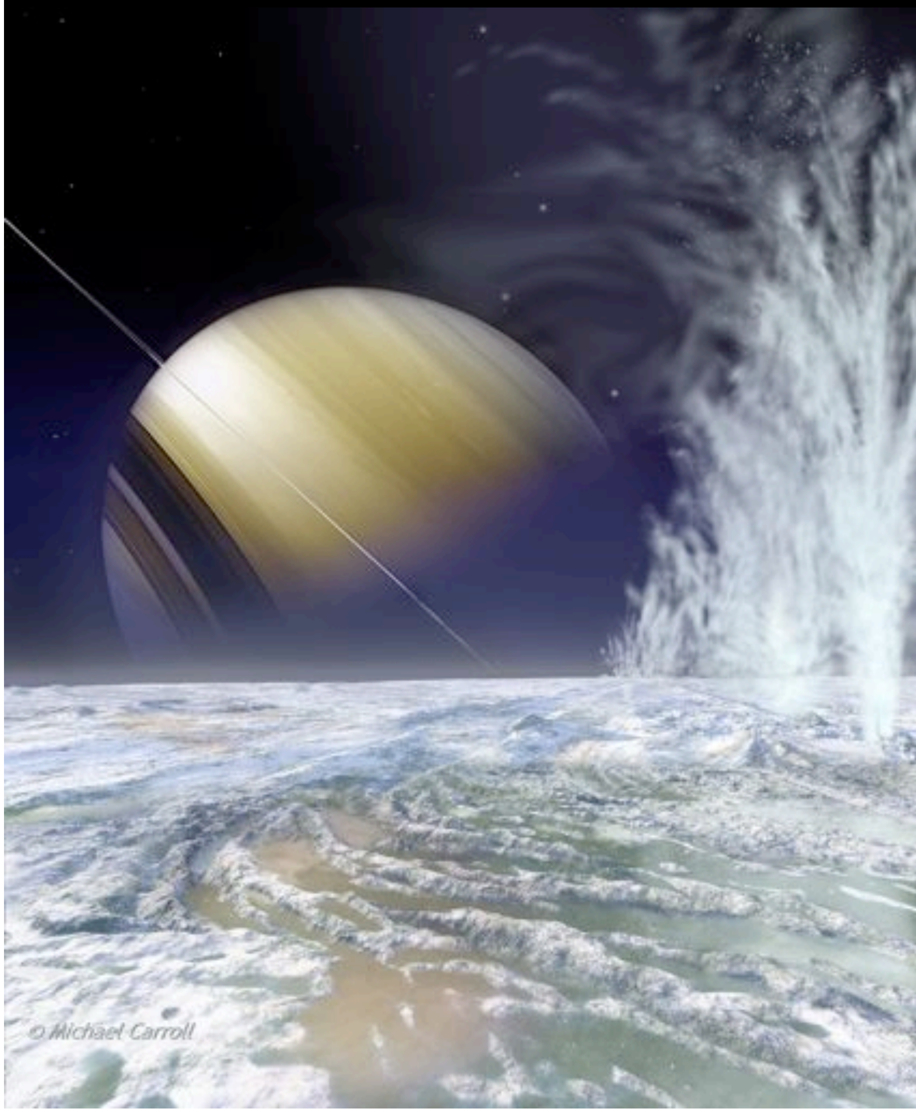
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Cassini Equinox and Solstice Missions: Titan, Enceladus, Icy Moons



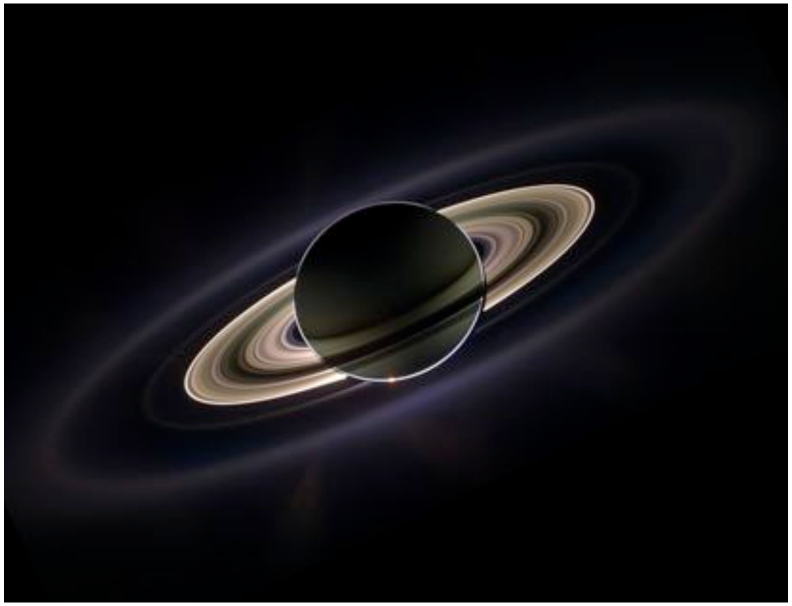
Linda Spilker
Cassini Deputy Project Scientist

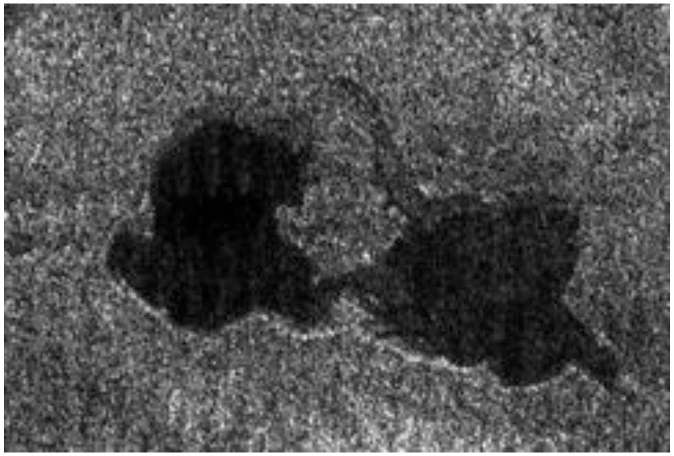
Giant Planet Satelites Decadal Panel

25 August 2009

Cassini Equinox and Solstice Science: Introduction

- Cassini's science structure
  - 12 Instrument Teams
  - 9 Interdisciplinary Scientists (IDSs)
  - 5 Disciplines
  - >250 Scientists world-wide
- Outstanding Science Questions
  - Titan
  - Enceladus
  - Icy Satellites
- Proximal Science
- Proposed Solstice Goal:
  - Observe seasonal and temporal change in the Saturn system to understand underlying processes and prepare for future missions.
- Objectives Categories:
  - Seasonal-temporal change
  - New Questions

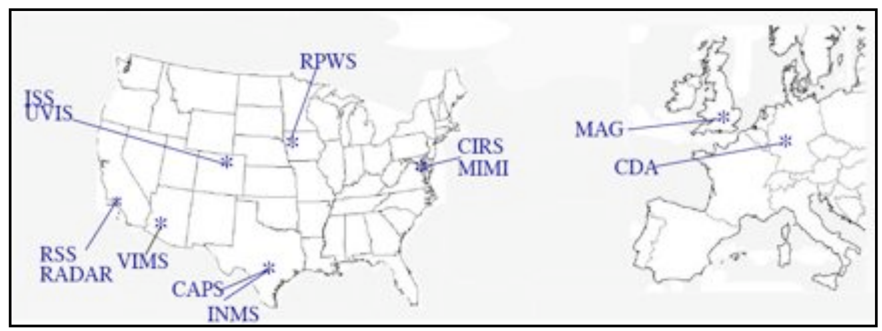




Cassini's Science Structure: 12 Instrument Teams

Investigation (Acronym)	Principal Investigator (PI) or Team Lead (TL)
Cassini Plasma Spectrometer (CAPS)	D. Young (PI), Southwest Research Institute
Cosmic Dust Analyzer (CDA)	R. Srama (PI), Max Planck Institute
Composite Infrared Spectrometer (CIRS)	M. Flasar (PI), NASA Goddard
Ion and Neutral Mass Spectrometer (INMS)	H. Waite (PI), Southwest Research Institute
Imaging Science Subsystem (ISS)	C. Porco (TL), Space Science Institute
Magnetometer (MAG)	M. Dougherty (PI), Imperial College
Magnetospheric Imaging Instrument (MIMI)	S. Krimigis (PI), Applied Physics Laboratory
Cassini Radar (RADAR)	C. Elachi (TL), Jet Propulsion Laboratory
Radio and Plasma Wave Science (RPWS)	D. Gurnett (PI), University of Iowa
Radio Science Subsystem (RSS)	A. Kliore (TL), Jet Propulsion Laboratory
Ultraviolet Imaging Spectrograph (UVIS)	L. Esposito (PI), University of Colorado
Visible and Infrared Mapping Spectrometer (VIMS)	R. Brown (TL), University of Arizona

- 6 fields and particles teams
  CAPS, CDA, INMS, MAG, MIMI, RPWS
- 4 optical remote sensing teams
  CIRS, ISS, UVIS, VIMS
- 2 teams using high-gain antenna
  RSS, RADAR

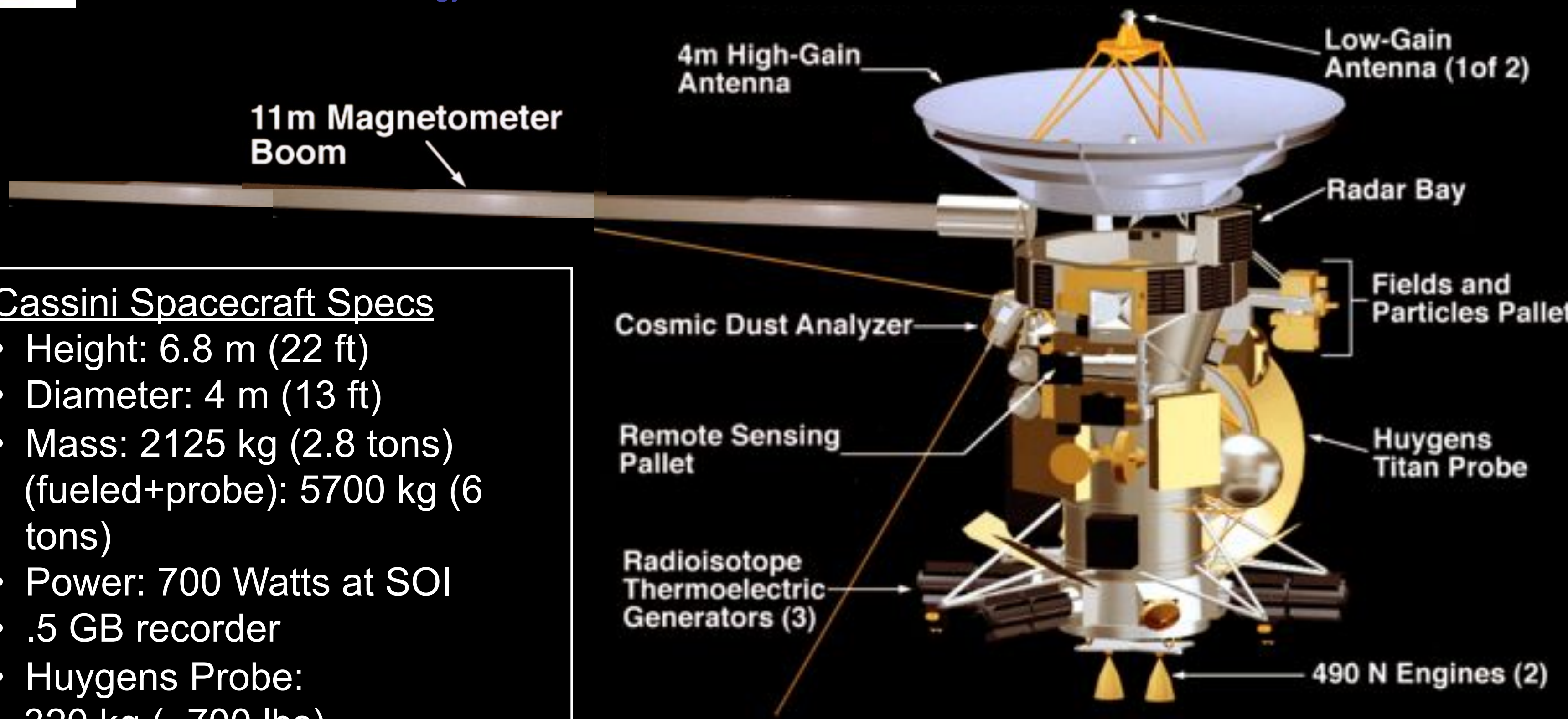


Cassini's Science Structure: 9 Interdisciplinary Scientists

Science Investigation	Scientist, Affiliation
Magnetosphere and Plasma	M. Blanc (IDS), Observatoire Midi-Pyrénées
Rings and Dust	J. Cuzzi (IDS), NASA Ames Research Center
Titan Aeronomy	D. Gautier (IDS), Observatoire de Paris-Meudon
Magnetosphere and Plasma	T. Gombosi (IDS), University of Michigan
Titan Atmosphere and Surface	J. Lunine (IDS), University of Arizona
Atmospheres	T. Owen (IDS), University of Hawaii
Titan Organic Chemistry	F. Raulin (IDS), Université Paris - Val de Marne
Satellites	L. Soderblom (IDS), US Geological Survey
Aeronomy & Solar Wind	D. Strobel (IDS), Johns Hopkins University

- Interdisciplinary Scientists lead the 5 Cassini Discipline Working Groups.

