X-shooter Science Verification Proposal

Emission lines from a DLA galaxy

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Abstract:

We propose to observe Lyα emission and other associated strong emission lines from a galaxy at $z = 3.317$ which gives rise to a damped Lyα system (DLA) in the background quasar PSS J2155+1358 at $z = 4.2$. As the QSO emission is entirely absorbed by the DLA at the wavelengths around the trough, we can observe the Lyα emission from the galaxy exactly at the same wavelength. With the full spectral coverage of X-shooter, we will observe other strong emission lines ([OII], Hβ, and [OIII] fall in the near-IR arm) and derive the oxygen abundance of the galaxy as seen in emission. We can then compare metallicities of the absorbing cloud and the emitting galaxy, which is essential in order to understand the origin of strong quasar absorption lines.

Scientific Case:

Quasar sight lines provide a wealth of information about the intervening intergalactic medium through the analysis of the absorption line systems. The strongest absorption lines, the damped Lyα systems (DLAs) presumably arise when the line of sight intersects a proto galaxy with large amounts of neutral hydrogen (e.g. Wolfe et al. 1986, ApJS, 61, 249). The column densities of DLAs are N(HI)$> 2 \times 10^{20}$ cm^{-2} which is similar to a cross section of the Galaxy. At high redshifts large disk galaxies are not common, and DLAs are likely to probe smaller gas rich ones.

To date $\sim$1000 DLAs at $z \gtrsim 2$ are known, mainly form the Sloan data base (Prochaska at al. 2005, ApJ, 635, 123). The associated metal absorption lines indicate metallicities of typically 1–10% solar (Pettini et al. 1994, ApJ, 426, 79). In comparison, the Lyman break galaxies detected in emission at similar redshifts have metallicities of typically $> 50\%$ solar. The discrepancy is in agreement with the hypothesis that since DLAs are selected from their HI cross section, they probe less massive and consequently less metal rich galaxies (Fynbo et al. 2008, ApJ, 683, 321). Detailed analyses of metal absorption lines from DLA systems have indicated the existence of two categories of DLAs; one in which stars form in situ, and the other where the ionising radiation from massive stars in galaxies in the environment effect the conditions of the cloud (Wolfe et al. 2008, ApJ, 681, 881).

To understand which galaxies give rise to high redshift DLAs, it is necessary to identify the absorbing galaxies in emission too, but at $z > 2$ very few galaxies have been identified despite intense observational efforts (e.g. Møller et al 2002, ApJ, 547, 51). Typically, deep, high spatial resolution images have obtained to identify potential DLA galaxies nearby the QSO line of sight (Warren et al. 2001, ApJ, 326, 759). Thereafter, spectroscopic observations are needed to verify that the galaxies lie at the same redshifts as the DLAs. Alternatively, IFU spectroscopy allows one to obtain images and spectra simultaneously, so it should be an ideally suited technique to identify the intervening galaxies. In practice, however, deep observations are still needed, since the sensitivity of current optical IFUs is low.

Previous work: Using IFU observations on several telescopes we have carried out observations of a large number of quasars with DLAs with the aim to detect the Lyα emission line where the emission from the background QSO is absorbed. From a total sample of about 40 DLAs, we detect candidate emission lines from 10 of these. The Lyα emission lines are relatively faint ($\sim$2–10$\times 10^{-17}$ erg s^{-1} cm^{-2}), and fall within 1-3$''$ from sight lines of the QSOs (Christensen et al. 2007, A&A, 468, 587).

Aim: Here we propose to observe one of the best candidates with X-shooter slit observations (Fig. 1).

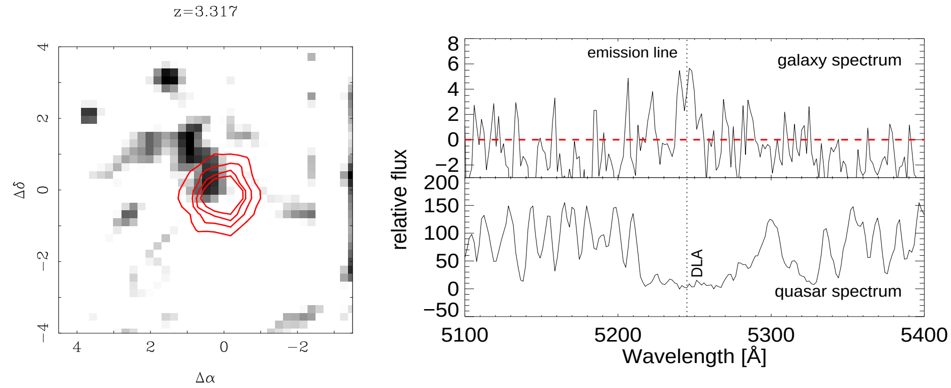

Figure 1: IFU spectroscopic results for PSS J2155+1358 from Christensen et al (2007). The grey scale image on the left shows a narrow band image with a field of $8'' \times 8''$ centered on the wavelength of Lyα at the redshift of the DLA, where the QSO emission has been absorbed. An emission line object is clearly present offset from the line of sight of the background QSO. The contours illustrate the PSF of the QSO in adjacent wavelengths. The spectra on the right show co-additions of spaxels for the DLA galaxy and the QSO. The Lyα emission line falls exactly in the absorption trough of the QSO spectrum.

The observations will have a two-fold gain: Firstly, we want to confirm the Lyα emission at an impact parameter of $1''$. Secondly, the simultaneous coverage in the near-IR allows us to observe the other strong emission lines. At the fortunate redshift of the DLA, we can observe simultaneously the [OII], Hβ, and [OIII] lines which fall in the H and K bands where the transmission is close to 100%. Using these lines with a commonly adopted strong line diagnostics, R_{23} (Pagel et al. 1979, MNRAS, 189, 95), we can determine the Oxygen abundance of the galaxy as seen in emission. The absorption line system in the QSO spectrum has revealed a metallicity of [Fe/H]=−1.65 (Prochaska et al. 2003, ApJL, 595, L3). A comparison of the metallicities in emission and absorption is a unique opportunity for us to gain insight into the selection and analysis of high redshift galaxies, and the possible biases that arise when probing galaxies by their absorption lines.

Calibration strategy:

A standard nod on slit observational strategy will be used. The slit orientation will be chosen to include both the QSO and the DLA galaxy.

Targets and number of visibility measurements

Target	RA	DEC	V mag	Mode (slit/IFU)	Remarks
PSS J2155+1358	21 55 02.1	13 58 26	17.9	slit	First priority

Time Justification:

The IFU data indicate a Lyα line flux of 9×10^{-17} erg s^{-1} cm^{-2}. If dust is present, the Lyα line is intrinsically brighter than measured. Weatherley et al. (2005, MNRAS, 358, 985) estimate for two DLA galaxies that the Lyα and [OIII] emission lines are approximately of equal strengths. The Hβ line is expected to be fainter, and so is the [OII] line. A reasonable assumption is that these lines will have fluxes around 1–2$\times 10^{-17}$ erg cm^{-2} s^{-1}. These faint line fluxes will allow us to probe metallicities of 10% solar according to the R_{23} abundance diagnostics.

With 2 hours in total on target we can reach S/N$\sim$3 at the peak of the line for the mentioned line flux in the near-IR, while integrated over the line (expected to be between 5 and 10 pixels) the S/N $\sim$ 10. A S/N better than 8 is necessary to make a firm determination of the abundance from the diagnostics.

The target is observable in both science verification runs.