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

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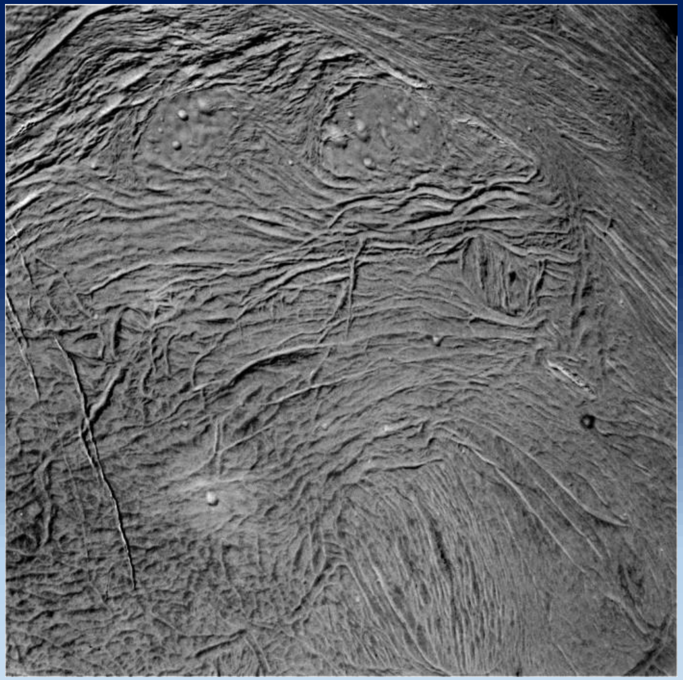
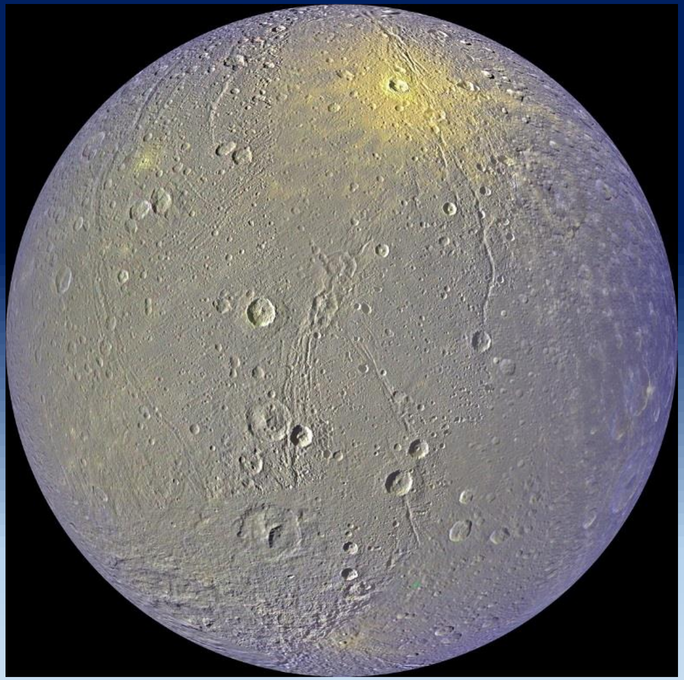
Summary of Talk

- 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

Flyby	Object	Date	Distance	Flavor	Goal
D4	Dione	06/16/15	516 km	Fields&Dust	Understand the particle environment
D5	Dione	08/17/15	475 km	Gravity	Understand the interior of Dione
E20	Enceladus	10/14/15	1842 km	Imaging	Map the N. Pole of Enceladus
E21	Enceladus	10/28/15	53 km	Fields&Dust	Understand the particle environment
E22	Enceladus	12/19/15	5003	Imaging	Understand energy balance and change





