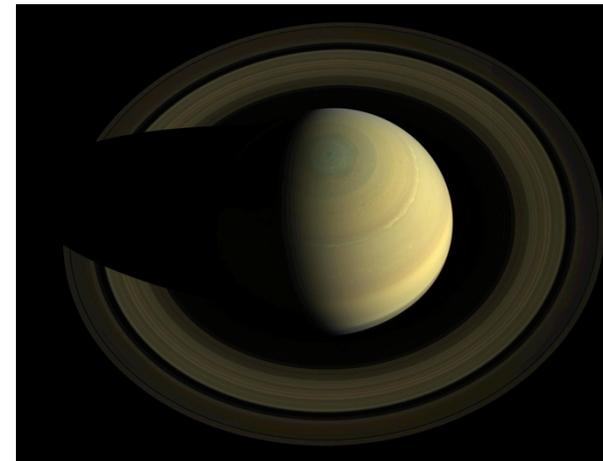
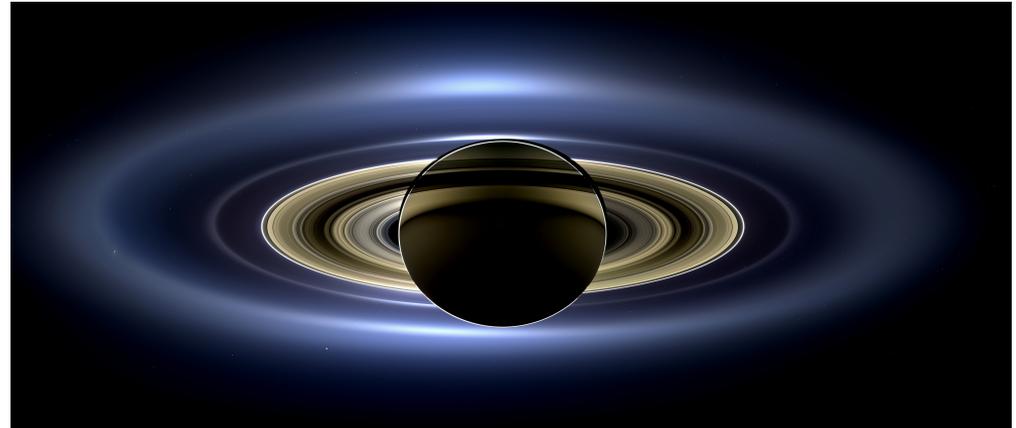




Linda Spilker
Cassini Project Scientist
Jet Propulsion Laboratory/
California Institute of Technology
Outer Planets Assessment Group
13 January 2013

Cassini Solstice Mission: Introduction

- Key Cassini events
 - 2013 Outreach Hits
 - New Participating Scientists
 - Cassini MAG team award
- Latest Science Highlights
 - Saturn
 - Hexagon
 - Auroral Campaign
 - Magnetopause Particle Accelerator
 - Titan
 - New Radar Polar Mosaic
 - First Determination of Sea Depth
 - New Views of Lake District
 - Discovery of Propylene in Atmosphere
 - Saturn Backlit Mosaic
- Upcoming Cassini Senior Review



Cassini Top Science 2013 Hits Multiple Year End Issues

Cassini Top 10 Science Highlights – 2013 Jan. 02, 2014



Top science posted to Cassini mission page
Thursday Jan 2:

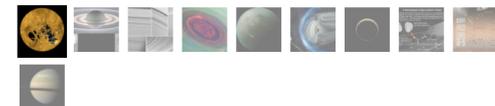
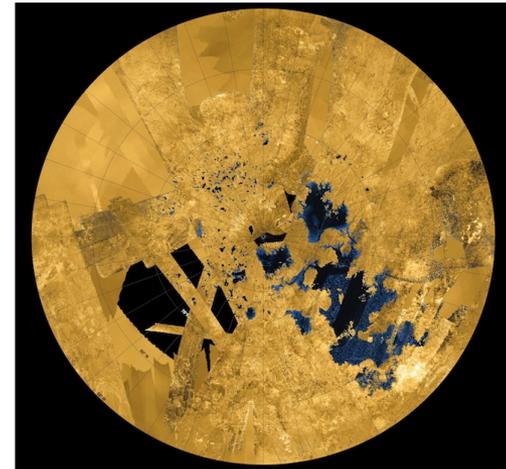
[http://saturn.jpl.nasa.gov/news/cassinifeatures/
feature20140102/](http://saturn.jpl.nasa.gov/news/cassinifeatures/feature20140102/)

14 January 2014

OPAG

WIRED

10 Awesome Things We Learned About Saturn in 2013



Posted to Wired Mag. Sat. Jan 4th

[http://www.wired.com/wiredscience/
2014/01/10-awesome-cassini-
saturn-discoveries/#slideid-486981](http://www.wired.com/wiredscience/2014/01/10-awesome-cassini-saturn-discoveries/#slideid-486981)

LJS-3

Cassini Top Science 2013 Hits Multiple Year End Issues

THE WALL STREET JOURNAL.

Year in Photos
2013

Date Category Top Rated Region



Part of Cassini mosaic taken July 19th of Saturn's rings, & Earth

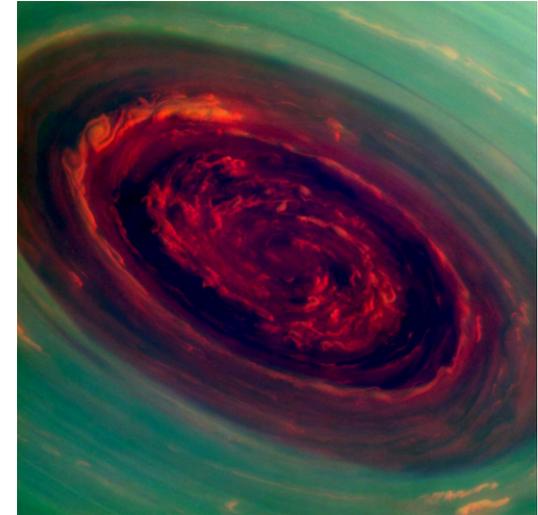
Second most voted image on Wall Street Journals online voting.
NASA/JPL/

Wall Street Journal: Photos of the Year (Cassini was the second most popular image of the year)

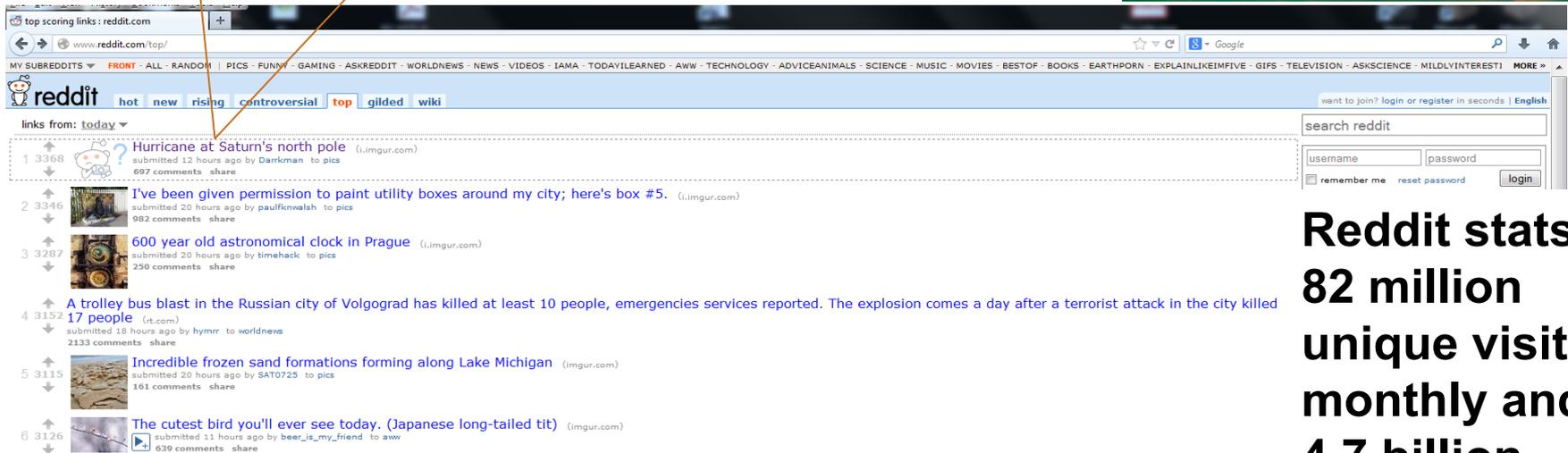
<http://graphics.wsj.com/Photos-of-the-Year/2013/#!|=en&o=2&q=&x=&y=&p=196>

Cassini Top Science 2013 Hits Multiple Year End Issues

Saturn's north pole hurricane top on reddit's "hot" section
Monday, December 30, 2013



<http://i.imgur.com/nAWGILI.jpg>



top scoring links: reddit.com

www.reddit.com/top/

MY SUBREDDITS FRONT ALL RANDOM PICS FUNNY GAMING ASKREDDIT WORLDNEWS NEWS VIDEOS IAMA TODAYILEARNED AWW TECHNOLOGY ADVICEANIMALS SCIENCE MUSIC MOVIES BESTOF BOOKS EARTHPOOR EXPLAINLIKEIFIVE GIFS TELEVISION ASKSCIENCE MILDLYINTERESTI MORE

reddit hot new rising controversial top gilded wiki

want to join? login or register in seconds | English

search reddit

username password

remember me reset password login

links from: today

1 3368 Hurricane at Saturn's north pole (i.imgur.com) submitted 12 hours ago by Darrkman to pics 697 comments share

2 3346 I've been given permission to paint utility boxes around my city; here's box #5. (i.imgur.com) submitted 20 hours ago by paufknlwalsh to pics 982 comments share

3 3287 600 year old astronomical clock in Prague (i.imgur.com) submitted 20 hours ago by timehack to pics 250 comments share

4 3152 A trolley bus blast in the Russian city of Volgograd has killed at least 10 people, emergencies services reported. The explosion comes a day after a terrorist attack in the city killed 17 people (rt.com) submitted 18 hours ago by hymir to worldnews 2133 comments share

5 3115 Incredible frozen sand formations forming along Lake Michigan (imgur.com) submitted 20 hours ago by SAT0725 to pics 161 comments share

6 3126 The cutest bird you'll ever see today. (Japanese long-tailed tit) (imgur.com) submitted 11 hours ago by beer_is_my_friend to aww 639 comments share

**Reddit stats:
82 million
unique visits
monthly and
4.7 billion
page views.**

Cassini Top Science 2013 Hits Multiple Year End Issues

Centerfold of Time magazine



Amateur Gordan Ugarkovic,
Croatian computer programmer,
first created this mosaic

Time Online did two photo reviews:

Time magazine's "Most Beautiful Photos from Space" (3 Cassini images):

<http://science.time.com/2013/12/10/the-years-most-beautiful-photos-from-space/>

Time: Science and Space, Top 10 Space moments (Cassini is #5 and #7)

<http://science.time.com/2013/12/04/science-and-space/slide/top-10-space-stories/>

Cassini Top Science 2013 Hits Multiple Year End Issues

Saturn makes cover of Discover magazine with Mars as the top science story of 2013

<http://discovermagazine.com/2014/jan-feb#.Usw4KaXVt-I>



Cassini Top Science 2013 Hits Multiple Year End Issues

Fold out image in Nature's images of the year

365 DAYS:
the year in science

IMAGES OF THE YEAR

In 2013, our Universe continued to amaze and delight as it was probed and prodded by scientists. During the course of the year, the gaze of researchers ranged near and far, from the vast to the minuscule, providing stunning visions of space and capturing images of the very bonds that tie molecules together. This is our selection of the pictures that highlight science's, and nature's, triumphs.

Images selected by Nature's art and design team. Text by Daniel Creswell.

350 | NATURE | 101 504 | 17-24 DECEMBER 2013

FIRE IN THE SKY
This huge meteor was created by the largest meteor known to hit Earth since the Tunguska rock landed in 1908. Russia was once again the unlucky recipient: the meteor exploded some 30 kilometres above Chelyabinsk in the Ural and shone brighter than the Sun.

MAGIC MOMENT
Rarest sort of an installation, these gamma-ray detectors in Japan captured evidence that calcium atoms with 20 protons and 24 neutrons are stable, identifying 34 as a 'magic number' of nuclear stability.

MIND READER
This is one of the first 'transparent brains' to be made with CLARITY, a new imaging method that renders brain — in this case a mouse hippocampus — transparent by stripping away lipids with detergent. The technique reveals neurons in 3D dimensions, instead of conventional two-dimensional slices.

FLOWER POWER
These images show hard-to-see electric fields around an idealised flower. UVF researchers found that bees sense these fields, use a bee's nose as a probe to charge behind and others use it to decide whether to visit the flower.

SMALL AND MIGHTY
Made of polystyrene, these reactions seem to defy magic — the stronger they get, the stronger and tougher they become. Made by electrospinning, in which a tiny charge stacks fibres from a liquid, their all-in build makes them as brittle as stronger than thicker wires, currently used in optics and electronics.

VISUAL LINK
Chemists have become almost blasé about taking images of individual atoms. But with skilful use of atomic force microscopy, researchers in Japan managed to capture the first pictures of hydrogen bonds, seen here as thin lines between four molecules of 8-hydroxyquinoline.

