PhD position, 2024

Machine-learning methods for the cosmological analysis of weak-gravitational lensing images from the ESA satellite Euclid

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 reveal the dark-matter distribution on large scales, constrain the properties of dark matter and dark energy, and limit models of modified gravity.

The European space satellite Euclid, and upcoming experiments such as Rubin/LSST [2] and the Roman space telescope [3] will measure cosmological parameters to unprecedented accuracy [4]. To achieve this ambitious goal, a number of sources of systematic errors have to be quantified and understood. One of the main origins of bias is related to the detection of galaxies. The probability of detecting a galaxy depends on many parameters, such as its luminosity, signal-to-noise ratio, galaxy type, colour, and more. In addition, there is a strong dependence on local number density and whether the galaxy's light emission overlaps with nearby objects. If not handled correctly, such "blended" galaxies will strongly bias any subsequent measurement of weak-lensing image distortions.

This PhD thesis

The goal of this PhD is to quantify and correct weak-lensing detection biases, in particular due to blending. To that end, modern machine- and deep-learning algorithms, including auto-differentiation techniques, will be used. Those techniques allow for a very efficient estimation of the sensitivity of biases to galaxy and survey properties without the need to create a vast number of simulations. The student can start with deep-learning methods already developed in our group [5]. State-of-the-art calibration methods will be employed, such as metacalibration and metadetection, allowing the debiasing of weak-lensing distortions directly from the data. In the context of Euclid, with very high space-based resolution, undersampled images, and a complex point spread function (PSF), those techniques need to be further developed and tested. The student will create auto-differentiable image simulations to validate those methods to ensure they provide measurements of weak-lensing distortions at very high precision. Very deep and high-resolution data available on Euclid fields from the Euclid Deep Survey, HST, and JWST will help in training and calibrating the developed algorithms to detect, remove, and calibrate blended images.

Outline of the project

The tasks and objectives of the internship are as follows.

1. Get familiar with weak-lensing imaging data, the analysis of those data, and calibration methods.
2. Set up Euclid-like image simulations with auto-differentiation ability. Ap-

ply state-of-the art calibration and (de-)blending algorithms to simulations.

3. Identify where these methods need to be improved or replaced to reach the required precision on weak-lensing distortion measurements from Euclid. Further develop calibration methods that do not fulfil Euclid requirements.

4. Apply calibration and de-blending methods to Euclid data. Compare the results of the distortion calibration developed here with previous methods. Implement the method in the Euclid science analysis.

Methods

During this internship, the student will perform statistical analysis of weak-lensing data. For this purpose, they will develop and use state-of-the-art machine-learning methods. They will learn how to analyse image and catalogue data on GPUs and in a High-Performance Computation (HPC) environment.

Scientific environment

The PhD will be carried out in the CosmoStat laboratory at the Département d'Astrophysique at CEA Saclay, under the supervision of Martin Kilbinger and Samuel Farrens. 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 space mission Euclid.

Requirements

The candidate should have a master 2 (or equivalent) degree 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 10/04/2024. The starting date is October 2024.

Contact

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References

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