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

E22: the last Enceladus Flyby (5003 km) Dec. 19, 2015

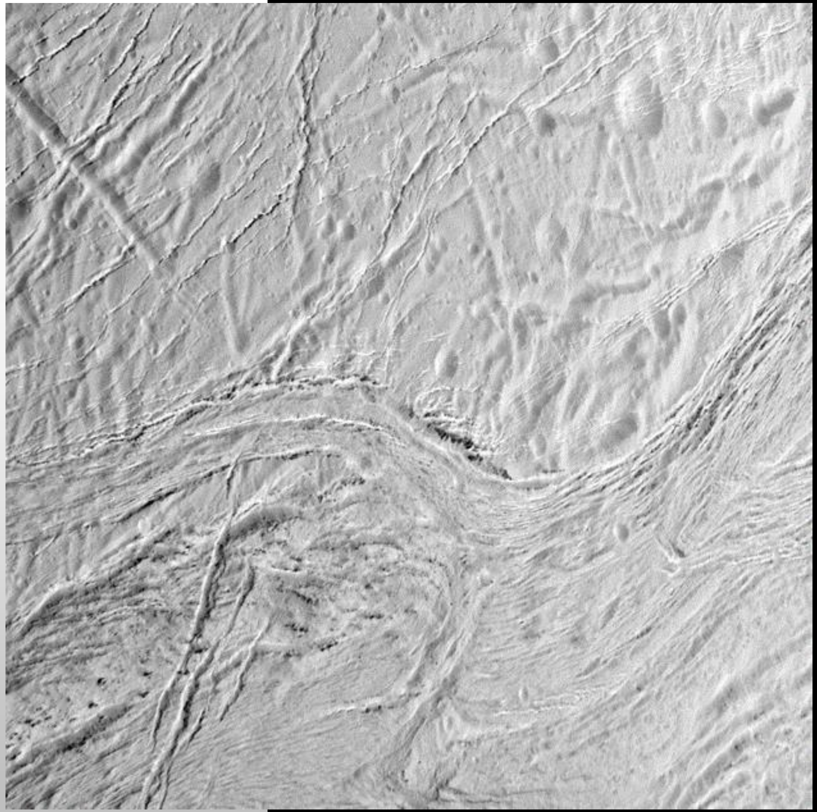
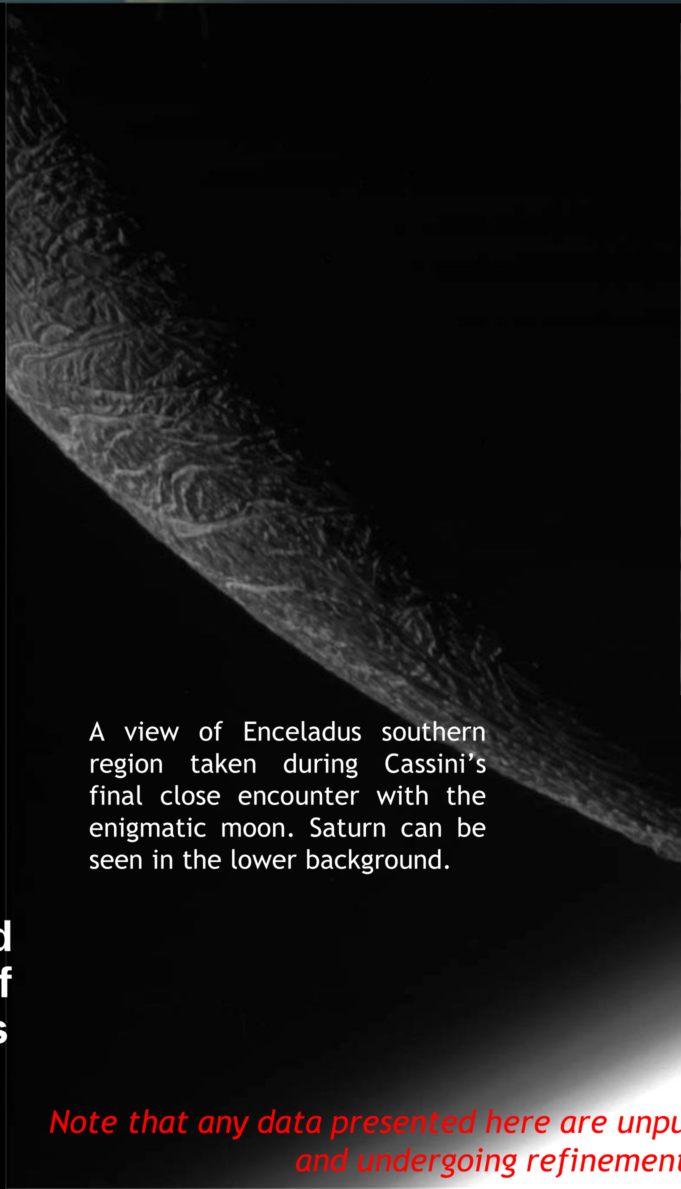
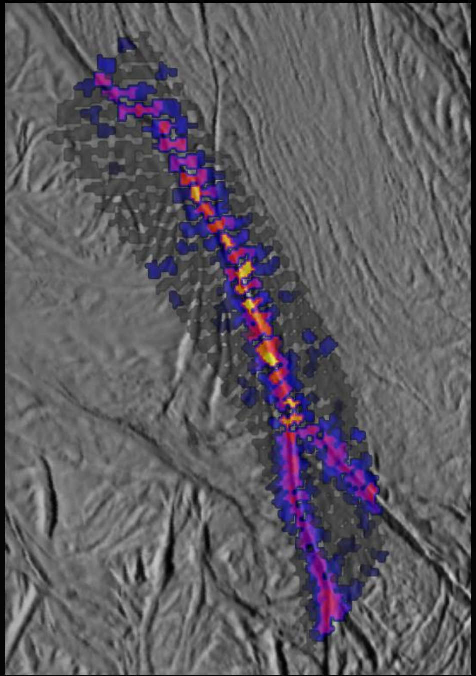


Image of Samarkand Sulci, obtained during the E22 flyby at a distance of about 12,000 km. “Dalmatian” spots appear as a new intriguing feature.



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.



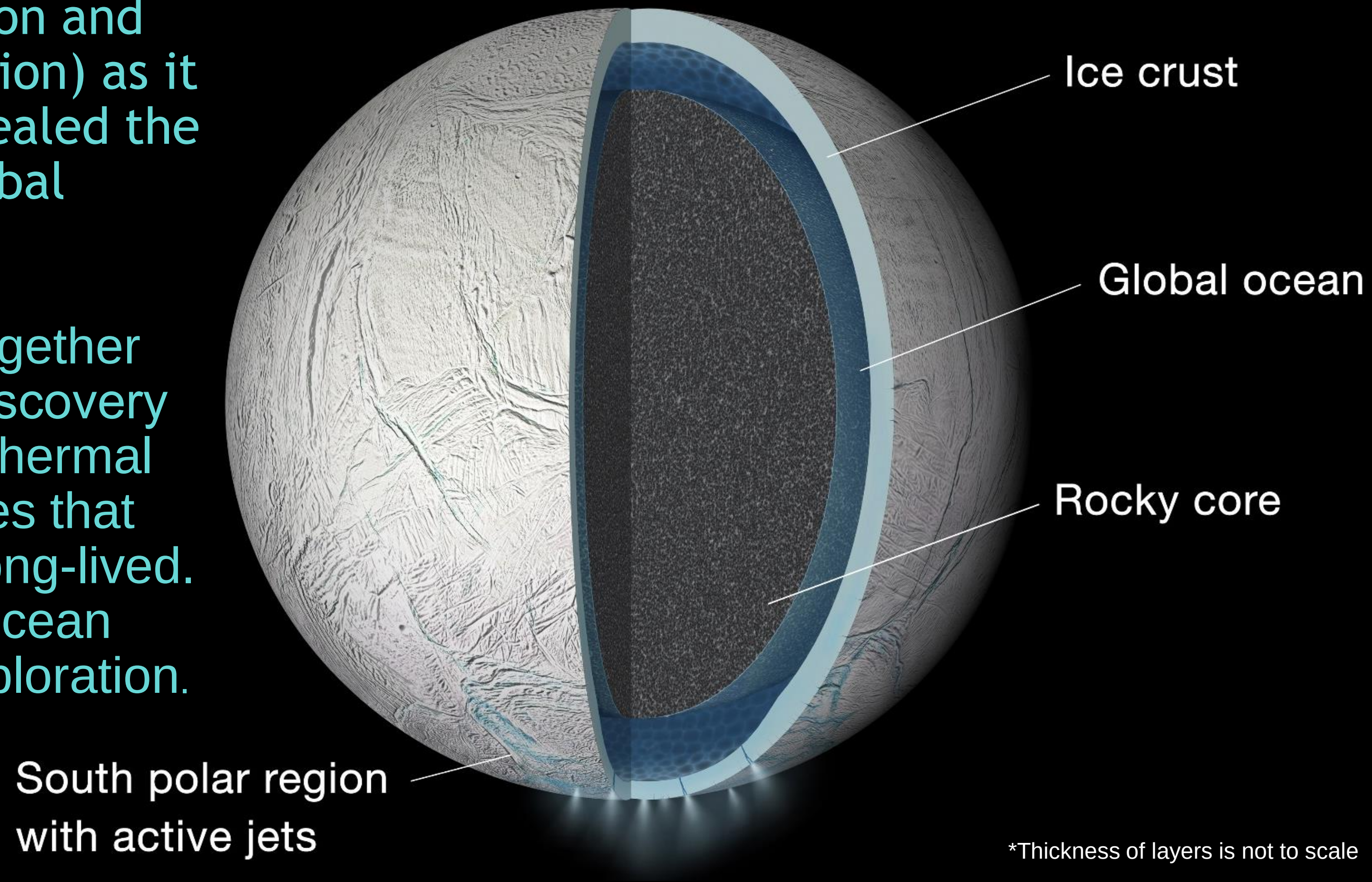
Thermal image of Damascus Sulcus, one of the four Tiger Stripes near the south pole.

