CLASS:
Cosmology with Large Scale Surveys

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IPhU Days - February, 10th 2022

Context: large spectroscopic and photometric surveys

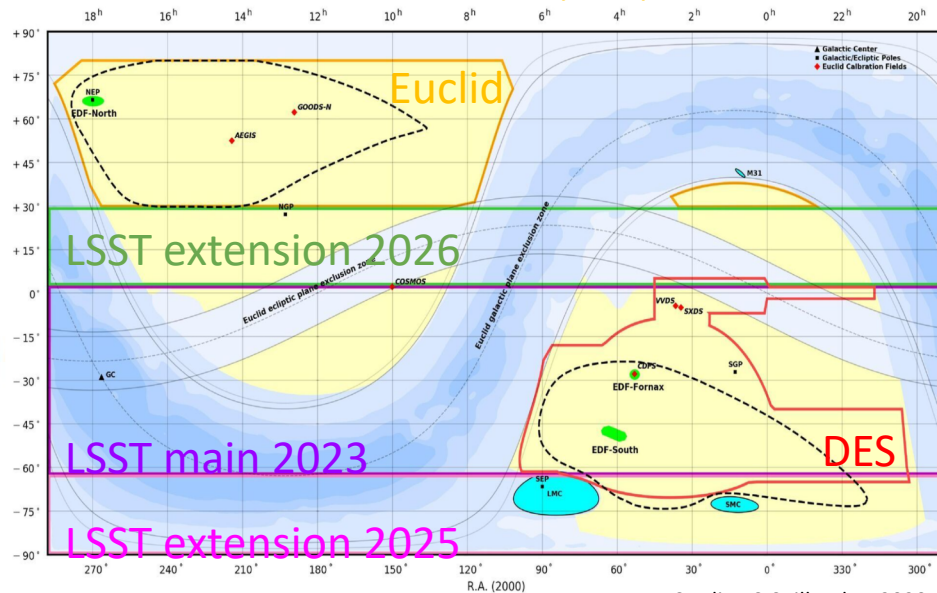Spectroscopic survey footprint

Credit: C Blake, 2019

Photometric survey footprint

Credit: JC Cuillandre, 2020

- DESI 14,000 deg² based on BASS, MzLS, DECaLS, DES imaging
- PFS 1,400 deg² in the 3 HSC footprints
- WEAVE-QSO will observe 400,000 spectra in 6,000 deg² in the SDSS footprint
- GOYA survey will observe high-redshift galaxies behind galaxy clusters
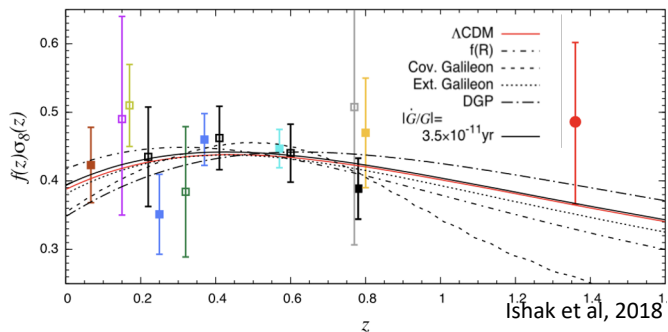
- Euclid will observe 15,000 deg²
- LSST will observe 12,000 deg²

Context: precision cosmology

Ishak et al, 2018
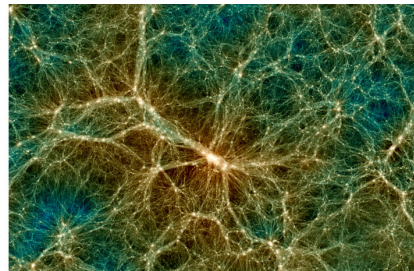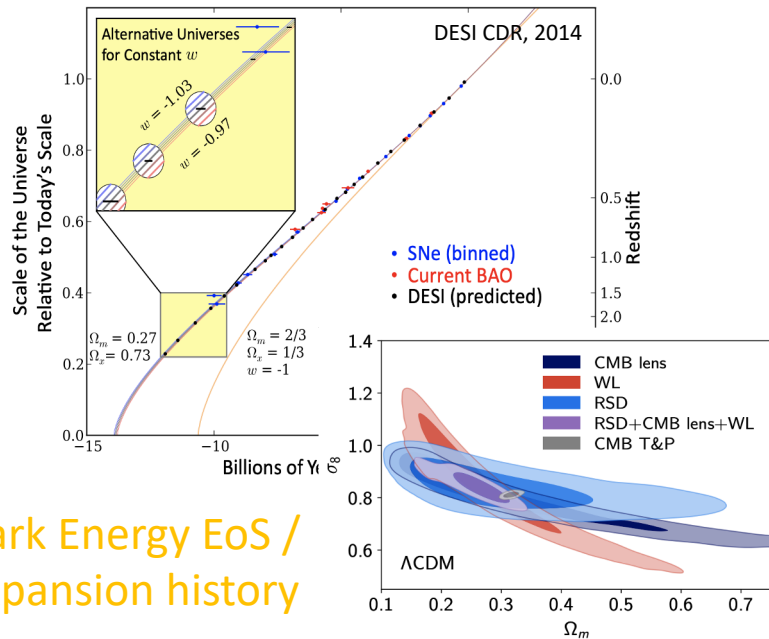

