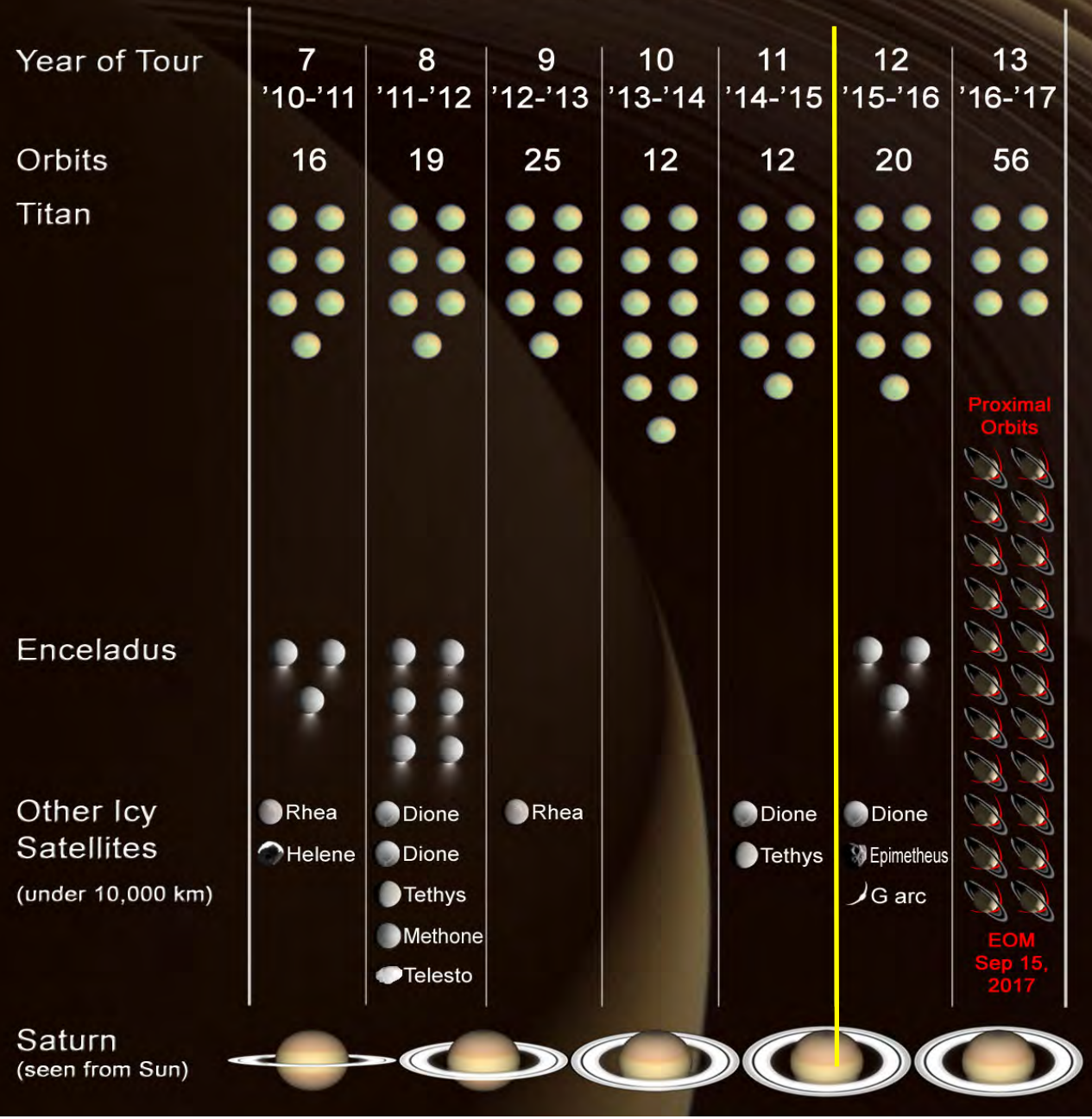
Dr. Linda Spilker
Cassini Project Scientist, JPL/Caltech

Outer Planets Assessment Group

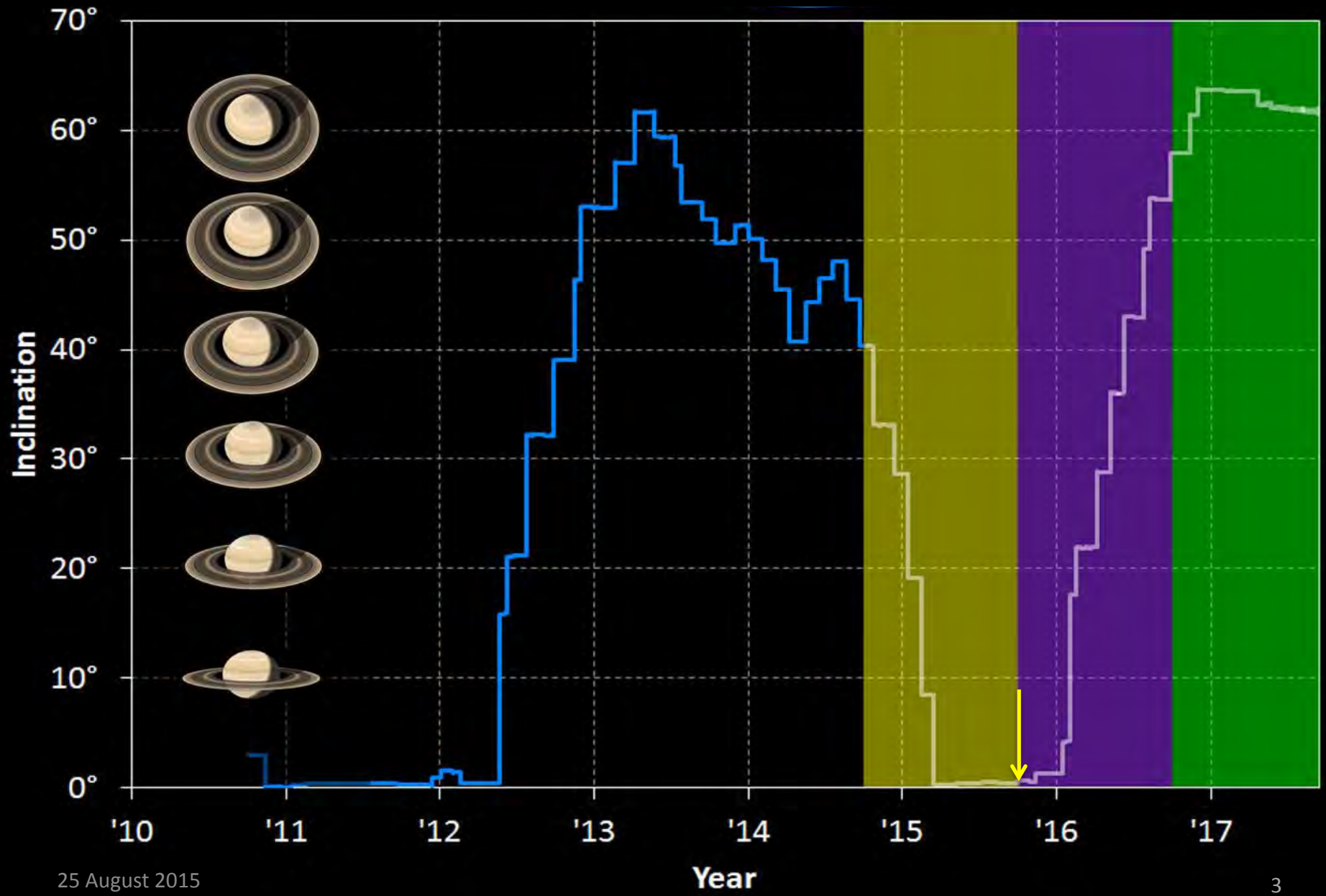
25 August 2015

Cassini Solstice Mission Overview

October 2010 - September 2017



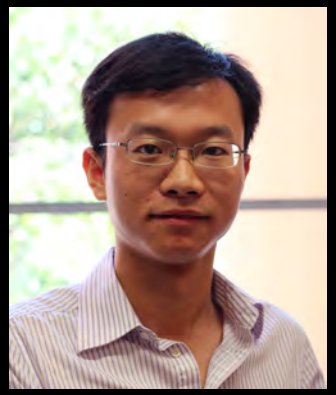
Solstice Mission Inclination Profile



New/Returning Cassini Participating Scientists

Sarah Badman

Hao Cao



Carolyn Ernst

Alex Hayes

Matt Hedman

Brigette Hesman

Liming Li

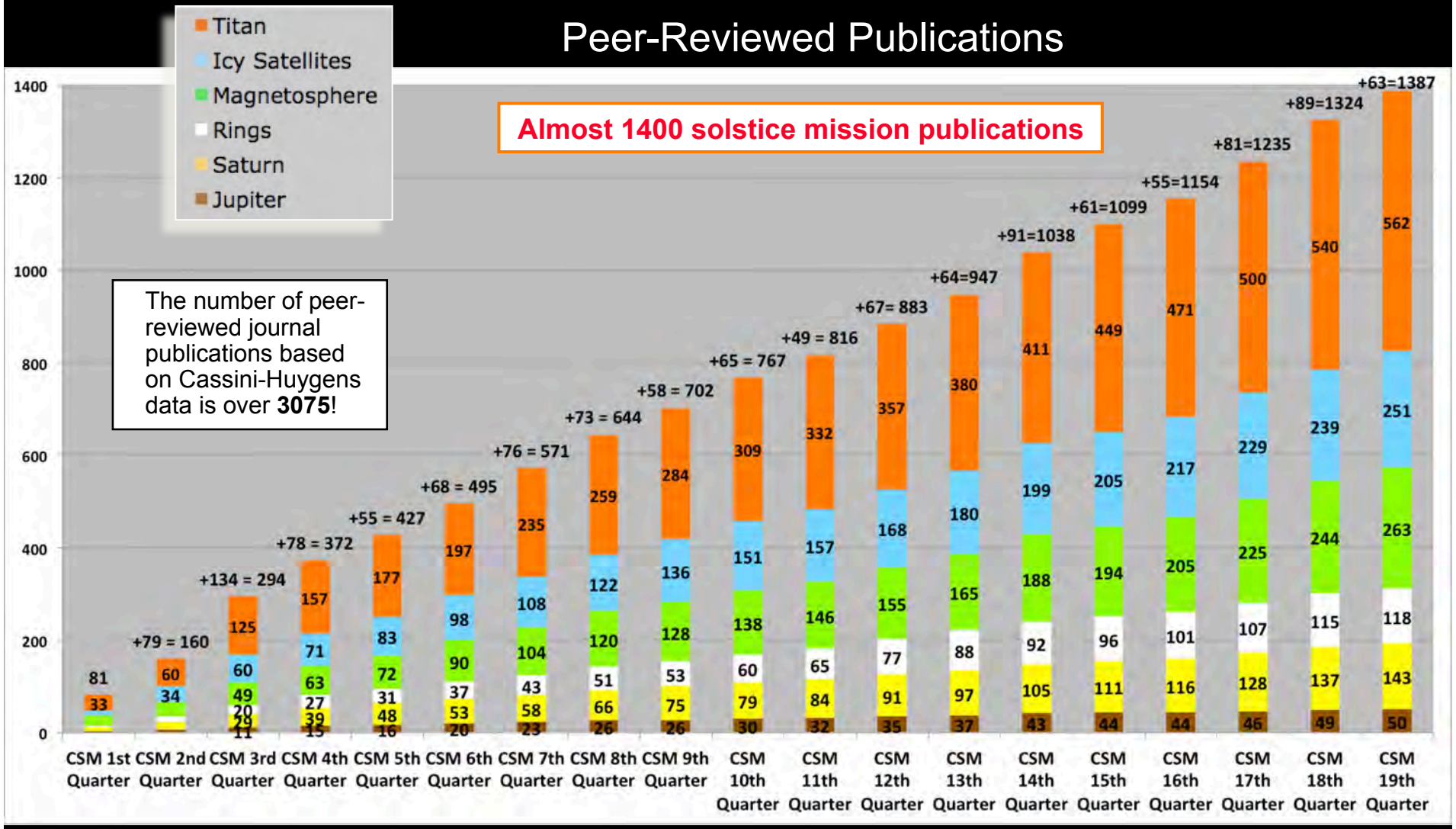
Jason Soderblom

Joe Spitale

New/Returning Cassini Participating Scientists

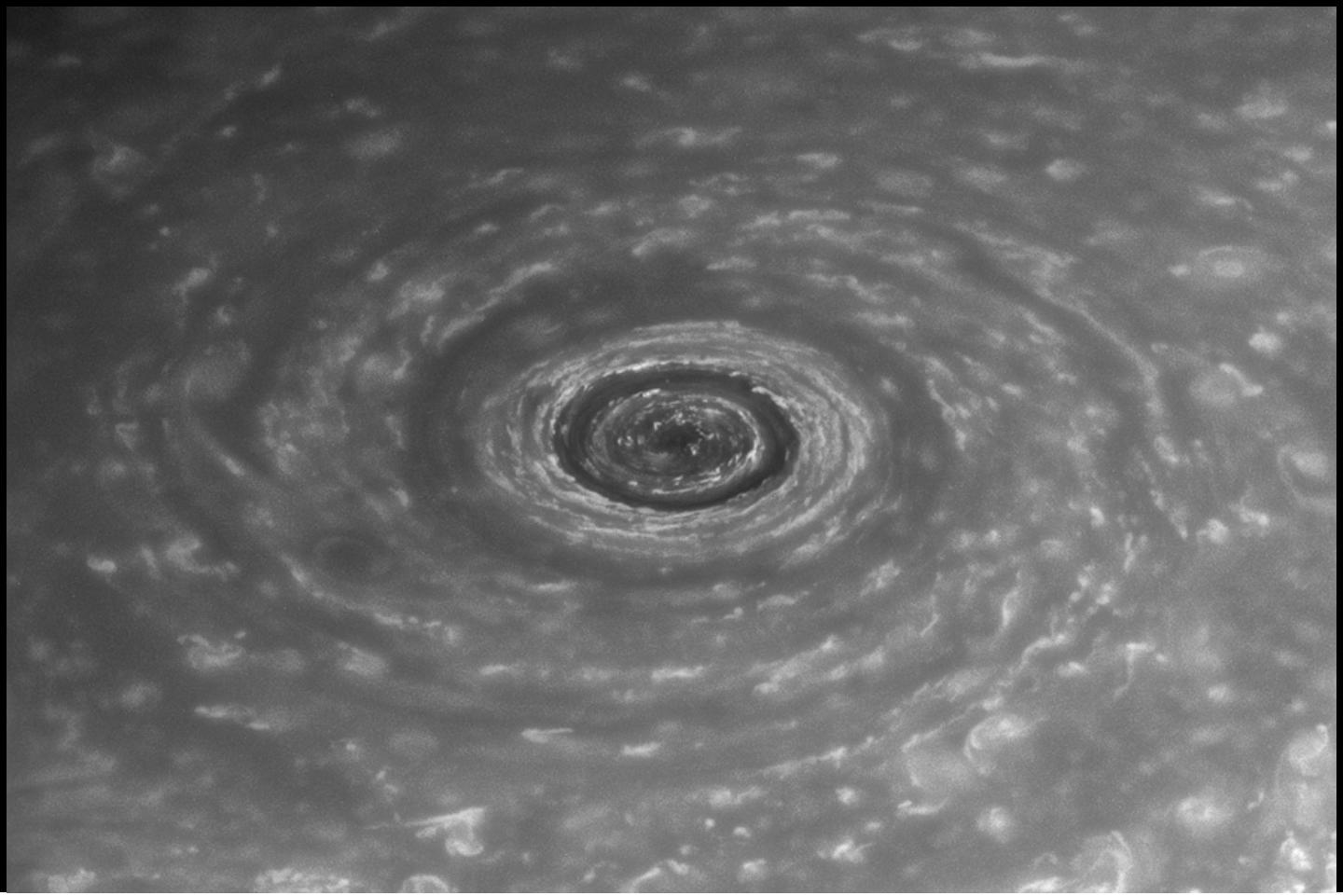
PI	Instruments/ DWG	Institution	Title	Discipline	E-mail
Sarah Badman	VIMS, UVIS, MAG	Lancaster Univ.	Seasonal Variation of Saturn's Aurora	Saturn, Magnetosphere	s.badman@lancaster.ac.uk
Hao Cao	MAG	Caltech	Understanding Saturn's Interior through Magnetic Field Observation and MHD Modeling	Saturn, Magnetosphere	haocao@caltech.edu
Carolyn Ernst	ISS	JHU APL	A Comparative Geological Study of Irregular Saturnian Satellites	Icy Satellites	carolyn.ernst@jhuapl.edu
Alex Hayes	RADAR	Cornell Univ.	Digging for Hydrocarbon Gold with the Cassini RADAR Altimeter	Titan	hayes@astro.cornell.edu
Matthew Hedman	ISS, VIMS	Univ. of Idaho	The Structure, Composition and History of Saturn's Faint Rings	Rings, Magnetosphere	mhedman@uidaho.edu
Brigette Hesman	CIRS	Univ. of Maryland / GSFC	The Water Enigma: Saturn's Stratospheric Water Vapor Distribution	Saturn	brigette.e.hesman@nasa.gov
Liming Li	CIRS, ISS, VIMS	Univ. of Houston	Investigation of Radiant Energy Budgets of Jupiter, Saturn, and Titan and Improvement of Cassini ISS & VIMS Data Calibration	Saturn, Titan	liming.uh@gmail.com; liming@astro.cornell.edu
Jason Soderblom	VIMS	MIT	Hydrocarbon Ices on Titan	Titan	jms4@mit.edu
Joseph Spitale	ISS, CIRS, UVIS	Planetary Science Institute	Linking Tidal Stress to Local and Global Eruption Activity Observed by Cassini ISS	Icy Satellites	jnspitale@psi.edu

