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Detection of a z=0.0515, 0.0522 Absorption System in the QSO S4 0248+430 Due to an Intervening Galaxy

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I. INTRODUCTION

In some of the few cases where the line of sight to a QSO passes near a galaxy, the galaxy redshift is almost identical to an absorption redshift in the spectrum of the QSO. Although these relatively low redshift QSO-galaxy pairs may not be typical of the majority of the narrow heavy-element QSO absorption systems, they provide a direct measure of column densities in the outer parts of galaxies and some limits on the relative abundances of the gas.

Observations are presented here of the QSO S4 0248+430 and a nearby anonymous galaxy (Kuhr 1977). The 14″ separation of the line of sight to the QSO (z_e=1.316) and the z=0.052 spiral galaxy, (a projected separation of 20 kpc (H_o=50, q_o=0)), makes this a particularly suitable pair for probing the extent and content of gas in the galaxy. Low resolution (6Å FWHM), long slit CCD spectra show strong Ca II H & K lines in absorption at the redshift of the galaxy (Junkkarinen 1987). Higher resolution spectra showing both Ca II H & K and Na I D1 & D2 in absorption and direct images are reported here.

II. OBSERVATIONS AND ANALYSIS

The spectroscopic observations were taken on 4-6 October, 1988 with the UV Schmidt system and TI CCD detector on the Lick 3m telescope. The spectral regions covering Ca II ($\lambda\lambda$3700-4300) and the predicted Na I ($\lambda\lambda$5700-6500) absorptions were observed with long, 2″ wide slits and spectral resolutions of 1.8 and 2.9Å FWHM, respectively. The data were reduced using an optimal extraction routine included with the VISTA image and spectrum reduction package. Besides sky subtraction and optimal profile weighting, this routine also provides an accurate error array (Horne 1986). Standard flat-fielding, wavelength and flux calibration techniques were used.

As indicated in figures 1 and 2, at least two narrow absorption components occur in both Ca II and Na I, separated by $\Delta v \simeq 220$ km s^{-1}. Because the resolutions obtained were not sufficient to resolve the individual lines, we assumed a 2-component system, consisting of two gaussian doublets, and used a maximum likelihood fitting technique to measure the equivalent widths in all four lines of both species. For each doublet, the free parameters were: redshift (z), amplitude of the stronger line (A) and half-width (σ) of the gaussian profile, and doublet-ratio (R) where $R=A_K/A_H$ for Ca II or $R=A_{D2}/A_{D1}$ for Na I. In each case, χ^2 was minimized by varying all eight parameters freely. Because of the relatively poor fit to the Na I lines (χ^2_ν= 2.466), the errors in these parameters were determined with a monte carlo simulation. For each of 1500 iterations, simulated data were produced (through introduction of gaussian deviates to the best fit data) and then refitted by minimization of χ^2. The errors in the Ca II fit (χ^2_ν= 0.785) parameters were determined by varying one parameter while holding all others constant until χ^2 changed by 2.706 ($\Delta\chi^2$ for ν=1, probability of 0.1). In both cases, the errors reported here are for a 90% confidence level. Plots of the best fits are indicated by the dashed lines in Figures 1 and 2.

The equivalent widths for each line with errors were determined from the fit parameters. Using the doublet ratio formalism of Strömgren (1948), and a calculated curve of growth accounting for both doppler broadening and natural damping, limits were obtained for the column densities in each system (see Table I). For a pure damping profile the doublet ratio equals $\sqrt{2}$. Only lower limits on the Ca II column densities could be determined because these doublet ratios (including errors) span from below to above the limiting value of 1.414. Because the Na lines in both systems are highly saturated (DR<1.4) both upper and lower limits could be obtained for this species.

Direct, broadband CCD images of the QSO-galaxy field were taken on 15 October, 1988 with the Lick 3m telescope. The data were flat-fielded only, no absolute flux calibrations were applied. The image of the galaxy shows a single spiral arm-like feature covering and extending past the position of the QSO by more than 15″. A second, symmetric arm is not evident.

