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# Saturn Interior and Atmosphere

Andrew Ingersoll, Caltech  
Saturn Discipline Working Group

This talk was originally presented at the  
Cassini Solstice Mission Senior Review  
on February 10, 2009



## XXM Prioritized Objectives for Saturn

**SC1a** - Observe seasonal variations in temperature, clouds, and composition in three spatial dimensions.

**SC1b** - Observe seasonal changes in the winds at all accessible altitudes coupled with simultaneous observations of clouds, temperatures, composition, and lightning.

**SC2a** - Observe the magnetosphere, ionosphere, and aurora as they change on all time scales - minutes to years - and are affected by seasonal and solar cycle forcing.

**SN1a** - Determine Saturn's rotation rate and internal structure despite the planet's unexpected high degree of axisymmetry.

**SN1b** - Study the life cycles of Saturn's newly discovered atmospheric waves, south polar hurricane, and newly rediscovered north polar hexagon.

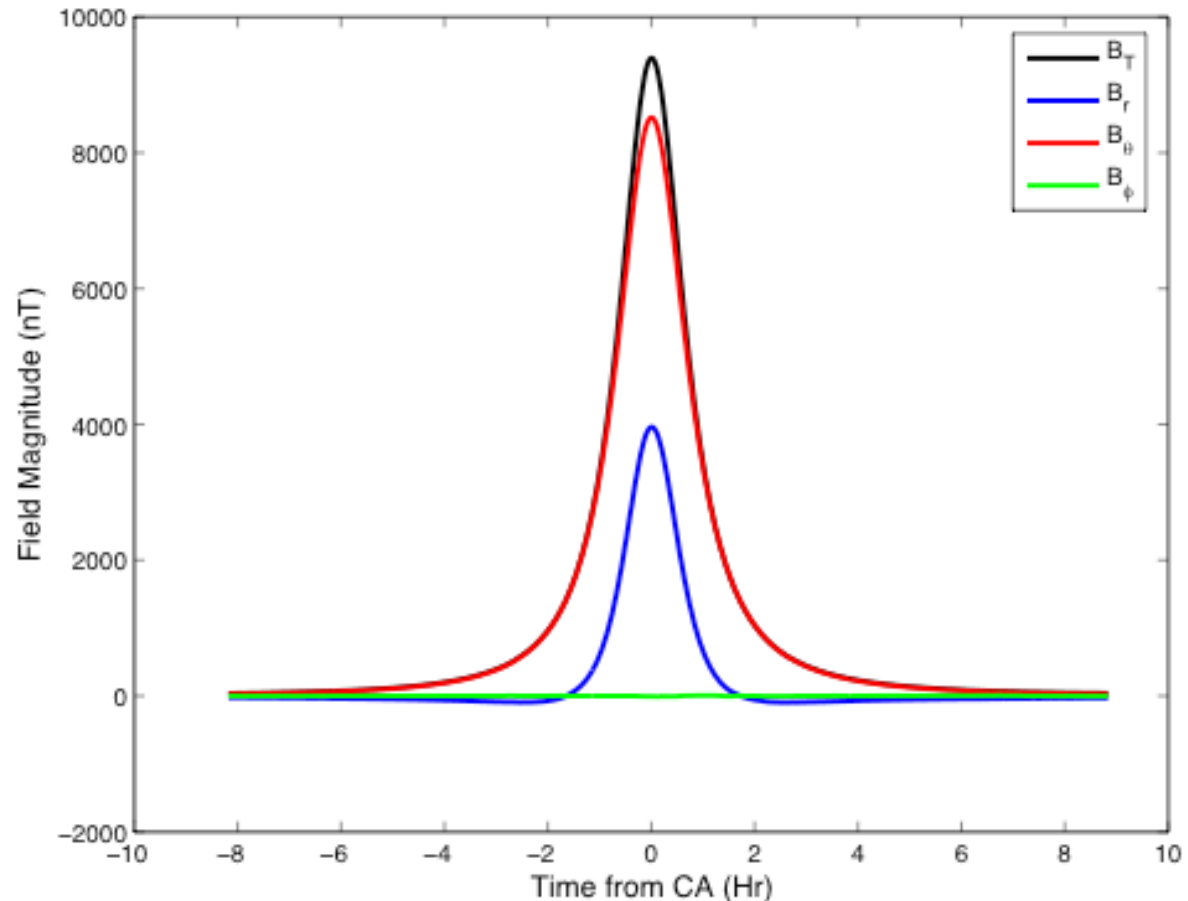
**SN1c** - Measure the spatial and temporal variability of trace gases and isotopes.

**SN2a** - Observe Saturn's newly discovered lightning storms

## XXM Priority 1 Objectives for Saturn

**SN1a** - Determine Saturn's rotation rate and internal structure despite the planet's unexpected high degree of axisymmetry.

MAG data during Saturn Orbit Insertion – field is axisymmetric so deep rotation is still unknown. Determination is possible during end-of-mission orbits



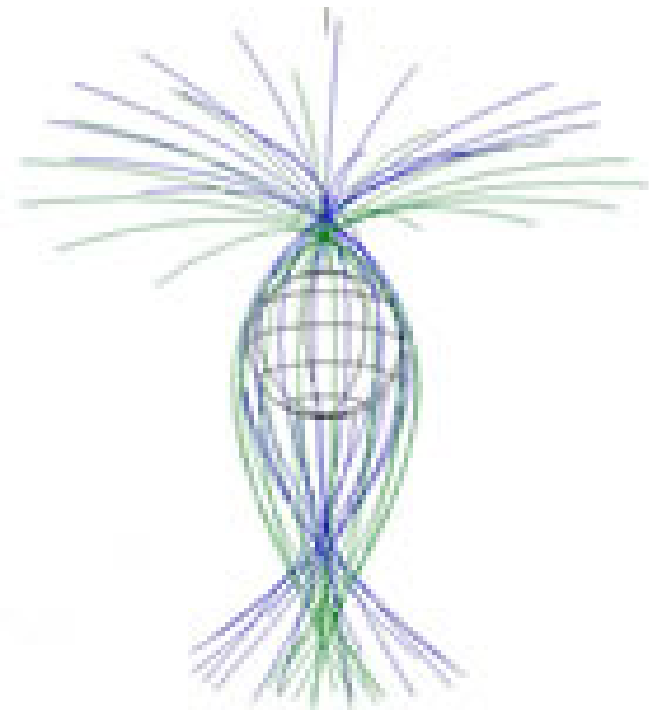


## XXM Priority 1 Objectives for Saturn

**SN1a** - Determine Saturn's rotation rate and internal structure despite the planet's unexpected high degree of axisymmetry.

*Cassini*

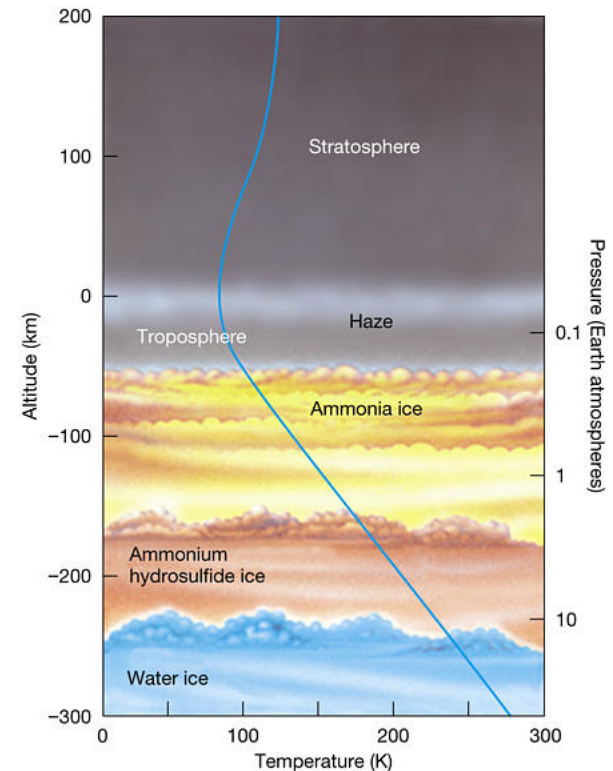
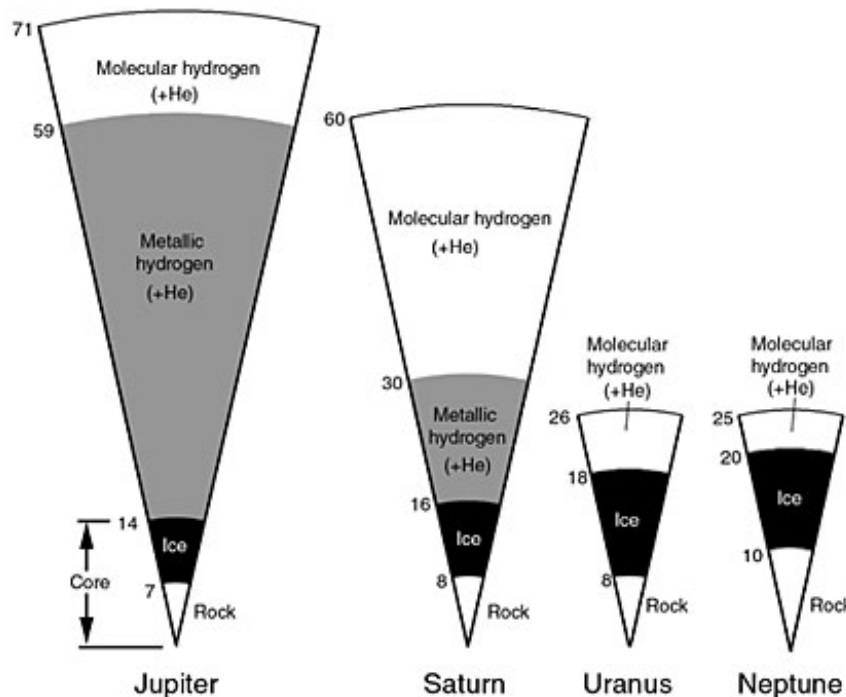
~~Juno~~ trajectories - mapping the internal gravitational and magnetic fields: latitude of periapse  $\approx 0^\circ$ , longitude of periapse  $\approx$  equally spaced at intervals of  $12^\circ$



# XXM Priority 1 Objectives for Saturn

**SN1a - Determine Saturn's rotation rate and internal structure despite the planet's unexpected high degree of axisymmetry.**

- Determine He/H<sub>2</sub> - Use IR spectrum from CIRS, or
- T from CIRS and T/m from RSS radio occ
- T from CIRS and T/m from VIMS stellar occ
- T and T/m from UVIS stellar occ



