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TIME-VARIABLE INTRINSIC ABSORPTION LINES IN THE QUASI-STELLAR OBJECT Q2343+125

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ABSTRACT

We discuss high-resolution Keck Observatory spectra of an intrinsic absorption-line system at redshift $z_a \approx 2.24$ in the radio-quiet QSO Q2343+125 ($z_e = 2.515$). The absorber's physical relationship to the QSO is confirmed by time-variable line strengths and partial line-of-sight coverage of the QSO continuum source. The N V, C IV, and Si IV doublets varied in unison by factors of $\gtrsim 4$ in less than 0.3 yr in the QSO rest frame. The resolved C IV doublet ratios show that the absorber occults $\lesssim 20\%$ of the QSO continuum source; therefore, the absorbing clouds are likely to have characteristic sizes less than 0.01 pc. There is evidence for smaller coverage fractions when the lines were weaker, which could explain the line-strength changes. Lower ionization species such as C II and Si II are not detected. The Lyα line at $z_a \approx 2.24$ is contaminated by the dense forest of cosmologically intervening absorption lines, but also appears to be weak or absent. The large uncertainties in the H I column prevent reliable constraints on the metal abundances.

The $z_a \approx 2.24$ lines clearly form in high-velocity ejecta from the QSO. The line profiles are smooth and rounded, with FWHM ~ 400 km s^{-1} and centroids shifted $-24,000$ km s^{-1} from the QSO emission redshift. Several narrow-line systems are present inside the broader absorption profiles, but they did not vary in strength and may be due to intervening gas. The large-amplitude variability, low coverage fractions, and large ratio of centroid to FWHM velocities imply different outflow properties than those inferred from the broad absorption lines (BALs) in other sources. Nonetheless, the ejecta identified by the $z_a \approx 2.24$ absorber could be related to the BAL phenomenon and could be ubiquitous in QSOs if the gas subtends a small fraction of the sky as seen from the emission source(s).

Subject headings: quasars: absorption lines — quasars: individual (Q2343+125)

1. INTRODUCTION

Absorption lines in QSO spectra are generally divided into three empirical categories: narrow lines far from the emission redshift ($z_a \ll z_e$), narrow "associated" lines near the emission redshift ($z_a \approx z_e$), and broad absorption lines (BALs) near the emission redshift but sometimes also "detached" and/or extending to maximum velocities above 30,000 km s^{-1}. The delineation of these categories is intended to correlate with the physical nature of the absorbers. For example, BALs clearly form in high-velocity winds that are intrinsic to QSO environments. Narrow $z_a \ll z_e$ lines are most likely due to cosmologically intervening gas, while $z_a \approx z_e$ systems could be either intervening or intrinsic. We are involved in a program to identify and study the various intrinsic absorbers (see also Hamann et al. 1997 and Barlow & Sargent 1997).

Some QSO absorption systems likely to be intrinsic do not fit into any of the standard empirical categories. Their lines are too broad and/or too far from the emission redshift to fit most $z_a \approx z_e$ definitions (Foltz et al. 1987; Anderson et al. 1987), yet too narrow or too weak to meet BAL criteria (Weymann et al. 1991). The frequency of these features in QSO spectra is not yet known, but, by analogy with current models of the BALs (cf. Hamann, Korista, & Morris 1993 and references therein), the outflows (or outflow components) that produce them might be ubiquitous in QSOs if they subtend a small fraction of the sky (i.e., a small fraction of 4π sr) as seen from the emission source(s).

The radio-quiet QSO Q2343+125 ($z_e = 2.515$; Sargent, Boksenberg, & Steidel 1988, hereafter SBS) contains an interesting example of this type of unclassified absorption. SBS detected a relatively broad absorption feature in this source that appeared resolved but very weak in their 90 km s^{-1} resolution spectra. They attributed this feature to C IV at $z_a \approx 2.24$ and suggested that it is intrinsic to the QSO, requiring ejection velocities of roughly 24,000 km s^{-1}. Here we describe high-resolution spectra of the $z_a \approx 2.24$ system obtained at the W. M. Keck Observatory. The main results, showing time-variable line strengths, partial line-of-sight coverage of the emission source(s), and smooth, rounded line profiles, confirm the identification with intrinsic high-velocity ejecta.

2. OBSERVATIONS AND DATA REDUCTIONS

We observed Q2343+125 on 1994 September 24 and 25 and 1995 October 18 with the High Resolution Echelle Spectrograph (HIRES) on the 10 m Keck I telescope. In 1994 September a slit width projected to 1".15 on the sky provided a resolution of 8.8 km s^{-1} across 4 pixels on the Tektronix 2048 × 2048 CCD. In 1995 October a 0".86 slit provided 6.6 km s^{-1} resolution across 3 CCD pixels. Two instrument setups with different grating tilts provided complete spectral coverage from $\lesssim 3900$ to above 6000 Å in 39 echelle orders. The total integration times were 5.0 hr in 1994 September and 2.5 hr in 1995 October, with small gaps between the echelle orders at long wavelengths receiving half to one-third of those total times. The 1994 September spectrum typically has a $\sim 50\%$ higher signal-to-noise ratio than the 1995 October data because of the wider slit and longer exposure time.

