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Mg II ABSORPTION BY PREVIOUSLY KNOWN GALAXIES AT $z \approx 0.5$

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ABSTRACT

We have obtained spectra at the Multiple Mirror Telescope of nine QSOs in order to search for Mg II λλ2796, 2803 absorption from intervening galaxies with previously determined redshifts between 0.2 and 0.7. We have detected two Mg II systems with the redshift of known galaxies, including one associated with a cluster of galaxies at $z = 0.362$. From the lack of detectable Mg II absorption for a large number of other galaxies, we conclude that the galaxies that *do* absorb must have an effective cross section for absorption at least twice as large in radius as previously thought, in order to account for Mg II absorber statistics. Contrary to previous work, we find that the galaxies with detectable absorption have the same distribution of absolute luminosities as galaxies which show no absorption.

Subject headings: galaxies: formation — quasars: absorption lines

1. INTRODUCTION

The narrow absorption lines in QSO spectra with $z_{abs} \ll z_{em}$ are thought to arise in halos or disks of galaxies which are generally too distant and hence too faint to allow much detailed study of their stellar content. Since the look-back times to many systems are a significant fraction of the age of the universe, QSO absorption lines yield clues to the physical conditions in galaxies during their early history. An important line of attack in this field is the statistical study of Mg II λλ2796, 2803 and C IV λλ1548, 1550 doublets as a function of redshift. The presence of two lines of a doublet of known separation and relative strength allow a secure identification of the redshift system; these particular doublets have large f-values and hence are strong transitions. A large number of relatively homogeneous spectra have been accumulated over the years, and many redshift systems are now known (e.g., Sargent, Steidel, & Boksenberg 1988 and references therein).

One of the puzzling results of these studies is that the mean free path for absorption is very much shorter than expected from simple models of the properties of the absorbing galaxies. One can predict the mean free path for absorption from the present-day luminosity function of galaxies, the expected cross-section for absorption based on (for example) 21 cm maps of nearby galaxies, an assumed spatial distribution of the absorbing clouds in each galaxy, and a guess at the fraction of galaxies which might contain absorbing gas (Burbidge et al. 1977). Assuming the gas is spherically distributed around *all* galaxies with filling factor of unity, the mean free path is still roughly 3 times too short for the C IV absorbers (Sargent, Boksenberg, & Steidel 1988), two times too short for the Mg II absorbers (Sargent, Steidel, & Boksenberg 1988), and 2 times too short for the damped Lyα systems (Lanzetta et al. 1991). These results are fairly insensitive to sampling statistics, q_0 or H_0; more realistic assumptions make this discrepancy worse. The implication is that the gaseous halos of galaxies were bigger in the past, or that the number density of gas-rich galaxies was different in the past. The comoving number density of C IV absorbers is in fact a function of redshift (between $z_{abs} = 1.0$ and 4.0) in such a way that indicates that evolution in galaxy properties has probably occurred (Sargent, Boksenberg, & Steidel 1988; Khare, York, & Green 1989).

It is widely recognized that the next major step in understanding the metal-line systems is to tie the properties of the absorbers to the properties of the absorbing galaxies. For high-redshift systems ($z > 1$), this is very difficult since the galaxies are faint (although see Elston et al. 1991; Lowenthal et al. 1991; Bergeron 1991). At low redshift ($z < 0.2$), a major portion of the time on the *Hubble Space Telescope* for QSO absorption-line studies is devoted to observing QSOs near bright, very nearby galaxies in order to detect Mg II and C IV absorption, and to find very low redshift metal-line systems for other follow-up work.

In this paper, we describe a program which complements these studies. We have searched from the ground for Mg II absorption associated with a sample of high-redshift galaxies ($z = 0.2$–0.7) found in detailed studies of the environments of QSOs (Yee, Green, & Stockman 1986; Ellingson, Green, & Yee 1991a, b). These studies yielded photometry and multiobject spectroscopy of many galaxies with small angular separations from bright QSOs. In many cases, the galaxies have redshifts $z_{gal} \ll z_{QSO}$ which place them well removed from the QSO. Several groups, most notably Bergeron and collaborators, have done the converse, i.e., looked for galaxies at the redshift of *known* Mg II absorbers (Bergeron & Boisse 1991 and references therein). Their success rate is ~80%, and their work is an important confirmation of the hypothesis that the metal-line systems in fact arise in intervening galaxies. Our approach, looking for Mg II absorbers at known galaxy redshifts, is complementary in nature. Because our galaxies were chosen *without* consideration of their being possible Mg II absorbers, they represent a fairly unique sample of faint galaxies with measured redshifts near bright background QSOs. In particular, our sample avoids any possible selection effects inherent in the searches for galaxies causing known absorption. For

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example, these data include photometry of galaxies in the quasar field to a well-determined limiting magnitude, and spectroscopy of many galaxies which are *not* likely candidates for absorbers, e.g., galaxies with red colors, and galaxies fainter than, or further from, the quasar than the identified absorber. We also have information about the cluster environment of the absorbing galaxies which is important in assessing whether a given galaxy is the Mg II absorber, or a different galaxy at the same redshift.

Another aim of this study was to increase the number of absorbers with identified galaxies that have redshifts in order to provide additional objects for further detailed work. The total number in the literature is ~16, which is large enough to suggest interesting trends, but still rather small. For example, Lanzetta & Bowen (1990) find a correlation of equivalent width of Mg II with impact parameter and conclude that the gas column density in the absorbing galaxies must fall off as r^3. However, their correlation is significant only at the 2.6 σ level and this result is sensitive to the possibility that the absorbing galaxy is actually an unidentified galaxy at a larger distance. Bergeron & Boisse (1991) have also suggested that Mg II absorbing galaxies are preferentially bright, with no absorbers found having $L < 0.3L^*$. More galaxies, including a larger sample of nonabsorbing galaxies for comparison, could improve the significance of these results.

With a larger sample, we could begin to address several interesting questions. What does the distribution of absorption cloud velocities relative to the galaxy velocities tell us about the dynamics of the clouds relative to the bulk of the galaxy light? Is the observed distribution consistent with what one expects from a rotation curve from a normal large spiral, or are the absorbing clouds arising in a population of dwarf galaxy companions on the outskirts (as some have suggested)? Is the metallicity of the clouds a function of impact parameter?

In §§ 1 and 2, we describe the new spectra of nine QSOs which have galaxies of known redshift with small projected separations to the QSO line of sight. In § 4, we discuss the results.

2. OBSERVATIONS

Spectra were obtained at the Multiple Mirror Telescope[2] with the Blue Spectrograph, "Big Blue" Image Tube and photon-counting Reticon (Latham 1982). The 832 lines mm^{-1} grating was used in second order with the image stacker (Chaffee & Latham 1982) resulting in spectral resolution, as measured from the comparison arc lamp lines, of ~85 km s^{-1} FWHM. The observations are summarized in Table 1, and the spectra are plotted in Figures 1–9. All data were taken on 1991 February 15, except the data for Q1641+399 which was obtained on 1991 May 12. Each QSO was placed alternatively in one of two sets of apertures, and sky spectra were recorded simultaneously in the other aperture. Pixel-to-pixel variations in detector response were divided out using a long quartz lamp exposure obtained during the day. During the night, every 20 minutes, a short exposure of a helium-neon-argon-cadmium-mercury lamp was obtained to calibrate the wavelength-to-pixel transformation. Root-mean-square errors in the wavelength calibration were formally ~0.3 pixels or 0.08 Å. However, shear in the fiberoptic bundle in the image tube chain may have caused somewhat worse errors in certain parts of the spectrum. Individual exposures of each QSO were wavelength calibrated with bracketing arcs, rebinned to a linear wavelength scale, and co-added. A variance array for each spectrum, derived from the gross object counts and sky counts, was maintained throughout. Exposures of IIDS standard stars were obtained at the beginning and end of each night to look for telluric absorption or residual instrumental features. Data were reduced using standard routines with the Ohio State IRS software package as implemented at Steward Observatory.

Analyses of the reduced QSO spectra were carried out essentially in the way described in detail by Bechtold (1992). A cubic spline was fitted to the spectra in order to define the continuum level. Pixels whose values deviated below the fit by more than 2.5 σ were flagged, and a new spline fit made; this was repeated until the rms of the pixels which deviated above the fit equaled the rms of the pixels which were below the fit and were equal to what is expected from the variance.

Significant absorption lines were found by measuring the equivalent width in a bin equal to 2.46 times the number of pixels of the FWHM of the comparison lines, and its error (see Young, Sargent, & Bokensberg 1982). All such bins where the equivalent width was significant at greater than or equal to 3.5 σ were flagged. The equivalent width of each feature was then measured by specifying start and stop wavelengths for the feature by hand. The equivalent width and its error (computed from photon statistics only) for each line found in this way is listed in Table 2 and indicated by vertical bars in Figures 1–9. The central wavelength of each line given in Table 2 is the centroid, weighted by the depth of each pixel in the line below the continuum. All wavelengths are vacuum and have been corrected to the heliocentric frame. No absorption lines were detected for PKS 0403−132 or Q1641+399. Several lines listed in Table 2 are not identified. While some of these may be Mg II $\lambda\lambda$2796 for which λ2803 is too weak to be detected, it is more likely that most are just not real lines, but are artifacts of the detector response or electronics. The unidentified lines are the weakest listed in Table 2, and if we had set the equivalent width threshold at 5 σ they would all be excluded. The lines we have identified as Mg II $\lambda\lambda$2796, 2803 are all highly significant, however.

The equivalent width threshold for detectable absorption is a strong function of wavelength, since the signal-to-noise ratio deteriorates significantly at the blue end of each spectrum. In Table 3, we tabulate the wavelength range over which the rest equivalent width threshold for Mg II λ2796 is 0.6 Å or better and 0.3 Å or better, in order to compare our results with previous surveys. However, we note that the QSOs studied here were chosen from the much larger Ellingson, Yee, &

[2] The Multiple Mirror Telescope Observatory is a joint facility of the University of Arizona and the Smithsonian Institution.

