# L'effet de lentille gravitationnelle faible: measure de formes de galaxies pour tester les lois de gravité aux échelles cosmologiques

**Spécialité** Astrophysique

**Niveau d'étude** Bac+5

**Formation** Master 2

**Unité d'accueil**

**Candidature avant le** 28/02/2017

**Durée** 5 mois

**Poursuite possible en thèse** oui

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## Résumé

Ce stage a pour but de mesurer des formes de galaxies pour étudier l'effet de lentille gravitationnelle faible avec des relevés optiques de grande taille. A partir de ces mesures, on créera des cartes de matière noire pour étudier les lois de gravité à très grande échelle.

## Sujet détaillé

L'effet de lentille gravitationnelle faible désigne les distortions d'image des galaxies à très haut redshift dues aux structures à grande échelle. Ceci est est une des sondes cosmologiques les plus importantes pour étudier le secteur sombre de l'Univers. Pour quantifier ces distortions, il est nécessaire de mesurer les formes de ces galaxies à très haute précision. Cette mesure de forme des galaxies typiquement de petite taille, de faible luminosité et de bas rapport signal-sur-bruit, qui en plus sont convoluées par la PSF (fonction d'étalement du point) par le système optique, est un des défis majeurs de l'analyse de l'effet de lentille faible.

Cette stage contribuera à l’analyse cosmologique de grands jeux de données pour avancer notre compréhension de lois de gravité. Elle aura pour but d'analyser des données optiques de grand champ, et de mesurer des formes de galaxies d'arrière-plan, pour créer des cartes weak-lensing de la masse aux très grandes échelles. Ces cartes seront cross-correlés à des cartes de surdensité de galaxies, obtenu par des relevé spectroscopique comme eBOSS et DESI. Cela nous permettra à distinguer l'effet de gravité sur la lumière (l'effet de lentille gravitationnelle) et les objects massive (les galaxies). Une différence signifiante de ces deux effets serait de forte évidence pour une théorie de gravité modifiée, au delà d'Einstein.

L'étudiant se servira des techniques de pointe de traitement d'image et de la statistique avancés qui sont développées dans le laboratoire inter-disciplinaire CosmoStat. Ces outils seront appliquées aux données larges et profondes des relevés optiques du sol, comme CFIS (Canada-France Imaging Survey) où CFHTLenS (Canada-France Hawaii Lensing Survey).

**Mots clés**

**Compétences**

**Logiciels**

C++, python Galsim, SExtractor, gfit

## Weak gravitational lensing: measurement of galaxy shapes to test gravity on cosmological scales

### Summary

The goal of this stage is to measure galaxy shapes for a weak-lensing analysis of large imaging surveys. and to contribute building a image processing pipeline. Weak-lensing maps of dark matter will be obtained to study the effect of gravity on very large, cosmological scales, and to test general relativity.

### Full description

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 ?m, the dark-energy equation of state w, and has put limits on modifications of general relativity.
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 has developed a weak-lensing shape measurement pipeline, that finished in the winning group of the challenge great3 [2]. This pipeline has yet to be applied to real optical imaging data. New, state-of-the-art methods for image denoising, PSF modeling, and calibration will be implemented and tested.
The goal of this stage M2 is to contribute to the weak-lensing analysis on optical wide-field imaging data, to measure shapes of background galaxies and obtain weak-lensing maps of dark matter on very large scales. The analysis will be carried out on the upcoming state-of-the-art CFIS, the Canda-France Imaging Survey. With 5,000 deg2 sky coverage this will be one of the largest weak-lensing surveys ever conducted. Our goal for this survey is to cross-correlate the weak- lensing dark-matter maps will then be cross-correlated with galaxy density maps from the large spectroscopic surveys eBOSS and DESI. This allows us to compare the effect of gravity on light (weak lensing) and on massive objects (galaxies). A significant difference between the two would provide unmistakable evidence for modified gravity, hinting of a theory beyond Einstein [3]. For this, we have to produce reliable and unbiased measurements of galaxy shapes.

Methods

During their stage, the student will work on astronomical optical images of faint galaxies and use image 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. Further, the student will familiarize themselves with the modeling of galaxy properties, such as their light, color, and shape distribution for different galaxy types. Models of galaxy light profiles will be fitted to pixel data, including error estimation and calibration of the measurement using image simulations. The methods will be tested on existing data from the well-studied CFHTLenS, the Canada-France Hawaii Lensing Survey, covering 154 deg2. Results from the analysis carried out during the stage will be compared to existing publications.
The codes used in the pipeline are written in python and C++.

Scientific environment

The stage will be carried out in the CosmoStat6 laboratory at the Service d'Astrophysique (SAp)7 at CEA Saclay, under the supervision of 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 Euclid8 (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). SAp works in close collaboration with Jean-Charles Cuillandre, PI of CFIS, and scientists at SPP (Christophe Yèche, Nathalie Palanque-Delabrouille), who have leading roles in DESI and eBOSS.
This stage M2 work could be continued as a PhD in our group.

References
[1] Kilbinger, M., Reports on Progress in Physics, 78(8):086901, 2015.
[2] Mandelbaum, R., Rowe, B., Armstrong, R., et al., MNRAS, 450:2963–3007, 2015.
[3] Reyes, R., Mandelbaum, R., Seljak, U., et al., Nature, 464:256–258, 2010.

Web sites
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www.sdss.org/surveys/eboss
desi.lbl.gov
www.cfhtlens.org
http://www.cosmostat.org
http://irfu.cea.fr/Sap/
http://sci.esa.int/euclid

**Keywords**

astrophysics, cosmology, gravitation

**Skills**

image processing, object detection, PSF correction, model fitting, numerical simulations

**Softwares**

C++, python Galsim, SExtractor, gfit