A Catalog of Absorption Lines in Eight HST/STIS E230M
1.0 < z < 1.7 Quasar Spectra *

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* Based on observations obtained with the NASA/ESA Hubble Space Telescope (HST) Space Telescope Imaging Spectrograph (STIS), which has provided a detailed view of absorption systems along the lines of sight. These data are available from the Multimission Archive at Space Telescope (MAST). However, in order to compile statistics of absorbers or to study particular systems, it is necessary to identify the spectral features. This can be complicated, particularly in the Lyα forest region, and when the available spectral coverage is limited.

1 INTRODUCTION

The most important chemical transitions for quasar absorption line systems at low redshift (e.g., z < 1) still lay in the ultra-violet spectral range. A limited number of the most UV-bright quasars have been observed with the Hubble Space Telescope (HST)/Space Telescope Imaging Spectrograph (STIS), which has provided a detailed view of absorption systems along the lines of sight. These data are available from the Multimission Archive at Space Telescope (MAST). However, in order to compile statistics of absorbers or to study particular systems, it is necessary to identify the spectral features. This can be complicated, particularly in the Lyα forest region, and when the available spectral coverage is limited.

In the course of our studies of the Lyα forest and metal-line systems we have studied in detail eight of the highest quality HST/STIS spectra, obtained with the E230M grating. In this paper we present these spectra with a list of metal-line absorption features and our suggested line identifications. In particular, metal-line system identifications are necessary in order to remove contaminants from the Lyα forest. In a recent paper (Kirkman et al. 2007), we measured statistics of absorption in the Lyα forest at 1 < z < 1.6 using 74 low resolution HST/FOS quasar spectra. As a check, and particularly to assess our ability to separate metal lines from the forest, we also used the available higher resolution E230M HST/STIS spectra. In the present paper, we present the relevant data and line identifications which were used in that paper. We expect that this catalog will facilitate future studies of the Lyα forest and of metal-line systems of various types.

Key words: intergalactic medium – quasars: absorption lines
also presented there. In §4 we present a general summary of the systems presented in this catalog.

2 DATA AND METHODS

We selected the eight $z > 1$ quasars observed with the HST/STIS E230M grating which had a signal to noise ratio, $S/N > 5$, over a reasonable fraction of the spectrum. These HST/STIS E230M spectra have a resolution $R = 30,000$, with two pixels per resolution element. Our sample is biased towards quasars that have Lyman limit systems, since most of the STIS observations were conducted in order to study those particular known systems in detail.

Several settings are possible covering different wavelength ranges. For seven of the eight quasars in our sample, 2280 - 3110 Å is covered. The quasars and the relevant observational details are listed in Table 1. Specifically, this table lists quasar redshifts, wavelength coverage, $S/N$ per pixel at 2350 Å and 2750 Å, primary investigator for the original observation, and proposal ID.

The data were reduced using the STIS pipeline (Brown et al. 2002). They were combined by simple weighting by exposure time (as in Narayanan et al. (2003)), rather than by, e.g., inverse variance methods that are often employed. A bias could be introduced by the latter method, since pixels with smaller counts would be weighted more heavily. This bias is significant only in cases such as these STIS spectra, where individual exposures have very small $S/N$, and is not typically important for reduction of ground-based high resolution echelle spectra.

Wavelengths were corrected to the heliocentric reference frame. When the same quasar was observed multiple times, there was often a small shift in wavelength between the spectra, due to the intentional shifting of the echelle angle of the instrument. In this case, we chose not to smooth the data by interpolating, but instead chose wavelength bins from one exposure and combined the flux from other exposures into the nearest bin. This results in a slightly decreased effective resolution. Continuum fits used the standard IRAF SFIT task.

Features were objectively identified by searching for an unresolved line at each pixel (as employed in Schneider et al. (1993)), and applying a $5\sigma$ criterion for detection. However, we found by inspection that some of these formal detections are not likely to be real. In some cases, only 1 pixel had significant absorption, and in other cases it appeared that correlated noise biased the measurement. Features that are broad and shallow can be $> 5\sigma$ and yet look unconvincing because they are sensitive to the continuum level. Such spurious features, estimated to be 10% of the total number of detections, were eliminated from consideration. We define a feature as all the pixels around a $\sigma$ detection that have not recover to the continuum after smoothing the spectra using an equation on p.56 of Schneider et al. (1993). This definition means that many features are clearly blends of well separated lines, and hence a feature can have more than one identification, each of which may be secure because they refer to different blended lines. Wavelength that we give for a feature is the flux-weighted central value, the mean of the wavelengths where the smoothed flux drops below the continuum, with weighting for the fraction of the photons that are absorbed at each pixel.

We attempted to identify all features in each of the quasar spectrum, and the transitions that were identified one or more times are listed with their vacuum wavelengths and oscillator strengths in Table 2. For our line identification we used the following procedure:

(i) Examine the spectrum at the expected positions of possible Galactic lines, and mark all possible detections.

(ii) Search for the strong resonant doublet transitions: Mg II $\lambda\lambda$2796, 2803, Si IV $\lambda\lambda$3939, 1402, C IV $\lambda\lambda$1548, 1551, NV $\lambda\lambda$1239, 1243, and OVI $\lambda\lambda$1032, 1038. In addition to these, we also search for low ionization gas through the combination C II $\lambda$1335 and Si II $\lambda$1260, which can be used in place of Mg II $\lambda\lambda$2796, 2803 when the latter is not covered Narayanan et al. (2003) Milutinović et al. (2006).

(iii) Check positions of other transitions that could be detected for systems found through the doublet search, including the Lyman series lines. If a system is ambiguous with the doublet alone, Ly $\alpha$ and other Lyman series lines were used to assess its reality.

(iv) Having completed these steps, all features that remain without plausible identifications are considered to be Lyman series lines.

(v) Begin by assuming that the highest order Lyman series line is the correct identification and search for all of the stronger (lower order) Lyman series lines corresponding to the same redshift. If reasonable ratios are found, mark these as possible identifications. Otherwise continue assessing the possible identifications of the feature in question until reaching Ly $\alpha$.

(vi) If no identification, including a Ly $\alpha$ identification, is plausible the feature is left unidentified.

(vii) If more than one identification is reasonable (or if there is likely to be a blend for which more than one system contributes significantly), this is noted.

3 RESULTS

Figure 1a is a sample of a portion of the normalized spectrum of PG0117 + 213, shown in the printed version. We present all other normalized quasar spectra in Figures 1b–8d (see the complete version), which are available electronically at http://www.blackwellpublishing.com/products/. Similarly, our list of line identifications are presented electronically at Table 2 with some sample listings appearing in the printed version. In this table, quasars are ordered by right ascension and is not typically important for reduction of ground-based high resolution echelle spectra.

