

HI OBSERVATIONS OF THE IRREGULAR GALAXY IC 10

G.S. Shostak and H. van Woerden
Kapteyn Astronomical Institute
University of Groningen, The Netherlands

IC 10 is seen optically as a patchy nebulosity, approximately 3×4 arcmin in size, possibly heavily obscured due to its low (-3°) Galactic latitude. De Vaucouleurs and Freeman (1972) have classified it as a Magellanic barred irregular. With a heliocentric radial velocity of -350 km/sec, its distance is uncertain, and various investigators have placed it as far away as 3, and as near as 1 Mpc (Bottinelli et al., 1972; Roberts, 1962). For the latter value, IC 10 would be a Local Group member.

Recent single-dish HI studies (Cohen, 1979; Huchtmeier, 1979) have shown IC 10 to have a hydrogen envelope ~ 70 arcmin in size, or more than 20 times the optical diameter. The linear size of the envelope is 20 kpc for a distance of 1 Mpc. The envelope has an overall velocity gradient from -300 to -360 km/sec, south to north, although substantial irregularities are present.

We have made radio synthesis observations of IC 10 with resolutions of 30 arcsec and 8 km/sec in the neutral hydrogen line using the Westerbork telescope. These confirm Shostak's (1974) result that, in the central region of IC 10, the velocity gradient is opposite to that later measured by single-dish in the outer regions. The suggestion by Cohen (1979) that the velocity gradient reversal is due to IC 10 being nearly face-on and warped is consistent with the new data. Note, however, the following:

- The reversal in velocity gradient, and therefore the presumed warp, begins to the south within 5 arcmin (1.5Δ kpc, where Δ is the distance to IC 10 in Mpc) of the dynamic center, or at only 15% of the total radius measured in HI.
- The central velocity field is consistent with a rotation having a maximum amplitude $20/\sin i$ km/sec. For $i = 15^\circ$, this is 77 km/sec, or typical of the rotation speed measured for irregulars of moderate luminosity.
- For reasonable assumptions about the shape of the rotation curve in the outer regions and the galaxy's inclination, the required warp

along the major axis is generally mild, with a maximum of $<35^\circ$ from the central plane. However, there are clearly strong azimuthal asymmetries, and in the extreme south a warp angle of $\sim 90^\circ$ is indicated.

- The velocity dispersion in the central regions is 8 - 10 km/sec, justifying the assumption of a thin HI disk.

Because of the improved resolution and sensitivity of the present observations, they have revealed considerable detail in the central, patchy, high surface brightness HI. This consists primarily of

- a roughly elliptical region with column density $N_{\text{H}} > 6 \cdot 10^{20} \text{ cm}^{-2}$, with a position angle of $\sim 50^\circ$ and dimensions 7×10 arcmin.

- a "tail" extending ~ 10 arcmin south, with $N_{\text{H}} \sim 1.5 \cdot 10^{20} \text{ cm}^{-2}$.

- a "spur" to the northwest, about 5 arcmin long, and similar in brightness to the tail.

The main body of the bright HI is rent with clearly defined holes. The most conspicuous of these have half-intensity diameters ~ 1 arcmin (0.3Δ kpc), and imply, on the basis of the observed HI deficit, the removal of $\sim 5 \cdot 10^5 \Delta^2 M_{\odot}$ of HI. At least one shows a double profile suggesting radial motions of ~ 20 km/sec. Assuming this to be a simple expansion, the energy required to remove HI from the hole is $2 \cdot 10^{51} \Delta^2$ ergs, or similar to or larger than that in massive supernovae. The time to evacuate the hole is $\sim 10^7 \Delta$ yr which, because of the small rotation velocity of IC 10, is less than, or comparable to, the time scale for smearing of such features by differential rotation, thus making such features visible.

Acknowledgement

The Westerbork Observatory is operated by the Netherlands Foundation for Radio Astronomy, with financial support from ZWO.

References

- Bottinelli, L., Gouguenheim, L., Heidmann, J. 1972, *Astron. Astrophys.* 18, 121
 Cohen, R.J. 1979, *Mon. Not. R.A.S.* 187, 839
 Huchtmeier, W.K. 1979, *Astron. Astrophys.* 75, 170
 Roberts, M.S. 1962, *Ap.J.* 67, 431
 Shostak, G.S. 1974, *Astron. Astrophys.* 31, 97
 De Vaucouleurs, G., Freeman, K.C. 1972, *Vistas in Astronomy*, Vol. 14, Pergamon Press, Oxford, p. 163