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BROAD ABSORPTION LINE QUASARS OBSERVED BY THE *ROSAT* PSPC

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ABSTRACT

Recent results from the *ROSAT* All-Sky Survey have shown that broad absorption line (BAL) QSOs are either highly absorbed or underluminous in the soft X-ray bandpass. Here we extend this work by analyzing all known bona fide BAL QSOs observed within the inner 20′ of the *ROSAT* Position Sensitive Proportional Counter. This sample includes both targeted and serendipitous exposures ranging from 8 to 75 ks. Despite these deep exposures, most of the BAL QSOs are undetected and have unusually weak X-ray emission, as evidenced by large optical–to–X-ray slopes α_{ox}. Large values of α_{ox} ($\gtrsim 1.8$) may prove to be a defining characteristic of BAL QSOs. We predict that samples of QSO candidates with large α_{ox} will yield a higher percentage of BAL QSOs, particularly at low redshift. As a corollary, X-ray–selected QSO samples should yield fewer BAL QSOs.

The optical/UV emission line spectra of BAL and non-BAL QSOs are quite similar, suggesting that their *intrinsic* spectral energy distributions are similar as well. Absorption thus seems the likely reason for the X-ray–quiet nature of BAL QSOs. To constrain the total absorbing column of the BAL clouds, we compare our measured soft X-ray fluxes or upper limits with those expected from normal radio-quiet QSOs of comparable optical continuum magnitude and redshift. From sensitive X-ray observations, we derive column densities of $\gtrsim 2 \times 10^{22}$ cm^{-2} for intrinsic cold absorbers of solar metallicity. These new results suggest columns *at least* an order of magnitude larger than the columns previously estimated from optical/UV spectra alone.

Subject headings: galaxies: active — quasars: absorption lines — X-rays: galaxies

1. INTRODUCTION

About 10%–15% of optically selected QSOs have optical/UV spectra showing deep, wide absorption troughs, displaced to the blue of their corresponding emission lines. Occasionally, these broad absorption lines (BALs), seen in the high-ionization transitions of C IV, Si IV, N V, and O IV, are also visible in low-ionization species, like Mg II and Al III. The BALs are found only among the radio-quiet (RQ) QSO population (Stocke et al. 1992) and are suspected to result from a line of sight passing through highly ionized, high column density (log $N_{\rm H} \sim 20$ cm^{-2}) absorbers, flowing outward from the nuclear region at speeds up to 0.1–0.2*c*.

For years it was debated whether BAL QSOs were a different class of QSO or normal RQ QSOs viewed at an orientation traversing a BAL cloud (thus implying that the BAL "covering factor" is 10%–15%). More recently, the low-BAL cloud covering factors and absence of emission lines at the high velocities observed in BAL QSOs (Hamann, Korista, & Morris 1993, hereafter HKM), along with the similarity of emission-line and continuum properties of BAL and non-BAL QSOs (Weymann et al. 1991, hereafter WMFH), suggest that orientation is indeed the cause of the BAL phenomenon, i.e., that *all* RQ QSOs have BAL clouds. Thus, BAL QSOs provide a unique probe of conditions near the nucleus of most QSOs. Still, the geometry, covering factor, temperature, density, metallicity, and ionization parameter of the absorbing clouds are poorly understood from optical/UV (OUV) absorption line studies (Lanzetta et al. 1991). This is because only a few lines are measured (e.g., O VI λ1035, C IV λ1549, N V λ1240), yielding column densities of a few ions but little information on the ionization state. Since the X-ray absorption is relatively insensitive to ionization and depletion (Morrison & McCammon 1983), X-ray spectra give a total column density. Techniques have recently been developed by Mathur (1994) and Mathur et al. (1994) that simultaneously exploit UV and X-ray spectra to constrain the allowed ranges of the BAL cloud conditions. An application of these techniques to BAL QSOs may eventually provide stronger constraints on BAL clouds, but, until recently, the X-ray properties of BAL QSOs as a class were unknown since few reports of X-ray detections of BAL QSOs exist. Furthermore, no homogeneous sample of BAL QSOs with available X-ray data existed. However, Green et al. (1995) recently investigated a sample of 36 BAL QSOs uniformly selected from 908 QSOs observed during the *ROSAT* All-Sky Survey in the Large Bright Quasar Survey (LBQS; see Hewett, Foltz, & Chaffee 1995 and references therein). Using a Monte Carlo technique, they found that the average number of Position Sensitive Proportional Counter (PSPC) counts for BAL QSOs (for an effective total exposure time of about 21 ks) was lower than the corresponding number for carefully chosen comparison samples at least 99.5% of the time. This indicates that BAL QSOs are (1) either highly absorbed, (2) intrinsically underluminous in X-rays, or (3) both. The great similarity of OUV *emission* lines in BAL and non-BAL QSO samples leads us to suspect that their ionizing continua are similar. This, together with known OUV absorption, makes strong absorption seem the likely explanation for the paucity of BAL QSO detections in the soft X-ray bandpass.