TABLE 1

OBSERVATIONS

QSO	Alternate Name	z_{em}	V	Exposure (minutes)	$\Delta\lambda$ (Å)
PKS 0403−132	...	0.571	17.2	50	3520–4450
PKS 0405−123	...	0.574	14.8	20	3520–4450
B2 0742+318	4C 31.30	0.462	16.0	120	3200–4135
PKS 0812+020	4C 02.23	0.402	17.1	120	3200–4135
PKS 1048−090	3C 246	0.344	16.8	100	3200–4135
PKS 1217+023	UM 492	0.240	16.5	60	3200–4135
PKS 1305+069	3C 281	0.602	17.0	40	3620–4550
PKS 1354+195	4C 19.44	0.720	16.0	20	3980–4880
Q1641+399	3C 345	0.592	16.0	25	3530–4460

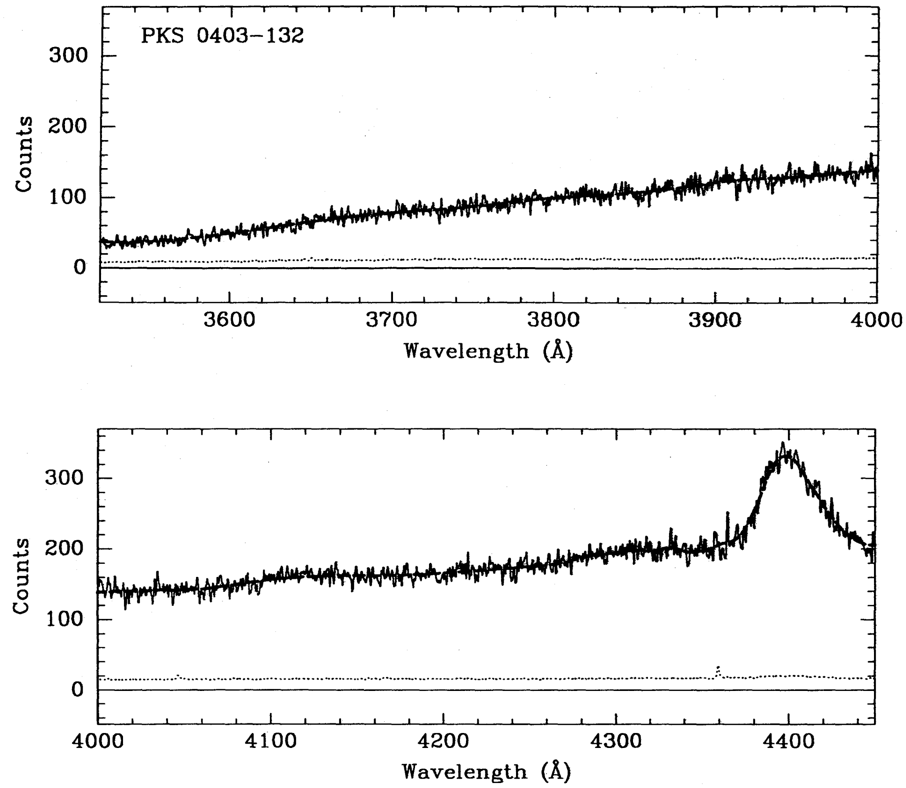

FIG. 1.—Spectrum of PKS 0403−132 obtained with the MMT Blue Spectrograph and photon-counting Reticon. Dashed line indicates continuum fit, and the dotted line indicates the 1 σ square-root of the variance at each pixel. The spectra have been smoothed for presentation only with a Gaussian of 2.5 pixel FWHM, but the error array has not been adjusted to reflect this. Significant lines are indicated by vertical bars.

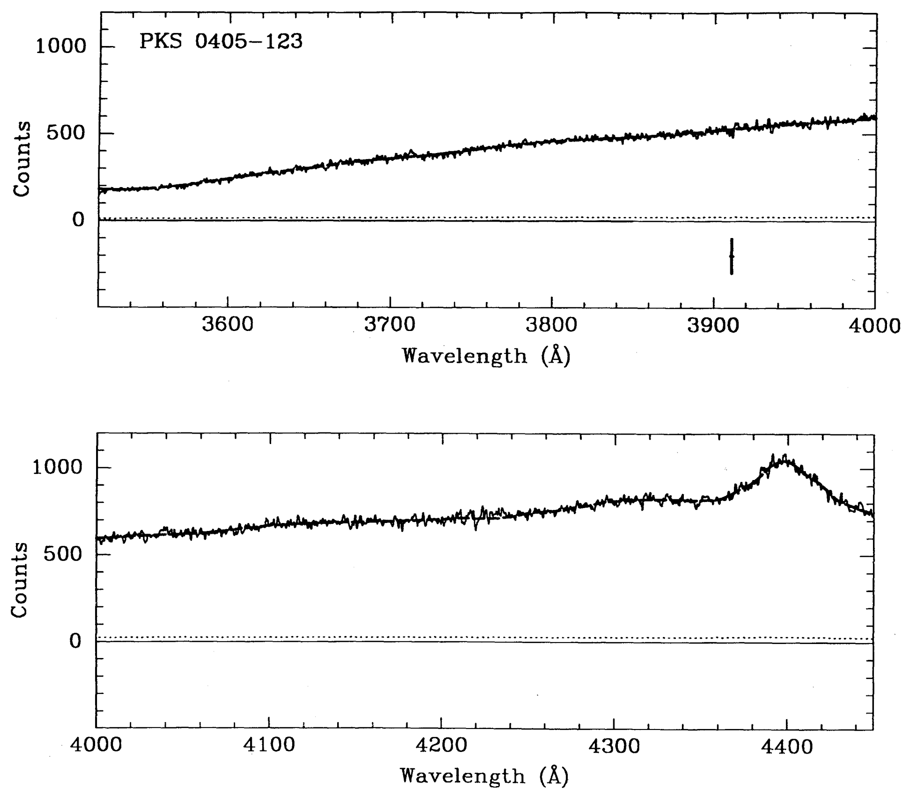

FIG. 2.—Spectrum of PKS 0405−123. See caption for Fig. 1.

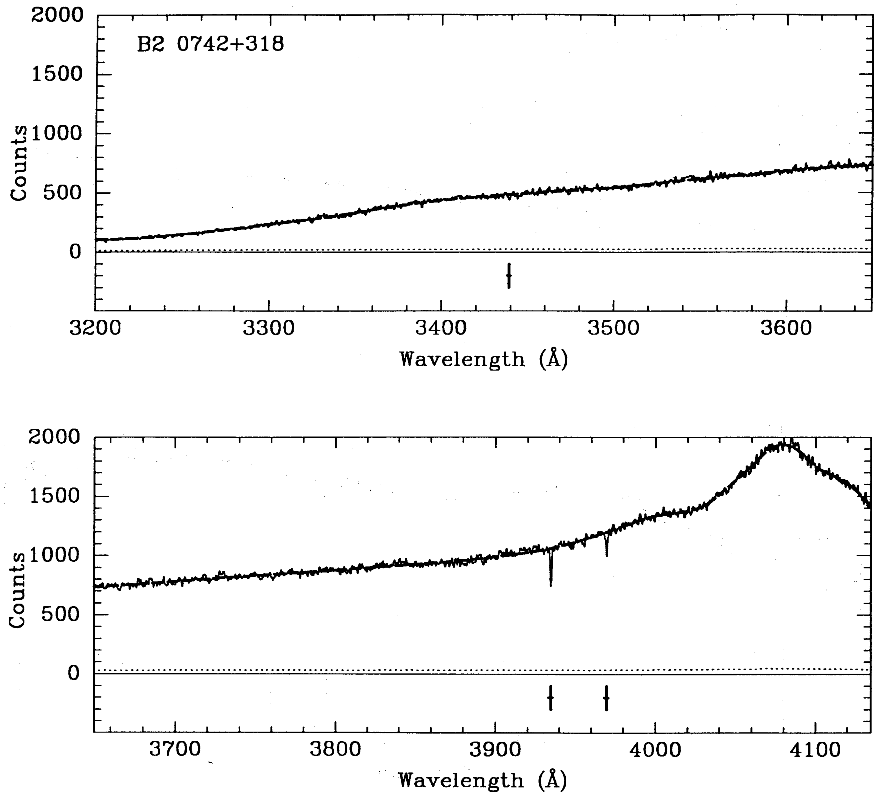

FIG. 3.—Spectrum of B2 0742+318. See caption for Fig. 1.

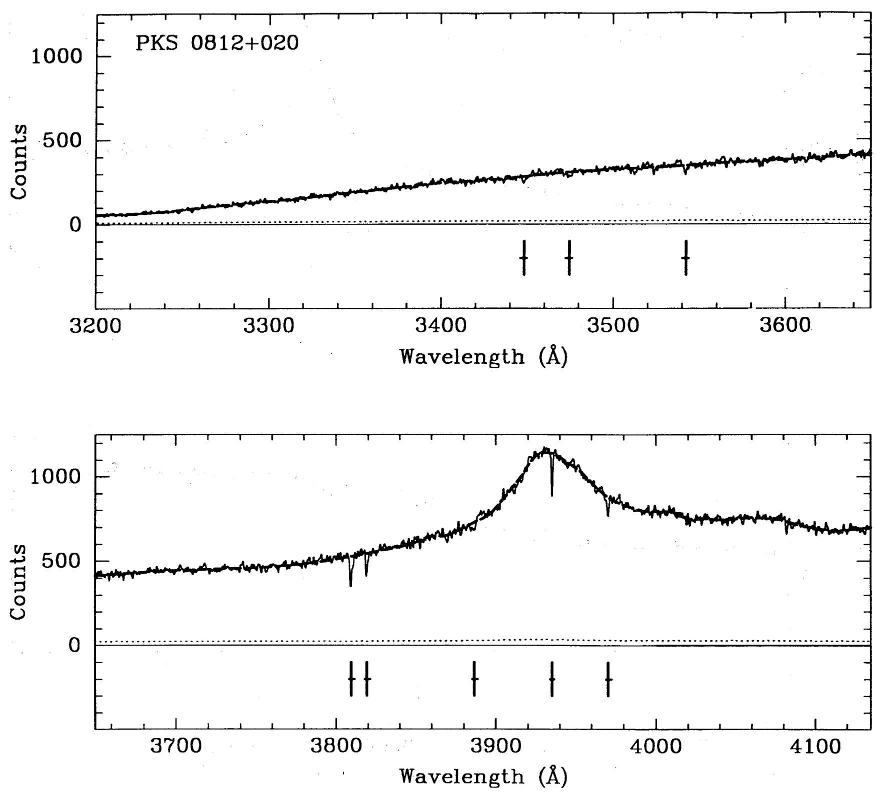

FIG. 4.—Spectrum of PKS 0812+020. See caption for Fig. 1.

