PhD thesis project, 2022 – 2025

Cross-correlating Euclid and DESI to probe the dark-matter – baryon connection in the cosmic web using weak gravitational lensing

Context

Weak gravitational lensing, the distortion of the images of high-redshift galaxies due to foreground matter structures on large scales, is one of the most promising tools of cosmology to Universe map the dark-matter distribution in the Universe [1]. By combining weak lensing observations with foreground galaxy samples, we can measure the connection between dark matter and baryonic mass in galaxies. This allows us to help understand how galaxies form and evolve in dark-matter halos.

The **lensing - galaxy cross-correlation** is one of the blocks in modern cosmological analysis of galaxy surveys, adding to weak lensing and galaxy clustering. This cross-correlation significantly improve cosmological parameters constraints compared to lensing and clustering alone [2]. Further, it is a major ingredient to test a variety of models of modified gravity, in which photons from weak lensing and galaxies experience different gravitational potentials. Finally, it allows to measure two of the most important astrophysical uncertainties in cosmology: the intrinsic alignments of galaxies [3], and galaxy bias [4], which are major sources of systematic error for weak gravitational lensing and galaxy clustering, respectively. Both of these effects are related to to date poorly understood interplay of dark and baryonic matter on cosmological scales.

In addition, galaxy-galaxy lensing provides a novel point of view to the clustering amplitude tension between the CMB and weak lensing [5].

The European satellite mission **Euclid**, to be launched end of 2022, will observe 150 billion galaxies over a large fraction of the sky in optical and infrared wavelengths, to map large-scale structures and weak-lensing distortions out to high redshifts. The round-based telescope **DESI**[1] (Dark Energy Spectroscopic Instrument), with first light in 2019, will take spectra of 30 million galaxies over the next 5 years, to provide spectroscopic redshifts of galaxies over a large range of cosmic epoch. The combination of those two surveys provides a unique data set to measure lensing - galaxy correlations at unprecedented accuracy.

The PhD project

The goal of this PhD thesis is to measure cross-correlations between weak lensing and galaxies, using the Euclid and DESI surveys. In preparation, existing weak-lensing data will be used from **Ultraviolet Near-Infrared Optical Northern Sky (UNIONS)**[2], an ongoing large imaging survey to cover $5,000$ deg^2 in the Northern sky in multiple optical bands. Lensing distortions of

[1] https://www.desi.lbl.gov

[2] https://www.cosmostat.org/projects/unions-cfis

galaxies on $3,600$ deg^2 area have been measured by CosmoStat under the lead of Martin Kilbinger. This existing weak-lensing data can be cross-correlated with BOSS/eBOSS spectroscopic data.

The main objectives of this PhD are:

1. Get familiar with weak-lensing and cross-correlation analyses and data sets.
2. Analyse existing data from UNIONS and (e)BOSS/DESI, and measure the cross-correlation between both surveys. Obtain first results on intrinsic alignments and galaxy bias as function of redshift and galaxy type.
3. Further develop these methods for next-generation data from Euclid and DESI. Obtain constraints on intrinsic alignment and galaxy bias at high redshift.

These objectives are aimed towards an optimal cosmological exploitation of galaxy surveys. A better understanding of the dark-matter – baryon connection will not only help to improve cosmological analyses, but also deepen our knowledge of how galaxies formed in their dark-matter envioronments in the early Universe.

Data access
Kilbinger and Pettorino are members of Euclid and UNIONS, IRFU is full member of DESI, and BOSS/eBOSS data is public. The student will have full access to all data required in this project.

Scientific environment
The thesis will be carried out in the CosmoStat[3] laboratory at the Département d'Astrophysique[4] (DAp) at CEA Saclay, under the supervision of Martin Kilbinger and Valeria Pettorino. CosmoStat hosts a multidisciplinary team whose research includes statistics, signal processing, machine learning, and cosmology. CosmoStat members are leading the weak-lensing analysis of UNIONS/CFIS. The group is strongly involved in the scientific preparation of Euclid. Martin Kilbinger is co-lead of the Weak Lensing Science Working Group of Euclid. Valeria Pettorino is lead of the combined-probe likelihood analysis of Euclid data.

Requirements
The candidate should have a Master 2 (or equivalent) degree in physics/astrophysics, applied mathematics/signal processing/data science, or a related field. Experience with python is not required, but would be advantageous.

The application deadline is 15/04/2022.

Contact
Martin Kilbinger `martin.kilbinger@cea.fr`
Valeria Pettorino, `valeria.pettorino@cea.fr`
CEA Paris-Saclay/Irfu/Dap, Laboratoire AIM
Orme des Merisiers, Bât 709, office 280
F-91191 Gif-sur-Yvette

[3] `http://www.cosmostat.org`
[4] `http://irfu.cea.fr/Sap/`

References

[1] Kilbinger, M., *Reports on Progress in Physics*, 78(8):086901, 2015.

[2] Tutusaus, I., Martinelli, M., Cardone, V. F., et al., *A&A*, 643:A70, 2020.

[3] Blazek, J., Mandelbaum, R., Seljak, U., & Nakajima, R., *JCAP*, 5:41, 2012.

[4] Prat, J., Sánchez, C., Miquel, R., et al., *Monthly Notices of the Royal Astronomical Society*, 473(2):1667–1684, 2017.

[5] Leauthaud, A., Saito, S., Hilbert, S., et al., *MNRAS*, 467:3024–3047, 2017.