

BEAM MASER MEASUREMENTS OF CH₃OH ROTATIONAL TRANSITIONS

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ABSTRACT

Precise measurements of $K = 2 \rightarrow 1$ rotational transitions in CH₃OH were made using beam maser spectrometers at Columbia and MIT. $\Delta J = 0$ transitions were observed in E -type states with $J = 2, 4, 5, 6, 7$, and 8. No hyperfine structure was resolved at a resonance line width of 8 kHz (full width at half-maximum). Accurate center frequencies for these transitions are useful for determining Doppler shifts for observed interstellar lines.

Subject headings: line identifications — molecules

I. INTRODUCTION

Observations of $K = 2 \rightarrow 1$, $\Delta J = 0$, E -type transitions in CH₃OH from the Orion Nebula were reported by Barrett, Schwartz, and Waters (1971) and more recently by Chui *et al.* (1974). Laboratory measurements of these transitions were reported by Hughes, Good, and Coles (1951). The labeling of states and allowed transitions were discussed by Lees (1973). Transitions with $J = 4-8$ were observed from Orion (Barrett *et al.* 1971). Some of the observed line widths were of the order of 50 kHz (Chui, *et al.* 1974) and the lines are strong so accurate frequency measurements can be made. It is therefore important to have precise laboratory measurements of center frequencies so that Doppler shifts may be accurately determined. From the data reported by Chui *et al.* (1974) it appears that Doppler shifts for interstellar lines due to $6_2 \rightarrow 6_1$ and $7_2 \rightarrow 7_1$ transitions are slightly different. These Doppler shifts were based on the original laboratory measurements of Hughes, Good, and Coles (1951). If the Doppler shifts for the data of Chui *et al.* (1974) are given relative to the present maser measurements, Doppler shifts are the same for all rotation states from the same region of space. This could be interpreted as an indication that there are some small errors in the original laboratory measurements.

Since there is likely to be further astronomical interest in CH₃OH, $K = 2 \rightarrow 1$, Q -branch transitions were measured using beam maser spectrometers. The molecular resonance line width of 8 kHz for the maser allows a precise determination of center frequencies and detection of possible hyperfine structure.

II. APPARATUS AND MEASUREMENTS

The maser spectrometers are similar in design to the original system developed by Gordon (1955). Improvements in sensitivity are obtained by using nozzle-type beam sources. Phase stabilized oscillators allow slower sweeps and longer integration times. Nozzle sources produce considerable rotational cooling in the beam.

The $J = 5$ transition was also observed with an effusive source. The rotational temperature from effusive sources is near 300° K, so if there were structure near our observed lines due to low lying torsional states it should have been observed. No structure was seen.

Superheterodyne receivers are used on both maser systems. At Columbia the stimulating signals are derived from a Hewlett Packard 5105A frequency synthesizer which is compared with WWVB. At M.I.T. the stimulating signal oscillator is phaselocked to a stable crystal oscillator. The crystal oscillator frequency is determined with a HP-5245L frequency counter with a stable and accurate reference oscillator which is also compared with WWVB. TM₀₁₀ cavities are used in the masers.

The measured frequencies are listed in table 1. In most cases line widths (f.w.h.m.) of 8-10 kHz were obtained. Wide sweeps of $J = 5$ and $J = 6$ transitions were made to search for possible hyperfine structure. No structure was observed for sweeps of 200 kHz either side of the main line. The signal-to-noise ratio was about 30/1. Some of the observed linewidths were significantly larger than expected values based on

TABLE 1
MEASURED LINE CENTERS FOR
E-TYPE TRANSITIONS
IN CH₃OH

Transition ($J'_K' \rightarrow J_K$)	Frequency (kHz)
$2_2 \rightarrow 2_1$	24 934 382 ± 5
$4_2 \rightarrow 4_1$	24 933 468 ± 2
$5_2 \rightarrow 5_1$	24 959 080 ± 2
$6_2 \rightarrow 6_1$	25 018 123 ± 2
$7_2 \rightarrow 7_1$	25 124 873 ± 2
$8_2 \rightarrow 8_1$	25 294 411 ± 3
$2_0 \rightarrow 3_{-1}$	12 178 595 ± 3

NOTE.—Levels are specified by J_K for emission transitions.

calculated transit time through the cavity. This effect was most evident on the $2_0 \rightarrow 3_{-1}$ transition. This line-broadening could be accounted for by unresolved spin-rotation splittings of 2–3 kHz. The newer notation (Lees 1973) is used to specify the transitions.

III. DISCUSSION

The lack of any observable hyperfine structure on the observed lines indicates that these lines should be useful for velocity determinations. It is interesting to note that if the present center frequencies are used to analyze the data of Chui *et al.* (1974) (see Fig. 1), the

strongest peaks of $J = 6$ and $J = 7$ transitions occur at the same Doppler shift velocity.

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