THE HUBBLE SPACE TELESCOPE QUASAR ABSORPTION LINE KEY PROJECT. XIII.
A CENSUS OF ABSORPTION LINE SYSTEMS AT LOW REDSHIFT

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ABSTRACT

We present a catalogue of absorption lines obtained from the analysis of the ultra-violet spectra of 66 quasars. The data were acquired with the Faint Object Spectrograph of the Hubble Space Telescope (HST) as part of the Quasar Absorption Line Survey, a Key Project for the first four cycles of HST observations. This is the third of a series of catalogues of absorption lines produced from the survey and increases the number of quasars whose higher resolution (R = 1300) spectra we have published from 17 to 83. The general properties and execution of the survey are reviewed, including descriptions of the final sample of observed objects and the algorithmic processes used to construct the catalogue. This database is suitable for a wide variety of studies of gaseous systems in the nearby Universe.

This third catalogue includes 2594 absorption lines and brings the total number of absorption lines in the combined catalogue to 3238. The third catalogue has 878 identified Ly-α lines, 27 extensive metal line systems (detected absorption lines from four or more metal ions), 88 C IV systems, and 34 O VI systems. The combined catalogue contains the following numbers of extragalactic absorption lines: 1,129 Ly-α lines, 107 C IV systems, 41 O VI systems, 16 Lyman–limit systems, and one damped Ly-α system (in the spectrum of PG 0935+416). In addition, there are 25 pairs of identified Ly-α lines that are candidate C IV doublets. Of the 122 identified C IV and candidate C IV systems in the completely identified sample of absorption lines, 24±5 are expected to be chance coincidences of other lines (based upon Monte Carlo simulations).

The detection of a single damped Ly-α system in a path length of Δz = 49 yields an observed number of damped systems per unit redshift of (dN/dz)_{damp}(z = 0.58) = 0.020 with 95% confidence boundaries of 0.001 to 0.096 systems per unit redshift.

We include notes on our analysis of each of the observed quasars and the absorption systems detected in each spectrum. Some especially interesting systems include low redshift Ly-α absorbers suitable for extensive follow-up observations (e.g., in the spectra of TON 28 and PG 1216+069), possibly physically associated pairs of extensive metal line absorption systems (e.g., in the spectrum of PG 0117+213), and systems known to be associated with galaxies (e.g., in the spectrum of 3C 292).

The spectra of five broad absorption line (BAL) quasars (UM 425, PG 1254+047, PG 1411+442, PG 1700+518, and PG 2112+059) can be found in this third catalogue, bringing the total number of BAL quasars in the combined catalogue to six (including PG 0043+039).

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Subject headings: cosmology: observations — galaxies: general — intergalactic medium — quasars: absorption lines and individual
1. INTRODUCTION

The Hubble Space Telescope (HST) and its spectrographs have revolutionized the study of low redshift gaseous systems and Galactic halo gas by providing the spectral resolution and sensitivity needed to observe ultra-violet (UV) absorption lines in the spectra of quasars. Since the majority of the strong resonance absorption lines of cosmically abundant ions, including many of the most powerful diagnostics for the physical conditions of an absorber, occur in the rest frame UV, the effective study of the nearby gaseous Universe requires the use of UV spectroscopy (Spitzer 1956).

The primary goal of the Quasar Absorption Line Survey, a Key Project during the first four cycles of observations with HST, was to produce a large and homogeneous catalogue of absorbers suitable for the study of gaseous systems at low redshifts. The results from our initial observations and analysis of the higher resolution ($R = 1300$) UV spectra of 17 quasars have been previously presented in our first two catalogue papers (Bahcall et al. 1993a, Paper I, but hereafter CAT1; Bahcall et al. 1996, Paper VII, but hereafter CAT2). The basic survey design, data calibration, and analysis software are discussed by Schneider et al. (1993; hereafter Paper II). In this paper (CAT3) we present the rest of the UV spectra obtained as part of the Key Project and also the Bahcall Guaranteed Time Observer (GTO) programs. The total number of observed quasars in our sample is 92, 83 of which have been observed with one or more of the higher resolution gratings. Our analysis of these higher resolution spectra yield this third and by far the largest of our catalogues of absorption lines. A series of companion papers present the results of the analyses of the combined catalogue (CAT1, CAT2, and CAT3 taken together).

The paper is organized as follows: a description of the observational properties of the survey including the final list of observed targets and a review of the calibration of the spectra ($\S 2$); a review of how this third catalogue of absorption line systems was constructed ($\S 3$), including a description of the algorithms used for the selection and measurement of the absorption lines ($\S 3.1$) and Lyman-limit systems ($\S 3.2$), a summary of the current algorithms for identifying absorption lines ($\S 3.3$), which have undergone some changes since CAT2, and our tests for the reliability of our C IV and O VI identifications ($\S 3.4$); line identifications for the spectra presented in this paper including comments on the identifications on an object-by-object basis ($\S 4$); a discussion of what the catalogue reveals about various types of absorbers in ($\S 5$); and a brief summary of this paper ($\S 6$).

2. OBSERVATIONS

In this section we review the sample of quasars observed during the survey, the instrumentation and techniques used for the observations, and the calibration of the UV spectra. The original design and observational procedures used in the survey are described in detail in Paper II and the first two catalogue papers (CAT1, CAT2). Here we review only the most important characteristics of the observed sample and observing procedures.

2.1. Final Sample of Observed Objects

The Quasar Absorption Line Survey was originally intended to be comprised of observations of two samples of objects. Observations of the “primary sample” were intended to provide the bulk of the absorption lines in the final catalogue. These objects were selected to have the following properties: Galactic latitude, $|b| > 20^\circ$; redshifts determined from slit spectroscopy which lie between 0.15 and 2.0; well determined apparent optical magnitudes with preference given to brighter targets. No reference was made to existing UV data on a potential target during the initial sample selection. The radio properties of the quasars were also ignored during selection of these targets. The spectra obtained of the primary sample were to be of sufficient spectral resolution ($R = 1300$) and signal-to-noise ratio (SNR=30) for our rest equivalent width limits on absorption lines to be similar to those of existing large ground-based surveys, and for important absorption line doublets (e.g., C IV separation of 2.57 Å) to be well resolved. To investigate the strong, but rare, absorption systems such as damped Lyman-$\alpha$ and Lyman-limit systems and to facilitate radio spectroscopic follow-up of these systems, we constructed a second list of targets with moderate redshifts ($0.8 < z < 2.0$), observed flux density at 11 cm greater than 0.15 Jy, and a declination range $-3^\circ < \delta(1950) < +60^\circ$. This sample was known as the “damped Ly-$\alpha$ sample”.

Changes to the original target list and our modes of observing, however, were required during the execution of the survey in response to updated information about our originally proposed targets, the telescope, and the spectrographs. The events leading to modification in the list of proposed targets and modes of observation included the following: changes in object brightnesses (i.e., improved ground-based photometry indicating a quasar was not as bright as originally believed, either because of errors in past photometry or variability of the source); discovery of the spherical aberration due to the primary mirror, requiring a change in spectrograph aperture in order to retain spectral resolution at the cost of increased exposure time per object; lower than anticipated efficiency of the Blue side of the Faint Object Spectrograph (FOS) initiating an attempt to switch the far UV spectroscopy observations to the Goddard High Resolution Spectrograph (GHRS); temporary loss of side 1 (the far UV detector) of the GHRS, requiring a switch back to the FOS at the cost of increased exposure time and hence a reduction in the number of targets that could be observed; installation of COSTAR, providing a favorable change in spectrograph aperture and reduction of observing overhead, but bringing a decrease in the total efficiency of the combined observing system; changes in the list of targets protected by guaranteed time observers (GTOs) as they adapted their own programs; cycle-to-cycle variations in the amount of observing time recommended by the TACs and assigned by STSCI to the survey. The cumulative effect of these modifications was the nearly complete elimination of the secondary “damped Ly-$\alpha$ sample” of targets from the survey, a decrease in the number of objects in the “primary sample”, and a reduction in the number of far UV observations that could be made. The latter observations were particularly expensive in observing time, but were also the only means of probing
the lowest redshifts \((z < 0.3)\) for Ly-\(\alpha\) absorbers. A total of 76 quasars was finally observed as part of the executed Key Project observations.

In addition to the Key Project, John Bahcall led several GTO programs designed to investigate many of the problems of interest to the Key Project. These observations used identical observing modes and were planned by a subset of the Key Project team. A result of the close coordination in the design of the two programs was the ability to plan complementary observations, including modifications of the GTO program to complete observations that had to be dropped from the original Key Project plan of observations. Twenty-two objects were observed as part of the Bahcall GTO program, 19 of which met the Key Project’s criteria for inclusion in the originally defined “primary sample”. Six of these objects were partially observed under the Key Project and had additional observations made as part of the GTO program.

The merged data from the GTO and Key Project surveys resulted in the final sample of 92 observed objects listed in Table 1. We have included the three GTO objects that have redshifts lower than the original sample definition criteria because the data that were obtained are in all other respects comparable with the typical data in the survey. In Table 1 we present basic information about the 92 quasars that are investigated in this study. We include the Vérón-Cetty & Vérón (1991) catalogued redshifts (with the exception of PG 1407+265 and PG 2302+029 as detailed in the notes on individual objects) also note that since 1991 improved redshifts have become available for some of the objects in the sample, but the redshifts in Table 1 are those that were used in our analysis), \(V\)-band magnitudes, and B1950 coordinates.

In addition we have listed the objects’ Galactic coordinates and their J2000 coordinates which were provided by the Space Telescope Science Institute (STScI). The coordinates were measured from the digitized version of the “Quick V” Survey plates (Epoch 1982) described in Lasker et al. (1990) using STScI’s Guide Star Selection System Astrometric Support Package (GASP) and should be accurate to better than 1."

Additional information listed in Table 1 includes the UT date on which each object was observed with a particular grating (indicating the wavelength region observed, see next section) and the observed continuum flux at a representative wavelength covered by that observation. If a strong emission line is present at the listed wavelength a measurement was made at the adjacent continuum with this shift noted in a footnote to Table 1. If there is not an entry under a particular grating no observation was made in that mode. In Figure 1 we display, on an Aitoff projection, the Galactic coordinates of all 92 objects observed as part of the quasar absorption line survey.

2.2. Observing Modes

All observations in the survey were made using the FOS of the \(HST\). The observing procedures are described in detail in Paper II. A description of the FOS is given by Ford & Hartig (1990). The FOS has two Digicon detectors, denoted as “Blue” and “Red”, which were used for observations below and above 1600 Å, respectively (with one exception being the use of the Blue detector for the G190H observation of PKS 0405–123). We used three higher resolution gratings (G130H, G190H, and G270H, \(R = 1300\)) to observe between 1150–3270 Å and a low resolution grating (G160L, \(R \approx 180\)) to observe some objects between 1150–2400 Å. Prior to the December 1993 \(HST\) servicing mission, all observations were made using the 0.25′′ × 2.0′′ slit aperture (effectively 0.25′′ × 1.4′′ in size as the height of the diodes limited the length of the slit). The resulting full width at half maximum (FWHM) of unresolved lines observed with the different gratings are the following: 1.1 Å (G130H), 1.5 Å (G190H), 2.0 Å (G270H), and 9.4 Å (G160L). After the servicing mission (cycle 4 observations), we changed to the 0.3′′ circular aperture (despite the designated name for the aperture, the size when used with COSTAR was 0.26′′) resulting in changes in the FWHM of unresolved lines to the following: 0.9 Å (G130H), 1.4 Å (G190H) and 1.9 Å (G270H). No observations were made for our program using the G160L grating in cycle 4.

2.3. Calibration of the Spectra

The details of the calibration of the spectra are discussed in Paper II, but we review a few of the critical steps in this section: corrections for noisy diodes, the setting of the wavelength zero-point, and corrections for small scale (and time dependent) variations in the sensitivity of the detectors.

Occasionally some observations were affected by the presence of a “noisy” diode. Once identified, such diodes were generally disabled and would not affect future observations. However, if a diode intermittently malfunctioned during an observation, one could usually mitigate the effects during processing of the data: since a long integration was divided into sub-units and the effect of a noisy diode was easy to identify, it was generally possible to exclude the affected subsets of the data and combine the rest. Corrections of this sort were made to the following spectra: NAB 0024+22 (G270H); PKS 0637–75 (G190H); US 1867 (G190H, G270H); PG 0953+415 (G130H); TON 28 (G130H); 1130+106Y (G160L); PG 1202+281 (G190H); PG 1216+069 (G130H); PKS 1252+11 (G160L); PG 1634+706 (G190H); PKS 2300–68 (G270H); and PKS 2344+09 (G190H).

We have placed all the higher-resolution observations for a given object obtained with the different gratings (e.g., G190H and G270H spectra) on a common wavelength scale by requiring that the strong, singly ionized interstellar medium (ISM) absorption lines are at rest (zero redshift; see Paper II for details). In Table 2 we list for each spectrum the wavelength zero-point-offsets that were added to the reduced spectra. No correction could be made for some of our observations (noted in Table 2) because the necessary Galactic absorption lines were not detected or well measured. In the final column of Table 2 we list the small additional offset that should be added to our spectra and line lists to place them in the heliocentric rest frame. These additional offsets are based on work described in Savage et al. (1993; hereafter Paper III) and in Lockman & Savage (1995). Vacuum wavelengths are quoted throughout this paper.

Corrections for variations in sensitivity of the photocathodes and diodes of the FOS detectors are made from flat-field exposures obtained from observations of stars. Because the variations in sensitivity were found to be time
dependent, we attempted to use the flat-field data generated from calibration observations that used the same spectrograph aperture (since the corrections are also aperture dependent) and obtained closest in time to the quasar observations. However, there were periods when the interval between calibration observations was too long to enable us fully to correct some portions of some spectra. The variations in sensitivity are particularly strong in the central portions of the G190H spectra. Residual errors from the flat-fielding process dominate the statistical noise in some portions of the spectra and can create spurious weak features (cf. Paper II and Jannuzi & Hartig 1994). Features that are sufficiently strong to be in the “complete sample” of lines (defined below), but are recognized by comparison with observations of standard stars and other quasars to be residual flat-field features (cf. Jannuzi & Hartig 1994) are listed at the end of the line lists for each object and are indicated by “FF” in both Table 3 and Figure 2.

The calibrated data consist of two arrays: the flux and the 1σ uncertainty in the flux as a function of wavelength. Figure 2 shows the fully calibrated HST data used to construct the database presented in this paper. From each spectrum and its associated flux uncertainty array an equivalent width detection limit array is constructed (see §3 and Paper II for the definition and further discussion). This array for each object is also shown in Figure 2.

3. CONSTRUCTING THE THIRD CATALOGUE OF ABSORPTION LINES

In this section we review the methods used to select, measure, and identify the absorption lines that comprise our catalogue.

3.1. Selection and Measurement of the Absorption Lines

Throughout our selection and measurement of the absorption lines in our spectra we have used well-defined and extensively tested algorithms developed by Key Project scientists in order to minimize the subjective elements in the absorption line measurement and identification processes. The details of our line selection and measurement software are described in Paper II and in §3 of CAT2. The notation for the line-fitting algorithms in this paper is the same as that used in Paper II. The Spectral Spread Functions (SSFs) in all of the Key Project observations have Gaussian profiles (see Figure 1 of Paper II). Each line is assigned a significance level, $SL$:

$$SL = \frac{|W|}{\sigma(W)},$$

where $W$ is the observed equivalent width, and $\sigma(W)$ is the 1σ error in the observed equivalent width of an unresolved line. Note that $\sigma(W)$ is calculated with the flux errors at the positions of strong absorption lines replaced by the errors interpolated from the surrounding continuum points (see Paper II). The significance level differs from the more familiar definition of signal-to-noise ratio, $SNR = |W|/\sigma(W)$, because of the use of the interpolated error array for the calculation of $SL$. This search procedure is iterated a number of times (nine times in the analysis described in this paper) so that features consisting of several closely spaced lines can be separated into individual components.

At this point one constructs the function $\sigma_{\text{det}}(\lambda_{\text{obs}})$ (the 1σ detection limit for an unresolved line) from the array of 1σ uncertainties in the flux $\langle \sigma(W) \rangle$; see Figures 9 and 10 in Paper II). A preliminary line list is created using the features whose equivalent widths exceed a selected $SL$ threshold $(W > C_{SL}\sigma_{\text{det}}(\lambda_{\text{obs}}))$; $C_{SL} = 3.0$ for the preliminary line lists in this paper. Each of these lines is fitted with a variable-width Gaussian profile; this allows one to characterize the properties of resolved lines. Note that this procedure was designed to detect and characterize unsaturated lines (see Paper II) and that parameters for individual lines whose profiles significantly deviate from the SSF or Gaussian shape cannot be reliably measured with this technique.

Some minor modifications had to be made to the version of the line measurement code used in the generation of the line lists presented in this paper because of the complexity of the spectra of the high redshift objects. Occasionally the Gaussian fitting software used for CAT2 would completely fail to decompose complicated blends into individual components. The Gaussian fitting procedure attempts to fit a blend with as few lines as possible to produce a reasonable representation of the data; a blend is fitted first with one line (the strongest component in the initial SSF search; see Paper II), then successive components are added until the fit does not significantly improve. When some complex features were modeled with one component, the fit was so poor that the algorithm did not converge; this of course produced a rejection of the line. The software has been modified so that if the fitting algorithm does not converge for any single SSF line, the blend is fit using the two strongest components as starting parameters, and the additional components are added in successive iterations just as in our previous studies.

We refer to the collection of lines having $SL > 4.5$ in a given spectrum as the “complete sample.” The minimum observed equivalent width as a function of wavelength that a line must have to be included in the complete sample is:

$$W_{\text{min}}(\text{complete sample}; \lambda) = 4.5 \times \sigma_{\text{det}}(\lambda),$$

i.e., $W > W_{\text{min}}(\lambda)$. We have also constructed lists of lines with $3.0 < SL < 4.5$; these unpublished lists are referred
to as “incomplete samples”. We do not use the lines in the incomplete samples in our statistical analyses, although we occasionally remark on such lines in the notes on individual spectra. In Figure 2 we display for each source the adopted 4.5\(\sigma\) minimum equivalent width limit as a function of wavelength that must be exceeded in order for an absorption line to be included in the complete sample (cf. Paper II).

If the Gaussian fitting software identified a feature with only a single component, we counted that feature as a single line, even though the FWHM of such lines are occasionally unphysically large. At higher resolution, we expect these broad features to break up into many components. Since blended, broad features are more likely to occur at the higher line densities found at the higher redshifts (and a much larger fraction of the objects in this third catalogue at \(z > 1.0\), compared with CAT1 and CAT2) we may be slightly under-counting the \(z \sim 1.3\) systems relative to lower redshift systems.

When an absorption line was detected in more than one spectrum (i.e., in both the G190H and G270H spectra), only the more accurate measurement (in general this was the G190H observation) is presented in Table 3.

Our combined catalogue (CAT1, CAT2, and this paper) now includes measured line lists for 78 of the 83 quasars observed with the higher resolution gratings. The only objects not yet included are five of the six BAL quasars (PG 0043+039 is in CAT1) whose continua and broad absorption lines have proved difficult for our automated software to analyze.

