

July 29,2008

Cassini-Huygens Mission to Saturn  
4<sup>th</sup> Anniversary CHARM, part 2

Dr. Claudia Alexander, Magnetosphere

Dr. Elizabeth Turtle, Titan

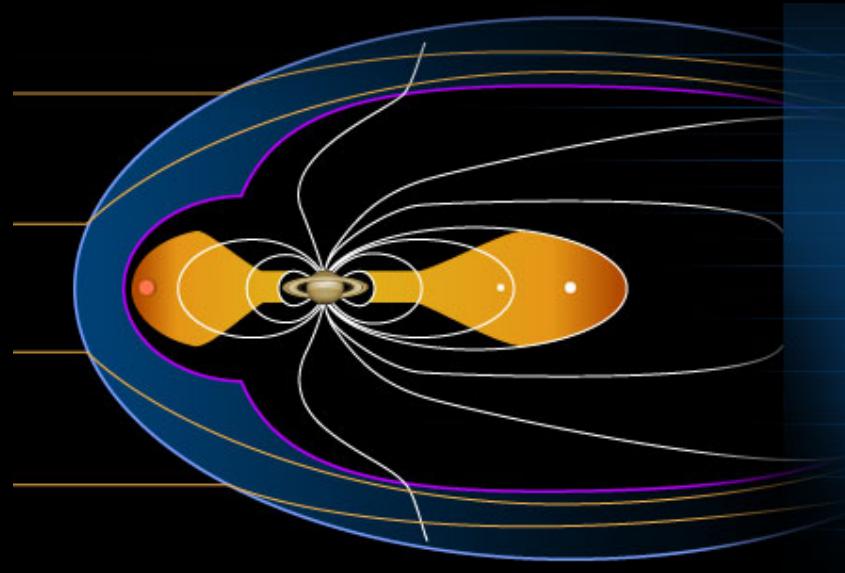
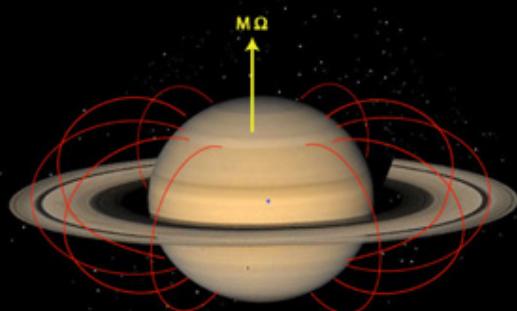
# Saturn's Magnetosphere at the end of the Prime Mission

Dr. Claudia Alexander  
Cassini Staff Scientist

# A. Completion of Primary MAPS Science Objectives (A)

- **Magnetosphere:**
  - Characterize this region of Saturn's environment:
    - the vector magnetic fields as a function of position and time.
    - the energy, composition and angular distribution of plasma (energetic charged particles) - including plasma wave phenomena - as a function of position and time.
- **Status:**
  - MAPS survey covered the inner magnetosphere for a 4-year period
  - **Some major discoveries:**
    - (A.1) Solar wind control is relatively weak compared to rotational and mass loading effects
    - (A.2) New radiation belt inside the D-ring
    - (A.3) Imaging of rotating dynamic ring current
    - (A.4 & B.1) Magnetosphere has time-varying rotation period

# Global Morphology

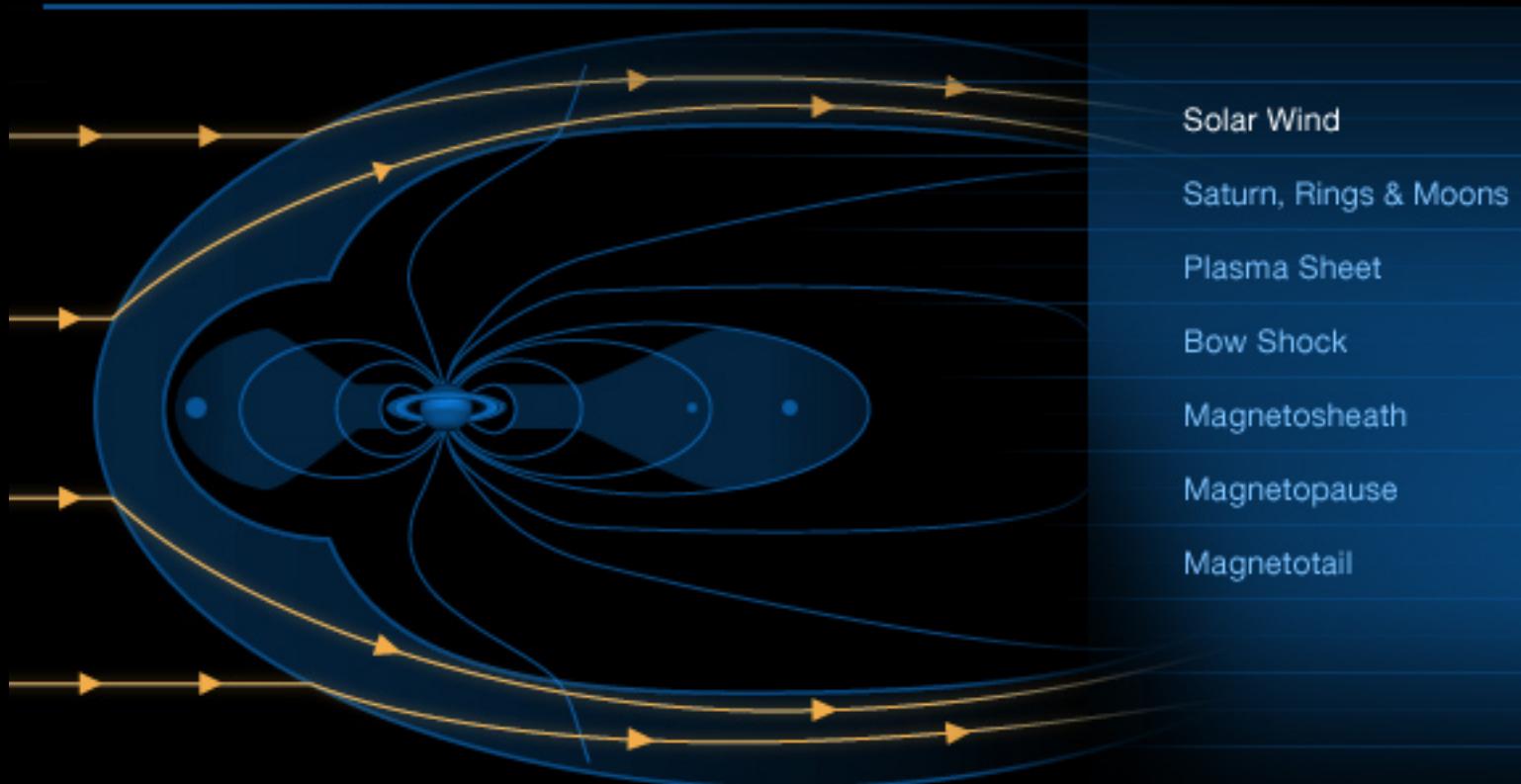


Very simple illustration

A more complex illustration,  
but what do the  
measurements tell us?

# Generic Schematic: Solar Wind

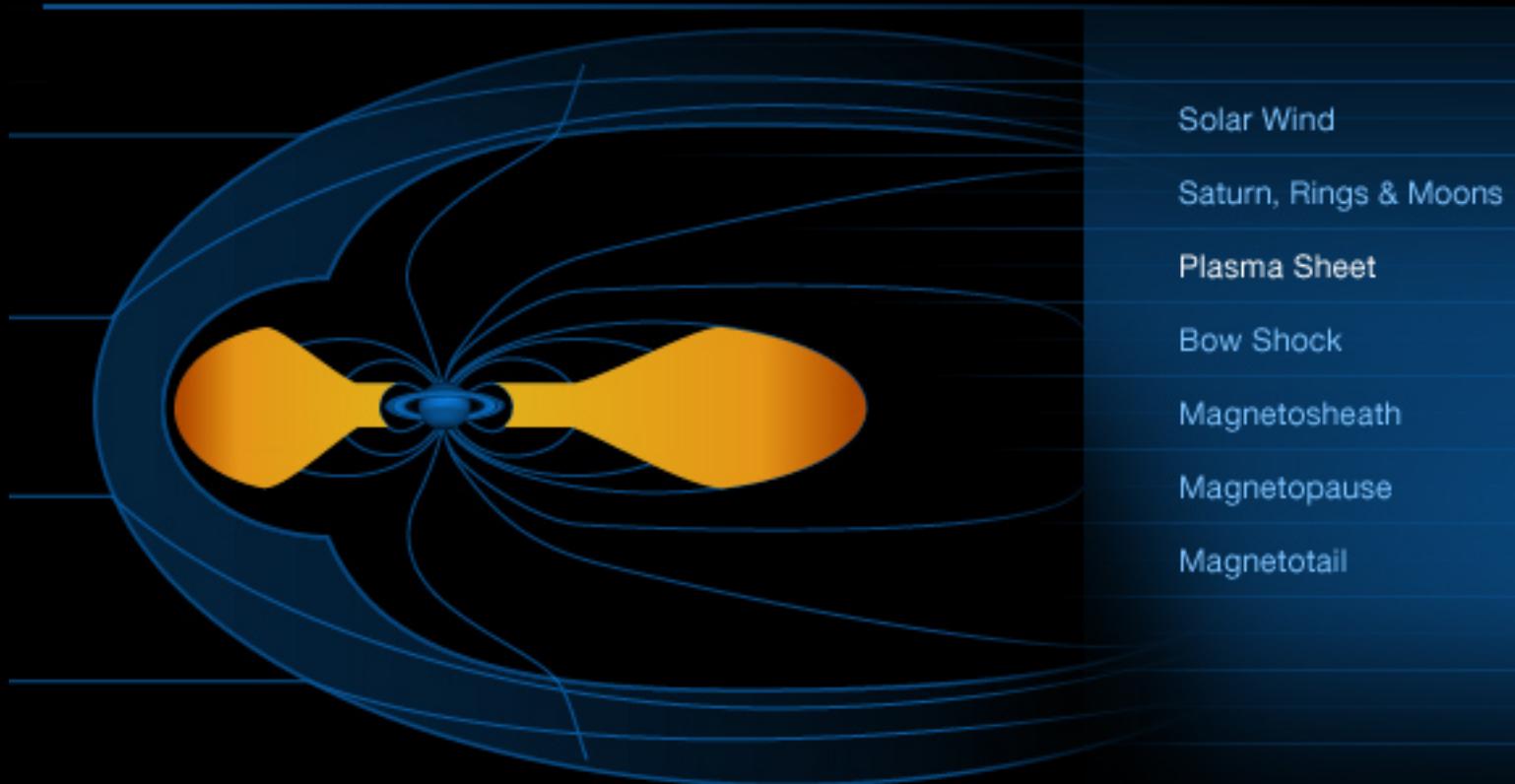
## Saturn's Magnetosphere



An outward flow of high-speed charged particles from the Sun's corona. The particles are mostly positively charged Hydrogen and Helium ions.

# Generic Schematic: Plasma Sheet,& Neutral Cloud

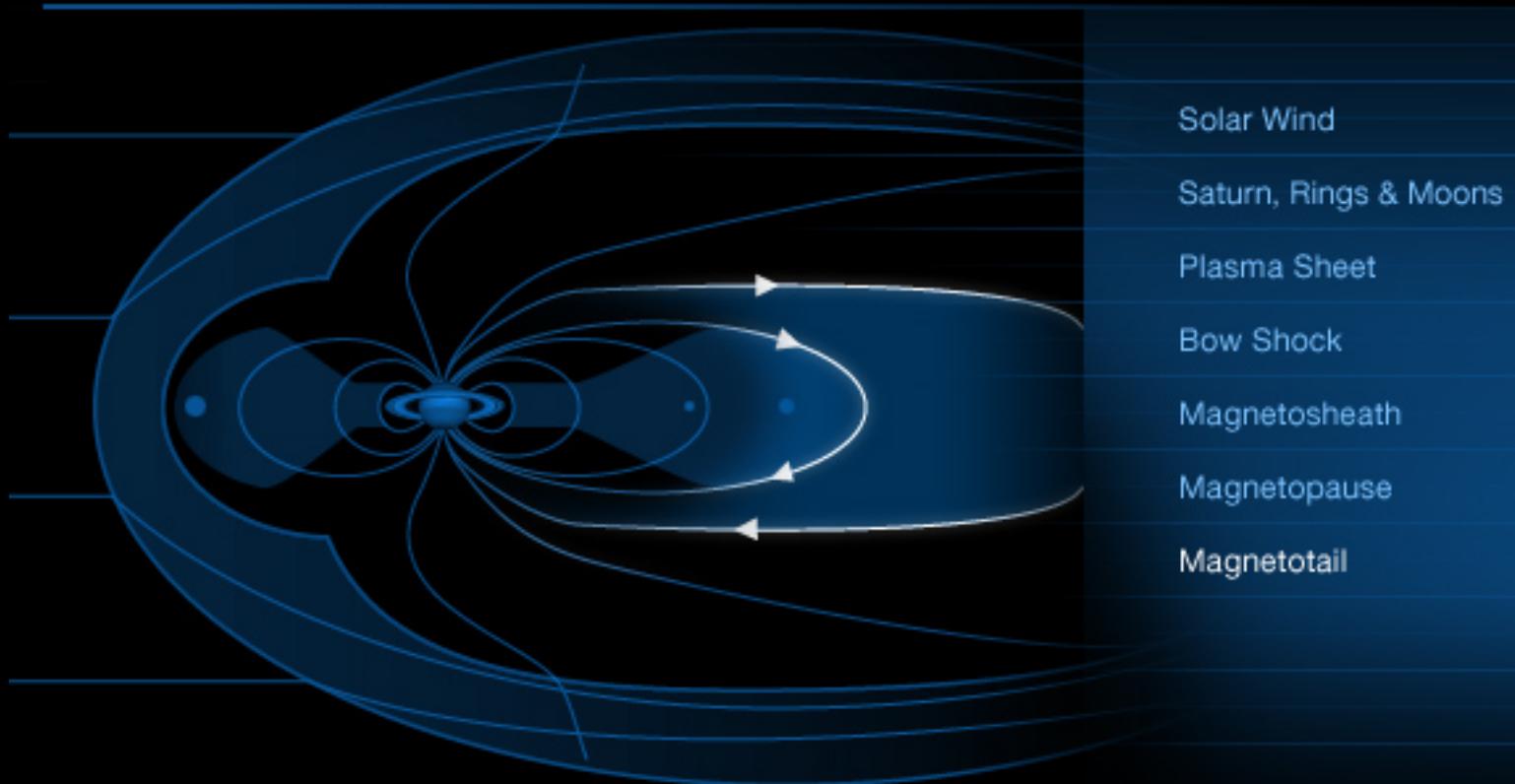
## Saturn's Magnetosphere



A resultant thin layer of high energy electron-rich particles that stream out of the interaction of solar wind and the magnetosphere.

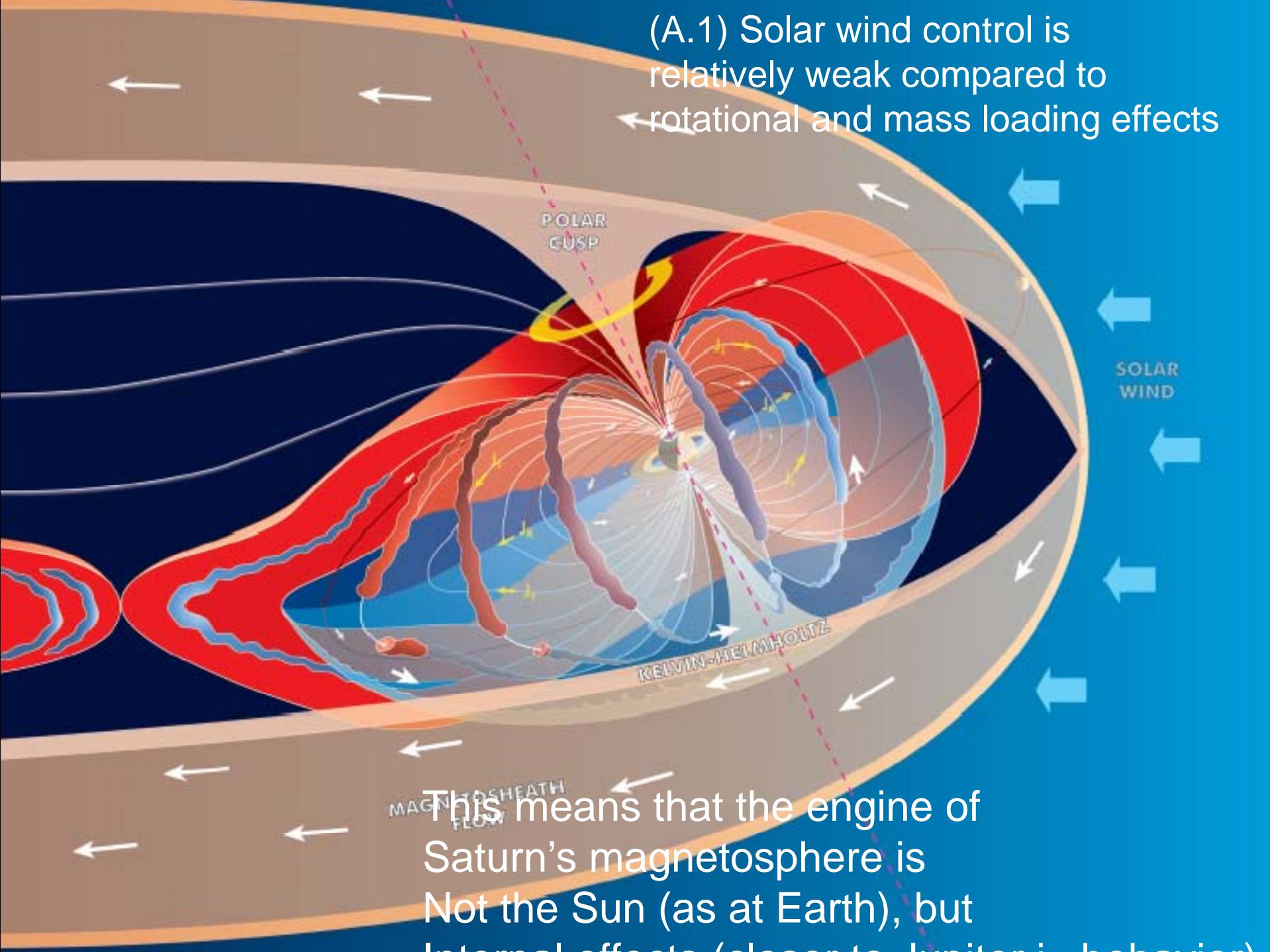
# Generic Schematic: Magnetotail

## Saturn's Magnetosphere



The long, trailing limb of Saturn's magnetosphere on the side facing away from the sun composed of trapped ionized particles.

