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ARE LYMAN-ALPHA CLOUDS ASSOCIATED WITH LOW SURFACE BRIGHTNESS GALAXIES?

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ABSTRACT

We have searched for low surface brightness (LSB) galaxies near the line of sight to QSO 3C 273 in two mosaic images covering a maximum area of $53' \times 52'$ on the sky down to a limiting central surface brightness of 26.4 (in Gunn *r*). From trials to detect simulated LSB galaxies of various sizes and appearances, we conclude that known types of such objects cannot be causing the two absorption lines at the lowest redshifts ($cz = 1012$ km s^{-1} and $cz = 1582$ km s^{-1}) if within 106 h_{75}^{-1} kpc and 164 h_{75}^{-1} kpc, respectively, of the line of sight. If galaxies are responsible for these two clouds, they must be either fainter than our detection limits or lie beyond the edges of our images. Galaxies close in velocity to one or the other of the two absorption systems occurring out to at least 1.1 h_{75}^{-1} Mpc (projected transverse separation) are found from the literature. We find mounting evidence that many Lyα absorption systems are tracing the same large-scale structures as galaxies although it is not clear whether in the majority of cases there is a physical connection between absorbers and galaxies other than association in redshift. Coherent absorption on Mpc scales is unlikely to be associated with a single galaxy.

Subject headings: quasars: absorption lines — quasars: individual (3C 273)

1. INTRODUCTION

The recent detection of low-redshift Lyα and heavy-element absorption systems (Morris et al. 1991; Bahcall et al. 1991, and subsequent papers of the *HST* QSO absorption-line key project) provides us with the opportunity to study absorbing gas in the local universe where one may hope to identify any luminous objects possibly associated with them. Beginning with the work of Bergeron (1986) the existence of a connection between galaxies and the low-redshift metal or heavy-element absorption systems has been demonstrated convincingly, but it is not clear whether this is true for the majority of absorption systems, in particular those referred to as Lyα forest absorbers.

A major objection to the interpretation of the physical nature of the absorption systems in terms of galaxies had been the huge sizes required if the absorption arises in lines of sight through known types of galaxies (Burbidge et al. 1977). To explain the high rate of incidence the underlying astronomical objects have to be either huge or very common, and if absorption lines arise in galaxies, gigantic galactic halos or disks are required to produce the large cross sections. A wide range of models has been studied, beginning with gaseous galactic halos, which had in fact been predicted to give rise to a variety of metal ions and their absorption lines as found in heavy-element absorption systems (Spitzer 1956; Bahcall & Spitzer 1969; Bahcall & Salpeter 1965). Alternatively, it has been suggested that the extended disks of known (Maloney 1992) or unknown (Salpeter 1993) galaxy populations may provide the cross section. Morris & van den Bergh (1994) have invoked a variant of the pressure-confinement model (Sargent et al. 1980) where gas from the tidal debris of galaxy-galaxy interactions may account for the Lyman absorption. Hydrogen gas confined by cold dark matter mini-halos has been suggested by Ikeuchi (1986) and Rees (1986). Nonequilibrium gas clouds forming and dispersing under the influence of gravity and photoheating were investigated by Bond, Szalay, & Silk (1988), Cen et al. (1994), Petitjean, Mücket, & Kates (1995), and Hernquist et al. (1995). Wang (1995) has examined radiatively cooling supernova-driven winds as sources of Lyα absorption.

On the observational side, Salzer (1992), Morris et al. (1993), and Hoffman, Lewis, & Salpeter (1995) have searched for galaxies giving rise to the Lyα forest absorption in the field near the line of sight (LOS) to 3C 273, the QSO in whose spectrum the low-redshift Lyα forest was first discovered. It turned out that none of their individual galaxies could be securely identified with one of the 17 Lyα systems visible in the spectrum of 3C 273, but there are several normal galaxies close enough in velocity space to some of the clouds that they could give rise to the absorption, assuming that at impact parameters of up to half a Mpc from the centers of the galaxies H I column densities of order 10^{13} cm^{-2} still occur. The low-redshift Lyα absorbers in the 3C 273 LOS do have a significant correlation with galaxies, but the absorber galaxy correlation function is much weaker on large (10 Mpc) scales than the galaxy-galaxy correlation function.

Mo & Morris (1994) have set limits on the possible composition of the absorber population, considering three simple model populations: (i) randomly distributed absorbers, (ii) absorbers with the same distribution as galaxies, but not physically part of detected galaxies, and (iii) absorbers which are part of detected galaxies (i.e., galaxy halos). A mixture of 75% "random" and 25% "halo" absorbers give the best match to the data, although the observed small-scale correlation with galaxies can be produced by a relatively small admixture of halo absorbers (as little as 10%), and the data are also consistent with galaxy halos producing up to 30% of the observed absorption lines. If none of the absorption is produced by such halos, i.e., if there are no absorbers physically associated with a galaxy in this sample with measured redshifts, then the

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observed correlation is marginally consistent with a 50:50 mix of random and galaxy-like absorbers.

In a complementary study, Lanzetta et al. (1995) publish results for a redshift survey of six QSO LOS containing 26 Lyα absorbers as detected in *HST* FOS spectra. Lanzetta et al. argue that a much higher fraction of the Lyα absorbers in their QSO LOS is produced by material in the halos of galaxies (68% ± 18%) than Mo & Morris found. This discrepancy is likely due to the different ranges of absorber column density in the two studies. While the (ongoing) Lanzetta et al. survey covers a considerably larger total path length, the *HST* FOS data used did not probe to as low a column density as the GHRS data used by Morris et al. (1993).