Cassini Publication Metric by Quarter

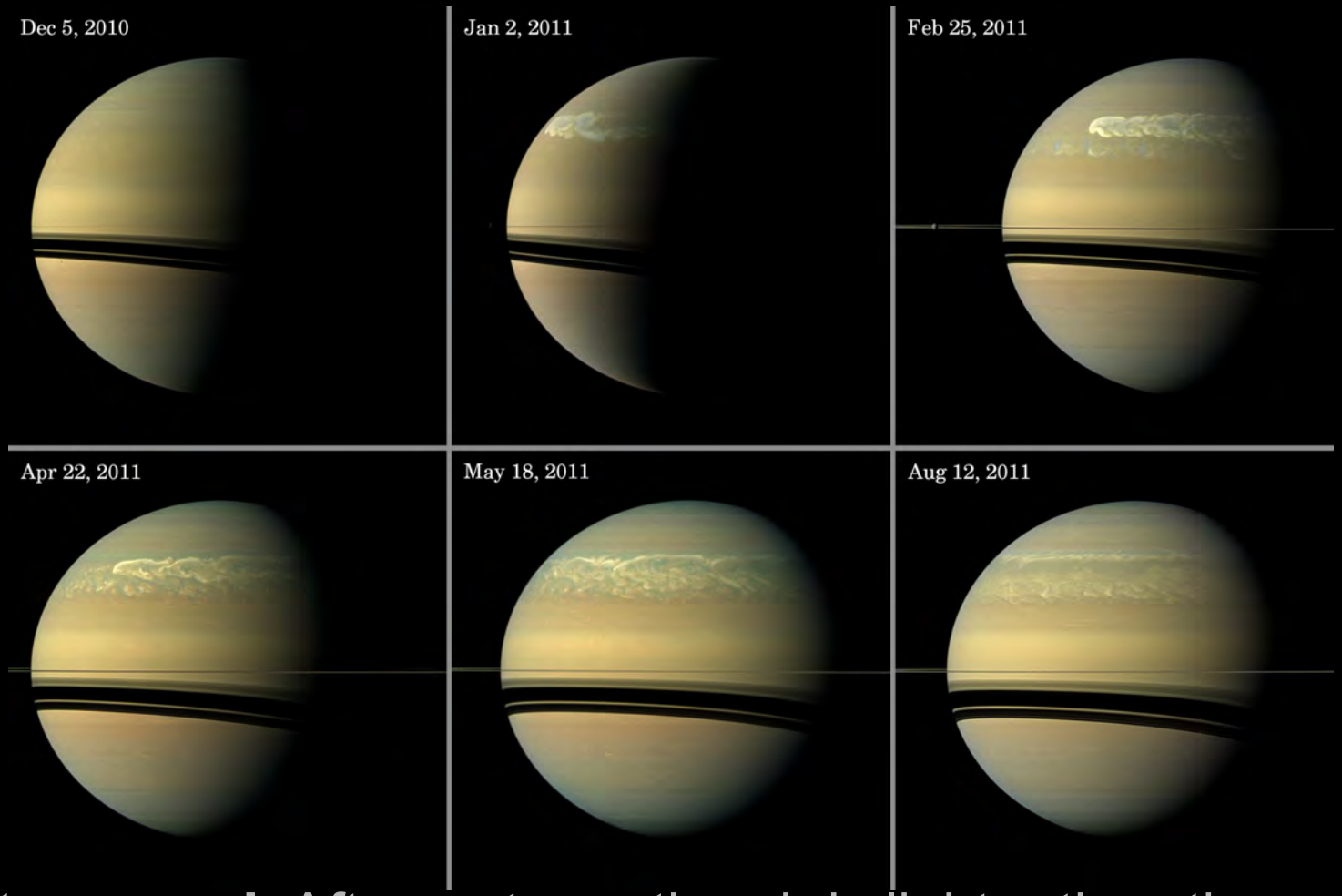


Powering Saturn's Polar Vortices

Over time, small, short-lived thunderstorms across the planet may build up angular momentum, or spin, within the atmosphere—ultimately stirring up a massive and long-lasting vortex at the poles.



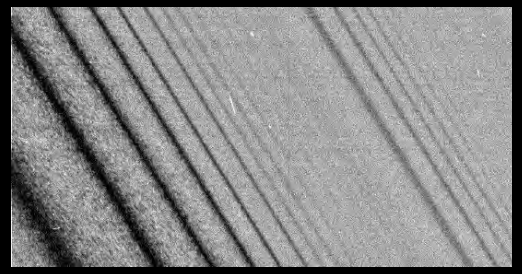
What Causes Saturn's 30-Year Tantrums?



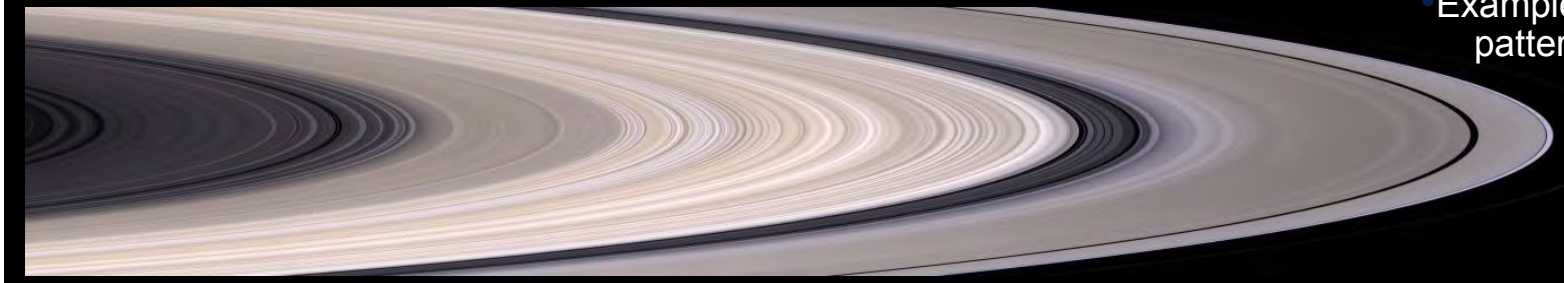
Water vapor! After a storm, the air is lighter than the water-laden atmosphere below. It takes ~30 years for the air to become dense enough to turn on convection again.

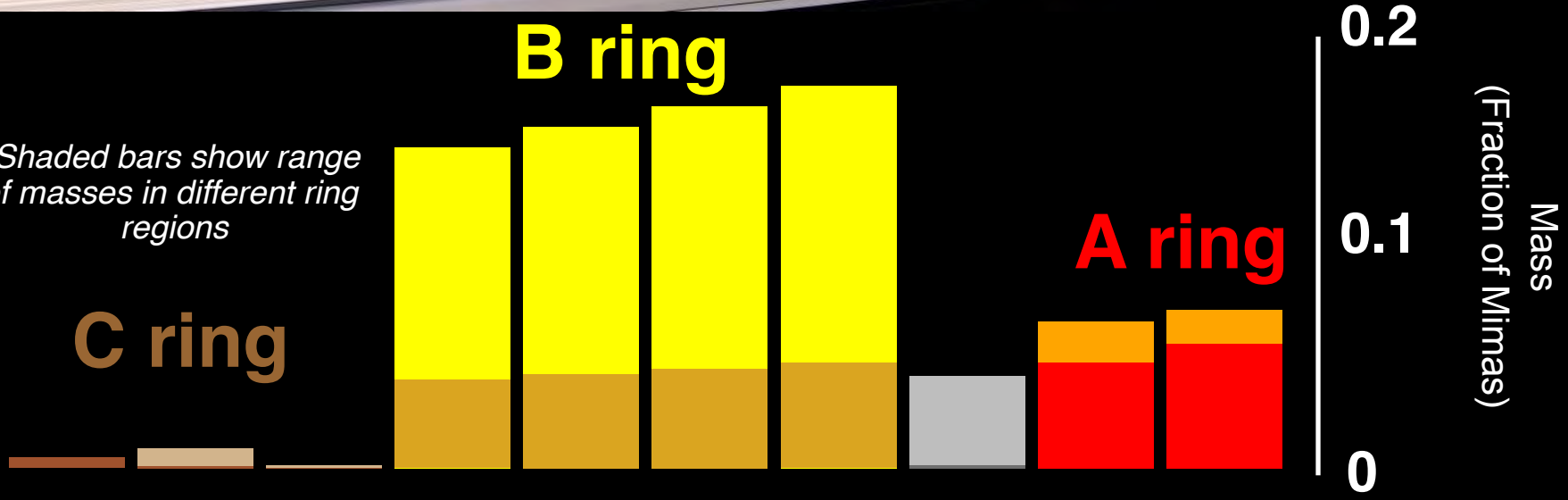
Weighing Saturn's Rings with Hidden Waves

- Spiral structures in Saturn's rings are generated at specific locations in the rings by tiny tugs from various moons.
- The rings' response to these forces depends on their mass density and can be used to estimate ring mass.



- Examples of similar spiral patterns in the A ring

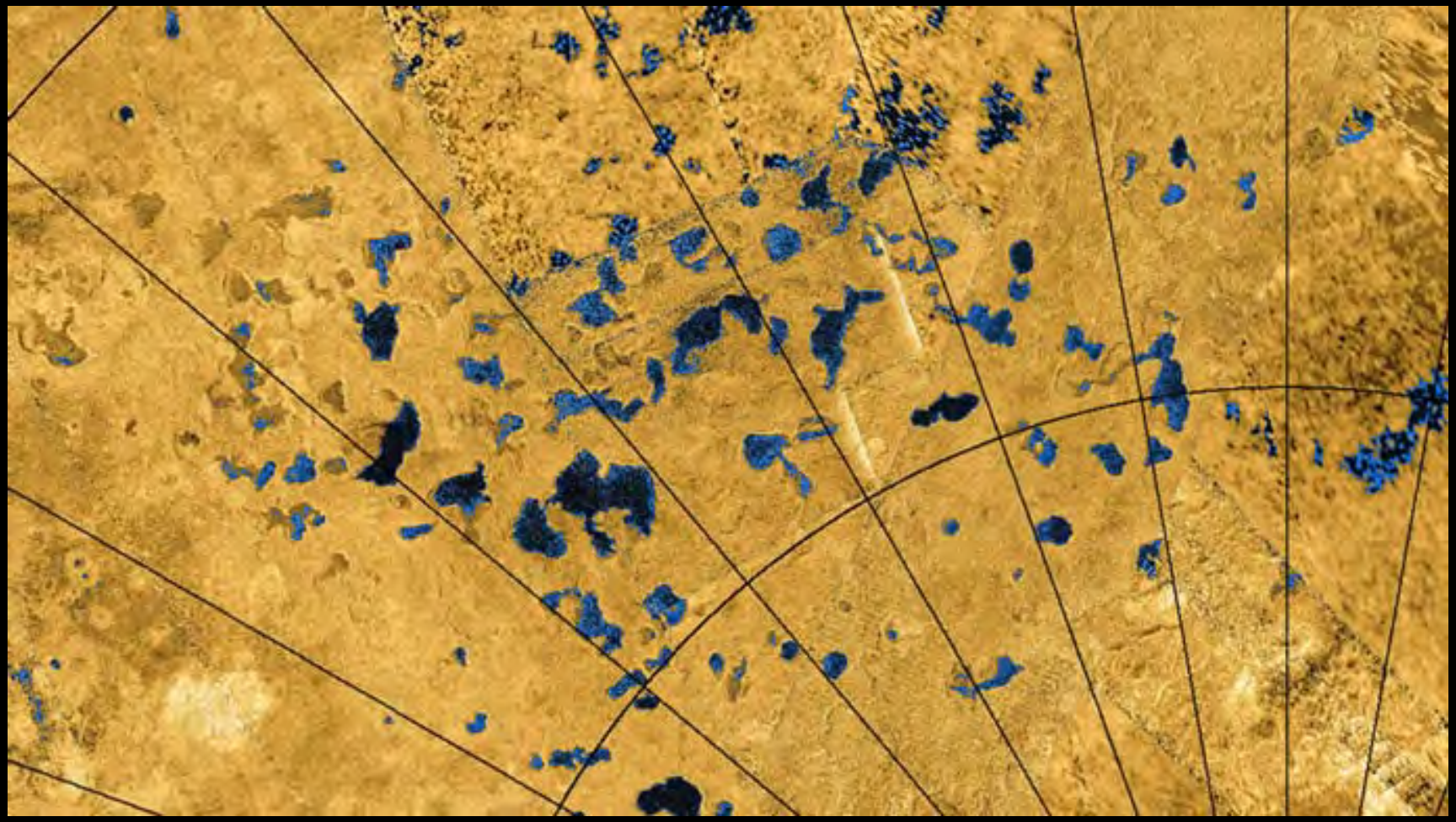




- *Shaded bars show range of masses in different ring regions*

- A new analysis of Cassini data uncovered spiral patterns in the B ring, the densest part of Saturn's rings, which reveal that the rings probably contain far less material than had been anticipated (less than Mimas).