The following subsections present the eight quasars along with discussion of noteworthy metal-line systems found in their spectra. Figure 9 presents an example “system plot” for the $z = 0.5764$ system toward PG0117 + 213. The transitions detected at $5\sigma$ for all of the metal-line systems are plotted in velocity space in the electronic versions of Figures 9–64 (see the complete version). The
This quasar was studied as part of the Quasar Absorption Line Key Project, using G270H grating of HST/Faint Object Spectrograph (FOS), with resolution of $R=1300$. Jannuzi et al. (1998) found possible metal-line systems at $z = 0.5764, 0.9400, 0.9676, 1.0724, 1.3389, 1.3426$ and $1.3868$. They also found tentative suggestions of metal-line systems at $z = 1.3256$ and $1.4952$. Mg II is detected in a Keck/HIRES spectrum at $z = 0.5764, 0.7290, 1.0480, 1.3250$ and $1.3430$ (Churchill & Vogt 2001; Churchill et al. 1999), and these five systems were modeled (including constraints from this STIS coverage) by Masiero et al. (2005).

Jannuzi et al. (1998) observed this quasar with HST/STIS to facilitate a statistical study of the Lyα forest. This spectrum covers the Lyα forest over almost all of its wavelength coverage, blueward of 3031 Å. The Lyβ line is covered blueward of 2558 Å, Lyγ blueward of 2423 Å, and Lyδ blueward of 2368 Å. There is also limited redshift coverage of higher order Lyman series lines. Along this line of sight are five Mg II absorbers. One of them is a DLA, two are strong Mg II absorbers, and the other two are multiple-cloud, weak Mg II absorbers. Three certain, and two possible O VI systems are also detected. The metal-line systems toward this quasar are plotted in Figures 9–18.

$z = 0.5764$. The $z = 0.5764$ system is a strong Mg II absorber. Based upon only a low resolution HST/FOS spectrum, obtained in spectropolarimetry mode (Koratkar et al. 1998), it is not clear whether this is a DLA or whether it has multiple undamped components. (Rao & Turnshek 2000). In the HST/STIS spectrum, C iv λ1548, 1551 are detected, but both transitions suffer from blending. The C iv λ1548 is blended in its blue component with Lyγ from a system at $z = 1.5088$. An unidentifiable blend appears on the red wing of C iv λ1550 and its blueward component also has a small contribution from Si ii λ1193 at $z = 1.0480$. Al iii λ1855, 1863 is detected, but the blueward member has a blend to its blue, probably with Lyα. Strong Al ii λ1671 is detected, as is Fe ii λ1608. The strong feature redward of Al ii λ1671 is probably Lyα at $z = 1.1671$. In addition to Mg II and Mg I, Ca ii and Ti ii were detected in the Keck/HIRES spectrum (Masiero et al. 2005).

$z = 0.7290$. The unusual multiple-cloud, weak Mg II absorber at $z = 0.7290$ is detected only in Al ii λ1671 and C ii λ1335 in the HST/STIS spectrum. C iv λ1548, 1551 is covered at a high sensitivity, yet it is not detected to a $3\sigma$ rest-frame equivalent width limit of 0.01 Å. This makes it “C iv-deficient”, possibly indicative of a low level of star formation so that a corona would be weak or absent in its very red, barred spiral galaxy host (Masiero et al. 2005).

$z = 1.0480$. The $z = 1.0480$ system was found not to have metal lines detected in the low resolution HST/FOS spectrum. The detections of Si ii, C ii, Si iii, Si iv λ1393, 1402 in the HST/STIS spectrum are consistent with those limits. Unfortunately, the STIS spectrum does not cover C iv λ1548, 1551, which would provide useful constraints on the system’s physical conditions. Based upon photoionization modeling (Masiero et al. 2005) it would appear that there is a significant blend with Si iii λ1207, which is most likely Lyα.

$z = 1.3250$. The $z = 1.3250$ system is just above the borderline to qualify as a strong Mg II absorber. It has six weak components in Mg ii λ2796, 2803 spread over $\sim 250$ km s$^{-1}$ (Churchill & Vogt 2001). There is a partial Lyman limit system detected in an HST/STIS spectrum (Jannuzi et al. 1998). In the HST/STIS spectrum Si ii and C ii are detected from the strongest of these six components. Si iii λ1207 is also detected over the full velocity range, but it suffers from a blend with Galactic Mg ii λ2803 to the blue. There may also be blends redward of this, based upon the photoionization models (Masiero et al. 2005), but we were unable to provide identifications besides possible Lyα. Unfortunately, C iv λ1548, 1551, which was detected in the HST/STIS spectrum (Jannuzi et al. 1998), is not covered in the STIS spectrum. There is a possible weak detection of N v λ1239 but it cannot be confirmed using N v λ1243 because it is in a noisy part of the spectrum. A strong O viλ λ1032, 1038 is detected, but O vi λ1032 is blended to the red with Lyβ from the system at $z = 1.3390$, and to the blue with possible Lyα. Also, O viλ λ1038 must have a blend, at least on the red wing of its strong component, since that profile is too strong relative to O viλ λ1032 at that velocity. This blend could be O viλ λ1032 from the $z = 1.3390$ system. If so, these systems would be “line-locked”.

$z = 1.3390$. We find the evidence for metal lines in the $z = 1.3390$ system to be inconclusive. Lyα is not detected in the redward portion range of the possible C iv λ1977 feature, so not all of that absorption can be C iv at this redshift. Two components of Si iii λ1207 are possible, but they do not align perfectly with the minima of the C iv profile and cannot be confirmed in any other way. Also, O viλ λ1032, 1038 may be detected. The alignment is reasonably good, though the feature redward of the O viλ λ1032 component is likely to be O viλ λ1038 from the system at $z = 1.3250$.

$z = 1.3430$. The $z = 1.3430$ system is also just at the border between strong and multiple-cloud weak Mg II absorption. Like the $z = 1.3250$ system, it has a partial Lyman limit break in the HST/STIS spectrum (Jannuzi et al. 1998). Lyα and Lyβ are detected in the HST/STIS spectrum along with C ii, Si ii, N ii, C iii. There is a feature at the expected position of N iii λ998, which appears to be too strong relative to the other transitions in this system (Masiero et al. 2005). We believe this feature could be Lyα at $z = 0.9076$. C iv is not covered in the STIS spectrum, but strong C iv absorption is detected in the FOS spectrum. N v λ1239, 1243 appears to be detected, but the N v λ1239 transition is blended, probably with Lyα at $z = 1.3866$.

$z = 1.4242$. There is an O vi system, with detected Lyα, Lyβ, and Lyγ at $z = 1.4242$.

$z = 1.4463$. Another weak, broad O vi doublet at $z = 1.4463$ is also detected in C ii and Si iii, as well as in Lyα. The feature in the Si iii λ1207 panel, at $\sim 40$ km s$^{-1}$, is at least partially Si iii λ1260 at $z = 1.3430$ (as is the stronger feature to its red).

$z = 1.4478$. At $z = 1.4478$ the Lyman series is detected down to Lyα, which is the last member covered in the HST/STIS spectrum. There is a possible O vi doublet at this redshift, but the feature at the position of O vi λ1032 transition does not match the profile of that at the position of O vi λ1038.