<http://www.nature.com/news/365-days-images-of-the-year-1.14303>



“All the News
That’s Fit to Print”

The New York Times

Late Edition

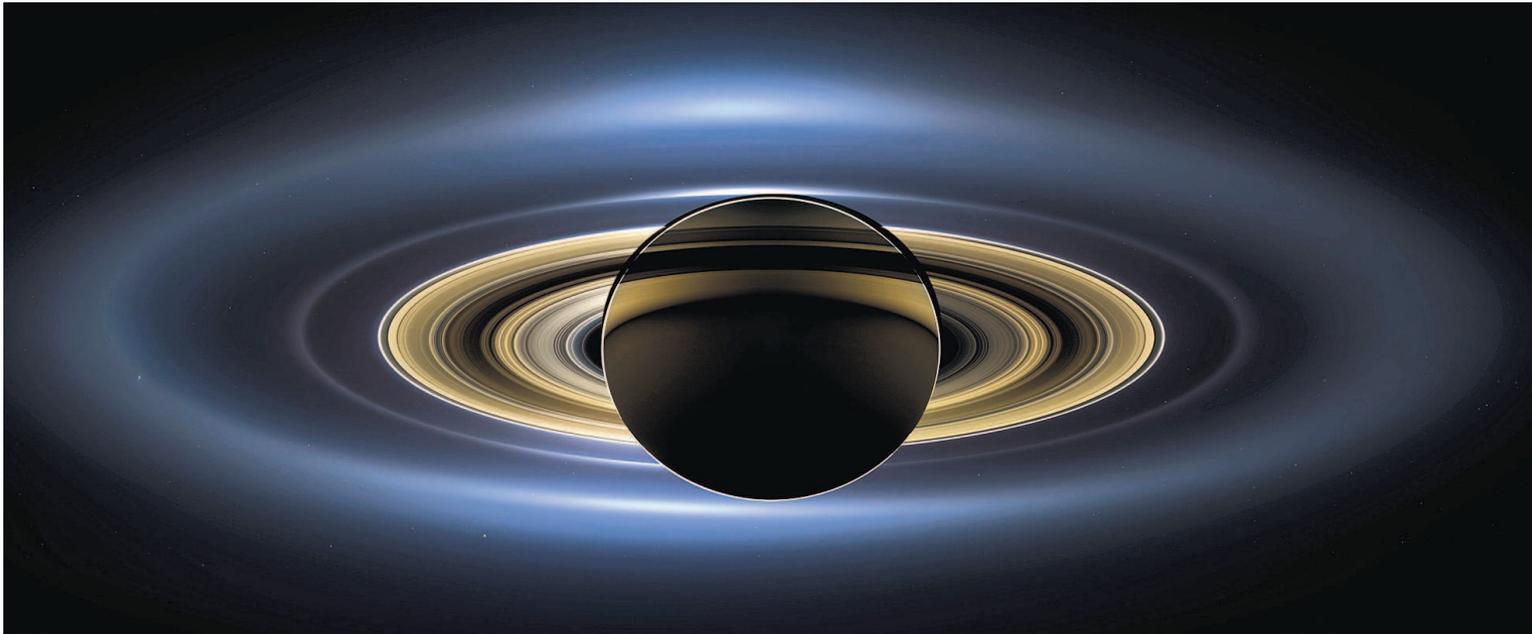
Today, sunny to partly cloudy, windy, cold, high 40. **Tonight**, clear skies, low 32. **Tomorrow**, mostly sunny, not as cold in the afternoon, high 50. Weather map, Page A26.

VOL. CLXIII . . . No. 56,319 +

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NEW YORK, WEDNESDAY, NOVEMBER 13, 2013

\$2.50



NASA/JET PROPULSION LABORATORY-CALTECH — SPACE SCIENCE INSTITUTE

Saturn, a (Really) Wide View

NASA’s Cassini spacecraft looked back from the shadow of Saturn to take a picture that sweeps 405,000 miles across the planet and the inner solar system. Cassini captured 323 wide-angle images on July 19, and this mosaic, released on Tuesday, used 141 of them. For some galactic perspective, Earth is 898 million miles away.

EXPERTS RESHAPE TREATMENT GUIDE FOR CHOLESTEROL

CHANGE IN STATINS’ USE

2 Groups See No Need
to Drop to a Specific
Level of LDL

By GINA KOLATA

The nation’s leading heart organizations released new guidelines on Tuesday that will fundamentally reshape the use of cholesterol-lowering statin medicines, which are now prescribed for a quarter of Americans over 40. Patients on statins will no longer need to lower their cholesterol levels to specific numerical targets monitored by regular blood tests, as has been recommended for decades. Simply taking the right dose of a statin will

New Cassini Participating Scientists

Tilmann
Denk



Tommi
Koskinen



Giuseppe
Mitri



Wes
Patterson



Darci
Snowden

Federico
Tosi



Veronique
Vuitton





New Participating Scientists

PI	Instruments/DWG	Institution	Title	Discipline	E-mail
Tilman Denk	ISS / ISWG	Freie Universität Berlin, Institute of Geological Sciences	Cassini Imaging of the Irregular Moons of Saturn	Icy Satellites	Tilman.Denk@gmx.de
Tommi Koskinen	UVIS / Titan, Saturn WGs	University of Arizona	Characterizing the density and temperature structure in the upper atmospheres of Saturn and Titan	Titan, Saturn	tommi@lpl.arizona.edu
Giuseppe Mitri	RSS / Titan WG	Istituto Nazionale di Astrofisica e Planetologia Spaziali (IAPS), Istituto Nazionale di Astrofisica (INAF)	Ice shell structure of Titan from gravity and topography	Titan	mitri@lpl.arizona.edu
(Gerald) Wesley Patterson	ISS / ISWG	APL	A Global Geologic Map of Enceladus	Icy Satellites	Gerald.Patterson@jhuapl.edu
Darci Snowden	CAPS, INMS / MAPS WG	Central Washington University	Magnetospheric ionization and energy deposition in Titan's upper atmosphere	Magnetosphere	dsnowden@lpl.arizona.edu
Federico Tosi	VIMS, RADAR / Titan WG	Istituto Nazionale di Astrofisica e Planetologia Spaziali (IAPS), Istituto Nazionale di Astrofisica (INAF)	Characterization of Titan's high latitude fluvial terrains, including the lakes district	Titan	federico.tosi@iaps.inaf.it
Veronique Vuitton	INMS, CAPS / Titan WG	Institut de Planétologie et d'Astrophysique de Grenoble	Titan's Ionospheric Chemistry	Titan	veronique.vuitton@obs.ujf-grenoble.fr

Cassini Magnetometer Team Receives RAS Award

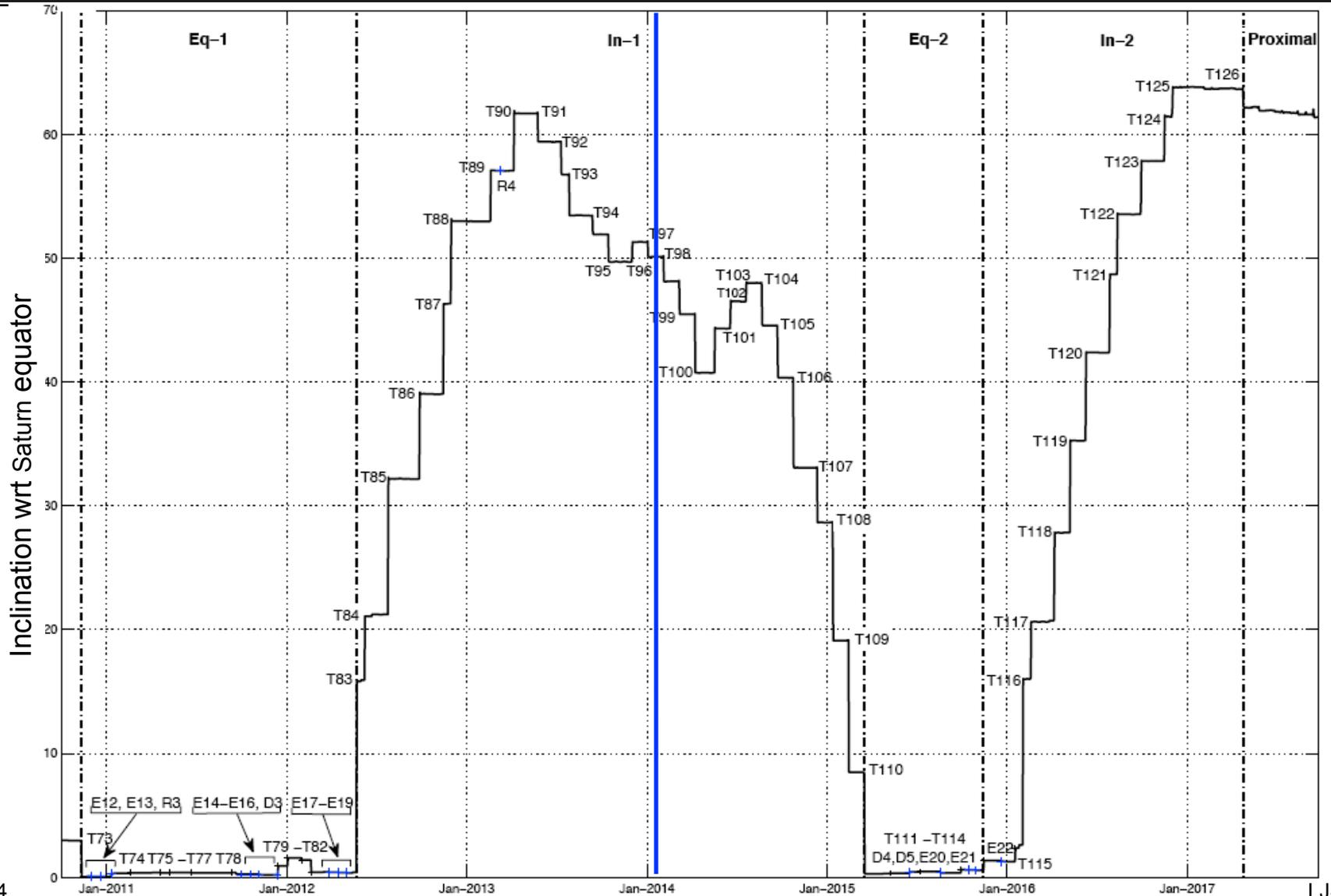


Cassini Magnetometer Team led by Michele Dougherty was awarded Royal Astronomical Society's 2014 Group Achievement Award

(Photo shows MAG team and other scientists)

