

## Two-sided radio emission in ON 231 (W Comae)

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Received 13 April 2000 / Accepted 17 May 2001

**Abstract.** Recent radio images of the BL Lac object ON 231 (W Com, 1219+285) show remarkable new features in the source structure compared to those previously published. The images were obtained from observations made with the European VLBI Network plus MERLIN at 1.6 GHz and 5 GHz after the exceptional optical outburst occurred in Spring 1998. The up-to-date *B* band historic light curve of ON 231 is also presented together with the *R* band luminosity evolution in the period 1994–1999. We identify the source core in the radio images with the brightest component having the flattest spectrum. A consequence of this assumption is the existence of a two-sided emission in ON 231 not detected in previous VLBI images. A further new feature is a large bend in the jet at about 10 mas from the core. The emission extends for about 20 mas after the bend, which might be due to strong interaction with the environment surrounding the nucleus. We suggest some possible interpretations to relate the changes in the source structure with the optical and radio flux density variation in the frame of the unification model.

**Key words.** BL Lacertae objects: general – individual: ON 231

### 1. Introduction

Historic light curves of some bright BL Lac objects have shown that fast luminosity fluctuations (typical of this class of AGNs) are frequently superimposed on long-term trends of relatively large amplitude. The origin of these long-term changes is not fully understood. An interesting hypothesis is that they can be related to changes of the jet orientation due, for instance, to the presence of a massive black hole binary system in the nucleus of the object (Abraham & Carrara 1998; Lehto & Valtonen 1996). We expect, therefore, that radio jets associated with these sources should exhibit large structural changes, detectable in VLBI images. To this aim we started to observe some BL Lac objects, which are intensively monitored in the optical, with the European VLBI Network (EVN). One of them is ON 231 (W Com, 1219+285), discovered by Wolf (1916) as a variable star and identified as the counterpart of a radio source by Biraud (1971) and Browne (1971). The historic light curve (Tosti et al. 1999a), although with gaps before 1970, shows that the mean source luminosity had a minimum in the early seventies and since that epoch has

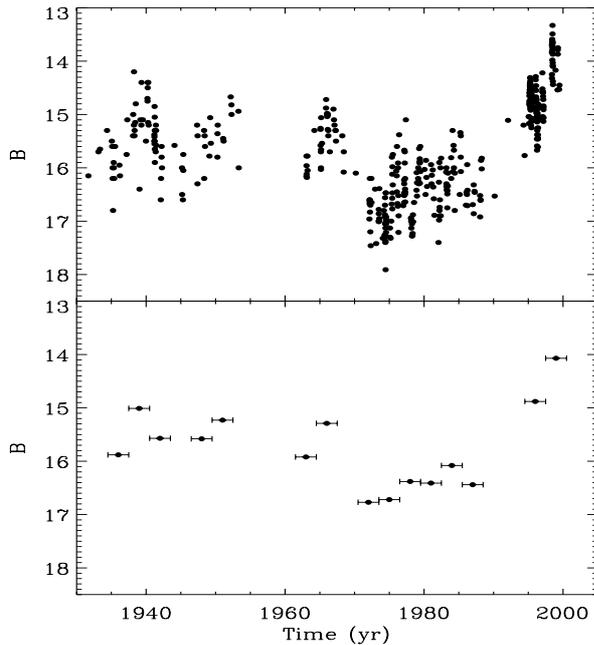
increased to reach its highest level in the spring of 1998, when the source also had a very bright outburst (Massaro et al. 1999).

The VLBI structure of ON 231 has been known for almost twenty years. The first 5 GHz image (observation epoch 1982.25) was presented by Weistrop et al. (1985) and showed a core, emitting about one third of the total flux, and a multicomponent jet elongated in Position Angle (PA)  $\sim 110^\circ$ . The same structure was confirmed by subsequent observations (Gabuzda et al. 1992; Gabuzda et al. 1994; Gabuzda & Cawthorne 1996). A recent image at 15 GHz can be found in Kellermann et al. (1998) in which the jet can be tracked up to about 10 mas from the nucleus. The innermost structure at 22 GHz, with a resolution of about 0.35 mas, can be seen in the three VLBA maps covering the period from 1995.31 to 1997.58 presented by Jorstad et al. (2001). Radio images of ON 231 on the arcsecond scale (de Bruyn & Schilizzi 1984; Kollgaard et al. 1992; Perlman & Stocke 1994) show emission from an extended faint region directed southwest (centred at PA  $\sim 310^\circ$ ) with respect to the core.