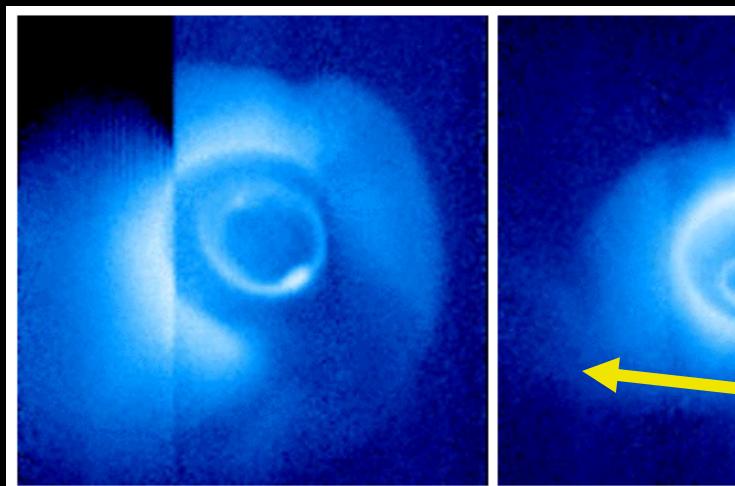
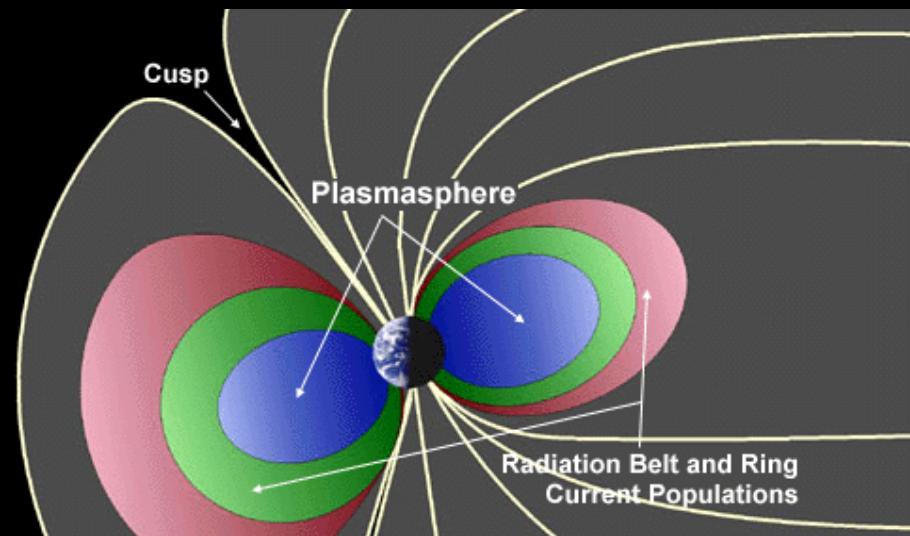
(A.1) Solar wind control is relatively weak compared to rotational and mass loading effects



This means that the engine of Saturn's magnetosphere is Not the Sun (as at Earth), but Internal effects (closer to Jupiter's behavior)

# (A.3) EUV “Images” of the Earth’s Plasmasphere

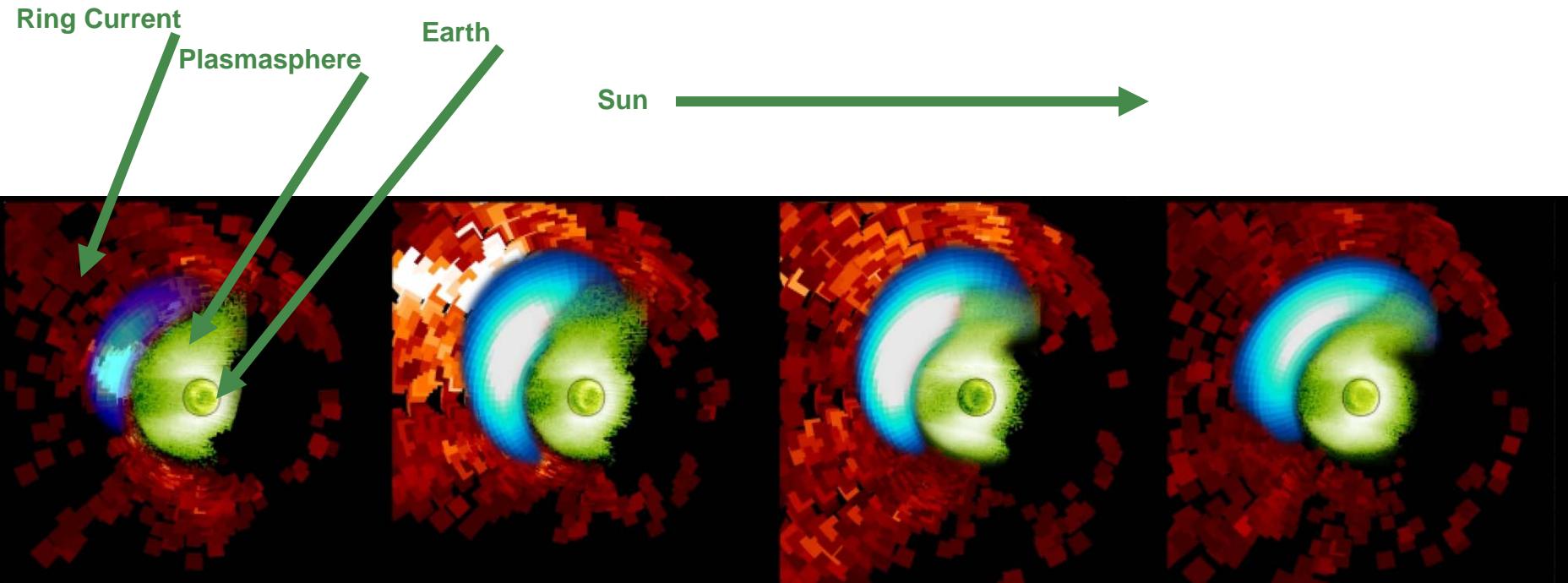
- Right: a schematic
- Left: actual images of the Earth; the surrounding particles; aurora at the pole.



- Sun at upper left.
- Earth's shadow
- Plasmaspheric particles middle left.

# From the IMAGE s/c

Background  
Plasma Injection at the Earth



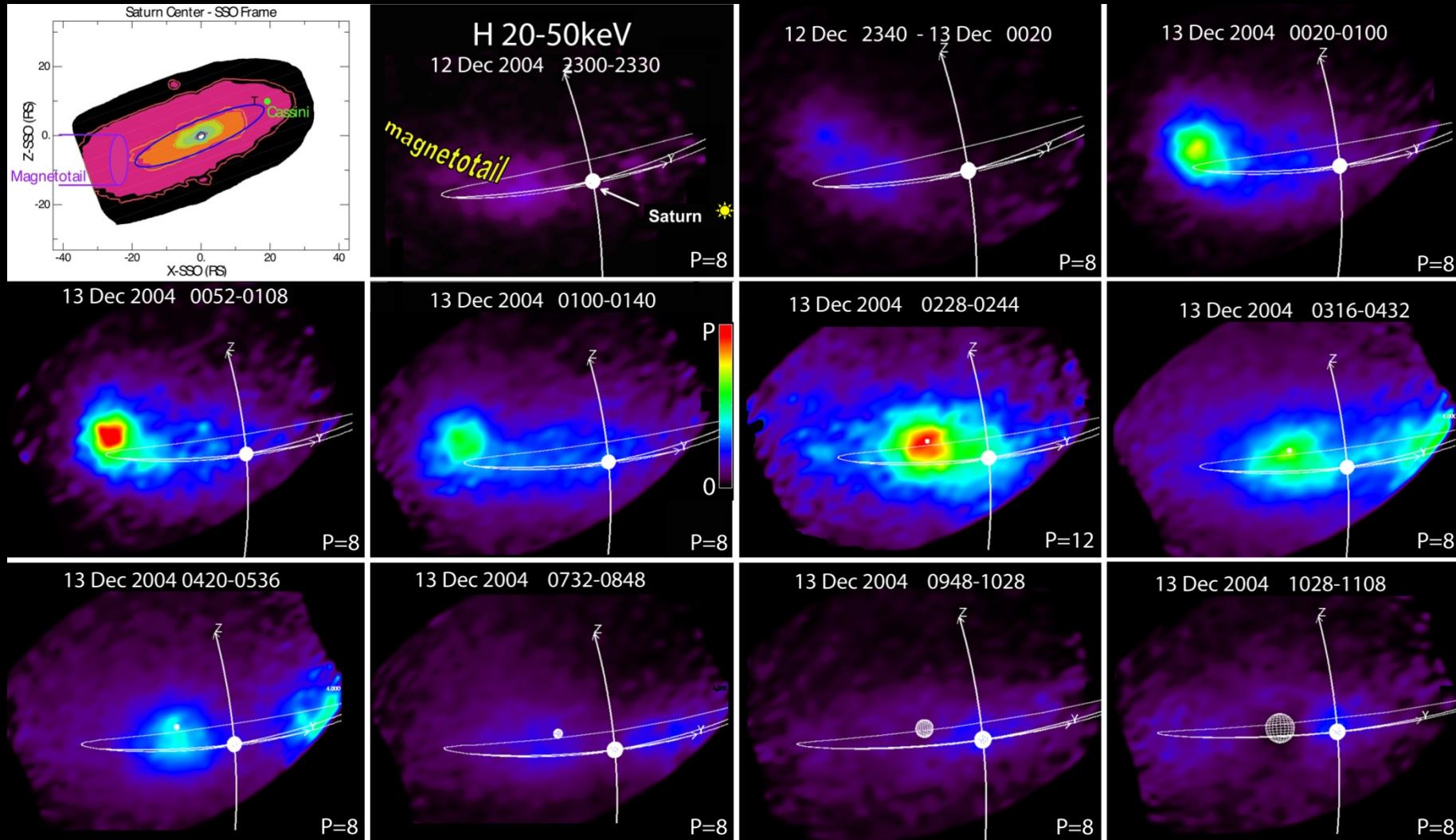
**Panel 1:**  
nominal plasmasphere

**Panel 2:**  
Ring current brightening  
as energetic particles  
from the tail impinge on  
the nightside of the  
Earth.

**Panel 3:**  
Plasmasphere grows  
as the ring current  
particles are injected  
into it

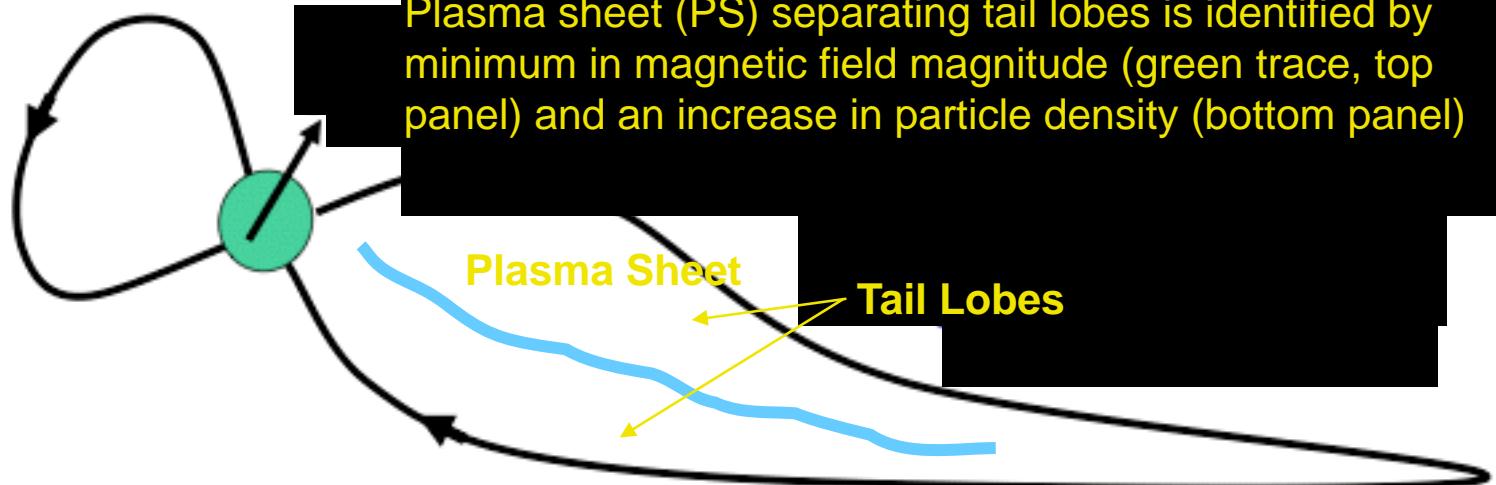
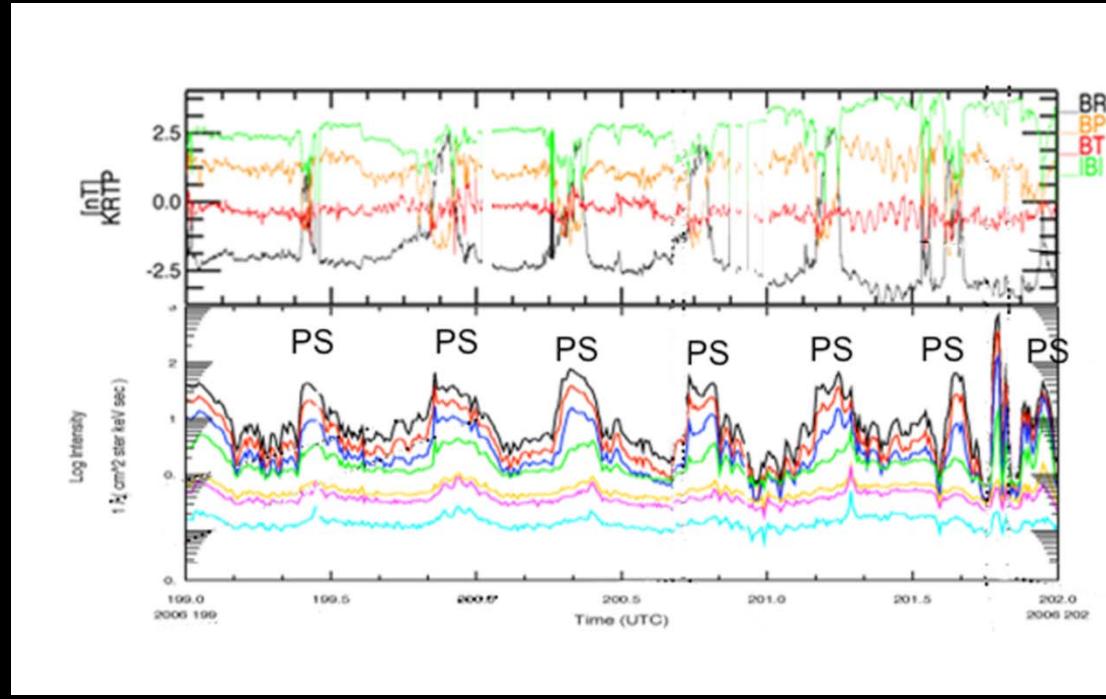
**Panel 4:**  
Plasmaspheric loss  
occurs as particles  
precipitate and rain  
out through the  
auroral zone.

# (A.3) MIMI evidence of plasma injection from the tail (imaging the ring current)



## A.4) Saturn has an (unexpected) time-varying component

- Though the rotational axis and the dipole axis are aligned, Saturn's rotational axis is tilted with respect to the ecliptic.
- Figure shows an example of MAG and MIMI data from a recent tail pass
- Spacecraft (s/c) will be above then below the plasma sheet (PS). So the plasma sheet will 'beat' past the s/c.

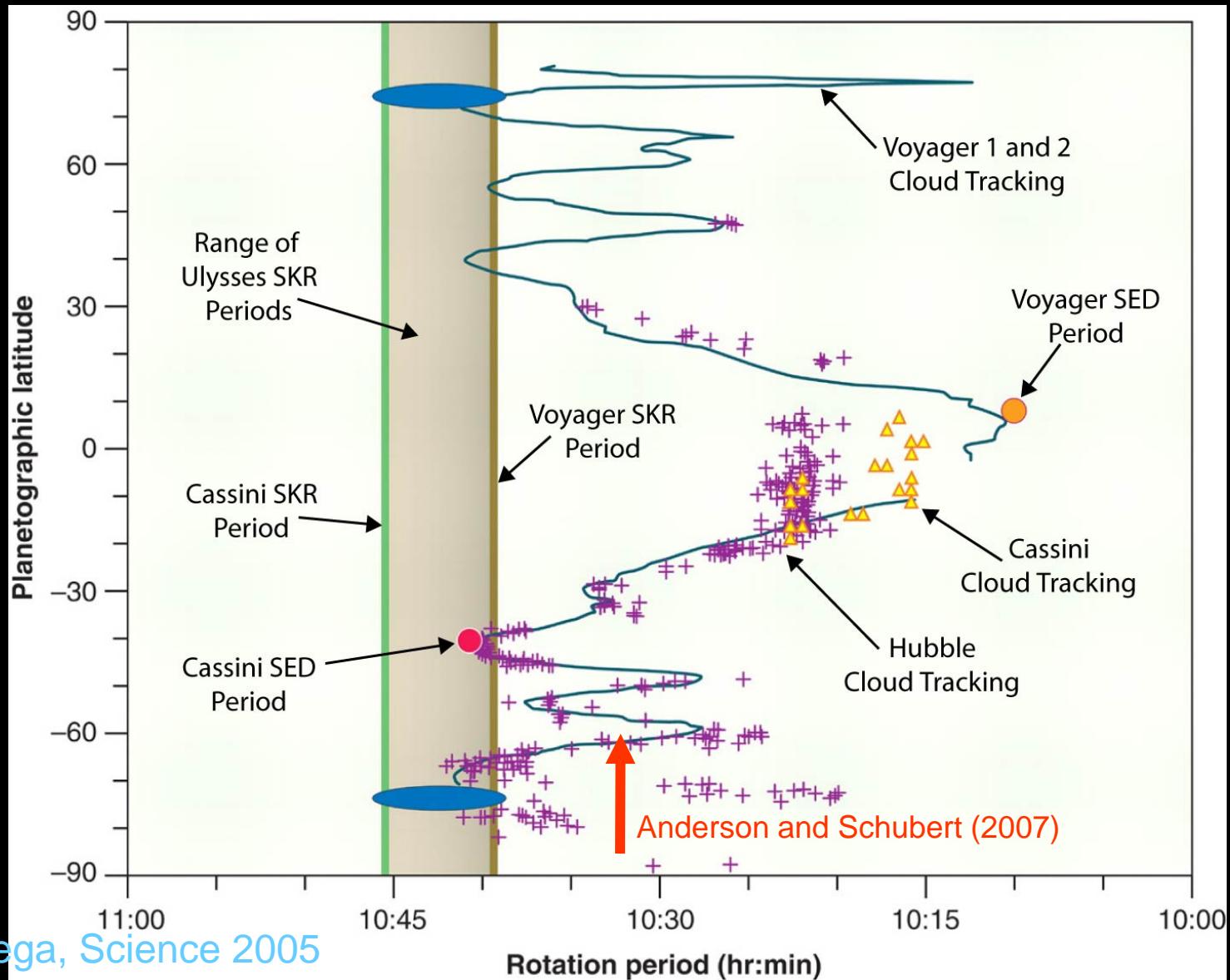


Plasma sheet (PS) separating tail lobes is identified by minimum in magnetic field magnitude (green trace, top panel) and an increase in particle density (bottom panel)

# B. Completion of Primary MAPS Science Objectives (B)

- **Saturn's Kilometric Radiation (SKR):**
  - Objective: Determine the relationship of the magnetic field orientation to SKR.
- **Status:**
  - Some major discoveries:
    - (B.1) It was determined that the SKR period does not represent the internal rotation period of the planet.
    - (B.2) The variable period of SKR has been confirmed; it continues to evolve.
    - (B.3) Many magnetospheric phenomena have a period similar to the SKR period.

# SKR Period is Different than the Internal Rotation



# What is Kilometric Radiation?

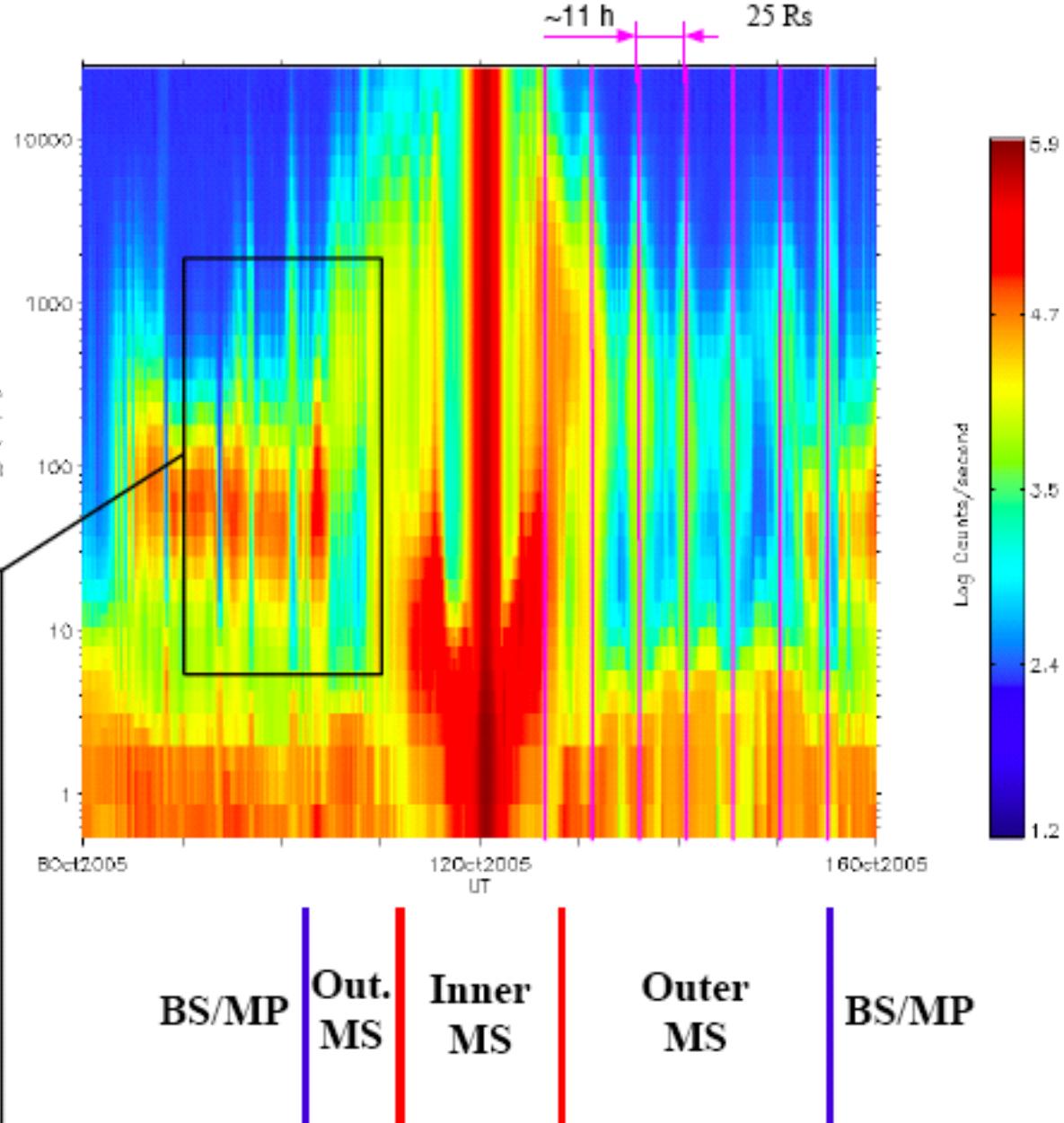
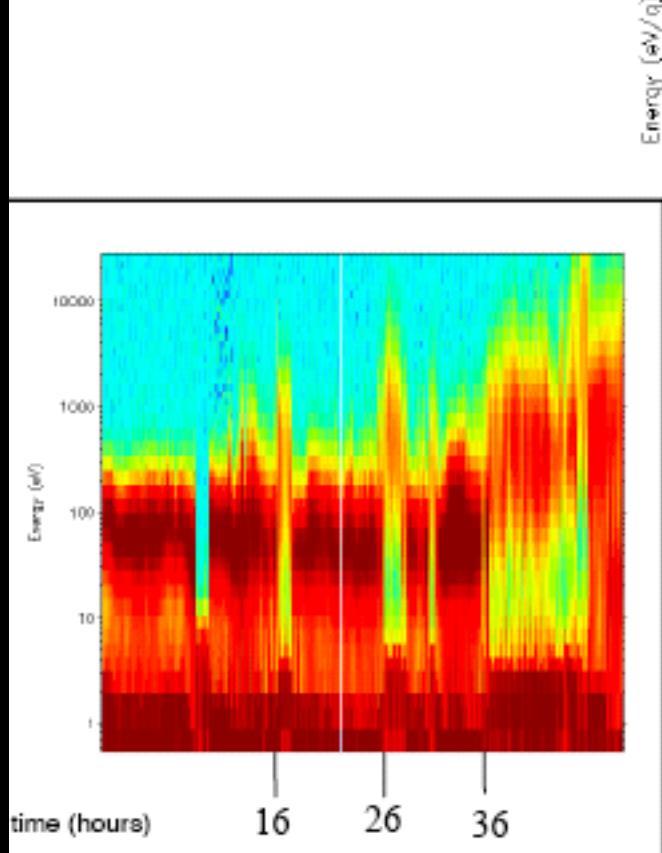
- **SKR is the Saturn analog of terrestrial AKR - at frequencies appropriate for Saturn.**
- **Auroral kilometric radiation** (AKR) is the intense radio emission in the acceleration zone (at a height of three times the radius of the Earth) of the aurora. The radiation mainly comes from cyclotron emission from electrons orbiting around the magnetic field lines of the Earth. The radiation has a frequency of between 50 and 500 kHz and a total power of between about 1 million and 10 million watts. The radiation is absorbed by the ionosphere. The sound produced by playing AKR over an audio device has been described as "whistles", "chirps", and even "screams". From Wikipedia.
- Earth's Auroral 'Radio Chatter' from Scientific American, June 30 2008.
- [http://www.windows.ucar.edu/tour/link=/earth/Magnetosphere/tour/tour\\_earth\\_magnetosphere\\_08.html](http://www.windows.ucar.edu/tour/link=/earth/Magnetosphere/tour/tour_earth_magnetosphere_08.html)

