Stage M2, 2018

Mass mapping with real weak-lensing data using sparsity-based techniques

Weak lensing and mass mapping

Weak gravitational lensing [1] has become a vital tool in cosmlogy for investigating the properties of the large-scale universe, in particular the still mysterious dark matter and dark energy components. Weak lensing describes the tiny distortions in the observed shapes (ellipticities) of distant galaxies due to the gravitational influence of massive structures along the path of light rays as they travel to us. Given observations of many lensed galaxies, we can exploit their pattern of coherent alignment to infer the distribution and proportion of total matter in the universe. Since all mass bends light, this includes the invisible dark matter that makes up the majority (by mass and by volume) of gravitating structures. Weak lensing therefore provides a powerful way to constrain the parameters of our cosmological models, such as the total proportion of matter density and the amplitude of its clustering. Such analyses are the focus of numerous current surveys, as well as future surveys like ESA's Euclid mission (launch in 2020), which will provide the largest sample of precisely measured galaxies to date.

Mass mapping entails the construction of two-dimensional maps using weak-lensing data, which represent the integrated total matter density along the line of sight. Small-field mass maps have been frequently used to study the structure and mass distribution of galaxy clusters, whereas wide-field maps have only more recently become possible given the broad observing strategies of surveys like CFHTLenS, HSC, DES, and KiDS. Mass maps contain significant non-Gaussian cosmological information and can be used to identify massive clusters as well as to cross-correlate the lensing signal with foreground structures.

Methods

A standard method to derive mass maps from weak-lensing observations is an inversion technique formulated by Kaiser & Squires [2]. It has many limitations, however, including the need to smooth the data before (and often after) inversion, thereby losing small-scale information. An alternative method called GLIMPSE has been developed in the CosmoStat laboratory based on sparse reconstruction that avoids this problem and improves the recovery of non-Gaussian features [3, 4]. The algorithm has been tested on simulations and was also recently used to study the A520 merging galaxy cluster with Hubble Space Telescope data [5].

Internship

The intern will work on applying the GLIMPSE algorithm to real public weak lensing data to derive and study small- and wide-field mass maps. A second task will be to compare these results to those of standard techniques and to compute the cross-correlation with foreground galaxies. The applicant should be a Master 2 student (or equivalent) in physics, astrophysics, applied maths, or a closely related field. Experience with modern programming languages like C++ and Python would be advantageous.

Location : CosmoStat laboratory of DRF/IRFU/Dap
Supervisors : Austin Peel and Jean-Luc Starck
Contact : austin.peel@cea.fr, jstarck@cea.fr
Duration : 4-6 months
Possibility to continue on for a PhD : Yes

References

1. Bartelmann, M. & Schneider, P. 2001, Phys. Rep., 340, 291.
2. Kaiser, N. & Squires, G. 1993, ApJ, 404, 441.
3. Leonard, A., Lanusse, F., & Starck, J.-L. 2014, MNRAS, 440, 1281.
4. Lanusse, F., Starck, J.-L., Leonard, A., & Pires, S. 2016, A&A, 591, A2.
5. Peel, A., Lanusse, F., & Starck, J.-L. 2017, ApJ, 847, 23.