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OBSERVATIONS OF COMETARY PARENT MOLECULES WITH THE IRAM RADIO TELESCOPE.

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Abstract

Several rotational transitions of HCN, H_2S, H_2CO and CH_3OH were detected in comets P/Brorsen-Metcalf 1989 X, Austin (1989c1) and Levy (1990c) with the IRAM 30-m radio telescope. This allows us to determine the production rates of these molecules and to probe the physical conditions of the coma.

OBSERVATIONS

Comets P/Brorsen-Metcalf 1989 X, Austin (1989c1) and Levy (1990c) were observed on September 2-7 1989, May 21-25 and August 26-31 1990, respectively, with the IRAM (Institut de Radio Astronomie Millimétrique) 30-m radio telescope at Pico Veleta (Spain). Three SIS mixer receivers were used simultaneously (85-115, 130-170 and 209-270 GHz). The spectrometers consisted in two banks of 128x100 kHz channels, two banks of 512x1 MHz channels, and an AOS (Acousto Optical Spectrometer) of 864 channels with a 505 MHz bandwidth.

RESULTS

The results concerning the detected species are summarized in the table. More details were (or will be) published by Bockelée-Morvan *et al.* (1990, 1991), Colom *et al.* (1990, 1992) and Crovisier *et al.* (1990, 1991).

HCN, H_2CO and H_2S production rates were derived from the observed line intensities using models treating the evolution of the excitation conditions from the collision dominated region (inner coma, collisions with H_2O, $s = 10^{-14}$ cm^2, $T_{kin} = 50$ K) to the radiation dominated region (outer coma, IR excitation of the vibrational bands by the Sun). For CH_3OH, we assume LTE and used a rotational temperature of 30 K, in agreement with the observed relative line intensities. For the density distribution we assumed isotropic outflow from the nucleus at constant velocity (0.8 km s^1) and took into account the molecular lifetime against photodissociation.

Hydrogen cyanide

The J(1-0) 89 GHz and J(3-2) 266 GHz rotational transitions of HCN were marginally detected in comet P/Brorsen-Metcalf, whereas clear detections were obtained in comet Austin (1989c1) and Levy (1990c). HCN seems to be more abundant by at least a factor of two in periodic comets (P/Halley, P/Brorsen-Metcalf) than in non periodic comets (Wilson, Austin, Levy). This suggests a chemical difference between periodic and new comets. The very low upper limit obtained on the relative abundance of HC_3N (5×10^{-5}) shows that it is not the major lacking source of CN radicals.

Formaldehyde

The observations of the H_2CO 3_{12}-2_{11} transition at 226 GHz in comet P/Brorsen-Metcalf gave only a marginal detection (S/N = 4). The 226 GHz line was easily detected in comet Austin (S/N = 10) and in comet Levy (S/N = 8). Observations of the 5_{15}-4_{14}, 2_{12}-1_{11}, 3_{03}-2_{02}, 3_{22}-2_{21} and 3_{21}-2_{20}

lines were negative, in agreement with excitation models (Bockelée-Morvan and Crovisier 1992). Production rates inferred in the assumption of release from the nucleus show that formaldehyde is a minor component of the nucleus with an abundance relative to water which ranges from 4×10^{-4} in Levy to 3×10^{-3} in P/Brorsen-Metcalf (Colom *et al.* 1992). These abundances are at least an order of magnitude less than the *Vega* IKS value for P/Halley (4%; Combes *et al.* 1988).