In addition, Lanzetta et al. found an anticorrelation between Lyα absorber equivalent width (EW) and impact parameter to the nearest galaxy. Such a correlation must clearly be present at some level given that at impact parameters of less than 10–20 kpc one would expect a damped Lyα absorber, while at sufficiently large impact parameters there should be no correlated absorption.

Stocke et al. (1995) have obtained new *HST* high-resolution spectra of three different LOS, comparing the redshift distribution of Lyα absorption systems to the spatial distribution of bright galaxies from existing galaxy catalogs. Their results confirm that *low* column density absorbers tend to occur at random positions relative to individual galaxies. Nevertheless, there seems to be a general tendency for the higher column density systems to reside in walls and superclusters of galaxies, although there are several instances of absorbers in voids.

It is always possible that *all* low-redshift Lyα absorbers could be associated with galaxies, but the galaxies would need to have extremely low surface brightness to have escaped detection in earlier studies. It has been argued that the detection of galaxies is subject to serious selection effects (Disney 1976; Davies 1993; McGaugh 1994), so existing surveys may be missing a substantial number (and possibly the majority of) galaxies because they do not exhibit a surface brightness suitable for detection. Thus it is not unreasonable to suspect that low surface brightness (LSB) galaxies could be the underlying population of all or most QSO absorbers, a possibility that has been proposed previously for the special class of Mg II metal absorption systems (Phillips, Disney, & Davies 1993).

The past decade has brought detections of LSB galaxies spanning the same range of luminosities as "normal" galaxies (by definition the ones known from existing surveys). In particular, the dwarfs in the Virgo Cluster (Sandage & Binggeli 1984) and the LSB giants like Malin 1 or F568-6 (Bothun et al. 1987, 1990) come to mind. Both numerous dwarfs as well as extended LSB giants could in principle make a contribution to the product of number density of absorbers times cross section, $n\sigma$, which determines the rate of incidence of absorption systems.

In the present paper we would like to address the question whether it is possible to identify the low-redshift Lyα forest absorption systems with any LSB galaxies. We describe a search for candidate types of LSB galaxies taken from both the high- and low-luminosity end of the galaxy luminosity function. For this purpose we have revisited the two lowest redshift column density Lyα systems in the LOS toward QSO 3C 273 (Weymann et al. 1995a). These two systems ($cz = 1012$ km s^{-1} and 1582 km s^{-1}) fall in the range of the assumed velocity extent of the Virgo Cluster and exhibit moderately high column densities ($\log N_{\rm col} = 14.19$ and 14.22). We have obtained two deep composite images at Palomar and Las Campanas observatories to look for any underlying galaxies. The proximity of the clouds to us and the limited angular field size of current CCD cameras made it necessary to create a mosaic of individual exposures to continuously cover a field with a radius of order 100 kpc.

(Since the two lowest redshift clouds coincide roughly with the assumed velocity extent of the virgo Cluster we note here for reference that a velocity of recession of $cz = 1200$ km s^{-1} *for a pure Hubble flow* implies a proper distance $D = 16\ h_{75}^{-1}$ Mpc, and a distance modulus $\mu = 31.01 - 5 \log h_{75}$. In reality, the velocity field in this region may, however, be much more complex; see for example, Fig. 12 of Jacoby et al. 1992).

2. OBSERVATIONS

2.1. *The COSMIC Image*

The first image (Fig. 1 [Pl. 5]) is a 15'.7 × 15'.9 mosaic of images obtained with the Carnegie prime focus camera COSMIC, installed on the 200 inch (5.1 m) Hale telescope on Mount Palomar. Three individual Gunn *r* band exposures of 600 s, duration were added for each quadrant of the image. The scale was 0''.28 per pixel. The image is oriented such that north is up and east is right.

This image was flatfielded with a skyflat obtained from 14 exposures offset by at least 15'' from each other.

Since the image extends only to about 31 h_{75}^{-1} kpc away from the LOS (for the lowest redshift cloud) to the QSO, we decided to also obtain a larger mosaic at Las Campanas giving approximately a 1° field.

2.2. *The Las Campanas Image*

The Las Campanas mosaic (Fig. 3) extends over 53'.3 × 52'.4 corresponding to a radial coverage out to about 109 h_{75}^{-1} kpc ($cz = 1012$ km s^{-1} cloud) or 164 h_{75}^{-1} kpc ($cz = 1582$ km s^{-1}) away from the LOS to 3C 273. It consists of 3 × 3 sets of 3 individual 1200 s exposures each in the Gunn *r* band, taken with the Las Campanas 1 m telescope. The large-scale gradients of the skyflat near sunset or sunrise were taken out and replaced by the large-scale variation of a superflat created from all nightsky exposures. Individual exposures on the 3C 273 field were offset by at least 1' with respect to each other to avoid dividing out any extended objects up to that size scale. While most parts of the image appear reasonably flat, some of the southernmost exposures show a significant variation both within their field and relative to their neighbors. This is presumably caused by reflections of bright stars in and near the field off the filter surfaces and edges. Unfortunately this reduces somewhat the value of the image for the detection of very extended LSB objects.

2.3. *Detection Limits*

Close inspection by eye shows nothing conspicuous in any of the images. Which types of galaxies would we have been able to see?