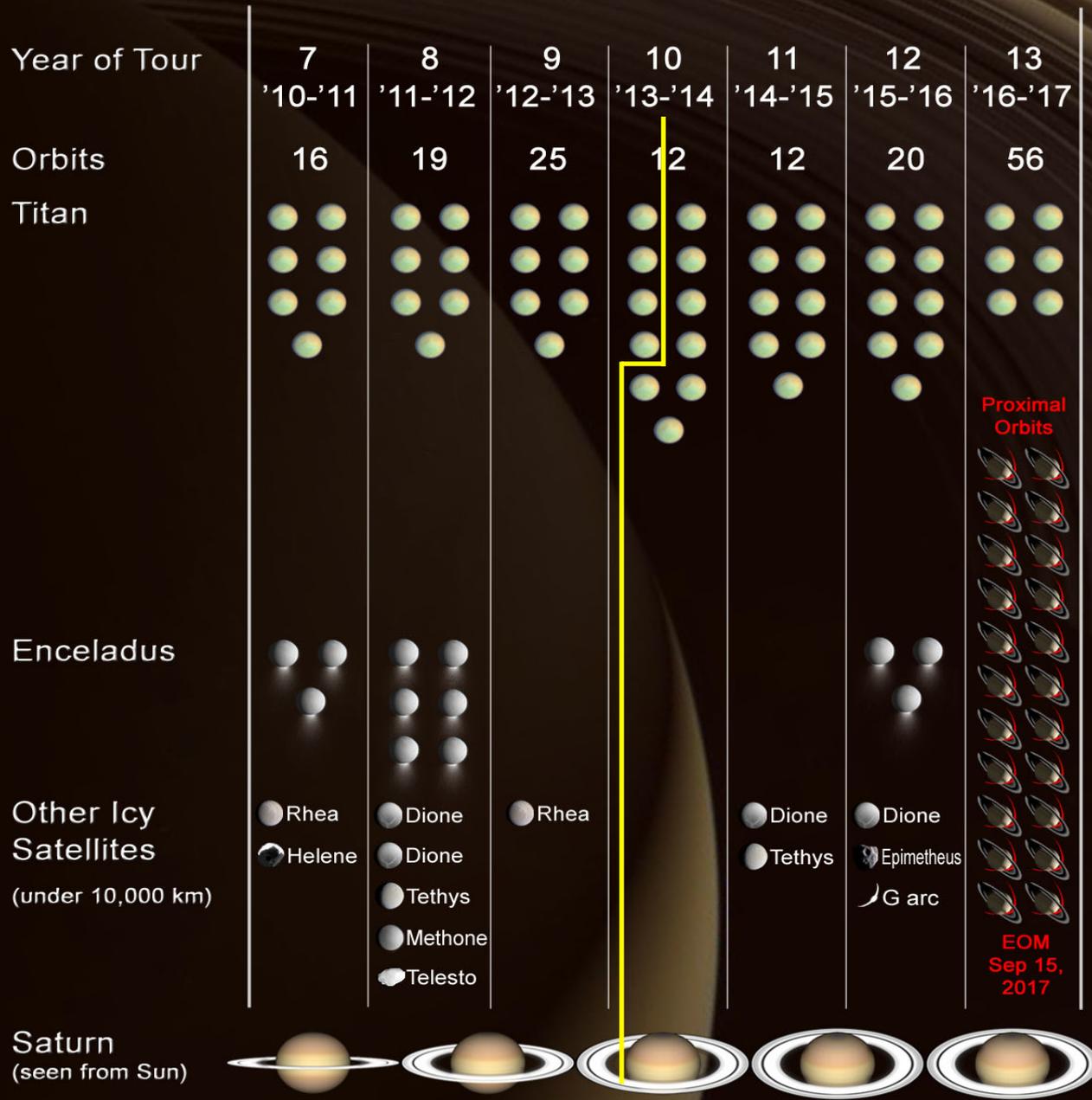


Solstice Mission Inclination Profile

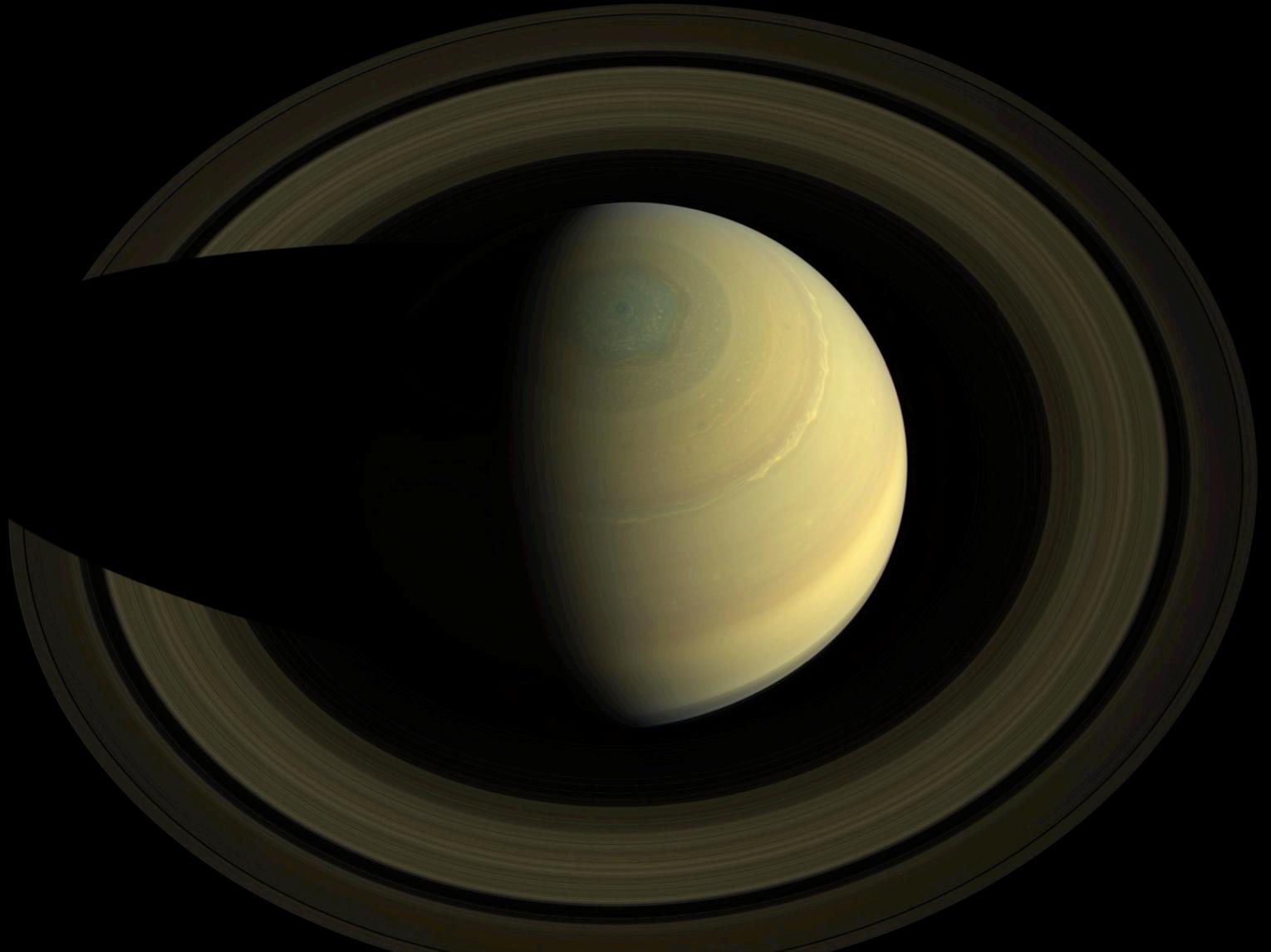


Cassini Solstice Mission Overview

October 2010 - September 2017



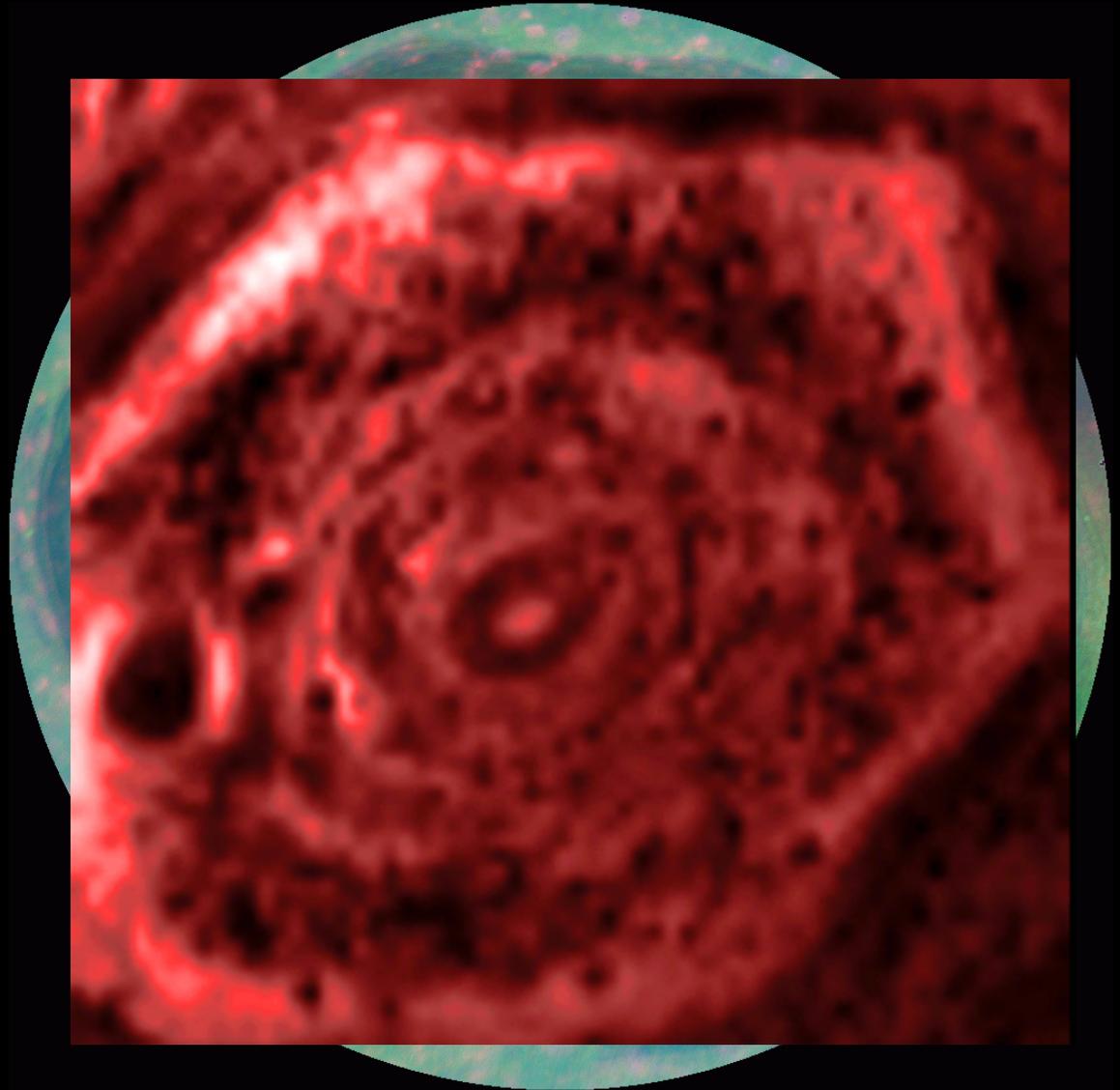
On Top of the (Ringed) World



Similar, highly-inclined orbits will dominate toward the mission's end in 2016-2017, and will allow unprecedented studies of Saturn' poles, rings and magnetic environment.

Cassini Delivers the Best-Yet Views of Saturn's Hexagon

- New 10-hour movie of Saturn hexagon
- Hexagon is 30,000 km across
- Winds blow at 350 km per hour
- Bluish tint indicates small haze particles dominate inside, larger haze particles dominate outside hexagon
- Ultra-stable jet stream, some similarities to Earth's unstable jet stream



The hexagon movies are online at: <http://go.usa.gov/Wtrk>

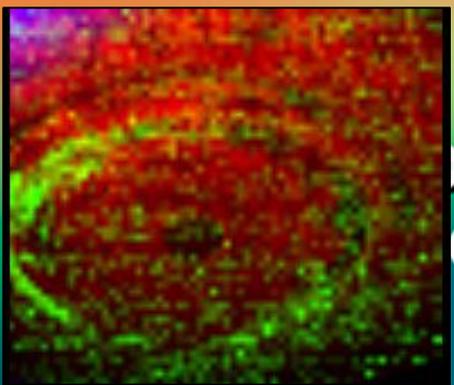
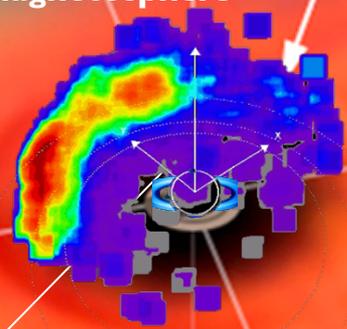
Solar Wind-triggered Auroral Storm

Cassini Auroral Campaign 2013

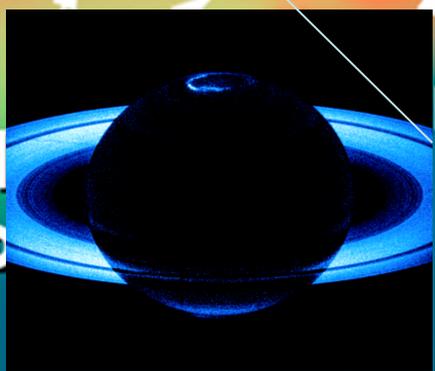
plasma sheet

Cassini-INCA detects evidence of energization in the magnetosphere

A major solar wind disturbance is on its way



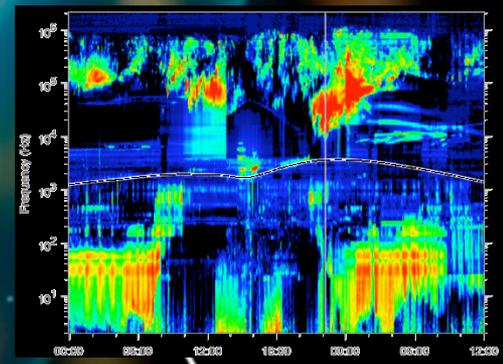
Cassini-VIMS observes a quiet aurora before the storm



Hubble Space Telescope captures the same event from across the Solar System



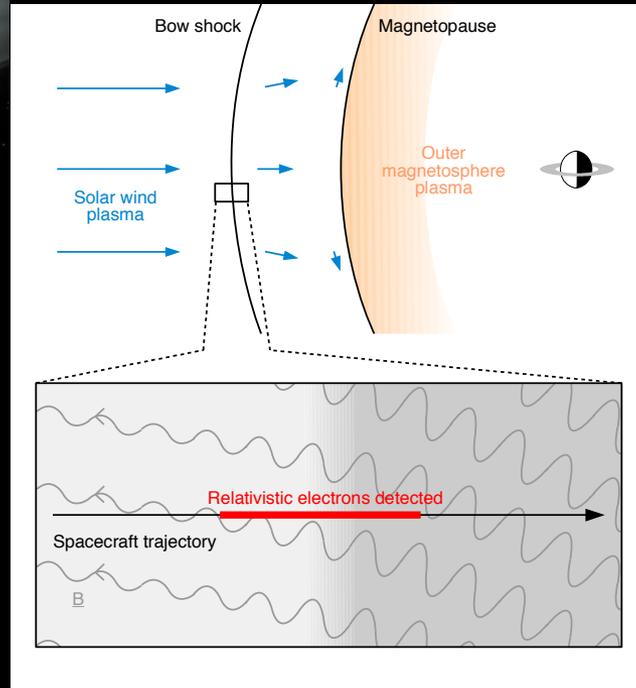
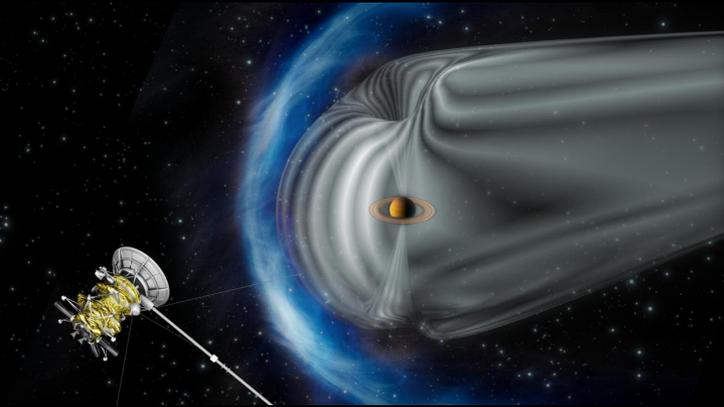
Cassini-UVIS scans the northern pole – watching the atmosphere react



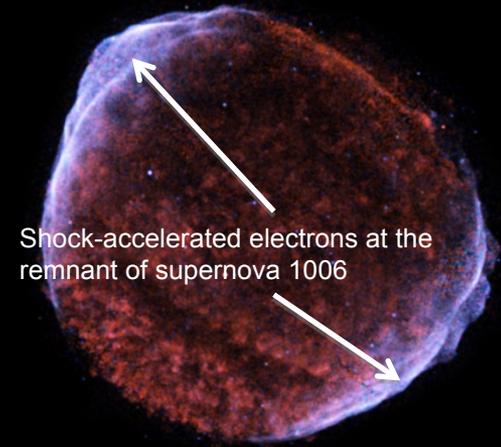
Cassini-RPWS sees a burst of auroral radio emission – a known response to solar wind activity

Saturn's Magnetopause: A Natural Particle Accelerator

- **Relativistic electrons discovered** coinciding with strongest magnetic bow shock ever encountered at Saturn and under unique magnetic conditions



- **Discovery is important for particle acceleration at supernova remnant shock waves**, where most galactic cosmic rays are thought to be produced.



