Cassini’s Coolest Results for Icy Moons during the Past Two Years

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Summary of Talk

- Review of targeted flybys of the last two years
- Review of small moons ("rocks") flybys
- Scientific results
- End-of-Mission: what’s coming up
  - Monitoring jets and plumes on Enceladus
  - Spectacular flybys of small moons
## The final flybys: Dione and Enceladus

<table>
<thead>
<tr>
<th>Flyby</th>
<th>Object</th>
<th>Date</th>
<th>Distance</th>
<th>Flavor</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>D4</td>
<td>Dione</td>
<td>06/16/15</td>
<td>516 km</td>
<td>Fields &amp; Dust</td>
<td>Understand the particle environment</td>
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<tr>
<td>D5</td>
<td>Dione</td>
<td>08/17/15</td>
<td>475 km</td>
<td>Gravity</td>
<td>Understand the interior of Dione</td>
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<tr>
<td>E20</td>
<td>Enceladus</td>
<td>10/14/15</td>
<td>1842 km</td>
<td>Imaging</td>
<td>Map the N. Pole of Enceladus</td>
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<tr>
<td>E21</td>
<td>Enceladus</td>
<td>10/28/15</td>
<td>53 km</td>
<td>Fields &amp; Dust</td>
<td>Understand the particle environment</td>
</tr>
<tr>
<td>E22</td>
<td>Enceladus</td>
<td>12/19/15</td>
<td>5003</td>
<td>Imaging</td>
<td>Understand energy balance and change</td>
</tr>
</tbody>
</table>
Small Moons ("Rocks") Best-ever Flybys on Dec. 6, 2015

Prometheus: 86 km wide; 37,000 km away

Atlas: 30 km; 32,000 km

Epimetheus: 86 km; 35,000 km

Note that any data presented here are unpublished, minimally processed, and undergoing refinement and analysis.

A view of Enceladus southern region taken during Cassini’s final close encounter with the enigmatic moon. Saturn can be seen in the lower background.

Image of Samarkand Sulci, obtained during the E22 flyby at a distance of about 12,000 km. “Dalmatian” spots appear as a new intriguing feature.

Thermal image of Damascus Sulcus, one of the four Tiger Stripes near the south pole.
Global Ocean Inside Enceladus

- Cassini imaging observations of Enceladus’ rotation and its wobble (libration) as it orbits Saturn revealed the presence of a global ocean\(^1\).

- This discovery, together with this year’s discovery of seafloor hydrothermal activity\(^2,3\), indicates that ocean could be long-lived. Enceladus, the "ocean world," invites exploration.

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\(^1\)"Enceladus’s measured physical libration requires a global subsurface ocean," P.C. Thomas, et al., 2015. doi:10.1016/j.icarus.2015.08.037


Unexpected Red Streaks on Tethys

Paul Schenk, ongoing work
Scientists have identified 101 distinct geysers erupting on Saturn's icy moon Enceladus in Cassini spacecraft images. Analysis strongly suggests the source of the eruptions is the potentially habitable sea beneath the moon's south polar ice shell.

The geysers spray icy particles, water vapor, and organic compounds. Scientists have found the geysers themselves are the source of the heat detected by Cassini's thermal instruments. Vapor condenses on fissure walls, releasing heat to the surface.

An alternate theory: curtains of emission

Cassini image (brightness enhanced)

Simulation of curtain eruption overlaid on Cassini image

Spitale et al. (2015) Nature
Cassini has found the first evidence of active seafloor hydrothermal vents, where seawater and the rocky core meet to form warm mineral-laden liquid, on Saturn’s moon Enceladus. This new finding provides additional evidence for Enceladus’ ocean as a possible habitat for life.

The Cosmic Dust Analyzer (CDA) has also detected tiny mineral particles in the plumes. They likely originate in the seafloor vents, which are similar to those in the Atlantic Ocean. These vents are ideal venues to life to arise.


A new analysis of Cassini VIMS data show the existence of trace organic molecules on Saturn's moon Iapetus: both aromatic and aliphatic hydrocarbon materials. The aromatics probably contain Polycyclic-Aromatic Hydrocarbons (PAH) and that the aromatic molecules are about ten times more abundant than aliphatic molecules, which is unusual. This is higher than observed in interstellar dust. The origin of the organic molecules may be from Saturn's moon Phoebe, whose dust is impacting the surface of Iapetus. Solar ultraviolet light would destroy organic molecules, implying the organic molecules are continuously recoating the surface, and the source probably is from the interior of Phoebe, thus very primitive material.

