Mg $\text{II}$ ABSORPTION CHARACTERISTICS OF A VOLUME-LIMITED SAMPLE OF GALAXIES AT $z \sim 0.1$* 

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ABSTRACT

We present an initial survey of Mg $\text{II}$ absorption characteristics in the halos of a carefully constructed, volume-limited subsample of galaxies embedded in the spectroscopic part of the Sloan Digital Sky Survey (SDSS). We observed quasars near sightlines to 20 low-redshift ($z \sim 0.1$), luminous ($M_r + 5 \log h < -20.5$) galaxies in SDSS DR4 and DR6 with the LIRIS-B spectrograph on the Keck I telescope. The primary systematic criteria for the targeted galaxies are a redshift $z > 0.1$ and the presence of an appropriate bright background quasar within a projected $75 \, h^{-1}$ kpc of its center, although we preferentially sample galaxies with lower impact parameters and slightly more star formation within this range. Of the observed systems, six exhibit strong ($W_{\text{eq}}(2796) > 0.3$ Å) Mg $\text{II}$ absorption at the galaxy’s redshift, six systems have upper limits which preclude strong Mg $\text{II}$ absorption, while the remaining observations rule out very strong ($W_{\text{eq}}(2796) > 1–2$ Å) absorption. The absorbers fall at higher impact parameters than many non-absorber sightlines, indicating a covering fraction $f_c \leq 0.4$ for $> 0.3$ Å absorbers at $z \sim 0.1$, even at impact parameters $< 35 \, h^{-1}$ kpc ($f_c \sim 0.25$). The data are consistent with a possible dependence of covering fraction and/or absorption halo size on the environment or star-forming properties of the central galaxy.

Key words: galaxies: evolution – galaxies: ISM – quasars: absorption lines

Online-only material: color figures

1. INTRODUCTION

Because gas consumption timescales in galaxies are short, massive galaxies must have large reservoirs of gas in order to fuel star formation throughout cosmic time. These reservoirs are likely quite diffuse and extended, and are therefore difficult to probe directly. Absorption lines in background quasars near galaxy sightlines allow a unique probe of this gas (e.g., Bergeron 
& Boissé 1991; Steidel & Sargent 1992; Steidel et al. 1994; Steidel 1995; Chen et al. 2001, and many more). Absorption-line studies in transitions like Mg $\text{II}$ have revealed a wealth of information about the absorbing gas and its relationship to galaxies (e.g., Bergeron 
& Boissé 1991; Steidel et al. 1994; Churchill et al. 1996; Nestor et al. 2005; Zibetti et al. 2005; Nestor et al. 2006, 2007; Zibetti et al. 2007). These results suggest that many—if not all—luminous intermediate-redshift galaxies are surrounded by Mg $\text{II}$-enriched gas that extends out to at least $\sim 40 \, h^{-1}$ kpc for luminous systems ($\sim 42 \, h^{-1}$ kpc if $\Omega_m = 0.7$; Steidel 1995) and likely much further in some cases (Churchill et al. 2005; Kacprzak et al. 2008). Estimates of the covering fractions of these gaseous halos range from $0.17 < f_c < 1$ (Steidel 1995; Bechtold 
& Ellingson 1992; Bowen et al. 1995; Kacprzak et al. 2008) in “strong” ($W_{\text{eq}}(2796) > 0.3$ Å) absorption systems. This threshold for strong absorbers is common and physically based; strong systems differ in character from weaker systems, which have higher covering fractions and different kinematics (Churchill et al. 1999, 2005; Nestor et al. 2005, 2006).

If gaseous halos around galaxies are reservoirs for star formation (Maller 
& Bullock 2004), the observed properties of galaxies likely depend on whether their gas halos are intact. Processes that may inhibit star formation in satellite galaxies include “strangulation,” where the outer hot gas halo of a satellite galaxy is removed by the surrounding environment (e.g., Larson et al. 1980; Kawata 
& Mulchaey 2008). This removal prevents the further infall of cool gas. A more violent and immediate process is ram pressure stripping, which acts to remove cold, star-forming gas from galaxies, possibly quenching star formation soon after infall (e.g., Gunn 
& Gott 1972; Moore et al. 1996). These processes likely play a role in the observed environmental dependence of galaxy properties like color and morphology (e.g., Gunn 
& Gott 1972; Dressler 1980; Postman 
& Geller 1984; Blanton et al. 2005a). If stripping of the outer gas reservoir does regulate star formation, we might expect to find correlations between the properties of the galaxies and those of their halos. Many Mg $\text{II}$ studies find dependence on galaxy luminosity or halo mass (e.g., Steidel et al. 1994; Bouché et al. 2006). Recently, Kacprzak et al. (2007) have shown that stronger absorbers also preferentially reside in asymmetric galaxies. Many early studies did not reveal trends with galaxy color or star-forming properties (Steidel et al. 1994; Guillemin 
& Bergeron 1997), although at least one study suggested that trends are possible (Bowen et al. 1995).

More recently, Zibetti et al. (2007) study a sample of nearly 3000 Mg $\text{II}$ systems with $W_{\text{eq}}(2796) > 0.8$ Å at $0.37 < z < 1$ by using image-stacking techniques to probe the amount, spatial distribution, and colors of the integrated galaxian light from the multiple, stacked absorbers. Their results demonstrate that Mg $\text{II}$ absorption is color dependent: the integrated galaxian light is bluer for stronger absorbers and for galaxies that are closer to the quasar probes. However, these results are aggregate and are luminosity-weighted; it is difficult to disentangle the possible effects that result if, say, Mg $\text{II}$ absorption is more common in lower-luminosity blue galaxies. Thus, while their creative statistical method has proven extremely powerful, it cannot reveal a one-to-one relationship that may exist between galaxy and Mg $\text{II}$ properties.

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Depending on their absorber abundances and covering fractions decline somewhat. To date, detections indicate that the redshifts are difficult to observe from the ground and, as a result, have not been studied as extensively. To date, detections indicate that the redshifts are difficult to observe from the ground and, as a result, have not been studied as extensively. 

Systems in lower-redshift galaxies (\(z \lesssim 0.2\)) are largely accessible from the ground, suggesting that volume-limited samples from SDSS with limits in the range of \(z \sim 21\) to \(z \sim 20\) are possible to probe. Here, we focus on the \(M_r + 5 \log h \lesssim -20.5\) sample. (A color version of this figure is available in the online journal.)

