THE H I ENVIRONMENT OF NEARBY LYMAN-ALPHA ABSORBERS

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ABSTRACT

We present the results of a VLA and WSRT search for H i emission from the vicinity of seven nearby clouds, which were observed in Ly alpha absorption with HST toward Mrk 335, Mrk 501, and PKS 2155–304. Around the absorbers, we searched a volume of 40′ × 40′ × 1000 km s−1; for one of the absorbers we probed a velocity range of only 600 km s−1. The H i mass sensitivity (5σ) very close to the lines of sight varies from 5 × 10^6 M_☉ at best to 5 × 10^8 M_☉ at worst. We detected H i emission in the vicinity of four out of seven absorbers. The closest galaxy we find to the absorbers is a small dwarf galaxy at a projected distance of 68 h^−1 kpc from the sight line toward Mrk 335. This optically uncataloged galaxy has the same velocity (V = 1970 km s^−1) as one of the absorbers, is fainter than the SMC, and has an H i mass of only 4 × 10^7 M_☉. We found a somewhat more luminous galaxy at exactly the velocity (V = 5100 km s^−1) of one of the absorbers toward PKS 2155–304 at a projected distance of 230 h^−1 kpc from the sight line. Two other, stronger absorbers toward PKS 2155–304 at V = 17 000 km s^−1 appear to be associated with a loose group of three bright spiral galaxies, at projected distances of 300 to 600 h^−1 kpc. These results support the conclusions emerging from optical searches that most nearby Lyalpha forest clouds trace the large-scale structures outlined by the optically luminous galaxies, although this is still based on small-number statistics. We do not find any evidence from the H i distribution or kinematics that there is a physical association between an absorber and its closest galaxy. While the absorbing clouds are at the systemic velocity of the galaxies, the H i extent of the galaxies is fairly typical, and at least an order of magnitude smaller than the projected distance to the sight line at which the absorbers are seen. On the other hand, we also do not find evidence against such a connection. In total, we detected H i emission from five galaxies, of which two were previously uncataloged and one did not have a known redshift. No H i emission was detected from the vicinity of the two absorbers, which are located in a void and a region of very low galaxy density; but the limits are somewhat less stringent than for the other sight lines. These results are similar to what has been found in optically unbiased H i surveys. Thus, the presence of Lyalpha absorbers does not significantly alter the H i detection rate in their environment. © 1996 American Astronomical Society.

1. INTRODUCTION

The plethora of low column density, intervening Ly alpha absorption lines in the spectra of high redshift QSO's (the "Lyalpha forest") was first recognized by Lynds (1971) and has been described in detail by Sargent et al. (1980) and in many recent reviews and articles (Bajtlik 1993; Weymann 1993; Bechtold 1993; Rauch et al. 1992; Rauch et al. 1993; Lu et al. 1991; Smette et al. 1992). A considerable amount has been learned about the nature of these systems at redshifts z ≥ 1.6, the redshift above which Lyalpha is observable from the ground. These redshifts are generally too large to directly detect the absorbing objects in emission. However, more recently, a modest number of Lyalpha absorbers at low redshift have been detected in the UV (Morris et al. 1991; Bahcall et al. 1991). The proximity of these systems make them ideal targets for searches for H i and optical emission from the vicinity of these clouds. One can also seek possible identifications of parent objects with which the clouds might be associated.

The first low-redshift Lyalpha forest absorption lines were
discovered in the IUE spectrum of PKS 2155-304 by Maraschi et al. (1988). Since then, the HST has revealed many low column density absorbers in the nearby universe (Bahcall et al. 1991; Bahcall et al. 1993; Morris et al. 1991; Bruhweiler et al. 1993; Stocke et al. 1995; Shull et al. 1996). Statistical studies have been made to determine the relative correlation between these Lyα absorbing clouds and optical galaxies (Morris et al. 1991; Salzer 1992; Stocke et al. 1995; Lanzetta et al. 1995; Mo & Morris 1994; Morris et al. 1993; Morris & van den Bergh 1994). The current consensus is that the systems do correlate weakly with bright galaxies, but less so than the galaxies with other galaxies (Stocke et al. 1995). Lanzetta et al. (1995) find good evidence that some of the stronger Lyα absorbers are physically close to galaxies, but there are also examples of clouds with no optical galaxy to within a few Mpc (Stocke et al. 1995; Shull et al. 1996). Morris et al. (1991) find, in one instance, an anti-correlation between a region of very high galaxy density and Lyα forest absorbing clouds. Stocke et al. (1995) find more generally that: "the higher equivalent width absorbers are distributed more like galaxies than the lower equivalent width absorbers, which are distributed in a manner statistically indistinguishable from clouds randomly placed with respect to galaxies."

In this paper, we present a search for H I emission from the vicinity of seven nearby Lyα absorbers. H I imaging surveys routinely find gas-rich, optically uncataloged galaxies, and as such our search is complementary to the optical surveys mentioned above. In addition to searching for a possible parent population of the Lyα absorbers, the H I morphology of galaxies close to the line of sight might betray hints of unusually large gaseous extents. In the first study of this kind (van Gorkom et al. 1993) a deep search for H I emission was made around two Lyα clouds on the SC 273 line of sight, which are located in the outskirts of the Virgo Cluster. No obvious associations between these two Lyα clouds and H I emitting galaxies were found. The seven systems studied here are located in a wide range of cosmic environments. The absorbers seen along the sight line toward Mrk 501 are located in a void and a very low density region, respectively, while the other five absorbers are located in regions of moderately high galaxy density, along the sight lines toward PKS 2155-304 and Mrk 335. The results of the H I search near the sight line toward Mrk 501 have already been presented by Stocke et al. (1995). Here, those observations will be presented in somewhat more detail. We describe the systems and observations in Secs. 2 and 3. We present the results in Sec. 4, and in Sec. 5 we briefly discuss their implications.

Throughout this paper we adopt heliocentric velocities, using the optical definition, \( V_{\text{opt}} = c z \), where \( c \) is the speed of light and the redshift is defined as \( z = \frac{\lambda - \lambda_0}{\lambda_0} \), where \( \lambda \) and \( \lambda_0 \) are the observed and rest wavelengths, respectively.

2. THE SYSTEMS

The seven absorption-line systems have been discovered by different authors and their properties can be found in the literature. In Table 1 we summarize the sources against which they have been found, the heliocentric velocities of the lines, and the measured equivalent widths. In this table we also give the projected distance to our H I detection closest to the line of sight and the difference between the velocity of the absorption line and the systemic velocity of the galaxy as derived from the H I.

