POLARIZATION OF BROAD ABSORPTION LINE QSOs. I. A SPECTROPOLARIMETRIC ATLAS

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ABSTRACT

We present a spectropolarimetric survey of 36 broad absorption line quasi-stellar objects (BAL QSOs). The continuum, absorption trough, and emission-line polarization of BAL QSOs yield clues about their structure. We confirm that BAL QSOs are in general more highly polarized than non-BAL QSOs, consistent with a more equatorial viewing direction for the former than the latter. We have identified two new highly polarized QSOs in our sample (1232+1325 and 1333+2840). The polarization rises weakly to the blue in most objects, perhaps owing to scattering and absorption by dust particles. We find that a polarization increase in the BAL troughs is a general property of polarized BAL QSOs, indicating an excess of scattered light relative to direct light, and consistent with the unification of BAL QSOs and non-BAL QSOs. We have also discovered evidence of resonantly scattered photons in the red wing of the C IV broad emission lines of a few objects. In most cases, the broad emission lines have lower polarization and a different position angle than the continuum. The polarization characteristics of low-ionization BAL QSOs are similar to those of high-ionization BAL QSOs, suggesting a similar BAL wind geometry.

Subject headings: atlases — polarization — quasars: absorption lines — quasars: general — techniques: polarimetric

1. INTRODUCTION

Many galaxies contain active galactic nuclei (AGNs), thought to be powered by accretion onto supermassive (\(M \approx 10^8 M_\odot\)) black holes. The most powerful AGNs are the quasi-stellar objects (QSOs), with luminosities in the range \(10^{44} - 10^{48}\) erg s\(^{-1}\). They outshine their host galaxies by factors of up to \(10^4\). These extremely luminous objects provide laboratories to study high-energy physics and also may play a crucial role in the formation and evolution of galaxies.

About 10\% (Weymann et al. 1991) of all QSOs have broad absorption lines (BALs) in their spectra indicating a fast (up to 0.1c or greater) outflow. These are the broad absorption line quasi-stellar objects (BAL QSOs). Sowinski, Schmidt, & Hines (1997) list 304 QSOs (plus 133 candidates) with associated absorption lines or BALs. The BAL phenomenon appears primarily in high-luminosity radio-quiet objects. BALs do not appear in Seyfert galaxies and have only recently been discovered in a few radio-loud QSOs (Becker et al. 1997). However, low-velocity intrinsic absorption systems are seen in all subtypes of broad-line AGNs, indicating that outflows are a common phenomenon.

A survey of 142 bright QSOs (Stockman, Moore, & Angel 1984) shows that the great majority (99\%) have low polarization (LPQs, \(P < 3\%\)). BAL QSOs make up a large fraction of the radio-quiet highly polarized QSOs (HPQs, \(P > 3\%\)). There is a strong selection bias against reddened and obscured QSOs in optical surveys. Some infrared-selected AGNs have been discovered that would be classified as QSOs if seen from a dust-free direction (e.g., Wills et al. 1992; Wills & Hines 1997; and Goodrich et al. 1996). These objects are very highly polarized (up to 30\%) because the unpolarized direct emission is more highly attenuated than the polarized scattered emission. The scattering region is located farther away from the nucleus than the broad-line region, as indicated by polarized broad emission lines.

The radio-loud HPQs are mostly blazars, which emit optical synchrotron light boosted by relativistic motion in a jet pointed close to the line of sight. Another class of highly polarized AGNs consists of reddened quasars (e.g., Goodrich & Miller 1988; Rudy & Schmidt 1988; Brotherton et al. 1998; De Breuck et al. 1998) and radio galaxies with hidden quasar nuclei (e.g., Tran, Cohen, & Goodrich 1995; Ogle et al. 1997; Tran et al. 1998; Cohen et al. 1999).

The question of whether BAL QSOs can be unified with other types of QSOs has important implications for the structure and physics of AGN outflows. It has been suggested that BAL QSOs are viewed from an equatorial direction, while non-BAL QSOs are viewed from a more polar aspect (Weymann et al. 1991). In this picture, the BAL clouds may be ablated from an accretion disk. An equatorial aspect is consistent with the higher mean polarization of BAL QSOs than non-BAL QSOs (e.g., Schmidt & Hines 1999). Our survey of BAL QSOs improves the accuracy and statistics of the BAL QSO polarization distribution. Ogle (1999a, hereafter Paper II) tests the hypothesis that high polarization is due to viewing angle by comparing the polarization distributions of BAL QSOs and non-BAL QSOs against a simple unification model.

The source of polarized light in low-polarization QSOs is a subject of debate (e.g., Webb et al. 1993). UV–optical emission from QSOs (the big blue bump) is commonly
thought to be dominated by thermal emission from an accretion disk (e.g., Sun & Malkan 1989). It was originally predicted that such emission should be highly polarized (up to 12%) owing to scattering (Lightman & Shapiro 1975; Chandrasekhar 1960). The polarization should also be perpendicular to the disk axis for an optically thick disk. The polarization should also be parallel to the disk axis for an optically thin disk. The polarization should also be parallel to the disk axis for an optically thin disk. 

The UV spectral components of QSOs include the blue featureless continuum (FC), broad emission lines (BELs), broad absorption lines (BALs), and sometimes narrow absorption lines (NALs). Most of the variance among QSO spectra can be associated with these components (Francis et al. 1992). Identifying and measuring individual lines and defining a continuum level can be difficult because of blending, especially of Fe II emission (see, e.g., Wills, Netzer, & Wills 1985). Spectropolarimetry provides a way of disentangling distinctly polarized spectral components.

Spectropolarimetry has been published for a small number of BAL QSOs (e.g., Stockman, Angel, & Hier 1981; Glenn, Schmidt, & Foltz 1994; Goodrich & Miller 1995; Cohen et al. 1995; Hines & Wills 1995; Brotherton et al. 1997; Schmidt & Hines 1999). In general, these studies reveal that the broad emission lines have lower polarization than the continuum and that the continuum polarization rises to the blue. Our survey extends these results to a much larger sample of objects. In addition, the large apertures of the Keck Telescopes allow us to study the emission- and absorption-line polarization of distant QSOs with unprecedented detail. This is particularly difficult in the deep BAL troughs, where the equivalent apparent magnitude is typically 20, and we are trying to measure the polarization to an accuracy of 1%. As a by-product, we have taken some of the highest signal-to-noise ratio (S/N) spectra of BAL QSOs to date. The authors will gladly provide total flux spectra in FITS format to those who can use them in their research.\footnote{Contact P. Ogle at pmo@space.mit.edu.}

This is the first in a series of three papers on the polarization of BAL QSOs. In §2 we discuss the sample selection. In §§3 and 4 we describe the Keck and Palomar observations. Data reductions and calibration procedures are presented in §5. In §6 we tabulate the results of the spectropolarimetric survey, including continuum and BAL polar-

\begin{table}[h]
\centering
\caption{BAL QSO Observation Log: Keck}
\begin{tabular}{lccccc}
\hline
IAU (B1950) & Name & $z^a$ & $V^b$ & UT Date & PA$^d$ & Notes$^c$ \\
\hline
0019 + 0107 & UM 232 & 2.123 & 17.6 & 1995 07 29 & 6240 & 315 \\
0043 + 0048 & UM 275 & 2.146 & 18.4 & 1994 10 29 & 10800 & 305 & np \\
0059 − 2735 & … & 1.593 & 17.0 & 1994 12 30 & 6240 & 20 \\
0105 − 265 & … & 3.488 & 17.3 & 1994 08 03 & 3600 & 0 & np \\
0137 − 0153 & UM 356 & 2.234 & 17.8 & 1995 12 17 & 6000 & 227 & np \\
0146 + 0142 & UM 141 & 2.892 & 17.8 & 1994 11 06 & 3600 & 60.6 & np \\
0226 − 1024 & … & 2.256 & 16.9 & 1994 12 31 & 6000 & 45 \\
07598 + 6508 & IRAS & 0.148 & 14.5 & 1995 01 28 & 2400 & 45 \\
0842 + 3431 & CSO 203 & 2.130 & 17.2 & 1994 11 06 & 3600 & 270 & np \\
0856 + 1714 & … & 2.327 & 19.0 & 1995 11 07 & 3600 & 283 & np \\
0903 + 1734 & … & 2.773 & 17.7 & 1995 04 17 & 4800 & 80 \\
0932 + 5006 & … & 1.911 & 17.2 & 1995 12 15 & 6000 & 215 \\
1212 + 1445 & … & 1.626 & 17.4 & 1995 05 19 & 7200 & 0 & np \\
1232 + 1325 & … & 2.361 & 18.1 & 1996 05 26 & 3600 & 325 & np \\
1235 + 0857 & … & 2.887 & 17.7 & 1995 06 20 & 3600 & 50 & np \\
1246 − 0542 & … & 2.226 & 16.4 & 1995 06 20 & 7050 & 315 & np \\
1331 − 0108 & UM 587 & 1.874 & 17.4 & 1996 05 19 & 3600 & 57 & np \\
1333 + 2840 & RS 23 & 1.910 & 18.7 & 1995 01 28 & 4800 & 270 \\
1413 + 1143 & Cloverleaf & 2.545 & 16.8 & 1995 05 19 & 3600 & 68 & np \\
1524 + 5147 & CSO 755 & 2.88 & 17.1 & 1995 04 17 & 3600 & 132 \\
2225 − 0534 & PHL 5200 & 1.980 & 18.4 & 1994 08 03 & 3600 & 180 \\
& & & & 1994 10 28 & 3600 & 35 \\
\hline
\end{tabular}
\end{table}

\footnote{Redshift (Weymann et al. 1991).}
\footnote{Apparent V-band magnitude (Barlow 1993).}
\footnote{Exposure time (s).}
\footnote{Spectrograph slit PA.}
\footnote{Object not in the Weymann et al. 1991 sample.}
\footnote{Nonphotometric (clouds or fog).}
ization. The general polarization characteristics of BAL QSOs are discussed in §7. The spectra of individual objects are presented and discussed in §8. Paper II (Ogle 1999a) covers the polarization distribution of BAL QSOs and the wavelength dependence of the polarization. Paper III (Ogle 1999b) is a detailed study of the broad absorption line and broad emission line polarization of BAL QSOs. For a preview of Papers I–III, see also Ogle (1998).

