VLBI DIAGNOSTICS OF JET INSTABILITIES IN 0836+710

M. Perucho, A. Lobanov
Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121, Bonn, GERMANY

Abstract: In this paper, we present new VLBA\textsuperscript{1} observations of the radio jet in the quasar S5 0836+710 at 8 and 22 GHz. The identification of the ridge lines allow us to interpret the jet structure in terms of Kelvin-Helmholtz instability. Combined with previous epochs of VLBA and VSOP\textsuperscript{2} data at 1.6 and 5 GHz, these new observations will allow us to study the evolution of the instabilities in the jet. We have detected signatures of possible jet disruption in the jet due to the growth of instabilities, which points towards a possible morphological classification of the source as an FRI, contrary to what previously thought in terms of luminosity criteria.

1 Introduction

The quasar S5 0836+710 is at a redshift of 2.16. At kiloparsec scales it was classified as a FRII source following luminosity criteria for a secondary component, located at 2" from the core. Its luminosity ($P_{21cm} = 10^{27}$ W/Hz, O’Dea et al. [1988]) is clearly over the threshold ($P_{21cm} = 10^{24.5}$ W/Hz) separating FRI and FRII sources. However, Hummel et al. [1992] observed a significant loss of collimation in the extended jet, contrary to the morphology expected for an FRII source. At parsec scales, a link was found between the ejection of a superluminal component (component B3) and a gamma-ray-optical flare (Otterbein et al. [1998]). The spectral evolution of the component B3 is consistent with the synchrotron self-absorption and adiabatic expansion in a synchrotron emitting plasma condensation. A Lorentz factor $\gamma = 12$ and a viewing angle of $\theta = 3^\circ$ were deduced for this component. Otterbein et al. [1998] also found several kinks in the jet and suggested that an apparent helical morphology at the jet can be due to growing MHD instabilities in the relativistic plasma.

\textsuperscript{1}Very Long Baseline Array, operated by the National Radio Astronomy Observatory, USA.

\textsuperscript{2}VLBI Space observatory Program led by the Japanese Institute at Space and Astronomical Science.
Lobanov et al. [1998], [2006] presented VLBA and VSOP observations of 0836+710 at 1.6 GHz and 5 GHz, and interpreted the helical structure in the jet as a result of growing Kelvin-Helmholtz instability. Using the linear stability theory they derived the Mach number of the jet ($M_j = 6$) and the density ratio between the jet and the external medium ($\rho_j/\rho_a = 0.04$).

In this paper, we present new VLBA observations of 0836+710 at 8 and 22 GHz at two different epochs separated by 16 months (July 1998 and November 1999) and combine them with the previous observations of this object by Lobanov et al. [1998], [2006]. The aim of this work is to obtain information about the jet morphology on scales of 2-200 mas, and study structural changes in the radio jet on timescales of $\sim 2$ years.

2 Observations

In Fig. 1 we show the maps from the two epochs of VLBA observations at 8 and 22 GHz. We can see structures in the jet from a few milliarcseconds to several tenths of milliarcseconds. Combined with previous observations (Lobanov et al. [1998], [2006]), these data enable to identify structures on scales from 2 mas (22 GHz) to 200 mas (1.6 GHz).

![Figure 1: VLBA images of the jet in 0836+710 at 8 and 22 GHz for two different epochs. Lines indicate the extent of the 22 GHz jets in the 8 GHz images. Structures few mas long are observed. Both frequencies are tapered in order to reveal extended emission.](image)

In order to measure the wavelengths of the perturbations developing in the jet, we identify the ridge line of the jet at different frequencies. The ridge line is traced by maxima of emission in brightness profiles taken across the jet.
In Fig. 2 we plot the locations of these maxima for the 1.6 GHz image from Lobanov et al. [2006]. The ridge line shown in Fig. 2 reveals a clear helical pattern extending up to \( \sim 150 \) mas distance from the jet origin. At larger distances, this pattern becomes disrupted, possibly reflecting real disruption of the jet flow. The same kind of plot for the 8 GHz image from the first of the two epochs presented here reveals structures on much smaller scales (2-4 mas). A combination of ridge line measurements made in a range of frequencies from 1.6 to 22 GHz, will provide reliable verification of the physical properties of the flow and the ambient medium on very different scales.