DESI CDR, 2014

Cosmic acceleration

Growth of structure / gravity

Dark Energy EoS / expansion history

Assembly of cosmic web and its constituents

Objectives of the project

Understanding cosmic acceleration (DE, gravity, expansion rate) from multiple cosmological probes and the build-up of the cosmic web

- Precision cosmology
    - Theoretical developments on Dark Energy/modified gravity
    - Development of cosmological simulations
    - Dark Energy and modified gravity constraints from the large-scale structure
    - Dark Energy and expansion history from standard candles/sirens

- Cosmic web mapping and early structure formation
    - First galaxies ($3 < z < 7$)
    - Intergalactic medium tomography ($2 < z < 4$)
    - Late-time evolution of the cosmic web ($0 < z < 2$)

Large surveys roadmap

Surveys	Start [- End]	Surveys	Expected start
eBOSS	2015 - 2019	WEAVE	2022
GOYA/EMIR	2018 - 2023	PFS	2023
DESI	2020 - 2025	Euclid	2023
HSC-CLAUDS	2016 - 2021	LSST	2022

- **eBOSS:** Final cosmological papers published eBOSS collaboration et al. , Press Release July 2020.
- **EMIR**: Technical issues. New detectors planned end of 2021. Survey starting 2022 (degraded mode) and ending in 2023.
- **DESI:** 47h SV observations in Dec 2021 (>50k redshifts). Lensing+clustering+void mock challenge.
- **HSC-CLAUDS:** Data acquired. Analysis on bright and faint galaxy evolution measurements up to z = 3.
- **WEAVE-QSO:** Science observations starting in 2022.
- **PFS:** Integration of 2nd & 3rd spectrographs at LAM. Science observations starting possibly in 2023.
- **Euclid:** NISP & VIS being integrated on spacecraft. Scientific preparatory work & papers on-going.
- **LSST:** 3200 megapixels camera took first image in Sept. 2020. Scientific preparatory work & papers on-going.

Project organisation

- Organisation
  - 3 labs involved: LAM, CPPM, CPT
  - 40 members in 2021
  - Duration: 2020-2024
  - Budget in 2021: 13 k€
  - Wiki page: https://projets.lam.fr/projects/class/wiki

- CLASS meetings
  - CLASS general meeting on Septembre 23, 2021
  - Several team meetings (videoconf.) in 2021
  - Planning of a meeting for the 1st semester 2022
  - Need more regular meetings between CPPM, LAM and CPT
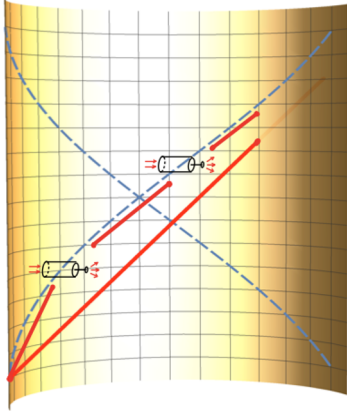
Project recruitments in 2021

New PhD:

- *Martin Kärcher* at LAM/CPT on modified gravity observational constraints (IPhU PhD grant)
- *Basheer Kalbouneh* at CPT on LSS relativistic effects
- *Vincent Duret* at CPPM to work on tomographic BAO with Euclid
- *Tyann Dumerchat* at CPPM on growth rate of structure with DESI and ZTF data
- *Vincenzo Aronica* at CPPM on growth rate of structure with DESI and ZTF data
- *Ilias Goovaerts* at LAM on budget of ionizing sources at 3<z<7

