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THE UNUSUAL FIELD OF THE QUASAR 3C 336: INDENTIFICATION OF THREE FOREGROUND Mg II ABSORBING GALAXIES

CHARLES C. STEIDEL[1,2,3] AND MARK DICKINSON[3]
Department of Astronomy, University of California, Berkeley, CA 94720
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ABSTRACT

We present imaging and spectroscopic observations of the field of the QSO 3C 336 ($z = 0.927$), whose absorption spectrum exhibits at least 3 Mg II $\lambda\lambda$2796, 2803 absorption systems with $z_{abs} < z_{em}$, making it the richest low-redshift absorption spectrum observed in a recently completed absorption line survey. We have tentatively identified the most intrinsically faint ($\sim 0.25L^*$) Mg II absorbing galaxy yet discovered. At $z = 0.472$ and with $B > 24$, its properties strongly resemble those of the so-called "faint blue galaxies" found in deep imaging and spectroscopic surveys for field galaxies. At the same time, the large impact parameter to the QSO sightline ($\sim 23\ h^{-1}$ kpc) would indicate that at such redshifts even dwarf galaxies with luminosities smaller than that of the LMC may have very extended gaseous envelopes. Spectroscopy of other galaxies in the field suggests that the large overdensity of faint galaxies first pointed out by Hintzen et al. may be due in part to a foreground cluster at $z = 0.66$, which corresponds to the redshift of one of the other Mg II absorption systems. If confirmed, this would be the first known case of Mg II absorption arising from a cluster galaxy at large redshift. We discuss the implications of this very complex field for the general properties of galaxies producing heavy element absorption systems in the spectra of QSOs.

Subject headings: galaxies: clustering — galaxies: distances and redshifts — quasars: absorption lines — quasars: individual (3C 336)

1. INTRODUCTION

Recently completed systematic imaging and spectroscopic surveys of faint field galaxies have resulted in a rather puzzling (and continually changing) picture of galaxy evolution. The most recent work reveals that the objects which dominate the faint number counts (the so-called "faint blue galaxies") are predominantly dwarf galaxies at modest redshift (e.g., Lilly, Cowie, & Gardner 1991), and their sheer numbers at these relatively modest look-back times and the lack of present-day analogs requires some combination of very substantial luminosity evolution and/or number evolution. A general result from all of the recent surveys is that it is exceedingly difficult to find high-redshift galaxies among the "swarm" of relatively low-redshift dwarfs if one selects magnitude limited samples in a particular broad bandpass (i.e., *B* or *K*). A completely independent and complementary approach to studying galaxies at high redshift is through the heavy element absorption systems observed in the spectra of QSOs. In this approach, rather than choosing galaxies on the basis of their stellar radiation in a particular observed bandpass, one is essentially selecting objects weighted by the cross-section of metal-enriched gas which they present to random lines of sight to background QSOs. The beauty of the absorption line studies is that they allow the investigation of the absorbing objects to very large redshift ($z > 4$) without the problems of severe dimming with distance; the problem of course is that one must establish the connection between the absorption systems and galaxies in order to interpret the observations at very high redshift. That is, what population of galaxies is picked out when one selects by the presence of heavy element absorption? Bergeron & Boisse (1991) have identified 13 galaxies reponsible for Mg II $\lambda\lambda$2796, 2803 absorption systems at $\langle z \rangle = 0.45$, finding that, contrary to the field galaxy redshift surveys, the absorption tends to be associated with bright objects, rather than dwarfs. However, the sample is still very small, and broad inferences about the absorbing galaxy luminosity function are not yet possible. In view of this, and in view of the importance of establishing whatever bias is involved in using Mg II absorption as a selection criterion, we are in the process of completing a comprehensive survey aimed at identifying the absorbing galaxies associated with a statistically homogeneous sample of Mg II absorption systems from a recently completed, very large survey (Steidel & Sargent 1992).

