HIGH-RESOLUTION STUDIES OF NEUTRAL HYDROGEN IN NGC 5383 AND M101

R. J. ALLEN, W. M. GOSS, R. SANCISI, W. T. SULLIVAN III, and H. VAN WOERDEN

Kapteyn Astronomical Institute, University of Groningen, The Netherlands

Abstract. Maps with 0′.5 resolution are presented of the distribution of neutral hydrogen in two galaxies. The barred spiral NGC 5383 contains much hydrogen, in strong differential rotation, in its outer parts; some H I concentrations with possibly anomalous velocities are observed in the regions of bar and nucleus. In the giant Scd spiral M101, the H I distribution corresponds closely with the optical spiral pattern, except for a lack of hydrogen in the central region.

1. Introduction

The Synthesis Radio Telescope at Westerbork has been operating in the continuum at 21 cm since 1970, at 6 cm since October 1972, and at 50 cm since last month. In addition, a filter spectrometer has been available since November 1971, allowing observations in the 21-cm line with $\approx$0′.5 angular resolution and 27 km s^{-1} velocity bandwidth. We present here some preliminary results of the observing programmes on the barred spiral galaxy NGC 5383 and the giant Scd galaxy M101.

2. NGC 5383; H I Distribution and Velocity Field

Very little is known about the distribution and motions of H I gas in barred spiral galaxies. The operating principles of our synthesis telescope favour observations at high northern declinations where the choice of suitable barred spirals is limited, and we have chosen to observe NGC 5383, of type SBb, with an optically measured redshift of about 2260 km s^{-1} (distance 47 Mpc with $H \simeq 50$ km s^{-1} Mpc^{-1}) and a well-defined bar about 100″ long (22 kpc) with a dust lane down the middle.

Figure 1 is a preliminary map of the H I distribution in this galaxy as determined with the 25″ × 37″ beam of the Westerbork telescope (linear resolution about 6.5 kpc). This is the first detection of H I in this galaxy as far as we know. The continuum radiation has been subtracted using channels located outside the velocity range of the H I emission. The map shows the angular distribution of the H I intensity integrated over all velocities; the effective noise on this map is such that the outer contour may be somewhat uncertain. At any point in the galaxy the H I is in general spread over several channels, the individual channels being 27 km s^{-1} wide and spaced by 20 km s^{-1}. The channel maps show peak brightness temperatures in the H I of 10 to 15 K, with an rms noise of 2–3 K. Since the signal/noise ratio is small over most of the galaxy, we will limit the present discussion to areas of stronger signals. Some of the features of Figure 1 are the following:

(a) There are several concentrations of H I which lie outside the apparent optical

John R. Shakeshaft (ed.), The Formation and Dynamics of Galaxies, 425–430.