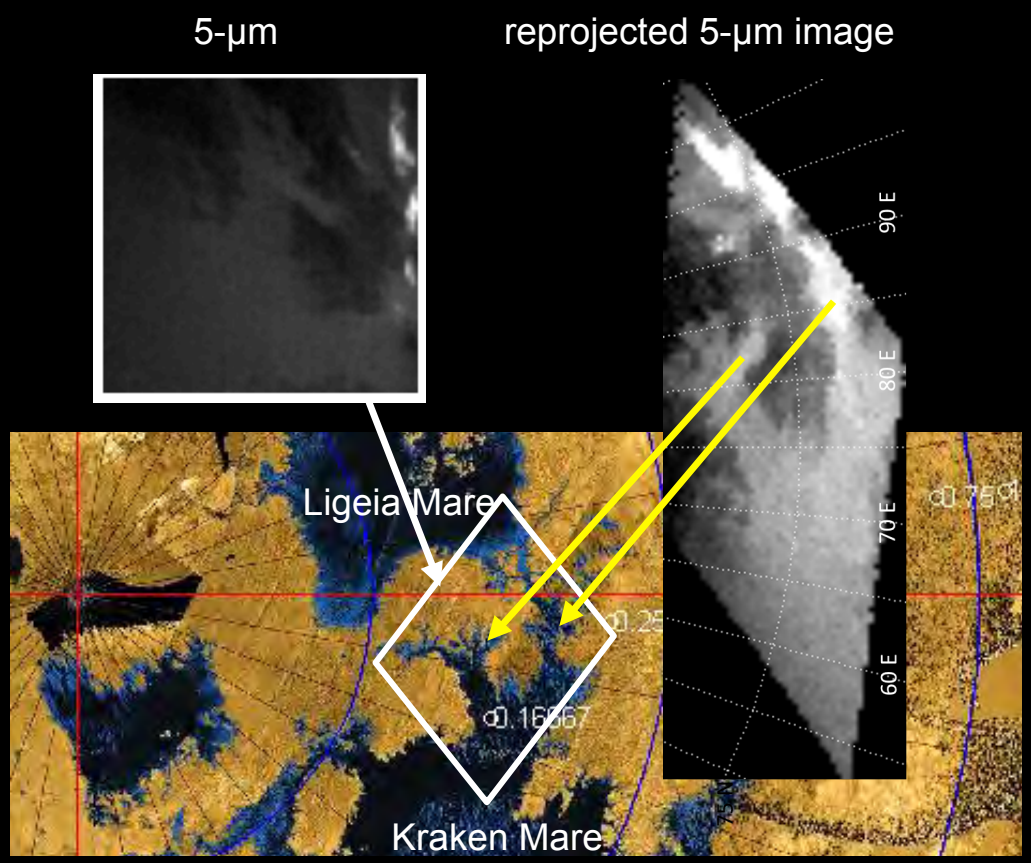
Mysterious Titan Lakes



- *Scientists have been puzzled by how depressions holding 'lakes' of liquid hydrocarbons on Titan were hollowed.*
- *A recent study finds the surface may be dissolved by liquids in a process that's similar to the creation of caves and sinkholes on Earth.*

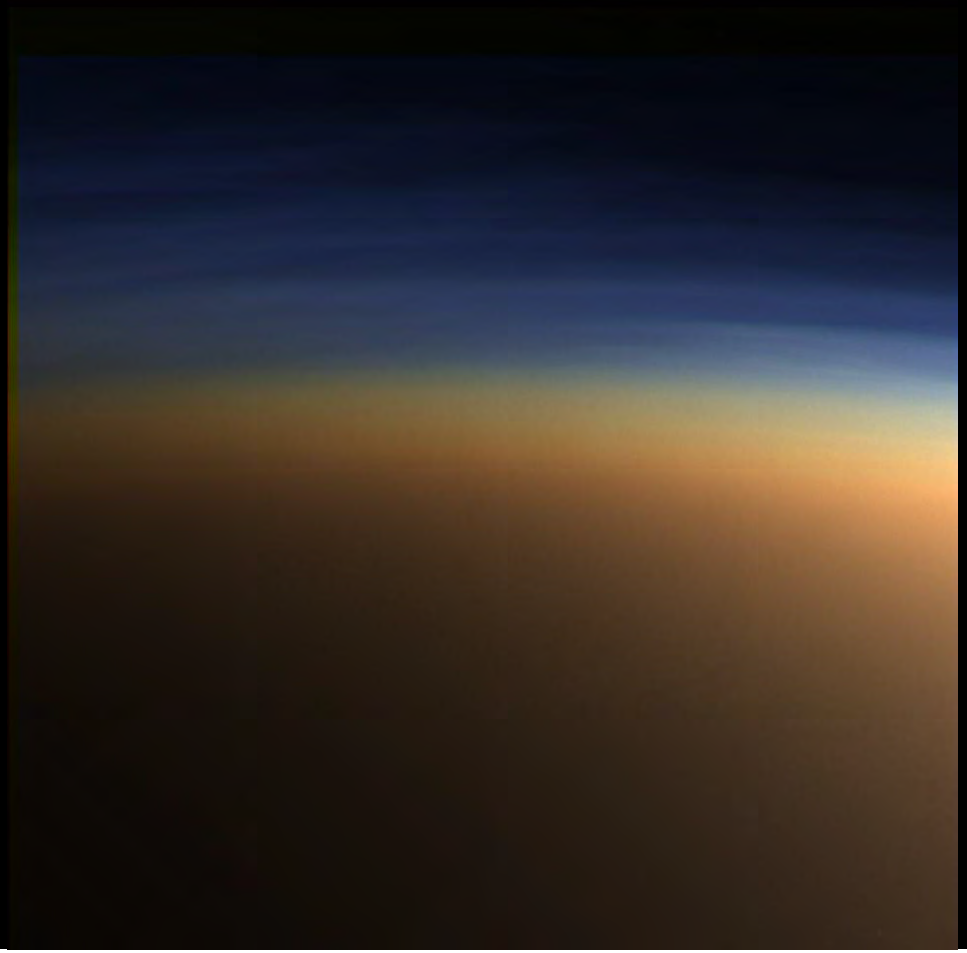
Liquid Strait Connects Two Titanian Seas

- Cassini observed reflections on the strait, Trevize Fretum, between Titan's seas Ligeia Mare and Kraken Mare, demonstrating that the strait is filled with liquid.
- 5-μm images, almost free of scattered light, display specular reflection on smooth surfaces such as liquids.



Escape from Titan: Polar Winds

- Interactions between Titan's atmosphere, Saturn’s magnetic field and radiation, create a wind of positively charged hydrocarbons and nitriles being blown away from its polar regions into space.
- This is very similar to wind observed coming from Earth's polar regions.

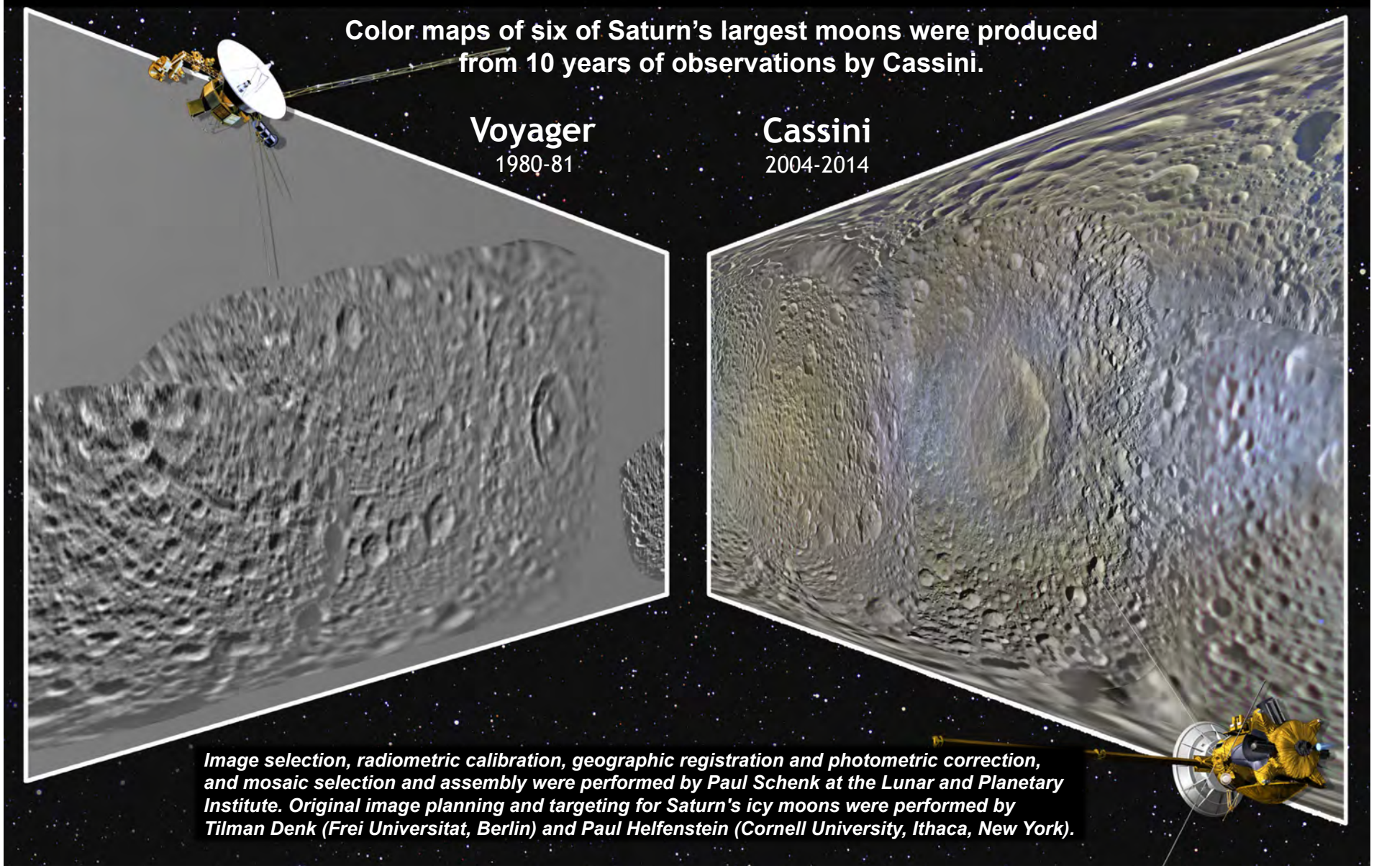


Titan and Pluto Compared

Left: Titan, Cassini, 2010. Right: Pluto, New Horizons, 2015. Phase angle about 165 degrees. Pluto image has been scaled to match size of Titan image.

Data: NASA / JPL / JHUAPL / SwRI. Comparison by Emily Lakdawalla.

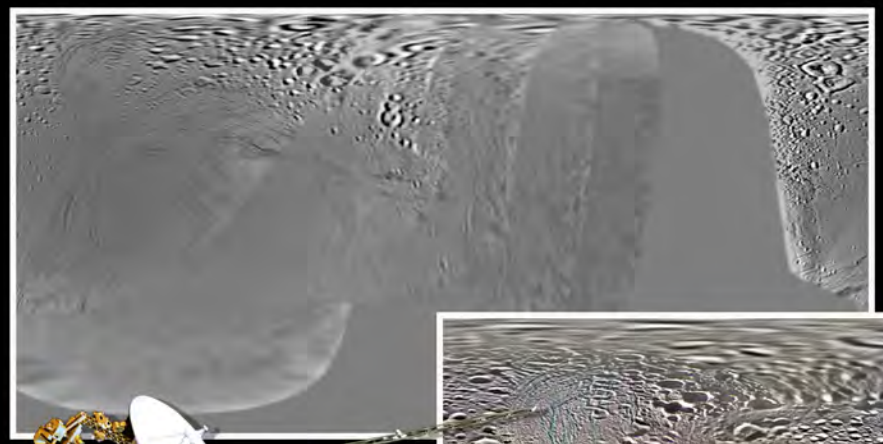
Mimas: Before and After Cassini

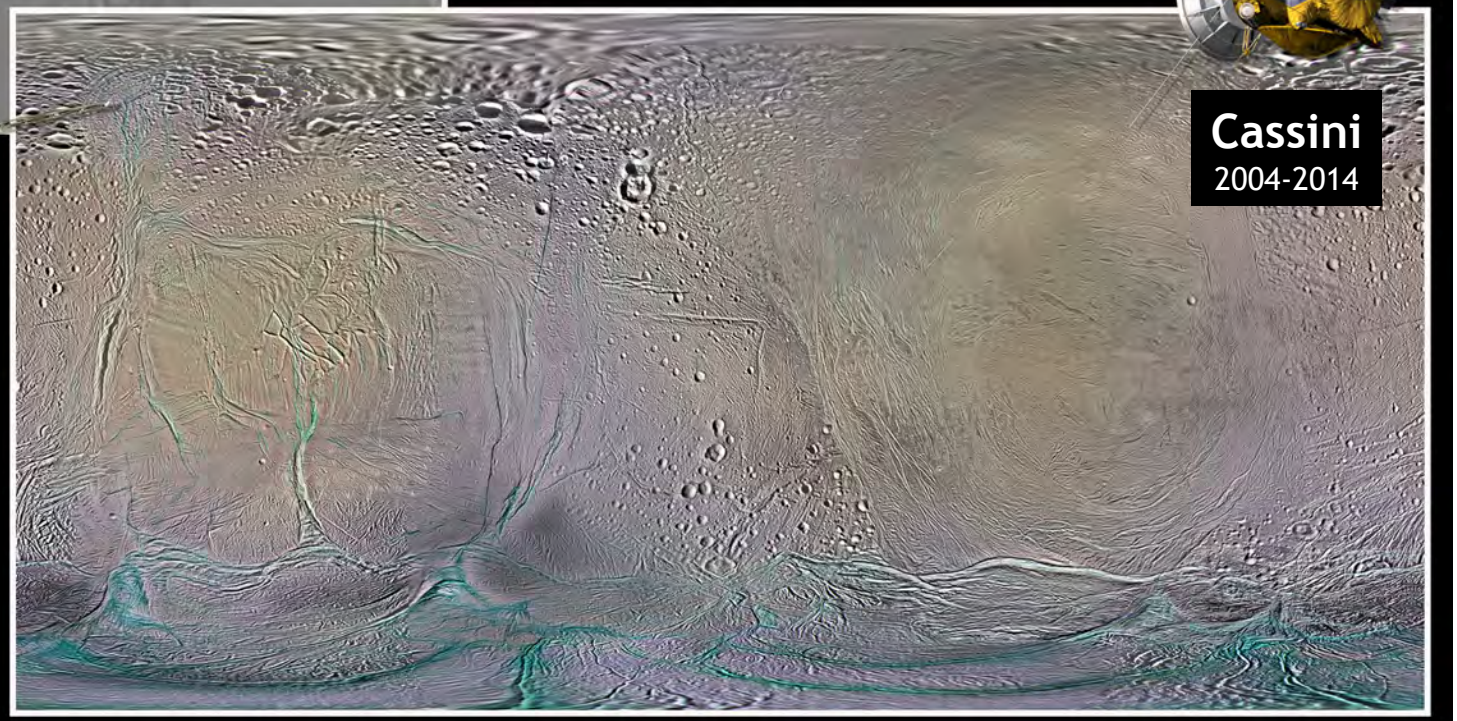


Enceladus: Before and After Cassini

Color maps of six of Saturn's largest moons were produced from 10 years of observations by Cassini.

Image selection, radiometric calibration, geographic registration and photometric correction, and mosaic selection and assembly were performed by Paul Schenk at the Lunar and Planetary Institute. Original image planning and targeting for Saturn's icy moons were performed by Tilman Denk (Frei Universitat, Berlin) and Paul Helfenstein (Cornell University, Ithaca, New York).





Voyager
1980-81

Cassini
2004-2014

Tethys: Before and After Cassini

Color maps of six of Saturn's largest moons were produced from 10 years of observations by Cassini. The Cassini map shows the striking differences between Tethys' dark leading hemisphere and bright trailing hemisphere. Craters and wispy grooves punctuate the icy surface.