In this paper, to better constrain the absorption, we study deep, pointed observations of BAL QSOs by the *ROSAT* PSPC that are available in the public data archive. We choose a sample of high-quality, deep soft X-ray images that provides several detections, as well as much more sensitive flux upper limits for about a dozen BAL QSOs. In every case, we estimate the intrinsic cold column density, $N_{\rm H}^{\rm intr}$,

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necessary to absorb the X-ray emission expected from an average RQ QSO. We also briefly consider the effects of metallicity and ionization on these estimates.

2. SAMPLE

We first generated a list of optical BAL positions from Hewitt & Burbidge (1993), Junkarrinen, Hewitt, & Burbidge (1991), and from an updated list kindly provided by T. Barlow (1995, private communication). From this list, we removed objects that are not listed definitively as BAL QSOs based on analysis of OUV spectra by all these authors. We then cross-correlated our list with the list of *ROSAT* PSPC archived pointings (version 1995 May 18). A matching tolerance of 20′ from each optical BAL position includes both serendipitous and targeted observations but avoids the ribs of the PSPC. This inner area of the PSPC also boasts the narrowest point-source response function, thereby optimizing signal-to-noise ratio (S/N) and decreasing source confusion. Last, we removed from the sample one QSO (0042−267) lying close to a rib and two QSOs (0104+318 and 0413−116) lying less than 1′ from known extended X-ray sources (NGC 383 and Abell 483, respectively). The resulting sample of 12 BAL QSOs is listed in Table 1. Five of these (with off-axis distances less than 1′ in Table 1) were observed serendipitously or as part of a general field, while the rest were targeted observations of the QSO. The resulting sample is neither complete nor uniformly selected, but it does minimize contamination from normal QSOs or from QSOs with narrow-line/intervening absorption systems.

3. DATA AND ANALYSIS

Table 1 shows B magnitudes, redshift, and Galactic column density $N_{\rm H}^{\rm Gal}$, as well as the raw X-ray data for each BAL QSO in our sample. We derived net PSPC source counts using circular apertures with radii $R_{\rm ap}$ (in arcseconds) listed in Table 1. Small radii were sometimes required to avoid nearby unrelated X-ray sources. To compensate for the exclusion of source flux from small apertures, we apply an aperture correction factor to source counts (taken from Fig. 11 of Brinkmann et al. 1994) for both detections and upper limits. Background counts are shown normalized to the source aperture area, although we use much larger areas for background estimation and exclude any overlapping sources. Upper limits to the source counts are set at 3 σ.

