Detection of Ca II absorption in the spectrum of the QSO 0446 – 208 due to an intervening galaxy

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Summary. We have detected the Ca II H and K lines in the spectrum of the QSO 0446 – 208 ($z_{\text{em}} = 1.896$) at a very similar redshift, $z = 0.0667$, to that of a galaxy which lies 13 arcsec away in the plane of the sky. This separation corresponds to 23 kpc ($H_0 = 50 \text{ km s}^{-1} \text{ Mpc}^{-1}$) at the redshift of the galaxy ($z = 0.0669 \pm 0.0002$). The column density of the Ca II absorption is $[11(+5, -3)] \times 10^{12} \text{ cm}^{-2}$ and the Doppler width $b$ is $(90 \pm 20) \text{ km s}^{-1}$. Spectroscopy and a direct plate of the galaxy indicate that it is probably an S0 system. It seems likely that the Ca II absorption originates in disc material in the galaxy, although halo absorption cannot be ruled out. A high ionization absorption system, $z_a = 1.8667$, also occurs in the spectrum of the QSO.

1 Introduction

There have been recently a number of detections of the optical interstellar lines of Ca II and Na I in gas associated with external galaxies. Blades (1980; and in preparation) has studied both species in the interstellar medium of the Magellanic Clouds and has determined column densities and line widths using luminous OB stars as background sources. In the Seyfert galaxy IC 4329A, Wilson & Penston (1979) studied the exceptionally strong interstellar Na I lines which presumably originate in gas associated with the prominent dust lane in that galaxy, and Graham (1979) reports the presence of interstellar Na I in dust in the peculiar galaxy NGC 5128 (Cen A). The recent supernova that occurred in the almost face-on spiral NGC 4321 (M100), and which appeared to be situated near a prominent H II region, exhibited strong interstellar Na I and Ca II at the redshift of the galaxy (Penston & Blades 1980).

It is clear from these examples that various background sources, such as compact galactic

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nuclei and supernovae, can serve as probes of the interstellar medium of the galaxies in which they occur. Another technique is to use QSOs situated close to galaxies in the plane of the sky and Burbidge et al. (1971) have drawn attention to a number of examples. Boksenberg & Sargent (1978) have studied one such case, namely that of the QSO 3C 232 which lies 1.9 arcmin away from the spiral galaxy NGC 3067. They detected Ca II H and K absorption at the redshift of the galaxy in the spectrum of the QSO; Na I was not detected. A second example is the observation of Ca II in the QSO 2020 − 370 which is situated close to an anonymous spiral galaxy. This QSO–galaxy pair was first noted by Peterson & Bolton (1972) and the detection of interstellar Ca II was reported by Danziger & de Jonge (1978).

We have observed a third example of a QSO–galaxy pair, namely 0446 − 208, which is a 17 mag QSO situated 13 arcsec from a disc galaxy. This system was found by one of us (RWH) in a separate programme dealing with radio source identifications in rich clusters of galaxies (Mills, Hunstead & Skellem 1978). The radio source 0446 − 208 lies 26 arcmin south-east of the nominal centre of A514 (Abell 1958) and is listed in the MCG Catalogue (Davies, Little & Mills 1973) as a point source of 0.71 ± 0.05 Jy at 408 MHz. The optical positions (1950.0) for the QSO and galaxy measured from the Palomar Sky Survey plate No. 1323 are given below, together with a recent Molonglo 408 MHz position:

<table>
<thead>
<tr>
<th>Type</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical</td>
<td>galaxy: 04h 46m 48s.97 ± 0.04, −20° 50' 08&quot;.1 ± 0.4</td>
</tr>
<tr>
<td></td>
<td>QSO: 04 46 49.22 ± 0.03, −20 49 55 .8 ± 0.3</td>
</tr>
<tr>
<td>Radio</td>
<td>04 46 49.2 ± 0.3, −20 49 55 ± 4</td>
</tr>
</tbody>
</table>

The Molonglo position clearly confirms the QSO as the identification.

A direct plate of part of the cluster A514 taken at the f/3.5 prime focus of the Anglo-Australian Telescope (AAT) is shown in Plate 1; this reproduction has been contrast enhanced (Malin 1978). The inset shows an enlargement of the region containing the QSO and galaxy. This plate was a sky limiting 80 min exposure on hypersensitized Kodak IIIaJ emulsion with a GG385 filter and was obtained through the AAT service photography programme.