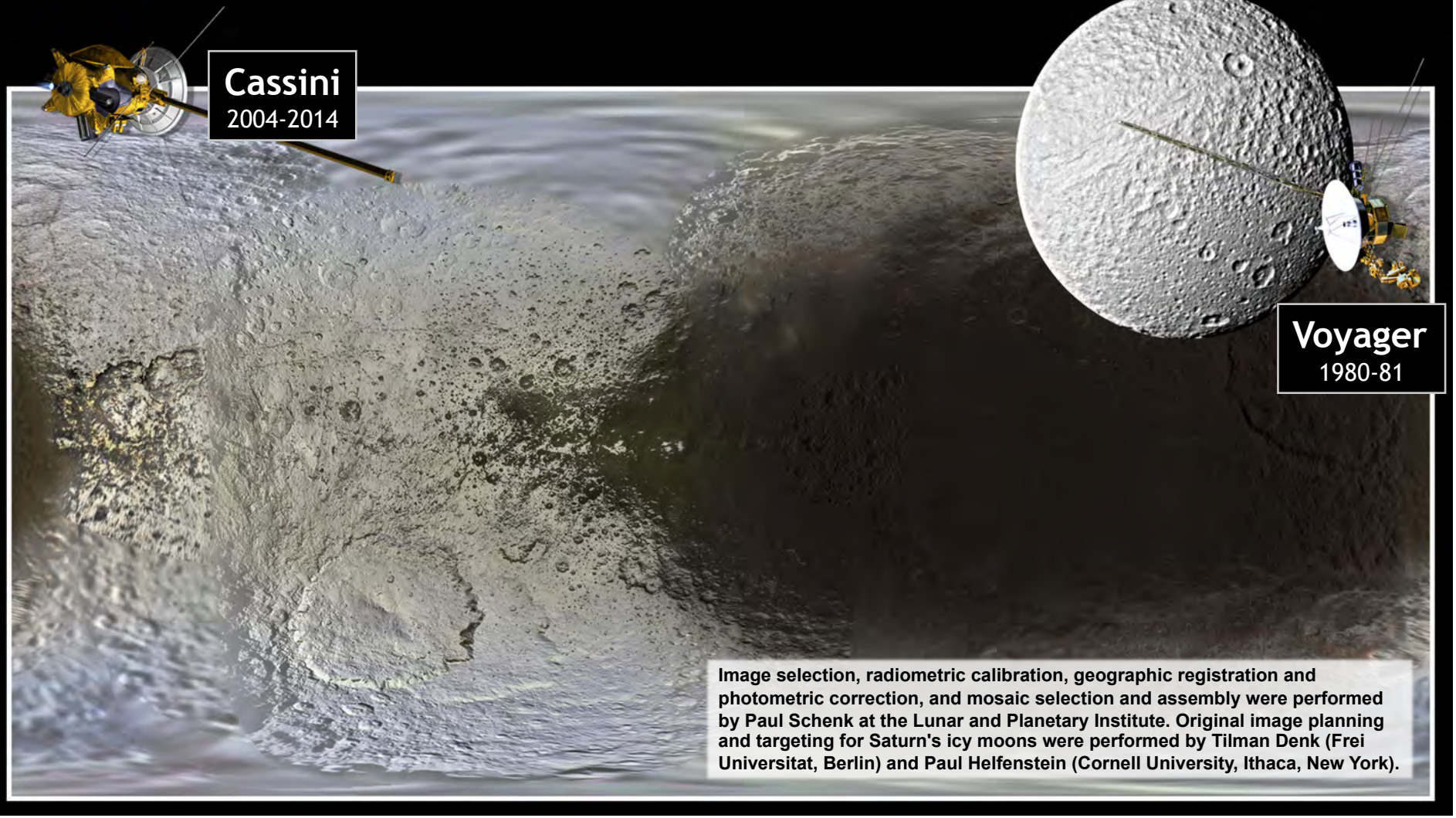


Image selection, radiometric calibration, geographic registration and photometric correction, and mosaic selection and assembly were performed by Paul Schenk at the Lunar and Planetary Institute. Original image planning and targeting for Saturn's icy moons were performed by Tilman Denk (Frei Universitat, Berlin) and Paul Helfenstein (Cornell University, Ithaca, New York).

Dione: Before and After Cassini

Color maps of six of Saturn's largest moons were produced from 10 years of observations by Cassini.

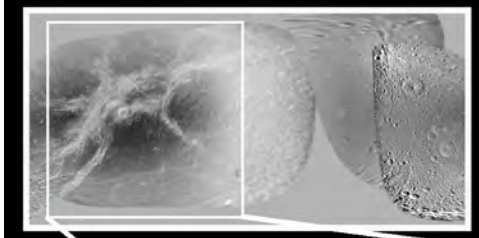
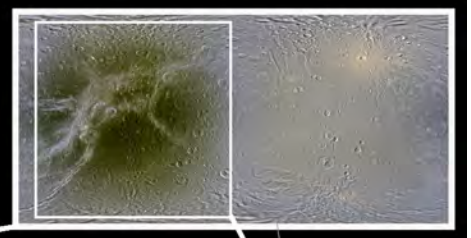
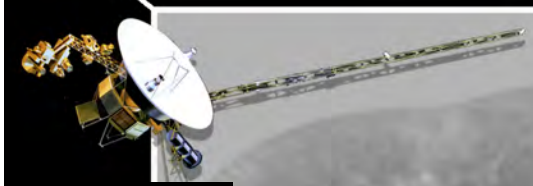
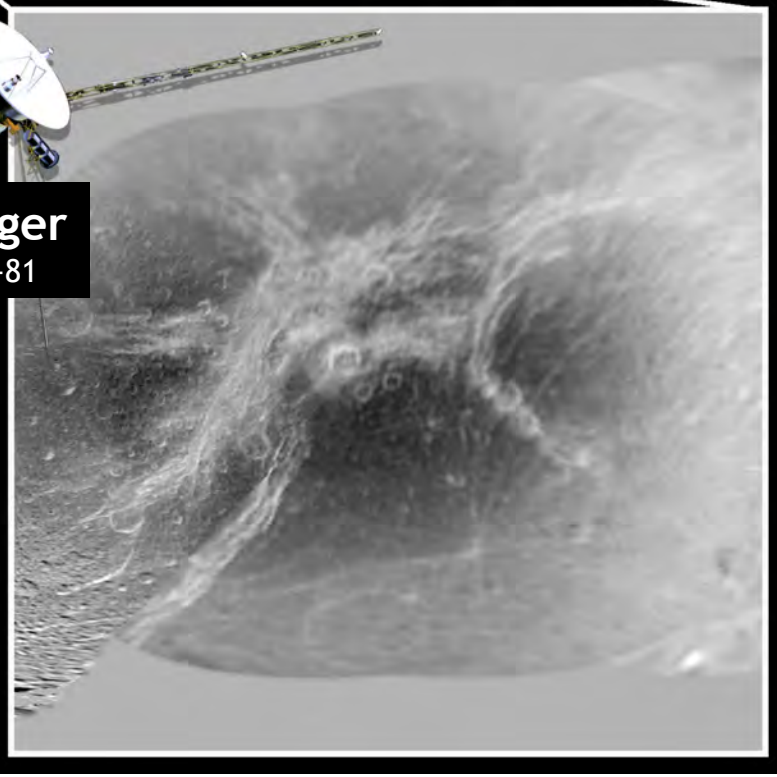


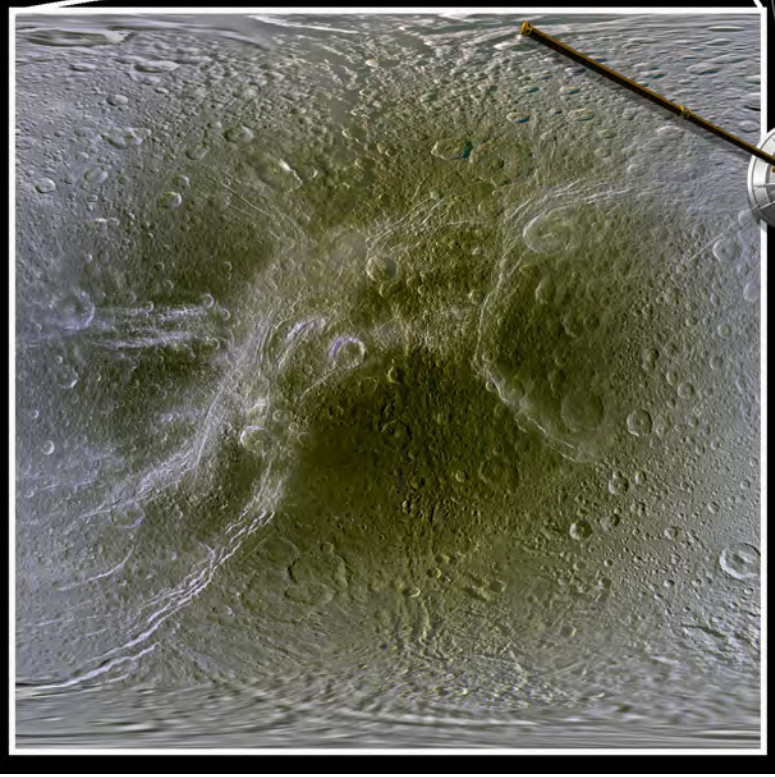
Image selection, radiometric calibration, geographic registration and photometric correction, and mosaic selection and assembly were performed by Paul Schenk at the Lunar and Planetary Institute. Original image planning and targeting for Saturn's icy moons were performed by Tilman Denk (Frei Universitat, Berlin) and Paul Helfenstein (Cornell University, Ithaca, New York).





Voyager
1980-81





Cassini
2004-2014

Rhea: Before and After Cassini

Cassini's detailed map of the moon Rhea (right) is compared with Voyager data of the same moon from 1980-81 (left). Color maps of six of Saturn's largest moons were produced from 10 years of observations by Cassini.

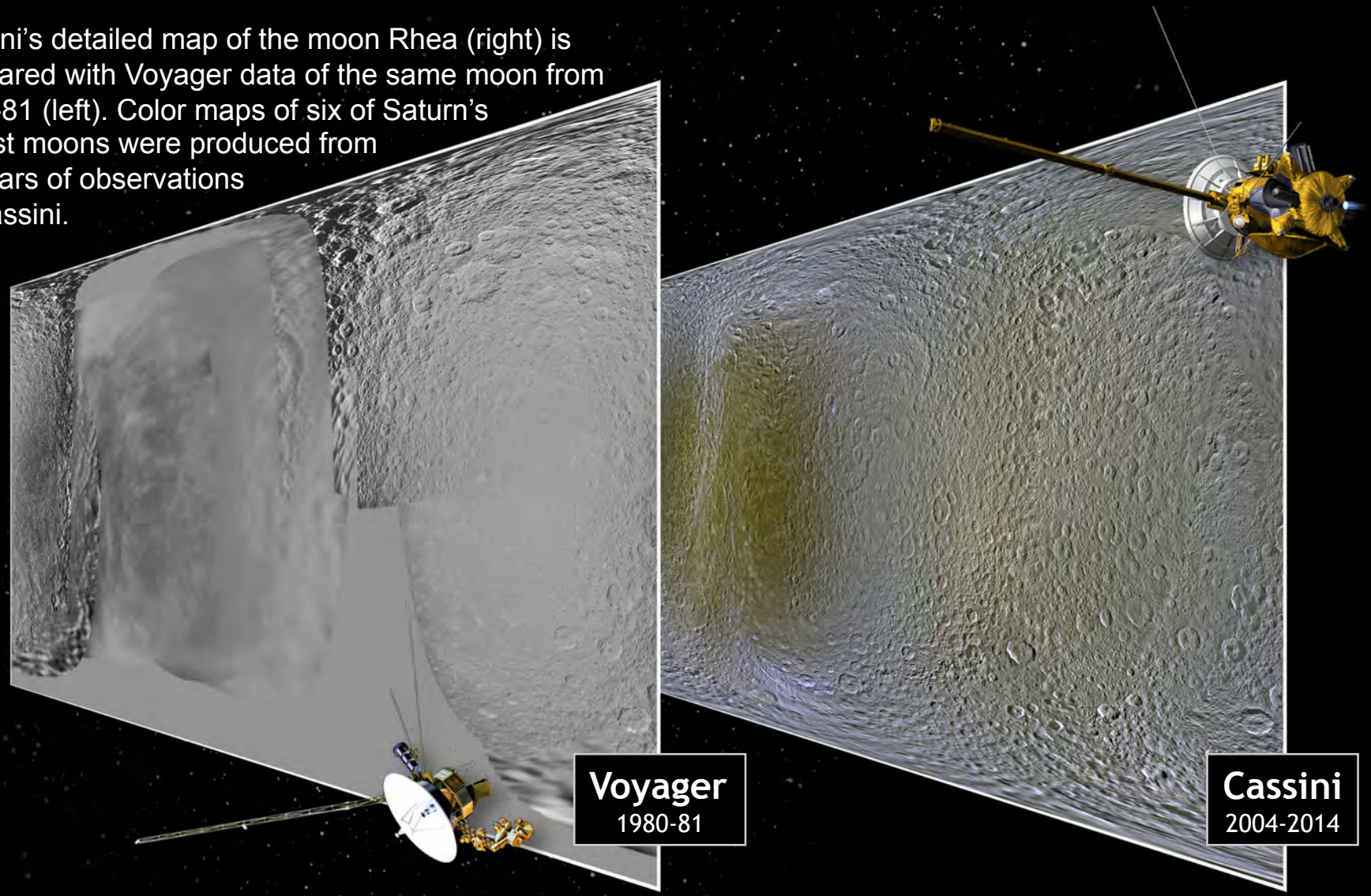


Image selection, radiometric calibration, geographic registration and photometric correction, and mosaic selection and assembly were performed by Paul Schenk at the Lunar and Planetary Institute. Original image planning and targeting for Saturn's icy moons were performed by Tilman Denk (Frei Universitat, Berlin) and Paul Helfenstein (Cornell University, Ithaca, New York).

Iapetus: Before and After Cassini

Color maps of six of Saturn's largest moons were produced from 10 years of observations by Cassini. The coal-dark leading hemisphere dominates this view of the icy moon.

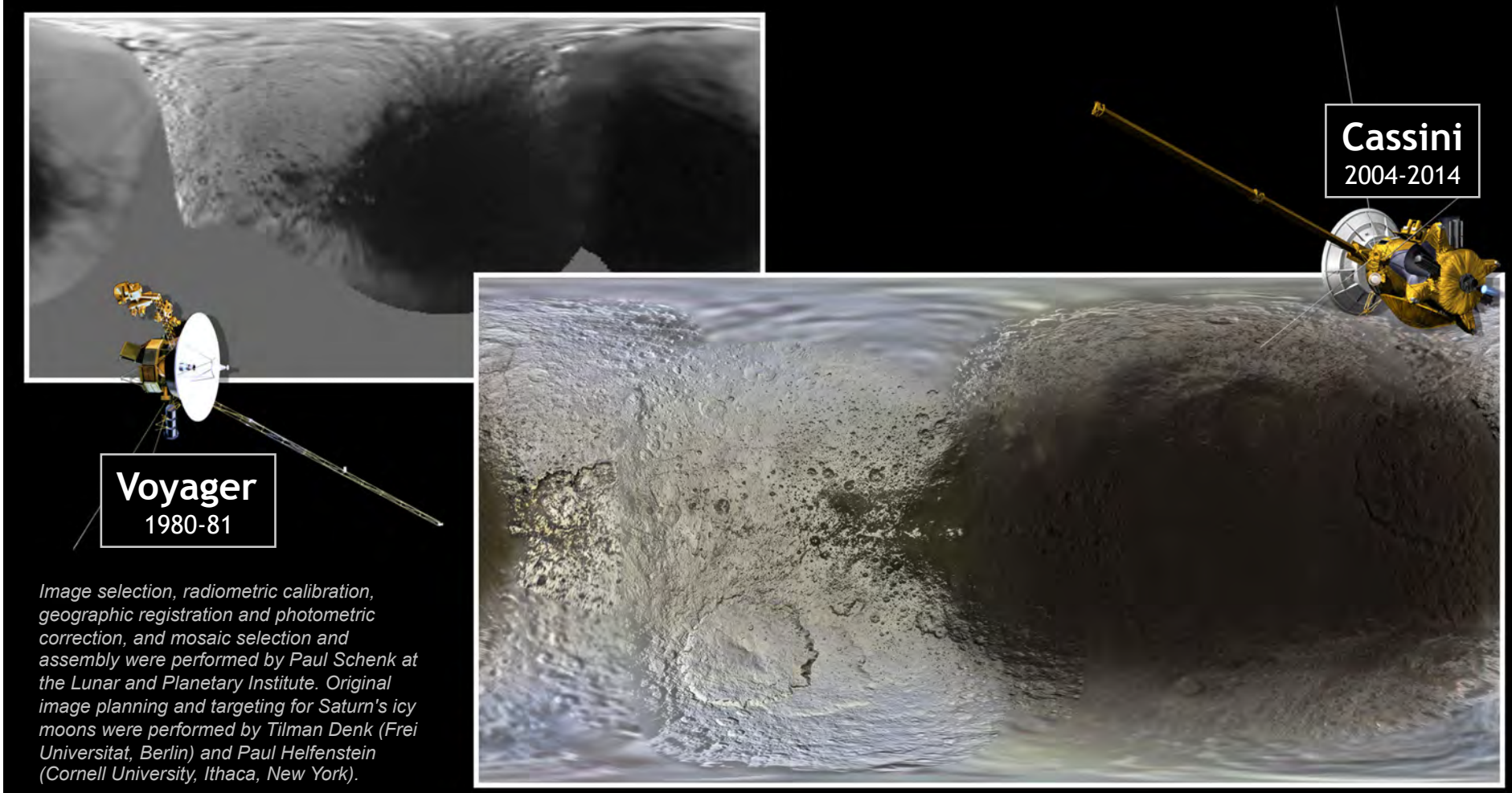
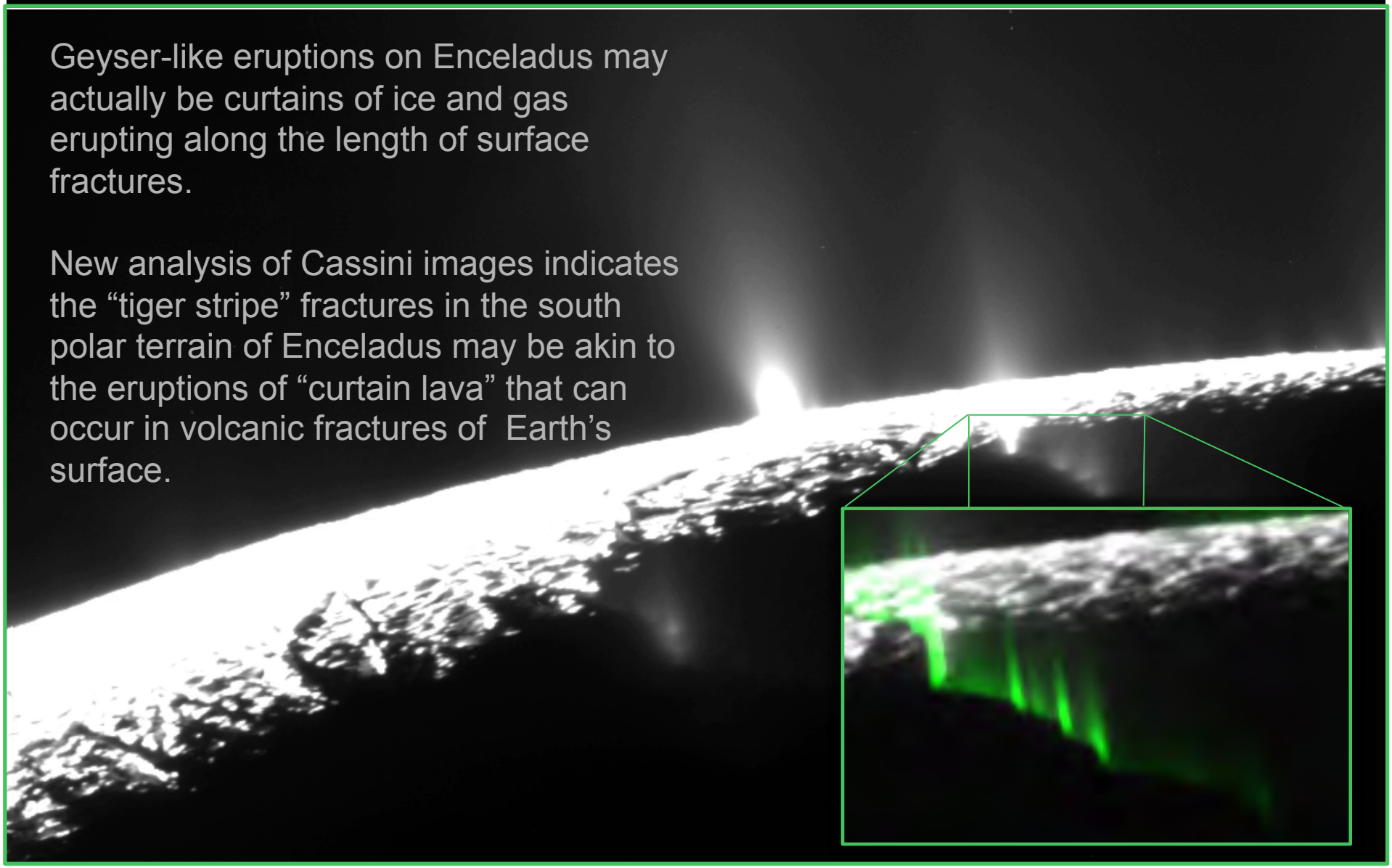


