Cassini's Grand Finale
Science Highlights & End of Mission

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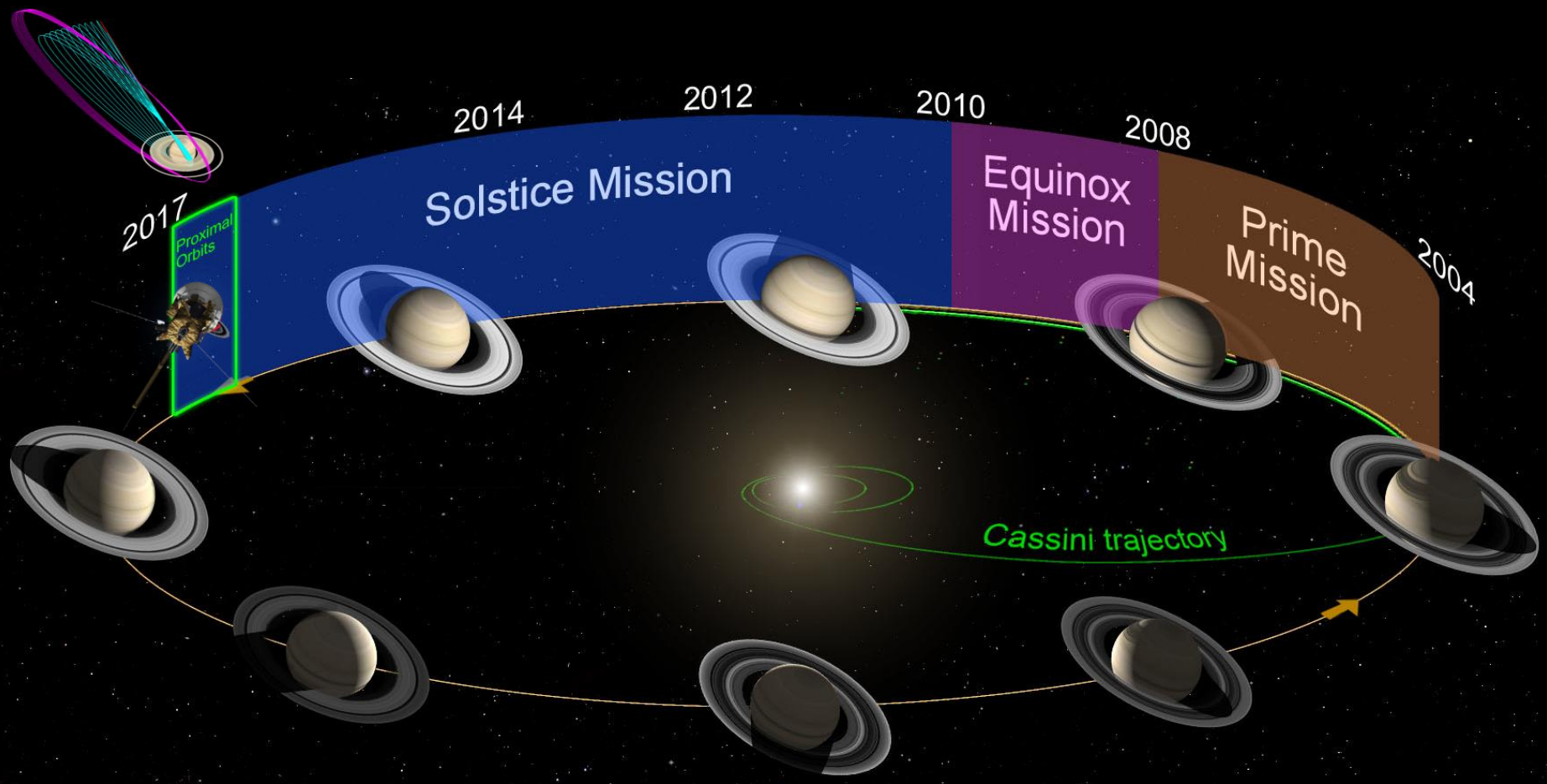
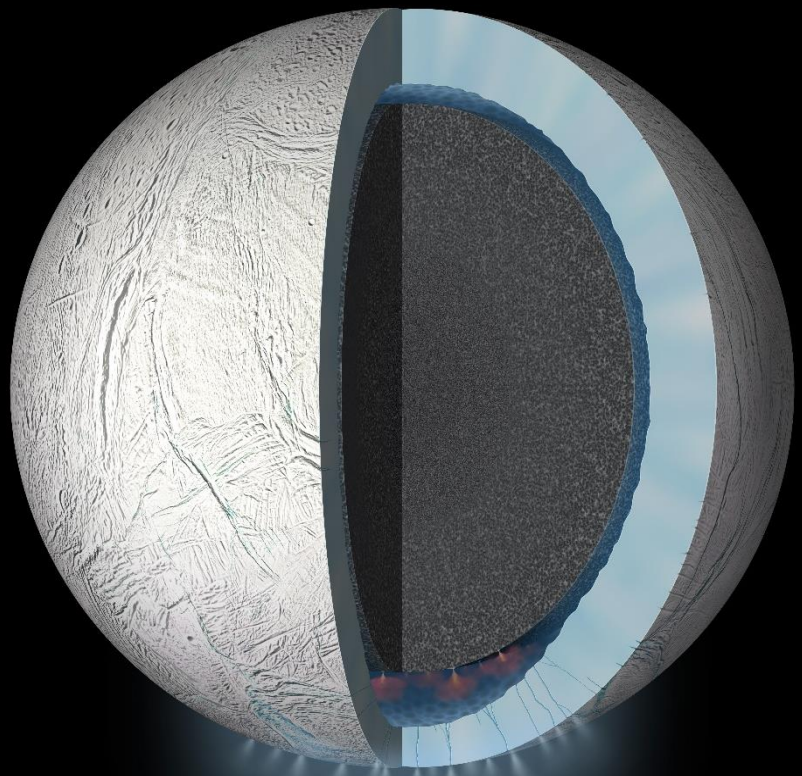
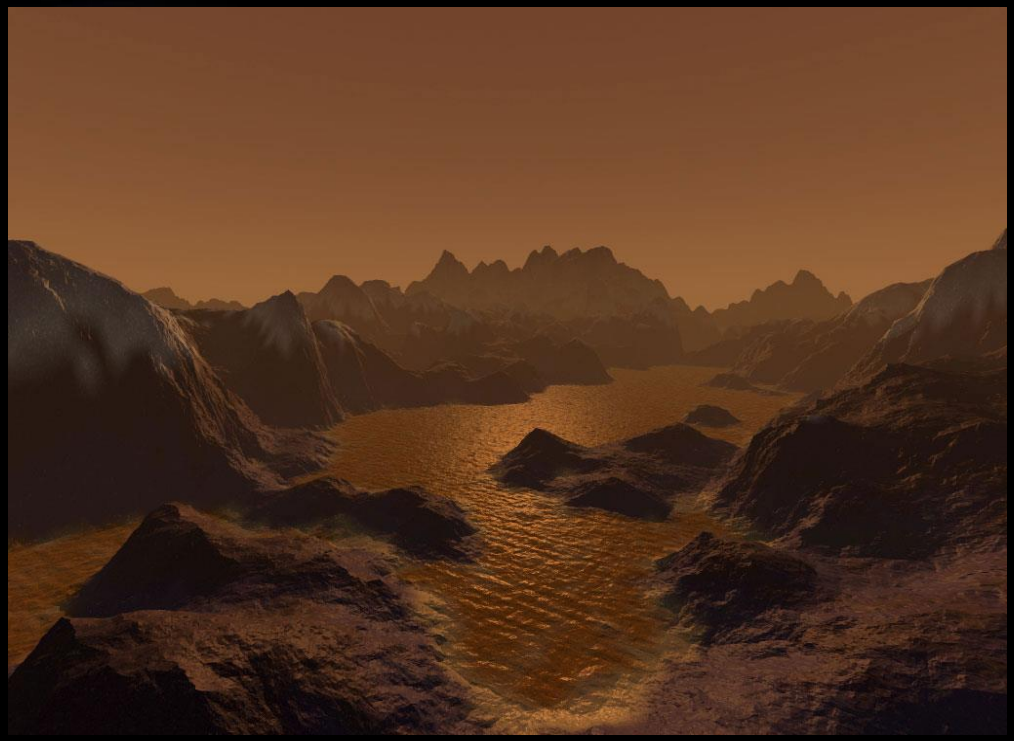
Jet Propulsion Laboratory, California Institute of Technology
October 19, 2017

Cassini-Huygens Mission Overview

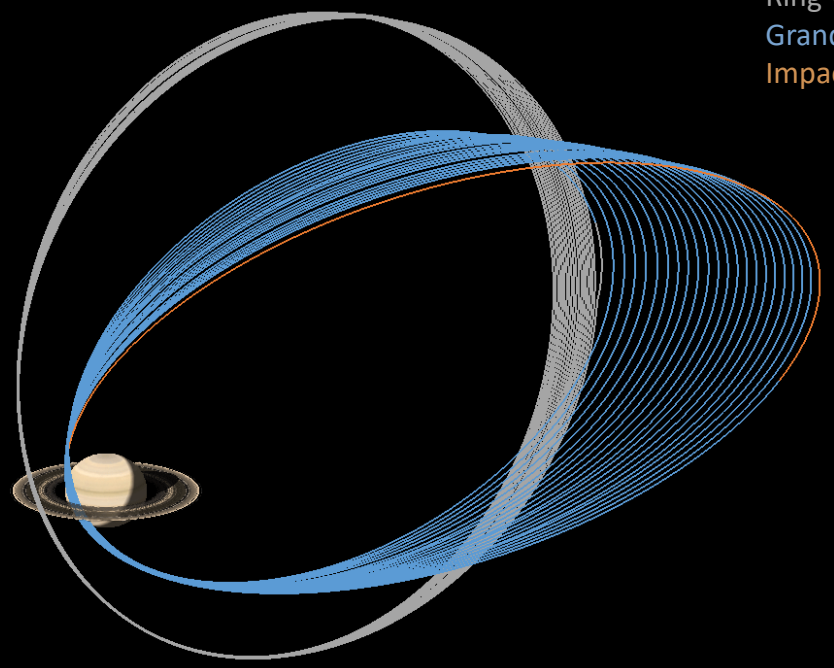


Protecting Saturn's Ocean Worlds

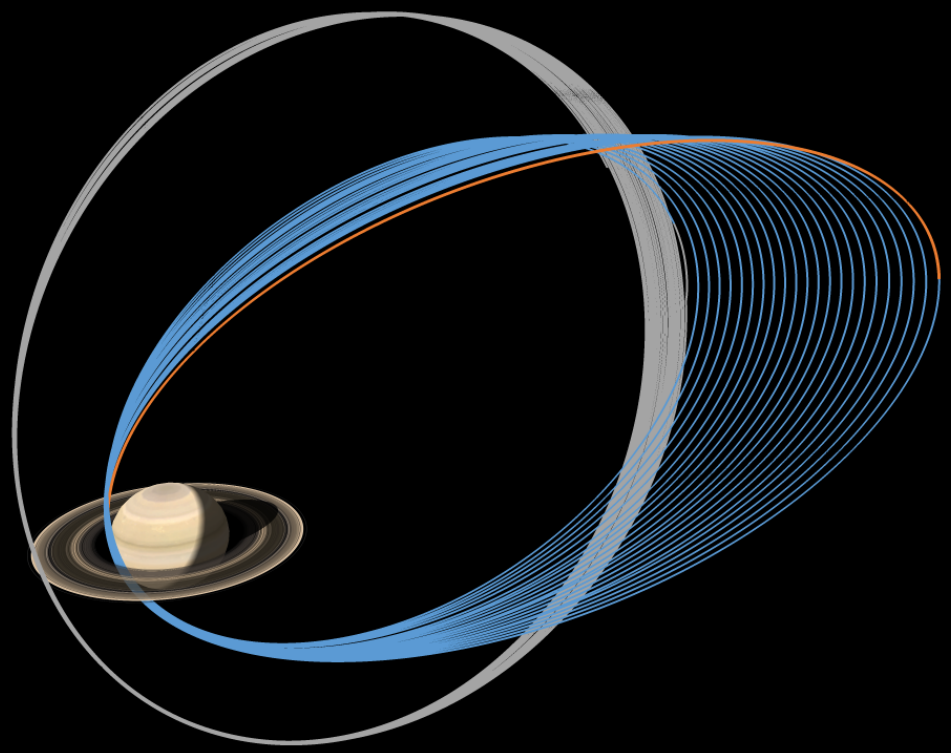




Solstice Mission Trajectory

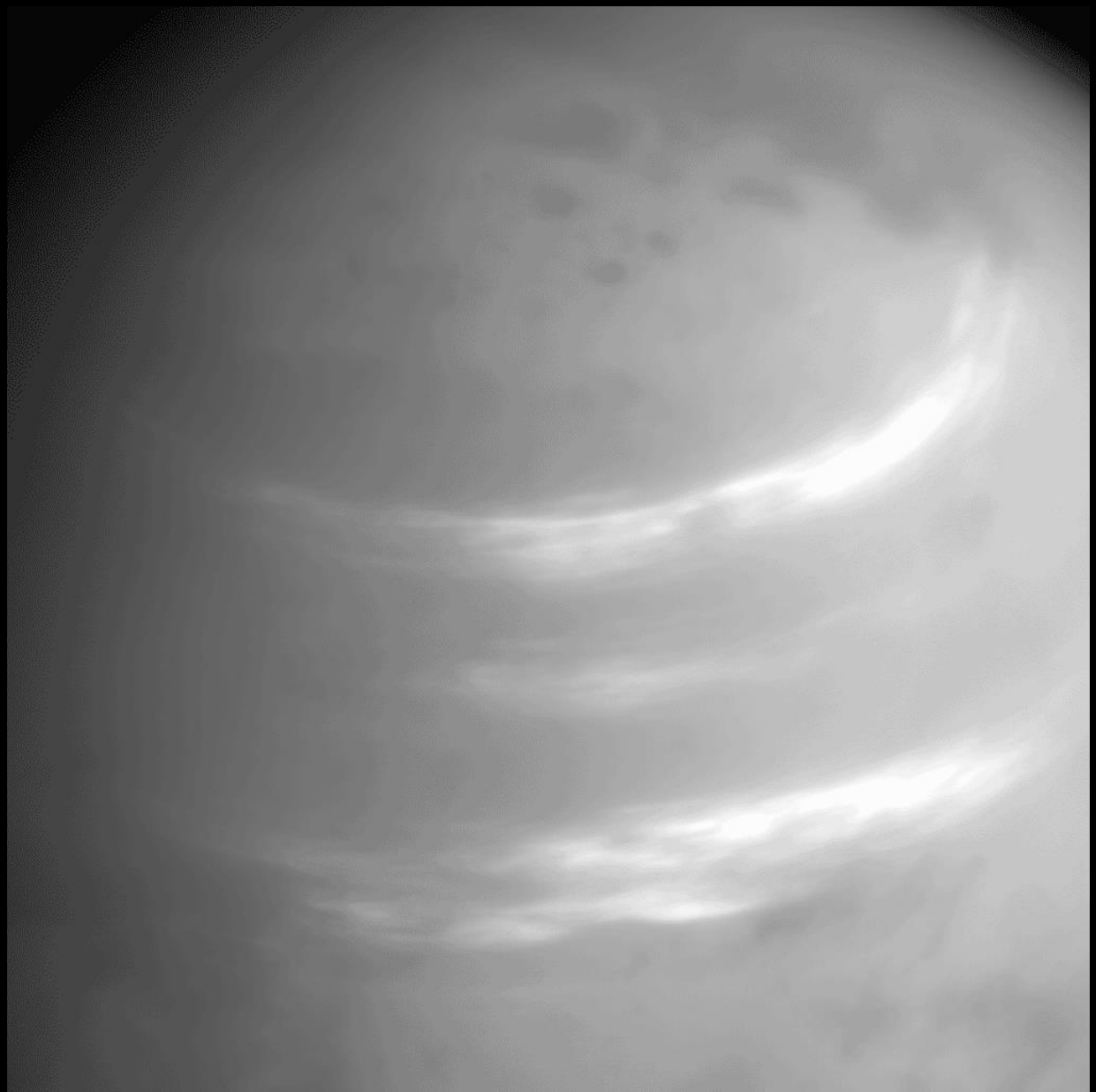


Key Characteristics of Final Orbits

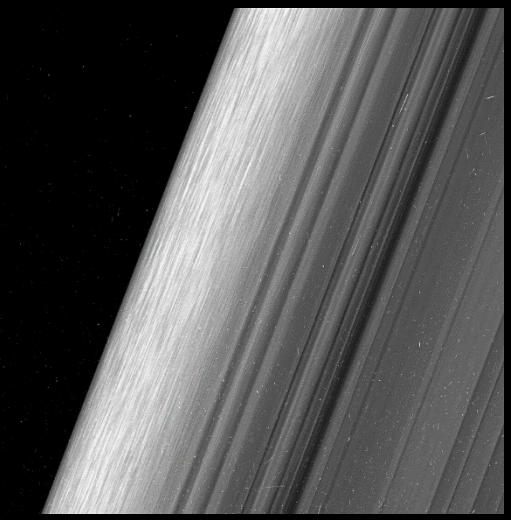


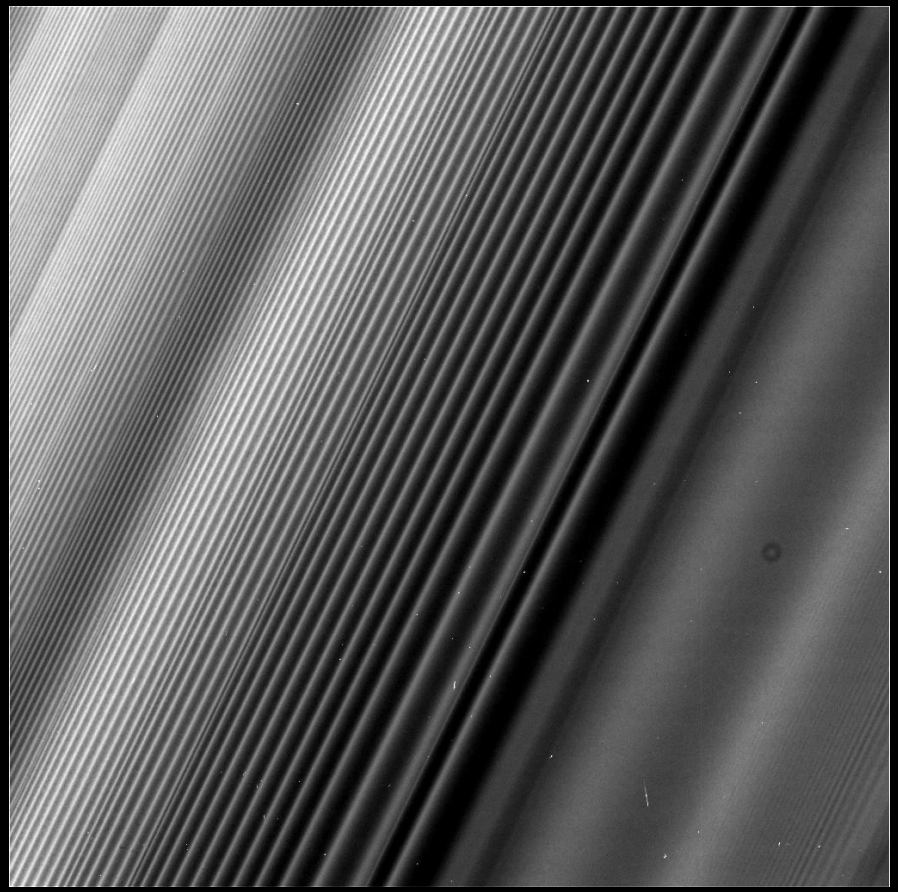
- 42 short-period orbits
  - Nov. 2016 to Sept. 2017
- 20 F ring orbits
  - Periapses just outside Saturn's F ring
  - Sets up Cassini for final jump to orbits inside D ring
- 22 Grand Finale orbits
  - Periapses in 2,400 km "clear" zone