Low resolution (~ 10 Å FWHM) spectra of both objects were obtained as part of the cluster radio source programme using the Boller and Chivens spectrograph and image dissector scanner (IDS) at the f/15 Cassegrain focus of the AAT. The spectra are shown in Figs 1 (QSO) and 2 (galaxy); the QSO spectrum was obtained on 1979 January 23 while the galaxy spectrum is the sum of data from 1980 February 21 and 22. Standard stars were also observed on these nights with the same spectrograph entrance aperture (normally 2 × 2 arcsec) and were used to calibrate the spectra. The QSO spectrum shows emission lines of Ly α, C IV and C III] at a redshift of 1.896 ± 0.002 based on measurements of Ly α and C IV. The spectrum of the galaxy shows numerous absorption lines, the most prominent of these being identified with CN, Ca II H and K, the G band and the Mg I b band. Weaker absorption features are identified with Fe I λ λ 4383, 5269 and Na I D; hydrogen Balmer lines are not detected.

In Fig. 2 the galaxy spectrum is shown compared with a spectrum of the nucleus of NGC 1553, a face-on SO galaxy which was observed as a template for cross-correlation analysis. The two spectra are quite similar in both the shape of the continuum and strength of absorption lines, the only difference being that NGC 1553 also shows hydrogen Balmer lines. This difference may be caused by the different viewing aspects of the two galaxies. A cross-correlation of the two spectra over the wavelength range 3600−6000 Å was carried out for both the narrow absorption lines and the broader continuum features. The derived redshifts showed good consistency. Assuming a heliocentric radial velocity of 1280 ± 18 km s⁻¹ for NGC 1553 (de Vaucouleurs, de Vaucouleurs & Corwin 1976), the heliocentric
redshift of the galaxy near the QSO 0446 – 208 is $0.0669 \pm 0.0002$ including the uncertainty in wavelength calibration.

The QSO and galaxy are sufficiently bright to allow intermediate dispersion spectroscopy and this paper presents the data obtained so far with the AAT. The main result is the detection of Ca II K and probably H absorption with $z_a = 0.0667$ in the QSO spectrum. The strength and asymmetry of the Ca II absorption are consistent with it occurring in

Figure 1. Spectrum of the QSO 0446 – 208 obtained with the IDS at $\sim 10$ Å resolution.

Figure 2. Spectrum of the nucleus of the galaxy 0446 – 208 compared with the spectrum of the nucleus of the face-on S0 galaxy NGC 1553. The spectrum of NGC 1553 has been shifted to $z = 0.0669$ to facilitate comparison of spectral features.
interstellar H\textsc{i} material, although it is not possible to determine whether the absorption arises in the disc or halo of the intervening galaxy. A high-ionization absorption system at $z_a = 1.8667$ is also present in the QSO spectrum.

2 Observations and reductions

The intermediate dispersion observations were obtained on four separate occasions during 1979 at the f/8 Cassegrain focus of the AAT. Details of the observations are contained in Table 1. The RGO spectrograph, with the 25-cm camera, was used in conjunction with the Image Photon Counting System (Boksenberg & Burgess 1973) to provide 0.5 Å channel$^{-1}$

<table>
<thead>
<tr>
<th>Date</th>
<th>Dwell (s)</th>
<th>Seeing (arcsec)</th>
<th>Wavelength region (Å)</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 30.4</td>
<td>4700</td>
<td>1–2</td>
<td>3700–4700</td>
</tr>
<tr>
<td>March 31.4</td>
<td>2660</td>
<td>2</td>
<td>3700–4700</td>
</tr>
<tr>
<td>August 31.7</td>
<td>9000</td>
<td>4–5</td>
<td>3700–4700</td>
</tr>
<tr>
<td>October 28.6</td>
<td>7000</td>
<td>4–5</td>
<td>3400–4400</td>
</tr>
</tbody>
</table>

with a 1200 line mm$^{-1}$ grating. The spectrograph slit was set to 1.5 arcsec on the sky which matched the detector resolution, but was generally smaller than the FWHM of the seeing disc (see Table 1). The measured resolution of the unsmoothed but summed spectra was 1.7 Å (FWHM) based on unresolved argon comparison lines summed in the same manner as for the object. The resolution for any one night was generally better than this but the effect of summing spectra obtained on quite separate occasions was to slightly degrade the final resolution.

