

Mean pulse polarization of southern pulsars at 1560 MHz

Wu Xinji,¹ R. N. Manchester,² A. G. Lyne³ and Qiao Guojun¹

¹*Center of Astronomy and Astrophysics, CCAST (World Laboratory) and Department of Geophysics, Peking University, Beijing 100871, China*

²*Australia Telescope National Facility, CSIRO, PO Box 76, Epping, NSW 2121, Australia*

³*Nuffield Radio Astronomy Laboratories, University of Manchester, Jodrell Bank, Macclesfield, Cheshire SK11 9DL*

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ABSTRACT

Mean pulse total intensity and polarization data at 1560 MHz are presented for 45 southern pulsars. The observations were made during 1988 at Parkes using a filter-bank polarimeter system. The results are discussed in terms of the rotating vector model for pulse polarization. Notable results include a highly polarized interpulse pulsar and several pulsars with very wide mean pulse profiles.

Key words: polarization – pulsars: general – radio continuum: stars.

1 INTRODUCTION

Measurements of the shape and polarization of the mean pulse profiles of pulsars have been fundamental in providing a basis for our current understanding of the beaming of pulsar radio emission. The original hollow-cone beam model of Radhakrishnan & Cooke (1969) has been developed and refined by many authors, including Komesaroff (1970), Rankin (1983) and Lyne & Manchester (1988, hereafter LM88). Questions of current interest include the shape of the pulsar beam and its variations with pulsar period and frequency (Narayan & Vivekanand 1983), the location within the light cylinder of the emission region (Cordes 1978; Rankin 1990; Blaskiewicz, Cordes & Wasserman 1991) and whether or not pulsar magnetic fields decay and/or align as pulsars age (Candy & Blair 1983; Kuzmin & Dagkesamanskaya 1983; Wu et al. 1986; LM88; Xu & Wu 1991).

While there has been a relatively steady flow of observational data on northern hemisphere pulsars, it is now more than a decade since extensive observations of the mean pulse polarizations of southern hemisphere pulsars were made by Hamilton et al. (1977), McCulloch et al. (1978, hereafter M78) and Manchester, Hamilton & McCulloch (1980, hereafter M80). In the intervening period, the second Molonglo pulsar survey (Manchester et al. 1978) provided a large sample of pulsars for which little or no pulse shape or polarization data have been published until recently. Some tabular data are included in the compilation by Lyne & Manchester (1988) and observations of the long-period pulsar PSR 0826–34, which has a very wide pulse profile, were published by Biggs et al. (1985). Recent observations of 17 southern pulsars at 600 MHz have been reported by Costa, McCulloch & Hamilton (1991). In this paper we present mean pulse shape and polarization data for 45 southern

hemisphere pulsars. These data were obtained at Parkes using a multi-channel filter system similar to that used by Hamilton & Lyne (1987) at Jodrell Bank which was assembled principally for a pulsar search programme (Johnston et al. 1992).

2 OBSERVATIONS

The observations were made using the Parkes radio telescope in the period 1988 May 30–June 2 and July 14–18. Cooled dual-channel pre-amplifiers receiving orthogonal linear polarizations in the band 1520–1600 MHz were used. The system was calibrated with reference to the source PSK 1934–63, assumed to have a flux density of 16 Jy, giving an equivalent system flux density on cold sky of approximately 68 Jy. Polarization calibration was achieved using a linearly polarized signal injected into the feed horn at 45° to the two signal probes. After conversion to an intermediate frequency, the signals were split into 16 adjacent frequency bands, each of 5-MHz bandwidth. The outputs of each frequency channel were separately detected to produce orthogonal linear total intensities and multiplied with phase shifts of $\pm 45^\circ$ to produce outputs which were subsequently rotated to form the Stokes parameters U and V . The Stokes parameters I and Q were computed from the sum and difference of the orthogonal linear total intensities. To allow reduction of the effect of phase errors in the system, all observations were done in pairs at feed angles of 0° and 90°. The 64 outputs were high-pass filtered to remove slow baseline drift, low-pass filtered to avoid aliasing, sampled every 1.068 ms by a one-bit digitizing system and recorded on magnetic tape.

In off-line analysis, individual frequency channels were folded at the apparent pulsar period, summed with the

appropriate dispersion delay, corrected for the distortion resulting from the high-pass filtering, and then combined and calibrated to form mean pulse profiles in the four Stokes parameters. The Stokes parameters were then transformed to rotate the reference direction by the parallactic angle to position angle zero. The 90° profiles of each orthogonal pair were scaled to have the same integrated pulse total intensity as the 0° profile (to avoid errors resulting from variation in the pulse mean flux density), then rotated by -90° and averaged with the 0° profile. Linear polarization parameters were then computed from the Stokes parameters using $L = (Q^2 + U^2)^{1/2}$ and $\psi = 0.5 \tan^{-1}(U/Q)$, where L is the linearly polarized intensity and ψ is the position angle (measured from north toward east). The circular Stokes parameter V is defined in the sense $I_L - I_R$, where I_L and I_R are respectively the left and right circularly polarized intensities.

3 RESULTS

Observational parameters and results for the 45 pulsars observed are given in Table 1. Following the pulsar name and pulse period in the first two columns, the profile resolution and the amount of smoothing due to pulse dispersion are given in the third and fourth columns, the number of pulses averaged is given in the fifth column and the time-averaged flux density at 1560 MHz is given in the sixth column. The next four columns give the fractional polarization integrated across the mean pulse profile for linear, unsigned circular and signed circular polarization, respectively, and the error (twice rms deviation). To allow for systematic errors in the polarization measurements, a constant 2 per cent was added quadratically to the random error. Because the linear polarization parameter L is positive-definite, noise makes a non-zero contribution to it. To compensate for this, the mean

Table 1. Polarization parameters for pulsars at 1560 MHz.

PSR	Period (ms)	Profile Resoln (ms)	Disp'n Smear (ms)	No. of pulses	S ₁₅₆₀ (mJy)	<L>/<I> (%)	< V >/<I> (%)	<V>/<I> (%)	Pol'n Error (%)	W ₅₀ (ms)	W ₁₀ (ms)	W _e (ms)	Fig. No.
0031-07	943	3.7	0.1	1888	15	11	7	3	2	53	112	58	-
0148-06	1468	5.7	0.3	1597	11	29	6	0	4	124	152	62	1
0254-53	448	1.8	0.2	3237	8	8	5	-4	2	9	12	8	-
0740-28	167	1.1	0.8	7365	13	82	7	-4	2	5.1	9	5.3	-
0905-51	254	1.1	1.1	7008	9	33	9	0	3	14	24	14	2
0906-49	107	1.1	2.1	22243	12	84	3	0	3	4.2	59	4.6	3&4
MP only	107	1.1	2.1	22243	9.5	88	2	0	2	4.2	8	4.5	-
IP only	107	1.1	2.1	22243	2.5	69	6	-1.3	6	4.8	9	5.0	-
0942-13	570	2.2	0.2	982	11	13	10	10	2	9	14	9	-
1054-62	422	1.7	3.6	2607	24	34	3	-1	2	20	40	23	5
1056-57	1185	4.6	1.2	428	2	2	9	-3	7	18	35	20	-
1114-41	943	3.7	0.5	626	3	5	10	10	6	12	22	13	6
1133-55	365	1.4	0.9	1507	4	4	10	2	4	14	27	15	7
1159-58	453	1.8	1.6	2097	2	16	13	-1	7	10	-	10	8
1221-63	216	1.1	1.1	278	7	29	14	13	4	6	10	6	9
1240-64	388	1.5	3.3	1495	16	7	9	-4	2	8	15	8.5	-
1323-58	478	1.9	3.1	2092	10	25	6	2	2	9	24	11	10
1325-43	533	2.1	0.5	3340	2	19	7	3	6	11	19	11	11
1356-60	128	1.1	3.2	7813	7	84	15	4	4	5.5	10	6.1	12
1358-63	843	3.3	1.1	1186	4	18	6	3	4	11	22	12	13
1424-55	570	2.2	0.9	1754	2	0	12	-2	8	14	-	14	14
1540-06	709	2.8	0.2	423	10	13	5	4	3	10	20	11	-
1556-44	257	1.1	0.7	233	16	36	8	-4	3	7.5	20	9.5	15
1557-50	193	1.1	3.0	6114	10	15	16	14	2	5.7	11	6.2	16

Table 1 – *continued*

PSR	Period (ms)	Profile Resoln (ms)	Disp Smear (ms)	No of pulses	S ₁₅₆₀ (mJy)	<L>/<I> (%)	< V >/<I> (%)	<V>/<I> (%)	Poln Error (%)	W ₅₀ (ms)	W ₁₀ (ms)	W _e (ms)	Fig. No.
1600-49	327	1.3	1.6	3058	4	3	6	0	4	5	13	6	17
1641-68	1786	7.0	0.5	973	2	24	11	-1	7	75	-	55	18
1647-52	635	2.5	2.0	3591	2	9	7	-4	6	16	25	16	-
1648-42	844	3.3	5.8	2749	10	33	11	-3	4	110	150	90	19
1718-32	477	1.9	1.4	2096	3	14	9	4	4	11	21	11	20
1719-37	236	1.1	1.1	5042	2	48	15	0	8	4.5	10	5	21
1736-29	323	1.3	1.5	9164	2.4	9	16	7	5	7	-	10	-
MP only	323	1.3	1.5	9164	1.6	4	15	6	5	7	11	7	-
IP only	323	1.3	1.5	9164	0.8	18	19	8	9	7	-	7	-
1737-30	607	2.4	1.7	4876	4	87	22	-22	3	6	13	7	22
1737-39	512	2.0	1.7	1953	3.5	11	9	0	4	9	24	12	23
1738-08	2043	8.0	0.8	577	3	31	6	3	5	66	96	63	24
1742-30	367	1.4	1.0	1608	9	47	8	-1	3	9	25	12	25
1800-21	134	1.1	2.6	17611	10	54	21	20	3	13	43	18	26
1804-08	164	1.1	1.3	6098	10	16	7	3	3	9.4	14	9.2	27
1813-36	387	1.5	1.1	5995	2	9	13	-7	4	10	28	11	-
1819-22	1874	7.3	1.4	1110	2	19	7	0	6	48	78	50	-
1820-31	284	1.1	0.6	3521	3	40	9	-2	4	4	9	5	28
1821-19	189	1.1	2.5	3148	4	9	12	2	4	4.5	9	5	-
1822-14	279	1.1	3.9	6380	2	6	25	-1	9	10	-	12	-
1831-04	290	1.1	0.9	8017	11	15	11	1	4	88	115	50	29
1839-04	1840	7.2	2.2	918	4	25	17	-1	6	262	335	146	30
1844-04	598	2.3	1.6	2909	2	13	13	2	6	20	30	16	31
1937-26	403	1.6	0.6	2481	3	43	13	-7	5	5	14	6	32
2152-31	1030	4.0	0.2	1728	1.5	8	12	5	5	19	32	18	-

off-pulse value of L was subtracted before computing the integrated value. This noise contribution to L has also been subtracted in the figures which follow. Pulse widths at 50 and 10 per cent of maximum flux density and the equivalent pulse width (pulse energy divided by maximum flux density) are given in the next three columns, and the final column gives the figure number where appropriate. For the two pulsars with detected interpulses, PSR 0906–49 and PSR 1736–29, parameters are given for the whole pulse and for the main pulse and interpulse separately.