The data were reduced by standard techniques using software developed by one of us (T. A. B.; see Barlow & Sargent 1997). The spectra are not flux calibrated and do not have reliable slopes across the broad emission line profiles, which

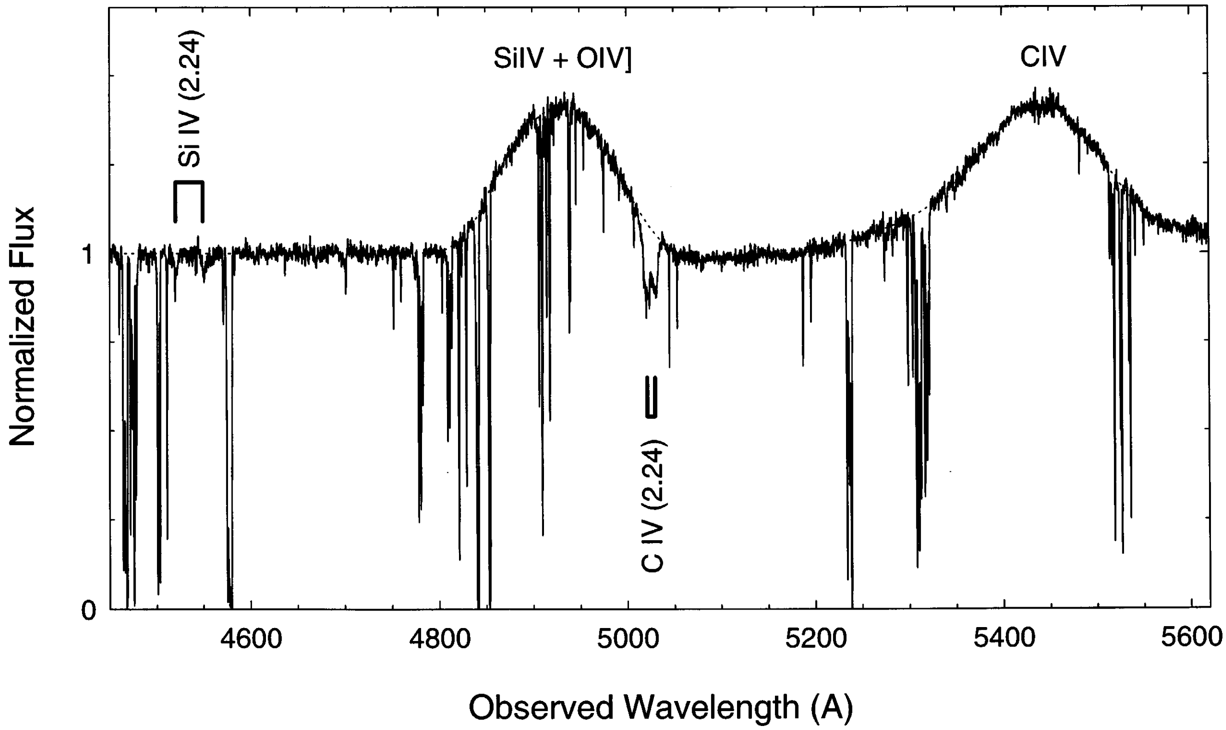

FIG. 1.—1995 October HIRES spectrum of Q2343+125 spanning the C IV and Si IV + O IV] broad emission line wavelengths. The $z_a \approx 2.24$ doublets of Si IV λλ1394, 1403 and C IV λλ1548, 1551 are marked above and below. The data are normalized to unity in the continuum and scaled to match the emission lines measured by SBS at wavelengths $\gtrsim$4800 Å (see § 2). The dotted curve defines the effective continuum used to measure the absorption lines.

span several HIRES echelle orders. We therefore used the spectrum measured by SBS, kindly provided by C. C. Steidel and W. L. W. Sargent, to calibrate the HIRES data and restore the emission-line profiles. The SBS spectrum, obtained with the Double Spectrograph at Palomar Observatory on 1984 October 26, covers ~4760–6000 Å at a resolution of ~90 km s^{-1}. We forced the HIRES spectrum outside the absorption lines to match the SBS data by fitting both with polynomials and multiplying the normalized HIRES spectrum by the SBS fit.[1] The recalibrated HIRES spectrum illustrates the relationship of the C IV and Si IV absorption features to the broad emission lines as they appeared in 1984 October.