Image selection, radiometric calibration, geographic registration and photometric correction, and mosaic selection and assembly were performed by Paul Schenk at the Lunar and Planetary Institute. Original image planning and targeting for Saturn's icy moons were performed by Tilman Denk (Frei Universitat, Berlin) and Paul Helfenstein (Cornell University, Ithaca, New York).

Are the Geyser-like Jets on Enceladus Really Curtains of Ice?

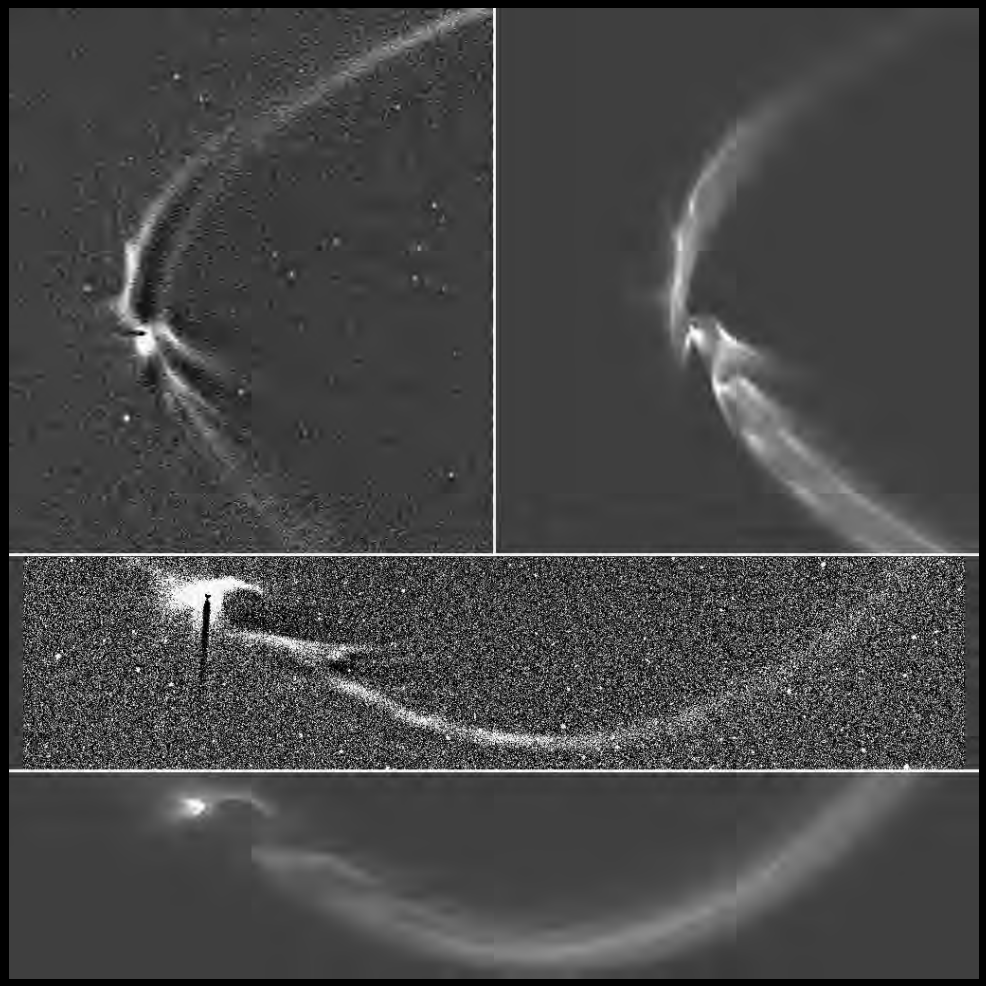
Geyser-like eruptions on Enceladus may actually be curtains of ice and gas erupting along the length of surface fractures.

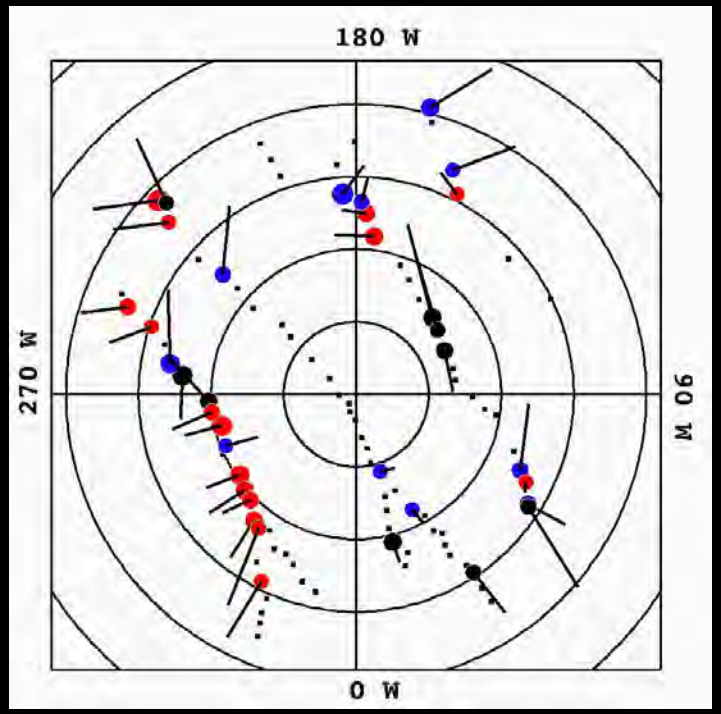
New analysis of Cassini images indicates the “tiger stripe” fractures in the south polar terrain of Enceladus may be akin to the eruptions of “curtain lava” that can occur in volcanic fractures of Earth’s surface.



Enceladus' Curtain Plumes

Enceladus Reaching Out



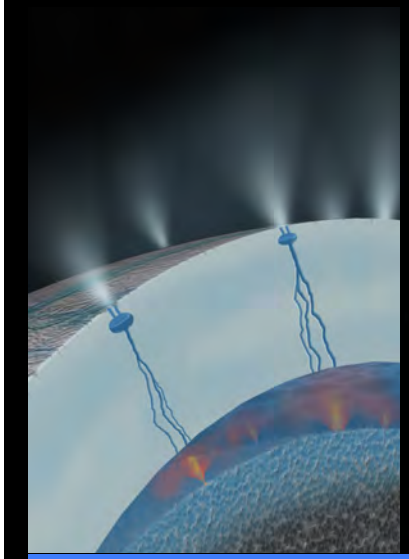


- Enceladus' plumes of water ice extend far its surface.
- Electrical charges that collect on small grains (>0.5 microns) modify their trajectories producing the observed structure.
- The tendrils can be mapped back to their source jets.

Telltale Geyser Dust from Enceladus Seafloor Vents

Silica nanoparticles captured by Cassini provides first evidence for ongoing seafloor hydrothermal activity on a body other than Earth.

Hydrothermal activity occurs when seawater infiltrates and reacts with a rocky core



There is a strong possibility that hot water rises from seafloor vents on Enceladus. This raises the potential for habitable environments beneath the ice crust of this small, active moon.

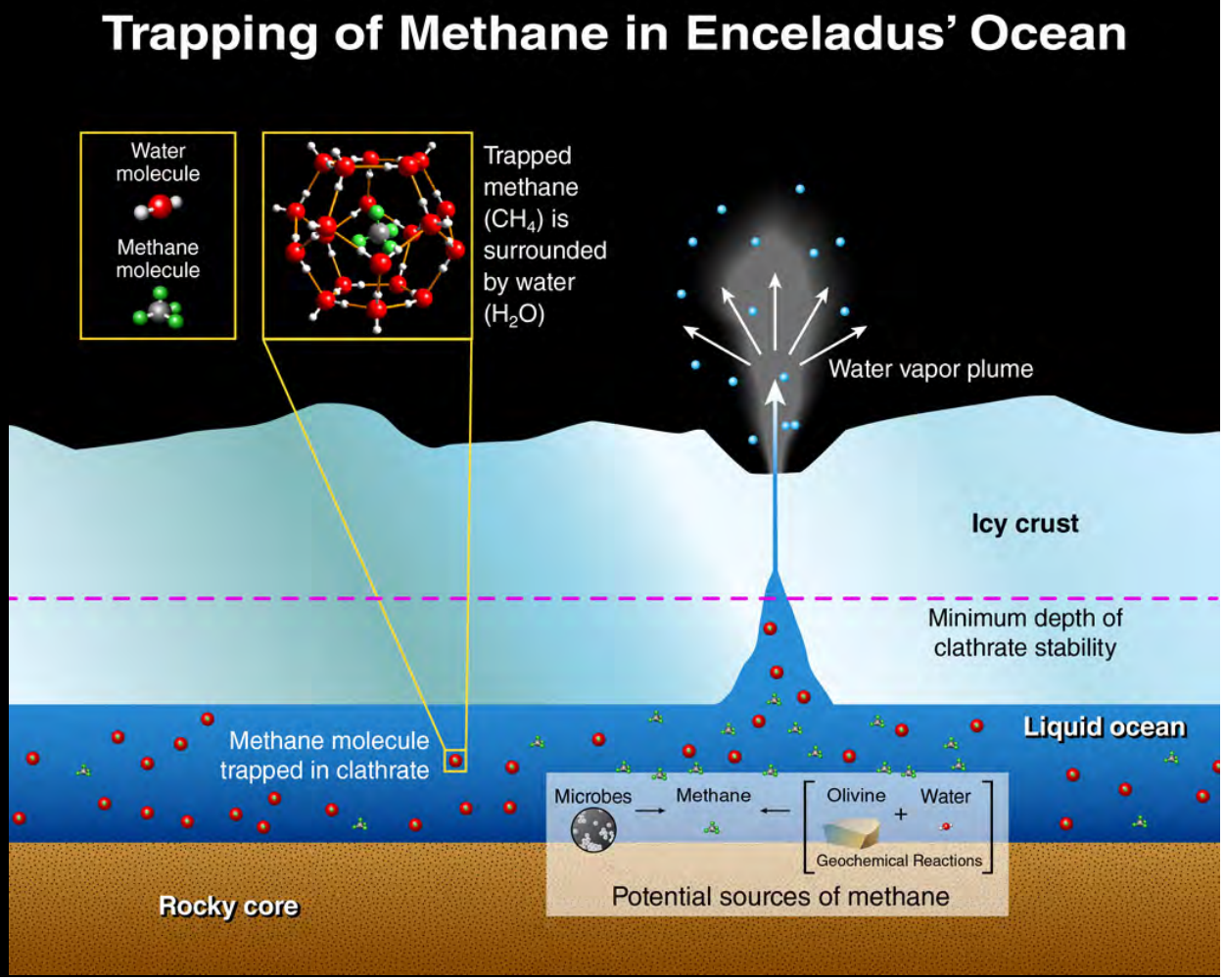
Enceladus similar to activity observed around mid-Atlantic seafloor vents, where some extreme life forms reside.

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

Methane in Enceladus Geysers Likely Originates from Seafloor Vents

Cassini found the first evidence of active seafloor hydrothermal vents, where seawater and the rocky core meet to form warm mineral-laden liquid.

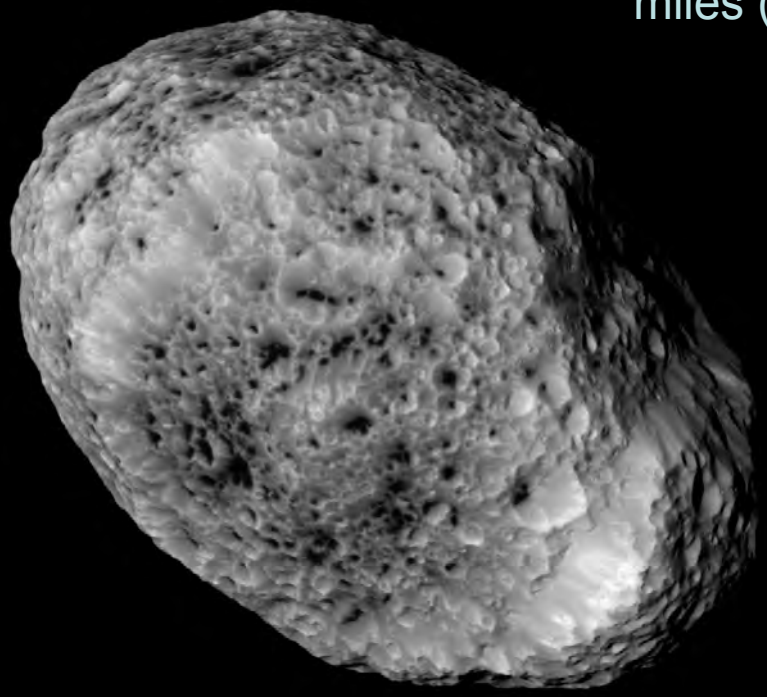
- Abundant methane found in Enceladus' vapor plumes can be explained by a source rapidly adding methane in the ocean, faster than it is trapped into clathrates (ice cages).
- Chemical reactions near warm hydrothermal vents are the most likely candidate for producing additional methane.

