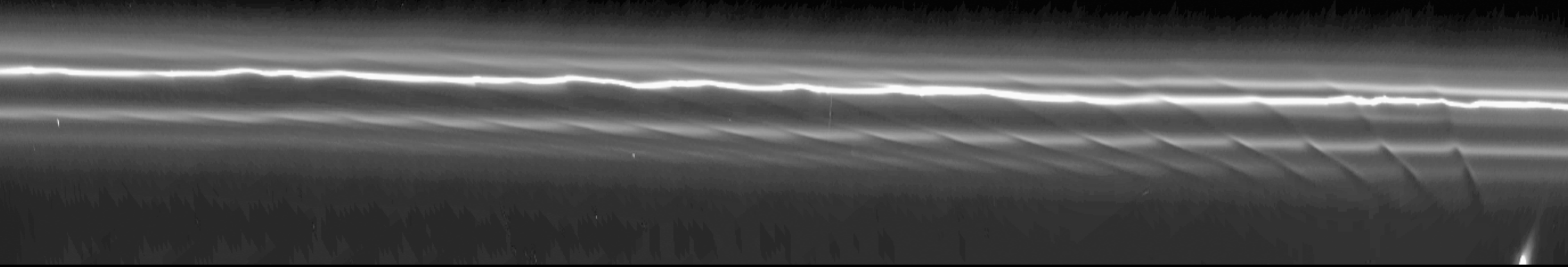
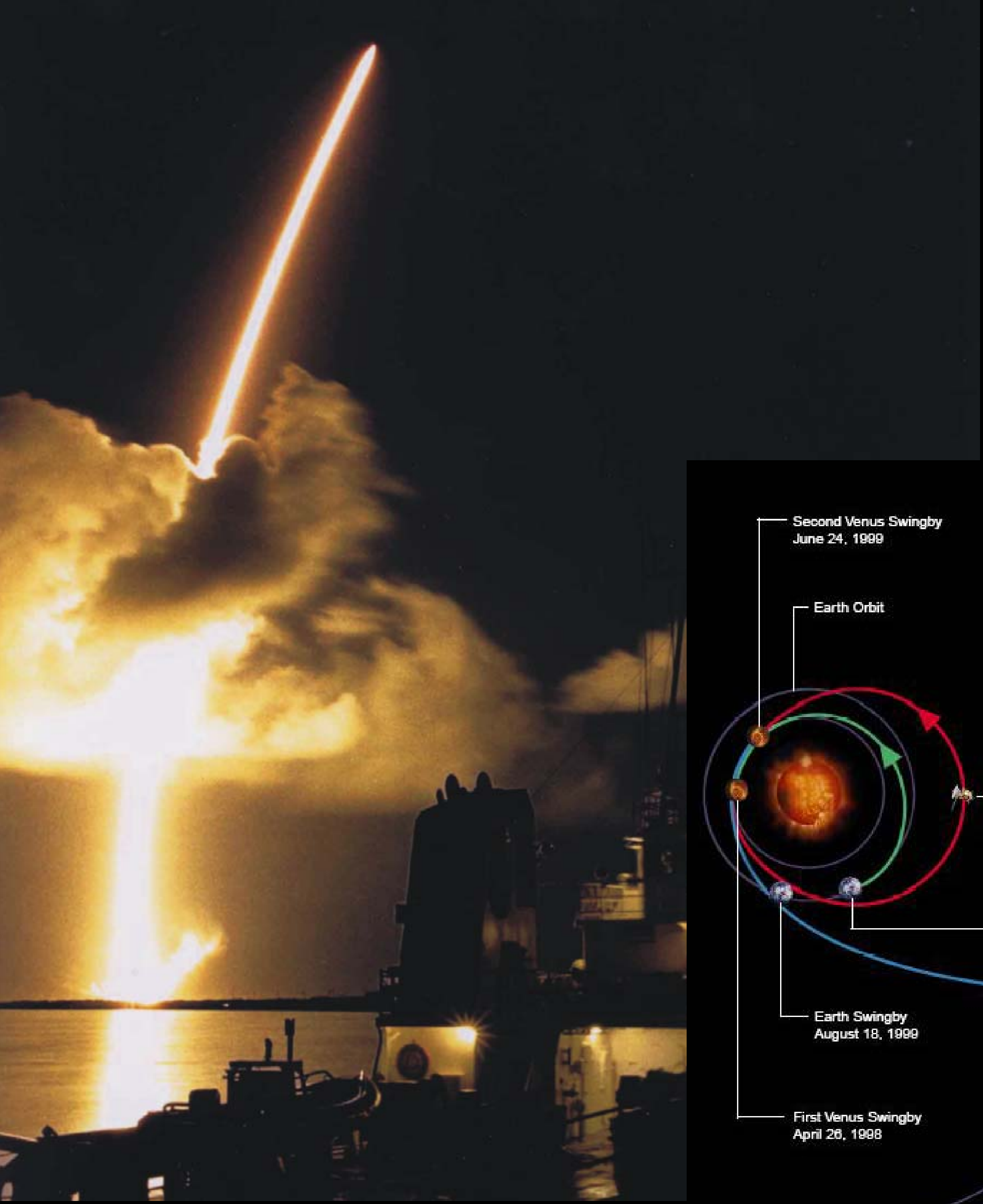


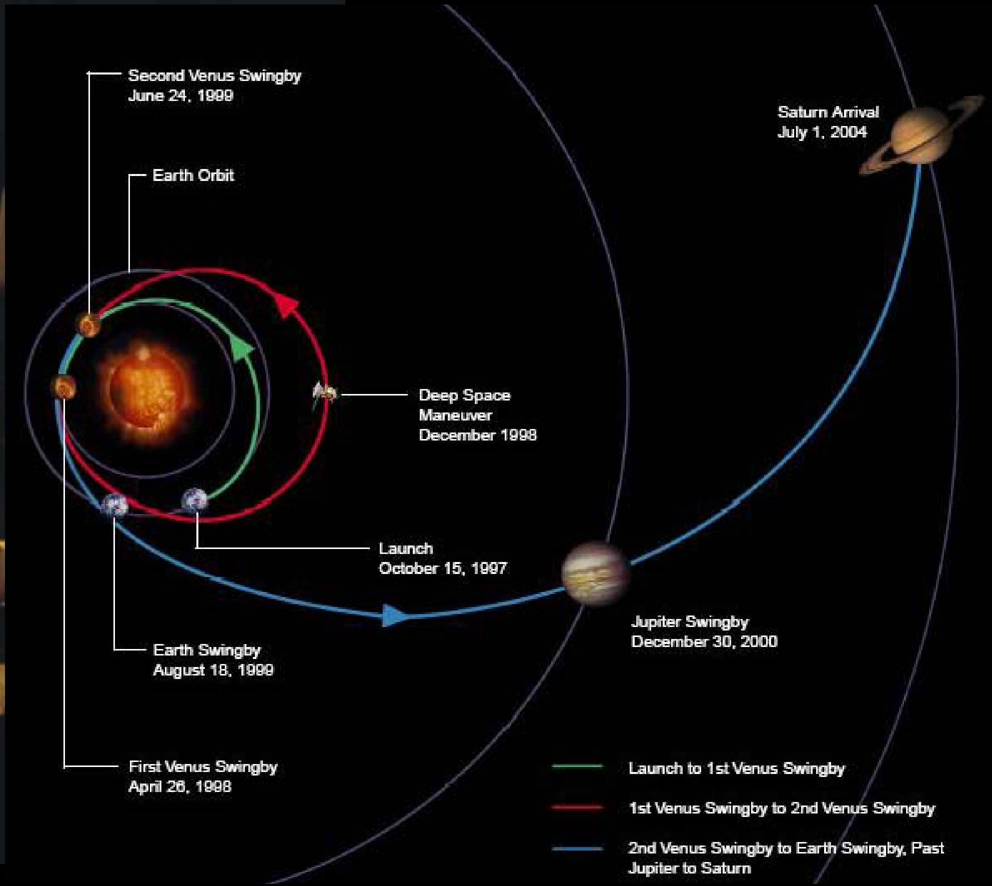
June 27, 2006

Cassini-Huygens Mission to Saturn 2nd Anniversary

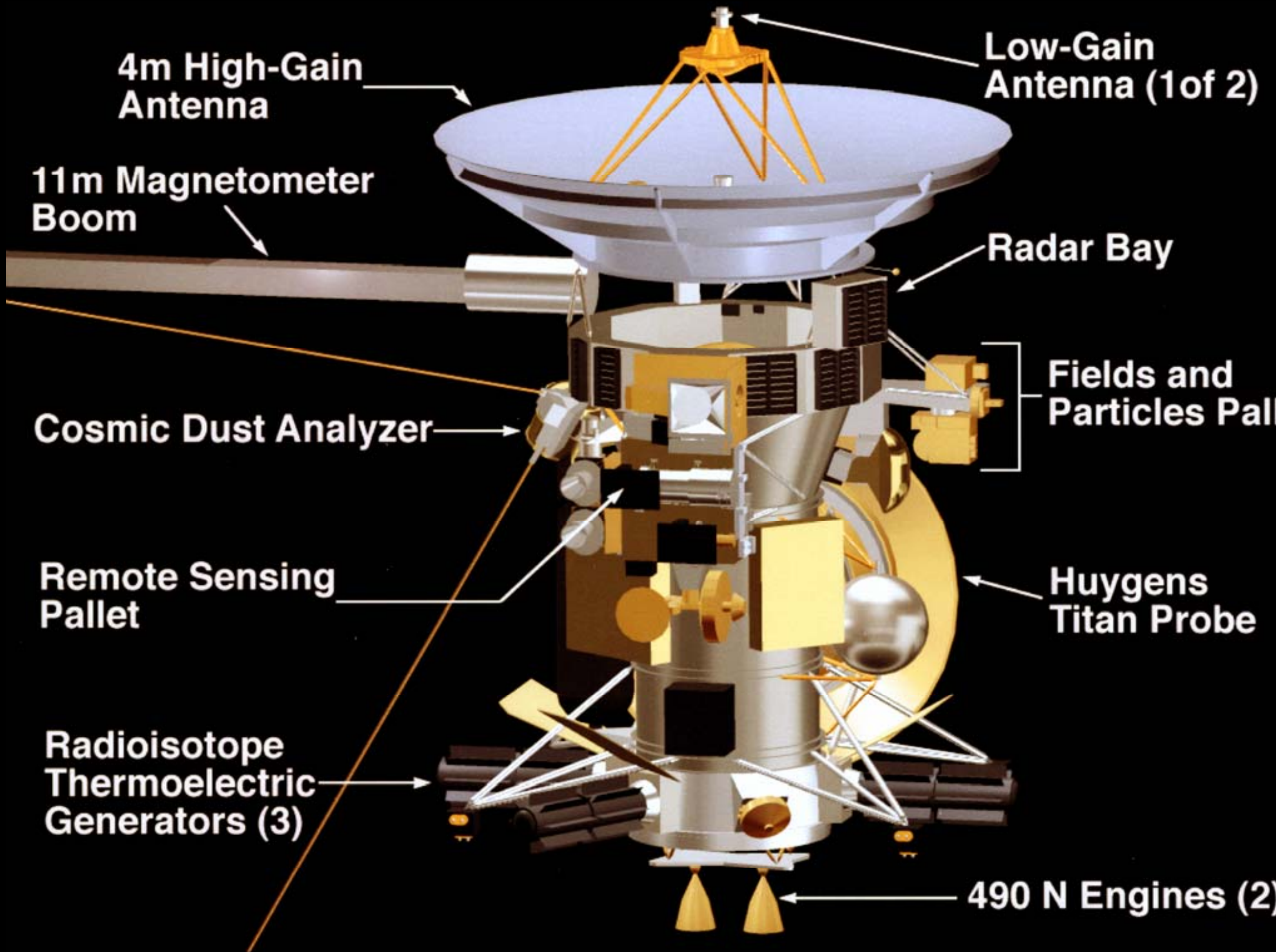


Launched on October 15, 1997 from KSC

7 year cruise on VVEJGA trajectory



Cassini Spacecraft



Spacecraft Specs

Height: 6.8 m (22 ft)

Diameter: 4 m (13 ft)

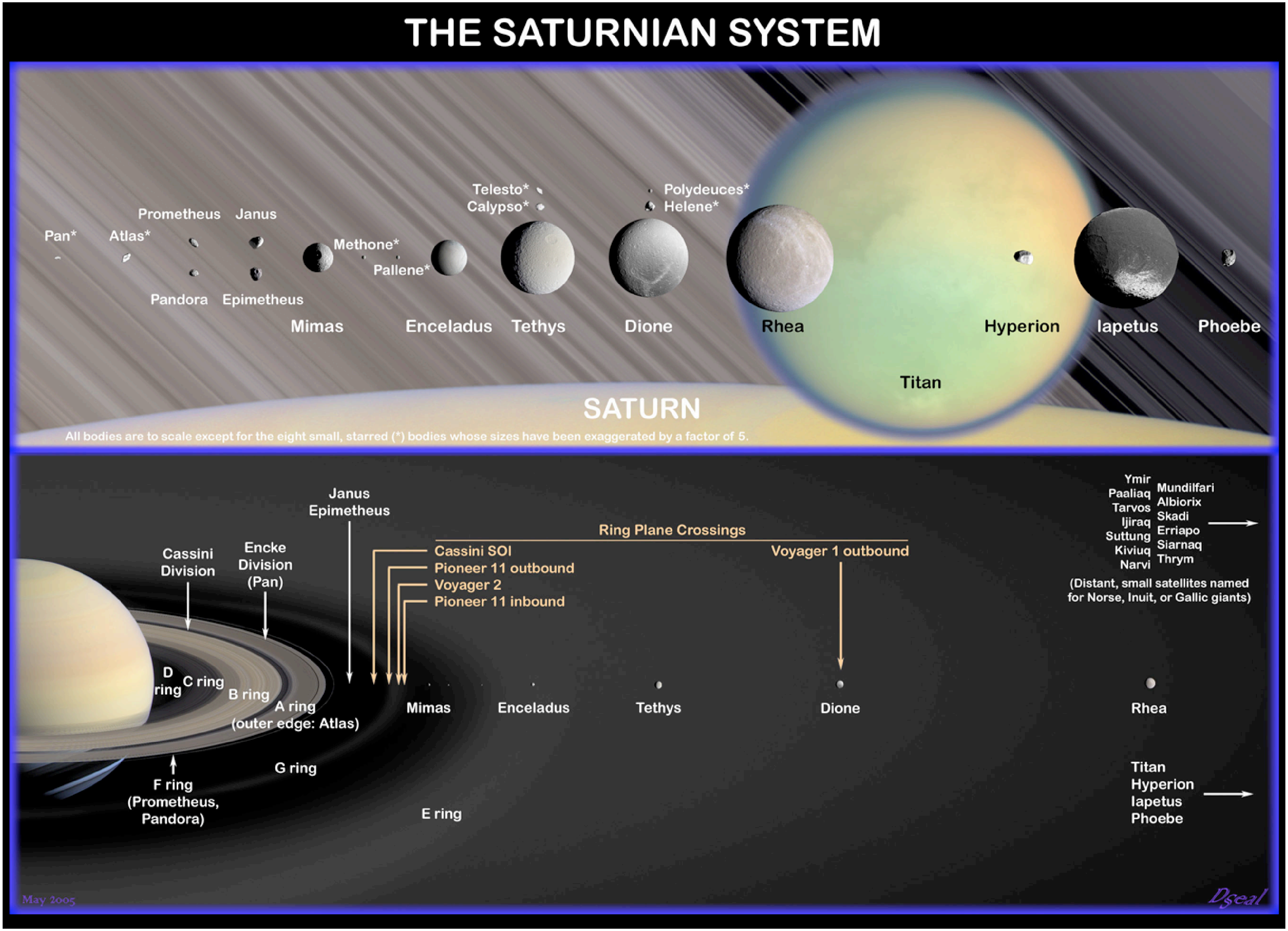
Mass: 2500 kg (2.8 tons)
(fueled): 5600 kg (6 tons)

Power: 700 Watts at SOI

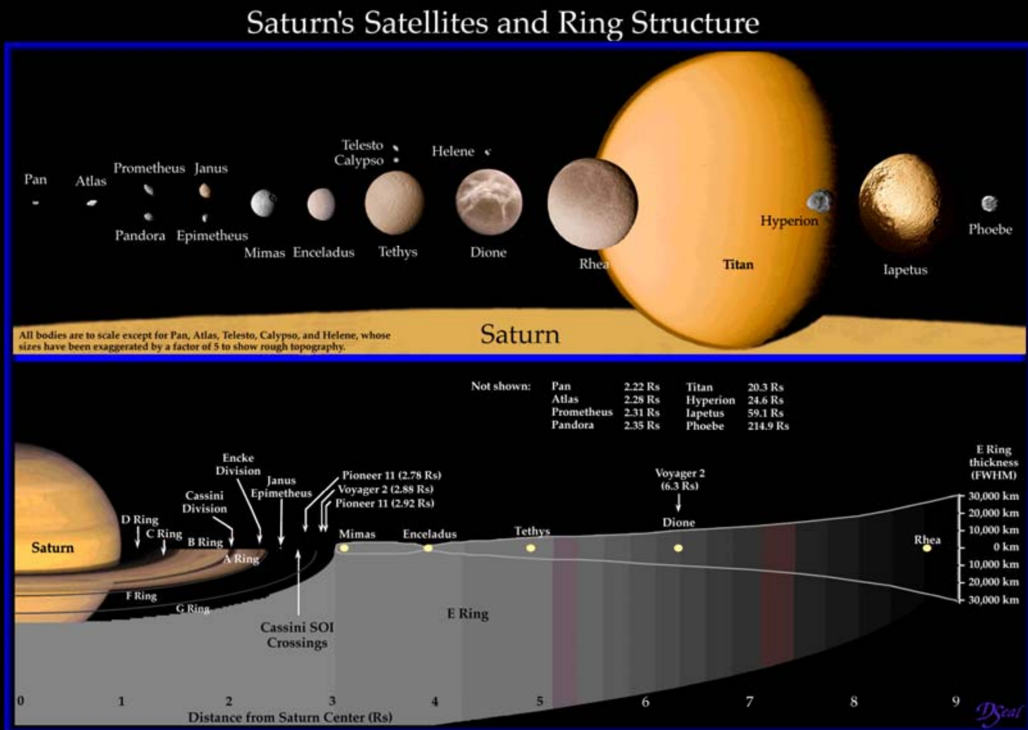
12 Instruments

- 4 Optical Remote Sensing
- 6 MAPS
- 2 microwave

.5 GB Solid State Recorder



THE SATURNIAN SYSTEM
Pan*
Atlas*
Prometheus
Pandora
Janus
Epimetheus
Mimas
Methone*
Pallene*
Enceladus
Telesto*
Calypso*
Tethys
Dione
Polydeuces*
Helene*
Rhea
Titan
Hyperion
Iapetus
Phoebe
SATURN
All bodies are to scale except for the eight small, starred (*) bodies whose sizes have been exaggerated by a factor of 5.
Cassini Division
Encke Division (Pan)
Janus Epimetheus
Ring Plane Crossings
Cassini SOI
Pioneer 11 outbound
Voyager 2
Pioneer 11 inbound
Voyager 1 outbound
D ring
C ring
B ring
A ring (outer edge: Atlas)
F ring (Prometheus, Pandora)
G ring
E ring
Mimas
Enceladus
Tethys
Dione
Rhea
Ymir
Paaliaq
Tarvos
Ijiraq
Suttung
Kiviuq
Narvi
Mundilfari
Albiorix
Skadi
Erriapo
Siarnaq
Thrym
(Distant, small satellites named for Norse, Inuit, or Gallic giants)
Titan
Hyperion
Iapetus
Phoebe
May 2005
Dseal



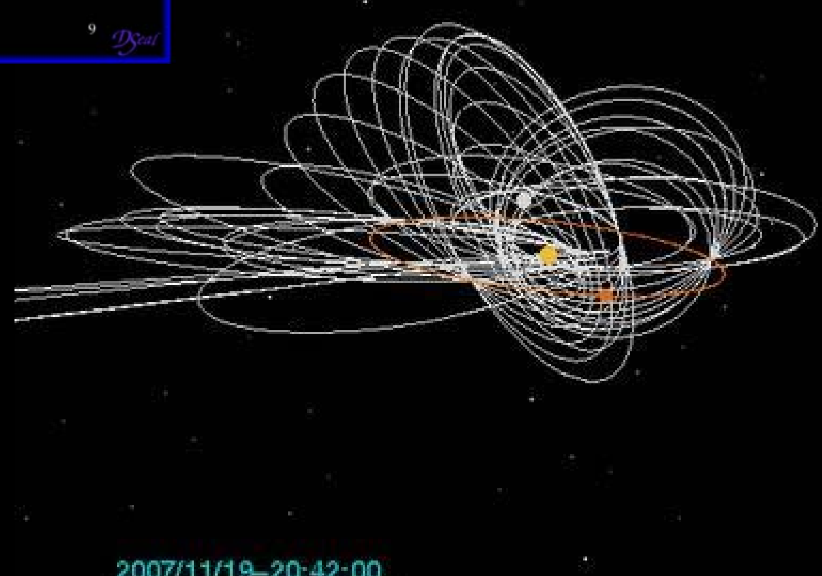
Tour Overview

4 year Prime Mission

- 75 orbits
- 45 targeted Titan flybys
- 8 targeted icy satellite flybys

5 Science Objectives

- Titan
- Saturn
- Rings
- Icy Satellites
- Magnetosphere

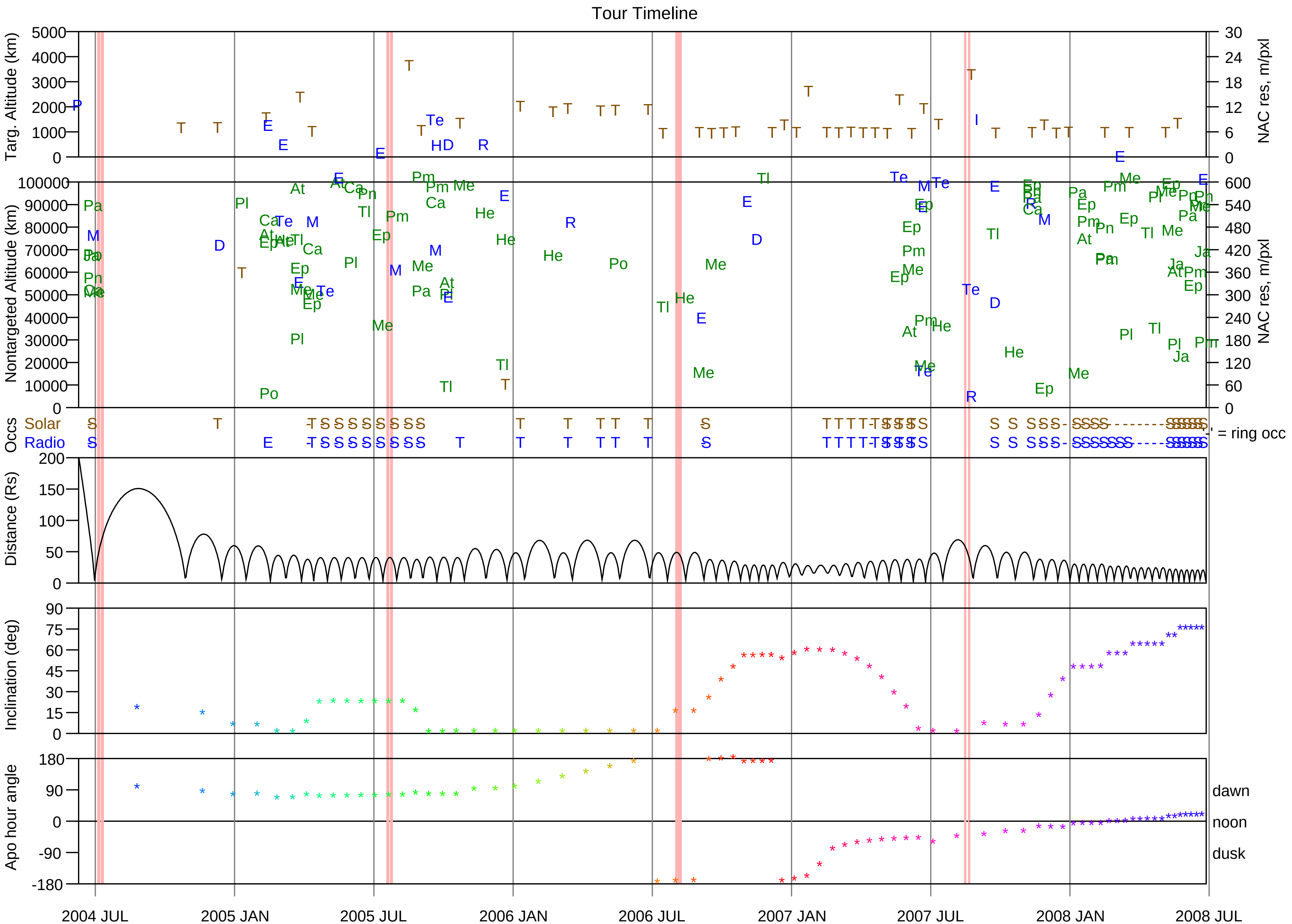


Petal Movie: http://jplis-stor-cache02.jpl.nasa.

http://saturn.jpl.nasa.gov/multimedia/videos/video-details.cfm?videoID=85

Mission Overview - 2nd year of tour

- The Cassini orbiter has completed the second of its four-year orbital tour of the Saturn system.
  - All orbiter systems are performing normally.
  - All consumables usage are running per predict.
- We completed the Occultation phase and begin the Magnetotail phase of the mission:
  - The rings of Saturn close during the lifetime of the Cassini mission, a set of occultations was designed. They occurred over the summer of 2005.
  - Then we returned to equatorial orbits and started rotating the petal of the orbit away from the sun to set up observations of the magnetotail.
  - Equatorial orbits are good for icy satellite encounters so many of the best targeted flybys occurred during this past year.
- ~14 orbits completed, 13 targeted flybys, 45 non-targeted (100,000km or less)


Tour Timeline
Targ. Altitude (km)
Nontargeted Altitude (km)
NAC res, m/pxl
Occs
Solar
Radio
'-' = ring occ
Distance (Rs)
Inclination (deg)
Apo hour angle
dawn
noon
dusk
2004 JUL
2005 JAN
2005 JUL
2006 JAN
2006 JUL
2007 JAN
2007 JUL
2008 JAN
2008 JUL

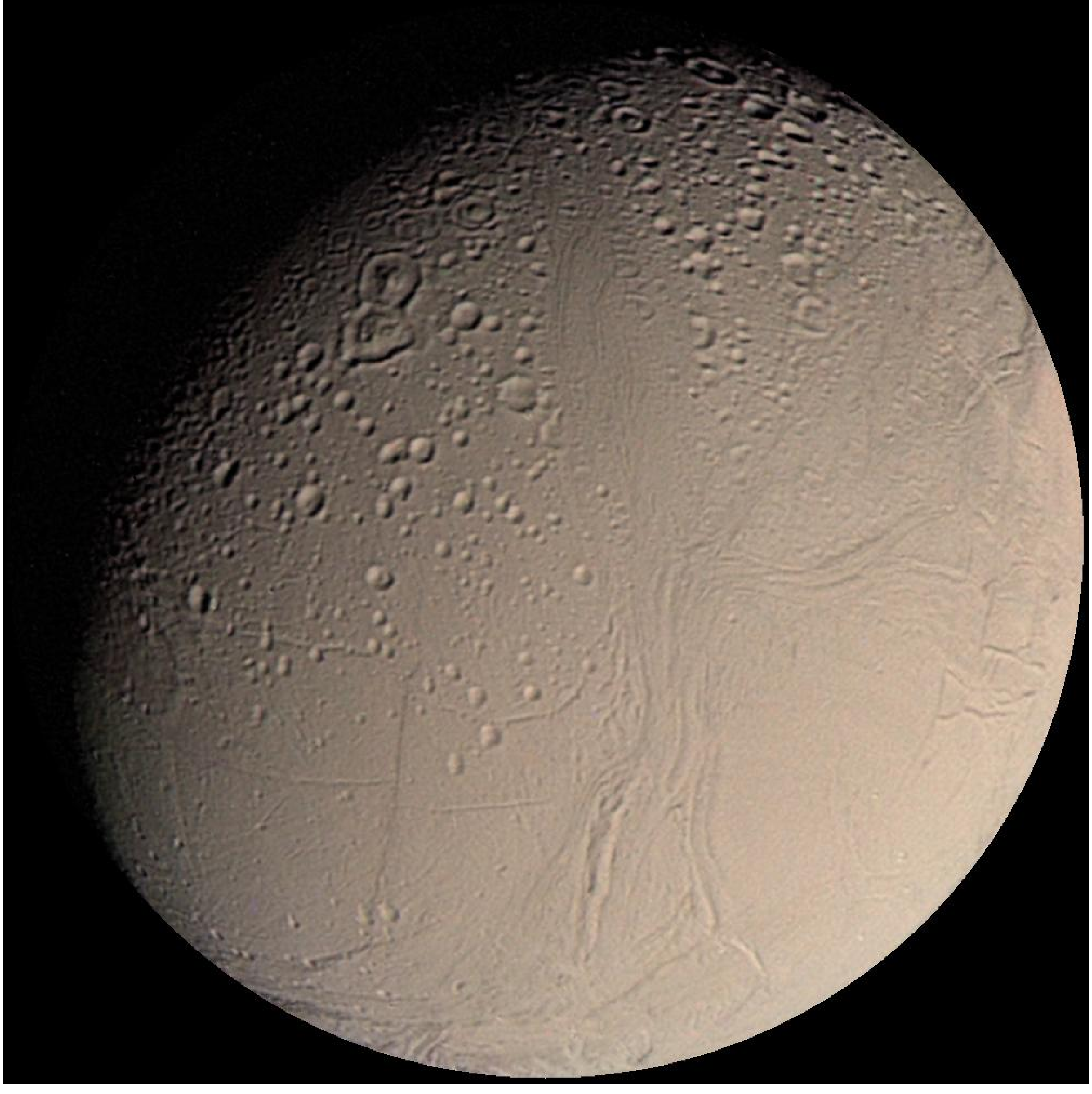
Targeted Flyby Summary - 2nd year

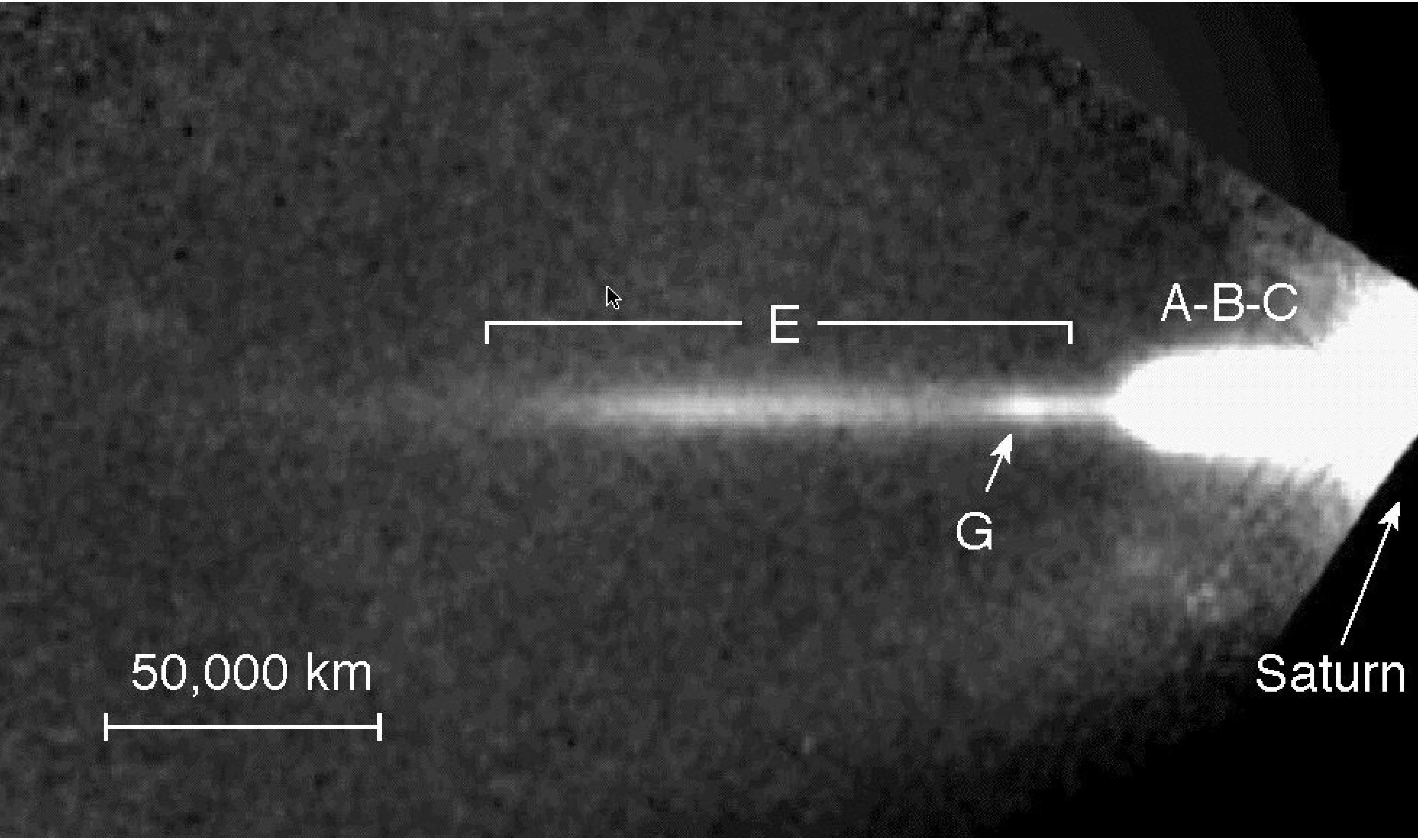
Seq	Rev	Name		Event	Epoch (SCET)	Date
S12	11	11EN (t)	[E2]	ENCELADUS	2005-195T19:55	Jul-14
S13	13	13TI (t)	[T6]	TITAN	2005-234T08:54	Aug-22
S14	14	14TI (t)	[T7]	TITAN	2005-250T08:12	Sep-07
S14	15	15HY (t)	[H1]	HYPERION	2005-269T02:25	Sep-26
S14	15	15TE (nt)		TETHYS	2005-267T02:42	Sep-24
S15	16	16DI (t)	[D1]	DIONE	2005-284T17:52	Oct-11
S15	17	17TI (t)	[T8]	TITAN	2005-301T04:15	Oct-28
S16	18	18RH (t)	[R1]	RHEA	2005-330T22:38	Nov-26
S17	19	19TI (t)	[T9]	TITAN	2005-360T18:59	Dec-26
S17	20	20TI (t)	[T10]	TITAN	2006-015T11:41	Jan-15
S18	21	21TI (t)	[T11]	TITAN	2006-058T08:25	Feb-27
S19	22	22TI (t)	[T12]	TITAN	2006-078T00:06	Mar-19
S20	23	23TI (t)	[T13]	TITAN	2006-120T20:58	Apr-30
S20	24	24TI (t)	[T14]	TITAN	2006-140T12:18	May-20

Mission Overview - continued

- The spacecraft has returned a staggering amount of data in the last year, ~60Gbytes.
- The reference trajectory has been modified to account for Titan's atmosphere.
- The extended mission planning work has begun:
  - Initial inputs from all instruments, all disciplines
  - Many tour types developed and analyzed
  - Hopefully (grin) consensus at the June Project Science Meeting on which tour classes deserve further consideration and refinement


10 March 2006 | $10
Science
Cassini at
Enceladus
AAAS




A-B-C
E
G
Saturn
50,000 km

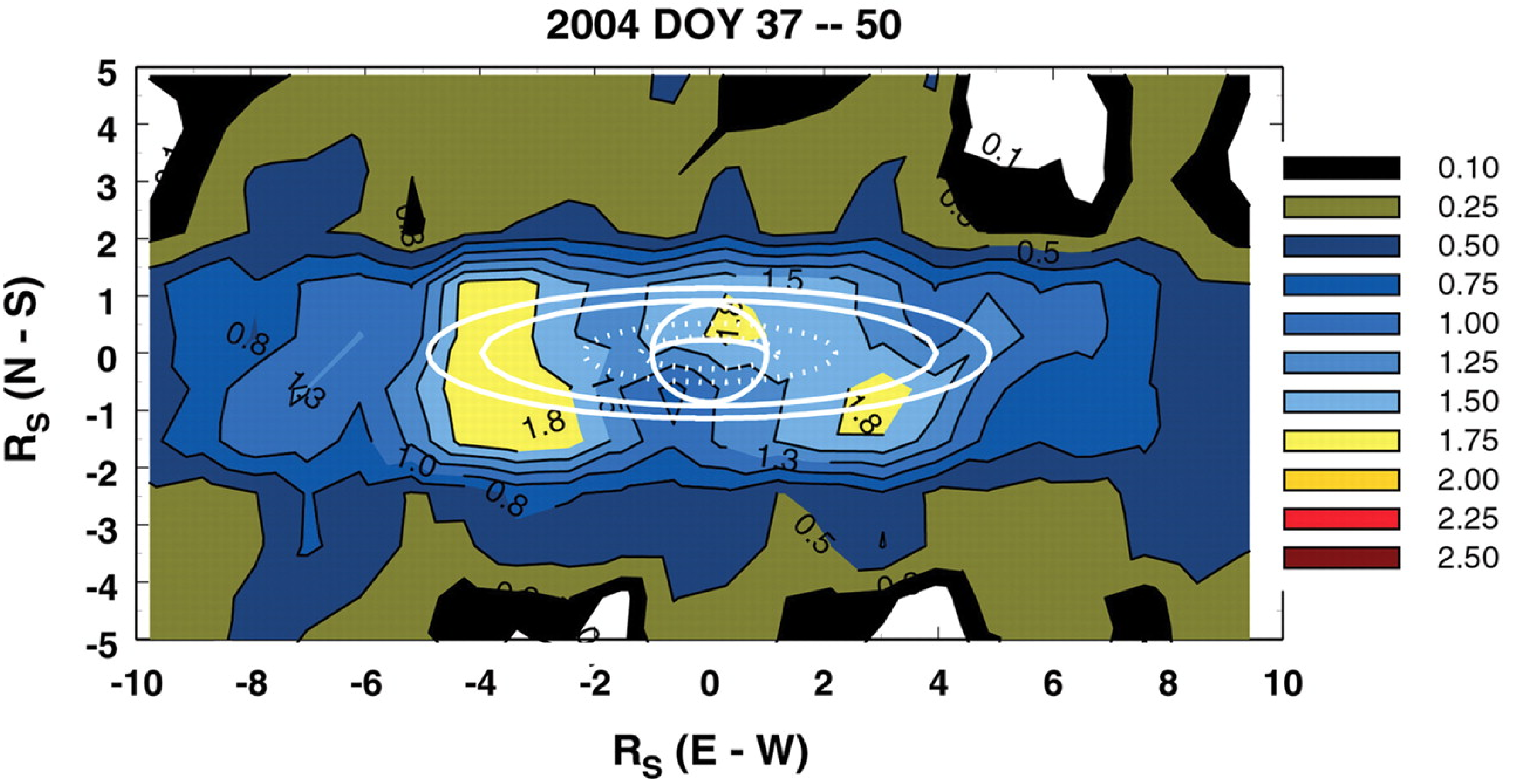
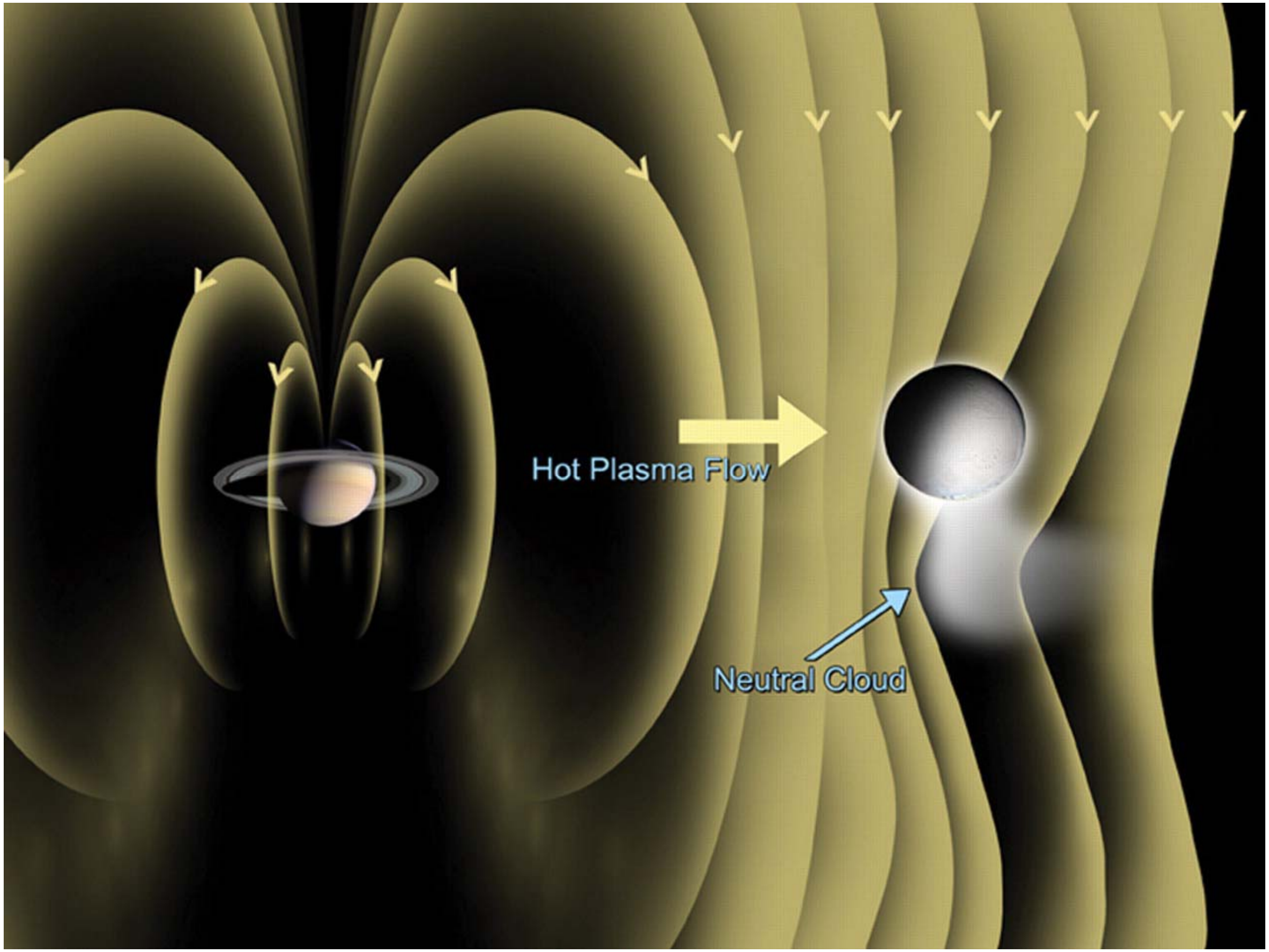
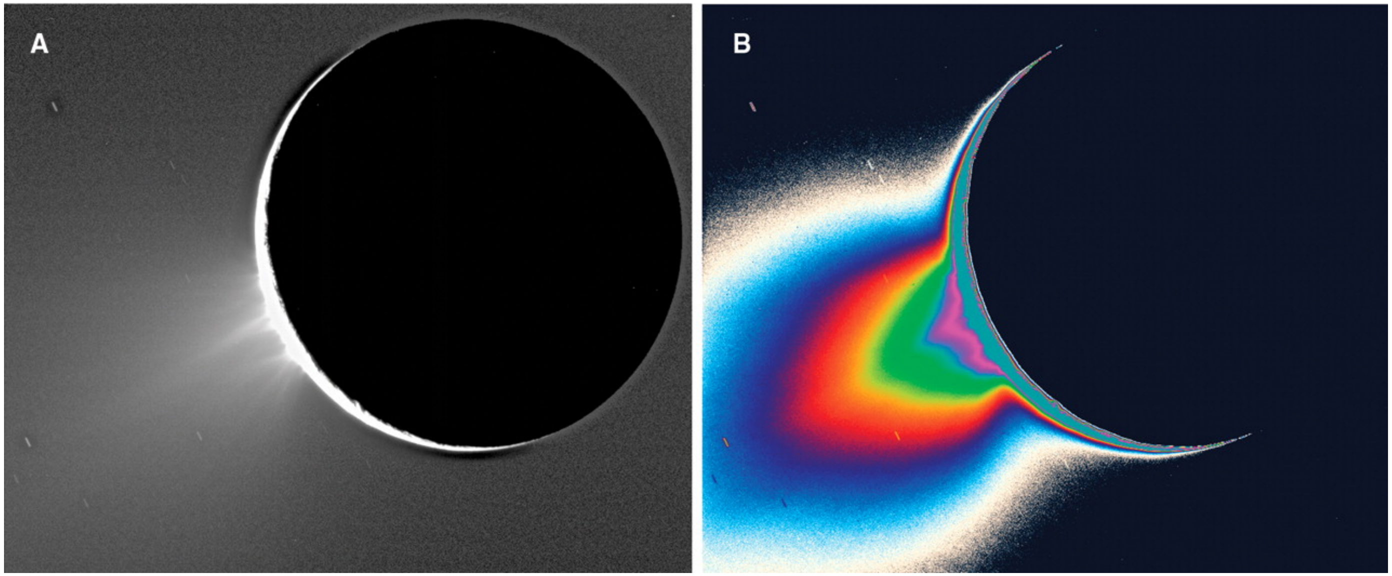

2004 DOY 37 -- 50
R_S (N - S)
R_S (E - W)
5
4
3
2
1
0
-1
-2
-3
-4
-5
-10
-8
-6
-4
-2
0
2
4
6
8
10
0.10
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
0.1
0.5
1.5
0.8
1.8
1.0
1.3
0.8
1.8
1.3
0.5

Fig. 4. A schematic (where Saturn and Enceladus are not to scale) showing the corotating Saturn magnetic field and plasma being perturbed by the neutral cloud that is produced by a polar plume generated close to the south pole of Enceladus