To measure the sensitivity for detection of any LSB objects we added fake galaxies with random positions and inclination angles to the image and tried to detect them by eye, using the IRAF[1] ARTDATA routines. All galaxies were assumed to be at the fiducial distance of the Virgo Cluster, for our purposes taken to be 16 Mpc. LSB galaxies may be drawn from the

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whole range of the galaxy luminosity function so we chose galaxies spanning large intervals in parameter space. The apparent magnitudes in Gunn r ranged from 10.4 to 18.5 with galaxy scale lengths R between 2 kpc and 92.3 kpc, thus allowing for the extended Virgo "dwarfs" as well as for giant LSB types like Malin 1.

The galaxies were taken to be exponential disks with radial surface brightness distribution

$$\Sigma(r) = \Sigma(0) \exp\left(-1.6783 \frac{r}{R}\right), \quad (1)$$

where R is the radius including half of the light. The central surface brightness $\Sigma(0)$ is related to the total flux $F_{\rm tot}$ by

$$\Sigma(0) = \frac{F_{\rm tot}(1.6783)^2}{2\pi R^2}. \quad (2)$$

Expressing Σ in terms of magnitudes per square arcsecond,

$$\Sigma^m(0) = m + 5 \log R'' + 0.8711, \quad (3)$$

where m is the apparent magnitude and R'' is the above scale length in arcseconds.

Figure 2 (Plate 6) shows a number of simulated galaxies superposed on the COSMIC mosaic. The numbers refer to the entries in Table 1. Two of us have independently tried to detect these objects (and others in other images), and reached good agreement as to what constitutes a detection. The entry in the last column of Table 1 indicates a certain detection in our judgment.

We also performed more systematic simulations of galaxies in the larger Las Campanas mosaic (Fig. 3 [Pl. 7]), including larger objects with the luminosities and scale lengths of the Malin 1 propotype. Generally, a particular combination of magnitude and brightness was considered to be detectable if nine out of 10 galaxies with these parameters were found by eye. Table 2 gives the limiting magnitudes versus half-light radius R which still could have been detected according to this criterion.

From this table (and also from Table 1) it is clear that the most important criterion for detection is the limiting central surface brightness, which varies very little for a wide range of radii and magnitudes. Only the smallest objects are more difficult to find (they tend to get confused with stars); the biggest objects (last row of Table 2) are slightly easier to detect in our particular case because their size exceeds the scale of the scattered light patterns in the individual frame (there is less spatial noise on the largest scales).

TABLE 1

EXAMPLES OF SIMULATED GALAXIES SHOWN IN FIGURE 2

Number	m_r	R (kpc)	$\Sigma^m(0)$	Detectable?
1	17.0	4.0	26.4	yes
2	17.0	2.0	24.9	yes
3	18.0	4.0	27.4	no
4	18.0	2.0	25.9	yes
5	17.5	4.0	26.9	yes
6	17.5	2.0	25.4	yes
7	17.0	3.0	25.8	yes
8	17.5	3.0	26.3	yes
9	18.0	3.0	26.8	yes
10	18.5	2.0	26.4	yes
11	18.5	3.0	27.3	no
12	18.5	4.0	27.9	no
13	19.0	2.0	26.9	no

TABLE 2

LIMITING CENTRAL SURFACE BRIGHTNESS IN THE LAS CAMPANAS MOSAIC

R (kpc)	m_r	$\Sigma^m(0)$
2.9......	17.5	25.4
4.0......	17.0	26.4
8.0......	15.5	26.4
40.0......	12.0	26.4
92.3......	10.9	27.2

In conclusion, we believe that we would have seen any object with a surface brightness exceeding about 26.7 r magnitudes in the COSMIC image and about 26.4 for the Las Campanas mosaic. This eliminates known types of Virgo dwarfs and LSB giants as a parent population for the majority of Lyα absorption systems, unless they have very large (radius > 100–160 h_{75}^{-1} kpc) absorption cross sections. Which galaxy candidates for Lyman α absorbers could have escaped detection? Very low luminosity objects like the nearby dE satellites (Sculptor-type, or dwarf spheroidals) of the Galaxy would have been below our detection threshold. With absolute luminosities between -8 and -12 magnitudes and scale lengths of a few kpc these are very difficult to find even at zero redshift; they were originally discovered only because they could be resolved into individual stars which individually exceeded the detection threshold (Cannon, Hawarden, & Tritton 1977; Irwin et al. 1990).

Objects with angular extent approaching the size of our images would obviously have been missed due to the lack of sky background to compare with. Davies et al. (1994) have recently argued that the population of Malin 1-sized objects in the field is rather limited, so larger LSB spirals are presumably even less frequent.

Nevertheless, it is not difficult to imagine objects large enough that their surface brightness may well peak beyond the boundaries of our images, or whose light-to-mass ratio is extremely low. The existence of the Giovanelli-Haynes H I cloud 1225+01 (Giovanelli & Haynes 1989) may serve as an example for a huge H I cloud (at least 200 kpc in optically thick H I gas) very inconspicuous in the optical. The optical counterpart is a young dwarf irregular LSB galaxy (Djorgovski 1990; Impey et al. 1990; McMahon et al. 1990; Salzer et al. 1991). Although this particular dwarf would have been found in our images, and H I column densities as high as in 1225+01 are not common, one could easily imagine that there are more, lower column density clouds in galaxies with even less star formation which we would have missed. Another clue that we may be searching on insufficiently large scales comes from the work by Salpeter & Hoffman (1995), who compile a list of several candidate galaxies from the literature and point out that for both absorption systems considered here there are multiple redshift coincidences with galaxies within several hundred kpcs from the LOS. We have amended their galaxy list by additional objects compiled from the NASA Extragalactic Database (NED). Those galaxies within a square of 200′ and within $\pm cz = 300$ km s^{-1} of the two absorption systems at 1012 and 1582 km s^{-1} are plotted in Figure 4, which is centered on 3C 273. The linear extent of the box shown in R. A. and decl. corresponds to 1.85 h_{75}^{-1} Mpc for a velocity of

