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Improved parameters for 40 pulsars

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Summary. Improved declinations have been measured for 40 weak pulsars with the Ooty Radio Telescope, together with flux densities at 327 MHz. For 32 of the pulsars, improved periods have been derived. It is demonstrated that PSR1922 + 20 is highly unlikely to be associated with the radio continuum source 4C20.48.

1 Introduction

The recent pulsar catalogue of Manchester & Taylor (1981), referred to below as MT, contains a number of objects whose declinations are uncertain to at least a few arcmin. The present work was undertaken to measure improved declinations for many of these objects with the Ooty radio telescope.

The pulsars observed were selected from the MT compilation using three criteria:

(i) the declinations had published uncertainties of $\geqslant 5$ arcmin;
(ii) the sources lay within the declination range of the Ooty radio telescope, $|\delta| \leqslant 35^\circ$;
(iii) the time-averaged flux densities at 400 MHz were $\geqslant 5$ mJy.

To the 38 pulsars resulting from this selection were added two with flux densities somewhat below this limit. One, PSR1926 + 18, lies near the HC40 emission complex (Velusamy & Kundu 1974), lending it intrinsic interest. For the other, PSR1922 + 20, Mantovani *et al.* (1982) have shown that the continuum radio source 4C20.48 lies within the published errors of the pulsar position. It was hoped that a more accurate declination for this pulsar would throw light on the possibility of an association between the two objects.

2 Observations and analysis

The observations were made between 1983 January 25 and March 23. The Ooty radio telescope was used in the total-power mode in conjunction with the 144-channel pulsar receiver. In this mode each of the 12 telescope beams has a half-power beamwidth of $2^\circ \times 5.5 \sec\delta$

arcmin, the individual beams being separated in declination by 3 sec δ arcmin. The 144-channel receiver permits the recording of 12 frequency-channels (bandwidth $\approx$ 300 kHz) for each beam, giving an effective total bandwidth of about 4 MHz. For each beam, data from the individual frequency channels are combined off-line with the appropriate time delays to 'de-disperse' the observed pulsar. The receiver time-constant was about 20 ms and the data were sampled at intervals of 16 ms. The data for each beam were folded with the predicted pulsar topocentric period to yield a pulse profile for each beam. Following detection of a pulsar, the north–south beamshape of the telescope was fitted to the observed response of the source in adjacent beams, giving the nominal declination of the source.

The observing time spent on each pulsar was chosen to provide an expected signal-to-noise ratio of $\geqslant 10$. This resulted in integration times between 16 and 80 min. For practical reasons, data from only the central eight telescope beams were recorded. If a pulsar was not detected within the comb of beams centred on the declination catalogued by MT, further observations were taken 12 arcmin to the north and south. This declination coverage proved sufficient for detection of all the objects in our observing list. A number of the pulsars were measured independently on two or more occasions to check the internal consistency of the results. Additionally, on each day we observed a pulsar whose declination was known to better than 5 arcsec in order to check the absolute consistency of the observations.

A careful calibration of the telescope pointing as a function of declination was made at the beginning of the experiment using strong continuum radio sources. This was checked in detail on a number of occasions during the experiment and found to have the same form. At least one continuum source was observed each day to determine the absolute offset of the pointing curve.

The flux density scale of the observations was set by measurements of the radio source 3C 161, assumed to have a flux density of 48 Jy at 327 MHz, consistent with the flux density scale of Baars *et al.* (1977). In deriving the mean observed flux densities of the pulsars, corrections for the background continuum radiation were made using brightness temperatures estimated from the 408-MHz all-sky survey of Haslam *et al.* (1982) and adopting a temperature spectral index of 2.6 between 327 and 408 MHz.

3 Results

The final declinations and mean flux densities derived for the 40 pulsars are given in Table 1, together with the flux densities of the pulsars of known declination that were observed daily. When more than one measurement of a source was made, the average value is given.

Where a pulsar was detected with a reasonable signal-to-noise ratio in three adjacent beams, a standard error in the measured declination of ± 30 arcsec is expected. For an object detected in only two adjacent beams, the equivalent error is ±45 arcsec. One pulsar, PSR 1740–03, was detected at only the 4.5 σ level and an error of ± 60 arcsec is applicable. The daily observations of pulsars of accurately known position were reduced in the same way as those of the 40 sample sources. Almost all were detected in three adjacent beams and the mean declination difference, defined as (actual – measured) was -15 ± 7 arcsec, with the standard deviation on a single measurement being 24 arcsec. It is thus possible that a small systematic error of about one-twentieth of the telescope half-power beamwidth exists in the measured declinations. For sample pulsars observed on two or more occasions, the internal consistency of the declination measurements is in good accord with our quoted uncertainties.

Our derived mean flux densities were compared with those given in MT for 408 MHz. For sources of flux density $S \geqslant 10$ mJy at both 327 and 408 MHz, the mean flux density ratio $S(237)/S(408)$ is 1.4 ± 0.1, with the standard deviation on an individual ratio being 0.55.

Table 1. Pulsar declinations, periods and flux densities.

