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Characterization of Venus' atmospheric dynamics with ground-based Doppler velocimetry

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We present an analysis of observations of Venus made with the Ultraviolet and Visual Echelle Spectrograph (UVES) instrument at ESO's Very Large Telescope. This instrument allows to perform Doppler velocimetry based on high-resolution spectra of solar Fraunhofer lines, probing an altitude close to cloud tops, where opacity in the visible reaches unity. Observations were made at a central wavelength of 580 nm.

The UVES instrument achieves both high spectral resolving power (R ˜ 100000) and high spatial resolution. The narrow slit width combined with the large angular size of the planet allows a direct determination of the latitudinal (slit perpendicular to equator) and longitudinal (slit parallel to equator) variation of the zonal winds in both hemispheres.

The circulation up to the cloud tops is characterized by a monotonically increasing zonal wind, reaching its maximum close to 70 km altitude. Cloud-top winds were measured from Doppler velocimetry, a technique which has been used previously to measure the winds of Titan from the Doppler shifts of the solar reflected spectrum (Luz et al. 2005, Icarus 179, 497; Luz et al., 2006, JGR 111, E08S90), and in Venus from Doppler shifts of solar Fraunhofer and CO_2 absorption lines (Widemann et al. 2007, PSS 55, 1741; 2008, PSS 56, 1320; Gaulme et al. 2008, PSS 56, 1335; Gabsi et al., 2008, PSS 56, 1454). 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.

The objective of this work is to measure zonal winds on Venus, in the context of the study of atmospheric super-rotation, in coordination with 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, using Doppler velocimetry techniques; (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 particular waves and wave-mean flow interactions, as well as the latitudinal extent of the cyclostrophic balance approximation at cloud top level.

The narrow slit width combined with the large angular size of the planet allows to characterize latitudinal and longitudinal variations of the wind. Relative Doppler shifts allow to retrieve relative variations in the latitudinal profile of the zonal wind and combined results of three nights of observation were used to deduce the variability of the circulation.

This technique allowed to create an approximate wind map in the case of observations obtained with the spectroscopic slit parallel to the equator and to estimate the hemispheric asymmetry of the zonal wind. We shall discuss these results in the light of previous spacecraft observations, in particular Venus Express observations by the VIRTIS and VMC instruments (Sanchez-Lavega et al. 2008, GRL 35, L13204; Moissl et al., 2009, JGR 114, E0031).

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