A SEARCH FOR MOLECULAR TRANSITIONS IN THE 22-25 GHZ BAND IN COMET KOHOUTEK 1973f

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Introduction

According to current theories, the radicals optically identified in cometary spectra stem from more complex parent compounds which have no transitions at visible wavelengths. In recent years radio transitions of likely molecules have repeatedly been searched for but were never found (e.g., Huebner and Snyder, 1970; Clark et al., 1971). Only in Comet Kohoutek 1973f have microwave lines of three molecules been detected, OH (Biraud et al., 1974; Turner, 1974), CH_3CN (Ulich and Conklin, 1974), and HCN (Snyder et al., 1974). Here we report on our search for transitions in the 22-25 GHz band of the molecules H_2O, NH_3, and CH_3OH in this Comet and give upper limits on line temperatures and column densities.

Observations

The observations of Comet Kohoutek 1973f have been made with the 100-m radio telescope of the Max-Planck-Institut für Radioastronomie in Bonn, West Germany. The antenna half-power beam width (HPBW) was ~40 arc sec and the aperture efficiency was ~0.17 (not accurately measured). The receiver was an uncooled tunnel diode mixer system with a double side band system temperature of ~2500 K. The observations were made by beam-switching with the signal beam on the electrical axis of the telescope and the comparison beam offset by 2 arc min; the switch rate was 1 cps. A calibration signal from a noise diode was injected into the signal channel every second cycle. The temperature equivalent of the noise diode was measured in the laboratory and checked periodically throughout the observations against NGC 7027. The pointing accuracy of the telescope was ≤10 arc sec.

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The observations were carried out in two periods, the first on January 7 and 8, 1974, when the Comet had passed perihelion (perihelion passage, T = 1973, Dec.28.4; perihelion distance, q = 0.14 AU) but had a high enough angular separation from the sun so that the sun was outside the beam pattern; the second on January 14 and 15, 1974, when the Comet reached its closest approach to the Earth (Jan. 15, 1974, Δ = 0.81 AU), thus giving the best ratio of source size (head of the Comet) to beam size.

The essential observational data is listed in Table 1. The ephemeris was calculated by Stumpff from elements communicated by Marsden (1974). The first six columns of Table 1 list the time of observation, position of the Comet, its heliocentric and geocentric distance, radial velocity, and the observed frequency. The total number of scans is given in column 7. Each scan lasted for 10 minutes. Since the Comet's position was not known with high accuracy on January 7 and 8, 1974, the telescope was pointed at the presumed position of the cometary nucleus and also at 4 positions surrounding it with $\alpha' = \alpha_o \pm 30''$ and $\delta' = \delta_o \pm 30''$, respectively (with α_o, δ_o the predicted position of the nucleus). In searching for H_2O on January 7 and 8, four scans each were made at the presumed nucleus' position as well as at $\alpha' = \alpha_o + 30''$ and $\delta' = \delta_o - 30''$. At each of the remaining two positions $\alpha' = \alpha_o - 30''$ and $\delta' = \delta_o + 30''$, three scans were made. During the search for NH_3 on January 8, three scans were made at the nucleus and two scans each at $\alpha' = \alpha_o \pm 30''$ and $\delta' = \delta_o \pm 30''$. Since the Comet's orbit had been confirmed before the second observation period on Jan. 14/15 started, the telescope was pointed only at the predicted position of the nucleus.

Table 1
Observational Data

Date (1974) UT	Comet Position (1950) R.A.	Comet Position (1950) Decl.	Heliocentric Distance (AU)	Geocentric Distance (AU)	Geocentric Radial Velocity (km/sec)	Observed Frequency (MHz)	No. of Scans
Jan. 7.71	$20^h44^m06^s.4$	$-14^\circ14'06''$	0.422	0.866	-27.07	22235.08	7
Jan. 8.54	20 55 55.1	-13 22 54	0.447	0.854	-24.25	22235.08	11
Jan. 8.71	20 55 55.1	-13 22 54	0.452	0.851	-23.34	23694.48	11
Jan.14.67	22 05 43.0	-07 47 48	0.621	0.807	- 2.71	23694.48	28
Jan.15.63	22 17 00.8	-06 49 01	0.647	0.806	0.25	24931.54/ 32.04	39

It was attempted to detect radio lines in the 1.3-cm band of three molecular species which had been detected in interstellar space but not in a comet.

NH_3 (ammonia) is chemically very stable and a common end product of reactions where polymers or hydrogen bonded molecules are pyrolyzed. This process is expected to take place during the Comet's closest approach to the sun. Also this molecule presumably has one of the greatest extents around the nucleus of any molecule observable at this frequency. It may be noted that the (1.1) transition at 23694.48 MHz is energetically the lowest in para-ammonia, whereas the (3.3) inversion transition at 23870.11 MHz is the lowest in orth-ammonia.

At the time of the search, H_2O (water) had not directly been observed in a comet. Although high excitation energies are required to observe the H_2O rotational transition line, the chemical stability of the molecule in conjunction with the high abundance of cometary OH and H seemed to warrant a search for this species. H_2O was subsequently found in Comet Bradfield 1974b (Clark et al., 1974).

CH_3OH (methyl alcohol) is a rather common molecule in the interstellar medium. The lines (2,2-2,1; 3,2-3,1; 4,2-4,1) lie within a very narrow frequency interval (24928.7 - 24934.4 MHz), but they arise from energy levels (unfortunately only of species E 1) with rather different energies. Thus they are expected to be sensitive to excitation conditions.

Discussion

No lines were detected above the noise. However, the observed noise can be used to derive an upper limit on the column densities, N_m which is given by

$$N_m = \frac{3k}{8\pi^3 |\mu_{ij}|^2 \nu} \int B\nu d\nu$$

Table 2 is a summary of the results. A line width $\Delta V_L = 0.53$ km/sec was assumed which is equivalent to that found for CH_3CN (Ulich and Conklin, 1974) when corrected for the half-intensity full width rather than half the 1/e-width. Listed are the molecules with corresponding transition and transition frequency, and upper limit on the mean column densities.

Table 2
Results

Molecule	Transition	Frequency (MHz)	ΔT_{op} (K)	T_{A_L} (rms) (K)	T_{B_L} (3σ) (K)	N(molecules/cm^2)
H_2O	$6_{16} - 5_{23}$	22235.08	1.07	≤ 0.2	≤ 2	$\leq 5.6 \times 10^{14}$
CH_3OH	$4_2 - 4_1$	24933.47	0.75	≤ 0.15	≤ 1.5	$\leq 6.6 \times 10^{12}$
NH_3	(1,1)	23694.48	0.7	≤ 0.14	≤ 0.47	$\leq 1.7 \times 10^{12}$

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