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The Cassini Mission

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Abstract.
Here we describe the main results obtained at the date of the Cassini Mission. The Cassini Mission was launched in October 1997 on a Titan IV-Centaur rocket from Cape Canaveral. The Cassini spacecraft first executed two gravity- assist flybys of Venus, then one each of the Earth and Jupiter to be injected in the right orbit that brought the spacecraft at Saturn in June 2004, becoming a new satellite of Satellite of Saturn (1^{st} of July 2004). With the use of the VVEJGA (Venus-Venus-Earth-Jupiter Gravity Assist) trajectory, it takes 6.7 years for the Cassini spacecraft to arrive at Saturn.

Key words. Planets: Saturn – Planets: icy satellites

1. Introduction

Cassini represents a great success of the international cooperation. The Cassini mission is, in fact, a NASA- ESA- ASI project. The main effort was made by NASA, that provided the launch, the integration and several instruments; ESA provided the Huygens probe and ASI a few key elements of the mission such as the high-gain antenna, the majority of the radio system and contributed to important instruments of the Orbiter, such as the Cassini Radar and the visual channel of the VIMS experiment. ASI contributed also to the development of HASI experiment on the Huygens probe. Besides the NASA, ESA and ASI contributions the Cassini team includes academic and industrial partners in 33 states and 18 other nations. The Cassini journey is very long and complicated, being characterized by a VVEJGA (Venus-Venus-Earth-Jupiter Gravity Assist) trajectory). The spacecraft, therefore has been designed to survive the thermal environment both inside the orbit of Venus (130 ˚C) and at Saturn (-210 ˚C). The first swing close to Saturn, just before permanent capture, has allowed to observe the Saturn pole and the rings in unprecedented conditions. A large periapsis raise manoeuvre was performed two months later to move the closest approach point at Saturn beyond Saturn's inner rings and also to establish the geometry required for probe entry at the first Titan. In late 2004, Cassini has released the ESA Huygens probe. The 14^{th} January 2005 Huygens encountered the upper atmosphere of Titan, beginning its descent and landing on the surface two and half hours later. During its the life the Cassini orbiter's will execute more then 40 close flybys of particular satellites, rings and their associated small moons: the most observed satellite will be Titan, that will have more than 30 encounters and that is also used to change the orbit of Cassini spacecraft. In addition, Cassini's orbits will also allow it to study Saturn's polar regions never studied before. The number of discoveries of Cassini, up to now, is very large

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and it will be difficult to review it in the limited number of pages of this report. Therefore here I will just review what, to date, I consider the most important results obtained. These discoveries have been possible thanks to a complex payload present both on the orbiter and on the Huygens probe . To reach the scientific objectives, during its hopefully long life, , the Cassini-Huygens spacecraft is equipped with 18 instruments: the Cassini orbiter carries 12 of them and the Huygens probe six.

2. Titan

The main discovery made by Cassini on Titan refers to its complexity, as well as to the recognition that previous models were too simple to describe the complex reality of this satellite. Since the time of Voyager Mission it was recognized that the atmosphere of Titan is mainly made by nitrogen. However, it also contains significant quantities of aerosols and organic compounds (hydrocarbons), including methane and ethane. Titan's peak surface temperature is about 95 Kelvin, and the pressure at the surface is 1.6 bar. At this temperature and pressure, chemicals such as methane, ethane, propane, ammonia, water-ice and acetylene may be involved in complex interior-surface-atmosphere chemical cycles resulting in eruptions, condensation and precipitation, as confirmed by the Cassini mass spectrometr(Hunten et al. 2005). The Cassini VIMS observations have shown first the surface of Titan, through the clouds, clarifying that the surface observed was solid and that an ocean wasn't covering all the surface (see figure 1) (Kerr, 2004, Kerr, 2005a)**.** The surface of Titan was observed through the atmospheric windows of Titan spectrum .

