High Signal-to-Noise GHRS Observations of H 1821+643: O VI Associated with a Group of Galaxies at z = 0.226 and Complex Lyman α Absorption Profiles at Low Redshift

Todd M. Tripp,1,2 Limin Lu,3,4 and Blair D. Savage1

Abstract. As part of a program to study the relationship between QSO Lyman α clouds and galaxies at low redshifts, we have obtained a high signal-to-noise (S/N) far UV spectrum of H 1821+643 (zem = 0.297) with the G140L grating of the GHRS. The spectrum, which has a resolution of FWHM ≈ 150 km s−1 and S/N ≈ 100:1, is adequate for detection of weak Lyα clouds with equivalent width as low as Wλ ≈ 50 mÅ (4σ) with complete spectral coverage from zabs = 0.03 to zabs = 0.26. In this paper we present some preliminary results of this study including the following. (1) The absorption profiles of three out of the four strongest extragalactic Lyα lines show complex component structure with a main strong component and several weaker outlying components spanning a full velocity range of ∼1000-1500 km s−1. The two-point correlation function does not show any evidence of Lyα cloud clustering but suffers from small number statistics. (2) Extragalactic O vi is clearly detected in the intervening absorption system at zabs = 0.225. Two galaxies at z = 0.2256 and z = 0.2263 are close to the sight line (the closer galaxy is at a projected distance of ∼90 kpc), so this O vi absorption could be due to the intracluster medium of a group of galaxies.

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1. A New GHRS Study of Lyα Clouds – Motivation

Quasar absorption lines provide a powerful tool for probing the evolution of the universe from z = 0 to 5, but to correctly interpret this information, one must understand the nature of the absorbers. Studies with the GHRS have yielded important results on the nature of low redshift “Lyα clouds,” low column density gas clouds which produce H I Lyα absorption lines in the spectra of background QSOs (see Morris 1996 for a brief review). GHRS observations of 3C273 shortly

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1Department of Astronomy, University of Wisconsin, Madison, WI 53706
2Present address: Princeton University Observatory, Princeton, NJ 08544
3Department of Astronomy, California Institute of Technology, Pasadena, CA 91125
4Hubble Fellow

Throughout this paper we use H0 = 100 km s−1 Mpc−1.
after the deployment of HST revealed that there are considerably more Lyα clouds at low redshift than expected based on the observed evolution of the number of clouds per unit redshift \( dN/dz \) at high \( z \) (Morris et al. 1991; see also the FOS study of Bahcall et al. 1991). This abundance of low \( z \) clouds provides an opportunity to learn about the nature of the absorbers by directly studying the environment (i.e., galaxies, galaxy clusters, voids, etc.) where the Lyα clouds are found. Studies of the relationship between low \( z \) Lyα clouds and galaxies using the GHRS have been carried out by Morris et al. (1993), Stocke et al. (1995), and Shull, Stocke, & Penton (1996). These programs find that (1) Lyα clouds are not randomly distributed with respect to galaxies, but the absorber-galaxy correlation is not as strong as the galaxy-galaxy correlation, and (2) some Lyα clouds are found in galaxy voids, although overall the clouds tend to “avoid the voids.” In general, the Lyα clouds studied with GHRS do not have nearby associated galaxies; Morris et al. (1993) report that there are no galaxies observed within 230 kpc of any of the 3C273 Lyα clouds, and Stocke et al. find that there are no galaxies within 450 kpc of their Lyα absorbers. These GHRS results seem to be in conflict with HST FOS studies of Lyα clouds. For example, based on a redshift survey of galaxies near QSOs observed with the FOS, Lanzetta et al. (1995) find that 32-60\% of the Lyα clouds in their sample are associated with luminous galaxies within \( \sim 160 \) kpc of the QSO sight lines. To reconcile these discordant results, it has been suggested that there are two populations of Lyα clouds at low redshift: (1) strong Lyα clouds with \( N(\text{H} \text{ i}) \geq 10^{14} \text{ cm}^{-2} \) which dominate the Lyα cloud sample of Lanzetta et al. and mostly occur in large halos of luminous galaxies, and (2) lower column density absorbers which are less closely tied to galaxies and are, in some cases, truly intergalactic gas clouds (the Morris et al. and Stocke et al. Lyα clouds have \( N(\text{H} \text{ i}) \leq 5 \times 10^{13} \text{ cm}^{-2} \)). Currently this suggestion cannot be rigorously tested, however, because the sample of weaker Lyα clouds is small.