![Figure 3](https://academic.oup.com/mnras/article-abstract/194/3/669/1001223/1001223) Figure 3. The spectrum of the QSO obtained with the IPCS at a resolution 1.7 Å. The separate 3400–4400 Å and 3700–4700 Å spectra have been joined at 3900 Å. The vertical scale is net counts but the scale differs for the two halves of the combined spectrum. The net counts in the vicinity of 3650 and 4200 Å are 90 and 235 respectively.
Plate. 1 A contrast-enhanced copy of portion of a direct AAT plate showing part of the cluster A514. The QSO 0446—208 and nearby galaxy (marked with horizontal bars) lie 26 arcmin south-east of the nominal cluster centre (marked with a cross).

Inset: An enlargement of the region containing the QSO–galaxy pair.
Plate 2. A density contour plot of the AAT plate in the region of the QSO and galaxy. The inset shows an enlargement of a similar region of the plate.
The IPCS was used in a two-dimensional mode with a long slit aligned at pa 19° to cover both the QSO and centre of the galaxy. The length of the slit was usually ~ 40 arcsec, but on one occasion was set to ~ 50 arcsec. This slit, in conjunction with the IPCS format, provided an array of 16 (or 20) spectra of which the QSO occupied two and the galaxy three. A scaled sky spectrum, obtained by summing all the individual sky spectra that occurred at the ends of the slit, was then used to remove the sky signal in the object spectra.

Two spectral regions, approximately 1000 Å long, were used. One region started at 3700 Å and was chosen so that the expected Ca II H and K lines in the galaxy would be centrally placed; this position also allowed the Si IV/O IV and C IV emission lines in the QSO to be recorded. The other started at 3400 Å to include Lyα in the QSO. The detection limit of a narrow line in the final QSO spectrum is estimated to be ~ 0.4 Å (equivalent width, \( W_{\lambda} \)) over the wavelength interval 3800–4700 Å; it is greater than this below 3800 Å due to a poorer signal-to-noise ratio.

Individual integrations on the QSO–galaxy system normally lasted 1000 s. Total integration times were 273 min for the 3700–4700 Å spectrum and 117 min for 3400–4400 Å. In addition, frequent comparison spectra using a Cu–Ar hollow cathode lamp were recorded and the wavelength calibration was based on argon lines from these spectra. The rms fitting error was \( \leq 0.1 \) Å for 40–45 lines uniformly spaced over the spectral region.

The IPCS spectrum of the QSO is shown in Fig. 3. This figure has been constructed from the separate spectra by joining them at 3900 Å after matching continuum levels. The instrumental sensitivity has not been removed and while this distorts the shape of the continuum it does not affect the line equivalent widths.

### 3 Results

#### 3.1 Emission lines in the QSO

Over the observed wavelength range of 1300 Å from 3400 to 4700 Å, the spectrum of the QSO shows five broad emission lines; the line identifications are contained in Table 2.

<table>
<thead>
<tr>
<th>( \lambda_{\text{obs}} ) (Å)</th>
<th>Ident</th>
<th>( \lambda_{\text{lab}} ) (Å)</th>
<th>( z_e^* )</th>
<th>Subjective weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>3527</td>
<td>Lyα</td>
<td>1215.7</td>
<td>1.901</td>
<td>2†</td>
</tr>
<tr>
<td>3586</td>
<td>N V</td>
<td>1240.1</td>
<td>1.892</td>
<td>1</td>
</tr>
<tr>
<td>4059</td>
<td>Si IV/O IV</td>
<td>1401.6</td>
<td>1.896</td>
<td>1</td>
</tr>
<tr>
<td>4294</td>
<td>N IV</td>
<td>1485</td>
<td>1.892</td>
<td>1</td>
</tr>
<tr>
<td>4486</td>
<td>C IV</td>
<td>1549.1</td>
<td>1.896</td>
<td>4</td>
</tr>
</tbody>
</table>

* All redshifts given in this paper are calculated from vacuum values of rest wavelength.
† Lymanα is given a lower weight than C IV due to the probable effect of absorption in the blue wing of the line.

