THE ASTRONOMICAL JOURNAL VOLUME 108, NUMBER 2 AUGUST 1994

NEW REDSHIFTS OF RADIO SOURCES FROM THE S4 AND S5 SURVEYS

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Received 1993 February 18; revised 1994 April 11

ABSTRACT

Redshifts are reported for 23 objects in the Caltech–Jodrell Bank VLBI survey.

1. INTRODUCTION

We are engaged in VLBI surveys of two complete samples of radio sources. The Pearson–Readhead (PR) survey (Pearson & Readhead 1988) contains 65 sources in the S4 (Pauliny-Toth *et al.* 1978) and S5 (Kühr *et al.* 1981) surveys with $S(5\ \mathrm{GHz})\geqslant 1.3$ Jy, $\delta > 35°$ and $|b|\geqslant 10°$. The Caltech–Jodrell Bank (CJ) survey [1] (Xu *et al.* 1993; Wilkinson *et al.* 1993) includes 135 sources in the S4 and S5 surveys with 0.7 Jy$\leqslant S(5\ \mathrm{GHz})<1.3$ Jy in the same sky region, which can be combined with the PR sample to form a flux-limited complete sample of 200 sources.[2] The CJ survey aims at mapping all objects strong enough for MK II VLBI at both 1.67 and 5 GHz. The combined PR and CJ sample will make possible a more detailed classification of AGNs and provide a sample which is sufficiently large to make interesting statistical tests by class.

When we began the CJ survey in early 1990, about one-third of the objects had unknown redshifts or optical identifications. We therefore began a project at the Palomar Observatory to determine as many of the missing optical identifications and redshifts as possible. Our observations are not yet complete; however, we have determined about half of the missing redshifts.

2. OBSERVATIONS

All of the spectra were taken with the Double Spectrograph on the Palomar 200 in. telescope. A 300 line/mm grating was used in the blue and a 158 line/mm grating in the red, providing resolution of 9 Å in the blue and 18 Å in the red, respectively. An 800 × 800 Texas Instruments CCD detector was used in both the blue and red. The incoming beam was divided with a dichroic beamsplitter either at 4800 Å, giving an overall wavelength coverage of 3200–9300 Å, or at 5200 Å, giving an overall wavelength coverage of 3800–10000 Å. The dates of observations and integration times are listed in Table 1.

The rms error in fitting He–Hg–Ar arc lines was typically about 0.3 Å in the blue and 0.5 Å in the red. The wavelength scale was shifted slightly based on the He comparison spectra obtained immediately after each object spectrum to compensate for flexure in the instrument. Correction for atmospheric absorption and absolute flux density calibration were based on observations of Oke & Gunn (1983) standard stars.

3. REDSHIFTS

After continuum subtraction, the emission and absorption features were modeled with Gaussian or Lorentzian functions. No statistical criteria were used to evaluate the quality of the fit; rather the residuals were compared visually to noise in adjacent parts of the spectrum. A weighted-mean redshift was calculated for each source, with the weight of each line component given by the ratio of height to width. An uncertainty was calculated by a weighted average of the deviations of the line components from the mean redshift and a 0.5 Å wavelength error, added in quadrature. The results are presented in Table 1, along with a list of the line components used in the calculation. Many of the objects have complex spectra as can be seen in the table. Additional features, both in absorption and emission, are seen in some of the objects, but were not useful in determining the redshift and are therefore not listed. The spectra and further analysis will be published when the project is complete.

[1]The Caltech-Jodrell Bank VLBI survey is in collaboration with P. N. Wilkinson and A. Polatidis of Nuffield Radio Astronomy Laboratories, University of Manchester, Jodrell Bank, U.K.

[2]Two sources in the S4 survey are not included in the CJ sample. One is a planetary nebula. The other is actually a quasar pair, each of which has a flux density less than 0.7 Jy.

TABLE 1. Redshifts of Caltech–Jodrell Bank VLBI Survey Sources.