$z = 1.5088$. The O vi system at $z = 1.5088$ is another example of associated O vi absorption that appears slightly redward of the quasar emission redshift. It is detected in Lyα and Lyβ. The Lyβ shows the same components as O vi, but clearly has a blend to the red, probably with Lyα. Lyγ is heavily blended with C iv λ1548 from the $z = 0.5764$ system. C iii λ977 is also detected in three components, though the blueward one is affected by a data defect.
3.2 HE0515-4414 (z_{em} = 1.713)

This quasar was observed with HST/STIS by Reimers et al. (2003) in order to study a sub-DLA at z = 1.15, for which they also have optical coverage. Their study of this system, particularly focused on six O VI systems, spanning Figures 19–27. Reimers et al. (2003) and Levshakov et al. (2003) report on six O VI systems along the line of sight (at z = 1.385, 1.416, 1.602, 1.674 and 1.697), based upon the HST/STIS spectrum in conjunction with VLT/UVES data. Lyα is covered over the entire STIS spectrum, Lyβ up to 2784 Å, and Lyγ is covered up to 2651 Å. There is more limited coverage of all other Lyman series transitions down to the Lyman limit of the quasar.

The HST/STIS spectrum is dominated by the sub-DLA at z = 1.15 and its many detected metal and molecular hydrogen transitions. In addition, there is one C iv system, four definite O VI systems, and three possible O VI systems. A couple of these O VI systems are associated. System plots for this quasar are given in Figures 19–27.

z = 0.9406. — A two component C iv doublet is detected at z = 0.9406, which also has Lyα and Si ii detected. Si iv is also probably detected in the redward component, but this can’t be confirmed because Si iv λ1394 is blended with an unknown line, probably Lyα.

z = 1.1508. — The sub-DLA at z = 1.1508 is a very complex system, spanning 800 km s⁻¹ for absorption in many low ionization transitions. It has many molecular hydrogen lines detected. Our identifications for the molecules follow exactly those of Reimers et al. (2003). The saturated region of the sub-DLA profile spans ~ 1100 km s⁻¹. A separate component at ~ 900 km s⁻¹ is likely also to be Lyα, but with no associated metals in the HST/STIS spectrum. Many neutral species of C i and N i are detected in a single, narrow component at ~ 0 km s⁻¹, presumably associated with the bulk of H I. Features at other velocities seen in the neutral transitions panels in Figure 20 are not related to this system (see line identifications in Table B). O i 1302 is blended with Lyα at z = 1.3039, and cannot be measured, and no other strong O i transitions are covered. Many singly ionized transitions are detected for the system, both in the 0 km s⁻¹ component and at many other velocities to the blue. These match the Mg ii and Fe ii from the VLT/UVES spectrum Levshakov et al. (2003). Strong Si ii absorption is detected in many components, spanning the full velocity range. Si iv λ1393, 1402 is detected as well, but there appears to be significant blending with Si iv λ1394, because Si iv λ1403 is much weaker at some velocities. C IV λ1548, 1551 is also detected in the VLT/UVES spectrum. N V λ1239, 1243 is covered, but not detected, and O vii λ1032, 1038 is not covered.

z = 1.3849. — An O vi doublet detected in the HST/STIS spectrum at z = 1.3849 has its λ1038 member blended to the blue with Lyβ at 1.4124. C IV λ1548, 1551 is detected at the same redshift in the VLT/UVES spectrum Levshakov et al. (2003). The corresponding, relatively weak (unsaturated) Lyα line lies blueward of a larger saturated Lyα feature. C iv may also be detected.

z = 1.4163. — There is a possible O vi system at z = 1.4163, as reported by Levshakov et al. (2003), however neither member of the O vi doublet aligns with the Lyα and Lyβ, which are also detected in the STIS spectrum. There could be C iv associated with this system, but it is badly blended with a probable Lyα line, thus its alignment cannot be verified. Therefore, there is not convincing evidence for detected metals in this system.

z = 1.6020. — The O vi system at z = 1.6020 is well aligned and is detected in Lyβ and Lyγ in the HST/STIS spectrum.

Lyα, and possibly C iv, is detected in the VLT/UVES spectrum Levshakov et al. (2003).

z = 1.6668. — There is a possible O vi system at z = 1.6668, though its identity is somewhat uncertain. O vi λ1038 is blended with a possible Lyα line, such that the profiles of the doublet members cannot be compared. Lyβ is not detected at the position, however Lyα is detected, with about the same profile shape and equivalent width as the O vi. Thus, this could be a fairly typical associated O vi absorber.

z = 1.6736. — There is an O vi system at z = 1.6736 detected in the HST/STIS spectrum. O vi λ1038 is blended to the red with a possible Lyα line. Lyβ is detected, as are higher order Lyman series lines, but the latter are blended with other transitions (see Table B). C IV λ1548, 1551 and Lyα are detected in the VLT/UVES spectrum Levshakov et al. (2003).

z = 1.6971. — The associated O vi absorber at z = 1.6971 also has C iv λ977 and probably S vi λ933 detected. Levshakov et al. (2003) also detected Lyα, Si IV λ1393, 1402, C IV λ1548, 1551, and N V λ1239, 1243 in their VLT/UVES spectrum. The Lyα profile is not black, again a signature of associated O vi absorbers.

z = 1.7358. — A possible O vi system at z = 1.7358 cannot be confirmed by other features in the HST/STIS spectrum. Although Lyβ is covered, it is blended with Galactic Mg ii λ2803. If real, this system would be significantly redshifted relative to the emission redshift of the quasar.

3.3 PG1206+459 (z_{em} = 1.16254)

This quasar was observed by HST/FOS as part of the Quasar Absorption Line Key Project, but they had difficulty in identifying many of the lines due to uncertain continuum fitting Jannuzi et al. (1998). They found evidence for an extensive metal-line system separated into subsystems at z ~ 0.925, 0.9277 and 0.9342, even at low resolution Churchill et al. (1999) modeled this system based on the HST/FOS data, along with Keck/HIRES data Churchill & Vogt (2001), Ding et al. (2003) refined these models once the HST/STIS spectra were available.

Churchill et al. (1999) observed this quasar with HST/STIS to facilitate a detailed study of the systems at z ~ 0.927. The HST/STIS spectrum covers the Lyα forest blueward of 2628 Å, but does not cover any higher order Lyman series lines. There are only three metal-line systems found in the HST/STIS spectrum: the extensive metal-line system at z ~ 0.927 mentioned above, a C iv system, and an associated N v system. Figure 28–32 presents system plots for these metal-line systems, detected toward PG1206 + 459.

z = 0.7383. — There is a weak C iv doublet at z = 0.7383. The C iv λ1548 is blended with Si iv λ1394 from the subsystem at z = 0.9254, and also to the red with an unknown blend, probably Lyα. The large feature blueward of the C iv λ1551 transition is Si iv λ1394 at z = 0.9276. Mg ii is not detected in the Keck/HIRES spectrum, nor any other low ionization transitions in the HST/STIS spectrum. However, the system is confirmed by Lyα in the HST/FOS spectrum.

