Results from First Orbit Around Saturn!

The Cassini RPWS instruments with Scandinavian participation reveals a dynamic Titan

The Cassini/Huygens spacecraft, with its numerous modern scientific instruments, passed twice just outside the visible rings of Saturn during the summer of 2004, and on October 26, 2004, it made a close encounter only 1200 km from the surface of the big moon Titan. The onboard camera and radar revealed a truly exotic place with possible ethane-propane oceans covering large parts of the surface. No craters were found, indicating a very geologically active and young icy surface indeed.

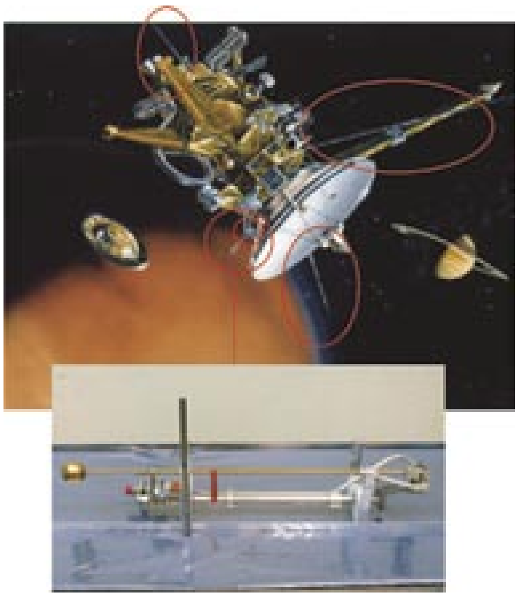

Fig 1: The Cassini orbiter and Huygens lander with Saturn and Titan in the background. The encircled areas include the RPWS instruments, which consist of three long radio and electric field antennas, a tri-axial search coil magnetometer at the boom of the Langmuir probe also belonging to RPWS. The Langmuir probe is shown expanded below.

The Huygens probe will be released from the larger Cassini orbiter during Christmas 2004 and enter the thick atmosphere and land on Titans surface on January 14, 2005. There it will make detailed measurements of for example composition, electrical conductivity, and wind speeds. There is even a small microphone onboard Huygens, which will be used for detecting thunders from lightning, and of course optical equipment to look around the landing place. The Cassini spacecraft will continue to orbit Saturn for an additional 4-6 years. Over 60 close flybys with Titan and other icy moons are already in the schedule. There will be some busy years to come for the participating scientists who have waited more than 7 years for their instruments to arrive to the Saturn system in the cold outer parts of our solar system. Among them is an instrument built and managed by the Swedish Institute of Space Physics in Uppsala. The University of Oslo have contributed to this instrument as well.

Cassini/Huygens is an ESA and NASA collaborative undertaking. Huygens is mostly of European origin, while Cassini is mostly of American origin. State of the art instruments from groups in both Europe and USA are mingled on both spacecraft into larger multinational instrument consortia. The Scandinavian participation occurs in the Radio and Plasma Wave Science (RPWS) investigation headed by Iowa University together with French, British

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Married with a Japanese space physicist and has soon 3 children

I have worked with optical, magnetometer and radar (EISCAT) ground facilities. With time I have worked more with varies spacecraft like Freja and Astrid-2. I am a Co-investigator on Rosetta, Cassini/Huygens, SMART-1 and now Bepicolombo. My field is experimental space physics were I contribute in the development of new instrumental techniques and methods. Even if my base is auroral physics, my research tend more and more to planetary space physics and aeronomy.

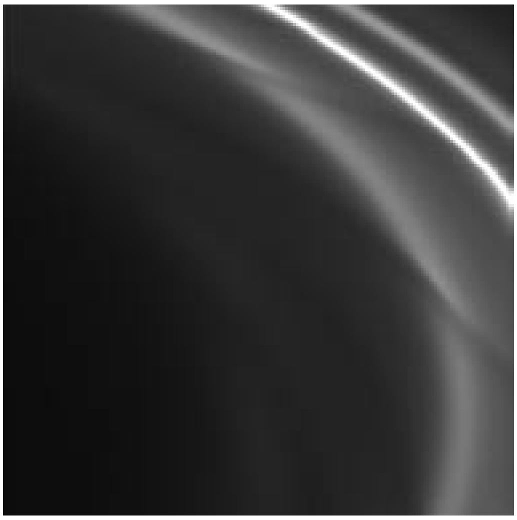

Fig 2: The outmost of the visible rings of Saturn is the narrow F-ring here enshrouded with dusty material that follows a twisted dynamic motion possibly induced by the electromagnetic forces. The Cassini orbiter passed just outside this ring on July 1, 2004. (Picture: NASA)

