EPSC Abstracts
Vol. 13, EPSC-DPS2019-145-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Venus' cloud top wind study: coordinated Akatsuki/UVI with cloud tracking and TNG/HARPS-N with Doppler velocimetry observations

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Abstract

We present new wind velocities and its variability at Venus cloud-tops (~70 km) based on coordinated observations with two complementary techniques: (1) space-based cloud-tracking using JAXA's Akatsuki/UVI imaging and (2) ground-based Doppler velocimetry using TNG/HARPS-N. This work is based on the first observations of a Solar system planetary atmosphere using HARPS-N. Venus atmospheric circulation is characterized by a global zonal superrotation that peaks at cloud level where cloud features spin nearly 60 times faster than the planet's surface. The measure of both zonal and meridional wind velocities at cloud top is essential to our understanding of the dynamics of Venus' superrotational circulation. Constraining temporal and spatial wind variability at cloud-top will help to determine the mechanisms which yield and maintain the superrotation state. From space, clouds features were tracked on images obtained by the Akatsuki instrument (UVI) operating in the ultraviolet range (365 nm filter), acquired in orbit #39, between 26 and 31 of January 2017. Ultraviolet images show the highest contrast features and the UV tracers are roughly located at about 65-70 km above the surface [1]. From the ground, data acquired on 28-29 January 2017 using TNG/HARPS-N, Doppler velocimetry measurements are based on high-resolution spectra (resolution of ~115,000) of Fraunhofer lines in the visible range (383-690 nm) using incoming solar radiation scattered by cloud top particles in the observer's direction ([9], [10], [5], [6]). The analysis and results of this new coordinated dataset indicate (1) cross-validation and complementarity of cloud-tracking and Doppler velocimetry measurements; (2) a significant North-South asymmetry of zonal wind circulation, of the order of +10 m/s higher in the South hemisphere in Akatsuki/UVI observations, in accordance with previous detection by Horinouchi et al. [2]; (3) a poleward meridional flow, symmetrical with respect to equator, is clearly measured in both hemispheres; its peaks around 40º N and S with an amplitude of vm = 30±5 m/s. This cloud-top meridional flow is retrieved with unprecedented precision using HARPS-N; (4) spatial and temporal variability of Akatsuki's zonal and meridional wind flow is also observed, with a significant increase of wind flow near evening terminator, which could be explained by the presence of thermal tide already discussed by [8], [3], [6], [2].

1. Introduction

Venus is the nearest planet to Earth and the most similar in mass, radius, density and bulk chemical composition. Yet, Venus has a massive carbon dioxide atmosphere with clouds of sulphuric acid and a hot (~740 K) and dry surface, with a surface pressure of ~90 bar. Understanding the similarities and differences between Earth and Venus motivated an intense exploration of this planet. The cloud tops are located at altitudes of 67-71 km at the equator with a nearly constant altitude until 45-50 and a drop of altitude poleward of 50, reaching about 61-63 km over both poles [4]. At UltraViolet (UV) wavelenghts dark features appear, which are originated by an yet unknown absorber [1]. The wind flow on Venus within the cloud and haze layers is dominated by a zonal wind in the retrograde sense (East to West), that peaks at the top of the upper clouds with zonal speeds higher than 100 m/s ([8], [5], [3], [6], [2]). The retrograde zonal superotation (RZS) is accompanied by a poleward meridional circulation which transports angular momentum from the equator to the poles. After the decommission of ESA's Venus Express (January 2015) the new era of Venus' space observations started with the successful orbit insertion of JAXA's Venus Climate Orbiter (VCO) Akatsuki mission, in December 2015 [7]. On Akatsuki, atmospheric circulation at 70 km is being monitored from cloud tracking by the UltraViolet Imager (UVI) - a camera operating in the ultra violet range (two filters centered at 283 nm and 365 nm) [11]. We present new zonal and merdional Venus' cloud top wind results from January 2017 observations based on (i) Doppler velocimetry technique with the HARPS-N at TNG, and (ii) simultaneous cloud-tracking observations with Akatsuki's instrument UVI.

2. Figures

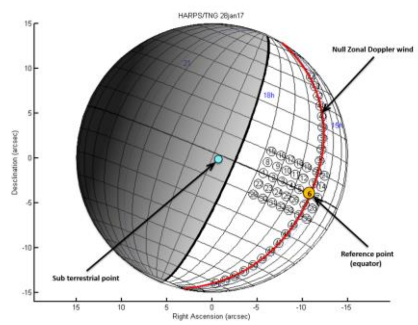

Figure 1: Aspect, angular size of Venus and pointing geometry as seen from Earth on 28 of January. RA and DEC axis are in arcsec in relation to the center of Venus. Celestial North is up. Dayside hemisphere on Venus is on the right. Solid black circles represent HARPS-N FOV as seen in Venus disk, in each position observed. Red solid line is along the half-phase angle (HPA) meridian.

Acknowledgements

We acknowledge support from the Portuguese Fundação para a Ciência e a Tecnologia (ref. PD/BD/128019/2016 and ref. UID/FIS/04434/2013) through national funds and by FEDER through COMPETE2020 (ref. POCI-01-0145-FEDER-007672). We thank the JAXA's Akatsuki team for support with coordinated observations. We gratefully acknowledge the collaboration of the TNG staff at La Palma (Canary Islands, Spain) - the TNG is operated on the island of La Palma by the Fundación Galileo Galilei of the INAF (Istituto Nazionale di Astrofisica) at the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofisica de Canarias.

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