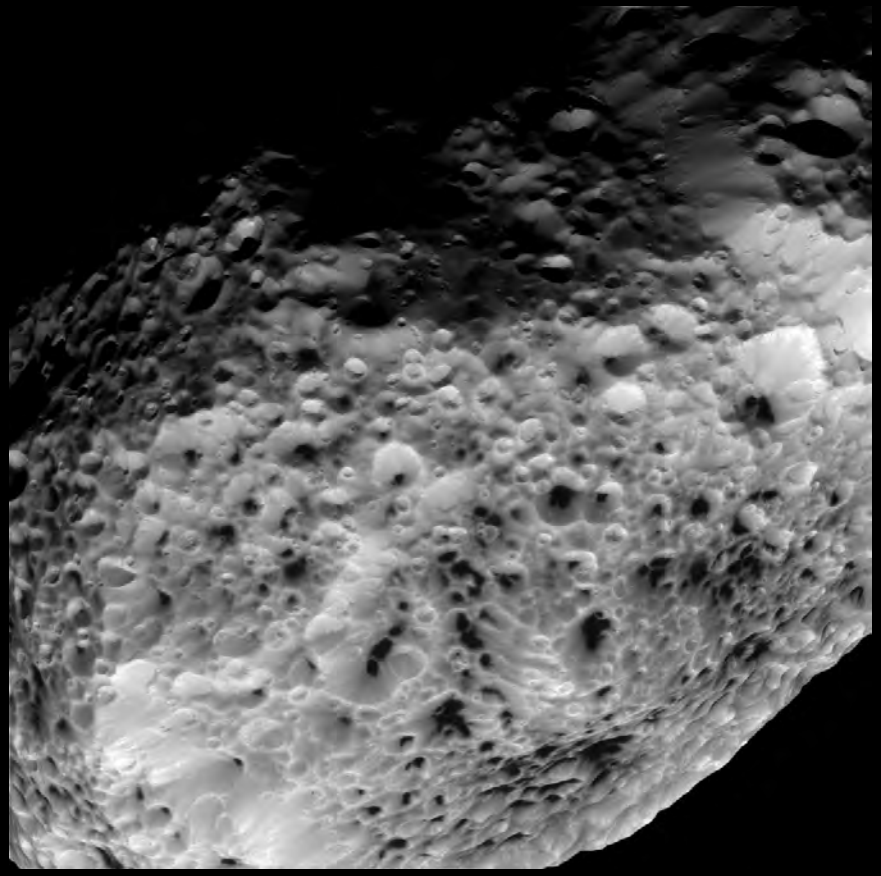


"Possible evidence for a methane source in Enceladus' ocean ," Bouquet *et al., Geophysical Research Letters,* March 12, 2015.

Last Up-Close Look at Hyperion

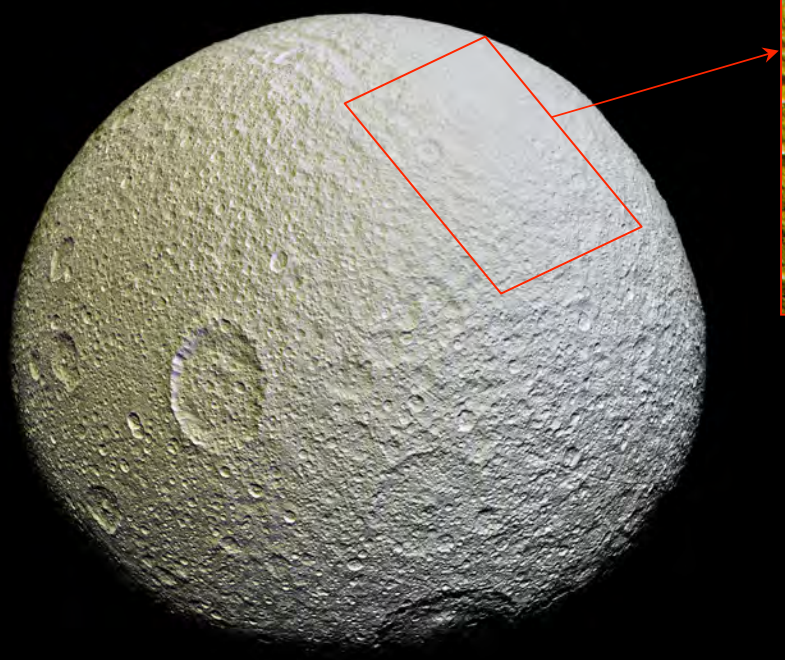
Cassini's last up-close flyby of Hyperion occurred on May 31, 2015 at a distance of about 21,000 miles (34,000 kilometers).

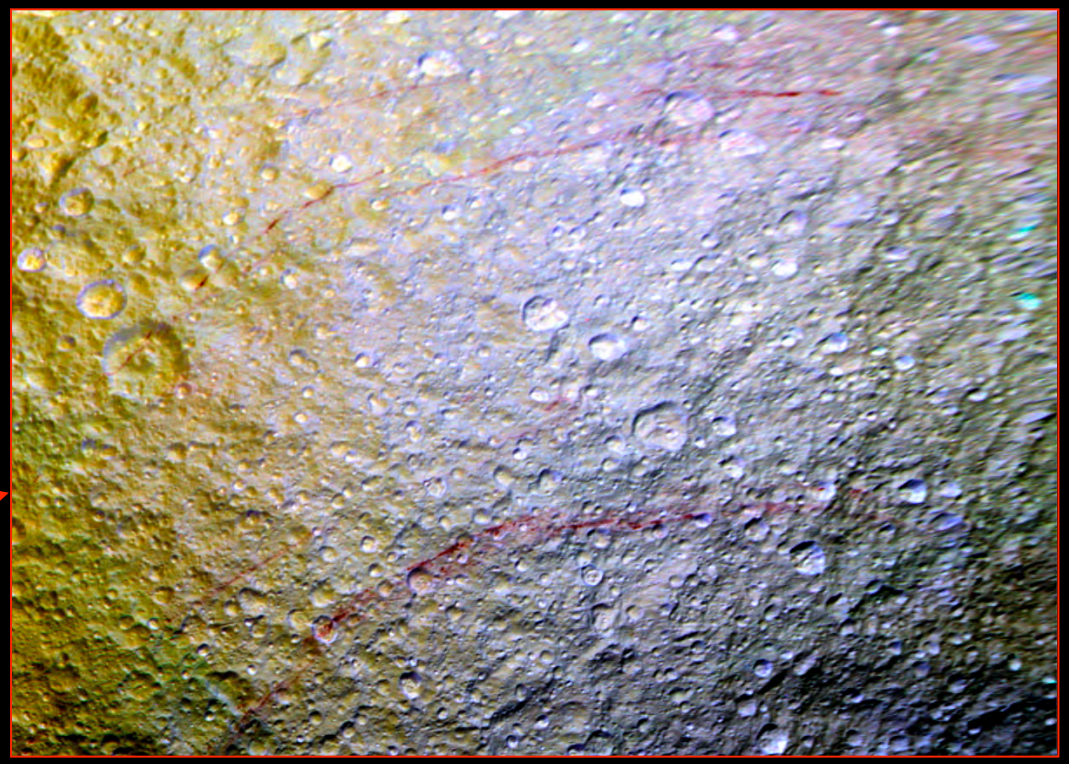




Graffiti on Tethys

Newly discovered red arcs on Tethys are mystifying because they are not linked to any obvious geologic features. The graffiti-like arcs were found in enhanced-color images taken by Cassini April 11, 2015. Their presence on the hemisphere coated by recent water-ice grains from Saturn's E ring suggests that the features are young or reddish material is being resupplied. The next opportunity to observe them even closer will be November 11, 2015 during a 8,300 km flyby.





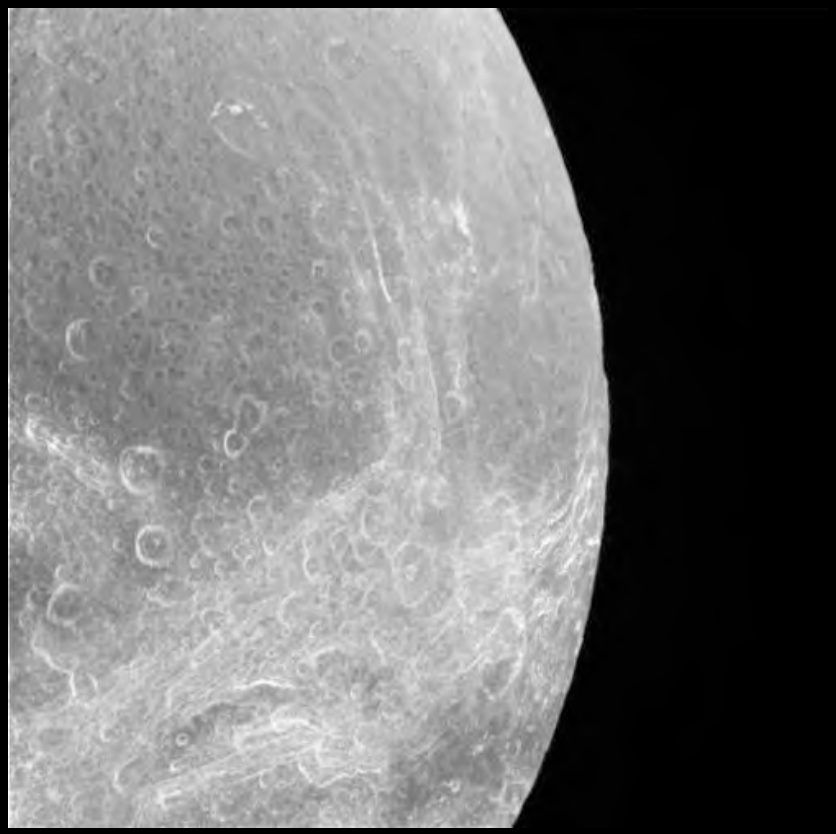
Reddish arcs are illustrated in this magnified, infrared-enhanced color image (above). The origin and composition of the red arcs are currently unknown, but there may be an analogy with reddish-tinted bands observed on Jupiter's ocean world, Europa.

Enhanced-color image (left) shows one hemisphere is stained by Saturn's radiation belts while the other is spray-painted white by water ice particles orbiting the planet.

Press Release - http://go.nasa.gov/1D98I5Y

Penultimate Dione Flyby

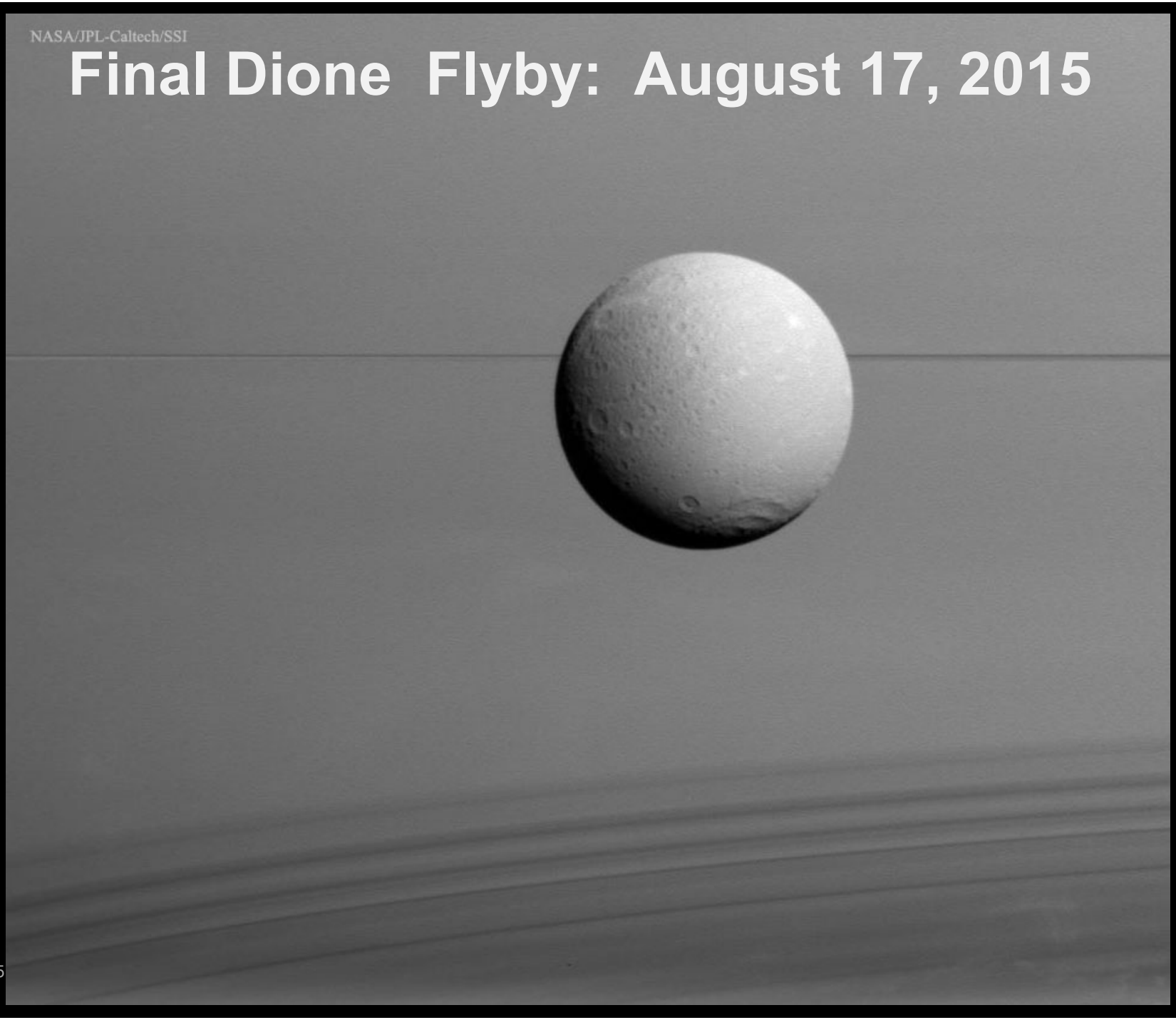
Cassini's fourth and penultimate Dione flyby occurred on June 16, 2015, coming within 516 kilometers (321 miles) of the moon's surface.



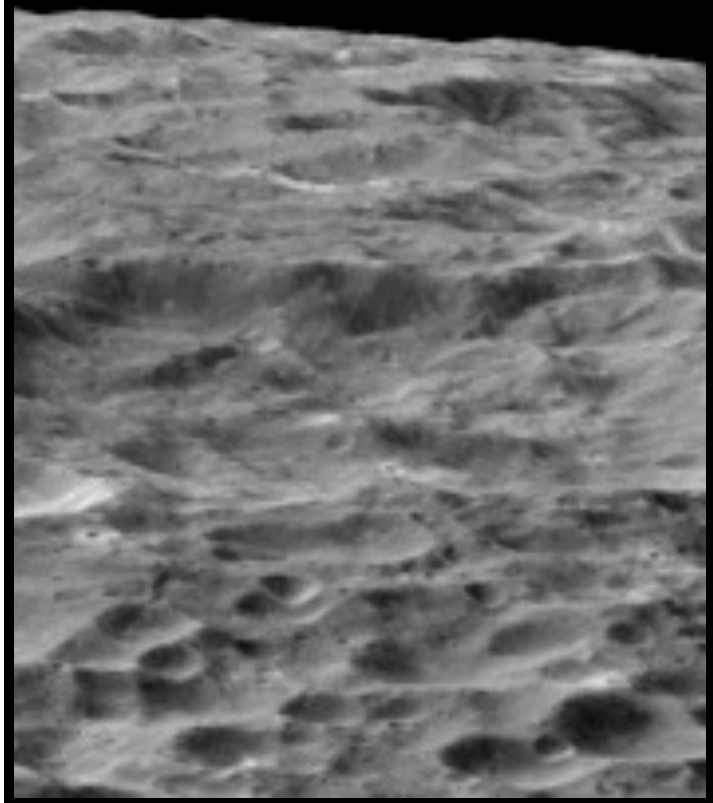
Celestial Dance of Rhea and Dione

Taken on April 11, 2015, Dione (698 miles) is much closer to the camera, making the moon appear much bigger than her larger sister moon Rhea (949 miles).

