Sujet de thèse 2015

Weak gravitational lensing: measurement of peak counts for cosmological parameters

Cosmology, weak lensing, and galaxy shape measurement

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]. Weak cosmological lensing has been used to constrain cosmological parameters such as the matter density Ω_{m}, the dark-energy equation of state w, and has put limits on modifications of general relativity. Recently, new methods such as weak-lensing peak counts have been developed as new and complementary probe of cosmology, which are sensitive to the non-Gaussian nature of the large-scale structure in the Universe [2].

To quantify the distortions induced on background galaxy images by matter structures, we have to accurately measure their shapes. Shape measurements to a few percent accuracy of typically small, faint, and low-SNR galaxy images that are blurred by the PSF (point-spread function) of the optical imaging system is one of the biggest challenges of weak gravitational lensing.

A weak lensing pipeline

Our group is developing a new weak-lensing shape measurement pipeline. We finished in the winning group of the challenge `great3`[1] [3], and we will participate in the next challenge (`great4`), which will start in 2016 and end in 2017.

The goal of this PhD is to perform a weak-lensing analysis on optical wide-field imaging data, and to use the measured shapes of background galaxies to obtain weak-lensing maps of the mass on very large scales. From these maps, peak count statistics are computed to infer cosmological parameters, including the dark energy parameter w.

Various public weak-lensing data sets are available: CFHTLenS (154 deg^2), NGVS (100 deg^2), KiDS (100 deg^2 for the current data release, 1 500 deg^2 upon completion in a few years). These surveys overlap with the SDSS and other spectroscopic and X-ray surveys, which will be used to identify galaxy clusters for mass measurement. Researchers at SAp are members of the CFHTLenS and NGVS survey collaborations.

The aim of this thesis is to improve on the existing shape measurement, and to obtain new results for cosmological parameters from peak counts. The removal of biases of existing methods, for example due to the rejection of close galaxy pairs with overlapping isophotes, is necessary to obtain reliable constraints on dark energy from peak counts.

[1] `www.great3challenge.info`

Methods

During their work, the PhD student will acquire a variety of skills: First, imaging processing techniques such as PSF (de-)convolution, object detection, image noise estimation, measurement of galaxy shapes, detection of image artifacts such as cosmic rays, dead columns, saturated pixels, or satellite trails. Second, the modeling of galaxy properties, such as their light, color, and shape distribution for different galaxy types. Third, statistical tools including model fitting of galaxy shapes to pixel data, and cluster mass profiles to weak-lensing data, including error estimation and calibration of the measurement using image simulations. Fourth, a likelihood analysis of weak-lensing peak count data and fitting of cosmological models.

Further code development (in python and C/C++) is necessary to apply the pipeline to real data.

Scientific environment

The thesis will be supervised jointly by Jean-Luc Starck and Martin Kilbinger. Both scientisits are members of the CosmoStat[2] laboratory at the Service d'Astrophysique (SAp)[3] at CEA Saclay. CosmoStat hosts a multidisciplinary team whose research includes statistics, signal processing and cosmology. CosmoStat scientists have leading roles in large current and future weak-lensing surveys and missions, such as CFHTLenS and Euclid, and are developing methods for all aspects of weak-lensing processing and cosmological interpretation.

The CosmoStat group is stongly involved in the ESO space-based mission Euclid. Kilbinger is co-leader of the weak-lensing science working group (WLSWG). Starck is head of the organizational unit "Level-3" (OU-LE3), responsible for the processing and production of science-ready data from Euclid.

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[2] `http://www.cosmostat.org`
[3] `http://irfu.cea.fr/Sap/`