Recently, many different features were observed on the Titan surface, including lakes, in the polar region, craters, identified in the radar imaging , and possibly an active volcano. The identification of the different surface structures has been possible thanks to the combination of different instruments, mainly the radar (Elachi et al. 2005), the VIMS instrument, CIRS and the ISS imaging system (Porco et al. 2005a): as an example the possible volcano has bee first

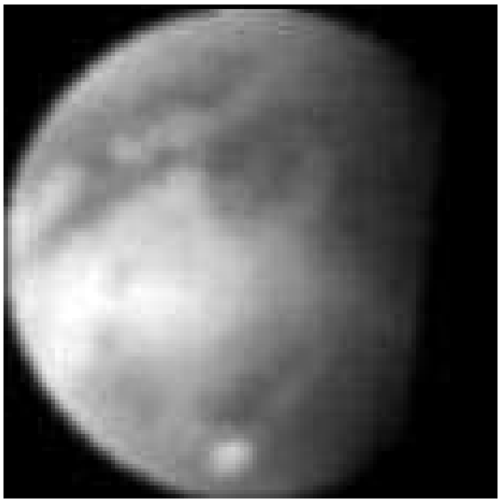

Fig. 1. VIMS Cassini image obtained by displaying the ratio of the bands 2.029/2.046μm- Elaboration by R. Jauman

revealed as an hot spot on the surface by VIMS, and only after a detailed analysis, interpreted as a volcano. The presence of volcanic activity can help in putting in relation the Titan interior, where most of the hydrocarbons should possibly reside, with the surface and, therefore with the atmosphere. The absence of an extended ocean on the Titan surface, able feed the carbon compound rich atmosphere (Hunter et al., 2005), that continuously looses methane through photodissociation (Lorenz et al. 2003) , has pushed the theoreticians to look for a subsurface reservoir. However some fluid on the surface seem to be still present, as indicated by the radar images collected by the Cassini spacecraft on Sept. 7, 2005, in which a shoreline seems to be present. The Titan soil could be also imbedded of hydrocarbons, that precipitate or sublimate, depending on the local thermodynamic conditions.

3. Icy Satellites

Saturn's 34 known moons, and all moons are unique and intriguing science targets. The small satellites, like Pan, Atlas, Prometheus, and Pandora, are "shepherd moons" that herd Saturn's orbiting particles into distinct ring.

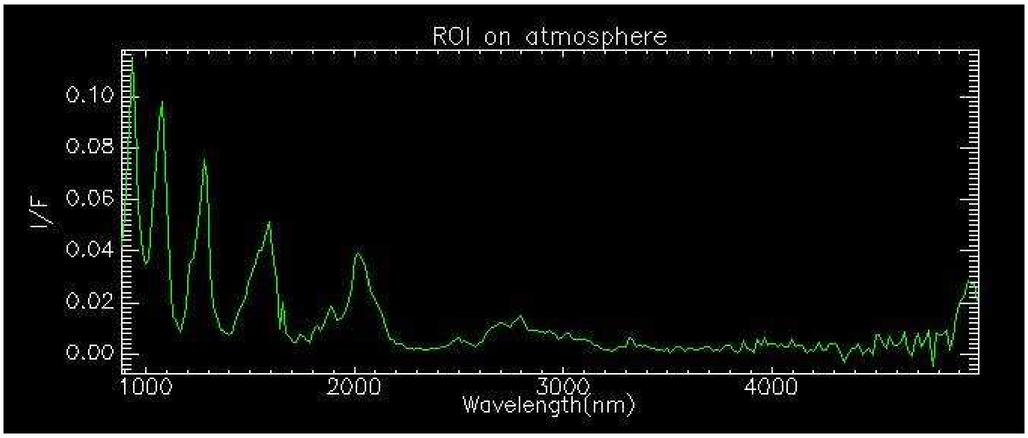

Fig. 2. VIMS Cassini spectrum of the Titan atmosphere where are apparent the methane band that are responsible for most of the Sun light absorption in the Titan atmosphere. However, the "non-absorbed" are pretty narrow, and don't allow to identify easily the Titan surface composition.