2. SAMPLE SELECTION

A sample of 24 BAL QSOs was observed with the Double Spectrograph polarimeter on the 5 m Hale telescope to determine their polarization spectra. Of these, 21 were selected from the Weymann et al. (1991, hereafter WMF) sample of 40 BAL QSOs. This was augmented by three other BAL QSOs fitting into gaps in the observing schedule. Observations were restricted to declinations δ > −30°. The WMF sample was derived from the LBQS and a number of other surveys. This sample is useful because it contains most of the well-studied bright BAL QSOs accessible from northern latitudes. However, owing to haphazard selection and serendipitous discovery of most BAL QSOs, the sample should not be considered uniform or complete.

In addition, we observed 21 BAL QSOs with the W. M. Keck 10 m telescopes. The Keck survey provided the high S/N necessary to study BAL and BEL polarization. A total of nine BAL QSOs from the Palomar survey were reobserved at Keck. The remaining 12 BAL QSOs were selected to be bright or have high polarization. In cases of overlap between the two surveys, we present the superior Keck data. The combined data set consists of Keck spectropolarimetry of 21 BAL QSOs and Palomar spectropolarimetry of 15 BAL QSOs.

We give a summary of the observations in Tables 1 and 2, including IAU and alternate designations, redshift, apparent visual magnitude, UT date, exposure time, and spectrograph slit position angle. Total exposure times range from 0.5 to 6.7 hr, for an average of 2.2 hr per object. Our results for 0105−265 and PHL 5200 were first presented by Cohen et al. (1995); we discuss them in additional detail. All objects have Galactic latitudes |b| > 30°, so interstellar polarization is typically less than 0.2%. (See Appendix B for a table of estimated interstellar polarizations.) The apparent visual magnitudes range from V = 16.5 to 19.

3. KECK OBSERVATIONS

Spectropolarimetry was taken with the Low Resolution Imaging Spectrograph (LRIS; Oke et al. 1995) and polarimeter combination. A 300 groove mm−1 grating with a dispersion of 2.49 Å pixel−1 gave a resolution of 10 Å. This translates into a velocity resolution of 600 km s−1 in the C iv λ1549 BAL for a QSO at redshift z = 2.2. The C iv doublet separation of 500 km s−1 is unresolved in our spectra. This resolution is sufficient for studying the polarization of the broad emission and broad absorption lines.

The spectra cover the observed wavelength range of 3800−8900 Å. This corresponds to the rest wavelength range between Lyα λ1216 and Mg II λ2798 for a z = 2.2 QSO. The

| IAU (B1950) | Name | z | V | UT Date | t | PA | Notes |
|------------|------|---|---|---------|---|----|------|
| 0021−0213  |      |   |   |         |   |    | np   |
| 0025−0151  | UM 245 | 2.075 | 18.1 | 1996 10 18 | 3600 | 25 | np   |
| 0043+0048  | UM 275 | 2.146 | 18.4 | 1994 10 27 | 3600 | 25 |     |
| 0059−2735  |      | 1.593 | 17.0 | 1994 10 27 | 5400 | 0  |     |
| 0119+0310  | NGC 470D8 | 2.10 | 18.1 | 1996 10 18 | 3600 | 30 | np   |
| 0137−0153  | UM 356 | 2.234 | 17.8 | 1995 11 24 | 6480 | 30 | np   |
| 0145+0416  | UM 139 | 2.028 | 18.3 | 1996 10 17 | 6000 | 20 | np   |
| 0226−1024  |      | 2.256 | 16.9 | 1994 10 27 | 3600 | 10 |     |
| 0846+1540  |      | 2.912 | 18.0 | 1996 10 18 | 3360 | 305| np   |
| 0903+1734  |      | 2.773 | 17.7 | 1995 11 24 | 6000 | 310|     |
| 0932+5006  |      | 1.911 | 17.2 | 1995 11 23 | 750 | 220| np   |
| 1011+0906  |      | 2.262 | 17.7 | 1996 02 23 | 7200 | 10 | np   |
| 1212+1445  |      | 1.626 | 17.4 | 1996 05 12 | 3600 | 20 |     |
| 1231+1320  |      | 2.383 | 18.0 | 1996 05 12 | 6000 | 45 |     |
| 1232+1325  |      | 2.361 | 18.1 | 1996 02 23 | 6000 | 0  | np   |
| 1235+0857  |      | 2.887 | 17.7 | 1996 05 13 | 3600 | 34 |     |
| 1235+1453  |      | 2.686 | 18.4 | 1996 05 13 | 7800 | 30 |     |
| 1243+0121  |      | 2.790 | 18.5 | 1996 02 23 | 5400 | 30 | np   |
| 1442−0011  |      | 2.216 | 18.2 | 1996 05 12 | 6000 | 35 |     |
| 1443+0141  |      | 2.444 | 18.2 | 1996 05 13 | 7200 | 35 |     |
| 1700+5135  | PG, IRAS | 2.092 | 15.1 | 1996 05 15 | 2400 | 130|     |
| 2154−2005  |      | 2.029 | 18.1 | 1994 10 27 | 3600 | 0  |     |
| 2201−1834  |      | 1.814 | 17.6 | 1995 11 25 | 5400 | 20 | np   |
| 2350−0045  |      | 1.624 | 18.6 | 1996 10 18 | 7200 | 10 | np   |

Notes:
- a Redshift (Weymann et al. 1991).
- b Apparent V-band magnitude (Barlow 1993).
- c Exposure time (s).
- d Spectrograph slit PA.
- e Object not in the Weymann et al. 1991 sample.
- f Nonphotometric (clouds or fog).
C IV $\lambda 1549$ line is the most useful for our study because this BAL is typically deep enough to show a large polarization signature and it is well isolated from other emission and absorption lines, including intervening Ly$\alpha$ absorption systems. There are Mg II and Fe II metal lines from intervening systems in the spectra of at least 10 objects, but their equivalent widths are much smaller than the BAL equivalent widths. The C IV BAL is not visible in the two objects with redshifts $z < 1.6$.

The detector is a 2048 $\times$ 2048 pixel charge coupled device (CCD) manufactured by Tektronix. It has an inverse gain of two electrons per data number and a readout noise of roughly six electrons. The maximum efficiency of the spectrograph plus CCD combination is approximately 40% at the blaze wavelength of the grating.

Slit widths of 1" and 1.5" were used to match the atmospheric seeing, and the pixel scale was 0.2 pixel $^{-1}$. The useful slit length is only 30" in LRIS polarimetry mode because of vignetting by the beam splitter. We assume that the extended emission from the narrow-line region and starlight from the host galaxy within the slit aperture are negligible. There are a few cases in which foreground galaxies fell in the slit, but they were never close enough to the BAL QSO to contaminate its spectrum (except for the undetected galaxy that lenses 1413+1143). Indeed, there is no evidence for narrow emission lines or stellar photospheric absorption lines in any of our spectra.

The relatively narrow slit widths along with variable weather and seeing conditions yield large uncertainties in the absolute photometry; however, we are interested only in relative fluxes. The slit orientation on the sky was held constant during each set of observations to avoid mixing the Stokes parameters. When observations from different nights were taken with different slit PAs, the Stokes parameters were averaged after calibration to the sky coordinate system. The spectrograph slit was set at the mean parallactic angle for most observations. This resulted in a minimum loss of light from differential atmospheric refraction, but there was still up to 20% differential loss between the blue and red ends of the spectra. This is seen in the ratio of spectra taken at different epochs. It is important to consider this distortion when analyzing the color of the flux spectra, but it does not affect the polarization.

Keck BAL QSO observations were taken without an order-blocking filter to obtain a wide wavelength coverage and may be contaminated by second-order blue light redward of 7000 Å. The magnitude of this effect (Putney & Cohen 1996) is less than 1.8% of the flux at the blue end of the spectrum (3500–4500 Å). Contamination due to second-order light is minimal, since the BAL QSO continua rise less than a factor of 3 over the observed wavelength range. This translates to an error of 5% in flux at the red end of the spectrum of the bluest object. Since the polarization in BAL QSOs rises to the blue, this could lead to a polarization error of $\delta P = 0.08\%$ in an object polarized at $P = 2\%$. There is a potentially larger effect from the Ly$\alpha$ emission line showing up in second order at 2432 Å, but we have not identified any instance of this in our spectra.

The performance of the LRIS polarimeter and the robustness of the reduction techniques are discussed by Cohen et al. (1997). The dual-beam polarimeter separates and simultaneously measures two orthogonal polarization senses using a calcite beam splitter. This nearly eliminates the effects of atmospheric transparency and seeing variations on the calculated Stokes parameters. Rotating a half-wave plate 45° swaps the ordinary and extraordinary beams, allowing a correction for the gain difference along the two optical paths. A full set of observations is taken at four wave plate settings ($0°, 45°, 22.5°,$ and $67.5°$), yielding eight spectra used to compute the Stokes parameters ($F$, $Q$, $U$, and $V$). The circular polarization is negligible for QSOs.

4. Palomar Observations

The Palomar observations are summarized in Table 2. Spectropolarimetry was taken with the Double Spectrograph (Oke & Gunn 1982) on the 5 m Hale Telescope. BAL QSOs were observed for 60–90 minutes, depending on their magnitudes and polarizations. Polarization spectra are measured with an accuracy of 0.1%–0.6% in 50 Å (rest) bins. The methodology of observations is largely the same for the Palomar and Keck samples. Here we concentrate on issues peculiar to the Palomar data.

We used a D55 dichroic filter, splitting the spectrum at 5500 Å. Separate gratings were used to disperse the spectra in the blue and red arms of the spectrograph. The transmittance of the dichroic is better than 90% redward of 5500 Å, so only a small fraction of the photons is lost. The dichroic filter has the additional advantage of blocking out second-order blue light. The polarimeter is above the dichroic in the optical path, so it serves both the blue and red arms of the spectrograph. Some spurious polarization effects are introduced near the wavelength of the dichroic split and do not calibrate out. We set the gratings on the blue and red sides to exclude this region, so there is typically a 200 Å gap in our spectra. For most objects, this gap falls in between the C IV and C III] lines. However, the gap falls in the C IV BAL region for three objects (0903+1734, 1235+1453, and 1243+0121), and on the C III] emission line for two objects (0932+5006 and 2201−1834).

