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Survey of Milliarcsec Structure in Eight Seyfert Galaxies: Results on NGC 1068 and NGC 4151

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Abstract. We are surveying eight nearby Seyfert galaxies (four Sy1s and four Sy2s) that have compact radio cores, using the VLBA. We are interested in parsec-scale morphology and low-frequency absorption effects, and so are observing four frequencies (1.6, 4.8, 8.4 and 15 GHz) to get spectral-index diagnostics. In this paper, we present results on two galaxies, NGC 1068 and NGC 4151. NGC 4151 shows a curved radio jet on the sub-parsec scale, with the smallest scale structure misaligned by 55° from the jet on scales of parsecs to hundreds of parsecs. NGC 1068 contains several components in the inner tens of parsecs, with those components showing a variety of absorption and resolution effects.

We have constructed a sample of eight Seyfert galaxies which we are imaging with the VLBA in order to study the parsec-scale morphology and low-frequency absorption effects. This paper reports results on two of the galaxies in the sample, NGC 4151 and NGC 1068, both observed in May 1996. Another galaxy, Mrk 231, is discussed by Ulvestad, Wrobel, & Carilli (these Proceedings, p. 199).

NGC 4151 is a type 1 Seyfert galaxy located at a distance of 13.3 pc ($H_0 = 75$ km s^{-1} Mpc^{-1}). It has a straight radio jet about 3.5 arcsec (220 pc) in length, with a major axis position angle of 75° (Pedlar et al. 1993), and a 3-arcsec bi-conical narrow-line region (NLR) with a position angle of 65° (Evans et al. 1993). European VLBI Network observations in the mid-1980s detected three VLBI components over ~ 0.5 arcsec (Harrison et al. 1986).

Our 5-GHz and 1.6-GHz VLBA images of NGC 4151 are shown in Figure 1. The 5-GHz image reveals a chain of knots 13 mas (0.8 pc) in length, with position angle 20°. This structure is most likely a radio jet, with a peak brightness temperature greater than 3×10^7 K. The NE part of the jet curves toward the east, and the 1.6-GHz image shows that it reaches the position angle of the larger scale jet within 1–2 pc. This implies that the symmetry axis of the galaxy on the sub-parsec scale is different from that on scales of parsecs and larger, associated with the NLR. The observed curvature complicates unified schemes for Seyferts, which usually assume that the symmetry axis of the NLR is similar to that near the central engine.

NGC 1068 is a Seyfert 2 galaxy located at a distance of 14.4 Mpc. It contains an arcsecond-scale radio jet (Wilson & Ulvestad 1987) and a string of four radio components on the sub-arcsecond scale (Muxlow et al. 1996). From south to north, these components are S2, S1, C, and NE. The jet apparently originates at component S1, which has been imaged with milliarcsec resolution by Gallimore, Baum, & O'Dea (1997), and is interpreted as the parsec-scale torus surrounding the active nucleus.

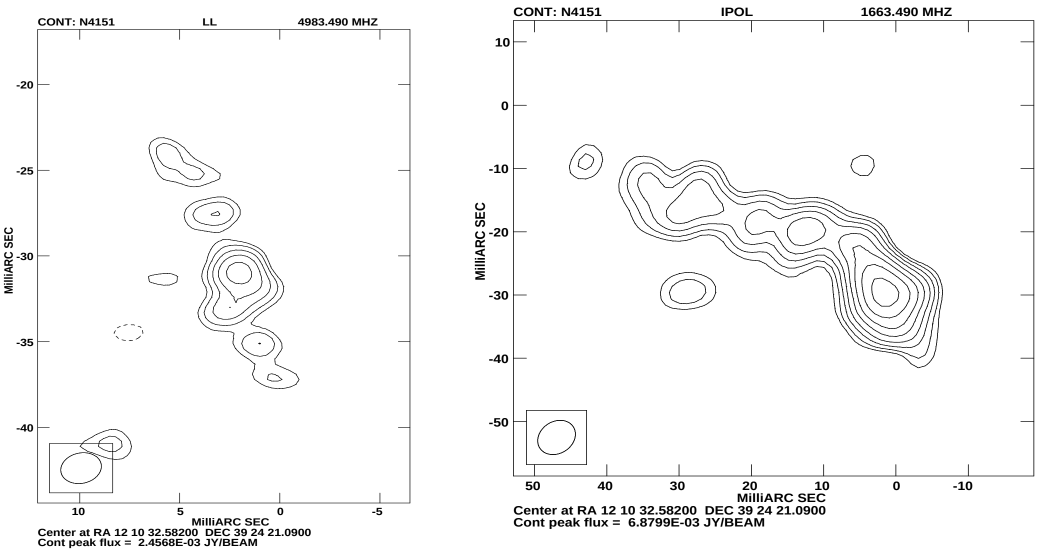

Figure 1. VLBA images of NGC 4151, both from data acquired in May 1996. An angular size of 1 mas corresponds to 0.06 pc. The left-hand panel shows the 5-GHz image, with a radio jet extending for approximately 0.8 pc in length. The right-hand panel shows the 18-cm image; the southwest part of this image corresponds to the 6-cm jet. The 18-cm jet curves sharply to the east, reaching a position angle similar to the arcsecond-scale jet within ~1–2 pc of the 6-cm jet, and continuing for a total length of ~ 3 pc.

Our multi-frequency VLBA observations reveal that component C, about 20 pc north of S1, has a spectrum that rises steeply between 1.7 and 5.0 GHz, with $\alpha > +2.7$, then falls sharply to 15 GHz ($\alpha < -2.2$). This is probably due to external free-free absorption, which can be accounted for if a typical NLR cloud lies along the line of sight to the radio source. Component S1 also has a rising spectrum ($\alpha \geq 1.0$) between 1.7 and 5 GHz, consistent with predictions of the free-free emission model for the torus.

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