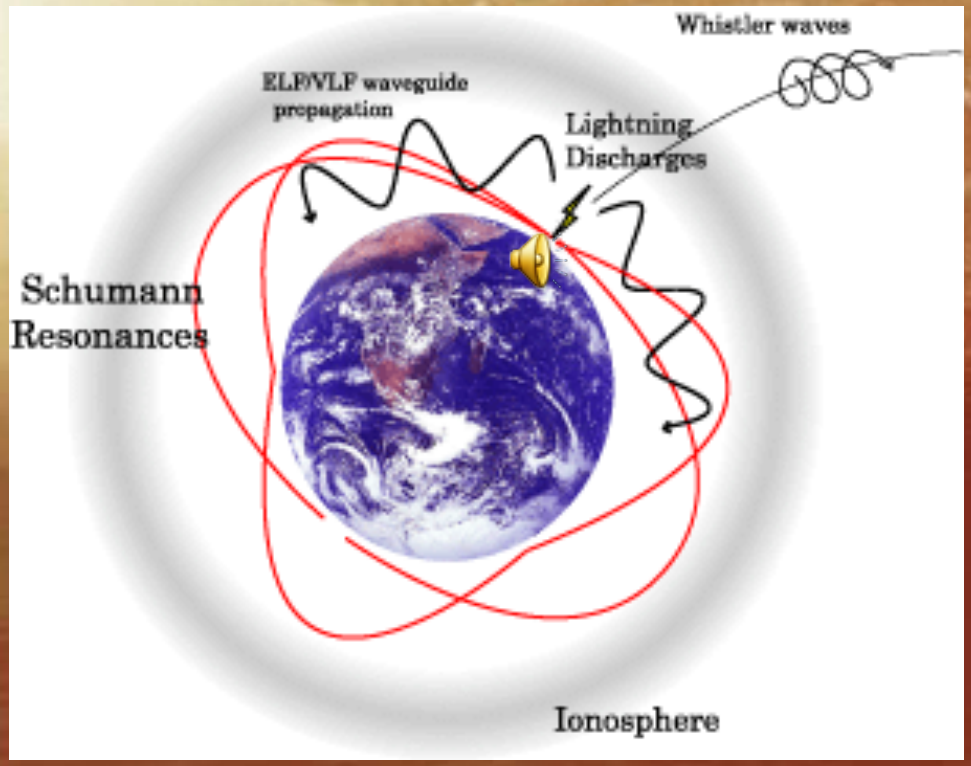
The Schumann Resonance: A Tool for the *In Situ* And *Remote Sensing* Exploration of the Deep Atmosphere of Giant Planets

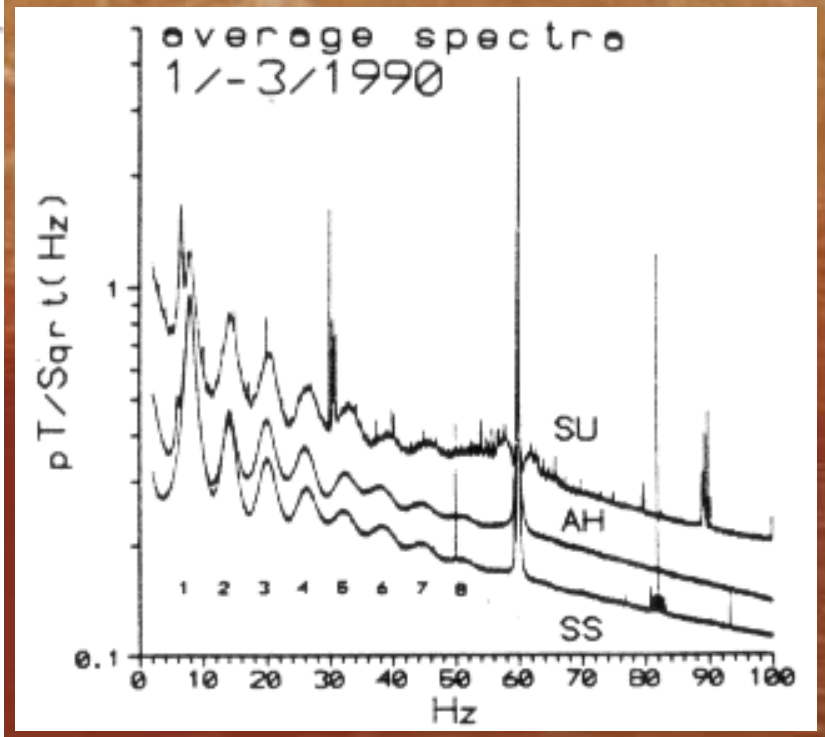
Jean-Pierre Lebreton (LPC2E, LESIA)
jean-pierre.lebreton@cnrs-orleans.fr
F. Simoes (NASA/GSFC), C. Béghin(LPC2E), J.-J. Berthelier (LATMOS), R. Grard (ESA/RSSD), M. Hamelin (LATMOS)