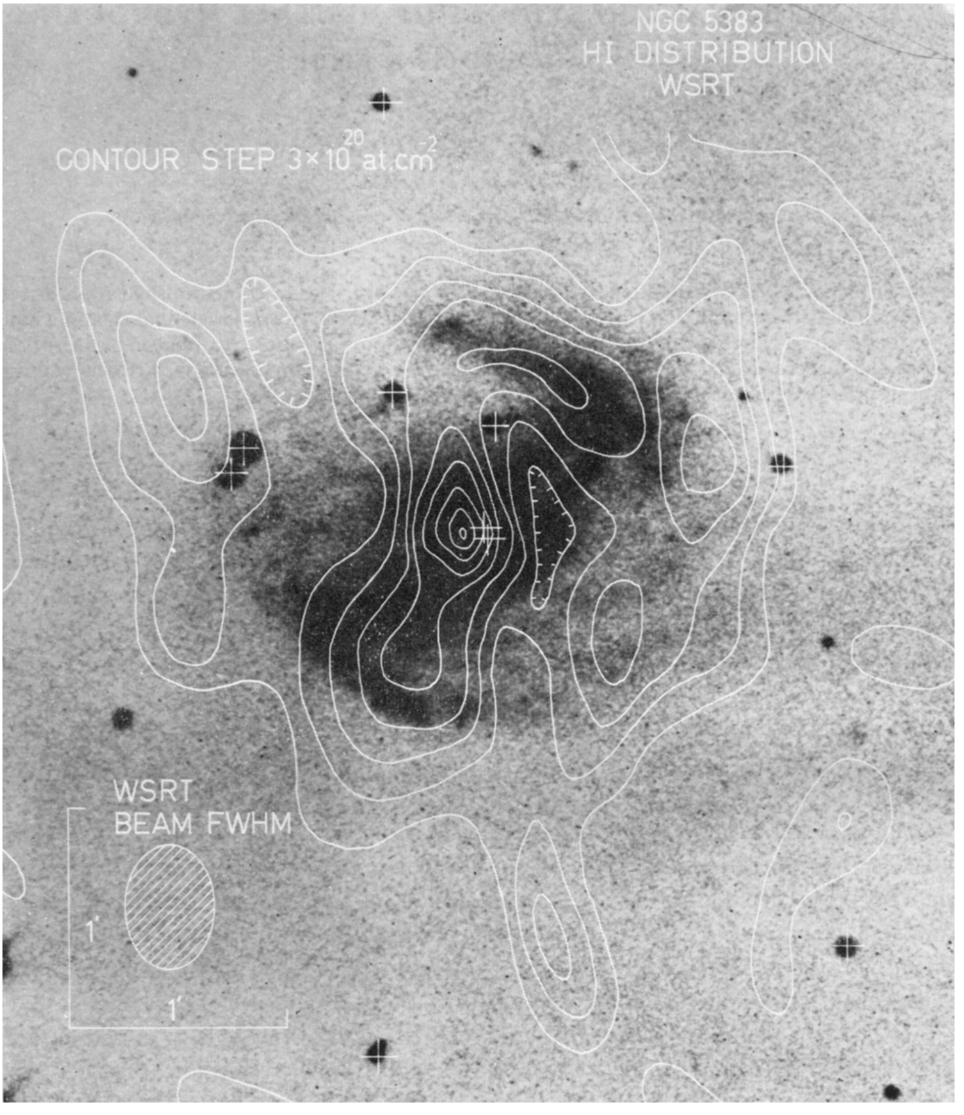

Fig. 1. The distribution of H I in NGC 5383 as observed with the 25″ × 37″ beam of the Westerbork telescope. The bar of this galaxy is about 100″ long, or 22 kpc at an assumed distance of 47 Mpc. North is at the top, east at the left in all figures.

boundary of the galaxy; one of them lies just beyond the eastern border of Figure 1.

(b) There is H I emission in the region of the nucleus and at the ends of the bar, and evidence for weak emission ($\simeq 5$ K or 2–3 × rms noise) in the direction of the bar; further observations to improve on the sensitivity are planned.

(c) The major part of the H I distribution is 6′ in diameter, or 80 kpc. The H I mass is then about $8 \times 10^9\ M_\odot$. There is some evidence for faint extensions in the H I on the southern side of the galaxy, up to perhaps 5′ away.

https://doi.org/10.1017/S007418090002461X Published online by Cambridge University Press

Some preliminary results on the velocity field of NGC 5383 have been obtained from the H I observations:

(a) The systemic velocity of the galaxy is 2250 km s^{-1} (heliocentric) with an estimated uncertainty of about 15 km s^{-1}. The total radial velocity spread is 350 km s^{-1}.

(b) There are large areas of rather constant radial velocity on both sides of the apparent minor axis of the galaxy. Along the major axis (approximately east-west) the radial velocity remains roughly constant (within 30 km s^{-1}) from about 0′.5 up to about 2′.5 from the centre. This implies that a substantial fraction of the mass of this galaxy lies outside the bar. The dynamical major axis determined from these observations agrees fairly well with the optical major axis adopted by Burbidge *et al.* (1962).

(c) Outside the region of the bar, the velocity field resembles that expected for a disk-shaped mass distribution in circular differential rotation. Within the region of the bar, there is a strong suggestion of velocity anomalies which may be associated with the bar.