The Hyperion Observing Campaign

• There was a campaign of observations of Hyperion, the odd, “spongy” moon of Saturn in a chaotic rotation state.

• Studying previous measurements, Cassini detected a charged surface on Hyperion. The only other known object in such a state is our own Moon. A combination of the solar wind and Saturn’s magnetic field cause the charging.
Named for the Lakota spider-god “Inktomi,” this long-legged crater stretches across most of the leading face of Saturn’s icy moon Rhea.

Infrared measurements from Cassini show that Inktomi’s icy splatter cools down more slowly at night than its surroundings. This means the Inktomi debris is either denser or made of larger particles, enabling it to retain heat.

Inktomi’s splatter stands out as much warmer than the rest of Rhea’s surface, which is comprised of fluffy, snow-like ice and cools rapidly at night.

We already know that impacts on Earth alter its surface composition. Now we know that the impact that formed Rhea’s creepy crater also changed its surface, from fluffy to snowballs!
Studying extreme conditions allows us to test the limits of our understanding of the solar system. Cassini’s data has revealed two record-breaking icy satellites orbiting Saturn.

Hati: Too fast...

- Hati has the fastest measured rotation of the 44 of Saturn’s 62 known moons studied so far.
- Hati spins so fast that the sun sets almost as soon as it rises (just 5½ hours later). If it was spinning much faster it would likely break up!
- The reason for Hati’s fast spin rate is unknown, but may be a result of its origin.

Rhea: ...Too furiously cold

- Rhea is tied with the permanently shadowed areas of Earth’s moon as the coldest directly observed territory in the solar system. Reflecting most of the sunlight it receives, the winter south-pole temperature is a frosty -415° F (-248° C).
- At these temperatures, most substances are frozen solid - including oxygen and carbon dioxide. Is this where Rhea’s tenuous atmospheric components hide during Rhea’s winter?

Above: Hati’s light curve as observed by Cassini’s imaging camera, from which its rotation period was calculated. Denk, T., and Mottola, S. (2013): AAS/DPS Abstract #406.08

Above: Rhea’s south polar surface temperatures

Right: Coldest directly observed surface temperatures in our solar system

Howett, C.J.A., et al. (2013): AAS/DPS Abstract #406.05
During these passages, Cassini will determine the composition and density of ring particles and of Saturn’s atmosphere, in addition to measuring magnetic and gravity fields probing Saturn’s internal structure and determining the mass of the rings. The spacecraft will continue to monitor jet and plume activity and heat on Enceladus to understand its origin and evolution with time. “Five fabulous flybys” of the small moons – almost a whole new mission – will occur.

Finally, on September 15, 2017, a final plunge into Saturn will vaporize Cassini. The mission’s planned ending protects the potentially habitable oceans underneath the icy crusts of the moons Titan and Enceladus from inadvertent contamination by any Earthly organisms.
Five Fabulous Flybys (Best ever!)

<table>
<thead>
<tr>
<th>Object</th>
<th>Date</th>
<th>Closest approach (km)</th>
</tr>
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<tbody>
<tr>
<td>Pandora</td>
<td>18 Dec 2016</td>
<td>20,000; closest by almost a factor of 3</td>
</tr>
<tr>
<td>Daphnis</td>
<td>16 Jan 2017</td>
<td>17,600; closest by over an order of magnitude</td>
</tr>
<tr>
<td>Epimetheus</td>
<td>30 Jan 2017</td>
<td>5900; closest by factor of 6</td>
</tr>
<tr>
<td>Pan</td>
<td>7 March 2017</td>
<td>25,350; closest by a factor of 2</td>
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<tr>
<td>Atlas</td>
<td>12 April 2017</td>
<td>13,170; Closest by factor of 2</td>
</tr>
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</table>
Summary

• Many more scientific discoveries are waiting to be made in the data already collected.

• The Proximal/F-Ring orbits are a whole new mission, especially with respect to the small moons. One of the goals of the Cassini mission was to understand the structure and evolution of the small moons and their relationship to the rings. The “Final Finale” is the best opportunity to do so.