The Schumann Resonance

A natural phenomena predicted in 1950 par Winfried Otto Schumann
Observed about 10 years later

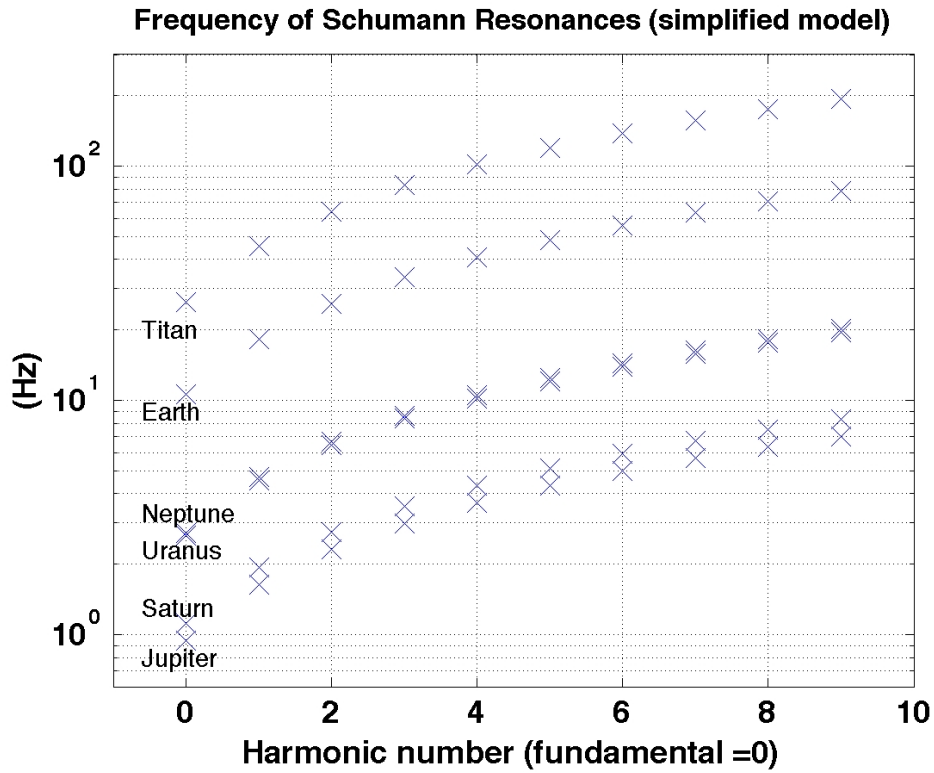
Stationnary EM Waves in the Earth's Surface-Ionosphere cavity