Cassini Spacecraft



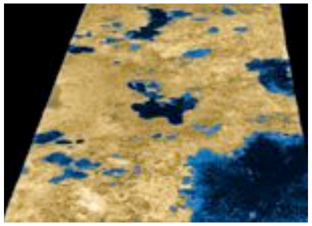
Cassini Spacecraft Specs

- Height: 6.8 m (22 ft)
- Diameter: 4 m (13 ft)
- Mass: 2125 kg (2.8 tons) (fueled+probe): 5700 kg (6 tons)
- Power: 700 Watts at SOI
- .5 GB recorder
- Huygens Probe: 320 kg (~700 lbs)

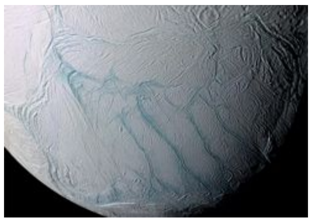
Spacecraft Status

- Overall Spacecraft health is good
- Reaction wheels: Launched with 4 reaction wheels, currently on backup wheel
- Thrusters: Recently swapped to backup thrusters
- Helium Magnetometer: No longer operating

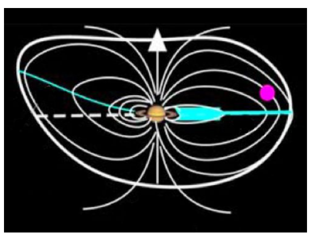
Cassini's Science Structure: 5 Science Disciplines



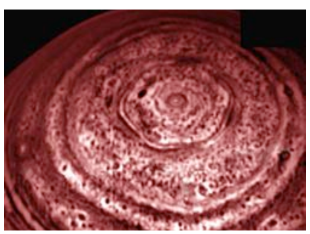
- Titan



- Icy Satellites



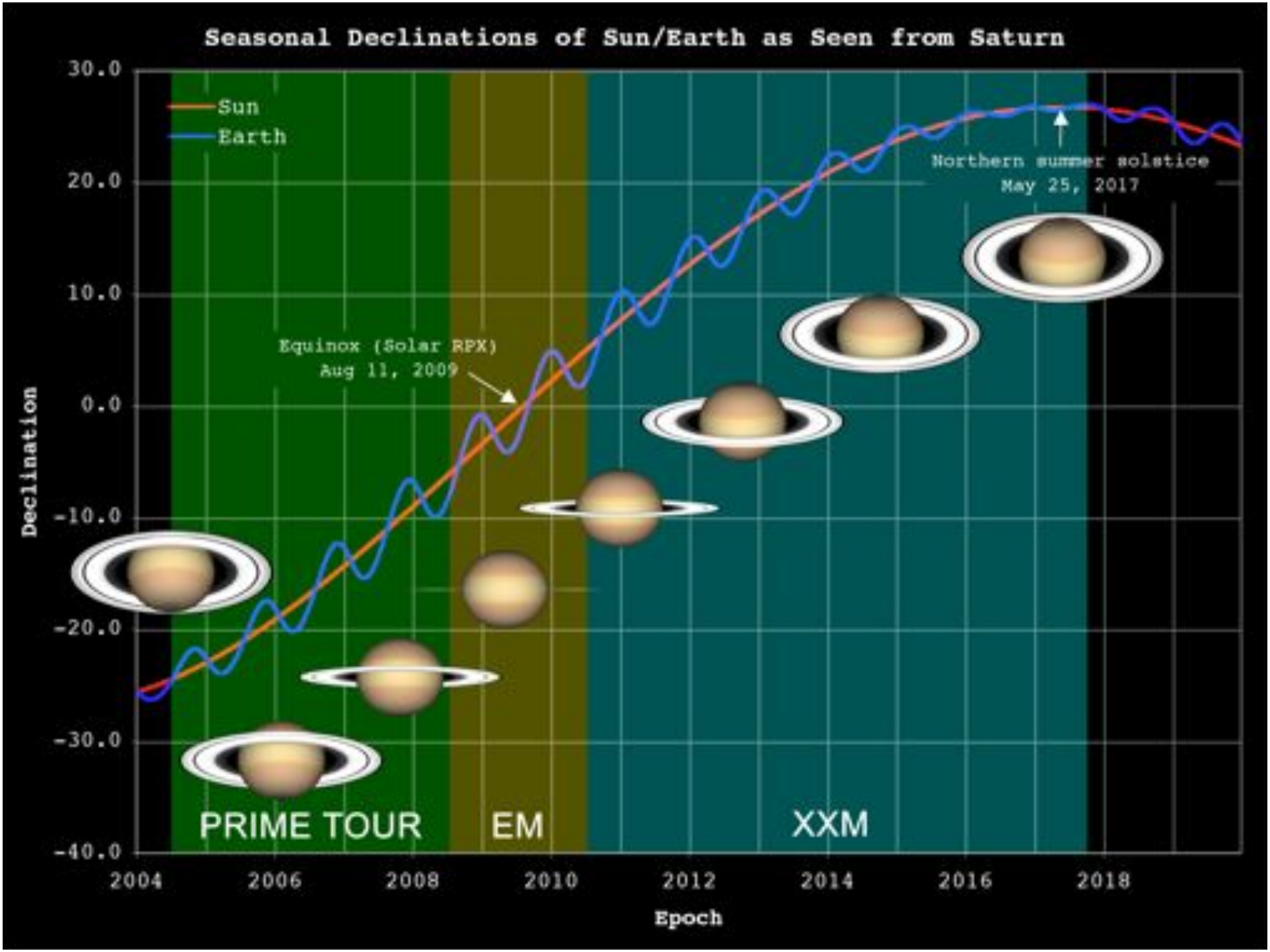
- Magnetosphere and Plasma Science (MAPS)



- Saturn

- Rings

Each discipline is like a mission in its own right!

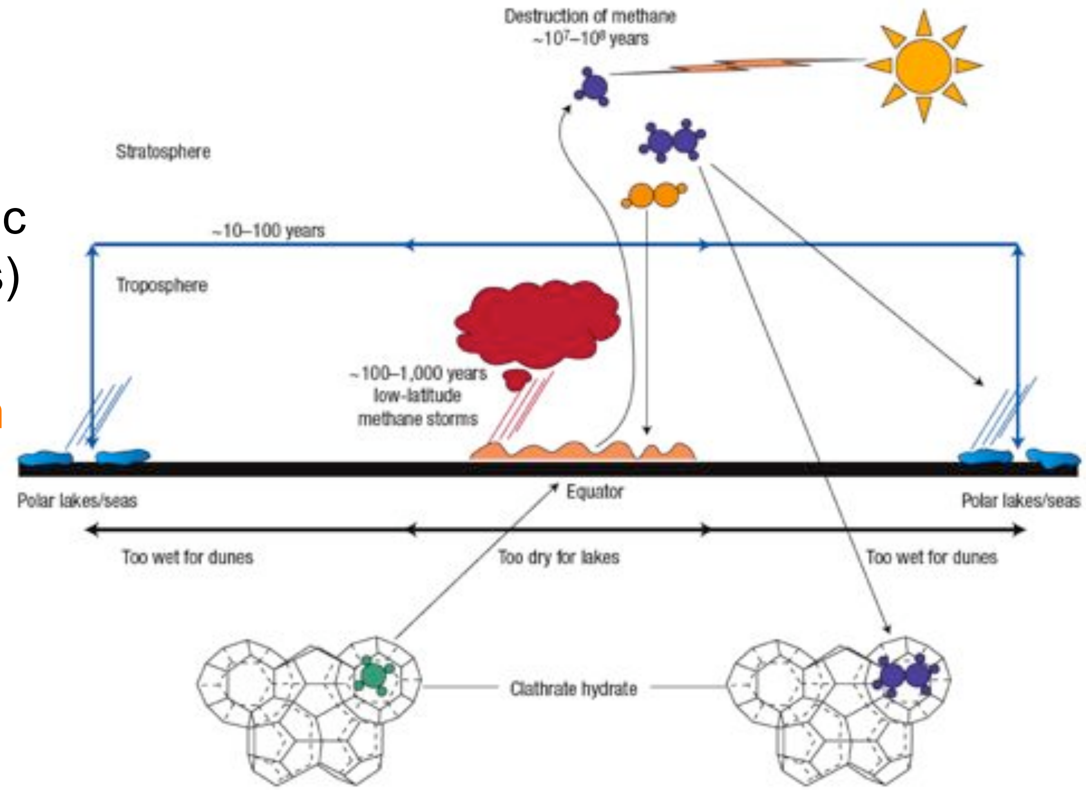


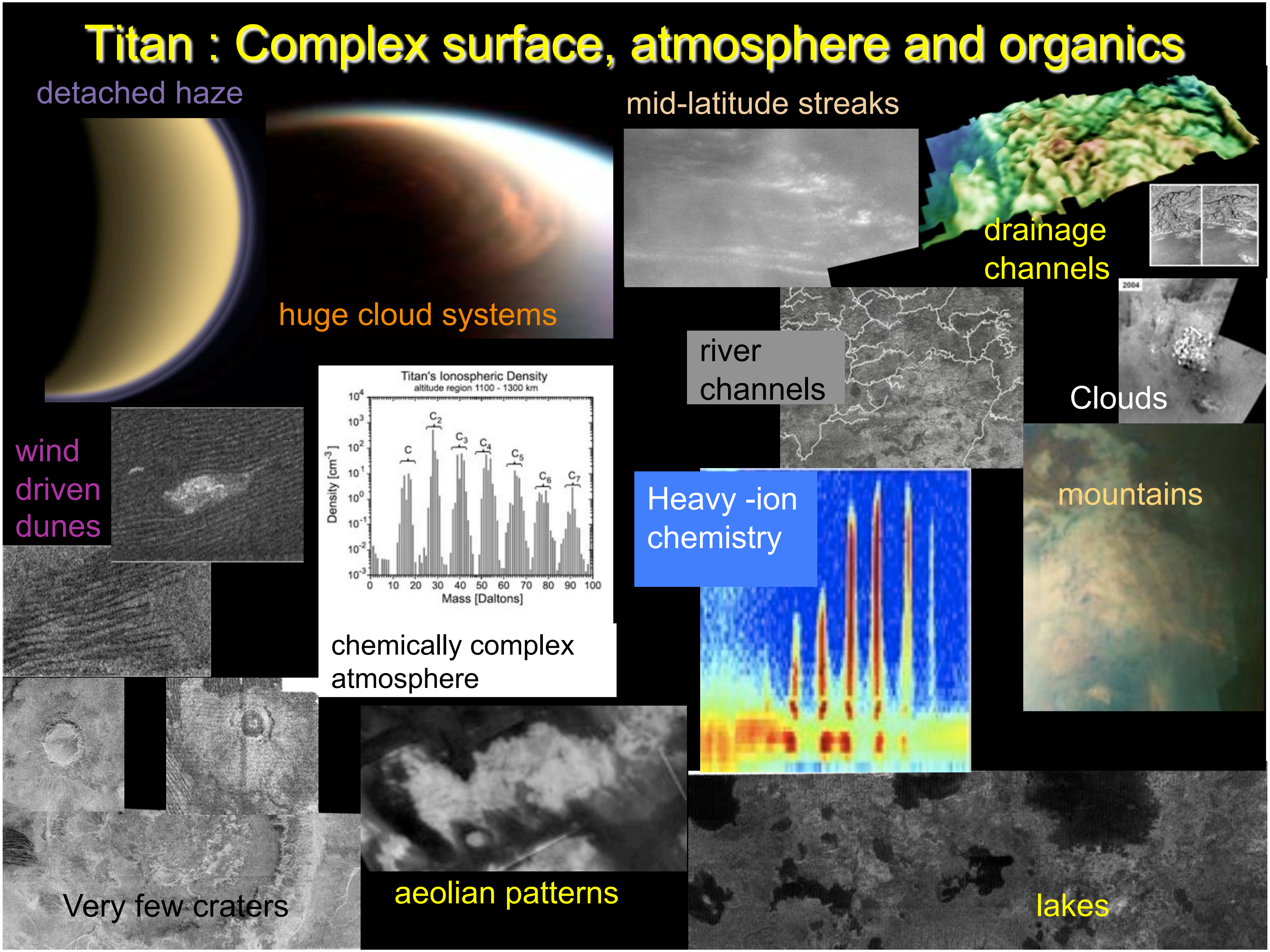
Seasonal Declinations of Sun/Earth as Seen from Saturn
Sun
Earth
Northern summer solstice
May 25, 2017
Equinox (Solar RPX)
Aug 11, 2009
PRIME TOUR
EM
XXM
Declination
Epoch
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
2004
2006
2008
2010
2012
2014
2016
2018


Cassini Mission Overview
Four-Year Prime Tour, Equinox Mission, and Solstice Mission (Proposed), July 2004 - July 2017
Prime Mission
Equinox Mission
Solstice Mission
Year of Tour
1 '04-'05
2 '05-'06
3 '06-'07
4 '07-'08
5 '08-'09
6 '09-'10
7 '10-'11
8 '11-'12
9 '12-'13
10 '13-'14
11 '14-'15
12 '15-'16
13 '16-'17
Orbits
11 15 22 27 39 21 16 19 25 12 12 20 56
Titan
Enceladus
Other Icy Satellites
(under 10,000 km)
Phoebe
Tethys
Hyperion
Dione
Telesto
Rhea
Rhea
Iapetus
Epimetheus
Rhea
Helene
Dione
G arc
Rhea
Helene
Dione
Dione
Tethys
Methone
Telesto
Rhea
Dione
Tethys
Dione
Epimetheus
G arc
Saturn
(seen from Sun)

Titan Discoveries of the Prime and Equinox Mission

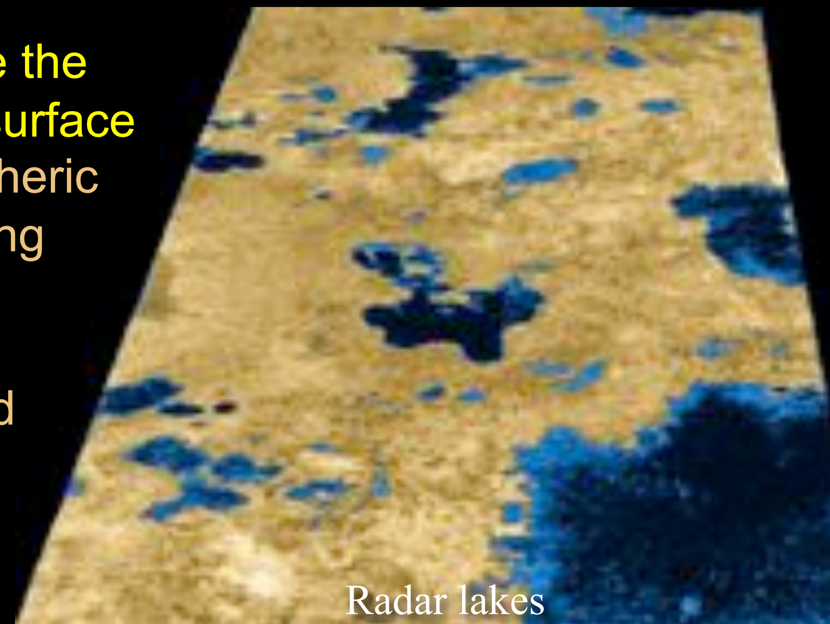
- Active methane cycle on Titan with
  - Polar lakes
  - Clouds/precipitation
  - Erosional features (dendritic channels, rounded pebbles)
  - Dunes
- Evidence for an internal ocean (presumably water)
- Complex organic chemistry in upper atmosphere
- Strong connections to Saturn magnetosphere
  - Imprint of Saturn magnetic field
  - Enceladus as a source of oxygen for Titan chemistry



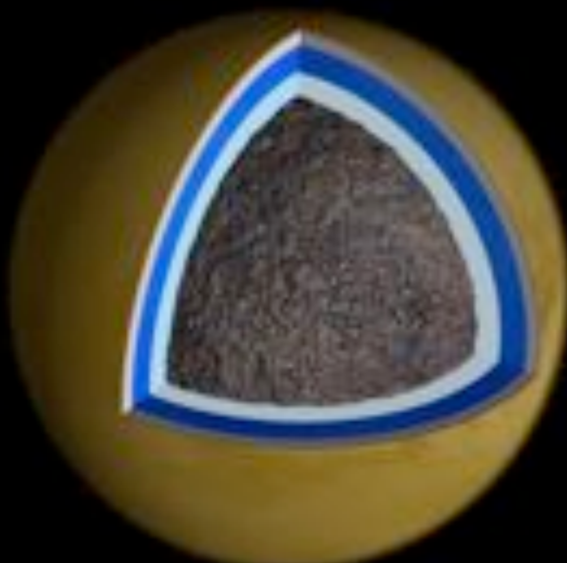

Titan : Complex surface, atmosphere and organics
detached haze
huge cloud systems
mid-latitude streaks
drainage channels
river channels
Clouds
wind driven dunes
Titan's Ionospheric Density
altitude region 1100 - 1300 km
Density [cm-3]
Mass [Daltons]
chemically complex atmosphere
Heavy -ion chemistry
mountains
Very few craters
aeolian patterns
lakes

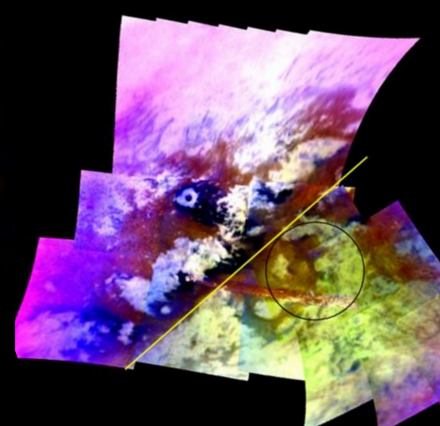
Equinox Mission Science Objectives: Titan

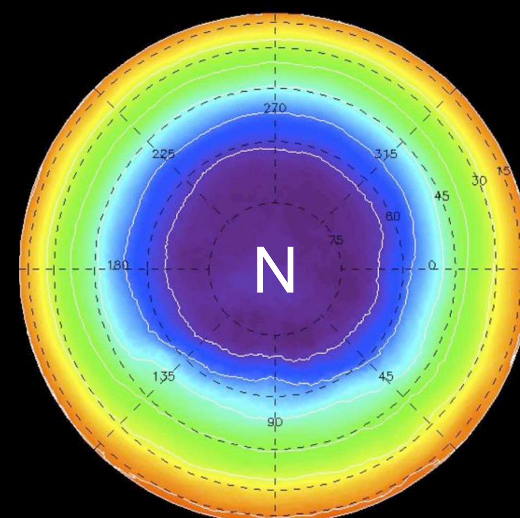
- Methane hydro-geo-chemical cycle: Observe the atmospheric, magnetospheric, interior, and surface manifestations (energetic chemistry, atmospheric processes, and geological processes including erosion, lakes, and crustal processes) to understand how mass and energy are exchanged among the various reservoirs and the extent to which this cycle is active today.


