QSO ABSORPTION LINES AND INTERGALACTIC HYDROGEN CLOUDS

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The absorption line spectra of some QSOs are similar to the absorption line spectra imposed by the interstellar medium in our own galaxy on the spectra of hot stars (see Figure 1). The spectra of other QSOs show P Cygni profiles similar to those of hot stars with mass outflow (see Figure 2). The absorption lines in both of these types of spectra are due to the resonant transitions of hydrogen and of the more abundant elements.

The spectra of high redshift QSOs show a multitude of absorption lines on the short wavelength side of the Ly-α emission line (see Figure 3). As almost none of these lines on the short wavelength side of the Ly-α emission line can be identified with heavy elements in recognizable redshift systems, these absorption lines are attributed to the neutral hydrogen component of clouds in the general intergalactic medium and in intervening galaxies.

In order to study the properties of the clouds in the intergalactic medium, spectra were obtained of QSOs with redshifts in the range $2 < z < 3.6$. The QSOs were selected to have similar luminosities. The preliminary results from a study of these spectra are reported here. The assumptions made are that the absorption lines have similar characteristics in these spectra (Figure 4) and that the wavelength distribution of the absorption lines in QSO spectra is related to the distance distribution along the line of sight to the QSO of the neutral component of hydrogen clouds which are part of the intergalactic medium.

If the clouds are assumed to have a characteristic radius and density which are constant with cosmic time, and if the co-moving density of clouds is also contant with cosmic time, then the number of absorption lines produced by the clouds in a given wavelength interval (which corresponds to a unit redshift interval) will be only a slowly varying function of redshift.

The number of clouds intercepted along the line of sight dl is given

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by $dN = \sigma\ \rho\ dl$, where σ is the cloud cross section, ρ is the cloud number density and dl is the proper length along the line of sight. Using the relations $\rho = (1+z)^3\ \rho_o$ and $dl/dz = c/[(1+z)H(z)]$, we have

$$dN/dz = \frac{c}{H_o}\ \sigma\ \rho_o\ \frac{(1+z)}{(1+2q_oz)^{\frac{1}{2}}} \qquad (1)$$

for the number of clouds in a unit redshift interval. As can be seen from equation (1), dN/dz varies slowly with z.

The observations have revealed a quite different result. In Figure 4 are shown the spectra of four QSOs which have been studied with 0.1 nm resolution. It can be seen in Figure 4 that many absorption lines lie on the short wavelength side of the Ly-α emission line, corresponding to absorbing hydrogen at intermediate distances, while virtually no absorption lines are seen on the long wavelength side of the Ly-α emission line, where the wavelength region corresponds to hydrogen at a greater redshift than the QSO, or to hydrogen falling into the QSO. The spectra in Figure 4 are arranged in order of redshift with the spectrum of the QSO having the highest redshift at the top of the figure. It can be seen in Figure 4 that the number of absorption lines in a fixed wavelength interval is correlated with the redshift of the QSO in the sense that the QSO with the larger redshift has the greater number of absorption lines.

The relation between N and z given by equation (1), for uniformly distributed clouds with invarient cross section and density, is compared in Figure 5 with the results obtained from the QSO spectra shown in Figure 4. The rapid increase of N with z which was found from the observations can be understood in terms of a progressive ionization of the intergalactic medium, starting at $z \sim 4$ with the turn on of QSOs (Bergeron and Salpeter 1970), or in terms of a change in cross section brought about by the collapse of the clouds, perhaps to form galaxies.

The spectra discussed above cover the same intrinsic redshift range for QSOs with different redshifts, but similar luminosity. What remains to be done, is to obtain spectra over a large redshift range in the same QSO so that the N of z relation obtained from spectra of a single object can be compared with the N of z relation found from objects at different redshifts, as discussed here. If the lines are produced by the Ly-α transition in intergalactic clouds, the N of z relations found from spectra covering different regions of the intrinsic QSO spectrum should agree.

Also, confirmation of the identification of the lines with the Ly-α transition should be obtained by observing the region of the spectrum where the corresponding Ly-β lines can be seen. While the identification of individual Ly-α, Ly-β systems may not be possible, a change in the character of the absorption spectrum due to the Ly-β lines should be detectable.

The observations discussed here were obtained with the Image-tube Dissector Scanner and the Image Photon Counting System on the Anglo-Australian Telescope in collaboration with Drs D. Jauncey, A. Wright and D. Morton.

REFERENCE

Bergeron, J., and Salpeter, E.E., 1970. Ap. Letters, 7, 115.

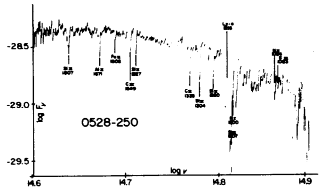

Figure 1. The spectrum of Pks 0528-250, an example of absorption lines produced in the metal enriched interstellar medium of an intervening galaxy.

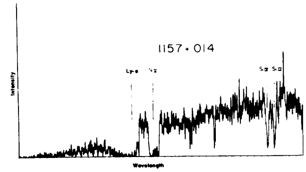

Figure 2. The spectrum of Pks 1157-054, an example of absorption lines produced in the H II region surrounding the QSO.

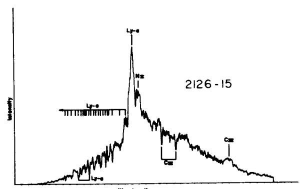

Figure 3. The spectrum of Pks 2156-15, an example of multiple absorption line redshifts produced by the neutral hydrogen component of clouds in the intergalactic medium.

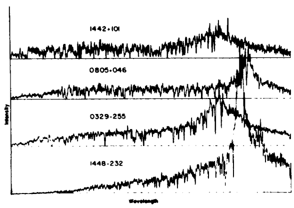

Figure 4. Spectra of Pks 1442+101, z = 3.53, Pks 0805+046, z = 2.88, Pks 0329-255, z = 2.68, and Pks 1448-232, z = 2.21. These spectra cover the same intrinsic wavelength range in the spectrum of each of the four QSOs. The Ly-α emission lines are prominent features near the right-hand ends of the spectra.

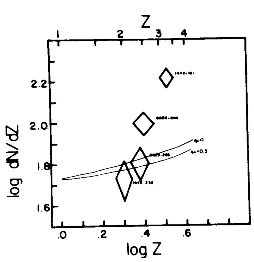

Figure 5. The relations between line density, dN/dz and redshift, z. The thin curves in the figure show the relation given by equation (1) for constant cloud properties. The diamonds were derived from the spectra in Figure 4. The z extent of each diamond represents the range in z covered while the extent in dN/dz represents an estimate of the error in determining dN/dz. These are preliminary results.

DISCUSSION

de Vaucouleurs: Is there any evidence which allows you to distinguish intergalactic HI clouds from ordinary galactic discs?

Peterson: Yes, in some cases we can see absorption lines of heavy elements in the absorption systems as would be expected in the gaseous discs of galaxies.

Silk: Can you comment on the metal content in any of the absorption line systems?

Peterson: No, not yet.