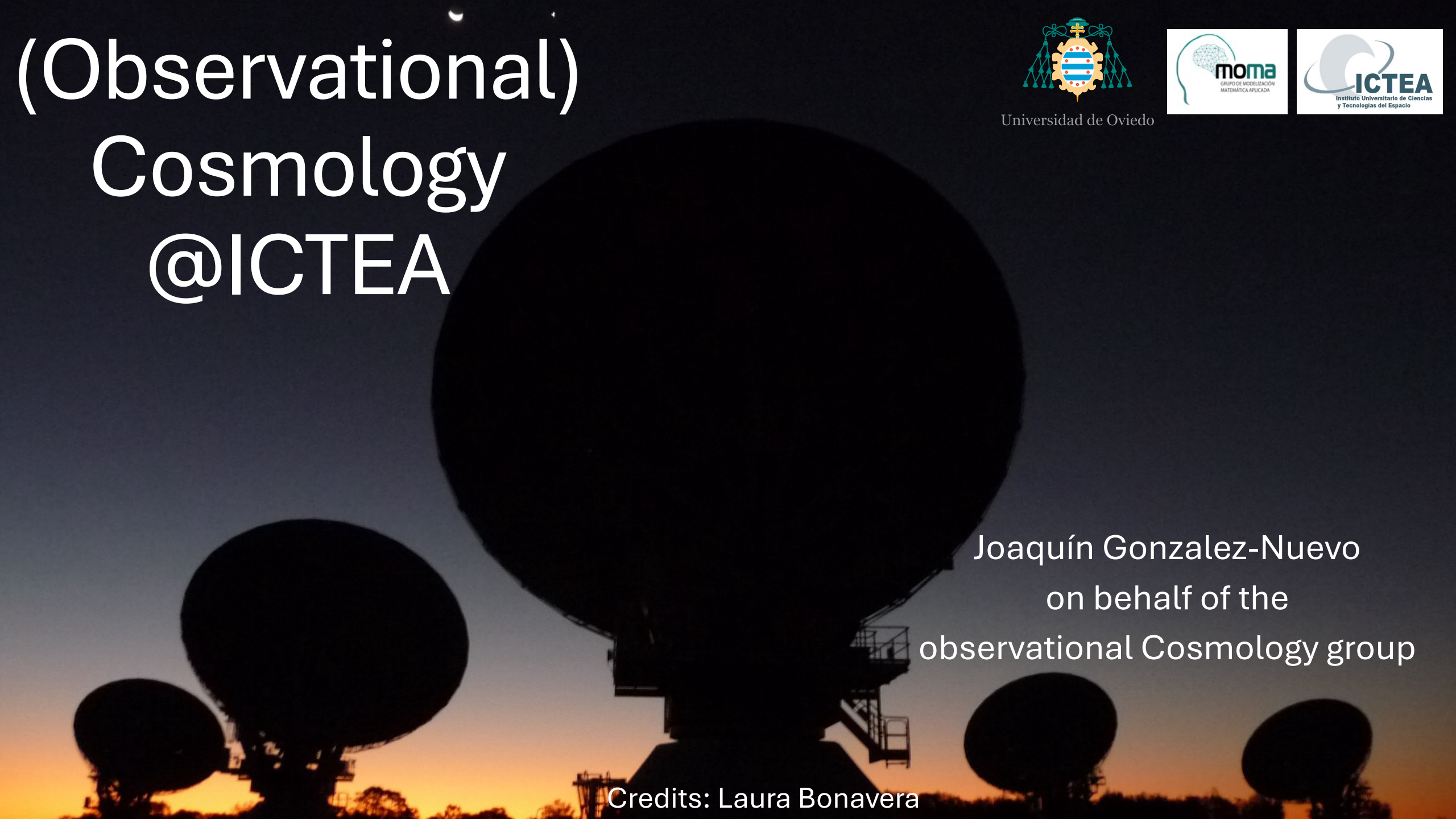
(Observational) Cosmology @ICTEA



Universidad de Oviedo

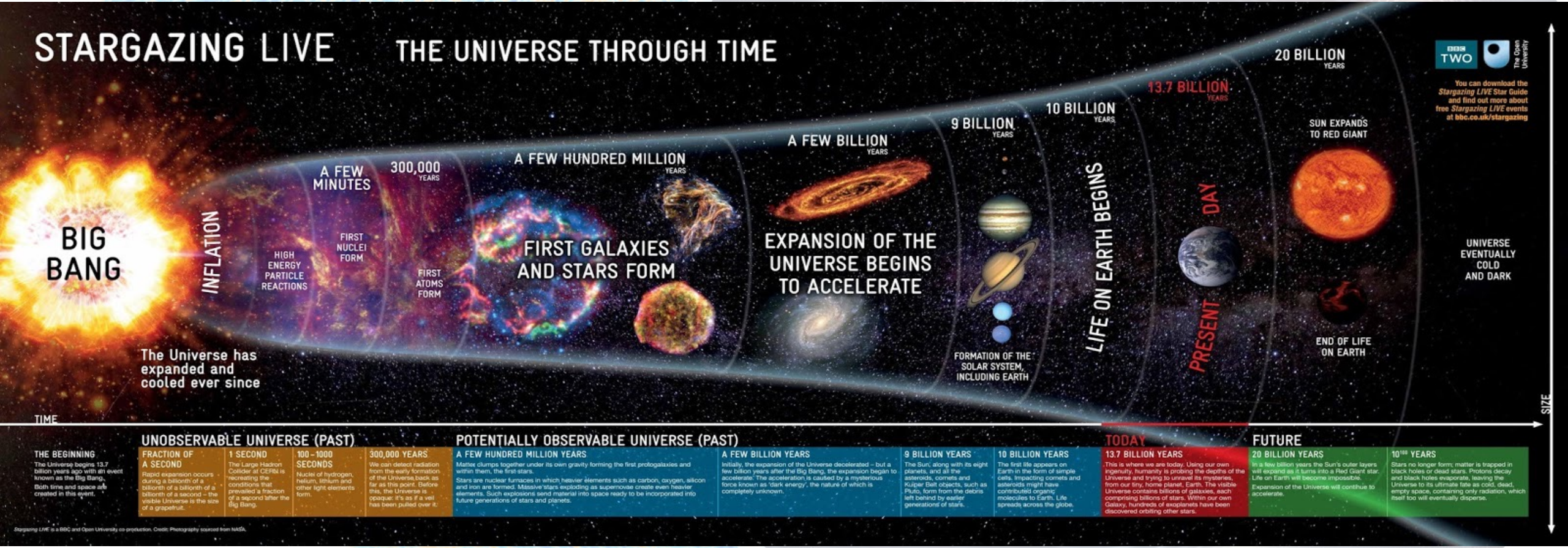
moma GRUPO DE MODELIZACIÓN MATEMÁTICA APLICADA

ICTEA Instituto Universitario de Ciencias y Tecnologías del Espacio

Joaquín Gonzalez-Nuevo
on behalf of the
observational Cosmology group

Credits: Laura Bonavera

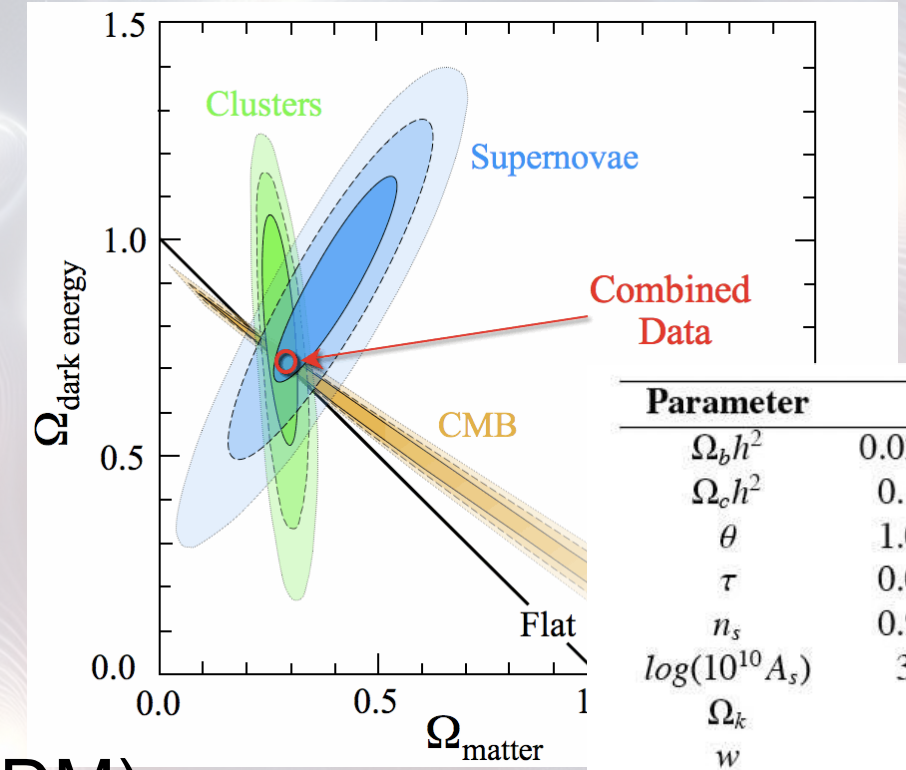
Cosmology (in physics) is the study of the universe's origin, evolution, composition, structure, and eventual fate



In Cosmology/Astrophysics we study the past to understand the future (as geology, antropology, …)

ΛCDM concordance model

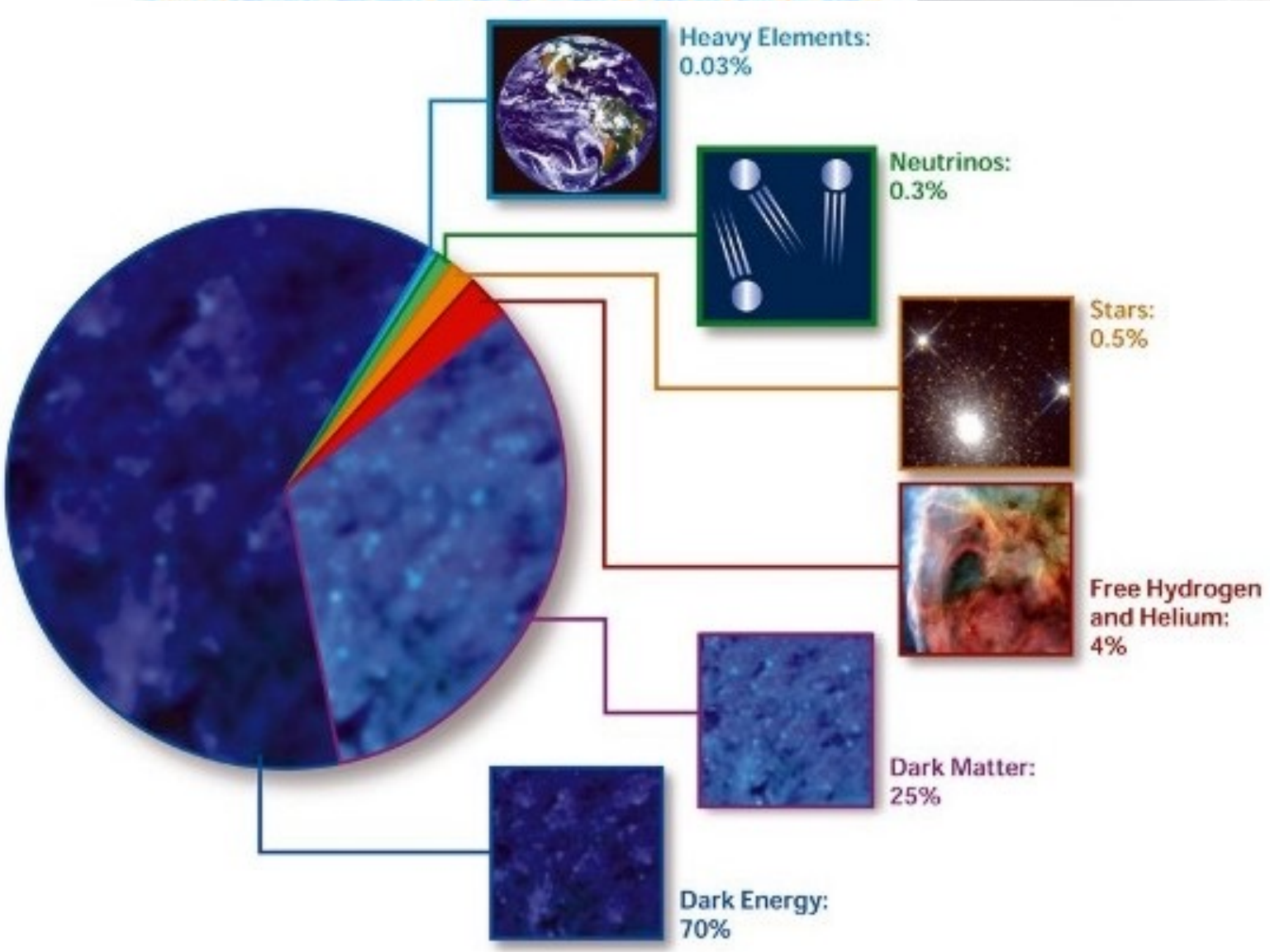
Sole successful cosmological model!
High predictive power!



