PhD project in ASTROPHYSICS

Title of the Project: The large-scale environment of QSOs at Cosmic Dawn

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Scientific Case: Theory and numerical simulations struggle to explain the presence of luminous QSOs powered by already massive SMBHs at Cosmic Dawn ($z \gtrsim 6$) ; i.e. $\lesssim 1$ Gyr after the Big Bang. However, nearly all models predict that the formation of the first SMBH seeds and their efficient growth are highly favoured in the peaks of the dark-matter distribution at z>10, characterised by galaxy densities in excess to the average field. A direct and testable consequence of this is that z>6 QSOs should be surrounded by galaxy overdensities on distances up to several physical Mpc. However, observational studies aimed to probe this forecast fail at providing a coherent picture. This is probably due to the small fields of view (FoVs) of the used instruments (i.e., a few arcmins), which only sample distances of <1Mpc from the central QSO at high redshift. This scale is significantly smaller than the sizes of the predicted galaxy structures (~1-8 Mpc). Recent observational campaigns with the James Webb Space Telescope (JWST) are providing breakthrough results in this respect, by detecting significant overdensities of [O III] emitting galaxies surrounding most of the targeted z>6 QSOs. Still, due to its limited FoV, JWST cannot probe the AGN environment further than ~1 Mpc from the targeted AGN for sizeable samples, leaving most of the expected galaxy structures completely unexplored. A complementary approach is to use optical/IR ground-based facilities with wide FoV (e.g., LBT, CFHT, Subaru) to select high-redshift galaxy candidates up to several Mpc distances from the central QSOs. Very few high-redshift QSO fields have been covered with such observations, and all of them have been found to reside in significant overdensities of galaxies, in qualitative agreement with numerical simulations. However, such studies are still sparse, rely on observations with different instruments and sensitivities, and applied heterogeneous techniques to select the

Outline of the Project: The candidate will study the large-scale environment of $z \gtrsim 6$ QSOs using a set of proprietary and homogeneous optical/IR observations obtained by our team with LBT (including a “INAF LBT Strategic Program”), CFHT, VLT, Magellan. The entire sample consists of 15 QSO fields, which is the largest one with the required datasets to perform this investigation, and include also radio-loud systems, whose environment at high redshift has been never explored to date. The PhD project will focus on a sub-set of such fields. The student will use these data to select high-redshift galaxy candidates around the targeted QSOs via the “Lyman-break technique”. By comparing the number of identified galaxies with the expectations from average fields at similar redshift, the student will derive the galaxy overdensity level and its variance, and compare these results, along with e.g. the overdensity extensions and radial profiles, with theoretical expectations. Possible developments of the project include the derivation of the galaxy-galaxy autocorrelation and galaxy-QSO cross-correlation functions to, e.g., constrain the masses of the dark matter haloes. Finally, the student will apply for spectroscopic follow-up observations with, e.g., LBT, VLT, ALMA, JWST to confirm the selected galaxy candidates. Some of the QSO fields in the sample are already part of multi-wavelength programs with, e.g., JWST, Chandra, XMM-Newton, VLA, that can be exploited to characterize the surrounding galaxies and search for possible satellite AGN. The project will include interactions with collaborators based in Italian and foreign institutes. Interested candidates are encouraged to contact us and discuss the project in person if they have questions or are willing to have more details.

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