z = 0.9254. — The complex metal-line system at z = 0.9277 is spread over more than 1000 km s⁻¹ Ding et al. (2003) separated it into three systems at z = 0.9254 (System A), z = 0.9277 (System B), and z = 0.9342 (System C). They suggest that these systems are produced by three different galaxies in a group. System A, at z = 0.9254, has detected C ii, Si iii, Si IV λ1393, 1402, C IV λ1548, 1551, and N V λ1239, 1243 in the HST/STIS spec-
trum. Many other transitions, including O\textsc{iv} λλ1032, 1038 and Lyman series lines, were detected in the HST/FOS spectrum. Si \textsc{iv} λ1394 is blended with C \textsc{iv} λ1548 from the z = 0.7338 C \textsc{v} system. Lyα is saturated and covers the entire velocity range between this system and System B.

z = 0.9276. — System B, at z = 0.9276, produces a partial Lyman limit break in the HST/FOS spectrum. It is detected in several transitions of Si \textsc{ii}, C \textsc{ii}, Si \textsc{iii}, Si\textsc{iv} λλ1393, 1402, C\textsc{iv} λλ1548, 1551, and N\textsc{v} λλ1239, 1243. Galactic Fe\textsc{ii} λ2344 is blended with the red wing of the Lyα profile. C \textsc{ii} λ1335 is blended to the red with an unidentified line, probably Lyα. The feature redward of Si \textsc{iv} λ1394 is C \textsc{iv} λ1551 from the z = 0.7338 system. C \textsc{iv} is self-blended, with the C \textsc{iv} λ1551 from System A superimposed on the C \textsc{iv} λ1548 from System B.

z = 0.9343. — System C, at z = 0.9343 is unusual in its high velocity relative to the main system, System B. For this system, which would be considered a single-cloud, weak Mg \textsc{ii} absorber if isolated from the other systems, is detected in Lyα, Si \textsc{ii}, C \textsc{ii}, Si \textsc{iii}, Si\textsc{iv} λλ1393, 1402, and C\textsc{iv} λλ1548, 1551. N\textsc{v} λλ1239 is blended with N\textsc{v} λ1243 from System B, but N\textsc{v} λ1243 is not detected in a clean part of the spectrum. Again, O \textsc{vi} and various other transitions are detected in the HST/FOS spectrum.

z = 1.0281. — The N\textsc{v} system at z = 1.0281 is almost certainly intrinsic judging by its broad profile and the “non-black” Lyα line, evidence for partial covering. No other metals are detected besides the N\textsc{v}.

3.4 PG1241+176 (z \textsubscript{em} = 1.273)

This was also a quasar studied for the Quasar Absorption Line Key Project (Jannuzi et al. 1998), and a Keck/HIRES spectrum was obtained by Churchill & Vogel (2001). Particular Mg \textsc{ii} systems, with optical and UV coverage, were studied in Churchill et al. (2000). The z = 0.5505, 0.5584 and 0.8954 systems were modeled in detail by Ding et al. (2005).

This quasar was observed with HST/STIS by Churchill et al. in order to provide constraints on the physical conditions in Mg \textsc{ii} absorbers. Lyα forest lines appear in HST/STIS spectrum quasar spectrum blueward of 2763 Å, and the Lyβ forest is covered blueward of 2332 Å. We find evidence for six metal-line systems: one strong Mg \textsc{ii} absorber, two weak Mg \textsc{ii} absorbers, one weak C \textsc{iv}, and two associated O \textsc{vi} absorbers. The system plots for these metal-line systems are shown in Figures 33–38.

z = 0.5507. — Jannuzi et al. (1998) found a metal-line system at z = 0.5507 with strong C \textsc{iv} detected. This system corresponds to a strong Mg \textsc{ii} absorber detected in a Keck/HIRES spectrum (Churchill & Vogel 2001), which also has detected Ca \textsc{ii}, Fe \textsc{ii}, and Mg \textsc{i}. In the HST/STIS spectrum, we also find Fe \textsc{ii} λλ1608, Al \textsc{ii} λ1671, and C\textsc{iv} λλ1548, 1551. There is a 3σ detection of Al \textsc{ii} λ1671 at v = 150 km s\textsuperscript{-1}, which coincides with a satellite component of Mg\textsc{ii} λλ2796, 2803 in the Keck/HIRES spectrum (Ding et al. 2005).

z = 0.5584. — For the multiple-cloud, weak Mg \textsc{ii} absorber at z = 0.5584, C\textsc{iv} λλ1548, 1551 was detected in the HST/STIS spectrum, but no low ionization transitions were detected, though Al \textsc{ii} λ1671, Al\textsc{iii} λλ1855, 1863, and Si \textsc{ii} λλ1527 were covered.

z = 0.7577. — A possible weak C \textsc{iv} doublet at z = 0.7577 cannot be confirmed, since Lyα is not covered in the Lyα forest system, and in the previous HST/FOS spectrum.

z = 0.8954. — The single-cloud, weak Mg \textsc{ii} absorber at z = 0.8954 has detected Lyα, Si \textsc{ii} λλ1207, Si \textsc{iv} λ1394, and C\textsc{iv} λλ1548, 1551. The Si \textsc{iv} λ1403 is affected by a blend. Although there is a detection at the position of Si \textsc{ii} λ1260, Ding et al. (2005) note that this may be a blend, since it is difficult to explain the strength of this feature in comparison to the weaker Mg\textsc{ii} λλ2796, 2803 lines.

z = 1.2152. — The O \textsc{vi} system, at z = 1.2152, found by Jannuzi et al. (1998) is confirmed here, showing O\textsc{vi} λλ1032, 1038 and Lyα in the HST/STIS spectrum. Although a feature is detected at the position of N\textsc{v} λ1239, also noted by Jannuzi et al. (1998), this is inconsistent with the lack of detection of N\textsc{v} λ1243, and so cannot be confirmed.

z = 1.2717. — Jannuzi et al. (1998) found a strong associated O \textsc{vi} absorber at z = 1.2717 in their HST/FOS spectrum, for which Lyα and Lyβ were also detected. In the higher resolution HST/STIS spectrum, we confirm these detections, but do not find any other associated absorption. The relatively weak Lyα, as compared to O\textsc{vi} λλ1032, 1038 is characteristic of a class of associated O \textsc{vi} absorbers (Ganguly et al. 2007, in preparation).

3.5 PG 1248+401 (z \textsubscript{em} = 1.030)

This quasar was studied by the HST Quasar Absorption Line Key Project using G190H and G270H spectra obtained with FOS (Jannuzi et al. 1998), who found metal-line systems at z = 0.3946, 0.7660, 0.7732 and 0.8553. The latter two systems correspond to strong Mg \textsc{ii} absorbers, modeled by Ding et al. (2005) based on Keck/HIRES data (Churchill & Vogel 2001) and the HST/STIS spectrum presented here. Another system, at z = 0.7011, with only C\textsc{iv} λλ1548, 1551 and Lyα detected, was discussed in Milutinović et al. (2006).