Broadband photometry obtained by us at the Lick Observatory 40 inch (1 m) telescope in 1994 August showed that Q2343+125 had $V = 17.1$ mag at that time. We have no reliable information on the continuum or emission-line fluxes in 1984 or 1995.

3. RESULTS

Figure 1 shows part of the 1995 October HIRES spectrum of Q2343+125 calibrated to match the SBS data (§ 2). At wavelengths $\lesssim$4800 Å, beyond the range of the SBS data, the HIRES spectrum is simply normalized to unity. The effective continuum used to measure the absorption lines is shown by the dotted curve in the figure. The resolution of the HIRES data is much greater than the resolution of this plot. We therefore smoothed the spectrum by 25 applications of a binomial smoothing algorithm, which lowers the pixel-to-pixel noise but also slightly reduces the depth of some of the narrow absorption lines. The $z_a \approx 2.24$ doublets of Si IV λλ1394, 1403 and C IV λλ1548, 1551 are marked above and below, and the broad emission lines of Si IV + O IV] and C IV are labeled near their peaks. Many of the unmarked narrow lines are due to C IV near the emission redshift, including a group with $z_a > z_e$ at ~5530 Å and a large cluster at ~5310 Å belonging to a damped Lyα system. These features will be discussed in forthcoming papers.

Here we focus on the broad system at $z_a \approx 2.24$, which changed dramatically in strength between the three observations (one by SBS and two by us with HIRES). Figure 2 compares the C IV and Si IV doublets measured in 1995 October to the SBS measurement (Fig. 2*a* for C IV only) and to the 1994 September HIRES results (Figs. 2*b* and 2*f*). The data are plotted on a velocity scale appropriate for the short-wavelength doublet members relative to the emission redshift, $z_e = 2.515$. The velocity shifts here and throughout this paper are computed with the relativistic correction. Figures 2*c* and 2*g* plot the ratio of the two HIRES spectra. The absence of narrow lines in this ratio shows that they did not vary between the two observations. We therefore used the narrow features in the 1994 September spectrum, where they are relatively more prominent and the signal-to-noise ratio is higher, to remove these lines from the 1995 October data. Specifically, we interpolated across the tops of the narrow profiles to produce a broad-line–only spectrum for 1994 September. We then divided the narrow lines extracted from this spectrum into the 1995 October data to produce a broad-line–only spectrum for that epoch. The

[1] These additional manipulations were performed with the IRAF software, which is distributed by NOAO under contract to the NSF.