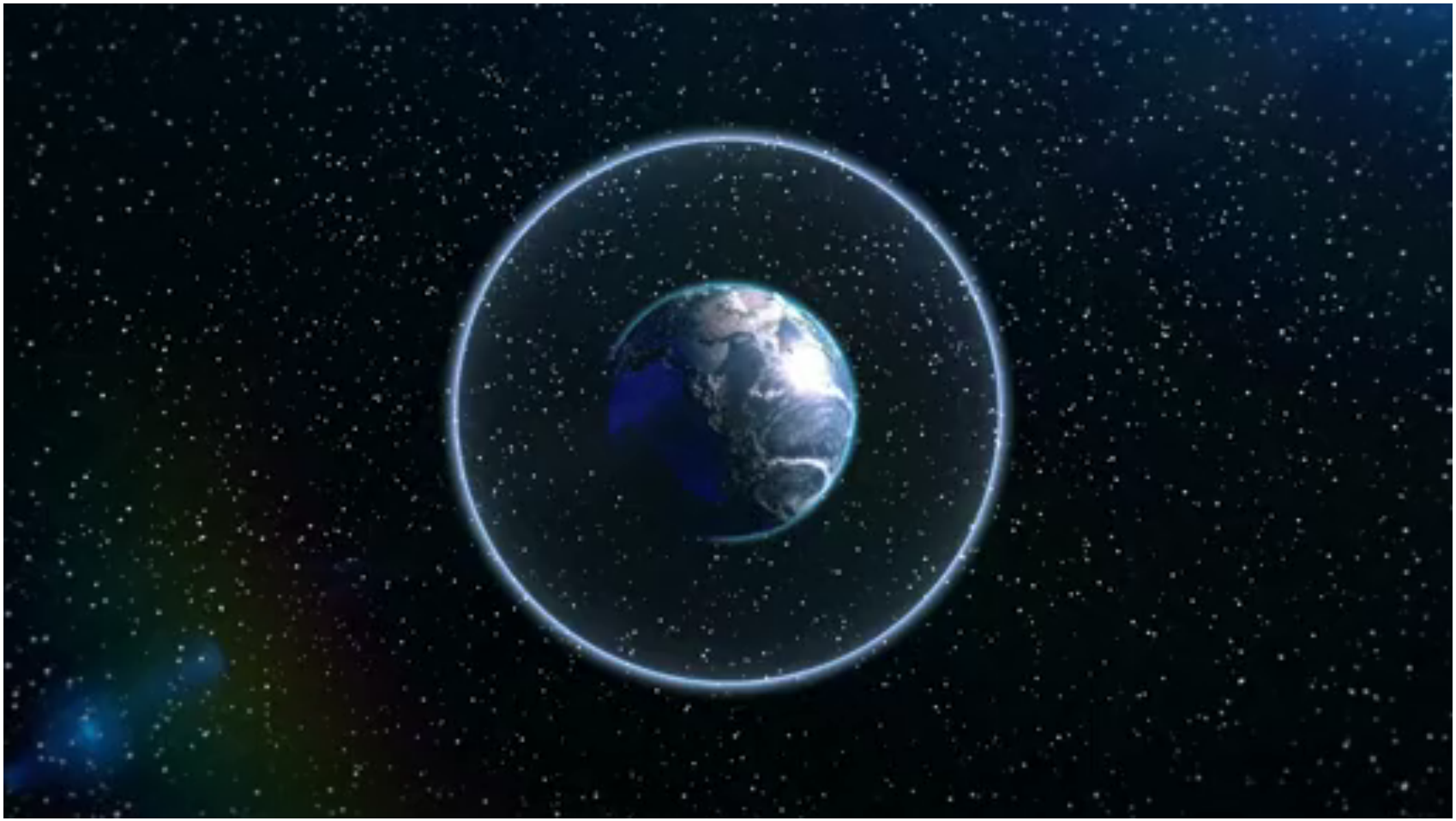
SR General Characteristics

$$f_n = \frac{c}{2\pi R}\sqrt{n(n+1)},$$



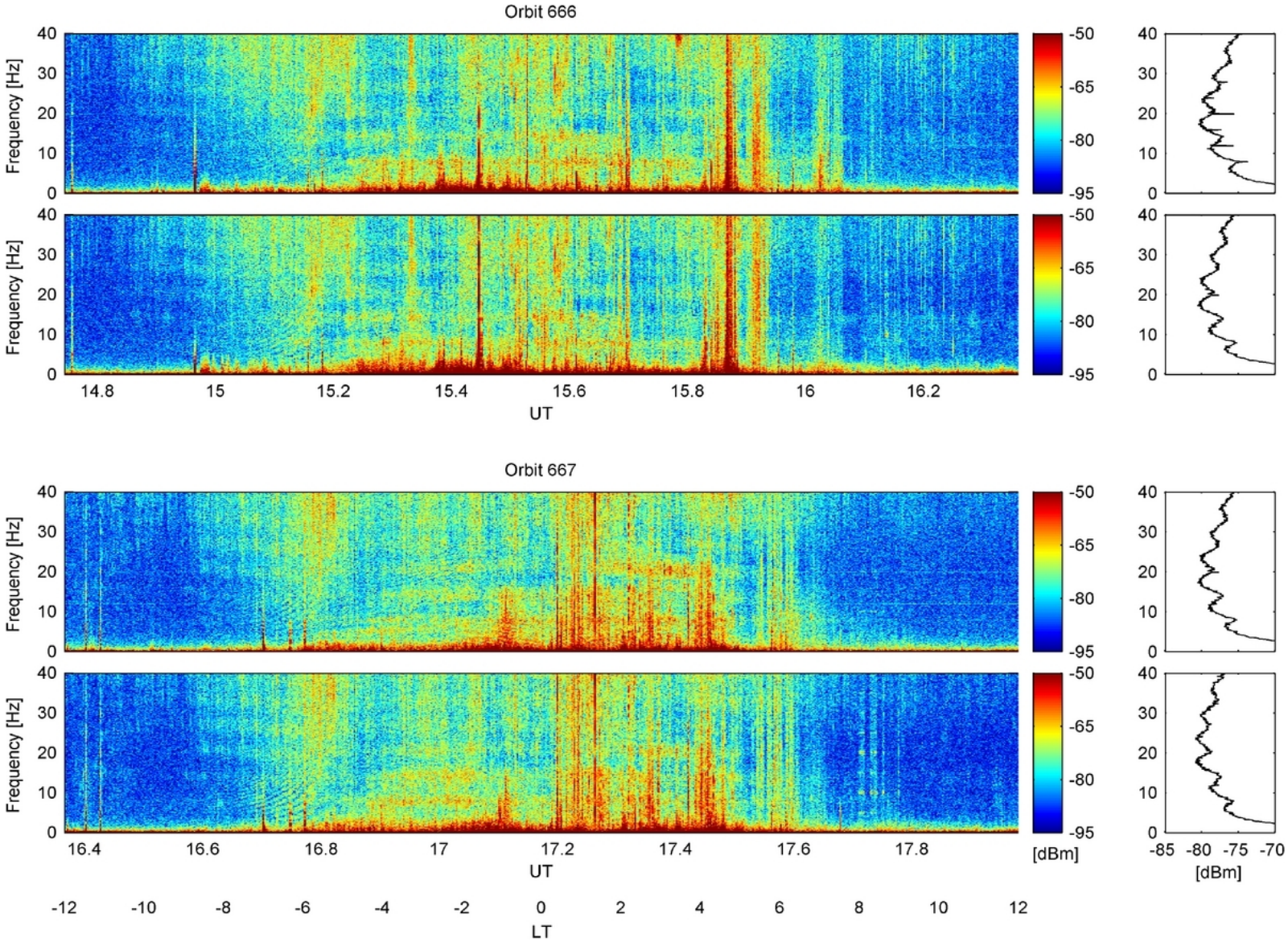
$$f_n \approx \frac{c}{2\pi R}\left(n(n+1)\frac{1-\frac{h}{R}}{\varepsilon_r\left(1+i\frac{\sigma}{\varepsilon_r\varepsilon_o 2\pi f_n}\right)}\right)^{1/2},$$

