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Venus' cloud top wind study: new Doppler velocimetry measurements

Ruben Gonçalves[1], Pedro Machado[1], and Thomas Widemann[2]
[1]Instituto de Astrofísica e Ciências do Espaço, IA-FCUL, Lisboa, Portugal (rgoncalves@oal.ul.pt)
[2]LESIA - Laboratoire d'Études Spatiales et d'Instrumentation en Astrophysique, Observatoire de Paris, CNRS, UPMC, Meudon, France

We present new measurements of zonal and meridional wind velocities at Venus cloud-tops (~70 km) based the Doppler velocimetry method.

Venus is usually referred to as Earth's twin due to its similarities, namely the mass, radius, density and bulk chemical composition. However, a retrograde and slow rotation of the planet (a day is longer than a year), a dense atmosphere with high concentration of CO2 and a dynamic circulation of high speed winds in a superrotational state are some of the characteristics make Venus a unique and very distinctive planet. The measure of both wind circulations at cloud top is essential to our understanding of the Venus' atmospheric circulation and to constrain the dynamics that maintain the superrotational state. The study of Venus' atmosphere can be a fundamental key in our understanding of atmospheric dynamics and evolution of any the so-called Earth-like planet, including Earth itself.

The observations were carried out between 25 and 29 March 2015, at the Echelle SpectroPolarimetric Device for the Observation of Stars (ESPaDOnS) at Canada-France-Hawaii Telescope (CFHT), in Mauna Kea, Hawaii. The spectrograph provides spectra from 370 to 1050 nm, with a resolution of up to 81000.

The Doppler velocimetry method used in this work was initially developed by Widemann et al. (2008) and further improved and fine-tuned by Machado et al. (2012, 2014). The technique has proven to be a reference on the retrieval of zonal and meridional wind at Venus' cloud top, with both long slit and fibre fed spectrographs, as shown in Machado et al. (2012) (UVES/VLT), Machado et al. (2014, 2017) (ESPaDOnS/CFHT) and Gonçalves et al. (2020) (HARPS-N/TNG). A detailed description of the method can be found in Machado et al. (2014, 2017).

The method uses visible Fraunhofer lines scattered by Venus' cloud tops. The Doppler shift measured in solar light scattered on Venus dayside is the result of two instantaneous motions: (1) a motion between the Sun and Venus upper clouds particles, which scatter incoming radiation in all directions including the observer's (this Doppler velocity is minimal near Venus sub-solar point); (2) a motion between the observer and Venus clouds, resulting from the topocentric velocity of Venus cloud particles in the observer's frame (this effect is minimal near Venus sub-terrestrial point). The measured Doppler shift is the combined effect of these instantaneous motions.

At half-phase angle (HPA), these two effects cancel out for the zonal component of the wind field, as the relative velocities of particles toward the source of incoming radiation and towards the observer cancel each other out. Along all points lying along this meridian we assume that the retrieved Doppler velocities cannot be attributed to a zonal component, thus, a non-zonal wind regime, such as meridional wind flow, should explain the Doppler shifts observed along the HPA meridian. The high precision of this method in the retrieval of meridional wind as shown to be of the same order of meridional winds from space observations (Gonçalves et al., 2020).

These new results provide new insights on (1) daily and spatial variability of zonal wind, (2) meridional wind profile and variability constrain, (3) long term analysis of zonal wind, (4) consistency of Doppler velocimetry method.

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