

Deep Sounding of Venus' Atmosphere by Near Infrared Spectroscopy of the Night Side

Until recently, it was believed that the deep atmosphere of Venus below the clouds could be probed essentially by in-situ measurements.

However, near infrared imaging of the planet by Allen and Crawford (*Nature*, 307, 222, 1984) made in 1983 showed that, quite unexpectedly, thermal emission from the night of the planet is strong (equivalent to that of blackbodies radiating at temperatures between 330 K and 480 K) in at least two spectral ranges of the near infrared (near 1.7 microns and near 2.3 microns). This results from a combination of two factors: 1) sub-lorentzian line profiles for CO₂ in the far wings, which minimizes residual CO₂ absorption in spectral regions located between strong CO₂ bands, and 2) a reduced opacity of the sulfuric acid clouds at wavelengths shorter than 3 microns. On the contrary, radiation from the day side of the planet is, at these wavelengths, essentially sunlight reflected by the clouds.

Studying the dark side of the planet near 1.7 and 2.3 microns therefore provides a unique opportunity to probe the planetary deep atmospheric layers.

In November 1989, B. Bézard (Observatoire de Paris), C. de Bergh (Observatoire de Paris), D. Crisp (Jet Propulsion Laboratory) and J.P. Maillard (Institut d'Astrophysique de Paris) obtained with the FTS at CFHT the first spectra of the dark side of Venus at high resolution (0.23cm⁻¹) in these two spectral "windows." A preliminary analysis indicates that the radiation observed is thermal radiation from atmospheric layers corresponding to pressure levels as deep as 8 bars in the 2.3 microns region, and even deeper in the 1.7 micron region. Numerous absorption features are detected. They are due to: CO₂, CO, H₂O, HDO, HF, COS (and maybe SO₂) in the 2.3 micron region (see Figure 18) and to CO₂, H₂O and HCP in the 1.7 micron region. There also remain unidentified features (particularly in the region near 4400 cm⁻¹).

These spectra provide the first measurements of the HCP and HF abundances below the clouds of Venus. They also confirm the factor

of about 100 enrichment of the Venusian D/H ratio over the terrestrial value that had been indicated by two different sets of in-situ Pioneer Venus measurements but was recently challenged by IUE measurements that refer to the upper atmosphere of the planet (Bertaux and Clarke, *Nature*, 338, 567, 1989). The first reliable measurement of COS in the deep atmosphere is also provided. The value obtained is more than two orders of magnitude lower than that suggested by in-situ gas chromatograph measurements by the Venera 13 and 14 probes.

This preliminary work (to appear in *Nature*) is extremely promising. A higher spectral resolution could easily be obtained (indeed, the spectra at 0.23 cm⁻¹ resolution were recorded in less than half an hour in each of the two windows). A more accurate measurement of the D/H ratio could then be obtained, as well as the vertical distribution of some of the constituents whose abundances are known to vary with altitude (CO, H₂O). Furthermore, new atmospheric windows have since been discovered at shorter wavelengths (between 1.1 and 1.3 microns) that will certainly be worth exploring at high spectral resolution with the FTS at CFHT. Finally, combining imaging and high resolution spectroscopy would be highly desirable since the night side of Venus is clearly non-uniform in brightness.

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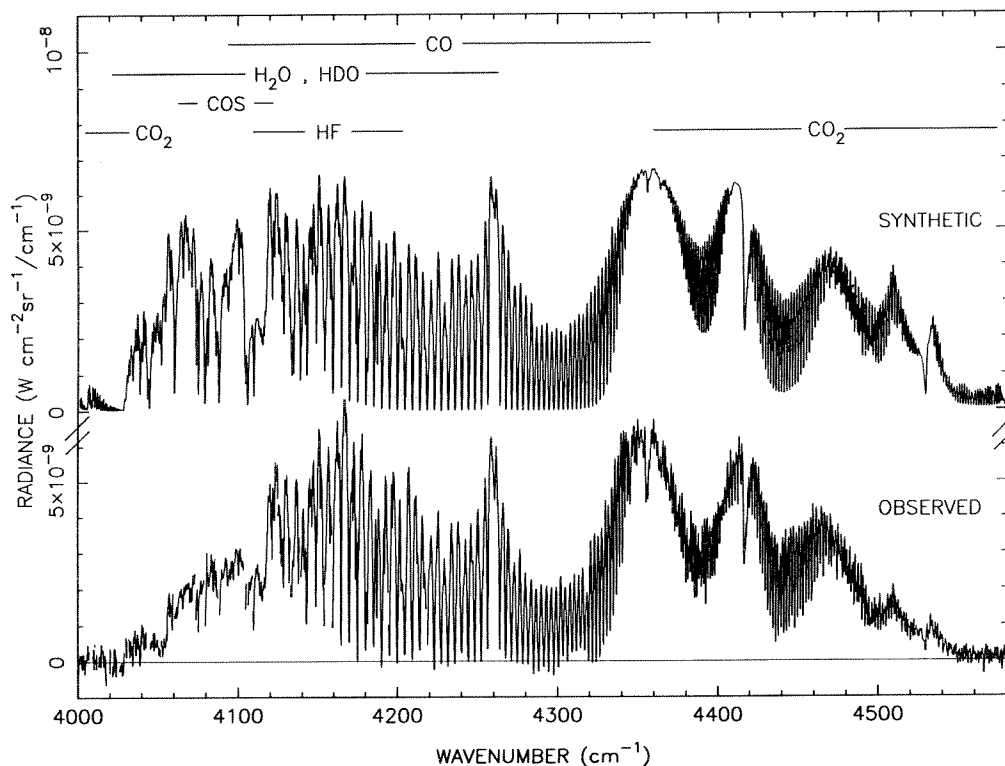


Figure 18: Lower curve: Spectrum of a bright region of the night side of Venus (a circular aperture 5" in diameter was used) recorded with the FTS at CFHT. The apodized spectral resolution is 0.28cm⁻¹. The spectrum, which has a signal-to-noise ratio of 50, was recorded in 27 minutes.

Upper curve: Synthetic spectrum of Venus computed for the CO, H₂O, HDO, COS and HF abundances that provide the best agreement with the observations. The part of the spectrum where CO₂ dominates is used to constrain the pressure levels from which thermal radiation originates.

The synthetic spectrum does not provide a good agreement with the observed spectra near 4050 cm⁻¹. This is probably due to the fact that absorption by the 3v₃ band of SO₂ has not yet been introduced in the computation because of the present lack of good laboratory data on that band.