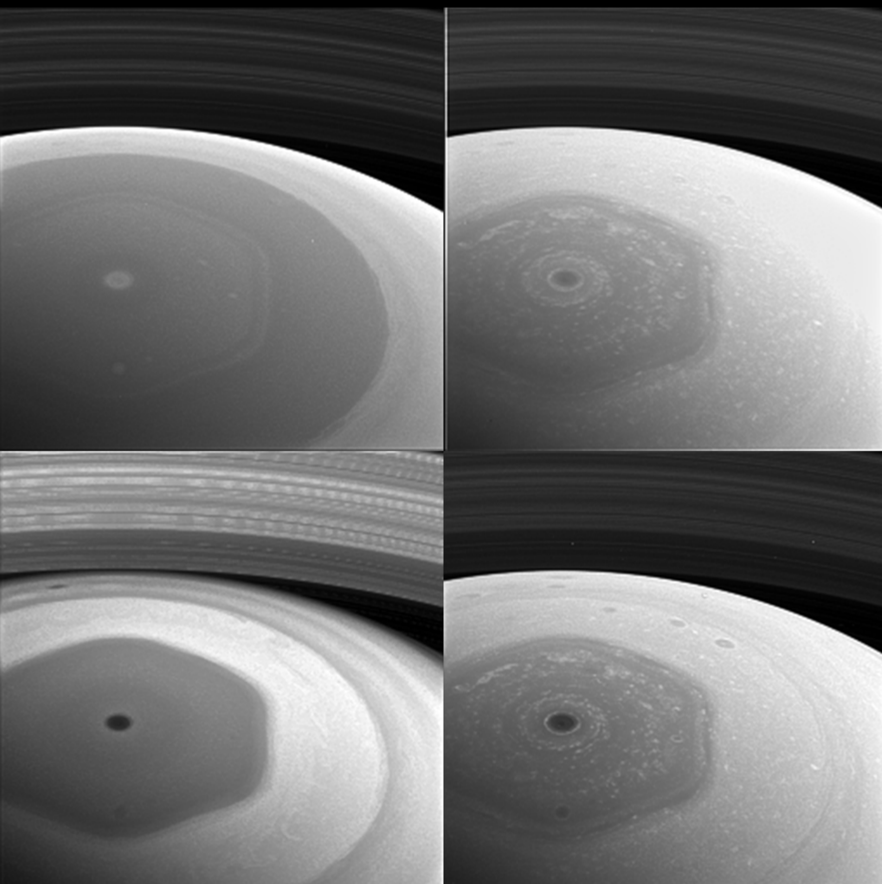
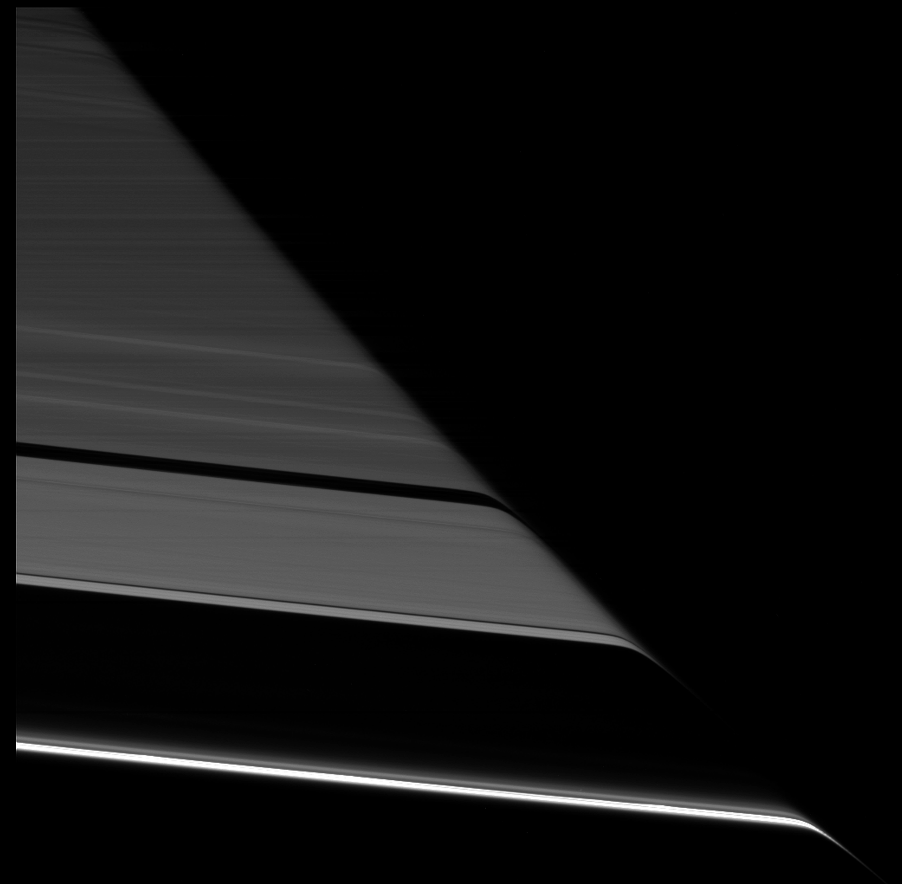
Jet Propulsion Laboratory
California Institute of Technology