In the remainder of this section we discuss the results for each pulsar separately. For most pulsars we present a figure showing the mean pulse profile and its polarization. In cases where our data are not significantly different from previously published results, or where the pulse profile is apparently of simple form, results are given in tabular form only.

PSR 0031–07

Polarization and pulse shape data for this pulsar are similar to those reported by Manchester (1971) and Morris et al. (1981). The triangular-shaped mean profile is weakly linearly polarized with slowly decreasing position angle. There may be some left-circular polarization, but it is of marginal significance. Manchester, Taylor & Huguenin (1975) showed that the leading edge of the drifting subpulses of this pulsar are often polarized in the opposite orthogonal mode to the trailing edge, thereby reducing the mean polarization to a low value as the subpulse drifts across the mean profile.

PSR 0148–06 (Fig. 1)

This pulsar has a classic double pulse with strong linear polarization and a well-defined ‘S’-shaped position angle

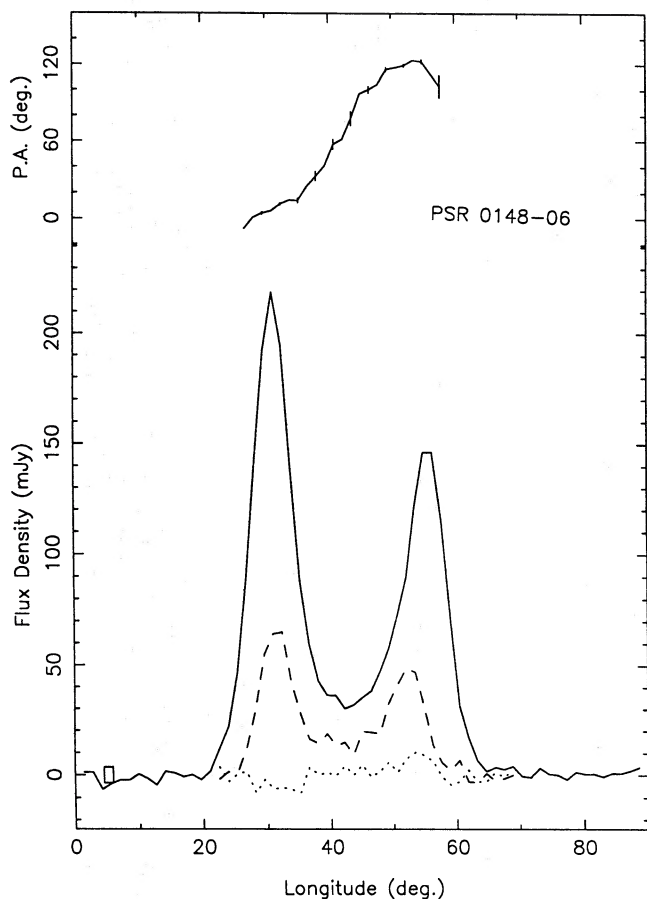


Figure 1. Mean pulse profile and polarization parameters for PSR 0148–06. In the lower part of the figure, the full line is the total intensity (Stokes parameter I), the dashed line is the linearly polarized intensity $(Q^2 + U^2)^{1/2}$, and the dotted line is the circularly polarized intensity (Stokes parameter $V = I_L - I_R$). The error box has a width equal to the effective resolution and an amplitude of twice the rms deviation of the baseline noise. In the upper part, the position angle of the linearly polarized emission is plotted where its uncertainty is less than 10° . Error bars (± 2 rms deviations) are given on every second point.

curve. As for other pulsars in this class, e.g. PSR 0525 + 21 (Stinebring et al. 1984), the pulsar period is relatively long and the polarization is highest on the inner edges of the two pulse components and low in the wings of the profile. There is weak circular polarization which changes sign from right hand to left hand near the middle of the pulse. The increasing position angle is in accordance with the correlation between the sense of circular reversal and sense of position angle rotation found by Radhakrishnan & Rankin (1990). Impact parameters and magnetic inclination angle for PSR 0148–06 are given by LM88. There is no evidence in these observations for an offset of the type discussed by Baskiewicz et al. (1991) between the centre of symmetry of the position angle variation and the mean pulse profile, although observations with higher signal/noise ratio may reveal such an offset.

PSR 0254–53

Our observations of this pulsar have lower time resolution but higher signal/noise ratio than those of M80 or M78. The

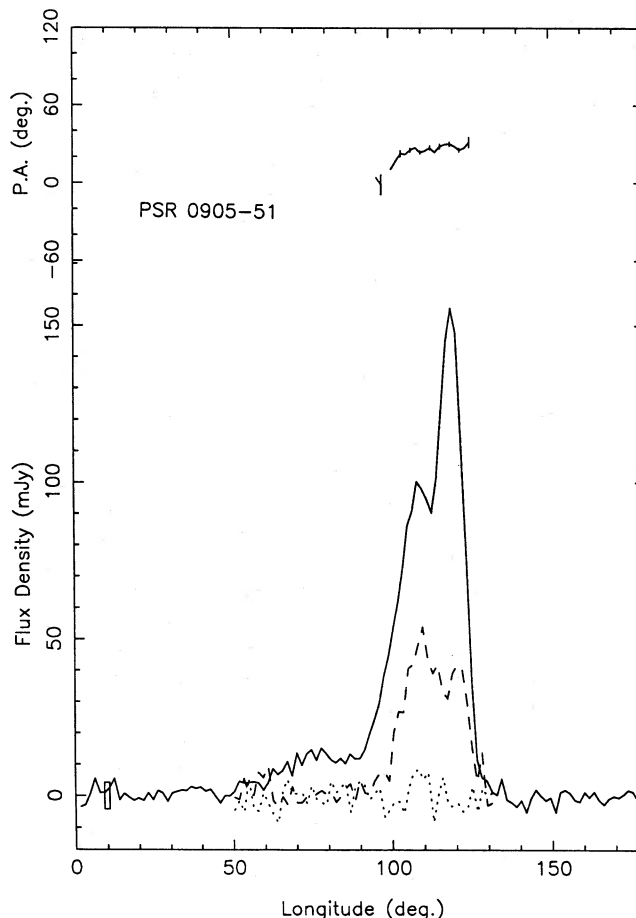


Figure 2. Mean pulse profile and polarization parameters for PSR 0905–51. See caption to Fig. 1 for details.

pulse profile is similar to that given in these earlier papers but, in contrast to the earlier results, significant linear polarization is detected, especially for the first component. The position angle is approximately constant at 120° across most of the profile but may increase near the trailing edge. There is weak right-circular polarization across the whole profile similar to that observed by M78 and M80.

PSR 0740–28

As previous observations have shown, this pulsar is very highly linearly polarized, especially at the leading edge. For the present observations, the mean linear polarization is 82 per cent, similar to the 78 per cent reported by M80. The observed position angle variation is also similar, decreasing across the profile with a value of about 85° at the pulse centre. Weak right-circular polarization is observed across the profile with a mean value of 4 per cent. This is of the same sign but marginally weaker than the 7 per cent right-circular polarization observed by M80. Small differences in fractional polarization such as these are commonly observed in profiles taken at different times, and generally can be attributed to pulse-to-pulse fluctuations in the pulse shape and its polarization.

PSR 0905–51 (Fig. 2)

This pulsar has a very unusual profile, with significant emission extending over more than 70° of longitude. The

shape and polarization of the trailing component strongly suggest that it is the trailing half of a wide double pulse. This interpretation is supported by the presence of the weak leading component. Other examples of incomplete pulse profiles, interpreted as ‘partial cones’, were discussed by LM88. The wide profile suggests that the magnetic axis is nearly aligned with the rotation axis. This pulsar has a moderate characteristic age, about 2 Myr, whereas most nearly aligned pulsars have larger ages (LM88). Young, nearly aligned pulsars, for example PSR 1800–21, do, however, exist.

PSR 0906–49 (Fig. 3)

This pulsar is distinguished in several respects: it has a short period (107 ms), is young (characteristic age 0.11 Myr), and has a relatively strong interpulse (pulse energy about one quarter of the main pulse). The separation of the midpoints of the main pulse and interpulse is $176^\circ \pm 1^\circ$, close to 180° and equal within the uncertainties to the 180° measured at 843 MHz by D’Amico et al. 1988). This strongly suggests that the main pulse and interpulse are emitted from opposite magnetic poles of the pulsar. Both the main pulse and interpulse have very high linear polarization (Table 1) and, consequently, well-defined position angle variations. The position angle at the centre of the main pulse is close to 40° , whereas for the interpulse the corresponding value is close to 130° . In the standard rotating vector model (cf. LM88), these two angles must be equal. We therefore suggest that the main pulse and interpulse are emitted in opposite orthogonal modes. With the interpulse rotated by -90° , the observed position angles are very well fitted by the rotating vector model as shown in Fig. 4.

Parameters derived from this fit, listed in Table 2, show that the observer’s line of sight is close to equatorial and that the impact parameters for the main pulse and interpulse are

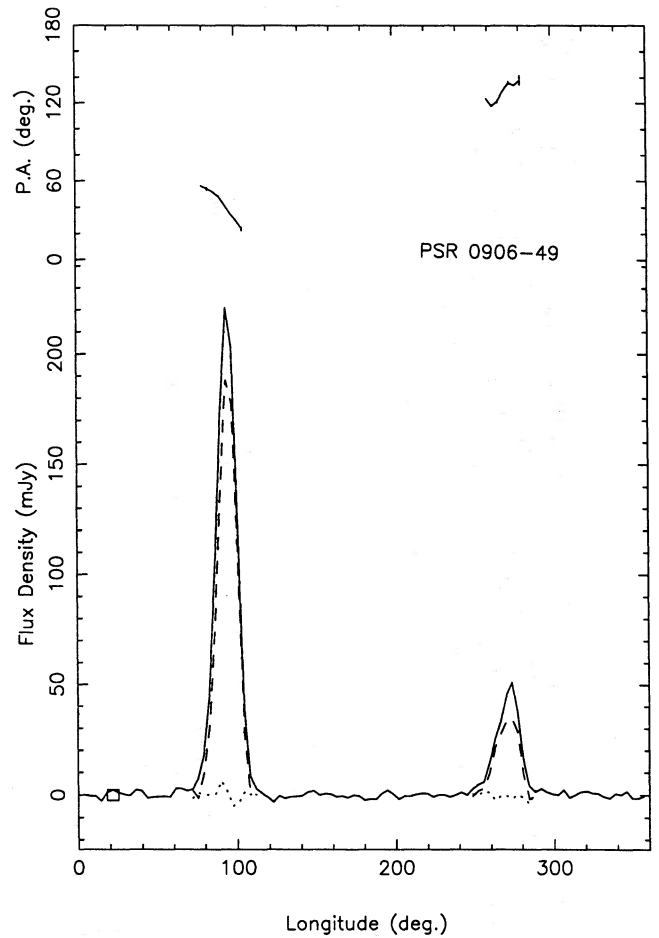


Figure 3. Mean pulse profile and polarization parameters for pulsar PSR 0906–49. See caption to Fig. 1 for details.

