ABSORPTION LINES IN QSOs

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ABSTRACT. A comparison between three types of intervening absorption line systems: the Lyα forest, the Lyα damped systems and the narrow metal line systems has been done for the observational properties including the frequency of the systems, the equivalent width distribution, the two point correlation function, the metal abundances, and the dN/dz vs. z behavior.

From cosmological point of view, the narrow absorption line systems, which include the Lyα forest, the narrow metal systems and the Lyα damped systems, and which are thought by most astronomers working in this field to be due to the absorptions of the intervening materials distributed along the line of sight between QSOs and the observers, are very important in probing the Universe at high redshift. Do these systems represent different populations of the objects at high redshift, or their distinctive characters simply reflect the same population but the different parts which intercept the light from QSOs or they represent the different stages of the evolution? Detail studies have been made for each of the individual classes of the systems in the past few years. A comparison between them may give us some hints about their relations and possible origin.

1) Frequency of the systems

The line number density per unit redshift for Lyα was estimated as N(z=2.44) =60.7 and N(z=0)=17.6 respectively for q_0=0 with rest frame equivalent width of line w_o>=0.32 Å from a uniform sample of 6 QSOs (1-2 Å resolution, Sargent et al. 1980). The number density increases rapidly with the decrease of the lower limit of W_o. From the systematic Lick survey of the Lyα damped systems Wolfe et al. (1986) found 47 candidates from 68 QSOs with a total redshift coverage of 56.07 with z=2.21, and confirmed 15 systems from 26 candidates . The derived number densities per unit redshift are N(z=2.21)=0.48 and N(z=0) =0.15

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respectively. The data of the narrow metal systems show a strong tendency to clump into close pairs, triplets, or even more complex structures. For statistical purpose, each clump or complex of redshift systems is counted here as one system. Using the sample of Young et al. (1982) of 30 QSOs without absorption "troughs", the mean line densities are N(z=1.71)=1.49 and N(z=0)=0.55 for CIV systems, which is nearly the same as that from an extended sample used by Bergeron and Boisse (1984). There might be some uncertainties due to the size of the sample, the blending, and the contaminating effect, but these number densities could give us some hints for the relative frequencies of the occurrence of these three types of systems. If they are from different part of the galaxies in the same population conforming to the Schechter's galaxy luminosity function and the Holmberg radius-luminosity relation, their size will be proportional to the square root of the number density. Adopting the formulae given by Sargent et al. (1979) and the parameters therein, one finds radii R* as 175/h, 31/h, and 16/h kpc, for the Lyα forest, the narrow metal system, and the Lyα damped system respectively, when no cosmological evolution is assumed. The number density for Lyα damped system could be an upper limit due to the blend or contamination of other narrow Lyman lines, while the number density for the Ly forest and the narrow metal systems are much underestimated by the requirement of the lower limit of W_o>=0.32 Å in Lyα sample and W_o>=0.6 Å in CIV sample leaving a great number of the latter two systems uncounted. Therefore, the R* for the Lyα cloud and the narrow metal system will be much larger than the deduced values. This might explain the fact that some of the common absorption line systems from QSO pairs (e.g. 0307-195 A, B, Shaver and Robertson (1983)) can have a projected linear separation larger than 300/h kpc if they are due to the extended halo of the intervening objects. However, the fraction of the volume of the universe occupied by the Lyα forest will be too large (Sargent et al. 1980). The R* deduced for Lyα clouds also conflicts with the result form double QSO observation, which gives R* as 10 kpc (Foltz et al. 1984). This may indicate that Lyα clouds either constitute a new population in the high redshift universe, which are confined in pressure equilibrium by the hot intergalatic medium reheated at z< 6 (Sargent et al. 1980, Ostriker and Ikeuchi, 1983, Ikeuchi and Ostriker, 1986), or are self-confined systems. The rapid increase in number counts will give high detection probability. The latter explanation is confronted with a difficulty (Sargent et al. 1980) that the mass of the Lyman-alpha cloud is too small to be gravitationally self-confined. This difficulty, however, may be overcome with the model recently proposed by Rees(1986) which states that the Lyα cloud can be stably confined by the gravitational field of the cool dark matter, being able to neither to escape, nor to settle towards the center and become self-gravitating.

2) Equivalent width distribution

Bergeron and Boisse (1984) have studied the equivalent width distribution of the Lyα lines for the Lyα forest as well as for the narrow metal systems. After correction of the evolution effect of the redshift, the overall W_o distribution for both types shows continuity and can be fit by an exponential form: $dN/(dzdW) = 20.5 \exp(-1.85W)$. The index is between 0.87 for CIV systems (Young et al. sample, 1982) and 2.76 for the Lyα forest (Sargent et al. 1980). With the density per unit redshift per rest equivalent width for Lyα damped system from the sample of Wolfe et al. (1986) being added (Chen 1986b), the plot of log (dN/dzdW) vs. W_o clearly shows that, within the quality of the sample presently available, there is no single exponential form in W_o distribution from the Lyα forest through the metal system to the Lyα damped system. It seems better to fit with a single power law, although there is a systematic difference between them. This result can be compared with that reported by Tytler (1984): the HI column density distribution is a single power law from the weakest Lyα line up to the strongest metal system.