Most of our knowledge of Mg\(\text{II}\) absorbers comes from redshifts \(z \gtrsim 0.4\), where the Mg\(\text{II}\) doublet (\(\lambda 2796.35, 2803.53\) Å) is redshifted into the optical. Systems in lower-redshift galaxies are difficult to observe from the ground and, as a result, have not been studied as extensively. To date, detections indicate that the absorber abundances and covering fractions decline somewhat. Depending on their \(W_{eq}(2796)\), the decline is not necessarily dramatic as redshifts approach zero (Bowen et al. 1995; Nestor et al. 2005, 2006).

The vast majority of existing Mg\(\text{II}\) studies of individual absorber-galaxy associations begin with quasar spectra and then use photometric or spectroscopic redshifts to identify the nearby galaxies responsible for the Mg\(\text{II}\) absorption (e.g., Bergeron & Boissé 1991; Steidel et al. 1994; Churchill et al. 1999, and many others). Studies that begin with quasar spectra frequently focus on galaxies already known to have Mg\(\text{II}\) absorption. Some also tabulate galaxies that clearly lack absorption, but Churchill et al. (2005) note that focused “control” studies are biased toward quasars near non-absorbers, or absorbers with patchier Mg\(\text{II}\)-absorbing gas. As Tripp & Bowen (2005) point out, “reversing” the problem by identifying a controlled galaxy sample first, and then finding a subset with background quasars, alleviates significant selection effects. Bowen et al. (1995) present a Hubble Space Telescope study of very nearby galaxies and Tripp & Bowen (2005) present preliminary results from a “reverse” study at \(z \sim 0.2\) using galaxies selected photometrically from the Sloan Digital Sky Survey (SDSS).

Here, we present a “reverse” study from a well-defined, volume-limited spectroscopic sample of \(\sim L^*\) galaxies from the SDSS. Their basic properties, such as environment, star-formation, and metallicity, can be placed into the very well-defined context of the SDSS. In Section 2 we describe our sample selection and observational approach, and present the data. Section 3 contains an analysis of our results, and we conclude in Section 4.

2. SAMPLE SELECTION AND DATA REDUCTION

Our observations were designed to probe for the presence or absence of Mg\(\text{II}\) absorption from the ground in a well-understood, volume-limited spectroscopic survey of \(\sim L^*\) galaxies at \(z \sim 0.11\), selected with the fewest biases possible. The choice of limiting absolute magnitude for the sample is informed by (1) the need to observe the strong (\(W_{eq}(2796) > 0.3\) Å) Mg\(\text{II}\) lines as far above the atmospheric cutoff as possible, and (2) the desire to include lower luminosity galaxies, thus sampling both the red sequence and the blue cloud.

We illustrate the relationships between Mg\(\text{II}\) wavelength, the upper redshift limit, and the magnitude limit of a volume-limited sample from SDSS in Figure 1. At \(z \sim 0.1\), substantial contributions to the blue cloud extend to roughly absolute magnitudes of \(M_r + 5 \log h \gtrsim -21\) (e.g., Blanton et al. 2003). A volume-limited sample fainter than \(M_r + 5 \log h \sim -20\) has an upper redshift limit at which Mg\(\text{II}\) is well below the atmospheric cutoff. Thus, after exploring the available quasars in the SDSS DR5 quasar catalog (Schneider et al. 2007), we focus on a limiting magnitude of \(M_r + 5 \log h \lesssim -20.5\), yielding a volume-limited sample with enough quasar-galaxy pairs at \(z \gtrsim 0.11\). This study is possible from the ground only with an optimally blue-sensitive spectrograph like the Low-Resolution Imaging Spectrometer-Blue channel (LRIS-B Oke et al. 1995; McCarthy et al. 1998). Few previous studies of this nature have been conducted because the low spectroscopic redshifts preclude ground-based observation of Mg\(\text{II}\).

All but one of our targets originate from a volume-limited subsample of the SDSS DR6 NYU Value-Added Galaxy Catalog.

Figure 1. Constructing a volume-limited sample of galaxies to probe for halo Mg\(\text{II}\) absorption. We illustrate the challenge inherent in the use of SDSS to construct a sample for ground-based observations of halo Mg\(\text{II}\) absorption. Bottom: we show the color-magnitude distribution of a volume-limited sample to \(z \lesssim 18.5\), showing both red and blue galaxies; observing as faint as possible is desirable to sample the blue cloud. As a function of absolute r-band magnitude limit chosen from the SDSS, we show the upper redshift limit (middle) and the expected Mg\(\text{II}\) absorption wavelength (top). As we demonstrate in this study, wavelengths above \(\sim 3050\) are largely accessible from the ground, suggesting that volume-limited samples from SDSS with limits in the range of \(z \sim 21\) to \(z \sim 20\) are possible to probe. Here, we focus on the \(M_r + 5 \log h \lesssim -20.5\) sample. (A color version of this figure is available in the online journal.)

Figure 2. Distribution of impact parameters probed in the study (dotted line) compared to a uniform distribution from 5–75 h\(^{-1}\) kpc. The sample is deficient in galaxies with impact parameters above \(\sim 50 h^{-1}\) kpc (\(P_{K,S} = 0.01\)).
Table 1
Basic Properties of Targeted SDSS Galaxies