Shock-accelerated electrons at the remnant of supernova 1006

A. Masters et al., Nature Phys., 9, 164-167, doi:10.1038/nphys2541

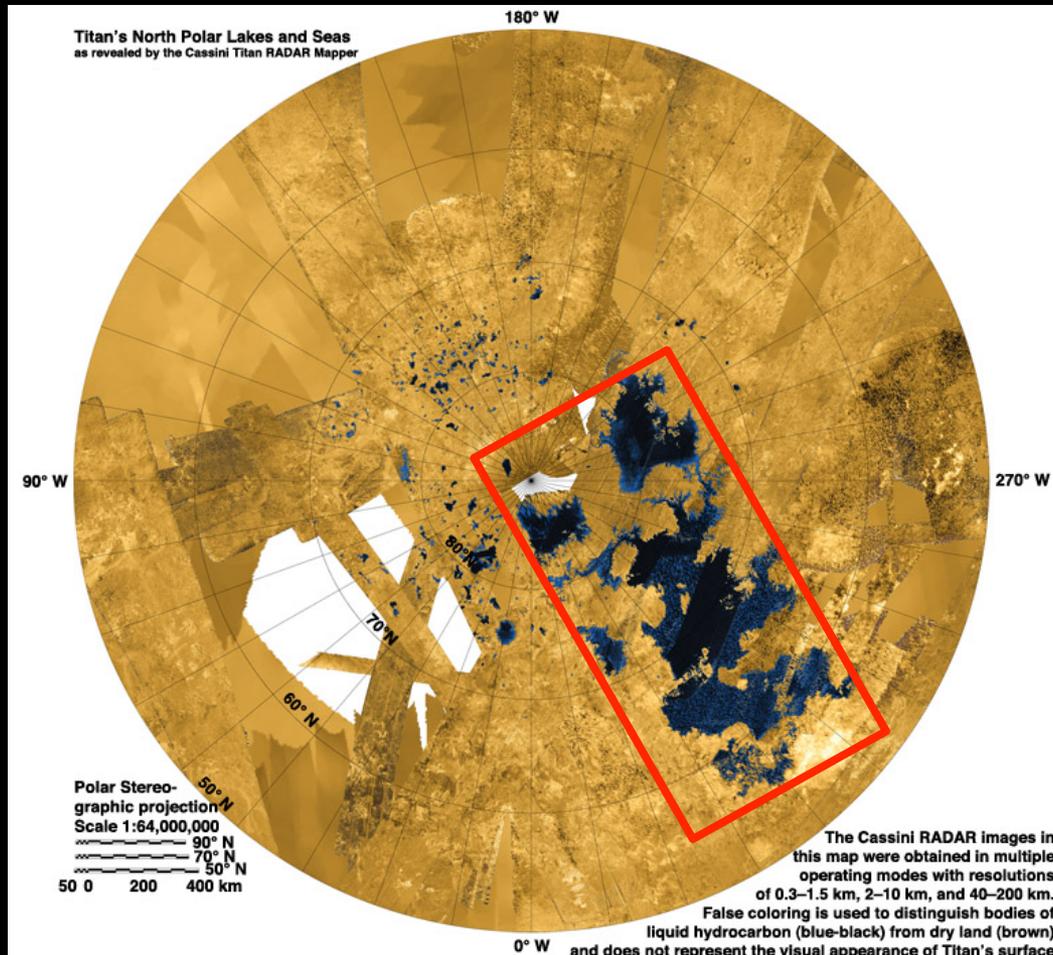
Credit: NASA/CXC/Rutgers/J.Hughes et al.

New Titan Polar Mosaic

Polar
Stereographic
projection down
to 50° N

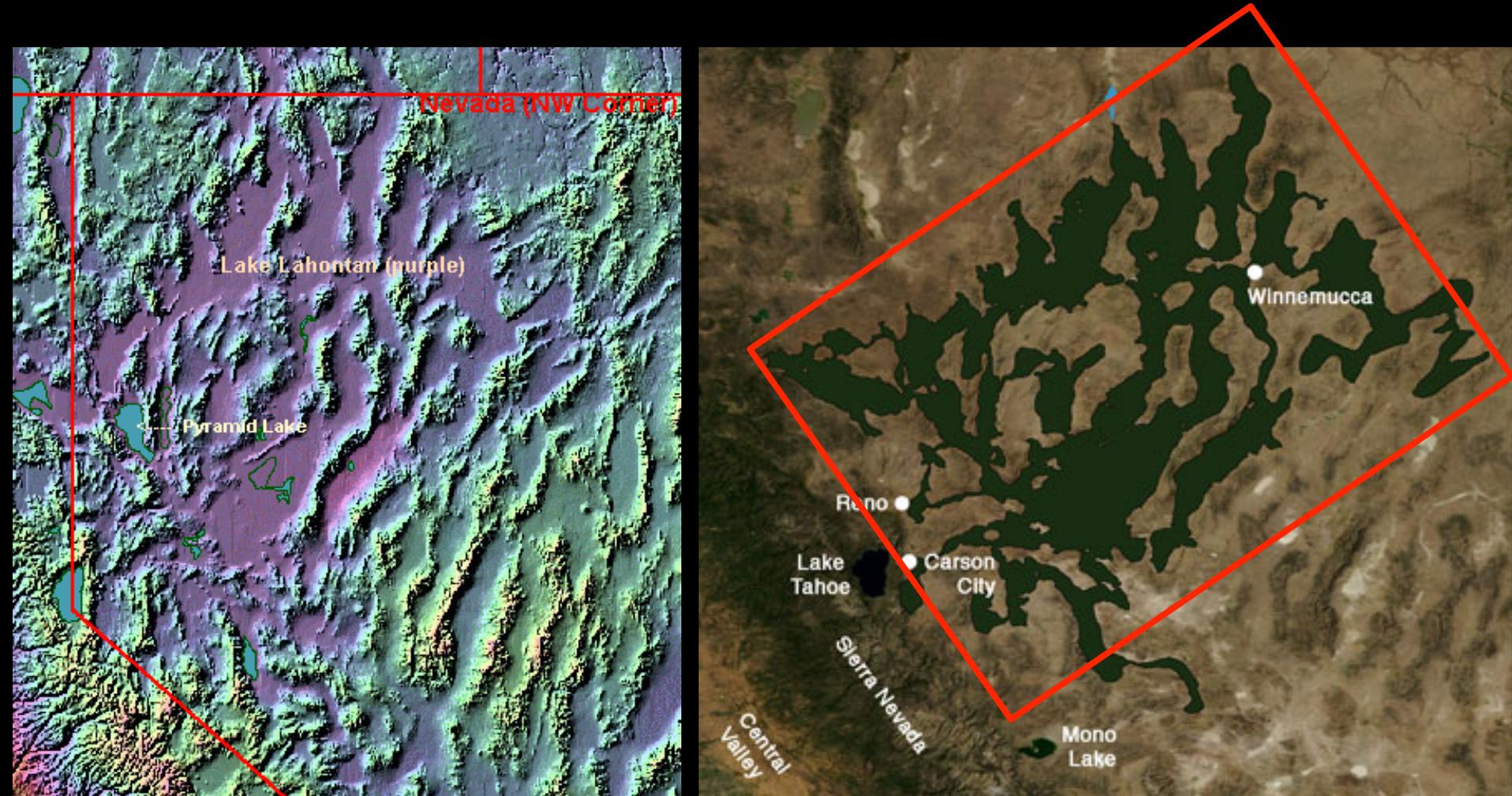
Radar mapping
data through July
10, 2013

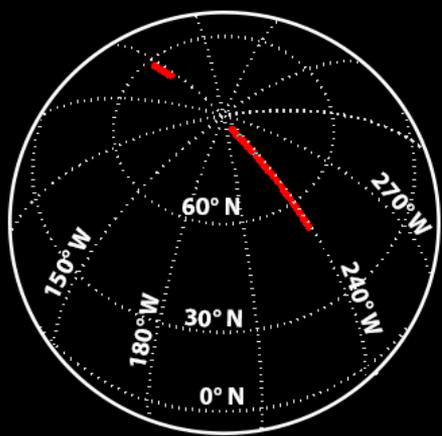
False colored to
emphasize seas
and lakes



All of “greater
Kraken” is
covered and all is
radar-dark

A Terrestrial Analog for Seas?





