Polarization of low-luminosity radio galaxies: The 6 cm data

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Received January 2; accepted March 13, 1997

Abstract. Polarization data are presented for 62 B2 radio galaxies. The sources were observed at 6 cm in different configurations of the VLA. The results are given as integrated and mean component parameters. We also present maps of total intensity with superimposed vectors representing the fractional polarization and position angle. We compare these new data with older data at 20 cm and discuss briefly depolarization, rotation of polarization angle and geometry of the magnetic field.

Key words: radio continuum: galaxies — galaxies: general — polarization

allowed a detailed investigation of the radio characteristics of LLRG with particular interest in radio jets. The results on the general properties of LLRG, summarized in de Ruiter et al. (1990), show that they are mainly edge-darkened, Fanaroff-Riley type-1 radio sources. Jets are very often observed in these objects ($\sim 60\%$) and they can also be very prominent (unlike in PRG). The jets also tend to be more symmetrical than in PRG. The characteristics of these radio jets (opening angle and brightness distribution) are consistent with their being low-Mach number jets when they are compared with a theoretical model (Bicknell et al. 1990). However, a more recent analysis of high-resolution radio data shows that asymmetries in the brightness distribution of the jets appear to be well in evidence on the scale of a few kpc (Parma et al. 1994, 1996a; Laing 1994, 1996). On such small scales therefore, this makes these objects more similar to PRG.

The polarization of the sample has been studied by Capetti et al. (1993, hereafter referred as Paper I) using the VLA data at 20 cm. Despite the fact that only one frequency was available, Parma et al. (1993) were able, making a number of assumptions, to investigate the asymmetry in polarization for LLRG. They concluded that, as in PRG, an asymmetry in polarization is visible in LLRG between the lobe with the jet and that with the counter-jet. This is an important result and deserves to be further investigated by a proper study of the depolarization using at least two frequencies.

Because of this, we have observed the B2 sample presented in Paper I at 6 cm with the VLA. In this paper we present the results of these observations. The estimated polarization and fractional polarization obtained at 6 cm will then be compared with those previously presented 20 cm data to investigate the integrated properties of polarization and depolarization for different types of radio galaxies. Moreover, this new set of data will allow us to do a detailed study of the depolarization in the sources with

1. Introduction

The B2 sample of radio sources represents an ideal sample for studying the characteristics of low-luminosity radio galaxies (LLRG). This sample, which contains about 100 objects, was obtained from identifying of B2 radio sources with bright elliptical galaxies (see Colla et al. 1975; Fanti et al. 1978). Because of the selection criteria, the sample is dominated by radio galaxies with a power typically between 10^{22} and 10^{25} W Hz⁻¹ at 20 cm. In the last few years this sample has been extensively used to investigate the properties of LLRG and to compare them with those of powerful radio galaxies (PRG).

Some of the objects in the sample are well known and well studied at different radio frequencies and resolutions (see list in Fanti et al. 1987). However, most of the sample has been studied in detail only at 20 cm with different VLA configurations (Fanti et al. 1987 and references therein). The data collected from these studies have

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double lobes and jet and counter-jet morphology. This is discussed in a companion paper (Morganti et al. 1996).

2. Observations and data reduction

The objects observed were selected from Paper I and so we refer to that paper for the selection criteria. However, there are a few exceptions. Three objects (0120+33, 0800+24, 1339+26) in the sample of Paper I were not observed because of their low brightness. Two others, 1204+34 and 0836+29I, were not observed because of scheduling problems, and 1358+30 is no longer part of the sample (see Parma et al. 1996b, for more details on this object). On the other hand, we have observed 1511+26 that was not included in Paper I.

Table 1. Log of the observations

Date	Array
13 & 19 MAR92	array C
02AUG92	array D
28MAR93	array B

For some objects, 6 cm data were already available in the literature. Five objects (0206+35, 1113+29, 1553+29, 2116+26 and 2236+35) were presented in Morganti et al. (1987). However, these data have been re-analysed here to get an estimate of polarized intensity and fractional polarization consistent with the other objects. For three more objects (0844+31, 0836+29II and 1521+28) 6 cm data were presented in Capetti et al. (1995).

Table 2. D Array observations

Object	σ_I	σ_P	Beam	
	mJy/beam	mJy/beam	arcsec	degree
0034+25	0.025	0.027	12.1×11.6	−10.8
0755+37	0.120	0.045	23.4×12.2	−73.8
0828+32	0.070	0.048	12.1×11.5	29.8
0913+38	0.036	0.030	13.1×12.7	−47.6
0915+32	0.065	0.047	12.1×11.4	16.6
0922+36	0.130	0.036	12.2×11.3	−12.4
1005+28	0.035	0.024	12.1×11.5	−21.4
1102+30	0.065	0.035	12.2×11.3	−10.9
1116+28	0.043	0.035	11.4×11.4	−44.6
1141+47	0.100	0.043	13.9×13.8	−45.9
1243+26	0.046	0.025	11.2×10.8	29.8
1300+32	0.040	0.030	13.5×13.2	−47.6
1316+29	0.100	0.047	13.4×13.2	−47.8
1357+28	0.040	0.037	13.0×10.3	12.4
1422+26	0.130	0.036	13.6×12.7	−74.5
1441+26	0.030	0.032	14.2×12.9	−83.9
1455+28	0.120	0.037	15.5×12.6	89.9
1528+29	0.027	0.025	11.2×10.7	27.0
1643+27	0.045	0.041	14.9×12.6	−86.6
1657+32	0.045	0.040	14.8×11.6	86.3
1658+30	0.085	0.046	18.9×12.5	77.9
1658+32	0.078	0.053	24.3×12.8	72.8
1752+32	0.045	0.040	28.3×13.2	68.1
1827+32	0.040	0.025	13.4×11.8	73.9

The observations at 6 cm were carried out, in most cases, by using the proper array to match the resolution of the previous 20 cm observations (e.g. B-array 20 cm/C-array 6 cm or C-array 20 cm/D-array 6 cm).