Leaking out: Detectable from above ionosphere



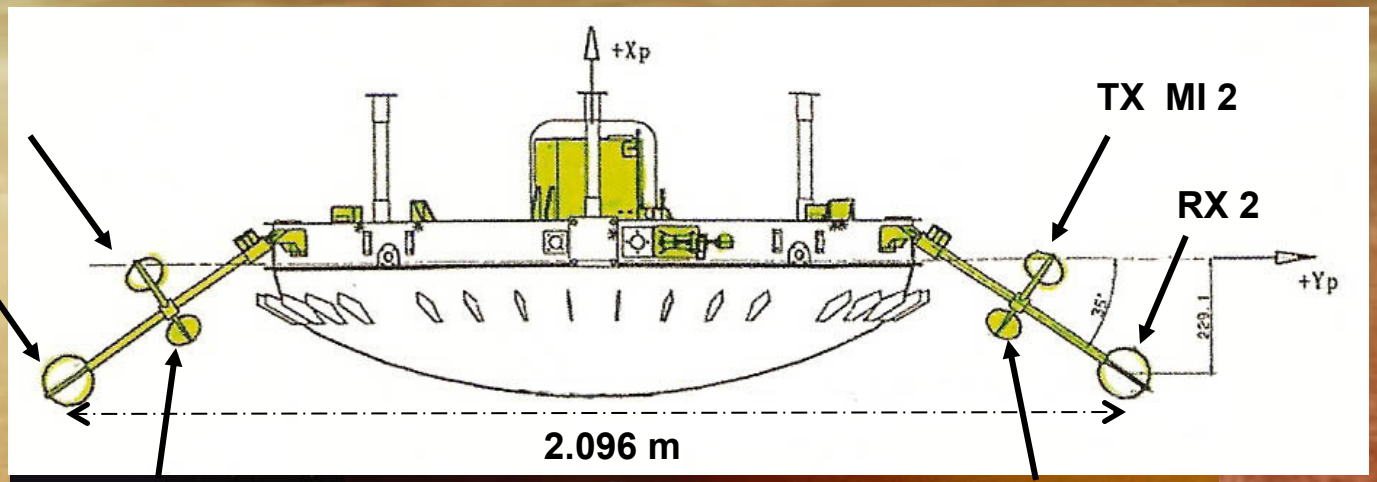
NASA video Clip

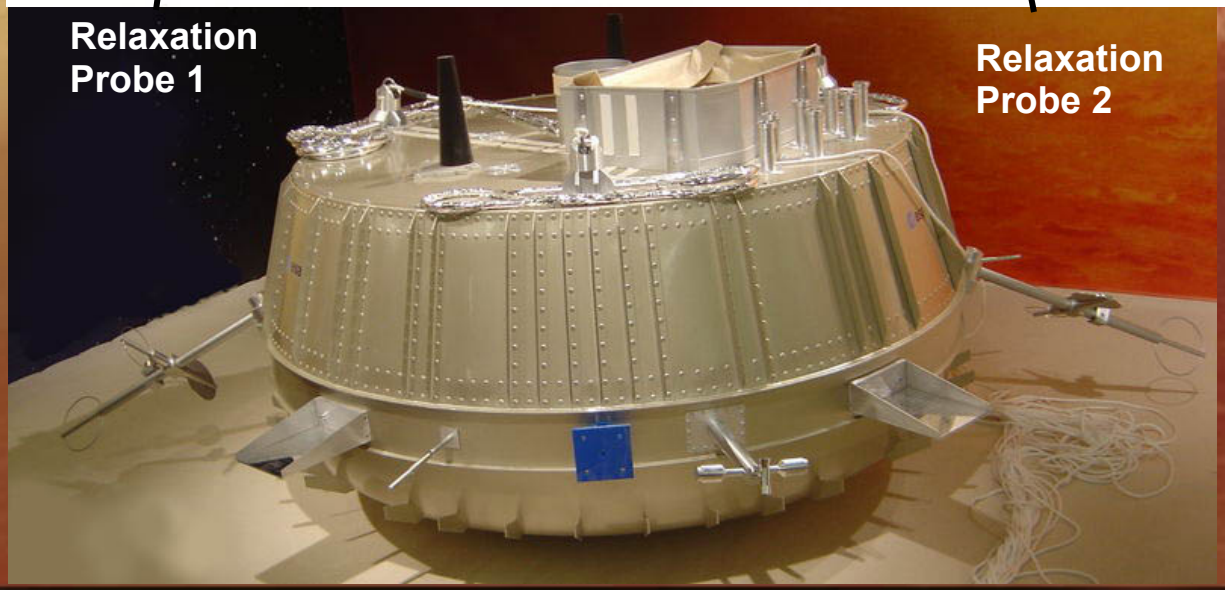
Figure 2 from Using Schumann Resonance Measurements for Constraining the Water Abundance on the Giant Planets—Implications for the Solar System's Formation
Fernando Simões et al. 2012 ApJ 750 85 doi:10.1088/0004-637X/750/1/85



