PhD thesis, 2017

The Euclid space mission: Redshift measurements uncertainties and their effect on cosmological constraints using weak gravitational lensing and galaxy clustering.

The Euclid mission: weak gravitational lensing and galaxy clustering

The ESA space mission Euclid [1] will observe one hundred billion galaxies out to high redshifts over 15, 000 square degrees to map galaxies and dark matter in the Universe, to shed light on the accelerating expansion, and to test the laws of gravity on large scales. 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 [2]. Together with galaxy clustering, weak lensing is one of the main cosmological probes of Euclid.

A crucial component of the Euclid survey are ancillary ground-based optical observations complementing the Euclid infrared filters and the broad visible band, to provide photometric redshifts for all lensed galaxies. One such ground-based survey is CFIS, the Canda-France Imaging Survey[1]. CFIS will observe the Northern part of the sky, covering 4, 800 deg^2 in the u- and r-band, using the wide-field imager MegaCAM on the 3.6 m Canada-France Hawaii Telescope (CFHT). Observations will be conducted over three years, starting in February 2017. Other surveys are DES and KiDS, covering the Euclid area in the Southern hemisphere.

The aim of this thesis is to assess the weak-lensing and galaxy clustering performance of Euclid, accounting for realistic uncertainties and systematic errors in redshift measurements. Existing ground-based and simulated Euclid data will be analysed to estimate redshifts using complementary methods.

Redshift measurements

Redshifts will be estimated from existing ground-based data from CFIS and other surveys, and simulated Euclid optical and infrared images. Apart from photometric redshifts, this thesis will apply the new technique of clustering redshift, making use of the spatial distribution of galaxies and their cross-correlation with spectroscopic galaxy samples. It makes full use of the available information for a given galaxy sample, and is not limited to color information. It is a promising method to determine the redshifts of galaxies, as has been shown recently by our team using CFHT data [3]. This method can overcome some of the potential limitations of photometric redshifts, in particular when only a small number of bands with inhomogeneous sky coverage and depth are available, as is the case for Euclid. More work is required to make this a mature and reliable method, and to ensure its accuracy for large surveys such as Euclid.

By the end of 2019, after the first year of this thesis, CFIS will have covered more than half of its area. We will thus be in the unique position to have very detailed knowledge of the actual

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

photometric properties of ground-based data over a large fraction of the Euclid area. In particular, a large part if not all of the $2,500$ deg^2 area of the first data release (DR1), to be made public in 2023, will be covered.

This thesis is therefore very timely to make realistic forecasts for the first cosmological results of Euclid, which will arrive ahead of competing experiments such as LSST and WFIRST. The student will assume optimistic and pessimistic scenarios of the performance of ground-based photometry for redshift estimation. This will result in updated, realistic forecasts of cosmological constraints from Euclid, for the joint combination of weak lensing and galaxy clustering. Similar forecasts will then be made for the two subsecquent Euclid data releases including the final one using the full $15,000$ deg^2 area.

The PhD student will use photometric data from CFIS and spectroscopic data from BOSS[2] and eBOSS[3]. In addition, DESI[4], a very deep spectroscopic survey in the Northern sky, will start observing in 2018-2019, and DESI data might be available during this thesis. Further, we will use simulations of spectroscopic data of the Euclid NISP instrument.

Euclid performance assessment

Realistic observational effects, such as non-uniform and inhomogeneous sky coverage of ground-based data, varying depth and seeing, and differences in optical filters from different telescopes, will be used to quantify redshift-dependent biases on weak-lensing and galaxy clustering observables.

Such biases come from properties of the galaxy sample that vary with redshift, for example galaxy colors, type, SNR. Further, instrumental effects such as the color-dependence of the Euclid PSF necessitates a redshift-dependent calibration of the PSF correction. It is therefore of great importance to verify the requirements for Euclid using realistic redshift estimates. If not accounted for, such effects can mimic a redshift-dependent dark energy equation of state and invalidate the cosmological interpretation.

PSF models generated in-house at Irfu/SAp are available that include all relevant instrumental effects of the Euclid telescope. Calibration techniques using image simulations of Euclid data will be applied. Weak-lensing shapes will be measured on these simulations using methods developed by our teams at SAp and IAP, which were among the winners of the great3 challenge [4].

Scientific environment

The thesis will be carried out in the CosmoStat[5] laboratory at the Service d'Astrophysique (SAp) of Irfu[6] at CEA Saclay, and at the Institut d'Astrophysique de Paris[7] (IAP). The thesis will be supervised by Martin Kilbinger, in co-supervision with Yannick Mellier.

CosmoStat hosts a multidisciplinary team whose research includes statistics, signal processing and cosmology. The CosmoStat group is strongly involved in Euclid[8] (launch in 2020). Irfu also has a strong intrumental group who develop the PSF model for Euclid, test Euclid optical hardware components, and produce simulations for Euclid. IAP is leading the data processing of the visible instrument aboard Euclid.

[2] `https://www.sdss3.org/surveys/boss.php`
[3] `www.sdss.org/surveys/eboss`
[4] `desi.lbl.gov`
[5] `http://www.cosmostat.org`
[6] `http://irfu.cea.fr/Sap`
[7] http://www.iap.fr
[8] `http://sci.esa.int/euclid`

Kilbinger is co-leader of the weak-lensing science working group, and has leading roles in weak-lensing science-ready data processing and shear validation. He is also a member of DESI. Yannick Mellier is the lead of the Euclid consortium. Kilbinger and Mellier have long experience with weak-lensing surveys, cosmological modeling, shape measurement, and redshift estimation. This thesis will be carried out in in close collaboration with Jean-Charles Cuillandre at SAp, PI of CFIS and member of DESI, Vivien Scottez (IAP), and Christophe Yèche (Irfu/SPP), member of BOSS, eBOSS, and DESI.

Contact

Martin Kilbinger, martin.kilbinger@cea.fr
http://cosmostat.org/kilbinger
☎ +33 1 69 08 17 53
CEA/Irfu/Sap, Laboratoire AIM
Orme des Merisiers, Bât 709, office 280
F-91191 Gif-sur-Yvette

References

[1] Laureijs, R., Amiaux, J., Arduini, S., et al., *arXiv:1110.3193*, 2011.

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

[3] Scottez, V., Mellier, Y., Granett, B. R., et al., *MNRAS*, 462:1683–1696, 2016.

[4] Mandelbaum, R., Rowe, B., Armstrong, R., et al., *MNRAS*, 450:2963–3007, 2015.