III. DISCUSSION

The column density ratio, N(Ca II)/N(Na I) is sensitive to the depletion of Ca onto grains. Both large and small Ca II/Na I ratios are observed in the disk of our Galaxy; the small ratios probably come from regions where Ca has been depleted onto grains (Spitzer 1978). Cohen and Meloy (1975) have found that gas above the disk typically has a large Ca II/Na I ratio. Our "best fit" values give N(Ca II)/N(Na I) = 0.036 and 0.013 for z_1=0.0515 and z_2=0.0522, respectively (assuming the lower column density solutions). If conditions are analogous to those in our Galaxy, the above Ca II/Na I ratios would imply a large Ca depletion and disk-type absorbing gas. However, within the formal 90% confidence intervals, larger Ca II/Na I are compatible with the data. A consequence of assuming very little depletion (say with N(Ca II)/N(Na I)$\sim$10), is that the observed lower limits on N(Na I) would imply N(Ca II)$\gtrsim 6 \times 10^{14}$cm^{-2} for the sum of the two components. This would result in N(Ca II) greater than 100 times that observed in other QSO-galaxy pair absorption systems (Blades 1988).

Of the six known absorption systems of this type, the Ca II and Na I lines measured in this object are amongst the strongest in total equivalent width (Blades 1988). Two others (0446−208, 1327−206) show large depletions of Ca – likewise implying disk absorption (Blades, *et al.* 1981, Baldwin, *et al.* 1985; Bergeron,*et al.* 1987). The column densities found here are considerably larger than in those intermediate redshift QSO absorption systems (with no apparent nearby galaxy) which have been observed at the predicted wavelength of Ca II (Blades 1988).

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References:

Baldwin, J. A., Phillips, M. M., and Carswell, R. F. 1985, *M. N. R. A. S.*, **216**, 41P.

Bergeron, J., D'Odorico, S. D., Kunth, D. 1987, *A. & A.*, **180**, 1.

Blades, J. C. 1988, in *QSO Absorption Lines: Probing the Universe*, eds. J. Blades, D. Turnshek, C. Norman (Cambridge: Cambridge Univ. Press), p.147.

Blades, J. C., Hunstead, R. W., and Murdoch, H. S. 1981, *M. N. R. A. S.*, **194**, 669.

Cohen, J. G., and Meloy, D. A. 1975, *Ap. J.*, **198**, 545.

Horne, K. 1986, *P. A. S. P.*, **98**, 609.

Kuhr, H. 1977, *A. & A. Suppl.*, **29**, 139.

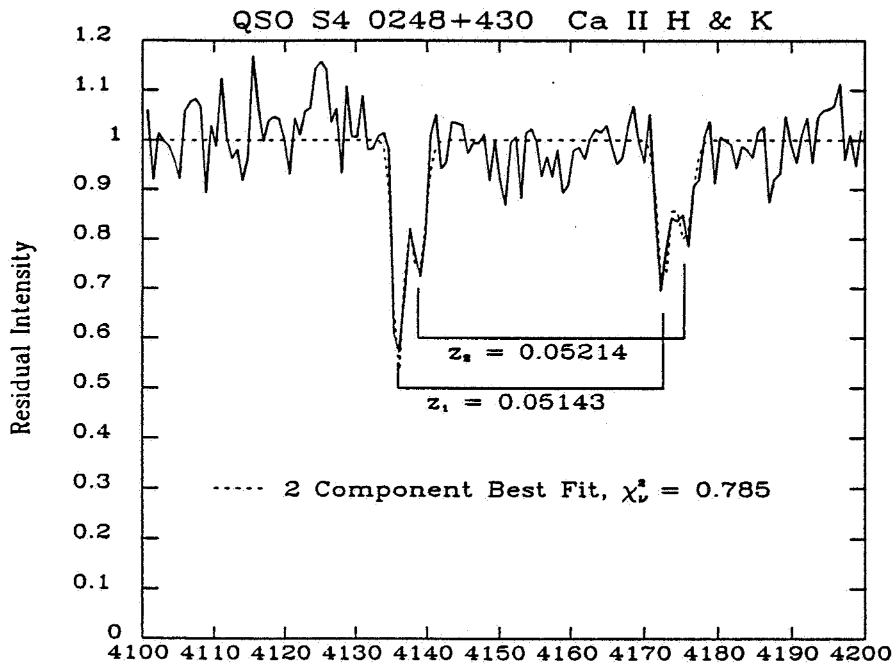
Junkkarinen, V. T. 1987, *B. A. A. S.*, **19**, 953.