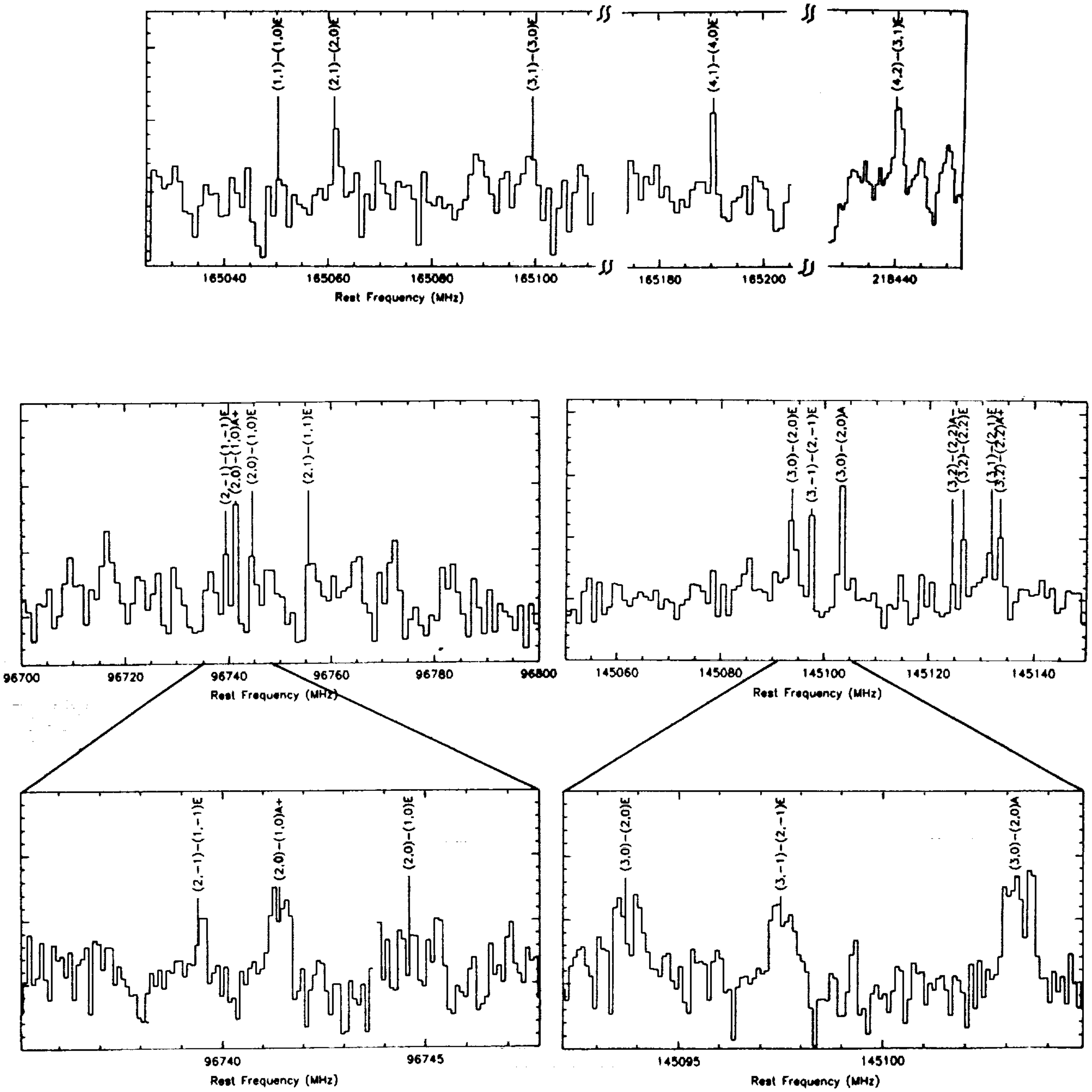
Hydrogen sulfide

The observation of H_2S 1_{10}-1_{01} at 169 GHz in comet Austin led to the first detection of hydrogen sulfide in a comet. In addition to the 169 GHz ortho line, the 2_{20}-2_{11} para line of H_2S at 217 GHz was detected in comet Levy. H_2S is a minor component, with a relative abundance of 2×10^{-3}. The other sulfur-bearing molecules observed (SO_2, OCS, H_2CS) are less abundant than hydrogen sulfide. (Crovisier *et al.* 1991.)