Note that any data presented here are unpublished, minimally processed, and undergoing refinement and analysis

Global Ocean Inside Enceladus

Press Release - http://1.usa.gov/1NDHVlV

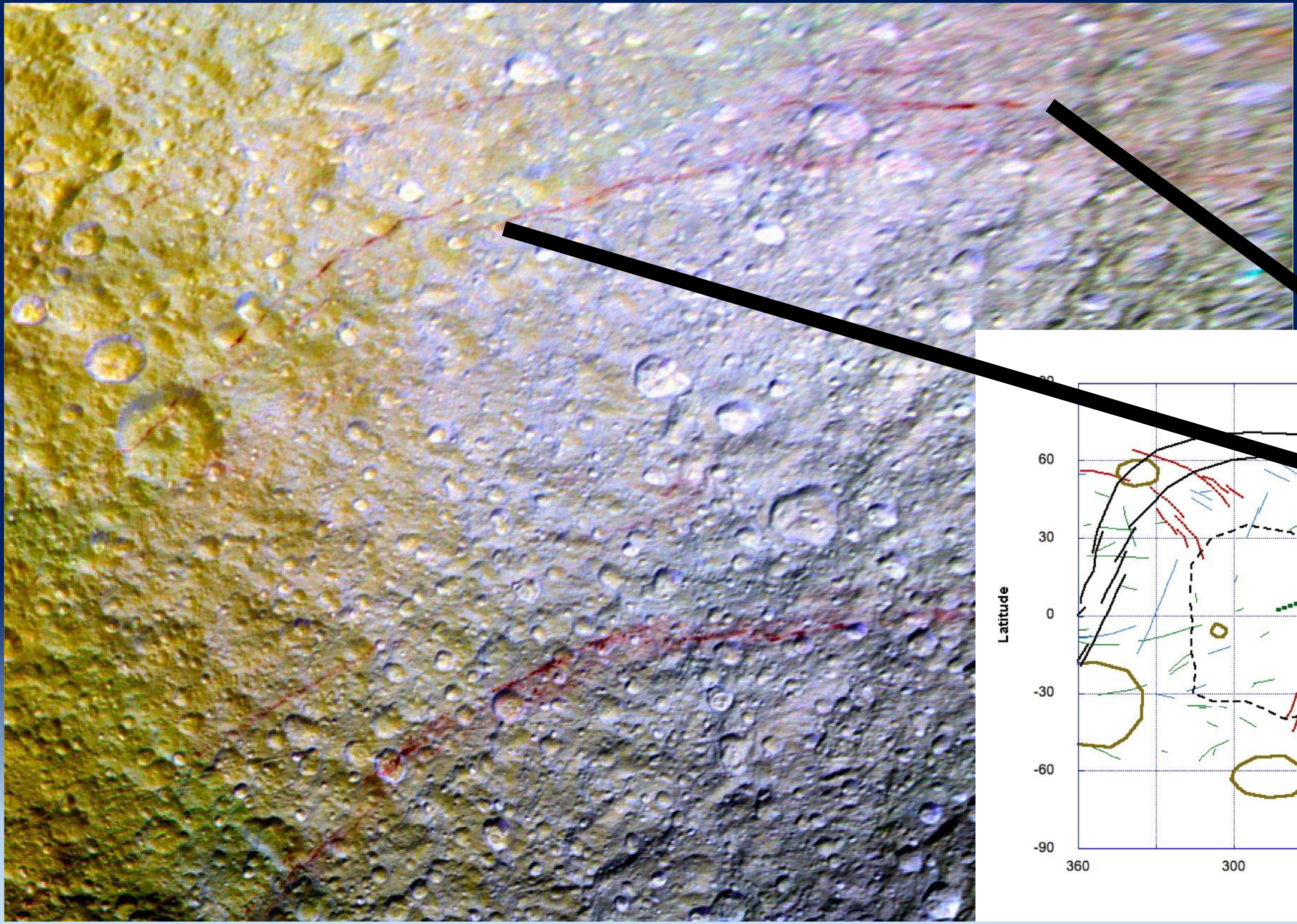
- Cassini imaging observations of Enceladus’ rotation and its wobble (libration) as it orbits Saturn revealed the presence of a global ocean[1].
- This discovery, together with this year’s discovery of seafloor hydrothermal activity[2,3], indicates that ocean could be long-lived. Enceladus, the "ocean world," invites exploration.



