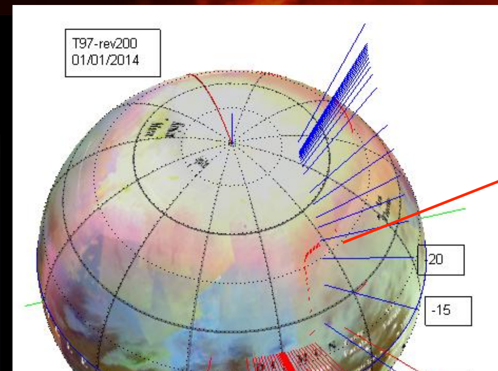
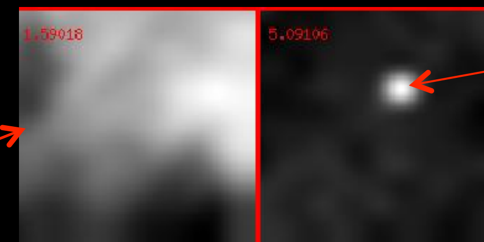
Cassini Solstice Mission

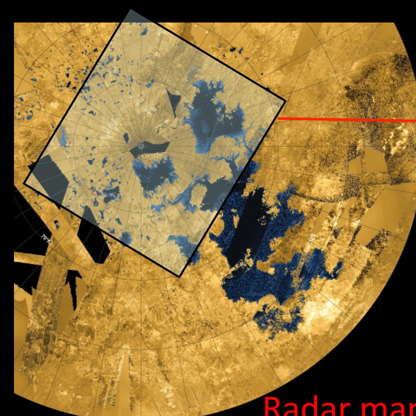
2014: The Year in Nuggets

New Year's Infrared Images from Cassini Titan Flyby

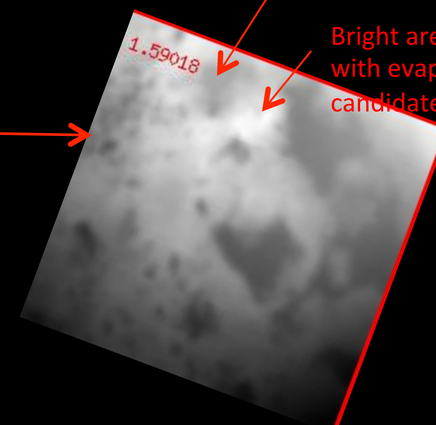




Near-IR and Mid-IR Images



Radar map



High resolution Near-IR Image

Titan's Equator and North Pole in Infrared

Cassini saw an unexpected specular reflection at northern mid-latitudes, mapped seas and lakes at the North Pole at seven different wavelengths, and acquired a high resolution strip of the equatorial region.

Note that the data presented here is minimally processed and is undergoing refinement and analysis

Titan Tectonics: Basin and Range Province?

Yet another remarkable Earth-like similarity has been found on Saturn's cold moon, Titan. Similar tectonic processes to those that created the Basin and Range Province of the Western U.S. may be responsible for Titan's northern cluster of lakes, according to new findings* from NASA's Cassini spacecraft.

Titan is the only world in our solar system other than Earth that has stable liquid on its surface. At –290 F, water on Titan is rock-hard but methane and ethane gases can exist as liquids. Titan's northern methane and ethane lakes are oddly clustered in a near-rectangle roughly the size of Greenland.

What are the geologic processes that are creating large depressions that hold Titan's northern seas in such a limited area? Future Cassini observations may hold the key.

Basin and Range Province of the Western U.S. that consists of roughly parallel mountain ranges with alternating nearly flat basins.
Image Credit: W.B. Hamilton, U.S. Geological Survey

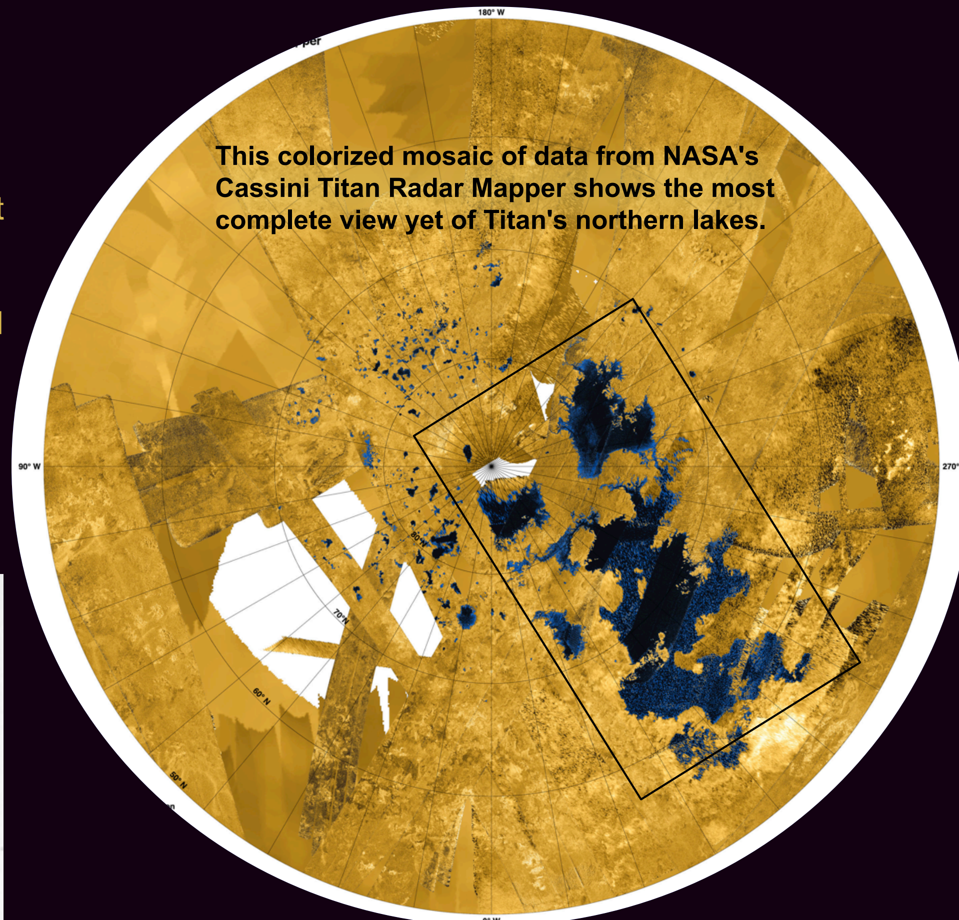
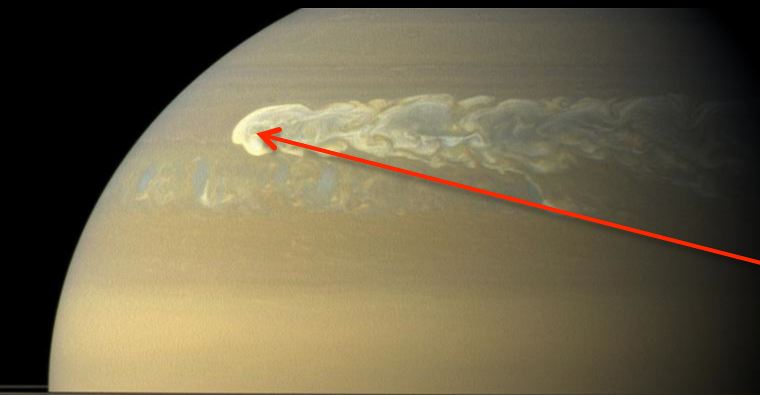


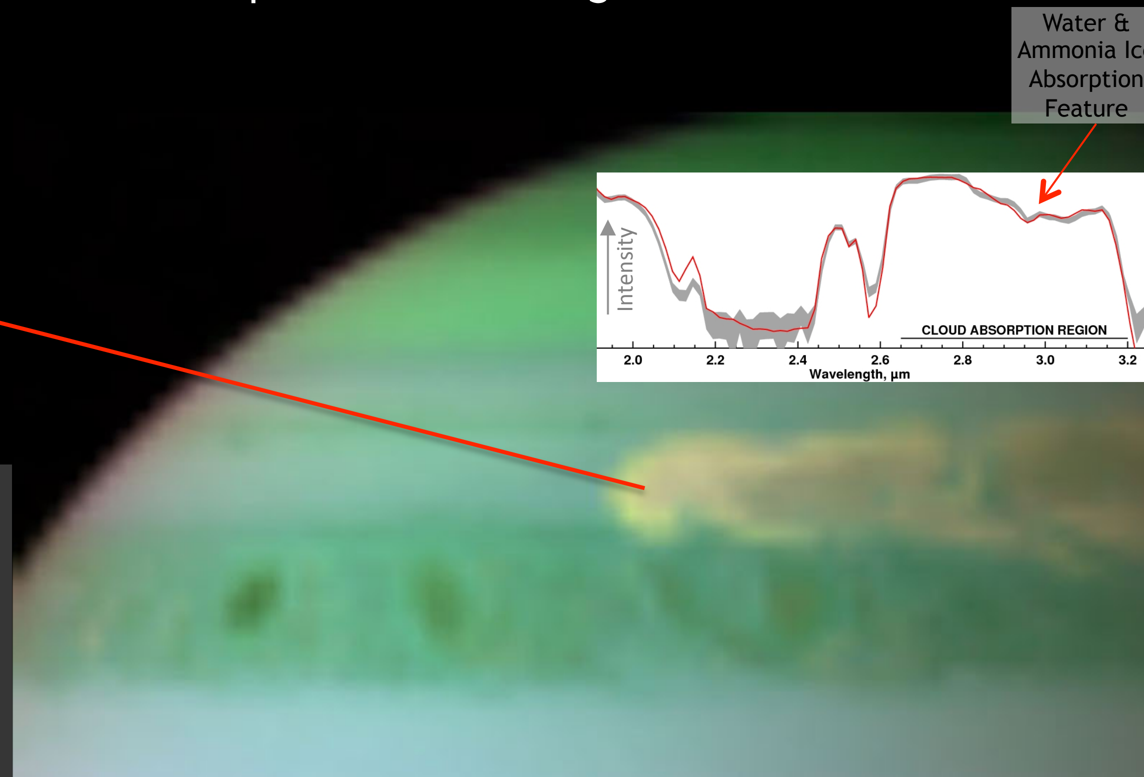
Image Credit: NASA/JPL-Caltech/ASI/USGS

**Cassini RADAR Observes Titan's Kraken Mare, The Largest Extraterrestrial Sea*
R.L. Kirk, *et al.* Presented at American Geophysical Union Fall Meeting, 2013.