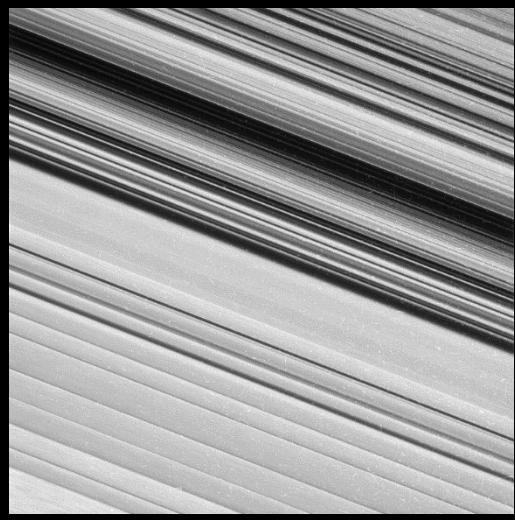
Titan Clouds Reappear

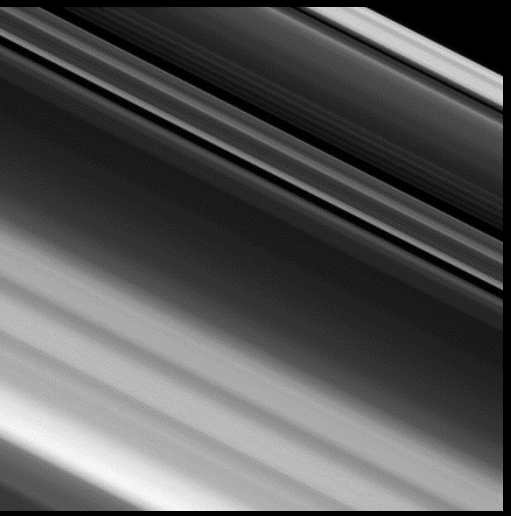


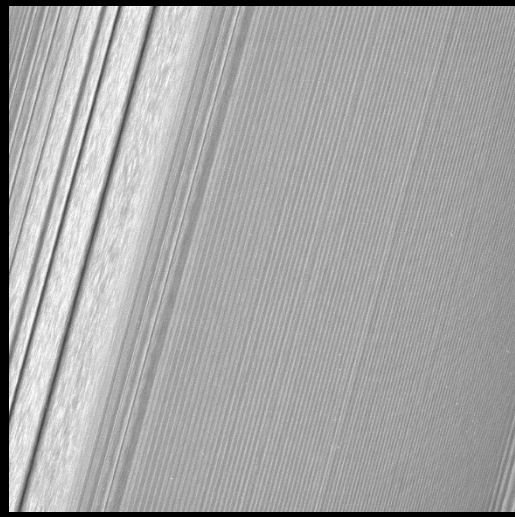
Saturn’s Rings in High-Def







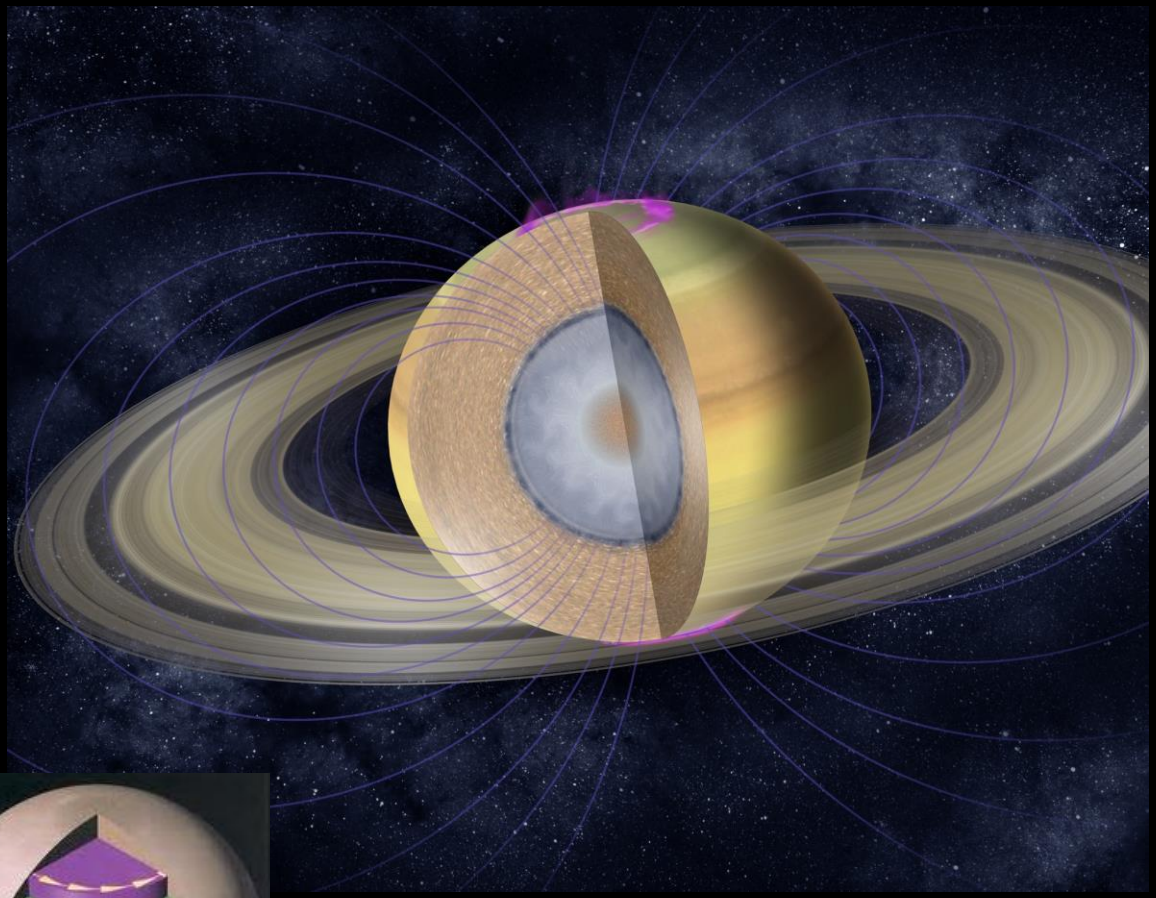




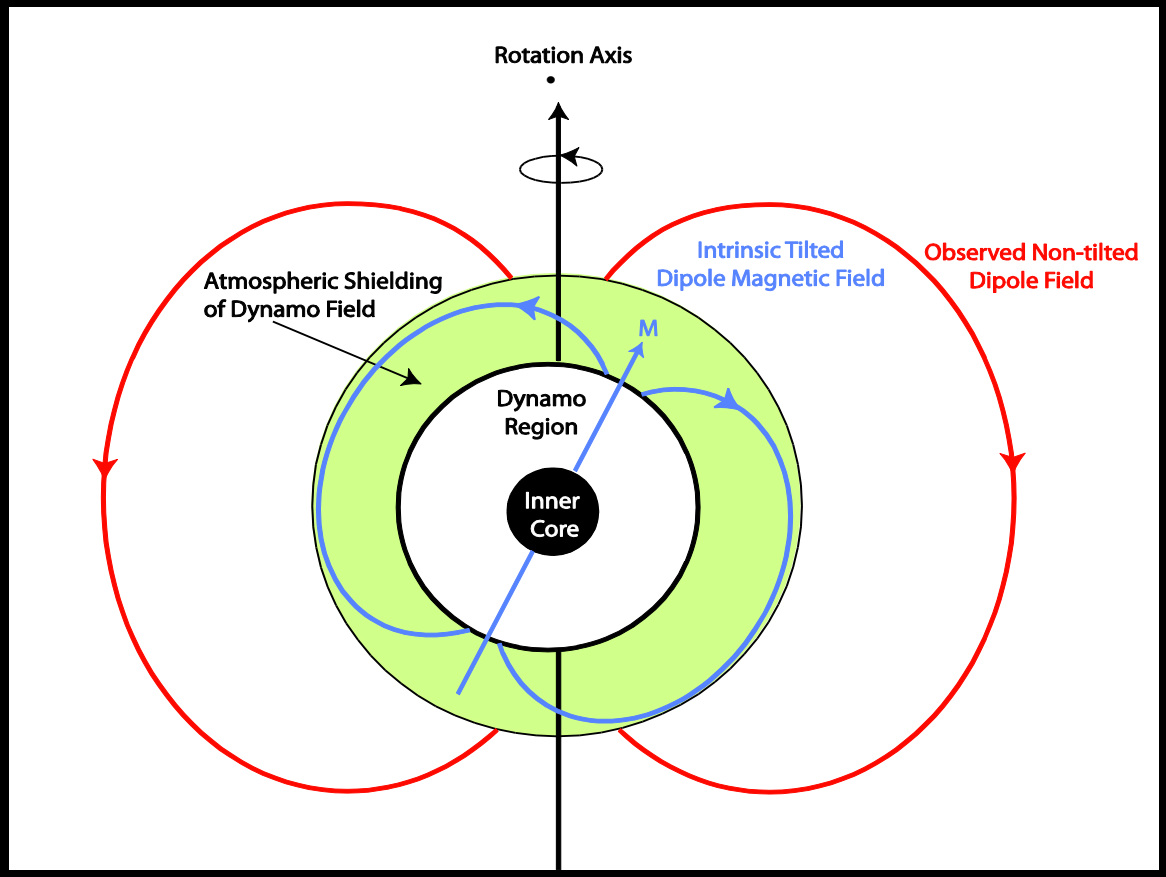
Probing Saturn's Interior

Gravity will estimate:

- Size of rocky core
- Depth of winds
- Mass distribution



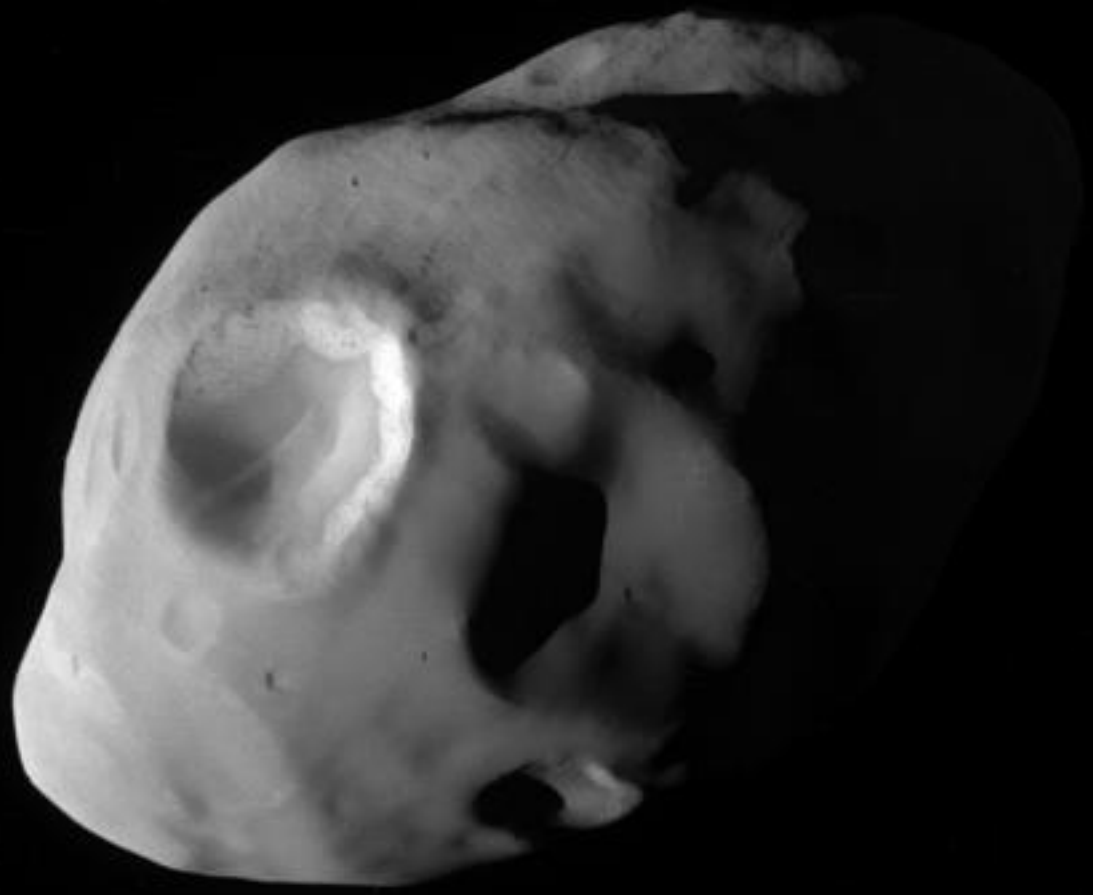
Probing Saturn's Interior



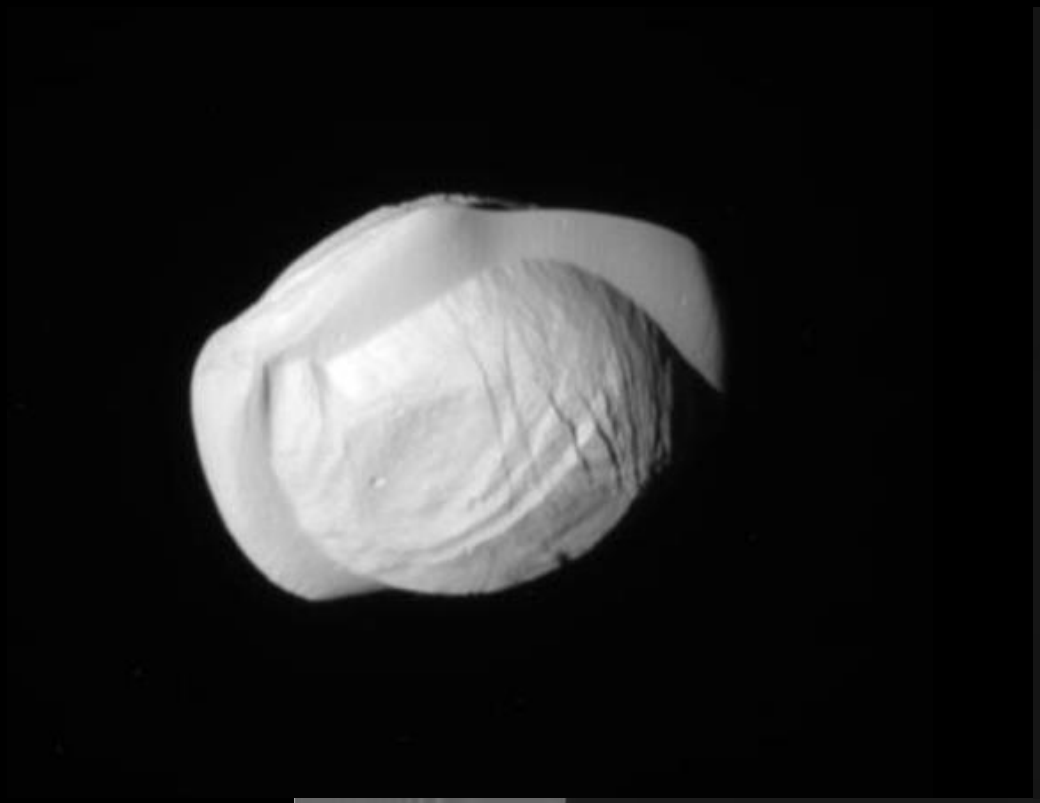
Magnetic field measurements will determine:

