Cassini CIRS:
Instrument, Operations, and Science

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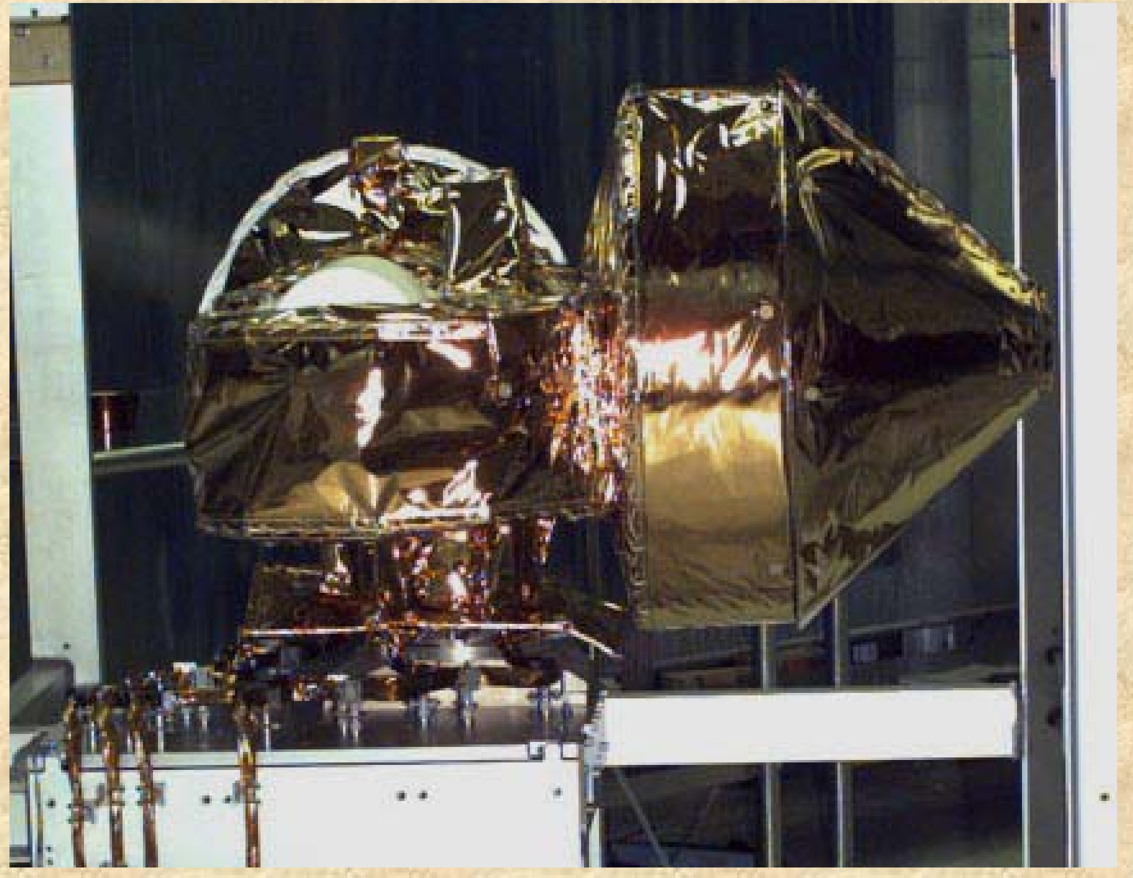
CHARM Telecon, September 30, 2008

CIRS: The Instrument

Specializing in Temperatures and Composition



CASSINI CIRS INVESTIGATION

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CIRS Capabilities & *Science Objectives*

Saturn, Titan Atmospheres

Map Global Thermal Structure	*Dynamics, General Circulation*
Map Global Gas Composition	*Photochem, Dynamics, Evolution*
Map Global Information on Hazes & Clouds	*Haze Formation, Cloud Physics*
Determine Information on Non-equilibrium Processes	*Energetics*
Search for New Molecular Species	*Photochemistry, Evolution*

Titan Surface

Map/Global Surface Temperature	*Lower Atmosphere Dynamics*

Rings and Icy Satellites

Map Composition Map Thermal Characteristics	*Origin, Evolution, and Process*

Description of Investigation

- Infrared spectroscopy of emission from atmospheres, rings, and surfaces in 10–1400 cm^{-1} (1000–7 micron) region.

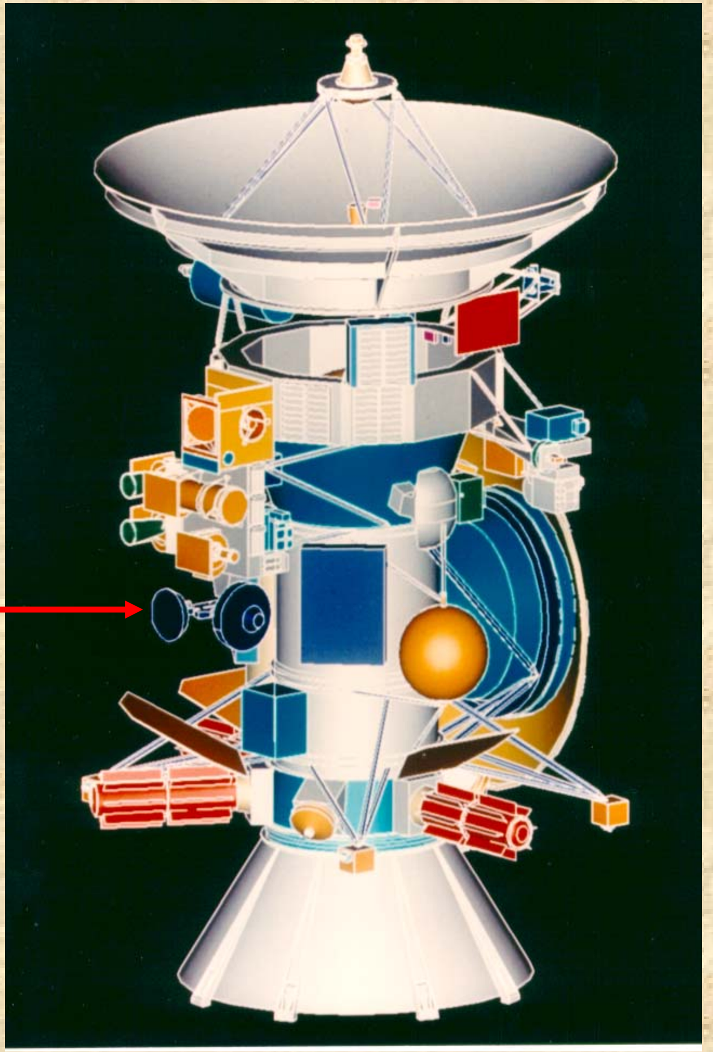
- Global mapping of atmospheres (Saturn, Titan, Jupiter)
  - Temperatures (vertical profiles and maps).
  - Gas composition (H_2, He, CH_4, NH_3, PH_3, CO_2, H_2O…), spatial distribution, and isotopic ratios
  - Aerosol and clouds opacities

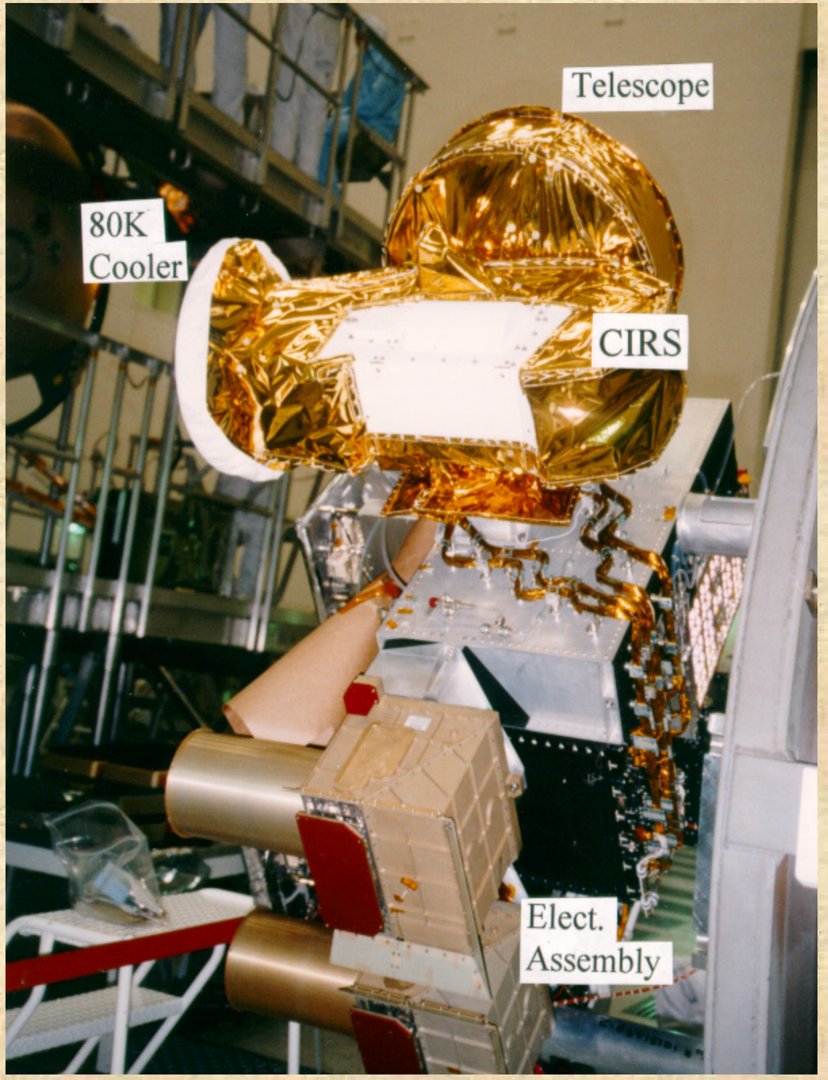
- Mapping of rings and icy satellite surfaces:
  - Composition.
  - Particle sizes.
  - Thermal properties of rings and subsurface regolith (~ few cm depth)

- Nadir and Limb Observational Modes.
  - Limb Scanning Provides Scale Height Altitude Resolution.