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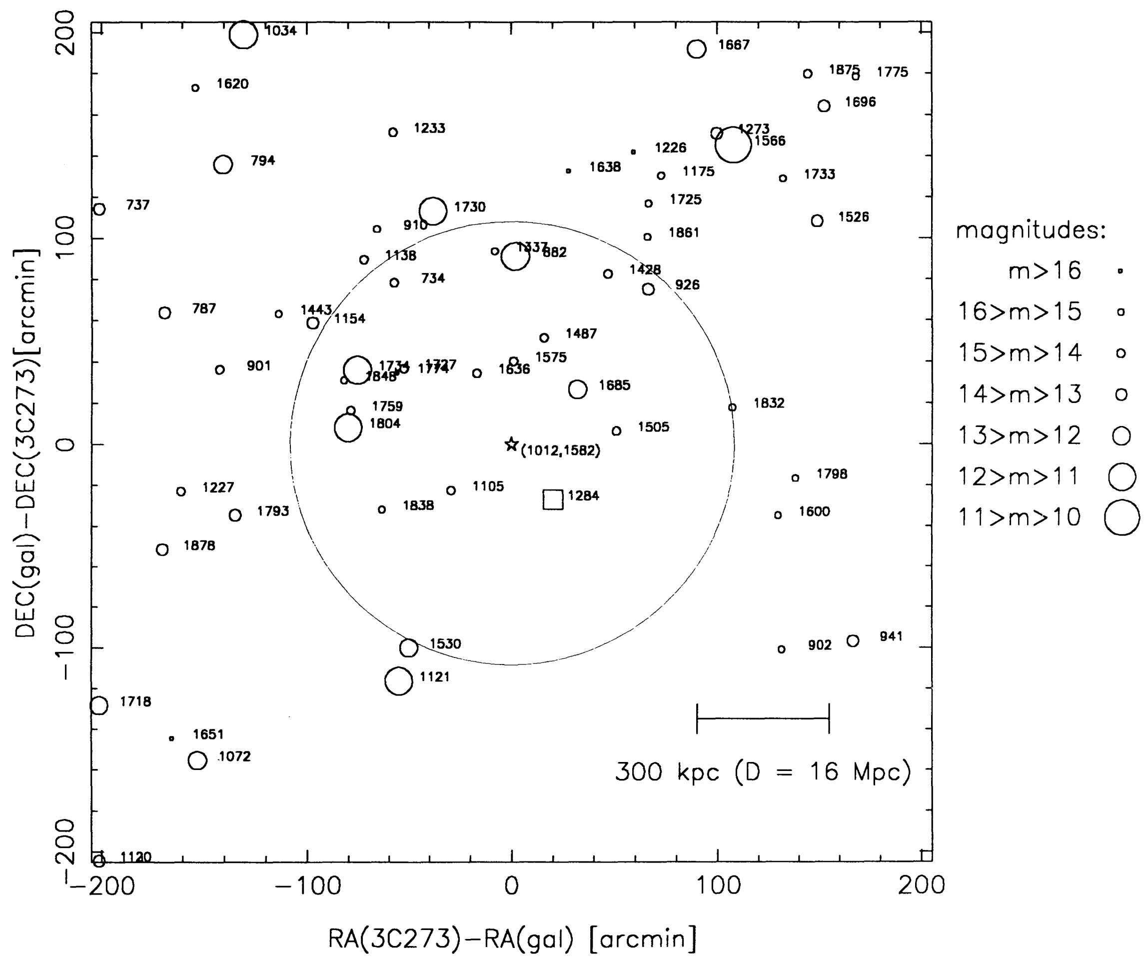

FIG. 4.—Schematic chart of galaxy positions in the field of 3C 273. The QSO is at the center (*star*). Numbers in brackets indicate velocities of recession in km s^{-1}. The double number at the position of the QSO gives the velocities of the two lowest redshift absorption systems seen in the LOS to the QSO. The round symbols denote galaxies within ± 300 km s^{-1} of the 1012 km s^{-1} and 1582 km s^{-1} absorption systems. The square box marks the position of H I 1225+01 (Giovanelli & Haynes 1989). The large circle centered on the QSO shows the average coherence length for Lyα absorbers measured by Dinshaw et al. (1995), given for an intermediate redshift of 1200 km s^{-1}.

recession of 1200 km s^{-1}. The plot shows two noteworthy features of the galaxy/absorber topology: first, we find galaxies close in redshift to each absorption systems out to at least the edges of the plot, and there are several cases for both absorbers where the galaxy redshift differs from the absorption redshift by less than 100 km s^{-1} even at distances of order a Mpc; such large radii are of the same order of magnitude as or larger than the size estimate for coherent Lyα absorption derived by Dinshaw et al. (1995), shown here schematically as a circle with radius 500 h_{75}^{-1} kpc at a distance of 16 Mpc. Second, the transverse separations between galaxies are typically *smaller* than the coherence length for Lyα absorption given by Dinshaw et al. (1995).