Radar lakes


Huygens image




VIMS Geological units



Winter polar vortex

Titan Science Objectives for CSM

Seasonal/Temporal Change

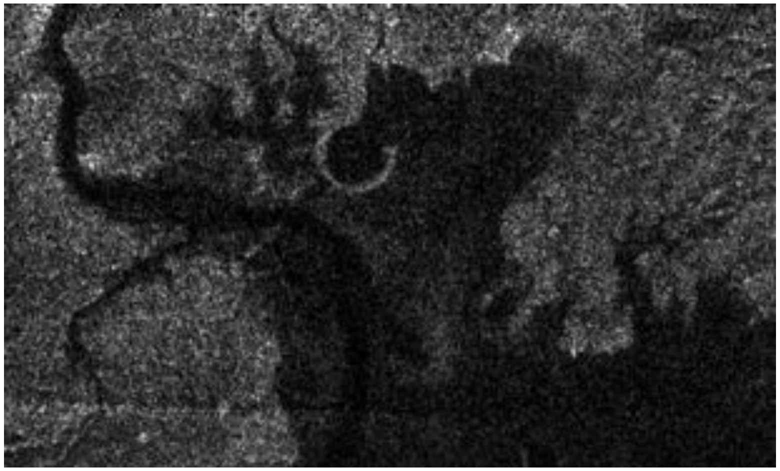
- **TC1a**. *Methane/Hydrocarbon cycle* Determine seasonal changes in the methane/hydrocarbon hydrological cycle: of lakes, clouds, aerosols, and their transport.
- **TC1b.** *High latitude atmosphere* Determine seasonal changes in high latitude atmosphere, speci:ically the temperature structure and formation and breakup of the winter polar vortex.
- TC2a. *Titan-magnetodisk interaction* Interaction between Titan and central-and-north sector of Saturn's magnetodisk, especially when the disk is well developed (dawn sector)

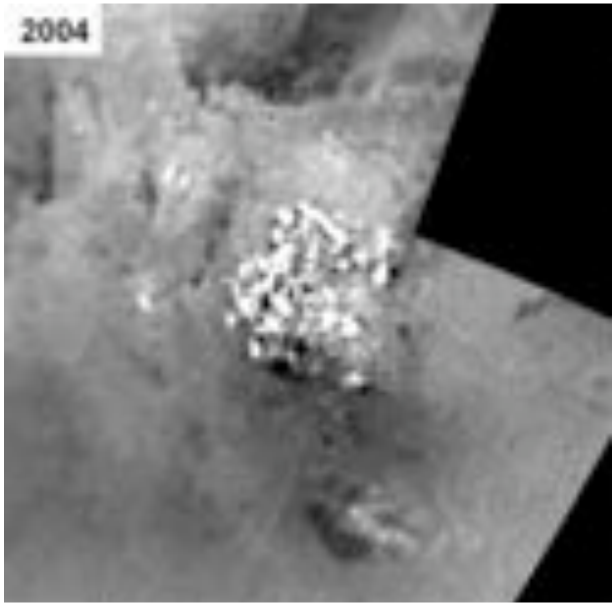
New Questions

- **TN1a.** *Surface Units* Determine the types, composition, distribution, and ages, of surface units and materials, most notably lakes (i.e. filled vs. dry & depth; liquid vs. solid & composition; polar vs. other latitudes & lake basin origin).
- **TN1b.** *Determine Internal and crustal structure* Liquid mantle, crustal mass distribution, rotational state of the surface with time, intrinsic and/or internal induced magnetic field
- **TN1c.** *Aerosol and heavy molecule layers and properties*
- TN2a. *Atmospheric drag* Resolve current inconsistencies in atmospheric drag measurements (crucial to a future Flagship mission)
- TN2b. *Determine shell topography and viscosity*. Additional gravity flybys to map the geoid and determine the presence of additional mass anomalies in Titan
- TN2c. *Surface temperature distribution and cloud distribution*
- TN2d. *Surface/tropospheric winds*

TC1a. Seasonal changes in methane/hydrocarbon hydrological cycle

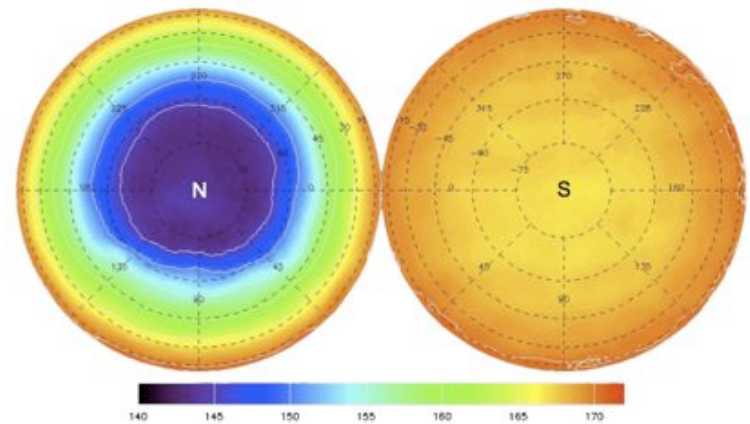
- What happens to methane over time on the surface and in the atmosphere?
  - Search for evidence of surface changes
- How is methane supplied to the surface?
- Observations
  - Lakes: RADAR, VIMS, ISS
  - Clouds: VIMS, ISS
  - Aerosols: INMS, CAPS, CIRS, ISS, VIMS, UVIS





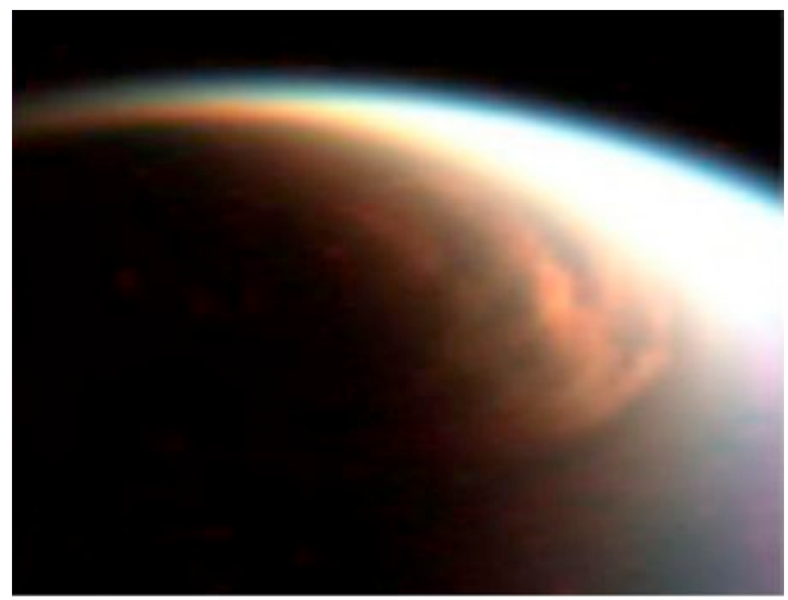
TC1b. Seasonal changes in the high latitude atmosphere

- Temperature and chemical atmospheric vortex exists in winter hemisphere
  - Analogous to Earth's ozone hole
  - When and how will it shift to the south?



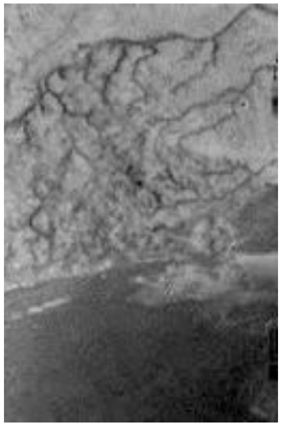
Observations

- Limb and nadir mapping of temperatures, aerosols, condensates, gas, with progression of the season: CIRS
- Polar imaging: ISS, VIMS
- Solar and stellar occs for composition: UVIS
- Radio occultation for temperature, moist convection: RSS



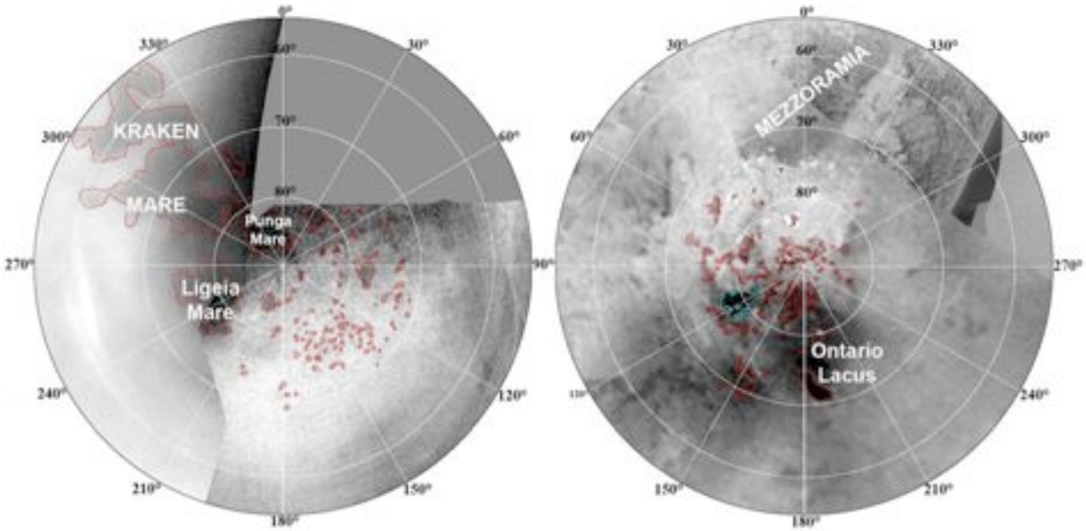
TN1a. Surface units: types, composition, distribution, and ages

- Hydrocarbon lakes are much more abundant in winter hemisphere
  - Key to understanding hydro-geochemical cycle
- When and how will liquid hydrocarbons shift to south?



Observations

- Composition of liquids and solids: VIMS
- Depth: RADAR
- Surface modification due to geologic activity (Origin of depressions, Xanadu, fluvial features, crypto-circles): VIMS, RADAR

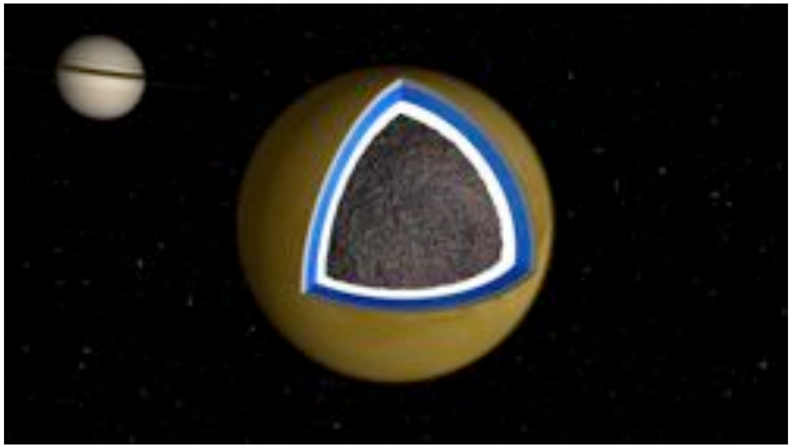


Lake Distribution: "shorelines," changes (Turtle *et al.* 2009)

New questions

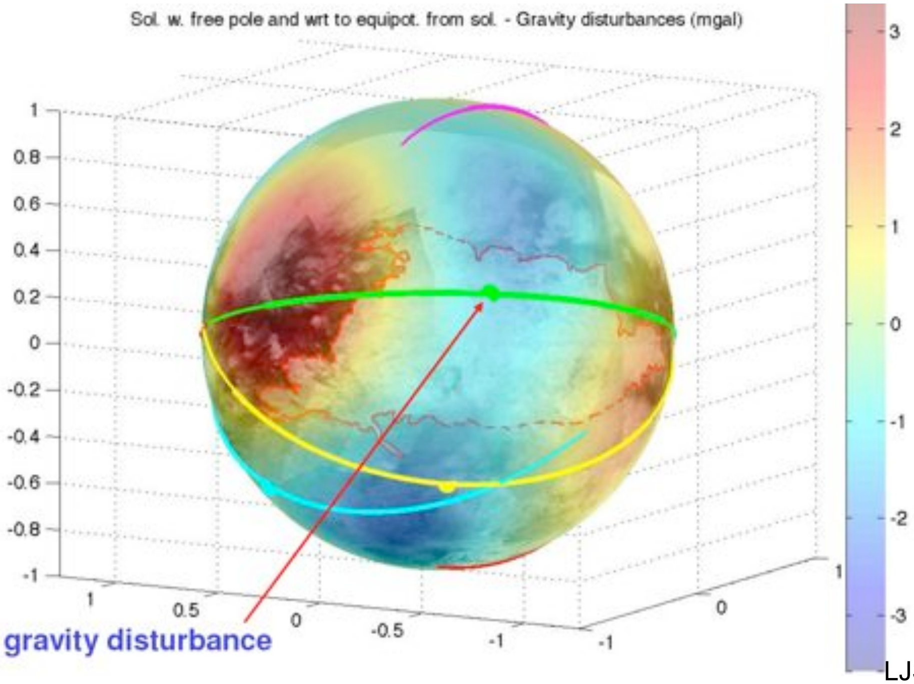
TN1b. Internal and crustal structure and magnetic field

- Does Titan have a global ocean?
- What is rotational state of Titan?
- Does Titan have a detectable magnetic field?



