CLUSTERING OF Lyα ABSORBING CLOUDS AT HIGH REDSHIFT

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ABSTRACT. High resolution observations of regions in the Lyα forest of QSO spectra have been obtained using the Anglo-Australian Telescope. The amount and quality of the data, and the analysis techniques used, have enabled the clustering properties of these objects to be explored on scales smaller than has previously been possible. The results suggest that the Lyα clouds are weakly clustered with $\langle\xi\rangle = 0.32\pm0.08$ over the velocity range 50-290 km/s.

1. Introduction

At present, the majority of existing spectra of the Lyα forest absorption lines are at a resolution (~ 1Å FWHM) such that individual absorption features are generally unresolved. Although statistical procedures have been defined and applied to the data to obtain homogeneous Lyα samples, (Young et al., 1979), at higher spectral resolution most or all of the stronger features are found to break up into more components. The absorption features can be more reliably located and profile fitting techniques (Carswell et al., 1984) may be used to obtain estimates of the column density of absorbing atoms, the velocity dispersion parameter and the redshift. With such a sample, the clustering properties of the Lyα clouds may be investigated down to scales ~ 50 km/s compared to ~ 300 km/s for the majority of the sample used by Sargent et al. (1980) who found their data to be consistent with clouds randomly distributed on scales between 300 and 30,000 km/s.

2. The data

We have collected, at the Anglo-Australian Telescope, high resolution spectra (~ ¼Å FWHM) covering regions in the Lyα forest of several QSOs. Combining these new data with existing data on Q1101-264 (Carswell et al., 1984) provides us with 13 Lyα regions of ~130Å each over the absorption redshift range $1.9<z<2.8$. A maximum likelihood optimization technique was employed in profile fitting to the data to obtain

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estimates for the cloud parameters and their associated errors. It is important to ensure that blended absorption features are not overfitted with too many components since this could cause an apparent small scale clustering. We have attempted to fit complex features with the minimum number of components required to give an acceptable fit. Additionally, we have tested the goodness of fit by comparing normalized chi-squareds for blended and single features for the whole sample. No evidence was found for either over or underfitting.

3. Clustering Analysis

To investigate the clustering properties of the Lyα clouds, all lines associated with known metal-containing systems were removed. Lines within 3000 km/s of the Lyα emission line were omitted to reduce effects caused by the drop in number density of absorption lines approaching the emission line (Weymann et al., 1981, Murdoch et al., 1986). Only lines redwards of the Lyβ emission line were used to avoid confusion with higher order Lyman transitions. The resulting sample comprised ~300 absorption lines.

For the remaining features, the two-point correlation function was calculated for each wavelength region (Sargent et al., 1980). The summed normalized correlation function is shown below.

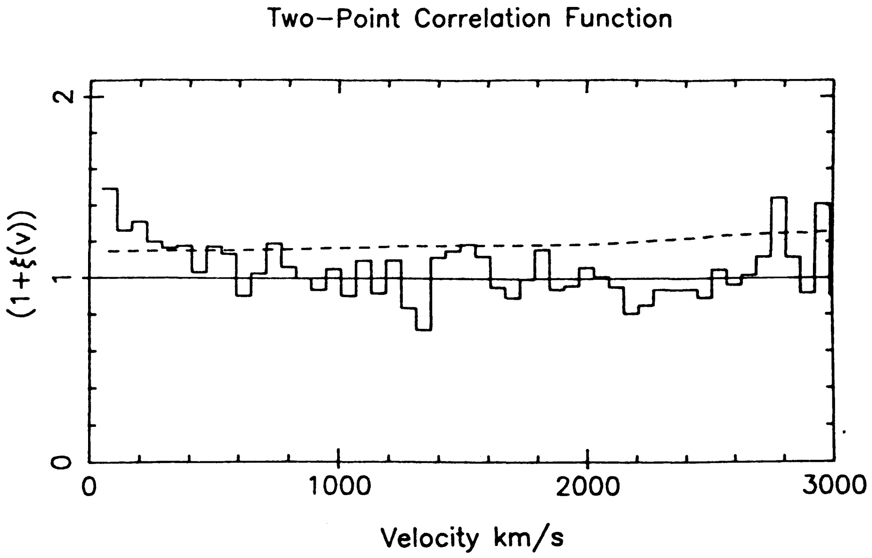

Figure 1 Two-point correlation function normalized to (1+ξ(v)). The bin size is 60 km/s and the fist bin starts at 50 km/s, below which blending problems are severe. The dashed line is the 1σ upper error contour derived from Poisson statistics.

In previous analyses the correlation function was incomplete on scales below ~300 km/s. Consequently we use the range 50–290 km/s to search for small scale velocity clustering and find that $\langle\xi\rangle = 0.32\pm0.08$.

A possible selection bias could occur if some of the features which have been assumed to be Lyα absorption lines are actually unidentified metal lines; these are believed to be strongly clustered (Sargent et al., 1980). However, an estimate of the number of contaminating lines that might be present suggests that there are not enough to account for the observed clustering.

Interestingly, there appears to be a weak trend for $\langle\xi\rangle$ to increase with decreasing redshift; dividing the samples into two redshift bins, $1.9<z<2.4$ and $2.4<z<2.8$, we find $\langle\xi\rangle = 0.44\pm0.12$ and $\langle\xi\rangle = 0.18\pm0.11$ respectively. Clearly, more data are required to check on this.

In conclusion, we find significant evidence for weak clustering on small velocity scales for the Lyα clouds.

References

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DISCUSSION

BAHCALL: If the clouds were moving with some Δν (~100 or 200 km s^{-1}), that would tend to weaken any intrinsic correlation function among these systems, then in principle, the correlations could be even stronger.

WEBB: I agree. Random motions could smear out the correlation function. Observations of suitable QSO pairs could eventually help us to understand how spatial and velocity correlations are related.

SILK: Could you compare the correlation length you have found for the Lyα clouds with that found for the CIV absorption systems at a similar redshift.

WEBB: The line of sight two-point correlation function has been calculated for a small sample of CIV lines by Sargent et al. (1980). They find a strong excess at ~150 km s^{-1} with an effect extending out to ~400 km s^{-1}. The clustering amplitude seems stronger than the one I find for the Lyα clouds.