To significantly improve the statistics of low redshift weak Lyα clouds, we are conducting a program to study the relationship between low \( z \) Lyα clouds and galaxies in the direction of three QSOs using the GHRS and the WIYN multiobject spectrograph (HYDRA). Using the G140L grating, we will obtain GHRS spectra with S/N \( \approx 100:1 \), adequate for detection of Lyα clouds with \( W_\lambda = 50 \text{ mA} \) (4\( \sigma \)), and this will increase the weak Lyα cloud sample size by a factor of 4-5. The WIYN HYDRA will be used to measure the redshifts of galaxies in the \( \sim 1^\circ \) fields centered on the QSOs. Figure 1 shows a portion of the GHRS spectrum of H 1821+643 (\( z_{\text{em}} = 0.297 \)) obtained for this program. The WIYN galaxy redshift survey for this field has been completed, and the full analysis of the GHRS and WIYN data for this sight line will be presented in a subsequent paper. Some preliminary results are summarized below.

2. **Highly Ionized Oxygen at \( z = 0.225 \)**

The O \( \text{v} \) 1031.9, 1037.6 Å doublet is well-detected at \( z_{\text{abs}} = 0.2250 \) in the H 1821+643 spectrum (see Figure 1) along with H \( \text{ i} \) \ Lyα and Lyβ, and we have G160M (FWHM = 15 km s\(^{-1}\)) GHRS observations of the O \( \text{v} \) 1031.9 Å and H \( \text{ i} \) Lyβ absorption profiles obtained in the Galactic ISM program of Savage et al. (1995). These G160M profiles are well-described by Voigt profiles with
the parameters listed in Table 1. The width of the O VI profile indicates that \( T \leq 1.8 \times 10^6K \), and the redshift difference between the H i and O VI profiles implies a 40 km s\(^{-1}\) centroid shift between the neutral and highly ionized gas. The H i Ly\(\alpha\) profile shows complex component structure (see Figure 2), and some of this structure could be due to a broad hot H i component associated with the O VI.

Table 1. O VI Absorber – Profile Fitting Results

| Species | Redshift (z) | log \( N \) (cm\(^{-2}\)) | \( b \) (km s\(^{-1}\)) |
|---------|--------------|-----------------|-----------------|
| H i Ly\(\beta\) | 0.224892 ± 0.000008 | 15.32 ± 0.07 | 50.7 ± 3.2 |
| O VI | 0.225026 ± 0.000010 | 14.29 ± 0.03 | 42.8 ± 3.5 |

Schneider et al. (1992) have detected an emission line galaxy at \( z = 0.2256 \) within 90 kpc of the sight line. Our WIYN redshift survey has discovered another emission line galaxy close to the sight line at \( z = 0.2263 \). Therefore it is possible that the O VI absorption at \( z = 0.2250 \) originates in the intracluster medium of a group of galaxies.

3. Clustered Ly\(\alpha\) Clouds?

The absorption profiles of three out of the four strongest H i Ly\(\alpha\) lines contain complex component structure with a main strong component and several weaker outlying components spanning \( \sim \)1000-1500 km s\(^{-1}\) (see Figure 2). Even the Ly\(\alpha\) line at \( z_{\text{abs}} = 0.1699 \) which does not show resolved weak components has
an asymmetric profile which is evidence of unresolved profile components. This
seems to suggest that there is some clustering of weak Lyα clouds at low redshift.
However, we have calculated the two-point correlation function using all of the
Lyα clouds detected in the H 1821+643 GHRS spectrum, and this does not
show evidence of clustering on any scale, but the sample of Lyα lines may be
too small for adequate statistics.

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Figure 2. Absorption profiles of the four strongest H i Lyα lines
detected in the GHRS spectrum of H 1821+643.