Cassini Solstice Mission

2016: A Year in Nuggets

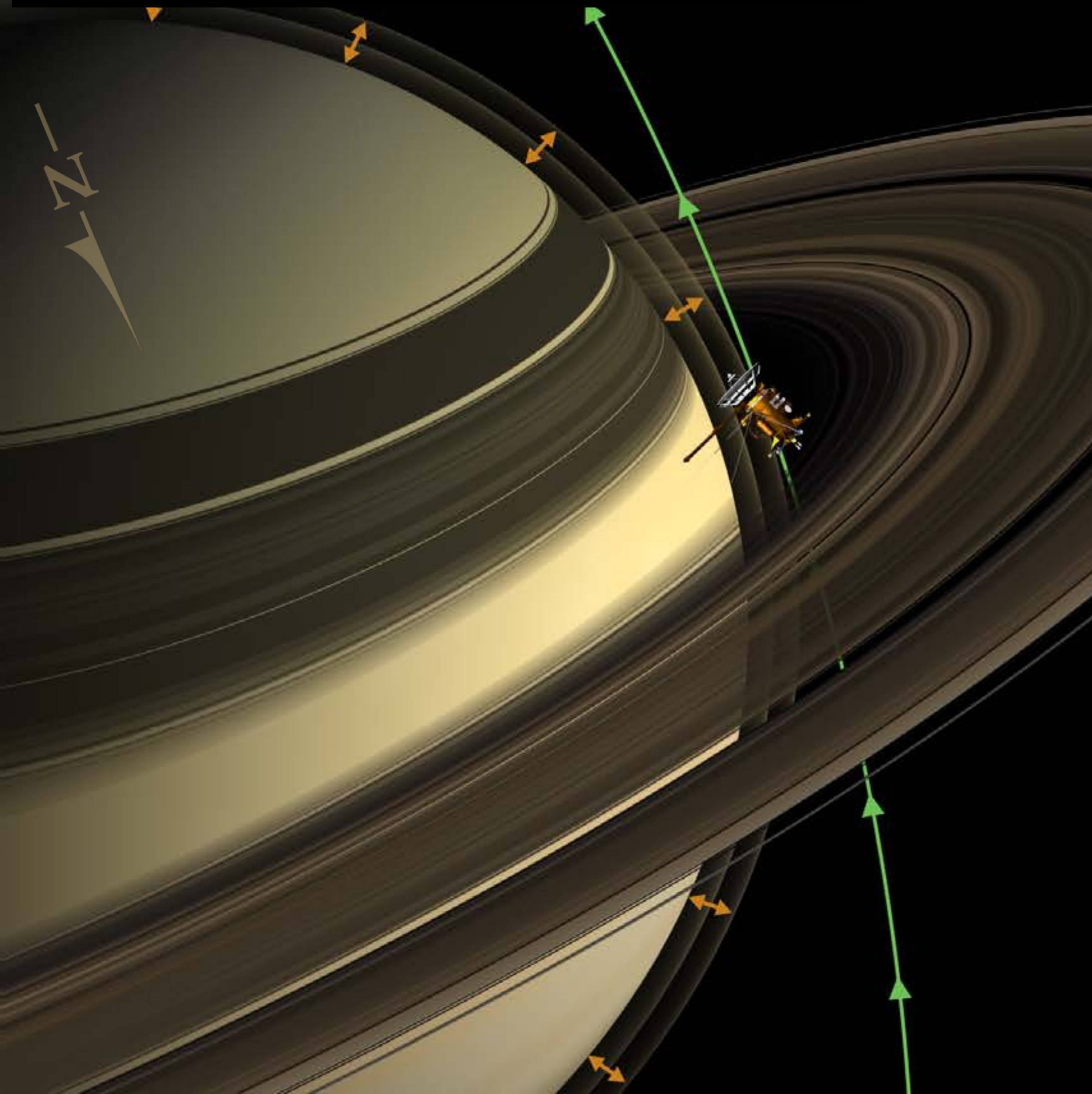




Cassini Project Science

Saturn's Breathing Atmosphere

Saturn's atmosphere has been found to "breathe" as it expands and contracts with seasonal heating and cooling.



Cassini's 2017 Grand Finale Tour will shoot the gap between Saturn's rings and atmosphere. The last five orbits will bring it near enough to Saturn to directly sample the upper atmosphere and help answer why the temperature of Saturn's upper atmosphere is much hotter than can be explained – an unsolved problem also seen at Jupiter, Uranus and Neptune.

Scientists were surprised when stellar occultations of Saturn showed the atmosphere's outer edge had expanded by a whopping 310 miles (500 kilometers) as Saturn's upper atmosphere heated by 180° F between 2005 and 2011.

