THE CLUSTERING EVIDENCE OF LYMAN α FOREST

WU YINGEN AND HUANG KELIANG
Department of Physics, Nanjing Normal University, China

Abstract. Using high resolution spectral data of the Ly α forest, we found evidence for clustering of Ly α absorbers on scales of 8-10h_0^{-1} Mpc.

1. Introduction, Sample, & Results

The absorption lines of quasars provide us chances to study the early universe, and they are a very important tool for understanding the formation and early evolution of galaxies, the early evolution of element abundances, and the large scale structure of the universe. Ly α forest lines are absorption lines in the spectra of QSOs produced by primeval intervening clouds. Analyses of low or medium resolution spectral data found no clustering of the clouds. However, blending in crowded regions of Ly α forest lines, means that spectral data of 1-2 A resolution can only be used to study clustering on scales greater than 300 km s^{-1}. To study the clustering on smaller scales, higher resolution spectral data are necessary.

We obtained echelle spectra of QSO 1225+317, using the echelle spectrogragh on the 4 m Mayall telescope at KPNO (Huang et al. 1995). The spectrogragh was equipped with a UV camera that transmits to the atmospheric cutoff near 3100 A. We used the echelle grating to obtain spectra of orders 96 through 65, or 3130 A to 4500 A. The spectrograph output was coupled through the camera to the intensified CCD detector. The detector consists of an RCA two-stage magnetically focused image tube with a 38 mm cathode, lens coupled to the T13 CCD. The system gain is about 20. The total exposure time was about 10 hours, which yielded an average $S/N = 20$. Each object exposure was preceded and followed by TH-A arc lamp images for wavelength calibration. The average FWHM measured in single Th-A arc exposures was 18 km s^{-1}. Data were reduced with stan-

C. S. Kochanek and J. N. Hewitt (eds), Astrophysical Applications of Gravitational Lensing, 105–106.

dard IRAF routines. The spectra were plotted and examined to identify lines stronger than 5σ.

We found 35 Ly α forest lines between Ly α emission and Ly β emission, that can be used to understand the Ly α forest. We combined our sample with high resolution data for the QSOs 2000−330 (Carswell et al. 1987), 2126−158 (Giallongo et al. 1993), 0420−388 (Atwood et al. 1985), 0014+813 (Rauch et al. 1992), 0055−269 (Cristiani et al. 1994), 1033−0327 (Williger et al. 1994), and 1331+170 (Kulkarni et al. 1995). We use the method of Liu & Liu (1992) (i.e. calculating the free path of a photon passing through two adjacent absorbers at $z = 0$ and comparing the distribution of free path with one when absorbers are distributed at random). The advantage of this method is that all available data can be used and the sample is much larger than one obtained from one quasar. We need to calculate the probability that the free path is less than $l_0 : P(< l_0) = 1 - Ae^{-\frac{l_0}{B}}$, here A and B are constants. If $A = 1$, it means the distribution of absorber is random. Fitting the data, we find $A = 0.97$ and $B = 17.31$. If deleting some points for which free path is in the range of $4.5 - 10h_0^{-1}(h_0 = H_0/100)$, the fitted probability distribution would be consistent with random distribution. It means that the absorber may be clustered on scale of 4.5-$10h_0^{-1}$ Mpc.

We also checked the clustering by use of the traditional two point correlation function. We calculated the correlation function of all the data instead of the data for each separate quasar (Mo et al. 1992). The result shows that correlation function has an obvious excess greater than 3σ at 8-$10h_0^{-1}$ Mpc in agreement with the previous result. Next we checked a high column density subsample with $\log N_0 > 13.5$, and found similar results. Thus our results show a possible clustering of Ly α absorbers on scales of 8-$10h_0^{-1}$ Mpc.

Acknowledgements: This work was supported by the National Climbing Programme on Fundamental Researches and the National Natural Science Foundation of China.

References

Atwood, B., Baldwin, J.A. & Carswell, R.F., 1985, ApJ, 292, 58.
Carswell, R.F., Webb, J.K., Baldwin, J.A. & Atwood, B., 1987, ApJ, 319, 709.
Cristiani, S., D'Odorico,S., Fontana, A., Giallongo, E., & Savalio, S., 1995, MNRAS, in press.
Giallongo, E., Cristiani,S., Fontana, A., & Trevese, D., 1993, ApJ, 416, 137.
Huang, K.L., et al., 1995, in preparation.
Kulkarni, V.P., Huang, K.L., Green, R.F., Bechtold,J., et al., 1995, MNRAS, in press.
Liu, Y.Z., & Liu, Y., 1992, AAp, 264, L17.
Mo, H.J., Xia, X.Y., Deng, Z.G., Borner, G., & Fang, L.Z., 1992, AAp, 256, L23.
Rauch, M., Carswell, R.F., Chaffee, F.H., et al., 1992, ApJ, 390, 387.
Williger, G.M., Baldwin, J.A., Carswell, R.F., Cooke, A.J., et al., 1994, ApJ, 428, 574.