The particular field discussed in this paper, that of 3C 336 ($z_{em} = 0.9265$), is the richest in moderate-redshift ($z < 0.9$) absorbing objects in the aforementioned survey, with $z_{abs} = 0.4720$, $z_{abs} = 0.6560$, and $z_{abs} = 0.8912$. The field also has the highest projected surface density of galaxies in the expected magnitude range ($20 < r < 24$) within 20″ of the QSO sightline of the ~ 50 absorber fields for which imaging is complete; thus, the very complicated nature of this field makes it the most difficult in which to identify the absorbing galaxy associated with each redshift system, but at the same time serves well to illustrate the variety of possible absorbing configurations. The same field is also of timely interest for other reasons: Hintzen, Romanishin, & Valdes (1991) have studied this field in the context of clusters of galaxies around QSOs at $z \sim 1$, finding that this particular field has the most significant over-density of galaxies within 15″ of the QSO in their sample; in addition, two groups (Thompson, Djorgovski, & Trauger 1991; Bremer et al. 1992) have independently found evidence for extended line-emitting gas in the vicinity of the QSO (at the QSO redshift). In this paper, we present imaging and spectroscopy of

[1] Guest Observer, Palomar Observatory, which is owned and operated by the California Institute of Technology.
[2] Hubble Fellow.
[3] Visiting Astronomer, Kitt Peak National Observatory, a division of National Optical Astronomy Observatories, which is operated by AURA, Inc., under contract with the National Science Foundation.

the 3C 336 field and detail our attempts to identify the galaxies giving rise to the three observed Mg II absorption systems.

2. DATA AND RESULTS

Images of the 3C 336 field in broad-band g(4900/700), $\mathscr{R}$(6930/1500), and i(8000/1450) were obtained during a run at the Kitt Peak 2.1 m telescope using the Cassegrain direct camera with a Tektronix 512 × 512 CCD in 1991 April. The image scale is 0".34 pixel^{-1}, giving a field size of 2'.9 square. The observing conditions were excellent, resulting in stellar images less than 1".1 FWHM in all three bands. The total exposure times were 2100, 1800, and 2400 s in g, $\mathscr{R}$, and i, respectively; individual exposures of 300 s were registered and co-added to produce the final frames. Residual fringing in the i band frames at the level of ∼1% of the night sky was removed using standard methods. Spectrophotometric standard stars were observed in order to place the photometry directly onto an AB-magnitude system; thus, in our system, $g_{AB} = \mathscr{R}_{AB} = i_{AB}$ corresponds to a spectrum which is flat in f_ν. Further details of the adopted photometric system will be discussed elsewhere (Steidel & Dickinson 1992). The photometry was performed using FOCAS (Valdes 1982), where we quote FOCAS "total" magnitudes in each bandpass, which correspond to magnitudes in an effective aperture having twice the area as the isophote which is 3 σ above the local sky. The formal 5 σ limiting magnitudes in a 3" circular aperture are 24.40, 23.90, and 23.70 for g_{AB}, $\mathscr{R}_{AB}$, and i_{AB}, respectively. In Table 1 are listed the magnitudes and positions relative to the QSO of the objects (stars and galaxies) for which spectroscopy was attempted. Contour plots of the field, on which the tabulated objects are marked, are shown in Figure. 1. A gray-scale representation of the field to a depth comparable to our images is shown in Figure 4*a* of Hintzen et al. (1991).

The primary objective of the spectroscopy was to obtain redshifts for as many of the objects close to the QSO sightline as possible in order to identify the three known absorbers. Because the possibility remained that even galaxies might be unresolved at the expected redshifts, we did not exclude objects for spectroscopy which appeared to be stellar on the basis of the images. In order to identify the presence of galaxies (and in order to perform photometry on such galaxies, even if they are evident from the images) we have subtracted the QSO from the images by modeling the PSF using several bright stars in the field. Contour plots of the region surrounding the QSO before and after the PSF subtraction are shown for the i band image in Figure 1. There are clearly two objects less than 3" from the QSO sightline, which we have designated G8 and G13 (see Fig. 1*b*). G8, which was evident even before PSF subtraction, is the same as object "B" in the recent paper by Thompson et al. (1992). Note that no continuum emission is found corresponding to their object "A", which they identify as extended emission-line gas at the redshift of the QSO.

Most of the spectra of galaxies in the 3C 336 field were obtained during observing runs in 1990 June, 1991 May, and 1991 August using the Lick Observatory 3 m Shane telescope Cassegrain spectrograph. A 420 lines mm^{-1} grism provided spectral coverage from 4000–8300 Å at ∼12 Å resolution. A 2".1 slit was used for all of the observations. The spectrum of one galaxy, 3C 336 G4, was obtained in 1990 July using the Palomar Observatory 5 m telescope and the Double Spectrograph. The instrumental configuration used resulted in spectral coverage from 3100–6980 Å at ∼10 Å resolution.