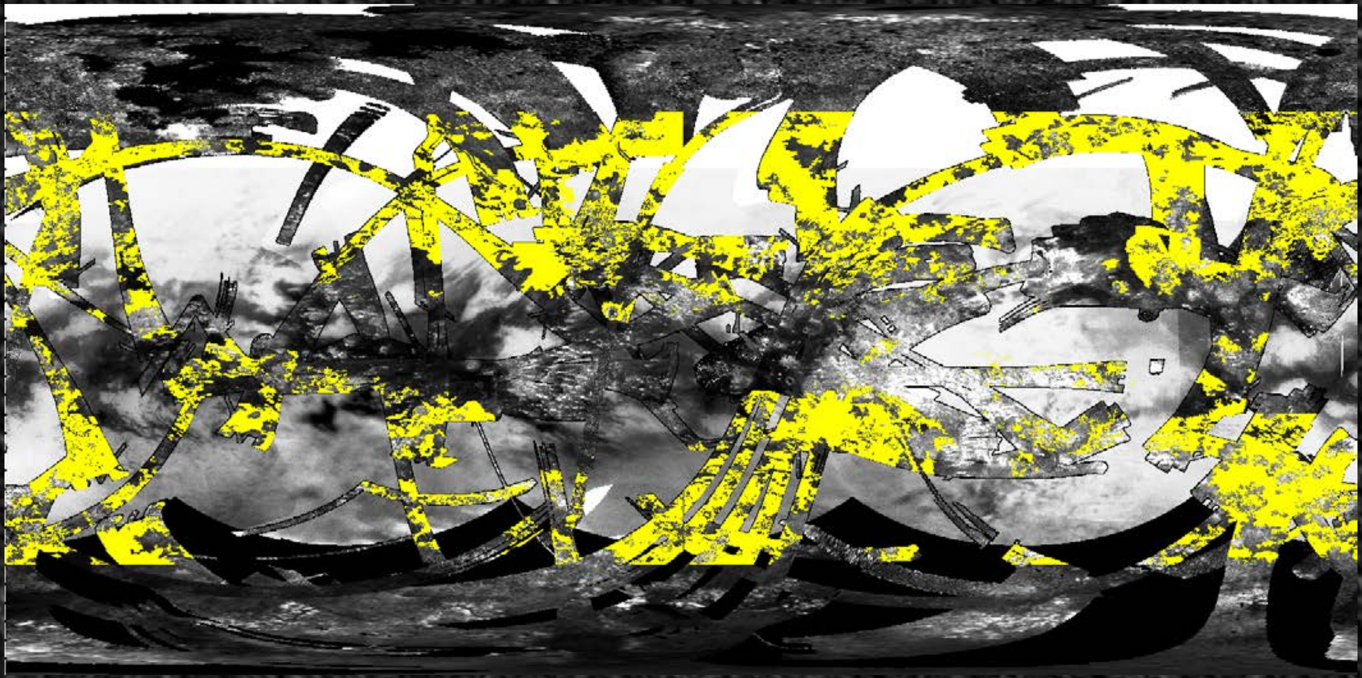
Recent occultations have shown the atmosphere had contracted again after 2011. Scientists now think that this behavior may be seasonal.

These findings will guide decisions for determining Cassini's safe flight path while allowing for successful atmospheric sampling to improve our knowledge of how atmospheres work. Scientists and engineers will continue to monitor atmospheric behavior as they plan the exciting Grand Finale.

"Saturn's variable thermosphere from Cassini/UVIS occultations", T.T. Koskinen, et al., Icarus, 260, 174-179, 2015.

“The Blandlands” of Titan

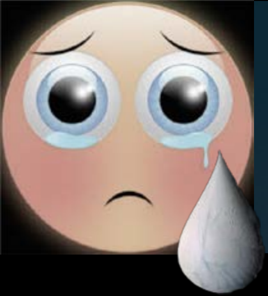
Titan's featureless (undifferentiated) plains, aka "The Blandlands," help improve our understanding of how organic chemicals evolve in Titan's environment. Characterizing the plains is key to understanding prebiotic chemistry occurring on this remarkably Earthlike world.



Cassini Radar Map of Titan, with “the Blandlands” Highlighted in Yellow.