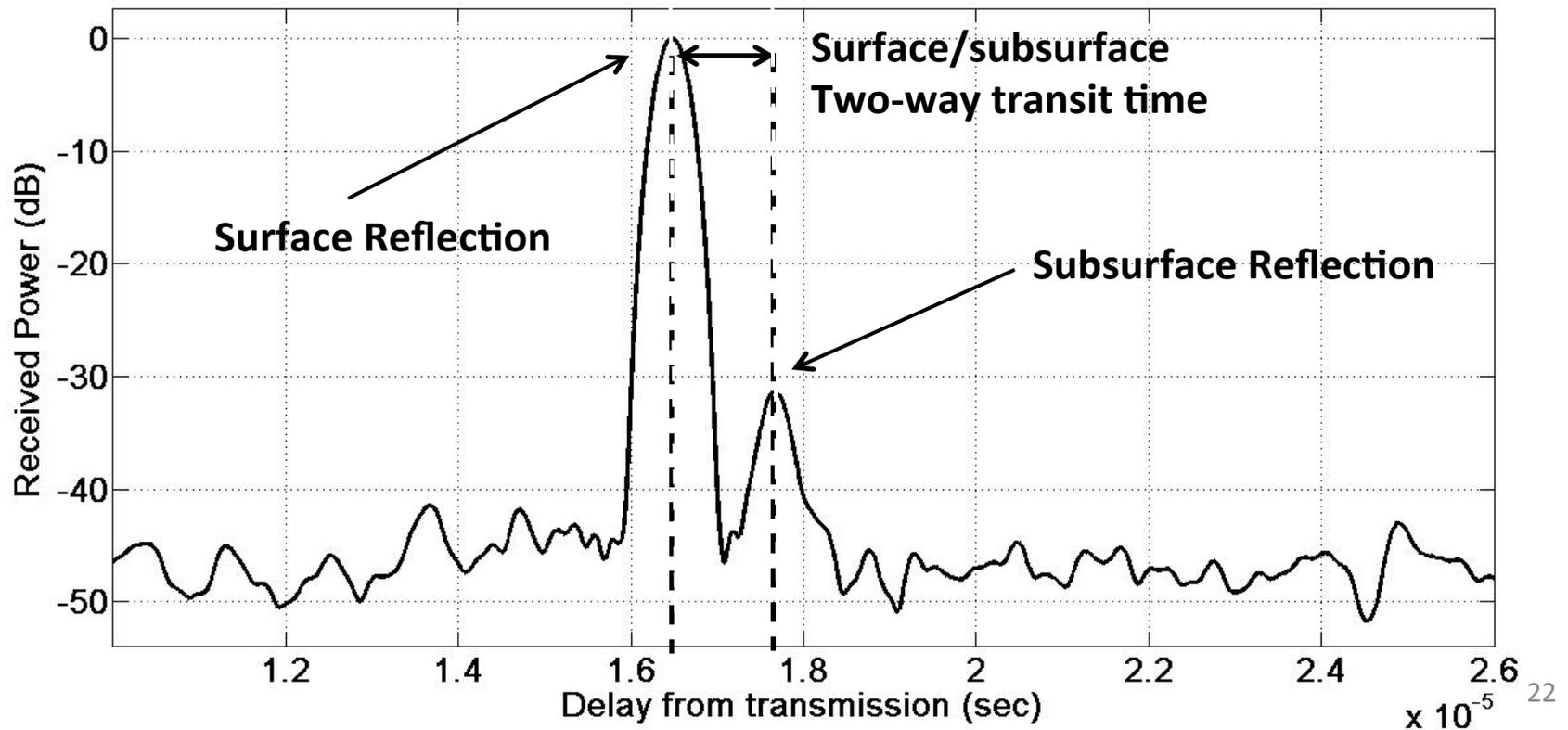
— ALT Track (T91) Fly-By

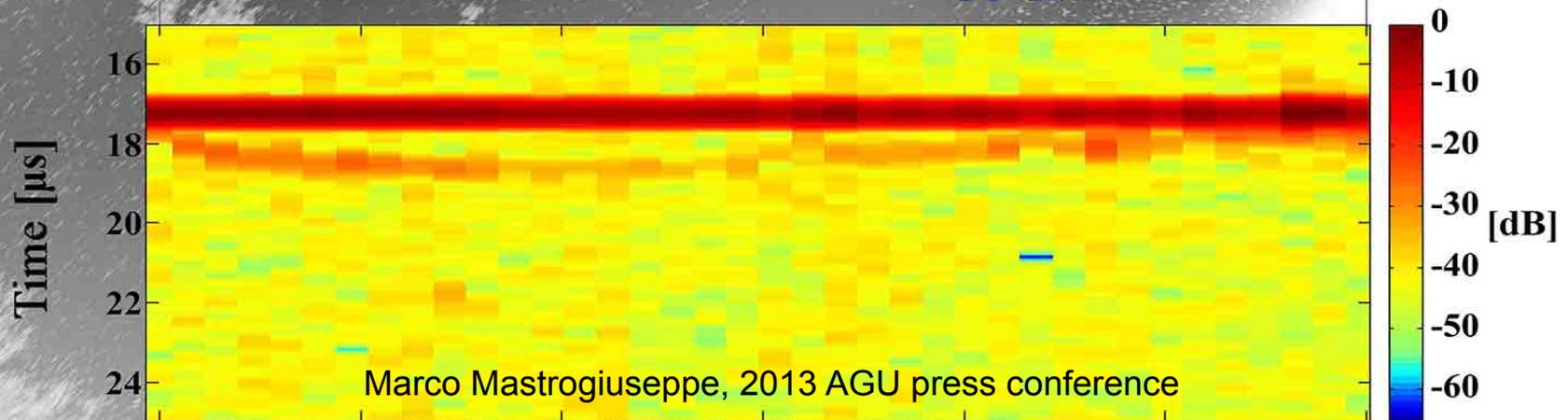
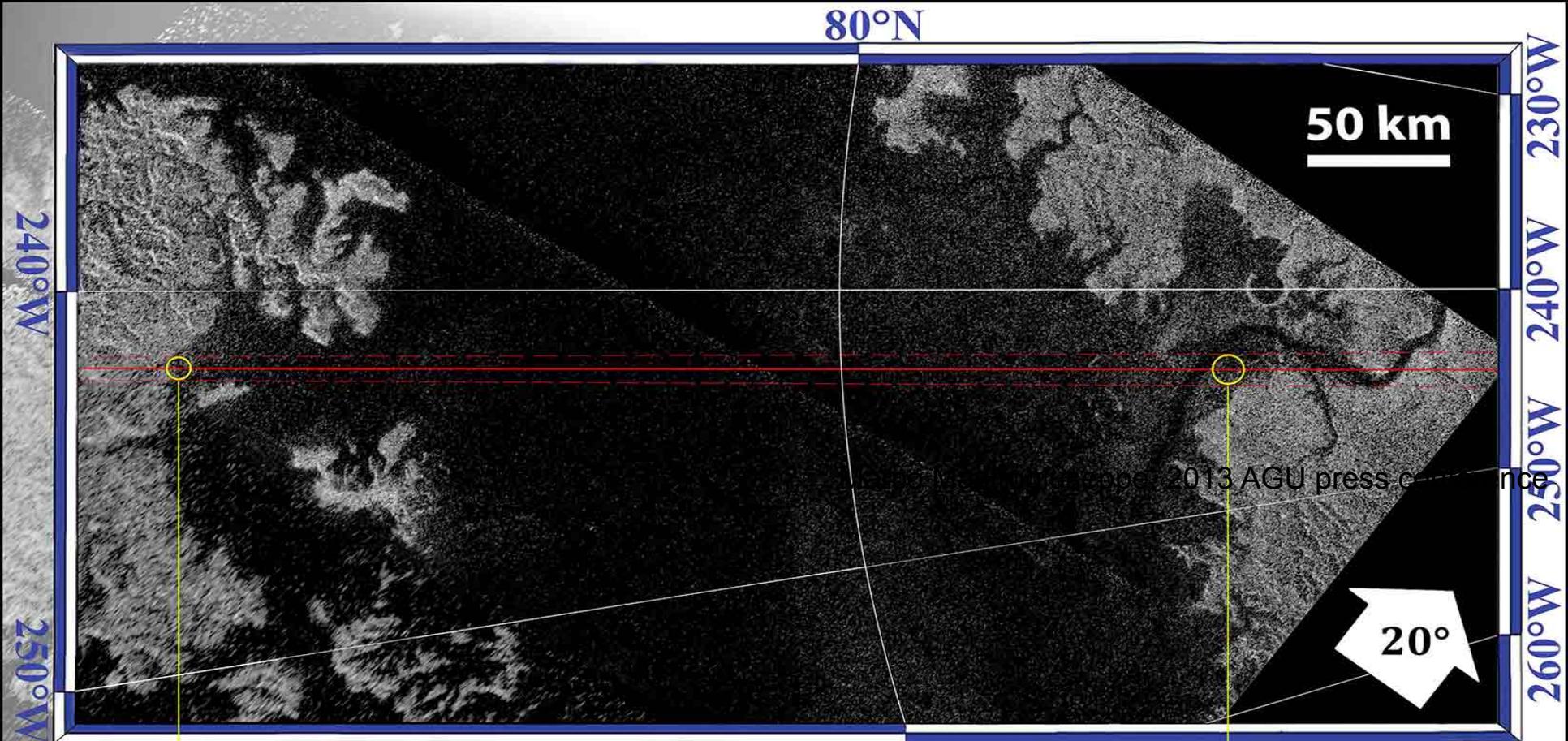
Ligeia Mare



Difference in time converted to depth

Marco Mastrogiuseppe, 2013 AGU press conference





Marco Mastrogiuseppe, 2013 AGU press conference

Results

- **Maximum depth: 160 to 170 meters (520 to 560 feet)**
- **Similar to average depth of Lake Michigan**

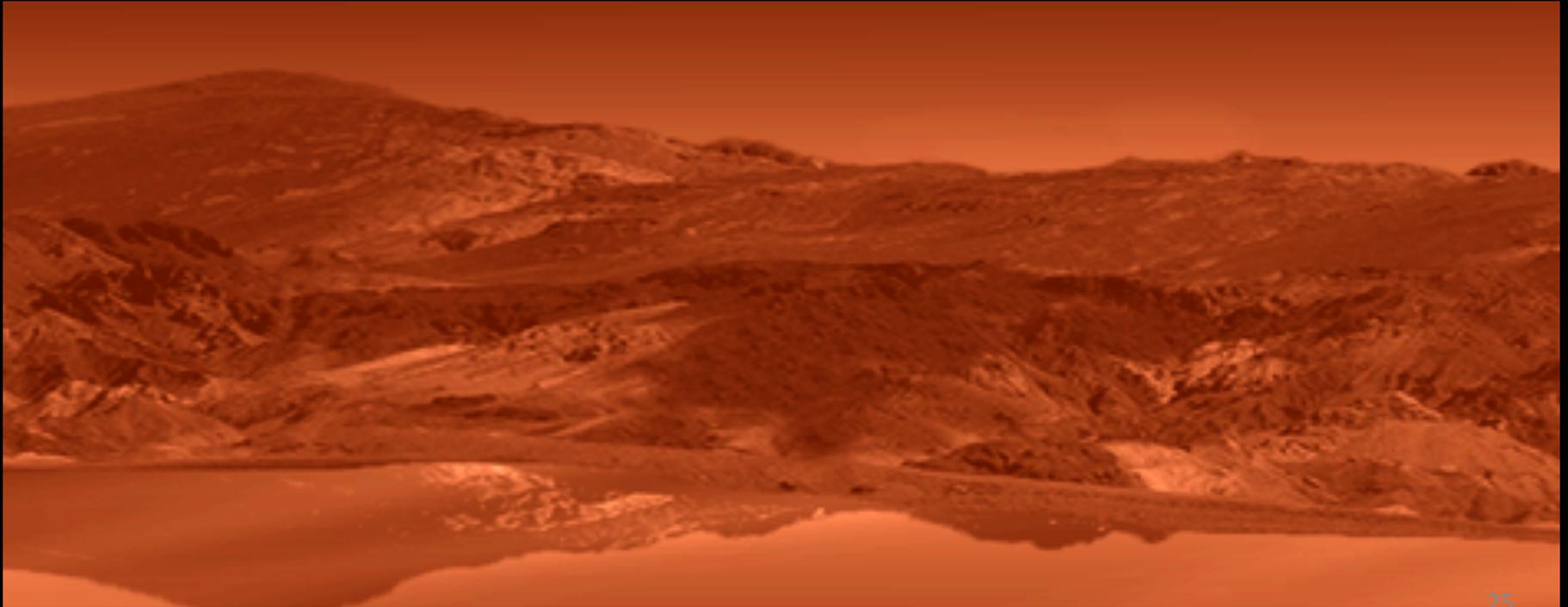


NASA/GSFC/SeaWiFS and
ORBIMAGE

Implications

Liquid in the lakes is very pure

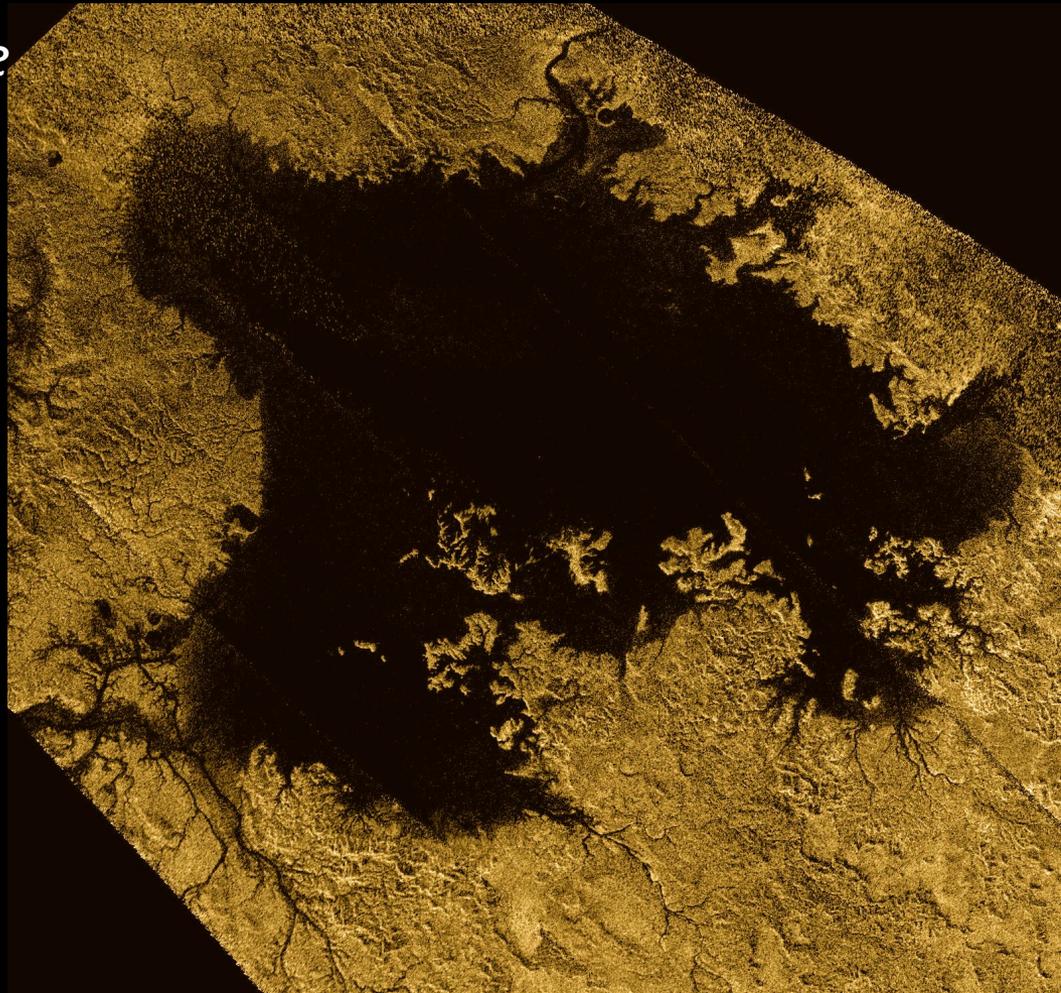
Mostly methane with few other components



Implications

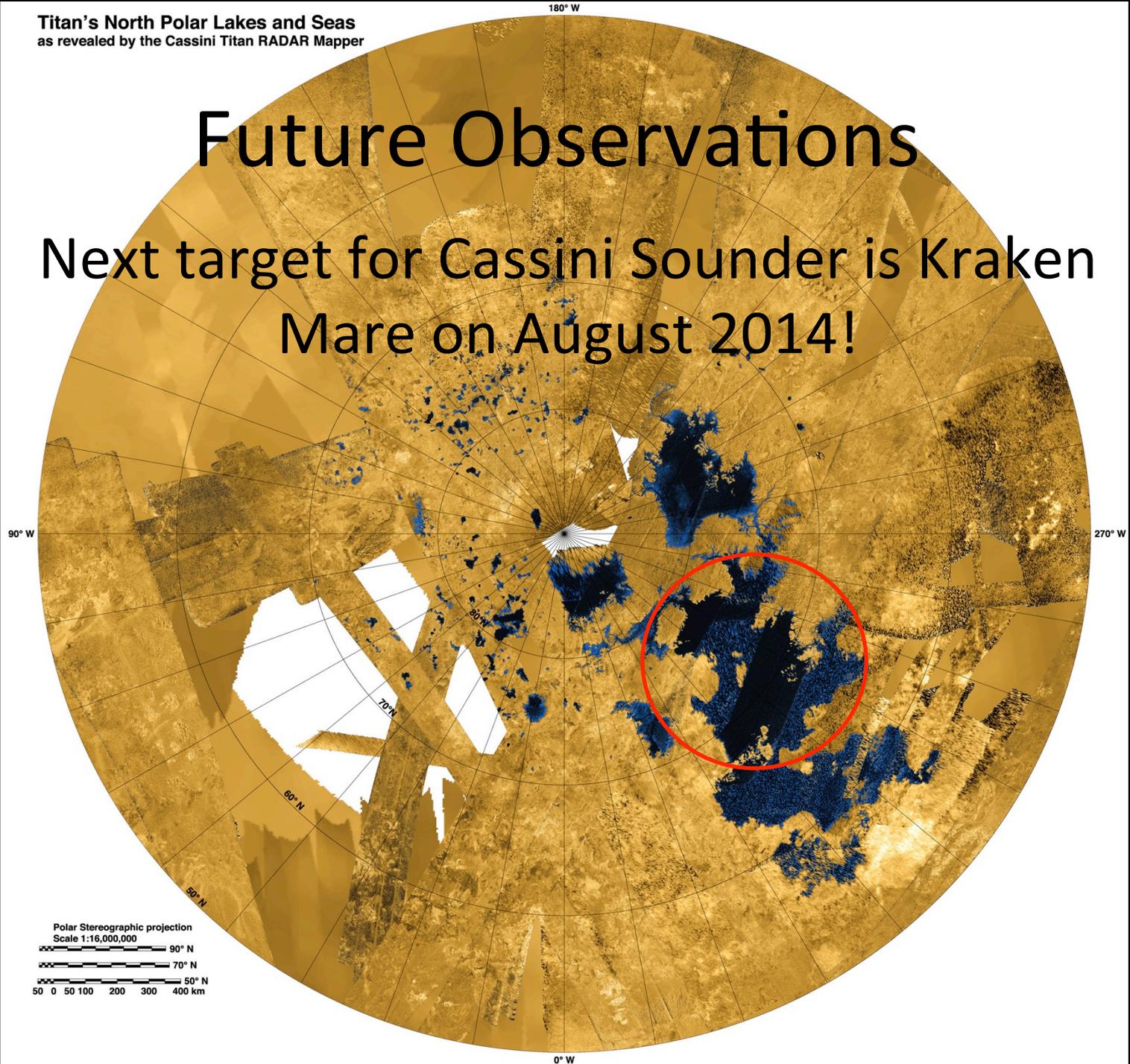
Extrapolated total liquid volume of Ligeia Mare: **about 2,000 cubic miles (9,000 cubic kilometers) OR 5,000 gigatons of carbon (Alex Hayes)**