For comparison of the observed count rate or its upper limit to that expected from a typical RQ QSO, we first derived an optical luminosity derived from the observed magnitude. Optical luminosities are calculated using the magnitudes listed in Table 1, with $H_0 = 50$ km s^{-1} Mpc^{-1} and $q_0 = 0.5$, and specific optical zero point from Marshall et al. (1984). We include a reddening correction of $E_{B-V} = \max\,[0, (-0.055 + 1.987 \times 10^{-22} N_{\rm H}^{\rm Gal})]$ and $A_V = 3E_{B-V}$. We then predict an intrinsic soft X-ray flux using the slope $\alpha_{\rm ox}$ of a hypothetical power law connecting rest frame 2500 Å and 2 keV, where $\alpha_{\rm ox} = 0.384 \log (l_{\rm opt}/l_x)$. Objects with large $\alpha_{\rm ox}$ thus have stronger optical emission relative to X-ray. We assume $\alpha_{\rm ox} = 1.6$, the mean for RQ QSOs in the *ROSAT* PSPC (Green et al. 1995). Using our predicted soft X-ray flux, we then used the Portable Interactive Multimission Simulator (PIMMS; Mukai 1993) to derive the expected PSPC count rate corresponding to this flux, assuming a power-law model with $\alpha_E = 1.5$ (the mean PSPC α_E for RQ QSOs; Laor et al. 1994) and the Galactic column density. If the expected PSPC count rate from PIMMS was greater than observed (as is the case for all BAL QSOs in our sample), we increased the column density of the absorber in the spectral model until the observed count rate or upper limit was reached. This results in a

TABLE 1

RAW DATA FOR BAL QSOs WITH *ROSAT* PSPC POINTINGS

Name	B^a	z^b	$N_H^{Gal\,c}$ (10^{20}cm^{-2})	PSPC Sequence	Off-Axis Dist (′)	Exposure^d (s)	Counts Source	Counts σ	Counts Bkg	Counts σ	R_{ap} (″)	B mag Refs
0043+008	17.2	2.141	2.03	rp700377	0.3	10858	< 34.0	...	79.8	2.8	90	1
0059−275	18.0	1.594	1.99	rp700121AO2	0.1	15154	< 36.6	...	104.4	3.2	90	1
				rp700121	0.1							
0226−104	17.0	2.256	2.59	rp700114	0.4	9517	< 36.0	...	76.0	3.4	90	1
0312−555	21.8	2.710	1.68	wp701036N00	11.5	56213	< 54.0	...	299.5	3.8	75	2
				wp701036AO1	11.5							
0340−450	18.7	2.004	1.61	rp900495N00	3.7	74784	< 60.0	...	367.40	4.4	75	3
				rp150029	3.7							
0759+651	14.5	0.148	4.33	wp700258	0.1	8354	< 32.4	...	74.0	1.6	90	4
0932+501	17.1	1.914	1.35	rp400243	10.7	10184	< 24.0	...	53.6	1.7	90	1
				rp400244	9.8							
				rp400245	9.8							
1246−057	17.1	2.222	2.10	rp60026	14.7	57591	84.4	15.7	690.1	8.8	45	1
				rp60026AO1	14.7							
				rp60026AO2	14.7							
1309−056	17.2	2.212	2.56	rp700376	11.8	12197	< 34.9	...	89.2	2.4	75	1
1413+117	17.0	2.542	1.78	rp700122	0.1	28066	< 80.1	...	576.7	8.0	120	5
1416−129	15.7	0.129	7.20	wp700527	0.3	9109	3440.	61.	177.7	8.0	120	5
1700+518	15.1	0.288	2.67	rp700123	0.2	8196	< 26.1	...	65.1	2.2	90	5

[a] B magnitude includes BAL k-correction from Stocke et al. (1992).
[b] Redshifts from Korista et al. (1993) when available, otherwise from Hewitt & Burbidge (1993).
[c] N_H^{Gal} from Stark et al. (1992) except for 0043+008 and 1416−129 from Elvis, Lockman, & Wilkes (1989).
[d] Summed exposure time of all listed PSPC sequences.