| QSO Name | Galaxy Position (2000) | Galaxy Position | D (kpc h\(^{-1}\)) | QSO Properties | Galaxy Properties | t\(_{\text{exp}}\) (s) | Sample |
|----------|------------------------|-----------------|---------------------|----------------|-------------------|-----------------|--------|
| SDSS J030313.02−001457.4 | 03°03'13.27" 00'00"14'20.5" | 0.1049 | 50 | 18.40 | −21.38 | 16.38 | 3600 | DR4 only |
| SDSS J080409.23+385348.8 | 08 04 11.30 38 53 17.8 | 0.0979 | 48 | 17.84 | −21.21 | 16.36 | 1800 |
| SDSS J080814.69+475244.6 | 08 08 13.79 47 51 53.8 | 0.1094 | 71 | 17.89 | −20.55 | 17.31 | 1800 |
| SDSS J081420.19+383808.3 | 08 14 21.97 38 33 49.2 | 0.0978 | 35 | 18.06 | −20.89 | 16.36 | 3600 |
| SDSS J081940.82+434649.6 | 08 19 38.29 43 46 37.0 | 0.1116 | 49 | 19.05 | −20.68 | 17.27 | 2700 |
| SDSS J090558.34+504538.0 | 09 05 55.34 50 45 16.4 | 0.1062 | 48 | 18.04 | −21.06 | 16.70 | 1800 |
| SDSS J091119.16+031152.9 | 09 11 16.70 03 12.10 | 0.0963 | 50 | 17.43 | −20.79 | 16.75 | 3600 |
| SDSS J092300.67+751058.2 | 09 23 01.04 75 10 51.5 | 0.1039 | 8 | 18.51 | −21.33 | 16.43 | 3600 |
| SDSS J102216.13+621836.7 | 10 22 17.72 62 18 07.8 | 0.1162 | 48 | 19.34 | −20.66 | 17.28 | 2400 |
| SDSS J102751.62+104532.6 | 10 27 49.99 10 46 05.2 | 0.1093 | 56 | 18.58 | −21.28 | 16.58 | 3600 |
| SDSS J102847.00+391005.5 | 10 28 46.44 39 10 43.0 | 0.1135 | 62 | 17.09 | −20.87 | 17.06 | 1800 |
| SDSS J140706.74+375315.4 | 14 07 06.24 37 53 25.8 | 0.1018 | 65 | 18.74 | −20.80 | 16.86 | 3300 |
| SDSS J141033.08−001354.8 | 14 10 30.79 00 13 33.0 | 0.1155 | 59 | 18.81 | −21.35 | 16.63 | 3600 |
| SDSS J111342.42−000730.7 | 11 13 42.52 00 07 55.6 | 0.1094 | 34 | 19.10 | −21.70 | 16.08 | 3600 |
| SDSS J112613.52+352002.6 | 11 26 09.80 35 20 08.6 | 0.1117 | 68 | 17.79 | −20.88 | 17.30 | 3600 |
| SDSS J114803.17+565411.4 | 11 48 03.81 56 54 25.6 | 0.1046 | 20 | 17.73 | −21.28 | 16.49 | 3000 |
| SDSS J124914.11+392615.0 | 12 49 17.42 39 26 33.3 | 0.1133 | 60 | 18.69 | −20.63 | 17.27 | 3300 |
| SDSS J140843.77+004730.4 | 14 08 42.00 00 47 30.7 | 0.1146 | 34 | 19.21 | −20.63 | 17.38 | 1800 |
| SDSS J144033.82+044830.9 | 14 40 35.55 04 48 50.4 | 0.1129 | 46^a | 18.52 | −21.03 | 16.90 | 1800 |
| SDSS J151541.23+334739.4 | 15 15 40.76 33 47 52.3 | 0.1156 | 20 | 18.57 | −20.59 | 17.39 | 1800 |

Notes. Properties of observations: (1) SDSS Name of quasar, (2) position of the targeted galaxy, (3) redshift of targeted galaxy, (4) impact parameter, or projected on-sky distance between quasar and center of targeted galaxy, (5) SDSS g-band magnitude of quasar, (6) and (7), absolute and apparent r-band magnitudes of the targeted galaxy, (8) total exposure time on quasar, and (9) comments on sample membership for targeted galaxy.

^a As noted in the text, there is a fainter companion galaxy (m_r = 18.1) with a coincident redshift (z = 0.1128) at 14^h 40^m 34.7^s, a projected distance of only ~18.6 h^{-1} kpc from the quasar.

Table 2
Galaxy and Absorption Properties

| QSO Name | g−r | M_*(log M_*) | EW(2796) (Å) | 3σ Limit. EW(2796) (Å) | Point Style in Figures |
|----------|-----|--------------|--------------|--------------------------|-----------------------|
| SDSS J091119.16+031152.9 | 0.692 | 10.47 | 0.50 | 0.23 | • |
| SDSS J092300.67+075108.2 | 0.823 | 10.71 | 1.93 | 0.55 | • |
| SDSS J102847.00+391005.5 | 0.450 | 10.15 | 0.36 | 0.09 | • |
| SDSS J111342.42−000730.7 | 0.770 | 10.65 | 1.92 | 0.30 | • |
| SDSS J114803.17+565411.4 | 0.703 | 10.65 | 1.92 | 0.30 | • |
| SDSS J144033.82+044830.9 | 0.603^a | 10.42 | 1.24 | 0.15 | • |
| SDSS J080409.23+385348.8 | 0.567 | 10.50 | 0.54 | 0.75 | • |
| SDSS J081940.82+434649.6 | 0.722 | 10.39 | 0.40 | 0.27 | • |

Notes. Description of results: (1) SDSS Name of quasar, (2) g− color of the targeted galaxy, (3) stellar mass of the targeted galaxy, (4) equivalent width of 2796 Å Mg ii line, (5) expected 2796 Å upper limit for 3σ detection, and (6) point style in figures.

^a The fainter companion galaxy with a coincident redshift 18.6 h^{-1} kpc from the quasar has g− r < 0.46.

^b Significance formally < 3σ in single line but ≥ 2.7σ in both lines; not readily apparent in by-eye examination (see Figure 7).
### Table 3
Galaxy Spectral Properties from the SDSS