Churchill et al. (1999) obtained a spectrum of this quasar with HST/STIS in order to provide constraints on the physical conditions in the two strong Mg \textsc{ii} absorbers along the line of sight. In the HST/STIS spectrum, the Lyα forest is only covered up to a wavelength of 2468 Å, and higher order Lyman series lines are not covered. We find evidence for two strong Mg \textsc{ii} and two weak C \textsc{iv} systems in the HST/STIS spectra. These systems are shown in Figures 39–45.

z = 0.3946. — Al \textsc{ii} λ1671 and Al \textsc{iii} λ1855 are the only prominent transitions from the possible z = 0.3946 system that are covered in the HST/STIS spectrum. Although there is a detection at the position of Al \textsc{ii} λ1671, the lack of detected Al\textsc{iii} λλ1855, 1863 and the lack of detection of C\textsc{iv} λλ1548, 1551 in the FOS spectrum leads us to question the reality of this system. Thus we prefer an identification of the feature at 2330.09 Å as Lyα.

z = 0.5648. — A C \textsc{iv} doublet is found at z = 0.5648 in the HST/STIS spectrum. It is confirmed by a Lyα detection in the G190H HST/FOS spectrum (Jannuzi et al. 1998). The weak feature at the expected position of Si \textsc{ii} λλ1327 is unlikely to be Si \textsc{ii} because of the absence of the stronger Si \textsc{ii} λ1260 transition in the FOS spectrum.

z = 0.6174. — There is a very weak possible C \textsc{iv} doublet at z = 0.6174 in the HST/STIS spectrum, however the alignment is not perfect. Also, there is no Lyα detected in the FOS spectrum to a rest frame equivalent width limit of 0.11 Å.

z = 0.7011. — The C \textsc{iv} absorption system at z = 0.7011 is confirmed by a Lyα detection in the FOS spectrum, but there are no additional detections in the HST/STIS spectrum.

z = 0.7728. — The strong Mg \textsc{ii} system at z = 0.7728 has detected Al \textsc{ii} λ1671, Si \textsc{ii} λλ1304 and Si \textsc{ii} λ1357, C \textsc{ii} λ1335, Si\textsc{iv} λλ1393, 1402, and C\textsc{iv} λλ1548, 1551 in the STIS E230M
spectrum. O i λ1302 may be detected in the strongest low ionization component, but the spectrum is very noisy in that region.

\[ z = 0.7760 \] — We cannot confirm a system at \( z = 0.7760 \), which was suggested by Jannuzi et al. (1998), however we note that we also do not detect CIV λ1548, 1551 to a 3σ rest frame equivalent width limit of 0.02 Å. It is still possible that this system exists, but is collisionally ionized, as proposed by Jannuzi et al. (1998).

\[ z = 0.8545 \] — The strong Mg ii system at \( z = 0.8545 \) has detected Si ii \( \lambda \lambda 1260, C \Pi \lambda \lambda 1335 \), SiIV λλ1393, 1402, CIV λ1548, 1551, and Nv λλ1239, 1243. Kinematically, this system is interesting, with satellite components in low ionization gas (offset \( \sim 300 \) km s\(^{-1} \) from the main absorption) having corresponding, broader C iv absorption.

### 3.6 CSO 873 (\( z_{\text{em}} = 1.022 \))

This quasar was previously studied through G190H and G270H HST/FOS spectra (Bahcall et al. 1996), but only three metal-line systems were indicated, at \( z = 0.2891 \), 0.6606, and 1.0022. The \( z = 0.6606 \) coincides with a strong Mg ii absorber (Churchill & Vogt 2001), and it was modeled by Ding et al. (2005).

The HST/STIS spectrum was obtained in a program (P.I. Churchill) to facilitate a study of the \( z = 0.6606 \) Mg ii absorber. This spectrum covers the Lyα forest up to a wavelength of 2458 Å, and does not cover any Lyβ lines.

\[ z = 0.6611 \] — Besides Galactic absorption, in the HST/STIS E230M spectrum, we detect metal-line absorption from only the system at \( z = 0.6611 \), which corresponds to a full Lyman limit break seen in a HST/FOS G160L spectrum (Bahcall et al. 1993, 1996). A system plot is shown in Figure 46. From this system we find Al i \( \lambda \lambda 1671 \), Si ii \( \lambda \lambda 1527 \), and CIV λ1548, 1551. Si iv is not detected. In fact, the C iv absorption at the velocity of the low ionization absorption is relatively weak, and this system classifies as "C iv--deficient" (Ding et al. 2005). The strongest C iv absorption is \( \sim 200 \) km s\(^{-1} \) redward of the strongest low ionization component. Jannuzi et al. (1998) note a complex of Lyα lines ranging from \( z = 0.6692 \) to 0.6771. They found no metals associated with this complex in the low resolution HST/FOS spectrum. We note that with the STIS data, it is possible to set a stronger limit, with a rest frame 3σ equivalent width limit \( W_c(1548) < 0.024 \) Å.

### 3.7 PG1634 + 706 (\( z_{\text{em}} = 1.334 \))

This was one of the HST QSO Absorption Line Key Project quasars, and its HST/FOS G270M spectrum was presented in Bahcall et al. (1996). In that spectrum, three extensive metal-line systems are present at \( z = 0.9060, 0.9098 \) and 1.0417. Also, there are possible C iv doublets at \( z = 0.5582, 0.6540, 0.6790 \) and 0.7796, and a possible O vi doublet at \( z = 1.3413 \). In a Keck/HIRES optical spectrum, strong Mg ii absorption is detected from the \( z = 0.9908 \) system, and weak Mg ii absorption from the \( z = 0.6540, 0.9060 \) and 1.0417 systems (Churchill & Vogt 2001; Churchill et al. 1999; Charlton et al. 2003). Weak Mg ii is also detected at \( z = 0.8181 \) in the optical spectrum (Churchill et al. 1999). The three single-cloud, weak Mg ii absorbers at \( z = 0.8181, 0.9056 \) and 0.6534 were modeled by Charlton et al. (2003), the multiple-cloud, weak Mg ii absorber at \( z = 1.0414 \) by Zonak et al. (2004), and the strong Mg ii absorber at \( z = 0.9902 \) by Ding et al. (2003).

Two programs contribute different wavelength coverage of this quasar with HST/STIS. Burles (1997, HST Proposal ID #7292) observed the quasar in order to measure the primordial D/H ratio. Jannuzi et al. (1998) provided redward coverage in order to conduct a detailed study of the Lyα forest. In the HST/STIS spectra, Lyα is covered up to 2837 Å, Lyβ up to 2395 Å, and Lyγ in the small region up to 2208 Å. There is detected absorption from the strong Mg ii absorber, and from the four weak Mg ii absorbers mentioned above. There are also several possible C iv systems and a possible O vi system, as well as an interesting "C iv/Si iii-only" system. There is a possible intrinsic N v system and an associated O vi system observed toward this quasar as well. We report on these systems here, and shown system plots in Figures 47–56.

\[ z = 0.2854 \] — We can only tentatively claim a C iv doublet at \( z = 0.2854 \). The C iv λ1548 and C iv λ1551 profiles match reasonably well, but C ivλ1551 may be a bit too strong at some velocities, and there is no coverage of transitions that could confirm this identification. This could relate to a blend with the C iv λ977 from the \( z = 1.0415 \) system (see below).

