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Doppler-Wind and Temperature Measurements in Venus' Upper Atmosphere by Ground-Based Infrared Heterodyne Spectroscopy

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Abstract

The dynamical structure and the behavior of temperatures in the Venusian upper atmosphere is not yet fully understood. Especially short and long term variations indicate that waves are present which might have a significant influence on the global structure. Ground-based observations to investigate this variabilities are carried out with the Infrared heterodyne spectrometers THIS and HIPWAC over the last few years and results will be presented. Temperatures and winds in planetary atmospheres can be retrieved from detection of fully resolved non-LTE emission lines of CO_2 at 10μm with a precision down to 5 K and 10 m/s. These emission lines are induced by solar radiation and can only occur within a narrow pressure/altitude region around 110 km (Lopez-Valverde et al., 2011).

1. Instrument and Method

Measurements of winds and temperatures on various time scales and on different locations on the planet are essential for validation of global circulation models and a comprehensive understanding of the atmosphere. One piece of the puzzle can be provided by detection and analysis of non-LTE CO_2 emission lines Sornig et al. (2013). Fig.1 shows a typical example of a measured non-LTE CO_2 emission line from Venus upper atmosphere at 10 μm (black).

Non-LTE lines are induced by solar radiation in the upper atmosphere around 110$\pm$10 km. The precise determination of the frequency position provides directly the line-of-sight wind velocity and the line width corresponds to the kinetic temperature according to the Doppler equation. To retrieve line width and position it is necessary to resolve this very narrow emission lines (40 MHz) and instrument with an extremely high spectral resolving power in the range of R=$\lambda/\Delta\lambda = 10^7$ is needed.

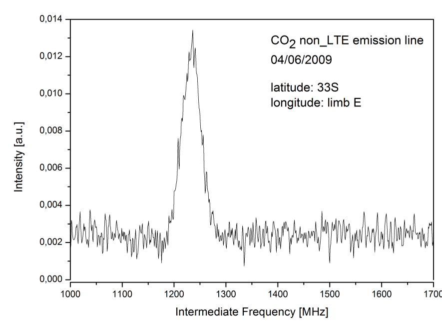

Figure 1: Typical spectrum of a non-LTE CO_2 emission line from Venus upper atmosphere.

In the infrared wavelength region this can only be provided by the heterodyne technique where an infrared laser is superimposed to the infrared signal from the sky. For now there are only two operating heterodyne IR instruments for planetary application worldwide. The receiver THIS (Tuneable Heterodyne Infrared Spectrometer) is developed and run by the University of Cologne. The second instrument HIPWAC (Heterodyne Instrument for Planetary Wind And Composition) is based at NASA GSCF in Goddard. The receivers have been installed at the McMath-Pierce-Solar Telescope on Kitt Peak in Arizona, USA and at the IRTF on Mauna Kea, USA.

2. Ground-based Observations of Wind and Temperatures

Several observing runs between 2007 and 2013 were dedicated to collect day-side temperatures and wind information from the Venusian upper atmosphere. An overview is given in Tab.1. Dates are chosen to cover different observing geometries. These runs were dedicated to investigate the spatial and short and long term temporal variability.

Table 1: Overview of gathered data

date	illu.[%]	size["]	instr.	data[1]
2007 May	54	20	This	w
2007 Oct.	50	20	HIPWAC	T
2007 Nov.	64	20	This	w
2009 March	5	60	This	w,T
2009 April	3	60	This	w,T
2009 June	50	24	This	w,T
2011 June	96	10	This	w,T
2012 March	50	23	This	w,T
2012 May	10	51	HIPWAC	w,T
2013 March	100	10	This	w,T

[1] w: wind data received, T: temperature data received

3. Results and Conclusions

From first observations we conclude a dominance of the SS-AS flow in the order of 140m/s (Sornig et al., 2013). Besides that global structure we do see additional wind components including short term temporal variations which needed further investigations.

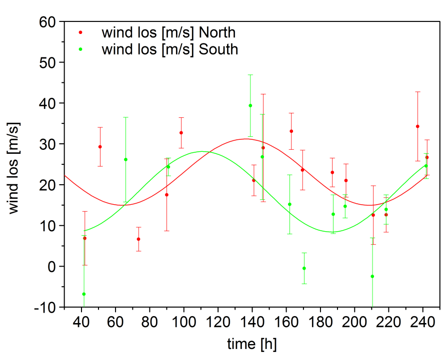

Figure 2: Line of sight wind velocities on Venus observed close to noon and the equator. One beam position was entirely on the northern hemisphere (red) and one on the southern hemisphere (green).

To avoid averaging over antisymmetric wind features between the northern and southern hemisphere within our beam we took observations close to the equator with the full beam on one of the hemispheres only. First results reveal a similar period of 6 and 6.2 days for the northern and southern beam respectively by fitting a simple sin function. Amplitudes are 8 m/s for the northern position and 10 m/s for the one on the southern hemisphere. See Fig. 2.

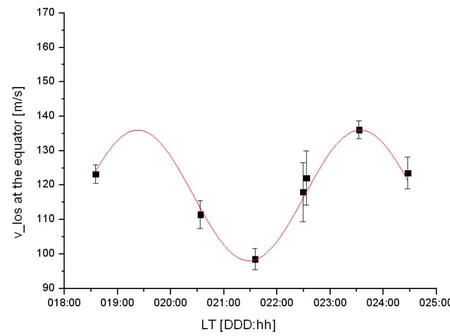

Figure 3: Typical spectrum of a non-LTE CO_2 emission line from Venus upper atmosphere.

These observations addressed a position close to the sub solar point and the amplitude was much lower compared to earlier observation at the the terminator in 2009 (Sornig et al., 2013). Looking once more on the terminator again higher amplitudes of 25 m/s and a period of 4 days were found (see Fig. 3).

Results are preliminary and data analysis is still ongoing. Temperature retrievals and the comparisons to wind variations is still work in progress. Detailed analysis of all observations and interpretations will be accomplished and results including conclusions will be presented at the conference.

References

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