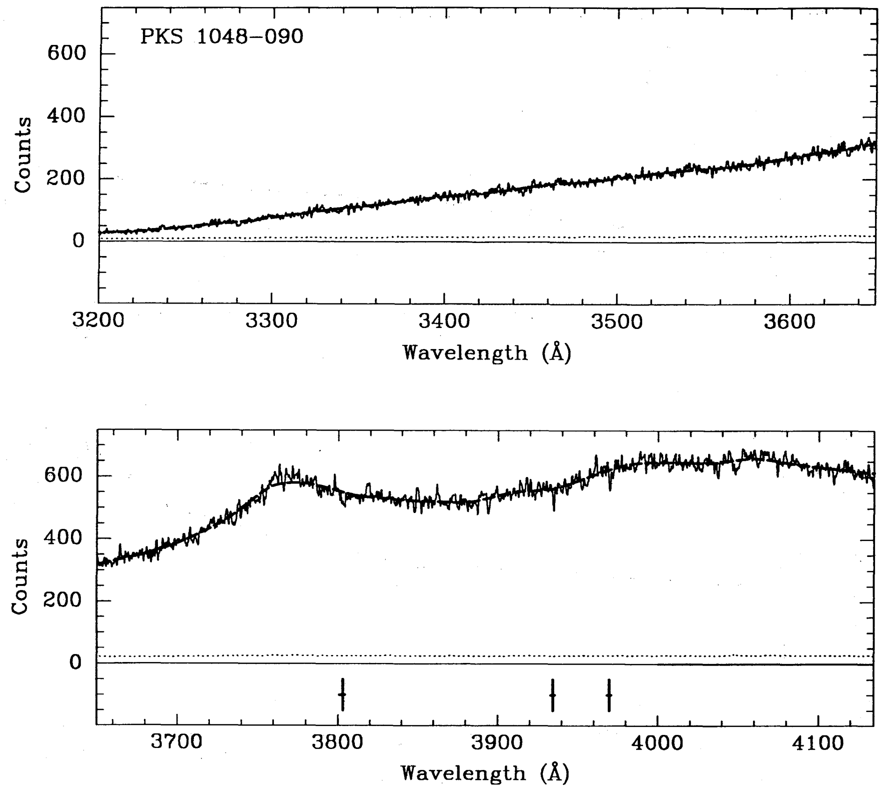

FIG. 5.—Spectrum of PKS 1048−090. See caption for Fig. 1.

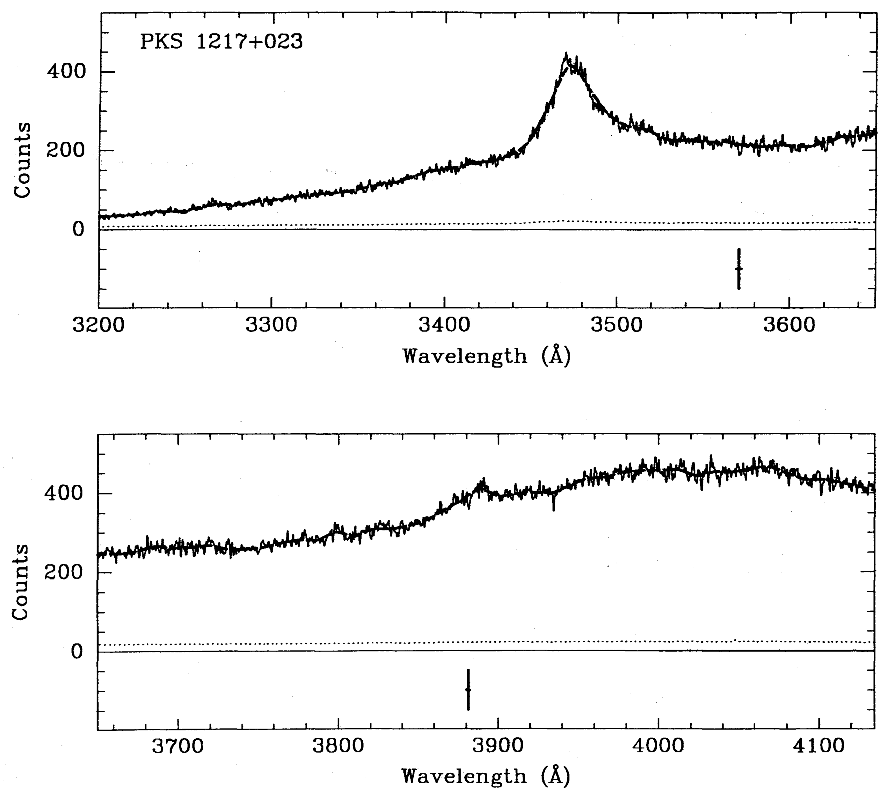

FIG. 6.—Spectrum of PKS 1217+023. See caption for Fig. 1.

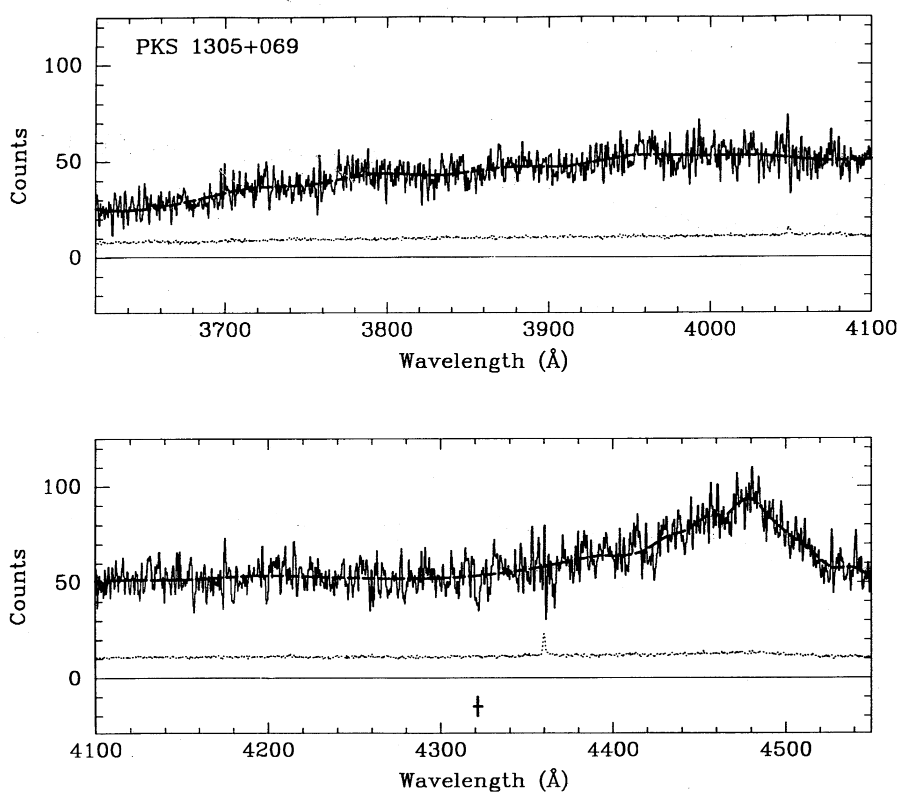

FIG. 7.—Spectrum of PKS 1305+069. See caption for Fig. 1.

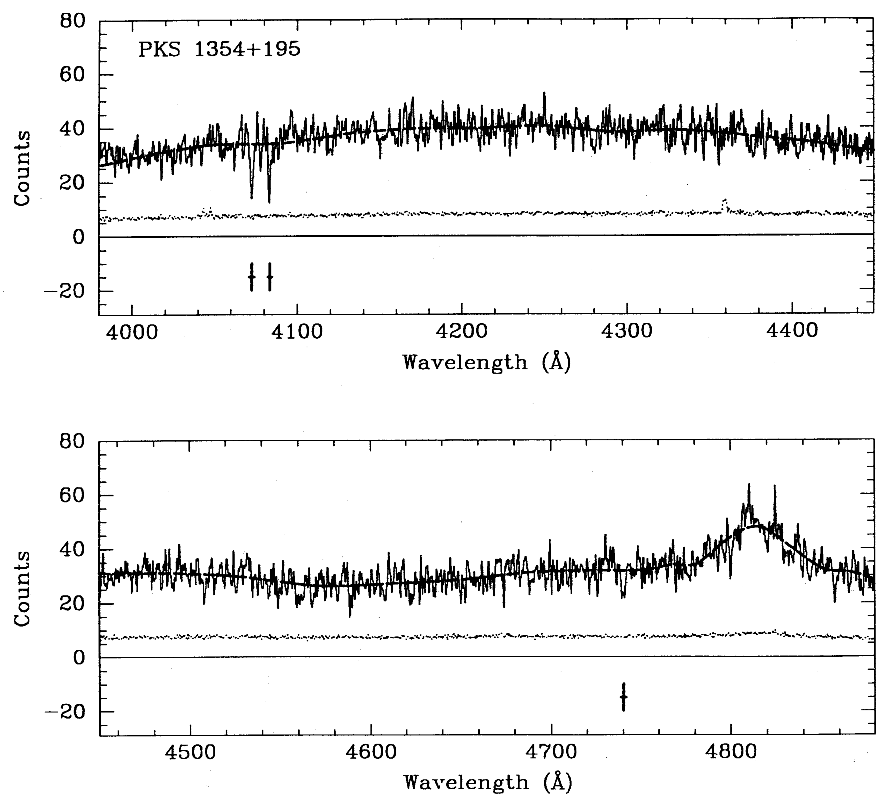

FIG. 8.—Spectrum of PKS 1354+195. See caption for Fig. 1.