We used the EVN+MERLIN facility to observe ON 231 at 1.6 GHz and at 5 GHz. In this paper we present images made at the two frequencies which show relevant

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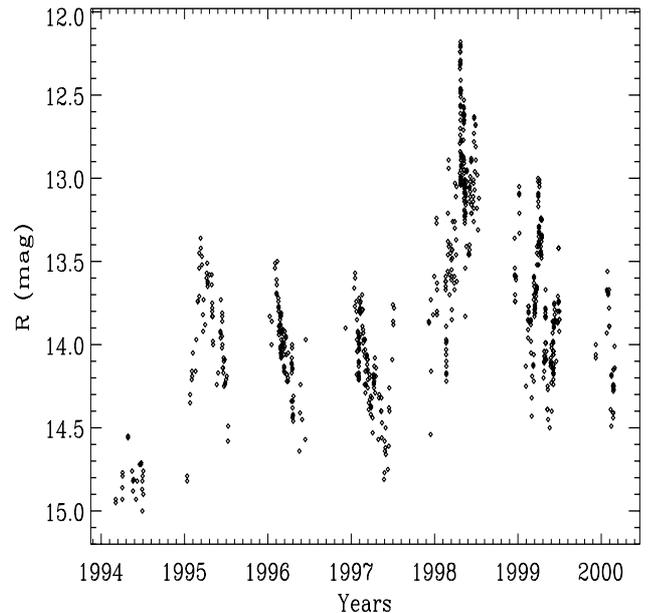
**Fig. 1.** The historic light curve of ON 231 in the *B* band after 1930. The data up to the spring of 1997 are taken from Tosti et al. (1998), while those of 1998 are given in Tosti et al. (1999b). In the lower panel the same data have been averaged over intervals of three years.

new features in the source structure compared to the previous published images. We propose some possible scenarios to relate these changes with the long-term luminosity evolution.

## 2. Long-term behaviour in the optical and radio

ON 231 is one of the few BL Lac objects whose variations have been known for about one century, although before the 1970s it was observed only occasionally. For the past six years it has been intensively monitored, in particular by the groups of Perugia and Rome. Our photometric data up to 1998 have already been published together with those of other collaborating groups in several papers (Tosti et al. 1998; Tosti et al. 1999b; Massaro et al. 1999). Additional recent data of the 1999 observational season have been obtained with the Automatic Telescope of the Perugia Observatory and the reflector of the Vallinfreda Astronomical Station, near Rome. Observational equipment and data reduction procedures are described in detail in the above references. The up-to-date historic light curve is reported in the upper panel of Fig. 1.

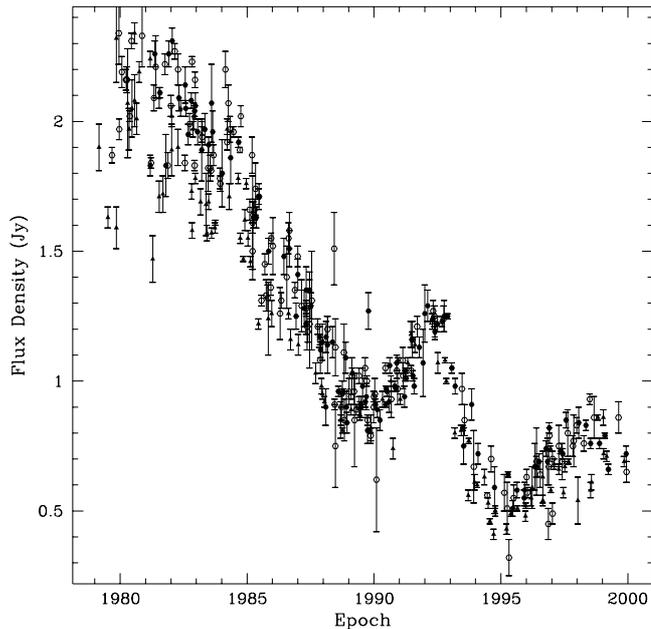
The sparse observations of ON 231 before 1970 show magnitude variations generally in the interval 14.5–16.5. It had a minimum around 1975 and after a few years a brightening phase began. This brightening trend is clearer if the data are averaged over time intervals longer than the typical fluctuation duration. In Fig. 1 (lower panel) we plotted the mean magnitude computed over three year intervals: the brightening trend after 1975 is evident despite the gap from 1990 to 1995. The luminosity evolution in



**Fig. 2.** The light curve of ON 231 in the *R* (Cousins) band after 1994.

the period 1994–1999 is shown in detail by the light curve in the *R* band of Fig. 2. Apart from the time intervals in which ON 231 is not visible because of its proximity to the sun, this light curve shows that the source behaviour after 1995 was characterized by a series of major bursts, at least one per year with the present time sampling, on which rapid variations are superimposed. These events had a typical time-scale of about five-six months and flux changes of a factor of about 3. In Spring 1998, ON 231 had an exceptional outburst and reached the highest recorded brightness level. In this episode the energy spectral index in the optical band hardened from  $-1.4$  to  $-0.5$  at the maximum and the linear polarisation increased up to about 10% with a PA in the range of  $130^\circ$ – $160^\circ$  (Massaro et al. 1999), as expected in the case of synchrotron radiation from freshly accelerated electrons. After the burst, the mean source luminosity decreased and was comparable to that observed in the previous years, but with variations on shorter time scales.