A 300 line mm $^{-1}$ grating blazed for maximum efficiency at 3990 Å gives a dispersion of 2.17 Å pixel $^{-1}$ at the focus of the blue camera. A 316 line mm $^{-1}$ grating blazed at 7500 Å gives a dispersion of 2.46 Å pixel $^{-1}$ in the red spectra. The wavelength coverage is typically 3600–5400 Å in the blue and 5600–8100 Å in the red. The low efficiency of the Double Spectrograph at wavelengths less than 3600 Å is not adequate for polarimetric observations of faint QSOs. The spectrograph slit had a 2" aperture and a useful (unvignettied) length of 35" in polarimetry mode. We used a wider slit at Palomar than at Keck because of the worse seeing. The spectral resolution was 6 Å in the red and 8 Å in the blue, slightly better than in the Keck observations.

The detectors in the blue and red cameras were both 800 $\times$ 800 pixel CCDs. The blue detector suffered from dead columns and transient gain variations near the blue end of the spectrum. We used chip regions with the best cosmetic quality, but the flux spectra may still be afflicted by nonlinearities at a level of 5% in localized wavelength regions. In fact, the flux standards of Oke (1990) were taken by nonlinearities at a level of 5% in localized wavelength regions. The Palomar and Keck samples. Here we concentrate on issues peculiar to the Palomar data.
spectra. We set the telescope focus to provide the sharpest image along the largest possible wavelength range. These focusing difficulties should not affect the polarimetry (except for lowering the S/N) since focusing and seeing variations are mitigated by the dual-beam polarimetry method. During the last year of our observing program (1995–1996), the red camera was upgraded to a $1024 \times 1024$ pixel CCD and other changes were made to its optics, removing the problems of multiple detector flaws and some of the focusing difficulties.

5. DATA REDUCTION AND CALIBRATION

Data reduction was accomplished with VISTA image processing software, using procedures described by Miller, Robinson, & Goodrich (1988) and Cohen et al. (1997). Cosmic-ray events were eliminated interactively from the CCD frames using a $3 \sigma$, $5 \times 5$ pixel median filter. It was sometimes impossible to remove cosmic-ray tracks falling on the object spectra, and these are flagged in the spectra as “hits.” To help identify and mitigate contamination from cosmic rays, the observations were typically split into two sets. The CCD frames were debiased using an average from the overscan region. No corrections were made for the negligible dark current. All object frames were divided by an internal halogen flat field to remove small spatial variations in the CCD response. Note that in the case of low sky background, the flat field cancels out of the equations for the Stokes parameters. Hence, the polarization is quite insensitive to flat-fielding.

The object spectra were extracted using $3''$–$6''$ wide windows centered along a slit fit to their centroids on the CCD chip. Night sky spectra were extracted from windows on both sides of the object, averaged, scaled, and subtracted from the object spectra. Spectra were wavelength calibrated using Ne, Ar, and Hg+$\text{Kr}$ internal lamps, and rebinned to a linear scale. Night-sky spectra were used to correct for wavelength zero-point offsets due to spectrograph flexure. Spectra were deredshifted using literature redshift values given in Tables 1 and 2 and binned by 5 Å (rest). The photon counts and statistics from the object and sky spectra were then used to compute the Stokes parameters ($F$, $Q$, and $U$) and their uncertainties. Binning reduces the biases that can be introduced by noisy data and enhances the S/N of the Stokes parameters. The total flux spectra (Figs. 3–5) are presented unbinned to show maximum spectral resolution.

Measurements of $(Q, U)$ and the derived fractional polarization and position angle ($P$, PA) are subject to a number of biases when the number of photons is small (Clarke et al. 1983; Naghizadeh-Khouei & Clarke 1993). $P$ is a positive definite quantity and therefore does not obey Gaussian statistics. It is therefore preferable to rotate $(Q, U)$ by a fit to the continuum PA curve instead of calculating a debiased $P$ (Simmons & Stewart 1985). This is possible only when the PA is a slowly varying function of wavelength. Where there are PA rotations across the emission and absorption lines, the polarization will be underestimated by this method; then it is necessary to inspect both $Q$ and $U$ to determine the line polarization.

Flux spectra were corrected for atmospheric extinction (Hayes 1971; Beland, Boulade, & Davidge 1988) and absorption in the telluric bands ($O_2$ A, B, and $\gamma$, and $H_2O$). Absolute flux calibrations were made using spectrophotometric standards (Oke 1990), but some nights were not photometric. Flux standards were observed at Keck both with and without a GG-495 order-blocking filter to eliminate contamination by second-order light.

Bright stars were observed through UV and IR polarizers to determine the position angle of the Keck and Palomar half-wave plate fast axes as functions of wavelength. The half-wave plates are superachromatic (Goodrich 1991), designed to give a retardance close to 180° over a large wavelength range. However, this design introduces a wavelength-dependent rotation into the instrumental PA curves. The Keck PA correction curve (Fig. 1) was measured on several occasions and averaged to obtain a curve with relative uncertainty of $<0\!:\!2$ at all wavelengths. All Keck observations were corrected by a spline fit to this average curve. A similar PA correction curve was measured for Palomar data.

The PA offset between the half-wave plate coordinate system and the sky coordinate system was determined for each observing run using polarized standard stars from the list of Schmidt, Elston, & Lupie (1992). $B$- and $V$-band polarizations of the standards were measured by averaging over the bands 3950–4900 Å and 5050–5950 Å, respectively. Some of the standards show curvature in the PA spectrum, amounting to $1''$–$2''$ over the range 3800–8900 Å. The PA variation within the $B$ or $V$ band is less than $0\!:\!5$, so the error introduced by not considering the shape of the Johnson filter curves is less than $0\!:\!2$. We used a set of secondary and tertiary PA standards (Table 3) dim enough to view with the Keck Telescope and covering the sky. The PA values of the tertiary standards were set by minimizing the difference between PA offsets determined from all sec-

![Fig. 1.—Keck PA calibration curve, showing rotation of half-wave plate fast axis with wavelength.](image)

| Star        | Band | $P\%$ | $\sigma$ | PA    | $\sigma$ |
|-------------|------|-------|---------|-------|---------|
| HD 155528   | $V$  | 5.00  | 0.17    | 92.61 | 0.37    |
| HD 245310   | $B$  | 4.38  | 0.004   | 145.97| 0.40    |
| VI Cyg 12   | $V$  | 9.16  | 0.06    | 116.41| 0.13    |
| Hiltner 102 | $V$  | 5.18  | 0.10    | 73.20 | 0.80    |
| HD 251204   | $V$  | 4.98  | 0.05    | 151.60| ...     |

Note.—No PA uncertainty is listed for HD 251204, because it was observed on only one occasion.
absolute PA calibration is internally consistent to 6. OGLE ET AL.

Uniform reflectivity of the primary and secondary telescope correction was required for Keck data. The lack of instrumental polarization effects, so no instrumental polarization (0.05%, 0.05%). There was no evidence for systematic instrumental effects as large as for the published secondary standards. 0¡.4 always found to be null to within 0.1% (4000 Å observed on several occasions at Keck (Table 4) and were null polarization standards (Schmidt et al. 1992) were measured in two narrow wavelength bands (1600–2200 Å, observed) are presented for comparison with polarization values in the literature. The polarization P was estimated by rotating the Stokes parameters by the angle 2PA, determined from a cubic spline fit to the PA curve. [The Stokes parameters become (Q = P, U = 0) in the rotated coordinate system.] P was then averaged over the appropriate bins in the spectrum. This introduced negligible bias in the high S/N continuum observations. Objects with significant PA rotations in the continuum are footnoted in the last column. Polarization values are given as percentages and PA values are given in degrees.

We measured the continuum polarization of the Palomar BAL QSOs in two continuum bands (1600–1840 Å and 1960–2260 Å). For most objects, only one of these two bands was available, and the other fell in the dichroic gap. Except for a few observations heavily affected by clouds, we

| Star          | Date  | Q%   | U%   |
|--------------|-------|------|------|
| G191B2B      | 1994  | 0.052| 0.009|
|              | 1995  | −0.050| −0.045|
|              | 1996  | 0.002| 0.037|
| BD +28°4211  | 1995  | −0.069| −0.079|
|              | 1996  | 0.033| −0.111|
| BD +32°3739  | 1995  | 0.057| −0.096|
| Mean         |       | −0.004| 0.047|
| σ            |       | 0.05  | 0.05 |

Note.—Stokes Q and U parameters were measured in the 4000–7000 Å band.

Table 5 gives the continuum polarizations for the Keck BAL QSO sample. We measured the continuum polarization in two narrow wavelength bands, P₁ (1600–1840 Å, rest) and P₂ (1960–2200 Å, rest). These bands are on either side of the C II λ1909 emission line, where the contamination from Fe II and other emission lines is relatively low. Broadband measurements P and PA (4000–8600 Å, observed) are presented for comparison with polarization values in Appendix B. We discuss and tabulate estimates of the interstellar polarization in Appendix B.

6. CONTINUUM AND BROAD ABSORPTION LINE POLARIZATION

Table 5 gives the continuum polarizations for the Keck BAL QSO sample. We measured the continuum polarization in two narrow wavelength bands, P₁ (1600–1840 Å, rest) and P₂ (1960–2200 Å, rest). These bands are on either side of the C II λ1909 emission line, where the contamination from Fe II and other emission lines is relatively low. Broadband measurements P and PA (4000–8600 Å, observed) are presented for comparison with polarization values in the literature. The polarization P was estimated by rotating the Stokes parameters by the angle 2PA, determined from a cubic spline fit to the PA curve. [The Stokes parameters become (Q = P, U = 0) in the rotated coordinate system.] P was then averaged over the appropriate bins in the spectrum. This introduced negligible bias in the high S/N continuum observations. Objects with significant PA rotations in the continuum are footnoted in the last column. Polarization values are given as percentages and PA values are given in degrees.

