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Thermal Structure of Venus and Mars as Observed by Ground-Based Mid-IR Heterodyne Spectroscopy

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Abstract

We want to introduce a new and unique opportunity to retrieve temperature profiles from the atmosphere of terrestrial planets using ground-based heterodyne spectroscopy in the mid-infrared. In recent years this method has been proven to be a powerful tool to study the atmosphere of terrestrial planets in terms of high altitude dynamics and temperature contribution [1, 2]. Currently two heterodyne spectrometer exist which are used for astrophysical observations of planetary atmospheres (Cologne based spectrometer "THIS" and NASA GSFC's "HIPWAC"). They uniquely provide the required ultra-high resolution to fully resolve molecular spectral lines. The application of this technique enables us to observe single molecular ro-vibrational transition features of CO_2 at 10µm in absorption.

1. Introduction

In the past decade the thermal structure of Venus atmosphere has been target of intense studies. The recent space mission Venus Express (VEX) has shed light on many open question concerning the thermal and dynamical behavior. But now, in the vicinity of the imminent shut down of the space craft, the importance of ground-based observations increases significantly.

2. Proof of Concept

The line shape of the pressure broadened CO_2 absorption line is depended on the pressure and temperature profile of the Venusian atmosphere. However the signal to noise is limited and strongly depended on the integration time. Therefore extensive studies on the proof of concept have been accomplished [3]. For artificial spectra, model and white noise according to realistic observations, we found an altitude sensitivity between ~60 km (upper cloud haze, ~100 hPa) and ~90 km (~0.1 hPa). Below 60km the Venusian atmosphere becomes opaque for infrared radiation. An altitude resolution of ~4.5km can be provided.

3. Measurements and Results on Venus

Four distinct observations of CO_2 absorption lines at 10µm on the night side of Venus have been made.

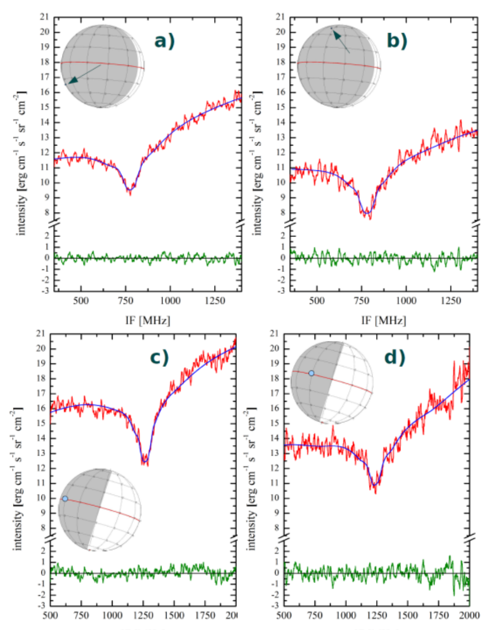

Figure 1: Red: CO_2 P(12) absorption feature observed at a) 33°S 4:00 Venusian local time (LT), at b) 67°N 0:00 am LT in May 2012, at c) Equator 22:00 LT and at d) Equator 20:00 LT in March 2012. Blue: output model of inverse fitting routine yielding corresponding pT-profile displayed in Fig.2. Green: Residuals between model and data indicating the SNR.

We addressed different latitudes and local times (see Fig. 1). From comparison to model calculation and other observation we do have a validation for our concept [4,5]. Additional results, comparisons and observing plans for the future will be presented at the conference.

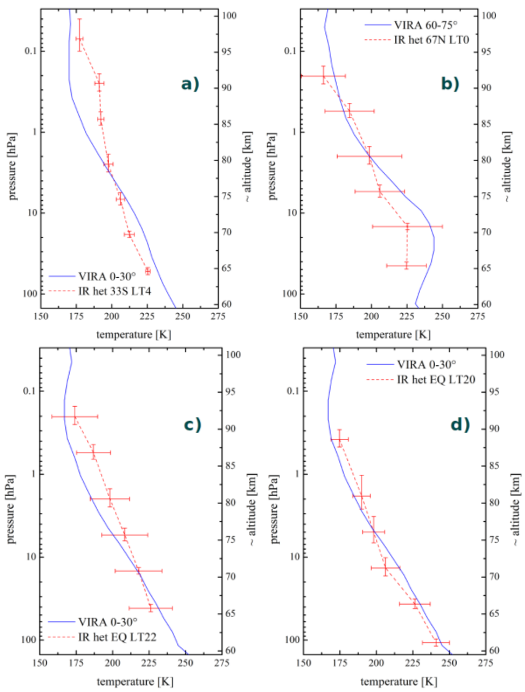

Figure 2: Red: Retrieved pT-profiel from IR heterodyne observations at a) 33°S LT 4, b) 67°N LT 0, c) 0°N LT 22 and d) 0°N LT 20. Blue: VIRA profiles for corresponding latitudes for comparison

For Venus observations of pressure broadened CO_2 absorption lines have proven to be a good tracer for analyzing the predominant temperature on the night side by comparison to other observations.

4. Extension of the Procedure to Mars

The opportunity to retrieve vertical temperature profiles from Martian atmosphere is still under investigation. We will present preliminary results from these studies. In the case of Mars, due to orbital constellation, ground-based observations are typically constrained to day-side measurements. A solar induced narrow non-LTE emission feature, originating from the 1 µbar pressure layer, is superimposed to the absorption, preventing a sophisticated analysis of the absorption line core. Since the absorption feature is strong, it seems that the non-LTE feature does not have the relevance it has on Venus spectra. The altitude level that can be addressed on Mars is from the surface (~6hPa) up to ~50km (~0.05hPa).

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