- Rotation rate
- Depth of magnetic dynamo region

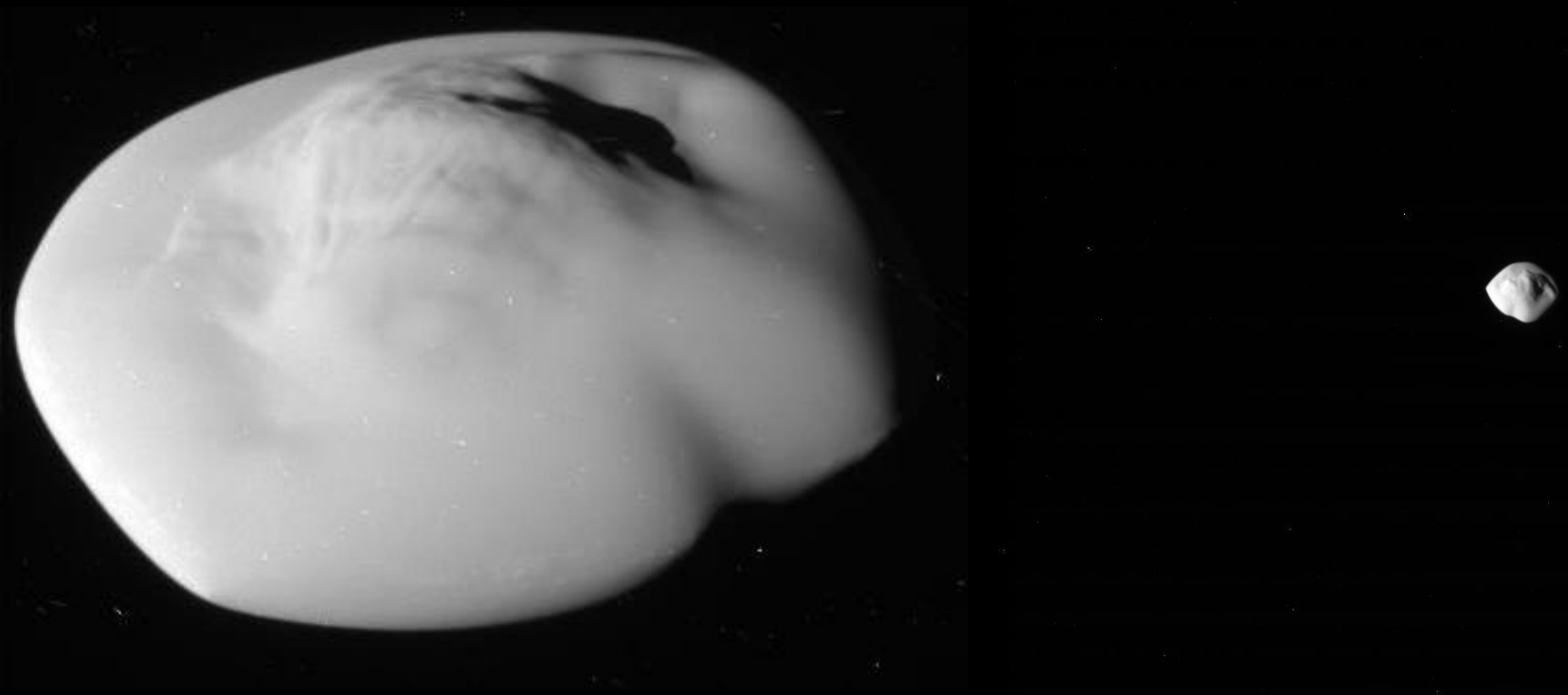
Opening Pandora's Box



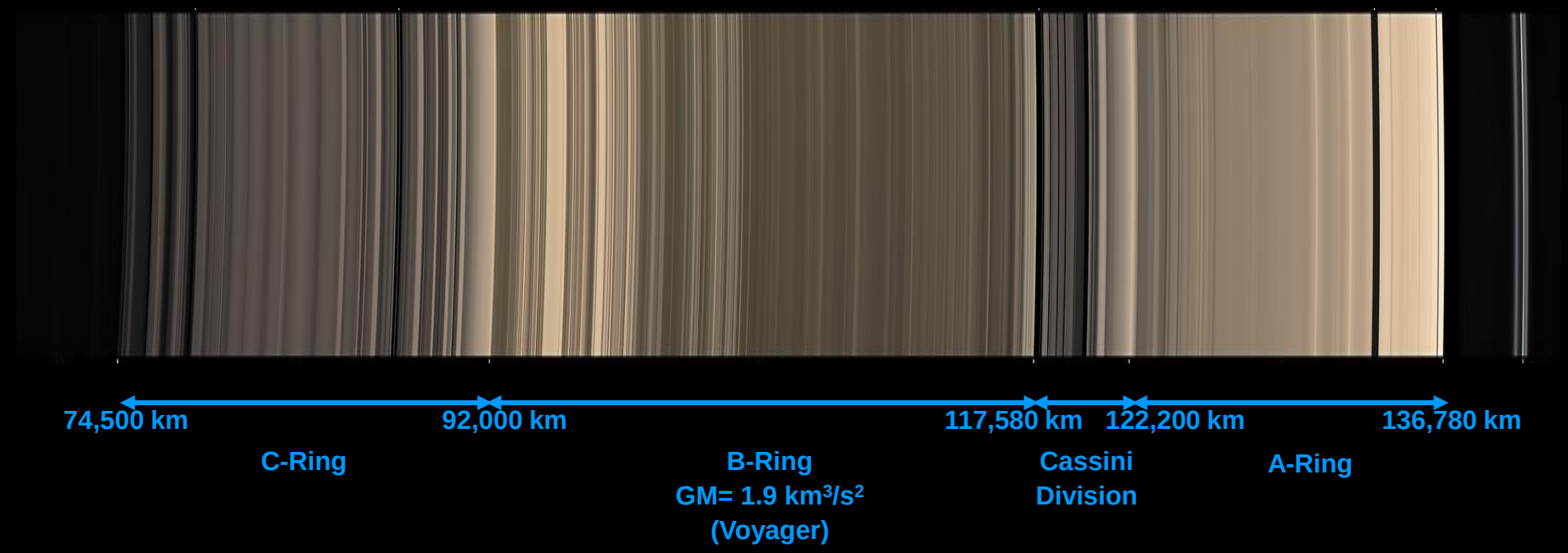
From Cassini's Vista: A Pan-tastic View



Atlas Shoulders the Weight of the Rings

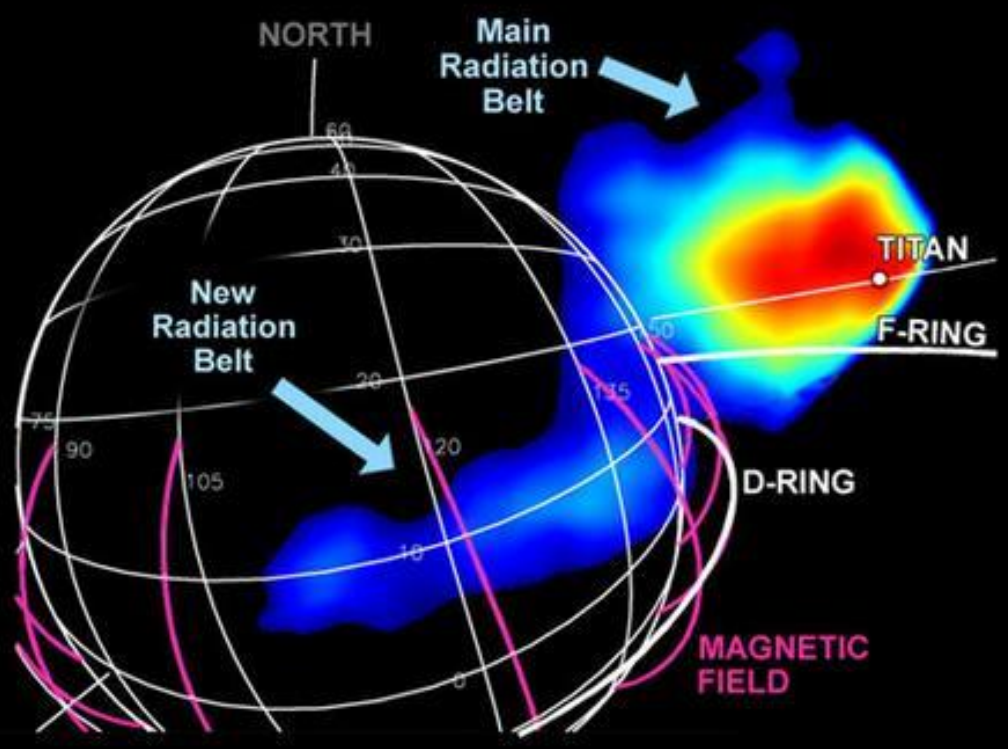


Ring Mass: Constrain age of rings



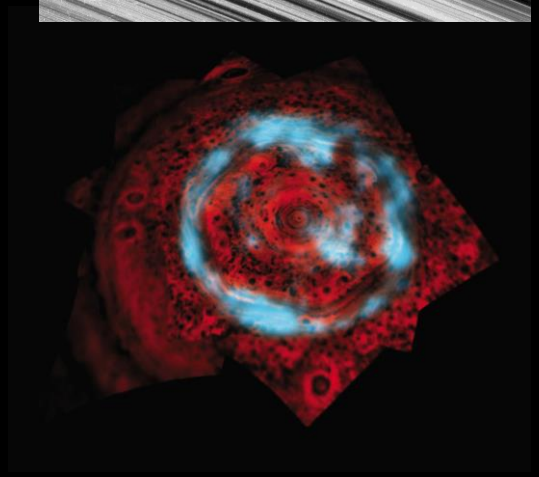
- Current uncertainty in ring mass is 100% of nominal value
- 6 gravity passes to measure total ring mass could reduce uncertainty to about 5%
- Less massive: young rings; more massive: old rings

First *In-Situ* Measurements of Exosphere and Innermost Radiation Belts



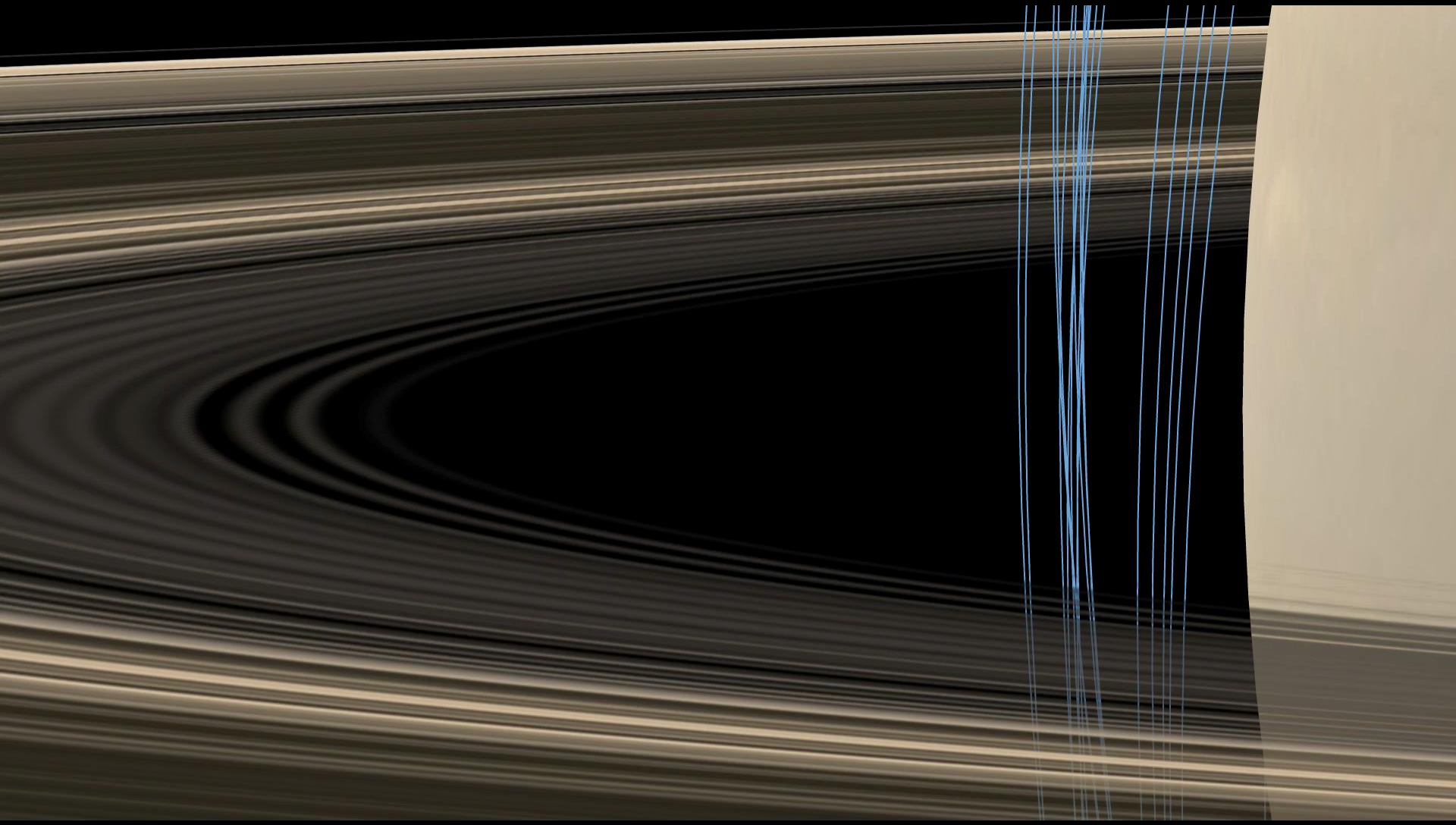
- Strength of innermost radiation belt
- Plasma composition
- Saturn's auroral magnetosphere

Final Orbits Science: Unique Observations

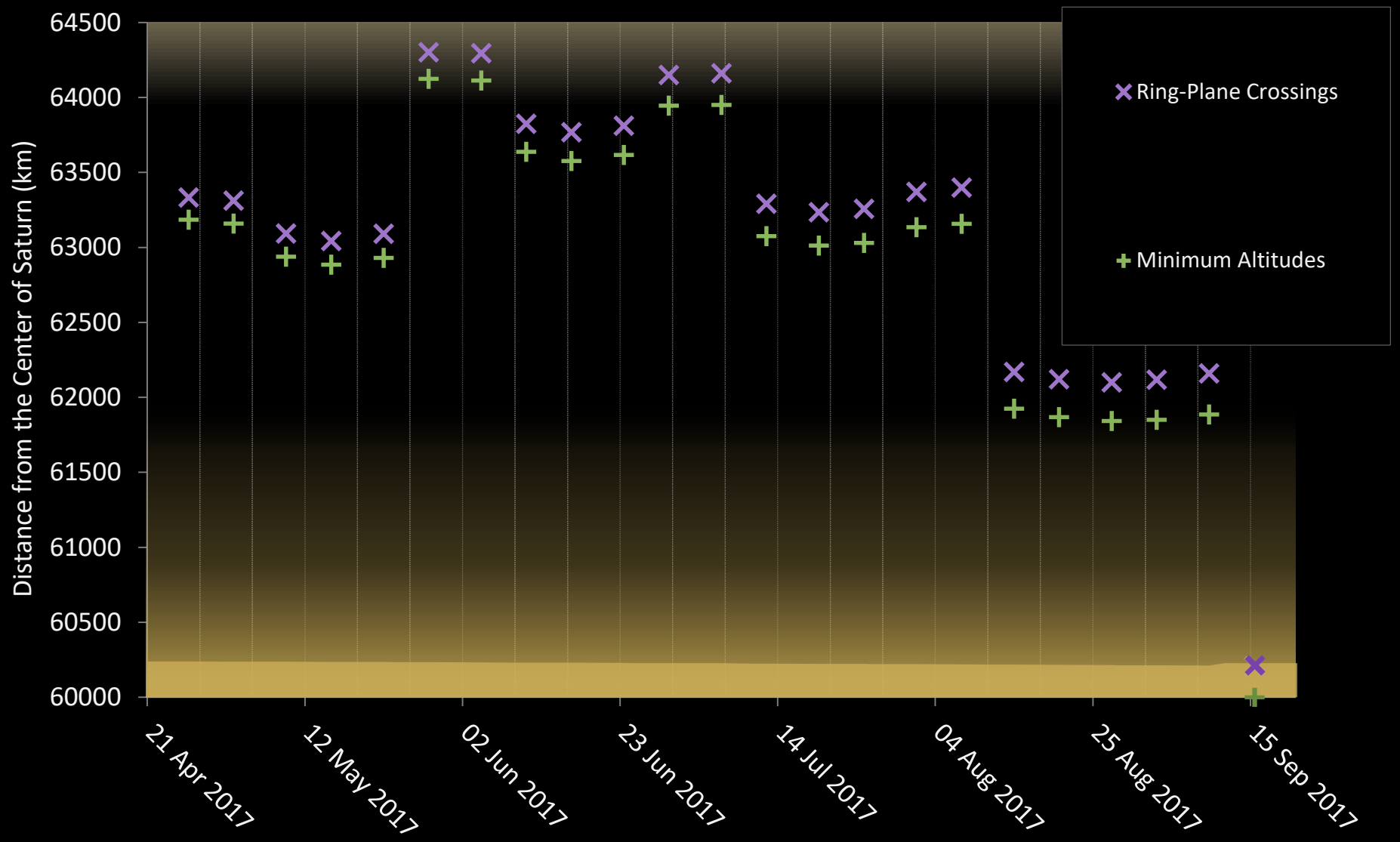


- First ever direct measurements of ring particle composition
- Highest resolution main ring observations
  - Radio occultation, imaging
  - First active Radar
- Highest resolution Saturn polar observations and aurora

