THE HI STRUCTURE OF THE NUCLEAR DISK

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It is nearly twenty years since Rougoor & Oort (1960) reported the discovery of neutral hydrogen (HI) emission from the galactic nucleus, and I would like to summarize some of the progress that has been made since then in observing and interpreting this emission. One of the most surprising properties to be found is the tilt of the HI distribution relative to the galactic equator. This was noted originally by Kerr (1967), and recent measurements indicate that the tilt is present from within 200 pc of the centre out to a distance of some 2 kpc. (Cohen & Davies 1976, 1978). Because of the tilted distribution the properties of the nuclear emission cannot always be deduced from observations at zero galactic latitude. For example, Rougoor & Oort (1960) deduced a sharp cut-off in the negative-velocity "nuclear disk" emission at $\ell \simeq -4^{\circ}$, from their measurements near zero latitude, whereas the more extensive observations by Kerr (1967) show that the cut-off is only an apparent effect. In reality the emission continues to more negative longitudes, but at higher galactic latitude because of the tilt.

The nuclear emission at the highest "permitted" velocities has very broad line profiles over the range of longitude where the tilt is seen, increasing in velocity dispersion from 8 km s^{-1} outside the tilted region to over 20 km s^{-1}. Such broad HI profiles occur only in the "nuclear disk" emission feature discovered by Rougoor & Oort (1960) and in a number of weaker HI features seen within a few degrees of the galactic centre (Cohen 1975, Cohen & Davies 1978).

An overall view of the emission can be taken from Fig. 1, which is a velocity-longitude map of the 21 cm emission averaged in galactic latitude between latitudes $\pm 3^{\circ}$. By averaging in this way we properly represent the emission which lies away from zero latitude because of the tilt. Within 5° longitude of the centre 34% of the high-velocity emission ($|V| > 50$ km s^{-1}) shown in Fig. 1 has velocities which are "forbidden" in terms of normal galactic rotation. At zero longitude there is detectable HI emission at velocities up to $\pm$ 200 km s^{-1}, indicating that the non circular motions are as large as the rotational

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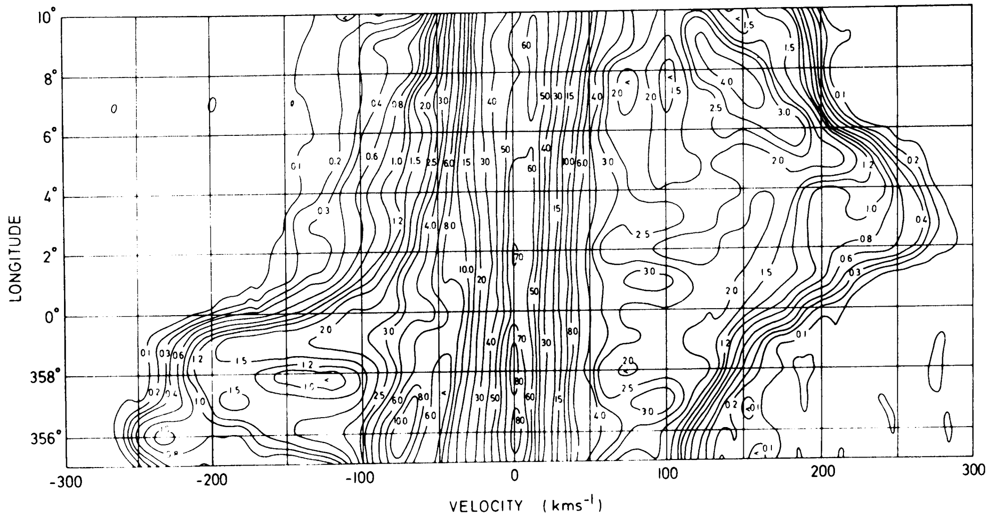

Fig. 1. Velocity-longitude diagram showing the mean HI emission from the nuclear region of the Galaxy, averaged between galactic latitudes $\pm 3^{\circ}$. The observations were taken at Jodrell Bank with the Mark II radio telescope (beamwidth 31 x 35 arcmin) and have a velocity resolution of 7.3 km s^{-1} (Cohen 1975). The region was fully sampled in latitude but undersampled in longitude ($\Delta\ell = 1^{\circ}$). Contours give line temperature in degrees K.

components of motion. The noncircular motions increase on the whole towards the centre, since the emission features with the largest "forbidden" velocities are seen over the smallest range in longitude. We know from absorption measurements of the strong radio continuum, source Sgr A near the galactic centre that in this direction most of the HI with "forbidden" velocities is moving away from the centre. However, the transverse velocities are not directly measurable, so we can derive the velocity field and distribution of the gas only by making further assumptions.

