ABSORPTION SYSTEMS IN HIGH REDSHIFT QSOs

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In addition to the characteristic emission lines, absorption lines frequently are seen in the spectra of QSOs, usually those with high redshift ($z_{em} \gtrsim 1.8$). About 10 percent of all QSOs listed in the compilation of Burbidge et al. (1976a) are recorded as having at least one 'identified' absorption system, meaning that a pattern of several selected observed lines can be matched with the apparent wavelengths of transitions (generally from the ground level) in a physical plausible group of atoms or ions at the same, although arbitrary, redshift (Bahcall 1968, Aaronson et al. 1975). Identified absorption line redshifts range from being comparable with the associated emission line redshifts, to having very much smaller values with relative velocities exceeding 0.5c in the QSO frame. Added to this, there are many QSOs having absorption lines not yet recognised as belonging to identified systems, both those objects already having one or more identifications, and others with none.

It is important to realise, however, that whether or not absorption lines are detected depends very much on observational technique. As in the similar case of interstellar absorption lines in the Galaxy, only when the instrumental spectral resolution is adequately high can such lines be seen at all. The survey resolutions used when first attempting to identify features in QSOs usually are too low to bring out any but the strongest of the absorption lines that may be present and this can give a misleadingly sparse picture of the line population. This point is well illustrated by the spectra of the QSO PHL 957 ($z_{em} = 2.69$) observed at low and high resolutions by Coleman et al. (1976). The low resolution spectrum, in their Fig.1, shows only a few absorption lines, including an extremely strong line of Lyα in a system at $z_{abs} = 2.309$. In contrast, the high resolution spectra in their Fig.3 reveal a rich absorption spectrum, and they list 203 individual lines (see also: Lowrance et al. 1972, Wingert 1975).

Again, for interstellar absorption lines, only by extending the range of observation into the middle and far ultraviolet (by observing from above the atmosphere) do lines of most of the available

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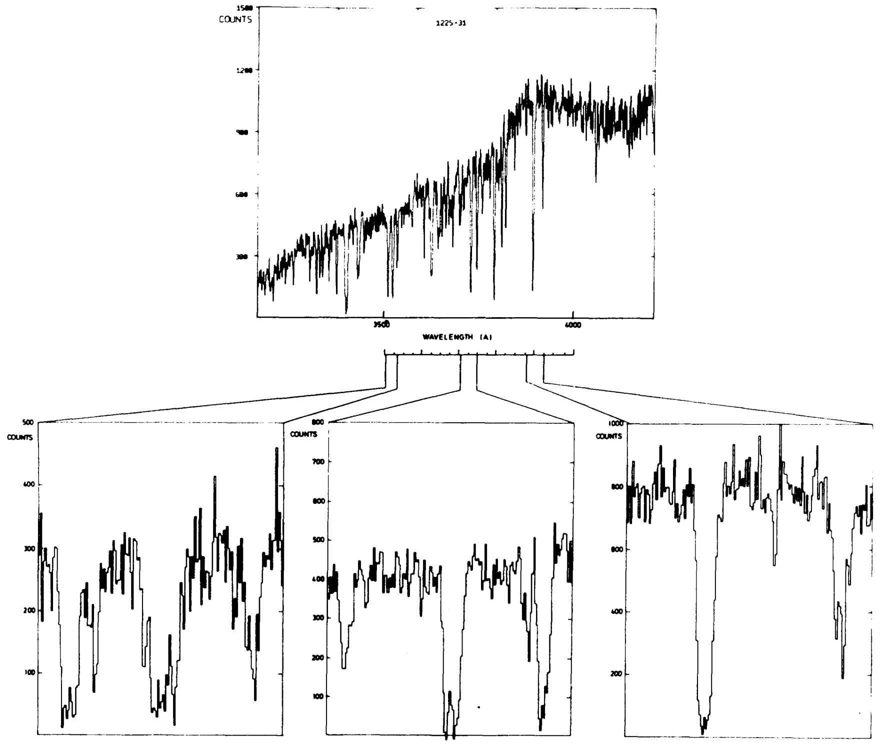
transitions become accessible: lines arising from ground-state transitions in a wide range of ionization stages of the more abundant elements (HI, MgI-II, CII-IV, FeII-III, SiII-IV, NI-III, NV, OVI, etc., e.g. Morton and Hu 1975). The same absorption lines as are seen in the interstellar gas also appear in QSO spectra. Furthermore, in both cases, lines arising from excited fine-structure levels generally are absent, but occasionally are observed. For QSOs, as has been well described by Lynds (1972), with increasing redshift the detection of absorption lines depends strongly first on the MgII doublet($\sim \lambda 2800$) then on the CIV doublet ($\sim \lambda 1500$), and finally on Lyα ($\lambda 1216$) which enters the observable range at $z \simeq 1.65$. Ionization conditions in the absorbing regions may in general work against the support of Mg^+, and this would result in an observational bias for the detection of the higher redshift systems. On the other hand, the fact that nearly all QSOs with $z_{em} \gtrsim 1.8$ have absorption lines in their spectra may be attributed to the dominance of neutral hydrogen, which persists in the absorbing regions as a relatively large residual despite the usually unfavourable ionization conditions.

With some few exceptions, the QSO absorption lines are very narrow and generally are unresolved even at the highest observed spectral resolutions. Lines which appear single at intermediate resolution are frequently revealed as finely split at high resolution. The observations of the QSO B2 1225+31 shown in Fig.1, which we obtained with Sargent and Lynds, serve as an example of this. The upper spectrum, at intermediate resolution ($\Delta\lambda \sim 2A$), shows several deep absorption lines each without apparent structure; the lower tracings are selected from spectra observed at high resolution ($\Delta\lambda \sim 0.7A$) and reveal fine velocity components and narrow features not detected in the upper spectrum. Structure such as this appears to be remarkably similar in all cases comparably observed (e.g. Boksenberg and Sargent 1975). A small portion of a spectrum of the BL Lac object Pks 0735+178 obtained (with Sargent) at still higher resolution ($\Delta\lambda \sim 0.3A$) is shown in Fig.2. At the top are the observed MgII H and K lines, having a redshift near 1.424; next, a computed profile based on four component clouds and convolved with the instrument profile is compared with the observed data points, for the K line; and at the bottom is the corresponding unconvolved computer profile for the K line. It is clear that there are (at least) four velocity components distributed over the range 165 km s^{-1}; the narrowest has a measured full width at half minimum of < 20 km s^{-1}. It is suggestive that the width of each component is comparable with the range of velocities over which cloud components are observed in the local interstellar gas (Boksenberg et al. 1975), and that the total width of the complex falls within the range expected for a galaxy (Burbidge 1975).

Referring again to Fig.1, evidently there is a dramatic increase in the density of absorption lines shortward of the Lyα emission line compared with longward. This is commonly seen in all high-redshift QSOs adequately well observed (Lynds 1972). Most of these lines



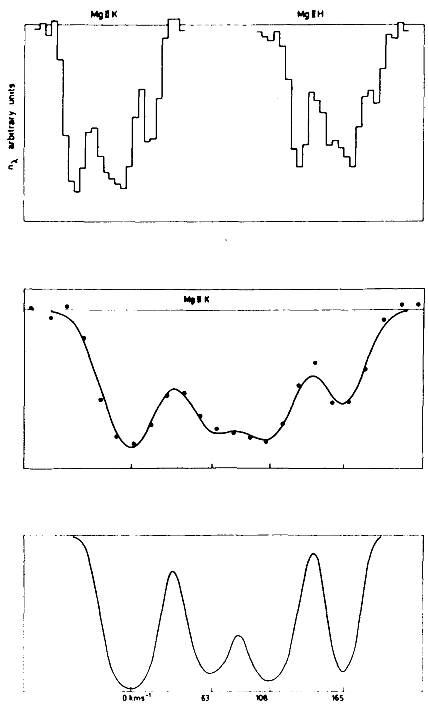


Fig.1: (above). Spectra of the QSO B2 1225+31 shown (upper) at intermediate resolution ($\Delta\lambda \sim$ 2A) and (Lower) selected sections at high resolution ($\Delta\lambda \sim$ 0.7A).

Fig.2: (left). Top: the MgII H and K lines (z_{abs} = 1.424) in the BL Lac object Pks 0735+178 observed at a resolution $\sim$ 0.3A. Middle: computed profile of K line based on 4 components and convolved with instrument function, compared with observations (points). Bottom: unconvolved computer profile for K line.

remain unidentified, in the sense that no corresponding patterns of other lines are observed with which to group them and enable redshift systems to be recognised. The most plausible explanation for these lines is that they represent Lyα absorption in clouds at lower redshift than the QSO against which they are observed and for which lines of other elements (and other Lyman lines) are too weak to be detected (Lynds 1971, 1972).

