# Radio Spectroscopy Study of the Water Masers in the Saturnian System

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Letter to the Editor

# Water masers in the Saturnian system

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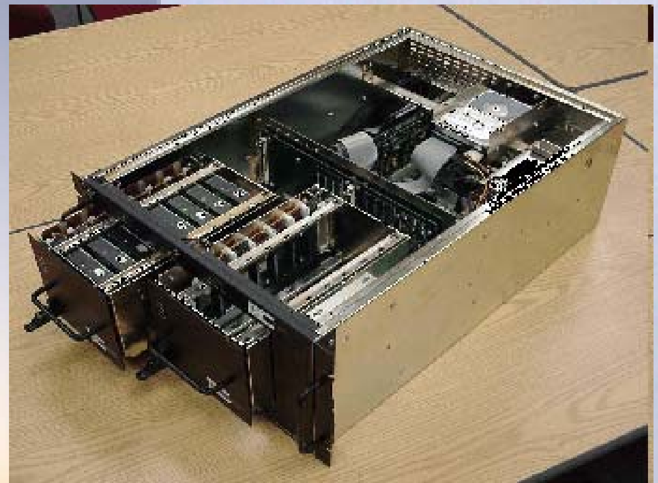
# Saturnian system

Saturn is the sixth planet from the Sun and the second largest planet in the Solar System, after Jupiter.

Saturn has a prominent system of rings, consisting mostly of ice particles with a smaller amount of rocky debris and dust.

Sixty-one known moons orbit the planet, not counting hundreds of "moonlets" within the rings.

# Observations and data processing

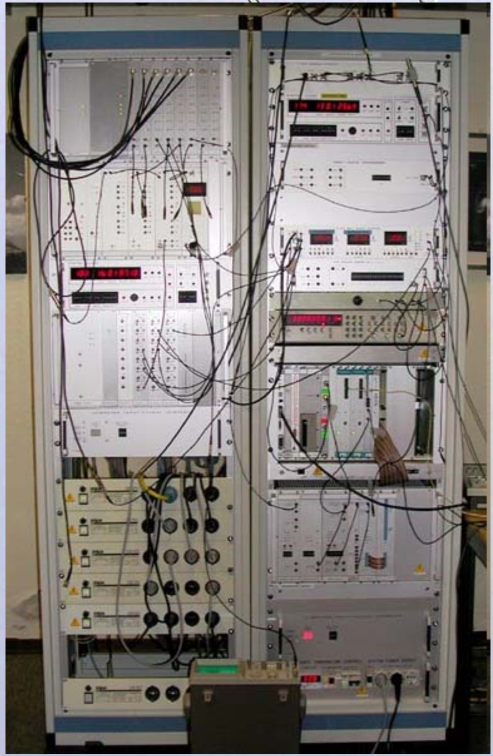


We conducted trial observations of the Saturnian system at 22 GHz with the Medicina 32-m radio telescope with a nominal gain of 0.1 K/Jy (INAF-IRA, Italy) in April and May 2006, using a Mk5 disk-based VLBI recording system and software correlator-spectrometer developed for the Huygens Probe VLBI tracking experiment (Lebreton et al. 2005). The data were acquired for two circular polarizations, each of 8 MHz bandwidth, centred on the 22 235.08 MHz water line shifted in accord with the predicted radial velocity of Saturn (calculated by the NASA JPL Horizons software, Giorgini et al. 1996).

# Observations and data processing


Metsähovi Radio Observatory
Helsinki University of Technology, Finland

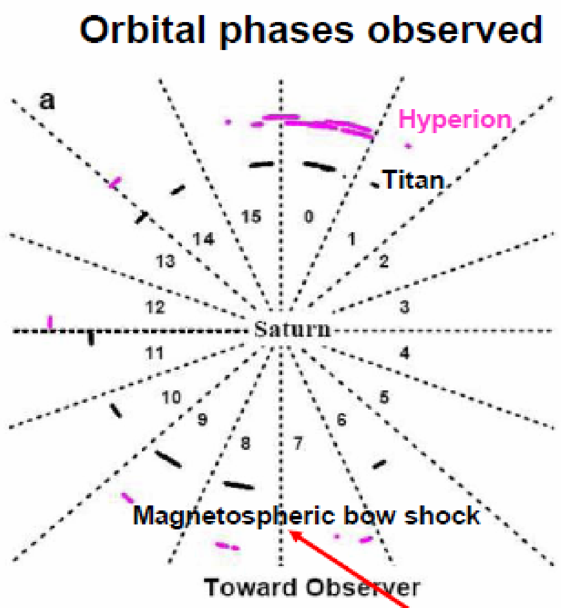
MSPEC0 – High-Resolution Spectrometer,
Medicina IRA-INAF Radiotelescopes

