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Characterization of Venus' cloud top dynamics using ground-based Doppler velocimetry

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Abstract

The most relevant aspect of the general circulation of the atmosphere of Venus is its retrograde superrotation. A full characterization of the zonal winds is crucial to understand this motion and the mechanisms that create and maintain it.
Here we present results of Doppler velocimetry of Venus made with the UVES (Ultraviolet and Visual Echelle Spectrograph) instrument at ESO's Very Large Telescope, based on high-resolution spectra of visible solar Fraunhofer lines. This method allowed us to simultaneously characterize spatial and temporal variations of the zonal wind in the dayside. The winds retrieved in each observation show an average magnitude consistent with other space and ground-base observations, but with a significant variability in local time (longitude) and in latitude.

1. Introduction

The UVES instrument achieves both high spectral resolving power and high spatial resolution. The observations were made at a central wavelength of 580 nm. The narrow slit width combined with the large angular size of the planet allows a direct determination of latitudinal (slit perpendicular to equator) or longitudinal (slit parallel to equator) dependence of the zonal winds in both the northern and southern hemispheres.
Cloud-top winds were measured from Doppler velocimetry, a technique which has been used previously to measure Titan´s winds from the Doppler shifts of the solar backscattered spectrum [4, 5], and Venus' winds from the Doppler shifts of CO_2 absorption lines [10,11]. The spatially-resolved velocity changes on the source are measured using the optimal weight of intensity variations along the spectra to perform absolute accelerometry, with respect to a reference spectrum [1, 2, 5].
The objective of this work is to help constrain the atmospheric dynamics of Venus, in particular as regards the study of atmospheric super-rotation, and to complement the effort under way with the European Space Agency's Venus Express mission (VEx). Major objectives are (1) to measure the latitudinal profile of the zonal winds in the cloud layer, mesosphere and in the thermosphere and to search for wave motions through ground-based spectroscopic observations; (2) to complement in-situ observations made by space missions (which use cloud tracking techniques or infer winds indirectly); (3) to improve our understanding of the nature of the processes governing super-rotation in the atmosphere of Venus, in particular waves and wave-mean flow interactions, as well as the latitudinal extent of the cyclostrophic balance approximation at cloud top level.

2. Measurements of zonal winds

Orienting the spectrograph's slit parallel to the equator enabled to derive absolute magnitudes of the zonal winds and to measure wind variations with local time. In addition, with the spectrographic slit parallel to the rotation axis allowed estimating the latitudinal gradient. Observations made at different offset positions combined with the high spatial resolution allowed to build a first approximation of a instantaneous zonal wind map, obtained with unprecedented spatial accuracy (of the order of 105 km/pixel near disk center).
We will discuss the results and their intercomparison with previous spacecraft observations, in particular with Venus Express observations by the VIRTIS and VMC instruments [6, 7, 9], and with other ground-based techniques [2, 10, 11].

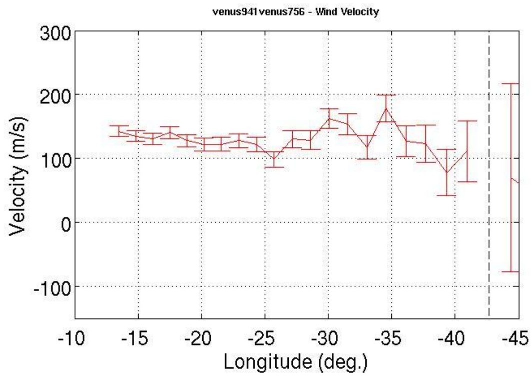

Figure 1: Zonal wind component versus longitude, obtained with the spectrograph's slit parallel to the equator (23° South).

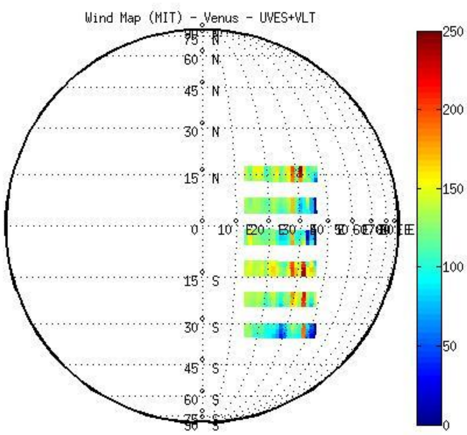

Figure 2: Map of the zonal wind obtained by Doppler velocimetry with the VLT/UVES instrument on June 4, 2007 (R~100 000). Observations were made at a central wavelength of 580 nm with the UVES red arm and at 437 and 860 nm in dichroic mode. Set of six offsets (latitudes: -33.5°, -23°, -13°, -2°, 8°, 18°, 30.5°).

2. Summary and conclusions

The Doppler velocimetry technique (absolute accelerometry) used allowed a data reduction with an accuracy in the obtained wind velocities on the order of a few tens of m/s.

The zonal wind magnitudes obtained are in general consistent with the ones obtained by Galileo SSI, VMC, VIRTIS [3, 8]. In the case of the slit perpendicular to the axis of rotation is possible to determine the absolute value of the zonal wind for the latitudes surveyed. Measurements near the limb show a latitudinal asymmetry in wind velocity and are suggestive of daily variability (~ 10-20 m/s).

Acknowledgements

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