Parameter	Vanilla
$\Omega_b h^2$	0.0227 ± 0.0005
$\Omega_c h^2$	0.112 ± 0.003
θ	1.042 ± 0.003
τ	0.085 ± 0.017
n_s	0.963 ± 0.012
$log(10^{10} A_s)$	3.07 ± 0.04
Ω_k	0
w	-1
Ω_Λ	0.738 ± 0.015
Age	13.7 ± 0.1
Ω_m	0.262 ± 0.015
σ_8	0.806 ± 0.023
z_{re}	10.9 ± 1.4
h	0.716 ± 0.014

Hot Big Bang
+
Flat → **Inflation**
+
Excess of mass → **Cold** Dark Matter (CDM)
+
Accelerated expansion → Cosmological Constant
(Λ as the simplest **Dark Energy** model)

Energy content of the Universe Today



4-5% Astrophysics

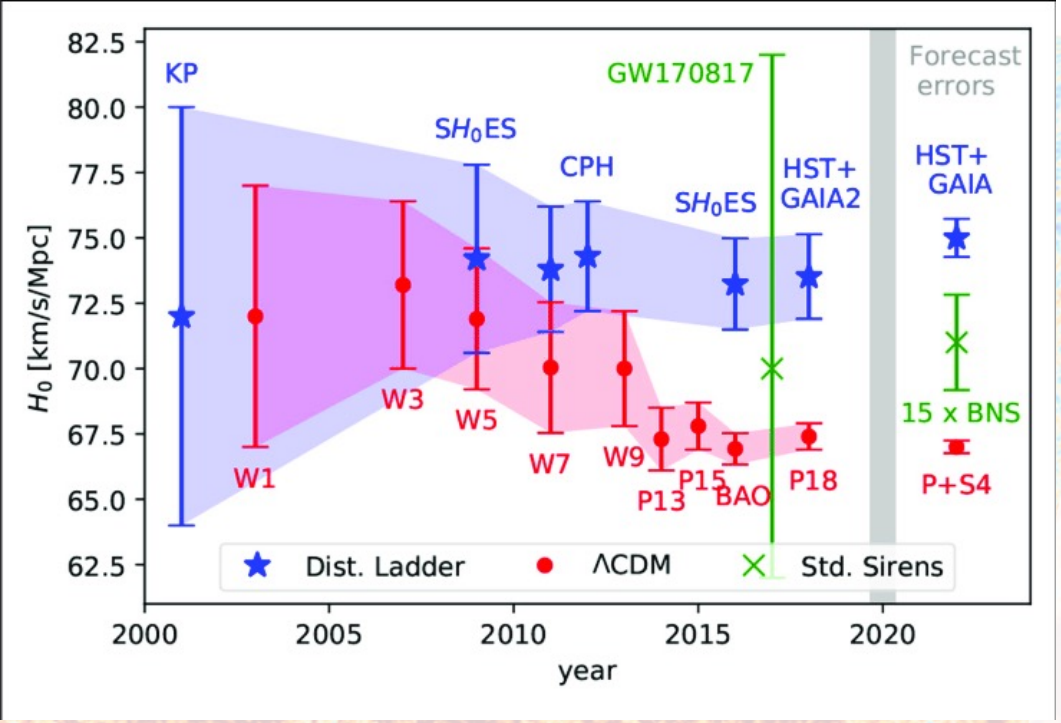
Well Known!!

vs

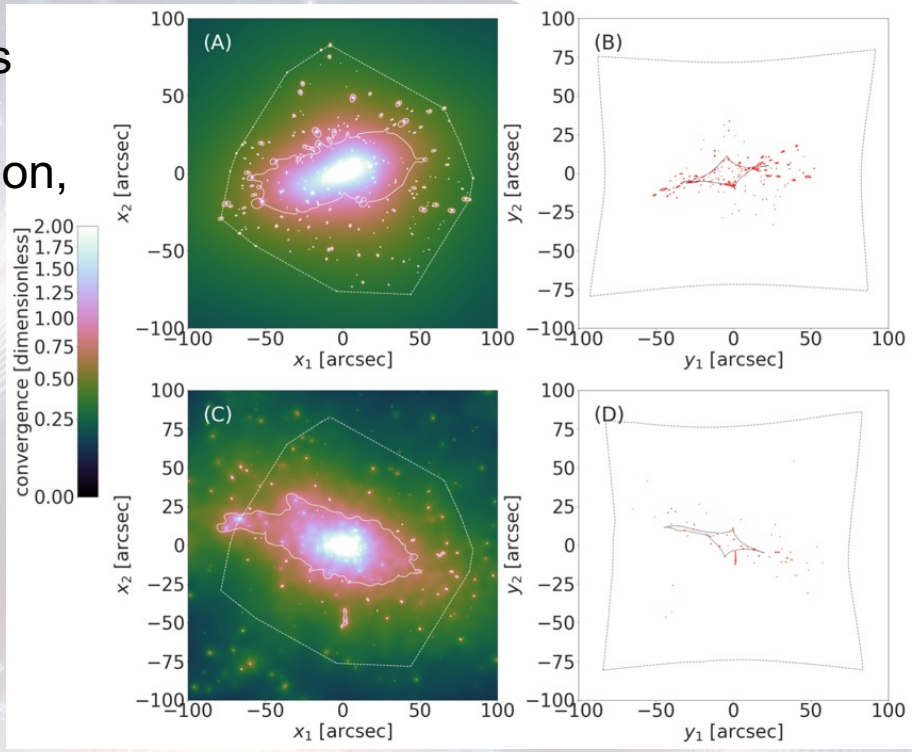
95-96% Dark Universe

Observationally needed but

Not well understood!

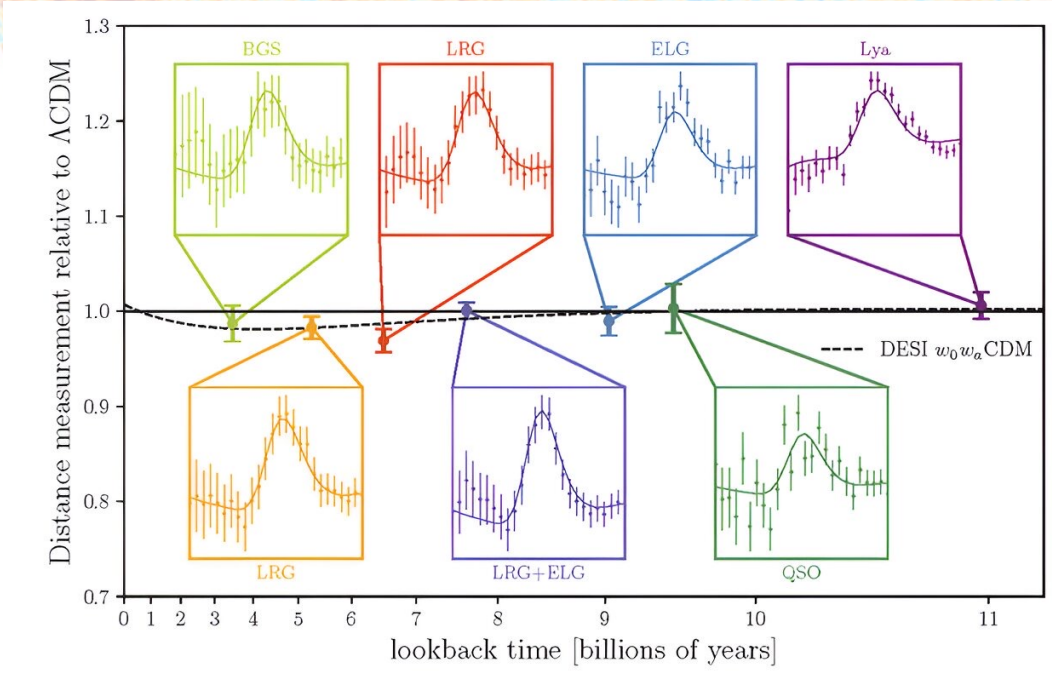


Sub-structures (σ_8, stronger lensing, distribution, …)



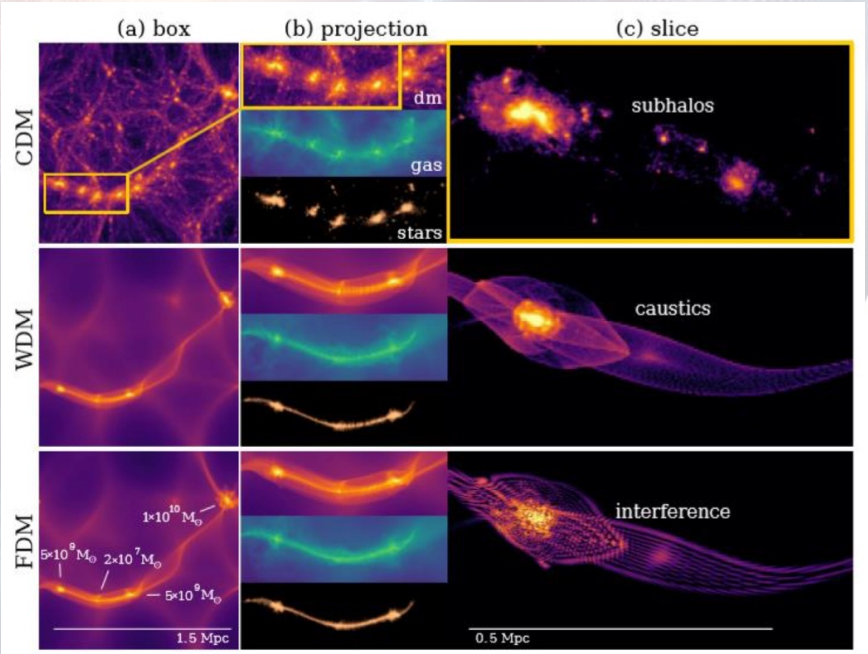
Hubble tension (early vs late)

ΛCDM Open problems

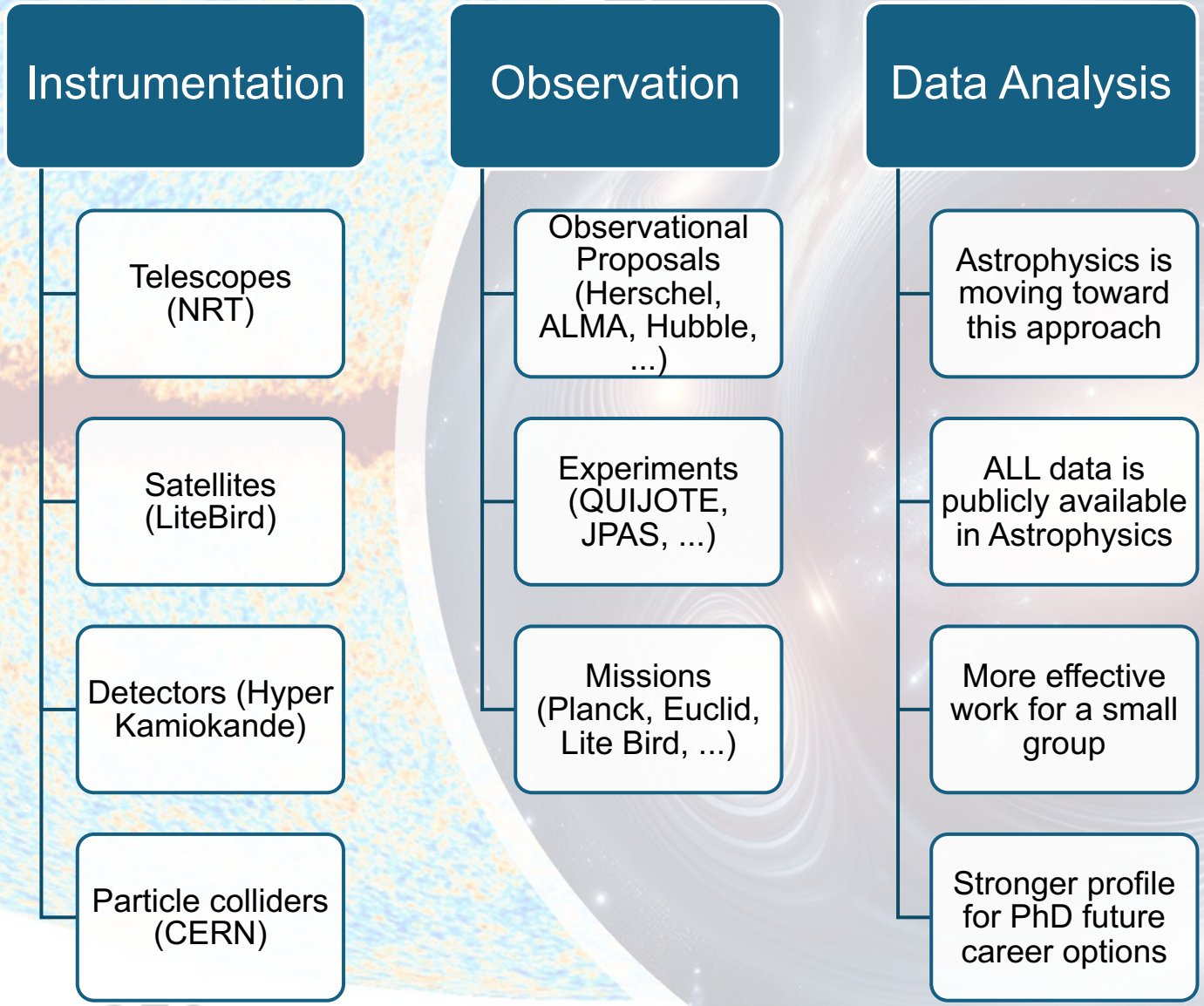


Evolving DE(z)

High resolution (DM nature)



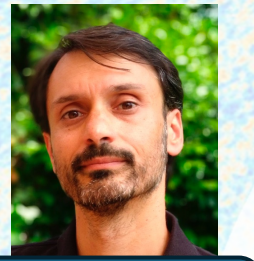
Approaches to work in moderm Cosmology



Who are WE?