### 3.2. Lyman–Limit Systems Search and Measurement Software

The spectra presented in CAT1 were examined for the presence of Lyman–limit systems (LLSs) with an automated software algorithm (see Paper II for details). In total ten LLSs were identified, and an analysis combining the HST results with previously published International Ultraviolet Explorer (IUE) and ground-based LLSs observations was presented in Stengler-Larrea et al. (1995; Paper V).

We have made two minor modifications to the Key Project LLS search procedure since the publication of CAT1. The redshift is now calculated using an “effective” LLS rest wavelength of 914 Å instead of the 912 Å used in CAT1; the new value attempts to compensate for the blurring of the high-order lines in the Lyman series that occurs at the FOS resolution. This, of course, leads to a slight reduction of the measured redshift. We have also modified the rest wavelengths used in the flux-ratio calculation; in CAT1 the “lower” and “upper” bands were 842–902 Å and 922–982 Å, whereas for this paper we adopted 883–903 Å and 933–953 Å. The widths of the bands were narrowed because examination of the FOS data showed that this produced measurements that were more acceptable to the “eye” than the earlier technique (especially on the short-wavelength side), and the short-wavelength cutoff on the upper band was moved redward to avoid the continuum roll-over produced by blending of the high-order Lyman lines. The major change from the CAT1 results is that the measured optical depths are, on average, slightly higher; this is primarily due to the lowering of the flux in the short-wavelength band.

All of the survey spectra were searched for LLSs using the new parameters; the results are discussed in §5.3.

### 3.3. Identification of Absorption Lines

The procedures for identifying the absorption lines for CAT3 remain essentially the same as those described in §4 of CAT2. Our procedure is embodied in the software package called ZSEARCH, described in CAT1, Bahcall et al. (1992a), and CAT2. Our goal is to create a set of physically sound identification algorithms that can be applied objectively and efficiently to analyze large numbers of simulated spectra that have the same characteristics as the observed data. We only outline here the main aspects of the procedure we use and highlight improvements or required modifications that have been made since CAT2 was published. Many of these improvements are required by the higher absorption line density in the spectra considered in this paper relative to the spectra in CAT1 or even CAT2.

The standard ultraviolet absorption lines that we considered as possible absorbers are the strongest allowed, one-electron, dipole transitions from ground or excited fine-structure states of cosmically abundant elements. Since the number of accidental coincidences increases with the number of standard lines considered, we included only standard lines that are likely to have significant equivalent widths in our spectra. We used the standard line search list presented in Table 7 of CAT1 with the modifications listed in CAT2 and the addition of higher Lyman series lines (\(\text{Ly-}\zeta\), \(\text{Ly-}\eta\), \(\text{Ly-}\theta\), \(\text{Ly-}\iota\), \(\text{Ly-}\kappa\), and \(\text{Ly-}\lambda\)) that were not included in the CAT2 version of ZSEARCH.

To be identified as absorption due to a heavy element (in this paper we will refer to such lines as metal lines) or as members of the Lyman series of hydrogen, lines must have observed wavelengths that are consistent with the identification and are required to have relative equivalent widths consistent with their known \(f\)-values and the uncertainties in the line measurements (CAT2). The maximum allowed discrepancy in wavelength is either 1 Å or \(3\sigma(\lambda)\), whichever is larger (where \(\sigma(\lambda)\) is the root-mean-square wavelength measurement error in the line center, see §6 of Paper II for a complete definition; note that any uncertainty in the wavelength zero-point-offsets is not included in this term).

The identification of absorption lines consists of four phases:

1.) ZSEARCH identifies candidate Galactic interstellar lines, which can constitute a significant “background” within which lines of extragalactic origin must be recognized.

2.) The version of ZSEARCH used for CAT2 considered every line in the spectrum that was not identified with a Galactic ISM line to be a candidate Ly-\(\alpha\) line at the appropriate redshift, \(z_{\text{cand}}\), and checked for lines that might be associated metal or Lyman series lines. Note that \(z_{\text{cand}}\) is constrained not to exceed the emission-line redshift of the quasar by more than 10,000 km s\(^{-1}\). The CAT2 version of ZSEARCH would not allow an extragalactic identification to supersede one as a Galactic ISM line. For CAT3 we modified this step to test all lines as possible Ly-\(\alpha\) lines, including those tentatively identified as Galactic ISM lines. This allowed for the possibility that an extragalactic absorption line might not only be blended with...
a Galactic ISM line, but actually be the dominant source of absorption at that wavelength. This was found to be necessary for ZSEARCH to be able to identify correctly the absorption line systems in the spectra of the sources with emission redshifts larger than approximately 1.3. Under the rules of CAT2 some metal line systems which require the presence of Ly-α to be identified would have been rejected because their Ly-α line had already been identified as Galactic ISM absorption.

3.) The third pass through the line list by ZSEARCH is used to perform independent searches for the strongest expected metallic doublets (C IV, N V, O VI, Mg II, Al III, Si IV, and Zn II) that are not found in the second phase. This allows for the identification of metal line systems for which the Ly-α line is not observable.

4.) Finally, ZSEARCH makes a fourth pass through the line list, testing individually all matches of standard lines with observed lines for candidate associated-absorption systems, i.e., for systems with redshifts within 3000 km s$^{-1}$ of the emission-line redshift. Despite the many strengths of ZSEARCH, we have not yet been able to construct complete identifications for the lines in eight of the higher redshift (all have $z > 1.0$ and 6 have $z > 1.6$) quasars in our sample: PG 0935+416, MARK 132, TON 34, Q 1101-264, PG 1206+459, S4 1435+63, PG 1715+535, and PG 1718+481. The spectra of these objects share one or more of the following properties that complicate their analysis: some have complex continua, sometimes the result of heavily blended lines, that are difficult to fit; the high-redshift objects ($z > 1.6$) can have Ly-β lines in the observed spectrum that are indistinguishable from Ly-α lines because the entire Ly-α path to the emission redshift of the quasar was not observed; many of the higher redshift objects contain LLSs (including six of the eight for which our identifications are incomplete), further reducing the observed path length in each spectrum and adding numerous metal lines to the spectra so increasing the blending with Ly-α lines. The low spectral resolution of our observations exacerbated all of the above problems. There is a ninth object that shares many characteristics with the eight just listed. The lines in the spectrum of UM 18 ($z = 1.89$) have a similar degree of blending and multiple possible identifications. In spite of these difficulties, we were able to generate a complete set of identifications for the lines in this spectrum. However, we caution that the identifications for this object are significantly less robust than those for the other objects in the catalogue. Efforts are in progress to improve our methods in order to obtain more complete identifications of the lines in these spectra.

The numerical redshifts given in this paper are calculated as in CAT2, by iterating, for multiple-line systems, the redshift initially found by ZSEARCH. The software finds the redshift that minimizes $\chi^2$, with $\chi^2$ calculated using the unweighted differences of the observed and predicted wavelengths. The redshift with the minimum $\chi^2$ is adopted and a final set of identifications based upon this redshift is determined. In CAT1, no iteration was performed to determine the best-fit redshift for multiple-line systems.

The probability for accidentally identifying metal-line absorption systems that satisfy all of the self-consistency rules is generally small. Even if there are only three lines in a candidate redshift system (e.g., Ly-α plus a strong doublet) the probability of these three lines being a chance identification is typically much less than 5% (see Table 4 and 5 in CAT2; §3.4, Table 4, and Table 5 in this work). Isolated doublets (doublet systems for which additional lines are not present in the line list) that occur at wavelengths shortward of the quasar Ly-α emission can have a significant probability of being the product of two Ly-α absorbers and we discuss such “false identifications” in §3.4. Furthermore, in some of the more complex cases of line identification considered in CAT3, multiple candidate metal line systems have measured features in common. While the arguments used in CAT2 and §3.4 below still justify the belief that a candidate system with 12 lines is real and not a chance coincidence, the membership of each individual line in that real system is less certain, particularly when some lines can plausibly be associated with more than two secure (i.e., multiple lined) redshift systems. If one line appears to occur in more than one absorption system with comparable plausibility, then we tabulate the dominant identification with the standard line and redshift but indicate in the notes on individual objects (§4) and/or Table 3 that the line is blended. It is in resolving these multiple identification issues among several plausible identifications that errors in the identifications of individual lines will undoubtedly be made.

Absorption lines that lie shortward of the Ly-α emission line are generally presumed to be Ly-α or higher members of the Lyman series unless they are identified as Galactic interstellar lines or as metal lines in a multiple-line absorption system. Candidate C IV doublet systems without additional lines in the system were occasionally identified, but the significant probability that these lines are actually Ly-α lines is noted with a “p”, indicating that there is a specific probability (see §3.4 for discussion) that the lines are due to Ly-α systems. Similarly, pairs of tabulated Ly-α lines that could alternatively be identified as part of a C IV doublet are indicated with a “p”. Finally, a small number of lines shortward of the Ly-α emission line were left unidentified when there was some secondary evidence that the line might not be real (e.g., an isolated line with a high $SL$, but a low SNR; such lines are often the result of slight errors in the continuum fit found only after the continuum fitting stage of the analysis has been completed). In such cases the identification was usually left blank. An identification that is part of an absorption system with multiple lines is preferred algorithmically over an identification with only one other line.

Examples of how the identification rules were applied in practice can be found in the notes on individual spectra that are presented in (§3.4). The identifications of the lines are listed in Table 3.

3.4. Reliability of C IV and O VI Identifications

We have performed Monte Carlo simulations with pseudo-C IV or -O VI doublets to estimate the probability that a pair of absorption lines might accidentally have the appropriate properties to be identified either as C IV or an O VI absorption doublet. The technique used is identical to that described in §5 of CAT2 with the one change that instead of 500 simulations per tested spectrum and type of simulation, 1,000 were performed. The procedure described in CAT2 preserves all of the complexities in the
observed spectra and in the identification algorithms while allowing us to estimate the probability of accidental identifications with pseudo-doublets.

An individual simulation to test for false doublet identifications consists of identifying the lines in an object’s complete sample of observed lines with the same software used for the normal identifications (ZSEARCH), but with a modified list of standard wavelengths for the line search list. Specifically, the doublet whose identification statistics we wish to test is removed from the standard line list and is replaced with a pseudo-doublet. The properties of each pseudo-doublet are a rest frame separation that ranges randomly between that of the tested doublet (e.g., 2.57 Å in the case of C IV) and 50 Å, and the ratio of the oscillator strengths of the two lines is reversed relative to the doublet being tested.

We searched for pseudo-doublets in all of the line lists of the observed spectra presented in CAT1 and this paper (simulations for the four objects in CAT2 are presented in that paper) with the same algorithmic software that was used to make the line identifications described in [S.3]. Searches were performed on line lists purged of multiple line absorption systems (metal line systems, systems with multiple Lyman series lines, and Galactic ISM lines). As discussed in CAT2, the multiple line systems have a negligible probability of being false identifications (i.e., chance systems) and their lines must be removed from the list prior to running the simulations as these lines would not be mistaken for C IV or O VI (or any other doublet). Leaving them in the line list to be tested would result in a large over-estimate of the number of expected chance systems. The lines which remain are those that might be identified with real doublets or pseudo-doublets; they are potential Ly-α lines (without Ly-β) and miscellaneous unidentified lines longward of the Ly-α emission line. Note that candidate C IV (with or without associated Ly-α absorption) and O VI doublets that do not have additional metal lines associated with them are left in the line list that will be tested as it is possible that these might not be secure identifications.

The generated numbers of chance pseudo-doublets can be used as an estimate of the number of false C IV and O VI doublet identifications in our final line lists. The pseudo-doublets and any incorrectly identified C IV and O VI doublets are being produced predominantly by the chance distribution of Ly-α lines. Any clustering among the Ly-α absorbers on scales larger than the natural splitting of the doublet might produce a slight increase in the number of pseudo-doublets detected. While there is evidence for some clumping of the Ly-α absorbers around extensive metal line systems (over velocity scales of a few thousand kilometers per second; CAT2, Jannuzi 1998), we expect this effect to be small.

The results of the simulations provide a guide to the reliability of our identifications of C IV and O VI doublets. We first describe the results for C IV doublets and then address the less complicated case of the O VI doublets. For the C IV doublets we are interested in two types of false identifications: 1) C IV doublet plus Ly-α absorption, 2) C IV doublet for which any associated Ly-α absorption is not accessible. Multiple line systems (more than three lines) including the C IV doublet have a negligible chance of being false systems and are not considered in this discussion.

Two sets of 1,000 simulations for pseudo-C IV doublets were created for each object. The first set was designed to determine the probabilities of finding false C IV doublets with Ly-α absorption and to understand how many C IV doublets would be identified if the requirement that Ly-α be present when observable were dropped. This set of simulations is identical in technique to those done in CAT2. The mean number of systems that would contain both lines of the pseudo-C IV doublet+Ly-α is one of the values returned. This is generally a very small number, as it is rare that three lines randomly have the correct properties. The number of chance systems with the C IV doublet redward of the quasar Ly-α emission was also determined by this set of simulations, and was in all cases negligible. As was done for CAT2, the simulation software also determined the average number of pseudo-doublets per simulation that were found when we dropped the requirement that Ly-α be present when accessible. Normally our identification software tests a candidate C IV doublet by requiring that if associated Ly-α absorption would be observable (appropriate wavelength coverage provided by the spectrum and of high enough SNR that a Ly-α line as strong as the stronger of the C IV lines would be detected) it is detected. If it is not possible to test for associated Ly-α, then a candidate C IV doublet without any additional lines in the system could be accepted. Note that the mean number of systems found without making this test is an upper limit on the mean number of expected false systems that would be found by our identification software.

The test for the presence of related Ly-α is not generally or uniformly made in the literature. The numbers of chance doublets found (see Table 4) is relatively large and shows that the test should always be applied if appropriate data are available.

To reproduce more closely what occurs when we make our identifications a second set of simulations for pseudo-C IV was run using a smaller input line list limited to lines shortward of the quasar Lyman-α emission for which, if identified as C IV, any associated Ly-α would not be accessible. This population of candidate C IV doublets is the largest source of misidentified C IV doublets in the combined catalogue.

In Table 4 we show the results of simulations for the incidence of chance C IV systems; the two lines for each object refer to the two types of simulations. The columns in Table 4 are as follows: (1) the name of the quasar; (2) the quasar’s emission redshift; (3) the number of potential lines that might be identified with pseudo-doublets; (4) the mean number of systems per spectrum that were found to have pseudo-C IV and an associated Ly-α absorber; by construction this was zero for the second set of simulations for each object; (5) the average number of pseudo-C IV identifications per simulation that were found when we dropped the requirement that Ly-α be present when observable (first line) and the mean number of pseudo-C IV doublets that would be expected in the spectrum without any associated Ly-α line being found (second line); (6)-(12) the percentage of the total number of simulations in which 0-6 individual pseudo-C IV identifications were found (without Ly-α); (13) the mean expected number of chance or false identifications of C IV doublets in the
given spectrum, the result of summing the mean number of a chance C IV doublets with an associated Ly-α absorber and the mean number of C IV systems that would have been accepted without Ly-α absorption because the expected associated Ly-α absorption was not observable (due to lack of wavelength coverage in the spectrum or poor SNR in that region of the spectrum).

An example will help clarify the contents of Table 4. For 3C 57 there are 23 lines in the line list purged of multiple line systems. Four additional lines are dropped when making the test for pseudo-C IV doublets for which checking for Ly-α absorption would not be possible because any Ly-α line associated with a candidate pseudo-doublet containing one of these lines would be observable. The first set of simulations yield a mean number of 0.01 pseudo-C IV doublets with an associated Ly-α absorber detected. In addition an average of 1.09 pseudo-doublets was found when the test for associated Ly-α absorption were ignored. The second set of simulations for 3C 57 reveal that a slightly lower number of false C IV doublets without Ly-α identifications is actually expected (0.97) when the rules are applied in exactly the same manner used when generating the real identifications. Thirty-six percent of the simulations yielded no pseudo-doublet systems without Ly-α absorption, but 20.2% of the simulations contained two pseudo-C IV doublets.

There is a range in accidental probability of an order of magnitude depending upon which spectrum is being searched for pseudo-doublets. The average number of pseudo-C IV doublets found in the real (observed) spectra varies from 0.0 to 2.35 (for PG 1634+706, z = 1.334, simulations in CAT2) per spectrum within the region that includes absorption by Ly-α absorbers and is negligible outside of this range. The numbers of pseudo-C IV doublets found in the observed spectra, and hence the implied number of false C IV identifications, are sufficiently large that for some applications of the catalogue they must be taken into account in the analysis.

In the combined catalogue there are 21 C IV doublets for which no other associated lines are identified and for which a check for associated Ly-α absorption could not be made (due to lack of wavelength coverage or SNR in the spectrum). Similar to these 21 C IV doublets there are also pairs of Ly-α lines listed in the tables of identified lines in CAT1, CAT2, and CAT3 (Table 3, this paper) that could have been identified as being part of a total of 25 C IV doublets. The choice between being identified as a C IV doublet without any other associated lines or as Ly-α absorption was not rigorous and we have selected the identification that seems most likely for each case (based on the goodness of fit to the C IV doublet and the plausibility of the absence of other metal lines), but noted that formally an alternative identification would meet all of our identification rules. In CAT3 Table 3 such systems are listed as either “C IV,p” (candidate C IV, associated Ly-α not observable, might be Ly-α lines) or “Ly-α,p” (candidate Ly-α, possibly C IV doublet). The “p” indicates that there is a specific probability that the identification of the indicated line should be Ly-α (or C IV). The results in Table 4 can be used to determine this specific probability, and we make use of this in our paper on the evolution of Ly-α absorbers (Weymann et al. 1998). In addition to the systems listed in Table 3, there are similar systems among the objects considered in CAT1 and CAT2. In general these systems in CAT1 and CAT2 are not indicated in the line identification tables with a special note or symbol, although four of the five pairs of lines that occur in PG 1634+706 and one of the three pairs in PG 1352+011 are noted in the CAT2 tables. For completeness, we now list the objects from CAT1 and CAT2 that have such candidate C IV or pairs of Ly-α lines and the wavelengths of the lines comprising such systems: PKS 0044+03 (1928.38, 1931.94 Å), 3C 454.3 (1786.37, 1789.08 Å), TON 153 (1995.69, 1999.03, 2029.16, 2032.06, 2034.49, 2036.95, 2038.76 Å), PG 1352+011 (1846.54, 1848.97, 1851.97, 1894.26, 1896.77 Å), PG 1634+706 (2412.04, 2416.80, 2453.03, 2457.65, 2557.44, 2560.88, 2564.86, 2599.88, 2603.34, 2755.05, 2759.96 Å).

For the purposes of this section of the paper only, we will consider all of the C IV doublets without other lines that have a significant probability of actually being two Ly-α lines (the “C IV,p” systems) and the pairs of Ly-α lines that could have been identified as C IV doublets (the “Ly-α,p” lines) as possible false identifications as C IV doublets. There are a total of 46 doublets of this type in the completely identified line lists in the combined catalogue.