\[ z = 0.6513 \] — There is also a probable, narrow C iv doublet at \( z = 0.6513 \). The C iv λ1550 transition is blended with C iv λ1548 from the \( z = 0.6535 \) system. If this is real, it is unusual in the weakness of Lyα relative to C iv. A weak, narrow N v doublet may also be detected.

\[ z = 0.6535 \] — The HST/STIS spectrum shows weak absorption in several low and intermediate transitions related to the \( z = 0.6535 \) single-cloud, weak Mg ii absorber. The C iv has two components redward of the dominant low ionization absorption, and Si iv is weaker but has similar kinematics.

\[ z = 0.8182 \] — The single-cloud, weak Mg ii absorber at \( z = 0.8182 \) has detected Si ii \( C \Pi \), Si iv, and C iv absorption, all centered at the same velocity as the Mg ii. Si ii λ1206 is blended with Lyβ from a system at \( z = 1.1382 \), and is apparent as a small depression in the red wing of that feature.

\[ z = 0.9056 \] — For another single-cloud, weak Mg ii absorber at \( z = 0.9056 \), Lyα, Lyβ, C ii, Si ii, Si iv, C iv, N v, and O vi are detected in the HST/STIS spectrum. The coverage of N v and O vi is unusual for single-cloud, weak Mg ii absorbers and is important for considerations of the phase structure of these objects.

\[ z = 0.9645 \] — There is an interesting system detected in the HST/STIS spectrum at \( z = 0.9645 \). Most of the common metal transitions have good coverage, but only C iii and Si iii are detected. Lyα and Lyβ confirm the reality of this system.

\[ z = 0.9904 \] — The C iv-deficient, strong Mg ii absorber at \( z = 0.9904 \) has detections in the HST/STIS spectrum of the first four Lyman series lines, O i, and a variety of singly to triply ionized transitions, including relatively weak C iv absorption. N v and O vi are covered, but not detected. The Lyδ line is detected, but suffers from a blend to the blue with H γ λ926 from the system at \( z = 1.0415 \). This system is of interest because the higher ionization transitions appear redward of the lower ionization transitions, indicating a density gradient across the system (Ding et al. 2005).

\[ z = 1.0415 \] — The \( z = 1.0415 \) multiple-cloud, weak Mg ii system has a partial Lyman limit break detected in a HST/STIS G230M spectrum. The higher order Lyman series lines are detected down to the break in the HST/STIS E230M spectrum, though past H γ λ919 they suffer badly from blending with the Lyman series lines from the \( z = 0.9904 \) system. Metal lines are detected in Si ii, C ii, Si iii, Si iv, and O vi from each of two subsystems. The low ionization transitions are centered at different velocities than the high ionization transitions. C iii λ977 is also detected, but may be blended with the possible C iv doublet at \( z = 0.2854 \). C iv is detected in a
low resolution HST/FOS spectrum, but is redward of the HST/STIS coverage.

$z = 1.1408$. — There is a possible O vi absorber at $z = 1.1408$, however its O vi $\lambda 1032$ transition is too strong relative to the O vi $\lambda 1038$ transition. Although Ly\(\alpha\), Ly\(\beta\), and Ly\(\gamma\) are detected at this velocity, their relative strengths are also inconsistent, perhaps due to unknown blends.

$z = 1.3413$. — An O vi doublet is detected from a system at $z = 1.3413$, which is slightly redward of $z_{em}$. It is confirmed by a very weak Ly\(\alpha\) detection, but Ly\(\beta\) is badly blended and provides no additional constraint. This is another example of an associated O vi system (e.g. Ganguly et al. 2007, in preparation).

3.8 PG1718 + 481 ($z_{em} = 1.084$)

The E23OM observation of this quasar with HST/STIS was proposed by Burles et al. (1997, HST Proposal ID #7292) to facilitate a study of the deuterium to hydrogen ratio in a system at $z = 0.701$ (Kirkman et al. 2001). An HST/STIS G23OM spectrum was also obtained, covering the Lyman series for this system (Kirkman et al. 2001). Earlier, this quasar was observed as part of the HST Quasar Absorption Line Key Project. Jannuzzi et al. (1998) found metal-line systems at $z = 0.8929, 1.0323$ and 1.0872.

In the HST/STIS spectrum, Ly\(\alpha\) is covered up to 2535 Å, Ly\(\beta\) up to 2138 Å, and Ly\(\gamma\) up to 2036 Å. All Lyman series lines are covered below 1902 Å. In addition to the $z = 0.701$ system, for which this observation was obtained, we find evidence for four definite and two possible O vi absorbers. These systems are all shown in Figures 57–64.

$z = 0.7011$. — The $z = 0.7011$ Lyman limit system has Ly\(\alpha\) and Si iv detected in the HST/STIS spectrum. Weak C iv $\lambda 1335$ also appear to be detected, consistent with the weak Mg ii absorption that Kirkman et al. (2001) found in a HIRES/Keck spectrum. C iv $\lambda 1548, 1551$ and Si iv $\lambda 1393, 1402$ are covered, but not detected.

$z = 0.8928$. — An O vi absorber is found at $z = 0.8928$ in the STIS spectrum, accompanied by detections of Si iv, Ly\(\beta\), and Ly\(\gamma\). Jannuzzi et al. (1998) also found C iv in a low resolution HST/FOS spectrum.

$z = 1.0065$. — Another O vi system is detected at $z = 1.0065$ in the HST/STIS spectrum. Ly\(\alpha\) and Ly\(\beta\) are also detected, confirming this O vi doublet.

$z = 1.0318$. — A stronger O vi absorber is detected at $z = 1.0318$, corresponding to the system found by Jannuzzi et al. (1998). In the HST/STIS spectrum the first five Lyman series lines are detected, along with C iv $\lambda 1335$, N v $\lambda 1239, 1243$, and O vi $\lambda 1032, 1038$.

$z = 1.0507$. — There is a feature detected (just above 5\(\sigma\)) at the position of O vi $\lambda 1032$ for a system at $z = 1.0507$ with detected Ly\(\alpha\) and Ly\(\beta\) absorption. The O vi $\lambda 1032$ is not detected, even at 2\(\sigma\), so it is uncertain whether there are detected metals for this system.

$z = 1.0548$. — The $z = 1.0548$ system, with Ly\(\alpha\), Ly\(\beta\), Ly\(\gamma\), and Ly\(\delta\) detected in the HST/STIS spectrum, appears to be an O vi absorber, with weak C iv absorption. The O vi doublet cannot be confirmed because the O vi $\lambda 1032$ member is blended with Ly\(\beta\) at $z = 1.0674$.

$z = 1.0867$. — There is an associated system with $z = 1.0867$, detected in Ly\(\alpha\), Ly\(\beta\), and Ly\(\gamma\). The Ly\(\alpha\) profile has a black, saturated region at this redshift. The $z = 1.0867$ component has detections in C iv and Si iv.

$z = 1.0874$. — There is also a non-black component at $z = 1.0874$. This system detected O vi $\lambda 1032, 1038$, and resembles many other associated O vi systems.