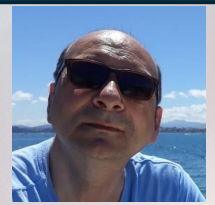
Senior Staff


Luigi Toffolatti


Joaquin Glez-Nuevo

PI


Laura Bonavera


Francisco Argüeso


Former PhD External Collaborators

Post Doc


Jose Manuel Casas

Marcos M. Cueli

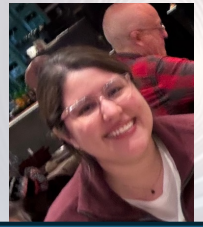
Jose Manuel Casas

PhD


David Crespo


Rebeca Fernandez


Juan Alberto Cano


Valentina Franco

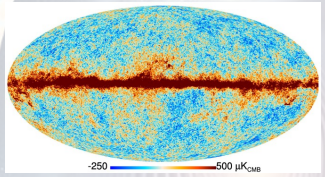
Jose Ignacio Calvo

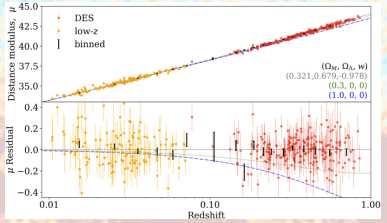

Sara Cabo

-250 + TFMs + TFGs

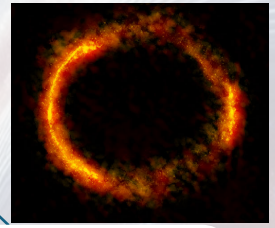
Main Cosmological Observables

CMB





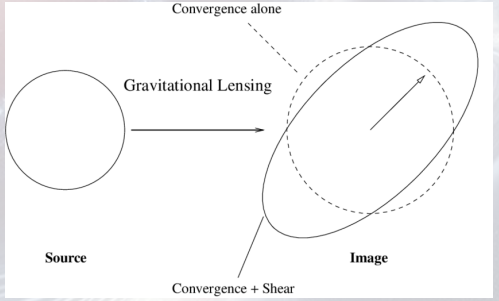
SuperNovae

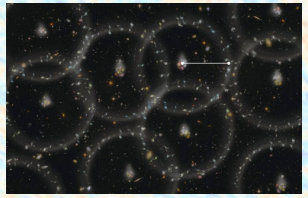


Gravitational Lensing

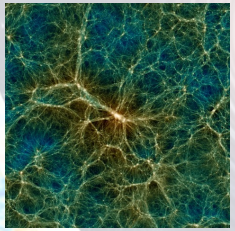
Shear

Magnification Bias





Barionic Acustic Oscilations

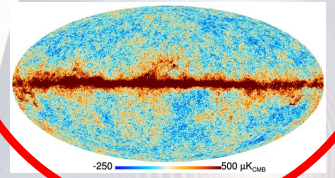


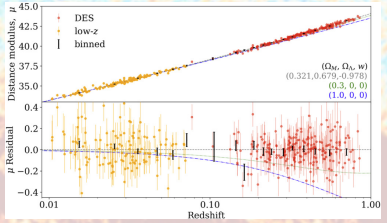
Galaxy clustering

Galaxy Clusters

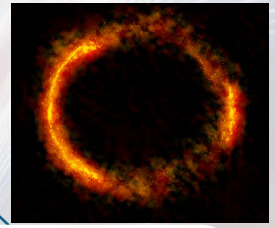
Main Cosmological Observables

CMB





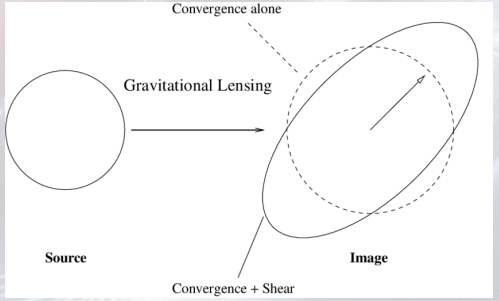
SuperNovae

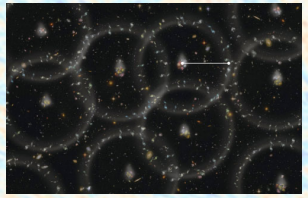


Gravitational Lensing

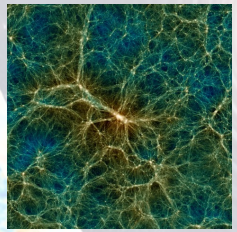
Shear

Magnification Bias





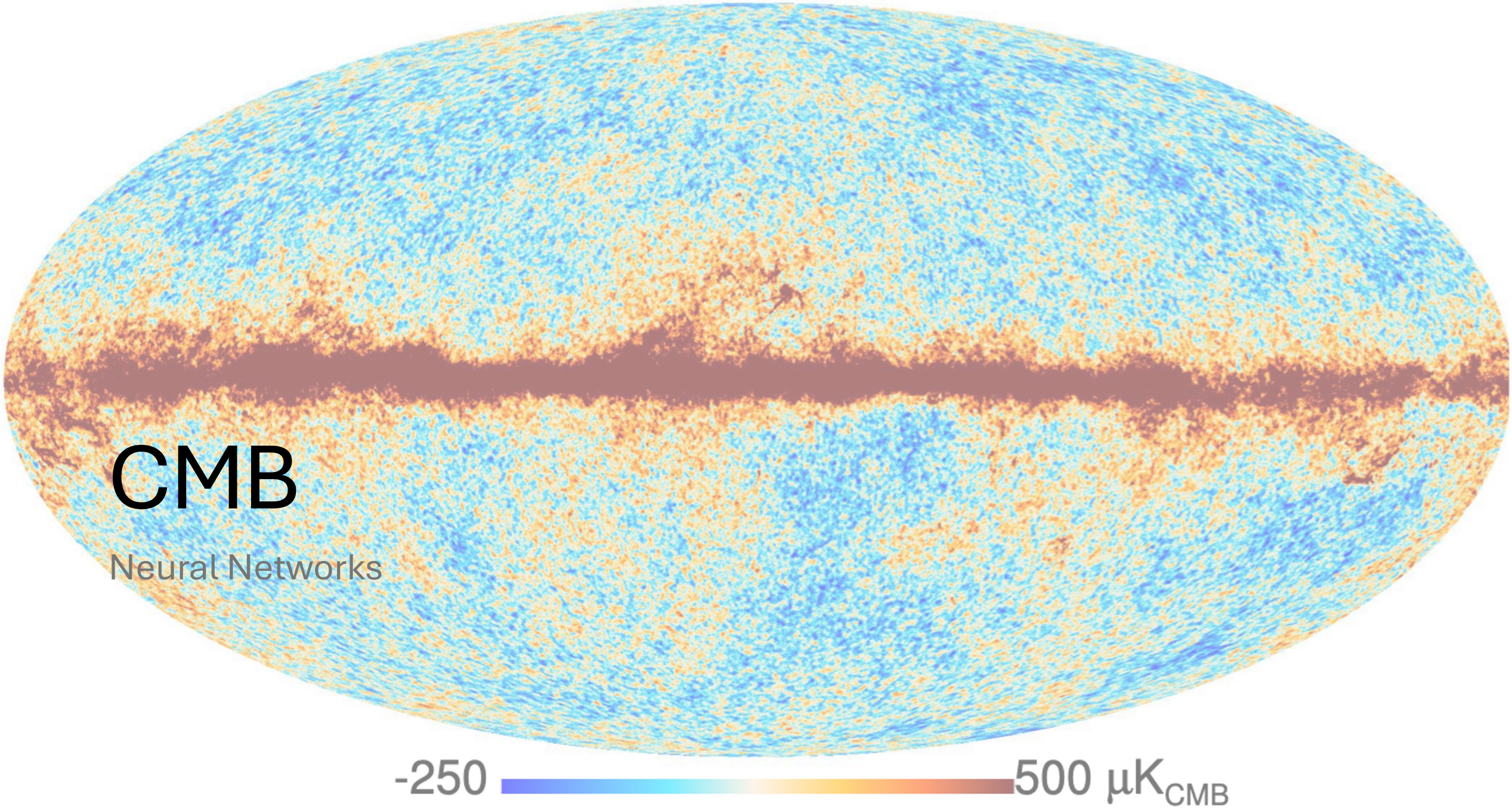
Barionic Acustic Oscilations



Galaxy clustering

Galaxy Clusters

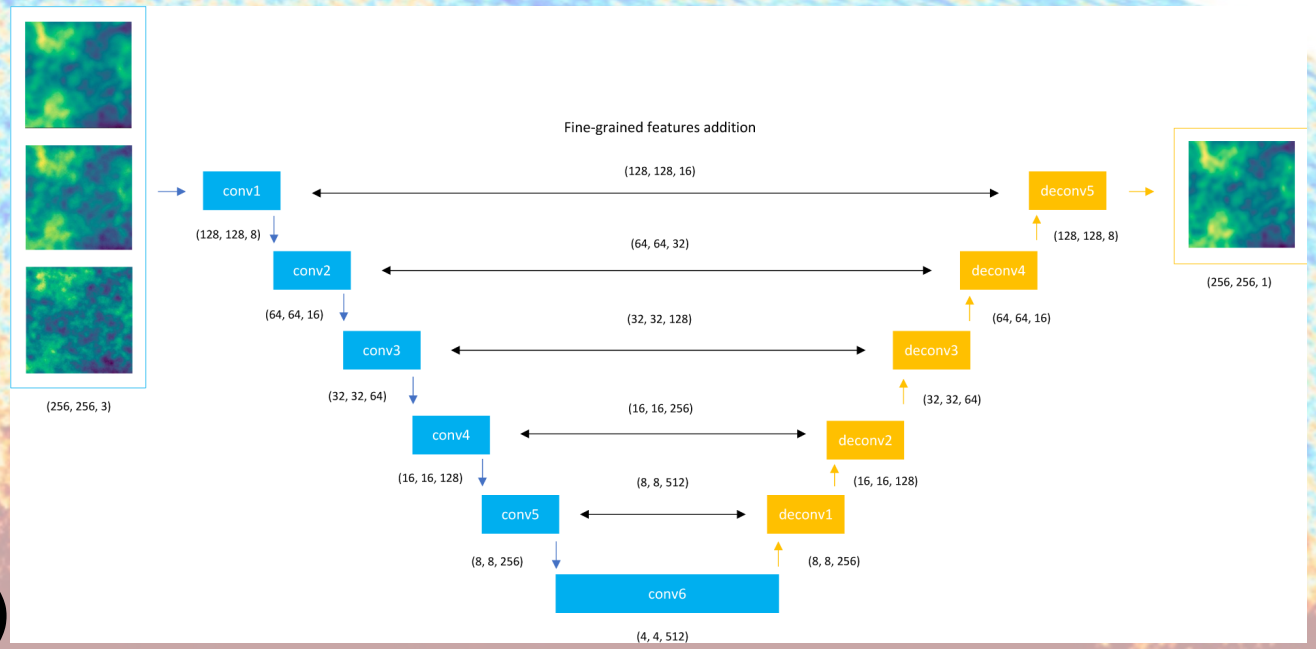
-250

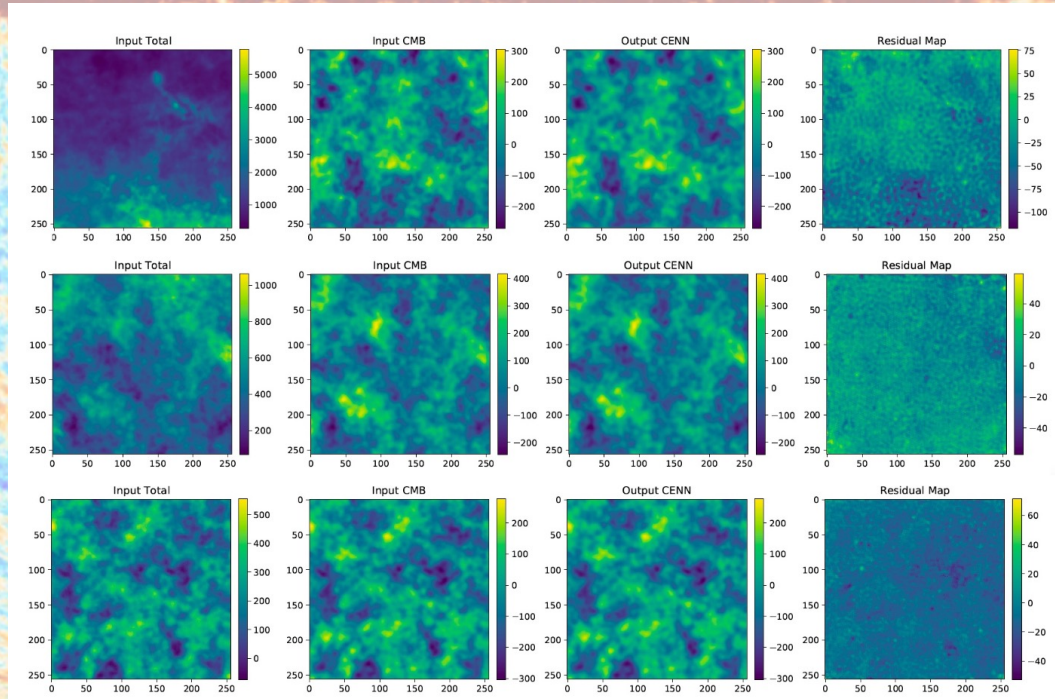

CMB
Neural Networks
-250
500 μK$_{CMB}$

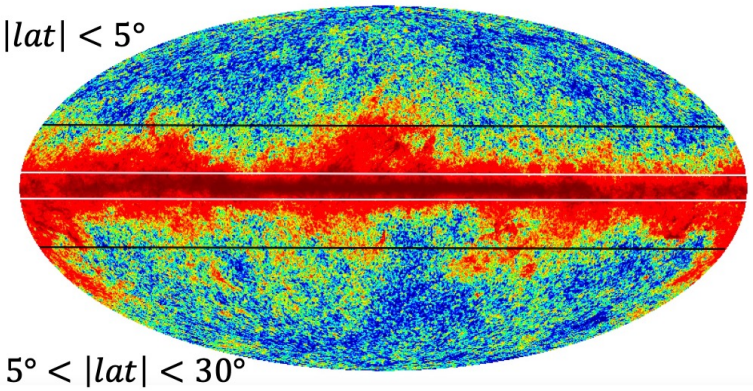
Component Separation

Retrive the cleanest CMB image possible from a noisy background

CENN (CMB Extraction Neural Network)