We can now consider the reliability of the C IV doublet identifications in our catalogue and estimate the fraction of the identified C IV systems that might be the result of the chance matching of Ly-α or other lines. There are 127 tabulated C IV absorption line systems in the combined catalogue of absorption systems, but since our simulations can only be generated for completely identified line lists we must restrict ourselves to 70 objects. There are 97 tabulated C IV systems in this subset of the entire catalogue and an additional 25 “Ly-α,p” systems, for a total of 122 candidate C IV systems. Fifty-nine of these systems occur redward (longward) of the quasar’s Ly-α emission and 63 occur at wavelengths blueward (shortward) of the quasar Ly-α emission. We will consider the reliability of these identifications as a function of being blueward or redward of the quasar redshift.

Of the 63 C IV systems observed blueward of the quasar Ly-α emission, 14 have an extremely small probability of being chance identifications: nine systems which include both lines from the doublet, Ly-α absorption, and additional associated metal line absorption and/or higher Lyman series lines; three systems have both lines from the doublet plus multiple other metal lines detected; two systems have one line of the C IV doublet detected (the stronger, C IV λ1548.20), Ly-α absorption, and additional metal lines. Three additional systems (composed of both lines from the C IV doublet, an associated Ly-α absorption line, but no additional lines) have a finite probability of being a chance system (in the entire survey, on average, only 0.48 systems of this type are expected, including both blueward or redward systems). The remaining 46 systems have a larger chance of being false identifications. These systems include 21 “C IV,p” and 25 “Ly-α,p” systems. Based on the results of our simulations we estimate that in the spectra of the 70 quasars with completely identified line lists we would expect 20.97±4.6 of the 46 candidate C IV systems to be the result of the chance alignment of other lines. In summary, approximately one third of
the C IV doublets which occur blueward of the quasars’ Ly-\(\alpha\) emission are expected to be Ly-\(\alpha\) lines.

Understanding the chance number of systems is more straightforward for the 59 systems with their C IV doublets redward of Ly-\(\alpha\) emission. Among the 59 are 32 systems with the C IV doublet, Ly-\(\alpha\), and additional metal and/or H I (Lyman series) absorption lines detected. The probability for a chance system with these characteristics is negligible. Similarly, the broad system in the spectrum of PG 2302+029 is certainly a real system (see the next section and Jannuzi et al. 1996). There are 11 additional C IV doublets observed redward of the quasar Ly-\(\alpha\) emission for which Ly-\(\alpha\) absorption is also detected, but no other metal lines are associated with the system. For these systems the simulations reveal that there is close to zero probability that there is a false identification. For two of the 59 redward C IV doublets any associated Ly-\(\alpha\) absorption was not accessible in our observed wavelength region. Based on our simulations, we expect 0.5 such systems to occur in our sample drawn from the 70 completely identified quasar spectra. Finally, the 59 redward C IV systems include 13 identifications that have only the strong line of the C IV doublet detected. Twelve of these include absorption by Ly-\(\alpha\); a subset of four systems include additional metal lines. In the 13th system the expected wavelength of associated Ly-\(\alpha\) absorption was not observable, but the system does have the weaker line of the C IV doublet in our incomplete sample. We estimate for the observed singlet redward C IV systems and those redward C IV doublet systems that do not have detected associated Ly-\(\alpha\) absorption that a total of 2.5±1.0 systems are the product of a chance occurrence of other absorption features.

Combining the results of the simulations for false C IV identifications, we estimate that among the 122 C IV systems (including the 25 Ly-\(\alpha\),p pairs) in the completely identified line lists there are 24±5 that are false identifications.

A similar analysis leads to an estimate of the number of false O VI identifications included in our sample of 31 O VI systems (from a total sample of 41) contained in the spectra of the 70 objects for which identifications are complete. The simulations of pseudo-O VI systems were carried out as described in CAT2 and the results are presented in Table 5. For pseudo-O VI doublets, the average number per spectrum varies from 0.0 to 0.08. Except for the case of UM 18 (see below), all of the identified O VI pseudo-doublets are associated with detected Ly-\(\alpha\) lines, as is required by our identification rules. Relatively few accidental O VI doublets are found in the observed spectra, principally because of the limited redshift range in which the O VI doublets are observable and because Ly-\(\alpha\) is nearly always accessible when O VI is detected and provides a strong constraint against chance identifications. For all but one of the objects for which we performed simulations any candidate O VI doublet would have to have its associated Ly-\(\alpha\) accessible. However, for the highest redshift quasars in our sample, and specifically for UM 18, this is not the case for the entire O VI path length; at the highest redshifts any Ly-\(\alpha\) associated with the candidate O VI system moves beyond the red edge of the G270H observations. This explains why the mean number of chance O VI systems without Ly-\(\alpha\) is different from the mean number with Ly-\(\alpha\) only for UM 18; for the rest of the higher redshift quasars the line identifications are not complete and we did not perform any simulations for these line lists.

Twenty-two of the 31 identified O VI systems have both lines of the O VI doublet detected and the vast majority of these systems (18) are extensive metal line systems that have a negligible probability of being a chance absorption complex. Although the reality of the associated O VI is less certain, these systems are probably real (e.g., see Table 5 for examples of the low probabilities for false isolated doublets in general). There are 8 systems for which only the stronger line of the O VI doublet is in the complete sample, but 6 of these are also part of extensive metal line systems. While the association of O VI absorption with these systems when traced by a single line is less secure, nearly all of these identified O VI systems are expected to be real. Using our simulations we find that the sum over all 70 objects of the mean expected number of false O VI doublet systems that would contain both lines of the doublet plus associated Ly-\(\alpha\) absorption is only 0.55.

We estimate that of the 31 O VI systems in the sample of 70 objects with completely identified lines, one is a chance coincidence or false identification.

4. NOTES ON INDIVIDUAL SPECTRA

In this section we present descriptions and notes on the spectra obtained as part of the survey. The notes are grouped by object and presented in order of the right ascension (B1950) of the object. Entries are presented for all of the 92 objects, but complete notes, table of identifications (Table 3), and figures (Figure 2), are only included for the objects being discussed for the first time or being reanalyzed because of the availability of additional wavelength coverage (a new G130H spectrum of PKS 2251+11 analyzed together with the G190H and G270H spectra from CAT1) or to use the same analysis software on the spectrum (PKS 0405–123 from the Bahcall GTO program).

For a small fraction of the detected features in the line lists we have included comments in that the feature detected by the line measurement software is not believed to be a real feature, but rather an artifact of an imperfect fit to the continuum. In the vast majority of cases these features are broad and shallow, are probably due to a systematic error in the continuum fit that placed the fit, and have a SNR in their measured equivalent width that is less than 4.5, while still having \(SL > 4.5\). Such slight systematic shifts of the continuum were not always caught during the review of the continuum fits, but once the line identification process was started for a particular line list we did not allow revision of the continuum fit in order to avoid introducing any additional bias into the line measurement process.

In general any detected Ly-\(\alpha\) absorption due to gas associated with our Galaxy was not properly measured by the software and in many cases the depression or dip in the spectrum was “taken out” by fitting the feature during the construction of the continuum fit. When the Galac-

tic Ly-\(\alpha\) absorption was present it was always a damped feature and contaminated by geocoronal Ly-\(\alpha\) emission, and would not have been well measured by our software in any case. Fitting the feature as part of the continuum fitting process allowed weaker, nearby intergalactic Ly-\(\alpha\) absorbers to be detected and measured by the soft-
UM 18 (RA: 00:02:46.3 DEC: 05:07:29.0, B1950; $z_{em}$=1.89, 108 lines) Our spectrum of UM 18 is an example of the spectra, all of moderate to high redshift quasars, that presented the greatest difficulties in the measurement and identification of their absorption lines. These spectra share the properties of heavy line blending, difficult continua to fit, and limited total observed wavelength coverage. We will use our discussion of the identification of the lines in UM 18 to illustrate these points.

The higher redshift objects have a larger density of observed absorption lines for at least three reasons: 1.) the rest equivalent width detection limits in the higher redshift quasar spectra tend to be lower (i.e., more sensitive to intrinsically weak Ly-$\alpha$ absorption lines) than those of the lower redshift quasar spectra because the survey was designed to deliver spectra of uniform signal-to-noise ratio (i.e., uniform in observed equivalent width limit; see Figure 1 of Weymann et al. 1998); 2.) many of the higher redshift quasars have at least one Lyman–limit system in their spectra, resulting in numerous associated metal lines and higher order Lyman lines in their spectra; 3.) the higher order Lyman series lines (Ly-$\beta$, Ly-$\gamma$, etc.) are more readily observable in these spectra due to a larger observed path length at the higher redshifts (i.e., more of the less numerous stronger systems are included) and the more sensitive rest equivalent width detection threshold. All of these effects are evident in the spectrum of even the moderate redshift quasar PG 1538+477 ($z_{em}$ = 0.770) as shown in Figure 3 of Jannuzi (1998).

The higher density of lines combined with the relatively low spectral resolution of our observations results in severe blending of features, complicating every aspect of the analysis: the fitting of the continuum, the selection and measurement of the absorption lines, and identification of the lines. For the objects with Lyman–limit systems (including UM 18 and six of the eight objects for which we have incomplete identifications) the observed path length is also reduced, limiting our ability to cross check candidate metal line identifications by looking for supporting lines elsewhere in the spectrum. Similarly, for any of the quasars with emission line redshifts greater than about 1.6, our G270H spectrum does not extend far enough in the red to reach the quasar’s Ly-$\alpha$ emission line. This results in a region of each of these observed spectra that might contain Ly-$\beta$ lines that are indistinguishable from Ly-$\alpha$ because we cannot check for an associated Ly-$\alpha$ absorber longward of 3200 Å.

Given the problems discussed above, while we have listed identifications for the lines in the spectrum of UM 18, we consider these identifications to be less robust than the complete identifications presented for most of the objects in the combined catalogue. As an example, while the strong lines at 2797.57 and 2802.84 Å are close to the wavelengths of Galactic ISM Mg II, ZSEARCH formally rejected this identification in favor of either Ly-$\alpha$ absorption systems or as a C IV doublet at $z = 0.8071$. There were also several additional possible identifications for each line.

As we were completing this paper, a G190H spectrum of UM 18, obtained as part of a program of A. Koratkar and collaborators, became available in the HST archive. This spectrum, taken in spectropolarimetry mode, was reduced in a manner consistent with our own observations, although since the Al II $\lambda$1670.79 Galactic ISM line was not detected we could not check the zero-point of the wavelength scale. We used the G190H spectrum to identify the redshift and measure the properties of the Lyman–limit system ($z = 0.86$) listed for this object in Table 6. This LLS might be associated with a candidate metal line system present at $z = 0.8519$ or one of the other systems identified between $z = 0.85$ and 0.87. Unfortunately, the generally poor signal-to-noise ratio of the G190H spectrum yielded only one line that would normally meet our criteria for inclusion in the complete sample (at 2011.75±0.76 Å, $W = 1.54±0.56$, FWHM= 4.24, $SL = 6.5$) if the spectrum had been taken in a manner consistent with our other observations; this single additional line does not significantly aid the identifications of the lines in the G270H spectrum.

The remainder of our notes on the UM 18 spectrum consist of a listing of alternative identifications for some of the observed lines. The discussion of these identifications is not exhaustive, but serves to demonstrate some of the complications faced when trying to identify all of the lines in the spectra of the higher redshift objects.

As we mentioned above, because our G270H spectrum ends near 3200 Å, there is a section of the UM 18 spectrum for which unidentified lines might be Ly-$\beta$ lines associated with Ly-$\alpha$ lines between 3200 and 3513 Å (the wavelength of Ly-$\alpha$ emission for the quasar). This wavelength range includes the measured lines between 2760 and 2965 Å. While an isolated Ly-$\beta$ line in this region could not be identified without additional data, if additional higher Lyman lines or metal lines are present such systems could be verified. This is the case for the system at $z = 1.8011$: we did not observe the region containing Ly-$\alpha$ absorption, but the system could be identified by the presence of the Ly-$\beta$, Ly-$\gamma$, Ly-$\delta$, and Ly-$\epsilon$ absorption lines. An analysis including ground-based observations of the near UV portion of the spectrum would help resolve some of the uncertainties in the identifications of the lines between 2760 and 2965 Å.

The lines at 2234.94 and 2238.33 Å could also be a C IV doublet at $z = 0.4433$. The line at 2334.08 Å might be Si III in a system at $z = 0.8519$ including candidate lines from Ly-$\alpha$, C II $\lambda$1334.53 (alternatively Ly-$\alpha$ at $z = 1.0335$), Al II $\lambda$1670.79 (observed at 2093.95; alternatively Ly-$\alpha$ at $z = 1.5452$), Fe II $\lambda$1608.45 (more probably Ly-$\alpha$ at $z = 1.4458$ or part of a C IV doublet at $z = 0.9204$), and Si IV $\lambda$1393.76 (more probably Ly-$\beta$ at $z = 1.5160$). This candidate system would also be in rough agreement with the redshift of a Mg II system detected by Churchill, Steidel, & Vogt (1996), although this fact was not used in choosing the above identifications and became known to us after completion of the identifications. The 2267.12 Å line would alternatively be Ly-$\alpha$ at $z = 0.8649$. The Ly-$\alpha$ line at $z = 0.8670$ (observed at 2269.66 Å) has candidate O I and Al II lines at respectively 2431.04 and 3118.56 Å. The Ly-$\alpha$ line at 2320.50 Å is unusually broad and is likely a blend of several lines. The line at 2360.65 Å could be Ly-$\beta$ at $z = 1.3011$ or Ly-$\alpha$ at $z = 0.9419$. The line at 2383.60 Å contains a component from the Galactic ISM Fe II $\lambda$2582.77 line, but is a broad blend that certainly contains additional lines.

The system at $z = 1.4721$ might also include the O VI doublet at observed wavelengths 2550.59 and 2564.25 Å.
although alternative identifications were marginally preferred. The Ly-γ line of this system is alternatively Ly-β at $z = 1.3436$.

The lines at 2418.33 and 2431.04 Å might be an O VI doublet associated with other lines at $z = 1.3436$ (including the Ly-α line currently listed at $z = 1.3438$, which is quite broad and probably a blend). The broad line (blend?) at 2540.53 Å might include N II at $z = 1.3436$. The line at 2944.45 Å had multiple equally probable identifications. The lines at 2973.27 and 2978.78 Å might be a C IV doublet at $z = 0.9204$. The candidate $z = 1.4377$ system currently includes identifications of absorption from Si II λ1260.42 and Si II λ1193.28 at respectively 3072.46 and 2908.15 Å, but these lines might alternatively be caused by Ly-α absorption. The metal line identifications were slightly preferred due to the presence of the higher supporting hydrogen absorption lines at the same redshift. The Ly-γ line (at 2465.91 Å) from the $z = 1.5359$ system is blended with the Si II line from the $z = 0.9564$ system. The Ly-β line from the same system would be blended with the ISM Fe II line at 2600.89 Å. The system at $z = 1.500$ might include the O VI blended with the observed lines at 2580.59 and 2595.98 Å. Any associated C IV in this system would be redward of the observed spectrum. The line at 2607.45 Å might include a component of Galactic ISM Mn II.

PKS 0003+15 ($z_{em} = 0.450$, 58 lines) In total there are 21 Ly-α lines identified along this line of sight, two of which are associated with detected metal line systems ($z = 0.3660$ and 0.4014). The strong Ly-α line in the $z = 0.3660$ system (at 1660 Å) is likely to have an associated C IV doublet contained in the very broad (most likely heavily blended) absorption complex between 2113 and 2118 Å. The expected wavelengths for the associated C IV would be 2114.82 and 2118.33 Å. The observed Ly-α line is intrinsically broader than 270 km s$^{-1}$, it would not be too surprising for the matching C IV to be contained in more than one component. This heavy blend of candidate C IV absorption was fitted by the software as two narrow and one broad components, but a fit to two doublets would be justifiable. We identify this complex collectively as C IV associated with the $z = 0.3660$ system. In the incomplete sample the Ly-ε line of this system is present at 1280.90 ± 0.21 Å ($W = 0.31 ± 0.10$ Å, $SL = 4.23$, FWHM = 1.36 Å). The two lines at 1408.87 and 1416.41 Å and identified as Ly-α lines might contain O VI associated with the $z = 0.3660$ system. The region of the spectrum between the lines at 2179.46 and 2183.15 Å was difficult to fit because of a narrow apparent emission line (probably not real) at 2184 Å and the resulting uncertainty in the continuum fit. These latter two absorption lines might be a C IV doublet at $z = 0.4078$.

Galactic ISM lines in the incomplete sample include Si III (1206.37 ± 0.23 Å; $W = 0.69 ± 0.23$ Å; $SL = 4.04$; FWHM = 1.39 Å), Si IV (1393.82 ± 0.20 Å; $W = 0.19 ± 0.06$ Å; $SL = 3.28$; FWHM = 1.10 Å), and Mg I (2026.46±0.30 Å; $W = 0.18±0.06$ Å; $SL = 3.68$; FWHM = 1.72 Å). The unidentified line at 2800.97 Å might be Mg II absorption by gas in a high velocity cloud associated with our Galaxy. In this, the asymmetry of the 2803 Å line is mirrored in the corresponding 2796 Å line, although it was not fitted separately by the software. There is strong Ly-α absorption from the Galactic ISM, but the line does not appear in the line list because the absorption was “taken out” by the continuum fit.

The average equivalent width of the eight unidentified lines is 0.23 Å, considerably less than the average strength of the identified lines and significantly less than the average Ly-α line identified in this spectrum (0.63 Å). A number of these unidentified lines may be unrecognized flat-field residuals or the results of errors in the continuum fit.

NAB 0024+22 ($z_{em} = 1.118$, 46 lines) This spectrum contains 16 identified Ly-α lines; five of these are associated with detected metal lines. There is a high excitation metal line system at $z = 1.1102$, approximately 2,300 km s$^{-1}$ from the redshift of the quasar. This system contains C III, the C IV and O VI doublets, as well as Ly-α, Ly-β, and Ly-γ. Lower excitation lines (e.g., of Si II, S II, N II, C II) were not detected. This system provides one of the few cases in our data set where a search for absorption by Ne VIII λ7704.7803.3 is possible; no statistically significant features are evident at 1625.7 and 1646.4 Å. However, the detection limits are large (more than 1 Å) because of the low signal-to-noise ratio of the spectrum near the short wave-length edge of the G190H spectrum. The redshift of this system is less than 3,000 km s$^{-1}$ from the quasar redshift and would meet most definitions of being an associated absorber.

A metal line system at $z = 0.8196$ includes lines from C III, Si III, the strong line of the C IV doublet, Ly-α, Ly-β, Ly-γ, and Ly-δ. There is a candidate C IV doublet at $z = 0.4069$ associated with the Ly-α line at 1710 Å. The stronger line of the doublet would be blended with one of the O VI lines in the $z = 1.1102$ system.

The incomplete sample of lines contains three candidate Galactic ISM lines. These are from Al II λ1670.79 at 1670.81 ± 0.28 Å ($W = 0.50 ± 0.15$ Å, $SL = 3.22$, FWHM = 1.51 Å), Mn II at 2594.26 ± 0.36 Å ($W = 0.24 ± 0.07$ Å, $SL = 3.36$, FWHM = 2.04 Å), and Mg I at 2852.98 ± 0.33 Å ($W = 0.38 ± 0.09$ Å, $SL = 3.75$, FWHM = 2.04 Å).

