Stage M2, 2021/2022

Weak gravitational lensing and intrinsic galaxy alignments with the Ultraviolet Near-Infrared Optical Northern Sky (UNIONS) survey

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 provide important constraints on the dark-matter distribution on large scales, and the nature of dark energy. However, systematic errors need to be carefully assessd and quantified for reliable cosmological inference of weak-lensing data for cosmology. One astrophysical contamination is the intrinsic alignments of galaxies. This denotes the shape alignment of galaxies with their surrounding dark-matter structures due to tidal stretching. If unaccounted for, these alignments will be mistaken for shape correlations due to weak gravitational lensing [2, 3].

The goal of this M2 stage is to carry out statistical analyses of weak-lensing data from the Ultraviolet Near-Infrared Optical Northern Sky (UNIONS[1]). UNIONS is an ongoing large imaging survey in multiple optical bands that will soon cover $5,000$ deg^2 in the Northern sky. The student will compute the galaxy shape correlations. By selecting galaxy samples with different properties such as color, type, and redshift range, the contribution of weak lensing and intrinsic alignment to those shape correlations can be modulated. The measurements will be compared to existing theoretical predictions, from non-linear models of the large-scale structure, and from numerical simulations produced in our group.

The measurement of intrinsic alignment can be boosted by using spectrosopic galaxies on the same sky area as UNIONS, from the (Extended) Baryon Oscillation Spectroscopic Survey (BOSS/eBOSS). The cross-correlation function of weak-lensing background with foreground galaxy populations can be constructed to measure intrinsic alignment around BOSS/eBOSS galaxies.

This work will contribute to assess the importance of the intrinsic alignments for current and future surveys such as the space-based satellite mission Euclid[2], and the ground-based Large Survey of Space and Time (LSST[3]) of the Vera C. Rubin Observatory (VRO).

Outline of the project

The tasks and objectives of the internship are as follows.

1. Get familiar with data and measurement techniques for weak-lensing data and intrinsic alignments, including as galaxy shape measurement, PSF correction, calibration, and cross-correlations.

[1] https://www.cosmostat.org/projects/unions-cfis
[2] `http://sci.esa.int/euclid`
[3] `https://www.lsst.org/`

2. Compute shape correlations of galaxies from UNIONS data, including cross-correlations with BOSS and eBOSS.

3. Compare to theoretical predictions.

4. Estimate the importance of intrinsic alignments for weak-lensing surveys, as function of galaxy properties.

Methods

During the stage, the student will analyse optical wide-field images, measure and calibrate galaxy shapes, and compute statistical quantities such as correlation functions, as well as cross-correlations between different data set. The student will apply theoretical and simulation-based models of the large-scale structure in the Universe, and carry out comparisons with measurements.

Scientific environment

The stage will be carried out in the CosmoStat[4] laboratory at the Département d'Astrophysique[5] (DAp) at CEA Saclay, under the supervision of Martin Kilbinger and François Lanusse. CosmoStat hosts a multidisciplinary team whose research includes statistics, signal processing, machine learning, and cosmology. CosmoStat members are working on the weak-lensing analysis of UNIONS/CFIS. The group is also strongly involved in the upcoming mission Euclid, as well as LSST.

Requirements

The candidate should be a Master 2 (or equivalent) student with 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 15/12/2021. 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] Joachimi, B., Cacciato, M., Kitching, T. D., et al., *Space Sci. Rev.*, 193:1–65, 2015.

[3] Fortuna, M. C., Hoekstra, H., Johnston, H., et al., 2021, arXiv:2109.02556.

[4] `http://www.cosmostat.org`
[5] `http://irfu.cea.fr/Sap/`