New members:

- *Pauline Vielzeuf*, postdoc at CPPM
- *Elena Sarpa*, postdoc at CPPM (soon)
- *Julian Bautista,* chaire d'Excellence at CPPM
- *Raphaël Gavazzi* moved to LAM in 2021 and joined CLASS

Theoretical developments on cosmological models

Piazza 2021

Cosmological models beyond homogeneity and isotropy

- Theoretical investigation on whether the cosmological principle might be an emergent quantum phenomenon, looking at alternative spacetimes including relevant quantum fluctuations

- The emerging picture is a distance operator analogous to chord distance of an embedded manifold. Cosmological consequences of these findings are on-going.
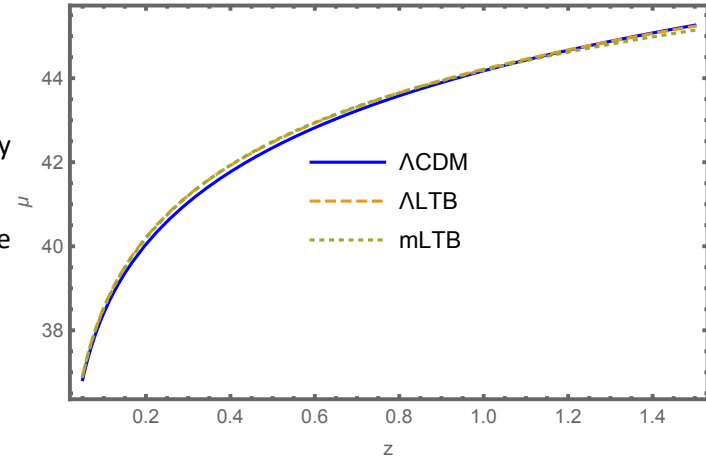
- Study of the viability of Lemaitre-Tolman-Bondi (LTB) spherically symmetric universes and theoretical predictions for redshift and drift

- LTB predicts Hubble diagrams almost indistinguishable from those of the standard cosmological model
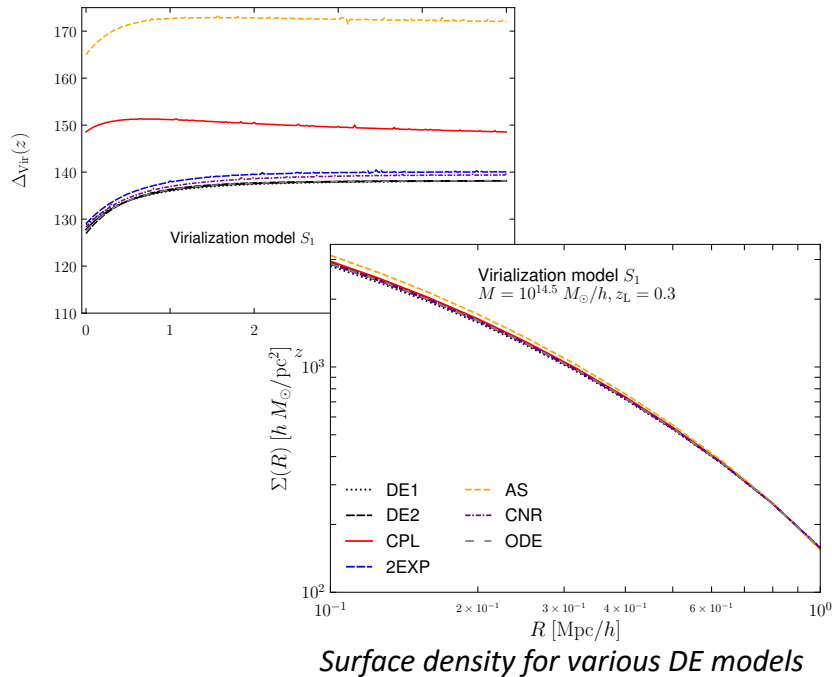
Codur & Marinoni 2021