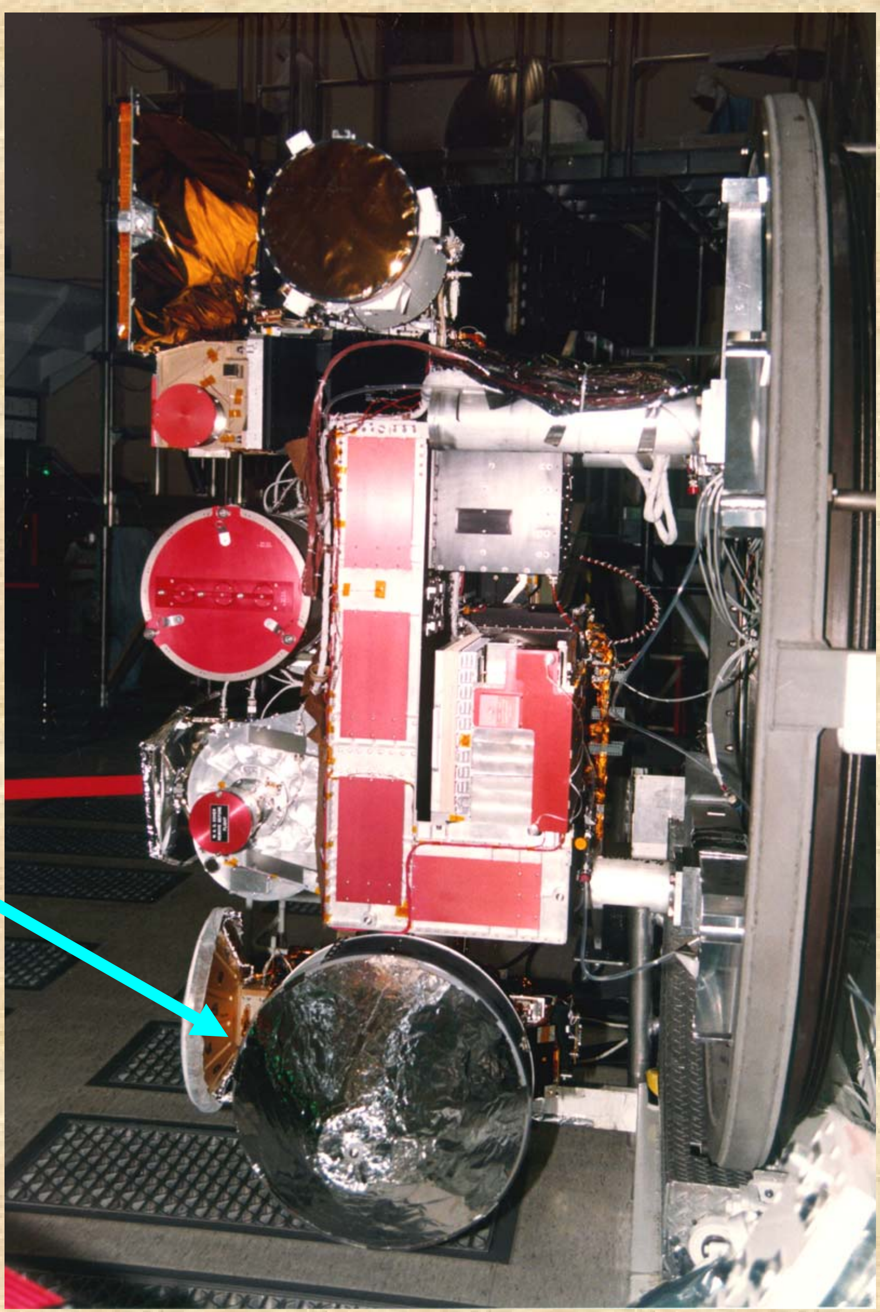
Cassini S/C – CIRS Location

CIRS

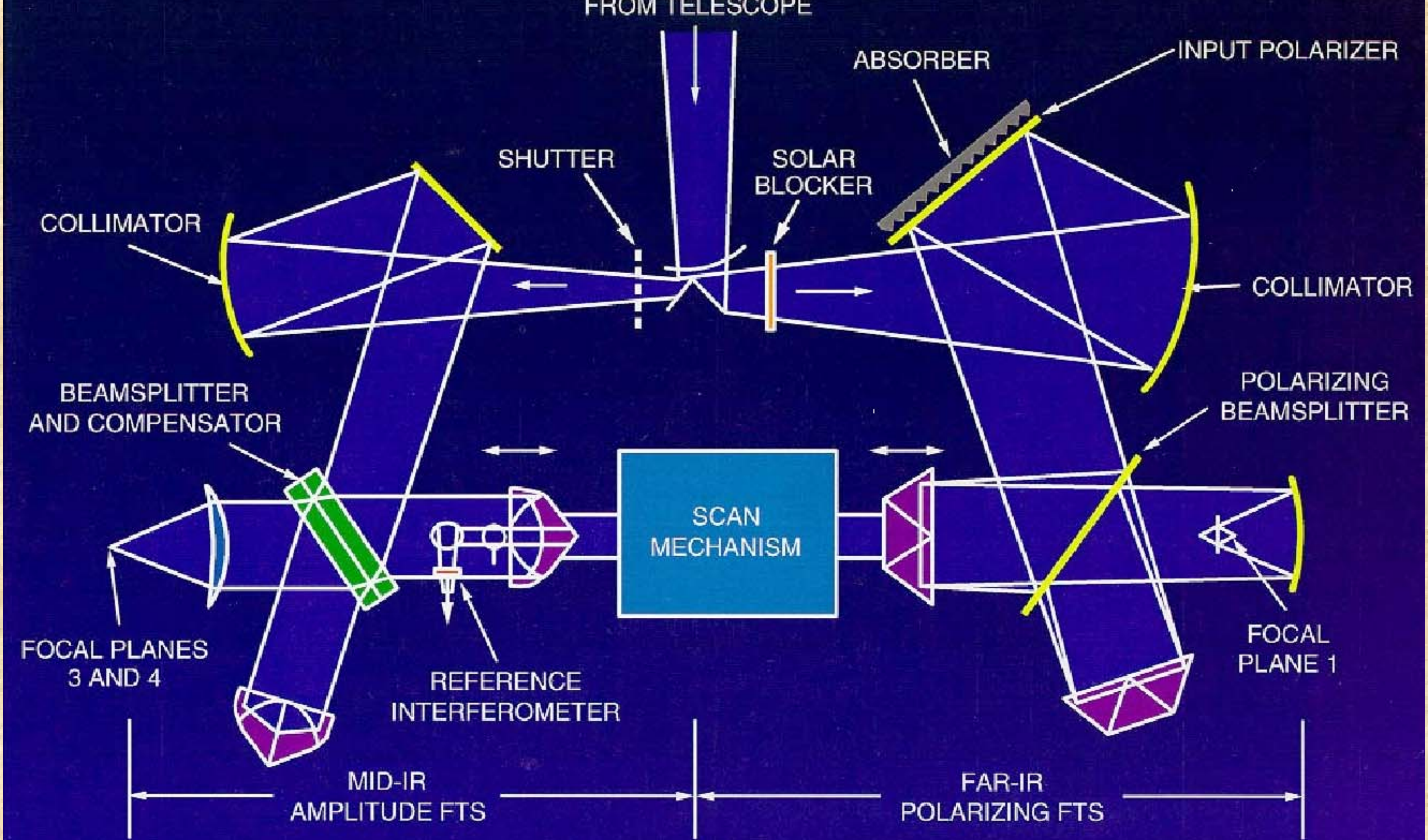




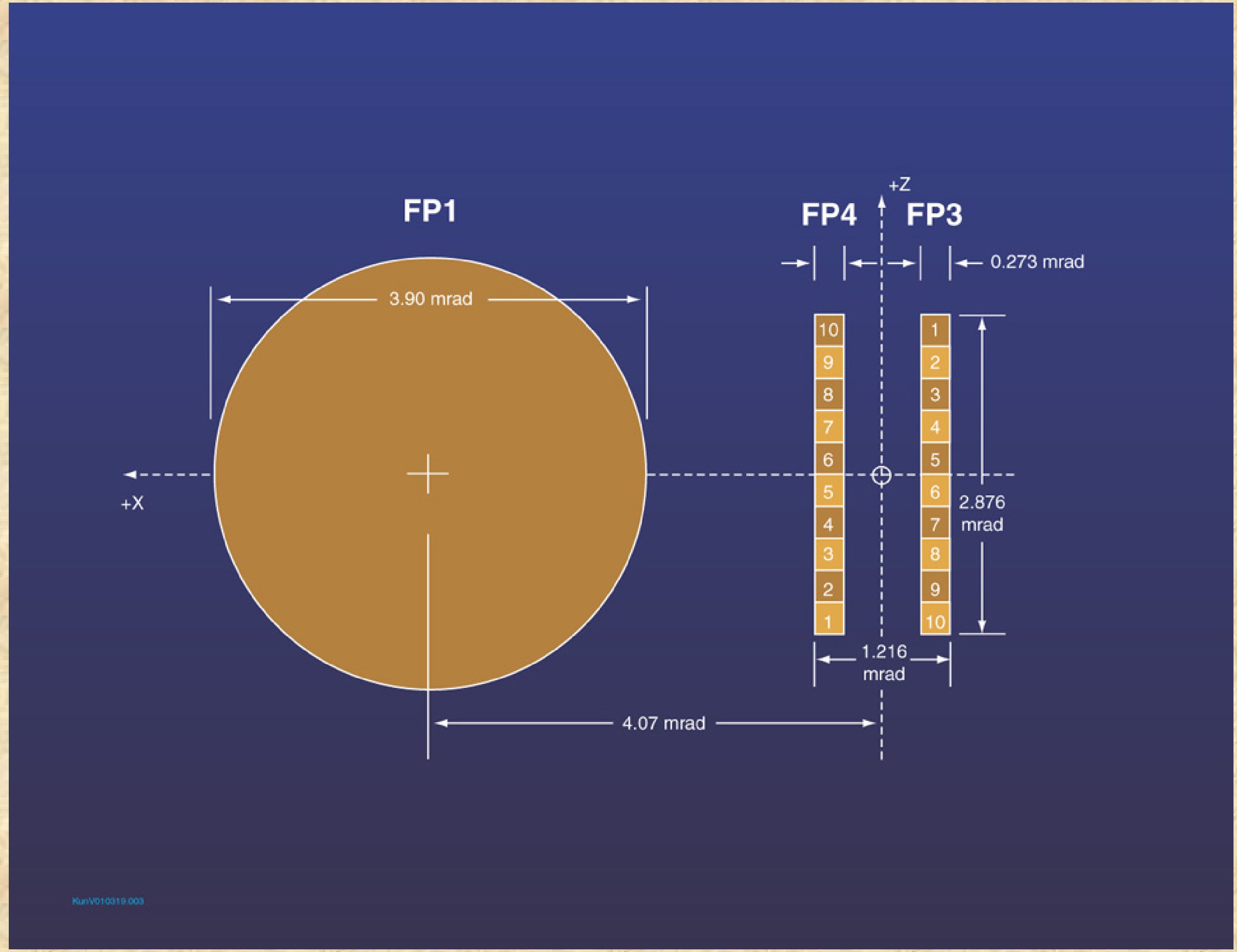
CIRS Instrument on Cassini Remote Sensing Pallet



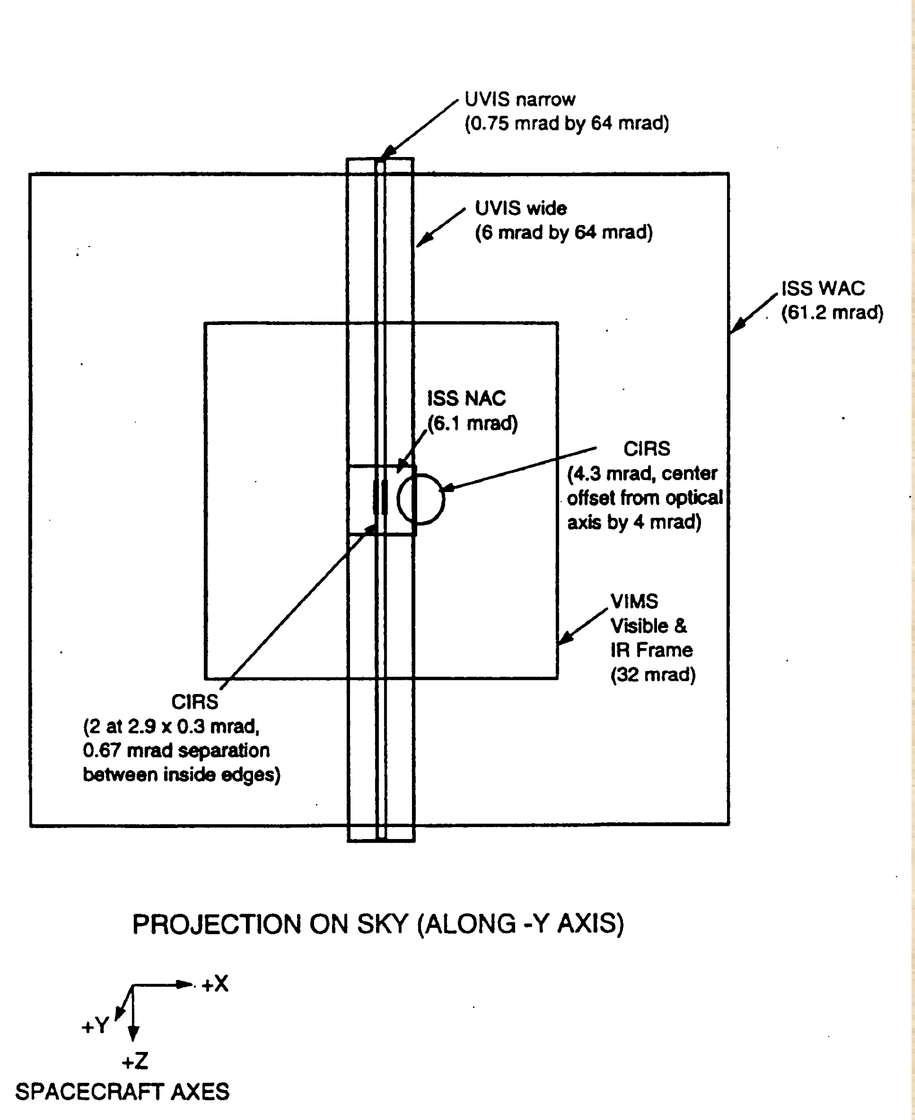
CONCEPTUAL LAYOUT



CIRS Fields of Views



Cassini's Optical Remote Sensing Fields of View



CIRS Operability

- Programmable spectral resolution (0.5 cm-1 to 20 cm-1)
- Lower spectral resolution, shorter integration times for extensive mapping of atmospheric temperatures & aerosols, thermal properties of rings & surfaces
- Higher spectral resolution, longer integration times for limited mapping of minor gaseous and surface constituents
- Different spatial resolution in far-infrared (4 mrad) and mid-infrared (0.3 mrad)
  - Far-infrared observations must generally be executed closer to target to achieve comparable resolution to mid-IR observations.
- Limb and nadir viewing
  - Limb viewing must be done closer to target than nadir observations, to achieve scale-height vertical resolution

Instrument Description

Telescope Diameter(cm):	**50.8**		
Interferometers:	**<u>FAR-IR</u>**	**<u>MID-IR</u>**	
Type:	**Polarizing**	**Michelson**	
Spectral range(cm^{-1}):	**10 - 600**	**600 -1400**	
Spectral range(microns):	**17 - 1000**	**7 - 17**	
Spectral resolution(cm^{-1}):	**0.5 to 20**	**0.5 to 20**	
Integration time(sec):	**2 to 50**	**2 to 50**	

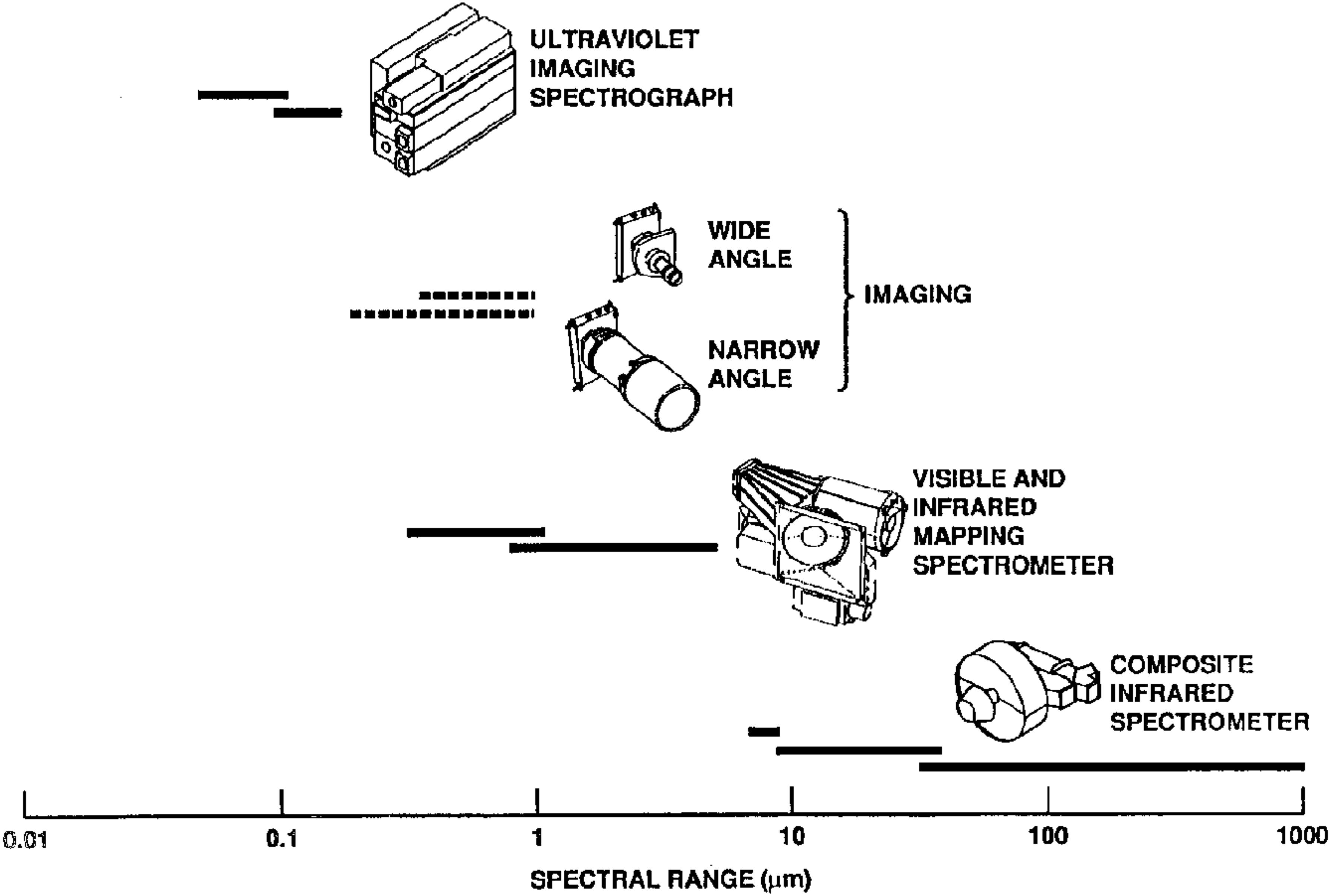
FOCAL PLANES:	**<u>FP1</u>**	**<u>FP3</u>**	**<u>FP4</u>**
Spectral range(cm^{-1})	**10 - 600**	**600 - 1100**	**1100 - 1400**
Detectors	**Thermopile**	**PC HgCdTe**	**PV HgCdTe**
Pixels	**2**	**1 x 10**	**1 X 10**
Pixel FOV(mrad)	**3.9**	**0.273**	**0.273**
Peak D*(cm $hz^{1/2}$ W^{-1})	**4×10^{9}**	**2×10^{10}**	**5×10^{11}**

Data Telemetry Rate(kbs)	**2, 4**
Instrument Temperature(K)	**170**
Focal Planes 3 & 4 Temperature(K)	**75 - 90**

