Astron. & Astrophys. 5, 240—243 (1970)

Peculiar Motions of Neutral Hydrogen in the Vicinity of the Orion Nebula

T. K. Menon
Institute for Astronomy, University of Hawaii

Received November 13, 1969, revised January 8, 1970

A detailed study of the distribution of 21-cm emission in the vicinity of the Orion Nebula shows the presence of a neutral hydrogen cloud close to the Nebula which is approaching the Nebula with a velocity of about 14.2 km/s. It is suggested that the conical absorbing band seen in projection against the Nebula is part of the above cloud. The minimum density of neutral hydrogen atoms in the cloud is about 100 cm^{-3}.

Key words: 21-cm emission — neutral hydrogen — Orion Nebula

I. Introduction

The distribution of neutral hydrogen in the vicinity of a number of H II regions has been studied by several investigators [see van Woerden (1966) and Riegel (1967)]. These studies were generally based on analysis of 21-cm emission profiles in the regions containing the emission nebulae. Any excess or deficiency in emission of neutral hydrogen correlated in position or velocity of the H II region was then attributed to the presence of the nebula. The velocities used were either optically measured velocities or those expected from galactic rotation at the photometric distances of the objects concerned. Since most of the regions studied previously were rather close to the galactic plane it was usually difficult to disentangle the effects of random variation in emission from real variation associated with the presence of the nebulae. The object studied in this paper is at a distance of about 450 pc and at a latitude $l^{II} = -19°.4$. Hence it is very much easier to disentangle the effects of random variation in emission. Furthermore the nebula being a strong continuum source we have also 21-cm absorption measurements in the direction of the source.

The neutral hydrogen in the general Orion Complex has been discussed by Menon (1958) and van Woerden (1967). However, the angular resolution used in these studies ranged from 1°.8 to 30′ and hence no detailed information regarding hydrogen in the immediate vicinity of this source could be obtained in those studies. Clark (1965) has made an interferometer study of the hydrogen absorption in the direction of the source Orion A.

The observations were made with the 300-foot and the 140-foot telescopes at Green Bank. The beam widths were 10′ and 20′ respectively at 21 cm. The receiver used was an auto-correlation receiver with an effective resolution of 7 kHZ. Since the 300′ telescope is a transit instrument observations consisted of drift curves at constant declination through the source with profiles being obtained every 10 seconds. Observations with the 140-foot telescope consisted of profiles taken every half beam width along constant lines of latitude covering about 2.5 square degrees around the source.

II. Discussion of Observations

The 21-cm absorption profile in the direction of this source had been studied earlier by Muller (1958), Clark, Radhakrishnan and Wilson (1962), and by Clark (1965). Muller reported only one absorption component at + 4 km/s with respect to the local standard of rest whereas Clark *et al.* deduced three components at + 4.0 km/s, − 0.8 km/s, and − 3.0 km/s from their single dish measurements and five components at + 8 km/s, + 5.1 km/s, + 2.3 km/s, + 0.2 km/s and − 3.0 km/s from their interferometer measurements. Later Clark (1965) suggested that his interferometer measurements could be represented by two components at velocities + 4.5 km/s and + 2.5 km/s with a possible third component at a lower velocity. In order to investigate the cause of the various discrepancies new absorption profiles were obtained using the 140-foot and the 300-foot telescopes. The 140-foot absorption profile was obtained by first averaging the profiles one beam width away on all four sides of the source and then subtracting this average profile from the one observed in the direction of the source. The derived absorption profile is shown in Fig. 1. All velocities

