June 24, 2008

Cassini-Huygens Mission to Saturn 4th Anniversary

Mission Overview

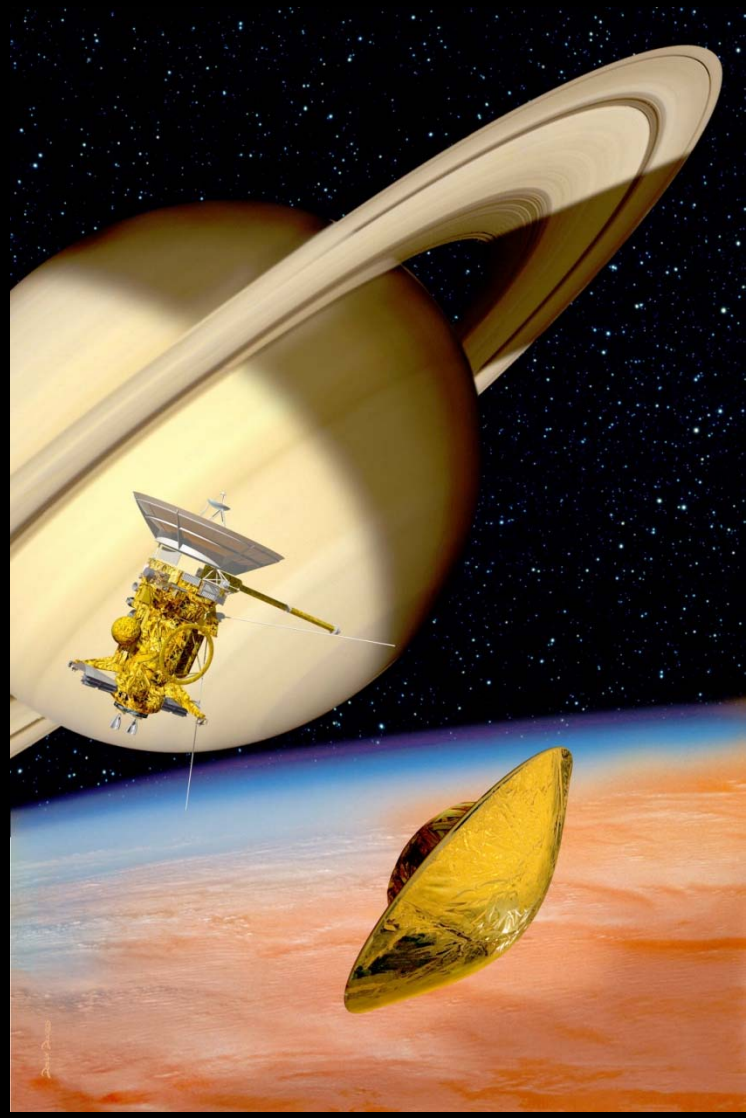
Huygens and Cassini
The Scientists and the Machines

Christiaan Huygens

Giovanni Domenico Cassini

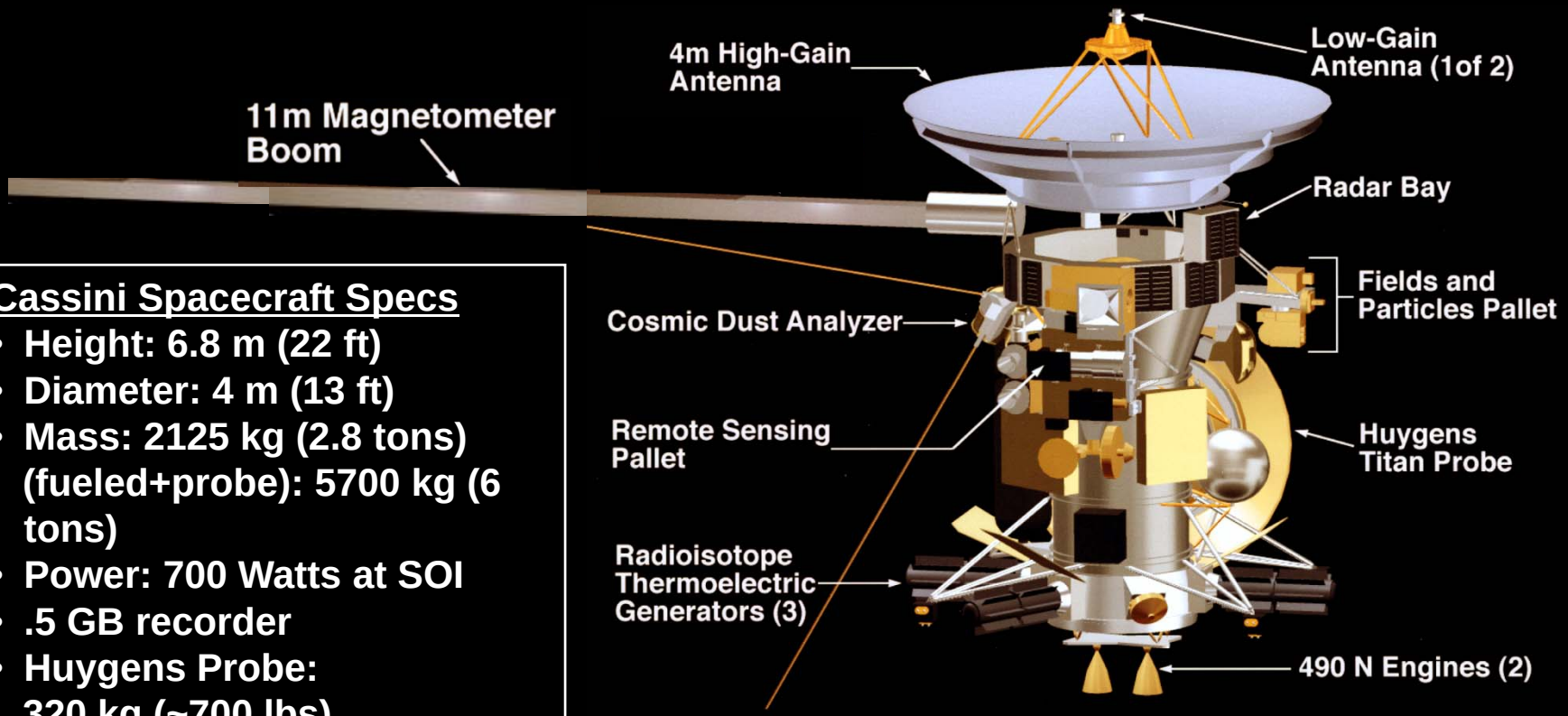
Christiaan Huygens (1629-1695) Dutch scientist, who discovered the true nature of Saturn's rings, and in 1655, Titan

Giovanni Domenico Cassini (1625-1712), Italo-French astronomer, who discovered several of Saturn's satellites: Iapetus, Rhea, Tethys and Dione. In 1675, he discovered what is today called "Cassini Division" the gap in-between the two main rings of Saturn



Cassini Orbiter & Huygens Probe

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)

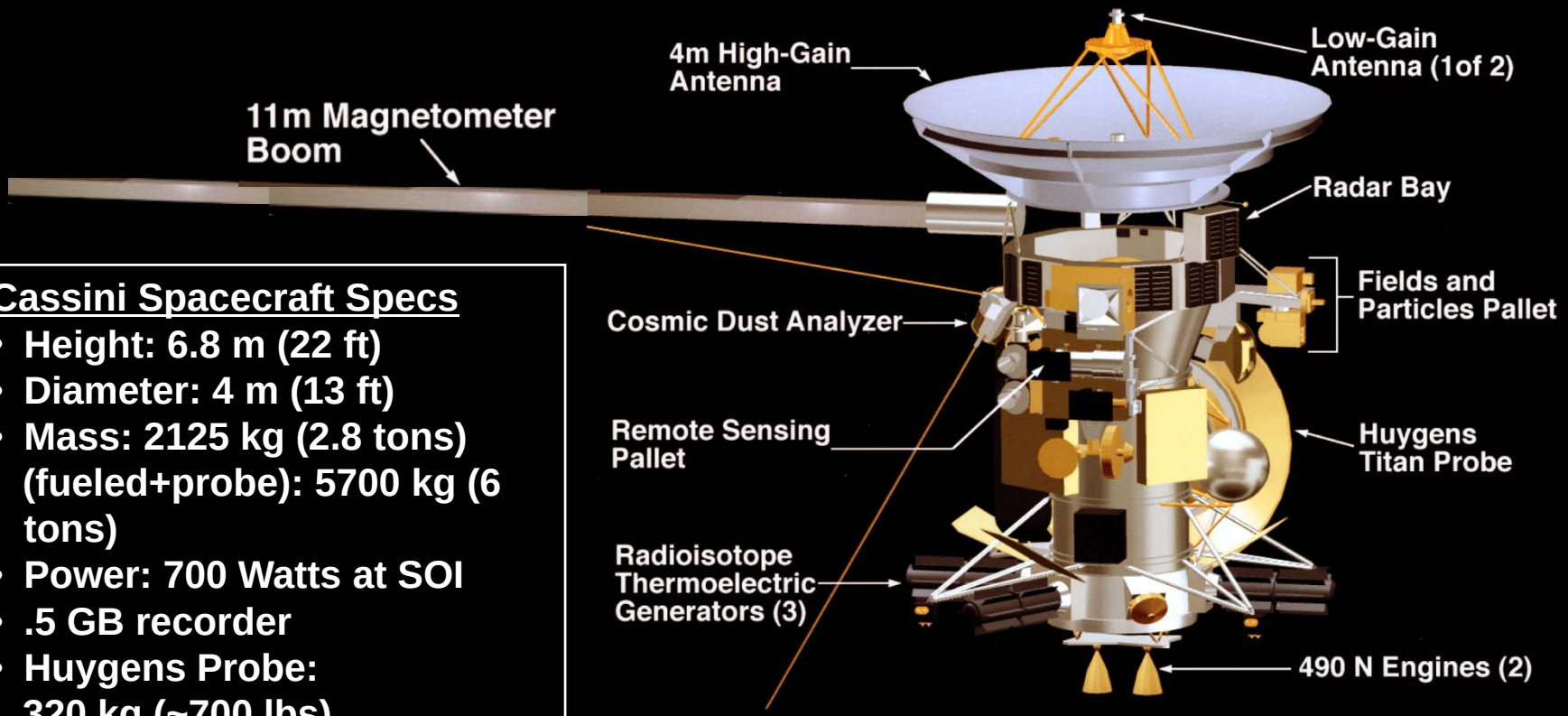
Cassini Instruments:

Optical Remote Sensing (ORS)
CIRS: Composite Infrared Spectrometer
ISS: Imaging Science Subsystem
UVIS: Ultraviolet Imaging Spectrograph
VIMS: Visual and Infrared mapping Spectrometer

Microwave Remote Sensing
RADAR: Cassini Radar
RSS: Radio Science Subsystem

Magnetospherie and Plasma Science (MAPS)
CDA: Cosmic Dust Analyzer
INMS: Ion and Neutral Mass Spectrometer
MAG: Dual Technique Magnetometer
MIMI: Magnetospheric Imaging Instrument
RPWS: Radio and Plasma Wave Science

Cassini Spacecraft



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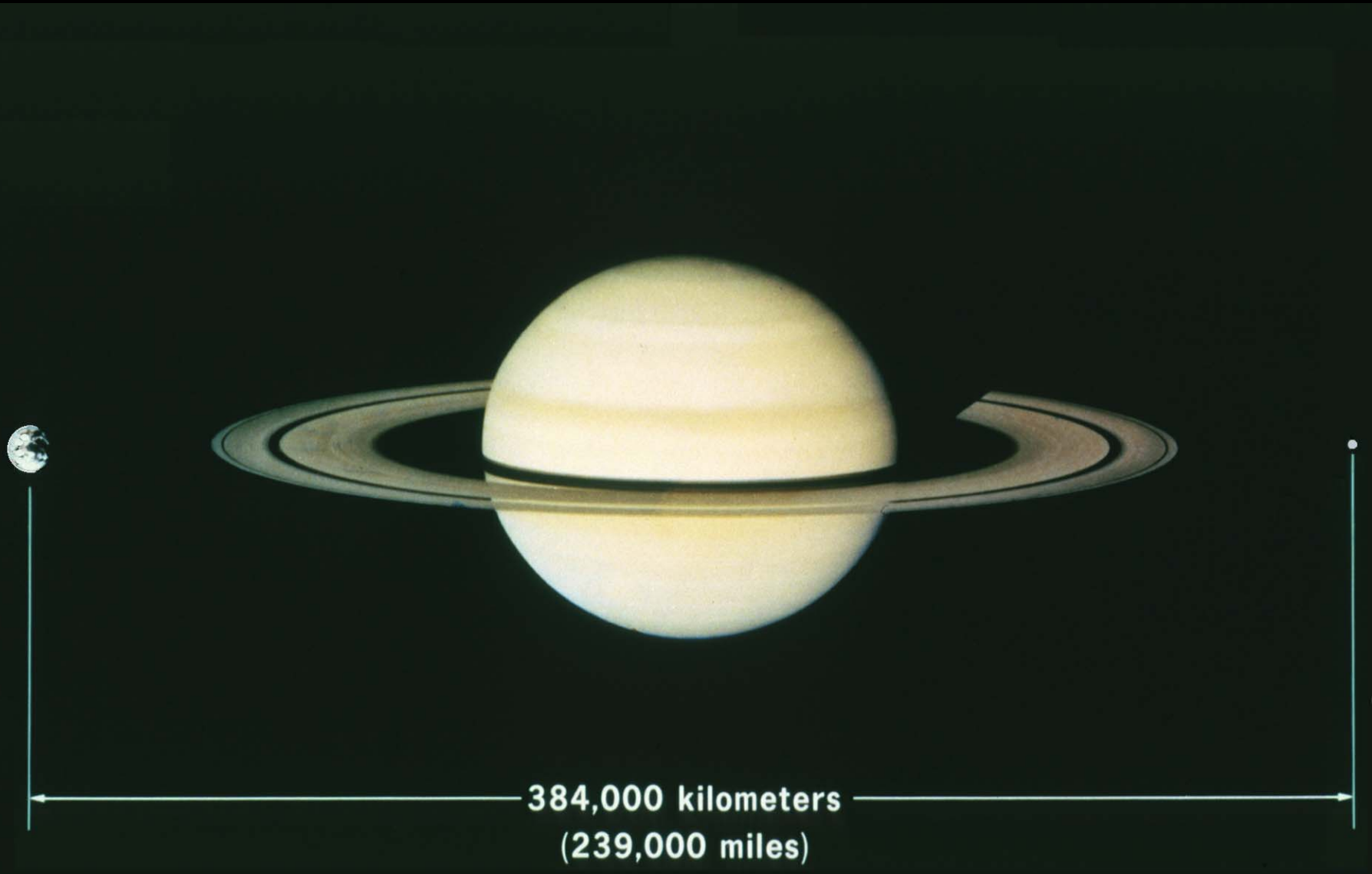
United States
France
Germany
Belgium
Italy
Denmark
United Kingdom
Switzerland
Netherlands
Czech Republic
Austria
Spain
Finland
Ireland
Hungary
Sweden
Norway
International
Participation in
CASSINI
Saturn Orbiter and
Huygens Titan
Probe

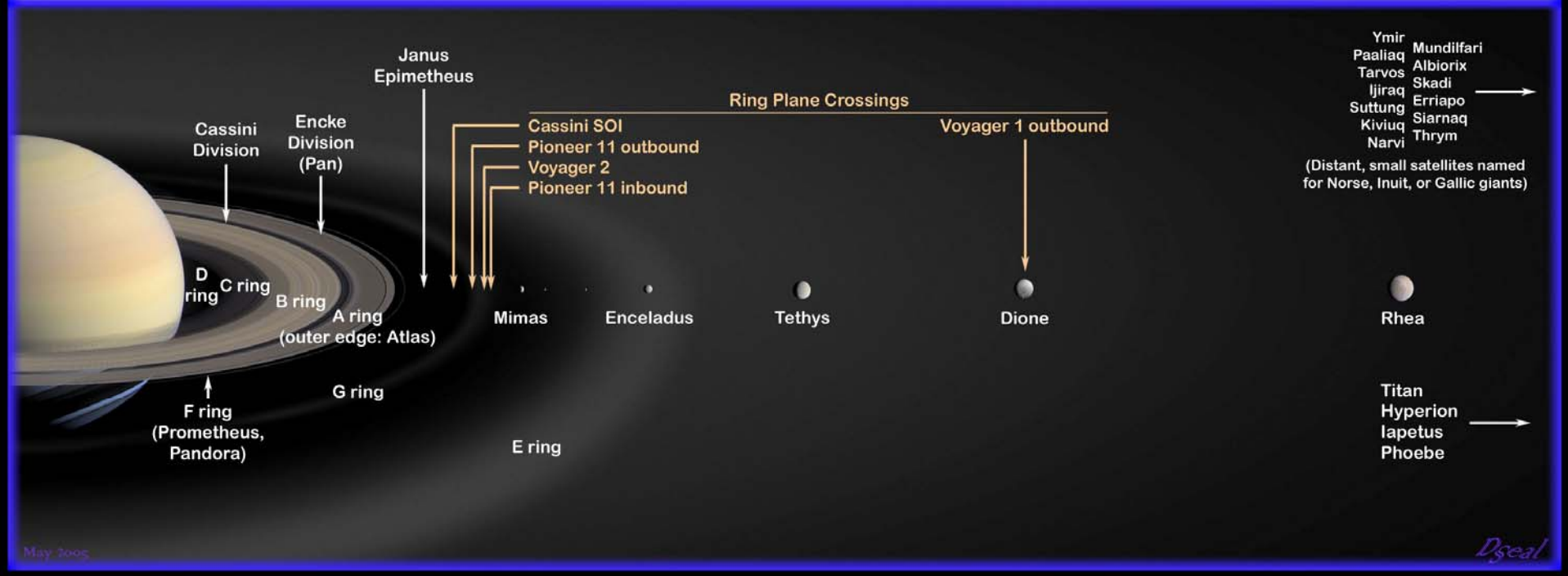
Cost

- Cassini total cost $3 billion
  - $2.5 B NASA for Cassini, $0.5 B ESA for Huygens
  - Spread over ~20 y -> $150 M/y
  - Cassini 0.5% of NASA annual budget ($16.8 B)

- NASA annual budget $16.8 B
  - 1.7% of U.S. discretionary spending ($982 B)
  - 0.6% total U.S. budget ($2800 B)


384,000 kilometers
(239,000 miles)

THE SATURNIAN SYSTEM



Mission Overview - 4th year of tour
The climb to high inclination

- ~27 orbits to complete, ~10 sequences, 13 targeted flybys, 74 non-targeted icy satellite (120,000 km or less) opportunities
- In the 4th year of the Cassini tour we started with equatorial orbits and we got our only targeted Iapetus flyby (September 2007) of the mission - a big highlight!
- We have two very low (<10,000 km) non-targeted flybys, one of Rhea (Aug 30, 2007) and one of Epimetheus (Dec 03, 2007).
- The last targeted Enceladus flyby of the prime mission (Mar 12, 2008).
- For most of the 4th year, we were increasing the inclination to near polar (over 70 degrees) orbits to look down on Saturn and its rings, this is the highest inclination of the prime and extended missions.
- The scientists and tour designers are beginning to work on proposals for an extended extended mission

Mission Summary Chart

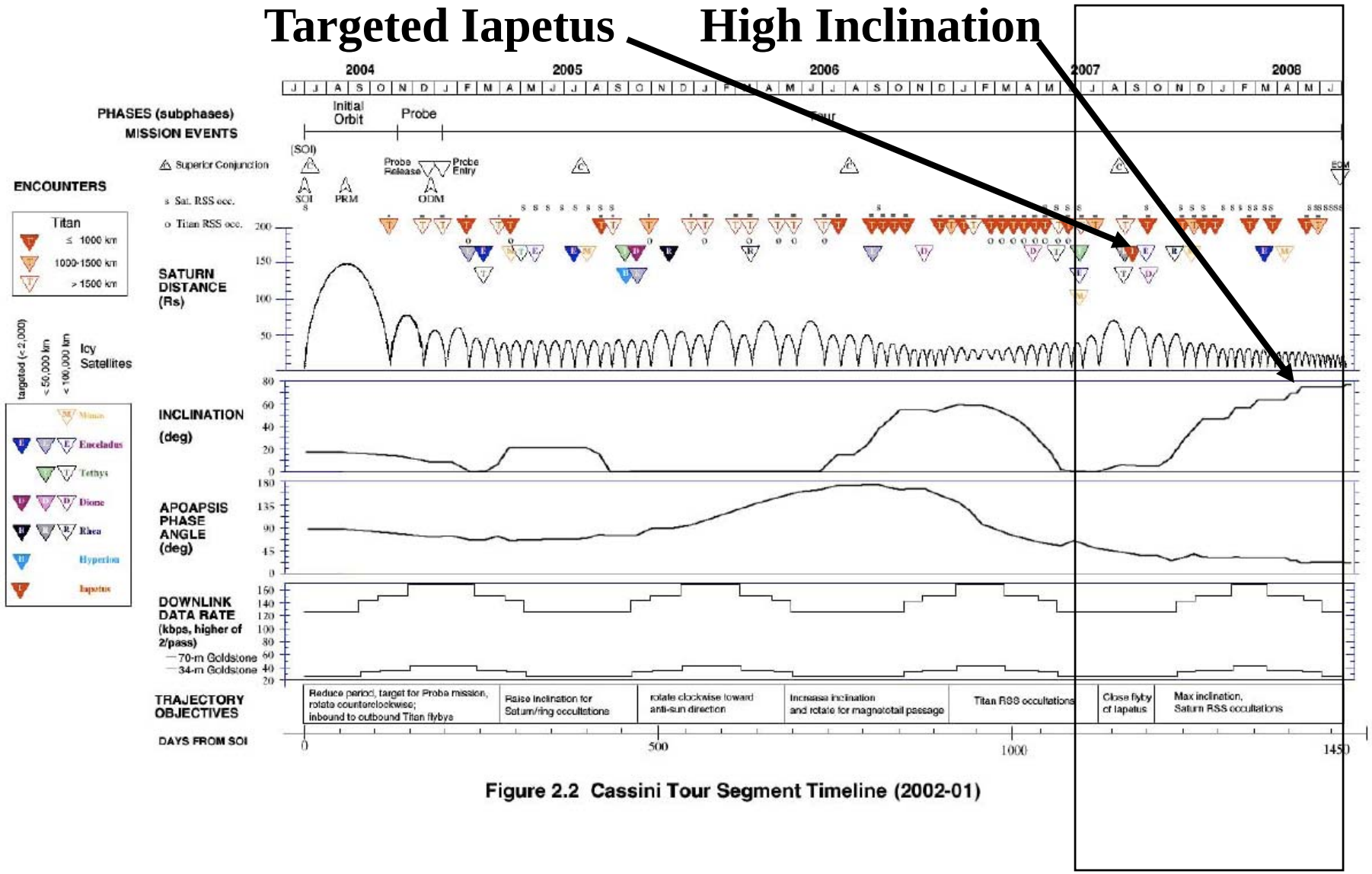


Figure 2.2 Cassini Tour Segment Timeline (2002-01)

Targeted Flyby Summary - 4th year

Seq	Rev	Name	Event	Epoch (SCET)	Date
S32	48	48TI (t) [T34]	TITAN	2007-200T01:11	Jul-19
S33	49	49TI (t) [T35]	TITAN	2007-243T06:33	Aug-31
S33	49	49IA (t) [I1]	IAPETUS	2007-253T14:16	Sep-10
S34	50	50TI (t) [T36]	TITAN	2007-275T04:43	Oct-02
S35	52	52TI (t) [T37]	TITAN	2007-323T00:47	Nov-19
S35	53	53TI (t) [T38]	TITAN	2007-339T00:07	Dec-05
S36	54	54TI (t) [T39]	TITAN	2007-354T22:58	Dec-20
S36	55	55TI (t) [T40]	TITAN	2008-005T21:30	Jan-05
S38	59	59TI (t) [T41]	TITAN	2008-053T17:32	Feb-22
S38	61	61EN (t) [E3]	ENCELADUS	2008-072T19:06	Mar-12
S39	62	62TI (t) [T42]	TITAN	2008-085T14:28	Mar-25
S40	67	67TI (t) [T43]	TITAN	2008-133T10:02	May-12
S40	69	69TI (t) [T44]	TITAN	2008-149T08:24	May-28

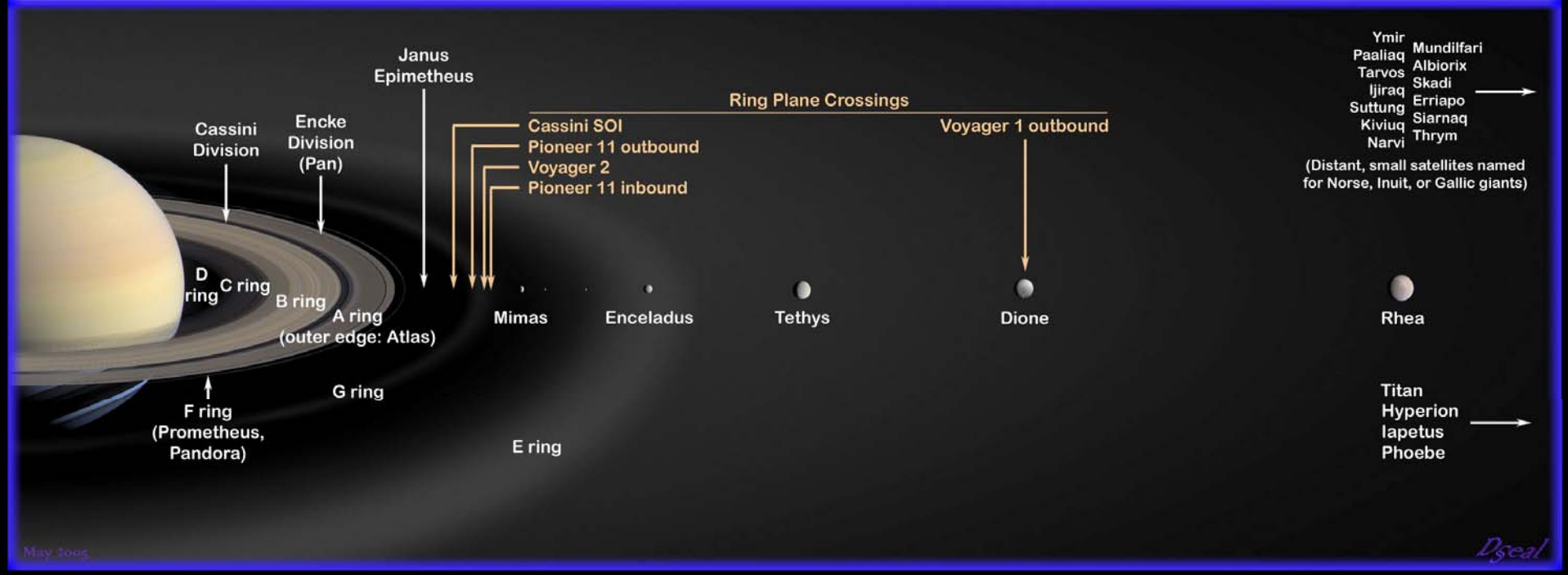
Saturn

- 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.