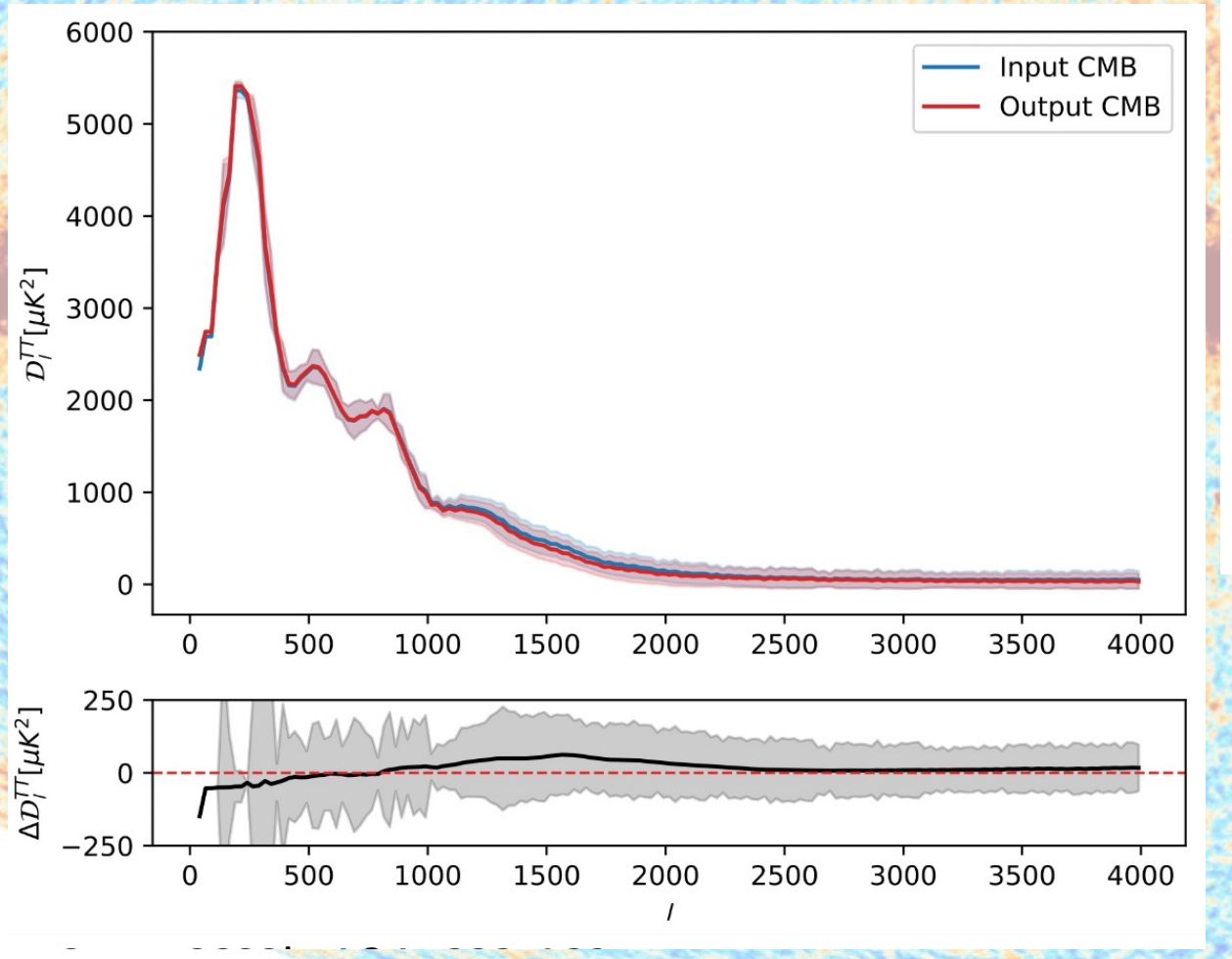


$|lat| < 5°$

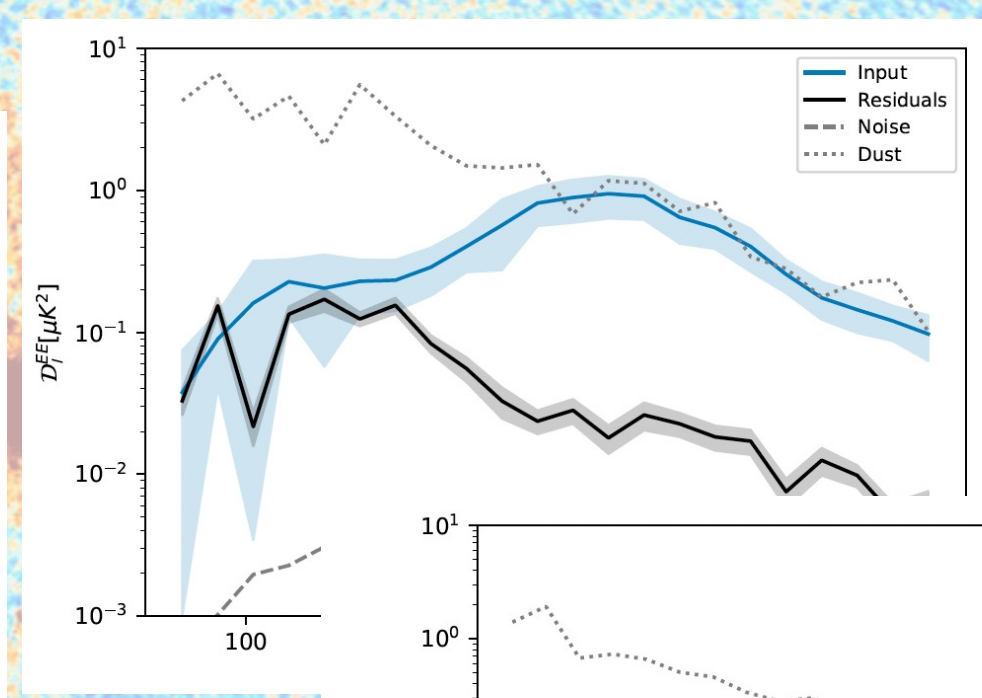
$5° < |lat| < 30°$

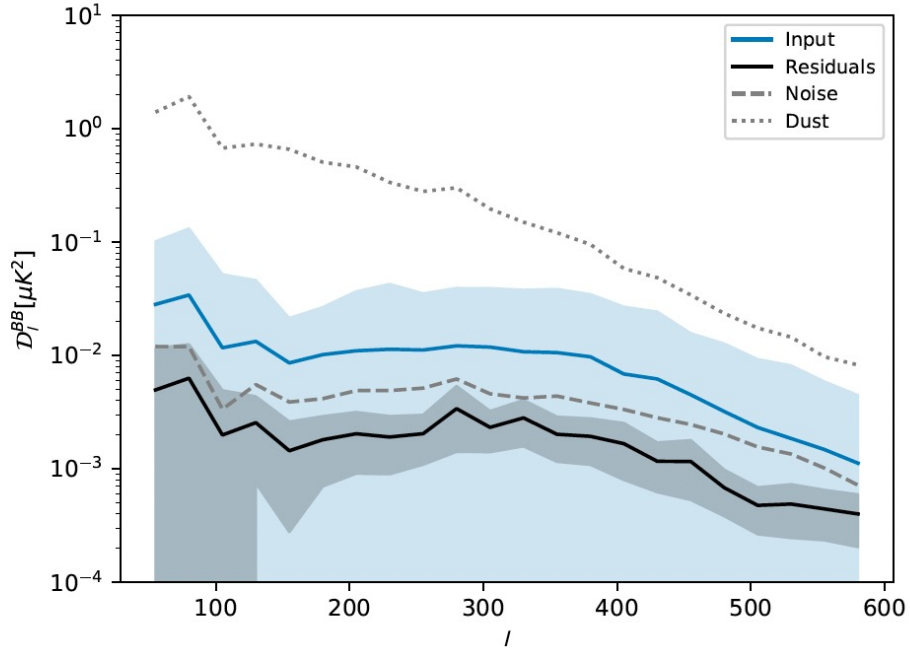
$30° < |lat| < 90°$

Total Intensity (CENN-T)
Casas et al. 2022b



Polarization (CENN-Pol)
Casas et al. 2025 (submitted)



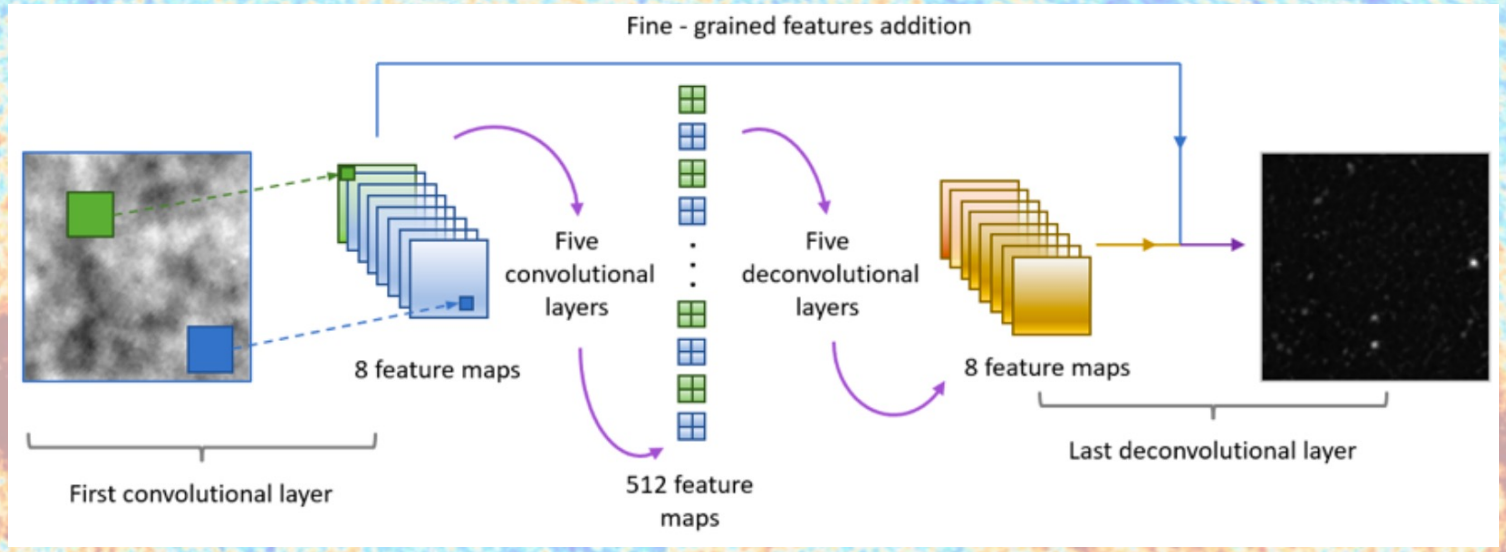


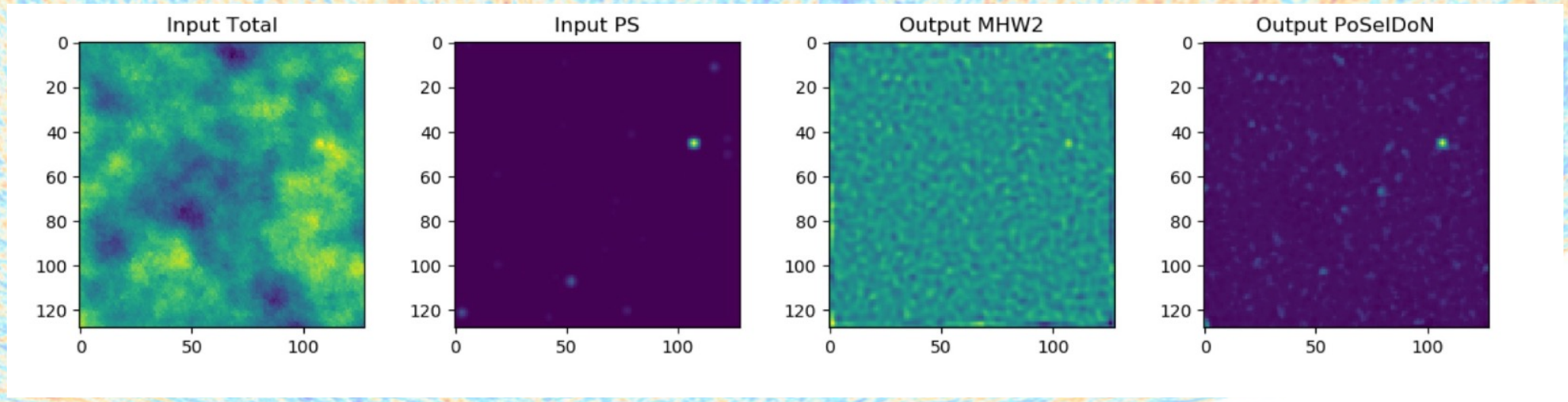
Point Source Detection

Extragalactic sources (Compact Sources) contaminates the small scales of CMB images.

Astrophysical interest by their own (Radiogalaxies, Blazars, IR Late-types, ...)

