FFI participating electron measurements at Saturn

The Cassini/Huygens project is a co-operative effort between NASA and ESA to study the planet Saturn, its system of rings and icy moons, the major moon Titan as well as the magnetosphere and its interaction with the solar wind. The spacecraft was launched in October 1997 from Florida. In order to build up the necessary speed to reach the outer planets, the spacecraft then had to execute a complex trajectory through the inner part of the solar system to make use of the gravitational fields of the planets to increase the orbital velocity.

On 1st July 2004 the spacecraft entered into orbit around Saturn. Here it will release the Huygens probe for an attempted soft landing on the moon Titan on 14th January 2005. The main spacecraft will then embark on a four years programme to study the Saturnian system utilizing its suit of twelve instruments for both in situ measurements and remote sensing.

Instrument Description

Among the suit of in situ instruments is the Cassini Plasma Spectrometer (CAPS). The fundamental scientific goals of the CAPS investigation are to understand the origins of the plasma, its sources of ionisation, its acceleration and transport processes, and the nature of plasma loss mechanisms. Hence, CAPS will also contribute to a number of planetary objectives including Titan’s atmosphere. Saturn, which is a planet with a much stronger magnetic field than Earth (and consequently possess a magnetosphere having much larger scale lengths) and additional plasma sources in the system of rings and moons (especially Titan), provides a different and probably a much more complicated interaction between the magnetosphere and the solar wind.

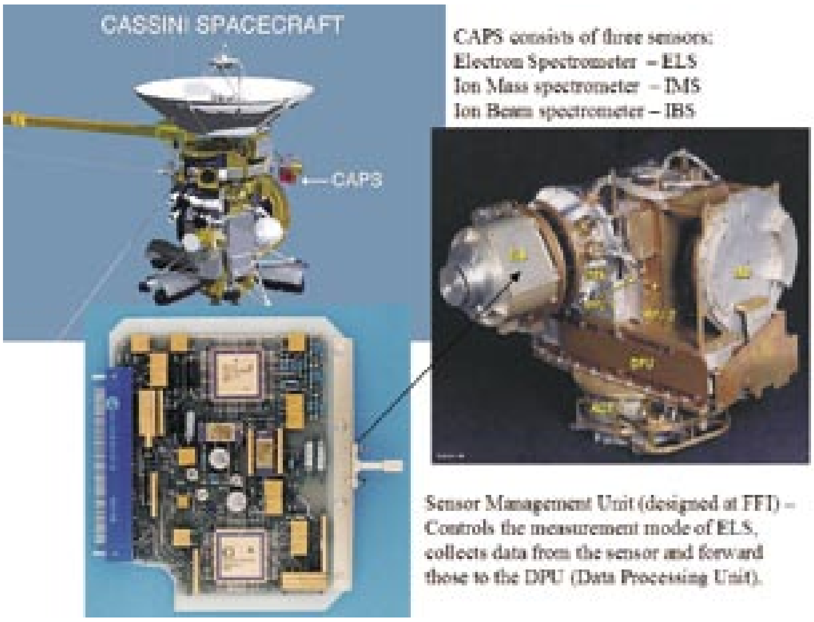

Figure 1
Composite picture showing the mounting of CAPS on the Cassini spacecraft, the three sensors comprising the instrument as well as the Sensor Management Unit designed at FFI.

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Graduated from TTS, Trondheim in 1966 where he studied electronics. Became an employee at FFI in 1968 and has since been involved with the development of space physics instrumentation for ground observations, sounding rockets and satellites. He has also been the project manager of many of these programs.

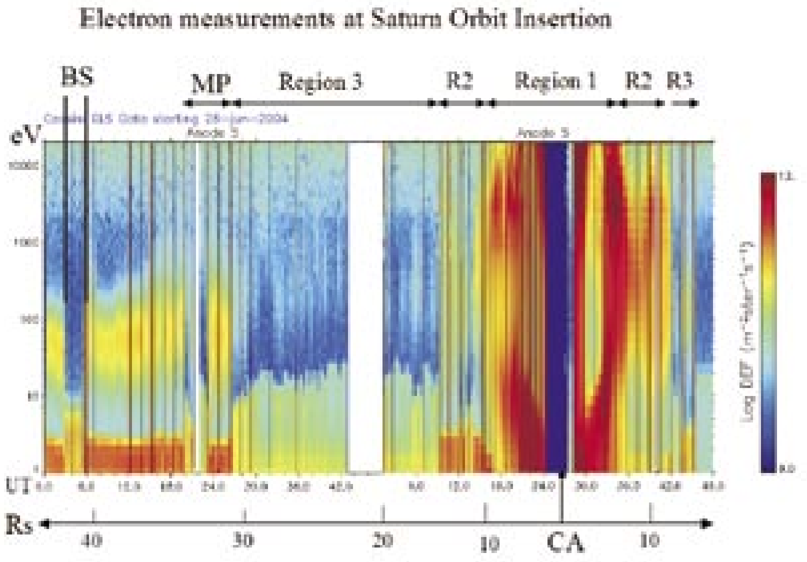


Figure 2
Plot showing the Differential Energy Flux of electrons (colour coded) as function of time and energy. This is an overview of the electron measurement obtained during the four days period around the time of closest approach to Saturn. Also indicated is the distance in Saturnian radii (1 $R_S \approx$ 60000 km) as well as the various plasma regimes encountered.