Icy Satellites

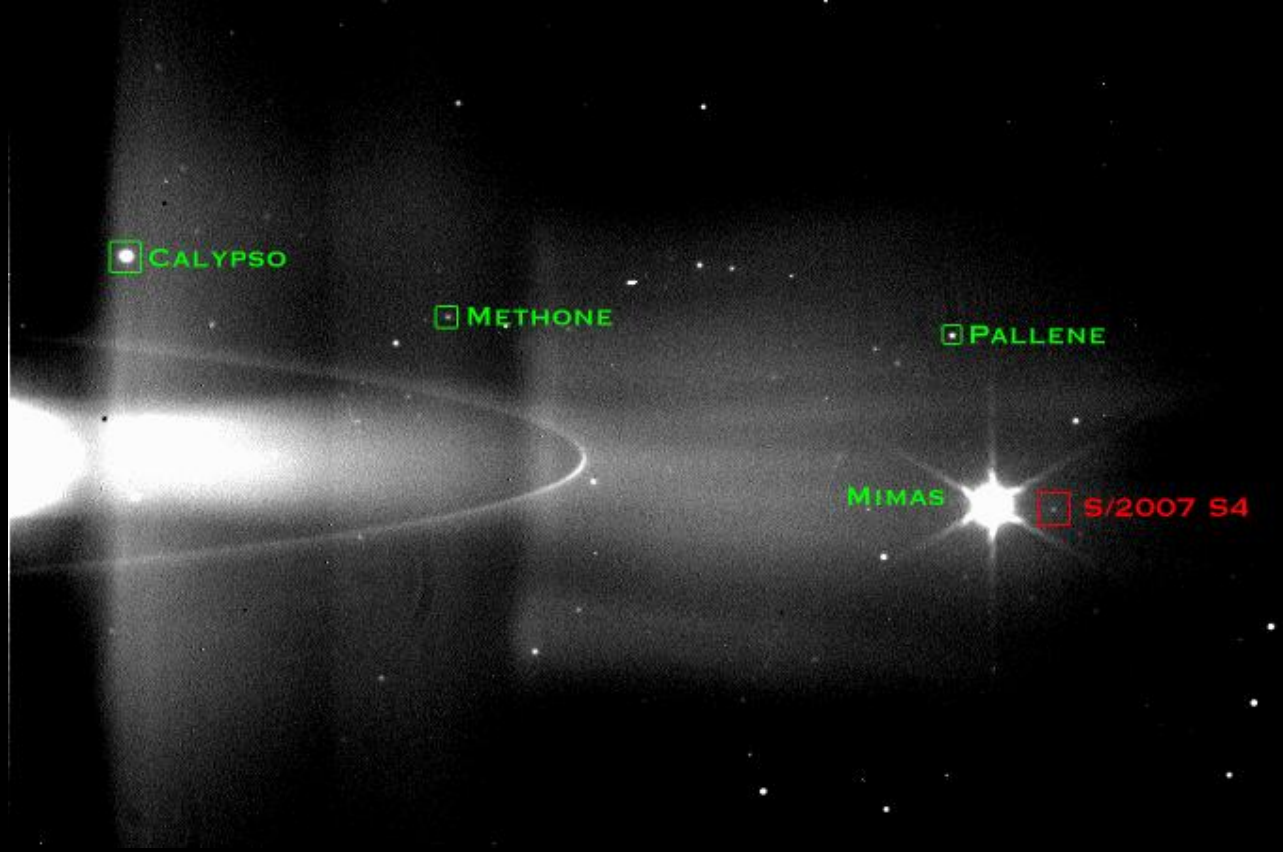
- The Saturn system has 60 confirmed satellites, most are small and far away from the planet.
- There are 8 major icy satellites (not including Titan)
  - Mimas, Enceladus, Tethys, Dione, Rhea, Hyperion, Iapetus, and Phoebe
- They are located outside the major ring system and vary in size from tiny Phoebe (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).

THE SATURNIAN SYSTEM



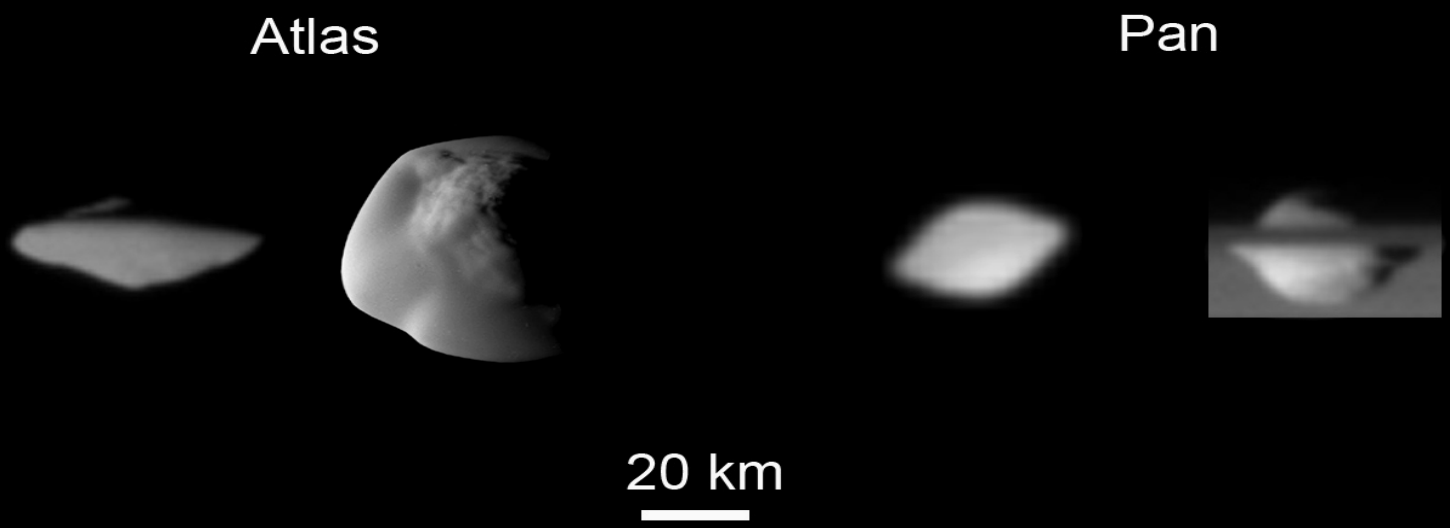
Saturn's Icy Moons

Saturn's 60th Moon: Anthe



ISS, 30 May 2007

Saturn's Small Flying Saucers

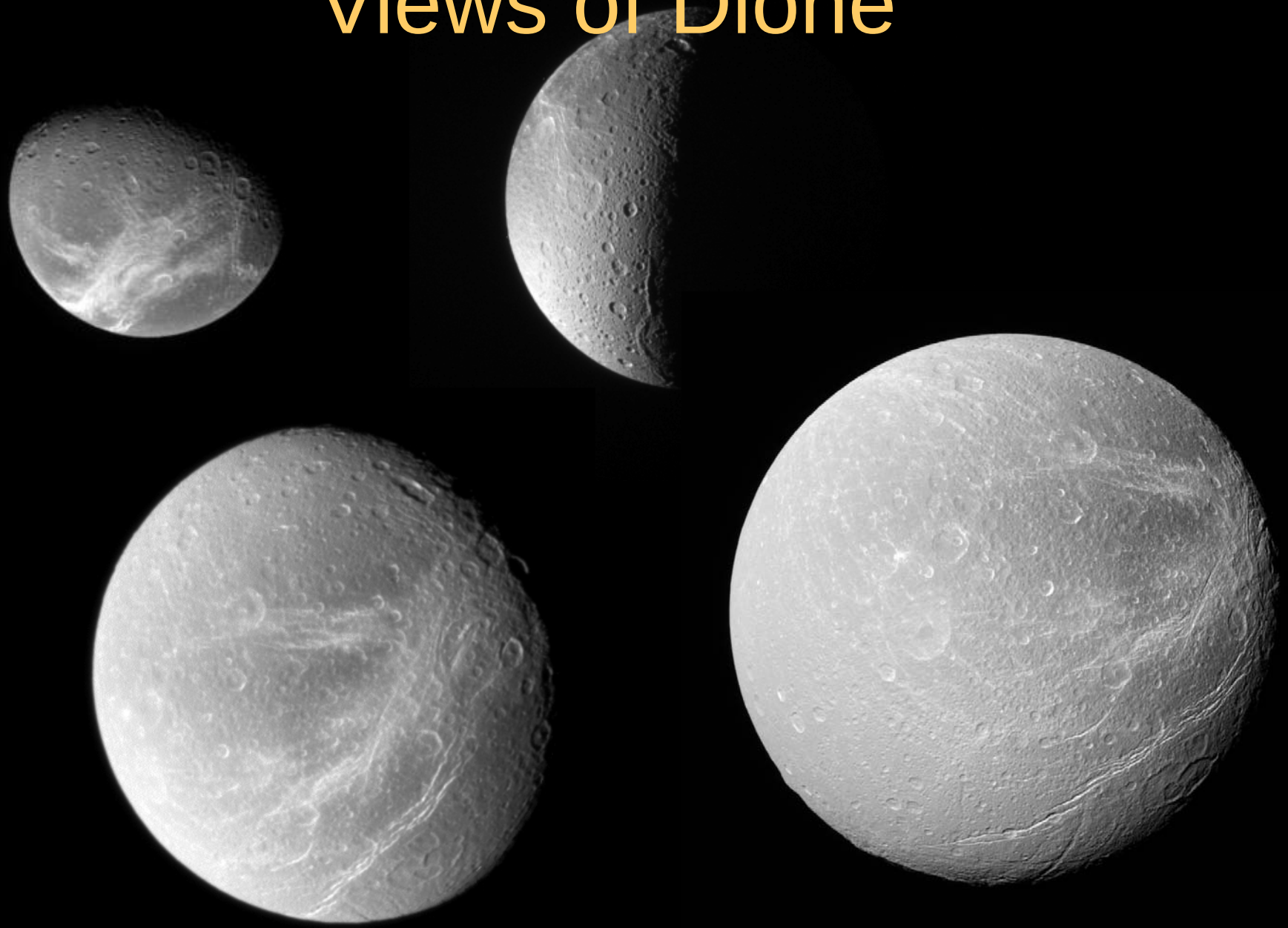


Porco et al., 2007; Charnoz et al., 2007

Icy Satellite Close Encounters

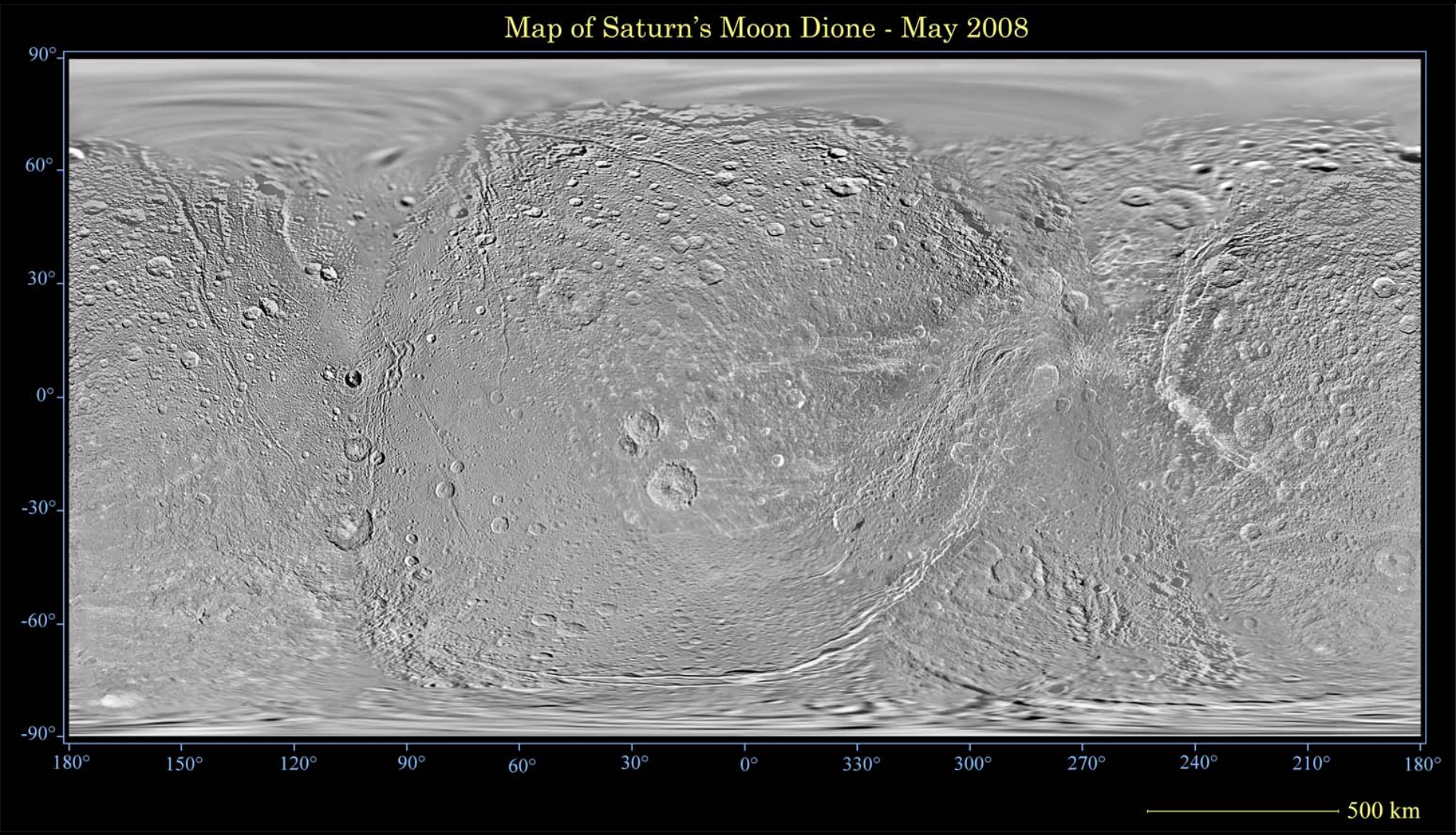
- Tethys 18,945 km 27 Jun 2007
- Rhea 5,737 km 30 Aug 2007
- Iapetus 1,644 km 10 Sep 2007
- Epimetheus 6,364 km 2 Dec 2007
- Enceladus 52 km 12 Mar 2008

Views of Dione



ISS, 15 February 2008; 30 September 2007; 22 March 2008; 8 February 2008

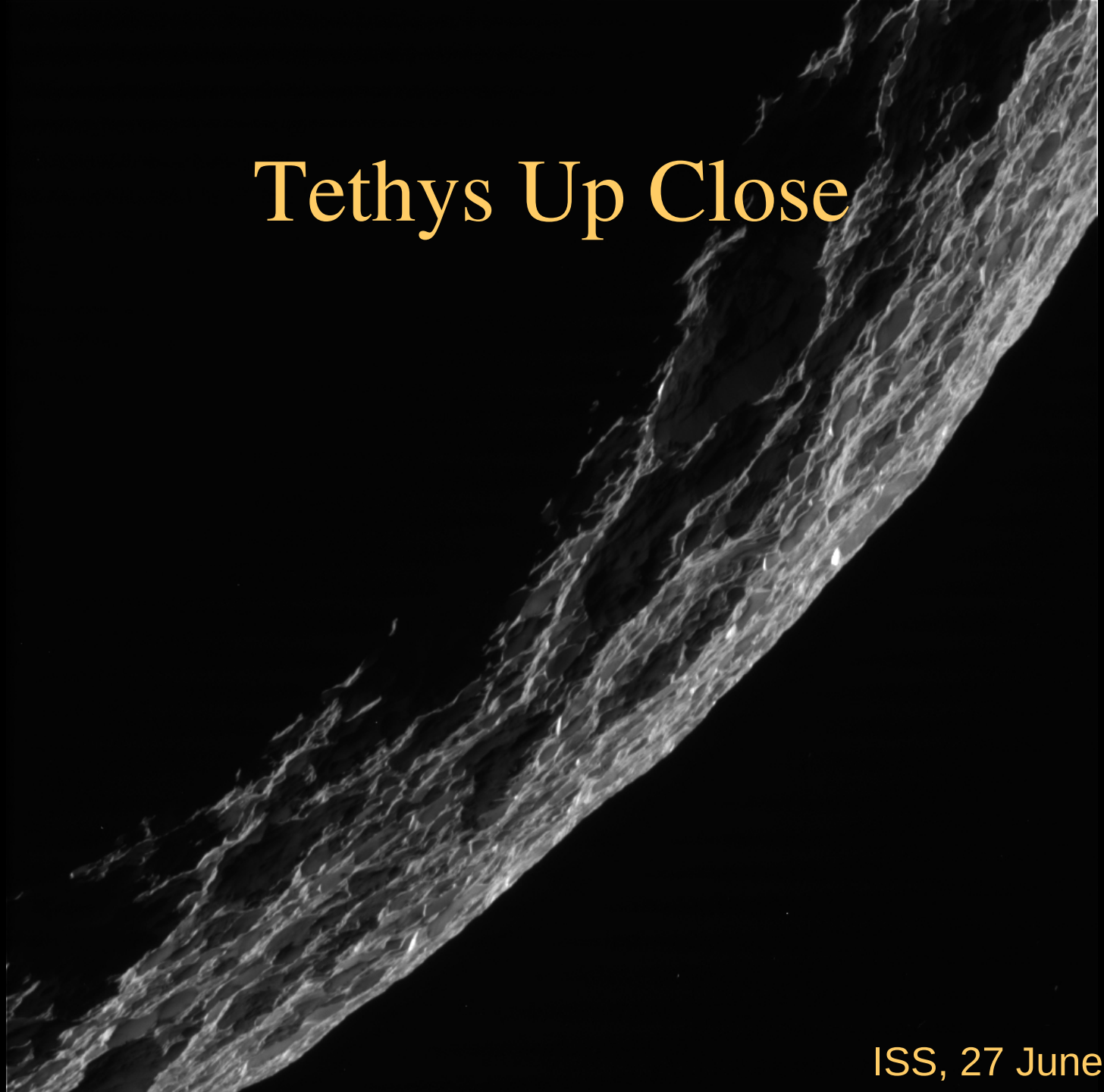
Map of Dione


Map of Saturn's Moon Dione - May 2008
90°
60°
30°
0°
-30°
-60°
-90°
180°
150°
120°
90°
60°
30°
0°
330°
300°
270°
240°
210°
180°
500 km

