CONSTRAINTS ON THE ACCRETION REGION IN NGC 1275 FROM VLBA OBSERVATIONS OF THE COUNTERJET

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1. Introduction

A northern feature, that is most likely related to a counterjet, was found on parsec scales in 3C 84 (which is in NGC 1275) in "First Science" observations on the VLBA[1] at 8.4 GHz (Walker *et al.*, 1994) and in Global VLBI observations at 22 GHz (Vermeulen *et al.*, 1994). The jet/counterjet length ratio, brightness ratio at 22 GHz, and speeds, as measured over many years with VLBI, fit a simple beaming model with symmetric jets oriented at 30–50 degrees to the line-of-sight and traveling at a speed of 0.3–0.5 times the speed of light. These ranges allow for Hubble constants of between 50 and 100 km s^{-1} Mpc^{-1}. The brightness of the counterjet at 8.4 GHz was very much lower than expected with this model, assuming that the spectral indices in the near and far side jets are similar. This was interpreted as the result of free-free absorption in an ionized medium that lies in front of the counterjet but not in front of the near-side jet. An accretion disk or torus has an appropriate geometry to show this effect (for an analysis, see Levinson *et al.*, 1995).

If the free-free absorption concept is correct, this opens the exciting possibility of constraining the physical parameters in the accretion region by using VLBI to measure $L\langle n^2 g/T^{3/2}\rangle$ where L is the path length, n is the density, T is the temperature, and g is the Gaunt factor. Both the value

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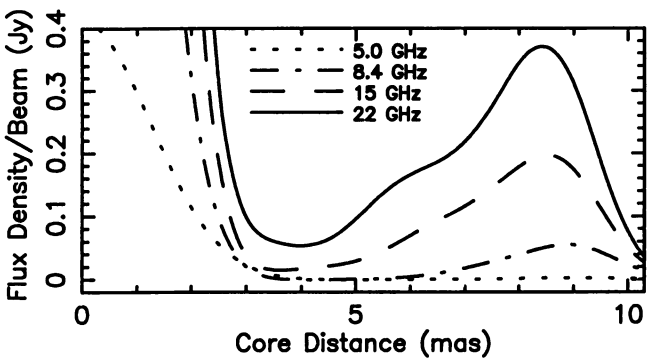

Figure 1. Slices along the ridge of the counterjet in 3C 84. The flux densities have been scaled so that they would match if the spectral index were −0.7.

and the radial dependence of this parameter can be measured on sub-parsec scales (at $z = 0.018$, 1 pc $= 4\ h$ mas, which is easily resolved).

In January 1995, in order to image the counterjet simultaneously at many frequencies, we made VLBA observations of 3C 84 at 2.3, 5.0, 8.4, 15, 22, and 43 GHz. The preliminary images are presented in the companion contribution by Romney *et al.* (1995) in this volume. The best images to use to study the absorption are those at 5.0, 8.4, 15, and 22 GHz. The counterjet is not seen at all at 2.3 GHz and, at 43 GHz, there were inadequate short spacings to image it. The images show clearly that the counterjet is cut off strongly at low frequencies.

2. The Data and Model

Figure 1 shows slices through the counterjet at the four good frequencies with the flux densities adjusted so that they would be the same if the spectral index were −0.70 as it is in the southern jet. To compare with absorption models, the effects of source structure need to be removed. This can be done by assuming a constant spectral index and by dividing the slices by the 22 GHz slice. A set of such ratios is shown in Figure 2. The region ≤ 4.5 mas from the core should be ignored: it is dominated by the core. The strong cutoff with frequency and the radial dependence of that cutoff in the counterjet can clearly be seen in the ratios beyond about 4.5 mas.

Figure 3 shows a very simple model for the absorption. In this model, $Ln^2/T^{3/2} = 3286R^{-2.5}$ (L and R in pc, n in cm^{-3}, and T in K) and $T = 10^4$K in the Gaunt factor. The constant and the power law index have been chosen to match the data curves for 8.4 GHz and to give the correct separation between 8.4 GHz and 5 GHz curves. The match to the data is reasonably good. Varying the index by about 0.5, while adjusting the

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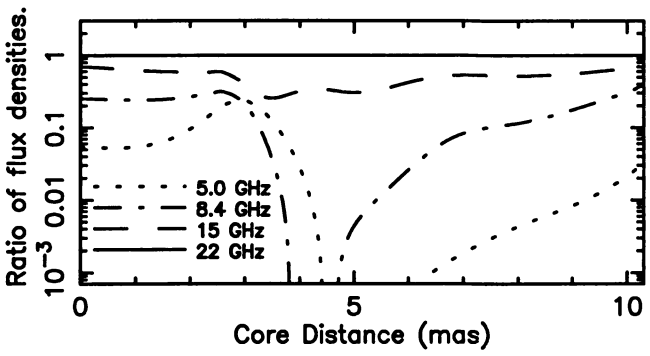

Figure 2. Ratio of scaled slices to the 22 GHz slice. This is a good observable for comparison with absorption models. Recall 1 pc = 4 h mas.

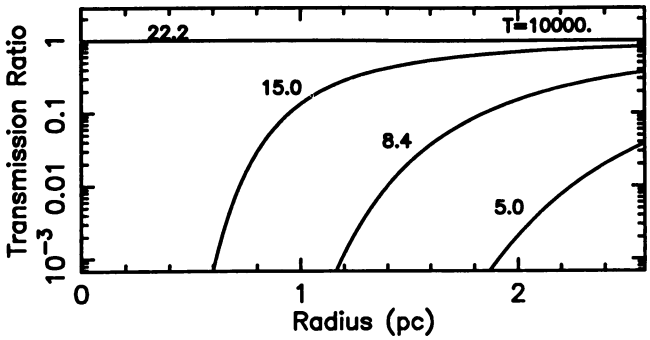

Figure 3. Model ratios of slices to the 22 GHz slice along the spine of the 3C 84 jet for the simple power law model described in the text.

constant to match the middle of the 8.4 GHz curve, significantly degrades the fit. This is a preliminary result both because the effect of the finite resolution of the observations has not yet been taken into account and because the 22 GHz image is preliminary. However, it is clear that these data can provide a good constraint on the parameters of the ionized gas near this active galactic nucleus and on its radial dependence.

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