4 SUMMARY OF SYSTEMS

This paper presents a catalog that is useful for investigations of metal-line systems and the Ly\(\alpha\) forest in eight of the highest S/N-ratio E23OM spectra from the HST/STIS archive. We have identified a total of 56 metal-line systems (with at least one metal line detected) toward the eight quasars listed in Table 4 as presented in Figures 9–64. For key transitions, Table 4 tabulates in how many of the 56 systems a given transition was covered and in how many it was detected. We must caution that clearly these numbers apply only to this particular dataset and are highly dependent on the detection limits of the spectra, to the exact wavelength coverage, and to biases toward certain kinds of quasars for the sample. In this sample of eight quasars, there may be a preference toward strong low ionization absorbers, since many of them were chosen for a program to study the C iv associated with Mg ii absorption (see Table 4).

Nonetheless, it is useful to note from Table 4 that for about half of the 56 systems we have coverage of the C iv and O vi doublets, and that in those cases these high ionization transitions were detected $\sim 90\%$ of the time. Intermediate ionization transitions such as C m $\lambda 977$ and Si m $\lambda 1207$ were also covered about half the time, and were detected in 50%/58% of the sight lines, respectively. C m $\lambda 1335$ is also covered for about half of the systems, and was detected 56% of the time, while Si m $\lambda 1260$ was only detected in 36% of the sightlines for which it was covered. We conclude that almost all $1 < z < 1.7$ metal-line systems have high ionization absorption detected, but that only half have detected low ionization absorption. These numbers are consistent with the findings of Milutinović et al. (2006), that half of all C iv absorbers at low redshift have detected low ionization absorption (sometimes weak), and that the other half do not. This is not surprising since the samples used for these studies have considerable overlap.

Studies of the statistics of the Ly\(\alpha\) forest can be significantly affected by metal lines in the forest. With our catalog we are able to give an indication of the level of contamination by metal lines in the 1.0 $< z < 1.7$ forest. Specifically, we scanned the wavelength regions of our catalog that are in the Ly\(\alpha\) forest of the quasar, but are redward of the Ly\(\beta\) forest. Table 4 lists how many Ly\(\alpha\) lines and how many metal lines were detected in this region for each quasar.

These numbers are consistent with the findings of Milutinović et al. (2006), that half of all C iv absorbers at low redshift have detected low ionization absorption (sometimes weak), and that the other half do not. This is not surprising since the samples used for these studies have considerable overlap.

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Table 1. *HST/STIS* E230M Quasar Observations

| QSO ID  | $z_{em}$ | $S/N^a$ | $\lambda_{lo}$ (Å) | $\lambda_{up}$ (Å) | $N_{tot}^b$ | $N_{metal}^c$ | $N_{Gal}^d$ |
|---------|----------|---------|--------------------|--------------------|--------------|----------------|--------------|
| PG 0117+210 | 1.491 | 8.5 | 14.2 | 8673 | 2278.7 | 3117.0 | 104 | 31 | 10 |
| HE 0515-4414 | 1.713 | 8.1 | 22.0 | Reimers | 8288 | 2274.8 | 3118.9 | 63 | 13 | 9 |
| PG 1206+459 | 1.160 | 8.4 | 15.4 | Churchill | 8672 | 2277.1 | 3116.4 | 85 | 33 | 9 |
| PG 1241+176 | 1.273 | 5.2 | 20.0 | Churchill | 8672 | 2276.9 | 3066.0 | 62 | 20 | 10 |
| PG 1248+401 | 1.030 | 8.1 | 9.6 | Churchill | 8672 | 2276.7 | 3107.7 | 41 | 14 | 10 |
| CSO 873$^e$ | 1.022 | 8.0 | 10.4 | Churchill | 8672 | 2278.4 | 3119.2 | 26 | 3 | 8 |
| PG 1634+706 | 1.334 | 19.8 | 28.5 | Jannuzi/Burles | 8312/7292 | 1860.7 | 3117.0 | 121 | 33 | 18 |
| PG 1718+481 | 1.083 | 15.9 | ... | Burles | 7292 | 1848.4 | 2672.7 | 81 | 15 | 14 |

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*a* $S/N$ per pixel at 2382 Å and 2796 Å. 
*b* Total number of absorption features between Ly$\alpha$ and Ly$\beta$ emission lines of quasar. 
*c* Number of identified metal absorption features between Ly$\alpha$ and Ly$\beta$ emission lines of quasar. 
*d* Number of Galactic metal absorption features in entire observed wavelength region. 

es Coordinate of this quasar: RA: 13:19:56.3 Dec: +27:28:09 (J2000.0).
Table 2. Detected Transitions

| Transition | $\lambda_{rest}$ (Å) | Oscillator Strength$^a$ |
|------------|----------------------|------------------------|
| Lyα        | 1215.6701            | 0.416400               |
| H iλ1026   | 1025.7223            | 0.079120               |
| H iλ972    | 972.5368             | 0.029000               |
| H iλ950    | 949.7431             | 0.013940               |
| H iλ938    | 937.8035             | 0.007799               |
| H iλ931    | 930.7483             | 0.004814               |
| H iλ926    | 926.2257             | 0.003183               |
| H iλ923    | 923.1504             | 0.002216               |
| H iλ921    | 920.9631             | 0.001605               |
| H iλ919    | 919.3514             | 0.001200               |
| C iλ1158   | 1157.910             | 0.021780               |
| C iλ1189   | 1188.833             | 0.016760               |
| C iλ1277   | 1277.245             | 0.096650               |
| C iλ1329   | 1328.833             | 0.058040               |
| C iλ1036   | 1036.3367            | 0.1231                 |
| C iλ1354   | 1355.6262            | 0.0127                 |
| C iiλ1336b | 1335.6262            | 0.0127                 |
| Mg iλ2796  | 2796.352             | 0.6123                 |
| Mg iiλ2803 | 2803.531             | 0.3054                 |
| Al iλ1671  | 1670.787             | 1.880000               |
| Al iλ1855  | 1854.716             | 0.539000               |
| Si iλ990   | 989.873              | 0.133000               |
| Si iλ1190  | 1190.416             | 0.250200               |
| Si iλ1193  | 1193.290             | 0.499100               |
| Si iiλ1195 | 1194.500             | 0.623300               |
| Si iiλ1260 | 1260.422             | 1.007000               |
| Si iiλ1304 | 1304.370             | 0.147300               |
| Si iiλ1527 | 1526.707             | 0.116000               |
| Si iiλ1207 | 1206.500             | 1.600000               |
| Si iiλ1394 | 1393.755             | 0.528000               |
| Si iiλ1403 | 1402.770             | 0.262000               |
| P iλ1153   | 1152.818             | 0.236100               |
| S iλ1251   | 1250.584             | 0.005453               |
| Cr iλ2056  | 2056.254             | 0.1403                 |
| Cr iλ2062  | 2062.234             | 0.1049                 |
| Cr iλ2066  | 2066.161             | 0.06982                |
| Mn iλ2577  | 2576.877             | 0.3508                 |
| Mn iλ2594  | 2594.499             | 0.2710                 |
| Mn iiλ2606 | 2606.461             | 0.1927                 |
| Fe iλ2524  | 2523.608             | 0.279000               |
| Fe iiλ1608 | 1608.4449            | 0.055450               |
| Fe iiλ2250 | 2249.8768            | 0.00182                |
| Fe iiλ2261 | 2260.7805            | 0.00244                |
| Fe iiλ2344 | 2344.214             | 0.109700               |
| Fe iiλ2374 | 2374.4612            | 0.02818                |
| Fe iiλ2383 | 2382.765             | 0.3006                 |
| Fe iiλ2587 | 2586.650             | 0.064570               |
| Fe iiλ2600 | 2600.1729            | 0.22390                |
| Zn iiλ2063 | 2062.664             | 0.252900               |