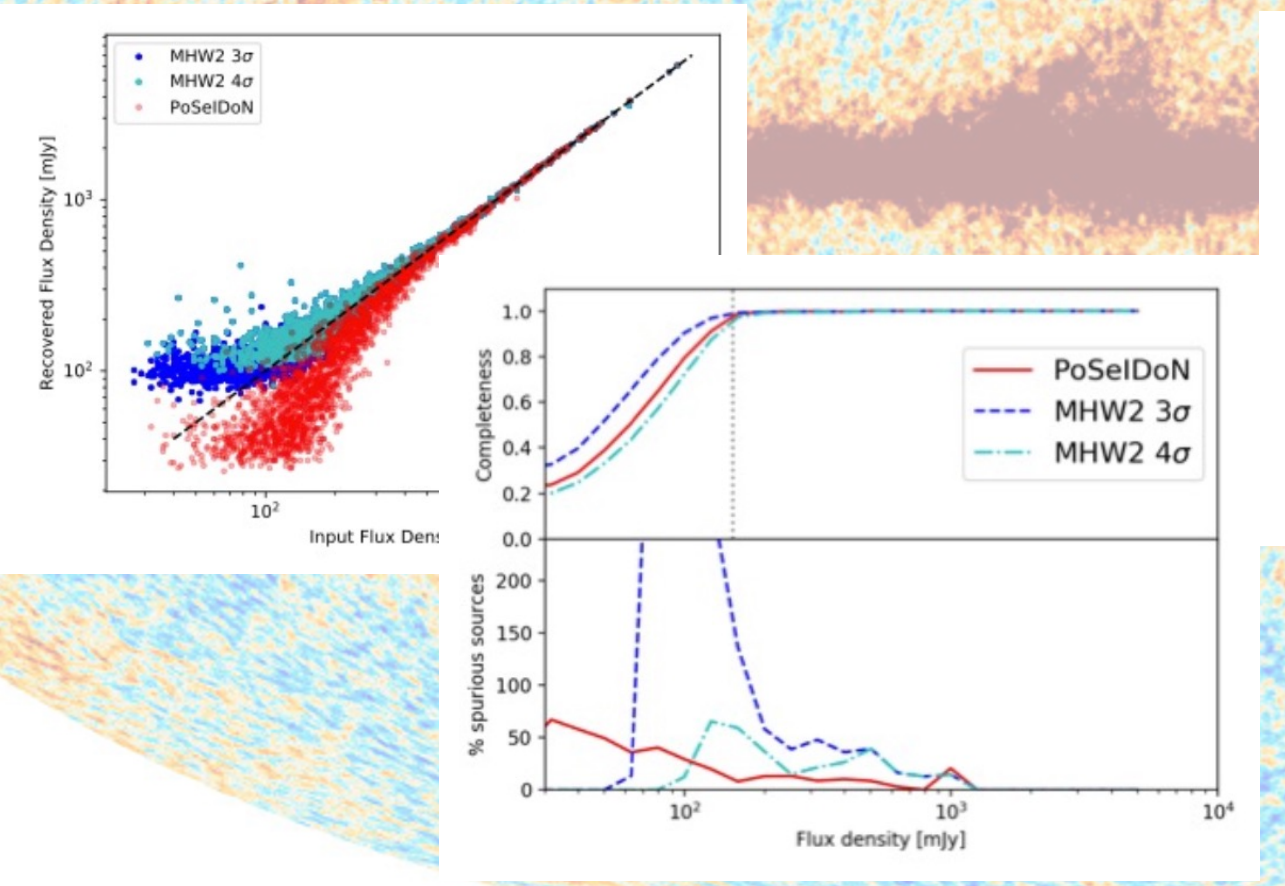
PoSeIDoN (Point Source Image Detection Network)



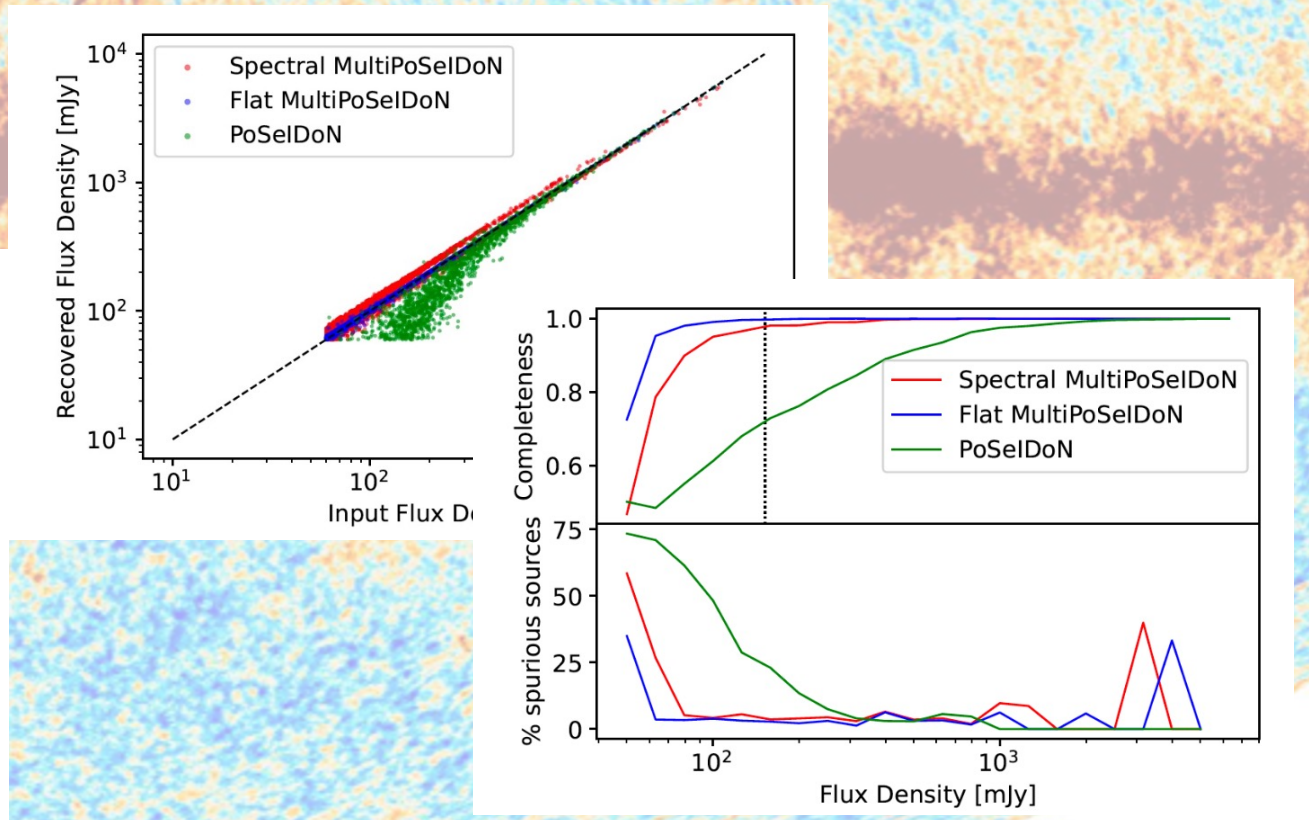


Total Intensity

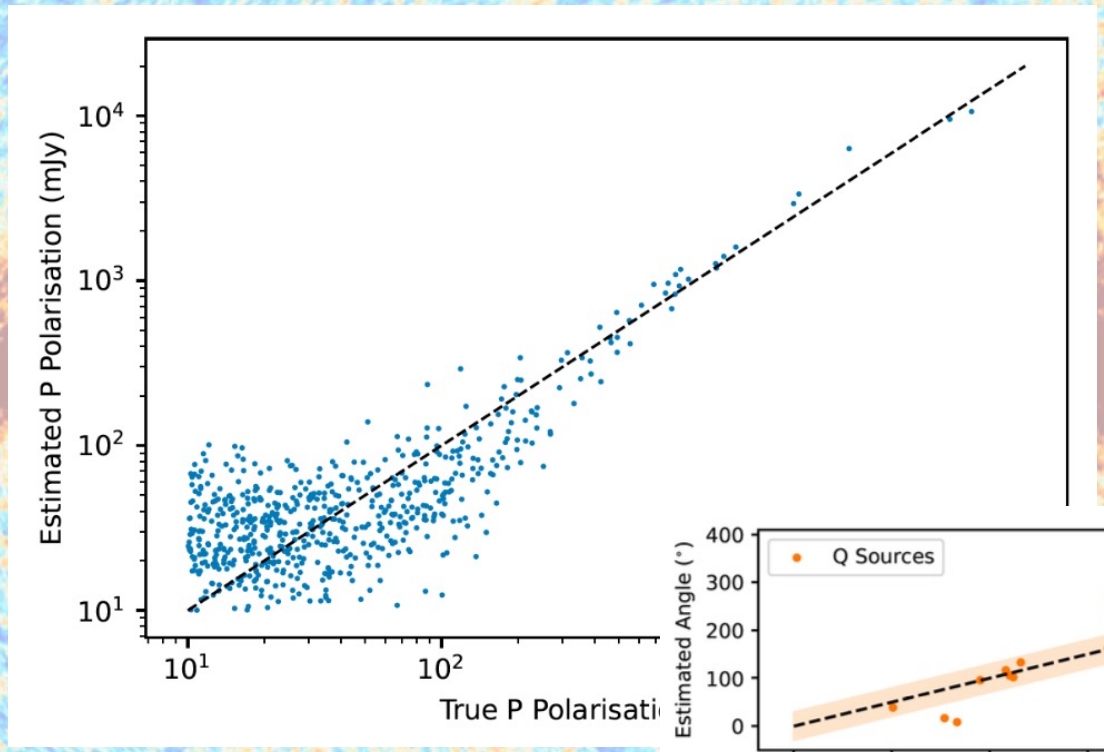
PoSeIDoN (single frequency)
Bonavera et al. 2021

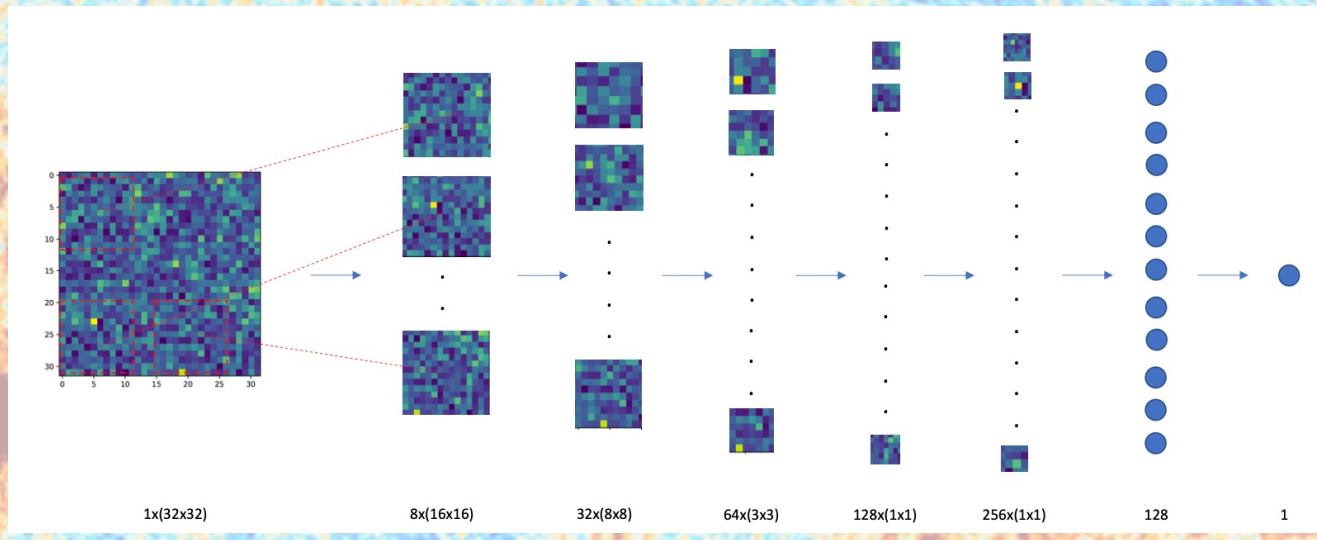


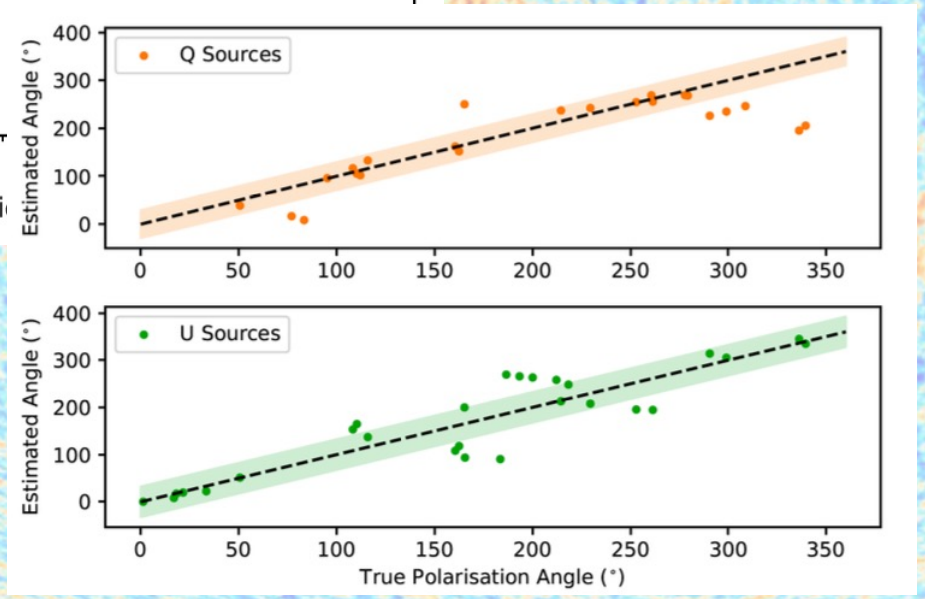
Multi-PoSeIDoN (multi-frequency)
Casas et al. 2022a