Some moons produce twisting and wave patterns in the rings. However, the most intriguing object are actually the large icy satellites (Porco et al. 2005a). *Phoebe*, the first satellite encountered, rich in water ice, and characterized also by the presence of CO_2 and other carbon-bearing molecules, has been interpreted as a captured Kuiper Belt object (Porco et al. 2005a).

Enceladus, is covered with water ice that reflects sunlight, and is the source of the E-ring. The high resolution images of the Enceladus polar area have revealed the presence of long linear bluish features that seem to be characterized by the presence of crystalline water ice. These areas are apparently warm, as shown by the CIRS long range infrared spectrometer of Cassini (Kerr, 2005b). These combined observations have been interpreted as fractures of the icy surface of Enceladus from which hotter (relatively- the temperature shall be around 170 K in the subsurface accordingly with the recent models by) water reaches the surface, where is iced again. This phenomenon is accompanied possibly by water ice sublimation, that is lost by the small satellite and gives rise to the E-ring. *Iapetus* has one side black as asphalt and the other as bright as snow. The 1st of January 2004, Cassini flew past Saturn's intriguing moon Iapetus, capturing visible light images. The scene is dominated by a dark, heavily-cratered region, called Cassini Regio, that covers nearly an entire hemisphere of Iapetus (1,436 kilometers). The most intriguing feature discovered on Iapetus by Cassini ISS is a topographic ridge extended along the satellite geographic equator. The physical origin of the ridge is not clear, and could be attributed to a compression process to or an extensional process that cracks the surface and through which material from inside Iapetus erupted onto he surface. *Hyperion* is also different from all the observed Saturn satellites. The images show a largely cratered surface, where the crates were filled with same unknown dark material. The last images, obtained during Cassini's very close flyby on September 26th , 2005, show a very unusual "sponge" surface (see figure 3). The images are too recent to try an interpretation, and have been added in order to show the diversity of the different "cratered" surfaces of the icy satellites

4. Saturn

Saturn is made up mainly of hydrogen and helium gases. Saturn's interior is similar to Jupiter's, consisting of a rocky core much like the size of Earth, a liquid metallic hydrogen layer and a molecular hydrogen layer. Traces