All of the redshifts obtained are listed in Table 1; note that objects 3, 9, and 19 are classified as galactic stars on the basis of the spectroscopy (the Galactic latitude of 3C 336 is $b = 42°$). Several of the galaxy spectra are shown in Figure 2. We identify G4 as a galaxy at $z = 0.4722$ on the basis of a rather strong

TABLE 1

OBJECTS IN THE FIELD OF 3C 336

Object	$\Delta\alpha''$	$\Delta\delta''$	$\Delta\theta''$	$\mathscr{R}_{AB}$	$(g - \mathscr{R})_{AB}$	$(\mathscr{R} - i)_{AB}$	z
QSO	0.0	0.0	0.0	17.51	0.29	−0.27	0.9265
1	−6.5	+9.7	11.7	19.70	1.70	0.39	0.327
2	−12.1	+9.8	15.6	21.20	1.05	0.03	...
3	+6.2	+5.8	8.5	21.87	0.43	0.13	star
4	−4.3	−3.8	5.8	22.49	1.39	0.30	0.4722
5	−8.8	+3.3	9.4	22.21	1.51	0.29	0.661
6	+6.3	−12.3	13.8	22.10	1.24	0.62	...
8	+2.9	−0.1	2.9	22.6	...	0.2	[a]
9	+8.6	+0.8	8.6	23.17	1.38	0.70	star
10	−1.1	+11.3	11.4	22.29	>2.2	0.77	[b]
11	+1.7	+14.1	14.2	21.84	1.67	0.01	0.6558
12	+25.6	+17.1	30.8	21.31	1.86	0.25	0.2611
13	+0.3	+1.6	1.6	(23.1)	...	(0.6)	[c]
14	+3.8	+13.5	14.0	23.45	>0.9	0.45	...
15	−3.8	+13.7	14.2	23.28	0.88	0.75	...
16	−4.7	+7.5	8.9	23.30	0.0	0.0	...
19	−15.8	−5.0	16.6	21.77	0.98	0.19	star
20	−21.3	−5.9	22.1	19.54	1.70	0.38	...

[a] As discussed in the text, spectroscopy of G8 has been inconclusive; however, the blue $(\mathscr{R} - i)_{AB}$ color and the marginal narrow-band deficit at the expected wavelength of the "G-band" at $z = 0.656$ (see Thompson et al. 1991) supports the assertion that G8 is probably the $z = 0.656$ absorber.

[b] The spectrum of G10 is inconclusive (see Fig. 2 and the text), but the very red color is consistent with that of an early-type galaxy at $z \sim 0.9$

[c] G13 is too close to the QSO sightline to allow conclusive spectroscopy, however no detectable line emission corresponding to the redshift of any of the three absorption redshifts has been found in wide-slit spectra of the QSO. We tentatively suggest that G13 may be the absorber at $z = 0.892$ (see § 3.2 of the text).