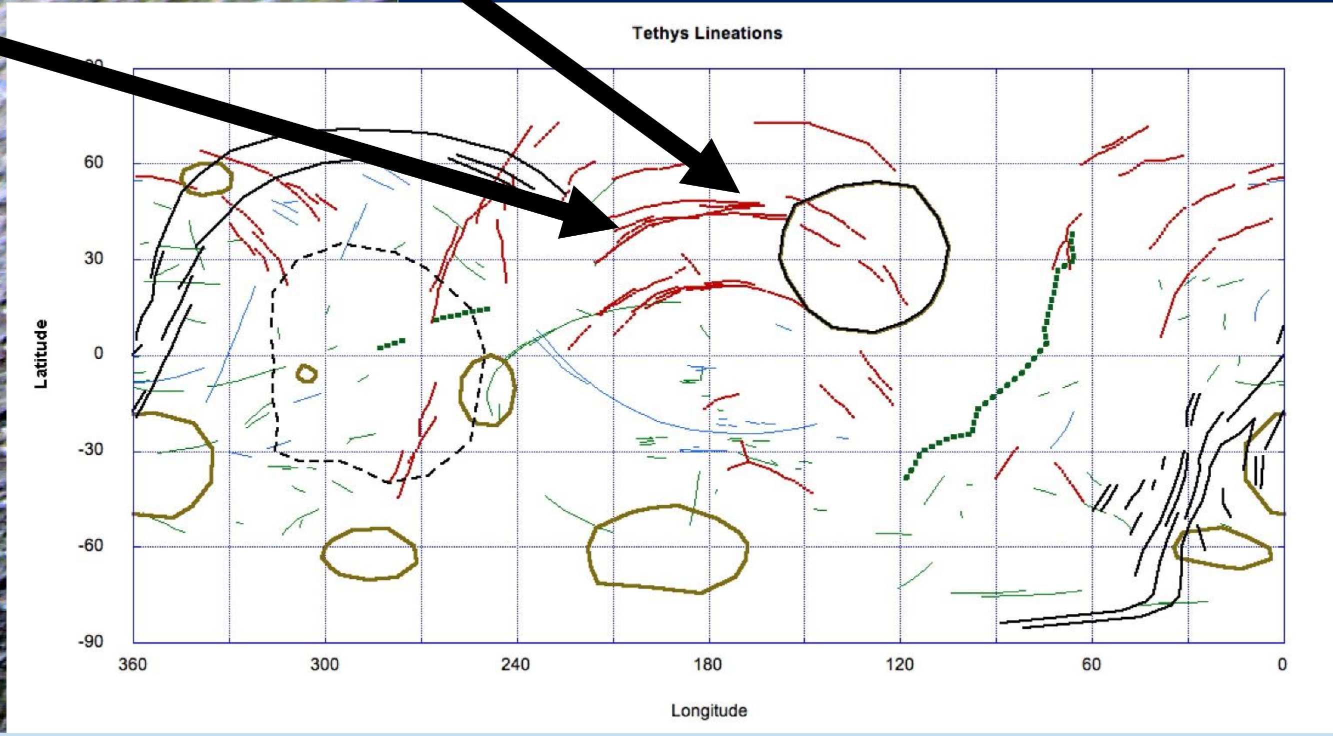
*Thickness of layers is not to scale

[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*
[2] *“Ongoing hydrothermal activities within Enceladus,” Hsu et al., Nature, 519, 207-210, 2015.*
[3] *“Possible evidence for a methane source in Enceladus’ ocean ,” Bouquet et al., Geophysical Research Letters, 42, 1334-1339, 2015.*

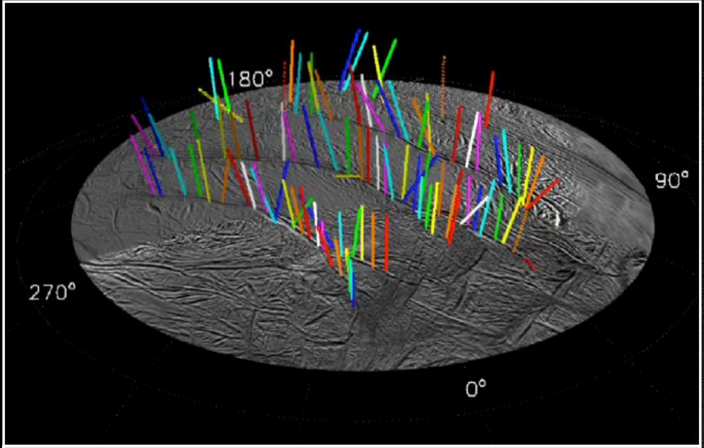
Unexpected Red Streaks on Tethys



Paul Schenk, ongoing work



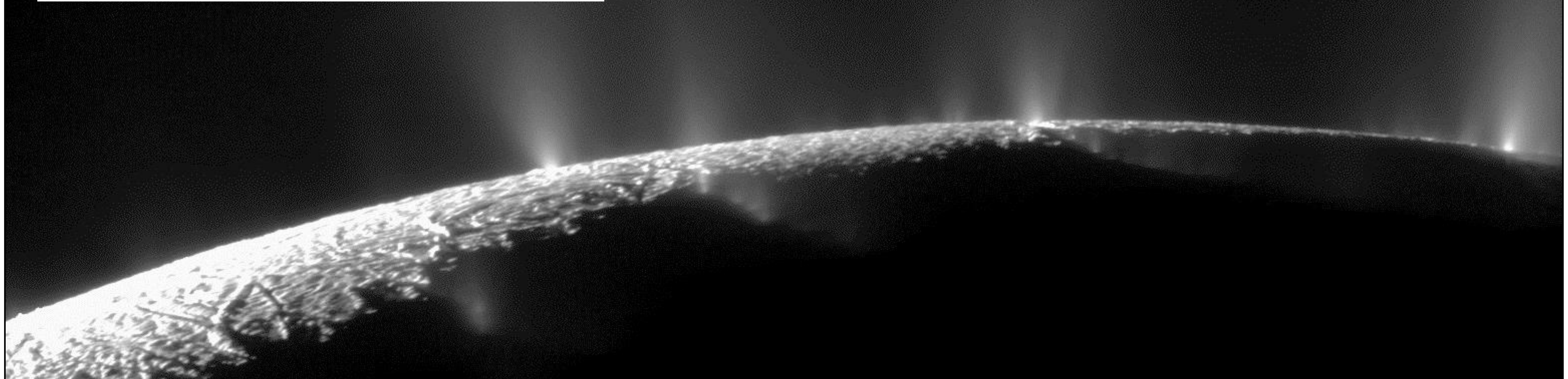
A Little Moon Bursting at the Seams



Vertical lines in this illustration indicate the paths of the icy particles erupting from the surface. Colors in this illustration help differentiate the trajectories of geysers found so far.