Two of the systems are seen in absorption against the BL Lac object Mrk 501, which is located in the "Great Wall" of galaxies at heliocentric velocity 10 300 km s\(^{-1}\). The two absorbing systems are at 7530 km s\(^{-1}\) and 4660 km s\(^{-1}\) (Stocke et al. 1995). The 7530 km s\(^{-1}\) system is located in the void between us and the great wall, it has no cataloged optical galaxies within 4.5h\(^{-1}\) Mpc, where \( h \) is the Hubble constant in units of 100 km s\(^{-1}\) Mpc\(^{-1}\). The 4670 km s\(^{-1}\) system has a sparse chain of galaxies located to the southwest, the closest of which is 25\(\prime\) (340h\(^{-1}\) kpc) off the line of sight to Mrk 501.

The detections of five, and possibly six, local Lyα forest lines have been reported for the sight line toward the BL Lac object PKS 2155-304 (Bruhweiler et al. 1993; Maraschi et al. 1988; Allen et al. 1993). We did an H I search around the three stronger lines, at 5100 km s\(^{-1}\), 16 488 km s\(^{-1}\) and 17 088 km s\(^{-1}\), respectively. The last two velocities are uncertain by about 140 km s\(^{-1}\). The lower velocity system is on the edge of the Perseus-Pisces supercluster; its nearest cataloged galaxy is ESO 466-G032, 15\(\prime\) (230h\(^{-1}\) kpc) east of the sight line toward PKS 2155-304 with a systemic velocity of 5187 km s\(^{-1}\). The higher velocity systems have a number of cataloged galaxies at similar velocities not far from the line of sight. The closest is 2155-3033 (from the CfA redshift catalog), an Sb spiral 6.4\(\prime\) (305h\(^{-1}\) kpc) to the SW of the line of sight to PKS 2155-304 with a systemic velocity of 17 300 km s\(^{-1}\).

The third sight line that we investigated is toward Mrk 335, which has four Lyα absorption lines (Stocke et al. 1995). Here, we observed the two lower velocity systems, which are close together in velocity at 1970 and 2290 km s\(^{-1}\). These systems are located in a supercluster region. The closest cataloged galaxy is NGC 7817, an SAbc spiral, 46.5\(\prime\) (311h\(^{-1}\) kpc) to the NE of the sight line toward Mrk 335 and with a systemic velocity of 2209 km s\(^{-1}\).

The H I column densities for the absorbing systems are all in the range of \( 10^{16.4} \) cm\(^{-2}\) (assuming a Doppler parameter \( b = 30 \) km s\(^{-1}\)), except for the complex absorption lines around 17 000 km s\(^{-1}\). For these, a large column density, \( \sim 10^{18} \) cm\(^{-2}\), has been derived (Maraschi et al. 1988), placing it in the lower column density range of heavy elements.

<table>
<thead>
<tr>
<th>Source</th>
<th>( V_{\text{opt}} ) km s(^{-1})</th>
<th>( \Delta V ) km s(^{-1})</th>
<th>( V_{\text{Lyα}} - V_{\text{HI}} ) of nearest galaxy</th>
</tr>
</thead>
<tbody>
<tr>
<td>MKN 501</td>
<td>4660</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MKN 501</td>
<td>7530</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>PKS 2155-304</td>
<td>5100</td>
<td>480</td>
<td>230 ( h^{-1} ) kpc</td>
</tr>
<tr>
<td>PKS 2155-304</td>
<td>16 488</td>
<td>350</td>
<td>0</td>
</tr>
<tr>
<td>PKS 2155-304</td>
<td>17 100</td>
<td>810</td>
<td>305 ( h^{-1} ) kpc</td>
</tr>
<tr>
<td>Mrk 335</td>
<td>1970</td>
<td>170</td>
<td>68 ( h^{-1} ) kpc</td>
</tr>
<tr>
<td>Mrk 335</td>
<td>2290</td>
<td>73</td>
<td>20 ( h^{-1} ) kpc</td>
</tr>
</tbody>
</table>

\( \Delta V \) is the heliocentric corrected central velocity, optical definition.

\( V_{\text{Lyα}} - V_{\text{HI}} \) of nearest galaxy.
quasar absorption line systems. Thus far, no firm detections of metal lines have been made in this system, implying a metallicity < 0.1 solar (Bruhweiler et al. 1993). Note that more recent ORFEUS observations by Appenzeller et al. (1995) find a column density of 5 × 10^{16} cm^{-2} for this system.

### 3. OBSERVATIONS AND DATA PROCESSING

One of the sight lines, the one toward Mrk 501, was observed with the Westerbork Synthesis Radio Telescope (WSRT), while the other searches were done with the Very Large Array (VLA). We describe the observations and data processing for each of the sight lines separately. Table 2 summarizes the observations.

#### 3.1 Mrk 501

The two Lyα absorption systems towards Mrk 501 were observed with the WSRT. Two dozen synthesis observations were made centered at 4885 km s^{-1} with short spacings of 36 m and 54 m, and a single 12 hour synthesis observation, centered at 7740 km s^{-1}. The total velocity range covered in each case was 1000 km s^{-1} at a resolution of 17 km s^{-1}. Standard calibration of the data was performed using the NEWSTAR data reduction software package at NFRA. Further data editing, imaging, and analysis were performed using the AIPS package.

Mrk 501 is a radio continuum source, with an observed flux density at 1.4 GHz of 1.3 Jy. The source is unresolved at 15'' resolution, with a position of 10^5 52' 11.65, 39° 50' 27.1'' (B1950). For the high-velocity system, the pointing center corresponded to the position of the continuum source, while the observations at 4675 km s^{-1} were made pointing 5' to the southwest of Mrk 501 in order to increase sensitivity at the sparse chain of galaxies to the southwest.

Subtraction of the continuum emission from the line data was performed in two ways. The first involved linear fits in frequency to the calibrated complex visibilities (Cornwell et al. 1992). The second involved linear fits in frequency to the multi-channel image cube. The results from the two methods were similar, although the residual artifacts towards the edges of the field were worse for the image-plane subtraction (as expected), and the analysis presented herein relies on the uv-data continuum subtraction method.

Images of Mrk 501 were made using "natural" weighting of the visibilities. The FWHM of the WSRT synthesized beam was 25'' × 15''. The image cubes were smoothed in velocity to 34 km s^{-1} resolution and visually inspected for 21 cm emission signal. No H I signal is seen anywhere in the system.