# Planetary Period Oscillations in Saturn's Magnetosphere (MIMI) Clarke, et al., GRL, in press

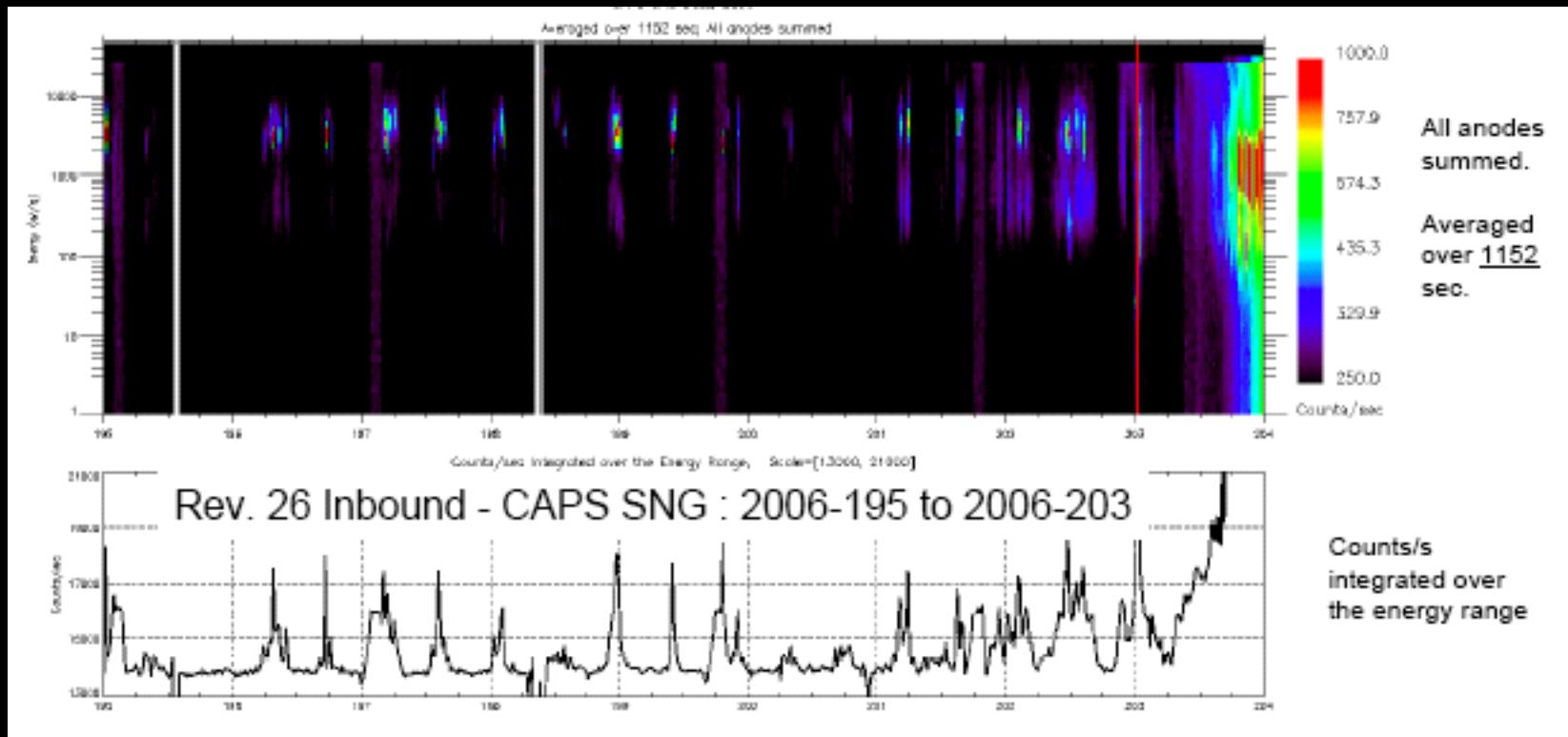
Saturn Result

These Oscillations  
are of global-scale

Rev. 16



# CAPS - Rotational Modulation of Ion Fluxes

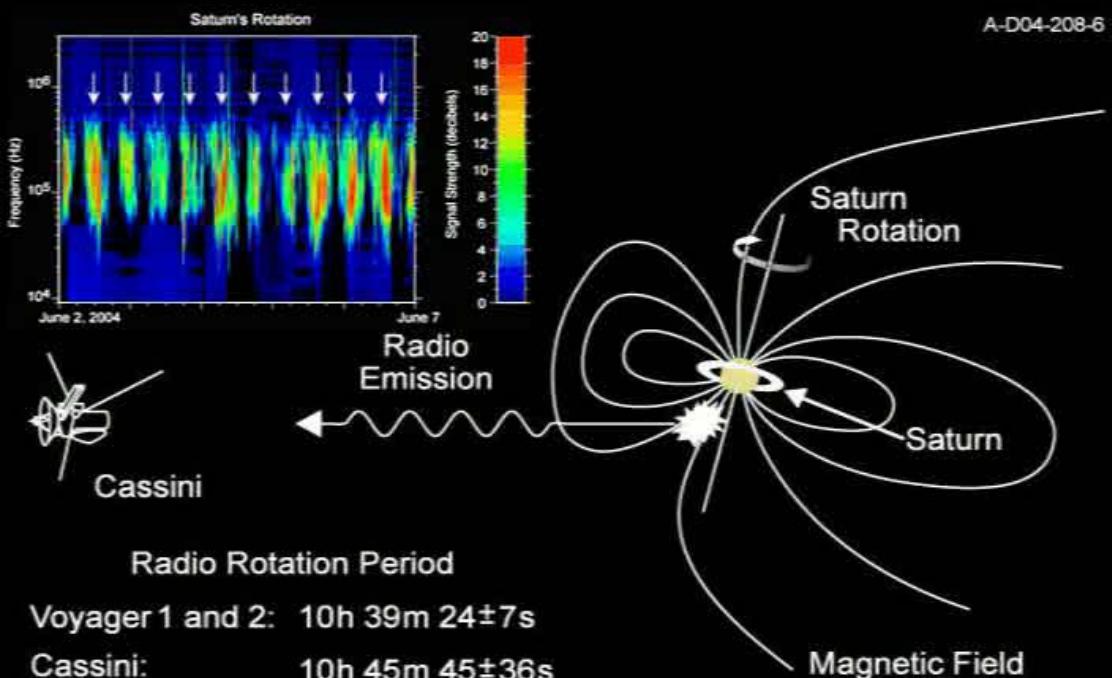
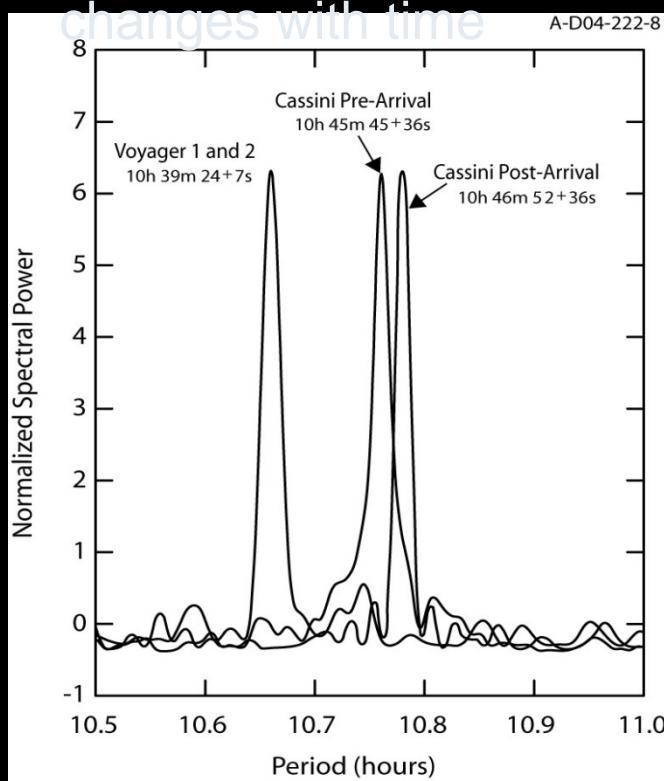


- Spectrograms (upper panel) show the modulation in ion fluxes in the magnetosphere at Saturn's rotational period of 10h 40m. Summation of ion energies (lower panel) also show the periodicity. Radial distance in the figure ranges from 48 Rs to 12 Rs

# These modulations are not explained by the periodicity that RPWS measures

- IAU longitude system cannot be used to organize the data
- SKR drifts in longitude and time and the rate of drift

~~changes with time~~



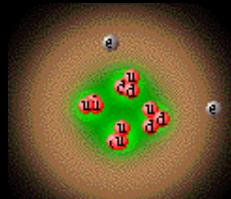
Cassini has found a different radio period than Voyager. The radio period is usually used to determine the rotation period of gas giant planets. A major mystery for Cassini to solve is the reason for the variation of the radio period. Once this mystery is solved, it will be possible to accurately determine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

# C) Completion of Primary MAPS Science Objectives (c.)

- Titan:
  - Investigate the upper atmosphere and ionosphere.
  - Investigate Titan-magnetosphere interactions.
- Status:
  - Some major discoveries:
    - (C.1) Heavy negative ions were detected in the ionosphere
    - (C.2) Nitrogen escaping from Titan's atmosphere is only a trace ion in the Saturnian magnetosphere

# What are Negative Ions?

- Electrons are negatively charged particles
- Ions are generally positively charged particles, an atom stripped of one or more electrons.
- What CAPS and INMS seem to have discovered are very heavy - > 2000 AMU particles, probably aggregates of Polycyclic Aromatic Hydrocarbons (PAH's), that drop down into the lower atmosphere after being created higher up.

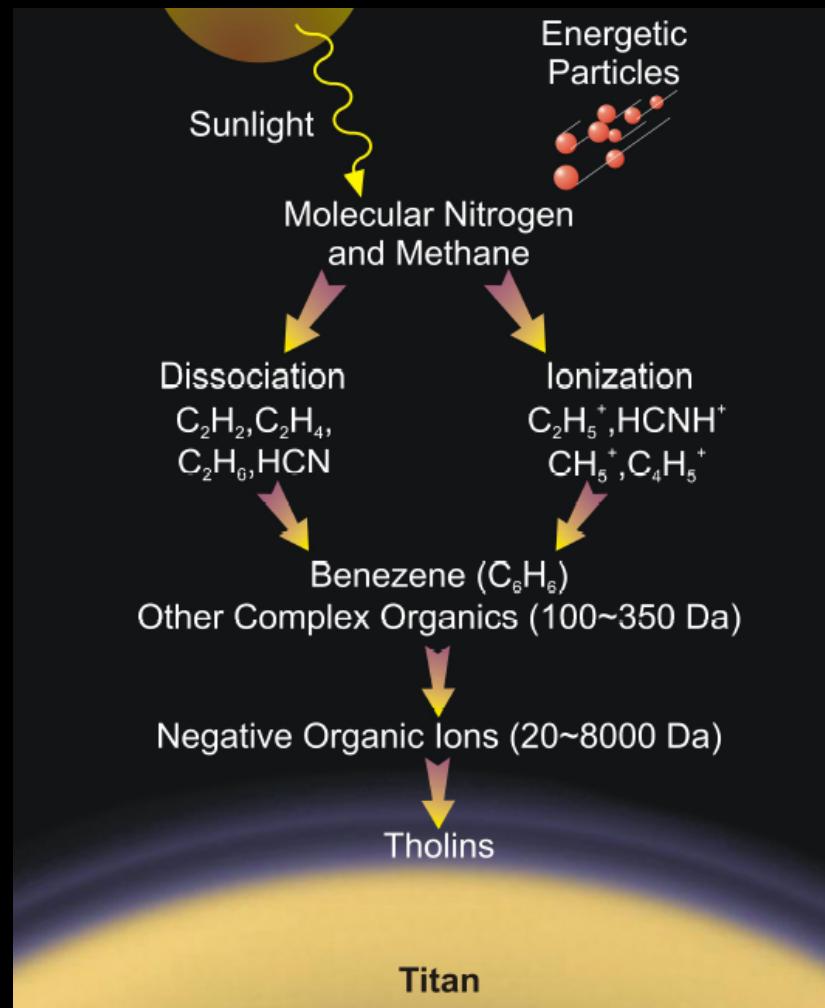


Model of an atom. The nucleus in green is made of protons (positive electric charge) and neutrons (electrically neutral). Protons and neutrons are made of smaller particles called quarks (shown in red). The white particles are electrons which have a negative electric charge. They orbit the nucleus at a considerable distance. Courtesy Windows to the Universe.

# Heavy Negative Ions Discovered in Titan's Ionosphere

A joint CAPS and INMS discovery

... massive negative ions<sup>↳ no longer in the gas phase, as compounds heavier than about 2,000 Da become aerosols in Titan's atmosphere</sup> then likely lose altitude, becoming condensation nuclei for supersaturated benzene and other components of Titan's atmosphere. As the particles grow and react, eventually they might become tholins, large hydrocarbon-nitrile particles thought to produce Titan's orange haze.



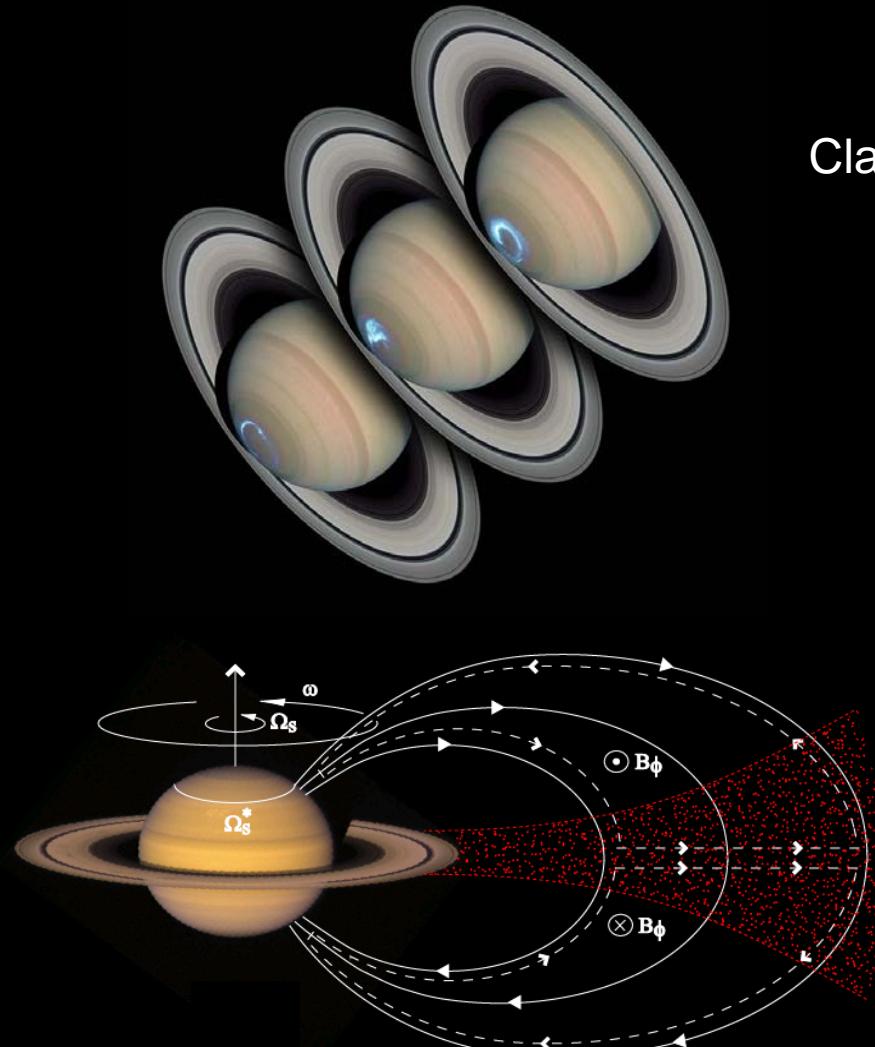
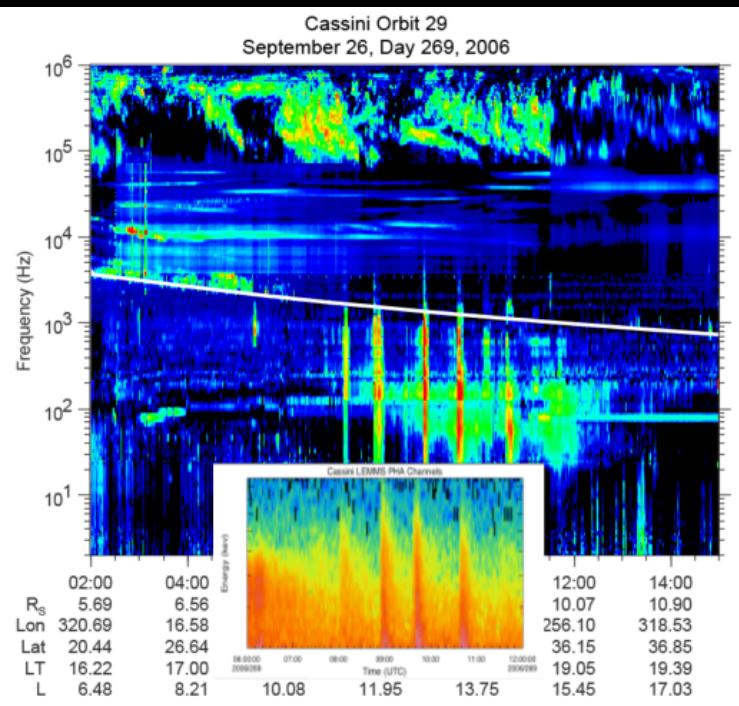
# (D) Completion of Primary MAPS Science Objectives (D)

- **Saturn:**
  - Investigate the upper atmosphere and ionosphere.
  - Investigate sources of lightning and Saturn electrostatic discharge (SED).
- **Status:**
  - Some major discoveries:
    - (D.1) A 2-cell convection pattern develops in Saturn's high latitude ionosphere, controlled by mass loading from Enceladus' geysers.
    - (D.2) Variable mass loading rates from Enceladus and perhaps seasonal ionospheric conductivity variations change the rotation rate of the ionosphere.
    - (D.3) HST-Cassini campaign during Cassini's approach demonstrated the strong influence of solar wind pressure on auroral UV and radio emissions.
    - (D.4) The detection of Saturn electrostatic discharges (SEDs) from lightning is tightly coupled with observations of convective storms
    - (D.5) The propagation and polarization of SEDs provide information on Saturn's ionosphere (e.g. density).