There are a few QSOs, already alluded to, which exhibit absorption features having a strikingly different appearance from the sharp lines seen in all other cases. Such an object is PHL 5200 (Lynds 1967, Burbidge 1968), whose spectrum (observed at $\Delta\lambda \sim 15$A, with Sargent) is shown in Fig.3a. The emission redshift of PHL 5200 is 1.985 and it has very broad absorption bands shortward of Lyα, NV λ1240 and SiIV λ1393,λ1402 in the wavelength range shown here, and also CIV λ1548,λ1551. The bands extend from $z_{abs} \sim 1.86$ right up to the emission redshift, a range of $\sim$ 12500 km s^{-1}. At slightly higher resolution, sharp absorption lines also are seen in this object (Burbidge 1968, Lynds 1972). The broad absorption features almost certainly arise in material flowing out from the QSO itself (Scargle et al. 1970). The range in velocities is comparable with the turbulent velocities commonly observed in the broad emission line regions in QSOs and Seyfert nuclei (e.g. Osterbrock et al. 1976, Boksenberg et al. 1975). Similar features, of several thousand km s^{-1} width, are seen in the equivalent ultraviolet spectra of stars, as in the case of ζ Pup (Fig.3b), where there is no doubt that material is being ejected (Morton 1975). Other QSOs of this class probably having intrinsic absorption are RS 23 (Burbidge 1970) and the recently discovered object Q1246-057 (Malcolm Smith, private communication). The latter is distinct in that it shows a clear separation of $\sim$ 15000 km s^{-1} between a broad-lined absorption system (width $\sim$ 4000 km s^{-1}) and the emission redshift.

Narrower absorption lines somewhat reminiscent of those in QSO spectra also appear in the spectra of some Seyfert galaxies. Such a case is Markarian 231, which is placed among the QSOs in optical luminosity (Boksenberg et al. 1976). A low resolution spectrum ($\Delta\lambda \sim 7$A) of the nucleus of this object is shown in Fig.4. Apart from the interesting broad-lined emission spectrum at a redshift of 12600 ± 200 km s^{-1} (the numbered multiplets refer to permitted transitions in FeII) there are several absorption features belonging to three separate systems indicated by bracketted roman numericals. System I contains resonance lines of CaII and NaI, and λ3889 of HeI, at a redshift of $\sim$ 8000 km s^{-1}. System II represented by the D-lines and λ3889, is at a redshift of 6250 km s^{-1}. System III, featuring the K-line and members of the Balmer series, is at 12900 km s^{-1}, close to the emission redshift; this may represent the intrinsic absorption spectrum of stars in the galaxy. Inserted in Fig.4 are high resolution ($\Delta\lambda \sim 0.5$A) profiles of the H, K and λ3889 lines, shown (with arbitrary vertical displacements) on a velocity scale with the positions of several possible velocity components in System I marked. The mean

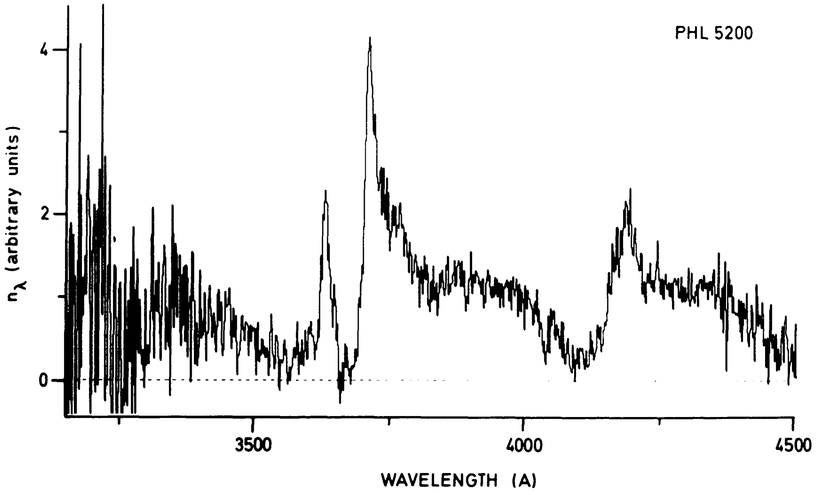


Fig. 3a: Spectrum of the QSO PHL 5200 showing broad absorption bands.

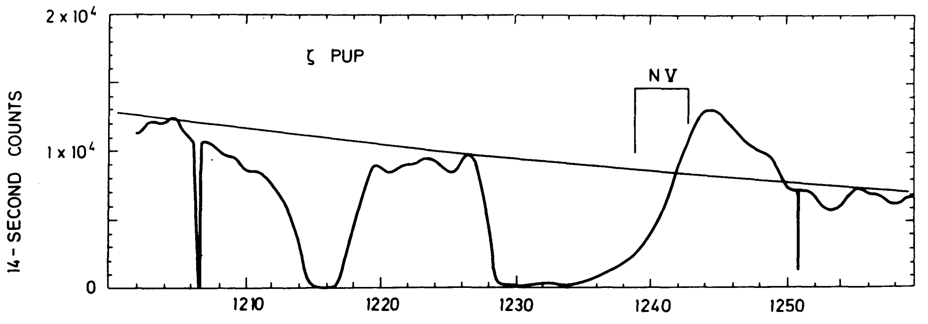


Fig. 3b: Spectrum of ζ Pup (Morton 1975)

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outward velocity is $\sim$ 4700 km s^{-1} for System I and $\sim$ 6350 km s^{-1} for System II. Although at first sight these lines appear similar to the narrower absorption lines seen in QSOs, the presence of the HeI line at once points to a clear distinction: in QSOs absorption lines have been seen to arise only from ground or excited fine structure states, whereas the HeI line arises from a metastable level 23 eV above the ground state. The presence of the HeI line argues strongly in favour of a close association of the absorbing regions with the nuclear activity in Markarian 231, and suggests that these are a geometrically favoured sample of the broad emission line region. The lower redshift absorption lines in Markarian 231 resemble those seen in NGC 4151 (Anderson and Kraft 1969, Weymann and Cromwell 1972, Boksenberg and Penston 1976) which not only has the HeI line, but also the Balmer lines which too are never seen in QSOs. Furthermore, all these lines vary greatly in strength on a timescale as short as about one month, making another important distinction between these and absorption lines in QSOs, for which there is no evidence for variability in strength or velocity over periods up to several years (with the possible exception of PHL 5200: Burbidge 1968).

Having dealt with the types of absorption lines which probably are intrinsic to the objects in whose spectra they appear, and clearly are characteristically different from the majority of absorption lines seen in QSO spectra, we now consider the origin of the latter. If the QSOs are at cosmological distances (which we shall assume here) the narrow absorption lines may, in principle, be intrinsic to the QSOs, arising in material ejected from them at velocities up to the very high values observed, or be produced in material residing at intervening cosmological distances in line to the QSOs, either in intergalactic clouds or directly associated with galaxies. In the remainder of this paper we review some of the arguments and evidence for and against these possibilities.

One of the first QSOs found to have a rich absorption line spectrum is 3C 191. In this object it was noticed that z_{abs} is only slightly lower than z_{em} and it was natural to think that this implied a physical relationship between the emitting and absorbing material. The evidence for such a relationship apparently was strengthened by the presence of absorption lines corresponding to the SiII λ1264 and λ1533 transitions from the J = 3/2 excited fine-structure level of the ground state (Stockton and Lynds 1966), suggesting that radiation from the QSO was providing the necessary excitation. As has been shown by Bahcall and Wolf (1968), the relative population of excited fine-structure levels is a powerful indicator of the physical conditions in the absorbing material. Bahcall et al. (1967) further analysed this object and deduced from the relative SiII line strengths that: (a) the absorption arose in a region of density $n \lesssim 10^3 cm^{-3}$, with equality holding if the fine-structure excitation is induced only by electron collisions and (b) the distance of the absorbing

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material from the QSO continuum source is R $\gtrsim 10^{2\pm1}$ pc, with equality holding if excitation is due only to ultraviolet fluorescence. Higher resolution studies by Williams et al. (1975) revealed that the absorption system is split into two components ($z_A = 1.945$ and $z_B = 1.949$) with a separation characteristic of the CIV resonance doublet ('line-locking': see below). A doubling of the absorption spectrum previously had been inferred by Scargle (1973) on the basis of a model invoking radiation pressure driven outflow for the absorbing material. This seemed to strengthen the case for the absorbing material being intrinsic to the QSO. However, on closer study Williams et al. (1975) found that the indications are not quite so clear. Assuming that the ionization of the absorbing material is due to photoionization by the QSO continuum source, and that the elemental abundances are solar, they found that for reasonable values of spectral index the computed ionization is much too high to account for the observed absorption spectrum of 3C 191 at densities $n < 10^3 cm^{-3}$ required by the fine-structure population unless R is greater than $\sim 10^3$pc, and then excitation of the fine-structure levels cannot occur by ultraviolet radiation (excitation due to infrared radiation was discounted as implausible). This led to the conclusion that the fine-structure excitation is due to collisions and hence $n \simeq 10^3 cm^{-3}$; the observed level of ionization then requires $R \approx 10^4$pc. The photoionization model gave a satisfactory fit to the observed absorption equivalent widths for a single cloud, but ran into difficulties when both clouds were considered, because essentially all of the ionizing radiation along the line of sight must be absorbed in the inner cloud, leaving none to produce NV probably but not definitely observed in the other. It seems to us that the deduction that the fine-structure excitation occurs by collisions not ultraviolet fluorescence, coupled with the apparent difficulty suffered by the two-cloud photoionization model, severely undermines the claim that the absorbing material is clearly intrinsic to 3C 191. Furthermore, it has since been found that excited fine-structure levels can be populated in absorption systems with redshift greatly different from the emission redshift, as in the cases of Pks 0237-23 (Boksenberg and Sargent 1975) and OQ 172 (Baldwin et al. 1974), which now makes the original case qualitatively less compelling; and such transitions also are observed in the interstellar gas (Morton 1976), a fact which sustains the cosmological hypothesis.