About **40 times the proven oil reserves on Earth**

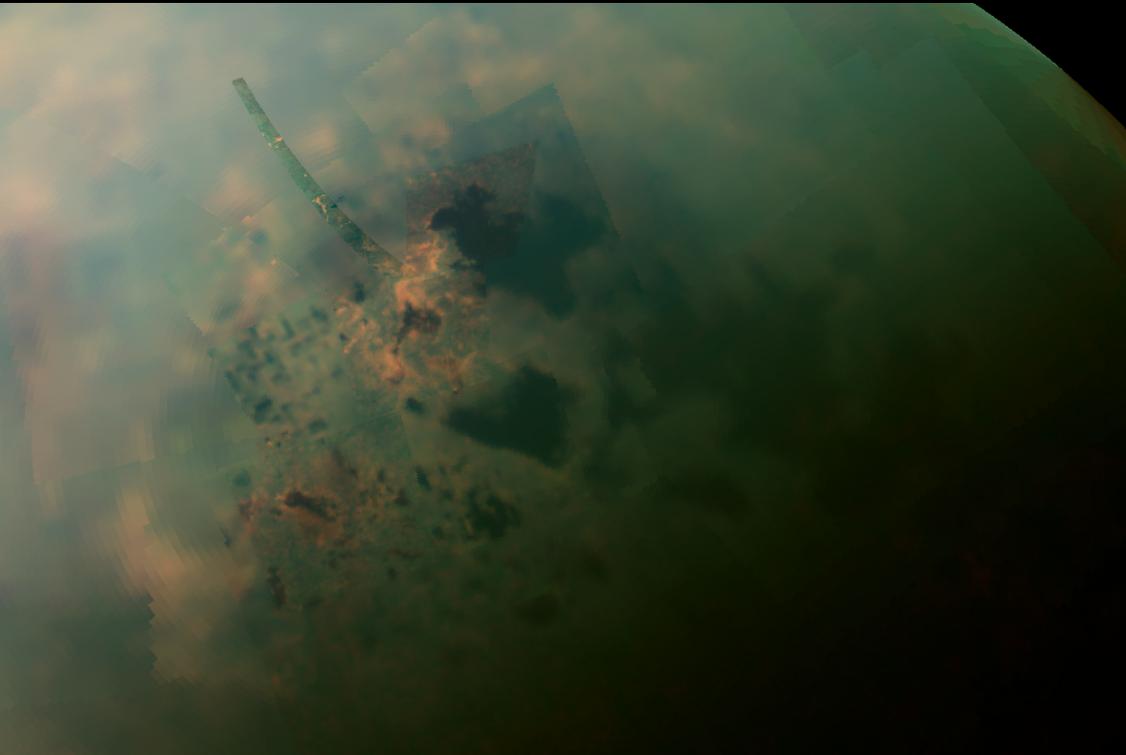


Future Observations

Next target for Cassini Sounder is Kraken
Mare on August 2014!



New Views of Titan's North Polar Lake District

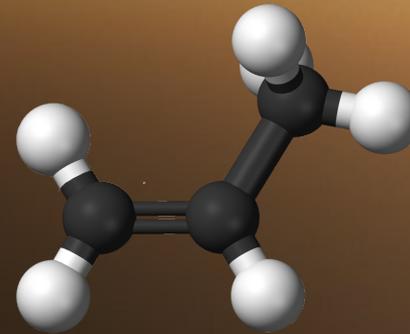
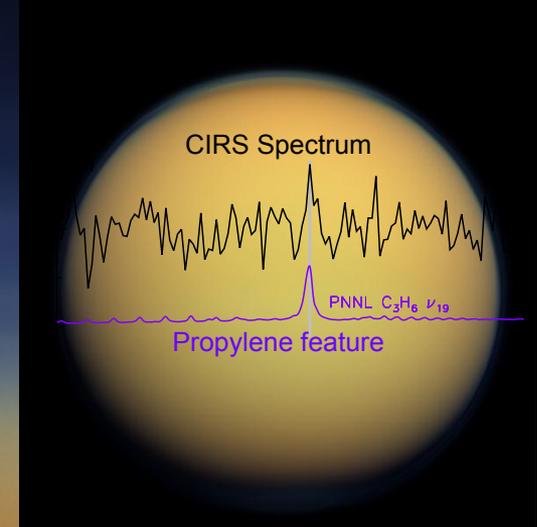


Dark splotches in the near-infrared views are Titan's lakes and seas.

Lower left: sunlight glinting off of Titan's Kivu Lacus.

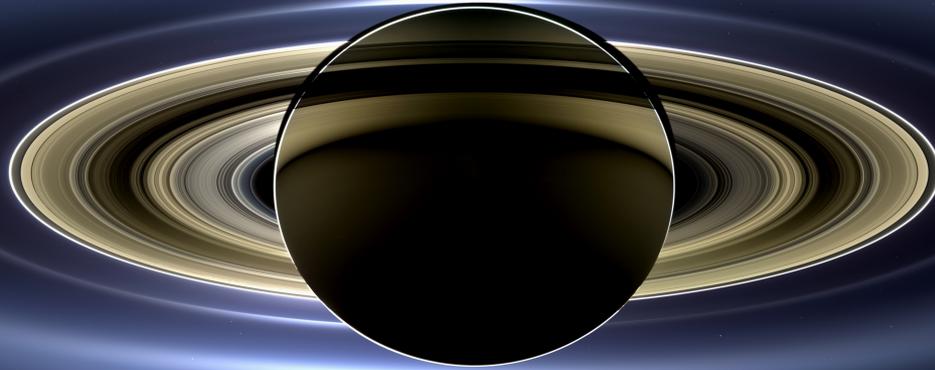
Cassini discovers Propylene on Titan

- CIRS Team detected a new molecule, **propylene (propene)**, in Titan's upper atmosphere.
- First definitive identification of propylene gas in a planetary atmosphere outside Earth.
- Propylene is an important raw material for our chemical industry, used to make polypropylene, a durable plastic that is molded into food storage containers.

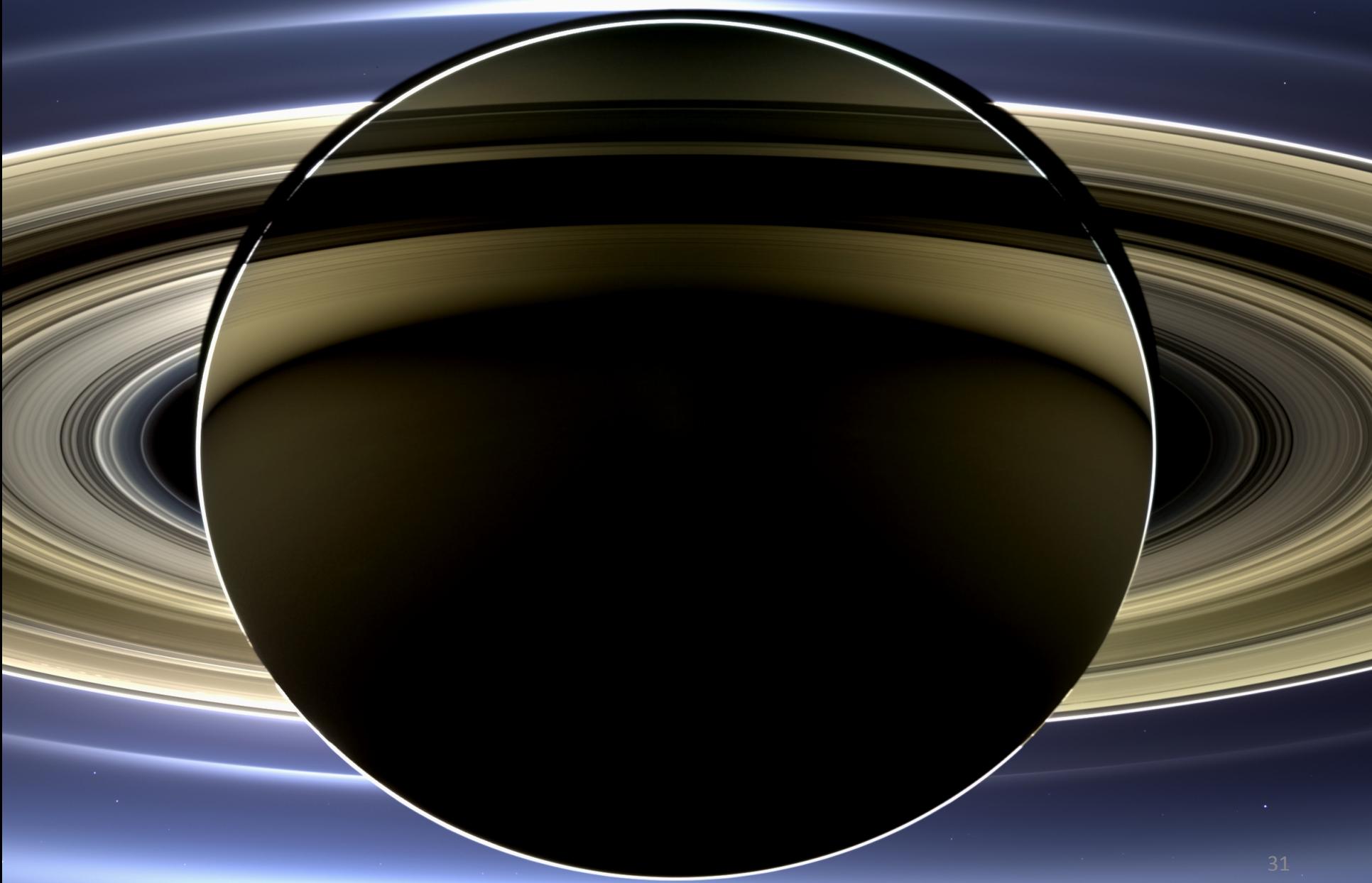


Detection of Propene [Propylene] in Titan's Stratosphere
C. Nixon, D. Jennings, B. Bézard, S. Vinatier, N. Teanby, K. Sung, T. Ansty, P. Irwin, N. Gorius, V. Cottini, A. Coustenis, F. M. Flasar. *Astroph.J.Lett.* 776, 2013

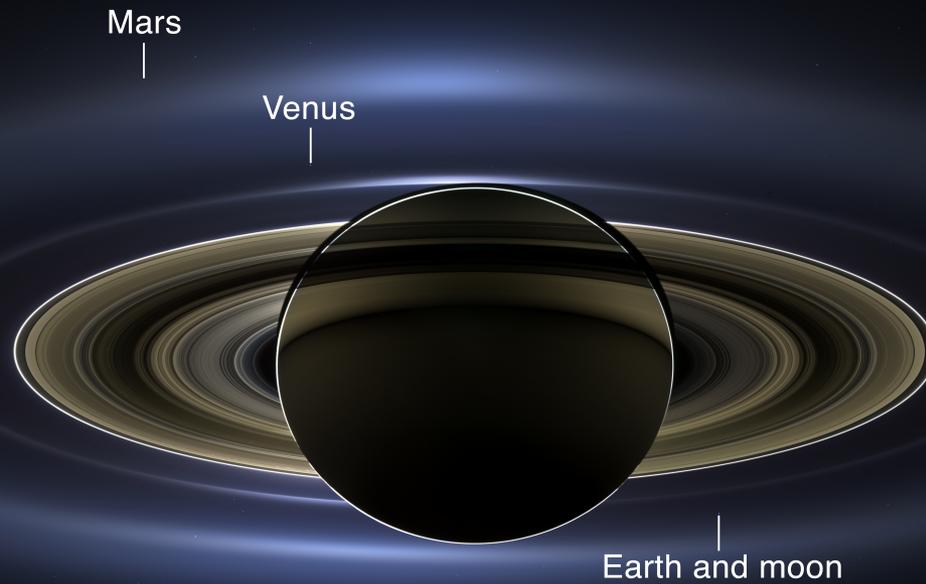
In Saturn's Shadow



Ring Shadows and Ringshine on Saturn



Familiar Worlds



40 Countries “Wave” Back!



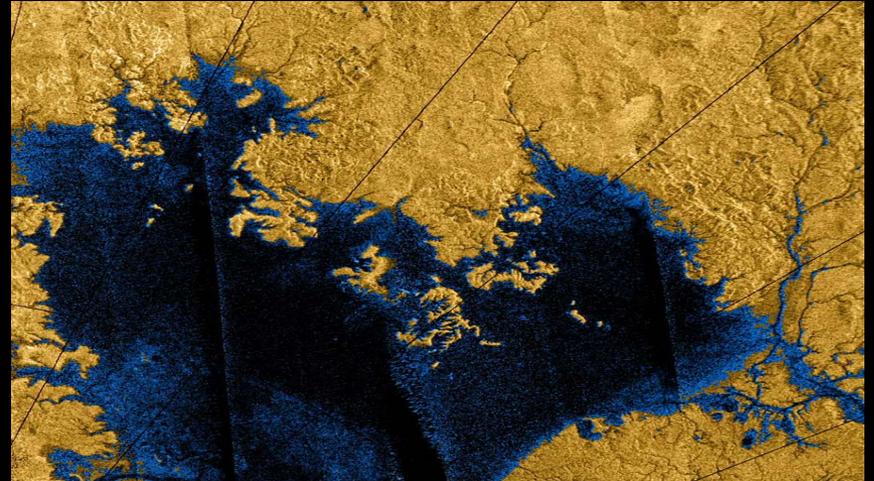
<http://go.nasa.gov/17qTDwD>

Cassini: An Investment not to be Wasted

- Cassini is the most sophisticated and successful deep space mission ever achieved---to waste it is inconceivable.
- The sheer distance and energy required to reach Saturn make Cassini a priceless resource, an achievement that will not be repeated for decades.
- Operating Cassini for 1 year is <2% of its total cost; completing the mission in 2015-2017 costs less than a Discovery mission.
- Cassini is a powerful astronomical observatory and chemical/physical laboratory, and it is already there—in orbit around Saturn
- Titan and Enceladus are key to understanding the origin of life's chemistry and of life itself.
- The Saturn system has all the elements of the whole solar system, perhaps even life. Much is still unexplored. Saturn is the endless frontier.