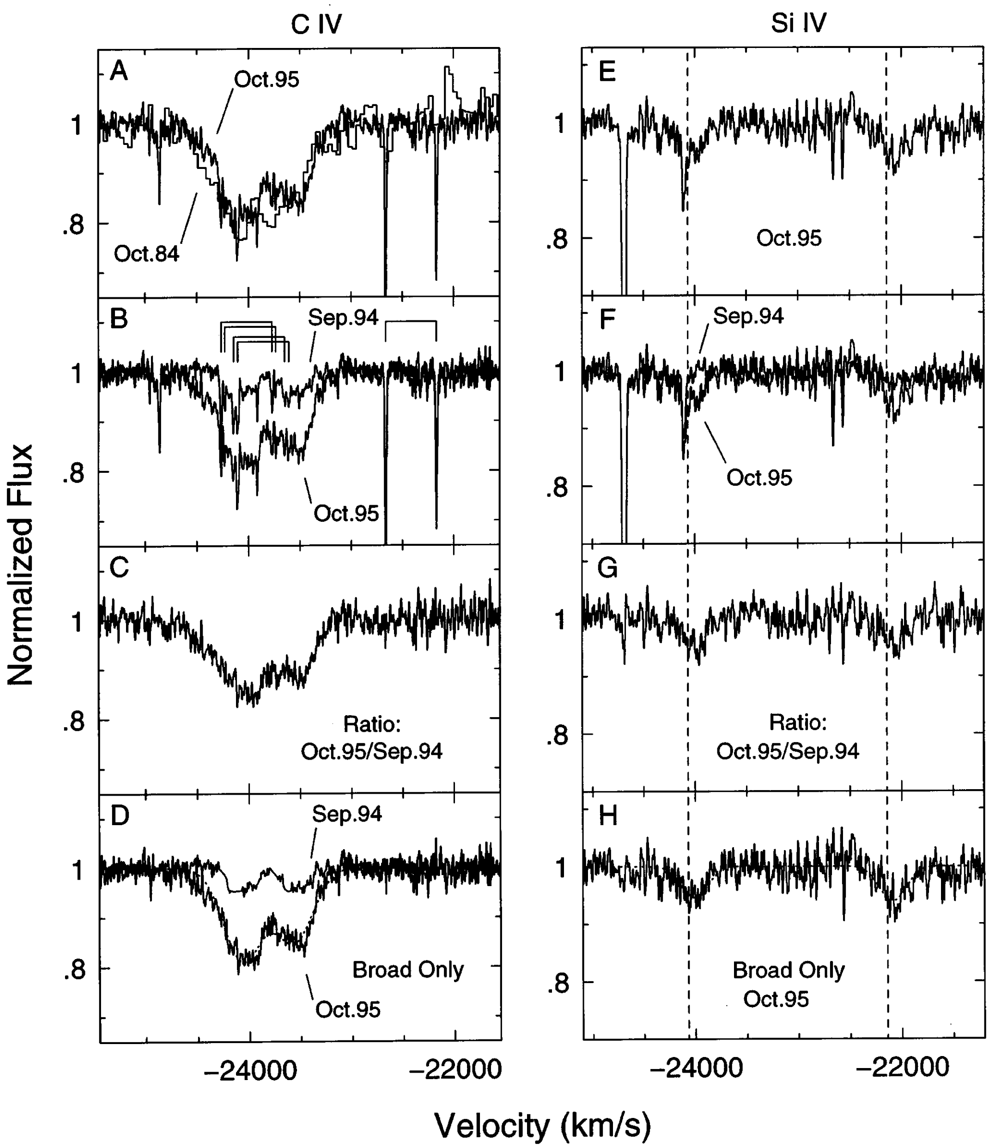

FIG. 2.—Line profiles of C IV $\lambda\lambda$1548, 1551 (*left*) and Si IV $\lambda\lambda$1394, 1403 (*right*) at $z_a \approx 2.24$ are shown on a velocity scale relative to the QSO emission redshift ($z_e = 2.515$). The velocities are appropriate for the short-wavelength doublet members. Note the slightly different vertical scales and velocity intervals between the left- and right-hand windows. The top two panels on both sides (*a*, *b* and *e*, *f*) compare observations on different dates. Several narrow C IV systems are marked by brackets in (*b*). Panels *c* and *g* show the ratio of the two HIRES spectra, and the bottom panels, (*d*) and (*h*), plot the spectra with the narrow lines removed. The dotted curves in the bottom panels are single-Gaussian fits. See § 3.

results are shown in Figures 2*d* and 2*h*. The dotted curves in those panels are single-Gaussian fits to each doublet component.[2] The fits were constrained to have the same FWHM and redshift within each doublet.

Figure 3 shows the HIRES spectra across Lyα and N V $\lambda\lambda$1239, 1243 in the $z_a \approx 2.24$ system. These features lie in the dense forest of intervening Lyα absorption lines, which are evident in the figure. The broad N V doublet is clearly present at $z_a \approx 2.24$ (Figs. 3*a* and 3*b*). The dotted curve in Figure 3*a* shows a Gaussian fit to N V λ1243 in 1995 October, plus an identical Gaussian (not fitted) at the position of λ1239. The Lyα line at $z_a \approx 2.24$ (Figs. 3*c* and 3*d*) is badly contaminated by intervening lines, but it cannot be substantially stronger than the N V or C IV features. For comparison, Figure 3*c* shows the Gaussian fit to C IV λ1548 at the velocity expected for Lyα.

Table 1 provides various measured quantities for each line in the $z_a \approx 2.24$ system: the rest wavelength ($\lambda_{\rm rest}$ in Å), the centroid wavelength ($\lambda_{\rm obs}$; in Å—vacuum heliocentric), the corresponding redshift (z_a) and velocity shift from $z_e = 2.515$ (V_a in km s^{-1}), the rest equivalent width (REW; in Å), and the full width at half-minimum (FWHM in km s^{-1}). The C IV measurements pertain to just the broad components in the HIRES spectra, after removal of the narrow features (Fig. 2*d*). We did not measure the C IV lines in the SBS spectrum, but it is evident from Figure 2*a* that they had essentially the same centroid, REW, and FWHM in 1984 October as in 1995 October. Separate centroids and REWs were derived for the blended C IV components by splitting the equivalent width integration at the wavelength corresponding to the intensity peak between the absorption minima (i.e., at roughly $-23{,}800$ km s^{-1} in Fig. 2). In all

[2] The Gaussian fits were performed with the spectral fitting software SPECFIT, written by G. A. Kriss and distributed by NOAO with the IRAF package.