As was mooted above, the intrinsic hypothesis gains some support from the apparent phenomenon of 'line-locking' observed in a number of cases (Strittmatter et al. 1973, Williams et al. 1975, Boksenberg and Sargent 1975). Such a process may occur naturally if radiation pressure were in some way instrumental in affecting the ejection of material from the QSO (Mushotsky et al. 1972, Scargle 1973). Qualitatively, the physical picture invoked for this effect is as follows: gas driven out from a QSO in some way (not necessarily by radiation pressure alone) will absorb radiation emitted from the QSO line and continuum regions, but which has been filtered through absorption by gas closer to the QSO and moving at different velocities. In their local frame, ions of any particular species in the outflowing material,

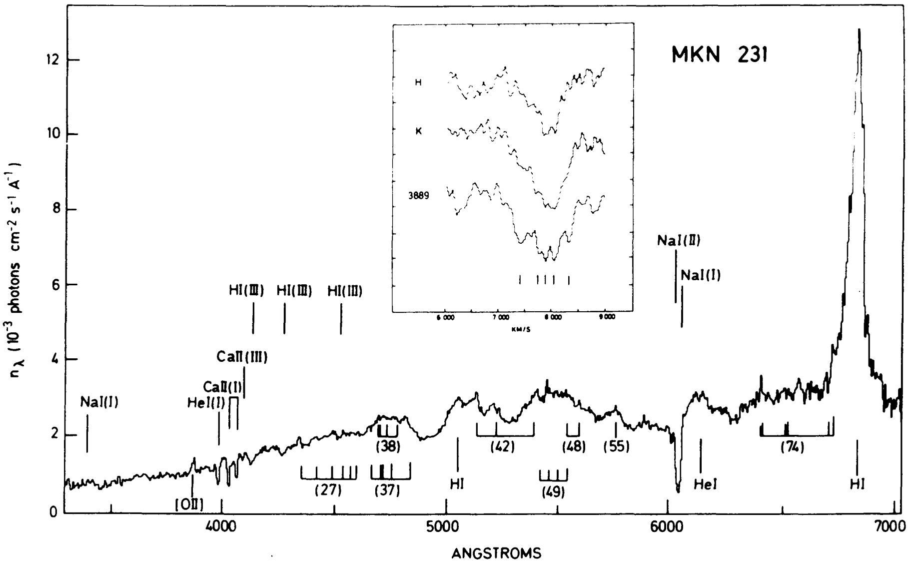

Fig. 4: Low resolution ($\Delta\lambda \sim 7$A) spectrum of the Seyfert galaxy Markarian 231. The insert shows high resolution ($\Delta\lambda \sim 0.5$A) profiles of the CaII and HeI absorption lines.

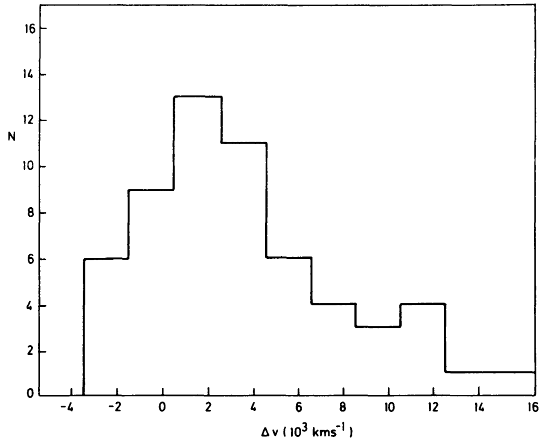

Fig. 5: Histogram of the distribution in relative velocities of emission and absorption systems for 39 QSOs.

if at the appropriate velocity, will be exposed to redshifted radiation from the central source that may have the blue wing of an emission line, an ionization edge, or a redshifted absorptuon line from intervening gas, falling at the frequency of one or more of their particular resonance lines. Such ions will experience less radiation pressure than those at neighbouring velocities and a balance with the inward gravitational force may be set up to provide an accumulation of ions in velocity space at certain velocities at which they experience no net inward or outward acceleration. This would be manifest as 'line-locking', in which the long wavelength component of a resonance doublet such as CIV $\lambda 1548, \lambda 1551$ in one absorbing cloud coincides with the short wavelength component in another moving out at a higher velocity (as is apparent in the case of 3C 191), or line-edge locking when an absorption line in a cloud coincides with a strong wavelength gradient in the radiation flux such as may occur at the HI or HeII ionization edges. Thus, in individual objects, certain preferred values may occur in $(1 + z_i)/(1 + z_j)$, i.e. in λ_m/λ_n where these are the rest wavelengths of features appearing at the same observed (redshifted) wavelength in two systems of different redshifts z_i and z_j and where z_i includes z_{em}. Quantitatively, radiative acceleration of QSO clouds has been studied by Kippenhahn et al. (1974), Kippenhahn et al. (1975) and Mestel et al. (1976) who showed, using simple models, that near-relativistic velocities could be achieved and that instabilities could occur to break up uniform flow. However, no quantitative explanation of line-locking or line-edge locking yet exists and, indeed, has serious theoretical difficulties (J.J. Perry, private communication). Furthermore, no theoretical treatment yet reproduced the observed character of the absorption lines; in particular, their extraordinarily narrow widths introduces special difficulties, as discussed by Williams (1972), Weymann (1973), McKee and Tarter (1975), and Weymann (1976). On the other hand, it is important to note that the radiative driving mechanism has no difficulty in explaining the broad emission lines in QSOs and Seyfert galaxies (Blumenthal and Mathews 1974), which clearly are intrinsic to these objects.

The occurrence of line-locking and line-edge locking recently has been reviewed and empirically studied by Burbidge and Burbidge (1975). Although the evidence for these phenomena seems at first sight to be suggestive, it is far from being conclusive and indeed may not be apparent at all when considered from a broader statistical base (Aaronsen et al. 1975, Sargent and Boroson 1976, Carswell et al. 1976, Carswell, Boksenberg and Sargent (1976, in preparation). Furthermore, Carswell et al. (1976) note that there is evidence for possible NV and SiIV line-locking in the QSOs 0736-06 and 4C 24.61, but that in both cases the resonance doublet concerned does not appear prominently in the spectrum; they suggest that the splittings probably are due to chance and comment that this may be true for other claimed line-lockings where the corresponding lines are indeed observed. Related comments in a similar context have been made by Bahcall (1975).

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A strong argument against the intrinsic hypothesis is made in the case of the QSO 3C 286 by the recent radio observations of Wolfe et al. (1976). This object has a radio absorption line at 839.4 MHz, which is identified with the 21 cm HI line at a redshift of $z_{abs} = 0.692$ (Brown and Roberts 1973), and an optical emission redshift of $z_{em} = 0.849$. From very-long-baseline observations Wolfe et al. were able to observe two closely spaced regions in the absorbing medium, one in front of each of the two strongest components of continuum emission, with full widths at half-minimum of 3.7 km s^{-1} and 7 km s^{-1} separated in radial velocity by 3 km s^{-1}. They considered a simple model in which the gas is confined to a thin spherical shell of radius R centred on one of the emission components and enclosing both, and derived the value R ≥ 20 kpc and a separation of 260 pc between the observed absorbing regions (assuming z_{em} is cosmological, $H_o = 50$ km s^{-1}Mpc^{-1}, and $q_o = 0$). On comparing the momentum of such a shell with that supplied by the centrally located source of optical and ultraviolet continuum radiation they find it to be greater by a very large factor, and conclude that radiation emitted by 3C 286 cannot drive the absorbing gas to the relative velocity observed ($\sim$ 0.1c). Other mechanisms, including the action of relativistic particles and magnetic fields stored in the radio source, are found to be implausible, and models involving large gravitational redshifts can be ruled out. However, the observations are consistent with absorption by gas in an intervening galaxy.

Redshifted 21 cm absorption also has been observed in the BL Lac object AO 0235+164 at $z_{abs} = 0.52385$ (Roberts et al. 1976). This redshift is identical, within the errors, to the optically derived redshift (Burbidge et al. 1976b) and is the first instance in which both radio and optical high-redshift absorption lines are detected; it provides a link, if one were needed, between objects of both types. The 21 cm line shape shows structure on a scale of $\sim$ 6 km s^{-1} and an overall range of $\sim$ 50 km s^{-1}. For $T_s = 100$ K the neutral hydrogen total column density in the direction of the source is $\simeq 2.3 \times 10^{21}$cm^{-2}.

The suggestive evidence afforded by 21 cm observations that at least some absorption lines in QSO spectra are due to material in or associated with intervening galaxies (Wolfe et al. 1976), is strongly supported by the more direct observations of Haschick and Burke (1975) and Grewing and Mebold (1975). Both groups took radio spectra near 21 cm wavelength of several close QSO-galaxy pairs whose projected separations at the galaxies are sufficiently small to expect a chance of detecting absorption of the QSO radiation by galactic neutral hydrogen. Hydrogen emission from the galaxies was detected in all cases. A narrow absorption feature (half-width $\lesssim$ 5 km s^{-1}) was found in the spectrum of one of the QSOs, 4C 32.33, close to the systemic velocity of the neighbouring galaxy NGC 3067 (of type Sb), giving a neutral hydrogen column density $N_{HI} \leq 2.7 \times 10^{17} T_s$cm^{-2} where T_s is the spin temperature of the gas (this is the result of Haschick and Burke, who give the slightly smaller upper limit). Assuming $T_s = 100$ K, $N_{HI} \leq 2.7 \times 10^{19}$cm^{-2}. No absorption features were detected in the other cases, but the observed line is not much stronger than the instrumental detection limit, so it cannot be inferred that no comparable absorption occurs in these, merely that it may be present undetected in the noise.