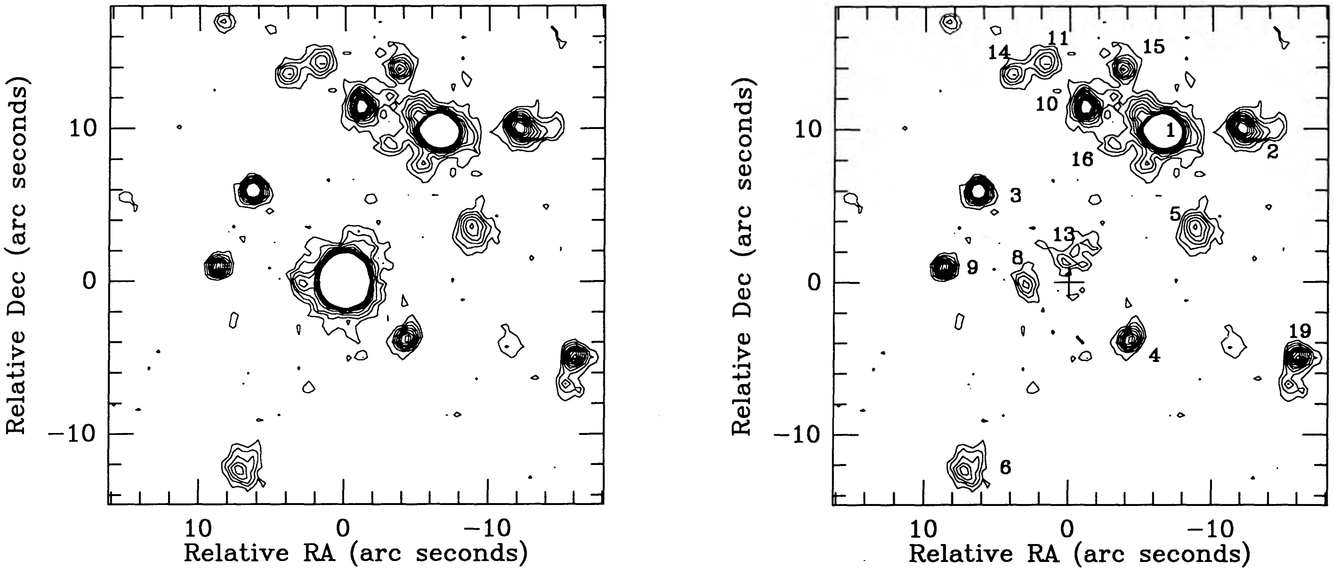

FIG. 1a FIG. 1b

FIG. 1.—Contour plots of the *i*-band CCD images of 3C 336 (*a*) before and (*b*) after PSF subtraction of the QSO (the orientation is north up and east to the left). The position of the centroid of the QSO image is marked on the second panel. The objects for which photometry is listed in Table 1 are indicated. Note the two faint galaxies (8 and 13) which are situated very near the QSO line of sight.

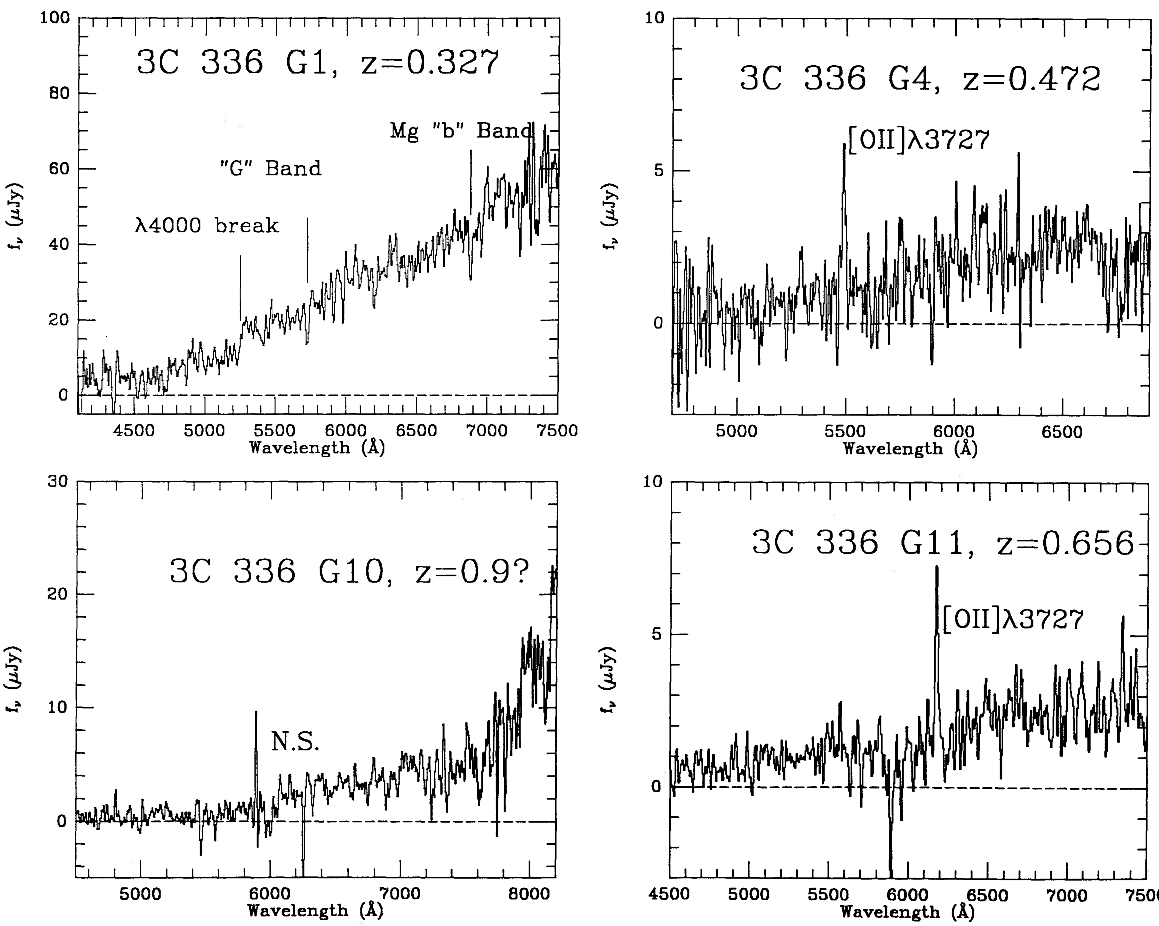

FIG. 2.—Spectra of several of the galaxies in the field of 3C 336; G1 is the brightest galaxy within 15″ of the QSO, G4 is probably responsible for the $z = 0.4720$ absorption system in the spectrum of 3C 336, and G11 had a redshift identical to that of the $z = 0.6560$ absorber. G10 has an indeterminate redshift, but its spectral energy distribution suggests that it may have $z \sim 0.9$. See Table 1 for galaxy positions and broad-band photometry.

