LENSING IMPRINT OF COSMIC VOIDS

BIST Barcelona Institute of Science and Technology



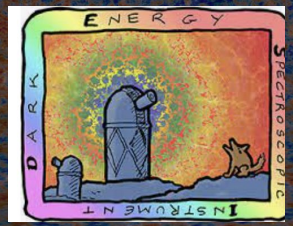
IFAE Institut de Física d'Altes Energies

Umut Emek Demirbozan

4th May 2022

UMUT EMEK DEMIRBOZAN

- PhD Student at Institut Fisica dáltes Energies(IFAE) in Barcelona
- Started Collaborating with Shadab et al on High-z Voids x CMB Lensing
- Using DESI Imaging DR9 Data with Firtsgen Mocks Cutsky mocks to focus on high-redshift voids using ELG's, QSO,LRG's



Millennium Simulation, Springel et al. 2005

What is Cosmic Microwave Background(CMB) ?

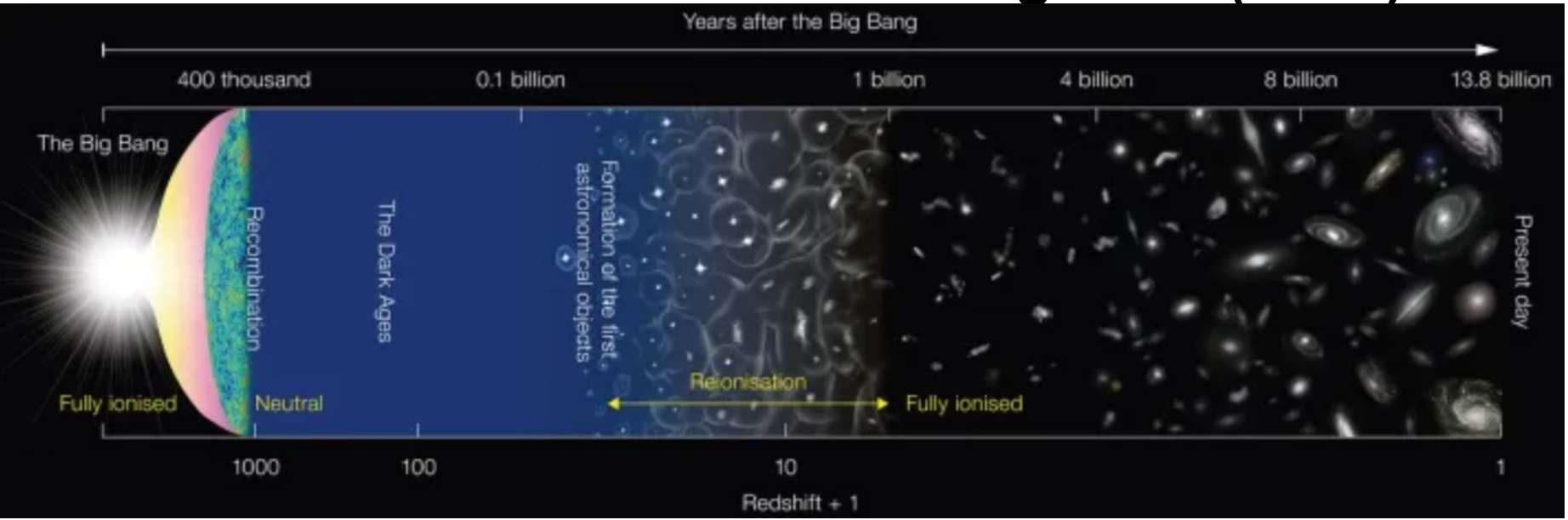


Image Credited to European Space Agency (ESA))

Roughly 380.000 years after the Big Bang, the photons decoupled during '*Recombination Epoch*'. This decoupling is referred as Cosmic Microwave Background (CMB).

What is Cosmic Microwave Background(CMB) ?

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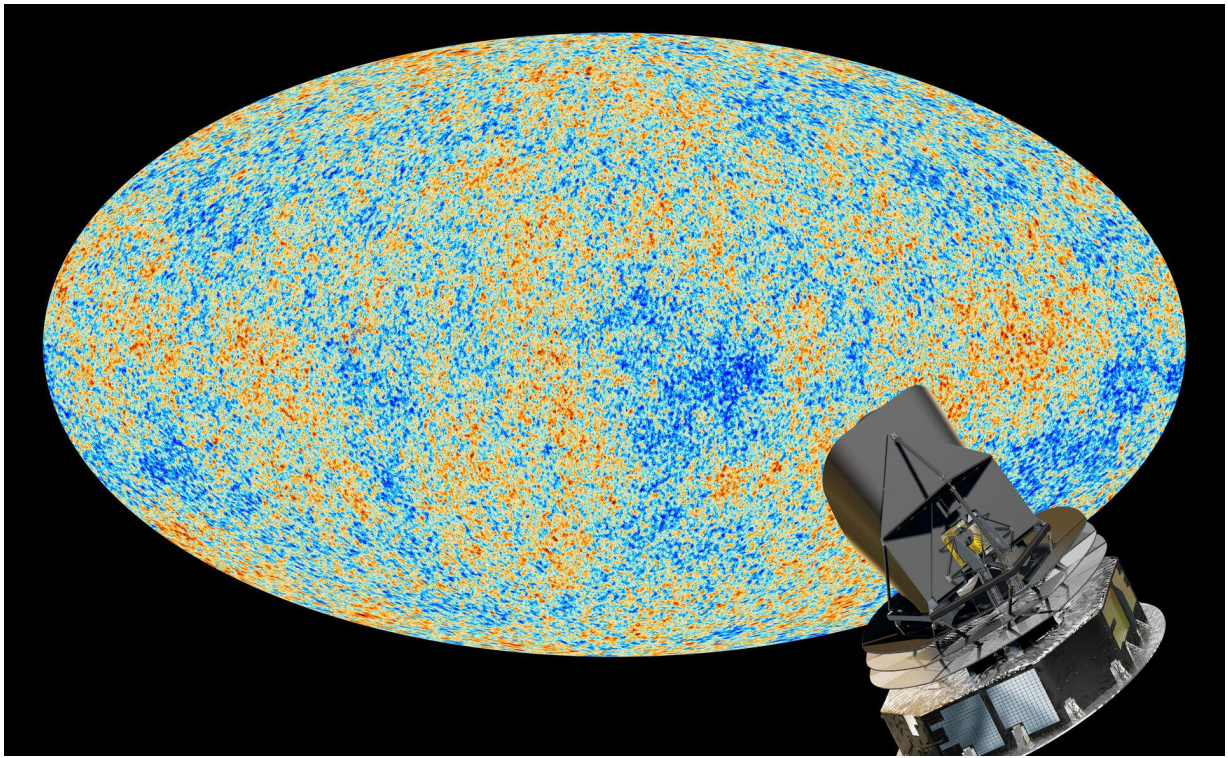
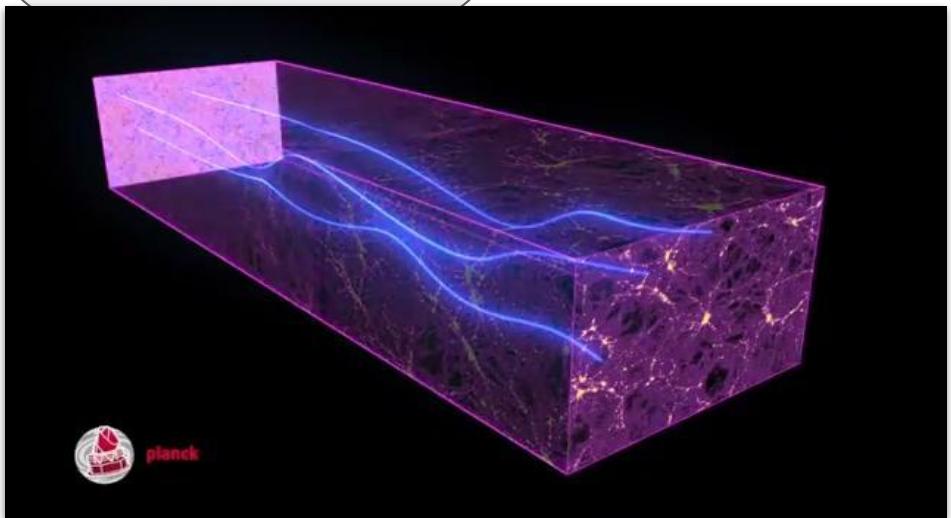


Image Credited to European Space Agency (ESA))

Cosmic Microwave Background(CMB) Lensing

Gravitational potential can be reconstructed from the lensed CMB images and the convergence (kappa) is directly related to lensing potential.

CMB photons are deflected due to underlying dark matter (weak lensing).