### Table 2. Observing log.

<table>
<thead>
<tr>
<th>Source</th>
<th>Telescope</th>
<th>Date</th>
<th>Configuration</th>
<th>Velocitya km sec^{-1}</th>
<th>Channel Width kHz</th>
<th>No. Channels</th>
<th>Integration Time Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>MKN 501</td>
<td>WSRT</td>
<td>1993 Dec 18</td>
<td>54m</td>
<td>4675</td>
<td>78</td>
<td>63</td>
<td>12</td>
</tr>
<tr>
<td>MKN 501</td>
<td>WSRT</td>
<td>1994 Jan 9</td>
<td>36m</td>
<td>7350</td>
<td>78</td>
<td>63</td>
<td>12</td>
</tr>
<tr>
<td>MKN 501</td>
<td>WSRT</td>
<td>1994 Feb 3</td>
<td>36m</td>
<td>4675</td>
<td>48.8</td>
<td>63</td>
<td>4</td>
</tr>
<tr>
<td>PKS 2155-304</td>
<td>VLA</td>
<td>1993 Sept 26</td>
<td>DnC</td>
<td>17 400</td>
<td>48.8</td>
<td>63</td>
<td>3</td>
</tr>
<tr>
<td>PKS 2155-304</td>
<td>VLA</td>
<td>1993 Sept 30</td>
<td>DnC</td>
<td>17 400</td>
<td>48.8</td>
<td>63</td>
<td>7</td>
</tr>
<tr>
<td>PKS 2155-304</td>
<td>VLA</td>
<td>1995 Apr 24</td>
<td>D</td>
<td>16 880</td>
<td>195</td>
<td>31</td>
<td>6</td>
</tr>
<tr>
<td>PKS 2155-304</td>
<td>VLA</td>
<td>1995 May 1</td>
<td>D</td>
<td>16 880</td>
<td>195</td>
<td>31</td>
<td>6</td>
</tr>
<tr>
<td>Mrk 335</td>
<td>VLA</td>
<td>1995 Apr 24</td>
<td>D</td>
<td>2135</td>
<td>97.7</td>
<td>63</td>
<td>2</td>
</tr>
<tr>
<td>Mrk 335</td>
<td>VLA</td>
<td>1995 May 1</td>
<td>D</td>
<td>2135</td>
<td>97.7</td>
<td>63</td>
<td>2</td>
</tr>
</tbody>
</table>

*aShortest WSRT spacing in meters, or VLA configuration.  
*bHeliocentric corrected central velocity, optical definition.

### Table 3. Sensitivities.

<table>
<thead>
<tr>
<th>Source</th>
<th>Velocity Range km sec^{-1}</th>
<th>Beam FWHM arcsec</th>
<th>Velocity Resolution km sec^{-1}</th>
<th>Noise(^a) mJy per beam</th>
<th>Mass(^b) × 10^{17} M(_{\odot})</th>
<th>Column Density(^c) cm(^{-2})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mrk 501</td>
<td>4175–5175</td>
<td>25×15</td>
<td>34</td>
<td>0.55</td>
<td>5</td>
<td>2.7</td>
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<tr>
<td>Mrk 501</td>
<td>4175–5175</td>
<td>25×15</td>
<td>34</td>
<td>0.35</td>
<td>7</td>
<td>3.5</td>
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<tr>
<td>Mrk 501</td>
<td>4175–5175</td>
<td>38×38</td>
<td>34</td>
<td>0.90</td>
<td>8</td>
<td>1.1</td>
</tr>
<tr>
<td>Mrk 501</td>
<td>7030–8030</td>
<td>25×15</td>
<td>34</td>
<td>0.80</td>
<td>18</td>
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<td>68</td>
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<td>25</td>
<td>5.5</td>
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<td>Mrk 501</td>
<td>7030–8030</td>
<td>38×38</td>
<td>34</td>
<td>1.40</td>
<td>31</td>
<td>1.6</td>
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<tr>
<td>PKS 2155–304</td>
<td>4844–5409</td>
<td>66×39</td>
<td>21</td>
<td>0.60</td>
<td>4</td>
<td>0.3</td>
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<tr>
<td>PKS 2155–304</td>
<td>4844–5409</td>
<td>66×39</td>
<td>43</td>
<td>0.43</td>
<td>6</td>
<td>0.4</td>
</tr>
<tr>
<td>PKS 2155–304</td>
<td>17100–17723</td>
<td>53×45</td>
<td>46</td>
<td>0.23</td>
<td>34</td>
<td>0.2</td>
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<tr>
<td>PKS 2155–304</td>
<td>16233–17525</td>
<td>98×47</td>
<td>46</td>
<td>0.3</td>
<td>50</td>
<td>0.16</td>
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<tr>
<td>Mrk 335</td>
<td>1660–2660</td>
<td>63×53</td>
<td>25</td>
<td>0.40</td>
<td>0.5</td>
<td>0.16</td>
</tr>
</tbody>
</table>

\(^{a}\) rms per channel. 
\(^{b}\) H I mass per beam per channel at the field center. 
\(^{c}\) H I column density per channel at the field center.
cubes above five times the rms in a given channel. The image cube was then smoothed in both velocity and spatially to 68 km s$^{-1}$ channel$^{-1}$ and to 38" spatial resolution. Again, no emission is seen anywhere in the cubes above five times the rms at any velocity or spatial resolution. The noise values at various resolutions are listed in Table 3.

3.2 PKS 2155–304

PKS 2155–304 was observed twice with the VLA. The first set of observations was done with the 1 km array with an extended (3 km) north arm (DnC configuration) to compensate for the southern declination of the source. The low-velocity system was observed for 4 hours, centered at 5100 km s$^{-1}$, covering 560 km s$^{-1}$ with a velocity resolution of 21 km s$^{-1}$. The high-velocity systems were observed for a total of 10 hours. These observations were centered at 17400 km s$^{-1}$ in an effort to also include a possible Ly$\alpha$ system at 17700 km s$^{-1}$. However, more recent HST data, obtained with the Faint Object Spectrograph and G130H grating do not confirm the reality of that system (Allen et al. 1993). The total velocity range covered was 620 km s$^{-1}$ with a velocity resolution of 23 km s$^{-1}$. All those data suffered from rather serious interference. The high velocity system was observed with the VLA in the 1 km (D) configuration to make up for the loss of data due to interference and to cover also the Ly$\alpha$ system at 16488 km s$^{-1}$. The time on source was again 10 hours. The observations were centered at 16480 km s$^{-1}$ and covered 1280 km s$^{-1}$ with a resolution of 46 km s$^{-1}$. Unfortunately, these observations were made during daytime and the data suffered rather badly from solar interference.