REFERENCES.—(1) Stocke et al. 1992; (2) Marano, Zamorani, & Zitelli 1988; (3) Boyle et al. 1980; (4) Low et al. 1989; (5) Schmidt & Green 1986.

lower limit to the "observed" column, on the assumption that the absorber is cold gas with solar metallicity. After deriving the ($z = 0$) additional column required to match the PSPC count rate or upper limit for the BAL QSOs in our sample, we then used XSPEC (an X-ray spectral fitting package; Arnaud 1995) to calculate the column density of the absorber at the source redshift z_{em}. Using the 1993 January PSPC response matrix, we first simulated a PSPC spectrum of a QSO with $\alpha_E = 1.5$. This slope is used, together with the corresponding total ($z = 0$) absorption and model normalization found via PIMMS. We then refitted the simulated spectrum with a five-parameter model: (1) Galactic column density (fixed at N_H^{Gal}), (2) intrinsic column density (free), (3) source redshift (fixed at z_{em}), (4) spectral slope (fixed at $\alpha_E = 1.5$), and (5) model normalization (fixed at the PIMMS normalization).

Table 2 shows the aperture-corrected PSPC count rate for each QSO, the derived X-ray luminosity, and α_{ox}. We then list the total column density at $z = 0$ required to obtain that count rate assuming the typical RQ QSO value of $\alpha_{ox} = 1.6$. The next column shows the intrinsic column density, N_H^{intr}, required if the absorber is at the source redshift, with formal 1 σ errors from XSPEC. We find $\alpha_{ox} > 1.8$ and $N_H^{intr} > 2 \times 10^{22}$ cm^{-2} for all the bona fide BAL QSOs with sensitive X-ray observations (but see notes on PG 1416−129 and 0312−555 in § 5).

We also tested our technique on a sample of 10 RQ QSOs studied by Laor et al. (1994). We found a sample mean of $\alpha_{ox} = 1.45 \pm 0.08$. To obtain the observed *ROSAT* PSPC count rates, none of the 10 QSOs required an additional ($z = 0$) column more than 1×10^{20} cm^{-2} over the Galactic value. Indeed, eight of the QSOs had higher PSPC count rates than we predicted, showing that our choice of $\alpha_{ox} = 1.6$ results in conservative estimates of the absorption. All our calculations assume $\alpha_E = 1.5$ and a cold absorber at solar metallicity. In the following section, we discuss the effects of these assumptions.

4. ESTIMATING THE INTRINSIC ABSORBING COLUMN N_H^{intr}

Since X-ray spectra cannot be adequately modeled for the weak or undetected QSOs in our sample, we must make several assumptions in order to derive an estimate of the intrinsic column. Essentially, we model the expected X-ray flux f_x as a function $f(B, N_H^{Gal}, \alpha_{ox}, \alpha_E, Z, U, N_H^{intr})$, where Z is the metallicity expressed in solar units and U is the ionization parameter. In most cases here (the nondetections), we know only B and N_H^{Gal}, and we assume values for the next four parameters (α_{ox}, α_E, Z, and U) to derive N_H^{intr}. In the following discussion, we briefly examine the effects of these four parameters on our results.

4.1. *Optical-to-X-Ray Slope* α_{ox}

Our assumed value of α_{ox} is 1.6, which we take to represent the intrinsic spectral energy distribution (SED) of the QSO, i.e., before absorption by BAL material. Since there may already be some absorption in normal RQ QSOs affecting this value, we are in effect deriving the additional absorption above a typical RQ QSO, rather than relative to the bare continuum. However, the difference is probably not important, since the majority of optically selected QSOs observed in soft X-rays to date show little evidence for any substantial N_H^{intr} (e.g., Fiore et al. 1994; Bechtold et al. 1994; Walter & Fink 1993).

