PHYSICAL CONDITIONS IN OUTFLOW QUASARS

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ABSTRACT

We present a detailed analysis of several high-redshift ($2.5 \leq z \leq 4.2$) quasars presenting resolved absorption doublets (such as CIV, SiIV and NV) in their spectra, based on high-resolution WHT+ISIS observations: 0217-0854, 0844+0503, 1236+4533 and 1624+3758, which have known radio counterparts observed by the VLA FIRST survey; and 0908+0658 and 1210+5256. Covering factors and column densities of several atomic species in the absorbing gas have been measured by comparison of the residual intensities in the two components of the doublets. From these, the ionisation parameters have been estimated providing constraints on the distance of the gas from the nucleus (for plausible assumed values of electron densities), and therefore the kinetic luminosity of the outflow. We infer that the outflows studied here are not energetic enough to significantly contribute to AGN feedback processes since the maximum percentage of the kinetic luminosity with respect to the bolometric luminosity of the quasar is $\leq 0.003\,\%$.

1. INTRODUCTION

Outflows from Active Galactic Nuclei (AGNs) are an important diagnostic of the physical conditions in the inner regions of AGN. Their kinetic luminosities $\dot{E}_k$ let us describe the role that outflows may play in various AGN feedback mechanisms (e.g. evolution of their host galaxies and enrichment of the intergalactic medium) (Elvis 2006). To derive $\dot{E}_k$, it's necessary to estimate the distance of the outflow from the quasar nucleus.

Broad Absorption Line (BAL) quasars (10 - 20 % of all quasars) are characterised by extended absorption troughs in the blue wings of ionised UV resonance emission lines. The absorption is thought to be caused by outflows of gas with velocities up to ~ 0.2 c (Hewett & Foltz 2003). Since these absorptions span hundreds or thousands of km/s, BALs are likely to be intrinsic to the quasar. However, their distances from the inner regions are still not well constrained. As described e.g. in Arav et al. 1999, we have analysed doublet lines in order to determine the covering factors and the optical depths, and therefore the column densities in the observed absorption feature. From these column densities, the ionisation parameters have been evaluated and, assuming the electron number densities, distances and kinetic luminosities have been estimated.

2. SAMPLE SELECTION

To estimate the ionisation parameter U at a given cloud in the outflow, we require measurements of the column densities of at least two ions e.g. CIV and SiIV. To measure the column density of a given ion, we require observation of at least two unsaturated, unblended absorption lines due to that ion e.g. the CIV 1549-$\AA$ doublet. We therefore selected from the SDSS DR4 catalogue (Data Release 4, Adelman-McCarthy, J. K. et al. 2005) all quasars satisfying the following criteria: (i) $r \leq 19.0$ (to allow spectra with good S:N to be obtained in a reasonable time); (ii) redshift: $2.5 \leq z \leq 4.2$, so that the doublets fall within the range of SDSS ($4000 - 9000\AA$); and (iii) likely, on the basis of visual inspection of the low-resolution SDSS spectra to show velocity-resolved (i.e. probably intrinsic), unsaturated, unblended doublets from the above ions. This yielded a sample of ~ 200 objects showing absorption lines. In this work, we present observations of six of these, listed in Table 1.

Name	RA (J2000) (h:m:s)	Dec (J2000) (d:':")	z	r	$S_{1.4GHz}$ (mJy)
(1)	(2)	(3)	(4)	(5)	(6)
0217-0854	02:17:40.97	-08:54:47.93	2.5712	18.22	5.6
0844+0503	08:44:01.95	+05:03:57.94	3.3465	17.87	7.4
0908+0658	09:08:32.29	+06:58:53.82	3.0729	18.40	
1210+5256	12:10:15.52	+52:56:53.19	3.1943	18.52	
1236+4533	12:36:51.28	+45:33:34.52	2.5594	17.75	1.9
1624+3758	16:24:53.48	+37:58:06.65	3.3802	18.45	56.4

Table 1: Outflow quasars presented in this work. The columns give: (5) SDSS psf (point spread function) magnitude in the r band; (6) FIRST total radio flux density.

3. OBSERVATIONS AND DATA REDUCTION

Medium-resolution (R $\sim$ 7000) spectra of the quasars were obtained with the Intermediate dispersion Spectrograph and Imaging System (ISIS) dual-arm spectrograph on the 4.2m William Herschel Telescope (WHT). The data were reduced in the usual way, using standard packages in IRAF for the bias subtraction, flat fielding, cosmic-ray removal and wavelength calibration.