First Spectral Identification of Water Ice In Saturn

The monster storm that erupted on Saturn in late 2010 has already impressed researchers with its intensity and long-lived turbulence. Now, scientists studying near-infrared data from NASA's Cassini spacecraft have found that the storm churned up water ice, not normally present in the uppermost clouds, from deep within Saturn's atmosphere. This finding is the first detection of water ice in Saturn's atmosphere.



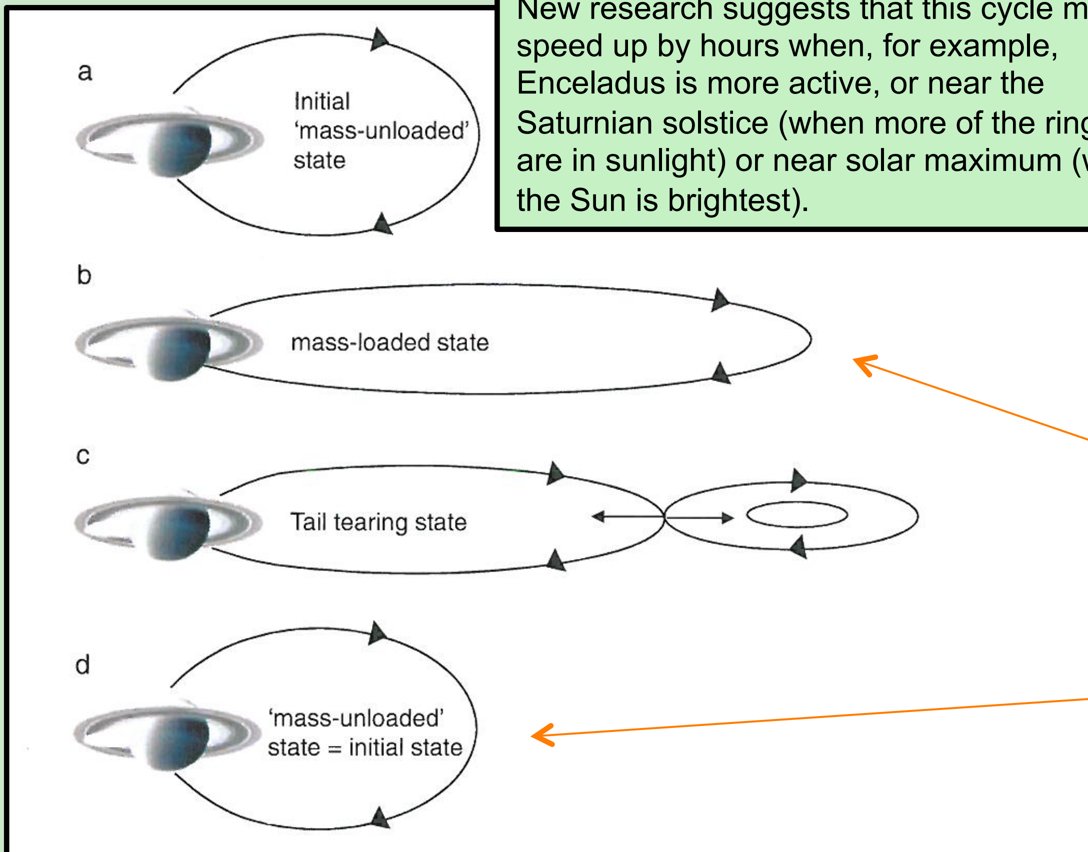


- The visible-light image (left) from Cassini's imaging camera shows giant storm clouds on Feb. 25, 2011.
- The infrared image (right) and spectrum (middle) was obtained a day earlier by Cassini's Visual and Infrared Mapping Spectrometer (VIMS). Together, they show water and ammonia ices dredged up from deep within Saturn's atmosphere.
- The presence of water ice at visible cloud levels requires powerful convection to loft materials from more than 200 km below.

From: *Saturn's Great Storm of 2010-2011: Evidence for ammonia and water ices from analysis of VIMS spectra*, 2013. Icarus 226, 402-418.

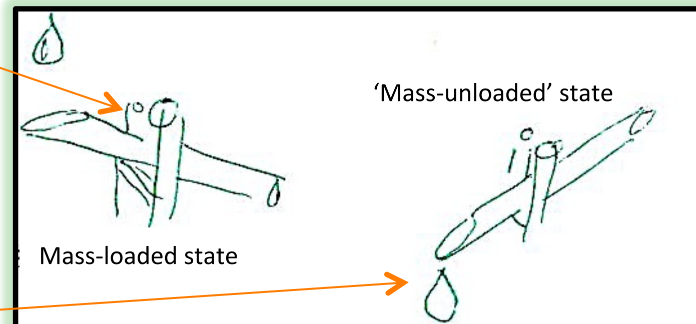
"Shishi Odoshi" Effect Controls the Frequency of Filling and Flushing Saturn's Magnetosphere

Cassini data have shown that Saturn's magnetosphere fills with material from Enceladus' jets and Saturn's rings. Some of this mass becomes ionized by sunlight and migrates to Saturn's night side where it stretches out the magnetotail and is shed from the system. With the mass unloaded, the magnetosphere elastically returns to its co-rotating flow around the planet. The period is estimated to take 8 to 31 hours.



New research suggests that this cycle may speed up by hours when, for example, Enceladus is more active, or near the Saturnian solstice (when more of the rings are in sunlight) or near solar maximum (when the Sun is brightest).

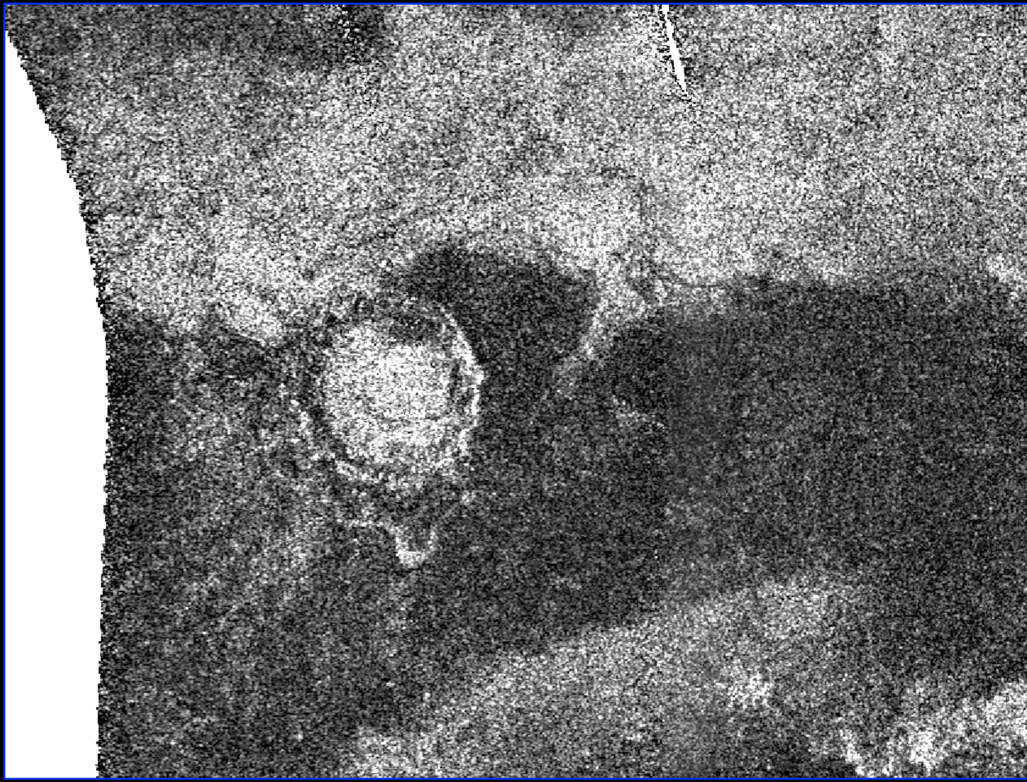
A "shishi odoshi" collects dripping water and when full, tips to empty its load. It returns to its resting state for the process to repeat. A faster flow of water means the bamboo tips more often.



A greater rate of mass flow into Saturn's magnetosphere will increase the frequency of mass unloading and restoration of the magnetosphere to its "refill" state.

"Saturn's Magnetospheric Refresh Rate" A.M. Rymer, D.G. Mitchell, T.W. Hill, E.A Kronberg, N. Krupp and C.M. Jackman, 2013. Geophysical Review Letters, 40, 2479-2483.

Cassini Radar Discovers a Crater: A Rare Find on Titan!

