

## Venus terminator temperature profiles using SPICAV-SOIR on board Venus Express

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### Abstract

The wavelength range probed by SOIR allows a detailed chemical inventory of the Venus atmosphere at the terminator in the upper mesosphere and lower thermosphere (70 to 170 km) with an emphasis on vertical distribution of the gases. In particular, measurements of CO<sub>2</sub> density vertical profiles have been routinely performed. From these density measurements, kinetic temperature profiles are derived using the hydrostatic equilibrium. A permanent cold layer is observed at the mesopause ( $\pm 120$  km).

A different and independent method is developed here, making use of the information obtained from the rotational structure of the CO<sub>2</sub> bands to derive rotational temperature profiles. The rotational temperature profiles are compared to the hydrostatic temperature profiles, and they confirm the presence of the cold layer at the mesopause.

### 1. Introduction

The SOIR (Solar Occultation in the IR) instrument has been designed to measure spectra in the IR region (2.2 – 4.3  $\mu\text{m}$ ) of the Venus atmosphere using the solar occultation technique [1]. This method derives unique information on the vertical composition and structure of the mesosphere and lower thermosphere [2-4]. SOIR is an extension mounted on top of the SPICAV instrument [5]. SPICAV/SOIR is one of the seven instruments on board Venus Express, a planetary mission of the European Space Agency (ESA) that was launched in November 2005 and inserted into orbit around Venus in April 2006 [6].

The instrument has already been extensively described elsewhere and will only be briefly outlined here. SOIR is an Echelle grating spectrometer operating in the IR, combined with an acousto-optic tunable filter (AOTF) for the selection of the recorded wavenumber interval. The wavenumber range covered by the instrument extends from 2250

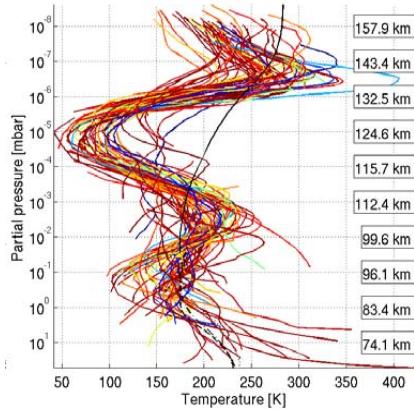
to 4370  $\text{cm}^{-1}$  (2.2 – 4.3  $\mu\text{m}$ ) and is divided into 94 diffraction orders (from 101 to 194). The limits of these diffraction orders are given in [1]. The bandwidth of the AOTF was originally designed to be 20  $\text{cm}^{-1}$ , as measured on ground before launch, to allow light from only one order into the spectrometer. However, the measured bandwidth of SOIR is  $\sim 24$   $\text{cm}^{-1}$  [2], creating some order leakage on the detector. The fact that the AOTF transfer function is wider implies that information from adjacent orders leaks onto the detector.

The SOIR instrument is unique in terms of spectral coverage and spectral resolution (0.15  $\text{cm}^{-1}$ ), and is ideally designed to probe the Venus atmosphere for CO<sub>2</sub> as well as trace gases. SOIR measurements take place at the Venus terminator, due to its measurement technique, i.e. either at 6AM or 6PM local solar time, and all latitudes are covered.

### 2. Results

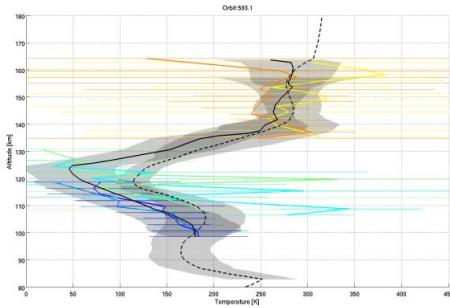
Two methods to derive atmospheric temperature are considered here. The first one [3] considers the hydrostatic equilibrium and the CO<sub>2</sub> number density profiles. In this method, the CO<sub>2</sub> volume mixing ratio is needed in the homopause (below 130 km) and is taken from VIRA [7, 8]. Above, CO<sub>2</sub> number density is directly used to calculate the kinetic temperature since each constituent follows its own scale height.

The density profiles present a change of slope between 120 and 140 km, and the temperature profiles show an unforeseen permanent cold layer in the same region. This feature is latitude and local solar time independent, with temperatures falling below 100 K. It is surrounded by two warm layers, as presented in Figure 1 for 60 profiles from all latitudes. The differences with the VIRA temperature profile are large. Error bars are not presented for clarity, and equal 5 to 40% for the density and 10 to 60 K for the temperature.



**Figure 1:** Kinetic temperature profiles obtained using the hydrostatic equation. Colour is the absolute latitude (blue is equator, red is polar). The VIRA model is the black profile.

Another independent method is developed to confirm and improve the retrieval of the temperature. It uses the CO<sub>2</sub> rotational lines, which are resolved in the SOIR spectra. This method does not require CO<sub>2</sub> number density profiles. From these, the rotational temperature is calculated accounting for instrumental and measurement characteristics to reduce the error bars and improve the retrieval.



**Figure 2:** Rotational temperature profile from different orders (coloured) and combination (black plain) with error bars compared to hydrostatic profile (black dashed) for orbit 593.1.

The comparison between rotational and kinetic temperature profiles is presented in Figure 2 for one profile, where a good agreement in most of the altitude regions is observed.

More profiles will be presented and discussed, in order to confirm the structure of the temperature profiles, and combination of both methods will be discussed.

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## References

1. Nevejans, D., et al., *Compact high-resolution space-borne echelle grating spectrometer with AOTF based on order sorting for the infrared domain from 2.2 to 4.3 micrometer*. Applied Optics, 2006. **45**(21): p. 5191-5206.
2. Mahieux, A., et al., *Densities and temperatures in the Venus mesosphere and lower thermosphere retrieved from SOIR onboard Venus Express: Retrieval technique*. J. Geophys. Res., 2010. **115**(E12014): p. 10.1029/2010JE003589.
3. Mahieux, A., et al., *Densities and temperatures in the Venus mesosphere and lower thermosphere retrieved from SOIR on board Venus Express: Carbon dioxide measurements at the Venus terminator*. J. Geophys. Res., 2012. **117**(E07001): p. doi:10.1029/2012JE004058.
4. Vandaele, A.C., et al., *Composition of the Venus mesosphere measured by SOIR on board Venus Express*. J. Geophys. Res., 2008: p. doi:10.1029/2008JE003140.
5. Bertaux, J.L., et al., *SPICAV on Venus Express: Three spectrometers to study the global structure and composition of the Venus atmosphere*. Planet. Space Sci., 2007. **55**(12): p. 1673-1700.
6. Titov, D.V., et al., *Venus Express: Scientific Goals, Instrumentation and Scenario of the Mission*. Cosmic Res., 2006. **44**(4): p. 334-348.
7. Zasova, L.V., et al., *Structure of the Venusian Atmosphere from Surface up to 100 km*. Cosmic Res., 2006. **44**(4): p. 364-383.
8. Hedin, A.E., H.B. Niemann, and W.T. Kasprzak, *Global empirical model of the Venus thermosphere*. J. Geophys. Res., 1983. **88**(A1): p. 73-83.