| QSO Name | EW(Hβ) (Å) | [NII]/Hα | EW(NaD) (Å) | EW(MgI b) (Å) | EW(Hδ) (Å) | EW(Hα) (Å) | EW([OIII]) (Å) |
|----------|------------|----------|-------------|---------------|------------|------------|---------------|
| SDSS J030313.02−001457.4 | 1.19 ± 0.20 | > 0.6 | 3.46 ± 0.17 | 7.47 ± 0.34 | 2.35 ± 0.21 | 1.58 ± 0.32 | ... |
| SDSS J050409.23+385348.8 | −21.39 ± 0.28 | 0.34 | 3.10 ± 0.20 | 6.22 ± 0.39 | −2.68 ± 0.18 | 2.94 ± 0.42 | −1.99 ± 0.30 |
| SDSS J080814.69+475244.6 | −1.00 ± 0.33 | 2.24 | 2.56 ± 0.23 | 6.34 ± 0.50 | 1.67 ± 0.37 | 1.31 ± 0.35 | −6.52 ± 0.55 |
| SDSS J081420.19+383408.3 | −9.67 ± 0.23 | 0.45 | 1.29 ± 0.26 | 3.65 ± 0.51 | −0.97 ± 0.15 | 3.62 ± 0.40 | −3.21 ± 0.35 |
| SDSS J081940.82+443649.6 | −1.10 ± 0.15 | 2.18 | 4.48 ± 0.23 | 7.13 ± 0.64 | 1.89 ± 0.30 | 1.57 ± 0.32 | −3.27 ± 0.51 |
| SDSS J090558.34+504538.0 | −1.86 ± 0.33 | 1.21 | 2.99 ± 0.39 | 10.43 ± 1.50 | 3.04 ± 0.90 | 3.38 ± 1.78 | −3.12 ± 1.63 |
| SDSS J091119.16+031152.9 | −2.09 ± 0.14 | 1.25 | 4.26 ± 0.20 | 4.87 ± 0.46 | 2.84 ± 0.48 | 1.17 ± 0.57 | 0.07 ± 0.20 |
| SDSS J092300.67+075108.2 | −0.06 ± 0.08 | > 0.6 | 5.77 ± 0.21 | 8.35 ± 0.69 | 3.54 ± 0.46 | 2.48 ± 0.72 | −2.68 ± 0.88 |
| SDSS J102216.13+062183.6 | −19.68 ± 0.48 | 0.35 | 2.23 ± 0.39 | 5.07 ± 1.44 | −4.36 ± 0.38 | 6.71 ± 1.12 | −7.59 ± 0.79 |
| SDSS J102751.62+104532.6 | −1.74 ± 0.28 | 1.80 | 2.35 ± 0.38 | 7.40 ± 0.70 | 2.64 ± 0.57 | −0.07 ± 0.25 | −3.09 ± 0.85 |
| SDSS J102847.00+391800.5 | −31.35 ± 0.49 | 0.35 | 1.86 ± 0.37 | 1.80 ± 0.38 | −5.25 ± 0.27 | 0.17 ± 0.13 | −7.54 ± 0.45 |
| SDSS J104706.74+375315.4 | −24.59 ± 0.50 | 0.76 | 0.33 ± 0.20 | 3.89 ± 0.73 | −13.04 ± 0.95 | −0.24 ± 0.22 | −1.40 ± 0.27 |
| SDSS J105053.08−001354.8 | −6.32 ± 0.23 | 0.55 | 3.38 ± 0.18 | 5.92 ± 0.43 | 0.88 ± 0.15 | 2.10 ± 0.40 | −1.26 ± 0.28 |
| SDSS J111342.42−000730.7 | 0.14 ± 0.05 | > 0.6 | 6.11 ± 0.21 | 9.16 ± 0.39 | 2.12 ± 0.30 | 1.07 ± 0.27 | 5.93 ± 2.27 |
| SDSS J112613.52+352002.6 | −1.31 ± 1.14 | ... | 4.10 ± 0.25 | 8.45 ± 0.53 | 2.96 ± 0.37 | 1.40 ± 0.38 | 13.10 ± 21.89 |
| SDSS J114803.17+565411.4 | −0.85 ± 0.23 | 3.44 | 6.71 ± 0.29 | 8.47 ± 0.74 | −0.16 ± 0.13 | −0.21 ± 0.39 | −7.26 ± 1.12 |
| SDSS J124914.11+392615.0 | −53.00 ± 5.00 | 0.6 | 4.63 ± 0.35 | 7.38 ± 0.79 | 2.25 ± 0.44 | 0.49 ± 0.40 | 1.89 ± 1.37 |
| SDSS J140434.77+004730.4 | −0.36 ± 0.15 | 0.6 | 4.63 ± 0.35 | 7.38 ± 0.79 | 2.25 ± 0.44 | 0.49 ± 0.40 | 1.89 ± 1.37 |
| SDSS J144033.82+044830.9 | −6.17 ± 0.17 | 0.51 | 2.65 ± 0.19 | 5.09 ± 0.41 | −0.46 ± 0.11 | 2.62 ± 0.36 | −3.02 ± 0.45 |
| SDSS J151541.23+334739.4 | −6.95 ± 0.24 | 0.75 | 3.97 ± 0.22 | 4.78 ± 0.41 | 2.25 ± 0.44 | 2.97 ± 0.38 | −2.29 ± 0.25 |

Notes. SDSS SpecLine properties of targeted galaxies: (1) SDSS Name of quasar, (2) Hα equivalent width, (3) ratio of [NII] 6586 Å line to Hα, (4)–(8) equivalent widths of NaD, MgI b, Hβ, Hα, and [OIII].

**Figure 3.** Detections. We plot raw object counts in detected electrons as a function of effective rest-frame (peculiar) velocity shift from the centroid of the 2796 Å line. The shading indicates the errors and vertical lines (dashed, red) indicate the expected positions of the MgII lines from the galaxies if they occur at the redshift centroid; thinner (dotted) lines indicate the velocity offset of the maximum detection signal. We list the quasar name in the upper left, and the significance of the detection in the lower right. The bottom two spectra are box-car smoothed by four and two bins, respectively.

(A color version of this figure is available in the online journal.)
Figure 4. Detected galaxies. We show SDSS images of the quasars and likely absorbers. The central object is the quasar, and the images are 40″ on a side, corresponding (left to right) to 58, 54, 58, 54, 50, and 51 h⁻¹ kpc, respectively.

(A color version of this figure is available in the online journal.)

(NYU-VAGC; Adelman-McCarthy et al. 2008; Blanton et al. 2005b). The volume-limited galaxy subsample constructed to $M_r + 5 \log h \gtrsim -20.5$ includes 88,532 galaxies with redshifts $0.0044 \lesssim z \lesssim 0.116476$. The colors and magnitudes we quote are k-corrected and Galactic reddening corrected (Blanton et al. 2005b); spectral line information comes from the SpecLine data distributed via the SDSS Web site. We ultimately select quasars at projected distances of $D \lesssim 75$ h⁻¹ kpc in the SDSS DR5 quasar catalog. The quasars satisfy $m_g \lesssim 19.5$, with redshifts at which the observed-frame Lyman $\alpha$ emission from the quasar is blueward of the expected Mg $\textsc{ii}$ (2796 Å) absorption of the galaxy, allowing us to avoid contamination in the quasar spectrum from intervening Lyman $\alpha$ forest systems.

We observed a total of 20 quasar–galaxy pairings. The signal-to-noise ratios of the resulting observations vary depending on the seeing conditions, the absorber redshift, and the flux of the quasar, as we describe below.

Our observations began with a pilot study that sampled the SDSS VAGC DR4 (Adelman-McCarthy et al. 2006), with a magnitude limit that extended to $M_r + 5 \log h \lesssim -20$. Because the lower-redshift systems were more difficult to target than expected, we eventually focused on the $-20.5$ sample and extended the study to DR6. After the detection of an Mg $\textsc{ii}$ absorber system at an impact parameter of 62 h⁻¹ kpc, we extended our impact parameter radius from 65 to 75 h⁻¹ kpc. As Figure 2 shows and a K–S test suggests, the sample is deficient in galaxies with impact parameters $\gtrsim 50$ h⁻¹ kpc ($P_{\text{K–S}} \sim 0.01$).