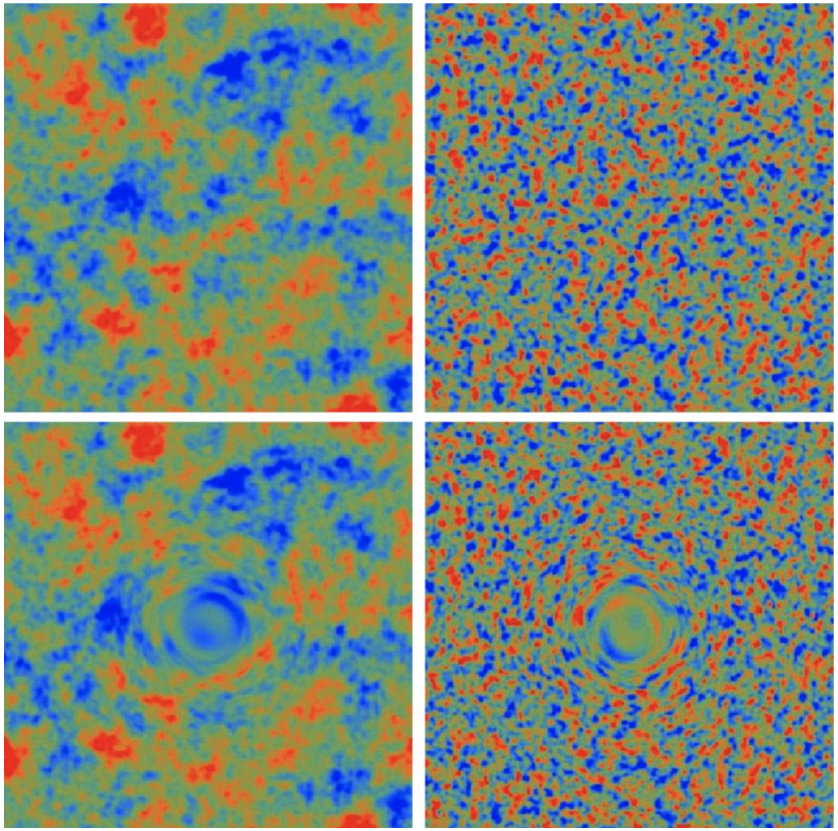


Image Credited to (Wayne Hu and Takemi Okamoto/University of Chicago)

Cosmic Microwave Background(CMB) Lensing

This convergence (Kappa) is negative in the case of CMB lensing by cosmic voids.

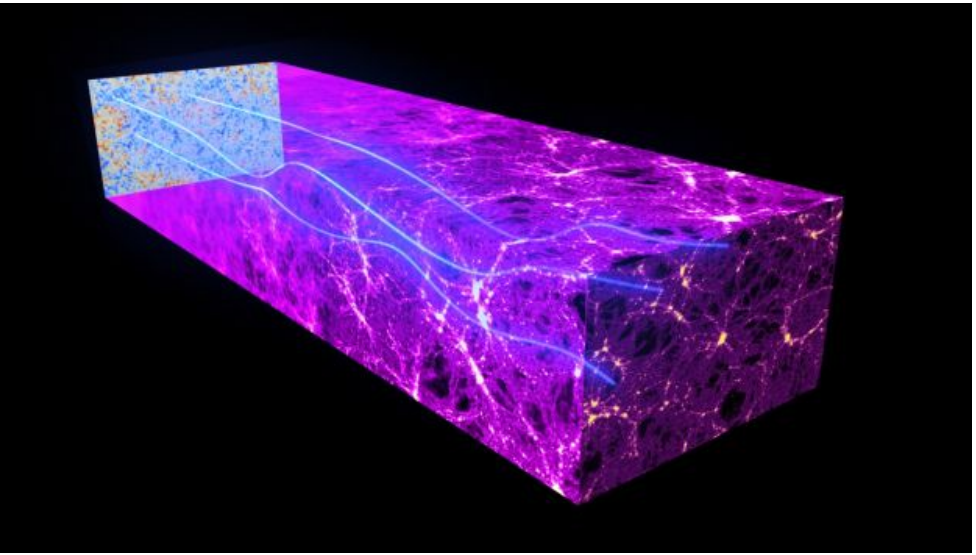


Image Credited to European Space Agency (ESA))

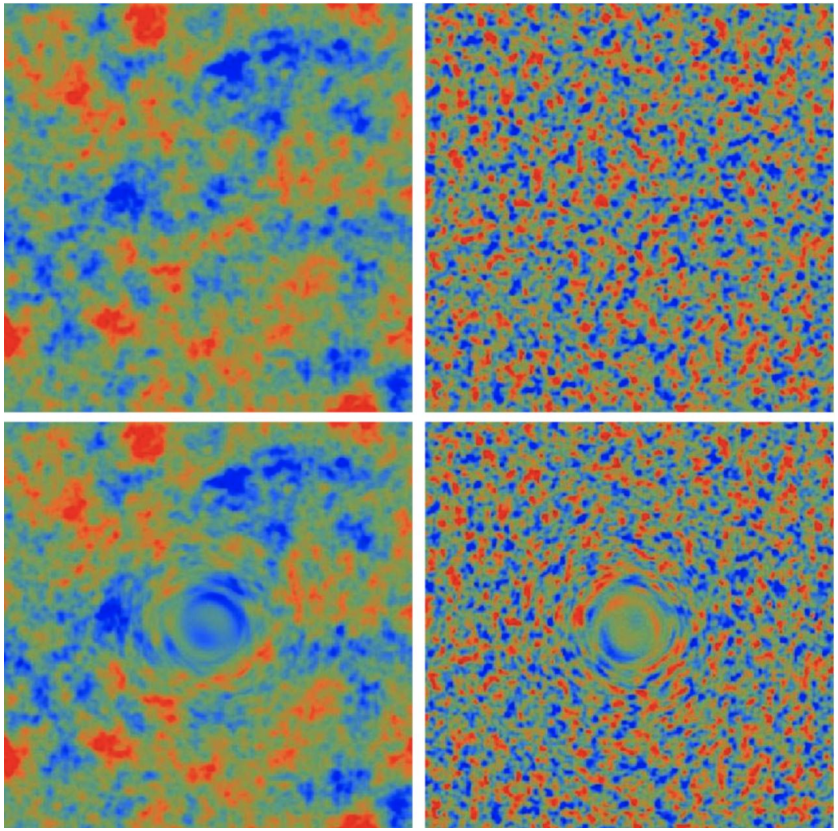
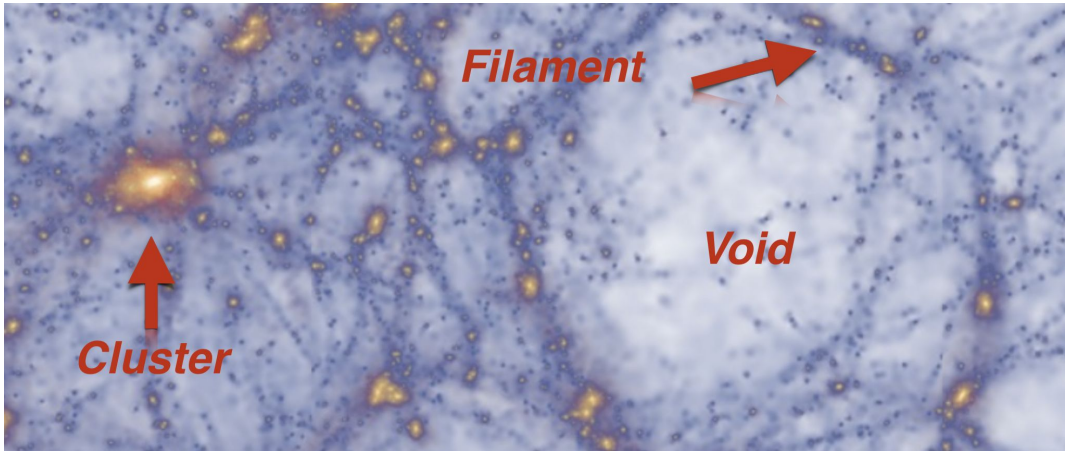


Image Credited to (Wayne Hu and Takemi Okamoto/University of Chicago)

What are cosmic voids ?

Cosmic voids are the large, underdense regions in the large scale structure in the Universe. Hence, they lack ordinary and dark matter.



They are typically 20-150 Mpc/h size and can be found by running different algorithms on the underlying galaxy distribution.