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**TABLE 5**

| IAU (B1950) | Name  | P₁ %  | P₂ %  | Pᵣ %  | PA    |
|------------|-------|-------|-------|-------|-------|
| 0019 + 0107| UM 232| 0.94 ± 0.03 | 1.10 ± 0.03 | 0.98 ± 0.02 | 35.0 ± 0.5 a |
| 0043 + 0048| UM 275| 0.05 ± 0.04 b | 0.11 ± 0.04 b | 0.11 ± 0.06 b | b |
| 0059 + 2735|       | 1.58 ± 0.10 | 1.62 ± 0.06 | 1.49 ± 0.02 | 173.0 ± 0.3 |
| 0105 + 265 |       | 1.45 ± 0.05 | 1.27 ± 0.05 | 1.24 ± 0.05 | 133.0 ± 0.5 |
| 0137 + 0153| UM 356| 1.06 ± 0.07 | 0.81 ± 0.08 | 1.09 ± 0.05 | 56.0 ± 1.3 |
| 0146 + 0142| UM 141| 1.12 ± 0.03 | 1.15 ± 0.08 | 1.24 ± 0.02 | 131.1 ± 0.5 |
| 0226 + 1024|       | 1.80 ± 0.02 | 1.73 ± 0.02 | 1.81 ± 0.01 | 167.1 ± 0.2 |
| 07598 + 6508| IRAS|       |       | 1.709 ± 0.005 | 123.05 ± 0.08 |
| 0842 + 3431| CSO 203| 0.52 ± 0.02 | 0.55 ± 0.03 | 0.51 ± 0.01 | 27.1 ± 0.6 |
| 0856 + 1714|       | 0.88 ± 0.13 | 0.91 ± 0.10 | 1.02 ± 0.10 | 165.7 ± 2.8 |
| 0903 + 1734|       | 0.52 ± 0.04 | 0.44 ± 0.05 | 0.67 ± 0.02 | 62.9 ± 0.6 |
| 0932 + 5006|       | 1.20 ± 0.02 | 1.19 ± 0.03 | 1.11 ± 0.02 | 168.7 ± 0.5 a |
| 1212 + 1445|       | 2.05 ± 0.06 | 1.88 ± 0.06 | 1.49 ± 0.03 | 17.3 ± 0.6 |
| 1232 + 1325|       | 3.38 ± 0.08 | 3.30 ± 0.06 | 3.19 ± 0.04 | 93.9 ± 0.3 |
| 1235 + 0857|       | 2.76 ± 0.06 | 2.65 ± 0.09 | 2.53 ± 0.07 | 25.1 ± 0.7 |
| 1246 + 0542|       | 1.31 ± 0.02 | 1.11 ± 0.02 | 1.26 ± 0.01 | 132.4 ± 0.1 |
| 1331 + 0108| UM 587| 1.76 ± 0.13 | 1.55 ± 0.09 | 1.56 ± 0.14 | 33.8 ± 2.2 |
| 1333 + 2840| RS 23 | 5.41 ± 0.11 | 5.61 ± 0.07 | 4.67 ± 0.02 | 161.5 ± 0.1 |
| 1413 + 1143| Cloverleaf| 1.49 ± 0.04 | 1.24 ± 0.08 | 1.52 ± 0.04 | 55.7 ± 0.9 |
| 1524 + 5147| CSO 755| 3.56 ± 0.03 | 3.42 ± 0.05 | 3.49 ± 0.01 | 98.6 ± 0.1 |
| 2225 + 0534| PHL 5200| 4.98 ± 0.05 | 4.63 ± 0.06 | 4.26 ± 0.02 | 162.0 ± 0.2 |

Notes.—P₁ and P₂ are measured in two narrow wavelength bands (1600–1840 Å and 1960–2200 Å, rest) to either side of C II λ1909. P and PA are the broadband “white-light” polarization and PA (4000–8600 Å, observed). Uncertainties are listed as standard deviations of the mean within the given band; they are slightly larger than the formal uncertainty from photon statistics, owing to polarization variation within the wavelength bands.

a Significant continuum PA rotation.

b UM 275 has insignificant polarization, so we list P = (Q² + U²)½ instead of P = Q; and the PA is highly uncertain, so we do not include it.

There is no measurement of P₁ for 0105 + 165 because of its high redshift, and no measurement of P₁ or P₂ for 07598 + 6508 because of its low redshift.
### TABLE 6

**BAL QSO Continuum Polarization: Palomar Measurements**

| IAU (B1950) | Name    | $P_1\%$ | $P_2\%$ | PA   |
|-------------|---------|---------|---------|------|
| 0025−0151   | UM 245  | ...     | 0.57±0.16 | 108±9 |
| 0059−2735   | ...     | 1.45±0.17 | ...     | 168±8 |
| 0137−0153   | UM 356  | ...     | 0.46±0.13 | 71±15 |
| 0145+0416   | UM 139  | ...     | 2.14±0.10 | 126±1* |
| 0226−1024   | ...     | ...     | 1.84±0.10 | 166±1 |
| 0903+1734   | ...     | 0.53±0.06 | ...     | 62±6 |
| 0932+5066   | ...     | 1.17±0.30 | 1.25±0.07 | 172±1* |
| 1011+0906   | ...     | ...     | 2.00±0.08 | 132±2 |
| 1212+1445   | ...     | 2.17±0.34 |       | 24±1 |
| 1232+1325   | ...     | ...     | 3.49±0.19 | 92±3 |
| 1235+0857   | ...     | 2.16±0.15 |       | 21±2 |
| 1235+1453   | ...     | 0.75±0.13 |       | 175±12 |
| 1243+0121   | ...     | 1.68±0.20 |       | 136±4 |
| 1700+5153   | PG, IRAS| ...     | 1.07±0.04 | 53±1* |
| 2154−2005   | ...     | ...     | 0.90±0.17 | 142±8 |

**Notes.**—$P_1$ and $P_2$ are the polarizations in two narrow wavelength bands (1600−1840 Å and 1960−2260 Å, rest) to either side of C III] 1909. For most objects, only one of the two bands is available, owing to the dichroic split. PA is the corresponding electric vector position angle in degrees (except for 0932+5006, where PA is the average of the two bands).

* Significant continuum PA rotation.

$^b$ 1700+5153 was measured in the band 3700−4100 Å, rest.

### TABLE 7

**BAL QSO Continuum Polarization: Palomar Nondetections**

| IAU (B1950) | Name    | $Q\%$ | $U\%$ | Band$^a$ |
|-------------|---------|-------|-------|----------|
| 0021−0213   | ...     | 0.28±0.12 | −0.42±0.23 | 2 |
| 0043+0048   | UM 275  | 0.12±0.19 | 0.06±0.19 | 2 |
| 0119+0310   | NGC 470D8 | 0.34±0.16 | 0.00±0.20 | 2 |
| 0846+1540   | ...     | 0.30±0.33 | 0.01±0.36 | 1 |
| 1231+1320   | ...     | −0.16±0.07 | −0.14±0.10 | 2 |
| 1442−0011   | ...     | 0.63±0.66 | −0.50±0.38 | 2 |
| 1443+0141   | ...     | 0.80±0.33 | 0.29±0.27 | 2 |
| 2201−1834   | ...     | 0.16±0.07 | 0.00±0.12 | 2 |
| 2350−0045   | ...     | −0.58±0.53 | 0.09±0.30 | 1 |

**Note.**—Stokes $Q$ and $U$ are listed for objects undetected in polarized flux ($<3\sigma$).

$^a$ Wavelength bands: 1 = 1600−1840 Å and 2 = 1960−2260 Å, rest.

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**Fig. 2.**—Comparison of Palomar and Keck polarization measurements. Note that there are no systematic differences between the two data sets. Also, there is no evidence of intrinsic variability between the sets.
measured continuum polarization with an uncertainty of less than 0.3%. This approaches the level of the systematic uncertainty in the instrumental polarization curve (see Appendix B). The results of our continuum polarization measurements at Palomar are presented in Tables 6 and 7. Several objects (nine of 24) are rated as polarization nonde-
not so for 1235 + 1453 (REW = 59 Å) or 1243 + 0121 (REW = 64 Å). The HPQ fraction is higher in high-REW BAL QSOs than in low-REW BAL QSOs, but the statistics are poor. Even though there is no direct relationship between $P$ and BEL REW, attenuation may still be important in some highly polarized BAL QSOs.

The wavelength dependence of the continuum polarization in BAL QSOs is weak. A few objects show variation of continuum PA with wavelength, indicating the presence of at least two polarization sources. The largest continuum PA rotations are seen in UM 232, 0145 + 0416, 0932 + 5006, and 1700 + 5153. While interstellar polarization may be important in some of these cases, the wavelength independence of the PA, unpolarized emission lines, and the high Galactic latitude of most objects suggests there is little contamination by interstellar dust (see Appendix B). Most BAL QSOs (14 of 21 objects observed at Keck) show a rise in polarization to the blue. Nine BAL QSOs show the polarization dilution signature of broad Fe II line emission between 2260 and 2800 Å. This contributes to but does not completely account for the wavelength dependence of the polarization (Paper II). Of the remaining objects, five have flat polarization spectra, one (UM 232) has polarization rising to the red, and one object is unpolarized (UM 275). The wavelength dependence of the polarization is most likely caused by dust scattering and absorption intrinsic to the QSOs. We consider the detailed implications of this in Paper II.

The peak C IV BAL polarization is at least 2 $\sigma$ greater than the continuum polarization for most objects (17 of 20) and can reach values as large as 17%. There are also PA rotations across the BALs of nine objects. The polarization variations across the troughs can be attributed to polarized light scattered around the BAL region. The scattered lines of sight on average pass through a lower BAL optical depth, and the BALs are shallower in polarized flux than in total flux. This is yet another indication that the BAL region does not uniformly cover the central source, and that a BAL QSO may appear as a non-BAL QSO from a different viewing direction. In some objects, the BALs are blueshifted in polarized flux, relative to their velocities in the total flux spectra. This may tell us something about the dynamics of the BAL outflow and is discussed in detail in Paper III.