Three simple kinematical models are often used to describe the large scale motion of the gas: pure rotation, rotation plus expansion, and motion about a central bar. Rougoor & Oort provisionally assumed that the motion within 800 pc of the centre was purely rotational, and that <u>all</u> the noncircular motions lay outside this region and were directed away from the centre. Using these assumptions Rougoor (1964) was able to construct a number of axially symmetric velocity models which gave the various "expanding arms" the appearance of spiral arms when they were located according to their measured radial velocities. Grape (1978) has extended this analysis, allowing the possibility of expansion nearer the centre, and has shown that the extreme "permitted" and "forbidden" velocities observed strongly constrain such axially symmetric models. A slightly different approach has been taken by

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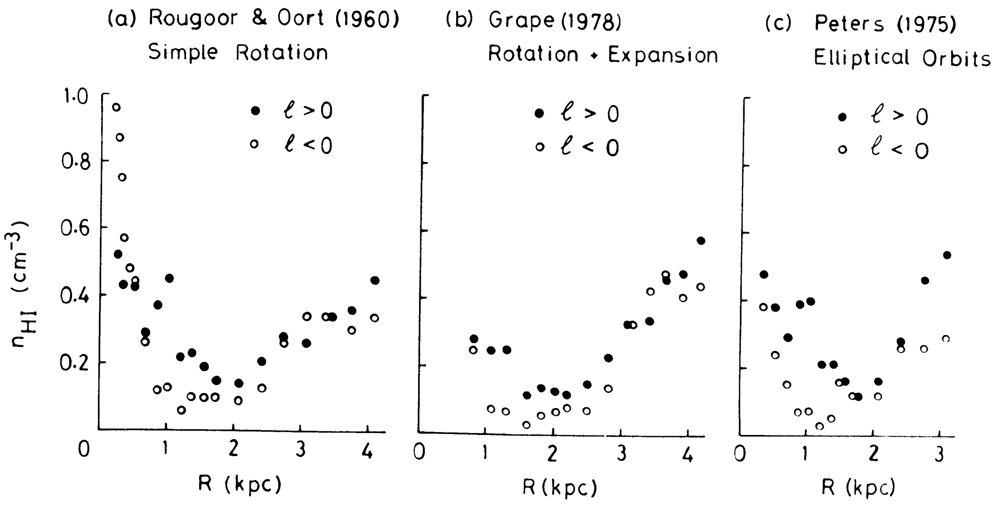

Fig. 2 Radial distribution of HI density in the nuclear disk, estimated from the terminal velocity emission using three different kinematical models: (a) pure rotation throughout the disk according to the Rougoor & Oort (1960) rotation curve, (b) axially symmetric rotation plus expansion (Grape 1978), and (c) motion in elliptical orbits about a central bar (Peters 1975, his case $\theta = 150^{o}$). Observational data were taken from Weaver & Williams (1973), Cohen (1975) and Kerr & Sinha (private communication).

van der Kruit (1971) and Sanders & Wrixon (1973), who treat the "expanding arms" as singular regions in an otherwise normally rotating galactic disk. Other workers have noted that it is possible for non-circular motions about a central bar to reproduce the measured radial velocities for these arms without there being any net outflow of gas from the galactic nucleus. Shane (1972), Simonson & Mader (1973), and Peters (1975) have constructed kinematical models of this kind in which gas moves in elliptical orbits which are closed when viewed from a frame co-rotating with the bar.

The three kinematical models can be used to estimate the radial distribution of HI in the nuclear disk. To avoid the problem of distance ambiguities we consider only the HI emission peak at the highest "permitted" velocity, for which there is no distance ambiguity in any particular model. In general this extreme velocity peak occurs at a non-zero galactic latitude. The path lengths contributing to this emission peak at a given longitude occur at different places along the line-of-sight in the three models and are different in length. Nevertheless the general character of the derived HI distribution is similar in all three cases, as shown in Fig. 2, the mean HI density having a minimum at a distance of 1.5 to 2 kpc from the centre and rising smoothly towards the centre. No evidence is found for the ring of enhanced density at 700 pc from the centre suggested by Rougoor & Oort (1960). Fig. 2 also illustrates the considerable differences between the emission seen on opposite sides of the galactic centre. These differences are as great as the detailed differences between the three estimates of HI density, and make it impossible to distinguish between the kinematical models on this basis alone.

New insight into the structure of the nuclear disk has come from the observations of molecular lines, which sample the regions of higher gas density. The structures which appear most prominent in molecular observations are often inconspicuous in the HI data (and vice versa) because of the great increase in molecular density in the nucleus. When this is allowed for then generally good agreement is found between the HI and molecular data (cf. Cohen & Few 1976, Bania 1977). The molecular data emphasize that most of the neutral gas in the galactic nucleus has strong noncircular motions. Thus it is becoming very difficult to support the Rougoor & Oort model of a nuclear disk in simple rotation: the real situation appears to be much more complex.

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