Stage M2, 2024

Intrinsic galaxy alignments: Probing galaxy formation and cosmology.

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 probe the dark sector of the Universe [1]. The statistical analysis of lensing distortions can measure the dark-matter distribution on large scales, constrains the properties of dark matter and dark energy, and limit models of modified gravity.

The upcoming surveys Euclid, Rubin/LSST, and the Roman space telescope will measure cosmological parameters to unprecedented accuracy [2]. To achieve this ambitious goal, a number of systematic behaviours have to be properly understood. One key challenge is a detailed understanding of *intrinsic galaxy alignment*. This systematic effect stems from the coherent deformation of galaxies by the tidal fields in which they form and evolve. Intrinsic alignment can produce correlations that are degenerate with those coming from the lensing of the light profile and, therefore, might bias the cosmological parameter estimation if not properly accounted for during the analysis phase.

This internship

The goal of this M2 stage is to obtain a direct measurement of intrinsic galaxy alignment using the combination of lensing and spectroscopic data. The student will build a pipeline that computes and models the monopole and quadrupole correlation functions, inspired by methods used for galaxy clustering. The codes developed in this internship will be tested on existing ground-based weak-lensing data available in the CosmoStat lab.

Today, different models exist to describe the contribution of intrinsic alignment in a weak-lensing analysis. To understand which of these models offers the most accurate prediction, one needs to directly measure intrinsic-alignment properties. This is achieved by correlating galaxies whose distances are very precisely known from spectroscopic data.

We will use weak-lensing data from UNIONS, the Ultra-violet Near-Infrared Northern Survey, and spectroscopic data from BOSS and eBOSS (SDSS-III's [extended] Baryon Oscillation Spectroscopic Survey), and DESI (Dark-Energy Spectroscopic Instrument).

Outline of the project

The tasks and objectives of the internship are as follows.

1. Get familiar with spectroscopic and weak-lensing data, as well as intrinsic-alignment models.
2. Run existing correlation function codes.
3. Develop the pipeline for measurement using the monopole and quadrupole components of the intrinsic-alignment correlation functions.
4. Apply the pipeline on data and constrain intrisic-alignement models.

Methods

During this internship, the student will work on statistical analysis of weak-lensing data, and the cross-correlation of different galaxy catalogues. They will learn how to analyse very large galaxy catalogues in a High-Performance Computation (HPC) environment. They will use Bayesian sampling methods such as MCMC for parameter inference.

Scientific environment

The stage will be carried out in the CosmoStat laboratory at the Département d'Astrophysique at CEA Saclay, under the supervision of Martin Kilbinger and Fabian Hervas Peters. CosmoStat hosts a multidisciplinary team whose research includes statistics, signal processing, machine learning, and cosmology. The group is strongly involved in the weak-lensing analysis of the upcoming mission Euclid.

Requirements

The candidate should be a master 2 (or equivalent) student with a background in either physics/astrophysics or applied mathematics/signal processing/data science. Experience with python is not required, but would be advantageous.

The application deadline is 15/12/2023. The duration of the internship is 4 – 6 months. This internship work can potentially be continued as a PhD in our group.

Contact

Fabian Hervas Peters
`fabian.hervaspeters@cea.fr`
Martin Kilbinger
`martin.kilbinger@cea.fr`

CEA/Irfu/Dap, Laboratoire AIM
Orme des Merisiers, Bât 709
F-91191 Gif-sur-Yvette

References

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

[2] Euclid Collaboration, Blanchard, A., Camera, S., et al., *A&A*, 642:A191, 2020.