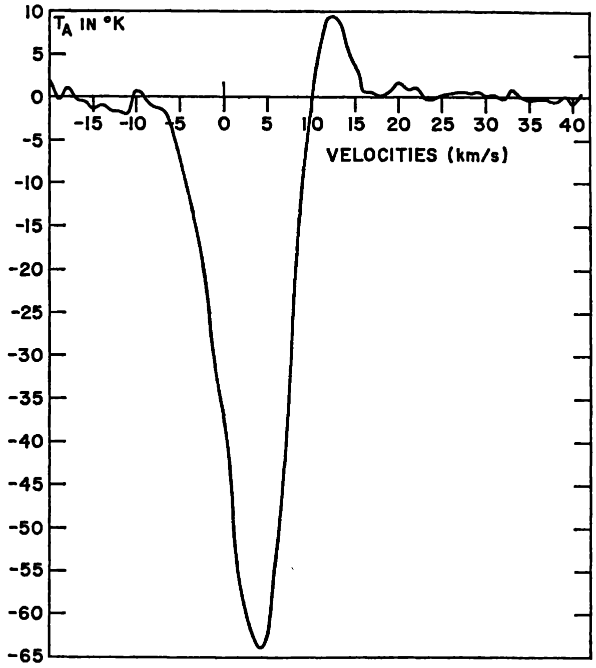

Fig. 1. The 21-cm absorption profile of Orion A obtained with the 140′ telescope at Green Bank

in this paper are with respect to the local standard of rest. The 300-foot absorption profile was derived in the same manner except that the expected profile was obtained by averaging the observed profiles 15′ away on either side of the source at the same declination. However, because of the shorter integration time and the higher antenna temperature of the source on the 300-foot telescope the signal to noise ratio is not as good as the 140-foot data.

Figure 1 shows that the difference profile has one main absorption component at + 4 km/s. The shape of this component on the low velocity side definitely suggests additional components on that side. The profile also shows significant excess emission at a velocity of about + 12 km/s. Since the beam widths of the two telescopes were considerably larger than the angular size of the continuum source, the excess line emission could be in principle anywhere within the beams depending on the kinetic temperature of the emitting cloud. Furthermore it is not possible to derive the true shapes of this excess emission as well as the absorption profile from the one difference profile because of their mutual interaction. However we can utilize the 300-foot data to obtain some idea of the distribution of the excess emission.

The expected profile obtained as explained earlier, for the 300-foot data, was subtracted from each of the observed profiles, at intervals of 10 seconds in right ascension, for 15′ on each side of the source. Fig. 2 shows the resulting difference profiles. The profile with the highest absorption depth corresponds to the position of the continuum source. The plot is in terms of channel numbers where the velocity of channel 58 is + 4.79 km/s with respect to LSR and channel width is 1.32 km/s. The velocity increases with decreasing channel numbers. The absorption profile in the direction of the source shows clearly two components at + 4.8 km/s and + 2.5 km/s respectively and a possible third component at lower velocity. This confirms Clark's analysis. However, in addition to the absorption components there is also the excess emission component at a velocity of about + 12.7 km/s confirming the result from the 140′ data.

In order to determine the distribution of the excess emission, the line intensities of the difference profiles at each velocity were plotted as a function of position along with the continuum intensities at these positions obtained at the same time. The continuum intensity as a function of position is, of course, the shape of the beam in that coordinate. If there were no variation in emission with position the absorption line intensities at each velocity should also have the same shape as the beam. However, it was found that the distribution of the absorption line intensities was significantly asymmetrical in position with lower absorption on the eastern side than is expected, even though the peak of the continuum and the peak of the absorption coincided in position. Also the maximum of the excess emission at + 12.7 km/s was displaced by about 15^s towards east. From the 300-foot data we can put an upper limit of about 10′ for the size of the cloud in right ascension, and from the 140′ data we can put an upper limit of 21′ in declination. However a comparison of the brightness temperatures of this excess emission obtained with the beam widths of 21′ and 10′ respectively suggest that the size of the excess emission region is considerably less than 10 minutes of arc. An examination of the photograph of the Orion Nebula shows a dark band seen in projection against the nebula but slightly displaced from the peak of both the optical and radio continuum emissions. The excess emission cloud may be related to this dark band. Higher resolution pencil beam observations will be needed to map this cloud more accurately.