## XXM Priority 1 Objectives for Saturn

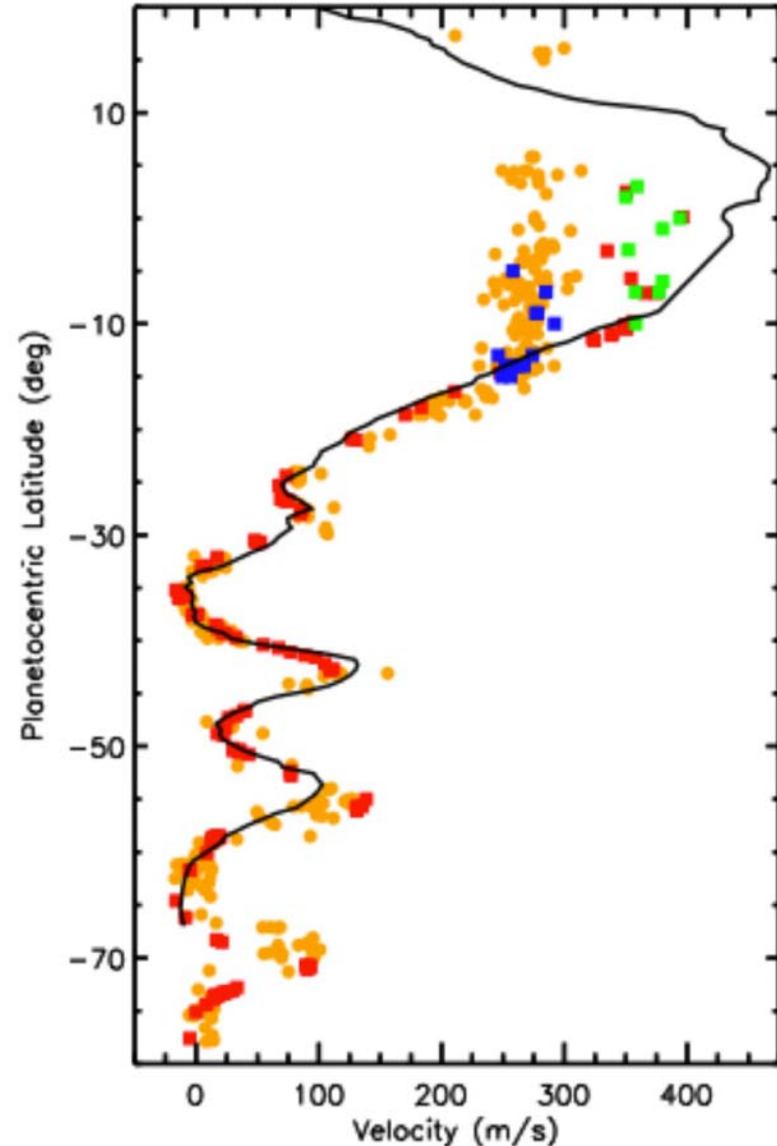
**SC1b** - Observe seasonal changes in the winds at all accessible altitudes coupled with simultaneous observations of clouds, temperatures, composition, and lightning.

Winds are measured relative to the internal rate of rotation

Are the winds changing, or are we seeing wind shear?

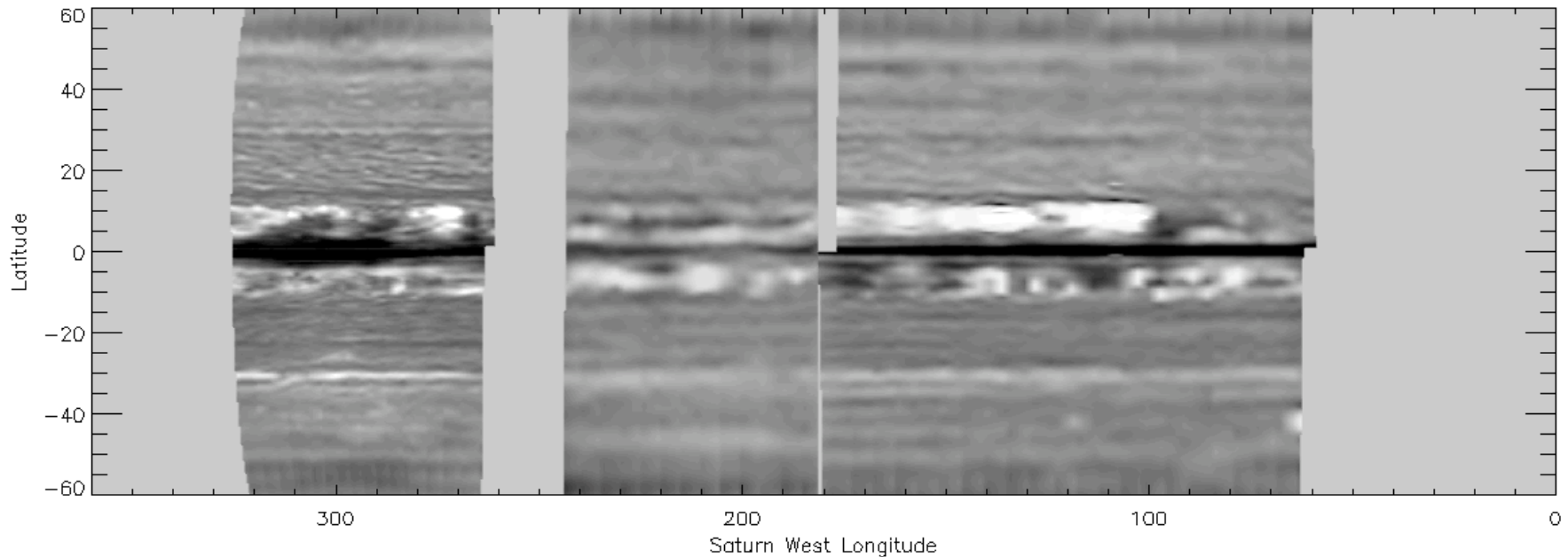
Black line: Voyager. Yellow: HST

Red & Green: ISS Cassini continuum  
Blue: ISS Cassini methane



## XXM Priority 1 Objectives for Saturn

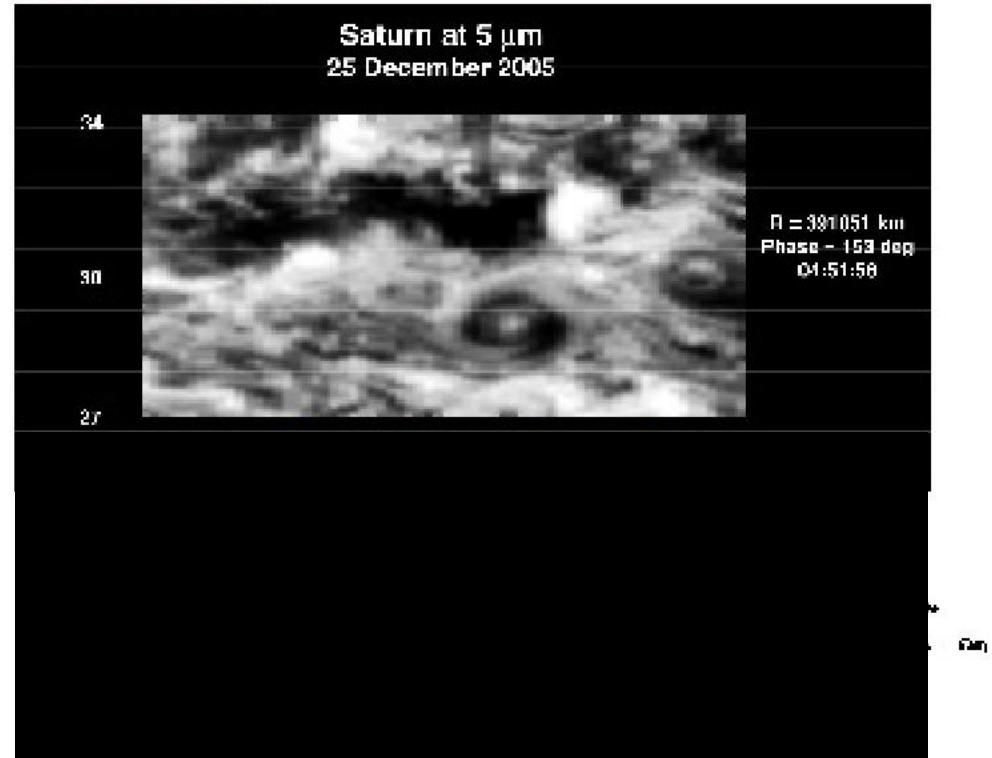
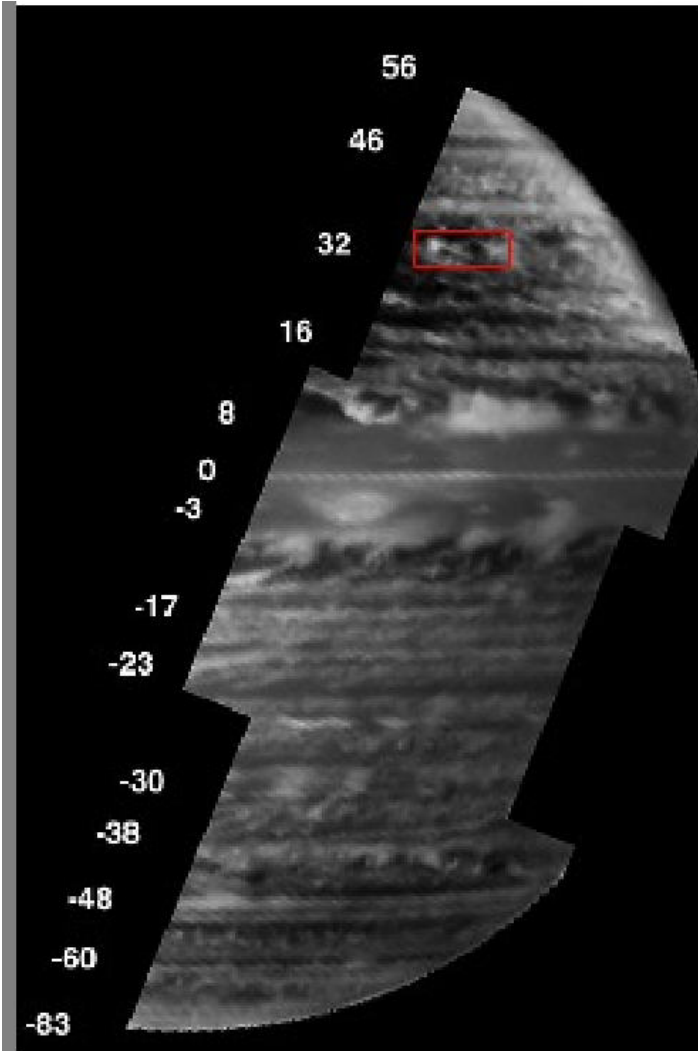
**SC1a** - Observe seasonal variations in temperature, clouds, and composition in three spatial dimensions.



Thermal emission at 2 cm – a new view of Saturn. Bright areas are regions of low ammonia abundance ( $\Delta T_b \approx 15$  K), possibly a sign of downwelling. Dark band at equator is due to the rings

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VIMS 5-micron imaging in thermal emission reveals deep clouds below the visible layers



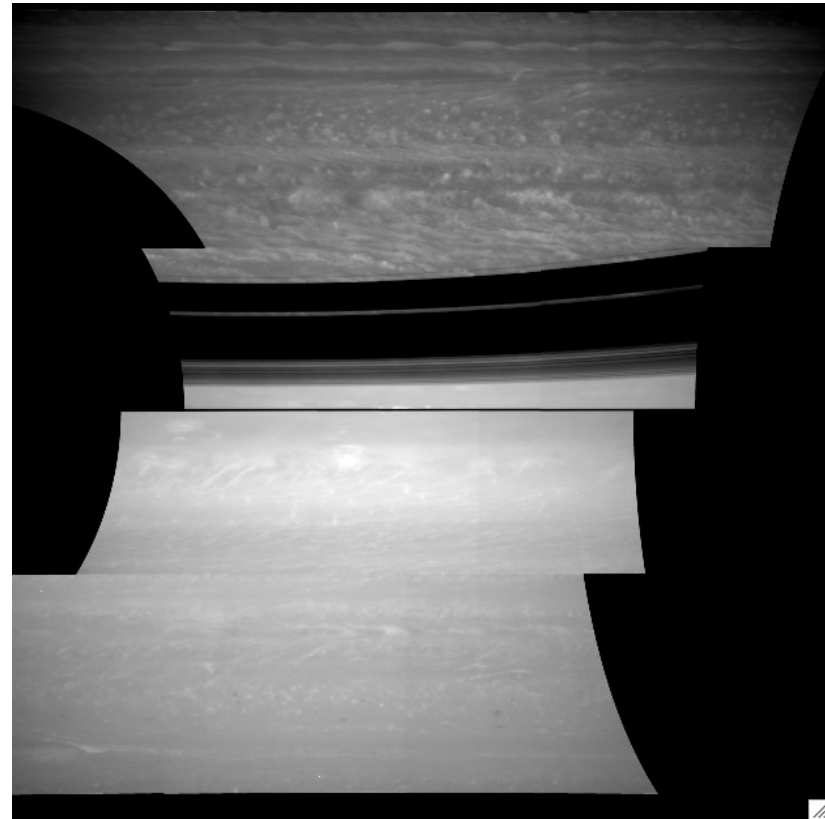
## XXM Priority 1 Objectives for Saturn

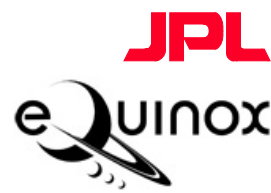
**SC1a** - Observe seasonal variations in temperature, clouds, and composition in three spatial dimensions.

