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Parsec-Scale Jets and Tori in Seyfert Galaxies

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Abstract.

What causes the dichotomy between very powerful and very weak radio emission from AGNs? Perhaps the engines are the same but the jets get disrupted by dense ISM in radio-quiet objects, or else the engines are intrinsically different with jet power scaling with, say, black hole spin. To distinguish, one can look for interaction between the jets and the NLR and measure the jet speed close to the core using VLBI, before environmental effects become important. We find that in radio-quiet AGN, the jets appear slower and have a greater tendency to bend, and that one-sidedness and flat-spectrum cores are probably due to obscuration.

1. Four Differences between Low-Power and High-Power Jets

1) In our VLBA observations of Seyfert galaxies at frequencies between 1.6 GHz and 15 GHz we have found sub-relativistic jet component speeds (typically $\leq 0.25\,c$) in several Seyfert galaxies, such as in Mrk 348 at a distance of 0.5 pc from the core, in Mrk 231 at 1.0 pc (Ulvestad et al. 1999), in NGC 5506 at 3.4 pc (Roy et al. in prep), and in NGC 1068 at 21 pc (Fig 1; Roy et al. in prep). In contrast, in more powerful radio sources such as QSOs, the jet speeds have usually proven to be relativistic. The difference could signify either an intrinsic difference between the engines or a deceleration of the flow in Seyfert galaxies in the BLR gas on scales < 0.5 pc. (Note though that if the Seyfert components are shocks, then their speeds would be different from the jet flow speed.)

2) We found one-sided jets in VLBA images of the Seyfert galaxies Mrk 348, Mrk 231, and NGC 5506. In these galaxies the jets are low power and slow and probably lie across the line of sight (NGC 5506 and Mrk 348 host water masers, indicating edge-on systems, and in Mrk 231 the jet is inclined at 45° if it is perpendicular to the 100 pc scale H I disc; Carilli et al. 1998). In powerful radio jets the one-sidedness is usually explained with Doppler boosting, but in these

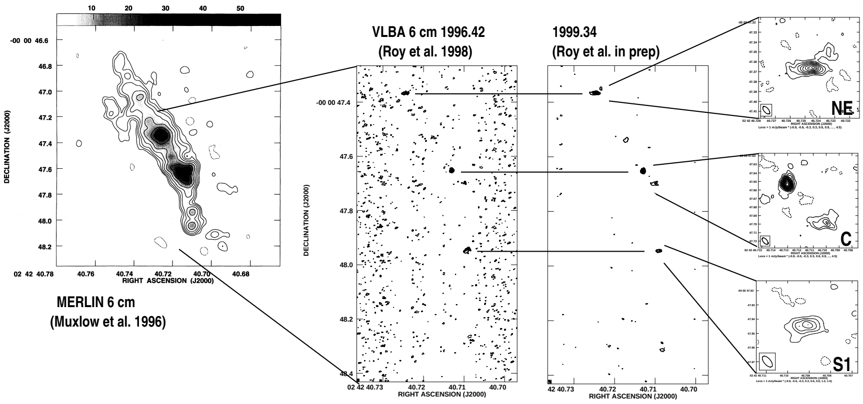

Figure 1. Centre and Right: VLBA images of NGC 1068 at 6 cm and resolution of (6 $\times$ 4) mas for two epochs, showing no motion ($v < 0.075\ c$ for $H_0 = 75$ km s^{-1} Mpc^{-1}). Left: MERLIN image at 60 mas for perspective.

Seyfert galaxies, boosting should be small, which leaves free-free absorption of the counterjet by a screen (perhaps the torus) as a more likely explanation.

3) Flat or absorbed spectra were found in some of the parsec-scale radio components in Mrk 348, Mrk 231, NGC 2639, and NGC 5506 and we found that these could be caused by free-free absorption by a foreground screen. Such absorption would be expected if the X-ray absorbing column seen in, say, Mrk 348 (10^{27} m^{-2}), occurred in a slab 0.1 pc thick like the expected inner torus edge; and is enough to extinguish our view of a counter-jet. However, note that the $T_{\rm b}$ values we measured are lower limits of $\simeq 10^7$ K, and so $T_{\rm b}$ could in principal be as high as 10^{10} K and then the spectra could be due to synchrotron self absorption (SSA). In contrast, flat-spectrum cores seen in high-power jets are rarely attributed to free-free absorption and are usually explained as SSA.

4) The jet in NGC 5506 bends through 90° at 3.4 pc to align with the large-scale outflow, and in Mrk 231 the jet base is misaligned by 65° with the 40 pc-scale lobes. The bends are probably intrinsic because the jet inclination is large, whereas in powerful jets such bends are usually interpreted as projection effects. The bends in Seyferts might be a sign of interaction between the jet and the NLR gas on parsec scales, and indeed by momentum arguments, low-power jets are more easily bent than high-power jets.

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