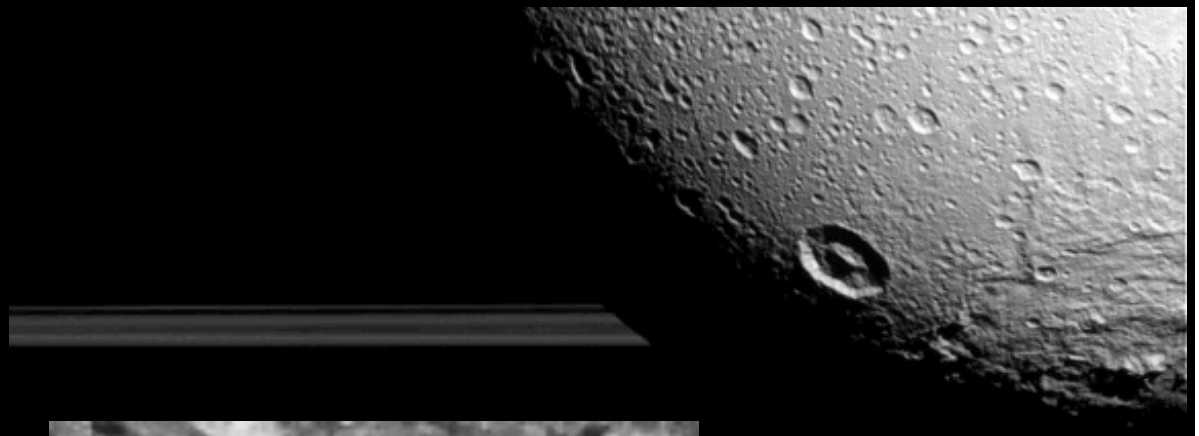
Final Dione Flyby: August 17, 2015

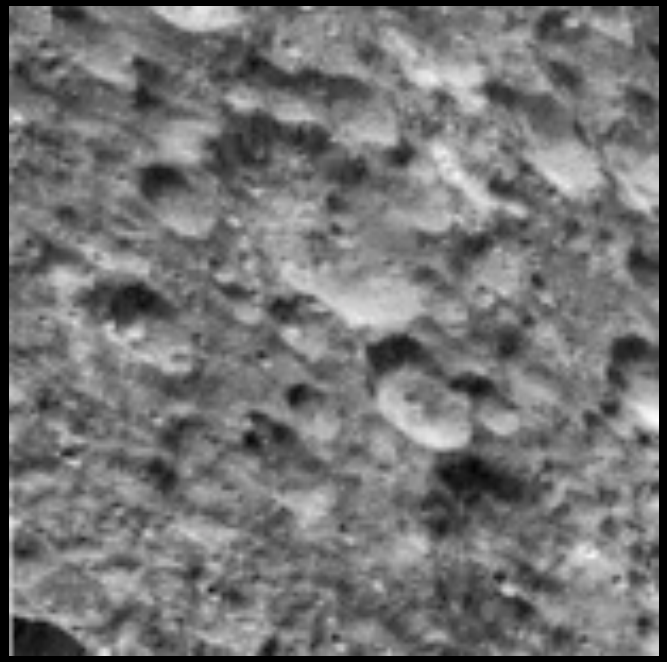


Final Dione Flyby: August 17, 2015
(474 km closest approach)



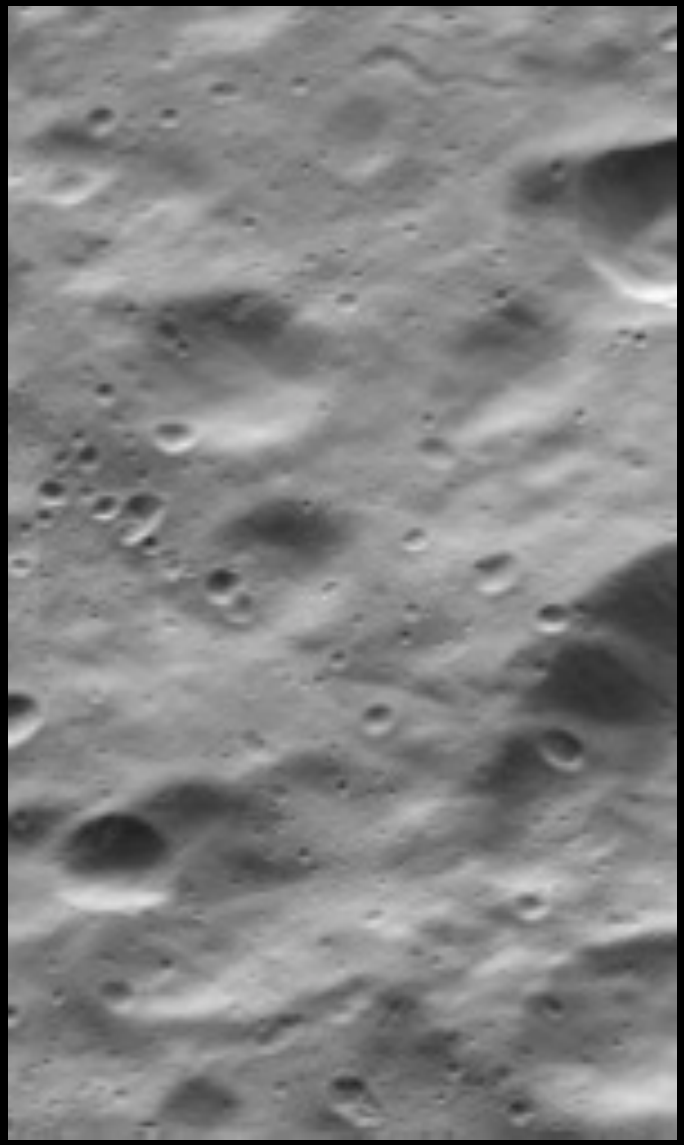
Impact-Battered Icescape
(45 m/pixel)

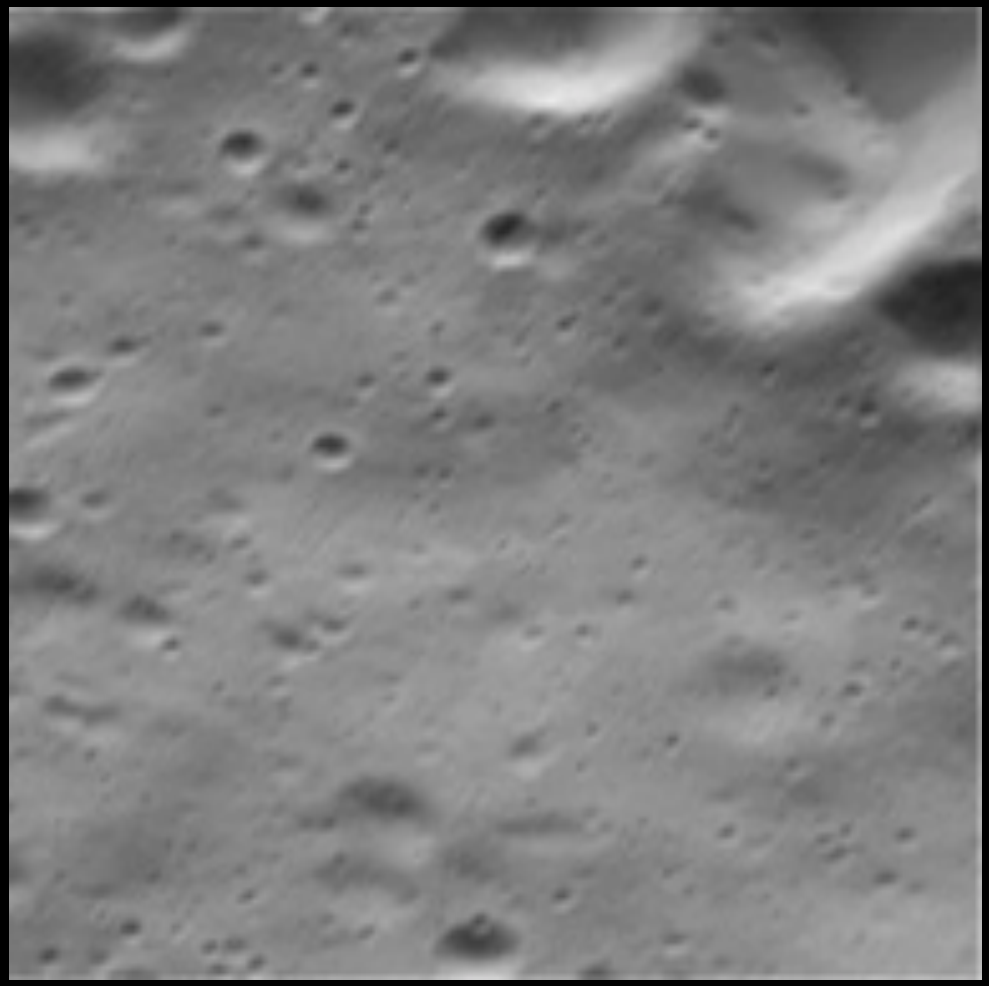




Saturn-lit Surface
(58 m/pxiel)

Closest Views of Dione





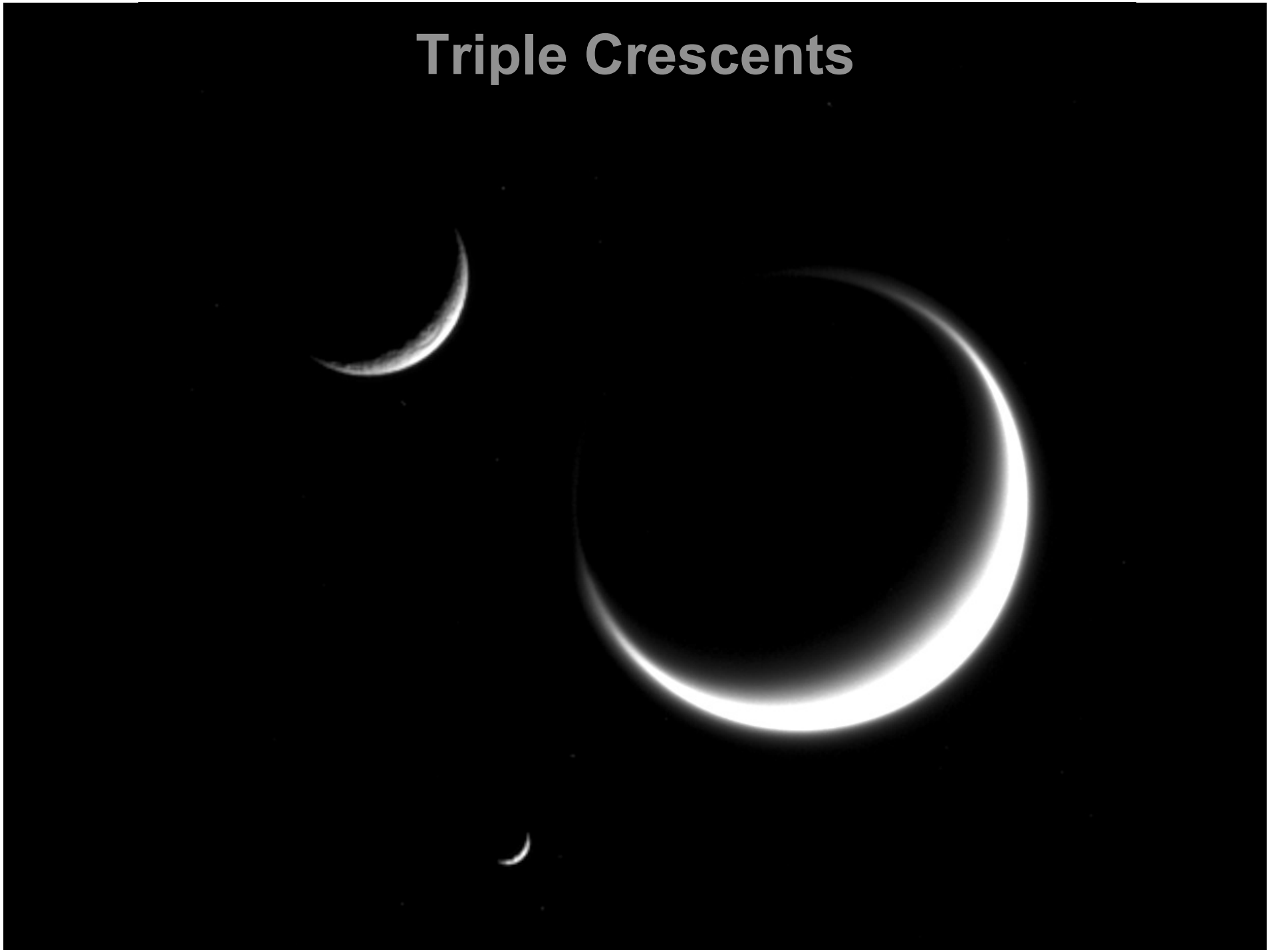
Sunlit NAC image (32m/pixel)

Closest Views of Dione

Saturn-shine fills in shadowed region (35m/pixel)

Departing Dione

Triple Crescents



END

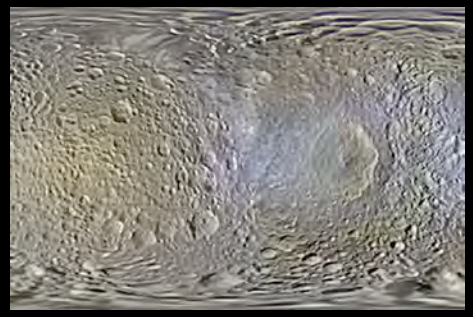
2014 Top 10 Science Discoveries

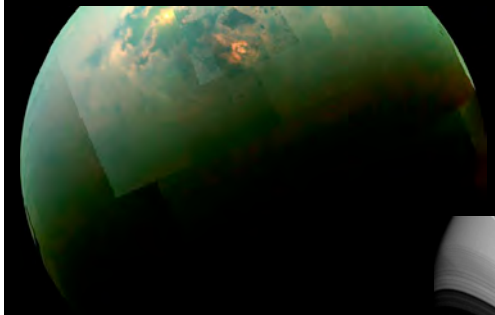
http://go.nasa.gov/1BlpgA8

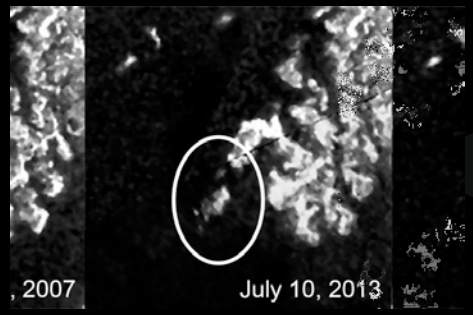
- Ocean Detected Inside Enceladus
- 101 Geysers Identified on Enceladus
- Possible Birth of a Saturn Moon
- Sunny Seas and Clouds Spotted on Titan
- Hyperion's Electrostatically Charged Surface
- 'Magic Island' Evolves in Titan Sea
- Mimas Hides Frozen Core or Ocean
- Bright Clumps Diminish in the F Ring
- Titan's Salty Sea
- New Views of Saturn's Auroras