**SC1b** - Observe seasonal changes in the winds at all accessible altitudes coupled with simultaneous observations of clouds, temperatures, composition, and lightning.

Cloud texture, a measure of dynamic activity, in north is different from that in south in late southern summer

Tilted structures (north in this image) and tilted velocity vectors are evidence of momentum transfer between eddies and jets

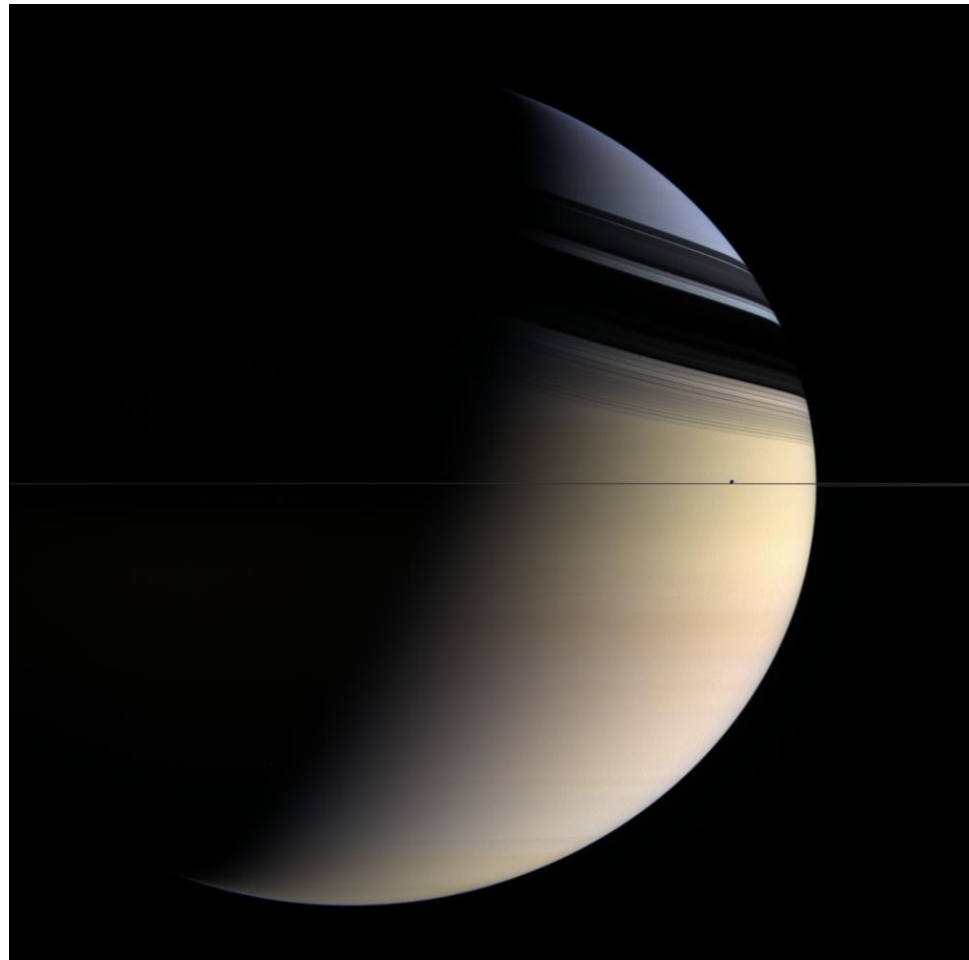


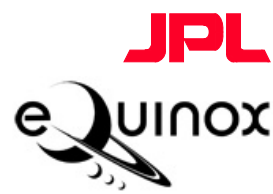


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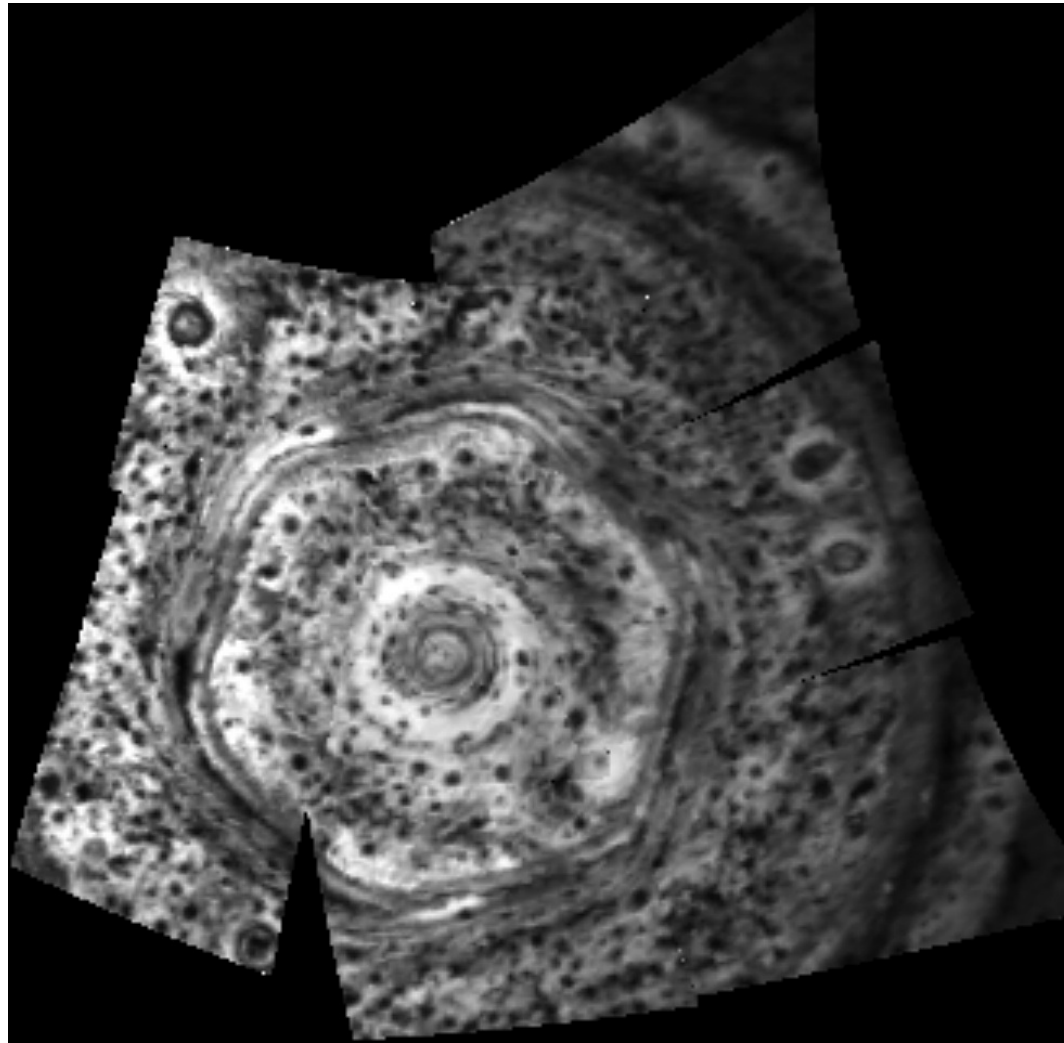
Blue color in north is Rayleigh scattering by gas. Pinkish-yellow in south is due to haze, which builds up in summer like LA smog





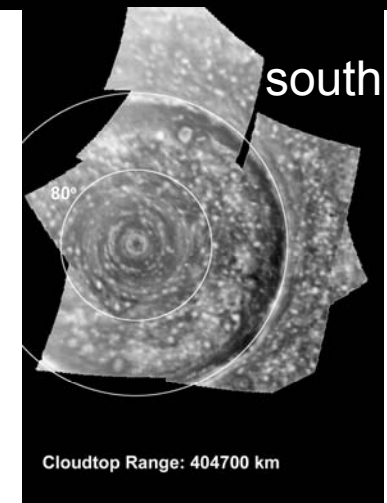
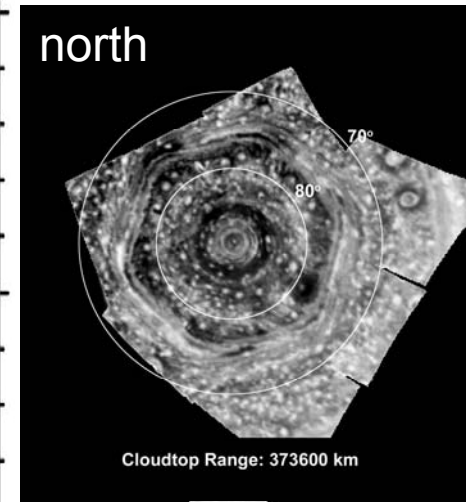
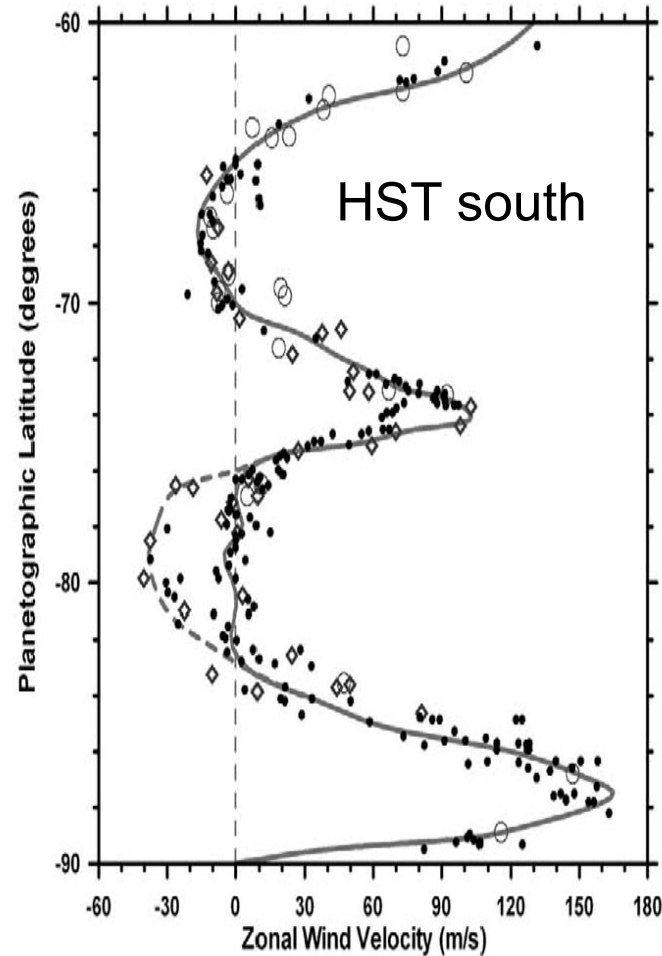
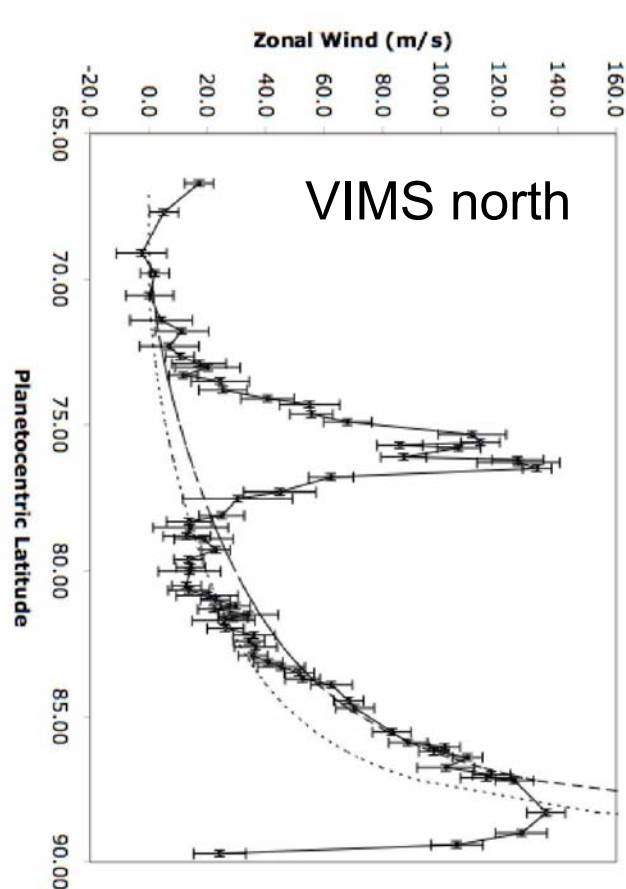
## XXM Priority 1 Objectives for Saturn