PKS 2155–304 is a radio continuum source, with a variable flux density. We measured a flux density of 0.45 Jy at 1.4 GHz. All observations were centered at the radio position of the BL Lac object, 21$^h$ 55$^m$ 58.30$^s$, $-30^\circ 27' 54.4''$ (B1950). Standard calibration procedures were followed, giving special care to the bandpass calibration. A bandpass calibrator was observed once every 2 hours, and for each data point we used the bandpass solution closest in time. Initially, we subtracted the continuum by making a linear fit in frequency to the calibrated complex visibilities, using the inner 75% of the band. After the continuum subtraction, the data were clipped to remove solar and man-made interference. Images were made of each of the observing runs separately. After inspection of the cubes to locate the channels with H$\alpha$ emission, the subtraction of the continuum was redone, making a fit to the line free channels only.

For the low velocity system, images were made using natural weighting, resulting in a FWHM of the synthesized beam of 66"×39". For the high-velocity systems the data of the various observing runs were combined in the uv plane, after Hanning smoothing the data of the first run down to the resolution of the second run. Images were made using natural weighting, resulting in a synthesized beam of 97.8"×47.2". Several galaxies were detected in H$\alpha$, one in the low-velocity data and three in the high-velocity data. These results are described in Sec. 4.

![Contour images of the velocity channels for the sight line toward Mrk 335. Only the area around the uncataloged dwarf, which was detected in H$\alpha$ emission is shown. The optical position of the galaxy center is shown with a cross. heliocentric velocities in km s$^{-1}$ are indicated in the top right corner of each panel. The ellipse in the top left panel is the size of synthesized beam. Contour levels are $-2.1, 1, 2.3, 4, 5, 6$, and 7 mJy per beam. Negative contours are dashed.](image-url)

FIG. 1. Contour images of the velocity channels for the sight line toward Mrk 335. Only the area around the uncataloged dwarf, which was detected in H$\alpha$ emission is shown. The optical position of the galaxy center is shown with a cross. heliocentric velocities in km s$^{-1}$ are indicated in the top right corner of each panel. The ellipse in the top left panel is the size of synthesized beam. Contour levels are $-2.1, 1, 2.3, 4, 5, 6$, and 7 mJy per beam. Negative contours are dashed.

3.3 Mrk 335

We observed Mrk 335 with the VLA in the 1 km (D) array for 4 hours in total. The observations were centered at 2135 km s$^{-1}$ in between the velocities of the two Ly$\alpha$ absorbers, covering a range of 1000 km s$^{-1}$ with a velocity resolution of 25 km s$^{-1}$. The observations were centered at the optical position of the Seyfert galaxy, at 00$^h$ 03$^m$ 45.2$^s$, 19$^\circ$ 55' 28.6" (B1950). The Seyfert galaxy itself is not a radio continuum source. We subtracted background continuum sources by making a linear fit to the calibrated complex visibilities. Images were made using natural weighting, resulting in a synthesized beam of 62.8"×52.7". One previously uncataloged galaxy was discovered in H$\alpha$. We describe this result in the next section.

For the H$\alpha$ detections, we made images of the total hydrogen emission by smoothing the data spatially and in velocity, using the smoothed cube as a mask for the full-resolution data. Only pixels above 2$\sigma$ in the smoothed cube were used in the sum. Throughout this paper we use images of the digitized POSS to show overlays of neutral hydrogen emission on optical images.

4. RESULTS

4.1 Upper Limits

Although the more interesting result of this work is the detection of so many galaxies, the upper limits we can place...
4.2 H I Detections

4.2.1 Mrk 335

Perhaps the most exciting result of these observations is the detection of the small dwarf near the sight line toward Mrk 335. Contour images of the velocity channels are shown in Fig. 1. Although the emission is not resolved in individual channels, the peak of the emission clearly shifts in position with velocity. The maximum displacement of the peaks gives us a lower limit to the H I extent, which is 45" or 4.2 h⁻¹ kpc. A position - velocity profile along the major axis of the galaxy (at a PA of 0°) is shown in Fig. 2. To put things in perspective, we show in Fig. 3 an overlay of the total H I emission onto an optical image, which includes Mrk 335 as well. Although the H I is more extended than the optical emission of this tiny dwarf galaxy, there is a huge distance (68 h⁻¹ kpc) between the lowest H I contour (at 4.8 × 10¹⁹ cm⁻²) and the sight line toward Mrk 335. The H I properties derived from this observation are summarized in Table 4. The systemic velocity as derived from the H I differs by only 20 km s⁻¹ from that of the higher column density absorber at 1970 km s⁻¹.

4.2.2 PKS 2155-304

At low velocities, we detect H I emission from ESO 466-G032, located 230 h⁻¹ kpc to the east of the line of sight. This dwarf is detected at a velocity of 12 km s⁻¹, which is consistent with the systemic velocity of Mrk 335. The H I properties derived from this observation are summarized in Table 4. The systemic velocity as derived from the H I differs by only 20 km s⁻¹ from that of the higher column density absorber at 1970 km s⁻¹.
sight to PKS 2155−304. This is the closest optically cataloged galaxy to the line of sight. The H I is seen over the velocity range 5080 km s$^{-1}$ to 5130 km s$^{-1}$. Contour images of the velocity channels at 11.7 km s$^{-1}$ resolution are shown in Fig. 4. Crosses mark the optical position of the H I emitting galaxy. The systemic velocity as derived from the H I profile is 5100 km s$^{-1}$, significantly less than the reported optical value of 5187 km s$^{-1}$. Optically, the galaxy looks rather disturbed, with a spiral arm (or tidal feature?) extending to the southwest. The H I emission is just barely above the noise. Although it appears to be slightly extended in the direction of the extended optical feature, the synthesized beam is extended in the same direction. There is a hint of rotation along the optical major axis of the galaxy, with the receding side to the northeast (Fig. 4). The angular resolution of the current data is not sufficient to say any more about the H I morphology; the signal is only barely resolved. The H I parameters are summarized in Table 4. Again, to put things in perspective we show in Fig. 5 an H I overlay on an optical image including both the galaxy and the BL Lac object.

The high-velocity data cube covers the velocity range from 16 240 km s$^{-1}$ to 17 720 km s$^{-1}$, but the quality varies across the band. At velocities in excess of 17 500 km s$^{-1}$, the data quality is poor. We detect H I emission from three galaxies. The galaxy closest to the line of sight, 2155−3033, is at a projected distance of 305 h$^{-1}$ kpc to the south. The H I emission from this galaxy is barely above the noise. A weak signal is seen over velocities from 16 900 km s$^{-1}$ to 17 300 km s$^{-1}$, with no detectable H I in the two middle channels (Fig. 6). The systemic velocity derived from the H I is 17 100 km s$^{-1}$, the optical redshift gives a velocity of 17 300 km s$^{-1}$.

