EPSC Abstracts
Vol. 6, EPSC-DPS2011-912, 2011
EPSC-DPS Joint Meeting 2011

Observation of Saturn and the Enceladus water torus at 557GHz with Odin

N. Biver (1), E. Lellouch (1), Aa. Sanqvist (2), U. Frisk (3), A. Lecacheux (1), D. Bockelée-Morvan (1), T. Cavalié (4), J. Crovisier (1), H.G. Florén (2), P. Hartogh (5), Å. Hjalmarson (6), C. Jarchow(5), T. Karlsson (3), S. Lundin (3), R. Moreno (1), H.L. Nordh (7) and the Odin team
(1) LESIA, Obs. de Paris, France, (nicolas.biver@obspm.fr / Fax: +33 1 45077809) (2) Stockholm Observatory, Sweden, (3) Swedish Space Corporation, Solna, Sweden, (4) Laboratoire d'Astrophysique de Bordeaux, France, (5) MPI for Solar System Research, Katlenburg-Lindau, Germany, (6) Onsala Space Observatory, Sweden, (7) Swedish National Space Board, Solna, Sweden

Abstract

The stratospheric water 557 GHz line was first observed in 1999 by the SWAS satellite which revealed a broad (20 km s^{-1}) emission line. But in 2009, the Herschel Space Observatory revealed an additional $\approx$ 20% deep and narrow (6 km s^{-1}) absorption line in the core [4]. Subsequent analysis implies that this absorption line is caused by the cold water vapor contained in a torus located at the Enceladus orbit position. It is thought to be populated by the water escaping Enceladus through the plumes put into evidence by the Cassini spacecraft. The tilt of Saturn equator relative to the Earth was unfavorable in 1999 to see it in absorption against Saturn disk but the geometry in 2011 was expected to enable such detection with the Odin satellite [5]. The Odin submm observatory astronomy program was specially reactivated to monitor the water line of Saturn between 21 and 24 January 2011 to cover two complete orbits of Enceladus around Saturn.

1. Observations

The basic observing scheme was Dicke Switching [3]. Most of the background emission is cancelled by switching every 3 s from the source to a reference about 42°away, through a wide beam. In addition 6 orbits of observation of a reference position 15' off Saturn were also used to remove additional emission from losses in the main beam. The 556.9 GHz H_2O ($1_{10} - 1_{01}$) line was observed in Saturn from 21.80 till 24.38 January 2011 using two receivers and three spectrometers (Sub-Earth Saturnocentric latitude $\beta = +10.3°$). The 555-B2 receiver was connected to the 1-GHz bandwidth AOS (0.6 MHz sampling and 1 MHz resolution) and 112-MHz bandwidth high resolution autocorrelator 2 (AC2, 0.15 MHz resolution) and the 549-A1 receiver was connected to the AC1 (0.17 MHz resolution). This setup and observing strategy is similar to that used with Odin since 2003 on Mars and Jupiter observations [1, 2].

2. Data reduction

Each spectrum has been reduced according to [6], with system temperatures (3180 K for 555-B2 and 2970 K for 549-A1, SSB) and every channel gain correction. Frequency scale was checked on the atmospheric line. Estimated resulting uncertainty in the velocity frame is 0.01 km s^{-1}.

2.1 Spectra reduction and averaging

Spectra were then averaged with the ≈ 45 min of best pointing accuracy data selected for each orbit. Reference position observations were also averaged, smoothed (replaced by sines + polynomial fit for ACs data) and subtracted to the on Saturn data.

2.2 Spectra analysis

Due to low signal-to-noise ratio spectra from different Odin orbits corresponding to similar positions of Enceladus on its orbit were averaged. These were averaged first in twelve $\approx$30° spans of Enceladus sub-Earth longitude and then further into only 4 groups (spanning $\approx$90° of Enceladus longitude) (Fig. 3). A $\approx$200 MHz "classical" ripple has been subtracted to AOS data. The total and quadrant averages of AOS spectra are shown in Figs 1 and 2.