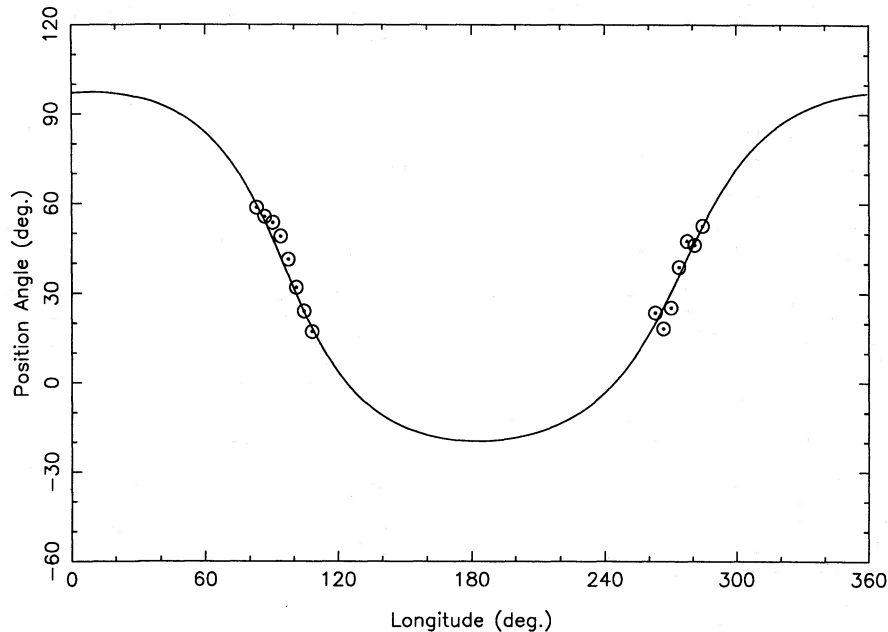
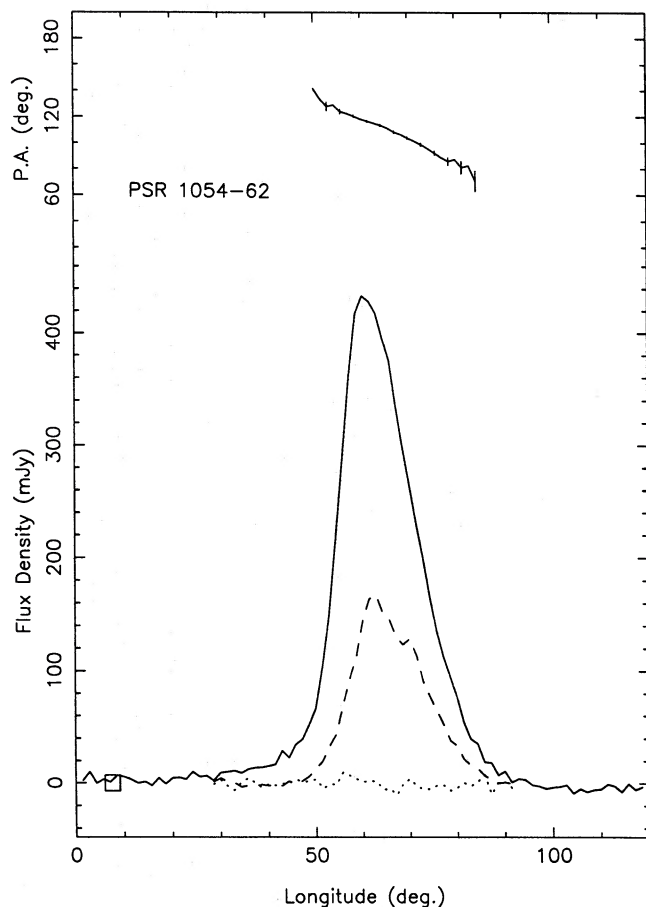


Figure 4. Observed position angles for PSR 0906–49, with those for the interpulse shifted by 90° , and a fit of the rotating vector model to these data.

Table 2. Geometric parameters for PSR 0906–49.

Magnetic axis inclination	$58^\circ \pm 3^\circ$
Observer's l-o-s inclination	$88^\circ \pm 3^\circ$
Rms residual	$3^\circ.6$
Main pulse impact parameter	30°
Interpulse impact parameter	34°

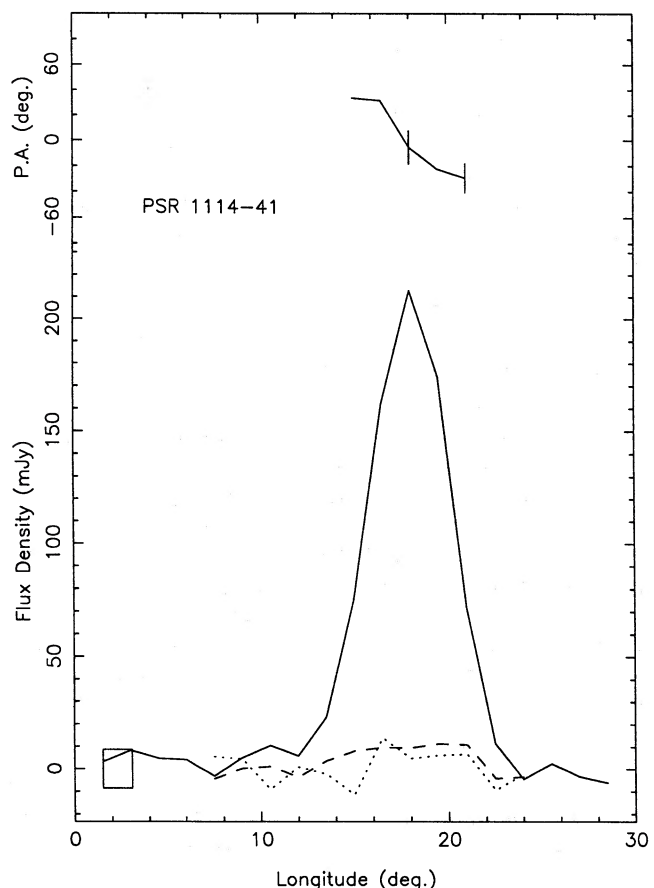
**Figure 5.** Mean pulse profile and polarization parameters for PSR 1054–62. See caption to Fig. 1 for details.

nearly equal and relatively large. This suggests that we are seeing emission from far out on the cone of both beams, which is consistent with the observed high linear polarization of both pulse components.

Apart from its interpulse emission, this pulsar seems to fall in the same class as the Vela pulsar (PSR 0833–45) and PSR 0740–28. All three pulsars are of short period and have very high linear polarization. Further examples of this class will be discussed below.

PSR 0942–13

This pulsar has a very narrow pulse (full width at half-maximum $\sim 6^\circ$) which is not well resolved by the present observations. The pulse shape is roughly Gaussian and there is about 10 per cent linear and left-hand circular polarization

**Figure 6.** Mean pulse profile and polarization parameters for PSR 1114–41. See caption to Fig. 1 for details.

across the pulse. The position angle increases through the pulse with a mean gradient of about 15° per degree of longitude and a position angle at the pulse centre of $30^\circ \pm 5^\circ$. The rapid swing of position angle and narrow pulse suggest that we may be seeing emission from only the central or ‘core’ region of the polar cap.

PSR 1054–62 (Fig. 5)

This pulsar has a wide, somewhat asymmetric, single-component pulse profile with relatively high linear polarization but no significant circular polarization. The position angle is well defined and decreases essentially linearly through the pulse. The asymmetric profile suggests that there are two unresolved pulse components, and this is supported by a hint of bifurcation in the linearly polarized intensity. A very similar pulse profile was obtained for this pulsar in observations at 600 MHz by Costa et al. (1991). These results suggest that PSR 1054–62 is a transition case between ‘conal single’ and ‘conal double’ in the notation of Rankin (1983), with the radiation originating near the edge of the emission cone. Its properties are very similar to those of PSR 0628–28 (M78). Following the notation of LM88, the ‘apparent’ impact parameter $\beta_{90} = 1/(d\psi/d\phi)_m = 40^\circ$. However, the wide profile indicates that the magnetic and rotation axes are nearly aligned; the relations of LM88 give $\alpha = 12.3$ and a ‘true’ β of 7.8 . The point of maximum gradient in the position angle appears to lag the mid-point of the pulse profile by about 7° . This may be a consequence of

the relativistic effects discussed by Blaskiewicz et al. (1991). If so, the implied height of the emission region is about 600 km.

PSR 1056 – 57

The profile of this pulsar at 1560 MHz is very similar to that given by Costa et al. (1991) for 600 MHz except that both linear and circular polarization are weaker at 1560 MHz (Table 1) than the 10 and 9 per cent respectively given by Costa et al.

PSR 1114 – 41 (Fig. 6)

As shown in Fig. 6, this pulsar has a narrow pulse with only marginally significant polarization.

PSR 1133 – 55 (Fig. 7)

Only a single component can be identified in this pulsar because of the rather low signal/noise ratio of the present observations. Significant linear polarization is seen at the leading edge of the pulse, but not elsewhere. In contrast, at 600 MHz, Costa et al. find linear polarization across the pulse with evidence for an orthogonal transition in position angle between the leading and central part. Costa et al. suggest that the profile has weak leading and trailing components, but there is no evidence for such components in Fig. 5

PSR 1159 – 58 (Fig. 8)

This pulsar had a mean flux density of only 2 mJy in the present observations, hence the profile is of low quality. The pulse is narrow, with one identifiable component and significant linear polarization near its centre.

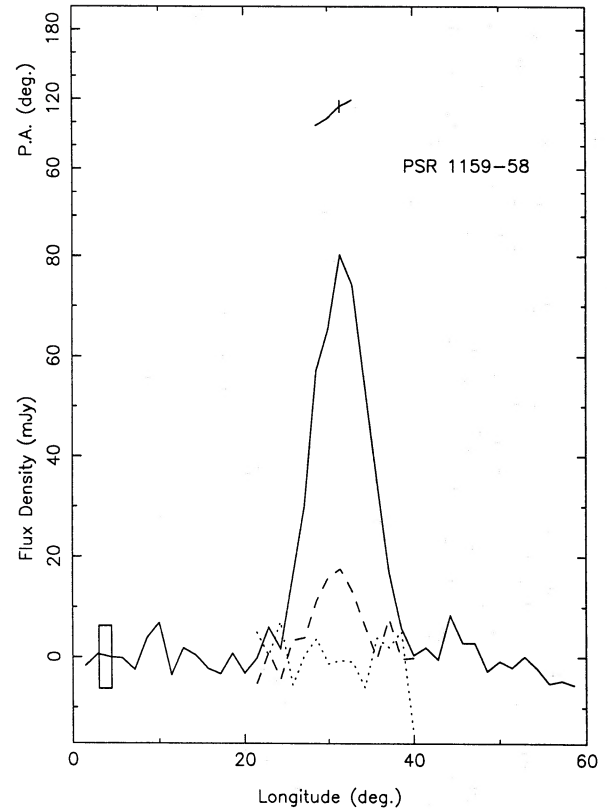


Figure 8. Mean pulse profile and polarization parameters for PSR 1159 – 58. See caption to Fig. 1 for details.

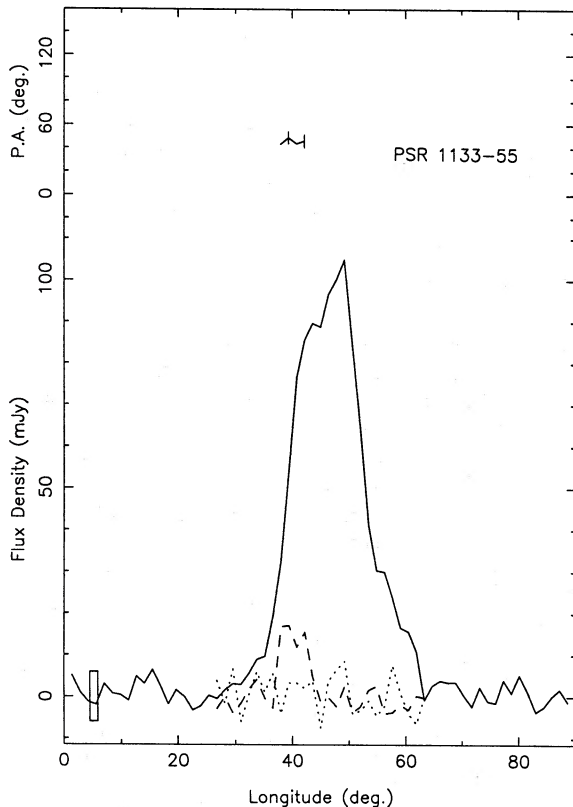


Figure 7. Mean pulse profile and polarization parameters for PSR 1133 – 55. See caption to Fig. 1 for details.