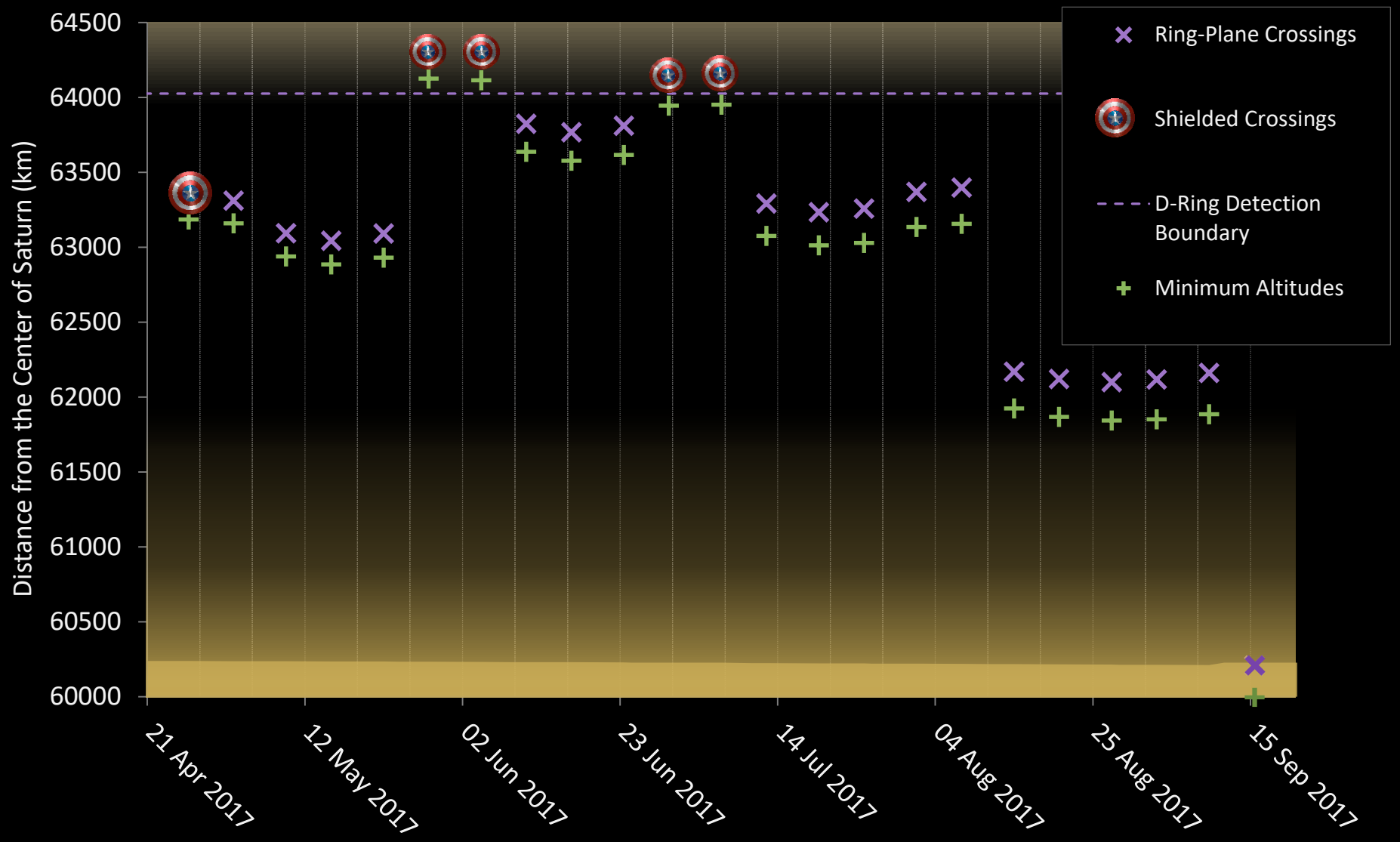
Flying **Through** the Gap 22 Times



Proximal Corridor

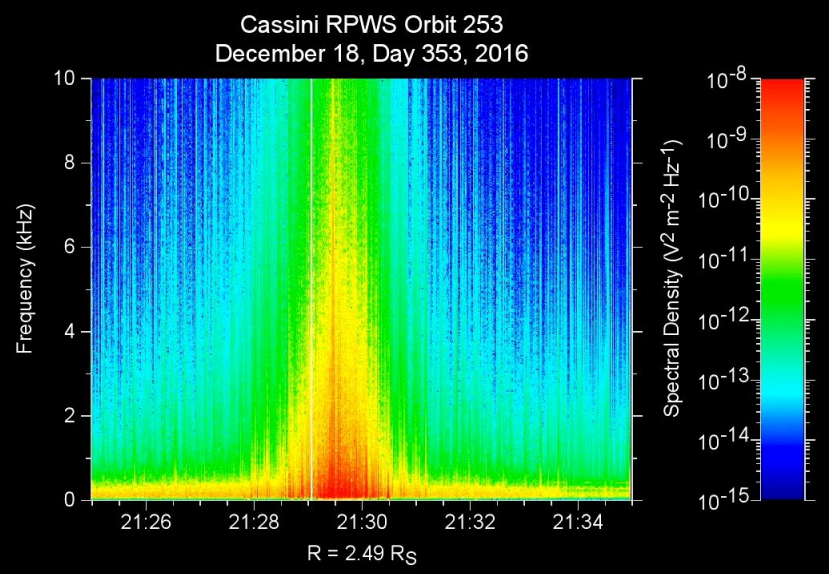


Dust Hazard Plan

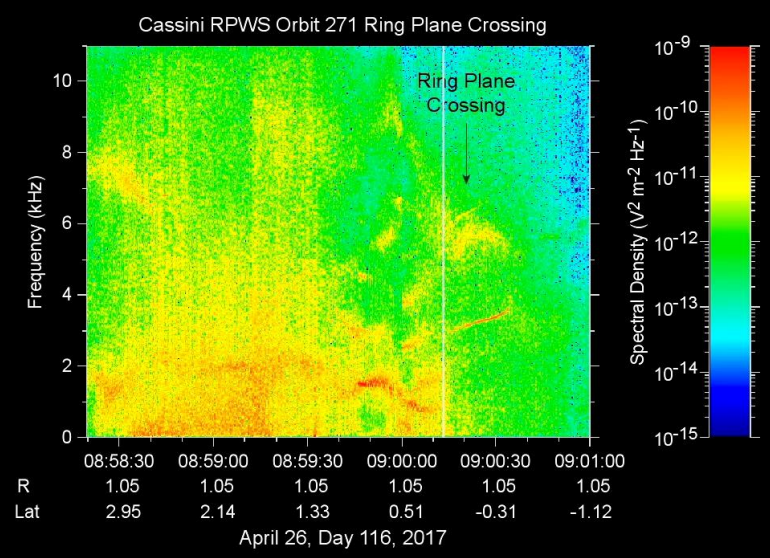


Saturn Radio Plasma Waves

What We Expected

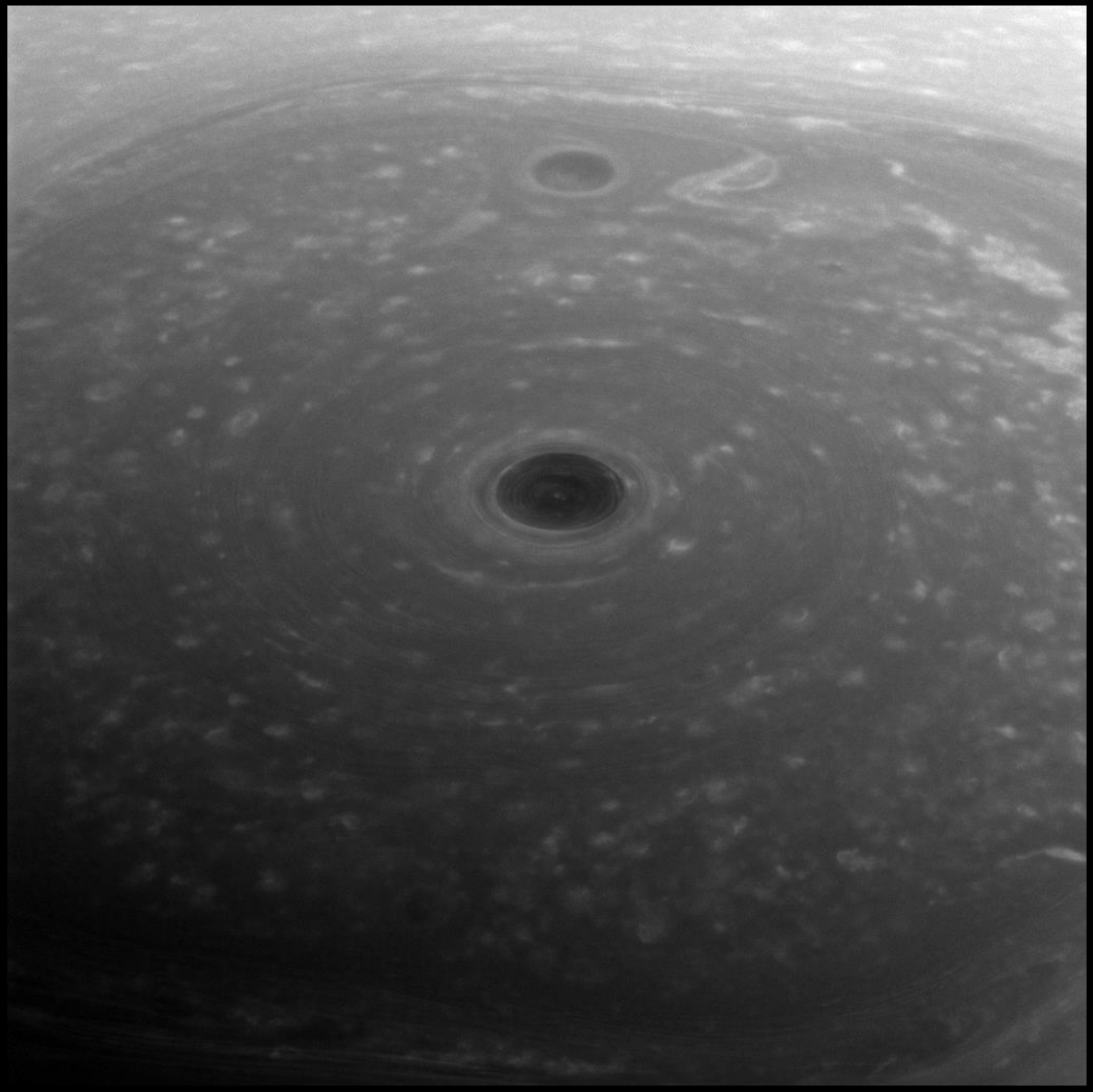


What We Saw

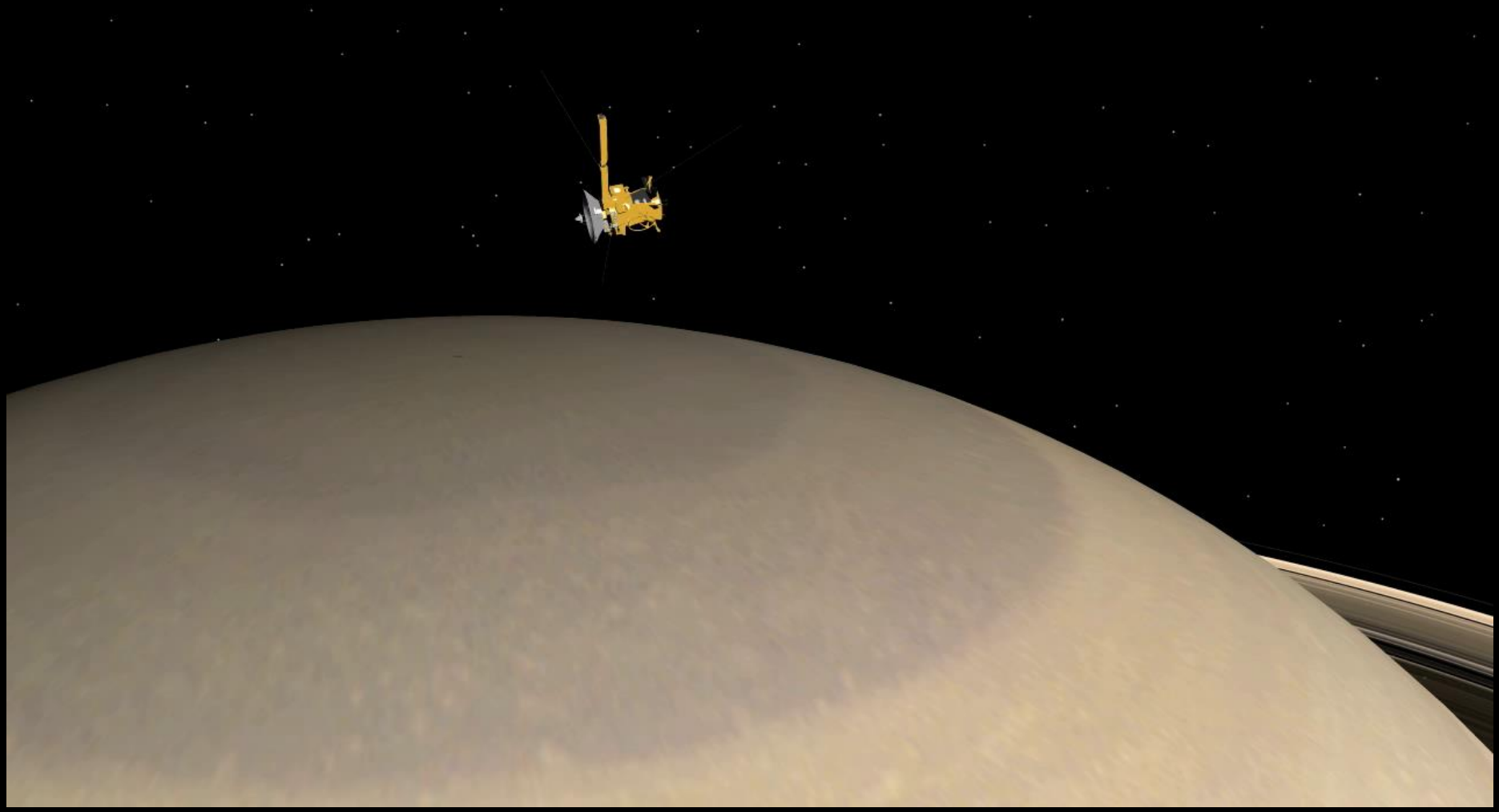


Where are the predicted large ring particles?