**Notes**
1. The \( \lambda_{\text{lab}} \) wavelength for the \( \lambda 1400 \) emission feature is taken from Wills & Netzer (1979) as described in the text.
2. The observed wavelengths, \( \lambda_{\text{obs}} \), have been measured directly from intensity plots after inspecting the emission peak and its profile down to half-height.
weighted mean value of the emission redshift is $1.896 \pm 0.003$, in close agreement with the IDS value.

For the emission feature at 4058.7 Å we have adopted a rest wavelength of 1401.6 Å which was determined recently by Wills & Netzer (1979). On the basis of a large body of QSO emission line data, these authors have argued that O IV rather than Si IV is the principal contributor (85 per cent) to the blend. Adopting their rest wavelength gives $z_e = 1.896$ for this feature in 0446 – 208, a value which is in very good agreement with the redshift of C IV (perhaps not surprising because Wills & Netzer used the C IV line as their wavelength calibration) and is consistent with the other lines in 0446 – 208.

3.2 ABSORPTION LINES IN THE QSO

A weak-lined, high-ionization, narrow absorption system — occurring at $z_a = 1.8667 \pm 0.0004$ — mimics the emission spectrum. The absorption lines at 4438.5 and 4445.9 Å on the blueward wing of C IV emission are attributed to the C IV doublet $\lambda\lambda 1548.19, 1550.76$, whilst the lines at 3995.2 Å and 4021.4 Å are identified with the Si IV doublet $\lambda\lambda 1393.76, 1402.77$. A weak line at 3550.8 Å is assigned to the stronger member of the N V doublet $\lambda\lambda 1238.81, 1242.80$, the expected intensity of the weaker member being well below the detection limit. Shortward of the Ly$\alpha$ emission peak there are a number of absorption lines, including those at 3484.4 and 3456.9 Å which are attributed to Ly$\alpha \lambda 1215.67$ and Si III $\lambda 1206.51$ respectively, in the $z_a = 1.8667$ system. Several other strong absorption lines blueward of Ly$\alpha$ remain unidentified although it should be emphasized that this region is very close to the edge of the observed window and has few photon counts in the sloping continuum. Confirmation of the unidentified features below Ly$\alpha$ emission should await further observations. Table 3 lists all the absorption lines detected in the QSO spectrum and gives their observed wavelengths, FWHM values and equivalent widths.

The prominent absorption line at 4159.6 Å cannot be attributed to any expected species in the $z_a = 1.8667$ system; nor can it be identified with any species arising in the interstellar

<table>
<thead>
<tr>
<th>$\lambda_{obs}^{(\text{air})}$ (Å)</th>
<th>Ident</th>
<th>$\lambda_{lab}^{(\text{vac})}$ (Å)</th>
<th>$z_a$</th>
<th>FWHM (Å)</th>
<th>$W_\lambda^{(\text{obs})}$ (Å)</th>
<th>$\log N$ (cm$^{-2}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4445.9</td>
<td>C IV</td>
<td>1550.762</td>
<td>1.8669</td>
<td>1.9</td>
<td>0.99</td>
<td>14.3 ± 0.2</td>
</tr>
<tr>
<td>4438.5</td>
<td>C IV</td>
<td>1548.188</td>
<td>1.8669</td>
<td>1.9</td>
<td>1.43</td>
<td></td>
</tr>
<tr>
<td>4338.1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>4233.5</td>
<td>Ca II H</td>
<td>3968.470</td>
<td>0.0668</td>
<td>—</td>
<td>—</td>
<td>0.4</td>
</tr>
<tr>
<td>4195.6</td>
<td>Ca II K</td>
<td>3933.663</td>
<td>0.0666</td>
<td>2.1</td>
<td>0.96</td>
<td>13.1 ± 0.2</td>
</tr>
<tr>
<td>4021.4</td>
<td>Si IV</td>
<td>1402.770</td>
<td>1.8667</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>3995.2</td>
<td>Si IV</td>
<td>1393.755</td>
<td>1.8665</td>
<td>NR</td>
<td>0.69</td>
<td></td>
</tr>
<tr>
<td>3550.8</td>
<td>N V</td>
<td>1238.808</td>
<td>1.8663</td>
<td>1.1</td>
<td>0.53</td>
<td>14.1 ± 0.4</td>
</tr>
<tr>
<td>3510.4</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1.06</td>
<td></td>
</tr>
<tr>
<td>3507.1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>3492.4</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>2.57</td>
<td></td>
</tr>
<tr>
<td>3484.4</td>
<td>Ly$\alpha$</td>
<td>1215.670</td>
<td>1.8663</td>
<td>2.2</td>
<td>2.77</td>
<td>&gt; 15</td>
</tr>
<tr>
<td>3479.5</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>4.6</td>
<td>1.4</td>
</tr>
<tr>
<td>3456.9</td>
<td>Si III</td>
<td>1206.510</td>
<td>1.8652</td>
<td>1.6</td>
<td>1.81</td>
<td>13.8 ± 0.8</td>
</tr>
<tr>
<td>3427.6</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>4.6</td>
<td>2.6</td>
</tr>
</tbody>
</table>