While the dominant BAL polarization effect is from partial coverage of the continuum scattering region, there are cases in which a small amount of resonantly scattered light from the BAL region is also detected (Paper III and Ogle 1997). This is important because it is the first time the expected resonance scattering profile (Hamman, Korista, & Morris 1993) is seen. It is proof that at least some photons resonantly scattered out of the line of sight by the BAL clouds escape the QSO. Higher S/N observations of the resonance scattering profile can potentially be used to constrain the geometry and dynamics of the BAL outflow. In some objects the PA in the high-velocity (≈ 10,000 km s$^{-1}$) red wing of the C IV BEL rotates in the opposite direction from the BAL PA rotation. Polarized flux at high velocities with a profile distinct from the BEL profile is a good indication of resonance back-scattering. Photons from the central source are reflected forward by the portion of the BAL wind flowing away from the observer. There are indications that C IV BEL photons are also back-scattered by the BAL (Paper III), but at a different PA. The location and nature of the scatterers is discussed in detail in Papers II and III.

In general, the BELs are polarized at a lower level than the continuum and to first order do not show up in polarized flux. A closer look shows small rotations and residual polarized flux across some emission lines in some objects (Paper III). Most notably, C III$^+$ is polarized in 2225—0534 and 0019 + 0107. Weakly polarized C IV photons are also detected in a few objects, as discussed above. The line polarization is used as a diagnostic of the geometry of the BAL, BEL, and scattering regions in Paper III.

In addition to the 10 previously known low-ionization BAL QSOs in our sample, we have found weak low-ionization BALs or associated NALs (Al III and/or Mg II) in nine of the objects with high S/N Keck observations. More than half (52%) of the objects in our sample have intrinsic absorption from low-ionization species. The polarization characteristics of the objects with strong low-ionization BALs (and even the Fe II low-ionization BAL QSO 0059—2735) are similar to those with weak or nonexistent low-ionization BALs. We therefore argue that there is no great difference in the geometry of the BAL outflow in high and low-ionization BAL QSOs.

8. Individual Objects

We discuss individual polarized BAL QSOs (and two interesting unpolarized BAL QSOs) in this section. The spectra of 29 BAL QSOs are presented in Figure 3. There are two spectra per page and four panels per object. The four panels show the flux $F_\lambda$, polarization $P = Q/\lambda F$, and position angle $\theta$. When viewing polarization data, it is useful to think of the total flux (panel 1) as mainly due to a direct, unpolarized component plus a small fraction of scattered light. The scattered light spectrum is well represented by the polarized flux (panel 3). The scaling between the total scattered flux and the polarized flux depends on the polarizing efficiency and optical depth of scatterers. The polarization (panel 2) is just the ratio of panels 3 and 1 and so does not contain any independent information. Short descriptions of the spectra are given below. Selected objects are discussed in more detail in Papers II and III. Palomar spectra (Fig. 4) typically reach farther into the blue than the Keck flux spectra. For example, the Palomar spectrum of 0059—2735 shows the entire C IV BAL, inaccessible at Keck. The flux spectra of the remaining objects with no detectable polarization are displayed in Figure 5.

1. 0019 + 0107 (UM 232).—The C IV and Si IV BALs show multiple narrow subcomponents. There is an intervening metal-line absorber. The continuum polarization drops rapidly blueward of 2000 Å. This is unique to UM 232 since all other objects have $P$ flat or rising to the blue. There is a PA rotation across the continuum corresponding to the drop in polarization. This strongly suggests at least two sources of polarized light. We consider the possibility of interstellar contamination in Paper II. There is a characteristic rise in polarization in the C IV trough, in spite of the rapidly falling continuum polarization at the position of the line. The C III$^+$ 1909 emission line shows up strongly in polarized flux. Polarized C IV emission is weakly present (a 4 $\sigma$ detection). Polarized C III$^+$ is also seen in PHL 5200 (see below) and may be due to resonance scattering in the BEL region.

2. 0025—0151 (UM 245).—This object has very shallow BAL troughs, punctuated by narrow absorption components. The C IV BAL changed dramatically between 1995
Fig. 3 — Spectropolarimetry of 29 BAL QSOs. From top to bottom the four panels display (1) total flux $F_\lambda$, (2) polarization fraction (rotated Stokes parameter $Q$), (3) polarized flux $Q \times F$, and (4) position angle $\theta$. Total and polarized fluxes are plotted in units of $10^{-16}$ ergs s$^{-1}$ cm$^{-2}$ Å$^{-1}$. Prominent emission lines are indicated in the top panel by tick marks. The horizontal line in the fourth panel is the mean PA listed in Table 5. Since 0043 + 0048 (UM 275) and 1231 + 1320 are unpolarized, we display $F_\lambda$ and the unrotated Stokes $Q$ and $U$ parameters only. Individual objects are discussed in the text.
Fig. 3.—Continued
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Fig. 3.—Continued
November and 1996 October (Fig. 3 shows the 1996 October state). It deepened, and three or four new narrow BAL components appeared. The presence of variability in such a weak BAL suggests that weak BALs may be missed in some QSOs, depending on the BAL equivalent width in the discovery spectra. This would decrease the apparent BAL QSO fraction. The polarization is low and may increase to the blue. The PA spectrum is quite noisy and the apparent rotation in the blue is not statistically significant.

3. 0043 + 0048 (UM 275).—This object is remarkable for its deep double troughs. The continuum polarization is null, with a formal 2σ upper limit of 0.2%. The broad emission lines have unusually narrow profiles and are unpolarized. Low polarization indicates a high degree of symmetry in the continuum-emitting region and a low optical depth to scattering throughout the nuclear regions. The BAL troughs show significant polarization ($Q = 4.4\% \pm 0.9\%$ at $-3700$ km s$^{-1}$). This measurement is difficult because the troughs

Figure 4.—Palomar spectra of objects reobserved at Keck. Flux units are $10^{-16}$ ergs s$^{-1}$ cm$^{-2}$ Å$^{-1}$. The Palomar spectra extend farther to the blue than the Keck spectra.
are deep, and it needs to be confirmed. The BAL polarization may be entirely due to resonance scattering since the continuum and emission lines are unpolarized. The C\textsc{iv} troughs are unusually deep for a BAL QSO, but residual flux appears at the bottom of the troughs. There are Mg\textsc{ii} and Al\textsc{iii} BALs, also consistent with a large column density of BAL plasma.

4. 0059 – 2735. — This was the first object discovered in the rare class of Fe\textsc{ii} low-ionization BAL QSOs (Hazard et al. 1987). The polarization increases in the Mg\textsc{ii} and Al\textsc{iii} BALs. There are possible PA rotations in these BALs, but they have low significance. The similar polarization behaviors in the BALs of low-ionization and high-ionization BAL QSOs suggest that they share a similar geometry. The
appearance of low-ionization BALs may require a total hydrogen column $N_H > 10^{22}$ cm$^{-2}$ (Hamann 1998). This is expected of lines of sight passing near the QSO accretion disk. Most BELs, including Fe II and Mg II, have low polarization, similar to those of high-ionization BAL QSOs.

In contrast to the BAL polarization, the polarization decreases in the narrow absorption lines (NALs), including Fe II, Zn II, Cr II, and Ni II (see Wampler, Chugai, & Pettitjean 1995 for a high-resolution spectrum and line identifications). As a result, the NALs appear deeper in polarized flux than in total flux. This is especially apparent in the Fe II NALs redward of C IV. We attribute the low polarization in the NALs to dilution by low-polarization emission lines, especially Fe II. The NAL region must have a significantly different geometry from the BAL region. It appears that (for our line of sight) the NAL clouds cover the scattering region more completely, but the BEL region less completely, than do the BAL clouds (see Paper III for details). The low line-of-sight covering fraction of the Fe II BEL region by the NAL suggests that the NAL clouds are located close to and perhaps intermingled with the BEL region.

The Fe II NAL at 2380 Å shows a 10° rotation in PA, but the other Fe II NALs do not. This effect may be due to weak polarization of the Fe II emission lines filling the saturated NALs and probably has no direct connection to the particular Fe II ionic transition. Perhaps the rotation is maximum at the wavelength of the Fe II 2380 NAL because this is where the Fe II emission line flux peaks. A similar PA rotation is seen in FIRST 0840 + 3633 (Brotherton et al. 1997).

5. 0105 − 265.—This is the highest redshift object in our sample, with $z = 3.488$, so it shows the largest number of absorption troughs. The spectropolarimetry was presented by Cohen et al. (1995). The troughs are wide, smooth, and deep, similar to those of PHL 5200 (see below). The continuum polarization rises steadily to the blue, and the PA is constant across the entire spectrum, even in the troughs, blueward of Lyz, and below the wavelength of the Lyman edge (912 Å). The lack of a strong Lyman edge feature in direct or scattered flux suggests that both the BAL region and scattering region are highly ionized.

There is a high contrast between the continuum and BAL polarization levels, with $P_c = 1.62\% \pm 0.07\%$ and $P_t \approx 10\%$. $P$ increases in all of the troughs, including C IV, Si IV, N v + Lyz, Lyβ + O VI, and S VI. Four of the troughs have nearly identical residual flux, suggesting they are saturated. However, the peak trough polarization values do not follow the trend of the continuum polarization, possibly owing to an ion-dependent line-of-sight covering fraction. The troughs are almost completely detached, so they are not contaminated by the BELs.

6. 0137 − 0153.—The BAL troughs have a complex morphology with several subcomponents, including a deep one at low velocity. There is a weak intervening metal absorption system. This BAL QSO has low continuum polarization increasing to the blue. $P$ rises in the C IV and Si IV BAL troughs, especially in the deepest subcomponent. The polarization falls at all of the emission lines, and they do not appear in the polarized flux spectrum. The spikes seen in the polarized flux and PA spectra at 1250 Å are probably due to a cosmic-ray event.

7. 0145 + 0416 (UM 139).—This object has BAL troughs similar in shape and depth to 1246 − 0542. There is a deep main trough superimposed on a broader trough of moderate depth. However, the main trough is less detached from the BEL in 0145 + 0416. The continuum polarization is moderate and may rise to the blue. There is a strong continuum PA rotation from 126° in the red to 98° in the blue. The rotation starts blueward of the C III] BEL, similar to the rotations at 0019 + 0107 and 0932 + 5006. However, it is not accompanied by a red polarization spectrum like that in 0019 + 0107. A strong PA rotation requires at least two sources of polarized light with different PAs and different spectral slopes. The maximum interstellar polarization of 0.25% could cause a PA rotation of less than 2.4. We conclude that the PA rotation is due to multiple polarizing agents intrinsic to the QSO.