Spitzer, L. 1978, *Physical Processes in the Interstellar Medium*, (New York: John Wiley & Sons).

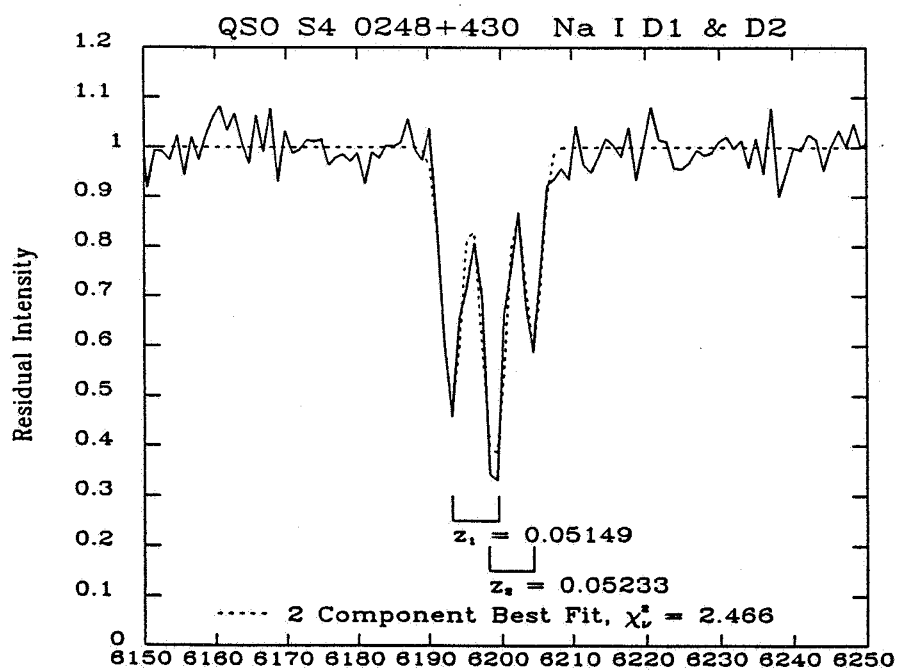
Strömgren, B. 1948, *Ap. J.*, **108**, 242.

TABLE I

	z_a	R	Equivalent Width (Å) (K or D2)	(H or D1)	Column Density ($\times 10^{13}$ cm^{-2})
Ca II	0.05143	$1.56^{+0.40}_{-0.27}$	0.90 ± 0.15	$0.58^{+0.18}_{-0.14}$	$0.9\leq N\leq 3.1$ or $N\geq 9.9\times10^3$
Na I	0.05149	$1.07^{+0.23}_{-0.16}$	1.78 ± 0.23	$1.66^{+0.41}_{-0.33}$	$2.6\leq N\leq 8.6\times10^3$
Ca II	0.05214	$1.33^{+0.47}_{-0.28}$	$0.70^{+0.18}_{-0.16}$	$0.52^{+0.23}_{-0.16}$	$N\geq 0.9$
Na I	0.05233	0.99 ± 0.25	$1.19^{+0.37}_{-0.31}$	$1.21^{+0.23}_{-0.19}$	$2.3\leq N\leq 4.4\times10^3$



Wavelength A Figure 1



Wavelength A Figure 2