Soaring Over Saturn’s North

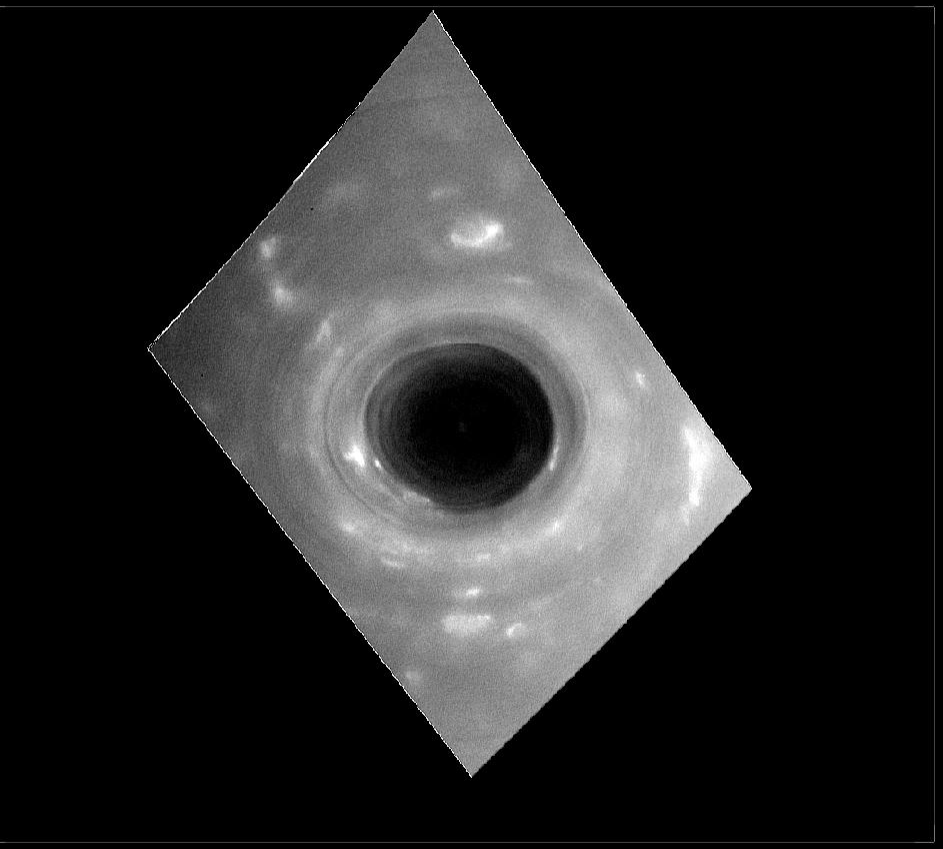


The First Grand Finale Crossing

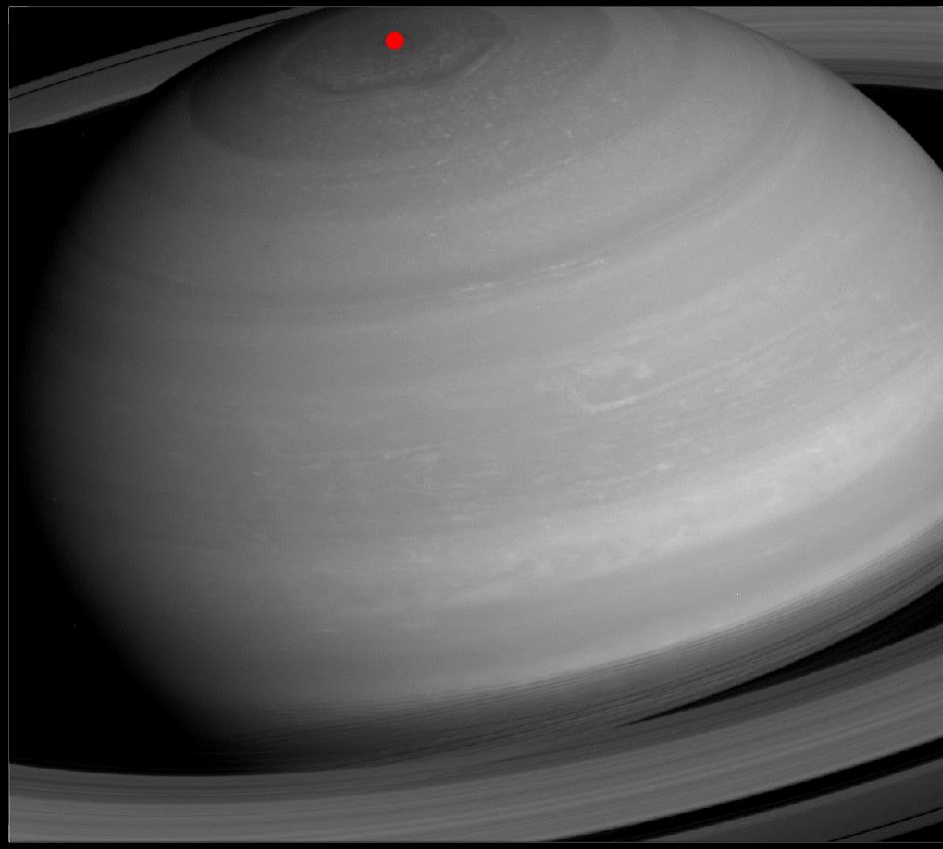


Saturn Noodle

Camera View



Reference View



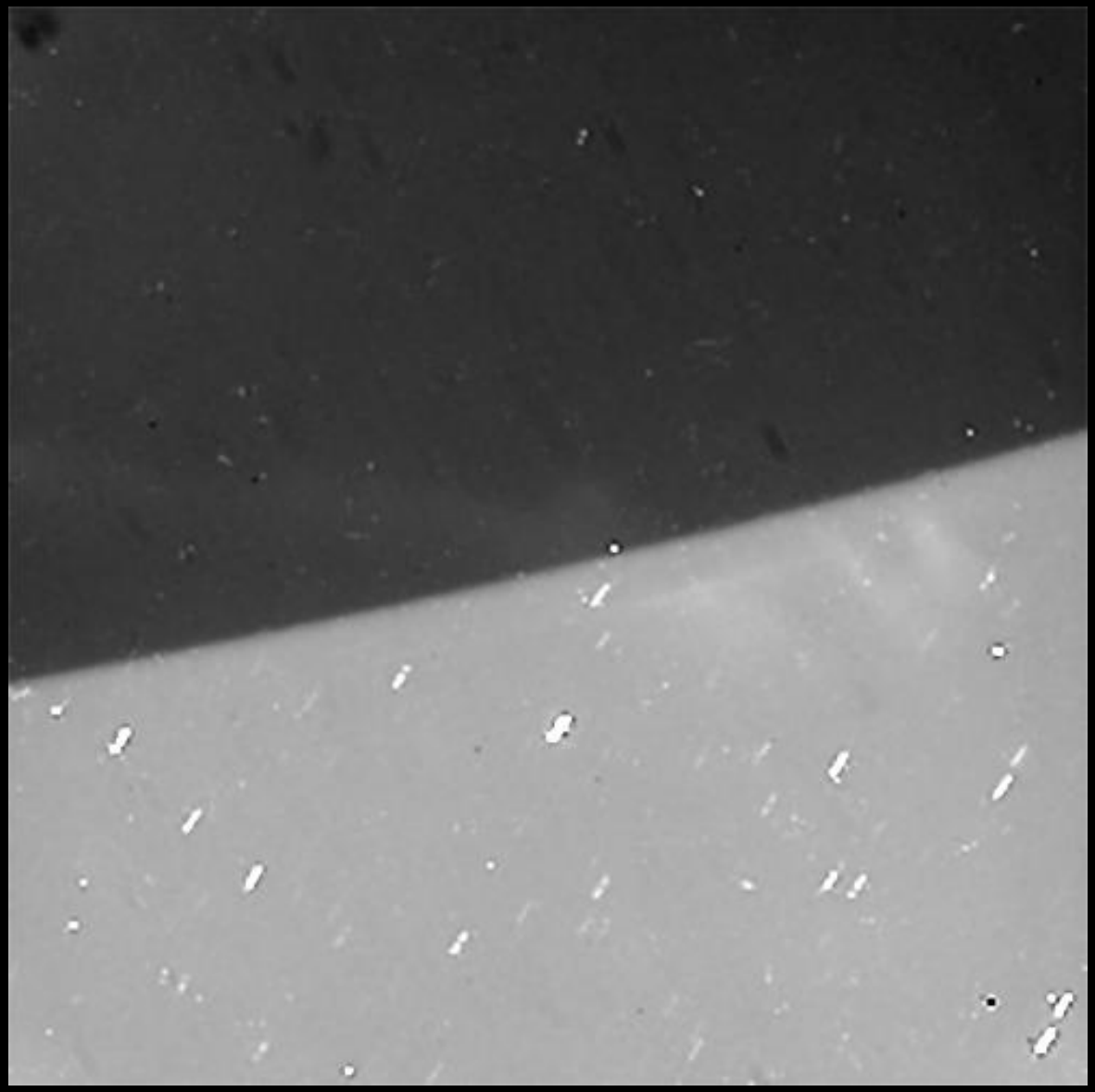
Saturn Noodle

April 26, 2017

June 29, 2017

Saturn Southern Aurora

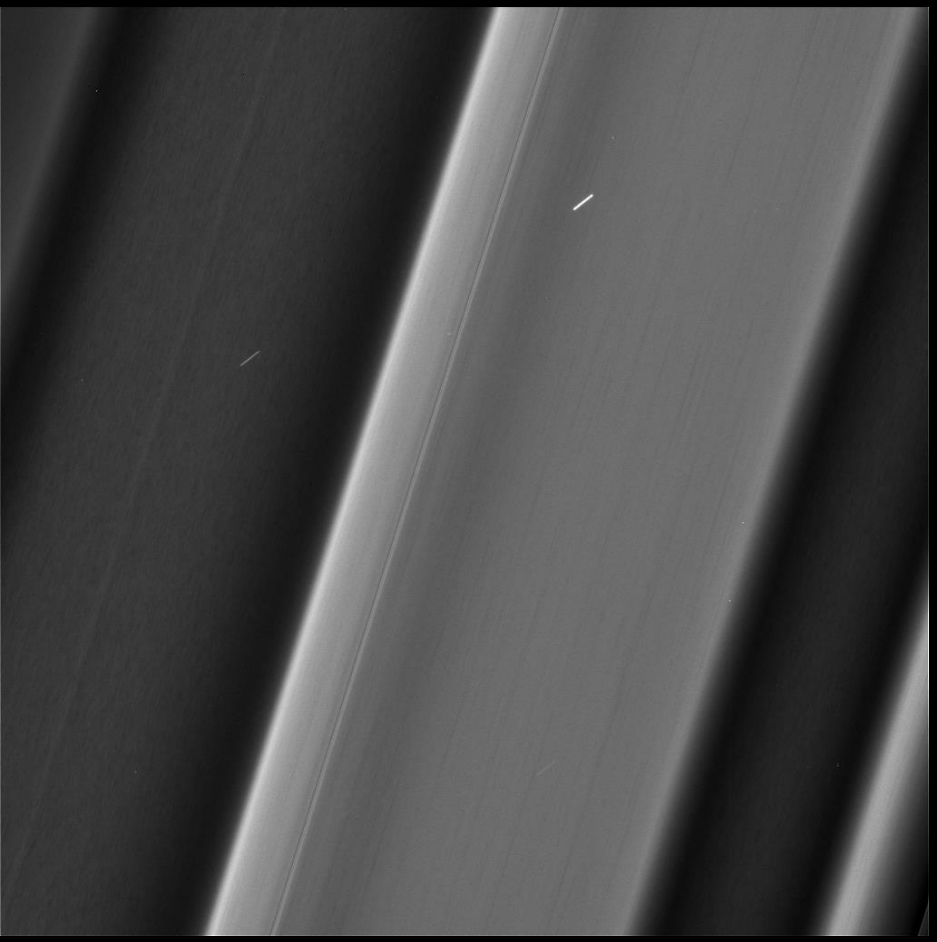
Nov 29, 2010



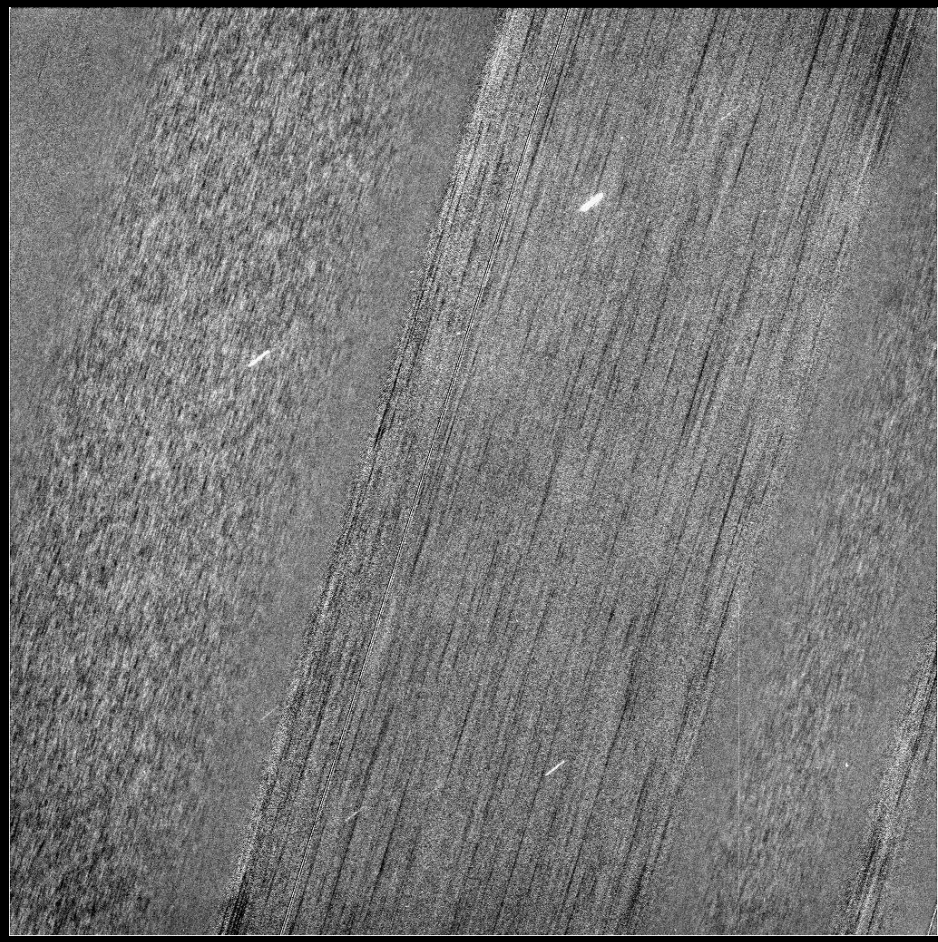
July 20, 2017

C Ring “Plateau” Structure

Highest Resolution Image

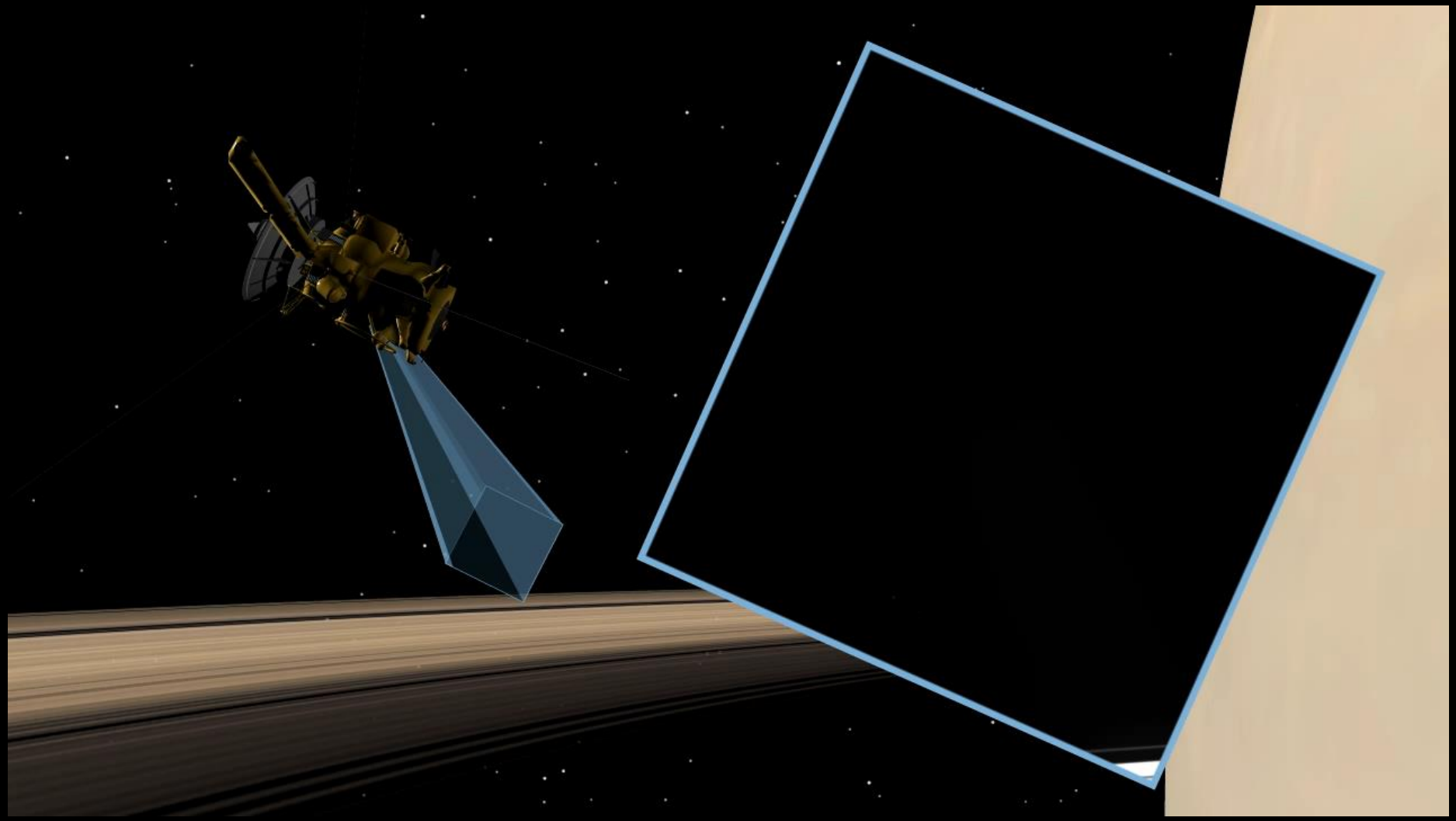


After Processing

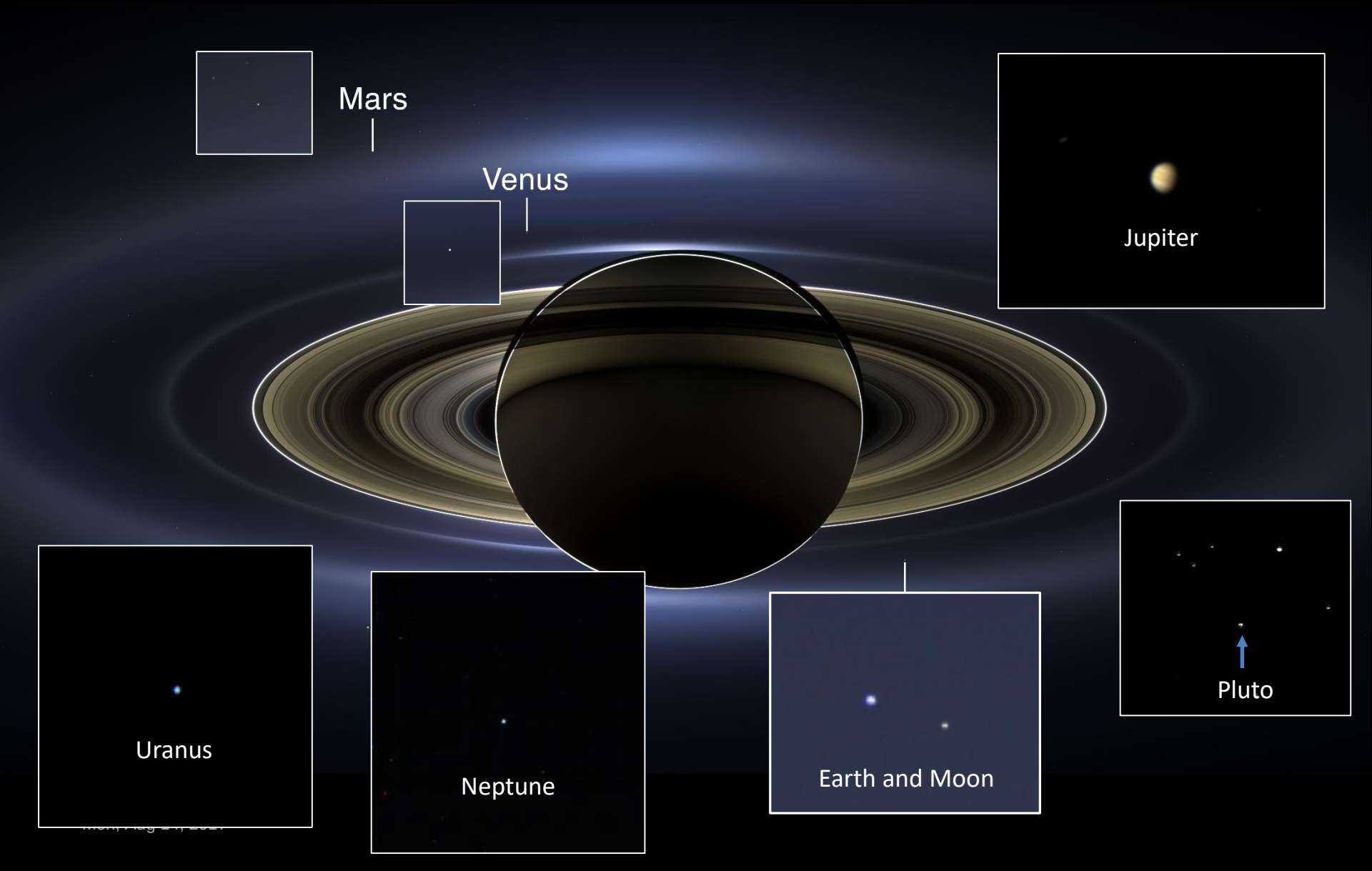


Rings Inside-Out

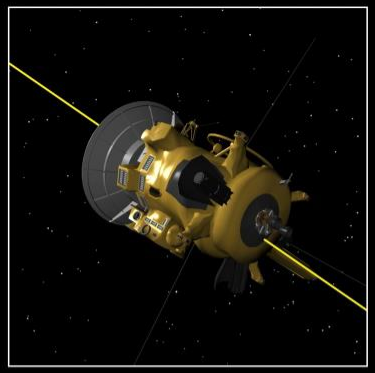
A few orbits ago, in a Ring System Not-Too-Far Away….

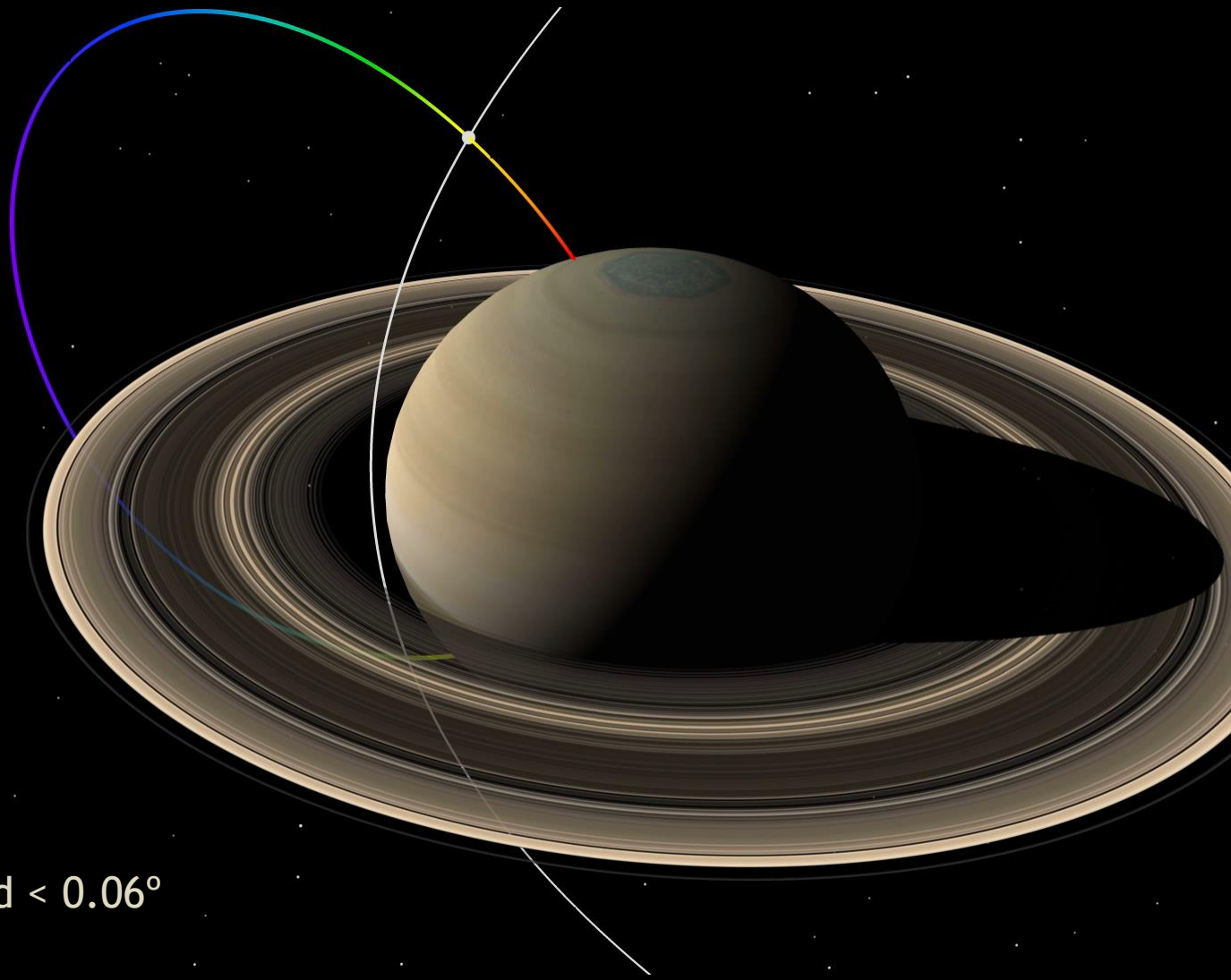


A Cassini Family Portrait



Magnetic Field Observations

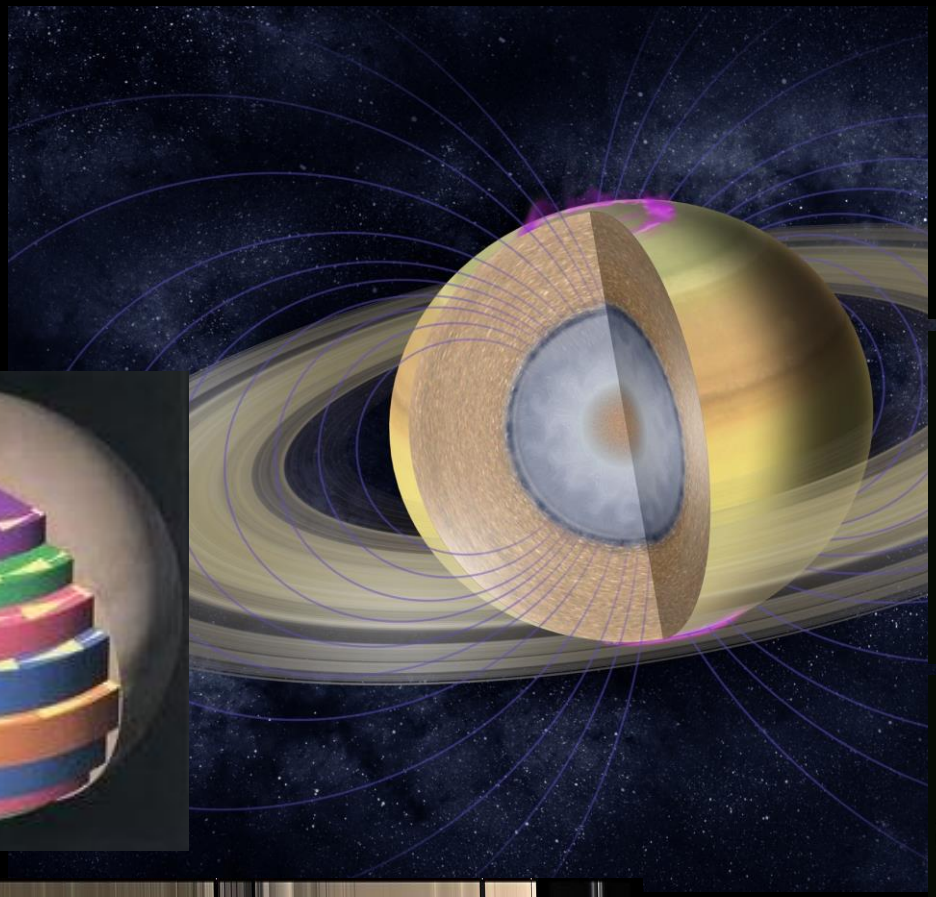


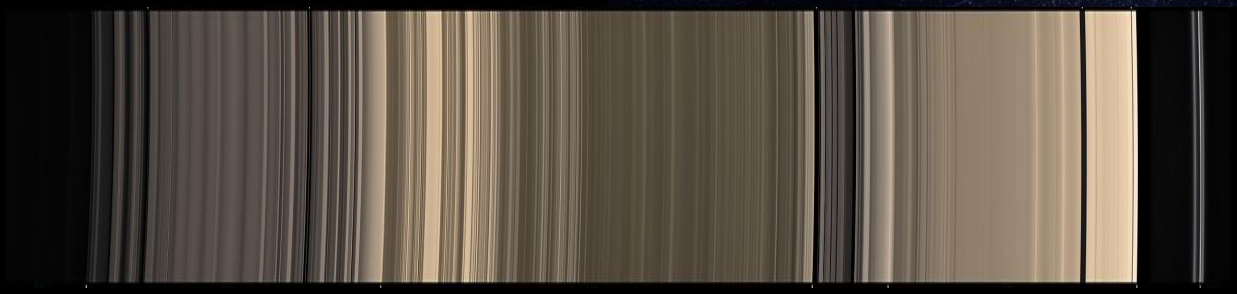


Tilt of Magnetic field < 0.06º

Probing Saturn's Interior & Ring Mass

Early analysis of gravity data so far shows discrepancies compared with parts of leading models of Saturn's interior.