Tethys Up Close

ISS, 27 June 2007

Tethys Up Close

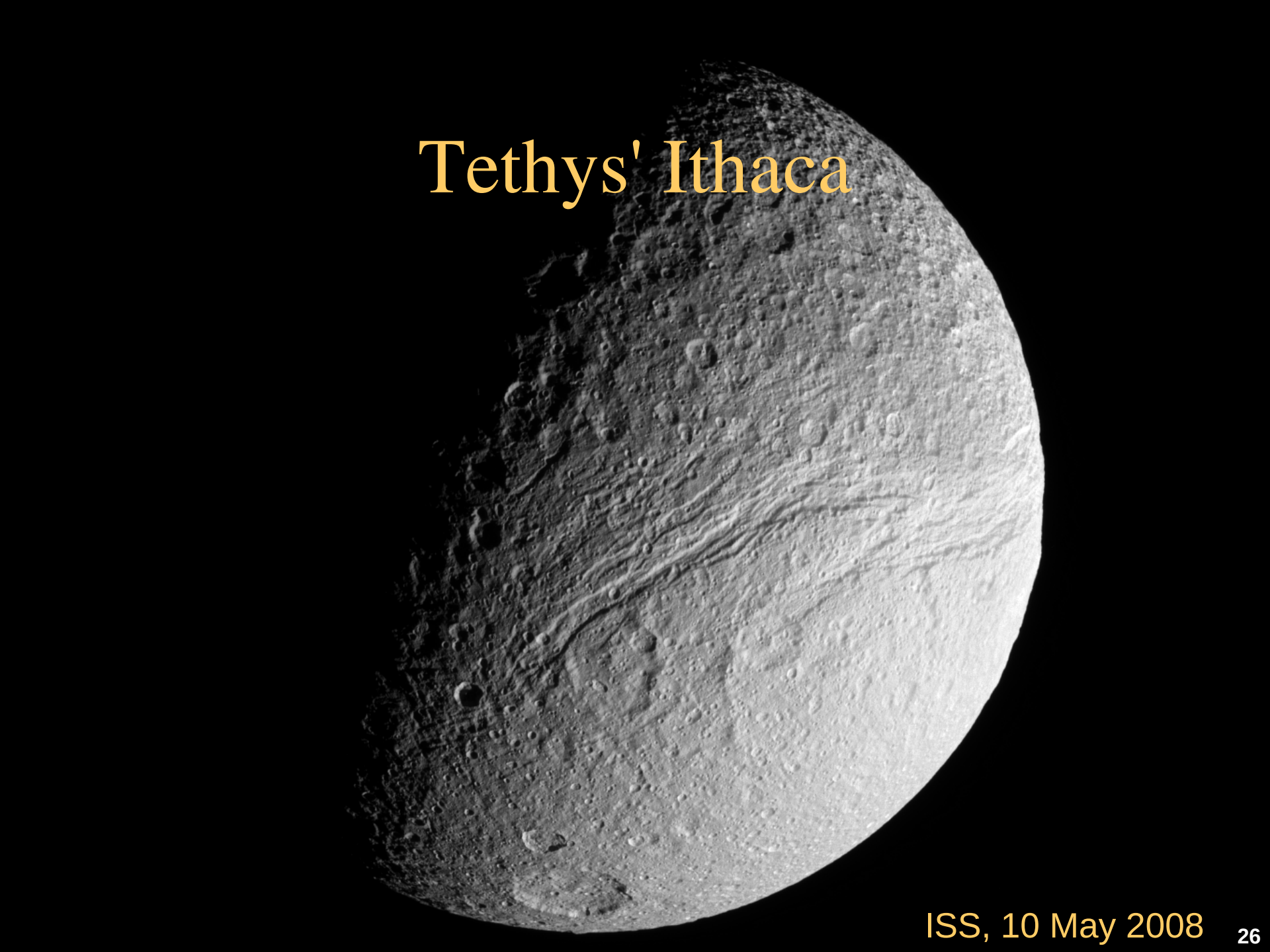


ISS, 27 June 2007

Crescent Tethys

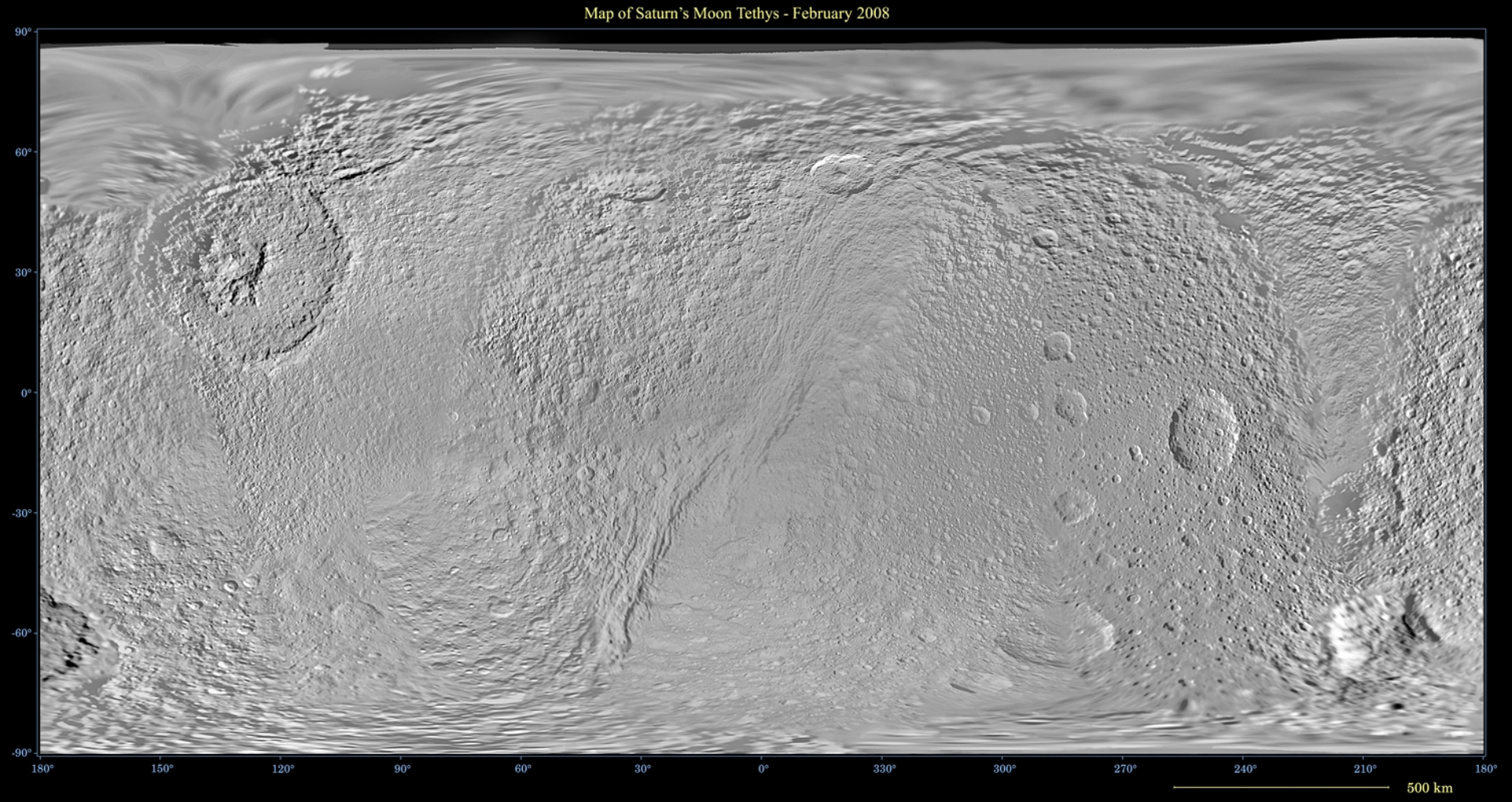
ISS, 29 June 2007

Tethys' Ithaca

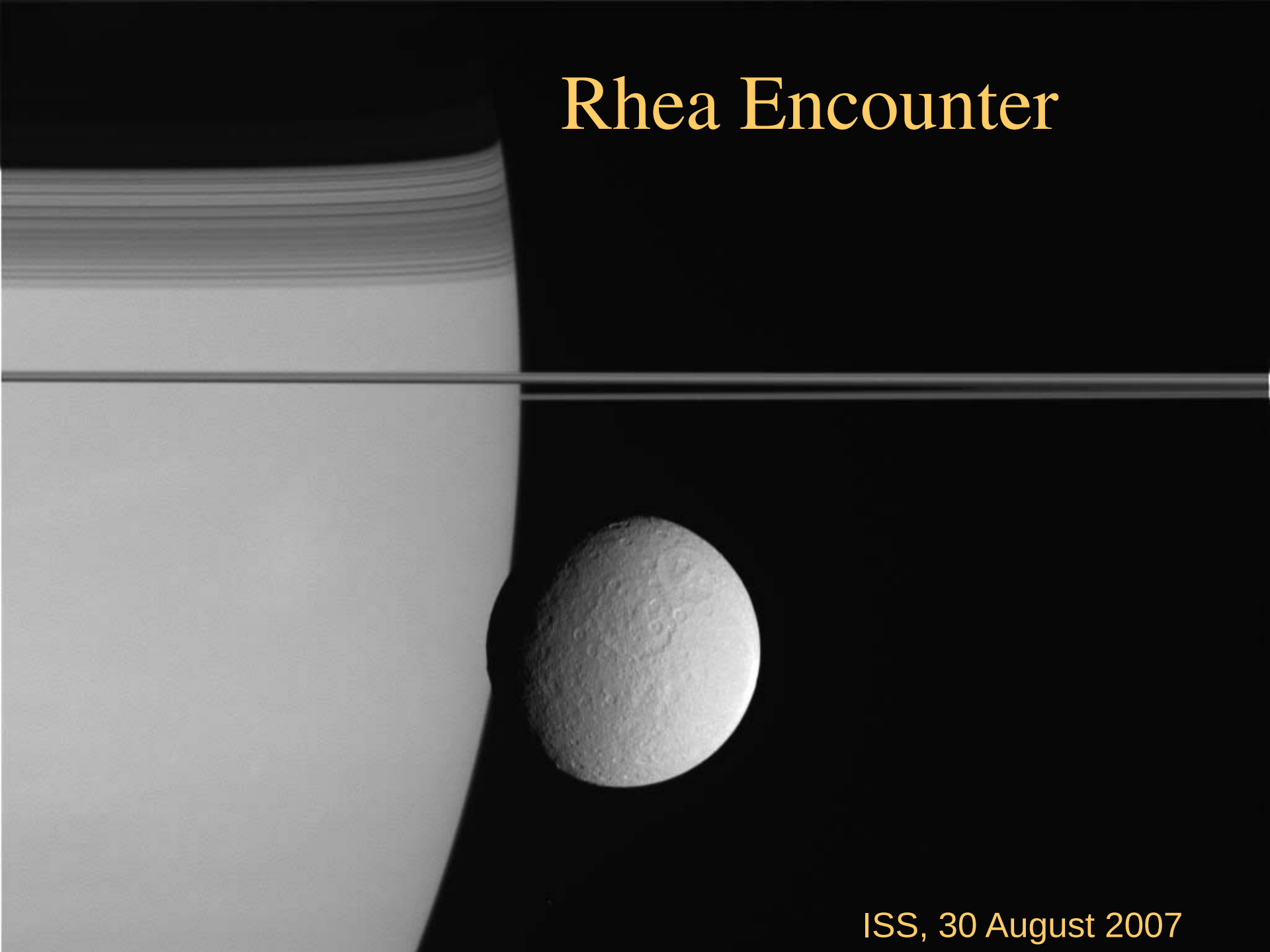


ISS, 10 May 2008

Map of Tethys



Rhea Encounter

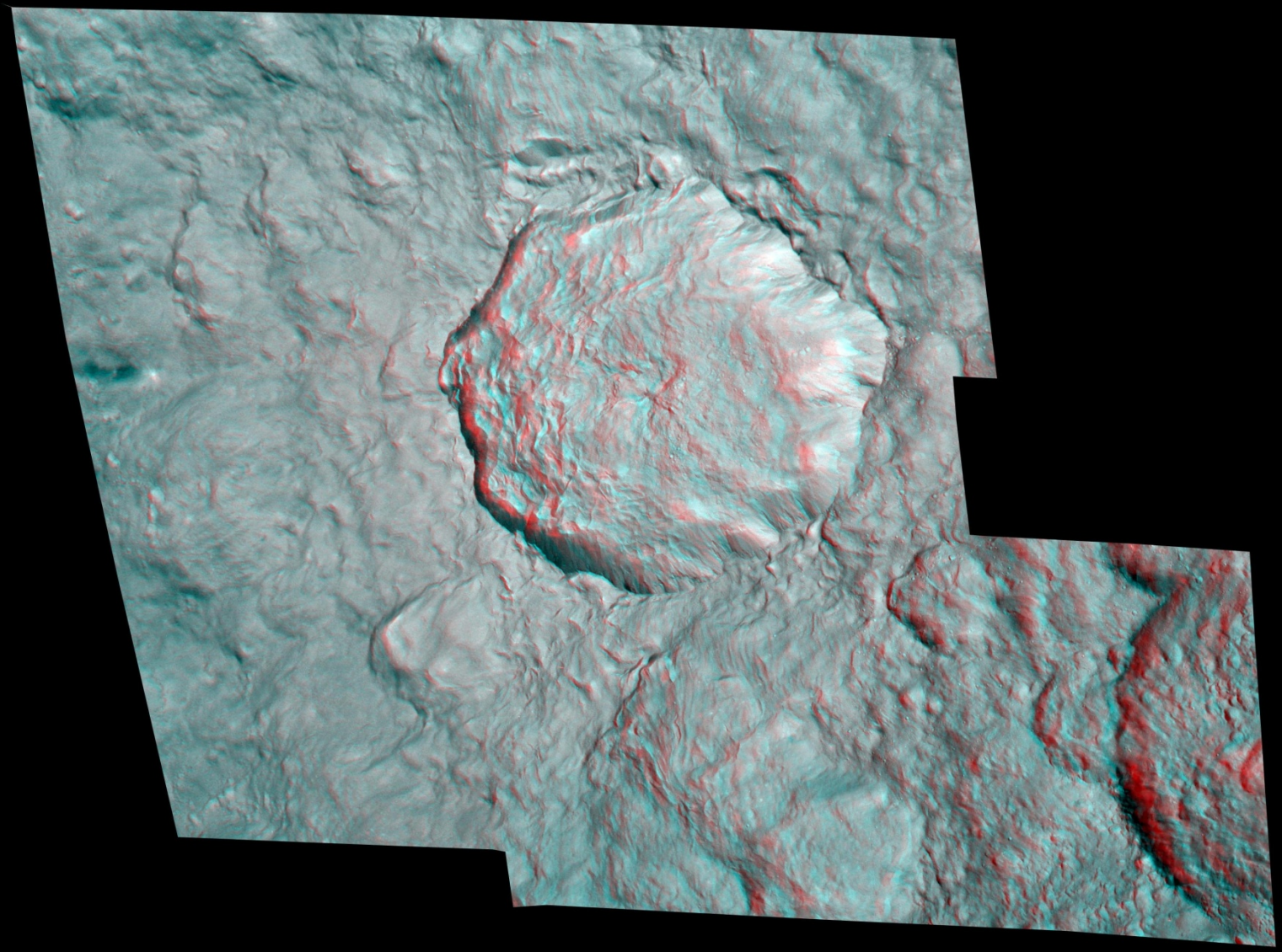


ISS, 30 August 2007

Rhea Up Close

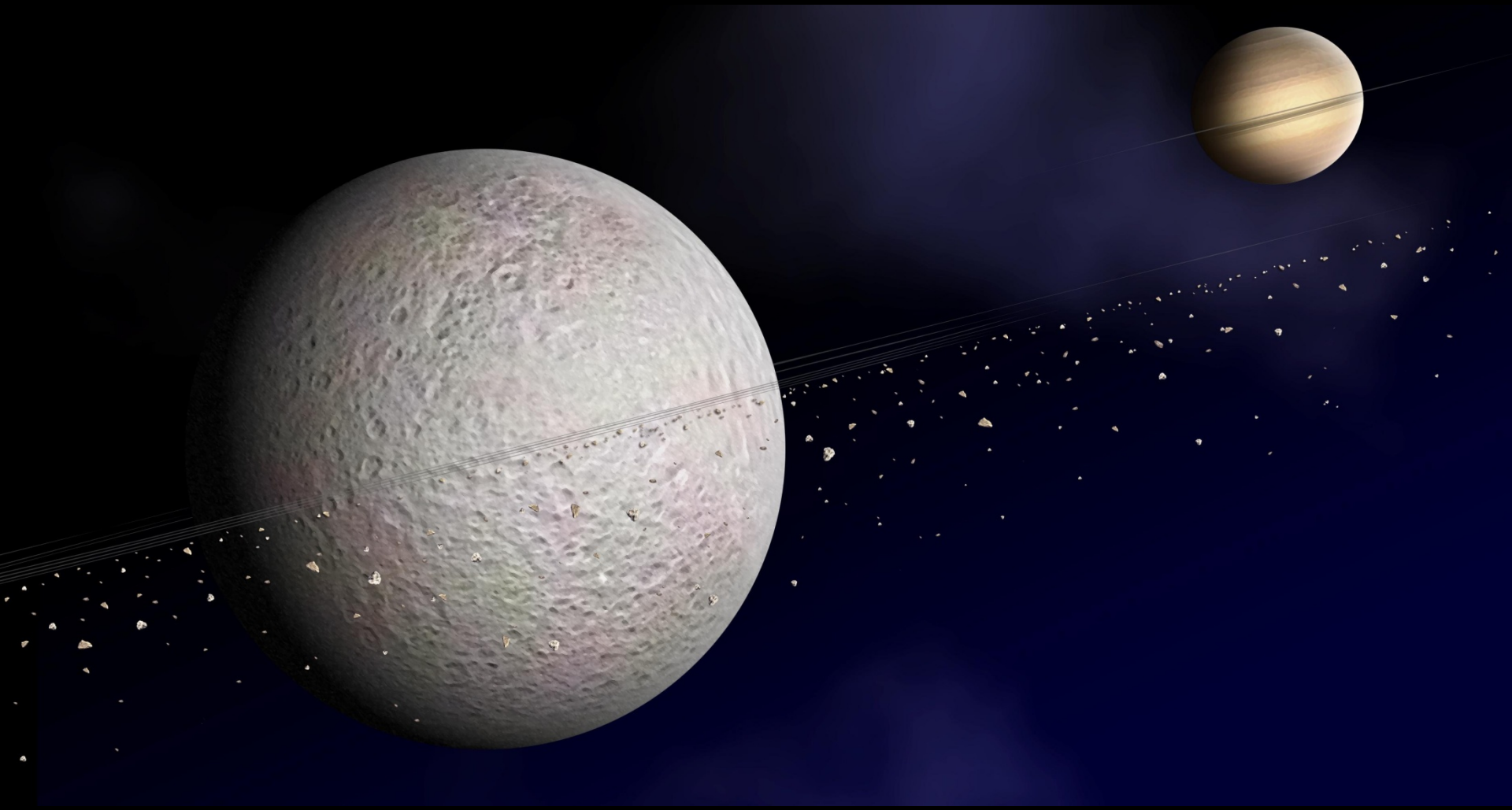
ISS, 30 August 2007

Rhea Up Close, In Stereo



ISS, 30 August 2007

Rhea's Ring

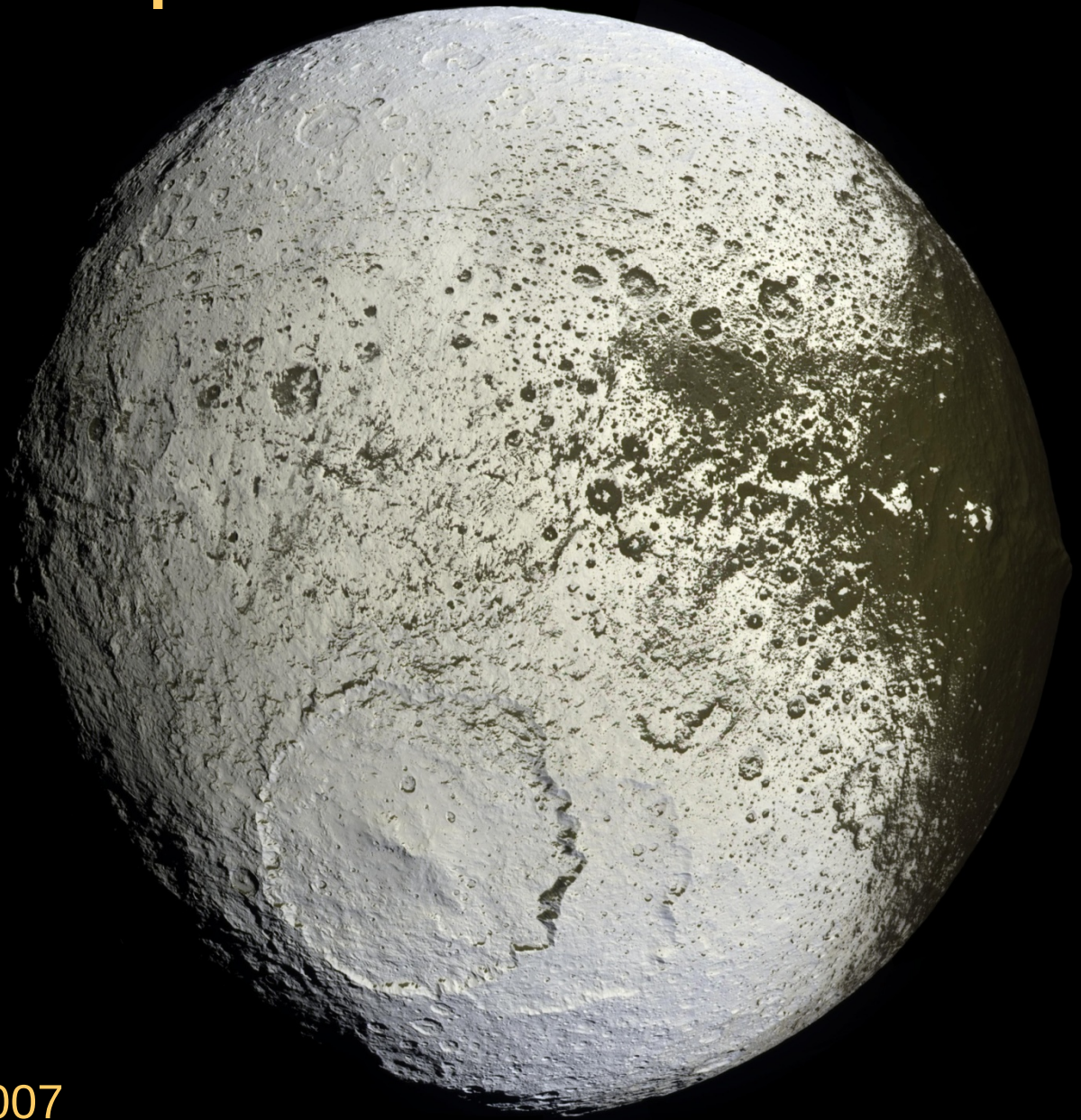


Jones et al., 2008

C[illegible]S

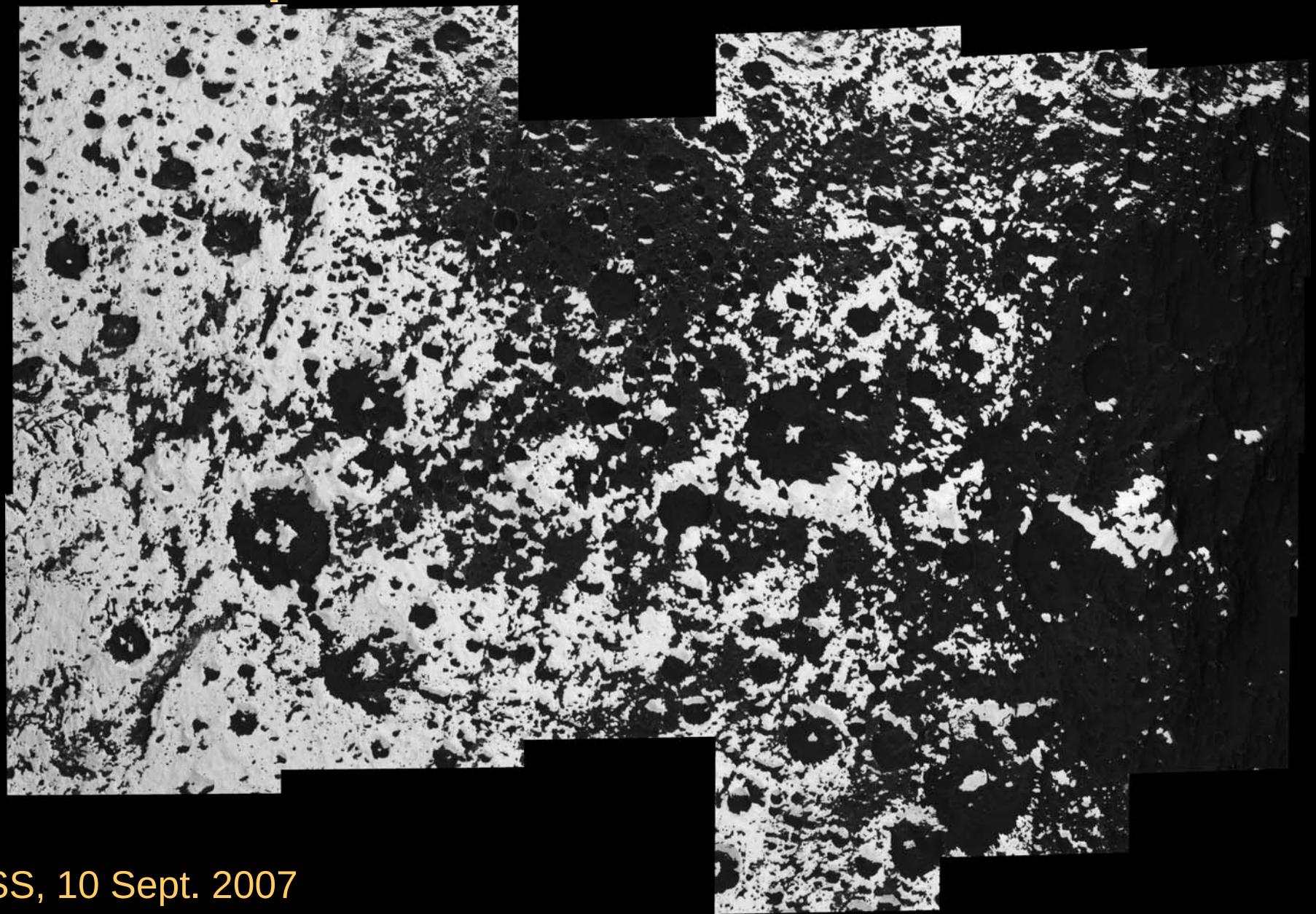
ISS, 31 December 2004

Iapetus' Other Side



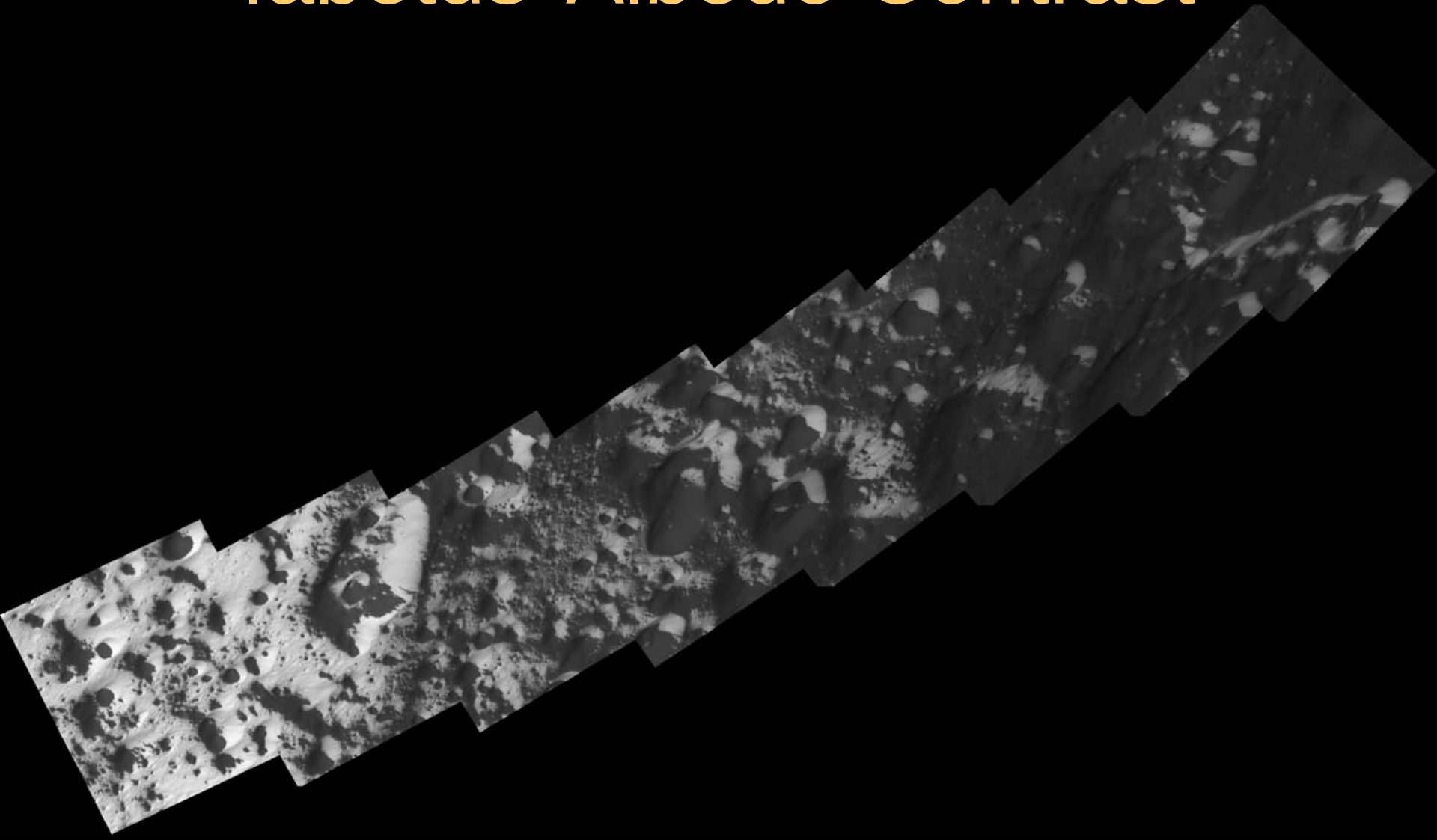
ISS, 10 Sept. 2007

Iapetus' Albedo Contrast



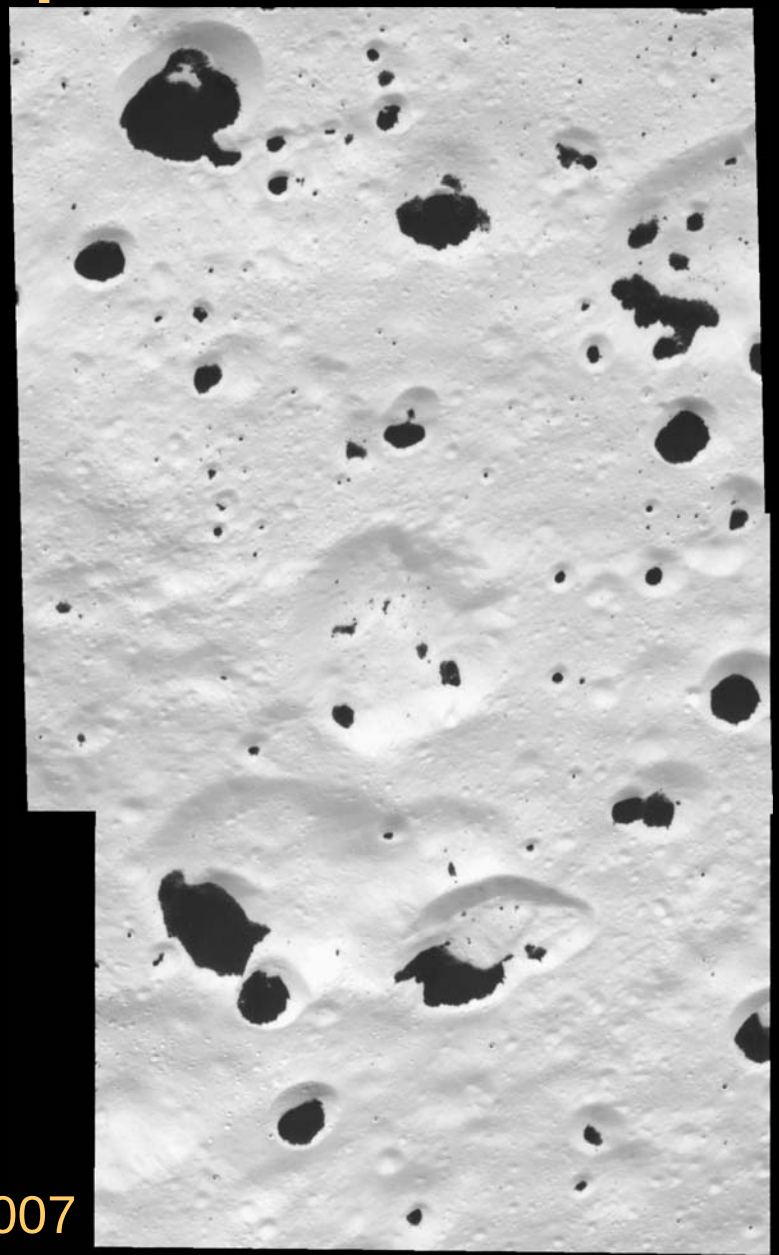
ISS, 10 Sept. 2007

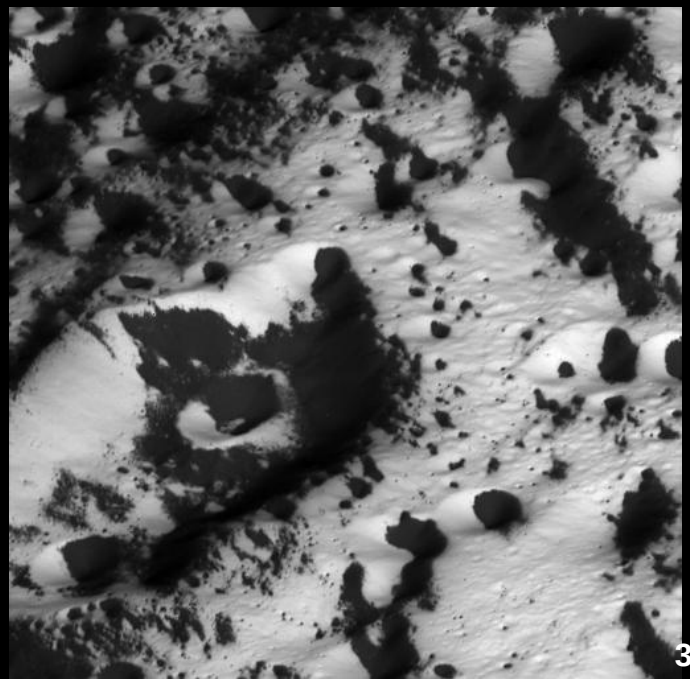