Fig 3: The thick nitrogen-methane atmosphere of Titan gives rise to an opaque orange-brown haze layer of complex organic compounds, which covers the surface in the visible. (Picture: NASA)

and Austrian research groups. RPWS consists of three types of instruments (see figure 1). Three 10 m antennas sample the electric field in the frequency range from a few Hz to 16 MHz, a tri-axial search coil magnetometer sample magnetic variations up to 12 kHz, and a so called Langmuir probe sample the density, temperature and other basic properties of electrically charged gas (plasma). Most of our contribution is in the Langmuir probe, which we operate.

When Cassini passed the ring-planes last summer the RPWS instruments detected, among other things, a doughnut-shaped dense ring-dust ionosphere (figure 2) together with over 100,000 micrometer sized dust impacts on the spacecraft. Energetic particles accelerated in the vast magnetosphere of Saturn hits dust particles just outside the visible rings and sputter away material from them. This volatile material, consisting mostly of water products, becomes partly ionised and is the main source of the charged dense gas torus around Saturn. This electrical gas is rotating with the magnetic field of planet, and it takes only some 10.5 hours to revolve around Saturn. The rotation period was also determined from periodic radio bursts (Saturn Kilometric Radiation, SKR) detected by RPWS (figure 3).

Above the visible rings no dense water gas was detected by RPWS. This is due to that the rings themselves absorb the energetic particles in the magnetosphere, and therefore no material is sputtered from the ring particles. The electrical charging of ring particles themselves and its effect on their dynamics together with the mapping of the structure and dynamics of the related charged gas is an objective for RPWS. Another important objective is to investigate the out-gassing of volatile materials from the inner icy moons (Mimas, Enceladus, Dione, Thetys and Rhea). One such indication of out-gassing was hinted near the distance of Dione (6 R_S) during the first approach (see figure 2).

The Langmuir probe has several important tasks related to the large moon Titan (figures 4-5). Titan has a thick atmosphere of mostly nitrogen and methane. This atmosphere is bombarded by ultraviolet light from the Sun and energetic particles in the Kronian magnetosphere, which has enough energy

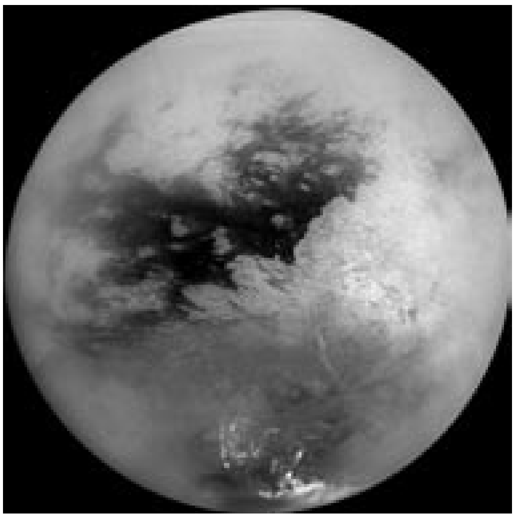

Fig 4: Operating the camera in the near infrared during the first Cassini flyby October 26 revealed the surface of Titan. The dark features could be ethane-propane oceans and the lighter an icy surface of water mixed with organics like poly-acetylenes. The bright white areas at the south are methane clouds. (Picture: NASA)

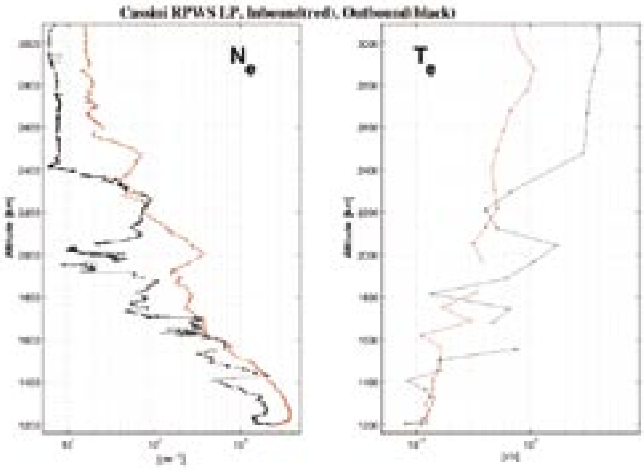

Fig 5: The density and temperature altitude profiles of the charged gas in the upper atmosphere of Titan as derived from the Langmuir probe measurements. The red is the inbound profile and the black the outbound. A very structured environment arises due to the dynamic interaction with the magnetosphere of Saturn.