Notes

The observed wavelengths, $\lambda_{obs}^{(\text{air})}$, are heliocentric values. Weighted mean values of the vacuum heliocentric redshifts of the two absorption line systems are $z_a = 0.0670 \pm 0.0005$ (Ca II) and $z_a = 1.8674 \pm 0.0004$. 

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gas of our Galaxy. We attribute the line to Ca\textsc{ii} \( K \lambda 3933.67 \) originating in intervening material of the nearby galaxy. With this identification the redshift of the line is \( z_a = 0.0666 \), which is very similar to the redshift of the nuclear region of the galaxy (\( z = 0.0669 \)). The strength of the \( K \) line is \( W_\lambda (\text{obs}) = 0.96 \, \text{Å} \). A probable line at 4233.5 Å can then be identified with the Ca\textsc{ii} \( H \lambda 3968.47 \) line at \( z_a = 0.0668 \). Its strength is \( W_\lambda (\text{obs}) \sim 0.4 \) Å which is at the detection limit of the spectrum and is consistent with its expected strength judged from the equivalent width of the \( K \) line and assuming a doublet ratio of 2.

No other strong absorption lines due to intervening material in the galaxy are expected to occur within the observed spectral window (3400–4700 Å). The weak interstellar lines due to the Na\textsc{i} \( \lambda \lambda 3302.38, 3302.99 \) UV doublet and Ti\textsc{ii} \( \lambda 3383.76 \) do lie within this wavelength region and are frequently found in interstellar H\textsc{i} clouds in the Galaxy when sufficiently high spectroscopic resolution is employed. They typically have strengths \( w_\lambda (\text{obs}) \leq 0.07 \) Å (de Boer & Pottasch 1974; Crutcher 1975; Stokes & Hobbs 1976) and therefore we would not expect to detect them unless they were very much stronger than in the Galaxy. At a redshift of 0.0667 the Na\textsc{i} UV doublet would occur near 3523 Å which is very close to the peak of the Ly\( \alpha \) emission in 0446 – 208.

The strong Na\textsc{i} \( \lambda \lambda 5889.95, 5895.92 D \) doublet would fall at 6282.9 and 6289.2 Å — well outside the observed spectral window. It is unfortunate that the stronger component is situated within 2 Å of a strong O\textsc{ii} atmospheric absorption and is also near the [O\textsc{i}] \( \lambda 6300 \) night sky emission. Finally, we point out that the strong Mg\textsc{ii} \( \lambda \lambda 2795.53, 2902.70 \) doublet at a redshift of 0.0667 remains frustratingly shortward (\( \sim 2986 \) Å) of the atmospheric cut-off.

Column densities have been determined from curves of growth provided by Dr D. C. Morton (private communication) using observed \( \log (W_\lambda / \lambda) \) and Doppler width \( b | b = w (4 \ln 2)^{-1/2} \) where \( w \) is the deconvolved FWHM, assuming a single absorbing cloud with a Gaussian velocity distribution. The resulting values are contained in Table 3. The column density of Ca\textsc{ii} is \( [11 (+5, -3)] \times 10^{12} \) cm\(^{-2}\) based on \( b = 90 \pm 20 \) km s\(^{-1}\) and \( W_\lambda (\text{obs}) = 0.96 \pm 0.25 \) Å for the \( K \) line. In addition, for the Ca\textsc{ii} lines the doublet ratio method has been used with the tables published by Strömgren (1948). Adopting a doublet ratio of 2 as indicated by the data, the calculated column density is consistent with that obtained from the curve of growth method.