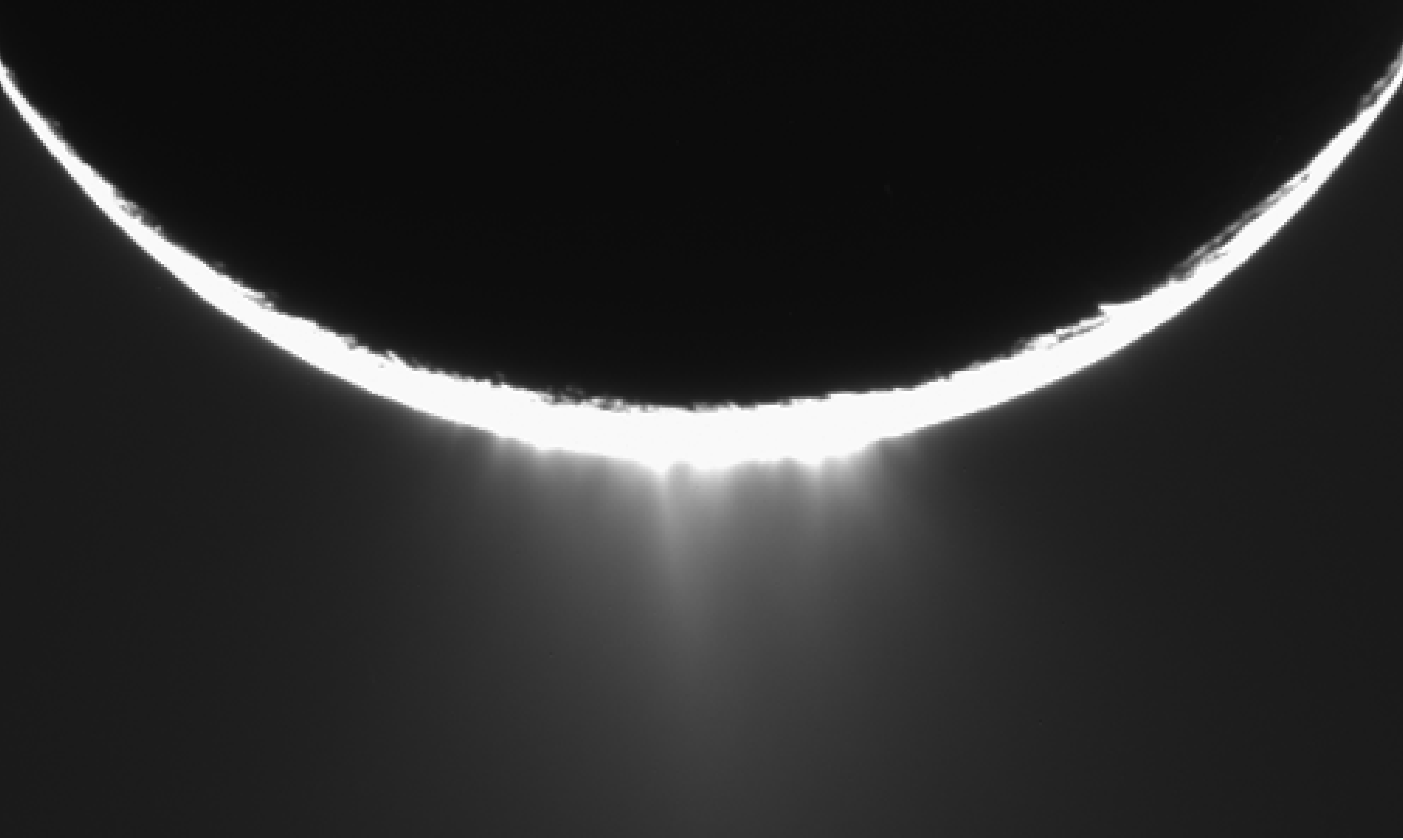


M. K. Dougherty et al., Science 311, 1406 -1409 (2006)

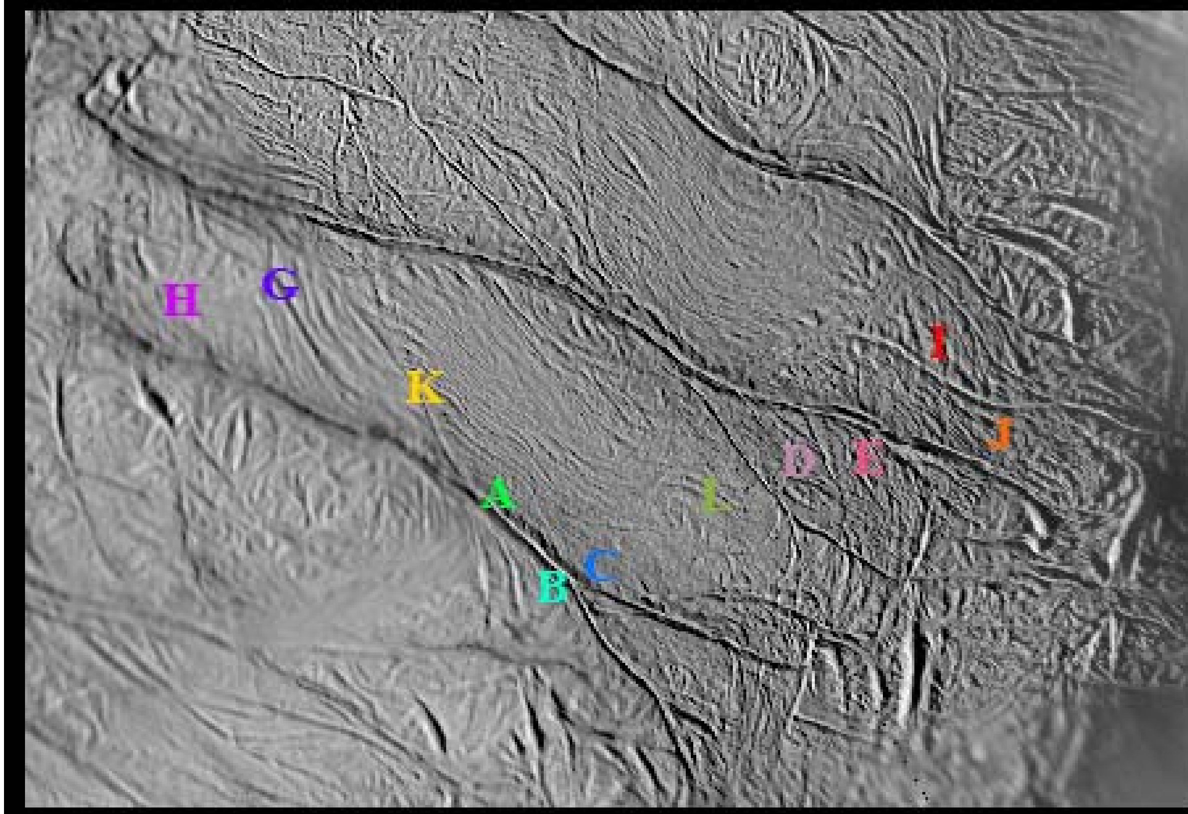
Fig. 6. (A) An ISS NAC clear-filter image (12) of Enceladus' near-surface plumes (which can be resolved into individual jets) taken on 27 November 2005 at a phase angle of 161.4{degrees} with an image scale of ~0.89 km/pixel

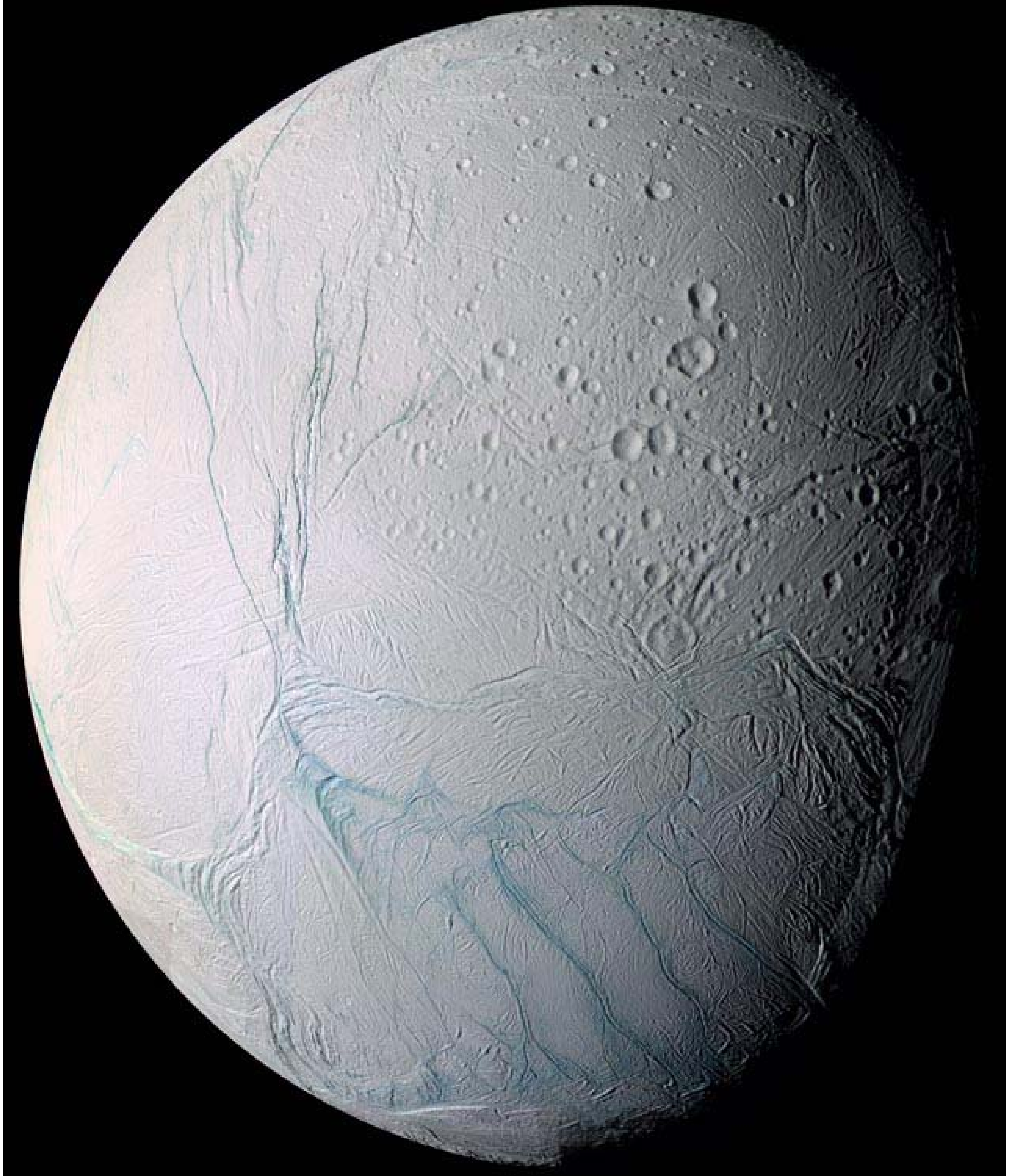


C. C. Porco et al., Science 311, 1393 -1401 (2006)



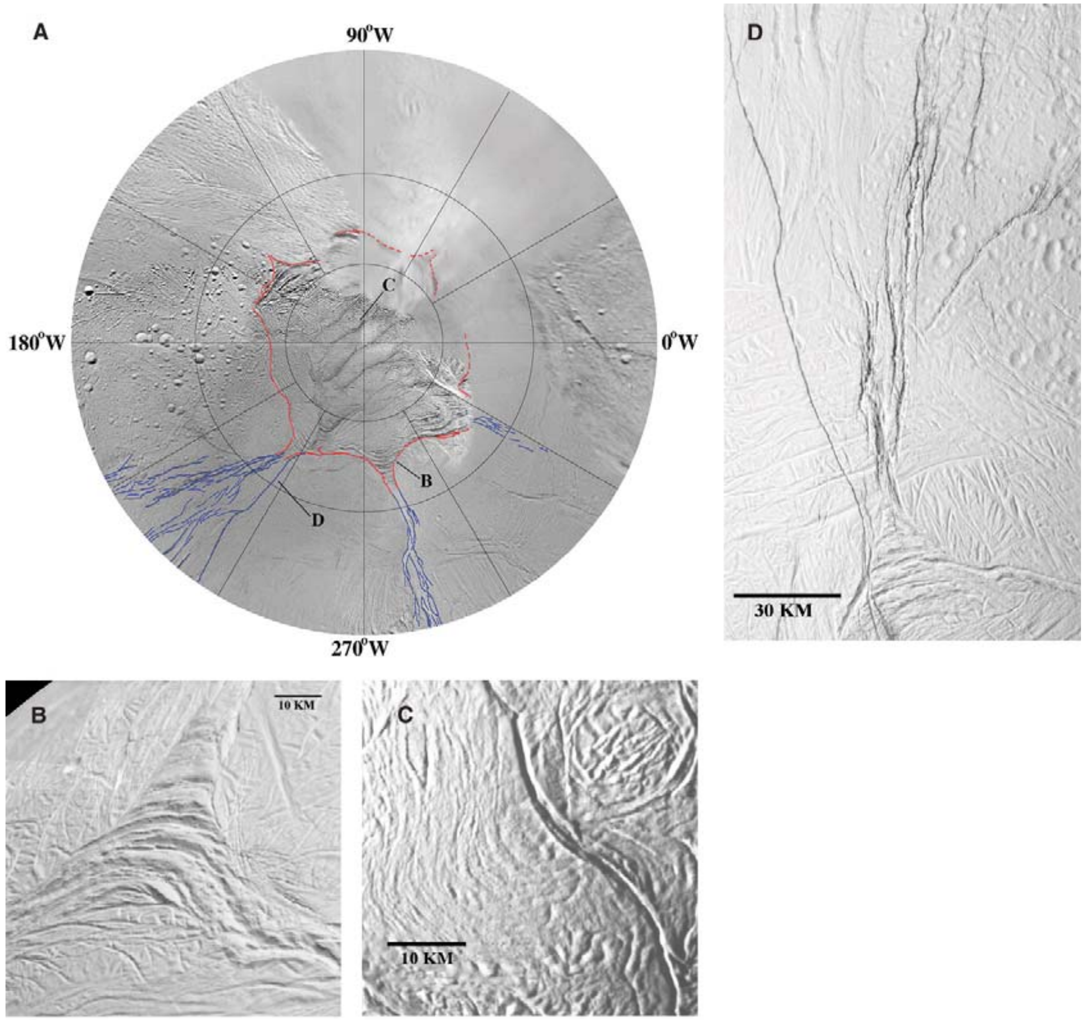

h g f k a b c d e i j


H G K A B C L D E I J

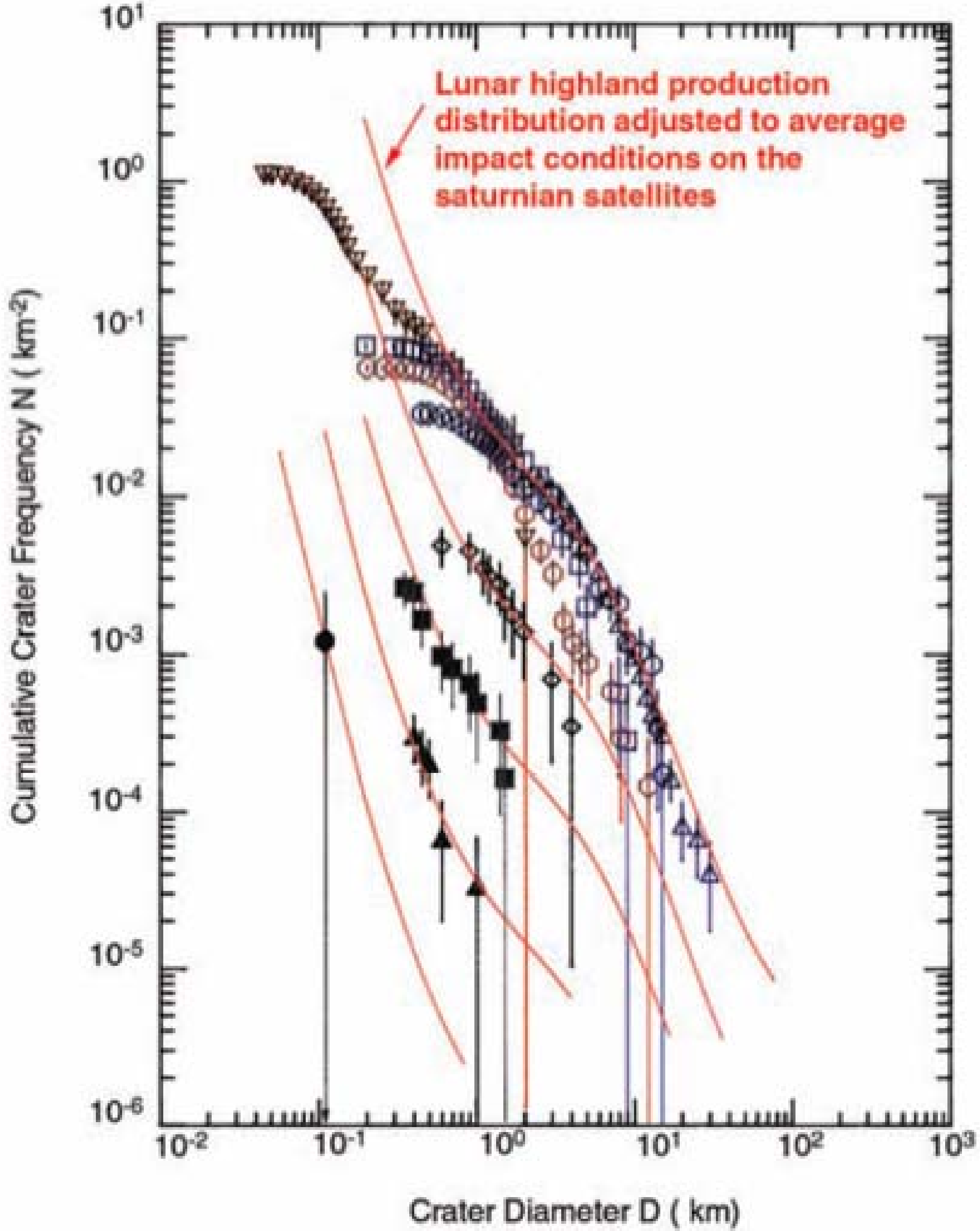


ISS

Fig. 2. (A) Polar stereographic basemap of the SPT covering latitudes from 0{degrees} to 90{degrees}S



C. C. Porco et al., Science 311, 1393 -1401 (2006)



Lunar highland production distribution adjusted to average impact conditions on the saturnian satellites
Cumulative Crater Frequency N (km^{-2})
Crater Diameter D (km)
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}

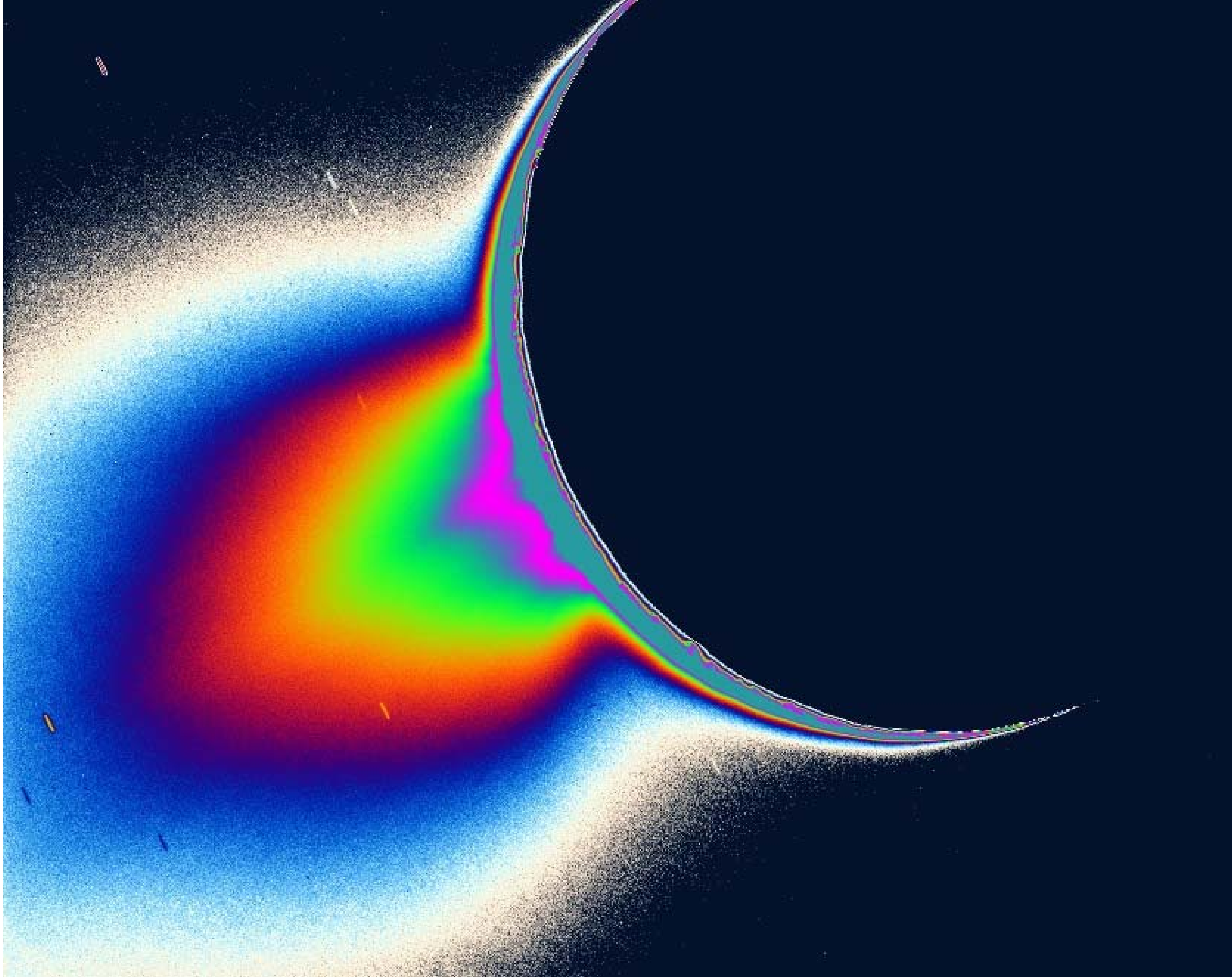
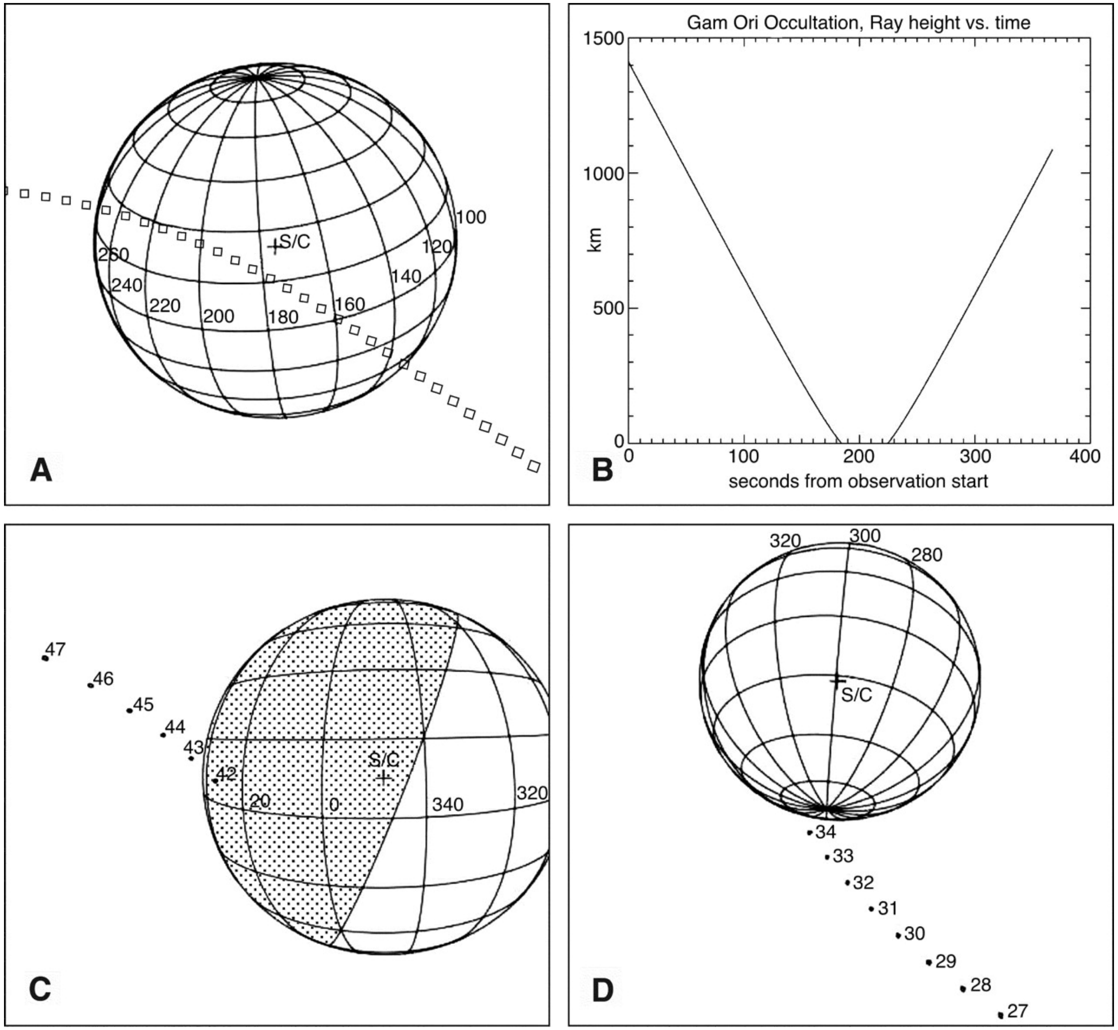
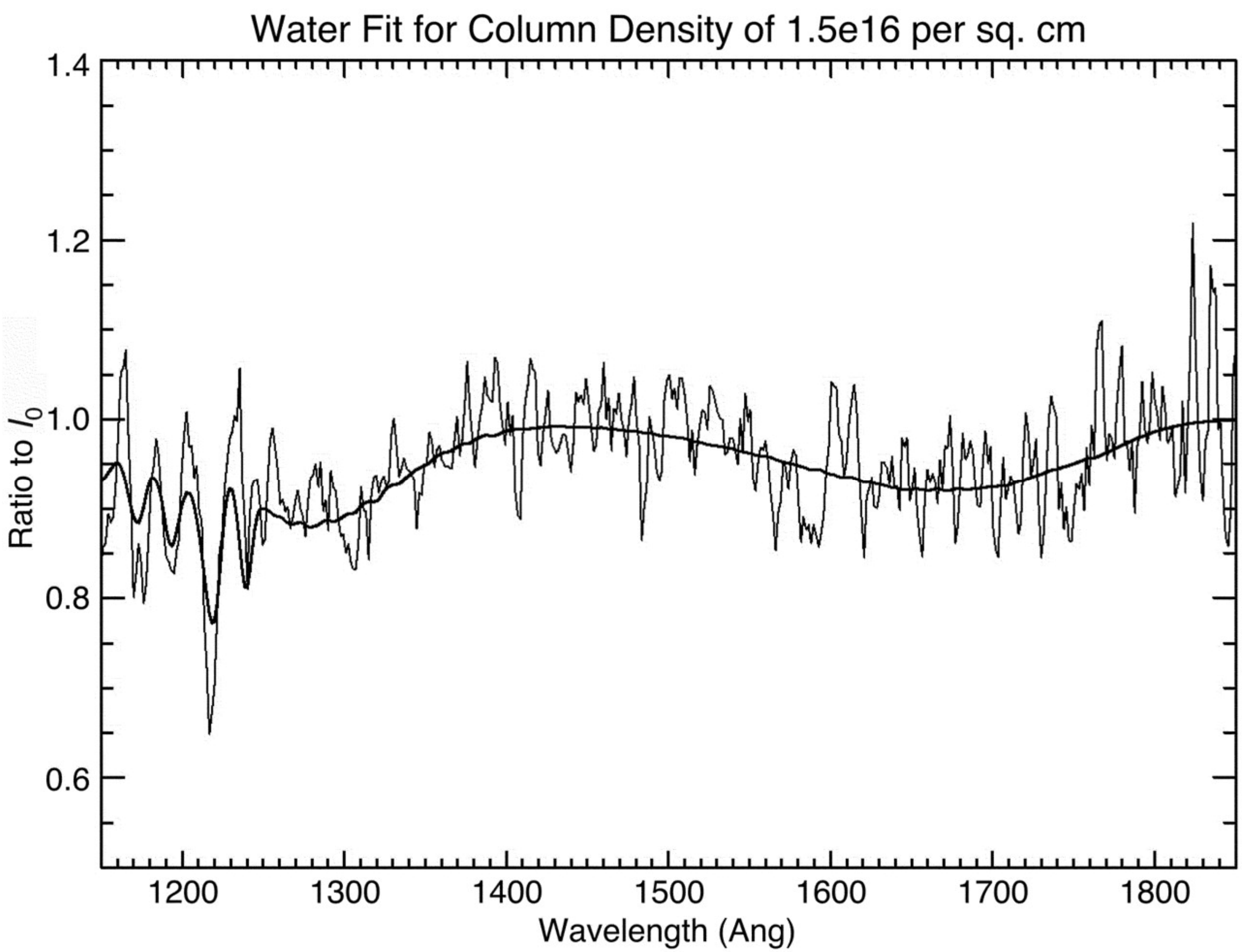


Fig. 1. (A) The path followed by the star lambda Scorpii as it was occulted by Enceladus, the first occultation observed by UVIS



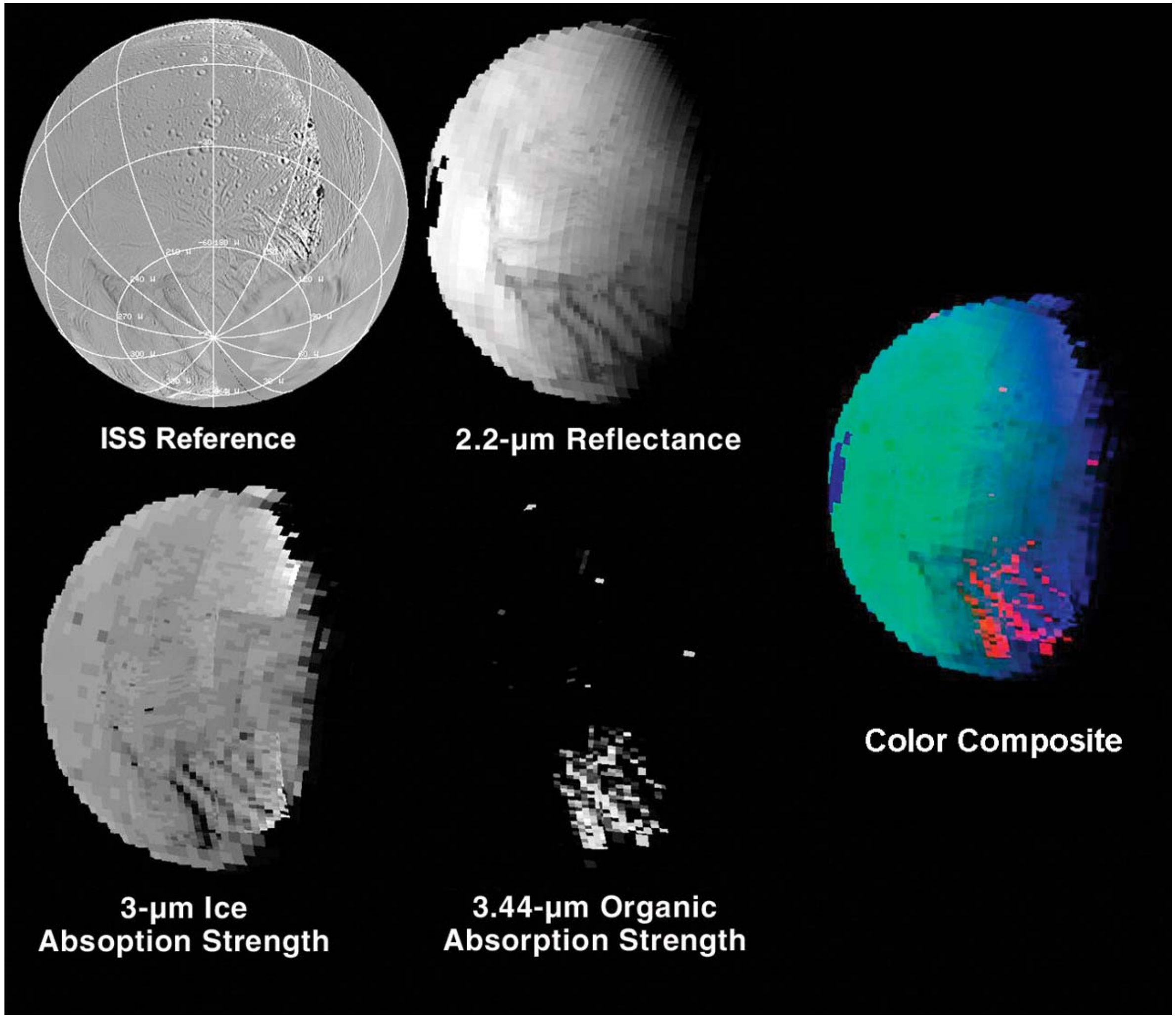
C. J. Hansen et al., Science 311, 1422 -1425 (2006)

Fig. 4. An average unocculted star spectrum (I0) was computed from 25 time records



C. J. Hansen et al., Science 311, 1422 -1425 (2006)

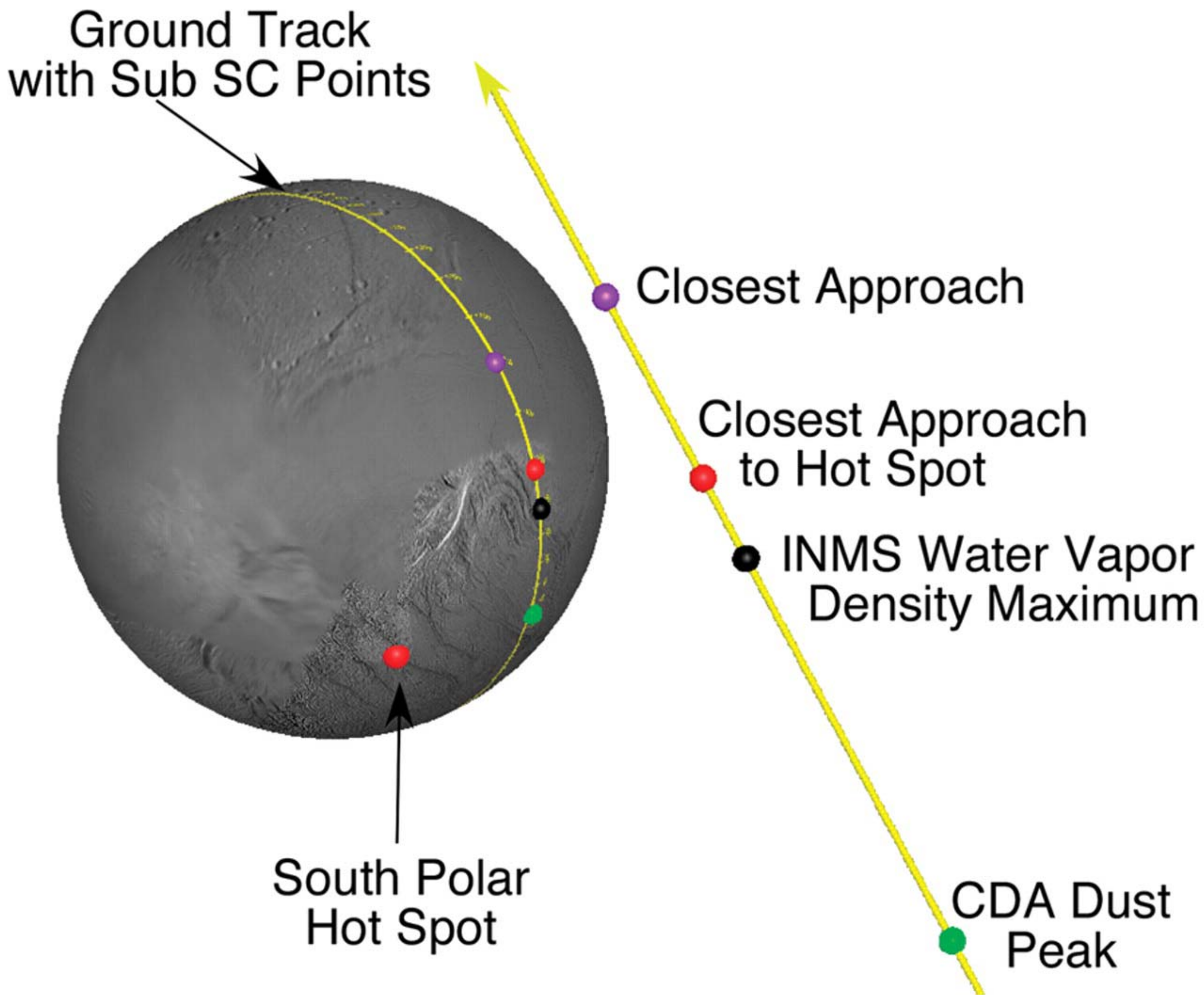
Fig. 2. A compositional map of Enceladus



R. H. Brown et al., Science 311, 1425 -1428 (2006)

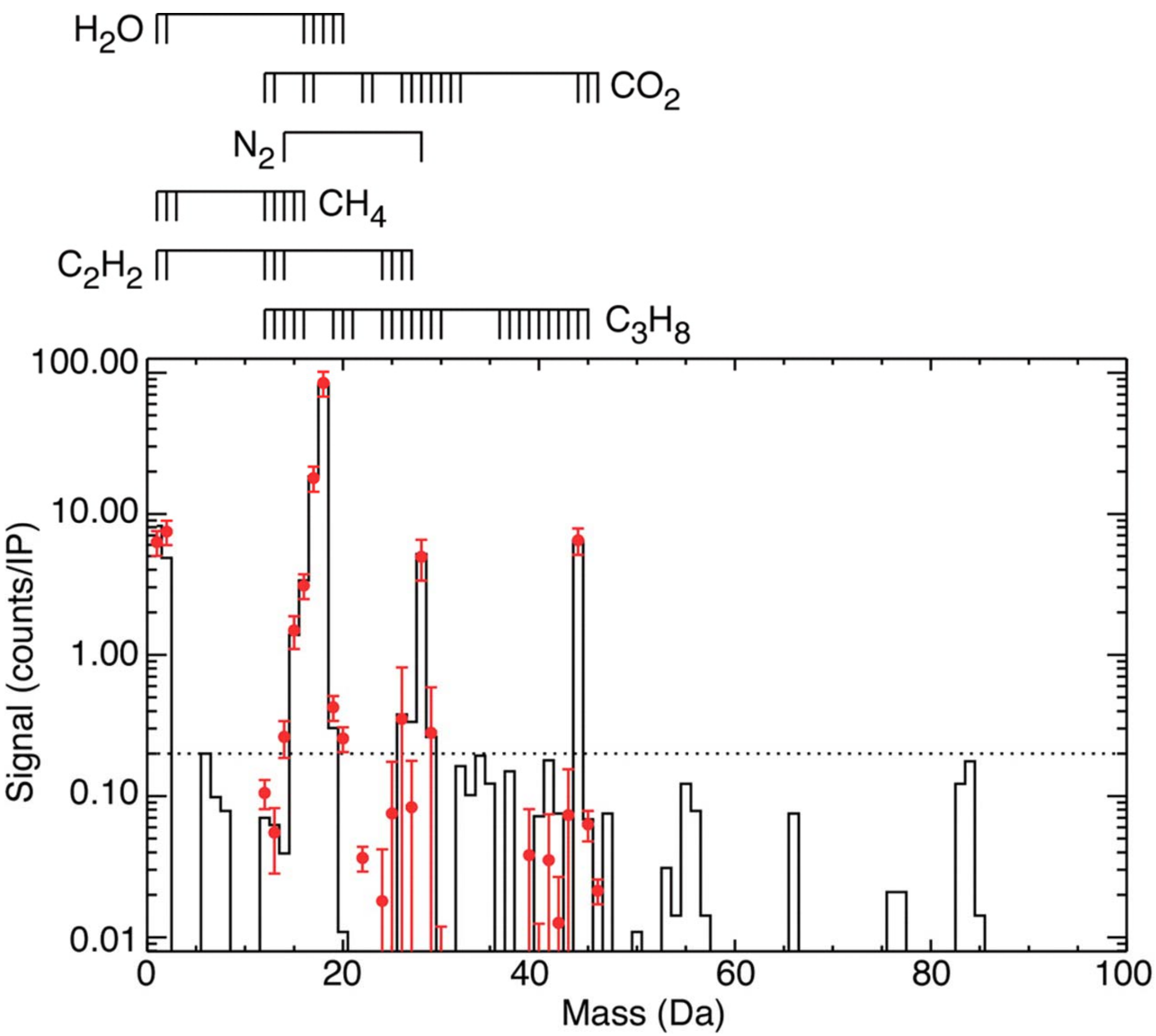
Published by AAAS

Fig. 1. View of Enceladus showing surface features and the Cassini ground track during the flyby on 14 July 2005



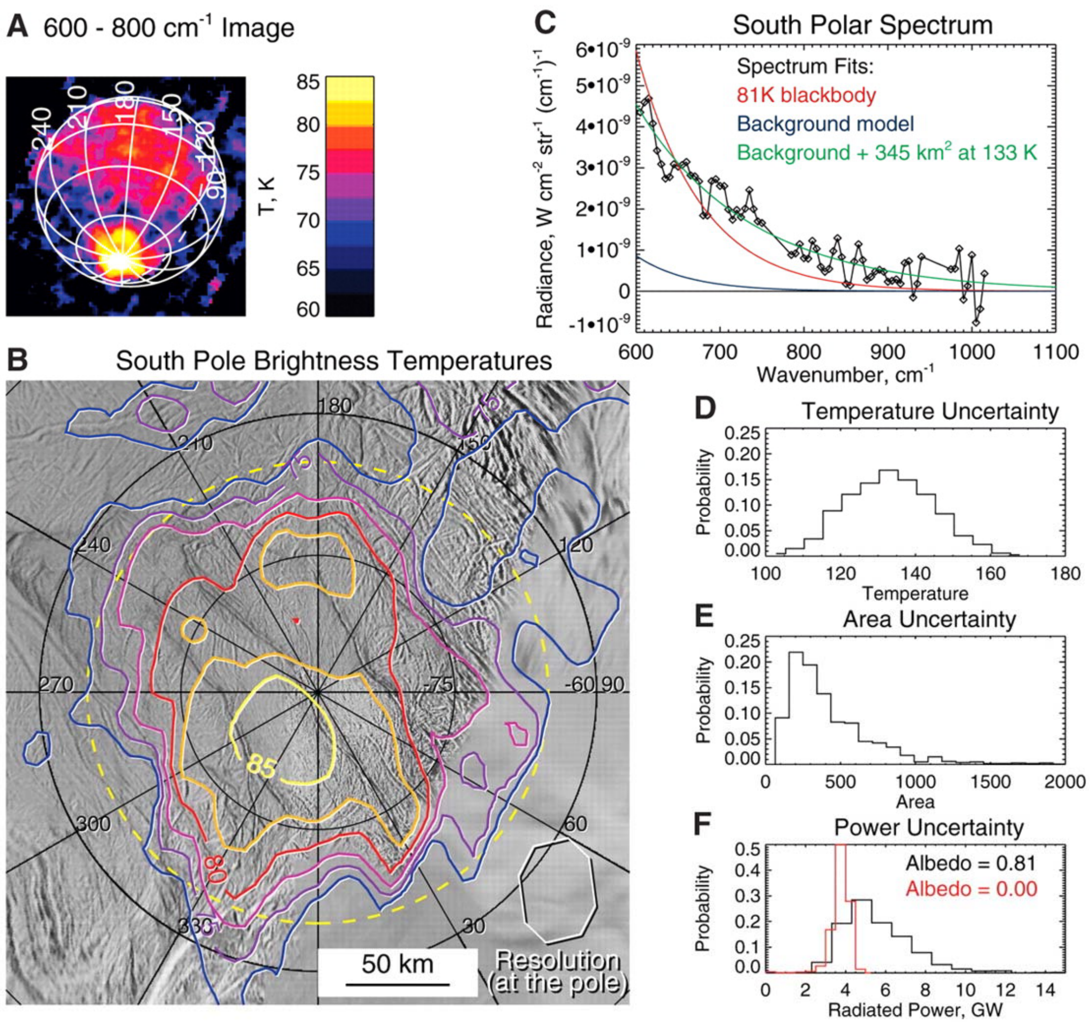
J. H. Waite et al., Science 311, 1419 -1422 (2006)

Fig. 2. Average mass spectrum for altitudes below 500 km



J. H. Waite et al., Science 311, 1419 -1422 (2006)

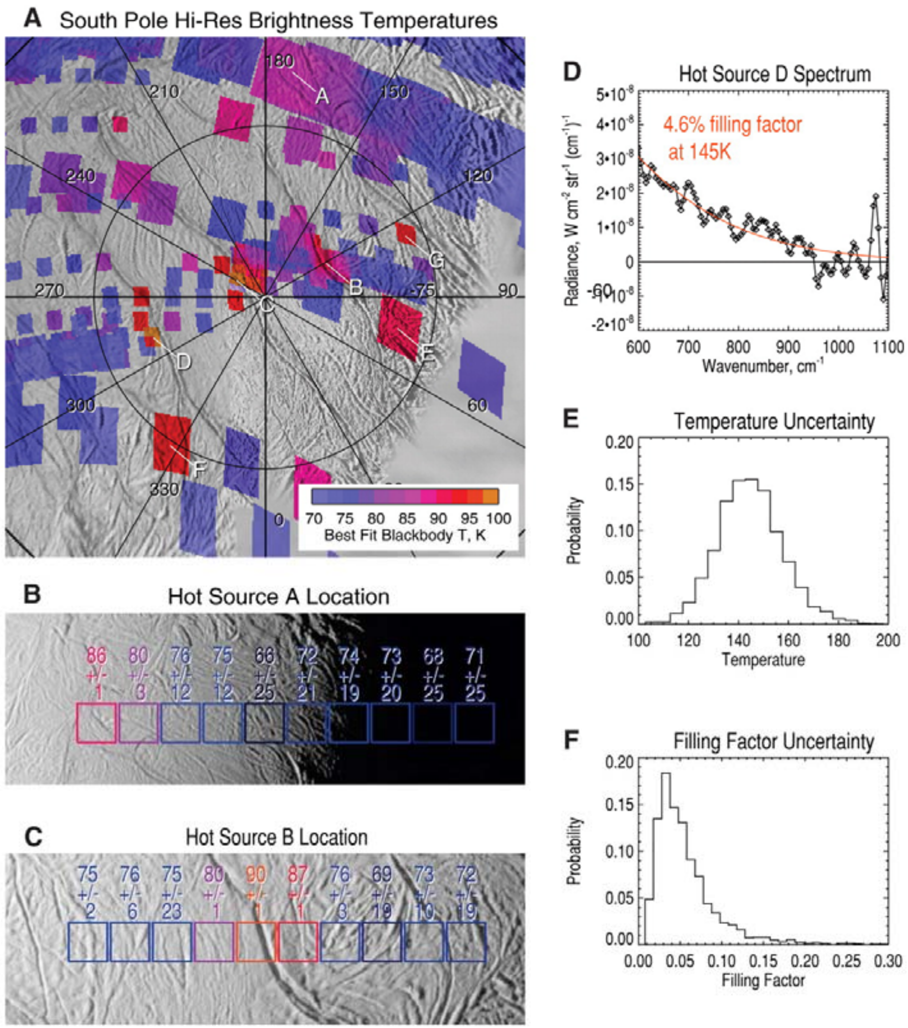
Fig. 2. (A) Mid-IR brightness temperature image of Enceladus from orbit 11, showing the prominent south polar hot spot