Observations:

- Gravity field of Titan: RSS
- Shape and topography: RADAR
- Rotational state: RADAR, VIMS
- Magnetic field: MAG

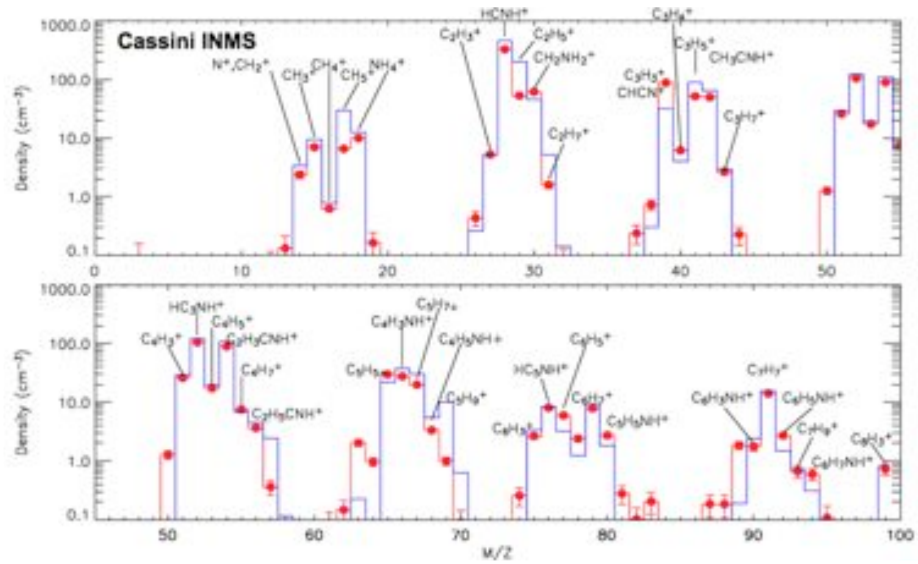


-2 mgal gravity disturbance

New questions

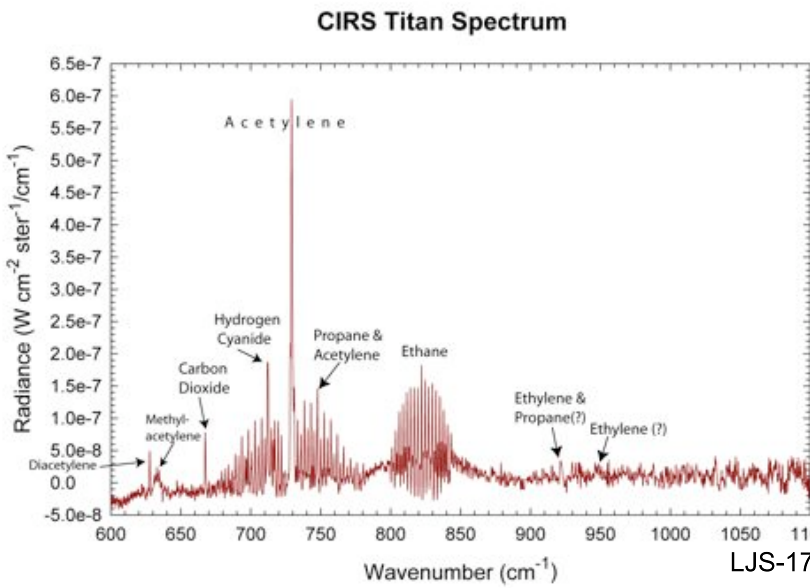
TN1c. Aerosol and heavy molecule layers and properties

- What are the properties of the complex polymers in Titan's upper atmosphere?
- How do they evolve with time?



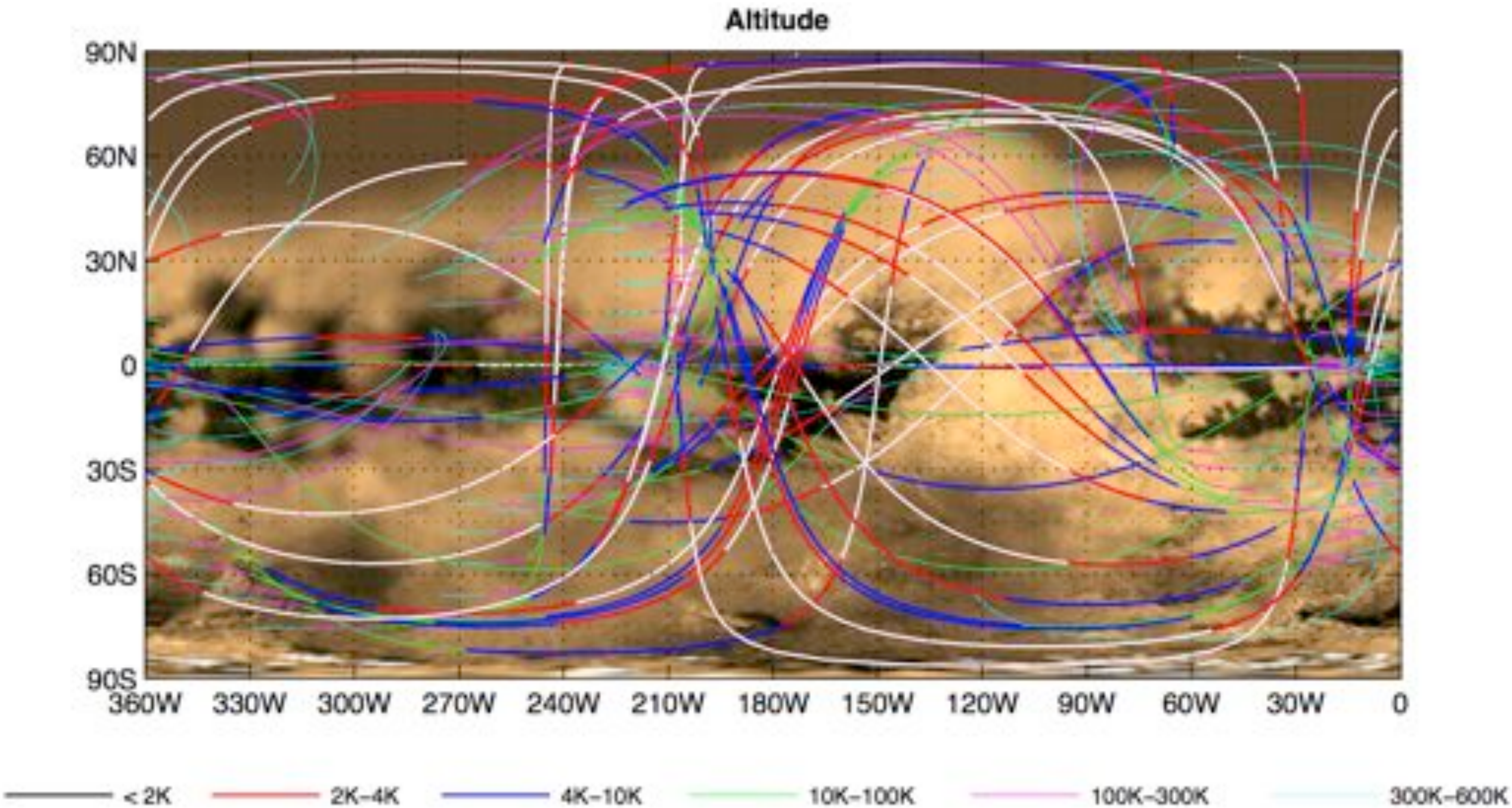
Observations:

- Aerosol properties
  - Limb, nadir mapping vs time: ISS, VIMS, CIRS
  - Stellar and solar occultations: UVIS
- Properties of complex molecules
  - Direct sampling vs latitude/time: INMS
  - Stellar and solar occultations; UVIS
  - Limb, nadir mapping: CIRS
- Properties of complex ions
  - Direct sampling: INMS, CAPS



New questions

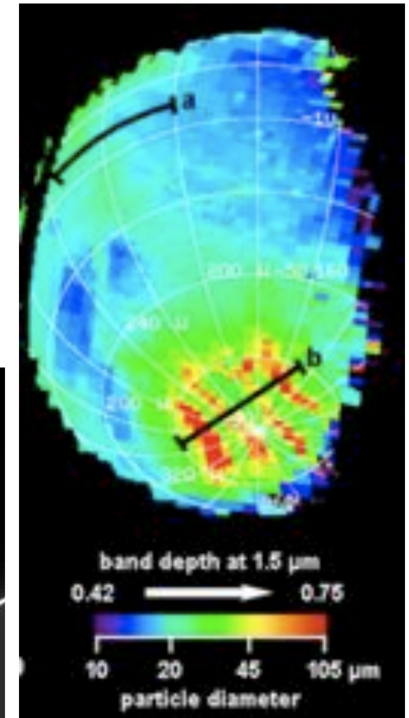
CSM Titan Surface Coverage

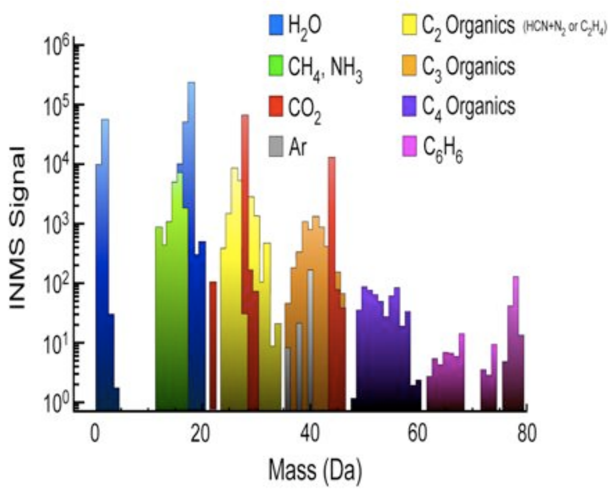


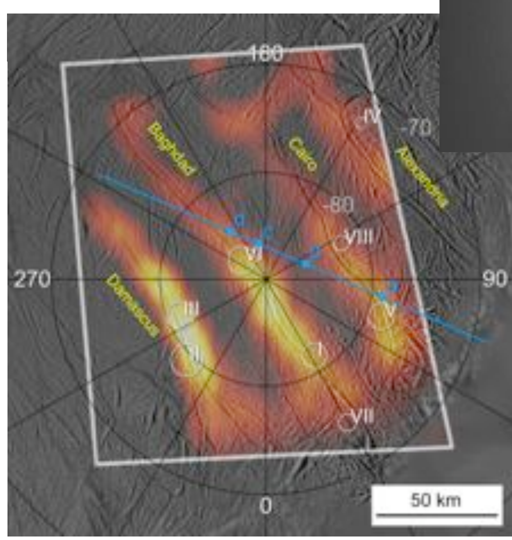
Highlights of Prime and Equinox Mission: Enceladus

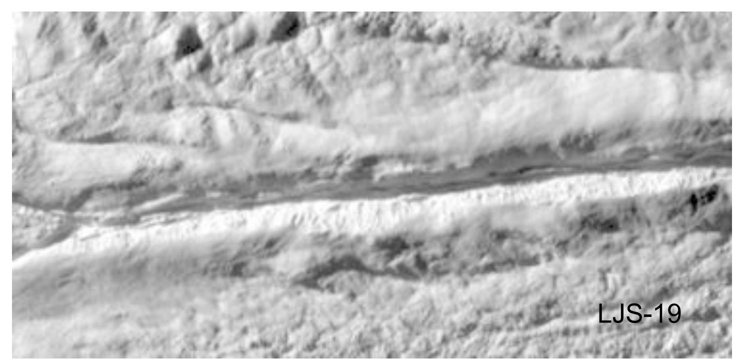
Endogenic activity discovered and studied by multiple Cassini instruments

- CIRS: Thermal emission from the tiger stripe fractures (temperatures, heat flow)
- VIMS: Anomalous surface composition, grain size, at tiger stripes
- ISS: Tectonics, vents, surface age, dust plume morphology, particle sizes, E-ring interaction
- UVIS: (Stellar occultations) Gas plume morphology
- INMS: Gas plume chemistry and morphology
- CDA: Dust plume morphology, chemistry
- CAPS: Plasma interaction
- MAG: Plasma interaction









Highlights of Prime and Equinox Mission: Dione

Low-level activity on Dione?

- Hints of plasma loading at Dione (~1/1000th of Enceladus load), from MAG
- Hints of material off edge of Dione in VIMS data
- Complex geology, fresh fractures
- Relatively high density

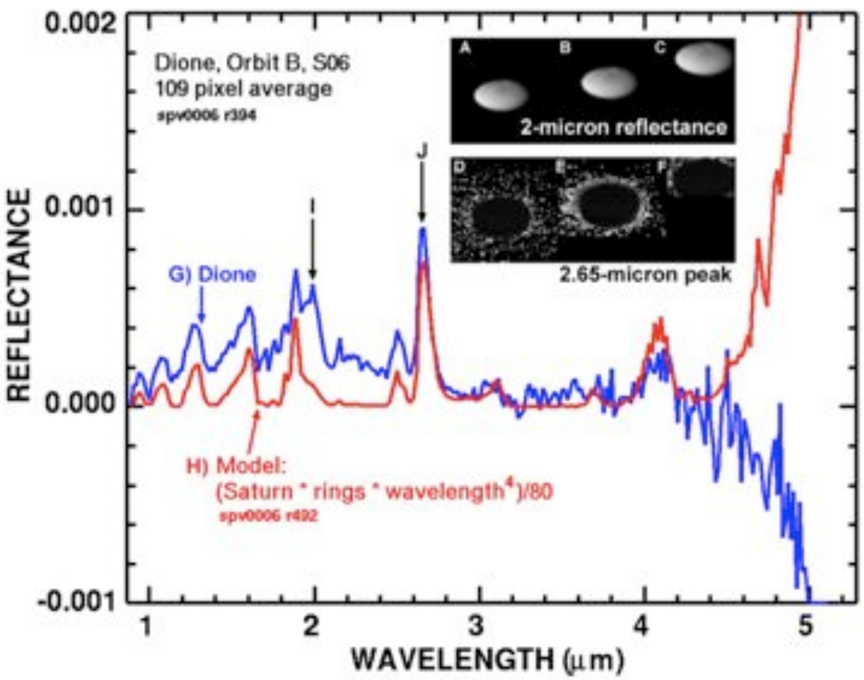
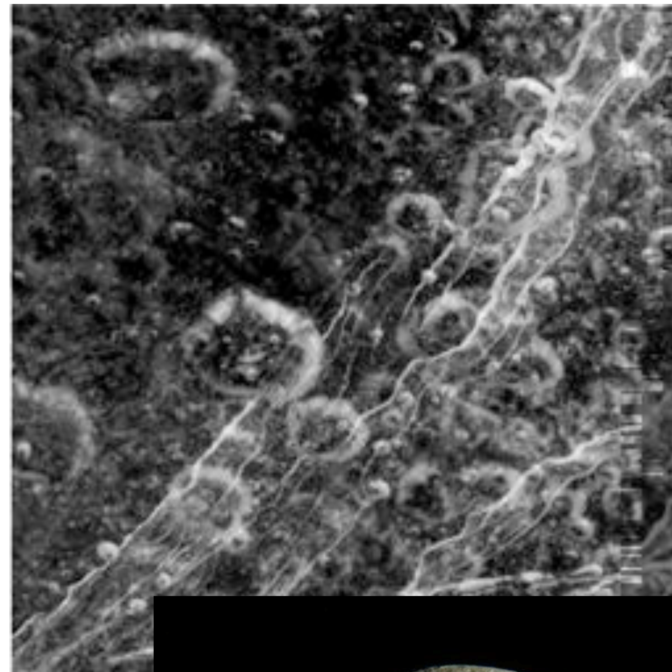
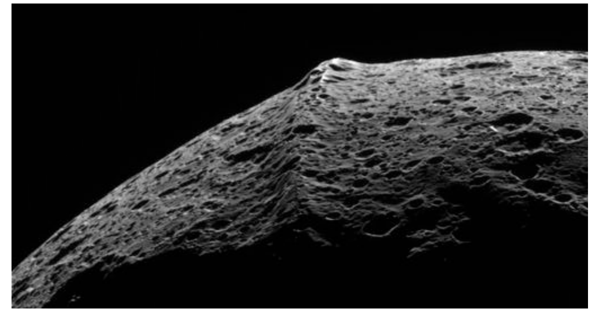


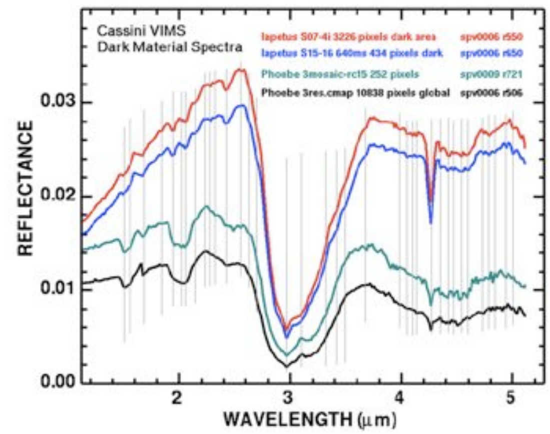
Figure 20.

