THE LARGE-SCALE DISTRIBUTION OF HI IN M33 AND IC342

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Distortions in the distribution of the HI in the outer parts of M33 are thought to be due to a warp in the HI plane. Measurements by Reakes and Newton with the Half Mile Telescope at Cambridge provide new evidence on the extent and kinematics of this gas. The integrated HI map with an angular resolution of 7 x 14 arcmin in shown in Fig 1a. The wings extend roughly symmetrically in outline to 70 arcmin (14 kpc) from the nucleus in the plane of the sky both to the NW and the SE. The radial velocity field in Fig 1b shows large deviations from normal rotation in a plane in the outer parts. A model in which the gas rotates in circular orbits whose inclination and position angle of the major axis vary with radius, fits the HI distribution and kinematics quite well. Much larger extensions in R and z are required than in the model of Rogstad et al. (1976) and with a slower trend of i and P.A. with radius.

All the spirals in the Local Group are now known to have warps in the outer parts of comparable amplitude, but much weaker in projected HI density, than those seen in more distant galaxies by Sancisi (1976). They would be very hard to detect in galaxies at a distance of 5 Mpc. So all spirals may have warps. These nearby ones are good systems for testing theories of warping such as gravitational tides. M31 and M33 are at the same distance, are quite close neighbours and have radial velocities corrected for galactic rotation differing by only 64 km/s. If their warps are due to mutual tides during a close approach in the past, then their amplitudes must be internally consistent. A crude calculation of the ratio of radii in the two galaxies at which the warps occur is consistent with a tidal origin. Alternatively one can say that all warps, including those found by Sancisi, occur at the edge of the optical image on well exposed plates. The main problem is the well-known one of maintaining the warps until the present time. The distance of closest approach of M33 to M31 in any bound orbit is about 40 kpc, near enough to raise adequate tides in both galaxies but at a time 1.3 x 10^9 years ago, since when the warps would be largely washed out by differential precession. Putting more mass into spherical galactic halos is one way of preserving them

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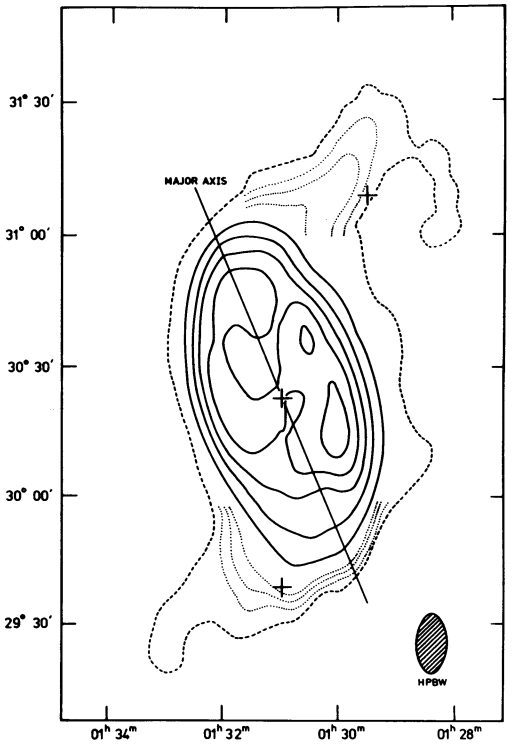

Fig 1a. HI in M33. Contours at 50, 75, 100, 125, 200, 350, 500 K km/s.

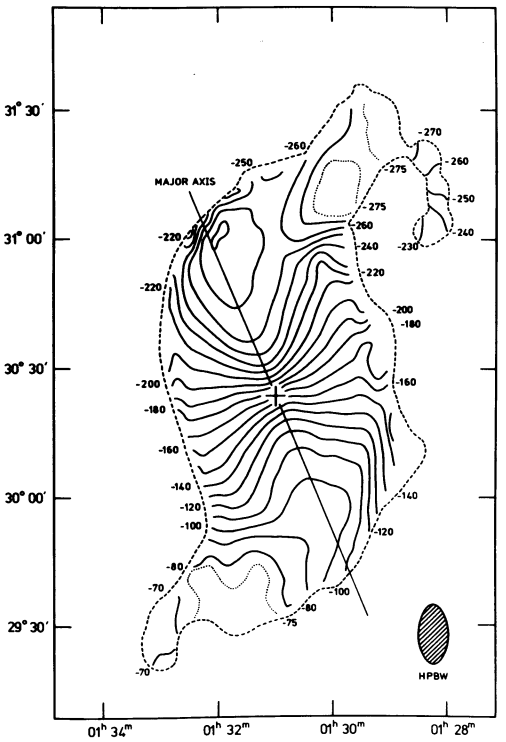

Fig 1b. Radial velocity field of M33.

for longer.