3. Data analysis

Odin has a system temperature much higher than Herschel ($T_{sys}(DSB) = 84$K) and a larger beam dilution, resulting in lower S/N ratio. But on the other hand the much longer allocated observation permits the monitoring of both the emission and absorption parts of the water line as Enceladus and its torus rotate around Saturn. The main goal was to see if variation in the absorption line could be seen with Enceladus orbital longitude and to derive information on the diffusion of water vapor in the torus away from its source.

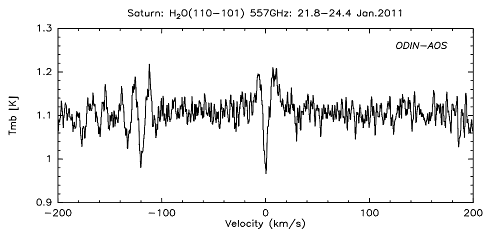

Figure 1: AOS spectrum: average of all data. The features around -130 km s^{-1} are due to an interference not completely removed and always present in these AOS spectra

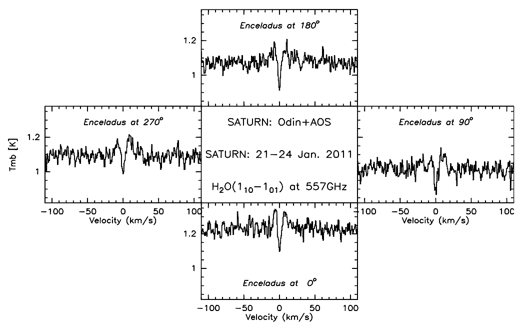

Figure 2: AOS spectra 4 “quadrants”

4. Results

Figs 1 and 2 show the line as observed with Odin low and high resolution spectrometers. On average the emission line is 17 ± 2 km s^{-1} wide and peaks at 12 ± 2 % of the continuum. The absorption feature has a 6.1 ± 0.3 km s^{-1} width and peaks 11 ± 2% below the continuum, in agreement with what was observed with Herschel-HIFI in June 2009 and 2010 at

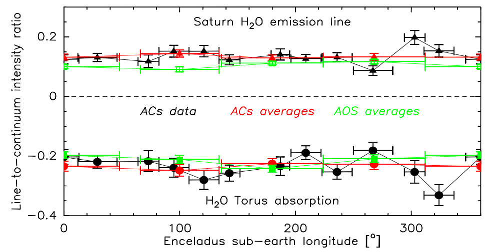

Figure 3: Plot of the evolution of the Saturn H_2O line characteristics (peak intensity of the emission and absorption components, based on fixed line widths and Gaussian fits), as a function of Enceladus position.

$\beta = -3^\circ$ and $+2^\circ$ respectively [4]. As shown in Fig.3, within the uncertainties and random fluctuations of the signal, there is no clear variation of the absorption along the orbit of Enceladus and its torus. If the diffusion time scale in the torus of the water vapor produced by Enceladus plumes was much longer than its destruction, we would expect a stronger absorption closer to Enceladus position (0°) than at the opposite position (180°). Within the ≈20% uncertainty, nothing is clearly seen.

Acknowledgements

Odin is a Swedish-led satellite project funded jointly by the Swedish National Space Board (SNSB), the Canadian Space Agency (CSA), the National Technology Agency of Finland (Tekes) and the Centre National d’Études Spatiales (CNES, France). The Swedish Space Corporation is the prime contractor, also responsible for Odin operations.

References

[1] Biver, N., Lecacheux, A., Encrenaz, T., et al. 2005, Astronomy and Astrophysics, 435, 765–772

[2] Cavalié, T., Biver, N., Hartogh, P., et al. 2011, Planetary and Space Science *in press*

[3] Frisk, U., Hagström, M., Ala-Laurinaho, J., et al. 2003, Astronomy and Astrophysics, 402, L27–L34

[4] Hartogh, P., Lellouch, E., Moreno, R., et al. 2011, Astronomy and Astrophysics, *submitted*

[5] Nordh, H.L., von Schéele, F., Frisk, U., et al. 2003, Astronomy and Astrophysics, 402, L21–L25

[6] Olberg, M., Frisk, U., Lecacheux, A., et al. 2003, Astronomy and Astrophysics, 402, L27–L34