The line at 2419 Å is quite broad. If this feature is real it is likely to be a blend of the listed identification and some other unidentified feature.

Three of the lines in the spectrum are broad or resolved and have multiple possible identifications. Although these lines are likely to be blends, we have listed only one identification for each in the table. The following are possible additional contributors to the observed absorption: 1685.88 Å, Ly-β at $z = 0.6432$; 1727.75 Å, Ly-γ at $z = 0.7760$; and 1773.50 Å, Si II at $z = 0.4069$.

PG 0043+039 ($z_{em}=0.384$) CAT1 One of six BAL quasars observed during the Key Project and Bahcall GTO program observations; the narrow absorption line identifications are presented in CAT1 and the object’s BAL properties are discussed by Turnshek et al. (1994).

PKS 0044+03 ($z_{em}=0.624$) CAT1

PG 0117+213 ($z_{em}=1.493$, 84 lines) There are 33 Ly-α lines in this spectrum, seven of which are associated with detected metal lines. This spectrum contains two extensive metal line systems occurring close together in velocity space. The systems at $z = 1.3389$ (seven identified lines, including the candidate N II absorption, see below) and 1.3426 (fourteen lines) are of the order of 1,000 km s$^{-1}$
apart. Both systems include lines from high-ionization states of O VI. The O VI λ1037.62 line of the z = 1.3389 system is in the incomplete sample at 2426.72±0.37 Å with an \( W = 0.24\pm0.07 \), a FWHM of 1.97 Å and a \( SL = 3.21 \).

The identification of 2271.87 and 3103.72 Å as respectively C III and C II in a \( z = 1.3256 \) system should be considered tentative. This system has both its Ly-\( \alpha \) and Ly-\( \beta \) lines blended with other lines. There is also a candidate O VI doublet associated with this system at 2399.18 and 2412.70 Å. The very strong line at 2488.89 Å is identified as Ly-\( \alpha \) at \( z = 1.0473 \). Surprisingly no other associated lines were detected in the system, although the expected wavelengths of lines from Si II, C IV, O I, and Fe II are all accessible in the spectrum. The 2574.75 Å line, a very broad feature, is likely a blend of absorption from several lines. While identified as Ly-\( \alpha \), it likely contains O VI from the z = 1.4952 system. The identification of 2700.63 Å is uncertain, possibly being Ly-\( \alpha \) at \( z = 1.2215 \), C II at \( z = 1.0237 \), and/or N I at \( z = 1.2503 \). The reality of this feature is also uncertain, as it might be the result of an error in the continuum fit. While our identification rules lead to the 2595.24 Å line being identified as Galactic Mn II, no other lines of Mn II were detected, including the 2503.17 Å line. The strong and broad feature at 2597.89 Å is therefore it is possible that this line is intergalactic and caused by Ly-\( \alpha \) at \( z = 1.1351 \). The matching line of the C IV λ1549.20 at \( z = 0.9676 \) (3047.02 Å) would be expected to be blended with the observed line at 3050.44 Å, which is identified as O I in the z = 1.3426 system.

There are candidate systems at \( z = 0.3159 \) (Al III doublet observed at 2440.62 and 2451.23 Å), 0.5766 (Si II λ1526.72, C IV λ1548.20,1550.77 doublet, Al II λ1670.79, and perhaps As II λ1608.45), and 0.9400 (Ly-\( \alpha \), Al II λ1670.79, and perhaps Si II λ1260.42 and C II λ1334.53) which include several of the same lines. With only the information contained in our data we are unable to firmly identify all of the possibly shared lines. However, the presence of Mg II absorption systems at \( z = 0.5764 \), 0.7289, 1.0478, and 1.3251 (Churchill 1997) support our independent decision of listing the \( z = 0.5766 \) identifications in the table when a choice had to be made. Alternative identifications for the lines in this system that have not already been mentioned include the following: 2407.08 Å (Ly-\( \alpha \) at \( z = 0.9800 \)), 2444.84 Å (Si II at \( z = 0.9400 \)), 2535.60 Å (N II λ1083.99 at \( z = 1.3389 \)), and 2634.62 Å (Ly-\( \alpha \) at \( z = 1.1672 \)). If the \( z = 0.9400 \) system is not real, then its C II line would most likely be Ly-\( \alpha \) at \( z = 1.130 \) and the Al II line would not have an identification.

Several pairs of lines in this spectrum are heavily blended or are asymmetric lines that our fitting software split into two components. As a result, equivalent-width measurements of the individual components are uncertain, although the total equivalent width of the blended feature is accurately measured. These measured pairs include the following lines: 2382.92, 2384.98; 2593.13, 2595.24; 2782.44, 2784.87; 2825.69, 2827.49 Å.

**PG 0122–00** (\( z_{\text{em}} = 1.070 \)) CAT2

**3C 57** (RA: 01:59:30.4 DEC: −11:47:00, B1950; \( z_{\text{em}} = 0.670 \), 35 lines) There are 19 lines identified as Ly-\( \alpha \) absorbers in this spectrum; none are associated with detected metal line systems. The line at 1934.94 Å, identified as Ly-\( \alpha \), is part of a candidate C IV system at \( z = 0.2498 \) that includes this line and the line at 1938.24 Å. The lines at 1762.32 and 1766.24 Å might be a C IV doublet at \( z = 0.1386 \). The line at 1902.42 Å is probably the result of an error in the continuum fit. The strong and broad feature at 1609.20 Å needs to be confirmed as a real feature since it occurs at the end of the observed spectrum and is subject to a large systematic error in the continuum fit. If the current measured line properties were confirmed, the line would be identified as Ly-\( \alpha \) at \( z = 0.3237 \) with lines of O I and C II observed respectively at 1723.17 and 1766.24 Å. The line at 1912.64 Å is probably an artifact of the continuum fit.

**PKS 0232–04** (\( z_{\text{em}} = 1.434 \), 49 lines) There are 25 Ly-\( \alpha \) lines in this spectrum and metal lines are associated with two of these lines. The broad and shallow line at 2775.90 Å is likely to be a composite of several other lines that could not be separated at the resolution of our spectrum. The line at 2686.94 Å is blended with other lines, and might not actually be an independent feature. The Ly-\( \alpha \) lines at 2890.85 and 2925.64 Å, which occur in the Ly-\( \alpha \) emission line, could be artifacts of the continuum fit. If the candidate C IV system at \( z = 0.7391 \) is not C IV, then the line at 2692.23 Å would be Ly-\( \alpha \) at \( z = 1.2146 \) with a matching Ly-\( \beta \) at 2270.76 Å. The 2597.12 Å line would be Ly-\( \alpha \) at \( z = 1.2186 \). The pair of lines at 2953.80 and 2961.95 Å were alternatively identified by ZSEARCH as a candidate doublet of Mg II absorption at \( z = 0.0564 \). ZSEARCH provides possible identifications of the lines at 2976.26 Å and 3175.91 Å as respectively N V (at \( z = 1.4021 \) and Si IV (\( z = 1.2788 \)), but in each case the weaker line of the doublet is not present. No damped systems or LLSs were detected in the G160L spectrum of this object.

**3C 95** (\( z_{\text{em}} = 0.614 \)) CAT1

**PKS 0405–12** (\( z_{\text{em}} = 0.574 \), 46 lines) We have reanalyzed and reanalyzed the FOS spectra of PKS 0405–12 previously published by Bahcall et al. (1993b) using the current versions of the line measurement and identification software. The most important case of change in the line list is the manner in which the complete sample was determined (see §3.1 and Paper II for discussion of the difference between using the ratio of the measured equivalent width to the uncertainty in that measurement and the definition we have chosen for the quantity \( SL \)). Other modifications included an improved adjustment of the zero point wavelength scale that resulted in a slight change of the measured velocities of the extragalactic absorption systems. A revised continuum fit for the G270H grating data caused significant changes to the measured strength of some lines.

Significant differences between the old and new line lists are the following:

1) The line at 1408 Å is now identified as Si III at a redshift of 0.1671, instead of Ly-\( \alpha \).

2) The complex blend at 1252.27 Å is now identified as Ly-\( \alpha \) at a redshift of 0.0301. Although S II λ1253.79 probably contributes to this blend, the wavelength difference between the expected and observed position of the line is too great for this line to be produced entirely by Galactic ISM S II. If the identification of this feature as Ly-\( \alpha \) is correct (and it would be valuable to confirm this with additional observations), then this system might be of par-
cular interest for detailed study given its proximity.

3.) We have identified three additional metal lines associated with the \(z = 0.1671\) system noted by Bahcall et al. (1993b) and associated with two galaxies by Spinrad et al. (1993). The system is now known to include absorption from Ly-\(\alpha\), C IV, Fe II, Mg II, Si II, and Si III.

4.) Eleven lines appear in the new complete sample that were not in the Bahcall et al. (1993b) line list. Ten of these lines have equivalent widths less than 0.3 Å. All of the lines appear in the new line list because of either the change in the way we determined the significance of the line or a revision of the continuum fit. Of the eleven new lines, two are metal lines associated with the 0.1671 system, one is a Galactic ISM line, five are identified as Ly-\(\alpha\), and three are unidentified. The unidentified lines are probably produced by slight errors in the continuum fit. The reason the continuum fit errors occur preferentially in the redward portion of the spectrum is because this region has a higher signal-to-noise ratio and the quasar continuum emission is not well fitted by a low-order spline. The resulting “false” lines, that would normally be too weak to be included in the complete sample have significance levels that are sufficient to require inclusion in the complete sample.

5.) Six lines in the Bahcall et al. (1993b) sample are not in the new complete sample. Five of these lines are in the incomplete sample of lines: two retain their identification as Galactic ISM C II* \(\lambda 1335.71\) and Al II \(\lambda 1670.79\); two were previously unidentified lines (at 2711 and 3034 Å); one was previously identified as a Ly-\(\alpha\) line at \(z = 0.3633\). One line from the old sample (at 2605 Å and previously identified as Galactic ISM Mn II) dropped below a SL of three, and hence out of the incomplete sample, due to the revised continuum fit. In summary, of these six lines five are probably real although they no longer appear in the complete sample. Additional notes on the current identifications follow. There are 19 lines identified as Ly-\(\alpha\) with one of these lines associated with identified metal lines. The \(z = 0.4056\) system might have an associated Mg II doublet detected in ground-based data (see Spinrad et al. 1993). Our revised measurements of the Ly-\(\alpha\) line that previously matched in velocity a galaxy in Spinrad et al. (\(z = 0.361\)) yield a larger separation in velocity than our original measurement. The line at 1577 Å is formally identified as Ly-\(\beta\) at \(z = 0.5385\), but the line center is more than 3σ away from the expected position, and this discrepancy might be due to another Ly-\(\alpha\) line at \(z = 0.2977\). The Galactic ISM C II* \(\lambda 1335.71\) line is in the incomplete sample at 1335.60±0.18 Å (\(W = 0.28±0.07\), \(SL = 4.00, FWHM = 1.10\) Å). The Al II \(\lambda 1670.79\) Galactic ISM line is also in the incomplete sample at 1670.83±0.21 Å (\(W = 0.30±0.06\) Å, \(SL = 4.39, FWHM = 1.51\) Å). The line at 1471 Å is identified as Si II \(\lambda 1260.42\) at \(z = 0.1671\), but the observed width of this line suggests that it is probably produced by a blend of Si II with some other unidentified feature. The Galactic ISM Fe II \(\lambda 2586.65\) line is affected by a flat-field residual.

3C 110 (RA: 04:14:49.2, DEC: −06:01:04.0, 1950; \(z_{\text{em}} = 0.773, 33\) lines) There are 22 Ly-\(\alpha\) lines in this quasar’s spectrum, but no extensive metal line systems were detected.

PKS 0439−433 (\(z_{\text{em}} = 0.593, 37\) lines) This spectrum contains an extensive metal line system at \(z = 0.1010\). This mixed ionization system is two to four times stronger than the absorption found along typical paths halfway through the Galactic disk/halo gas observed from the position of the Sun. A total of 11 lines from this system are in the complete sample. Two additional candidate lines of Fe II (\(\lambda\lambda 1608.45, 2374.46\)) are detected in the incomplete sample (at 1770.40±0.28 Å, \(W = 0.29±0.09\) Å, \(SL = 3.26, \text{FWHM} = 1.51\) Å; and at 2614.49±0.49 Å, \(W = 0.29±0.10\) Å, \(SL = 3.94, \text{FWHM} = 2.47\) Å). There are seven Galactic ISM lines in the complete sample and one line in the incomplete sample (Mg I, at 2852.79±0.29 Å, \(W = 0.36±0.08\) Å, \(SL = 3.40, \text{FWHM} = 2.03\) Å). The lines observed at 2865.09 and 3088 Å are blended with respectively the Fe II \(\lambda 2600\) line and the Mg II \(\lambda 2803\) line of the \(z = 0.1010\) system. They are very likely components of the Fe II and Mg II absorption from this system. There are seven identified Ly-\(\alpha\) lines in this spectrum with two of these lines associated with identified metal lines. The C IV \(\lambda 1550.77\) of the redshift 0.4075 system is in the incomplete sample (at 2182.76±0.23 Å, \(W = 0.20±0.06\) Å, \(SL = 4.26, \text{FWHM} = 1.63\) Å). The C IV \(\lambda 1550.77\) of the redshift 0.4268 system is in the incomplete sample (at 2212.56±0.26 Å, \(W = 0.15±0.04\) Å, \(SL = 3.41, \text{FWHM} = 1.50\) Å).

HS 0624+6907 (\(z_{\text{em}} = 0.370, 34\) lines) There are eleven lines identified as Ly-\(\alpha\) lines in this spectrum, including several at very low redshifts. The line at 2808.10 Å is on the wing of the Galactic ISM Mg II \(\lambda 2803\) line, and is likely just a result of the Gaussian fit to the line not properly including all of the absorption in the wings. The line identified as the Galactic ISM C IV \(\lambda 1548.20\) might be a blend of both features that were not well measured in this spectrum. The Galactic ISM Si IV doublet is in the incomplete sample at 1393.67±0.17 and 1403.21±0.20 Å with equivalent widths of 0.23±0.06 and 0.18±0.05 and SLs of 3.85 and 3.28, respectively. The Galactic ISM Zn II (Mg I) blend at 2026 Å is also in the incomplete sample at 2026.56±0.20 Å with \(W = 0.24±0.06\) Å and a SL of 4.06. The line at 1808.08 Å, identified as Si II \(\lambda 1808.01\), is somewhat stronger than expected.

PKS 0637−75 (\(z_{\text{em}} = 0.654, 22\) lines) Nine Ly-\(\alpha\) lines are identified in this spectrum, one of which is associated with the single extragalactic metal line system detected along this line of sight. This heavy element system has a redshift of 0.4168 and has the strong line of the C IV doublet, Ly-\(\alpha\), and Si III in the complete sample. The incomplete sample contains the C IV \(\lambda 1550.77\) line observed at 2197.18 Å with an equivalent width of 0.24±0.06 Å and a SL of 4.1. Note that the Si III line at \(z = 0.4168\) is blended with the Ly-\(\alpha\) line observed at 1711 Å; this affects its measured properties.

In addition to the Galactic ISM lines in the complete sample (including lines from Al II, Fe II, and Mg II), the incomplete sample contains lines from the Zn II (Mg I) blend at 2026 Å (observed at 2025.42 Å, \(W = 0.18±0.056\) Å) and Mn II \(\lambda 2576.88\) (observed at 2576.15 Å, \(W = 0.35±0.08\) Å). The presence of high velocity gas along this line of sight (\(l = 286.4°, b = −27.2°\)) in the velocity range be-
between +230 to +270 km s$^{-1}$ has previously been reported by (Bajaja et al. 1985). We therefore expect to see the combined absorption from local gas and this high-velocity gas extending from −40 to +270 km s$^{-1}$. This is reflected in our observations of the Galactic ISM lines in several ways. First, Al II λ1670.79 and four of the Fe II lines have very broad profiles. Second, the Fe II λ2600.17 line and Mg II lines are resolved into two components. Additional discussion of the Galactic ISM lines can be found in Savage et al. (1998).

**B2 0742+31 (zem=0.462, 12 lines)** The Galactic ISM Mg II absorption lines occur on top of a strong quasar emission line. Together with the non-Gaussian shapes of these absorption lines, the difficulties in fitting the continuum are probably responsible for the line fitting software splitting the very strong and broad Mg II λ2796 line into two lines, one at 2796 Å and the second at 2790 Å. The line at 1600 Å occurs on the blue edge of the wavelength coverage of the G190H grating, a region of particularly low signal-to-noise ratio in almost all our G190H spectra and in this quasar’s spectrum a particularly difficult region in which to fit the continuum. The feature at 2025 Å, identified as being produced by Galactic ISM Zn II, is quite broad and unlikely to be due exclusively (if at all) to absorption by Zn II.

**PKS 0743−67 (zem=1.51, 76 lines)** There are 44 Ly-α lines identified in this spectrum; four are associated with detected metal lines and a fifth is less than 300 km s$^{-1}$ from the velocity of a metal line system. There are at least three systems that include absorption by the C IV doublet along this line. There is a very strong blend near 2435 Å that was separated by the analysis software into a non-unique fit consisting of a broad line and two narrower lines. With the current data we are unable to identify the broad component of the fit at 2432 Å. The line at 2290 Å might be a continuum artifact. The line at 2612 Å is heavily blended with the line at 2615 Å and might be a component of the 2615 Å system. Several additional lines in the complete sample might be continuum artifacts since slightly different versions of the continuum fit developed during analysis of this spectrum caused these lines to disappear. These lines are at 2464.36, 2734.18, and 2738.69 Å. These last two lines comprise a candidate C IV doublet that lacks additional supporting lines. The Galactic ISM Mg I λ2852.96 line is blended with a stronger Ly-α line at z = 1.3473.

**US 1867 (zem=0.513) CAT1**

**OJ 287 (RA: 08:51:57.2, DEC:+20:17:58, B1950; zem=0.306, 9 lines)** No extragalactic absorption lines are identified in the complete sample. There are eight Galactic lines in the complete sample and one in the incomplete sample (Al II λ1670.79, at 1670.40 ± 0.20 Å, W = 0.72 ± 0.20 Å, SL = 4.37, FWHM = 1.55 Å). Planned G130H observations of this object were unsuccessful because this object became too faint at the time the observations were scheduled. There are candidate C IV absorption lines in the incomplete sample. The line at 1934.89 Å is near a feature in the flat-fields, but is stronger than the typical residual seen in Key Project data. Future STIS observations of this normally bright (but variable) object (it is a well known BL Lacertae object) would be valuable.

**NGC 2841 UB3 (RA: 09:16:30.0 DEC: +51:18:53, B1950; zem=0.553, 26 lines)** There are twelve Ly-α lines identified in this spectrum, one of which is resolved and associated with a strong metal line system detected at z = 0.5116. Lines from Si III, C II, and the C IV and Si IV doublets are detected in the complete sample. The stronger line of the N V doublet is present in the incomplete sample (at 1872.48 ± 0.28 Å, W = 0.14 ± 0.04 Å, FWHM = 1.51 Å, SL = 3.27). The line at 1639.68 Å and identified as Ly-α at z = 0.3488 might be blended with N II λ1083.99 associated with the z = 0.5116 system. Galactic ISM lines are detected from Fe II, Mg II, and Al II. It is possible that the broad unidentified line at 2596 Å is associated with Galactic ISM Mn II, but this identification was not made by ZSEARCH because the other expected Mn II lines were not present in the line list. However, this region of the spectrum is blended with the wings of the strong Fe II Galactic ISM absorption. Blending plus uncertainties in the continuum fit might cause the other two lines of the Mn II triplet to have been missed.