Although HI warps are detectable most clearly in edge-on systems their effects may also show up in the kinematics of face-on spirals. IC342 may be such a case. Newton has mapped the HI with an angular resolution of 1.75 arcmin and radial velocity resolution of 16 km/s. The large scale structure is best indicated by the low resolution map (7 x 7.5 arcmin) shown in Fig 2 superimposed on an optical photograph. The HI extent is roughly elliptical, with the exception of the NW quadrant which reaches 43 arcmin from the nucleus in the plane of the sky (52 kpc assuming a distance of 4.5 Mpc to IC342). Fig 3 shows the observed radial velocity field. The central region exhibits normal differential rotation, but again the outer parts show large scale deviations from normal rotation. The dynamical major axis deviates from a straight line, in opposite directions at the NW and SE ends, in a similar way to that observed in other nearby galaxies. The whole of the NW extension is apparently rotating faster than expected for normal rotation, the perturbation beginning at R=12 arcmin and increasing to R=30 arcmin but decreasing thereafter.

Fig 4 is a photographic representation of the 1.75 arcmin resolution integrated HI map. Spiral structure, with a high contrast ratio,

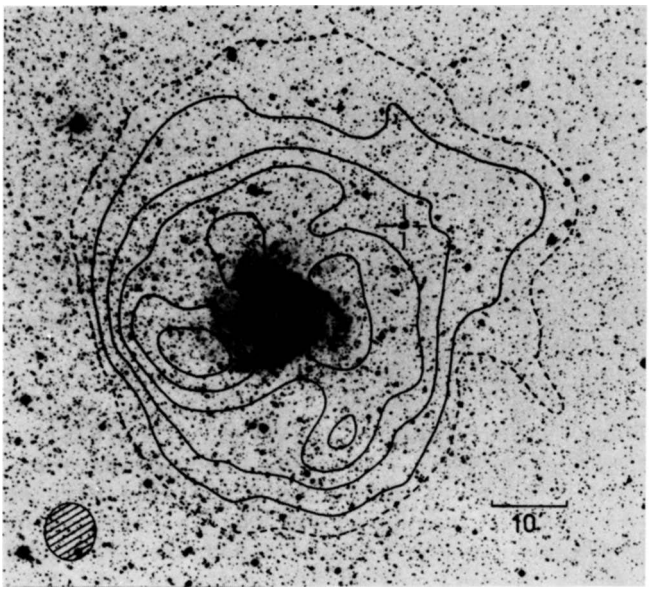

Fig 2. Integrated HI in IC342. Solid contours at 75, 175, 275, 375 K km/s.

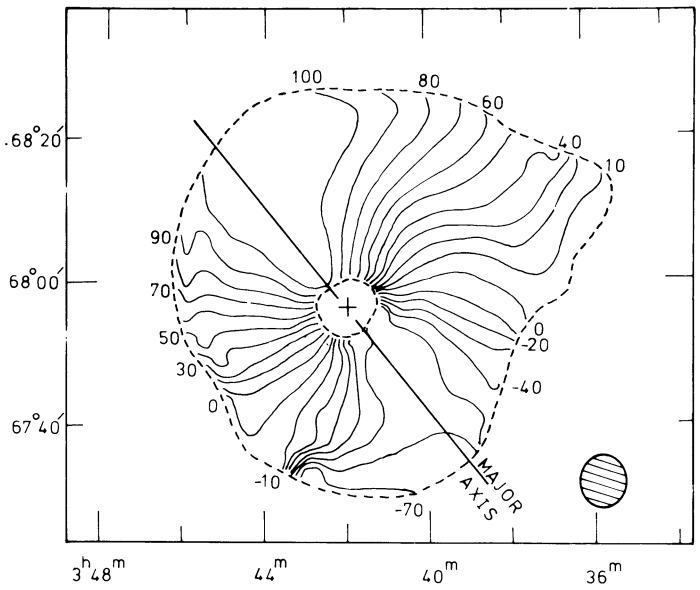

Fig 3. The radial velocity field of HI in IC342. Contour interval 10 km/s.