# D.3 Auroral Electrons

Field-aligned currents associated with precipitating particle fluxes are responsible for the aurora.

The MAPS instruments (CAPS, MAG, MIMI, RPWS) did find these precipitating beams and associated effects.



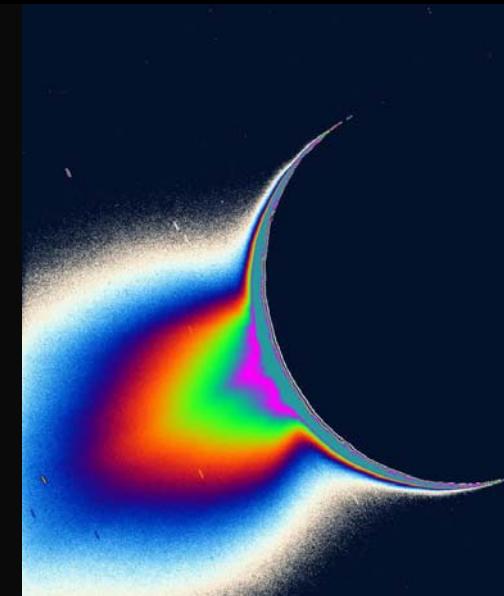
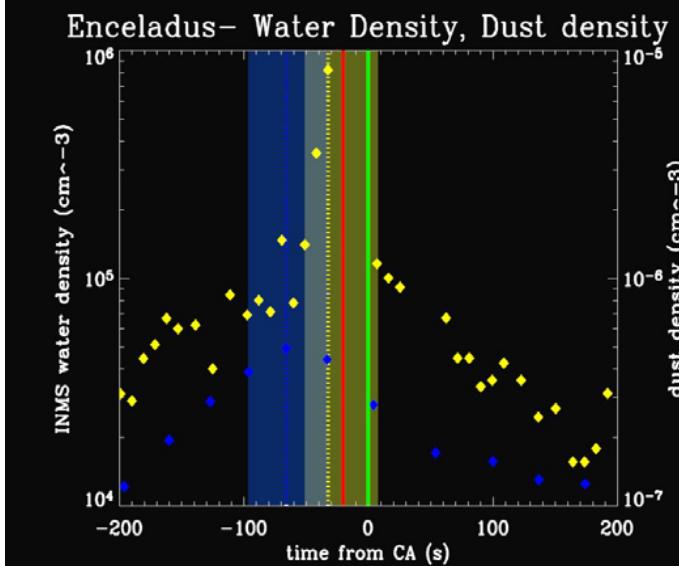
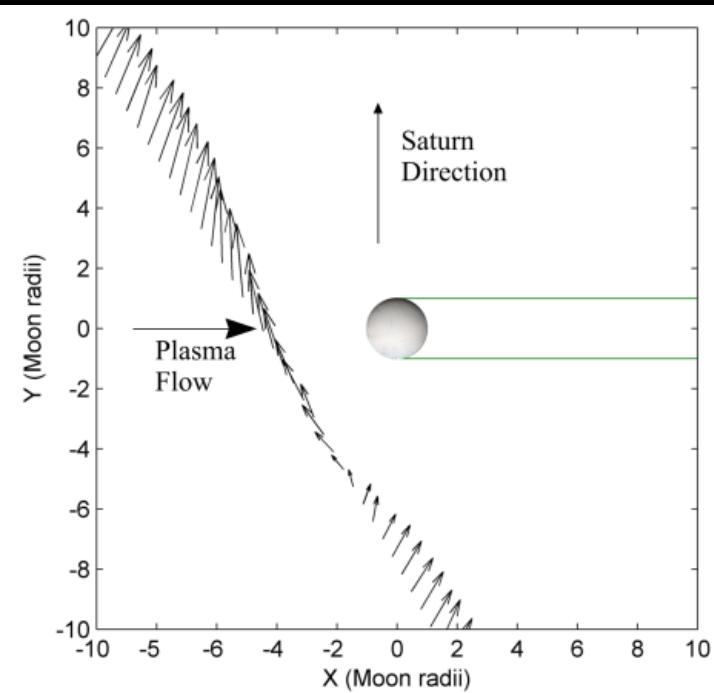
Clarke et al.

## RPWS & MIMI

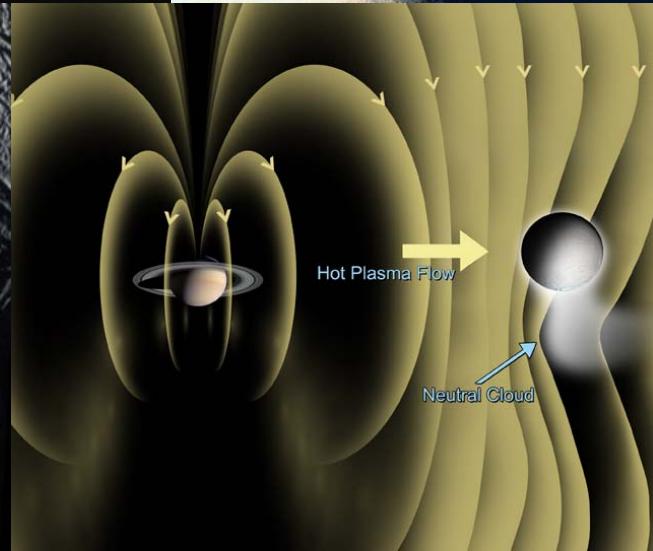
# (E) Completion of Primary MAPS Science Objectives (E)

- Major icy satellites:
  - Determine the gravitational & magnetic fields, and their dynamic properties.
  - Study satellite atmospheres and ionospheres, any extended gas clouds; their interactions with the magnetosphere and rings.
- Status:
  - Some major discoveries:
    - (E.1) Enceladus is the ‘engine’ of the Saturnian magnetosphere
    - (E.2) Interesting, unique charged particle interaction with Rhea may be due to cloud of dust particles trapped within the Hill sphere.

# E.1 & D.2) Enceladus is the Engine of Saturn's Magnetosphere



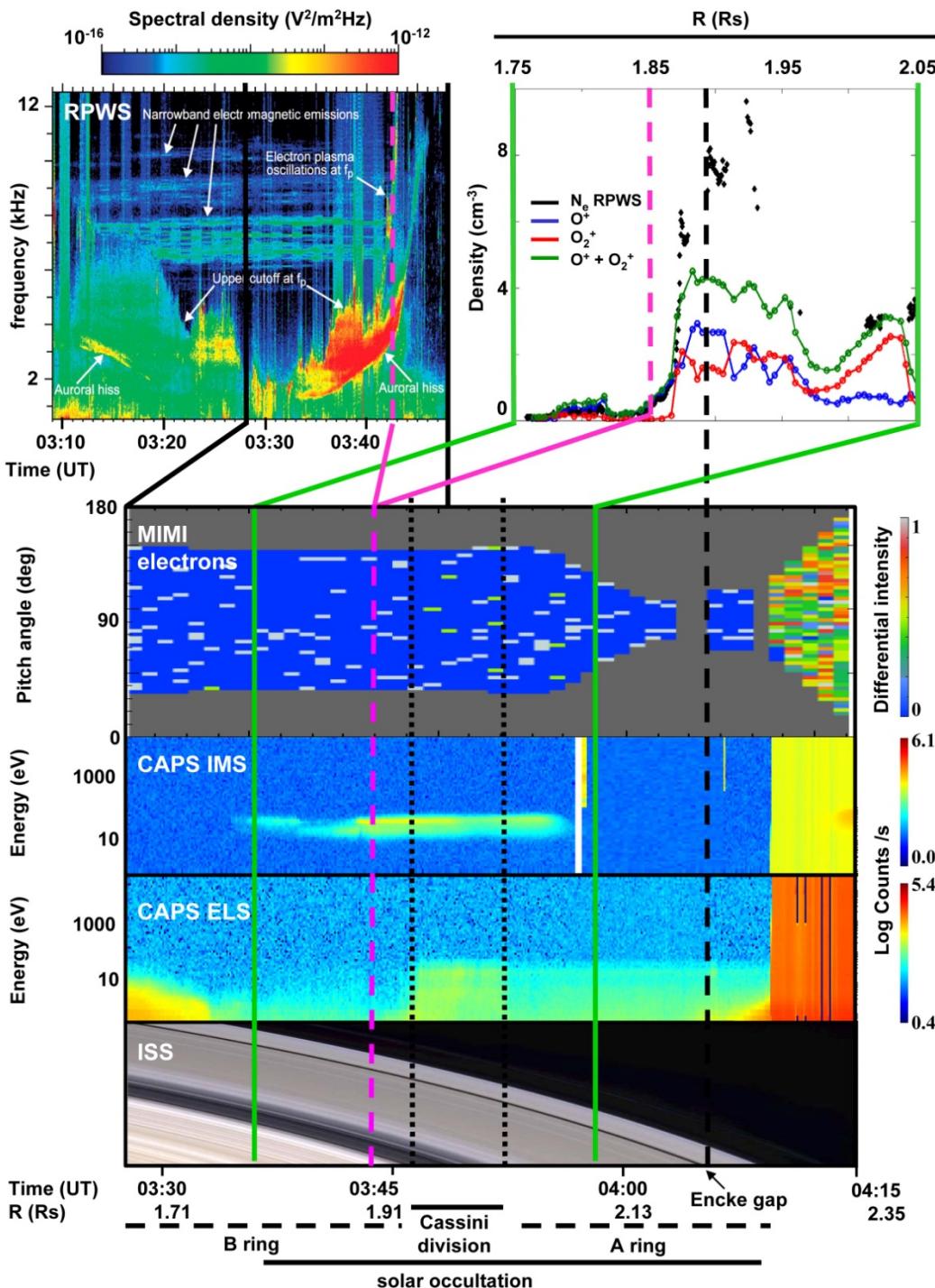
During the E1 flyby the magnetometer observed magnetic field draping that is characteristic of magnetospheric plasma interaction with a neutral gas cloud. This led to the discovery of the plumes of Enceladus.



# (F) Completion of Primary MAPS Science Objectives (F).

- **Saturnian rings:**
  - Investigate ring-magnetosphere, ring-ionosphere, and ring-atmosphere interactions.
  - Investigate electromagnetic processes responsible for ring structure.
  - Determine the dust and meteoroid distribution.
- **Status:**
  - Some major discoveries:
    - (F.1) Discovery of ring-ionospheres
    - (F.2) Identification of particle fluxes, mass distributions and composition of grains in the E ring
    - (F.3) Interactions between rings and magnetosphere.

# F..1) Ring ionosphere



The main rings create a cavity inside Saturn's radiation belts in which production of neutrals and plasma are due to UV and low-energy particle irradiation, and to micrometeorite bombardment of the ring particles.

This production is important enough to maintain an exosphere and a tenuous ionosphere, which have been probed by the MAPS instruments and display specific chemical and dynamical features.

# More to Do ...

## – Magnetosphere Objectives:

- Cassini's orbit did not reach the magnetotail reconnection region and the neutral sheet. These will be covered during Equinox and Cassini Solstice Mission.
- Cassini's orbit allowed *in-situ* observation of the auroral zones only late in the prime mission. These will be covered further during the Equinox Mission.
- Temporal variations are observed only for 4 years. More complete coverage will be accomplished during the Equinox and Solstice Missions.
- To accurately determine the planetary magnetic field of Saturn, complete spatial coverage at a wide range of latitudes and longitudes and close distances is required.

## – Saturn - both SKR & SED Objectives:

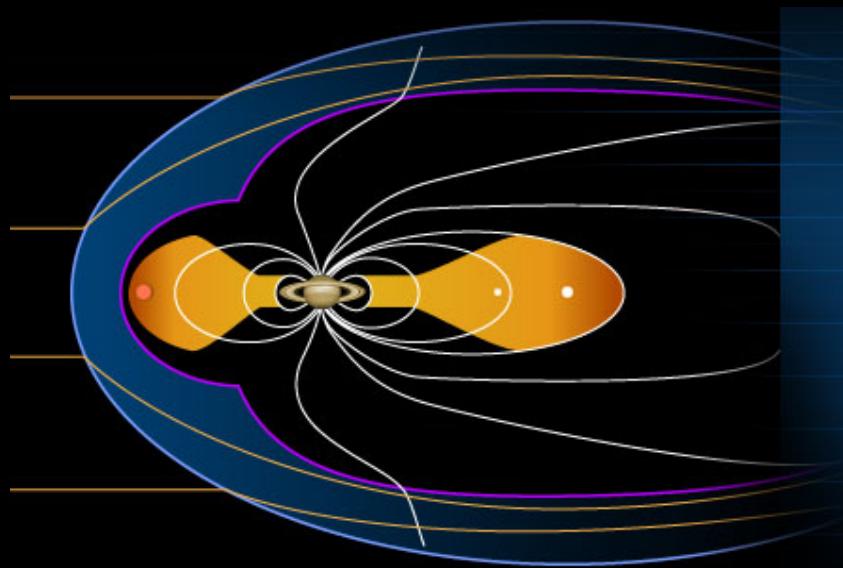
- Cassini's orbit allowed only very limited observations in the  $3-5 R_S$  region
- The 4 year prime mission did not allow enough time to distinguish between competing theories of why the SKR period varies and why it does not reflect the internal period of the planet.
- Internal period is still not determined.

# More to Do ...

- Icy Satellite Objectives
  - We need additional close fly-bys (both upstream and downstream) with unexplored icy satellites (Mimas, Dione, Thetys, Rhea).
  - We need to explore the details of Enceladus' plume and its interaction with the magnetosphere.
- Titan Objectives
  - There was only one distant wake crossing, T9, that provided an excellent, but confusing data set of the distant interaction.
  - Only 2 dusk sector flybys were in the prime mission. In this geometry the magnetospheric flow is into the sunlit hemisphere of Titan, likely to produce strong ionospheric effects.
- MAPS Ring Objectives:
  - SOI demonstrated the unique and highly interesting nature of the region just above the main ring system. However, some instruments were not configured for optimum (or any) science observations during SOI because of the critical nature of SOI and the main engine burn, itself. Returning to this very interesting region would enable proper configuration of MIMI, CAPS, INMS, and RPWS to properly measure the ring ionosphere and would provide an additional very close periapsis for MAG to observe the internal field of Saturn.

# Basic Elements of the Magnetosphere

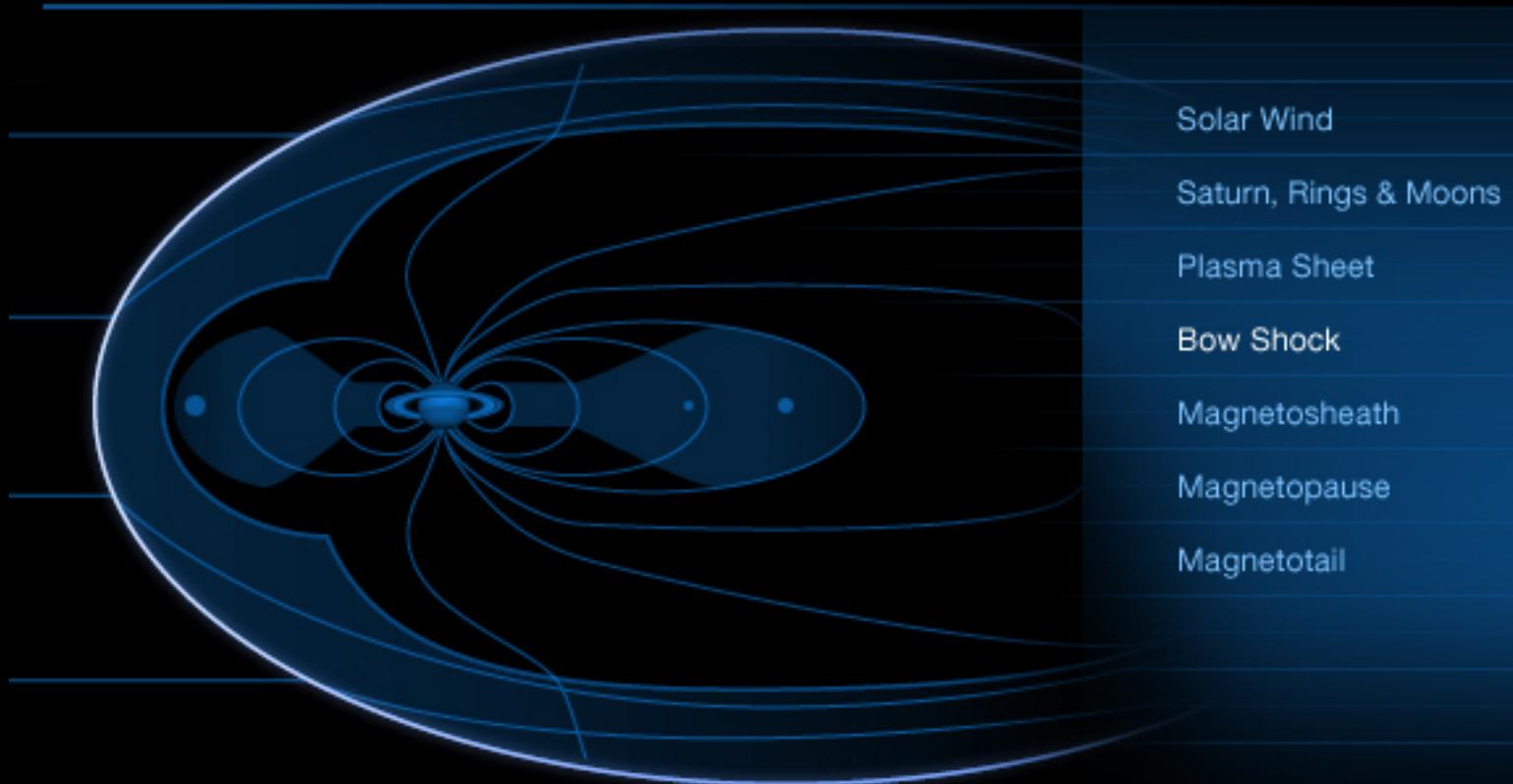
- Bow Shock
- Magnetosheath
- Magnetopause
- Moons & Rings
- Plasma Sheet/  
magneto-disc
- Neutral Cloud
- Magnetotail



All of these parts  
ARE IN MOTION!

# Bow Shock

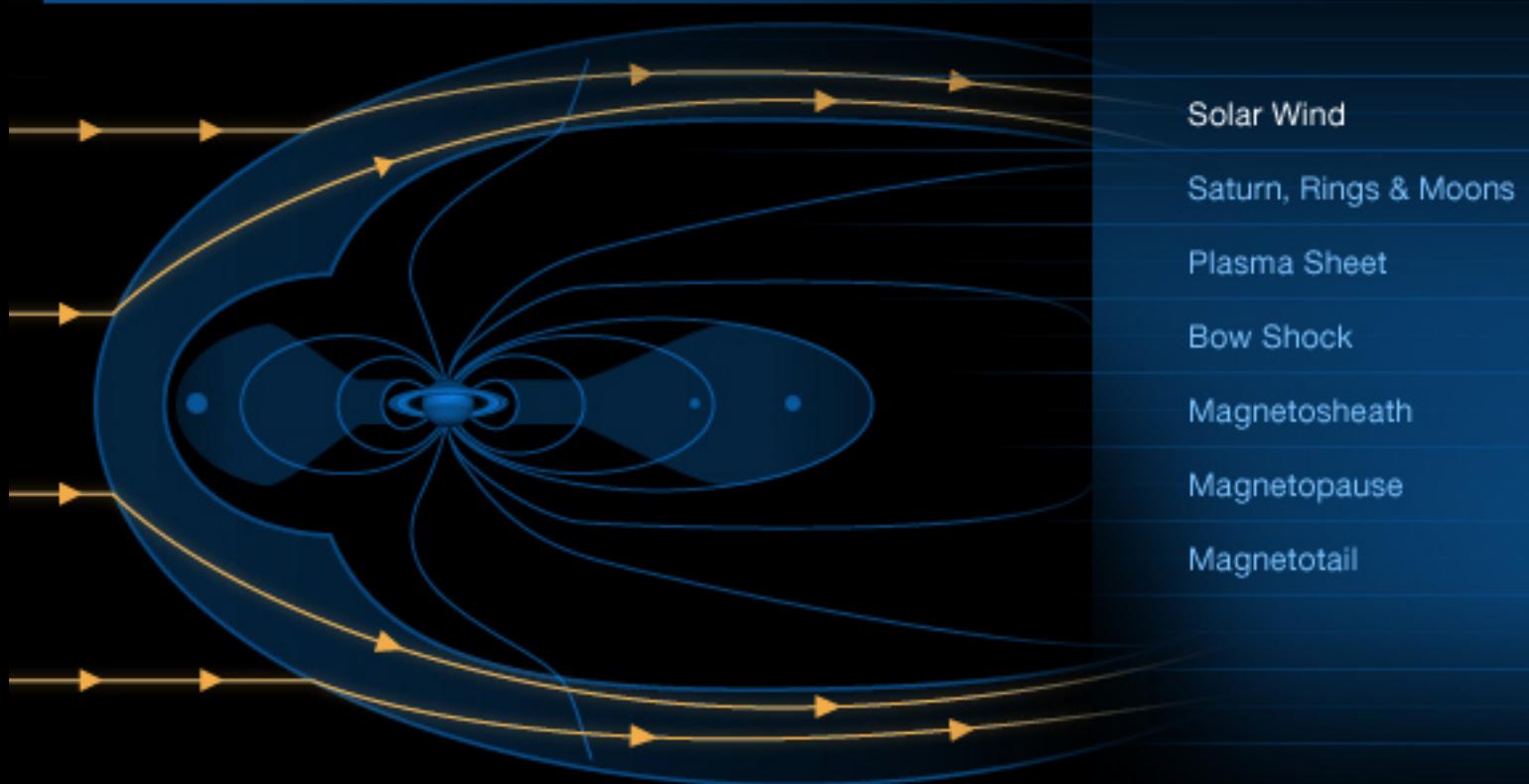
## Saturn's Magnetosphere



A supersonic shock wave that is formed as the solar wind interacts with the outermost layer of Saturn's magnetosphere.

