An H I Study of the NGC 6744 System

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Abstract

We present the preliminary results of our 5-configuration, 20-pointing mosaic with the Australia Telescope Compact Array of the neutral hydrogen in the nearby spiral galaxy NGC 6744. The bulk of the H I resides in a "ring" underlying the outer optical disk, with 2 H I spiral arms extending further out to almost 1.5 optical radii. The velocity field is fairly regular, apart from evidence for streaming motions along the H I arms, and the influence of the companion IB(s)m galaxy NGC 6744A. We associate a cloud of H I at a heliocentric velocity of 846 km s^{-1} with another companion object, ESO 104-g44. Our attempts to construct a mass model for NGC 6744 suffer from poor resolution in the inner disk, and the uncertainty in the total H I flux of NGC 6744. We anticipate that HIPASS observations will be crucial in resolving the latter issue.

Keywords: galaxies: individual (NGC 6744) — galaxies: interactions — galaxies: kinematics and dynamics — galaxies: spiral

1 Introduction

NGC 6744 is one of the largest, nearest ($D \sim 11$ Mpc), and most spectacular spiral galaxies in the southern sky, and yet it has received surprisingly little attention. In part, this can be attributed to its large angular size (the $B = 25$ mag arcsec^{-2} isophote spanning some $20' \times 13'$) which, besides yielding a relatively low surface brightness disk, exceeds the field of view of most existing optical and radio imaging systems. The recent advent of large format optical CCD arrays, and a mosaic observing mode with the Australia Telescope Compact Array (ATCA) have at last made it feasible to carry out a full investigation of the stellar and gaseous components of NGC 6744. This paper outlines some preliminary results of our H I observations.

Our study of NGC 6744 was primarily motivated by a desire to understand the influence of the spiral density wave pattern on star formation. NGC 6744 is morphologically very similar to our Galaxy (de Vaucouleurs 1983), but is unusually isolated, with no nearby companion akin to M31. However, deep optical images suggest also some form of interaction between NGC 6744 and

Table 1: ATCA observing parameters for NGC 6744.

Parameter	Value
α (J2000 pointing centre)	$19^{\rm h}\,09^{\rm m}\,45\overset{s}{.}3$
δ (J2000 pointing center)	$-64^\circ\,01'\,21''$
Distance adopted	10.4 Mpc
Configurations[a]	0.375, 0.75A, 0.75D, 1.5A, 1.5D
Natural-weighted beam FWHP	$54'' \times 51''$ (2.7×2.6 kpc)
Channel map rms noise	3.6 mJy beam^{-1}
Channel increment	9.9 km s^{-1}

[a]For further details about the configurations, consult the *ATCA Users' Guide*.

the small blue irregular galaxy NGC 6744A, and possibly with a host of other dwarf galaxies in the vicinity. In addition, NGC 6744 is listed in the *Catalog of Southern Ringed Galaxies* (Buta 1995) as having an inner ring $3\overset{'}{.}3$ in diameter. As has been shown in our earlier ATCA H I study of the ringed barred spirals NGC 1433 and NGC 6300 (Ryder et al. 1996), associating such ring features with specific orbital resonances (in this case, the inner second harmonic resonance) is a powerful technique for measuring directly such fundamental dynamical parameters as the bar pattern speed.

2 ATCA Observations

NGC 6744 was observed with a total of 5 different configurations of the ATCA in the period between April and November of 1996. Further details of the observations are given in Table 1. To be sure of covering the entire H I disk of NGC 6744 and its nearest neighbours, we mapped a 20 pointing mosaic covering almost $120' \times 100'$, as indicated in Figure 1. The calibrator PKS B1934–638 served as both the primary and secondary flux calibrator, on account of its close proximity (3.3°) to NGC 6744. The data for each configuration were edited and calibrated with AIPS. Mosaicing, imaging, and deconvolution were carried out using the MIRIAD suite of software (Sault, Teuben & Wright 1995), which implements the "joint approach" to interferometric mosaicing discussed in Sault et al. (1996).