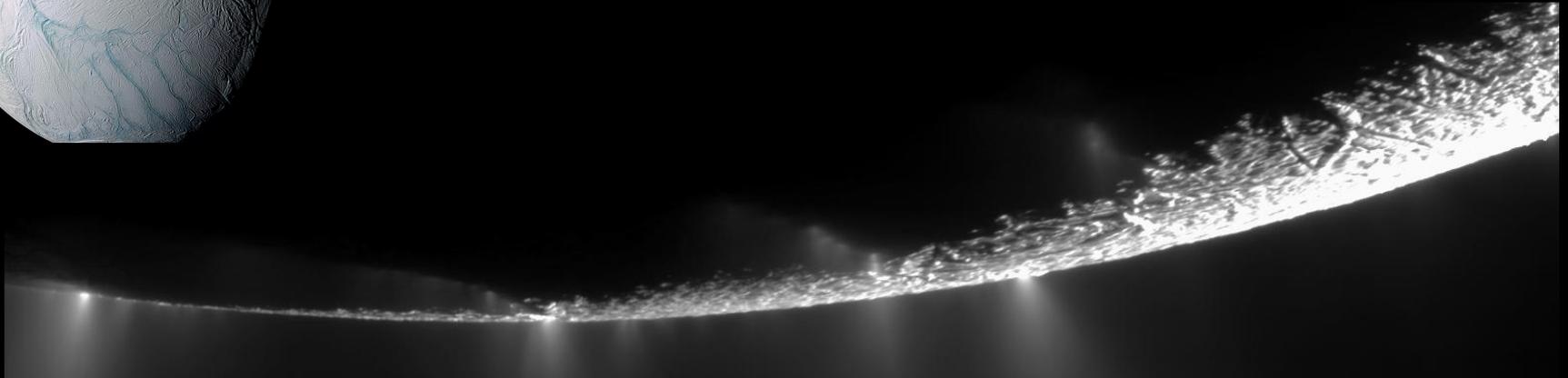
Titan and Enceladus: Redefining the Habitable Zone

- In its tour of the Saturn system, Cassini has discovered
 - liquid water oceans beneath the icy crusts of Titan and Enceladus
 - organic molecules upwelling from their interiors
 - hydrocarbon lakes on Titan
 - water vapor plumes erupting from salty oceans on Enceladus
- No longer the exclusive domain of Earth, the habitable zone now includes the icy moons of the outer solar system





The mysterious power of Enceladus' jets



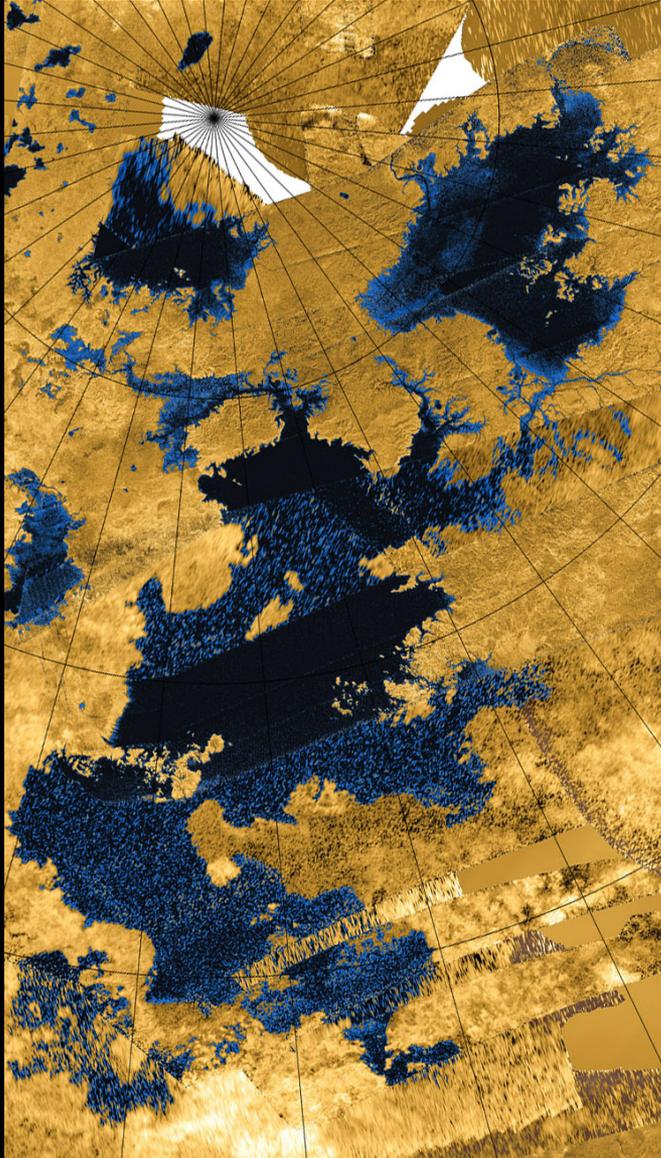
In the past couple of years:

- Cassini measured the power in the jet region to be several times Yellowstone's geysers
 - No explanation yet of the energy source of such a tiny moon.
- Cassini found the jets to vary as Saturn's gravity opens and closes chasms on the moon

In the coming three years:

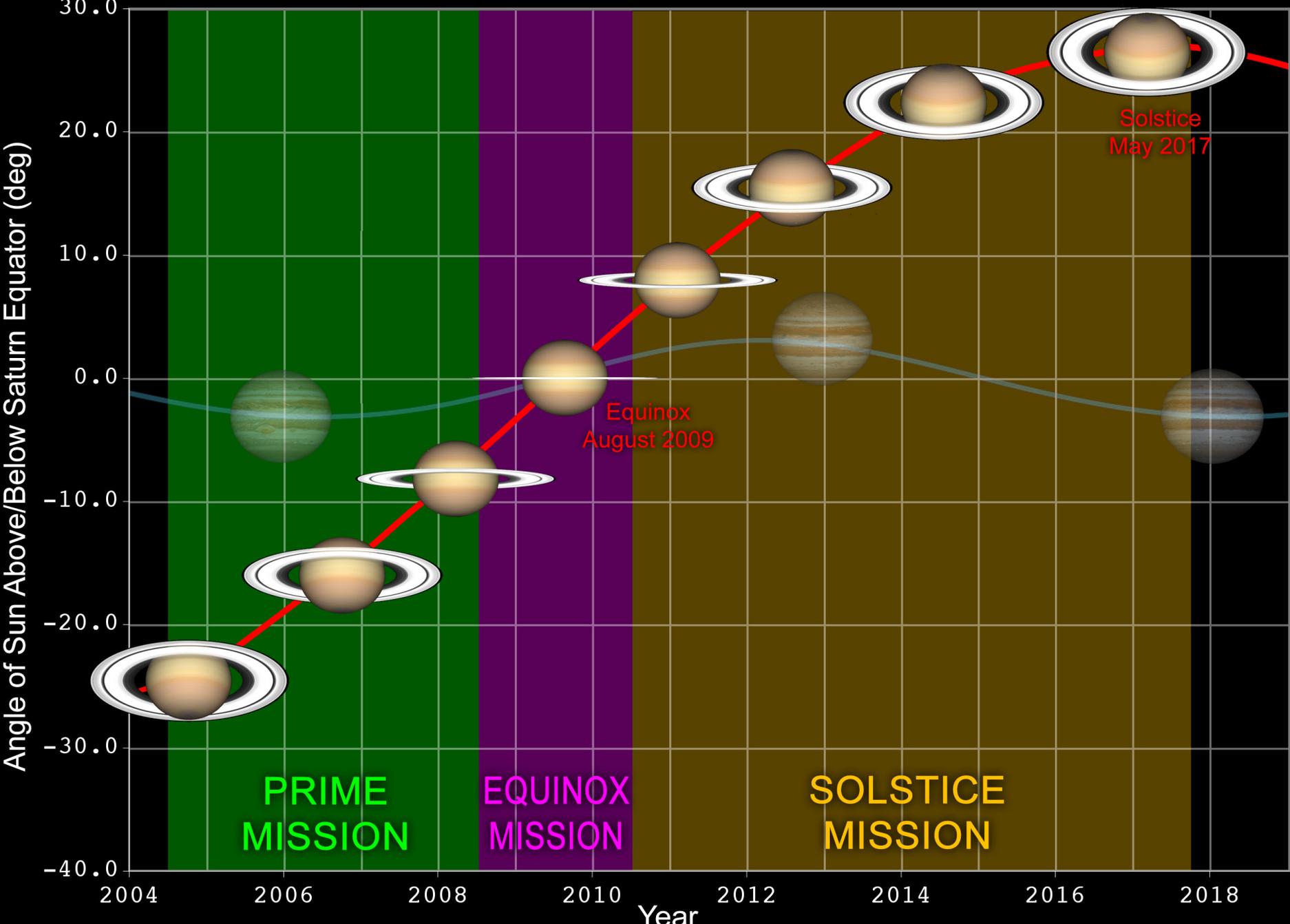
- Cassini will sniff the jets once more to see if their composition varies
- Cassini will check the north pole, illuminated for the first time, for ancient chasms.
- Best measurement of heat coming from south polar jets when south pole is in darkness. 36

100 times as much hydrocarbons than all the oil and gas on Earth!



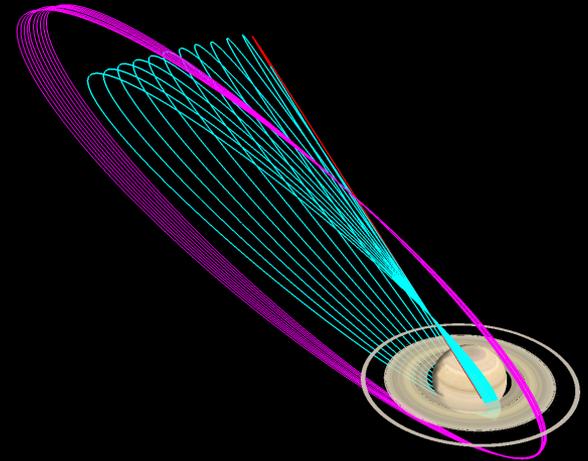
- In 2013 Cassini:
 - Expanded the known seas on Titan by *a factor of three*.
 - Measured the depth of a Titan sea.
- From 2014-2016 Cassini will:
 - Measure depth of largest sea
 - Look for waves not ever seen
 - Watch seas evaporate in summer Sun

Saturn Seasons: Northern Winter to Summer



The End Game: Proximal Mission

- Final orbits skim through the 2,000 km clear gap between inner edge of D ring and Saturn's upper atmosphere
- Unique science collected during final orbits deep within Saturn and up close to the rings
- Current impact date: 15 September 2017
- 2014-2016 is a critical preamble to F-Ring/Proximal Orbit Phase
 - Provides proper orbital geometry for orbiting inside the rings without hitting them and gives the best view inside Saturn



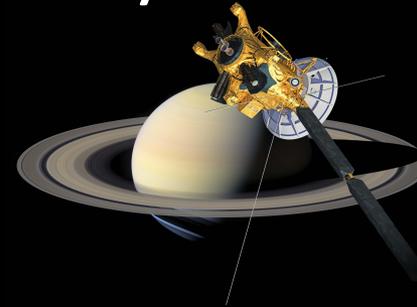
Cassini and Juno allow us to compare the two gas giants of our solar system