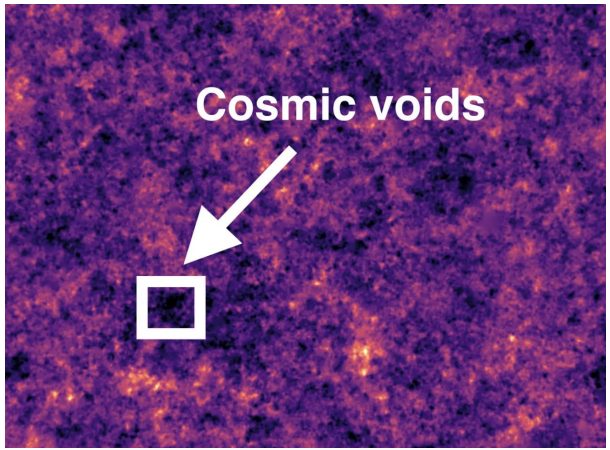
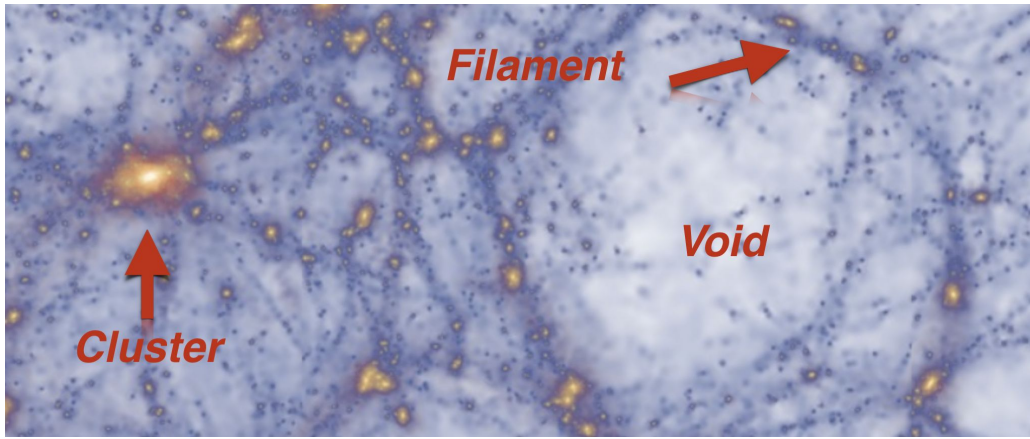


Image Credited to European Space Agency (ESA))

What are cosmic voids ?

Cosmic voids are ideal environment to see the effects of '*screening mechanisms(i.e Vainshtein screening)*' to test the deviation between GR and MG(i.e Horndeski theories) due to their low-density(Pisani et al,2019).



As **neutrino mass fraction** is higher with respect to CDM in void environments, it makes cosmic voids attractive places to study neutrinos as their size is about **neutrino free-streaming scales**.

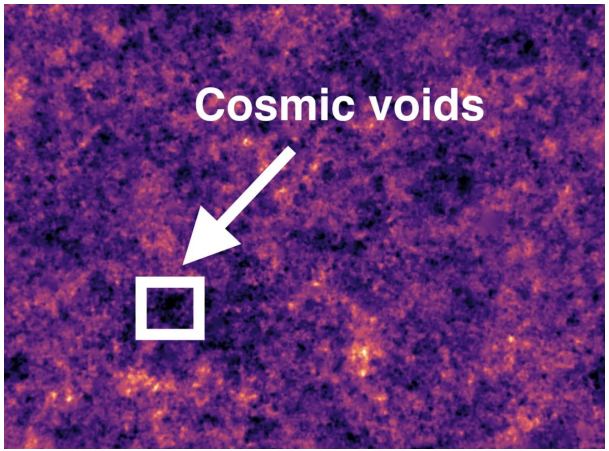
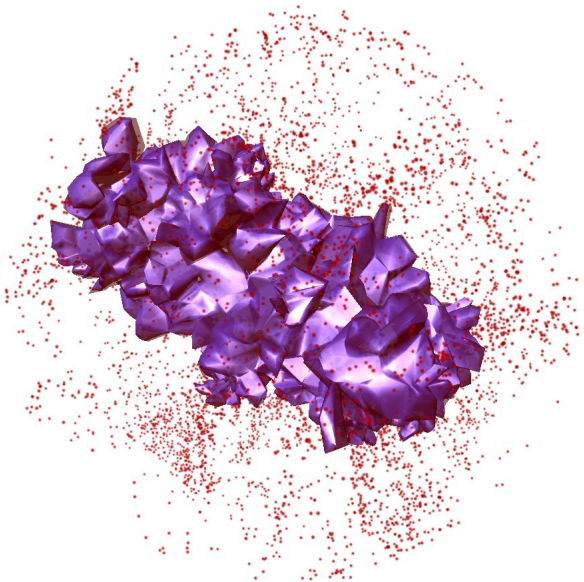


Image Credited to European Space Agency (ESA))

What are cosmic voids ?



3D VIDE Voids Image Credited to Sutter P.M et al IU Symp.308 (2014)

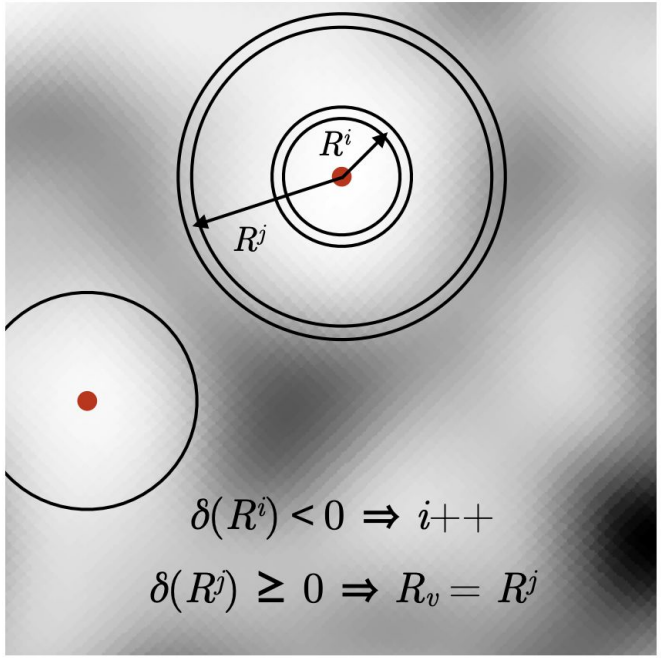


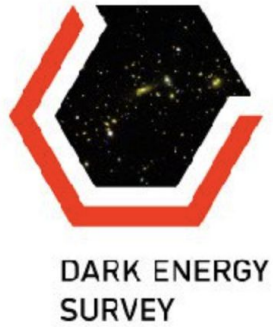
Image Credited to (Sanchez et al,2016) Carles Sanchez was also a PhD student at IFAE

3D voids that are based on ZOBOV-based algorithms

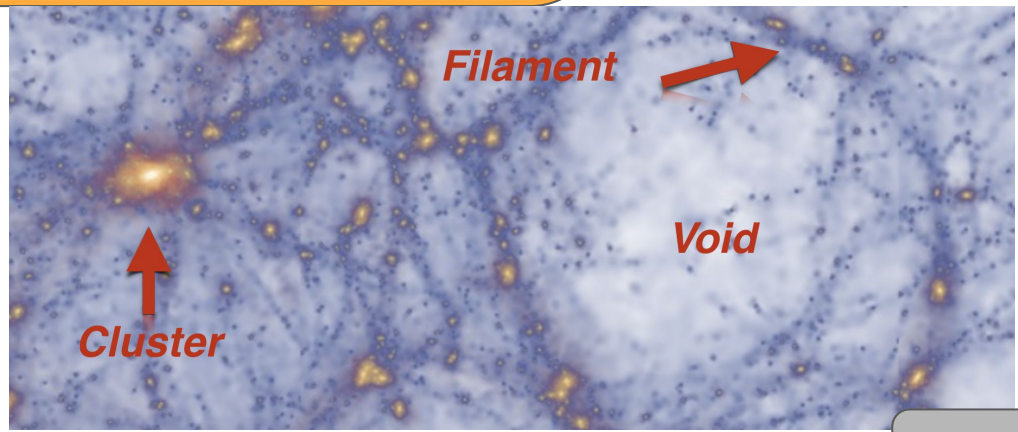
2D voids that are circular and defined on tomographic redshift bins.

What is our goal ?

We basically want to check the CMB Lensing signal from cosmic voids by stacking void positions on the Planck CMB lensing map.



We use one of the largest available cosmological surveys called (Dark Energy Survey) and publicly available Planck CMB lensing map.



What is our goal ?

Some previous studies reported an Integrated Sachs-Wolfe (ISW) signal excess with respect to consensus cosmological model ΛCDM. ISW is also measured by stacking voids positions, but on the CMB temperature map instead of the lensing map.

DARK ENERGY SURVEY

ISW is sensitive the time derivative of the gravitational potential, where CMB lensing is sensitive to gravitational potential.