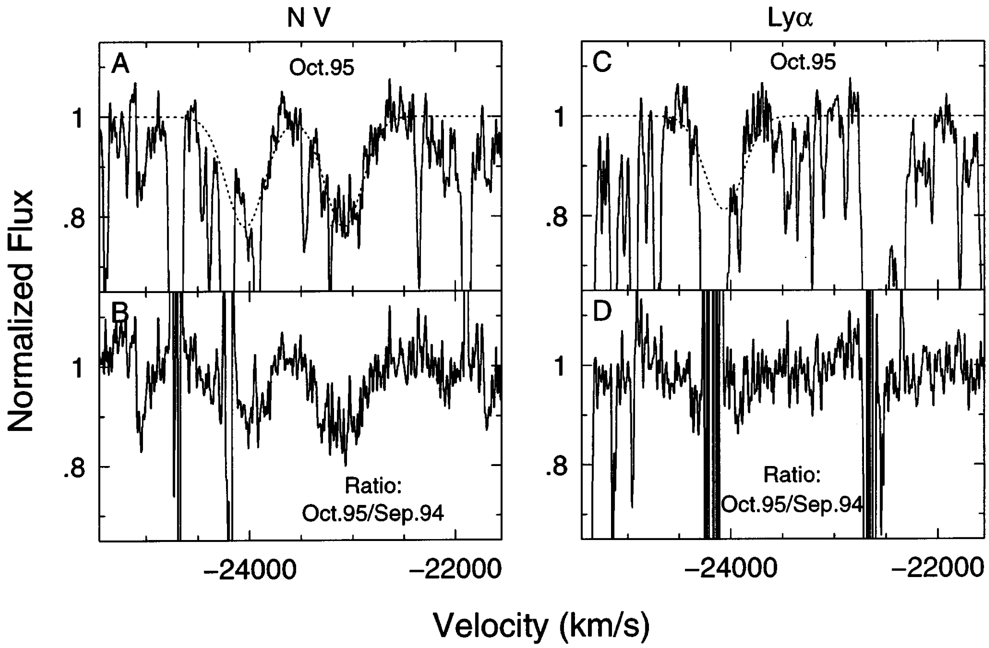

FIG. 3.—Line profiles of N V λλ1239, 1243 (*left*) and Lyα (*right*) at $z_a \approx 2.24$ are shown on a velocity scale relative to the emission redshift. Both spectral regions are badly contaminated by intervening Lyα absorption lines. The Lyα line in the $z_a \approx 2.24$ system is not clearly present. See Fig. 2 and § 3.

cases, the centroids and REWs are within a few percent of the values derived from the Gaussian fits shown in Figure 2 and 3. All of the FWHMs in Table 1 are from the fitted Gaussians. The uncertainties listed in the table are due strictly to photon counting statistics. The actual uncertainties are dominated by the continuum placement and, for C IV only, the doublet blending. Repeated measurements indicate that the actual 1 σ uncertainties in the REW and FWHM are closer to ~10% for C IV and 15%–20% for N V and Si IV.

We searched all three spectra for lines of other ions in the $z_a \approx 2.24$ system, including C II λ1335, Si II λλ1260, 1527, etc. These features are not present with conservative upper limits of REW $\lesssim 0.1$ Å.

4. ANALYSIS OF THE BROAD $z_a \approx 2.24$ SYSTEM

The thermal velocity of carbon is $\gtrsim 4.5$ km s^{-1} for gas temperatures $\gtrsim 15{,}000$ K. This minimum velocity is comparable to the ~6.6 km s^{-1} spectral resolution in 1995 October, leaving little prospect for strong narrow lines undetected in those data. We will assume, therefore, that all of the broad $z_a \approx 2.24$ profiles are "fully" resolved in at least the 1995 October spectrum.

4.1. *Implications of Time-Variability*

Figures 2 and 3 and Table 1 show that the broad C IV lines at $z_a \approx 2.24$ weakened by a factor of ~4 between 1984 October and 1994 September, and then strengthened again with N V and Si IV by roughly the same factor by 1995 October. The narrow lines inside the broad troughs did not vary, indicating that they are physically distinct from the broad system and perhaps due to cosmologically intervening gas.

The variability timescale, $\lesssim 0.3$ yr in the QSO rest frame, requires a minimum gas density if the line changes were caused by changes in the ionization (see Voit, Shull, &

TABLE 1

MEASURED QUANTITIES

ID	λ_{obs}	z_a	V_a	REW	FWHM
		1994 September			
N V λ1242.80	...	...	...	<0.10	...
Si IV λ1393.75......	...	...	...	<0.03	...
Si IV λ1402.77......	...	...	...	<0.03	...
C IV λ1548.20......	5021.23	2.2433	−24,070	0.079±0.004	...
C IV λ1550.77......	5029.97	2.2435	−24,045	0.072±0.004	...
		1995 October			
Lyα λ1215.67	...	...	...	<0.50	...
N V λ1242.80	4031.06	2.2435	−24,045	0.390±0.015	440 ± 17
Si IV λ1393.75......	4520.46	2.2434	−24,055	0.080±0.006	310 ± 28
Si IV λ1402.77......	4550.59	2.2441	−23,990	0.086±0.008	310 ± 28
C IV λ1548.20......	5021.05	2.2432	−24,080	0.470±0.005	440 ± 7
C IV λ1550.77......	5029.81	2.2434	−24,055	0.340±0.006	440 ± 7