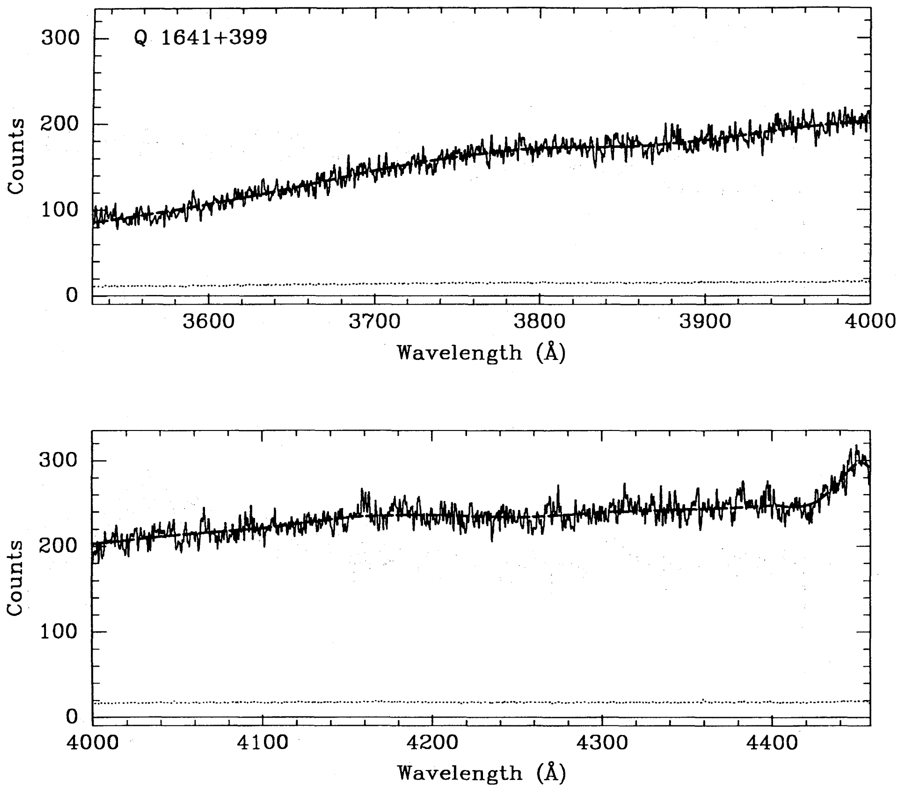

FIG. 9.—Spectrum of Q1641+399 = 3C 345. See caption for Fig. 1.

TABLE 2

ABSORPTION LINES

QSO	Number	λ_{obs}	W_λ (Å)	Identification
PKS 0405−123	1	3911.13	0.106 ± 0.029	...
B2 0742+318	1	3969.47	0.218 ± 0.024	Ca II λ3969, Galactic
	2	3934.63	0.339 ± 0.025	Ca II λ3934, Galactic
	3	3438.98	0.144 ± 0.036	...
PKS 0812+020	1	3970.10	0.183 ± 0.030	Ca II λ3969, Galactic
	2	3935.13	0.254 ± 0.021	Ca II λ3934, Galactic
	3	3886.42	0.141 ± 0.035	Mg I λ2852, z_{abs} = 0.3623
	4	3819.19	0.357 ± 0.040	Mg II λ2803, z_{abs} = 0.3623
	5	3809.42	0.557 ± 0.042	Mg II λ2796, z_{abs} = 0.3623
	6	3542.11	0.275 ± 0.060	...
	7	3474.57	0.256 ± 0.067	...
	8	3448.09	0.242 ± 0.066	...
PKS 1048−090	1	3969.71	0.124 ± 0.032	Ca II λ3969, Galactic
	2	3934.46	0.130 ± 0.036	Ca II λ3934, Galactic
	3	3803.13	0.191 ± 0.042	...
PKS 1217+023	1	3881.30	0.143 ± 0.038	...
	2	3570.74	0.254 ± 0.063	...
PKS 1305+069	1	4321.49	0.874 ± 0.223	...
PKS 1354+195	1	4740.29	0.722 ± 0.184	...
	2	4083.29	1.075 ± 0.180	Mg II λ2803, z_{abs} = 0.4564
	3	4072.61	1.175 ± 0.193	Mg II λ2796, z_{abs} = 0.4564

TABLE 3

REDSHIFT INTERVALS FOR REST EQUIVALENT WIDTH THRESHOLDS OF 0.3 AND 0.6 Å

QSO	z_{em}	$W_\lambda = 0.6$ ($z_{min} - z_{max}$)	0.3 Å ($z_{min} - z_{max}$)
PKS 0403−123......	0.571	0.287–0.571	0.425–0.571
PKS 0405−123......	0.574	0.258–0.605	0.259–0.574
B2 0742+318........	0.462	0.144–0.462	0.176–0.462
PKS 0812+020......	0.402	0.153–0.402	0.196–0.402
PKS 1048−090......	0.344	0.174–0.344	0.242–0.344
PKS 1217+023......	0.240	0.164–0.240	0.218–0.240
PKS 1305+069......	0.602	0.405–0.602	...
PKS 1354+195......	0.720	0.454–0.586	...
	...	0.666–0.720	...
Q1641+399..........	0.592	0.262–0.592	0.315–0.592

Green (1991a, b) sample because they were *known* to have intervening galaxies within 30″ of the line of sight with redshifts that place Mg II in the observed wavelength range. Thus, we expect a bias in favor of finding Mg II absorption in these spectra compared to more typical lines of sight. Hence, it is not valid to combine them with other samples for determining statistical properties such as the number density of Mg II absorbers as a function of redshift. We have therefore not attempted to do so.

In Table 4, we list the galaxies in each field of the nine QSOs of our sample. We list all galaxies brighter than $m_r = 22$ within 30″ of the QSO found photometrically, along with their redshifts, if known. In addition, we note that there are 15 other galaxies in these fields with measured redshifts which place

TABLE 4

NEW Mg II DETECTIONS AND LIMITS FOR GALAXIES

				R_{obs} (kpc)		$M(r)$		
QSO (1)	ΔΘ (2)	r (3)	z_{gal} (4)	$q_0 = 0$ (5)	$q_0 = 0.5$ (6)	$q_0 = 0$ (7)	$q_0 = 0.5$ (8)	W_λ(2796) (Å) (9)
PKS 0405−123	12″8	20.08	...	...	...	...	...	...
	13.5	20.09	0.5703	58.4	50.5	−21.68	−21.37	<0.082
	14.9	21.65	0.5667	64.2	55.6	−20.11	−19.79	<0.085
	8.0	21.76	0.5722	34.6	30.0	−20.02	−19.71	<0.081
	28.2	21.69	0.5788	122.7	106.0	−20.12	−19.80	<0.084
	12.2	21.21	...	...	...	...	...	...
B2 0742+318	14.7	20.93	0.4164	53.6	48.2	−20.02	−19.80	<0.089
	26.1	20.71	...	...	...	...	...	...
	24.4	16.78	...	...	...	...	...	...
	20.8	21.59	...	...	...	...	...	...
PKS 0812+020	26.2	21.30	0.3592	87.3	79.7	−19.28	−19.08	<0.149
	9.5	20.27	...	...	...	...	...	...
	9.0	20.19	0.4030	32.2	29.0	−20.68	−20.46	<0.090
	14.3	20.58	0.4030	48.7	43.6	−20.29	−20.08	<0.090
	10.1	20.07	...	...	...	...	...	...
	9.0	21.11	...	...	...	...	...	...
	4.6	20.95	(0.3623)[a]	(15.4)	(14.1)	(−19.65)	(−19.45)	(0.41)
	13.8	21.54	...	...	...	...	...	...
	11.0	21.00	...	...	...	...	...	...
	18.4	21.87	...	...	...	...	...	...
PKS 1048−090	26.4	18.64	...	...	...	...	...	...
	6.5	20.16	0.3449	21.1	19.3	−20.32	−20.13	<0.140
	23.7	21.44	...	...	...	...	...	...
	23.4	20.81	...	...	...	...	...	...
	23.0	19.34	...	...	...	...	...	...
	26.2	21.54	0.3309	82.9	76.2	−18.84	−18.66	<0.162
PKS 1217+023	19.5	20.36	...	...	...	...	...	...
	17.9	21.37	0.1939	38.8	36.9	−17.72	−17.61	<0.417
PKS 1305+069	16.3	20.26	0.5037	66.1	58.1	−20.49	−20.21	<0.552
	27.3	21.47	...	...	...	...	...	...
	29.5	21.68	...	...	...	...	...	...
	14.5	21.26	...	...	...	...	...	...
	27.2	21.06	...	...	...	...	...	...
	8.9	21.26	...	...	...	...	...	...
	26.8	21.74	0.3266	84.1	77.4	−18.75	−18.57	<0.759
	21.2	20.80	0.5024	85.8	75.5	−20.64	−20.36	<0.555
	5.2	21.26	0.6053	23.1	19.8	−20.64	−20.34	<0.555
PKS 1354+195	25.1	21.49	0.4406	94.5	84.5	−19.61	−19.37	<0.619
	8.1	21.46	0.4592	31.2	27.8	−19.75	−19.49	0.807
	20.6	21.11	...	...	...	...	...	...
	7.2	21.91	(0.4592)[a]	(27.8)	(24.7)	(−19.29)	(−19.04)	(0.807)
Q1641+399	27.5	21.67	...	...	...	...	...	...
	6.8	20.32	0.5910	29.9	25.7	−21.55	−21.22	<0.163
	23.3	21.73	0.5822	101.7	87.8	−20.10	−19.78	<0.177

[a] Values of R_{obs} (kpc) and $M(r)$ are given in parentheses, computed by assuming the galaxy has the redshift of the Mg II absorber. See text.

Mg II in the observed spectral range, with separations greater than 30″ but less than 3′. These are not listed in Table 4; none produced detectable Mg II absorption. Photometric data are taken from Green & Yee (1984), Yee, Green, & Stockman (1986), and unpublished images from Yee. Spectroscopy is from Ellingson, Green, & Yee (1991b) and Ellingson & Yee (1992).

For each galaxy with a redshift, we also list the separation, $R_{\rm obs}$, in kiloparsecs, derived from the angular separation, $\Delta\Theta$, in arcseconds, using (e.g., Weedman 1986) for $q_0 = 0$,

$$R_{\rm obs} = \Delta\Theta\left(\frac{1453}{H_0}\right)\frac{z(1 + z/2)}{(1 + z)^2} \quad (1)$$

and for $q_0 = 0.5$,

$$R_{\rm obs} = \Delta\Theta\left(\frac{2907}{H_0}\right)\frac{(1 + z)^2}{(1 + z) - \sqrt{1 + z}} \quad (2)$$

for $H_0 = 100$ km s^{-1} Mpc^{-1}. We also compute the absolute r magnitude for each galaxy, $M(r)$, from the apparent magnitude, m_r, which for $q_0 = 0$ is

$$M(r) = m_r - 5\log z\left(1 + \frac{z}{2}\right) + 42.447 \quad (3)$$

and for $q_0 = 0.5$ is

$$M(r) = m_r - 5\log 2[(1 + z) - \sqrt{1 + z}] + 42.447\,, \quad (4)$$

where again we have taken $H_0 = 100$ km s^{-1} Mpc^{-1}. Finally, we list the 5 σ rest equivalent width limit for Mg II λ2796 for each galaxy, assuming that the line is unresolved.

