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Probing the Accretion Region of NGC 1275 with VLBI

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Abstract. Multi-frequency VLBA observations were used to study the magnitude and radial dependence of free-free absorption of the radio emission from the counterjet in 3C 84.

NGC 1275 is a Seyfert galaxy and is the dominant member of the Perseus Cluster. It contains the radio source 3C 84 which has structure on all scales from sub-parsec to hundreds of kiloparsecs, although it is dominated by bright emission in the inner 15 mas. It is one of the brightest compact radio sources in the sky at cm wavelengths. The redshift of NGC 1275 is 0.0172. For this contribution, $H_o = 75$ is assumed so 1 mas= 0.35 pc.

In 1993, a 10 mas counterjet was discovered by Walker, Romney, & Benson at 8.4 GHz (1994; WRB) and by Vermeulen, Readhead, & Backer at 22 GHz (1994; VRB). It was much stronger at the higher frequency which, combined with a large size, suggested that the counterjet emission is free-free absorbed.

The source brightened dramatically in about 1960 and a backward extrapolation of the VLBI size, with measurements available for about half that time, goes to zero about then. This special circumstance makes it more reasonable here than in most sources to associate the main outer features (eg. overall VLBI size) of the jet and counterjet with material ejected from the core at the same time. The jet/counterjet brightness ratio at 22 GHz, the ratio of the lengths of the jets, and the apparent speeds measured with historical VLBI observations were used by WRB to show that the jets have an intrinsic velocity of about a third of the speed-of-light and an angle to the line-of-sight of about 40 degrees.

The above facts drive one toward a scenario with an inclined disk/jet system in which the counterjet, but not the main jet, is free-free absorbed by material associated with the disk (perhaps not the disk itself, but an atmosphere above it). Levinson, Laor, & Vermeulen (1995) discuss some of the implications of this scenario for the disk, its heating etc.

Near-simultaneous VLBA observations of 3C 84 were obtained at 2.3, 5.0, 8.4, 15.3, 22.2, and 43 GHz in both January and October of 1995. The counterjet is seen without significant missing flux density in the 5.0, 8.4, 15.3, and 22.2 GHz observations. At 2.3 GHz, it is so absorbed that it is not seen in a very good image. It is seen at 43 GHz, but there is inadequate short baseline coverage to study it properly.

We use the multi-frequency VLBA observations to derive the magnitude and radial dependence of the combination of physical parameters that can be measured using the absorption, $Ln_e^2T^{-3/2}$, where L is the path length, n_e is the electron density, and T is the temperature. The counterjet is very sharply cut off at low frequencies. A free-free absorption model fits fairly well. The deviations are in the sense that the cutoff is not as sharp as pure free-free absorption in a uniform medium. This would be expected if there is some spatial variation.

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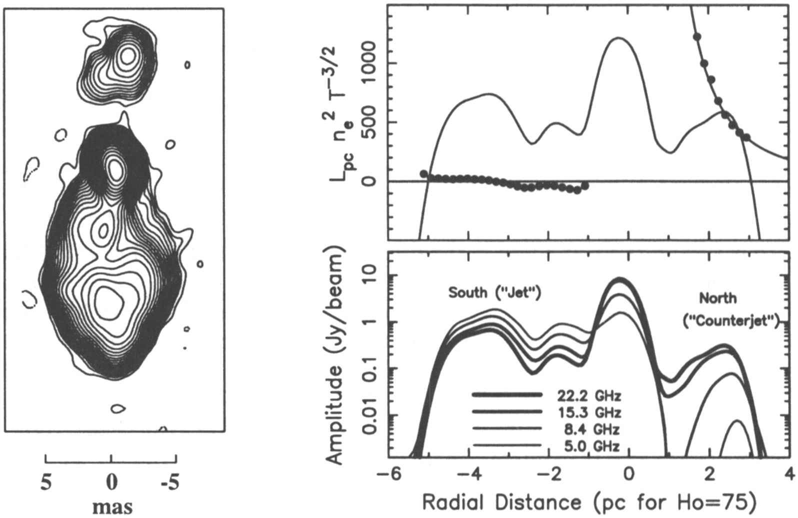

Figure 1. A sample 3C 84 image (1995 January, 8.4 GHz, contours: -2, 2, 4, $2^{n/2}$ mJy/beam) and results of fitting the 1995 January multi-frequency VLBA observations with a free-free absorption model. The top right panel shows the fit results as a function of position along the ridge of the jet and counterjet, plus a sample profile. The dots are the fitted opacity ($L_{pc}n_e^2T^{-3/2}$). A constant spectral index of -0.7 was assumed. The curved line through the counterjet opacity points shows a parameterization of the opacity as $L_{pc}n_e^2T^{-3/2} = 529(R_{pc}/2.5)^{-2.2}$. The bottom right panel shows the profiles that were fit. Note the strong, low-frequency cutoff in the counterjet.

The results of a fit for opacity (parameterized as above), assuming a fixed spectral index, to profiles along the ridge line of the VLBI structure are shown in Fig 1. The amount of absorption of the counterjet at about 2.5 pc from the core is equivalent to what would be caused by a 5000 K medium, 0.1 pc thick, with a density of about $4 \times 10^4\,\text{cm}^{-3}$. The absorption drops with roughly the square of the core distance. If this decrease is entirely due to the electron density, it suggests a linear drop with distance.

When the 8.4 GHz results from April 1993 are included, it is clear that the counterjet is moving outwards and more of it is appearing from behind the absorbing screen (see also Dhawan et al., these Proceedings p. 79). This may help explain why the counterjet was not seen in old data—it may not be just because of the much enhanced image quality available with the VLBA.

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