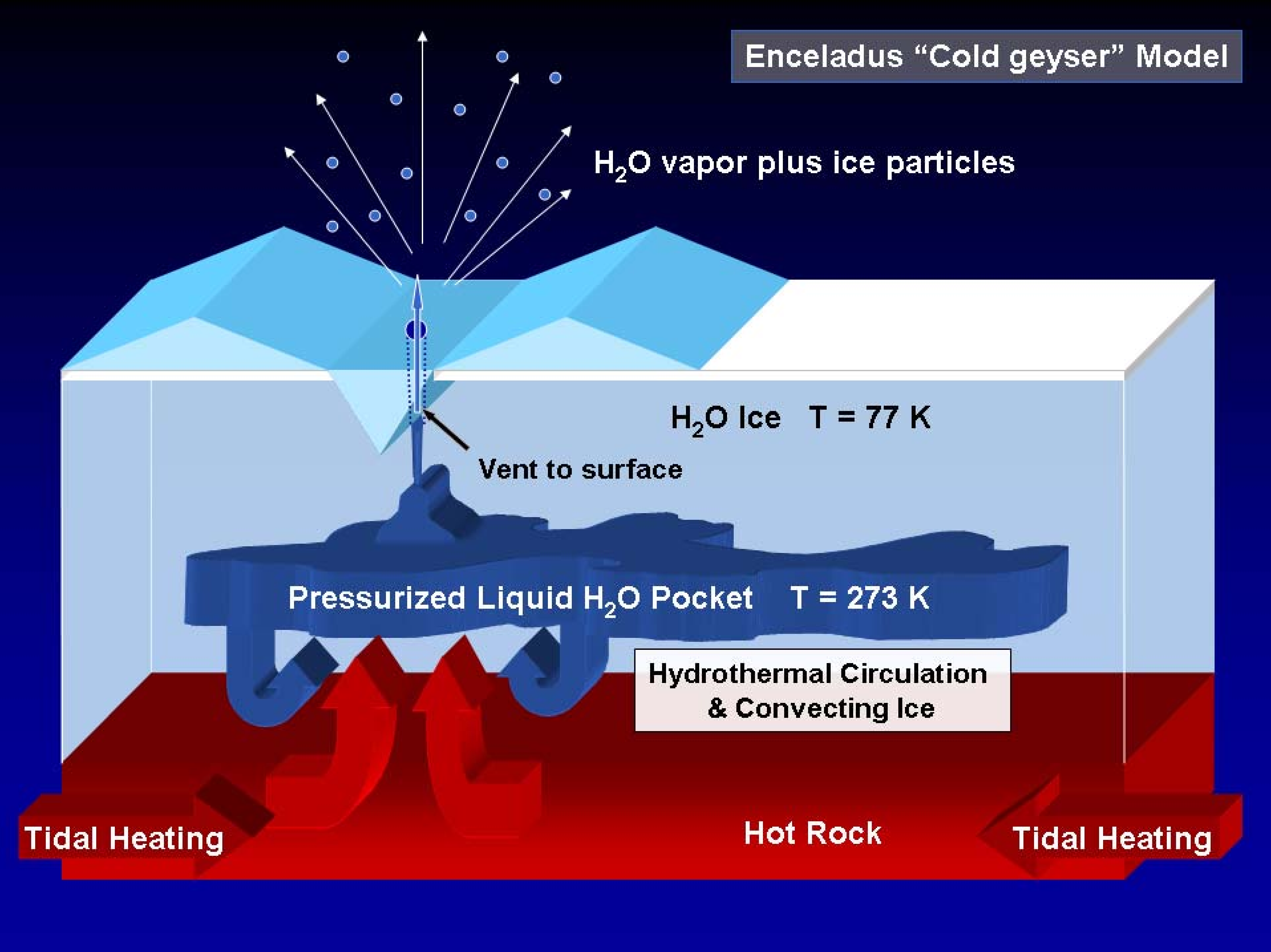
J. R. Spencer et al., Science 311, 1401 -1405 (2006)

Published by AAAS

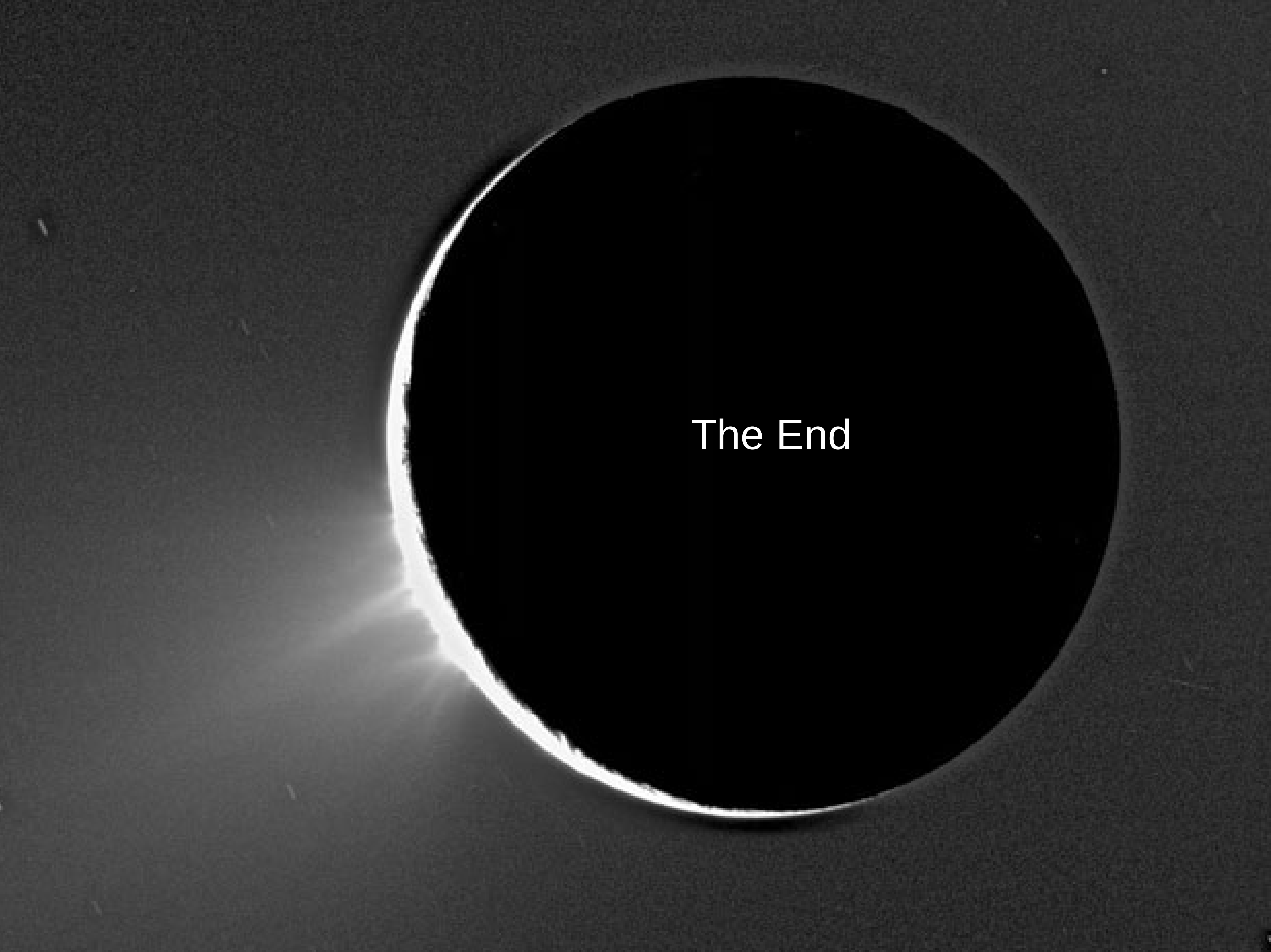
Fig. 3. (A) Color-coded south polar brightness temperatures at high spatial resolution, derived from the ISS ride-along CIRS observations, superposed on an ISS base map (19)



J. R. Spencer et al., Science 311, 1401 -1405 (2006)

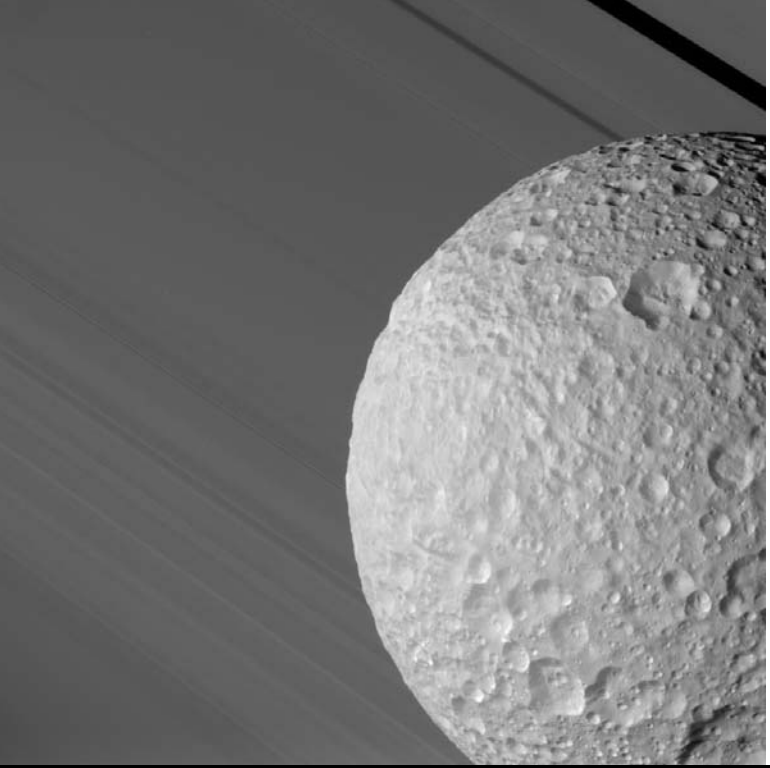


Enceladus "Cold geyser" Model
H_2O vapor plus ice particles
H_2O Ice T = 77 K
Vent to surface
Pressurized Liquid H_2O Pocket T = 273 K
Hydrothermal Circulation
& Convecting Ice
Tidal Heating
Hot Rock
Tidal Heating

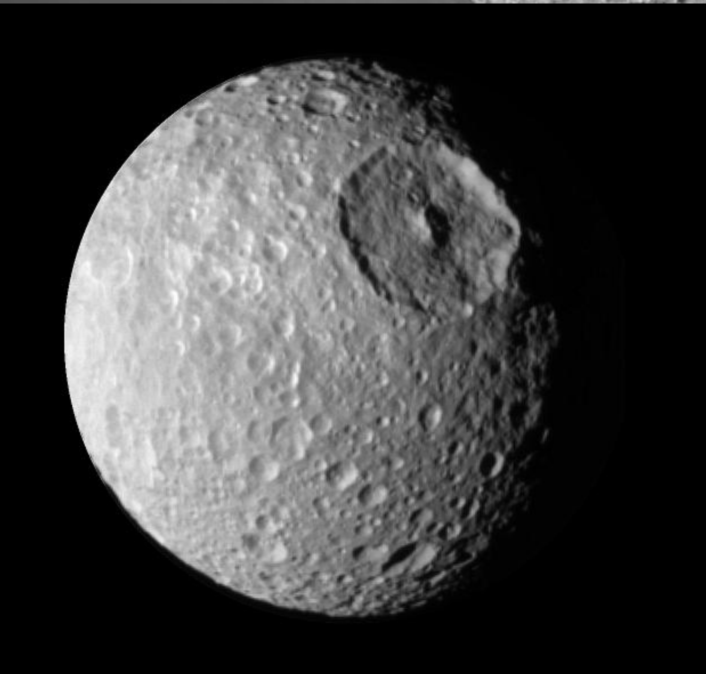
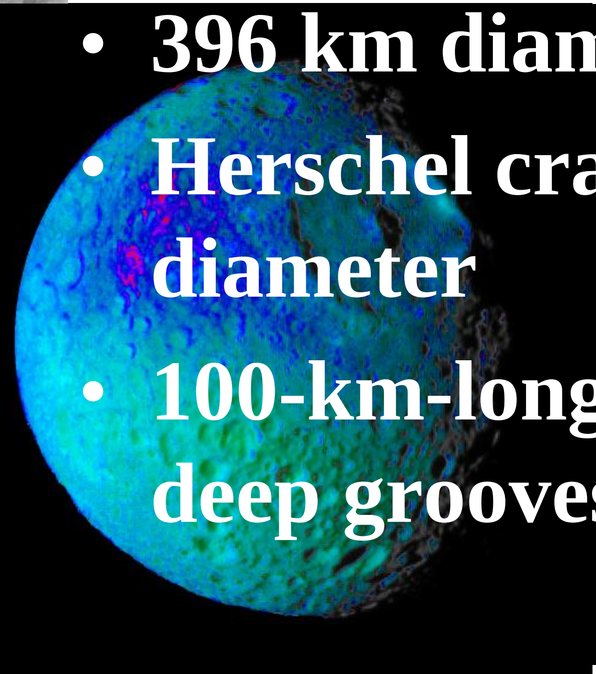
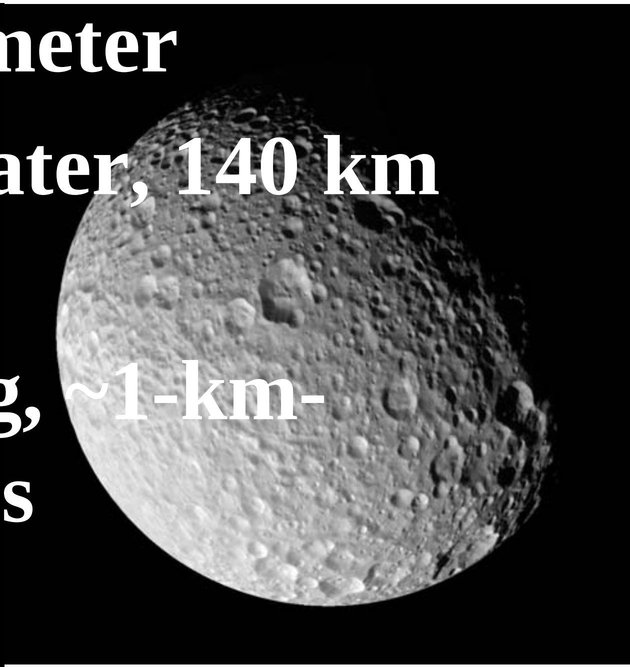

The End

Icy Satellites

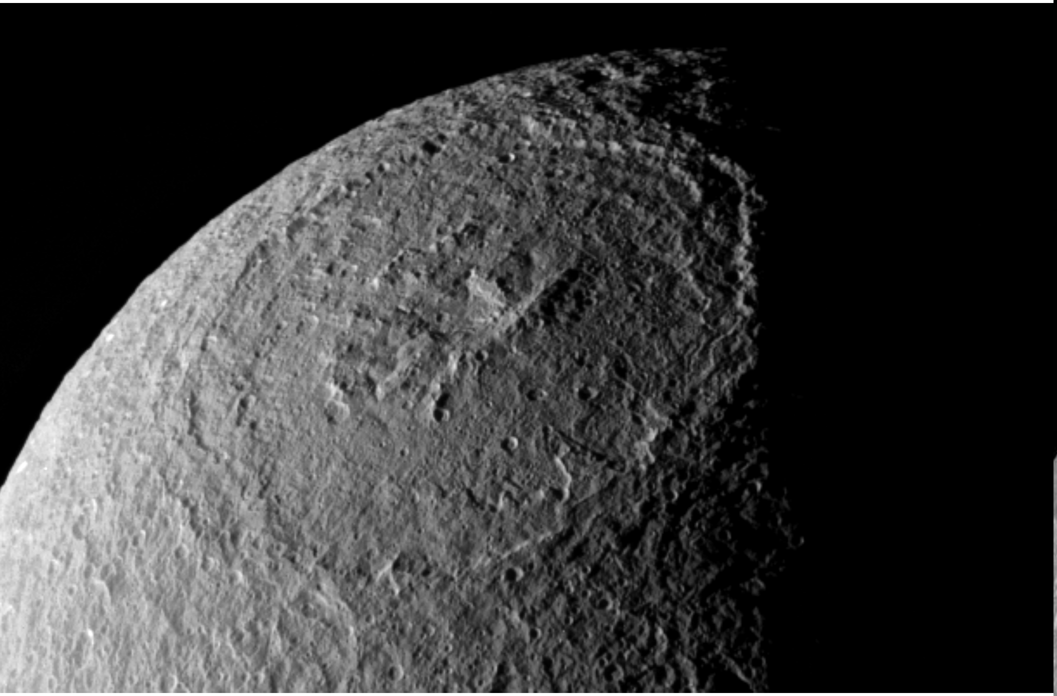
- The Saturn system has 47 confirmed satellites, most are small and far away from the planet.
- There are 8 major icy satellites (not including Titan)
  - Mimas, Enceladus, Tethys, Dione, Rhea, Hyperion, Iapetus, and Phoebe
- They are located outside the major ring system and vary in size from tiny Phoebe (D=137 miles) up to Rhea (D=950 miles) the seventh largest moon in the solar system)
- Their surfaces are dominated by water ice and shaped by the forces of tectonics, impact cratering, erosion, and even volcanism.
- The densities range from .6 g/cm^3 (Hyperion) to 1.6g/cm^3 (Enceladus).

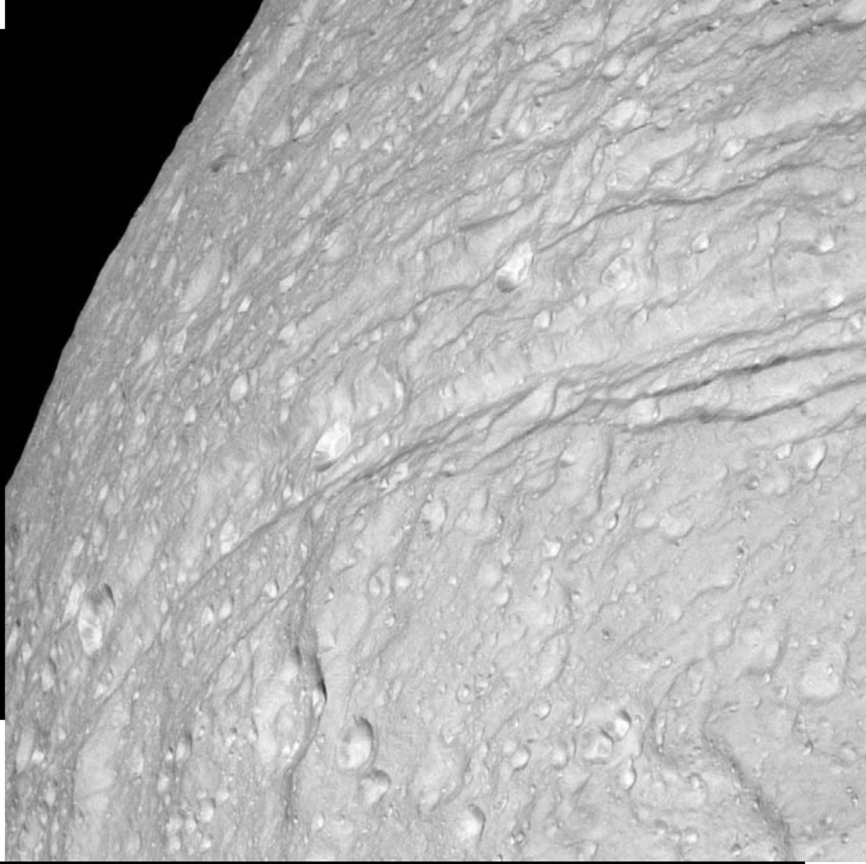


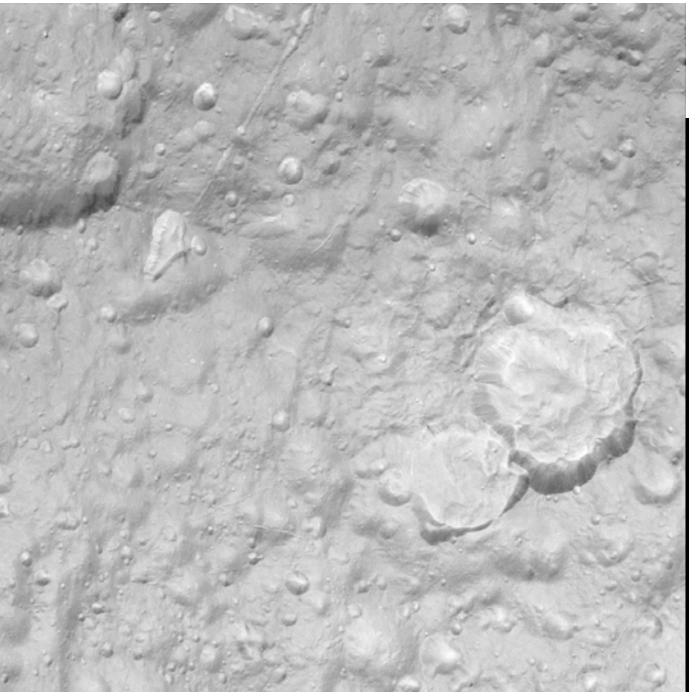
Mimas

- **396 km diameter**
- **Herschel crater, 140 km diameter**
- **100-km-long, ~1-km-deep grooves**

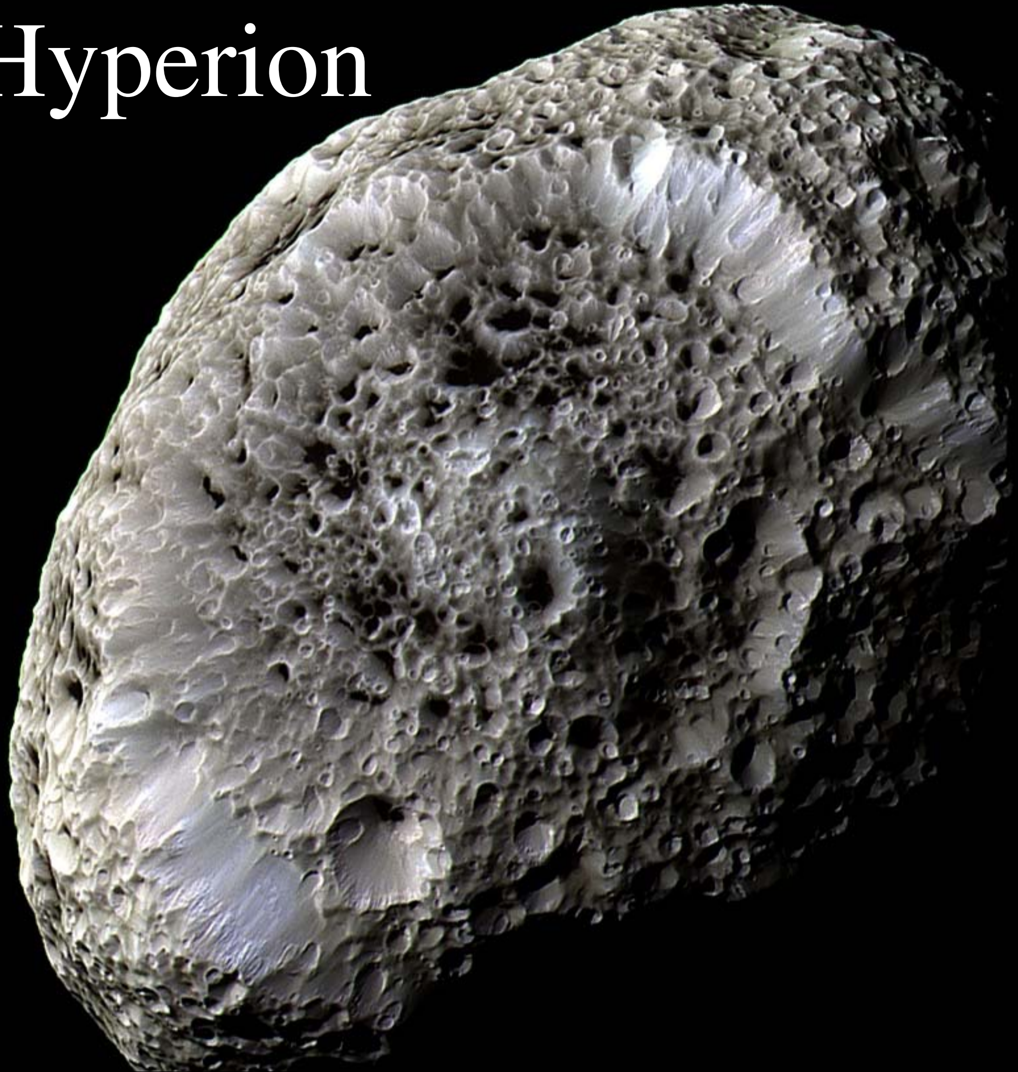


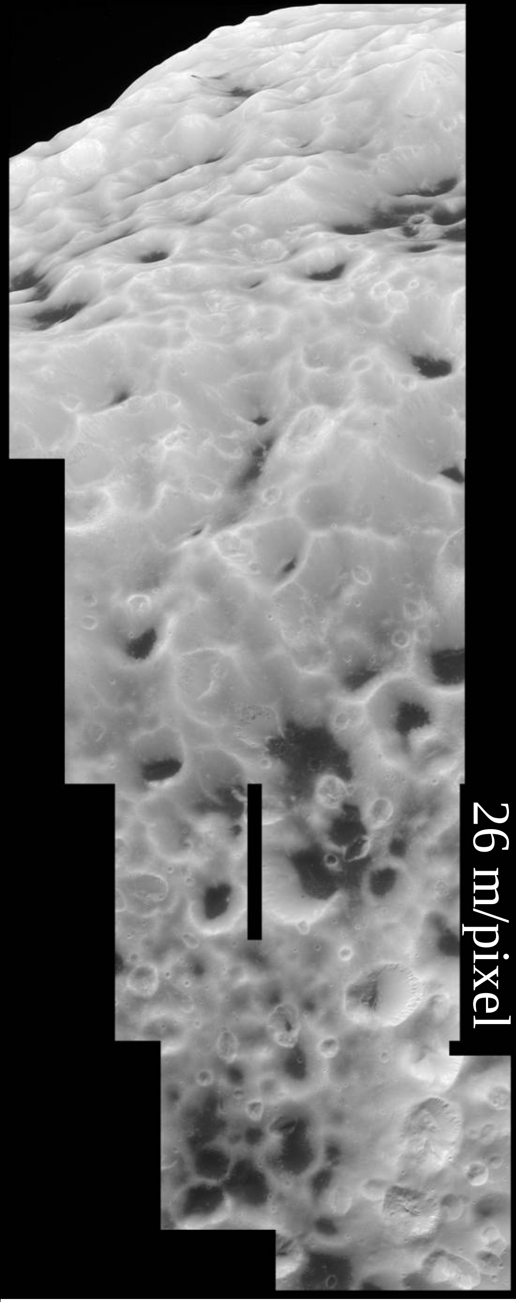




- Closest flyby of nominal tour = 1500 km on 24 September 2005
- 1066 km diameter
- Odysseus crater, 400 km diameter
- Ithaca Chasma, 2500 km long, several kilometers deep

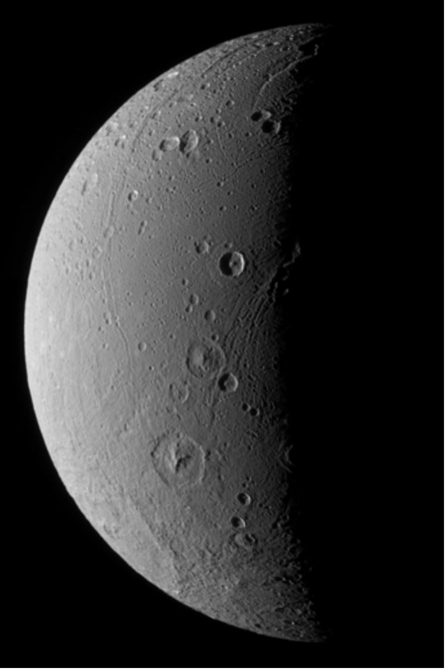
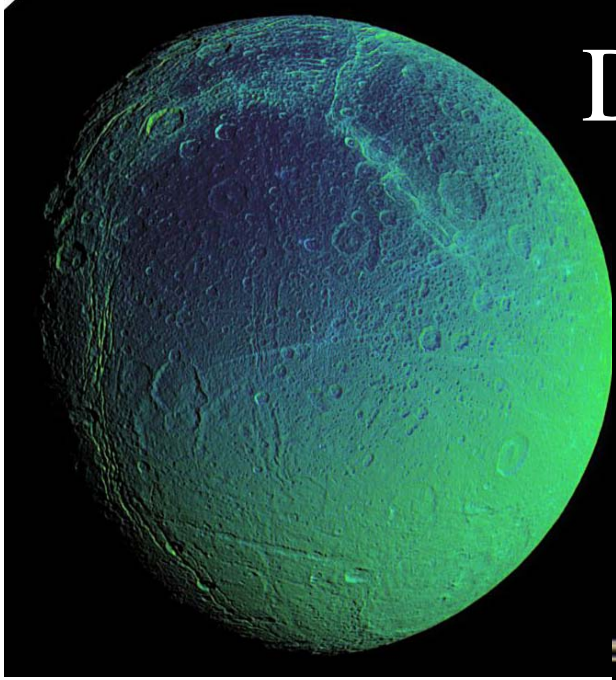
Hyperion



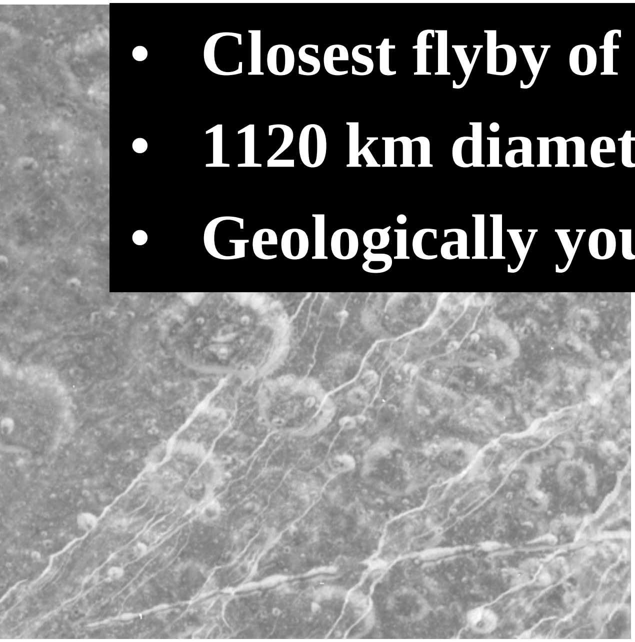
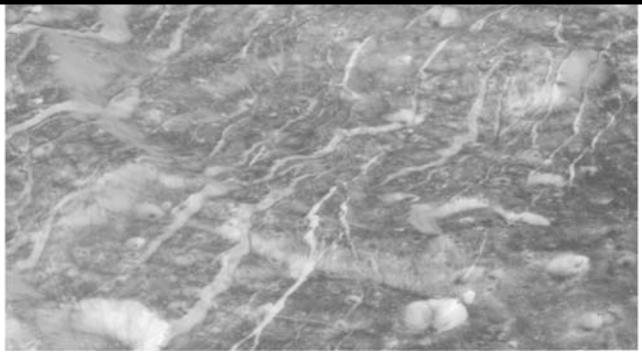
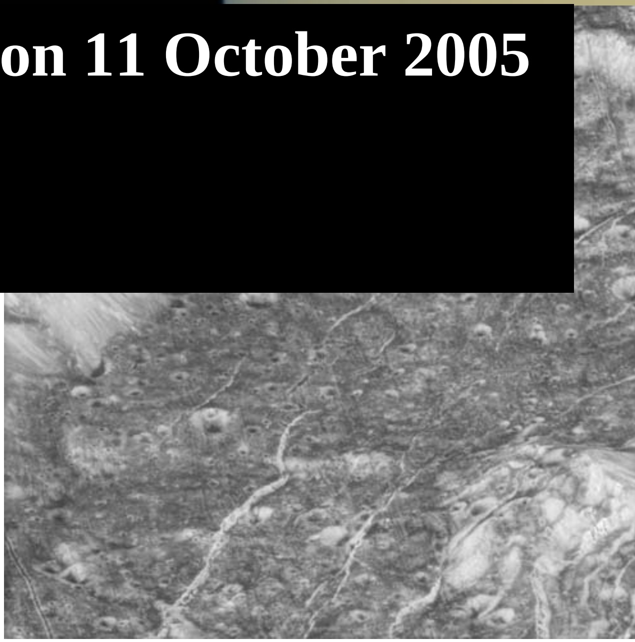


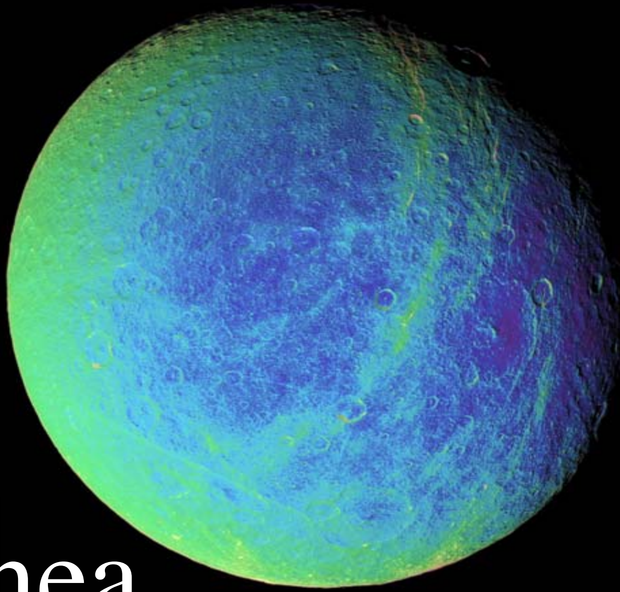
- **Closest flyby of nominal tour = 514 km on 26 Sept. 2005**
- **164 km x 130 km x 110 km**
- **http://saturn.jpl.nasa.gov/multimedia/videos/video-details.cfm?videoID=103**
- **http://saturn.jpl.nasa.gov/multimedia/videos/movies/PIA07742_full_movie2.mov**

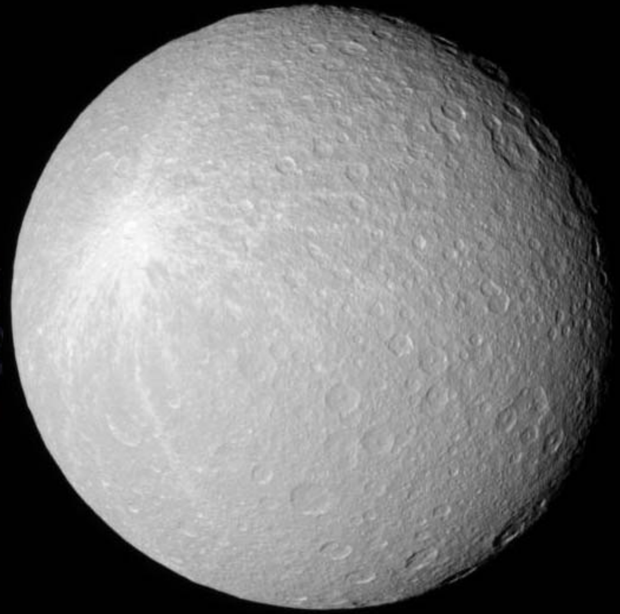
Dione

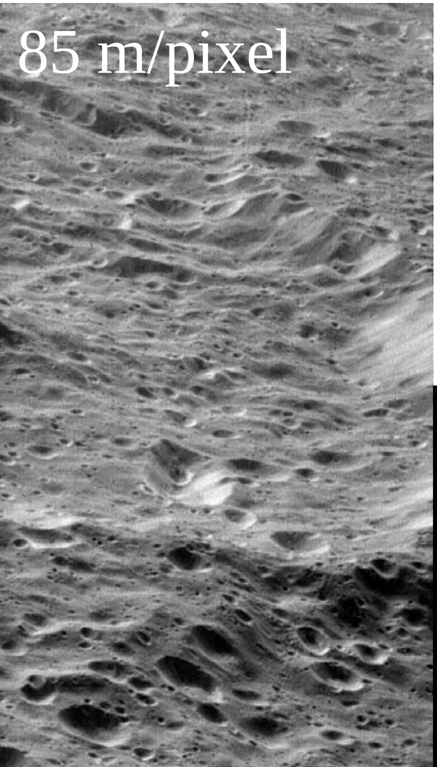

- **Closest flyby of nominal tour = 500 km on 11 October 2005**
- **1120 km diameter**
- **Geologically young fractures**

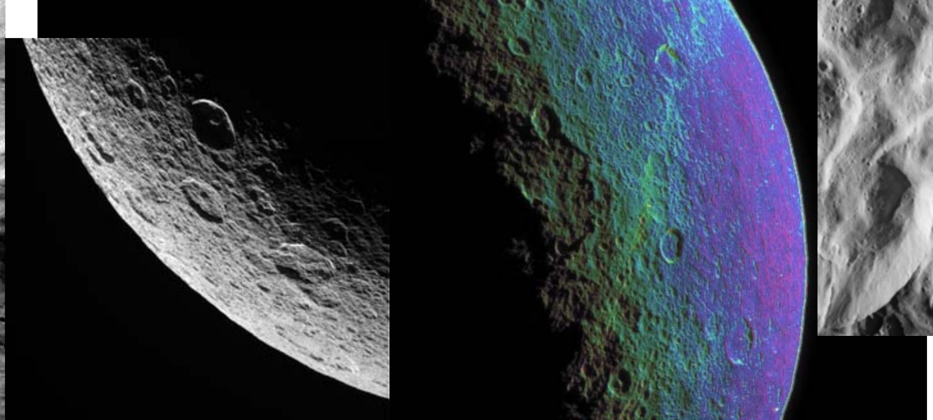


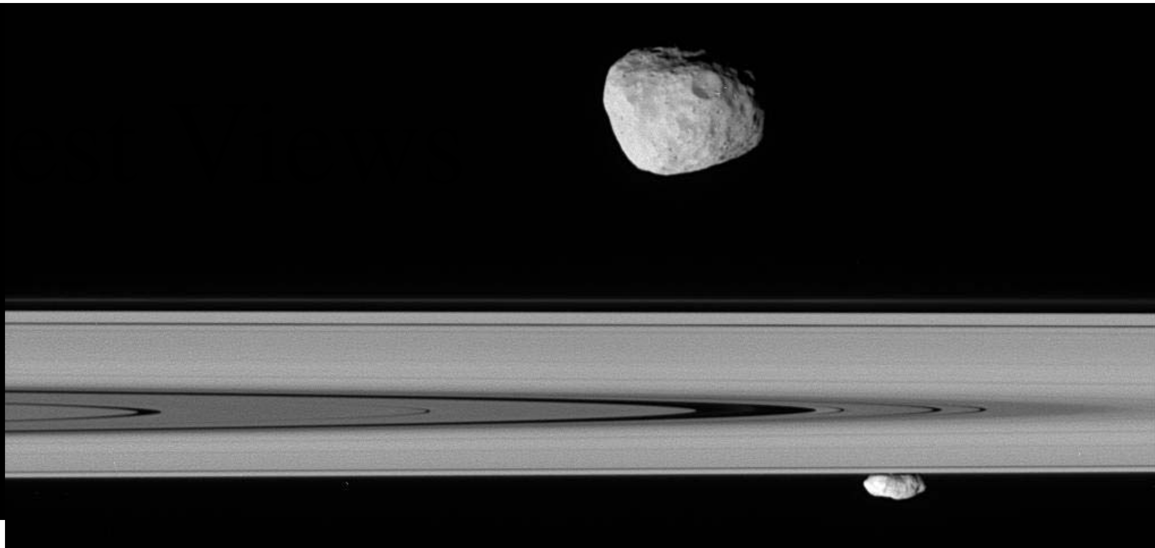


Rhea

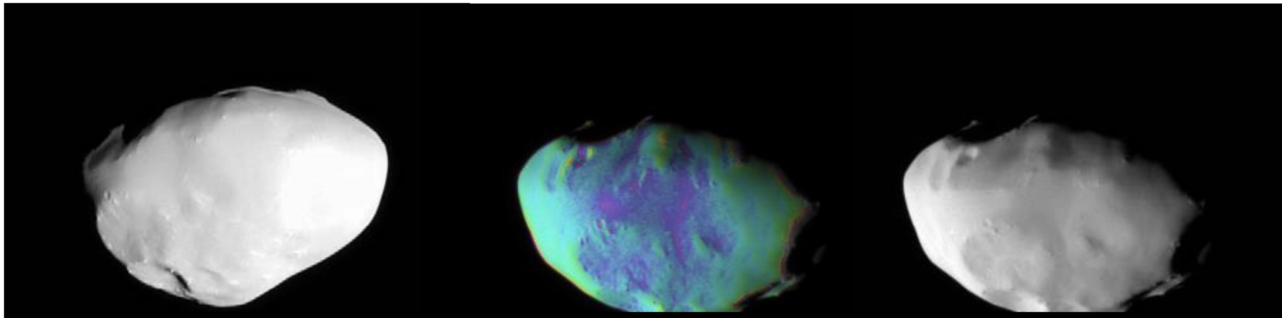


- **Closest flyby of nominal tour = 500 km on 26 November 2005**
- **1526 km diameter**





Janus, 150-190 km, co-orbital with Epimetheus
Prometheus; 60-145 km ; inner F-Ring shepherd
218,000 and 236,000 km, 29 April 2006



Telesto, 28-36 km across, leading Tethys Trojan
14,500 km, 11 Oct. 2005 and 20,000 km, 25 Dec. 2005

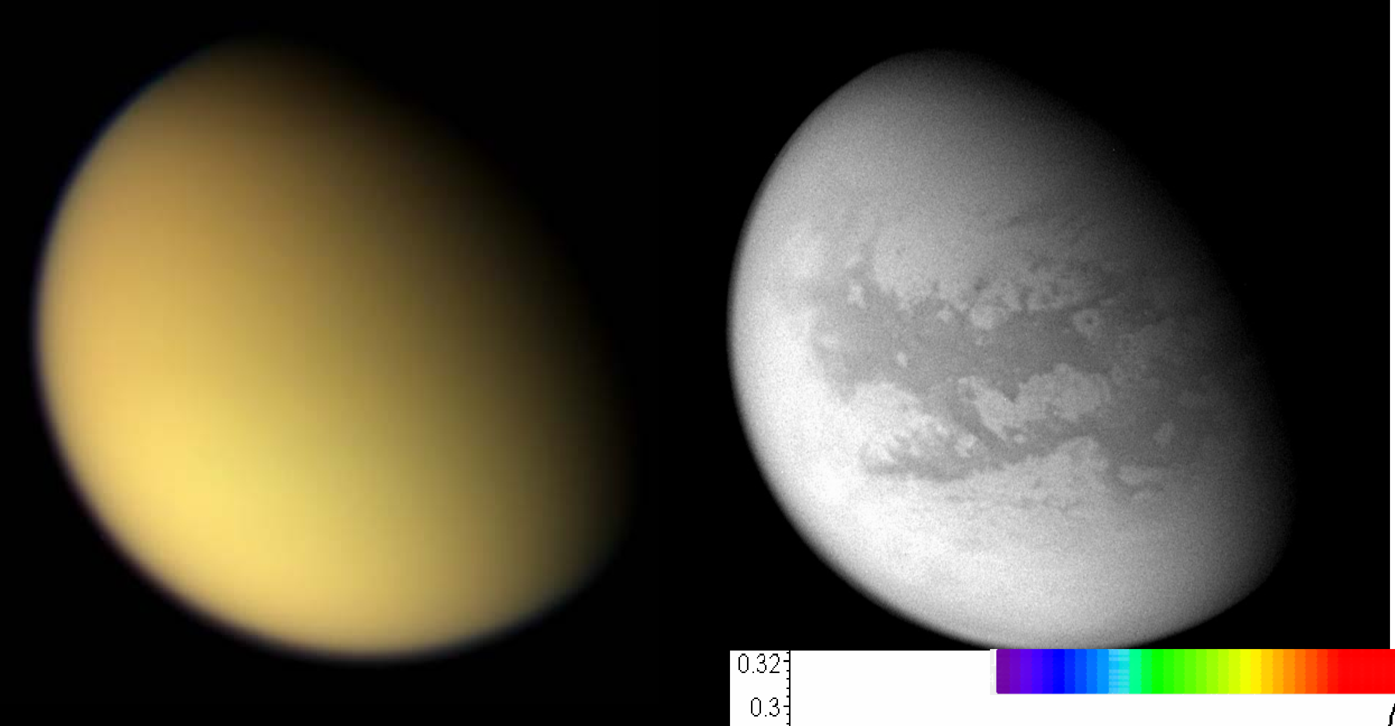
Titan

- Titan is the largest satellite of Saturn, and the second largest moon in the solar system. It is larger than the planets Mercury and Pluto.
- The bulk density of Titan is ~1.8 g/cm^3, and D=5, 150 miles.
- Titan has the second-densest atmosphere of the solid bodies of the solar system (1) Venus (2) Titan (3) Earth (4) Mars.
  - It consists basically of nitrogen-methane → organic chemistry
  - Hydrocarbons cover the surface
- The surface P,T=1.5bars, 95K
- The surface is covered in frozen water, modified by impact cratering, erosion, tectonics, and volcanism
  - BUT another molecule on Titan acts just like water on the Earth - that molecule is methane (CH_4)