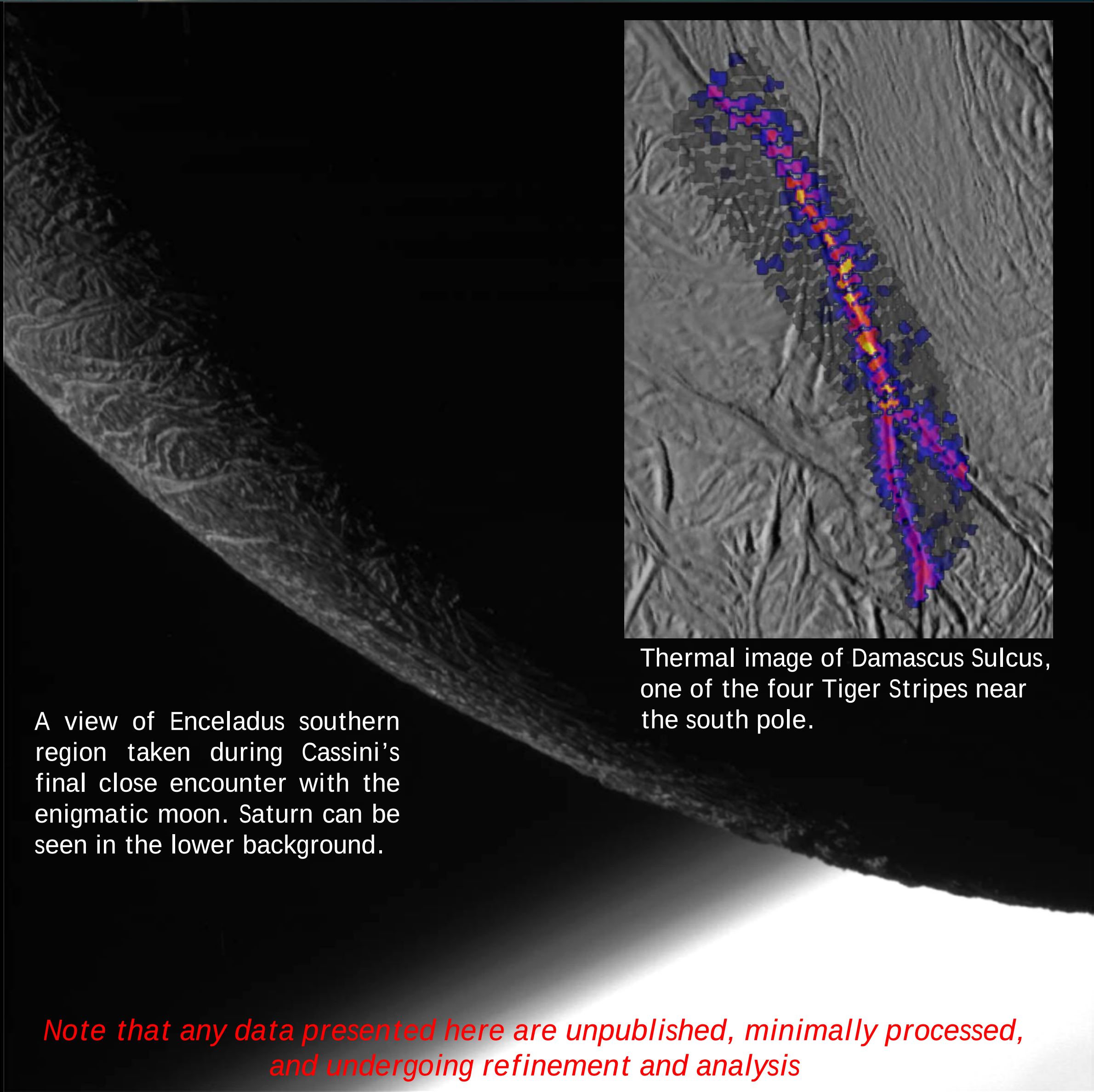
The featureless plains (shown in yellow) dominate much of Titan’s surface and are full of geologic intrigue as one of the solar system’s largest reservoirs of carbon-rich organic materials. Cassini data indicate the plains are not made of water ice but instead made of organic chemicals that form in the atmosphere and fall onto the surface where wind and other geologic and chemical processes redistribute them.

R. Lopes, et al., 2015. “Nature, Distribution, and Origin of Titan’s Undifferentiated Plains.” Icarus, in press.



Saying Farewell, for Now, to Enceladus

- Cassini had its 22nd and last close flyby of Enceladus on December 19, 2015.
- The aim was to observe Enceladus' active south polar region, which is in winter darkness, where any observed heat is from Enceladus' hot vents and not reflected sunlight.
- Cassini used two instruments to look at the vents in infrared light to better understand their temperatures and heat flow.
- Measurements of heat flow on Enceladus are helping scientists understand conditions on moons and planets that can lead to environments potentially hospitable to life.
- Cassini will continue to observe Saturn's Enceladus for the rest of the mission but from greater distances.