The targets are listed in Table 1; only galaxy SDSS J030313.02−001457.4 is missing from the DR6 database, for reasons that are unclear. As a result, we analyze all the spectra in the context of the SDSS VAGC DR6 $M_r + 5 \log h \lesssim -20.5$ sample, referred to as the DR6 $-20.5$ sample hereafter.

2.1. The Observational Approach and the Data

We conducted observations on 2008 March 2 and 2009 January 24–25 using the 1200 lines mm⁻¹ grism blazed at 3400 Å with LRIS-B; the longslit spectra approximately cover the wavelength range 2910–3890 Å. The objects for which we use...
Figure 5. Solid non-detections of $\geq 0.3$ Å absorbers. We plot raw object counts in detected electrons as a function of effective rest-frame (peculiar) velocity shift from the centroid of the 2796 Å line. The shading indicates the errors and vertical lines (dashed, red) indicate the expected positions of the Mg ii lines from the galaxies if they occur at the redshift centroid. We list the quasar name (upper left), and the 3σ upper limit (rest-frame; lower right). The spectra are box-car smoothed by three bins. SDSS J151541.23+334739.4 likely has an absorber but it satisfies $W_{\text{eq}}(2796) \leq 0.19$ Å and is therefore not a strong absorber. Note that if the feature at 100 km s$^{-1}$ in SDSS J111342.42−000730.7 were the 2976 Å line its equivalent width would only be 0.2 Å.

(A color version of this figure is available in the online journal.)

For the detections, we measure the equivalent widths of 2796 Å (only) by fitting Gaussians directly to the spectra and, simultaneously, the background. To estimate the quality of the spectra and the upper limits for the non-detections on an object-by-object basis, we compute a running signal-to-noise estimate of the spectra in the region around the expected Mg ii absorption at 2796 Å. Taking a value that is intermediate between the fit widths of our first two detections, we assume an 8-pixel ($\sim 1.9$ Å) line width for each line and compute the total absorption “signal” from within these 8 pixels for each of the two lines as a function of potential redshift within 300 km s$^{-1}$ of the galaxy center.

We take the continuum from the surrounding area. The assumed noise estimate includes contributions from the object counts, the background, readnoise, and an estimate of the error from not flat-fielding the data. We assign upper limits based on the rest-frame equivalent width of a S/N = 3 detection. These results are listed in Table 2, and other spectral properties of the targets are tabulated in Table 3.

Figures 3–7 show the raw-count spectra and images for the sample classified by whether we find a significant detection of Mg ii within 300 km s$^{-1}$ of the systemic redshift of the galaxy. We only show images of the clear detections and non-detections. Table 2 lists the detection status of the galaxies, as well. Two additional sources, SDSS J080409.23+385348.8 and SDSS J081940.82+443649.6, are formally detected at the $\leq 3\sigma$ level in the 2796 Å line but at $\geq 3\sigma$ significance in the combination of both lines, although the absorbers are not visually evident in the data. We list these two sources as “probable detections.” Figure 8 describes the redshifts and quasar magnitudes for the observations, illustrating that the significant non-detections—the most stringent requirements on the spectra—are much more readily obtained at relatively high redshifts, as expected from the sharp atmospheric cutoff near 3050–3100 Å.
Figure 6. Galaxies that were not detected. We show SDSS images of the quasars and galaxies with \( \lesssim 0.3 \) Å upper limits that are non-detections of strong absorbers. The central object is the quasar and the images are 40\' on a side, corresponding (left to right) to 59, 59, 57, 56, 56, and 58 \( h^{-1} \) kpc, respectively.

If we increase the assumed width used to calculate the upper limits from 8 to 12 pixels, the upper limits increase by \( \sim 20\% \), pushing SDSS J111342.42–000730.7 and SDSS J140843.77+004730.4 below the limit. If a small feature at \( \sim 100 \) km s\(^{-1} \) in SDSS J111342.42–000730.7 were real and the blue line were masked by the unrelated absorption feature at 900 km s\(^{-1} \), its \( W_{\text{eq}}(2796) \) would still be only be 0.2 Å, so it is not a strong absorber. SDSS J140843.77+004730.4 is a potential (barely) 3\( \sigma \) detection, but it would be at \( \sim -316 \) km s\(^{-1} \), which is probably unphysical.

Most of the galaxies do not have evident faint companions closer to the quasar. However, the strong absorber in SDSS J144033.82+044830.9 has a companion with \( m_i = 18.1 \) and \( M_R = -19.8 \) at a projected 18.6 \( h^{-1} \) kpc from the quasar. Although its redshift was not acquired as part of the SDSS, we obtained a spectrum with the Keck telescope on 2009 January 25, measuring \( z = 0.1128 \) after correcting to the local standard of rest using the IRAF task RVCORRECT. This redshift is within the measurement error of the redshift for the primary galaxy. The companion is even bluer than the luminous galaxy, however, with \( g - r \sim 0.46 \). Both the companion and the Mg\( \text{ii} \)-absorbing gas are almost certainly within the dark matter halo of the more luminous galaxy. Thus, they are all likely associated with the potential fuel for star formation in the outskirts of the central galaxy.

3. RESULTS

To explore the characteristics of “strong” \( (W_{\text{eq}}(2796) > 0.3 \) Å) Mg\( \text{ii} \) absorbers in the local universe, we compare the properties of the detected absorbers with the non-absorbers and the full volume-limited sample.

Table 1 and Figure 9 show properties of the samples, including rest-frame colors, luminosities, and stellar masses from the kcorrect fitting results distributed with the NYU-VAGC
Figure 7. Potential detections (top row) and weaker non-detections that are inconclusive with respect to strong (> 0.3 Å) absorbers. We plot raw object counts in detected electrons as a function of effective rest-frame (peculiar) velocity shift from the centroid of the 2796 Å line. Shading indicates the errors and vertical lines (dashed, red) indicate the expected positions of the Mg\textsc{ii} lines from the galaxies if they occur at the redshift centroid. We list a short-hand version of the quasar name (upper left), and either the significance of the potential detection or the 3σ upper limit of non-detection (rest-frame; lower right). The spectra are box-car smoothed by three bins.

