Stage M2, 2025

Field-level inference of weak lensing map statistics in the Ultraviolet Near Infrared Optical Northern Survey (UNIONS)

Context

Weak gravitational lensing, the deflection of light by the large-scale structures of the cosmic web, has proven to be a powerful probe to constrain cosmological parameters describing the dark-matter structure formation and the expansion history of the Universe (1). Recent work introduced elaborated statistics to extract information beyond the power spectrum from the shear field to provide tight constraints on cosmological parameters. Usually lacking theoretical predictions, those statistics mostly rely on numerical simulations. Advances in deep learning and generative models now allows us to exploit those simulations to perform the inference (2).

This internship

UNIONS is a photometric survey that targets around $5,000$ deg^2 of the Northern sky. Carrying out a simulation-based analysis of UNIONS weak lensing data is of interest to compare with other surveys, such as DES (3; 4) or KiDS (5)), and to prepare the data processing of the European space mission Euclid. The goal of the internship is to set up a pipeline to perform full-field inference of UNIONS.

Outline of the project

The tasks and objectives of the internship are as follows.

1. Get familiar with weak lensing, its estimators, and simulation-based inference (SBI).
2. Build a pipeline to perform the full-field inference using convolutional neural networks (CNNs).
3. Validate the pipeline on UNIONS-like mock data.
4. If time allows, apply the pipeline on the weak-lensing catalog from UNIONS.

Methods

The methods used to perform this analysis are the following:

- Forward modeling/N-body simulations.
- Neural compression/Neural density estimation
- Validation statistics

Scientific environment

The stage will be carried out in the CosmoStat laboratory at the Département d'Astrophysique at CEA Saclay, under the supervision of Sacha Guerrini and 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 15/12/2024. The duration of the internship is 4 – 6 months. This internship work can potentially be continued as a PhD in our group.

Contact

Sacha Guerrini
sacha.guerrini@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*, 78:086901, 2015.

[2] Lueckmann, J.-M., Boelts, J., Greenberg, D. S., Gonçalves, P. J., & Macke, J. H. Benchmarking Simulation-Based Inference, 2021.

[3] Jeffrey, N., Whiteway, L., Gatti, M., et al. Dark Energy Survey Year 3 Results: Likelihood-Free, Simulation-Based wCDM Inference with Neural Compression of Weak-Lensing Map Statistics, 2024.

[4] Gatti, M., Campailla, G., Jeffrey, N., et al. Dark Energy Survey Year 3 Results: Simulation-Based Cosmological Inference with Wavelet Harmonics, Scattering Transforms, and Moments of Weak Lensing Mass Maps II. Cosmological Results, 2024.

[5] von Wietersheim-Kramsta, M., Lin, K., Tessore, N., et al. KiDS-SBI: Simulation-Based Inference Analysis of KiDS-1000 Cosmic Shear, 2024.