A log of the observations is given in Table 1. Each object was observed for about 1h at 4885 MHz with a bandwidth of 50 MHz. The beams and rms noises of the resulting maps are listed in Table 2.

Calibration and post-calibration reduction was done using the National Radio Astronomy Observatory (NRAO) AIPS package. The flux densities were brought on the scale of Baars et al. (1977) using 3C 286 and 3C 48 as primary flux calibrators. Polarization angles were measured relative to those of 3C 286 and 3C 138 and, by observing a secondary calibrator at enough parallactic angles, we were able to estimate a good solution for the instrumental polarization calibration ($\sim 1\%$).

Maps of the Stokes parameters I , Q and U were produced for each source. Maps of the polarized flux density $p = (Q^2 + U^2)^{1/2}$ and position angle $A = 0.5 \arctan(U/Q)$ were then obtained.

For each source we have estimated the integrated value of I , Q , U and p by using only the points that in the I maps have signal-to-noise ratios $> 5\sigma_I$, following the same procedure described in Paper I. Using these values, we have derived both the vector mean fractional polarization ($m = [(\Sigma Q)^2 + (\Sigma U)^2]^{1/2}/\Sigma I$) and the associated position angle A and the mean fractional polarization ($m' = \Sigma p/\Sigma I$) with their associated errors. More details about these calculations are given in Paper I.

3. Results

The final images obtained for the whole sample are shown in Fig. 1. The contours correspond to the total intensity, the position angles of the vectors correspond to the polarization position angle ($\mathbf{E}$ vector) and their length is proportional to the fractional polarization.

In Table 3 we summarize the values of a number of parameters obtained for the entire source and for the individual components in the same way as done at 20 cm (see Table 1 of Paper I). In Col. 2 we indicate jet and counter-jet for the sources for which this classification was possible (following Parma et al. 1993 and the latest unpublished data); in Cols. 4, 6 and 8 we give the mean vector (m) and scalar (m') fractional polarization and the polarization position angle A together with their associated errors as defined in Paper I. The depolarization between 20 and 6 cm (DP_6^{20}) and the difference in position angle (ΔA) between these two frequencies are also included in Table 3 and will be described in more details in Sect. 4.

Table 2. continued, C array observations

Object	σ_I	σ_P	Beam	
	mJy/beam	mJy/beam	arcsec	degree
0149+35	0.040	0.029	3.6×3.3	12.1
0838+32	0.045	0.034	3.8×3.4	12.3
1108+27	0.037	0.025	3.7×3.4	7.3
1122+39	0.036	0.033	3.6×3.4	-16.2
1254+27	0.032	0.032	3.7×3.4	-15.1
1322+36	0.060	0.035	3.5×3.1	16.2
1347+28	0.027	0.025	3.6×3.5	-39.5
1430+25	0.033	0.033	3.6×3.4	-31.8
1450+28	0.030	0.030	3.1×2.8	-29.2
1457+29	0.032	0.023	3.9×3.7	-44.3
1512+30	0.025	0.022	4.1×3.6	-54.2
1511+26	0.050	0.036	3.6×3.5	-39.7
1527+30	0.040	0.034	3.5×3.5	-43.9
1553+29	0.033	0.030	4.1×3.7	-58.1
1609+31	0.036	0.034	3.6×3.5	-38.8
1613+27	0.035	0.039	2.9×2.7	-37.4
1615+32	0.127	0.045	4.4×3.6	-66.8
1626+39	0.080	0.045	3.9×3.7	-65.4
1726+31	0.083	0.055	4.7×3.7	-79.5
1747+30	0.039	0.034	4.5×3.9	-65.5
1833+32	0.600	0.100	3.7×3.4	-20.8

Table 2. continued, B array observations

Object	σ_I	σ_P	Beam	
	mJy/beam	mJy/beam	arcsec	degree
0708+32	0.045	0.041	1.3×1.0	18.5
0722+30	0.032	0.030	1.3×1.0	6.9
0908+37	0.040	0.040	1.0×1.0	-37.9
1003+26	0.032	0.031	1.3×1.0	9.9
1204+24	0.053	0.045	1.4×1.1	24.1
1303+31	0.061	0.034	1.4×1.0	20.1
1317+33	0.042	0.042	1.4×1.0	16.5
1525+29	0.048	0.037	1.4×1.0	23.9
1621+38	0.063	0.036	1.3×1.0	20.5
1855+37	0.073	0.038	1.3×1.0	5.6

Table 2. continued, data from literature

Object	References
0206+35	Morganti et al. 1987
0836+29II	Capetti et al. 1995
0844+29	Capetti et al. 1995
1113+29	Morganti et al. 1987
1521+28	Capetti et al. 1995
1553+29	Morganti et al. 1987
2116+26	Morganti et al. 1987
2236+35	Morganti et al. 1987

4. Discussion

4.1. Fractional polarization and depolarisation

Following Garrington et al. (1991), we have measured for each source (and for each component in the source) the mean scalar polarization, m' , defined as the integrated polarization flux over the total intensity. For the lobes, typical values of m' (at 6 cm) range from 10% to 30%, with a median value $15.5 \pm 1\%$. The m' values of the two lobes are rather similar, contrary to what was found at 20 cm (see Paper I), where the lobe containing the brighter jet was significantly more polarized than the other lobe.