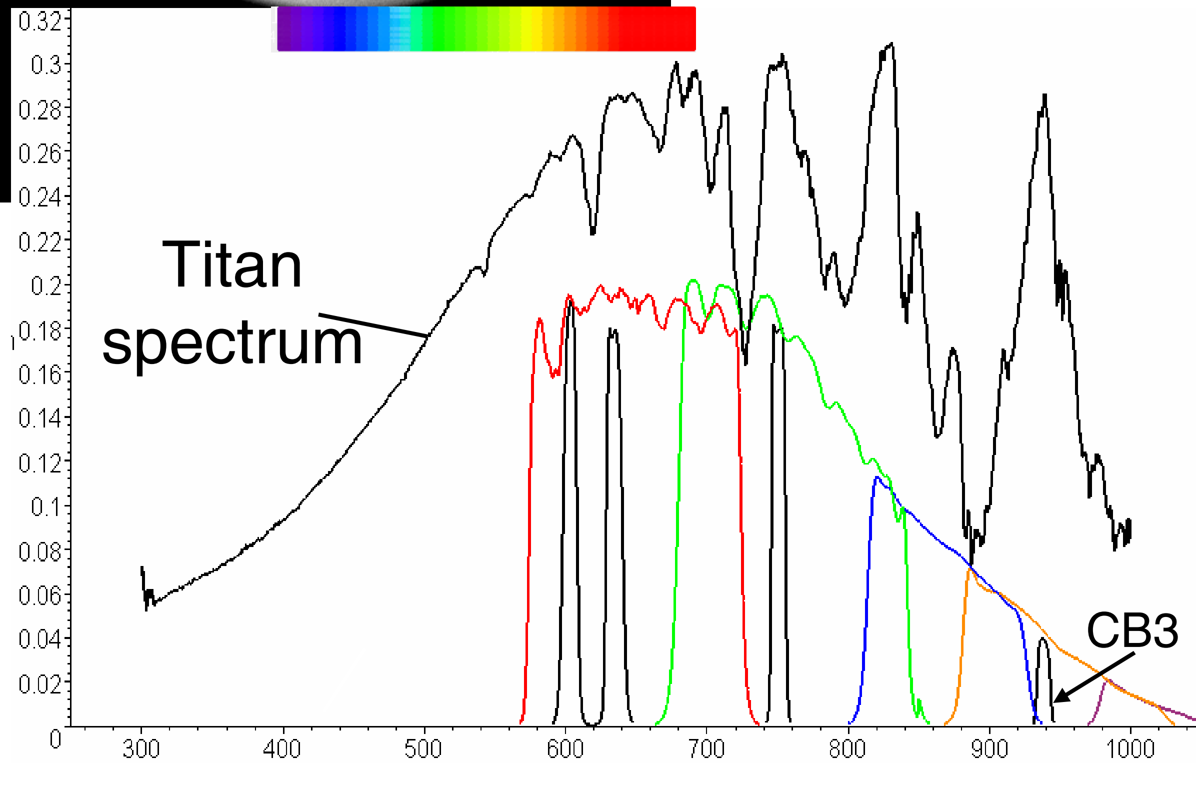
Titan Encounters

T0 (000)	~341,000	2 July 2004
TA (00A)	1200	26 October 2004
TB (00B)	1200	13 December 2004
TC (00C)	62575	14 January 2005
T3 (003)	1577	15 February 2005
T4 (005)	2523	31 March 2005
T5 (006)	1025	16 April 2005
T6 (013)	3669	22 August 2005
T7 (014)	1025	7 September 2005
T8 (017)	1458	27 October 2005
T9 (019)	10562	26 December 2005
T10 (020)	2068	15 January 2006
T11 (021)	1836	27 February 2006
T12 (022)	1951	18 March 2006
T13 (023)	1859	30 April 2006
T14 (024)	1879	20 May 2006

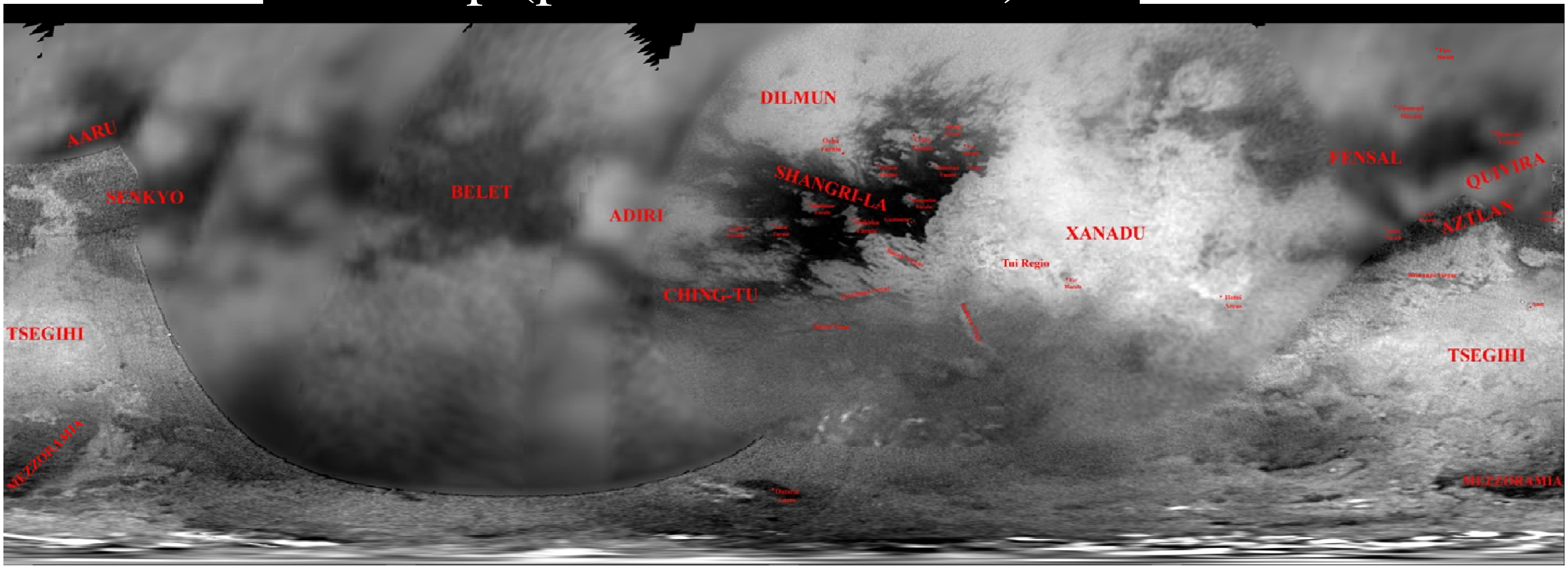
@ 938 nm

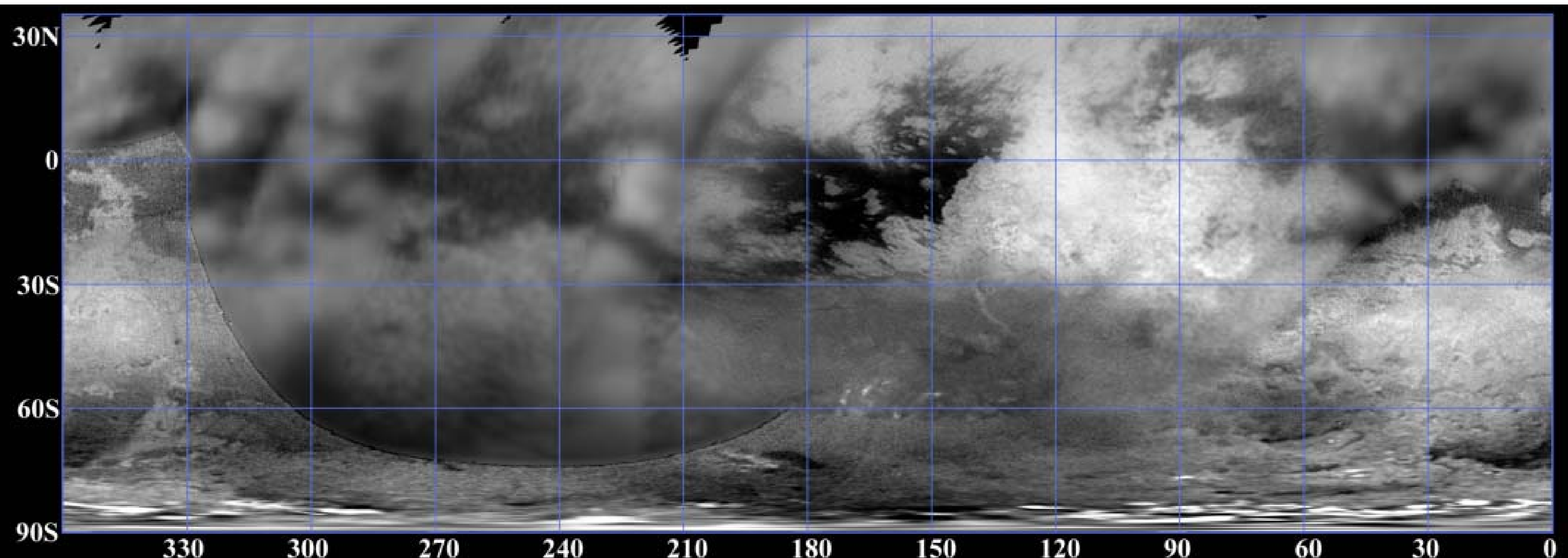


22 August 2005 (T06)

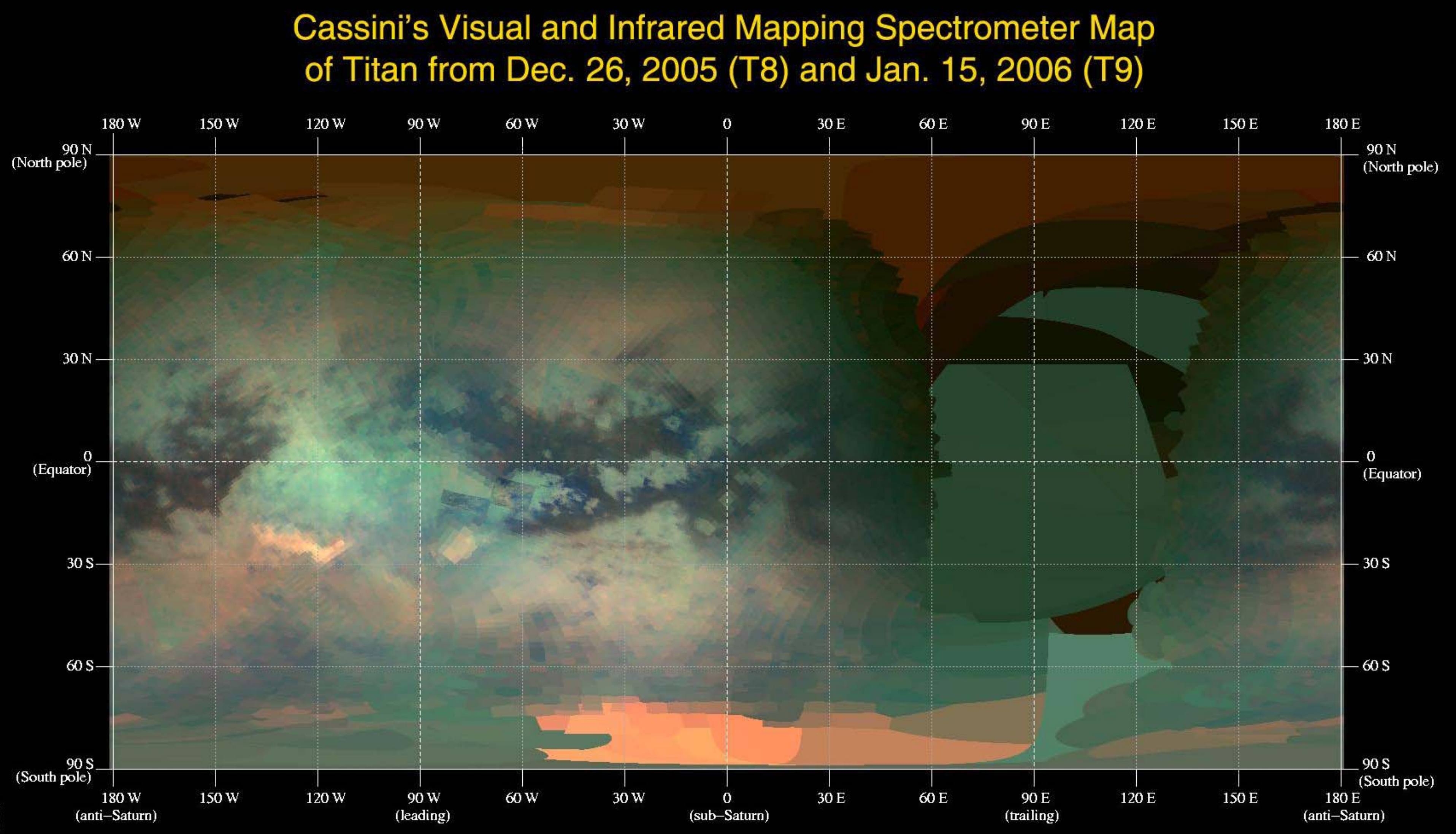


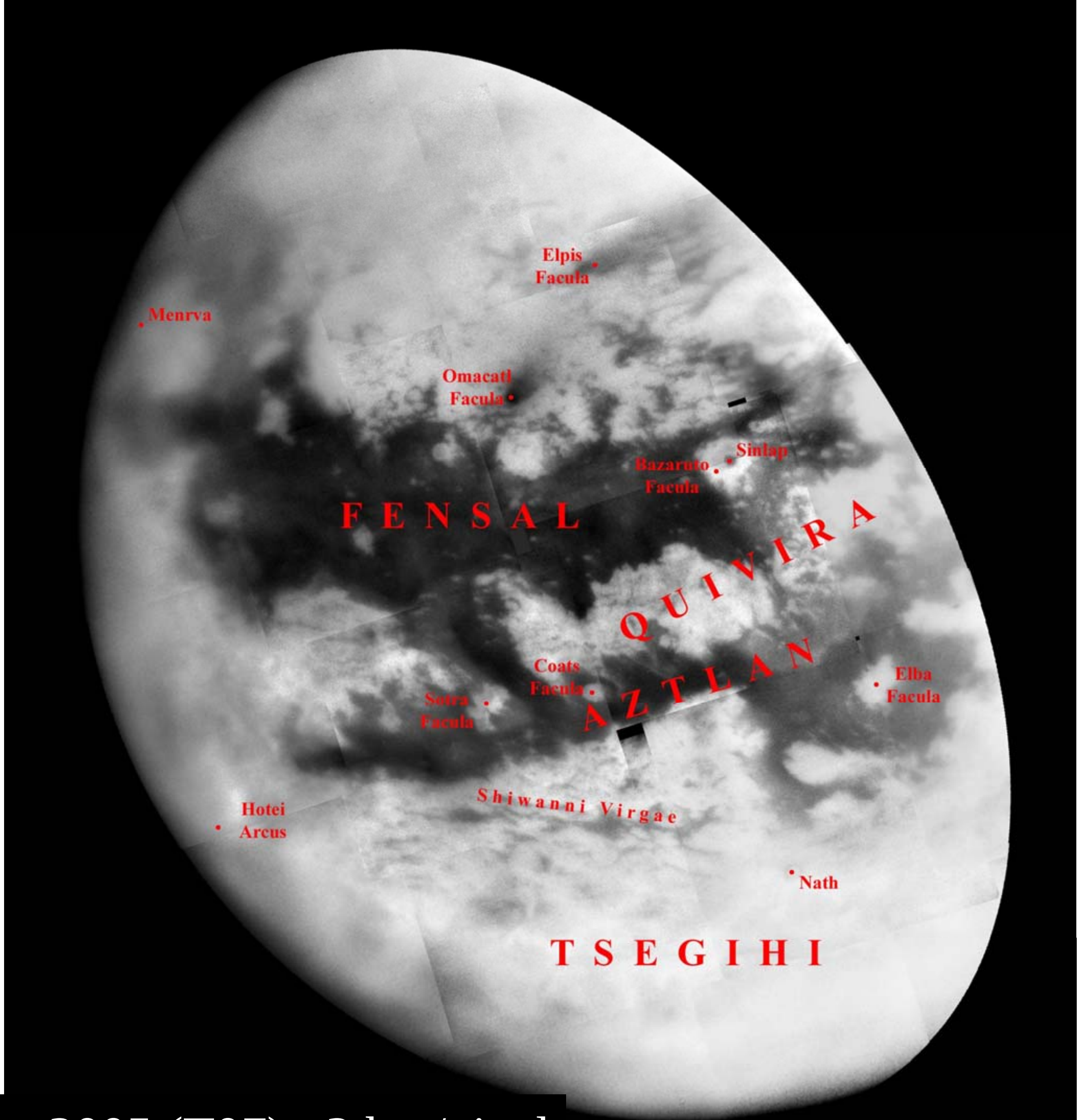
ISS map (provisional names)



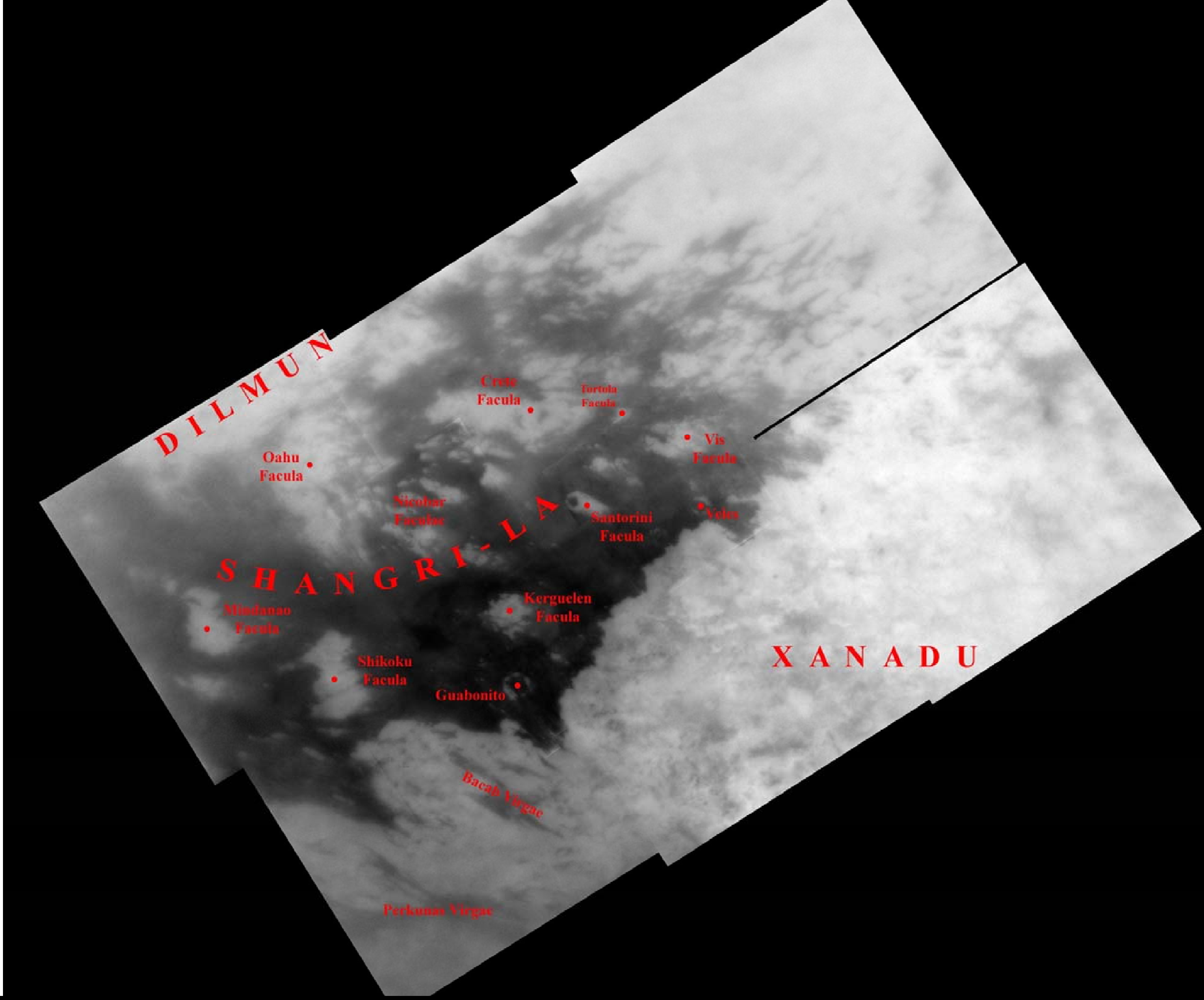


VIMS map (r = 5 μm; g = 2 μm; b = 1.6 μm)





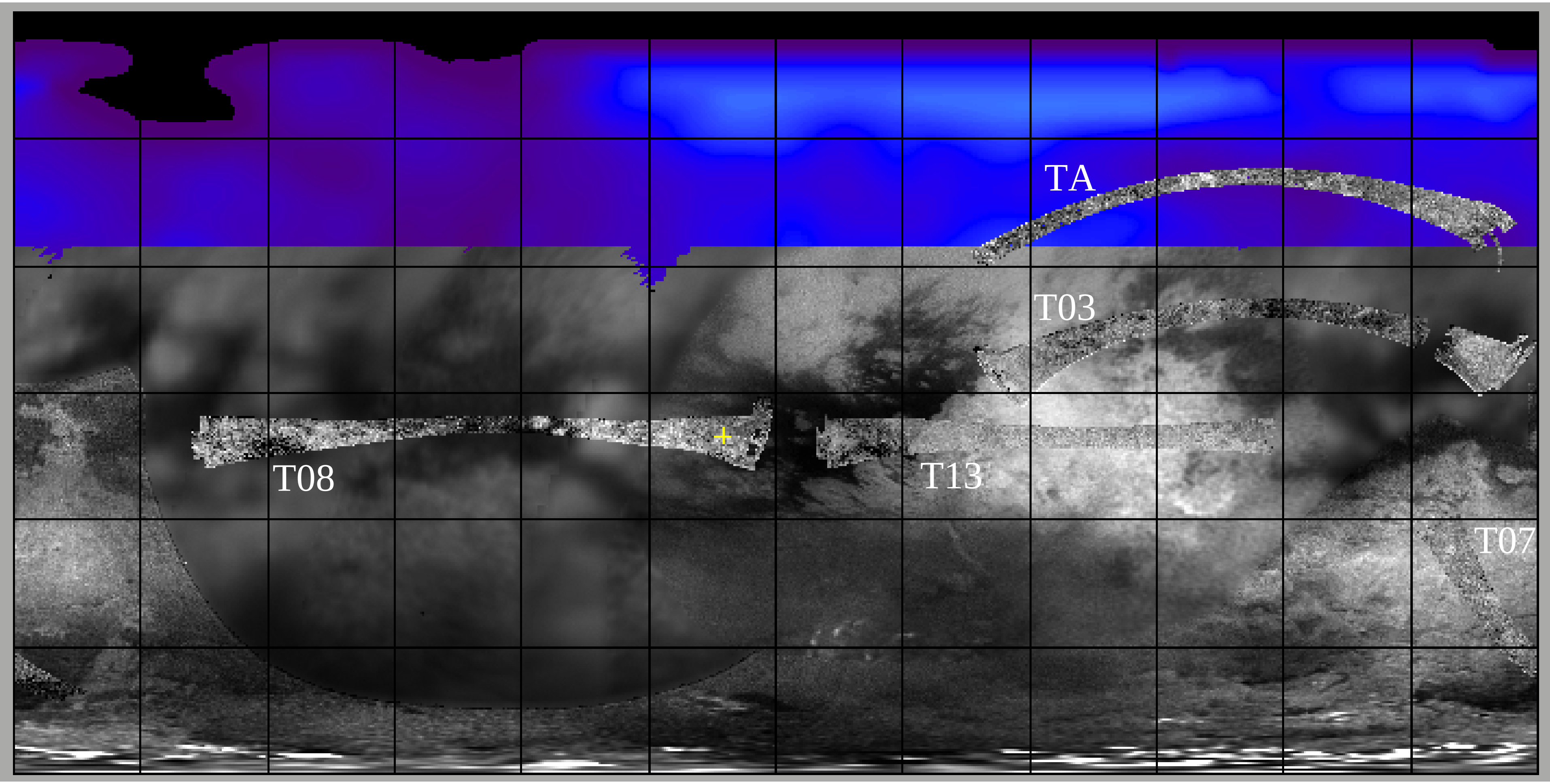
7 September 2005 (T07) ~2 km/pixel



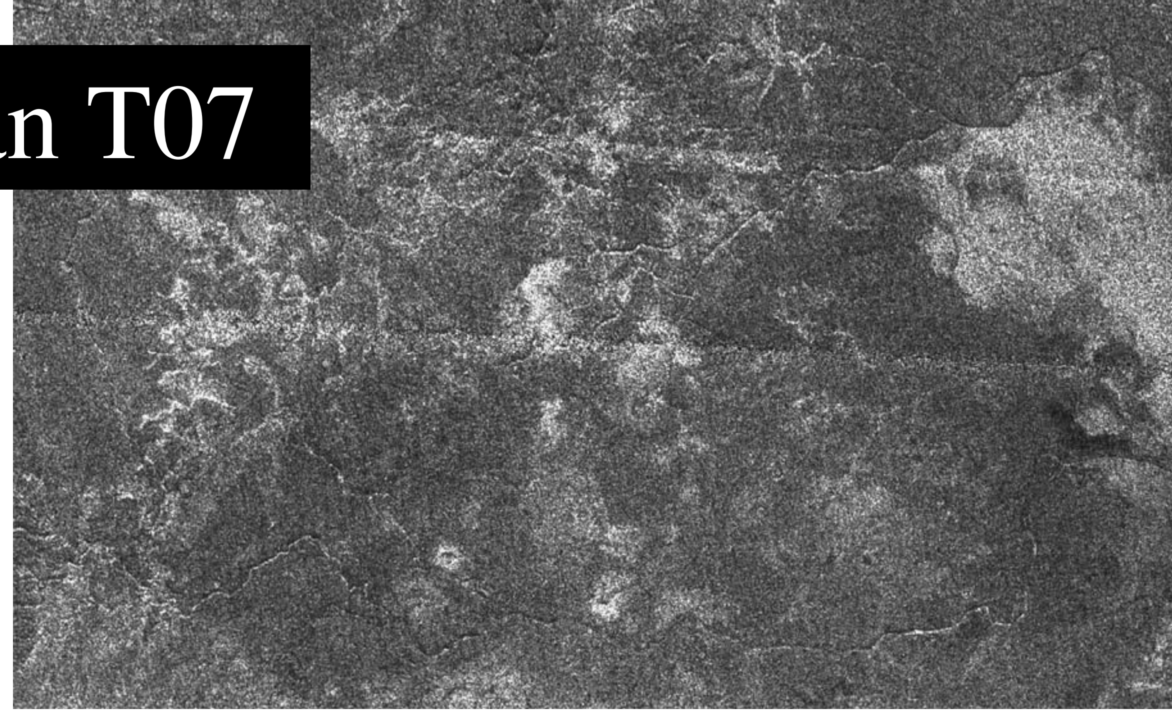
28 Oct. 2005 (T08) ~1 km/pixel

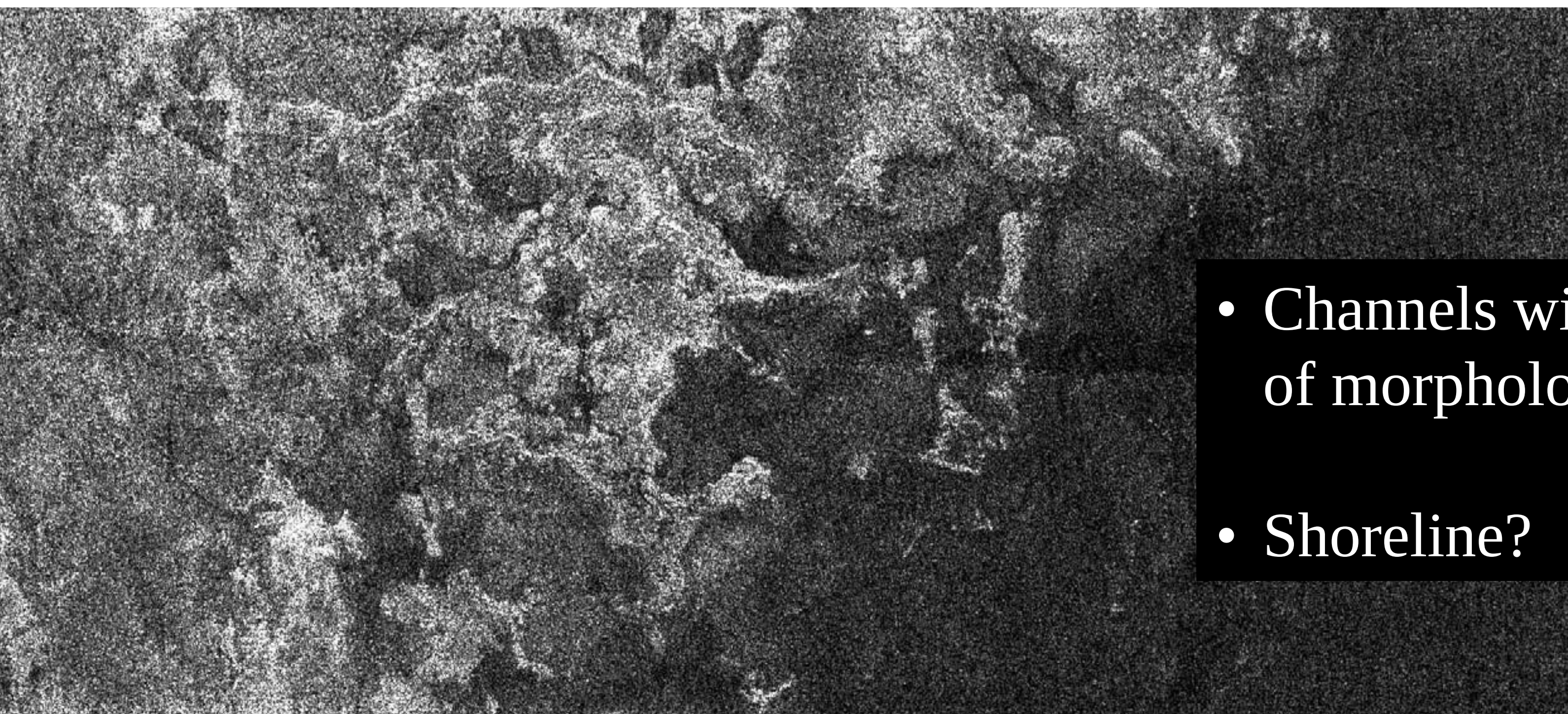
Titan

- *Cassini* RADAR SAR (synthetic aperture radar) coverage



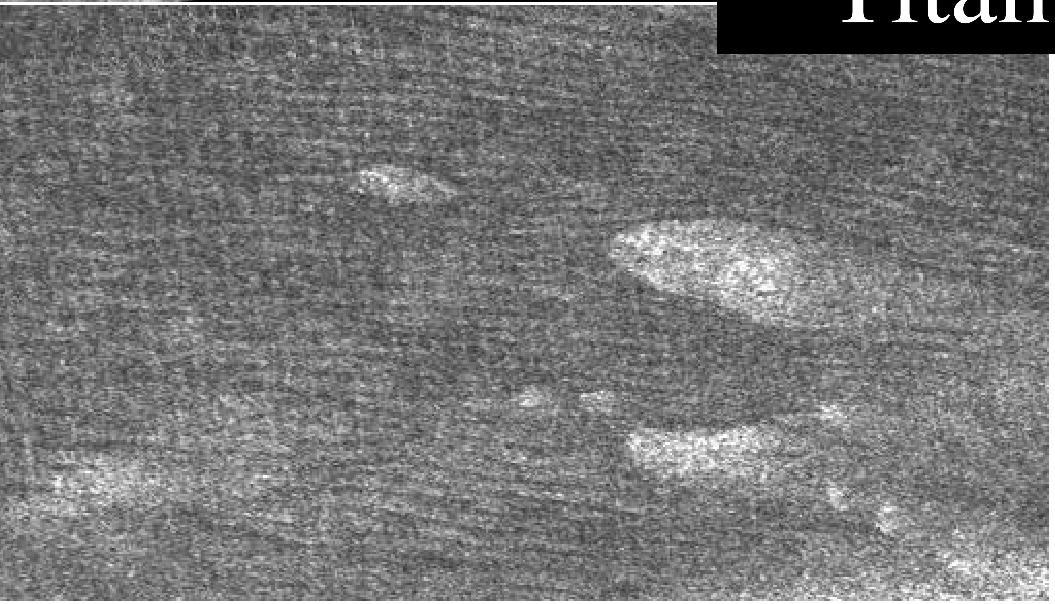
Titan T07

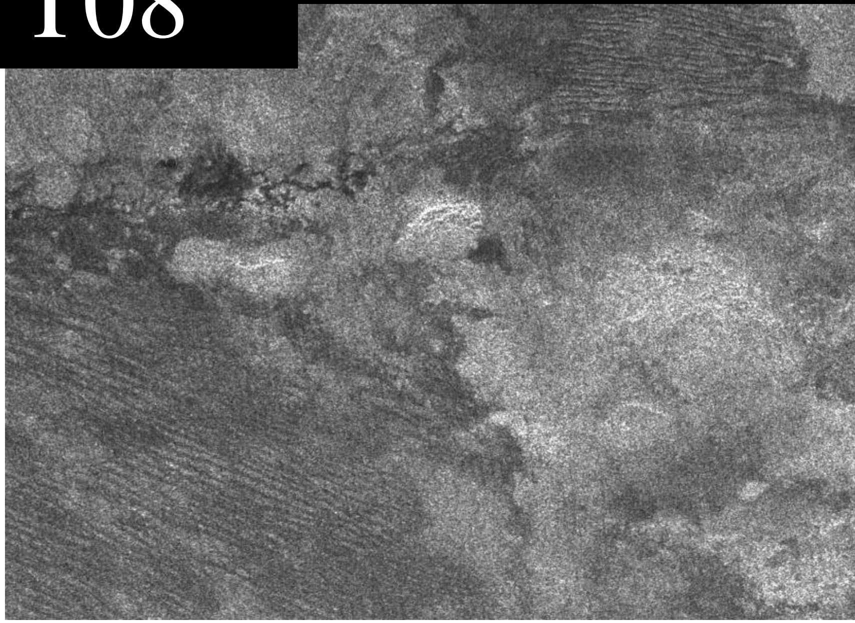




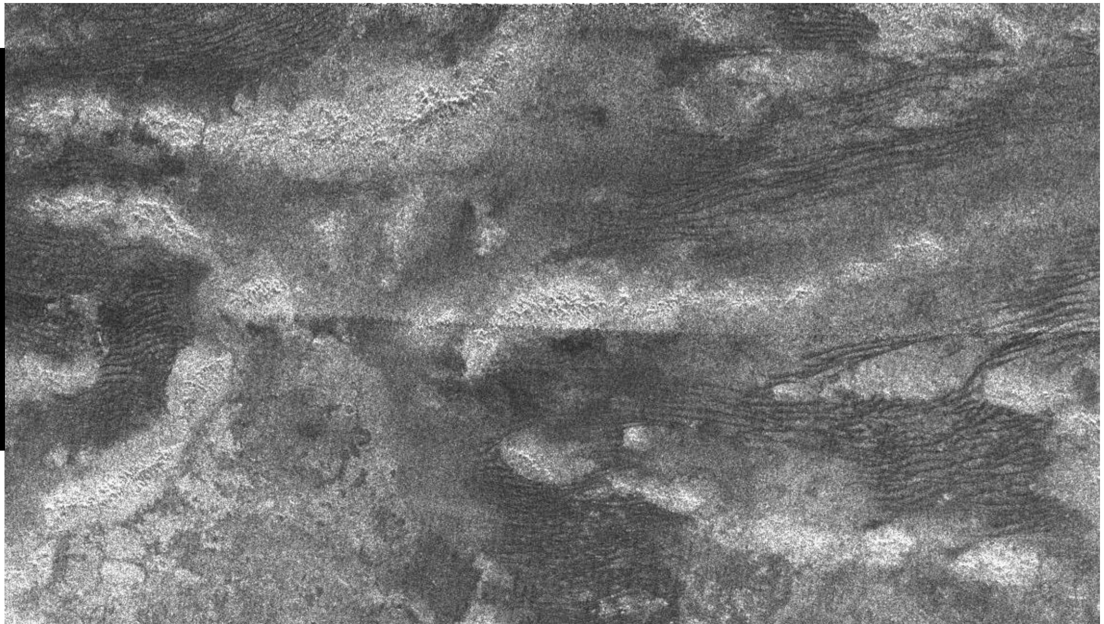
- Channels with variety of morphologies
- Shoreline?

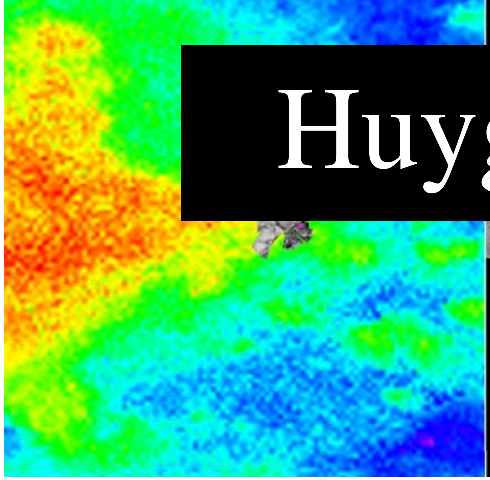
Titan T08

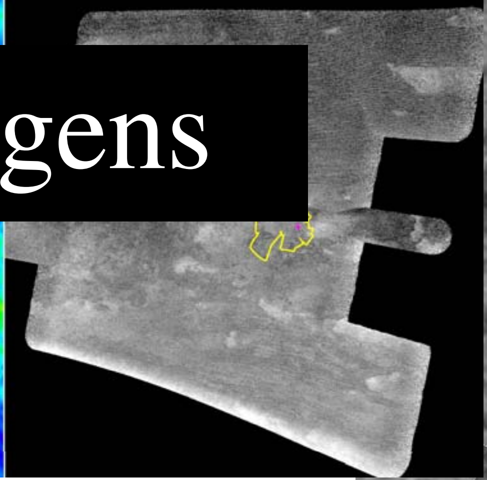


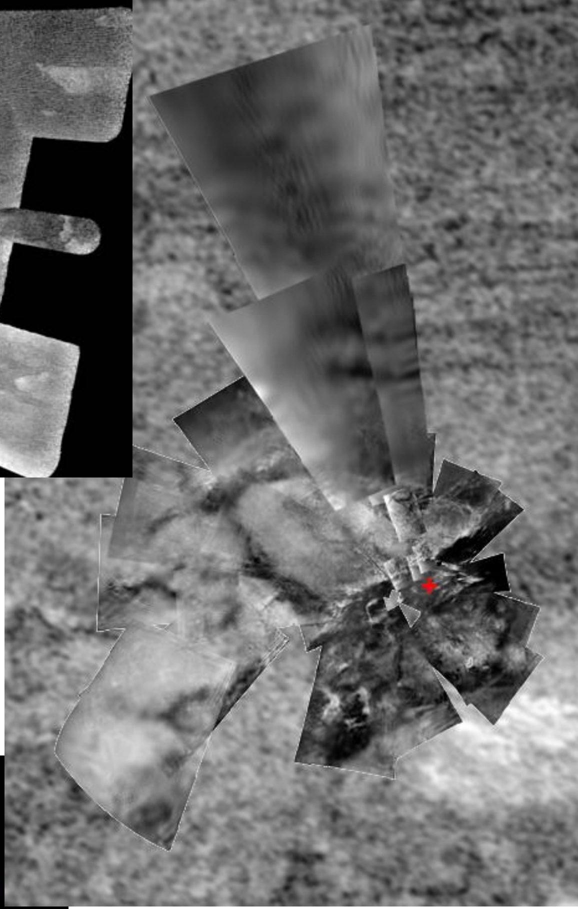


- Dunes
- Mountain chains
- *Huygens* landing site



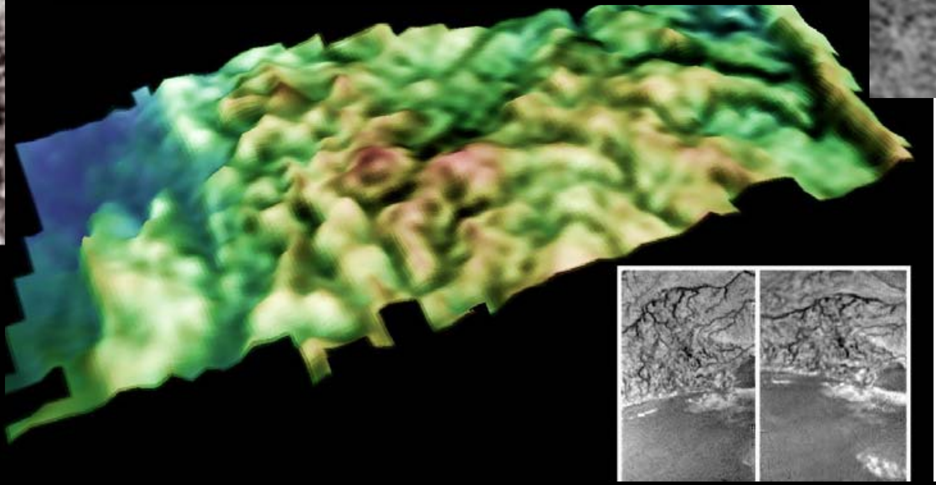






Huygens

- Landing site identification in orbiter data sets (T08 RADAR SAR)
- Ongoing analyses



http://saturn.jpl.nasa.gov/multimedia/videos/video-details.cfm?videoID=117

http://saturn.jpl.nasa.gov/multimedia/videos/movies/pia08118-320-cc.mov

Titan T13

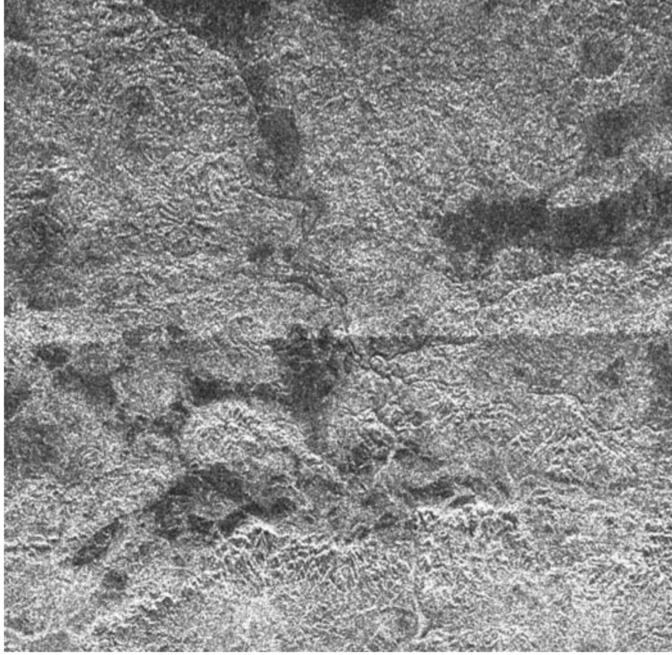
Xanadu

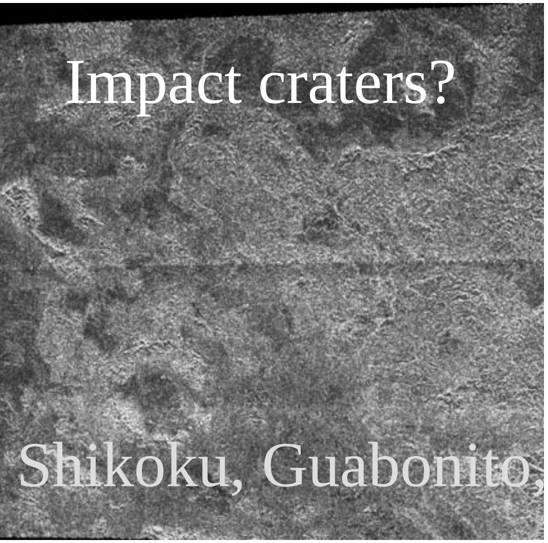
Mountains

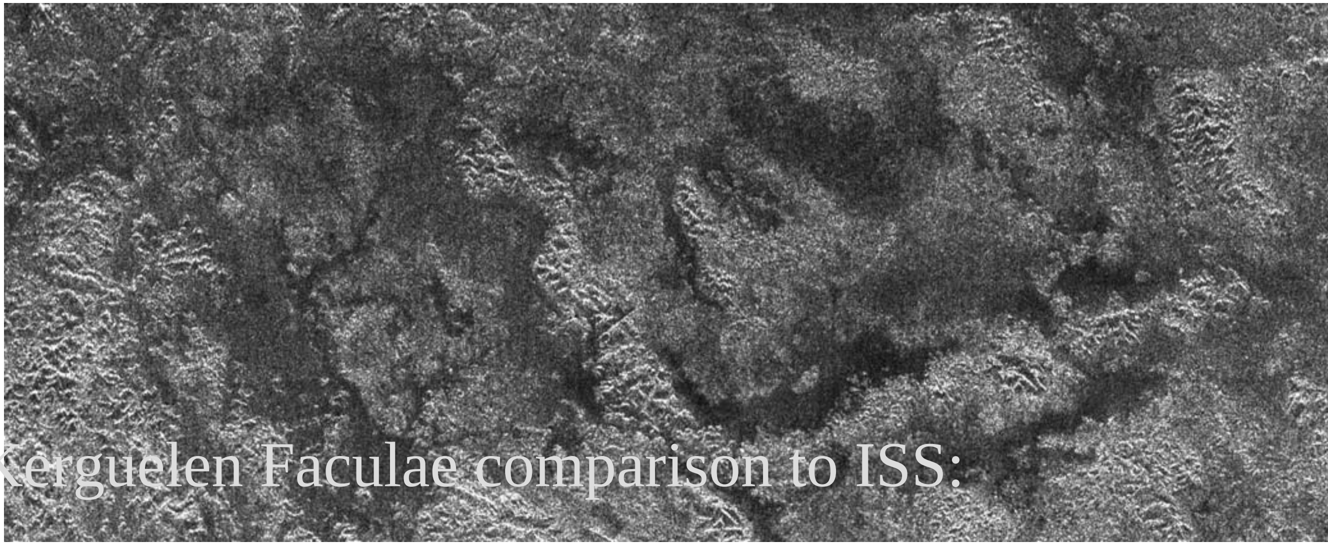
Channels

Impact craters?