Begelman 1987; Ulrich 1988; Barlow et al. 1992; Hamann et al. 1995; Hamann et al. 1997). This minimum density follows from the density dependence of the recombination rate. Even if the ionization changes were triggered by abrupt changes in the ionizing flux, recombination sets the timescale if the ionization state goes up and down—as appears to be the case for Q2343+125. In highly ionized gas, where the upper ionization stages are more populated than the observed ones, the timescale for changing the observed stages by recombination from higher stages is $t_r \approx (n_i/n_{i+1})(n_e \alpha_{i+1})^{-1}$, where n_e is the electron density, n_i and n_{i+1} are the ion densities in the observed stage i and the next higher stage $i+1$, and α_{i+1} is the rate coefficient for recombination from $i+1$ to i (Krolik & Kriss 1995). In less ionized gas, where $(n_i/n_{i+1}) \gtrsim 1$, the observed stages recombine to lower ones on a timescale given by $t_r \approx (n_e \alpha_i)^{-1}$ (see Hamann et al. 1997 for a general discussion).

For the variability time of $\lesssim$0.3 yr in Q2343+125, the minimum densities needed for changes in C IV are $n_e \gtrsim 1.5 \times 10^4 (n_i/n_{i+1})$ cm^{-3} for $(n_i/n_{i+1}) \lesssim 1$ or $n_e \gtrsim 2.9 \times 10^4$ cm^{-3} for $(n_i/n_{i+1}) \gtrsim 1$ (with recombination rates from Arnaud & Rothenflug 1985 assuming $T_e \lesssim 15{,}000$ K). These results show that the density must be very high if the ionization is low to moderate. High densities in turn require that the gas be close to the QSO for photoionization. We conservatively estimate a maximum distance of 2 kpc to achieve the minimum ionization derived in § 4.4 below with $n_e \gtrsim 2.9 \times 10^4$ cm^{-3}. This distance follows from the ionization versus distance calculations in Hamann et al. (1995; their Fig. 3) after scaling for the magnitude and redshift of Q2343+125 ($V \approx 17.1$ mag; § 2). If the ionization is much higher, such that $(n_i/n_{i+1}) < 1$, the inferred minimum density is less but the ionization parameter must be larger. The net result is that the absorbers must still be close to the QSO. Therefore, in either case, time variability caused by changes in the ionization identifies the absorber as intrinsic to the QSO.

Another possible cause of the line variability is clouds moving across our line of sight to the emission source(s). If significant differences in the cloud column densities occur only over length scales comparable to the cloud sizes, the absorbers must travel distances comparable to their size in less than 0.3 yr to explain the observed factor of $\gtrsim$4 line changes. Any absorber traveling at sub–light speeds must therefore have size scales of less than 0.1 pc. These sizes should be prohibitively small for cosmologically intervening clouds (see Hamann et al. 1995 and references therein). Therefore, time variability caused by cloud motions also identifies the absorber as intrinsic.

4.2. *Partial Coverage of the Emission Source(s)*

The broad C IV and Si IV doublets in Figures 2 and 3 are shallow, but the line depths do not have the ~2:1 ratio expected for optically thin absorption. This immediately indicates that the absorbers do not fully cover the emission source(s) (Hamann et al. 1997; Barlow & Sargent 1997). If the doublet lines were well separated and accurately measured, we could derive the optical depths and coverage fractions at each velocity across the profiles. Here we limit our analysis to the line centers because of the measurement uncertainties and the blending in the C IV pair. Table 2 lists the coverage fractions, C_f, and line-center optical depths, τ, derived from the broad-only C IV data (Fig. 2*d*) using equations (5) and (6) in Hamann et al. (1997). Lower limits on C_f are also listed for N V and Si IV based on the central depth of the strongest line in those doublets (eqn. [4] in Hamann et al. 1997). The uncertainties in Table 2 follow from the 1 σ uncertainties in the measured intensities averaged over roughly $\pm$100 km s^{-1} of the centroid velocity. The uncertainty of $+\infty$ listed for τ in 1994 September indicates that the absorption troughs are consistent with a 1:1 ratio and thus fully opaque absorption.