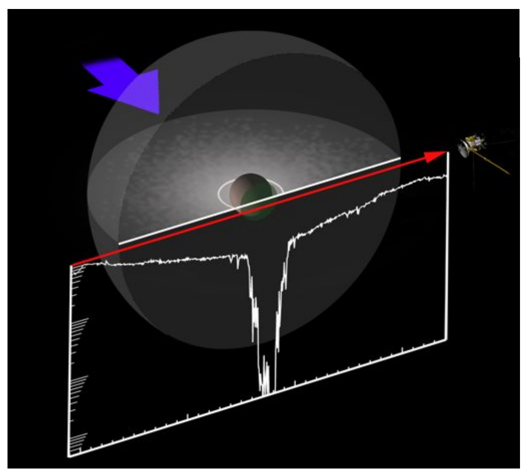


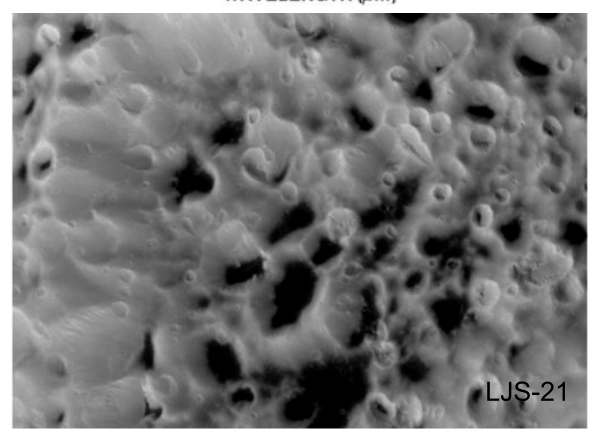
Highlights of Prime and Equinox Mission: Other Satellites

- Iapetus:
  - Equatorial ridge and fossil bulge
  - Thermal influence on albedo dichotomy
  - Hint of an ocean
  - Rich surface chemistry
- Hyperion
  - “Sponge-like” appearance, unusual dust particles nearby
- Rhea
  - Hints of a ring
  - Differentiated state uncertain
- Tethys
  - Smooth terrain and fractures, heavily cratered and apparently old

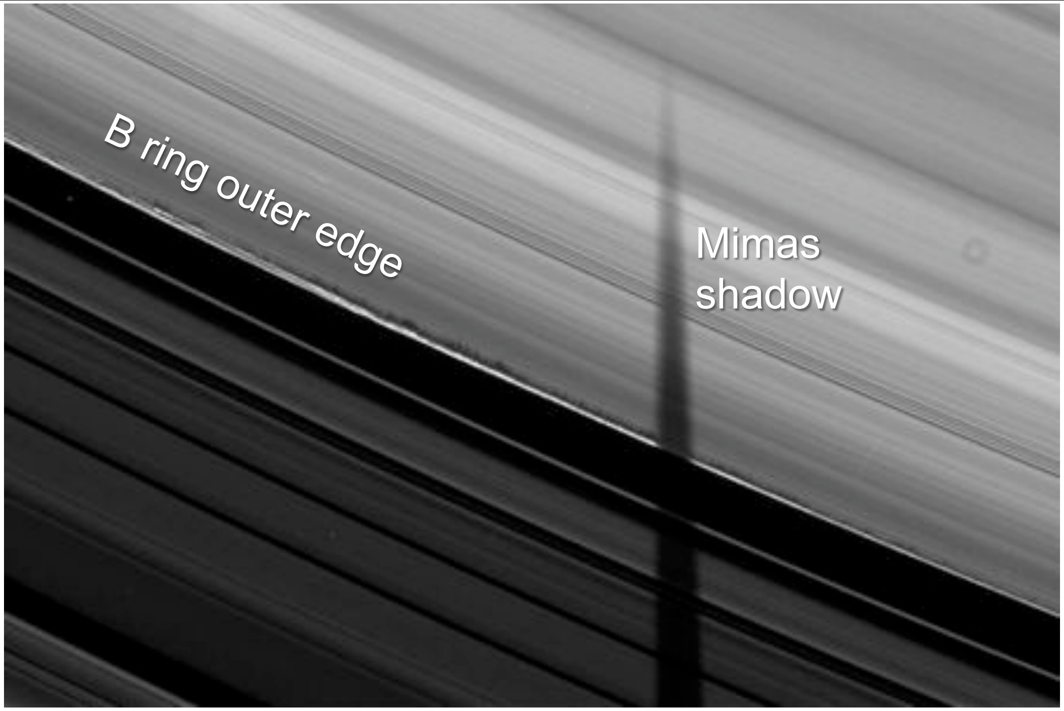


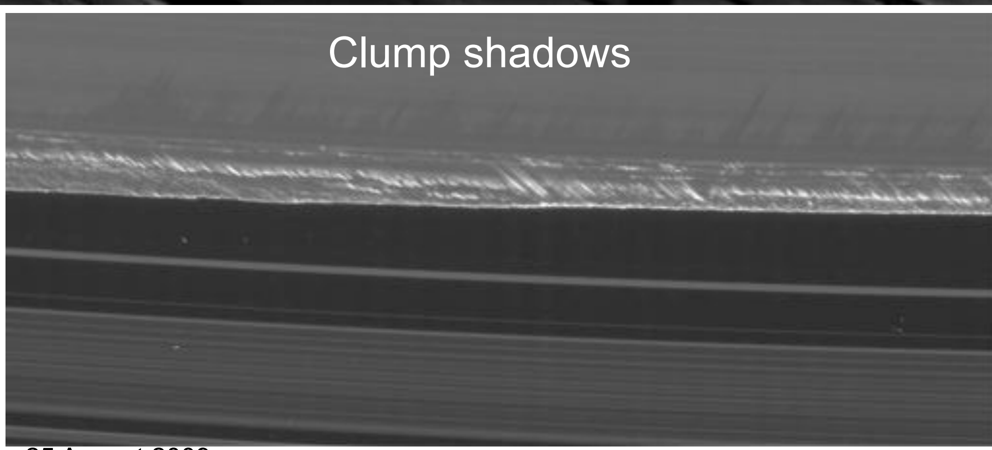






Temporal Change: B ring clumping and accretion



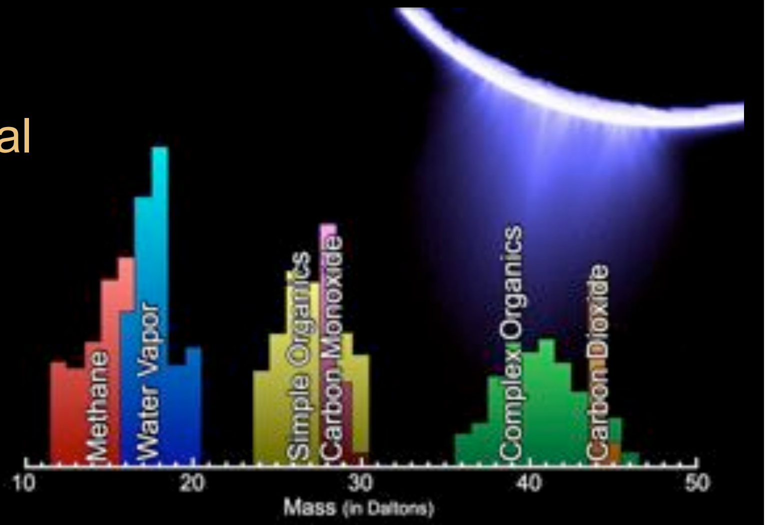


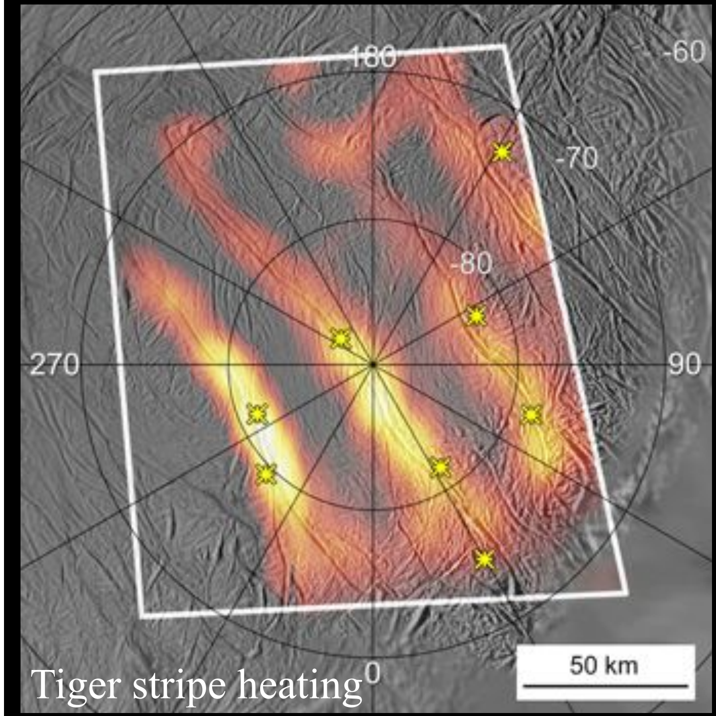
- At equinox B ring clumps detectable by their shadows in ISS images (New!)
- B ring outer edge shows major time and longitude variability in UVIS stellar occultation data (New!)
- Amount of sub-km structure is increasing since 2004! (New!)
- Continue to track this structure after equinox with UVIS occultations
- May resemble planetary accretion processes

(Note: The UVIS and ISS results have not yet been released.)

Equinox Mission Science Objectives: Icy Satellites

- Map the composition, thermal signature and particle emission from the south polar plumes on Enceladus, to constrain temperatures and physical state in the crust from which the geysers are emitted.
- Search for evidence of activity elsewhere on Enceladus and other icy satellites





Tiger stripe heating


Dione tectonics

Icy Satellite Science Objectives for CSM

Seasonal/Temporal Change

- **IC1a**. *Enceladus changes* Identify long-term secular or seasonal changes at Enceladus, through observations of the south polar region, jets, and plumes.

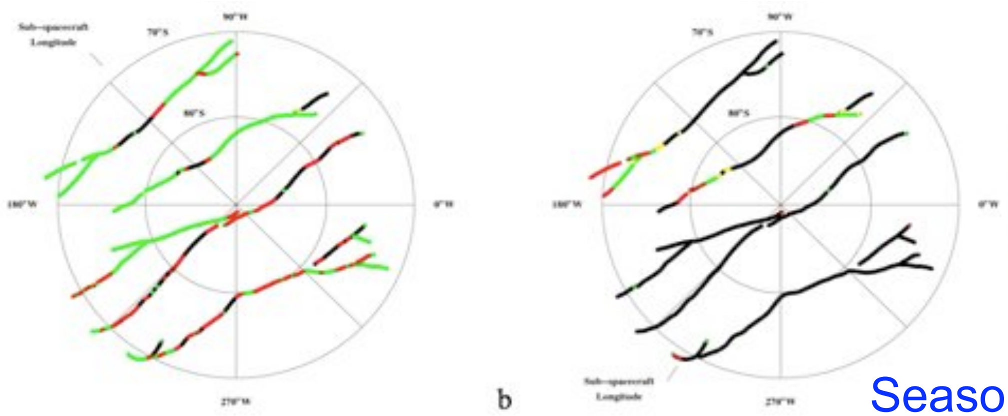
New Questions

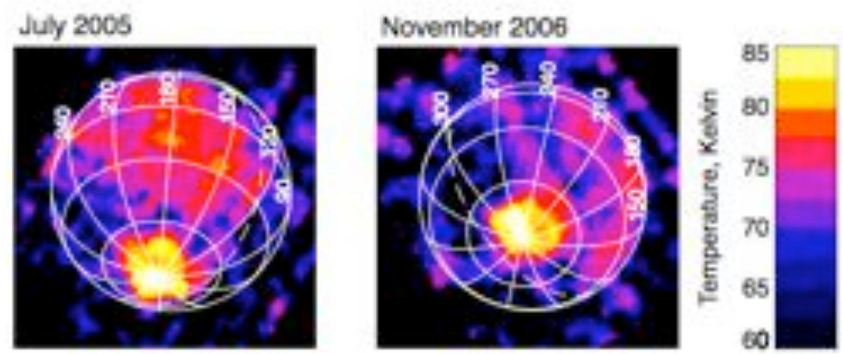
- **IN1a.** *Enceladus ocean* Determine the presence of an ocean at Enceladus as inferred from induced magnetic field and plume composition, search for possible anomalies in the internal structure of Enceladus as associated with plume sources, and constrain the mechanisms driving the endogenic activity by in situ observations and remote sensing
- (**IN1b.** Understand Iapetus' enigmatic magnetic signature.)
- **IN1c**. *Dione activity* Determine whether Dione exhibits low level activity, now or in recent geological time.
- IN2a. *Rhea Ring Material* Determine whether there is ring material orbiting Rhea, and if so, what its spatial and particle size distribution is.
- (IN2b. Determine whether Tethys contributes to the E-ring and the magnetospheric ion and neutral population.)
- IN2c. *Differentiation of Rhea and Dione* Determine the extent of differentiation and internal inhomogeneity within the icy satellites, especially Rhea and Dione.
- (IN2d. Understand the unusual appearance and environment of Hyperion with high-resolution remote sensing and in-situ observations.)
- (IN2e. Complete the comparative study of Saturn's mid-sized satellites and their geological and cratering histories with high-resolution remote sensing of Mimas.)
- (IN2f. Use remote sensing of Iapetus to test models for the albedo heterogeneity of the satellite and the cratering history of the Saturn system.)