CAPS is designed to make comprehensive three-dimensional mass-resolved measurements of planetary and solar wind plasma populations. It consists of three sensor subsystems: the Electron Spectrometer (ELS), the Ion Beam Spectrometer (IBS) and the Ion Mass Spectrometer (IMS). The three sensors are mounted together with a common data processing unit attached to a motor-driven actuator that also forms the mechanical interface to the spacecraft as shown in Figure 1. In order to minimise intrusions into the field-of-view by the spacecraft and other instruments, CAPS is mounted outboard on the Cassini Orbiter (see Figure 1). It is attached to the fields-and-particles pallet so that the rotation axis of the actuator is aligned with the main rotational axis of the spacecraft. Except for the apertures, CAPS is entirely covered in conductive carbon-filled multi-layer thermal blankets during the mission.

The ELS sensor is a hemispherical top-hat electrostatic analyser set up to sample electrons over a detectable energy range from 0.6 eV to 27.0 keV with an energy resolution of 16%. Energy separation in this mode is matched to the analyser pass-band to ensure continuous energy coverage. The sensor has a field-of-view of 5°×160° divided into eight segments (anodes) of 5°×20°, which provides the resolution in elevation (from the main rotational axis) of the observations. The azimuthal (around the main rotational axis) angular resolution and range is limited by the operation of the actuator to about ±100°.

During regular observation ELS executes consecutive energy sweeps in which the selected energy is held for a fixed accumulation time and then stepped down to the next level. This will produce a 64-level logarithmic energy spectrum every two seconds. However, even though this data resolution is always provide by the ELS, overall telemetry restrictions result in an available data rate to the ground, which at times will be much lower. This is accomplished either by averaging the energy spectra over time only, or by averaging over both time and energy for the lowest data rates. The operational mode of ELS is controlled by the Sensor Management Unit (SMU) designed at FFI in the form of a separate electronics card as shown in Figure 1.

Saturn Orbit Insertion (SOI)

After a 1.5 hour burn of the main engine Cassini/Huygens entered into orbit around Saturn on 1st July 2004. However, CAPS had by then already been observing the solar wind for around half a year. This provided a broad context for studying the interaction between the solar wind and the Saturnian magnetosphere.

In Figure 2 the electron measurements obtained during the four days around SOI are displayed. The multiple plasma populations encountered during this period is readily visible in this figure and are indicative the different interaction regions around the planet. It should also be noted that the strong fluxes at the lowest energies are photo-electrons, created on the spacecraft surface by solar ultraviolet radiation, returning to the spacecraft due to the ensuing positive surface potential. This cloud of “artificial” electrons are always surrounding the spacecraft (except during eclipse), and represent a significant source of uncertainty when observing low energy plasma.

The first observational sign in ELS when approaching Saturn is the detection of the bowshock (BS). This is where the supersonic solar wind is thermalised upon encountering the obstacle of the Saturnian magnetosphere. The bowshock was observed several times between about 50 and 40 Saturn radii (R_S) during the approach, and it is suggestive of a fairly inflated magnetosphere during the Cassini/Huygens approach to Saturn. The last few of these crossings are clearly visible to the left in Figure 2, where the main electron fluxes observed change from below 10 eV (solar wind) to several tens of eV’s (magnetosheath).

Later on and somewhat closer to the planet, several magnetopause (MP) crossings were observed between a distance of 30 R_S and 35 R_S from Saturn. This marks the transition into the region of space dominated by the intrinsic magnetic field of Saturn, but it still occurred almost two days before the point of closest approach (CA). For quite a while after the last magnetopause crossing there was still observed a diffuse magnetosheath electron population mixed in with low energy electrons apparently originating inside the Saturnian system (corresponding to Region 3 in Figure 2). This is similar, but more pronounced, to the corresponding mixing layers observed at Earth.