Hubble diagram

Theoretical developments on cosmology

Cosmological models beyond standard

Spherical overdensity for collapse

Surface density for various DE models
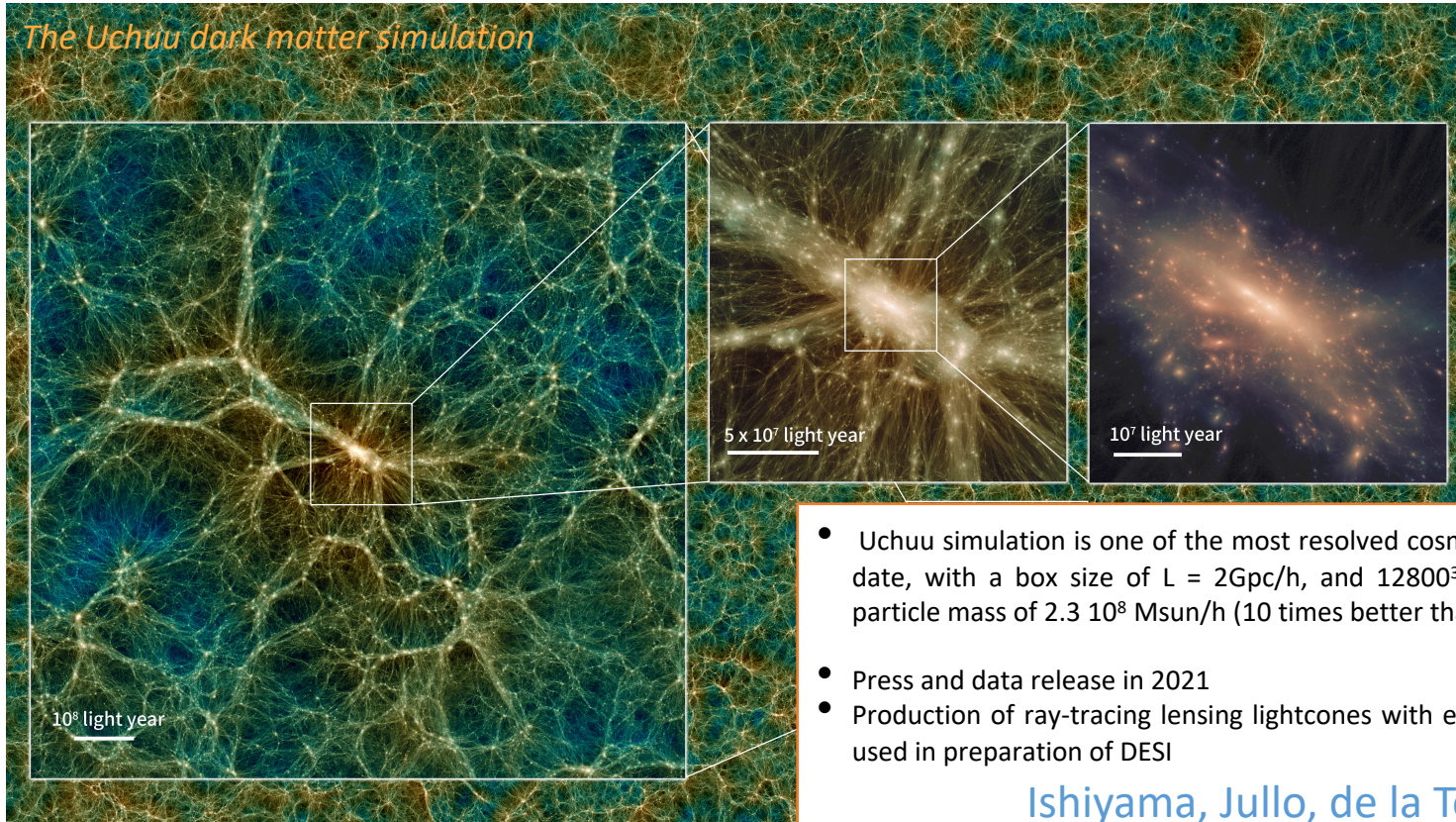
- Extension of the spherical collapse model for seven dynamical dark-energy (DE) models, in which virialization is naturally achieved as an effect of tidal forces (shear and rotation)

- Clustering DE models have quite different collapse properties compared to standard model

- Usable to interpret surface density and SZ peaks counts in surveys

Pace & Schimd 2021

Developments in cosmological simulations

The Uchuu dark matter simulation

5×10^7 light year

10^7 light year

10^8 light year

- Uchuu simulation is one of the most resolved cosmological simulations to date, with a box size of L = 2Gpc/h, and 12800^3 particles leading to a particle mass of 2.3 10^8 Msun/h (10 times better than existing simulations)

- Press and data release in 2021
- Production of ray-tracing lensing lightcones with exquisite accuracy to be used in preparation of DESI