For the absorption near NGC 3067, Haschick and Burke derive a 'disc distance' (the radial distance from the centre of the galaxy at which the line of sight to the QSO intersects a disc lying in the galactic plane) of about 60 kpc ($H_o \simeq 50$ km $s^{-1}Mpc^{-1}$) and point out that this implies that the neutral hydrogen responsible for the absorption feature lies at a distance of more than 4 Holmberg radii from NGC 3067.

Although for the great majority of QSOs the absorption redshifts are smaller than the emission redshifts, there are some which have $z_{abs} > z_{em}$ (e.g. Lynds 1972, Weymann et al. 1976). The relative velocities of these absorption systems with respect to the emission systems has never been observed to exceed a few thousand km s^{-1}. No spectroscopic differences between the $z_{abs} > z_{em}$ systems and the more common blueward absorption systems (both those with $z_{abs} \lesssim z_{em}$ and $z_{abs} << z_{em}$) are apparent, either in the types of neutral or ionized species observed or in their characteristic line widths and fine splittings. A histogram of the distribution in relative velocities of emission and absorption systems for $z_{abs} \approx z_{em}$ for 39 QSOs drawn from Burbidge and Burbidge (1975), Carswell et al. (1976) and a recently observed sample of QSOs with $z_{em} \sim 2$ by Carswell, Boksenberg and Sargent (1976) is shown in Fig. 5. In some objects there is more than one system, and systems with $z_{abs} > z_{em}$ and $z_{abs} < z_{em}$ co-exist. The fact that $z_{abs} \approx z_{em}$ strongly implies that the absorbing material is located in the vicinity of the QSOs; but it need not be directly associated with them, as is suggested by the case of PHL 1222 (Weymann and Williams 1976). This object has $z_{em} = 1.903$ and an absorption system with $z_{abs} = 1.934$, among others; from the absence of absorption lines arising from the excited fine-structure levels of CII and SiII and a consideration of the ionization equilibrium assuming photoionization by the QSO Weymann and Williams tentatively deduced that the gas must have a density $n_e \lesssim 15$ cm^{-3} and a distance > 4 x 10^5 pc from the QSO. If gravity is responsible for the observed infall velocity of 3190 km s^{-1} the simplest model of a cloud falling from rest at infinity requires a QSO mass > $10^{14}M_\odot$, much greater than the value $\sim 10^8M_\odot$ sometimes cited (Burbidge and Perry 1976). On the other hand, Weymann and Williams point out that the inferred mass of > $10^{14}M_\odot$ and the velocity and distance of the cloud to the QSO are similar to the masses, velocity dispersions and sizes of large clusters of galaxies, and is suggestive evidence that systems with $z_{abs} > z_{em}$ are clouds of gas moving in the gravitational field of such clusters. The fact that carbon and silicon are observed in the PHL 1222 cloud argues for the actual association of the gas with a galaxy in the cluster, in which case the radiation field producing the observed ionization could have a strong contribution from the galactic stars; this makes the derived cloud distance very much a lower limit. Alternatively, the gas may have been tidally disrupted from a galaxy and is more accurately identified as intracluster gas, and then the stellar radiation field is relatively weak. If the above interpretation of $z_{abs} > z_{em}$ systems is true it is a small step to include all systems with $z_{abs} \approx z_{em}$ in the same category. The shape of the histogram in Fig.5 lends support to this suggestion: it can be decomposed into a sharply peaked component with equal distribution in relative velocity about z_{em} (± 3500 km s^{-1}) and a shallower one with $z_{abs} > z_{em}$ extending to large relative velocities, merging with the systems of $z_{abs} << z_{em}$. The sharply peaked component can be interpreted as being due to absorption by intervening material contained in the supposed QSO clusters themselves, either in or out of galaxies, whereas the extended component could arise from material in unrelated clusters, and field galaxies (Lynds 1972). For the latter we would expect their dispersion in peculiar velocities about the mean Hubble flow to increase as (1 + z) and, say, would be about 1000 km s^{-1} at z = 2, taking 300 km s^{-1} as the present value of dispersion (Burbidge 1975). An explanation not including cluster galaxies, but only unbound field galaxies, is not consistent with the observations (Weymann et al. 1976).

We now turn to a direct consideration of the hypothesis that the QSO absorption lines with $z_{abs} << z_{em}$ are due to cosmologically distributed intervening material. Bahcall and Peebles (1969) pointed out that this question is open to statistical analysis, and they proposed two specific tests. Both of these are based on the expectation that the absorbing material is randomly distributed along the line of sight to the QSO: test 1 examines the distribution in total number of absorption redshifts found in each QSO of a uniformly observed sample; test 2 examines the relative frequency of occurrence of different values of absorption redshifts either in one object, or in several not necessarily uniformly observed. In test 2 the possibility that the absorbers may also have a z-dependent evolution must not be forgotten (Bahcall 1971). Such tests have been attempted in a direct or implied fashion by, for example, Roeder (1972), Aaronsen et al. (1975), and Carswell et al. (1976), but the observational material they used has not been sufficiently consistent or uniform to give valid results. The importance of strict observational uniformity (for test 1) was stressed by Bahcall and Peebles (1969) and reiterated by Bahcall (1971). The first uniformly observed sample of absorption lines in QSOs on which a proper test can be based has been obtained recently by Carswell, Boksenberg and Sargent (1976) (hereinafter referred to as CBS). A total of 17 QSOs contained in a relatively narrow redshift range ($1.9 \leq z_{em} \leq 2.2$) were observed with the same instrument at uniform resolution (about 5A), wavelength coverage and (approximately) signal-to-noise. Great pains were taken to define the detection of absorption lines in a consistent way by use of numerical limits on a probability criterion based on the signal-to-noise in the data. Spectra of two of the objects observed are shown in Fig.6. A typical noise curve is shown with the spectrum of 3C 9 (z_{em} = 2.012): the smooth line is the 1σ noise level in the sky-subtracted spectrum of the object; the small spikes indicate the

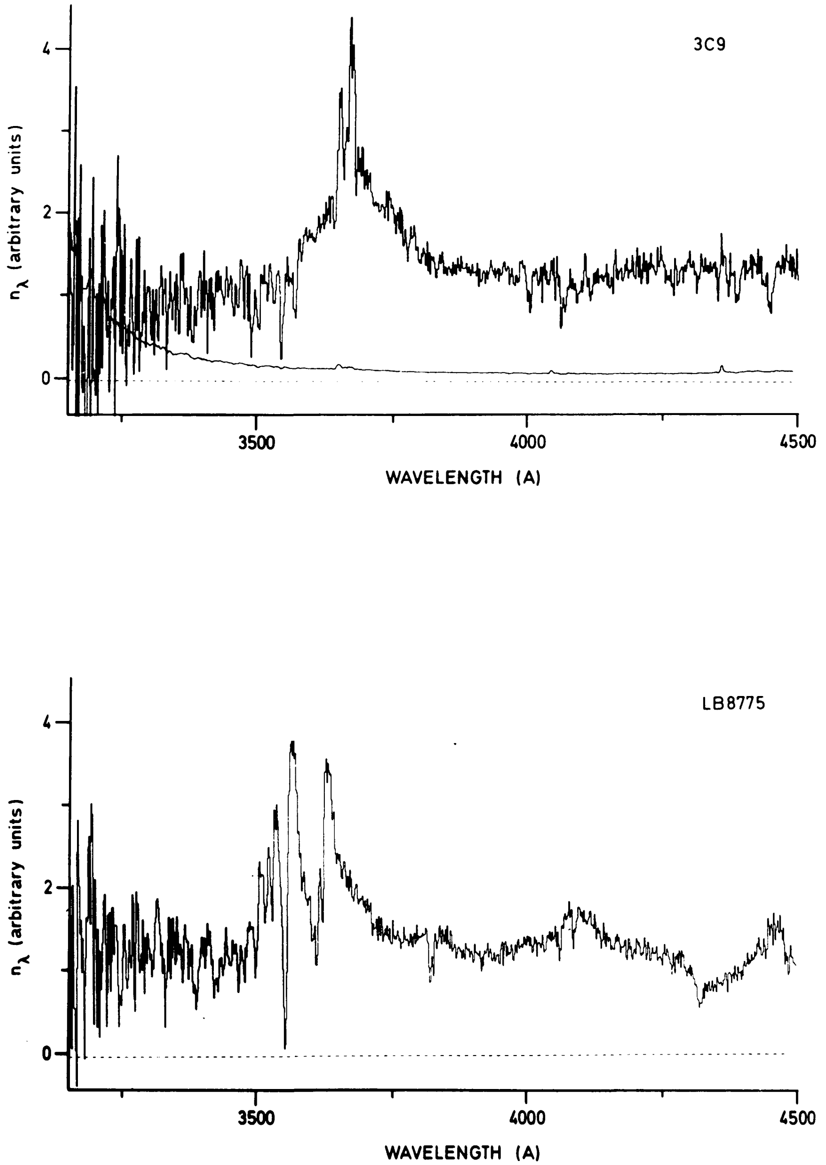

Fig. 6: Spectra of two of the QSOs from the $z \sim 2$ survey of Carswell, Boksenberg and Sargent. A noise curve is shown for 3C 9 as explained in the text.

