Stage M2, 2018

Weak gravitational lensing: shear measurement and calibration in CFIS data

Cosmology, galaxy surveys and weak lensing

Galaxy surveys allow us to study the nature of the Universe and its evolution from the statistics of the galaxy and matter distributions. One of the most important techniques for cosmological analyses in modern surveys is weak gravitational lensing, which allows us to measure the total mass distribution (including dark matter) of the Universe from galaxy images [3]. The trajectory of light is affected by the gravitational potentials coming from mass fluctuations. Then, by studying the distortions on galaxy images we can infer the total mass fluctuations in the Universe. Weak cosmological lensing has been used to constrain cosmological parameters such as the matter density $\Omega_{\rm m}$, the dark-energy equation of state w, and has put limits on modifications of general relativity.

Shear measurement and calibration

The quality of weak lensing measurements in observations depends on the accuracy of the ellipticity estimation of the galaxy images and its correct calibration. There are many systematics that make this measurement challenging, such as atmospheric effects, pixelization, noise, model bias from the ellipticity estimators, etc. [1] These systematics cause biases in the final shear estimation that can be addressed by a) using a shape estimator which selfcalibrates its possible biases [2], or b) using a biased estimator and calibrate the bias produced based on simulation tests [4].

The internship will consist on applying both approaches on the real images coming from the Canada-France Imaging Survey[1]. With $5,000$ deg^2 sky coverage this will be one of the largest weak-lensing surveys ever conducted. On one side, the student will implement Metacalibration in CFIS data to produce a weak lensing catalogue which is independent on simulations. On the other side, the student will use a bias calibration based on machine learning techniques on CFIS image simulations that will be applied to the real data. We will compare the performance and consistencies of both methods and will also study the impact of this calibration on different statistics and cosmological analyses.

Methods

During the stage, the student will work on astronomical optical images of faint galaxies and use shape estimators Metacalibration and KSB [5] to measure the ellipticities of galaxies. The student will also use image simulations to test the performances of the different methods, their shear biases and their consequences on different statistics such as mass mapping and two-point correlation functions.

[1] http://cfht.hawaii.edu/en/science/LargePrograms/LP_17_19/index.php

Scientific environment

The stage will be carried out in the CosmoStat[2] laboratory at the Département d'Astrophysique (DAp)[3] at CEA Saclay, under the supervision of Arnau Pujol and Martin Kilbinger. CosmoStat hosts a multidisciplinary team whose research includes statistics, signal processing and cosmology. The CosmoStat group is strongly involved in the upcoming ESO space-based mission Euclid[4] (launch in 2020), and manages the weak-lensing data processing of Euclid data. Kilbinger is co-leader of the weak-lensing science working group (WLSWG). Arnau Pujol is co-leader of the weak-lensing shear measurement work package. The Cosmostat group is also developing a pipeline to carry all the weak lensing analysis on the CFIS imaging data.

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References

[1] S. Bridle, J. Shawe-Taylor, A. Amara, and et al. Handbook for the GREAT08 Challenge: An image analysis competition for cosmological lensing. *Annals of Applied Statistics*, 3:6–37, 2009.

[2] E. Huff and R. Mandelbaum. Metacalibration: Direct Self-Calibration of Biases in Shear Measurement. *ArXiv e-prints*, Feb. 2017.

[3] M. Kilbinger. Cosmology with cosmic shear observations: a review. *Reports on Progress in Physics*, 78(8):086901, July 2015.

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[5] M. Viola, P. Melchior, and M. Bartelmann. Biases in, and corrections to, KSB shear measurements. *MNRAS*, 410:2156–2166, Feb. 2011.

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