Iapetus' Albedo Contrast



ISS, 10 Sept. 2007

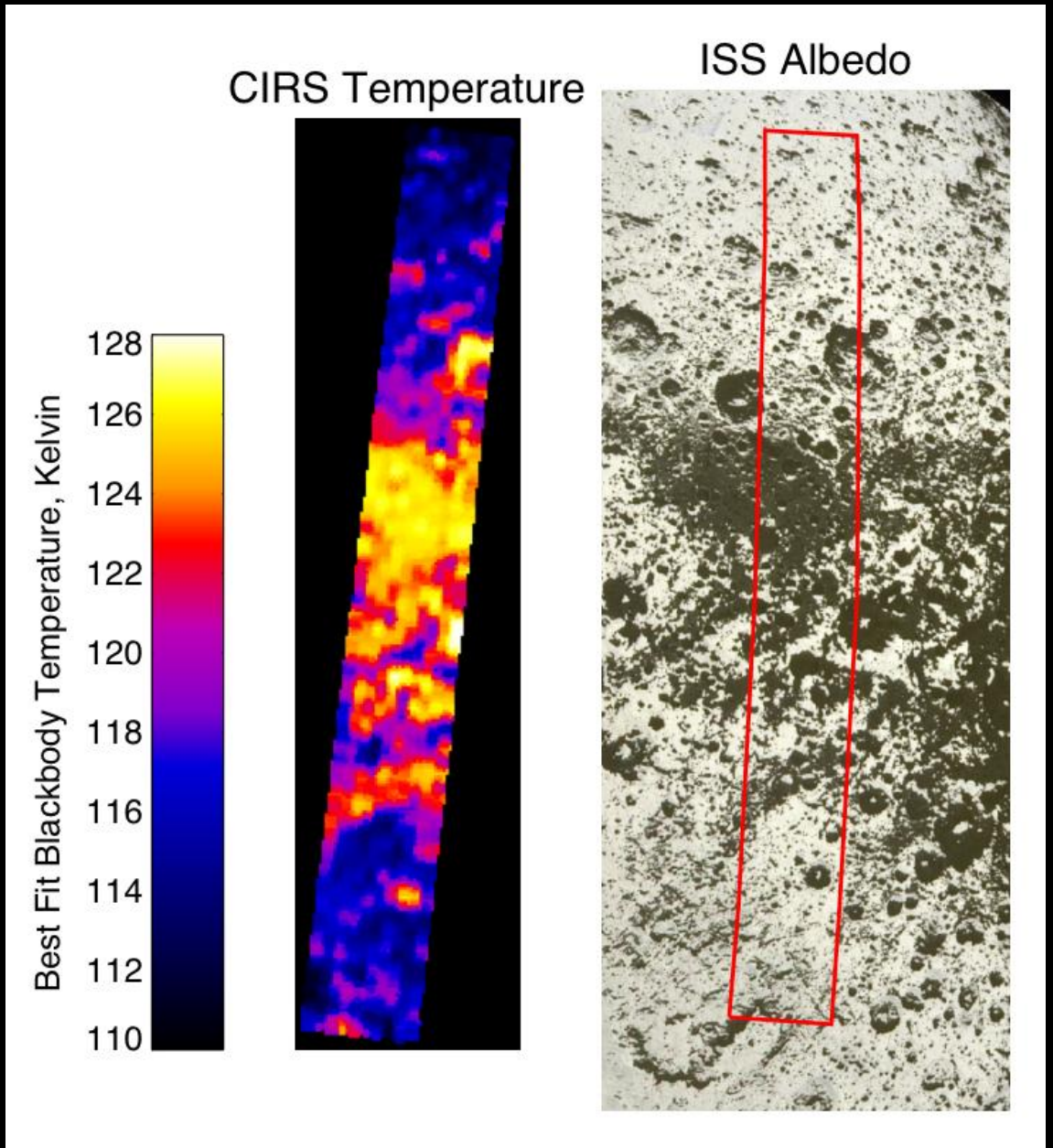
Iapetus' Albedo Contrast





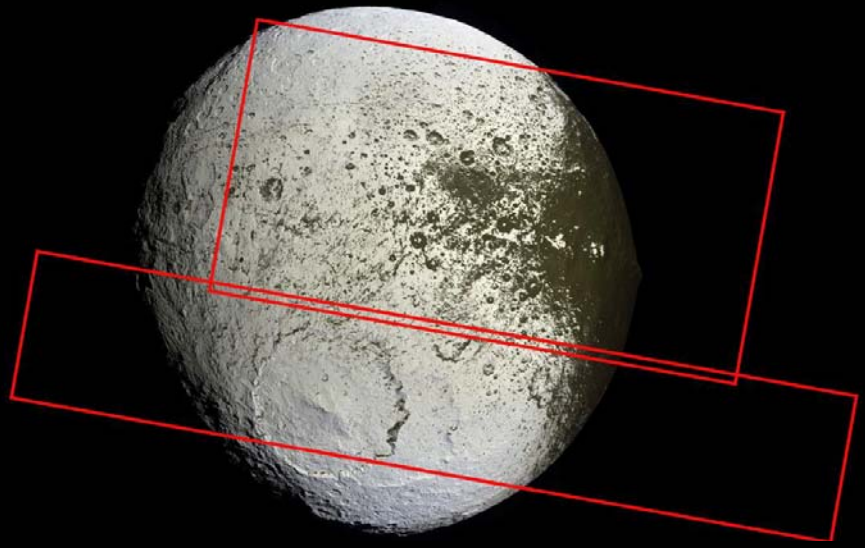
ISS, 10 Sept. 2007

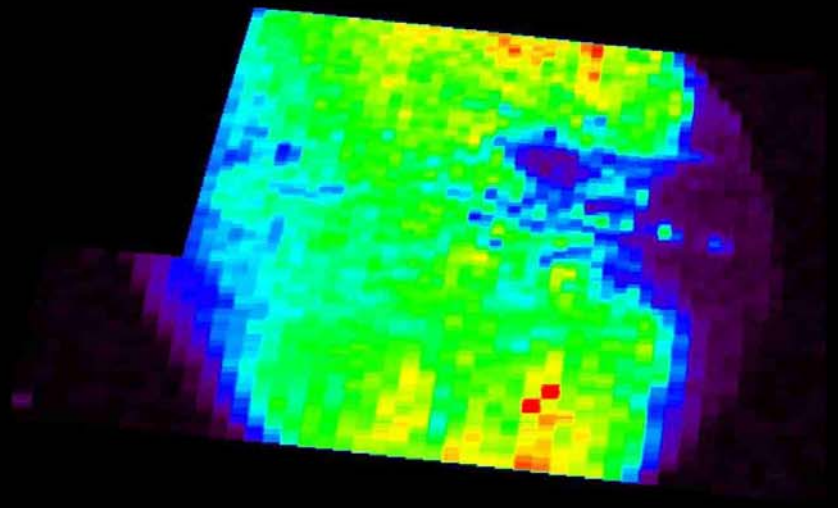
Iapetus' Temperatures

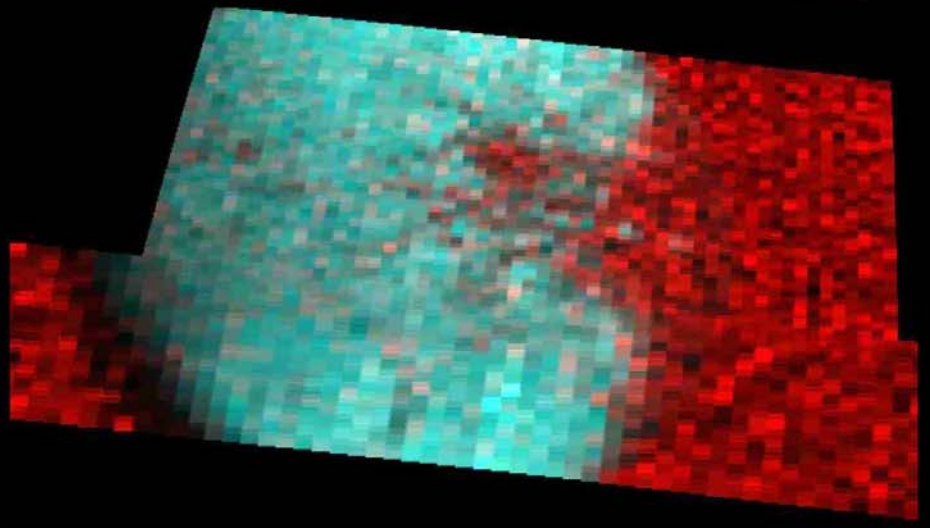


CIRS, 10 Sept. 2007

Iapetus in UV

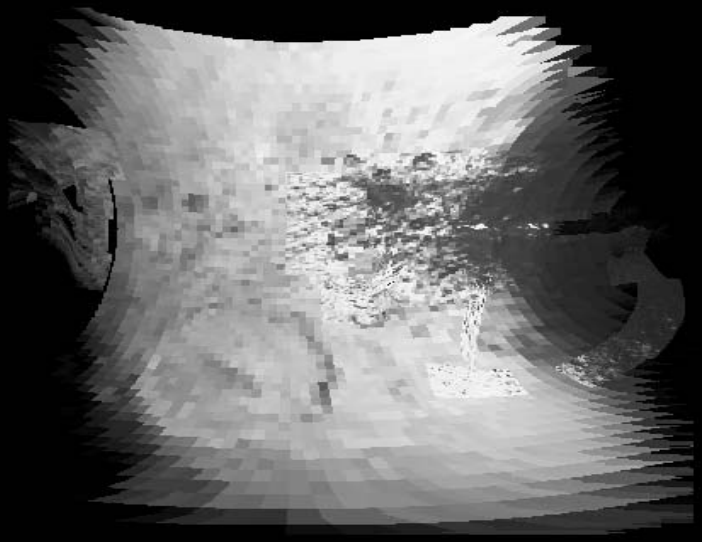




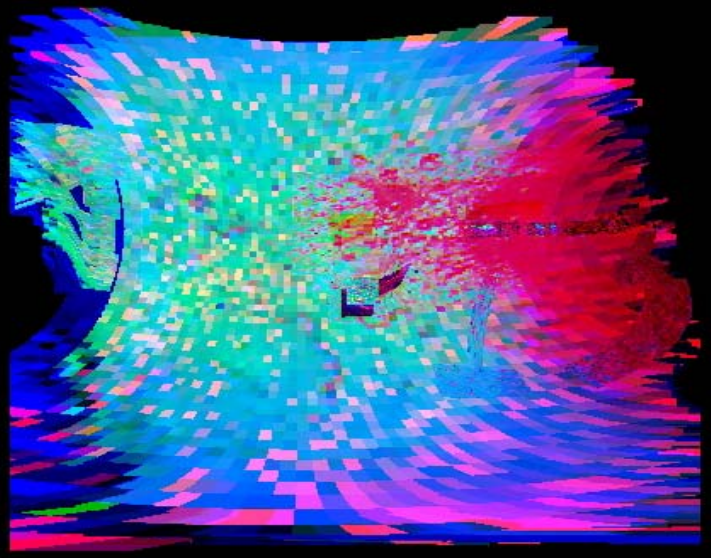


UVIS, 10 Sept. 2007

Iapetus' Composition



1.75-micron Reflectance

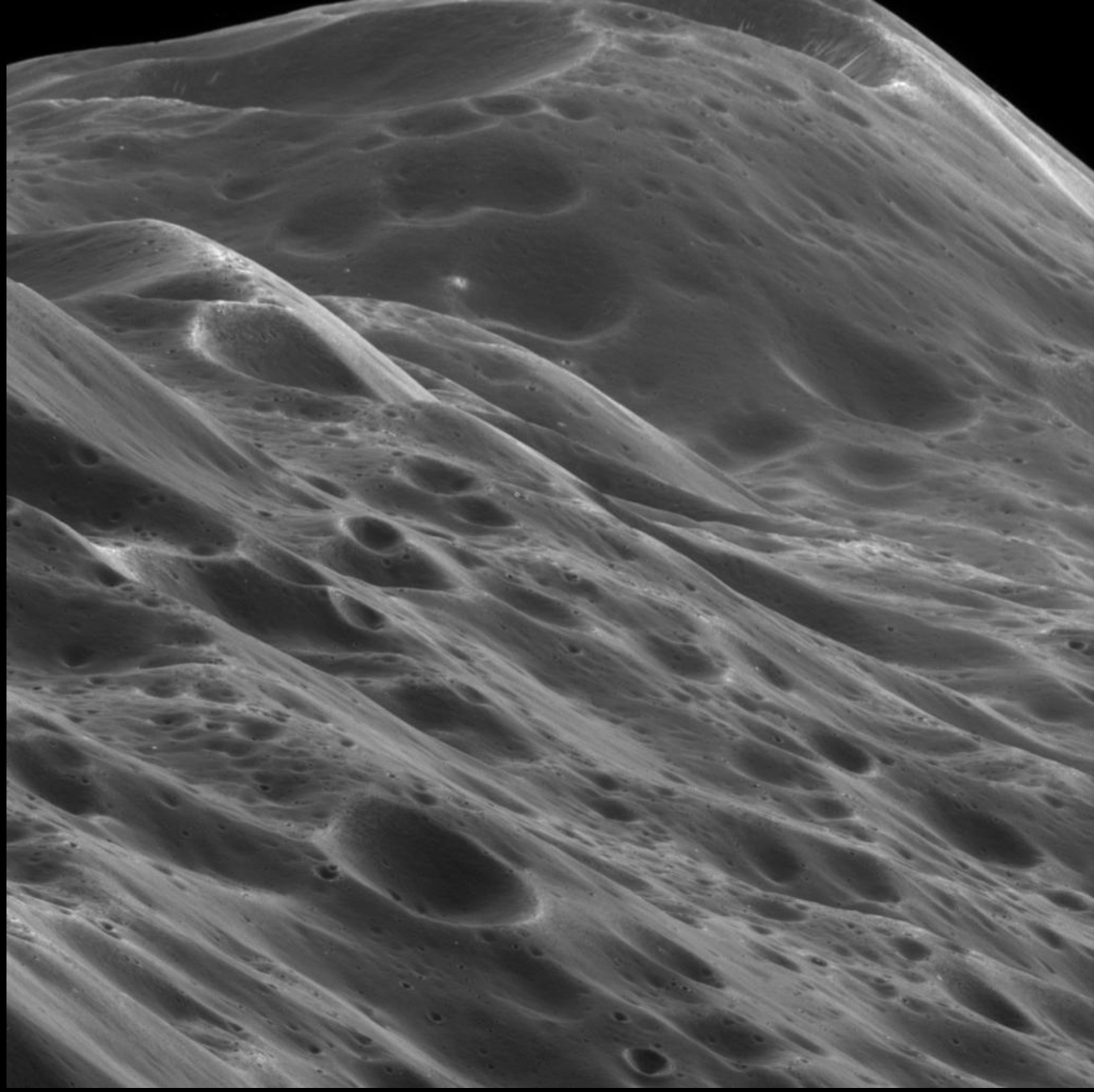


Iapetus Composition Map

Red = CO_2 strength
Green = H_2O strength
Blue = Rayleigh scattering strength

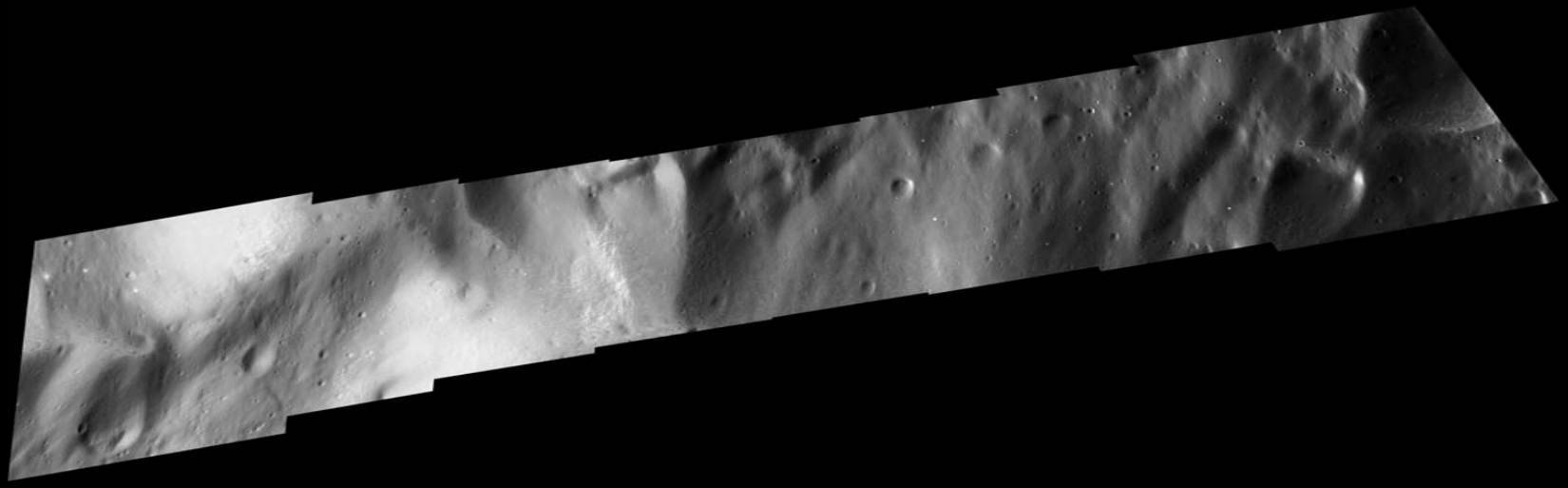
VIMS, 10 Sept. 2007

Iapetus' Ridge



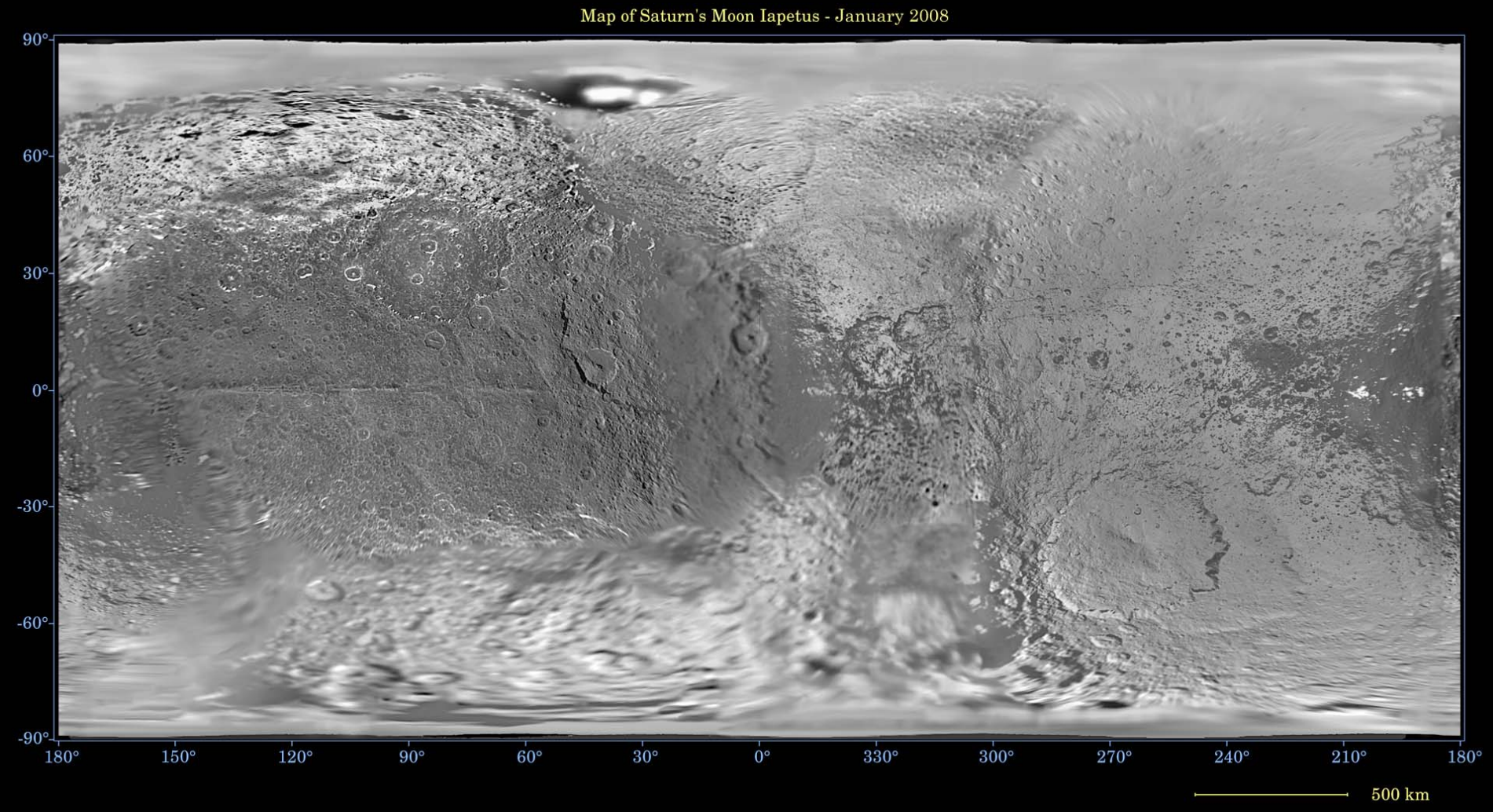
ISS, 10 Sept. 2007 (http://photojournal.jpl.nasa.gov/catalog/PIA08404)