Figure 5 shows a projection of the NED galaxy redshift sample plotted versus redshift. All galaxies within a radius of 5° from the LOS to the QSO are taken into account, and the redshift position of the 1012 and 1582 km s^{-1} absorbers plus that of a weak third absorption line at $cz = 2240$ km s^{-1} are indicated by vertical dotted lines. While there is not a very clean correspondence we can still discern a tendency of the absorption systems to coincide in redshift with groups of galaxies, basically confirming the suspicions by Stocke et al.

3. DISCUSSION

What do these observations tell us about the large-scale distribution of absorbing gas, and how are the absorbers related to galaxies?

Obviously, higher column density Lyα absorption systems often occur coincident in redshift with galaxies, as found by Lanzetta et al. (1995) and Stocke et al. (1995). However, there are many instances, as Figures 4 and 5 illustrate, for which there are *several* galaxies within a few hundred km s^{-1} with separations comparable to the impact parameter to the nearest galaxy. Moreover, the transverse coherence length for common absorption appears to be larger than the average transverse distance between the galaxies (see also Weymann et al. 1995b) so it seems doubtful that the large "cloud sizes" or "coherence lengths" derived from studies of common Lyα absorption in multiple QSO spectra (Bechtold et al. 1994; Dinshaw et al. 1994, 1995) could refer to absorption produced by a *single* galactic disk or halo. Stocke et al. (1995) found that most of the absorbers in their admittedly small sample of lines coincide with galaxy clusters or superclusters, and our results appear to confirm this association of absorbers and galaxy groups for the

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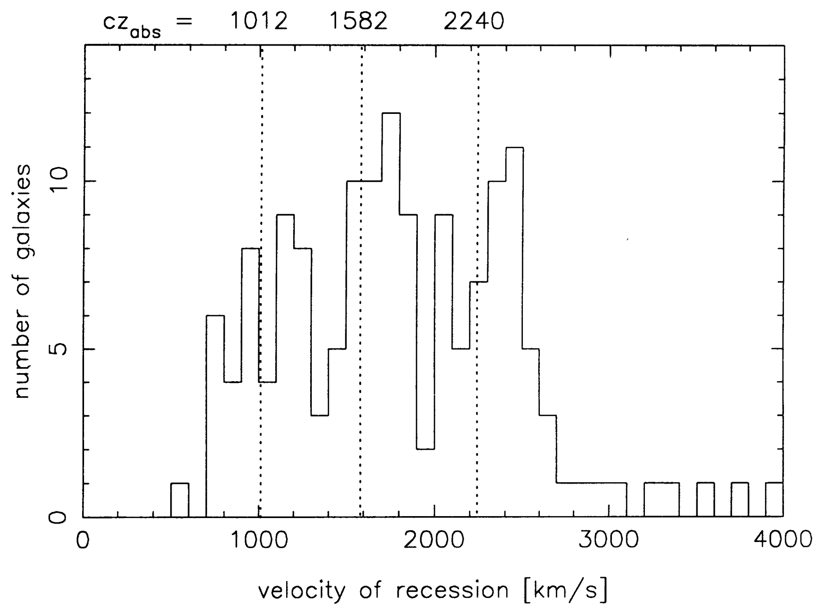

FIG. 5.—Histogram of the velocities of recession for galaxies within 5 degrees of the line of sight to 3C 273. The bin size is 100 km s^{-1}, and the positions of the three lowest redshift absorption systems are indicated by dotted lines.

three absorption lines considered here. Taken together the evidence favors the *identification of most* Lyα *absorbers at low redshift with the same large-scale structures known from galaxy surveys* (e.g., da Costa et al. 1994, and references therein), lending support to an earlier idea by Oort (1981), who suggested identifying superclusters with possible sources of Lyα absorption.

This idea is consistent with the frequencies with which a LOS intersects absorbers and galaxy large-scale features: we find that the typical mean free path between Lyα absorption systems in the low-redshift *HST*/GHRS observations (3800 km s^{-1}) is fairly similar to the average velocity separation between the "walls" of the cellular structure in the large-scale distribution of galaxies over a similar redshift range (5000 km s^{-1}, see, e.g., Shectman et al. 1992). While most of the absorbers may arise in the gas inhabiting the structures defined by the bulk of the general matter distribution, the good agreement between the above numbers may be sensitive to the detection threshold for the absorption lines, and the mean free path is bound to become shorter as more and weaker lines are being discovered; Morris et al. (1993) and Stocke et al. (1995) have indeed shown that there are additional absorbers in "voids."

The relative success in relating Lyα absorption to galaxy groups (Stocke et al. 1995; Salpeter & Hoffman 1995; Weymann et al. 1995b; the present work) implies that gas occupies these structures with a significant filling factor. One may think of numerous individual objects (e.g., the galaxies themselves) or, alternatively, large continuous gaseous bodies filling the structures in which the galaxies are embedded. The large transverse sizes and small velocity differences of Lyα absorbers measured by Bechtold et al. (1994) and Dinshaw et al. (1994, 1995) appear to favor spatially coherent and rather quiescent gaseous structures on scales significantly larger than the virial radii of individual galaxies. Moreover, these size estimates, together with the nucleosynthesis upper limit on the baryonic Ω imply that the Lyα forest absorbing structures must be flattened to avoid overfilling the universe with baryons (Rauch & Haehnelt 1994). At present this observational picture appears to be qualitatively consistent with the results of gas-dynamical simulations of gravitational structure formation (Cen et al. 1994; Petitjean et al. 1995; Hernquist et al. 1995). These studies envisage the absorbers as gaseous bodies of low dimensionality (sheets and filaments), connecting and containing the more overdense regions where galaxies have formed. At present it cannot be excluded that there are more, lower column density systems which are not accounted for by gas condensations arising from the gravitational structure formation scenario, but could be due to secondary gasdynamical processes like the outflows suggested by Wang (1995).