**SN1b** - Study the life cycles of Saturn's newly discovered atmospheric waves, south polar hurricane, and **newly rediscovered north polar hexagon.**



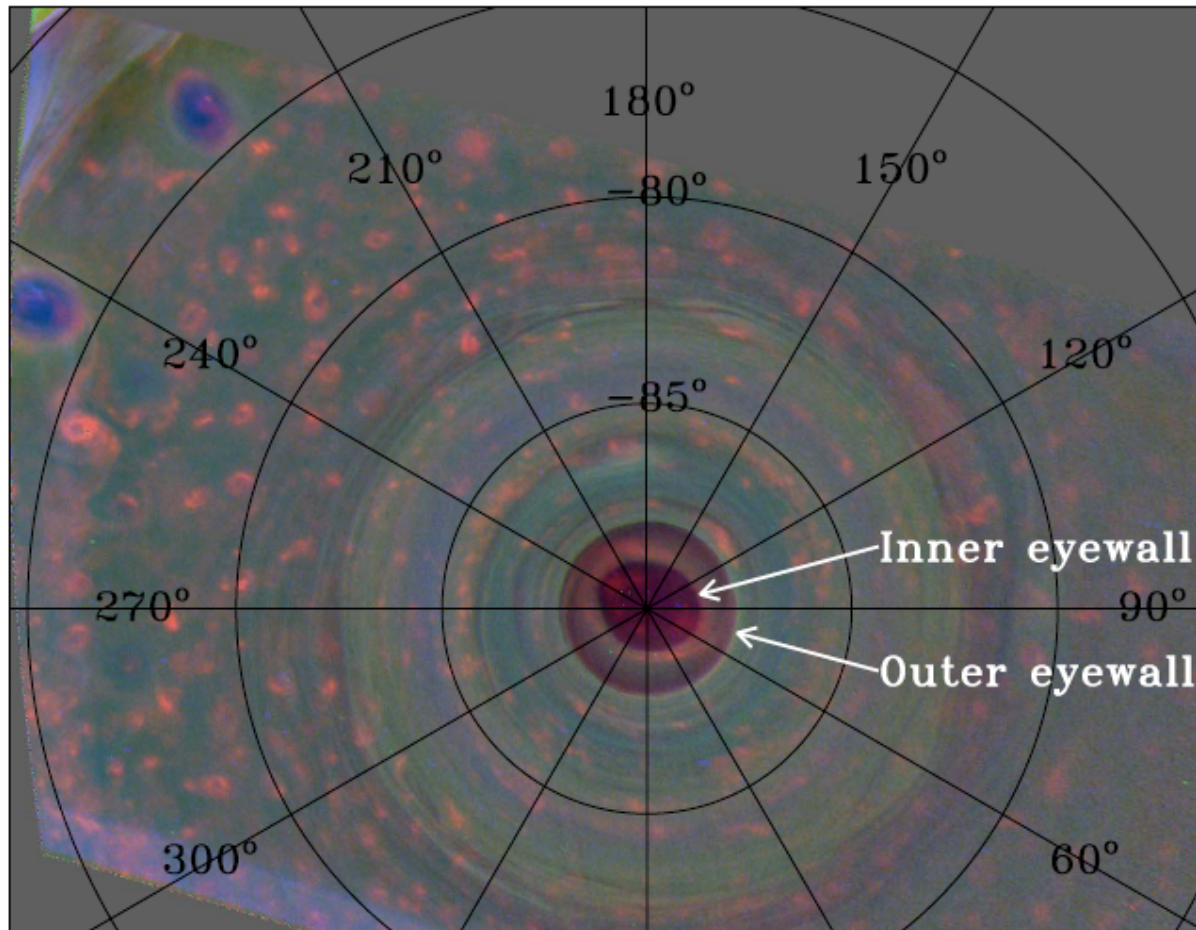
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## XXM Priority 1 Objectives for Saturn

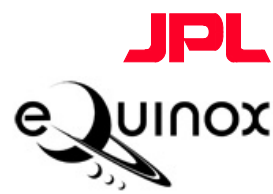
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National Aeronautics and Space  
Administration  
Jet Propulsion Laboratory  
California Institute of Technology

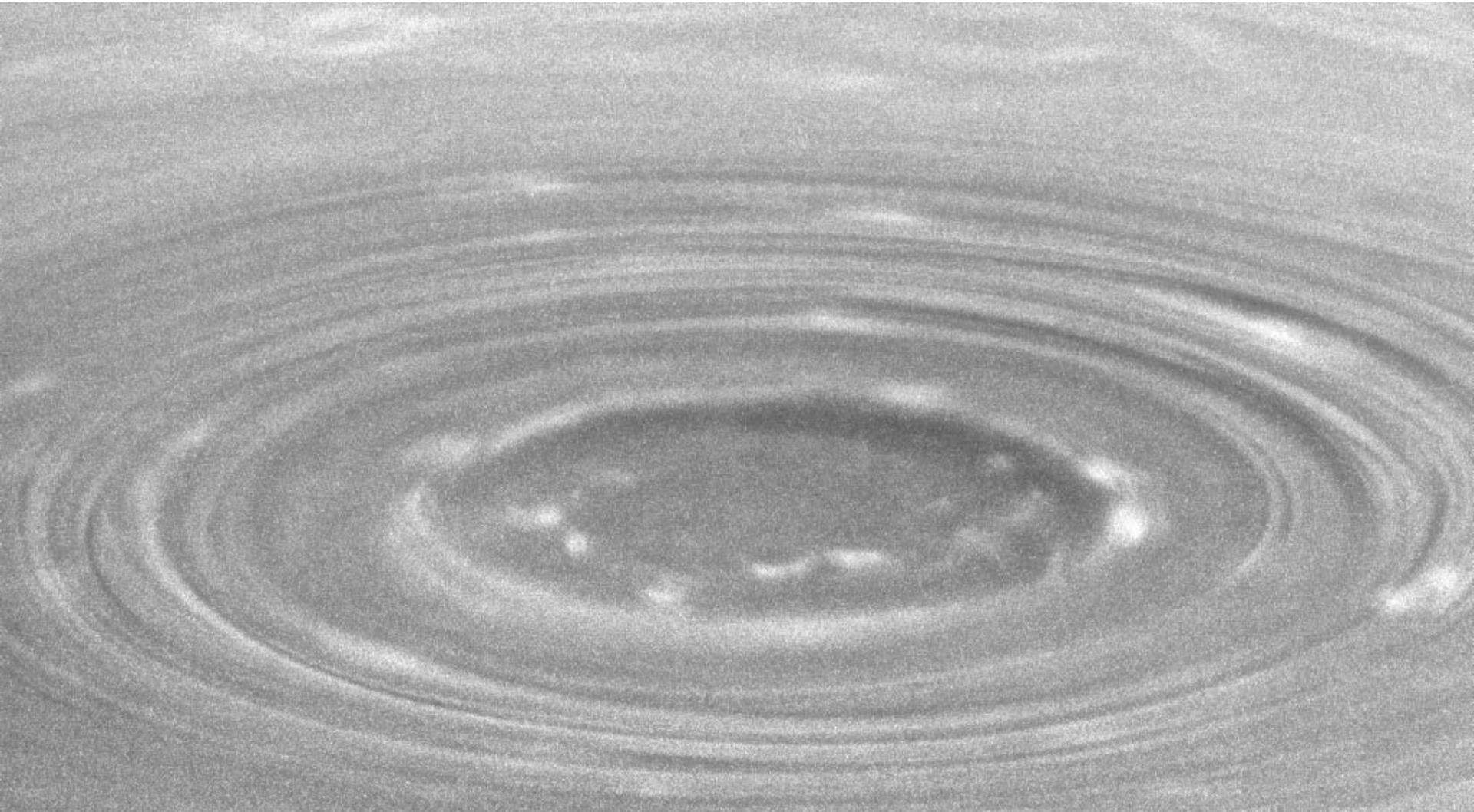
*Cassini Program*



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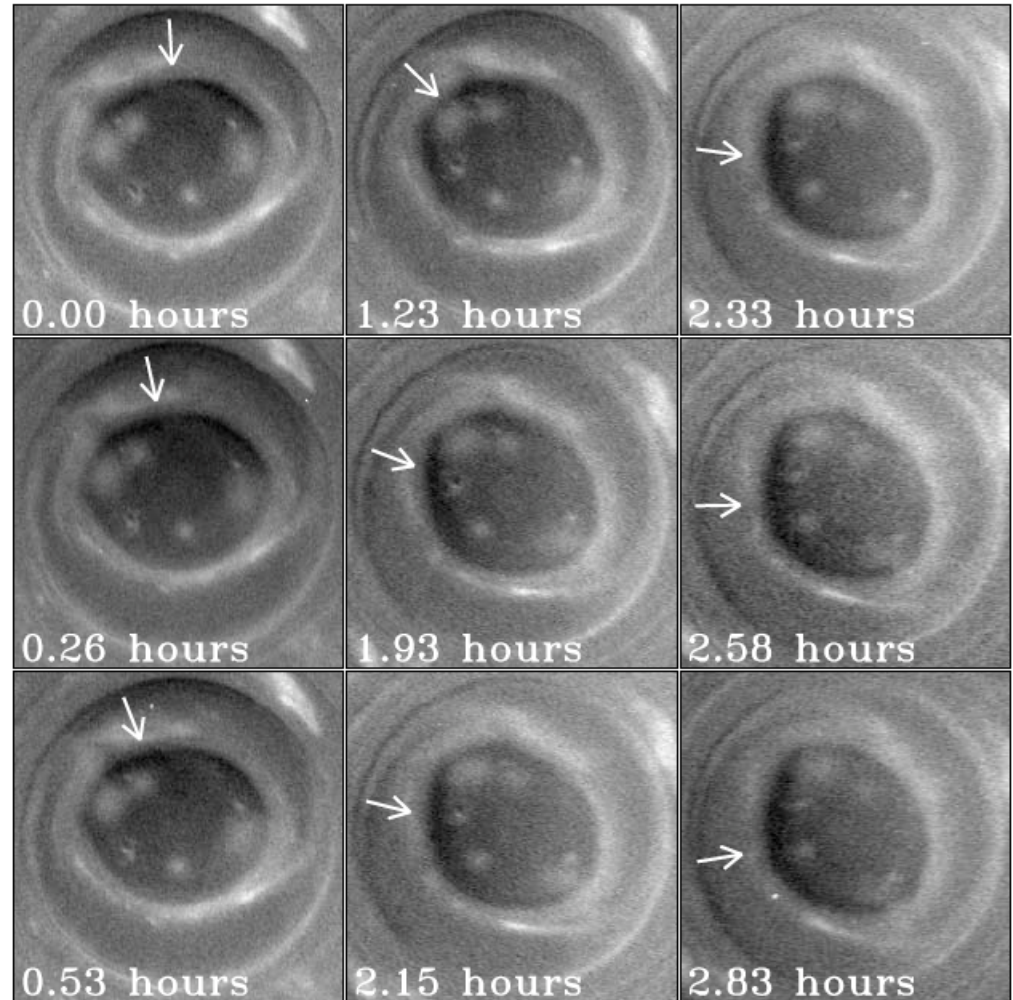