(d) Good agreement between our H I radial velocity measurements and the optical observations along the bar made by Burbidge *et al.* (1962) is obtained in regions where a comparison can be made, namely, near the nucleus and near the ends of the bar.

An estimate of the hydrogen-to-total mass ratio gives a value in good agreement with that commonly obtained for Sb galaxies (Roberts, 1969).

3. M101; Distribution of the Small-Scale Structure in H I

The desire to obtain high-resolution observations of the H I content of this galaxy was one of the many reasons for constructing the multi-channel spectrometer at Westerbork. The observations obtained by Rogstad and Shostak (1971) with a resolution of 4′ were insufficient to resolve one spiral arm from another in this galaxy, since these arms have separations of about 3′ or less. The Westerbork maps, obtained in 16 half-days of observing, provide an angular resolution of 25″ × 30″ or about 1 kpc at an assumed distance of 7 Mpc. The data have not yet been corrected for attenuation by the primary beam at the edge of the maps. In addition, the absence of interferometer spacings shorter than 36 m means that structures in the H I on scales of about 10′ and larger are not adequately observed; we therefore confine our present remarks to structures on angular scales smaller than 10′.

Figure 2 shows on the left a 'radiograph' representation (Ekers *et al.*, 1973) of the H I distribution in M101 and, to the same scale, an optical photograph taken from Arp (1966). The radiograph contains small crosses at nine fiducial points as well as at the positions of six alignment stars. The mottled appearance of the background arises from noise in the observations; the size of the smallest spots is approximately that of the telescope beam.

The following features can be seen in Figure 2:

(a) The H I tends to appear in long, more-or-less connected features closely coincident with optical spiral arms and H II region complexes. On deeper optical exposures almost all of the hydrogen features have optical counterparts, including the outer H I

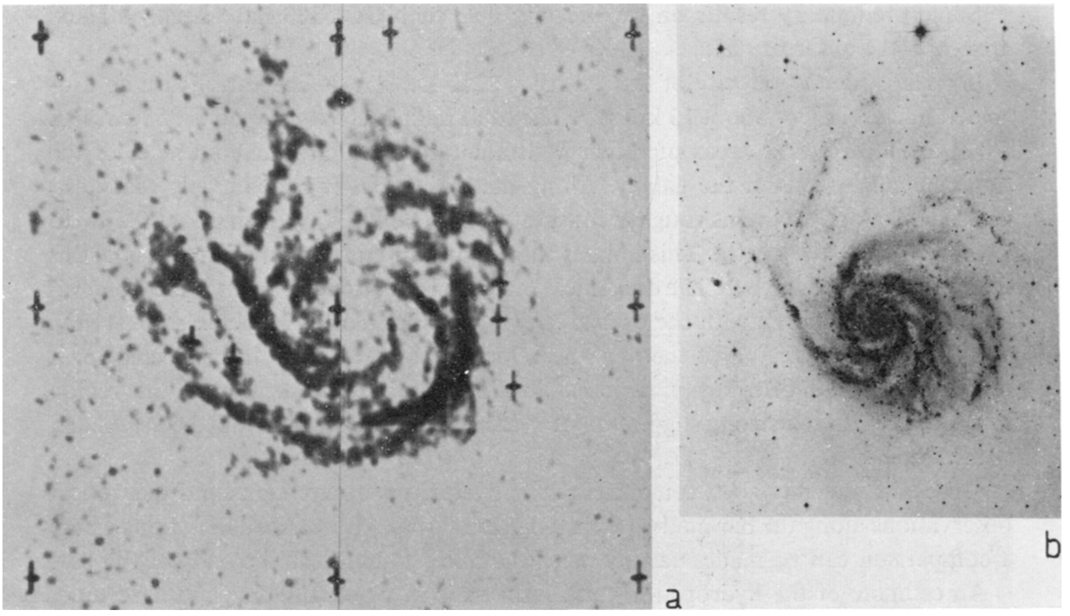

Fig. 2. (a) Radiograph showing the distribution of neutral hydrogen surface density in M101. Large-scale (> 10′) components in the distribution are not recorded. The radiograph contains crosses at nine fiducial points as well as the positions of six stars. The mottled appearance of the background in the radiograph arises from noise in the observations; the size of the smallest spots is about that of the telescope beam.
(b) Blue photograph of M101, from Arp's *Atlas of Peculiar Galaxies*. Scale same as Figure 2(a).