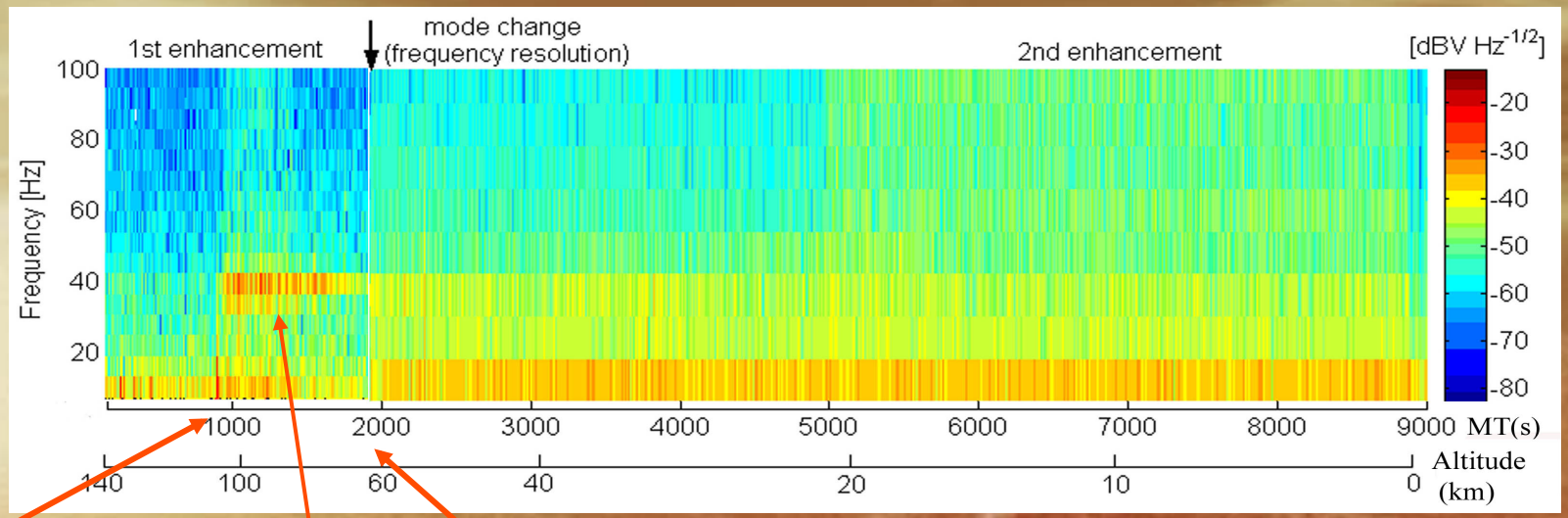
Huygens HASI/PWA Experiment

Objectives: Measure conductivity of atmosphere and surface (Solid or Liquid); Detect associated EM waves (and sound) associated to putative lightnings



