A SENSITIVE SINGLE-DISH HI-SURVEY OF THE GALAXY M33

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Extended HI-distributions around late-type galaxies have been found at a surface density of roughly 10^{20} atoms cm^{-2} (e.g. Roberts 1972, Davies 1973). For the northern part of M33 a low density HI-component ($\sim 10^{19}$ cm^{-2}) was observed to extend to about 1.5 Holmberg radii (Huchtmeier 1973). As part of a program to study the HI-distribution and kinematics of HI-shells (i.e. the HI outside the Holmberg diameter, d_H) and to search for high-velocity cloud phenomena in a dozen nearby late-type galaxies the 100-m radio telescope in Effelsberg has been used to map the neutral hydrogen in and around M33 with high sensitivity to the limit where sidelobe contributions become important. Unpublished studies of the antenna pattern and that of Reich et al. (1976) place this limit to about 10^{18} cm^{-2} in the case of this galaxy. This limit can be reached in one hour of observing time. In 1973 an area of approximately $2\overset{\circ}{.}5$ by $2\overset{\circ}{.}5$ has been observed, which has been undersampled with the chosen grid separations of 9' in δ and $12\overset{'}{.}9$ in α. Integration times inside d_H were considerably shorter than outside.

The integrated HI-distribution (over the velocity range -350 to -50 km/s heliocentric) is given in Fig. 1. The peak of the distribution reaches 856 K km/s (1.6×10^{21} atoms cm^{-2}). The integral over this map yields under the usual assumptions of low optical depth in the HI-line a total HI mass of 1.35×10^9 $M_\odot$ (± 7%) of which 10% are outside the Holmberg limit. The most striking features of this HI-distribution are its large extent ($\sim$ 2.2 Holmberg radii) and the different orientation of the lower contours compared to the optical image of the galaxy. This is reflected in the orientation of the velocity field, too. There are some obvious indications of structure in the HI-shell of M33, for example a number of local density maxima. In the South a separate condensation is located on the major axis but clearly separated from the galaxy by its radial velocity. In the Northwest the wing splits into a northern and a western branch. In the Northeast an extended region (6' x 9') shows multiple line structure. The lowest contour in Fig. 1 is dotted in three places where significant HI signal is present at the border of the observed grid.

E. M. Berkhuijsen and R. Wielebinski (eds.), Structure and Properties of Nearby Galaxies, 197-201. *All Rights Reserved. Copyright © 1978 by the IAU.*

https://doi.org/10.1017/S0074180900143815 Published online by Cambridge University Press

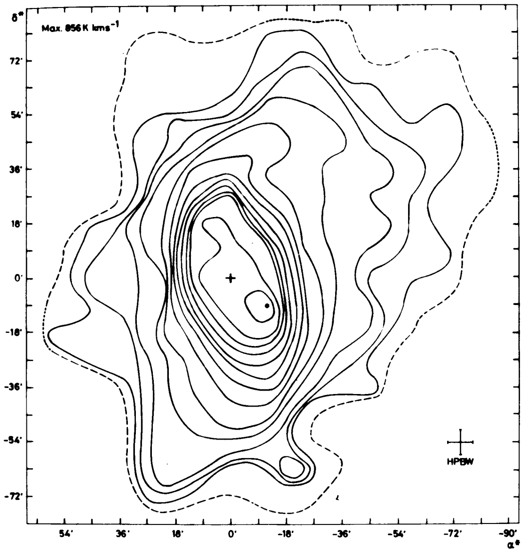

Fig. 1. HI distribution around M33. Contours are in 10% of the maximum; lower contours correspond to 5, 2, 1, and 0.5%. The broken line is the limit to which HI has been found.

