Stage M2, 2022/2023

Weak gravitational lensing statistics for the Euclid space mission

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, constrain the properties of dark matter and dark energy, and limit models of modified gravity.

The upcoming European space mission Euclid will measure cosmological parameters to unprecedented accuracy [2]. To achieve this ambitious goal, Euclid will measure the shapes of 1.5 billion high-redshift galaxies, and compute their spatial correlations. To carry out these very large number of correlations is challenging, and dedicated algorithms are being developed in our group. These correlation statistics are the base data ingredients to the Euclid likelihood, which is evaluated and sampled to obtain constraints on cosmological parameters.

This internship

The goal of this M2 stage is to validate the correlation algorithms using dedicated Euclid simulations. The output will then be interfaced to the Euclid likelihood modules to infer cosmological parameters. The codes developed in this internship will be tested on existing ground-based weak-lensing data available in the CosmoStat lab.

The Euclid simulations contain realistic effects based on the expected performance of galaxy shape measurement, the Euclid point spread function (PSF), CCD degradations by cosmic rays and more. Astrophysical systematics are included such as correlations between galaxy shapes and the tidal field of their dark-matter halos (intrinsic galaxy alignment). The student will assess the influence of those different effects on the weak-lensing correlations.

The interface between the correlation output data and the likelihood is a crucial part in the Euclid pipeline. The student will help to develop tools to manipulate this output, perform sanity checks, and transform the data into a suitable format for further processing.

The output on simulated Euclid data will be used by the student to test the proper functioning of the likelihood modules. Cosmological parameter inference can be performed to assess whether the simulated input model can be recovered.

Outline of the project

The tasks and objectives of the internship are as follows.

1. Get familiar with the second-order weak-lensing statistics that will be computed for Euclid, together with their covariance matrices as error estimates.

2. Run correlation function codes on Euclid simulations. Test and validate the results, and assess the impact of various systematic effects.

3. Develop missing part of the interface between Euclid weak-lensing output and

the likelihood module. Test and validate this interface.

4. (Optional, if time permits:) Perform cosmological parameter analysis of Euclid simulation and compare with input parameters. Run codes on existing weak-lensing data.

Methods

During the stage, the student will work on statistical analysis of weak-lensing data, in particular correlation functions of weak-lensing galaxy shapes. They will learn how to handle very large catalogues.

Code development will be done using object-oriented programming in the python language. The student will use collaboration and code quality methods such as version control, code review, unit testing, and continuous integration/continuous delivery (CI/CD).

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. 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 15/12/2022. The duration of the internship is 4 – 6 months. This internship work can potentially be continued as a PhD in our group.

Contact

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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.