THE REDSHIFT DISTRIBUTION OF Ly α FOREST LINES IN SPECTRA OF QSOs[1]

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Numerous narrow absorption lines in the region of wavelength shorter than $1216(1+z_{em})$ (z_{em} is the emission redshift), i.e. so-called Ly α forest lines, detected in QSO spectra are usually thought to be produced in intervening primeval clouds. The study of Ly α clouds may reveal how matter distributes in space and how it evolves with time at the early universe and provide valuable information about the large scale structure of the universe and its evolution. Based on intermediate resolution ($1 \sim 2$ A) spectra, many authors (e.g. Lu et al. 1991) deduced that the evolutionary index $\gamma \simeq 2$, ($dN/dz \sim (1+z)^{\gamma}$, dN/dz is the number of clouds per unit redshift interval at redshift z). It means that Ly α clouds have strong cosmological evolution. In recent years, there appear high-resolution ($< 30 km/sec$) spectra of QSOs. High resolution spectra may provide more information than medium resolution spectra. Hence, it is necessary to study the evolution of Ly α clouds, using the spectra with higher resolution. Carswell et al. (1987) found γ=1 in the redshift interval 1.9-3.8. But Rauch et al. (1992) found γ=2.1 for the line sample with $logN(HI) \geq 13.75$. It is more interesting that Giallongo (1991) found a differential evolution: γ is depended on the equivalent width W of line and no evolution for the strong line sample with 0.5>W>0.3. However, these studies involved very few QSOs (three or four). In this paper, we use a larger sample of QSOs to study the evolution of Ly α clouds.

So far, there are spectra of Ly α forest region of five QSOs with high-resolution published: QSOs 2000-330 ($z_{em} = 3.78$; Carswell et al. 1987), 0420-388 ($z_{em} = 3.12$; Atwood et al. 1985), 2206-199N ($z_{em} = 2.56$; Pettini et al. 1990), 1101-264 ($z_{em} = 2.14$; Carswell et al. 1991) and 0014+813 ($z_{em} = 3.38$; Rauch et al. 1992). Recently We obtained spectral data of other two QSOs: 1331+170 ($z_{em} = 2.08$; York et al. 1993, Kulkarni et al. 1993) and 1225+317 ($z_{em} = 2.22$; Huang et al. 1993). By use of the data of these seven QSOs, we study the evolution of Ly α clouds. Following Giallongo (1991), we take W= 0.14 as the threshold of equivalent width to select lines. Besides, we do not consider those Ly α lines for which their observing wavelengths are shorter than 1025 $(1+z_{em})$. These lines may confuse with Ly β of other clouds. In our sample, there are 378 Ly α lines with 0.5> W> 0.14. The redshift interval the sample covered is 1.60-3.78.

The value of γ can be easily derived by use of the maximum likelihood method (Murdoch et al. 1986, Lu et al. 1991). Many authors studied the evolution of strong lines with W>0.36 when they analysed the data of medium-resolution spectra. Giallongo (1991) discussed the cases of differential evolution with various intervals of equivalent width. Following these authors, we also discuss the cases with different intervals of W, as a comparison.

The following table is the result of analysing our sample. In the table, nt is the total number of lines in the intervals of W, Q the Q-test and K-S the Kolmogorov-Smirnov test. The values in parenthesis are the results after removing the lines within 8 Mpc of the QSOs to eliminate the influence of the inverse effect.

	W>0.36	0.5>W>0.3	0.3>W>0.2	0.2>W>0.14
γ	1.93±0.48 (2.49±0.48)	2.00±0.53 (2.29±0.58)	1.66±0.55 (1.97±0.61)	2.41±0.60 (2.56±0.67)
nt	171 (162)	138 (125)	126 (111)	114 (97)
Q	0.24 (0.19)	0.25 (0.22)	0.31 (0.28)	0.22 (0.22)
K-S	0.10 (0.25)	0.49 (0.72)	0.54 (0.38)	0.86 (0.95)

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1. We can see $\gamma \simeq 2$ for all the intervals of equivalent width. We did not find the differential evolution Giallongo (1991) found. The data of high-resolution spectra show that Ly α clouds indeed have strong cosmological evolution, as that concluded by use of medium-resolution data.

2. Although the values of γ are derived, the statistical test is disappointing. Considering the inverse effect, we obtained only slightly better statistic. This implies that the density distribution of Ly α lines of individual QSOs strongly departs from the grobal distribution. In fact, we obtain quite different values of γ if the data of individual QSOs is seperately used. Therefore, in order to understand the evolution of Ly α clouds better, we need more data of high-resolution spectra.

3. Lu et al.(1991) found a broken power-law form of redshift distribution of Ly α clouds: γ=4.60 for $z<2.32$ and γ=1.71 for $z>2.32$. It means that the evolution at lower redshift is faster than that at higher redshift. The number of Ly α lines at lower redshift predicted by this law is even more less than that observed by Hubble Space Telescope for 3C 273 (Bahcall et al. 1991; Morris et al.1991). We examined this broken power-law form by use of the sample in this paper. The sample could not be fitted well by the law.

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