CIRS Advantages Over Voyager IRIS

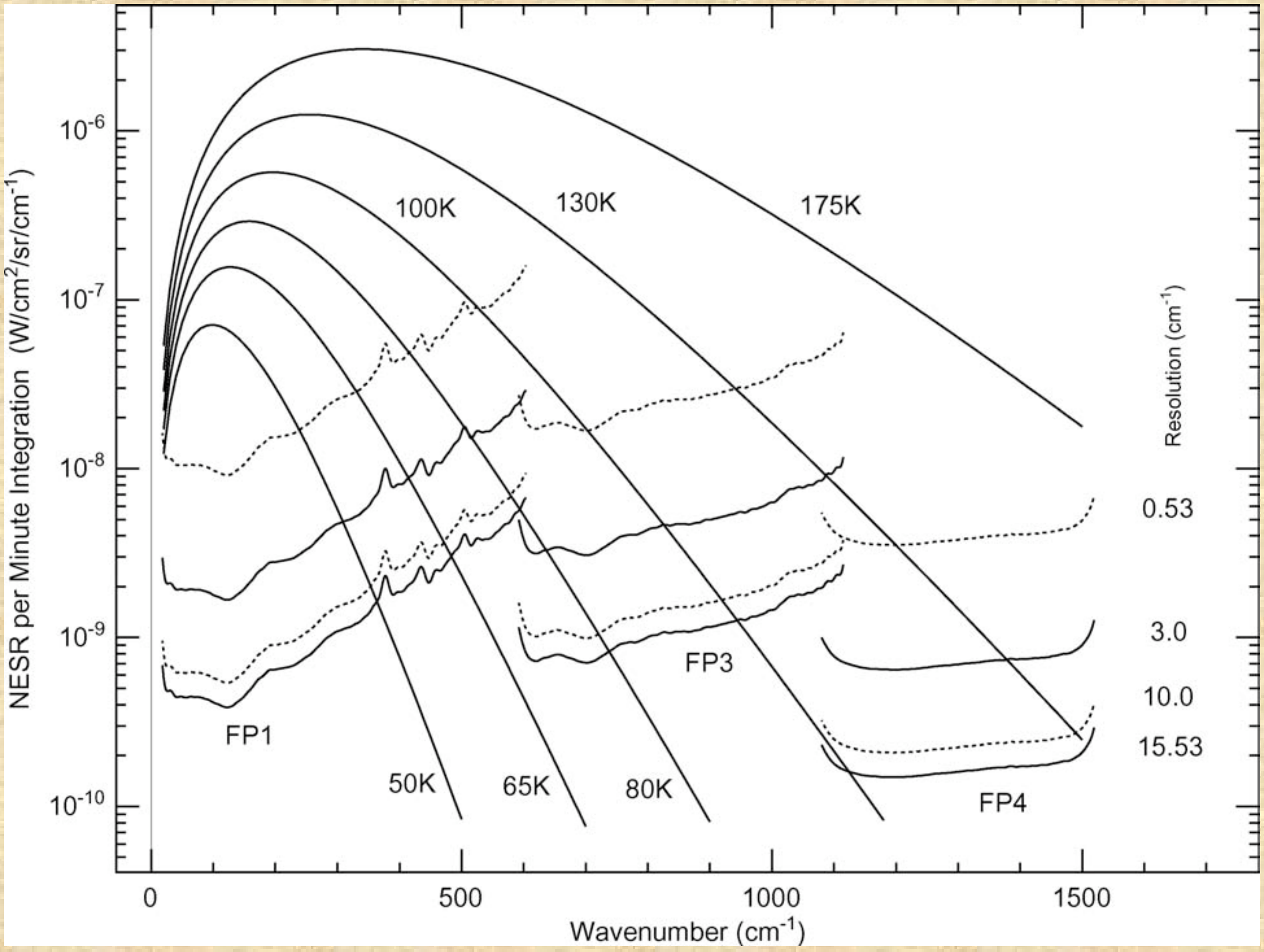
- Extended far-infrared coverage: 10 - 180 cm^{-1} not accessible to IRIS. (Better performance than ISO, too.)
- Higher spectral resolution (up to 0.5 cm^{-1}) than IRIS (4.3 cm^{-1}).
- Improved sensitivity in mid-IR (HgCdTe vs. thermopiles).
- Higher spatial resolution (also big advantage over ISO).
- Limb-viewing capability: better vertical resolution from geometry and deep space as background.
- Orbiting platform: permits detailed global mapping

Cassini ORS instruments: Spectral coverage

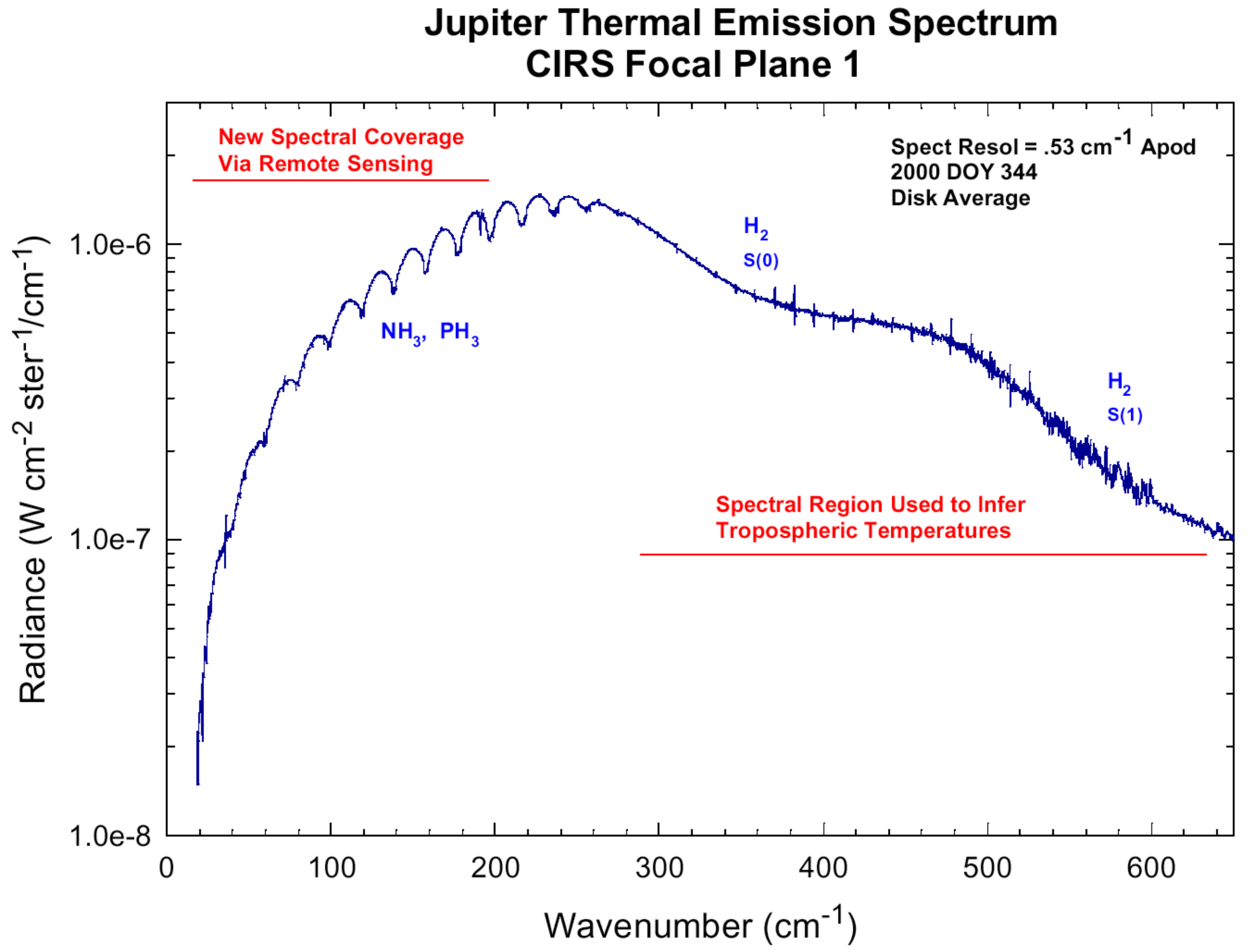


Blackbody Radiation

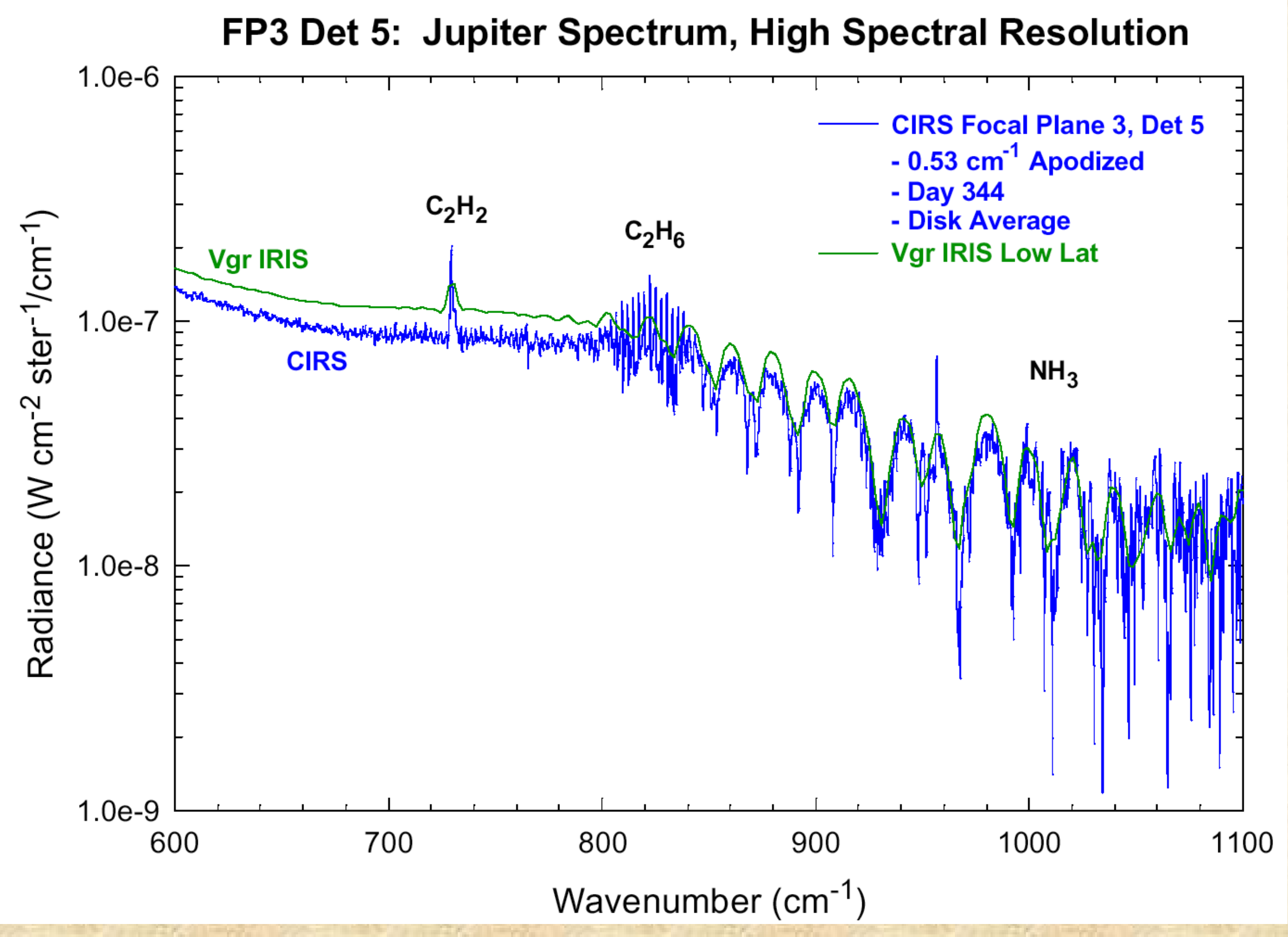
- CIRS measures photons at frequencies were bodies give off thermal blackbody radiation
- The intensity of these photons are modulated by the composition and scattering properties of the bodies in question
- From Flasar, et al. 2004