Smaller assumed values of α_{ox} would increase our estimated values of N_H^{intr}. For RQ QSOs, a range of values from about 1 to 2 is observed (Green et al. 1995). The difference between our assumed value of 1.6 and the extremes of this range represents a factor of up to 30 in our predicted broadband fluxes. The lower than expected soft X-ray fluxes of BAL QSOs could be entirely accounted for without excess absorption if the intrinsic SEDs of BAL QSOs have $\alpha_{ox} \gtrsim 1.8$. However, given such different SEDs, we would expect much larger differences between the continua and emission lines of BAL and non-BAL QSOs than are seen (WMFH). On the other hand, there is as yet no detailed study of whether large differences in UV spectral properties are indeed seen in QSOs with widely divergent α_{ox}. Such a study is now underway using *IUE* and LBQS spectra (Green et al. 1996). The bottom line is that our assumed value of α_{ox} probably results in conservative estimates of the intrinsic absorption, as determined above from tests on a similarly sized sample of radio-quiet non-BAL QSOs from Laor et al. (1994).

TABLE 2

DERIVED PROPERTIES OF BAL QSOs WITH *ROSAT* PSPC POINTINGS

Name	Count Rate (corrected)	l^a_{2keV}	α_{ox}	($z = 0$)	N^b_H ($z = z_{em}$)	error
0043+008	<0.0034	<27.00	>1.89	35	560	230
0059−275	<0.0027	<26.55	>1.83	20	180	100
0226−104	<0.0041	<27.24	>1.83	30	500	220
0312−555[c]	<0.0019	<26.70	>1.36	...	...	...
0340−450	<0.0009	<26.27	>1.90	30	420	140
0759+651	<0.0042	<24.66	>2.13	200	280	50
0932+501	<0.0025	<26.62	>2.00	55	790	380
1246−057	0.0019	26.62	1.98	65	1240	130
1309−056	<0.0032	<27.09	>1.84	30	480	200
1416−129[c]	0.3863	26.56	1.40	...	...	...
1413+117	<0.0029	<27.08	>1.93	40	920	160
1700+518	<0.0034	<25.02	>2.30	250	460	80

[a] Monochromatic luminosity at 2 keV in ergs s^{-1} Hz^{-1}.

[b] Inferred intrinsic column density in units 10^{20} cm^{-2}.

[c] See discussion in § 5.

4.2. *X-Ray Spectral Slope* α_E

If the intrinsic X-ray spectra were not as steep as we assume (i.e., if $\alpha_E < 1.5$), then our estimates of $N_{\rm H}^{\rm intr}$ would be systematically lower. Fits to high S/N X-ray spectra of low-redshift QSOs yield values of α_E from ~ 1.0 to 2.2 about the mean of $\alpha_E \sim 1.5$ that we use here (Laor et al. 1994; Fiore et al. 1994). Such a reasonable variation of the assumed spectral slope in the X-ray bandpass makes no more than a 20% difference in the derived broadband flux and, correspondingly, no more than a $\sim 30\%$ difference in the derived $N_{\rm H}^{\rm intr}$.

A strong, intrinsic soft excess or spectral curvature, typically below rest-frame energy 0.5 keV, may exist in a large fraction of RQ QSOs (Schartel et al. 1995). Our analysis is not affected for all but the three lowest redshift QSOs in our sample, since the PSPC bandpass excludes this spectral region. For these three QSOs, our assumption of a simple power law of $\alpha_E = 1.5$ results in a *more conservative* lower limit to $N_{\rm H}^{\rm intr}$.

4.3. *Ionization Parameter U*

We have assumed a cold, neutral gas as the intrinsic absorber. The soft X-ray opacity of the absorbing gas decreases with increasing ionization state, so that our assumption results in conservative estimates of the actual gas column. If, instead of neutral gas, we assume $U \sim 0.1$, based on photoionization models of the OUV data (HKM), then our typical result of a few times 10^{22} cm^{-2} would rise by about an order of magnitude. Even higher ionization parameters are likely to be required to reproduce observed emission-line spectra; $U \sim 0.1$ was derived assuming lower column densities than we find here. Newer theoretical calculations with column densities $N_{\rm H} \gtrsim 10^{22}$ cm^{-2} require $1 \lesssim U \lesssim 60$ (Murray et al. 1995; Hamann, Zuo, & Tytler 1995).