Radio light curves at various frequencies in the range from 4.8 GHz to 22 GHz (Aller et al. 1999; Teräsranta et al. 1998) show a behaviour not correlated with that in the optical. Figure 3 gives an up-to-date version of the multiband light curve to the end of 1999 taken from the University of Michigan Radio Astronomy Observatory database. ON 231 showed a general decreasing trend of the radio luminosity starting from about 1980. After a four year long flare with a peak in 1992, the source flux started to increase again in 1995. The comparison with the optical light curve, despite the different behaviour in the first portion, indicates that in 1995 ON 231 likely entered a new phase in which both the optical and radio flux levels started to increase. Recall that our present knowledge about possible correlations between the long-term behaviour of BL Lac objects in the radio and optical bands is



**Fig. 3.** The radio light curve of ON 231 from the UMRAO data base: 4.8 GHz filled circles; 8.0 GHz open circles; 14.5 GHz triangles.

rather poor because of the small number of studied sources and of the irregular time coverage. It is therefore hard to reach a firm conclusion regarding whether the increase of the radio and optical fluxes of ON 231 after 1995 is just a coincidence or it has a real origin. The latter possibility can be adopted as a working hypothesis, and can be used to formulate some scenarios for the evolution of the jet geometry, as we will discuss in the last section.

### 3. VLBI and MERLIN observations and data reduction

ON 231 was observed with the EVN plus MERLIN on 05 June 1998 at 1.6 GHz and on 17 February 1999 at 5 GHz. The data were recorded with the MarkIII A terminals at the stations in Mode B (28 MHz bandwidth). During each experiment, the source was tracked for about 11 hours together with the calibration sources OQ 208 and 3C 286, observed for 13–minutes scans, regularly spaced over the experiment. The VLBI data were correlated at the MarkIII A correlator of the Max-Planck-Institut für Radioastronomie (Bonn, Germany). The raw data, output from the correlator, were integrated for 4 s. Of the 11 stations of the EVN, namely Jodrell Bank and Cambridge (UK), Westerbork (NL), Effelsberg (D), Medicina and Noto (I), Onsala (S), Sheshan (Shanghai, China), Nanshan (Urumqi, China), Torun (PL), Simeiz (Ukraine), nine gave fringes at 1.6 GHz (all but Sheshan and Torun). At 5 GHz Effelsberg could not observe because of snow and Simeiz could not take part in the observations. At the Jodrell Bank Observatory, the Lovell telescope was used at 1.6 GHz and the Mark2 telescope at 5 GHz.

The correlator output was calibrated in amplitude and phase using *AIPS*<sup>1</sup> and imaged using DIFMAP<sup>2</sup> (Shepherd et al. 1995). Total power measurements taken at the same times as the VLBI observations and the gain curve of the telescopes were applied in the amplitude calibration process. The self-calibration procedure, which uses closure amplitudes to determine telescope amplitude corrections, gave calibration factors that were within 10% of unity for all the telescopes but Cambridge, Simeiz and Torun, which were in the range 15–20%.

The source was also tracked by MERLIN. Initial values for the telescope and correlator gains were determined from a short observation of a bright, unresolved calibration source. The primary calibrator 3C 286 was scheduled during the observations in order to fix the absolute flux density scale. Images from the MERLIN LHC polarization data were produced using *AIPS*. An *AIPS* analysis path for processing joint EVN+MERLIN data was then followed and the relative images were made using DIFMAP.

### 4. The structure of ON 231 on the parsec scale

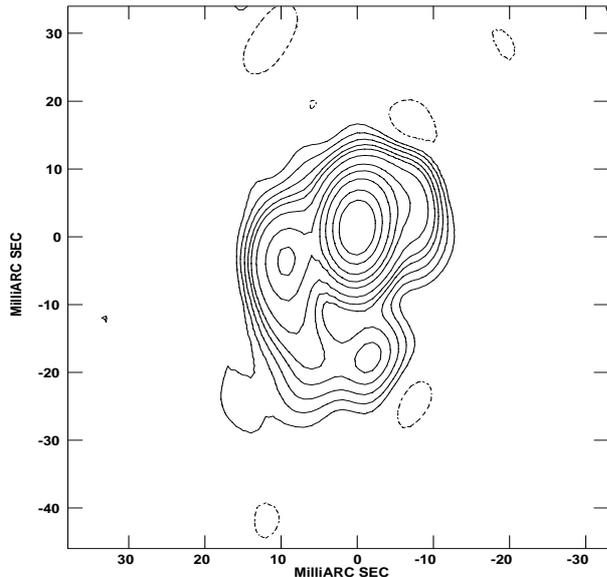
The complex structure of ON 231 is evident from the two full-resolution VLBI images of Figs. 4 and 5 at 1.6 GHz and 5 GHz respectively. The source shows a straight collimated East-West jet at PA  $\sim 110^\circ$  which bends twice by  $\sim 90^\circ$ , in a spiral-like structure. This extension South of the jet was not present in previously published images, but it was partially detected by observations with the VLBA at 2.3 GHz in January 1997<sup>3</sup>, included in the Radio Reference Frame Image Database (RRFID). Charlot et al. (1997) obtained a 5 GHz image with EVN observations in February 1994. The achieved mean beam size of about 20 mas was not adequate to resolve the jet but good enough to show the presence of a component South-East of the core, which is likely the jet extension seen in our images.