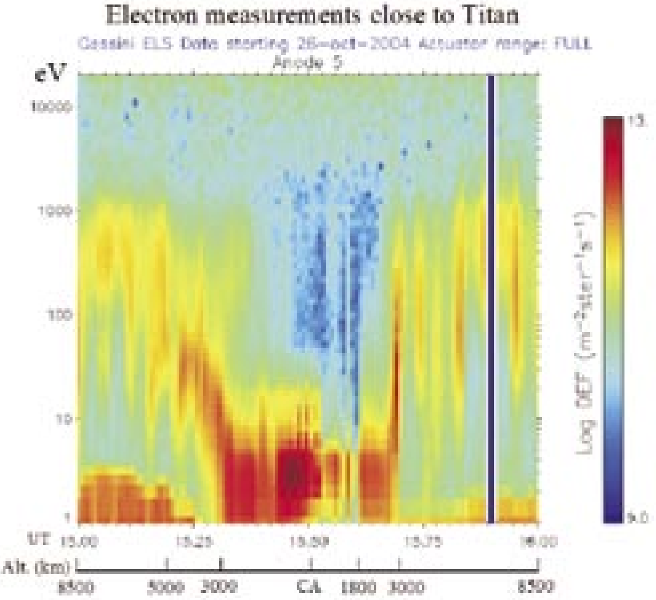


Figure 3
Plot showing the Differential Energy Flux of electrons (colour coded) as function of time and energy. This is an overview of the electron measurement obtained during a one hour period centred on the time of closest approach (CA) to Titan. Also indicated is the altitude above the surface.

Inside about 15 R_S a transition region containing more energetic electrons was transversed (Region 2), before a strong flux of electrons at several keV's was encountered (Region 1). These latter observations are reminiscent of plasmasheet electrons observed at Earth, but differ in that the energy seemed to diminish as the distance to Saturn itself decreased. Hence, it seems that this inner magnetospheric electron population is strongly influenced by ions whose co-rotational energy vary in just such a fashion.

Most experiments were turned off for the main engine burn which continued somewhat past the point of closest approach, but CAPS was again operating during the outbound ring plane crossing were electrons of very low energy (only a few eV's) were observed. The same three magnetospheric regions were then transversed again on the outbound leg of the orbit.

Titan

During the mission Cassini will make several close approaches to the giant moon Titan, and the first of these occurred on 26th October 2004. In fact, the spacecraft passed Titan at an altitude below 1200 km above the surface at the time of closest approach (15:30 UT). In Figure 3 is displayed the electron measurements obtained during an hour centred around this time.

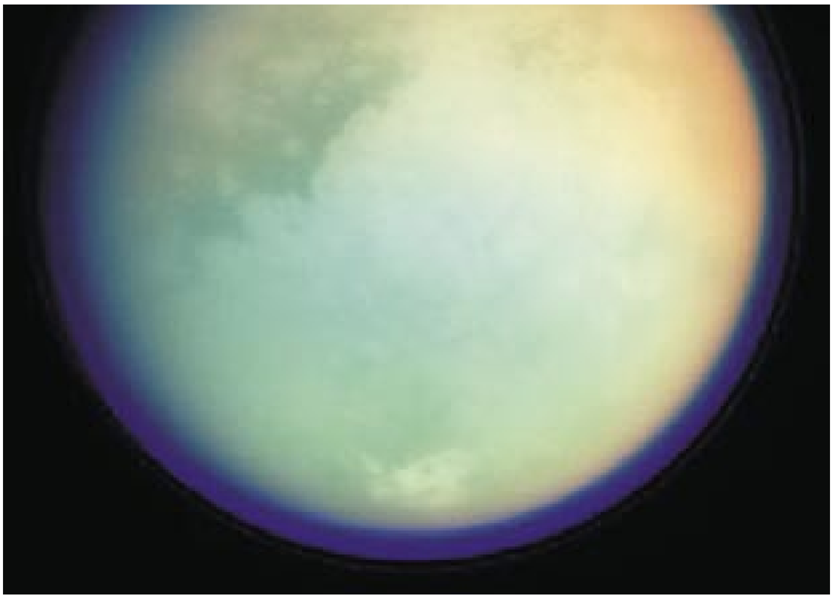
As is seen here the electron energy changes from between 100 eV and 1000 eV at an altitude of about 5000 km to less than 10 eV during the descent to around 3000 km. This is because the observed plasma is gradually becoming more dominated by the cooler (and heavier) plasma originating from the Titan atmosphere. This is similar to what is observed in the ionosphere of Earth.

However, there is also an asymmetry between the measurements obtained during the descent in the sunlit hemisphere and the ascent on the darkened side. In addition, there were also observed small scale structures around the time of closest approach which await further interpretation. Many similar fly-bys coming up later on in the mission will undoubtedly also provide a wealth of additional data on the ionosphere of this fascinating moon.

Continuing Mission

This first glimpse of the Saturnian magnetosphere has already provided examples of both familiar structures as well as new questions to ponder. From the quality of the data obtained there is no doubt the instrument is performing to our expectations. Hence, scientists here at FFI, as well as our many international colleagues, can look forward to several years of challenging analysis.

The Cassini spacecraft will now proceed on a four years tour throughout the Saturnian system. A complex set of orbital manoeuvres will enable it to make several more observations of Titan, many icy bodies, the magnetotail as well as Saturn at higher latitudes towards the end of the mission. Hence, CAPS will be able to obtain in situ plasma measurements throughout most parts of the Saturnian magnetosphere. ■



Titan in false colour, seen during fly-by.
Photo: NASA/JPL/Space Science Institute.