NEARBY MOLECULAR HYDROGEN

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Abstract

If the gas-to-dust ratio is sufficiently uniform throughout the local interstellar medium, galaxy counts may provide a useful probe of the large scale structure of the interstellar gas. This idea substantiated by gamma-ray observations has led to the discovery of nearby molecular cloud complexes. The reddening studies indicate that one of them lies between 80 and 140 pc from the sun. From CO observations, its molecular mass is estimated to be a few 10^3 $M_{\odot}$.

1 INTRODUCTION

The observations of the U-V absorption lines by the Copernicus satellite have shown that even in the solar neighborhood, molecular hydrogen (H_2) is an important component of the ISM. This type of observations can put useful constraints on the gas distribution but cannot reveal its detailed structure. 21 cm radio surveys on large angular scales (e.g. Heiles and Habing 1974) have determined precisely the atomic hydrogen (HI) distribution but that of H_2 is still lacking. Three independent ways of assessing the large scale distribution of the nearby molecular hydrogen will be discussed in this paper: i) galaxy counts ii) gamma-ray obervations iii) CO line observations. Galaxy counts (Shane and Wirtanen 1967) provide a uniform survey of the interstellar extinction over the entire northern celestial hemisphere (δ >-25°). If the gas-to-dust ratio is sufficiently uniform in the nearby interstellar medium, this survey may provide one of the best current estimate of the total gas (HI + H_2) distribution. Diffuse gamma rays (E>50 MeV) are produced by the interactions of cosmic rays in the interstellar gas. Collisions of cosmic-ray protons with gas nuclei produce π^0 mesons which decay in two gamma-rays. High energy bremsstrahlung radiation is emitted by cosmic-ray electrons in the electric field of the interstellar-gas nuclei. If the cosmic-ray density is uniform within a few hunded parsecs, gamma-ray emission may be considered a total gas column density tracer. After H_2, CO is the most abundant molecule in the interstellar medium. Its 1→0 rotational transition is easily observable at 2.6 mm by standard radioastronomical

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techniques. If the velocity-integrated intensity of that line is closely related to the H_2 column density ($N(H_2)$), CO would be the best tracer of H_2.

Heiles (1976) and Burstein and Heiles (1978) studied the relationship between galaxy counts, interstellar reddening and atomic hydrogen column density (N(HI)). They found that the ratio between N(HI) and the interstellar absorption (Apg) - as traced by galaxy counts - is non uniform over the sky. Some regions where this ratio is low correspond to well-known molecular complexes, namely Orion, Taurus, Perseus and ρ Ophiuchi, where with a constant gas-to-dust ratio, the HI deficiency can be well accounted for by molecular hydrogen formation (Strong and Lebrun 1982). The lowest values of N(HI)/Apg are located inside the Ophiuchus-Sagittarius region. Lebrun and Paul (1983) noted that in the same region, HI is also deficient compared to the gamma-ray intensity observed by *SAS-2* and concluded that there exists gamma-ray-emitting material linked to the dust, this material being most likely molecular hydrogen. This conclusion is also supported by the *COS-B* gamma-ray observations (Strong et al.1982).

2 THE CO OBSERVATIONS

We have undertaken an extended survey (370 square degrees) in the CO (1→0) line of the northern part of Ophiucus and Sagittarius. The observations were performed in frequency switching mode with the 1.2 m millimeter-wave telescope at Columbia University with an angular resolution degraded to 0.5 ° and a velocity resolution of 0.65 km s^{-1}. Further details concerning the observational procedure and the data processing can be found elsewhere (Lebrun and Huang 1984). The results in the form of a map of the integrated CO line intensity ($W_{CO} = \int T_a^* \, dv$) are presented in figure 1.

3 RESULTS AND DISCUSSION

The molecular clouds found here (see fig. 1) appear as an extension towards higher latitudes of the very extended CO complex associated with the Aquila Rift (Dame and Thaddeus 1984). The eastern clouds have the same velocity as this complex (6 – 7 km s^{-1}), while the western ones have the same velocity (~ 3 km s^{-1}) as the ρ Oph cloud complex which is 15° away. These clouds are located in or near the plane of the Gould Belt and the average velocity of these clouds matches that of the HI feature A of Linblad et al. (1973).