The old maps at 20 cm and the new at 6 cm have been analysed to determine the depolarization, DP_6^{20} , between these two frequencies. The depolarization is defined as the ratio of the mean scalar fractional polarization, m' , at 20 cm over that at 6 cm: $DP_6^{20} = m'_{20}/m'_6$. The m' values we find at 6 cm are larger than the values of m'_{20} , implying depolarization between the two frequencies.

The values of DP_6^{20} are presented in Col. 10 of Table 3. They are peaked around 0.7 and extend down to ~ 0.25 . Only about 25% of the objects show little or no depolarization ($DP_6^{20} > 0.9$). Head-tail sources seem to be more depolarized, although the statistics is small.

4.2. Rotation angles

The differences between the position angle of the polarization at 6 and 20 cm (ΔA) are presented in Col. 12 of Table 3. The values obtained cover a broad range with a number of sources showing little or no rotation between the two wavelengths. We used the component polarization position angles to derive two-point Faraday rotation measures (RMs). Since position angles are ambiguous by $n\pi$, the calculated RMs are ambiguous by $\pm n86 \text{ rad m}^{-2}$. In practice we have:

$$\text{RM} = (0.47 \Delta A \pm n86) \text{ rad m}^{-2}$$

with ΔA in degrees.

For 22 sources the integrated polarization data in Parma & Weiler (1981) at 2.7 GHz and of Mack et al. (1994) at 10.8 GHz were used to resolve the ambiguity (see Appendix). We find $n = 0$ in 13 sources (0034 + 25, 0828 + 32, 0836 + 29, 1102 + 30, 1113 + 29, 1122 + 39, 1141 + 35, 1243 + 26, 1316 + 29, 1322 + 36, 1357 + 28, 1422 + 26, 1455 + 28), $n = \pm 1$ in seven cases and $n = 2$ in two cases (see Appendix). In this subsample, which we consider free of ambiguity, two thirds of the sources have RMs less than 50 rad m^{-2} . These figures are mostly consistent with Faraday rotation in the galactic foreground screen (Simard-Normandin et al. 1981).

We note that of the three sources with $|\text{RMs}|$ larger than 100 rad m^{-2} , two (1254+27 and 1626+39) are in rich Abell clusters and the third (2116+26) is at low galactic latitude ($b \approx -16$).

For the remaining sources for which we do not have additional data we choose the n value which minimizes the absolute value of RM. For them we expect, statistically, a comparable fractional number of ambiguities.

We have compared the RMs of the two lobes for the double sources (38 objects). Following the result of Conway et al. (1983), we assume that the differences in RM (ΔRM) are free of ambiguity. The rms difference is $\sigma(\Delta \text{RM}) = 12 \text{ rad m}^{-2}$. About two thirds of the sources have $\Delta \text{RM} \leq 10 \text{ rad m}^{-2}$, in agreement with what Simonetti & Cordes (1986) found. Only in three cases did we find differences in the rotation angles of the two lobes

above 40° , implying RM differences above 20 rad m^{-2} . These few cases are mentioned in the Notes on individual sources in the Appendix.

As for the sample of PRG studied by Garrington et al. (1991), we do not find any correlation between rotation measure and depolarization.

4.3. Magnetic field geometry

On the basis of the obtained RM, we conclude that the polarization position angle at 6 cm is within 15° of the intrinsic position angle and we derive the magnetic field projected geometry from the maps at this wavelength by a rotation of 90° .

In the double sources, the magnetic field appears in general very well oriented along the outer borders of the component, in agreement with earlier findings (e.g. Bridle et al. 1991). The best examples of this geometry are: 0755+37, 0828+32, 1141+37, 1322+36, 1441+26, 1455+28, 1658+30.

In general the direction of the magnetic field in jets is perpendicular to the jet orientation, in agreement with what found in Bridle & Perley (1984), for the typical range of radio powers of our sample. In a number of double sources the jet shows up in the polarisation map for its magnetic field orientation which contrast with that of the radio lobes (see, for example, 0755+37, 1322+36, 1613+27, 1658+30). In some double sources the jet, which is not well distinguished from the lobe in the total-intensity map, emerges clearly in the polarization map (0828+32, 1457+29 1609+31).

There are, however, situations where we see a parallel magnetic field. The first is at the jet sides, as in 1357+28 and, most notably, in 1553+24. This characteristic has already been found in 3C 31 (R.A. Laing et al. in preparation). The second is in the final part of the jets, in sources dominated by jet emission (see 0915+32 and 1243+26).

For the hot-spots the situation is not very clear. In general we find low fractional polarization and an unclear field geometry. We believe that the generally inadequate resolution of our observations mixes regions with different field geometry and causes beam depolarization.

In the head-tail sources the magnetic field tends to run parallel to the tail.

4.4. The depolarizing halo

As discussed in Laing (1988) and Garrington & Conway (1991), the depolarization observed in PRG is likely to be caused by an inhomogeneous, unresolved, foreground Faraday screen, which rotates the polarization position angle randomly across the observing beam. The more depolarized lobe is, therefore, the lobe seen through a larger halo depth. The depolarization ratio DP_6^{20} is related to

the standard deviation of the Faraday depth, Δ , by the relation

$$\text{DP}_{\lambda_1}^{\lambda_2} = \exp[-2K^2\Delta^2(\lambda_2^4 - \lambda_1^4)]$$

where $K = 0.81$, Δ is in units of $\text{cm}^{-3}\mu\text{G pc}$ and λ_1 and λ_2 are in metres (Garrington & Conway 1991).