3. NOTES ON INDIVIDUAL OBJECTS

PKS 0403−132.—No galaxy redshifts are available for this field at the present time, although deep images reveal seven galaxies within 30″ of the QSO (Ellingson & Yee 1992).

PKS 0405−123.—This quasar is located at the center of a rich cluster of galaxies at the quasar redshift $z = 0.57$. There are four galaxies in this field with redshifts essentially at the QSO emission line redshift, and an additional two galaxies within 30″ of the QSO for which no redshifts are available. Tytler et al. (1987) searched for Mg II absorption in a spectrum covering 3705–4638 Å, at 0.6 Å resolution. They report a single line which they identify as Ca II λ3934, with an observed equivalent width of 0.26 ± 0.07 Å. We do not see this line, with a limit on the equivalent width of 0.18 Å (5 σ), in apparent conflict with their result. The line we detect at 3911.13 Å (see Table 2) is weaker than their quoted equivalent width threshold and so is consistent with their data. It is unlikely that this line is Mg II λ2796, since if it were, one would expect a detectable Lyman limit in the *IUE* spectrum of Green et al. (1980) at $\sim$1274 Å, which is not seen.

B2 0742+318.—Tytler et al. (1987) obtained a spectrum of this QSO covering 3826–4141 Å, at 0.6 Å resolution. They report Galactic Ca II $\lambda\lambda$3934, 3969 absorption with central wavelengths and equivalent widths consistent with our detection. Their data do not extend blue enough for them to have detected our marginally significant line at 3438.98 Å. If this line is Mg II λ2796, then $z_{\rm abs} \approx 0.23$. There are no known galaxies at this redshift in this field (see Table 4). Boulade et al. (1987) report a Mg II system at $z = 0.1917$ with rest equivalent width $W_\lambda = 0.33$ Å for λ2796. We do not see this system, with a 5 σ limit of 0.24 Å (rest), which is inconsistent with their result.

PKS 0812+020.—The only previously published absorption-line spectrum of this QSO is a photographic spectrum given by Peterson & Strittmatter (1978), which had an equivalent width detection threshold of 0.75 Å. Danziger et al. (1987) reported extended emission-line gas associated with this QSO and suggested that the QSO resides in a rich cluster of galaxies at $z \approx 0.40$. Deep photometric imaging by Yee (private communication) also suggest the presence of excess galaxies in the field. Galaxy redshifts reveal that while there are several galaxies associated with the quasar, there is also a foreground group or cluster at $z \approx 0.36$. Mg II $\lambda\lambda$2796, 2903 absorption is detected at $z_{\rm abs} = 0.3623$, and probably arises from a galaxy in this cluster. There is a galaxy at this redshift located 26″ from the quasar which might be responsible for the absorption. However, it is also possible that the absorber is another galaxy in the same cluster. One candidate, for which no redshift has been determined, is separated by only 4″.6 from the QSO. No absorption is seen at the QSO emission-line redshift.

PKS 1048−090.—Morton, York, & Jenkins (1986) searched for Ca II H and K absorption from the Galaxy, and also from a nearby ($\Delta\Theta \approx 172''$) galaxy at $z = 0.1255$ which was found by Monk et al. (1986). Our detection of Galactic Ca II is at a weaker level than their limits and hence consistent with their work. Ca II H and K and Mg II $\lambda\lambda$2796, 2803 for the $z = 0.1255$ galaxy are outside our wavelength range.

PKS 1217+023.—A photographic spectrum was obtained of this QSO by Ford & Rubin (1966) who reported the detection of Ca II H and K absorption at $z = 0.240$. None of the galaxies with known redshifts in this field have $z = 0.240$, and the corresponding Mg II λ2796 should be seen in our spectrum at λ3467, but is not, with a rest equivalent width limit of 0.18 Å. Since it is unlikely for Mg II λ2796 to be weaker than Ca II λ3934 (Petitjean & Bergeron 1990), this redshift system is probably not real.

PKS 1305+069.—Several galaxies with known redshifts are close to the line of sight of this QSO, but no Mg II absorption is seen for any of them (see Table 4). Our single detected weak line at λ4321 could be identified with Mg II λ2796 at $z = 0.5452$, but there are no galaxies known at that redshift in this field.

PKS 1354+195.—Weymann et al. (1979) presented a photographic spectrum of this QSO and found a Mg II system at $z = 0.457$ which we confirm as a system with redshift $z = 0.4564$. It probably originates in the $z = 0.4592$ galaxy which is relatively close to the line of sight (see Table 4).

Q1641+399 = 3C345.—Tytler et al. (1987) obtained a spectrum with 0.9 Å resolution covering 4175–4500 Å. They saw no Mg II system with rest equivalent width greater than 0.25 Å, consistent with our results. There are two galaxies with known redshifts in this field near the line of sight, but no absorption is detected for them.

4. RESULTS

From Tables 2 and 4, we see that in our nine new QSO spectra, we have identified two Mg II absorption-line systems with galaxies near the line of sight: the $z = 0.36$ system of PKS 0812+020 and the $z = 0.45$ system of PKS 1354+195. No Mg II absorption was seen which did not have a galaxy identification. In addition, no Mg II absorption was seen for 33 other galaxies with measured redshifts, of which nine are within 60 kpc of the line of sight and three are within 30 kpc ($H_0 = 100$ km s^{-1} Mpc^{-1}, $q_0 = 0$).

Interestingly, the $z = 0.36$ absorber of PKS 0812+020 is apparently a member of a cluster of galaxies. There are four galaxies with known redshifts which place them in the cluster (three of these have $\Delta\Theta > 30''$ and hence are not listed in Table 4). The four closest galaxies to the QSO line of sight unfortunately have no measured redshifts, but may also be cluster members. The absorption profile is narrow ($\Delta v \approx 200$ km s^{-1} FWHM), i.e., there is no sign of a complex absorption profile with large velocity dispersion. Such absorption-line systems have been attributed to galaxy clusters (e.g., Pettini et al. 1983).

No Mg II absorption is seen associated with any galaxy in any of the other clusters associated with the quasars in our sample. In general, one might expect *not* to find Mg II absorption associated with galaxies in clusters, since galaxies in dense environments are typically deficient in cold gas. On the other hand, clusters at these redshifts associated with quasars may contain a significantly higher fraction of gas-rich galaxies than normal low-redshift clusters of the same richness (Yee et al. 1988). Indeed, the cluster surrounding PKS 0405−123 includes several emission-line galaxies close to the cluster center, half of which might be expected to lie in front of the quasar. However, none of these caused detectable Mg II absorption, despite relatively small separations with the QSO line of sight.

We have carefully reviewed the literature in order to compile a sample of Mg II absorbers with galaxy identifications to compare with ours. In Table 5, we list known galaxies with detected Mg II absorption, galaxies in each field with known redshifts but no Mg II absorption, and other galaxies known photometrically only if they are closer to the line of sight than the galaxy identified with the absorber. These last are included since they *could* be the proper identification, with the galaxy further out being associated with the absorber in a group or cluster. We have required that the redshift of the galaxy be confirmed spectroscopically, and so our list differs slightly from those given by Bergeron & Boisse (1991) or Lanzetta & Bowen (1990). Also, we have included the emission-line objects which are spectroscopically confirmed by Yanny (1990), but not the other candidates in the same fields found through narrow-band imaging by Yanny, York, & Williams (1990). Three Mg II systems have no plausible identification despite extensive searches (Bergeron & Boisse 1991); these may arise in galaxies too faint to have been seen, or too close to the quasar to have been distinguished from the QSO light.

5. DISCUSSION

5.1. *The Effective Cross Section for Absorption*

In this section, we compare the observed distribution of impact parameters for the galaxies in Tables 4 and 5 with the expectations from previous surveys for Mg II absorbers. The statistics of the Mg II absorbers have been studied by Sargent, Steidel, & Boksenberg (1988), Lanzetta, Turnshek, & Wolfe 1988), Tytler et al. (1987) and others. These studies yield an estimate of the number of absorbers per unit redshift, $N(z)$, stronger than some rest equivalent width threshold, $W_{\rm thr}$, as a function of redshift. Sargent, Steidel, & Boksenberg (1988) combined their data with the high-redshift sample of Lanzetta, Turnshek, & Wolfe (1988) and the sample drawn from the literature of Tytler et al. (1987) to derive a sample of 37 redshift systems. They found that for $W_{\rm thr} = 0.6$ Å, $N(z) = 0.54 \pm 0.08$, for a sample of absorbers with mean redshift $\langle z_{\rm abs} \rangle = 1.116$. If the evolution is parameterized in the usual way,

$$N(z) \propto (1+z)^{\gamma} , \qquad (5)$$

then they found that $\gamma = 1.45 \pm 0.63$, which is consistent with no evolution in absorber mean free path. For $W_{\rm thr} = 0.3$ Å, the Lanzetta, Turnshek, & Wolfe sample was unfortunately not sensitive enough to be included, so that the redshift interval over which the sample is drawn is limited. However, for this $W_{\rm thr}$, Sargent, Steidel, & Boksenberg constructed a sample of 31 systems and found that $N(z) = 1.13 \pm 0.20$ for $\langle z_{\rm abs} \rangle = 0.732$. In this case, $\gamma = -0.16 \pm 1.20$, again consistent with no evolution, although the error is large.

