# OBSERVATIONS OF PARENT MOLECULES IN COMETS AT RADIO WAVELENGTHS: HCN, $H_2S$, $H_2CO$ AND $CH_3OH$

P. COLOM[1], D. BOCKELEE-MORVAN[1], J. CROVISIER[1],
D. DESPOIS[2], G. PAUBERT[3]
[1]Observatoire de Paris, Section de Meudon, F-92195 Meudon, France
[2]Observatoire de Bordeaux, BP 89, Avenue Pierre Sémirot, F-33270 Floirac, France
[3]IRAM, Avenida Divina Pastora, 7, N.C., E-18012 Granada, Spain

ABSTRACT. We present observations of cometary parent molecules at the IRAM radio telescope which led to the first detections of $\mathbf{H_2S}$ and $\mathbf{CH_3OH}$ in comets, and confirmed the presence of $\mathbf{H_2CO}$ and **HCN**. Production rates and abundances relative to $H_2O$ are given.

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. The observations [1] were performed with the IRAM (Institut de Radio Astronomie Millimétrique) 30-m telescope at Pico Veleta (Spain). The J(1-0) 89 GHz and J(3-2) 266 GHz transitions of HCN were marginally detected in P/Brorsen-Metcalf, whereas clear detections were obtained in comets Austin and Levy. The $3_{12}$-$2_{11}$ 226 GHz line of $H_2CO$ was searched for and detected in the three comets [2]. 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 [3]. Cometary $H_2S$ was confirmed in Levy, through both the 169 GHz and the $2_{20}$-$2_{11}$ 217 GHz lines [4, 5]. Methanol was identified in comet Austin through several J(2-1) $\Delta K = 0$ (97 GHz) and J(3-2) $\Delta K = 0$ (145 GHz) rotational transitions [1,3]. A dozen of $CH_3OH$ lines around 97, 145, 165 and 218 GHz were detected in comet Levy [1].

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 $H_2O$, $\sigma = 10^{-14}$ 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 use a rotational temperature of 30 K, in agreement with the observed relative line intensities. For the density distribution we assume isotropic outflow from the nucleus at constant velocity of 0.8 km s$^{-1}$ and take into account the molecular lifetimes against photodissociation. The results are summarized in the table.

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. Production rates inferred with 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 $4 \times 10^{-4}$ (Levy) to $4 \times 10^{-3}$ (P/Brorsen-Metcalf) [2]. These abundances are at least an order of magnitude less than the IKS Vega value (4%) [6]. $H_2S$ is a minor component, with a relative abundance of $2 \times 10^{-3}$. The other sulfur-bearing molecules observed ($SO_2$, OCS, $H_2CS$) are less abundant than hydrogen sulfide [4, 5]. Implications for Solar System formation are given in [5, 7]. Methanol is a substantial component of the nucleus, with a relative abundance of the order of 1% in comets Austin and Levy.



*P. D. Singh (ed.), Astrochemistry of Cosmic Phenomena,* 439–440.

TABLE : Production rates and abundances.

| Molecule | Line | Frequency GHz | Date | $Q^a$ $[s^{-1}]$ | $Q/Q[H_2O]^b$ |
|---|---|---|---|---|---|
| *P/Brorsen-Metcalf (1989 X )* | | | | | |
| HCN | J(1-0) | 88.6 | 89/09/04-07 | $4.5x10^{26}$ | $1.8x10^{-3}$ |
| $H_2CO$ | $3_{12}-2_{11}$ | 225.7 | 89/09/04-07 | $1.1x10^{27}$ | $4.4x10^{-3}$ |
| *Austin (1989c1)* | | | | | |
| HCN | J(1-0) | 88.6 | 90/05/23 | $2.0x10^{25}$ | $5.0x10^{-4}$ |
| $H_2CO$ | $3_{12}-2_{11}$ | 225.7 | 90/05/21-25 | $4.6x10^{25}$ | $1.1x10^{-3}$ |
| $H_2S$ | $1_{10}-1_{01}$ | 168.8 | 90/05/24-25 | $1.1x10^{26}$ | $2.7x10^{-3}$ |
| $CH_3OH$ | (3,0)-(2,0)A | 145.1 | 90/05/25 | $4.9x10^{26}$ | $1.2x10^{-2}$ |
| *Levy (1990c)* | | | | | |
| HCN | J(1-0) | 88.6 | 90/08/29 | $6.6x10^{25}$ | $2.6x10^{-4}$ |
| $H_2CO$ | $3_{12}-2_{11}$ | 225.7 | 90/08/26-30 | $1.0x10^{26}$ | $4.0x10^{-4}$ |
| $H_2S$ | $1_{10}-1_{01}$ | 168.8 | 90/08/30-31 | $5.0x10^{26}$ | $2.0x10^{-3}$ |
| $CH_3OH$ | (3,0)-(2,0)A | 145.1 | 90/08/27 | $1.8x10^{27}$ | $7.2x10^{-3}$ |
| $HC_3N$ | J(24-23) | 218.3 | 90/08/27 | $< 1.2x10^{25}$ | $< 5.0x10^{-5}$ |
| $SO_2$ | $7_{17}-6_{06}$ | 165.2 | 90/08/29 | $< 6.0x10^{26}$ | $< 2.5x10^{-3}$ |
| OCS | J(18-17) | 218.9 | 90/08/28 | $< 5.0x10^{26}$ | $< 2.0x10^{-3}$ |
| $H_2CS$ | $4_{14}-3_{13}$ | 135.3 | 90/08/28 | $< 2.5x10^{26}$ | $< 1.0x10^{-3}$ |

**a**. Assuming a parent distribution; **b**. $Q[H_2O]$ from OH-18 cm observations.

## References


[1] Bockelée-Morvan D., Crovisier J., Colom P., Despois D., Paubert G. (1990), *Observations of parent molecules in comets P/Brorsen-Metcalf (1989o), Austin (1989c1) and Levy (1990c) at millimetre wavelengths: HCN, $H_2S$, $H_2CO$ and $CH_3OH$*, Proceedings of the 24th ESLAB Symp. "The Formation of Stars and Planets, and the Evolution of the Solar System", Friedrichshafen, 17-19 Sept. 1990, ESA **SP-315**, 243-248

[2] Colom P., Crovisier J., Bockelée-Morvan D., Despois D., Paubert G. (1992), *Formaldehyde in comets: microwave observations in P/Brorsen-Metcalf (1989 X), Austin (1989c1) and Levy (1990c)*, Astron. and Astrophys. (in press)

[3] Bockelée-Morvan D., Colom P., Crovisier J., Despois D., Paubert G. (1991), *Microwave detection of hydrogen sulfide and methanol in comet Austin (1989c1)*, Nature **350**, 318-320

[4] Crovisier J., Despois D., Bockelée-Morvan D., Colom P., Paubert G. (1991), *Microwave observations of hydrogen sulfide and searches for other sulfur compounds in comets Austin (1989c1) and Levy (1990c)*, Icarus (in press)

[5] Despois D., Crovisier J., Bockelée-Morvan D., Colom P. (1991), *Formation of comets: constraints from the abundance of hydrogen sulfide and other sulfur-bearing molecules*, IAU Symposium 150, this volume

[6] Combes et al. (1988), *The 2.5-12 μm spectrum of comet Halley from the IKS-VEGA Experiment*, Icarus **76**, 404-436

[7] Despois D. (1991), *Solar System - Interstellar Medium, a chemical memory of the origins*, IAU Symposium 150, this volume