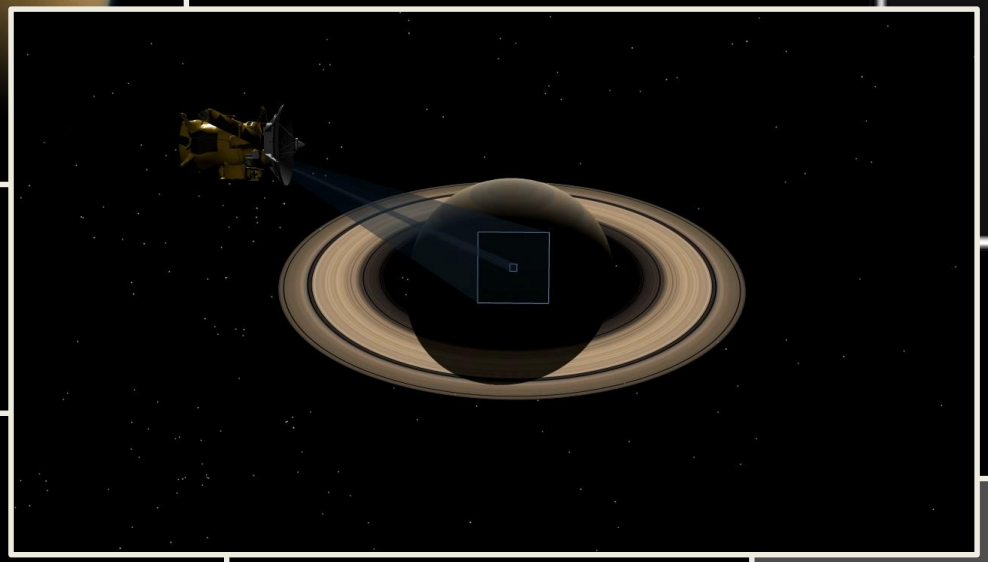


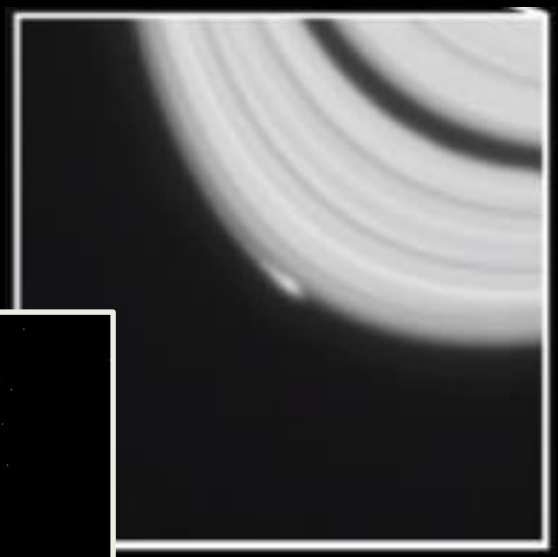


Cassini's Last Days

Titan

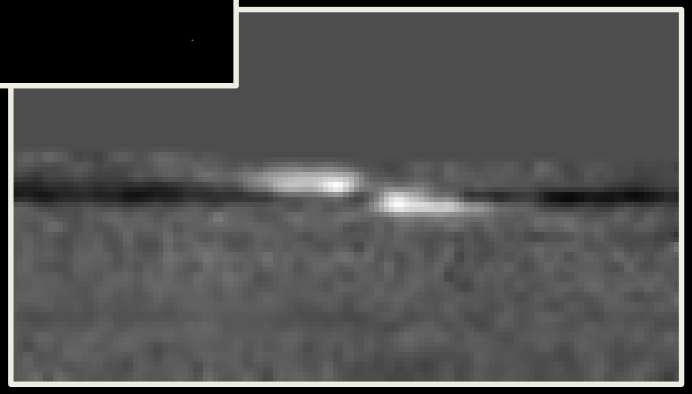
Saturn and Rings





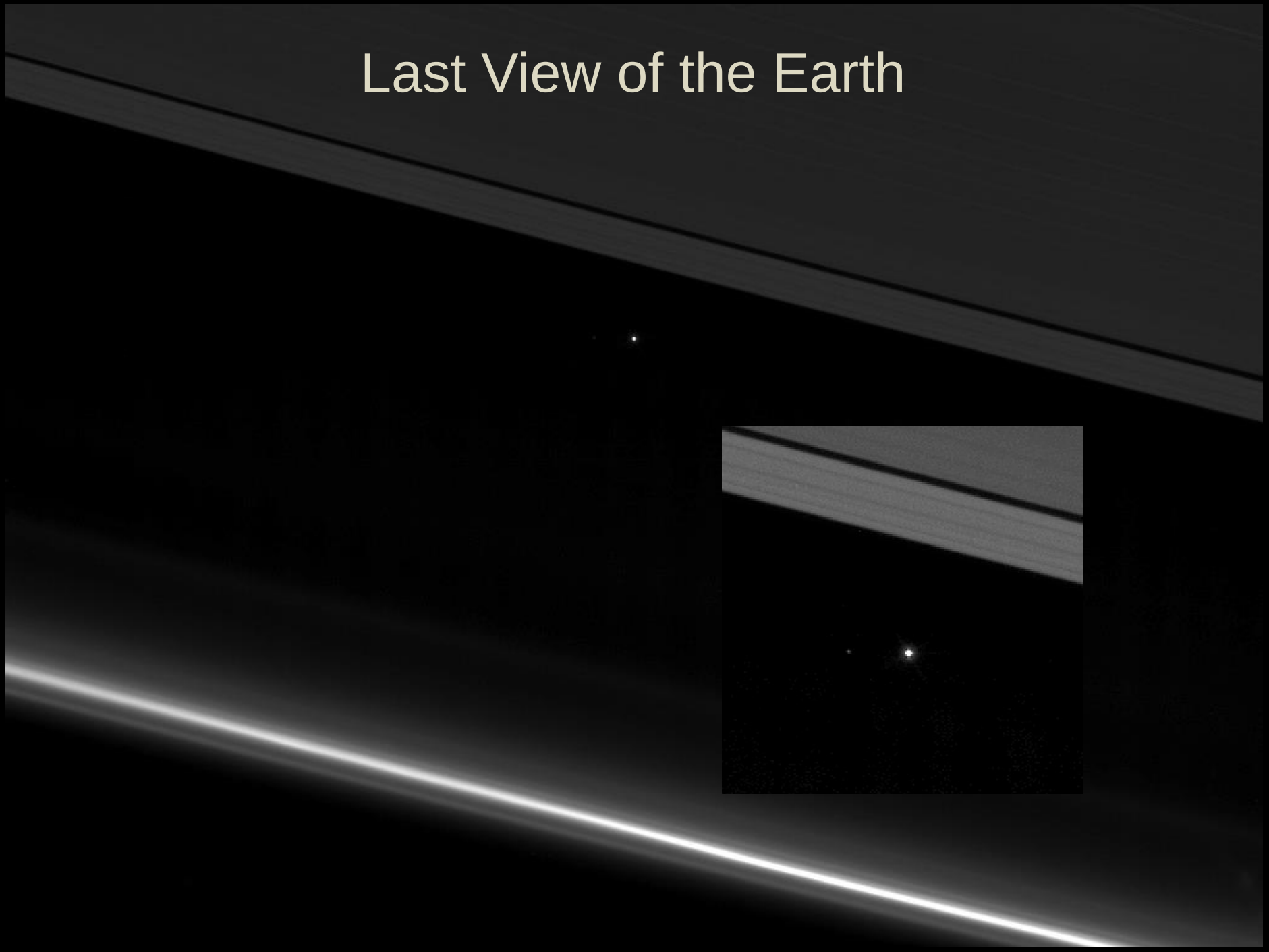
Peggy

Enceladus setting behind Saturn

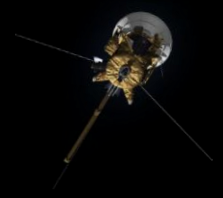


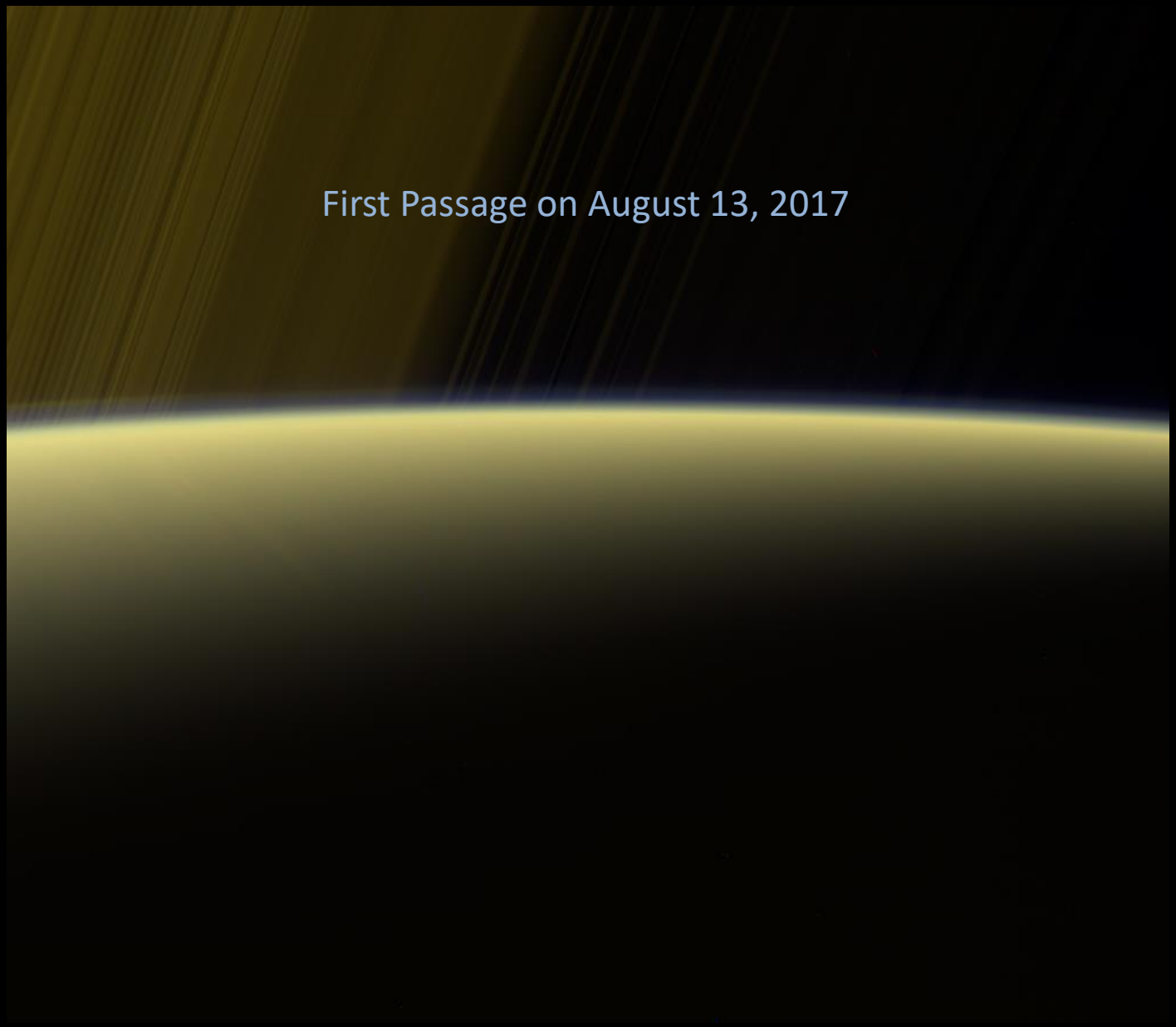
Propellers

Last View of the Earth

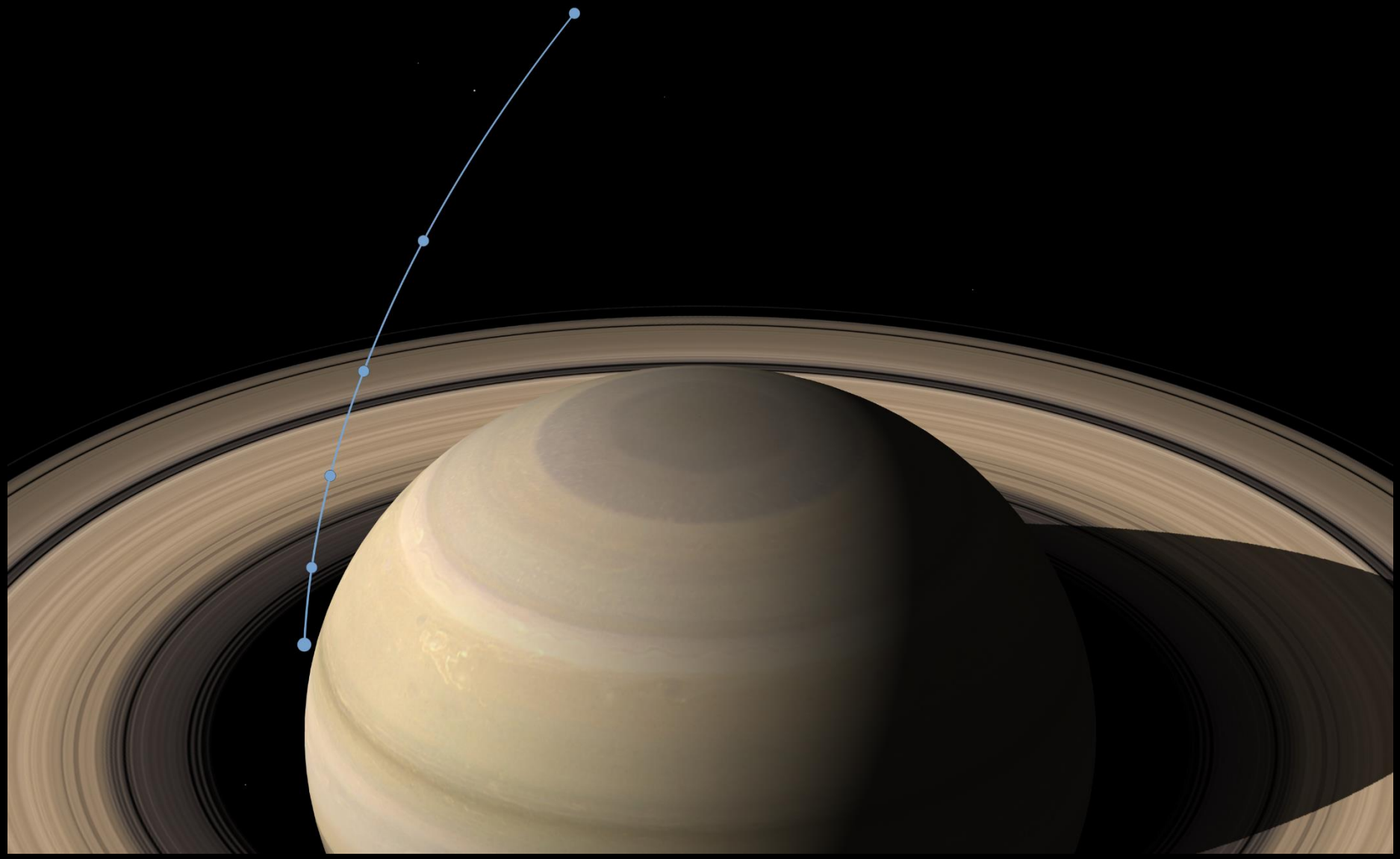


Skimming the Atmosphere

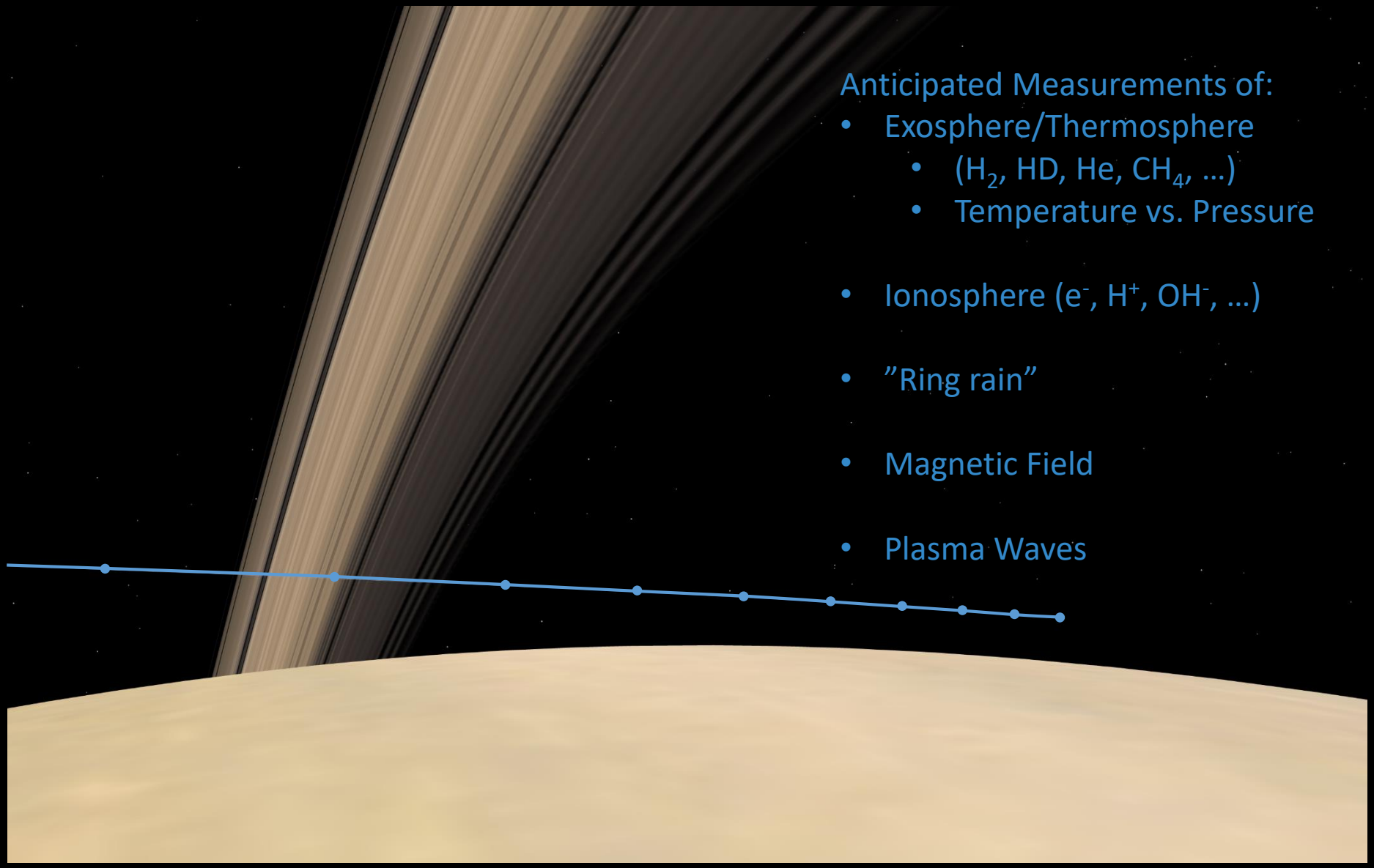




Final Hour with 10°-Lat Ticks



Final 90 Seconds with 10-sec Ticks

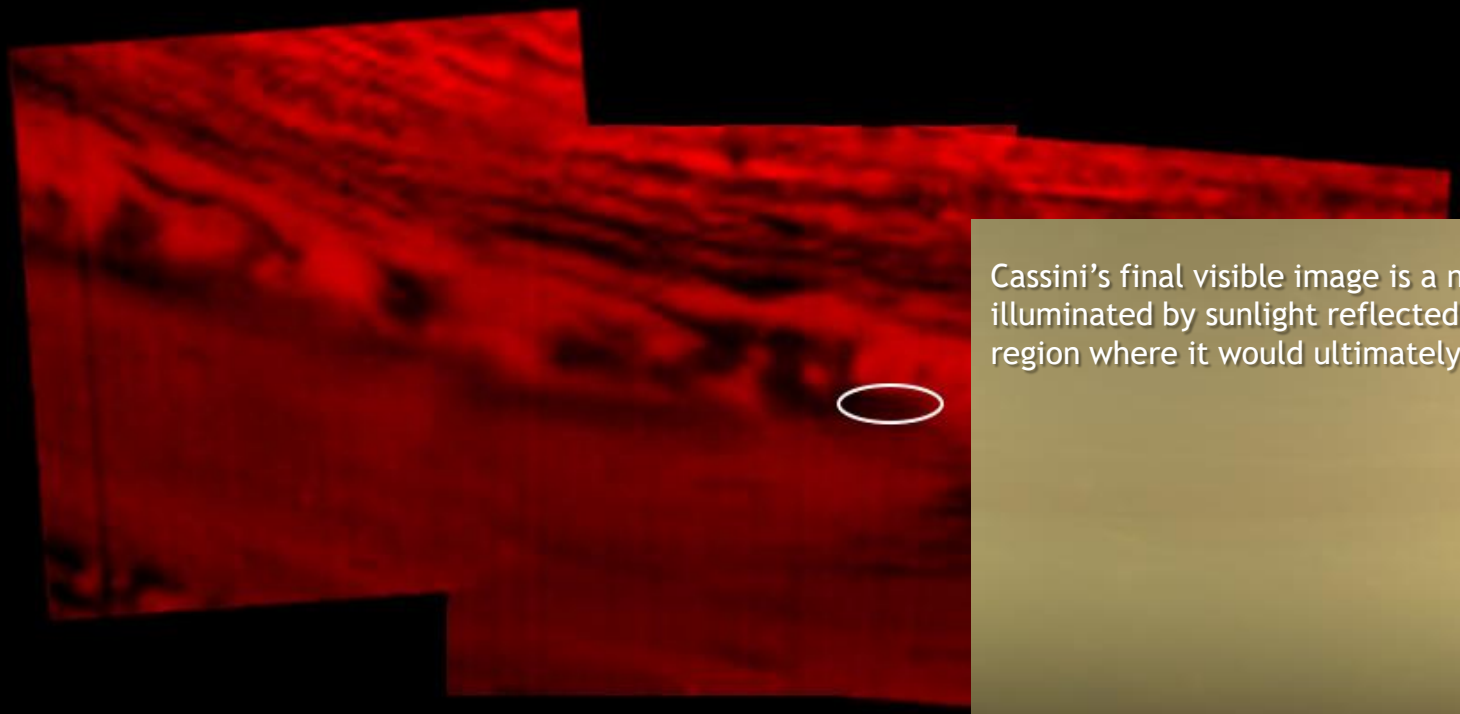


Anticipated Measurements of:

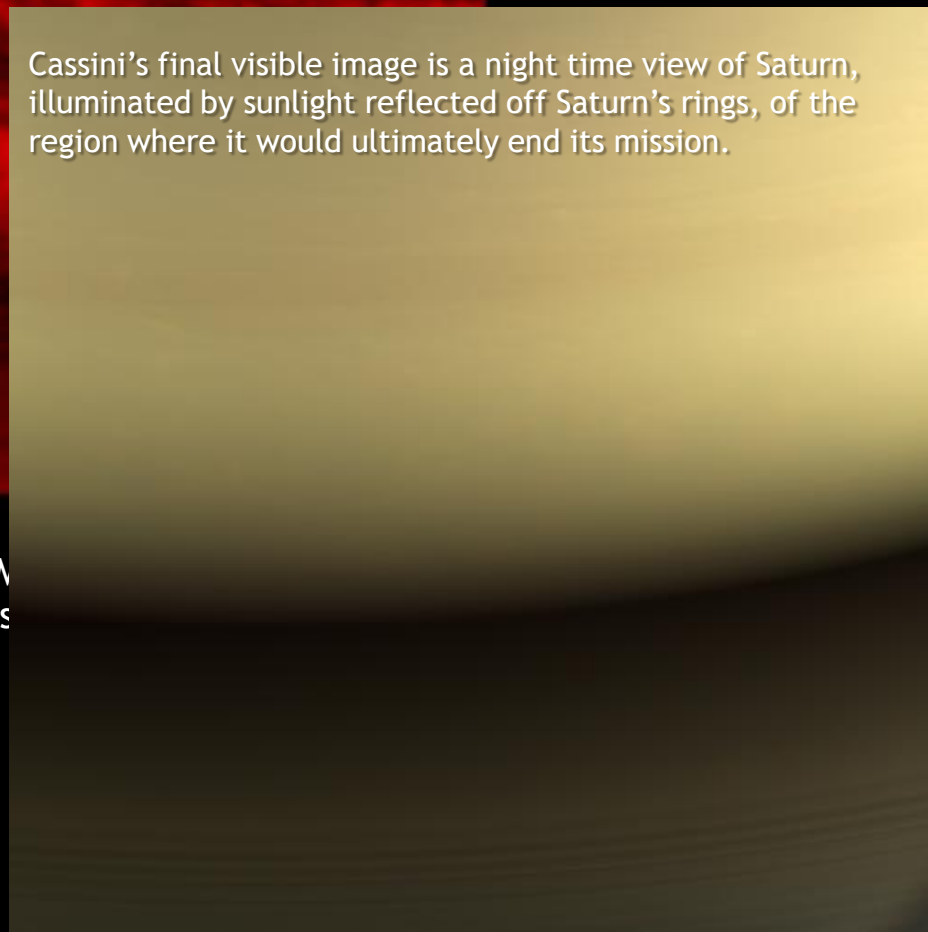
- Exosphere/Thermosphere
  - (H_2, HD, He, CH_4, …)
  - Temperature vs. Pressure
- Ionosphere (e^-, H^+, OH^-, …)
- ”Ring rain”
- Magnetic Field
- Plasma Waves

Cassini's Final Images

Cassini's final images were taken September 14, 2017, at 12:59 PM PDT



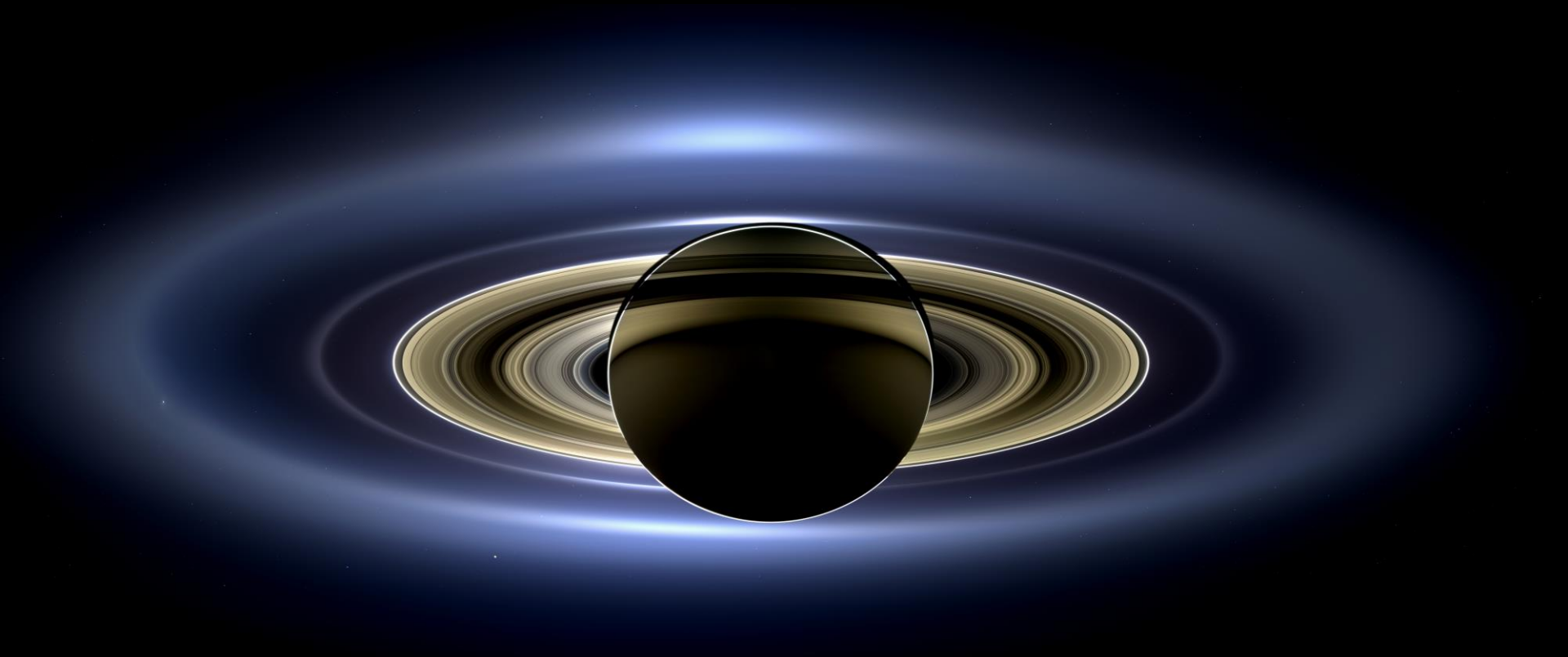
- Saturn in the thermal infrared (5 microns, from VIM
- White ellipse is where Cassini plunged into Saturn's
  north latitude, 53 degrees west longitude)



Cassini's final visible image is a night time view of Saturn, illuminated by sunlight reflected off Saturn's rings, of the region where it would ultimately end its mission.

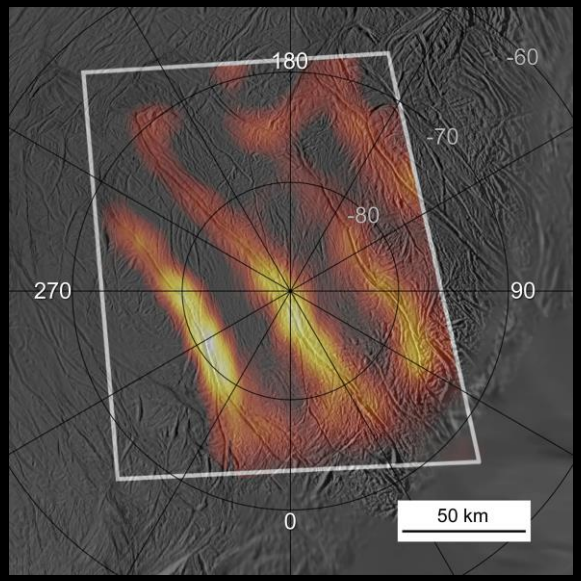
Grand Finale Movie

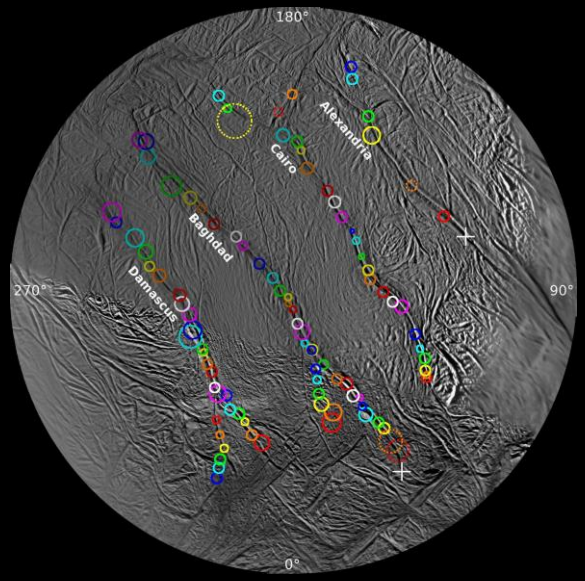
Questions?

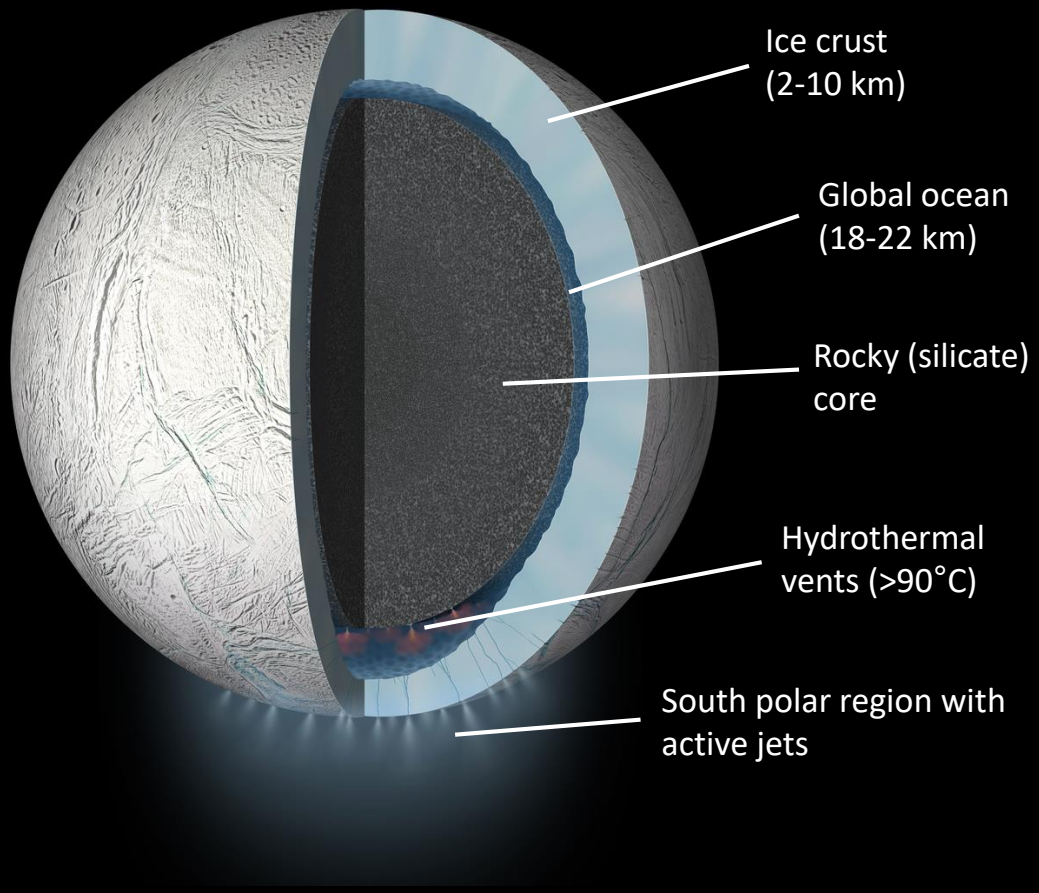


Backup

Enceladus: Active, Astrobiologically Relevant, Accessible



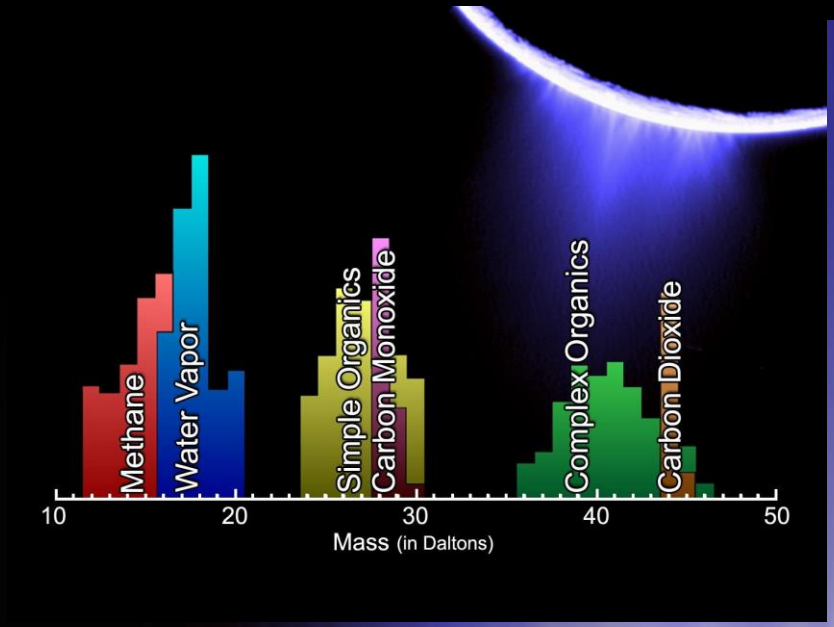


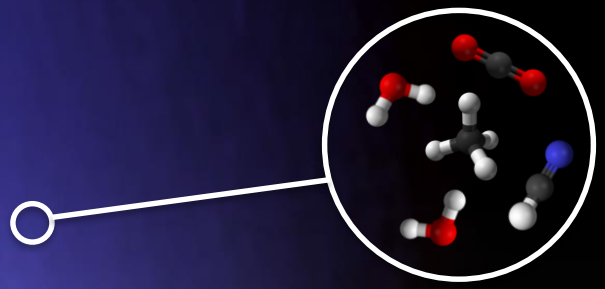


- ~100 distinct, collimated jets emanating from Tiger Stripes that form a single plume
  - Modulated by diurnal tidal flexing

Porco et al. (2014) Astron. J., 148, 3, 45.

Enceladus: Active, Astrobiologically Relevant, Accessible





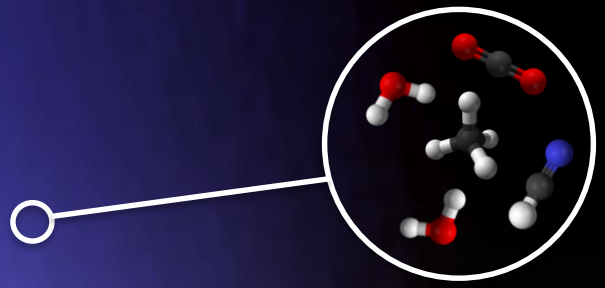
Plume gas

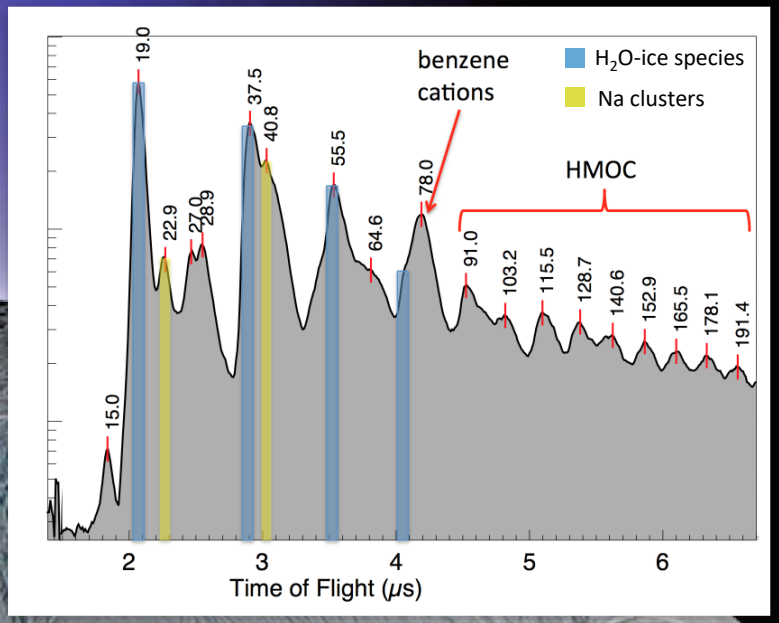
- H_2O, CO_2, CH_4, NH_3, H_2 (yay!), heavier hydrocarbons, simple and complex organics
- Mass flux: 200 kg/s

Constituent	Mixing ratio (%)
H_2O	96 to 99
CO_2	0.3 to 0.8
CH_4	0.1 to 0.3
NH_3	0.4 to 1.3
H_2	0.4 to 1.4

Waite et al. (2009) Nature 460, 487-490. Waite et al. (2017) Science 356, 155-159.

Enceladus: Active, Astrobiologically Relevant, Accessible



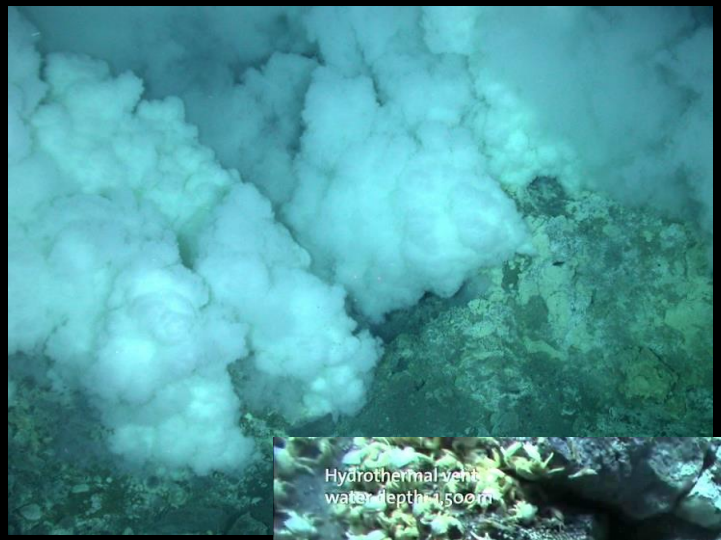


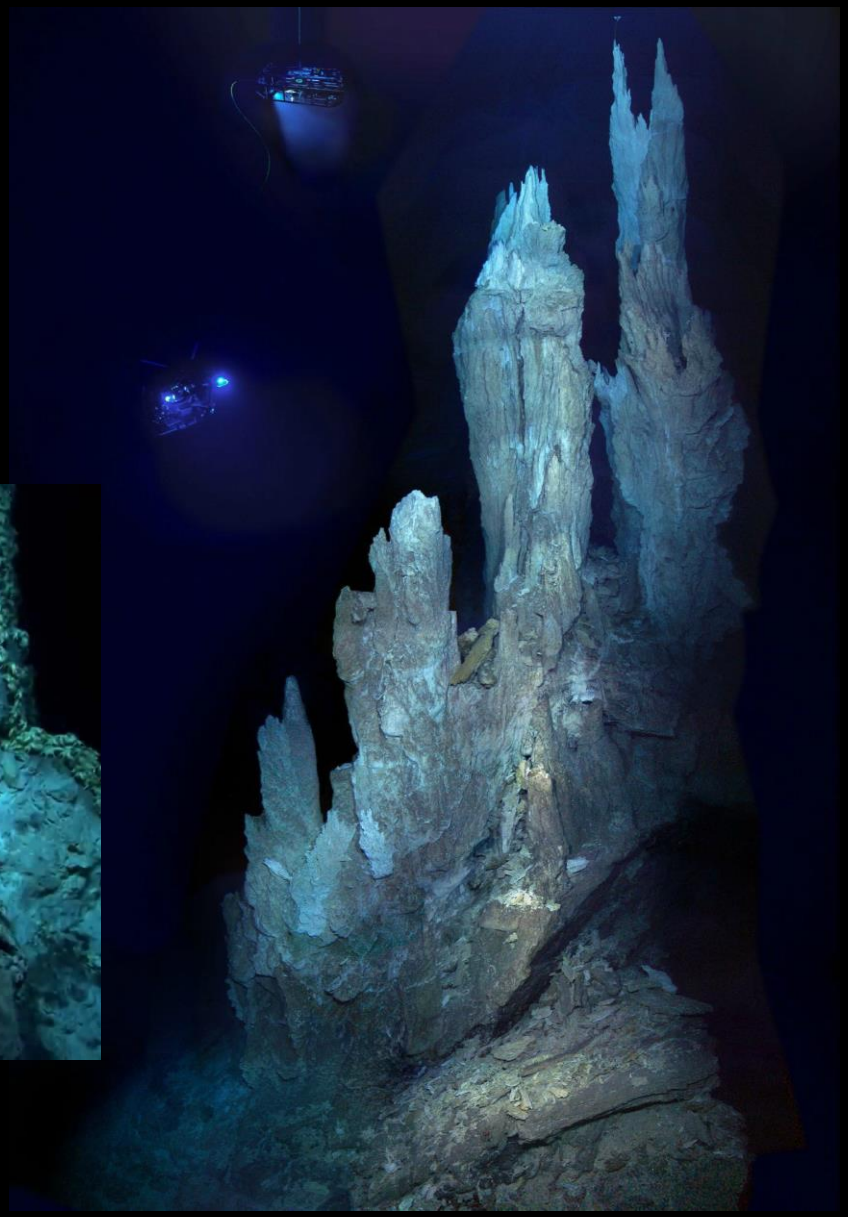
Plume grains

- Water-ice, salts (mostly NaCl), SiO_2, high mass organic cations (HMOC)
- Mass flux: 50 kg/s (~10% of particles reach escape velocity)

Postberg et al. (2009) Nature, 459, 1098-1101. Postberg et al. (2017) LPSC abstract no. 1401.