The jet shows a multicomponent structure and the most relevant difference with respect to literature images (Gabuzda et al. 1992, 1994; Gabuzda & Cawthorne 1996) is that the brightest component is no longer at the western extreme of the source, but rather in a central location. In fact, we clearly detect an extension on the western side of the brightest component at both frequencies. Such an extension is also visible on a larger scale. The phase referenced MERLIN image at 5 GHz shows that the source is resolved by the interferometer at a 50 mas resolution scale. In Fig. 6 we can see an extension of the brightness distribution on both sides of the central bright component, along the source major axis at PA  $\sim 110^\circ$ , plus an extension on

<sup>1</sup> *AIPS* is the NRAO's *Astronomical Image Processing System*.

<sup>2</sup> DIFMAP is part of the *Caltech VLBI software Package*.

<sup>3</sup> The VLBA images at 2.3 GHz and 8.4 GHz of 1219+285 are available in the Radio Reference Frame Image Database (RRFID) of the United States Naval Observatory (USNO). <http://maia.usno.navy.mil/rorf/rrfid.html>



**Fig. 4.** VLBI map of ON 231 at 1.6 GHz. The contour levels are  $-3, 3, 6, 10, 15, 20, 30, 50, 70, 100, 150, 200$  mJy. The peak brightness  $284.1$  mJy beam $^{-1}$ . The beam is  $10.3 \times 4.8$  mas $^2$  at PA  $0^\circ$ .

the South-Eastern part of the source. We performed several tests to ensure that the western extension detected on the mas scale (component C0 in the 5 GHz EVN image) is real. In the process of producing the hybrid radio images at both frequencies, the self-calibration was done, windowing out the clean components from the western emission. The images we obtained were worse than those presented in the paper, showing a poor fit between model and visibilities on the longest baselines. In particular, the amplitude gain corrections required for the two Chinese stations (which allowed high resolution in the East-West direction) were of the order of  $\sim 25\%$  at 5 GHz. In the “normal” process, i.e. cleaning on the emission from the western area persisting in the residual map, the corrections were  $\leq 8\%$ , comparable to those applied to the other stations and in agreement with the corrections required when self-calibrating the data set of the calibrator source OQ 208. We note that the images were made using both the analysis packages *AIPS* and *DIFMAP*, obtaining almost identical structure for ON 231.

These results raise the question of a proper identification of the source core. Two hypotheses can be considered: *i*) the core is the brightest component and we observed the development of a new component on the opposite side of the jet, *ii*) the core is located at the western extreme of the jet and we observed an exceptionally bright intermediate component. To tackle the problem, we produced two further images by combining EVN and MERLIN data at both frequencies. The images were made with the same resolution and were used to map the distribution of the spectral index ( $S \propto \nu^\alpha$ ), reported in grey scale in Fig. 7, superposed on the contour map at 5 GHz. The uncertainties in the phase centre locations in the two images (lost in processing the data), are at the pixel level and can slightly

affect the spectral index estimate. Of course, we assumed that the mean flux of the various components did not change dramatically in the eight months between the observations, as expected from the behaviour at these intermediate radio frequencies, shown in Fig. 3. The measured overall flux densities at both frequencies in the MERLIN images and EVN+MERLIN images agree to better than 1%. We measured total fluxes of 903.3 mJy and 755.5 mJy at 1.6 GHz and at 5 GHz respectively, corresponding to an overall spectral index of  $-0.16$ . The only component showing a flat spectrum ( $\alpha = 0.06$ ) is the brightest one, labelled *b* in Fig. 7. We point out that the value for the East-Southern rim could be affected by the relatively low signal to noise ratio. The spectral index values of the other, more prominent components, labelled *a*, *c* and *d*, are  $-0.60$ ,  $-0.57$  and  $-0.89$ , respectively. This result suggests that the core is likely the brightest component in *b*, i.e. component C1 in Fig. 5, rather than C0 at the western edge of *b*, although we cannot rule out the latter hypothesis.