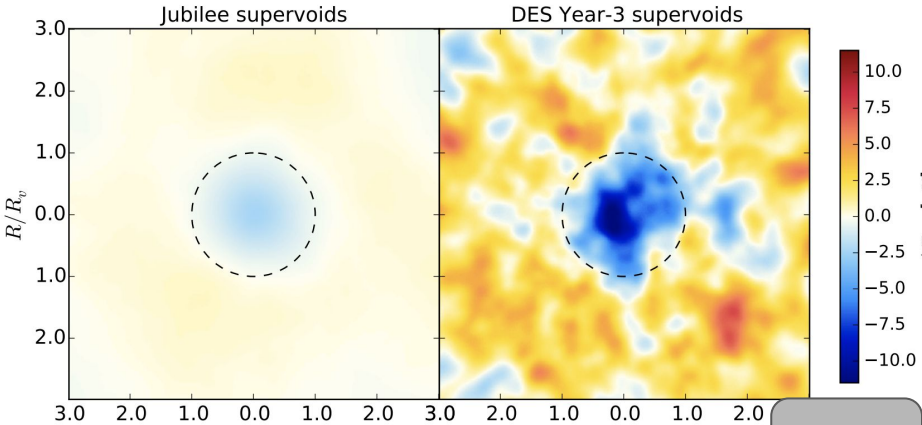


Image Credited to *Kovacs et al, 2019.*

The Dark Energy Survey(DES)

DARK ENERGY SURVEY

It is a photometric survey with almost 5000deg^2 survey area.

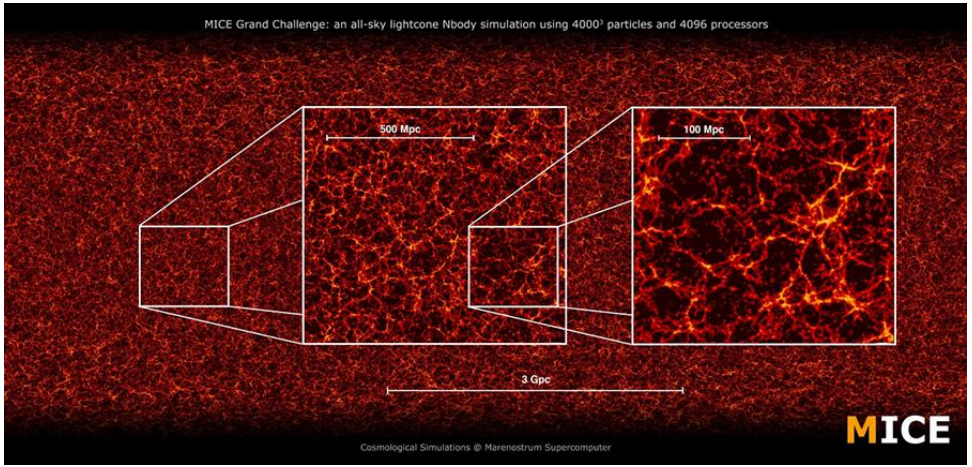
It is an international collaboration which uses DeCam mounted on CTIO in Chilean Andes.

A total of 300 million galaxies are observed in 5 bands.

Image Credited to Dark Energy Survey(DES)

MICE Simulaton

MICE
Marenostrum Institut de Ciències de l'Espai Simulations



We use MICE N-body simulation to compare our signal with ***ΛCDM expectations.***

We define **voids** in MICE and also use **MICE CMB Lensing kappa map**.

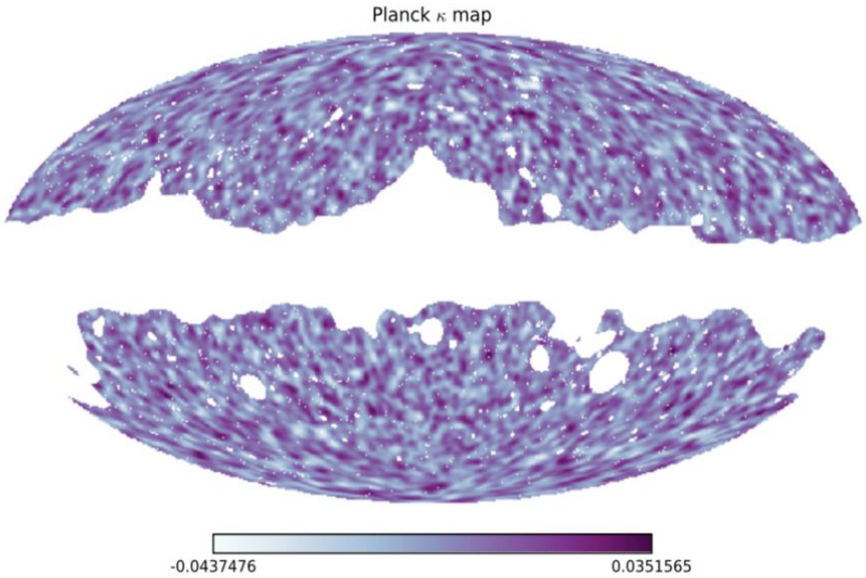
flat standard ΛCDM

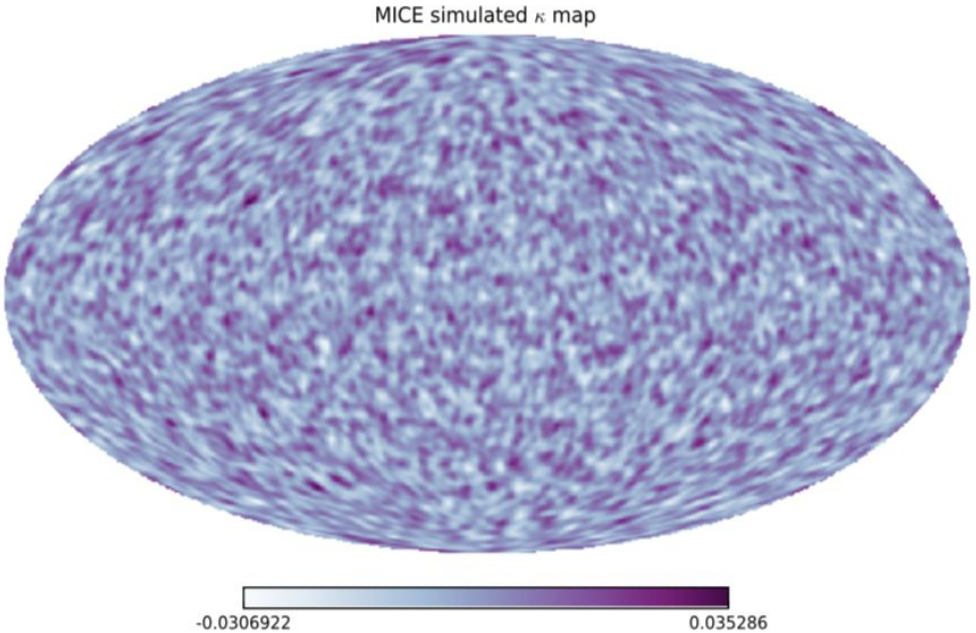
$\Omega_m = 0.25, \Omega_\Lambda = 0.75, \Omega_b = 0.044,$

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

MICE Simulaton

MICE
Marenostrum Institut
de Ciències de l'Espai
Simulations

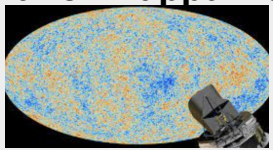




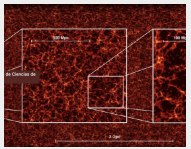
METHODOLOGY

DES Y3 VOIDS

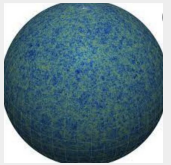
Planck Kappa Map



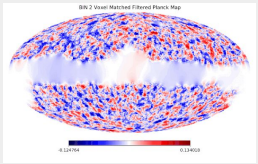
MICE Voids



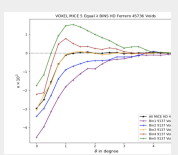
MICE Kappa Map

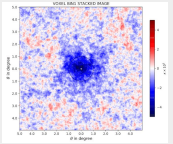


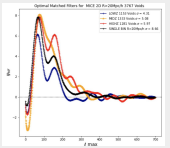
Applying Matched Filters from MICE to Planck Map



Creating Matched Filters







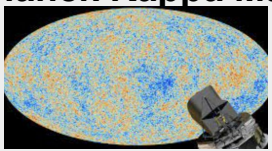
Final Stacked Central Pixel for DES

Final Stacked Central Pixel for MICE(ƛCDM)

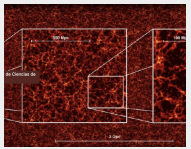
METHODOLOGY

DES Y3 VOIDS

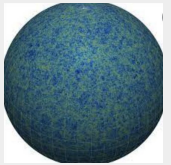
Planck Kappa Map



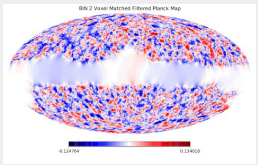
MICE Voids



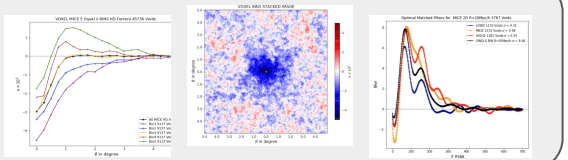
MICE Kappa Map



Applying Matched Filters from MICE to Planck Map



Creating Matched Filters



Final Stacked Central Pixel for DES

We compare these two to find the lensing amplitude !