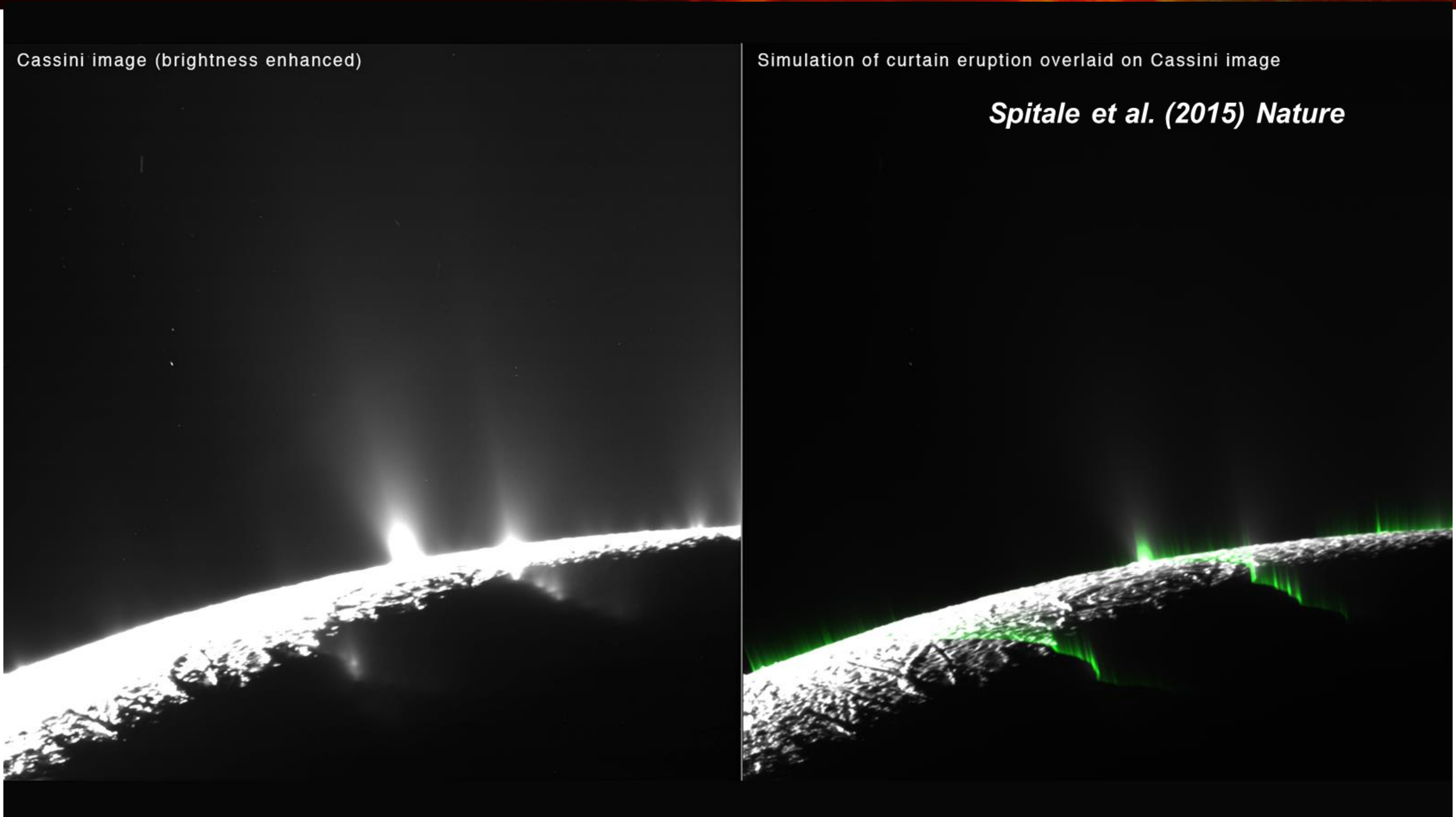
Scientists have identified 101 distinct geysers erupting on Saturn's icy moon Enceladus in Cassini spacecraft images. Analysis strongly suggests the source of the eruptions is the potentially habitable sea beneath the moon’s south polar ice shell.

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.



“How the Geysers, Tidal Stresses, and Thermal Emission Across the South Polar Terrain of Enceladus are Related,” Porco, C. et al. The Astronomical Journal, 148:45 (24pp), 2014, doi:10.1088/0004-6256/148/3/45.