Objectives in parentheses cannot be met by the selected tour

IC1a. Temporal Change at Enceladus

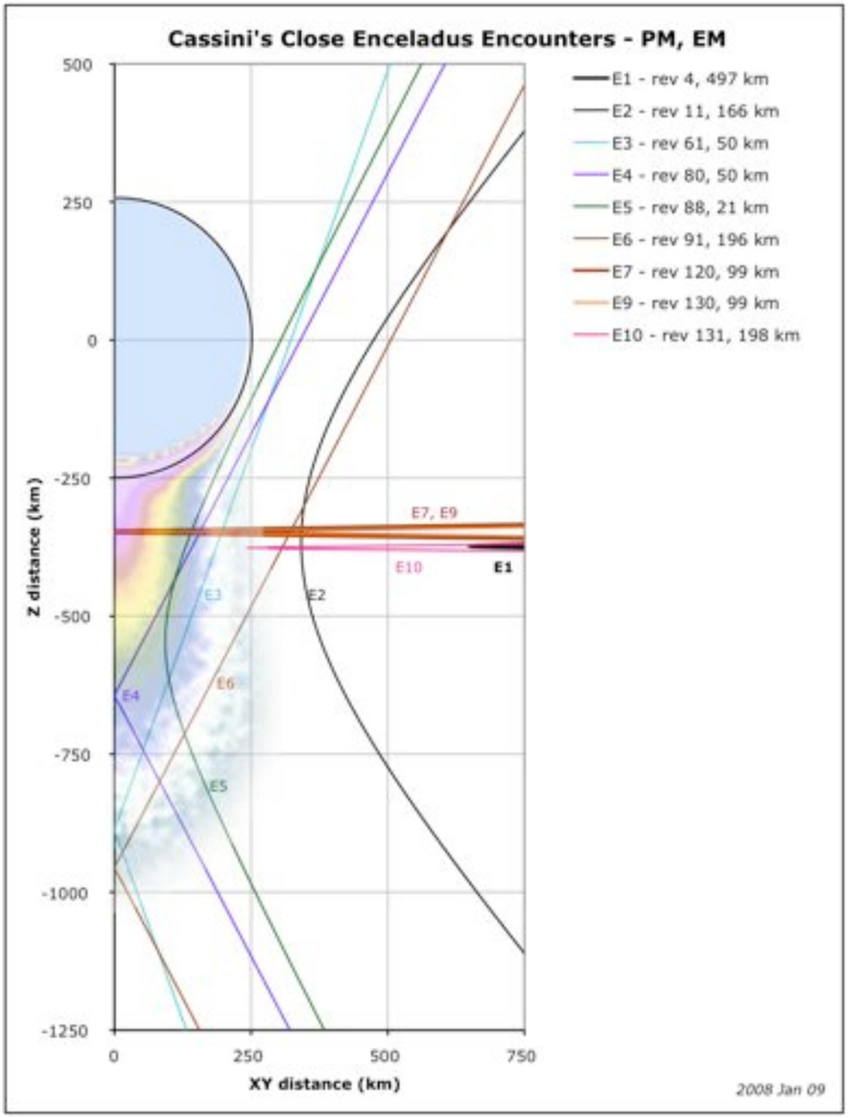
- Enceladus is only ice world in solar system (so far) where we can watch geology as it happens, thereby illuminating processes on all other icy bodies
- Are current activity levels typical?
  - 2-fold variations in plume H_2O density between 2005 and 2007 (Hansen al. 2008)
  - Understanding activity bears directly on possible habitability of Enceladus
- Can cyclic or secular variations in activity illuminate geological processes?
  - Cyclic temporal variations in plume activity are predicted from tidal flexing models (Hurford et al. 2007)
  - Current models of plume jets predict clogging of individual jets in a few years due to ice precipitation (Ingersoll and Pankine 2009)
- Observations: 8 close plume flythroughs , steller occs, thermal observations, high phase ISS

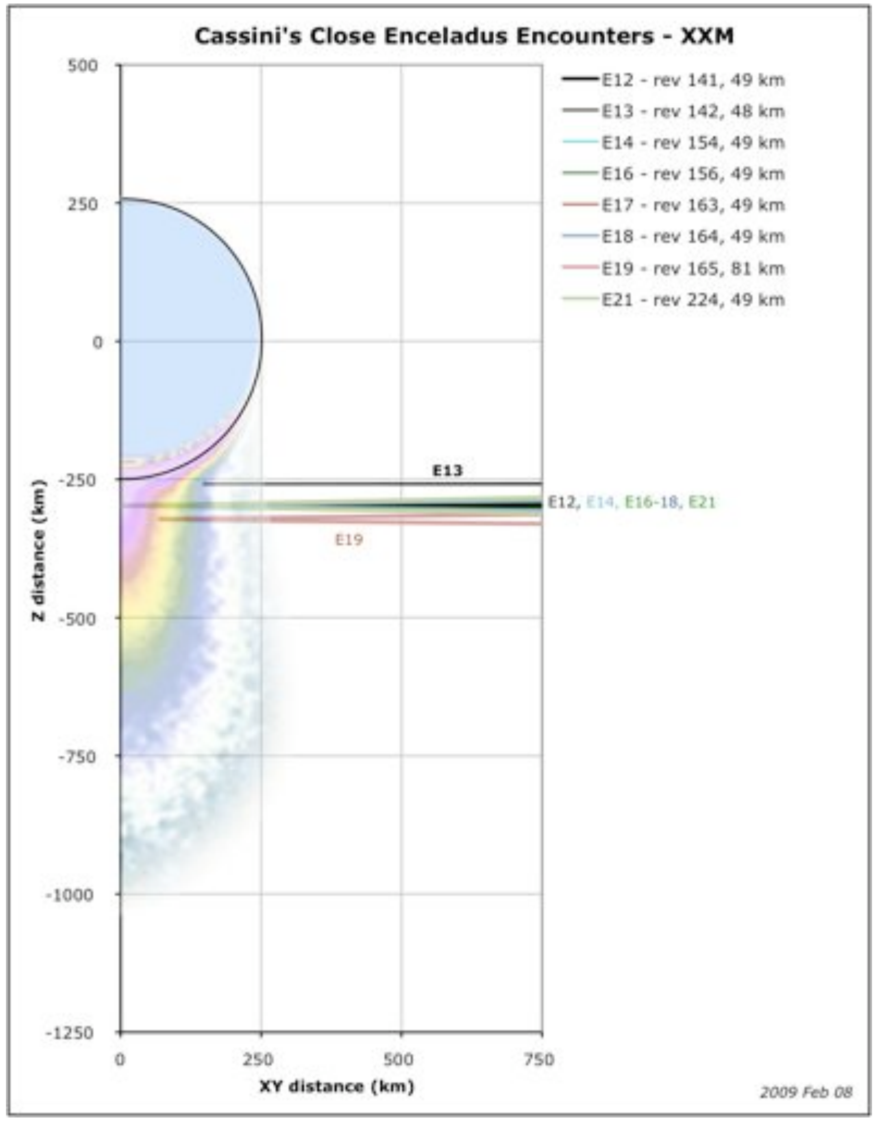




Seasonal Change

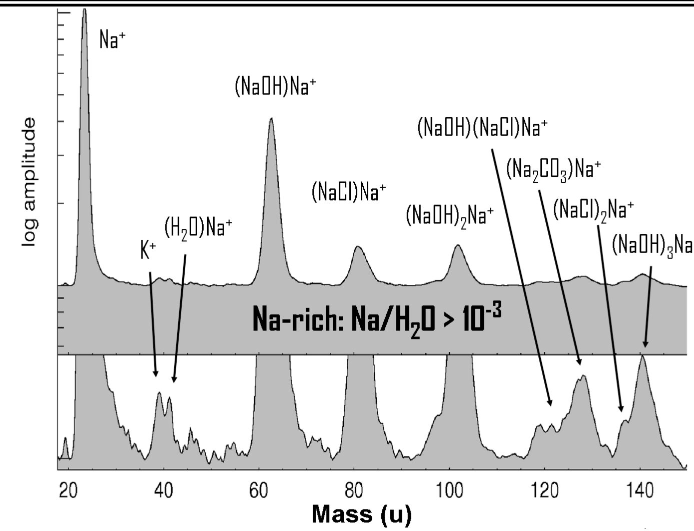
Enceladus Flybys

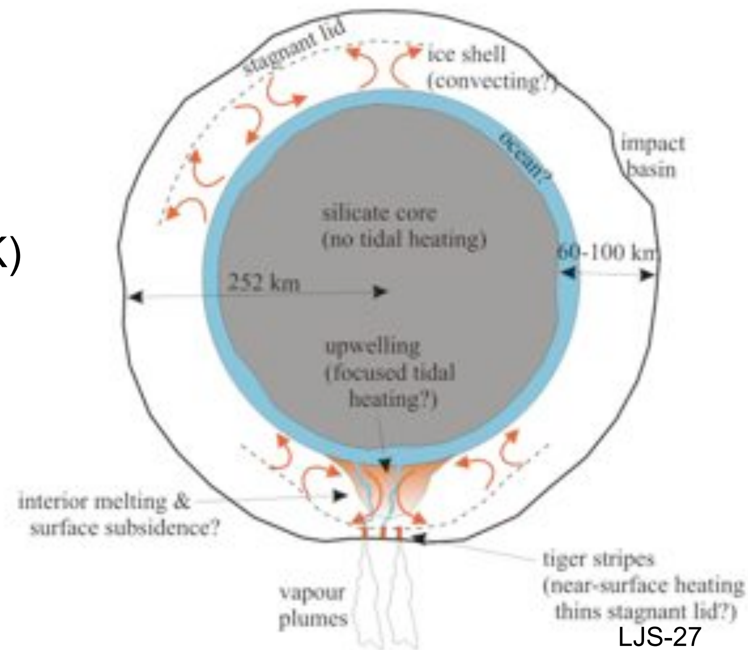




IN1a. Internal Structure of Enceladus: Ocean?

- Presence or absence of an ocean strongly affects potential habitability of Enceladus (and by extension, that of other icy worlds)
- Tidal heat generation (15 GW) probably requires an ocean for sufficient flexing (Nimmo et al. 2007)
- Shape indicates non-hydrostatic (Thomas et al. 2007)
- Why is activity exactly at south pole- mass anomaly? (Nimmo and Pappalardo 2006, Collins et al. 2007)
- Plume composition strong constraint on interior structure and chemistry
    - Salt-rich particles strongly suggest presence of liquid, perhaps from a salty ocean, near the source (Postberg et al. 2009)
    - Presence of N_2 suggests high-temperature (>273 K) chemistry in interior (Matson et al. 2007)
    - Surprisingly high ^{40}Ar abundance?
    - Where do the organics come from?

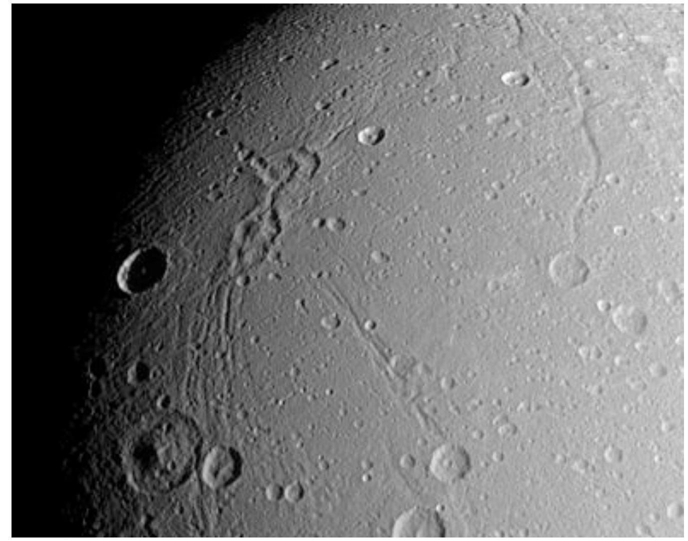


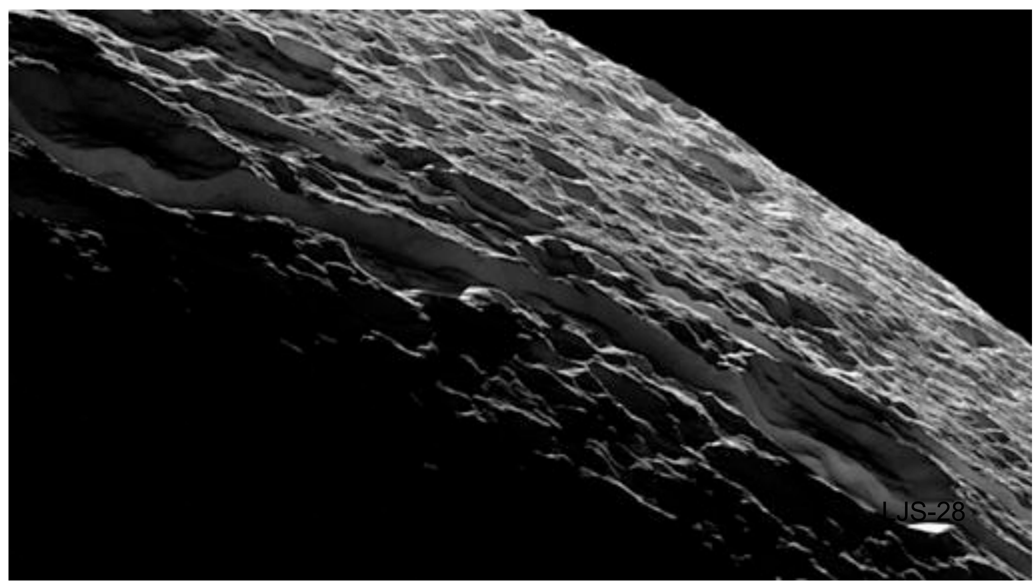


New Questions

IN1c. Present or Past Activity on Dione

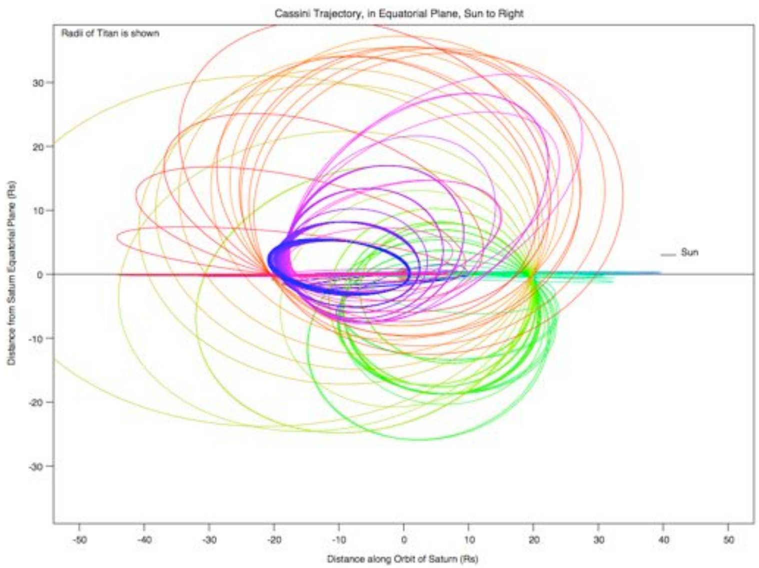
- High Density: ~1.48 g cm^{-3}, second only to Enceladus among the inner satellites
- Possible mass loading at Dione from MAG: up to a few gm/sec (compared to kgs/sec at Enceladus), contrasted with no evidence for mass loading at Tethys
- Possible icy material above the surface (Clark et al. 2008)
  - Is there ongoing low-level activity or outgassing on Dione?
- Complex surface geology second only to Enceladus: numerous puzzling fractures, ridges, smooth terrain, and vent-like structures. Some fractures appear very fresh
  - What is the origin of these features?
  - How young are they?
  - Has there been extrusive activity on Dione in the past?
- Observations: 3 close flybys, stellar occs, thermal emission