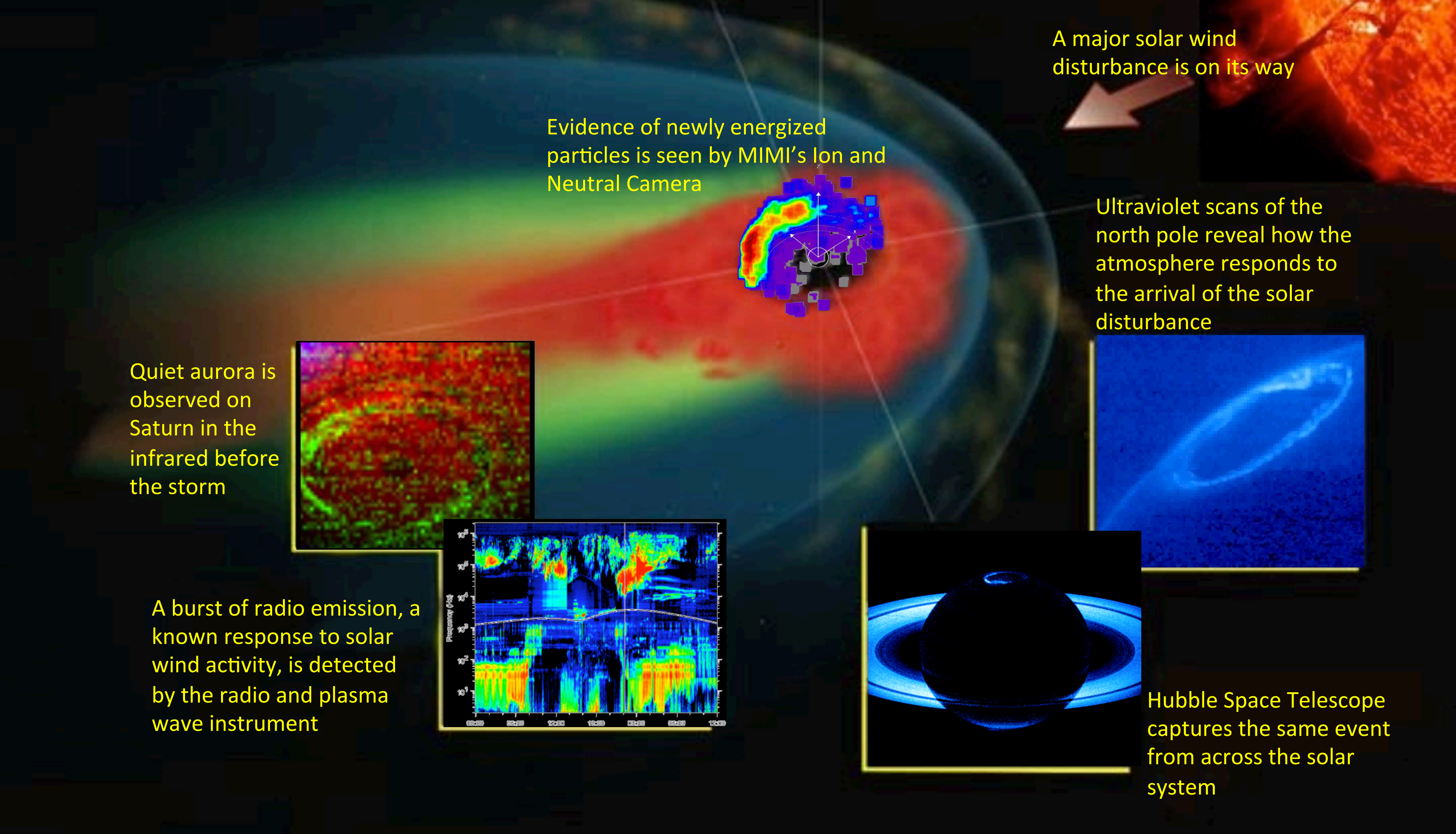


On this Titan flyby, Cassini Radar looked at both previous and newly-covered territory. Scientists are looking for changes to Ontario Lacus and are eagerly processing this data for what it might show. A quick look at data from newly-covered territory has revealed a never before seen impact crater on the surface. Impact craters are rare on Titan's surface given its thick atmosphere and surface erosion.

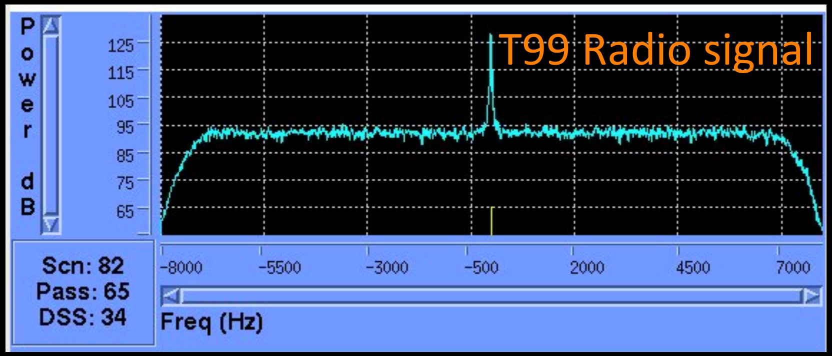
Note that the data presented here is minimally processed and is undergoing refinement and analysis

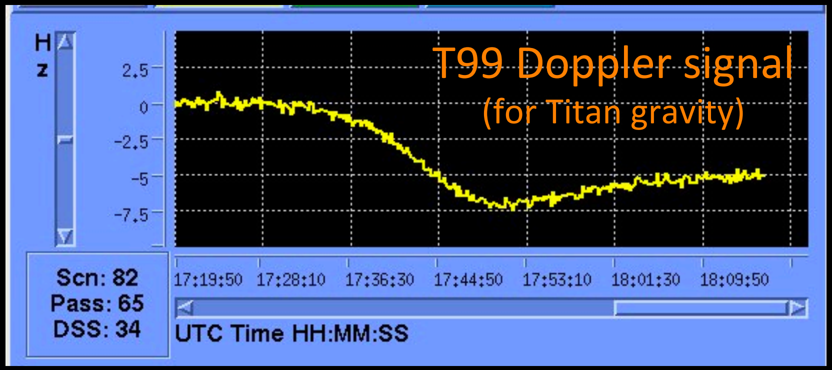
Tracking ‘Space Weather’ from the Sun to Saturn:
Cassini Sees the Birth of an Aurora

How does a disturbance from the sun energize a planetary environment different from the Earth? Where do similarities lie and differences begin?



100th Titan Flyby: Oh, The Gravity Of It All





Radio Science shined on the 100th pass (occurred on March 6, 2014) to:

1) determine the exact shape and the presence of large scale gravity anomalies
2) improve the measurement of tides to confirm the presence of a global subsurface ocean
3) determine how the icy crust changes due to tides

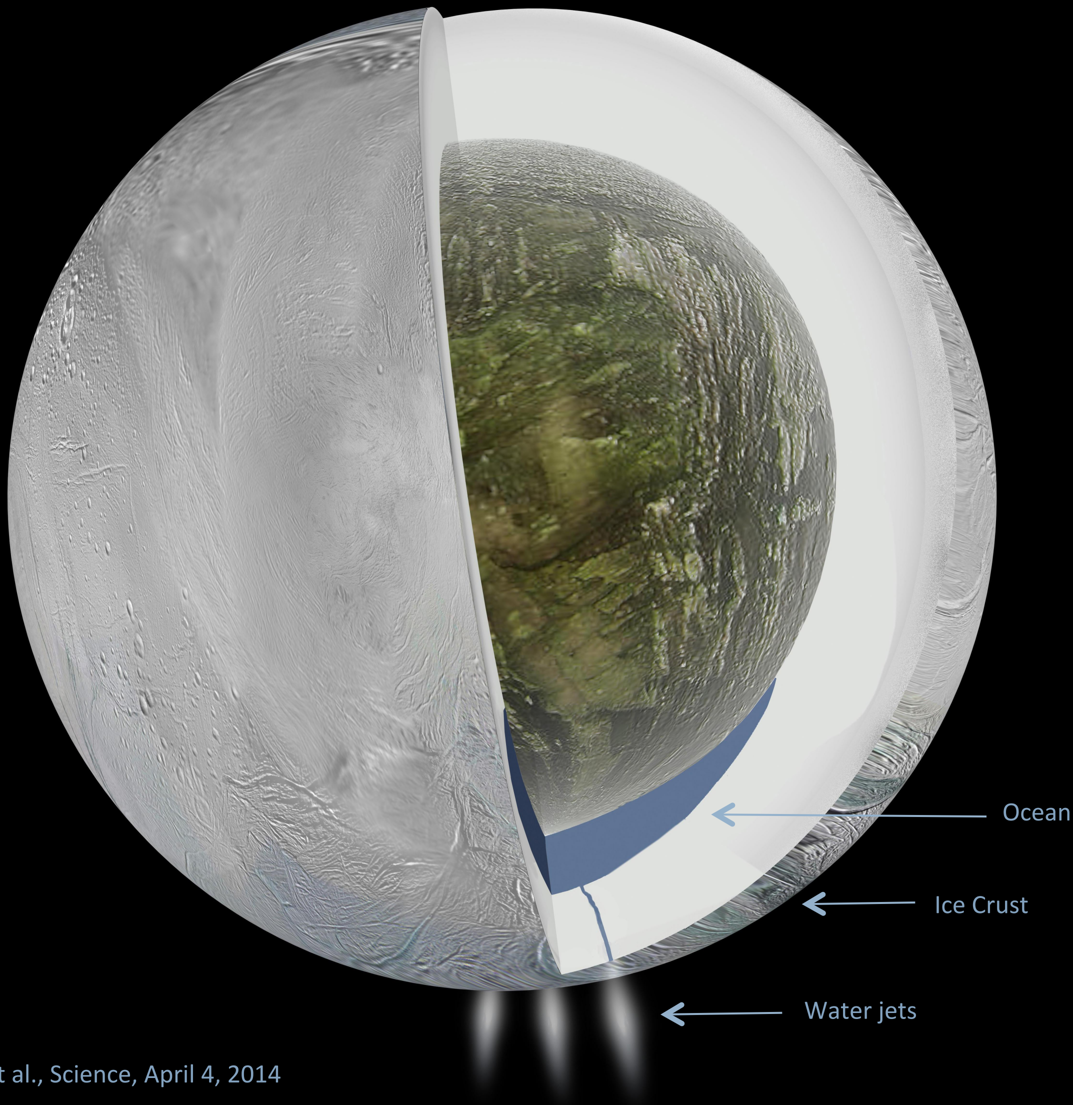
T99 is the 100th flyby due to the addition of a Titan flyby to recover the Huygens Probe data

Note that the data presented here is minimally processed and is undergoing refinement and analysis

Cassini Detects Enceladus Ocean: A Habitable World?

Saturn's moon Enceladus harbors a large, 6-mile deep underground ocean of liquid water, indicated by gravity measurements by the Cassini spacecraft and Deep Space Communications network.

- Radio measurements of Enceladus' gravity indicate an interior reservoir of liquid water, which may be connected to water jets gushing from fractures near the small moon's south pole.
- The newly reported finding validates the inclusion of Enceladus among the most likely places in our solar system to potentially host life.



"The Gravity Field and Interior Structure of Enceladus," Luciano Iess, et al., Science, April 4, 2014

A New Moon is Born???