A maximum entropy-based deconvolution task was used to deconvolve the mosaiced dirty image. While being well-suited to imaging of extended objects, the algorithm leads to an inherently positive bias in the flux. This bias can be minimised if the total source flux is known *a priori*, but of course, one of the reasons for doing a mosaic of NGC 6744 in the first place was to determine the total extent and mass of H I. Since the total flux is not yet well-constrained, each of the channel maps in the cleaned H I cube exhibits a "pedestal" of emission underneath the dominant gaseous component at each velocity. For this reason, we confine the present analysis mainly to the kinematical aspects of NGC 6744, which are less affected by this positive bias.

3 Results

In Figure 2, we have superimposed contours of the H I column density on an optical image of NGC 6744 extracted from the *Digitised Sky Survey*. As can be seen, the gas disk extends over some 30′, or 1.5 times the size of the stellar disk. A "ring" of gas underlies the optical spiral arms,

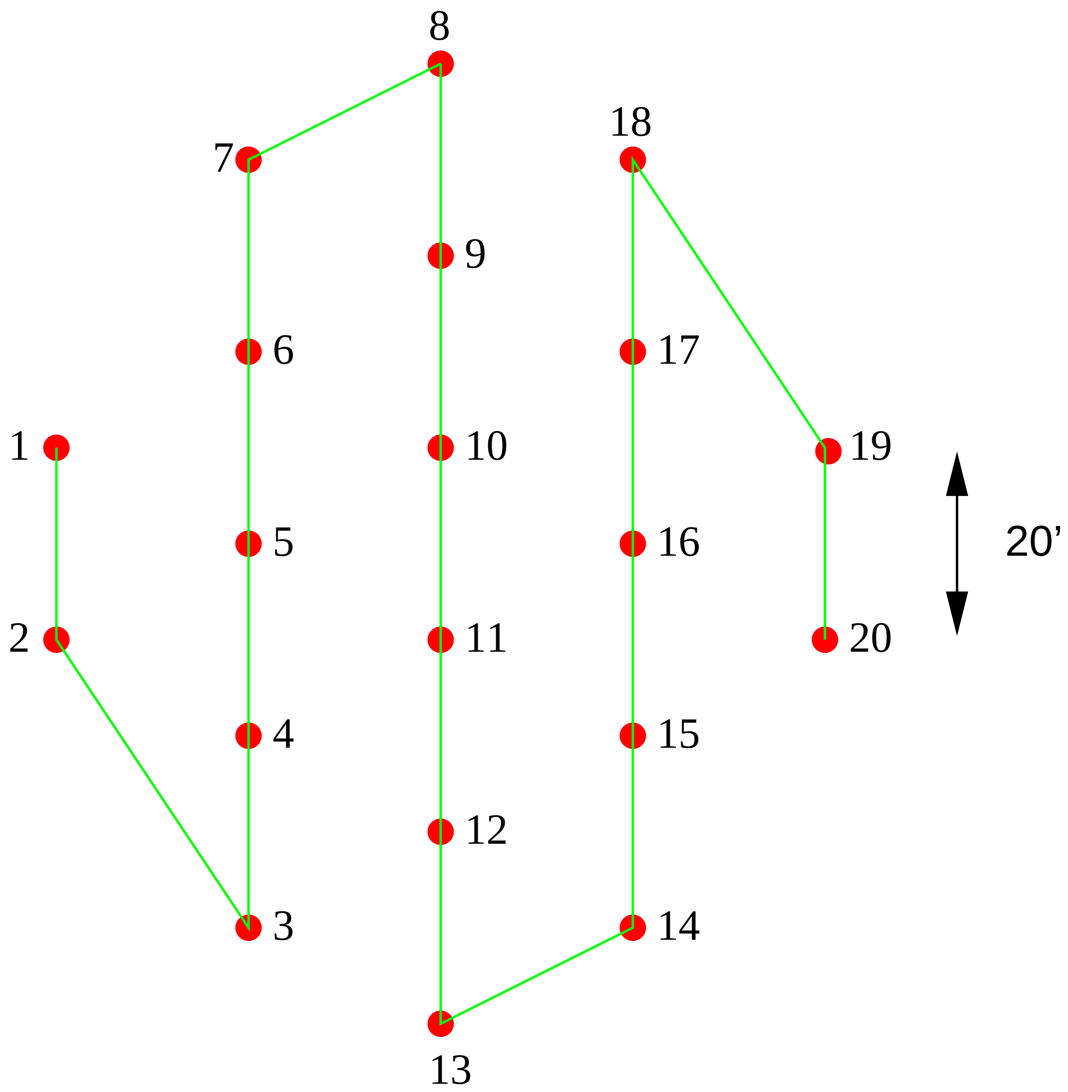

Figure 1: Mosaic pattern on the sky for NGC 6744, as traced by the ATCA antennas. Integrations of 3×10s were averaged before moving on to the next position.