Iapetus Up Close



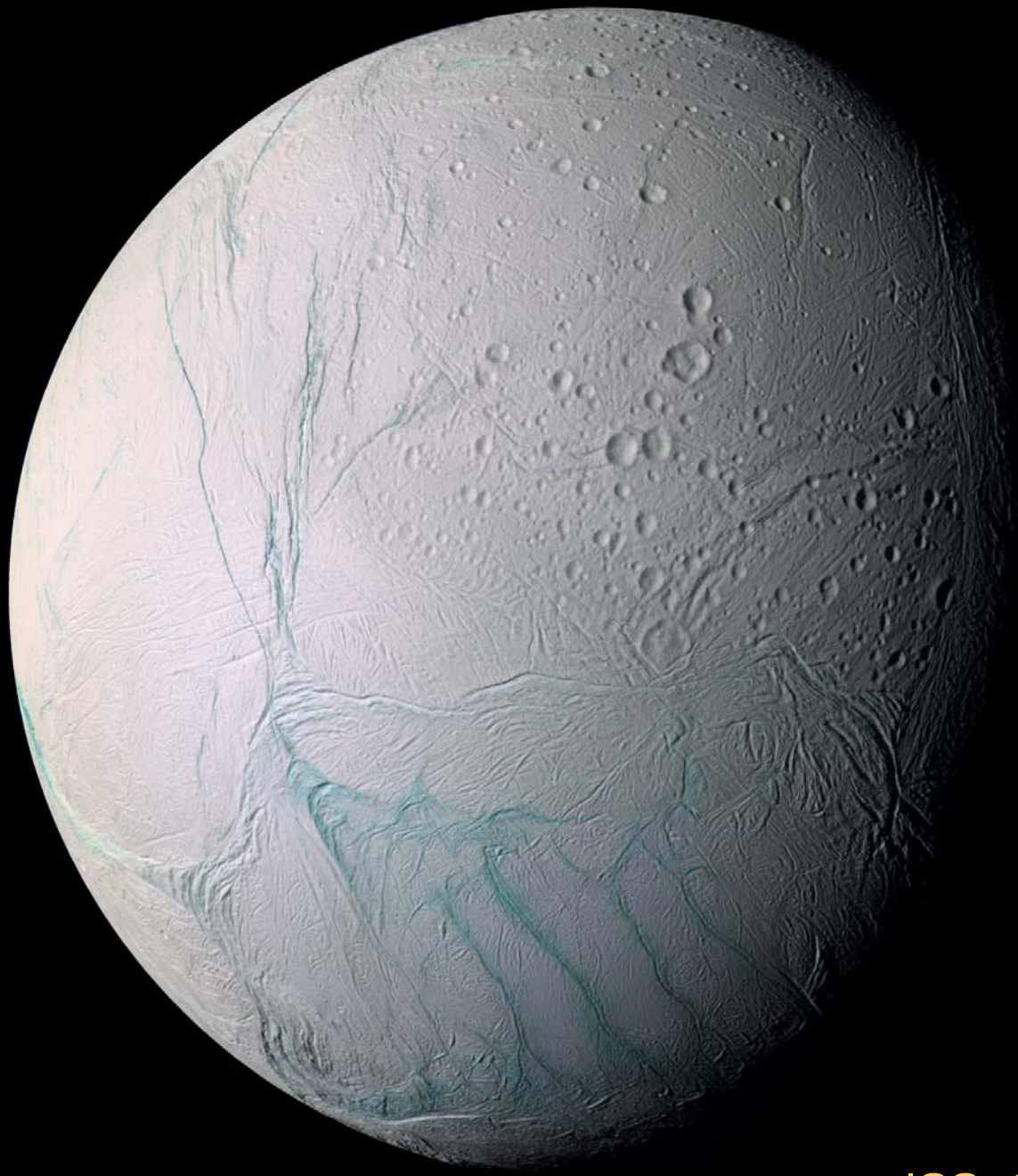
ISS, 10 Sept. 2007

Map of Iapetus



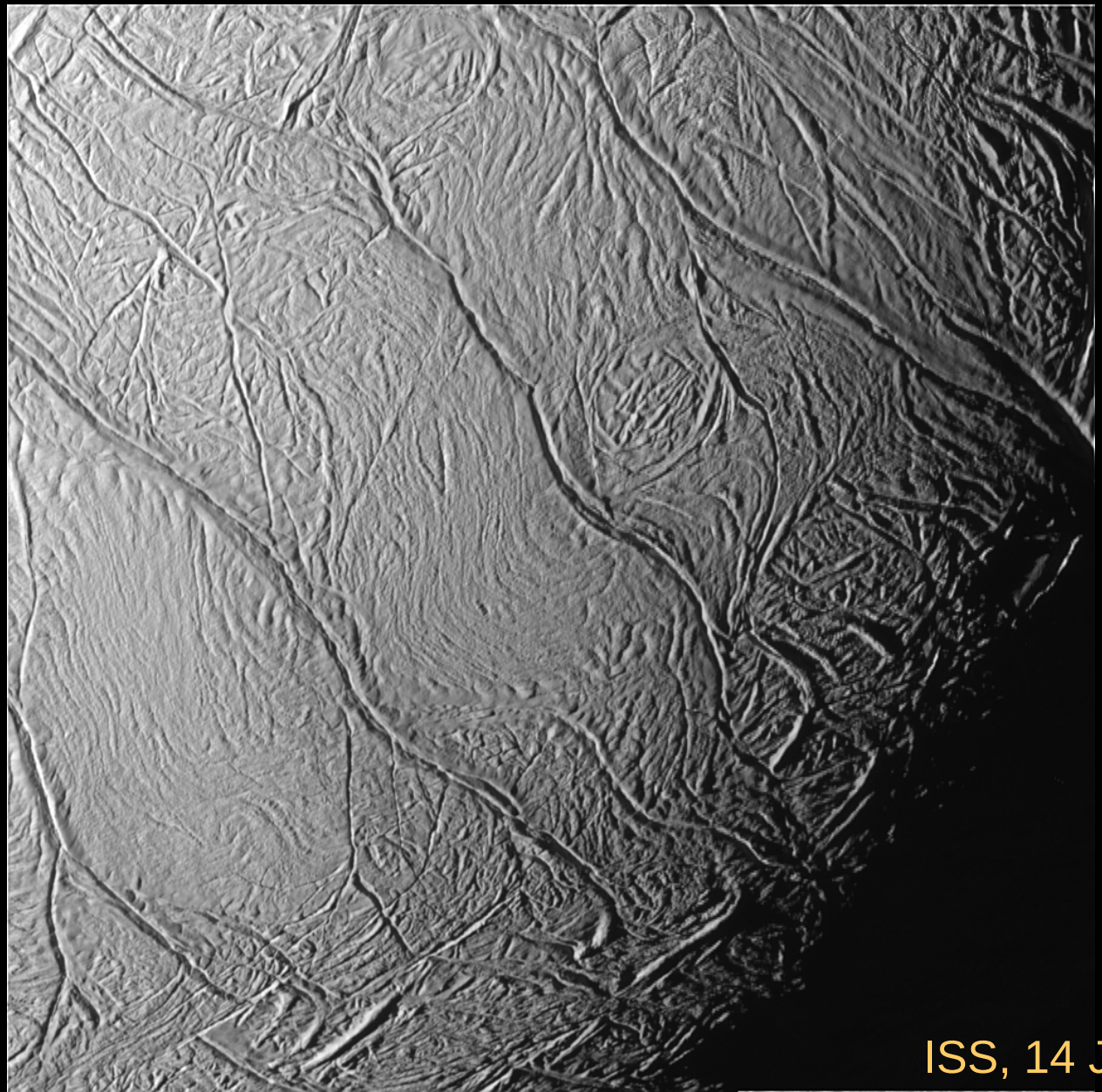
Epimetheus

ISS, 3 December 2007



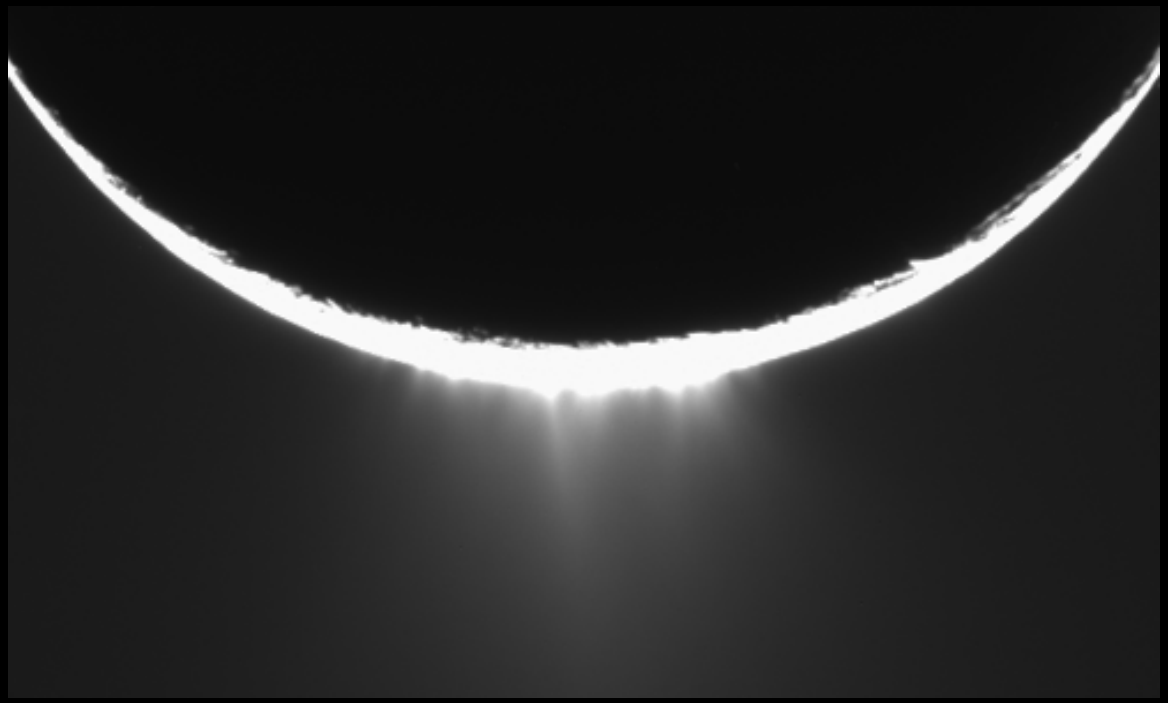
ISS, 14 July 2005

Enceladus' South Polar Terrain



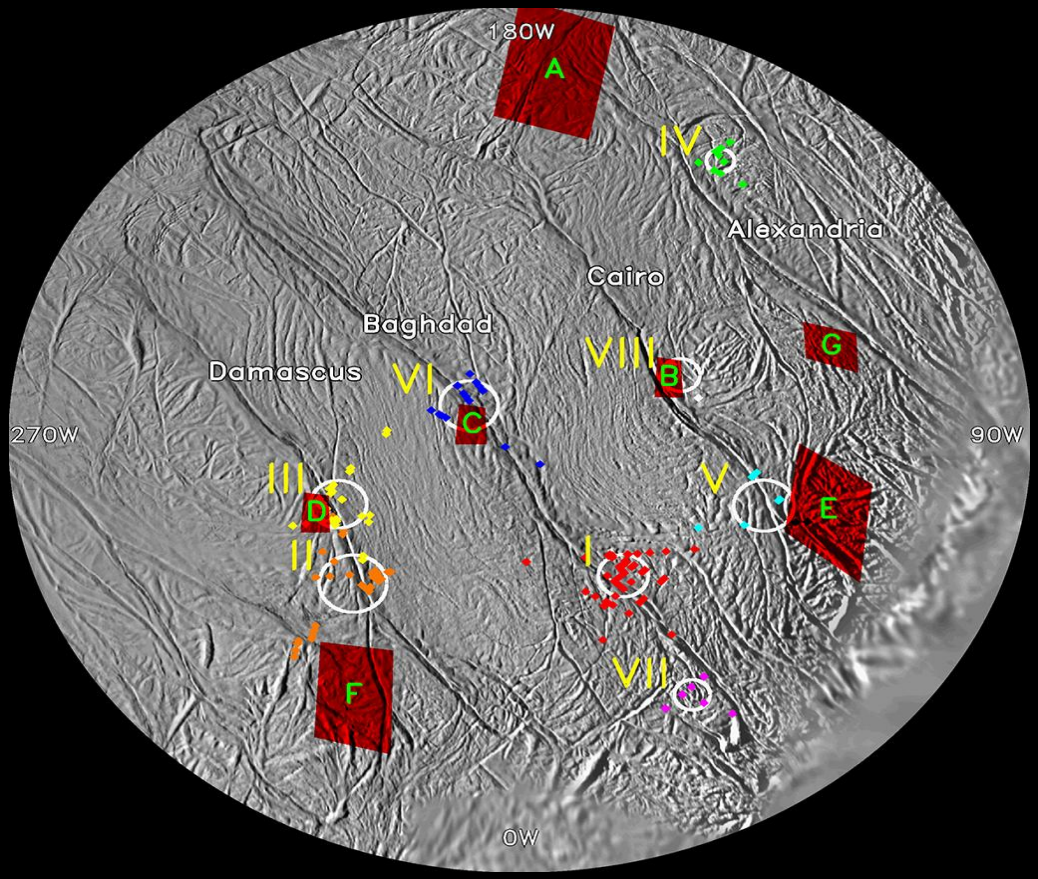
ISS, 14 July 2005

Enceladus' Plumes



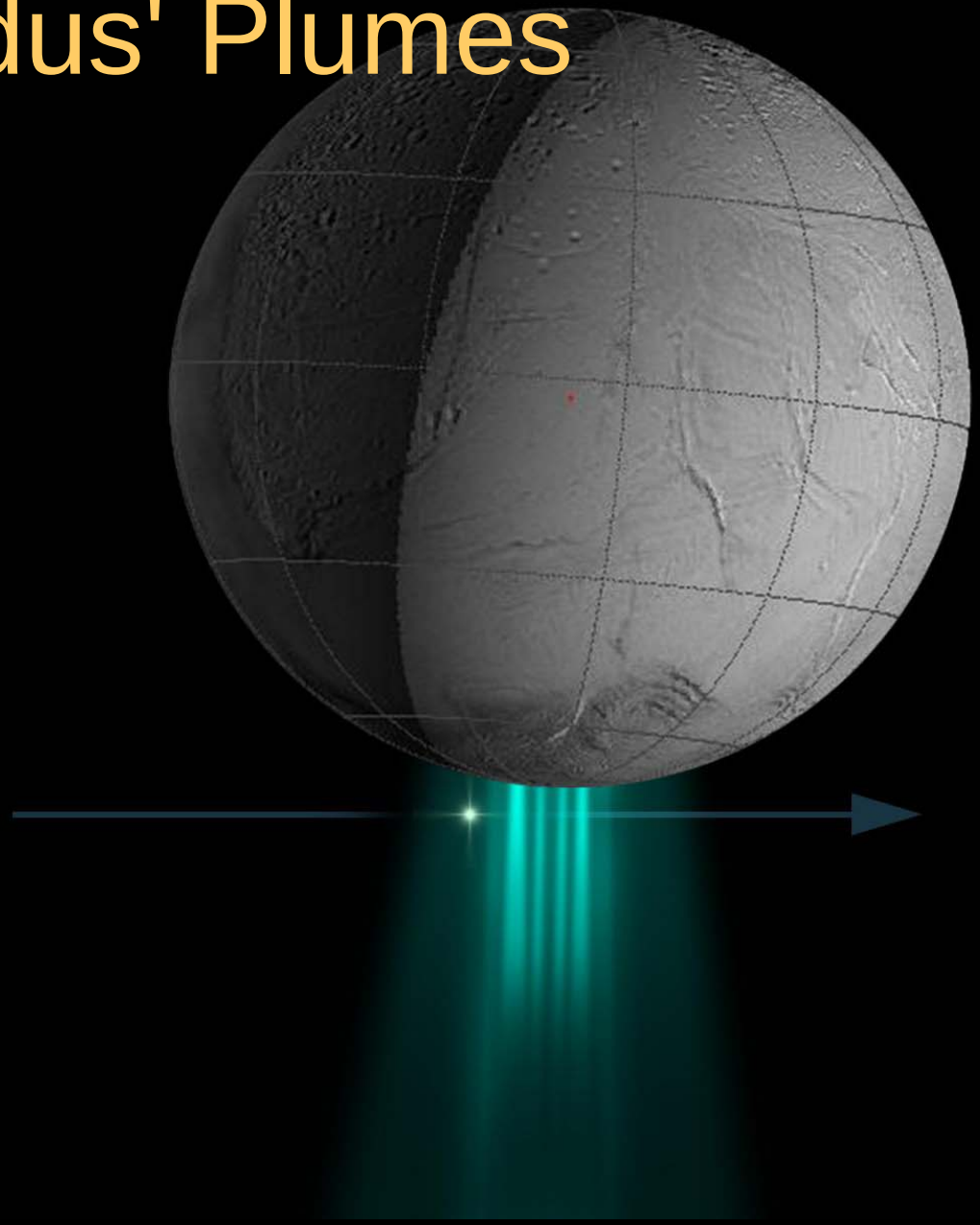
ISS, 27 November 2005 (http://photojournal.jpl.nasa.gov/catalog/PIA07762)

Enceladus' Plume Sources



Spitale and Porco, 2007

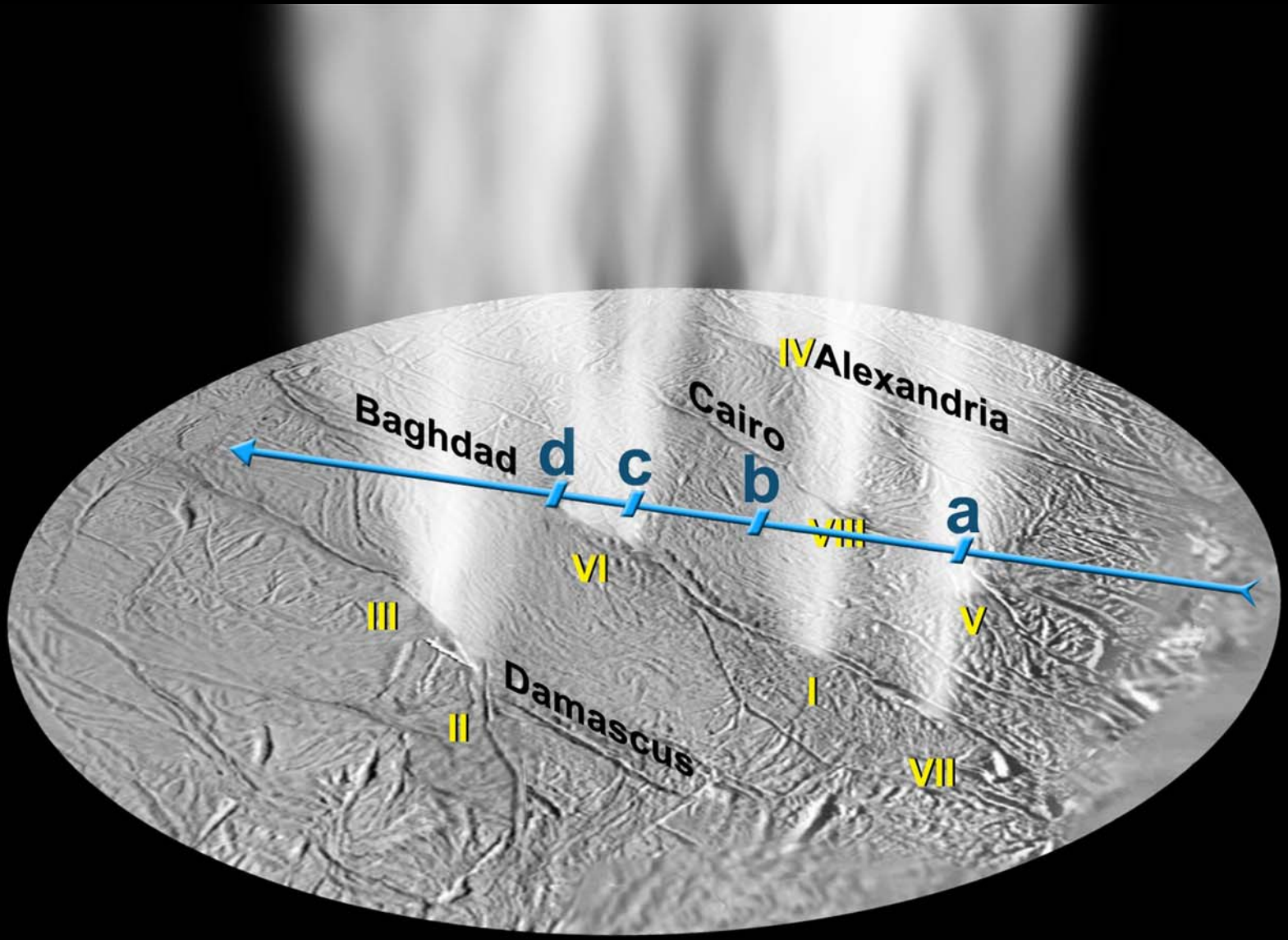
Enceladus' Plumes



ISS, 30 September 2007

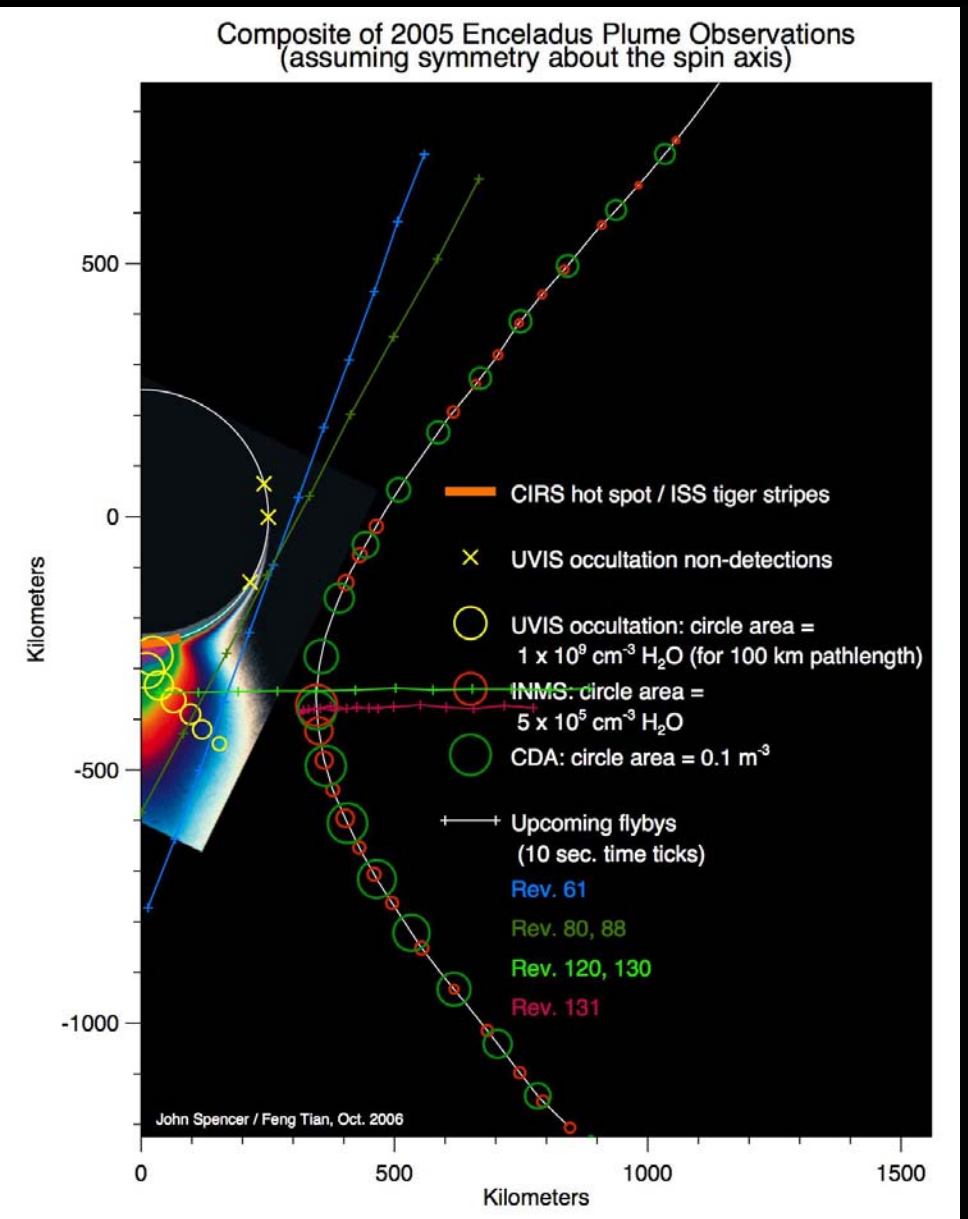
UVIS stellar occultation, 24 October 2007

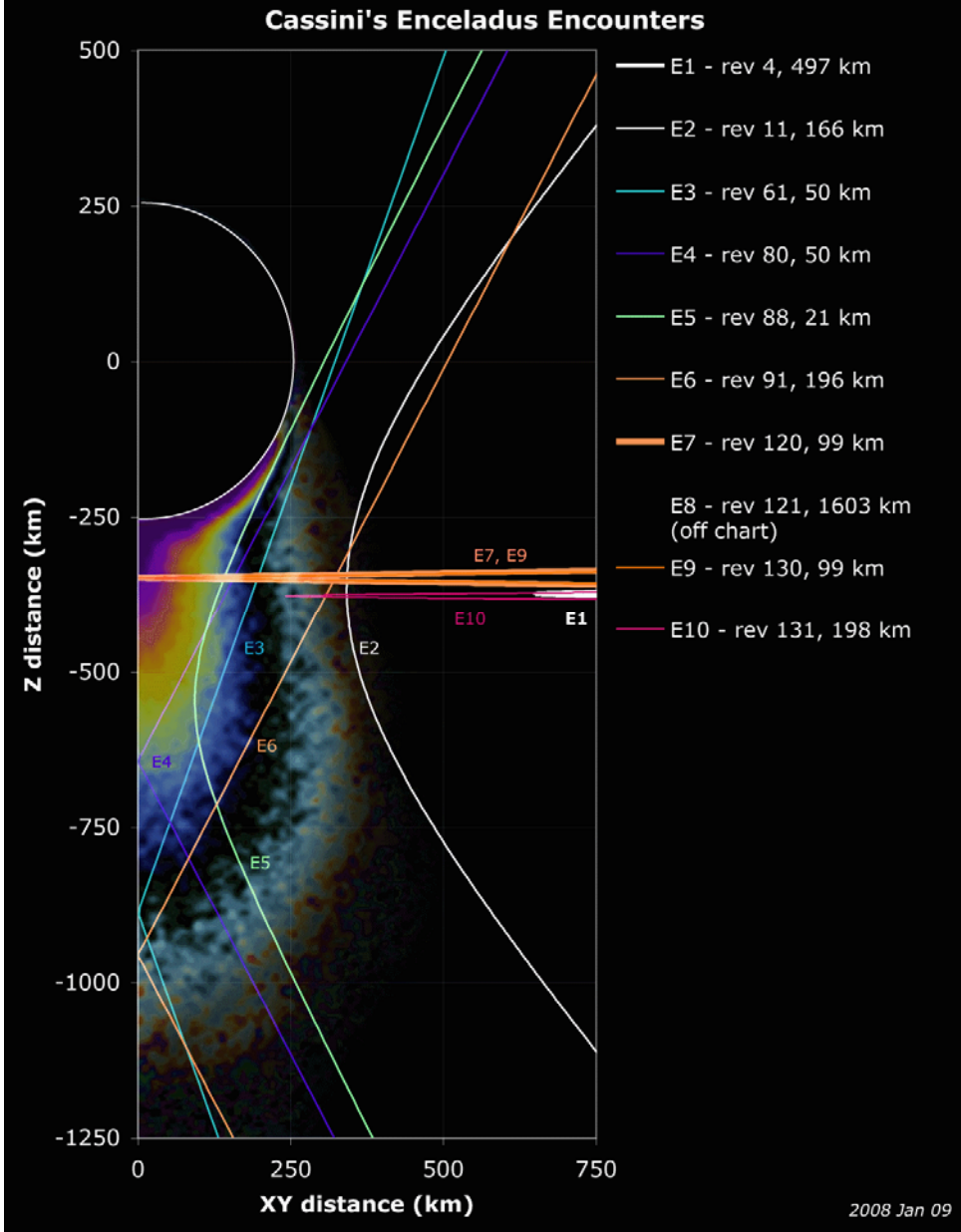
Enceladus' Plumes



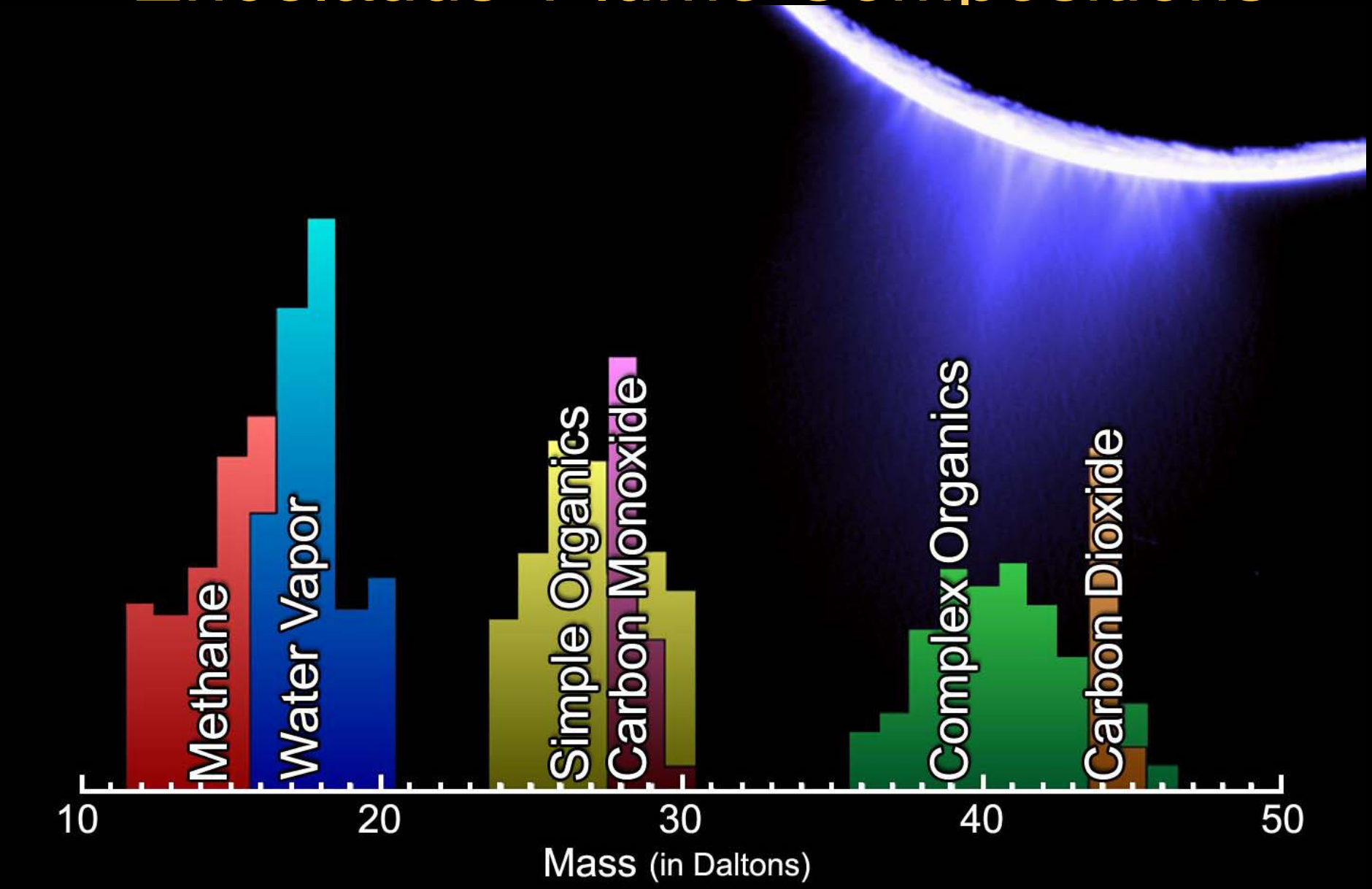
UVIS stellar occultation, 24 October 2007

