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THE 3.4μm EMISSION FEATURE IN COMET HALLEY

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Several teams of ground-based observers reported observations of the emission feature centered at 3.36μm in comet Halley following its discovery by the Vega 1 spacecraft (Ref. 1-6). The position and shape of the band (Fig. 1) indicate a superposition of emissions by C-H groups. But the mechanism for the excitation of these $C\text{-}H_3$ groups is still not agreed upon. Three possibilities are summarized below. Elucidation of the emission mechanism is needed to determine whether the source is predominantly solid or gas. In addition, Table 1 shows that the derived carbon abundance in Halley depends strongly on the assumed mechanism.

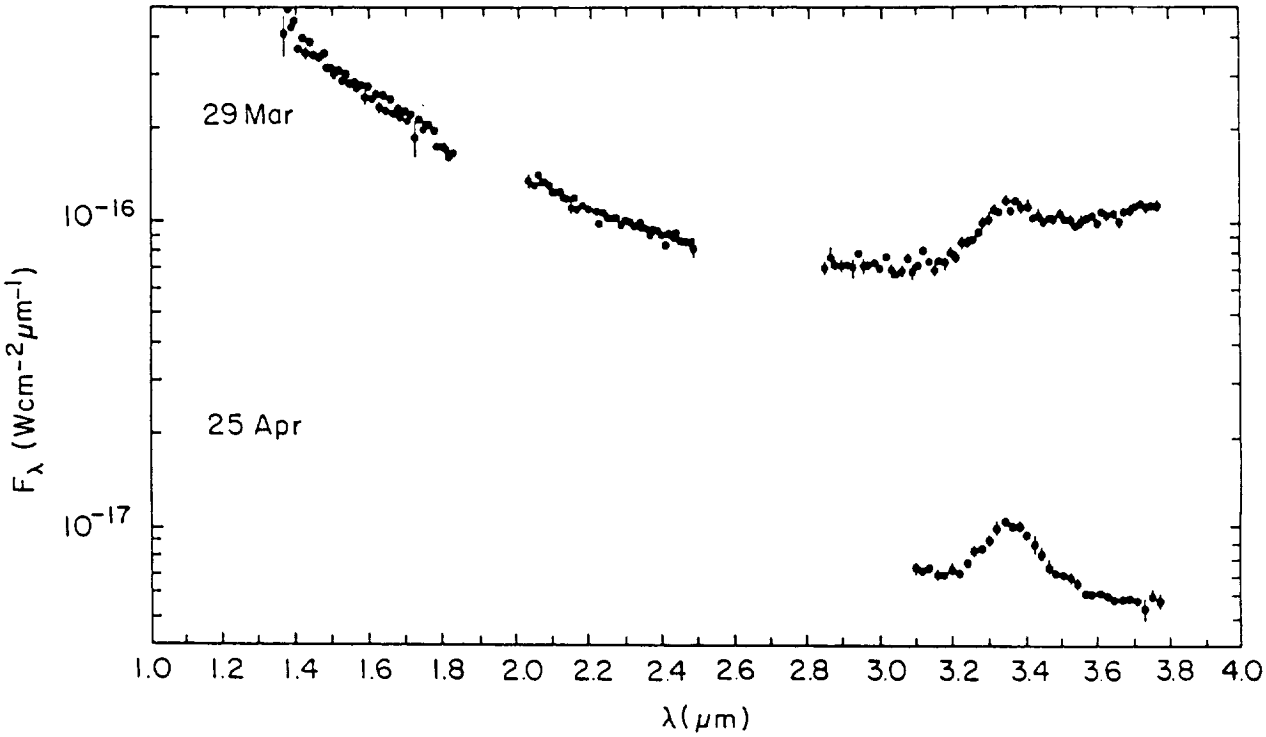

Figure 1. Spectra of comet Halley (Ref. 3)

1) THERMAL EMISSION FROM HOT GRAINS ($a < 0.1\mu$m)

Hydrocarbons in small grains could account for the observed 3.4μm flux if they were heated to T > 500 K, an equilibrium temperature for absorbing grains of radius $a < 0.1\mu$m at 1 A.U. (Ref. 3). The required C-H production rate was ~1 percent of the water production on 26 Mar UT 1986 (Table 1).

One difficulty with ascribing the 3.4μm feature to thermal emission is that a relatively high-hydrocarbon band strength may be required to raise the feature above the observed continuum (Ref. 4). Another problem is the absence of strong emission features at longer wavelengths (6-8μm) in comet Halley (Ref. 7, 8). These could be overwhelmed by the thermal emission from noncarbonaceous grains (Ref. 9).