**PG 0935+416 (zem=1.937, 131 lines)** The continuum fit for this spectrum was particularly difficult, and given the low spectral resolution of the observations and the high density of lines, is probably inadequate in several regions, adversely affecting the measurement, separation, and identification of the lines. Despite these problems, this spectrum also provides the only damped Ly-α system, z$_{abs}$ = 1.3720, in the entire survey. The damped line is not well fitted by our software, which assumes Gaussian line profiles for all lines. As a result, an additional line was included in the software’s automated fit, at 2889.27 Å. The resulting redshift of the system (which includes absorption from C II, C III, N I, O I, Fe II, Si II, Si III, Ly-α, and Ly-β) is therefore different from that measured from a proper fit to the damped absorption, z = 1.396, which we include in §5, our general discussion of damped systems. In addition to the detected damped system, there is an extensive metal line system at z = 1.4649 with an associated Lyman–limit system. The properties of the LLS as determined by the LLS fitting software are listed in Table 6.

The numerous possible identifications for many of the lines prevented us from completing the identifications. Even for the lines we have identified, many are likely to be blended with absorption from other species. For example, three identifications for the line at 2317.90 Å are C III at z = 1.3720 (our current identification), Fe III in a candidate system at z = 1.5085, and C IV at z = 0.4946. Higher spectral resolution observations, perhaps with the Space Telescope Imaging Spectrograph (STIS), of this interesting line of sight would be valuable.

**PG 0953+415 (zem=0.239, 28 lines)** Galactic interstellar absorption lines are identified from ten different ions: C II, C IV, N I, O I, Al II, Mg I, Mg II, Si II, Si III, and Fe II. In the incomplete sample, Si IV λ1393.76 is present at 1393.75 ± 0.16 Å with an equivalent width of 0.26 ± 0.06 Å and SL = 4.13. The line at 1190.37 Å includes a contribution from Si II, but its large equivalent width and FWHM suggest that it is possible that the line is a blend of Si II and S III λ1190.21. The continuum was particularly difficult to fit in the region between 2570 Å to 2610 Å, making the measured equivalent widths of lines...
in this region more-than-usually uncertain and possibly affecting how many lines the software required to fit the region. Among the lines with particularly large uncertainties in their equivalent widths is a line at 2593 Å. There is some indication that this strong line might be Mn II λ2594.50 since there is a line in the incomplete sample that could be identified as Mn II λ2576.88 (this line occurs at 2576.48 Å, has an equivalent width of 0.30±0.11 Å, and SL = 4.49), but there is no sign in the spectrum of the expected Mn II λ2606.46, so the identification as Mn II is formally rejected. The line identified as Galactic ISM Mg I λ2852.96 is unusually strong and broad.

A total of five Ly-α absorption features are identified in the complete sample, although three of the five are too broad (FWHM larger than the instrumental resolution) to be single, unresolved Ly-α absorbers. There is a Ly-α absorption line at z = 0.2336, only 1300 km s\(^{-1}\) from the emission line redshift. The Ly-β line for this system appears in the incomplete sample at 1265.6±0.153 Å with an equivalent width of 0.24±0.07 Å and a significance level of 4.4, very close to the level of 4.5 required for inclusion in the complete sample.

There is weak evidence in some of the other G270H quasar spectra taken contemporaneously with these data for a flat-field contribution to the line we identify as Ly-α at z = 0.0934 (at 1329 Å), but there is no evidence for a flat-field feature in the standard star observations at the same epoch.

The unidentified line at 2028 Å is part of a blend and falls on top of a quasar emission line. Both of these occurrences contribute to an additional unquantified uncertainty in the measured equivalent width. Despite the wavelength agreement of this line with the expected position of Al III λ1854.72 at a redshift matching that of the Ly-α line at 1329 Å (z = 0.0934), this identification is rejected because of the absence of any of the other metal lines that might also be expected when Al III is detected.

**MARK 132 (RA: 09:58:08.1, DEC:+55:09:05.0, B1950; z\(_{\text{em}}\)=0.533, 24 lines)** Burbidge et al. (1971) first drew attention to the close projection of 3C 232 and the nearby bright Sb III spiral galaxy NGC 3067. The separation of the quasar and the galaxy center is 1.9 on the sky, well beyond the extent of the visible disk. Haschick and Burke (1975) discovered narrow (≤ 5.5 km s\(^{-1}\)) H I 21 cm absorption at a redshift near 1420 km s\(^{-1}\), close to the mean redshift of the galaxy; this was confirmed by Grewing and Mebold (1975), and followed by higher resolution observations (Wolf 1979; Rubin, Thomard & Ford 1982). In high-dispersion optical spectra Boksenberg and Sargent (1978) found Ca II H and K absorption at nearly the same redshift as the H I but of substantially broader (and structured) velocity profile. This was the first instance of metal absorption lines in a quasar spectrum observed at large extension from an identified galaxy. From the large ratio of N(Ca\(^{+}\))/N(Na\(^{+}\)) obtained from their data (inferred from upper limits on the equivalent widths of Na I) they suggested that the absorption arises either in gas in the outer halo of the galaxy or in high-velocity gas in the plane. Low-dispersion ultraviolet observations of 3C 232 made with the IUE satellite (Bergeron, Savage, & Green 1987) provided a detection of Mg II in this system and set limits on the presence of C IV and Si IV. Further optical observations by Stocke et al. (1991), in which both Ca II and Na I were detected, resolved the system into two and possibly three components spread over ~ 160 km s\(^{-1}\), and from archival IUE low-dispersion spectra they added Fe II to the list of detected lines. The morphology of the absorbing gas was clarified by Carilli, van Gorkom & Stocke (1989) who obtained a VLA H I map showing a remarkably long and disturbed tail extending from the galaxy and appearing as a chance projection at the quasar position (Stocke et al. 1991).

This absorption system is strongly detected in our data, and includes lines from Al II, Fe II, Mg II and Mg I. There are five Ly-α lines in the spectrum, one of which is identified with a strong associated metal line system at z = 0.5314 (480 km s\(^{-1}\) from the redshift of the quasar). The 1242 Å line of the N V doublet in this system is in the incomplete sample (at 1903.34±0.22 Å, W = 0.32±0.08 Å, SL = 4.13, FWHM= 1.51 Å), while the 1550.77 Å line of the C IV doublet is blended with the Galactic ISM Fe II λ2374.46 line. The Ly-α line at z = 0.5167 probably is related to weak Fe II and possibly Mg II absorption also found by Boksenberg and Sargent (1978) in their spectrum. The Galactic ISM Fe II λ2260.78 Å is in the incomplete sample (at 2261.61±0.38 Å, W = 0.38±0.11 Å, SL = 3.20, FWHM= 2.04 Å). A GHRS spectrum has been obtained of 3C 232 and is being analyzed by J. T. Stocke and collaborators.

**TON 28 (RA: 10:01:12.0, DEC:+29:13:00, B1950, z\(_{\text{em}}\)=0.329, 30 lines** There is some indication that this strong line might be a single, unresolved Ly-α absorber. There is a Ly-α absorption system near 1420 km s\(^{-1}\) with a significance level of 4.4, very close to the level of 4.5 required for inclusion in the complete sample.

The unidentified line at 1658 Å is a 20 identified Ly-α lines. The line at 1658 Å is a composite of several features in a noisy region of the spectrum. Possible contributors to the feature include Ly-β at z = 0.6179 and a known flat-field residual. The lines at 1771 and 1809 Å might both be artifacts of the continuum fit.
(at 1220 and 1234 Å). These lines are excellent targets for followup investigations to study in detail the nature of low redshift Ly-α absorbers. The pairs of lines located at 1474, 1475 Å and 1495, 1496 Å are heavily blended. The line observed at 1548.48 Å is predominantly Ly-α at a redshift of 0.2738, although there is probably a small amount of Galactic ISM C IV λ1548.20, since the weaker line of this doublet is detected in the incomplete sample at 1551.20 ± 0.20 Å (W = 0.13 ± 0.04 Å, SL = 3.37, FWHM= 1.10 Å). Another candidate Galactic ISM line in the incomplete sample is Si IV at 1403.05 ± 0.17 Å (W = 0.18 ± 0.05 Å, SL = 3.95, FWHM= 1.11 Å). There is strong Galactic Ly-α absorption that was not included with the current continuum fit (see figures). A very broad and shallow feature near 2338.73 Å was not included in the final line list because it is an artifact of the continuum fit.

4C 41.21 (RA: 10:07:26.1 DEC: +41:47:24, B1950; zem=0.613, 36 lines) This line of sight includes 18 Ly-α lines, of which two have associated metal line systems including the C IV doublet and a third has an associated Si II line. All of the lines between 1630 Å and 1665 Å were difficult to measure because of the lower signal in this region and the difficulty of placing the continuum fit. The lines at 1677, 1820, and 1866 Å might be alternatively identified as respectively N I, O I, and C II at z = 0.3979. The line at 1937 Å is strongly affected by a flat-field residual, but does match in wavelength the expected position of Si IV from the z = 0.3902 system. There is weaker evidence that the line at 1948 Å is influenced by a flat-field residual, but the evidence is not sufficient to remove the line. For all of the metal line systems identified in this spectrum any associated Mg II absorption would be observable in ground-based spectra. The broad non-Gaussian wing of Galactic Mg II λ2796.35 is producing the feature the line fitting software found at 2797.56 Å.

PG 1008+133 (zem=1.287, 42 lines) There are 25 lines identified as Ly-α. It is difficult to determine the reality of the multiple candidate C IV systems in this spectrum because the wavelengths at which associated Ly-α absorption might be observed are not in the available spectrum and there is a significant probability that one to two of the identified systems are just the chance coincidence of Ly-α lines (see §3.4 and Table 4). For each of the observed doublets the alternative identification for the lines would generally be Ly-α. The Galactic ISM Fe II λ2382.77 line is very strong and may be blended with a Ly-α line.

TON 34 (RA: 10:17:06.0 Dec: +27:59:00.0, B1950; zem=1.924, 67 lines) The heavy blending of the lines in this spectrum and limited observed wavelength coverage lead to numerous possible identifications for almost every line and here prevent complete identification of the line list. The Ly-γ line for the z = 1.6420 system is in the incomplete sample at 2569.71±0.28 Å with W = 0.68 ± 0.14, FWHM= 1.97 Å, and SL = 4.39. Several metal line systems were identifiable. We now consider the candidate LLS listed in CAT1 not to be a real system (see Paper V for discussion) and no longer list it as part of our Catalogue. See Table 6 for a complete listing of LLSs found in the survey.

4C 19.34 (RA: 10:22:01.6, DEC:+19:27:35, B1950; zem=0.828) CAT1 Note the slight revision (see Table 6) of the properties of the LLS first reported in CAT1. These are as a result of the changes made to the software measuring the LLSs and not due to any change in the reduction of the spectrum.

4C 06.41 (RA: 10:38:40.9, DEC: +06:25:58, B1950; zem=1.270, 39 lines) The G270H spectrum contains 22 Ly-α lines. Given the short observed path length at the higher resolution, it is difficult to test the reality of all the candidate C IV doublets observed in this spectrum because additional lines from these systems do not fall in the spectral range covered by our higher resolution observations. We have identified these systems in the table, but caution that the lines might alternatively be due to Ly-α systems. The lines comprising the candidate C IV system at z = 0.4415 are almost certainly real as they are very likely associated with the Lyman–limit system detected in the G160L spectrum. The LLS is measured to have a redshift of z = 0.44 (see Table 6 for other measured properties). The weaker line of the candidate C IV doublet at z = 0.4928 is affected by a known flat-field feature. If this line is entirely a flat-fielding artifact, or if this doublet is a chance match of two otherwise unrelated lines, then the lines at 2310.28 and 2315.40 Å would be Ly-α at z = 0.9009 and 0.9046. The C IV doublet at z = 0.6093 would be Ly-α at z = 1.0493 and 1.0530. The Ly-β line of the Ly-α line at z = 1.2452 might be blended with the lines near 2301 Å.

3C 245.0 (RA: 10:40:06.0, DEC:+12:19:15, B1950; zem=1.028) CAT1

PG 1049−005 (zem=0.3570, 15 lines) The C IV system at z = 0.3414 has an associated Ly-α line in the incomplete sample at 1631.33 Å with an equivalent width of 0.52 ± 0.14 Å and SL = 3.55. There are a large number of Galactic ISM lines detected, including lines from Al II, Zn II, Fe II, Mn II, and Mg II. In the incomplete sample are additional Galactic ISM Fe II λ2249, λ2260, and λ2374 (observed at 2249.44 ± 0.33, 2260.30 ± 0.29, and 2373.80 ± 0.29 Å with equivalent widths of 0.39 ± 0.10, 0.14±0.5, and 0.44±0.10 Å and SL = 3.72, 3.09, and 4.23) and Mn II λ2576.88 (observed at 2576.51 ± 0.30 Å with an equivalent width of 0.30±0.07 Å and SL = 4.02). The line at 2107.34 Å is located on top of a narrow emission line, and might be structure in the emission line rather than an absorption feature.

PKS 1055+20 (zem=1.11) CAT1 Note the slight revision (see Table 6) of the properties of the LLS first reported in CAT1. These are as a result of the changes made to the software measuring the LLSs and not due to any change in the reduction of the spectrum.

3C 249.1 (RA: 11:00:27.4, DEC: +77:15:08, B1950; zem=0.311, 48 lines) This line of sight contains 15 Ly-α lines (one associated with metal lines) and 19 Galactic ISM lines. The line at 1402.64 Å, although matching the expected wavelength of Galactic ISM Si IV, is not identified as Si IV since the stronger line of the doublet is not present. This interpretation is supported by the weakness of C IV λ1548.20 observed at 1548.07 Å: W = 0.19 ± 0.04 Å. Galactic ISM lines from C II* (at 1335.80±0.20 Å, W = 0.18±0.05 Å, SL = 3.61, FWHM= 1.10 Å) and Si II (at 1193.17±0.17 Å, W = 0.55±0.14 Å, SL = 3.97, FWHM= 1.11 Å) are in the incomplete sample. The line at 1465 Å may be an artifact of the
continuum fit. The line at 1657.18 Å was identified by ZSEARCH as possibly the stronger line of a C IV doublet at \( z = 0.0706 \). However, this identification was rejected because the supporting Ly-\( \alpha \) line would be blended with the line at 1301 Å; which was identified as Galactic ISM O I.

**Q 1101−264 (\( z_{em} = 2.148, 71 \) lines)** The heavy blending of the lines in this spectrum and limited observed wavelength coverage (exacerbated by the presence of a LLS in this spectrum) made the fitting of the continuum very uncertain and caused some problems for the line fitting software (e.g., near 2800 and 3150 Å), where alternative fits to the blends are certainly possible and would be chosen by the software with only slight changes in the continuum fit. The numerous possible identifications for almost every line prevented complete identification of the line list here. We are working on using supplementary ground-based observations to assist in the line identifications, but that analysis is beyond the scope of the current paper. We do include tentative identifications of the strong lines at \( z = 1.8377 \) associated with the LLS observed at \( z = 1.84 \), as well as some of the other strong lines in the spectrum. Additional properties of the LLS are listed in Table 6. The broad line at 2802 Å includes Galactic ISM Mg II \( \lambda 2803 \).

**MC 1104+167 (\( z_{em} = 0.634, 23 \) lines)** There are nine Ly-\( \alpha \) systems along this line of sight, one of which (\( z = 0.4549 \)) includes metal lines from C IV and Si III. The feature at 1966 Å, which occurs on the side of a strong quasar emission line, is probably an artifact of the continuum fitting process. If the line is real, it would be Ly-\( \alpha \) at a redshift of 0.6179. There is a candidate Galactic ISM Zn II line in the incomplete sample at 2062.09 ± 0.22 Å (\( W = 0.17 ± 0.04 \) Å, \( S/L = 4.05, \) FWHM= 1.51 Å)

**PG 1116+215 (\( z_{em} = 0.177, 37 \) lines)** The spectrum of Galactic ISM lines detected along this line of sight is among the richest found in the Key Project sample of observations. A total of 25 Galactic ISM lines are identified in the complete sample and AI III (at 1855.09 ± 0.40 Å, \( W = 0.15 ± 0.06 \) Å, \( S/L = 4.03, \) FWHM= 2.23 Å) and Zn II (at 2062.51 ± 0.21 Å, \( W = 0.14 ± 0.03 \) Å, \( S/L = 4.01, \) FWHM= 1.51 Å) are in the incomplete sample. There is strong Galactic Ly-\( \alpha \) absorption that has an approximate observed equivalent width of 2.96 Å.

There are seven lines identified as extragalactic Ly-\( \alpha \) lines, two of which have an associated metal line. The line identification software accepts the line at 1203 Å as the stronger line of the O VI doublet associated with the Ly-\( \alpha \) line at 1417.79 Å, \( z = 0.1663 \), although there are no other lines in the complete sample to provide additional support for this identification. In the incomplete sample of lines there is a possible match to the expected positions of the C IV doublet, but at very low significance level. The candidate O VI line might be part of an associated absorption line system being produced either by gas intrinsic to the quasar or associated with the group or cluster of galaxies that is associated with the quasar (Jannuzi 1997).

There is weak evidence that a flat-field residual might be affecting the measurement of the line at 1454 Å, but not enough to remove the feature from the complete sample. If this line were produced by a Ly-\( \alpha \) absorber it would have a redshift over 5000 km s\(^{-1}\) larger than the emission redshift of the quasar. All of the detected lines from 1393 to 1454 Å occur on top of a strong quasar emission line and are particularly uncertain due to the subjective nature of the continuum fit. In particular, the line at 1434.96 Å can be made to appear or disappear completely with slightly different continuum fits. The lines at 2386.12 and 2798.74 Å are not identified, but are blended with or near strong Galactic ISM lines and might be related to high velocity Galactic ISM clouds. Alternatively they might be a result of our choice of fitting Gaussian profiles to the strong non-Gaussian profiles of the strong ISM lines, leaving portions of the wings to be fitted as separate lines.

**UM 425 (RA: 11:20:46.6, DEC:+01:54:17, B1950; \( z_{em} = 1.465 \))** This is one of the six BAL quasars observed by the Key Project and Bahcall GTO program. The spectrum is displayed in Figure 2, but the analysis of this spectrum will be presented in Turnshek et al. 1998.