The total width of the double-peaked global profile is considerably larger than twice the maximum rotational velocity (the rotation curve is given by Huchtmeier 1975). Most of the HI at the excess velocities is located inside the 20% contour of Fig. 1 and not in the wings. Within observational errors the absolute value of the excess is the same at low and high velocities. There is definitely a low intensity wing at velocities lower than -286 km/s (i.e. at the 20% level). At -328 km/s a significant HI signal is still observed. The high velocity wing is disturbed by local hydrogen. A cautionary remark may be due for all those procedures taking the total line widths of profiles as a criterium (for total masses or for distance measures) as the noted discrepancy seems to be different between galaxies.

The model of tilted rings (i.e. different inclinations and position angles of concentric outer rings of the galaxy) by Rogstad et al. (1976) does not predict these excess velocities. In that model velocities of the highly inclined outer rings are always closer to the systemic velocity than the bulk of the HI. Another difficulty of that symmetric model is the asymmetry of the HI-shell.

A consequence of our finite spatial resolution should be broad profiles in the central part of our map because the steep velocity gradient there is the most important cause for line broadening. Once the maximum rotational velocity has been reached local effects like streaming motions and turbulence determine the line width. Half-power widths of profiles near the border of the shell are of the order of 25 km/s (similar values have been observed for M31, i.e. Roberts and Whitehurst 1975). In Fig. 2 the distribution of line widths at the 25% level is presented. This distribution is rather unusual showing unexpected maxima in the HI-shell in addition to the expected maximum in the centre. Great values of line width can originate in a great velocity gradient like in the centre of the galaxy and in those regions NE and SW (e.g. Huchtmeier 1973) as seen in high resolution observations (Warner et al. 1973). Large profiles in the wing areas probably do not correspond to steep velocity gradients but rather to different HI complexes along the line of sight. There are several local maxima in line width in the HI-shell. Multiple profiles and the fact of several

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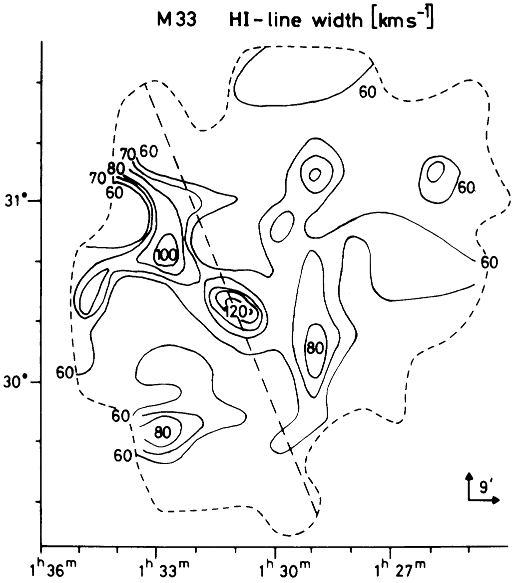

Fig. 2. Lines of equal width at a level of 25% of the maximum of the profiles are presented. Major axis and HI-extent (0.25% of the maximum) are given by broken lines.

peaks per channel map are in favour of different HI complexes in the shell.

An exception seems to be the HI complex at the lower end of the major axis. Its velocity is clearly separated from the bulk of the galaxy by 20 to 30 km/s. Its limited diameter of $\sim$ 7' corresponds to 1 kpc linear extent at the distance of M33 and its HI mass to about 10^6 $M_\odot$. The line width (corrected for instrumental broadening: 12 km/s) is typical for single HI complexes and HVC's. It should be noted that this relatively weak signal would escape detection when projected onto the bulk of the HI in this galaxy. We do not know whether this cloud is local or proper to M33. The fact that there are a number of associations between HI-complexes and nearby galaxies (Huchtmeier 1976) is taken in favour of an extragalactic solution.