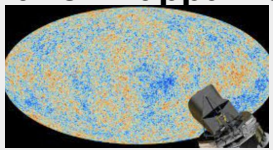
Final Stacked Central Pixel for MICE (ǎCDM)

ERROR ESTIMATION

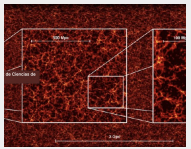
We repeat 1000 times with new simulated kappa map

DES Y3 VOIDS

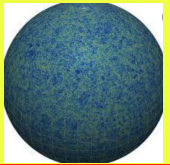
Planck Kappa Map



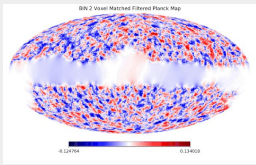
MICE Voids



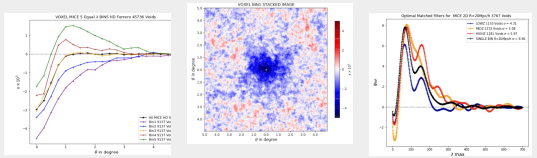
MICE Kappa Map



Applying Matched Filters from MICE to Planck Map



Creating Matched Filters



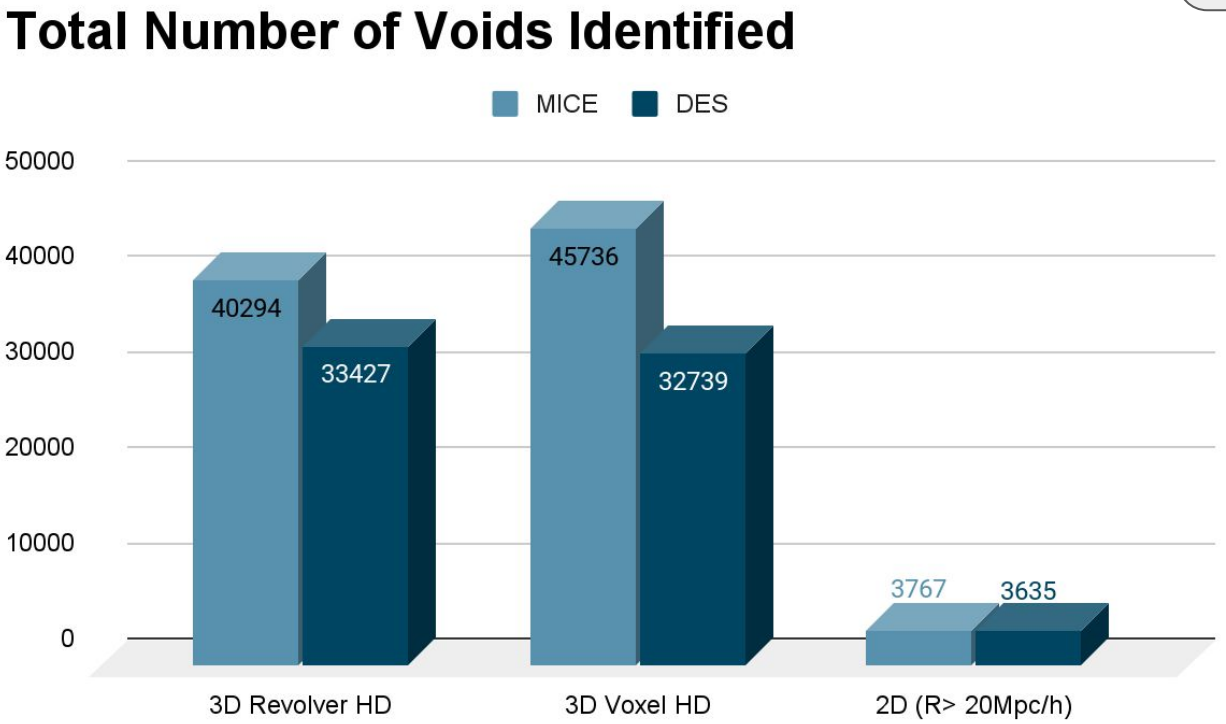
Final Stacked Central Pixel for DES

We compare these two to find the lensing amplitude !

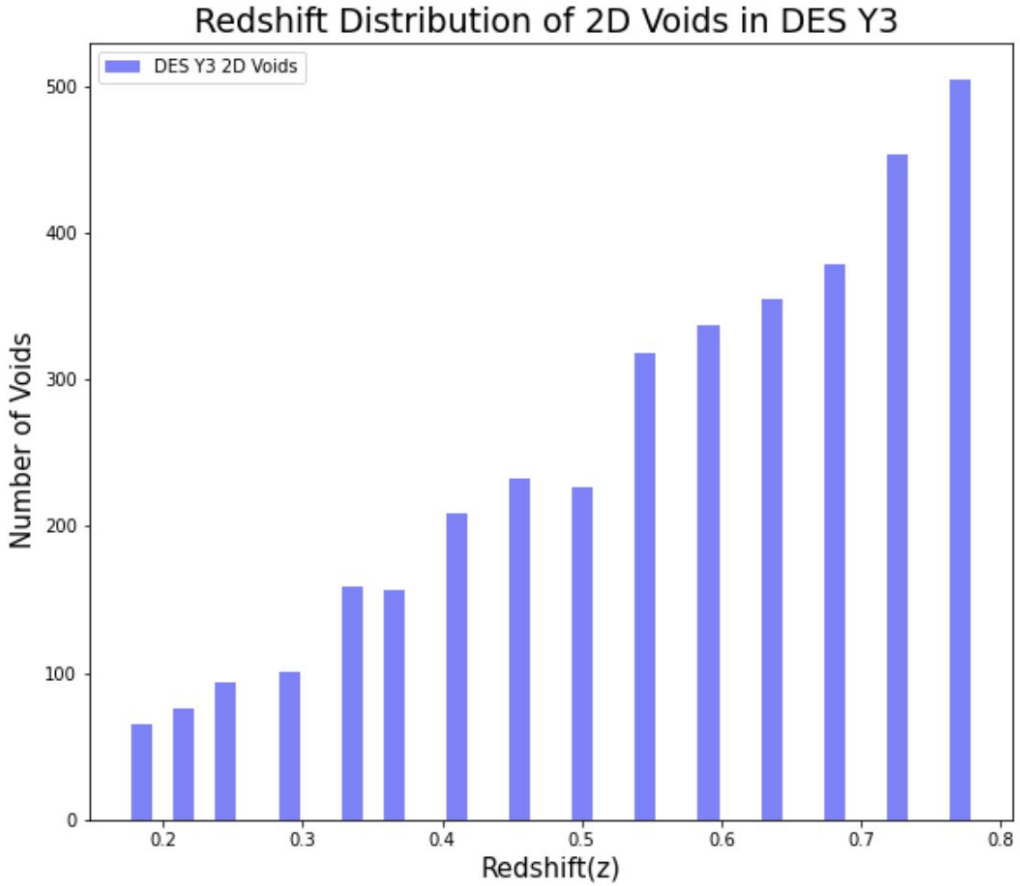
Final Stacked Central Pixel for MICE (ΛCDM)

