EPSC Abstracts
Vol. 6, EPSC-DPS2011-1807, 2011
EPSC-DPS Joint Meeting 2011

Ground-Based Doppler-Wind and Temperature Measurements by Infrared Heterodyne Spectroscopy

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Abstract

There are only few options to measure wind velocities in the venusian atmosphere directly without any additional assumption or model predictions. One elegant method to investigate high atmospheric winds from Earth is by observing infrared CO_2 emission lines at 10 μm with high spectral resolution heterodyne spectroscopy. From Doppler shifted lines velocities of the emitting/absorbing gas can be directly deduced and kinetic temperatures can be derived from the line width. With the Tuneable Heterodyne Infrared Spectrometer THIS based at the University of Cologne we measured winds and temperatures from 2007 up to 2011. We will present the results hopefully including newest values from an observing run in June 2011 and give a comparisons to other ground and space based measurements.

1. Introduction

Dynamics of the Venusian atmospheric transition zone between the sub-solar to anti-solar (SS-AS) flow dominated region above 120 km and the superrotation dominated region below 90 km is not yet fully understood and temperatures in the same region are not very well constrained neither. In particular recently ground-based observation e.g.[1, 2, 3, 4] along with VEX measurements [5, 6, 7] have shown that Venus has a much more complex dynamical and thermal structure than formerly believed. Atmospheric conditions vary strongly with the location on the planet, altitude in the atmosphere and also with time on different scales.

Additional measurements are essential to gain a global understanding of the atmosphere and to validate global circulation models. Hence measurements on various time scales and on different locations with sufficient spatial resolution on the planet are important.

2. Method & Instrument

One piece of the puzzle can be provided by high spectral resolved detection of so called non-LTE CO_2 emission lines [8, 9]. A typical spectrum is given in the figure 1 below. The lower panel shows a typical example of a measured non-LTE CO_2 emission line from Venus upper atmosphere at 10 μm (black) including a Gaussian fit (dashed line). The inlet displays the fitted line position (vertical dashed line) relative to the zero wind case (vertical dotted line). The upper panel shows the reference gas absorption line from a cell implemented into the instrument for absolute frequency calibration.

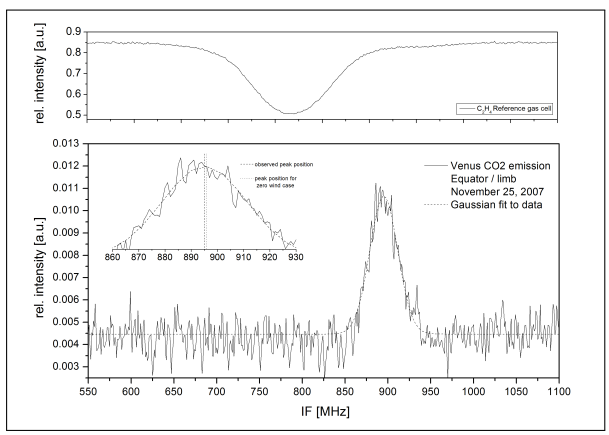

Figure 1: Typical spectrum of a non-LTE CO_2 emission line from Venus upper atmosphere.

Non-LTE lines are induced in the upper atmosphere (110±10 km) by solar radiation. The precise determination of the frequency position provides directly the line-of-sight wind velocity and the line width corresponds to the kinetic temperature according to the Doppler equation. To evaluate the line width and position it is necessary to resolve single line features.
In the infrared this can only be provided by the heterodyne technique where an infrared laser is superim-

posed to the infrared signal from the sky. Such an instrument is developed and run by the I.Physikalisches Institut at the University of Cologne.

It is based in Cologne but can be shipped to any telescope in the world. The Venus measurements are accomplished at the McMath-Pierce-Solar Telescope on Kitt Peak in Arizona, USA. Compared to observations at longer wavelength (sub-millimeter and millimeter) infrared observations can provide a good spatial resolution. Hence the 1.6 m mirror of the McMath-Pierce-Solar Telescope is sufficient to resolve the planet and measurements at various locations on Venus are possible.

3. Observations & Objectives

Starting in 2007 we have already accomplished 5 observing runs and there will be an additional run at the end of June 2011 (see table 1). Observing dates were chosen in a way to gain maximum information from the line-of-sight velocities by taking advantage of the different observing geometries. The telescope provides a field-of-view of 1.7″ relative to an apparent diameter of Venus of 20″ at greatest elongation, 60″ at inferior conjunction and 10″ at superior conjunction. Observations at greatest elongations provide good information about the superrotation. We found only a small contribution of the superrotational component in the targeted altitude of $\sim$110 km (< 45 m/s). Observing close to inferior conjunction allowed to focus on the SS-AS flow component. Wind velocities close to the terminator around 140 m/s were found decreasing significantly at high latitudes. We did not see a significant superrotational component contribution and the variability between these two runs was moderate.

Table 1: Overview of gathered data

#	date	config	size	T	wind
1	2007 May	gr.E-elong.	20	-	x
2	2007 Nov.	gr.W-elong.	20	-	x
3	2009 March	inf.conj.	60	x	x
4	2009 April	inf.conj.	60	x	x
5	2009 June	gr.W-elong.	24	x	x
6	2011 June	sup.conj.	10	x	x

Looking at Venus at superior conjunctions allows us to target the entire illuminated planetary disk. Meridional winds and coordination with sub-millimeter observation will be the main focus.

At the conference we are going to present analyzed data from these runs including a brief comparison to our previous results and other ground-based observations.

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