A much stronger H I emitter is found to the southeast at a projected distance of 610 h$^{-1}$ kpc. This is an IRAS source, F21569-330, with a hitherto unknown redshift. The H I emission can be seen over a velocity range from 16 650 km s$^{-1}$ to 16 925 km s$^{-1}$ (Fig. 7). The kinematic major axis lies along the optical major axis at a PA of $-40^\circ$, with the north side receding. A position velocity profile along the major axis is shown in Fig. 8.

Almost due north of PKS 2155–304 we detect an optically uncataloged galaxy at a projected distance of 515 h$^{-1}$ kpc from the line of sight. H I can be seen in emission from 17 063 km s$^{-1}$ to 17 248 km s$^{-1}$ (Fig. 9). The kinematic major axis is east–west and a position velocity profile along this axis is shown in Fig. 10. Optically the galaxy looks distorted, slightly extended to the northwest with what are possibly two dwarf companions. The H I parameters derived from these observations are listed in Table 4. Finally, to put things in perspective, we show in Fig. 11 an overlay of the H I emission of the three galaxies detected in the high velocity cube on an optical image, which shows, in addition to the galaxies, PKS 2155–304.

5. Discussion

Our search for H I emission from the vicinity of nearby Ly$\alpha$ absorbers has resulted in the detection of five galaxies, two of which were previously uncataloged. We shall first discuss whether this detection rate is unusual in any sense: does the presence of a Ly$\alpha$ absorber increase the chance of finding H I in emission? Following that, we shall discuss what we have learned from the detections, and whether there is any indication that the H I in emission is related to the Ly$\alpha$ absorption. Finally we will discuss whether the present observations have illuminated the nature of the nearby Ly$\alpha$ absorbers.

A variety of data is available to assess whether our detection rate of H I-rich systems is unusual in any way. Briggs

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**Table 4. Galaxies detected in H I.**

<table>
<thead>
<tr>
<th>Sight line</th>
<th>Name</th>
<th>RA (1950)</th>
<th>Dec (1950)</th>
<th>$V_{\text{sys}}$ (km s$^{-1}$)</th>
<th>Velocity Range (km s$^{-1}$)</th>
<th>$M_{\text{HI}} \times 10^{10} h^{-2} M_\odot$</th>
</tr>
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<tr>
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<td>00 02</td>
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<td>+19</td>
<td>56</td>
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</tr>
<tr>
<td>PKS 2155−304</td>
<td>ESO 466–G032</td>
<td>21 57</td>
<td>+08.8</td>
<td>−30</td>
<td>25</td>
<td>25.8</td>
</tr>
<tr>
<td>PKS 2155−304</td>
<td>F21569-330</td>
<td>21 56</td>
<td>+56.0</td>
<td>−30</td>
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<tr>
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<td>+03.6</td>
<td>−30</td>
<td>17</td>
<td>08.7</td>
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</tbody>
</table>

---

**Fig. 4.** Contour images of the velocity channels of ESO 466–G032, which is located close to the sight line of PKS 2155–304 at the same velocity as the absorber at 5100 km s$^{-1}$. The optical position of the galaxy center is shown with a cross, heliocentric velocities in km s$^{-1}$ are indicated in the top right corner of each panel. The ellipse in the top left panel is the size of synthesized beam. Contour levels are $-1.3, 1.3, 2.6, 3.9,$ and $5.2$ mJy per beam, negative contours are dashed.
Fig. 5. An overlay of the H i column density distribution (contours) of ESO 466-G032 on an optical image (greyscale), which shows both the galaxy and PKS 2155-304. The contour interval is $4.2 \times 10^{19}$ cm$^{-2}$. The arrow points to PKS 2155-304.

(1990) summarized the results of all major unbiased H i surveys, while the currently most accurate H i luminosity function has been constructed by Rao & Briggs (1993). More specific and directly comparable to our result is the work by Weinberg et al. (1991) and Szomoru et al. (1994, 1996), who used the VLA to do unbiased H i surveys in environments of differing galaxian density. Szomoru et al. (1994) probed voids as well as supercluster environments and compared fields centered on optically known galaxies and optically blank fields.

For simplicity sake, we take as the volume searched in our survey the region within a radius of 22' from the pointing center. This is the 20% point of the primary beam; beyond that, the shape of the beam is highly uncertain. Our search within that volume is complete to the 5\sigma limits listed in Table 3, multiplied by five (correcting for the primary beam response). The volume searched down to a mass limit of $2 \times 10^9 M_\odot$ of H i is $60 h^{-3}$ Mpc$^3$. In this volume, we detected three galaxies with H i masses of a few times $10^9 M_\odot$ of H i, giving a density of $0.05 \pm 0.02$ Mpc$^{-3}$. The volume searched down to $5 \times 10^8 M_\odot$ of H i is much smaller, $6.8 h^{-3}$ Mpc$^3$. Two galaxies of even smaller masses were detected in that volume, bringing the galaxy density in the mass range of $10^7 M_\odot$ to $5 \times 10^8$ to $0.3 \pm 0.2 h^3$ Mpc$^{-3}$. These H i mass densities are quite consistent with the results of Briggs (1990), who found a density of $0.07 h^3$ Mpc$^{-3}$ and $0.1 h^3$ Mpc$^{-3}$ for H i masses of a few times $10^9 M_\odot$ and

Fig. 6. Contour images of the velocity channels of the galaxy 2155-3033, south of PKS 2155-304. The optical position of the galaxy center is shown with a cross, heliocentric velocities in km s$^{-1}$ are indicated in the top right corner of each panel. The ellipse indicates the size of the synthesized beam. Contour levels are $-1.2$, $-0.6$, $0.6$, $1.2$, and $1.8$ mJy per beam. Negative contours are dashed.

Fig. 7. Contour images of the velocity channels of F21569-330, a galaxy to the south east of PKS 2155-304. The optical position of the galaxy is shown with a cross, heliocentric velocities in km s$^{-1}$ are indicated in the top right corner of each panel. The ellipse indicates the size of the synthesized beam. The contour levels are $-0.7$, $0.7$, $1.4$, and $2.1$ mJy per beam. Negative contours are dashed.
Fig. 8. A position velocity profile along the major axis of F21569-330 at a position angle of $-40^\circ$. Contour levels are $-1, 1, 2,$ and $3$ mJy per beam. Negative contours are dashed.

