Thesis subject

Laboratory : LAM

Thesis supervisor : Raphael Gavazzi

Co-supervisor :

Title of the thesis subject : Disentangling baryons and dark matter with joint weak and strong lensing in Euclid and JWST

Description of the thesis subject :

The Dark Matter drives the cosmic evolution of structure in the Universe and its distribution can reflect some of its fundamental properties but also it has a strong impact of the formation and evolution of galaxies and the visible baryonic matter therein. Gravitational lensing plays a key role in modern observational cosmology and wide field imaging surveys because of its ability to directly trace the mass.
By exploiting the so-called strong, weak and intermediate (flexion) lensing regimes of distortions experienced by faint background sources, we propose to uniquely investigate the small scale dark matter distribution, and the overall stellar to halo mass relation (SHMR). Host halo mass is the main parameter driving galaxy evolution models. Building a coherent picture of the mass assembly model as a function of environment (central/satellite dichotomy, location in the cosmic web), host mass (from galaxies to galaxy clusters) and look-back time helps disentangle baryonic processes from signatures of the dark matter and lift degeneracy contained in a pure description of the total gravitational potential.

At the beginning of this project, the PhD student will join the Euclid consortium, take part of strong lensing and weak lensing activities, and play a leading role in the scientific exploitation of the first data release (Oct 2026). We will build advanced Bayesian hierarchical models of the galaxy-halo relationship, fit the weak shear signal and the distribution of Einstein radii that will be freshly determined thanks to the large sample of strong lenses supplied by Euclid.
This first step will require numerical developments with advanced auto-differentiable optimization approaches to describe the SHMR and to efficiently explore the parameter space. A parallel similar study will be conducted in JWST data. Leveraging the abundant redshift information and exquisite depth of the Cosmos-Web survey, we will push further the redshift span of the analysis and pave the way for the scientific exploitation of the second data release of the Euclid deep fields.

The second pillar of the project will consist in measuring even more detailed aspects of the shape of distant galaxies, namely the third order moments of the light distribution (so called flexion signal) which allows to bridge the gap between strong and weak lensing regimes. We will develop new ‘’morphometry’’ features of the SourceXtractor++ astronomical code to perform more advanced shape measurements in the Euclid data than currently implemented in the MER photometric pipeline. Mock images coming from hydrodynamical simulations will also be used to test and calibrate the shear and flexion shape measurement techniques.

The PhD student will work at LAM under the supervision of Dr Raphael Gavazzi, who is co-leading strong lensing activities in the Euclid Consortium and coordinator of a mass modeling joint cosmology

Key Project for the first DR1 data release. He is also member of the SourceXtractor++ development team. Several other experts in machine learning, gravitational lens modeling, morphometry and image simulation and in the broader scientific exploitation of Euclid and JWST will also contribute to the ideal environment for the conduction of this thesis project and in a timely manner given the availability of outstanding new space-based imaging datasets.

References :

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