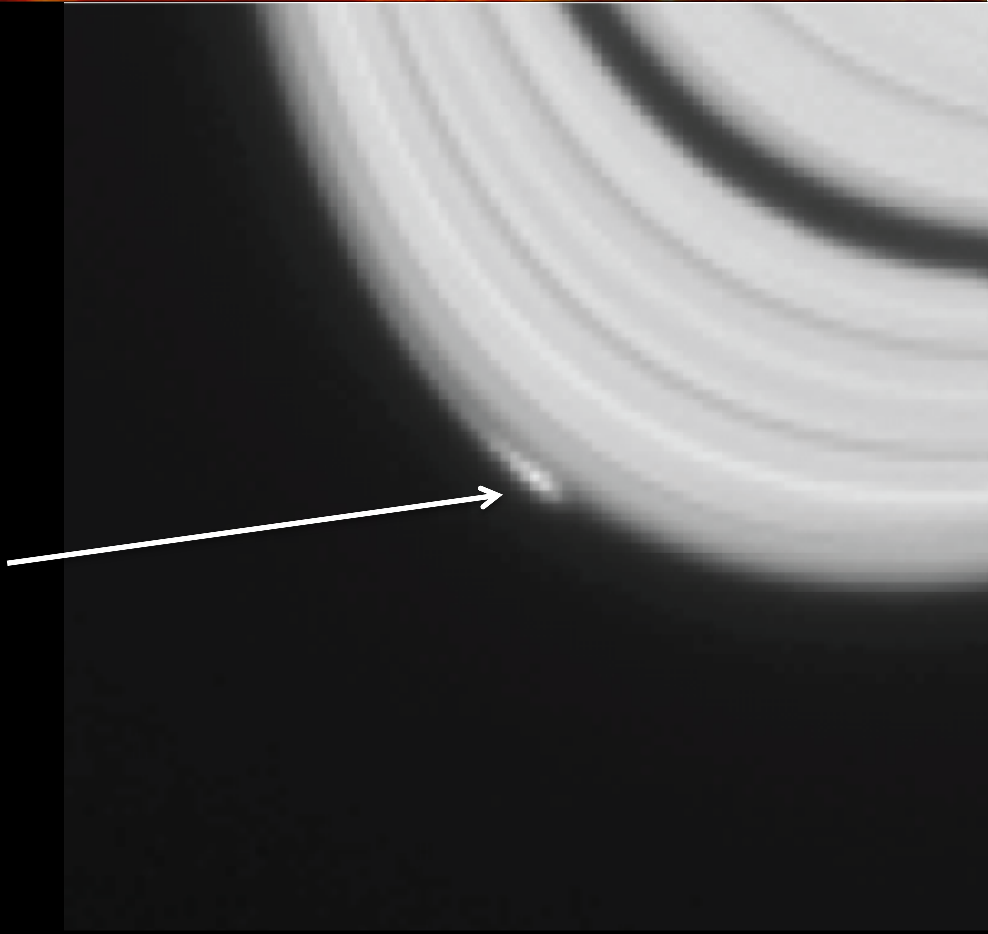
A commotion at the very edge of Saturn's outer bright ring appears to be associated with the birth of a small, icy infant moon.

- NASA's Cassini spacecraft has been documenting the birth process, which may demonstrate how many of Saturn's other moons formed.

- The object, nicknamed "Peggy," appears to be disturbing nearby ring particles as it moves to exit the rings. In time, it may assume a place in orbit among Saturn's 62 other known moons.

- "Peggy" appears to be about the size of three soccer fields. It has gathered an entourage of particles that stick together in a bright arc about 750 miles (1,200 kilometers) long and about 6 miles (10 miles) wide.

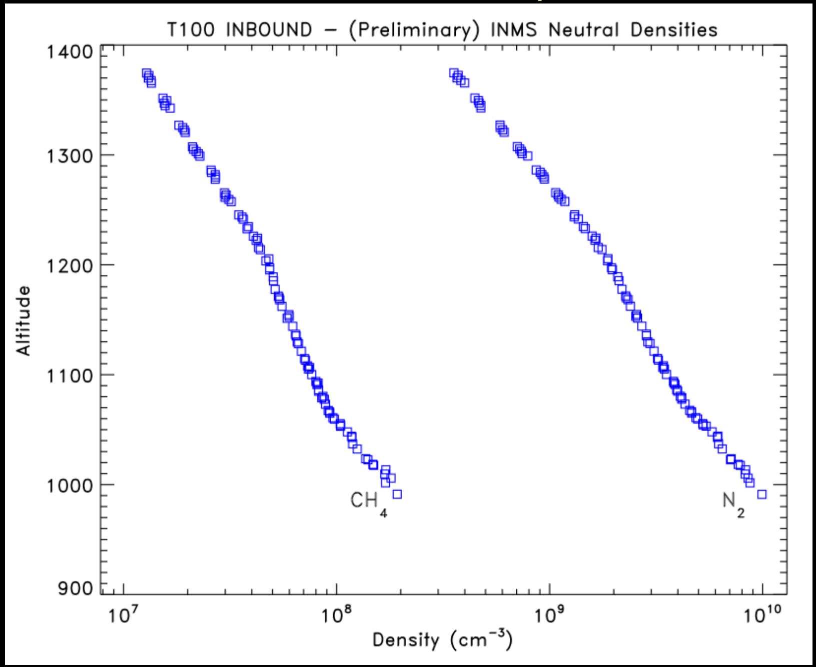
- Scientists have long theorized that our solar system's planets formed in a similar fashion from a ring-like disk around our early sun.



"The discovery and dynamical evolution of an object at the outer edge of Saturn's A ring," Murray, C.D., Cooper, N.J., Williams, G.A., Attree, N.O., Boyer, J.S., Icarus (2014), doi: http://dx.doi.org/10.1016/j.icarus.2014.03.024

The Case of the Missing Methane

Titan's Neutral Atmosphere



- New samples from Cassini's Ion and Neutral Mass Spectrometer collected from Titan's atmosphere at 598 miles (963 kilometers) altitude show a depletion in the amount of methane and nitrogen.
- Methane densities remain up to one third lower than those measured during earlier phases of the Cassini mission when the sun was less active.
- Increased solar activity during solar maximum may be accelerating the photochemical destruction of Titan's atmospheric methane.

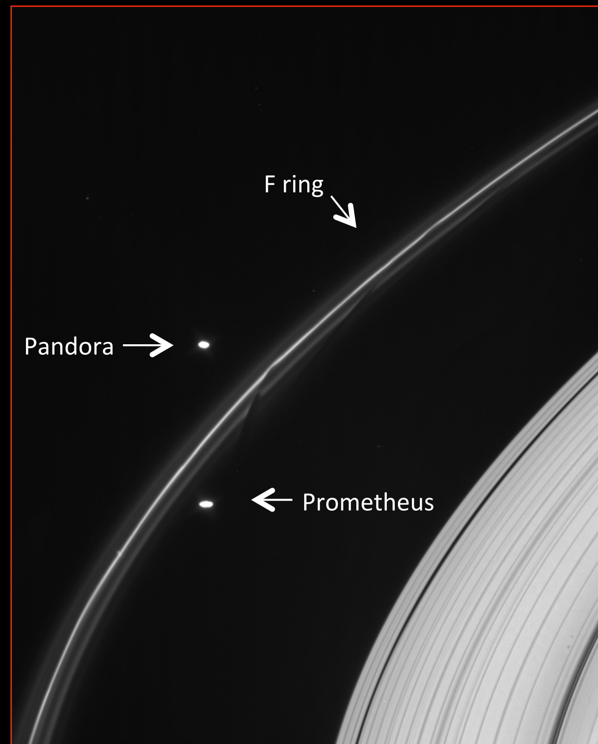
Note that the data presented in this Quick Nugget is minimally processed and is undergoing refinement and analysis

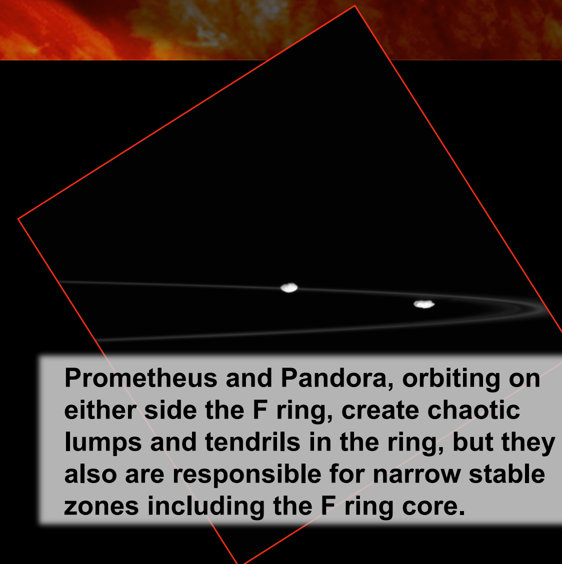
Saturn's F Ring: A Calm Core in the Midst of Chaos

Long-term stability of the narrow F ring core (center right) has been difficult to understand. Instead of acting as "the shepherd moons", Prometheus and Pandora together stir the region into a chaotic state where the orbits of particles and moonlets sporadically change in unpredictable ways.

In new research*, Cassini scientists present numerical integrations of tens of thousands of test particles over tens of thousands of Prometheus and Pandora orbits. The findings show that the two shepherds, while creating confusion in the F ring, also maintain its peaceful core.

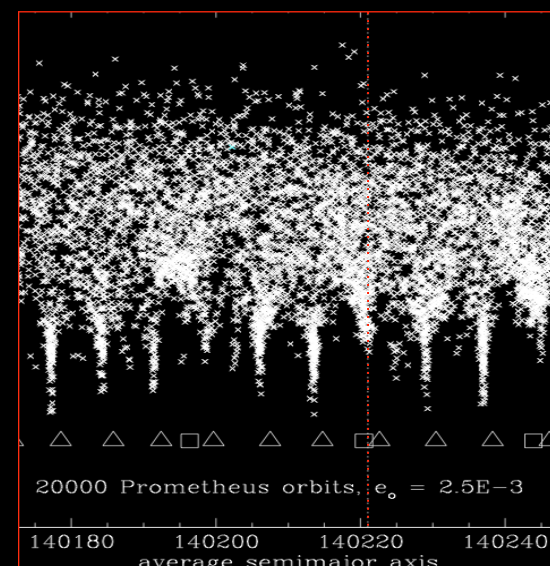
At select, very narrow locations, orbits of particles can remain essentially constant for long periods of time due to the perturbations of Prometheus at one encounter being promptly cancelled at the next encounter. The long-lived F ring core lies precisely at one of these locations. This work has implications for understanding how shepherd moons shape the ring systems that they are embedded in.





Prometheus and Pandora, orbiting on either side the F ring, create chaotic lumps and tendrils in the ring, but they also are responsible for narrow stable zones including the F ring core.

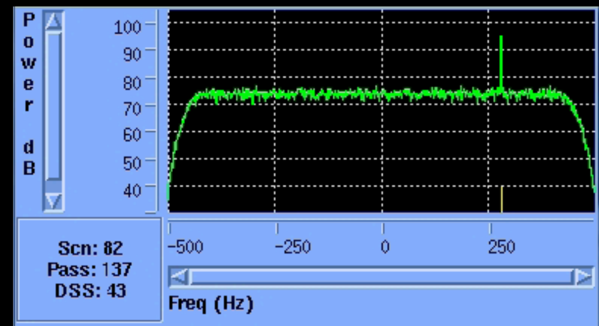
Computer simulations (right) reveal the presence of narrow, stable zones (the icicle-like clusters of points) which are associated with gravitational resonances of Prometheus and Pandora (triangle and square symbols). F ring material could be stable in any of these zones. The red dotted line shows the observed location of the F ring core, lying in one of the theoretically stable zones.