with comparatively little H I in the bulge and inner disk. Two gaseous spiral arms emanate from either end of this ring, and wind for almost 270° each before fading out. The peak gas column densities occur where these arms join the ring, and near the location of NGC 6744A, the irregular galaxy visible to the NW.

A better impression of the structure of the H I disk, together with its velocity field, can be had from Figure 3. The rotation pattern is basically that expected for gas in uniform circular motion, but distortions are evident, particularly in the gaseous spiral arms. and around NGC 6744A. By examining the H I datacube, we have been able to kinematically resolve NGC 6744A from the H I arm behind it, and find a redshift for this galaxy of 765 ± 10 km s^{-1}. As Figure 3 shows, we have also detected a cloud of H I to the SE. According to the *NASA/IPAC Extragalactic Database*, this cloud coincides with the location of the SABm galaxy ESO 104-g44. However, we observe H I line-of-sight velocities in this cloud of 846 ± 3 km s^{-1} (with virtually no gradient), in contrast with the H I heliocentric velocity of 779 km s^{-1} measured by Longmore et al. (1982) using the Parkes 64 m antenna. The difference is most likely due to spillover into the beam from blue-shifted gas in the disk of NGC 6744.

4 Rotation Curve and Dark Matter Model

Using both the VELFIT task within MIRIAD and the GAL task within AIPS, we have attempted to model the velocity field of Figure 3. By fixing only the rotation centre, we find a best-fitting systemic velocity $V_{\rm sys} = 838 \pm 2$ km s^{-1}, an inclination $i = (50 \pm 4)^\circ$, and a line-of-nodes position angle $\theta = (16 \pm 2)^\circ$. Fixing all of these parameters then yields the rotation curve in Figure 4, where the error bars reflect the differences from analysing separately the receding and approaching halves of the disk. As can be seen, the rotational velocity rises fairly quickly within the first 3 kpc (due to beam smearing, the actual rise is probably steeper), and then stays just below 200 km s^{-1} over the rest of the disk. There is the hint of a rise in the last few points, but the analysis is complicated here by the influence of NGC 6744A, and apparent streaming motions along the arms.

In order to derive the contribution of a dark matter halo to the rotation curve of NGC 6744, we must first compute the contributions of the stellar and gaseous components. Using a 2K$\times$2K CCD on the Mount Stromlo and Siding Spring Observatories' 40″ reflector, we have constructed a B-band mosaic of NGC 6744 covering some $35' \times 37'$, which has allowed us to determine the run of mean surface brightness with radius in the disk. As a starting point, we assume $M/L_B = 1$ (although this is almost certainly a lower limit) which then gives the radial distribution of stellar surface density. We derive the radial atomic gas mass profile by scaling the H I surface density by 4/3 (to account for He). The relative contributions of the gas, stars, and dark matter to the rotation curve of NGC 6744 have been computed (assuming that the stellar disk dominates in the very inner disk), and the results are shown by the various curves in Figure 4.

There are a number of points to note about this mass model. First, the model curve cannot account for all of the structure in the observed rotation curve, and has particular difficulty in the central 10 kpc. Also note that for the first 20 kpc or so, the rotation velocity of the gas is negative. This comes about as a result of the concentration of H I in the ring producing a net outward force, so that the balance of gravitational and centripetal forces requires that the square of the circular velocity, $V_{\rm c}^2$ be negative. $V_{\rm c}$ must therefore be imaginary, but by convention is plotted as the negative of the real part. The implied isothermal dark halo core radius is 1.83 kpc, which is low but not unreasonable, while the halo central density is 2.10×10^{-3} M$_\odot$ pc^{-3}. This mass model must be considered preliminary until we can better constrain the total H I mass in NGC 6744, and measure the inner rotation curve at higher resolution.