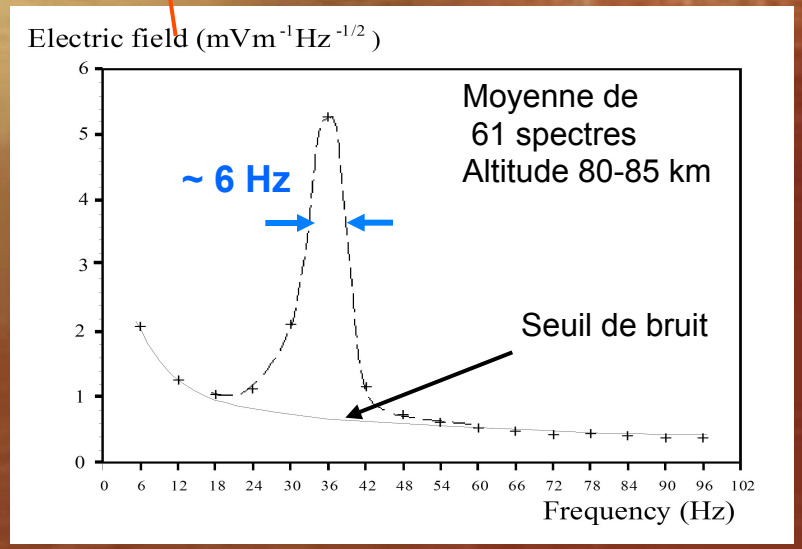


Narrow Band Signal with High Q Factor



MT ~ 900 s Parachute exchange

Mission Time 1930 s => Pre-programmed Mode Change

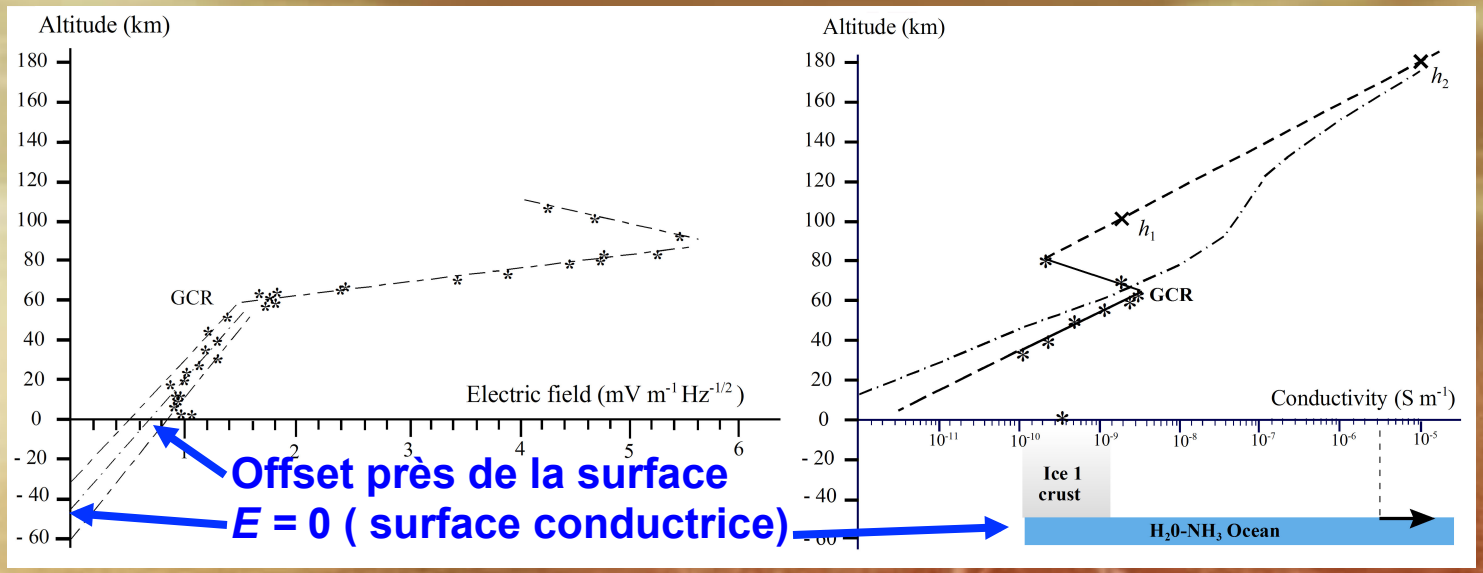


$$Q = \left.\frac{f}{\Delta f}\right|_{\substack{\text{half}\\ \text{power}}} \approx \frac{36}{6} = 6$$

Comparable To Earth SR Signal

Beghin et al. 2009; 2011

Titan Ocean: Huygens HASI/PWA Result



La couche réflectrice dans l'ionosphère est en accord avec les modèles

Une couche inférieure est indispensabe pour une resonance Schumann

L'offset observé au sol est consistent avec la faible conductivité de la glace

Le facteur de qualité Q = 6 contraint une couche de glace sans perte

Extrapolation of the *E* profile implies an ocean ~ 50-90 km under the ice

Une source d'excitation permanente existe plus efficace en ELF que des éclairs d'orage

