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Search for Neutral Hydrogen in the Galactic Cluster NGC 2287*

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Observations were made in the direction of the galactic cluster NGC 2287 and its neighbourhood with the radiotelescope at Parque Pereyra Iraola. The results do not give a definite conclusion about the presence of neutral hydrogen in the cluster because of the complexity of the region. An upper limit to neutral hydrogen associated with this cluster and within 1.° of it is found to be 600 $M_\odot$.

Foram feitas observações na região do cúmulo galático NGC 2287 com o radiotelescópio instalado no Parque Pereyra Iraola. Os resultados não dão uma conclusão definitiva sobre a presença de hidrogênio neutro no cúmulo devido a complexidade da região. Foi encontrado que o limite superior do hidrogênio neutro associado a esse cúmulo, dentro de 1.° de seu centro, é de 600 $M_\odot$.

1. Introduction

The open cluster NGC 2287 (M41 or Cr 118) has a position $l = 231''.10$, $b = -10°.20$ (Alter-Ruprecht 1963) and an apparent diameter of 35' (Buscombe 1963) making it suitable for a 21-cm line study. Cox 1954 obtained the color diagrams. The equivalent spectral type is B3 and the photometric and spectrographic color excesses $E_{(B-V)}$ are 0.01 and -0.03 respectively (Hoag-Applequist 1965). Since its distance is $r = 0.67$ kpc and its altitude over the galactic plane is $Z = -0.120$ kpc (Becker 1963), its real diameter is 7 pc. The age of the cluster can be estimated from a diagram of Sandage 1958 as being $\sim 1.6 \times 10^8$ years. The radial velocity was measured by Schmidt-Kaler 1961, who derived $v_r' = +34 \pm 3$ km/s

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from 20 members. Correcting this value to the LSR by means of MacRae and Westerhout's 1956 table we obtain $v_r = +15$ km/s. The radial velocity due to galactic rotation, computed in the galactic plane for a distance of 0.67 kpc in the direction of the cluster is $+10$ km/s.

With all this in mind, we decided to make a 21-cm study of the cluster in order to measure the amount of neutral hydrogen – if any – associated with it. Evaluation of this quantity in galactic clusters is valuable for the study of the process of star formation. A general discussion of hydrogen associated with galactic clusters has been given by Gordon *et al.* 1968. According to D'Odorico and Felli 1970, clusters in which the spectral type of the earliest stars is B3 or earlier in general show both the presence of dust and of neutral hydrogen.

2. Observations

Observations were made with the 30 meter radiotelescope at Parque Pereyra Iraola, operated by the ***Instituto Argentino de Radioastronomia*** (IAR) and the Carnegie Institution of Washington (CIW). At $\lambda = 21$ cm, its beam width is $\sim 0°.5$. The accuracy of the coordinates is better than $0°.02$. The receiver is of the Dicke type and has 56 channels with passbands of 10 kHz. Its first amplifier stage has a parametric amplifier with an input noise of the order of 180° K, although the total noise, adding spill-over radiation, losses in cables and other noise sources is estimated to be $\sim 250°$ K. Observations are made usually with the local oscillator at two different frequency positions, displaced by 47.5 kHz (10 km/s). In this manner, a hydrogen profile for a given point on the sky consists of 112 values for the antenna temperature T_a, spaced at 2 km/s. The total integration time used for each profile was 6 minutes. The output is obtained directly on punched cards (by means of an analog to digital converter system), which are reduced with the help of an IBM 1620 computer.

The observations in the cluster's direction were made during august and september 1968 over a net of 33 points on the sky centered at the cluster. A set of 94 profiles was obtained. The antenna temperature scale was calibrated by assuming that the peak intensity of the profile observed at the reference point $l = 356°.00$, $b = -04°.00$, is 80.00° K. The resultant averaged profiles are shown in Fig. 1. Their average noise level is estimated to be of the order of 0.8° K, while the smearing of velocities is less than 0.4 km/s. This is small compared with the passband of the filters (~ 2.0 km/s).

3. Discussion and Conclusions

In order to find a possible correlation between the neutral hydrogen distribution and the cluster's position, different sets of isophotes were made. The isophotes for T_a were drawn for several constant values of v_r: -10, $-5, \ldots +70$ km/s, but they did not show any evident correlation, except for $v_r = +40$ km/s, for which a feature is revealed in the cluster's direction. Since this velocity is very different from the value derived optically by Schmidt-Kaler 1961, it probably has nothing to do with the cluster. Isophotes of integrated values of T_a in the interval $+10$ to $+20$ km/s did not show any correlation either.

