Recent results on high frequency polarimetric VLBI observations of relativistic jets

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The availability of higher quality polarization images at short wavelengths has permitted the study of the magnetic field of the compact radio sources at the base of the relativistic jets. These images have shown a variety of polarization configurations with stationary and moving components, showing the presence of standing shocks, planar and oblique shocks, interactions between the jet and external medium, etc. In these proceedings, we show the results for two of the best studied compact radio sources 3C 120 and 4C 39.25.

1. The case of 3C 120

The compact structure of the nearby radiogalaxy 3C 120 (z=0.033, placing it at a distance of approximately 140 h_{65}^{-1} Mpc) consists of a core and a bent jet. It is one of the first objects in which superluminal motion was detected (Walker et al. 1987). We have performed 22 and 43 GHz simultaneous polarimetry VLBA observations of 3C 120 during 16 epochs between 10 November 1997 and 19 march 1999 (Gómez et al. 1998, Gómez et al. 2000). Due to its proximity, our observations provide an ultra-fine linear resolution (0.1 h_{65}^{-1}pc at 43 GHz). Our observations have shown a multi-component jet structure with apparent velocities for the components of the order of 4-5 $h_{65}^{-1}c$ with respect to the core (see Fig. 1). There is evidence for a strong interaction between the jet and a denser external medium coming from the stratification of the magnetic field accross the jet and the related rotation of the polarization angle.

The most striking result from our observations is the existence of a region in the jet where the superluminal components flash on and off on timescales of months, while the apparent velocity of the components remains constant and the polarization angle rotates. The rapid flux decays cannot be explained by expansion and/or radiative losses. This can be explained by the interaction between the jet and an interstellar cloud, although the passing of the component through a jet rarefaction cannot be excluded as a possible reason.

2. The case of 4C 39.25

VLBI monitoring of the peculiar superluminal radio source 4C 39.25 at centimeter wavelengths (e.g. Marcaide et al. 1994, Alberdi et al. 1997, and references therein) have revealed the presence of a superluminal component, $\underline{b}$, moving between the western component $\underline{c}$ and the easternmost component $\underline{a}$, and a weak and inverted spectrum component $\underline{d}$, the putative core of 4C 39.25, located ~2.7 mas west of $\underline{a}$ (Alberdi et

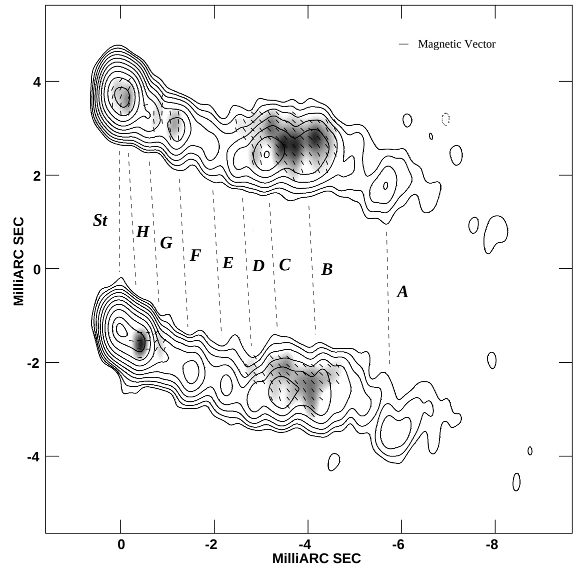

FIGURE 1. VLBI maps of 3C 120 at 22 GHz for epochs 1996 Nov.11 (top) and 1996 December 22 (bottom). Total intensity is plotted as contour maps. while the linear gray scale shows the linearly polarized intensity. Bars show the direction of the magnetic field vector.

al. 1993; Alberdi et al. 1997, 1999). Components a and c have steep spectra and have remained constant in flux density and stationary relative to each other; on the other hand, component b brightened and slowed down as it approached component a (Alberdi et al. 1993, Guirado et al. 1995, Fey et al. 1997). Component b has stopped at the projected position of component a. Polarization VLBI observations (Alberdi et al. 1999) have shown that the polarized emission is mainly associated with the eastern part of the source (components a + b). In the framework of the relativistic jet model, the motion and flux density evolution of component b can be explained as a shock wave travelling along a bent relativistic jet (Gómez et al. 1994).