8. 0146 + 0142 (UM 141).—This object is distinguished by high velocity absorption extending past 0.12c. The Si IV emission line appears to be completely occulted by the C IV BAL. There is a strong P v BAL (Barlow 1993), and there may be a weak Al III BAL. There is also an intervening metal absorption system. The continuum polarization is wavelength independent. $P$ rises in the N v + Lyz BAL, the C IV BAL, and possibly the P v BAL. The spectrum is too noisy to determine the polarization of the O VI BAL. The PA rotates by $-10°$ in the Lyz + N v, C IV, and Si IV troughs. $P$ decreases at the emission lines, but there is residual polarized emission line flux in O VI + Lyβ, N v + Lyz, and C IV. However, the semiforbidden C III] BEL does not appear in polarized flux. This difference between the polarization of the permitted and semiforbidden BELs is discussed in Paper III.

9. 0226 − 1024.—This is the second brightest high-z BAL QSO in our sample, with $V = 16.9$. It has several distinct subcomponents to its BALs. Weak absorption features in the wavelength range 1740−1840 Å may be due to an Al III BAL. 0226 − 1024 was the target of higher resolution spectropolarimetric observations, discussed in Paper III. Preliminary results were reported by Ogles (1997).

The continuum polarization rises to almost 2% in the blue, and the continuum PA is independent of wavelength. $P$ increases to 7% in the C IV BAL and to 4% in the Si IV BAL. $P$ does not rise in the subtrough with lowest outflow velocity, suggesting that the corresponding BAL cloud covers the polarized light source more completely than the higher velocity BAL systems. The low-velocity associated absorber therefore has a different geometry and may have a different origin from the other BAL clouds. (This is discussed in more detail in Paper III.) There are PA rotations of up to $-10°$ in the BALs owing to asymmetric partial coverage of the polarized continuum source. PA rotations in the opposite direction, in between the troughs, indicate the presence of resonantly scattered flux.

There is a large peak in polarized flux just redward of the N v BEL. It is difficult to tell if this peak belongs to the polarized continuum or BEL because the continuum is not well defined at its wavelength. A similar peak is seen in BAL QSO 1524 + 5147. The origin of these peaks could be Rayleigh scattering by neutral hydrogen (Korista & Ferland 1998). This may also be the source of the excess Lyz + N v flux in the spectra of BAL QSOs relative to non-BAL QSOs (see, e.g., Weymann et al. 1991).

$P$ dips across all broad emission lines, including Fe II. There are deficits of polarized flux (below the continuum level) at the locations of the Lyz, Si IV, and C IV BELs, indicating that the BELs are polarized at a low level, nearly
perpendicular to the continuum. In Paper III we suggest that this phenomenon is due to BEL photons resonantly scattered by the BAL region.

10. IRAS 07598+6508.—This is a low-redshift object with strong Fe II emission and a weak Na I BAL. There are few windows in the spectrum not heavily contaminated by broad emission lines. The continuum polarization and polarized flux rise to the blue. We confirm the rise in $P$ in the Na I BAL seen by Hines & Wills (1995). In addition, we find a PA rotation across the Na I BAL. This is similar to the high $P$ and PA rotations seen the C IV BAL of high-redshift BAL QSOs. However, it is puzzling that such strong effects are seen in such a weak BAL. It is possible that the true depth of the Na I BAL is filled in by an Fe II BEL.

Our high S/N observations reveal that the BELs are polarized at a low level ($\sim 0.5\%$) and at a PA different from the continuum. The PA rotates in one direction in the blue wing and line core and in the opposite direction in the red wing of H$\alpha$, an effect commonly seen in Seyfert 1 galaxies (Goodrich & Miller 1994) and broad-line radio galaxies (Cohen et al. 1999). The PA rotations are seen out to a velocity of $\pm 12,000$ km s$^{-1}$ in the line wings. Most of the line flux contributes to a positive rotation across the Fe II line blends.

11. 0842 + 3431 (CSO 203).—This BAL QSO has relatively narrow, detached BAL troughs. There is a weak Al III BAL, but it is contaminated by Fe II absorption from an intervening system at $z = 1.161$. There are two more intervening metal absorption systems. The continuum polarization is low ($P_c = 0.51 \pm 0.01$) and rises to the blue. $P$ rises to 3% in the C IV BAL, a large contrast to the continuum polarization. The polarization drops at the N V emission line and there is no evidence for BELs in the polarized flux spectrum. The C IV trough depth increased by 7% and the Si IV trough depth increased by 16% between the 1994 November and 1995 December observations. The Al III BAL depth also increased noticeably. Neither the continuum nor peak C IV trough polarization changed significantly between the two epochs. This is not surprising, since the changes in trough depth were small. Trough variability was also reported for this object by Barlow et al. (1992) over the years 1989–1991. It would be interesting to monitor this object with sufficient precision to look for correlations among trough depth, trough polarization, and continuum polarization.

12. 0856 + 1714.—The BALs are deep and show several subcomponents, similar to those in 0226–1024. One of these subcomponents, showing up in both C IV and Si IV, is unusual because it is redshifted with respect to the BEL ($\Delta v = +1700$ km s$^{-1}$). There is a weak Al III BAL. The polarimetric data are noisy since the object is faint and there were clouds. They are only useful for an estimate of the continuum polarization, which rises to the blue.

13. 0903 + 1734.—The troughs of this BAL QSO are deep and show several subcomponents. One of the narrow subcomponents (at $z = 2.473$) appears in Al III absorption as well as in C IV and Si IV. Other than this, there is no indication of an Al III BAL. There are two additional intervening metal absorption systems. $P$ rises in the C IV, Si IV, and Ly$\alpha$ + N V BAL troughs, with a large contrast to the low continuum polarization. $P$ drops in the broad emission lines.

14. 0932 + 5006.—This object has multiple distinct BAL subtroughs well separated in velocity. There are weak Mg II and Al III BALs showing the same velocity structure as the C IV trough. However, the relative depths of the subtroughs are different in the low ionization lines, suggesting either a velocity-dependent ionization or velocity-dependent line-of-sight covering fraction.

$P$ rises in the multiple Si IV and C IV troughs, but the low-ionization troughs are too shallow to affect the polarization. The polarization rises by only a factor of 2.3 in the deep portion of the C IV trough, a small contrast relative to other objects in our sample. The polarized continuum flux is reddened below 2000 Å, similar to that in 0019 +0107. The reddening is accompanied by a 15° PA rotation across the continuum, another effect seen also in 0019 +0107. The reddening and PA rotation may be due to patchy absorption of the scattered flux by dust in the scattering region.

15. 1011 + 0906.—This is a low-ionization BAL QSO, with a prominent Al III BAL and unusually strong Al III BEL. There are two intervening metal absorption-line systems. The continuum polarization is a moderate 2%. The PA rotation at the blue end of the spectrum is of low significance. Both the total flux and polarized flux spectra are redder than spectra of typical high-ionization BAL QSOs, suggesting dust extinction and reddening. There can only be a small difference between the reddening of the direct and scattered flux since there is no significant polarization wavelength dependence.

16. 1212 + 1445.—The C IV BAL of this object has three narrow components at low velocity and a broad component at high velocity. The lowest velocity component is extremely narrow and unresolved in our spectrum and cuts into the peak of the C IV BEL. The deepest narrow component ($\Delta v = -2500$ km s$^{-1}$) is also visible in Al III and Mg II. However, the red component of the Al III doublet is confused with Fe II absorption from an intervening system at $z = 0.875$. The continuum polarization rises strongly to the blue. There is a $\sim 10^\circ$ PA rotation in the red wing of the C IV BEL at $+6000$ km s$^{-1}$, indicating polarized line emission and strongly suggesting a resonantly scattered component to the C IV flux. The other BELs are unpolarized, and the polarization dilution signatures of the Fe II blends and C III] emission are prominent.

The polarization changes strongly in magnitude and position angle across the broad portion of the C IV BAL trough. It appears that the narrow low-velocity components do not participate in this behavior. At $-14,300$ km s$^{-1}$ the polarization drops below the continuum level, and the PA rotates strongly (120°). For this object, $Q'$ is not a reliable estimate of $P$ in the trough because of the large PA rotation. Therefore, we use $P = (Q'^2 + U'^2)^{1/2}$ (not debiased) in the vicinity of the trough, and $P = Q'$ elsewhere. The net effect is that the high velocity BAL is deeper in polarized flux than in total flux and is also blueshifted.

17. 1231 + 1320.—This is a low-ionization BAL QSO with a strong Al III BAL and a large ratio of Al III to C III] emission. The spectrum is extremely unusual for a BAL QSO, for a number of reasons. There are multiple high-velocity subtroughs in Al III, C IV, and Si IV, with the highest velocity subtrough being the deepest. There is an overlap between the Si IV and C IV BALs because of their large velocity ranges. The Si IV BAL appears to be deeper in some of its subtroughs than the C IV BAL. This would imply an unusually low ionization state for the corresponding BAL clouds. However, some of the extra depth in the Si IV trough
may be due to extremely high velocity C IV absorption. The Lyα + N V BEL is unusually weak and flat-topped. This is probably due to high-velocity Si IV BAL absorption. While the flux spectrum of 1231 + 1320 is quite interesting, the polarization is very weak at \( P_2 = 0.21\% \pm 0.09\% \). Such a low polarization is only seen in two other BAL QSOs: 0043 + 0048 and 2201 – 1834.

18. 1323 + 1325.—This is a low-ionization BAL QSO like 1011 + 0906 and 1231 + 1320 with a strong Al III BAL and large Al III to C III] \( \lambda 1534 \) BEL flux ratio. The C IV and Lyα + N V BALs are saturated and go nearly black in the low-velocity portion of the trough, similar to 0059 – 2735 (Fig. 4). The Si IV BAL shows a distinct subtrough at 1290 Å that is not apparent in the C IV BAL. The wavelength of this structure does not coincide with the wavelengths of O I \( \lambda 1302 \) or C II \( \lambda 1335 \) or their corresponding BALs, so it must be due to Si IV. Saturation of the C IV BAL probably smooths out its profile. The high-velocity C IV BAL clouds are optically thick but only partially cover the continuum sources. Unlike other low-ionization BAL QSOs in our sample, there is no indication of reddening.

