THE INFRARED SPECTRUM OF COMET HALE-BOPP AS SEEN BY THE INFRARED SPACE OBSERVATORY

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Abstract. Spectra of comet C/1995 O1 (Hale-Bopp) were obtained with the Infrared Space Observatory (ISO) at medium resolution with the grating spectrometer in the photometer (PHT-S) and/or at high resolution with the short wavelength spectrometer (SWS) and long wavelength spectrometer (LWS) in April 1996 (Crovisier *et al.*, 1996), September–October 1996 (Crovisier *et al.*, 1997a, 1997b) and December 1997, at distances from the Sun of 4.6, 2.9 and 3.9 AU, respectively. For the first time, high-resolution spectra of a comet covering the entire 2.4 to 200 μm spectral range were obtained.

The vibrational bands of H_2O, CO_2 and CO are detected in emission with PHT-S. Relative production rates of 100:22:70 are derived for H_2O:CO_2:CO at 3 AU pre-perihelion. H_2O is observed at high spectral resolution in the ν_3 group of bands around 2.7 μm and the ν_2 group around 6 μm with SWS, and in several rotational lines in the 100–180 μm region with LWS. The high signal-to-noise ratio of the ν_3 band observed on September–October 1996 allows accurate determinations of the water rotational temperature (28 K) and of its ortho-to-para ratio (2.45 ± 0.10, which significantly differs from the high temperature limit and corresponds to a *spin* temperature of 25 K).

Longward of 6 μm the spectrum is dominated by dust thermal continuum emission, upon which broad emission features are superimposed. The wavelengths of the emission peaks correspond to those of Mg-rich crystalline olivine (forsterite). In the September–October 1996 spectra, emission features at 45 and 65 μm and possible absorption at 2.9–3.2 μm suggest that grains of water ice were present at 3 AU from the Sun.

The observations made post-perihelion in late December 1997 led to the detections of H_2O, CO_2 and CO at 3.9 AU from the Sun (Figs 1 and 2). The production rates were $\approx 3. \times 10^{28}$, 3.5×10^{28} and $\approx 1.5 \times 10^{29}$ s^{-1}, respectively. This corresponds to H_2O:CO_2:CO = 100:110:500 and confirms that at such distances from the Sun, cometary activity is dominated by sublimation of CO and CO_2 rather than by H_2O.

Key words: C/1995 O1 Hale-Bopp, Comets, Infrared spectroscopy, ISO

References

Crovisier, J., Brooke, T.Y., Hanner, M.S., *et al.*: 1996 "The infrared spectrum of comet C/1995 O1 (Hale-Bopp) at 4.6 AU from the Sun" *Astron. Astrophys.* **315**, L385–L388.

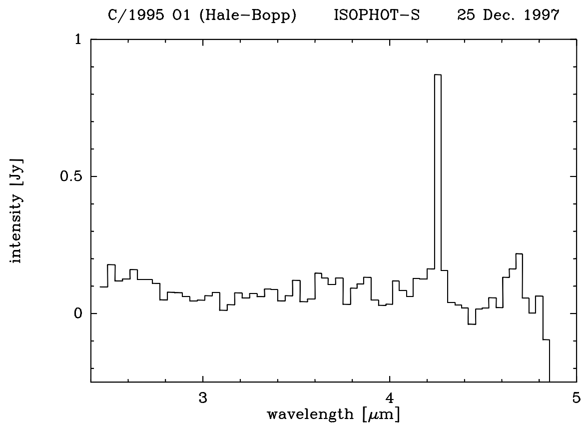

Figure 1. The 2.5 to 5 μm spectrum of C/1995 O1 (Hale-Bopp) observed with the PHT-S instrument of ISO on 25 December 1997, at 3.85 AU from the Sun. The bands of CO_2 at 4.25 μm and CO at 4.65 μm can be seen.

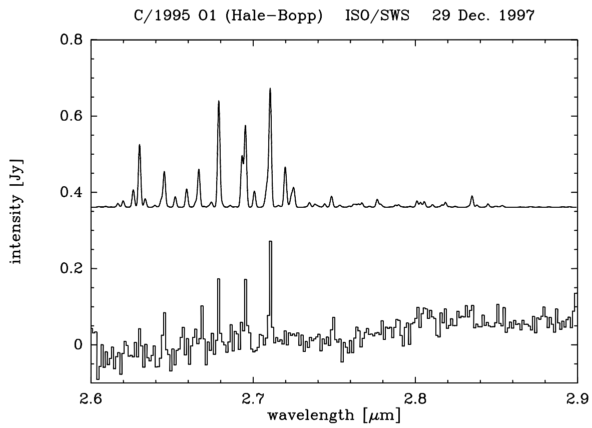

Figure 2. The region of the ν_3 band of water observed in C/1995 O1 (Hale-Bopp) on 29 December 1997 at 3.89 AU from the Sun with the ISO short wavelength spectrometer (bottom). The strongest lines of the ν_3 band are detected. The upper curve is a synthetic spectrum.

Crovisier, J., Leech, K., Bockelée-Morvan, D., *et al.*: 1997a "The spectrum of comet Hale-Bopp (C/1995 O1) observed with the Infrared Space Observatory at 2.9 AU from the Sun" *Science* **275**, 1904–1907.

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