A measure of the HI-shell of a galaxy is the ratio of the HI-radius (at a constant surface density) to d_H. For a number of galaxies we can plot this ratio as a function of the velocity difference Δv = total profile width (at 20% of maximum) minus twice the maximum rotational velocity. This excess velocity has not been corrected for inclination as a certain amount of it is due to an "expected" line width (10 to 25 km/s) and as it is not clear that the corresponding HI is located in the plane of the galaxy. From Fig. 3 it is evident that for small values of the shell extent (i.e. $\gamma = r_{HI}/r_{Ho} < 2$) there are no excess velocities greater than 25 km/s (or about the "expected" widths for low resolution observations in spiral galaxies). For extended HI-shells ($\gamma > 2$) we always observe velocity excesses greater than 30 km/s. The relation does not seem to be type-dependent. Irregular galaxies cover the whole range of observed

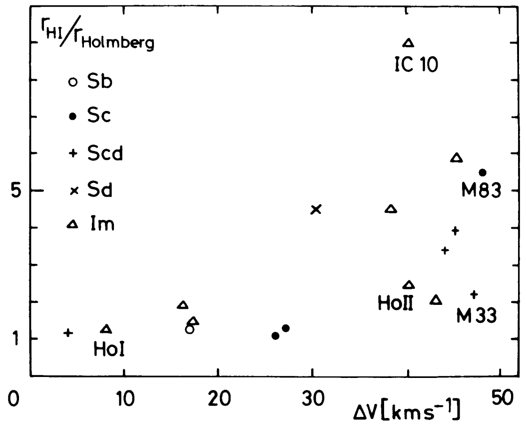

Fig. 3. The ratio r_{HI}/r_{Ho} is given as a function of the excess velocity Δv.

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values. For example: Holmberg I does not seem to have any HI-shell whereas IC10 has one of the greatest shells and a large velocity excess. This phenomenon is not limited to irregular galaxies. The giant Sc I-II galaxy M83 has the greatest known HI-shell so far and the greatest excess velocity.

Unfortunately the sample of galaxies with reliable rotation curves and with sensitive observations is only small and suffers severely from selection effects. However, it seems clear that the shell phenomenon can reach important dimensions and can be a phenomenon related to either high velocity clouds or intergalactic hydrogen. To a given limiting sensitivity (surface density of 3×10^{18} to 6×10^{18} atoms cm^{-2}) the shell phenomenon is not found in all galaxies.

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DISCUSSION FOLLOWING PAPER III.8 GIVEN BY W.K. HUCHTMEIER

TOOMRE: Do you gentlemen corroborate the claims by Rogstad et al. (1976, Ap.J. 204, 703) about the more slowly rotating "weak component" in M33?

BALDWIN: We would not be able to detect such a weak component.

HUCHTMEIER: Because of our relatively large beam width this component would be just in the wing of the profile, and therefore invisible.

WRIGHT: Recent, as yet incomplete, observations at Arecibo show that the narrow feature extending south from the north-preceding wing of M33 continues as a narrow clumpy HI feature. This feature is separate from the main HI distribution but its velocity follows that of the M33 rotation isovelocities. The peak surface density is $\sim 10^{20}$ atoms cm^{-2} and a typical clump has an HI mass of 5×10^5 $M_\odot$.

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D'ODORICO: SUPERNOVA REMNANTS IN M33

The emission line intensity ratios in HII regions and supernova remnants (SNR) in the Galaxy and in the LMC have been compared to predict the [SII]/Hα intensity ratio in SNR in M33. The different value of this ratio in normal HII regions and in SNR allows the separation of the two types of nebulae. On this criterion we have identified 3 SNR candidates in an area 8' in diameter centered on the main southern arm of M33 by comparing Hα and [SII] narrow filter photographs taken with the Asiago 1.82-m telescope (D'Odorico et al. 1977, A.A., submitted). The most striking example is a half circle 4 arc sec in diameter (10 pc) facing an HII region. This object, which resembles IC 443 in the Galaxy, suggests that the shock wave from a SN explosion has given origin to an optical emission when interacting with the denser medium associated with the HII region. The three SNR candidates have been detected in the high resolution, 21-cm radio survey of M33 by Israel and van der Kruit (1974, A.A. 32, 363). The fluxes are consistent with the values expected from galactic SNR of that size.

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