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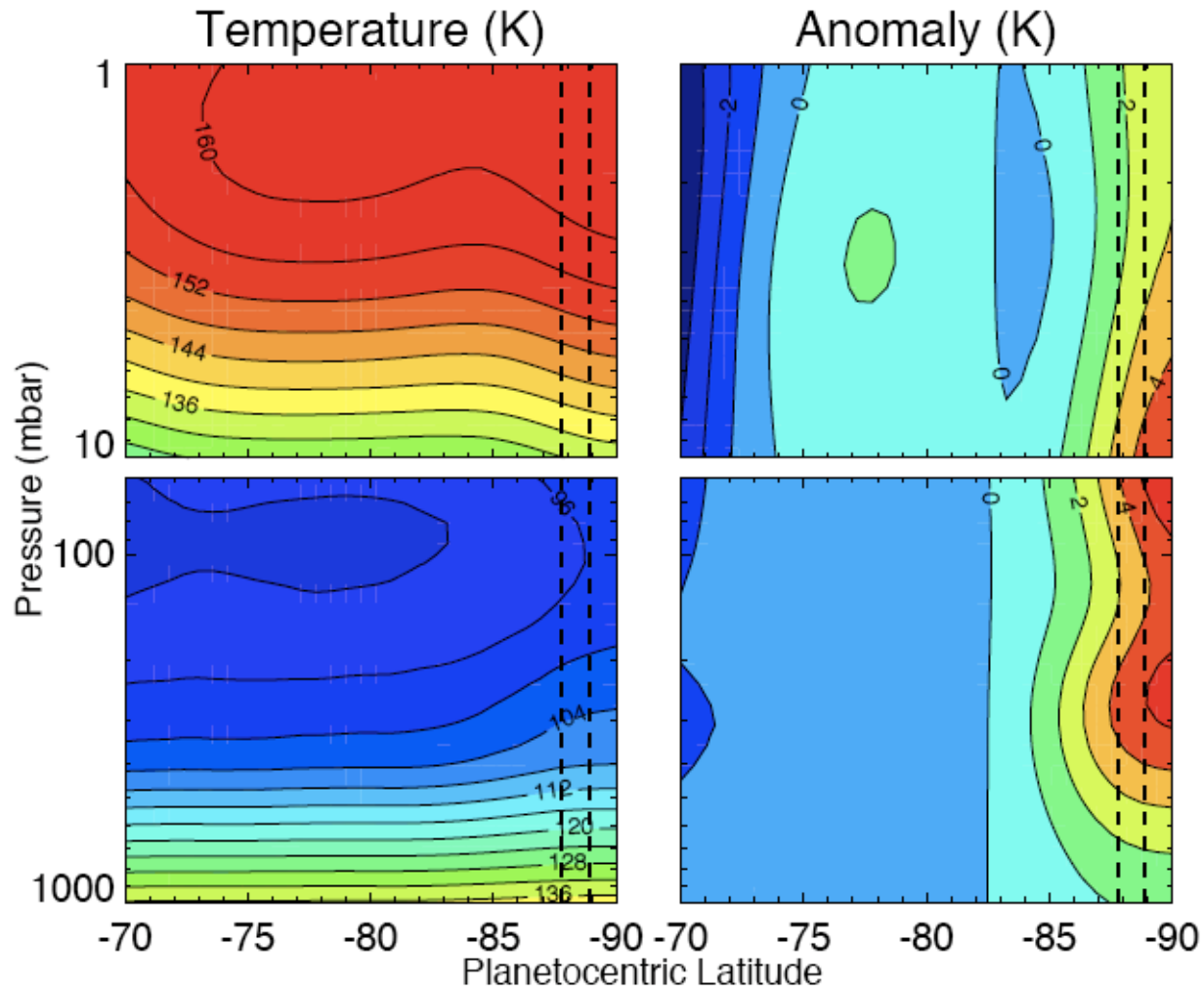
Arrows point in direction of incident sunlight. From shadows, the cloud heights range up to 70 km above the inner cloud deck.

Inner and outer ring diameters are 2000 and 4000 km, respectively



## XXM Priority 1 Objectives for Saturn

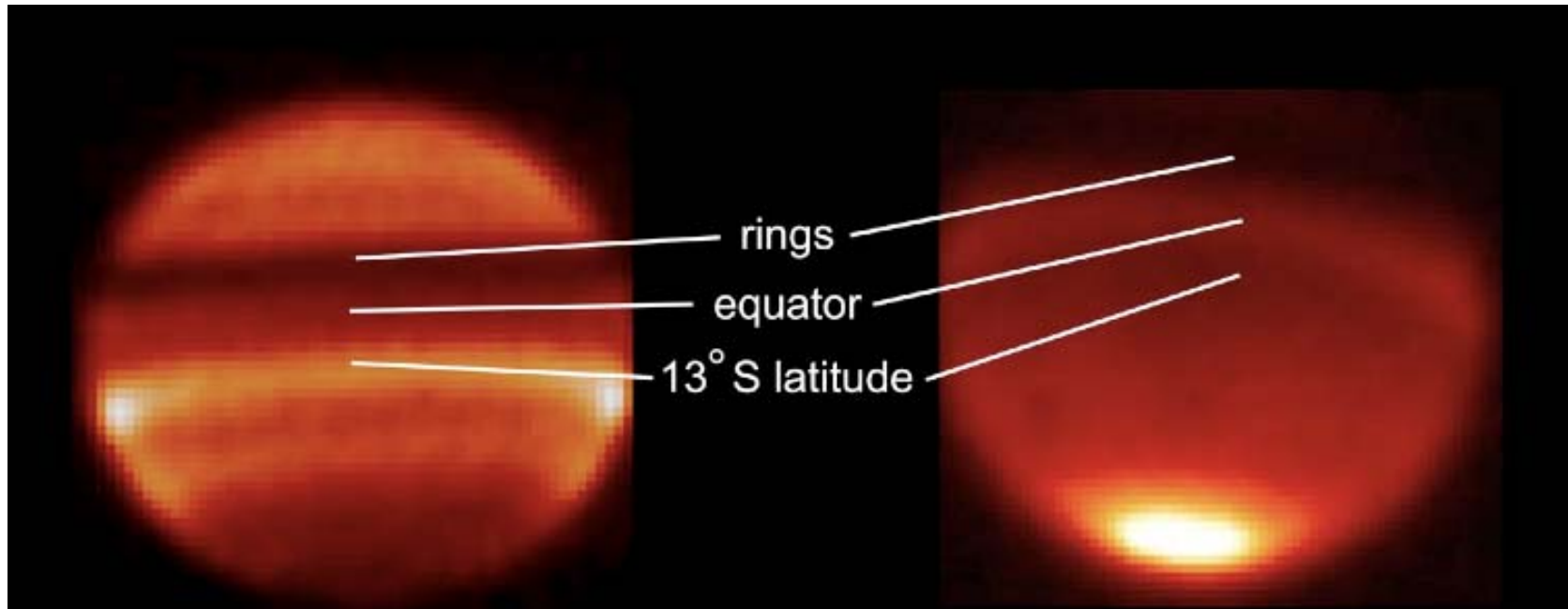
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September 1997

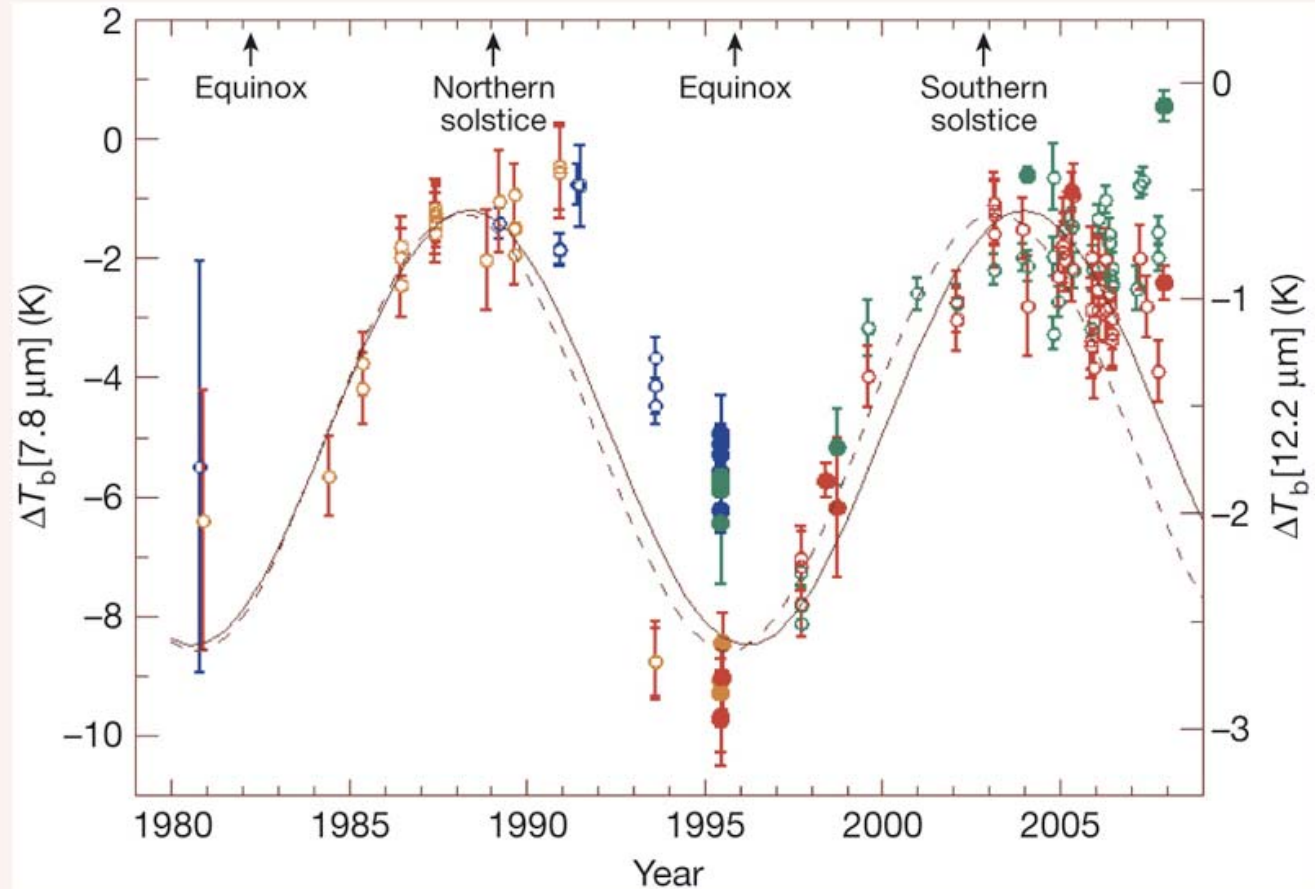
May 2006

Orton et al. (Nature, 2008). Earth-based infrared images showing stratospheric temperatures in 1997 and 2006

