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The close QSO pair Q1548+114A, B*

P. A. Shaver *European Southern Observatory, Karl-Schwarzschild-Str. 2, D-8046 Garching bei München, Federal Republic of Germany*

J. G. Robertson *Anglo-Australian Observatory, PO Box 296, Epping, NSW 2121, Australia*

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Summary. IPCS spectroscopic and CCD imaging observations have been made of the QSOs Q1548+114A and B, which are separated by 4.8 arcsec and have redshifts of 0.44 and 1.90. There is no evidence either for line-locking in the absorption spectrum of B or for associated absorption in B at the redshift of A, both of which had previously been reported. Galactic *H* and *K* absorption is present in both spectra.

This remains the closest pair of distinct QSOs, although the number of QSOs has increased tenfold since its discovery, and its existence is consistent with a random distribution of QSOs on the sky.

1 Introduction

The QSO pair Q1548+114A, B has been known now for over a decade (Wampler *et al.* 1973), but it is still exceptional. The redshifts of the two QSOs are 0.44 and 1.90, and their angular separation, 4.8 arcsec, remains the smallest of any known distinct pair of QSOs. This fact, and early spectroscopic data on these QSOs, generated considerable interest.

The very existence of a QSO pair with such a small angular separation and such different redshifts, among the relatively small number of QSOs known at that time, was regarded by some as possible evidence for a non-cosmological origin of QSO redshifts (e.g. Wampler *et al.* 1973; Hazard *et al.* 1973), although others regarded such a conclusion to be premature (e.g. Bahcall & Woltjer 1974; Burbidge, Burbidge & O'Dell 1974; Gott & Gunn 1974). Wampler *et al.* (1973) were also struck by several coincidences in the spectra of the two objects: an absorption feature (probably C IV) in B near the wavelength of the Mg II $\lambda 2800$ emission line in A, an emission feature in A near the wavelength of the C IV $\lambda 1549$ emission line in B, and a wavelength ratio $(1+z)_A/(1+z)_B$ very close to 2. Q1548+114A is a radio source comprising a compact core and an extended double, whereas B is radio-quiet (Argue *et al.* 1974, and references therein). A close group of three galaxies is located 10 arcsec from Q1548+114A (Hazard *et al.* 1973; Argue *et al.* 1974); Stockton (1974) found their mean redshift to differ by only 376 km s^{-1} from that of Q1548+114A, and took this as support for the cosmological

*Based on observations made at the Anglo-Australian Observatory, and at the European Southern Observatory at La Silla.

interpretation of redshift. Gott & Gunn (1974) discussed gravitational lens effects in this pair of QSOs; they showed that the absence of a second image of Q1548+114B requires the mass of A to be less than $7\times10^{12} M_{\odot}$. Finally, Burbidge *et al.* (1977) suggested that the spectrum of Q1548+114B contains five line-locked sets of C IV doublets at z_{abs}=1.6, and Mg II absorption only 1400 km s^{-1} from the redshift of A.

This pair, because of its small angular separation, is of special interest in studies of the absorption-line properties of QSO pairs (Shaver & Robertson 1984). By looking for *common absorption* (absorption in both spectra at the same redshift) and *associated absorption* (absorption at the redshift of the foreground QSO in the spectrum of the other), one may hope to learn something about the properties of absorption systems, the presence of absorbing matter around QSOs, and the cosmological interpretation of redshifts. In the case of Q1548+114A, B, we would like to know whether the Mg II absorption reported by Burbidge *et al.* (1977) is in fact common to both QSOs, whether there is associated absorption closer still to the emission redshift of A, and whether there is common absorption at lower redshifts. To answer these and other questions, we have made new spectroscopic and imaging observations of the Q1548+114A, B pair.

2 Observations

The spectroscopic observations were made with the Anglo–Australian Telescope on 1983 May 8–9 using the Image Photon Counting System with the Royal Greenwich Observatory spectrograph. The dispersion was 33 Å mm^{-1} with a slit width of 1.3 arcsec resulting in an instrumental resolution of 1.2 Å at the centre of each wavelength range, degrading to 2–3 Å at the extremities. The image format was 2044 spectral elements by 60 spatial increments, each of 2.2 arcsec. Both QSOs were observed simultaneously. Two overlapping wavelength ranges were observed, 3290–4190 Å (175 min integration) and 4050–4950 Å (170 min integration). These were later combined into one composite spectrum for each of the two QSOs. Special care was taken to avoid any contamination of one image by the other, although with subarcsecond seeing this was not a significant problem. The spectra were then lightly smoothed, reducing the central resolution from 1.2 to 1.5 Å. Standard calibration techniques were used for wavelength and instrumental response.