$10^8 M_\odot$, respectively. Only a small fraction of the volume searched, $7h^{-3} \text{Mpc}^3$, is in a true void; the remaining volume is more characteristic of supercluster densities. Weinberg et al. (1991) found a cumulative space density of $0.13h^3 \text{Mpc}^{-3}$ for gas rich dwarfs above $10^8 M_\odot$ of H I in the Perseus-Pisces supercluster, a result similar to ours. In conclusion, although the statistics are small, it appears that the influence of nearby Lya forest absorbers has not significantly altered the detection rate of H I emitting objects in either the void or the high-density regions.

5.1 The Markarian 335 Sight Line

Nevertheless, the detections of two galaxies almost exactly at the velocity of their nearby Lya absorbers, and the fact that these are the only detections in a 500 and 1000 km s$^{-1}$ range for PKS 2155−304 and Mrk 335, respectively, beg the question whether there is a possible association between the galaxies and the absorbers. The most tantalizing system is the uncataloged dwarf galaxy at a projected distance of $68h^{-1}$ kpc from the line of sight toward Mrk 335. The absolute magnitude of this dwarf has been estimated to be $M_B = -15.4$ based upon a linear extrapolation of the calibration supplied by eight, nearby HST guide stars on the digitized version of the POSS-E plate material. This approximate magnitude assumes that $H_0 = 100$ km s$^{-1}$ Mpc$^{-1}$ despite the location of this object within the bounds of the local supercluster. The proximity, spatially and in velocity, of the Lya absorber and dwarf irregular could mean no more than that they originated in a common larger scale structure, e.g., a filament (Cen et al. 1994; Hernquist et al. 1996; Miralda-Escudé et al. 1996; Mücke et al. 1996). Alternatively, it could imply that the Lya cloud is gravitationally bound to the dwarf. Perhaps, it is still falling in or has been ejected in a galactic wind. The kinematic structure does not help to choose between these various possibilities. The minimum dynamical mass in the Lya cloud + dwarf galaxy system needed to make it a bound system can be derived by requiring that the total kinetic energy of the system is less or equal to the potential energy. Thus,

$$
M_{\text{dyn}} = \frac{1}{2} G (\Delta V)^2 \Delta R,
$$

where $G$ is the gravitational constant, $\Delta V$ the line-of-sight velocity difference, and $\Delta R$ the projected distance between absorber and galaxy. The minimum dynamical mass is $4.6 \times 10^8 M_\odot$. A crude estimate of the mass of the dwarf galaxy can be obtained from the H I kinematics. Assuming a total H I extent of 3.8 kpc and a rotation velocity of 55 km s$^{-1}$, we find $M = 6.7 \times 10^8 M_\odot$. Thus, in order for the Lya

Fig. 9. Contour images of the velocity channels of the galaxy north of PKS 2155-304. The cross indicates the optical position of the galaxy, heliocentric velocities (km s$^{-1}$) are indicated in the top right corner of each panel. Contour levels are $-0.7, 0.7,$ and $1.4$ mJy per beam. Negative contours are dashed.
cloud to be bound to the galaxy, the dwarf needs to be embedded in a massive dark halo.

An intriguing possibility is that the Lyα absorption arises from within a mostly ionized gas disk of the dwarf galaxy. Maloney (1992) and Stocke et al. (1995) discussed the possibility that nearby Lyα lines could be produced by gas at large radii in the disks of spiral and irregular galaxies. Maloney concludes that the unexpectedly large number of low-redshift Lyα absorption lines seen with HST toward 3C 273 can be produced by extended ionized gas disks in the halos of spiral and irregular galaxies. The observed frequency of absorbers requires that either local galaxies have huge (several hundred kpc) halos or, more plausibly, that the decrease of absorption cross section with declining luminosity is slow enough for low-luminosity galaxies to dominate the integrated cross section. Shull et al. (1996) make the case that, for absorbers of mean radius $R = (100 \text{kpc})R^{100}$, only dwarf galaxies have the comoving space densities

$$\phi_0 = (0.9 \text{Mpc}^{-3})R^{-2}$$

necessary to explain the frequency of low-redshift Lyα clouds. For reference, this density is over 20 times that of $L_\star$ galaxies, recently estimated as $\phi(L_\star) = 0.04h^3 \text{Mpc}^{-3}$ (Marzke et al. 1994).

A first hint that low-luminosity galaxies may indeed dominate the cross section comes from the discovery (Barcons et al. 1995) of possibly corotating Lyα absorption at large (50 kpc) projected distance from two small, late-type spiral galaxies. Contrary to the cases found by Barcons et al. (1995), we have no evidence for corotation of the ionized gas with the galaxy, the Lyα absorption occurs too close to the minor axis of the galaxy. The small velocity difference between the absorber and the systemic velocity of the galaxy is of course not inconsistent with corotation, but at that large distance anything that is bound to the galaxy is expected to have a velocity close to the systemic velocity of the galaxy.

Although Stocke et al. (1995) discussed the possibility of huge ionized halos around a single bright spiral galaxy, it might be possible that the Lyα absorption at $68h^{-1}$ kpc from the dwarf arises in an ionized halo. Using
the model calculations of Maloney (1992) and Dove & Shull (1994), we find that an ionized 80–100 kpc halo is not at all unlikely for a dwarf galaxy. For example, consider a spherical dark-matter halo, with central density \( \rho_0 \), core radius \( r_c \), and asymptotic halo velocity \( v_A = (4 \pi G \rho_0 r_c)^{1/2} = (50 \text{ km s}^{-1}) v_0 \). The three-dimensional velocity dispersion is \( (\sigma_z^2) = (3/2) v_A^2 \). In equilibrium, the gaseous hydrogen will settle into an atmosphere above the disk plane, with density

\[
n_h(z) = n_h(0) e^{-(z^2) / (2 \sigma_z^2)},
\]

where \( \sigma_z = R \sqrt{\sigma_z / \sigma_A} \) is the vertical scaleheight and \( \sigma_A = (18.1 \text{ km s}^{-1}) T_A^{-1/2} \) is the thermal velocity of hydrogen at temperature \( T = (10^3 \text{ K}) T_A \). At a radius \( R = (100 \text{kpc}) R_{100} \) from the galactic center, we may express the total hydrogen density at the disk midplane as,

\[
n_h(0) = \frac{N_H v_A}{(2 \pi)^{1/2} \sigma_z R} = (5.57 \times 10^{-6} \text{ cm}^{-3}) N_{18} R_{100} T_A^{-1/2},
\]

where \( N_H = (10^{18} \text{ cm}^{-2}) N_{18} \) is the total column density of hydrogen, neutral and ionized, integrated through the disk.