As pointed out earlier it is difficult to derive the exact velocity profile of the excess emission. However

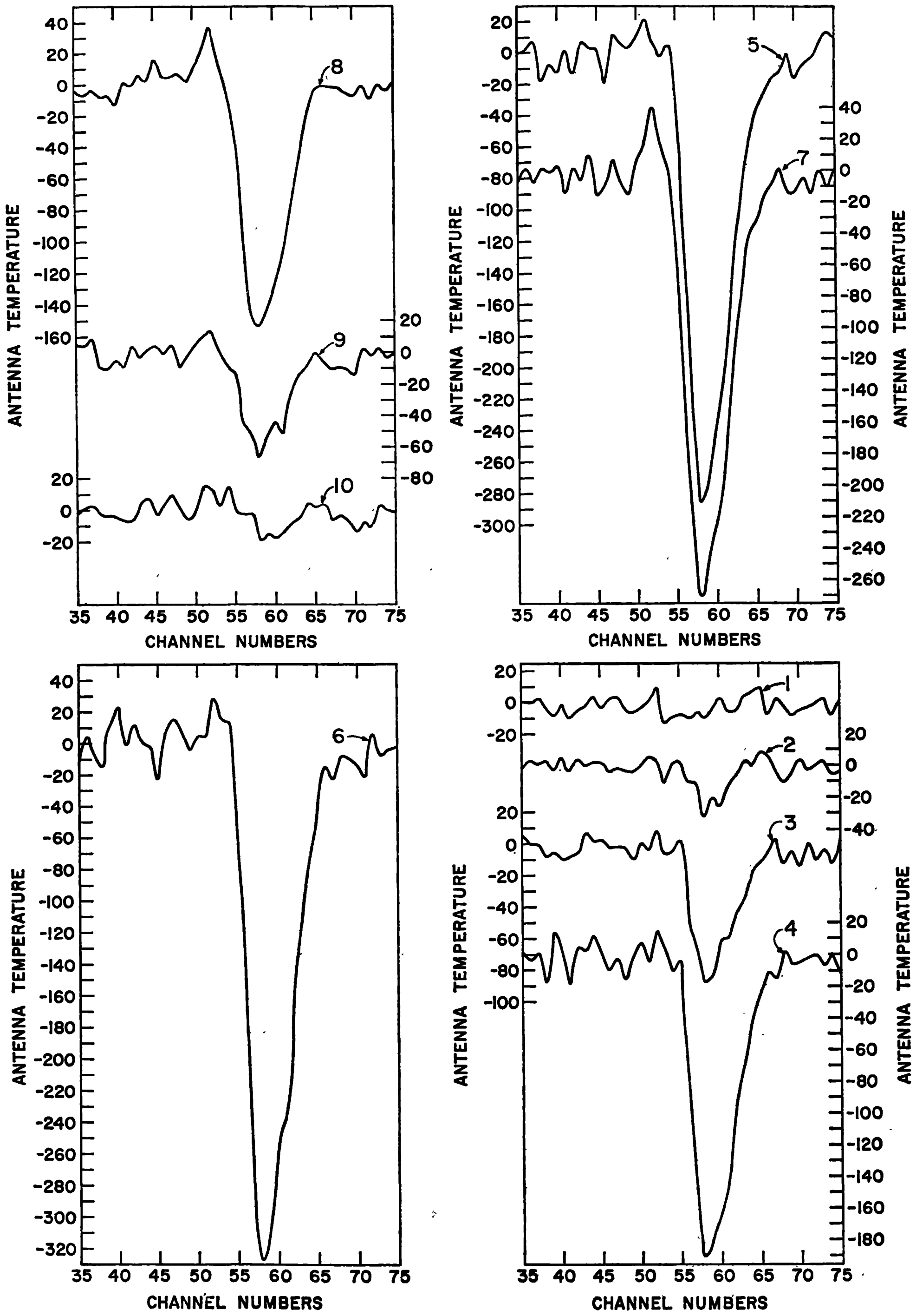

Fig. 2. 21-cm difference profiles obtained at 10^s intervals through Orion A at constant declination with the 300′ telescope at Green Bank. Profile numbers (1 . . . 10) are in the order of increasing right ascension and profile number 6 is in the direction of the peak of the continuum source. 1 unit of $T_A = 1.34$ °K of T_B. (See text for details)