4. PHYSICAL PARAMETERS OF THE ABSORBERS

4.1. 0217-0854

The BAL quasar 0217-0854, at redshift z = 2.5712, has a known radio counterpart observed by the VLA FIRST survey. Its magnitude is r = 18.22 and the total radio flux density is 5.6mJy. We present the WHT spectra in Fig. 1. The absorber (e), $\sim -18090\,km/s$, is thought to be associated to the central source because in CIV the absorption is well resolved and we find velocity structure. If this absorber were unrelated, i.e. if it were located in the surrounding host galaxy, or in intervening galaxies or clouds that happen to be in the line of sight, all the ions would lack velocity structure. Results for this absorber are shown in Tables 2, 3, & 4.

Ref. abs.	Velocity (km/s)	ion	C	τ	N $(\times 10^{12}\,cm^{-2}/(km/s))$
(1)	(2)	(3)	(4)	(5)	(6)
(e)	18090	SiIV	> 0.74	1.4 ± 0.10	0.32 ± 0.02
		CIV	1.0	$2.7^{+1.2}_{-0.6}$	$3.5^{+1.5}_{-0.8}$
		AlIII	0.35	> 1.8	> 0.64

Table 2: 0217-0854: results for the studied ions of the absorber (e) presented in Fig. 1. The columns give: (2) approximate velocity with respect to the quasar (unsigned); (6) column density N $(\times 10^{12}\,cm^{-2}/(km/s))$ ($N(v) = 3.77 \times 10^{14} f^{-1} \lambda^{-1} \tau(v)$, Savage & Sembach 1991).

Ref abs.	ions	$log\,f$	$log\,U$	U
(1)	(2)	(3)	(4)	(5)
(e)	CIV - SiIV	$2.05^{+0.18\dagger}_{-0.14}$	-1.2 ± 0.1	$0.063^{+0.016}_{-0.013}$
	SiIV - AlIII	< 0.8	$\sim [-3.0, -1.9]$	$\sim [0.013, 0.001]$
	CIV - AlIII	$< 3.0^{\dagger}$	$\sim [-2.8, -1.3]$	$\sim [0.05, 0.0016]$

Table 3: 0217-0854: ionisation parameter estimate for the absorber (e) presented in Fig. 1. The columns give: (3) logarithm of the ionisation fraction $log\,f$; (4) logarithm of the ionisation parameter $log\,U$, determined using the results described in Hamann 1997 (right panel in fig. 2c).

Ref abs.	$log\,U$	R_i (pc)	R_{ii} (pc)	$\dot{E}_{ki}$ $(\Omega_{0.2} ergs^{-1})$	$\dot{E}_{kii}$ $(\Omega_{0.2} ergs^{-1})$	% $(\Omega_{0.2}\%)$
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(e)	-1.2	$0.15 - 9$	$2700 - 27000$	$5 \times 10^{38} - 3 \times 10^{40}$	$9 \times 10^{42} - 9 \times 10^{43}$	≤ 0.003

Table 4: Estimates of the distance R between the nucleus of the quasar 0217-0854 and the absorber (e) and the kinetic luminosity $\dot{E}_k$ of the outflow ($z \sim 2.363$; $\sim -18090\,km/s$). The columns give: (3) distance estimate, R_i, and (5) kinetic luminosity estimate, $\dot{E}_{ki}$, using typical values for the electron densities of the Broad Line Region (BLR) ($n_e \sim 10^{9.5} - 10^{13}\,cm^{-3}$, e.g. Osterbrock 1993, Tavecchio & Ghisellini 2008); (4) distance estimate, R_{ii}, and (6) kinetic luminosity estimate, $\dot{E}_{ki}$, using typical values found recently for outflows in quasars ($n_e \sim 10^{2.5} - 10^{4.5}\,cm^{-3}$, e.g. Dunn et al. 2010, Bautista et al. 2010); (7) maximum percentage of the kinetic luminosity with respect to the bolometric luminosity of the quasar.