Ishiyama, Jullo, de la Torre et al. 2021
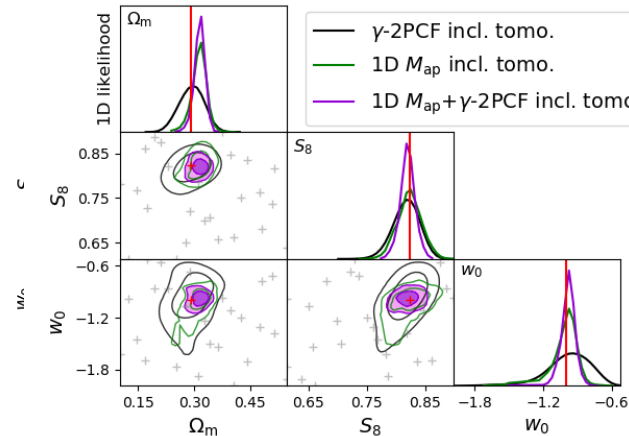
Developments in cosmological simulations

Testing new and complementary lensing observables

Simulated lensing peak statistics
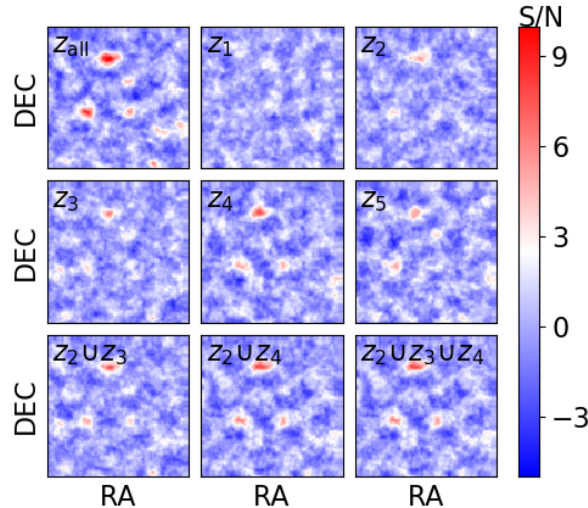
Martinet et al. 2021a,b

- Constraints on cosmological parameters based on peak statistics in WL mass maps in preparation for Euclid.

