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# The Two-Sided VLBI Source in the Seyfert Galaxy Mrk 231

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**Abstract.** The Seyfert 1/starburst/IR galaxy Mrk 231 (UGC 08058), at $z = 0.0422$, has been imaged with the VLBA at frequencies ranging from 1.4 GHz to 22 GHz. The radio image shows a triple source of total size 50 mas ($30h^{-1}$ pc), with a self-absorbed central component and two detached lobes. The northern lobe, located $12h^{-1}$ pc from the core, is free-free absorbed at the lowest frequencies; there also seems to be free-free absorption in the southern component. The linear scale over which this absorption takes place is several times larger than that seen in NGC 1275/3C 84.

The axis of the 50-mas radio source is approximately 60° from the elongation of the central component on the 1-mas scale. The spectrum of this central component becomes optically thin between 5 and 8.4 GHz, and resolves into a small triple source of size $\sim 1.0h^{-1}$ pc at 15 GHz. There is no hint of a jet or other structure directly connecting this central component to the outer VLBI lobes.

## 1. VLBA Imaging

VLBA observations of Mrk 231 were made at 1.4, 2.3, and 5.0 GHz in November 1995, and at 5.0, 8.4, 15, and 22 GHz in December 1996. The 1996 observations also included a single VLA antenna at 5.0, 8.4, and 15 GHz, as well as the phased VLA at 22 GHz. The left-hand panel of Figure 1 is an image of the large-scale VLBI triple source at 5 GHz from the December 1996 observations; the size and orientation of this triple are consistent with the lower-resolution EVN image made in the 1980s (Neff & Ulvestad 1988). The brightness temperature of the core is $\sim 3 \times 10^9$ K. A north-south slice through the spectral-index map between 1.4 and 2.3 GHz clearly shows a spectral inversion 20 mas north of the core, indicating free-free absorption $12h^{-1}$ pc from the nucleus. The emission measure is $\sim 2 \times 10^7$ cm$^{-6}$ pc, and $\langle {n_e}^2 \rangle^{1/2} \sim 3 \times 10^3$ cm$^{-3}$, consistent with the inner narrow line region. This absorption takes place further from the core than in NGC 1275 (Walker et al., these Proceedings, p. 133).

The right-hand panel of Figure 1 is an image of the central source at 15 GHz. Here, the core resolves into a triple source of size $\sim 1.0h^{-1}$ pc. The position angle of this triple is very different from the larger-scale VLBI source, implying that the symmetry axis on the sub-parsec scale may be very different from that on the scale of a few parsecs or greater. The peak flux density in the small triple source decreases rapidly from 5 GHz to 22 GHz, with $\alpha \approx -1.0$. A map of the spectral index between 8.4 and 15 GHz confirms that there is no flat-spectrum component at these frequences, so the identity of the galaxy nucleus within the central triple is still uncertain. Since the radio core becomes optically thin near 5 GHz, we infer a magnetic-field strength of $\sim 0.1$ mgauss.

## 2. VLA Imaging

Mrk 231 is well known to have diffuse, large-scale emission up to $\sim 30''$ south of the radio core, and Balmer-line emission roughly $10''$ south of the core (de Bruyn & Wilson 1976; Hamilton & Keel 1987; Hutchings & Neff 1987). Our scaled-

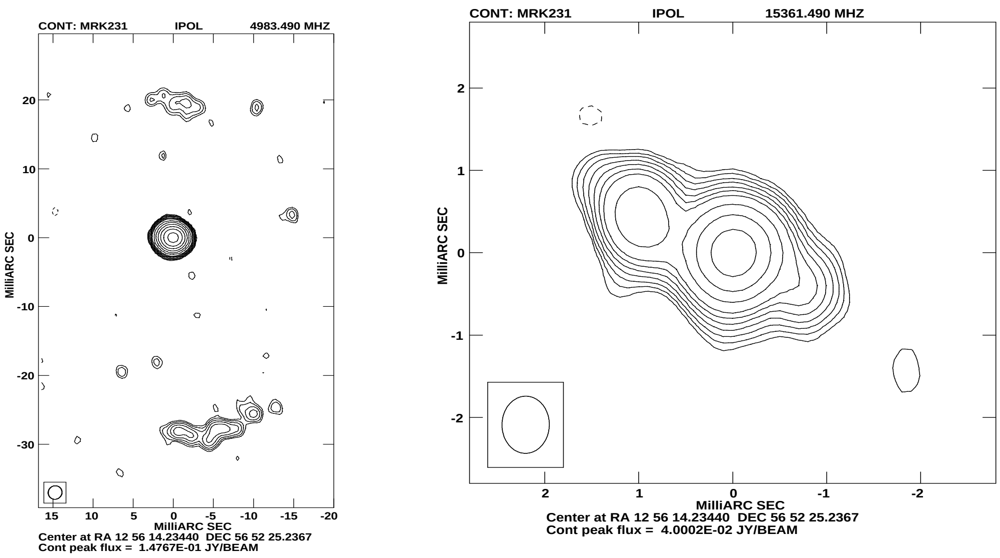


**Figure 1.** VLBA images of Mrk 231, both from data acquired in December 1996. An angular size of 1 mas corresponds to $0.6h^{-1}$ pc. The left-hand panel shows a 5-GHz image; the total north-south extent of the source is approximately $30h^{-1}$ pc. The right-hand panel shows the 15-GHz image of the central component of the VLBI source, which has a diameter of approximately $1.0h^{-1}$ pc.

array VLA observations at 1.4, 5, and 15 GHz show no evidence for thermal radio emission from this region. A 1.4-GHz A configuration VLA image made from phased-array VLBI observations in December 1996 shows a high-brightness ridge extending from the south of the radio core; this southern diffuse component is linearly polarized, with a maximum fractional polarization of nearly 60%. Similar results have been found in multi-configuration VLA imaging by Colbert (1997). This VLA source on a scale of tens of kiloparsecs shares roughly the same position angle as the larger VLBI scale, implying that the source symmetry axis may be constant outside the inner few parsecs.

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