IN SEARCH OF $\lesssim$ 5 K GALACTIC MOLECULAR GAS

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ABSTRACT

Existing surveys of our galaxy are able to detect CO clouds with an excitation temperature $T_{ex} \gtrsim 5$ K. We have made observations to determine if a substantial molecular component is colder than ~ 5 K. We compared CO emission features with H_2CO absorption against 17 continuum sources near the galactic plane. After elimination of features in the spectra that are probably associated with known H II regions, there were 39 clouds remaining, most of which show an excellent kinematic agreement between H_2CO and CO. The results do not suggest the existence of a large amount of mass in ultra-cold molecular clouds.

INTRODUCTION

Current CO J = 1 → 0 emission surveys are sensitive to molecular clouds of optically thick CO at an excitation temperature $T_{ex} \gtrsim 5$ K (e.g. Gordon and Burton: 1976, Ap. J. 208, 346). Extremely cold molecular clouds with $T_{ex} \lesssim 5$ K should show up well in 6 cm absorption spectra against continuum sources, but not in CO emission. The non appearance of CO emission at the position and velocity of formaldehyde absorption would indicate an ultra-cold cloud, since the absence of CO in a region of H_2CO would be unlikely.

OBSERVATIONS

The H_2CO observations made with the 100 m Bonn telescope were kindly provided by Dennis Downes and Tom Wilson, 1978. We used these spectra to select a sample for our CO observations, which were made with the 4.9 m antenna at the Millimeter Wave Observatory (MWO) of the University of Texas at Austin. The use of the MWO telescope for 3 mm CO and the Bonn dish for 6 cm H_2CO gave us a useful combination since the HPBWs of ~ 2ʹ.5 were comparable. Observations were first made in

B. H. Andrew (ed.), Interstellar Molecules, 113–114.

January 1978, using 128 filters each 250 KHz wide, providing a velocity resolution of 0.65 km s^{-1} over a range of 83 km s^{-1}. Both beam and frequency switching were used, and the reference positions and spectra were checked to be free of lines. Because of poor weather conditions our antenna temperatures were good to only ~ ± 50%. However, additional observations under improved conditions in 1979 of all the weaker (≤ 1.5 K) CO lines, using position switching only, provided calibrations that should be reliable to ± 20%.

RESULTS AND DISCUSSION

Because we intended to look for ultra-cold gas, we separated those clouds that have velocities within ± 10 km s^{-1} of the recombination line velocity, since they presumably are associated with H II regions. The recombination line velocities are from observations of the H110α line kindly provided from the Bonn telescope. The H110α line is the closest H-α line in frequency (and hence resolution) to the 6 cm H_2CO line. The remaining clouds show an excellent velocity agreement between CO and H_2CO, which is strong evidence for the physical association of the two molecular species. In some cases of spectral features associated with the continuum source there is apparent self-absorption. In G9.6+0.2 the most intense H_2CO line occurs at 1.6 km s^{-1}, precisely at a local minimum in the most intense CO emission. This is also close to the H110α line velocity of 3 km s^{-1}. Observations of ^{13}CO would be useful to test whether self-absorption is occurring. Similar situations have been found for G24.8+0.1, V_{LSR} = 108 km s^{-1}, and G34.3+0.14, V_{LSR} = 60 km s^{-1}.

Evans et al. (1979, in preparation) have found lower limits of 4.7 and 4.9 K for T_{ex} for the two coldest features in the study. It is noted that lower temperatures may exist but, in order to ascertain this, better H_2CO data would be needed to allow a more sensitive search program for CO. If these colder clouds do exist, they would correspond to clouds with substantially smaller visual extinctions (A_v ~ 0.3) than those seen in dark clouds. Such ultra-cold clouds would not likely have a sufficient average density to thermalize the CO transition (Snell, 1979, unpublished dissertation, the University of Texas at Austin) which would cause low CO antenna temperatures. Also, clouds with such low extinctions are not likely to contain a significant mass. In a statistical sense, our results do not suggest the existence of a substantial population of cold CO clouds, since none of the definite H_2CO features are lacking a corresponding CO line.