From this we derive for each source the lobes' Faraday dispersion parameters, Δ_{max} and Δ_{min} corresponding to the lobe with higher and lower depolarization, respectively. The values we find range mostly from 4 to $30 \text{ cm}^{-3} \mu\text{G pc}$. These values are similar to those of the low redshift ($z < 0.2$) sources of the Garrington & Conway (1991) sample, and are much lower than the values of the sources at high redshift. For each source with lobes, we have also estimated r_{DP} defined as the ratio of the highest to the lower depolarization ($\text{DP}_{\text{max}}/\text{DP}_{\text{min}}$). Using this parameter, we have searched for correlation between r_{DP} and source size. Although we find a marginal tendency for large r_{DP} in large sources, no obvious relation has been found between r_{DP} and source size.

In their work on PRG, Garrington & Conway (1991) conclude that the major contribution to depolarization arises from a halo of hot gas surrounding the radio source. By using a Montecarlo simulation, we have derived the parameters of such a halo. From the distributions of the r_{DP} and of the ratio $r_\Delta = \Delta_{\text{max}}/\Delta_{\text{min}}$ we find the following parameters:

$$\begin{aligned} \text{halo radius} &\approx 150 \text{ kpc} \\ < B_0 n_0 > &\approx (0.3 - 3) 10^{-3} \mu\text{G cm}^{-3} \end{aligned}$$

where B_0 and n_0 are the halo's central magnetic field and density. These parameters agree well with those found by Garrington & Conway (1991) for the low redshift ($z < 1$) radio galaxies.

A discussion on the depolarization asymmetry in the source components is presented in a companion paper (Morganti et al. 1996).

5. Conclusions

We have presented new polarization data at 6 cm for a sample of 62 B2 radio galaxies. We have measured integrated m and mean m' polarization parameters and compared them with the old data obtained for the same sample at 20 cm. We find the following results:

- a) the lobe median value of m' for double sources is $15 \pm 1\%$, larger than the corresponding median value found at 20 cm. This implies depolarization between the two wavelengths;
- b) the distribution of depolarization ratios is consistent with the halo depolarization model presented by Garrington & Conway (1991);

Table 3.

