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REDSHIFTS OF SOUTHERN RADIO SOURCES. II.

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ABSTRACT

Further redshifts, derived from observations with the image-tube dissector scanner on the 4 m Anglo-Australian telescope, are reported for 30 objects associated with Parkes radio sources. Included are redshifts for 25 QSOs and one QSO–galaxy pair.

Subject headings: galaxies redshifts — quasars — radio sources: general

I. INTRODUCTION

We present further observations from a continuing program designed to provide comprehensive optical and radio data for southern QSOs selected from the Parkes 2700 MHz survey. The aims of this program have been outlined in an earlier *Letter* (Peterson *et al.* 1976).

Briefly, two criteria are used to establish the optical identification with a Parkes source: (i) an optical-radio position coincidence, supported by an ultraviolet excess as shown by two-color photography (see, e.g., Shimmins *et al.* 1971) (this method is used for radio sources with positions of moderate [10″] accuracy); (ii) an optical-radio position coincidence alone for sources remeasured using the NRAO three-element interferometer (these positions have a typical accuracy of $\lesssim 2''$ [Condon, Balonek, and Jauncey 1976]).

The use of these two criteria will allow an assessment of the effects of color selection in making QSO identifications.

II. OBSERVATIONS

The image-tube dissector scanner (Robinson and Wampler 1972) was used at the f/15 Cassegrain focus of the 4 m Anglo-Australian telescope (see Wampler 1975) to obtain spectral scans covering the wavelength range from about 3800 Å to 8000 Å with a resolution of about 10 Å. Scans of 37 objects were obtained, principally from observations on the nights of 1976 January 27 and 28, when the seeing disk did not exceed 1″.5 and was normally less than 1″. A small number of scans were also acquired on the nights of 1975 November 11, 12, and 26–29 under poorer seeing conditions.

Details are given in Table 1 for the 30 extragalactic objects for which redshifts could be determined. The positions given are normally accurate to about 8″, except where extra figures denote positions accurate to about 1″. The magnitudes given are from the integrated spectrum scans and are accurate to about 0.3 mag: known optical variables are indicated by parentheses. The radio flux densities are from the most recent Parkes measurements. In the "color" column, the letters UVX and BSO indicate objects with ultraviolet excess and blue stellar objects, respectively.

Details of the line identifications and strengths used to determine redshifts are given in Table 2. Values given in parentheses are of relatively low accuracy. The letter A against an observed wavelength denotes an absorption line. The line-to-continuum ratio is the excess height of the line above the continuum divided by the height of the continuum, and is thus negative for absorption features. (This differs from the definition given in Peterson *et al.* 1976.) The line width, $\Delta\lambda_{1/2}$, is the full width at half-maximum intensity. The notation NR implies that the line was not resolved by the instrument.

Apart from the objects given in Tables 1 and 2 for which we have determined redshifts, three other objects, 0301−234, 1216−010, and 0521−36 (see note in following section), were found to have essentially "continuous" spectra—i.e., no lines were observed at greater than 10% of the continuum. Two other objects observed were clearly stars: these are the object suggested as the identification for 0629−418 by Peterson and Bolton (1973) and the 13th mag object close to the radio position of 0937−328. For three sources a second object with an ultraviolet excess lies in the field. In two cases, 0506−61 and 0642−349, this second object was also found to have a stellar spectrum. In the case of 0254−334 the second ultraviolet object was described in our earlier *Letter* (Peterson *et al.* 1976). It was reobserved in 1976 January to cover the red end of the spectrum. No further strong emission lines were seen.

III. NOTES ON INDIVIDUAL OBJECTS

0005−239, 0514−161. Redshifts have already been obtained by Wills and Wills (1976), and we confirm their values.