- Using the SLICS N-body simulations, that they could enhance this precision by an extra 50% on S8 and 66% on the Dark Energy equation of state, using a novel tomographic technique
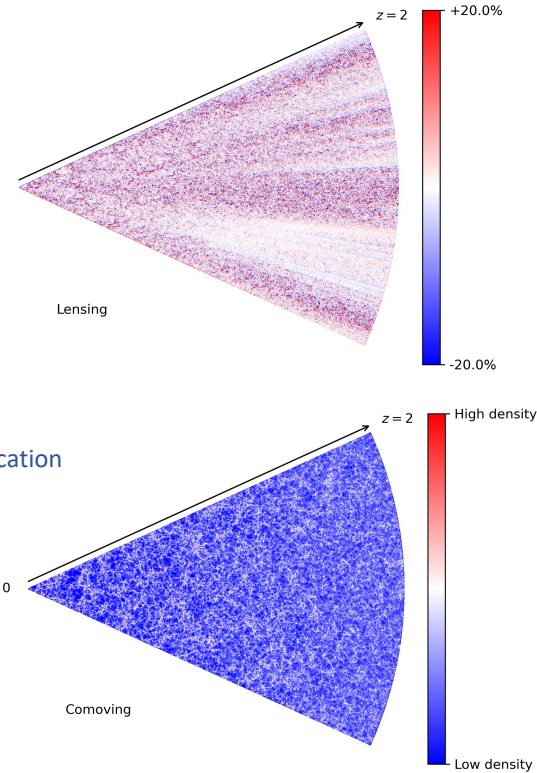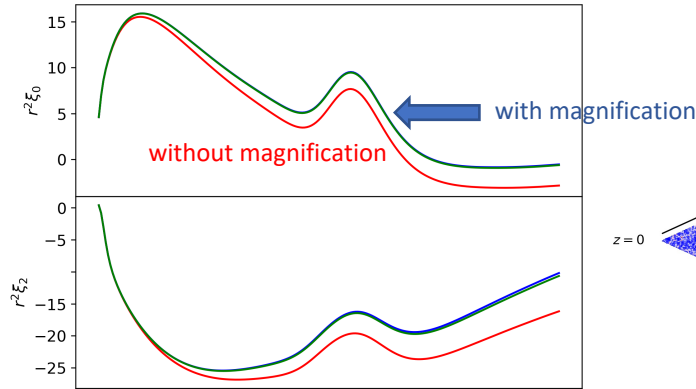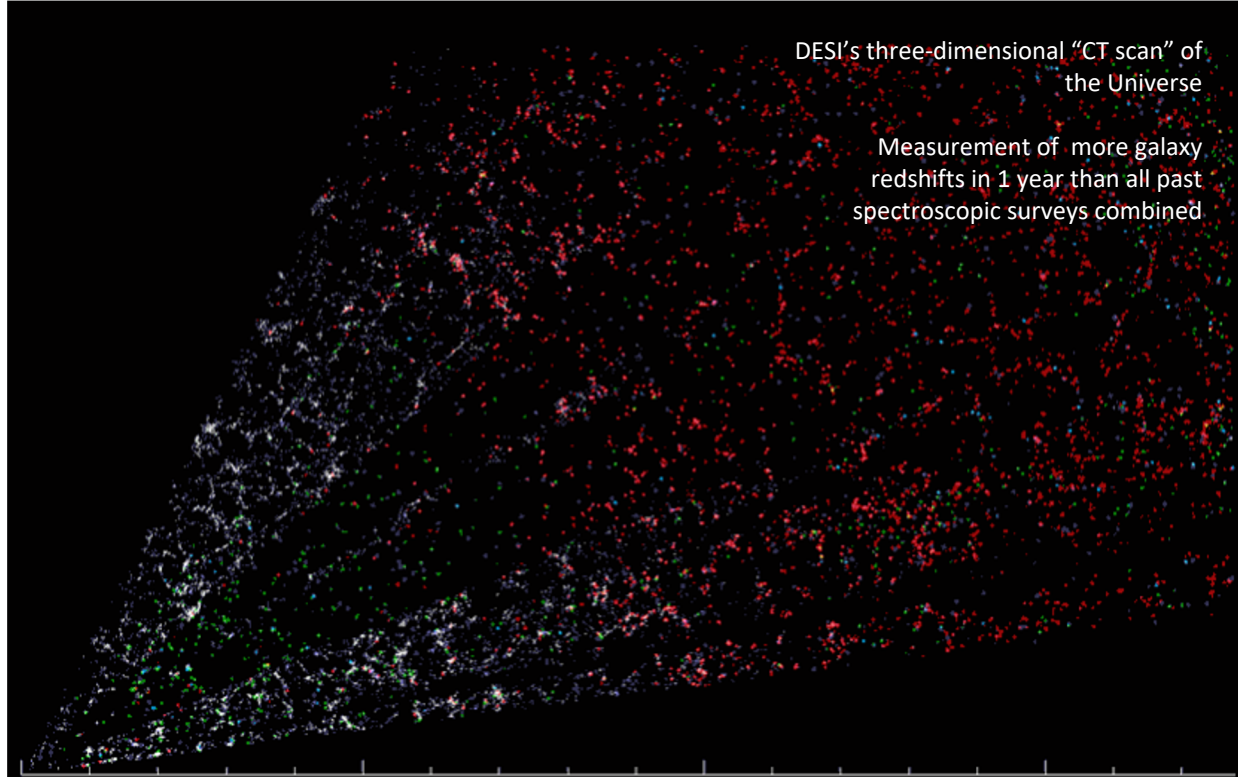
Developments in cosmological simulations

Impact of gravitational lensing on galaxy clustering observables

function correction

the line of sight, $r_\parallel$ and $r_\perp$, using that $r_\parallel$ =

and $r = \sqrt{\chi_1^2 + \chi_2^2 - 2\chi_1\chi_2 \cos\theta}$.

We implement the magnification b

Anisotropic halo correlation function at z = 1.8

n principle derive the lensing cor-
ation bias on the correlation func-
l framework as for RSD. Nonethe-
eyond the scope of the present pa-
a simple correction based on linear
ed on top of any RSD model.