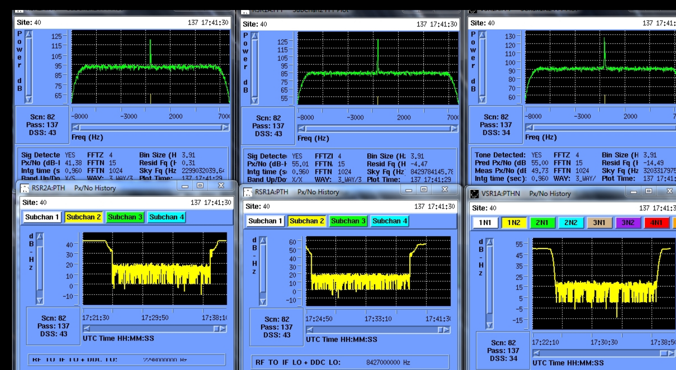
**Saturn's F Ring Core: Calm in the Midst of Chaos*, J.N. Cuzzi, et al., Icarus, (2014)*

Bouncing Radio Signals Off Titan Seas

First Earth-based detection of RSS bistatic echoes from Titan seas



Cassini's Radio Science Team: science operations in real-time



- *Three* firsts for Cassini Radio Science (RSS)
  - First time bouncing a RSS radio signal off from Titan seas (bistatic experiment)
  - First ever detection of Ka-band echoes off of Titan during a RSS bistatic experiment
  - First radio occultations of Titan's atmosphere with new "2-way" radio science mode
- Bistatic experiments yield information on a surface's electrical properties, and in turn composition, and on surface roughness
- Occultations provide information on the thermal structure of the atmosphere

Note that the data presented in this Quick Nugget is minimally processed and is undergoing refinement and analysis

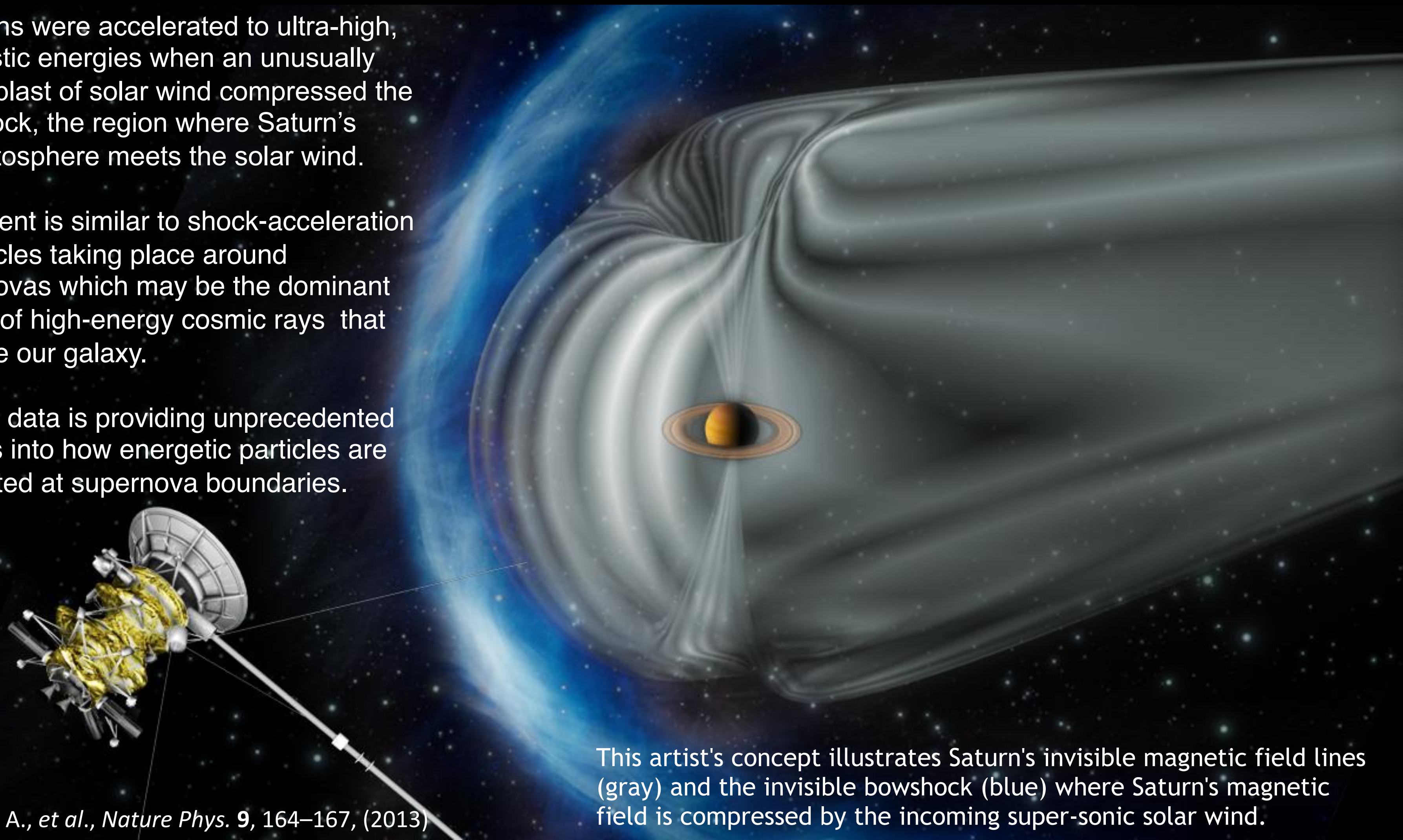
"Supernova" Science at Saturn

The next best thing to a spacecraft orbiting a supernova is Cassini being present for the first ever observation of near-relativistic electrons accelerated within Saturn's bowshock (represented by blue region in the graphic below).

Electrons were accelerated to ultra-high, relativistic energies when an unusually strong blast of solar wind compressed the bowshock, the region where Saturn's magnetosphere meets the solar wind.

This event is similar to shock-acceleration of particles taking place around supernovas which may be the dominant source of high-energy cosmic rays that pervade our galaxy.

Cassini data is providing unprecedented insights into how energetic particles are generated at supernova boundaries.



This artist's concept illustrates Saturn's invisible magnetic field lines (gray) and the invisible bowshock (blue) where Saturn's magnetic field is compressed by the incoming super-sonic solar wind.

Masters, A., *et al.*, *Nature Phys.* **9**, 164–167, (2013)

Cassini: A Decade at Saturn and Counting

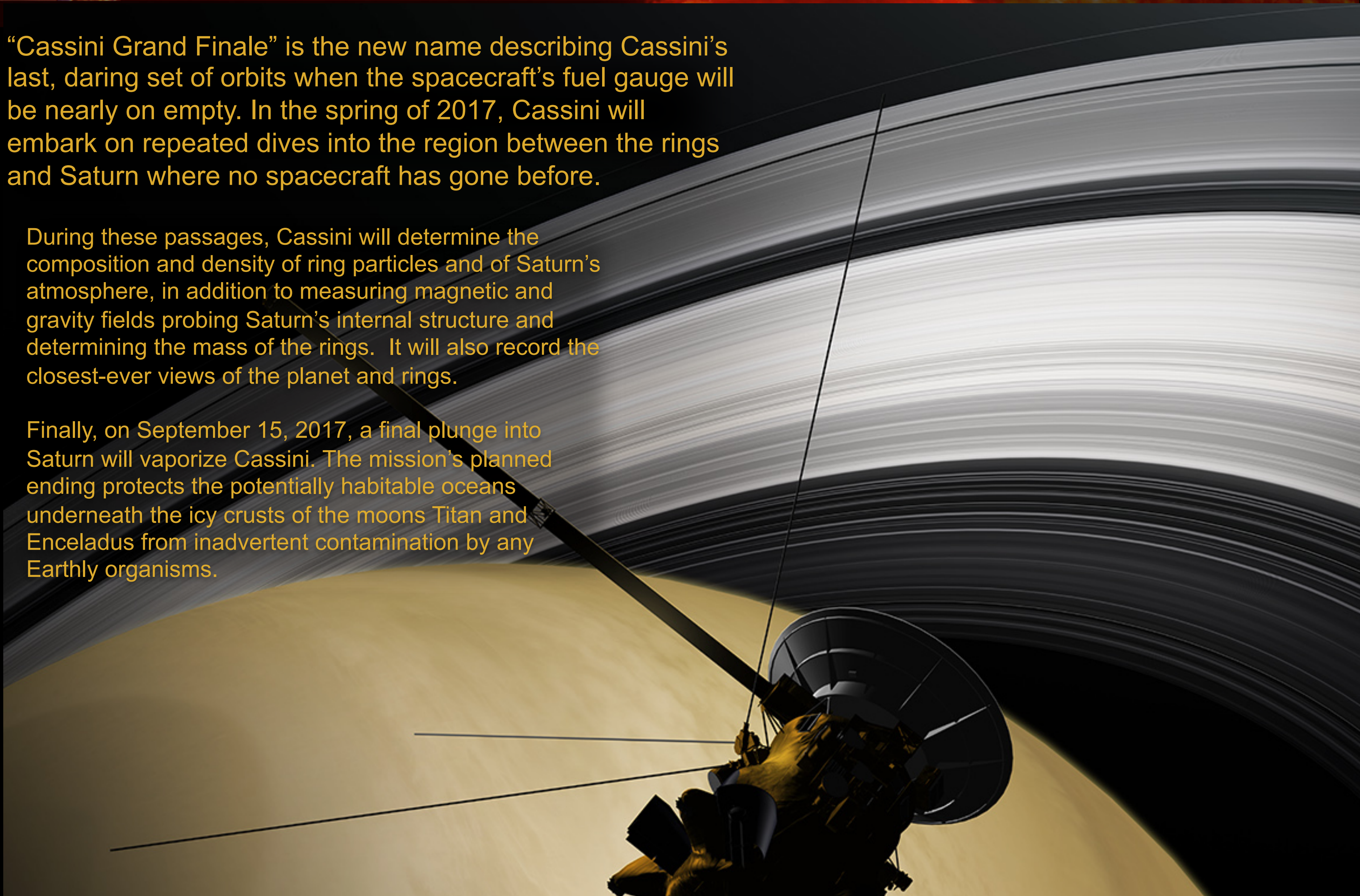
On June 30, 2014, Cassini marks 10 years of exploring the Saturn system.