We performed a test to confirm the identification of C1 with the core. Making use of the *AIPS* task *JMFIT*, we evaluated the angular distances between the main jet components in the low resolution EVN+MERLIN images. One would expect that if the core is actually located at the western edge of *b*, the angular distance from the bright, isolated, component *c* in Fig. 7 (corresponding to C3 in Fig. 5) and the core component *b*, which is a blend of C0, C1 and C2, should be greater in the image at 5 GHz than in the image at 1.6 GHz. In fact, in the former case, C0, supposed to be the core, should contribute much more than C2 (almost equal in flux density) to the total flux density of *b* due to its flat or inverted spectral index between 1.6 GHz and 5 GHz, producing a shift of the centre of the Gaussian component(s) fitting *b*. To check this we have tried to fit the brightness distribution of the main part of the jet region with a three-Gaussian component model, leaving their central positions as free parameters. The position of the most Eastern component *c* was then taken as reference point. In the 1.6 GHz case we found that the centres of the two Gaussians other than *c*, were located in PA  $\sim 70^\circ$  at distances of 10.4 and 12.6 mas respectively. The solution for the brightness distribution at 5 GHz failed to converge to the three Gaussian components of the input model. The output was a two component model separated by 10.4 mas each other, equal to the separation found for a pair of components in the previous solution. The above solutions were found to be a stable convergence of the model fit process achieved by *JMFIT* in both cases, and suggest C1 as the core of ON 231. A further point in favour of this suggestion comes from the analysis of the behaviour of the spectral indices of the individual components C0, C1 and C2, which give a total flux density of 454 mJy at 5 GHz for *b* (from the model in Table 1) and conspire to give a flat spectrum to it. Let us take C0 as the core component in ON 231 with an inverted spectral index of  $+2.5$ , as expected for a synchrotron self-absorbed source, and a spectral index  $-0.7$  for C2. C1 will then contribute for about 260 mJy to the total flux density

of  $b$  at 1.6 GHz, implying it has an almost flat spectral index, rather unusual for a jet component. A more normal inverted spectral index for  $C0$ , say  $\alpha = +1$ , makes the spectral index of the two other components even flatter. All these results indicate that the core is likely the brightest component  $C1$  in  $b$  rather than  $a$  at the western edge, even though we cannot rule out the alternative hypothesis. We will further discuss this point in Sect. 4.1.

The total jet extent along the axis in our images is  $\simeq 15$  mas, while it is shorter in the previous images, ranging from about 9 to 11 mas. A weak component at 14 mas is visible in the 8.4 GHz image by Gabuzda & Cawthorne (1996) and a much farther one, at about 25 mas along the jet axis at PA  $\sim 110^\circ$ , was reported by Gabuzda et al. (1994). We found no evidence for emission at such long distances from the source centre. We stress that according to the core identification given above, the extension of the eastern jet would reduce to about 13 mas, closer to the previous estimates.

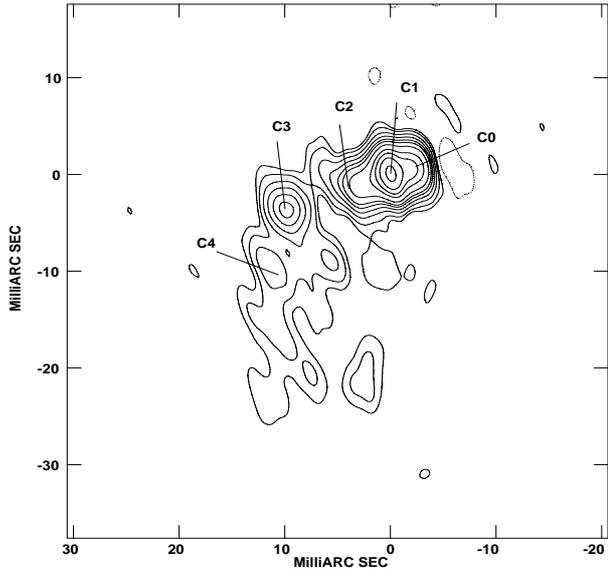
#### 4.1. Components of the jet structure

The occurrence of various emitting components in the jet of ON 231 has been recognized from early VLBI images. Weistrop et al. (1985) reported the detection of at least three components. Gabuzda et al. (1992) detected four components, later increased to eight/nine by Gabuzda et al. (1994) and Gabuzda & Cawthorne (1996). From these observations, which span a time interval of about three years, the authors estimated component velocities  $\beta_{\text{app}}h$  in the range 0.62–2.42, increasing with the distance from the core. Jorstad et al. (2001) at 22 GHz found a component moving at 1.5–2.3 in the inner part of the jet.