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

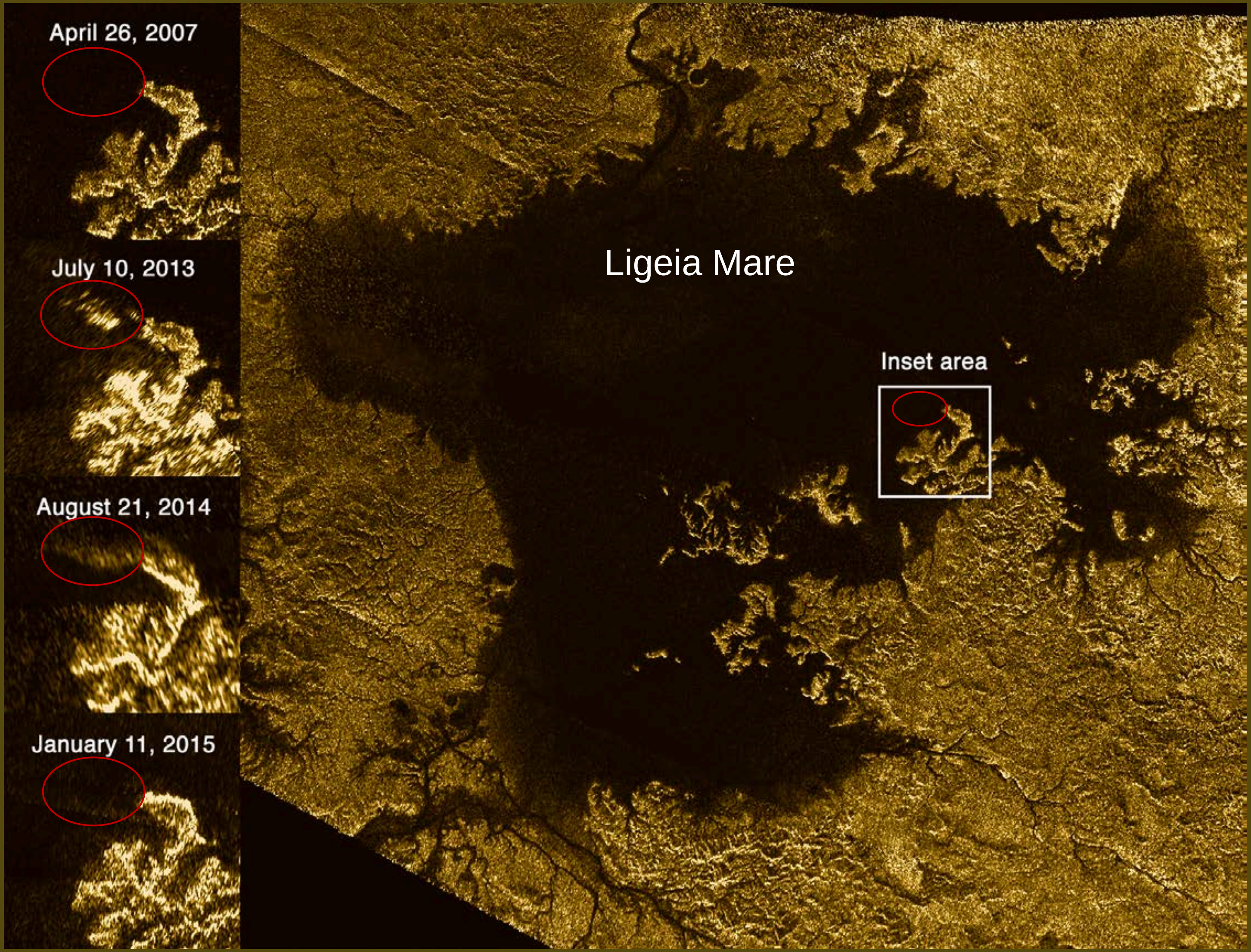
Evolution of Titan's "Magic Island"

Titan's "Magic Island" has disappeared again. Cassini's radar has seen the feature brighten several times, then disappear into the darkness of Ligeia Mare, a hydrocarbon sea near Titan's north pole.

Cassini scientists believe the feature is not an island at all, but instead could be caused by waves, solids that are floating on or suspended in the liquid, or even bubbles. Data indicate that neither tides nor sea level or seafloor changes are the cause.

The Cassini team plans to observe the "Magic Island" feature once more during the final close Titan flyby of the mission.

Cassini's studies of Titan's seas are revealing familiar physical processes that can occur in exotic liquids on other worlds.



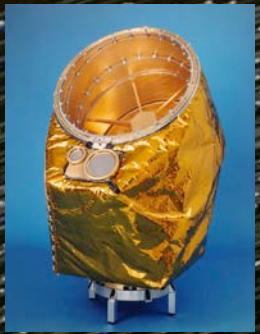
Hofgartner et al., Titan's "Magic Islands": Transient features in a hydrocarbon sea, Icarus, 271, 338-349, 2016.

Cassini Snags Rare Specks of Speeding Interstellar Dust

Three dozen interstellar particles zooming through our solar system smashed into Cassini's bucket-shaped cosmic dust analyzer, giving scientists new information about the raw material from which stars are made.

- The dust grains were each smaller than a smoke particle. Their origin from beyond the solar system was betrayed by their high speed of more than 45,000 miles per hour (72,000 kilometers per hour) and distinctive angle of flight.
- Cassini analyzed the composition of the interstellar dust particles for the first time, finding them to be a homogeneous mix of rock-building elements such as magnesium, silicon, calcium and iron, in proportions similar to those that make up our local galactic neighborhood.
- The dust particles were deficient in reactive elements such as carbon and sulfur, likely due to changes induced by shock waves in the interstellar medium.
- The homogenous composition of the interstellar dust grains detected by Cassini indicates that most dust grains that go into creating new solar systems are not the fresh, pristine dust produced by stellar explosions. The finding provides new understanding of the "DNA" of stars and planets.

