Deep VLT spectroscopy of Lyα envelopes around z=4.5 radio quiet quasars

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The context:

Haiman & Rees (2001, ApJ 556, 87) have proposed high z Lyα emitting envelopes as possible diagnostics of galaxy formation. Gas falling into the gravitational well of a dark matter halo would dissipate the resulting heat through faint Lyα emission, but a central quasar would ionize the gas further, making the emission strong enough to be detected. For $3 < z < 8$, they predicted typical sizes of a few arcsec and surface brightnesses $10^{-18} < \mu < 10^{-16}$ erg s^{-1}cm^{-2}arcsec^{-2}. For z=3, Alam & Miralda-Escudé (2002, ApJ 568, 576) predicted more compact and fainter emission. On the observational side, radio loud quasars at z=2-3 are known to be surrounded by large Lyα emitting envelopes (Heckman et al. 1991, ApJ 381, 373; Wilman et al. 2000, MNRAS 317, 9). This is interpreted as being due to the interaction of the radio jets with the gas (Villar-Martin et al. 2006, MNRAS 366, L1) or to direct excitation by the UV continuum of the central source (Best et al. 2000, MNRAS 311, 23). Lyα emitting envelopes around radio quiet quasars (RQQs) have been reported but are less frequent (e.g. Steidel et al. 1991, AJ 101, 1187; Bunker et al. 2003, ApSS 284, 357; Christensen et al. 2006, A&A 459, 717). No systematic search of the latter has been carried out so far; we intend to fill that gap by searching for Lyα envelopes around quasars with various intrinsic luminosities at z=4.50±0.06, i.e. in a spectral region devoid of telluric emission lines.

The questions:

- What is the frequency of these envelopes around RQQs?
- What are their typical size and surface brightness?
- What are their luminosities, and luminosity function?
- Is the envelope luminosity related to that of the QSO?

The observations and their analysis:

3 RQQs were observed in ESO Period 79 (April-Sept. 2007, service mode) with the FORS2 multi-object spectrograph attached to VLT-UT1. We used the ESO grism G1200R+93 with a 2'' slit, providing a resolving power R=1070. The order separating filter GG435+81 gives a spectral coverage 6000 to 7200 Å, with a maximum efficiency coïnciding with the redshifted Lyα wavelength, 6686 Å. The multi-slit MXU mode is used, allowing to observe at once the quasar and several stars dedicated to a precise determination of the spectral PSF, in view of an efficient spatial deconvolution (Courbin et al. 2000, ApJ 529, 1136). This allows us to separate well the quasar spectrum from that of the envelope. 4 to 8 × 1300s exposures of each object were taken, giving total integration times of 5200 to 10400s. The 2D spectra were then sky subtracted, co-added and spatially deconvolved.

The (partial & provisional) answers

- Envelopes discovered around 2 out of 3 radio quiet quasars
- Sizes larger and surface brightnesses fainter than expected
- Envelope luminosities of 10^{43} and 10^{41} erg s^{-1}
- Lyα luminosity of the envelope correlates with that of the Broad Line Region

See the results in Courbin, North et al. 2008, arXiv:0803.2519

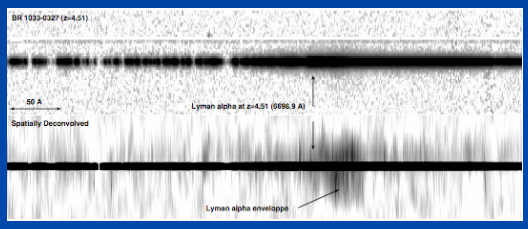

Fig. 1a – Top: Combined ans sky-subtracted FORS2 Spectrum of BR1033-0327. Bottom: spatially deconvolved spectrum, showing the Lyα emission much better. The spatial (vertical) extent is 16''.

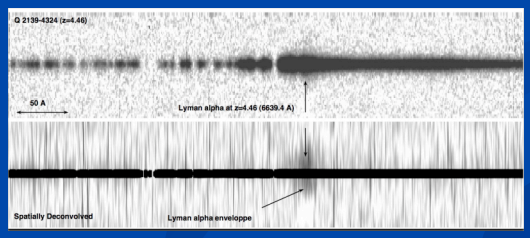

Fig. 1b – Same as a, for Q2139-4324.

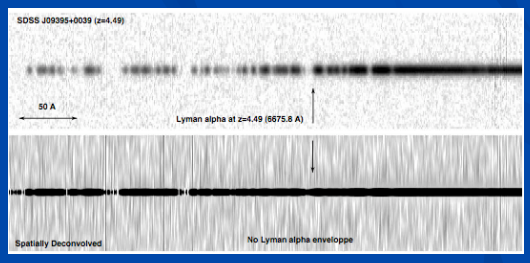

Fig. 1c – Same as a, for SDSS J09395+0039.

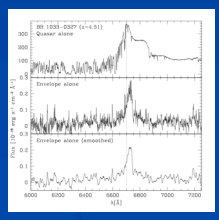

Fig. 2a – BR1033-0327 Top: BLR spectrum. Middle: envelope spectrum Bottom: smoothed (8 Å) envelope spectrum.

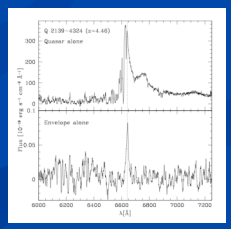

Fig. 2b – Same as a, for Q2139-4324 (except middle panel).

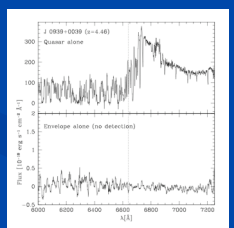

Fig. 2c – same as b, for SDSS J09395+0039.

Object	λ [Å]	mean F_λ [erg s^{-1} cm^{-2} Å^{-1}]	FWHM [Å]	Extent ($''$, kpc)	Surface brightness [erg s^{-1} cm^{-2} $''^{-2}$]	$1-\sigma$ detection limit [erg s^{-1} cm^{-2} Å^{-1}]
BR 1033−0327	6725.0 ± 0.5	4.0(±0.4) × 10^{-19}	50 ± 10	13, 86	7.7(±0.8) × 10^{-19}	2.7 × 10^{-20}
Q 2139−4324	6641.0 ± 0.3	7.2(±1.4) × 10^{-21}	22 ± 2	10, 66	8.0(±1.6) × 10^{-21}	2.5 × 10^{-21}
SDSS J0939+0039	–	–	–	–	–	2.0 × 10^{-20}

Table 1 – Main properties of our Lyα envelopes. The 1-σ detection limit is the standard deviation of the background (after smoothing with a boxcar of 8 Å) integrated along the whole slit, but it is given per Å. Surface brightness is integrated in wavelength and given per arcsec².

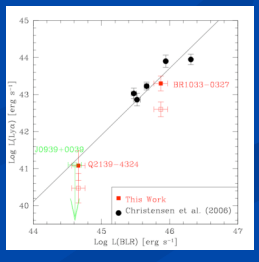

Fig. 3 – Lyα total luminosity of the envelope versus the luminosity of the BLR. Open and full red dots refer to luminosities observed and corrected for slit clipping.

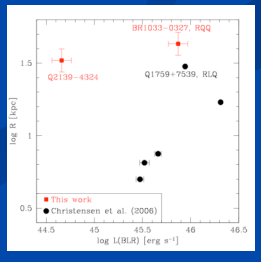

Fig. 4 – Size of the envelope versus the luminosity of the BLR.