Stage M2, 2020/2021

Cosmological analysis of weak gravitational lensing 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 these lensing distortions can provide important constraints on the dark-matter distribution on large scales, and the nature of dark energy. In addition, the cross-correlation of lensing data with foreground galaxies contains additional cosmological information, and measures the relation between dark and luminous matter.

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], an ongoing large imaging survey that will cover $5,000$ deg^2 in the Northern sky in multiple optical bands. Lensing distortions of galaxies on around half of that area, to date, have been measured in our group. The student will first compute the weak-lensing correlation function, or power spectrum, and the corresponding covariance matrix. Using existing non-linear models of the large-scale structure and lensing quantities, a likelihood function will be defned and implemented. From that, the student will obtain constraints on cosmological parameters via Monte-Carlo sampling.

In addition, using spectrosopic galaxy redshifts 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. This cross-correlation can be added to the weak-lensing likelihood analysis to improve constraints on cosmological parameters.

Outline of the project

The tasks and objectives of the internship are as follows.

1. Get familiar with weak-lensing analysis concepts, such as the weak-lensing shear correlation function, its covariance, and likelihood inference of cosmological parameters.
2. Compute the above-mentioned quantities from UNIONS weak-lensing data.
3. Using models of the large-scale structure, obtain constraints on cosmological parameters such as the matter density $\Omega_{\rm m}$ and the power-spectrum normalisation σ_8.
4. If time permits, data from the spectroscopic redshift surveys BOSS and eBOSS will be cross-correlated with UNIONS weak-lensing data.

[1] https://www.cosmostat.org/projects/unions-cfis

Methods
During the stage, the student will compute statistical quantities such as correlation functions, power spectra, their covariance matrices, as well as cross-correlations between different data set. Using those quantities, the student will use state-of-the-art Monte-Carlo sampling methods to carry out Bayesian parameter inference.

Scientific environment
The stage will be carried out in the CosmoStat[2] laboratory at the Département d'Astrophysique[3] (DAp) at CEA Saclay, under the supervision of Martin Kilbinger. 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[4] (launch in 2022), the weak-lensing data processing and likelihood analysis of Euclid data.

This internship work can potentially be continued as a PhD in our group.

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 15/12/2020. The duration of the internship is 4 – 6 months.

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References
[1] Kilbinger, M., *Reports on Progress in Physics*, 78(8):086901, 2015.

[2] `http://www.cosmostat.org`
[3] `http://irfu.cea.fr/Sap/`
[4] `http://sci.esa.int/euclid`