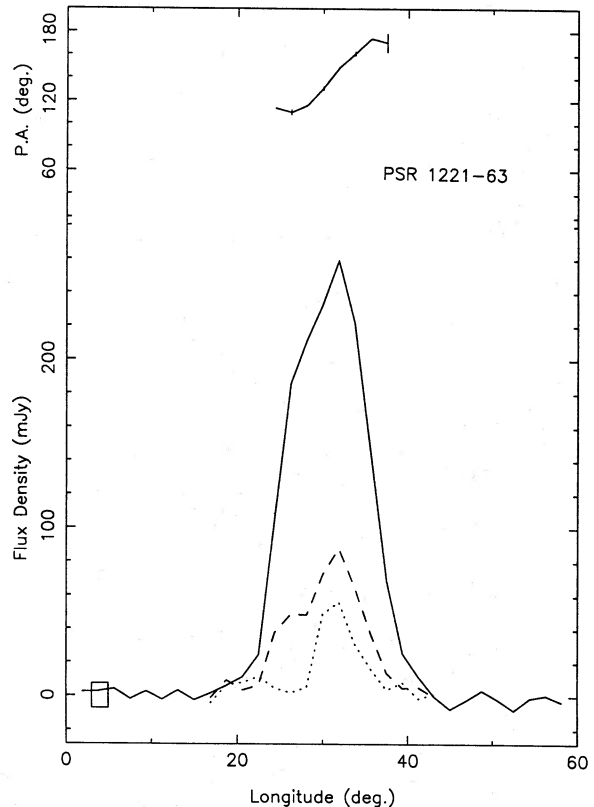


Figure 9. Mean pulse profile and polarization parameters for PSR 1221 – 63. See caption to Fig. 1 for details.

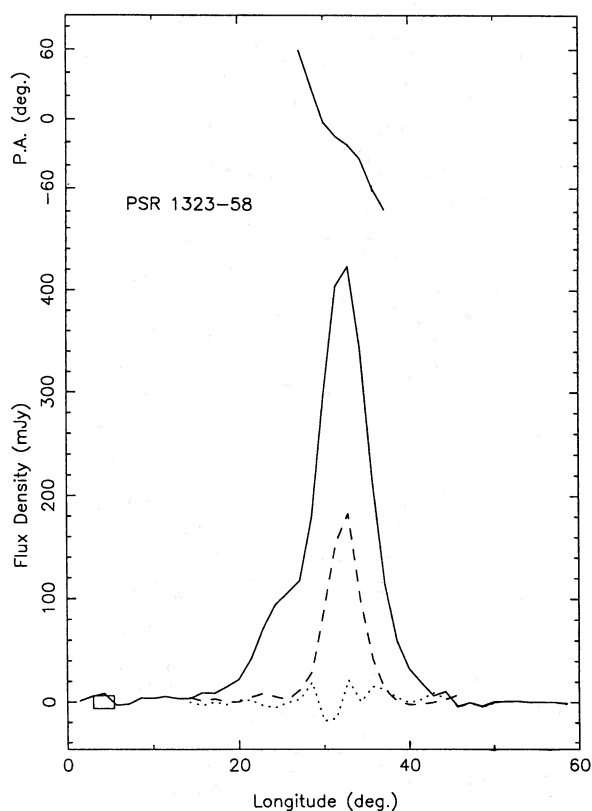


Figure 10. Mean pulse profile and polarization parameters for PSR 1323 – 58. See caption to Fig. 1 for details.

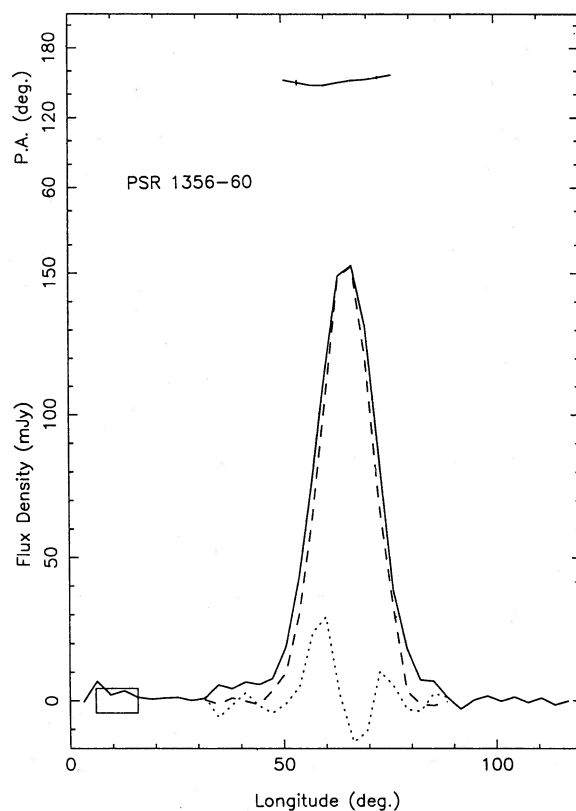


Figure 12. Mean pulse profile and polarization parameters for PSR 1356 – 60. See caption to Fig. 1 for details.

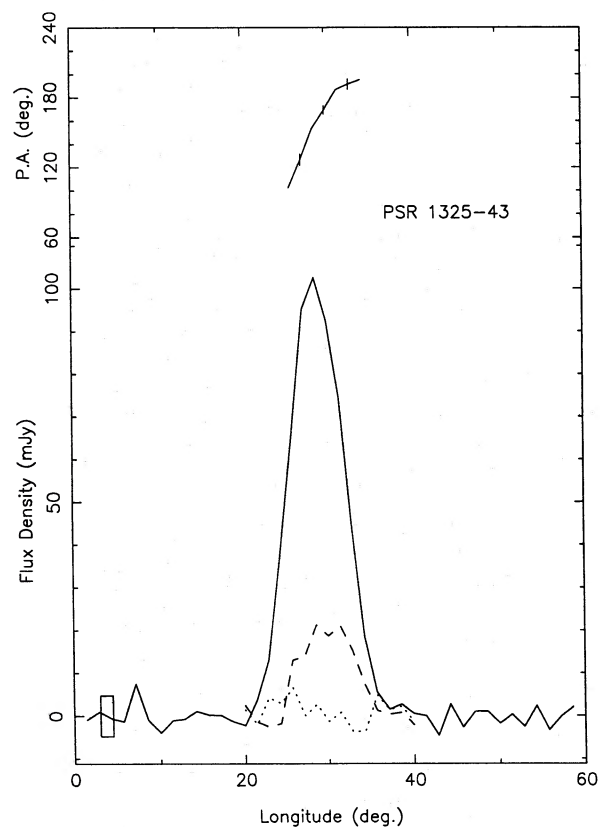


Figure 11. Mean pulse profile and polarization parameters for PSR 1325 – 43. See caption to Fig. 1 for details.

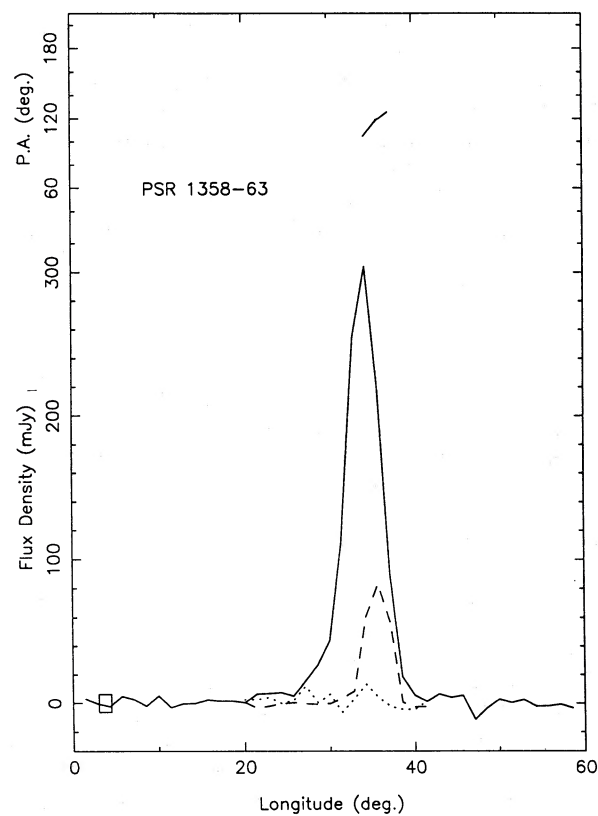


Figure 13. Mean pulse profile and polarization parameters for PSR 1358 – 63. See caption to Fig. 1 for details.

PSR 1221 – 63 (Fig. 9)

This pulsar is notable for its strong left-circular polarization (M78; M80). The present observations are broadly consistent with these earlier results, except that the linear polarization is stronger than the circular (Table 1). In the observations at the similar frequency of 1612 MHz by M80, circular polarization dominated near the centre of the profile. LM88 identified this pulsar as an example of partial-cone emission. In the present observations, the linear polarization is stronger near the leading edge of the pulse and the position angle variation is more symmetric, suggesting that we may be seeing emission from most of the cone. The relations of LM88 give a magnetic inclination of 90° and an impact parameter of 6.7. Within the uncertainties, the centre of symmetry of the position angle curve coincides with the centre of the pulse total intensity profile.

PSR 1240 – 64

The present observations confirm the asymmetric profile and the relatively strong right-circular and weaker linear polarization just preceding the pulse peak observed at 1612 MHz by M80.

PSR 1323 – 58 (Fig. 10)

Previous observations of this pulsar by Costa et al. (1991) showed that it has relatively high linear polarization. However, this pulsar has a large dispersion measure ($283 \text{ cm}^{-3} \text{ pc}$) and the pulse is severely broadened by interstellar scattering at 600 MHz, which prevents determination of the intrinsic polarization properties. The present observations at 1560 MHz (Fig. 10) do not suffer from this problem and show that the pulse profile has two or possibly three unresolved components. The main peak is highly linearly polarized with a rapid sweep of position angle, suggesting that it is emitted close to the central or core region of the polar field lines. There appears to be significant circular polarization in this central region of the pulse, which supports the idea that it is emitted near the core region, but it has a complex structure rather than the single sense reversal often observed. The position angle, also, does not follow in detail the rotating vector model, but has a reduced gradient near the pulse centre. These complexities may result from multipole components in the magnetic field.

PSR 1325 – 43 (Fig. 11)

This rather weak pulsar has a narrow, apparently single-component pulse with a moderate degree of linear polarization. The position angle gradient appears to decrease across the pulse, perhaps suggesting that we are seeing only the trailing side of the emission cone.

