Remote Sensing of Venus' atmosphere during the June 2004 transit

P. Hedelt[1)], H. Rauer[1),2)], R. Titz[1)], F. Schreier[3)], T. Brown[4)] , H. Schmidt[5)], H. Schleicher[5)], R. Alonso[6)], and M. Collados[6)]

[1)]Institut für Planetenforschung, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Rutherford Str. 2, 12489 Berlin; [2)] Zentrum für Astronomie und Astrophysik, Technische Universität (TU) Berlin, Hardenbergstr. 36, 10623 Berlin; [3)]Institut für Methodik der Fernerkundung, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Oberpfaffenhofen; [4)]High Altitude Observatory, National Centre for Atmospheric Research, Boulder, Colorado; [5)] Kiepenheuer Institut für Sonnenphysik (KIS), Schöneckstr. 6, 79104 Freiburg; [6)]Instituto de Astrofisica de Canarias (IAC) Tenerife

I. Introduction

During the Venus transit in June 2004 (see Fig. 1), we investigated the solar radiation passing through the atmosphere of Venus and tried to detect CO_2 absorption lines.
CO_2 isotope measurements are relevant to atmospheric loss processes and for constraining accretion models.
We used a radiative transfer program to model the measured spectrum and identify the measured lines.

Figure 1: Venus in front of Sun

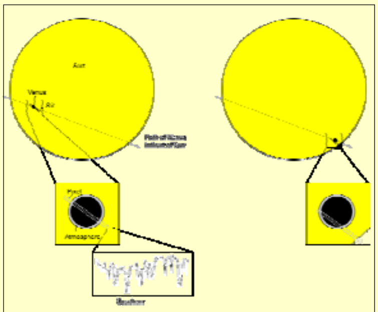

Figure 2: Observing geometry

II. Observation & Data Reduction

- The Venus transit was observed at the Vacuum Tower Telescope (VTT) in Tenerife, using an Echelle-spectrometer and an attached IR-CCD with 256x256 pixel.
- The spectral resolution of 200,000 corresponds to approx. 8×10^{-6} µm at a wavelength of 1.5977 µm.
- Slit length: 90", slit width: 0.35".
- The Venusian disc and part of the surrounding solar disc were covered in each long-slit exposure (see Fig. 2).
- The exposure time was 50 ms.
- Three wavelength regions covered in total 1.5965 to 1.6132 µm with 0.031 Å/pixel.
- The basic CCD spectral data reduction was performed.
- The Venus atmosphere spectra were extracted at the limb of Venus.
- The Venus spectra were divided by an average spectrum of the adjacent solar surface.

III. Measured Spectra

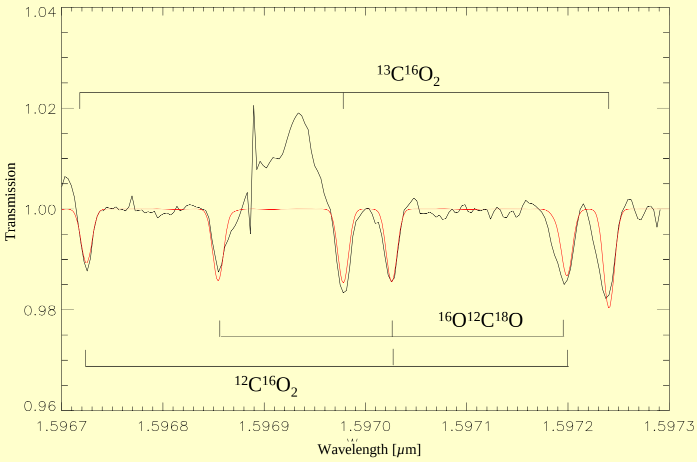

Figure 3: Comparison of one measured (black) and modeled (red) spectral region. Clearly visible are absorption lines of the three most abundant isotopes of CO_2. The emission line at 1.59693 µm is a residual solar absorption line. Model parameters are: 105 km tangential height, day-side temperature profile.