Source	RA (1950.0)	Dec (1950.0)	z	Integration Time(s)	Observation Date	Features used in redshift determination
0010+775	00:10:22.31	77:32:06.4	0.326 ± 0.001	3000	22 Jan 1990	Mg II λ2798, [O II] λ3727, [O III] λλ4959,5007, Hα, [S II] λλ6717,6734.
0022+390	00:22:46.67	39:02:59.0	1.946 ± 0.002	3000	31 Dec 1989	Lyα, O I λ1303, Si IV/O IV λ∼1400, C IV λ1549, C III] λ1909, Mg II λ2798.
0218+357	02:18:04.13	35:42:32.0	———[a]	3000	31 Dec 1989	Featureless spectrum.
0402+379	04:02:29.88	37:55:26.9	0.055 ± 0.001	3000	31 Dec 1989	[O I] [S III] λ6300, O I] λ6364, Hα, [N II] λ6549, [N II] λ6583, [S II] λλ6717, 6734.
0407+747	04:07:04.6	74:43:29	———	3000	31 Dec 1989	Featureless spectrum.
0620+389	06:20:51.53	38:58:27.3	3.469 ± 0.004	3000	23 Jan 1990	Lyα, N V λ1240, Si IV/O IV λ∼1400, C IV λ1549, C III] λ1909.
0707+689	07:07:55.24	68:57:12.7	1.141 ± 0.002	3000	23 Jan 1990	C III] λ1909, Mg II λ2798, [O II] λ3727.
0716+714	07:16:13.03	71:26:15.2	———	1500	24 Jan 1990	Featureless spectrum.
0740+828	07:40:33.18	82:49:24.2	1.991 ± 0.001	1180	22 Jan 1990	Lyα, N V λ1240, Si IV/O IV λ∼1400, C IV λ1549, C III] λ1909, Mg II λ2798.
0805+410	08:05:33.63	41:01:33.1	1.420 ± 0.003[b]	3000	22 Jan 1990	C IV λ1549, C III] λ1909, Mg II λ2798.
1003+830	10:03:25.84	83:04:56.7	0.322 ± 0.001	3000	23 Jan 1990	Mg II λ2798, [O III] λλ4959, 5007, Hα, [N II] λ6549, [N II] λ6583.
1020+400	10:20:14.59	40:03:27.2	1.254 ± 0.002[b]	1500	23 Jan 1990	Si IV/O IV λ∼1400, C IV λ1549, C III] λ1909, Mg II λ2798.
1053+704	10:53:27.72	70:27:47.9	2.492 ± 0.001	3000	23 Jan 1990	Lyα, N V λ1240, C IV λ1549, C III] λ1909.
1053+815	10:53:36.22	81:30:35.6	0.706 ± 0.006[h]	3000	23 Jan 1990	C III] λ1909, Mg II λ2798.
1128+385	11:28:12.52	38:31:51.5	1.733 ± 0.003	3000	23 Jan 1990	Lyα, N V λ1240, Si IV/O IV λ∼1400, C IV λ1549, C III] λ1909, Mg II λ2798.
1144+402	11:44:21.02	40:15:14.1	1.088 ± 0.001[c]	2400	24 Jan 1990	C IV λ1549, C III] λ1909, Mg II λ2798, Hγ.
1144+542	11:44:04.58	54:13:22.8	2.201 ± 0.007	3000	24 Jan 1990	Lyα, N V λ1240, Si IV/O IV λ∼1400, C IV λ1549, C III] λ1909, Mg II λ2798.
1225+368	12:25:30.77	36:51:47.0	1.973 ± 0.002[h]	3000	24 Jan 1990	Lyα, C IV λ1549.
1242+410	12:42:26.40	41:04:30.0	0.813 ± 0.002	3000	24 Jan 1990	C III] λ1909, Mg II λ2798, Hβ, [O III] λλ4959,5007, [O II] λ3727, Hζ.
1333+459	13:33:15.70	45:57:56.4	2.449 ± 0.001[d]	2000	22 Jan 1990	O VI λ1035, Lyα, N V λ1240, Si IV/O IV λ∼1400, C IV λ1549, He II λ1640, O III λ1667, C III] λ1909.
1342+663	13:42:41.04	66:21:13.1	1.351 ± 0.003	3000	23 Jan 1990	Si IV/O IV λ∼1400, C IV λ1549, C III] λ1909, Mg II λ2798.
1347+539	13:47:42.57	53:56:08.4	0.980 ± 0.003[e]	1500	22 Jan 1990	C III] λ1909, Mg II λ2798, [Ne V] λ3426, [O II] λ3727, Hδ, Hγ.
1418+546	14:18:06.19	54:36:58.0	———[f]	3000	22 Jan 1990	Featureless spectrum.
1557+708	15:57:37.1	70:49:45	0.026 ± 0.001	900	22 Jan 1990	Cross-correlation with an averaged spectrum of 3C galaxies in the Pearson–Readhead sample (Lawrence *et al.* 1994).
1738+476	17:38:36.32	47:39:28.6	———[i]	1800	9 Aug 1991	Featureless spectrum.
1842+681	18:42:43.49	68:06:19.6	0.472 ± 0.002[e]	1800	9 Aug 1991	Mg II λ2798, [Ne V] λλ3341,3426, Hβ, [O III] λλ4959, 5007, Hα.
1926+611	19:26:49.65	61:11:20.7	———[g]	1800	9 Aug 1991	Featureless spectrum.
2010+723	20:10:16.21	72:20:20.7	———[g]	3000	9 Aug 1991	Featureless spectrum.
2207+374	22:07:11.72	37:27:33.0	1.493 ± 0.004[b]	3000	9 Aug 1991	C IV λ1549, He II λ1640, Al III λ1863, C III] λ1909, Mg II λ2798.
2229+695	22:29:11.65	69:31:02.7	———[g]	3600	9 Aug 1991	Featureless spectrum.
2255+416	22:55:04.68	41:38:13.2	———[i]	3000	24 Jan 1990	Featureless spectrum.
2311+469	23:11:28.87	46:55:54.4	0.742 ± 0.001	1500	23 Jan 1990	C III] λ1909, Mg II λ2798, [Ne V] λ3426, [O II] λ3727, [Ne III] λ3869, [Ne III] Hϵ λ3970, Hδ, Hγ, [O III] λ4363, Hβ, He I λ4922, [O III] λλ4959, 5007.

Notes to Table 1

[a] O'Dea *et al.* (1992) reported a tentative redshift of 0.68 for the lens object. Carilli *et al.* (1993) confirmed it via HI absorption, and Browne *et al.* (1993) also confirmed it. However, the redshift of the quasar is still unknown.
[b] Confirms redshifts suggested by Wills, Wills & Douglas (unpublished).
[c] Confirms redshift reported by Vigotti *et al.* (1990).
[d] Confirms redshift published in the Veron-Cetty & Veron catalog (5th edition).
[e] Confirms redshifts reported by Walsh *et al.* (1984).
[f] Stickel *et al.* (1991) reported a redshift of 0.152. Our observation cannot confirm their result.
[g] There were thin clouds scattered on the sky during observation.
[h] Tentative redshift.
[i] A preliminary redshift from our work, referred by M. Stickel & H. Kühr (1994, A&AS, 103, 349), is not correct.

The reference search has made use of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration. This work is supported in part by the National Science Foundation under Grants Nos. AST-8814554 and AST-9117100 to the Owens Valley Radio Observatory.

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