In the optically thin limit, the neutral hydrogen density is set by photoionization equilibrium,

\[
n(H^0) = \frac{n_j n_{H^0} \alpha_H^{(1)}}{\Gamma_H},
\]

where we adopt a case-A radiative recombination rate coefficient

\[
\alpha_H^{(1)} = (2.48 \times 10^{-13} \text{ cm}^3 \text{s}^{-1}) T_A^{-0.726}
\]

and a hydrogen photoionization rate \( \Gamma_H = (2.64 \times 10^{-14} \text{s}^{-1}) f_{-23} \). Here, we express the metagalactic ionizing radiation field, \( f = (\nu / \nu_0)^{-\alpha} \), with

\[
I_0 = (10^{-23} \text{ ergs cm}^{-2} \text{s}^{-1}) H_1^{-1/2} f_{-23}
\]

at \( h\nu_0 = 13.6 \text{ eV} \) and adopt a spectral index \( \alpha = 1.5 \). For a fully ionized gas with \( n_H / n_H^0 = 0.1 \) and \( n_j / n_H = 1.2 \), we find \( n(H^0) = (11.25) n_j T_A^{0.67} \Gamma_2^{-1/2} \) and

\[
N_{H^0}(R) = (2.84 \times 10^{13} \text{ cm}^{-2}) N_{18} T_A^{0.67} R_{100}^{-1} T_A^{-1.23} \Gamma_2^{-1/2}.
\]

Note that \( N_{H^0} \) is proportional to \( N_{H^0} / R \), owing to the \( n_j \) dependence of the recombinations that form \( H^1 \). In the inner portions of disks, where the gas layer is optically thick to external ionizing radiation, the \( H^1 \) radial distribution, \( N_{H^1}(R) \), closely tracks that of total hydrogen, \( N_{H}(R) \). However, in the extended disk, beyond the radius at which the integrated column of \( H^1 \) drops below several times \( 10^{19} \text{ cm}^{-2} \), the disk becomes optically thin to ionizing radiation, and the above photoionization analysis applies. In this regime, the radial \( H^1 \) distribution falls off as \( N_{H^1}^2 / R \), which in an exponential gaseous disk results in a very sharp falloff in \( H^1 \). However, in disks with power-law gaseous distributions, \( N_{H^1}(R) \approx R^{-\Gamma} \) \((1 \leq \Gamma \leq 2)\), the \( H^1 \) decreases with radius as \( N_{H^1}(R) \approx R^{-(\Gamma + 1)} \).

Let us now compare these expectations to the observed \( \text{Ly} \alpha \) absorbers, which typically have columns \( N(H^1) \approx 10^{13} \text{ cm}^{-2} \). From Eq. (8), the \( H^1 \)-absorbing \( \text{Ly} \alpha \) cloud has \( H^1 \) column density, \( 10^{13.5} \text{ cm}^{-2} \) at \( R = (68 \text{kpc}) h^{-1} \), the gaseous disk at that radius must have a total hydrogen column density

\[
N_{H}(R) = (0.87 \times 10^{18} \text{ cm}^{-2}) u_{10}^{-1/2} h^{-1/2} T_A^{-1/2} J_{14.3}^{261}, \tag{9}
\]

assuming the optically-thin limit. The VLA observations of the dwarf \( H^1 \) galaxy toward Mrk 335 yield an \( H^1 \) column of \( N_0 = 2.4 \times 10^{19} \text{ cm}^{-2} \) at \( 1' \), corresponding to \( R_0 = 5.73h^{-1} \text{ kpc} \) at the recessional velocity of \( 1700 \text{ km s}^{-1} \). If we assume that the radial distribution of total hydrogen column density is \( N_H(R) = N_0 (r / R_0)^{-1} \) \((i.e., \Gamma = 1)\) and integrate over radii \( R_0 < r < R_{\text{max}} \), where \( R_{\text{max}} = 68h^{-1} \text{ kpc} \), the total gaseous mass of the extended disk is

\[
M_{\text{disk}} = 2 \pi \rho_0 R_0 (R_{\text{max}} - R_0) = (6 \times 10^8 M_\odot) h^{-2}, \tag{10}
\]

where we adopt a mean molecular mass \( \mu = 1.4m_\text{H} \). The mass of the isothermal dark-matter halo required to confine the gas in equilibrium is given by

\[
M_{\text{halo}} = \frac{2 \langle v^2 \rangle R}{G} = (4 \times 10^{10} M_\odot) v_{50}^2 h^{-1}. \tag{11}
\]

The ratio of halo mass to gas mass is therefore \( 66v_{50}^2 / h \), not dissimilar from values in other galaxies.

### 5.2 The PKS 2155–304 Sight Line

A possible physical association between the \( \text{Ly} \alpha \) absorber at \( 5100 \text{ km s}^{-1} \) toward PKS 2155–304 and ESO 466–G032 is even less clear cut. The projected distance between the two is \( 230h^{-1} \text{ kpc} \). Lanzetta et al. (1995) find that only 1 out of 9 galaxies at projected distances larger than \( 160h^{-1} \text{ kpc} \) from the line of sight toward \( H^1 \)-absorbing quasar QSO's gives rise to associated \( \text{Ly} \alpha \) absorption, while 5 out of 5 galaxies at distances less than \( 70h^{-1} \text{ kpc} \) give rise to associated \( \text{Ly} \alpha \) absorption. However more recent data by Bowen et al. (1996) and Le Brun et al. (1996) show that the covering factor of galaxies between 50 and \( 300h^{-1} \text{ kpc} \) is roughly 0.5 for equivalent widths larger than 0.3 A. Thus, our discovery does not seem that unusual.

The galaxy is a small SB spiral with \( M = -19.2 \). It would be quite extraordinary if it had a gaseous halo extending out to 250 kpc or so. The long dynamic time scales of those distances make it unlikely that the gas has virialized or settled into a disk (Stocke et al. 1995). Note, however, that Zaritski & White (1994) find that isolated spirals have dark halos extending out to 200 or 300 kpc, thus even if the \( \text{Ly} \alpha \) absorber is not part of a halo of ionized gas, it may still sit in the potential of the galaxy. As in the case of Mrk 335, the kinematics of the galaxy do not help to elucidate the situation, the \( \text{Ly} \alpha \) absorber is at the systemic velocity of the galaxy.