TABLE 2

Coverage Fractions and Column Densities

ID	C_f	τ	log N ($C_f = 1$)	log N ($C_f < 1$)
1994 September				
C IV λ1548.20	$0.045^{+0.03}_{-0.00}$	$2.2^{+\infty}_{-1.3}$	13.2	$15.1^{+\infty}_{-0.8}$
C IV λ1550.77	$0.045^{+0.03}_{-0.00}$	$1.1^{+\infty}_{-0.6}$	13.6	$15.3^{+\infty}_{-0.5}$
1995 October				
N V λ1242.80	>0.15	>0.16	13.6	...
Si IV λ1393.75......	>0.07	>0.14	13.1	...
Si IV λ1402.77......	>0.07	>0.07	13.3	...
C IV λ1548.20	$0.19^{+0.04}_{-0.02}$	$1.6^{+1.3}_{-0.5}$	14.1	$15.2^{+0.2}_{-0.3}$
C IV λ1550.77	$0.19^{+0.04}_{-0.02}$	$0.8^{+0.6}_{-0.2}$	14.3	$15.2^{+0.1}_{-0.2}$

The results in Table 2 show that (at least) the C IV absorbing region covers $\lesssim$20% of the emission source(s) along our line of sight. Interestingly, the C IV coverage fraction is significantly smaller for 1994 September when the lines were also weaker, which might account for the line-strength variability (see § 4.4 below). In any case, partial coverage indicates that the absorbers have size scales comparable to, or less than, the projected size of the QSO emission source(s) (see Barlow & Sargent 1997). The low values of $C_f \lesssim 20\%$ and the small contribution of the broad emission lines to the total emission across the C IV absorption wavelengths imply that the absorbers do not fully occult the UV *continuum* source in Q2343+125. Standard accretion disk models of QSO emission therefore indicate that the absorbers have size scales less than 0.01 pc (Netzer 1992; this is a conservative upper limit based on a massive black hole, $10^9\ M_\odot$, and very extended emission, over 100 Schwarzschild radii). These sizes are much too small for cosmologically intervening clouds (see Hamann et al. 1995 and references therein). The partial coverage, therefore, also identifies the absorbers as intrinsic to the QSO.

4.3. *Column Densities*

Table 2 also lists the total column densities (log N in cm^{-2}) derived by integrating the line optical depths across each of the broad profiles in the $z_a \approx 2.24$ system (see Savage & Sembach 1991). The optical depths follow from the line residual intensities (eq. [6] in Hamann et al. 1997) assuming either complete coverage ($C_f = 1$) or partial coverage ($C_f < 1$) with C_f held constant at the value listed in the table. The column densities assuming $C_f = 1$ are firm lower limits because partial coverage can only increase the derived optical depths and column densities. The actual column densities should be closer to the $C_f < 1$ results. The uncertainties in the $C_f < 1$ case follow from the 1 σ deviations estimated for C_f and the residual intensities. The integration across the blended C IV doublet is split at the wavelength of maximum intensity between the absorption minima (as for the REW in § 3). Although the optical depths in this simple integration are overestimated in the doublet's overlap region, the net effect on the derived column densities appears to be negligible; the same results (within 0.1 dex) follow from the deblended Gaussian fits (§ 3).

4.4. *Ionization and Metal Abundances*

The measurements of C IV, Si IV, and N V and the nondetections of C II and Si II imply that the $z_a \approx 2.24$ absorber is highly ionized. We can place more quantitative constraints on the ionization by assuming that all of the ions in 1995 October occulted the same fraction of the emission source(s) as C IV, namely, $C_f \approx 19\%$. However, it is important to keep in mind that there is no evidence to support this assumption. In fact, there is strong evidence in some other $z_a \approx z_e$ systems (Barlow & Sargent 1997; Hamann et al. 1997) for different coverage fractions in different ions. Weak or absent lines do not necessarily imply low column densities, because the coverage fractions might be substantially less than C IV. Nonetheless, assuming $C_f \approx 19\%$ implies that the Si IV and N V column densities (derived as in § 4.2) are log N(Si IV) ≈ 14.0 cm^{-2} and log N(N V) > 15.5 cm^{-2}. The conservative upper limits on Si II $\lambda\lambda$1260, 1527 and C II λ1335 (§ 3) imply log N(Si II) < 13.5 cm^{-2} and log N(C II) < 14.5 cm^{-2}. If the gas is photoionized by a "nominal" QSO continuum spectrum, the combined column density constraints imply ionization parameters log $U > -2.5$ (where U is the dimensionless ratio of Lyman continuum photon to free-electron densities; see Fig. 2 in Hamann 1997). This minimum ionization, which implies a neutral fraction of log (H I/H) < -2.5, is consistent with non–Mg II BALs and many $z_a \approx z_e$ systems (also lacking low-ionization lines; see Hamann 1997 and references therein).

The Lyα line is not clearly detected, but the conservative upper bound on the line strength is consistent with arbitrarily large H I columns if $C_f \approx 19\%$. Therefore, we cannot place reliable constraints on the metal abundances. Observations of lines such as Lyβ, O VI $\lambda\lambda$1032, 1038, C III λ977, and N III λ990 are needed to estimate the metallicity and improve the ionization constraints.