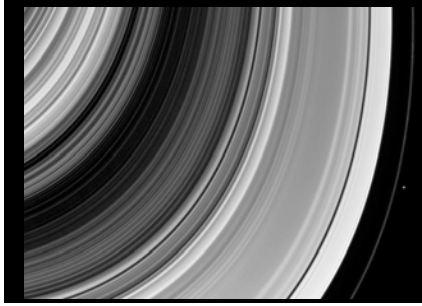
2014 Top 10 Images

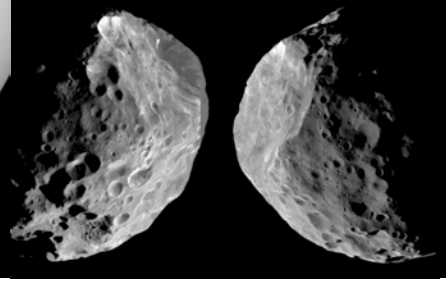
http://go.nasa.gov/1CMCMkS

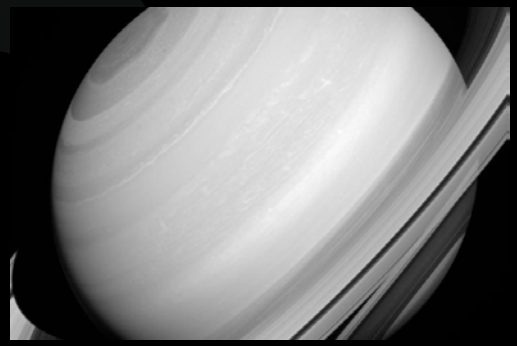




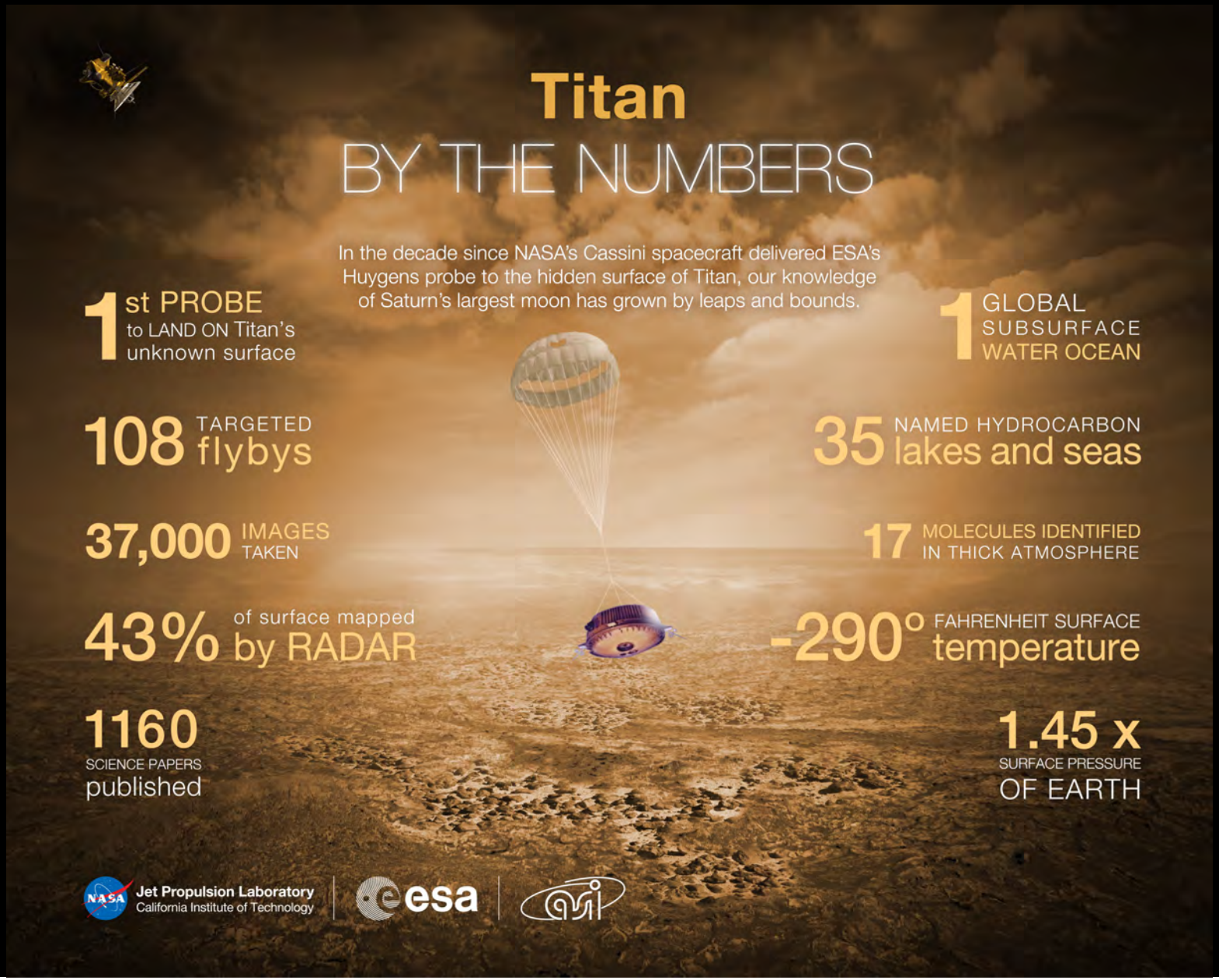




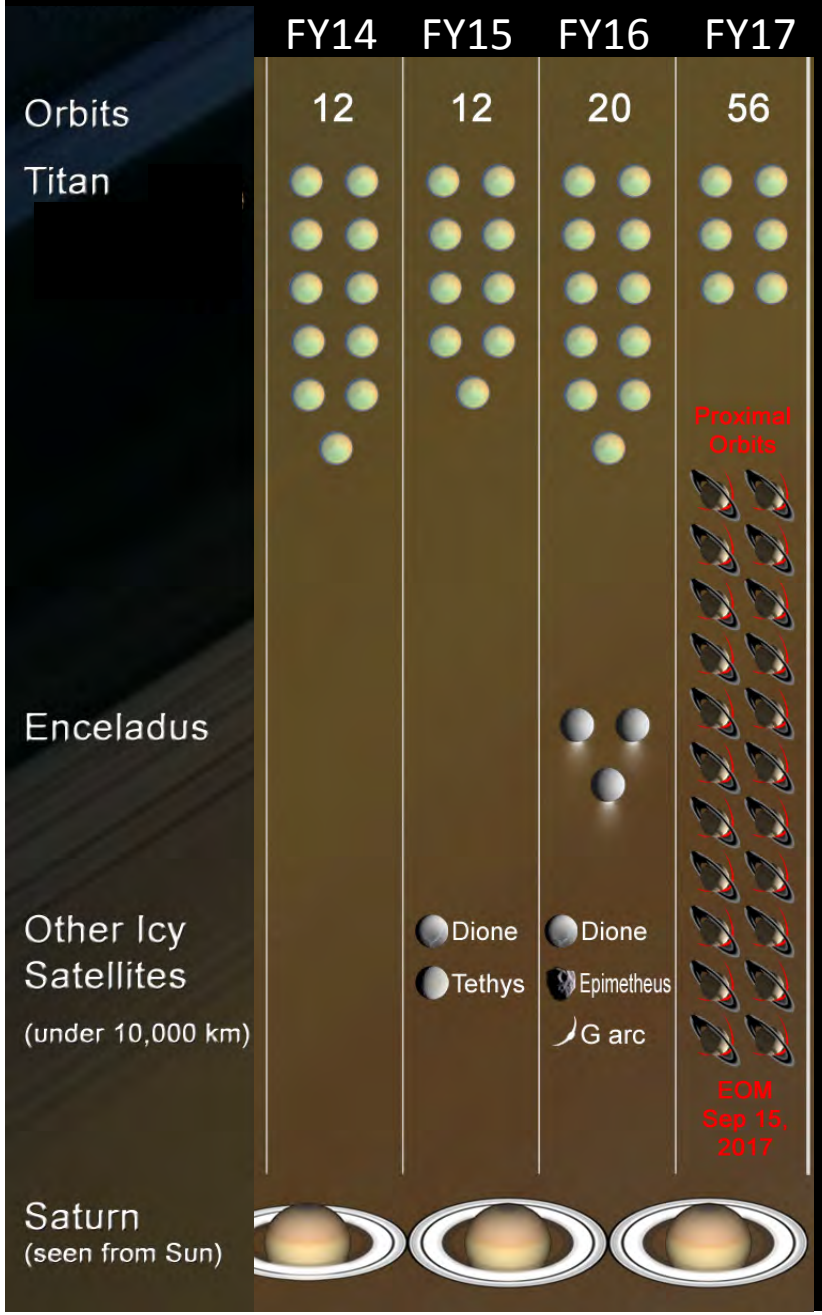




10 Years of Cassini-Huygens at Titan

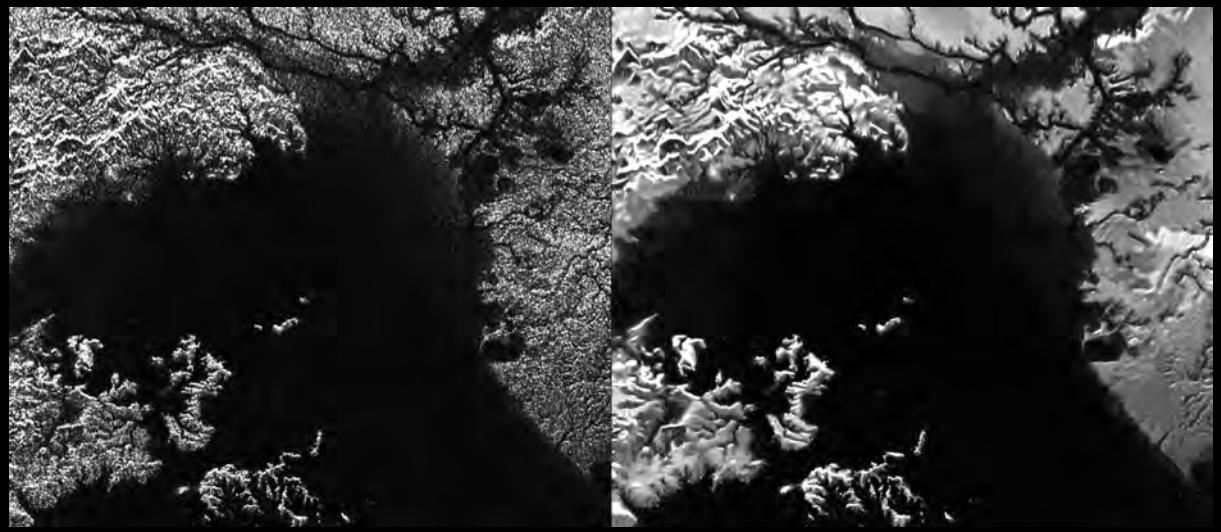


Cassini's Final Four Years: Unique Science

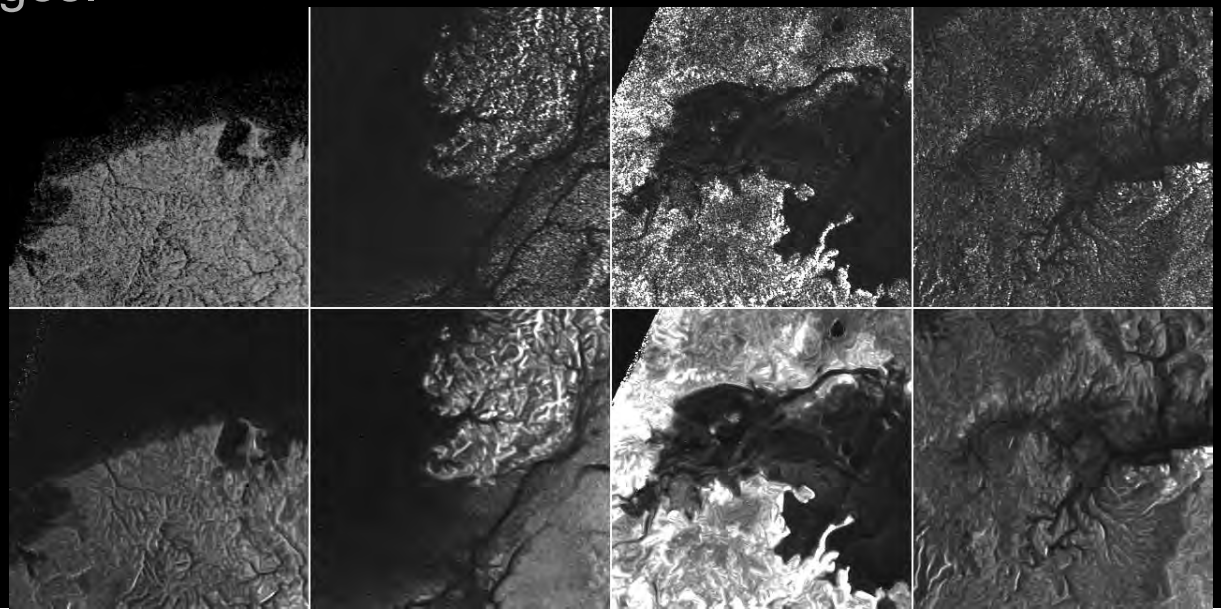


- Explore new seasons at Saturn and Titan until northern summer solstice
- Titan: Look for waves on lakes and seas; measure depth of largest lake
- Enceladus: Sample plume at maximum emission for first time; best high resolution view of north pole
- Rings: Best lighting angle on lit rings (spring 2015 onward)
- Late, close orbits provide *completely new, in-situ* measurements
- 2014-2016 accomplishes great science while setting up proper orientation of final orbits
- Without Cassini, these types of observations could not be fulfilled for decades to come

A New Way of Looking at Titan



A recently developed technique called Despeckling clarifies Cassini's radar images.



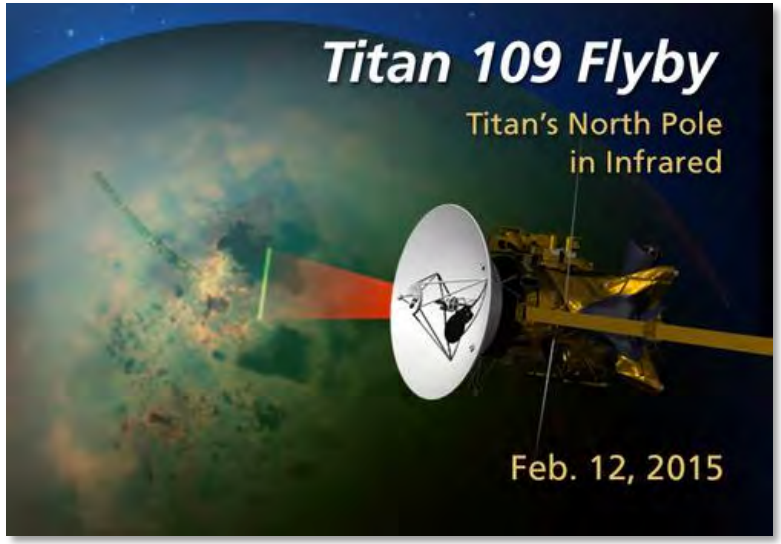
Best Polydeuces

Polydeuces is a Dione Lagrangian that was discovered by Cassini. This observation, best by a factor of 2, was taken on May 10, 2015), with a closest approach around 34,000km with a moderate solar phase angle.

Key Flybys Since January 2015

T109 – Titan flyby (1200 km)

- February 12, 2015
- **VIMS/ORS flyby**
- VIMS imaged south polar vortex, tropical dune fields and plateaus, mid-latitude clouds, and high-resolution north polar cap and lakes.
- Looked for specular reflection on northeastern tip of Kraken Mare.



T110 – Titan flyby (2275 km)

- March 16, 2015
- **VIMS/CIRS/ORS flyby**
- VIMS high-res (<5 km/pixel) northern polar lakes and seas; CIRS atmospheric studies (structure, dynamics, composition, temperature)
- **RSS LGA Gravity pass** (1st of mission)

Key Flybys Since January 2015

T111 – Titan flyby (2722 km)

- May 7, 2015
- **VIMS/CIRS/ISS flyby**
- VIMS imaging Xanadu region (10 km/pixel), high-res imaging of Minerva impact crater; CIRS limb sounding of southern winter polar vortex.
- Imagery of eastern Shangri-La, western Xanadu.

D4 – Dione flyby (516 km)

- June 16, 2015
- **ISS/RSS/CIRS flyby**
- Mapping trailing side of Dione (sub-Saturn quarter), including "Eurotas Chasmata" terrain.
- Gravitational field measurements using RSS to determine internal structure and rigidity.
- CIRS mapping of dark side to study heat loss
- MAPS observations to detect dust particles emitted from Dione.

Key Flybys Since January 2015

T112 – Titan flyby (10,953 km)

- July 7, 2015
- **VIMS/CIRS flyby**
- CIRS limb sounding at high northern and southern latitudes; VIMS mosaic of Fensal, Aztlan dune fields, and Quivira plateau; VIMS observation of south polar vortex

D5 – Dione flyby (474 km)

- August 17, 2015
- **ISS/RSS/CIRS flyby**
- Final targeted flyby of Dione.
- Gravity experiments at closest approach.
- Imaging of lit anti-Saturn side of Dione, as well as north pole at high resolution (few meters).
- CIRS mapping of thermal anomalies.