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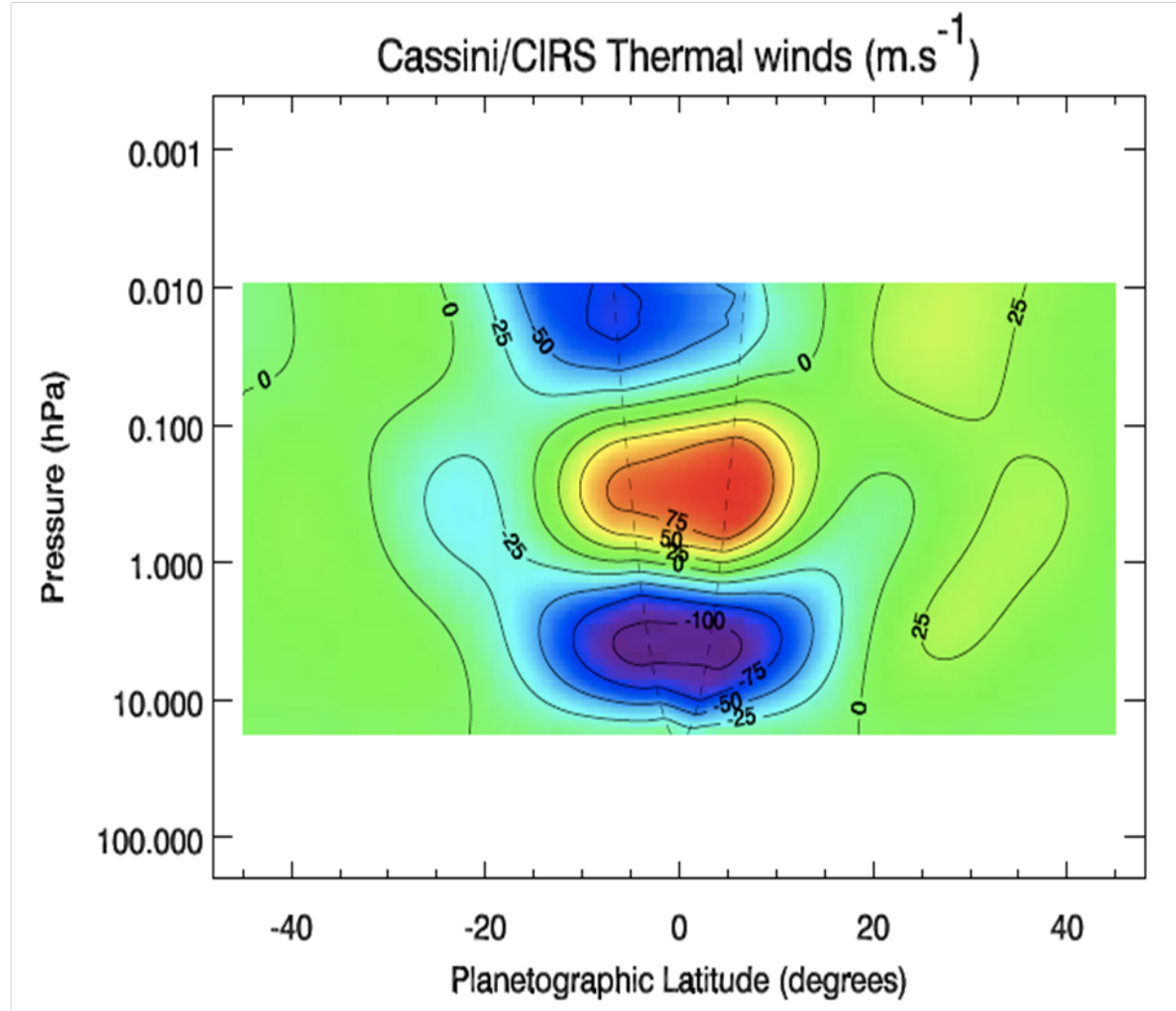
Stratospheric temperatures:  
15-year oscillation  
in temperature difference  
between equator and surroundings  
(13° latitude)  
Orton et al.  
(2008)  
IRTF data



## XXM Priority 1 Objectives for Saturn

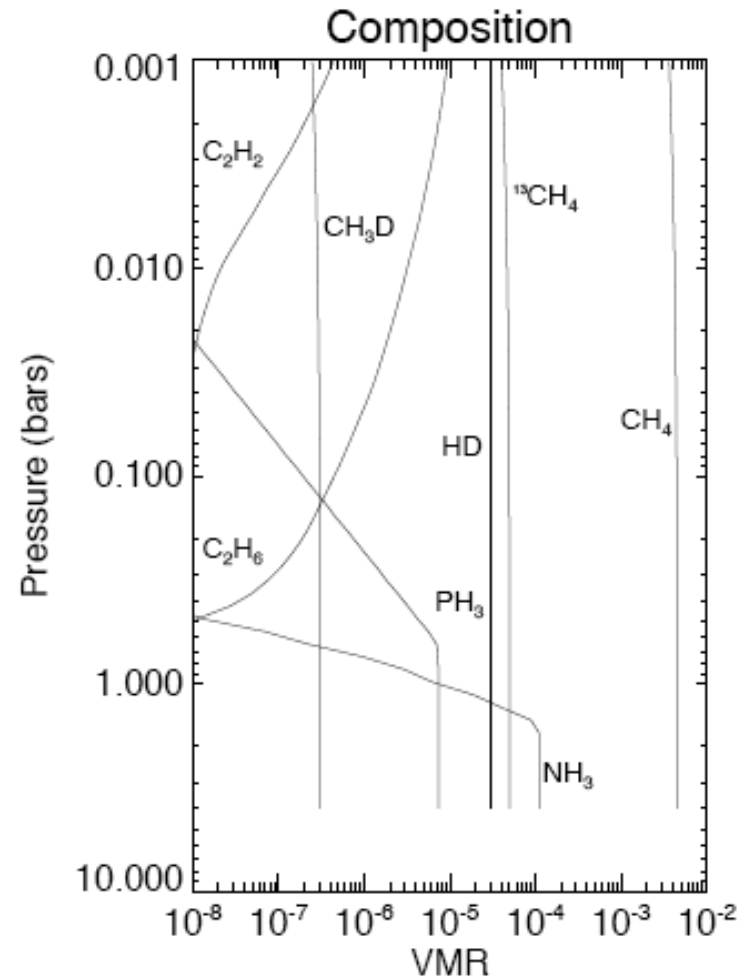
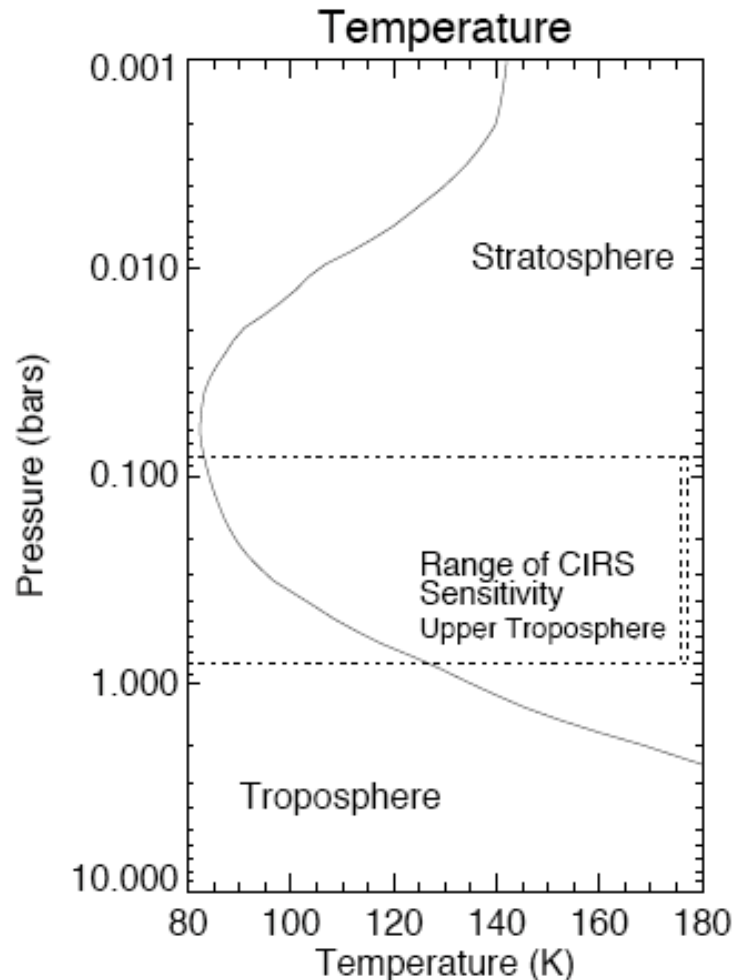
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Cassini  
Alternat  
zonal velo  
equat  
is analog  
Earth's QBO  
is coupled  
15-ye  
oscilla  
in temper