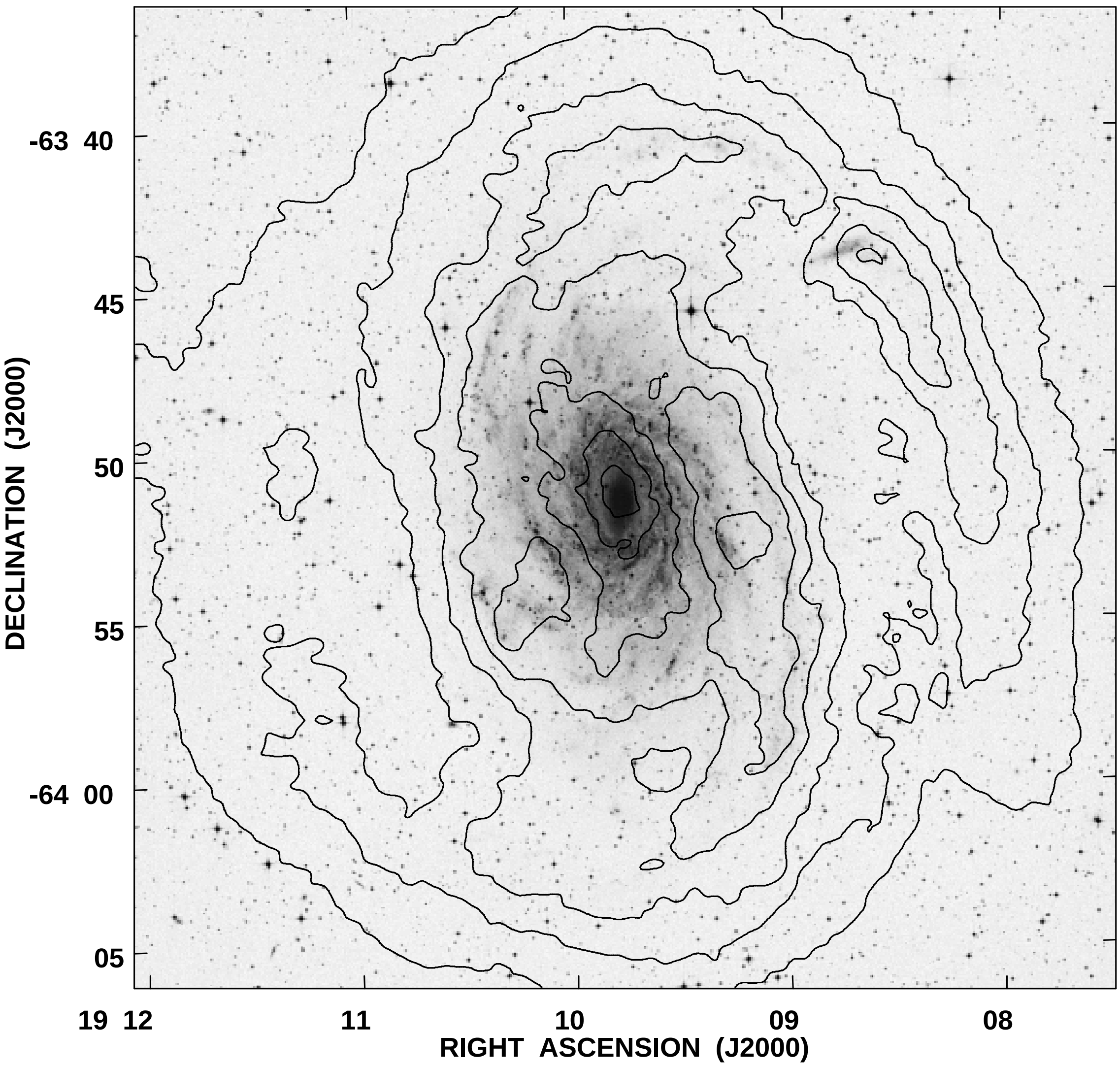

Figure 2: Contours of the H I column density (resolution $\sim 55''$) overlaid on a blue image of NGC 6744 from the *Digitised Sky Survey*. The IB(s)m galaxy NGC 6744A can be seen near $(19^{\rm h}\ 09^{\rm m}, -63^\circ\ 44')$.

