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A search for interstellar CH_2D^+

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Abstract. We report on a search for interstellar CH_2D^+. Four transitions occur in easily accessible portions of the spectrum; we report on emission at the frequencies of these transitions toward high column density star-forming regions. While the observations can be interpreted as being consistent with a detection of the molecule, further observations will be needed to secure its identification. The CH_2D^+ rotational spectrum has not been measured to high accuracy. Its lines are weak, as the dipole moment induced by the inclusion of deuterium in the molecule is small. Astronomical detection is favored by observations toward strongly deuterium-fractionated sources. However, enhanced deuteration is expected to be most significant at low temperatures. The sparseness of the available spectrum and the low excitation in regions of high fractionation make secure identification of CH_2D^+ difficult. Nonetheless, owing to the importance of CH_3^+ to interstellar chemistry, and the lack of rotational transitions of that molecule owing to its planar symmetric structure, a measure of its abundance would provide key data to astrochemical models.

Keywords. Astrochemistry, line: identification, ISM: molecules, radio lines: ISM, submillimeter

1. Introduction

The symmetric species CH_3^+ is a reactant of extreme importance in interstellar organic chemistry, as it initiates the formation of more complex hydrocarbons. Unfortunately CH_3^+ cannot be observed through its rotational lines, as it is symmetric. CH_2D^+ is asymmetric, however, and emits a rotational spectrum. Because the deuterium is bound to CH_2D^+ more tightly than hydrogen to CH_3^+, and because the binding energies are similar to typical molecular cloud temperatures, CH_2D^+ becomes more abundant relative to its undeuterated counterpart in cold clouds. This binding energy is higher for the deuterium in CH_2D^+ than for that in H_2D^+, so that in warmer clouds, CH_2D^+ remains heavily fractionated to much higher temperatures than H_2D^+. This expectation is borne out by observations of its deuterated derivatives. Since DCO^+ derives from reaction of CO with H_2D^+, the temperature dependence of its fractionation mimics that of $[H_2D^+]/[H_3^+]$, as demonstrated in observations of a cross-section of clouds by Wootten, Loren & Snell (1982). The observed $[DCO^+]/[HCO^+]$ ratio reaches high values only in the coldest clouds; DCO^+ is practically unobservable in a warm cloud such as OMC1. Persistence of a high [DCN]/[HCN] ratio to high temperatures, as observed by Greason (1986) and discussed by Wootten (1987), by the same effect mimics the behavior of $[CH_2D^+]/[CH_3^+]$. Both because it remains abundant at relatively high temperatures, and because rotational lines are accessible, CH_2D^+ is an ideal candidate for observation and confirmation of deuterium fractionation theory. The three accessible mm-wave transitions of CH_2D^+ are $J_{K_{-1}K_1} = 1_{01}$-0_{00} near 280 GHz, 2_{11}-2_{12} near 200 GHz, and 1_{10}-1_{11} near 67 GHz. All should be detectable in warm molecular clouds, given model abundances of CH_3^+, the expected degree of deuteration, and the temperatures of appropriate sources.

Good frequency estimates for rotational lines are available from Rosslein *et al.* (1991) and Jagod *et al.* (1992). The estimated accuracy of the frequencies is estimated by

Rosslein *et al.* (1991) to be $\pm 2 \times 10^{-5}$ (1 σ) times the frequency. Four lines are relatively easily observed by radiotelescopes; we have attempted to detect all four. The lowest frequency but highest excitation line, at 23.01595 GHz, was sought in 1992 April at the NRAO 43 m telescope; no emission was detected. The $J_{K_{-1}K_1} = 1_{01} \rightarrow 0_{00}$ line was observed at a center frequency of 278.69162 GHz in 1992 at the 10.4 m CSO telescope on Mauna Kea, Hawaii. The $J_{K_{-1}K_1} = 1_{01} \rightarrow 0_{00}, 1_{11} \rightarrow 1_{10}$ and $2_{11} \rightarrow 2_{12}$ lines were observed at center frequencies of 278.69162 GHz, 67.27371 GHz and 201.76264 GHz at various times between 1992 April and 1997 September at the 12 m NRAO telescope at Kitt Peak, Arizona. At the frequencies where emission from CH_2D^+ was expected, emission was detected in , NGC6334N, SgrB2OH N and W51M. The detections were most convincing for NGC 6334N.

The NGC 6334N region is complex, with several sources appearing within the 30″ beam of our telescopes. The dominant sources within our beam include SMA1, SMA2, SMA3 and SMA4. In high excitation ammonia studies, SMA1 and SMA2 dominate the emission; emission was not detected toward SMA3 and SMA4. Column densities on the order of $N_{Tot} = 2 \times 10^{14}$ are indicated for T_{rot} ~50 K. The study of deuterium fractionation in warm clumps recently published by Roueff, Parise and Herbst (2007) predicts $[CH_2D^+]/[CH_3^+]$ ~0.03 for 50 K, declining by a factor of a few as T rises. Our data would suggest then that $N_{Tot}(CH_3^+)$ exceeds 7×10^{15}. Additional laboratory data is urgently needed to secure the identity of the lines we report.

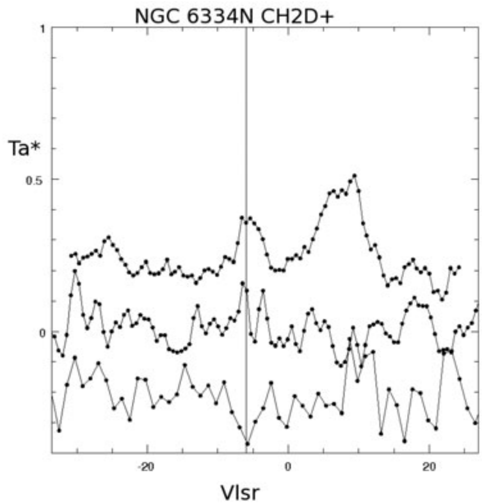

Figure 1. Spectrum of NGC 6334N in the vicinity of the $J_{K_{-1}K_1} = 2_{11} \rightarrow 2_{12}$ (201 GHz, top, 12m SSB data, center, offset by 0.2 K), $1_{01} \rightarrow 0_{00}$ (278 GHz, center, CSO DSB data, upper) and $J_{K_{-1}K_1} = 1_{11} \rightarrow 1_{10}$ (67GHz, lower, 12m SSB data, lower, offset by -0.2 K) lines of CH_2D^+. The center spectrum has been multiplied by a factor of four. The pointing center was 17^h 17^m 32.0^s $-35°$ $44'$ $20''$. (B1950); $V_{lsr} = -6.0$.

References

Greason, M. R. 1986, *M.S. Thesis*, U. of Va.

Jagod, M., Roesslein, M., Gabrys, C. M., & Oka, T. 1992, *J. Molecular Spectroscopy*, 55, 153, 666

Roesslein, M., Jagod, M., Gabrys, C. M., & Oka, T. 1991, *ApJ* (Letters), 382, L51

Roueff, E., Parise, B., & Herbst, E. 2007, *A&A*, 464, 245

Wootten, A. 1987, in: Vardya, M. S. and Tarafdar, S. P. (eds.), *IAU Symposium 120, Astrochemistry* (Dordrecht, D. Reidel Publishing Co.), p. 311

Wootten, A., Loren, R. B., & Snell, R. L. 1982, *ApJ*, 255, 160

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