Rotation Measure in two CSSs

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Two Compact Steep-Spectrum sources (CSSs), namely 0548+165 and 1524−136, from a list of CSSs with decreasing polarization percentages and high values of Rotation Measures on the arcsecond scale, were observed with the VLBA at 4.9 GHz and 8.4 GHz. Values for the RM up to 10^4 rad m^{-2} were found in several regions along the jet in the two sources. We suggest that a 'thin slab' is responsible for the high values of the RM found. The depolarization might be due to beam depolarization and/or inhomogeneities in the magnetic field.

1. Introduction

The CSSs (e.g. Pearson et al. 1985; Fanti et al. 1990) are physically small objects with sub-galactic dimensions. Their structure and sizes are possibly affected by the ambient gas in the central regions of the parent optical objects. At sub-arcsecond resolution these sources often show to have strongly distorted structures with recognizable jet-like features (Fanti et al. 1986; Spencer et al. 1991), consistent with strong dynamical interactions between the jets and the ambient media.

Subarcsec polarimetry has often provided evidence in favour of the interaction of these components with dense clouds of gas; see for example the cases of 3C147 (Junor et al. 1999) and 3C99 (Ferrari et al., *this conference*).

Two sources, namely 0548+165 and 1524−136 were selected for further VLBA observations from a list of CSSs with reasonable degrees of polarized emission, decreasing polarization percentages and high values of the Rotation Measure RMs > 400 rad m^{-2}. On the arcsecond scale in 0548+165, most of the polarized emission comes from the main component. This emission is strongly depolarized going from 15 GHz and 5 GHz and has a Rotation Measure RM $= 1934$ rad m^{-2} in the source rest frame (Mantovani et al. 1994). From recent MERLIN observations at 5 GHz, the source 1524−136 shows an asymmetric structure. The outer regions are 4.1% and 7.5% polarized with a factor of $\sim$5 difference in brightness. The central component does not show any polarized emission above the rms noise ($\sim$ 0.3 mJy/beam). The VLA observations (Mantovani et al. 1994) gave a RM$=-840$ rad m^{-2} in the source rest frame and no depolarization going from 15 GHz and 5 GHz.

The present polarization observations with the VLBA plus Y1 at 4.9 GHz and 8.4 GHz enable us to study the polarization characteristics of the jets, lobes and cores of these sources, and to study the interactions of the jet with the dense ambient media on milli-arcsecond scales. Amplitude and polarization data calibrations were done in $\mathcal{AIPS}$ following Cotton (1993).

2. Results

All the images at the five observing frequencies, namely 8405 MHz, 5094 MHz, 4852 MHz, 4657 MHz and 4619 MHz were convolved with a two-dimensional, circular-symmetric

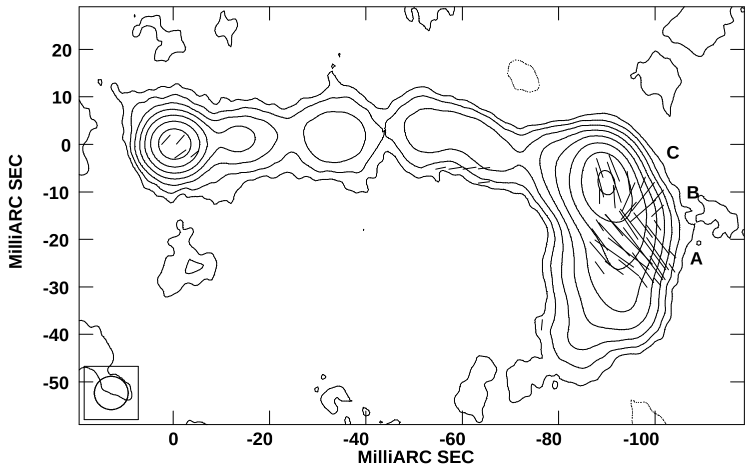

FIGURE 1. VLBA+Y1 image of 0548+165 at 4619 MHz convolved with a 6 mas beam. Contours are –1, 1, 2, 4, 8, 16, 32, 64, 128 mJy/beam. The peak flux density is 142.9 mJy/beam. A vector of 1 mas = 0.2 mJy/beam.