Looking for a more auspicious method, the differences between the profile for the cluster's centre and for the 4 extremes of each of 4 crosses whose arm half-lengths were 0.5, 1.0, 1.5 and 2.0" were made. Results are shown in Fig. 2a and 2b. Finally, in Fig. 3 are shown the corresponding average differences, which were made in order to neutralize possible gradient effects in Fig. 2. As can be seen from this Fig., for $v_r \sim +15$ km/s evidence of the existence of a maximum at the cluster's centre is not very striking since the structure of the observed region is extremely complex. On the other hand, neutral hydrogen associated with the cluster can not be excluded, due to the presence of a peak in Fig. 3 for $v_r \sim +18$ km/s. The peak is clearly distinguishible for $\Delta\varphi = 2°$ and its intensity decreases with angular width, disappearing almost for $\Delta\varphi = 0.5$". If this feature is associated with the cluster, an extension greater than 3° in diameter is implied, with a density decreasing from the centre outwards. In Fig. 3 two other peaks can be seen, one for $v_r \sim +40$ km/s, also present in Fig. 2, and the other for $v_r \sim +30$ km/s. There are also two negative structures (deficits of hydrogen). for $v_r \sim 0$ and $v_r \sim +10$ km/s. All these probably correspond to structures present in the line of sight to the cluster, but at different distances from it, but since their velocities are rather different from those observed optically, they are probably not associated with the cluster. Now, if we assume the peak at $v_r \sim +18$ km/s, visible in Fig. 3, is associated with the cluster, it is interesting to estimate the neutral hydrogen mass corresponding to it. This is difficult because of the adjacent peak at $\sim +30$ km/s and the depression at $\sim +10$ km/s and because of the lack of detailed information as to its spatial distribution. Therefore we give only an upper limit for the mass of the neutral hydrogen present in a small region surrounding the cluster. Assuming low optical depth, the mass M_H (in $M_\odot$) of a spherical structure subtending an angle φ (in degrees) is given by

$$M_H \sim 3.5\varphi^2 r^2 \left(\overline{\bar{T}_a \cdot \Delta v_r}\right), \qquad (1)$$