0222−00. The original identification with an S0

TABLE 1

OBJECTS WITH REDSHIFTS

Name	Position (1950) R.A. (h m s)	Dec. (° ' ")	Ident.	m	z	S_{2700} (Jy)	S_{5000} (Jy)	Colour	Finding chart ref.*
0005-239	00 05 27.43	-23 56 00.0	Q	17.2	1.407	0.58	0.53	-	A
0150-334	01 50 57.8	-33 24 57	Q	18.6	0.610	0.92	0.86	UVX	B
0222-00	02 22 35.02	-00 49 02.0	Q	18.4	0.687	0.68	0.42	Neutral	C
0338-214	03 38 23.23	-21 09 07.6	G?	15.6	0.048	0.82	0.94	Neutral	A
0355-483	03 55 52.57	-48 20 50.2	Q	16.9	1.005	0.61	0.57	UVX	D
0422-380	04 22 55.6	-38 03 02	Q	(16.5)	0.78	0.49	0.81	UVX	E
0448-392	04 48 01.3	-39 16 20	Q	(18.0)	1.288	0.90	0.87	UVX	E
0454+039	04 54 08.72	+03 56 16.5	Q	17.0	1.345	0.40	0.42	UVX	F
0506-61	05 06 08.55	-61 13 33.1	Q	17.5	1.093	1.89	2.05	UVX	G
0514-161	05 14 01.09	-16 06 22.2	Q	17.1	1.278	0.80	0.74	-	
0528-250	05 28 05.24	-24 05 43.0	Q	17.7	2.805	1.25	1.13	RED	H
0602-319	06 02 22.5	-31 55 48	Q	18.3	0.452	1.89	1.25	UVX	G
0622-441	06 22 02.70	-44 11 24.2	Q	16.6	0.688	0.77	0.84	UVX	B
0642-349	06 42 36.8	-34 56 36	Q	18.5	2.165	1.07	1.00	UVX	G
0723-008	07 23 17.86	-00 48 54.6	N	17.8	0.127	3.03	2.25	Neutral	J
0819-032	08 19 09.54	-03 13 38.8	Q	(18.2)	2.352	0.42	0.26	BSO	K
0906+01	09 06 35.16	+01 33 48.0	Q	17.3	1.020	1.20	1.01	UVX	L
0959-443	09 59 58.91	-44 23 25.1	Q	15.5	0.840	0.87	0.81	UVX	E
1101-325	11 01 08.2	-32 35 05	Q	15.4	0.3545	0.93	0.73	UVX	B
1103-006	11 03 58.07	-00 36 37.7	Q	15.4	0.426	0.68	0.42	UVX	F
1146-037	11 46 23.9	-03 47 30	Q	16.4	0.341	0.39	0.29	UVX	F
1157+014	11 57 10.99	+01 28 51.0	Q	(17.0)	1.986	0.14	-	BSO	M
1158+007	11 58 50.1	+00 44 54	Q	19.0	0.325	0.26	-	UVX	M
1203+011	12 03 14.4	+01 10 54	Q	18.2	0.104	0.13	-	UVX	F
1205-008/Q	12 05 07.90	-00 49 54.8	Q	18.6	1.002	0.11	0.25	-	M
1205-008/G	12 05 07.7	-00 49 45	G	17.5	0.306			-	M
1215+013	12 15 54.11	+01 19 18.1	G?	17.4	0.118	0.10	-	-	M
1240-294	12 40 30.05	-29 26 57.7	Q	17.3	1.135	0.57	0.41	UVX	G
2326-477	23 26 33.6	-47 46 52	Q	17.0	1.302	2.48	2.36	UVX	D

*Finding Chart references: A, Bolton, Shimmins, and Wall (1975); B, Peterson and Bolton (1973); C, McEwan, Browne, and Crowther (1975); D, Wall and Cannon (1973); E, Peterson and Bolton (1972); F, Bolton and Wall (1970); G, Peterson, Bolton, and Shimmins (1973); H, Jauncey, Wright, and Peterson (1976); J, Browne, Crowther, and Adgie (1973); K, Browne and McEwan (1972); L, Bolton, Shimmins, and Merkelijn (1968); M, Condon, Balonek, and Jauncey (1976).

galaxy given by Bolton and Ekers (1967) is incorrect (McEwan, Browne, and Crowther 1975).

