

Unbiased Shear Estimation for Euclid with Automatically Differentiable and GPU Accelerated Modeling

PhD Position

Laboratory: [CEA Paris-Saclay/IRFU/AIM/CosmoStat](#)

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Context

Weak gravitational lensing, the apparent distortion of the shapes of galaxies caused by matter along the line of sight, is a powerful method for probing the nature of dark matter, dark energy, and gravity. Following the launch of the Euclid satellite in 2023, we are entering a new era of precision cosmology. The instruments onboard Euclid have been designed to measure weak-lensing signals across a large fraction of the sky to unprecedented levels. The success of this mission, however, is predicated on the ability to measure the degree to which galaxy images are distorted — an anisotropic distortion called shear.

Traditionally, and as is currently implemented within the Euclid pipeline, the shear field is probed by measuring the shapes of galaxy images and examining how these shapes are correlated on different scales. However, all shape-estimation methods introduce a bias into the measurement of shear, as the modelling does not account for the full morphological diversity of galaxies in the Universe. While significant effort has been invested in recent years in methods to calibrate for this bias, another approach would be to investigate unbiased estimators of shear.

One such technique, pioneered within the CosmoStat team (Rémy et al. 2022; Centofanti et al., in prep.; Ayçoberry et al., in prep.), has been to build a forward model of the problem in order to directly infer the shear field. This involves simulating galaxy images using state-of-the-art deep-learning architectures, applying a known shear, and comparing the results with real observations. This forward-modelling approach has demonstrated very compelling results on simulated data.

PhD Subject

The successful PhD applicant will work on extending this forward-modelling framework to real Euclid data. This will involve updating the pipeline to account for the full complexity of the Euclid Science Ground Segment (SGS) and ensuring the robust scalability of the technique to handle $\sim 14\,000\text{ deg}^2$ of sky. The student will be able to build upon existing efforts within the Euclid Consortium to develop forward-modelling tools, as well as to directly compare with the shape-measurement methods implemented within the SGS.

This topic is particularly well timed with the first public release of Euclid data expected in October 2026. This will provide the student with an active and dynamic environment of researchers aiming to quantify the impact of measured shear bias on cosmological parameter inference. Any advancement towards a truly unbiased shear estimate could therefore have a significant impact on the field.

Objectives

The objectives of this PhD will be to:

1. Become familiar with the state of the art in shear estimation and the Euclid SGS
2. Understand and contribute to the forward-modelling pipelines developed within the CosmoStat team and the Euclid Consortium
3. Update the pipeline to handle the full complexity of Euclid data
4. Develop novel multi-GPU and HPC implementations to scale the approach to the full Euclid area

Scientific Environment

The PhD will be carried out in the CosmoStat laboratory at the Département d'Astrophysique (DAP-AIM) at CEA Paris-Saclay, under the supervision of Dr. Samuel Farrens and Dr. François Lanusse. 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 Euclid space mission.

Candidate

The candidate should hold a Master's degree in either physics / astrophysics or applied mathematics / signal processing / data science. Experience with Python and Git is not required but would be advantageous.

Applicants should send a CV and a summary of past research (max. 2 pages) to Dr Samuel Farrens and Dr. François Lanusse before the application deadline. In addition, applicants should arrange for a reference letter (ideally from the Master's project supervisor) to be submitted directly to Dr Farrens.

Applicants should be aware that selection may occur prior to the deadline; early submission is strongly encouraged.

References

- Remy, Benjamin ; Lanusse, Francois ; Starck, Jean-Luc, 2022 - Towards solving model bias in cosmic shear forward modeling (<https://arxiv.org/abs/2210.16243>)