Are Lyα absorbers associated with *individual* galaxies? The finding of large-scale structures producing both galaxies and hydrogen absorption with a large cross section links galaxies and absorbers to the same topology but the question whether an individual absorption system is caused by the nearest galaxy (as opposed to intergalactic gas) may boil down to semantics, being testable only for truly isolated galaxies and on scales smaller than the typical intergalactic separation where one may hope to establish a kinematic connection between galaxy and absorption system, as in the case of Mg II or damped Lyα absorbtion systems.

While apparently only a small fraction of all low column density Lyα absorbers occurs within, say, a hundred kpc of a bright galaxy (Morris et al. 1993; Stocke et al. 1995), there could well be a more numerous population of much fainter galaxies which either have faded or never have had conspicuous star formation and whose original gas content has now spread over a large volume, as discussed in the context of faint blue galaxies by Babul & Rees (1992), Bechtold et al. (1994), and Wang (1995). The metal contamination of intermediate column density Lyα absorbers recently found by Cowie et al. (1995) and Tytler et al. (1995) appears to favor gas expelled or tidally stripped from galaxies, but as yet these results refer only to a small fraction of all Lyα absorbers and it remains to be shown that the chemical composition of the majority of systems deviates from that of a primordial gas.

Both gaseous sheets or weakly clustered arrays of now invisible low-mass "galaxies" arranged in a similar geometry could in principle explain the large coherence length and weak corre-

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lation with bright galaxies. If the gravitational wells of such faint galaxies are sufficiently shallow the motion of the gas may be dominated by the large-scale motion (e.g., Hubble expansion) of the embedding structure rather than by the velocity dispersion of an individual galaxy, consistent with the observational finding of only small velocity differences between two widely separated lines of sight.

How can we distinguish between these scenarios? From high-resolution observations with the *HST* GHRS (Weymann et al. 1995a) we know that at least the two lowest redshift Lyα absorption lines toward 3C 273 show Doppler widths in excess of photoionization temperatures. At the signal-to-noise level obtained the line profiles are consistent with single Voigt profiles, but both have Doppler parameters (40.7 and 34.2 km s^{-1}) higher than expected from photoheated gas without bulk motions. This is quite similar to systems at much higher redshift (Carswell et al. 1984), so we have reason to believe that this is a general feature of Lyα forest systems. If the gaseous regions responsible for the absorption are large, flattened, coherent objects (e.g., "pancakes"), the gas may still partake in the Hubble expansion along the collapsed plane, and a LOS hitting at angles less than 90° would find absorption broadened by the bulk motion of the gas (the orientation of the galaxy "plane" could be derived by measuring the position of galaxies in redshift space, assuming the validity of the Hubble law as a first approximation). If, however, the absorption arises in individual bound galactic halos we would not expect a correlation between line broadening and aspect angle. Such a test performed on many absorber-galaxy groups may be able to distinguish between an intergalactic or galactic origin of the absorption systems.

4. SUMMARY

We conclude that low surface brightness dE/dIm dwarf galaxies typical of those of the Virgo Cluster, or giant LSB disk galaxies like Malin 1 are not responsible for the two lowest redshift Lyα forest clouds seen toward QSO 3C 273. We may have missed objects of these types whose surface brightness peaks beyond the edges of our images. Although many absorption systems do not occur close to galaxies in transverse projection, they do agree in redshift with galaxies at large impact parameters of order Mpcs. The transverse projected distances between galaxies coincident in redshift are *smaller* than recent estimates of the transverse sizes of the absorption systems. This argues against *single* extended galactic disks or halos contributing the bulk of the coherent absorption cross section on these large scales.

The mean free path between two absorbers at low redshift (~ 3800 km s^{-1}) is fairly similar to the average distance between "walls" in the galaxy distribution (~ 5000 km s^{-1}).

These findings favor the idea that in many cases both galaxies and coincident absorption systems trace the general matter distribution on large scales. Sheetlike or filamentary gaseous structures, as predicted by recent simulations of gravitational structure formation, appear to be consistent with these observations. Gas stripped or blown away from galaxies as well as truly intergalactic gas tracing the large-scale matter distribution may cause the Lyα absorption phenomenon at low redshift.