4.4. *Metallicity Z*

We have assumed solar metallicity. Emission-line ratios in high-redshift QSOs suggest higher Z values in non-BAL QSOs (e.g., Hamann & Ferland 1993). Studies of the chemical enrichment of gas in BAL QSOs (e.g., HKM) support values between 2 and 10 solar. Our estimated values of $N_{\rm H}^{\rm intr}$ are inversely proportional to the assumed metallicity. Unless the nuclear environment typically has abundances 100 times solar (Turnshek 1988), we still require column densities at least an order of magnitude higher than typical for RQ QSOs (Fiore et al. 1994), all else being equal.

5. NOTES ON INDIVIDUAL OBJECTS

5.1. *0312−555 = MZZ 9592*

At $B = 21.8$, this is the optically faintest QSO in our sample. Even with a total PSPC exposure time of 56 ks, the X-ray observation is not sufficiently sensitive to put interesting limits on $\alpha_{\rm ox}$ or $N_{\rm H}^{\rm intr}$ for this object. An exposure time of at least ~ 250 ks would be required.

5.2. *0759+651 = IRAS 07598+6508*

This object is a member of the rare class of low-ionization BAL QSOs. These show a strong blend of broad absorption and emission lines in both low and high states of ionization. It is also an extreme (optical) Fe II emitter, and an "ultraluminous" IRAS source. Hines & Wills (1995) find the SED to be reddened by $E(B-V) \sim 0.12$ relative to non-BAL QSOs. Sprayberry & Foltz (1992) find that such reddening is typical for low-ionization BAL QSOs and accounts for the spectral differences from the generally bluer high-ionization BAL QSOs.

Assuming a gas-to-dust ratio given by Burstein & Heiles (1978), and the same reddening equation used in our calculation of $L_{\rm opt}$, the observed OUV reddening implies an equivalent Galactic column of only $\sim 10^{21}$ cm^{-2}. From our X-ray analysis, we find a ($z = 0$) column greater than 2.0×10^{22} cm^{-2}. This illustrates that the absorber is probably warm—sufficiently ionized, so that its effects are not seen in the OUV, and with a low dust-to-gas ratio. A low dust-to-gas ratio might seem strange in an IRAS QSO where much of the far-IR luminosity is expected to be from warm dust (possibly merger related); however, much of the IR-emitting region may be extranuclear.

5.3. *1246−057*

Based on the PSPC image, there appear to be two sources near to the optical QSO position. Source A is at $12^{\rm h}49^{\rm m}3\overset{\rm s}{.}1$ and $05°59'13\overset{''}{.}0$, only 14" from the optical QSO position. Source B, at $12^{\rm h}49^{\rm m}14\overset{\rm s}{.}7$ and $06°00'34\overset{''}{.}6$, is 77" from the optical QSO position and has no obvious optical counterpart on the POSS. We assume that source A is the BAL QSO. Net counts in the hard (0.41–2.45 keV) band are 74 ± 12. The soft (0.12–0.40 keV) band shows only a 3 σ upper limit of 32.4 counts.

Although this is one of only two detections (see PG 1416−129 below) in our sample, it still shows a value of $\alpha_{\rm ox}$ that is at the extreme X-ray weak end of the observed range for QSOs. The intrinsic column we derive, 1.2×10^{23} cm^{-2}, is the highest in the sample. This indicates that our lower limits to $N_{\rm H}^{\rm intr}$, in the case of nondetections, are probably conservative.