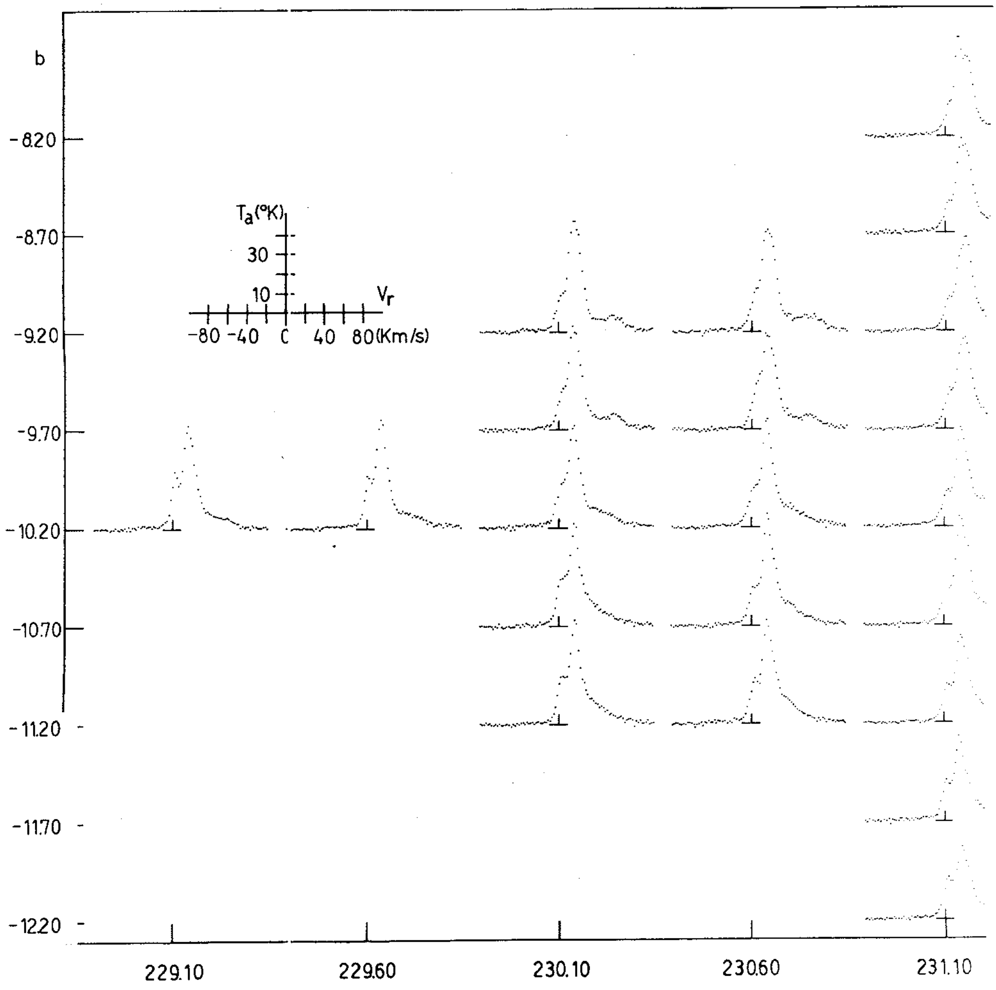
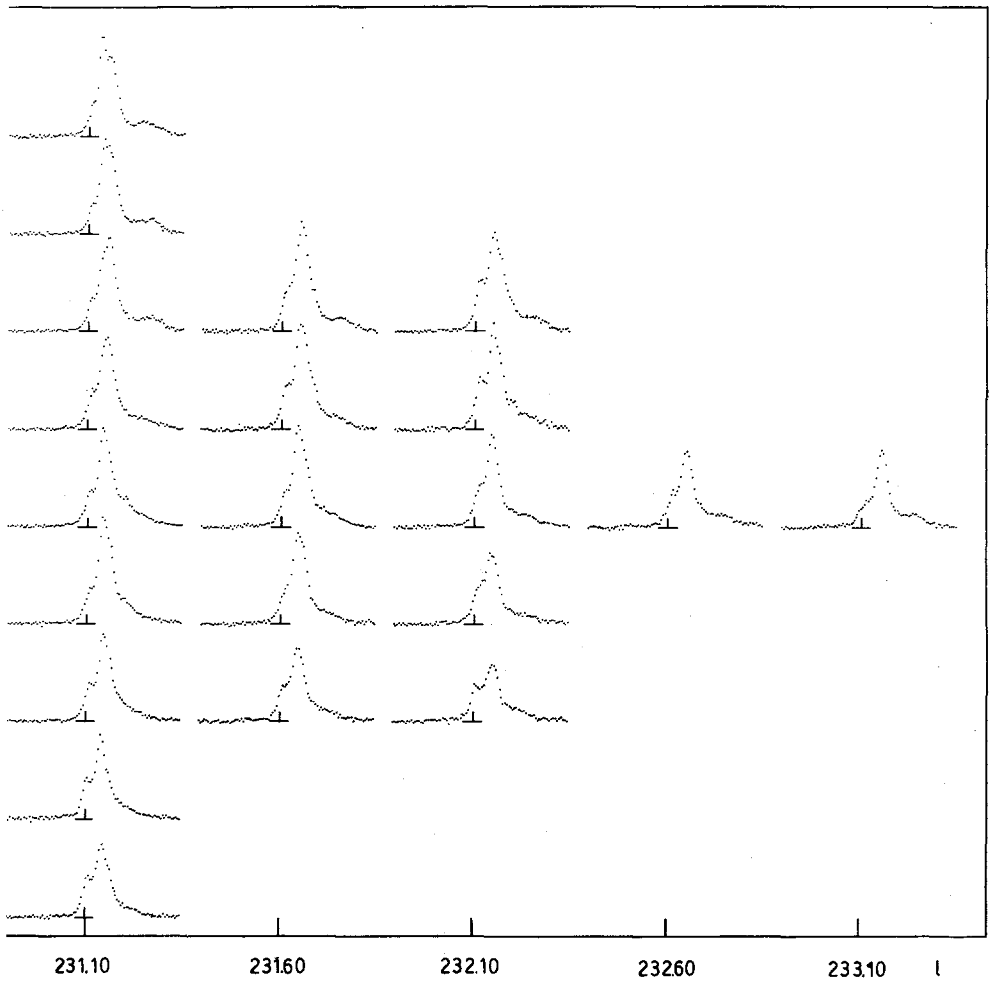


Fig. 1 - Resultant averaged profiles for the observed points.


