EPSC Abstracts
Vol. 11, EPSC2017-562, 2017
European Planetary Science Congress 2017
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Wind measurements in Saturn's atmosphere with UVES/VLT ground-based Doppler velocimetry

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Abstract

We will present final Doppler wind velocity results of Saturn's zonal flow at cloud level. Our aim is to study the planet's global system of winds at the 70 mbar region, to help constraining the characterization of the equatorial jet and the latitudinal variation of the zonal winds, to measure its spatial and temporal variability and to contribute to monitor the variability in order to achieve a better understanding of the dynamics of Saturn's zonal winds, which Sánchez-Lavega et al. (2003, Nature, 423, 623) have found to have changed strongly in recent years. They have reported a decrease of 200 m/s of the speed of Saturn's equatorial zonal jet from 1996 (450 m/s) to 2002 (250 m/s), as the planet approached southern summer solstice. Finally, the complementarity with Cassini, whose "grand finale" is planned for September this year, will provide an independent set of observations to compare with and help validate the method.

1. Introduction

The UVES/VLT instrument has been used, which simultaneously achieves high spectral resolving power and high spatial resolution. The field has been derrotated in order to have the aperture aligned perpendicularly to Saturn's rotation axis. In this configuration, spatial information in the East-West direction is preserved in a set of spectra in the direction perpendicular to the dispersion.

1.1 Theoretical basis

The technique of Absolute Accelerometry (AA, Connes, 1985, ApSS 110, 211) has been applied to the backscattered solar spectrum in order to determine the Doppler shift associated with the zonal circulation. Our measurements have been made in the wavelength range of 480-680 nm. Previously we successfully adapted this Doppler velocimetry technique for measuring winds at Venus cloud tops (Machado et al. 2012, 2014, 2017). In the present study we will show the adaptation of the method for Saturn's case. Since the AA technique only allows to compare spectra where the line shifts are within the line width, in fast rotating atmospheres (such as Saturn) the spectra must be compared by pairs from adjacent areas of the disk (adjacent pixels in the slit). We will use coordinated observations from the Cassini's Visible and Infrared Mapping Spectrometer (VIMS), in order to compare with the Doppler winds obtained from the UVES/VLT high-resolution spectra.

2. Observation settings

The observations consisted of 4 blocks of 15 exposures of 90 seconds, plus two shorter blocks of 9 exposures, totaling 7.3 hours of telescope time. In order to cover the whole disk, the aperture has been offset by 1 arcsec in the North-South direction between consecutive exposures. Unfortunately, most of the northern hemisphere was covered by the rings. Saturn's diameter was 17.4 arcsec and the slit aperture was 0.3 x 25 arcsec. The two shorter observation blocks of 9 exposures only covered the central part of the disk. The sub-terrestrial point was at -26.1°S. The presence of the rings led to severe order superposition. The dark region between the rings and the disk may not be present, depending on the slit position. On the other hand, defects in the response of the UVES slit in the upper part preclude its use for accurate Doppler measurements such as these. For these reasons only the central part of the aperture has been considered for the measurements.

3. Summary and Conclusions

The Doppler velocimetry is currently the only ground-based technique able to derive instantaneous wind's velocities, allowing cross-comparison with cloud-tracked winds from Cassini VIMS images, and the study of short-term variability.

This is still an ongoing work, on the next steps we will obtain the zonal wind as a function of local time for all slit's offset positions, except for the cases with ring overlapping. For that we will estimate the ring system keplerian velocity at each pixel position, and then, superpose the planet + rings spectra and adjust the most spectral lines possible (the residual components will be due to methane contribution).

We will separate the spectra contribution from methane (and also ammonia) and study the altitude from its contribution. Detection of finer latitudinal variations in zonal winds in the future will require precise modeling (radiative transfer model) of the probed level and an improved treatment of methane lines (and NH_3 as well) and order superposition effects. However, our Doppler velocimetry technique stands out as a promising ground-based method for wind monitoring in the giant planets.

Acknowledgements

This work was supported by FCT (ref. UID/FIS/04434/2013) through national funds and by FEDER through COMPETE2020 (ref. POCI-01-0145-FEDER-007672).

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