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greater noise at the positions of the sky emission lines, and the rapidly increasing noise towards shorter wavelengths is due to the loss of signal at the encroachment of atmospheric extinction (the mean level of the QSO spectrum is everywhere approximately corrected by use of an observed standard). The strong emission line is Lyα (with greater or lesser contributions from NV λ1240 and SiIII λ1206) and clearly is cut by absorption lines in these examples. Considerable absorption structure also is present shortward of the Lyα emission, merging with the noise near the atmospheric cutoff. As mentioned earlier, for most well-observed high redshift QSOs it is striking that the density of absorption lines is much greater in the wavelength region below the Lyα emission line than above and that most of the former remain unidentified. The only plausible explanation is that the unidentified lines actually are Lyα absorption lines in clouds at lower redshift than the QSO, and for which lines of other elements are not detectable (Lynds 1971). Further implications of this will be discussed later. Accepting this explanation, it is easy to see that a non-random observational bias could act in favour of the higher redshift objects in the range of the sample, since the detection of lines shortward of the Lyα emission line becomes rapidly easier as the position of this line moves to longer wavelengths, away from the noisy region approaching atmospheric cutoff. The highest redshift object in the sample, Pks 0424-13 ($z_{em} = 2.165$), is particularly favoured in this respect and indeed it has by far the largest number of unidentified absorption lines.

The absorption line spectra were subjected to a computer search program in an attempt to identify redshift systems. As is usual in such analyses, a number of absorption lines, both shortward and longward of emission Lyα remain unidentified. Since the Bahcall-Peebles test is valid for any uniform selection criterion, several ways of examining the data were tried: for example, one case included only the most probable identified redshift system, and in another all unidentified lines were included and counted as belonging each to its own redshift system. Furthermore, in examining the distribution in number of absorption redshifts per object to test the assumption that the material of lower redshift is cosmologically distributed, systems with $z_{abs} \approx z_{em}$, assumed to be in the vicinity of the QSOs as previously discussed, should be omitted. This was done by supposing that a redshift within 4000 km s^{-1} (in the QSO frame) of z_{em} is associated with a QSO while one below this limit is not. Then, to avoid the non-random observational bias just pointed out, only those absorption systems with $z_{abs} < 1.88$ were included, where this value was chosen to be clear of any possible cluster material associated with the object of lowest redshift in the sample, PHL 1222. In all cases examined (with $z_{abs} < 1.88$) no significant difference between the observed and Poisson distributions was found. Although more similar work must be done (and is already planned) to increase the statistical significance of the results, it is clear that the observations are not inconsistent with the hypothesis of intervening cosmological material. It is interesting to note that Carswell et al. (1976), commenting on their observations but not entering into a statistical analysis, state that the richness of the absorption spectrum of 3C 9, contrasting with the complete absence of lines in LB 8755 and BSO 6, suggests that the absorption line regions cannot be randomly distributed at lower cosmological redshifts and therefore are intrinsic to the QSOs. CBS did not observe BSO 6 in their survey, but did include 3C 9 and LB 8755: absorption lines were detected in LB 8755, and both this object and 3C 9 were included in the statistical analysis just described, which yielded random distributions. For studies of this kind, this points once more to the strict need for uniform observational material and consistent treatment in its reduction and analysis.

As an additional outcome of the survey by CBS, there is an interesting peak near $z_{abs} = 1.6$ in the number of identified redshift systems plotted against redshift. This seems to occur for objects clustered around R.A. 23 - 1^h and 0 - 40^o Dec. Although the result is only of marginal statistical significance, if the absorption arises in intervening cosmological material, this may be evidence for large scale clustering in the Universe, which perhaps is not surprising as galaxy clusters and possibly superclusters are a common observational feature locally. If this enhancement is real then not only does it provide confirmation that intervening cosmological material is responsible for at least some of the absorption lines, but paradoxically also makes the basic form of the Bahcall-Peebles tests invalid: thus, departures from the expected random distributions in numbers of redshift systems (possibly with a mean varying smoothly with z_{abs} for test 2) do not necessarily imply that the absorbing material is intrinsic to the QSOs. Further evidence of this nature comes from a high resolution study of the QSO Pks 0237-23 by Boroson et al. (1976): on examining the redshift distribution of CIV lines, they find a clear excess in number of systems near $z_{abs} = 1.65$. This already is apparent in Fig.1 of Boksenberg and Sargent (1975). It is suggestive that the velocity spread in observed redshift grouping is a few thousand km s^{-1}, typical of a large cluster of galaxies.

We may go further than simply studying the distribution in redshift. Wagoner (1967) has computed the probability that light received from a distant QSO be intercepted by an intervening galaxy and show absorption lines (see also Roeder and Verreault 1969). Wagoner used a conventional galactic luminosity function, including only spiral galaxies without evolution, and found the probability P(z) that photons emitted by a source of cosmological redshift z have passed within the Holmberg dimensions of an intervening galaxy (i.e. the locally measured 25 mag $(\mathrm{arcsec})^{-2}$ isophote) is a strong function of z, and in the range $0.6 < z < 1.88$ (appropriate for the systems in the survey data of CBS) his results give $P \simeq 0.08 - 0.06$ for $q_o = 0 - \frac{1}{2}$. Corresponding values of the mean number of redshift systems observed by CBS are 0.55 ± 0.15 for the systems defined by several lines, i.e. the 'identified' systems, and 2.1 ± 0.8 when all unidentified lines are counted in as single systems (the limits indicate the range from 'certain' systems to 'certain + probable'). However, for the latter, the unidentified lines assumed to be Lyα span only the far more restricted redshift range from $z = 1.88$ to a value near $z = 1.65$ defined by the atmospheric cutoff, and not the whole range appropriate for the identified systems in which lines of other elements at longer wavelengths still are observable at much lower redshift. Wagoner's value for the restricted range is $P \simeq 0.015 - 0.01$ for $q_0 = 0 - \frac{1}{2}$ (within the Holmberg dimensions). CBS's corresponding value for 'Lyα only' systems is 0.7 ± 0.3. A point to mention is that the spectral resolution used by CBS ($\Delta\lambda \sim 5$A) corresponds to a range in velocity ~ 400 km s^{-1}; this masks the fine splittings apparent at higher resolution and ensures that in general any intervening galaxy is counted only once. Comparing the observations with Wagoner's predictions we note that the computed results fall short by about one order of magnitude for the 'identified' systems and nearer two orders for the 'Lyα only' systems. All other things being equal, this requires that the effective dimensions of a galaxy seen by its absorption lines be larger by factors about three and ten respectively than its Holmberg dimensions.

However, as pointed out by Bahcall and Spitzer (1969), the gas density required to produce absorption lines is so low that it would not be surprising if the maximum radius for measurable absorption in a line were appreciably greater than that detected in other ways, and they suggested that the observed lines are produced in extended low density haloes of normal galaxies (see also Bahcall 1975 and Röser 1975). In support of this, Kormendy and Bahcall (1974) have shown that many spiral galaxies and small groups of galaxies indeed have very large optical haloes, several times the Holmberg dimensions at a surface brightness ~ 27 mag (arcsec)$^{-2}$. This alone may be enough to explain the observations for the 'identified' systems. We distinguish here between 'identified' systems and 'Lyα only' systems. Because the former include lines of heavy elements, we associate these systems with gas in the inner region of a galaxy where stars have formed; this region clearly extends well beyond the arbitrary 25 mag (arcsec)$^{-2}$ isophote used as a representative, but not strict, boundary by Wagoner (Wagoner recognised this by introducing a factor Σ by which to multiply the cross-section of a galaxy defined by the 25 mag (arcsec)$^{-2}$ isophote and obtain the effective cross-section for a given interaction). The 'Lyα only' systems, on the other hand, probably are due to very extended outer regions where the density is too low to allow star formation and the gas still has primordial composition.

In clear support of this contention, there is much direct evidence from 21 cm emission measures for the presence of neutral hydrogen at large distances from spiral galaxies (e.g. Roberts 1972, Davies 1974, Mathewson et al. 1975, Rogstad et al. 1974), in addition to the absorption measurements of Haschick and Burke and Grewing and Mebold described before. The measures of Davies (1974) reveal appreciable quantities of hydrogen at distances out to 2 to 5 Holmberg radii in the M81/M82/NGC 3077 system, M31, M33, IC 342 and M51. In all cases the gas is at velocities consistent with being bound to the parent galaxy, and in several galaxies there is as much neutral hydrogen outside the Holmberg dimensions as inside. Davies' (1974) Fig.1 showing the enormously extensive hydrogen region associated with the M81/M82/NGC 3077 group is particularly striking. Mathewson et al. (1975) found HI clouds near the galaxies NGC 55 and NGC 300 in the Sculptor group with velocities similar to the systemic velocities of the two galaxies and at linear projected distances up to 80 kpc from NGC 55 and 180 kpc from NGC 300 (taking 3 Mpc as the distance to the Sculptor group). They also found a long tail of HI extending along the major axis of NGC 300 to a projected distance of 140 kpc from the centre. Such tails also are seen in M83 (Rogstad et al. 1974) and IC 10 (Shostak 1974). Again, it is striking to note the enormous extent of the HI regions compared with the relatively small optical dimensions of these galaxies (e.g. Mathewson et al. 1975, Fig .1 and 2; Rogstad et al. 1974, Fig.6). The nearby 'high velocity' HI clouds and the Magellanic Stream probably are related phenomena (de Vaucouleurs and Corwin 1975, Mathewson et al. 1974). Evidence for large extensions of HI beyond the observed optical dimensions of galaxies comes also from a study of galactic rotation curves (Roberts and Rots 1973, Rogstad and Shostak 1972).