[O II] λ3727 emission line (35 Å equivalent width in the rest frame). This corresponds to within $\sim$50 km s^{-1} with the absorption redshift of $z_{\rm abs} = 0.4720$ measured by Steidel & Sargent (1992) in the spectrum of 3C 336. We tentatively conclude that G4 is the object responsible for the $z = 0.472$ absorption; while we cannot rule out that either G8 or G13 is a fainter galaxy at this redshift, we will argue below that other considerations more naturally place these fainter galaxies at the higher redshifts of the other absorption systems.

Several attempts were made to obtain spectra of G8, the object 2".9 directly east of the QSO; there is considerable difficulty with scattered light from the QSO, and it turns out that the expected position of [O II] λ3727 emission at $z = 0.656$ corresponds almost exactly with the He II λ3203.7 line at the QSO emission redshift, which we believe we have detected in the QSO spectrum, based on the accompanying O III λ3133 Bowen fluorescence line (see Fig. 3). After subtracting suitably scaled spectra of the QSO from the spectra of G8, we find no evidence for significant [O II] emission corresponding to any of the three known absorption redshifts (or the QSO redshift). We have also examined a high signal-to-noise ratio spectrum of the QSO (taken with a 2".1 slit), and no obvious weak emission lines are present at any of the expected redshifts which might be due to G13. Curiously, G11, a galaxy 14".2 from the QSO sightline, has emission at the expected position for a galaxy at $z = 0.656$ (see Figs. 2 and 3). If G11 is the absorbing galaxy, it would have an impact parameter with the QSO sightline of 65h^{-1} kpc, which would be unprecedented for published examples of absorbing galaxies (see Bergeron & Boisse 1991); we tentatively conclude that G11 is an object in the same group or cluster as that of the object responsible for the $z = 0.656$ absorption system. The cluster interpretation is supported by the redshift of G5, which is $\sim$900 km s^{-1} greater than that of the absorber and G11, $z = 0.661 \pm 0.001$. It is interesting to note that Steidel & Sargent (1992) found preliminary evidence for structure in the $z = 0.656$ absorption system, identifying a tentative second (much weaker) component of absorption at $z = 0.660$ largely on the basis of a Mg II doublet ratio λ2796/λ2803 which was less than one (see the caption to Fig. 4), suggesting that there may be an additional Mg II component for which λ2796 is blended with λ2803 of the $z = 0.6562$ component. In order to check that this was not due to noise in the original spectrum, we obtained a higher resolution (FWHM $\sim$ 2.6 Å) spectrum of 3C 336, and again the unphysical doublet ratio is observed (see Fig. 4). Thus, it is possible that a component of absorption due to G5, which lies at the proper $z = 0.660$, is in fact observed; a spectrum with higher resolution and (especially) signal-to-noise ratio would be required to confirm this.

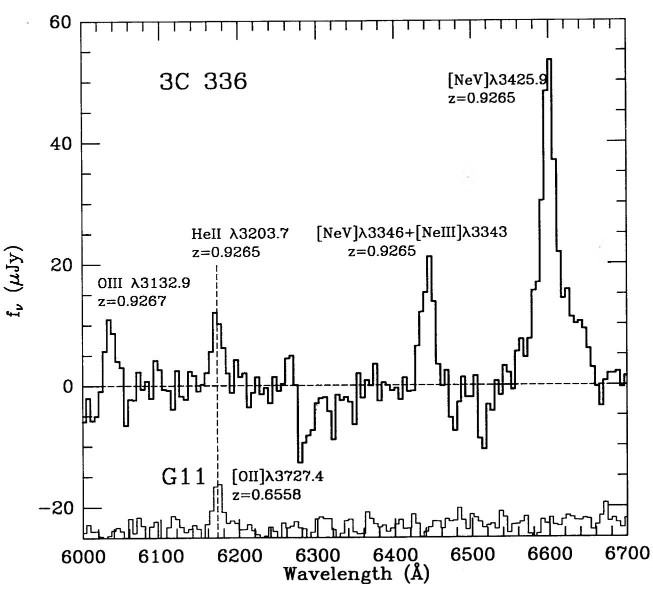

FIG. 3.—Continuum-subtracted spectum of 3C 336, produced in an effort to detect [O II] emission from the $z = 0.6560$ absorbing galaxy, presumed to be G8 (see text). The spectrum of G11, which is 14".2 from the QSO sightline, is also shown with a zero point offset of -25 μJy. Note that the expected position of λ3727 emission corresponds exactly to the line in the QSO spectrum which we identify with He II λ3203.7 at $z = 0.9265$. There is no net emission detectable from G8 after subtraction of scattered QSO light.