Polarization: POSPEN (POint Source Polarization Estimation Network) [Casas et al. 2023]







Foregrounds: Synchrotron emission

Casas et al. 2025 (to be submitted)

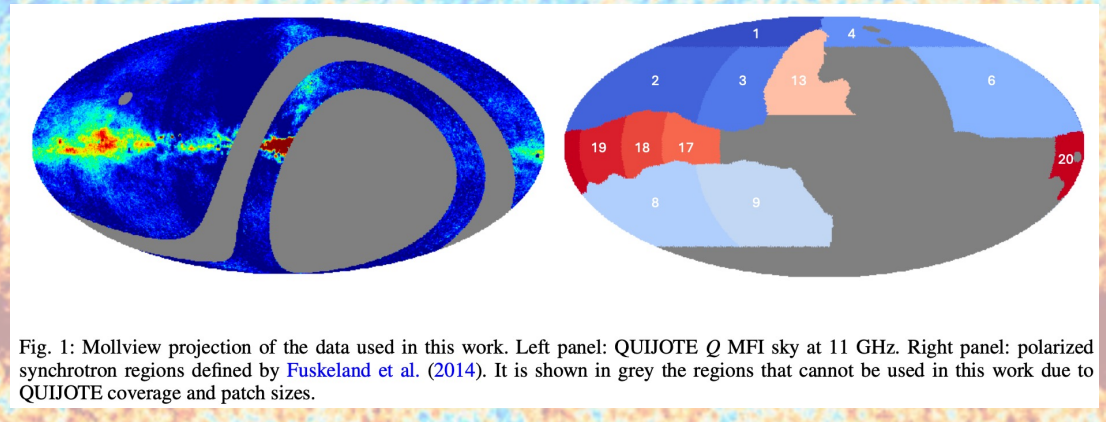
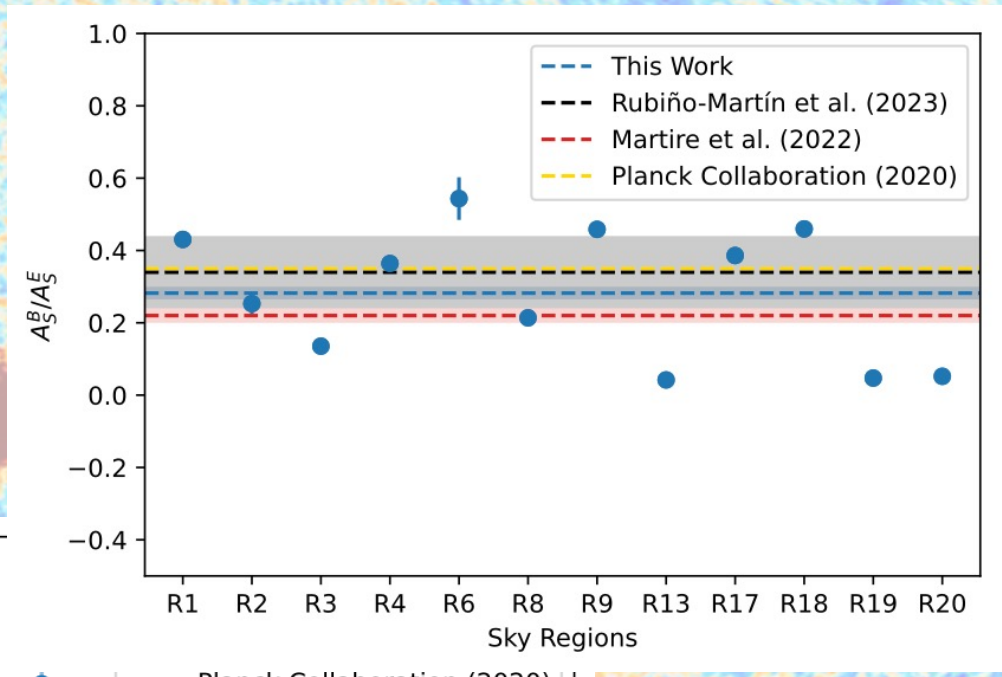
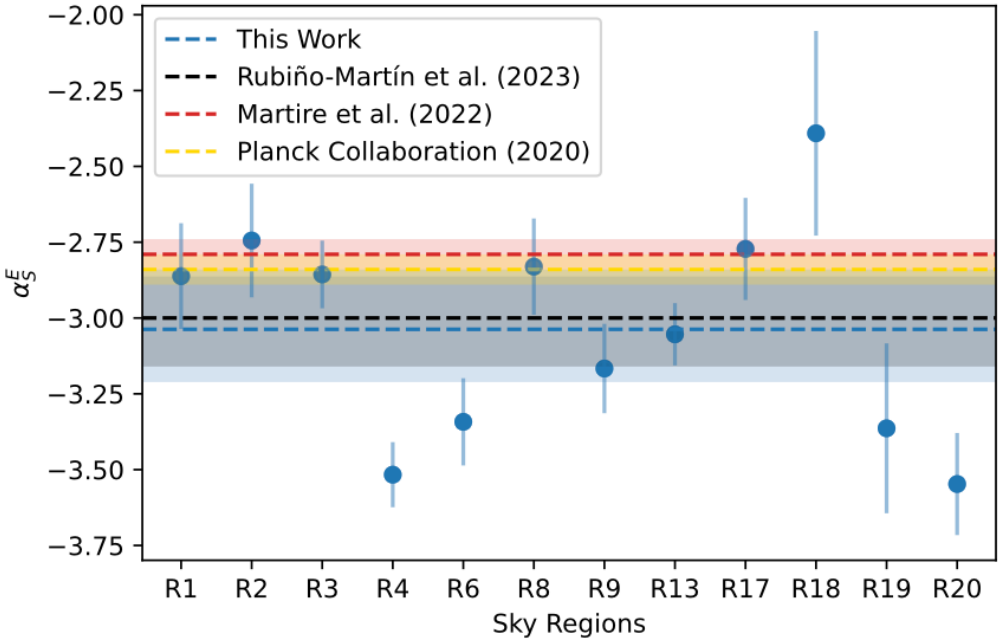
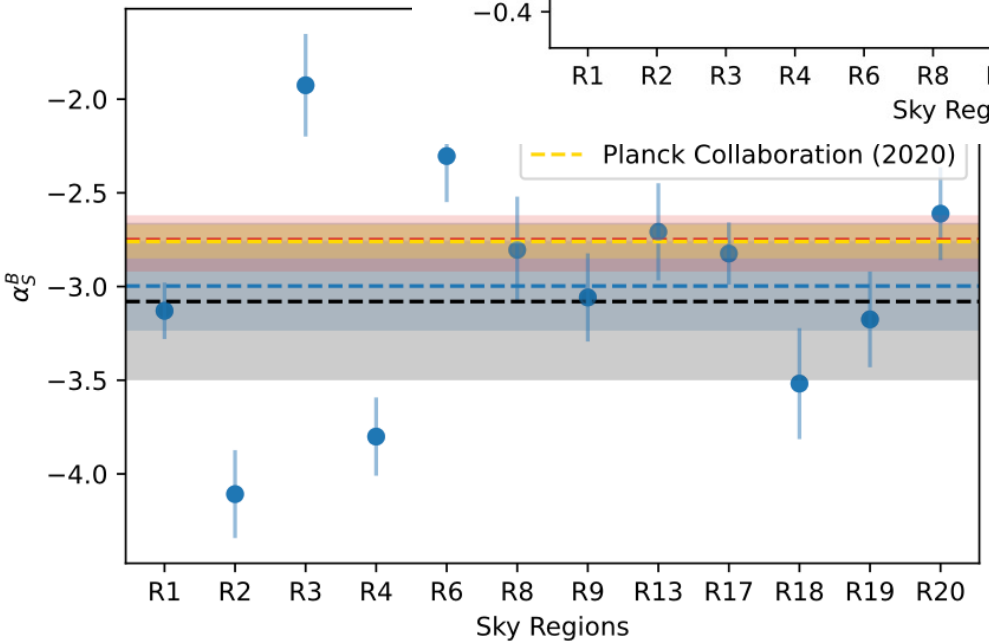


Fig. 1: Mollview projection of the data used in this work. Left panel: QUIJOTE Q MFI sky at 11 GHz. Right panel: polarized synchrotron regions defined by Fuskeland et al. (2014). It is shown in grey the regions that cannot be used in this work due to QUIJOTE coverage and patch sizes.



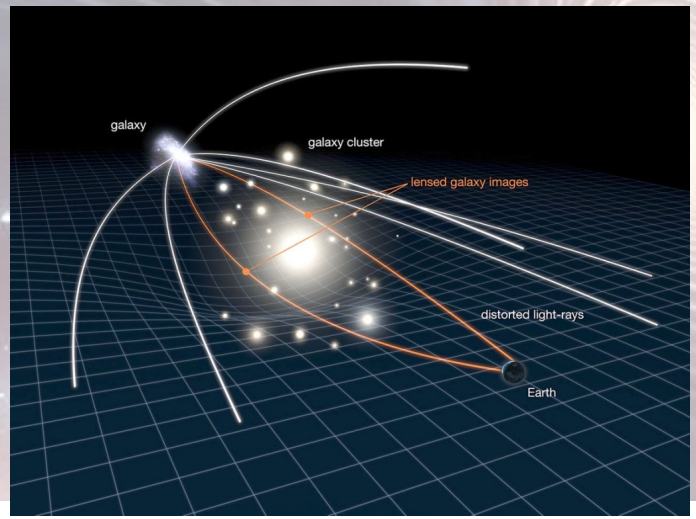


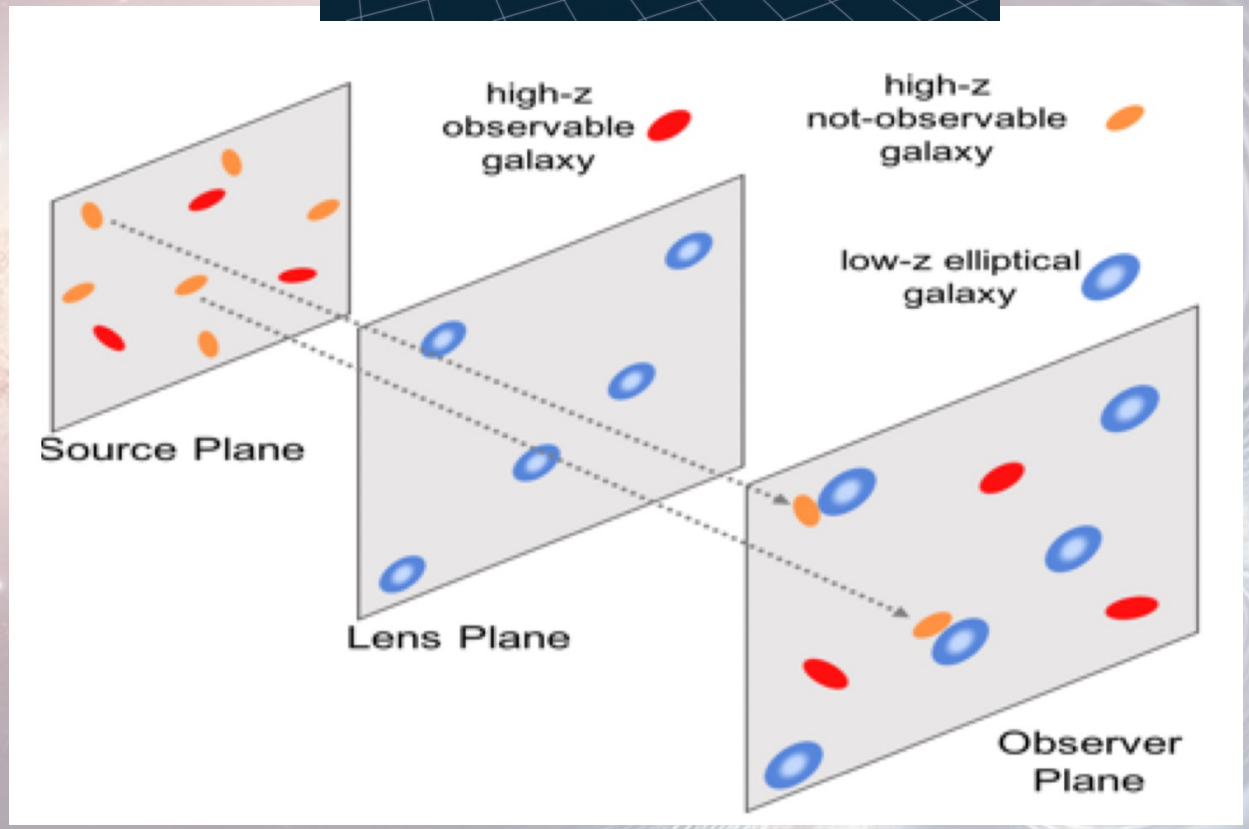


Magnification Bias

Magnification Bias

- A (weak) gravitational lensing effect.
- In our case, it produces an excess of background sources around massive galaxies (lenses)
- It's a cosmological probe!
  - Depends on total matter, cosmological distances and cosmological parameter.