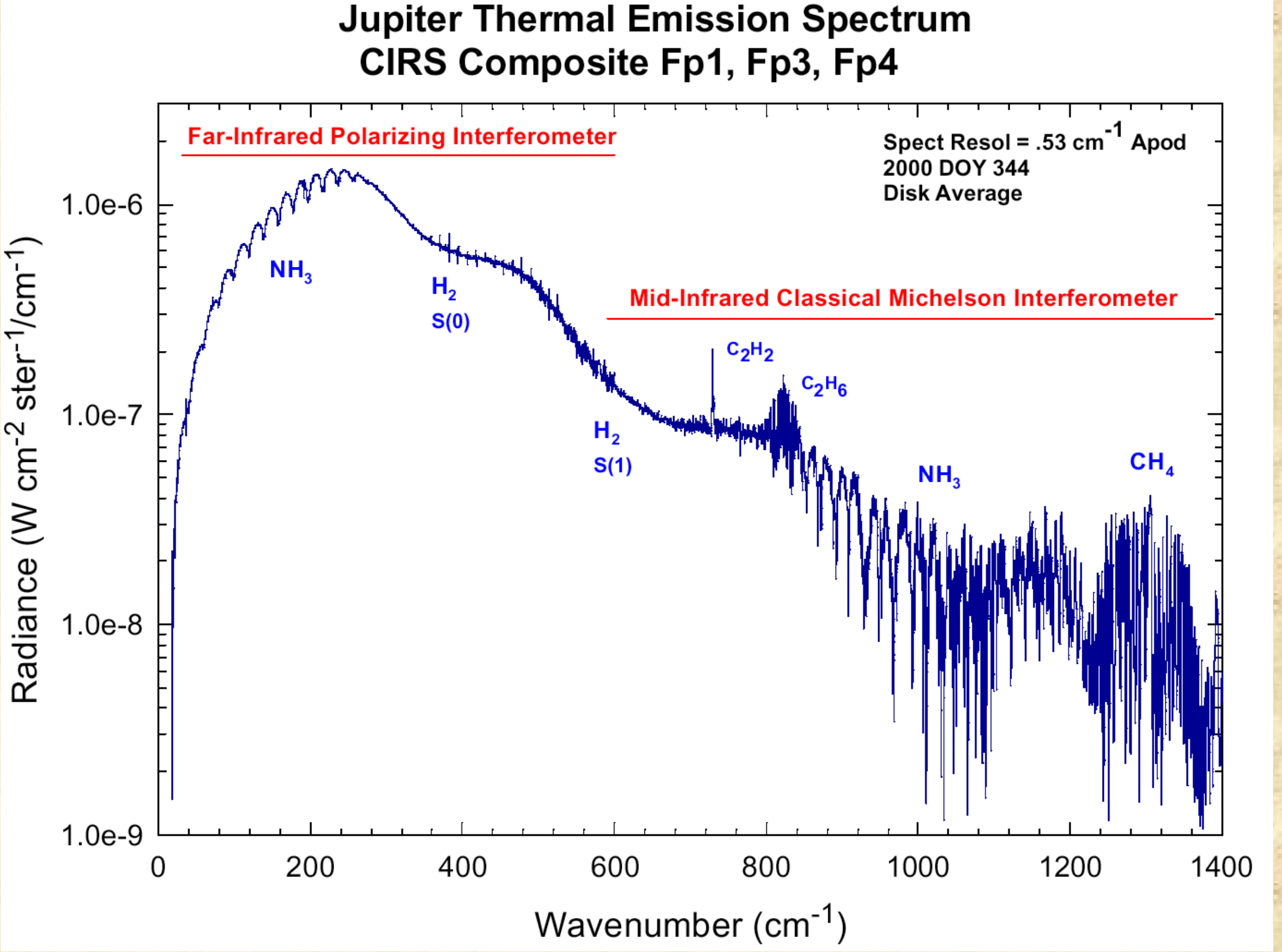
CIRS Examples From Jupiter

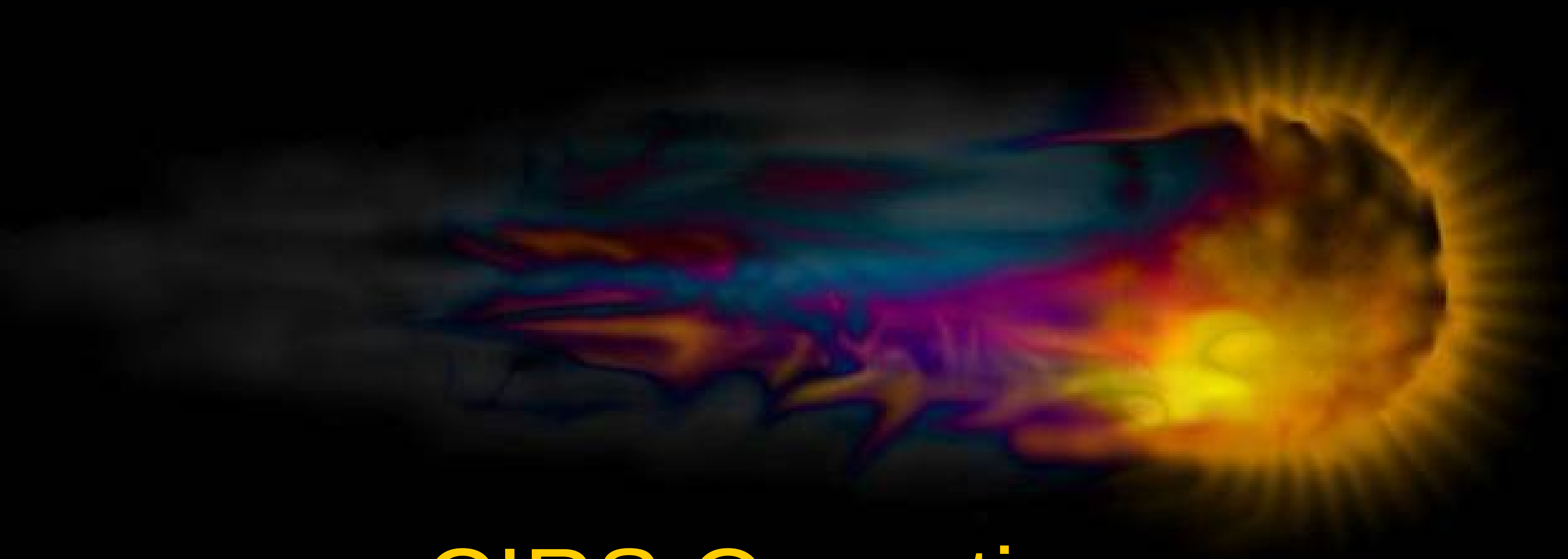


CIRS Examples From Jupiter (cont.)



CIRS Examples From Jupiter (cont.)





CIRS Operations

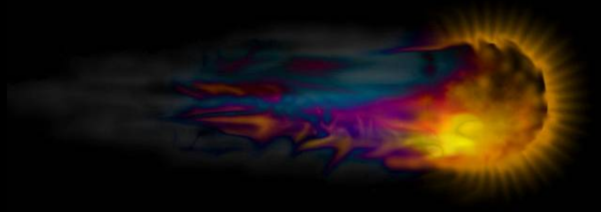
Marcia Segura
CIRS Operations Team Lead

CHARM – Sept 30, 2008

Operations – What is it?

Making Cassini program science objectives a reality!

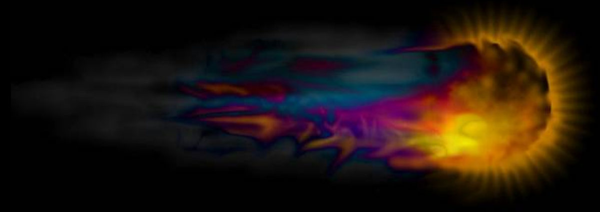
It's a challenge!



Operations – HOW?

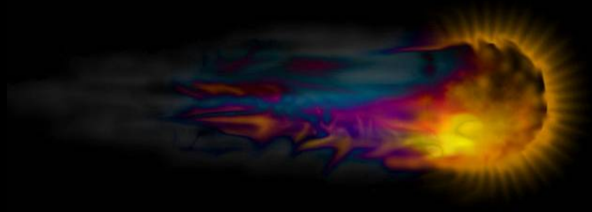
Not only is it a challenge …. It's a BIG job! So … We break it down into manageable chunks.

- Uplink
- Execution
- Downlink



Uplink

- Integration or science planning – the tour (time) is divided first by discipline and then by team.
  - A lot of friendly competition/ bickering occurs at this step!
- Implementation – the time allocated in integration is turned into actual observations – spacecraft and instrument commands.
  - Rubber hits the road here – all flaws in the planning are quickly revealed and fixed!

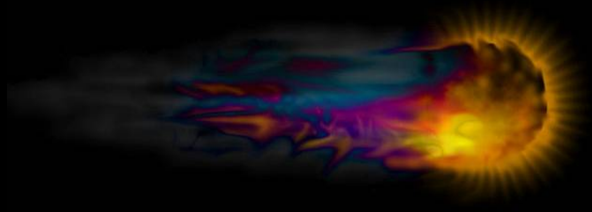


Execution

- While the sequence is executing on board Cassini; the team:
  - Monitors the health and safety of CIRS
  - Monitors the data collection
  - Responds to instrument or spacecraft anomalies
    - Late night, holiday, weekend calls – spacecraft and CIRS have not regard for human schedules!
  - Does any real-time commanding needed

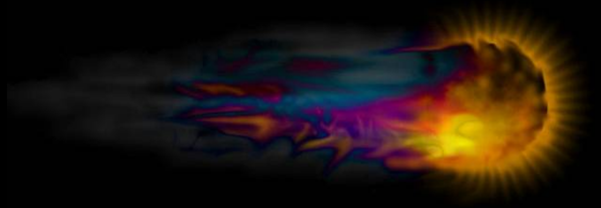
Downlink

- Last step in Operations – tasks include:
  - Collecting the data from JPL
  - Processing the data.
  - Calibration of the data
  - Data validation
  - Delivering data to science team
  - Archiving the dataset to Planetary Data System



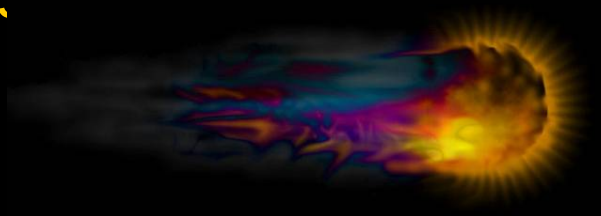
Operating CIRS

CIRS is a marvelous instrument and has taken a great dataset but …. it has it's own unique "personality" which makes the operation both rewarding and challenging.

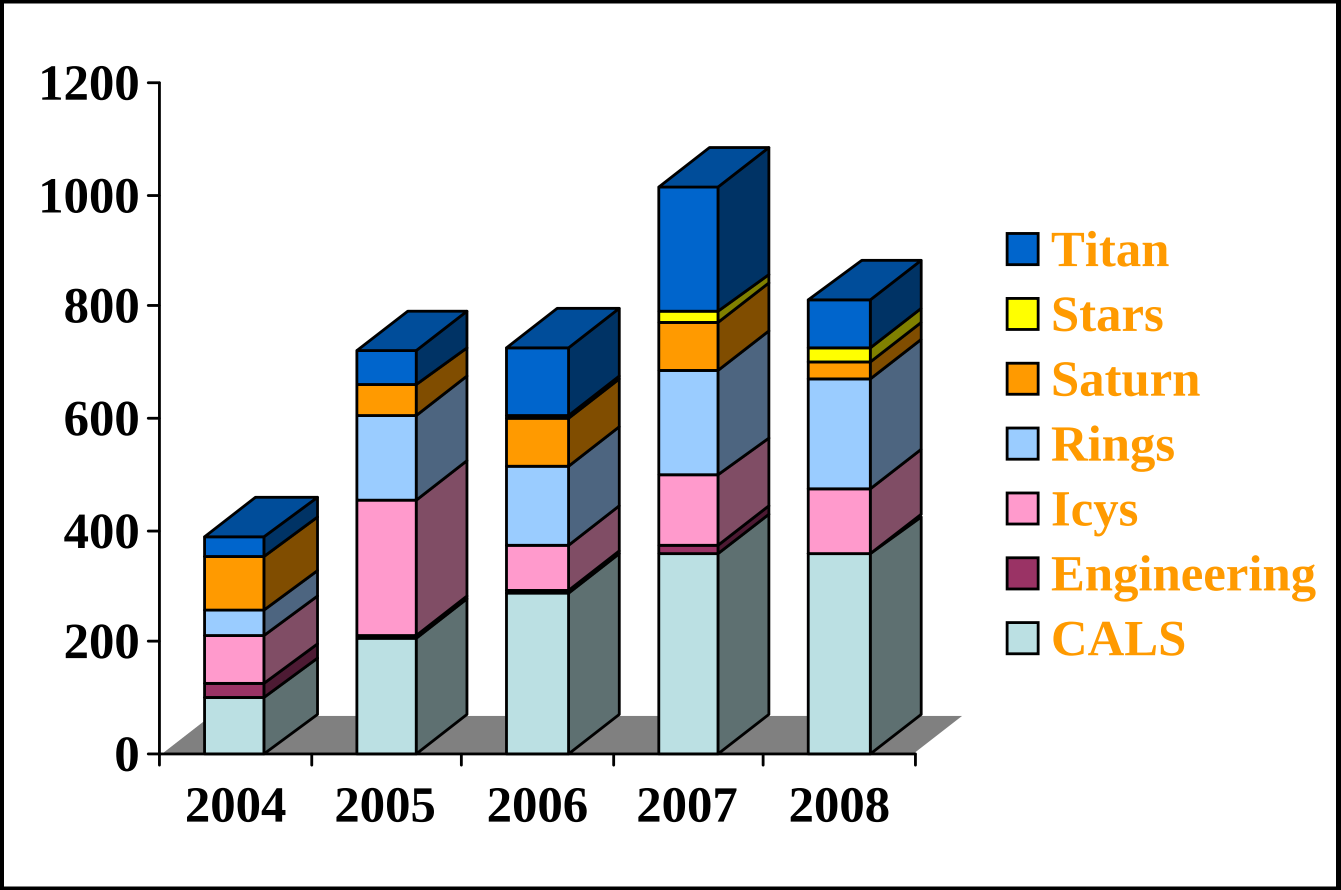


The Challenges

- Thermal Stability
  - It is a thermometer and takes its own temperature!
- Jitter
  - It is the spacecraft seismometer detecting high wheel motion.
- Spikes
  - It senses electrical interferences

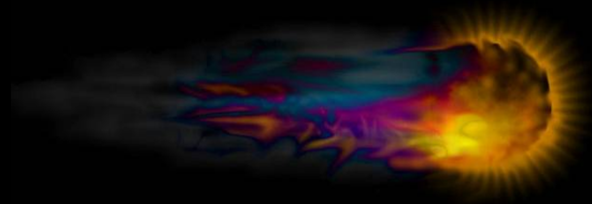


CIRS Activities for PRIME mission



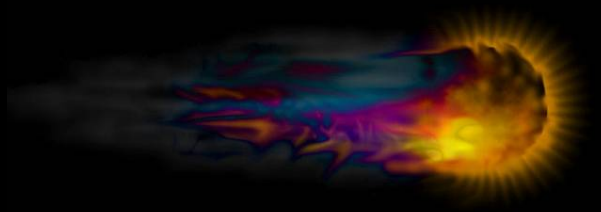
CIRS Activities for Prime Mission

Target	2004	2005	2006	2007	2008	Totals - Target
CALS	102	209	289	360	356	1316
Engineering	24	3	5	14	4	50
Icys	87	242	78	123	116	646
Rings	43	151	143	187	196	720
Saturn	96	53	86	88	29	352
Stars	0	0	5	17	25	47
Titan	36	61	122	222	84	525
Totals - year	388	719	728	1011	810	3656



CIRS Gee Whiz facts for the Prime Mission

- During the last 4 years CIRS (the instrument and/or team) has:
  – Been commanded over 8000 times
  – Had 4 new versions of flight software
  – Planned and designed over 3600 observations
  – Collected, processed, and calibrated 52,718,732 spectra (as of 24 Sept 2008)
  – Published over 50 papers



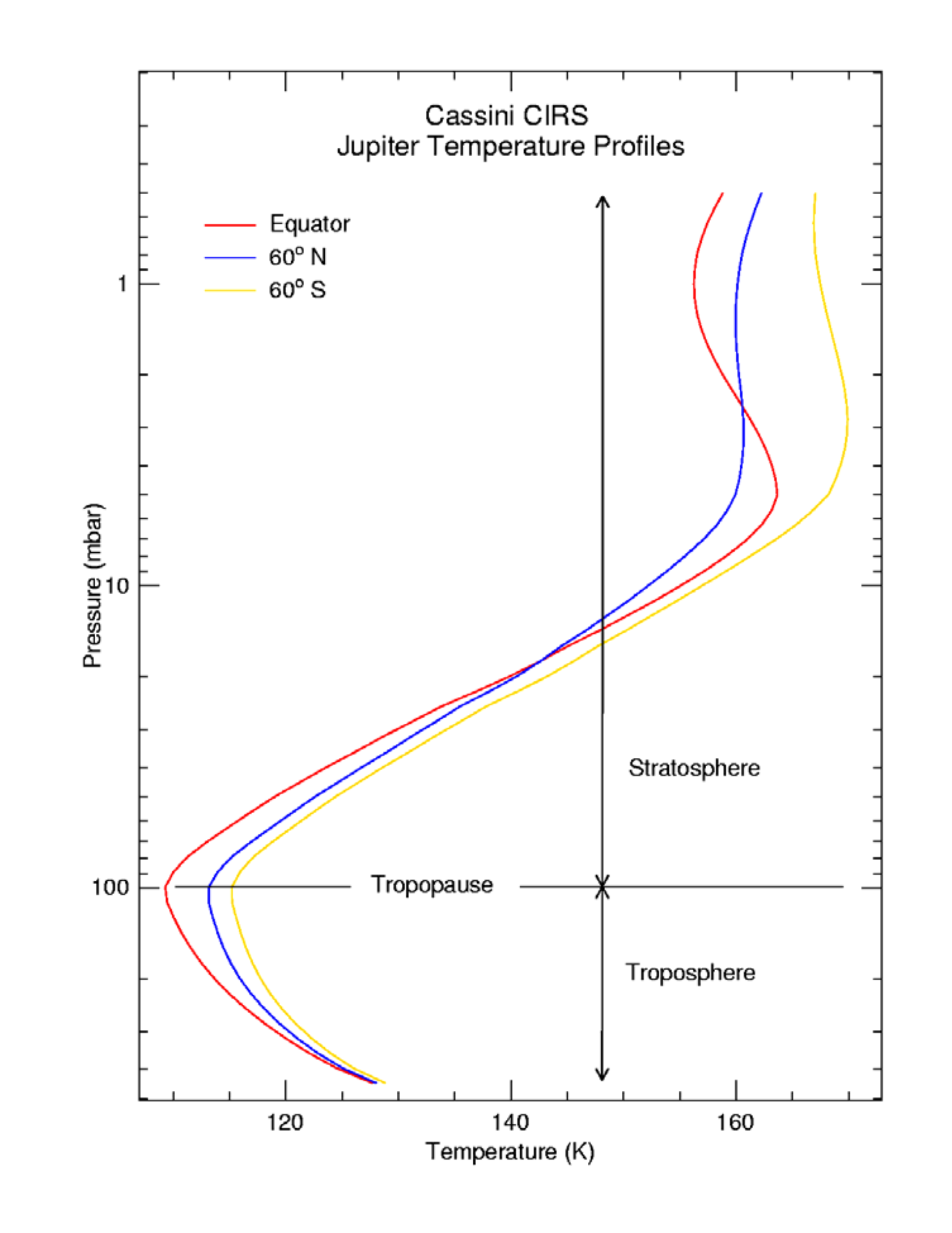
A Day in the Life an OTL

- NO 2 days are alike!!!
- Very fluid and dynamic situation.
- 24 hours per day, 7 days per week, 365 days per year.
- Some days I put out fires and some days I create them!
- E-mail, telecons, crisis management, fielding questions, providing guidance, Icy satellite designs, sequence implementation, solving problems, team meeting organization, preparing presentations, anomaly response, task/team management – herding cats, etc ….
- It's a juggling act and can be very stressful!