The Best for Last: “Cassini Grand Finale”

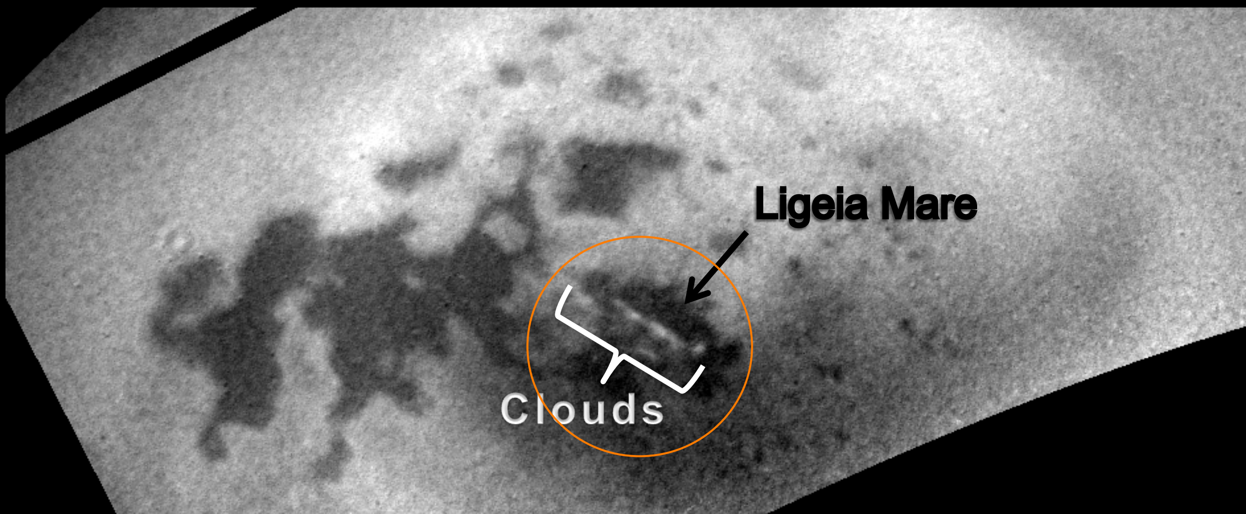
“Cassini Grand Finale” is the new name describing Cassini’s last, daring set of orbits when the spacecraft’s fuel gauge will be nearly on empty. In the spring of 2017, Cassini will embark on repeated dives into the region between the rings and Saturn where no spacecraft has gone before.

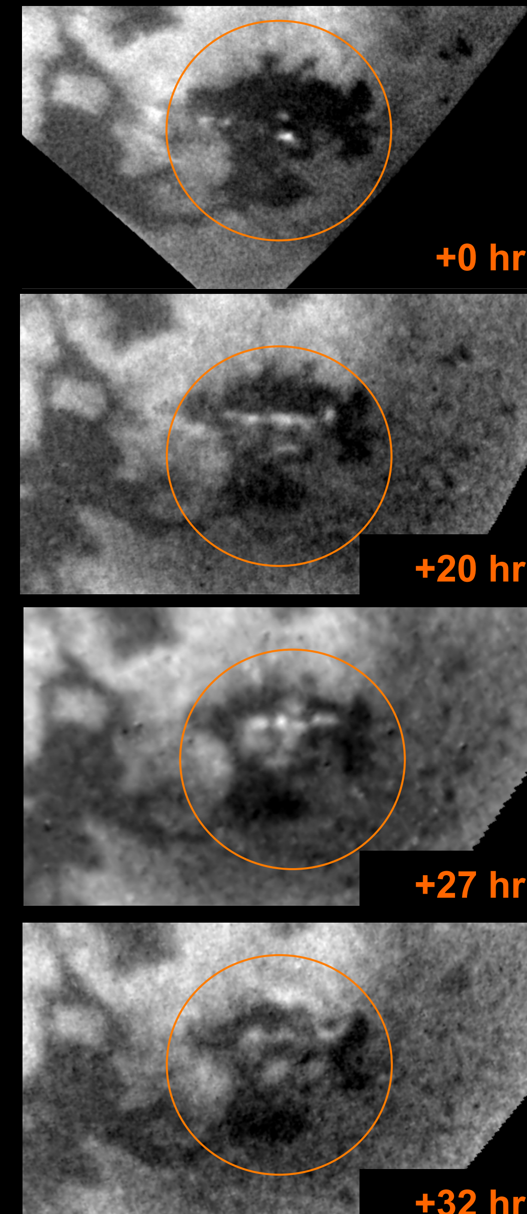
During these passages, Cassini will determine the composition and density of ring particles and of Saturn’s atmosphere, in addition to measuring magnetic and gravity fields probing Saturn’s internal structure and determining the mass of the rings. It will also record the closest-ever views of the planet and rings.

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.



Titan Storm Watch!

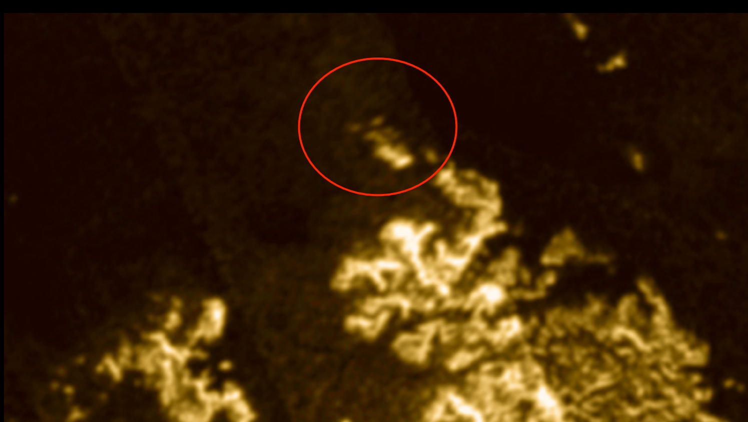




- Cassini scientists are finally seeing spring clouds that were predicted to start appearing in Titan's northern hemisphere several years ago. Significant cloud activity had not been seen anywhere on Titan since 2010.
- Cloud activity was tracked over the Great Lake-sized sea, Ligeia Mare, during a July 2014 flyby. The weather system was observed for about two days as it developed and dissipated. Wind speeds were measured at about 3 to 4.5 meters per second (7 to 10 miles per hour).
- Cassini will continue to look for further signs of the anticipated spring storms during several upcoming flybys.
- Movie: http://go.nasa.gov/1AbiPBA

Abracadabra!
Will “Magic Island” Reappear in Titan’s Sea?

Above, the coastline of Ligeia Mare as it appeared in Cassini radar data prior to July 2013. Below, in data from July 2013, bright new features appeared where none had been before. The features later disappeared.



Cassini scientists will be on the lookout for a strange, island-like feature that appears to come and go in a great lake of Saturn’s largest moon. A flyby on Aug. 21, 2014, will focus on this feature and Titan’s northern lakes region.

- The 100-square mile “Magic Island” was observed in Titan’s Ligeia Mare, a mostly liquid methane lake about the size of New Mexico, where no such feature had appeared before. The “island” may be related to waves, rising bubbles, floating solids akin to icebergs, or solids that are suspended in the lake just below the surface.

- “Magic Island” may be a sign of change that could be linked to seasonal processes such as wind and rain as Titan’s northern hemisphere shifts from spring toward summer.

- Cassini will monitor this region and search for other changes on Titan as the mission heads toward its conclusion in 2017.

“Transient features in a Titan sea,” J.D. Hofgartner, et al., Nature Geoscience 7, 493–496, June 22, 2014

Titan's "Magic Island" Gets Even More Mysterious

- Radar data from Cassini's latest flyby of Titan (August 2014) show that a strange, island-like feature first spotted during a July 2013 flyby is again present in Ligeia Mare. *However, its appearance has changed.*

- The feature could be surface waves, rising bubbles, floating solids, solids that are suspended just below the surface, or something even more mysterious.

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

Hidden Reservoirs of Propane and Ethane on Saturn's Moon Titan?

New research indicates that Titan's methane rainfall may transform into propane or ethane underground through interaction with a layer of icy sediments called "clathrates."

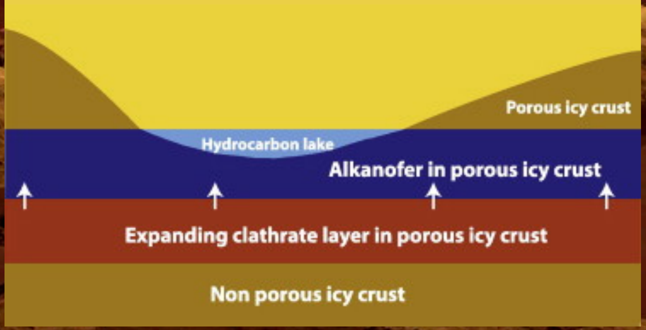
- Cassini may be able to differentiate between rivers or lakes that emanate from hidden reservoirs of propane and ethane, as opposed to rivers or lakes that are dominated by rainfall.

- The research could help scientists better understand the volume of Titan's underground hydrocarbon reservoirs and their role in the exchange of methane between the surface and atmosphere.

- The research contributes to models of Titan's methane cycle which drives Titan's active weather processes, and is akin to the cycle of water on Earth.

Rain-fed methane aquifers, or "alkanofers," may interact with Titan's porous icy crust to form a lower layer of clathrates - compounds in which molecules of one component are physically trapped within the crystal structure of another.

The clathrate layer grows into the methane reservoir, transforming the liquid into propane and ethane. Rivers and lakes fed by such reservoirs may be detectable.



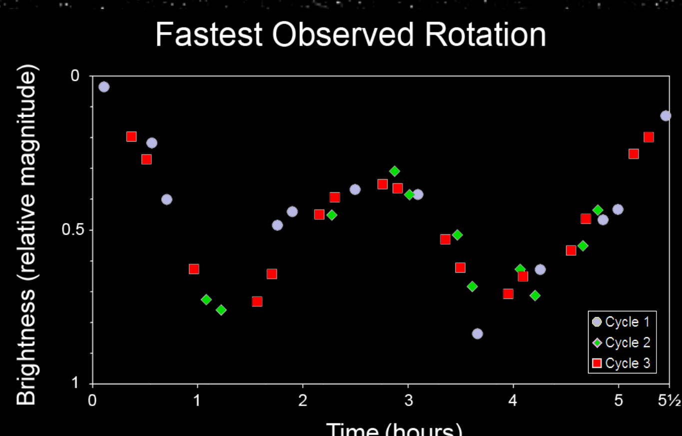
"Equilibrium composition between liquid and clathrate reservoirs on Titan," Mousis et al., Icarus, 239, 39-45, 2014.