PSR	Dec (1950.0) (° ′ ″)	± (″)	Period (ns)	Overall error (ns)	Epoch JD−2440000	Flux density (mJy)
0559 − 05	–	–	–	–	–	15
0656 + 14	14 18 31	45	384 863 839	6	4327.50	11
0740 − 28	–	–	–	–	–	227
0853 − 33	− 33 19 58	45	1 267 532 672	22	4328.50	18
0940 + 16	16 45 08	45	1 087 417 727	23	4329.00	15
1010 − 23	− 23 23 02	30	2 517 944 579	33	4328.01	8
1039 − 19	− 19 26 07	30	1 386 367 735	19	4329.01	10
1552 − 31	− 31 25 07	30	518 109 751.4	4	4328.01	23
1552 − 23	− 23 33 10	30	532 577 402	4	4328.03	3
1600 − 27	− 27 04 12	30	778 311 740	6	4328.04	19
1604 − 00	–	–	–	–	–	38
1612 − 29	− 29 32 38	45	2 477 567 322	19	4327.00	7
1620 − 09*	− 09 01 13	45	1 276 444 847	13	4328.00	5
1632 + 24	24 39 56	45	–	–	–	9
1649 − 23	− 23 58 40	45	–	–	–	9
1700 − 32	− 32 51 22	30	1 211 784 624	14	2005.1	55
1700 − 18	− 18 41 28	30	–	–	–	16
1702 − 19*	− 19 01 34	30	298 985 852.1	1.5	4326.98	30
1717 − 29	− 29 30 09	45	620 447 861	7	2005.0	41
1718 − 32	− 32 05 04	30	477 157 077.4	5	2005.1	74
1730 − 22	− 22 26 43	45	871 682 810	11	2005.0	29
1732 − 07	− 07 22 57	30	–	–	–	38
1738 − 08	–	–	–	–	–	11
1740 − 03	− 03 36 08	60	444 644 291	14	4328.99	2.5
1742 − 30	− 30 39 02	30	367 421 492.9	4	2005.1	105
1745 − 12	–	–	–	–	–	36
1754 − 24	− 24 21 40	30	234 094 343	12	4327.98	50
1756 − 22	− 22 05 33	30	460 969 062.1	1.4	4327.98	36
1804 − 27	− 27 15 40	30	827 770 612	3	4326.98	23
1813 − 26	− 26 50 55	30	592 885 093	7	2004.6	24
1819 − 22	− 22 57 58	45	1 874 267 731	20	2004.7	31
1820 − 31	− 31 08 16	30	284 052 887.6	0.7	4326.98	42
1821 − 19	–	–	–	–	–	44
1826 − 17	− 17 52 45	45	307 129 196.8	3	2005.1	86
1831 − 03	− 03 40 55	30	686 676 816	8	2004.3	107
1834 − 10	–	–	–	–	–	50
1846 − 06	− 06 40 26	30	1 451 292 579	16	2005.2	49
1859 + 03	–	–	–	–	–	276
1900 + 06	06 11 25	30	–	–	–	28
1900 + 01	–	–	–	–	–	78
1900 − 06	− 06 36 30	45	431 884 718.9	4	2004.8	63
1920 + 20	20 12 16	45	–	–	–	4
1920 + 21	–	–	–	–	–	40
1922 + 20	20 34 06	30	237 790 138	8	3957.99	4
1926 + 18	18 39 50	30	–	–	–	3
1929 + 20	–	–	–	–	–	57
1937 − 26	− 26 08 54	45	402 857 434.1	1.5	4326.98	12
1942 − 00	− 00 48 14	45	1 045 630 957	10	4329.01	8
1943 − 29	− 29 21 02	30	959 447 364	5	4326.98	10
1946 − 25	− 25 32 17	45	957 615 458	5	3956.54	4
2110 + 27	27 43 21	30	–	–	–	24
2113 + 14	–	–	–	–	–	8

* Pulsar designation is changed by the improved declination measurement.

This mean value implies a spectral index of about 1.6 between the two frequencies, consistent with that expected from previous work (i.e. McLean 1973). The standard deviation on a single ratio of about 40 per cent of the mean value is considered to be satisfactory in view of the contributory factors. Apart from the intrinsic experimental errors on the 327- and 408-MHz measurements, and the residual effects of interstellar scintillation, pulsars themselves are highly variable. Additionally, the Ooty radio telescope accepts only a single linearly polarized component of the incident radiation. Thus, for a significantly linearly polarized pulsar, our measurements will contain an additional uncertainty which could be particularly marked for objects of lower rotation measure (an object of rotation measure $150\,\mathrm{rad\,m^{-2}}$ will have a 180° rotation of its plane of polarization across the 4-MHz bandwidth).

With a time constant of some 20 ms most of the observed pulsars showed unresolved, or only marginally resolved, integrated pulse profiles, although we find broadened trailing edges to the profiles of a number of pulsars of higher dispersion measure. This is believed to be due to interstellar scattering and will be discussed in another paper.

4 Discussion

Lyne, Ritchings & Smith (1975) and Ashworth & Lyne (1981) have published accurate period measurements made at Jodrell Bank for a large number of weak pulsars. The overall error of their period determinations were set by uncertainties in the positions of the pulsars rather than by the measurements themselves. We have used our improved declination determinations, together with the right ascensions from MT, to re-evaluate these periods and reduce the overall errors. This re-evaluation was made for 32 pulsars using an ephemeris generated at theLincoln Laboratory, MIT. The updated periods and their overall errors are given in Table 1, together with the appropriate epoch. The overall errors in the table include positional terms and the statistical errors published by the Jodrell Bank workers and represent the formal standard deviation.

The improved declination measurement for PSR 1922 + 20 seems to resolve the possibility that the object is coincident with the continuum source 4C 20.48. The revised position for the pulsar lies well outside the confines of the continuum source, even allowing for the error given in Table 1. In fact, the pulsar is separated from the centre of 4C 20.48 by some 10 σ. This is compatible with the conclusion of Mantovani *et al.* (1982) that the continuum source has an extragalactic origin.

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