# Solar Wind

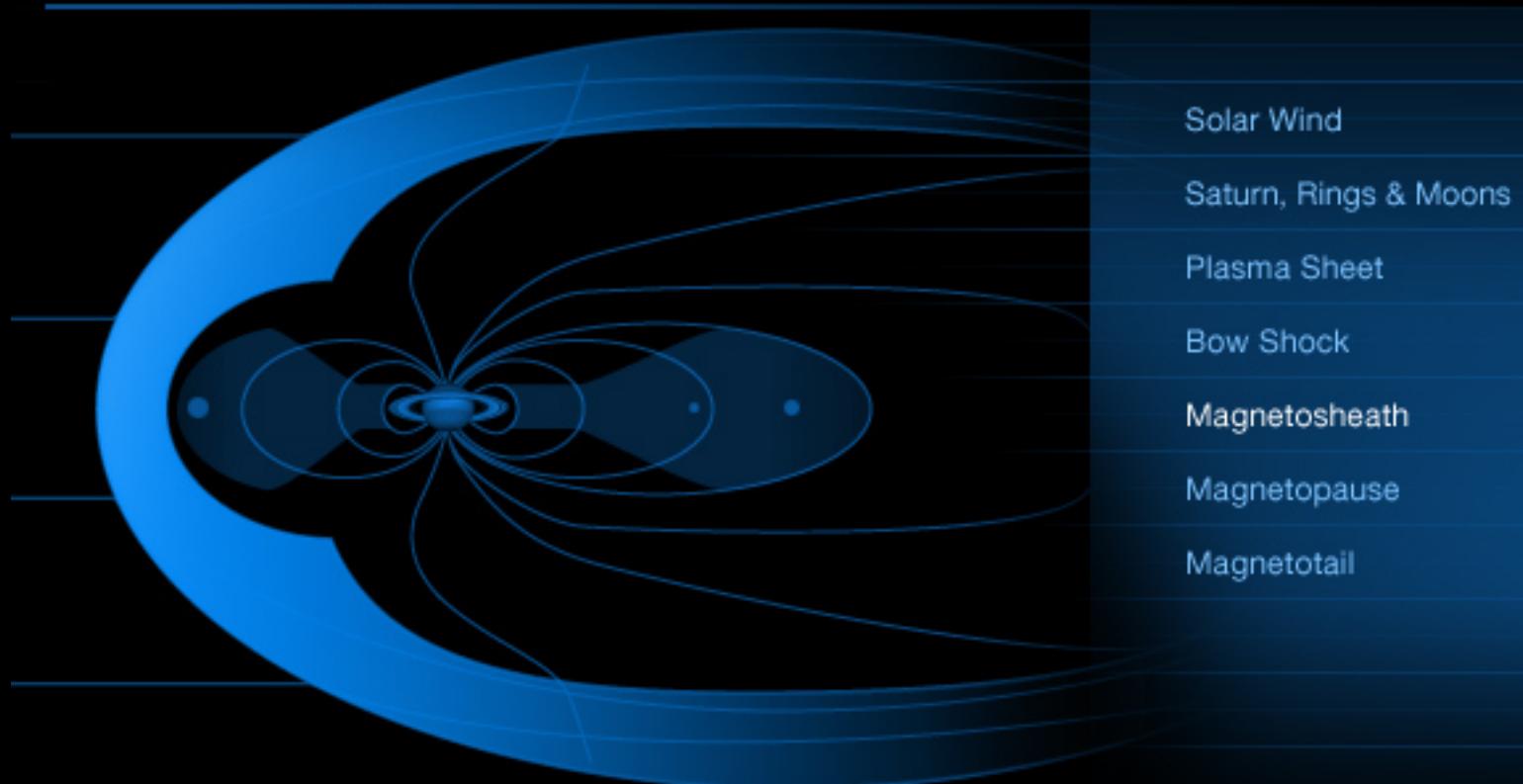
## Saturn's Magnetosphere



An outward flow of high-speed charged particles from the Sun's corona. The particles are mostly positively charged Hydrogen and Helium ions.

# Magnetosheath

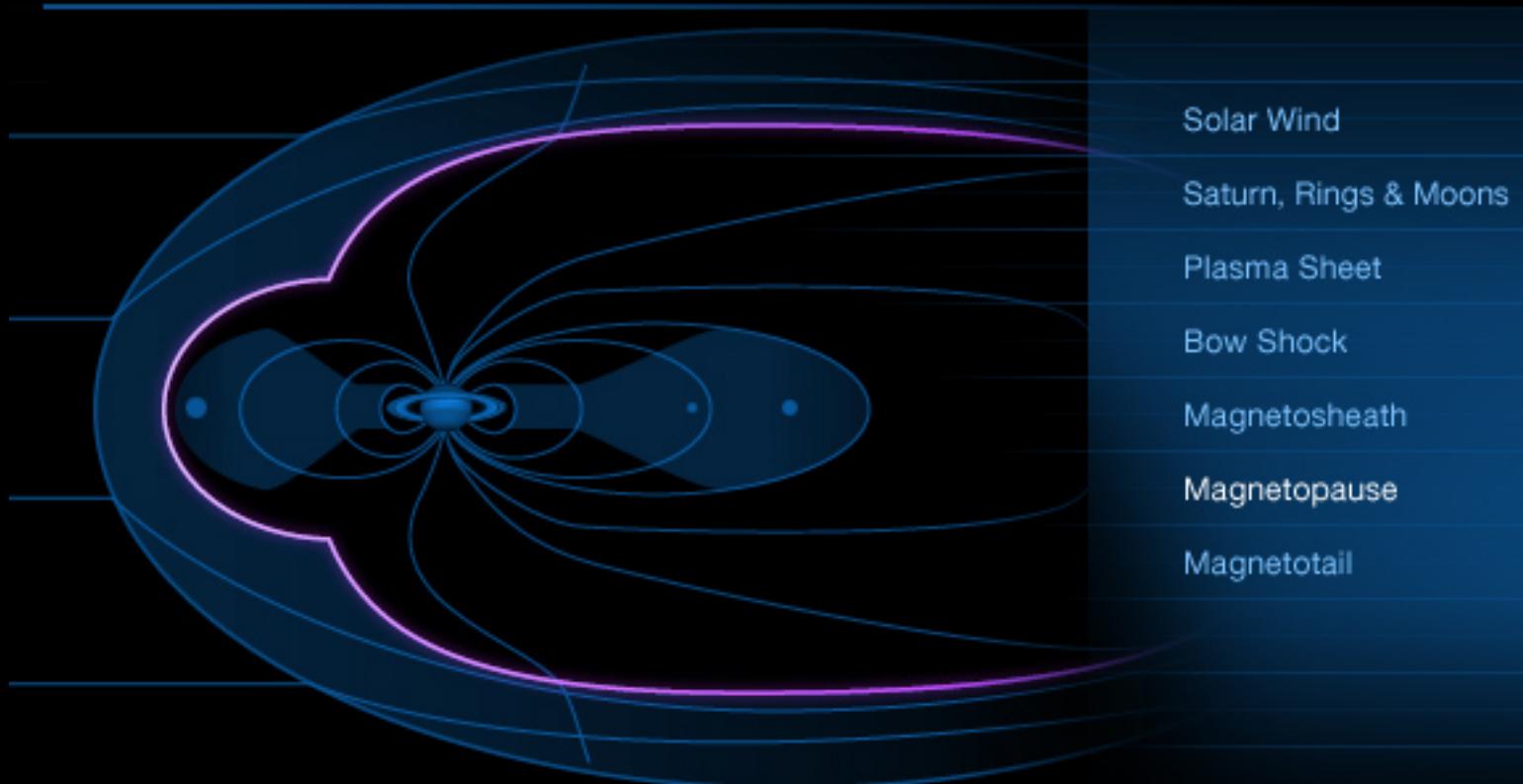
## Saturn's Magnetosphere



The very turbulent plasma region between the bow shock and the magnetopause.

# Magnetopause

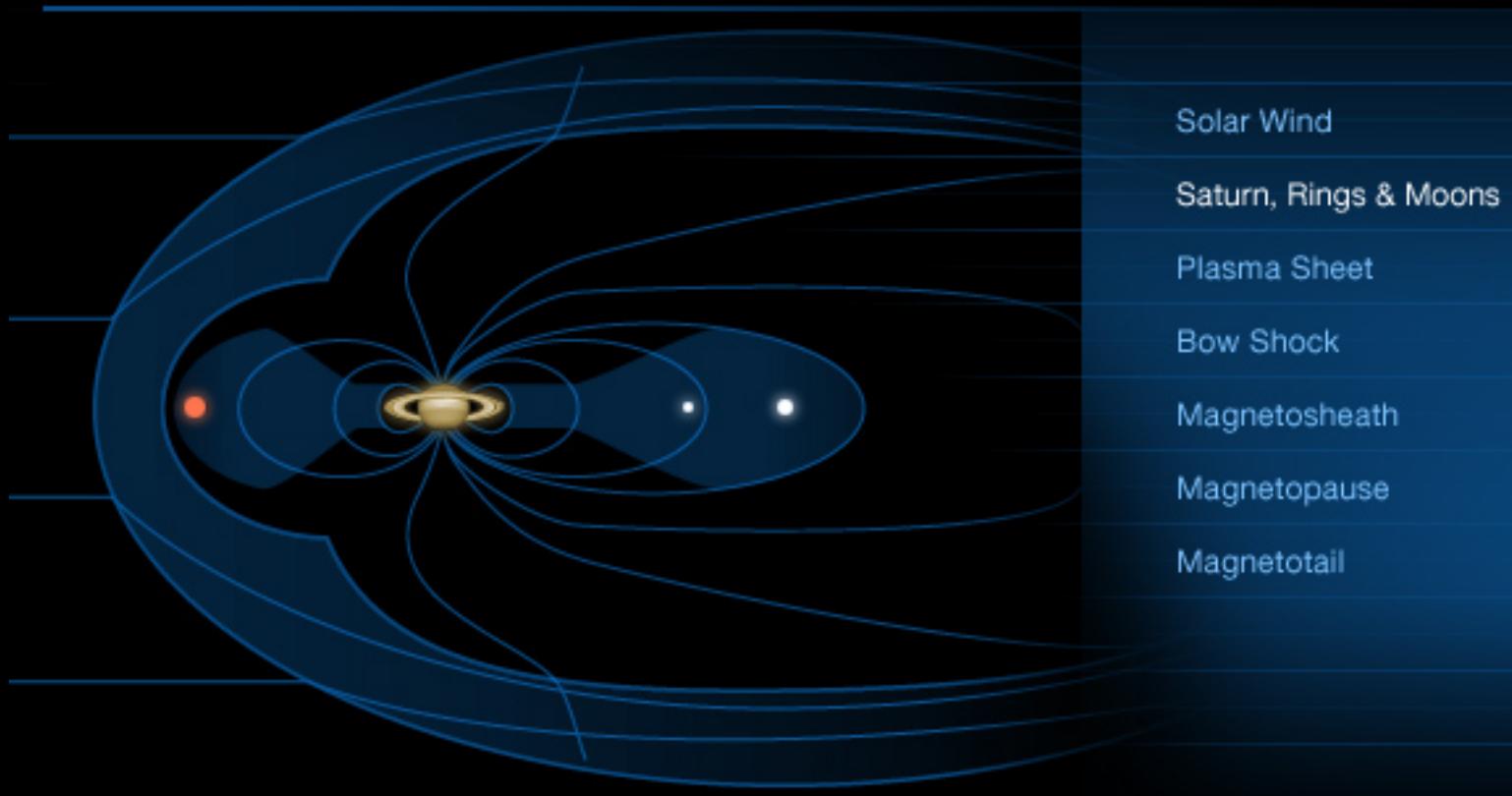
## Saturn's Magnetosphere



The outer boundary of the magnetosphere where the solar wind and magnetosphere interact.

# Rings & Moons

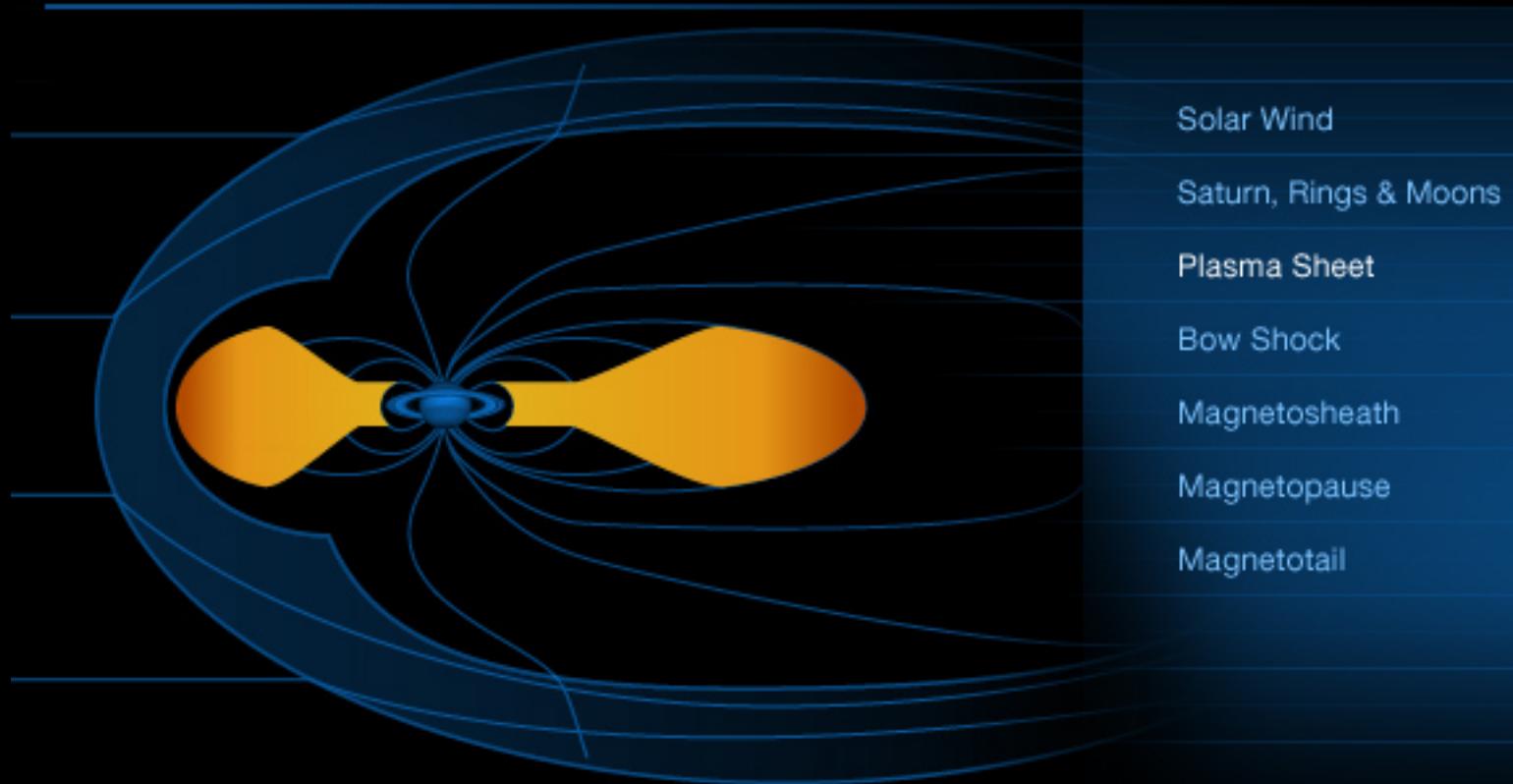
## Saturn's Magnetosphere



Saturn's metallic-rocky core creates a magnetosphere that forces the charged particles to stream around Saturn, its rings and most of the moons.

# Plasma Sheet, Magnetodisc,& Neutral Cloud

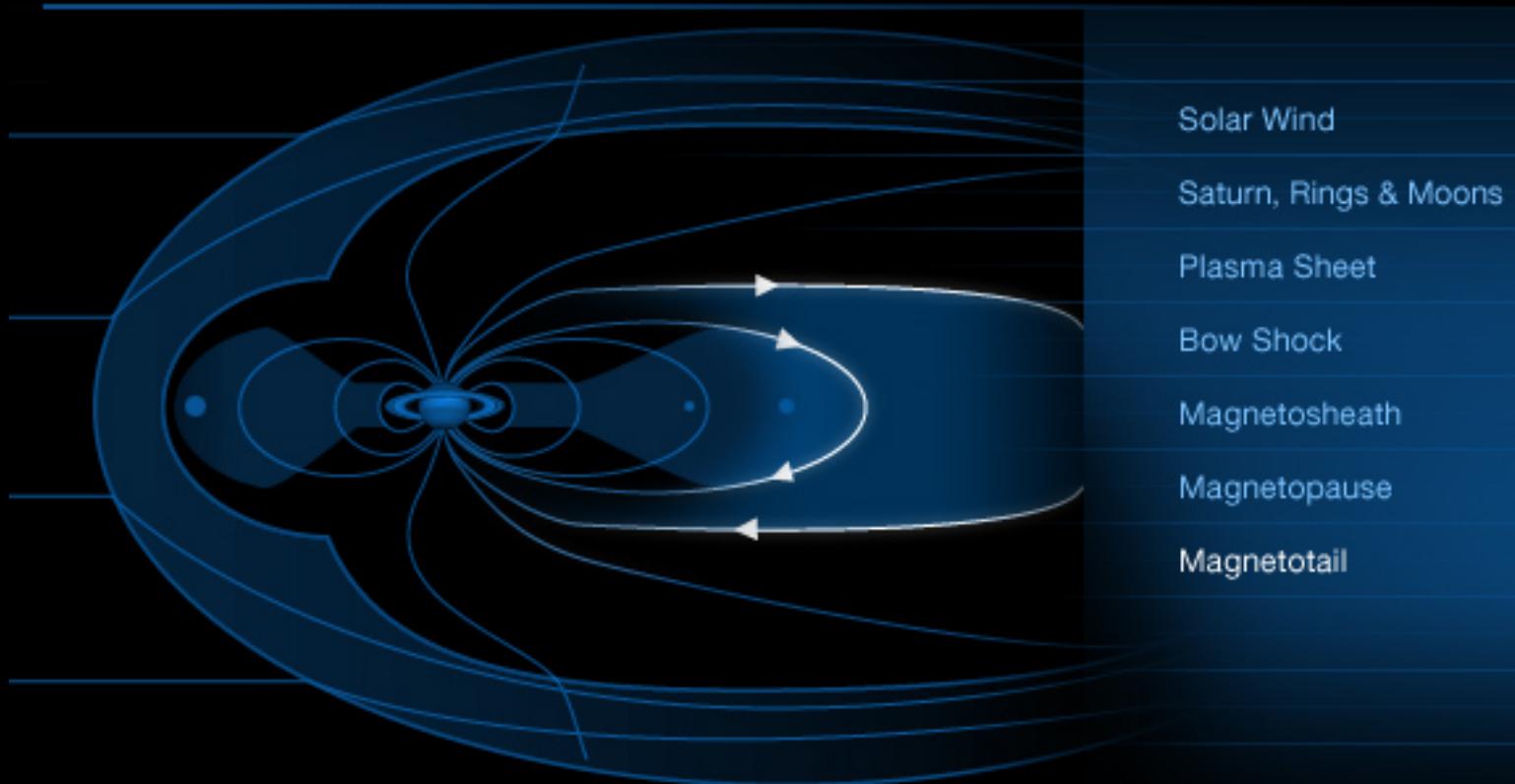
## Saturn's Magnetosphere



A resultant thin layer of high energy electron-rich particles that stream out of the interaction of solar wind and the magnetosphere.