Flux de puissance EM ~ 10^{-7} $Wm^{-2}Hz^{-1}$

Densité de puissance ~ 10^{4} WHz^{-1}

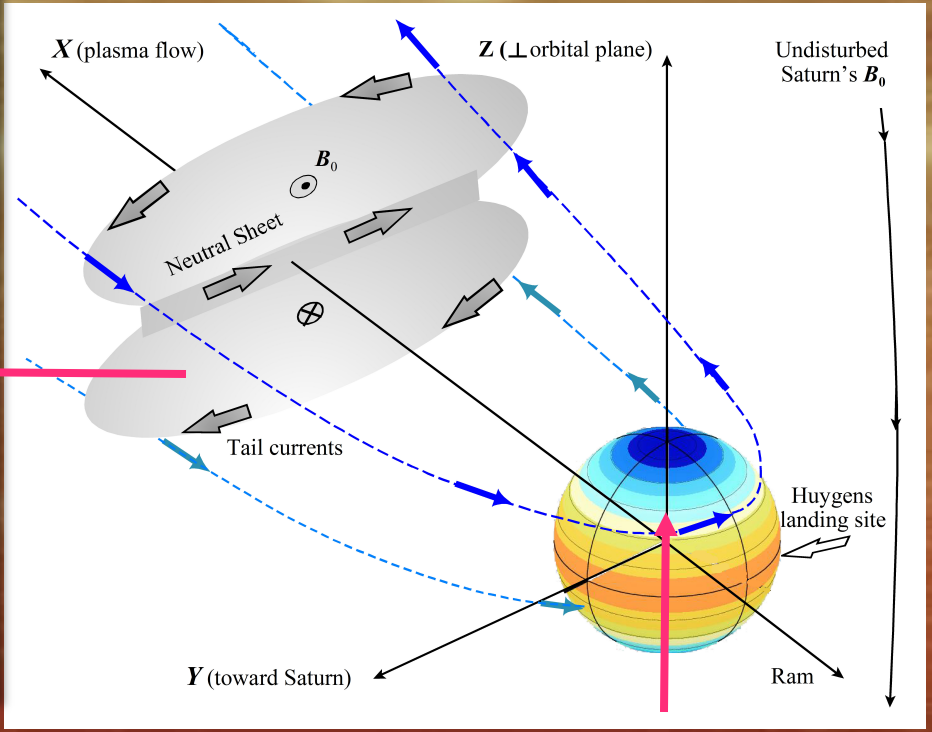
Puissance ELF nécessaire ~ 10^{7} W

Courants ionospheriques ~ 10^{5} A

Voltage trans-méridien ~ 5 10^{3} V

Puissance totale disponible ~ 510^{8} W

Efficacité de conversion requise ~2%



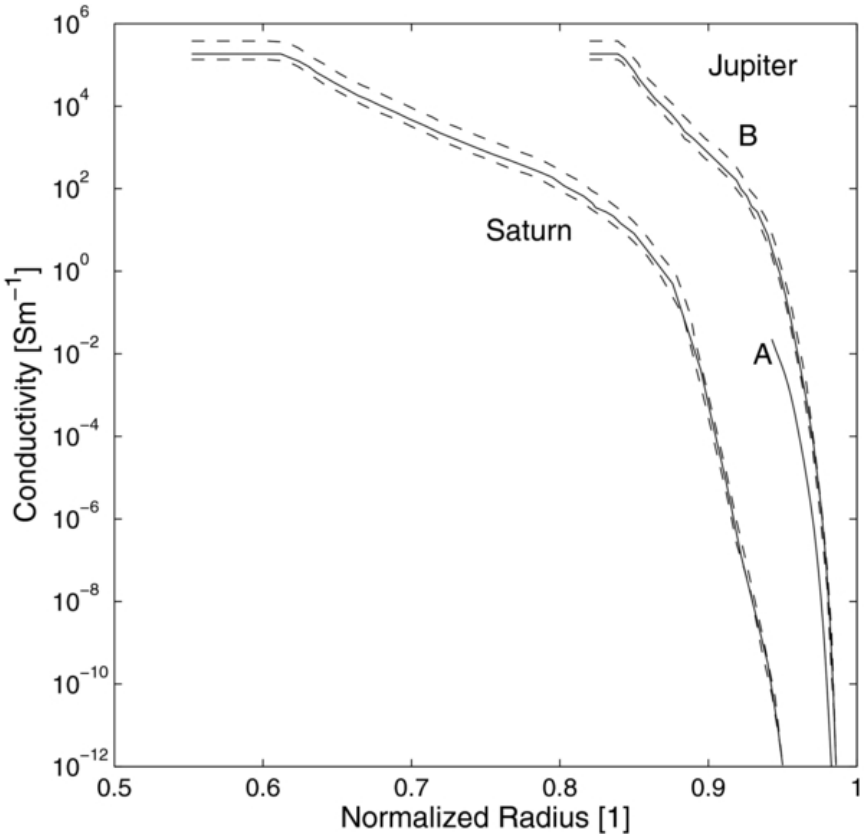
Mécanisme de conversion : Instabilité acoustique-ionique