In the high-velocity range toward PKS 2155–304, we see three galaxies at rather large projected distances from the line of sight. The three galaxies have a mean velocity of \( 17 \text{021 km s}^{-1} \) and a line of sight velocity dispersion of \( 138 \text{ km s}^{-1} \), typical of a loose group of galaxies. The \( \text{Ly} \alpha \) absorption at \( 17100 \text{ km s}^{-1} \) occurs close to the mean velocity. In this case, it seems more plausible that the absorption...
arises in some general intergalactic gas within a small group, rather than from one galaxy in particular (Mulchaey et al. 1993, 1996). The galaxy to the southwest is in projection closest to the line of sight toward the quasar at a distance of 305h⁻¹ kpc. Thus, if the absorption arises in the halo of the nearest galaxy, the halo would have to extend well beyond 300 kpc. The existence of such a huge ionized halo is problematic by itself (Stocke et al. 1995), in a group environment it will definitely not survive. Of course the intragroup gas may be just that, the remains of the shredded halos. It is interesting that the absorption at 17 100 km s⁻¹ is one of the stronger absorption systems. The situation is reminiscent of the absorbers found toward 3C 273 in the outskirts of the Virgo cluster (Bahcall et al. 1991; Morris et al. 1991). Several galaxies are found at distances of 200 to 300 kpc from the sight line, but it is not possible to associate the absorbers with individual galaxies (Morris et al. 1993; Salpeter & Hoffman 1995; Rauch et al. 1996). As in the present case, the absorbers toward 3C 273 have slightly higher column density. Although the current data for the PKS 2155–304 system, plagued as they are by interference, are not sensitive enough to detect small gas rich dwarfs, such as the one found toward Mrk 335, the 3C 273 data definitely rule out the existence of such dwarfs within 100 kpc from the line of sight toward 3C 273 (van Gorkom et al. 1993).

The absorption at 16 488 km s⁻¹ seems more difficult to explain. It is quite far off from the mean velocity of the group. The H I emission from F21569-330 at a projected distance of 610h⁻¹ kpc comes closest in velocity going down to 16 650 km s⁻¹, but not only is the distance to the sight line huge, the approaching side of the galaxy is on the far side from the sight line to the quasar. Since for this group we have only sampled the upper end of the H I mass function it is not unlikely that other galaxies are present which have H I at the same velocity as the absorber. Thus it seems plausible that this absorber is associated with the group as well.

In a recent paper Lanzetta et al. (1996) report the identification of a group of galaxies at a redshift of 0.26, that produce a complex of corresponding Lyα absorption lines. As in the present case one of the absorption systems has a slightly higher column density. Thus it seems that Lyα absorption arising in intra group gas may be quite common and that the column densities in those environments may be somewhat higher than what is seen near more isolated galaxies.

5.3 The Nature of Nearby Lyα Absorbers

A search for H I emission from the vicinity of nearby Lyα absorbers has resulted in the discovery of some low luminosity galaxies at the same redshift of some of the absorbers, but at large (70 to 250 kpc) projected distances from the sight line. In addition a group of galaxies was found near two absorbers at a velocity of about 17 000 km s⁻¹. This confirms previous suggestions that nearby Lyα absorbers are weakly correlated with galaxies. Individual, more isolated, galaxies may have absorbers that are physically associated with them, either due to infall, galactic winds or tidal disturbances. In regions of higher galactic density this material may be stripped from individual galaxies and distributed more uniformly through the intergalactic medium.

This project was undertaken in the hope of finding a possible parent population associated with nearby Lyα absorbers: either luminous galaxies with very extended gaseous envelopes or very low luminosity, but gas rich galaxies, which could have escaped optical detection. We did indeed find a few optically uncataloged galaxies, which turned out to be very close in velocity to, but at large projected distances from the Lyα absorbers. Two of the absorbers appear associated with a group of galaxies. These results are very similar to searches for a possible parent population at optical wavelengths. Most absorbers at low redshift appear to coincide with the large scale structure outlined by the more luminous galaxies (Rauch et al. 1996; Stocke et al. 1995) as was first suggested by Oort (1981).

One of the outstanding questions is whether the nearby Lyα absorbers are actually connected to individual galaxies or simply coincide in redshift. Our observations do to a certain extent strengthen the idea that at least some nearby Lyα absorbers may be arising in mostly ionized halos of individual galaxies. The discovery in our most sensitive observation of a very small galaxy at 68h⁻¹ kpc from the line of sight toward Mrk 335, suggests that: (1) deeper surveys may turn up more such candidates; and (2) the suggestion (Maloney 1992; Shull et al. 1996) that the ionized halos of smaller galaxies may contribute significantly to the total Lyα absorbing cross section in the nearby universe may be valid. The strongest evidence for a physical connection between nearby Lyα absorbers and galaxies comes from the statistical work by Lanzetta et al. (1995), who showed that within 70h⁻¹ kpc from a galaxy there is a 100% chance of detecting Lyα absorption. There are however also some Lyα clouds with no optical galaxy within a few Mpc (Stocke et al. 1995; Shull et al. 1996). In one case, an anticorrelation between a region of high galaxy density and Lyα forest absorbing clouds has been found (Morris et al. 1991). The difference between these results may primarily be due to a difference in cloud column densities. The Lanzetta et al. (1995) absorbers have significantly higher H I column densities than those studied by Morris et al. (1991), Stocke et al. (1995) and Shull et al. (1996).

Even if a physical connection is apparent, it is not obvious what the nature of the extended gas is. While Barcons et al. (1995) find in two cases Lyα absorption that could possibly be interpreted as arising in a corotating halo, there are several examples of even higher column density absorbers and metal lines, where the gas, although clearly associated with galaxies, is not corotating, but instead arises in tidally disturbed gas (e.g., Womble 1992; Carilli & van Gorkom 1992; Bowen et al. 1995). Thus the final verdict is not yet out. Low column density gas is likely to be found near galaxies, and many possible scenarios can bring it there: retarded infall, outflow, corotating ionized disks, tidal disturbances. Quite likely, all of these occur. Perhaps most puzzling are the clouds that don't have any galaxies within many Mpcs. These may arise in the filamentary structures as produced in simulations of gravitational structure formation (Cen et al. 1994; Hernquist et al. 1996; Miralda-Escudé et al. 1996;
Mücket et al. (1996), or they may be associated with as yet undetected dwarf galaxies.

This brings us to the final question, what is the connection, if any, between the high redshift Lyα forest clouds and nearby Lyα absorbers? As was pointed out by Rauch et al. (1996), the size estimate for coherent Lyα absorption at large redshifts (Bechtold et al. 1994; Dinshaw et al. 1994; Fang et al. 1996) is typically larger than the transverse separation between galaxies near low redshift Lyα absorbers. This not only argues against single extended galactic disks or halos as the main origin for the coherent absorption on large scales seen at high redshifts. It also argues against the low redshift absorbers being physically the same as the high redshift absorbers. However, it may well be that at low redshifts galaxies and absorption systems trace the general matter distribution on large scales, a hypothesis that can only be tested statistically using a large ensemble of nearby Lyα clouds.

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