3) Two point correlation function

The question whether the Lyα forest really does not show fine velocity splitting with peak at 150 km/s as pointed out by Sargent et al. (1980) is still being debated. Bergeron and Boisse discussed the selection effect that the CIV line splitting is seen preferentially in systems with large W_o, and the rest equivalent width W_o (Lyα)/W_o(CIV) ratio is usually (much) larger than unity, therefore the same property is expected only for Lyα lines with individual components of $W_o > 1$-2 Å. The Lyα lines will then be either more blended than the CIV doublets (higher opacity) or may be saturated. On the other hand, Webb et al. (1984) have reported that there is some evidence from high resolution spectra that the Lyα absorbing clouds show velocity clustering on scales of up to about 150km/s. If the fine line splitting does reflect the clustering of the galaxies at the high redshift, then the Lyα damped system, which are generally thought to be due to the absorption of the disk components of the galaxies, should exhibit the same phenomena. The broad Lyα absorption troughs extended as wide as few thousands km/s make it impossible to resolve the splitting even if it does exit. The only possible way to detect such a splitting in Lyα damped systems is to observe in 21 cm absorption. The detected and well resolved 16km/s splitting 21 cm Lyα damped absorption system at z=2.03937 and 2.03953 in the QSO PKS 0458-02 (Wolfe et al. 1985) demonstrates its great capability. Therefore, it is highly desirable to collect a large 21 cm absorption sample to answer the question : whether the CIV fine splitting is due to the clustering of the galaxies or it is the mere complex structure of the individual object.

4) Metal abundances

One of the widely discussed problems concerns with the metal abundances in the Lyα clouds. Since the primeval matter consisted almost entirely of hydrogen and helium, and the nucleosynthesis of heavy elements in the Lyα clouds would imply that the abundances of the clouds have been enriched by stellar material, and that the Lyα clouds are associated with galaxies. Searches have been made for OVI in OQ172 and 4C05.34 by Norris et al. (1983), in Q1623+269 by Sargent and Boksenberg (1983) and in Q2000-330 by Norris and Peterson (Peterson , 1985), and the results are conflicting. Chaffee et al. (1985) examined a double Lyα absorption system in the QSO 0014+81 and marginally detected two features which could be SiIII (1206 Å). However, in a subsequent paper, Chaffee et al. (1986) discussed their ionization model, which predicts that if SiIII is detectable, CIII will be even stronger and must also be detectable. On the basis of further observations they concluded that the 3 sigma upper limit for CIII is log N(CIII) =12.9, five times weaker than predicted by their model from the strength of previously found SiIII lines. Thus, the detection of neither OVI nor SiIII has been confirmed. But on the other hand, the available observations are not sufficient to exclude the presence of the lowest heavy element abundances found in the galaxies. The problem remains open.

5) dN/dz vs. z for absorption line systems

Many authors have studied the number density of Lyα lines per unit redshift interval, as a function of redshift (see Table II of Chen(1986a), and Murdoch et al., 1986) and led to the result that the Lyα lines do evolve with redshift as a power law of (1+z), with a gamma index around 2. The statistical significance is much improved by adding the BL Lac object 0215+015 (z=1.50) and the QSO 2000-330 (z=3.78) extending thereby the interval of the redshift of the absorption line sample in both directions. In the pressure-confined model, the evolution of the number density of Lyα clouds is explained by the spectrum of the mass of the clouds and the evolution of the column density of the neutral hydrogen (Atwood et al., 1985, Ikeuchi and Ostriker, 1986) and therefore gives a constraint for the galaxy formation theory. For metal line systems, Bergeron and Boisse (1984) indicated that the number of CIV systems reveals a possible cosmological evolution with gamma around 1.8 in the redshift range 1.4 - 2.0. If this result could be confirmed and extended to redshift over 3, it would mean that the CIV systems, which is widely accepted to be associated with haloes of galaxies, have the same evolution law as the Lyα forest, while the QSOs themselves have a completely different evolution behavior with number density decreasing beyond z=3 and probably cut off around z=4. The Lyα damped systems of Wolfe et al. (1986) sample is too small to estimate the gamma. Bian et al. (1986) have argued that if the dN/dz of Lyα lines for each individual QSO shows no consistent tendency of evolution while the dN/dz for the overall QSO lyα lines sample strongly evolves with redshift, it would mean that dN/dz varies with Zem instead of Zabs. The statistics for the sample presently available support this point with an even better significance. If this can be confirmed in the future, It would cast doubt on its intervening nature.

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