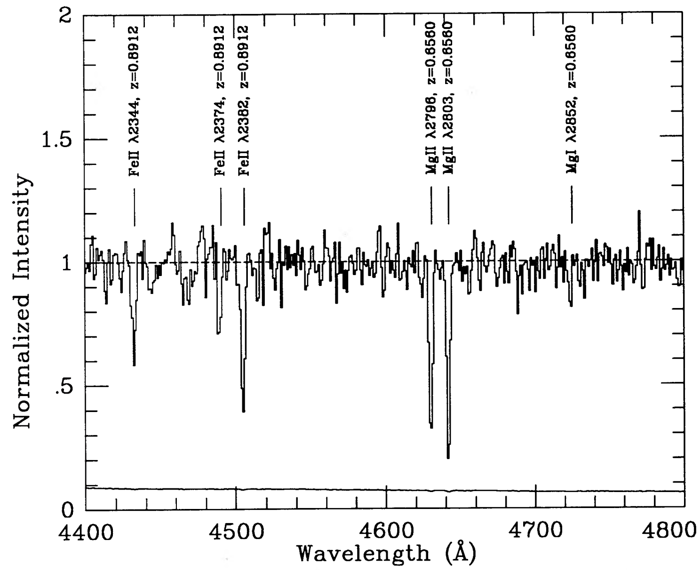

FIG. 4.—A spectrum of 3C 336 (obtained at the Lick Observatory 3 m telescope) normalized to the continuum, showing the Mg II absorption doublet from the $z = 0.6560$ system, together with the 1 σ error spectrum. The strength of the λ2803 component significantly exceeds the λ2796 component (which is not a physically possible doublet ratio unless there is contamination of the longer wavelength component), in agreement with a spectrum previously obtained at Palomar Observatory. We suggest the possibility that there may be an additional Mg II absorption component whose λ2796 component coincides with λ2803 at $z = 0.6560$, or a velocity shift of $\sim$800 km s^{-1}. As discussed in the text, object G5 has a redshift which is consistent to within the errors with this value.

The brightest galaxy within 15" of the QSO, G1, we identify as an elliptical or early type spiral galaxy at $z = 0.327$; no absorption at this redshift was detected in the spectrum of 3C 336 by either Steidel & Sargent (1992) or Thompson et al. (1992); the 5 σ upper limit on the rest equivalent width of the Mg II λ2796 absorption line at this redshift is 0.2 Å (Steidel & Sargent 1992). The projected separation of the QSO sightline from G1 is 37h^{-1} kpc for $h = H_0/100$ km s^{-1} Mpc^{-1} and $q_0 = 0$. G10 has an inconclusive spectrum, although it is extremely red [$(g - i)_{AB} > 3$], and we argue that on the basis of its spectral shape (which is corroborated by the broadband color), it is consistent with being a galaxy at either $z = 0.892$ (one of the absorber redshifts) or $z = 0.927$ (the QSO redshift). Thus, the concentration of galaxies to the north of the QSO consists of galaxies having at least three different redshifts, and at least two of them may be members of a putative cluster of galaxies at $z \sim 0.66$.

3. DISCUSSION

3.1. *The* $z = 0.472$ *Absorbing Galaxy*

The most interesting property of galaxy G4, which we have asserted is the $z = 0.4722$ absorber, is its faint apparent magnitude. In the sample recently published by Bergeron & Boisse (1991), the typical r magnitude of the absorbing galaxies at comparable redshift is ~ 21, whereas we find $\mathscr{R}_{AB} = 22.5$ for G4 (note that $\mathscr{R}$ is a significantly redder bandpass than r, so that the difference is even more significant for a normal reddish galaxy spectrum). By using the observed spectrum of G4 in combination with the broadband photometry, we estimate that the observed B-magnitude in a Vega-normalized photometric system (e.g., the Johnson system) would be $B \sim 24.1$. This places G4 at roughly the same magnitude as the faintest galaxies observed in the recent spectroscopic survey of Lilly et al. (1991). To estimate the absolute (rest frame) B-magnitude of G4, we use the following relation:

$$M_B = m(B') + 5 - 5 \log [6 \times 10^9 z(1 + z/2)] + 2.5 \log (1 + z) - 0.07$$

where $m(B')$ is the AB-magnitude evaluated synthetically from our spectrum over the redshifted B bandpass $[(1 + z)B_{\lambda 0}]$, and the final term is the correction between B_{AB} and Johnson B obtained from the spectral energy distribution of Vega. This expression assumes that $H_0 = 50$ km s^{-1} Mpc^{-1} and $q_0 = 0$. Thus, we find $M_B(\mathrm{G4}) = -19.55$. With the adopted cosmological parameters, the absolute magnitude of an L^* galaxy is $M_B = -21.0$, thus the luminosity of G4 is $\sim 0.25L^*$, which is less luminous than the LMC ($\sim 0.36L^*$). Comparing G4 with the sample of Bergeron & Boisse (1991), it is ~ 0.7 mag less luminous than the faintest galaxy in that sample. On the other hand, the observed impact parameter of the QSO sightline with G4 is $\theta = 5\overset{''}{.}8$, corresponding to $D = 23h^{-1}$ kpc for $q_0 = 0$, which is equal to the median impact parameter observed by Bergeron & Boisse (1991). Admitting the possibility (which we regard as unlikely, for reasons given in § 3.2 below) that one of the fainter galaxies (G8 or G13) closer to the QSO sightline might also be at $z = 0.472$, the impact parameter would be smaller, but the absolute magnitude of the absorber would be even less luminous.

The implications are that the absorbing galaxy luminosity function extends at least down to dwarf galaxies less luminous than the LMC, and that, if our interpretation of G4 as the $z = 0.472$ absorber is correct, then even such an intrinsically faint object possesses a very extended gaseous envelope.

3.2. *A Cluster at* $z = 0.656$?

Thompson et al. (1992) have argued that it is unlikely that the concentration of galaxies near 3C 336 on the plane of the sky is due to a rich cluster at the redshift of the QSO, as suggested by Hintzen et al. (1991), based on the absence of [O II] $\lambda 3727$ emission at the putative cluster redshift. Our spectra of galaxies in the field strongly support this conclusion, as we have demonstrated that the galaxies within 15" of the QSO (the radius used by Hintzen et al. (1991) for evaluating the statistical significance of excess galaxy counts near the QSOs) are situated at many different redshifts, and none of the galaxies for which redshifts could be determined have $z = 0.927$. On the other hand, we find marginal evidence for a galaxy cluster at $z = 0.656$ based on only three measured redshifts, two of which are identical within the errors (G11 and whatever galaxy is responsible for the $z = 0.6560$ absorption system, assuming we are correct that G11 is not the absorber) and one which differs from those two by ~ 900 km s^{-1}. Clearly one cannot claim the existence of a foreground cluster until many more galaxies have confirmed redshifts; however, there is still a rather significant concentration of galaxies with comparable apparent magnitudes ($\mathscr{R}_{AB} \sim 23$) in the 3C 336 field (several of which do comprise the dense concentration to the NW of the QSO). If they are at $z = 0.656$, they are within a few tenths of a magnitude of L^*, thus requiring no substantial luminosity evolution to be reconciled with present-day cluster galaxies; their colors [i.e., steep $(g - \mathscr{R})_{AB}$ and relatively flat $(\mathscr{R} - i)_{AB}$] are consistent with galaxies at that redshift.