We identify this object as an HPQ, with continuum polarization \( P_s = 3.38\% \pm 0.08\% \). This makes it a rare QSO in three senses—BAL, low-ionization, and HPQ. There is little wavelength dependence of the continuum polarization, and there is no PA rotation. This, along with the lack of reddening in the total flux spectrum, is consistent with a simple electron scattering geometry. \( P \) rises in the C IV, Si IV, and Lyα + N V BALs, and perhaps in the Al III BAL. Consequently, the BALs are shallower in polarized flux than in total flux. \( P \) rises distinctly in the high-velocity Si IV subtrough. \( P \) drops strongly in all of the BELs, so they do not appear in the polarized flux spectrum. In all of its polarization properties, the low-ionization BAL QSO 1323 + 1325 is similar to the high-ionization HPQ BAL QSO in our sample. This is consistent with a similar geometry for the BAL outflow in low- and high-ionization objects.

19. 1325 + 0857.—This object has deep, narrow BAL troughs cutting into the broad emission lines. There are at least seven additional weak subcomponents extending to \( -24,100 \text{ km s}^{-1} \), giving the high-velocity BAL a ragged profile. There is a shallow Al III BAL at a velocity of \( -4100 \text{ km s}^{-1} \) corresponding to the blue edge of the deep C IV subtrough, but it does not cut into the peak of the Al III BEL. As in 0932 + 5006, this suggests a velocity-dependent ionization. There is also a weak intervening metal absorber.

The continuum polarization is moderately high (\( P_s = 2.53\% \pm 0.07\% \)) and constant with wavelength. This is the only object in our Keck sample (other than 1331 – 0108, with low S/N) where the polarization does not rise in the troughs. However, there are large PA rotations in the blue wings of the C IV, N V, and Lyα BELs. These are significant at the 3–4 \( \sigma \) level. It is difficult to tell if the rotations are due to polarized emission line flux or partial coverage of the polarized continuum source by the BAL. The rotation in the Lyβ + O VI BAL is not significant because it occurs where the trough goes black. \( P \) drops in the core and in the red and blue wings of the BELs, including the portions partially absorbed by the BALs. The BELs do not appear in the \( Q' \times F \) spectrum, but there are narrow emission spikes in \( U' \times F \) corresponding to the PA rotations. The spike in \( Q' \times F \) at the wavelength of Lyβ + O VI is due to noise. The BEL profiles are nicely recovered in the unpolarized (diluting) flux spectrum (Paper II).

20. 1235 + 1453.—This object has low polarization, with no significant wavelength dependence. The deep part of the C IV BAL is lost in the dichroic split between the red and blue spectra.

21. 1243 + 0121.—The ragged velocity profile of the C IV BAL is similar to that of 0137 – 0153 (Fig. 3), with the deep portion of the trough only slightly detached from the BEL. There is a deep \( O VI + Ly\beta \) BAL. The continuum polarization is moderate and wavelength-independent as well as can be judged from our noisy spectra. The polarization drops at all of the BELs, though this is of low significance in each instance.

22. 1246 – 0542.—This is the brightest \( V = 16.4 \) high-redshift object in our sample. The BAL troughs consist of a shallow component that extends from \( v = 0 \) to 0.1c and a deep component centered at \( -16,000 \text{ km s}^{-1} \). Closer inspection reveals a number of narrower subtroughs in the shallow region of the trough. There are weak Al III and Mg II BALs, centered at \( -16,000 \text{ km s}^{-1} \). There are also two intervening metal absorption-line systems (\( z = 1.644 \) and \( z = 1.200 \)). (Note that the narrow feature at 1270 Å in the Si IV trough appears to be a combination of Al III and C IV absorption from the two intervening systems and does not have a counterpart in the intrinsic C IV trough.)

The continuum polarization rises steadily to the blue, and the polarized continuum flux closely follows a power law with \( x = 0.2 \). The C IV and Si IV broad emission lines have low polarization with PAs perpendicular to the continuum PA and are weakly present as dips in the polarized flux spectrum. We interpret their polarization as evidence for resonance scattering of BEL photons by the BAL clouds (Paper III).

The polarization rises from 1.3% in the continuum to 7.2% in the C IV BAL, a large contrast. The BALs are shallow in polarized flux and appear to be blueshifted. This indicates a very small line-of-sight covering fraction of the polarized light source by the BAL region. This covering fraction is also highly dependent on outflow velocity. The blueshift could be a projection effect due to the different geometry of the direct and scattered rays. This object is discussed in detail in Paper III.

23. 1331 – 0108.—This low-ionization BAL QSO was observed for a short time and has relatively low S/N. There is very strong Fe II emission, common to objects with strong low-ionization BALs. The deep Al III trough has a smaller velocity range than the C IV trough; it is missing the high-velocity absorption tail. The Mg II trough is not as deep as the Al III trough and has an indistinct high velocity edge because it is partially filled in with Fe II emission. There is an intervening metal absorber. The continuum polarization is moderate, rises to the blue, and has a constant PA. Owing to the short exposure time, there is little information about emission-line and trough polarization.

24. 1333 + 2840 (RS 23).—This classic object has P Cygni line profiles. The BELs have unusually large equivalent widths. Their peaks are also extremely narrow; the Si IV, Al III, and Mg II doublets are all resolved. We observed RS 23 on the suggestion of R. Goodrich, who hypothesized that large BEL equivalent widths may be an indicator of high polarization and attenuation of the continuum (Goodrich 1997). This is indeed the most highly polarized object in our
sample \( (P_2 = 5.61\% \pm 0.07\%) \), and we identify it as a new HPQ.

The polarization rises by only 4% in the C IV BAL, not nearly as dramatic a rise as in the polarization spectra of other BAL QSOs such as 0105−265. This is consistent with a continuum spectrum highly attenuated and dominated by scattered light. Further absorption by the BAL has only a relatively small effect on the polarization. Dilution by the blue wing of the C IV BEL and resonantly scattered photons from the BAL region may also reduce the trough polarization. There is a +10° PA rotation in the C IV BAL, peaking blueward of the deepest part of the trough and the peak in \( P \). As in 0226−1024, we attribute this rotation to uneven coverage of the continuum scattering region by the BAL region.

Polarized C III] emission is marginally detected at the 2.1 \( \sigma \) level and shows up as a dip in the polarized flux spectrum. There is a −10° PA rotation in the blue wing of the C IV BEL, in the opposite direction from the trough PA rotation. In addition, there is negatively polarized flux in the red wing of C IV from photons resonantly scattered in the BAL region. The complicated polarization spectrum across the C IV line results from multiple sources of scattered light. We discuss this object in detail in Paper III.

25. 1413+1143 (Cloverleaf).—This BAL QSO is lensed into a quadruple source by an intervening galaxy and perhaps a distant cluster of galaxies (Magain et al. 1988; Kneib et al. 1998). Magnification by the lens is proving to be a useful tool for studying the structure of the QSO. The line profiles are P Cygni–like, with more velocity substructure than RS 23 (see above), and the C IV trough is nearly black. There is a weak Al III BAL at a velocity corresponding to the deepest part of the C IV BAL. There are three intervening metal-line absorption systems \( (z = 1.354, 1.437, \text{and } 1.659) \) apparent in our spectrum.

The polarization properties of 1413+1143 have been reported by Goodrich & Miller (1995), including evidence of variable continuum polarization. In spite of the variability, they suggest a scattering origin for the polarization. The continuum polarization rises to the blue and the continuum PA is constant with wavelength. The polarization rises strongly in the BAL troughs, including Ly\( \alpha \), N \( \upsilon \), Si IV, C IV, and perhaps P \( \upsilon \) \( P \) reaches the very high value of 17% \( \pm \) 5% in the C IV trough. This is one of the first BAL QSOs to show \( P \) rising in the absorption troughs (Goodrich & Miller 1995). There is also a consistent PA rotation of about −20° across the deep BALs.

The permitted BELs are polarized (at a lower level than the continuum), while the semirombside C III] line is unpolarized. This is opposite to the polarization behavior in 2225−0534 and 0019+0107, where only the C III] BEL is polarized. The permitted BELs in 1413+1143 are probably polarized by scattering in the same region as the continuum since they have a similar PA, and the scatterers must be relatively cold since they preserve \( B \) ELP width.

26. 1524+5147 (CSO 755).—This is a very bright BAL QSO with multiple, shallow troughs. There is Mg II absorption from two intervening systems \( (z = 1.395, 1.453) \). The polarization properties of CSO 755 were first reported by Glenn et al. (1994). The continuum polarization is high (3.5%) and rises to the blue. The BAL and BEL profiles are quite different from those of the other HPQ in our sample (RS 23, 1232+1325, and PHL 5200). The BALs of CSO 755 are detached, narrow, and shallow, while the BALs of the other HPQ have deep P Cygni profiles. The BELs have normal equivalent widths, in contrast to the high equivalent width BELs of the other HPQ. As we discuss further in Paper II, there is no correlation between BAL and BEL properties and continuum polarization in our sample as a whole.

The polarization rises by only 1%−2% in the Ly\( \alpha \) and C IV troughs because they are not very deep. There are no polarization increases in the two lowest velocity associated absorption systems, indicating that they cover the polarized light source more completely than the other absorption systems. However, the low-velocity systems only partially cover the BEL region (see Paper III).

There is a −5° PA swing across the Ly\( \alpha \)+N \( \upsilon \) BAL and a +5° rotation across the corresponding BEL. This effect is absent in the C IV BAL and BEL. In addition, the polarized flux peaks in the red wing of N \( \upsilon \). As in 0226−1024, this may be due to polarization by Rayleigh scattering in the Ly\( \alpha \) BEL. There is a small deficit of polarized flux in the red wings of all permitted lines because they are polarized at a low level, perpendicular to the continuum.