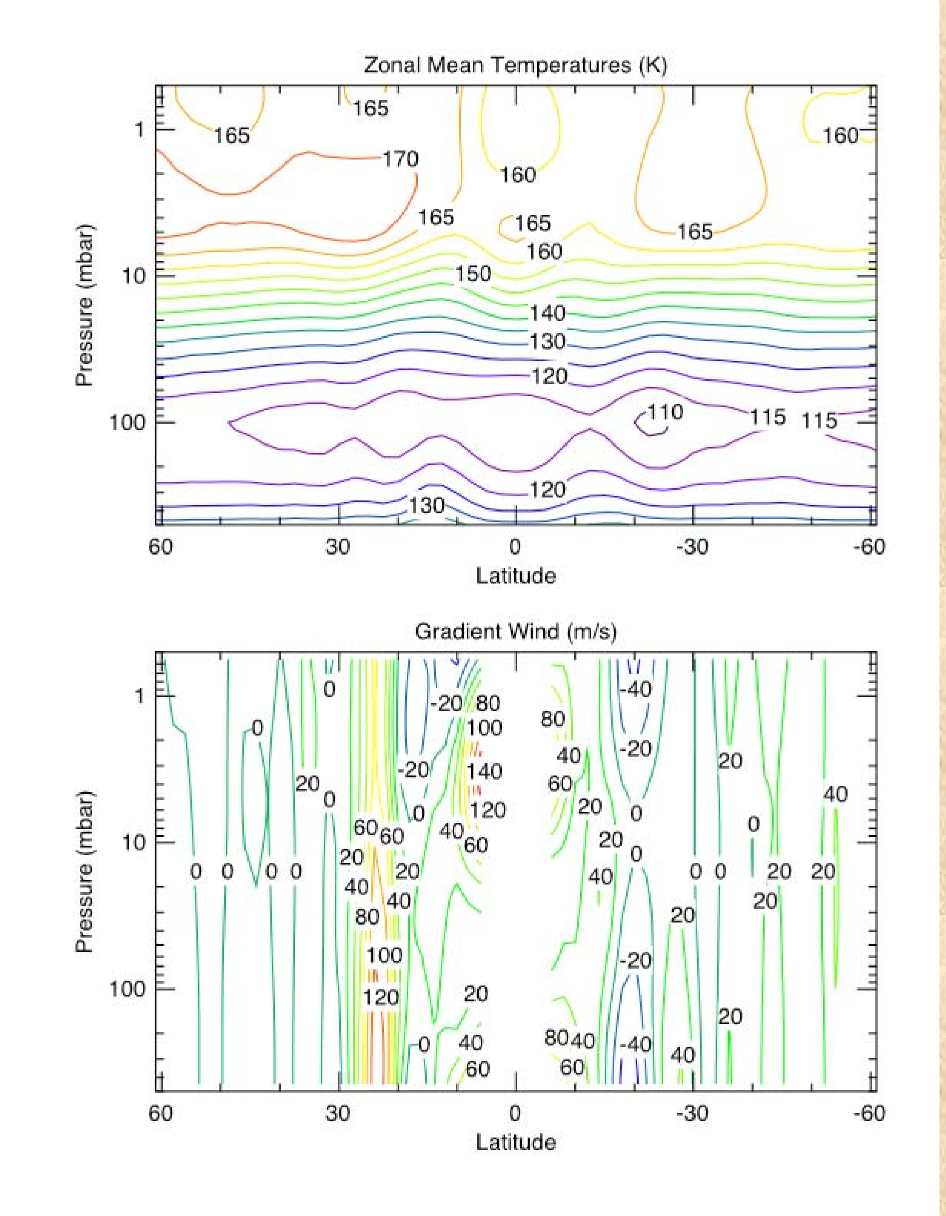
CIRS: The Science

Jupiter's Atmosphere

Temperature Retrievals



Derivation of Stratospheric Winds

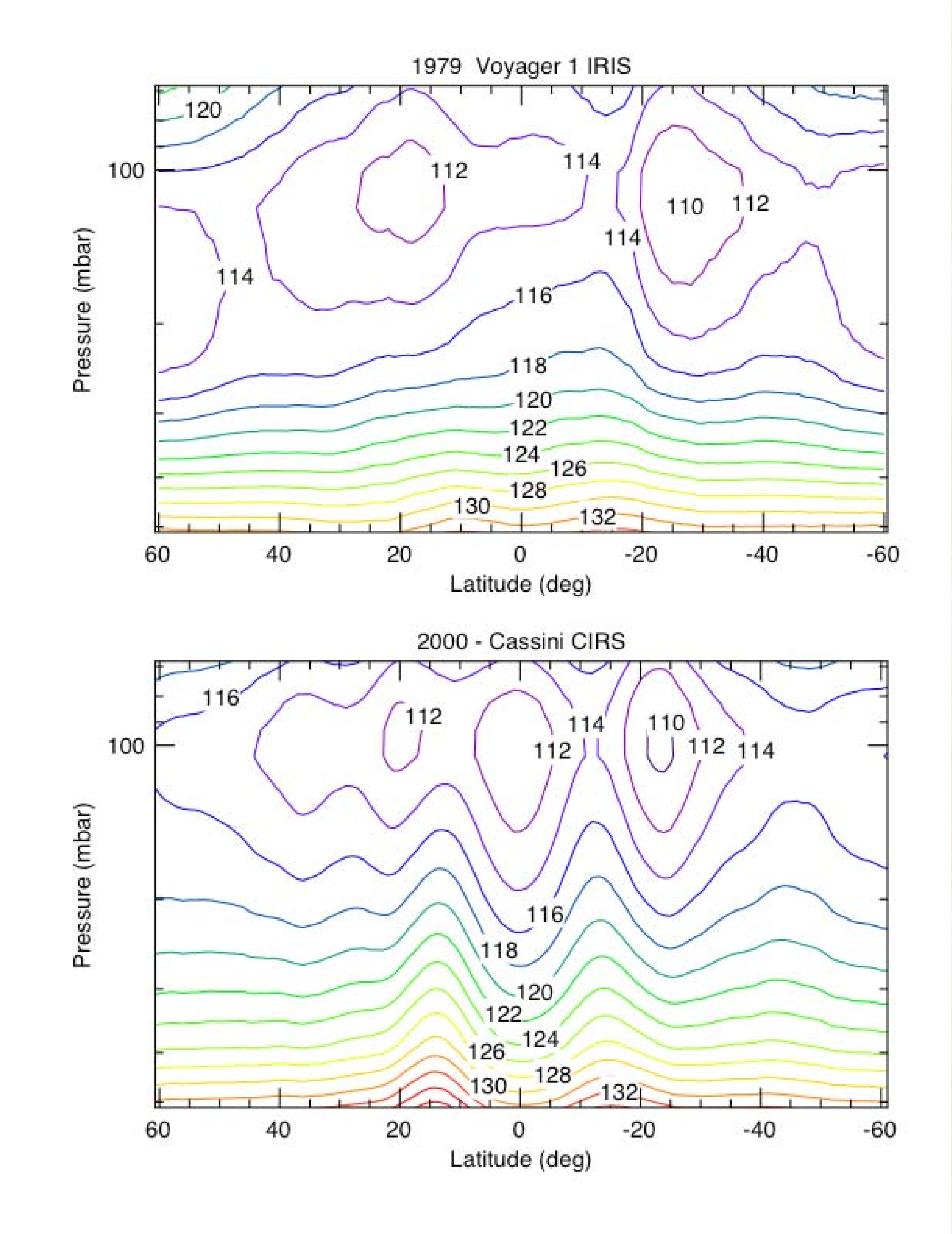


Thermal Wind Equation

$$\left(\frac{\partial u}{\partial \ln P}\right)_y = \frac{R}{f}\left(\frac{\partial T}{\partial y}\right)_P$$

