Testing the cosmological model with cosmic voids and CMB lensing in Euclid and DESI surveys

Simone Sartori [1], Stephanie Escoffier [1], Pauline Vielzeuf [1], William Gillard [1]

[1] Aix Marseille Université, CNRS/IN2P3, CPPM, Marseille, France

RÉPUBLIQUE FRANÇAISE
Liberté Égalité Fraternité

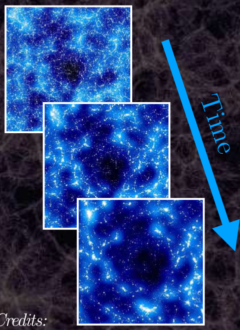
CNES CENTRE NATIONAL D'ÉTUDES SPATIALES

COSMIC VOIDS

Vaste underdense regions that dominate the Late Universe in terms of Volume.

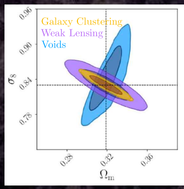
Cosmic voids evolve through time becoming more spherical and underdense but remaining in *mildly non-linear* regime, feature that make them easier to model than their overdense counterparts.

Cosmological informations from: number counts, density profiles, shapes, geometrical and dynamical distortions, **lensing**, velocity profiles...



Credits: van de Waygaert & Platen (2011)

Complemental with standard cosmological probes!



Credits: Contarini et al. (2022)

GRAVITATIONAL LENSING OF THE COSMIC MICROWAVE BACKGROUND (CMB)

Effect due to the presence of density fluctuation in the line of sight: gravitational fields change in space.

$$\phi \rightarrow \phi(x)$$

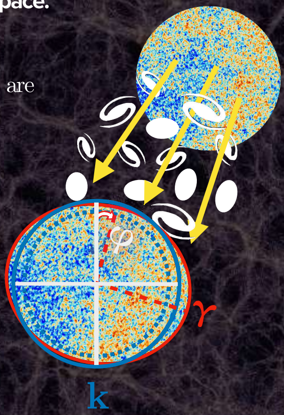
The observed CMB is modified and anisotropies are introduced.

Overdensities: $\phi(x)$ acts like a convergent lens. **Positive magnification**

Underdensities: $\phi(x)$ acts like a divergent lens. **Negative magnification**

Three main observables:

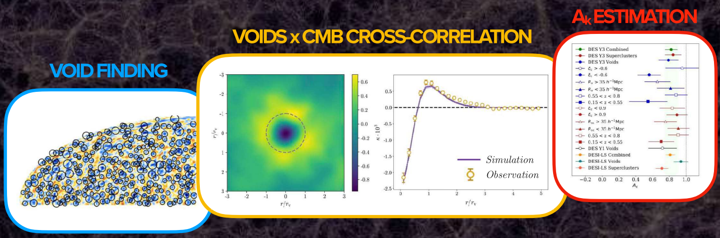
- **Convergence** k *(magnification)*
- **Shear** γ *(distortion)*
- **Rotation** φ



COSMIC VOIDS x CMB LESING

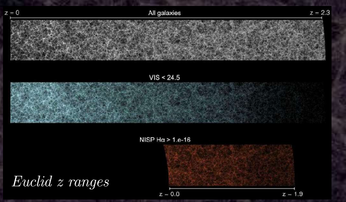
The cross-correlation between cosmic voids and CMB convergence maps is a powerful tool to test the cosmological model

Cosmic voids are identified in the galaxy field through specific void finding algorithms (*left panel*). Then, the CMB convergence patches behind every voids are stacked together in order to let the lensing signal arise from the instrumental noise. The radial profile of the stacked CMB patch (*central panel*) provides us our cross-correlation signal. The cosmological information is provided by the ratio between the observed cross-correlation and the simulated ΛCDM signal, in form of the *best-fitting CMB lensing amplitude parameter* $A_\kappa = \kappa_{\text{Obs}}/\kappa_{\text{Sim}}$ *(right panel, credits: Kovacs et al., 2022,* $A_k = 1$ *for ΛCDM)*



EUCLID AND DESI SURVEYS

The epoch of the large galaxy survey is started, mapping the Universe to understand its composition and to unravel the mystery of dark energy

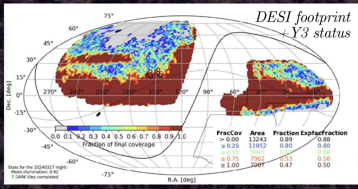


ESA Euclid Mission

1.2m-diameter space telescope with two scientific instruments: a visible-wavelength camera (VIS) and a near-infrared camera/spectrometer (NISP). Euclid will provide observation of billion of galaxies and about 30 million spectra. Currently at the second year of operations.

The Dark Energy Spectroscopic Instrument (DESI)

Installed on the 4-diameter Mayall telescope, DESI exploits 5000 robot-fibres to measure around 40 million galaxy and quasar spectra up to a redshift z=3.5 in a time span of 5 years. Currently at the fourth year of operations.



DESI LEGACY SURVEY VOIDS x PLANCK 2018 CMB CONVERGENCE MAP

A new solution to the cosmological lensing tensions

Tensions exist in previous cross-correlation analysis between cosmic voids and CMB lensing:

Different analysis leaded to different tensions with the ΛCDM simulations, depending by the void populations analysed and the identification strategies used. On average, a weaker lensing signal than the prediction is observed.

Exploitation of the DESI Legacy survey, waiting for the spectroscopic Euclid and DESI data

In order to investigate the tensions and to provide a new measurements of the signal, we exploited the photometric DESI legacy survey, that provides the targets for the DESI spectroscopic observation with more than 10 millions Luminous Red Galaxies (LRGs) over more than 13000 square degrees.

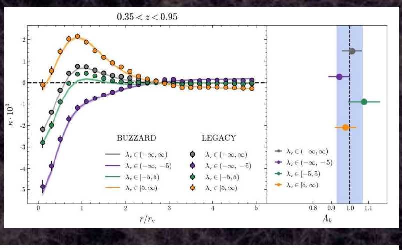
We cross correlate the voids identified in this galaxy sample with the convergence map from Planck 2018.

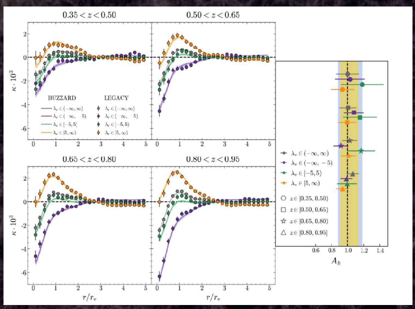
A new approach: mock calibration exploiting the spectroscopic data

To ensure the perfect matching between observation and mocks (Buzzard, *de Rose et al. 2019*), avoiding the arising of fake tensions due to the unaccounted systematics, we calibrate the mocks matching the sparseness and the redshift error distribution of the observations for the full redshift range, exploit the matching between 1 million spectra of the DESI Y1 observation and our photometric observations.

A tension-free set of measurements

Our cross-correlation measurement are resulting perfectly in agreement with the ΛCDM simulated predictions for all the redshift ranges and the void populations considered, with record significances for our detection up to 18σ (an improvement of around 30% compared to the best previous measurements).





Phd thesis co-funded by CNES and CNRS

sartori@cppm.in2p3.fr

Euclid consortium · amU Aix Marseille Université · CNRS · CPPM Centre de Physique des Particules de Marseille