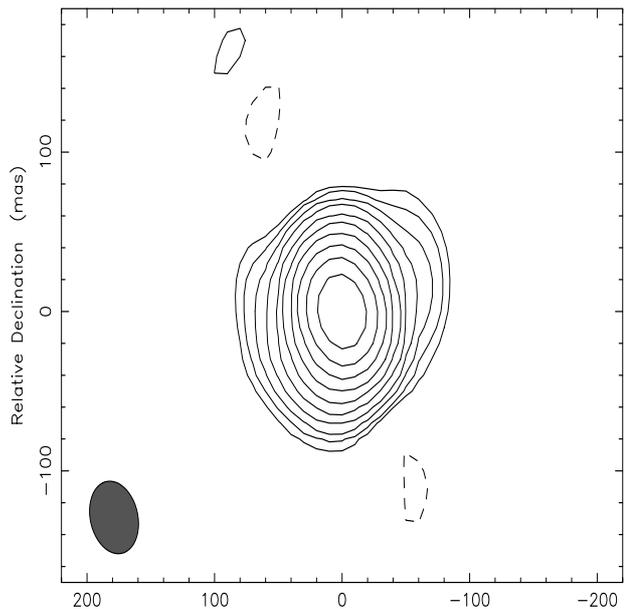
We present in Fig. 5 the most resolved source structure at 5 GHz that can be modelled with five Gaussian components, with a good formal agreement between data and model, with  $\chi^2_\nu$  quite close to unity. In Table 1, together with the flux of each component, we report the angular distances from the centre of the brightest component  $C1$ , the corresponding PAs, the major axis, the axial ratios and the orientation of the best fitted Gaussians. The component  $C1$  is the one giving the major contribution to the flux of the flat spectrum component  $b$  in the map of Fig. 7. Taking into account that both components are in the same position despite the different resolution, we can identify  $C1$  as the core of ON 231. The model parameters of Table 1 fit well the visibilities of the longest baselines at 1.6 GHz, while it does not account for the total flux density on the short baselines.

#### 4.2. Jet orientation and intrinsic speed

In the following, we derived some estimates for the source orientation with respect to the line of sight and for the intrinsic plasma speed based on a comparison of our images and previously published data used to derive proper mo-



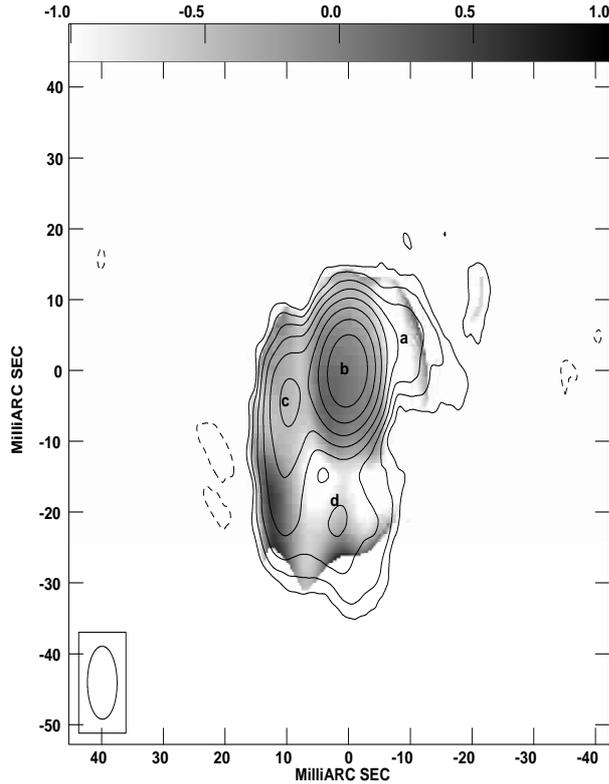
**Fig. 5.** VLBI map of ON 231 at 5 GHz. The contour levels are  $-1.5, 1.5, 3, 6, 10, 15, 20, 30, 50, 70, 100, 150$  mJy. The peak brightness is  $170.17$  mJy beam $^{-1}$ . The beam is  $3.8 \times 1.4$  mas $^2$  at PA  $13^\circ$ .



**Fig. 6.** MERLIN image of ON 231 at 5 GHz. The contour levels are  $-0.1, 0.1, 0.2, 0.4, 0.8, 1.6, 3.2, 6.4, 12.8, 25.6, 51.2\%$  of the peak brightness of  $672.6$  mJy beam $^{-1}$ . The beam is  $47 \times 37$  mas $^2$  at PA  $23^\circ$ .

tion estimates. We also investigate the possibility that the steep-spectrum emission to the west of  $C1$  is indicative of the counter-jet. For our purposes we used the full resolution 5 GHz image reported in Fig. 5 and the components from the model fitting given in Table 1.