We have not been able to spectroscopically confirm the $z = 0.6562$ absorber, but either G8 or G13 is very likely to be the galaxy responsible. At $z = 0.656$, G8 and G13 would have absolute magnitudes of $M_B = -20.5$ and -20.0, respectively, (although the magnitude of G13 is highly uncertain because of problems with systematic error introduced in subtracting the bright QSO image), or $\sim 0.6L^*$ and $\sim 0.4L^*$, and impact parameters with the QSO sightline of $D = 13h^{-1}$ kpc and $D = 7h^{-1}$ kpc, respectively. It is interesting to note that G8 was found to have a marginal excess in the narrow band tuned to [O II] $\lambda 3727$ at $z = 0.927$ by Thompson et al. (1992); we find no evidence for line emission in its spectrum, but it turns out that the off-band frame centered at 7110 Å used by Thompson et al. (1992) to establish narrow-band excess falls very close to the $\lambda 4300$ Å "G-band" absorption feature due to Fe lines and CH molecular bands at a redshift of $z = 0.656$. This could conceivably produce the marginal apparent "line excess." We therefore tentatively suggest that G8 is the $z_{\mathrm{abs}} = 0.656$ absorbing galaxy, and that, by the process of elimination, G13 is likely to be the $z_{\mathrm{abs}} = 0.892$ absorber. This redshift is supported by the rather red $(\mathscr{R} - i)_{AB}$ color (see Table 1), since the two bandpasses are essentially on either side of the 4000 Å break at $z = 0.89$. If G13 is at $z = 0.892$, it would have a rest frame blue luminosity of $\sim L^*$ and an impact parameter with the QSO sightline of $D \sim 8.5h^{-1}$ kpc. It will prove extremely difficult to confirm the redshift of G13, but the inferred properties and impact parameter are quite consistent with the findings of Bergeron & Boisse (1991), although their results generally apply to galaxies at somewhat lower redshift. We also note that the absorption line properties of the $z_{\mathrm{abs}} = 0.8912$ system, i.e., very strong Mg II absorption, detectable Mg I, and strong Fe II lines, are consistent with the types of systems expected to arise from relatively small galactocentric impact parameters according to qualitative models of gaseous galaxy halos (cf. Lanzetta & Bowen 1990; Steidel & Sargent 1992). Similarly, the relatively large impact parameter of the $z = 0.472$ absorption system is consistent with the weaker Mg II absorption observed and the absence of detectable Fe II or Mg I lines. Finally, we have observed marginal evidence for the presence of absorption at $z = 0.660$ in the spectrum of 3C 336, possibly due to G5. The projected separation of G5 from the QSO sightline is $43h^{-1}$ kpc, somewhat larger than the largest separation in the sample of Bergeron & Boisse (1991); however, the absorption, if real, is weaker than the typical system in their sample.

3.3. *General Implications*

The field of 3C 336 is just one of the 52 absorber fields we are investigating in an effort to establish the luminosity function and general properties of the Mg II absorbing galaxies; however, it is not only the richest in terms of the number of moderate redshift absorbers ($z < 0.9$), but it has yielded two possible "counter-examples" to what has become the standard picture of Mg II absorbing galaxies. The first is an example of a dwarf galaxy *with an extended gaseous halo*; there has been some controversy about whether the galaxies heretofore identified as Mg II absorbers are really the objects responsible for the absorption, or whether it is really a dwarf which is "hidden" beneath the bright QSO image. If dwarfs (as well as brighter galaxies) in general possess the large gas cross-section implied for G4, then on average, even if the object responsible for Mg II absorption is intrinsically faint, it is likely to be observable in deep images, particularly if care is taken in PSF subtraction of the QSO image wherever possible. It is interesting to note in passing that it is galaxies with properties similar to G4 which appear to be dominating the faint B band number counts (see, e.g., Lilly et al. 1991, and references therein), which are too numerous by a very large factor as compared with the local galaxy luminosity function. Perhaps the most successful model to date to account for the evolution of the faint blue galaxies is one in which intrinsically low-mass galaxies are undergoing a burst of star formation at moderate redshift, and by the present time they have ceased forming stars and have therefore settled to their much fainter quiescent luminosities and are therefore not included in local estimates of the luminosity function (cf. Broadhurst, Ellis, & Shanks 1988; Colless et al. 1990; Lilly et al. 1991). Under this hypothesis, however, it might be unexpected that such low-mass systems would have such large gaseous envelopes. It remains to be seen what fraction of the total gas cross-section of galaxies is contributed by low-luminosity objects such as G4.

The second example is the possibility that we have found Mg II absorption arising in a cluster galaxy at $z = 0.66$, although more work is certainly required to prove that the putative cluster exists. (There are several examples in the literature of *groups* of objects at the same redshift as QSO absorbers [e.g., Yanny, York, & Williams 1990]). There are some good reasons to believe that cluster galaxies are likely to lose whatever extended gaseous halo they might have initially possessed on a much shorter time scale than field galaxies because of frequent tidal interactions which would tend to strip away loosely bound gas; in this sense, observations of absorption by cluster galaxies at high redshift may represent an interesting probe of the state of the cluster evolution. Several of our fields (for which the spectroscopy is not yet complete) exhibit rich concentrations of galaxies, and it is likely that absorption by cluster galaxies is not unique to the 3C 336 line of sight. It will be interesting to see whether there is a correlation between Mg II absorption systems with kinematics indicating large velocity spreads ($\gtrsim 500$ km s^{-1}) and the presence of a foreground cluster.

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