**1130+106Y, (\( z_{em} = 0.51, 22 \) lines)** Four Ly-\( \alpha \) lines are detected along this line of sight, two of which are associated with metal line systems. There is a strong high-excitation associated absorption line system at \( z = 0.5088 \) which includes Ly-\( \alpha \) and the C IV and N V doublets. The \( z = 0.5061 \) system consists of Ly-\( \alpha \) and the strong line of the C IV doublet (observed at 2331 Å). This line is identified as C IV even though the weaker line of the doublet is not detected because it is probable that the strong C IV \( \lambda 1548.20 \) line at \( z = 0.5088 \) is blended with C IV \( \lambda 1550.77 \) from the \( z = 0.5061 \) system. The incomplete sample contains the AI II Galactic ISM line at 1670.70 ± 0.19 Å (\( W = 0.72 ± 0.14 \) Å, \( S/L = 4.39, \) FWHM= 1.50 Å). The line fitting software did not handle well the strong, non-Galactic Galactic ISM Mg II absorption. The feature at 2799 Å is actually the blended wings of the Mg II \( \lambda 2796,2803 \) absorption. There are no candidate damped Ly-\( \alpha \) or LLSs along this line of sight (based on the G190H and G160L observations).

**PKS 1136−13 (\( z_{em} = 0.554, 18 \) lines)** There are seven Ly-\( \alpha \) lines identified in this spectrum, one of which is associated with a detected metal line system. For the \( z = 0.4064 \) system, a candidate N V \( \lambda 1238.82 \) line is detected in the incomplete sample at 1741.86 ± 0.31 Å (\( W = 0.31 ± 0.10 \) Å, \( S/L = 3.10, \) FWHM= 1.51 Å)

**3C 263 (RA: 11:37:09.4, DEC:+66:04:27, B1950; \( z_{em} = 0.652 \))** CAT1 While our G190H and G270H spectra have been previously published, the G160L spectrum shown in Figure 2 was not available when CAT1 was written. We have included the G190H and G270H spectra in Figure 2 along with the new G160L spectrum.

**PG 1202+281, (\( z_{em} = 0.165, 6 \) lines)** Only Galactic ISM lines were detected along this line of sight. The Fe II \( \lambda 2600.18 \) line is in the incomplete sample at 2600.16 ± 0.27 Å (\( W = 0.52 ± 0.11 \) Å, \( S/L = 4.48, \) FWHM= 2.04 Å).

**PG 1206+459 (\( z_{em} = 1.158, 122 \) lines)** Our identifications of the lines in the UV spectra of PG 1206+459 are incomplete. This is in part due to the irregular nature of the continuum of this quasar and the difficulty of obtaining a good fit. The Galactic ISM lines, some remarkable extensive metal line systems (at \( z = 0.9254, \) 0.9277, 0.9342), and a few additional lines have been successfully identified. The Lyman—limit fitting software also found a candidate system at 0.928, a redshift in remarkable agreement with the narrow line system already mentioned.
However, we have not included this candidate LLS in Table 6 as we consider it not to be a real system, but most likely just the result of the irregular behavior of the quasar’s continuum (Paper V). The majority of the lines in this spectrum have multiple plausible identifications and we have not yet been able to assign a “most probable” identification for all of them. Most of the lines in the table 3 marked “notes” probably include a contribution from a line in another system as well. The other lines for which “notes” are indicated in table 3 refer to the following: the feature at 1995.68˚ is likely to be real systems (see Paper V for discussion) and no signal-to-noise ratio are needed to test these candidate absorbers produced by an error in the continuum fit.

MC 1215+113 (zem=1.396) CAT1 We now consider the candidate Lyman-limit systems listed in CAT1 not to be real systems (see Paper V for discussion) and no longer list them as part of our Catalogue. See Table 6 for a complete listing of LLSs found in the survey.

PG 1216+069 (zem=0.334, 29 lines) The spectrum contains nine identified Ly-α lines, including one of the strongest Ly-α absorbers detected in the Key Project observations. The remarkable line at 1223.34˚ (zem=0.0063; 1890 km s\(^{-1}\)) has no detected associated metal lines in the complete sample; however there are possible detections of Si II λ1260.42, C II λ1334.53, and Mg II λ2796.35 in the incomplete sample. New observations with an improved signal-to-noise ratio are needed to test these candidate identifications and to test whether the broad Ly-α line at 1223˚A can be resolved into separate components. It will be extremely interesting to look at other wavelengths (optical and radio imaging) for a counterpart to this very low redshift system.

The only acceptable identification for the line at 1741˚A is C IV associated with the Ly-α line at 1367.21˚A (zem=0.1247). ZSEARCH formally identifies this line as the stronger component of the C IV doublet, but it is possible that the single broad feature found by the line measurement software is produced by both lines of the doublet blended together. In addition, the Ly-α line at z=0.1236 is close enough in velocity (<300 km s\(^{-1}\)) that C IV from that system might also be blended with the z=0.1247 lines. A shallow and broad line at 2664˚A was removed from the list because it is produced by an error in the continuum fit.

PG 1244+32B (zem=0.949) CAT1

PG 1248+401 (zem=1.030, 88 lines) This line of sight includes four metal line systems (two very extensive) in addition to the 37 Ly-α (four of which are associated with the metal line systems) and eight Galactic ISM lines. The metal line system at z = 0.8553 includes a broad Ly-α feature that was split by the fitting software into two components. Absorption by Ly-α, Ly-β, Ly-γ, Ly-δ, Ly-ε, C II, C III, C IV, N III, N V, O VI, Fe III, and Si III is observed in this system. The second extensive system, at z = 0.7732, includes lines from Ly-α, Ly-β, Ly-γ, Ly-δ, Ly-ε, C II, C III, C IV, N II, N III, N V, O VI, Fe III, Si II, Si III, and Si IV. The Fe III line in this system was found as part of a candidate system at z = 0.7734 that included many, but not all of the lines in the candidate system at z = 0.7732 – while formally the wavelength agreement is insufficient for this line to be identified with this system, it is likely to be the correct identification and that the redshift is slightly in error. The line at 1922.34˚A is listed in the table as C II in the z = 0.8553 system, but is blended with the N II line from the z = 0.7732 system. The line at 1924.96˚A is listed as O VI in the z = 0.8553 system, but there is a small probability that this line is blended with N II in the z = 0.7660 system. The candidate metal line system at z = 0.7760 is of particular interest because there is no detected C IV doublet to accompany the detected O VI lines. This is an excellent candidate to be an absorber produced by collisionally excited gas, perhaps associated with a group or cluster of galaxies. If the candidate O VI lines in the z = 0.7760 system are not O VI (and identified lines in this system only include Ly-α, Ly-β, and C IV doublet was not detected in either the complete or incomplete samples, raising the possibility that the line at 1548.20˚A is actually a Ly-α line at z = 0.2736.

MARK 205 (RA: 12:19:33.5, DEC:+75:35:16.0, B1950; zem=0.070) Although too low a redshift to have been included in the original Key Project sample of targets, MARK 205 was one of the GTO observations of Bahcall and is now included in this summary for the sake of completeness. The spectrum and line identifications for this object were presented by Bahcall et al. (1992b).

3C 273 (RA: 12:26:33.3, DEC:+02:19:43, B1950; zem=0.158) CAT1 Our FOS spectra of this quasar were first analyzed by Bahcall et al. (1991a,b) and reanalyzed with the Key Project analysis software in CAT1.

PG 1241+176 (zem=1.273, 41 lines) This spectrum contains 19 Ly-α lines (two are associated with detected metal lines), and there is a remarkably strong candidate O VI doublet at a redshift close to that of the quasar. The only additional lines in the system are Ly-α and Ly-β. Other features that might have been expected (e.g., the N V and C III) are not present. However, it is possible that there is N V absorption present in the spectrum and that it has been removed by our choice of continuum fit (see Figure 2). If the lines comprising the candidate O VI doublet at z = 1.2720 are misidentified, the alternative identifications for the lines are Ly-α at z = 0.9286 and 0.9395. The line at 2344.53˚A also includes a small contribution from the Galactic ISM Fe II λ2344.21 line. The line at 3205.24˚A is probably the result of an imperfect continuum fit. The feature at 2532˚A is the result of a flat-fielding residual and an error in the continuum fit. The Ly-α line at 2244˚A might be the result of the continuum fitting.

B2 1244+32B (zem=0.949) CAT1

PG 1248+401 (zem=1.030, 88 lines) This line of sight includes four metal line systems (two very extensive) in addition to the 37 Ly-α (four of which are associated with the metal line systems) and eight Galactic ISM lines. The metal line system at z = 0.8553 includes a broad Ly-α feature that was split by the fitting software into two components. Absorption by Ly-α, Ly-β, Ly-γ, Ly-δ, Ly-ε, C II, C III, C IV, N III, N V, O VI, Fe III, and Si III is observed in this system. The second extensive system, at z = 0.7732, includes lines from Ly-α, Ly-β, Ly-γ, Ly-δ, Ly-ε, C II, C III, C IV, N II, N III, N V, O VI, Fe III, Si II, Si III, and Si IV. The Fe III line in this system was found as part of a candidate system at z = 0.7734 that included many, but not all of the lines in the candidate system at z = 0.7732 – while formally the wavelength agreement is insufficient for this line to be identified with this system, it is likely to be the correct identification and that the redshift is slightly in error. The line at 1922.34˚A is listed in the table as C II in the z = 0.8553 system, but is blended with the N II line from the z = 0.7732 system. The line at 1924.96˚A is listed as O VI in the z = 0.8553 system, but there is a small probability that this line is blended with N II in the z = 0.7660 system. The candidate metal line system at z = 0.7760 is of particular interest because there is no detected C IV doublet to accompany the detected O VI lines. This is an excellent candidate to be an absorber produced by collisionally excited gas, perhaps associated with a group or cluster of galaxies. If the candidate O VI lines in the z = 0.7760 system are not O VI (and identified lines in this system only include Ly-α, Ly-β, and
the O VI doublet), then they are most probably Ly-α lines at $z = 0.507$ and 0.516.

Alternative identifications for the 1887.55 and 1890.21 Å lines are the lines in a C IV doublet at $z = 0.2190$. Galactic ISM Fe II $\lambda 2260.78$ and Fe II $\lambda 2382.77$ are probably blended with the Ly-α lines at respectively $2259.30$ and the blend at 2383, 2387 Å.

PKS 1252+11 ($z_{\text{em}}=0.870$, 49 lines) There are 24 identified Ly-α lines in this spectrum, including one that may be associated with a detected metal line system. The O VI $\lambda 1037.62$ line in the $z = 0.6395$ system is in the incomplete sample at $1702.45\pm0.22$ Å with $W = 0.45 \pm 0.10$ Å, FWHM= 1.51 Å, and a $SL = 1.51$. Any Mg II associated with this system should be observable from the ground. The line at 2027.19˚ is a very broad feature produced by a real feature and an uncertain continuum fit. The features at 2063.78 Å, 2214.15 Å, and 2637.55 Å similarly appear to be blends of weaker features and/or slight errors in the continuum fit. The 1780.14 and 1878.12 Å lines, identified as Ly-β at the $z = 0.7357$ and Ly-α at $z = 0.5449$, possibly include contributions from respectively Ly-γ and Ly-β at $z = 0.8307$. Alternative identifications for the Ly-α lines at $2266.75$ and 2276.58 Å are as the Al III doublet at $z = 0.2222$.

PG 1254+047 ($z_{\text{em}}=1.024$) This is one of the six BAL quasars observed by the Key Project and Bahcall GTO program. The spectrum is displayed in Figure 2, but the analysis of this spectrum will be presented in Turnshek et al. 1998.

B201 1257+57 ($z_{\text{em}}=1.375$, 25 lines) This spectrum contains 13 Ly-α lines, three of which are associated with metal lines. The Ly-δ line of the associated absorption system (at $z = 1.3799$) is blended with the line identified as Galactic ISM Fe II $\lambda 2260.78$. Candidate Fe II lines from the Galactic ISM are in the incomplete sample at $2248.60\pm0.29$ Å, $W = 0.70 \pm 0.16$ Å, FWHM= 2.04 Å, $SL = 4.19$ and $2375.02\pm0.35$ Å, $W = 0.45 \pm 0.12$ Å, FWHM= 2.04 Å, $SL = 3.48$. The Galactic ISM Fe II $\lambda 2382.77$ line is anomalously strong, relative to the other Galactic ISM lines, and probably includes a blend from another line.

PG 1259+593 ($z_{\text{em}}=0.472$) CAT1

PKS 1302−102 ($z_{\text{em}}=0.286$, 39 lines) A total of 21 Galactic ISM lines was detected in the complete sample including absorption from N I, Si II, S II, O I, C II, C IV, Si IV, Al II, Mg I, Fe II, Mn II, and possibly Zn II. In the incomplete sample S II $\lambda 1253.81$ at 1253.70 ± 0.19 Å is observed with an equivalent width of $0.22 \pm 0.06$ Å and $SL = 3.49$, and C IV $\lambda 1550.77$ at $1551.01 \pm 0.16$ Å with an equivalent width of $0.11 \pm 0.03$ Å and $SL = 4.05$. Both of the Galactic ISM C IV lines occur on top of a strong quasar emission line that makes their measured equivalent widths uncertain due to the uncertainty in the continuum fit. Fe II $\lambda 2249.88$ is seen as a broad blend located at 2249.3 Å, and Mg I (Zn II) is in the incomplete sample (2026.89±0.28 Å with $W = 0.15 \pm 0.05$ Å, FWHM= 1.51 Å, and $SL = 3.30$).

There are 14 Ly-α lines identified in the spectrum of this object. The line at 1283.96 Å, fitted by the software as a single “resolved” line, is probably a blend of more than one line. If we force a fit with two lines, the individual components have centers at approximately 1283.8 and 1284.8 Å. The single line in the complete sample may be composed of the Ly-β line from a system at redshift 0.2521 and a Ly-α line at a redshift of 0.0562; higher resolution spectroscopy is needed to resolve this question. The Ly-α line at 1489.49 Å is strong and broad. Any associated C IV was too weak to appear in either the complete or incomplete samples.

TON 153 (RA: 13:17:34.3, DEC:+27:43:52, B1950; $z_{\text{em}}=1.022$) CAT2 Note the slight revision (see Table 6) of the properties of the Lyman—limit system first reported in CAT1. These are as a result of the changes made to the software measuring the LLSs and not due to any change in the reduction of the spectrum.

PG 1333+176 ($z_{\text{em}}=0.554$, 14 lines) Three Ly-α lines appear in this spectrum, one of which is associated with a C IV system at a redshift 0.3458. The C IV $\lambda 1550.77$ line is present in the incomplete sample with an equivalent width of $0.21 \pm 0.05$ Å, an observed wavelength of $2087.31 \pm 0.25$ Å, and a $SL = 3.69$. Ly-α for this system is in the complete sample and Si IV at 1893 Å is in the incomplete sample. The Si IV absorption observed at 1887 and 1893 Å occurs on top of one of the quasar's emission lines and the continuum placement affected the detection of the Si IV $\lambda 1393$ at 1887 Å, which is clearly present on inspection of the spectrum.

At the redshift of the Ly-α line at 1861.9 Å ($z = 0.5316$) there are no detected metal lines in the complete sample; however, there is a line in the incomplete sample that matches the expected wavelength of C IV $\lambda 1548.20,1550.77$ and would be blended with Galactic Fe II $\lambda 2374$. Formally, we identify the 1861.9 Å line as a Ly-α absorber with no associated metals, but it is worth remembering that such statements have the implied qualifier: “no metal lines strong enough to be included in the complete sample”.

Galactic ISM lines in the complete sample are detected from Fe II, Mg II, and Mg I. Al II $\lambda 1670.79$ is present in the incomplete sample with an observed wavelength of 1670.78 Å, an equivalent width of 0.46 ± 0.11 Å, and a significance level of 4.00.

There is some evidence that both the 2019 and 2958 Å lines could arise from imperfect flat-field correction, but is not sufficient to allow us to identify these features as flat-fielding artifacts.

PG 1338+416 ($z_{\text{em}}=1.219$, 39 lines) This spectrum has a lower signal-to-noise ratio than the vast majority of the Key Project spectra. Combined with the presence of several strong blends or broad absorption features, the poor signal made fitting the continuum of this spectrum particularly difficult and the resulting line measurements particularly uncertain. Despite these problems, this line of sight is unusual for the number of strong Ly-α lines observed in the spectrum. In total 22 Ly-α lines are identified, two of which have associated metal lines. An extensive metal line system is identified at $z = 1.2152$. Only one Fe II line (1144 Å) is observed in this system, and the line (observed at $2535.85$ Å) might alternatively be part of a C IV doublet at $z = 0.6351$. The line at 2400 Å might include a contribution from N II in the $z = 1.2152$ system. The second line of the C IV doublet at $z = 1.0778$ is in the incomplete sample at $3222.17\pm0.37$ Å with $W = 0.34\pm0.10$ Å, FWHM= 2.04 Å,
and $SL = 3.30$. The strong line at 2383.17 Å must include some Galactic ISM Fe II in addition to the identified Ly-α line. The most probable alternative identifications for the lines comprising the candidate C IV doublets at $z = 0.6213$ and $z = 0.6863$ are as Ly-α lines. Galactic ISM Fe II $\lambda\lambda 2586.65$, which is stronger than expected, probably includes a contribution from another line (e.g., Ly-α line at $z = 1.1274$).

**B2 1340+29 ($z_{em}=0.905$) CAT1**

4C 53.28 (RA: 13:47:42.7, DEC:+53:56:09, B1950; $z_{em}=0.976$) CAT1

PG 1352+011 ($z_{em}=1.121$) CAT2

PKS 1354+19 ($z_{em}=0.720, 23$ lines) Eight Ly-α lines are identified in this object’s spectrum, one of which is associated with an extensive metal line system at $z = 0.4563$ that almost certainly corresponds to the LLS detected in our G160L spectrum (see CAT1 and Paper V) at $z = 0.45$; the properties of the LLS are listed in Table 6. Absorption by Si II $\lambda 1190.42$ associated with this system is detected in the incomplete sample at 1733.28 ± 0.21 ($W = 0.47 \pm 0.10$ Å, $SL = 4.34$, FWHM= 1.51 Å).

Galactic ISM Fe II $\lambda 2382.77$ is in the incomplete sample at 2382.89 ± 0.33 Å ($W = 0.43 \pm 0.11$ Å, $SL = 3.73$, FWHM = 2.04 Å). Contrary to expectations, the equivalent width of Galactic ISM Mg II $\lambda 2803$ is observed to be stronger than the Mg II $\lambda 2796$ line by 0.26 Å. If the 2803 Å line is contaminated by high velocity Mg II $\lambda 2796$ absorption, the implied velocity is approximately +800 km s$^{-1}$. Such extreme high velocity clouds are unlikely.

**PG 1407+265 ($z_{em}=0.944, 82$ lines) Our HST observations of this quasar have been previously published by Mc Dowell et al. (1995) when they discussed the unusual emission-line properties of this radio quiet quasar. As they reported, the vast majority of the emission lines have comparatively small equivalent widths and cover a very wide range in redshift (over 10,000 km s$^{-1}$). Because different emission lines yielded quite different redshifts, Mc Dowell et al. quote a redshift for the quasar of $z = 0.94 \pm 0.02$. Given our detection of a metal line absorption system at $z = 0.9566$, the systemic redshift of the quasar is likely to be at least as large as 0.95.