Cassini Encounters with Enceladus



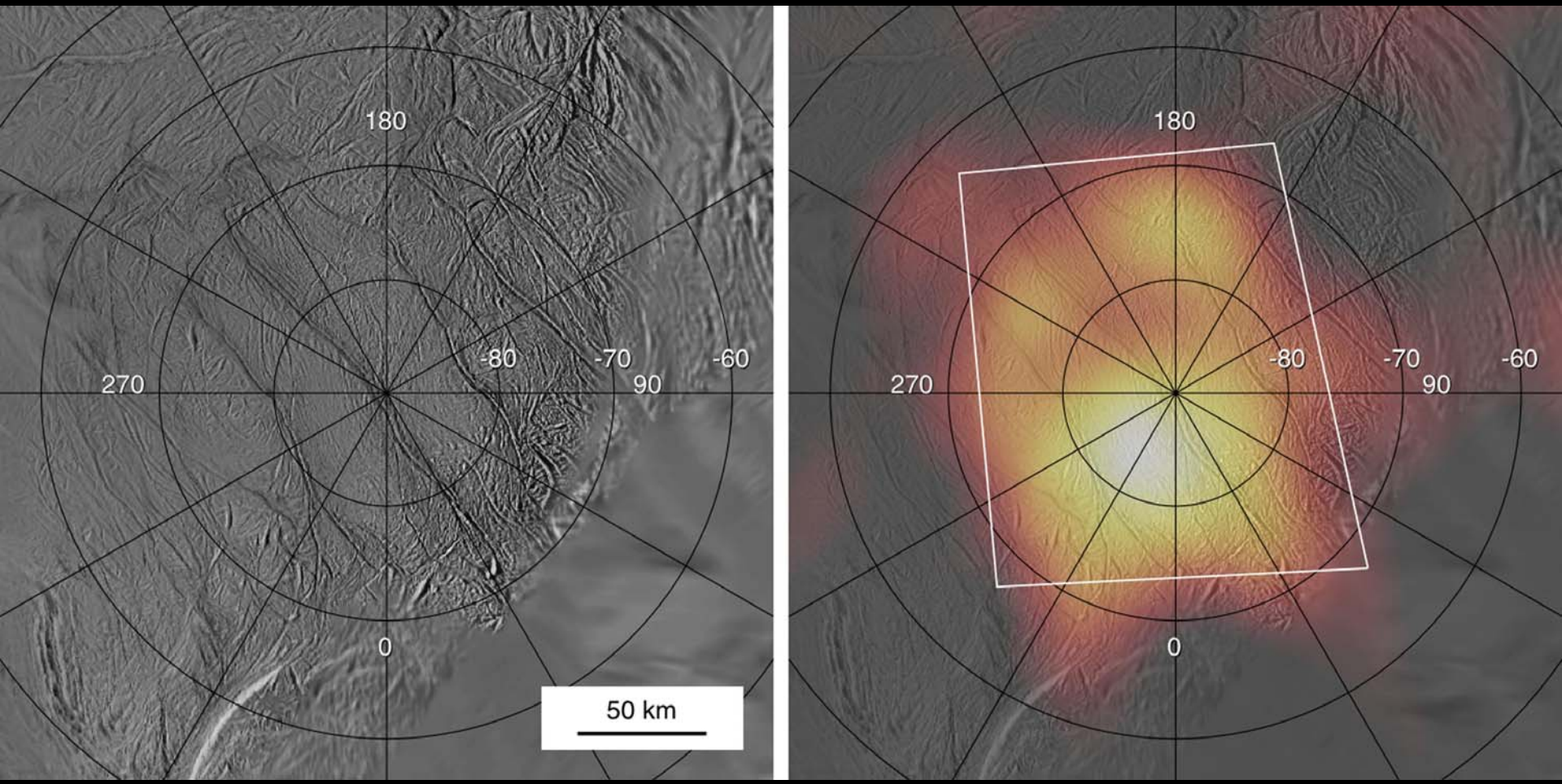


Enceladus' Plume Compositions



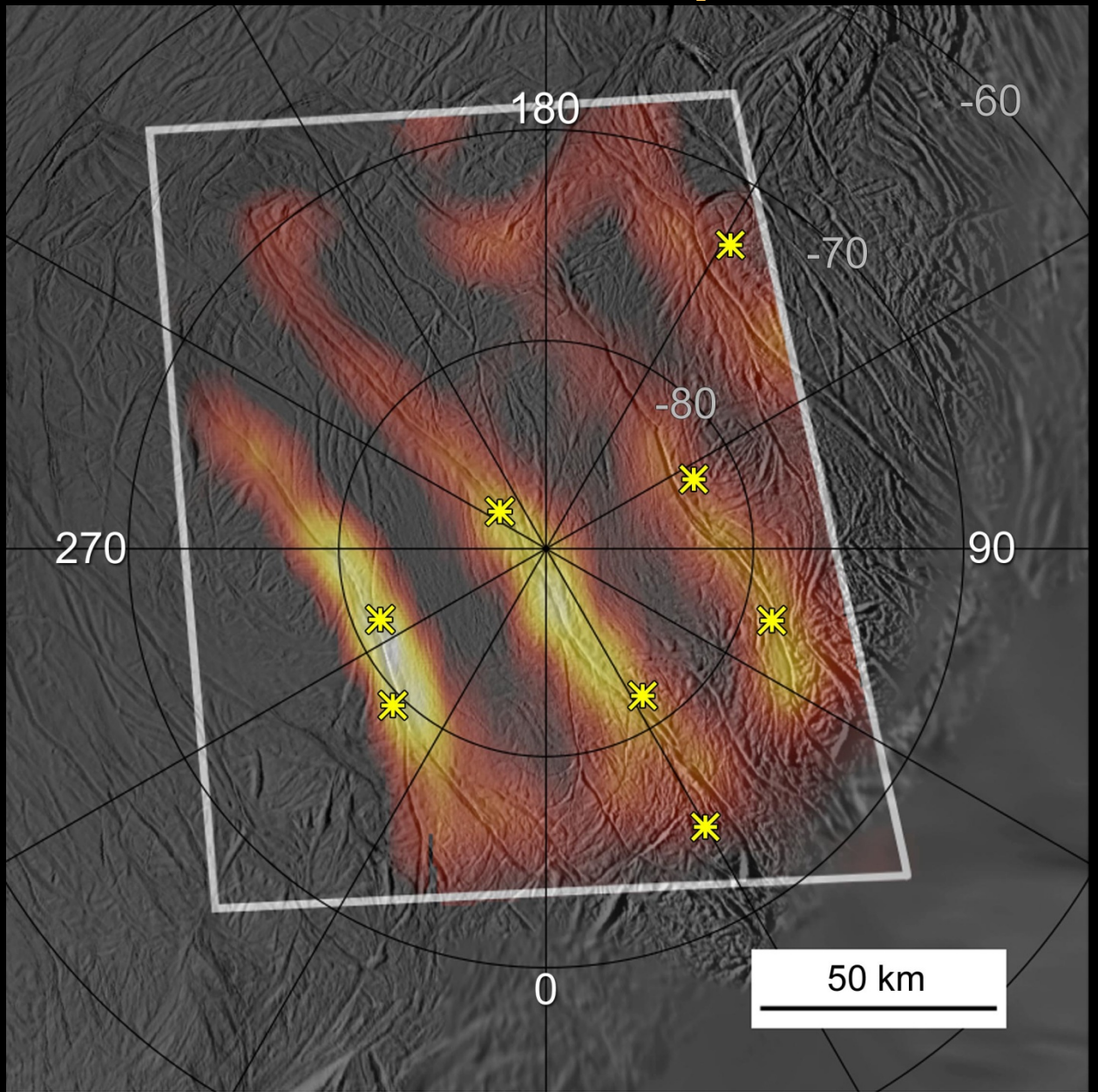
INMS, 12 March 2008

Enceladus' Temperatures

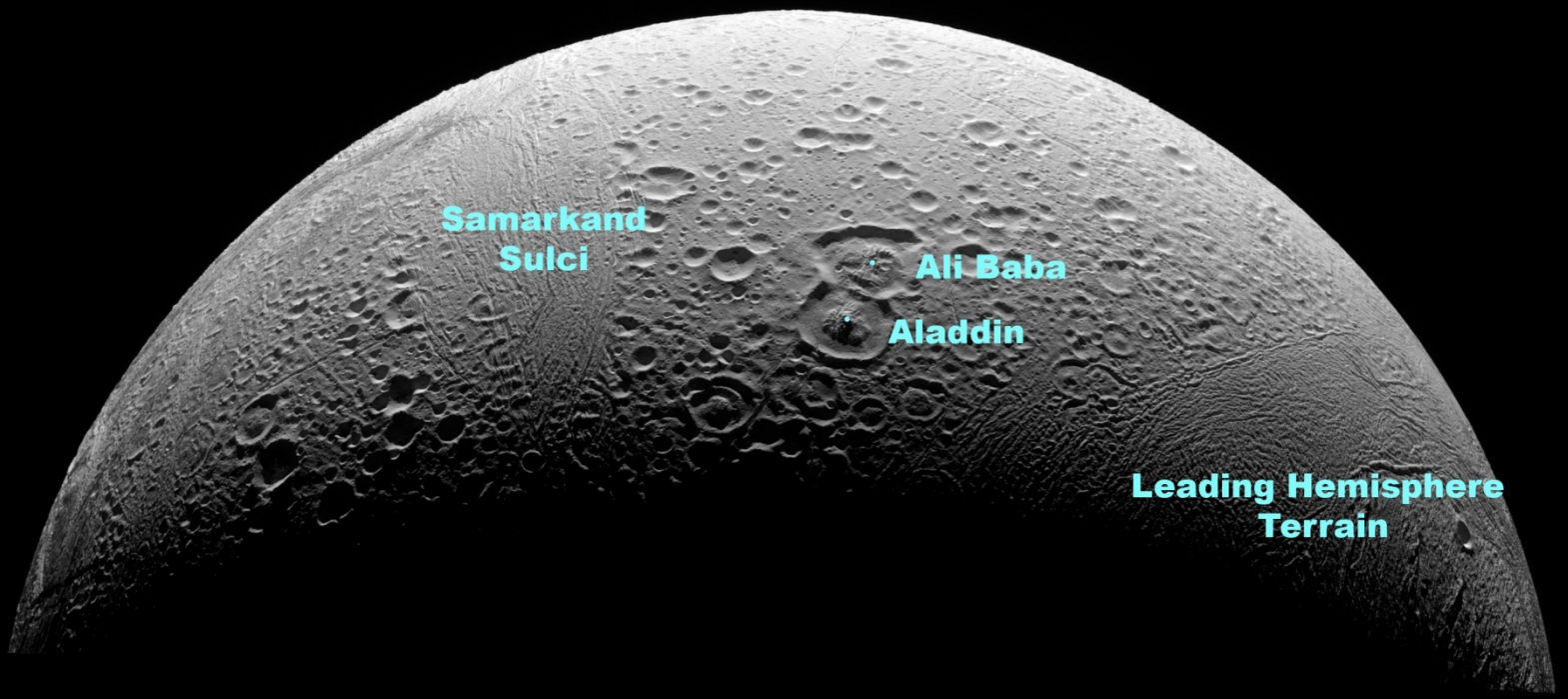


CIRS, 12 March 2008

Enceladus' Temperatures



Enceladus' Northern Territory

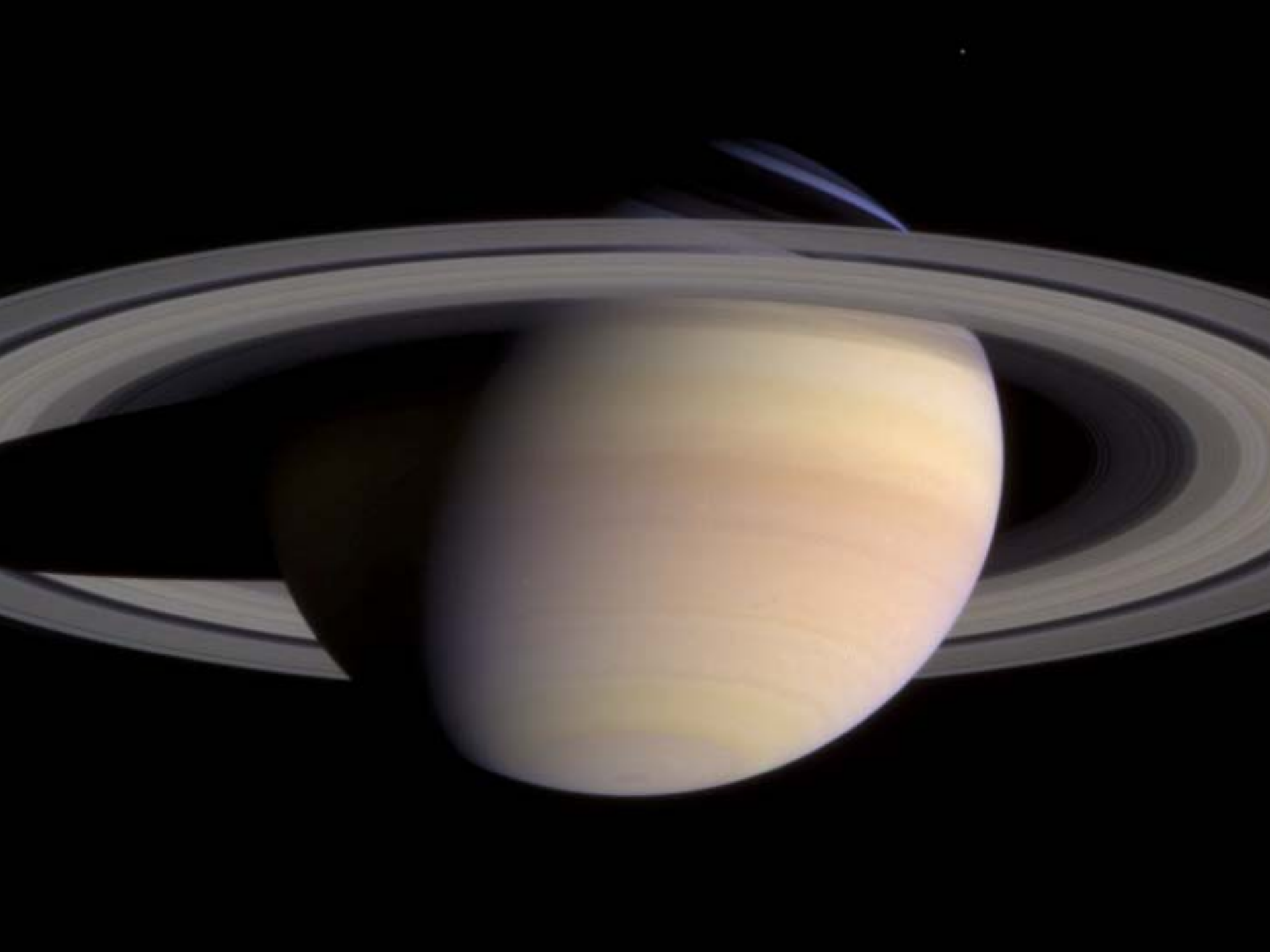


ISS, 12 March 2008

Saturn's Atmosphere: Results from Cassini

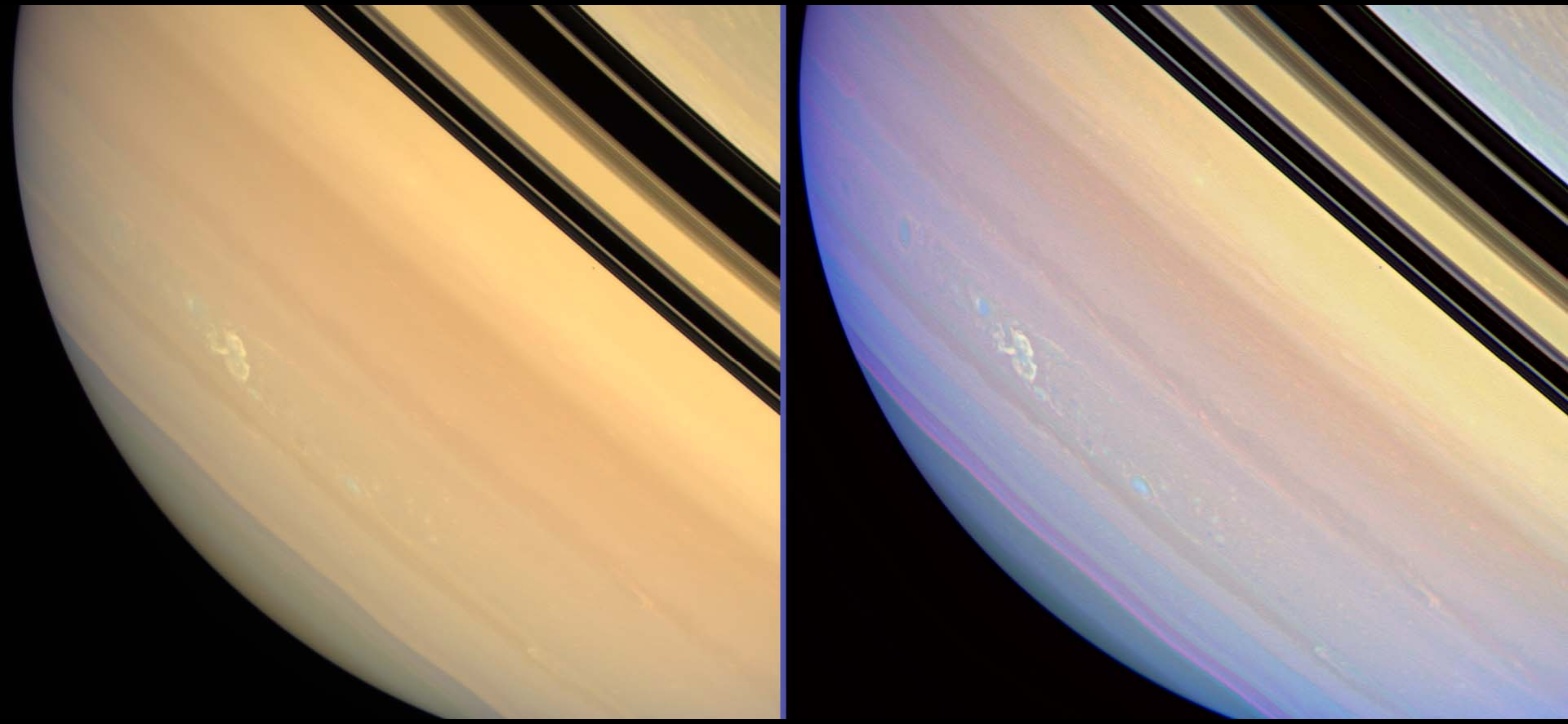
Andrew P. Ingersoll

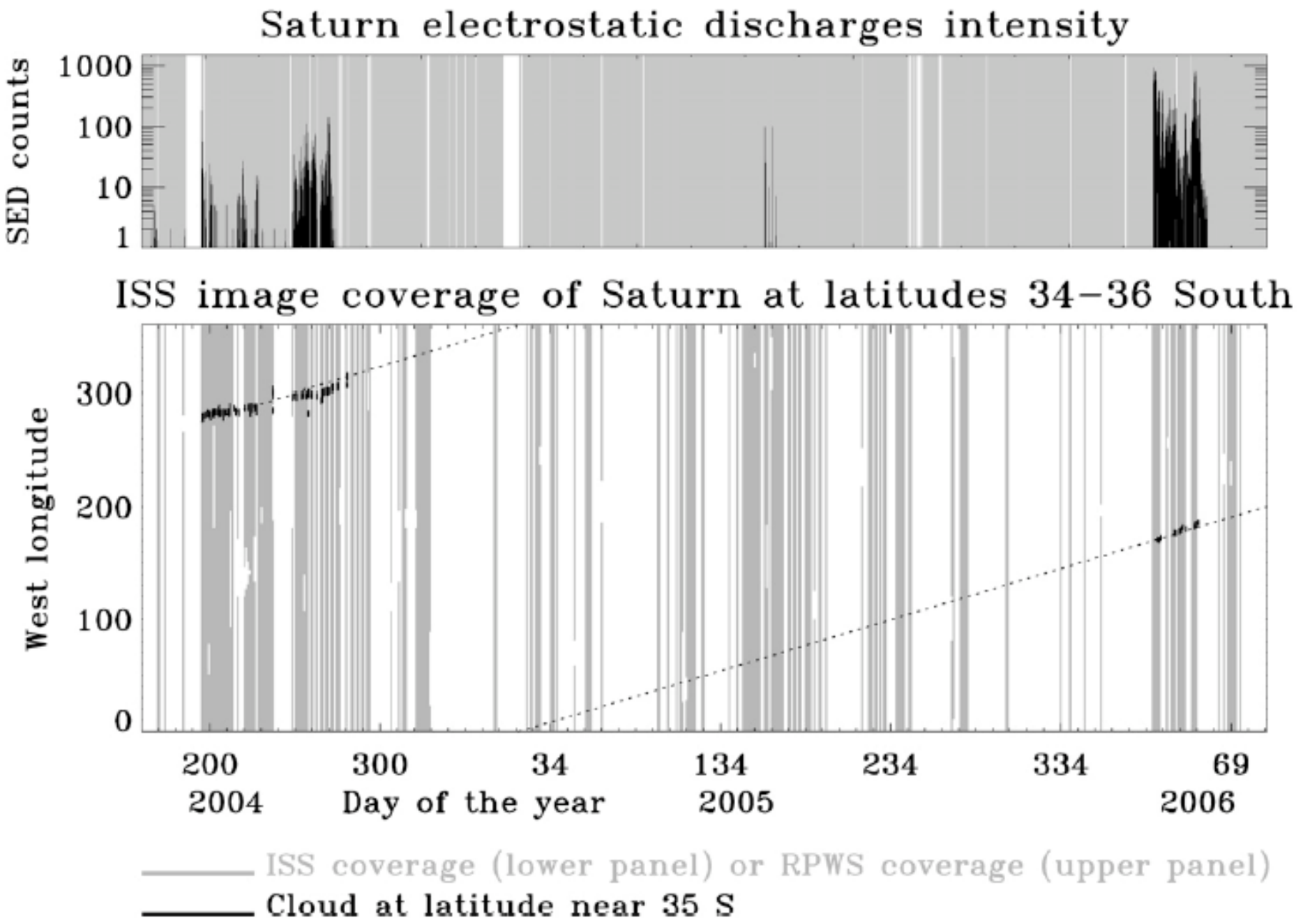
June 24, 2008

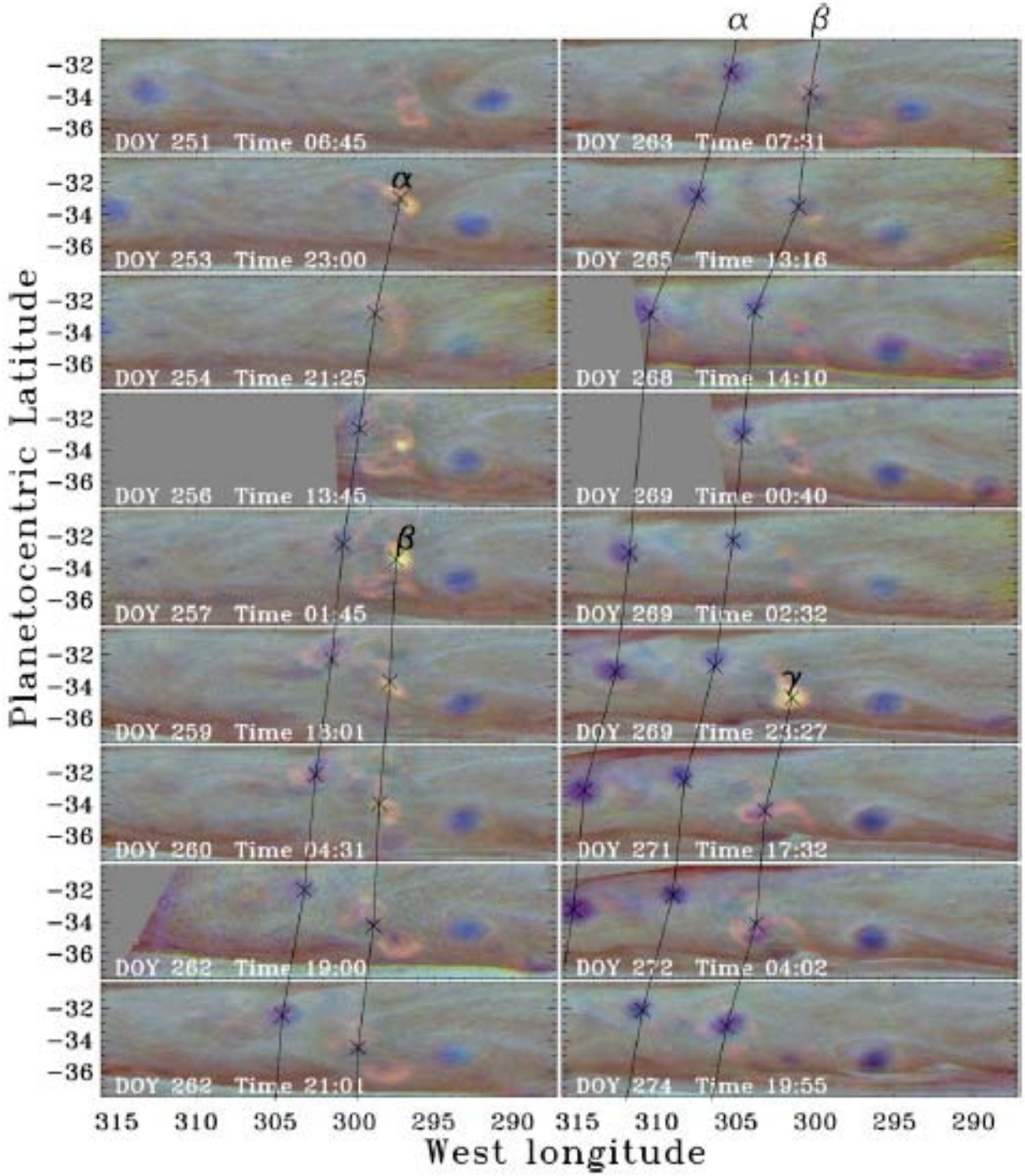


Electrical storms, but where’s the lightning?