Cassini's Cosmic Dust Analyzer



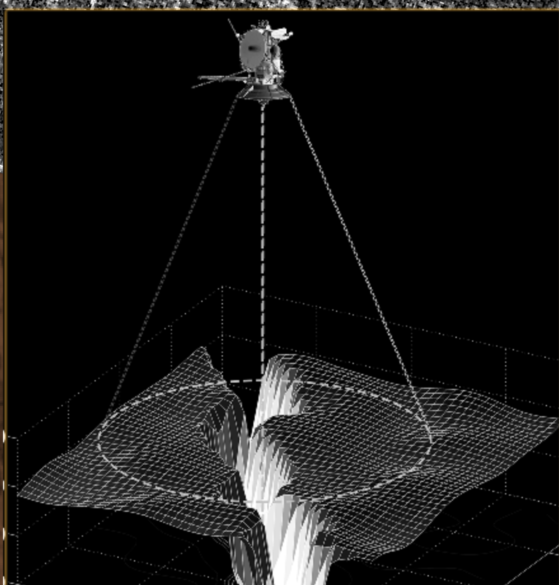
"Flux and Composition of Interstellar Dust at Saturn from Cassin's Cosmic Dust Analyzer," N. Altobelli *et al*., Science, 352, 312-318, 2016.
https://saturn.jpl.nasa.gov/news/2895/

Rivers of Hydrocarbons Flow Through Titan's Narrow Canyons

Cassini radar and altimeter echoes have revealed surprisingly deep (up to 1000 feet), steep canyons that are home to rivers of hydrocarbons on Saturn's moon Titan. These canyons appear to be connected to Titan's northern lake, Ligeia Mare.

The Titan canyons may have formed either when the land rose tectonically or the sea level temporarily dropped. Both mechanisms helped to carve the river canyons of the American Southwest. On Titan, however, the liquid is methane and ethane, not water, and the surface is rock-hard mix of water ice and solid hydrocarbons.

Upstream tributaries were found to be much higher than Ligeia's sea level. This difference would cause flow that could erode Titan's deep canyons in the way the Colorado River carved the Grand Canyon. The liquid at the river's mouth and main trunk, however, was level with the sea. This may be a sign of backflooding, producing a drowned river valley similar to the Georges River in Australia.



In the "Vid Flumina" river channel network, radar found nearly vertical canyons up to one-third mile deep and less than a half-mile wide.
The radar echo from the canyon bottom showed the presence of liquid.

"Liquid-filled canyons on Titan". Poggiali, V., et al. (2016), Geophys. Res. Lett., 43, doi:10.1002/2016GL069679.

A Surprisingly Young Region in Saturn’s Rings

Chunks of solid ice in the middle of Saturn’s A ring suggest an unexpectedly young ring region.

- Recent results from Cassini’s infrared spectrometer found that particles in one section of Saturn’s rings are much denser than the normally fluffy particles elsewhere.
- After equinox, when the sun shines edge-on to Saturn’s rings, one section of the A ring did not cool down as much as expected, providing a unique window into the interior of the ring particles.
- Perhaps a tiny moon broke apart only 100 million years ago and its solid, icy fragments are slowly spreading through the rings.

Saturn’s rings may therefore be a mix of young and old material, providing clues to their formation and evolution.

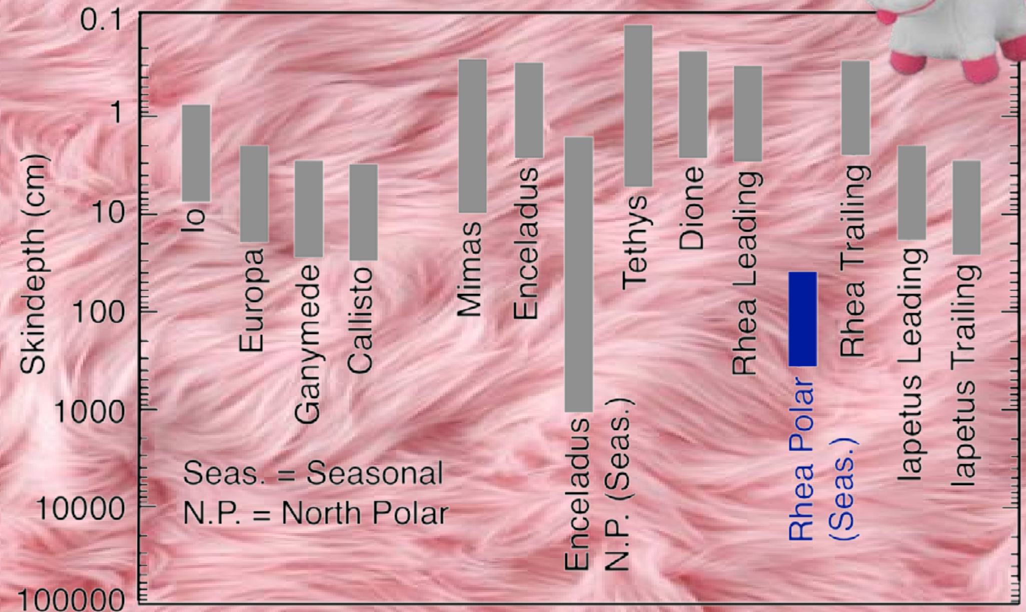
Above: Model of Saturn’s rings showing both small and large particles.
Below: Estimated location in A ring of denser particles.