spiral arms to the south-east of the centre. This close correspondence weakens some of the arguments advanced by Piddington (1973) in his criticism of the observational evidence favouring the density-wave theory of spiral structure.

(b) Not every optical feature has an H I counterpart; in particular the central regions of the galaxy seem devoid of small-scale H I features, a fact already noted by Rogstad (1971) and by other observers.

(c) We have detected hydrogen in NGC 5477, an object classed as a small irregular companion of M101. The H I feature is located on the far left of the radiograph about one centimetre above the middle fiducial mark. The optical photograph does not cover this feature.

The radio H I contours are superposed on the optical photograph in Figure 3, illustrating again the detailed correspondence of the narrow, elongated H I features with optical spiral arms. The observed peak-to-average brightness temperature ratio is about 3, but since the H I is in many places not resolved across the spiral arms the true peak-to-average ratio is certainly greater.

Further discussion of these preliminary results on M101 will be published in *Astronomy and Astrophysics* (see **29**, 447, 1973 for Paper I).

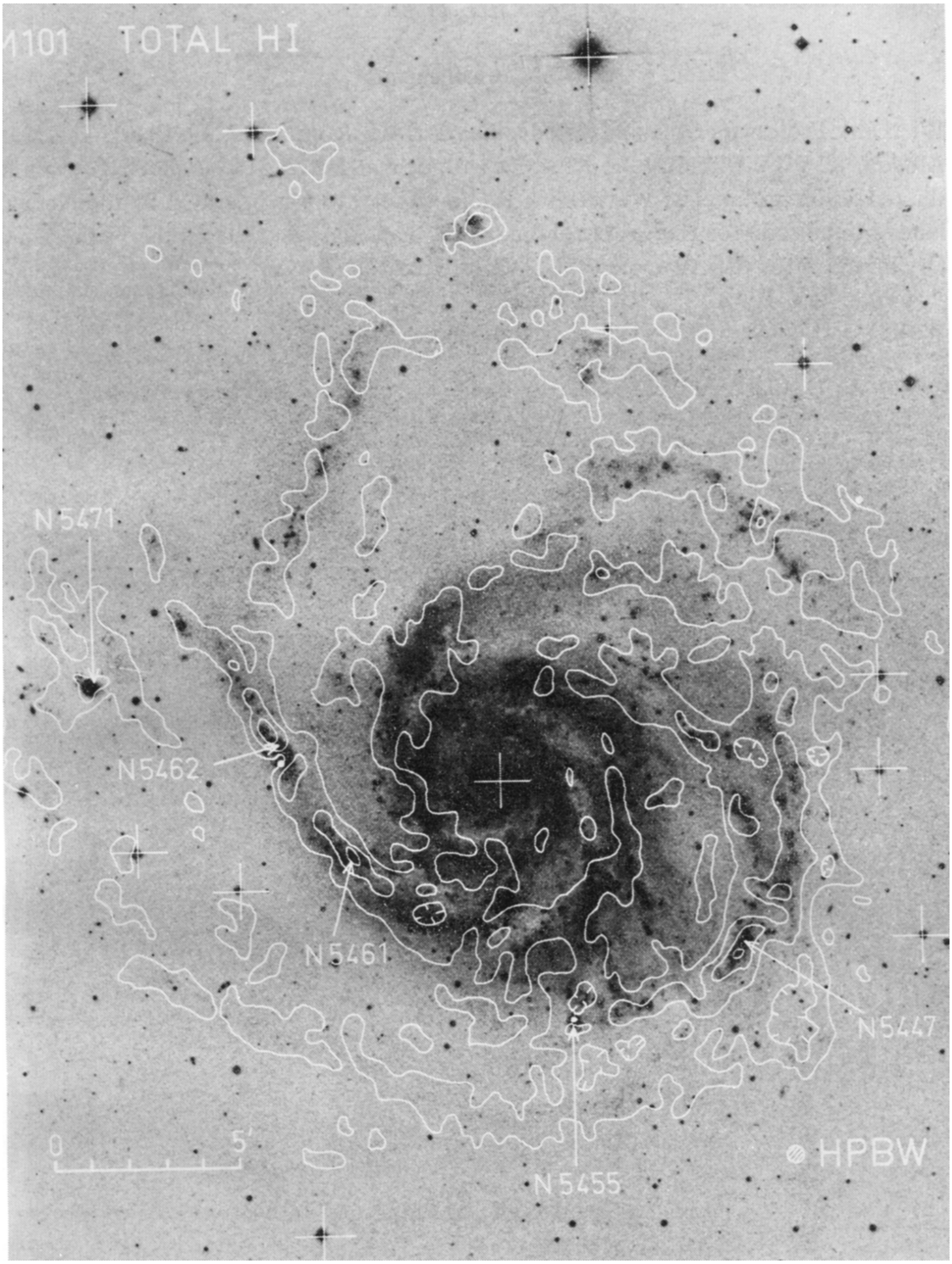

Fig. 3. Overlay of contours of hydrogen surface density (N_H) on the blue photograph. Contour levels are approximately: (4, 12, 20, 28) $\times 10^{20}$ atom cm^{-2}. However, for reasons discussed in the text, the N_H scale increases somewhat away from the centre of the galaxy and the zero level of the N_H contours is uncertain. The angular scale is shown at lower left (1 arc min = 2 kpc), the synthesized beam in the lower right corner.