Object	Jet	$I(\text{mJy})$	$m(\%)$	σ	$m'(\%)$	σ	$A(^{\circ})$	σ	DP_6^{20}	σ	$\Delta A(^{\circ})$	σ
0034+25		37.6	8.9	1.1	15.1	1.1	79	3	0.95	0.10	109	4
core		12.1	13.2	1.1	13.2	1.1	86	2	–	–	86	2
E	j	13.5	6.5	1.3	16.7	1.3	85	5	0.74	0.08	111	6
W	cj	10.5	8.7	1.6	15.0	1.6	61	5	1.08	0.13	106	3
0149+35		19.5	5.8	1.2	10.0	1.2	–27	6	0.54	0.16	–27	3
core		6.8	<3.5	–	<3.5	–	–	–	–	–	–	–
E	cj	4.7	15.8	2.1	20.9	2.1	–9	3	0.38	0.12	–49	2
W	j	7.7	15.1	1.5	9.9	1.5	–74	3	0.50	0.22	–35	2
0206+35		668.0	7.8	1.0	15.4	1.0	63	3	0.77	0.09	34	13
core		106.0	2.6	1.0	2.8	1.0	64	11	–	–	91	8
NW	j	296.3	7.0	1.1	14.8	1.1	70	4	0.77	0.09	46	24
SE	cj	314.9	8.4	1.0	14.5	1.0	54	3	0.67	0.08	34	9
0708+32		27.9	<3.1	–	9.9	1.2	–	–	0.36	0.17	–	–
core		15.8	2.6	1.1	3.0	1.1	–77	12	–	–	–77	5
N		5.9	<10.2	–	16.6	2.3	–	–	0.25	0.11	–	–
S		6.7	<9.0	–	13.3	2.1	–	–	0.31	0.12	–	–
0722+30		57.7	3.2	1.1	7.1	1.1	–23	9	0.98	0.29	–23	4
core		23.3	2.0	1.0	2.6	1.0	–41	14	–	–	–41	5
W	cj	14.1	<6.8	–	13.5	1.7	–	–	0.85	0.17	–	–
E	j	20.5	<4.3	–	7.8	1.3	–	–	0.73	0.18	–	–
0755+37		1235.0	5.1	1.0	17.7	1.0	–69	5	0.71	0.07	–15	6
core		288.3	1.8	1.0	1.9	1.0	–58	16	–	–	–23	19
E	j	535.4	4.8	1.0	23.5	1.0	–58	6	0.73	0.05	–11	6
W	cj	415.8	8.5	1.0	19.7	1.0	–75	3	0.51	0.06	–24	7
0828+32		487.7	8.6	1.0	21.4	1.0	78	3	0.99	0.07	118	4
core		3.5	13.8	2.4	15.4	2.4	77	5	–	–	77	3
E	cj	218.5	14.6	1.0	25.3	1.0	85	2	0.94	0.05	107	2
W	j	268.9	4.8	1.0	18.3	1.0	61	6	1.05	0.08	122	5
0836+29		337.6	5.7	1.0	12.6	1.0	3	5	0.73	0.10	–84	15
core		163.4	1.7	1.0	1.7	1.0	–78	17	–	–	–2	15
N	j	83.3	<1.4	–	13.0	1.0	–	–	0.69	0.09	–	–
S	cj	93.1	23.8	1.0	31.3	1.0	4	1	0.50	0.04	–48	6
0838+32		221.8	5.2	1.0	10.7	1.0	72	5	0.44	0.10	112	14
0844+31		406.5	<1.0	–	11.7	1.0	–	–	0.89	0.11	–	–
core		44.2	2.2	1.0	2.3	1.0	82	12	–	–	153	5
S	cj	152.5	3.7	1.0	10.4	1.0	12	7	0.59	0.11	97	4
N	j	212.0	1.2	1.0	14.7	1.0	–64	24	0.85	0.09	–107	7
0908+37		196.2	4.8	1.1	21.4	1.1	41	6	0.31	0.07	37	9
core		37.0	<1.5	–	<1.5	–	–	–	–	–	–	–
N	j	94.1	10.0	1.2	25.0	1.2	58	3	0.34	0.04	60	7
S	cj	66.3	8.6	1.3	27.5	1.3	6	4	0.19	0.04	6	3
0913+38		140.7	9.3	1.0	10.4	1.0	–80	3	1.04	0.15	–84	5
W	j	78.3	10.2	1.0	11.0	1.0	–83	2	1.05	0.15	–113	6
E	cj	61.1	8.7	1.0	9.5	1.0	–75	3	1.06	0.19	–30	7
0915+32		102.3	3.0	1.1	17.1	1.1	–69	10	0.75	0.07	–63	7
core		3.2	<12.9	–	<12.9	–	–	–	–	–	–	–
S	cj	62.9	6.4	1.1	21.8	1.1	–75	5	0.98	0.07	–77	3
N	j	26.0	<4.4	–	14.3	1.3	–	–	0.60	0.09	–	–
0922+36		244.7	4.7	1.0	11.0	1.0	–78	6	0.21	0.09	–78	3
core		17.0	<1.9	–	<1.9	–	–	–	–	–	–	–
Scomp		67.1	12.6	1.0	13.0	1.0	–78	2	0.28	0.08	–86	10
N		80.0	3.6	1.0	13.4	1.0	–66	8	0.12	0.08	–66	4
S		147.6	5.9	1.0	10.7	1.0	–82	4	0.34	0.10	–90	10
1003+26		7.3	<7.3	–	7.4	1.8	–	–	–	–	–	–
1005+28		34.7	8.2	1.1	17.0	1.1	–5	4	0.61	0.07	–63	7
core		6.3	16.2	1.2	16.5	1.2	–10	2	0.59	0.08	–73	4
S	j	16.3	6.8	1.2	18.3	1.2	0	5	0.69	0.07	–49	13
N	cj	13.0	6.2	1.3	14.3	1.3	–8	6	0.65	0.09	–60	12
1102+30		131.4	10.1	1.0	15.3	1.0	80	3	0.80	0.08	163	3
core		19.2	<1.8	–	2.1	1.1	–	–	–	–	–	–
E	j	61.6	17.5	1.0	19.6	1.0	80	1	0.77	0.07	165	2
W	cj	51.4	5.2	1.0	15.0	1.0	79	5	0.65	0.08	154	7
1108+27		55.8	9.8	1.1	14.7	1.1	67	3	0.94	0.12	97	4
core		19.0	<1.3	–	<1.3	–	–	–	–	–	–	–
E	cj	2.0	<17.9	–	<17.9	–	–	–	–	–	–	–
W	j	31.4	17.2	1.1	20.1	1.1	67	2	0.78	0.08	95	3
1113+29		655.5	4.9	1.0	15.0	1.0	65	5	0.93	0.10	157	9
core		48.6	2.0	1.0	2.2	1.0	70	14	–	–	27	9
E	cj	289.1	8.6	1.0	19.2	1.0	48	3	0.63	0.08	73	18
W	j	364.6	7.9	1.0	19.0	1.0	79	3	0.82	0.08	83	4
1116+28		159.1	2.9	1.0	9.7	1.0	89	10	0.79	0.13	163	18
core		75.3	5.5	1.1	5.7	1.1	–82	5	0.89	0.24	–15	6
E	cj	38.4	7.8	1.1	15.6	1.1	49	4	0.77	0.09	–6	6
W	j	56.1	3.9	1.1	10.2	1.1	–54	7	0.67	0.12	–25	9
1122+39		41.7	6.8	1.1	8.6	1.1	–48	4	1.40	0.21	1	4
core		12.3	<2.7	–	<2.7	–	–	–	–	–	–	–
NW	j	13.5	10.3	1.9	11.6	1.9	–46	5	0.80	0.16	1	5
SE	cj	15.4	9.3	1.7	12.1	1.7	–49	5	1.09	0.17	3	4