“Incomplete cooling down of Saturn's A ring at solar equinox: Implication for seasonal thermal inertia and internal structure of ring particles,” Morishima, et al., Icarus, 279, 2-19, 2016. doi:j.icarus.2015.06.025

FLUFFY RHEA

New Cassini results show that Saturn's moon Rhea has a very fluffy, powder-like polar surface, even down to several meters (blue bar at the right).

The new study used seasonal temperature variations of the polar regions to probe deeper below Rhea's surface. Previous studies were sensitive only down to a few centimeters.



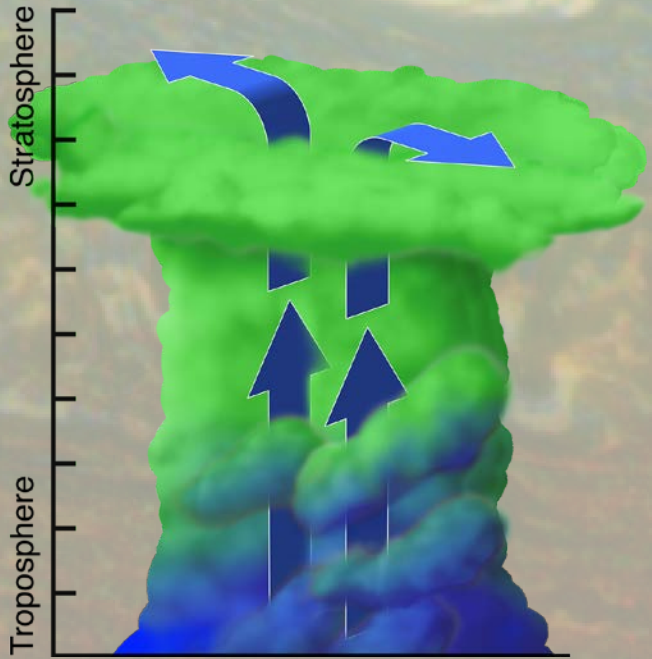
Scientists previously speculated that Rhea's icy subsurface would compact, becoming denser with depth. This new result shows that fluffy surfaces (seen on several moons across the Saturn system) may exist even at great depths.

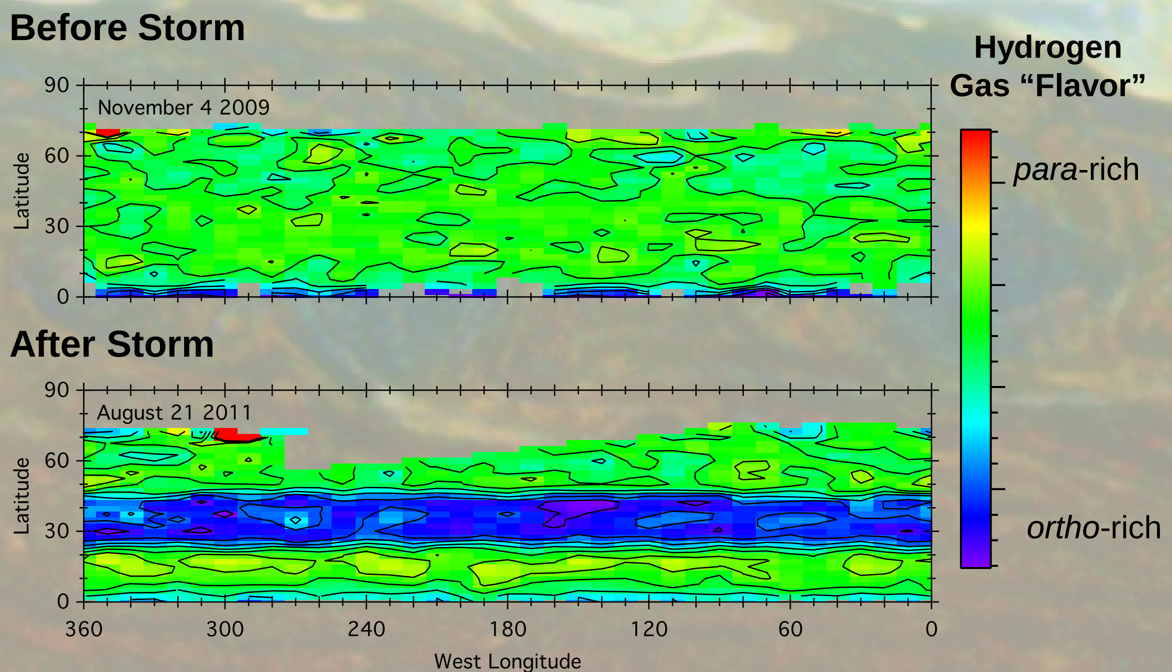
A possible cause may be the slow but continual surface bombardment by ice ring grains from the E-ring. This discovery reminds us that the relationship between Saturn's moons and the rings may be more complex than initially thought.