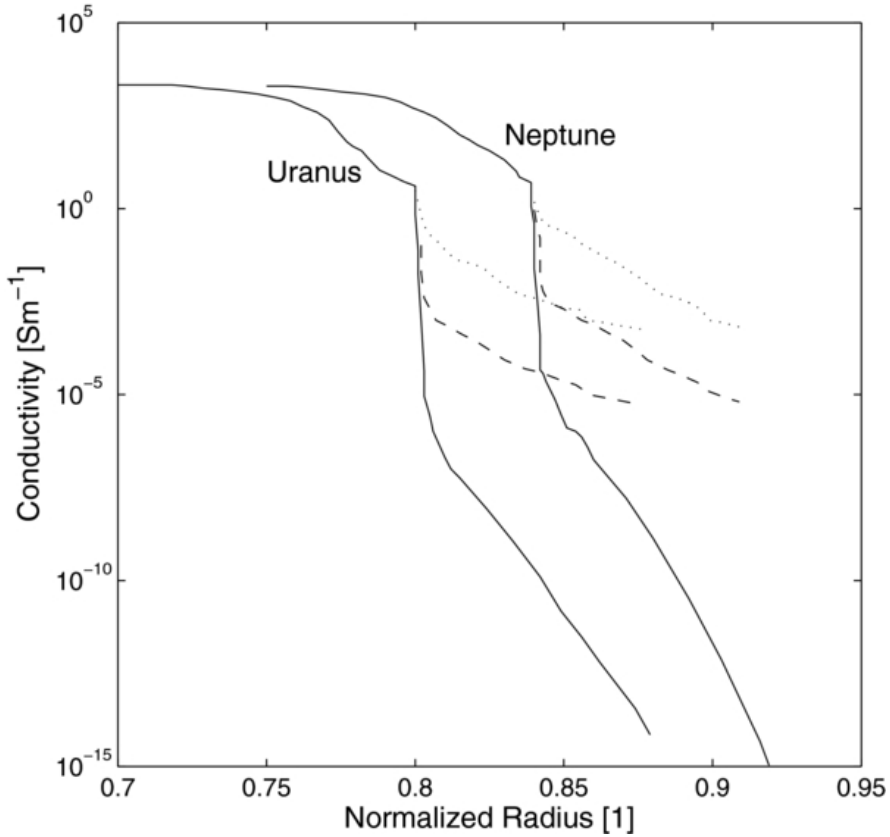
Turbulence ES <=> Conductivité anormale de 0 à 1000 Hz

Emission par dipôles magnetiques ELF verticaux

Source idéale d' harmoniques sphériques en modeTE, *E* horizontal

Giant Planet Atmosphere Conductivity Profile Sensitivity to Water Content





Simoes et al, 2012

Figure 8 from Using Schumann Resonance Measurements for Constraining the Water Abundance on the Giant Planets—Implications for the Solar System's Formation
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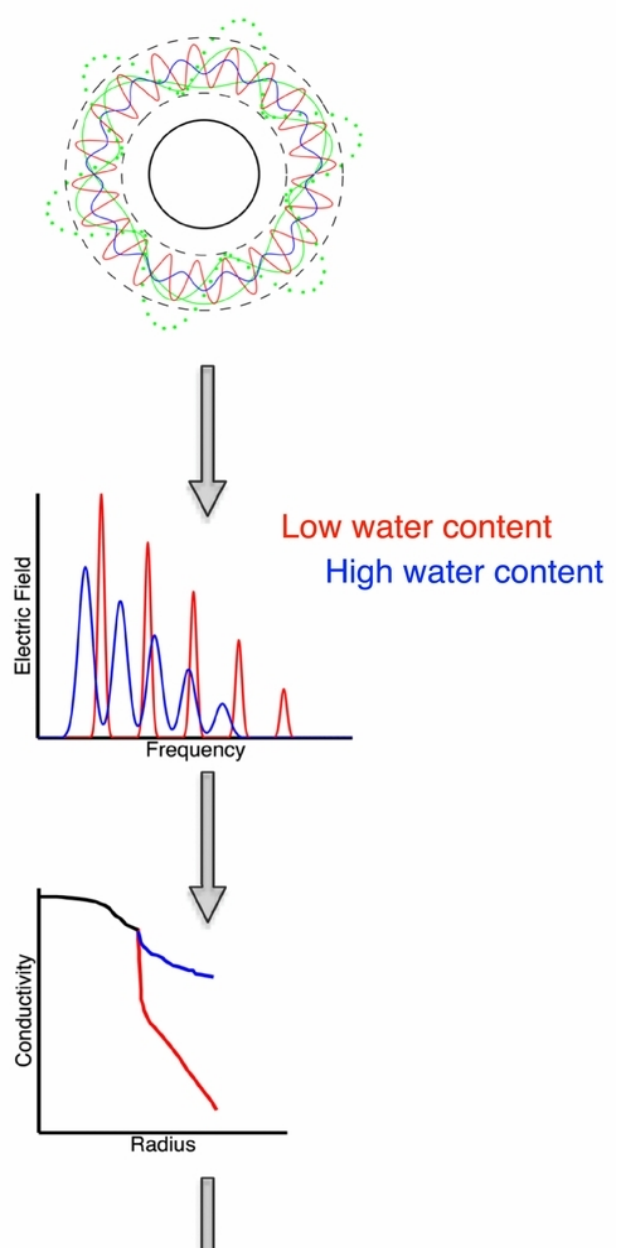

Saturn: Cassini Opportunities

- Titan flyby: RPWS ?
  - Leak out to be studied : No intrinsic B Field
  - Need to study if specific observation possible/worth
- Saturn peripase passages: RPWS, MAG ?
  - Best opportunity may arise during end-of-mission proxima phase
  - Lots of lightnings; Strong B-field
  - Leak out mecanism to be studied

Future *In situ* Missions

- In situ E vs B ?
  - E-field more sensitive
  - Requires E-field sensitive antennae
    - Low-resources instrument concept was studied for TSSM (Montgolfière and Lake lander) by members of the French Huygens PWA team
    - Alternative concept that may be worth studying: Integrated wire(s) within the parachute system
- Mars: MAEVEN ?