The 2008 electrical storm: Same latitude as previous storms but much longer lived (6 months and still going)



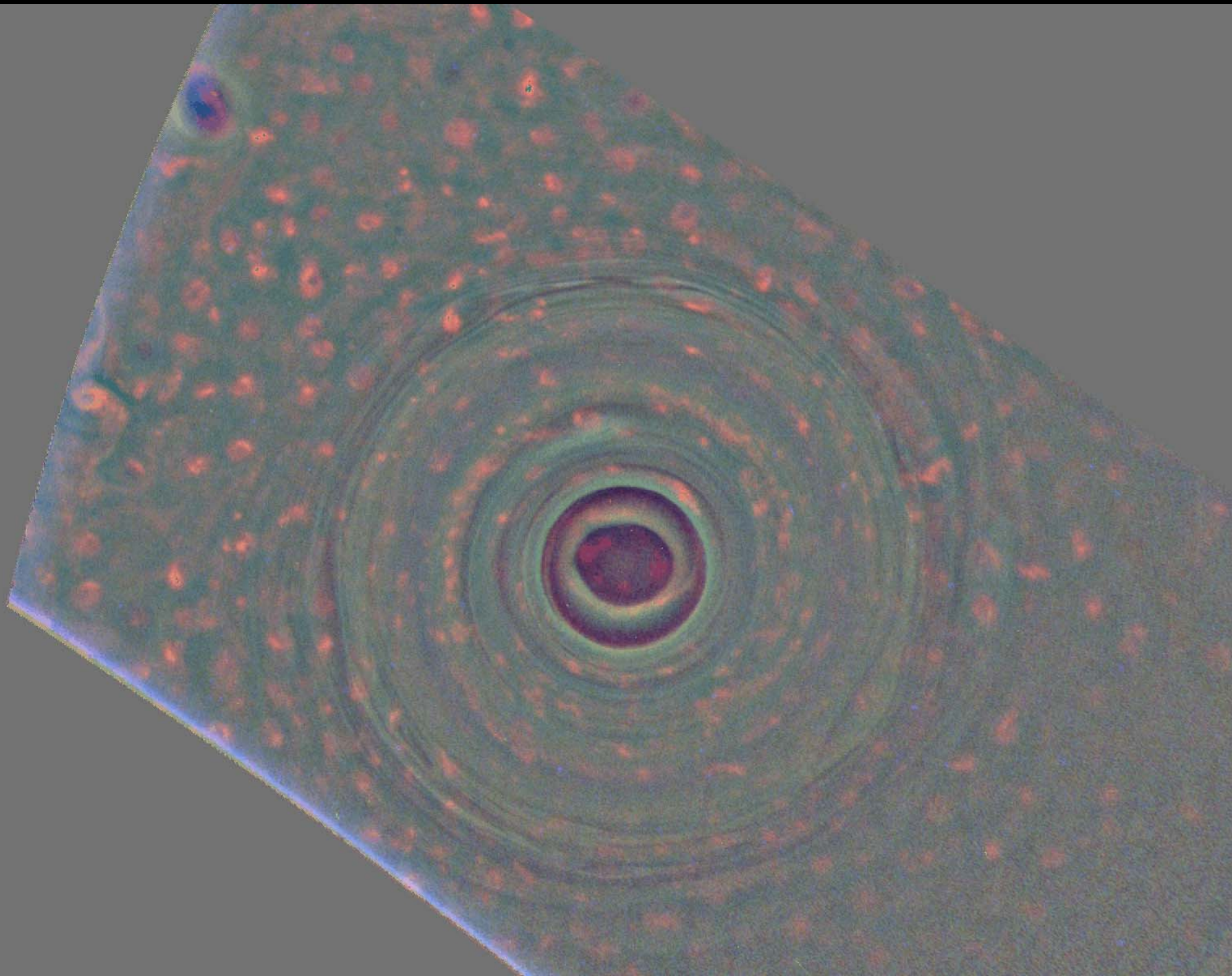

Saturn electrostatic discharges intensity
SED counts
1000
100
10
1
ISS image coverage of Saturn at latitudes 34−36 South
West longitude
300
200
100
0
200
2004
300
Day of the year
34
134
2005
234
334
69
2006
ISS coverage (lower panel) or RPWS coverage (upper panel)
Cloud at latitude near 35 S

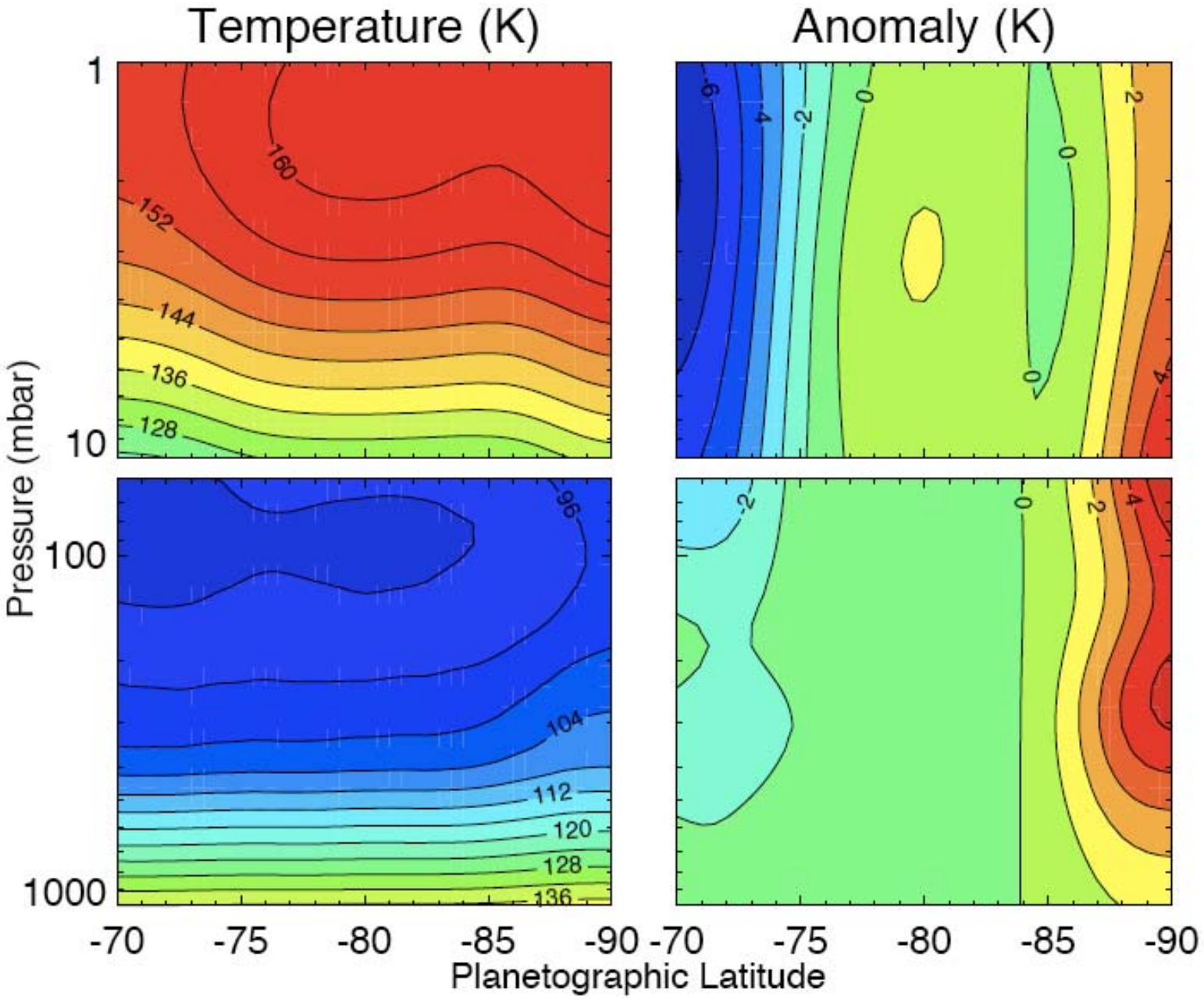

α
β
DOY 251 Time 06:45
DOY 253 Time 23:00
DOY 254 Time 21:25
DOY 256 Time 13:45
DOY 257 Time 01:45
DOY 259 Time 13:01
DOY 260 Time 04:31
DOY 262 Time 19:00
DOY 262 Time 21:01
DOY 263 Time 07:31
DOY 265 Time 13:16
DOY 268 Time 14:10
DOY 269 Time 00:40
DOY 269 Time 02:32
γ
DOY 269 Time 23:27
DOY 271 Time 17:32
DOY 272 Time 04:02
DOY 274 Time 19:55
−32
−34
−36
Planetocentric Latitude
315 310 305 300 295 290
West longitude

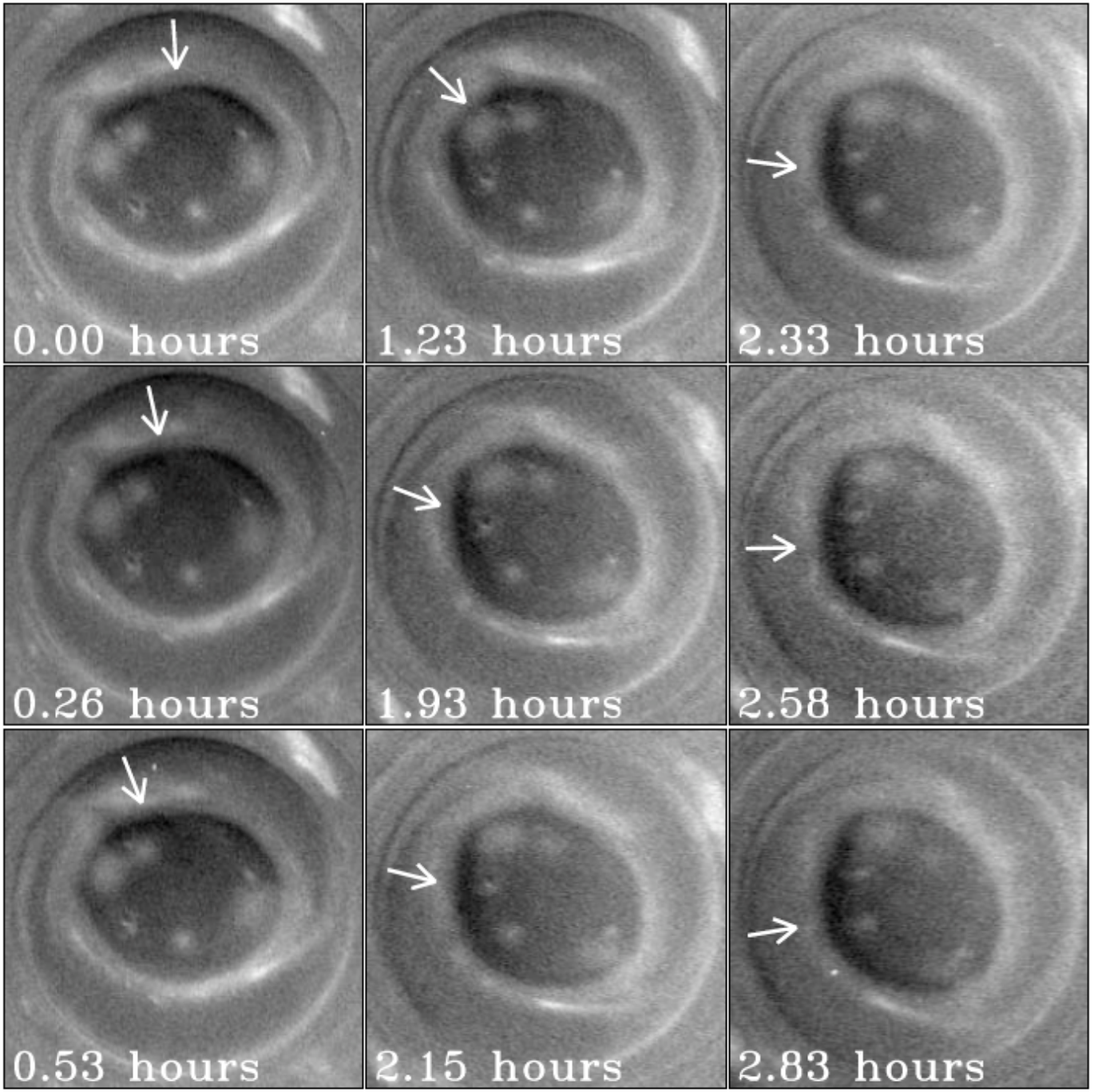
Night time on Saturn:

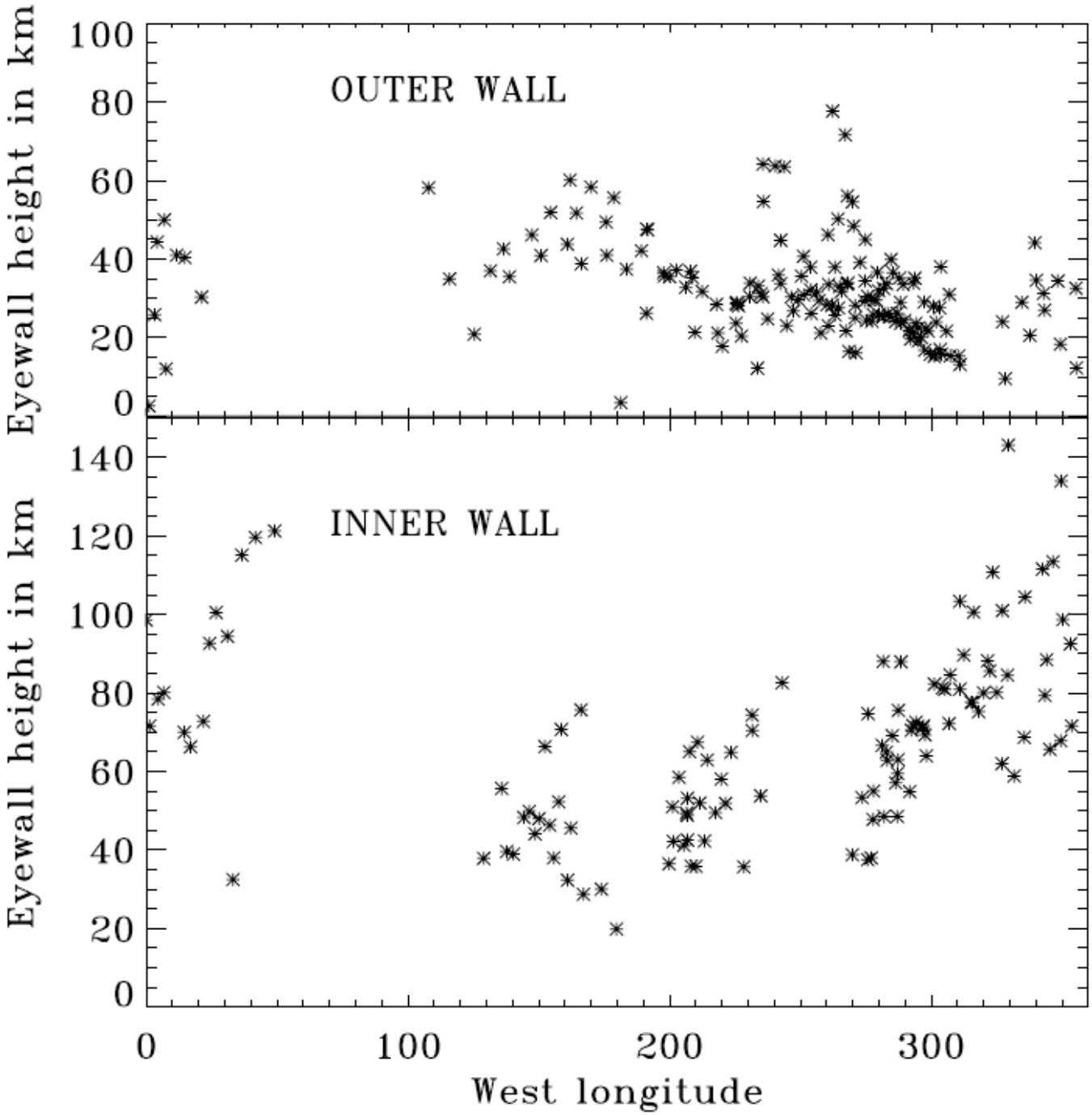
More light than on Earth under a full moon, except at the winter pole (currently the north pole) where the rings are over the horizon

South polar hurricane:
It has an eye but no ocean

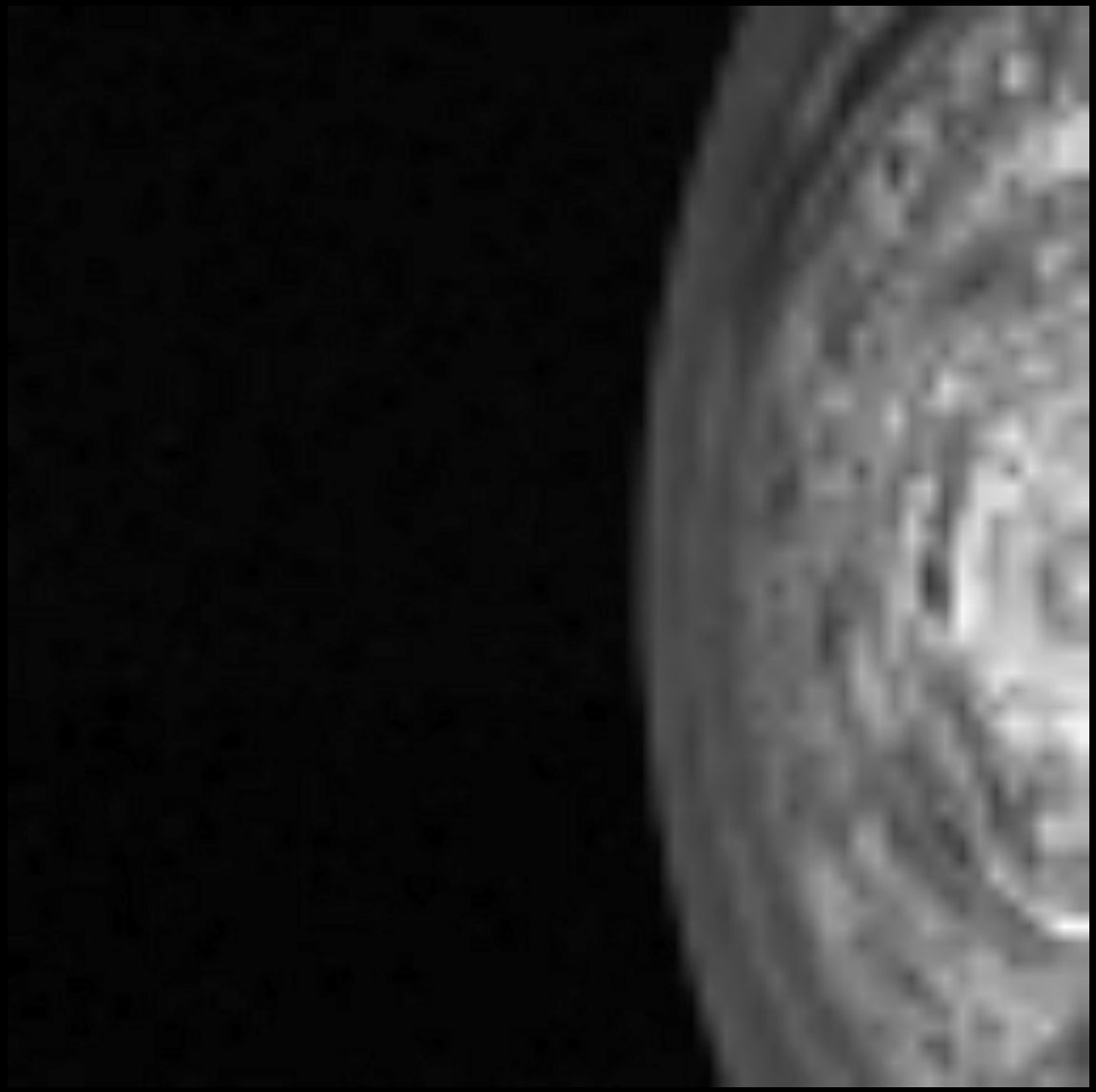



Temperature (K)
Anomaly (K)
Pressure (mbar)
1
10
100
1000
160
152
144
136
128
96
104
112
120
128
136
-6
-4
-2
0
0
0
2
4
-2
0
2
4
-70
-75
-80
-85
-90
-70
-75
-80
-85
-90
Planetographic Latitude


0.00 hours
1.23 hours
2.33 hours
0.26 hours
1.93 hours
2.58 hours
0.53 hours
2.15 hours
2.83 hours

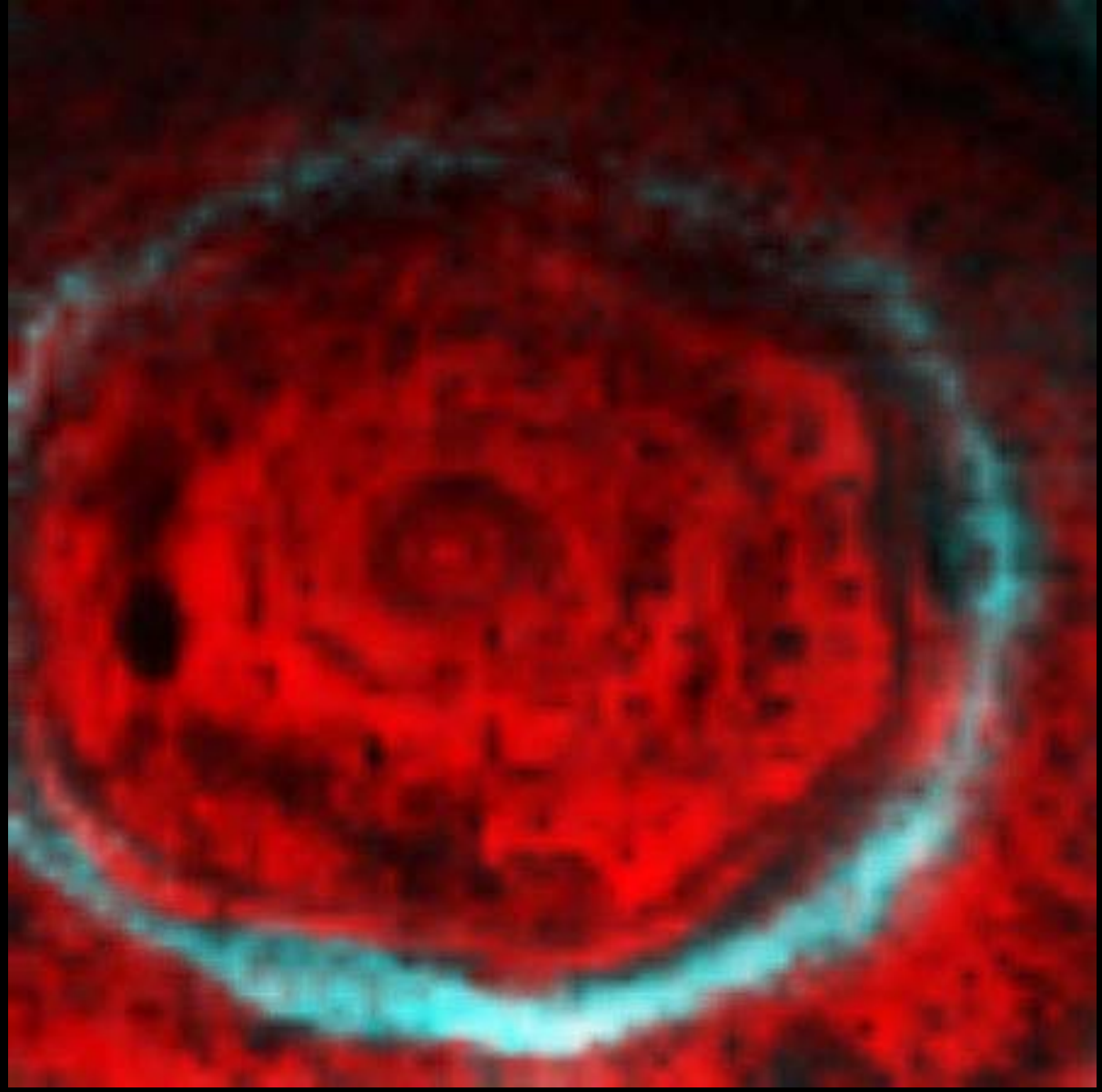

OUTER WALL
INNER WALL
Eyewall height in km
Eyewall height in km
West longitude
0
20
40
60
80
100
120
140
0
100
200
300

North polar hexagon and aurora

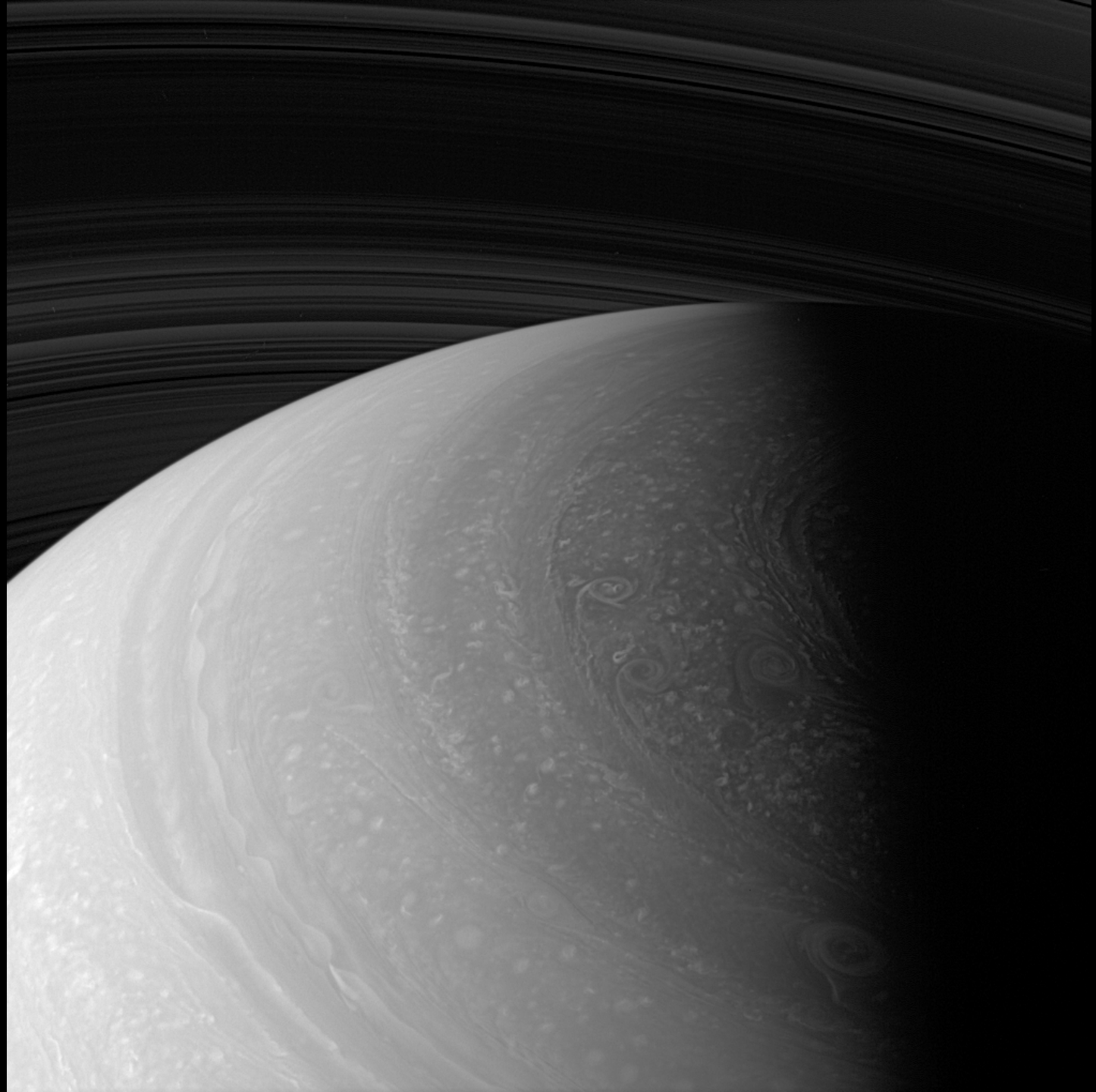


Saturn North Pole: K. Baines, Cassini VIMS

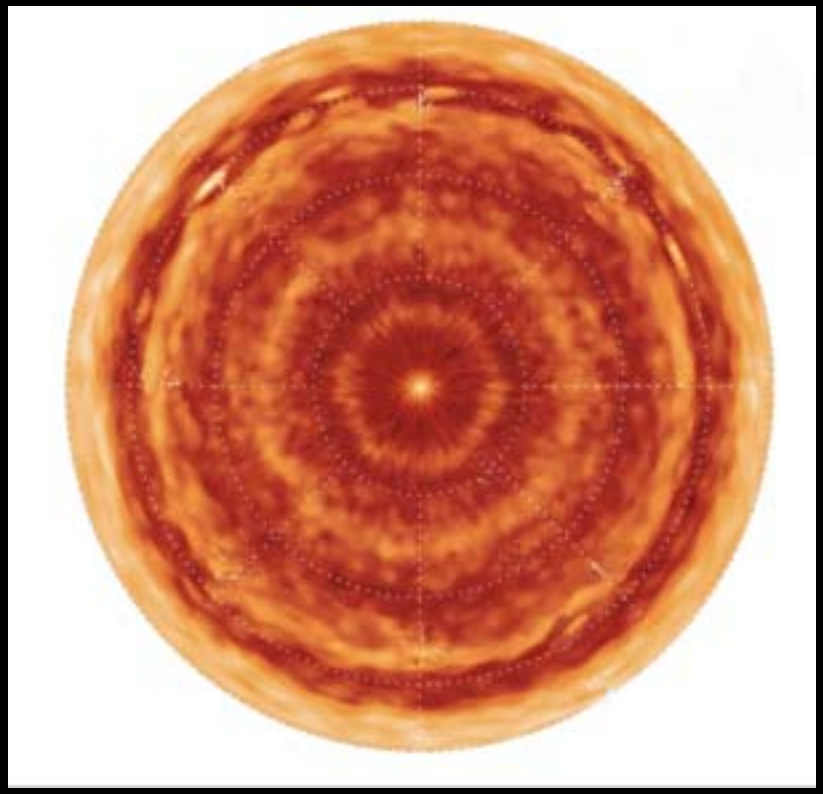
This slide contains a movie: No_Hexagon.mov