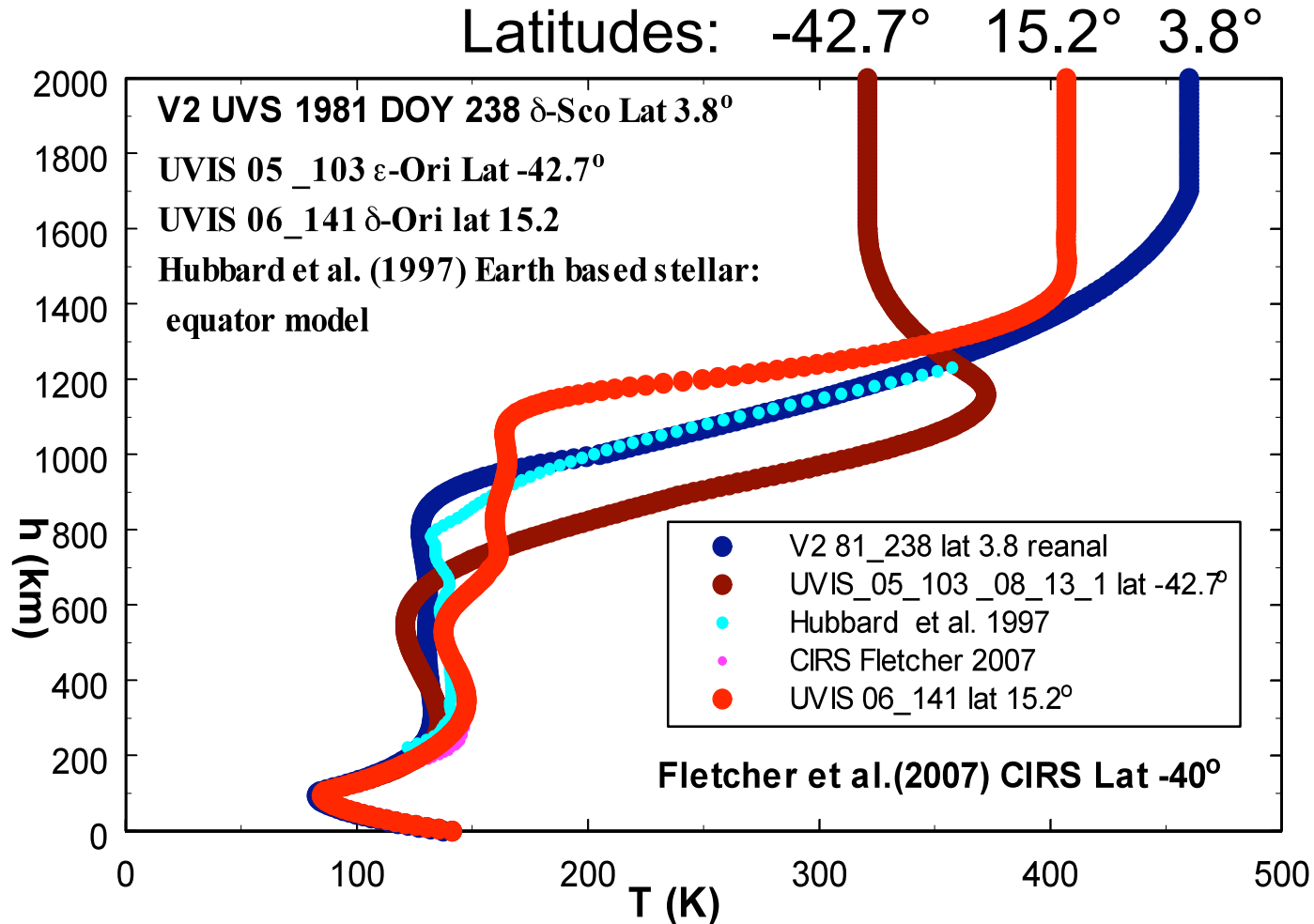
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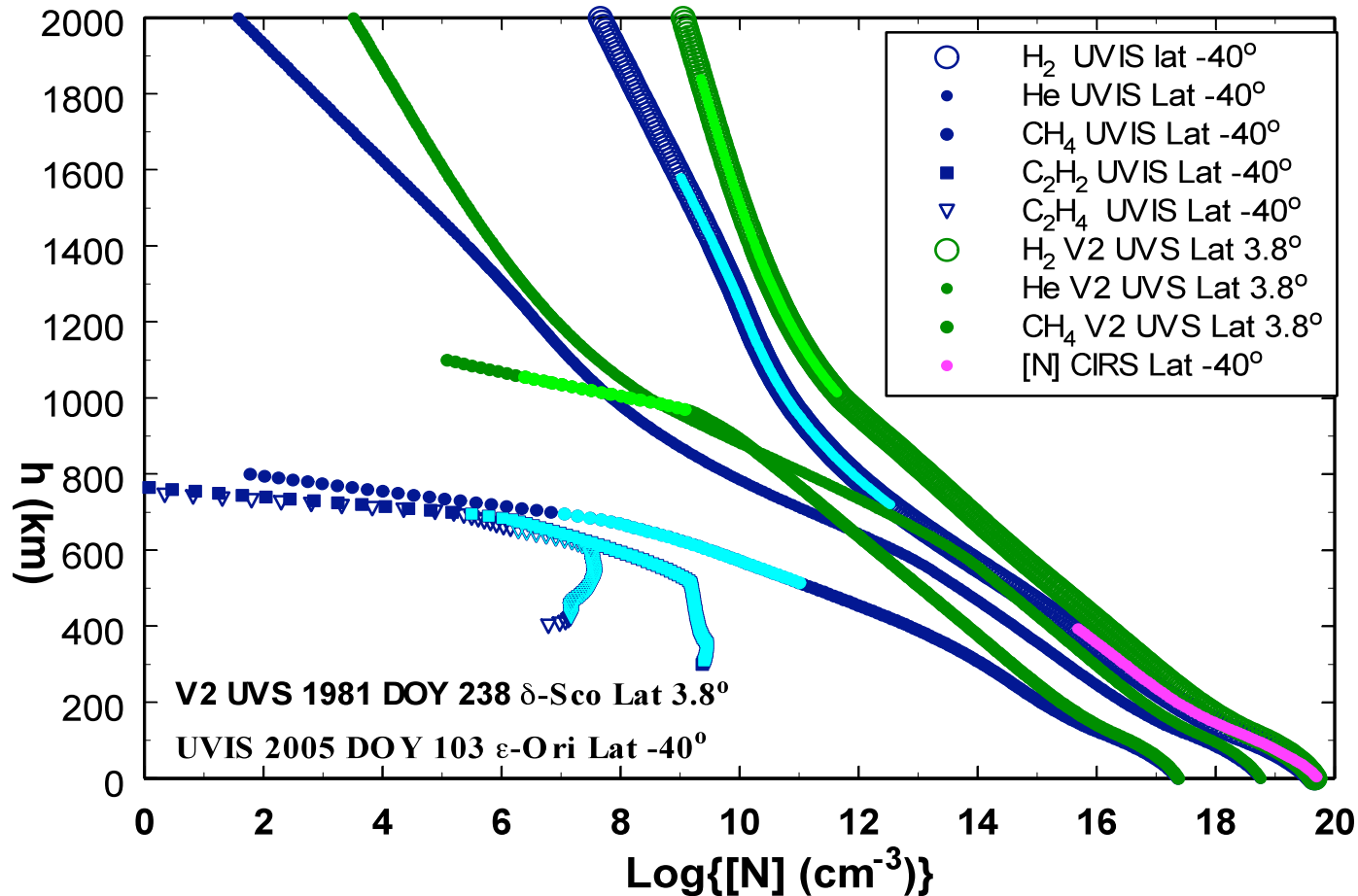
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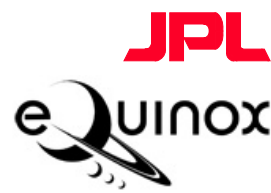
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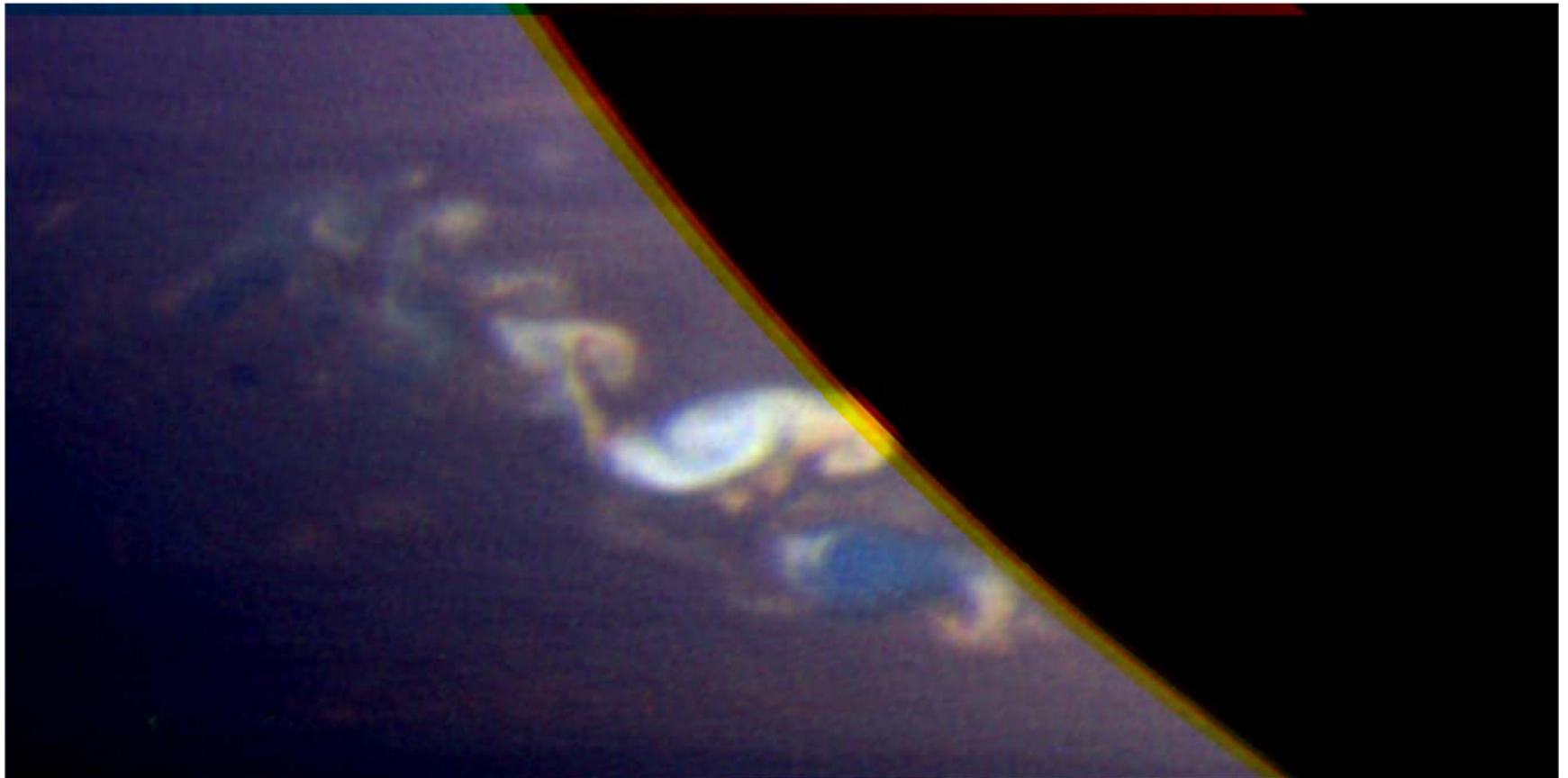


## XXM Priority 2 Objectives for Saturn

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### **SN2a - Observe Saturn's newly discovered lightning storms**

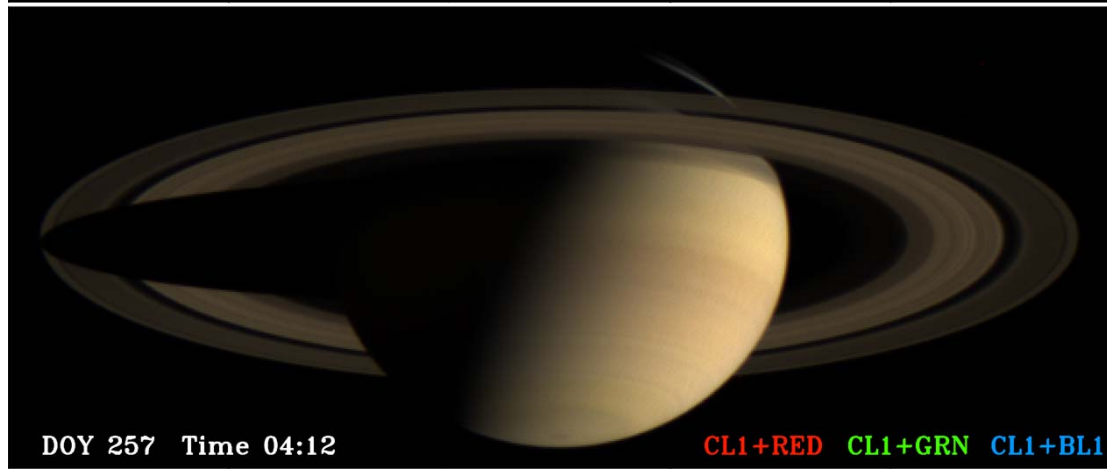
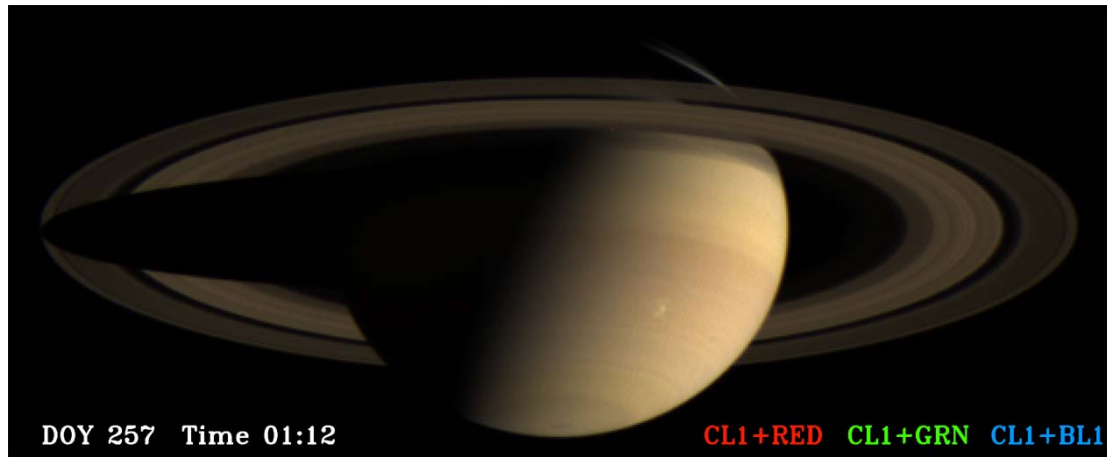
January 2009 – RPWS detects the electrostatic discharges from lightning. ISS sees the storms but has not seen the lightning flashes