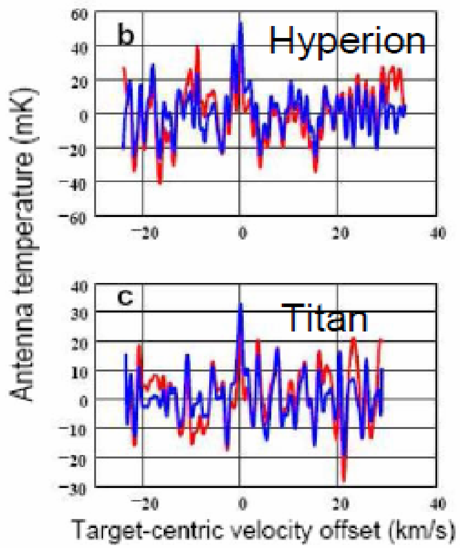


Systematic observations with the Medicina radio telescope commenced in December 2006 with the Direct-FFT Spectrometer. The observing setup was basically the same as in the Mk5-based observations, but with one polarization only and an ON/OFF nodding 50% duty-cycle of 2.7 min. Between December 2006 and December 2007, we compiled about 200 h of observations.
In addition, the Metsähovi 14-m radio telescope with a nominal gain of 0.04 K/Jy continued the observing campaign in April 2008, adding another 35 h in two polarisations with a system noise temperature between 90 K and 130 K. The Metsähovi data were recorded and processed using a locally-developed software spectrometer.

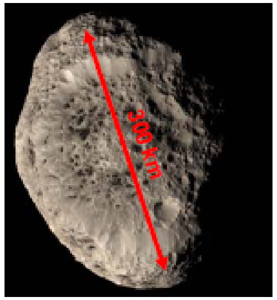
# Summary plot of Hyperion and Titan detections

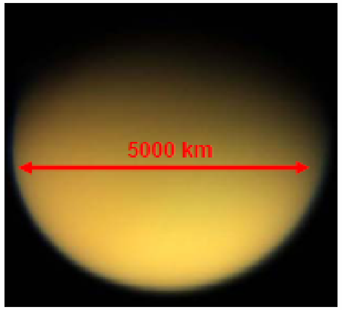
**a)** Distribution of orbital phases for Titan (black) and Hyperion (magenta), for which the data were collected. The observer (Earth) is located along the border between phases 7 and 8. **b)** The raw Doppler-corrected spectrum (red line) and baseline-fitted spectrum (blue line) for Hyperion orbital phase 8. **c)** The same for Titan, orbital phases 6 and 8 co-added. The signal-to-noise ratio (SNR) is at the 3.8σ level for Titan and 4.0σ for Hyperion.



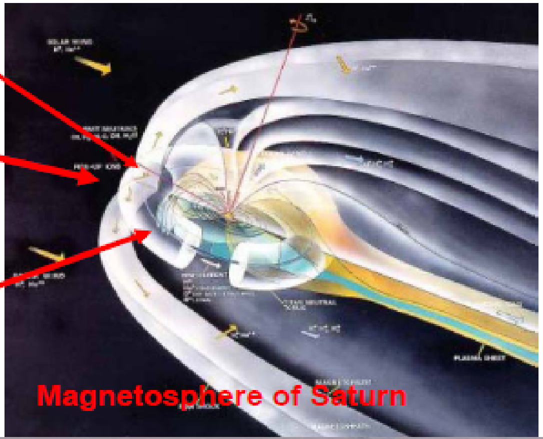

Sponge-like shape of Hyperion might be a result of a selective sublimation of ice, enhanced by interaction with Solar wind when the satellite is outside the Kronian magnetosphere.




