IV

COMETARY DUST :

OBSERVATIONS AND EVOLUTION

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SPECTROSCOPIC EVIDENCE OF ORGANIC MOLECULES RELEASED BY THE DUST OF HALLEY'S INNER COMA

J. CLAIREMIDI, P. ROUSSELOT, G. MOREELS
Observatoire de Besançon
BP 1615
25010 BESANCON Cedex
FRANCE

ABSTRACT. New spectroscopic arguments supporting the probable presence of organic molecules in the material released by comet Halley are deduced from the data obtained by the Vega three-channel spectrometer. Two excesses of emission on the UV side of the OH and CN bands at 305 and 383 nm are interpreted as being due to "prompt" radiation emitted by electronically excited OH and CN radicals directly produced by the photolysis of water vapor and an organic X-CN molecule. A broad-band emission progressively appears between 342 and 375 nm when the solar scattered continuum has been substracted. This emission increases approximately as the inverse of the projected distance to the nucleus. It is interpreted as a fluorescence emission of organic molecules, possibly condensed polycyclic hydrocarbons. Present observations support the hypothesis of grains coated with organic material and give arguments in favor of a probable interstellar origin for cometary dust.

1. Introduction

Two major observational facts obtained during Halley's investigation program suggest that the matter released by the comet contains organic molecules. First, a spectral signature was detected in emission in the near-infrared spectrum at 3.3 - 3.4 μm both from space (Combes et al., 1988) and from the ground (Baas et al., 1986; Danks et al., 1987). This feature is attributed to a vibration C-H band of an organic compound. Secondly, a large fraction of dust particles, approximately 30%, contain light elements (CHON particles, Kissel et al., 1986; Jessberger et al., 1988). The presence of organics in cometary grains has been suggested by Greenberg (1982) and has been argumented recently (Greenberg and Hage, 1990) on the basis of a possible similarity of composition between interstellar and cometary material.

Additional arguments supporting the probable presence of organic molecules in cometary dust may be found in the data of the Vega three-channel spectrometer. Spectra originating from gas jets (Clairemidi et al., 1990) as well as spectra obtained close to the nucleus show emission features directly produced by organic molecules or their primary photoproducts.

2. Spectroscopic data and monochromatic composite images

Between 300 and 400 nm, the main features of cometary spectra are the OH ($A^2\Sigma^+$ - $X^2\Pi_i$) (0,0) band at 309 nm, the NH ($A^3\Pi_i$ - $X^3\Sigma^-$) (0,0) band at 336 nm and the CN ($B^2\Sigma^+$ - $X^2\Sigma^+$) (0,0) band at 388 nm. The excitation mechanism is principally fluorescence excited by solar radiation. An excess of emission is detected on the UV side of the OH band at 305 nm and of the CN band at 383 nm (fig.1). The additional emission in the case of OH is probably due to the R branch of the (0,0) band. The OH ($A^2\Sigma^+$) would be produced directly by the photolysis of water vapor between 120 and 137 nm (Shafizadeh et al., 1988). In the case of CN, the excess of emission would

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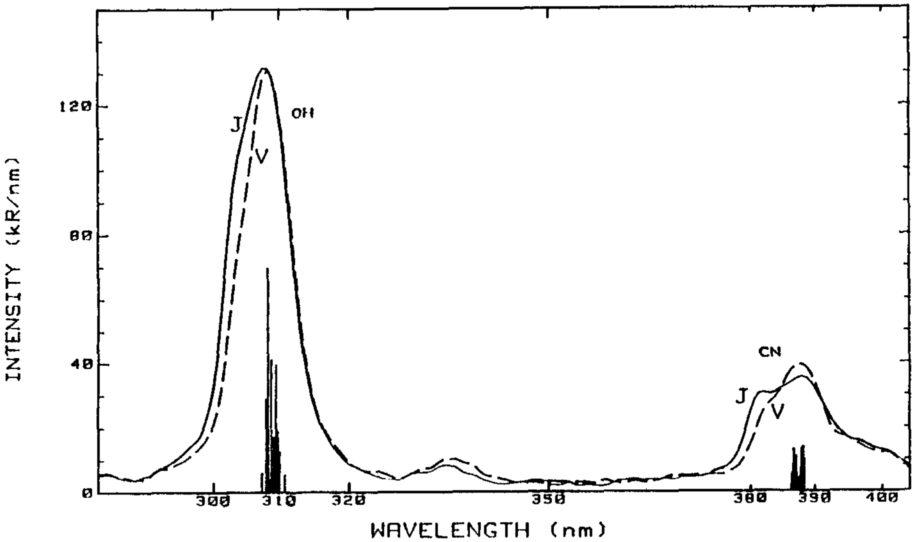