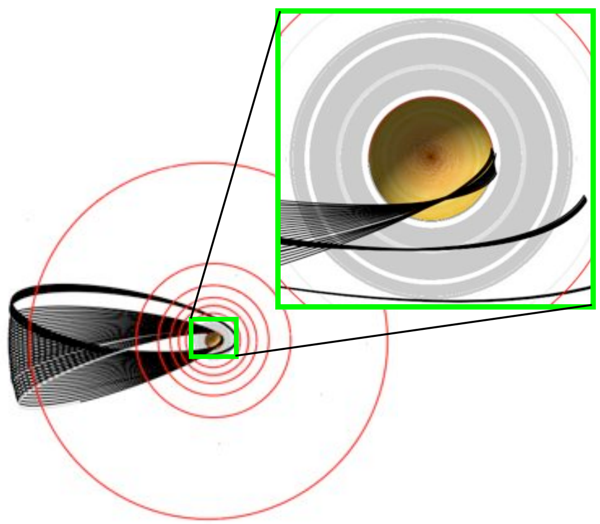




New Questions

Proposed Solstice Mission Tour

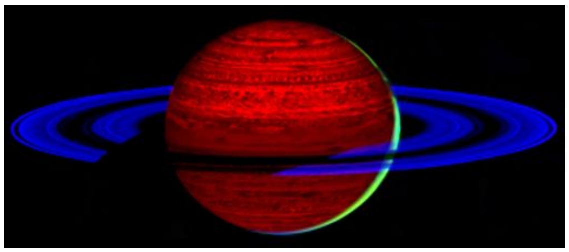


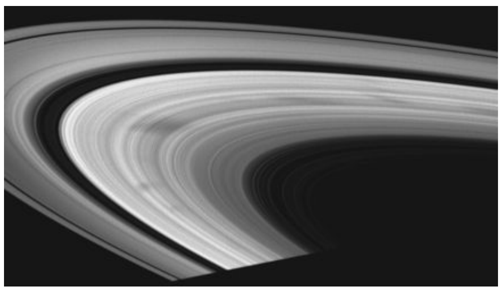


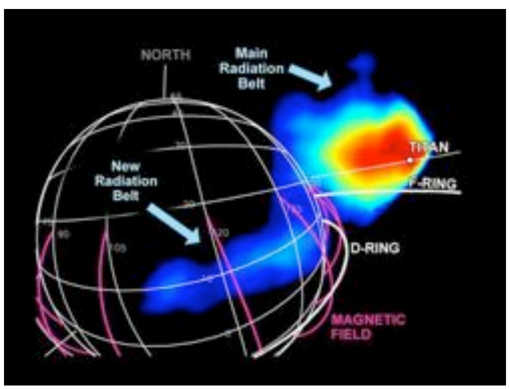
- Solstice Tour
  - 10/1/2010
  - 7 years
  - 160 orbits
  - 56 Titan flybys
  - 12 Enceladus flybys
  - 5 Other Icy flybys

- Proximal Orbits
  - 42 short period orbits from Nov. 2016 to Sept. 2017
  - 20 F ring orbits with periapses just outside Saturn's F ring
  - 22 Proximal orbits between D ring and Saturn atmosphere prior to ballistic impact
  - Periapses in 3,000 km "clear" region between inner edge of D ring and Saturn's upper atmosphere
  - Critical inclination of 63.4° to prevent orbit rotation from J_2
  - Current impact date: 15 September 2017

Key science objectives during Proximal Orbits

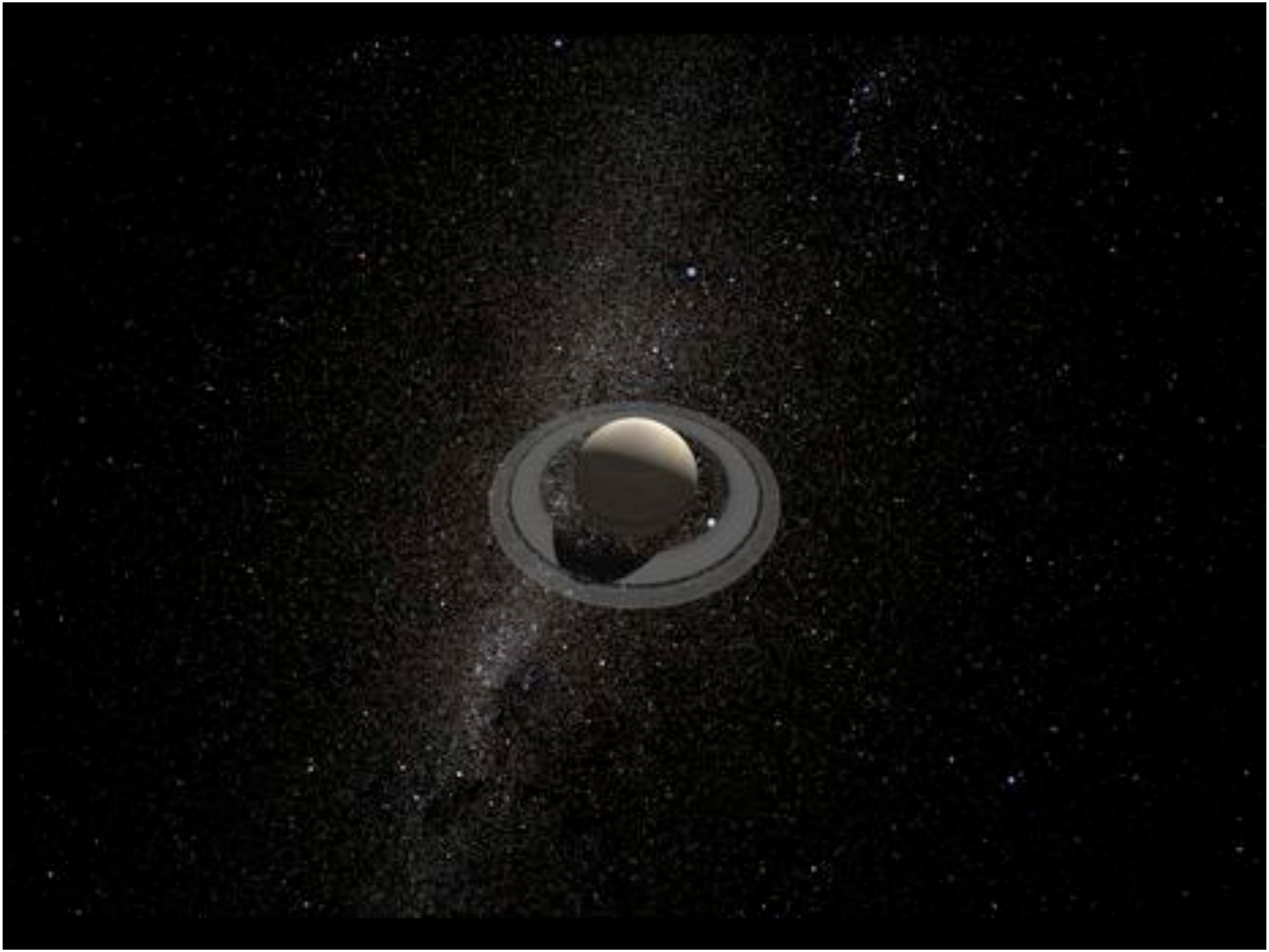


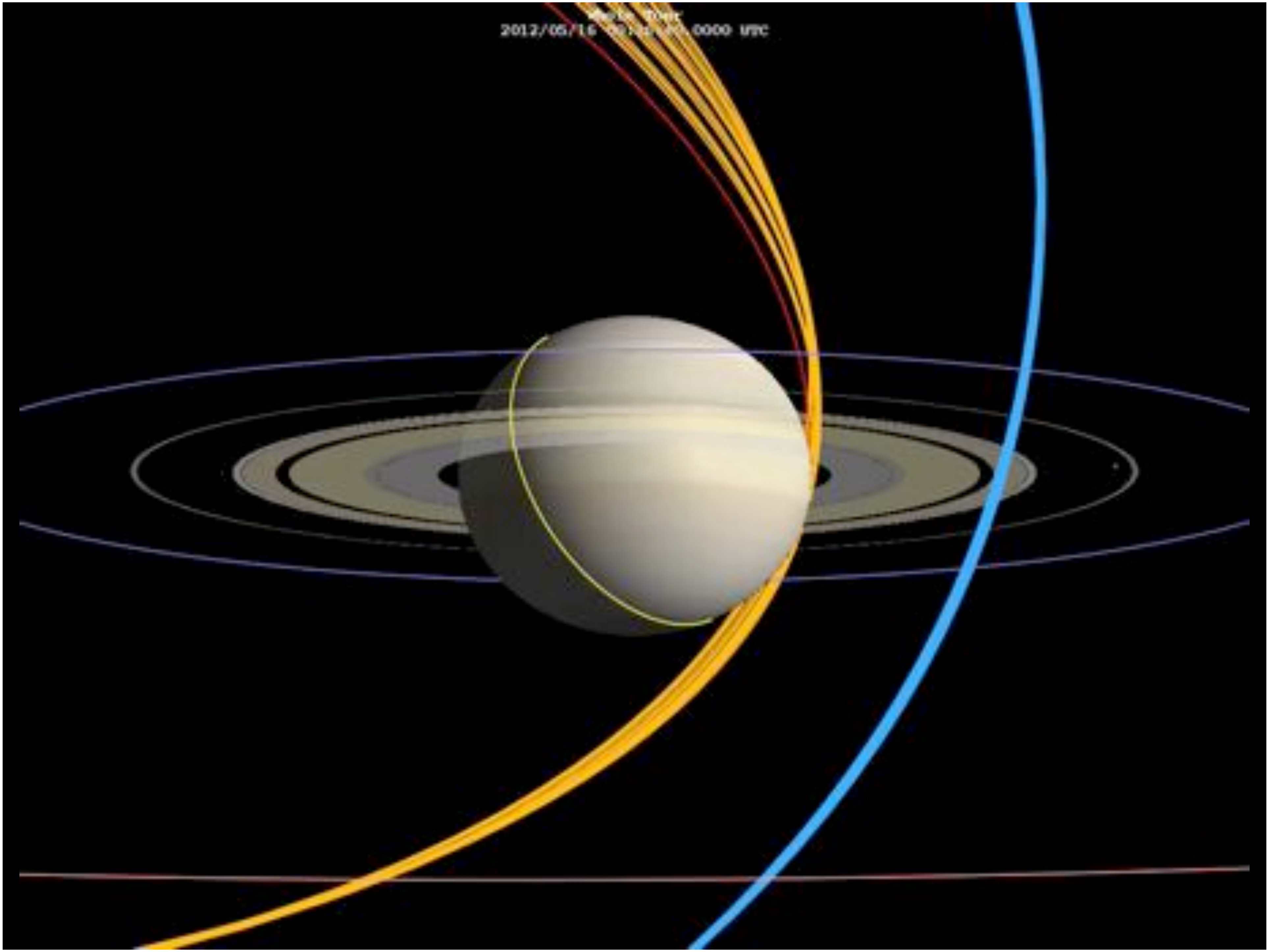




- Saturn internal structure
  - Determine Saturn's gravity field to J_{10}
  - Determine Saturn's higher order magnetic field components to degree 6
  - Measure internal rotation rate for Saturn
- Ring mass
  - Estimate mass of main rings to 5% to address age of main rings
- Saturn's ionosphere, innermost radiation belts & D ring
  - Measure *in situ* plasma of Saturn's ionosphere, innermost radiation belts and D ring for the first time
  - *In situ* observations of Saturn's auroral magnetosphere at solstice
- Highest resolution main ring studies
- High resolution Saturn atmospheric studies

Cassini Saturn science complements that from Juno mission to Jupiter

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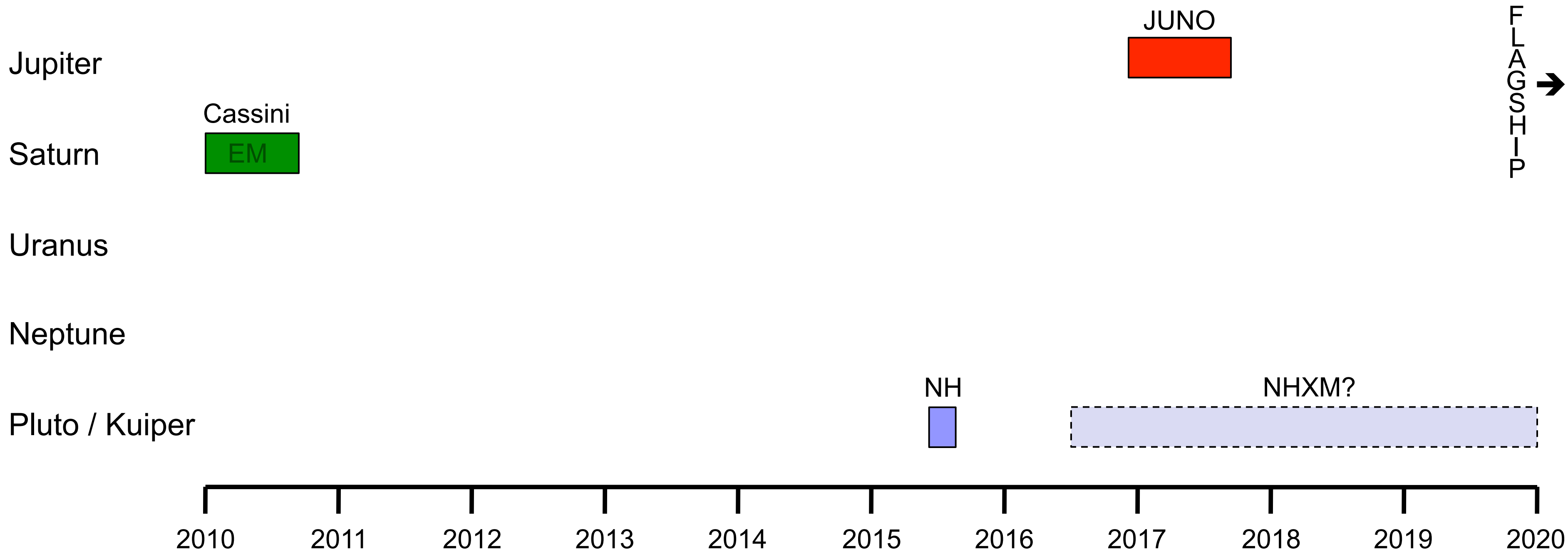
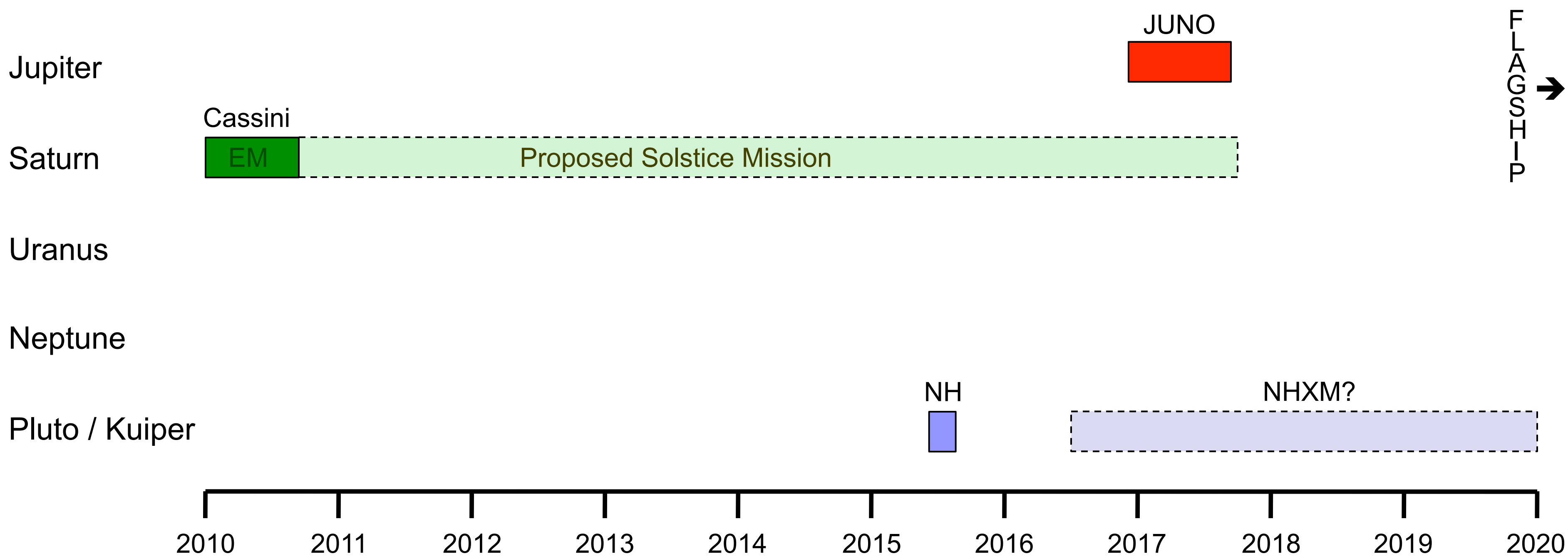
Outer Planets Missions, 2010-2020



