A CIRCUMNUCLEAR HI DISK IN THE COMPACT SYMMETRIC OBJECT 4C31.04?

J.E. CONWAY
Onsala Space Observatory and J.I.V.E
Onsala, S-43992, Sweden

1. Introduction

Compact Symmetric Objects (CSO's) are strong, compact (<1kpc) objects with radio structure and luminosity similar to classical double radio sources (i.e. two lobes and a weak core), but thousands of times smaller (Wilkinson et al 1994). It has been proposed that CSO's are either young radio sources which will later evolve into classical sources, or sources whose growth is 'frustrated' by dense surrounding gas. In a recent survey of $z< 0.1$ CSO's searching for HI absorption, approximately 50% were detected (see Conway et al 1996), a much higher percentage than found in surveys of general radio loud ellipticals with similar sensitivity (see van Gorkom et al 1989).

2. Observations and Interpretation

To investigate further the nature of the HI absorption in CSO's we have begun a program of spectral line VLBI observations in order to spatially resolve the HI absorption. The first object we have observed, 4C31.04, (at z=0.0598, 1mas = 1pc for H_o = 75kms^{-1} Mpc^{-1}) was discovered by Mirabel (1990) to have strong HI absorption. Two absorption systems, one broad (FWHM 133 kms^{-1}) and the other narrow (< 20kms^{-1}) were detected (Fig 1a). Recent 1.6GHz and 8.4GHz VLBI continuum observations (Cotton et al 1995) have shown that 4C31.04 has a CSO morphology.

Spectral line observations of 4C31.04 were made in July 1995 using the 10 station VLBA array and a single antenna of the VLA. The resulting continuum map at the redshifted HI frequency (1340MHz) is shown in Figure 1b, this image confirms the CSO classification of Cotton et al (1995), with evidence for both a core component and a compact hotspot within a

R. Ekers et al. (eds.), Extragalactic Radio Sources, 92–94.
© 1996 *IAU. Printed in the Netherlands.*

https://doi.org/10.1017/S0074180900080153 Published online by Cambridge University Press

diffuse Western lobe. Figure 1c shows the HI opacity integrated over the deepest part of the broad absorption line, it is large ($\tau \approx 0.07$) and fairly uniform over the E lobe but in the W lobe there is a sharp 'edge' to the opacity, on the core side of the edge the HI opacity is approximately 0.02 while on the other side it is consistent with zero. On the zero side of the HI edge we see strong depressions in the continuum emission (see Figure 1d), possibly caused by free-free absorption by unresolved clouds. Also seen in this region are individual narrow ($< 14\mathrm{kms}^{-1}$) HI clouds (not shown), both in the broad and in the narrow, high velocity gas. The visibility of these continuum and spectral features in this region might be partially due to the bright background continuum. High velocity HI and possible free-free absorption features are also seen in front of bright parts of the Eastern lobe.

The fact that the HI edge is roughly perpendicular to the vector from the core to W hotspot strongly suggests that the obscuring gas 'knows' about the radio axis and is associated with the AGN rather than being random foreground gas in the host galaxy. The observations can be explained assuming a disk geometry whose axis is that of the radio jet (see Figure 2), and in which the jet axis is close to the sky plane (as is likely for an isotropically emitting CSO selected on total flux density). The dimensions of the disk required are similar to the disks seen in HST images (e.g. Jaffe et al 1993). In this model the disk completely covers the more distant, Eastern lobe, generating a large opacity, while the HI edge in the Western lobe is caused by the finite thickness of the disk or torus. Matter evaporated from the inner edge of the disk and closer to the AGN could then provide the high velocity HI and ionized clouds which are observed beyond (see Fig 1d) the HI edge. A possible gradient in the centroid of the absorption velocity in directions perpendicular to the radio axis is consistent with this disk model; for a jet inclined at 15° to the sky plane an enclosed mass of 10^8 solar masses within 150pc of the central engine is implied. Satisfying simultaneously the observations of free-free absorption, HI absorption and minimum pressure in the radio emitting plasma gives strong constraints on gas physical parameters and will be discussed elsewhere.

References

Conway, J.E., Readhead, A.C.S., Taylor, G.B., (1996), *ApJ in preparation.*

Cotton, W.D., Feretti, G., Giovannini,G., Venturi, T., Lara, L., Marcaide, J., Wehrle, A.E., (1995), *ApJ*, **452**, 605.