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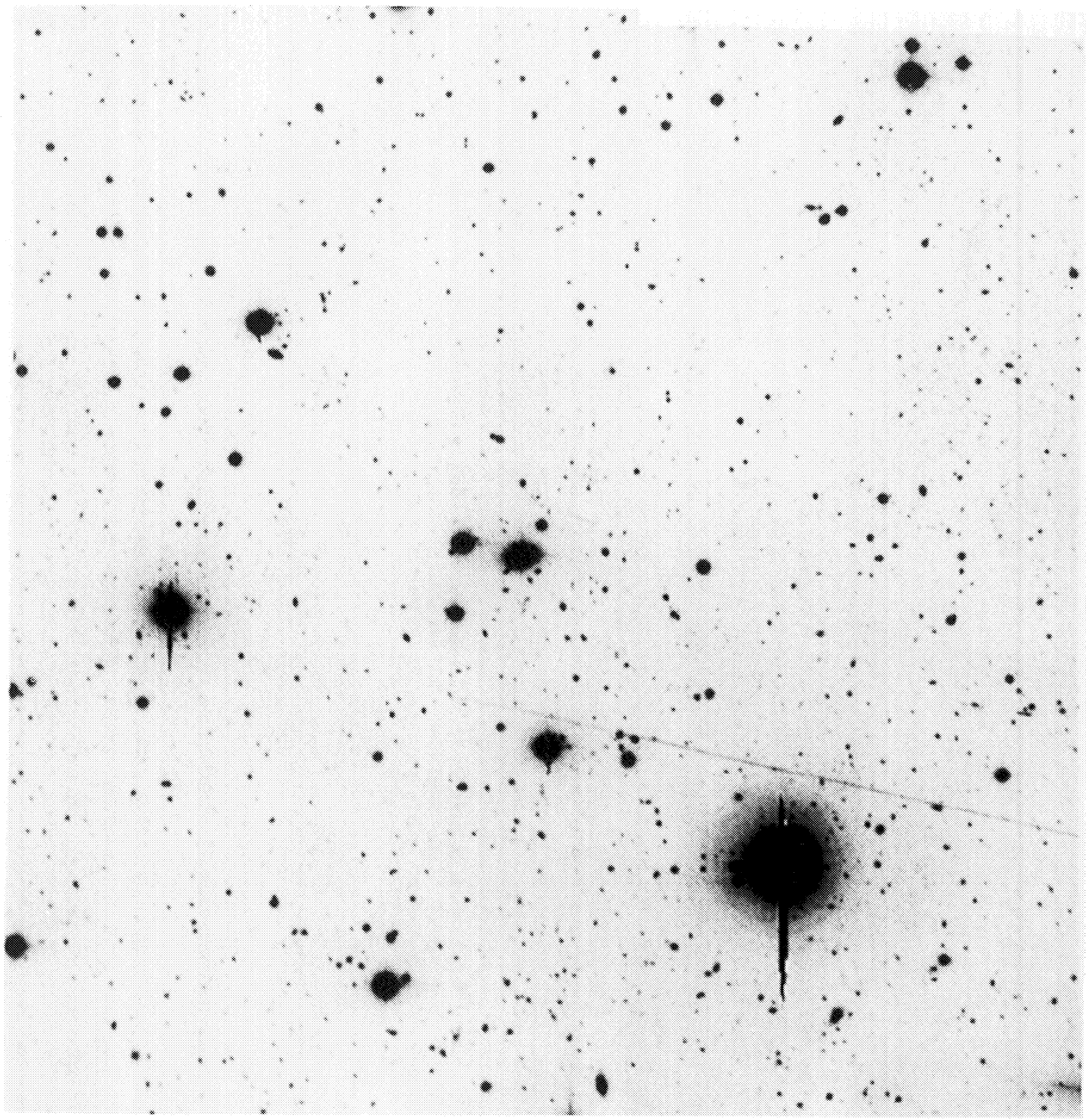

FIG. 1.—The COSMIC 200 inch (5.1 m) image of the field of QSO 3C 273. The field size is approximately 15′.7 × 15′.9. North is up, and east is right.

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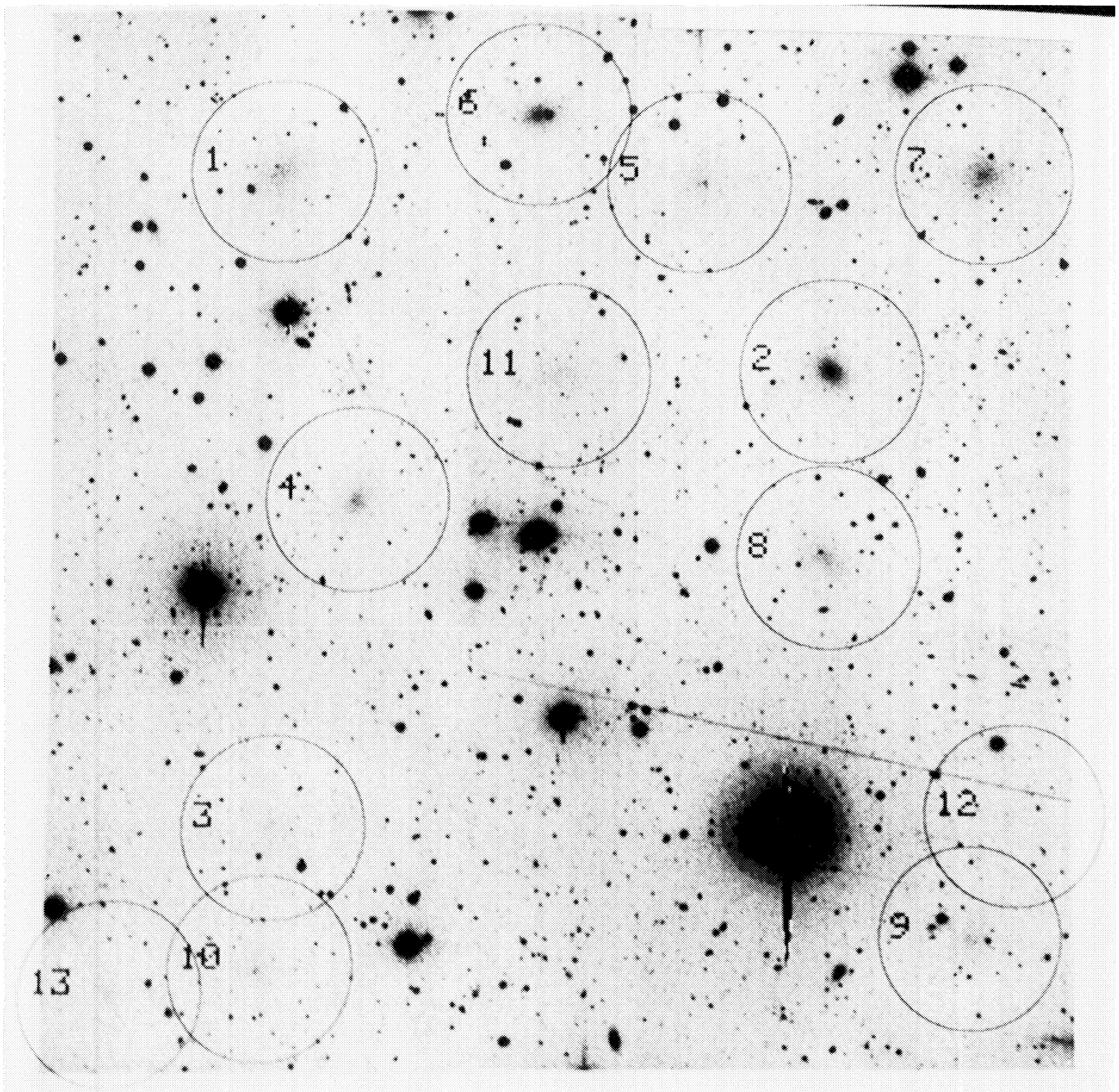