we can obtain a measure of the minimum number of hydrogen atoms through the cloud by assuming a symmetric profile centered on 12.7 km/s in Fig. 2. The value of N_H turns out to be about 4×10^{20} atoms cm^{-2} in the line of sight through the cloud if the optical depth is small and if the cloud fills the beam. An inspection of Fig. 4b of Schraml and Mezger (1969) shows clearly that the distribution of the radio continuum – and therefore, probably also of the optical continuum – is symmetric, so that the dark band must be located in front of most of the nebular emission. On the other hand long exposure photographs show evidence of some emission overlying the dark band, suggesting that the band is very nearly at the same distance as the Orion Nebula. Assuming a maximum size for the cloud of 10′ the average minimum density of neutral hydrogen atoms in the cloud is about 100 atoms cm^{-3}. The major uncertainties in the estimate of the density are due to lack of knowledge of the size of the cloud and the assumption of low optical depth of the emission line. However, as suggested earlier, the size of the cloud is likely to be only smaller than the beam and thus the true density is expected to be larger than the above estimate. Even at the minimum value of about 100 atoms cm^{-3}, the kinetic temperature is according to Field, Goldsmith and Habing (1969) only about 20 °K. Hence the assumption of low optical depth is not justified. Any correction for finite optical depth will again increase the density. For the above two reasons the true density in the emission cloud is likely to be considerably higher than the value of 100 atoms cm^{-3} estimated above. Since the interferometer investigations of Clark (1965) do not show any absorption component at + 12.7 km/s it would appear that, either the excess emission cloud does not extend to the front of the continuum source or that there is a velocity gradient along the cloud such that one of the observed absorption components belongs to that cloud. The present observations do not provide us with any basis for choosing between the alternatives.

According to Gordon and Meeks (1968) the average velocity of the central parts of the Orion Nebula is -3.0 ± 0.8 km/s and that of a region 3.7′ east is -1.55 ± 0.9 km/s respectively. The velocity of the peak of the excess 21-cm emission was found to be $+12.7 \pm 0.5$ km/s. However, as pointed out earlier, the true velocity may be somewhat lower than this value. The fact that we see any excess emission at all implies that the true peak velocity of the excess emission is displaced towards higher velocities from the peak velocity of the absorption. Since the angular resolution is not sufficient for any unambiguous estimate of the displacement we shall continue to use the + 12.7 km/s value in our discussions. Hence the ionized material in the line of sight to the cloud is approaching the cloud with a velocity of at least 14.2 km/s. We have no direct method of determining the spatial orientation of the neutral cloud with respect to the center of the Orion Nebula. However the conical shape of the absorbing band and the fact that the apex of the cone ends very close to the Trapezium suggest that the true motion of the cloud may be directed towards the center of the H II region.

Summarizing our results we can state the following conclusions. We have identified a neutral hydrogen cloud, in the immediate vicinity of NGC 1976, part of which may be a dark nebula seen in projection against the nebular emission in the form of a conical absorbing band. The main cloud appears to be approaching the nebular mass with a velocity of about + 14.2 km/s in the line of sight. The density of the main cloud at a distance of about 5′ from the center of the emission nebula is about 100 atoms cm^{-3} assuming low optical depth and a size of 10′. Further high resolution observations are needed to elucidate the physical and kinematical properties of this most interesting cloud.

The observations reported in this paper were made while the author was on the staff of the National Radio Astronomy Observatory[1]).

References

Clark, B. G. 1965, *Ap. J.* **142**, 1398.
Clark, B. G., Radhakrishnan, V., Wilson, R. W. 1962, *Ap. J.* **135**, 151.
Field, G. B., Goldsmith, D. W., Habing, H. J. 1969, *Ap. J.* (Letters), **155**, L149.
Gordon, M. A., Meeks, M. L. 1968, *Ap. J.* **152**, 417.
Heiles, C. 1967, *Ap. J. Suppl.* No. 136.
Menon, T. K. 1958, *Ap. J.* **127**, 28.
Muller, C. A. 1958, in Paris Symposium on Radio Astronomy, ed. R. N. Bracewell, Stanford University Press, Stanford p. 370.
Riegel, K. 1967, *Ap. J.* **148**, 87.
Schraml, J., Mezger, P. G. 1967, *Ap. J.* **156**, 269.
Woerden, H. van 1967, Radio Astronomy and the Galactic System I.A.U. Symposium No. 31, ed. H. van Woerden, Academic Press, New York p. 3.

T. K. Menon
Institute for Astronomy
University of Hawaii
Honolulu, Hawaii 96822, USA

1) The National Radio Astronomy Observatory is operated by Associated Universities, Inc. under contract with the National Science Foundation.