- Reconstruction of the full geodesics between sources and observer in N-body simulations (RayGal sim.)

d galaxy number counts, which ac-
lensing perturbations (the full ex-
e terms at first order in metric per-

- Test the impact of magnification bias on the anisotropic clustering, which ac-

- Magnification bias (usually neglected in observational analyses), can be accounted for at linear level and crucial at z>1.5 for galaxy samples with steep magnitude selection

bo et al. 2009, Challinor & Lewis

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erian linear bias, $\Delta_{rsd} = -\partial_r v_r / \mathcal{H}$

with magnification

without magnification

Our theoretical model for the
function therefore consists in CLPT-GS prediction for non-
linear RSD, and the curved-sky linear theory prediction for
the additional lensing magnification correction. Formally, the
anisotropic correlation function model is given by

Breton, de la Torre 2022

Cosmological constraints from the large-scale structure

DESI's three-dimensional "CT scan" of the Universe

Measurement of more galaxy redshifts in 1 year than all past spectroscopic surveys combined

- Press release in 2021: first observations

- Involvement in the lensing mock challenge organised within the C3 working group of the DESI collaboration

- Assessment of the sensibility of lensing observables (such as voids lensing) given the DESI and lensing data at hand (KiDS, DES and HSC).

DESI first observations & prospects

R. Boschetti, E. Jullo, M.-C. Cousinou, S. Escoffier

Cosmological constraints from the large-scale structure

Cosmic voids cosmology

- Final redshift-space distortions analysis around voids in eBOSS, using the three main eBOSS targets from z=0.6 to z=2.2
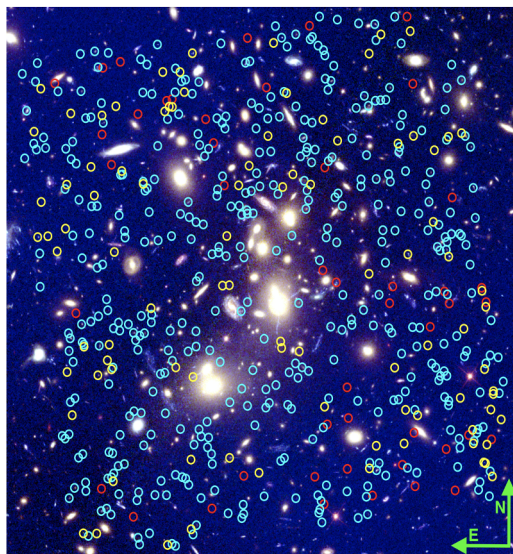- Forecast havent been conducted on simulated Euclid data using the Flagship simulation

Growth rate of structure constraints

Euclid forecast
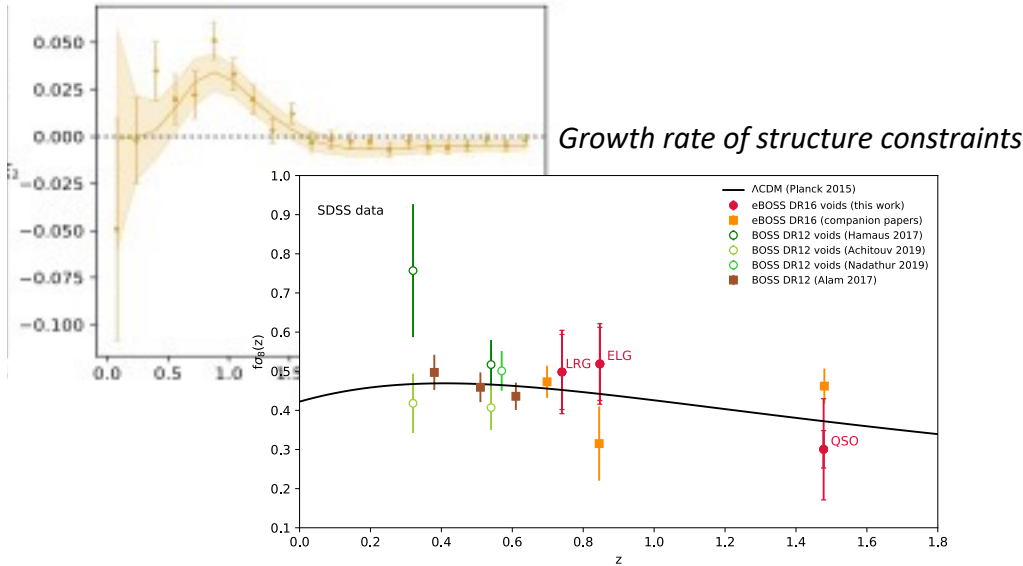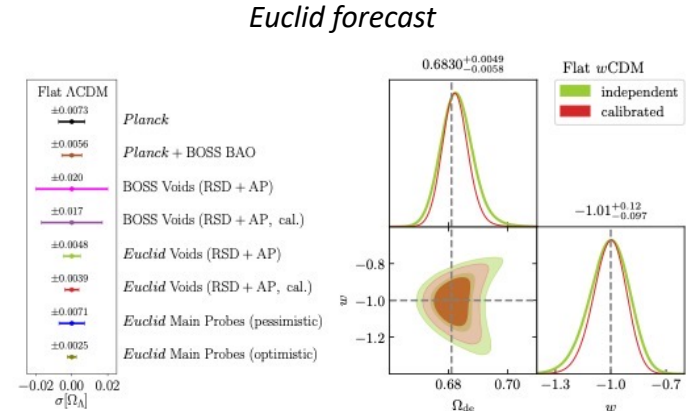
Aubert et al. 2021