Note the detailed correspondence of optical and radio features. The brightest H II regions, indicated by their NGC numbers, have all been detected in the continuum. The cross in the nucleus of the galaxy corresponds to: (1) an optical H II region, (2) a weak associated radio source, and (3) the centre of the galaxy as defined by the light distribution on blue photographs. The other crosses are fiducial marks in the hydrogen map corresponding to positions of stars. The three historical supernovae in M101 (SN1909a at 12′ NW, SN1951 at 6′ E, and SN1970g at 6′ S) are indicated by white dots.

https://doi.org/10.1017/S007418090002461X Published online by Cambridge University Press

Acknowledgements

We thank Professors Oort and van der Laan, D. H. Rogstad, R. D. Ekers, T. S. van Albada, K. W. Weiler and the telescope group, and H. W. van Someren Greve and the reduction group. The Westerbork Radio Observatory is operated by the Netherlands Foundation for Radio Astronomy with financial support from the Netherlands Organisation for the Advancement of Pure Research (ZWO).

References

Arp, H. A.: 1966, *Atlas of Peculiar Galaxies*, California Institute of Technology, Pasadena.
Burbidge, E. M., Burbidge, G. R., and Prendergast, K. H.: 1962, *Astrophys. J.* **136**, 704.
Ekers, R. D., Allen, R. J., and Luyten, J. R.: 1973, *Astron. Astrophys.* **27**, 77.
Piddington, J. H.: 1973, *Astrophys. J.* **179**, 755.
Roberts, M. S.: 1969, *Astron. J.* **74**, 859.
Rogstad, D. H.: 1971, *Astron. Astrophys.* **13**, 108.
Rogstad, D. H. and Shostak, G. S.: 1971, *Astron. Astrophys.* **13**, 99.

DISCUSSION

E. M. Burbidge: You are presumably getting a high angular momentum out of these observations, and this is interesting in that the meagre other data on barred spirals also suggest high angular momenta for barred spirals (cf. Burbidge, E. M., Burbidge, G. R., and Prendergast, K. H.: *Astrophys. J.* **136**, 704, 1962).