Cosmological parameters (single redshift bin)

Gonzalez-Nuevo et al. 2021
Fernandez-Fernandez et al. 2024
Cueli et al. 2024

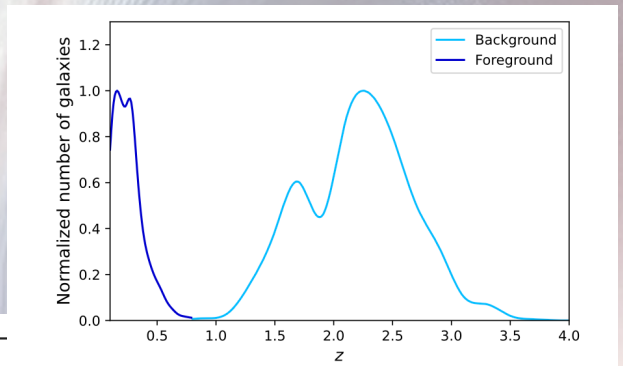


Fig. 1. Normalized redshift distribution of the background (light blue) and foreground (dark blue) samples of galaxies.

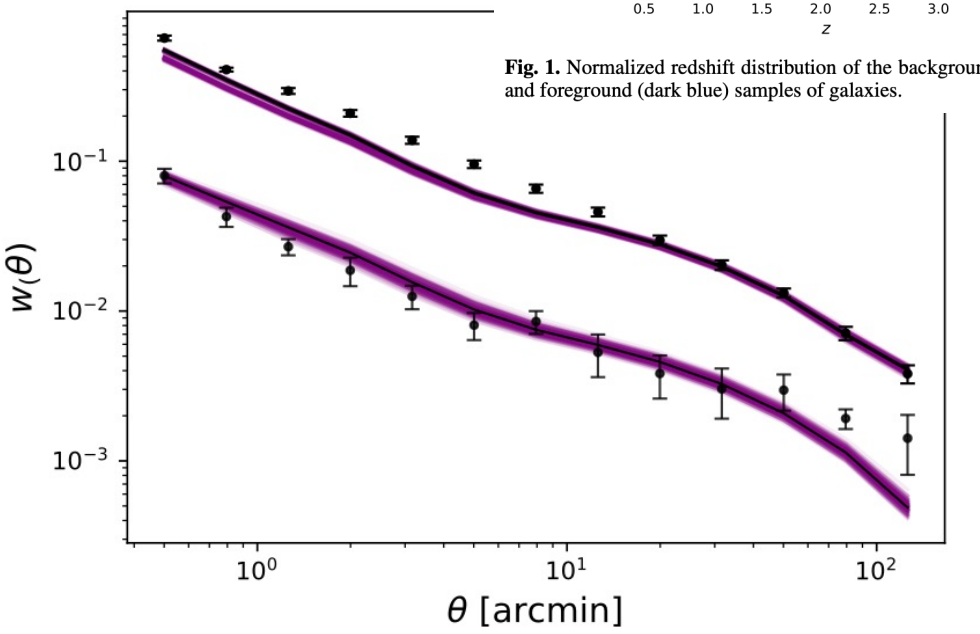
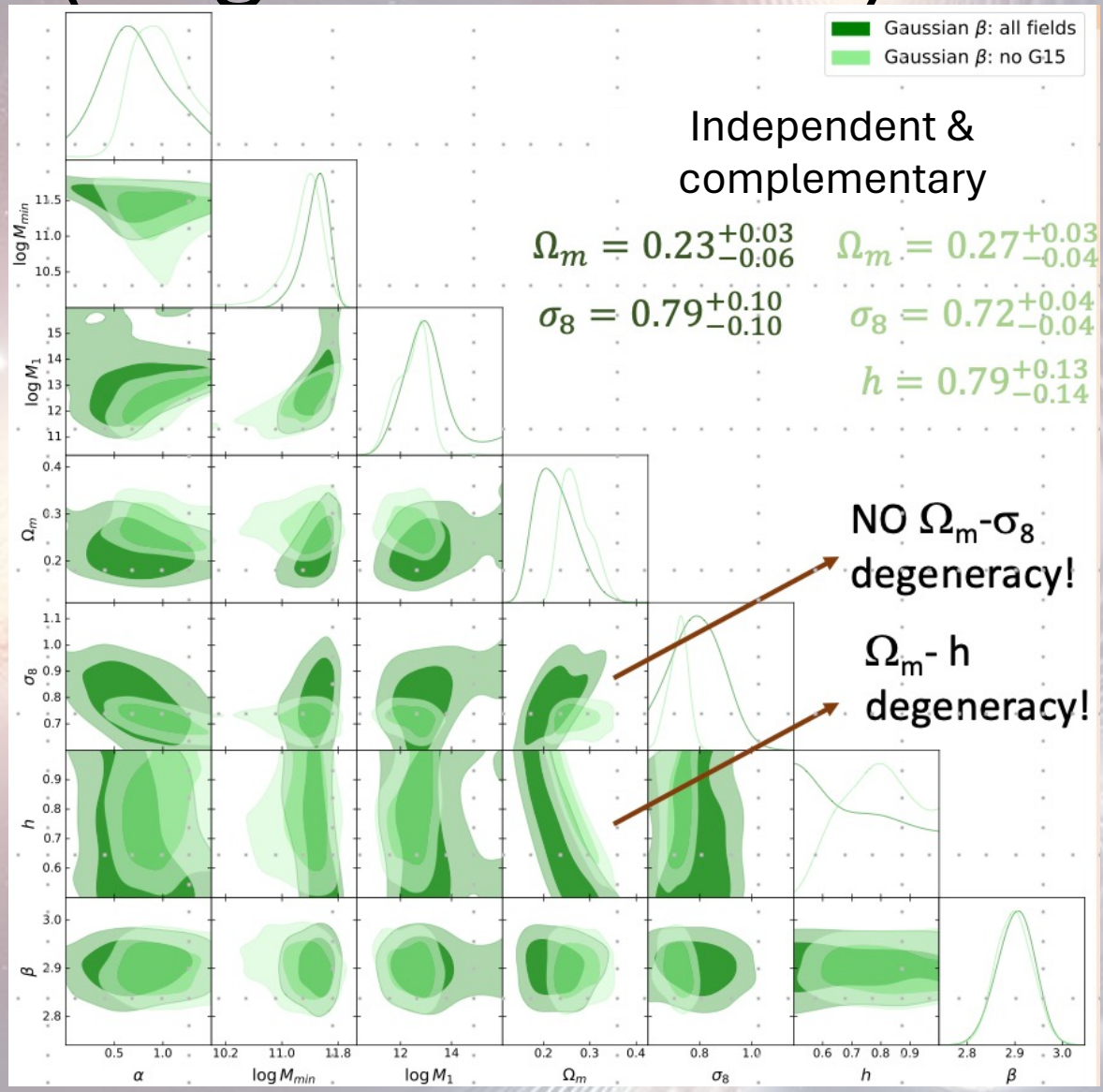
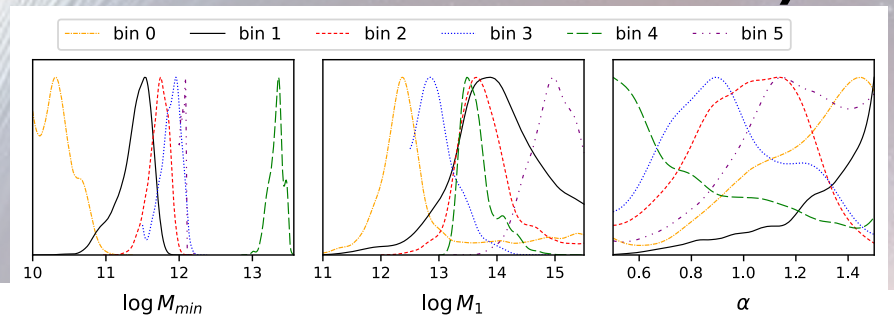
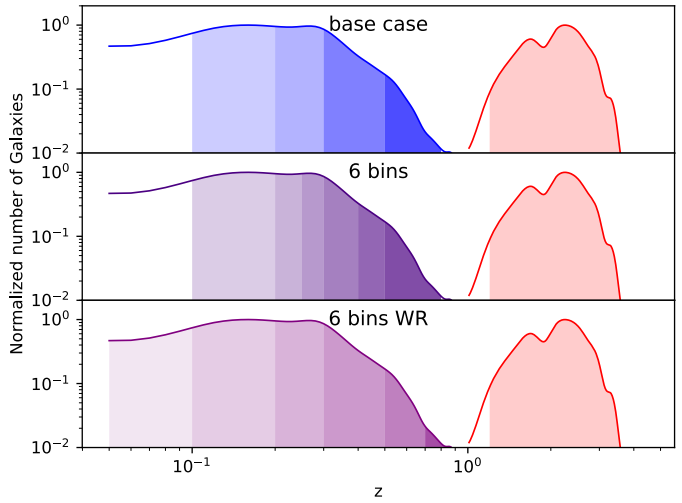


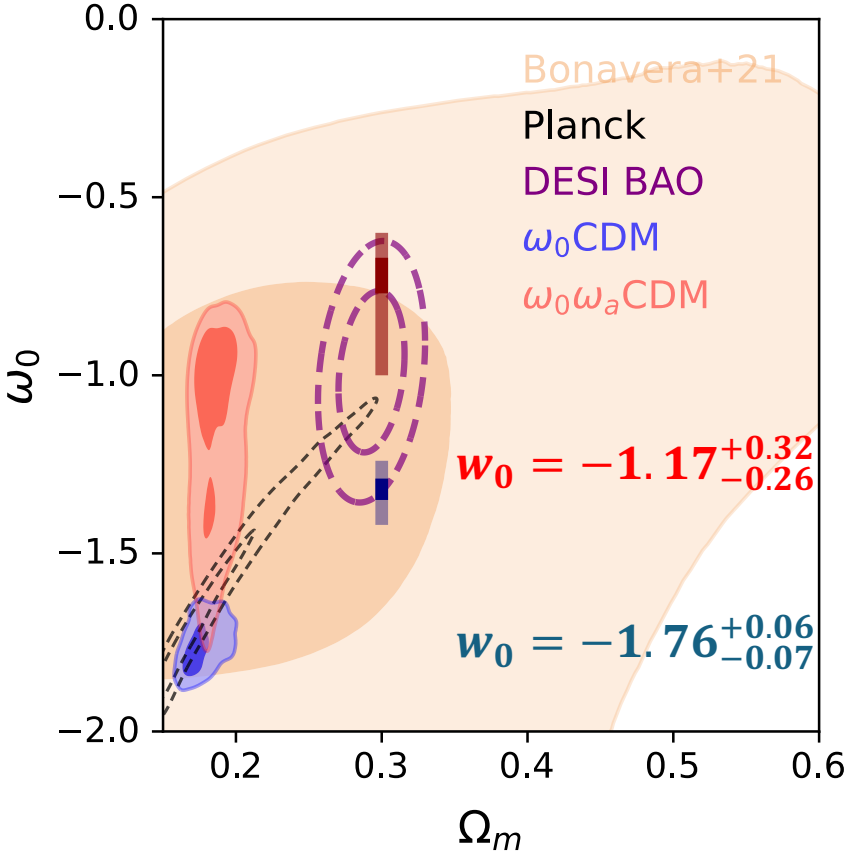
Fig. 10. Posterior-sampled angular auto- and cross-correlation functions from the joint analysis of both observables. The data are shown in black.



Tomography (ΛCDM vs wCDM)



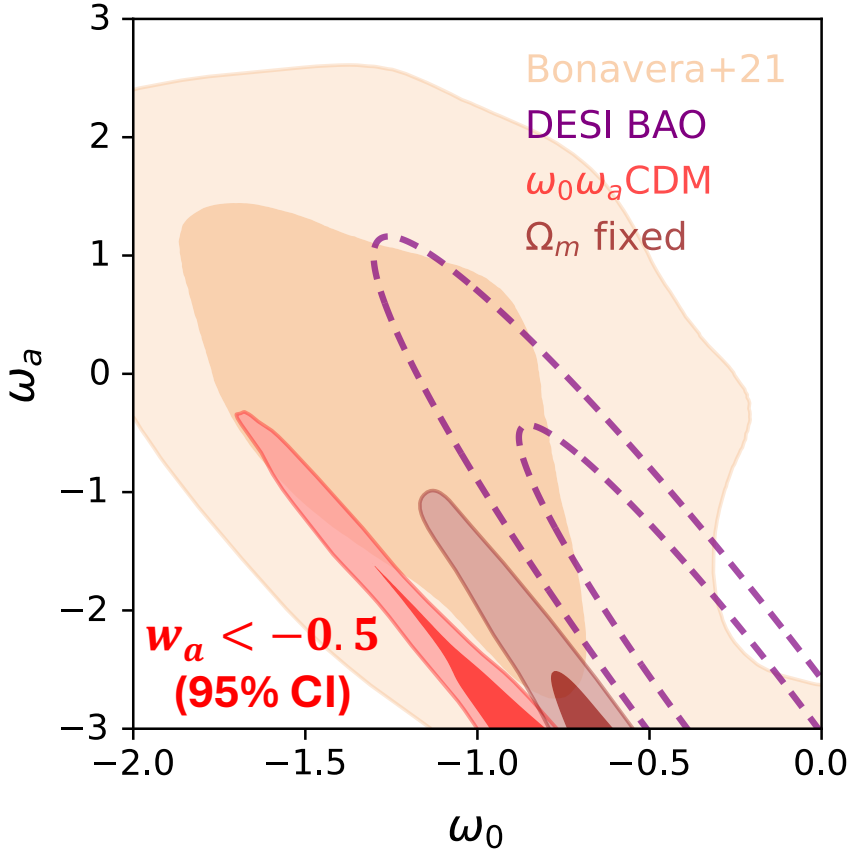




Bonavera et al. 2021
Bonavera et al. 2024
Bonavera et al. 2025 (submitted)