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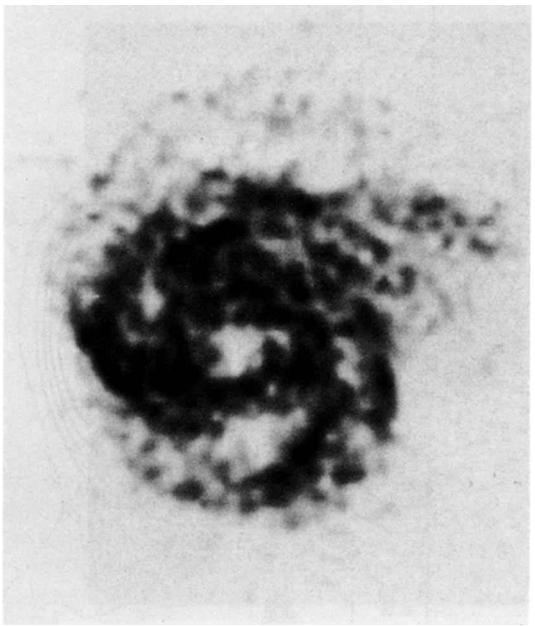

Fig 4. Photographic representation of the HI in IC342. Resolution 1.75 x 2.0 arcmin.

is clearly extending into the outermost regions of detected emission. The NW extension is also resolved into spiral arms. A likely interpretation of the velocity perturbations is that the outer spiral arms are warped away from the plane of the central disc. The low inclination of IC342 (25 degs to the line of sight) means that small changes of inclination give rise to large variations of observed radial velocity. A difference in inclination of 10^{o} produces a change in radial velocity of 30 km/s. The measured radial velocities along the spiral features in the NW may be explained by hydrogen moving in orbits with inclination increasing with radius (ie becoming more edge-on). However, the magnitude of the warp varies for each spiral arm, the maximum effect being not in the outermost arm but in the centre of the NW extension.

The most likely candidate for an interacting companion to IC342 is marked by a cross in Fig 2. It is located in the centre of the NW extension in the region of largest velocity perturbation but at present we have no redshift for this galaxy.

References

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DISCUSSION FOLLOWING PAPER III.7 GIVEN BY J.E. BALDWIN

HUNTER: Baldwin has suggested that all spiral galaxies may be warped, and have integral sign shapes. There must be projection effects to be considered. Not all edge-on galaxies with integral sign shapes can be expected to be viewed from the angle at which the warp is most noticeable. Hence Sancisi's observations (1976, A.A. 53, 159) may be giving conservative indications of the true warps, and the galaxy in which he observed no warp may really be warped, but with the warp not visible because we are viewing along the integral sign.

SANCISI: I would like to emphasise that in all cases of edge-on galaxies I have studied, and especially in NGC 5907 and 4565, the bending of the HI layer is not entirely restricted to the two extreme ends of the galaxy, perpendicular to the line of sight (i.e. in the line of nodes of galactic plane on sky plane), as the shown pictures seem to suggest. In fact the bending continues through a large range of azimuth angles away from the line of nodes. In the case of NGC 891, which has been reported as the exception (no warp), there is indeed HI emission at large z-distances on both sides of the plane, which might be interpreted as due to a bending in the line of sight direction (at 90^{o} to the line of nodes). But there are reasons for preferring alternative explanations such as a thickening of the HI layer in the outer parts of the system.

As regards the statistics of HI warps in galaxies it should be noted that the present sensitivity limits for most HI observations of galaxies are so high ($N_{HI} \simeq 5 \times 10^{19}$ cm^{-2} with resolutions of several kiloparsecs) that in the outermost parts of the disks of galaxies the HI density may become too low for detecting the bending. There may be more cases of warps like M33 and M31 in more distant galaxies, which could not be detected at present. Also for NGC 5907 and 4565 the present observations probably show only the beginning of the warp in the high density region; the warped layer may extend at lower brightness temperatures much farther from the optical plane and from the center.

SHOSTAK: I might remark that HI Westerbork syntheses of two nearly edge-on spirals, NGC 3556 and NGC 7640, show no warps. These galaxies have no obvious companions for interaction.

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