Juno



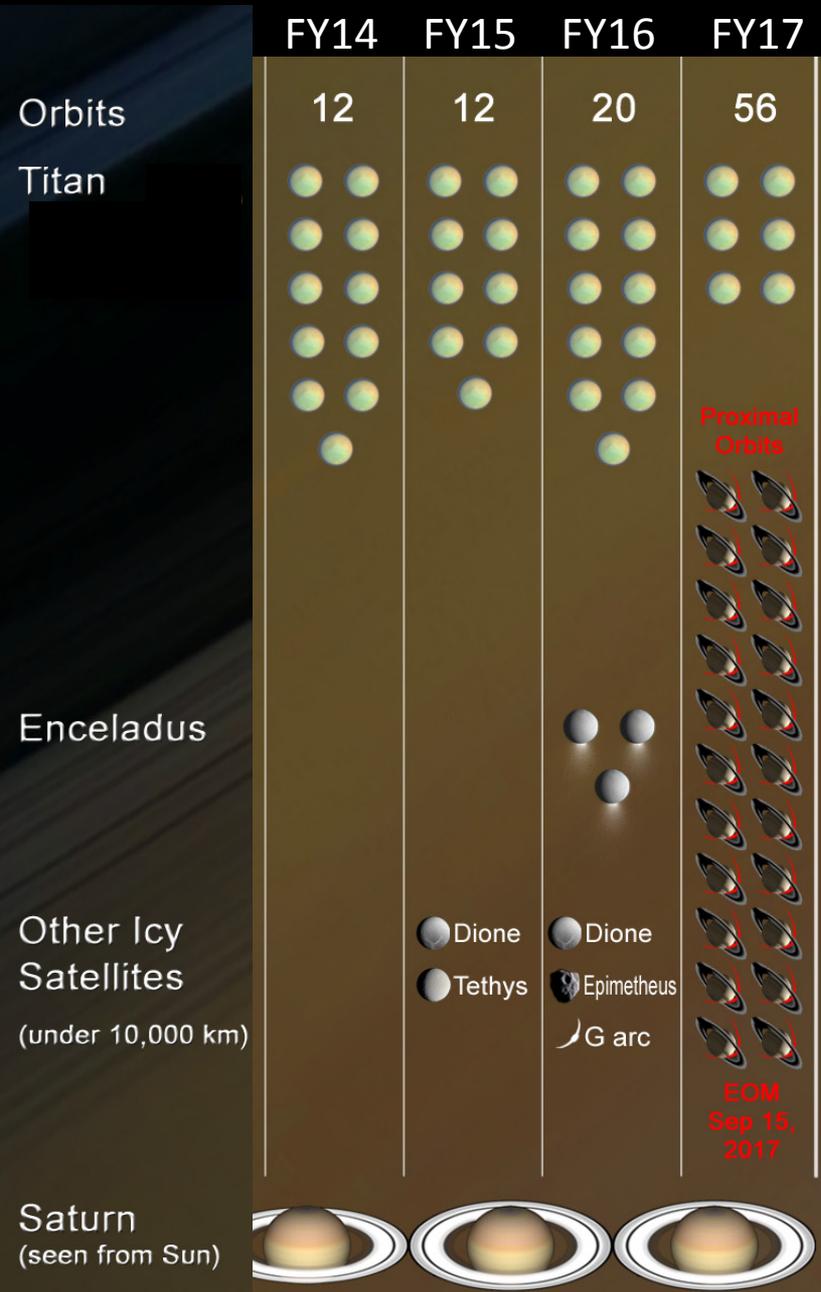
- Jupiter internal Structure
 - Gravity Field
 - Magnetic Field
- Deep atmosphere to 100 bars
 - Water and ammonia
- Aurora & polar magnetosphere
- Weather at Poles
- Inner radiation belts & ionosphere
- New spacecraft custom-designed for this mission. The cost is \$1 billion and well worth it

Cassini



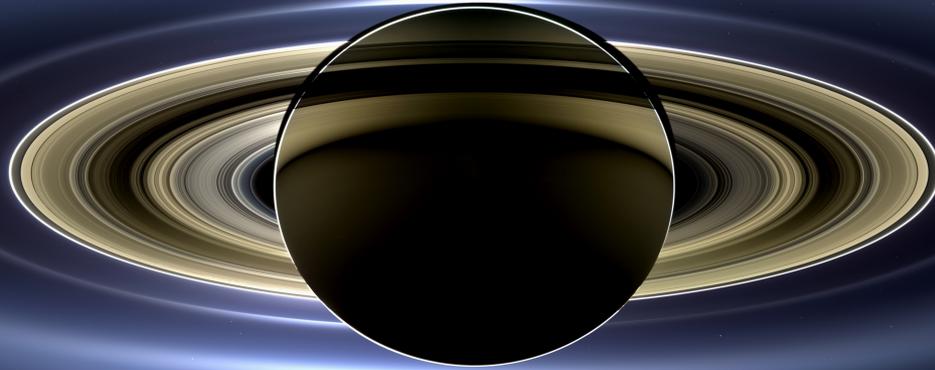
- Saturn internal Structure
 - Gravity Field
 - Magnetic Field
 - Determine unknown rotation rate
- Deep atmosphere to 2 bars
- Aurora & magnetosphere
- Weather at Poles
- Inner radiation belts & ionosphere
- Ring mass, ring moons
- With Cassini already in orbit, the cost is \$60 million per year, or \$180 million for FY15-FY17

Cassini's Final Four Years: Unique Science



- Explore new seasons in Saturn system 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; best measurement of heat coming from south pole
- Best lighting angle on lit rings (spring 2015 onward)
- Probe new regions of magnetosphere
- Late, close orbits provide *completely new, in-situ* measurements
- Without Cassini, these types of observations could not be fulfilled for decades to come

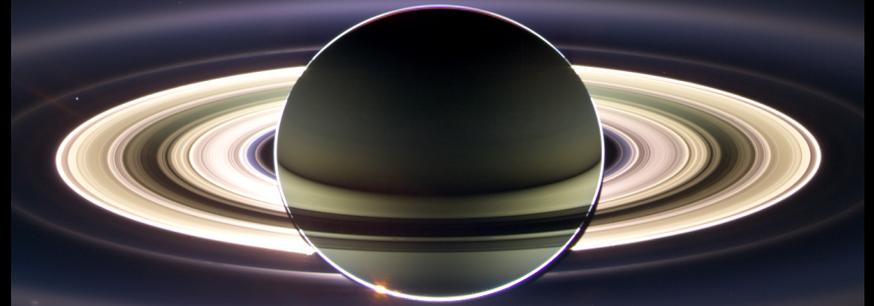
More Wonders Await Cassini



BACKUP MATERIAL

Rich Diversity of the Saturn System

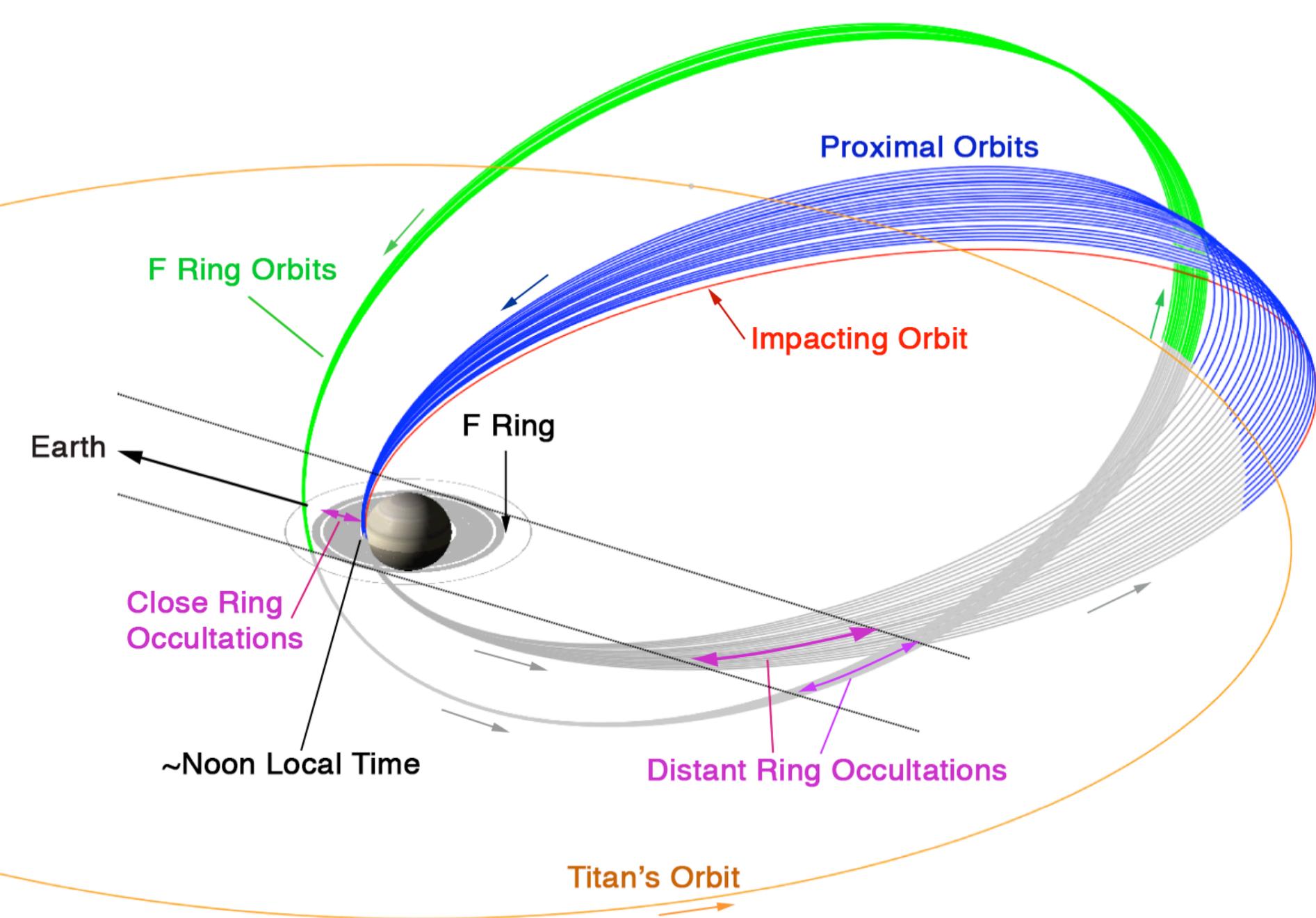
- The Saturn system is as complex as the Solar system, and we will never fully explore it
- The planet is a meteorological laboratory and a model of giant planets around other stars
- The rings are a test bed to study processes in the disk out of which the planets formed
- The magnetic field ties it all together and controls the exchange of matter and energy throughout the Saturn system





2012 Consolidated Senior Review

- **Assume** similar format and schedule as past Planetary Science Division (PSD) Consolidated Senior Review (no guidelines released yet)
 - Senior review in 2014 (SR every 2 years) to provide best balanced science for scarce funding available
 - Missions: **Cassini**, LRO, MSL, MER, MEX, MRO, ODY
 - Science merits and performance will be evaluated
 - 35-page proposal to address FY15 – FY16 extended mission
 - Cassini requesting addition of FY17 (final year of tour) to proposal as well
 - Two funding options: baseline and 85% option
- Cassini Proposal Submitted Late May
- **Questions from Panel to Project Offices** **Mid-June**
 - In addition, **report on changes in Operations and Science**
- **Face to Face visit/oral presentation** **Late June**
- Senior Review Report submitted to PSD Mid-July
- PSD Notification to Project Offices FY15 start – 2 months



Proximal Orbits

F Ring Orbits

Impacting Orbit

Earth

F Ring

Close Ring Occultations

~Noon Local Time

Distant Ring Occultations

Titan's Orbit

SEASONAL CYCLES AT SATURN



Winter Solstice



Vernal Equinox



Summer Solstice



Autumnal Equinox



Winter Solstice

May '73 Mar '80 Dec '87 Nov '95 Nov '02



Pioneer 11 V1 V2 (Voyagers)

Cassini

PRIME

EM

SOLSTICE MISSION

Outer solar system goes dark: No flying missions

Nov '02

Aug '09

May '17

May '25

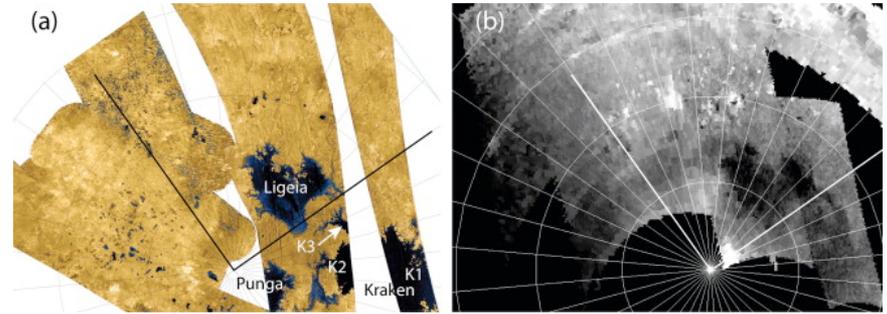
Apr '32

Seasonal events refer to northern hemisphere conditions

Flybys

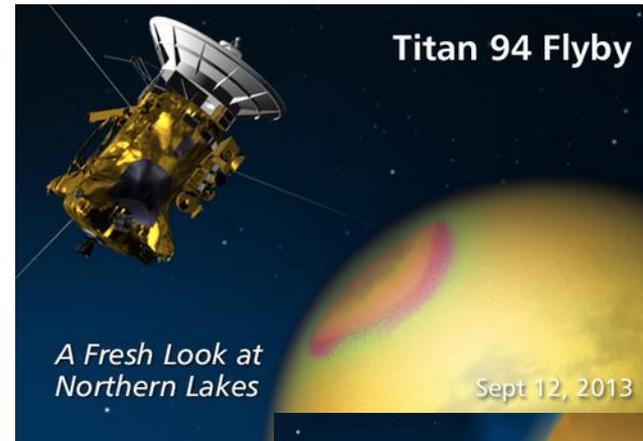
T94 – Titan flyby (970 km) Sept. 12, 2013

- ORS flyby
- Looked for any seasonal changes in Titan's lakes



T95 – Titan flyby (961 km) Oct. 15, 2013

- RADAR/INMS flyby
- Best pass in the Solstice mission to study the effects of solar input on Titan's atmosphere
- SAR to edge of lake region targeted to hit Selk, a region not well studied previously



Flybys

T96 – Titan flyby (1400 km) Dec. 1, 2013

- ORS flyby
- North and south pole medium and high-resolution mapping of seas, lakes, surface, & cloud monitoring

T97 – Titan flyby (1400 km) Jan. 1, 2014

- ORS flyby
- Lakes and seas mapping in the north, & equatorial surface coverage
- Temperature and trace gas atmospheric observations and cloud tracking