Jaffe, W., Ford, H.C., Ferrarese, L., van den Bosch, F., O'Connell, R.W., (1993), *Nature*, **364**, 213.

Mirabel, I.F., (1990), *ApJ*, **352**, L37.

van Gorkom, J.H., Knapp, G.R., Ekers, R.D., Ekers, D.D., Laing, R.A., and Polk, K.S., (1989), *AJ*, **97**, 708.

Wilkinson P.N., Polatidis, A.G., Readhead, A.C.S., Xu, W., Pearson, T.J., (1994), *ApJ*, **432**, L87.

https://doi.org/10.1017/S0074180900080153 Published online by Cambridge University Press

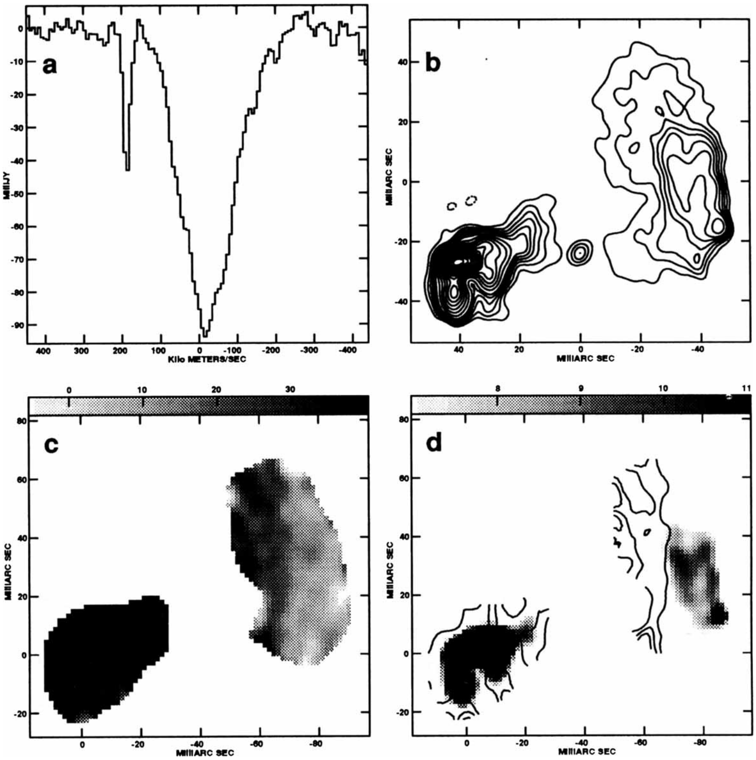

Figure 1. **(a) HI Absorption spectrum integrated over the whole source. (b) Continuum (1340MHz) MEM image, 3mas FWHM resolution, first 6 contours are at 1.5mJy/beam intervals, rest at 3.0mJy/beam intervals. (c) HI Opacity averaged over central part of broad absorption line. Greyscale image from -0.005 to 0.040, resolution 12 by 9mas, PA=5 degrees. (d) Greyscale continuum 3mas resolution, plotted from 7 to 11mJy/beam, showing local depressions in the continuum emission. Contours show HI opacities of 0.02, 0.03, 0.04, 0.06, 0.08.**

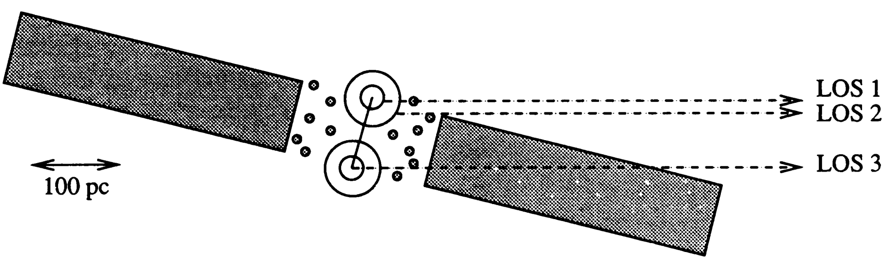

Figure 2. **Possible model, grey indicates a gas disk whose axis is parallel to the radio axis, small clouds are shown evaporating off its inner edge. The contours of radio emission from the lobes are shown schematically as two sets of concentric circles, the West lobe in Fig 1 at the top and the East lobe at the bottom. Three lines of sight are shown, to the West hotspot (LOS1), at the edge of the HI absorption (LOS2) and to the East lobe (LOS3).**

https://doi.org/10.1017/S0074180900080153 Published online by Cambridge University Press