TABLE 1
Relative Abundance of C-H in Comet Halley Derived from the 3.4μm Feature.

	Mechanism	Ref	UT 1986	Q(C-H) (sec^{-1})	$\frac{Q(C\text{-}H)}{Q(H_2O)}$
1)	Thermal emission from hot grains	3	26 Mar	$2x10^{27}$	~ 1%
2)	UV-pumped IR fluorescence from large molecules	4	25 Apr	$3x10^{26}$	0.15%
3)	Resonance scattering by molecules	3	26 Mar	$4x10^{28}$	30%
		6	28 Mar	$2x10^{28}$	10%
		8			20%

2) ULTRAVIOLET-PUMPED INFRARED FLUORESCENCE ($a \sim 5$Å)

Large molecules or small clusters can absorb UV photons through electronic transitions and release the energy through excited vibrational transitions in the infrared. This mechanism has been invoked to explain the unidentified interstellar emission feature (Ref. 10, 11). All of the emission is in narrow bands so large line-to-continuum ratios are possible.

According to Reference 4, this fluorescence mechanism is efficient enough that the sun could have provided sufficient UV flux to excite the 3.4μm emission in comet Halley. They give a required molecular production of only 0.15 percent of the water production on 25 Apr UT 1986 (Table 1). While in principle the process may be highly efficient at converting UV photons to 3.4μm photons, considerable uncertainties do remain and a more detailed calculation for specific molecules in the solar radiation field is needed to test its applicability to the cometary emission.

3) RESONANCE SCATTERING BY MOLECULES

Simple infrared resonance scattering of sunlight by gas molecules could also explain the 3.4μm feature. Derived production rates depend on the assumed band strength, but are a few times 10 percent of the water production (Table 1).

The signature of resonance scattering would be the detection and measurement of relative intensities of vibration-rotation lines in the feature which would be absent in a solid. The highest resolution spectrum of Halley shows possible features in the band (Ref.

4), but there is no obvious candidate to date.

Resonance scattering provides a natural explanation for the absence of longer wavelength features since the solar flux drops with increasing wavelength (Ref. 8).

Even though the emission mechanism is still uncertain, some progress has been made at identifying the spectral groups responsible for the emission (Refs. 3, 4, 5, 8, 12). A feature at 3.52μm has been attributed to oxygen-containing molecules, possibly formaldehyde (Refs. 3, 5, 12). A feature at 3.28μm coincides with an interstellar emission feature and may be due to the =C-H stretch in aromatic hydrocarbons. The bulk of the cometary emission, like the interstellar absorption feature, is at longer wavelengths where alkyl groups (-CH_3 and others), possibly attached to the ring molecules, can absorb. The presence of such side chains may be indicative of low-temperature formation environments (Ref. 13).

Further progress towards identifying the 3.4μm emitter lies in high signal-to-noise and higher spectral resolution observations of a bright comet. In May 1987, the 3.4μm emission feature was detected in comet Wilson (Ref. 14).

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DISCUSSION

SANDFORD: A nice talk! I think that we need to be careful not to present the thermal and resonance processes as exclusive as far as the source of the 3.4mum feature goes. I would expect that both processes are occurring. Certainly IDPs contain hydrocarbons and contributions from these would be predominantly thermal. On the other hand, these grains probably also shed hydrocarbons with intermediate velocities, and these should contribute via fluorescence (laboratory experiments on photolyzed ices show that these intermediate velocity hydrocarbons are easy to form and are likely to be common).

BROOKE: Thus, I expect that a truly satisfactory explanation of the 3.4μm feature will include a variety of thermal and fluorescence processes.

LYNCH: Have you looked at the dependence of the 3.4μm feature on heliocentric distance?

BROOKE: No, it should be done.

CAMPINS: The 3.4μm feature in Comet West may have been masked by the strong thermal continuum when the comet was at 0.3 AU.

BROOKE: If the 3.4μm-emitting material were present in abundance, we should see it even in the presence of a strong continuum; it should be enhanced close to the sun. It should be noted that Comet West showed the silicate feature, but did not show the 3.4μm feature. However, the apparent variability of the 3.4μm feature on the timescale of one day makes the prediction of when one should see the feature very difficult. The non-detection of the 3.4μm feature on one day does not imply that that comet does not have the 3.4μm feature at all other times. Clearly, more observations are required.