Following Burbidge et al. (1977) and others, these number densities of absorbers can be related to an average cross section for absorption of a typical galaxy. Here we rederive an expression for the cross section in order to show explicitly its dependence on various parameters and to critically assess its uncertainties. The number density of galaxies is assumed to be described by the Schechter (1976) luminosity function,

$$dn = \phi^* \left(\frac{L}{L^*}\right)^{-\alpha} \exp\left(\frac{-L}{L^*}\right) d\left(\frac{L}{L^*}\right) , \qquad (6)$$

where L is the galaxy luminosity, and L^*, ϕ^*, and α are parameters which characterize the luminosity function. The radius-luminosity relation of Holmberg (1976) is adopted, so that the cross-section of a galaxy of luminosity L is given by σ, where

$$\sigma = \pi R^{*2} \left(\frac{L}{L^*}\right)^{10/12} , \qquad (7)$$

i.e., R^* is the radius of the effective cross section for absorption of an L^* galaxy. Then the mean-free-path for absorption, l_0, can be written

$$l_0 = \left(\int_0^{+\infty} f\sigma\, dn\right)^{-1}$$
$$= [f\sigma^* \phi^* \Gamma(\alpha + \tfrac{22}{12})]^{-1} , \qquad (8)$$

where $\Gamma(x)$ is the γ-function and $\sigma^* = \pi R^{*2}$. The factor f is the probability that a galaxy will absorb at a particular impact parameter, R. If all galaxies absorb with spherical halos and the filling factor of the absorbing clouds is unity, then $f = 1$. Now, assuming that the γ in equation (5) is consistent with no evolution, in the standard Friedman cosmologies,

$$N(z) = N_0(1+z)(1+2q_0 z)^{-1/2} , \qquad (9)$$

where N_0 is the local density of absorbers at $z = 0$. Combinining equations (6)–(9),

$$R^*(z) = \left[\frac{1}{\pi}\frac{H_0}{c}\frac{1}{\phi^*}\frac{1}{\Gamma(\alpha + 22/12)}\right]^{1/2} \left(\frac{1}{f}\right)^{1/2} \times \left(\frac{N(z)}{1+z}\right)^{1/2} (1+2q_0 z)^{1/4} . \qquad (10)$$

If we adopt the galaxy luminosity function parameters of Efstathiou, Ellis, & Peterson (1989), $\alpha = -1.07$, $\phi^* = 1.56 \pm 0.34 \times 10^{-2}$ Mpc^3 for $H_0 = 100$ km s^{-1} Mpc^{-1}, then

$$R^*(z) = 75.0 h^{-1} \left(\frac{1}{f}\right)^{1/2} \left[\frac{N(z)}{1+z}\right]^{1/2} (1+2q_0 z)^{1/4}\ {\rm kpc} . \qquad (11)$$

If one adopts the luminosity function of de Lapparent, Geller, & Huchra (1988) then the numerical coefficient becomes 65.2 kpc; for the Schechter (1976) parameters, the coefficient is 59 kpc.

For $W_{\rm thr} = 0.6$ Å and $\langle z_{\rm abs} \rangle = 1.116$, and adopting the

TABLE 5

GALAXIES WITH Mg II DETECTIONS OR LIMITS

QSO (1)	ΔΘ (2)	r (3)	z_{gal} (4)	R_{obs} (kpc) $q_0 = 0$ (5)	R_{obs} (kpc) $q_0 = 0.5$ (6)	$M(r)$ $q_0 = 0$ (7)	$M(r)$ $q_0 = 0.5$ (8)	W_λ(2796, 2803) Å (9)	References (Abs; Gal) (10)
0109+200........	7″.1	21.7	0.535	29.7	25.9	−19.9	−19.6	2.26, 1.71	1; 2
	11.9	23.0	...	...	...	...	...	...	...
0119−046........	3.1	23.3	0.6577	14.3	12.1	−18.9	−18.5	0.27, 0.19	3; 4
	44.7	22.5	0.6578	206.7	175.0	−19.7	−19.3	<0.27	...
0151+045........	6.4	19.1	0.160	11.9	11.5	−19.5	−19.4	1.55, 1.55	5; 5
	10.9	20.2	0.160	20.3	19.5	−18.4	−18.3	...	...
0229+131........	17.1	20.1	0.372	58.3	53.0	−20.6	−20.4	0.34, 0.21	6; 2
	6.8	20.5	0.417	24.8	22.3	−20.5	−20.2	0.67, 0.75	...
0235+164........	1.9	21.2	0.524	7.9	6.9	−20.3	−20.1	2.42, 2.34	7, 8; 4, 7, 8, 9, 10
	3.9	22.3	0.5243	16.1	14.1	−19.3	−19.0	<2.42	...
	6.8	22.4	0.525	28.2	24.7	−19.2	−18.9	<2.42	...
	26.4	22.1	0.5252	109.4	95.7	−19.5	−19.2	<2.42	...
0453−423........	6.0	22.6	(0.746)[a]	(29.3)	(24.3)	(−19.9)	(−19.5)	...	11; 2, 12
	19.3	22.7	...	...	...	...	...	...	...
	30.3	21.4	...	...	...	...	...	...	...
	30.4	22.8	0.746	148.4	122.3	−19.7	−19.3	1.4, 1.1	...
0952+179........	26.3	19.8	0.332	83.4	76.6	−20.6	−20.4	<0.56	13; 2
	24.8	22.2	...	...	...	...	...	...	...
	30.3	21.7	0.381	104.7	95.0	−19.0	−18.8	<0.54	...
	...	...	(0.2377)[b]	...	...	...	...	0.66, 0.44	...
1038+064........	9.4	22.1	0.441	35.4	31.7	−19.0	−18.8	0.30, 0.25	14; 2
	20.6	19.6	0.306	61.9	57.3	−20.6	−20.4	<0.30	...
	11.7	22.5	...	...	...	...	...	...	...
1101−264........	12.2	20.4	0.359	40.7	37.1	−20.2	−20.0	0.49, 0.40	15; 2
	...	...	(0.356)[b]	...	...	...	...	0.22, 0.19	...
1127−145........	5.3	22.4	(0.313)[a]	(16.2)	(14.9)	(−17.8)	(−17.7)	...	2; 2
	9.6	20.1	0.313	29.3	27.0	−20.1	−20.0	2.21, 1.90	...
	16.1	21.5	...	...	...	...	...	...	...
	17.7	20.4	0.312	53.9	49.8	−19.8	−19.7	...	...
1209+107........	7.1	21.9	0.3922	25.0	22.6	−18.9	−18.7	1.00, 0.54	16; 17
1229−021........	...	...	(0.395)[b]	...	...	...	...	2.22, 1.94	18; 2
1332+552........	5.0	20.7	0.373	17.1	15.5	−20.0	−19.8	2.9, 2.9	19; 19
1511+103........	6.9	22.0	0.437	25.9	23.1	−19.1	−18.8	0.45, 0.35	13; 2
1912−549........	13.4	22.6	(0.403)[a]	(47.9)	(43.2)	(−18.3)	(−18.0)	...	20; 20
	16.8	22.1	...	...	...	...	...	...	...
	15.7	21.5	...	...	...	...	...	...	...
	19.1	21.2	0.403	68.3	61.6	−19.7	−19.4	1.8, 1.4	...
	8.3	21.4	0.402	29.6	26.9	−19.5	−19.2	...	...
2128−123........	8.6	21.0	0.430	31.9	28.6	−20.0	−19.8	0.40, 0.37	21; 2, 22
2145+067........	5.5	22.2	0.790	27.5	22.6	−20.5	−20.0	0.61, 0.46	6; 2

[a] Values of R_{obs} (kpc) and $M(r)$ are given in parentheses, computed by assuming the galaxy is associated with the Mg II absorber; no redshift for the galaxy is available, however. See text.

[b] Redshift of Mg II absorber, since no galaxy identified.

REFERENCES.—(1) Wills et al. 1980; (2) Bergeron & Boisse 1991; (3) Sargent, Young, & Boksenberg 1982; (4) Yanny 1990; (5) Bergeron et al. 1988; (6) Sargent, Steidel, & Boksenberg 1988; (7) Smith, Burbidge, & Junkkarinen 1977; (8) Cohen et al. 1987; (9) Stickel, Fried, & Kuhr 1988; (10) Yanny, York, & Williams 1990; (11) Sargent et al. 1979; (12) Yanny et al. 1987; (13) Foltz et al. 1986; (14) Weymann et al. 1979; (15) Carswell et al. 1984; (16) Young, Sargent, & Boksenberg 1982; (17) Cristiani 1987; (18) Briggs et al. 1985; (19) Miller, Goodrich, & Stephens 1987; (20) Bergeron & Boisse 1986; (21) Petitjean & Bergeron 1990; (22) Bergeron 1986.

Efstathiou et al. parameters, we then have $R^* = 37.8$ kpc for $q_0 = 0$, and $R^* = 45.6$ kpc for $q_0 = \frac{1}{2}$. For $W_{thr} = 0.3$ Å and $\langle z_{abs} \rangle = 0.732$, $R^* = 60.6$ kpc for $q_0 = 0$, and $R^* = 69.5$ kpc for $q_0 = \frac{1}{2}$. These values for R^* are 10%–30% larger than the numbers quoted by Sargent, Steidel, & Boksenberg (1988) or Lanzetta, Turnshek, & Wolfe (1988) since we have adopted more modern values for the galaxy luminosity function parameters and slightly different values for the density of absorbers than these authors.