The resulting spectra are shown in Fig. 1. Emission lines are identified and absorption lines indicated, and they are listed in Tables 1 and 2 respectively: observed centroid wavelengths, observed equivalent widths, identifications, redshifts, and (Table 2) absorption system membership.

The spectrum of Q1548+114A contains many emission lines, but the only absorption lines are galactic *H* and *K*. By contrast, B has a rich absorption spectrum, with systems at z_{abs}=1.8923, 1.7563, 1.6085, and 1.4228, in addition to galactic *H* and *K*.

CCD imaging observations of Q1548+114A, B were made using the Danish 1.5-m telescope at La Silla on 1983 March 16. The CCD camera is based on the RCA CID 53612 chip, whose 320×512 pixels covered a field of 2.5×4.0 arcmin^2. An image of Q1548+114A, B from two 20-min exposures in *R* is shown in Plate 1. The seeing was 1.3 arcsec FWHM, as measured from the CCD frame. The two QSOs and the nearby galaxies are marked on Plate 1. Q1548+114A and B have *R* magnitudes of 18.1±0.1 and 18.8±0.1 respectively, based on the photometric system of Thuan & Gunn (1976).

3 Discussion

The spectra of these two QSOs appear to be completely normal, and unrelated to each other. The wavelength of the feature near 4500 Å in A is that expected for the O III λ3134 Bowen