It is not easy to support a proper association between any of the components in our model and those from observations made roughly 10 years ago by Gabuzda et al. (1994). The brightness profile along the jet in our images is quite different from those resulting from previous



**Fig. 7.** Spectral index (grey scale) map computed from the EVN-MERLIN combined images at 1.67 and 5 GHz, with a resulting beam of  $10.3 \times 4.8$  mas at PA  $0^\circ$ . The 5 GHz contours correspond to  $-0.4, 0.4, 0.8, 1.6, 3.2, 6.4, 12.8, 25.6, 51.2$ , per cent of the peak brightness of  $426.4$  mJy beam $^{-1}$ .

observations, as shown in Fig. 8. Note that the peak flux of the component  $C1$ , which we identify as the core of the radio emission, decreased from 250 mJy in the early observations by Gabuzda et al. (1992) to 170 mJy in our data with a ratio in agreement with the total flux decrease in this time interval (Fig. 3).

A plausible association could be made between our component  $C3$  and the  $K2$  of Gabuzda et al. (1994). According to their study, this component moved eastward at  $\sim 0.37$  mas/year in 1.88 years. Assuming that its velocity remained constant in the following ten years, it should now be at about 11.3 mas from the core, compatible with the distance of  $C3$  from the component  $C1$ .

A proper motion  $\mu = 0.37$  mas/year corresponds to  $\beta_{\text{app}} = 1.66$  for  $H_0 = 100$  km s $^{-1}$  Mpc $^{-1}$  and  $q_0 = 0.5$  (same cosmology as in Gabuzda et al. 1994). Using the standard formulae given in Pearson & Zensus (1987), the derived apparent superluminal speed implies a minimum value for the intrinsic plasma speed  $\beta_{\text{intr}} = 0.84$ , which can be obtained if the viewing angle  $\theta \sim 31^\circ$ . The maximum allowed angle is  $\sim 62^\circ$ , which is a large value for BL Lac, even considering that it is an upper limit.

Let us now test whether it is plausible that the steep-spectrum emission to the west of  $C1$  is a counter-jet; i.e. the Doppler de-boosted jet that is receding from the observer. If we assume that the intrinsic source structure is

**Table 1.** Modelfitting 5 GHz data set.

Comp.	Flux (mJy)	Radius (mas)	PA (deg)	Major (mas)	Axial ratio	Phi (deg)
$C0$	110.6	2.36	$-71.6$	1.8	0.32	$-86.1$
$C1$	243.0	0.00	0.0	1.5	0.45	$-81.1$
$C2$	100.3	3.32	109.0	3.0	0.67	88.6
$C3$	66.6	10.4	113.4	5.7	0.45	21.8
$C4$	19.5	14.7	135.8	3.7	0.60	$-76.2$

*Note:* components are ordered from West to East.

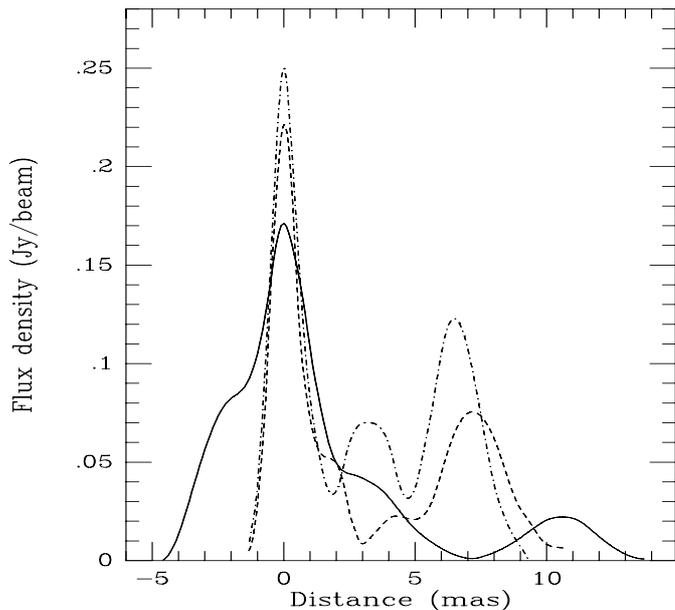
symmetrical, an estimate of  $\beta_{\text{intr}}$  and  $\theta$  can be derived. If  $C1$  is the core, in order to estimate the jet to counter-jet brightness ratio  $R(S)$ , we should compare the flux of the component  $C0$  to the sum of the fluxes from  $C2$ ,  $C3$  and  $C4$ . This leads to a ratio  $R(S) \sim 1.7$ , corresponding to  $\beta \cos \theta \sim 0.11$ . As indicated above, based on the observed apparent superluminal motion,  $\beta_{\text{intr}} \geq 0.84$ ; this implies a *maximum* value of  $\cos \theta \sim 0.13$ , or a minimum viewing angle of  $\theta \sim 82^\circ$ . This value is far too large to be plausible; in other words, the emission to the West of  $C1$  is far too bright to be a counter-jet. We discuss alternative interpretations of this emission below.

## 5. Discussion

The intensive optical monitoring of some bright BL Lac objects shows the existence of long-term trends, which can be related to structure modifications of the source. Our recent VLBI images of ON 231 were obtained during the very bright and active phase in the optical beginning in 1995, following the twenty-year increase in the mean luminosity, and show significant changes with respect to several previous VLBI images taken since 1987.