PSR 1356 – 60 (Fig. 12)

This pulsar, which has the relatively short period of 128 ms, has a pulse which is essentially 100 per cent polarized. The linear polarization is total at the centre of the pulse; on the leading and trailing edges there is substantial circular polarization, up to about 30 per cent (near longitude 60° in Fig. 12). There is little variation in the position angle of the linear polarization across the pulse, but the circular polarization has a sense reversal near the pulse centre. There may be a further sense reversal toward the trailing edge of the pulse, but, in these observations, this is of marginal significance. PSR 1356 – 60 has many similarities to the Vela pulsar,

PSR 0833 – 45 (M80; Krishnamohan & Downs 1983). Both pulsars have short period, a relatively narrow pulse with one dominant component and, most notably, almost total linear polarization. The main differences are that, for Vela, there is a much greater swing of position angle and the circular polarization is of one hand through the profile. These two pulsars, along with PSR 0740 – 28 and PSR 0906 – 49, form a distinct subset of the known pulsars, characterized by shorter than average period and almost total linear polarization. It is of interest to note that the Crab pulsar precursor pulse (Rankin et al. 1970), which has been identified as corresponding to the Vela radio pulse in some models (e.g. Smith 1986), and the similar precursor pulse in PSR 1822 – 09 (M80; Fowler, Wright & Morris 1981) are also essentially 100 per cent linearly polarized.

PSR 1358 – 63 (Fig. 13)

The pulse shape and linear polarization near the trailing edge suggest that, as in PSR 0905 – 51, we may be observing only the trailing part of the emission cone in this pulsar. A profile with higher signal/noise ratio is required to confirm this speculation.

PSR 1424 – 55 (Fig. 14)

The pulse profile at 1560 MHz is similar to that observed by Costa et al. at 600 MHz but, whereas they observed 17 per cent linear polarization near the middle of the pulse, we observed none. An inverse relationship between degree of linear polarization and frequency is observed in other pulsars (Manchester, Taylor & Huguenin 1973), but this dependence seems somewhat stronger than that normally observed.

PSR 1540 – 06

This pulsar has a narrow pulse of apparently simple shape which is not well resolved by the present observations. There is weak linear polarization with position angle about 50° near the centre of the pulse.

PSR 1556 – 44 (Fig. 15)

This pulsar, previously observed at 631 MHz (M78) and 1612 MHz (M80), has an interesting profile consisting of three overlapping components at the higher frequencies. As remarked previously (M80), the outer components have a flatter spectral index than the more central component. It is now recognized that this is a common property (Rankin 1983; LM88). There is a complex variation of linear polarization through the pulse, with two clear orthogonal transitions in the mean position angle. When account is taken of these, there is an S-shaped variation of classic form through the pulse profile, with the centre of symmetry lying midway between the outer edges of the profile. It is noteworthy that the steeper spectrum component is located well away from the pulse centre. As in the previous observations, right-hand circular polarization is observed near the centre of the profile, but the degree of polarization is less than that observed previously. Based on the properties at lower frequencies, LM88 interpreted this pulsar as having emission from only part of the polar cone. At the higher frequency of the present observations, we see emission from the entire cone. The maximum position angle gradient is about 16 and, using the relations of LM88, the magnetic inclination angle $\alpha = 45^\circ$ and the impact parameter $\beta = 2.5$.

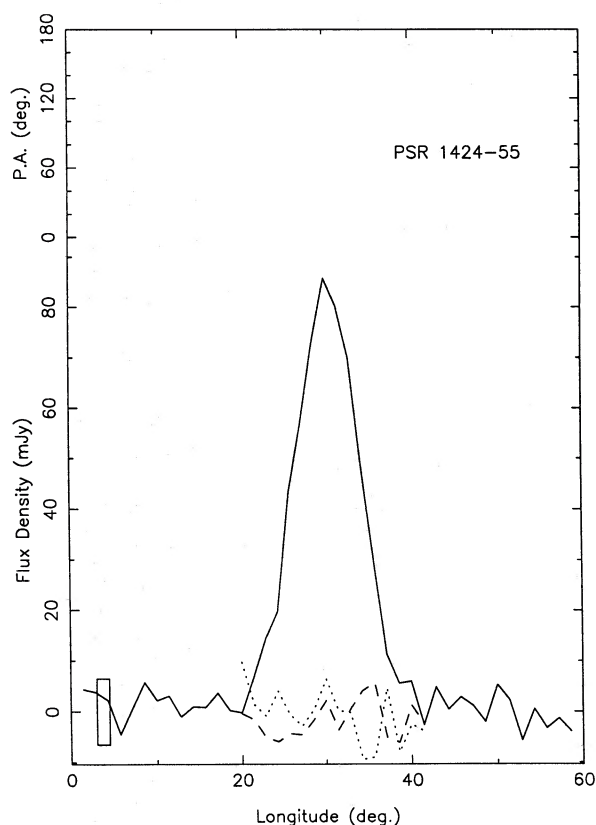


Figure 14. Mean pulse profile and polarization parameters for PSR 1424 – 55. See caption to Fig. 1 for details.

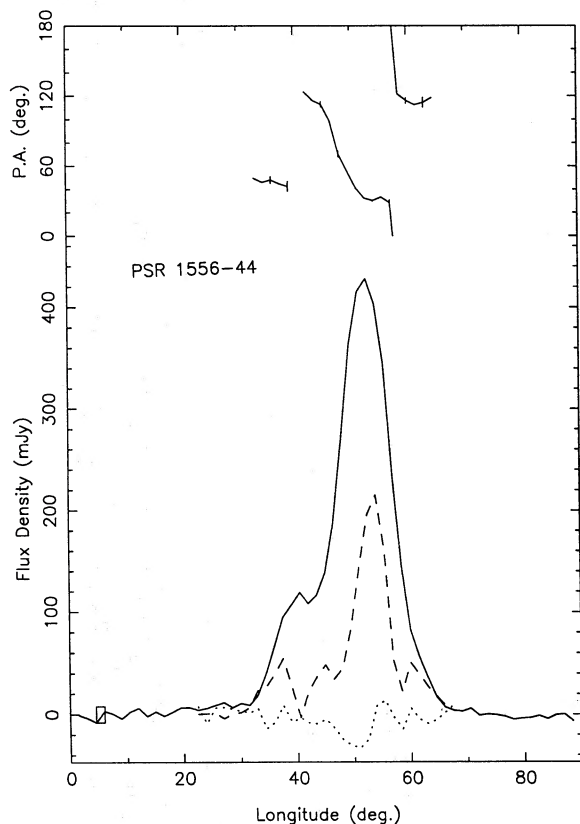


Figure 15. Mean pulse profile and polarization parameters for PSR 1556 – 44. See caption to Fig. 1 for details.

PSR 1557 – 50 (Fig. 16)

The results obtained for this pulsar are of higher signal/noise ratio than those of M80, but show a similar variation of polarization across the profile. In particular, the strong left-hand polarization near the profile centre is confirmed.

PSR 1600 – 49 (Fig. 17)

This rather short-period pulsar has a three-component profile with little or no polarization.

PSR 1641 – 68 (Fig. 18)

This pulsar is very weak and the observations are of low signal/noise ratio. There is little variation in position angle across the pulse, indicating either a grazing cut of the edge of the emission cone or that our line of sight passes close to the symmetry axis. The 'double' nature of the profile, with steep outer edges and central saddle emission, makes the latter interpretation more probable.

PSR 1647 – 52

Our observations show this pulsar to have a narrow, single-component pulse with only marginally significant linear polarization near its leading edge.

PSR 1648 – 42 (Fig. 19)

The mean profile for this pulsar is a very wide double and has a high degree of linear polarization except in the wings. Significant circular polarization is also observed, possibly with a sense reversal near the centre of the pulse. The position angle decreases across the pulse, with a higher rate of decrease toward the trailing edge. This variation is not of the usually observed 'S' shape and suggests that emission is seen

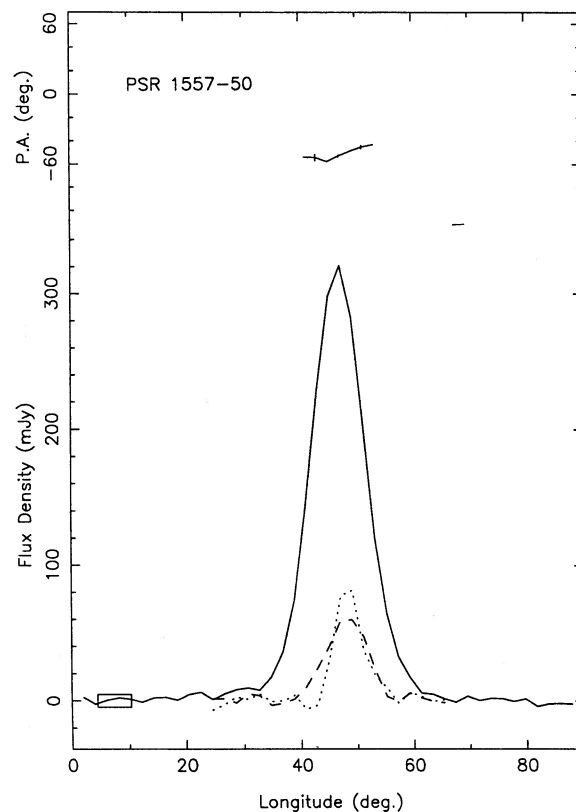


Figure 16. Mean pulse profile and polarization parameters for PSR 1557 – 50. See caption to Fig. 1 for details.

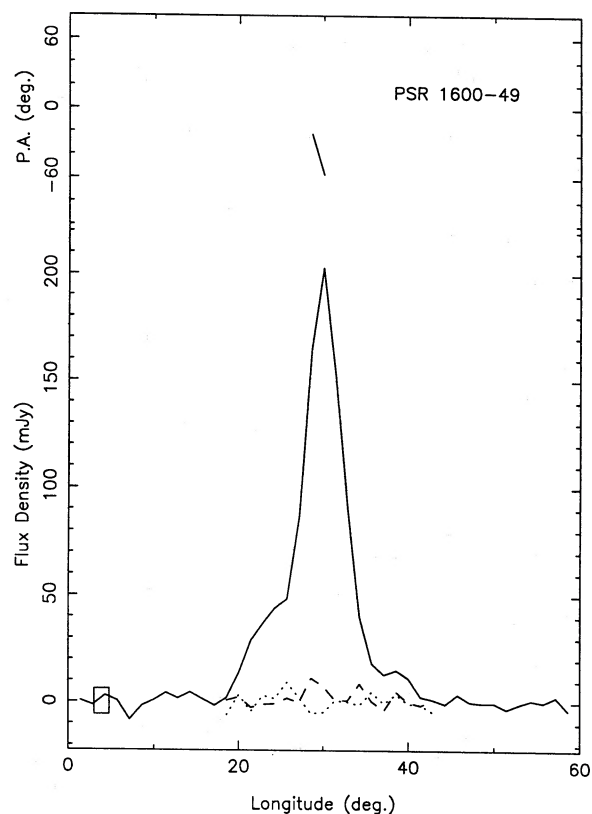


Figure 17. Mean pulse profile and polarization parameters for PSR 1600–49. See caption to Fig. 1 for details.