METHODOLOGY

The redshift range is $0.2 < z < 0.8$

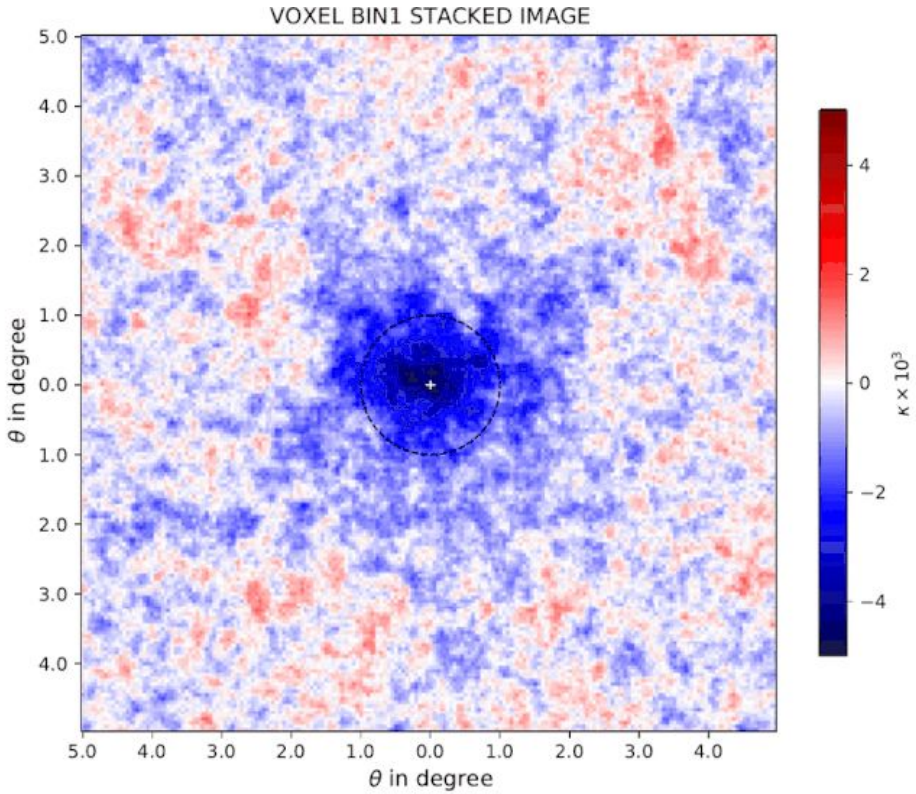


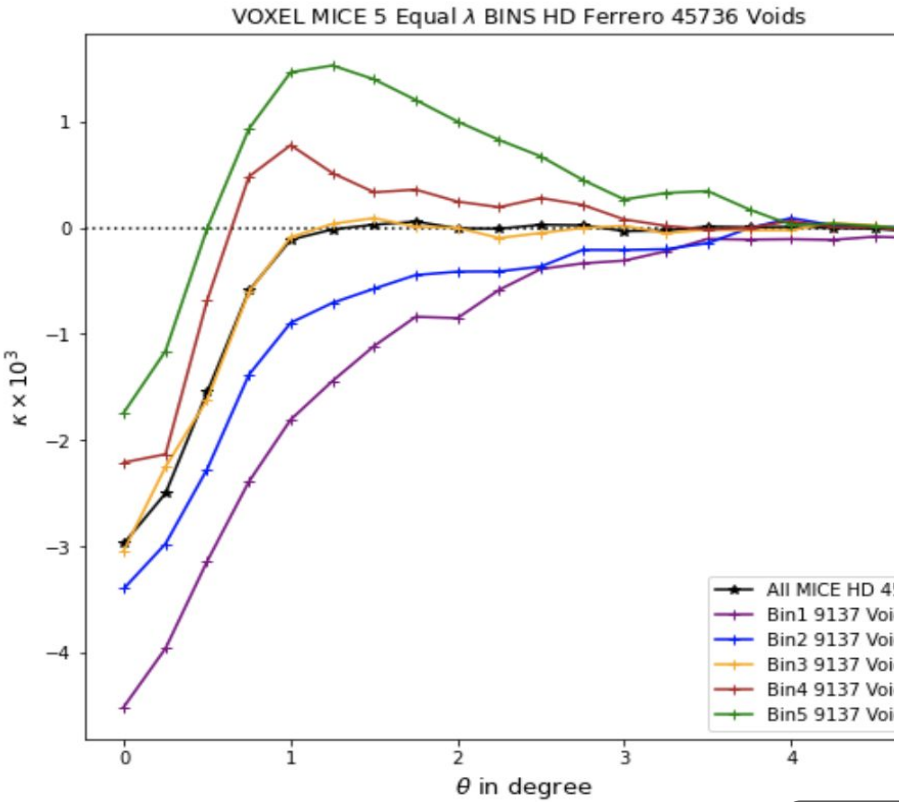
2D Voids Redshift Histogram



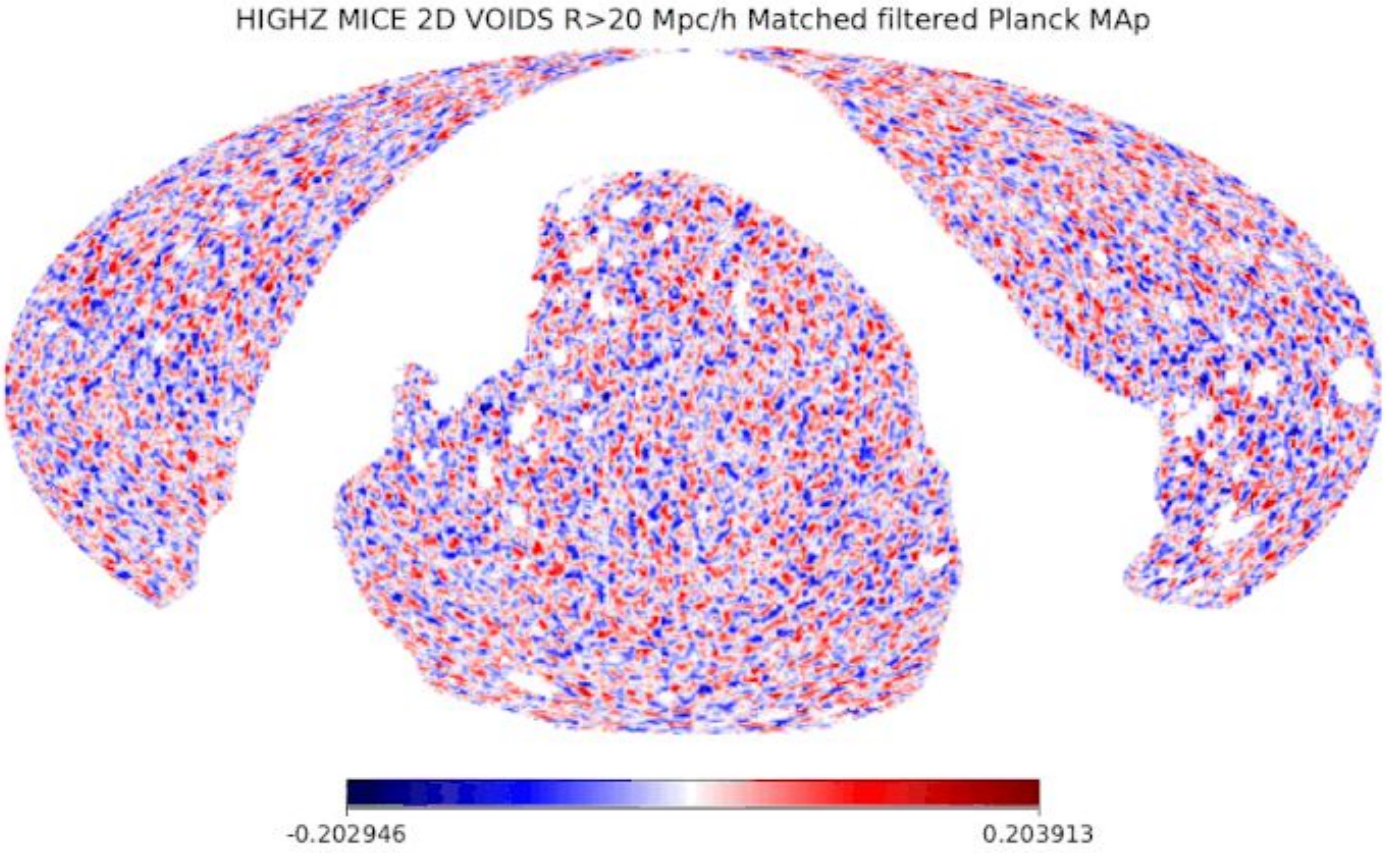
- The 2D voids are defined on **tomographic redshift slices** as opposed to smooth redshift distributions of 3D revolver voids.