When outside thy magnetosphere, Hyperion is about there

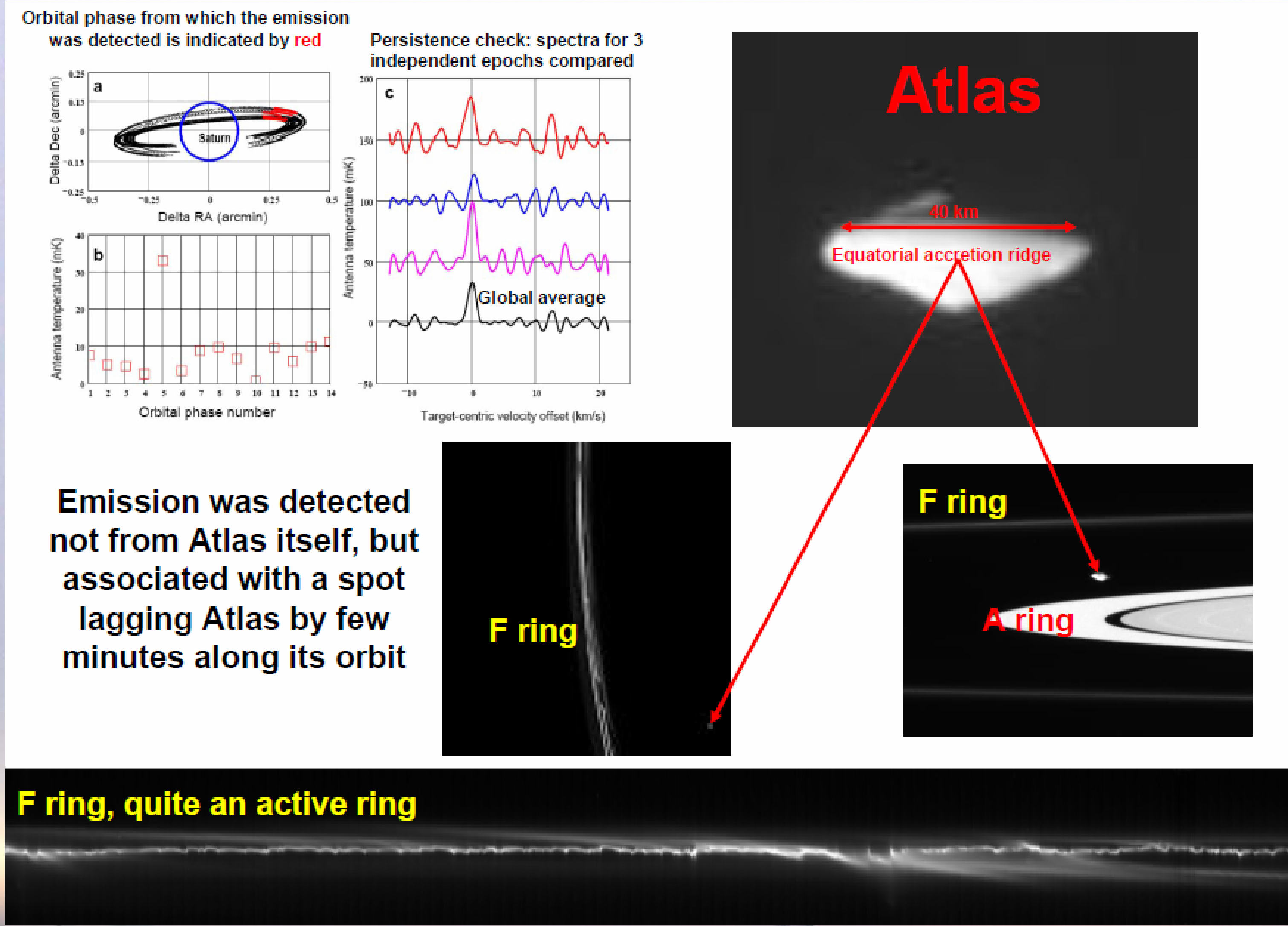
Titan's neutral torus




Titan has a lot of gases in its exosphere to provide collisional pumping for trapped water molecules.

# Summary plot of Atlas-associated detections

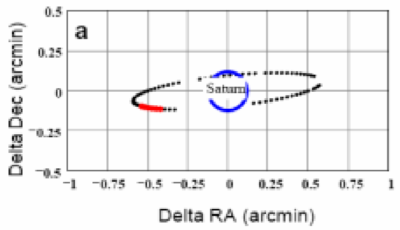
**a)** Atlas track in delta RA/Dec (arc minutes) with respect to Saturn during our observations. Each dot represents a single 3-min ON+OFF acquisition time. Red dots indicate the Atlas orbital positions from which the emission was detected. **b)** The antenna temperature at the0 kms−1 target-centric velocity offset for each of the 14 orbital phases processed (phases 0 and 15 were in occultation). **c)** Spectra. The red, blue and magenta lines represent the spectra integrated for 3 different epochs for Atlas orbital phase 5, about 2 h integration per each epoch. The black line shows the averaged spectrum with a peak antenna temperature of 32 mK and an SNR at the level of 7.0σ.