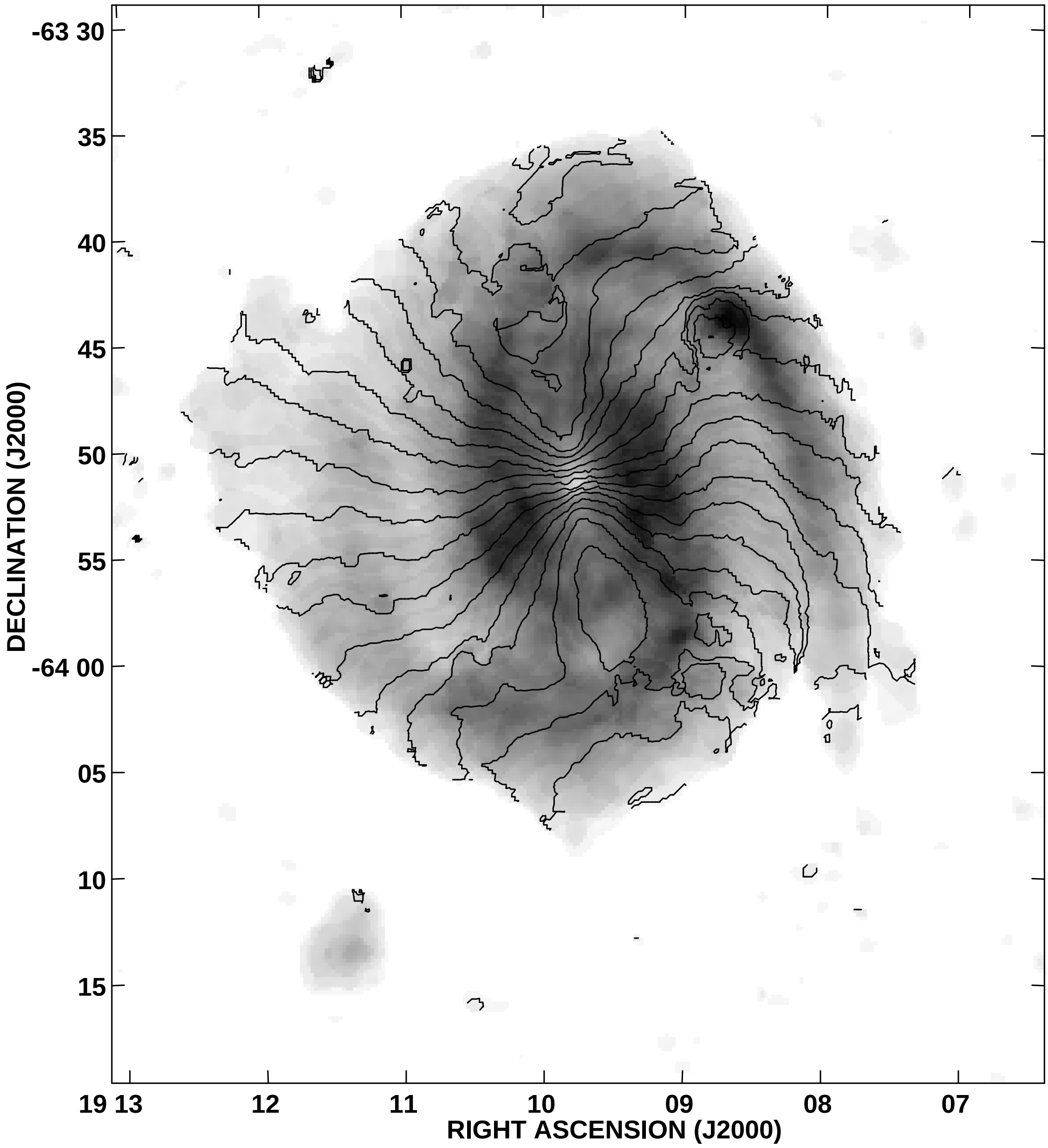

Figure 3: Isovelocity contours for the H I in NGC 6744, overlaid on a grey-scale of the same H I distribution as in Figure 2. Notice the severe distortion in the contours due to NGC 6744A. The isolated patch of H I to the SE is associated with ESO 104-g44.

