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Pruning the Lyman-α forest of Q1331+170

Varsha P. Kulkarni and Donald G. York
Department of Astronomy and Astrophysics, The University of Chicago, Chicago IL, 60637

1 Introduction

A multitude of absorption lines seen shortward of QSO Ly-α emission, that cannot be traced to heavy element absorption systems, are assumed to be Ly-α lines arising in intervening clouds. Studies of these Ly-α clouds, typically done at 1 Å or lower resolution, have shown N(HI) $\sim 10^{13} - 10^{17} cm^{-2}$ and b $\sim$ 35 km/s. Sargent *et al* 1980, on the basis of a flat pair velocity correlation function (PVCF), argued that these clouds are intergalactic. But Crotts 1989 showed that the strong Ly-α lines are spatially clustered. High resolution studies of Webb 1987 and Rauch *et al* 1992 also report some evidence for weak clustering, but overall such high resolution studies have been rare. Here we report a study of the Ly-α forest of Q1331+170 over $z_{abs} = 1.60 - 2.19$ based on 18 km/s resolution data at $S/N \sim 15$, with metal-line deblending incorporated.

2 Observations and Sample Generation

The study of Q1331+170 ($z_{em} = 2.08$) made by York *et al* 1992 consisted of : (a) 18 km/s, mean S/N $\sim$ 15 Kitt Peak Echelle Spectra (over 3170-3970 Å) (b) 1 Å, S/N $\sim$ 40 MMT spectra (3900-9400 Å) (c) limited 35 km/s resolution MMT scans over 6400-6820 Å. Heavy element lines, including those in a previously known damped Ly-α system at $z_{abs} = 1.7765$, were identified and analyzed (York *et al* 1992). On the basis of analysis of heavy element lines from known systems longward of the emission Ly-α, we derive contributions of heavy element lines to lines in the Ly-α forest using profile fitting techniques. The remaining contribution is then the deblended Ly-α lines. The sample of lines thus derived is further searched for previously unknown metal line systems. Two samples are derived from the analysis of the resultant list of pure Ly-α lines : one consisting of single component profile fits (S1) and the other consisting of the minimum required number of multiple components (S2). Unidentified lines slightly longward of the presumed QSO redshift ($z_{em} = 2.08$) are also included. Sample S1 consists of 83 and sample S2 of 124 lines between $z_{abs} = 1.60 - 2.19$. Compared to a sample which would have ignored the metal-blended Ly-α lines completely, our procedure of metal line deblending adds $\sim$ 20% lines to each of the samples S1 and S2, and $\sim$ 23% and $\sim$ 29% lines to the sub-samples of strongest lines from S1 and S2, respectively.

3 Equivalent widths, Column densities, Doppler parameters

The highest S/N is achieved between $\sim 3500 - 3880$Å resulting in rest equivalent width sensitivity of 20 mÅ (4-5 σ) in the best parts of the spectrum. At this sensitivity, most Ly-α lines are found to be weak. Distributions of HI column densities for samples S1, S2 are shown in Fig. 1. Only a very small fraction of lines from sample S2 possess $N(HI) > 10^{14} cm^{-2}$. This is different from the power law distribution ($\sim N(HI)^{-1.7}$, $log N(HI) > 13$), which is common in the literature. (See for example, Carswell *et al* 1984.) According to this distribution, one would have expected about 9 lines with $N(HI) > 10^{14.5}$ in sample S2, whereas we see none. This is probably a result of the high resolution of our observations. High resolution studies of Ly-α lines in more sightlines would be needed to verify the generality of this. The b values range between 10 and 40 km/s for most of the lines, with a mean of $\sim$ 27 km/s. No obvious correlation is apparent between N(HI) and b. Lines within $\pm$ 10,000 km/s of the presumed QSO emission redshift, $z_{em} = 2.08$, are predominantly weaker than 100 mÅ, while lines 'outside' 10,000 km/s of the QSO are relatively stronger.