Alternative identifications for the lines at 1855.06 and 1858.13 Å are as a C IV doublet at $z = 0.1984$. No Ly-α absorption is detected in association with the candidate C IV doublet at $z = 0.4115$. Alternative identifications of this doublet are as Ly-α lines at $z = 0.7976$ and 0.8006. If the candidate N V doublet with associated Ly-α at $z = 0.4053$ identifications are correct, then the strength of any associated C IV absorption is less than 0.12 Å (for the stronger line of the doublet). The 2344.30 Å line is expected to include a contribution from Galactic ISM Fe II, but has been identified as Ly-α because of its large equivalent width. The line at 2030.67 Å has numerous possible identifications, and we have chosen the one that would place the line in the most extensive of the candidate systems; however, the identification of this line should be considered quite uncertain.

**PG 1411+442 ($z_{em}=0.089$)**  

PG 1411+442 has too low a redshift to have been included in the original Key Project sample of targets. It was one of the GTO targets of Bahcall and is included in this paper for completeness since our catalogue contains the results of the analysis of all of the objects observed as part of both the Key Project and the Bahcall GTO program. The spectrum is presented in Figure 2. This is one of the six BAL quasars observed by the Key Project and Bahcall GTO program. The analysis of this spectrum will be presented in Turnshek et al. 1998.

**PG 1415+451 ($z_{em}=0.114, 6$ lines)** In the spectrum of PG 1415+451 we detect in the complete sample only the familiar Galactic ISM lines of Fe II, Mg I, and Mg II. There are three Galactic ISM lines in the incomplete sample from Fe II (at 2250.77 ± 0.45 Å, $W = 0.33 \pm 0.12$ Å, $SL = 3.50$, FWHM= 2.40 Å and 2374.70 ± 0.28 Å, $W = 0.36 \pm 0.08$ Å, $SL = 4.36$, FWHM= 2.04 Å) and Mg I (at 2852.83 ± 0.45 Å, $W = 0.25 \pm 0.09$ Å, $SL = 3.77$, FWHM= 2.53 Å).

**MC 1415+172 ($z_{em}=0.821$) CAT1**

PKS 1424−11 ($z_{em}=0.805, 28$ lines) There are 15 Ly-α lines identified in the spectrum of this object, one of which is associated with a detected C IV doublet at $z = 0.6553$. This metal line system’s redshift is in agreement with the measured LLS redshift, $z = 0.65$, evident in the G160L spectrum (see Table 6 for measured properties of the system). In some of our other spectra there is a flat field feature at 2120 Å, but not strong enough to produce the feature observed in this spectrum. There is a candidate C IV doublet at $z = 0.0965$ whose identification lacks any additional supporting evidence (for example the presence of other lines in the system), and these lines (1697.87 and 1700.23 Å) have been identified as Ly-β lines in other systems. If these lines are not caused by Ly-β or C IV, they most likely are Ly-α lines. Similarly, there is a candidate C IV system at $z = 0.3485$, consisting of lines at 2087 and 2091 Å currently identified as being produced by Ly-α absorption; however there are no additional lines detected that support the existence of the candidate C IV system.

**S4 1435+63 ($z_{em}=2.060, 73$ lines)** The heavy blending of the lines in this spectrum and limited observed wavelength coverage (exacerbated by the presence of a LLS) made the fitting of the continuum highly uncertain and the possible identifications for some lines too numerous to allow complete identification of the line list at this time. We do include identifications of the strong hydrogen lines and tentative identifications of a few metal lines that might be associated with the LLS observed at $z = 1.9254$ (see Table 6 for additional properties of the LLS, measured by the Lyman—limit search software to have $z = 1.92$), as well as some of the other strong lines in the spectrum. Three of the Lyman series lines associated with the LLS are heavily blended with other lines (Ly-δ, Ly-ε, and Ly-λ).

There might be a slight error in the zero point of the wavelength scale of this spectrum, since the Galactic ISM Fe II lines that we normally use to set the zero point were not observable due to the LLS. Strong lines that are likely to have been produced by Mg II and Mg I in the Galactic ISM are present at an observed redshift of 0.0003. If these identifications are correct and the lines are due to gas in the Galaxy, the true redshift of these lines is likely to be closer to zero and all of the wavelengths presented in the table of identifications need to be shifted by approximately −0.9 to −1.0 Å. However, the redshift of the LLS measured in our G160L spectrum is in excellent agreement with the
redshift measured in the system’s narrow lines, suggesting that in fact the lines at 2797.28 and 2804.78 Å might have an alternative identification or be blended with other lines that are displacing the line centers. Higher spectral resolution observations would remove this uncertainty.

**PG 1444+407 (zem=0.267, 9 lines)** All the identified absorption lines are from the Galactic ISM. Planned G130H observations of this object had to be dropped when the original time allocation was reduced. Galactic ISM Mg I A2852 is in the incomplete sample at 2852.90 ± 0.33 Å (W = 0.21 ± 0.05 Å, SL = 3.74, FWHM = 2.04 Å).

**B2 1512+37 (zem=0.370) CAT1**

**PG 1538+477 (zem=0.770, 81 lines)** This line of sight contains 31 identified Ly-α lines, including four lines associated with detected metal lines. Two extensive metal line systems (at z = 0.7300, 21 lines, and z = 0.7705, 11 lines), are also present along this line of sight. The z = 0.7300 system is associated with a LLS detected in the G160L spectrum (see Table 6 for the properties of the LLS as determined by the Lyman–limit search software). The weaker line of the N V doublet in the z = 0.7300 system is heavily blended with the Ly-α line at z = 0.7705, and the measured properties of the line are very uncertain. The z = 0.4863 system consists of a Ly-α line at 1806 Å and a candidate C IV doublet with its two lines at 2301.14 Å and blended with the line at 2305 Å, identified as O I at z = 0.7705. The Ly-α line at 1622.40 Å occurs in a region of the spectrum with poor flat-fielding and flux calibration; we suspect that the true uncertainties in the measured line parameters are larger than the tabulated values. The weaker line of the candidate C IV doublet at z = 0.5166 is blended with a strong flat-fielding residual at 2353 Å. The expected Ly-β line from the z = 0.7071 system would be blended with the line at 1750.90 Å, which is identified as Ly-α. The Ly-α line at 1866.98 Å is possibly affected by a flat-fielding residual and is heavily blended with the Ly-α line at 1868.51 Å. The lines at 1890.06 and 1892.90 Å (1928.52 and 1931.07 Å), identified as Ly-α lines could be, under our identification rules, listed as a C IV doublet at z = 0.2207 (z = 0.2456). This spectrum provides some very weak lines (W < 0.20 Å) for the complete sample line list. The reality of these weak features is uncertain since our ability to identify flat-field residuals in this spectrum is limited to lines of this strength. Note that redshift of this quasar has been revised since the value we used for the analysis in this paper (from the Véron-Cetty & Véron 1991 catalogue) and is now believed to be 0.772 (see reference in Véron-Cetty & Véron 1996).

**3C 334.0 (RA: 16:18:07.3, DEC: +17:43:29.0, B1950; zem=0.555, 27 lines)** Eleven Ly-α absorption lines are identified in the complete sample. There is no evidence in the G160L spectrum for any damped Ly-α or LLSs in the region between 1200 and 1600 Å.

This spectrum possesses a rich collection of Galactic ISM lines including 14 lines in the complete sample from the following: Al II, Al III, Zn II, Mg I, Mg II, Fe II, and Mn II. The large FWHM of the Al III A1854.72 and Mn II lines suggests that they are blended with other lines. Weaker lines of Al III and Mn II are found in the incomplete sample (Al III λ1862.79 at 1862.73 Å with an equivalent width of 0.17 ± 0.04 Å, SL = 3.84; Mn II λA2576.88,2594.50 with line centers, equivalent widths, and significance levels of 2577.9 and 2594.57 Å; 0.25 ± 0.06 Å and 0.29 ± 0.06 Å; and 3.66 and 4.04).

**PG 1634+706 (zem=1.334) CAT2** After the line list derived from our G270H spectrum of this object was published in CAT2, we obtained the G190H spectrum of Impey et al. (1995, 1996) from the HST archive and processed the spectrum in a manner consistent with our reductions of the other spectra. We measured the properties of the LLSs identifiable in the G190H spectrum and added their properties to the systems listed in Table 6. Both of the LLSs can be associated with extensive metal line systems first reported in CAT2. Since the Al II A1670.79 Galactic ISM line was not detected in the G190H spectrum (due to the LLSs) we could not check the zero-point of the wavelength scale for that portion of the spectrum.

**PKS 1656+053 (zem=0.879) CAT1**

**PG 1700+518 (zem=0.290)** This is one of the six BAL quasars observed by the Key Project or Bahcall GTO program. The spectrum is displayed in Figure 2, but the analysis of this spectrum will be presented in Turnshek et al. 1998.

**3C 351 (RA: 17:04:03.5, DEC:+60:48:31, B1950; zem=0.371) CAT1**

**PG 1715+535 (zem=1.929, 32 lines)** The very low signal-to-noise ratio of the spectrum, heavy blending of the lines, and limited observed wavelength coverage made the fitting of the continuum uncertain and the possible identifications for some lines too numerous to allow complete identification of the line list. Some lines associated with the LLS at z = 1.6333 were identified (note that the Lyman–limit search software found a slightly different redshift based on measurement of the general depression of the continuum near 2400 Å, z = 1.64; the method used in Paper V finds z = 1.626). The properties of the LLS as measured by the Lyman–limit search software are listed in Table 6. The stronger of the N V doublet lines for the z = 1.6333 system is in the incomplete sample at 3262.15±0.34 Å with W = 0.84±0.25 Å, FWHM = 2.42 Å, and SL = 4.40. Galactic ISM Fe II A2382.77 is in the incomplete sample at 2382.27±0.34 Å with W = 1.32±0.43, FWHM = 2.30 Å, and SL = 3.92.

**PG 1718+481 (zem=1.1084, 88 lines)** The line identifications for this spectrum are not complete. There are several metal line systems, including two C IV doublets at z = 1.0323 and 1.0872. The 1037 Å line of the O VI doublet in the z = 0.8929 system is in the incomplete sample at 1964.12±0.21 Å with W = 0.19±0.04 Å, FWHM = 1.51 Å, and SL = 4.28. The line at 1801.34 Å might be N III at z = 0.8200. The broad feature at 1866.63 Å might include Ly-β at z = 0.8200 and Fe II at z = 0.7012. The absorption at 2517.30 Å might include a contribution from Si III at z = 1.0872. The Galactic ISM Mg II A2796.35 line has a negative velocity wing suggesting high velocity gas.

**H 1821+643 (zem=0.297) CAT1**

**4C 73.18 (RA: 19:28:49.4, DEC: +73:51:45, B1950; zem=0.302, 12 lines)** There are eleven Galactic ISM lines in the complete sample. Originally far UV observations using the G130H grating were planned for this object, but reductions in subsequent time allocations necessitated dropping the G130H observations from the program. The broad line at 1884 Å might be a C IV doublet that was not well resolved because of the low signal-to-
noise ratio in this spectrum.

PG 2112+059 \((z_{\text{em}}=0.457)\) This is one of the six BAL quasars observed by the Key Project and Bahcall GTO program. While the continuum of this particular BAL is not as difficult to fit, we defer the analysis of this spectrum to our discussion of the other BAL quasars, which will be presented in Turnshek et al. 1998. The spectrum is displayed in Figure 2.

PKS 2128−12 \((z_{\text{em}}=0.501, \text{ 28 lines})\) The spectrum contains a rich low-excitation metal line system at \(z = 0.4296\) that includes twelve lines in the complete sample \((C II, C IV, O I, N I, S I II, S i III, S i IV, F e II, A l II, \text{ and } L y-\alpha)\). The Ly-\(\alpha\)-of this system is strong \((\text{rest equivalent width of } 2.9 \AA)\). There are five additional Ly-\(\alpha\) lines in this spectrum, none that are associated with identified metal lines.

The weak lines on top of the strong quasar emission line between 1800 Å and 1824 Å have larger systematic uncertainties than the quoted formal uncertainties as it is difficult to fit the continuum in this region.

PKS 2145+06 \((z_{\text{em}}=0.990)\) CAT1

PKS 2243−123, \((z_{\text{em}}=0.630, \text{ 26 lines})\) Ten Ly-\(\alpha\) lines are identified in the complete sample. The line at 1822 Å is possibly an artifact of the continuum fit. Galactic ISM Al II 1670.79 is in the incomplete sample at 1670.76±0.21 Å, with \(W = 0.33 \pm 0.07 \AA\), FWHM= 1.51 Å, and a \(SL = 4.44\). The non-Gaussian wing to the Mg II \(\lambda 2796.35\) absorption produces the component near 2793 Å.

PKS 2251+11 \((z_{\text{em}}=0.323, \text{ 38 lines})\) In this paper we combine a new G130H spectrum of this object with the previously presented G190H, G270H, and G160L spectra (CAT1). All of these data have been analyzed with the current version of the line fitting and identification software and the measurements and identifications presented in this paper replace those presented in CAT1. The G130H data confirm the metal line system identified in CAT1 at \(z = 0.3256\) from only the four lines in the G190H and G270H spectra \((L y-\alpha, C IV \text{ doublet, and } N V \lambda 1238.82)\).

The new lines in this system found in the G130H spectrum are Ly-\(\beta\) and the O VI doublet. The G130H data also resolve the possible damped Ly-\(\alpha\) system noted in CAT1 \((\text{based on our lower resolution G160L data})\) into a combination of weaker absorption features and quasar emission. The continuum between 1300 to 1400 Å was particularly difficult to fit.

Differences between our current analysis of the G190H and G270H spectra and that appearing in CAT1 include the following: the line previously identified as Galactic ISM Fe II 1608.08 is now L y-\(\alpha\) at \(z = 0.3236\); one unidentified line from the CAT1 list dropped out of the complete sample; four new lines appear in the revised complete sample, including three unidentified lines and Si IV \(\lambda 1303.76\) in the \(z = 0.3256\) system. The lines at 1841 and 1853 Å were selected by XSEARCH as a candidate Si IV absorption doublet at \(z = 0.3214\), but no other lines are found at this redshift to support this identification. The 1853 Å line might be partially produced by Galactic ISM Al III \(\lambda 1854.72\). The identification of 1393 Å as Galactic ISM Si IV is weakened by the lack of any Galactic ISM lines from C IV or N V in the complete sample and the absence of the 1402 Å line in the incomplete sample. The line at 1453.30 Å appears to be a blend of several lines that the software fit as a single line. The Ly-\(\alpha\) identification at 1233.80 Å should be considered quite uncertain, despite the high measured significance level of the lines, because the low signal in this region makes the systematic error in the continuum fit large. The total number of identified Ly-\(\alpha\) lines in this spectrum is 15, with one of these lines associated with the previously discussed metal line system at \(z = 0.3256\).

3C 454.3 \((\text{RA: } 22:51:29.6, \text{ DEC:+15:52:54}, \text{ B1950}; z_{\text{em}}=0.859)\) CAT1

PKS 2300−683 \((z_{\text{em}}=0.512, \text{ 7 lines})\) Only seven lines are in the complete sample from the G190H and G270H spectra of this object. There are two Ly-\(\alpha\) lines detected, one of which lies about 2000 km s\(^{-1}\) shortward of the quasar emission-line redshift. The continuum was adjusted subjectively to fit the quasar emission lines in the wavelength regions 2340 to 2390 Å and 1800 to 1890 Å. As a result, absorption lines in these regions probably have larger errors than the tabulated values and some lines might have been added or removed from the complete sample with a slightly different continuum fit. Galactic ISM lines of Fe II and Mg II are identified. Additional Galactic ISM Fe II \(\lambda \lambda 2260, 2586\) lines can be found in the incomplete sample with line centers of 2260.78 and 2585.97 Å, equivalent widths of 0.22 ±0.06 Å and 0.45 ±0.11 Å, and significance levels of 3.65 and 3.99. The G160L spectrum allowed a search for Lyman−limit or damped systems between 1200 and 1600 Å; no significant features were detected although there is weak evidence of a LLS near 1310 Å.

PG 2302+029 \((z_{\text{em}}=1.052, \text{ 80 lines})\) The HST spectra of this quasar were previously published and some of its absorption line systems discussed in Janzui et al. 1996. The quasar emission redshift we list is from Steidel & Sargent 1991. The spectrum includes a high-ionization broad absorption line system at a redshift of \(z = 0.695\) and a narrow line system at 0.7160 which may be caused by either ejected or intervening material. Additional discussion of this object’s unusual absorption systems is presented by Hamann (1997). In this paper we present measurements for the complete sample of lines in the spectrum. In total 35 Ly-\(\alpha\) lines are identified, five of which are associated with identified metal line systems. The lines at 1932.49 and 1934.56 Å are heavily blended, resulting in a large uncertainty in the measurement of the equivalent widths of each line. A single fit to the feature near 1933 Å would be justifiable. This would produce better agreement between the expected wavelength of the Ly-\(\alpha\) in the \(z = 0.5904\) system and the measured line. If the line at 2062.62 Å is not due to Galactic ISM Zn II, then it is Ly-\(\alpha\) at \(z = 0.6967\). The identification of the line at 2652.77 Å is uncertain, but it is plausibly caused by additional C IV absorption in the \(z = 0.695\) system. The Galactic ISM Mg II \(\lambda 2796.35\) line has a positive velocity wing implying the presence of high velocity gas.

PKS 2340−036 \((z_{\text{em}}=0.896, \text{ 79 lines})\) There are 31 Ly-\(\alpha\) lines identified in this spectrum, of which seven are associated with metal line systems. Six candidate C IV doublets are detected along this line of sight at the following redshifts: 0.1509, 0.1691, 0.4088, 0.4212, 0.4621, and 0.6841. Note that there is a significant probability that some of these are false systems produced by the chance combination of other lines (see §3.4). If the lines at 1781
and 1784 Å are not a C IV doublet at \( z = 0.1509 \), the 1781 Å line is probably C III at \( z = 0.8238 \) and the line at 1784 Å would be Ly-\( \beta \) corresponding to the Ly-\( \alpha \) line at \( z = 0.7401 \). If the lines at 1809 and 1813 Å are not a C IV doublet at \( z = 0.1691 \), the 1809 Å line is probably Ly-\( \alpha \) at \( z = 0.4888 \) and the 1813 Å line would be Ly-\( \beta \) at \( z = 0.7679 \). Absorption by the weaker line of the Si IV doublet in the \( z = 0.4212 \) system is detected in the incomplete sample at 1993.56 ± 0.22 Å (\( W = 0.24 ± 0.06 \), \( SL = 4.23 \), FWHM= 1.51 Å).

Systems with candidate O VI absorption are observed at redshifts of 0.6841 and 0.8238. The O VI doublet identifications for the \( z = 0.8238 \) system are uncertain because several other systems also have lines expected at the wavelength of these lines (e.g., 1893 Å might be partially Ly-\( \beta \) at \( z = 0.8463 \)). The O VI identification is strengthened by the possible identification of C IV \( \lambda \lambda 1550.77 \) for this system in the incomplete sample (2823.18 ± 0.38 Å, \( W = 0.25 ± 0.08 \), \( SL = 9.35 \), FWHM= 2.04 Å). Even if the O VI identifications are correct, it is likely that the Ly-\( \beta \) line at \( z = 0.8463 \) contributes to the broad absorption observed at 1893 Å. Systems like the one at \( z = 0.8238 \) are of particular interest because they might be tracing material that has been collisionally excited by gas associated with a group or cluster of galaxies.