![Figure 2: Ridge line of the jet in 0836+710. The ridge line is measured from the 1.6 GHz VLBA image (Lobanov et al. [2006]). The grey scale shows the flux density of the peak. A helical pattern with a \( \sim 100 \) mas wavelength is observed. After about two wavelengths the jet is no more visible, either because of dimming, or due to disruption.](image)

3 Discussion

In Fig. 2 we observe a possible signature of disruption of the flow at distances > 150 mas. The fact that the jet becomes decollimated at kiloparsec scales and shows an irregular structure in the region of interaction with the external medium (Hummel et al. [1992]), points also towards this possibility. In this scenario, the secondary component observed at kiloparsec scales could be a subrelativistic remnant of the disrupted flow advancing through the intergalactic medium. Such features are commonly seen in numerical simulations (e.g., Perucho et al. [2005], [2006], Rosen & Hardee [2000]).

Higher dynamic range observations should enable verifying this scenario. If it is confirmed, this source, first thought to be an FRII due to luminosity...
arguments, would have to be considered as an FRI object, based on its morphology and evolution. This dual nature would turn 0836+710 into a peculiar object requiring further studies.

Our plans for this project include application of gaussian fits to the emission profiles in order to identify the ridge lines at all epochs and frequencies and use observations at four different epochs to derive the wave speeds of the observed structures. Further structural analysis will be performed by applying wavelet analysis and deriving the characteristic wavelengths and physical parameters of the jet. These measurements will be confronted by performing multidimensional RHD/RMHD numerical simulations (Perucho et al. [2006]). Finally, new high dynamic range observations with MERLIN\(^3\) will be proposed in order to investigate the link between parsec-scale and kiloparsec-scale structures in this object.

Acknowledgements: This work was supported by the Spanish DGES under grant AYA-2001-3490-C02 and Conselleria d’Empresa, Universitat i Ciència de la Generalitat Valenciana under project GV2005/244. M.P. benefited from a postdoctoral fellowship in the Max-Planck-Institut für Radioastronomie in Bonn and a Beca Postdoctoral d’Excel·lència from Generalitat.

References

[1992] Hummel, C.A, Muxlow, T.W.B., Krichbaum, T.P., Quirrenbach, A., Schalinski, C.J., Witzel, A. & Johnston, K.J. 1992, A&A, 266, 93

[1998] Lobanov, A.P., Krichbaum, T.P., Witzel, A., Kraus, A., Zensus, J.A., Britzen, S., Otterbein, K., Hummel, C.A. & Johnston, K. 1998, A&A, 340, L60

[2006] Lobanov, A.P., Krichbaum, T.P., Witzel, A. & Zensus, J.A. 2006, PASJ, 58, 253 (astro-ph/0507667)

[1988] O’Dea, C.P., Barvainis, R. & Challis, P.M. 1988, AJ, 96, 435

[1998] Otterbein, K., Krichbaum, T.P., Kraus, A., Lobanov, A. P., Witzel, A., Wagner, S.J. & Zensus, J.A. 1998, A&A, 334, 489

[2005] Perucho, M., Martí, J.M. & Hanasz, M. 2005, A&A, 443, 863

[2006] Perucho, M., Lobanov, A.P., Martí, J.M. & Hardee, P.E. 2006, A&A, in press (astro-ph/0606109)

[2000] Rosen, A. & Hardee, P.E. 2000, ApJ, 542, 750

\(^3\)Multi Element Radio Linked Interferometer operated by Jodrell Bank Observatory at the University of Manchester, UK.