4 Velocity Correlations

Fig. 2 shows the inner 8000 km/s of the histogram of 'corrected' number of line pair separations for all lines in sample S2 with $W_{rest} > 30 m\mathring{A}$, for $q_0 = 0.5$. Here, 'corrected' number means the number of pairs after correcting for the finite redshift range of the data by using a ramp-shaped function, as in Sargent *et al* 1980. Shown overlaid on the histogram are the mean and the $\pm 2\sigma$ levels expected in samples of randomly distributed Ly-α lines, computed as average of 100 simulated linelists, each having the observed number of lines with the observed set of equivalent widths, but distributed randomly between $z_{abs} = 1.6079$ and 2.1914. An excess in number of velocity pairs out to 100 km/s is apparent in the Ly-α lines toward Q1331+170. This result seems to differ from that of Rauch *et al* 1992, who, with observational setup almost identical to ours and data at 23 km/s resolution, did not report such a clustering. This could be a result of different methods of analyzing the data. However they do report clustering among the narrow Ly-α lines. We also find a marginal excess in the number of line pairs over $v <\sim 500$ km/s in the weakest ($30 < Wrest < 100 m\mathring{A}$) lines, and the two findings could be related. An excess in number of velocity pairs out to ~ 200 km/s is also seen in the (admittedly small) sample of the strongest ($W_{rest} > 190 m\mathring{A}$) lines. This excess comes entirely from a strong clump of Ly-α lines at $z_{abs} = 1.9637$.

5 Conclusions

We have pruned the Ly-α forest of Q1331+170 with metal line deblending and find that our sample of Ly-α clouds have low N(HI) and show an excess in the number of line pair separations on scales of $<\sim 200$ km/s. We have searched for CIV doublets and OI λ1302-SiII λ1304 pairs, since these have $\Delta v \approx 500$ km/s. We found only one, which has been taken out of the samples. The implied excess in the PVCF could be either due to clustering of the Ly-α clouds or due to complex structure in the clouds. The former conclusion is not expected in an intergalactic interpretation of the Ly-α clouds. This effect will have to be tested by more high resolution, high S/N studies of the Ly-α forest in other QSO's.

This work is part of a more detailed paper by Kulkarni *et al* 1992.

REFERENCES

Carswell, R., Morton, D., Smith, M., Stockton, A., Turnshek, D., and Weymann, R., 1984, ApJ, 278, 486

Crotts, A. 1989, ApJ, 336, 550

Kulkarni, V. P., Welty, D. E., York, D. G., Huang K.-L., Green, R. P., and Bechtold J., 1992, to be submitted

Rauch, M, Carswell, R., Chaffee, F., Foltz, C., Webb, J., Weymann, R., Bechtold, J., and Green, R. F., 1992, ApJ, 390, 387

Sargent, W., Young, P., Boksenberg, A., and Tytler, D. 1980, ApJS, 42, 41

Webb, J. 1987, in IAU Symposium 124, Observational Cosmology, eds. A. Hewitt, G. Burbidge, and L. Fang (Dordrecht: Reidel), p. 803

York, D. G., KeLiang Huang, Green, R. P., Bechtold, J., Welty, D. E., Carlson, M., and Khare, P. 1992, to be submitted

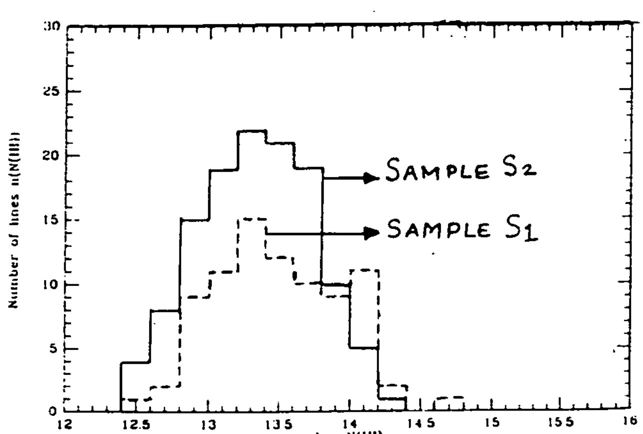

Fig. 1 Distribution of N(HI): Samples S1, S2

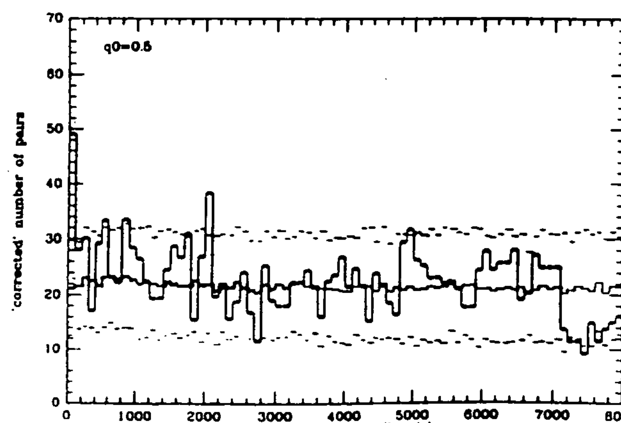

Fig. 2 Velocity Correlations: Sample S2: 114 lines (6841 pairs) Wrest > 30 mA