(Blanton et al. 2005b; Blanton & Roweis 2007). The solid lines show the full volume-limited samples, where measurements are available, and the filled histograms show the probed galaxies. The detected Mg\textsc{ii} absorbers span the full range of colors and \(W_{\text{eq}}(\text{H}\alpha)\), and most of the range of luminosities and stellar masses of the sample. For this small sample of six absorbers, K–S tests reveal no significant differences between the distributions of the absorbers and the full sample. However, we note that K–S tests are not uniformly sensitive to all kinds of trends.

K–S tests reveal no evident unfairness in the sampling of parameter space except in H\(\alpha\). The 20 sampled galaxies fall preferentially at somewhat smaller \(W_{\text{eq}}(\text{H}\alpha)\) (stronger emission) than the full volume-limited sample (\(P_{\text{K–S}} = 0.05\)), with an average of -9.4 Å for the 20 probed systems as compared with -7 Å for the full volume-limited sample.

3.1. Star Formation

The data suggest, but do not conclusively establish, the existence of trends in Mg\textsc{ii} properties and star-forming properties. The most striking potential color dependence on absorption characteristics is that confirmed non-strong-absorbers (medium shading) are green or red but not blue. Although the trend does not yield a low K–S probability, there is a somewhat significant effect in the measured average \(g-r\) color. The average color for the full sample is \((g-r) = 0.643\), while it is 0.723 for the non-detections of strong absorbers. If we randomly draw six \(g-r\) colors at random from the full volume-limited DR6 sample 10,000 times, the average is only as red as 0.723 by chance 15% of the time, a ∼1σ result. A larger sample is crucial for confirming this possible trend. For \(W_{\text{eq}}(\text{H}\alpha)\), the non-absorbers are relatively weaker star-formers, but at lower significance.

For the full sample is \(W_{\text{eq}}(\text{H}\alpha) = -9.4\) Å while it is -2.7 Å for the six non-absorbers, but an average this large happens by chance 28% of the time.

Figure 10 depicts the relationships between the colors, impact parameters, and strengths of the absorbers. We plot \(W_{\text{eq}}(2796)\) as a function of impact parameter for galaxies with different absorption status, also color-coding based on \(g-r\) color, where blue points have \(g-r < 0.6\), green points have 0.6 < \(g-r < 0.7\), and red points have \(g-r > 0.7\). In the right-hand side of the figure, we eliminate the most ambiguous points to give a clearer view of the possible trends.

Among the absorbers, the tendency for stronger absorbers to appear at smaller impact parameters, as noted by Steidel (1995) and more recently Zibetti et al. (2007), is also suggested by our data. All of the bluest galaxies are either strong absorbers...
or inconclusive, although the “green” galaxies can be non-absorbers. The confirmed absorbers at higher impact parameters are all blue. Furthermore, the only definitive red absorbers are at very small impact parameter (<20 h⁻¹ kpc), although one possible red absorber (SDSS J081940.82+443649.6) lies at 48 h⁻¹ kpc. We note that the red absorbers all exhibit some emission-line flux in their spectra, with [N II]/Hα flux ratios characteristic of LINERs; these red, emitting galaxies are very common (e.g., Yan et al. 2006; Grav et al. 2007).

Overall, the data are suggestive that in the low-z universe, the absorption and covering fraction may depend on the star-forming properties of galaxies. Specifically, non-absorbers may be primarily green or red galaxies, and red absorbers may favor lower impact parameters. These relationships are in broad agreement with the possibility that a gas halo is required to replenish continuously star-forming galaxies (e.g., Larson et al. 1980) and with the statistical finding of Zibetti et al. (2007) that stronger Mg ii absorbers in SDSS quasars are surrounded by bluer light distributions. Confirming these results would require better sampling by color that includes more blue galaxies at lower impact parameters and more red galaxies at higher impact parameters.

3.2. Environment

A modification of the method described in Barton et al. (2007) allows us to characterize the environments of the galaxies in the volume-limited sample objectively, by comparison to a cosmological dark matter simulation (Zentner & Bullock 2003; Zentner et al. 2005; Allgood et al. 2006). Using number-density matching to match the $M_\star + 5 \log h \leq -20.5$ sample to dark matter halos in the simulation with circular speeds $\geq 240$ km s⁻¹, we create an artificial redshift survey with the simulation and bin model halos by the distance to the nearest massive neighbor within 1000 km s⁻¹, $D_N$, and the number of neighbors it has in total within 700 h⁻¹ kpc and 1000 km s⁻¹, $N_{700}$. Then, for each bin in $D_N$ and $N_{700}$, we compute the probability that a halo in that bin is alone with respect to other halos in the sample, $P(N = 1)$, the probability that a galaxy in each bin has 1–7 companions, $P(2 \leq N \leq 8)$, and the probability that it resides in a cluster with $\geq 8$ other halos, $P(N \geq 9)$. For each galaxy in the volume-limited SDSS sample, we measure $D_N$ and $N_{700}$ from the data then compute $P(N = 1)$, $P(2 \leq N \leq 8)$, and $P(N \geq 9)$ using the corresponding bin in the simulation.

Figure 11 shows the distributions of these probabilities for the portion of the full volume-limited sample that falls into relatively complete regions of the SDSS. Again, because of the small sample sizes, K–S tests reveal few significant trends; comparing the distribution of $P(2 \leq N \leq 8)$ shows that the sample of 20 galaxies probed this study as a whole differs at a minor level from the population at large at ($P_{K-S} = 0.10$).

![Figure 8](image_url) Figure 8. Absorber result as a function of galaxy redshift and quasar g-band apparent magnitude. Using data from Table 2, we plot detections of strong (> 0.3 Å) absorbers (filled circles), non-detections of strong absorbers (open circles), potential strong absorbers (filled triangles), and weak non-detections (stars) which could be strong absorbers but not very strong absorbers (see Table 2). The significant non-detections of strong absorbers, which require the best data quality, cluster at higher redshifts because of atmospheric extinction.