MICE Templates for Voxel HD 5 BINS

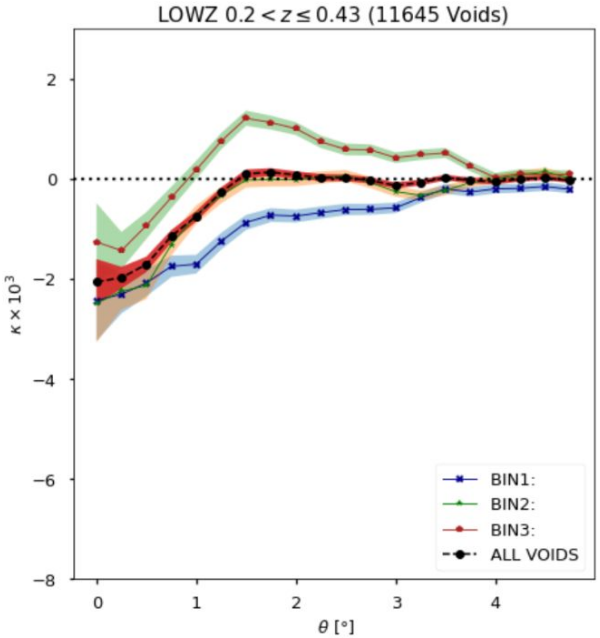


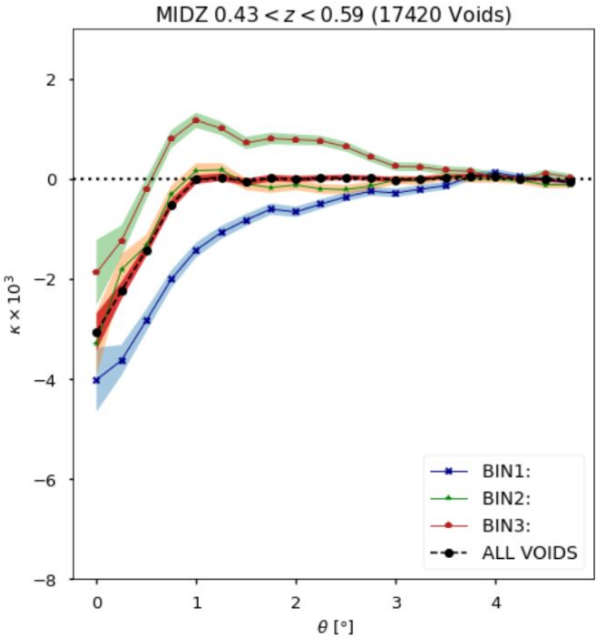


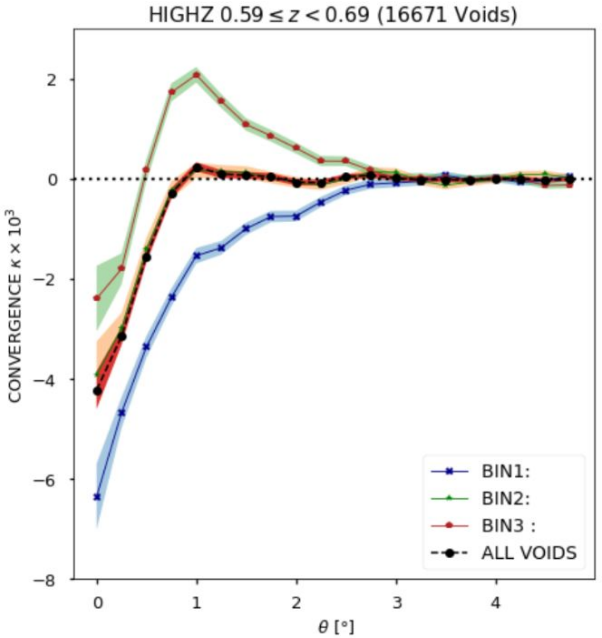
Matched Filtered Planck Maps for 2D Voids



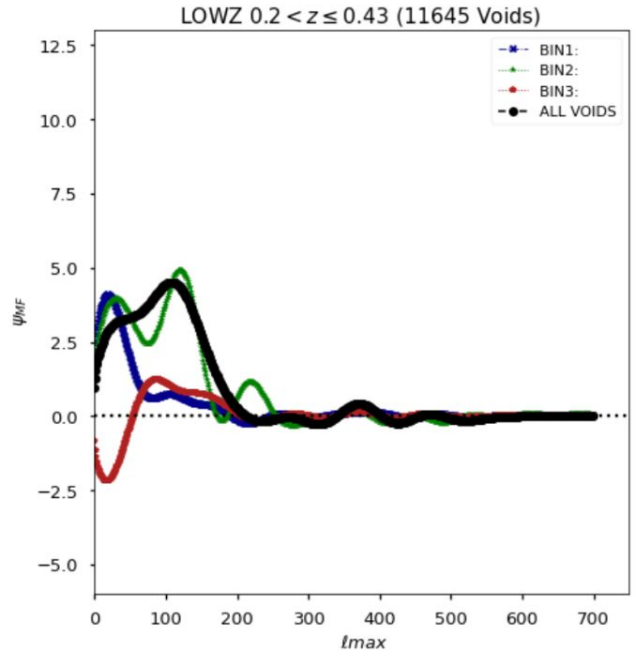
MICE Templates for 3 Redshift BINS

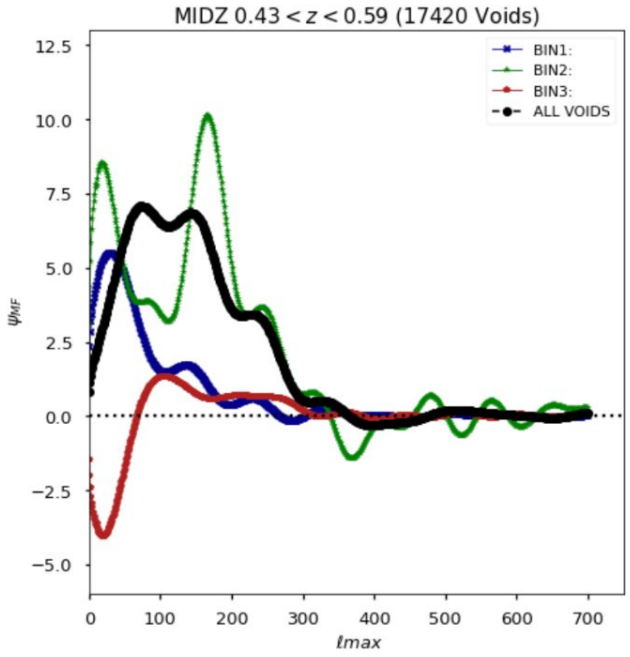


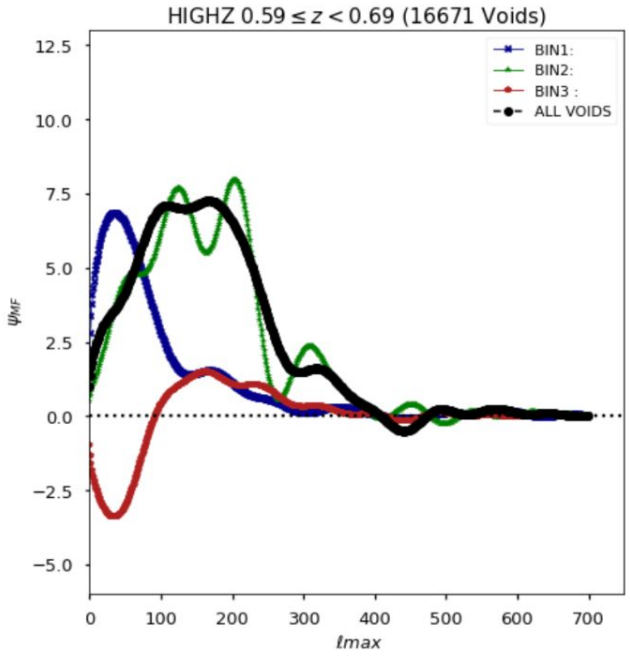




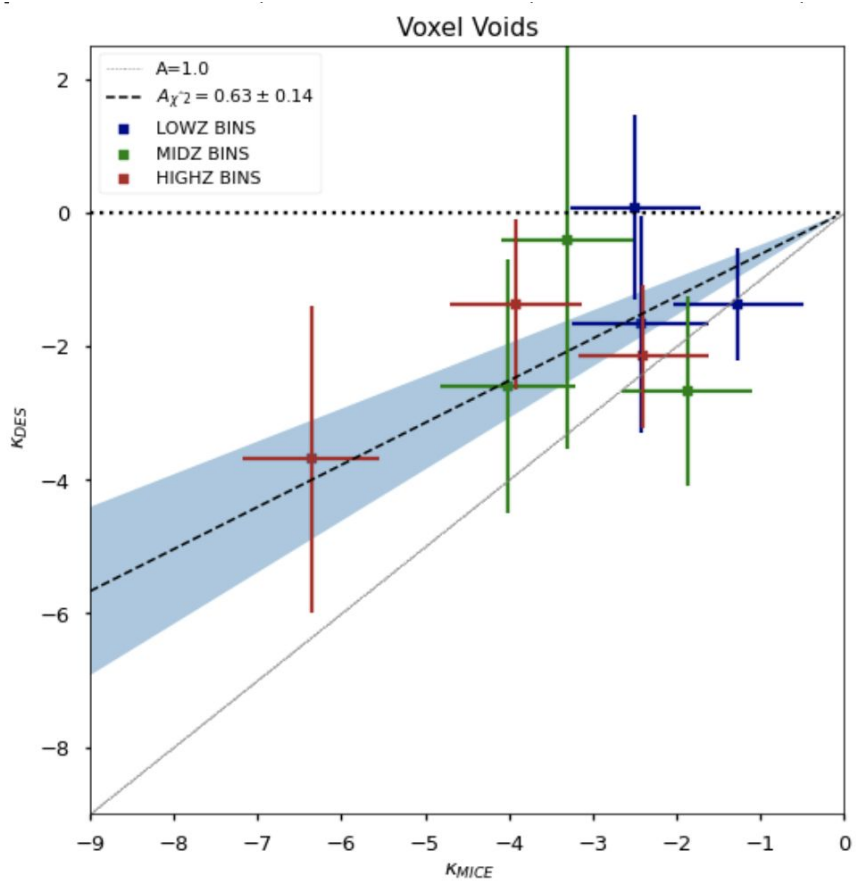
Optimal Matched Filters for 3 Redshift BINS