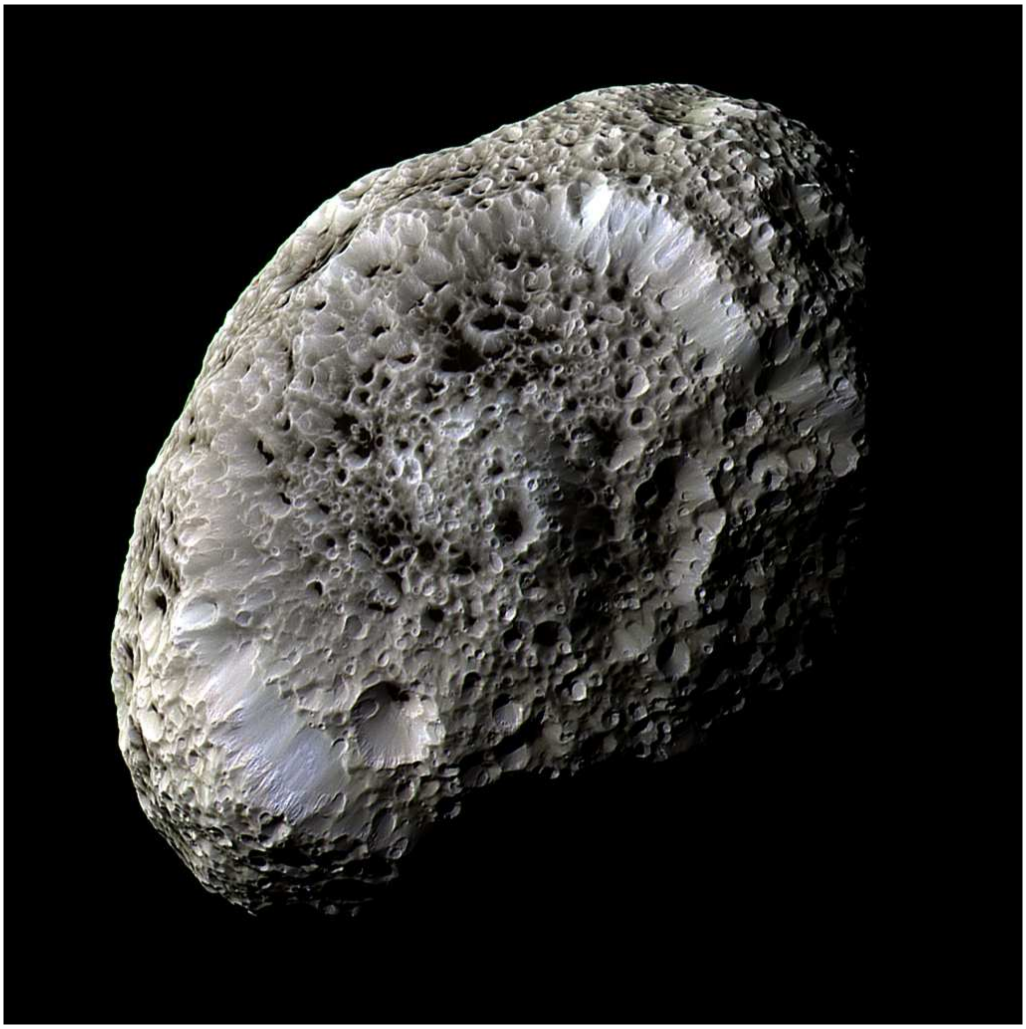

Fig. 3. The false-color view of Hyperion reveals differences in color across the moon's surface that could represent differences in the composition of surface materials.

of various ices are also present. One of the main goals of the Cassini mission, as far as Saturn is concerned, is the determination of the internal structure, and in particular of the size of the rocky core. The problem of the Saturn core size is extremely important in terms of deciphering what is the most probable origin of giant planets. At present the most accepted theory foresees the formation of the core, at first, and only later the acquisition of nebular gas. However the incertitude on the core size don't allow to exclude completely the possibility of a gas instability. This determination will be possible thanks to the complex radio-science experiment that the mission hosts. The determination of the masses and gravity fields of Saturn as well as Saturn's icy satellites will be performed through two-way tracking during fly-bys. The Cassini spacecraft is the first Radio Science platform to provide three downlink frequencies. In addition to the X-band telemetry link (3,56 cm w.l.), two other frequencies, S-band (13.04 cm), and Ka-band

(0.94 cm) are available. This, plus the high SNR (>50 dB Hz at X-band) afforded by the 4 m diameter s/c high gain antenna in combination with the excellent low noise receivers of the DSN, as well as overall system stabilities of 1 x 10^{-13} when referenced to the on-board ultra-stable oscillator (USO) in one-way operation, and 1 x 10^{-15} for a two-way link, make Cassini an unprecedented instrument of radio science. At present two main discoveries were performed by Cassini: 1) the determination of the winds velocity, that can reach, in Saturn's upper atmosphere, speeds of 1,800 kilometers per hour at the equator. These super-fast winds, combined with heat rising from within the planet's interior, cause the yellow and gold bands visible in Saturn's atmosphere. 2) the discovery of Saturn's new radiation belt. A new and completely unexpected radiation belt was discovered around Saturn between the inner edge of the D ring and the top of Saturn's atmosphere. Moreover, the entire northern hemisphere of Saturn has a completely new look since the Voyager encounters. It now appears deep blue, much like the deep, clear atmospheres of Uranus and Neptune. The shadow of the rings on the northern hemisphere probably cools it down, so the tan clouds sink to depths where they are no longer visible. Powerful lightning storms occur in huge, deep thunderstorm columns. The storms occasionally boil up to the visible surface. Concluding, we are only at the beginning of the Cassini mission. The elaboration of the data already obtained is not yet completed. We are only at the beginning of the story, since the nominal mission will last three more years, and the extended mission, if everything goes correctly, four more years. The next years will give to the scientific community a new view of the Saturn universe.

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