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.

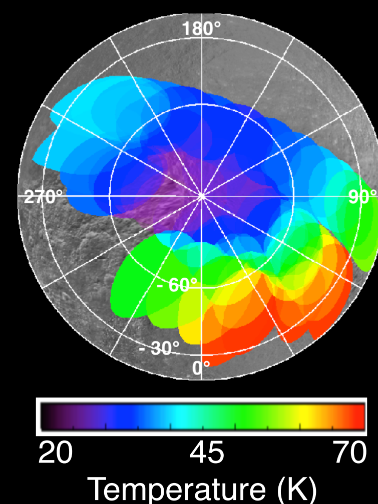


Above: Hati's light curve as observed by Cassini's imaging camera, from which its rotation period was calculated

Denk, T., and Mottola, S. (2013): AAS/DPS Abstract #406.08

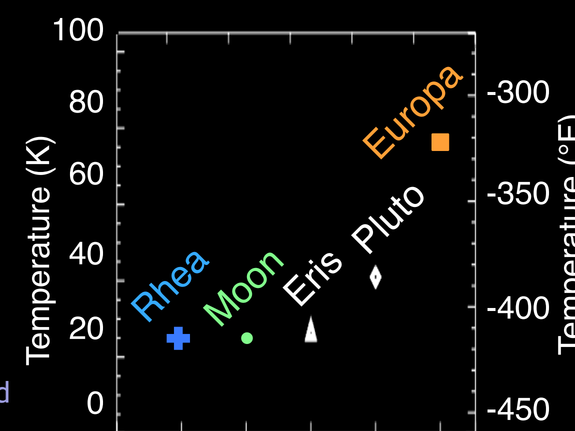
Rhea: ...Too furiously cold

- 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).
- 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: Rhea's south polar surface temperatures

Right: Coldest directly observed surface temperatures in our solar system



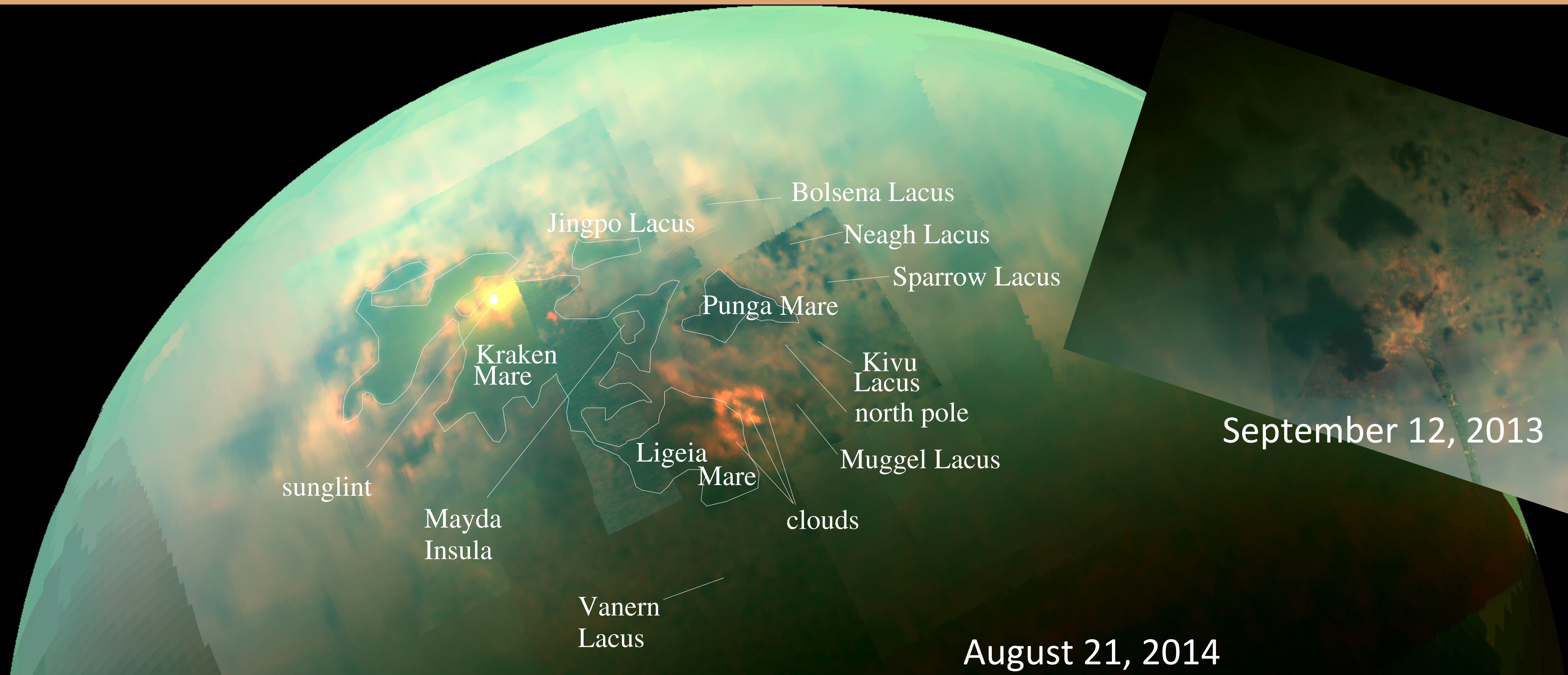
Howett, C.J.A., et al. (2013): AAS/DPS Abstract #406.05

Titan's Northern Seas: One Year Later

A mosaic of infrared measurements from an August 2014 flyby looking for seasonal change on Titan shows these features:

- **High brightness along Kraken Mare shorelines possibly indicating the presence of evaporates.**
- **Sunlight reflecting off Kraken Mare**
- **25,000 square kilometer (10,000 square mile) cloud**
- **Channel between Ligeia Mare and Kraken Mare**

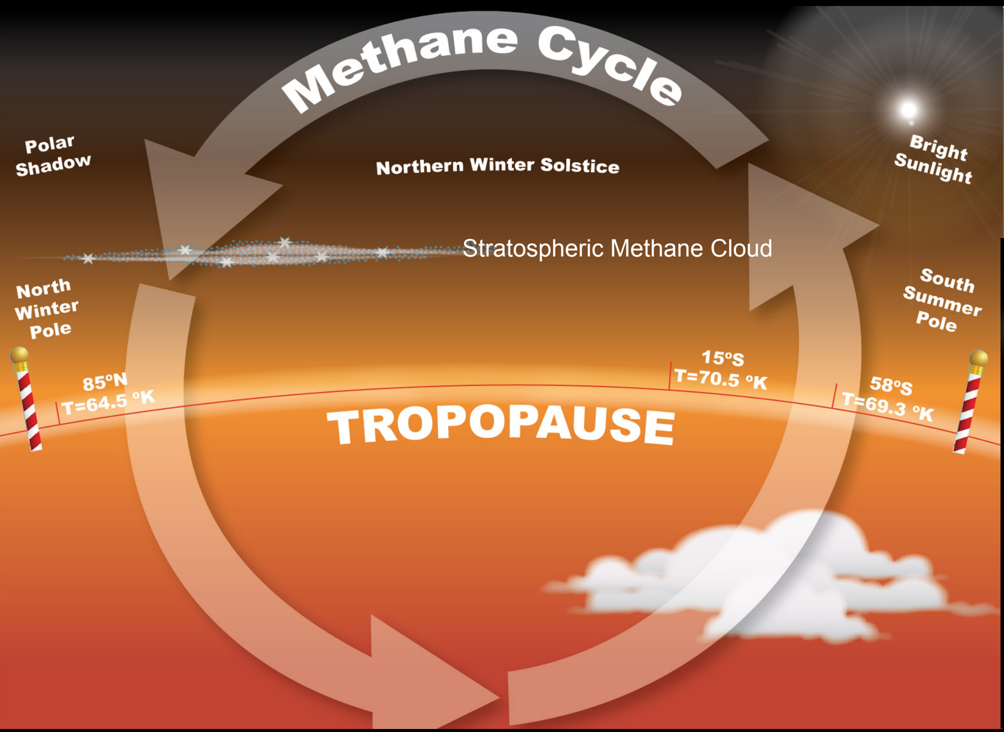
Similar data from the most recent September 2014 flyby are being analyzed for short-term changes.



Note that the data presented in this Quick Nugget is minimally processed and is undergoing refinement and analysis

Cassini Finds Methane Ice in Titan's Stratosphere

New findings from Cassini show that Saturn's moon Titan shares yet another similarity with Earth – high-altitude ice clouds – indicating seasonal change. However, unlike Earth's Polar Stratospheric Clouds (PSCs) that are composed of water ice, these are composed of methane ice.



Even though methane vapor rises in Titan's summer hemisphere, general circulation causes it to subside and cool over Titan's winter pole. This gives rise to methane ice clouds in Titan's lower stratosphere. These clouds are similar to Earth's Polar Stratospheric Clouds, like those shown below near Iceland.

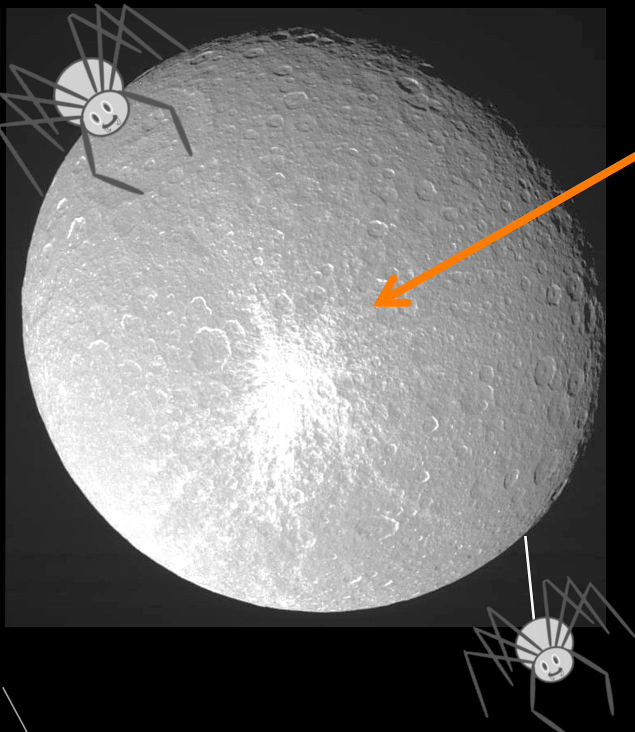
(above) Polar Stratospheric Clouds observed over Iceland (image credit: NCAR)

(left) Polar Stratospheric Cloud observed in Titan's Northern Hemisphere

Analyses of data from infrared and radio instruments reveal that temperatures near the tropopause above 65°N latitude are unexpectedly several degrees colder than at lower latitudes. At that frigid temperature, some of the available methane vapor will condense into ice crystals forming PSCs. This Earthlike phenomenon, previously thought to be highly unlikely at Titan, shows yet another characteristic shared by these two worlds.