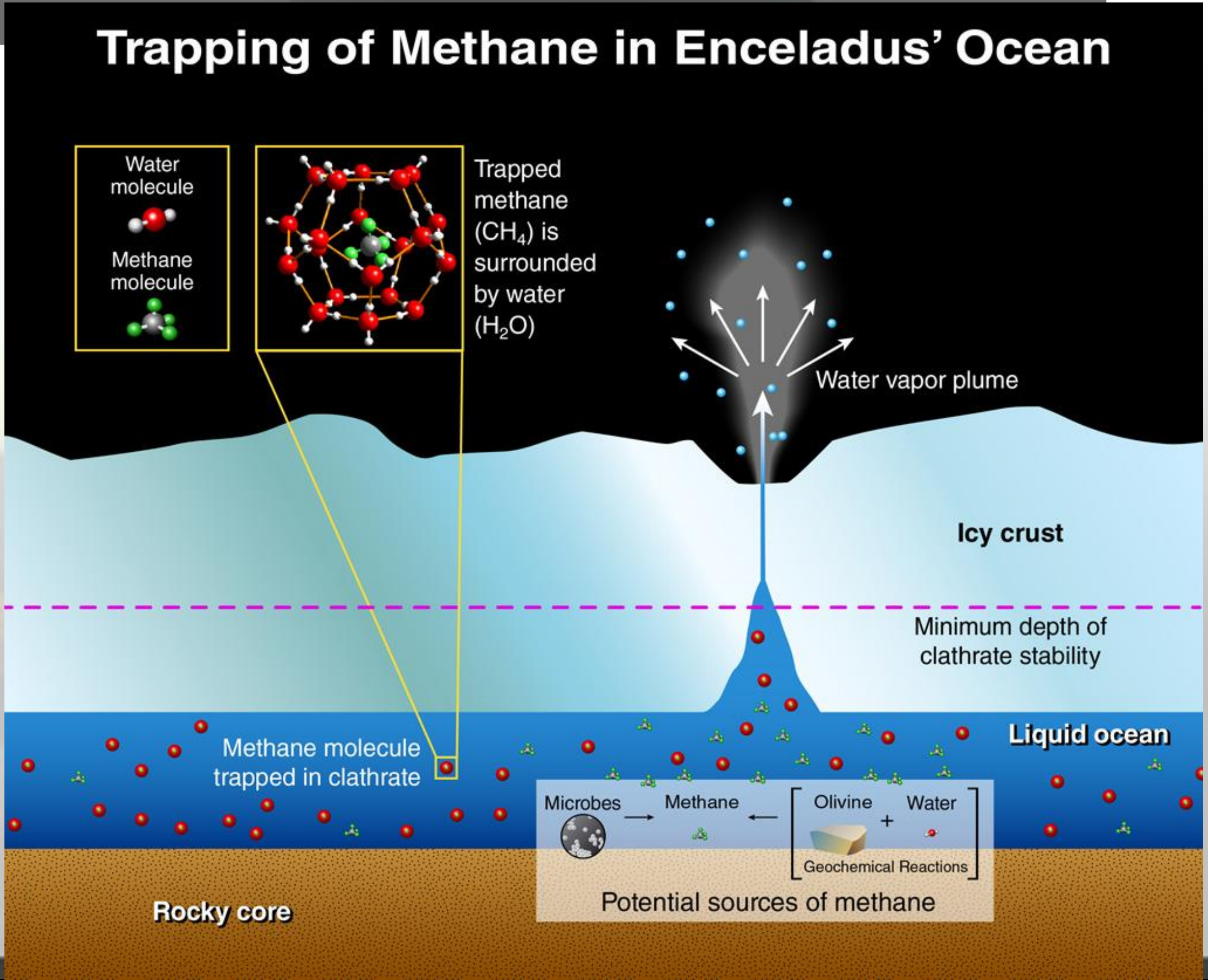
An alternate theory: curtains of emission



Methane and Rock Particles in Enceladus Geysers Likely Originates from Seafloor Vents

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. Thesevents are ideal venues to life to arise.

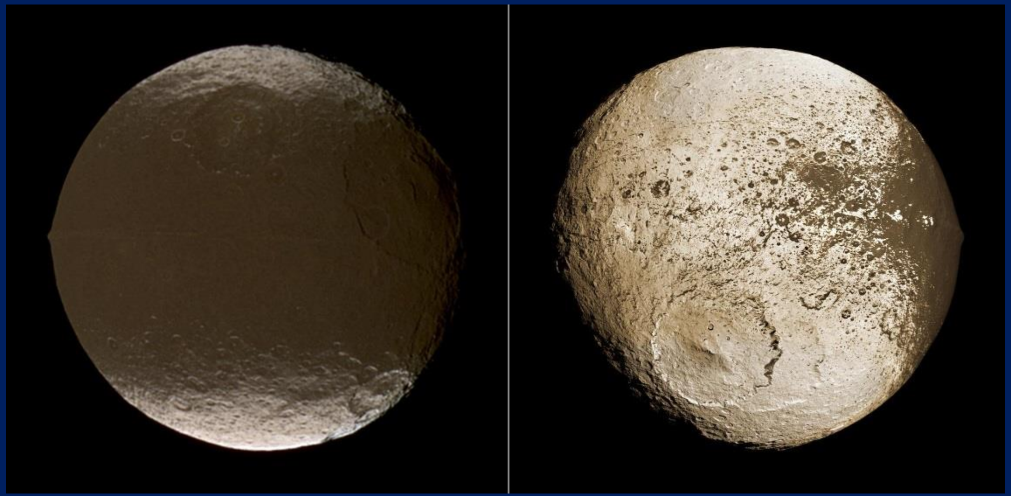


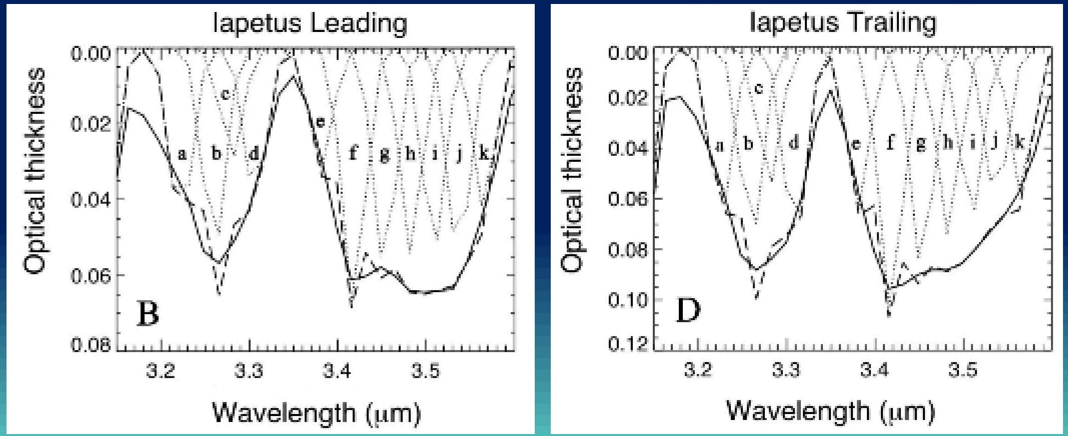
"Possible evidence for a methane source in Enceladus' ocean ," Bouquet *et al.*, *Geophysical Research Letters,* March 12, 2015.