to break up the nitrogen molecules into two or ionize it. The nitrogen radicals and ions are very reactive, and they react primarily with the atmospheric methane, forming heavy hydrocarbons, polycyanides and nitriles (nitrogen containing organic molecules). A very complex organic chemistry is therefore resulting in the upper atmosphere and ionosphere of Titan. The heavy products of this catalytic factory drizzle downward deeper into the atmosphere under the action of gravity, where they continue to undergo more and more complex chemistry. Even amino-acids like adenine are predicted by models to form in this environment. The orange-brown haze layers, which makes the atmosphere opaque in the visible and makes the surface hard to study, are created from long chains of organic molecules which clumps together and forms an aerosol. Over the age of the solar system a km thick layer of ethane, propane, acetylene and many other substances should have deposited on the surface. Ethane and propane are liquid at the surface temperature of –180°C, while acetylene is believed to form a number of poly-acetylenes (plastics) depending on where they fall. We don't think life can form here, but we believe the chemistry leading to life can be studied here. On the surface there might even exist 0°C water volcanoes, and when liquid water reacts with the other organics (so called hydrolysis) really advanced pre-biotic chemistry can result.

The Langmuir probe will measure the ionization degree of impacting energetic radiation and the thermal state of the upper atmosphere. Temperatures determine the chemical reaction rates. An example of these measurements during the first Titan flyby is depicted in figures 6-8. One surprise during the encounter was that the ionized part of the upper atmosphere was very dynamic and structured. This, we think, is due to the interaction of the rotating magnetosphere, which at the distance of Titan impinges with a velocity of a few hundred km/s. The pressure of the magnetic field seems to be of the same order as the thermal pressure of large parts of the ionosphere. This interaction causes a substantial erosion of the atmosphere over geologic time. The erosion is estimated to about 10^{25}–10^{26} particles per second, or a few kg/s. This does not perhaps sound much, but over millions of years it adds up. In fact the N^{15}/N^{14}-ratio was estimated to well above Earth values, indicating that the atmosphere probably was some 50-200 atmospheres of nitrogen from the beginning. Today it is about 1.5 atmospheres at the surface. The Langmuir probe has a special mode that can directly estimate the erosion flux by the flowing action of the magnetosphere of Saturn. However, we have to wait until Titan flyby number 11 for this measurement to take place. Several years of investigation is waiting us ahead.

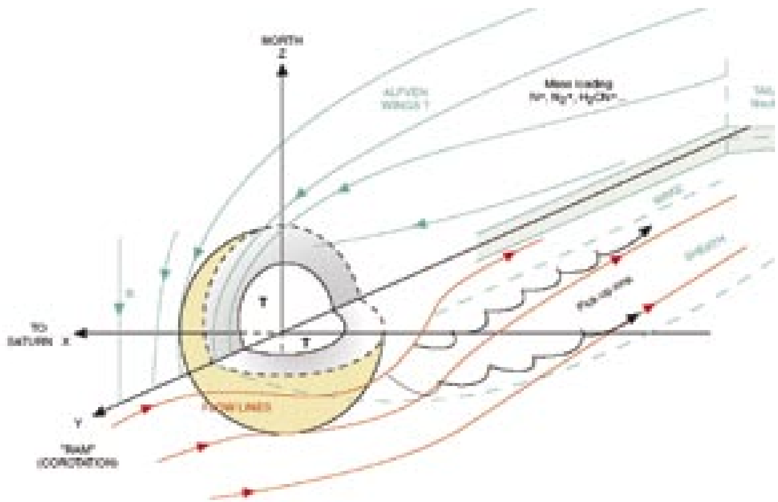

Fig 6: A schematic cartoon of Titans interaction with the magnetosphere of Saturn. Many scientists will study the details of this interaction over the coming years. Over 40 flybys are scheduled of the moon.

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