0422−380. Only the Mg II line was seen with a good signal-to-noise ratio. However, the presence of a shallow trough extending shortward of the emission line is typical of this region in other QSO spectra, and this, together with the presence of the other weaker lines, supports the identifications given.

0338−214. This object appears stellar, and its radio flux density increases to higher frequencies, suggestive of a QSO. However, the presence of the MgH absorption feature, the low redshift, the neutral color, and a rather steep optical spectrum suggest that it is a very compact galaxy.

0521−36. Spectra for this object have been obtained by Westerlund and Stokes (1966) and Searle and Bolton (1968). They describe it as a galaxy with a redshift of about 0.06. The spectrum now appears to be essentially continuous.

0528−250. This object appears to have no emission lines but a particularly rich absorption spectrum showing over 20 lines. It will be described in more detail in a separate paper. Only the most prominent absorption lines are used here to obtain the redshift.

0602−319. The [O III] line at an observed wavelength of 6336 Å is contaminated by the O I λ6300 and λ6364 night-sky lines.

0723−008. A redshift has been obtained for this object by Strittmatter *et al.* (1974), and we confirm their value. However, a strong emission line at a rest wavelength of about 4785 Å remains unidentified.

0906+01. A redshift has already been obtained by Burbidge and Strittmatter (1972), and we confirm their value.

1103−006. [O II] λ3727 is predicted at an observed wavelength of about 5320 Å but was not seen. This implies a line-to-continuum ratio of less than 0.08.

1157+014. This object was observed on two nights. The C IV λ1549 line is strongly self-absorbed to the blue side, making accurate estimation of the observed center wavelength difficult.

1203+011. The [O III] λ5007 line at an observed wavelength of 5563 Å is contaminated by the O I λ5577 night sky line. This probably explains why it appears weak relative to [O III] λ4959. In spite of the very low redshift, the stellar appearance, an inverted radio spectrum, and an ultraviolet excess indicate that the identification of this object with a QSO rather than a galaxi- is correct.

