Doctoral School 352 Physics and Science of Matter

Thesis subject

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Subject's title: **Galaxy evolution within the cosmic web to z~2**

Abstract: This thesis will investigate the influence of the large scale structure on galaxy properties. It will exploit the HSC+u band Deep Survey, a state-of-the-art dataset, mimicking LSST in depth and passbands. Photometric redshifts will be performed with Deep Learning techniques. The cosmic web (CW) will be reconstructed in redshift slices up to z~2, near the peak of the cosmic star formation activity where its influence on galaxy properties is expected to be the strongest. This work will provide the first investigation at this particular epoch down to the low-mass/dwarf regime. It will be confronted to simulations, which will also be used to predict the ability of future surveys to perform 2D and 3D CW investigations. The PhD student will also be involved in the preparation of the PFS survey and will collaborate with researchers in different institutions on these various topics.

Subject description: The cosmic web (CW) is a complex network of voids, walls, filaments and knots in which galaxies form and evolve. Almost 90% of the baryonic mass is located in this CW, called the inter-galactic medium. The exchanges of gas and energy (infalls/outflows) between the galaxies and their environment are thought to play a crucial role in shaping galaxy properties. Theoretical predictions have emphasized the close link between the large scale cosmic flows and the spin orientation of galaxies, recently confirmed with spectroscopic surveys at low redshift (z<0.2; Tempel et al., 2014). More recently, a dependence between the stellar mass or the star formation activity of galaxies and their distance to CW features has also been detected at low (z<0.3; Kraljic et al., 2017) and intermediate (z~0.8; Malavasi et al., 2017) redshifts. All these trends are expected to be even more significant at higher redshift near the peak of the cosmic star formation activity and will become a major topic of research with the forthcoming large spectroscopic surveys such as PFS, Euclid and WFIRST. In parallel, the improvement in photometric redshift (photo-z) determination also led to a reliable description of the cosmic-web in thin 2D redshift slices (Laigle et al., 2017), providing an alternative method to investigate this topic with LSST.

In this thesis project, we propose to exploit the ongoing photometric survey HSC+CLAUDS. The Hyper Suprime Cam (HSC) Deep Survey is a ~100 night project on Subaru with the HSC imager. It will cover 25 sqdeg with multi-band (grizY) imaging down to r~27 and is complemented by deep U band imaging at CFHT (U~27, french PI: Arnouts). The U band is essential to provide highly accurate photo-z and to yield high-quality SFR estimates down to 0.1, 0.3, 0.8 Mo/yr at z=0.5,1.0, 1.5 (i.e. deeper than COSMOS and with 10 times the area). This will provide a unique combination of depth and area with rich ancillary data, making it ideal for galaxy evolution and large scale structure studies. This dataset will only be superseded by LSST after 10 yrs of data acquisition, and therefore represents a major forerunner to prepare LSST science ! It will allow galaxy properties to be studied simultaneously in multiple bins of redshift, stellar mass and environment, as well as rudimentary morphology (in the r-band Subaru yields a median of 0.65", or 4 kpc at z=0.5).

To reach this goal, accurate photo-z's are crucial. In this thesis we propose to develop a new approach based on deep learning algorithms (DL). One limiting factor of the current photo-z techniques is the extraction of photometric quantities (magnitudes or colors) used as input, which capture only a fraction of the information present in the images. Taking advantage of the latest DL techniques (convolutional, recurrent Neural Networks), of the GPU acceleration and of the large size of spectroscopic samples, we propose to bypass this limitation by dealing directly with multi-band galaxy images at the pixel level. DL algorithms already outperform traditional astrophysics techniques on morphology prediction (Dieleman et al., 2015) and photo-z estimates (Hoyle et al., 2016, d'Isanto, 2017). They are natural tools to exploit the upcoming large astrophysical dataset (e.g. LSST). We will also push this technique one step further by investigating how the knowledge of a predefined 3D CW can improve photo-z accuracy. When bright spectroscopic samples are dense enough to build the density field and reconstruct the 3D CW, the photo-z probability distribution can be combined with the highly anisotropic distribution of the CW to restrict the set of possible redshifts along the line of sight of each galaxy (Aragon-Calvo et al., 2014). The PhD student will implement and test such a method using the available VIPERS and COSMOS surveys.

The best photo-z estimates will be adopted to slice the universe in thin redshift bins and the DisPerSE code (Sousbie, 2011) will be used to reconstruct the 2D projected CW. The segregation of galaxies as a function of their distance to nodes and filaments will then be investigated. We will also provide a definitive census of the star formation rate density over the last 11 Gyrs ($0<z<3$) and the relative contributions of galaxies with different stellar masses and in different environments. The drastic flattening of the UV luminosity function slope (from α ~-1.8 at high z to -1.2; Alavi et al., 2014) is likely regulated by feedback, so tracing the evolution of the slope will help identifying the main regulator of feedback in low-mass galaxies. It could discriminate between environmental quenching, thought to affect mainly satellite galaxies (Peng et al., 2010), and feedback mechanisms that reduce the star formation efficiency in small dark matter potential wells by disrupting or heating the gas supply (Bouché et al., 2010), an open question in galaxy formation scenarios. The PhD student will confront her/his results with the Horizon-AGN hydrodynamic simulation (Dubois et al., 2014).

The simulation will also be used to predict the ability of future surveys to perform 2D and 3D CW investigations according to their expected spectroscopic sampling (PFS, Euclid-Deep, WFIRST) or photo-z accuracy (LSST). The PhD student will be involved in the preparation of the spectroscopic follow-up of the HSC-Deep field with the Prime Focus Spectrograph (PFS) instrument on Subaru, starting in 2020, a project to which LAM is a major contributor. She/he will be prepared to exploit the first reconstruction of the 3D CW near the peak of the cosmic star formation activity.

In addition to working within the LAM team, the student will have the opportunity to develop her/his skills on galaxy evolution with M. Sawicki, J. Coupon, T. Moutard (CLAUDS team), on simulation and CW with C. Pichon, Y. Dubois (IAP) & C. Laigle (Oxford) and on deep learning with E. Bertin (IAP) & J. Pasquet (CPPM). Besides the science motivation, programming skills and an interest in data mining will be assets to this project.

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