Thesis subject

Name of the laboratory: LAM

Thesis advisor: Matthew M Pieri
Email and address: matthew.pieri@lam.fr
Tel: +33-(0)4-91-05-69-87

Co-advisor: Stéphane Arnouts

Subject's title: Exploring the gaseous environment of galaxy formation with WEAVE-QSO

Subject description:

One of the great tasks of modern astrophysics is developing an understanding of galaxy formation. In order to understand the formation of galaxies we must study them when they assemble most of their stars and acquire the gaseous fuel necessary to do so. We must therefore study them at or above z=2 where the star formation rate peaks and where the extragalactic gas is probed most effectively. This gas is known as the 'intergalactic medium' (or IGM) and forms a large-scale 'cosmic web' of structure along with dark matter and galaxies. Over the coming years it will become possible to develop a holistic picture of galaxies, structure and gas properties on all scales: the local environment of inflows and outflows in the circumgalactic medium and the larger scale environmental dependence of the cosmic web and large-scale separation from quasars. We are able to probe various properties of the gas: metallicity, density, temperature, abundance pattern, UV background radiation, dust, gas clumping and associated dark matter halo masses. Furthermore, large-scale structure in the IGM can be used to perform cosmology such as measuring the standard ruler known as 'Baryon Acoustic Oscillations' (BAO) to probe the Hubble parameter and other cosmological parameters. These studies are not independent because a good understanding of the astrophysics of the IGM has knock-on benefits for our cosmological constraints.

We have a wealth of information from the study of absorption by the IGM along the line of sight to bright background quasars (and sometimes galaxies or GRBs). Each quasar spectrum is like having an ice core for the history of the universe. With the ever-increasing density of these 'sight-lines' we are beginning to build up a 3D map of the cosmic web. This data is at its richest when the Lyman-alpha transition is in the optical window at z>2, providing us the information rich phenomenon known as the Lyman-alpha forest. Efforts have been underway since 2009 (with the Sloan Digital Sky Survey III) to provide the largest possible sample of these z>2 quasars.

This thesis project will involve developing methods to initially exploit the WEAVE-QSO survey, but these methods will be applicable to various other surveys including PFS. WEAVE-QSO is a large multi-object spectroscopic survey (following in the tradition of the Sloan Digital Sky Survey) starting in 2020 and lasting at least 5 years. It is part of the wider WEAVE survey, which will be a next generation survey facility hosted on the 4.2 meter William Herschel Telescope. WEAVE-QSO will deliver a major improvement in survey gas resolving power. It will achieve unprecedented densities of quasar sight-lines and so spatial resolution of gas structure, and will do so with at least double the spectral resolution of Sloan. WEAVE-QSO will improve our data on rare close groups of quasars, galaxies in absorption, and allow comparisons with samples of z>2 galaxies in conjunction with other surveys (such as J-PAS, HETDEX and Euclid).

The student is expected to study large-scale structure and galaxy environment by exploring machine learning methods to decompose the Lyman-alpha forest and then reconstruct the cosmic web using (either traditional Weiner filtering methods or by developing new machine learning methods). The properties of the gas in a cosmic web and galaxy proximity context will then be studied using the stacking methods developed by Pieri. A possible extension or alternative to this work would be to perform cross-correlations and autocorrelations using the software package picca to constrain dark matter halo masses and measure BAO using the Lyman-alpha forest.

The computer science aspects of this these will benefit from expertise WEAVE-QSOs emerging partnership with computer scientists in both academia and industry. These methods will also be impactful for facilities such as PFS, ELT-MOSAIC and DESI. The student will be fully integrated into the WEAVE-QSO survey team to pursue this thesis.

Bibliography:

Pieri et al (2016), “WEAVE-QSO: A Massive Intergalactic Medium Survey for the William Herschel Telescope” https://arxiv.org/abs/1611.09388
Japelj et al (2019), “Simulating MOS science on the ELT: Ly-alpha forest tomography” https://arxiv.org/abs/1911.00021
Blomqvist et al (2019) “Baryon acoustic oscillations from the cross-correlation of Lyα absorption and quasars in eBOSS DR14”, https://arxiv.org/abs/1904.03430