Fig. 1 Spectra in the 290-400 nm range from a jet (J) and from the valley (V); below : fluorescence spectra of OH and CN

correspond to the sequence $\Delta v=0$ of CN with $v' \leq 7$. The CN ($B^2\Sigma^+$, $v' \leq 7$) would be produced directly by the photolysis of an organic molecule of formula X-CN.

Monochromatic composite images of the prompt OH and CN emissions are displayed in Fig.2 and Fig.3. Both emissions are clearly located inside the gas jets which are present up to distances as long as 40000 km. As shown by Clairemidi et al., 1990, the gas jets are correlated with dust jets which contain a relatively important fraction of submicronic particles. They constitute a distributed source of water vapor and organic molecules detected through the OH and CN prompt emissions. It seems probable that these particles are directly connected with the CHON particles detected by Kissel et al. (1986).

3. Broad-band emission in the 342-375 nm spectral region

In the innermost region of the coma, at cometocentric distances smaller than 5000 km, a broad-band emission arises between 342 and 375 nm. This region, between the NH and CN bands, is free of emission in ground-based spectra. The intensity increases approximately as the inverse of the projected distance to the nucleus p (Fig.4 and 5). A perspective view of this increase, showing the progressive emergence of the broad band is presented in fig.6. Four peaks, at 346, 357, 363 and 373 nm may be distinguished in the band.

The 1/p intensity variation shows that the emission is due to a parent molecule fluorescence mechanism. Molecules with fluorescence in the near-UV are numerous, but their spectra are generally obtained in a solvant liquid phase. In this region, possible candidates are methanol, naphtalene, anthracene or phenanthrene, or substituted compounds. If a condensed polycyclic aromatic hydrocarbon (PAH) was the emissive species, this would support the proposition made by Léger and Puget (1984) that interstellar matter contains PAHs, since cometary and interstellar material are supposed to present some degree of similarity in composition.

4. Conclusion

Two sources of organic molecules are revealed by their spectroscopic characteristics and their spatial distribution. The first is connected with the jets which extend to distances of the order of 40000 km or more. The jets contain very small submicronic particles which release water vapor