TABLE 1. Rotation Measures, PAs at 0 λ and polarization percent

Source	Reg	RM (rad m^{-2})	PA$_{der}$ (deg)	RM$(1+z)^2$ (radm^{-2})	8405 %	5094 %	4852 %	4657 %	4619 %
0548+165	A	–530±26	170±5	–1150±56	6.2	3.2	2.1	2.0	1.6[a]
	B	–753±65	153±13	–1636±141					
	C	–1968±36	140±7	–4275±78					
1524–136	A	–1185±85	299±17	–8556±613	5.2	6.9	6.4	6.0	5.2[b]
	B	–1385±99	254±20	–10000±715	30.2	46.4	18.1	38.5	19.6
	C	–448±82	166±17	–3235±592	63.5	7.9	8.0	17.5	7.1
	D	–913±112	194±23	–6592±809	12.1	7.7	6.5	5.3	5.0
	E	–1239±52	259±11	–8946±375	3.0	2.4	1.9	2.1	2.8
	F	–522±99	35±20	–3769±715					

[a] Values are for region A+B+C; [b] values are for region A+F

Gaussian beam 6 mas in width. As an example we show in Figs. 1 and 2 the Total Intensity images with superposed Polarized Intensity vectors for 0548+165 and 1524−136 respectively. The rms noise of the polarized images are 0.15 mJy/beam at 5 GHz and 0.4 mJy/beam at 8.4 GHz.

Three regions, labelled A, B and C were considered for the source 0548+165. Five regions, labelled from A to F were considered for 1524−136. The values of the PA for each IF have been measured considering the distribution of values in a small box (5×5 pixels) around the peak of the polarized emission.

In Table 1 the RM values for each of those components, as a result of the linear best fit of the five available points in the PA *vs* λ^2 plane, are given. The zero wavelength (de-rotated) PAs of the Electric vectors are also reported, as well as the RM values in the source rest frame, and the percentage of polarized emission at each frequency. The large changes in percentage polarization for component B and C might be due to a combination of both frequency and resolution effects.

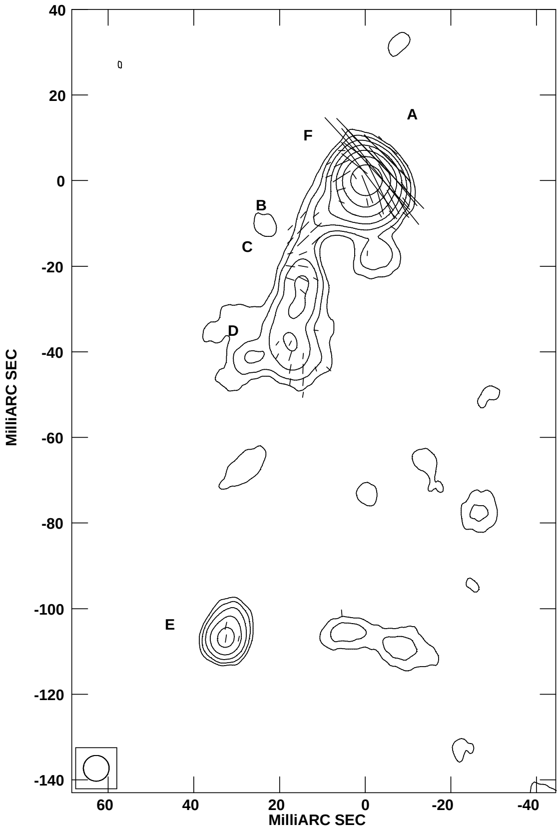

FIGURE 2. VLBA+Y1 image of 1524−136 at 4854 MHz convolved with a 6 mas beam. Contours are –2, 2, 4, 8, 16, 32, 64, 128 mJy/beam. The peak flux density is 217.9 mJy/beam. A vector of 1 mas = 0.5 mJy/beam.

3. Discussion

The linear size projected on the plane of the sky for 0548+165 is ∼330 pc. The three regions A, B and C all show large values of the RM, much larger than the RM $\leq$ 100 rad m^{-2} produced by the ISM of the Galaxy. The largest value of the RM is found in region C, where the jet starts bending. The value of the RM then decreases when going further out along the jet, from region B to A. In the three regions, the PAs rotate by angles larger than $\pi/2$, which means that the rotation is produced by a 'thin slab'.