Table 3. continued

Object	Jet	$I(\text{mJy})$	$m(\%)$	σ	$m'(\%)$	σ	$A(^{\circ})$	σ	DP_6^{20}	σ	$\Delta A(^{\circ})$	σ
1141+37		621.6	2.0	1.0	8.7	1.0	-74	14	0.69	0.14	4	13
core		5.1	<6.6	—	<6.6	—	—	—	—	—	—	—
N		323.4	4.2	1.0	8.0	1.0	72	6	0.71	0.15	148	11
S		292.9	4.5	1.0	9.4	1.0	-43	6	0.68	0.13	16	7
1204+24		24.1	<5.5	—	10.3	1.5	—	—	1.48	0.29	—	—
core		12.9	<4.0	—	<4.0	—	—	—	—	—	—	—
N	cj	5.1	<18.2	—	<18.2	—	—	—	—	—	—	—
S	j	7.8	<11.9	—	17.7	2.6	—	—	1.09	0.19	—	—
1243+26		128.7	4.2	1.0	11.5	1.0	26	7	0.62	0.10	-40	9
N	j	62.5	5.6	1.0	13.3	1.0	35	5	1.05	0.11	-53	3
S	cj	58.0	4.3	1.1	9.7	1.1	10	7	0.52	0.12	10	3
1254+27		23.4	<3.7	—	13.5	1.2	—	—	0.52	0.13	—	—
N	j	12.8	<6.8	—	16.8	1.7	—	—	0.57	0.13	—	—
S	cj	9.2	<7.5	—	11.0	1.8	—	—	0.34	0.11	—	—
1300+32		111.7	5.0	1.0	13.5	1.0	22	5	0.12	0.07	22	3
NE		40.5	6.9	1.0	9.9	1.0	-18	4	0.16	0.10	-18	2
SW		66.2	8.5	1.0	16.3	1.0	36	3	0.09	0.06	36	2
1303+31		22.3	<2.7	—	6.1	1.1	—	—	0.77	0.40	—	—
1316+29		361.1	14.1	1.0	21.0	1.0	-81	2	0.75	0.06	-5	2
core		26.9	12.3	1.0	12.6	1.0	88	2	1.24	0.13	174	3
W	cj	180.6	10.4	1.0	17.4	1.0	-85	2	0.77	0.07	-6	3
E	j	180.5	18.0	1.0	24.5	1.0	-78	1	0.71	0.05	-5	2
1317+33		24.1	<5.8	—	13.3	1.5	—	—	0.79	0.18	—	—
core		8.7	<5.1	—	<5.1	—	—	—	—	—	—	—
N		10.3	<9.7	—	16.8	2.2	—	—	0.58	0.14	—	—
S		7.1	<12.0	—	16.6	2.6	—	—	0.91	0.22	—	—
1322+36		443.8	5.7	1.0	16.2	1.0	9	5	0.84	0.09	-1	7
core		93.7	1.3	1.0	2.3	1.0	24	22	—	—	0	20
N	cj	173.6	10.1	1.0	18.1	1.0	33	3	0.68	0.08	25	4
S	j	176.2	10.4	1.0	21.6	1.0	-13	2	0.85	0.07	-21	4
1347+28		89.3	5.6	1.0	10.9	1.0	29	5	0.75	0.14	-12	6
core		7.3	<3.4	—	3.4	1.2	—	—	—	—	—	—
NE	cj	42.1	4.8	1.1	11.7	1.1	41	6	0.68	0.13	-3	6
SW	j	40.8	7.8	1.1	11.3	1.1	22	4	0.65	0.15	-18	8
1357+28		120.0	1.7	1.0	10.0	1.0	54	17	0.50	0.11	-24	11
core		33.9	6.9	1.0	8.0	1.0	15	4	0.67	0.15	21	6
N	j	42.6	8.0	1.1	10.6	1.1	74	3	0.55	0.11	-6	11
S	cj	34.7	3.5	1.1	13.5	1.1	-40	9	0.29	0.08	-105	14
1422+26		298.5	9.7	1.0	14.4	1.0	-71	3	0.55	0.08	-7	5
core		20.4	<1.4	—	4.7	1.0	—	—	—	—	—	—
E	cj	131.9	8.1	1.0	14.5	1.0	-76	3	0.40	0.07	0	6
W	j	143.6	12.5	1.0	15.8	1.0	-67	2	0.65	0.08	-10	3
1430+25		128.0	4.8	1.0	14.8	1.0	-76	6	0.73	0.09	-46	19
N		46.7	6.9	1.1	15.7	1.1	52	4	1.02	0.10	0	3
S		78.2	9.3	1.1	14.3	1.1	-62	3	0.57	0.09	-14	10
1441+26		58.1	8.9	1.1	14.6	1.1	-13	3	0.64	0.08	-24	4
core		3.4	<8.3	—	<8.3	—	—	—	—	—	—	—
E		37.4	13.5	1.1	17.1	1.1	-7	2	0.68	0.07	-26	3
W		18.2	6.7	1.3	11.5	1.3	-49	5	0.31	0.09	-21	15
1450+28		49.4	5.2	1.1	12.3	1.1	-74	6	0.63	0.15	-74	3
E	j	32.2	4.4	1.1	11.5	1.1	-77	7	0.65	0.17	-77	3
W	cj	17.2	6.6	1.4	14.0	1.4	-71	6	0.59	0.17	-71	3
1455+28		271.0	3.1	1.0	13.2	1.0	-46	9	0.60	0.09	-31	12
core		1.4	25.0	3.4	27.1	3.4	44	4	—	—	44	2
N		140.0	1.7	1.0	13.8	1.0	-60	16	0.57	0.08	-38	22
S		129.9	5.1	1.0	12.4	1.0	-41	5	0.63	0.10	-27	7
1457+29		144.1	10.8	1.0	14.9	1.0	-31	2	0.85	0.09	-52	3
core		20.4	3.7	1.0	4.3	1.0	-63	8	—	—	-63	4
N		63.5	15.4	1.0	18.5	1.0	-29	2	0.78	0.07	-50	2
S		60.6	9.0	1.0	14.3	1.0	-32	3	0.74	0.09	-53	3
1511+26		695.2	8.8	1.0	23.5	1.0	-52	3	—	—	-52	2
core		158.5	5.6	1.0	6.9	1.0	79	5	—	—	79	3
N		263.1	8.3	1.0	32.4	1.0	-82	3	—	—	-82	2
S		397.6	10.0	1.0	30.3	1.0	-47	3	—	—	-47	2
1512+30		31.9	12.0	1.1	14.1	1.1	-3	2	0.90	0.10	-20	3
N		15.8	8.6	1.1	9.7	1.1	8	3	0.84	0.18	-23	4
S		16.1	16.5	1.1	18.6	1.1	-9	2	0.92	0.09	-19	2
1521+28		260.8	3.5	1.0	16.6	1.0	-29	8	0.64	0.07	-11	8
core		69.6	5.8	1.0	5.9	1.0	54	5	0.96	0.24	8	5
S	j	140.6	10.9	1.0	22.0	1.0	-27	2	0.70	0.06	-5	3
N	cj	55.2	9.3	1.0	15.9	1.0	63	3	0.23	0.06	0	8
1525+29		65.5	3.0	1.1	14.2	1.1	-49	10	0.90	0.15	-49	4
S	j	33.8	<5.2	—	15.7	1.4	—	—	0.82	0.11	—	—
N	cj	29.8	<5.9	—	13.2	1.6	—	—	0.98	0.16	—	—
1527+30		16.9	6.6	1.3	13.0	1.3	-71	5	0.46	0.13	-110	3
core		9.3	11.6	1.2	12.9	1.2	-73	3	0.20	0.13	-30	18
E		4.8	<18.7	—	<18.7	—	—	—	—	—	—	—
W		4.0	<18.1	—	<18.1	—	—	—	—	—	—	—