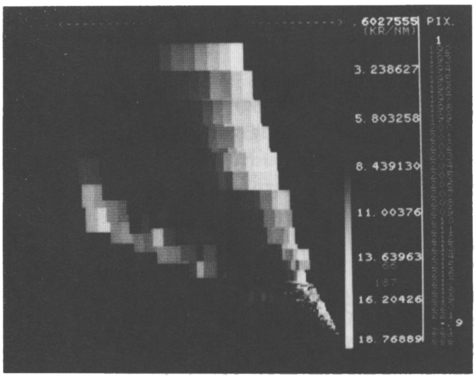

Fig. 2 Prompt emission of OH p ≤40000 km

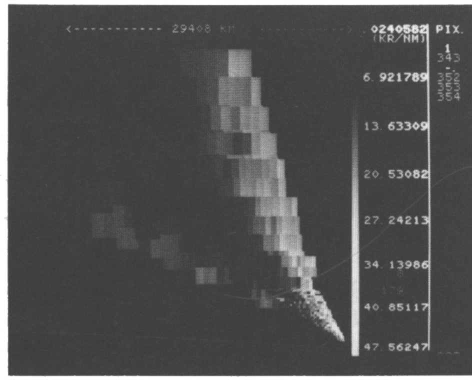

Fig. 3 Prompt emission of CN p ≤40000 km

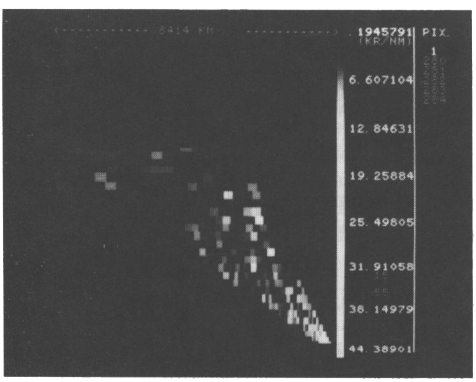

Fig. 4 Broad-band emission $\lambda = 346$ nm
$\Delta\lambda = 3$ nm $p \leq 8000$ km

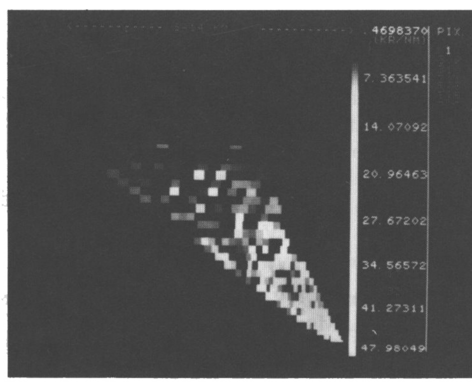

Fig. 5 Broad-band emission $\lambda = 363$ nm
$\Delta\lambda = 3$ nm $p \leq 8000$ km

and carbon-bearing organic molecules which are detected by the prompt emission of their OH and CN photoproducts. The second is connected with the nucleus which releases organics, possibly condensed polycyclic aromatic hydrocarbons, which are detected by their broad-band fluorescence emission in the near UV. Present observations provide arguments in favor of the hypothesis of grains coated with refractory organic material (Greenberg, 1982) and in favor of an interstellar origin for cometary material (Encrenaz et al., 1989).

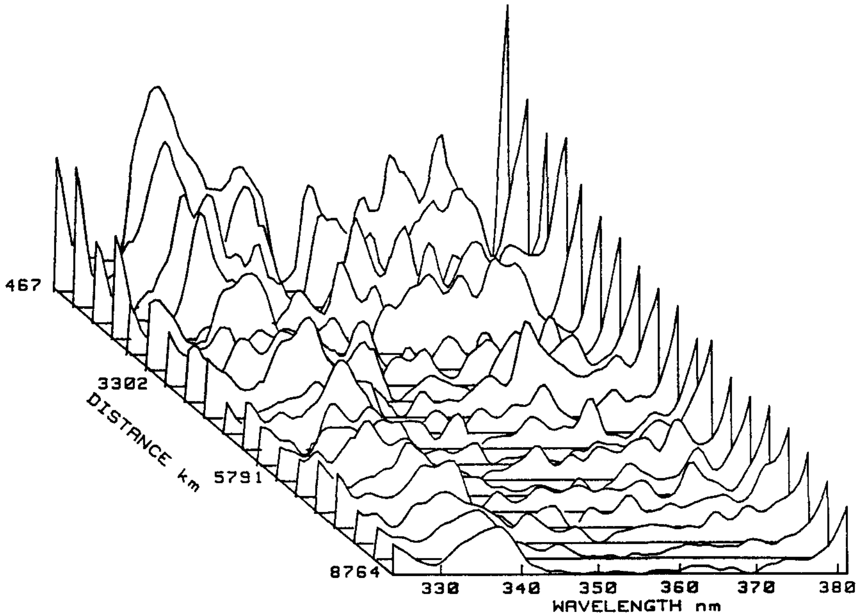

Fig. 6 Progressive emergence of a broad-band emission between 342 and 375 nm

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