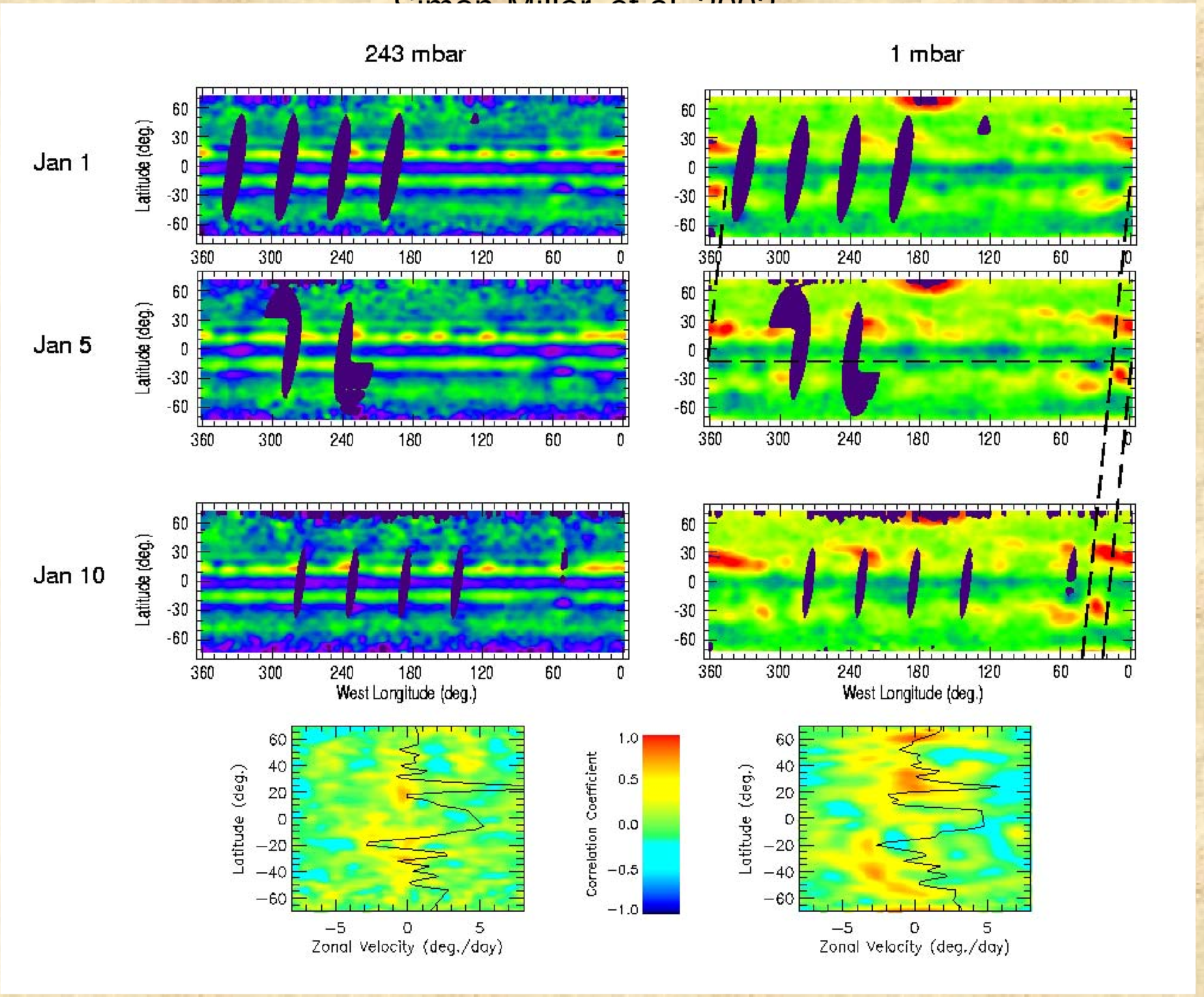
$$f = 2\Omega \sin(latitude)$$

Temperature In Two Epochs



Temperature Variation with Altitude

Simon Miller, et al. 2002



Hydrocarbon Photochemistry

Jupiter's & Saturn's Major Constituents

H_2

He

CH_4

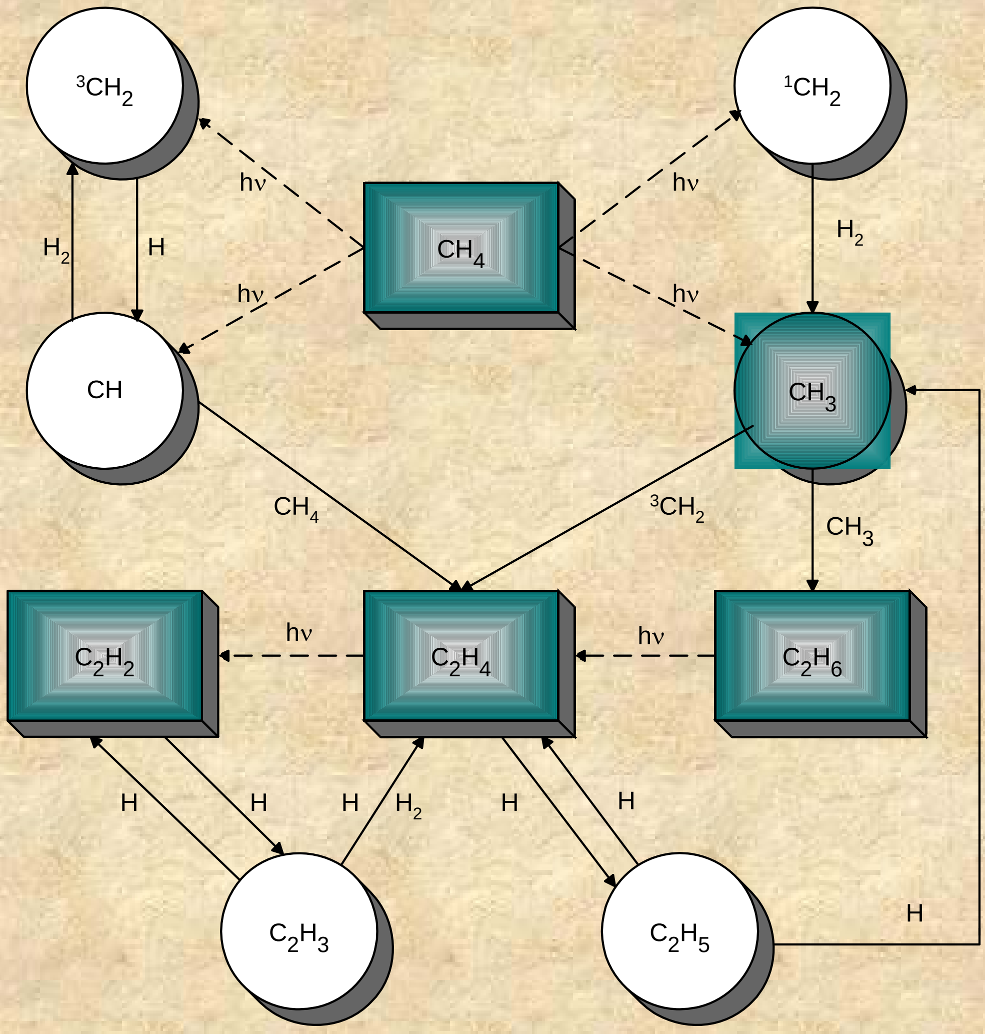
NH_3

PH_3

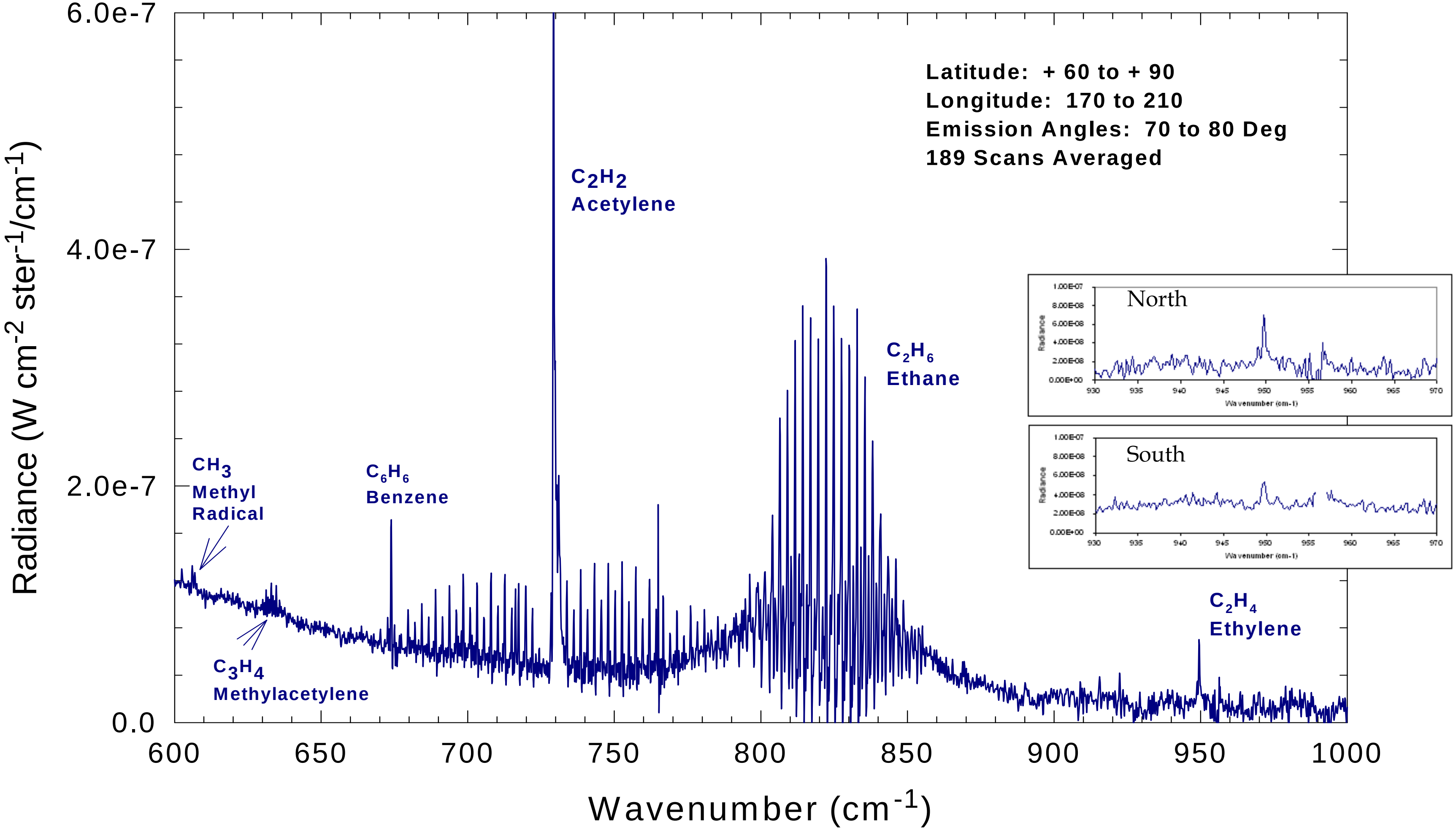
H_2O

CO

Noble Gases

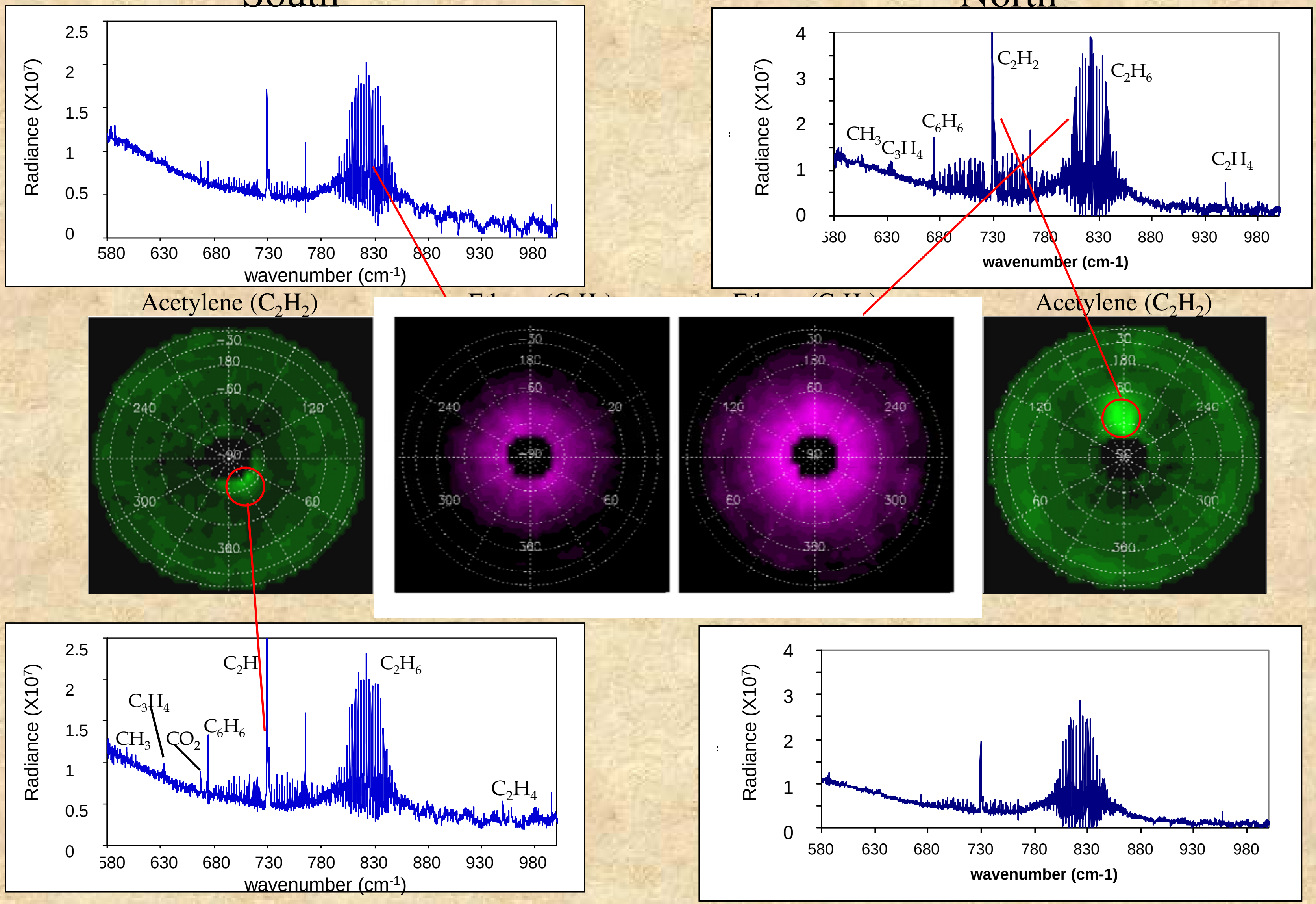


CIRS at Jupiter: Dec. 2000 - Jan. 2001



CIRS at Jupiter: Dec. 2000 - Jan. 2001

South North

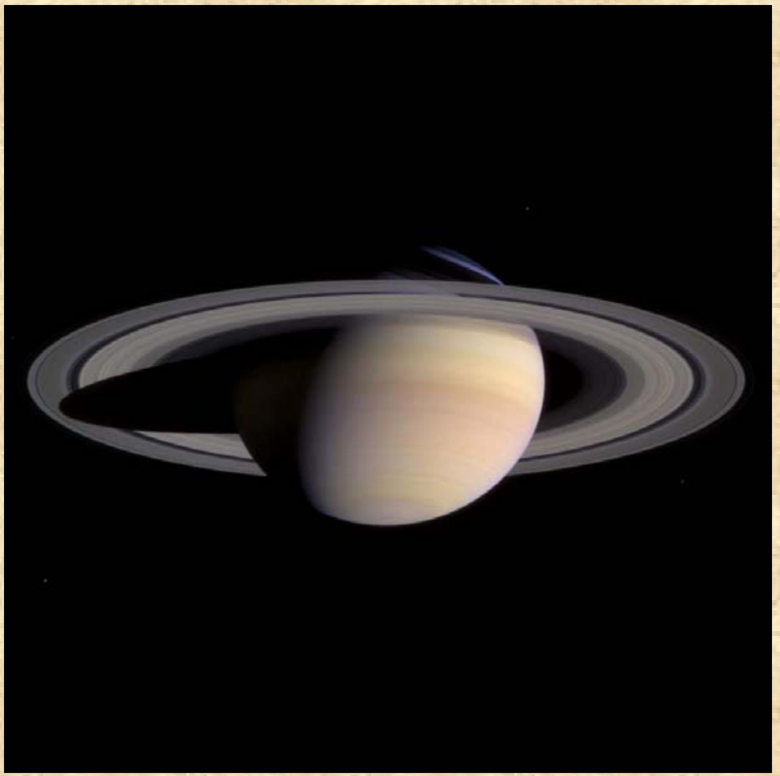


Composition Detected To-Date by CIRS

	Gas	Spectral Region (cm^{-1})	Comments
Main Constituents	(new)		
Hydrogen	H_2	Pressure Induced: 50 - 600	
		Dimer: 384; Quadrupole: 587	
Methane	CH_4	Rotational: 73.0, 83.3, 94.3	
		ν_4: 1250 - 1350	Auroral Enhanced
Tropospheric Constituents			
Ammonia	NH_3	Rotational: 100 - 250	
		ν_2: 900 - 1100	
Phosphine	PH_3	Rotational: 20 - 100	
Stratospheric Constituents			
Hydrocarbons			
Acetylene	C_2H_2	700 - 760	Auroral Enhanced
Ethane	C_2H_6	800 - 840	Auroral Enhanced
Methyl Radical	CH_3	606	Auroral Enhanced
Ethylene	C_2H_4	949	Auroral Enhanced
Methylacetylene	C_3H_4	630 - 635	Auroral Enhanced
Benzene	C_6H_6	673.5	Auroral Enhanced
Diacetylene	C_4H_2	628	
Nitrilres			
Hydrogen cyanide	HCN	712	
Oxygen Compounds			
Carbon dioxide	CO_2	667.4	Excess at High Southern Latitudes
Isotopes			
Deuterated Hydrogen	HD	Rotational: 88.2, 178.1, 265.3	
Monodeuterated methane	CH_3D	1156	
Isotopic ethane	$^{13}C_2H_6$	822	
Isotopic ammonia	$^{15}NH_3$	863, 883, 903, 943	

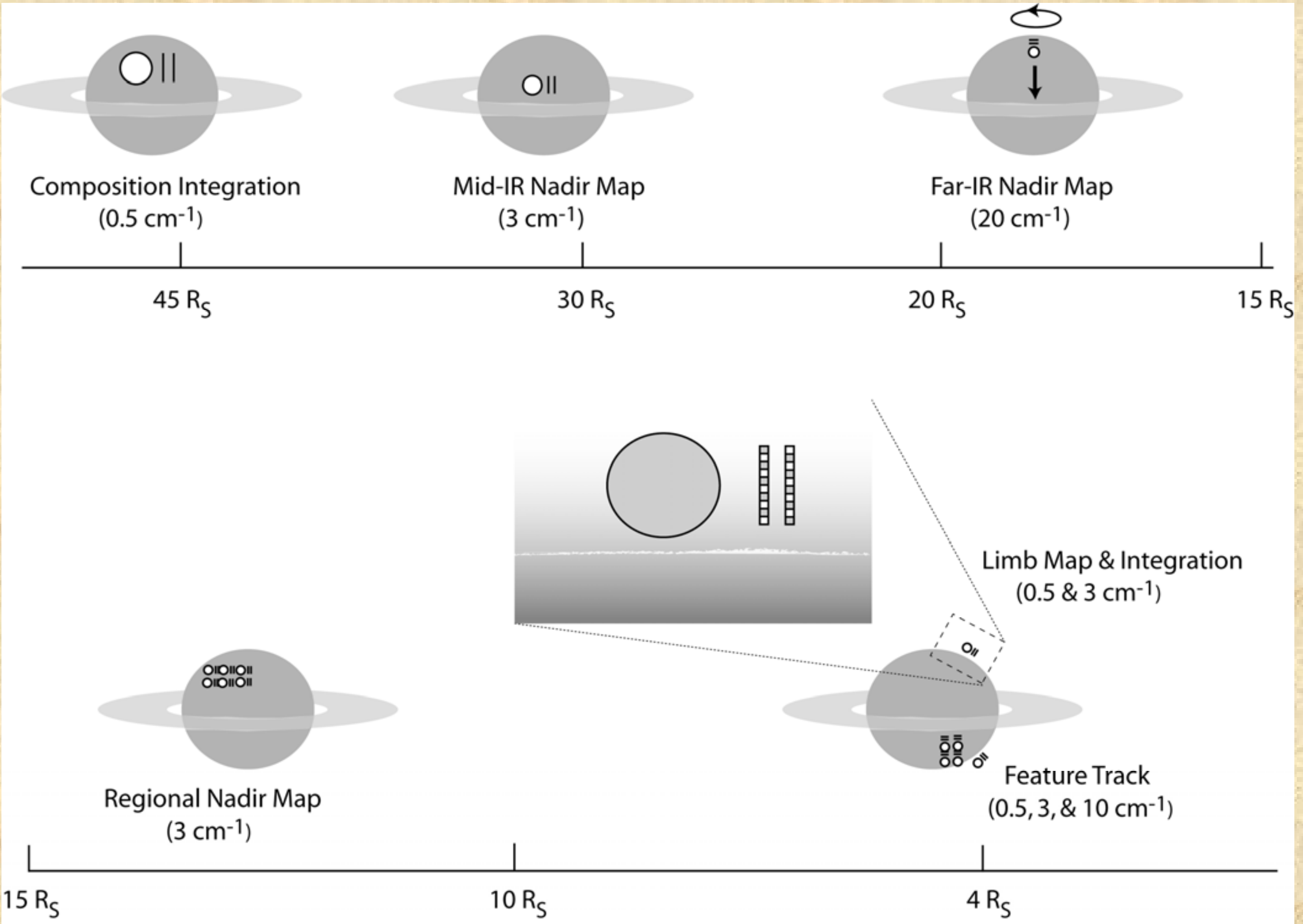
CIRS: The Science

Saturn's Atmosphere



Saturn Observations by Range

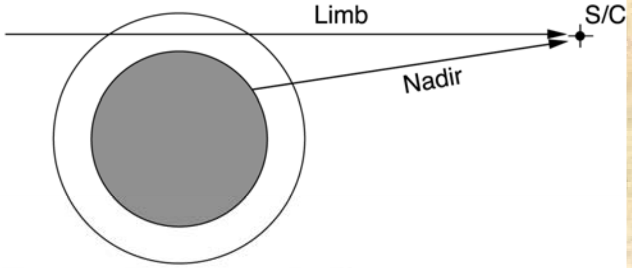
- Five basic types of observations conducted by CIRS depending on range and goal
- Thermal Characterization: Mosaics across the disc. Requires low spectral resolution.
- Composition: Long long sit and stares. Requires high spectral resolution.