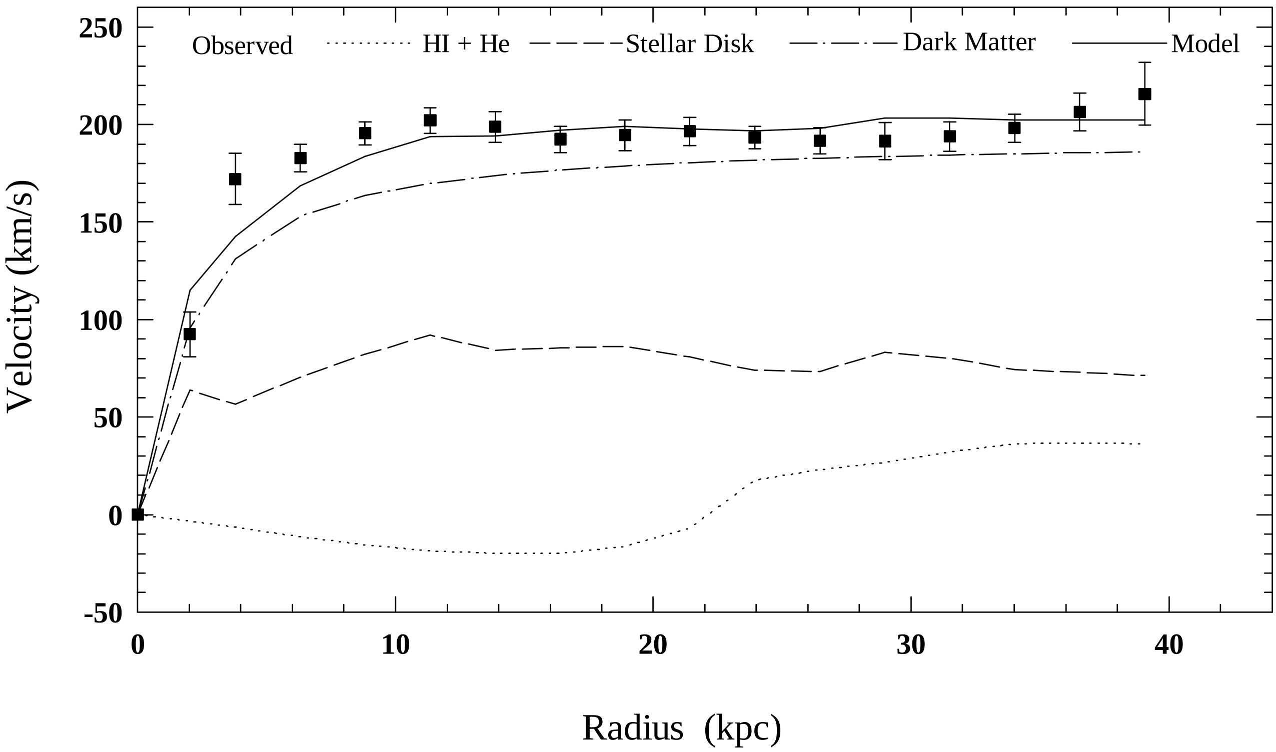

Figure 4: Rotation curve for NGC 6744, derived from a kinematical analysis of the H I disk. The points with error bars correspond to the range of values found by analysing both the entire disk, and the receding and approaching halves separately. The dotted curve indicates the rotation due to the atomic gas only, the dashed curve indicates the rotation due to the stellar disk, the dash-dot line is rotation due to the inferred dark matter component, and the solid curve is the sum of all three components.

5 Future Work

Because the H I in NGC 6744 overfills the Parkes beam, measuring the total H I flux requires either an elaborate mapping strategy, or a smaller antenna. However, we are optimistic that with appropriate processing, the multiple HIPASS scans of the environment of NGC 6744 will enable us to extract a total H I flux that will serve to constrain the maximum-entropy deconvolution. We have recently acquired Hα Fabry-Perot scans of the inner disk of NGC 6744; as the images by Ryder & Dopita (1993) indicate, there is diffuse Hα emission interior to the ring which should enable us to trace ionised gas motions in the bar region. In addition, we plan to map the CO emission from the inner disk of NGC 6744 with the Swedish-ESO Sub-millimetre Telescope. Together, these complementary observations should enable us to understand the internal kinematics of NGC 6744, just as our ATCA mosaic of the H I has begun to teach us about the large-scale dynamics of the NGC 6744 system.

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