5.4. *1416−129 = PG*

PG 1416−129 is a strong detection that has been analyzed by deKool & Meurs (1994). Their results for the *ROSAT* bandpass were quite typical for a RQ QSO (α_E = 1.2), while earlier *Ginga* results were very flat ($\alpha_E \approx 0.1$, Williams et al. 1992). The 4 yr separation of those observations, however, could render the data difficult to interpret, since flat-spectrum QSOs in particular can vary enormously. The BAL classification was originally awarded by Turnshek & Grillmair (1986), based on a single *IUE* spectrum in each of the SWP and LWR instruments. However, we have examined the higher quality, optimally extracted and co-added spectrum of PG 1416−129 of Lanzetta, Turnshek, & Sandoval (1993), and we believe that the object is *not* a BAL QSO. At the very least, it unquestionably shows the weakest UV absorption of any QSO in our sample. A *Hubble Space Telescope* spectrum would resolve the issue once and for all.

Using the standard technique we have described (which assumes $\alpha_E = 1.5$ and only $N_{\rm H}^{\rm Gal}$), we derive an expected count rate consistent with that observed. That is, no $N_{\rm H}^{\rm intr}$ is required. Furthermore, $\alpha_{\rm ox}$ for this QSO is on the *low* (X-ray bright) end of the range for RQ QSOs. These X-ray results, consistent with deKool & Meurs (1994), thus also suggest that PG 1416−129 is not a bona fide BAL QSO.

6. CONCLUSIONS

Using deep-pointed observations from the *ROSAT* PSPC, we demonstrate that BAL QSOs are weak in the soft X-ray bandpass in comparison with RQ QSOs with normal

OUV spectra. The only object in our sample with a sensitive X-ray observation that is not anomalously weak in the *ROSAT* PSPC bandpass is PG 1416−129, which has a low value of α_{ox} and thus requires no intrinsic absorption. However, of all the QSOs in our sample, PG 1416−129 has the weakest BALs. Consideration of optimally extracted *IUE* data and our *ROSAT* analysis leads us to propose that it is not a bona fide BAL QSO.

True BAL QSOs have proved notoriously difficult to detect in X-rays, but evidence, until recently, has been mostly anecdotal. As an example, Bregman (1984) obtained *Einstein* IPC observations of three BAL QSOs and reported detection of only one, UM 232, that showed no evidence of an absorption cutoff. It turns out that the X-ray source is not UM 232 but a low-redshift, non-BAL QSO projected nearby (Junkkarinen, Barlow, & Cohen 1993). Our work extends and complements that of Green et al. (1995). Their sample of 36 BAL QSOs was chosen from a large uniformly selected QSO sample (the LBQS) and forms the most "complete" sample ever observed in X-rays. The short (∼600 s) exposure times of the *ROSAT* All-Sky Survey meant that the upper limits (for 35 of the 36 QSOs) were not very sensitive. By stacking the X-ray data, they achieved a total exposure time of about 21 ks. By using the mean $N_{\rm H}^{\rm Gal}$ and redshift for that sample, we find here that no intrinsic column is required within the large errors. However, Green et al. (1995) were able to show that the BAL QSO sample was X-ray quiet at the 99.5% level compared with carefully chosen RQ QSO samples. Although the sample we study here is by nature much more heterogeneous, the mean exposure time of ∼25 ks for *each* object means that we are able to provide much more interesting limits ($\alpha_{ox} > 1.8$) on the optical–to–X-ray slope of bona fide BAL QSOs with sensitive X-ray observations.

We speculate that large values of α_{ox} may prove to be a defining characteristic of BAL QSOs. At the very least, we predict that samples of QSO candidates with large α_{ox} will yield a higher percentage of BAL QSOs, particularly at low redshift, where BALs are less easily detected in the optical and X-ray surveys are more sensitive to low-luminosity objects. As a corollary, X-ray–selected QSO samples should yield fewer BAL QSOs.