This calculated value for the absorption cross-section can be compared with the observed distribution of distances between the absorber galaxy and the quasar line of sight. To represent the results of Tables 4 and 5, in Figure 10 we plot the rest equivalent width of Mg II λ2796, $W(\lambda 2796)$, versus R/R_{gal},

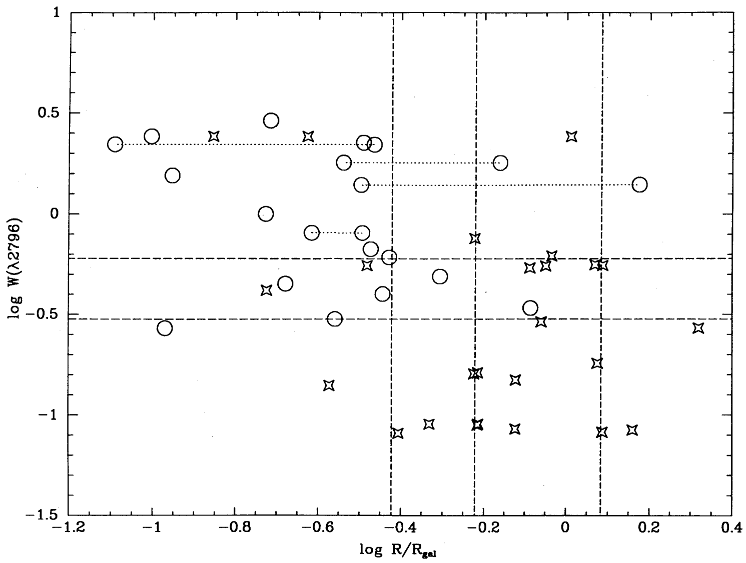

FIG. 10.—Rest equivalent width of Mg II $\lambda 2796$, $W(\lambda 2796)$, vs. normalized impact parameter, R/R_{gal} (for $H_0 = 100$ km s^{-1} Mpc^{-1} and $q_0 = 0$). Open circles indicate galaxies for which absorption has been detected; stars indicate galaxies for which no absorption is seen. The vertical dashed lines correspond to $R^* = 38$, 60, and 120 kpc, respectively; the horizontal dashed lines correspond to $W(\lambda 2796) = 0.3$ and 0.6 Å, respectively. See text.

where

$$\frac{R}{R_{gal}} = \left(\frac{R_{obs}}{100 \text{ kpc}}\right)\left(\frac{L}{L^*}\right)^{0.4} \tag{12}$$

and R_{obs} is the observed projected distance derived from equation (3), for $q_0 = 0$, i.e., column (5) in Tables 4 and 5. Thus we have scaled each R_{obs} by the galaxy luminosity, in units where an L^* galaxy has an effective radius for absorption of 100 kpc. We chose to normalize to 100 kpc instead of the R^* discussed above, since the value of R^* is somewhat uncertain, and depends on equivalent width limit. Vertical dashed lines in Figure 10 indicate the R/R_{gal} corresponding to $R^* = 38$, 60, and 120 kpc, respectively. We have not plotted the three absorption systems for which no galaxies are known. For L^*, we have adopted Efstathiou et al.'s $M^*_{B(T)} = -19.68$ since our r-magnitudes at these redshifts more or less correspond to B-magnitudes at $z = 0$. (If we had adopted de Lapparent et al.'s $M^*_B = -19.00$ instead, there would be very little change in our result.) In Figure 10, galaxies with detected absorption are indicated by open circles, and upper limits are indicated by stars. In cases where there were two possible galaxy identifications for an absorber, both galaxies are plotted, connected by a dotted line. We have not plotted the limits for galaxies of known redshifts with distances of greater than 30″ (corresponding to $R = 130$ kpc at $z = 0.2$, or 256 kpc at $z = 0.6$); none of these were found to cause absorption.

From Figure 10, we see that for the galaxies with detectable absorption (which are mostly drawn from the literature), most of the points lie within the $R^* = 60$ kpc line (corresponding to $W_{thr} = 0.3$ Å), and all but one lie within the $R^* = 38$ kpc line (corresponding to $W_{thr} = 0.6$ Å). A similar result led Bergeron & Boisse (1991) to conclude that $f \approx 1$. That is, if f were very different from one, then one would expect that the average R_{obs} would be larger than R^*, which was derived assuming $f \equiv 1$.

However, our results, which are mostly upper limits to detectable absorption, do not indicate that $f \approx 1$. We find that within $R^* = 60$ kpc, we detected only two galaxies out of eight with limits of 0.3 Å or better; within 38 kpc, we detect only two out of seven with limits better than 0.6 Å. If we include objects in clusters associated with the quasars, half of which are likely to be in front of the quasar, f drops to 0.2. However, it may not be appropriate to add these objects to our sample because of possible systematic differences in the gas content of these cluster galaxies in comparison with field galaxies. Thus, from our data alone, for $z_{gal} \ll z_{em}$, we would conclude that $f \approx 25\%$.

The value of $f = 25\%$ is in fact plausible. If every absorbing galaxy has gas distributed in a disklike geometry with random orientations, then $f \approx \frac{1}{2}$. (Bergeron & Boisse (1991) were able to rule out linear structures for the distribution of Mg II absorption, but found that their data were compatible with both spherical and disk-shapes halos.) To be in harmony with our results, then, the fraction of all galaxies with gas would also have to be $\sim\frac{1}{2}$, which may be a reasonable guess at the spiral fraction of all galaxies. It is possible that Bergeron & Boisse (1991), by choosing fields with known absorbers, preferentially found emission-line, gas-rich spiral galaxies. Our sample of galaxy redshifts, on the other hand, contains mostly absorption-line galaxies selected in the red and may be more representative of the general galaxy population.

If $f \approx 25\%$, then from equation (10), we must also conclude that R^* is actually a factor of 2 *bigger* than previously stated, i.e., $R^* = 120$ kpc for $W_{thr} = 0.3$ Å and $R^* = 76$ kpc for $W_{thr} = 0.6$ Å. This is significantly larger than the H I extent of local galaxies which are typically 1–2R_H, where the Holmberg radius of an L_* galaxy is $R_H = 11\ h^{-1}_{100}$ kpc. It is also significantly larger than the distance of most identified absorbers to the quasar line of sight, although it should be noted that the identified absorber is always chosen to be the closest galaxy observed to have the proper redshift.

There are two ways to solve this discrepancy arising from a lower value for f. First, we explore the possibility that the absorption cross sections are as large as is implied by the calculation of R^*. In this case, some of the galaxies identified by Bergeron & Boisse (1991) are not the true absorber, but rather the actual absorbing galaxy lies at an even larger distance. Since most of the galaxy redshifts in the Bergeron & Boisse (1991) sample were taken one at a time, only the nearest few galaxies to the QSO line of sight were studied; there are almost always more galaxies farther out with no redshifts measured. It will, of course, be difficult to verify this hypothesis without a further large investment of telescope time. Moreover, if more galaxies at the proper redshift are found, it is difficult or impossible to determine which are definitely responsible for the absorption. In any event, we find this scenario unattractive in that it requires cold absorbing gas at such great distances from the visible galaxy. Further, we note that it is possible that most of the absorbers arise in galaxies or H II regions superposed on the QSOs, and the galaxies identified with the absorber in Tables 4 and 5 are actually nearby galaxies (York 1992). In this case, the quantity R measures the distance to the nearest neighbor, not the impact parameter in the sense discussed here.

A second possibility is that our assumptions about a nonevolving galaxy population, on which our calculations of R^* are based, are not valid for $0.3 < z < 0.7$. There is increasing evidence in support of this—both imaging and spectroscopic surveys of faint galaxies imply evolution of some type in galaxy properties since $z \approx 1$. Imaging surveys (Tyson 1988; Colless et al. 1990) find an excess of at least a factor of 2 in the number of blue-selected galaxies at these magnitudes.

Bergeron & Boisse (1991) suggest that this phenomenon is linked to Mg II absorption and show that the discrepancy between the calculated effective radius, R^*, (derived assuming $f = 1$), and the mean observed impact parameters between the QSOs and galaxies, $\langle R_{\rm obs} \rangle$, can be reconciled by assuming luminosity evolution in the galaxy absorbers and hence a corresponding increase in size of the absorbing region (through eq. [7]). For our smaller value for the filling factor, however, the amount of luminosity evolution necessary for this scenario is much larger than is observed in the field galaxies.

It is also not clear that simple luminosity evolution in the galaxies, e.g., a monotonic brightening with redshift of the galaxy luminosity function, is an accurate description of their behavior. Results from the spectroscopic survey of Colless et al. (1990) are not consistent with these models, and instead they suggest that the excess galaxies are a population of moderate luminosity, actively star-forming objects at $z \sim 0.3$, which subsequently fade (see also Broadhurst, Ellis, & Shanks 1988). Most of these galaxies show strong [O II] λ3727 emission lines, which may be associated with Mg II absorption (see § 4.2 below), and it is tempting to identify these galaxies with a population of Mg II absorbers existing at $z > \sim 0.3$ but absent at current epochs. We defer a quantitative calculation of R^* in the context of this scenario until more is known about the luminosity function of these objects, and about the properties of Mg II absorbers. Note, however, that the increase by a factor of 2 in the space density of absorbers, as is suggested by the Colless et al. results, will lower the calculated value of R^* by $\sqrt{2}$, partially offsetting our lower values for the filling factor (eq. [10]). More detailed analysis must await better understanding of the evolution of galaxies and their gas content. It would of course be of great interest to correlate any evolution in the Mg II absorbers with the evolution of these galaxies. Unfortunately, the small numbers of Mg II absorbers known result in large uncertainties in the evolutionary parameter γ (of eq. [5]) so that almost any evolutionary scenario is allowed by the absorption-line data.

5.2. *Galaxy Properties*

One of the goals of this study was to obtain a large sample to allow examination of the properties of galaxies which cause Mg II absorption. In this section, we look at three properties: the absolute magnitudes of the absorber galaxies, their emission-line luminosities, and the radius-luminosity relation adopted in the previous section (eq. [7]).

First, we compare the distribution of absolute magnitudes of the galaxies which show detectable Mg II absorption with those which do not. Figures 11*a*, 11*b*, and 11*c* show the distribution of redshift, apparent magnitude and absolute magnitude, respectively, for the galaxies in Tables 4 and 5. The distributions of the absorbers versus the nonabsorbers are indistinguishable in all three parameters. The Kolmogorov-Smirnov probabilities that the distributions in z, m, and $M(r)$ are the same for the absorber versus nonabsorber samples are 0.98, 0.76, and 0.16, respectively.

This contrasts with the results of Bergeron & Boisse (1991) who argued that the galaxies which show absorption are preferentially bright compared to galaxies in the field, with those galaxies having $L < 0.3\ L^*$ lacking halos of cool gas. Their absorber sample was essentially the same as ours. However, their "test" sample was a sample of field galaxies, not necessarily galaxies whose Mg II absorption properties were known. In fact, their "test" sample contains a significant fraction of galaxies with redshifts too low to shift Mg II λλ2796, 2803 up into the spectral range of available data (see their Fig. 4). Although the apparent magnitudes of the "test" sample were brighter than the absorber sample on average, this did not compensate for the different redshift distribution and so the absorber sample turned out to be intrinsically brighter on average than their "test" sample. Thus, this comparison did not take into account the strong selection effect in redshift for the absorber sample; specifically, most absorbers have $z \geq 0.3$ in order for Mg II to have been detected from ground-based data, whereas the "test" sample had no such constraint. Since the absorber galaxies are on average farther away, they turned out to be intrinsically brighter.