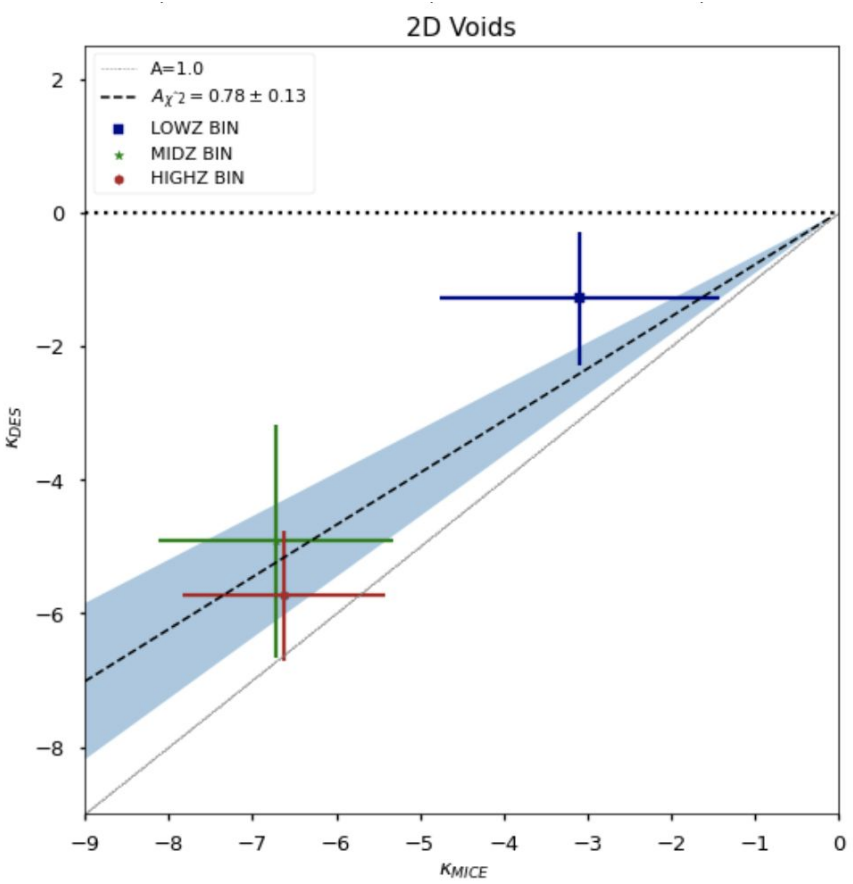




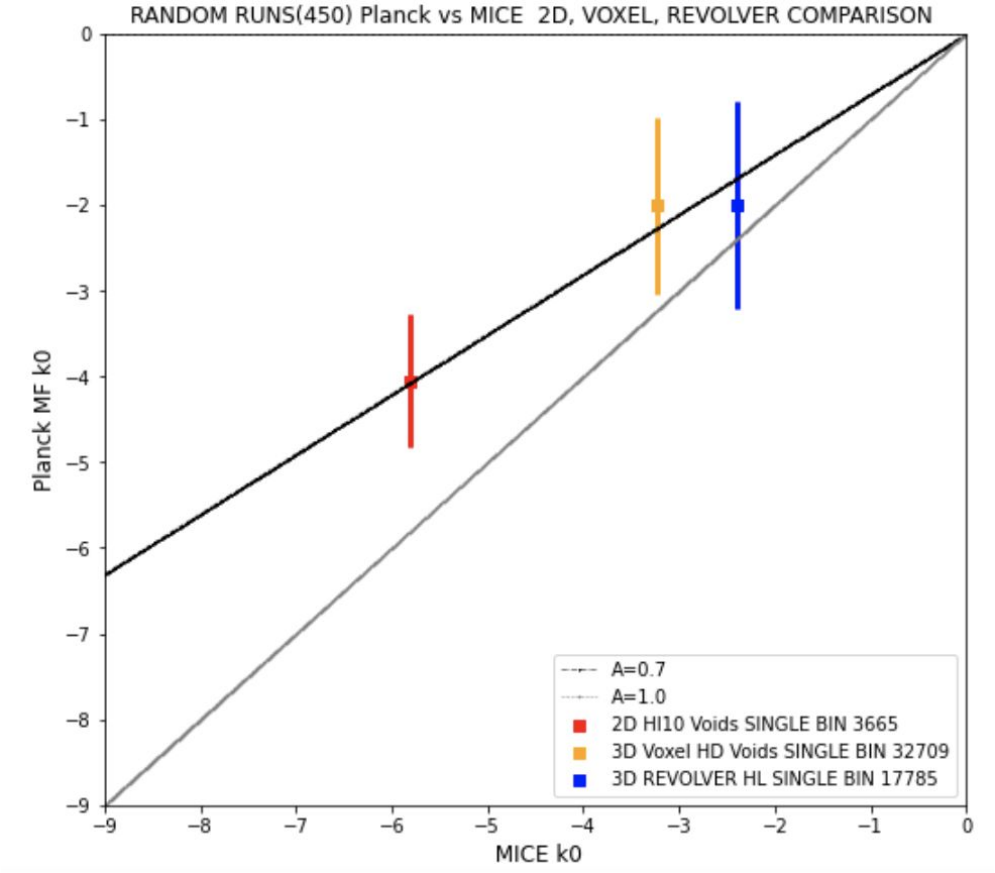


Preliminary Results





Preliminary Results (No Binning)for different types of voids

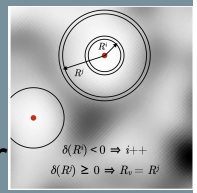


Conclusions

We see that Planck signal is actually **lower than MICE *ΛCDM* prediction(i.e 2σ)** both for two different type of voids.

More studies are needed(i.e **DESI** to increase the precision)

2D voids may be **better suited** for lensing studies in general.



Hang et al 2021 using DESI Imaging DR9 and **Kovacs et al 2021** using DESY3 but another method also **finds the same result !**

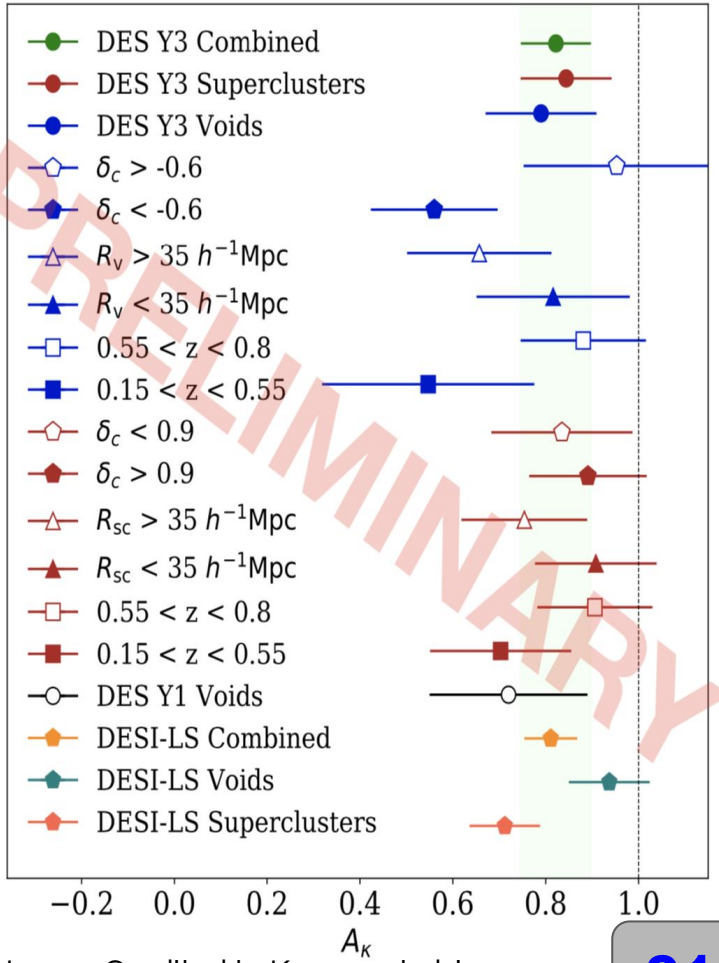


Image Credited to Kovacs et al, in prep

THANK YOU

COSMOLOGY MARCHES ON