2.1. *Observations and data reduction*

We performed continuum polarimetric observations of 4C 39.25 with the VLBA on 19 January 1998, 29 May 1998, 25 October 1998 and 8 February 1999, each time at 15, 22, and 43 GHz. Data imaging in total intensity was performed using the Difmap package. Imaging in polarized intensity was performed using the AIPS package.

2.2. *Results*

Fig. 2 shows the VLBA total and linearly polarized intensity images of 4C39.25 at 15, 22 and 43 GHz. E-vectors are shown overlaid on the total flux density images. For each image, the maps have been aligned vertically such that the bright eastern component (component b) is at the same angular position in each image.

These images confirm the previously reported parsec-scale structure of 4C 39.25. Components b and a are at about the same projected position. The curvature has not changed with time and does not show any frequency dependence. Although at each frequency the intensity maps at all epochs are similar, the flux density associated with the a+b region is decreasing with time.

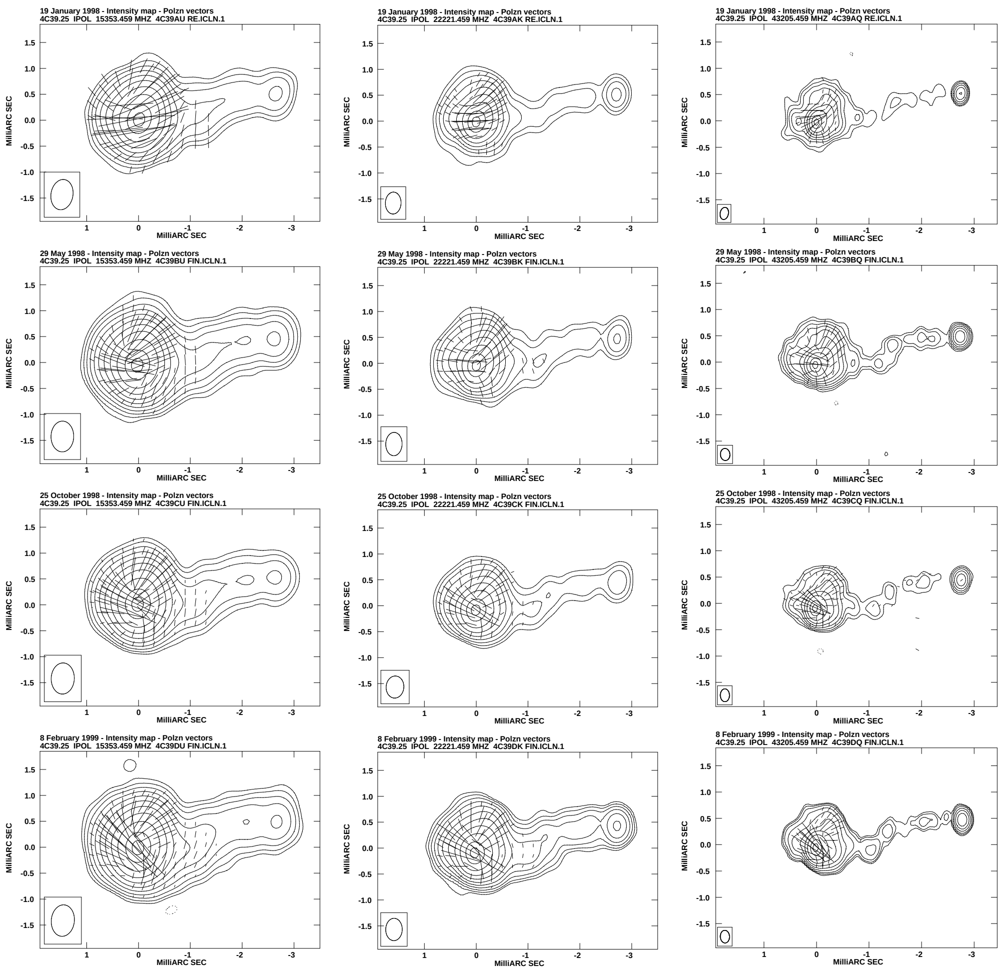

FIGURE 2. Polarized flux intensity images (E-vectors with length proportional to the polarized intensity) of 4C 39.25 overlaid to the total flux density images (contours). The maps correspond (from top to bottom) to the epochs 19 January 1998, 29 May 1998, 25 October 1998, 8 February 1999 and frequencies 15, 22 and 43 GHz (from left to right). In all maps, contours are spaced by factors of $\sqrt{2}$ in brightness, with the lowest at 3 times the rms noise level. For each map we list the rms noise ($\mathrm{mJy\,beam^{-1}}$) / the peak of brightness ($\mathrm{Jy\,beam^{-1}}$) levels at 15, 22 and 43 GHz, respectively: *19-Jan-98:* 5.23/6.278; 6.21/3.729; 3.26/1.958; *29-May-98:* 2.59/6.218; 6.28/3.768; 1.56/1.871; *25-Oct-98:* 4.70/5.638; 5.59/3.356; 2.64/1.584; *8-Feb-99:* 2.25/5.389; 1.41/3.382; 2.26/1.693.

The polarized emission is mainly associated with the eastern part of the source (components $\underline{\mathrm{a}}$ and $\underline{\mathrm{b}}$). There are two systematic trends:

• First, a change in the relative orientation of the E-vectors of components $\underline{\mathrm{a}}$ and $\underline{\mathrm{b}}$, for each frequency, as a function of time. At the three frequencies, the VLBI polarized maps are mainly dominated by two sub-components with a different magnetic field orientations. The rotation is detected in the VLBI maps at all frequencies with the easternmost polarized component polarization vector rotating clockwise.