In the bent region, where the interaction between the jet and the ISM should take place, the depolarization between 8.4 GHz and 4.6 GHz is $p_{4.6}/p_{8.4} = 0.26$. We cannot determine if this depolarization is intrinsic or due to beam depolarization. Following Tribble (1992), it is possible to calculate the depolarization produced by a Faraday screen. We found a value of $p_{4.6}/p_{8.4} = 0.32$, in agreement with the value above. Thus the observed depolarization might be due to beam depolarization if the RM scale fluctuation is of the order of the achieved resolution. The RM values in A and B are similar (at the 3σ level) and can be understood as due to an external screen. In region C, the excess RM might be due to the presence of a NLR, which may also be responsible for the large bend in the jet. 3-D hydrodynamical simulations of jet-cloud interactions (Norman & Balsara 1993) have shown that a jet can be deflected by angles up to 90°, yet preserving its collimation after the bend and inheriting the original properties of the jet. De Young

(1991) has shown that a jet can be deflected after interacting with a cloud in the NLR on a time scale of $\sim 10^6$ years at a distance of 2–4 kpc from the nucleus.

The region of the jet-cloud interaction in 1524−136 extends over 475 pc. The RM values change going from component A to E, making the astrophysical analysis more intriguing. The peak of the polarized emission is found in region A. The jet changes direction in region F, where, however, the RM is lower. Regions A+F, D and F show depolarization while region E does not show any. Following Tribble (1992), in 1524−136 the depolarization is $p_{4.6}/p_{8.4} = 0.33$. Integrating the Total Flux and the Polarized Flux of the whole source, a similar depolarization value is found ($p_{4.6}/p_{8.4} = 0.28$). This result might suggest that the depolarization can be due to inhomogeneities in the structure of the magnetic field which produce changes in the RM, on a scale comparable to that of the distances between the components. Since the differences between PAs is $> 90°$, one can say that the RM is due to an external screen.

4. Conclusions

These observations allowed us to find values for the Rotation Measures in several highly polarized regions along the jet of two CSSs. Values > 4000 rad m^{-2} and up to 10^4 rad m^{-2} for 0548+165 and 1524−136 respectively, were found. Such large values of the RMs are likely due to an external screen in the case of 1524−136, and due to an external screen plus a NLR in the case of 0548+165.

Estimates of the magnetic field in the external screen as seen along the line of sight were possible assuming an 'a priori' electron density $n_e \simeq 0.1 - 1$ cm^{-3} and a slab thickness of 1 kpc. The values obtained for 1524−136 — up to 100 μGauss — are larger than those for 0548+165, which were in the range 1.5 – 15 μGauss. Since X-ray measurements are not available and the angle of the jet axis to the observer's line-of-sight is not known, for either of the sources, the parameters cannot be better constrained.

The depolarization might be due to beam depolarization. For 1524−136, inhomogeneities in the magnetic field, and/or in the electron density of the external screen, can also account for the depolarization.

REFERENCES

Cotton, W. D. 1993, *AJ* **106**, 1241.

De Young, D. S. 1991, *ApJ* **371**, 69.

Fanti C., Fanti R., Schilizzi, R. at al. 1986, *A&A* **170**, 10.

Fanti, R., Fanti C., Schilizzi, R. et al. 1990, *A&A* **231**, 333.

Junor, W., Salter, C.J., Saikia, D.J., Mantovani, F. & Peck, A. 1999, *MNRAS* **308**, 955.

Mantovani, F., Junor, W., Fanti, R., Padrielli, L., & Saikia, D. J. 1994, *A&A* **292**, 59.

Norman, M. L. & Balsara, D.S. 1993, in: *Jet in Extragalactic Radio Sources* eds. K. Meisenheimer & H.-J. Röser, Springer Verlag, Berlin, p.229.

Pearson, T. J., Pearley, R. A., & Readhead, A. C. S. 1985, *AJ* **90**, 738.

Spencer, R.E. 1994, *Compact Extragalactic Radio Sources*, eds. J.A. Zensus & K.I. Kellermann, NRAO

Tribble, P. C. 1992, *MNRAS* **256**, 281.