EVN and MERLIN observations of ON 231 after the great optical flare of spring 1998

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Recent images of the BL Lac object ON 231, obtained from observations made with the European VLBI Network plus MERLIN at 1.6 GHz and 5 GHz after the exceptional optical outburst of Spring 1998, show remarkable new features in the source structure if compared to those previously published. Identifying the source core with the brightest flat spectrum component, we detected the existence of a (possible) counter-jet. We also found a new low brightness feature, a large bend in the jet at about 10 mas from the core. The emission extends for about 20 mas after the bend. We suggest some possible interpretations to relate the changes in the source structure with the optical and radio flux density variations in the frame of the unification model.

1. Introduction

Secular variations, on time scales of a few dozen of years, are apparent in the historic light curves of some bright Bl Lac objects. These slow changes are generally superposed by faster luminosity fluctuations, over typical time scales ranging from days to months. The nature of the secular variability has been very poorly investigated up to now mainly because it has been recognised only in a small number of objects. The most outstanding case is that of OJ 287 in which a period of 11.9 years for the changes of the optical luminosity has been safely established (Sillanpää et al. 1996). This long term variability might be related to modifications of either the orientation or the structure of the jet, as expected if a massive black hole binary system is in the nucleus of the object (Abraham and Carrara 1998; Lehto and Valtonen 1996). We can expect, therefore, that parsec scale radio jets associated with these radio sources should exhibit large structural changes detectable in VLBI images, possibly related to the activity in other spectral bands, like the optical, where the spectral energy distribution of red BL Lac objects is peaked.

To these aims we started an observing programme with the European VLBI Network (EVN) of some BL Lac objects, whose historic light curve show long term trends and which are the targets of intensive optical monitoring programs. One of these BL Lac objects is ON 231 (W Com, 1219+285). Its historic optical light curve (Tosti et al. 1999) shows that the mean source luminosity had a minimum in the early seventies and, since that epoch, it has increased. The highest level was reached in the course of a large outburst occurred in April-May 1998 (Massaro et al. 1999).

Radio light curves at various frequencies (from 4.8 GHz to 22 GHz, Aller et al. 1999, Teräsranta et al. 1998) are characterised by a behaviour not correlated with the optical: since 1980, ON 231 showed a general decreasing trend of the radio luminosity, and, after a four year long flare with a peak in 1993, its flux started again to increase in 1995.

In this contribution we present recent radio images of ON 231, obtained in 1998 and 1999, after the great optical outburst. The comparison with previous images, taken several years before, reveals interesting modifications of the parsec-scale structure of the jet.

2. The structure of ON 231 at the parsec scale

We observed ON 231 with the EVN+MERLIN facility at 1.6 GHz on 05 June 1998 and at 5 GHz on 17 February 1999. In both experiments the source was tracked for about 11 hours, providing images with a good dynamic range. The VLBI data were correlated with the Mark IIIA correlator at the MPI für Radioastronomie (Bonn). The row data output from the correlator, were calibrated using $\mathcal{AIPS}$ and were imaged with DIFMAP (Shepherd et al. 1995). Images from the MERLIN LHC polarisation were produced using $\mathcal{AIPS}$. An $\mathcal{AIPS}$ analysis path for processing join EVN+MERLIN data was then followed and the relative images made using DIFMAP. In the following we comment on the images made at the two frequencies which show relevant new features in the source structure if compared to the previously published images.

The complex structure of ON 231 is evident from the VLBI images of Figures 1 and 2. The source shows a straight collimated East-West jet at PA $\sim$110° which bends twice by $\sim$90°, in a spiral-like structure. This extension South of the jet was not detected in previous observations (Gabuzda et al. 1992, 1994, Gabuzda & Cawthorne 1996). The brightest component in the jet shown in Fig. 2 is no longer at the western extreme of the source, but in a rather central location. These results raise the question of a proper identification of the source core. To this aim, we produced two further images by combining together EVN and MERLIN data at 1.6 GHz and 5 GHz. The only component showing a flat spectrum ($\alpha = -0.06$; $S \propto \nu^{-\alpha}$) is the brightest, labelled 1 in Fig. 2. The spectral indices values of the other more prominent components, range between 0.60 and 0.90. As a consequence, we associate that component "1" with the core while the component "0" extends in the direction of a possible counter-jet.