Production rates and abundances.

Comet and molecule	Date	Q a) [s^{-1}]	Q/Q[H_2O] b)
P/Brorsen-Metcalf (1989 X)			
HCN J(1-0)	89/09/04-07	4.5×10^{26}	1.8×10^{-3}
H_2CO 3_{12}-2_{11}	89/09/04-07	7.6×10^{26}	3.0×10^{-3}
Austin (1989c1)			
HCN J(1-0)	90/05/23	2.0×10^{25}	5.0×10^{-4}
H_2CO 3_{12}-2_{11}	90/05/21-25	4.6×10^{25}	1.1×10^{-3}
H_2S 1_{10}-1_{01}	90/05/24-25	1.1×10^{26}	2.7×10^{-3}
CH_3OH (3,0)-(2,0)A	90/05/25	2.0×10^{26}	5.0×10^{-2}
Levy (1990c)			
HCN J(1-0)	90/08/29	6.6×10^{25}	2.6×10^{-4}
H_2CO 3_{12}-2_{11}	90/08/26-30	1.0×10^{26}	4.0×10^{-4}
H_2S 1_{10}-1_{01}	90/08/30-31	5.0×10^{26}	2.0×10^{-3}
CH_3OH (3,0)-(2,0)A	90/08/27	1.8×10^{27}	7.2×10^{-3}
HC_3N J(24-23)	90/08/27	$< 1.2\times10^{25}$	$< 5.0\times10^{-5}$
SO_2 7_{17}-6_{06}	90/08/29	$< 6.0\times10^{26}$	$< 2.5\times10^{-3}$
OCS J(18-17)	90/08/28	$< 5.0\times10^{26}$	$< 2.0\times10^{-3}$
H_2CS 4_{14}-3_{13}	90/08/28	$< 2.5\times10^{26}$	$< 1.0\times10^{-3}$

a Assuming a parent distribution.
b Q[H_2O] from OH 18-cm observations: 2.5×10^{29} s^{-1} for P/Brorsen-Metcalf and Levy, 4.0×10^{28} s^{-1} for Austin.



The spectra of methanol (CH_3OH) observed with the IRAM 30-m radio telescope in comet Levy (1990c). The upper panels show spectra observed with a 1-MHz spectral resolution. The lower panel shows parts of the spectra around 97 GHz and 145 GHz observed with a 100-kHz resolution.

Methanol

CH_3OH was detected in comet Austin through its J(2-1) $\Delta K = 0$ transitions at 97 GHz and its J(3-2) $\Delta K = 0$ transitions at 145 GHz. It was the first detection of methanol in a solar system body. A dozen of CH_3OH lines were detected in comet Levy, as is shown in the Figure. Methanol is a substantial component of the nucleus, with a relative abundance of the order of 1% in comets Austin and Levy.

Other molecules.

Limits on many other interesting lines of potential parent molecules were also obtained, either during dedicated searches or serendipitously. Here is a preliminary list (some of the corresponding limits on the production rates are given in the table; the other ones are presently under evaluation):

Hydrocarbons: CH_3CCH (propyne; several lines at 85.3 GHz); c-C_3H_2 (cyclopropenylidene: many lines).
OH species: HDO (deuterated water: 3_{12}-2_{21} line at 225.897 GHz).
CHO species: many lines of HCOOH (formic acid), CH_3CHO (acetaldehyde), C_2H_5OH (ethanol).
Nitrogen compounds: HC_3N (cyanoacetylene: 24-23 at 218.325 GHz); CH_3NH_2 (methylamine: lines around 85.4 and 88.6 GHz); CH_2NH (methanimine: 1_{10}-0_{00} at 225.5 GHz); HNCO (isocyanic acid); NH_2CHO (formamide).
Sulfur compounds: SO_2, OCS, H_2CS (see Crovisier et al. 1991).

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