27. 1700+5153 (PG, IRAS).—This low-redshift BAL QSO has an Mg II BAL and other BALs in the observed UV (e.g., Pettini & Boksenberg 1985). There is no apparent Na I BAL. PG 1700+5153 belongs to a class of AGNs with strong Fe II emission and extremely weak [O III] emission, including 07598+6508, Mrk 231, and 14026+4341 (Boroson & Meyers 1992). This is one of the few known low-redshift BAL QSOs, difficult to identify because the BALs are in the UV. It is bright and nearby, allowing high S/N spectropolarimetry of it from Palomar. The optical continuum polarization is low (1.1%) and increases mildly to the blue. The same polarization behavior is seen in the UV spectra of high-\( \zeta \) BAL QSOs, making it an extremely broadband phenomenon (900−6400 Å). \( P \) drops in H\( \beta \) and the Fe II emission lines, so they do not show up in the polarized flux spectrum.

There is a moderate PA rotation (12°) across the continuum. This may be partly due to interstellar polarization, as large as 0.3% at the Galactic latitude of 1700+5153 (\( b = 37°8 \)). Depending on the orientation of the interstellar polarization, it could cause a rotation of up to 7°. It is necessary to measure a nearby interstellar polarization probe star to determine the proper correction. Schmidt & Hines (1999) also measure a 10° PA rotation in the continuum, confirming our result, and find a PA rotation across H\( \alpha \), outside of our spectral coverage.

This is one of the very few BAL QSOs bright and near enough to have a resolved radio structure. It consists of two unresolved sources separated by 1° at PA ≈ 100° (Kellermann et al. 1994). This can be considered neither parallel nor perpendicular to the optical polarization vector \( (PA = 53°) \). This is contrary to the suggestion of Goodrich & Miller (1995) that the polarization PA and radio axis are parallel, as would be expected for scattering in the equatorial plane. If the radio structure is due to a weak double-lobed jet, it may be deflected and may not give a reliable indication of the spin axis of the central black hole. The misalignment of the radio jet and polarization axis would not surprising in this context.

Ground-based and HST images have shown an interacting companion galaxy to the QSO (Stockton, Canalizo, & Close 1998; Hines et al. 1999), located 2° to the north at PA ≈ 0° (roughly perpendicular to the radio axis). Keck
spectroscopy by Canalizo & Stockton (1997) shows a strong starburst component in the companion that may be indirectly related to the QSO activity, with a flux ~1000 times weaker than the QSO. We do not see this stellar component in our spectrum, consistent with its faintness and location on the edge of our slit.

28. 2154–2005.—This object has very shallow BALs that appear to have weakened since the observations of Weymann et al. (1991). This is similar to the case of 0025–0151, which also has weak variable BALs. The continuum polarization of 2154–2005 is low (0.9%) and rises gradually to the blue, while the PA is independent of wavelength. This object has typical BAL QSO polarization characteristics in spite of its unusually weak BALs. It may be considered a transition object between BAL QSOs and non-BAL QSOs.

29. 2201–1834.—(Fig. 5). This is an unusual BAL QSO in a few respects. The spectrum is highly reddened. The C IV BAL has a very low equivalent width (16.3 Å), and there is no Mg II BAL, atypical of reddened BAL QSOs. Finally, the continuum has very low polarization (P = 0.16% ± 0.07%), unexpected for an object with high extinction. Perhaps we are viewing a high-ionization BAL QSO through a foreground dust screen in the host galaxy ISM that is not directly connected to the AGN phenomenon. The dust grains are not aligned, or they would induce a measurable polarization.

30. 2225–0534 (PHL 5200).—Spectropolarimetric measurements of this object were reported by Cohen et al. (1995), Goodrich & Miller (1995), and Stockman et al. (1981). While often called the prototypical BAL QSO, it is not well representative of its class. Its BELs have extreme equivalent widths like those of 1333 + 2840 (see above). This may indicate an attenuated continuum seen primarily in scattered light. Its deep, broad BALs start at 0 km s⁻¹ and absorb the blue wings of the BELs. There is a modest Mg II BAL corresponding to the deepest portion of the saturated C IV trough.

PHL 5200 is the second-most highly polarized BAL QSO in our sample, with P rising to 5% in the blue. This is another extreme characteristic for its class. The electric vector PA is roughly constant with wavelength. The polarization increases to 10% in the Si IV and C IV BALs, indicating an excess of scattered light unabsorbed by the BAL clouds. This is one of the first objects in which this phenomenon was detected (Cohen et al. 1995).

P drops in the emission lines, including the blended Fe II features, but dilution by Fe II is insufficient to account completely for the wavelength dependence of the continuum polarization. There is residual polarized flux and a small PA rotation at the C III] BEL, but the C IV BEL is unpolarized. The difference in polarization between C III] and C IV has been attributed to resonance scattering in the low–optical depth C III] line (Cohen et al. 1995).

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APPENDIX A

PALOMAR INSTRUMENTAL POLARIZATION

There is a large instrumental polarization correction for the Palomar observations taken after 1994 October. Figure 6 shows the mean instrumental polarization curves for 1995 November–1996 October, derived from observations of null polarization standards. The curves are displayed in instrumental coordinates for a slit position angle of PA = 0°. The blue

FIG. 6.—Mean Palomar instrumental polarization correction fraction for Stokes Q and U parameters. Note that these are in instrumental coordinates, not sky coordinates.
curve is corrected for an extra reflection at the dichroic filter. All BAL QSO data were corrected by subtracting a spline fit to the raw instrumental polarization curve from the Stokes parameters. The instrumental polarization correction is of the same magnitude as the typical BAL QSO continuum polarization, so it is important to use an accurate curve. The instrumental polarization correction is of the same magnitude as the typical BAL QSO continuum polarization, so it is important to use an accurate curve. The instrumental polarization correction is of the same magnitude as the typical BAL QSO continuum polarization, so it is important to use an accurate curve. The instrumental polarization correction is of the same magnitude as the typical BAL QSO continuum polarization, so it is important to use an accurate curve.

The instrumental polarization varied less than 0.2% from run to run, and the small variations were probably due to weak polarization in the null standards. Typically two or three null standards were averaged to obtain the correction curve for each run, reducing the effect of slight interstellar polarization in some standards. It is assumed that the correction is additive and does not depend on the true polarization of the object. This is similar to interstellar polarization correction, where the intervening dust can be approximated by a single partial-polarizing screen. The second-order corrections are less than the linear correction by a factor of the object polarization $P_e$ (Goodrich 1986), so are of order 0.01% in our observations. We checked the accuracy of the correction by comparing Palomar and Keck observations of the same objects. These agree well, giving confidence in the correction (see Fig. 2).

The Double Spectrograph and polarimeter are mounted on a ring at Cassegrain focus. When the ring is rotated, the PA of the instrumental polarization rotates by the same amount. This means the source of instrumental polarization is not the spectrograph or polarimeter, but either the primary or secondary mirror of the telescope. The 1994 October observing run showed little or no instrumental polarization. It is possible that cleaning and subsequent realignment of the telescope secondary mirror is to blame for the large increase in instrumental polarization between 1994 October and 1995 November. If the secondary mirror is not aligned perfectly normal to the primary mirror, then the projection of the secondary will be slightly elliptical and induce a net polarization.
The chromatic nature of the instrumental polarization suggests that it is not simply due to mirror misalignment. Another possibility is uneven re-aluminization of the primary mirror, which can induce a net polarization. In this case the wavelength dependence could come from tarnished spots that selectively absorb blue light. In fact, re-aluminization of the 200 inch (5 m) primary at Palomar is a very tricky business and sometimes gives less than uniform coverage. There are similar difficulties with instrumental polarization in Lick Observatory spectropolarimetry (Martel 1996), which is also due to irregular aluminization of the telescope mirrors. The wavelength dependence of the instrumental correction is somewhat different at Lick; it does not increase monotonically to the blue as at Palomar. Also, the magnitude of the effect is somewhat less (∼1.5%) at Lick.

APPENDIX B
INTERSTELLAR POLARIZATION

A prevalent concern in polarimetry is contamination of the Stokes parameters by intervening dust. Polarization can be induced by selective absorption by magnetically aligned dust grains. Interstellar dust polarization in the Galaxy should have only a small effect on the Stokes parameters since all objects have a Galactic latitude of \( b > 30^\circ \). Table 9 gives the Galactic latitude for each object in the Keck and Palomar samples. The maximum interstellar polarization \( P_{\text{max}} \) was estimated using the prescription of Serkowski, Mathewson, & Ford (1975) and the extinction values of Burstein & Heiles (1984), which are listed in NED.\(^9\) We used the formula \( P_{\text{max}} = 9E(B - V) = (9/4)A_g \) to convert from extinction values to polarization. The maximum expected interstellar polarization is typically less than 0.2%.

We also list the polarization \( P_p \), position angle \( \text{PA}_p \), distance \( d \), and separation \( d\theta \) of the closest field star within 5° of each QSO from Mathewson & Ford (1970). This is at best a crude estimate of the interstellar polarization in the direction of the QSO. Some of these stars are too close to the observer to sample the total dust column in the Galactic disk. Ideally, we would like to take spectropolarimetry of several stars within a few arcminutes of the QSO that have large spectroscopic distances (>0.5 kpc). Then it would be possible to make a more reliable correction for the interstellar polarization (see, e.g., Tran 1995). The number of observations required for this would be prohibitively large and impractical for the current study. We consider any measured QSO polarization greater than 0.2% to be intrinsic to the QSO. However, we also investigate the possibility of interstellar contamination in objects which show rotation of the electric vector PA with wavelength (Paper II).

Another possible source of dust polarization is the ISM of intervening galaxies. Many of the BAL QSOs in our sample show intervening metal absorption line systems. Typically, the impact parameter of these systems is large, so we don’t expect a large amount of extinction and associated dust polarization. QSOs with damped Ly\( \alpha \) absorbers at small impact parameters typically have an extinction at 1500 Å of \( A < 0.1 \) magnitudes (Pettini et al. 1997). We expect even less extinction and negligible dust polarization by the lensing galaxy. However, 1413 +1143 is lensed by a foreground galaxy, so dust absorption by the lensing galaxy may be a consideration. Dust absorption by the QSO host galaxy may be important in some QSOs with reddened spectra, and this will be considered along with other intrinsic polarization sources in Paper II.

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