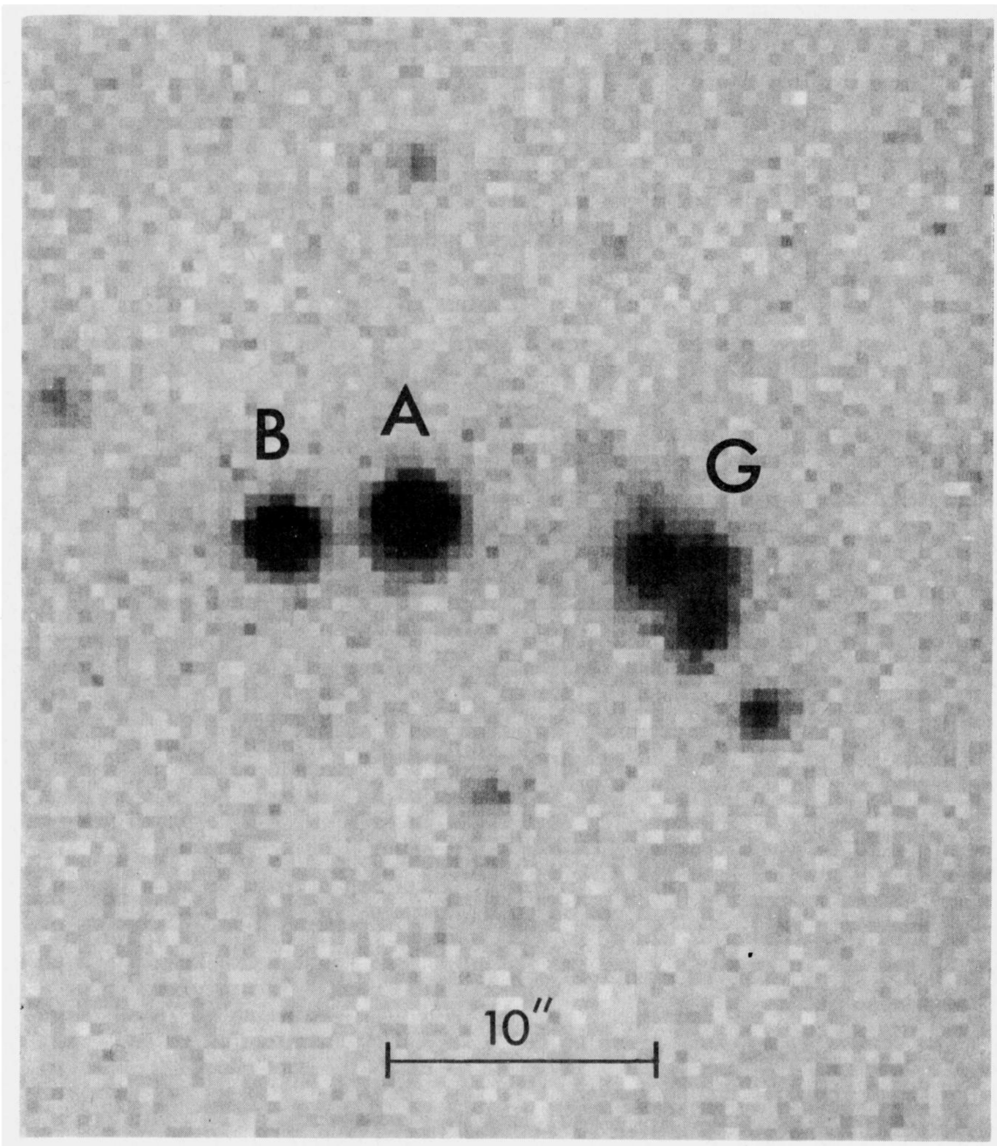

Plate 1. CCD *R*-band image of the QSO pair Q1548+114A, B. The nearby galaxies at a redshift of 0.4340 are also indicated. North is to the top, east to the left, and the scale is shown by the horizontal bar.

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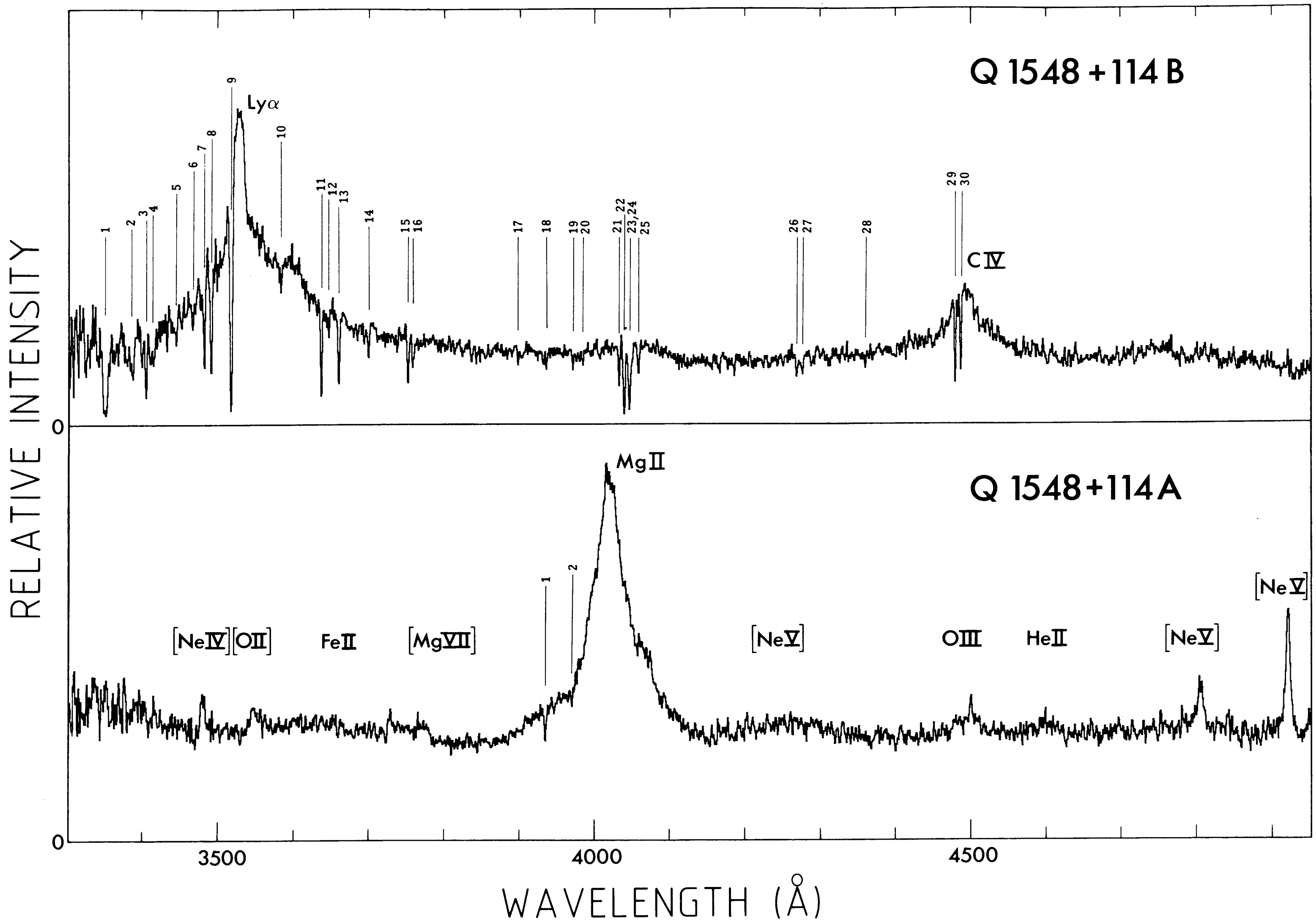