### 3.3 The Galaxy Near 0446 – 208

Visual inspection of the AAT plate from which Plate 1 is reproduced shows clearly that the galaxy has a compact nucleus surrounded by an extended envelope. There is no evidence of spiral structure in the galaxy nor can a dust lane be discerned, although such features are unlikely to be detected in a galaxy at a redshift of 0.0669.

A density tracing of part of the AAT plate was made using the PDS microdensitometer at the AAO laboratory and the resulting contour map is shown in Plate 2. If the galaxy is symmetric as it appears to be, the outermost contour of the galaxy would reach almost to the position of the QSO. This reinforces the impression from the deep plate (see inset Plate 2) that the visible envelope extends to the vicinity of the QSO on the plane of the sky.

A section of the IPCS spectrum of the galaxy covering the region of the Ca\textsc{ii} doublet is shown on an expanded scale in Fig. 4 along with the corresponding region of the QSO spectrum. The galaxy spectrum was obtained by integrating over an area 7.5 × 1.5 arcsec centred on the nucleus and aligned at \( \text{pa} 19\degree \). The \( H \) line in the galaxy spectrum is stronger than \( K \) but this is probably an artefact of the noise. The strength of the Ca\textsc{ii} \( H \) line is unlikely to be inflated by blending with He\( \lambda 3970 \) because the other hydrogen lines in this
Figure 4. The IPCS spectra of the QSO and galaxy in the region containing Ca II absorption. For this presentation the spectra have been subjected to smoothing resulting in an effective resolution of 2.0 and 2.3 Å respectively to the QSO and galaxy.

region of the spectrum, namely Hγ and Hδ, are not detected. The spectrum is consistent with the IDS spectrum but in addition contains weak [O ii] λ3727 emission. The spectral features, including strong Ca II H and K lines and the absence of conspicuous Balmer lines, indicate that the galaxy is of late spectral type.

On the basis of its direct image and spectrum it is concluded that the galaxy is a probable S0. In general, galaxies belonging to this case are considered to have a low gas content (see, e.g. Burstein 1979).

4 Discussion

The QSO lies 13 arcsec in the plane of the sky away from the galaxy. The angle between the major axis of the galaxy and the line joining the centre of the galaxy to the QSO is 10°. Two extreme geometrical configurations may be considered: if the ellipticity of the galaxy contours (Plate 2) is due solely to the inclination of a thin disc to the line-of-sight then, the the sight-line to the QSO intercepts the plane of the galaxy at 25 kpc (H₀ = 50 km s⁻¹ Mpc⁻¹ and q₀ ≈ 0) from the centre. If, in the other extreme, the galaxy is inclined so that its plane is exactly parallel to the line-of-sight, then the sight-line to the QSO passes 4 kpc above the plane of the galaxy. In either case it is likely that the sight-line will intercept both the outer disc and the halo. The radial velocity of the absorbing material detected in the QSO spectrum, relative to the nucleus of the galaxy is −60 ± 60 km s⁻¹ (based on the uncertainty in the respective redshifts). This does not allow any conclusive distinction to be made between disc and halo absorption.

The Ca II K line is asymmetric, being unresolved blueward of the peak but broadened to the red; even though the H line is only weakly detected its appearance is consistent with the same degree of asymmetry. The strength of the Ca II absorption and the profile asymmetry,

*This value of H₀ is used to facilitate comparison of object separation with other recent work and does not imply acceptance of this value as the best current estimate.
which may be due to multiple-cloud absorption, are consistent with the gas occurring in the plane of the galaxy.