Shikoku, Guabonito, Kerguelen Faculae comparison to ISS:







Titan Surface RADAR and ISS Movie

http://saturn.jpl.nasa.gov/multimedia/videos/video-details.cfm?videoID=115

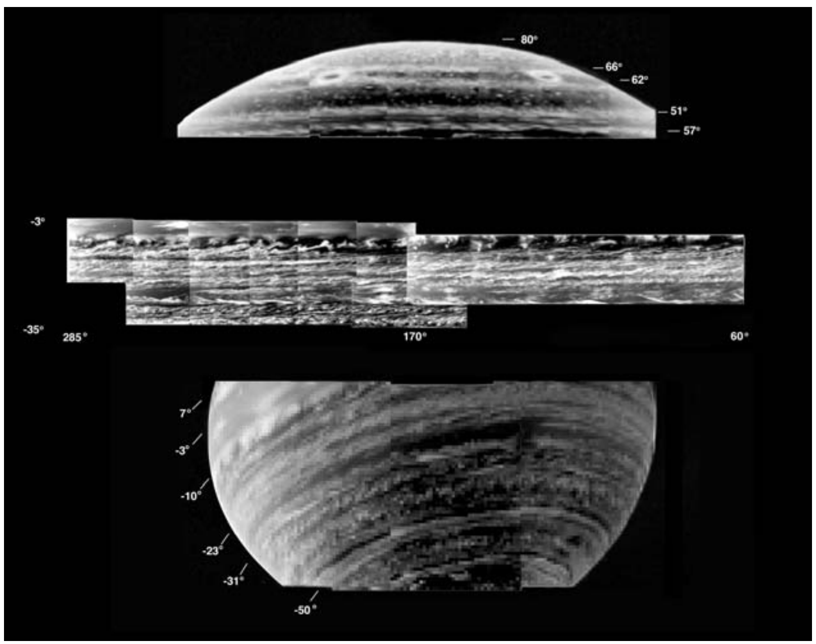
http://saturn.jpl.nasa.gov/multimedia/videos/movies/PIA07785_full_movie.mov

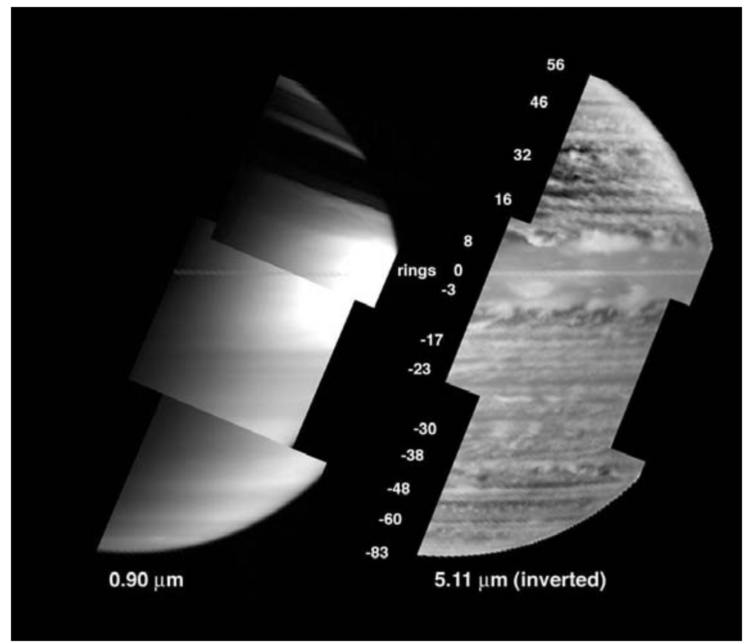
Saturn

- Saturn is the 6th planet from the Sun. It is a giant gas planet, the 2nd largest in the solar system.
- Known since ancient times it is named after the Roman god of agriculture (Greek god “Cronus”), and “Saturday” is the only day of the week to retain it’s Roman origin in the English language.
- Saturn consists mostly of Hydrogen (H) and Helium (He), and has a density of .7 g/cm^3 (less than that of water).
- Saturn’s atmosphere exhibits a banded pattern similar to Jupiter, but the bands are much fainter and wider.
- Saturn’s winds are the fastest in the solar system.

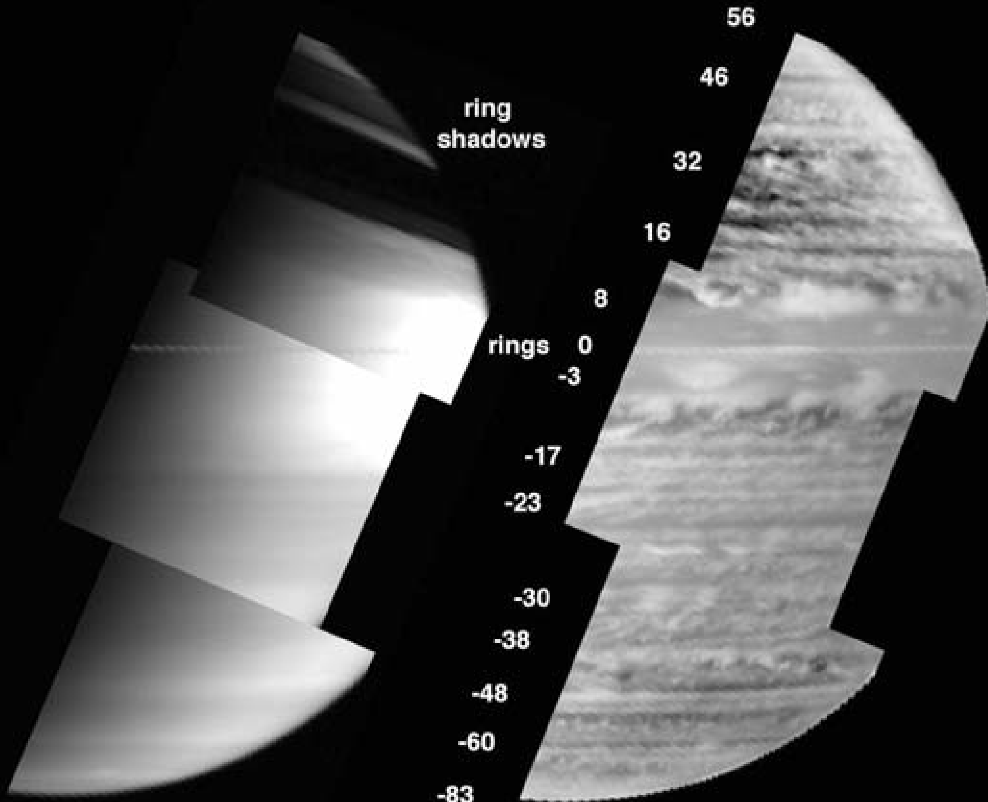
Science Highlights - Deep Atmosphere

- New images provided by the visual infrared mapping spectrometer on the Cassini spacecraft reveal a diverse array of clouds in the depths of Saturn. This new view was obtained at the 5-micron wavelength, using Saturn's own thermal radiation emanating from Saturn's interior as the light source instead of the Sun. Clouds at the 2-bar depth block this upwelling radiation to varying degrees, depending on the thickness of the cloud. These clouds are about 30 kilometers (19 miles) underneath the clouds usually observed on Saturn. This is distinctly different from the typical view of Saturn in reflected sunlight (see colorized image on the right).





The Depths of Saturn Revealed by Cassini/VIMS



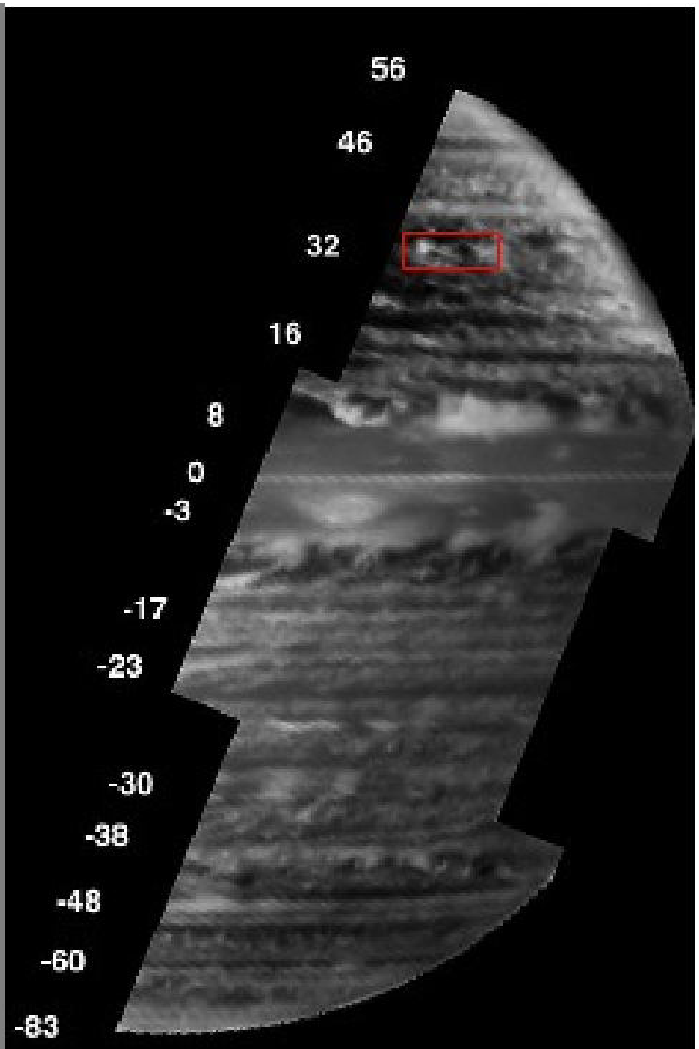
0.90 μm
Reflected Sunlight from Cloudtops

5.11 μm (inverted)
Thermal Heat Blocked by Deep Clouds (white)

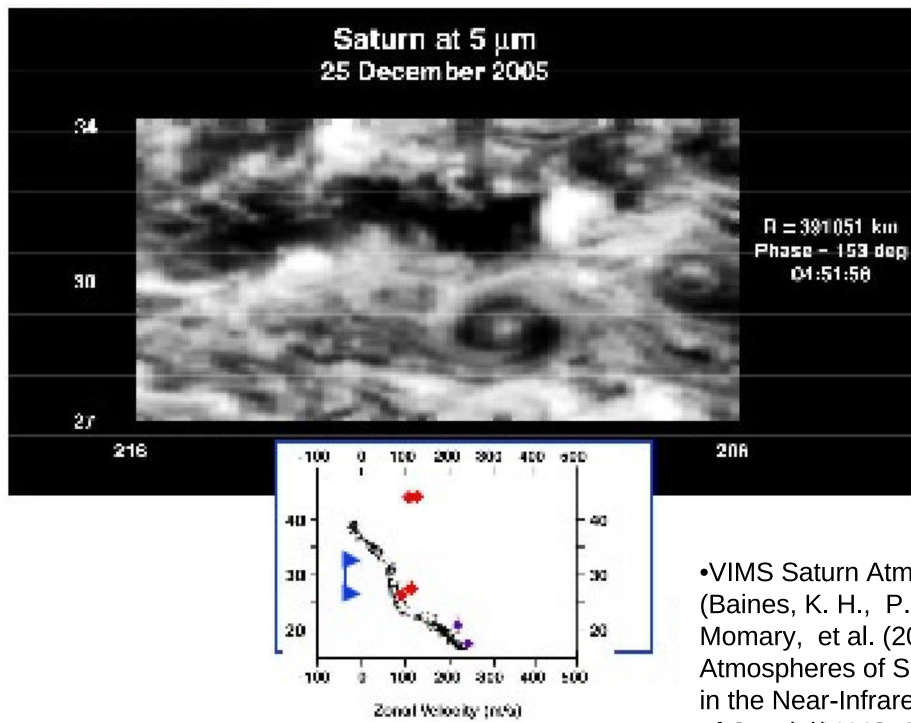
- First views of Saturn's deep clouds below the 1 bar level
- New dynamical regime discovered in the 2-3 bar region
- Equatorial Region displays surprisingly dynamic cloud structures hidden underneath overlying hazes
- Unusually fine zonal structures span nearly the entire globe
- New 5-micron imaging technique enables Saturn's deep-cloud meteorology to be imaged under both daytime and nighttime conditions

K.H. Baines and T.W. Momary

Science Highlights - Deeper into the Depths (VIMS)



• VIMS continues to discover new meteorologic features in the deep atmosphere, i.e., about 20 km underneath the ammonia hazes that obscure the underlying planet in the visual.
• These and other views seem to indicate that organized storm systems (ovals,circles, “donuts”, etc) correlate with relatively stagnant latitudinal wind shears (i.e, the winds are constant with latitude) as seen at the ammonia cloudtops, some 20 km above the discrete clouds seen here. This indicates that the latitudinally-stagnant winds extend on down to these levels as well.

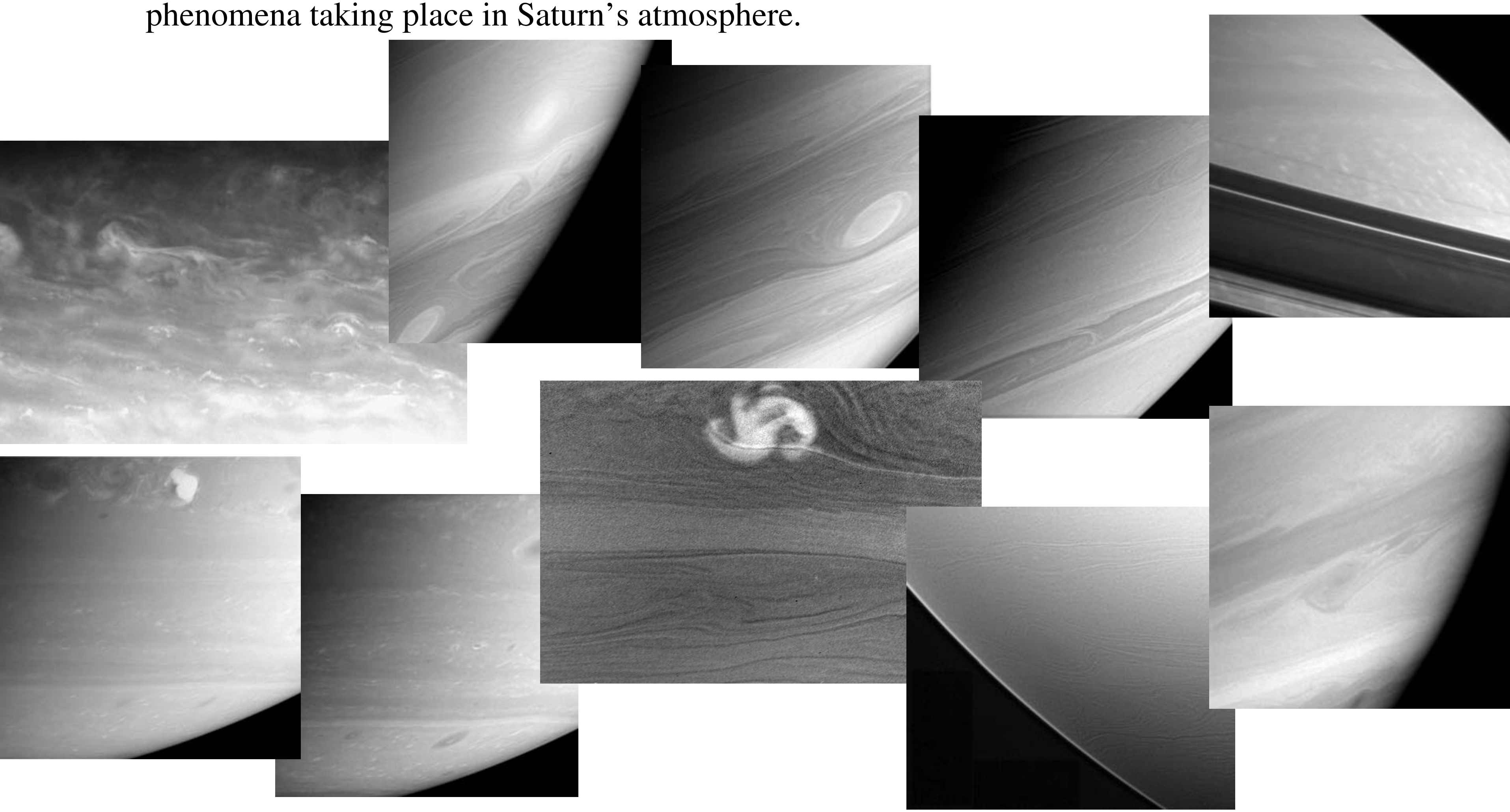


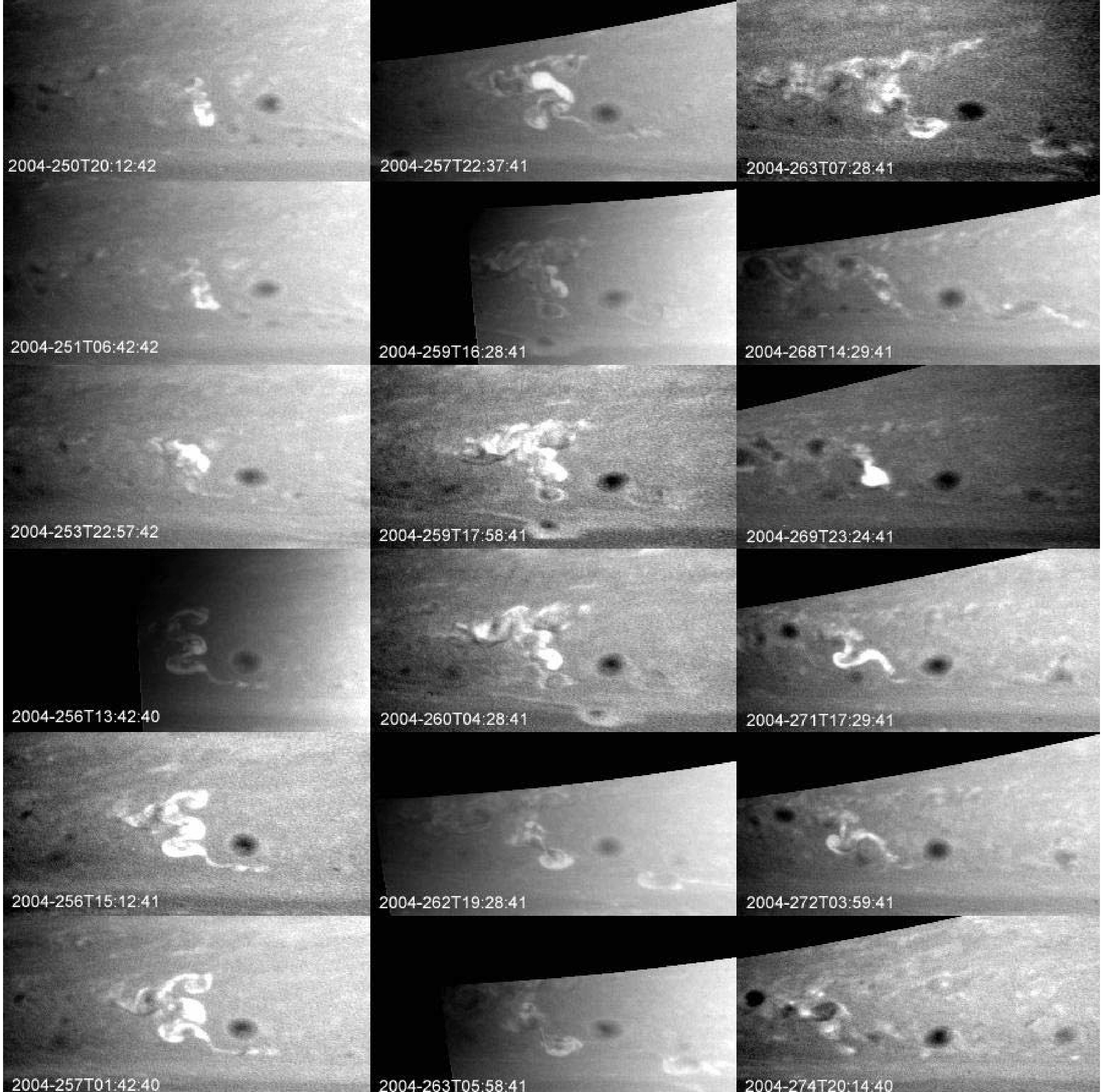
•VIMS Saturn Atmosphere (Baines, K. H., P. Drossart, T.W. Momary, et al. (2006). The Atmospheres of Saturn and Titan in the Near-Infrared: First Results of Cassini/VIMS. *Earth, Moon, and Planets* in press.)

S. Edgington, K.Baines, and A. Ingersoll

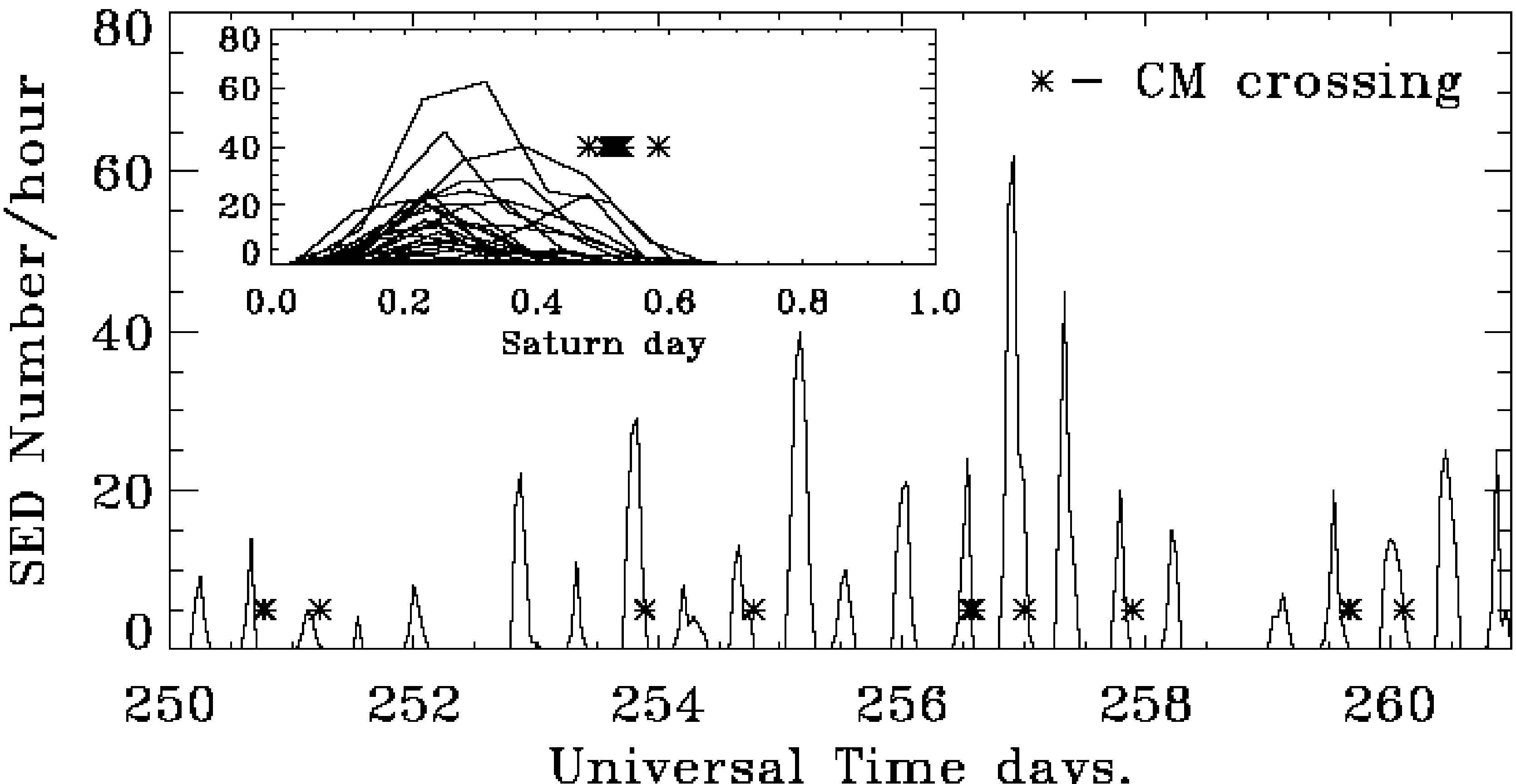
Science Highlights - Upper Level Clouds (ISS)

- This montage illustrates shows a remarkable number of different types of atmospheric phenomena taking place in Saturn’s atmosphere.



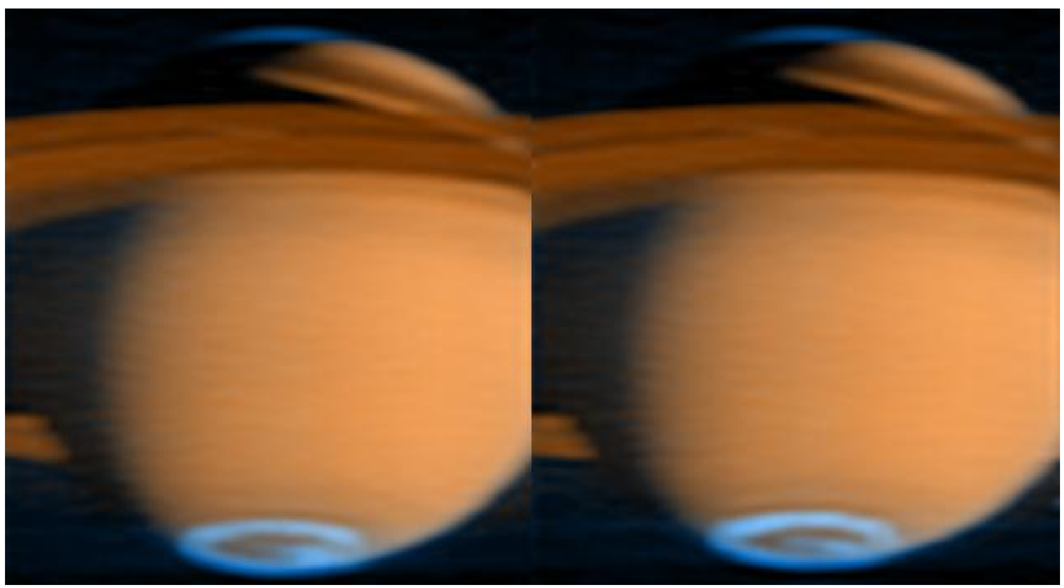

2004-250T20:12:42
2004-257T22:37:41
2004-263T07:28:41
2004-251T06:42:42
2004-259T16:28:41
2004-268T14:29:41
2004-253T22:57:42
2004-259T17:58:41
2004-269T23:24:41
2004-256T13:42:40
2004-260T04:28:41
2004-271T17:29:41
2004-256T15:12:41
2004-262T19:28:41
2004-272T03:59:41
2004-257T01:42:40
2004-263T05:58:41
2004-274T20:14:40

RPWS & ISS: Electrostatic discharges & storms



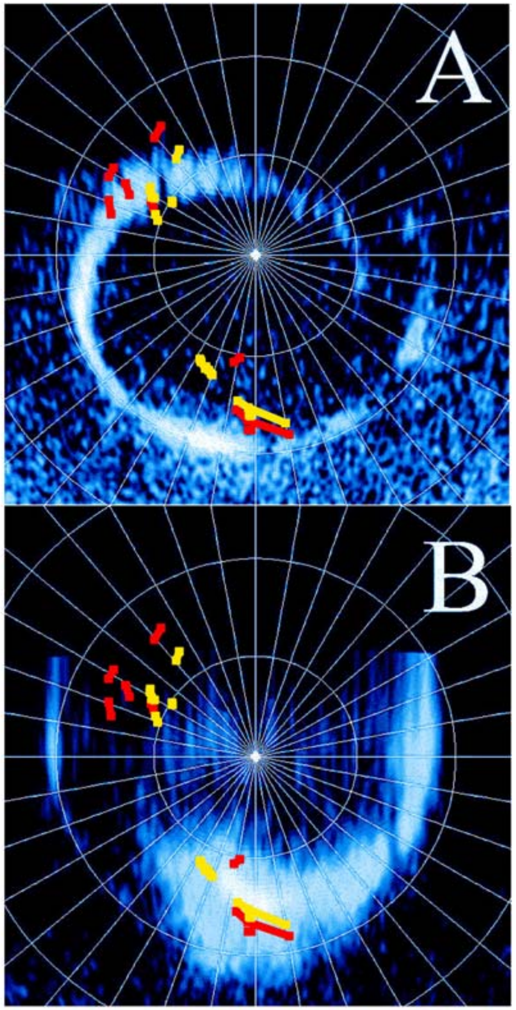
Science Highlights - Aurora

- Images taken on June 21, 2005, with Cassini's Ultraviolet Imaging Spectrograph (UVIS) are the first from the mission to capture the entire "oval" of the auroral emissions at Saturn's south pole. In the side-by-side, false-color images, blue represents aurora emissions from hydrogen gas excited by electron bombardment, while red-orange represents reflected sunlight. The images show that the aurora lights at the polar regions respond rapidly to changes in the solar wind. Changes in the emissions inside the Saturn south-pole aurora are visible by comparing the two images, taken about one hour apart. The brightest spot in the left aurora fades, and a bright spot appears in the middle of the aurora in the second image.



Saturn’s auroral emissions and field-aligned electron beams From MIMI Data (Saur et al, Nature, in press, 2006)

:



o Auroral Images by Gerard et al.[2004]

o Red: Beams mapped to Saturn with Khurana model

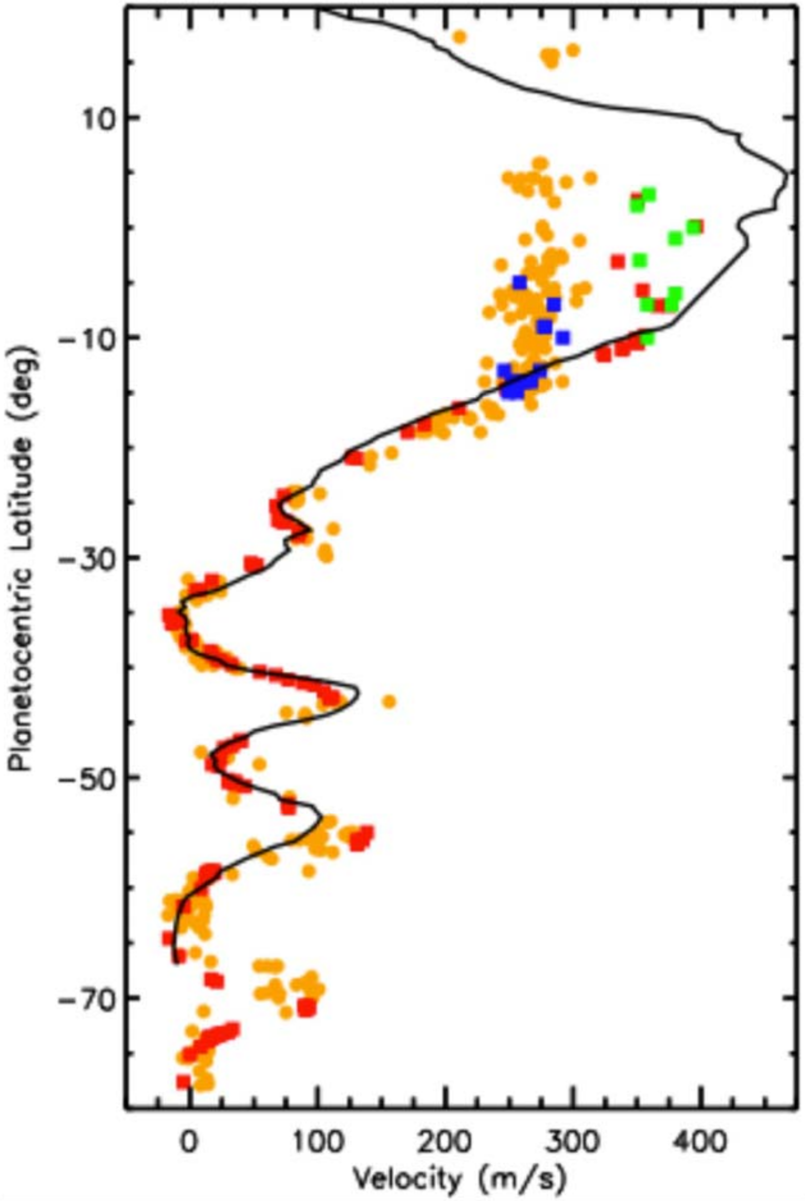
o Yellow: Mapped with dipole model

Line: Voyager

Yellow: HST

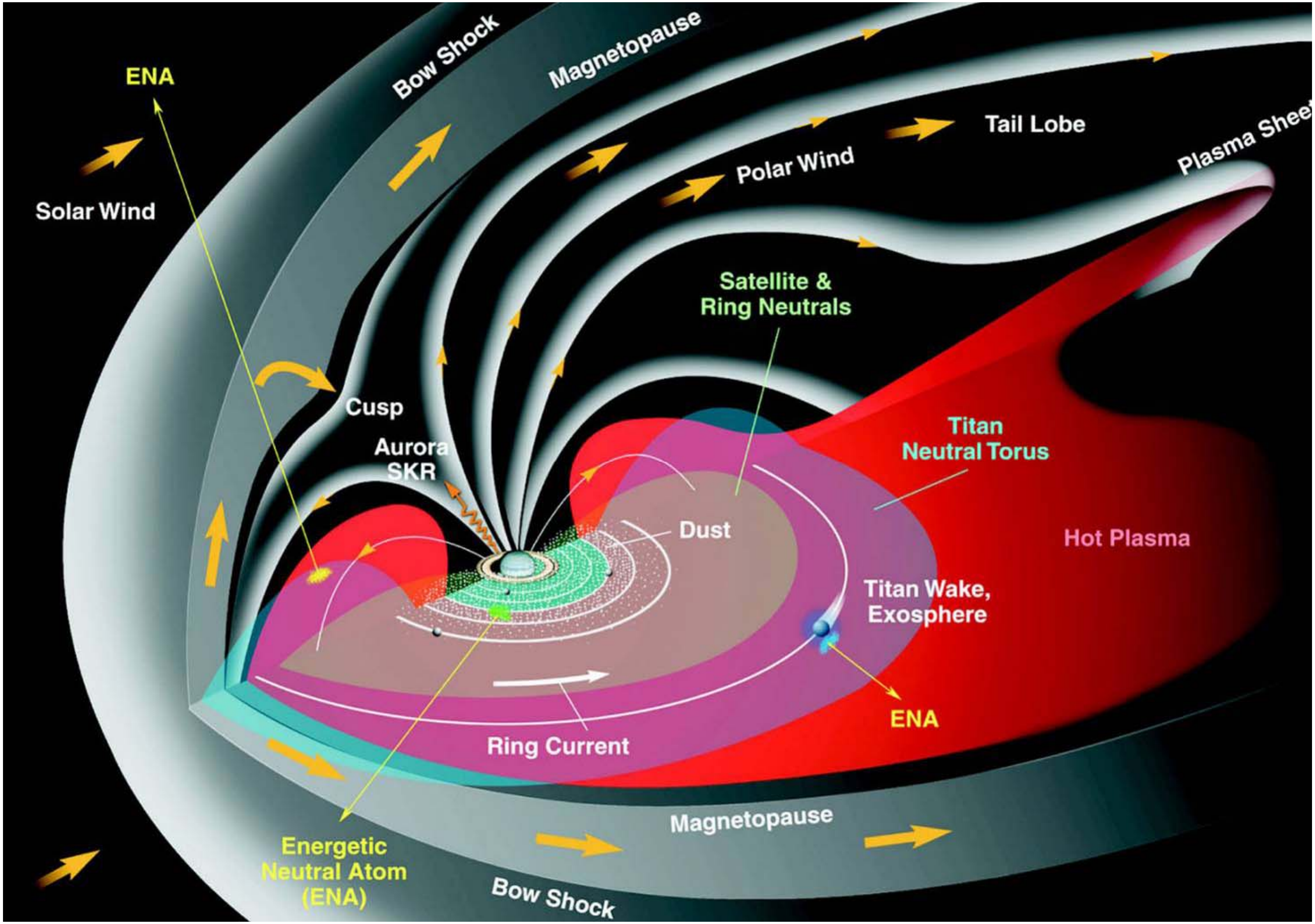
Red & Green: ISS Cassini continuum

Blue: ISS Cassini methane



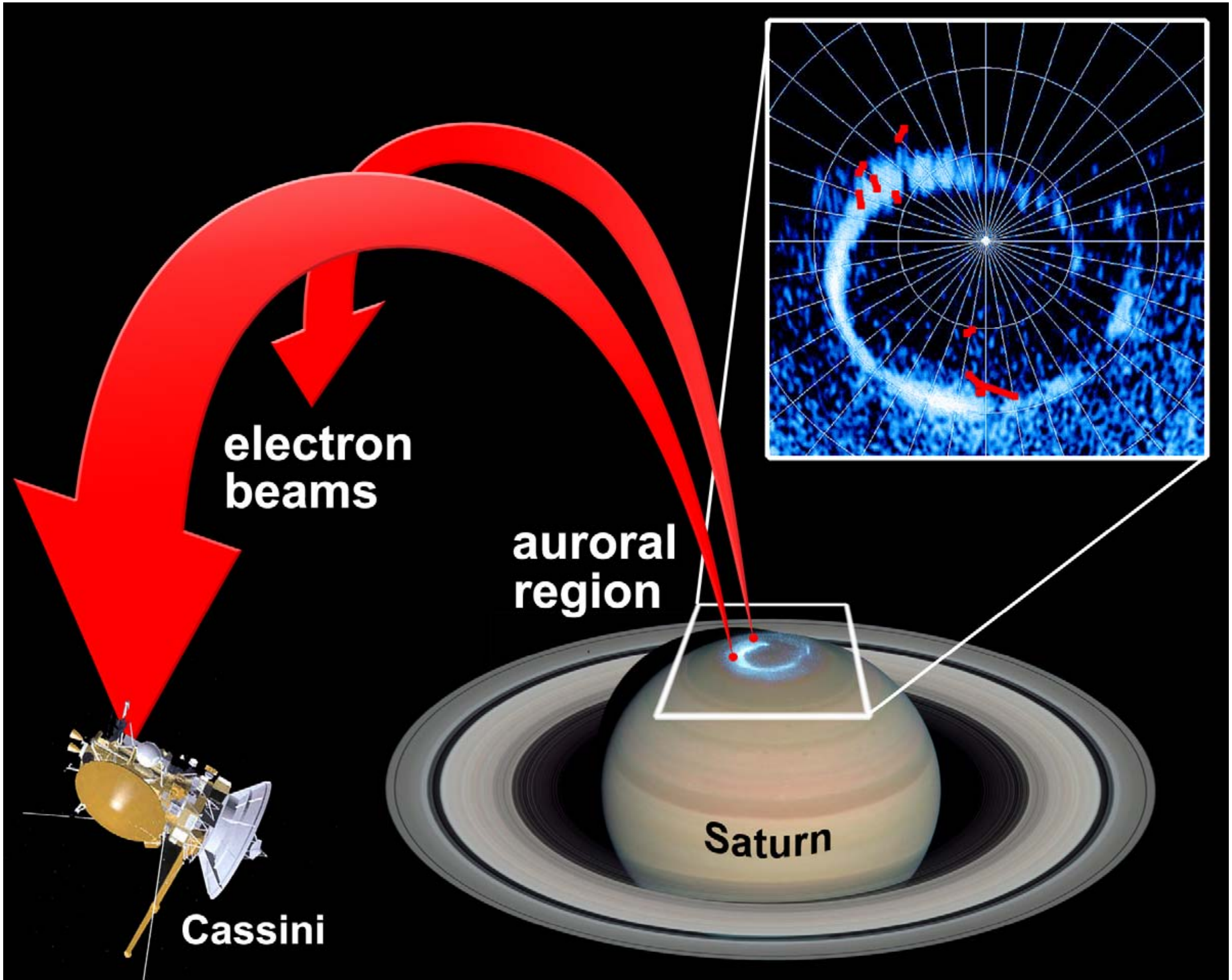
Magnetosphere

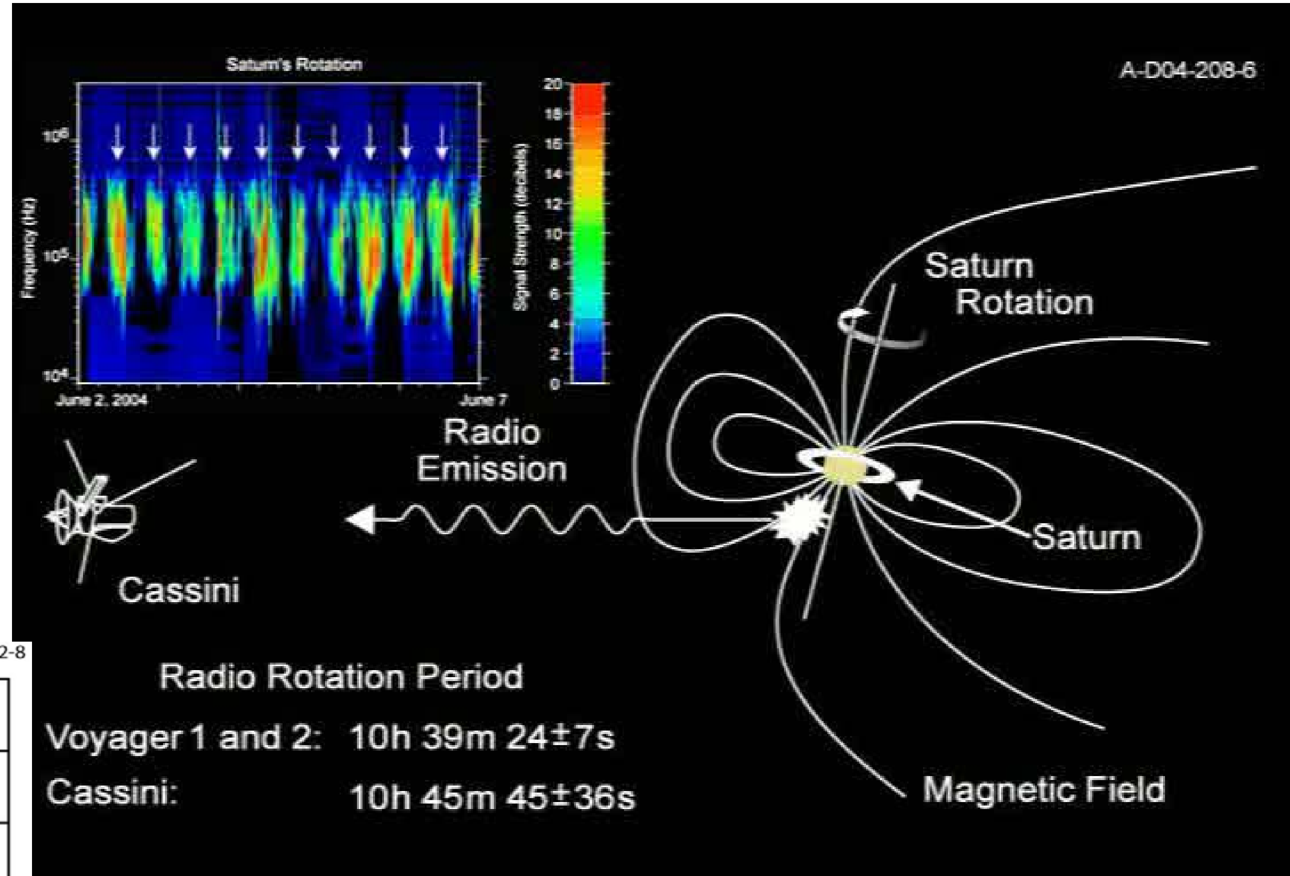
- The Magnetosphere is a giant magnetic bubble surrounding the planet Saturn.
- The source of the magnetic field is a highly conductive material (metallic hydrogen) inside the planet rotating very quickly (once every 10.8 hours).
- There is a very complex interaction between the icy satellites and rings of Saturn, the plasma trapped in the magnetic field, the neutral gases in the bubble, and the solar wind (a stream of ionized particles flowing from the Sun, which blows the magnetosphere into a blunt-nosed, long-tailed windsock).
- The icy moon Enceladus, with its strong emission of water into the magnetosphere at 4Rs, dominates the neutral and ionized gas populating the magnetosphere inside 10Rs, while Saturn's atmosphere and ionosphere also contribute in the outer regions.
- Typical constituents found in the system are O, H_2, H, OH, CH_4 , in both neutral and charged states, and from the solar wind, He^{++}.