Their absorber sample is also prone to selection effects in that not all of the galaxies are observed to well-defined limiting magnitudes, either by imaging or spectroscopically. As noted above, incomplete studies of these fields will produce only the brightest and nearest probable galaxy. The tendency for galaxies to cluster suggests that such results will be biased toward higher luminosity galaxies. While the observations of our fields are not spectroscopically complete, the well-defined detection limits for the imaging surveys and the fact that the objects for spectroscopy were chosen based on different criteria (a search for galaxies in clusters at the quasar redshift) suggest that we may be sampling galaxies which are more representative of the general galaxy population, or at least are quite different from the galaxies sampled by searches for Mg II absorbers. While the current identifications may be correct, a convincing statistical study of their properties requires a complete spectroscopic survey of these fields to very faint magnitudes.

Second, we examine the distribution of galaxy emission-line luminosities. Almost all of the Mg II absorbers identified in the literature show strong emission lines in their spectra, which seems to be a striking characteristic of these objects (Bergeron & Boisse 1991 and references therein). Our two new Mg II absorption systems do not significantly challenge this tendency. The galaxy at $z = 0.36$ in the PKS 0812+202 field which was studied spectroscopically does show emission lines, but may not actually be the absorbing galaxy. The identified absorber in the PKS 1354+195 field shows no strong [O II] λ3727 emission, but unfortunately detection limits are not

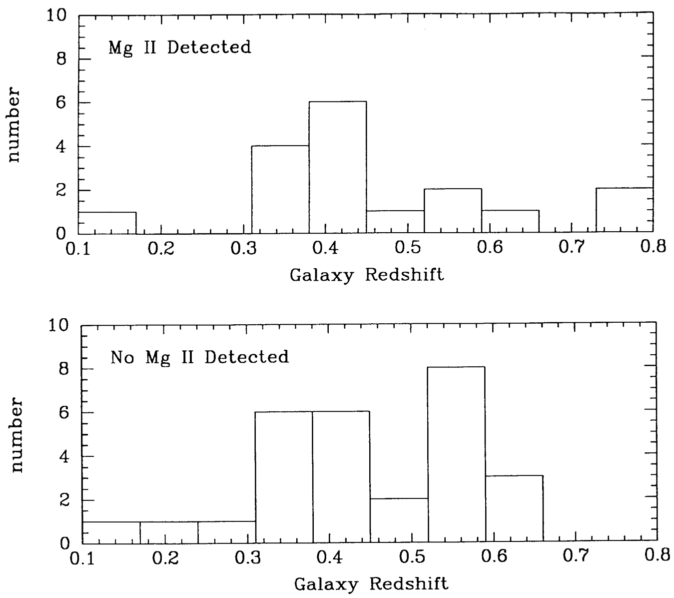

FIG. 11*a*

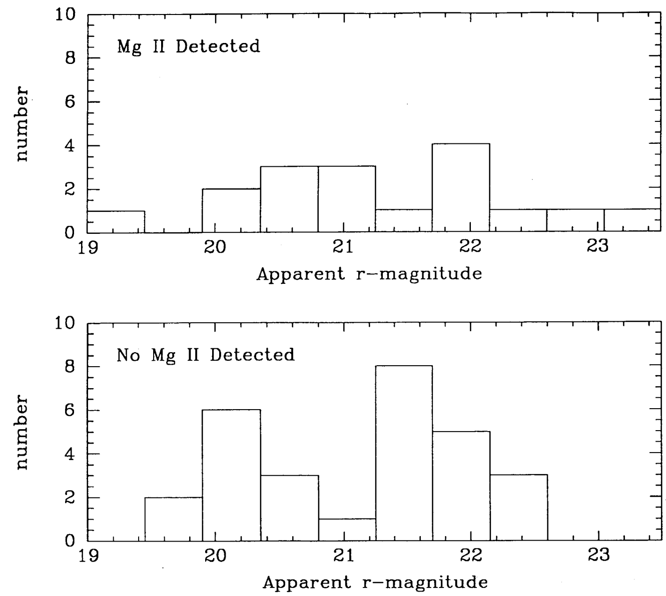

FIG. 11*b*

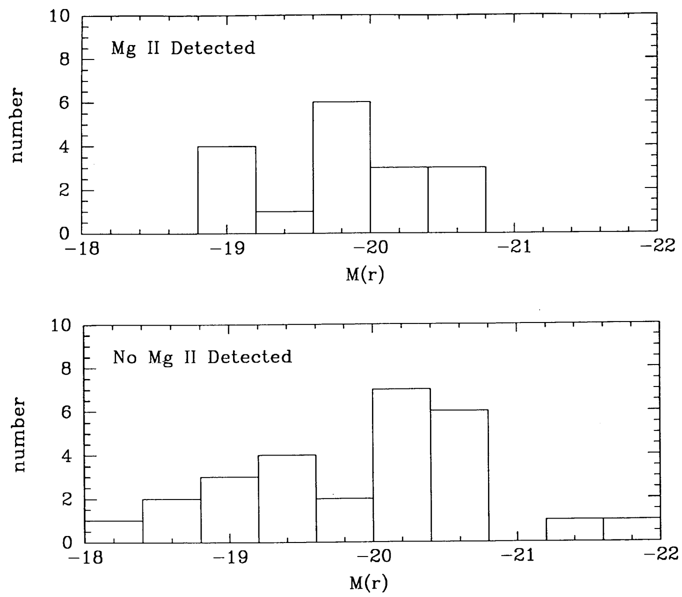

FIG. 11*c*

FIG. 11.—(*a*) Distribution of redshifts for galaxies with detected Mg II absorption (*upper panel*) and galaxies with no detected Mg II absorption (*lower panel*). (*b*) Distribution of apparent *r*-magnitudes for galaxies with detected Mg II absorption (*upper panel*) and galaxies with no detected Mg II absorption (*lower panel*). (*c*) Distribution of absolute *r*-magnitudes, $M(r)$, (for $H_0 = 100$ km s^{-1} Mpc^{-1} and $q_0 = 0$), for galaxies with detected Mg II absorption (*upper panel*) and galaxies with no detected Mg II absorption (*lower panel*).

available due to the difficulties in accurate flux calibration in multislit spectroscopy. The galaxies with $z_{\rm gal} \ll z_{\rm QSO}$ which do *not* cause Mg II absorption have no detectable emission lines, and have colors and spectra similar to normal elliptical galaxies. Two galaxies in the PKS 0405−123 field and one in the PKS 1305+069 show [O II] λ3727 and [O III] λλ4959, 5007 emission, but these galaxies are all members of clusters at the quasar redshift, and therefore may actually be located behind the quasar. As members of a galaxy cluster they may not be representative of field galaxies in any case. Overall, there is no strong evidence that contradicts a scenario where all Mg II absorbers are disk systems showing strong emission lines.

Finally, we examine the validity of the $R \propto L^{0.4}$ luminosity-radius scaling relation of equation (7). Following Bergeron & Boisse (1991), in Figure 12 we plot log $R/R_{\rm gal}$ versus $M(r)$ for the galaxies of Tables 4 and 5 (see their Fig. 9). The symbols are the same as in Figure 10. For the galaxies with detected absorption, the observed impact parameter is a lower limit to the extent of the absorbing gas in the galaxy. Thus all the open circles should lie below the solid line indicated which shows the expected upper envelope for $R^* = 60$ kpc if R and L are related as in equation (7). Clearly, the data are consistent with this relation.

6. CONCLUSIONS

We have obtained spectra of nine QSOs in order to search for Mg II absorption from known galaxies along the line-of-sight. Our success rate of only ∼25% contrasts with previous suggestions that the filling factor, f, for absorption gas in galaxies is effectively ∼1. If instead, $f \approx \frac{1}{4}$, then the galaxies which do absorb must have an effective cross section for absorption at least twice as large in radius than previously thought. If this is the case, then the apparent discrepancy between this calculated effective radius, and the observed mean radius between the QSOs and identified absorber galaxies may be too large to explain in terms of the amount of galaxy evolution suggested by recent deep imaging and galaxy spectroscopic surveys. We further find that there is no detectable difference in the distribution of absolute magnitudes between galaxies which show Mg II absorption and ones which do not, when an appropriately chosen comparison sample is constructed.

Clearly, the number of objects is still frustratingly small. With the recent development of efficient multi-aperture spectrographs on 4 m class telescopes, we hope it will be practical to enlarge the sample size in the near future.

We thank the staff of the MMTO for their assistance at the telescope. H. K. C. Yee graciously supplied images in advance of publication. This work would not have been possible

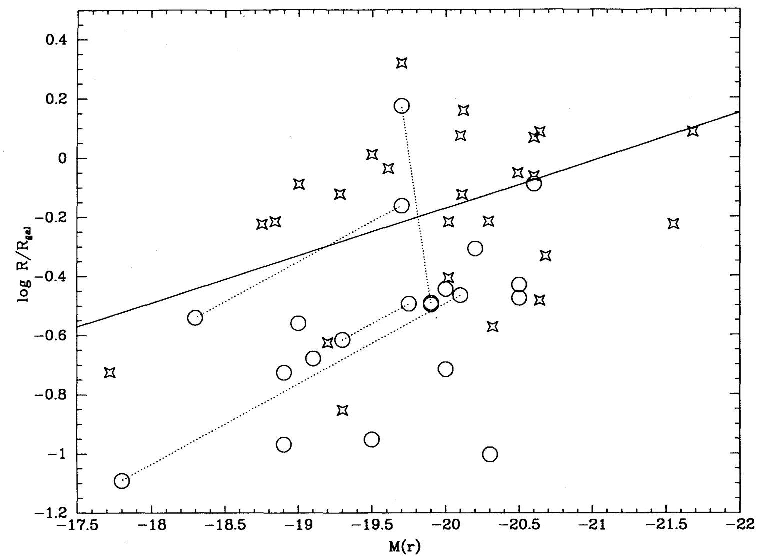

FIG. 12.—Normalized impact parameter, R/R_{gal}, vs. galaxy absolute magnitude, $M(r)$ (for $H_0 = 100$ km s^{-1} Mpc^{-1} and $q_0 = 0$). Solid line indicates the scaling relation of eq. (7).

without the extensive previous work in this area by Yee & R. F. Green. We thank the referee, Don York, for his careful reading of the text. J. B. completed the manuscript while on a long-term visit at CTIO; the hospitality of the Director and staff there is gratefully appreciated. This research was supported by AST-9058510 from the National Science Foundation.

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