Figure 1. Spectra of the QSOs Q1548+114A and B. The resolution is 1.5 Å over the bulk of the wavelength range. Emission lines are identified, and absorption lines are indicated as in Table 2.

Table 1. Emission lines.

λ(Obs.) Å	W_λ(Obs.) Å	Identification	z_{em}
Q1548+114A			
3479.9±0.2	2.6±0.1	[Ne IV] 2425	0.4350±0.0001
3547.3±0.8	2.5±0.3	[O II] 2471	0.4355±0.0003
3772.6±0.5	2.9±0.3	[Mg VII] 2627	0.4361±0.0002
4019.3±0.3	180±5	Mg II 2799	0.4361±0.0001
4498.8±0.4	6.1±0.4	O III 3134	0.4356±0.0001
4600.8±1.0	3.8±0.4	He II 3204	0.4359±0.0003
4804.5±0.2	3.9±0.3	[Ne V] 3347	0.4356±0.0001
4920.4±0.2	9.6±0.4	[Ne V] 3427	0.4358±0.0001
			$\langle z_{em}\rangle$=0.4356±0.0001
Q1548+114B			
3527.2±0.4*	150±10*	Lyα 1216	1.9014+0.0003
3598.0†	30:	N V 1240	1.9014†
4061.1†	22±4	Si IV+O IV 1400	1.9014†
4489.4±0.5*	50±5*	C IV 1549	1.8982±0.0003
			z_{em}=1.9014±0.0003

All wavelengths throughout this paper are vacuum, heliocentric values. The quoted errors are 1 standard deviation.
*Corrected for the effects of the narrow absorption lines with z_{abs}~z_{em}.
†Based on the Lyα line.

fluorescence line, and is clearly different from that of the C IV emission line in B. There is no indication of C IV (or Lyα) emission at the redshift of B in the spectrum of A, as had been discussed by Wampler *et al.* (1973), and by Latham (1982) as possible evidence for gravitational lensing.

The group of lines clustered together in the range $\lambda\lambda$4030–4060 Å are not five line-locked sets of C IV absorption doublets as Burbidge *et al.* (1977) had suggested, but rather the C IV $\lambda\lambda$1548, 1551 doublet from the z_{abs}=1.6085 system straddled by the Si IV $\lambda\lambda$1394, 1403 doublet of the z_{abs}=1.8923 system and partially blended with the Al II λ1671 line at z_{abs}=1.4228.

Furthermore, the Mg II absorption reported by Burbidge *et al.* (1977) at z_{abs}=0.4293 does not appear to be present. The upper limit on the equivalent width is 0.3 Å. It therefore appears that this pair of QSOs does not exhibit associated absorption, in spite of the very small separation (nor is there absorption at the redshift of the nearby galaxies, z=0.4340). This may be due to the comparatively high excitation of gas in the immediate vicinity of QSOs, so that only absorption lines of high ionization, such as C IV, would normally be present (see discussion by Shaver & Robertson 1983).

There is galactic H and K absorption which is common to both spectra at $V_{LSR}=\pm 8\,\mathrm{km\,s^{-1}}$. The equivalent widths of the K lines in the two spectra appear to differ by almost a factor of two, yet the projected separation of the two lines-of-sight is only 0.02 D pc, where the distance D is in kpc. If this difference is real, it indicates that the absorbing cloud is small or highly structured, and relatively dense. It is probably located in the galactic disc within ~1 kpc (*cf.* Blades & Morton 1983).

