THE LISM AT INFRARED AND MILLIMETER WAVELENGTHS

MOLECULAR CLOUDS WITHIN 100 PC

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ABSTRACT

Observations at the 2.6 mm line of CO reveal the presence of a large number of molecular clouds at high galactic latitude. If the velocity dispersion of the clouds is a measure of their scale height, the mean distance of the ensemble we have detected is 100 pc. The clouds are unusual in that either they are not gravitationally bound or they are very deficient in CO relative to molecular hydrogen. These clouds represent a heretofore unrecognized component of the local interstellar medium. If they are pervasive in the Milky Way, they probably represent the small molecular cloud component of the interstellar medium.

OBSERVATIONS

The observations were based on a careful search of the Palomar Sky Survey prints for regions of apparent obscuration. All of the prints at $|b|>20^{o}$ were examined and 457 candidate regions were identified. Of these, 439 were observed in the J = 1-0 transition of CO using the 5m dish at the Millimeter Wave Observatory near Fort Davis, Texas. CO was detected from 105 (24%) of the sources, a number in complexes of large angular extent. More than half of the clouds at $|b|>30^{o}$ have been mapped, and there are a limited number of observations at the J = 2-1 transition of CO and at the J = 1-0 transition of ^{13}CO.

CO observations were also made of two regions which show ultraviolet excesses (Paresce, Jakobsen and Bowyer 1983, Paresce private communication) and of Cloud X, identified by Low et al. (1984) as a region of diffuse, cold infrared emission detected by IRAS. We did not detect CO from any of these.

RESULTS

The clouds are generally well distributed on the sky, but a number of them are clustered together in complexes. The richest of these appear to be high latitude extensions of complexes which occur predominantly at $b<20^{o}$, such

https://doi.org/10.1017/S0252921100098250 Published online by Cambridge University Press

as the ρ Oph complex. The only empty region extends from $180^{\circ}<\ell<315^{\circ}$ at positive latitudes (a large fraction of this range at negative latitudes is not accessible from the northern hemisphere).

Of the clouds at $|b|>30^{\circ}$, CO was detected from 37 directions; these appear to be in 29 distinct clouds. The CO lines tend to be relatively strong, indicating that the observations are not sensitivity limited. Sixteen of the clouds have been mapped, including 5 clouds previously mapped by Montani and Morris (unpublished). Some have large angular extents (up to 5.4 square degrees) indicating that the high latitude molecular clouds may be responsible for at least some of the ´infrared cirrus´ detected by IRAS (Low et al. 1984).

The observed and derived properties of the clouds are given in Table 1. The internal velocity dispersion of a cloud, σ_v(internal) is determined from the velocity at the emission peak of each observed position within a given map. The quantity σ_v(c-c) is the velocity dispersion of the ensemble; the ensemble mean is 1.3 ± 0.2 (km s^{-1}) relative to the LSR.

The derived properties are based on a mean distance to the clouds at $|b|>30^{\circ}$ of 100 pc. This number is based on the scale height the clouds would have with the measured velocity dispersion and the surface density of stars in the solar neighborhood (van der Kruit and Shostak 1984). A longitude velocity plot of the clouds indicates, however, that the velocity dispersion may not be random and that the derived distance may be in error. The H_2 column density $N(H_2)$ is based on the conversion $N(H_2) = 2.5\times10^{20}\int T_A^*(CO)dv$ cm^{-2} derived from X-ray, CO and HI observations of the inner Galaxy (Lebrun et al. 1983; Bloemen, et al. 1984). Our ^{13}CO observations indicate, however, that $N(H_2)$ may be overestimated by a factor of 3 using this conversion. N(HI) is determined from the survey of Heiles and Habing (1974), and A_v is based on the gas-to-extinction ratio of Savage and Mathis (1979). The quantity ε is the fractional completeness of the survey.

If the clouds are virialized, the velocity dispersion is given by $\sigma_v(\text{internal}) = 0.0657(M/R)^{0.5}$ km s^{-1} if M is in $M_\odot$ and R is in pc. Table 2 gives the measured velocity dispersion of ten clouds we mapped and the expected velocity dispersion based on the derived mass and radius for each cloud. The table shows that six of the ten clouds have measured dispersions which exceed the expected dispersions by a factor of 2.3 to 6.9. Since the expected value of the velocity dispersion varies only as the square root of the distance to a cloud, and since the masses may be overestimated, it appears that the discrepancy between the expected and measured velocity dispersion is real. The clouds are not gravitationally bound unless the masses or distances (or a combination of the two) of the first six clouds in Table 2 is underestimated by a factor of 20 on average. If the clouds are indeed expanding, their ages are less than the crossing time of a gas clump within a cloud: $\lesssim10^{6}$ y! These clouds appear to be extraordinarily young and may represent the earliest stages of molecular clouds condensing from the interstellar medium.

In any event, the high latitude molecular clouds are a heretofore unrecognized and uncatalogued component of the local interstellar medium. If the solar vicinity is representative of the galactic disk, the clouds probably represent the small molecular cloud component of the interstellar medium.

References

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Table 1

Properties of the High Latitude CO Clouds

Observed Properties

quantity		range or value	mean
$T_A^*(CO)$	(^oK)	0.6-6.8	2.6
$\int T_A^*(CO)dv/\int T_A^*(13CO)dv$		2.3-18	10.5
$\Delta V(CO)$(FWHM)	(km s^{-1})	1.0-5.7	1.9
σ_v(internal)	(km s^{-1})	0.2-2.2	0.73 (median)
σ_v(c-c)	(km s^{-1})	5.7±1.2	
Projected area	(sq deg.)	0.1-5.4	1.3
Number detected		29	

Derived Properties

Distance	(pc)	100 (mean of ensemble)	
Size	(pc)	2.0 (mean of ensemble)	
Mass	($M_\odot$)	2.0-260	66
H_2 density	(cm^{-3})	46-250	170
$N(H_2)/N(HI)$		0.2-30	5
$A_v(H_2)$	(mag)	0.3-1.4	0.7
Age	(yr)	$\lesssim 10^6$y	
Number within 100 pc		$64/\varepsilon$	
Surface filling fraction within 100 pc		$2.5\times10^{-3}/\varepsilon$	
$\sigma(H_2)$	$M_\odot$ pc^{-2}	$0.1/\varepsilon$	

https://doi.org/10.1017/S0252921100098250 Published online by Cambridge University Press

Table 2

cloud	σ_v[1](expected)	σ_v (observed)
30	0.48	2.18
2	0.15	1.04
18	0.27	0.95
16	0.20	0.87
8	0.35	0.82
24	0.20	0.64
	Stable Clouds	
12	0.34	0.43
23	0.19	0.25
25	0.10	0.17
27	(0.15)	(0.10)

[1]σ_v(expected) = $0.0657(M/R)^{1/2}$ km s^{-1}

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