231.10
231.60
232.10
232.60
233.10

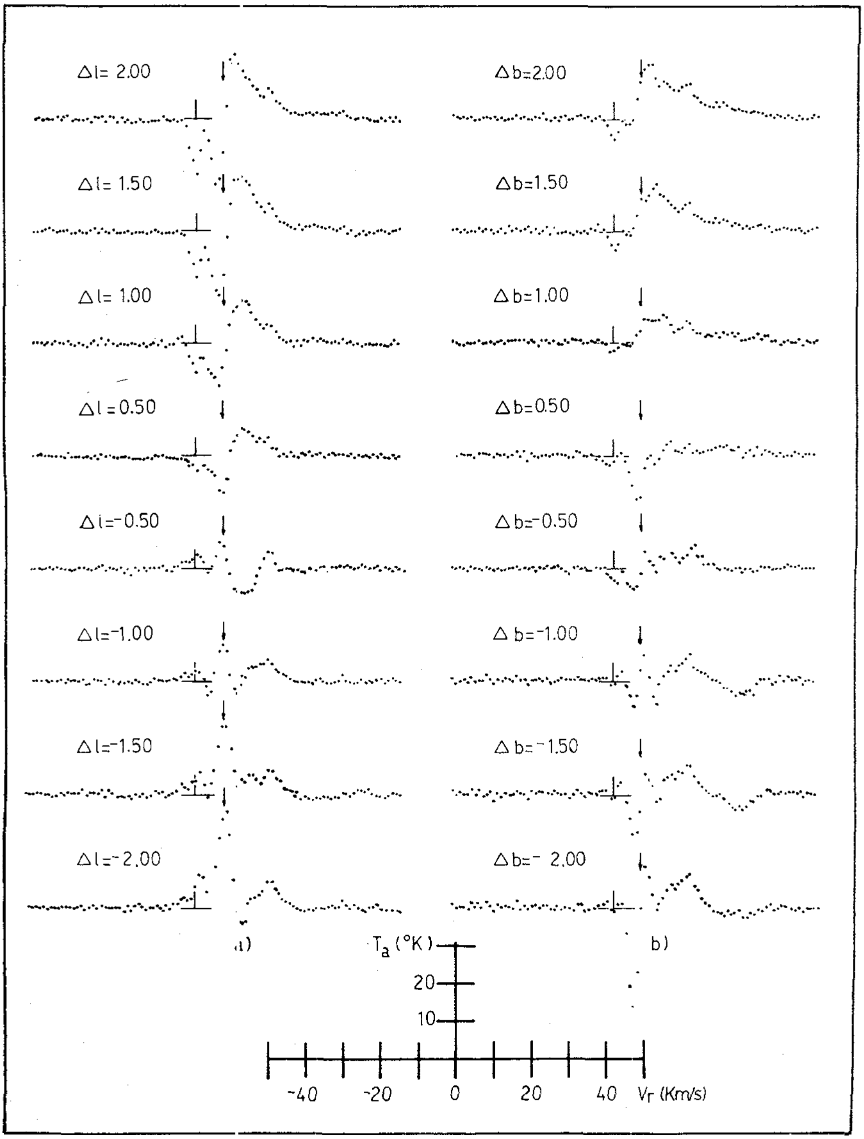


Fig. 2a, b - Results from making the differences between the profile for the cluster's centre and those on a cross centered at the cluster.

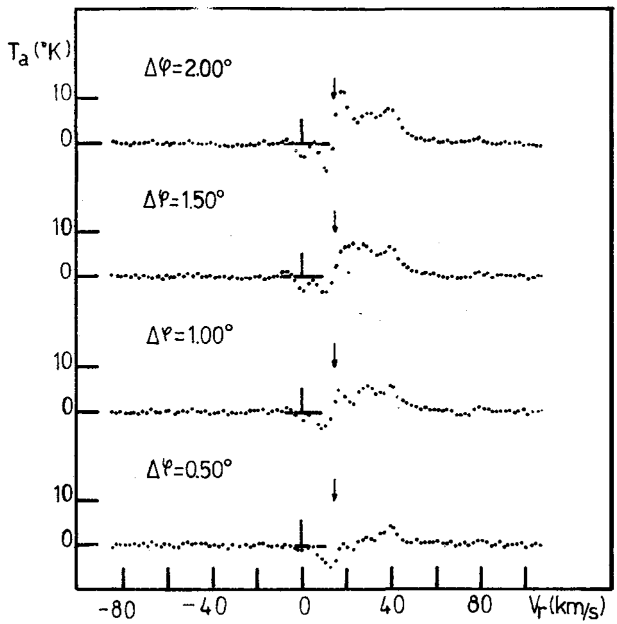


Fig. 3 - Average differences obtained from Fig. 2.

where the effective velocity interval is given in km/s, T_a's mean value over it in °K and the distance r in kpc. Clearly, the expression between parenthesis gives the area under the curve while the bar over it means an angular average. Taking for the area under the peak for $\Delta\varphi = 2"$ in Fig. 3, the value 100" K.km/s, which would correspond to the maximum density of hydrogen at the centre of the cluster, and taking a surrounding region of 2° in diameter, the resulting upper limit for the mass of the inclosed neutra1 hydrogen is 600 $M_\odot$. On the other hand, the stellar mass of NGC 2287 has been estimated by Schmidt 1963, on the basis of the observed luminosity function as being 815 $M_\odot$.

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