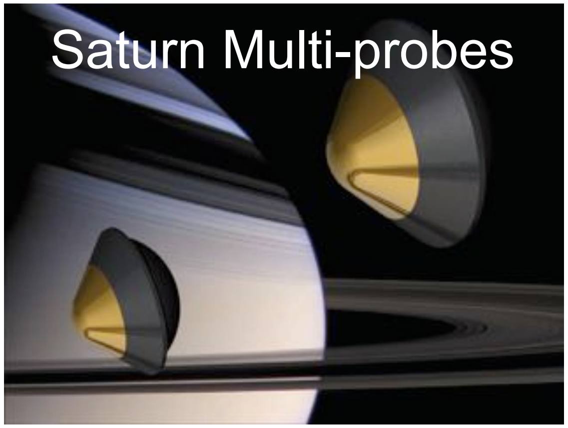
Outer Planets Missions, 2010-2020

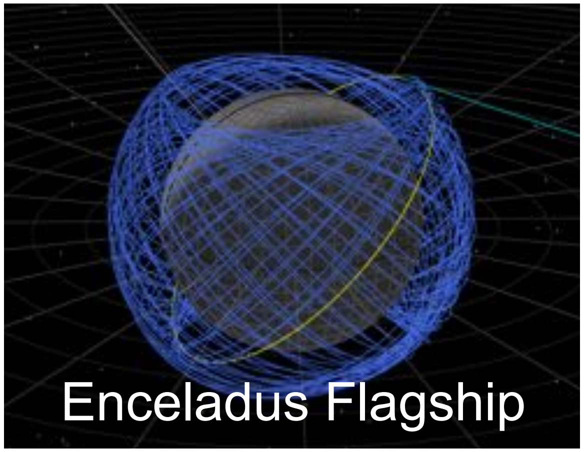


Cassini CSM will fill a critical gap in NASA's outer solar system exploration.

Proposed Cassini Solstice Goal and Objectives

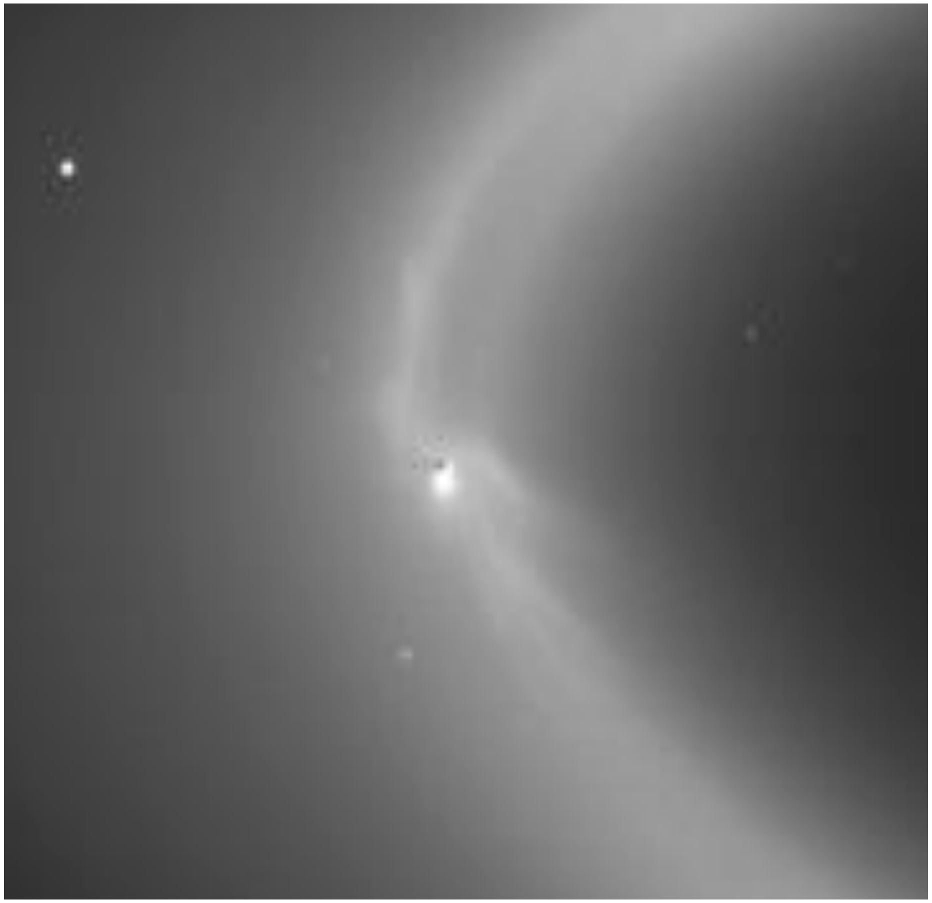
- Proposed Solstice Goal:
  - Observe seasonal and temporal change in the Saturn system to understand underlying processes and prepare for future missions.
- Objectives Categories:
  - Seasonal-temporal change
  - New Questions





Cassini Solstice Science

- Proposed Cassini Solstice Mission enables unprecedented opportunities for unique, groundbreaking science
- Proximal science unique
- Direct relevance to the Planetary Decadal Survey and NASA's exploration program.



Backup Slides

		SATURN	RINGS	MAPS	ICY SATS	TITAN
SEASONAL-TEMPORAL CHANGE	Priority 1	**SC1a** - Observe seasonal variations in temperature, clouds, and composition in three spatial dimensions.	**RC1a** - Determine the production mechanisms of spokes, and the microscale properties of ring structure, by observing at the seasonally maximum opening angle of the rings near Solstice.	**MC1a** - Determine the temporal variability of Enceladus' plumes.	**IC1a** - Identify long-term secular and seasonal changes at Enceladus, through observations of the south polar region, jets, and plumes.	**TC1a** - Determine seasonal changes in the methane-hydrocarbon hydrological cycle: of lakes, clouds, aerosols, and their seasonal transport.
		SC1b - Observe seasonal changes in the winds at all accessible altitudes coupled with simultaneous observations of clouds, temperatures, composition, and lightning.	**RC1b** - Understand the time-variability of ring phenomena on decadal timescales (Encke gap, D ring, ring edges, etc) by substantially increasing the time baseline of observations.	**MC1b** - Observe Saturn's magnetosphere over a solar cycle, from one solar minimum to the next.		**TC1b** - Determine seasonal changes in the high-latitude atmosphere, specifically the temperature structure and formation and breakup of the winter polar vortex.
	Priority 2	**SC2a** - Observe the magnetosphere, ionosphere, and aurora as they change on all time scales - minutes to years - and are affected by seasonal and solar cycle forcing.	**RC2a** - Focus on F Ring structure, and distribution of associated moonlets or clumps, as sparse observations show clumps, arcs, and possibly transient objects appearing and disappearing.	**MC2a** - Observe seasonal variation of Titan's ionosphere, from one Solstice to the next.		**TC2a** - Observe Titan's plasma interaction as it goes from south to north of Saturn's solar-wind-warped magnetodisk from one solstice to the next.
NEW QUESTIONS	Priority 1	**SN1a** - Determine Saturn's rotation rate and internal structure despite the planet's unexpected high degree of axisymmetry.	**RN1a** - Constrain the age of the rings by determining the meteoroid mass infall contamination rate, and by measuring the ring mass.	**MN1a** - Determine the dynamics of Saturn's magnetotail.	**IN1a** - Determine the presence of an ocean at Enceladus as inferred from induced magnetic field and plume composition, search for possible anomalies in the internal structure of Enceladus as associated with plume sources, and constrain the mechanisms driving the endogenic activity by in situ observations and remote sensing.	**TN1a** - Determine the types, composition, distribution, and ages, of surface units and materials, most notably lakes (i.e. filled vs. dry & depth; liquid vs. solid & composition; polar vs. other latitudes & lake basin origin).
		SN1b - Study the life cycles of Saturn's newly discovered atmospheric waves, south polar hurricane, and newly rediscovered north polar hexagon.	**RN1b** - Focus on still-unresolved puzzle of how narrow gaps are cleared, by performing deep searches for small embedded moonlets and studying gap edges.	**MN1b** - Conduct *in situ* studies of Saturn's ionosphere and inner radiation belt.	**IN1b** - Understand Iapetus' enigmatic magnetic signature.	**TN1b** - Determine internal and crustal structure: Liquid mantle, crustal mass distribution, rotational state of the surface with time, intrinsic and/or internal induced magnetic field.
		SN1c - Measure the spatial and temporal variability of trace gases and isotopes.	**RN1c** - Determine particle compositional variations at high resolution across selected ring features of greatest interest.	**MN1c** - Investigate magnetospheric periodicities, their coupling to the ionosphere, and how the SKR period is imposed from close to the planet (3-5 Rs) out to the deep tail.	**IN1c** - Determine whether Dione exhibits evidence for low-level activity, now or in recent geological time.	**TN1c** - Measure aerosol and heavy molecule layers and properties.
	Priority 2	**SN2a** - Observe Saturn's newly discovered lightning storms.	**RN2a** - Conduct in-depth studies of ring microstructure such as self-gravity wakes, which permeate the rings.	**MN2a** - Determine the coupling between Saturn's rings and ionosphere.	**IN2a** - Determine whether there is ring material orbiting Rhea, and if so, what its spatial and particle size distribution is.	**TN2a** - Resolve current inconsistencies in atmospheric density measurements (critical to a future Flagship mission).
			RN2b - Perform focused studies of the evolution of newly discovered "propeller" objects.		**IN2b** - Determine whether Tethys contributes to the E-ring and the magnetospheric ion and neutral population.	**TN2b** - Determine icy shell topography and viscosity.
					IN2c - Determine the extent of differentiation and internal inhomogeneity within the icy satellites, especially Rhea and Dione.	**TN2c** - Determine the surface temperature distribution and cloud distribution.
					IN2d - Understand the unusual appearance and environment of Hyperion with high-resolution remote sensing and in-situ observations.	**TN2d** - Determine surface and tropospheric winds.
					IN2e - Complete the comparative study of Saturn's mid-sized satellites and their geological and cratering histories with high-resolution remote sensing of Mimas.	
					IN2f - Use remote sensing of Iapetus to test models for the albedo heterogeneity of the satellite and the cratering history of the Saturn system.	

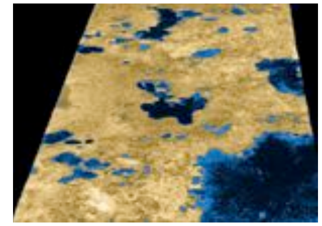
Proposed Cassini CSM Objectives

first letter = Discipline (**S**aturn, **R**ings, **M**APS, **I**cy, **T**itan)
second letter = Objective Type (**C**hange or **N**ew question)
third number = Priority Level (**1**, **2**)
fourth letter = Distinction within Priority Level (**a**, **b**, **c**, etc.)

Mapping of Cassini Solstice Potential to Decadal Survey

Fundamental Scientific Question	Saturn	Rings	MAPS	Icys	Titan
1. Planet and satellite formation processes	✓	✓	✓	✓	✓
2. Formation and timing of gas giants	✓	✓	✓	✓	✓
3. Timing of impactor flux decay				✓	✓
4. History of volatiles, especially water	✓	✓	✓	✓	✓
5. Nature of organic material	✓	✓	✓	✓	✓
6. Global mechanisms of volatile evolution				✓	✓
7. Habitable zones and processes for life			✓	✓	✓
8. Does (or did) life exist beyond Earth?				✓	✓
9. Differences among terrestrial planets					✓
10. Hazards to Earth's biosphere				✓	
11. Processes that shape planetary bodies	✓	✓	✓	✓	✓
12. Evolution of exoplanets	✓	✓	✓		

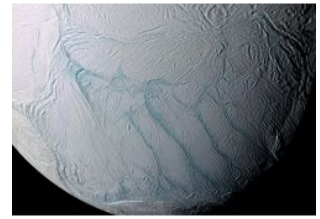
Prime Mission Science Objectives: Titan



1. **Determine abundances of atmospheric constituents (including any noble gases; establish isotope ratios for abundant elements; constrain scenarios of formation and evolution of Titan and its atmosphere.**
2. **Observe vertical and horizontal distributions of trace gases; search for more complex organic molecules; investigate energy sources for atmospheric chemistry; model the photochemistry of the stratosphere; study formation and composition of aerosols;**
3. **Measure winds and global temperatures; investigate cloud physics, general circulation and seasonal effects in Titan's atmosphere; search for lightning discharges;**
4. **Determine the physical state, topography and the composition of the surface;infer the internal structure of the satellite;**
5. **Investigate the upper atmosphere, its ionization, and its role as a source of neutral and ionized material for the magnetosphere of Saturn.**

	CAPS	CDA	CIRS	INMS	ISS	MAG	MIMI	RADAR	RPWS	RSS	UVIS	VIMS	Huygens
1.	✔		✔	✔			✔			✔	✔	✔	✔
2.	✔		✔	✔	✔		✔			✔	✔	✔	✔
3.			✔		✔				✔	✔	✔	✔	✔
4.			✔		✔				✔	✔	✔	✔	✔
5.								✔		✔			✔
6.	✔			✔		✔	✔		✔	✔	✔		
7.								✔		✔			✔

Prime Mission Science Objectives: Icy Satellites



1. **Determine the general characteristics and geological histories of the satellites.**
2. **Define the mechanisms of crustal and surface modifications, both external and internal.**
3. **Investigate the compositions and distributions of surface materials, particularly dark, organic rich materials and low melting point condensed volatiles.**
4. **Constrain models of the satellites' bulk compositions and internal structures.**
5. **Investigate interactions with the magnetosphere and ring systems and possible gas injections into the magnetosphere.**

✓ = pre-PM predictions of applicable instruments

	CAPS	CDA	CIRS	INMS	ISS	MAG	MIMI	RADAR	RPWS	RSS	UVIS	VIMS	Huygens
1.			✔		✔						✔	✔	
2.	✔	✔			✔						✔	✔	
3.			✔		✔						✔	✔	
4.			✔		✔					✔		✔	
5.	✔	✔	✔		✔	✔	✔		✔		✔	✔	

Fulfillment of PM Objectives was addressed at AO Assessment Review (Aug. 7, 2008).