# Magnetotail

## Saturn's Magnetosphere



The long, trailing limb of Saturn's magnetosphere on the side facing away from the sun composed of trapped ionized particles.

# MAPS-Focused Instruments

- CAPS
  - Ion Mass Spectrometer
  - Ion Beam Spectrometer
  - Electron Spectrometer
- MAG
- MIMI
  - LEMMS: Suprathermal particles
  - CHEMS: Ion charge-state
  - INCA: Ion and Neutral Camera
- RPWS
  - Wave Electric Field Sensors
  - Wave Magnetic Field Sensors
  - Langmuir Probe
  - 1 Hz – 16 MHz receivers, including waveform capabilities

# Multiple-Purpose Instruments

- INMS
  - Measures ion and neutral composition
    - in the upper atmosphere of Titan,
    - during ring plane crossings and
    - at icy satellites.
- CDA
  - Investigates dust as a source/sink of charged particles.
- RSS
  - Observes ion and neutral density profiles in the upper atmospheres of Saturn and Titan.
  - Measures the exospheres of icy satellites.
- ISS
  - Investigates lightning, aurora and airglow.
- UVIS
  - Observes the aurora and neutral tori.



Titan

# Titan Flybys in 4th year

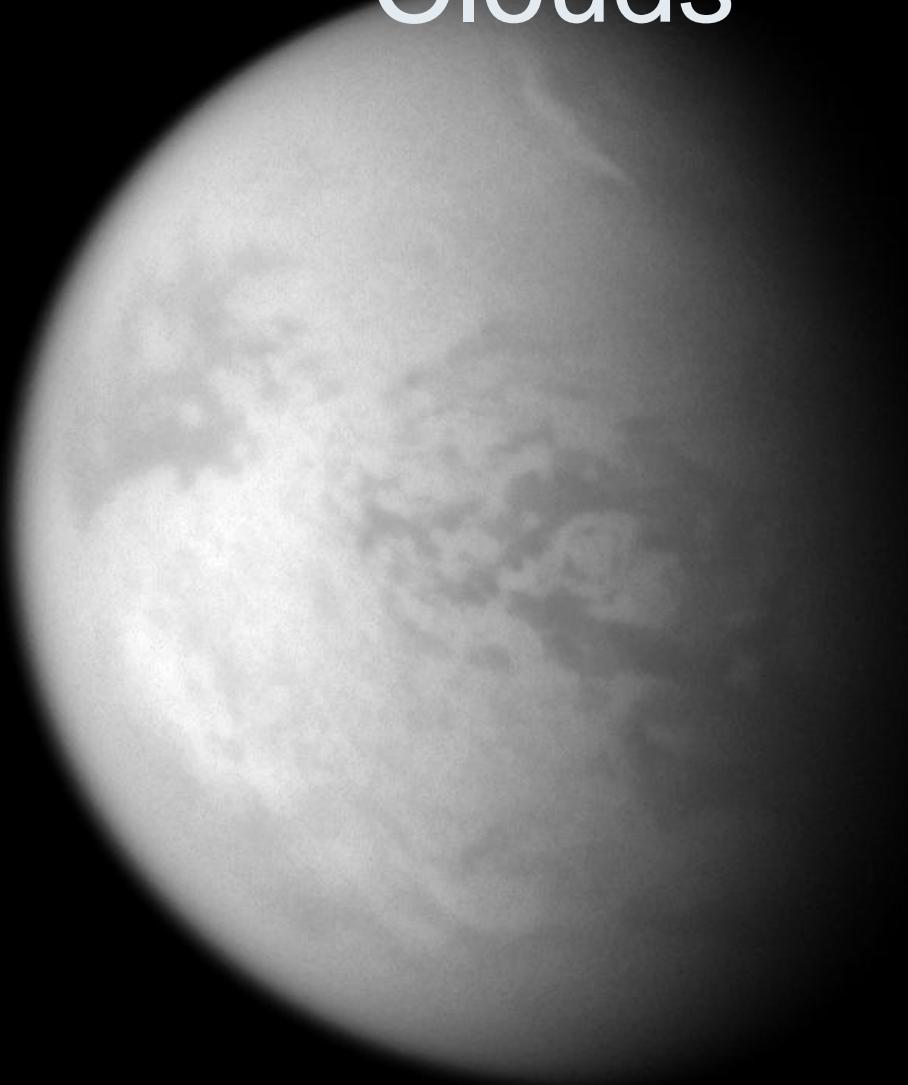
T34	19 Jul 2007	VIMS high-res mapping
T35	31 Aug 2007	VIMS stellar occultation, high-res mapping
T36	2 Oct 2007	INMS; RADAR SAR, HiSAR, altimetry
T37	19 Nov 2007	INMS; VIMS high-res mapping
T38	5 Dec 2007	VIMS high-res of Ontario Lacus
T39	20 Dec 2007	First RADAR SAR of South Pole
T40	5 Jan 2008	INMS; VIMS high-res of Huygens LS
T41	22 Feb 2008	RADAR SAR of Hotei Arcus, Huygens LS
T42	25 Mar 2008	INMS; VIMS high- to medium-res mapping
T43	12 May 2008	RADAR SAR of Xanadu, Tortola Facula
T44	28 May 2008	RADAR SAR of Xanadu, Tui Regio

# Titan Flybys

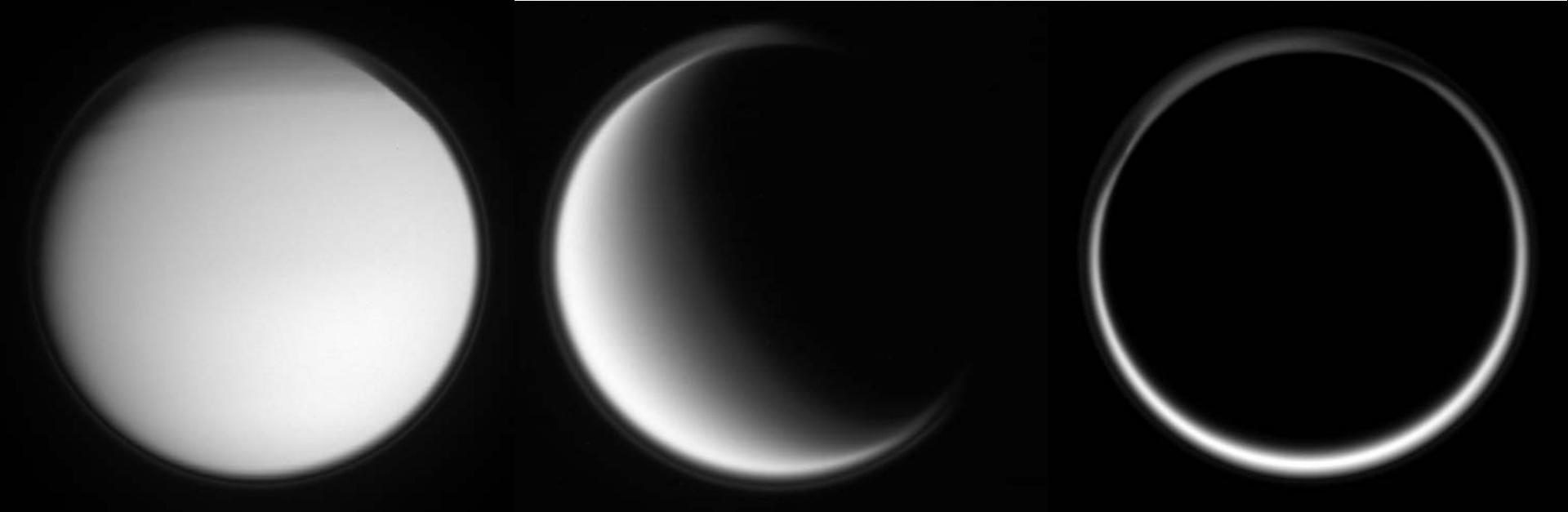
TIMEING	RANGE (Km)	Angular Diameter (degrees)	REFERENCE TRAJECTORY 060323																		
			299k ccn	200k ccn	149k ccn	81k ccn	81k ccn	148k ccn	200k ccn	299k ccn	Outbound from c/a (hours)	Inbound to c/a (hours)	Outbound from c/a (hours)	Inbound to c/a (hours)							
T9	REV 865	3-8-04	341000	-22	-20	-18	-16	-14	-12	-10	-8	-6	-4	-2							
TA	A	26-Oct-04	390T15:29:30	101a	111a	CRS	I	CIRS	VIMS	ISS	RADAR	VIMS	DSN Pass	181a	148k						
TB	B	13-Dec-04	348T11:39:13	141	111a	GRS Mod		GRS Earth	UVIS	ISS	UVIS	UVIS	DSN Pass	181a	148k						
TC	C	8-Jan-05	391T09:30:XX	088000										181a	148k						
T9	3	16-Feb-05	049T06:54:21	101a	1079	GRS	I	CIRS	ISS	DSN Pass	RADAR	UVIS	ISS	CIRS	DSN Pass	181a	148k				
T4	5	9-Mar-05	091T18:53:13	348000		CIRS	ISS	RADAR	I	CIRS	UVIS	CIRS		DSN Pass		181a	148k				
T5	6	510	16-Apr-05	106T12:11:46	261	1642	GRS	I	UVIS	ISS	ISS	M		IMMPS			181a	148k			
T6	19	515	23-Aug-05	234T06:53:35	348000						GRS						181a	148k			
T7	14	514	7-Sep-05	250T07:59:26	211	1079	I	VIMS	ISS	SU	RADAR		CIRS		M DSN Pass		181a	148k			
T8	17	515	28-Oct-05	301T03:58:16	101a	1083	I	VIMS	I	RADAR			CIRS		M DSN Pass 10hr		181a	148k			
T9	19	511	26-Dec-05	360T16:54:11	101a	1081	GRS	VIMS	I	UVIS			DSN Pass				181a	148k			
T10	20	511	15-Jan-06	019T11:41:20	260	1640	GRS	I	CIRS	ISS	ISS	C	V	UVIS	BS		181a	148k			
T11	21	516	27-Feb-06	056T08:25:18	1612		VIMS	ISS	UVIS	RSS	RSS	UVIS	CIRS FP1		DSN Pass		181a	148k			
T12	22	516	19-Mar-06	078T00:39:57	291.5	1949	VIMS	CIRS FP1	ISS	SS Global	V	RSS	RADAR	VIMS Cloud Map	CIRS	M DSN Pass		181a	148k		
T13	23	520	23-Apr-06	120T12:33:31	101a	1088		CIRS FP1	FP2	I	CIRS	ISS	V	RADAR	UVIS	CIRS FP1		181a	148k		
T14	24	520	26-May-06	140T12:38:12	241	1079	CIRS FP1	FP2	UVIS	UVIS	FP	RADAR		CIRS		M DSN Pass 11hr		181a	148k		
T15	25	521	2-Ju-06	183T09:12:16	100000		VIMS	CIRS FP1	ISS	UVIS	CIRS FP1	UVIS	UVIS	UVIS	CIRS FP1	UVIS		181a	148k		
T16	26	522	22-Ju-06	203T09:25:15	310	948	VIMS	CIRS	VIMS	RADAR	I	CIRS		VIMS		DSN Pass		181a	148k		
T17	28	525	7-Sep-06	250T20:12:04	405	1068	I	CIRS	I	VIMS	CIRS	UVIS	UVIS	VIMS	G DSN Pass			181a	148k		
T18	29	524	25-Sep-06	266T16:58:41	333	946	GRS	I	CIRS	I	UVIS	CIRS	UVIS	VIMS	G DSN Pass			181a	148k		
T19	30	524	9-Oct-06	280T17:23:24	210	1068	GRS	I	CIRS		RADAR	CIRS	I	CIRS		DSN Pass		181a	148k		
T20	31	525	25-Oct-06	286T15:58:57	231	1068	GRS Option		VIMS Cloud Map		RADAR	V	ISS	CIRS	UVIS	M DSN Pass	G DSN Pass		181a	148k	
T21	36	526	12-Dec-06	346T11:41:31	213	1068		GRS	I	CIRS	UVIS	I	SU	RADAR	ISS	CIRS		DSN Pass			
T22	36	526	18-Dec-06	362T10:58:12	101a	1088	GRS	FP1	RSS	CIRS	RSS	ISS	ISS	CIRS	RSS	CIRS		M DSN Pass			
T23	37	527	13-Jan-07	013T08:34:02	863	1068	GRS	I	CIRS	I	RADAR		ISS	GRS	ISS	V	GRS	BS	G DSN Pass		
T24	38	527	29-Jan-07	029T07:56:55	260	1068	DHS	CIRS FP1	UVIS	I	CIRS	VIMS	ISS		CIRS			G DSN Pass			
T25	38	526	22-Feb-07	055T03:10:18	230	1068		CIRS FP1	I	CIRS		RADAR		ISS	CIRS	ISS	V	CIRS	G DSN Pass 9hr		
T26	49	526	10-Mar-07	060T01:47:22	411	969		CIRS FP1	I	CIRS	UVIS	CIRS	ISS	C	UVIS	CIRS	UVIS	M DSN Pass			
T27	41	525	25-Mar-07	185T02:21:52	873	1018	CIRS FP1	I	CIRS	I	UVIS	RSS	CIRS	UVIS	I	CIRS	UVIS	VIMS	G DSN Pass 9hr		
T28	42	529	40-Apr-07	160T22:58:56	312	969	CIRS FP1	VIMS	UVIS		RADAR	V	ISS	C	ISS	SU	CIRS		G DSN Pass 9hr		
T29	43	525	29-Apr-07	116T21:32:52	340	969	CIRS FP1	I	VIMS	CIRS	RADAR	VIMS	UVIS	CIRS	ISS	UVIS		M DSN Pass			
T30	44	538	18-May-07	132T26:08:14	340	968	CIRS FP1	VIMS	UVIS		RADAR		ISS	CIRS	ISS	V	CIRS		M DSN Pass		
T31	45	538	28-May-07	148T16:51:27	2998		CIRS FP1	I	UVIS	RSS	Y	ISS	VIMS	ISS	CIRS		M DSN Pass				
T32	46	531	13-Jun-07	174T17:47:57	580	975	CIRS FP1	I	VIMS	CIRS	UVIS	C	V	CIRS	ISS	V	CIRS		G DSN Pass		
T33	47	531	29-Jun-07	180T18:59:44	1048		CIRS FP1	I	RSS	UVIS	RSS	V	ISS	C	RSS	CIRS	VIMS	M - DSN	G DSN Pass 10hr		
T34	48	532	19-Jul-07	200T09:39:55	281	1039	CIRS	I	CIRS	UVIS	UVIS	I	ISS	VIMS	ISS	C	ISS	CIRS		G DSN Pass	
T35	49	533	21-Aug-07	243T06:34:25	3300		CIRS	I	CIRS	UVIS	VIMS	ISS	C	ISS	SU		CIRS		M DSN Pass 12hr		
T36	50	534	2-Oct-07	275T04:49:55	3401	979		CIRS	I	CIRS		RADAR		VIMS	CIRS	ISS	V	CIRS		M DSN Pass 16hr	
T37	52	535	19-Nov-07	325T00:52:55	580	1069	VIMS		CIRS		VIMS	ISS	C	ISS	CIRS			CIRS		M DSN Pass 16hr	
T38	53	535	5-Dec-07	330T00:07:17	3400		CIRS	I	VIMS	CIRS	I	V	ISS	C	CIRS	V	CIRS		M DSN Pass 16hr		
T39	54	534	20-Dec-07	354T22:56:45	340	979	VIMS	CIRS	RADAR		RADAR	CIRS	ISS	V	JRSS	VIMS		CIRS		M DSN 9hr	
T40	55	536	5-Jan-08	065T21:26:24	101a	1018	CIRS	I	UVIS	C	VIMS	ISS	C	VIMS	ISS		CIRS		M DSN 9hr		
T41	56	531	22-Feb-08	053T17:11:36	880	1069	CIRS	I	VIMS		RADAR		ISS	C	VIMS	ISS	CIRS		M DSN 9hr		
T42	52	535	25-Mar-08	065T14:36:12	580	1069	VIMS		CIRS		VIMS	ISS	C	VIMS	ISS		VIMS		M DSN 9hr		
T43	67	541	12-May-08	133T10:09:55	340	1069	C	I	VIMS		RADAR		CIRS	I	DSN		MTO - SH				
T44	63	540	28-May-08	148T06:33:21	200	1068	CIRS	I	CIRS	VIMS	UVIS	I	RADAR	ISS	CIRS	ISS	VIMS	C	VIMS		

Please direct questions or comments regarding this Summary to Douglas Equity (64-5141).

# Clouds

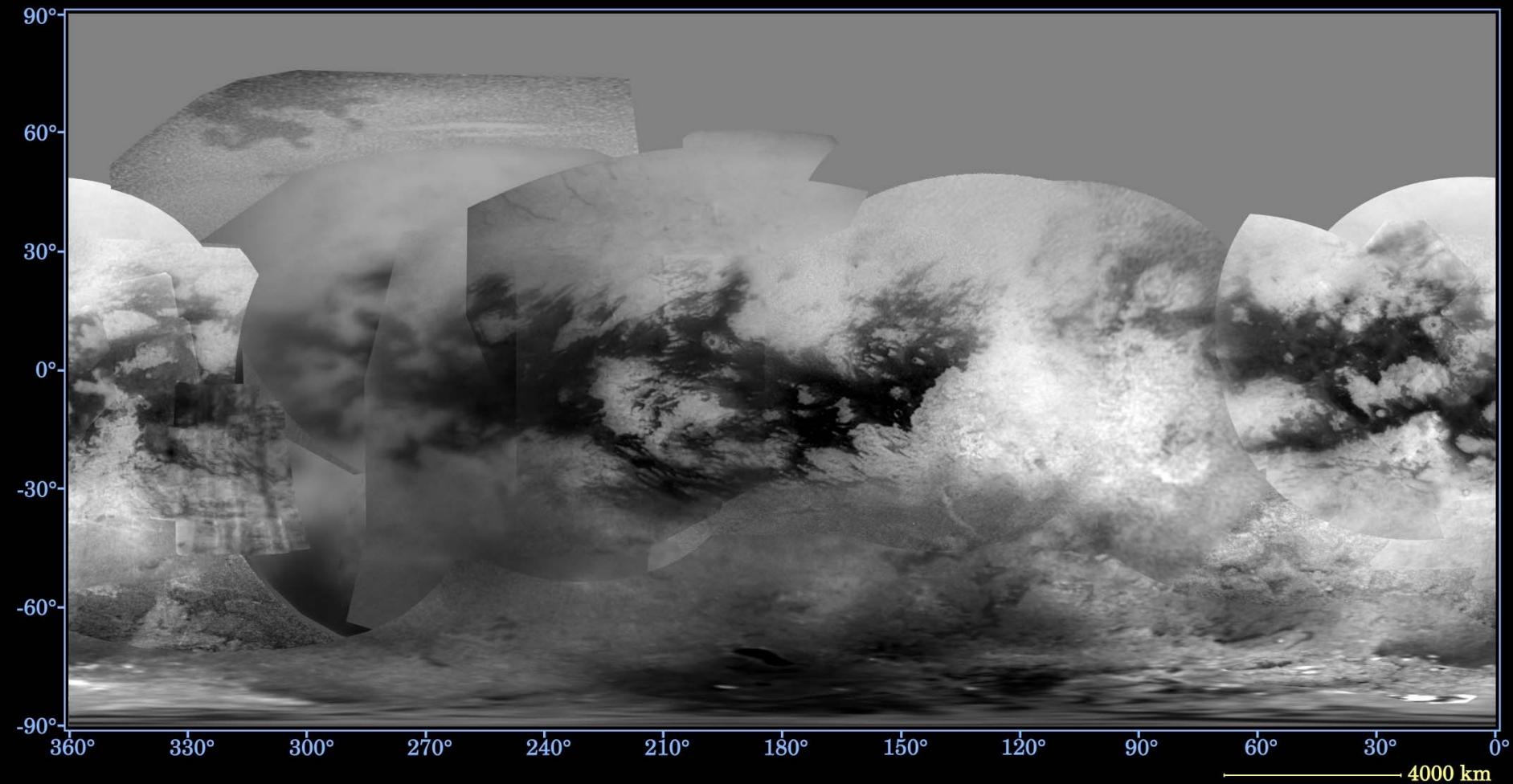


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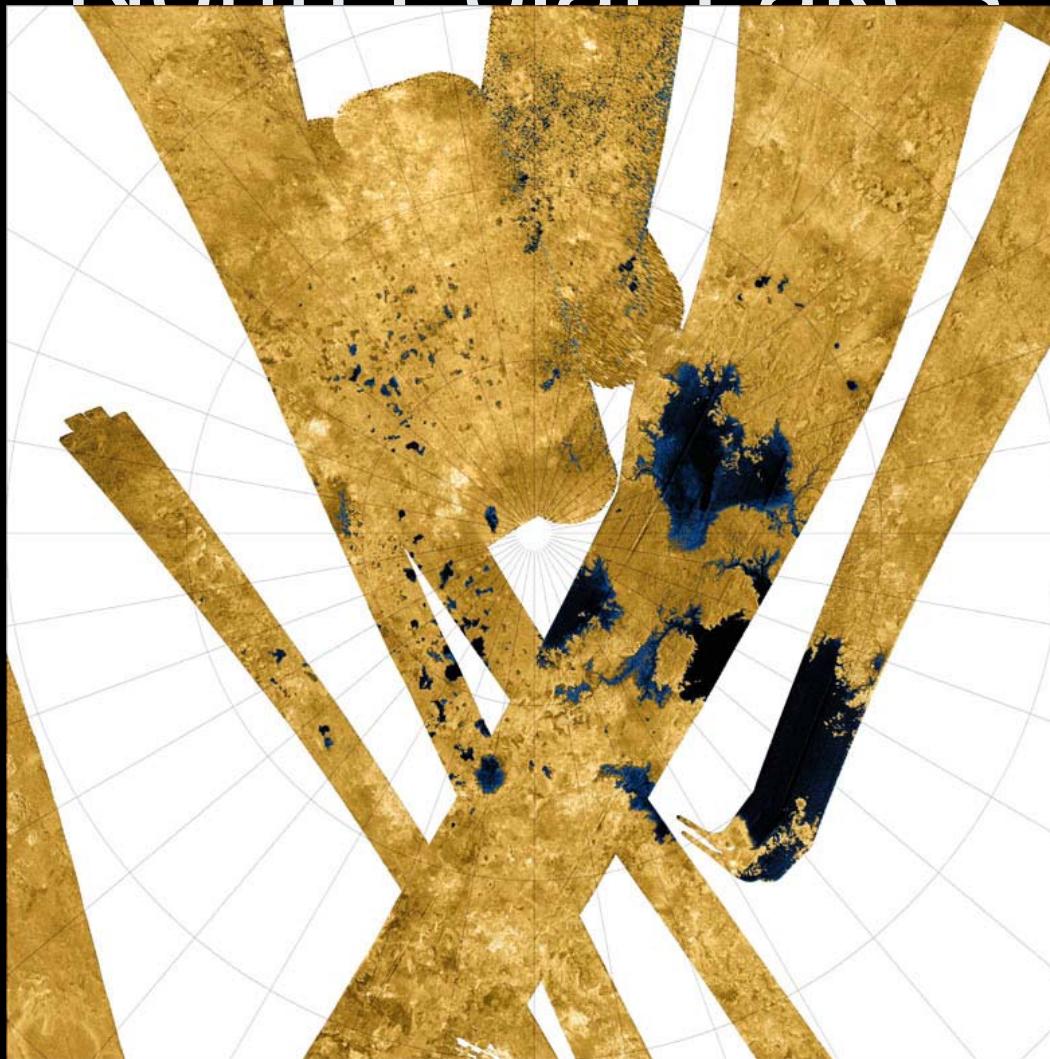