"Ongoing hydrothermal activities within Enceladus," Hsu et al., Nature, March 12, 2015.

Organic Molecules on Saturn's Moon Iapetus

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 probablt contain Polycyclic-Aromatc Hydrocarbos (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.



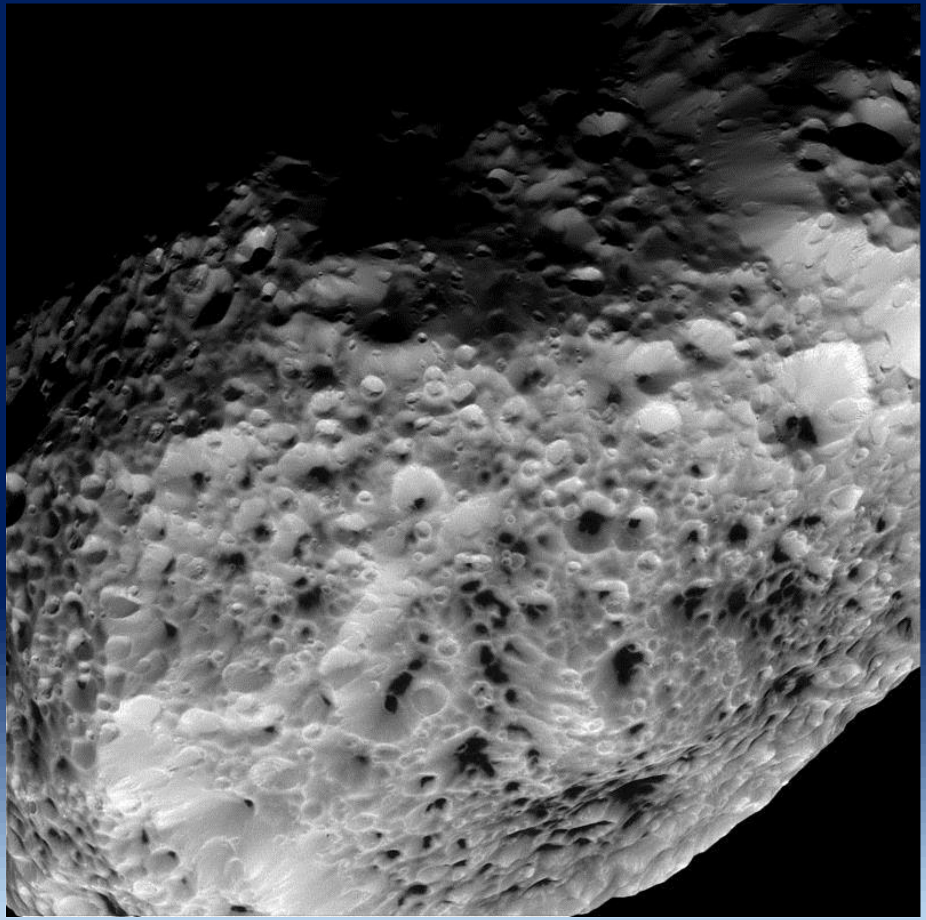


Cassini VIMS spectra showing weak absorption features due to aromatic (left envelope) and aliphatic (right envelope) organic molecules.

Cruikshank, D. P., Dalle Ore, C. M. Clark, R. N., Pendleton, Y. J. 2014. Aromatic and aliphatic organic materials on Iapetus: Analysis of Cassini VIMS data. Icarus 233, 306-315.

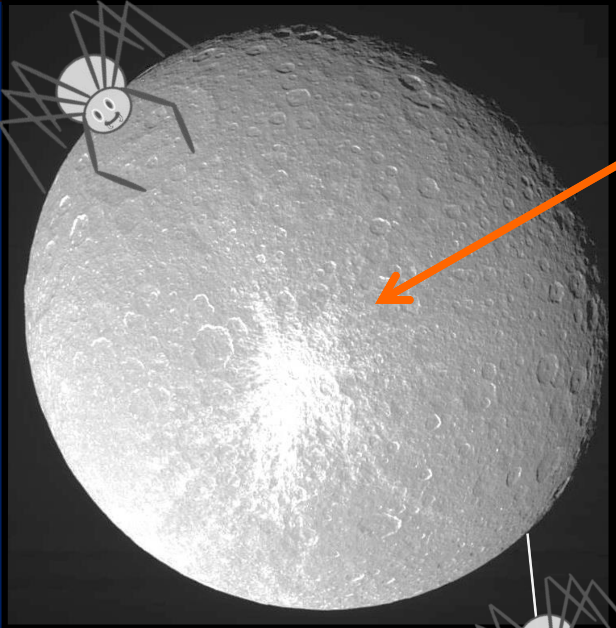
The Hyperion Observing Campaign

- **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 know object in such a state is our own Moon. A combination of the solar wind and Saturn’s magnetic field cause the charging**