Table 3. continued

Object	Jet	$I(\text{mJy})$	$m(\%)$	σ	$m'(\%)$	σ	$A(^{\circ})$	σ	DP_6^{20}	σ	$\Delta A(^{\circ})$	σ
1528+29		61.7	5.4	1.1	15.6	1.1	75	5	0.55	0.07	162	7
core		7.6	5.1	1.1	5.4	1.1	45	6	–	–	–3	6
NE	j	24.6	11.3	1.1	18.7	1.1	54	3	0.46	0.06	–19	4
SW	cj	30.4	7.8	1.1	15.5	1.1	–73	4	0.55	0.08	–9	5
1553+24		96.4	<1.1	–	8.1	1.0	–	–	1.28	0.20	–	–
core		56.7	4.0	1.0	4.4	1.0	45	7	–	–	130	8
SE	cj	7.7	8.1	1.7	14.5	1.7	–37	6	1.11	0.15	–30	12
NW	j	25.1	6.3	1.2	14.9	1.2	–45	5	1.09	0.11	–52	8
1609+31		65.2	12.4	1.0	17.0	1.0	11	2	0.86	0.09	–4	3
N		36.1	14.5	1.1	18.2	1.1	20	2	0.81	0.09	–5	3
S		28.3	12.7	1.1	15.8	1.1	–3	2	0.90	0.12	–6	4
1613+27		95.3	5.3	1.0	12.1	1.0	–37	5	0.83	0.17	–62	16
core		14.4	<10.6	–	<10.6	–	–	–	–	–	–	–
SE	j	38.6	<4.0	–	12.2	1.3	–	–	0.87	0.13	–	–
W	cj	41.0	8.0	1.2	13.9	1.2	–37	4	0.68	0.11	–61	8
1615+32		872.8	7.9	1.0	14.6	1.0	–62	3	0.32	0.07	–3	7
core		22.0	7.9	1.1	8.2	1.1	–11	3	–	–	–11	2
N	cj	450.6	7.9	1.0	13.0	1.0	–56	3	0.39	0.08	1	6
S	j	387.9	9.3	1.0	16.7	1.0	–71	3	0.25	0.06	–10	8
1621+38		45.0	3.6	1.1	8.9	1.1	55	8	0.35	0.15	55	4
core		18.0	4.2	1.1	4.9	1.1	76	7	–	–	76	3
N		6.4	<10.7	–	<10.7	–	–	–	–	–	–	–
S		11.0	8.3	1.6	11.3	1.6	54	5	0.27	0.11	66	15
tail		10.3	<6.2	–	12.8	1.6	–	–	0.40	0.13	–	–
1626+39		463.5	3.3	1.0	6.7	1.0	–78	8	0.51	0.18	–63	10
core		154.3	<1.0	–	<1.0	–	–	–	–	–	–	–
E	cj	153.2	4.2	1.0	10.6	1.0	–73	7	0.29	0.11	–89	14
W	j	147.0	5.1	1.0	8.4	1.0	–79	5	0.44	0.14	–61	9
1643+27		41.7	<1.7	–	9.7	1.1	–	–	0.54	0.12	–	–
core		8.2	4.7	1.2	5.2	1.2	–67	7	0.46	0.22	–67	3
N	j	19.1	7.7	1.1	10.1	1.1	36	4	0.70	0.13	–52	5
S	cj	18.3	5.3	1.1	13.1	1.1	–49	6	0.30	0.08	–49	3
1657+32		7.2	<15.2	–	20.7	3.2	–	–	0.24	0.06	–	–
1658+30		319.3	8.5	1.0	18.3	1.0	71	3	0.71	0.07	147	4
cor		97.8	4.9	1.0	6.0	1.0	60	5	0.72	0.21	137	8
NE	cj	93.9	16.0	1.1	23.0	1.1	88	2	0.58	0.05	137	4
SW	j	123.2	9.9	1.0	23.9	1.0	54	3	0.65	0.05	140	3
1658+32		65.5	5.9	1.1	10.5	1.1	–69	5	0.28	0.10	–20	12
1726+31		988.3	3.3	1.0	16.8	1.0	41	8	0.36	0.06	–44	4
core		154.3	<1.0	–	<1.0	–	–	–	–	–	–	–
E		440.6	8.1	1.0	17.4	1.0	45	3	0.35	0.06	131	9
W		481.8	1.4	1.0	15.8	1.0	24	20	0.37	0.07	24	6
1747+30		20.5	<4.7	–	10.0	1.4	–	–	1.92	0.33	–	–
core		10.0	<3.7	–	<3.7	–	–	–	–	–	–	–
N	j	3.9	<13.6	–	<13.6	–	–	–	–	–	–	–
S	cj	3.4	<22.1	–	<22.1	–	–	–	–	–	–	–
1752+32		67.3	9.2	1.0	10.8	1.0	60	3	1.26	0.18	64	4
core		33.0	10.2	1.0	10.3	1.0	67	3	0.81	0.15	65	5
SW	j	12.2	<6.8	–	7.2	1.7	–	–	1.86	0.51	–	–
NE	cj	14.6	14.3	1.5	16.3	1.5	57	3	1.12	0.15	64	3
1827+32		108.3	2.2	1.0	8.4	1.0	–54	13	0.73	0.15	–54	5
core		36.5	2.5	1.0	3.3	1.0	–38	11	0.43	0.33	–38	4
SW	cj	53.3	<1.8	–	8.8	1.1	–	–	0.70	0.14	–	–
NE	j	17.8	7.8	1.3	17.4	1.3	–74	4	0.68	0.08	–60	5
1833+32		1477.5	4.2	1.0	16.1	1.0	67	6	0.82	0.09	46	9
core		205.9	1.6	1.0	1.6	1.0	61	18	–	–	64	10
NE	j	792.8	1.9	1.0	17.7	1.0	29	15	0.75	0.08	72	14
SW	cj	474.4	11.9	1.0	19.4	1.0	75	2	0.76	0.07	64	4
1855+37		90.2	1.9	1.0	11.8	1.0	10	15	–	–	10	5
2116+26		92.8	3.1	1.0	5.7	1.0	44	9	1.84	0.38	–12	11
core		60.1	1.3	1.0	1.6	1.0	80	21	–	–	24	7
N	cj	4.0	<20.1	–	<20.1	–	–	–	–	–	–	–
S	j	15.3	10.7	1.6	14.4	1.6	39	4	0.64	0.10	45	18
2236+35		152.7	15.2	1.0	23.6	1.0	–24	2	0.87	0.07	–63	3
core		10.5	<8.7	–	<8.7	–	–	–	–	–	–	–
SW	cj	75.1	20.5	1.0	23.7	1.0	–25	1	0.99	0.07	–58	4
NE	j	67.6	11.3	1.1	24.6	1.1	–24	2	0.78	0.07	–66	3