# Titan Surface Map (Oct. 2007)

Map of Saturn's Moon Titan - October 2007



# North Polar Lakes

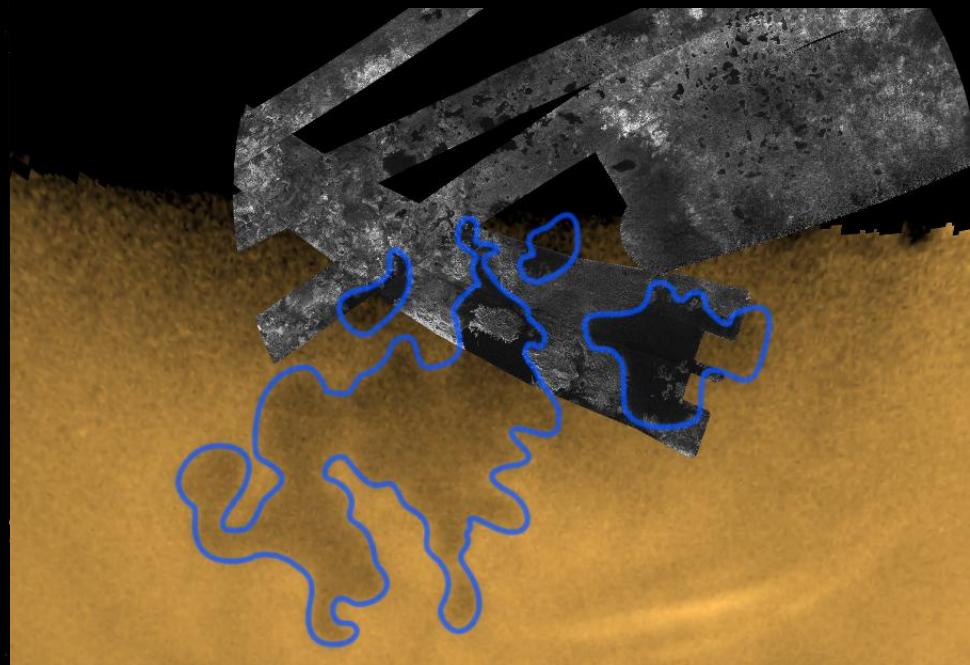
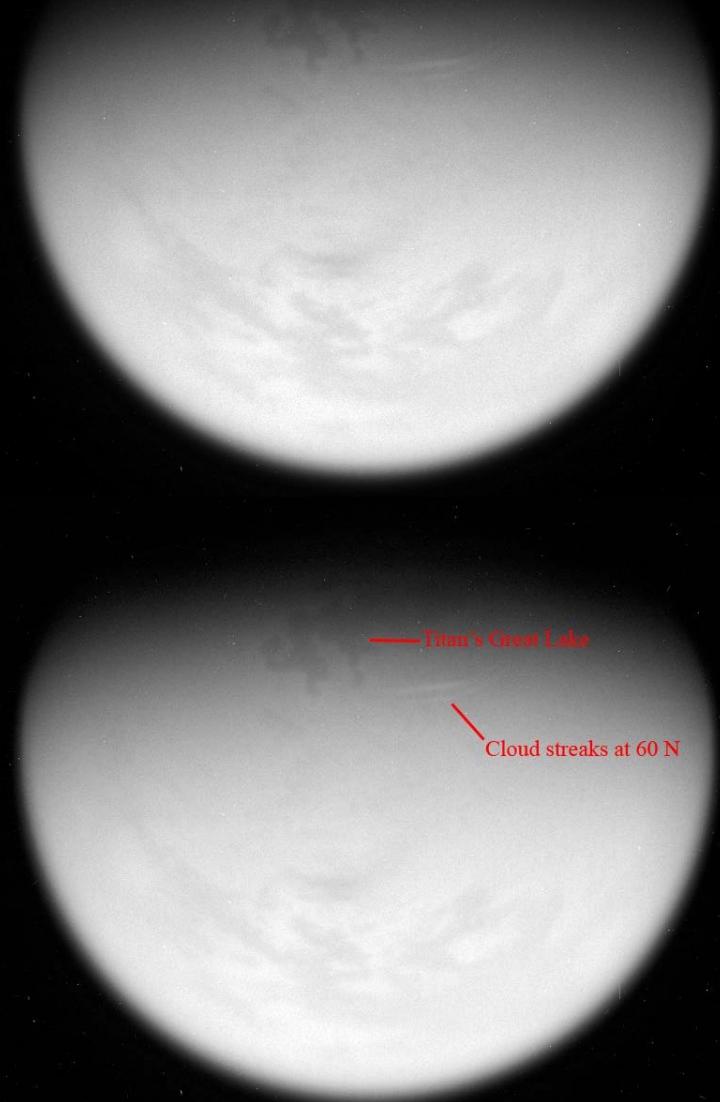


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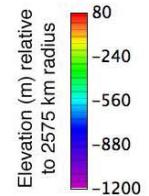
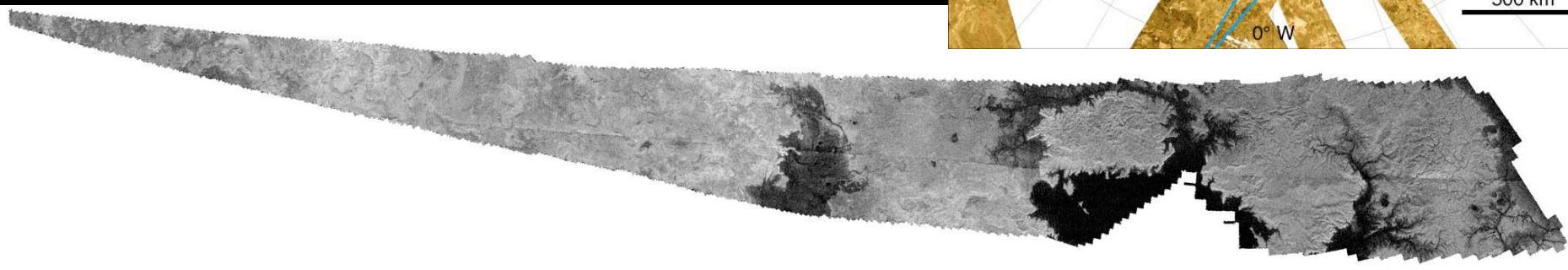
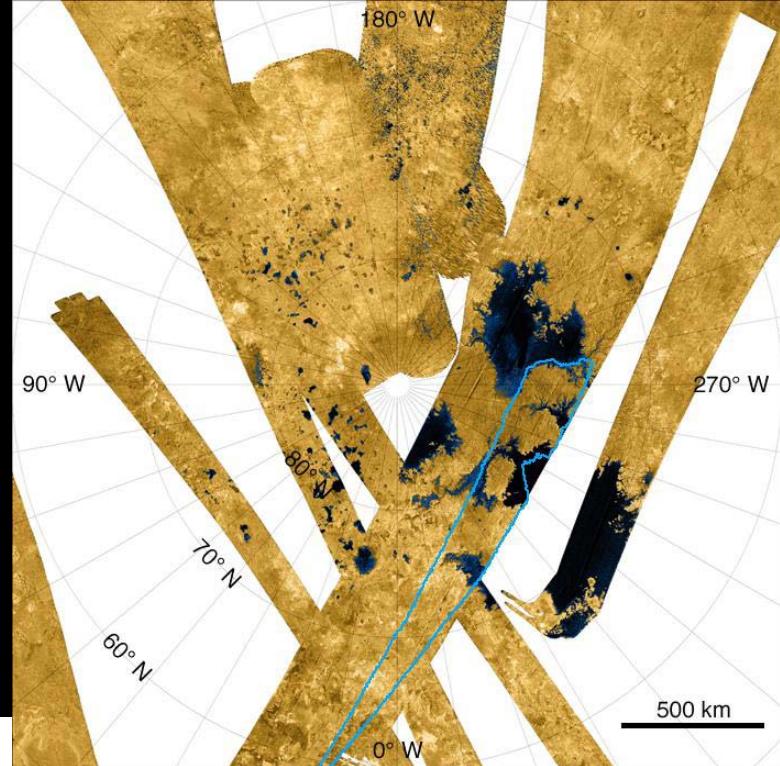
-cia- July, 2008