## XXM Priority 2 Objectives for Saturn

### SN2a - Observe Saturn's newly discovered lightning storms

Only one lightning storm at a time. Storm visible in the top image has rotated over the limb in the bottom image

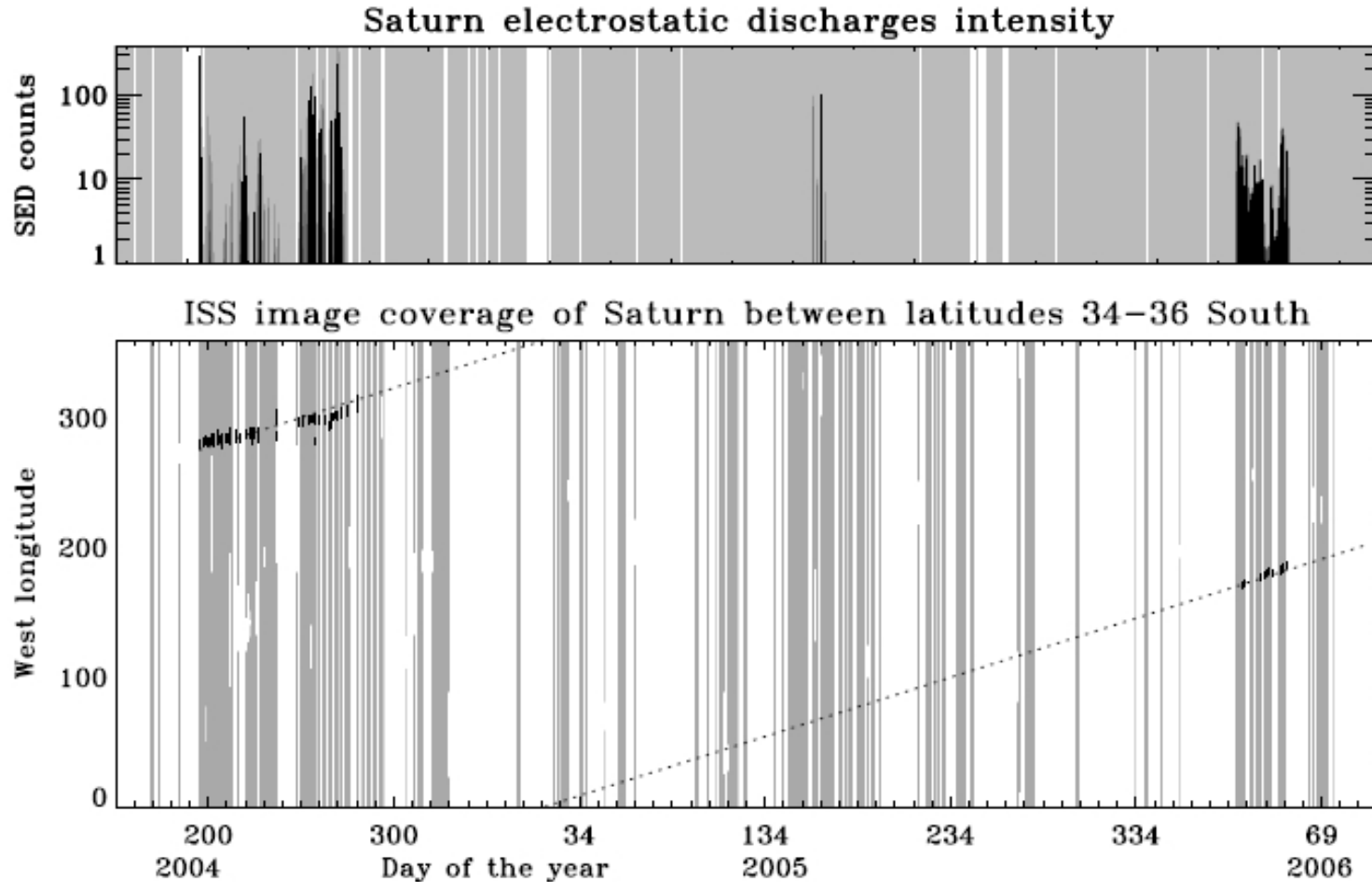




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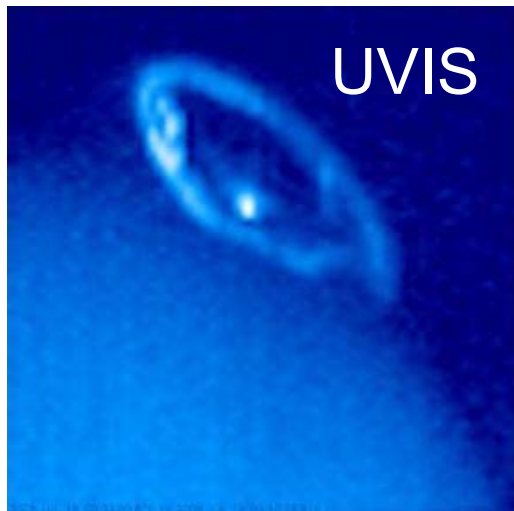
One lightning storm in late 2004, another in early 2006, and another in 2008, which lasted for 6 months.



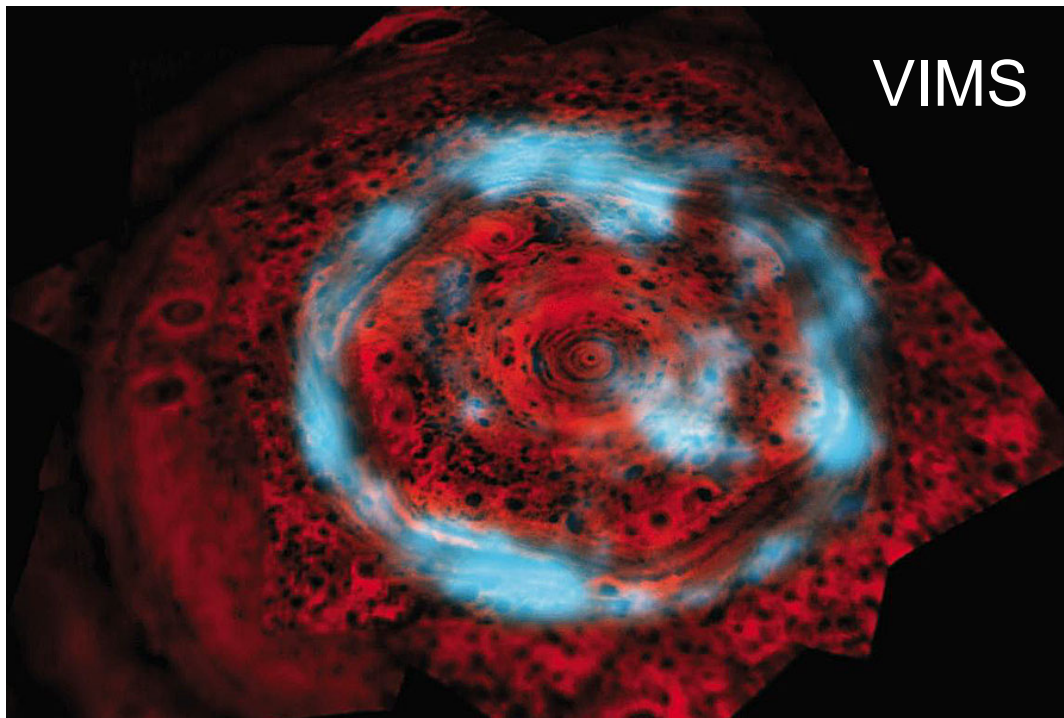


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**SC2a** - Observe the magnetosphere, ionosphere, and aurora as they change on all time scales - minutes to years - and are affected by seasonal and solar cycle forcing.



UV and IR auroras  
northern hexagon



# Giant Planet Questions - Interiors

Decadal Survey Questions	Measurement	Instrument	Why Now
What is the nature of convection <b>and winds</b> in giant planet interiors?	Higher harmonics of gravity field (?)	RSS (gravity) End of Mission orbits	No chance in PM or XM
How does the composition vary with depth? <b>Probe below the visible clouds</b>	NH <sub>3</sub> and deep clouds, relation to visible clouds	RADAR/VIMS low equatorial orbits	Capability discovered at end of PM
What is the nature of phase transitions within the giant planets?	Core mass and radius, J <sub>2</sub> , J <sub>4</sub> , J <sub>6</sub> ,	RSS (gravity) - End of mission orbits	No chance in PM or XM
How is energy transported through the deep atmosphere? Do radiative layers exist?	T, clouds, winds, chemistry	All remote sensing instruments	Seasonal change – go to solstice
How and where are planetary magnetic fields generated? <b>Use B field to determine rotation</b>	B field, structure and rotation	MAG - End of mission orbits	No chance in PM or XM

# Giant Planet Questions - Atmospheres

<b>Decadal Survey Questions</b>	<b>Measurement</b>	<b>Instrument</b>	<b>Why Now</b>
What energy source maintains the zonal winds, and how do they vary with depth?	Negative eddy viscosity, thermal winds	ISS/VIMS/CIRS cloud tracking, temperatures	Seasonal change, new oscillations
What role does water and moist convection play?	Lighting/dragon storms	RPWS/ISS/VIMS	Statistics – only 3 in PM
How and why does atmospheric temperature vary with depth, latitude, and longitude?	Limb profiles of T, latitude coverage	CIRS equat limb, RSS & UVIS occ	Seasonal change, new equat waves
What physical and chemical processes control the atmospheric composition and the formation of clouds and haze layers?	T, clouds, winds, chemistry	All remote sensing instruments, phase angles	Seasons, go to solstice, all latitudes
How does the aurora affect the global composition, temperature, and haze formation?	Aurora time scales minutes to years	All remote sensing, polar passes	Solar cycle, seasons, experience
What produces the intricate vertical structure of giant planet ionospheres?	Electron/ions H/H <sub>2</sub> /He all latitudes	RSS/UVIS radio solar/stellar occultations	Latitude & seasonal coverage



## Studying Saturn - relevant key questions from the Decadal Sur

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- **What is the nature of organic material in our solar system and how has this matter evolved?**
- **How do the processes that shape the contemporary character of planetary bodies operate and interact?**
- **What does our solar system tell us about the development and evolution of extrasolar planetary systems, and *vice versa*?**
- **Over what period did the gas giants form, and how did the birth of the ice giants (Uranus, Neptune) differ from that of Jupiter and its gas-giant sibling, Saturn?**
- **What is the history of volatile compounds, especially water, across our solar system?**

**Note: The Decadal Survey had 12 key questions, and listed the first 3 above in connection with the Cassini Extended Mission. The last 2 questions are also relevant and have been added to the list.**