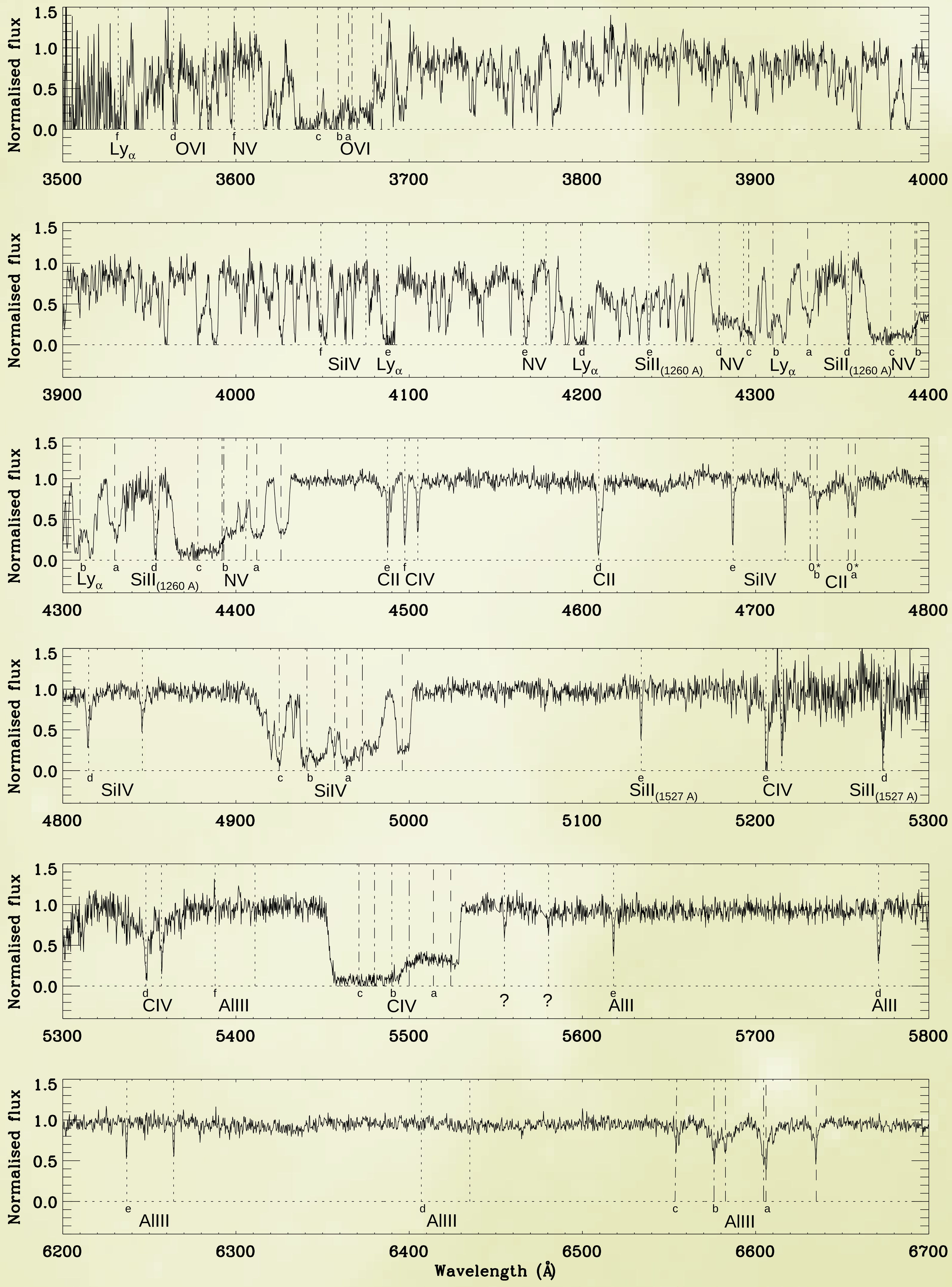

Figure 1: 0217-0854 WHT spectra. The subscripts correspond to the blue component of the following absorbers: (a) $z \sim 2.562$; (b) $z \sim 2.546$; (c) $z \sim 2.534$; (d) $z \sim 2.454$; (e) $z \sim 2.363$; and (f) $z \sim 1.905$.

5. CONCLUSIONS AND FUTURE WORK

We have found that 0217-0854 has absorbers that are extended from 0.15 – 9 pc if we consider that they lie in a Broad Line Region and from 2.7 – 27 kpc if we assume the typical values found recently for outflows in quasars. From these results, we infer that the outflows studied in this quasar are not energetic enough to significantly impact on its evolution or on the intergalactic medium.

Extending this analysis for the totality of the observed sample is our first aim in the near future, improving the global overview of this kind of objects. We are also looking for excited/ground level lines for the same ion in order to estimate more accurately electron density values which will lead to a significant improvement in the distance estimate of the outflows.

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