Several arguments in the literature suggest that BAL QSOs are not a separate population ∼10% as large as normal RQ QSOs, but rather RQ QSOs viewed along a line of sight through an absorber typified by a ∼10% covering fraction. First, the emission-line parameters indicate similar ionizing continua in both BAL and non-BAL QSOs (WMFH). Also, constraints on the covering fraction of BAL QSOs (HKM) suggest that all RQ QSOs have BAL regions. In any case, the intrinsic spectral energy distributions of BAL QSOs are likely to be similar to their unabsorbed analogs, but BAL QSOs provide a special view into the gasdynamics around normal RQ QSOs. Although with these data we cannot definitively identify the OUV and X-ray absorbers as the same material, based on the arguments just presented, we expect that the large observed values of α_{ox} in BAL QSOs may be caused by absorption by high column density, ionized, outflowing material along the line of sight. If this is indeed the main difference between BAL QSOs and normal RQ QSOs, the intrinsic absorbing columns in BAL QSOs are more than 100 times higher. Using a sample of 12 QSOs observed in the soft X-ray regime by the *ROSAT* PSPC, we place high lower limits on this absorption of $N_{\rm H}^{\rm intr} > 2 \times 10^{22}$ cm^{-2} for 10 QSOs. Of the two that do not require excess absorption, one is at best a marginal BAL QSO (1416−129), while the other (0312−555) has an X-ray observation too shallow to provide sensitive limits to $N_{\rm H}^{\rm intr}$. The one detected, definitive BAL QSO, 1246−057, yields the highest column estimate of all, $N_{\rm H}^{\rm intr} = 1.2 \times 10^{23}$ cm^{-2}.

We note that some variability has been seen in the BAL spectra of three QSOs in our sample. Smith & Penston (1988) found changes in the BALs of 1246−057 and possibly 1309−056 at the ∼20% level, indicating lower limits to column changes of only about 10^{14} cm^{-2}. A demonstration of correlated variability between BALs and soft X-ray flux would provide more evidence that the UV and soft X-ray absorbers are physically associated but is a daunting task given the weak X-ray fluxes. The case for 1413+117 is more complicated since it is gravitationally lensed (Hutsemekers 1993).

Most models for BAL QSOs (e.g., Arav, Li, & Begelman 1994) have been tailored to reproduce the columns inferred from OUV data alone. At least one recent model (Murray et al. 1995) predicts a column density of 10^{23}–10^{24} cm^{-2}, consistent with the total absorbing columns we derive here. Murray et al. (1995) explain BAL spectra in QSOs as the result of a (nearly edge-on) line of sight along an accretion disk, where the inner edge of a radiatively accelerated wind entrains dense gas off the disk. The large column and warm ionization state of this gas blocks the soft X-rays from the nucleus but transmits UV photons. In this way, cloud material farther out can continue to be radiatively accelerated to ∼0.1c, since its CNO ions will not be entirely stripped by the soft X-ray emission. This model is consistent with our findings here of very high intrinsic column densities in BAL QSOs.

The much lower absorbing columns (e.g., $N_{\rm H} \sim 10^{19}$–10^{20}) inferred for the BAL clouds from the OUV data (HKM; Turnshek 1988) are such that, a priori, we would have expected very little soft X-ray absorption ($\tau \ll 1$). Soft X-ray observations thus prove useful in constraining the total line-of-sight column. If the BAL QSO phenomenon is indeed only a viewing angle effect, then, in the hard X-ray range (>3 keV), BAL QSOs should have spectral slopes similar to normal RQ QSOs. Some early evidence for this is that an *Advanced Satellite for Cosmology and Astrophysics* (*ASCA*) spectrum of the prototype BAL QSO, PHL 5200, is best fitted using a typical RQ QSO power law with large intrinsic absorption, $N_{\rm H}^{\rm intr}$ a few times 10^{23} (Mathur, Elvis, & Singh 1995). We have been awarded *XTE* time to further pursue hard X-ray studies of BAL QSOs.

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