We point out that although the extended regions of HI emission near galaxies appear to be broken up into separate 'clouds', actually their bounding contours simply represent the minimum signal that can be detected by the radio technique. Typically this corresponds to a column density of $\sim 10^{19}\,cm^{-2}$, comparable with the 21 cm absorption measures (assuming T_s = 100 K). Neutral hydrogen at lower column densities probably fills in the space between the higher density 'clouds', and also extends still further out from the associated galaxies than do the already extensive regions mapped in 21 cm emission. Such regions of lower density would be readily detected spectroscopically at Lyα wavelength if seen as an absorption line against a continuum source, and may appear like the Lyα absorption lines observed in the spectra of high-redshift QSOs. The limiting detectable column density of HI when observed in this way typically may be $\sim 10^{13}\,cm^{-2}$ (assuming absorption here is occurring near the linear section of the curve of growth and $z_{abs} \sim 2$): this is 10^6 times lower than has been measured by radio techniques.

If a considerable fraction of all spiral galaxies possess such enormous hydrogen haloes, even if several orders of magnitude less dense than those mapped locally at 21 cm, then the observed frequency of 'Lyα only' systems in QSOs of $z \sim 2$ is entirely explained by the large effective cross-section they present. (Incidentally, the assumption that the 'Lyα only' systems are to be identified with neutral hydrogen is well borne out by the appearance of corresponding Lβ and other Lyman lines in QSOs of high enough redshift to bring these into the observable spectral range). That such material probably is primordial is indicated by the similarity in appearance between the Lyman lines having corresponding lines of heavy elements and those which do not. The spectrum of OQ 172 is a good illustration of this (Baldwin et al. 1974). It is unlikely that the distinction between such systems is explained by different degrees of ionization, with the 'hydrogen' systems being essentially neutral, because the general QSO radiation field at, say, $z \gtrsim 2$ is expected to keep all unshielded tenuous matter moderately to highly ionized (Arons 1972).

The spectrum of the high redshift (z_{em} = 3.4) QSO OH 471(Carswell et al. 1975) in Fig.7 (obtained with Sargent) clearly shows the multitude of hydrogen absorption lines shortward of emission Lyα, extending in this figure to Lyβ/OVI. We estimate the mean difference in velocity between adjacent detected absorbing regions in the range $2.78 < z < 2.95$ as $\sim$ 1200 km s^{-1}. Assuming that the material is cosmologically distributed in a Friedmann universe ($\Lambda = 0$, pressure negligible) the mean interception distance is in the range 3 - 6 Mpc for H_o = 50 km s^{-1} Mpc^{-1} and $q_o = \frac{1}{2} - 0$. It is interesting that we obtain a similar result in this redshift range for the material in line to the QSOs OQ 172 (z_{em} = 3.53) and 0830+115 (z_{em} = 2.97), the latter from our observations with Sargent and Lynds. There is also a suggestion of periodic clustering in the density of the absorption lines in OH 471 with a velocity separation $\sim$ 10000 km s^{-1}, and a corresponding interception distance 26 - 52 Mpc when making the same assumptions as before.

We point out in passing that the presence of both primordial and enriched material argues against the intrinsic interpretation of QSO absorption lines, because for this we expect ejected material all to be enriched, as is observed for the line emitting regions.

Going further in the above vein, it is our impression from the comparatively little evidence yet available that there are proportionately few absorption systems definitely containing heavy elements in the highest range of redshifts observed, say $z \gtrsim 3$. If so, we may be seeing evidence that most galaxies have not yet fully formed before $z \sim 3$. Interpretation of the observations in terms of absorption in protogalactic material previously has been made by Arons (1972) and Röser (1975). If, as it seems, the space density of QSOs dramatically decreases at some high redshift (say, $z \sim 3.5$) then correspondingly the protogalactic haloes may be largely neutral.

Returning to Wagoner's estimates for the number of galaxies in line to a distant source, there are two more factors which could considerably increase the chance of encounter, apart from the points already made. The first is the possibility that the number and size of galaxies in general may be grossly underestimated because of observational selection, as has been pointed out by Disney (1976). Thus, an apparently insignificant dwarf actually may be the core of a large galactic system, most of it not seen above the sky background on conventional plates. The observations of Kormendy and Bahcall (1974), Arp and Bertola (1969, 1971) and de Vaucouleurs (1969) support this. The second concerns elliptical galaxies, which are not included in Wagoner's estimates, The contention that there is little gas in

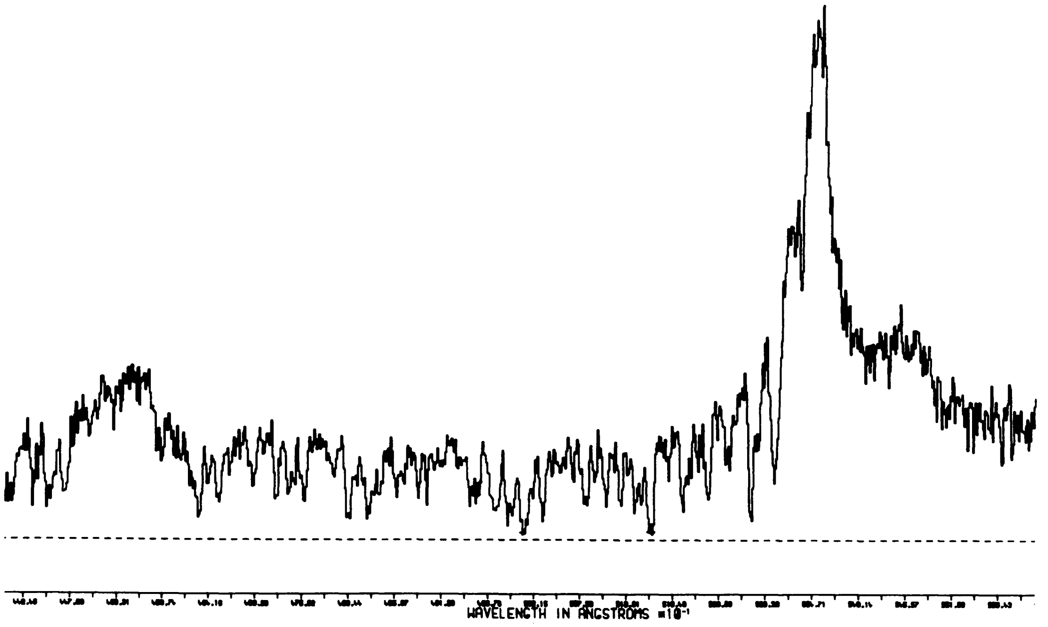

Fig. 7: Spectrum of OH 471 (z_{em} = 3.4). The strong emission line is Lyα, the weaker is Lyβ/OIV.

these objects is based on the general lack of 21 cm emission, although now some marginal detections may exist (Huchtmeir et al. 1975). It is consistent with the previous discussion that although the radio technique may (just) not be sufficiently sensitive to detect neutral hydrogen in most ellipticals it does not follow that absorption lines of hydrogen (and heavy elements) will not be detected optically. Further weight is given to this by the likelihood that all gas in elliptical galaxies is ionized by ultraviolet stars (Rose and Tinsley 1973); such gas may be readily detectable optically (at high redshift) but not be evident when observed at 21 cm. Added to this is the possibility that no major difference exists between ellipticals and spirals at the protogalaxy stage (Gott and Thuan 1976), which would increase the expected number of absorption lines at high redshift. Evolutionary effects in general were not included by Wagoner.

In conclusion, we contend that apart from the very broad absorption lines seen in a few QSOs, such as those in PHL 5200, which most likely are due to intrinsic mass outflow from these objects, the great majority of narrow absorption lines in QSO spectra, ranging in relative velocity from a large fraction of c outward to a few thousand km s^{-1} inward, all of which are characteristically similar and resemble interstellar lines, can be most naturally explained as being produced in cosmologically distributed intervening material, and there is no need to invoke any intrinsic mechanism for these.

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DISCUSSION

H.E. Smith: I have several comments.

1) In the high redshift QSO's, Margaret Burbidge and I have uniform spectroscopic data on several, but I speak in particular of M 0830+115 (z_e = 2.97). One sees a sharp discontinuity in the absorption line density at Ly α emission, of a factor of five or so. In general one cannot identify most of the lines shortward of Ly α emission and it is most reasonable to assume that the majority are Ly α absorption from clouds with insufficient column density to produce absorption from less abundant species. In the case of 0830+115 one then requires on the order of 100 separate intervening systems. If, as is common, the lines break up at higher dispersion then even more systems are required. This object is not extreme, rather it seems to be the rub for high z systems.