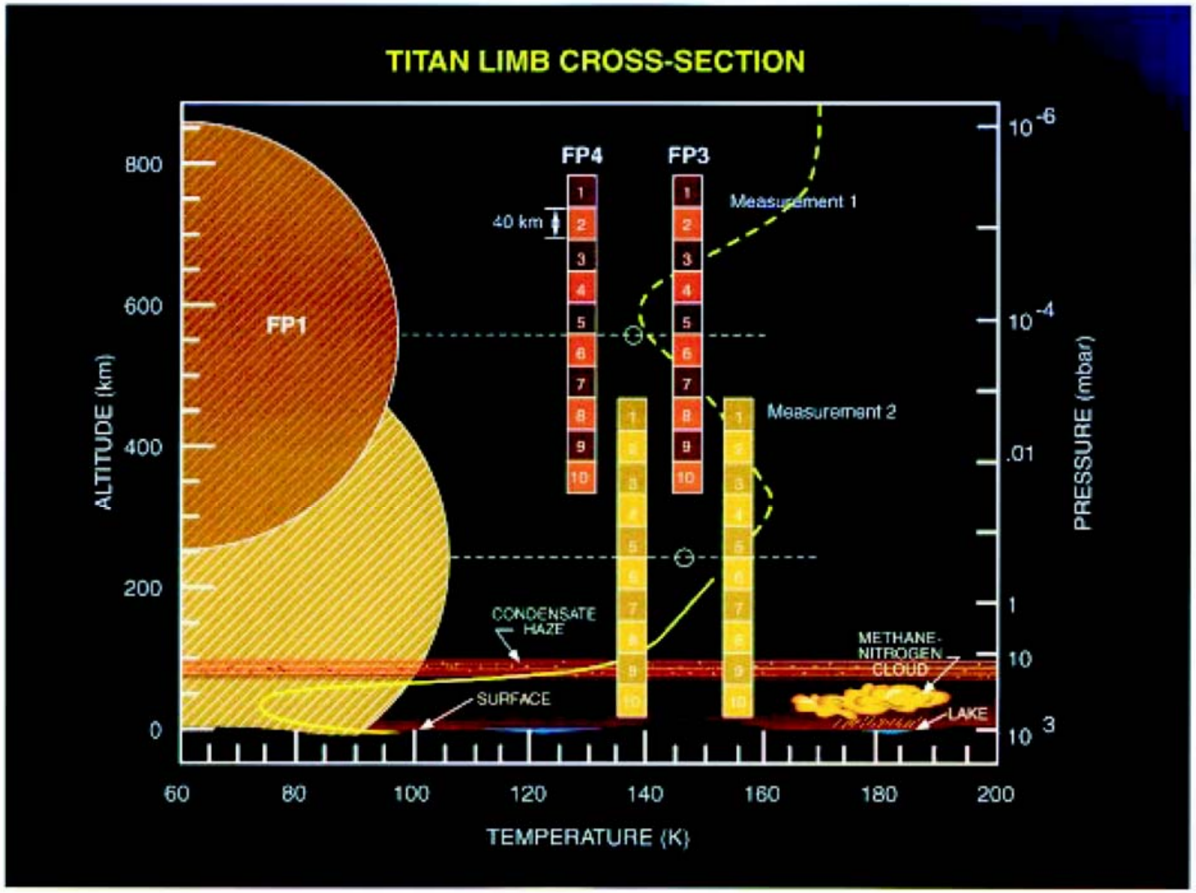


CIRS Saturn Timeline

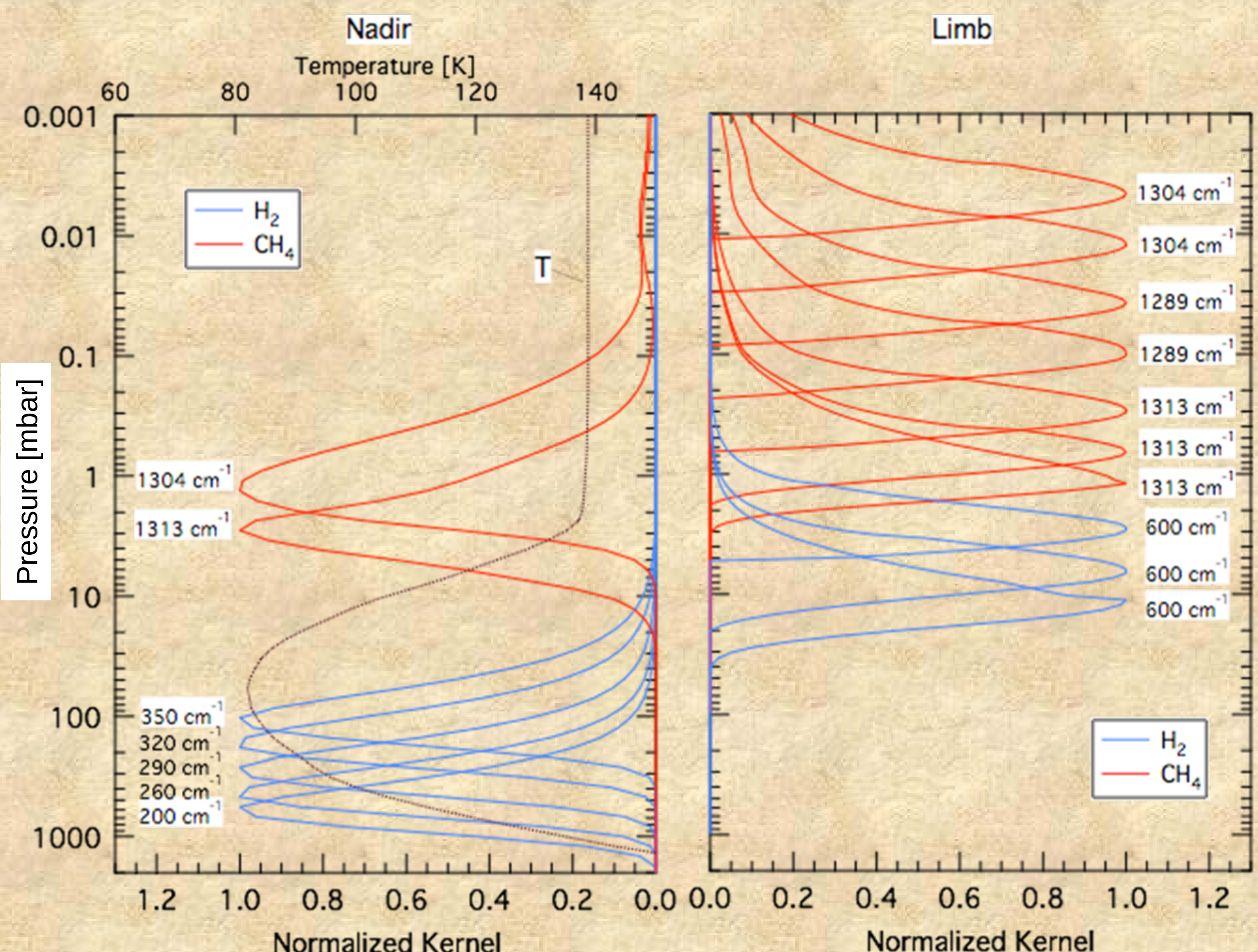
CIRS Limb Observations

Fig. 6 *Right*: Schematic of limb and nadir viewing. *Bottom*: Limb sounding on Titan. The arrays are placed in two successive positions to map the tropopause region and higher altitudes.

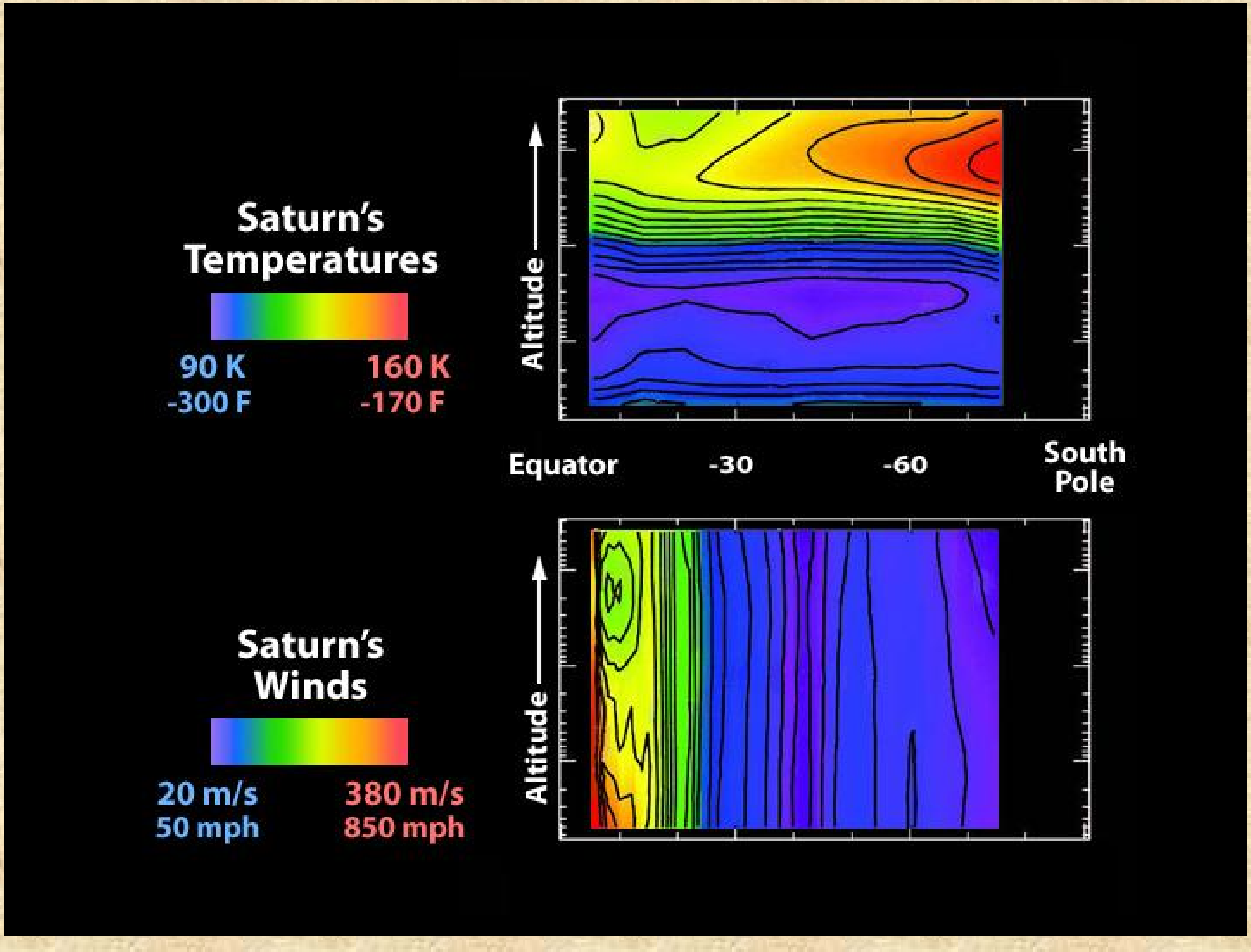




Saturn Temperature-Inversion Kernels



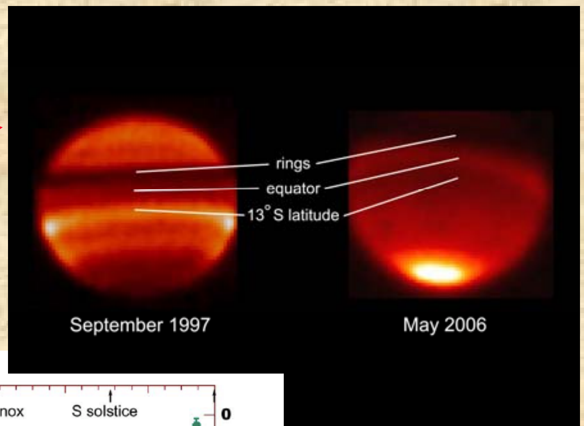
Saturn’s Temperatures and Winds

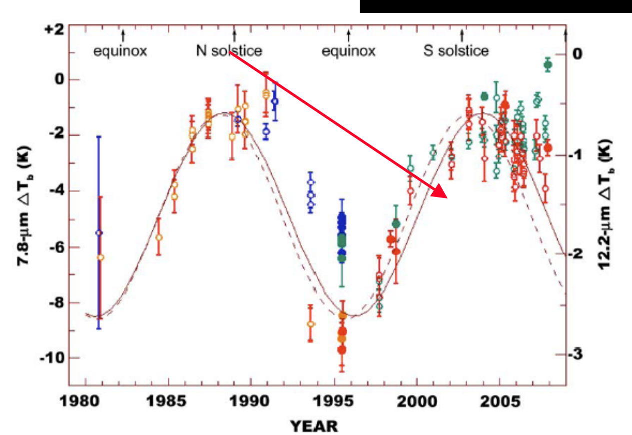


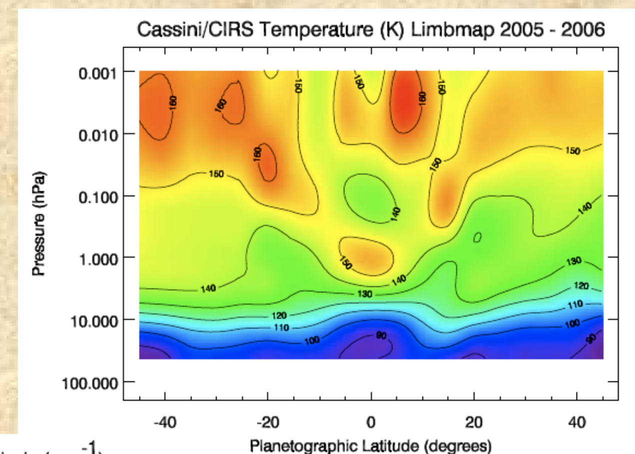
Saturn’s 15 Year Thermal Oscillation

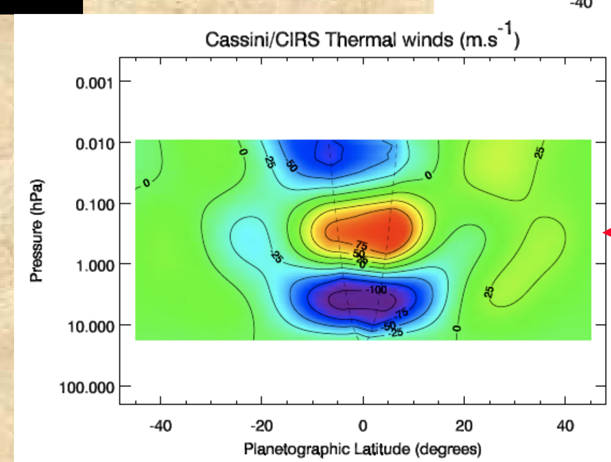
- CIRS has observed the spatial variation of temperature in Saturn’s atmosphere during Cassini’s Prime Mission. CIRS observations in the Cassini epoch have been compared to the temporal coverage provided by ground-based observations.
- Together, they indicate an semi-annual (with a period of ~15 years) oscillation in the stratosphere. The temperature at Saturn's equator switches from hot to cold, and temperatures on either side of the equator switch from cold to hot every Saturn half-year.
- This phenomenon is similar to the quasi-biennial oscillation on Earth and quasi-quadriennial oscillation on Jupiter.
- Fouchet, et al. 2008.

