THE ASTROPHYSICAL JOURNAL, 232:400–403, 1979 September 1

REDSHIFTS OF SOUTHERN RADIO SOURCES. V.

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Received 1978 October 3; accepted 1979 February 21

ABSTRACT

Redshifts derived from further observations with the image-tube dissector scanner on the 4 m Anglo-Australian Telescope are reported for 19 QSOs and three galaxies associated with southern radio sources. Included are the red stellar object PKS 1402+044 with a redshift of 3.202, and a QSO–galaxy pair separated by 15″.

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

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 (see Wall, Wright, and Bolton 1976 and references therein). Previous observations in this program have been reported in Papers I (Peterson *et al.* 1976), II (Wright *et al.* 1977), III (Jauncey *et al.* 1978), and IV (Wright *et al.* 1979). Our primary aim is to determine the redshifts and other characteristics of a complete sample of QSOs with flat radio spectra so that we may investigate their evolution and luminosity function.

Two criteria are being used to identify the optical counterparts of the radio sources. Where radio positions of only moderate accuracy (~10″) are available, the identification is based upon the presence of an object with an ultraviolet excess within the radio error box [see Peterson, Bolton, and Savage 1976 and references therein]. For radio positions of high accuracy (2″ or better) measured with the NRAO three-element interferometer (Condon, Hicks, and Jauncey 1977), the identification is based on coincidence of the optical and radio positions, without reference to color or morphology. These two approaches will allow an assessment of the effects of color selection on QSO identification.

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 spectrum scans covering the wavelength range from about 3500 to 7250 Å with a resolution of about 10 Å. Useful scans of 30 objects were obtained on the nights of 1977 April 15 and 16, and 1977 July 12, 13, 14, and 15.

The 22 objects for which redshifts have been determined are listed with their optical positions in Table 1. The positions given to 1″ have a standard error of 8″. The positions given to 0″.1 have a standard error of 2″. The magnitudes are from the integrated spectrum scans and have a standard error of 0.3 mag. The radio flux densities are the most recent Parkes measurement. The colors for the objects were derived from a comparison of the red and blue Palomar sky survey prints, or from the results of two-color (blue and ultraviolet) photographs.

The strengths and widths of lines used to determine the redshifts are given in Table 2 along with the observed wavelength and the identification. The line-to-continuum ratio is the height of the line above the continuum divided by the height of the continuum and is therefore negative for absorption features. The line width is the full width at half-maximum intensity.

In addition to the objects for which redshifts were determined, the following PKS objects were found to have apparently continuous spectra in that no features with a line-to-continuum ratio of greater than 0.2 were seen: 0754+100, 0823−223, 0829+046, and 1336+237. Wills and Wills (1976) also found that 0829+046 had a continuous spectrum. Tapia *et al.* (1977) have found variable polarization in 0754+100. These four sources are probably BL Lacertae objects. Only 0829+046 is clearly blue. The other three are slightly blue or neutral, and were not identified until the accurate radio positions became available (Condon, Hicks, and Jauncey 1977).

[1] Alfred P. Sloan Foundation Fellow.

[2] NRAO is operated by Associated Universities, Inc., under contract with the National Science Foundation.

TABLE 1

RADIO SOURCES WITH REDSHIFTS

Name	Equinox 1950 R.A. h m s	Dec ° ' "	Optical type	mag.	Redshift z	Radio flux density 2700 MHz Jy	5000 MHz Jy	Color	Finding chart reference
0748+126	07 48 05.10	+12 38 45.8	QSO	17.8	0.889	1.69	2.22		A
0921-213	09 21 21.82	-21 22 52.4	Galaxy	16.8	0.052	0.53	0.42		B
0925-203	09 25 33.55	-20 21 45.0	QSO	16.3	0.348	0.81	0.70		C
1104-445	11 04 50.2	-44 32 54	QSO	18.2	1.598	1.84	2.03	UVX	D
1111+149	11 11 21.32	+14 58 48.5	QSO	18.1	0.864	0.55	0.71		A
1327-311	13 27 29.6	-31 07 46	QSO	17.4	1.326	0.52	0.56	UVX	E
1335+023	13 35 07.00	+02 22 12.8	QSO	17.5	1.350	0.11			F, G
1336-000/G	13 37 00.5	-00 01 10.0	Galaxy	17.4	0.144	-			G
1402+044	14 02 30.03	+04 29 55.2	QSO	19.7	3.202	0.58	0.71	RED	B
1406-076	14 06 17.94	-07 38 15.9	QSO	18.4	1.494	0.92	0.82		C
1424-11	14 24 54.9	-11 50 19	QSO	17.5	0.805	0.76	0.33		E
1555-140	15 55 33.82	-14 01 26.2	Galaxy	19.0	0.097	0.73	0.83		C
1656+053	16 56 05.72	+05 19 46.5	QSO	16.7	0.879	1.60	2.10		A
1705+018	17 05 02.9	+01 52 34	QSO	18.9	2.568	0.53	0.58	UVX	H
1725+044	17 25 56.31	+04 29 28.1	QSO	18.2	0.293	0.78	1.21		B
1942-571	19 42 28.2	-57 07 50	QSO	17.4	0.527	0.27		UVX	I
2008-159	20 08 25.88	-15 55 36.7	QSO	17.2	1.180	0.74	1.35	UVX	J
2135-248	21 35 45.38	-24 53 29.0	QSO	18.6	0.819	0.77	0.69		C
2245-328	22 45 51.5	-32 51 43	QSO	18.6	2.268	2.01	1.80	UVX	H
2302-279	23 02 33.4	-27 55 02	QSO	17.8	1.435	0.22	0.12		K
2303-052	23 03 40.13	-05 16 02.0	QSO	19.5	1.139	0.54	0.45		B
2351-154	23 51 55.85	-15 29 52.9	QSO	18.6	2.668	1.08	0.93		C