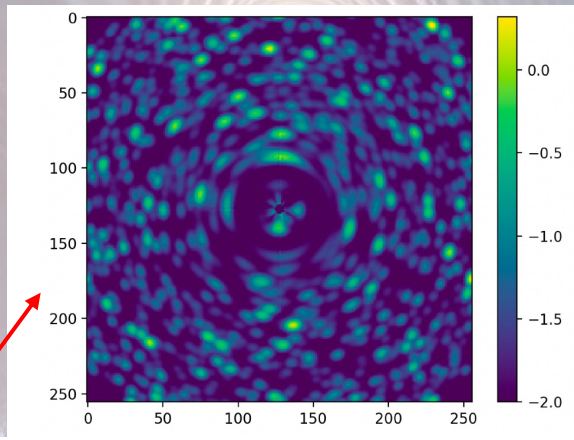
$$\omega(z) = \omega_0 + \omega_a \frac{z}{1+z}$$

$\Lambda \rightarrow w_0$=-1; w_a=0

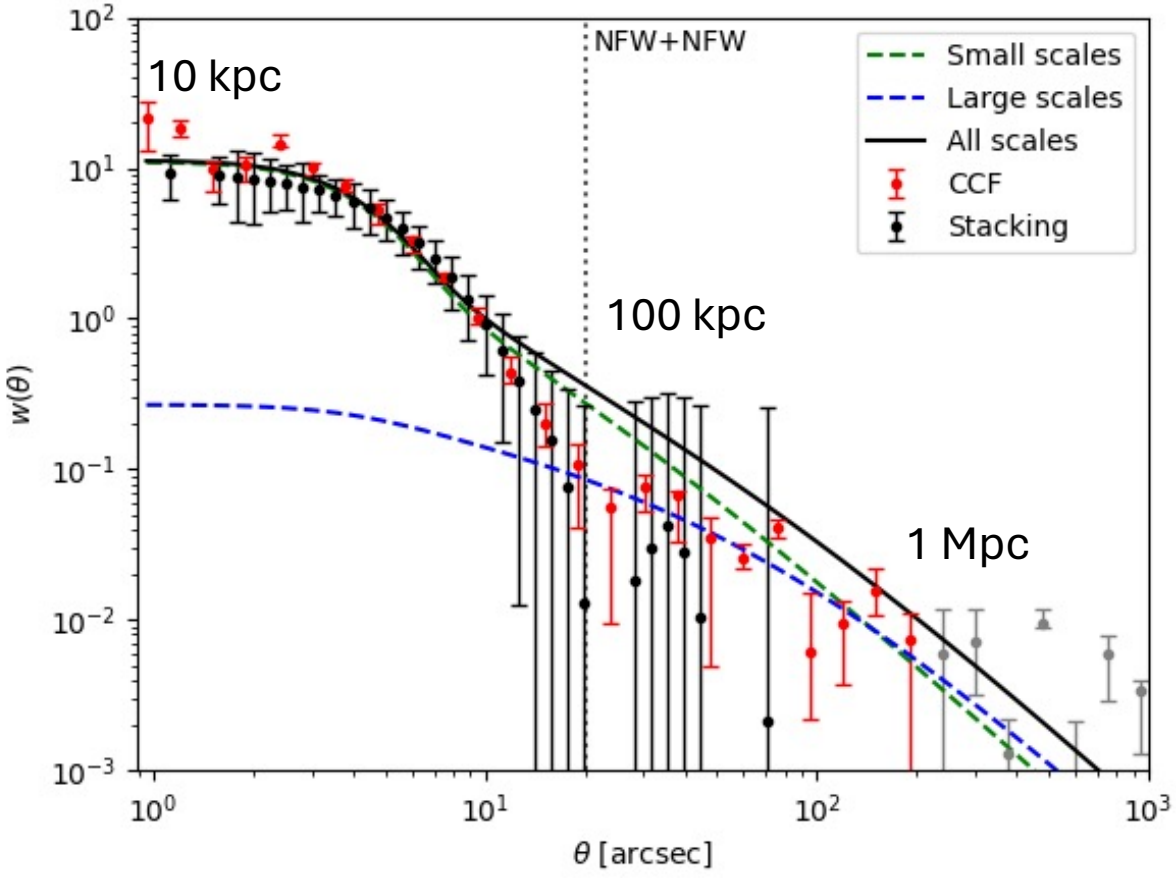


Mass density distribution (DM nature)

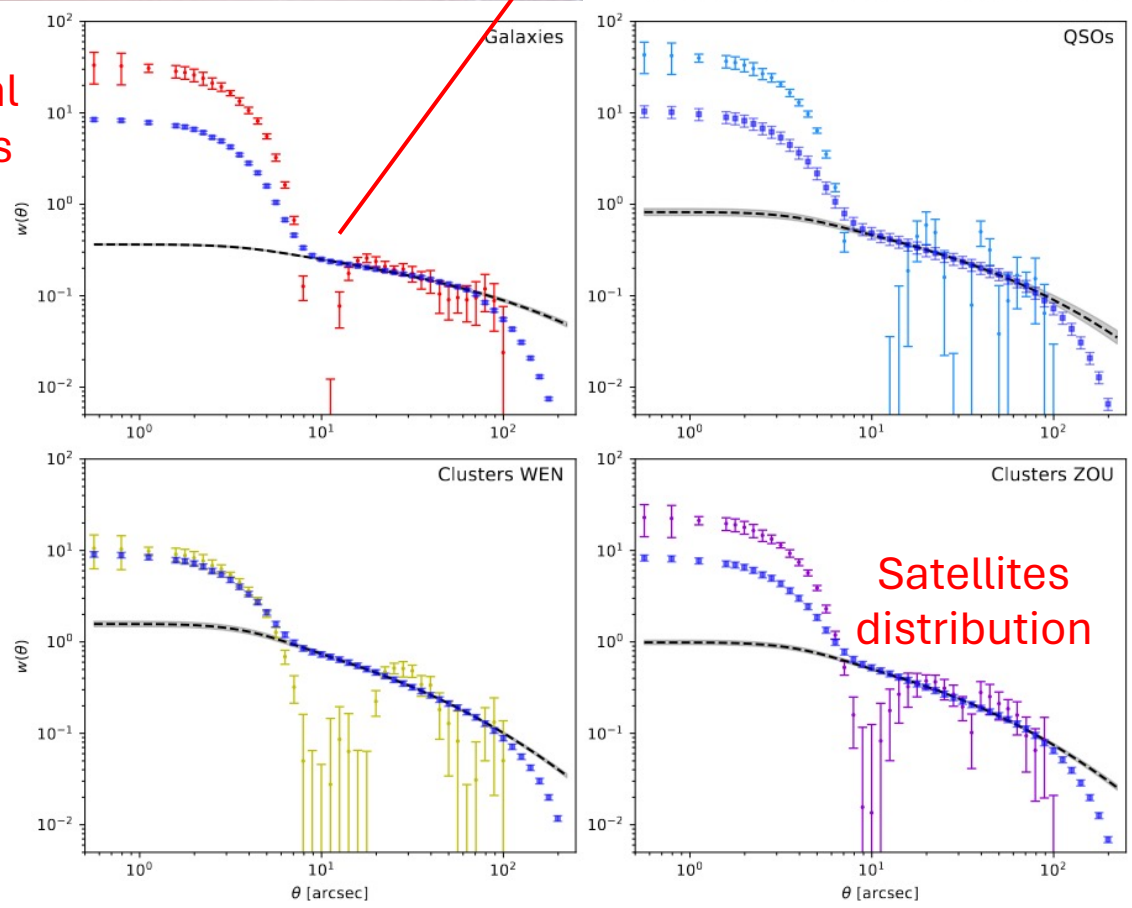
Fernandez et al. 2021; Crespo et al. 2022
Crespo et al. 2024; Crespo et al. 2025 (submitted)



Einstein “gap”



Central excess

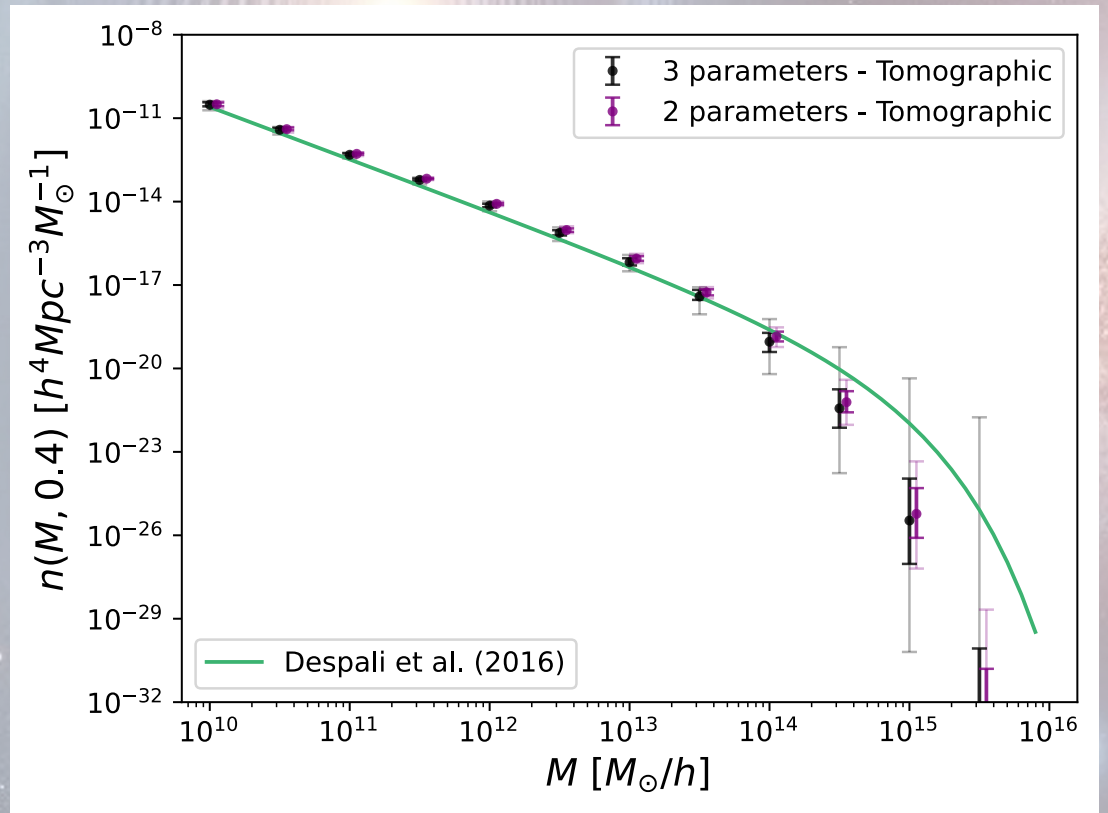


Satellites distribution

Astrophysics (HMF, neutrinos)

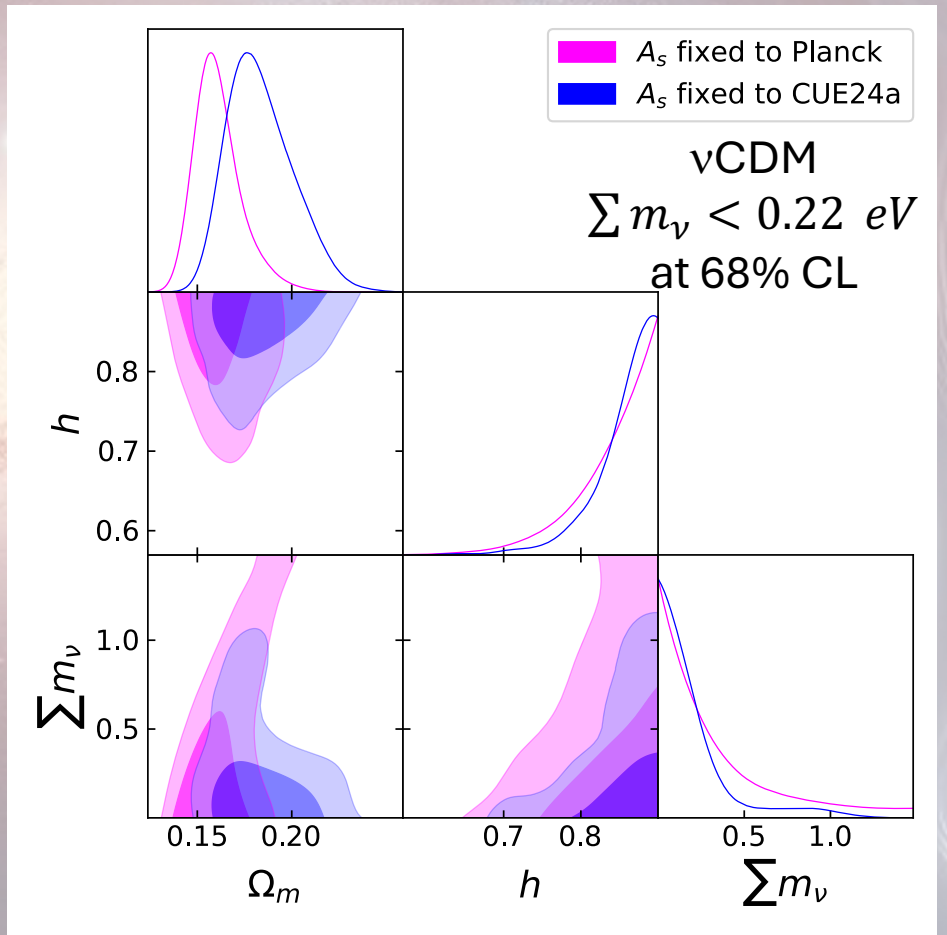
Observational constrainst of the HMF

Test of its universality
Cueli et al. 2021
Cueli et al. 2022



ΛCDM with massive neutrinos (νCDM)

Cueli et al. 2024



Conclusions

Young, small but very active group!

Cosmology is in crisis → Research opportunities!

More research ideas than manpower!