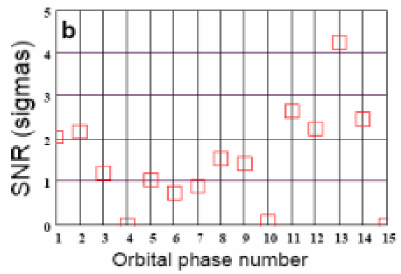


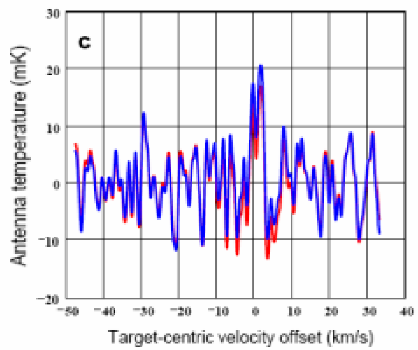
# Summary plot of Enceladus-associated detections

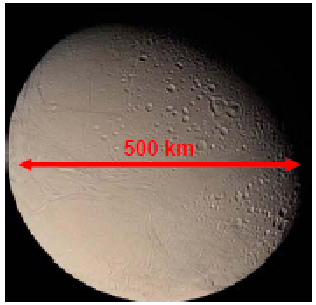
**a)** Enceladus track in delta RA/Dec (arc minutes) with respect to Saturn during our observations with Metsähovi radio telescope – black dots. Each dot represents a single 20-min ON+OFF acquisition time. Red dots indicate the Enceladus positions from which the emission was detected. Saturn's limb is indicated by a blue circle. **b)** SNR at the 0 kms−1 target-centric velocity offset for each of the orbital phases processed. **c)** Spectra for the orbital phase with SNR of 4.2σ; the red line indicates the raw accumulated spectrum, blue line – baseline ripple corrected.

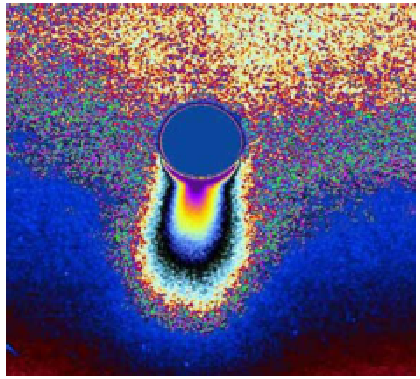
## Enceladus



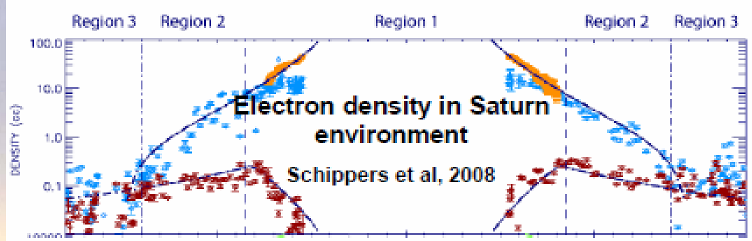



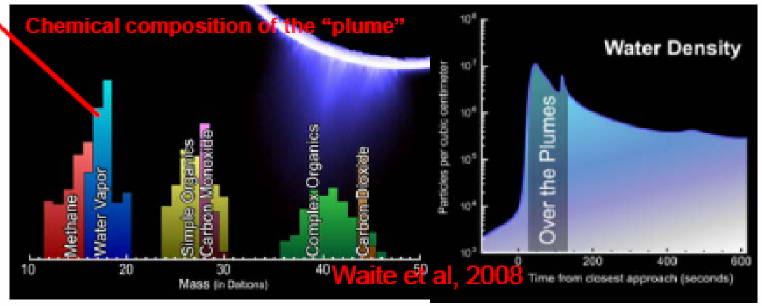



Water-water collisions dominated pumping ?

Presence of low energy electrons can also help (Elitzur & Fuqua 1989)




**Possibility to compare astrophysical models with *in situ* measurements**

Thank you for your attention!