Hamaus, Aubert et al. 2022

From first galaxies to late-time cosmic web

LBG + LAE   LBG only   LAE only

I. Goovearts, R. Pello

- Blind selection of Lyα Emitters (LAE) at 2.9 < z < 6.7 with **MUSE/VLT** behind A2744 Complete census of Star Forming galaxies at the epoch of the reionization

- New developments initiated on estimating the total budget of ionizing sources at 3<z<7 detected behind lensing clusters, based also on the full sample of lensing clusters

- GOYA project (Galaxy Origins and Young Assembly) with EMIR: a multi-object NIR spectrograph mounted on the 10m telescope GTC (Canary Islands). GTO observations delayed, possibly starting in 2022

From first galaxies to late-time cosmic web

Cosmic web reconstruction and IGM tomography

- WEAVE-QSO projections and simulations on cosmic web and IGM reconstruction using Ly-Ha forest

- To be extended to PFS IGM tomography covering a smaller field but with much higher spectroscopic sampling leading to a high resolution HI gas mapping (resolution ~ 3-4 Mpc).

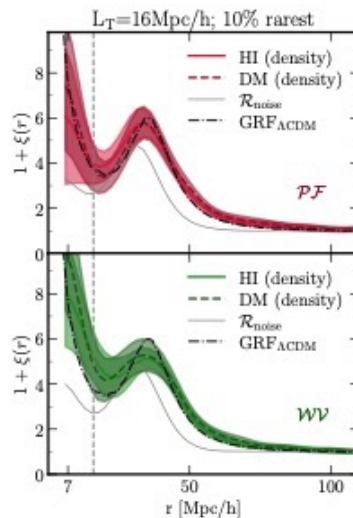*Cross-corr. Ly-Ha dark matter*
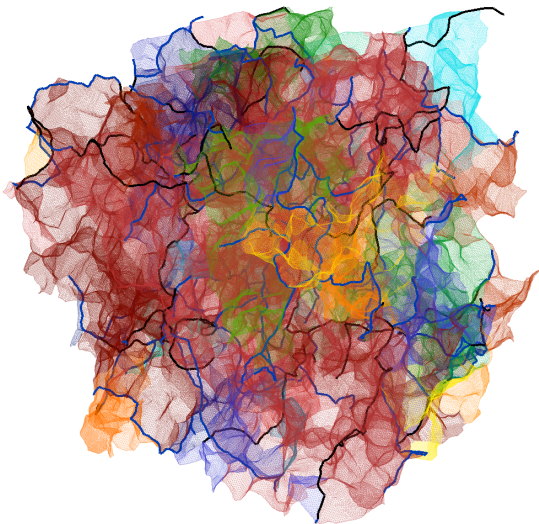
Cosmic web reconstruction
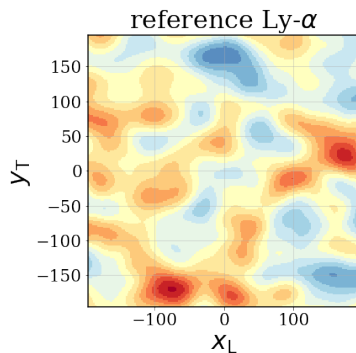
Simulated Ly-Ha fields for WEAVE

Kraljic, Arnouts, Pieri et al. 2022

Summary

- Significant activity within in CLASS in 2021

- We acknowledge the financial support from OCEVU and IPhU

- Delays in the start of several cosmological surveys, observational activities are more focused on preparatory work related to improvement of methods or theory

- Soon we will have new data, many systematic errors and new physical effects must be studied taken into account

- DESI observations have started at high rate, very exciting prospects

- Cosmic web mapping has a growing impact on cosmological studies and has grown in importance also in CLASS