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The 1.10- and 1.18-µm nightside windows of Venus observed by SPICAV-IR aboard Venus Express

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1. Introduction

Thermal emission from the deep atmosphere of Venus observed on the night side in the 1.10- and 1.18-µm windows provides information on the water vapor abundance in the altitude range 0-25 km. The H_2O mole fraction near the surface is still controversial and the various analyses of in situ measurements and observations of the nightside windows do not yield consistent results [4]. We present here an analysis of the 1.10- and 1.18-µm nightside windows observed by the infrared channel of the SPICAV (Spectroscopy for the investigation of the characteristics of the atmosphere of Venus) instrument aboard Venus Express [3]. We investigated the influence of the various sources of opacity (CO_2 and H_2O linelists, CO_2 far wing and "continuum" opacity) on the spectrum and of the associated uncertainties or unknowns. The results were used to propose a best representation of the CO_2 and H_2O opacity and to derive a best fit H_2O mixing ratio.

2. Observations

We used nadir observations by the LW range of the visible-infrared channel (Vis-IR) of SPICAV, a single pixel spectrometer based on AOTF technology [3]. The spectral resolution is about 5.2 cm^{-1} (0.7 nm at 1.18 µm) . We made a large average of LW spectra recorded during Orbits 800 and 825, yielding a S/N ratio of 500 at the peak of the 1.18-µm window (Fig. 1).

3. Spectral modelling

Synthetic spectra were generated using a line-by-line radiative transfer model with scattering [4] and compared with the SPICAV selection. We allowed the use of a constant scaling factor as a free parameter to account for the unknown cloud optical depth.

We first investigated the CO_2 far wing lineshape, which is constrained by the high-wavelength wing of the 1.18-µm window. We found that the line profile model of Afanasenko and Rodin [1] underestimates the CO_2 absorption and we derived instead an empirical sub-lorentzian profile that reproduces this wing. It provides more absorption than those previously derived for CO_2 bands near 2.3 µm at room temperature.

The variation of the 1.10- and 1.185-µm radiance with surface elevation, as observed by the Venus Express / VIRTIS-M instrument, requires an additional "continuum" opacity, besides that provided by the CO_2 and H_2O allowed bands. We have re-analyzed the dataset of Bézard et al. [4] to constrain this additional absorption at 1.10 and 1.185 µm and derived a constant absorption coefficient, equal to $0.7 \pm 0.2 \times 10^{-9}$ cm^{-1} amagat^{-2}.

We have modeled the SPICAV spectra using either the high-T [5] or CDSD [6] CO_2 line lists. The latter provides less absorption than "High-T" in the interval 1110-1190 nm and reproduces worse the observed spectrum, due to the absence of the $5\nu_1+\nu_3$ series of CO_2 bands. On the other hand, CDSD agrees better with the observations shortward of 1100 nm although the data clearly show evidence for a missing absorption between 1085 and 1100 nm. In this work, we have used a composite CO_2 line list combining "High-T" and CDSD.

Absorption by HDO had not been previously added in the modeling of the 1.10- and 1.18-µm windows. Using a recently published line list (VTT) [7], we found that the influence of HDO is significant in the range 1140-1190 nm, inducing a 7% drop in radiance at 1185 nm and slightly improving the fit of the SPICAV spectrum. We also confirm that the $H_2{}^{16}O$ BT2 database [6] yields more opacity than the GEISA or HITRAN databases, being more accurate and more complete in high-energy lines [2].

Using the sources of atmospheric opacity described above, we determined a best-fit value for the H_2O mole fraction of 30^{+10}_{-5} ppm (assumed constant below the clouds) (Fig. 1). The emission in the H_2O band is most sensitive to the region 5-25 km.

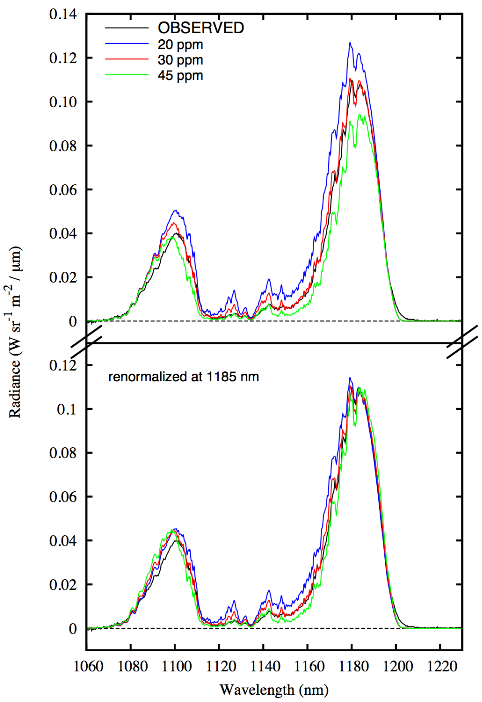

Figure 1: The SPICAV spectrum is compared to synthetic spectra calculated with H_2O mole fractions of 20, 30 and 45 ppm using our best estimate for the representation of the H_2O/HDO and CO_2 opacity. *Upper panel*: raw calculations; *Lower panel*: spectra renormalized to the observed radiance at 1185 nm.

4. Discussion and conclusion

We have used observations of the night side of Venus by the Venus Express / SPICAV-IR instrument in the 1.10- and 1.18-µm windows to better characterize the various sources of molecular opacity at these wavelengths and determine the average mole fraction of water vapor in the 5-25 km altitude range.

The 30-ppm mole fraction we derived is smaller that that derived from VIRTIS-M spectra (44 ± 9 ppm) [4], even though the error bars overlap. This value is fully consistent with the mole fraction derived at 30-45 km from the 2.3-µm window and at 15-25 km from the 1.74-µm window. This result gives strong evidence that the water mole fraction is constant from approximately 5 to 40 km, as predicted by chemical models.

Our best fit model still shows some discrepancies with the SPICAV spectrum, e.g. between 1085 and 1100 nm. They likely result from an inaccurate representation of the CO_2 opacity. Laboratory measurements would help in this regard.

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