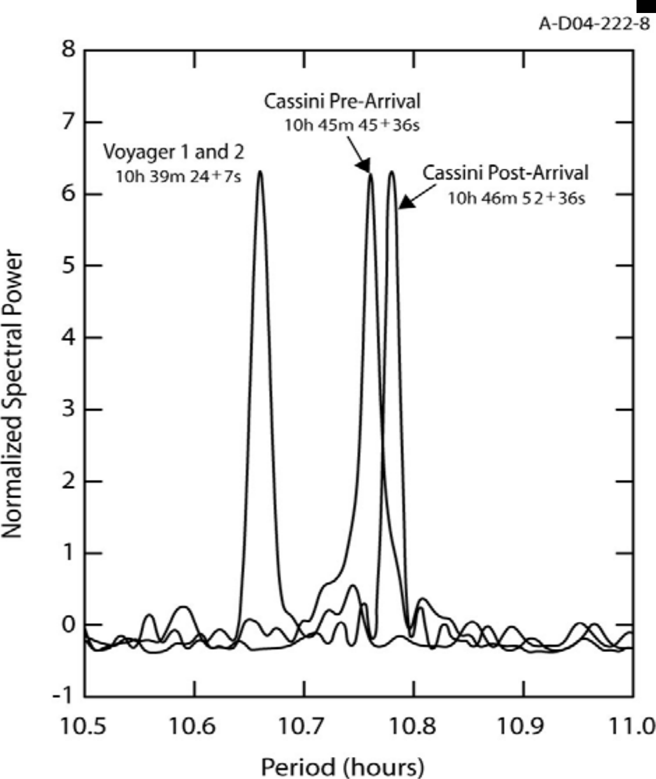

ENA
Bow Shock
Magnetopause
Tail Lobe
Plasma Sheet
Polar Wind
Solar Wind
Satellite &
Ring Neutrals
Cusp
Aurora
SKR
Titan
Neutral Torus
Dust
Hot Plasma
Titan Wake,
Exosphere
ENA
Ring Current
Magnetopause
Energetic
Neutral Atom
(ENA)
Bow Shock

Electron Beams moving away from Saturn

(Saur et al, Nature, Feb. 9, 2006)

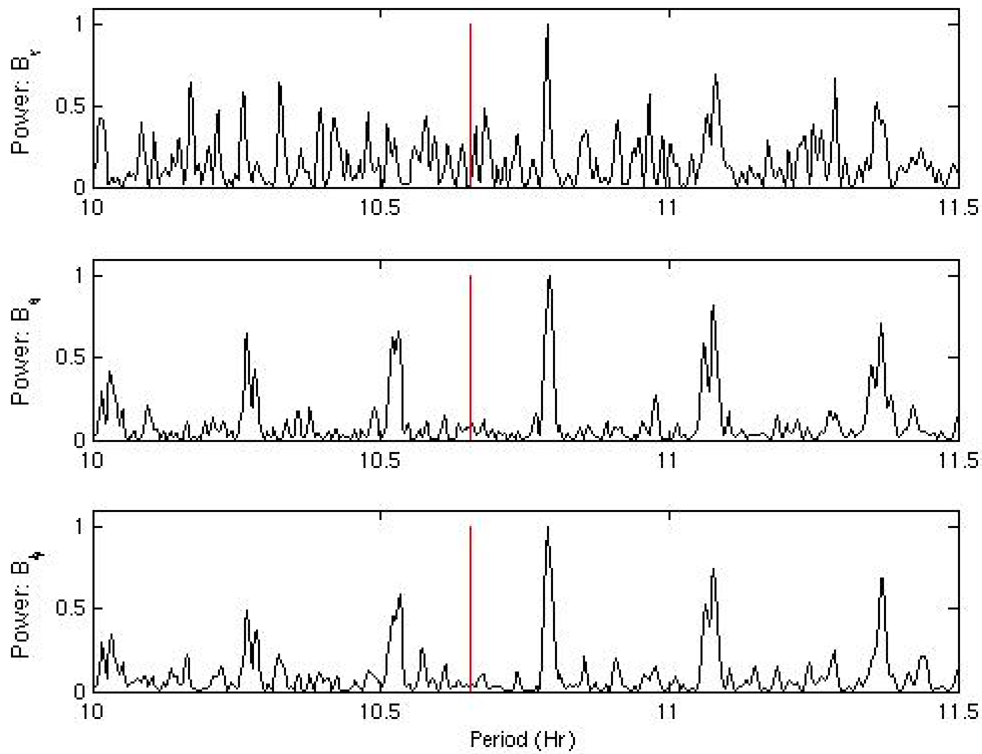






Cassini has found a different radio period than Voyager. The radio period is usually used to determine the rotation period of gas giant planets. A major mystery for Cassini to solve is the reason for the variation of the radio period. Once this mystery is solved, it will be possible to accurately determine the rotation period of the deep interior of Saturn.

First Detection of Rotation Period of Saturn's Magnetic Field

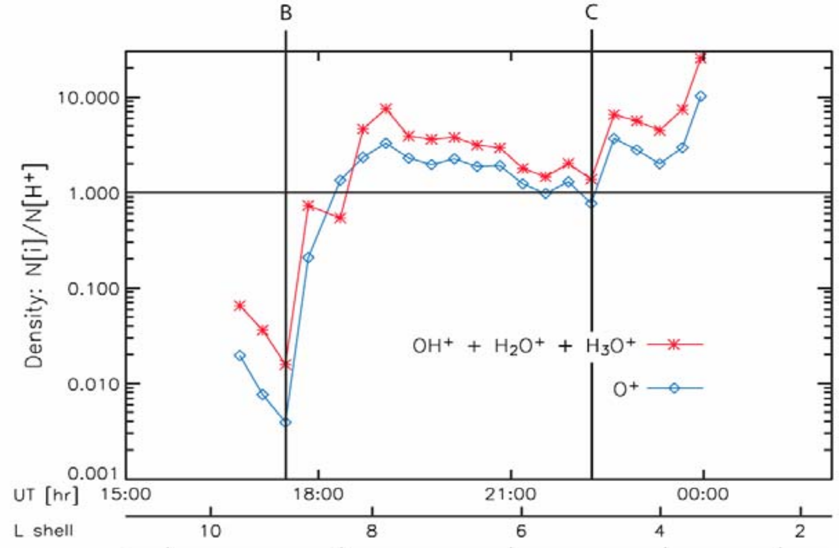


Analysis of the first two years of Cassini magnetic field data has led to a new rotation rate of Saturn's magnetic field of 10 hr 47 min 6 sec ± 40 sec

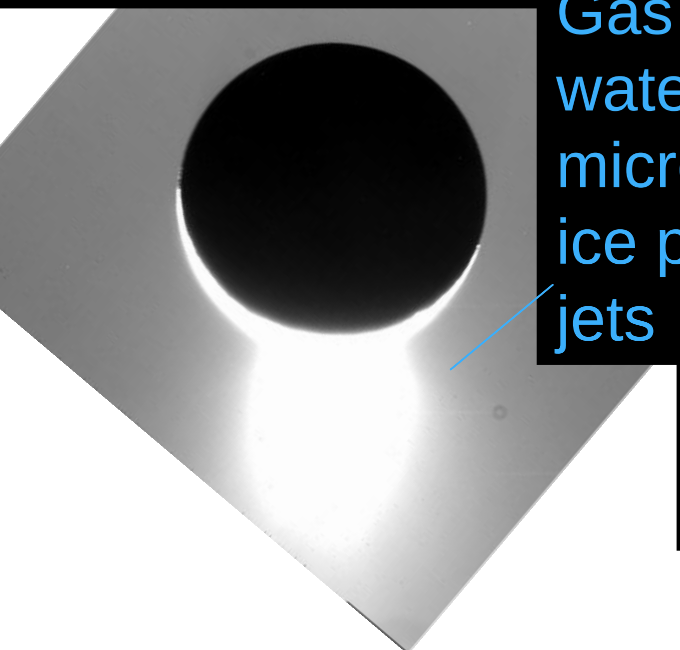
Nature (Giampieri, Dougherty, Smith and Russell, 2006)

As Io is to Jupiter, Enceladus is the dominant influence on Saturn's magnetosphere.

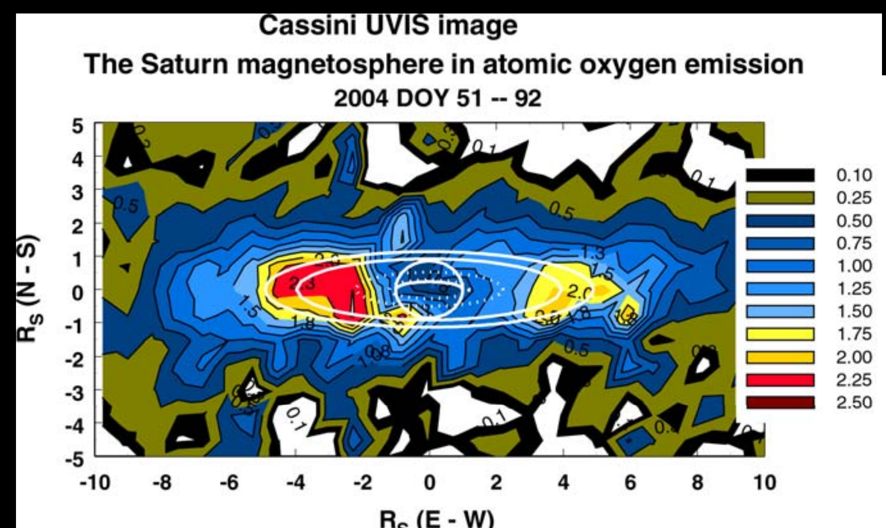
Water-product plasma



Young et al., Science, Feb. 25, 2005 -- Cassini CAPS

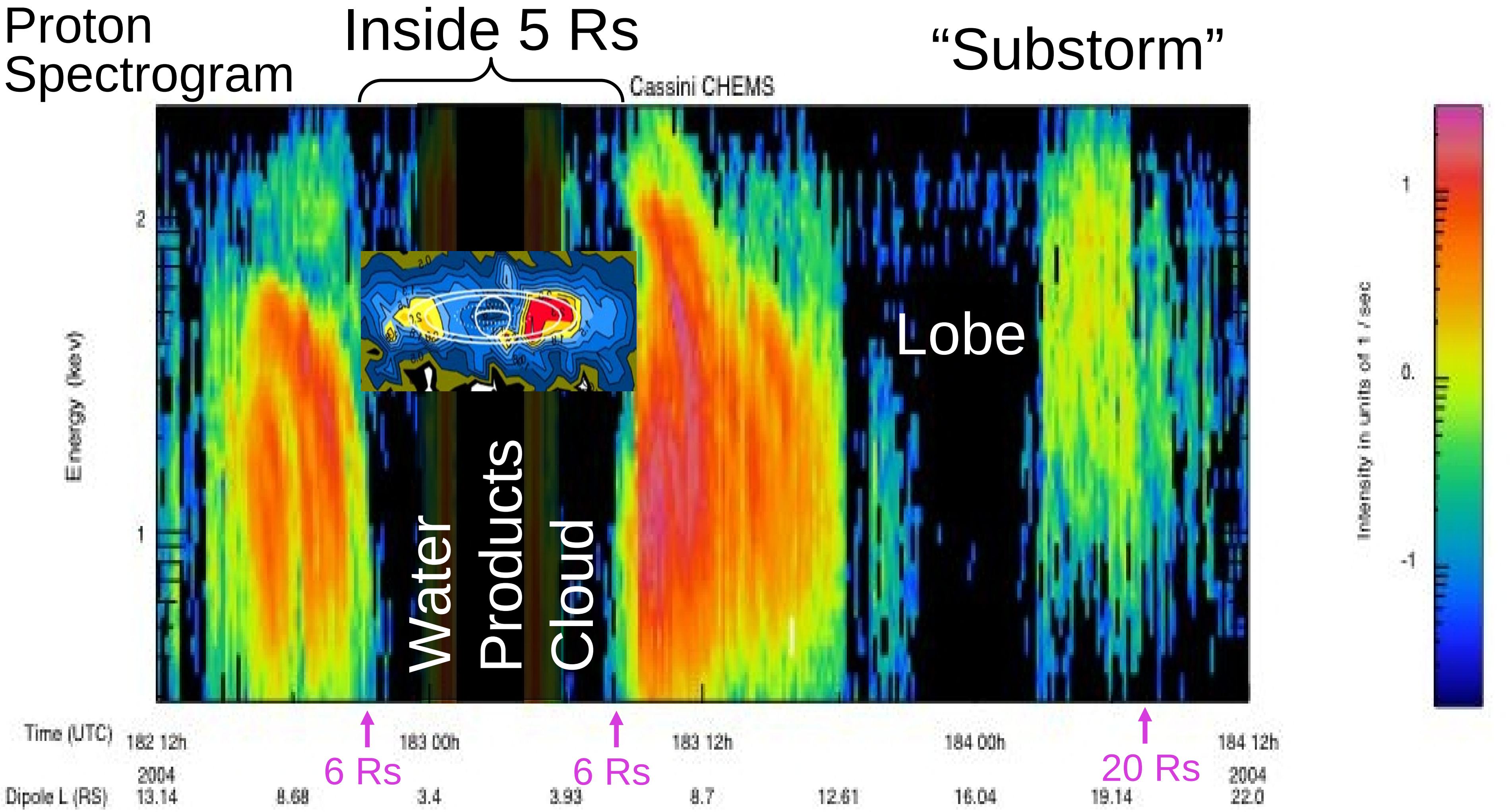


Gas (mostly water) and micron-size ice particle jets

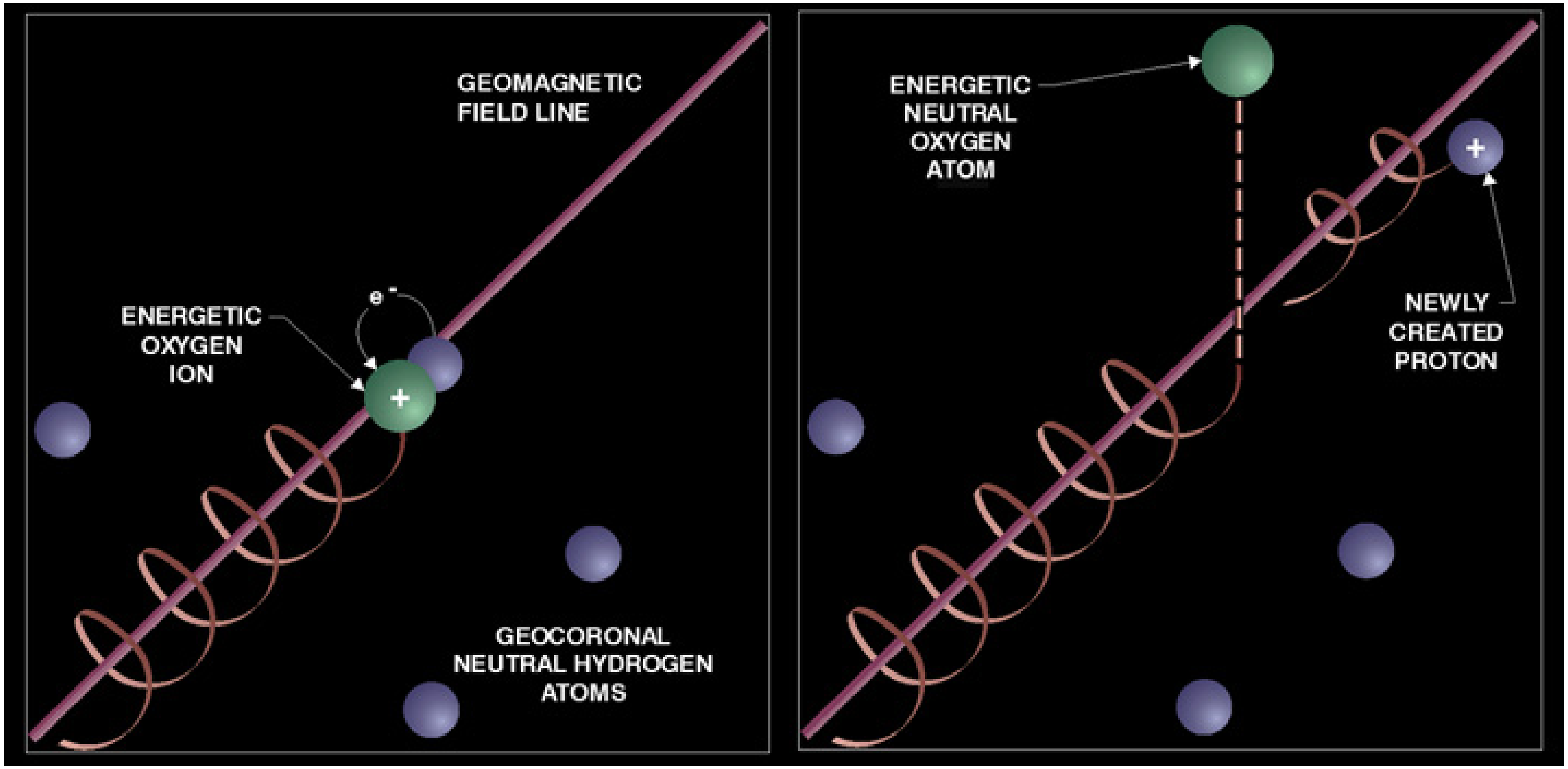


Water-product gas

Esposito et al., Science, Feb. 25, 2005 -- Cassini UVIS



Proton Spectrogram
Inside 5 Rs
"Substorm"
Cassini CHEMS
Energy (keV)
2
1
Water Products Cloud
Lobe
Intensity in units of 1 / sec
1
0.
-1
Time (UTC)
182 12h
183 00h
183 12h
184 00h
184 12h
2004
2004
Dipole L (RS)
13.14
8.68
3.4
3.93
8.7
12.61
16.04
19.14
22.0
6 Rs
6 Rs
20 Rs



ENA generation mechanism

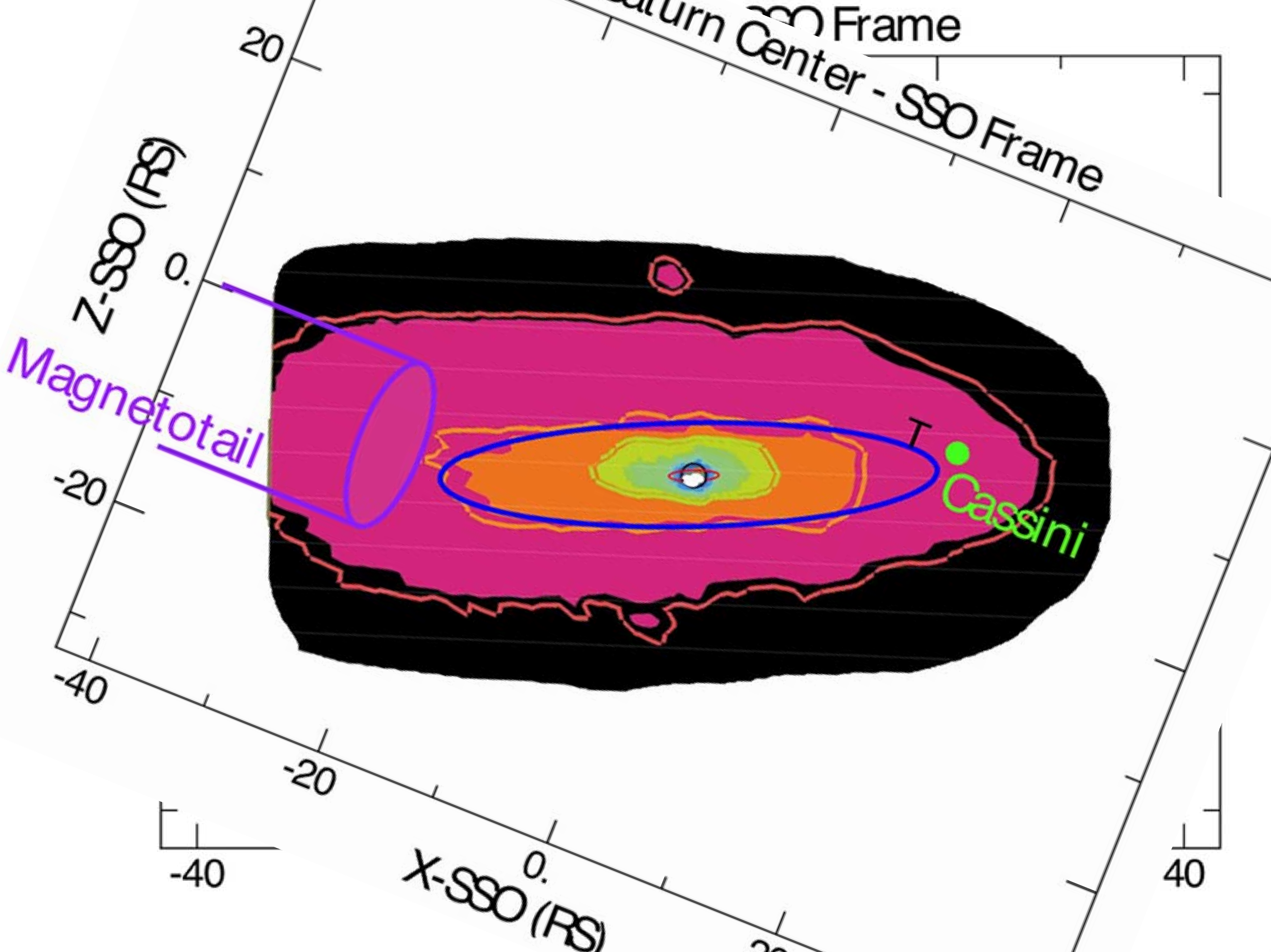
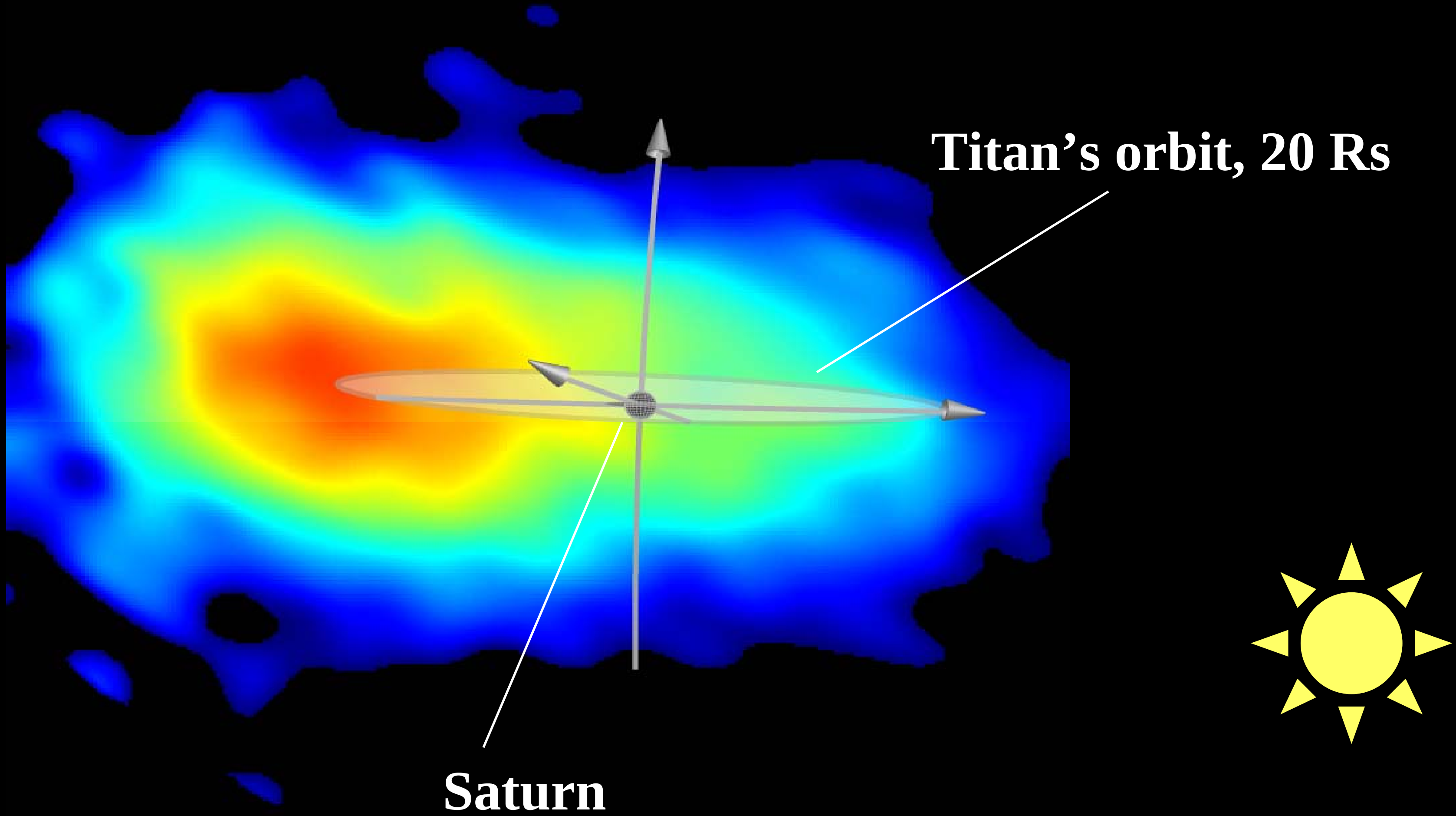
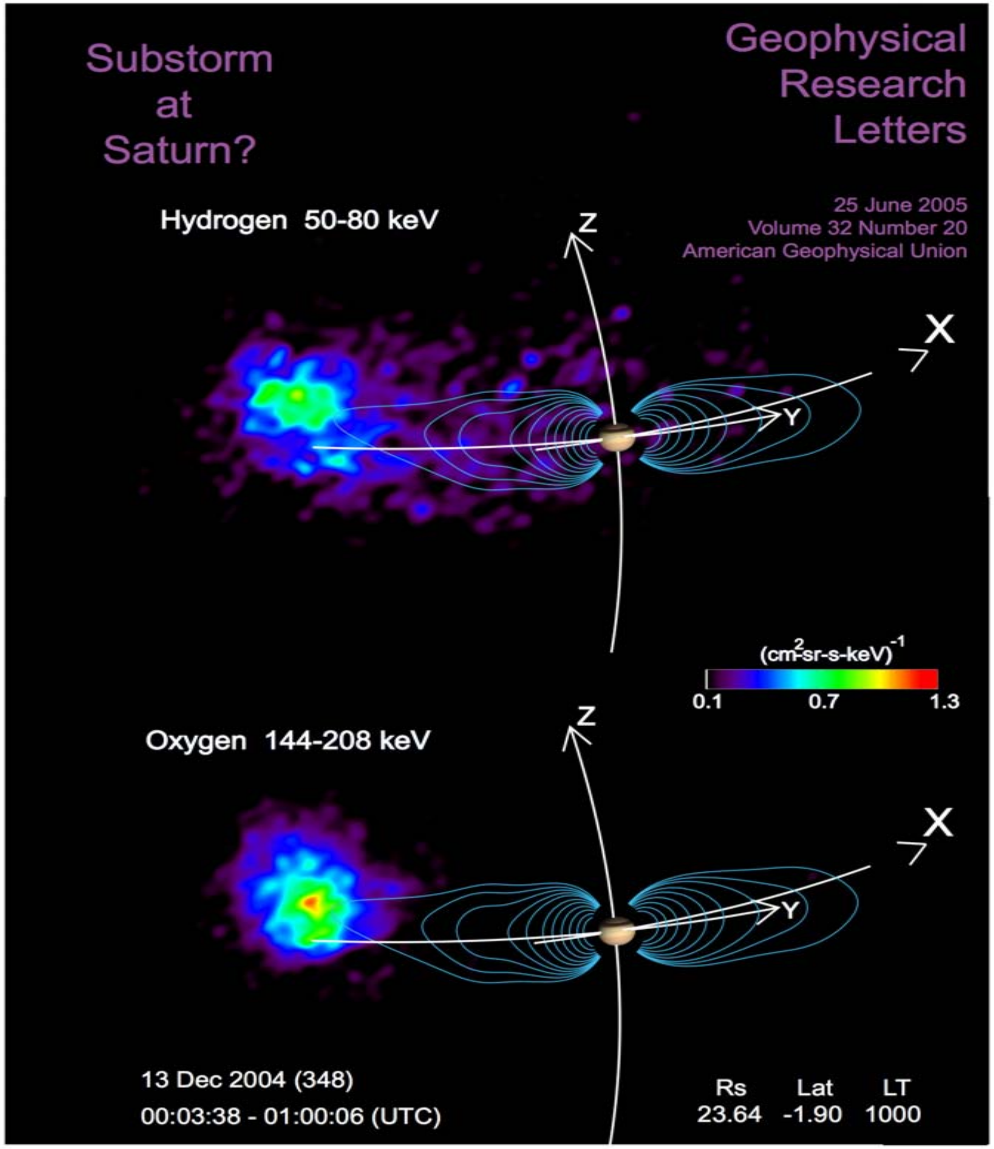

SSO Frame
Saturn Center - SSO Frame
Z-SSO (RS)
X-SSO (RS)
Magnetotail
Cassini
20
0.
-20
-40
-20
0.
-40
40

Image of the magnetosphere in the emission of energetic neutral atoms, created when trapped ions charge-exchange with ambient cold neutral gas.

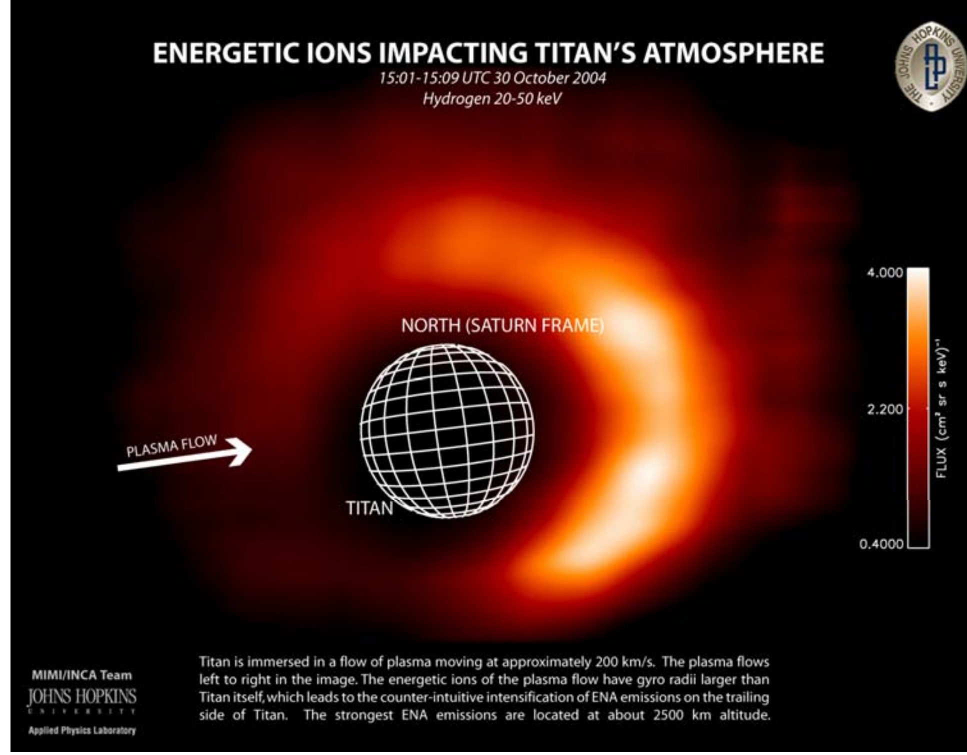


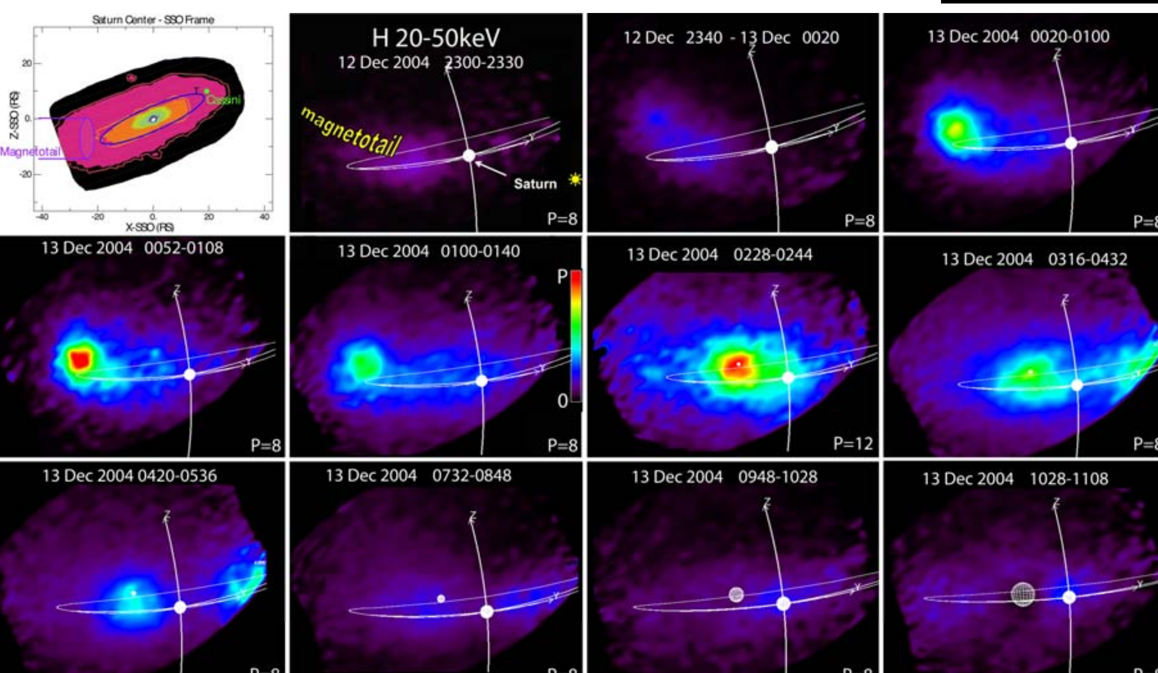
Energetic Ion Acceleration in Saturn's Magnetotail



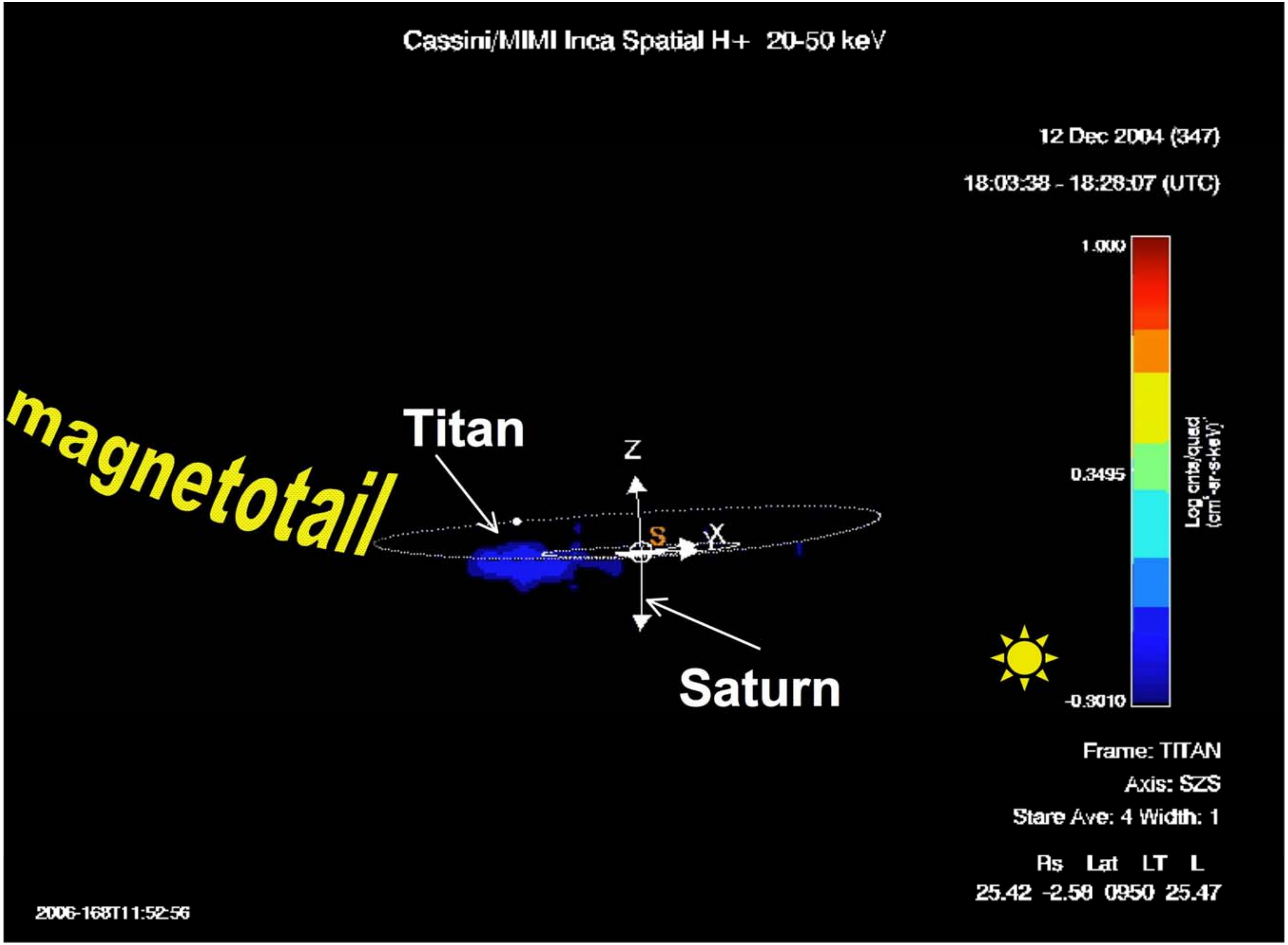
- INCA data from a recent Geophysical Research Letters (GRL) cover.
- Discusses similarities between substorms at Earth and observations by MIMI of Saturn's tail region.
- Article: Energetic ion acceleration at Saturn's magnetotail: Substorms at Saturn? (Mitchell et al. 2005, GRL, 32, 2005GL022647),

Interaction of Saturn's trapped energetic ion population with Titan's exosphere. Asymmetry of this halo of energetic neutral atom (ENA) emission results from the complex MHD interaction of the corotating plasma with Titan's ionosphere. In the dark region close to the surface, energetic ions lose all of their energy and precipitate into Titan's dense atmosphere, hence no ENA emission escapes.





Substorm-like activity imaged in Saturn's magnetosphere. ENA images of ion acceleration deep in Saturn's magnetotail. From Mitchell, D. G.,et al. (2005), Energetic ion acceleration in Saturn's magnetotail: Substorms at Saturn?, Geophys. Res. Lett., 32, L20S01, doi:10.1029/2005GL022647



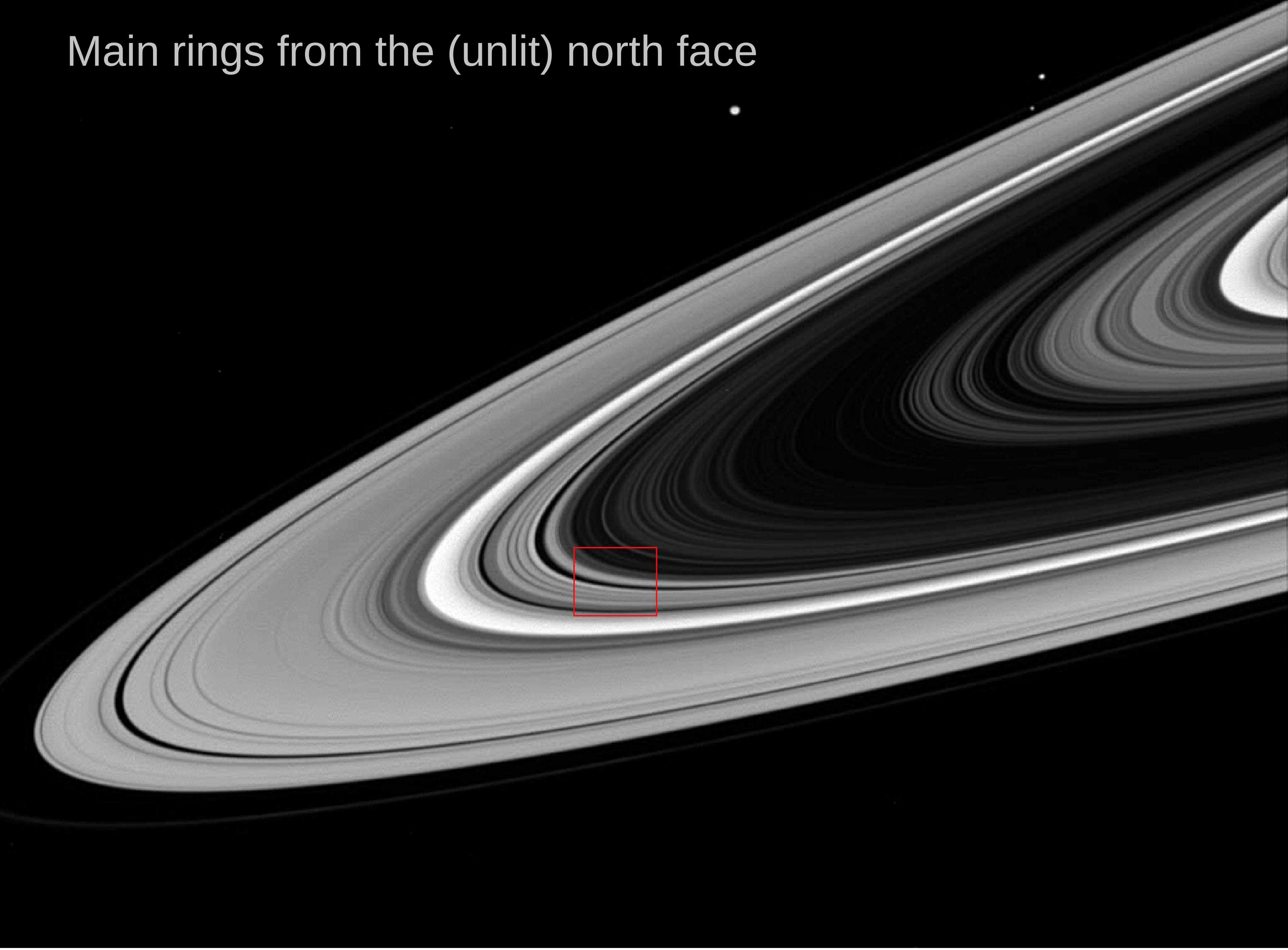
TB Substorm Movie: http://jplis-stor-cache02.jpl.nasa.gov/doclib/CHARM/index.cfm

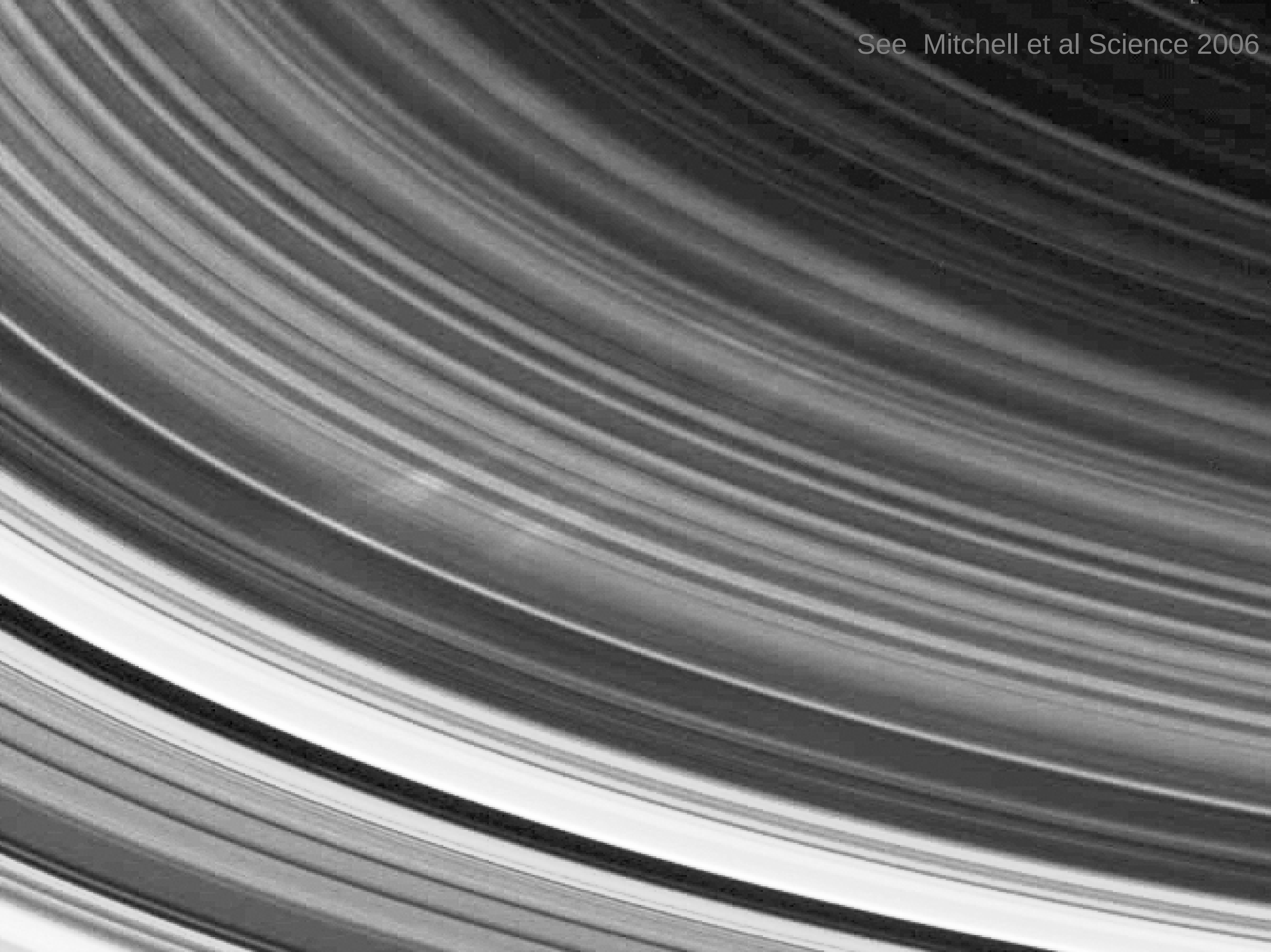
Rings

- The rings of Saturn consist of billions and billions (☺) of tiny ring particles all orbiting Saturn separately.
- The particles closer to Saturn orbit faster (like on a race track).
- The range in size extend from smoke-sized particles to football field-sized particles.
- The rings consist largely of water ice mixed with smaller amounts of rocky material.
- The macro structure of the rings is dominated by the interactions of the ring particles with the icy satellites and embedded moons.

