DUST AND NEUTRAL HYDROGEN IN THE REGION OF IC 1396

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Abstract. A 21-cm survey at Dwingeloo of a 5° square containing IC 1396 shows several neutral hydrogen concentrations that correspond in shape and position with dust clouds, particularly the bright-rimmed clouds involved with the H II region.

1. Introduction

IC 1396 is a large H II region of low surface brightness excited by the O6 trapezium system HD 206267 and the stars of the early-type cluster Trumpler 37, whose distance modulus is 9.6 mag. (Simonson, 1968). Since the angular size of the nebula and the bright-rimmed dust clouds with which it is interacting are a few times larger than the beamwidth of the Dwingeloo 25-m radio telescope, the region has some advantages for studying the relation of neutral hydrogen and dust. However, its location at $l = 100°$ presents problems in separating discrete neutral hydrogen features from the general foreground and background neutral hydrogen since the velocity range $v = 0$ to -10 km s^{-1} corresponds to a distance range of 0 to 1.5 kpc. The results of a survey of neutral hydrogen and a comparison with the dust distribution are given briefly here; the details will be presented elsewhere.

2. Observations

A 5° square containing IC 1396, from $l = 97°$ to 102°, $b = +1°$ to $+6°$, was surveyed on a 0°.5 grid with the Dwingeloo 25-m radio telescope using a bandwidth of 8 kHz (1.7 km s^{-1}). Contour maps of brightness temperature were constructed in all three coordinate planes – l, b; b, v; and l, v – at every interval in the orthogonal coordinate. The l, b maps were compared with the Palomar Observatory Sky Survey and with Khavtassi's (1960) and Lynds's (1962) atlases of dark nebulae, all reproduced on the same scale.

3. Results

In order to confirm the reality of supposed correlations of 21-cm and optical features, one must have some idea of the size of fluctuations in the general field. In this instance it is possible to use an unpublished large-scale 21-cm survey by H. van Someren Greve made at Dwingeloo and covering the region $l = 90°$ to 115°, $b = -1°$ to $+15°$, on a 1°.4 grid. The large-scale survey shows a general concentration of 21-cm line emission

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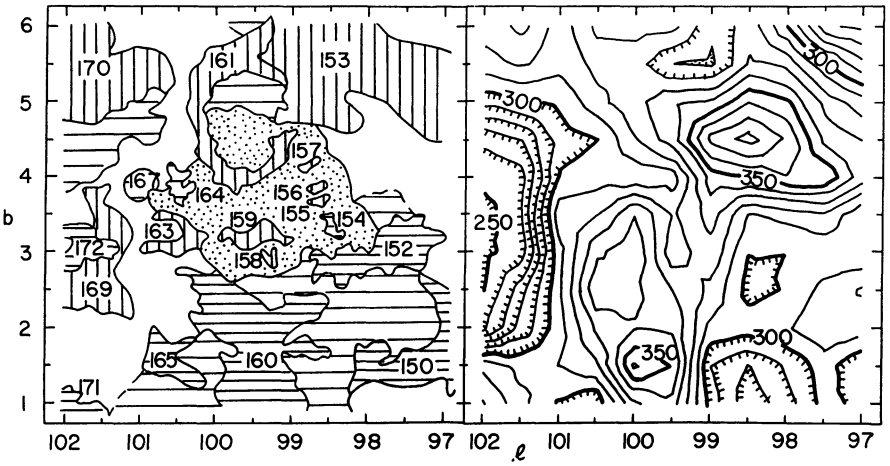

Fig. 1. Comparison between dust clouds (Khavtassi, 1960), left, and neutral hydrogen brightness temperature, summed over $v = -4$ to 0 km s^{-1}, right. Cross hatches indicate dust clouds of three levels of opacity; stippling indicates Hα emission. The 21-cm contour intervals are 10 K.

at the position of IC 1396 in the velocity range of the cluster stars and the Hα emission, about -5 to $+5$ km s^{-1}. At velocities below -5 km s^{-1} a galactic feature, perhaps a 'spur', extends into the region from the direction of Cygnus.

The present detailed survey resolves the concentration around IC 1396 into several smaller concentrations. Figure 1 shows the comparison with dust clouds in the velocity range containing the strongest features. We note the following correlations between 21-cm features and dust clouds:

(1) Bright-rimmed dust clouds, which are obviously connected with IC 1396, appear to be associated with H I emission features at velocities between -5 and $+5$ km s^{-1}. These include Kh 155, 156, 157, 159, 160, 163, 164, 167, and portions of Kh 153 and 161. There is a tendency for the very densest parts of the dust clouds to be associated with somewhat less 21-cm emission than less opaque parts, but there is no evidence in the line profiles for self-absorption. This would indicate the gas temperature exceeds 80 K, but there may also be some foreground emission.

(2) Dust clouds seen projected against IC 1396 but without bright rims, e.g., Kh 152, 154, and parts of 161, are apparently associated with 21-cm emission of somewhat lower intensity at velocities between 0 and $+10$ km s^{-1}.

(3) Other dust clouds associated with 21-cm emission at $v = -5$ to $+5$ km s^{-1} are Kh 150, 165, 170, 171, and parts of Kh 153 and 161.

(4) A region bright in H I but only moderately obscured occupies about 1 deg^2 at $l = 98°$, $b = +4°.5$, at $v = 0$ to $+5$ km s^{-1}.

(5) Beginning rather abruptly at $l = 101°$ between $b = +1°.5$ and $+5°$ and extending into higher longitudes is a region very low in 21-cm emission and low in optical obscuration except for several sharp-edged opaque dust clouds, e.g., Kh 169 and 172. Van den Bergh (1967) has suggested that this area is a 'fossil H II region'. The ap-

pearance in H I tends to bear this out, as if some general expansion had swept the neutral gas away.

Overall, in the velocity range -4 to $+10$ km s^{-1}, where there appears to be significant correlation of dust and neutral hydrogen, the mean column density of neutral hydrogen, N_H, amounts to 1.5×10^{21} cm^{-2}, uncorrected for the effects of optical depth. For 28 stars in the survey area with a mean distance modulus of 9.6 mag. (Simonson, 1968), the ratio $N_H/3E_{B-V} = 8 \times 10^{20}$ cm^{-2} mag.$^{-1}$.

Judging by van Someren Greve's large-scale survey, about 80% of N_H may be due to foreground and background hydrogen. (It is unnecessary to allow for absorption against the thermal radiation of IC 1396; at 1400 MHz the peak brightness temperature is less than 3 K (Lynds, 1961).) The mass in the concentrations may therefore be estimated as $2 \times 10^4 \mathcal{M}_\odot$, uncorrected for optical depth and taking the distance as that of IC 1396. For comparison, the mass of ionized hydrogen is about $7 \times 10^3 \mathcal{M}_\odot$ (Pottasch 1965) and the mass of stars earlier than B3 is about $10^3 \mathcal{M}_\odot$ (Simonson, 1968).

4. Conclusions

The dust clouds in the region of IC 1396 are apparently associated with neutral hydrogen concentrations, and the association is clearest for the clouds with bright-rim structures. The major exception is a 'fossil H II region'. Provided the optical depth in the neutral hydrogen does not exceed a value of the order unity, the ratio of neutral hydrogen in dust clouds to ionized hydrogen to early-type stars is 20:7:1 in IC 1396 and its environs. The overall ratio of N_H/A_V amounts to 8×10^{20} cm^{-2} mag.$^{-1}$, quite an ordinary value.

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