![Figure 9](image_url) Figure 9. Properties of the targeted galaxies in the context of the volume-limited SDSS sample. When they are available, we show the approximate stellar masses (top left), r-band absolute magnitudes (bottom left), $g-r$ colors (top right), and $W_\text{eq}(H\alpha)$ (bottom right) for the full volume-limited $M_\star + 5 \log h \leq -20.5$ sample (solid line), the galaxies we have already targeted. We show the ambiguous potential detections and weak non-detections (lightest shading) the strong non-detections (medium shading) and the detections (darkest shading). Here, we plot the luminous galaxy for the absorber SDSS J144033.82+044830.9 ($\log M_\star = 10.42, M_\text{r} = -21.3, g - r = 0.603$), although its bluer and fainter minor companion is the likely source of at least some of the Mg ii absorption. The histograms for the targeted galaxies are non-overlapping.
Mg\textsc{ii} absorption as a function of impact parameter from our volume-limited SDSS sample. Left: we plot the measured \( W_{\text{eq}}(2796) \) or upper limit of the 2796 Å absorption line as function of impact parameter between the quasar and the targeted galaxy. Points are segregated based on color (blue: \( g - r < 0.6 \), green: \( 0.6 < g - r < 0.7 \), or red: \( g - r > 0.7 \)) and on the presence or absence of 2796 Å absorption as described in Table 2. Right: we show the same figure without the ambiguous, lower S/N spectra. SDSS J144033.82+044830.9 is plotted at the luminous galaxy’s position, but with an arrow pointing to the position of its confirmed minor companion.

Environmental properties of the targeted galaxies in the context of the volume-limited SDSS sample. We use numerical simulations to estimate the probability that the galaxies are (bottom) alone in their dark matter halos with respect to other luminous galaxies, \( P(N = 1) \), (middle) in systems with 2–8 luminous members, \( P(2 \leq N \leq 9) \), or (top) in dense systems with \( N \geq 9 \). The graph types follow Figure 9. Here, we plot the results for luminous galaxy near the absorber SDSS J144033.82+044830.9, with \( P(N = 1) = 0.93 \), \( P(2 \leq N \leq 8) = 0.06 \), and \( P(N \geq 9) = 0.009 \).

As the distribution of \( P(N = 1) \) shows, most of the galaxies in the volume-limited sample are isolated by these criteria, primarily because the magnitude limit of the sample is quite luminous. Nonetheless, the detected absorbers are even more isolated than the population at large, with probabilities \( P(N = 1) \gtrsim 60\% \). We note that although 71\% of the galaxies in the full sample fall into this regime, the probability that all six absorbers fall into the \( P(N = 1) > 0.6 \) regime by chance is still modest (12\%). The possible environmental effects are further accentuated by the results for the non-absorbers. Only 18.5\% of the full volume-limited sample have \( P(N = 1) < 0.20\% \), while 3/6 of the non-absorbers are in this category. The binomial probability that three or more would fall into the \( P(N = 1) < 0.2 \) regime by chance is \( \sim 8\% \). Taken together, the two constitute a \( \gtrsim 2\sigma \) result, although this significance is somewhat overstated because of the a posteriori nature of the estimate. Thus, the data suggest that absorbers tend to be isolated and that non-absorbers are more likely to have companions.

This result is broadly consistent with “strangulation,” or the stripping of a galaxy’s outer gas halo when it falls into a
denser system (e.g., Larson et al. 1980). When galaxies become substructure in a larger system, this stripping eventually cuts off the fuel for star formation, explaining why galaxies in denser environments gradually turn red. As the data suggest, these galaxies in denser environments may be less likely to exhibit Mg $\upi$ absorption.

3.3. Covering Fraction

The covering fraction of Mg $\upi$ absorption is a fundamental property that describes the statistical amount of Mg $\upi$-absorbing gas around typical galaxies; it provides an important constraint on the behavior of gas in models (e.g., Kaufmann et al. 2009; Kacprzak et al. 2009). Hydrodynamic simulations predict a range of Mg $\upi$ covering fractions depending in detail on the temperature and entropy of the gas. For example, Kaufmann et al. (2009) show that a change in temperature of a factor of two can change the Mg $\upi$ covering fraction by a factor of $\sim 30$. Thus, an accurate and unbiased measure of this fraction around a uniform set of galaxies, even with accuracy that is within a factor of a few, is a strong constraint on the nature of halo gas in galaxies.

Several empirical studies explore models in which the size of the absorbing gas “halo” scales with galaxy luminosity (Bowen et al. 1995; Steidel 1995; Guillemin & Bergeron 1997; Kacprzak et al. 2008). Because our luminosity range is extremely small, we primarily constrain the gas “halo” near $L_\star$ ($\sim 20.44$; Blanton et al. 2003). We show the relationship between absorber status, impact parameter, and galaxy luminosity in Figure 12. The dotted line is the line from Steidel (1995), albeit for $K$-band luminosities. In their study, almost all of the intermediate-redshift sample are non-absorbers above the line, while below the line, their galaxies are almost exclusively absorbers. Our data are very inconsistent with this picture, with absorbers and non-absorbers falling above and below the line in nearly equal numbers. Furthermore, because one of the galaxies with the largest impact parameters exhibits Mg $\upi$ absorption, our only constraint on the gas halo radius is that $R \gtrsim 62 \, h^{-1}$ kpc near $L_\star$. This inconsistency could arise from selection effects, redshift differences, or by chance.

Because of the non-uniformity in the quality of the spectra, we are forced to cull our sample in order to yield an estimate of $f_c$, the covering fraction of gas or the fraction of sightlines through the gas “halo” that will exhibit “strong” ($W_{eq}(2796) \gtrsim 0.3$ Å) absorption (Steidel 1995). To measure the covering fraction of strong absorbers, we exclude all spectra from Table 2 with $3\sigma$ upper limits $> 0.3$ Å, which must necessarily exclude the strong absorbers SDSS J092300.67+075108.1 and SDSS J081420.19+383408.3, and could exclude SDSS J114803.17+565411.4, with an upper limit equivalent to 0.3 Å. These lower-S/N quasar spectra can reveal strong absorbers but cannot detect strong non-absorbers; thus, their inclusion could bias the sample toward finding more absorbers. We also exclude SDSS J144033.8+044830.9 because of its minor companion ($M_R = -19.8$) closer to the quasar. Unfortunately, SDSS J081940.82+443649 is an ambiguous case, as the formal $3\sigma$ limit is $< 0.27$ Å but the detection remains relatively tentative. Depending on whether we include or exclude J114803 and/or J144033, we estimate an overall covering fraction within $\sim 75 \, h^{-1}$ kpc of $f_c = 2/8 - 10/0.25 - 0.4$. If we consider only those probes within the traditional $\sim 35 \, h^{-1}$ kpc, our statistics become sparse, yielding an estimate of $f_c = 0/3 - 1/4 = 0 - 0.25$, depending on how we treat SDSS J114803.17+565411.4.