1205−008. The QSO and galaxy are separated by

TABLE 2

DETAILS OF INDIVIDUAL SPECTRA

(1) Name	(2) Mean z	(3) Obs. λ (Å)	(4) Ident.	(5) Emitted λ (Å)	(6) z	(7) Line-to-continuum ratio	(8) $\Delta\lambda_{1/2}$ (Å)
0005-239	1.407	(3730)	C IV	1549	(1.408)	0.7	80
		4605	C III]	1909	1.412	0.40	(120)
		5557	C II]	2326	1.389	0.18	130
		6750	Mg II	2798	1.412	0.45	110
		(6832)	[A IV]	2860	1.389	0.2	(40)
0150-334	0.610	(3780)	C II]	2326	(0.625)	0.5	(30)
		4505	Mg II	2798	0.610	0.59	100
		4793	[Ne V]	2974	0.612	0.2	(20)
		5550	[Ne V]	3426	0.620	0.5	25
		5610	N IV	3485	0.610	0.4	25
		5990	[O II]	3727	0.607	0.3	65
		6930	Hγ	4340	0.597	0.6	30
0222-00	0.687	(4703)	Mg II	2798	(0.68)	(0.55)	200
		(5032)	[Ne V]	2974	(0.69)	(0.30)	35
		6284	[O II]	3727	0.686	0.71	20
		(6525)	[Ne III]	3869	(0.686)	0.32	50
		(8460)	[O III]	5007	(0.69)	0.8	50
0338-214	0.048	5110 A	Hβ	4861	0.051	-0.1	(40)
		5510 A	Mg H	5269	0.046	-0.1	(50)
		6875 A	Hα	6563	0.048	-0.2	50
0355-483	1.005	5610	Mg II	2798	1.005	0.38	110
		(5730)	[A IV]	2860	(1.003)	(0.1)	-
0422-380	0.78	4982	Mg II	2798	0.781	0.15	60
		6083	[Ne V]	3426	0.776	0.08	50
		(6540)	[O II]	3727	(0.755)	0.12	50
0448-392	1.288	4360	C III]	1909	1.284	0.77	80
		6420	Mg II	2798	1.294	0.45	80
0454+039	1.345	4490	C III]	1909	1.352	0.20	50
		4830 A	?				
		5210 A	?				
		6557	Mg II	2798	1.343	0.38	100
0506-61	1.093	4003	C III]	1909	1.097	(0.40)	(75)
		5850	Mg II	2798	1.091	0.32	150
		(6228)	[Ne V]	2974	(1.094)	0.16	NR
0514-161	1.278	4350	C III]	1909	1.279	0.35	100
		6380	Mg II	2798	1.280	0.56	120
		6645	[Mg V]	2931	1.267	0.23	75
		6778	[Ne V]	2974	1.279	0.21	30
0528-250	2.813	4543 A	Si II	1194	2.814	-0.52	NR
		(4633 A)	Ly α	1216	2.813	-0.94	(100)
		4801 A	Si II	1260	2.814	-0.32	NR
		4964 A	Si II	1304	2.811	-0.40	NR
		4081 A	C II	1335	2.813	-0.36	NR
		4809 A	Si II	1527	2.813	-0.25	NR
		5901 A	C IV	1549	2.812	-0.27	25
0602-319	0.452	4997	[Ne V]	3426	0.459	0.10	50
		5411	[O II]	3727	0.452	0.32	50
		5613	[Ne III]	3869	0.451	0.28	60
		5766	[Ne III]	3970	0.452	0.17	60
		6336	[O III]	4363	0.452	(0.19)	(100)
		7190	[O III]	4959	0.450	0.30	50
		7272	[O III]	5007	0.452	1.00	50
0622-441	0.688	(3970)	C II]	2326	(0.71)	(0.2)	-
		4710	Mg II	2798	0.683	0.46	80
		4790	[A IV]	2860	0.675	0.08	50
		5466	He II	3203	0.707	0.07	70
		5680	[Ne V]	3346	0.698	0.08	NR
		(8146)	Hβ	4861	(0.68)	(0.5)	(80)
0642-349	2.165	3839	Ly α	1216	2.157	2.20	60
		3934	N V	1240	2.173	0.34	70
		4900	C IV	1549	2.163	0.89	50
		5185	He II	1640	2.162	0.20	20
		6050	C III]	1909	2.169	0.31	130
0723-008	0.127	(4200)	[O II]	3727	(0.13)	(0.5)	-
		5392 A	?			0.55	35
		5491	Hβ	4861	0.130	0.20	70
		5585	[O III]	4959	0.126	0.38	30
		5643	[O III]	5007	0.127	0.84	30
		7394	Hα	6563	0.127	0.50	80