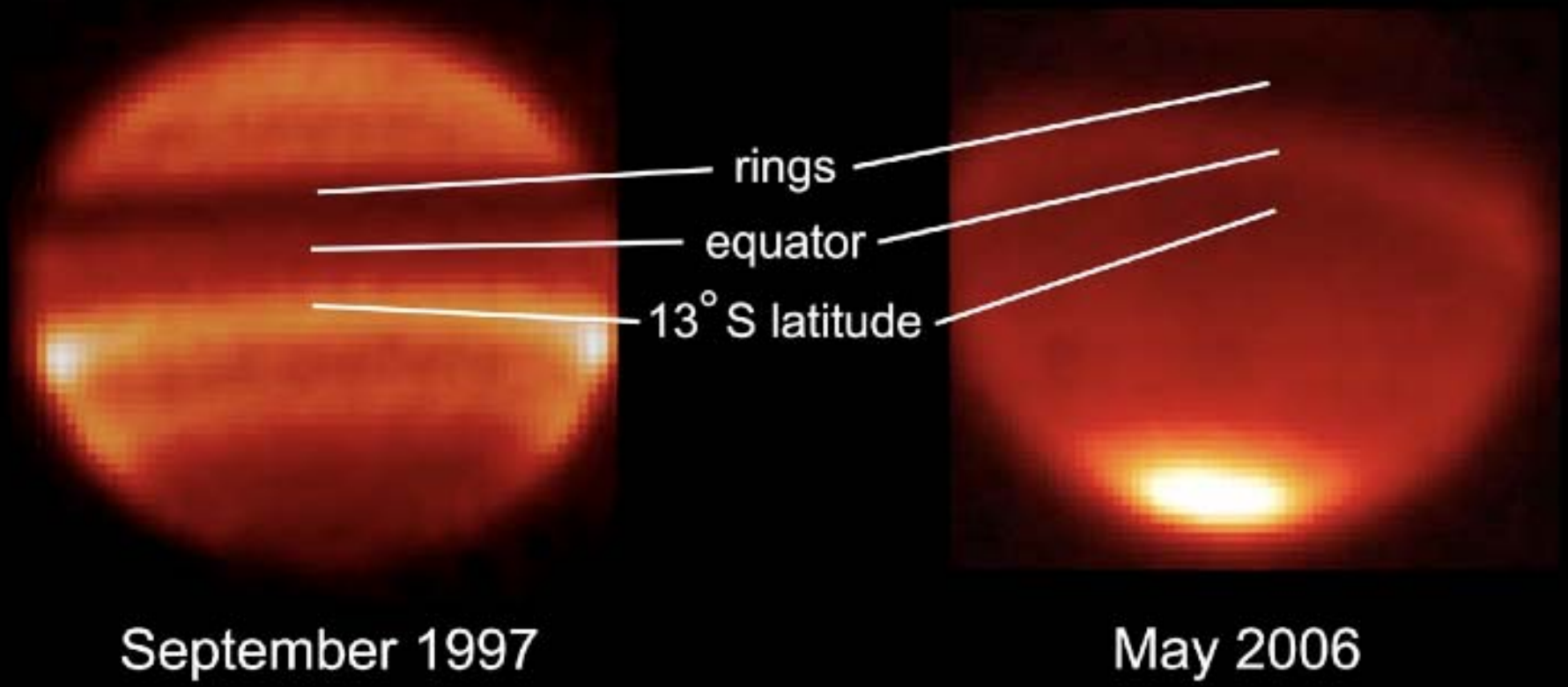
Saturn’s north polar hexagon (red) and aurora (blue)

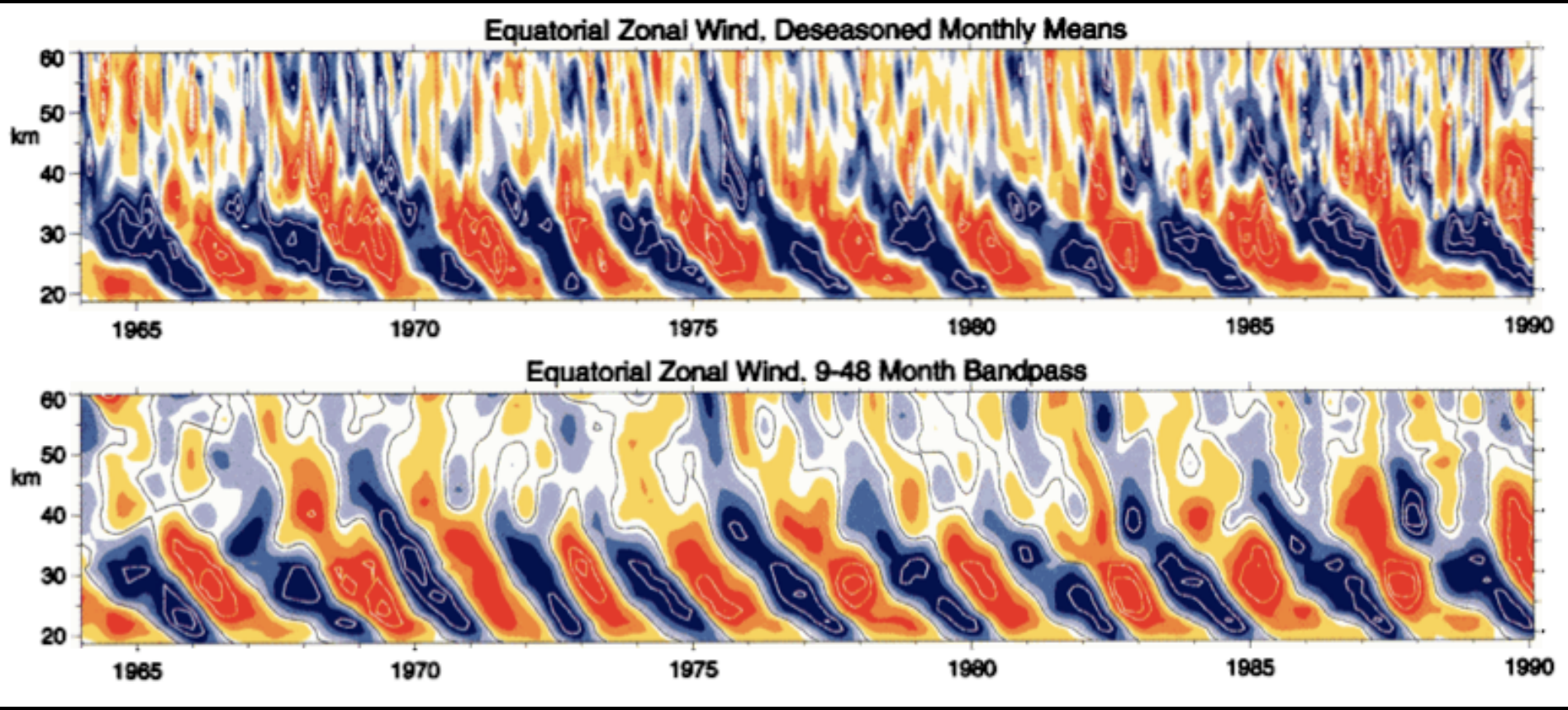


Temperature map of Saturn’s north pole: hot spot from 89° latitude to the pole

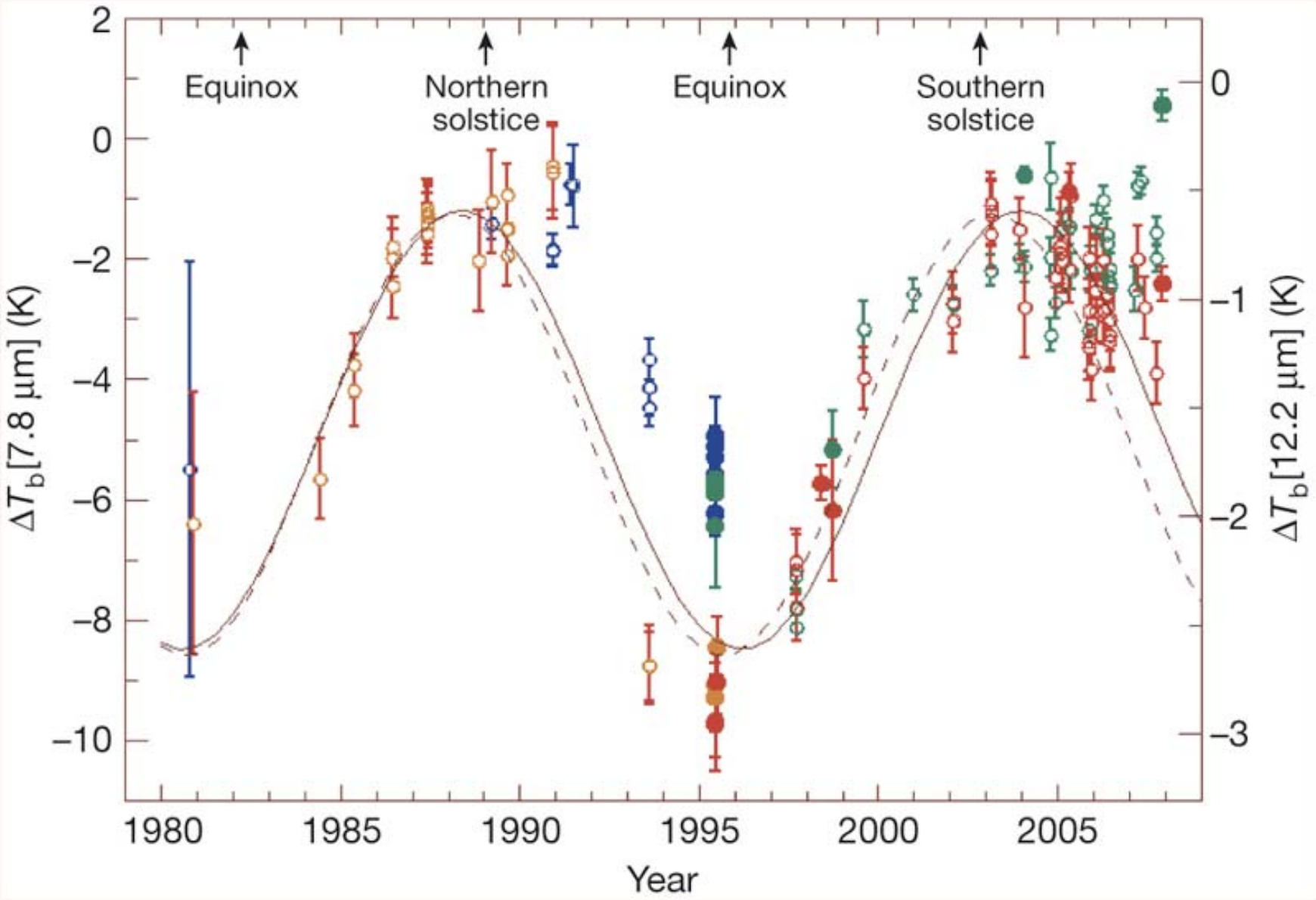


Equatorial oscillation: like the Earth's QBO


rings
equator
13° S latitude
September 1997
May 2006



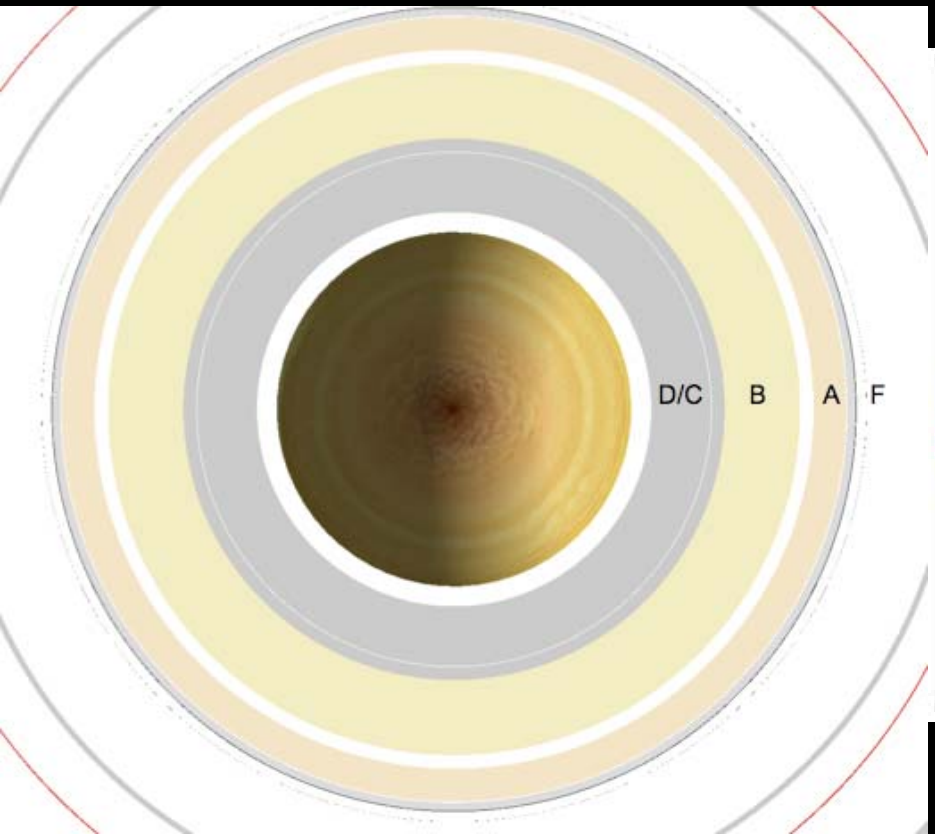
Earth's quasi-biennial oscillation (QBO). The pattern circles the Earth and varies with time. Equator is warmer than neighboring latitudes when westerly wind (red) is increasing with height

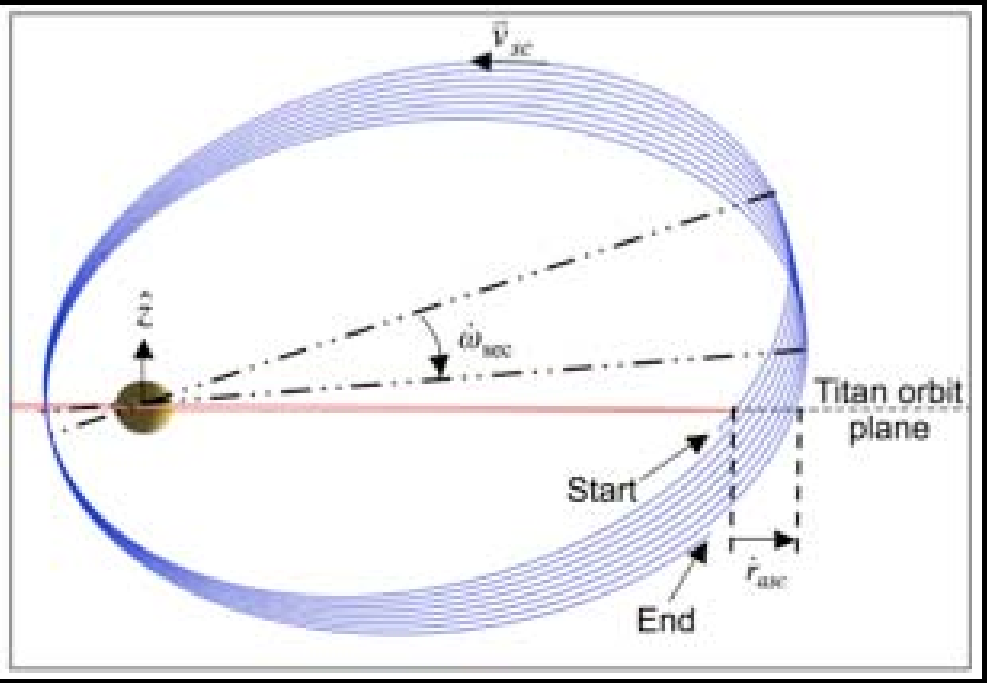

Equinox
Northern solstice
Equinox
Southern solstice
2
0
−2
−4
−6
−8
−10
0
−1
−2
−3
ΔTb[7.8 μm] (K)
ΔTb[12.2 μm] (K)
1980
1985
1990
1995
2000
2005
Year

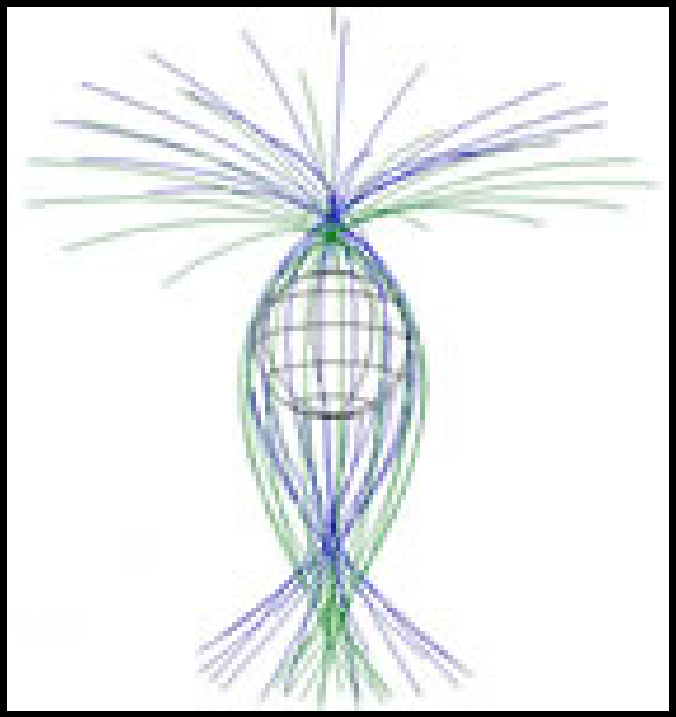
End of mission scenario:
Burn up in the planet's atmosphere;
Collect data for preceding 6 months

End of Mission Scenario:

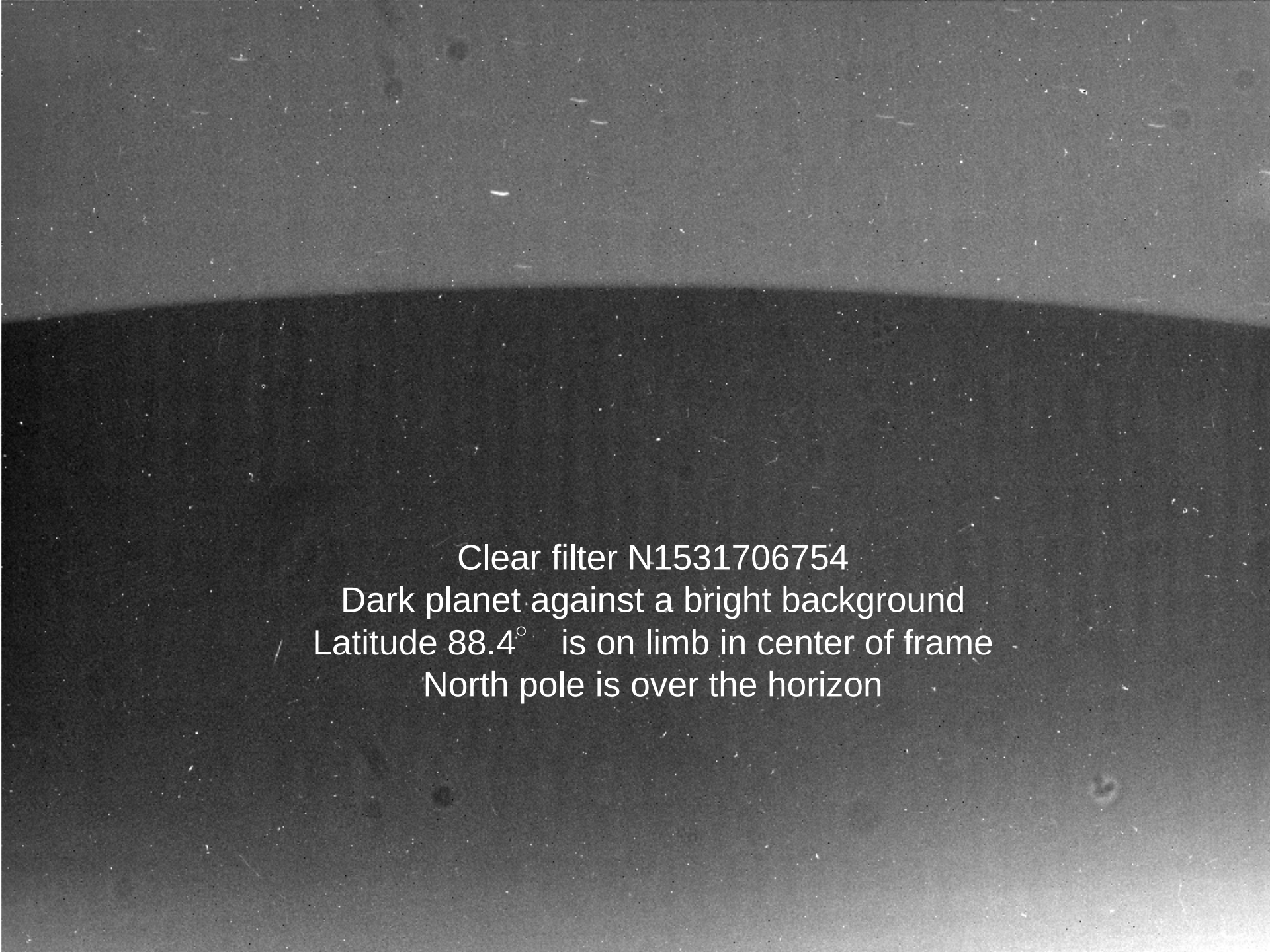
Put Cassini into a polar orbit (blue ellipses on the right) that skims through the atmosphere inside the D ring (the white gap on the left). Measure gravity (internal structure), magnetic field (internal rotation), and atmospheric composition. At the end, Cassini burns up in the atmosphere

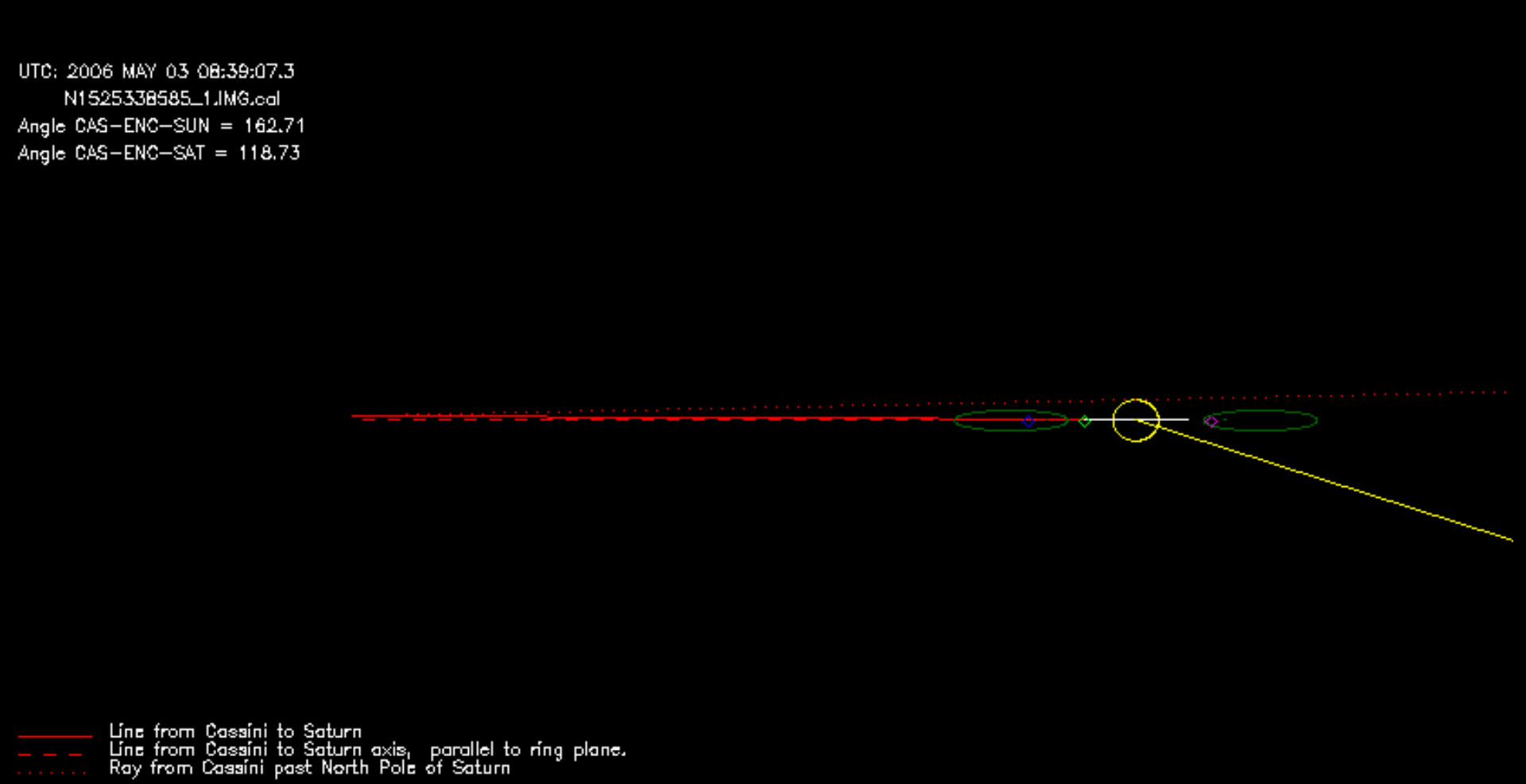






Juno trajectories - mapping the internal gravitational and magnetic fields: latitude of periapse ≈ 0°, longitude of periapse ≈ equally spaced at intervals of 12°


Clear filter N1531706754
Dark planet against a bright background
Latitude 88.4° is on limb in center of frame
North pole is over the horizon



View from equatorial plane; Saturn and Cassini are in the plane of the diagram. Faint red dotted line is from Cassini to north pole of Saturn. Yellow is to Sun. Phase angle (Cassini-Saturn-Sun) = 162°