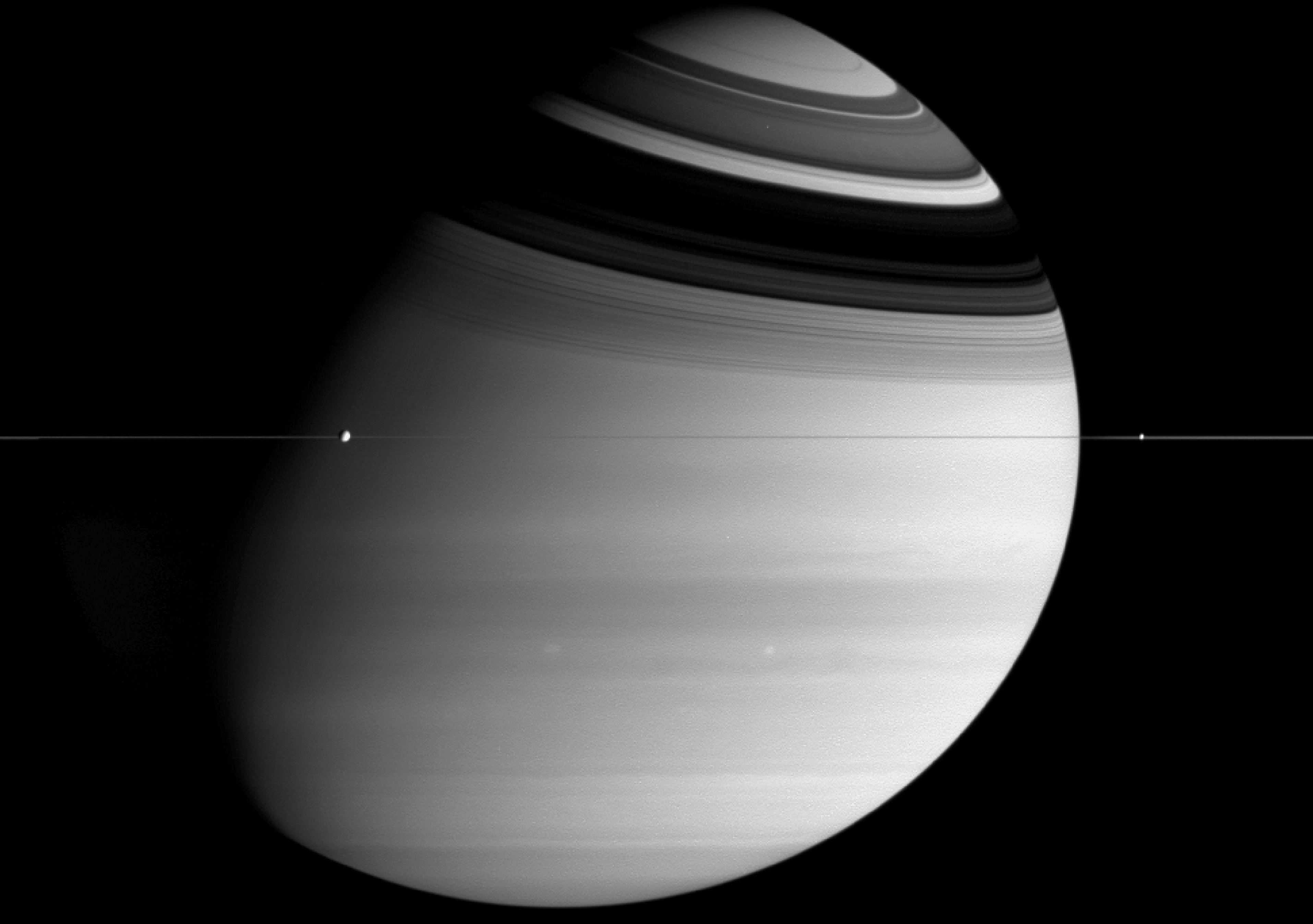

C
B
C D
A
F
ISS approach color composite

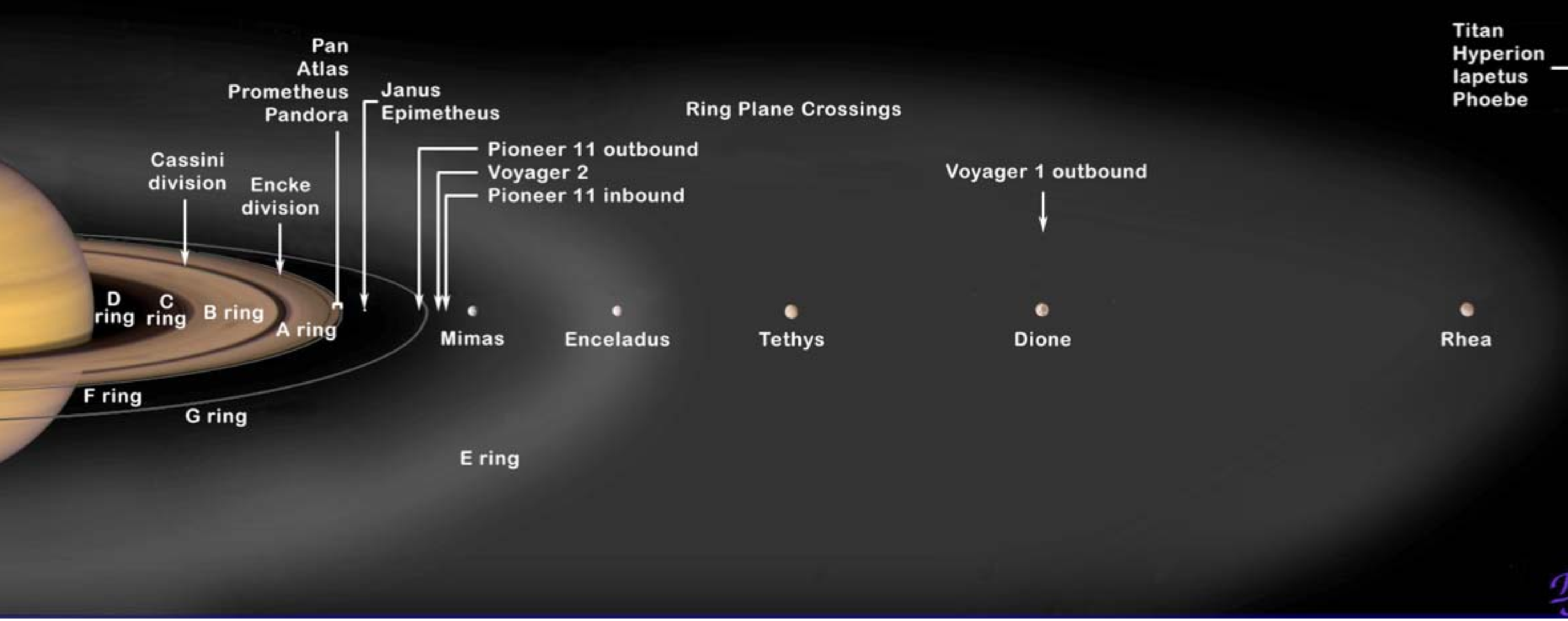
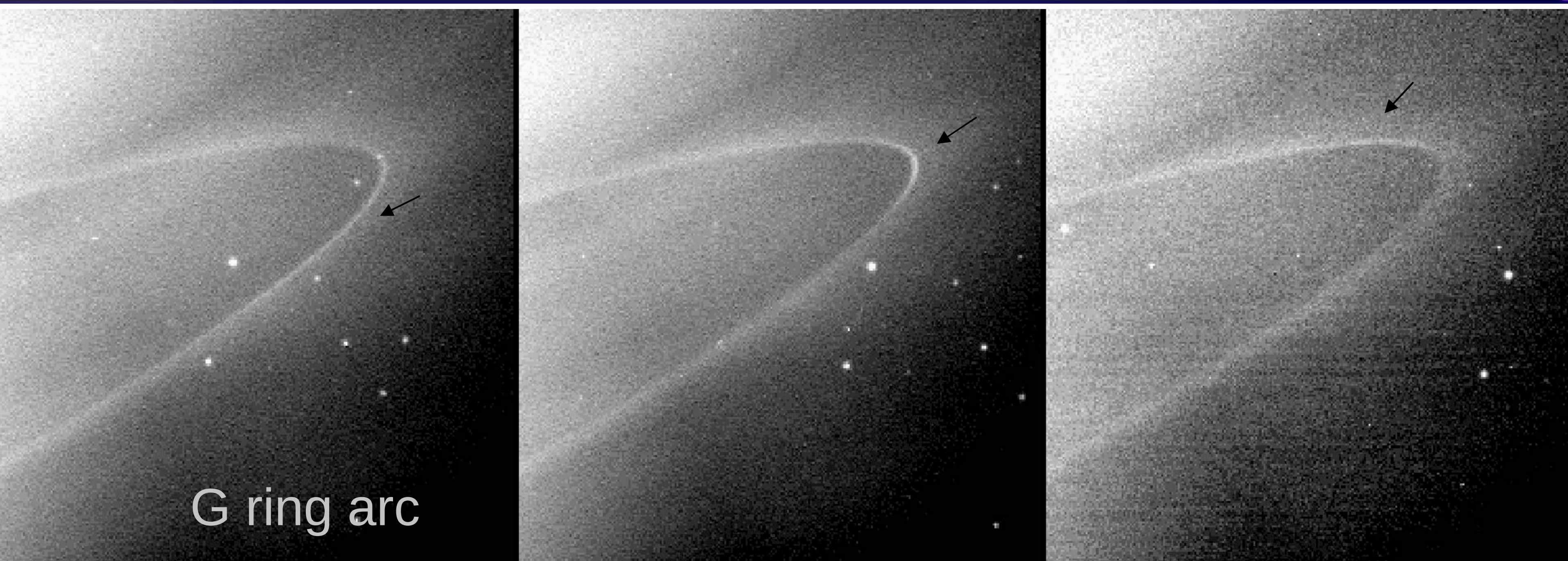
Main rings from the (unlit) north face



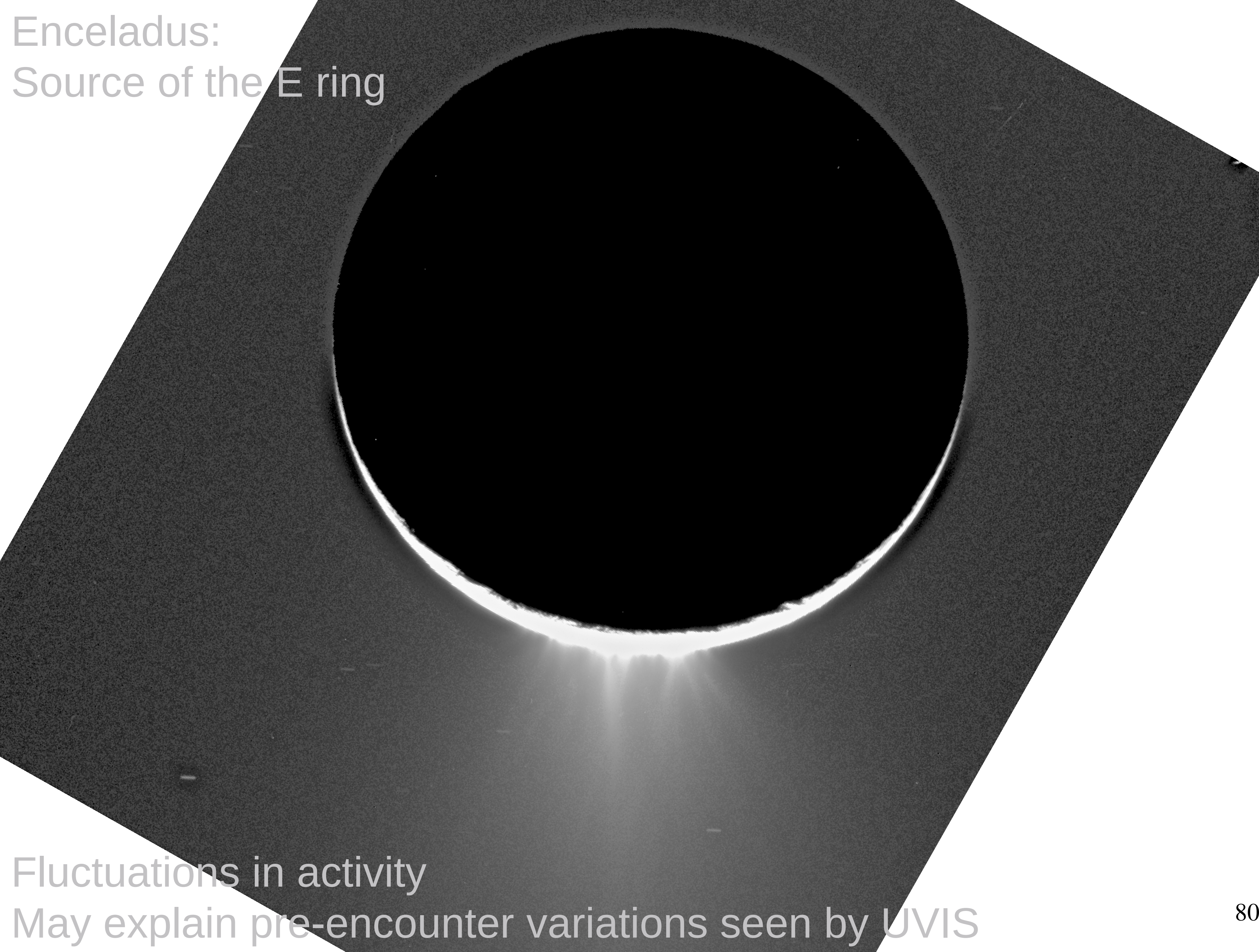

See Mitchell et al Science 2006

Cassini's view of the rings for the last 9 months




Pan
Atlas
Prometheus
Pandora
Janus
Epimetheus
Ring Plane Crossings
Titan
Hyperion
Iapetus
Phoebe
Cassini
division
Encke
division
Pioneer 11 outbound
Voyager 2
Pioneer 11 inbound
Voyager 1 outbound
D
ring
C
ring
B ring
A ring
Mimas
Enceladus
Tethys
Dione
Rhea
F ring
G ring
E ring

G ring arc

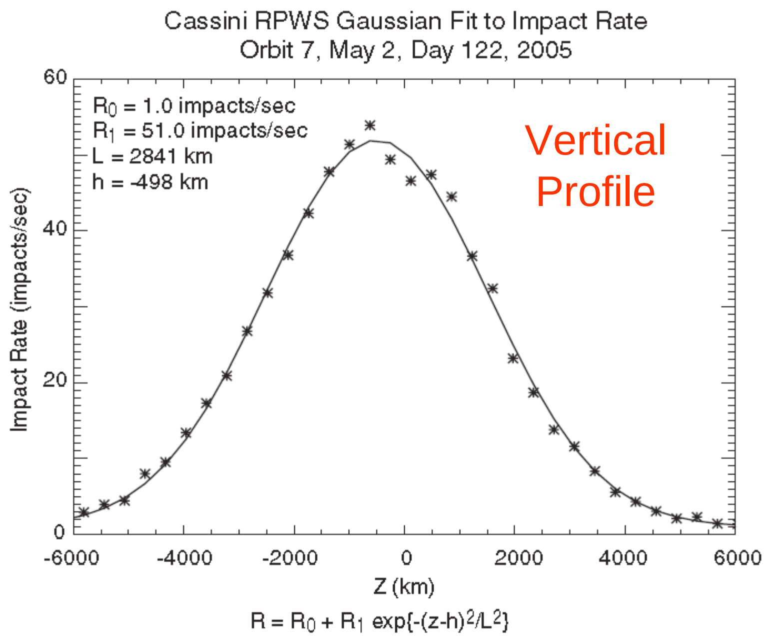
Enceladus:
Source of the E ring

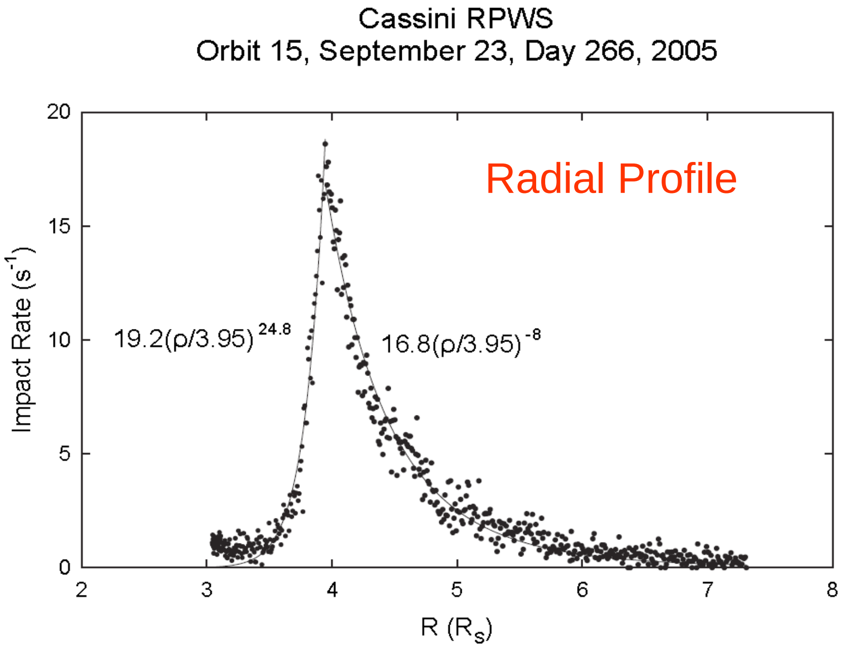


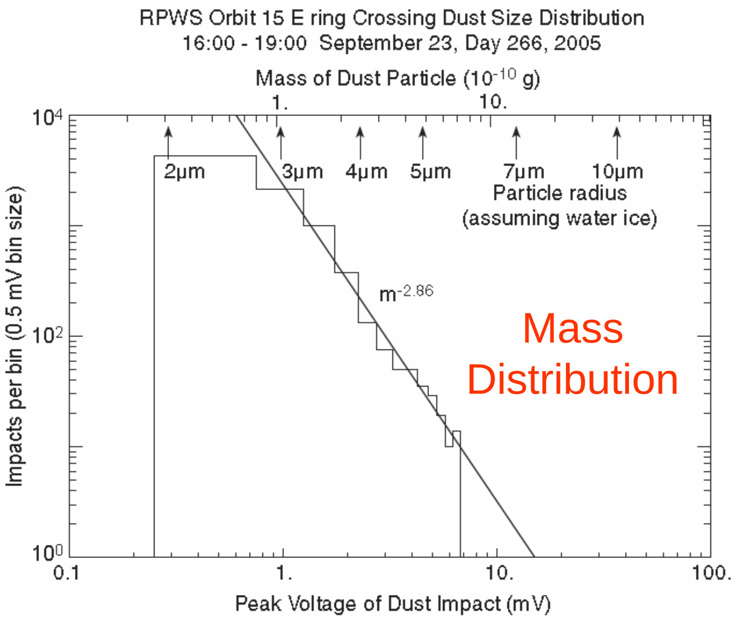
Fluctuations in activity

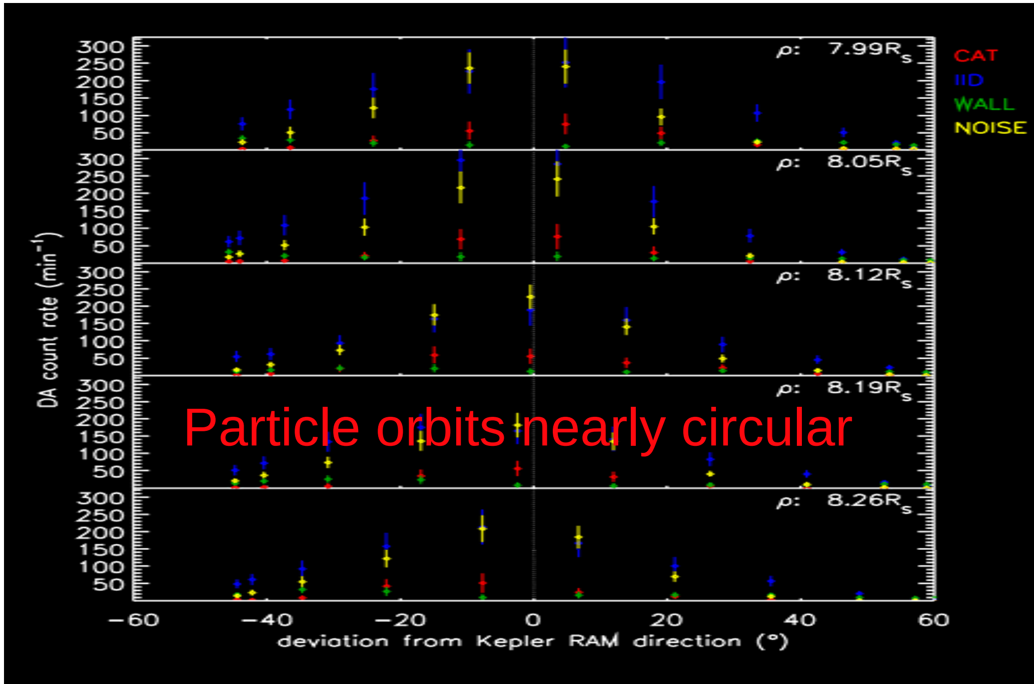
May explain pre-encounter variations seen by UVIS

CDA: E-ring Dust Measurements

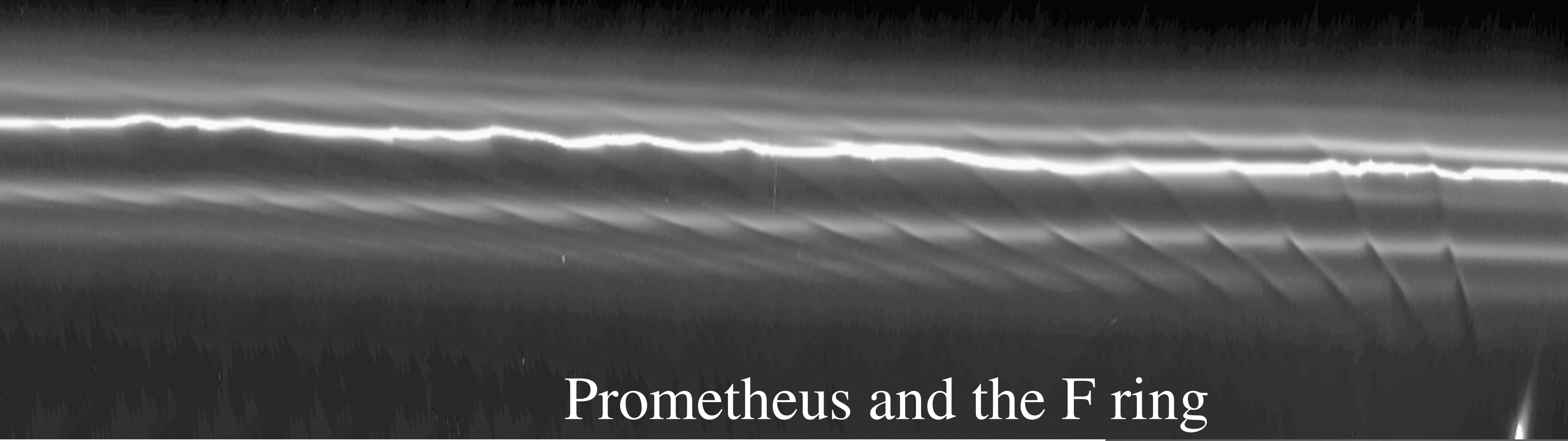


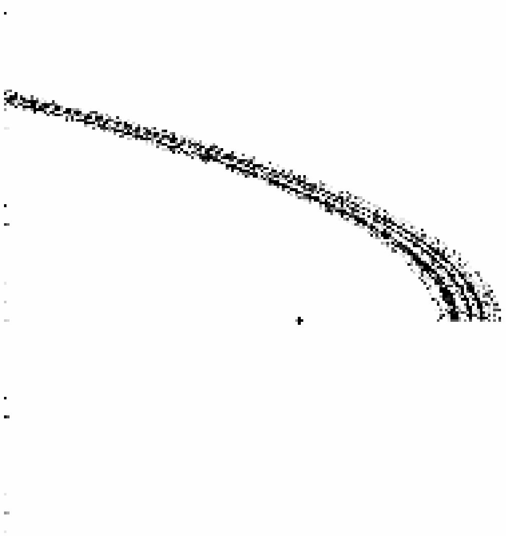


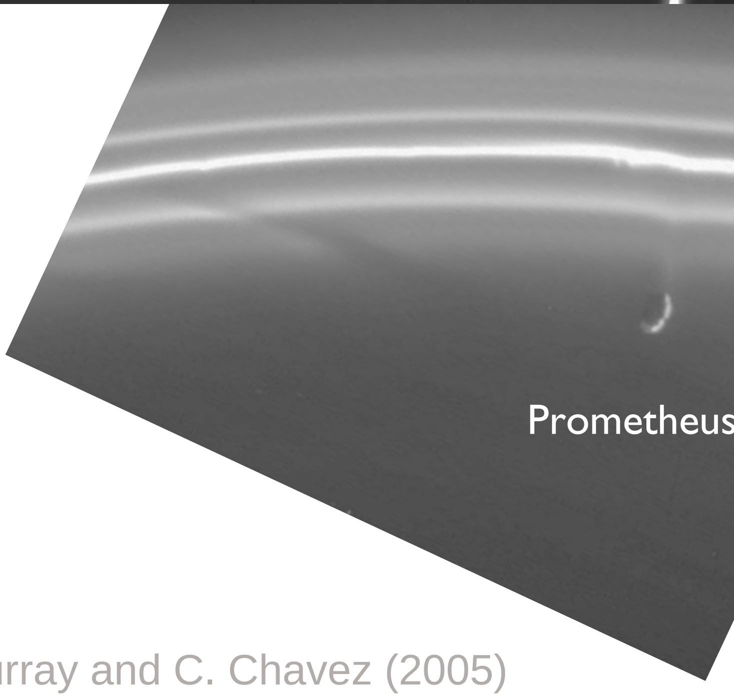




Prometheus and the F ring





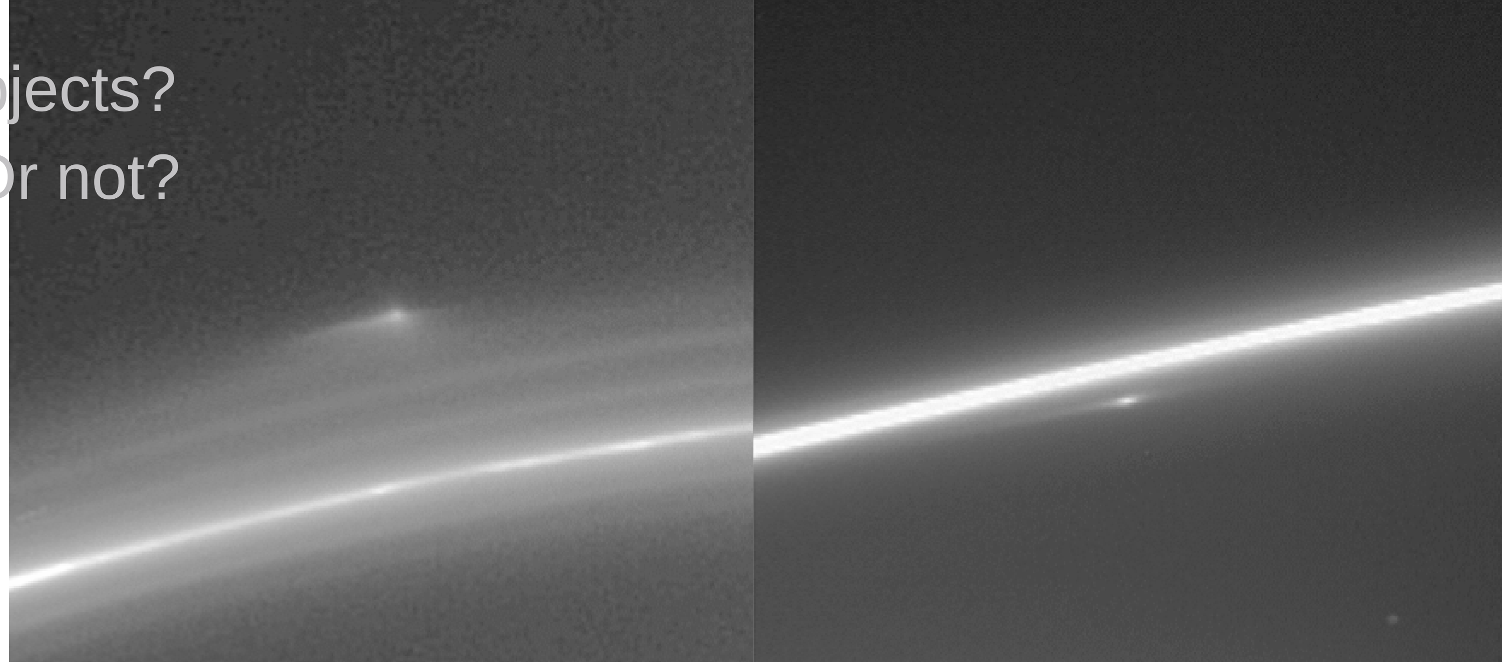


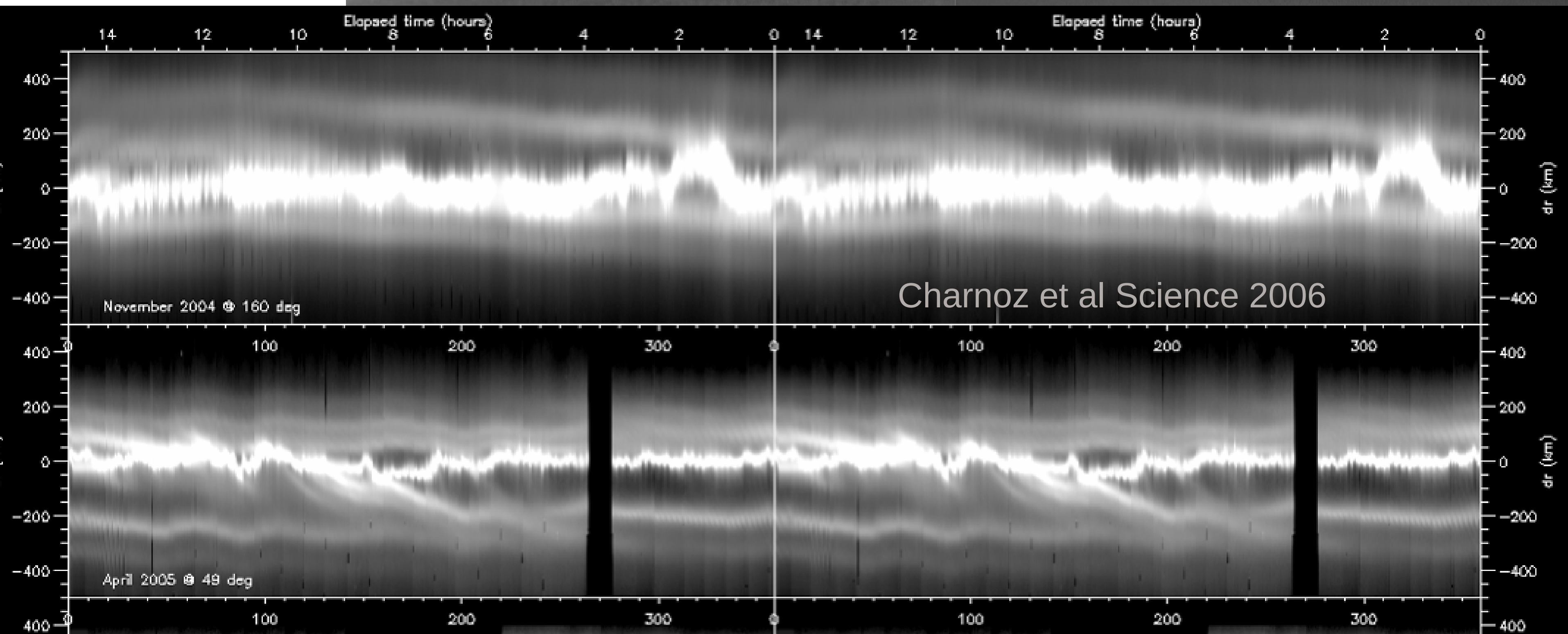
Simulation by C.Murray and C. Chavez (2005)

F Ring Movie: http://jplis-stor-cache02.jpl.nasa.gov/doclib/CHARM/index.cfm

Transient objects?

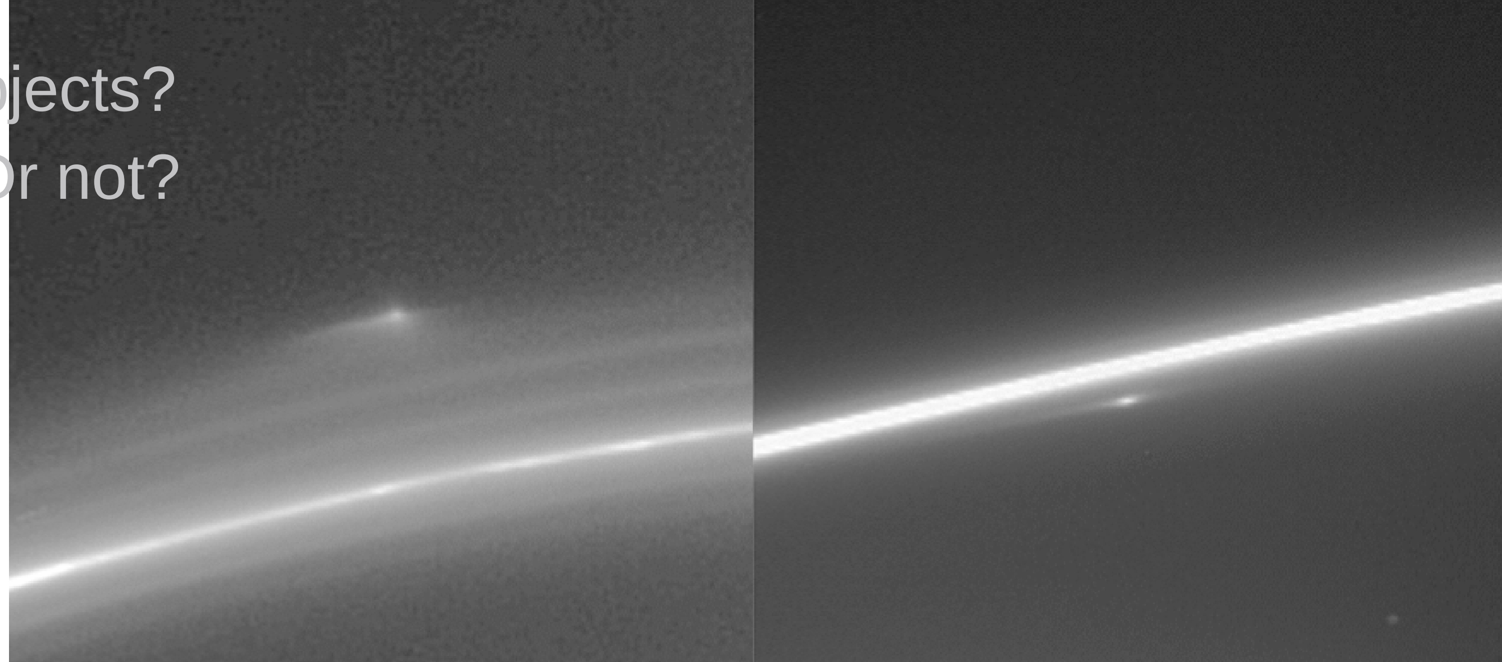
"2004S6".. Or not?

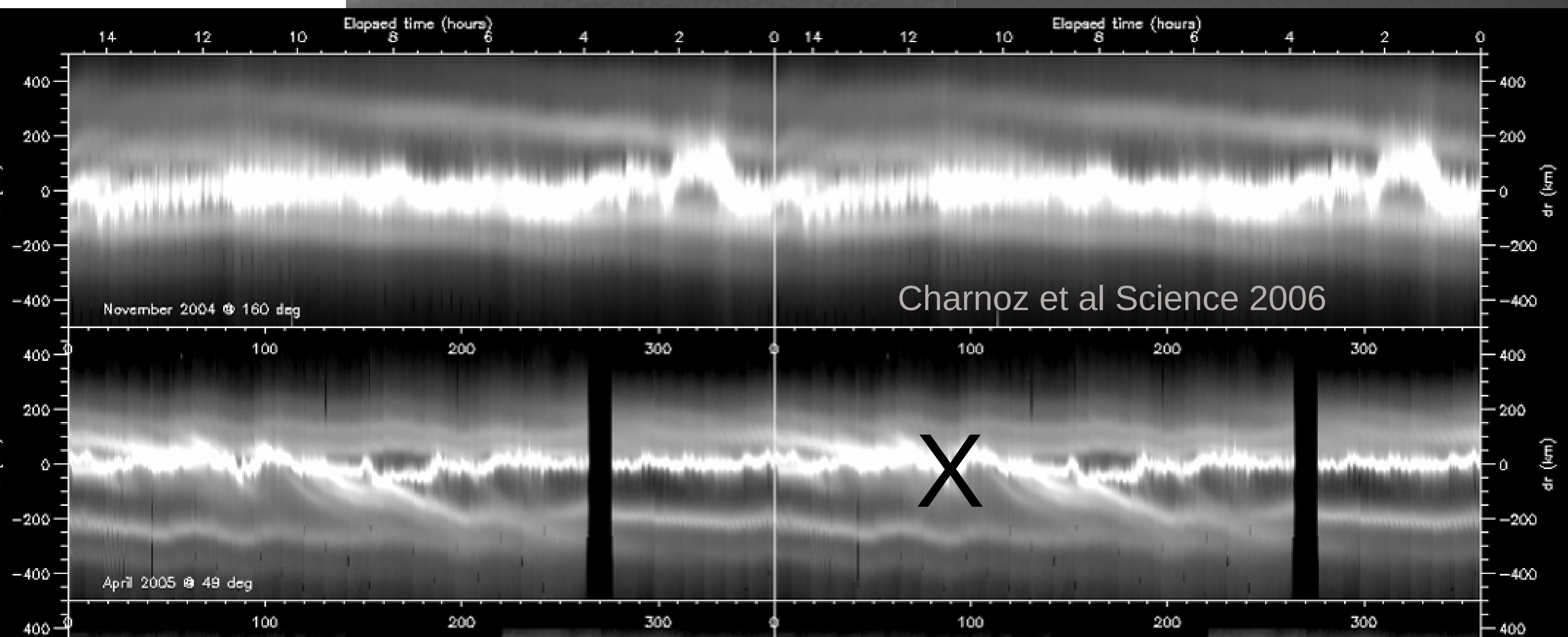


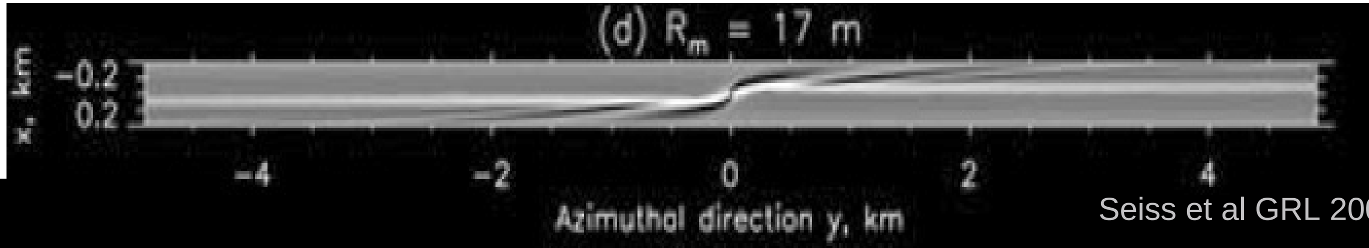


Charnoz et al Science 2006

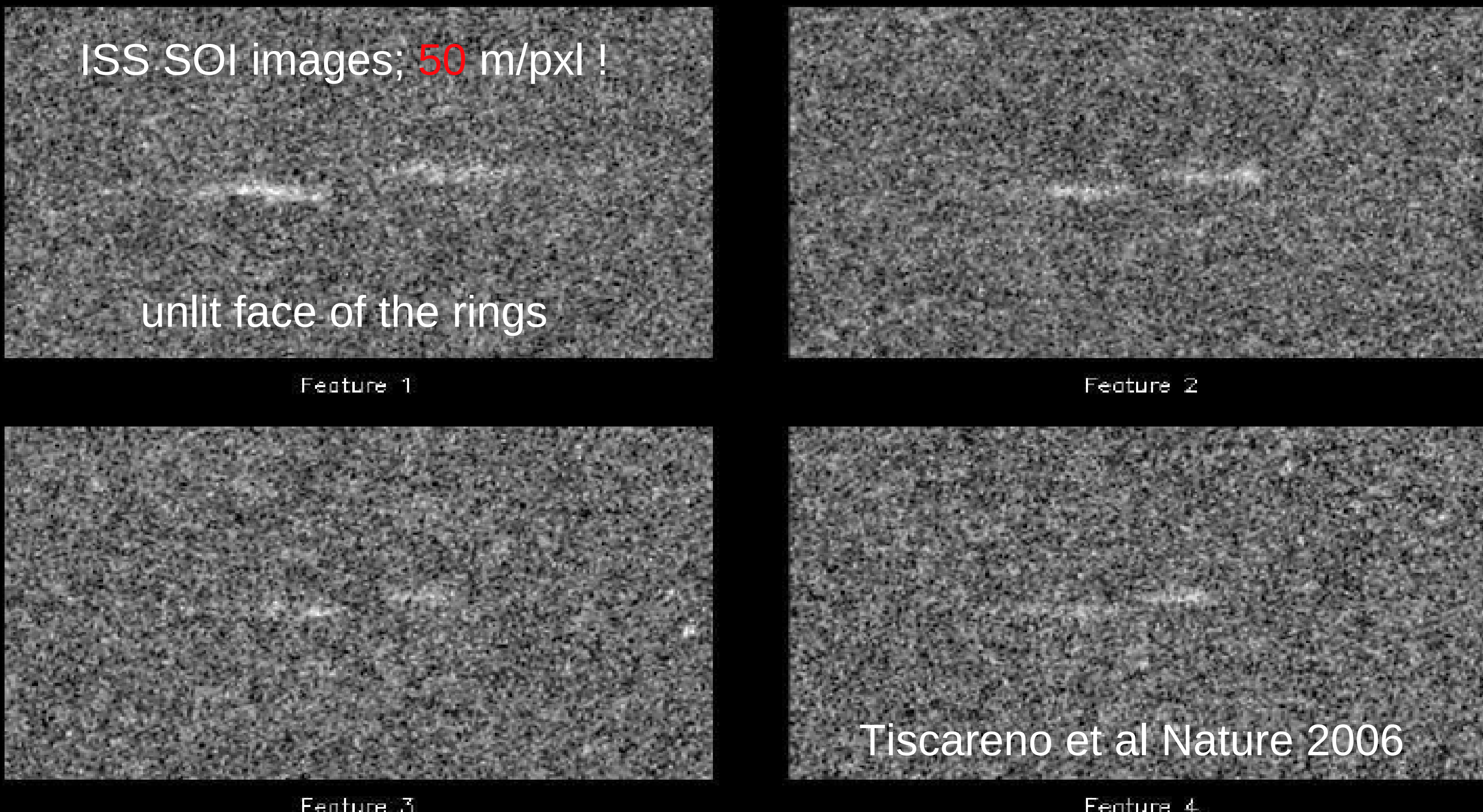
Transient objects?
“2004S6”.. Or not?