2) For systems with absorption lines from heavy elements (CIV, SiIV, etc.) one must restrict the cross section to less than a Holmberg radius. The observations clearly show a strong decrease in heavy element abundance with radius (on the order of a factor of ten or more) for spiral galaxies. If our understanding of galaxies is correct the abundances of heavy elements must be exceedingly low outside the optical radius since these regions simply could not have processed material through stars in any amount.

3) Some objects, PHL 5200 and RS23 in particular, are clearly ejecting material with velocities on the order of 10,000 km s^{-1} which can be seen from the broad P-Cygni type profiles on the lines 10,000 km s^{-1}. Ray Weymann has shown us observations of galactic novae which show similar profiles at some stages which then break up into large numbers of very narrow absorption lines. The analogy to absorption line systems in QSO's may be quite apt.

4) If line-locking coincidences can firmly be established, then one must accept that these systems have been ejected from the QSO. There are a number of suggestive cases, but I'm not sure if one can say for certain that it is operating in any given case.

5) Finally I am impressed by the case of the highly active BL Lac object AO 0235+164. It is peculiar in that it has not only shown two very strong outbursts ($\Delta m \simeq 5$ mag) in the past 30 years, but that it is the only object known with two absorption line systems with $z < 1$. This suggests that the absorbing material may be material associated with previous outbursts. With respect to the distribution of absorption line redshift systems, I'd like to emphasize the difficulty of identifying systems in high redshift QSO's. In many cases one sees a sharp discontinuity in the density of lines at Lyman α emission. In these cases we are probably seeing absorption line systems containing only Lyman α, distributed uniformly in redshift from just below z_{em} to a redshift with respect to the QSO corresponding to a relation velocity ~ 0.5 c.

Boksenberg: This is clearly for the highest redshift objects (say, $z \gtrsim 3.0$) which have been adequately well observed, for example OH471, OQ172 and 0830+115. Furthermore the line density in a given redshift range (but between emission Lα and Lβ to avoid confusion) is about the same for all these objects. For intermediate redshift objects ($z = 2$) the sharp discontinuity in the density of lines at emission Lα is not as pronounced in some cases as in others (indeed some objects have a distinctly sparce appearance below emission Lα). From a brief consideration of such data I very much favour the explanation that the absorption is occurring in intervening material and is not intrinsic to the QSO's.

Burke: I see no reason at our present state of knowledge to assume that the HI clouds in the vicinity of galaxies are primeval, lacking heavy elements. They could be well-enriched material ejected from the parent galaxy, and such ejection could occur at a very early stage in the life of the galaxy. The present sensitivity of HI detection in absorption is approaching $10^{18}/\text{cm}^2$.

Carswell: I do not believe that the Palomar $z_{em} \simeq 2$ survey data is in conflict with either of the "intrinsic to the QSO" or "intervening cosmological material" hypotheses. There were some problems in analysing that material because the signal-to-noise was poor below the Lα emission, and there were a large number of unidentified lines even above that feature. It appeared at first sight, taking all possible systems, that the observed distribution was significantly different (< 0.1% by chance) from the poisson distribution the cosmological cloud model predicts. However there are a large number of choices available, depending on how you believe you have to select objects from our sample to make a genuinely homogeneous one, and it seems possible to make a case for any answer you want on this basis. The data we have is really not good enough to distinguish between the two models.

On the basis of less homogeneous material obtained at Steward Observatory by E. Coleman, P.A. Strittmatter and R.E. Williams and myself, I believe that there is a serious conflict with the cosmological cloud hypothesis, but further observational work remains to be done before the statistical test can usefully be applied. However, cases we have with no absorption lines and one with about 18 shortward of emission $L\alpha$ suggest that a poisson distribution does not fit the data well.

QSO-GALAXY PAIRS AND OPTICAL OBSERVATIONS

J.N. Bahcall and B.F. Burke

We would like to call to the attention of optical observers some potentially crucial observations. As has been discussed in this symposium, 21 cm absorption-lines caused by the neutral hydrogen halos of two nearby galaxies (NGC 3067 and NGC 6053) have been recently detected in the spectra of two quasars. It has also been suggested (see Bahcall, Ap. J. (Letters) 200, L1, (1975) and references quoted therein) that the extended halos of galaxies may cause many of the ultraviolet absorption lines that are seen in the spectra of large-redshift quasars. A problem with this suggestion is that it implies that the halos of galaxies (at large distances from where most of the stars are presently observed) contain appreciable quantities of heavy elements. Many astronomers believe that this is impossible (cf., however, Bahcall 1975), but direct evidence is lacking on the heavy element content of large galactic halos (radii $\sim 10^2$ Kpc).

We urge optical astronomers to undertake sensitive searches for possible heavy-element absorption lines at the known redshifts of the 21-cm-absorbing galactic halos (e.g., 1494 km/s for NGC 3067, 4C 32.33). In the visible this may be done by looking for traditional interstellar lines (e.g., H and K) that could occur at the same redshift as the 21-cm absorption lines. With a Large Space Telescope, one would look for the resonant absorption lines of such abundant heavy elements as C, N, and Si. It is very difficult to estimate accurately the expected equivalent widths since the physical conditions in the halo clouds are not well known (and may be different from the conditions that existed when the quasar absorption lines were produced). Nevertheless, the search for heavy-element absorption lines in the spectra of quasars (that are part of quasar-galaxy pairs) at the redshifts of the galaxy halo offers a unique opportunity to possibly observe heavy elements in extended galactic halos. The astrophysical and cosmological implications of such a discovery could be great.

E.M. Burbidge: Gene Smith covered very well the arguments for the multiple redshift systems being associated with the QSO itself, rather than being produced in intervening galaxies, or intergalactic clouds, and I have only a few remarks to add.

First: I believe that people get worried by the use of the adjective "intrinsic" for these redshift systems - people seem to link this instinctively with "intrinsic" redshifts - i.e. non-doppler redshifts. So I would like to emphasize that we are indeed talking about doppler displacements, due to pressure-driven gas outflow from a central continuum source.

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That radiation pressure must produce outflow of gas has been clear from theoretical work, for example by Bill Mathews and colleagues at U.C. Santa Cruz, and by Kippenhahn, Mestel and Perry at Max Planck Institute, Munich, and by others. This must occur even in the emission-line producing gas. Outflow, even if it starts with a very optically thick supernova-like shell moving out at around 10^4 km/sec as in PHL 5200, must accelerate as does all gas outflow going towards lower density, and instabilities will set in and will lead to break-up as in expanding nova shells where very narrow absorption lines can be seen.

Now a word about the distribution of absorption-line QSO's. There are some objects (in particular PKS 0237-23) where there is a large number of redshift systems running all the way from 2.20 to 1.36. Yet there are still 2 objects at redshifts $\gtrsim 2$ which do not have even one absorption-line redshift system (from recent high-resolution work by the U. of Arizona astronomers). This is very difficult to explain on the intervening galaxy hypothesis. Third, I should reiterate that apart from Ly α the most characteristic lines seen are the CIV doublet. In our galaxy, rocket and Copernicus observations show this is produced in circum-stellar shells associated with hot stars, not in the cool interstellar gas. Thus it is difficult to associate such features with cloudlets of cold HI several Holmberg radii outside galaxies.

Lastly, a word about line-locking. Radiation - pressure driven outflow can be affected by a strong gradient in flux with wavelength - i.e. by coincidences between absorption lines and ionization edges and other strong absorption lines from different ions at different redshifts. This will produce preferred ratios in (1 + z). This effect is well seen in a number of QSO's, and Jeff Scargle has also discussed its occurrence in certain hot stars where UV lines seem to produce the same kind of line-locking.

Scargle: One of the general objections often made to the picture in which the narrow high-velocity QSO absorptions are "intrinsic", or due to outflowing gas, is the difficulty of understanding the large ratio of $V_{total}/\Delta V$ (ΔV = velocity dispersion within the system). This number is a few x 10^4 for the most extreme cases in QSO's. It does not seem to be generally realized that there exist shell stars for which the ratio is nearly as great, namely a few x 10^3. Thus whatever difficulties exist for QSO's also exist for shell stars, for which the intrinsic nature of the absorptions is well-established.

Bahcall: Which QSO's at high redshift do not have absorption redshifts?

E.M. Burbidge: They are BSO6 and LB8755; they are not particularly faint and very detailed studies have been made of them.

Van der Laan: How many cases of $z_{abs} > z_{em}$ are there now and do they contain multiple z_{abs} systems?

E.M. Burbidge: There are about half a dozen, and about half contain multiple absorption redshift systems.

NEUTRAL HYDROGEN ABSORPTION FEATURES IN THE SPECTRA OF QUASAR - GALAXY PAIRS

B.F. Burke

We have continued the search for 21 cm neutral hydrogen in absorption in quasar - galaxy pairs to a total of 8 pairs. In addition to the feature found in the pair 4C32.33-NGC3067 (Haschich and Burke, Ap. J. (Lett) 200 L137, 1975) we have found a further feature in the pair 1749+701-NGC6503. That 2 out of 8 pairs show absorption features strengthens the evidence that neutral hydrogen exists far away from spiral galaxies, and suggests that the average cross section is approximately 6 times larger than the visual image. Thus, galaxies may be considered as candidates for the discrepant absorption lines seen in QSO's.

Secondly, we note the similarity of the observed 21 cm absorption lines: their column densities and velocity widths lie within one order of magnitude. Furthermore the apparent velocities of the identified clouds range from 70 to 192 km sec $^{-1}$ with respect to the galaxies. These properties are close to the characteristics of high velocity clouds and we suggest that our clouds are of the same nature. This may supply the needed absorption line structure and may also act in favour of an association of high velocity clouds with galaxies.