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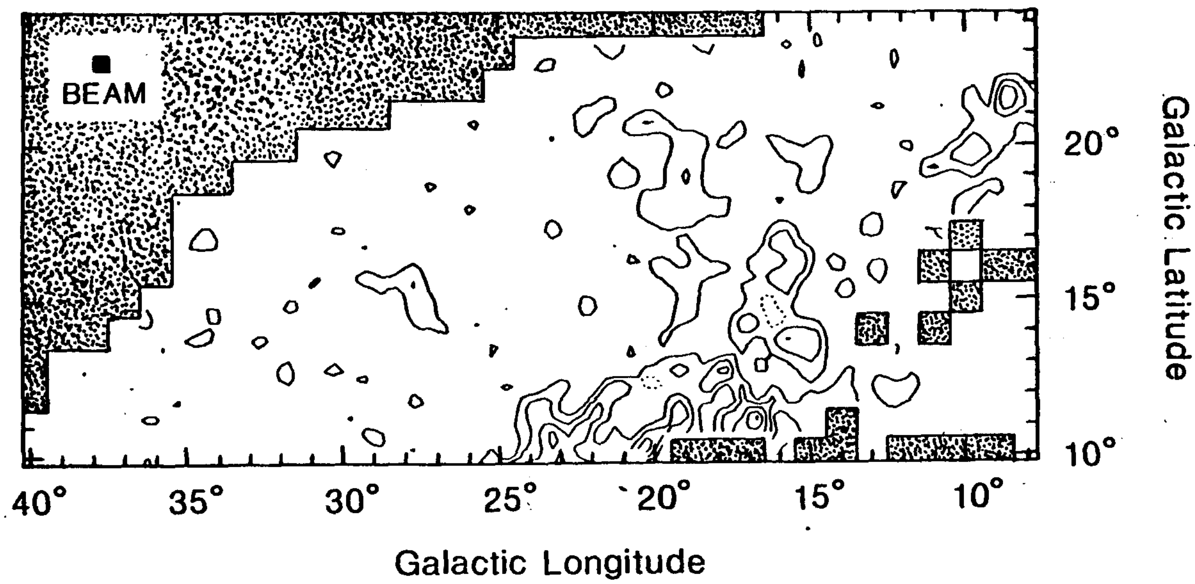

Figure 1. Contour map of the integrated CO line intensity, Wco. The contour interval is 2.5 K km s^{-1}. The shaded areas indicate unobserved regions.

Although this dicovery confirms qualitatively the predictions based on galaxy counts and gamma-ray observations, a quantitative study is necessary. Lebrun and Huang (1984) studied the relations between CO,HI and Apg (traced by star counts) in the upper part (b>16°) of this region. They found that the gas to dust ratio is normal and proposed a calibration of NH_2 estimates from CO measurements: $NH_2/Wco = 10^{20} cm^{-2} K^{-1} km^{-1} s$. However, the column densities predicted with this calibration, based on star counts, are at least 50% lower than those based on galaxy counts and HI. The origin of this discrepancy must lie in the calibration of the absorption measurements. It could be either an underestimate of the absorption by the star counts or an overestimate of the absorption by the galaxy counts.

Another interesting effect is that the observed gamma-ray intensity (70-5000 MeV) appears higher (~40%) than that predicted from galaxy counts (Strong et al. 1982). An underestimate of the absorption by the galaxy counts is hard to believe since it would imply an unrealistic underestimate of the absorption by the star counts. It seems more reasonable to consider this region as having a gamma-ray emissivity higher than the local average. This could be either the result of an

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additional gamma-ray component (inverse Compton emission, unresolved weak point sources) or the result of an enhanced cosmic-ray density throughout the complex.

The distance of these clouds can be estimated from the distribution of the interstellar reddening material along the line of sight. In the study of OB stars in the solar neighborhood by Lucke (1978), this region stands out as having the highest reddening per unit distance of the entire sky. The reddening distribution suggests that the complex lies between 50 and 375 pc from the sun. On the basis of the study by Knude (1978) of the reddening of A and F stars, Arnaud et al.(1980) derived a distance consistent with Lucke's estimate: 80-150 pc. Therefore this cloud complex seems to be one of the closest to the sun. The fact that at these latitudes it is unlikely that a line of sight intercepts any other cloud, makes it a good candidate for detailed study. If we adopt the calibration proposed by Lebrun and Huang (1984) and a distance of 100 pc the H_2 mass of the complex is a few $10^3 M_\odot$. Although this mass may be considered a lower limit, the total mass of the complex is probably dominated by that of HI.

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