• Second, a change in the relative polarization intensities of the subcomponents that dominate the polarized maps: the polarized intensity of the easternmost component with respect to the westernmost within the $\underline{\mathrm{a}}$+$\underline{\mathrm{b}}$ complex is increasing with time. For the first two epochs, the polarization images are dominated by the westernmost component, while the emission for the other two epochs is strongly dominated by the easternmost one.

2.3. *Discussion*

The polarization maps trace significant changes that are occuring in the source. Although components a and b are at the same projected position, the polarized maps provide evidence for an ongoing a+b interaction. If we assume that the collision is occurring, the easternmost emission would correspond to the extension of b as it turns around a, and the maximum of the brightness distribution corresponds to the interacting components a+b seen in projection. Several strong arguments give support to this scenario (Alberdi et al. 2000). We mention some of them: i) the total flux density maps are very similar for all epochs. While b is turning around a, the source structure will look rather similar due to projection effects, but the flux density of the region will decrease slowly, and steadily; ii) the polarized flux density maps change dramatically: the rotation of the polarization vectors mark and trace the projected bend in the jet trajectory as it turns away from the observer. This scenario would require a bend in a plane that does not contain the observer. This rotation is consistent with the strengthening in polarized flux of the easternmost component with time and with the slight decrease in the total intensity brightness maximum, due to a decrease in the Doppler-boosting of the radiation intrinsic to component b.

We conclude that the eastern limb of the superluminal component b is emerging from the downstream side of a. Our images are showing the effects of the interaction between a superluminal component, b, and a stationary component, a, that is, the effects of a moving shock crossing a bend in the jet in a plane that does not contain the observer.

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