"Subsidence-induced methane clouds in Titan's winter polar stratosphere and upper troposphere," C.M. Anderson, et al. Icarus, 243, 129-138, 2014.

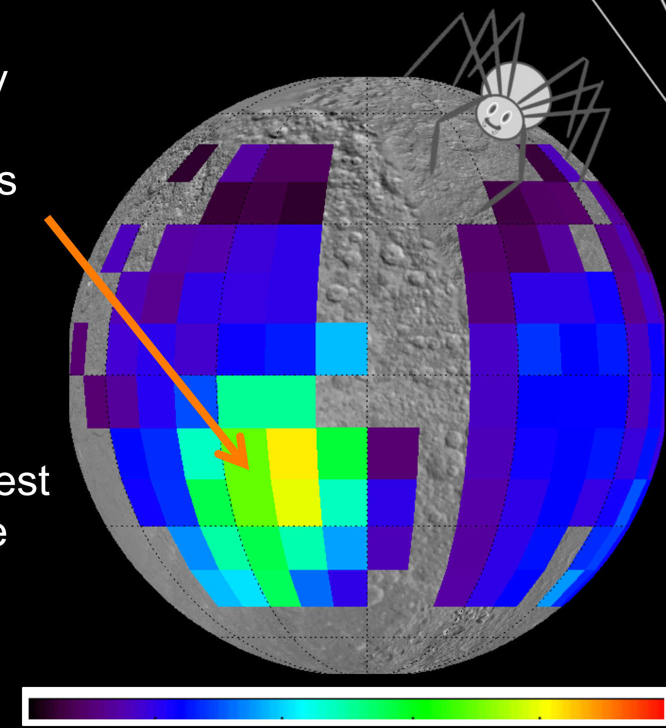
Rhea's Creepy Crater



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.

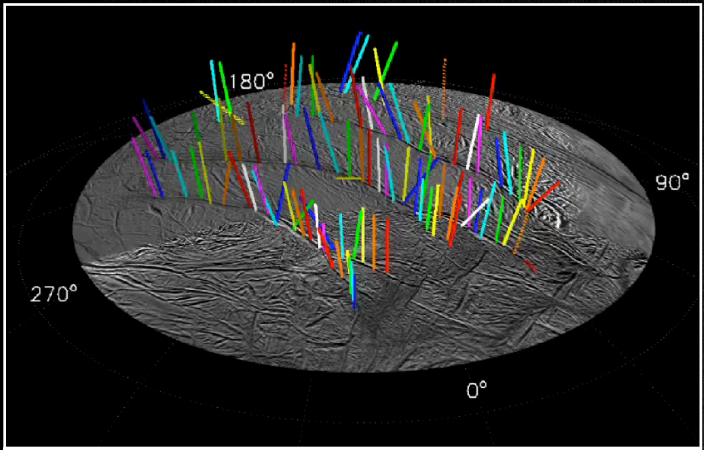
Inktomi's splatter stands out as much warmer than the rest of Rhea's surface, which is comprised of fluffy, snow-like ice and cools rapidly at night.



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!

Howett, C. J. A.; Spencer, J. R.; Hurford, T.; Verbiscer, A.; Segura, M. Thermophysical property variations across Dione and Rhea, Icarus 241, 239-247, 2014. doi:10.1016/j.icarus.2014.05.047

A Little Moon Bursting at the Seams

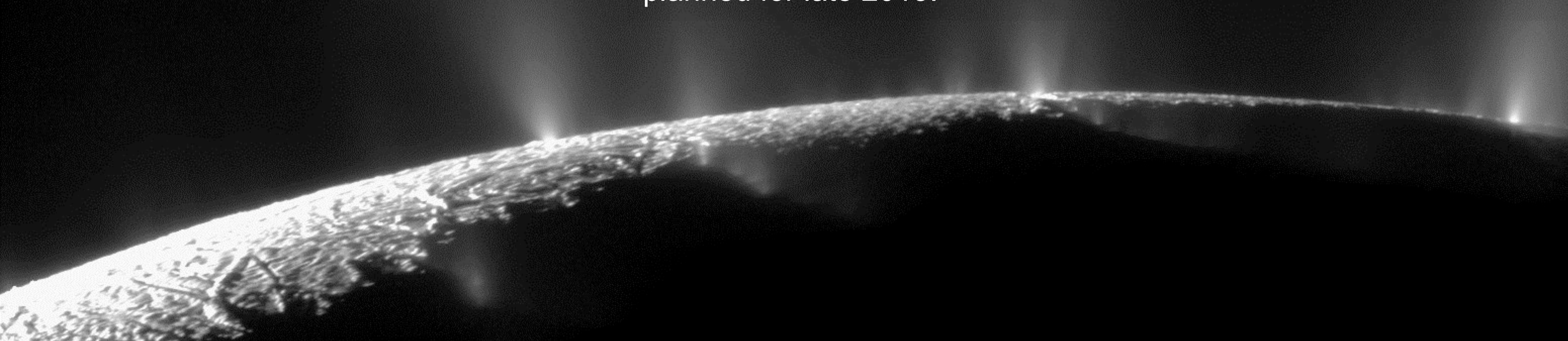


Vertical lines in this illustration indicate the paths of the icy particles erupting from the surface. Colors in this illustration help differentiate the trajectories of geysers found so far.

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.

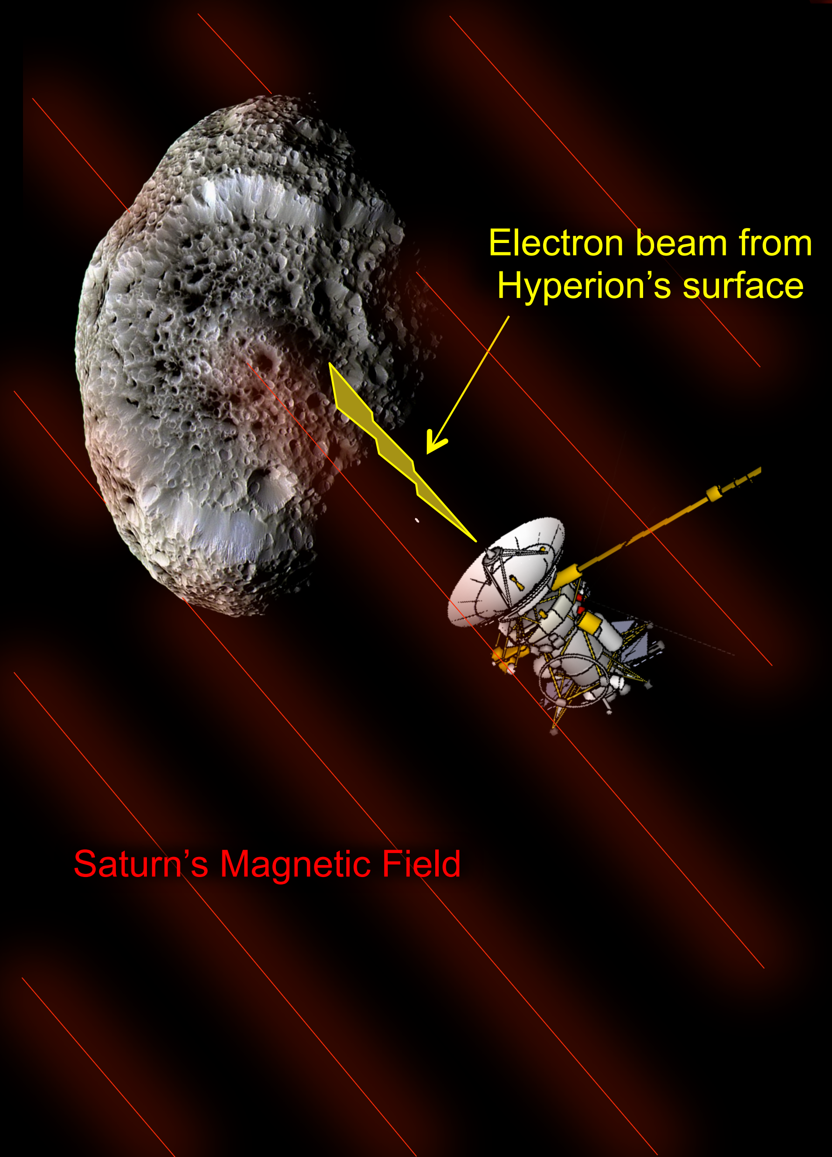
The geysers spray icy particles, water vapor, and organic compounds. Scientists have found the geysers themselves are the source of the heat detected by Cassini's thermal instruments. Vapor condenses on fissure walls, releasing heat to the surface.

Cassini's sampling of the material jetted from the moon's sub-surface sea has revealed Enceladus to be a potential habitat for microbial life. Continued studies of the moon remain a major focus of the Cassini mission with an additional flyby through the geysers planned for late 2015.



"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.

Cassini Makes a "Shocking" Discovery at Saturn's Moon Hyperion



- **Scientists analyzing plasma spectrometer (CAPS) data from a 2005 flyby were surprised to find that small, sponge-faced Hyperion reached out across 1,200 miles to zap Cassini with a 200-volt electron beam.**
- Measurements indicated a strongly negative surface potential (or voltage) on Hyperion and that low-energy electrons were accelerated up to the spacecraft by the large potential difference. There were no signs of damage to the spacecraft from the electron beam.
- Hyperion resides in a highly variable environment between Saturn's magnetosphere and the solar wind. This active environment is likely the source of Hyperion's surprising electrical charge.
- **This is the *first confirmed* detection of a charged surface on an object other than our Moon.** Such effects are predicted to occur on many other bodies including asteroids and comets. Strong electric charging effects could be a hazard to future robotic and human explorers of solar system objects without atmospheres, including Earth's moon.

"Detection of a strongly negative surface potential at Saturn's moon Hyperion," T. Nordheim, *et al.*, *Geophysical Research Letters*, 41, 7011-7018, 2014.