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The Nature of Flat-Spectrum Nuclear Radio Emission in Seyfert Galaxies

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Abstract. Parsec-scale VLBA imaging of five Seyfert galaxies with flat-spectrum radio nuclei was conducted to determine whether the flat spectrum represents thermal emission from the accretion disk/obscuring torus or nonthermal, synchrotron self-absorbed emission. Four of the five show emission consistent with synchrotron self-absorption, with intrinsic sizes $\sim$0.05$-$0.2 pc (or 10^4 gravitational radii for a 10^8 $M_\odot$ black hole for the smallest). In contrast, NGC 4388, which was detected with MERLIN but not the VLBA, shows thermal emission with similar properties to that detected in NGC 1068. It is notable that the two Seyfert galaxies with detected thermal nuclear radio emission both have large X-ray absorbing columns, suggesting that columns in excess of $\sim 10^{24}$ cm^{-2} are needed for such disks to be detectable.

1. Introduction

AGN are thought to be powered by accretion of material onto a central supermassive black hole via a disk that regulates the fueling rate. The extent of these disks is not well established but AGN unification schemes advocate a geometrically thick or warped thin disk that hides the nucleus when viewed edge-on and accounts for the observed differences between broad (type 1) and narrow-line (type 2) AGN. Theoretical work indicates that UV/X-ray radiation from the central engine can heat, ionize and evaporate gas on the inner edge of the torus (Pier & Voit 1995) and recent high angular resolution VLBA radio observations of the archetypal Seyfert 2 galaxy, NGC 1068, have shown that emission from the flat-spectrum radio component 'S1' may be associated with the thermal gas on the inner, ionized edge of the torus (Gallimore et al. 1997). This discovery highlights the possibility of using the VLBA to image the pc-scale disks or tori in other Seyfert galaxies. Flat-spectrum nuclei in radio galaxies and quasars often represent non-thermal synchrotron self-absorbed radio emission with a much higher brightness temperature ($>10^8$ K) than is characteristic of component S1 in NGC 1068, so high resolution radio observations are required to distinguish between the two emission processes.

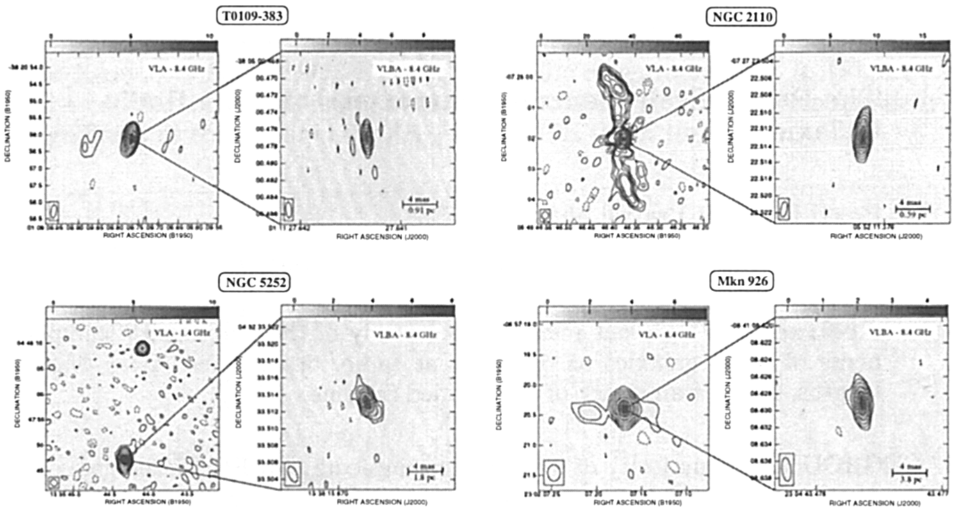

Figure 1. 8.4-GHz continuum images (right-hand panel) of sources detected with VLBA: T0109-383, NGC 2110, NGC 5252 and Mkn 926; VLA image of larger scale structure also shown (left-hand panel).

2. The Search for Thermally-Emitting Disks

Four of five sources imaged with the VLBA at 8.4 GHz were detected (Figure 1) and show compact, unresolved nuclei with brightness temperatures, $T_{\rm B} > 10^8$ K, monochromatic luminosities $\sim 10^{21}$ W Hz^{-1} and sizes less than $\sim$1 pc. We conclude that the sub-pc scale radio emission in these sources is non-thermal and self absorbed, and hence dominated by the central engine. We find no significant evidence of thermal disk-like emission extended perpendicular to the collimation axis in these sources. In contrast, the nucleus of NGC 4388 is not detected with the VLBA but is detected with MERLIN at 5 GHz. The inferred brightness temperature of 2.4×10^4 K $< T_{\rm B} < 2.2 \times 10^6$ K is too low for synchrotron self absorption to be important and we propose a model in which the emission is optically thin thermal bremsstrahlung from a gas with electron temperature of $T_{\rm e} > 10^{4.5}$ K and density $n_e > 1.6 \times 10^4$ f $^{-0.5}$ cm^{-3} (f is the volume filling factor). The larger inferred values of $T_{\rm e} = 10^{6.8}$ K and $n_e = 1.8 \times 10^6$ f $^{-0.5}$ cm^{-3} for the smaller source size set by the VLBA limit, are similar to the values of $\sim 10^{6.8}$ K and $\sim 10^{6.8}$ cm^{-3} found for thermal emission in NGC 1068 (Mundell et al. 2000), thus implying that we may be seeing the same phenomenon in NGC 4388. It is notable that these two Seyferts with detected thermal nuclear radio emission have large X-ray absorbing columns, suggesting that columns in excess of $\sim 10^{24}$ cm^{-2} are needed for such disks to be detectable.

References

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