TABLE 2—*Continued*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
0819-032	2.352	4080	Ly α	1216	2.355	4.1	80
		4708	O IV]	1406	2.349	0.26	150
		5193	C IV	1549	2.352	1.56	70
		(5498)	He II	1640	(2.352)	(0.18)	(80)
		6390	C III]	1909	2.347	0.33	130
0906+01	1.020	(3870)	C III]	1909	(1.027)	(0.5)	(100)
		5648	Mg II	2798	1.019	0.34	110
0959-443	0.840	5177	Mg II	2798	0.850	0.37	150
		(5261)	[A IV]	2860	(0.840)	0.16	(50)
		(5325)	[Mg V]	2931	(0.817)	(0.1)	(50)
		5459	[Ne V]	2974	0.836	0.14	50
		6087	[Ne V]	3346	0.819	0.10	70
		6277	[Ne V]	3426	0.832	0.07	70
1101-325	0.3545	3790	Mg II	2798	0.3545	0.6	(50)
		4650	[Ne V]	3426	0.3573	0.26	50
		4722	N IV	3485	0.3549	0.13	60
		4920	He I	3643	0.3539	0.13	50
		4985	He II blend	(3688)	0.3535	0.11	80
		5051	[O II]	3727	0.3552	0.18	NR
		5246	[Ne III]	3869	0.3559	0.24	50
		5379	Hε	3970	0.3549	0.12	NR
		5560	Hδ	4102	0.3554	0.23	50
		(5903)	Hγ + [O III]	(4350)	(0.356)	(0.3)	(100)
		6345	He II	5686	0.3540	0.11	60
		6410	[A IV]	4740	0.3523	0.14	50
		6591	Hβ	4861	0.3559	1.46	90
		6717	[O III]	4959	0.3545	1.29	NR
		6782	[O III]	5007	0.3545	3.25	NR
1103-006	0.426	3995	Mg II	2798	0.428	0.62	100
		6191	Hγ	4340	0.426	0.30	110
		6939	Hβ	4861	0.427	0.29	100
		(7065)	[O III]	4959	(0.425)	0.13	-
		7124	[O III]	5007	0.423	0.40	60
1146-037	0.341	(3755)	Mg II	2798	(0.34)	(0.5)	-
		4479	[Ne V]	3346	0.339	0.16	30
		4602	[Ne V]	3426	0.343	0.20	25
		(4670)	N IV	3485	(0.340)	(0.1)	(100)
		5003	[O II]	3727	0.342	0.30	NR
		5188	?			0.52	40
		5236	?			0.22	50
		(5459)	Hδ	4102	0.331	0.13	-
		5820	Hγ + [O III]	(4350)	0.338	0.20	(110)
		6509	Hβ	4861	0.339	0.60	60
		6643	[O III]	4959	0.340	1.75	25
		6711	[O III]	5007	0.340	5.81	25
1157+014	1.986	4640	C IV	1549	1.995	-	-
		5685	C III]	1909	1.978	0.26	170
1158+007	0.325	(4525)	[Ne V]	3426	(0.32)	(0.4)	(120)
		4956	[O II]	3727	0.330	0.35	80
		6631	[O III]	5007	0.324	0.50	120
1203+011	0.104	(4110)	[O II]	3727	(0.103)	(0.5)	-
		5414	Hβ	4861	0.114	0.44	40
		5491	[O III]	4959	0.093	0.29	30
		5563	[O III]	5007	0.111	(0.2)	30
		7290	Hα	6563	0.111	0.75	(60)
1205-008/Q	1.002	5601	Mg II	2798	1.002	0.65	80
1205-008/G	0.306	5119 A	K-Ca II	3933	0.302	-0.37	35
		5168 A	H-Ca II	3967	0.303	-0.33	60
		6378	Hβ	4861	0.312	0.25	100
		(6530)	[O III]	5007	0.304	0.13	(30)
1215+013	0.118	(4150)	[O II]	3727	(0.113)	(0.4)	-
		5432	Hβ	4861	0.117	0.21	25
		5547	[O III]	4959	0.119	0.1	25
		5597	[O III]	5007	0.118	0.34	25
		7345	Hα	6563	0.119	0.36	50
1240-294	1.135	(4060)	C III]	1909	(1.127)	0.47	80
		5985	Mg II	2798	1.139	0.43	90
		6065	[A IV]	2854	1.136	0.1	-
		6130	[A IV]	2869	1.137	0.1	-
2326-477	1.302	(4400)	C III]	1909	(1.305)	0.27	(75)
		6435	Mg II	2798	1.300	0.40	80

only 9″.4. However, if both objects were at the distance, of the galaxy, assuming a Hubble constant of 75 km s^{-1} Mpc^{-1}, the projected linear separation would be 56 kpc. This is about a factor of 4 larger than that found for other QSO–galaxy associations (see, e.g., Burbidge, O'Dell, and Strittmatter 1972).

1215+013. The [O III] λ5007 line at an observed wavelength of 5597 Å is possibly contaminated by the O I λ5577 night sky line.

The red color of this object, a curved optical continuum spectrum, and the low redshift suggest that it is a very compact galaxy.

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