c) After correcting for Faraday rotation, the magnetic fields in the lobes show preferentially a circumferential geometry. In the jets the field is mostly perpendicular to the source axis, although with a few noticeable exceptions.

Acknowledgements. The National Radio Astronomy Observatory is operated by Associated Universities, Inc., under contract with National Science Foundation.

A. Notes on individual sources

0206+35 Using the 2.7 GHz polarization position angle in Parma & Weiler (1981), we obtain a rotation measure of 70 rad m^{-2} ($n = 1$, see Sect. 4.1).

0755+37 Using the 2.7 GHz polarization position angle in Parma & Weiler (1981), we obtain a rotation measure of -70 rad m^{-2} ($n = -1$, see Sect. 4.1).

0913+38 The rotation of the polarization angle between the two wavelengths is rather large ($83^\circ \pm 10$).

1108+27 Using the 2.7 GHz polarization position angle in Parma & Weiler (1981), we obtain a rotation measure of -45 rad m^{-2} ($n = -1$, see Sect. 4.1).

1141+47 The core of the source is now detected in the 4.8 GHz map.

1243+26 The bright spot at R.A. = $12^{\text{h}}43^{\text{m}}52^{\text{s}}.8$ and Dec = $26^{\text{d}}42^{\text{m}}32^{\text{s}}$ is the radio core of another galaxy. In the southern lobe there is very likely a mixture of the radio emission from the two galaxies.

1254+27 Using the 2.7 GHz polarization position angle in Parma & Weiler (1981), we obtain a rotation measure of -165 rad m^{-2} ($n = -2$, see Sect. 4.1).

1300+32 Head-tail source (see Fanti et al. 1986).

1303+31 Head-tail source (see Fanti et al. 1986)

1322+36 The difference in polarization rotation angle between the two lobes is $46^\circ \pm 8^\circ$.

1357+28 The difference in polarization rotation angle between the two lobes is $82^\circ \pm 20^\circ$.

1430+25 Head-tail source (see Parma et al. 1986).

1441+26 Using the 10.8 GHz polarization position angle in Mack et al. (1994), we obtain a rotation measure of 87 rad m^{-2} ($n = 1$, see Sect. 4.1).

1455+28 The source core is detected in the 4.8 GHz map.

1528+29 Using the 10.8 GHz polarization position angle in Mack et al. (1994), we obtain a rotation measure of -78 rad m^{-2} ($n = -1$, see Sect. 4.1).

1615+32 (3C 332) A jet in the southern lobe, not visible in our maps, has been found by Christiansen (1988).

1626+39 Using the 2.7 GHz polarization position angle in Parma & Weiler (1981), we obtain a rotation measure of 116 rad m^{-2} ($n = 1$, see Sect. 4.1).

1833+32 (3C 382) A bright jet is visible in the northern lobe in the map by Black et al. (1992). Using the 2.7 GHz polarization position angle in Parma & Weiler (1981), we obtain a rotation measure of 64 rad m^{-2} ($n = 1$, see Sect. 4.1).

2116+26 Using the 2.7 GHz polarization position angle in Parma & Weiler (1981), we have two equally acceptable values for the rotation measure: -165 or 178 rad m^{-2} ($n = \pm 2$, see Sect. 4.1).

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Fig. 1. Contour plots of the total intensity. The position angles of the superposed vectors correspond to the polarization position angle ($\mathbf{E}$ vector) while their length is proportional to the fractional polarization

Fig. 1. continued

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