$^a$ These numbers are from Verner et al. (1996).
### Table 3. Sample – Features with $5\sigma$ Identified in the HST/STIS E230M Spectra of 8 Quasars

| # | $\lambda_{\text{obs}}$ | $W_{\text{obs}}$ | $\sigma(W_{\text{obs}})$ | $S$ | Line ID | $z$ | Notes |
|---|---|---|---|---|---|---|---|
| 1 | 2278.83 | 0.21 | 0.02 | 9.5 | H $\lambda$972 | 1.3430 |
| 2 | 2285.29 | 0.97 | 0.04 | 25.7 | C m$\lambda$977 | 1.3390 |
| 3 | 2287.19 | 0.11 | 0.02 | 6.3 | Ly$\alpha$ | 0.8814 |
| 4 | 2288.62 | 1.62 | 0.03 | 49.4 | C m$\lambda$977 | 1.3430 |
| 5 | 2292.90 | 0.14 | 0.02 | 7.9 | Ly$\alpha$ | 0.8861 |
| 6 | 2293.51 | 0.14 | 0.02 | 6.8 | Ly$\alpha$ | 0.8866 |
| 7 | 2295.47 | 0.14 | 0.02 | 21.4 | H $\lambda$938 | 1.3478 |
| 8 | 2301.45 | 1.31 | 0.05 | 28.4 | Ly$\alpha$ | 0.8932 |
| 9 | 2306.53 | 0.05 | 0.01 | 4.2 | Ly$\alpha$ | 0.8973 |
| 10 | 2306.91 | 0.20 | 0.01 | 13.9 | C $\lambda$1335 | 0.7290 |
| 11 | 2311.85 | 0.18 | 0.02 | 11.8 | C $\lambda$1335 | 0.7290 |
| 12 | 2313.76 | 0.15 | 0.02 | 20.9 | Ly$\alpha$ | 0.9033 |
| 13 | 2316.57 | 0.09 | 0.01 | 6.0 | Ly$\alpha$ | 0.9056 |
| 14 | 2318.26 | 0.04 | 0.01 | 5.5 | Ly$\alpha$ | 0.9070 |
| 15 | 2320.72 | 0.83 | 0.03 | 33.0 | H $\lambda$972 | 1.3486 |
| 16 | 2321.88 | 0.11 | 0.01 | 9.3 | H $\lambda$931 | 1.4242 |
| 17 | 2324.65 | 0.46 | 0.02 | 21.8 | Ly$\alpha$ | 0.9104 |
| 18 | 2324.75 | 0.13 | 0.02 | 6.9 | Ly$\alpha$ | 0.9104 |
| 19 | 2324.80 | 0.46 | 0.02 | 21.8 | H $\lambda$950 | 1.4478 |
| 20 | 2325.78 | 0.06 | 0.01 | 5.5 | Ly$\alpha$ | 0.9132 |
| 21 | 2331.23 | 0.20 | 0.01 | 13.9 | C $\lambda$1335 | 0.7290 |
| 22 | 2332.47 | 0.37 | 0.02 | 16.4 | H $\lambda$972 | 1.3983 |
| 23 | 2334.98 | 0.19 | 0.02 | 10.1 | Ly$\alpha$ | 0.9207 |
| 24 | 2339.13 | 0.40 | 0.02 | 12.7 | H $\lambda$938 | 1.4949 |
| 25 | 2342.22 | 0.08 | 0.01 | 5.5 | Ly$\alpha$ | 0.9267 |
| 26 | 2343.96 | 0.77 | 0.02 | 35.2 | Fe $\lambda$2344 | 0 |
| 27 | 2349.69 | 0.53 | 0.02 | 24.8 | Fe $\lambda$2374 | 0 |
| 28 | 2352.69 | 0.14 | 0.02 | 9.0 | Ly$\alpha$ | 0.9353 |
| 29 | 2353.30 | 0.08 | 0.02 | 5.2 | H $\lambda$972 | 1.4242 |
| 30 | 2357.58 | 0.38 | 0.02 | 16.9 | Ly$\alpha$ | 0.9393 |
| 31 | 2359.25 | 0.34 | 0.03 | 13.5 | Ly$\alpha$ | 0.9407 |
| 32 | 2369.23 | 0.35 | 0.02 | 18.1 | H $\lambda$950 | 1.4949 |
| 33 | 2374.49 | 0.99 | 0.03 | 31.7 | Fe $\lambda$2374 | 0 |
| 34 | 2380.41 | 0.66 | 0.02 | 27.7 | H $\lambda$972 | 1.4478 |

### Table 4. Detection Rate of Important Transitions

| Transition | $\#_{\text{cov}}$ | $\#_{\text{det}}$ | Detection Rate (%) |
|---|---|---|---|
| C m$\lambda$1335 | 27 | 15 | 56 |
| C m$\lambda$977 | 26 | 13 | 50 |
| C iv$\lambda$1548 | 26 | 23 | 88 |
| N m$\lambda$1084 | 31 | 1 | 3 |
| N v$\lambda$1239 | 37 | 9 | 24 |
| O vi$\lambda$1032 | 30 | 27 | 90 |
| Al ii$\lambda$1671 | 18 | 7 | 39 |
| Al ii$\lambda$1855 | 10 | 2 | 20 |
| Si ii$\lambda$1260 | 36 | 13 | 36 |
| Si iii$\lambda$1207 | 36 | 21 | 58 |
| Si iv$\lambda$1394 | 26 | 13 | 50 |
| Fe ii$\lambda$1608 | 22 | 2 | 9 |

$^a$ Number of systems in which transition is covered, $^b$ Number of systems in which transition is detected, $^c$ Probability that transition is detected at $>5\sigma$ for system in which it is covered.
Figure 1a. Sample – Normalized flux versus wavelength for a portion of the HST/E230M spectrum of quasar PG 0117 + 213. This is an example of a set of figures for all quasars and all wavelength coverage, which are given in the electronic version. The histogram displayed beneath the data represents the error for all features detected at a 3σ level. Numbered ticks mark spectral features detected at a 3σ level. These are listed in Table 3.
Figure 9. Sample – System plot for the $z = 0.5764$ system toward PG0117+213. Important transitions are plotted, unless they are so badly compromised by a blend that no useful constraints can be gathered. The transitions are aligned in velocity space, with 0 km s$^{-1}$ corresponding to $z=0.5764$. The error spectrum is plotted beneath the data, and a dashed line shown at zero flux.