May 31, 2015; 38,000 km

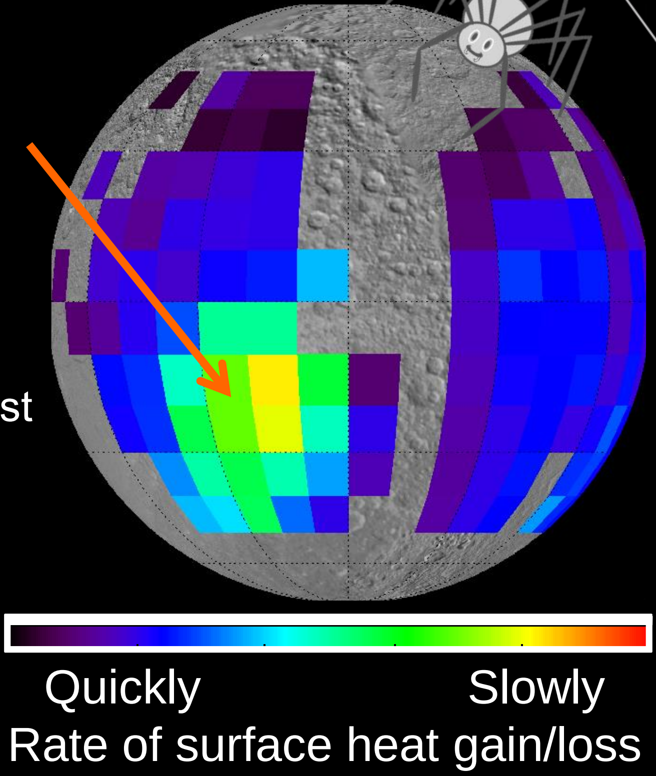
Rhea’s Creepy Crater



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.



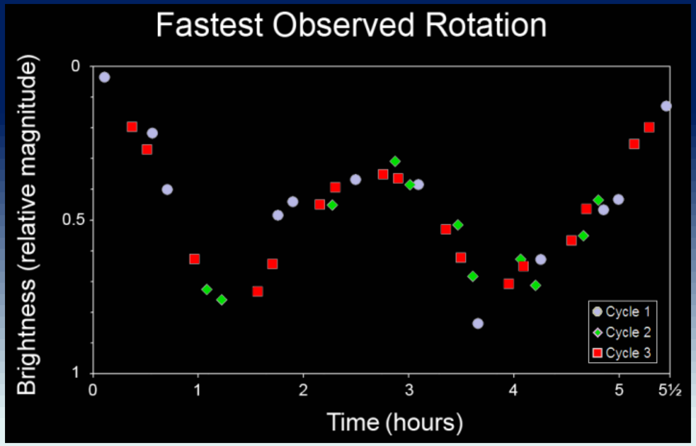
We already know that impacts on Earth alter its surface composition. Now we know that the impact that formed Rhea’s creepy crater also changed its surface, from fluffy to snowballs!

Too Fast and Too Furiously Cold

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...

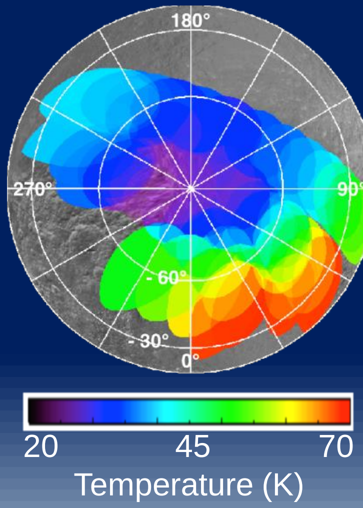
- Hati has the fastest measured rotation of the 44 of Saturn's 62 known moons studied so far.
- Hati spins so fast that the sun sets almost as soon as it rises (just 5½ hours later). If it was spinning much faster it would likely break up!
- The reason for Hati's fast spin rate is unknown, but may be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



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*

Rhea: ...Too furiously cold

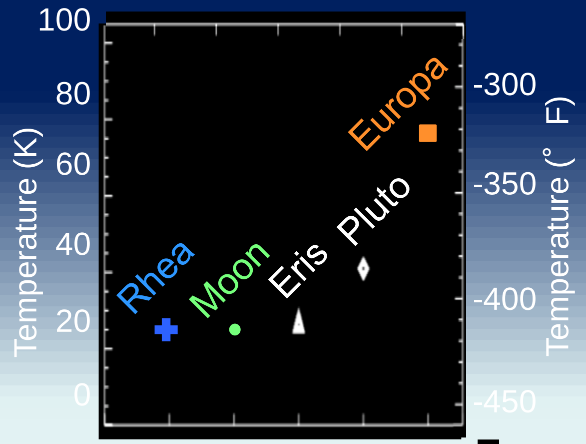
- Rhea is tied with the permanently shadowed areas of Earth's moon as the coldest directly observed territory in the solar system. Reflecting most of the sunlight it receives, the winter south-pole temperature is a frosty -415° F (-248° C).



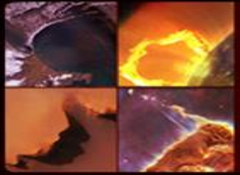
Above: Rhea's south polar surface temperatures

Right: Coldest directly observed surface temperatures in our solar system

- 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?



Howett, C.J.A., et al. (2013): AAS/DPS Abstract #406.05

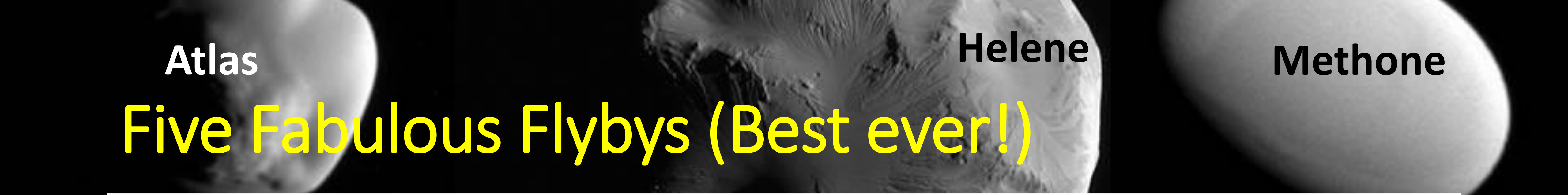


The Best for Last: "Cassini Grand Finale"

"Cassini Grand Finale" is the new name describing Cassini's last, daring set of orbits when the spacecraft's fuel gauge will be nearly on empty. In the spring of 2017, Cassini will embark on repeated dives into the region between the rings and Saturn where no spacecraft has gone before.

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!)

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

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.