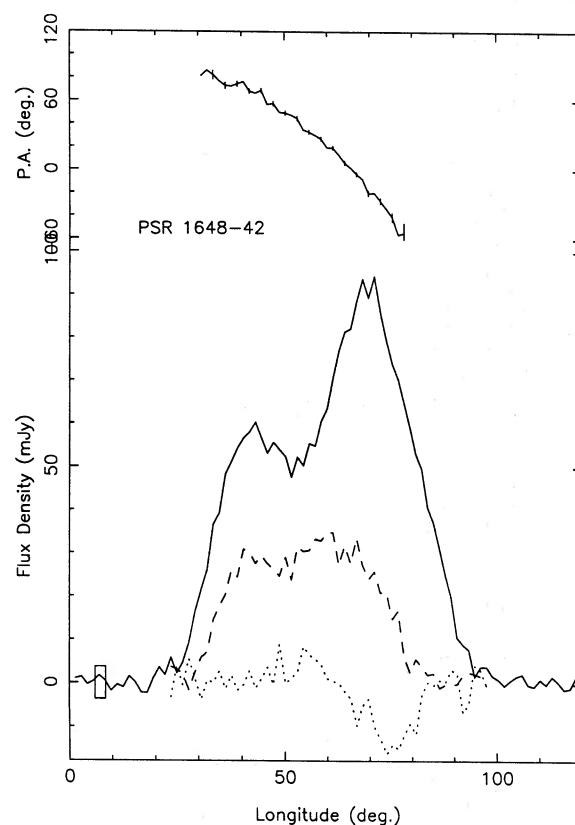


Figure 19. Mean pulse profile and polarization parameters for PSR 1648–42. See caption to Fig. 1 for details.

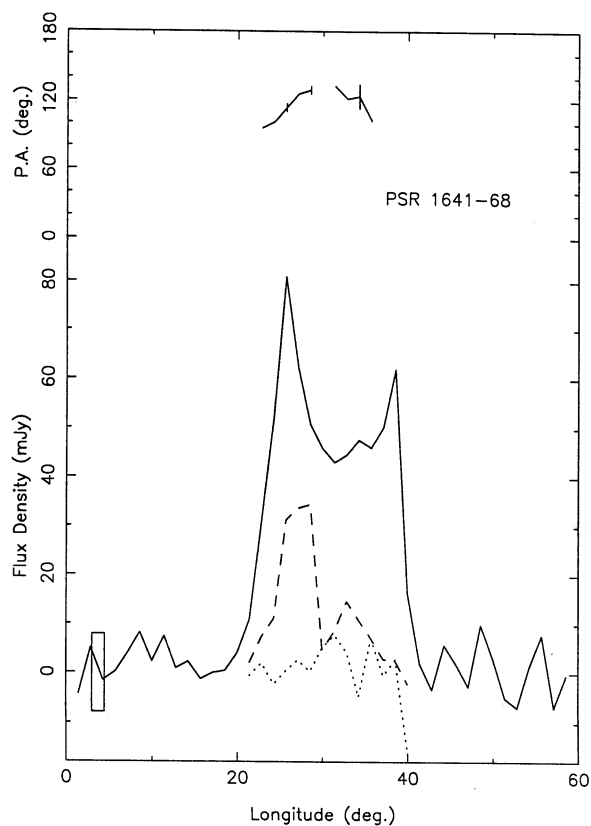


Figure 18. Mean pulse profile and polarization parameters for PSR 1641–68. See caption to Fig. 1 for details.

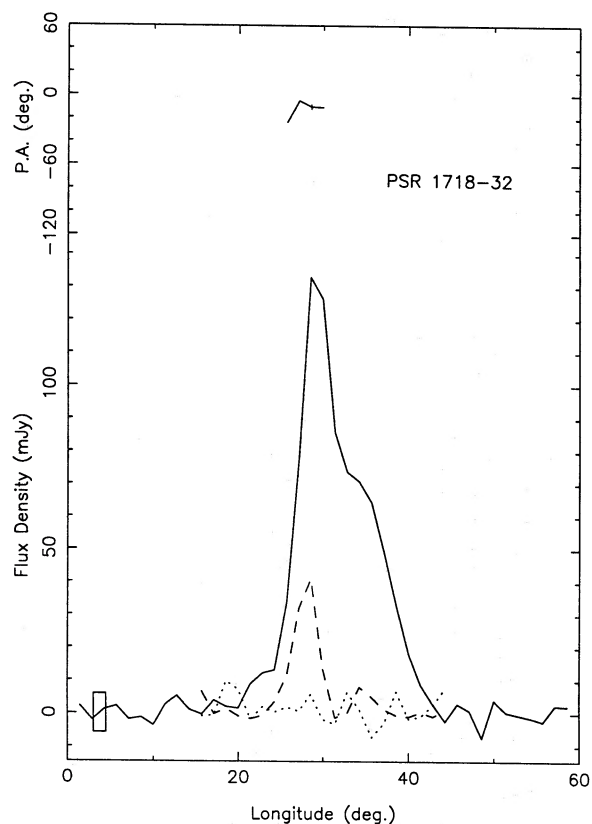


Figure 20. Mean pulse profile and polarization parameters for PSR 1718–32. See caption to Fig. 1 for details.

from only part of the emission cone (LM88). If we are seeing the whole emission cone (as suggested by the circular sense reversal), the observed steepening of the position angle curve may indicate some distortion of the magnetic field structure in the emitting region. Alternatively, the lag of the point of maximum position angle gradient may be due to the relativistic effect discussed by Blaskiewicz et al. (1991), although, if this is the case, the phase of the circular sense reversal precedes the phase of the maximum position angle gradient. Since the gradient continues to increase to the end of the polarized emission, it is not possible to determine the lag. However, it will be large, implying a large altitude for the emission region. The wide profile may then be attributable to the greater opening angle of the field lines at the emission altitude.

PSR 1718–32 (Fig. 20)

The present observations of this pulsar are of much better signal/noise ratio than those by M78, the only previously published observations. They show a two- or possibly three-component pulse profile with significant linear polarization near the leading edge. There is no significant variation of position angle across the polarized portion.

PSR 1719–37 (Fig. 21)

This pulsar has a narrow, highly linearly polarized pulse and a uniform change of position angle across the profile. The polarization variations suggest that we are observing the edge of the conal beam. The relations of LM88 give a normalized impact parameter $\beta_n = 0.93$ and magnetic inclination $\alpha = 32^\circ$.

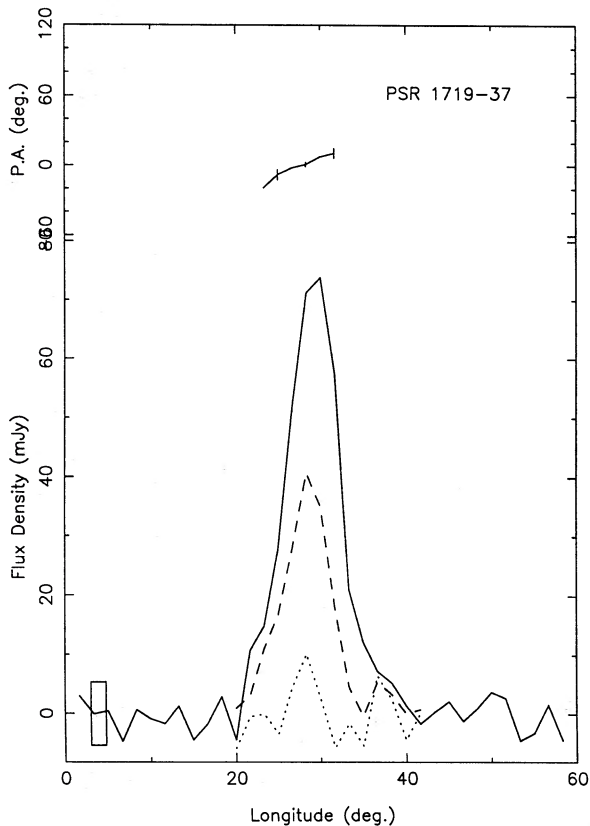


Figure 21. Mean pulse profile and polarization parameters for PSR 1719–37. See caption to Fig. 1 for details.

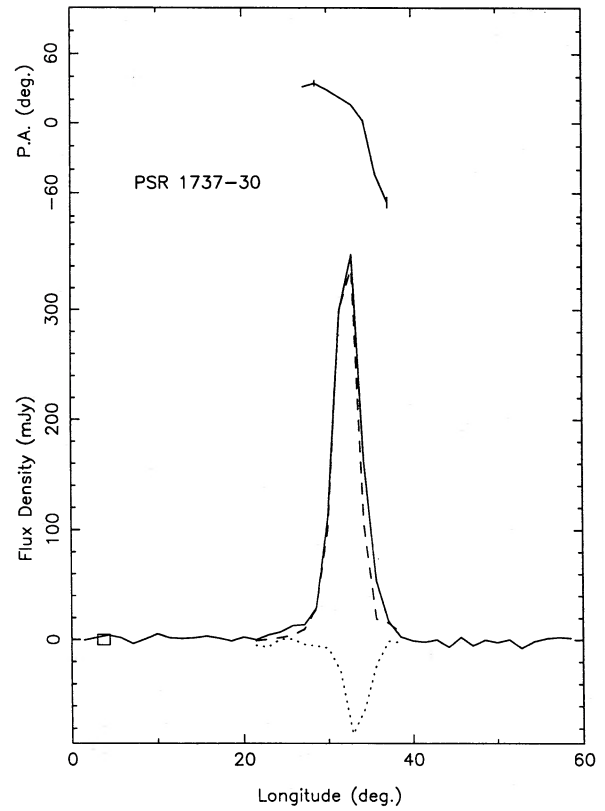


Figure 22. Mean pulse profile and polarization parameters for PSR 1737–30. See caption to Fig. 1 for details.

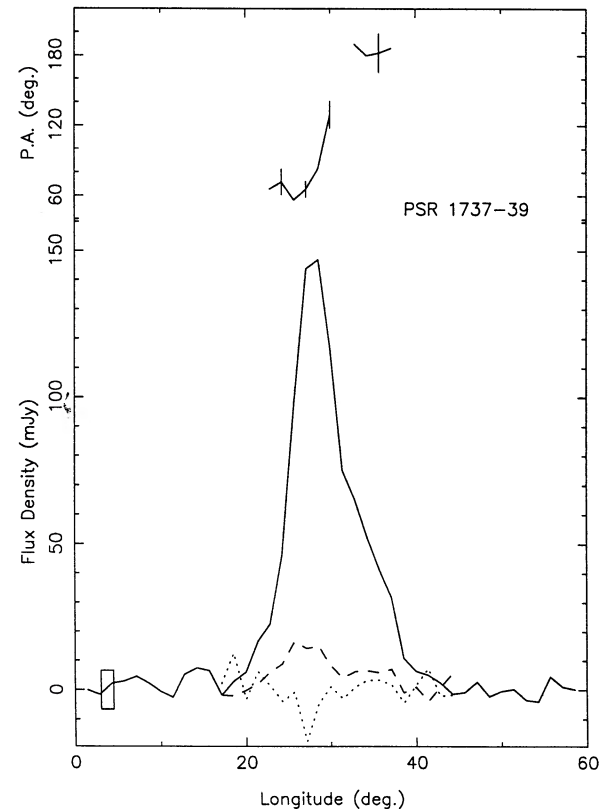


Figure 23. Mean pulse profile and polarization parameters for PSR 1737–39. See caption to Fig. 1 for details.

Apart from its narrower width and, hence, larger derived magnetic inclination, this pulsar is very similar to PSR 1054–62 (Fig. 5).

PSR 1736–29

The discovery observations by Clifton et al. (1992) showed this pulsar to have an interpulse with a flux density of about 50 per cent of the main pulse. The present observations confirm this and show that both the main pulse and the interpulse are very weakly polarized (Table 1). Only the interpulse has marginally significant linear polarization, with an observed position angle of about 140° .