As already discussed in Sect. 4 we identified the source core with the brightest component on the basis of its flat spectrum. The most important consequence of this result is that we detected a new component, not visible in older images, at PA  $\sim -70^\circ$ , opposite to the main jet. The absence of this component in the subsequent 22 GHz map (epoch 1997.58) by Jorstad et al. (2001) could be due to its rather steep spectrum. We stress, however, that those images indicate a brightening of a component at about 2 mas East of the core whose flux density remained the strongest.

Parsec-scale jets of BL Lac objects are generally one-sided, and this is explained by the strong Doppler boosting of the jet pointing to the observer line of sight and by the corresponding deboosting of the jet at the opposite direction. In a few cases, however, indication for double jet and complex structures have been reported in the literature, like those found in 1308+326 by Pyatulina et al. (1999), who analysed a series of 8 GHz images from the geodetic VLBI data base. In particular, they noticed the appearance of components in different directions. Furthermore, jet structures in BL Lac sources are frequently not very well aligned and show wiggles, suggesting either a strong



**Fig. 8.** 5 GHz intensity profiles along the jet at PA  $\sim 110^\circ$  at different epochs: 1987.41 (dot-dashed line) from Gabuzda et al. (1992), 1989.29 (dashed line) from Gabuzda et al. (1994) and 1999.13 (solid line), our data.

interaction with the surrounding medium or some kind of motion, regular (e.g. precession) or not, of the jet itself.

We can consider a few possible scenarios for interpreting both the time evolution of the optical luminosity and the changes of the jet structure of ON 231 on the parsec scale. A first possibility is that the jet, pointing very close to the observing direction, undergoes strong instabilities and oscillations, and therefore the new western component is the result of one episodic large amplitude displacement. Again, emitting blobs from the nuclear source can be distributed around a mean direction of the motion and one of them could be displaced toward West at an angle greater than that of other blobs. Future VLBI images will then show the evolution of this unique component, while the others will continue to move along the former direction. It will be interesting to verify if the occurrence of new very bright optical outbursts are related to the presence of components on the west side (or other directions) of the core.

Another possible scenario is that of a slowly precessing jet approaching the observer's line of sight over the past few decades. The progressive increase of the beaming factor would then be responsible for the mean brightening optical trend shown by this source, and the minimum angular distance was likely reached in 1997–98 when the source was observed at the highest level. After this phase, the apparent jet direction changed to the opposite side as in our images. A more detailed model, which takes into account the evolution of the emitting electron population and the radiation transfer, is necessary to explain the absence of a positive correlation between the radio and optical light curves, but it is beyond the aim of the present pa-

per. In this framework, we can expect that in the next five or ten years a further development of the western jet and a fading of the eastern jet will be observed. The absence of radio emission on the North side of the jet axis, even on the arcsecond scale (Kollgaard et al. 1992; Perlman & Stocke 1994), indicates that the precession cone axis lies South-Southwest respect to the line of sight.

If the above core identification is not correct and the core corresponds to the weak component at the western extreme, it is necessary to understand why a jet component achieved a spectrum flatter than the core itself. A possible explanation is that the jet suffered a strong interaction with the surrounding matter and changed its direction, as in the recent model proposed by Pohl & Schlickeiser (2000). A relativistic hadronic blast wave is emitted by the central engine and a radiation burst is produced when it interacts with near dense clouds. Synchrotron emitting electrons can be originated from the decay of charged pions produced in the nuclear collisions between the blast wave particles and those of the cloud. We expect, therefore, that gamma rays having energies greater than about 50 MeV are copiously produced in such an event. ON 231 is known to have been detected by EGRET (Mukherjee et al. 1997), but unfortunately no data after 1995.5 are available.

The extension of the jet after the bend is clearly detected in our images for the first time. Since this is not a new emitting region, it was not detected in previous images due to sensitivity limits. In the above scenario of a precessing jet, it could be the trace of the jet itself, rotating clockwise from South to North. A second possibility is that the bending of the jet is the consequence of a strong interaction with the near environment.

Finally, we would like to stress the relevance of a coordinated study of multifrequency variability with VLBI mapping, particularly for BL Lac objects like ON 231 which have the synchrotron peak in the near IR-optical band. Our data suggest that the occurrence of a long-term trend in the optical luminosity and of periods of enhanced activity could be related to changes in the innermost radio structure. A better understanding of these phenomenon requires both an intense optical monitoring and VLBI mapping, spaced not longer than one year apart. Such a program can be realised only for a small sample of sources and ON 231 should be one of the primary targets.

*Acknowledgements.* 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. This research has made use of the data from the University of Michigan Radio Astronomy Observatory which is supported by funds from the University of Michigan. This research has made use of the United States Naval Observatory (USNO) Radio Reference Frame Image Database (RRFID).

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