Finding chart references: A - Shimmins, Bolton and Wall (1975); B - Condon, Hicks and Jauncey (1977); C - Bolton, Shimmins and Wall (1975); D - Shimmins, Bolton, Peterson and Wall (1971); E - Peterson, Bolton and Savage (1976); F - Bolton, Kinman and Wall (1968); G - Bolton and Wall (1970); H - Peterson and Bolton (1973); I - Wall and Cannon (1973); J - Peterson, Bolton and Shimmins (1973); K - Savage and Wall (1976).

The bright stellar objects near the radio positions of the following PKS sources were found to have the spectra of galactic stars: 0814−02, 1158−302, 1451−19, and 1950−613 (see Savage, Browne, and Bolton 1976).

III. NOTES ON INDIVIDUAL OBJECTS

0748+126.—The spectrum shows a strong line which we identify as Mg II. The forbidden lines of Ar IV, Mg V, and Ne V are present. See also Wills and Wills (1976).

0921−213.—The lines of [O III] λ4959 and λ5007 in this galaxy are narrow. The Balmer lines are broad, with Hα having multiple components.

0925−203.—The forbidden lines in this QSO are narrow. The Balmer lines are broad.

1104−445.—There is a strong absorption feature at 4764 Å.

1111+149.—The spectrum shows a single strong line which we identify as Mg II. An identification as Lα, C IV, or C III] is ruled out because these identifications would place other lines which should have been seen within the observed wavelength range of the spectrum. The C III] and Mg II lines have been observed in the spectrum of this object by Wills and Wills (1976) and Peterson, Craine, and Strittmatter (1978).

1335+023.—Bolton, Kinman, and Wall (1968) derived a provisional redshift of 0.61. We confirm the line seen by them at 4500 Å but identify it as C III] λ1909. Our redshift is based upon that line and upon an additional strong line in the red at 6584 Å which we identify as Mg II λ2798. The C IV line is clearly present although it lies near the limit of our useful sensitivity, and its strength and wavelength are uncertain. The C IV and C III] lines are also seen by Wills and Lynds (1978).

1336−000G.—We give the redshift for the galaxy which lies 15″ south of the QSO. The QSO was identified by Bolton and Wall (1970) with the radio source on the basis of color and position. Our scans of the QSO were inconclusive. Wills and Lynds (1978) report a line at 4358 Å in the spectrum of the QSO which they identify as Mg II λ2798.

1402+044.—In addition to the lines given in Table 2, there are features at 4340 Å, a blend of Lα and O VI, and at 5194 Å, N V blended with Lα. This object is discussed more fully by Peterson *et al.* (1978).

1424−11.—The spectrum shows a strong, broad, asymmetrical line which we identify as Mg II. The forbidden lines of Ne V and Ne III are probably present. The continuum on the short-wavelength side of the Mg II emission line has a dip characteristic of the continuum seen in other objects with the Mg II emission line (see Paper III).

1656+053.—The spectrum shows a single strong line which we identify as Mg II. The continuum on the short-wavelength side of the line has a dip characteristic of the continuum seen in other objects with the Mg II emission line. This line is also seen by Strittmatter *et al.* (1974) and by Baldwin *et al.* (1973).

1725+044.—The lines of [O III] λ4959 and λ5007 in this QSO are narrow. The Balmer lines are broad.