IV. Radiative Transfer

We used the high-resolution line-by-line radiative transfer program SQuIRRL (Schwarzschild Quadrature InfraRed Radiation Line-by-line) [Schreier and Böttger, (2003)] to model the observed spectra. SqUIRRL uses the HITRAN-Database [Rothman et al. (1998)] to calculate the absorption coefficient and solves the Schwarzschild equation with trapezian quadrature assuming LTE. Scattering and atmospheric chemistry are neglected. We used a temperature and pressure profile from [Yung and DeMore (1999)] and isotopic abundances from [Bézard et al. (1987)] to calculate the transmission spectra for all wavelength regions with a tangential beam having 40 km width.

Results

We get the best fit with a tangential height of about 105 km. A temperature profile close to the day side profile of Venus' atmosphere is consistent with the data (see Fig. 3, red line). Averaged over the three bandpasses, the best fit CO_2 isotope abundances are:

- $(98.5 \pm 30)\%$ $^{12}C^{16}O_2$
- $(1.1 \pm 0.3)\%$ $^{13}C^{16}O_2$
- $(0.4 \pm 0.2)\%$ $^{16}O^{12}C^{18}O$

With our estimated abundances we get a ratio of

- $^{12}C/^{13}C = {}^{12}C^{16}O_2/{}^{13}C^{16}O_2 = 90 \pm 53$
- $^{16}O/^{18}O = 2\ {}^{12}C^{16}O_2/\ {}^{16}O^{12}C^{18}O = 492.5 \pm 394$

These ratios are in good agreement with the literature values in [Bézard et al. (1987)]. We note that our fit parameters may be affected by baseline variations. Nevertheless, the results are consistent with literature values.

Future Prospects: The next transit of Venus is observable on 6th of June 2012 from Eastern Asia. With optimized measurements it is possible improved data with higher SNR and one can do better fitting of modelled and measured data.

V. Parameter Variation

We varied three main model parameters: tangential height, temperature profile (see Fig. 4) and abundance of the three most abundant isotopes of CO_2 ($^{12}C^{16}O_2$, $^{13}C^{16}O_2$ and $^{16}O^{12}C^{18}O$):

- Reducing tangential height and increasing isotopic abundance results in a stronger absorption depth of all isotopic lines.
- Increasing temperature (see Fig. 5) results in:
  - line depth of most abundant $^{12}C^{16}O_2$ increasing
  - line depth of second most abundant isotope $^{13}C^{16}O_2$ remaining constant
  - line depth of third most abundant isotope $^{16}O^{12}C^{18}O$ decreasing

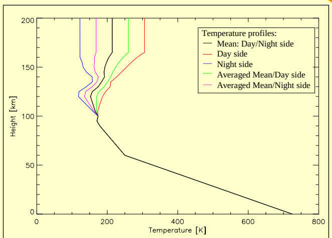

Figure 4: Different temperature profiles used for the parameter variations [Yung and DeMore (1999)]
The region between 100 and 150 km is of special interest due to increasing differences in temperatures. Profile colors correlate with colors used in Fig. 5.

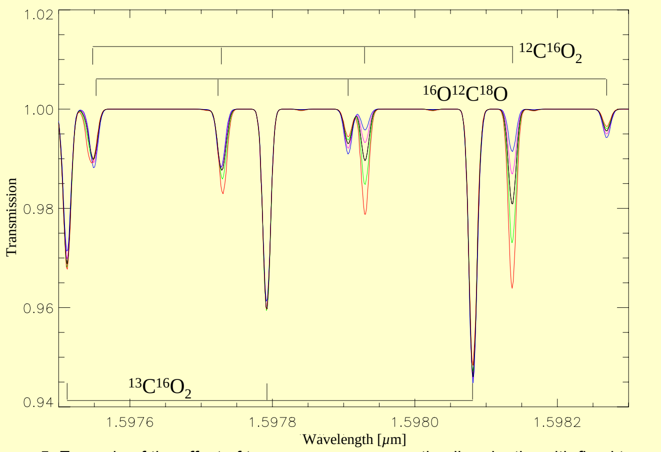

Figure 5: Example of the effect of temperature on absorption line depths with fixed tangential height at 102 km. The absorption of $^{12}C^{16}O_2$ increases with increasing temperature, while the absorption of $^{16}O^{12}C^{18}O$ decreases. The lines of $^{13}C^{16}O_2$ show no effect on varying temperature.

References

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