4.5. *Line Velocities and Gas Kinematics*

The time variability and low coverage fractions show that the broad $z_a \approx 2.24$ lines form very near the QSO. The centroid velocities (relative to $z_e = 2.515$) are therefore indicative of ejection speeds from the QSO, roughly 24,000 km s^{-1}. The line profiles are smooth and rounded, but the comparatively small FWHM $\sim$400 km s^{-1} implies little line-of-sight velocity dispersion. The large ratio of centroid to FWHM velocities in this system, $\sim$60, is much larger than the ratios (of order unity) that characterize BAL outflows (see Turnshek 1988; Weymann et al. 1991; Korista et al. 1993). The $z_a \approx 2.24$ gas cannot be continuously accelerated from rest along our line of sight unless there is an abrupt decrease in the ionization to the observed levels at the flow velocity of $\sim$24,000 km s^{-1}. It seems more likely that the large centroid-to-FWHM ratio is caused by either episodic ejection or a continuous collimated flow that crosses our line of sight and reveals only part of its full velocity extent (Hamann et al. 1997). In either case, the velocity structure must be reasonably stable because the line shapes and centroids did not change significantly during the total of 3.1 yr (rest frame) spanned by our observations. If the lines form in the same gas during this time, with the changes caused by changes in the ionization, the distance traveled by the gas sets a minimum distance from the QSO. At 24,000 km s^{-1}, that minimum distance is $\sim$0.08 pc.

5. SUMMARY AND DISCUSSION

We have described high-resolution ($\sim$7 and 9 km s^{-1}) spectra of an intrinsic absorption-line system at redshift $z_a \approx 2.24$ in the radio-quiet QSO Q2343+125 ($z_e = 2.515$). The measured lines of C IV, N V, and Si IV have smooth, rounded profiles with FWHM $\sim$400 km s^{-1} and centroids shifted $-24{,}000$ km s^{-1} from the emission redshift. The physical relationship to the QSO is confirmed by time-variable line strengths and partial line-of-sight coverage of the QSO continuum source. Observations at three epochs show that the lines weakened and then strengthened again by factors of $\gtrsim$4 on a timescale of $\lesssim$0.3 yr in the QSO rest frame. The resolved C IV doublet ratios show that the absorbers occult $\lesssim$20% of the UV continuum emission region. The partial coverage indicates that the absorbing clouds have size scales less than, or comparable to, the continuum source, i.e., $<$0.01 pc. There is evidence for smaller coverage fractions when the lines were weaker, which might account for the line-strength changes. Our best estimate of the column density is log $N \sim 15.2$ cm^{-2} from C IV. Limits on other column densities, assuming the same coverage fraction as C IV, indicate that the absorbing gas is at least moderately ionized, with ionization parameters log $U \gtrsim -2.5$. Large uncertainties in the H I column density prohibit reliable constraints on the metal abundances.

The broad $z_a \approx 2.24$ lines clearly form in ejecta from the QSO, but the large-amplitude variability, small coverage fractions, and large ratio of centroid to FWHM velocities imply a different outflow (or outflow component) than those revealed through the BALs in other sources. The $z_a \approx 2.24$ system in Q2343+125 appears to be a high-velocity analog of the $z_a \approx z_e$ absorber in another radio-quiet QSO, UM 675 (Hamann et al. 1995). Both systems are known to be time variable, to occult just a fraction of the background light source(s), and to be dominated by smooth, rounded absorption profiles with velocity widths of order 400 km s^{-1}. The most important difference between these systems appears to be their centroid velocities, which in UM 675 are just -1500 km s^{-1} away from the emission redshift (a factor of $\sim$16 smaller than in Q2343+125). We suggest that the broad-line systems form either in episodic ejection events or in stable collimated winds that cross our line of sight and reveal only part of their full velocity extent. Whatever the origin, the velocity structure must be fairly stable because the line centroids and FWHM did not change during the times of 3.1 and 1.8 yr (rest) spanned by the observations of Q2343+125 and UM 675, respectively. If the lines formed in the same comoving gas during our observations, the distance traveled by the gas sets a minimum distance from the QSO. The 24,000 km s^{-1} outflow speed and 3.1 yr monitoring period for Q2343+125 require a minimum distance of $\sim$0.08 pc.

The frequency of features like these in QSO spectra remains to be determined, but even if they are measured rarely, the outflows they identify might be ubiquitous in QSOs if they subtend just a small fraction of the sky as seen from the emission source(s). In spite of the obvious differences between the BALs and the $z_a \approx 2.24$ system in

Q2343+125, it is tempting to attribute both to the same generic outflow phenomenon. There is at least one QSO, CSO 755 (Barlow & Junkkarinen 1996), where both types of absorption are present in the same spectrum.

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