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PhD Thesis

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PhD title: ***Gravitational lensing of galaxy clusters and filaments: simulations and observations with BATMAN*.**

Subject description:

According to theoretical models and numerical simulations and confirmed by spectroscopic galaxy surveys such as SDSS, 2dF, GAMA or VIPERS, the large-scale structure of the Universe appears as a cosmic-web made of knots, which corresponds to galaxy clusters and super-clusters, filaments of dark matter and gas mildly populated by galaxies, and low-density walls that surround voids. The relationship between large-scale morphological features and physical properties of tracers is a topic at the forefront of current research (e.g. Kraljic et al. 2018).

Gravitational lensing provides unbiased map of the mass distribution around specific object. The direct detection of filaments and clusters' outskirts is however challenging because of their intrinsic low density, and usually investigated by stacking techniques. Some remarkable exception in optical wavebands are the large-scale filament feeding the massive galaxy cluster MACS J0717.5+3745 detected by weak gravitational lensing (Jauzac et al. 2012) or the filament bridging the cluster system A399-A401 detected combining Planck, WISE, and SDSS data (Bonjean et al. 2018).

In statistical studies of galaxy-galaxy lensing (e.g. Leauthaud et al. 2017), lensing by stacked filaments (e.g. Epps & Hudson 2017), or in cosmic shear measurements (e.g. Joudaki et al. 2019), low-accuracy photometric redshifts are sufficient to model the mass distribution of foreground lenses. Instead, aiming at modelling the specific mass map of filaments or clusters of galaxies (Jullo et al. 2010), a high-accuracy measurement of redshift is needed to localize these structures along the line-of-sight. The spectroscopic redshift of a subset of (background) sources is also necessary to calibrate the photometric redshifts. This study can be addressed by cross-correlating different data sets, e.g. HSC images and SDSS spectra, usually achieved with different instruments.

An instrument such as BATMAN (Zamkotsian et al. 2014, 2018), a DMD-based spectro-imager with 2-20 arcmin^2 field-of-view and spectral resolution R $= 500$-1000 that will be mounted on TNG ($\sim$2021) and GEMINI-S ($\sim$2023) could allow simultaneous measurement of spectroscopic redshift of galaxies in the foreground filaments or clusters (along caustics and critical lines) with DMD-programmable slits put on the specific objects, and the imaging of the background galaxies observed in the same field, eventually augmented by multi-filter photometry.

This Ph.D. project is intended to establish a BATMAN-oriented observing strategy for lensing studies. It will start by defining the observational constraints based on existing data sets (e.g. CFHTLenS and SDSS), i.e. the typical size and surface density of filaments and galaxy clusters as function of redshift and magnitude, and will continue with the design and realization of a modular exposure-time-calculator (ETC) in collaboration with the CESAM group. Simulations of simultaneous imaging and spectroscopy will then define the optimal observational strategy for BATMAN@TNG and BATMAN@GEMINI as function of the S/N, limiting magnitude, field-of-view, observing time, spatial and spectral resolutions (the student will have access to the BATMAN's demonstrator installed at LAM). The ETC will be used to optimise both the instrument performances and the data reduction pipeline for this science case. Observational strategy and data reduction pipeline could benefit from deep-learning methods. The student will eventually participate to the installation of BATMAN@TNG and participate to the first observations, data reduction, and data analysis, to be considered as benchmark for future installation at GEMINI.

Bibliography:

- Jauzac et al. 2012*, A weak lensing mass reconstruction of the large-scale filament feeding the massive galaxy cluster MACS J0717.5+3745*, MNRAS, 426, 3369.
- Bonjean et al. 2018, *Gas and galaxies in filaments between clusters of galaxies. The study of A399-A401,* A&A, 609, 49.
- Kraljic et al. 2018, *Galaxy evolution in the metric of the cosmic web,* MNRAS, 474, 547.
- Leauthaud et al. 2017, *Lensing is low: cosmology, galaxy formation or new physics?*, MNRAS, 467, 3024
- Epps, Hudson 2017, *The Weak Lensing Masses of Filaments between Luminous Red Galaxies*, MNRAS, 468,2605
- Joudaki et al. 2019, *KiDS+VIKING-450 and DES-Y1 combined: Cosmology with cosmic shear*, arXiv:1906.09262.
- Jullo et al. 2010, *Cosmological Constraints from Strong Gravitational Lensing in Clusters of Galaxies*, Science, 329, 924.
- Zamkotsian et al. 2014, *BATMAN: a DMD-based multi-object spectrograph on Galileo telescope*, SPIE, 9147, id. 914713.
- Zamkotsian et al. 2018, *BATMAN@TNG: instrument integration and performance*, SPIE, 10702, id. 107025P.