The line at 1773 Å identified as Ly-\( \gamma \) at \( z = 0.8238 \) probably includes a contribution from Ly-\( \beta \) at \( z = 0.7296 \). The lines at 2044 and 2047 Å (both identified as Ly-\( \alpha \) at \( z = 0.6817 \) and 0.6841) are blended together. There are three features that appear to be real lines in the reddest portion of the G270H spectrum that remain unidentified (3125, 3131, and 3138 Å).

The Galactic ISM Mg II \( \lambda \lambda 2796.35,2803.53 \) lines have similar profiles and both appear to have high velocity wings on their blue sides which were fitted as separate components by the software. The incomplete sample includes absorption by Galactic ISM Fe II at 2260.71±0.26 Å (\( W = 0.11 ± 0.03 \), \( SL = 3.53 \), FWHM= 1.50 Å).

**PKS 2352–342 (\( z_{\text{em}}=0.702 \), 20 lines)** Fitting the continuum near 1750 Å was particularly difficult and subjective, therefore the reality of the tabulated lines at 1765 and 1775 Å is suspect. There are twelve Ly-\( \alpha \) lines identified in this spectrum. We have identified the strong line at 1743.5 Å as Ly-\( \alpha \) since there is no other plausible identification. Note, however, that this line is well resolved at the 270 km s\(^{-1}\) resolution of the FOS and is likely to be a blend. No evidence for any metal lines associated with this line was found in either the complete or incomplete samples. The line at 2000.8 Å is quite broad and located on the wing of a quasar emission line. The placement of the continuum fit might have artificially inflated the significance of this line. There is no evidence of the expected Ly-\( \beta \) line, but the formal uncertainty is high enough that ZSEARCH accepts the Ly-\( \alpha \) identification. The Ly-\( \beta \) line at \( z = 0.6727 \) is considerably broader (FWHM= 3.0 Å) than its matching Ly-\( \alpha \) line (FWHM= 1.95 Å). It is likely that the Ly-\( \beta \) line is blended with a Ly-\( \alpha \) absorber at a redshift of about 0.42. The two Galactic Mg II absorption lines bracket a strong “emission” line that we are unable to identify (as either real or an instrumental artifact, although we strongly suspect the later). This strong feature affects the measurement of the Mg II absorption and the inferred value for the equivalent of the Mg II \( \lambda 2796.35 \) line (probably making it larger than its true value). In addition to the Fe II and Mg II Galactic ISM lines identified in the complete sample there is a line produced by Mg I \( \lambda 2852.96 \) in the incomplete sample with an equivalent width of 0.33 ± 0.08 Å and \( SL = 4.1 \). There is no evidence in the G160L spectrum for any Lyman-limit or damped Ly-\( \alpha \) systems between 1200 and 2000 Å.

5. RESULTS FOR DIFFERENT CLASSES OF SYSTEMS FROM THE CENSUS

The combined catalogue of absorption lines includes 3238 lines in the complete sample of lines, found in the spectra of 78 quasars observed with the higher resolution gratings. Eight of these 78 objects do not have complete identifications for the observed lines (see §3.3). We have also not yet constructed measured line lists for the five BAL quasars presented in this paper and they do not contribute to the total quoted above. Nine additional objects were only observed with the G160L grating and do not contribute any lines, other than some LLSs (which were not included in the total of 3238 lines), to the catalogue. A rough indication of the redshift distribution of the total path lengths of the survey for selected types of absorption line systems is presented in Figure 3. The total path lengths (\( \Delta z \), ignoring for this paper variations in equivalent width limit between the spectra) for Lyman-limit, damped Ly-\( \alpha \), Ly-\( \alpha \), C IV, and O VI absorption systems are respectively 21, 49, 31, 44, and 17. Almost all of the survey observations (including the objects observed only with the G160L grating, but excluding the five BAL quasars presented in this paper), were included in constructing the plots of the Lyman-limit and damped Ly-\( \alpha \) system paths. For the weaker Ly-\( \alpha \), C IV, and O VI systems only the higher resolution data (again, not including the five BAL quasars in this paper) were included. Mean or effective redshifts for Lyman-limit, damped Ly-\( \alpha \), Ly-\( \alpha \), C IV, and O VI absorber surveys are respectively 0.76, 0.58, 0.72, 0.47, and 0.95. A more complete discussion of the effective path length for Ly-\( \alpha \) systems is included in Weymann et al. (1998).

While the notes on individual spectra include discussions of many interesting individual absorption line systems, in the following subsections we present brief descriptions of what the survey found regarding selected classes of absorption systems.

5.1. The Ly-\( \alpha \), C IV, and O VI Absorption Systems

The study of the evolution of Ly-\( \alpha \) systems is a major focus of the Key Project. Preliminary versions of our analysis have been presented previously (e.g., CAT2; Jannuzi 1997, 1998). Our analysis based on the entire combined
catalogue is presented by Weymann et al. (1998), including discussion of the evolution of the number of Ly-α absorbers with redshift and their distribution of rest equivalent widths. The combined catalogue includes 1,129 identified Ly-α lines. A total of 1068 Ly-α lines was detected in the higher resolution spectra of the objects whose line lists were completely identified (i.e., excluding five of the six BAL quasars and the eight higher redshift quasars for which the identification of the absorption lines are substantially incomplete; see §3 & §4). In Figure 4 we show the observed distribution in redshift of the catalogued Ly-α lines.

Similarly, the evolution and nature of C IV and O VI systems are the subject of separate papers and we will not discuss these systems in detail in this paper. A total of 107 C IV systems was identified in the combined catalogue; 97 in the completely identified line lists. Forty-one systems were identified that included absorption from O VI; 31 in the completely identified line lists. In Figure 4 we show the observed distribution in redshift of the catalogued C IV and O VI systems. The reliability of the C IV and O VI identifications is discussed in §3.4.

5.2. The Incidence of Damped Ly-α Systems

The Ly-α redshift path of the HST Quasar Absorption Line Survey is comparable to previous surveys that investigated the incidence and properties of damped Ly-α systems. During the course of our survey a redshift path of $\Delta z \approx 49$ was surveyed with sufficient sensitivity to find all damped Ly-α systems with $N_{HI} > 2 \times 10^{20}$ cm$^{-2}$. The effective redshift of the damped Ly-α survey was $z < 0.58$. Over the redshift path, one damped Ly-α system was identified (in the spectrum of PG 0935+416). This system has $z_{abs}=1.396$ as determined from a fit to the Ly-α line, independent of the algorithmic fit discussed in the notes on individual spectra. The damped line and fit, with $N(HI) = 3.3 \times 10^{20}$ cm$^{-2}$, is shown in Figure 5. The discovery of just one system at $z < 1.65$ yields an observed number of damped systems per unit redshift at $z = 0.58$ of $(dN/dz)_{KP-damp}(z = 0.58) = 0.020$. Poisson statistics apply to the determination of the uncertainty in this measurement. Given our observation of one system in a path length of 49, the minimum mean number of damped Ly-α lines per unit redshift such that there is a probability of 5% that we see one line or more in our sample is 0.001 systems per unit redshift. The maximum mean number of damped Ly-α lines per unit redshift such that there is a probability of 5% that we observe at most one line (i.e., 0 or 1 line) is 0.096 per unit redshift. We adopt these values as our 95% confidence boundaries on the density per unit redshift of damped systems.

It is useful to compare our result with those from other studies on the incidence of damped Ly-α at $z < 1.65$. Specifically, we can compare the Key Project result to what is obtained from an interpolation of results at lower and higher redshifts. Rao & Briggs (1993) used 21 cm emission studies of gas in nearby galaxies to infer that, for systems with $N(HI) > 2 \times 10^{20}$ cm$^{-2}$, the local value of the incidence of damped systems should be $(dN/dz)_{damp}(z = 0) \approx 0.015 \pm 0.004$. Moreover, the work of Wolfe et al. (1995) suggests that the corresponding value at moderate redshift is $(dN/dz)_{damp}(z = 2) \approx 0.20 \pm 0.03$. Based on a linear interpolation of these results, the expected value for the Key Project study is $(dN/dz)(z = 0.58) \approx 0.069$ marginally consistent with our findings.

A number of previous direct studies of the incidence of damped Ly-α at $z < 1.65$ have been performed. The IUE-based survey of Lanzetta, Wolfe, & Turnshek (1995) and the initial Mg II-selected survey of Rao, Turnshek, & Briggs (1995) reported $(dN/dz)_{IUE-damp}(z = 0.8) \approx 0.082$ and $(dN/dz)_{MgII-damp}(z = 0.8) < 0.12$, respectively. However, more information about the IUE-based survey and the initial Mg II-selected survey is now known in comparison to what was known at the time of their publication.

In the case of the IUE-based survey, for which the quoted redshift path was $\Delta z = 49$ (virtually identical to the size of path length available in our HST survey), five “high-probability” candidate systems with Ly-α rest equivalent widths $> 10$ Å were assumed to be damped, but it has been subsequently found that two of the candidates ($z_{abs} = 0.519$ in Q1329+412 and $z_{abs} = 0.204$ in Q2112+059) can be rejected on the basis of new FOS observations, while one was ruled out at the time of publication ($z_{abs} = 0.399$ in Q1318+290B). Only one of the five high-probability candidate systems is confirmed and the remaining high-probability system ($z_{abs} = 0.484$ in Q2223−052) must still be observed. The confirmed high-probability candidate system is the same one found in the Key Project ($z_{abs} = 1.369$ system in PG 0935+416). At the same time, a “low-probability” candidate system (with Ly-α rest equivalent width $< 10$ Å as measured in an IUE spectrum) was found to be damped ($z_{abs} = 1.014$ in Q0302−223), bringing the total number of confirmed candidates in the IUE-based survey to two. While this is a factor of two lower than was assumed at the time of the Lanzetta et al. (1995) publication, one high-probability candidate and one low-probability candidate still need to be investigated to formally finish the work on the IUE sample. The success rate also raises the concern that the redshift path over which damped Ly-α could be found was somewhat over-estimated in the IUE survey. Ignoring this for now, based on the statistics of only two confirmations we find $(dN/dz)_{IUE-damp}(z = 0.8) \approx 0.041$, but note that this result would increase if either of the two remaining candidates were confirmed or if it was, in fact, determined that the redshift path was over-estimated. Using the $z = 0$ result to interpolate to lower redshift we find $(dN/dz)_{IUE-damp}(z = 0.58) \approx 0.034$; a result consistent with the findings of this paper.

Finally, the initial Mg II-selected survey results of Rao et al. (1995) have now been considerably expanded by making new FOS observations of Mg II absorption-line systems (Rao & Turnshek 1998; Turnshek 1998). Nine damped Ly-α lines in Mg II systems were uncovered and these new results indicate $(dN/dz)_{MgII-damp}(z = 0.8) = 0.10 \pm 0.04$. Interpolating the Mg II survey result to $z = 0.58$, again making use of the $z = 0$ point, we find $(dN/dz)_{MgII-damp}(z = 0.58) \approx 0.077$, which is completely consistent with the “expected” result obtained from interpolation between the zero redshift and high redshift statistics. However, even assuming that none of the proposed damped lines is really a complex blend of weaker Ly-α lines, there is some possibility that the $(dN/dz)_{MgII-damp}$ statistic is over-estimated due to gravitational lensing bias (Smette et al. 1997). But Smette et al. (1997) point out that this bias might af-
fect the Key Project and IUE survey statistics for damped Ly-α, since both of those surveys also utilized bright objects. While the Mg II-selected result is nearly four times the Key Project result \([dN/dz]_{\text{damp}}(z = 0.58) \approx 0.077\) versus \(0.020\), available statistics for making a comparison are poor. For example, if the Mg II-selected result is taken to be the true value, we estimate that the probability of finding zero or one damped system in the Key Project survey is \(\approx 10\%\), even though the most probable observed number would then be four. Clearly more work is required to improve the accuracy of these statistics.

5.3. Lyman—limit Systems in the Combined Catalogue

In Table 6 we list the 16 candidate Lyman—limit systems observed in the objects that were targets for the combined catalog. Our analysis of the evolution of LLSs has been previously presented in Paper V. Of the 14 LLSs for which higher resolution spectroscopy is available to search for associated metal lines (for all but the systems in 4C 19.34 and PKS 1055+20), all but the system in the spectrum of MARK 132 have identified metal lines associated with the LLS. In the cases of the systems in the spectra of PG 0935+416, MARK 132, Q 1101–264, S4 1435+63, and PG 1715+535 the line identifications are quite incomplete and the association of additional metal lines with the LLS (or in the case of MARK 132, any metal lines) can not be ruled out. For eight of the 13 LLSs with detected metal lines the systems are “extensive” (absorption systems with four or more observed metal ions). The detection of strong metal lines, often part of an extensive system including lines from both low and high ionization states, is consistent with what was found in CAT1 and CAT2 regarding the correspondence between LLSs and metal line systems and provides additional circumstantial evidence that LLSs are likely to be associated with galaxies (see CAT1 and CAT2 for further discussion).

5.4. Extensive Metal Line Systems

There is a total of 37\(^{13}\) extensive metal-line systems (absorption systems with four or more observed metal ions) listed in the tables of identified lines (in CAT3, Table 3) in the combined catalogue of absorption lines. Twenty-seven of these systems were added by the analysis presented in this paper. These systems are potentially valuable laboratories for understanding galaxies at intermediate redshifts if they can be associated with a particular galaxy (e.g., the case of the galaxy in the field of PKS 2145+06, Bergeron et al. 1994). Of the 37 extensive metal line systems, four (six) are associated absorption systems, i.e., have velocities within 3,000 (5,000) km s\(^{-1}\) of the quasar emission lines. Two additional systems in the spectrum of PG 2302+029 might be associated with the quasar although they are more than 50,000 km s\(^{-1}\) from the redshift of the quasar (Jannuzi et al. 1996). Excluding these two systems as well as the known associated systems, we are left with 29 extensive metal line systems that appear to be intervening systems. For 25 of the extensive metal line systems the portion of the quasar spectrum that would contain any associated LLS was observed. Of these 25 systems, 21 (19) are more than 3,000 (5,000) km s\(^{-1}\) from the quasar, i.e. are intervening extensive metal line systems. Of these 21 (19), eight have an associated Lyman—limit system. None of the associated extensive systems have an accompanying LLS.

5.5. BAL Quasars

Extremely broad high-ionization absorption complexes with velocity extents of 2,000 to 25,000 km s\(^{-1}\) occur in approximately 10\% of radio-quiet quasars (Weymann et al. 1991). This absorption is almost certainly produced by material ejected from the source producing the observed emission. Such objects are broad absorption line quasars (BALS; see Weymann et al. 1991 and Turnshek 1995 for reviews). In this third catalogue we have included the reduced spectra of five BAL quasars observed during our survey: UM 425, PG 1254+047, PG 1411+442, PG 1700+518, and PG 2112+059. This brings the total number of BAL quasars in the combined catalogue to six (including PG 0043+039). There is nothing we are aware of in the selection of targets for observation in the survey that would have biased us toward including or excluding any of these objects in our sample, even though most were known to be BAL objects before we observed them.

6. SUMMARY AND COMPANION PAPERS

Using the FOS of the HST we have produced a large and homogeneously constructed database of quasar absorption line systems at low to moderate redshifts. The database is suitable for the study of many problems, and we have undertaken some of these examinations including studies of the evolution of Ly-α (CAT2; Weymann et al. 1998) and C IV absorbers (CAT1; Sargent et al. 1998), the evolution of Lyman—limit systems (Paper V), the evolution of damped Ly-α systems (§5 of this paper), the clumping of Ly-α absorbers around extensive metal line systems (CAT2; Jannuzi 1998; Jannuzi et al. 1998), and the Galactic halo (Savage et al. 1993; Savage et al. 1998). Some especially interesting systems include low redshift Ly-α absorbers suitable for extensive follow-up observations (e.g., in the spectra of TON 28 and PG 1216+069), possibly physically associated pairs of extensive metal line absorption systems (e.g., in the spectrum of PG 0117+213), and systems known to be associated with galaxies (e.g., in the spectrum of 3C 232). The spectra of five broad absorption line (BAL) quasars (UM 425, PG 1254+047, PG 1411+442, PG 1700+518, and PG 2112+059) can be found in this third catalogue, bringing the total number of BAL quasars in the combined catalogue to six (including PG 0043+039).

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FIG. 1.— The distribution in Galactic coordinates (Aitoff projection) of the 92 quasars observed as part of the HST quasar absorption line survey. The solid circles, open circles, and open diamonds are the 89 objects observed as part of the Key Project and Bahcall GTO observations that meet the original selection criteria for Key Project targets. The open circles indicate the location of 15 objects whose spectra include coverage of 1150 to 1600 Å observed at higher resolution (FOS G130H observations). The open diamonds are the nine objects that were only observed at low resolution, using the G160L grating. The three triangles (two of which are blended together) indicate the location of the three Bahcall GTO targets whose redshifts are too low to have met our original selection criteria (MARK 205, PG 1411+442, and PG 1415+451), but which are included in our final catalogue. PG 1411+442, indicated with an open triangle, was observed with the G130H grating while the other two objects in this set were not. See §2.1 for further discussion of the sample of observed objects and Table 1 for the list of the observed objects.

FIG. 2.— aa through cn – Ultraviolet spectra of 67 quasars obtained with the Faint Object Spectrograph of the Hubble Space Telescope. The panels contain the combined spectrum of these objects obtained with the indicated gratings (G160L, G130H, G190H, and/or G270H). The short vertical bars indicate the positions of absorption lines in the complete sample. The dotted line is the “continuum fit”; see §3.1 and Paper II. The lower line in each spectrum plot is the 1σ uncertainty in the flux as a function of wavelength. For the higher resolution observations, the 4.5σdet equivalent width limit (Å) for unresolved lines is also shown as a function of wavelength. Flat-field residuals that are strong enough to have a significance level greater than 4.5σ are marked with the symbol FF. To be included in the complete sample, a feature’s equivalent width must exceed the value of the 4.5 σdet curve at the relevant wavelength [see Eq. (2)]. The objects are presented in order of increasing Equinox 1950 right ascension, the same order in which the spectra are discussed in the notes on individual objects section of the paper, §4.

FIG. 3.— a through d – Shown in these four panels are the number of lines-of-sight as a function of redshift that could contribute to the total path length observed for the listed type of absorption system (Lyman–limit, Damped Ly-α, Ly-α, and C IV). In constructing this figure no effort was made to determine what corrections are necessary for the varying level of sensitivity of each FOS spectrum and as a consequence this figure should only be used as a rough guide of the redshift distribution of the survey path length. Lines-of-sight that were on the short-wavelength side of a τ > 1 Lyman–limit systems were not included in the histograms.

FIG. 4.— a through c – The observed redshift distributions of absorption from H I (Ly-α), C IV, and O VI are shown in these three panels. For the plots of the distribution of C IV and O VI doublets, each observed doublet is only counted once. Absorption features due to gas in our Galaxy were excluded.

FIG. 5.— Fit to the damped Ly-α absorption line in the spectrum of PG 0935+416. The derived neutral column density for this system is \( N(\text{HI}) = 3.3 \times 10^{20} \) cm\(^{-2}\). This system is discussed further in §4 & §5.2.