PSR 1737–30 (Fig. 22)

This pulsar has a very narrow pulse which is almost totally polarized. Both the linear and circular polarizations peak at the same longitude as the total intensity, although the fractional linear polarization is highest along the leading edge. The position angle gradient increases across the profile and is very steep on the trailing edge. This may indicate that we are only observing the leading edge of the emission cone. The period of PSR 1737–30 is 0.607 s, longer than that of the similarly highly polarized pulsars 0833–45, 0740–28, 0906–39 and 1356–60. Like these pulsars, though, it has a small characteristic age: about 20 000 yr. It is also notable for suffering numerous Vela-like giant glitches (McKenna & Lyne 1990). PSR 1737–30 apparently belongs in the same class as these four young pulsars.

PSR 1737–39 (Fig. 23)

The pulse profile for this pulsar appears to consist of a main pulse plus outlier components. The degree of linear polari-

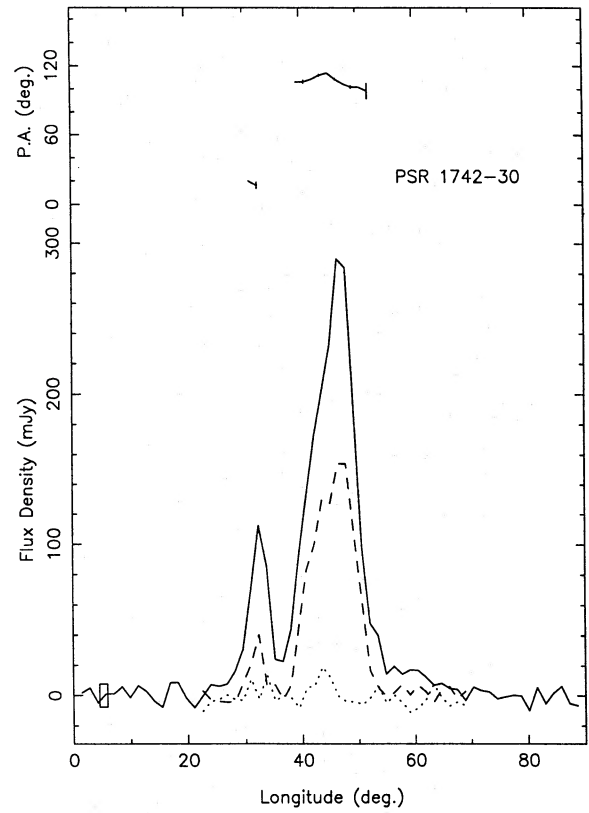


Figure 25. Mean pulse profile and polarization parameters for PSR 1742–30. See caption to Fig. 1 for details.

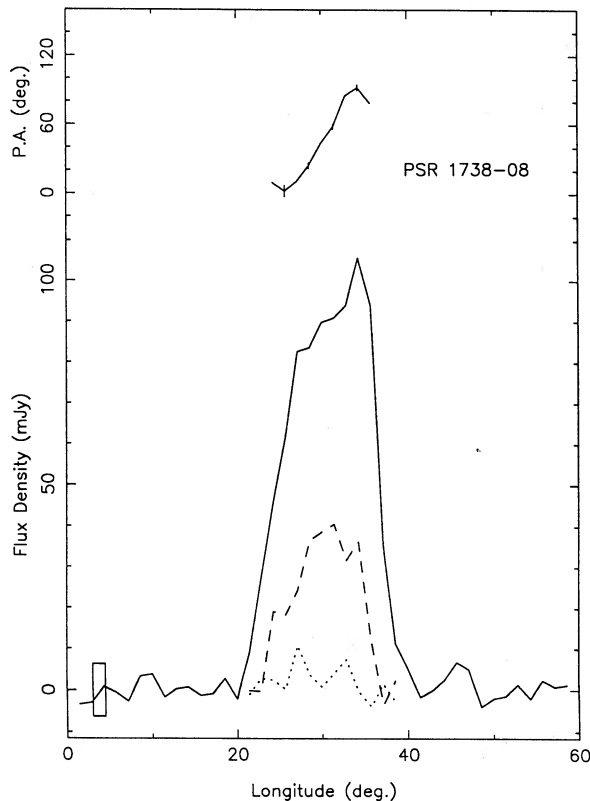


Figure 24. Mean pulse profile and polarization parameters for PSR 1738–08. See caption to Fig. 1 for details.

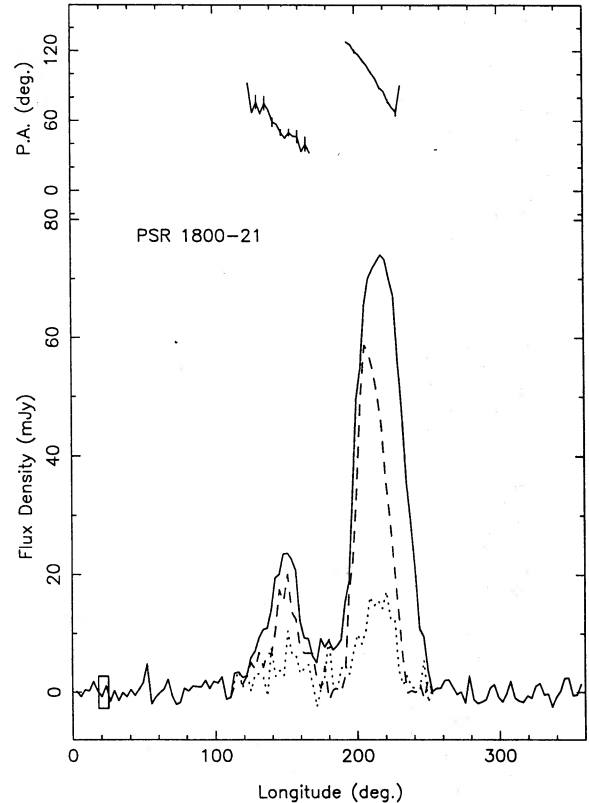


Figure 26. Mean pulse profile and polarization parameters for PSR 1800–21. See caption to Fig. 1 for details.

zation at 1560 MHz is slightly greater than that at 600 MHz (Costa et al. 1991) and there is an indication that the position angle has an 'S'-shaped variation through the profile. Higher signal/noise ratio observations are required to confirm this. Assuming the reality of the 'S'-shaped position angle variation, the relations of LM88 give $\alpha = 90^\circ$ and $\beta = 3:1$.

PSR 1738 – 08 (Fig. 24)

The degree of linear polarization of this flat-topped profile is high and the position angle has the 'S'-shaped characteristic of conal emission. No significant circular polarization is seen. Beam parameters are given by LM88. There is no measurable lag between the point of maximum position angle gradient and the mid-point of the profile.

PSR 1742 – 30 (Fig. 25)

This pulsar has an unusual profile with an isolated leading component, a central component which probably consists of two overlapping components, and a weak trailing component. All except the trailing component have significant linear polarization. The position angle is essentially constant through the central component(s) and displaced by about 90° from the position angle of the leading component. It is not clear whether there is an orthogonal transition or a more gradual change after the leading component. If there is an orthogonal transition, the flat position angle variation probably indicates that the line-of-sight trajectory passes close to the emission-cone axis.

PSR 1800 – 21 (Fig. 26)

This is a young (characteristic age only 16 000 yr) short-period pulsar discovered in the Jodrell Bank high-frequency survey (Clifton et al. 1992). As shown in Fig. 26, it has an extraordinarily wide double profile with high linear polarization and significant circular polarization, especially in the stronger trailing component. The fractional linear polarization is very high along the inner edges of the two components – a common feature in double pulse profiles. The position angle has an essentially constant gradient across both components, but the two portions do not join smoothly when extrapolated, suggesting a steeper position gradient near the profile centre. Apart from its great width, the profile of this pulsar has the characteristics of a typical double profile. This supports the suggestion of LM88 that the wide profile is due to near alignment of the rotation and magnetic axes, and indicates that some pulsars are born with this near alignment.

PSR 1804 – 08 (Fig. 27)

The pulse profile for this pulsar has several components and moderate linear polarization. There may be an orthogonal transition near the leading edge of the profile.

PSR 1813 – 36

This pulsar probably has a two-component profile with the second component much weaker than the first. There is significant linear polarization near the peak of the stronger component with a position angle of about 70° .

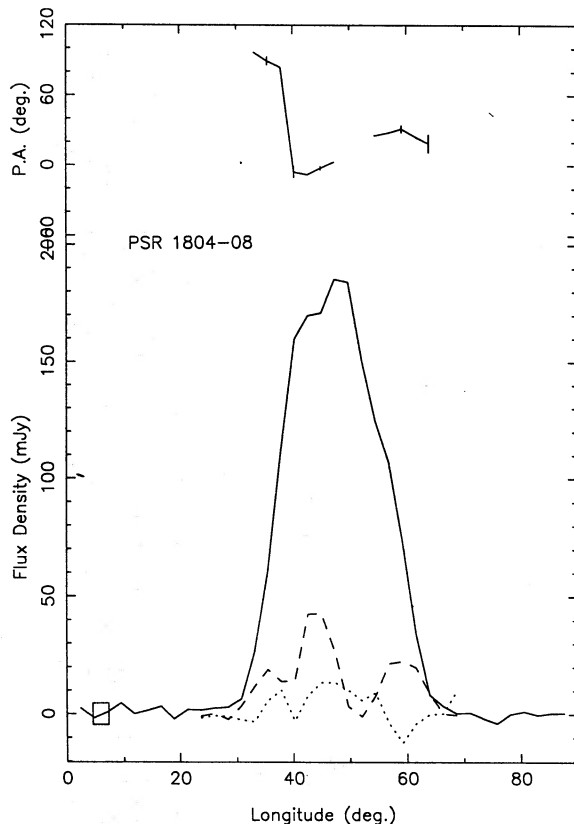


Figure 27. Mean pulse profile and polarization parameters for PSR 1804 – 08. See caption to Fig. 1 for details.

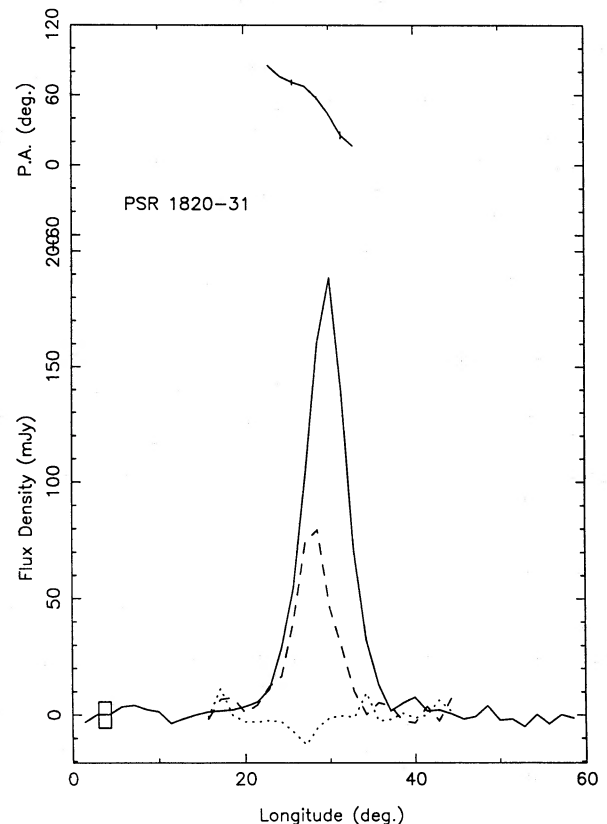


Figure 28. Mean pulse profile and polarization parameters for PSR 1820 – 31. See caption to Fig. 1 for details.