"Thermal Properties of Rhea's poles: Evidence for a meter-deep unconsolidated subsurface layer," C.J.A. Howett, et al., Icarus, 272, 140-148, 2016.

Saturn Storm Serves Up Two "Flavors" of Hydrogen

- A new study of temperature and composition changes shows that air was lofted more than 200 km (120 miles) higher by powerful convective forces during Saturn's massive storm in 2010-2011 (background image).
- This confirms earlier evidence of powerful convection in Saturn's atmosphere, revealed by the presence of water ice within storm clouds. Water ice normally resides at the level where water condenses, 200 km deep.
- Cassini used infrared measurements to find a significant change in the "flavor" of hydrogen gas, with deeper *ortho*-rich hydrogen, usually found deeper in the atmosphere (shown in blue, below) replacing the higher altitude *para*-rich "flavor" (green).
- These results infroms us about complexity in large-scale storms in giant planet atmospheres.





Changes to Saturn's Zonal-Mean Tropospheric Thermal Structure After the 2010-2011 Northern Hemisphere Storm, Achterberg, et al., *Astrophysical J*. 786, 92-99, 2014

Saturn's Lopsided Magnetosphere: Mystery Solved?

Cassini has observed puzzling asymmetries in Saturn's equatorial magnetosphere. Plasma wakes of moons are shifted radially outward at dawn and radially inward at dusk.

Saturn has a strong magnetic field and spins rapidly around its axis, and there is a strong interplay between the distribution of charged particles and the magnetic field. Charged particles move easily along the magnetic field in response to both *rotational stresses and changing pressure*.

Simulations show that the particle distribution changes the shape of field lines. The field lines are more 'stretched out' on the dawn side, where the *rotational stresses* are dominant, and less 'stretched out' on the dusk side, where *pressure gradients* dominate. This lopsidedness produces local-time dependent inward and outward flows similar to what is observed by Cassini.

Cassini continues to shed light on mysterious physical processes that may be common to other planets within our solar system.

Dawn

Rotational stresses dominant

Dusk

Pressure gradients dominant

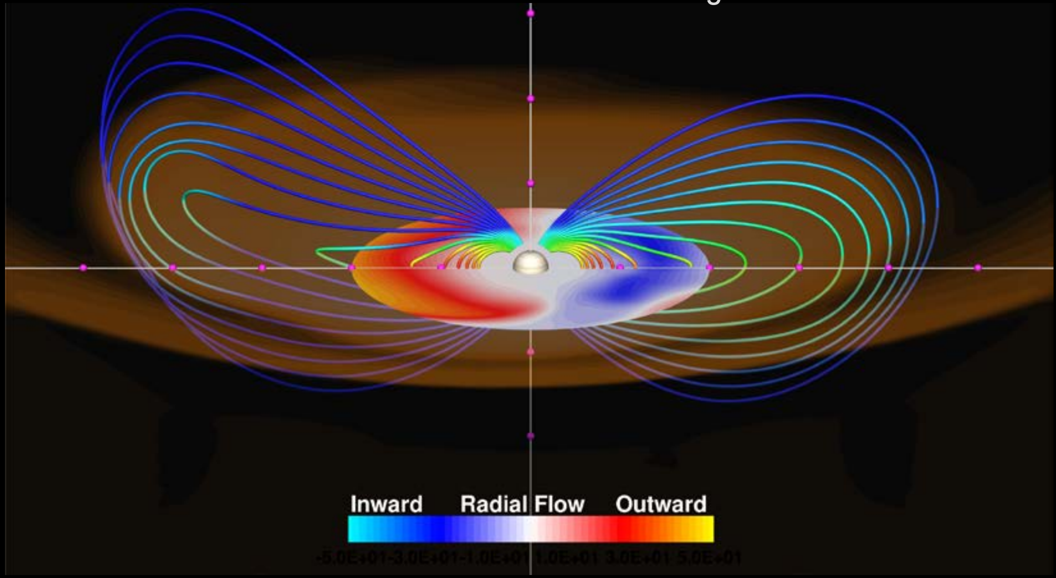


Illustration of Saturn's asymmetric (lopsided) magnetic field. Color code applies to the equatorial circular disk and indicates the flow direction of plasma. Brown background illustrates magnetospheric plasma.

Dawn-dusk asymmetries in rotating magnetospheres: Lessons from modeling Saturn, X. Jia and M.G. Kivelson, J. Geophysical Research, 121, 1413-1424 , 2016.