The early studies of Mg $\upi$ absorption suggested that $f_c$ is near unity. In our study, several absorbers have larger impact parameters than some of the non-absorbers. Our low-$z$ data are inconsistent with a gas covering fraction of 1. Some previous studies agree with our results, finding gas covering fractions well below 1 (Bechtold & Ellington 1992; Bowen et al. 1995; Churchill et al. 2005; Tripp & Bowen 2005; Kacprzak et al. 2008), while others favor fractions much closer to 0.8–1 (Steidel 1995; Chen & Tinker 2008). Broadly speaking, “reverse” studies such as ours, that identify galaxies first and then explore Mg $\upi$ properties, may measure lower covering fractions. The
discrepancies among studies could also result from dramatic differences in redshift, halo mass, and galaxy properties for the systems that are probed; both factors are likely to make a difference (e.g., Bowen et al. 1995; Tinker & Chen 2008).

3.4. Other Properties of the Interstellar Medium

The possible color dependence noted here and elsewhere and the environmental dependence our data support the expectation that there are fundamental relationships between the abundance of halo gas in a galaxy and its star-forming properties. The Mg $\text{ii}$ halo gas may also relate to the interstellar medium (ISM), as observed "down-the-barrel" in galaxy spectra. The Na $\text{i}$ D absorption-line doublet ($\lambda$5890,5896 Å) is a sensitive, well-studied ISM diagnostic that falls into the optical regime at low redshift. Unfortunately, it suffers from contamination by starlight. Nonetheless, high-resolution studies of the doublet show clear-cut winds in the Na $\text{i}$ D line in rapidly star-forming ultraluminous infrared galaxies (Martin 2005; Rupke et al. 2005a, 2005b).

The contamination from a stellar component to the Na $\text{i}$ D line can be estimated from the equivalent width of the Mg $\text{b}$ triplet ($\lambda$5167,5173,5185 Å). Various authors assume a stellar contribution to $W_{\text{eq}}(\text{NaD})$ of $(1 - 1/2)W_{\text{eq}}(\text{Mg b})$. In Figure 13, we plot $W_{\text{eq}}(\text{Mg b})$ as a function of $W_{\text{eq}}(\text{NaD})$. Following Rupke et al. (2005a), we plot the line $W_{\text{eq}}(\text{NaD}) = 0.5 W_{\text{eq}}(\text{Mg b})$ (solid line); points further to the right of the solid line are more likely to have contributions from the ISM to the Na $\text{i}$ D absorption. The dotted line is the approximate location of starbursting galaxies with strong winds observed in the Na $\text{i}$ D feature for the Rupke et al. (2005a) sample. We code the points based on Mg $\text{ii}$ absorption status in the halo of the galaxy. None of the DR6 $-$20.5 sample galaxies observed thus far lie in the strong-wind regime. Nonetheless, there is a suggestion that the galaxies with Mg $\text{ii}$ halo absorption lie at relatively large $W_{\text{eq}}(\text{NaD})$-$W_{\text{eq}}(\text{Mg b})$ ratio, as illustrated by the right-hand side of the plot. All of the red absorbers have relatively strong Na $\text{i}$ D absorption given their $W_{\text{eq}}(\text{Mg b})$. In fact, only one absorber lies at $W_{\text{eq}}(\text{Mg b}) > 0.5 W_{\text{eq}}(\text{NaD})$ and it is blue (SDSS J081420.19+383408.3). Perhaps red galaxies with halo Mg $\text{ii}$ must actually be either very dusty or gas-rich enough to exhibit significant Na $\text{i}$ D from the ISM which has not yet resumed star formation. Blue galaxies with little interstellar Na $\text{i}$ D could be systems at the end of their star-forming cycle that have used up or cleared out their low impact parameter Na $\text{i}$ D gas, but have retained their outer halo gas; the relatively strong Balmer absorption in SDSS J081420.19+383408.3 [$W_{\text{eq}}(\text{H}\beta) = 3.6$ Å] supports this hypothesis.

4. CONCLUSIONS

We use ground-based spectroscopy with LRIS-B on the Keck I telescope to evaluate the Mg $\text{ii}$ absorption characteristics of a sample of $\sim$L*$ galaxies selected as cleanly as possible from a volume-limited subsample to $M_r + 5 \log h \gtrsim -20.5$ of the SDSS DR6 Value Added Galaxy Catalog (Blanton et al. 2003). We target 20 systems, achieving a range in the quality of spectral observations that reveals six "strong" ($W_{\text{eq}}(2796) > 0.3$ Å) absorbers and six non-absorbers. We find the following.

1. Ground-based observations of Mg $\text{ii}$ absorption are possible—with relatively low S/N ratio—to redshifts as low as $z \sim 0.1$ with modest amounts of observing time.

2. The overall covering fraction, $f_c$, of gas capable of creating strong ($\gtrsim 0.3$ Å) Mg $\text{ii}$ absorption must be $< 1$ at $z \sim 0.1$, broadly consistent with some previous studies. Even inside the traditional absorption halo radius of $\sim 35$ h$^{-1}$ kpc, the covering fraction of strong absorption is $< 1$, with a naive estimate of $f_c \lesssim 0.25$.

3. The Mg $\text{ii}$ detection in the quasar with the largest impact parameter lies $62$ h$^{-1}$ kpc from the center of the associated galaxy. Thus, at least in rapidly star-forming $z \sim 0.1$ galaxies, strong, but possibly unfilling, Mg $\text{ii}$ absorption gas halos can extend to at least this distance from a luminous galaxy.

4. The data suggest, at the $\lesssim 2\sigma$ significance level, that the Mg $\text{ii}$ absorption properties of the outer halos of galaxies may depend on the larger-scale environment of the absorbing galaxy. Absorbers appear to favor low-density environments, while non-absorbers show a possible preference for denser regions. This result is consistent with "triangulation" models in which satellite galaxies are red because their outer gas halos are stripped when they become substructure.

5. The relationships between galaxy color, impact parameter, and absorbing halo $W_{\text{eq}}(2796)$ are consistent with a model in which red galaxies with Mg $\text{ii}$ absorption are typically LINERs which are observed at smaller impact parameters. Blue galaxies are possible Mg $\text{ii}$ absorbers to very large impact parameters (at least $62$ h$^{-1}$ kpc); in fact, all of the bluest galaxies in this study are either strong absorbers or inconclusive. These color trends are consistent with the results from statistical image-stacking studies (Zibetti et al. 2007), and with the broad expectations of theoretical models.

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