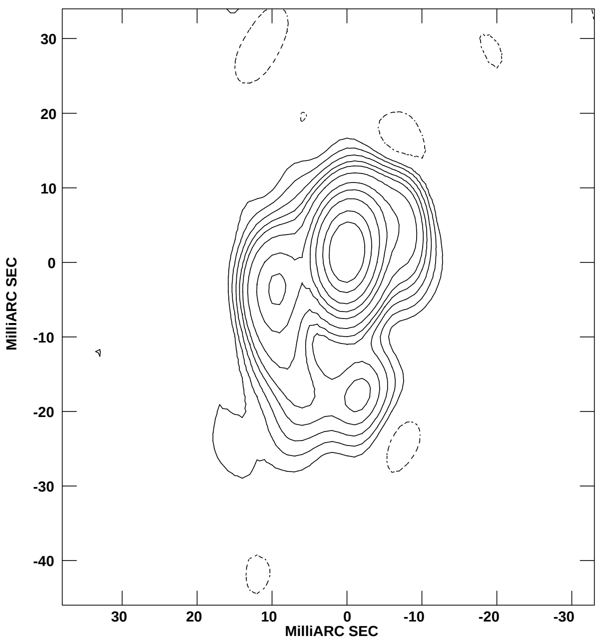

FIGURE 1. EVN image of ON 231 at 1.6 GHz. The contours levels are -3, 3, 6, 10, 15, 20, 30, 50, 70, 100, 150, 200 mJy. The peak brightness is 284.1 mJy beam^{-1}. The beam is 10.3×4.8 mas^2 at PA 0°.

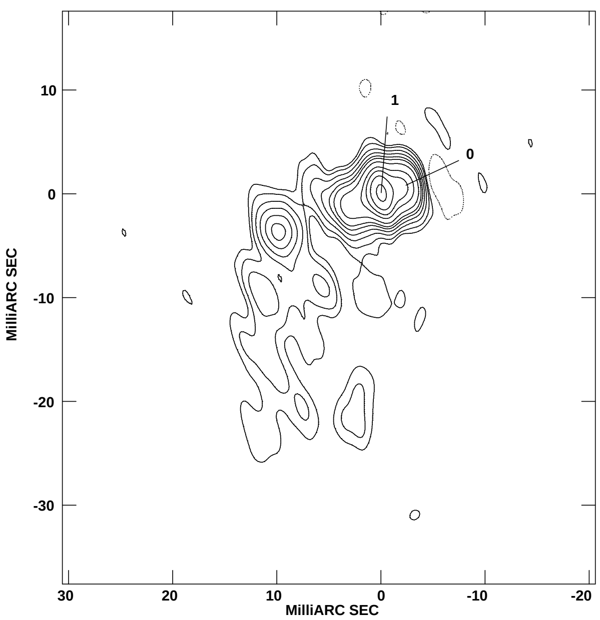

FIGURE 2. EVN image of ON 231 at 5 GHz. The contours levels are -1.5, 1.5, 3, 6, 10, 15, 20, 30, 50, 70, 100, 150 mJy. The peak brightness is 170.17 mJy beam^{-1}. The beam is 3.8×1.4 mas^2 at PA 13°.

3. Discussion

Parsec-scale jets of BL Lac objects are generally one-sided and this fact is explained in terms of strong Doppler boosting of the jet pointing close to the observer's line of sight and by the corresponding deboosting of the jet at the opposite side. In the case of ON 231, we detected the appearence of a new component just on the opposite side of the main jet, never seen in the previous images.

Several geometrical models can be considered to explain this finding. A first possibility is that the jet, pointing very close to the observer direction, undergoes strong instabilities and oscillations, and therefore the new western component is the result of one episodic large amplitude displacement. Another possibility is that emitting blobs from the nuclear source have a statistical distribution around a mean direction of the motion and that, by chance, one of them had a strong fluctuation towards West of an angle greater than those of other blobs towards East. Finally, a third scenario is that of a slowly precessing jet, which had moved approaching the observer line of sight during the past decades. The progressive increase of the beaming factor would then be responsible for the mean brightening optical trend shown by this object. At the same time the increase of the absorbing plasma column could explain the decrease of the core radio flux. The minimum angular distance was likely reached in 1997-98 when the source was observed at the highest level in the optical. After this phase, the apparent jet direction changed to the opposite side like in our images. We expect then in the next five or ten years we will observe a further development of the western jet and a fading of the eastern jet.

As shown in Section 2, the extension of the jet after the bend is clearly detected in our images for the first time. Since it cannot be a new emitting region, the limitation in sensitivity prevented its detection it in previous observations. In the case of a precessing jet, this extension could be the trace of the jet itself, rotating clockwise from South to

North. Of course, the possibility that the bending of the jet is the consequence of a strong interaction with the near environment cannot be excluded.

The geometrical models presented above of ON 231 do not require the existence of a real counter-jet in order to explain the milli-arcsecond structure. The name given to the West component has been used here in a descriptive sense: a component on the opposite side of the jet respect to the source core.

The Roma and Perugia groups acknowledge the financial support by the Italian Ministry for University and Research (MURST) under the grant Cofin 98-02-32. We acknowledge support from European Commission's TMR-LSF programme, Contract No. ERBFMGECT950012.

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