3C 286 : A COSMOLOGICAL QSO?

A.M. Wolfe, J.J. Broderick, J.J. Condon and K.J. Johnston

Ap. J. (Letters) 208, L47 (1976)

Wolfe: To compare the narrow 21 cm absorption features you find in the QSO-galaxy pairs with the line in 3C 286 it is important to compare the linear dimension subtended by the radio source at the absorbing galaxy. In 3C 286 the VLB sources subtend ~ 200 pc at the "intervening galaxy"; but in 4C 32.33 the region subtended is < 10 pc. Thus it is easier to understand the narrow widths of the absorption feature in the latter object than in the former. Could you say something about the linear distances subtended in the new objects you have discovered?

Shaffer: 1749 + 701 is unresolved at about 0.01 arc seconds.

G.R. Burbidge: The simplest interpretation of the galaxy-QSO pairs is that they are physically associated. In this case presumably the QSO has been ejected from the galaxy. If this were the case it would not be surprising if much of the gas seen in this galaxy was ejected also; i.e. it may not be a normal galaxy as far as a hydrogen halo is concerned.

Burke: The absorption lines are very narrow, suggesting undisturbed gas. No quasars have been located close to the M81-M82 system, which has associated hydrogen clouds well outside the Holmberg diameters, and we suggest that the observed absorption lines in our work come from similar outlying gas.

SOUTHERN HIGH REDSHIFT QSO'S

J.G. Bolton, R.D. Cannon, D.L. Jauncey, B.A. Peterson,
Ann Savage, M.G. Smith, K.P. Tritton, and A.E. Wright.

A considerable number of southern QSO's with high redshift have been recently discovered from both optical and radio investigations. The optical searches have made use of objective prisms on southern Schmidt telescopes and favour the discovery of QSO's with a strong Lyman α emission line within the wave length range of the plate response. Detections from radio investigations have resulted from identification of neutral or non UV excess stellar objects on the basis of accurate, $\lesssim 2''$, radio positions. Some of the objects found in the latter search could not have been found either by using colour criteria or objective prism spectra. One such example is PKS 0528 - 250 (Jauncey, Wright, Peterson and Condon, in preparation) whose spectrum is shown in the earlier paper by Bolton. This object has a prominent absorption spectrum with a redshift of 2.813 but has no emission lines. Another object, PKS 2126-15, has an emission line redshift of 3.275 with a very rich absorption line spectrum below Ly α emission.

Examination of the first plates taken with the 0.73 degree objective prism on the U.K. 1.2 metre Schmidt telescope has shown that it is possible to detect quasars with remarkably low line to continuum ratios. Objects previously selected as possible quasars on the basis of colour can be separated into quasars or galactic stars with a high degree of certainty and this results in a considerable saving of large telescope time in spectroscopic examination. Two examples of U.K. Schmidt spectra are shown in Figure 1.

The Tololo Schmidt objective prism plates have provided a considerable number of very high redshift quasars where the line to continuum ratio for Lyman α is very strong. Quantitative data on the emission-line spectra of the Tololo QSO's are summarised by Osmer and Smith (Ap. J. in press). Comparison of the spectral characteristics of emission-lines and continuum in the newly-discovered Tololo QSO's and a set of 8 quasars previously identified with radio sources shows the two sets to be indistinguishable, with the possible exception of the NV/Lα ratio (Osmer, Ap. J. in press). The absorption-line spectra of these QSO's are now being studied. Q 1246-057 (z_{em} = 2.212) has already been mentioned earlier by Boksenberg. Absorption lines in the broad-lined system (z_{abs} = 2.05) with velocity dispersion ~4000 km^{-1} were even visible (with hindsight) on the Schmidt discovery plate. High velocity dispersion has been found in PHL 5200 for example (Lynds, C.R., Ap.J. (Lett) 164, L73, 1967; Burbidge, E.M., Ap. J. (Lett) 152, L111, 1968), but this new object provides the first example where a high-velocity-dispersion cloud is clearly separated from the emission region by speeds of thousands of kilometres per second. It seems unlikely that such broad lines can arise in an intervening galaxy. A preliminary analysis by Carswell, Smith and Whelan of the spectrum of Q0002 - 422, z_{em} = 2.758 shows a definite absorption system with a redshift of only z_{abs} = 0.835; all the expected lines are present (FeII, MgII, MgI) with reasonable equivalent widths.

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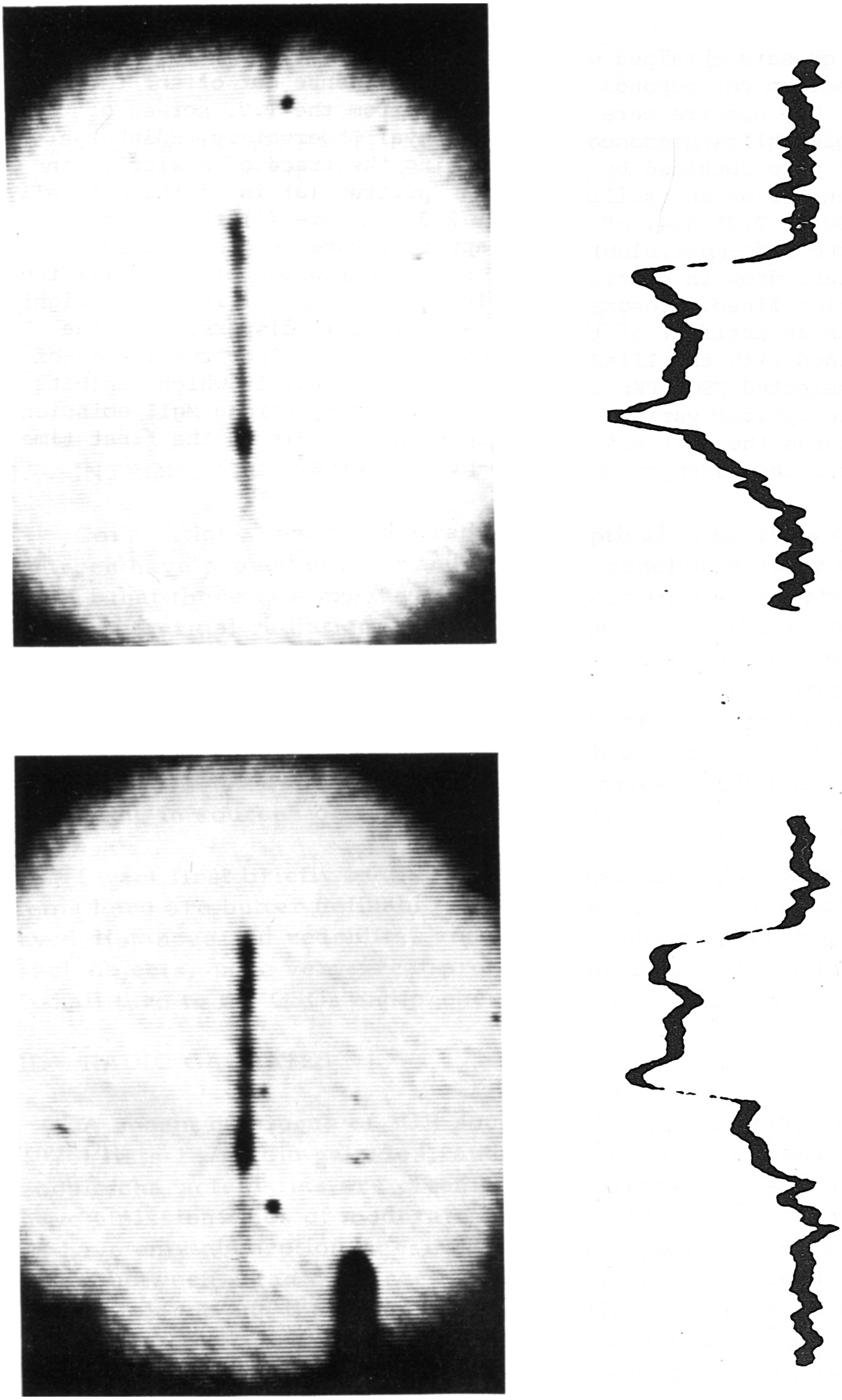

Fig. 1

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Fig. 1.

Spectra of quasars obtained with the U.K. Schmidt. The right hand end of each spectrum corresponds to the green response cut off of the IIIaJ emulsion. The spectra were photographed from the T.V. screen of the modified Zeiss blink microscope at the Royal Observatory, Edinburgh. The "scans" were obtained by photographing the trace of a single line of the T.V. monitor on an oscilloscope. Spectrum (a) is of the optically-selected QSO, Q 2225-404, of redshift 2.02. Note (i) the strong Lα emission (the left-most blob) at an apparent wave length of 3363 Å (ii) the sharp drop in continuum intensity shortwards of Lα, (iii) the other emission lines, presumably including C IV and Si IV. The right-most blob is an artifact of the reduced prismatic dispersion in the green combined with the IIIaJ emulsion response. Spectrum (b) is of the radio selected QSO, PKS 2227-399 of redshift 0.319 which exhibits considerable optical variability. Note the very strong MgII emission feature towards the left end of the spectrum. This is the first time that MgII has been seen on objective-prism plates.

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