PSR 1819 – 22

The pulse profile for this pulsar has a simple shape and has a significant linear polarization across the central portion. The position angle increases through the pulse as reported by LM88.

PSR 1820 – 31 (Fig. 28)

This pulsar has a narrow pulse with high linear polarization near its leading edge. Marginally significant right-hand circular polarization is seen near the pulse centre.

PSR 1821 – 19

Another weakly polarized pulsar with an apparently simple pulse shape. The marginally significant linear polarization in the trailing half of the pulse has a position angle of about 110° .

PSR 1822 – 14

Observations of this pulsar are of poor signal/noise ratio and show a single-component pulse with no significant polarization.

PSR 1831 – 04 (Fig. 29)

This pulsar has an extraordinarily wide pulse profile (a 50 per cent width of 110° of longitude) with steep outer edges. The present observations have rather low signal/noise ratio, but indicate that there are two or three central components in addition to the stronger outer components. There is significant linear polarization, but unfortunately no systematic variations in position angle can be discerned from the present data. This pulsar has the very large characteristic age of 23 Myr (Backus, Taylor & Damashek 1983) and almost certainly has a nearly aligned magnetic axis.

PSR 1839 – 04 (Fig. 30)

This pulsar also has a wide profile, although not as wide as that of PSR 1831 – 04. It has a classic double form with high fractional linear polarization near the inner edges of the components and an 'S'-shaped variation of position angle. Following the notation of LM88, the 'apparent' impact parameter $\beta_{90} = 5.7$. However, the wide profile indicates that the magnetic and rotation axes are nearly aligned; the relations of LM88 give $\alpha = 9.3$ and hence a 'true' β of only 0.9 .

PSR 1844 – 04 (Fig. 31)

This pulsar also has a double profile, but, unlike the previous two pulsars, the profile is narrow. Significant linear polarization is observed in the trailing component; unfortunately, the signal/noise ratio is such that the variation of position angle through the profile cannot be determined.

PSR 1937 – 26 (Fig. 32)

The pulse profile for this pulsar appears to have two unresolved components, with the first having strong linear polarization. The variation of polarization parameters across the profile suggests that there may be emission from the leading and central sections of the emission cone only, with the trailing component missing. Higher sensitivity observations could confirm this conjecture.

PSR 2152 – 31

This pulsar has a simple one-component pulse profile with little or no significant polarization.

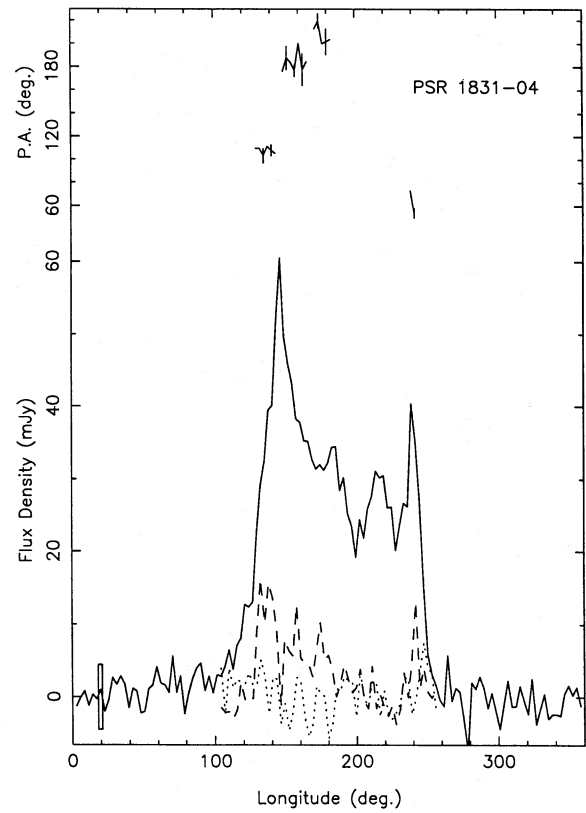


Figure 29. Mean pulse profile and polarization parameters for PSR 1831 – 04. See caption to Fig. 1 for details.

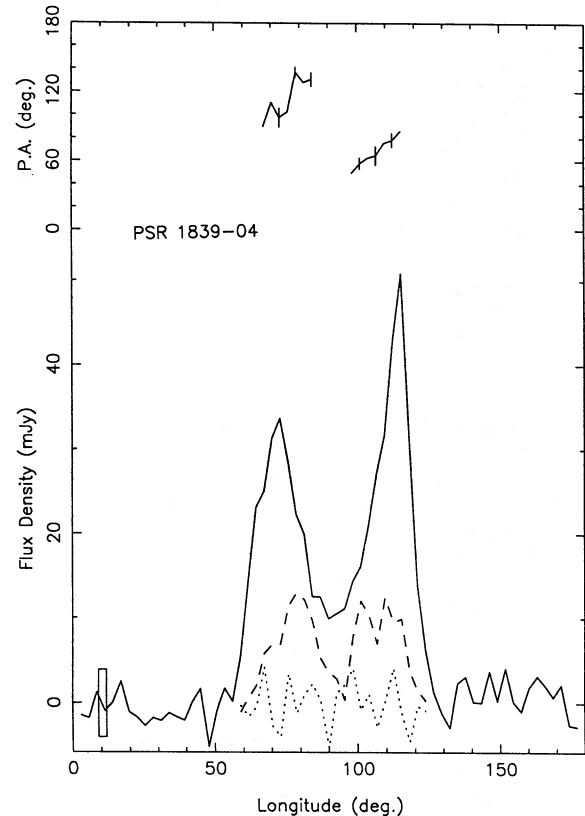


Figure 30. Mean pulse profile and polarization parameters for PSR 1839 – 04. See caption to Fig. 1 for details.

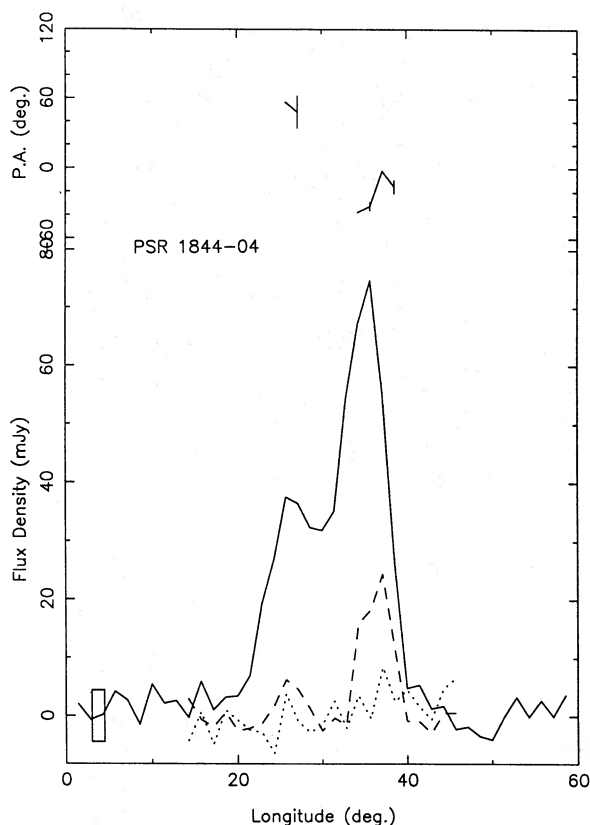


Figure 31. Mean pulse profile and polarization parameters for PSR 1844–04. See caption to Fig. 1 for details.

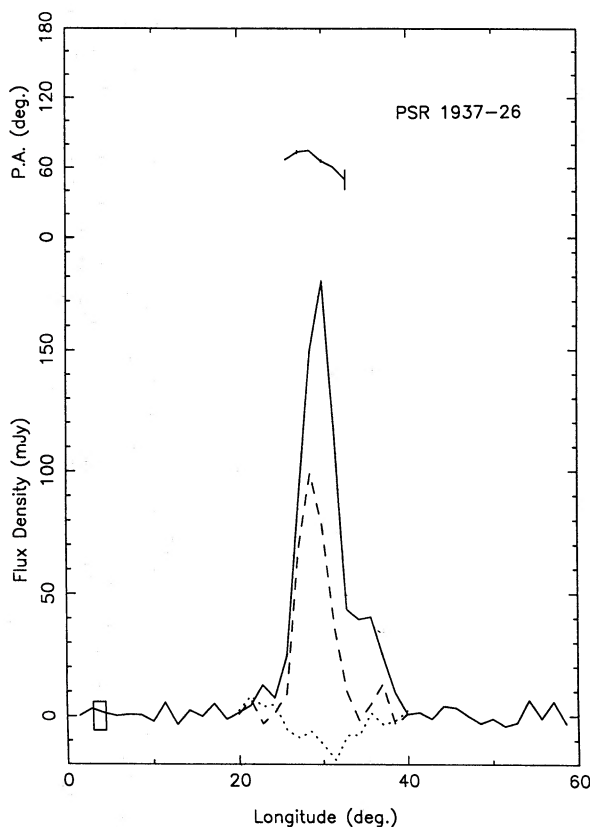


Figure 32. Mean pulse profile and polarization parameters for PSR 1937–26. See caption to Fig. 1 for details.

4 CONCLUSIONS

The polarization and mean profile data presented in this paper add significantly to the available data base for these important parameters. Several new examples of well-known classes of pulsars are presented: for example, a classic double profile (PSR 0148–06, Fig. 1), an incomplete emission core (PSR 0905–51, Fig. 2), a pulsar with a strong interpulse and high polarization allowing model fitting to the observed position angle variations (PSR 0906–49, Fig. 3), a pulsar in which the observer's line of sight grazes the emission cone (PSR 1054–62, Fig. 5), a very highly polarized, short-period pulsar (PSR 1356–60, Fig. 12), and several pulsars with wide double profiles (PSR 1648–42, Fig. 19; PSR 1800–21, Fig. 26; PSR 1831–04, Fig. 29 and PSR 1839–04, Fig. 30). These results will assist in analyses of the emission beam characteristics, such as those undertaken by Rankin (1983, 1990) and LM88.

With the exceptions of PSR 1323–58 (Fig. 10) and PSR 1648–42 (Fig. 19), and provided that one accepts the notion of incomplete emission cones, all of the observed position angle variations are consistent with the standard rotating vector model (Radhakrishnan & Cooke 1969). Some pulsars (e.g. PSR 1054–62, Fig. 5; PSR 1648–42, Fig. 19) appear to have a phase lag between the point of maximum gradient of the position angle curve and the mid-point of the total intensity profile, but others do not (e.g. PSR 0148–06, Fig. 1; PSR 1738–08, Fig. 24). Offsets such as these could result either from variations in the emission intensity across the polar emission region, or from the relativistic lag discussed by Blaskiewicz et al. (1991). PSR 0905–51 (Fig. 2) is an excellent example of a strong trailing component; the weak leading component could easily be missed in observations of lower signal/noise ratio.

The interpulse pulsar PSR 0906–49 (Fig. 3) is unique in having a relatively strong interpulse and very high polarization in both pulse components. After allowance for orthogonal modes, the observed position angles are very well fitted by the rotating vector model (Fig. 4). It is notable that the derived impact parameters are very large, 30° and 34° for the main pulse and interpulse respectively. This could be taken as evidence for elongated emission beams (Narayan & Vivekanand 1983); alternatively, it may be that we are observing just the extreme wings of the emission beams. In this case, the true radio luminosity of this pulsar would be much greater than the apparent value.

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