45

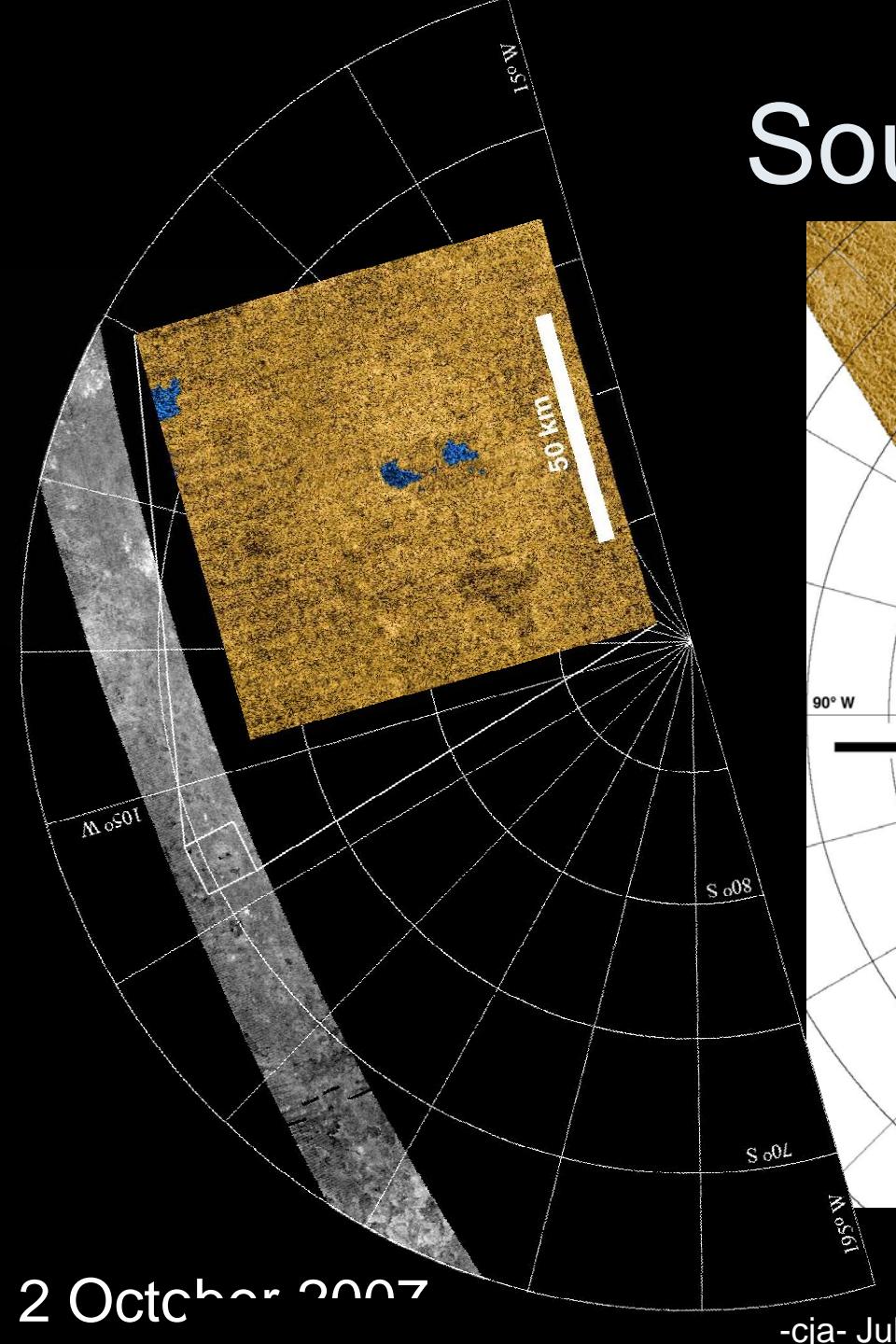
# North Polar Lakes



# Topography

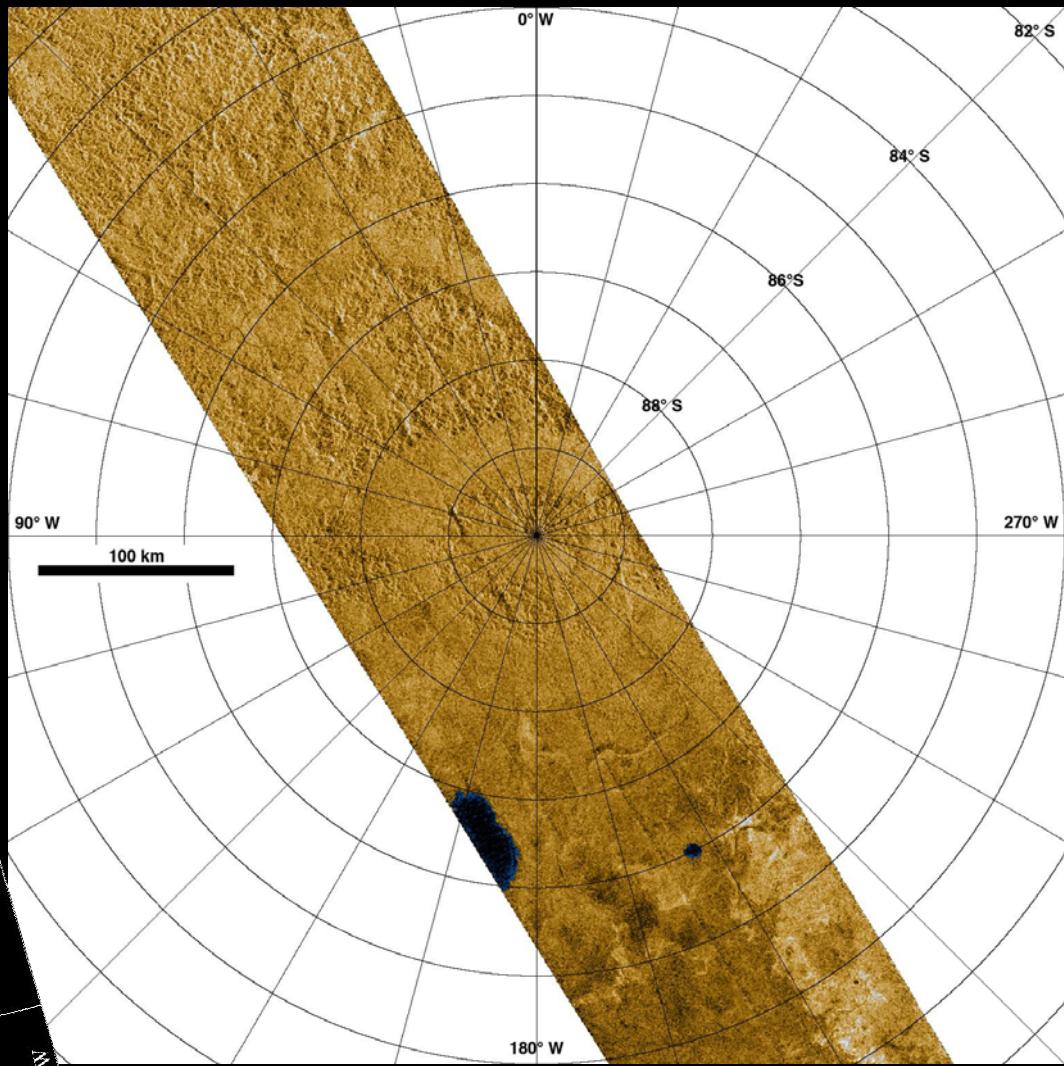


# South Polar Lakes



2 October 2007

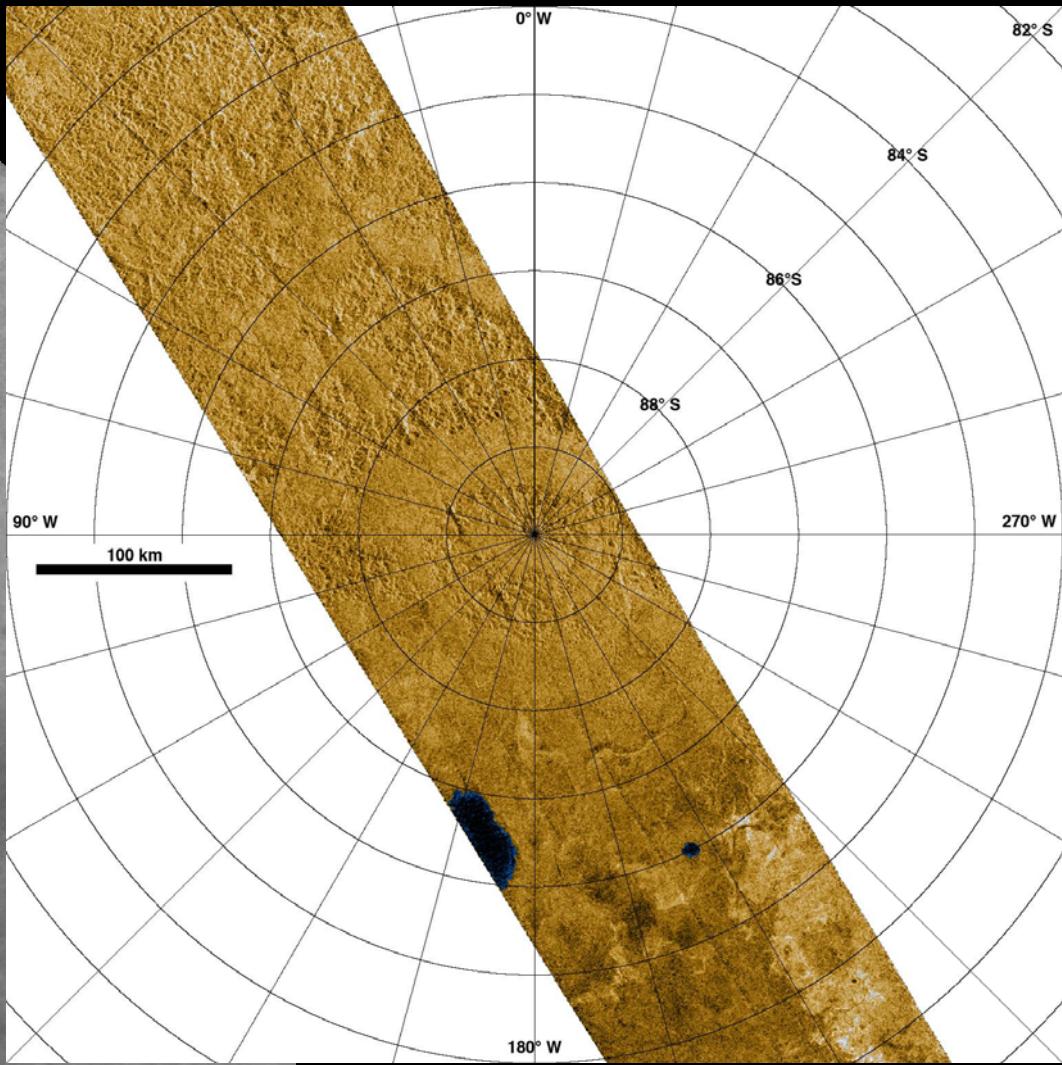
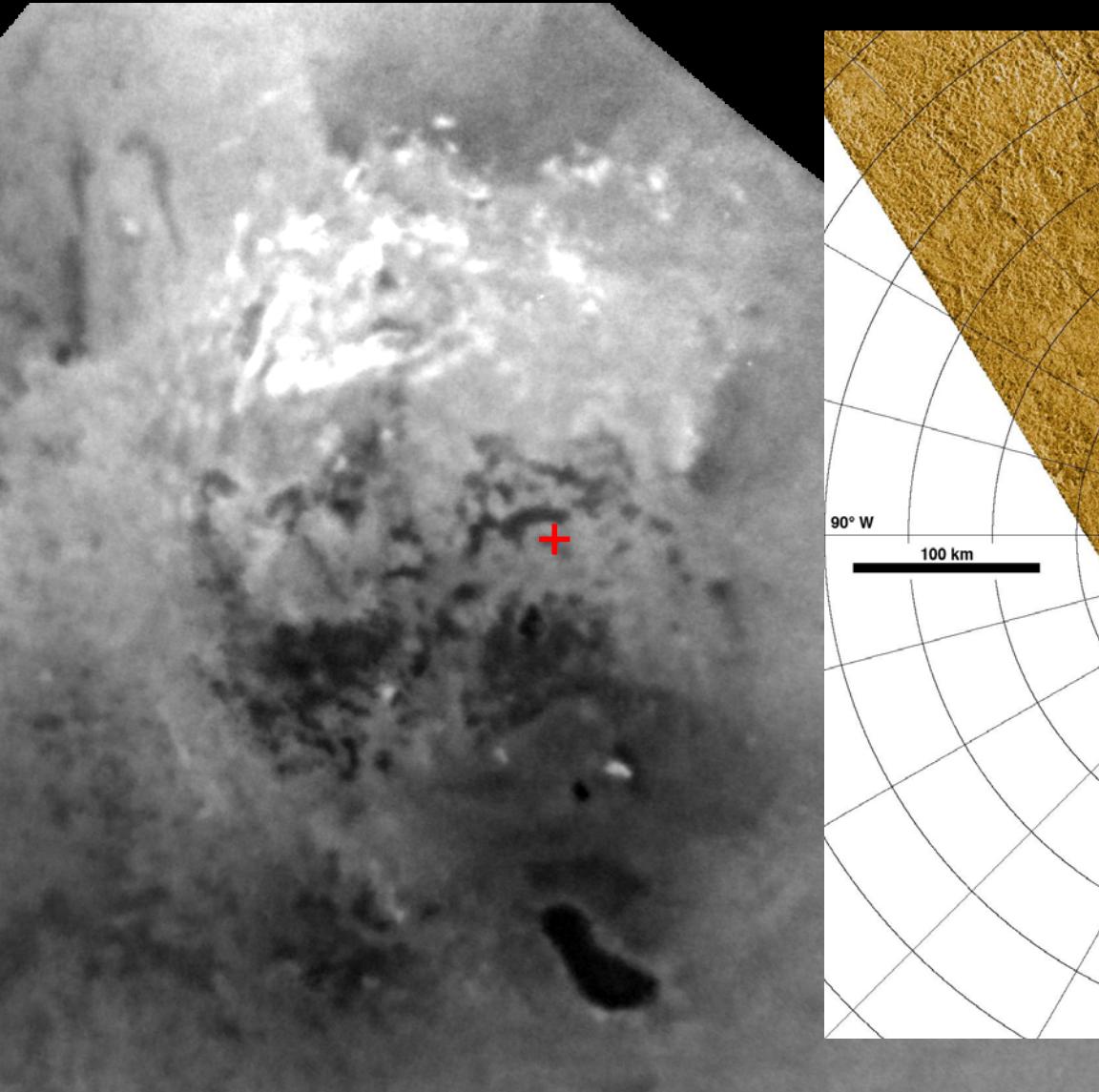
-cja- July, 2008



20 December 2007

48

# South Polar Lakes

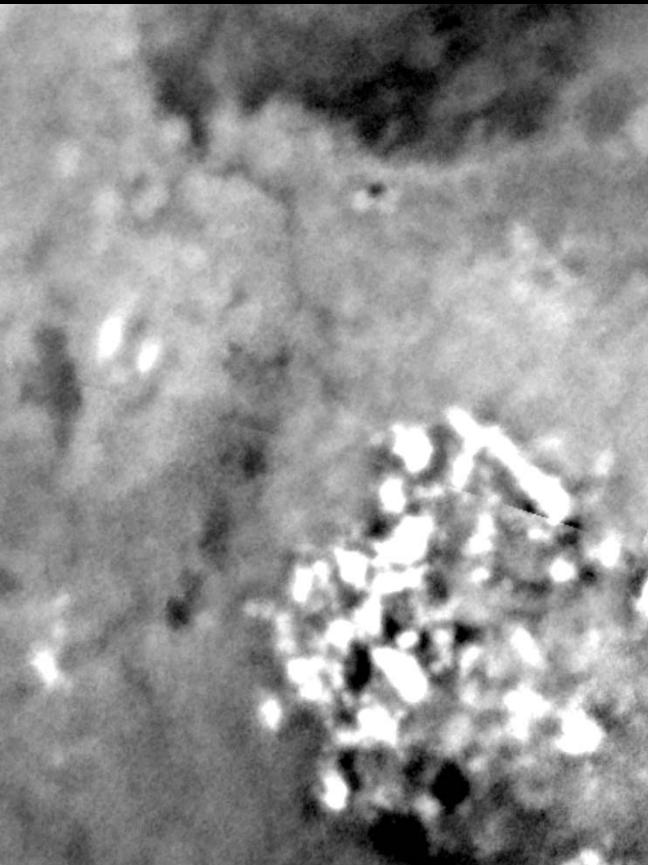


6 June 2005

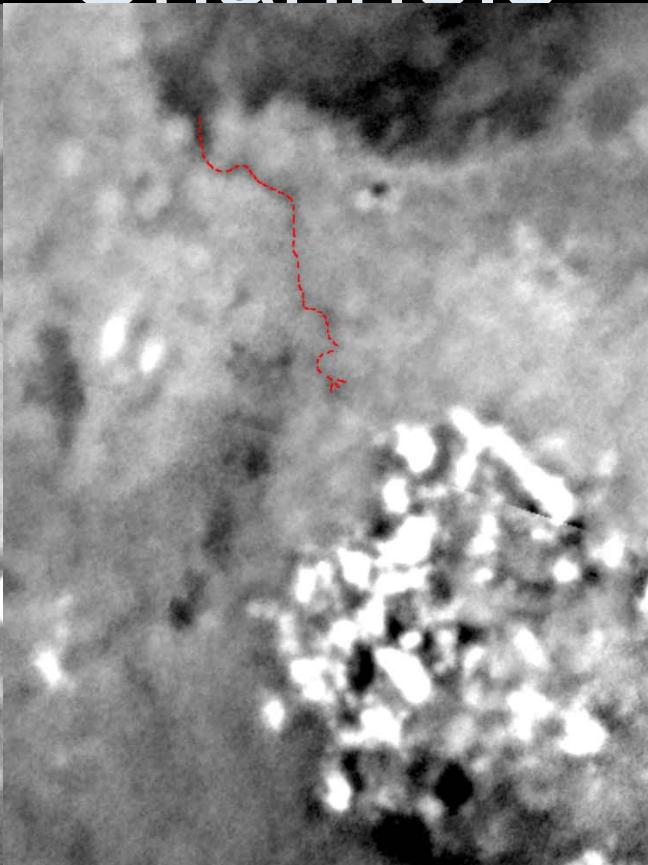
-cja- July, 2008

20 December 2007  
49

# Channels



3 July 2004

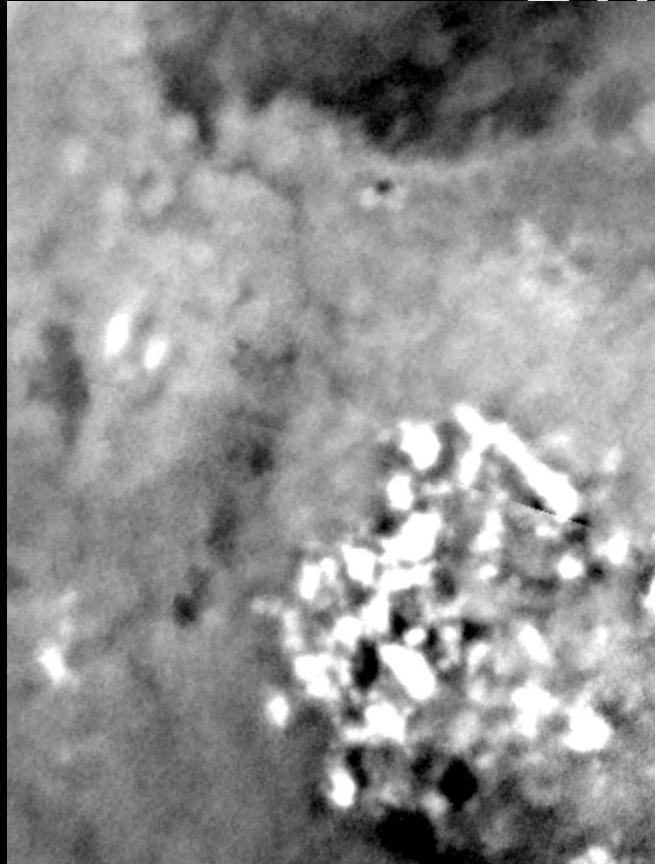


-cja- July, 2008



20 December 2007  
50

# Channels

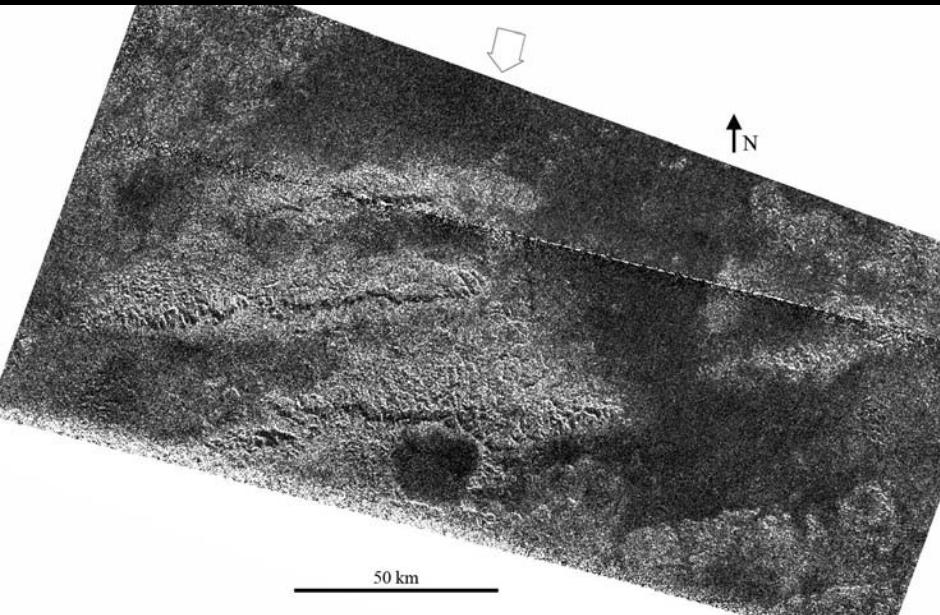


3 July 2004

20 December 2007  
-cja- July, 2008



# Tectonics



12 May 2008

-cja- July, 2008

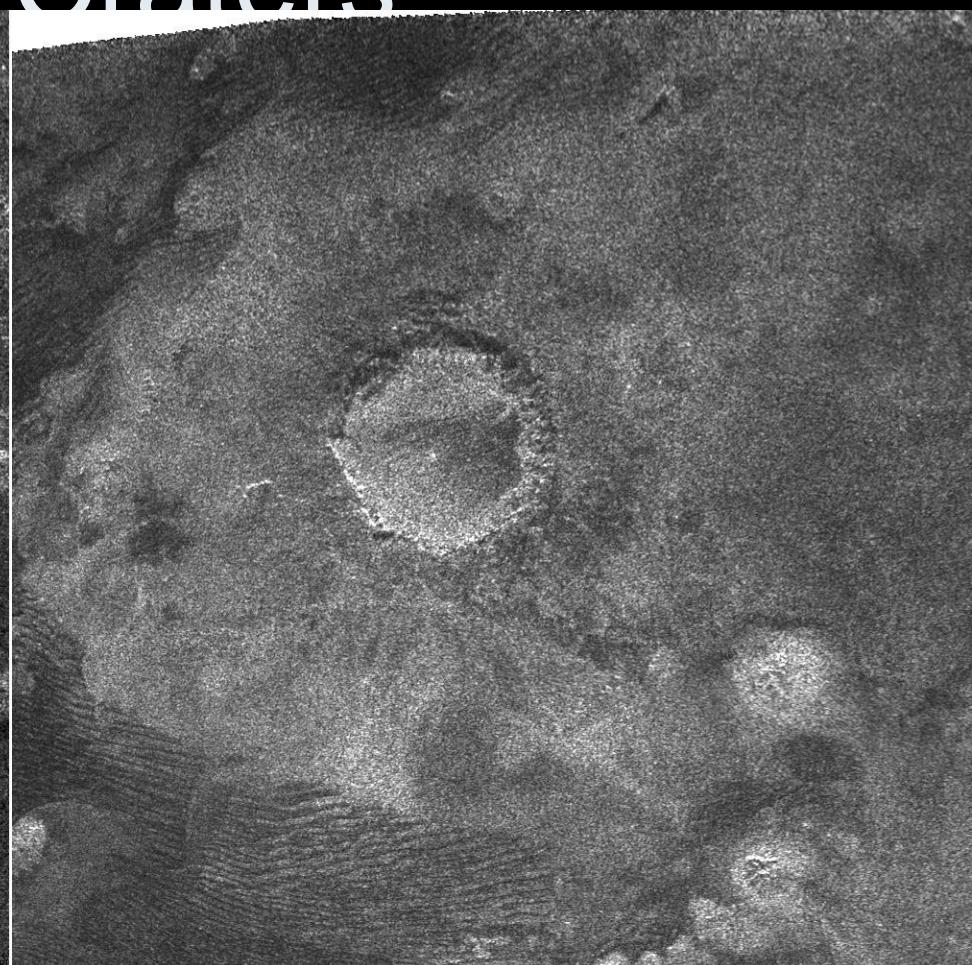
28 October 52  
2005

# Impact Craters



12 May 2008

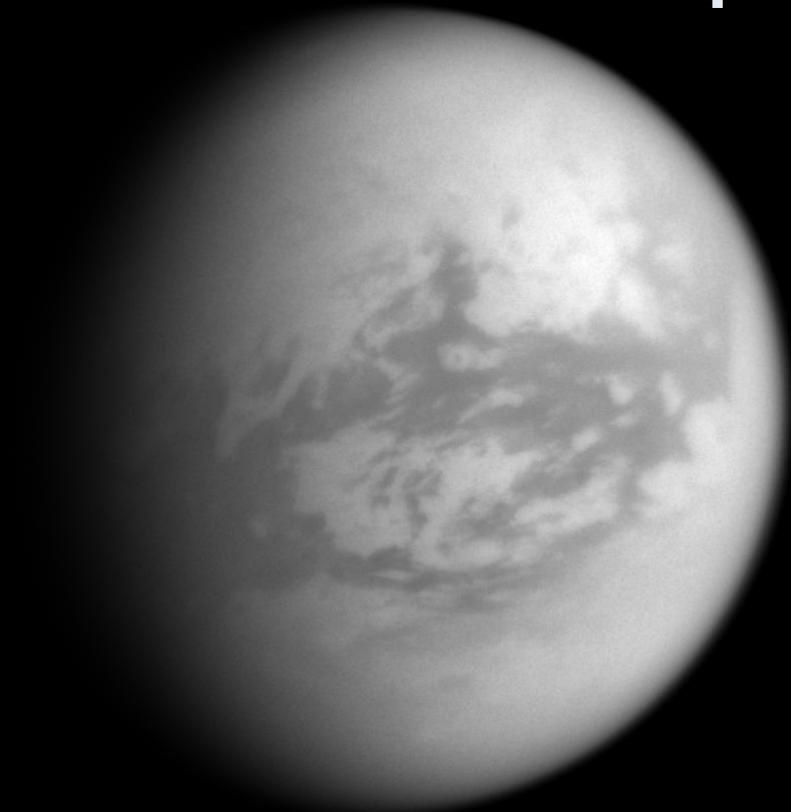
-cja- July, 2008



15 February 2005

53

# Impact Craters

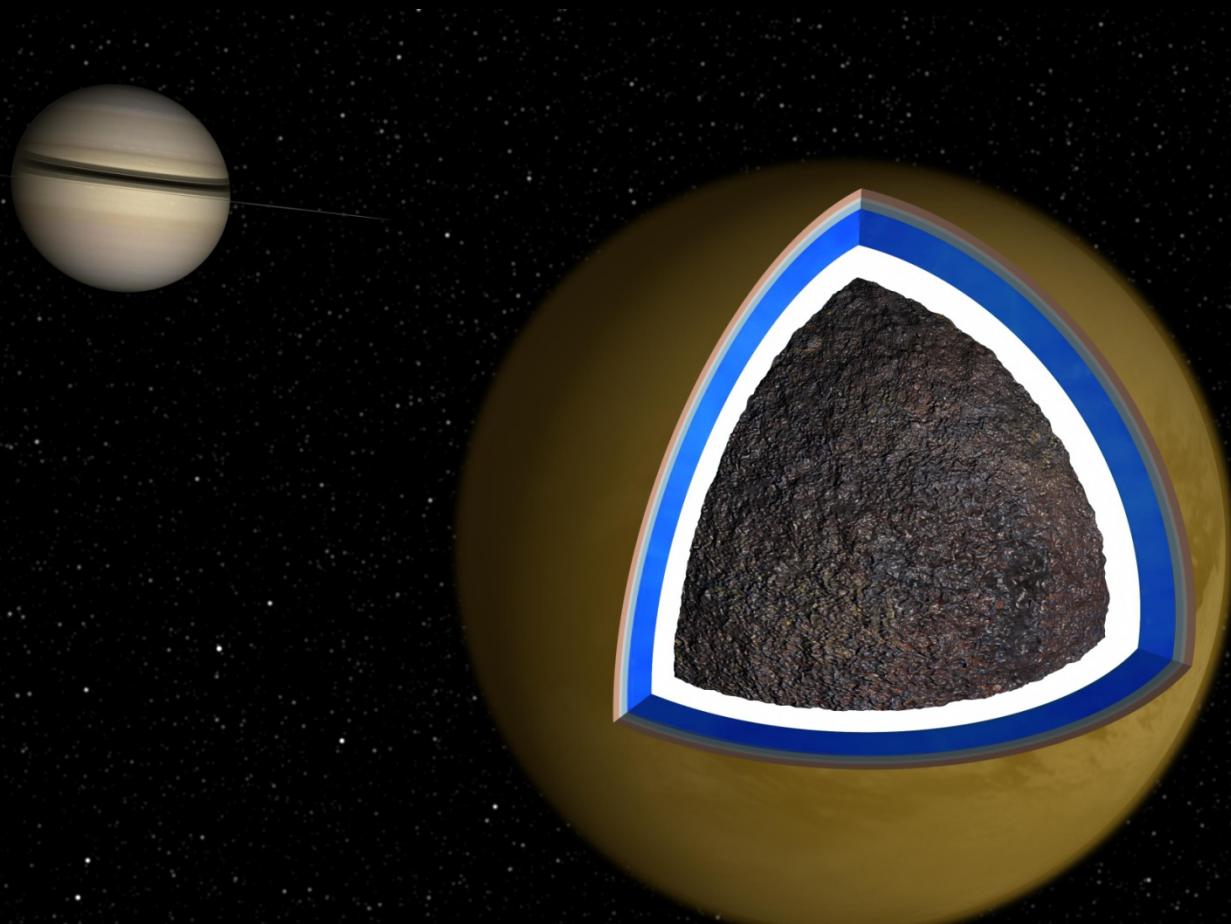


19 November 2007

-cja- July, 2008

13 May 2007  
64

# Interior Ocean Revealed



Year 5 = T45 through T57!