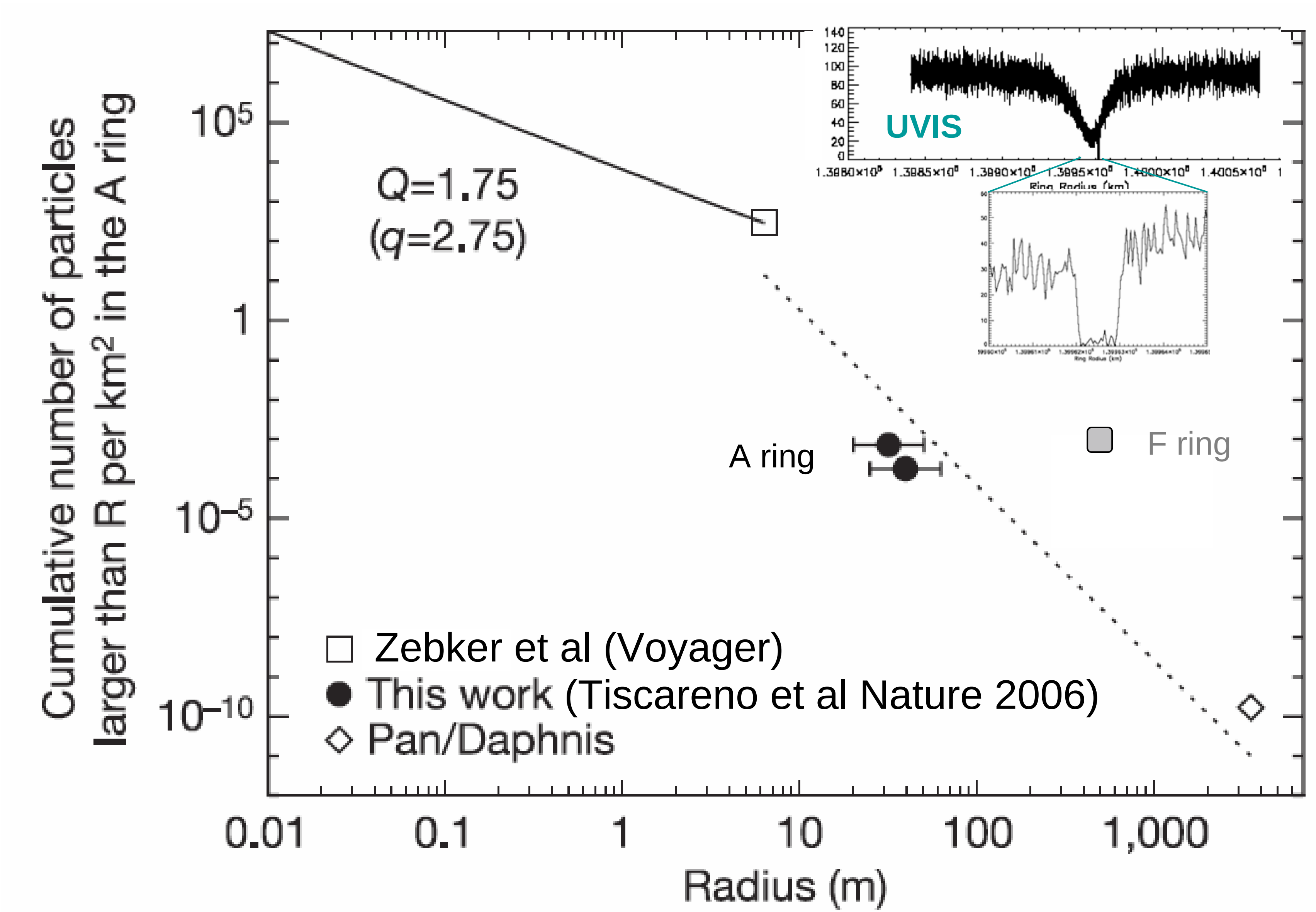




Seiss et al GRL 2005

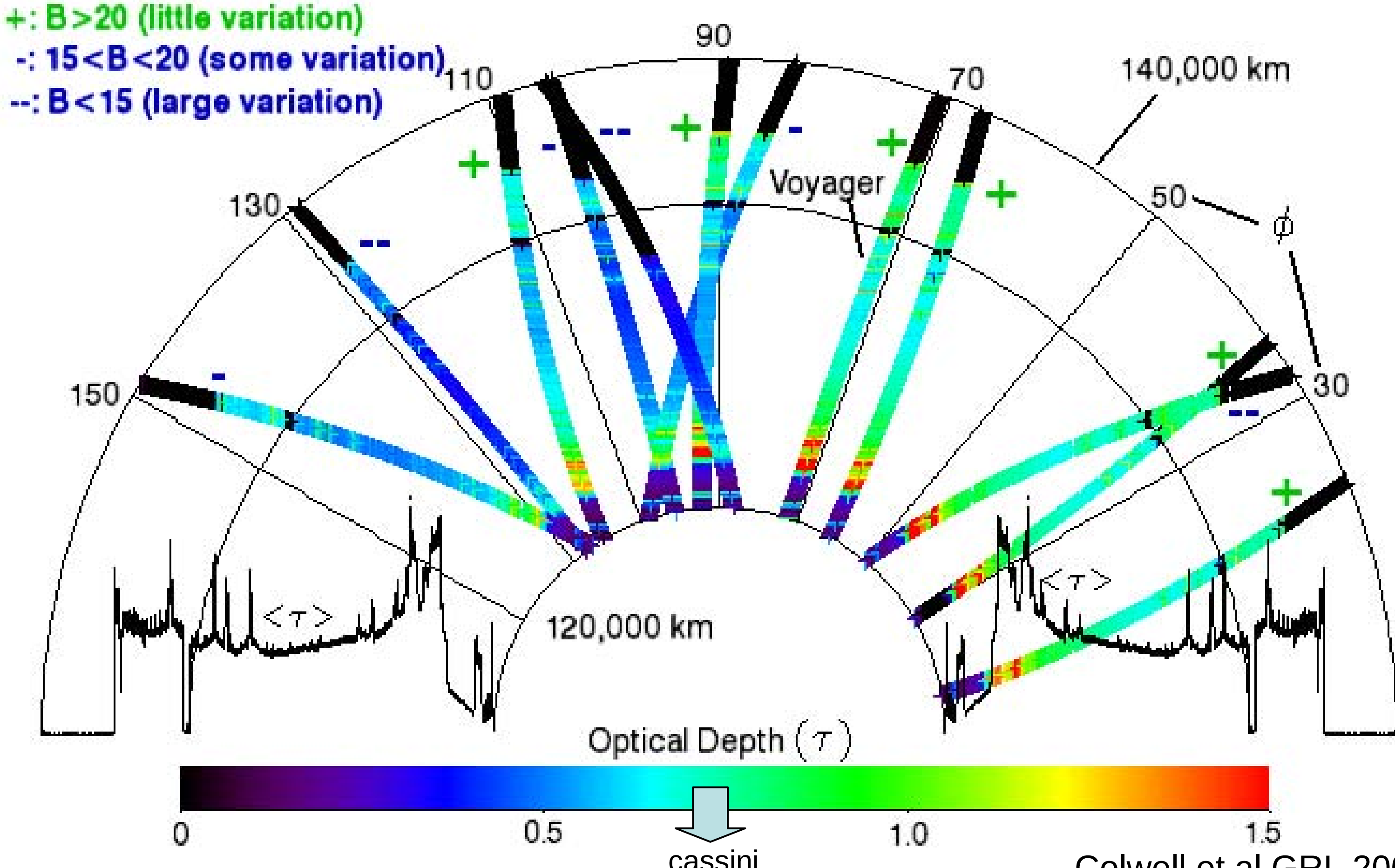


Tiscareno et al Nature 2006


Cumulative number of particles larger than R per km² in the A ring
Q=1.75
(q=2.75)
UVIS
Ring Radius (km)
A ring
F ring
Zebker et al (Voyager)
This work (Tiscareno et al Nature 2006)
Pan/Daphnis
0.01
0.1
1
10
100
1,000
Radius (m)
10⁵
1
10⁻⁵
10⁻¹⁰

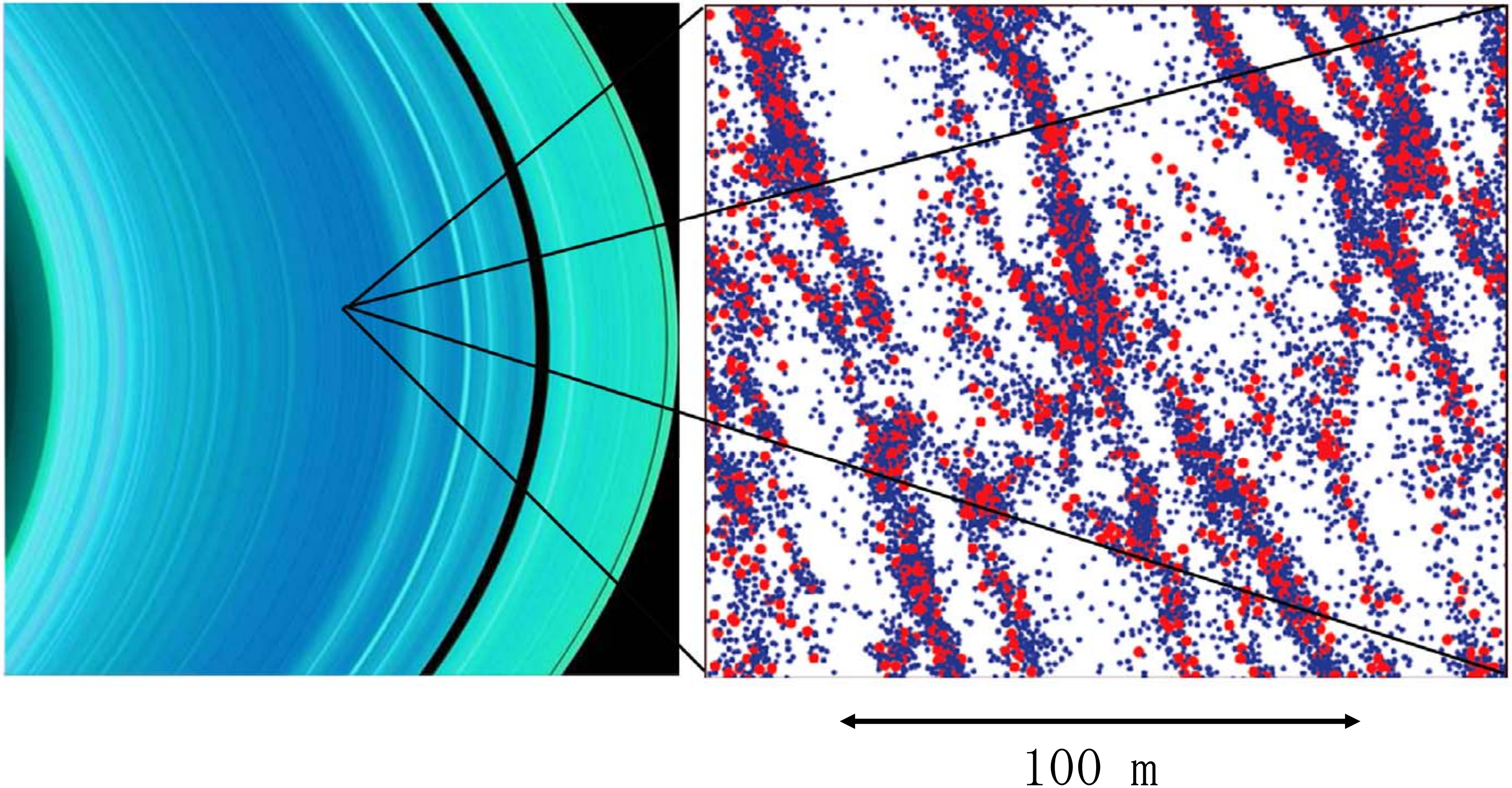
UVIS

Stellar Occultation Variation Summary



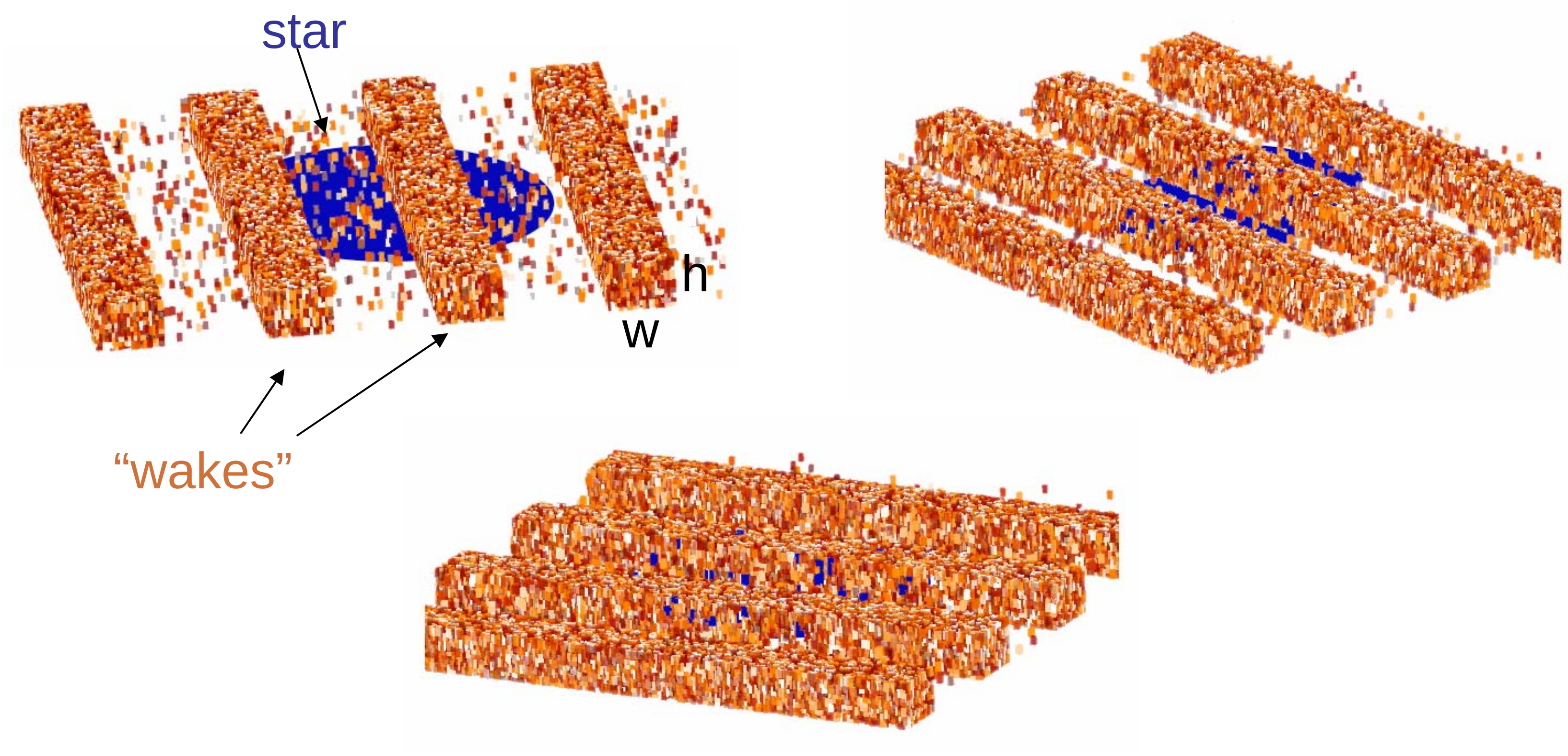
Colwell et al GRL 2006

Blue represents larger clusters of particles.
Bright represents higher opacity.

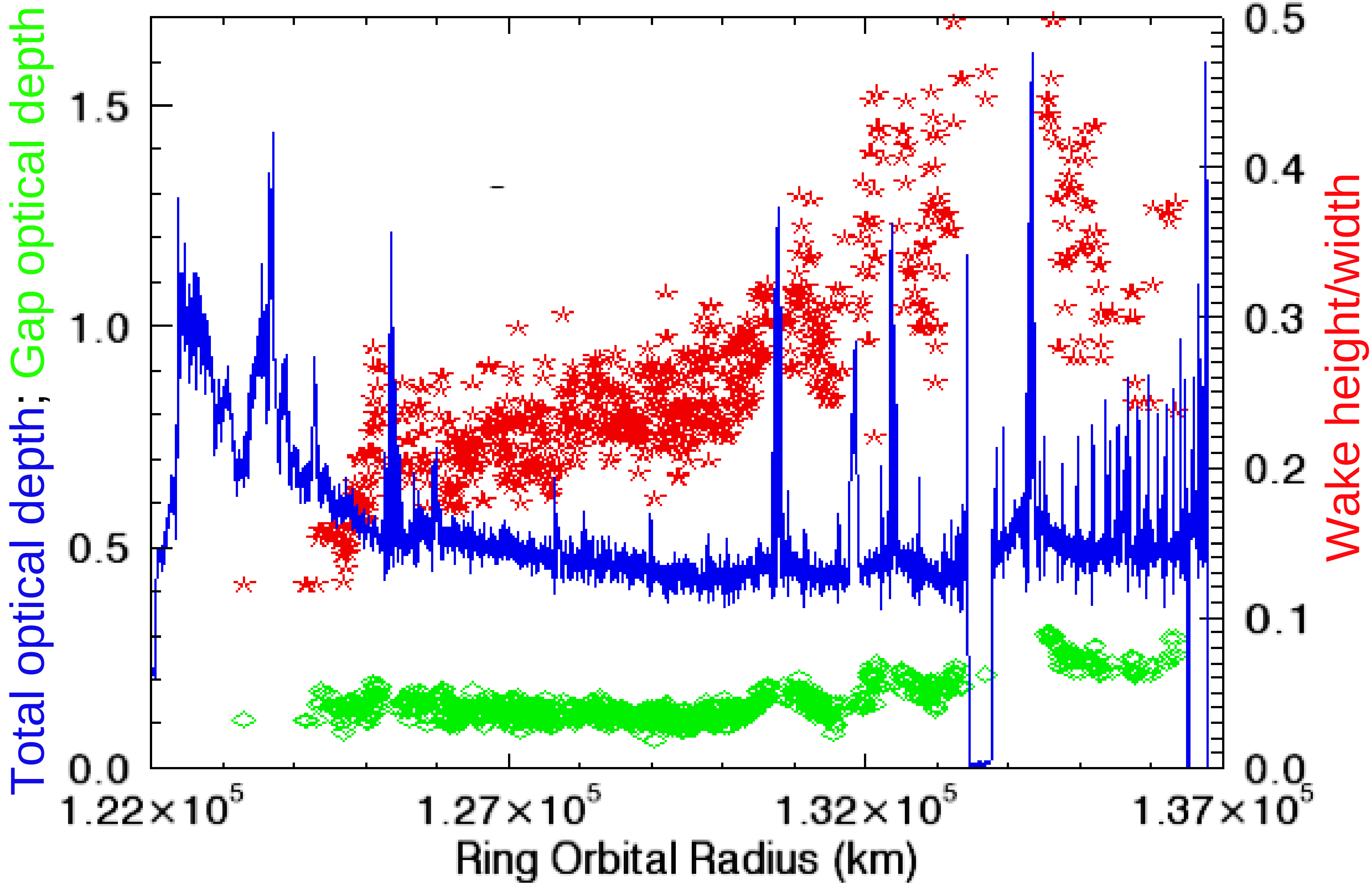


Simulation: John Weiss and Glen Stewart

Azimuthal View Angle Determines Opacity



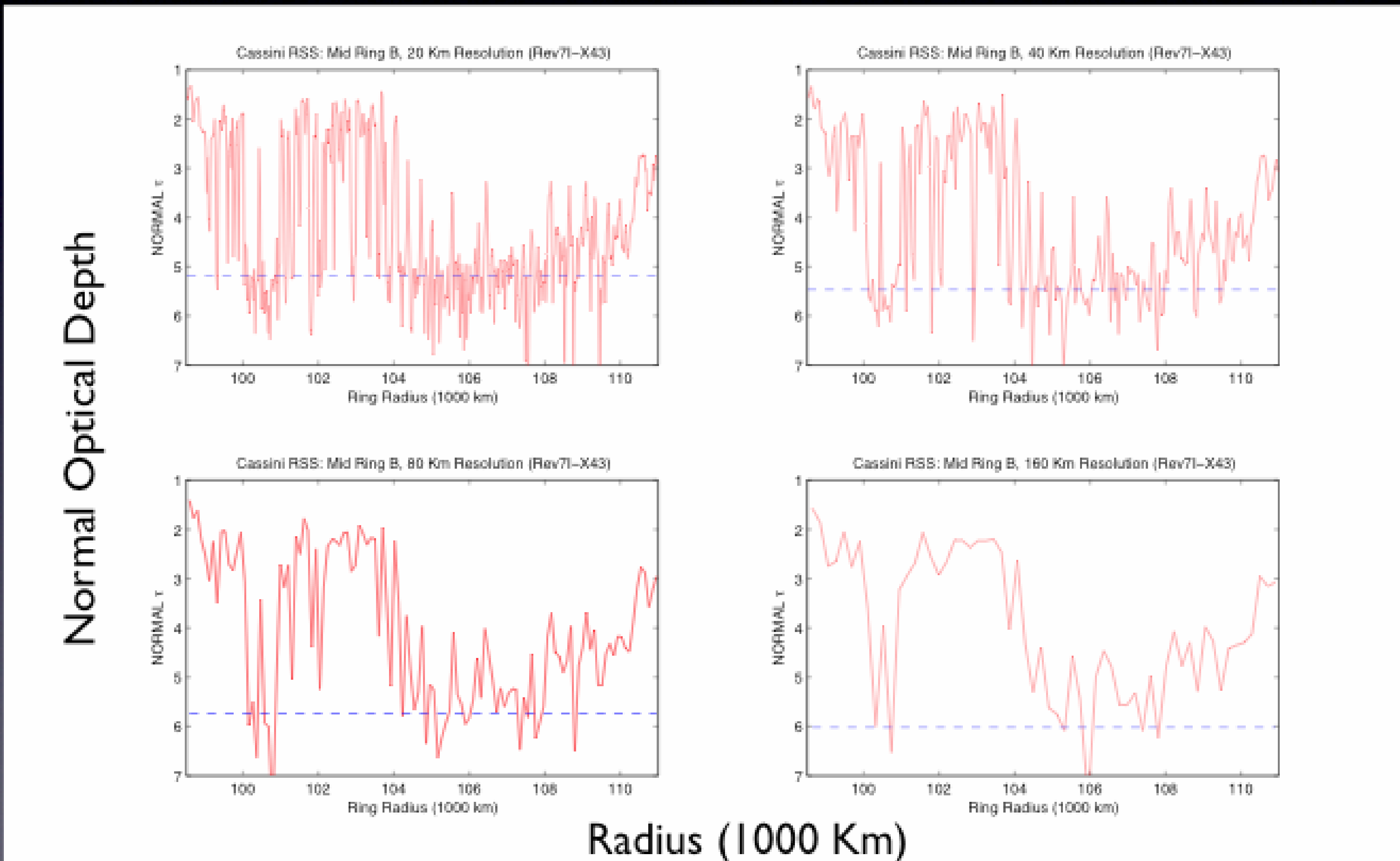
Self-Gravity Wake Properties in A Ring



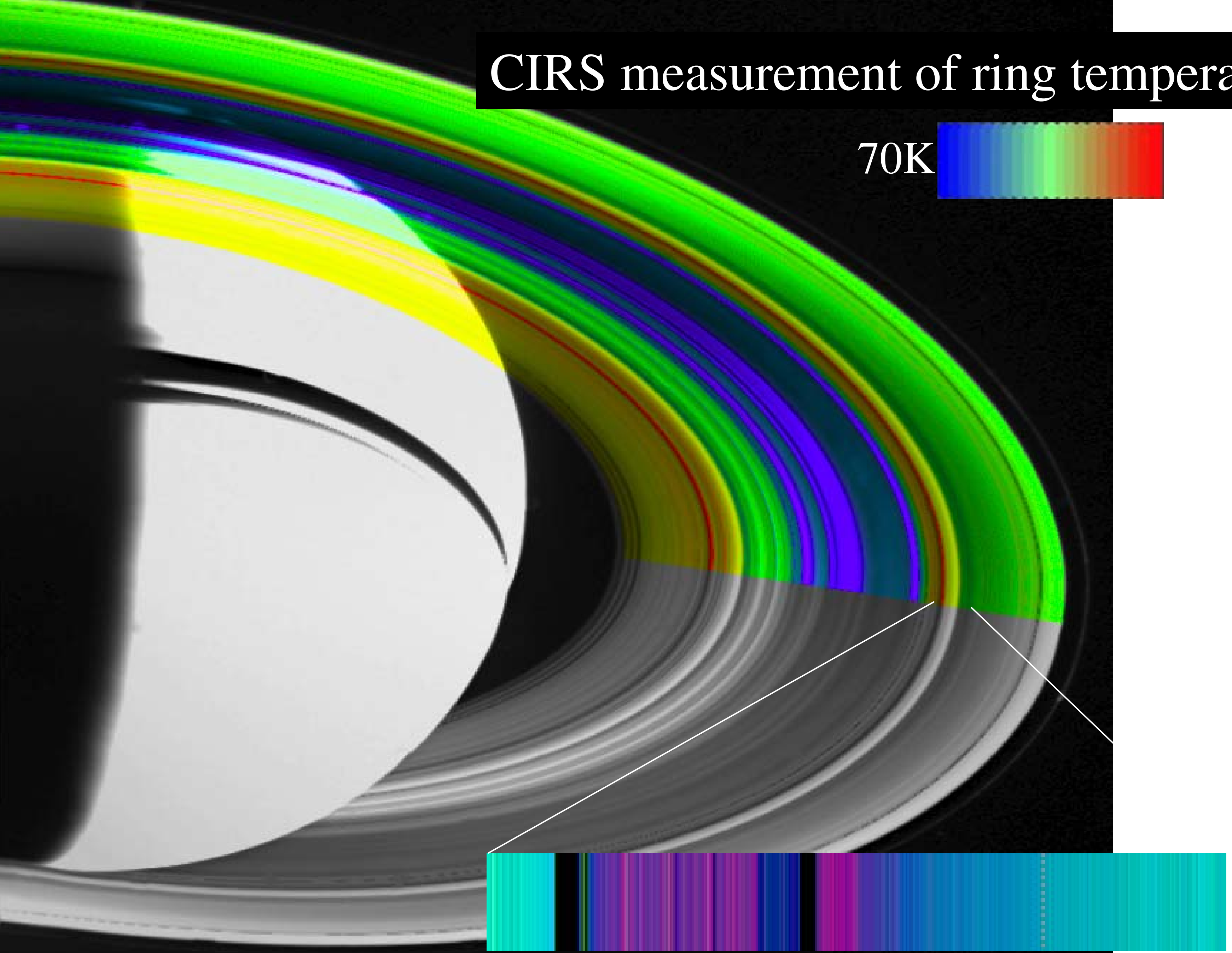
Colwell et al GRL 2006

RSS occultations:

How Optically Thick is the “Core” of Ring B ?

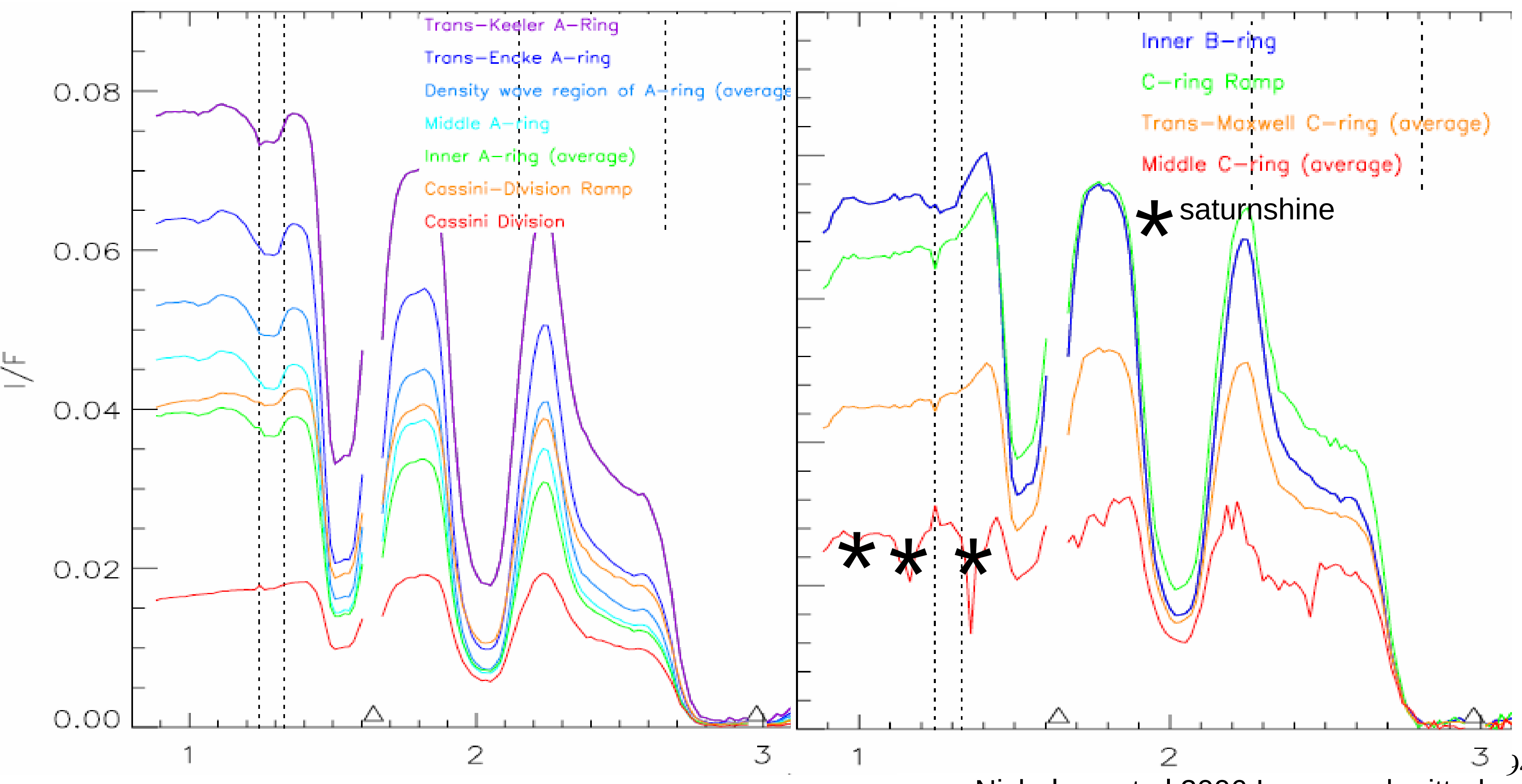


CIRS measurement of ring temperatures



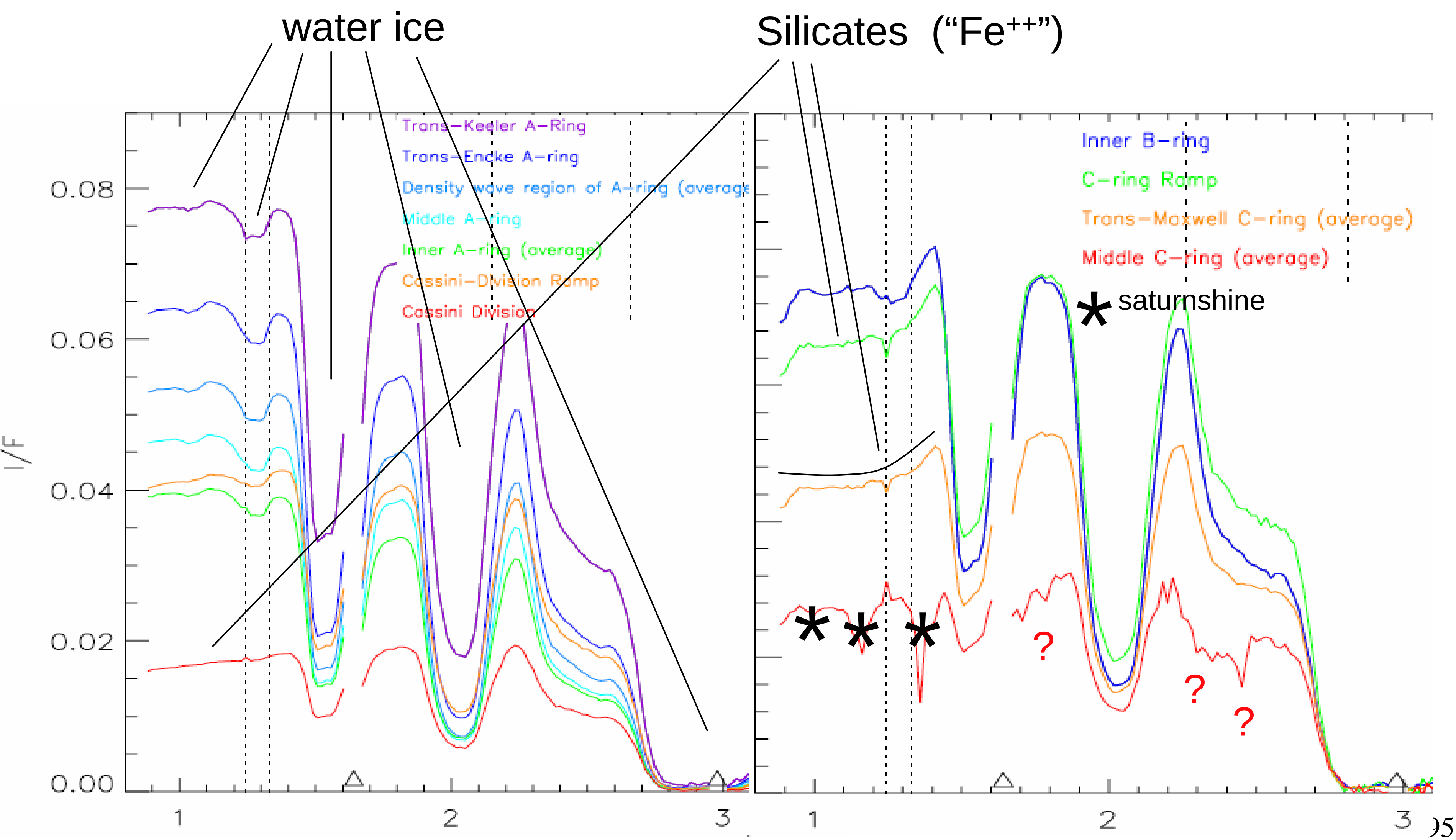
VIMS measurement of variable composition - interplanetary

VIMS reflectance spectra show “fingerprints” of several different materials, in different amounts in different places



Nicholson et al 2006 Icarus, submitted

VIMS reflectance spectra show "fingerprints"
of several different materials, in different amounts in different places



Nicholson et al 2006 Icarus, submitted

Summary of Cassini year two for Rings

Last year of ring studies has emphasized data analysis and interpretation

Modeling has explained several curious structures in F ring
- “channels and spirals”: interactions with Prometheus
- “strands”: collision with a marauding, possibly chaotic moonlet

New observations of 100-500m size objects in main rings and F ring

Stellar occultations at multiple azimuths, two different instruments:
- mapping out 3-D structure of gravitational instability “wakes”

VIMS compositional mapping reveals several distinct components:
- water ice, silicates, “Phoebe”-like organics, reddish “stuff”
- More “pollution” in low optical depth rings: meteoroids?

Spokes! Expect to see more as ring opening angle decreases

Looking forward to seeing the rings again starting in July

Gee Whiz Cool Facts

- How many orbits, sequences, and commands?

  ~14 orbits (Rev 11-Rev 25); ~10 sequences (S11-S21); ~350,000 commands

- Which instrument has returned the most data from the S/C in the last year? Which instrument the least?

Inst	First Year	Second Year
RPWS	16.5 (Gbytes)	17.6 (Gbytes)
CAPS	9.8	10.8
ISS	9.7	10.6
MAG	4.5	4.9
MIMI	3.1	4.0
CIRS	2.8	3.5
VIMS	1.8	3.2
UVIS	2.7	2.2
CDA	0.7	1.3
RADAR	0.7	0.8
INMS	0.3	0.3
RSS - S/C	0.0	0.0
Total	52.6	59.2
(RSS - DSN	220.0	277.0)

Gee Whiz Cool Facts (cont)

- How many Orbit Trim Maneuvers (OTMs)

  Planned 44, Deleted 16, and executed 28

- How many miles has Cassini traveled? What is our miles per gallon rating?

  First Year: 100 million km (63 million miles)
  Second Year: 117 million km (73 million miles)

  First Year :879.0 kg of NTO, 528.9 kg of MMH, and 7.6 kg of N2H4 [325 gallons]
  Second Year: 47.1kg of NTO, 28.3 kg of MMH, and 7.5 kg of N2H4 [19 gallons]

  First Year: Miles/gallon=194,000 miles/gallon (includes SOI)
  Second Year: Miles/gallon= 3.7 million miles/gallon

What to Expect in Year 3!

- Complete the magnetotail phase and begin the 180 degree transfer
  - Arrive at the magnetotail
  - Rotate the petals over to the other side of Saturn. This gives us the highest inclinations we will experience to date, and kills two birds with one stone
    - Rotates the petals towards noon
    - Sets up the occultations in the 4th (last) year
  - Many Titan flybys!
- Complete extended mission planning, choosing the final tour, and begin the detailed scientific integration
- ~22 orbits completed, 19 targeted flybys - almost all of Titan, 35 non-targeted (100,000km or less)

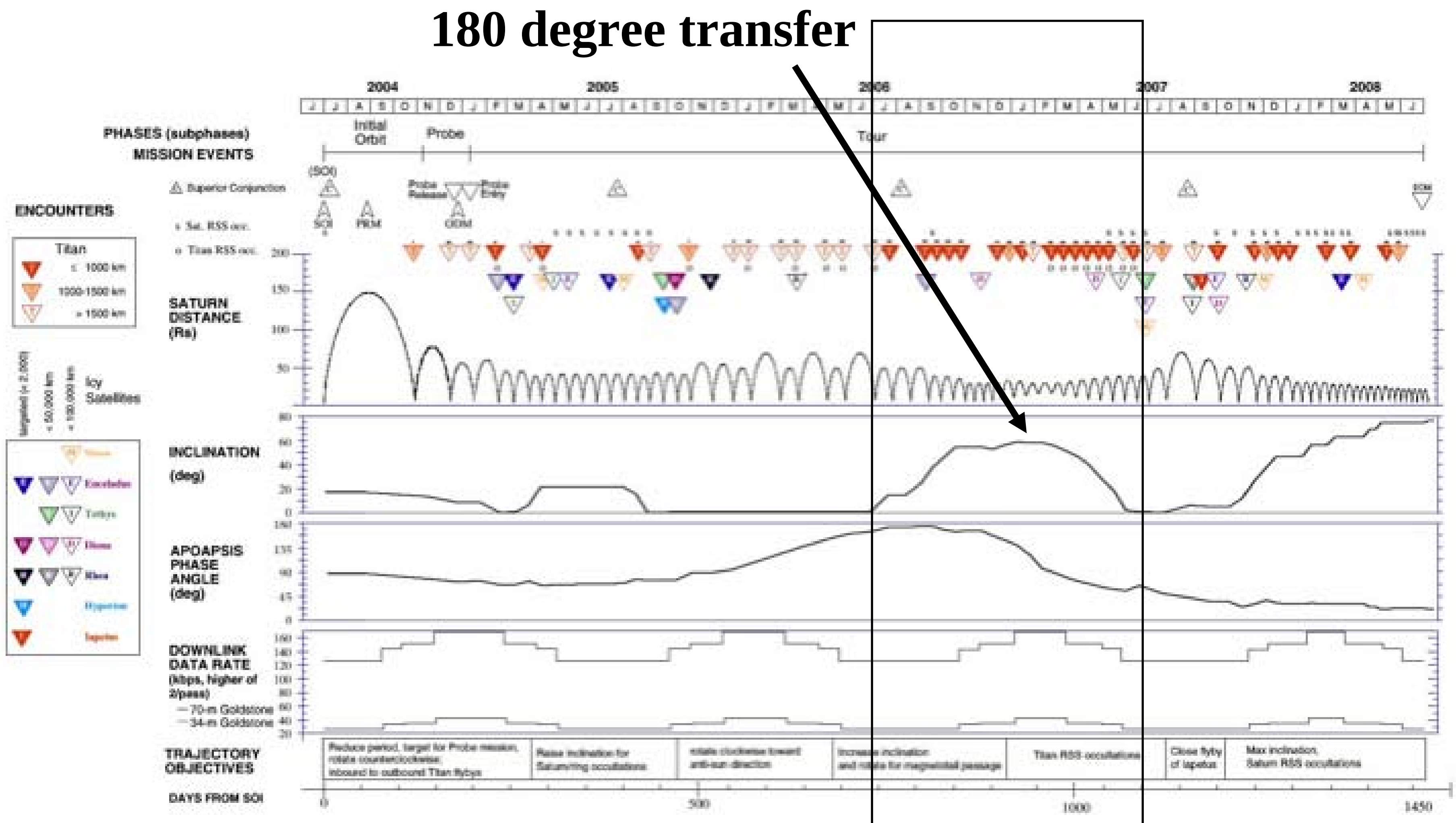


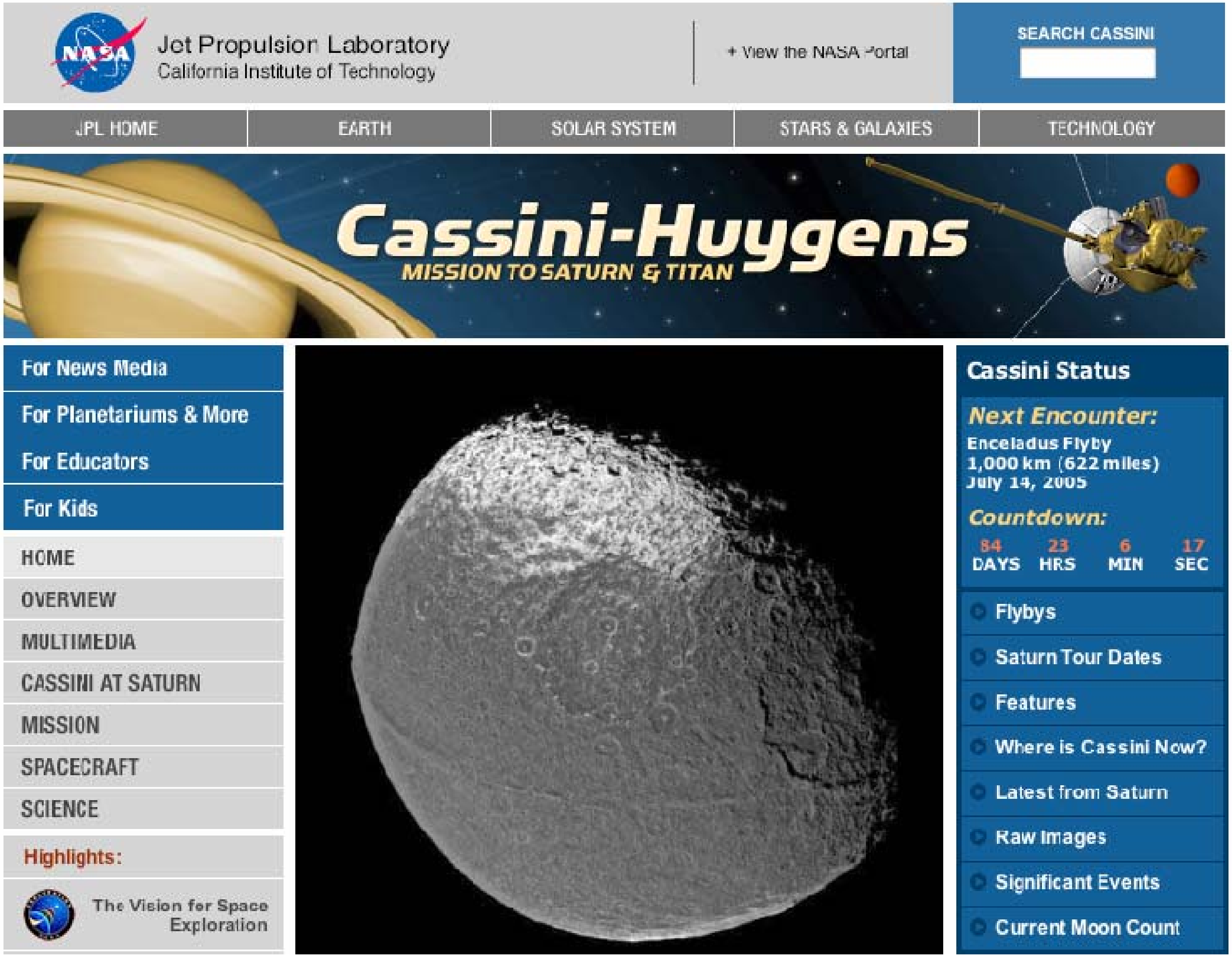
Figure 2.2 Cassini Tour Segment Timeline (2002-01)

Targeted Flyby Summary - 3rd year

Seq	Rev	Name		Event	Epoch (SCET)	Date
S12	11	11EN (t)	[E2]	ENCELADUS	2005-195T19:55	Jul-14
S21	25	25TI (t)	[T15]	TITAN	2006-183T09:21	Jul-02
S22	26	26TI (t)	[T16]	TITAN	2006-203T00:25	Jul-22
S23	28	28TI (t)	[T17]	TITAN	2006-250T20:17	Sep-07
S24	29	29TI (t)	[T18]	TITAN	2006-266T18:59	Sep-23
S24	30	30TI (t)	[T19]	TITAN	2006-282T17:30	Oct-09
S25	31	31TI (t)	[T20]	TITAN	2006-298T15:58	Oct-25
S26	35	35TI (t)	[T21]	TITAN	2006-346T11:42	Dec-12
S26	36	36TI (t)	[T22]	TITAN	2006-362T10:05	Dec-28
S27	37	37TI (t)	[T23]	TITAN	2007-013T08:39	Jan-13
S27	38	38TI (t)	[T24]	TITAN	2007-029T07:16	Jan-29
S28	39	39TI (t)	[T25]	TITAN	2007-053T03:12	Feb-22
S28	40	40TI (t)	[T26]	TITAN	2007-069T01:49	Mar-10
S28	41	41TI (t)	[T27]	TITAN	2007-085T00:23	Mar-26
S29	42	42TI (t)	[T28]	TITAN	2007-100T22:58	Apr-10
S29	43	43TI (t)	[T29]	TITAN	2007-116T21:33	Apr-26
S30	44	44TI (t)	[T30]	TITAN	2007-132T20:10	May-12
S30	45	45TI (t)	[T31]	TITAN	2007-148T18:52	May-28
S31	46	46TI (t)	[T32]	TITAN	2007-164T17:46	Jun-13
S31	47	47TI (t)	[T33]	TITAN	2007-180T17:03	Jun-29

Come join us!

http://saturn.jpl.nasa.gov



Narrative to accompany Enceladus slides Andrew Ingersoll's CHARM presentation 6/27/06

1. Special issue of Science (10 March 2006): Cassini instrument teams report on their Enceladus results.
2. Hints before the Cassini encounter with Enceladus - Voyager image from 1981: Apparent flow feature partially covers older craters. The flow feature has no large craters and is therefore geologically young - a sign of recent internal activity. Ammonia-water, which is liquid down to -98°C, was thought to be the working fluid.
3. More hints - the E ring: Discovered from Earth in early 1990's during ring plane crossing, when light from main rings is minimized. The E ring is most dense at orbit of Enceladus, implying Enceladus is the source of E ring particles. Particles are micron-sized ($r \sim 10^{-6}$ m).
4. Still more hints - neutral H, O, and OH molecules in orbit around Saturn. The image shows atomic oxygen (O) concentrated near the orbit of Enceladus. Data is from Cassini UVIS (ultraviolet spectrometer). Water is the likely parent molecule.

5. In February and March of 2005, Cassini MAG observed perturbations in magnetic field, which is largely from Saturn, consistent with charged particles above Enceladus south pole. Based on these observations, the Cassini project altered the spacecraft trajectory to fly close to Enceladus on July 14, 2005.
6. The flyby was an interdisciplinary effort. First discuss the ISS (imaging) results from this flyby and another flyby in November. The sun is nearly behind Enceladus (phase angle of 161.4 degrees means the light is bent by only 18.6 degrees). What you see are particles, not gas. Other instruments measure particle size and gas composition.The plumes are emanating from the south pole.
7. The motion of the spacecraft produces the motion apparent in this four-frame movie, which allows us to locate the sources relative to the surface. The south pole is on the horizon in the middle.
8. The plumes are coming from these cracks, called tiger stripes, which are grooves 2 km wide and a few hundred meters deep.
9. The south pole is in the middle of the tiger stripes, which occupy the region from 50 degrees south to the pole. The blue-green color is characteristic of water ice in sand-size crystals rather than fine snow.

10. The geologic setting: The red lines are compression features, which surround the south pole at a latitude of 50°S; the blue lines are extensional features, which run north-south across the equator. Both sets of features are consistent with an event that flattened the satellite and made it more oblate (less spherical). The tiger stripes are a mystery; the absence of tiger stripes in the north is also a mystery. There are no measurable craters in the south polar region.
11. Crater density (number of craters per unit area) for various regions on Enceladus. The lowest curve is for the south polar region and is an upper bound, implying the surface there is less than a few million years old. Something is destroying or covering the older craters.
12. High-resolution (2 meters per pixel) image of the south polar region showing boulders of ~10 m size. No one knows how they formed.
13. Over-exposed image showing particles escaping the gravity field of Enceladus. Each level of brightness is represented by a different color, with white the faintest.
14. Stellar occultations, in which the motion of the spacecraft makes stars pass behind Enceladus. A and B show the path of the star lambda Scorpii; C and D show the path of the star gamma Orionis, which passed through the plumes at the south pole.

15. Effect of the plume on the ultraviolet spectrum of starlight as measured by UVIS. The smooth curve is for a certain column abundance (density times path length) of water vapor.
16. Near-infrared spectrum of the surface as recorded by VIMS. The surface has a reflectivity close to one. Water ice is the dominant feature, but CO_2 is also present. Organic molecules (the C-H chemical bond) shows up only in the tiger stripes.
17. Path of the spacecraft, showing that the dust analyzer (CDA) and the gas detector (INMS) saw their maximum signals shortly after passing over the south pole but before closest approach to Enceladus.
18. Mass of molecules measured by INMS. The peaks at mass 18, 44, and 28 are water, CO_2, and either N_2 or CO. Since other instruments did not see CO, the mass 28 peak is probably N_2. The signal near mass 16 is probably CH_4.
19. Mid-IR brightness temperature showing the south polar hot spot. The right panels show that to match the short wave part of the spectrum, there must be a region at 135 K (-138°C) that occupies a small part of the field of view.
20. The tiger stripe is the hottest place, but 5% of the region in the tiger stripe is at a temperature of 145 K (- 128°C), which is very warm!

21. What's happening below the surface? At 145 K, the surface in the tiger stripe is radiating much more heat than it absorbs from the sun. To deliver this heat by thermal conduction from the interior, the temperature must increase with depth and must be at the melting point of water just ten meters below the surface. Since ammonia was not detected, the liquid is pure water at $T > 273$ K. When a crack opens up, the water boils and erupts into the vacuum above the surface. With liquid water, organics, and a hydrologic cycle (for chemical energy), Enceladus might be a good place to find extra-terrestrial life. The big question is what heats the interior of Enceladus. Radioactive decay and tidal heating together fall short by a factor of 10, according to accepted models. Enhanced tidal heating, due to a partly molten silicate core, might do the trick. But how did the core become molten in the first place?

22. The end, but not the end. Cassini will be learning more about Enceladus during the next two years.