EPSC Abstracts
Vol. 11, EPSC2017-367, 2017
European Planetary Science Congress 2017


# Cassini: Going out in a Science-Rich Blaze of Glory

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## Abstract

After 13 years in orbit, the Cassini-Huygens Mission to Saturn, a collaboration of NASA, ESA, and ASI, ended in a science-rich blaze of glory. Cassini sent back its final bits of unique science data on September 2017, as it plunged into Saturn's atmosphere, vaporizing and satisfying planetary protection requirements. Before that time Cassini made amazing new science discoveries. The science highlights of the Ring Grazing and Grand Finale orbits will be discussed.

## 1. Saturn System Exploration

Cassini's exploration of the Saturn System is composed of five broad, overlapping scientific disciplines: Titan, the atmosphere of Saturn, rings, magnetosphere, and icy satellites.

In each area, Cassini made major discoveries, provided answers to old questions, and posed new questions that could only be answered in the mission's final orbits. Among many firsts, Cassini: discovered icy jets of material streaming from tiny Enceladus' south pole, revealed a global ocean underneath its icy crust, found evidence for active hydrothermal vents on its seafloor and revealed an ocean world that was potentially habitable. Enceladus is the source of the E Ring and water from its jets dominates the magnetosphere. Cassini also found hydrocarbon lakes and seas on Titan; detected a sub-surface ocean Titan as well; provided multi-wavelength coverage of a great northern storm, the first of its kind on Saturn since 1990; demonstrated that the Saturn Kilometric Radiation period does not reflect the planet's internal rotation; revealed curtain-like aurorae and their true color flickering over Saturn's poles;; and constrained and complicated our understanding of the 3D structure and dynamics of multi-particle ring systems. In addition, the Huygens probe sent back amazing images of Titan's surface and made detailed measurements of atmospheric composition, structure and winds. Cassini's ocean world discoveries required a mission end that would not allow the spacecraft to impact and potentially contaminate these worlds once Cassini was out of fuel and could no longer navigate the Saturn system.

In its final year, Cassini completed its investigation of the Saturn system throughout half the planet's year. During this time, Cassini's science instruments probed as-yet unsolved mysteries, observed seasonal and temporal changes, and addressed new questions that have arisen during the mission.

## 2. Ring Grazing and Grand Finale Orbits

The final phase of Cassini's mission covered a period of roughly ten months and ended with the exploration for the first time of the region between the rings and planet, a rich source for discovery.

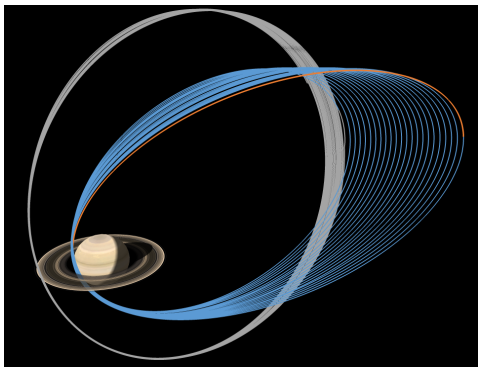

Figure 1: Cassini's 20 Ring Grazing (gray) and Grand Finale (blue) orbits. The last orbit (orange) will take Cassini into Saturn's atmosphere for vaporization.

In November 2016, Cassini transitioned to a series of 20 Ring Grazing orbits with peripases just outside Saturn's F ring (Figure 1, gray orbits). These orbits included close flybys of tiny ring moons, including Pan, Daphnis and Atlas, and excellent views of Saturn's F ring and outer A ring. The 127th and final close flyby of Titan propelled Cassini across Saturn's main rings and into its Grand Finale orbits.

Cassini's Grand Finale, began in late April 2017. It was comprised of 22 orbits at an inclination of 63 degrees (Figure 1, blue orbits). Cassini repeatedly dove between Saturn's innermost rings and upper atmosphere providing insights into fundamental questions unattainable during the rest of the mission. Cassini was the first spacecraft to explore this region. The last orbit took the spacecraft into Saturn on 15 September 2017, where it was vaporized by the planet's atmosphere.

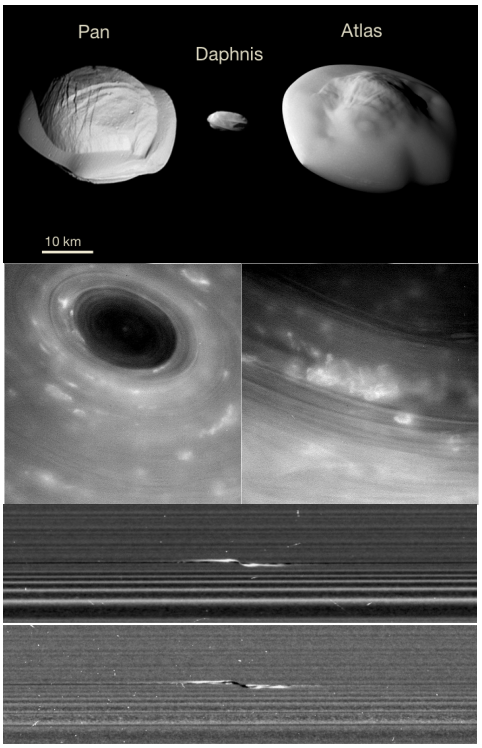


Figure 2: Comparison of the ring moons, Pan, Daphnis, and Atlas (above). Saturn's north polar vortex (middle left) and convective clouds over the hexagon jet stream (middle right). Ring propeller Santos-Dumont on lit (top) and unlit (bottom) sides of the rings.

The Grand Finale orbits provided the highest resolution observations of both the rings and Saturn, and direct in-situ sampling of the ring particle composition, plasma, Saturn's exosphere and the innermost radiation belts. Saturn's gravitational field was measured to unprecedented accuracy, providing information on the interior structure of the planet, winds in the outer layers of Saturn's atmosphere, and the mass distribution in the rings. Probing the magnetic field provided insight into the nature of the magnetic dynamo, and the structure of the internal magnetic field. The ion and neutral mass spectrometer sampled the exosphere and upper atmosphere for molecules that escape the atmosphere itself and water-based molecules originating from the rings. The cosmic dust analyzer directly sampled the composition of main ring particles for the first time from different parts of the main rings. Until the execution of these final orbits, the answers to such new questions remained mysteries.

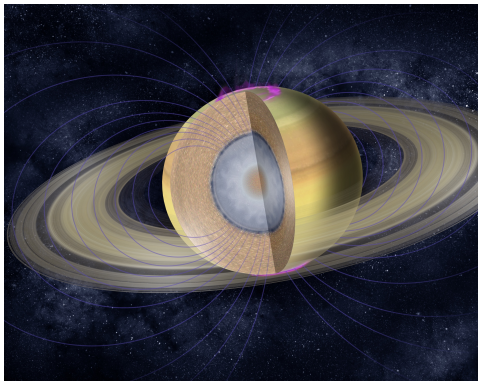

Figure 3: Grand Finale science goals focus on studying ring mass and composition, interior structure, magnetic dynamo, aurora, and atmospheric composition.

## 3. Summary and Conclusions

Cassini-Huygens exploration of Saturn has yielded 13 years of unprecedented discoveries, and answers to many scientific mysteries. The Ring Grazing and Grand Finale orbits returned unprecedented new science.

## Acknowledgements

This work described here was carried out in part at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. 