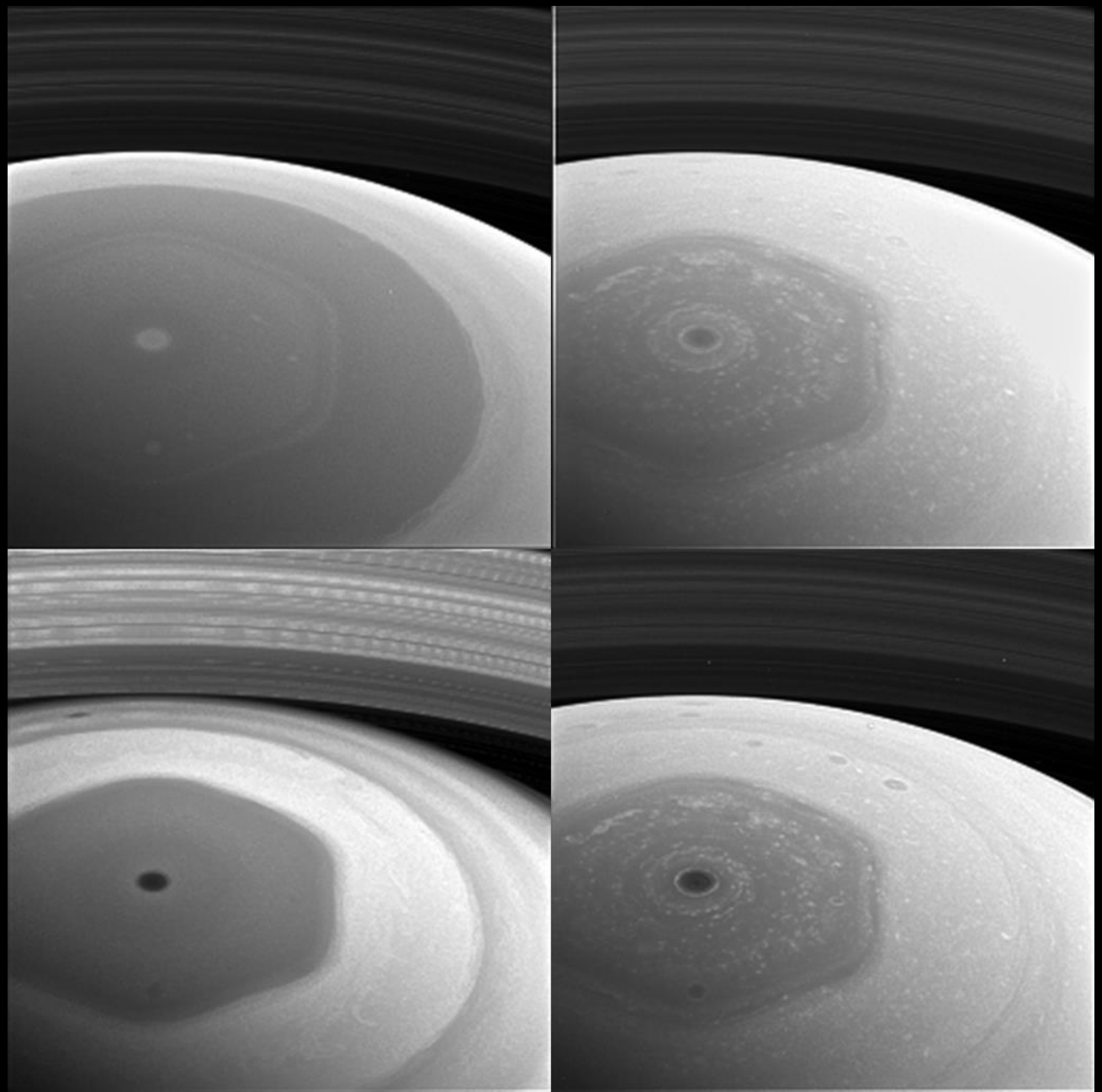
Enceladus: Active, Astrobiologically Relevant, Accessible



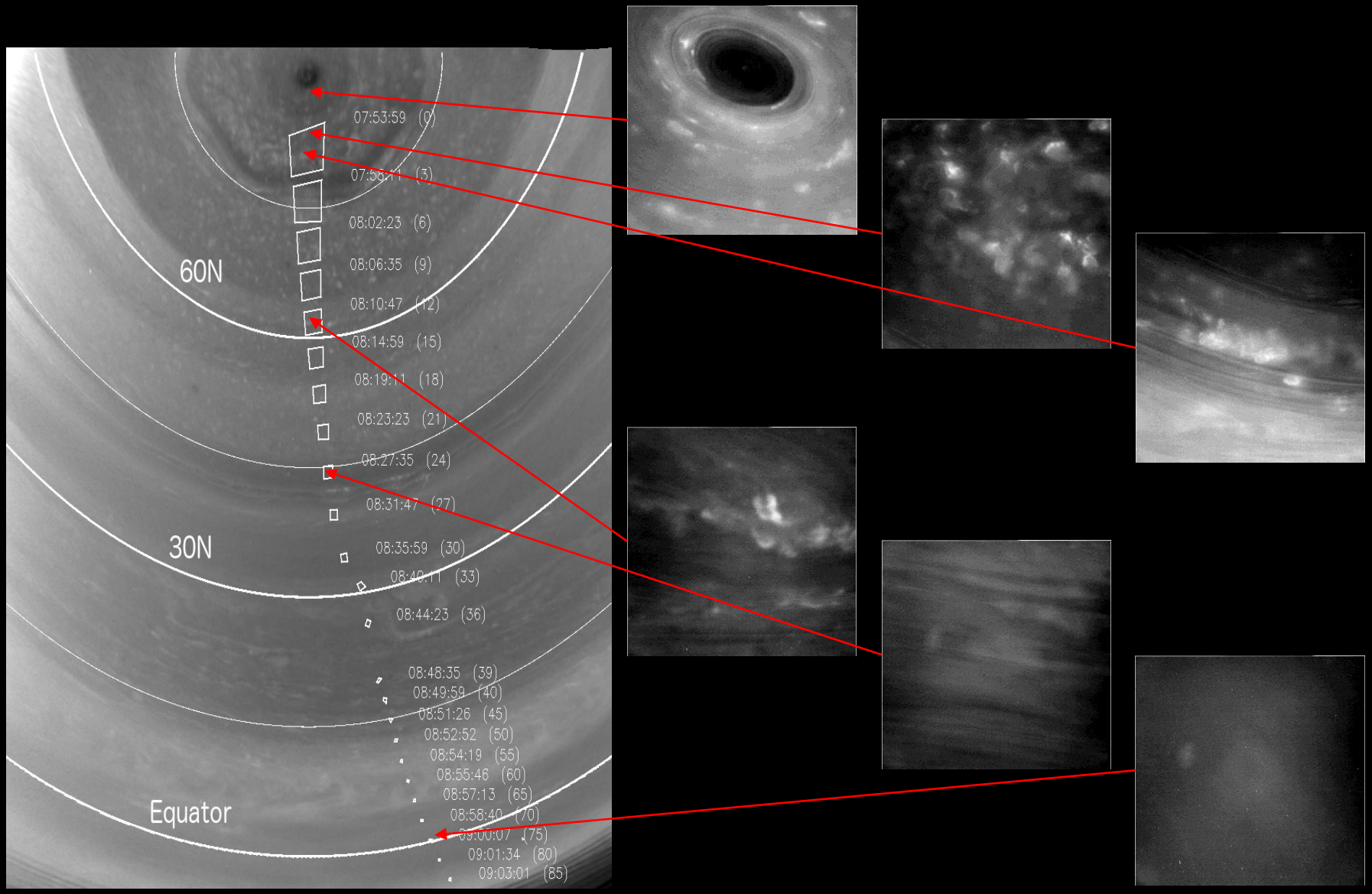


Kelley et al. (2005) Science, 307, 1428-1434.

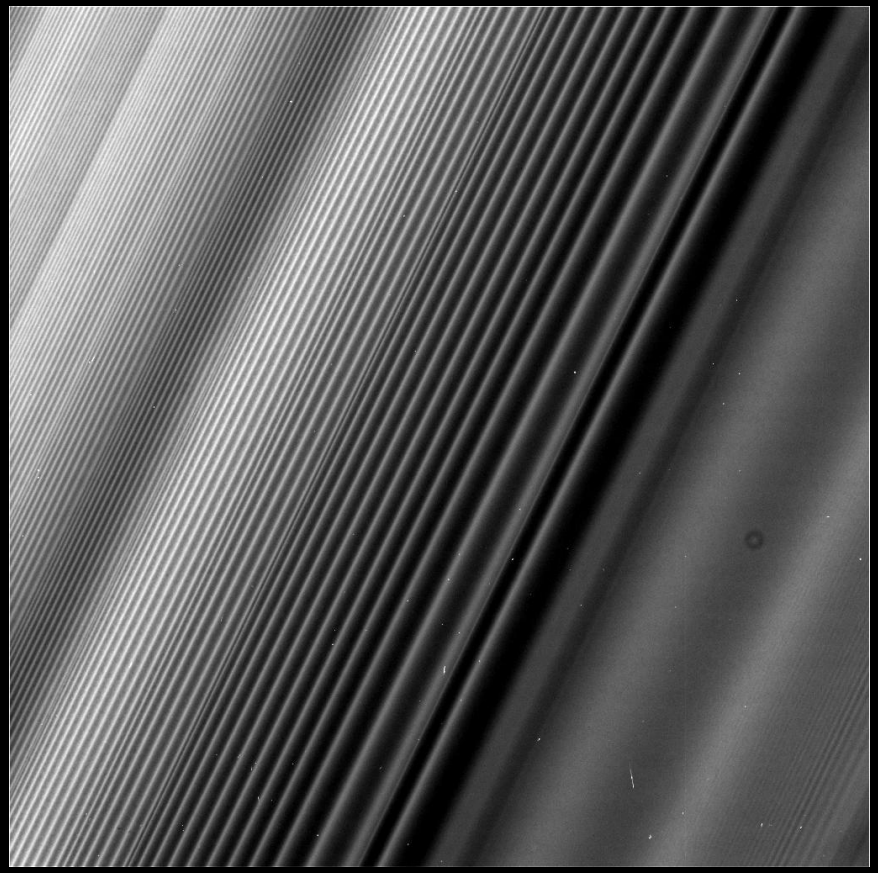
Soaring Over Saturn's North

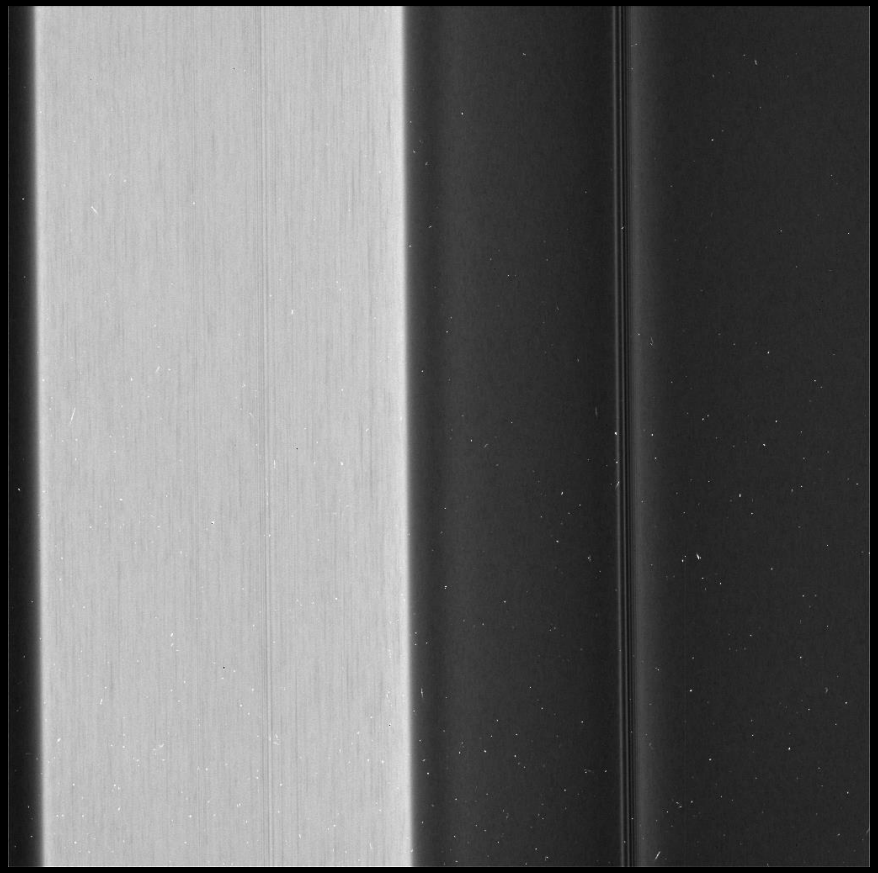


The View from the Gap



Saturn’s Rings at High Resolution





Grand Finale Timeline

November 30, 2016

- F-ring Orbits Begin
  - 20 orbits
  - 3 maneuvers

April 22, 2017

- Last Targeted Titan Flyby
  - Produces Grand Finale trajectory

April 23, 2017

- Grand Finale Begins
  - 22½ orbits
  - 9 non-targeted Titan flybys

April 26, 2017

- First dive through gap

September 11, 2017

- Last Non-targeted Titan Flyby
  - Puts Cassini on impact trajectory

September 15, 2017

- Saturn Impact

Cassini Grand Finale

Rev	271	272	273	274	275	276	277	278	279	280	281
	Intermediate Altitude Periapses (~63,000 km)					High Altitude Periapses (~64,000 km)					
RCS control at periapse		RCS 3:08									
Sequence	S99	S99	S99	S99	S99	S100	S100	S100	S100	S100	S100
Segment owner	Saturn	XD	Maps	Rings	Saturn	Rings	Rings	Saturn	Maps	XD	Saturn
peri-12 to -6 hrs			RSS	RSS	RSS			RSS		RSS	
peri -6 to -5 hrs			RSS	RSS	RSS			RSS		RSS	
peri -5 to -4 hrs		MAG	RSS/MAG	RSS	RSS			RSS		RSS	
peri -4 to -3 hrs		MAG	RSS/MAG	RSS	RSS			RSS		RSS	
peri -3 to -2 hrs		MAG	RSS/MAG	RSS	RSS			RSS		RSS	
peri -2 to -1 hrs	CIRS N Pol	MAG	RSS/MAG	RSS	RSS	RADAR Rings	ISS Rings	RSS		RSS	ISS Saturn
peri-60 to-45 min	ISS Saturn	MAG	RSS/MAG	RSS/CDA	RSS/CDA	RADAR Rings	ISS Rings	RSS/CDA	INMS/CDA	RSS/CDA	ISS Saturn
peri -45 to-30 min	ISS Saturn	MAG	RSS/MAG	RSS/CDA	RSS/CDA	RADAR Rings	ISS Rings	RSS/CDA	INMS/CDA	RSS/CDA	ISS Saturn
peri-30 to-10 min											
peri-10 to -0 min											
peri 0 to +10 min											
peri+10 to+30 min											
peri+30 to +45min	ISS Saturn		RSS/MAG	RSS/CDA	RSS/CDA	ISS Rings	RADAR Rings	RSS/CDA	INMS/CDA	RSS/CDA	ISS Saturn
peri +45 to +60 min	ISS Saturn	MAG	RSS/MAG	RSS/CDA	RSS/CDA	ISS Rings	RADAR Rings	RSS/CDA	INMS/CDA	RSS/CDA	ISS Saturn
peri+1 to +2 hrs	CIRS S Pol	MAG	RSS/MAG	RSS	RSS	ISS Rings	RADAR Rings	RSS		RSS	CIRS S Pol
peri+2 to +3 hrs		MAG	RSS/MAG	RSS	RSS			RSS		RSS	
peri+3 to +4 hrs		MAG	RSS/MAG	RSS	RSS			RSS		RSS	
peri+4 to +5 hrs		MAG	RSS/MAG	RSS	RSS			RSS		RSS	
peri+5 to +7 hrs			RSS	RSS	RSS			RSS		RSS	
peri+7 to +12 hrs			RSS	RSS	RSS			RSS		RSS	

Rev	282	283	284	285	286	287	288	289	290	291	292
	Intermediate Altitude Periapses (~63,000 km)					Low Altitude Periapses (62,000 km)					
RCS control at periapse				RCS 3:55			RCS 2:17	RCS 2:10	RCS 3:19	RCS 2:15	RCS 2:15
Sequence	S100	S101	S101	S101	S101	S101	S101	S101	S101	S101	S101
Segment owner	Rings	Rings	Saturn	Maps	SOST	Maps	Saturn	Maps	Saturn	Saturn	Saturn
peri-12 to -6 hrs			RSS								
peri -6 to -5 hrs			RSS								
peri -5 to -4 hrs			RSS/MAG	MAG							
peri -4 to -3 hrs			RSS/MAG	MAG							
peri -3 to -2 hrs			RSS/MAG	MAG							
peri -2 to -1 hrs	UVIS Rings		RSS/MAG	MAG					RCS xtion		
peri-60 to-45 min	UVIS Rings	INMS/CDA	RSS/MAG	MAG	COLD AUR	INMS/CDA	INMS/CDA*	AUR INB	RADAR Saturn	INMS**	INMS***
peri -45 to-30 min	UVIS Rings	INMS/CDA	RSS/MAG	MAG	COLD AUR	INMS/CDA	INMS/CDA*	COLD	RADAR Saturn	INMS**	INMS***
peri-30 to-10 min											
peri-10 to -0 min											
peri 0 to +10 min											
peri+10 to+30 min											
peri+30 to +45min	RADAR Rings						INMS/CDA*	CIRS S Pol	RADAR Saturn		
peri +45 to +60 min	RADAR Rings	INMS/CDA	RSS/MAG	MAG	COLD AUR	INMS/CDA	INMS/CDA*	CIRS S Pol	RADAR Saturn	INMS**	INMS***
peri+1 to +2 hrs	RADAR Rings		RSS/MAG	MAG	COLD AUR		RCS xtion		RCS xtion	RCS xtion	RCS xtion
peri+2 to +3 hrs			RSS/MAG	MAG	COLD AUR/ENC						
peri+3 to +4 hrs			RSS/MAG	MAG	COLD ENC						
peri+4 to +5 hrs			RSS/MAG	MAG	COLD ENC						
peri+5 to +7 hrs			RSS		COLD ENC						
peri+7 to +12 hrs			RSS								