FIG. 2.—Same image as in Fig. 1, but now with simulated galaxies superposed. Numbers refer to the entries in Table 1.

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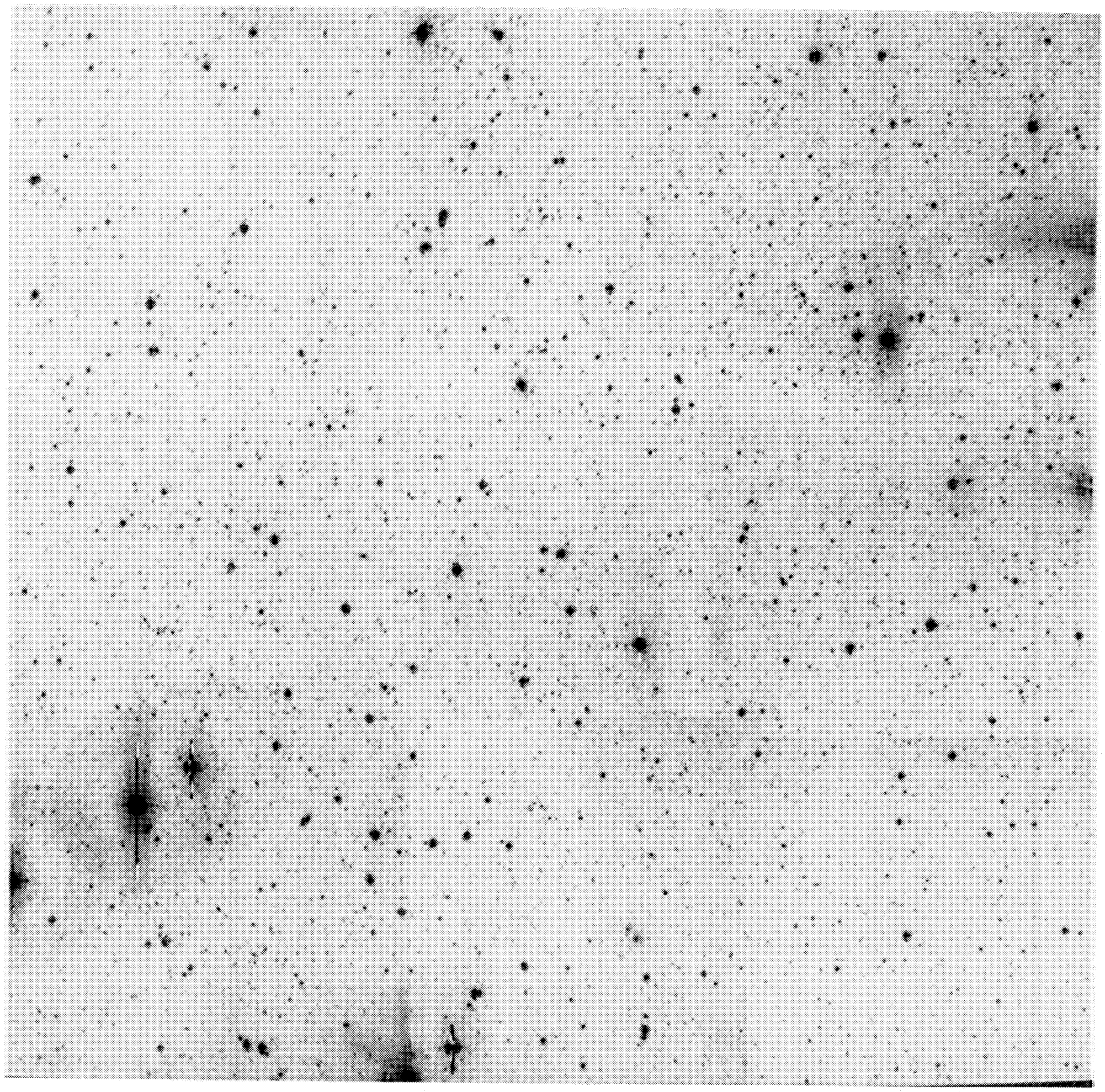

FIG. 3.—The Las Campanas 40 inch (1 m) image (approximate size 53′.3 × 52′.4)

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