On the other hand the Ca II profile asymmetry is not inconsistent with a halo origin. For example, the spectrum of interstellar $K$ in the direction of HD38268, the central source of the 30 Doradus nebula in the LMC, shows an asymmetric absorption with a line width $\sim 100 \text{ km s}^{-1}$ (Blades & Meaburn 1980). The ultraviolet interstellar lines in this direction (de Boer & Savage 1980) and in other sight-lines in the LMC (Gondhalekar et al. 1980) show similar behaviour, confirming the existence of extensive halo material. Furthermore the galactic halo models of Weisheit (1978) predict asymmetric profiles for a sight-line through an intervening halo that is corotating with the disc.

A diagnostic test of whether absorption has either a halo or disc origin is to determine the Ca II/Na I ratio. For gas in our Galaxy the typical value for the $N$(Ca II)/$N$(Na I) ratio is $\sim 1$ for disc material and $\gtrsim 8$ for halo material (Cohen & Meloy 1975). An estimate of this ratio in the galaxy near 0446 – 208 would be of considerable value. The strength of the Ca II $K$ line found in the QSO predicts that $W_\lambda (\text{obs}) \approx 1 \text{ Å}$ for Na I in the plane of the galaxy and $\lesssim 0.5 \text{ Å}$ for halo gas (following Cohen & Meloy 1975). As mentioned earlier the wavelength region where Na I is expected to occur in the spectrum of the QSO is contaminated by telluric absorption and emission features. Despite this it should be possible to maintain a detection limit of $0.4 - 0.5 \text{ Å}$ for narrow lines.

For the case of NGC 3067, Boksenberg & Sargent (1978) argued that the Ca II absorption seen in the QSO spectrum originated in the outer halo of the galaxy based on their non-detection of Na I, although it was not possible to rule out absorption in the disc. The Ca II absorption in the QSO 2020 – 370 probably occurs in the halo of its foreground galaxy judging from the orientation of the QSO and galaxy on the plane of the sky.

The origin of interstellar absorption seen in intervening galaxies is an important question in view of the current debate over whether the narrow absorption lines commonly found in high-redshift QSOs are intrinsic to, or separate from, the central source. Bahcall & Spitzer (1969) were the first to suggest that QSO absorption lines in general could arise in extended haloes of galaxies. The work of Burbidge et al. (1977), however, has shown that to account for the multiplicity of absorption line systems in QSOs the proposed intervening haloes containing heavy elements must be huge with radii $\gtrsim 100 \text{ kpc}$.

For the Galaxy there is evidence of absorbing material in the inner halo. In particular, Cohen & Meloy (1975) found that the Ca II $K$ line increased in strength for sight-lines that extended 1 – 3 kpc above the plane in comparison to nearby ($\lesssim 1 \text{ kpc}$) sight-lines. However, the equivalent width of the $K$ line does not continue to increase as one penetrates the outer halo by using extragalactic background sources. For example, in 3C 273 ($b = 64.4^\circ$) $W_\lambda (K) = 0.22 \text{ Å}$ (Ulrich et al. 1980); in the SMC ($b = -45^\circ$) and LMC ($b = -32^\circ$) the $K$ line strength is $\sim 0.2$ and $\lesssim 0.1 \text{ Å}$, respectively (Blades, in preparation); in the supernova in NGC 4321, $W_\lambda (K) = 0.17 \text{ Å}$ (Penston & Blades 1980). Other examples are consistent with these data. High velocity $K$ components do occur (Blades & Meaburn 1980), but these are very weak absorption features. Recent ultraviolet work with the high dispersion camera on IUE has shown the presence of halo absorption in the Galaxy (Savage & de Boer 1979). These observations suggest a scale height of 2 kpc for the C IV and Si IV lines, and the high velocity components — present in both the ultraviolet and optical lines — may correspond to a distance of $\sim 8 \text{ kpc}$ below the plane. The data should be interpreted with some caution, especially in view of possible saturation effects. Even so, there is no compelling evidence, as yet, for strong absorption in an outer halo of the Galaxy.

Nevertheless, observations of the three QSO – galaxy pairs, as well as the other galaxies mentioned in the Introduction, demonstrates convincingly that strong interstellar absorption
does occur in external galaxies, with some of the absorption probably arising in outer halo material. This result is consistent with the view that the narrow absorption lines seen in QSOs can originate in intervening galaxies. It is evident that further spectroscopy on the halo of the Galaxy and nearby external galaxies is urgently required.

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References