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Searching for Lyα halos around radio-loud quasars

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Motivation:

Quasars are extremely luminous active galactic nuclei powered by supermassive black holes at their centers. About 10% of them are radio-loud (RL) with powerful radio jets that are thought to trigger the growth of SMBHs and contributing to feedback processes in massive galaxies [1,2]. Research on high-redshift quasars ($z > 2$) has revealed Lyman-alpha Halos (LAHs) extending over tens of kiloparsecs, mapping the Circumgalactic Medium (CGM), a key component in understanding galaxy formation and evolution. Different studies have shown varied results regarding the density of environments around RL quasars compared to radio-quiet (RQ) ones; some studies are observing denser environments around RL quasars [3], and others are reporting no significant differences between the LAHs of RL and RQ sources at lower redshifts ($z \sim 3.5$) [4,5]. The CGM of RL quasars is not yet fully understood, especially at the highest redshifts ($z > 5$), where only one RL quasar has been observed [6,7]. This lack of data means there is currently no systematic studies to suggest any correlation between radio properties and LAHs, nor any differences between RL and RQ sources.

Here we aim to study LAHs around high-redshift RL quasars using the Multi Unit Spectroscopic Explorer (MUSE) of the Very Large Telescope (VLT). This project will help to place radio jets in the context of galaxy and quasar evolution in the early universe and study any interaction between the radio jets and the gas reservoirs in the quasars CGM.

1. The Data Sample:

Our sample consists of 18 quasars in the redshift range $3.66 < z < 6.44$, which is the largest sample of RL quasars at these redshifts with such datasets. This sample has available MUSE observations present in the ESO Archive, with more than 78 hours of observations.

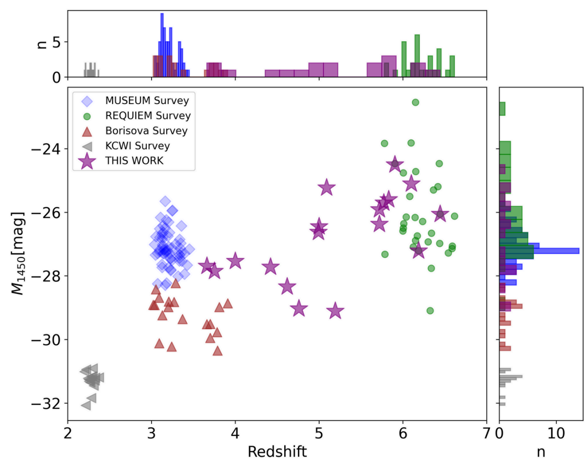


Fig. 1: Distribution of all known quasars observed with IFUs in the redshift vs. absolute magnitude plane [4,5,7,8,9]. The sample of this project is highlighted with purple stars.

2. Performing the PSF Subtraction:

Example of PSF subtraction of the RL quasar J2228+0110 at z=5.9.

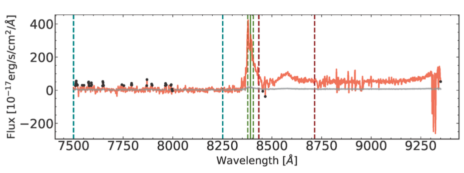


Fig. 2: 1D spectrum of the quasar; dashed blue lines is the foreground region, green lines show where Lya emission is located and the dark red lines are the PSF region.

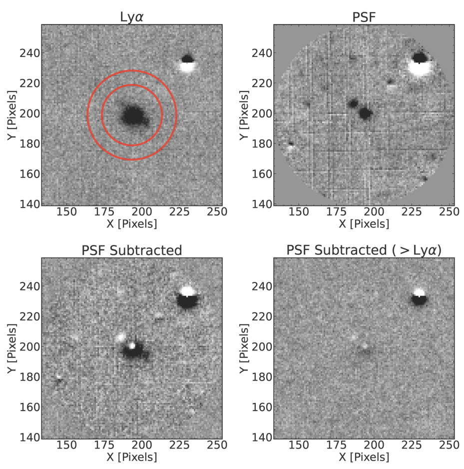
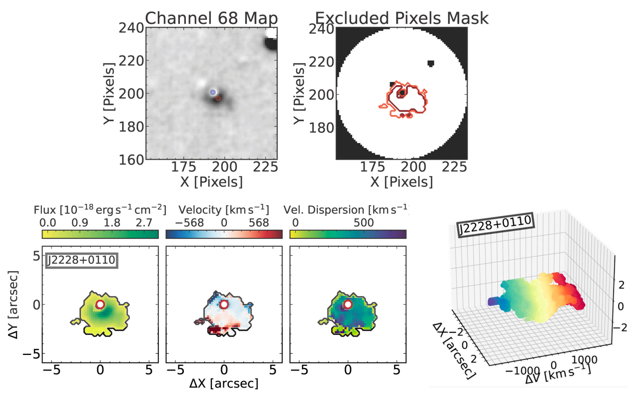


Fig. 3: Top left: QSO emission where the Lyα is expected, Top right: PSF model, Bottom left: PSF subtracted image of QSO emission, but redward, where the Lyα extended emission is expected), Bottom right: PSF subtracted image of QSO emission.

3. Searching for LAHs

To find the possible LAHs around the RL quasars, we aim to use the finding halo python package developed in [10]. It follows several steps, such as: creating a smooth model based on the datacube and the PSF model, applying a friends-of-friends algorithm that connects voxels for the smooth cube and finally creating a three-dimensional mask containing all connected voxels in case a LAH is detected. We show here an example of the quasar J2228+0110 at z=5.9 which was also studied by [7].



4. Current status and Future prospective

We completed the 90% of data reduction in our sample, and obtained PSF subtracted files for 15 sources. Currently, we are in the stage of identifying LAHs. Then, we will perform the stages described below.

4.1 Analyzing the sample

We will search for any evidence of ongoing outflows possibly triggered by the jets. The evidence could be in the form of broad Lyα FWHM, of a systematic offset of the Lyα line peak with respect to the systemic redshift of the quasar, and/or disturbed kinematics.

4.2 Comparing with the sample of high redshift RQ quasars.

We will also compare the properties such as luminosities, FWHM, kinematics, and morphology of LAHs around RL quasars with those surrounding RQ ones. Additionally, we will study the evolution of LAHs around RL quasars with redshift and luminosity. To do this, we will consider samples from the literature (see Fig. 1).

References:

[1] Hardcastle and Croston+2020, Nar, 101539.88; [2] Wylezalek+2013, Apj, 769.79; [3] Lin+2024; [4] Borisova+2016, Apj, 831/39; [5] Arrigoni Battaia+2019, A&A,631.23; [6] Drake+2019, Apj, 881.131; [7] Farina+2019, Apj,887.196; [8] Cai+2019, Apj, 245.23; [9] Schindler+2023 Apj, 943.67; [10] Farina+2017, Apj, 248.78.