TABLE 2

LINE MEASUREMENTS AND IDENTIFICATION

Name	Redshift $\bar{z}$	Observed wavelengths λ_o	Identification	Emitted wavelength λ_e	$\lambda_o/1+\bar{z}$	z	Line to continuum ratio	Line width $\Delta\lambda$
0748+126	0.889	5286	Mg II	2798	2798	0.889	0.71	50
0921-213	0.052	4318	Hδ	4102	4105	0.053	0.18	75
		5102	Hβ	4861	4850	0.050	0.27	140
		5212	[O III]	4959	4954	0.051	0.65	35
		5262	[O III]	5007	5002	0.051	1.74	20
		6637	[O I]	6300	6309	0.053	0.32	40
		6701	[O I]	6364	6370	0.053	0.30	40
		6920	Hα	6563	6578	0.054	1.95	200
0925-203	0.348	3773	Mg II	2798	2799	0.349	0.62	60
		5015	[O II]	3727	3720	0.346	0.18	55
		5218	[Ne III]	3869	3871	0.347	0.12	70
		5344	[Ne III]	3970	3964	0.346	0.17	95
		5525	Hγ	4102	4099	0.347	0.24	120
		5860	Hδ	4340	4347	0.350	0.43	75
		6550	Hβ	4861	4859	0.348	0.79	70
		6746	[O III]	5007	5005	0.348	0.69	30
1104-445	1.598	4028	C IV	1549	1550	1.600	0.68	45
		4954	C III]	1909	1907	1.595	0.31	105
1111+149	0.864	5216	Mg II	2798	2798	0.864	0.49	50
1327-311	1.326	4462	C III]	1909	1918	1.337	0.41	50
		6526	Mg II	2798	2806	1.332	0.45	60
		6628	[Ar IV]	2854	2850	1.332	0.28	30
		6659	[Ar IV]	2869	2863	1.321	0.16	20
		6788	[Mg V]	2931	2918	1.316	0.22	50
1335+023	1.350	3663:	C IV	1549	1131	1.365	1.08:	50
		4480	C III]	1909	1902	1.347	0.38	70
		6584	Mg II	2798	2796	1.353	0.46	80
1336-000/G	0.144	4503	KCaII	3934	3936	0.145	-0.45	50
		4536	HCaII	3968	3965	0.143	-0.39	15
		4922	G	4304	4302	0.144	-0.29	50
		5916	Mg I	5175	5171	0.143	-0.30	80
1402+044	3.202	5107	Ly-α	1216	1215	3.200	4.05	70
		5911	Si IV+O IV]	1406	1407	3.204	1.00	40
		6508	C IV	1549	1549	3.201	0.85	140
1406-076	1.494	4753	C III]	1909	1906	1.490	0.38	90
		5806	[C II]	2326	2328	1.496	0.22	50
		6983	Mg II	2798	2800	1.496	0.66	90
1424-11	0.805	5050	Mg II	2798	2798	0.805	0.44	140
1555-140	0.097	4085	[O II]	3727	3724	0.096	6.82	33
		5490	[O III]	5007	5004	0.096	0.68	30
		7212	Hα	6563	6574	0.099	1.83	50
		7369	[S II]	6724	6718	0.096	1.14	35
1656+053	0.883	5271	Mg II	2798	2798	0.883	0.20	70
1705+018	2.565	4339	Ly-α	1216	1217	2.568	3.90	60
		4411	N V	1240	1237	2.557	0.97	60
		4989	Si IV	1397	1399	2.571	0.35	60
		5533	C IV	1549	1552	2.572	1.24	110
		5923	O III]	1664	1661	2.559	0.38	80
		6816	C III]	1909	1912	2.570	0.63	90
1725+044	0.293	5309	Hδ	4102	4106	0.294	0.23	55
		5576	Hγ	4340	4312	0.285	0.36	60
		5641	[O III]	4361	4363	0.294	0.40	70
		6296	Hβ	4861	4869	0.295	1.01	90
		6423	[O III]	4959	4968	0.295	0.42	50
		6485	[O III]	5007	5015	0.295	1.16	30
1942-571	0.528	4272	Mg II	2798	2796	0.527	0.47	60
		7432	Hβ	4861	4864	0.529	0.92	110

TABLE 2—*Continued*

Name	Redshift $\bar{z}$	Observed wavelengths λ_o	Identification	Emitted wavelength λe	$\lambda_o/1+\bar{z}$	z	Line to continuous ratio	Line width $\Delta\lambda$
2008-159	1.180	4159	C III]	1909	1908	1.179	0.52	90
		6099	Mg II	2798	2798	1.180	0.60	100
2135-248	0.819	5090	Mg II	2798	2798	0.819	0.49	150
2245-328	2.268	4036	Ly-α	1216	1235	2.319	0.67	180
		4559	O IV]	1406	1395	2.242	0.41	100
		5023	C IV	1549	1537	2.243	0.38	160
2302-279	1.435	3782	C IV	1549	1553	1.442	0.65	120
		4651	C III]	1909	1910	1.436	0.22	205
		6790	Mg II	2798	2789	1.427	0.35	90
2303-052	1.138	4974	[C II]	2326	2326	1.138	0.35	130
		5976	Mg II	2798	2795	1.136	0.88	80
		6105	[Ar IV]	2854	2855	1.139	0.44	40
2351-154	2.668	4475	Ly-α	1216	1220	2.680	2.25	90
		4553	N V	1240	1241	2.672	1.28	80
		5658	C IV	1549	1543	2.653	0.98	60

The night-sky line at 5577 Å makes the strengths of Hγ and [O III] λ4363 uncertain.

1942−571.—In addition to the lines given in Table 2, the [Ne V] λ3426 line may be present.

2245−328.—We give the redshift for the QSO identified with the radio source by Peterson and Bolton (1973). A second object with an ultraviolet excess lies 1.″2 away at a position angle of 180°. See Bolton *et al.* (1976) for a discussion of QSO pairs.

J. J. C. was supported in part by National Science Foundation grant AST 77-08013. We thank Miss Lynette Taaffe for assisting with the data reductions.

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