The most striking feature of these two QSOs, that which attracted so much attention in the first place, is the simple fact that they are so close on the sky and yet have very different redshifts. However, the passage of ten years since their discovery, and the increase over that time in the number of known QSOs by an order of magnitude, has greatly diminished their

Table 2. Absorption lines.

No.	λ(Obs.) (Å)	W_λ(Obs.) (Å)	Identification	z_{abs}	System
	Q1548+114A				
1	3934.3±0.2	0.7±0.1	Ca II 3935	−0.0001±0.0001	a
2	3969.5±0.2	0.2±0.1	Ca II 3970	−0.0000±0.0001	a
	Q1548+114B				
1	3350.1±0.3	5.6±0.4	Lyα 1216	1.7558±0.0002	b
2	3386.0±0.4	2.2±0.4	–	–	–
3	3404.0±0.2	1.5±0.3	Si II 1304	1.6097±0.0002	c
4	3411.7±0.3	1.7±0.3	–	–	–
5	3444.1±0.2	0.8±0.3	–	–	–
6	3465.7±0.2	0.5±0.2	–	–	–
7	3481.0±0.2	1.3±0.2	C II 1335	1.6048±0.0001	c
8	3490.1±0.2	1.7±0.2	Si III 1207	1.8927±0.0002	a
9	3516.2±0.2	3.9±0.3	Lyα 1216	1.8924±0.0002	a
10	3582.0±0.2	0.3±0.1	N V 1239	1.8915±0.0002	a
11	3635.5±0.2	1.9±0.1	Si IV 1394	1.6084±0.0001	c
12	3645.5±0.2	0.4±0.2	Si II 1260	1.8923±0.0002	a
13	3658.9±0.2	1.7±0.1	Si IV 1403	1.6083±0.0001	c
14	3698.6±0.2	0.6±0.1	Si II 1527	1.4226±0.0001	d
15	3751.1±0.2	1.3±0.1	C IV 1548	1.4229±0.0001	d
16	3757.3±0.2	0.7±0.1	C IV 1551	1.4229±0.0001	d
17	3897.0±0.2	0.3±0.1	Fe II 1608	1.4228±0.0001	d
18	3934.3±0.2	0.4±0.1	Ca II 3935	−0.0001±0.0001	e
19	3969.9±0.2	0.3±0.1	Ca II 3970	0.0001±0.0001	e
20	3983.3±0.2	0.3±0.1	Si II 1527	1.6091±0.0001	c
21	4031.3±0.2	1.0±0.1	Si IV 1394	1.8924±0.0001	a
22	4038.1±0.2	2.7±0.1	C IV 1548	1.6083±0.0001	c
23	4044.9±0.2	2.6±0.2	C IV 1551	1.6083±0.0001	c
24	4048.0*	0.6±0.2	Al II 1671	1.4228*	d
25	4057.0±0.2	0.9±0.1	Si IV 1403	1.8921±0.0001	a
26	4267.3±0.2	0.7±0.1	C IV 1548	1.7563±0.0001	b
27	4275.3±0.3	0.6±0.1	C IV 1551	1.7569±0.0002	b
28	4358.6±0.2	0.3±0.1	Al II 1671	1.6087±0.0001	c
29	4478.1±0.2	1.4±0.1	C IV 1548	1.8925±0.0001	a
30	4485.6±0.2	1.3±0.1	C IV 1551	1.8925±0.0001	a

*from the other lines in the system.

significance. They remain the closest known pair of distinct QSOs, in spite of determined efforts to find more such cases (*cf.* Wills 1978). From current estimates of the QSO surface density (Véron 1983), the number of pairs of QSOs brighter than 20 mag and separated by ≦5 arcsec expected to occur by chance amongst the ~2500 QSOs with known redshift is ~0.4. The existence of Q1548+114A, B is therefore by no means inconsistent with the hypothesis of QSOs at cosmological distances randomly distributed on the sky.

Our CCD image of Q1548+114A, B (Plate 1) reveals no secondary image of B with an intensity greater than 1 per cent of B further than 1 arcsec from A. Nor is there any indication that the secondary image of B might be superimposed on that of A – the image of A is highly symmetrical, and its spectrum does not appear to be contaminated by the emission or absorption lines found in the spectrum of B. ST observations of this QSO pair will clearly be of special interest: detection of a second image of B would provide yet another gravitational lens, show that B is behind A, and yield an estimate of the mass of A.

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