Ground-based observations reveal a thermal oscillation. CIRS data adds to this temporal dataset.



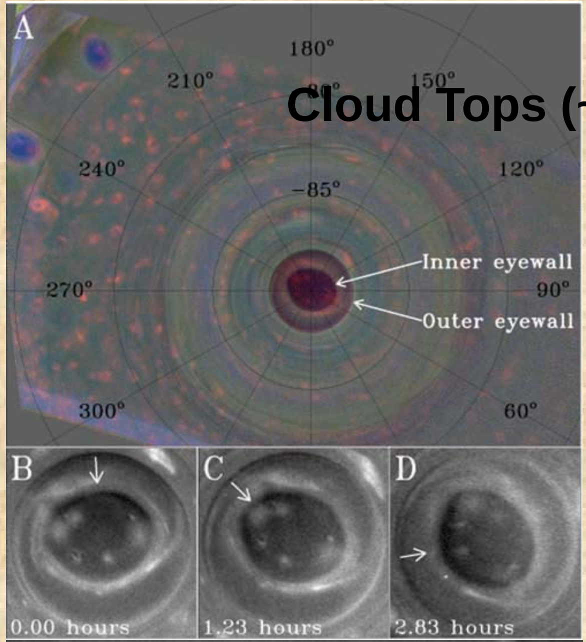




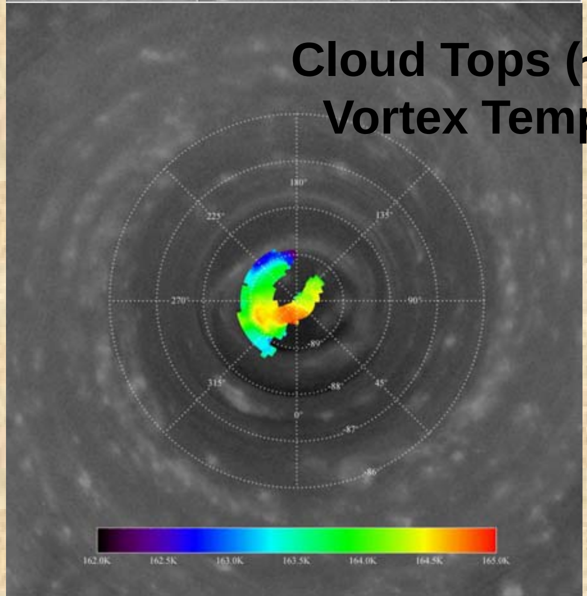


Spatial variation of temperature & thermal winds by Cassini/CIRS

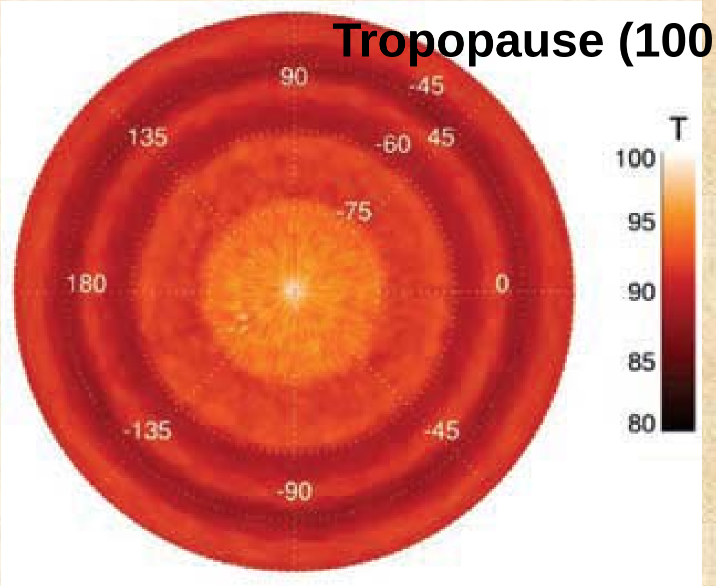
South Polar Storm Temperatures



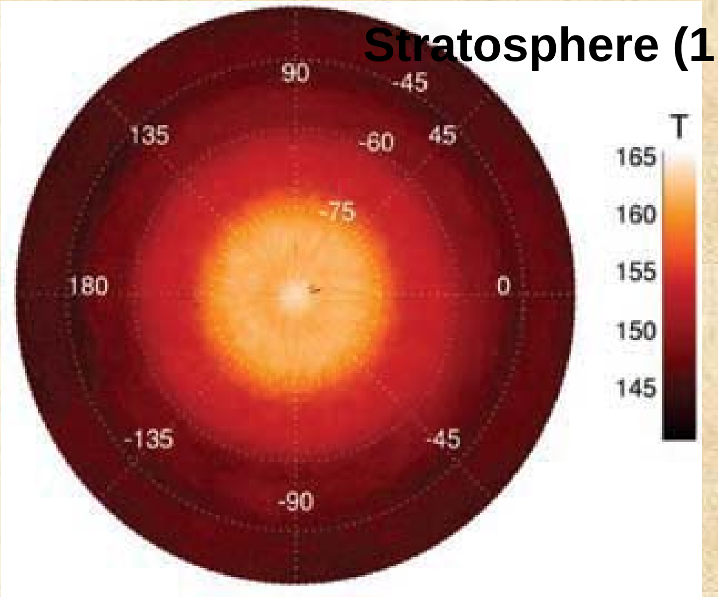
Cloud Tops (~0.5 bar)



Cloud Tops (~0.5 bar) & Vortex Temperatures



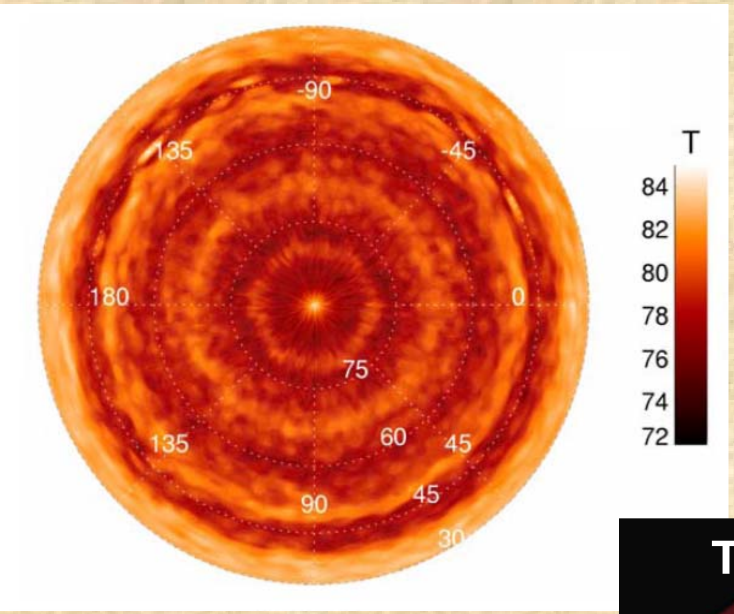
Tropopause (100 mbar)



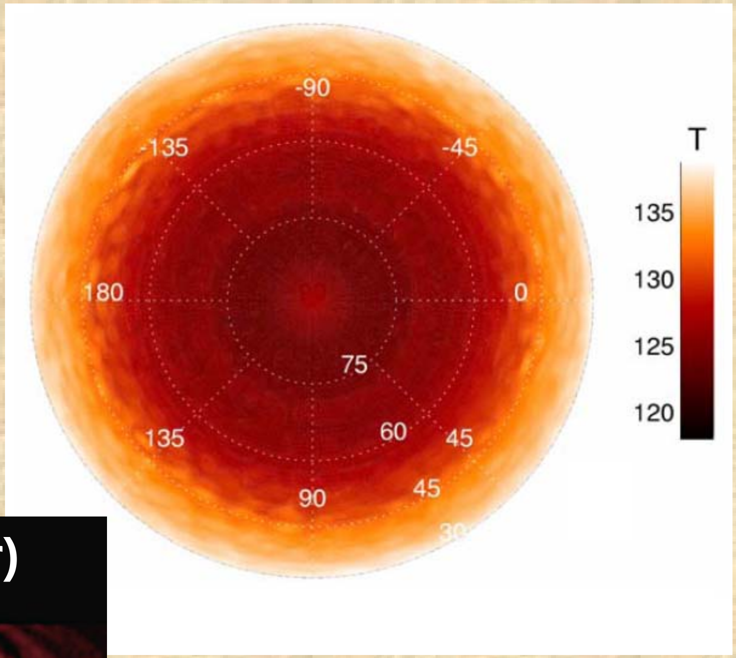
Stratosphere (1 mbar)

North Polar Hexagon Temperatures

Tropopause (100 mbar)

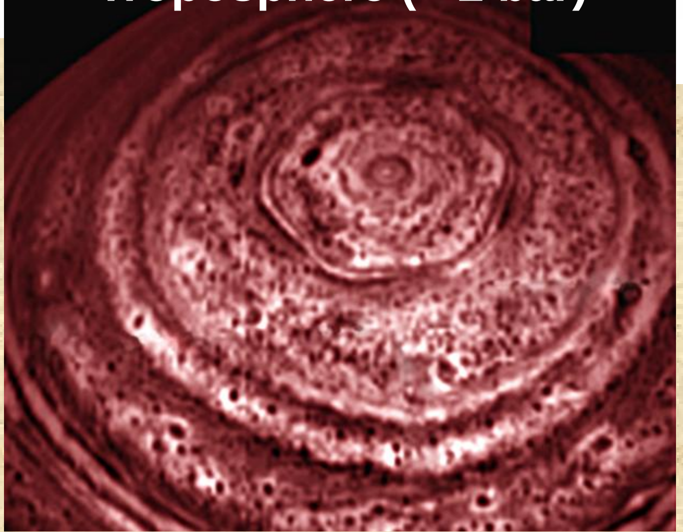


Stratosphere (1 mbar)



- **View of the North Polar Hexagon at 3 levels in Saturn's atmosphere.**
- **CIRS measures thermal black body radiation originating from the upper troposphere and stratosphere**

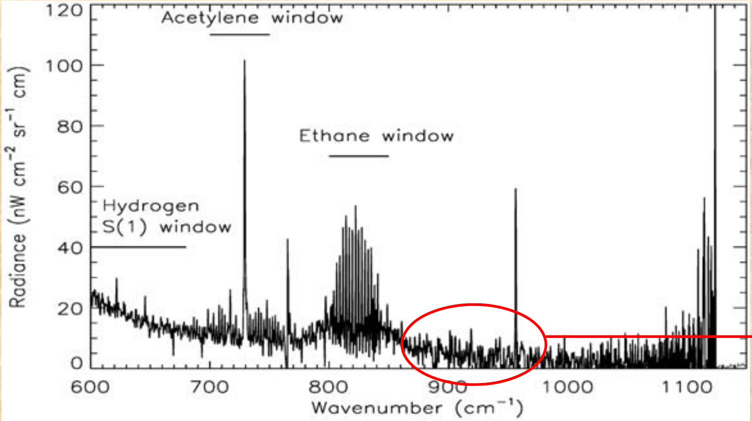
Troposphere (> 2 bar)



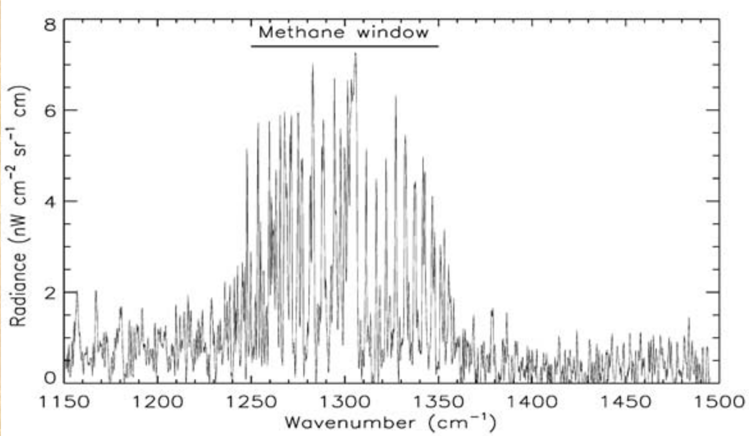
- **VIMS measures infrared photons at 5 μm, which originate from the deep troposphere. Storm systems which provide enough opacity will block these photons creating the dark features observed.**

Saturn's Spectra

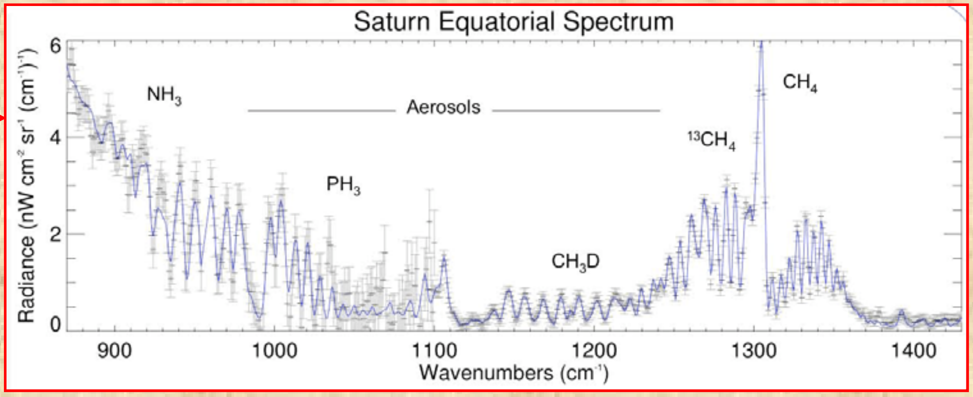
• Like Jupiter, Saturn's far-infrared spectra is complicated with the presence of many different molecules, e.g. Fletcher, et al. (2008) and Howett, et al. (2007)



(a) Typical FP3 spectra

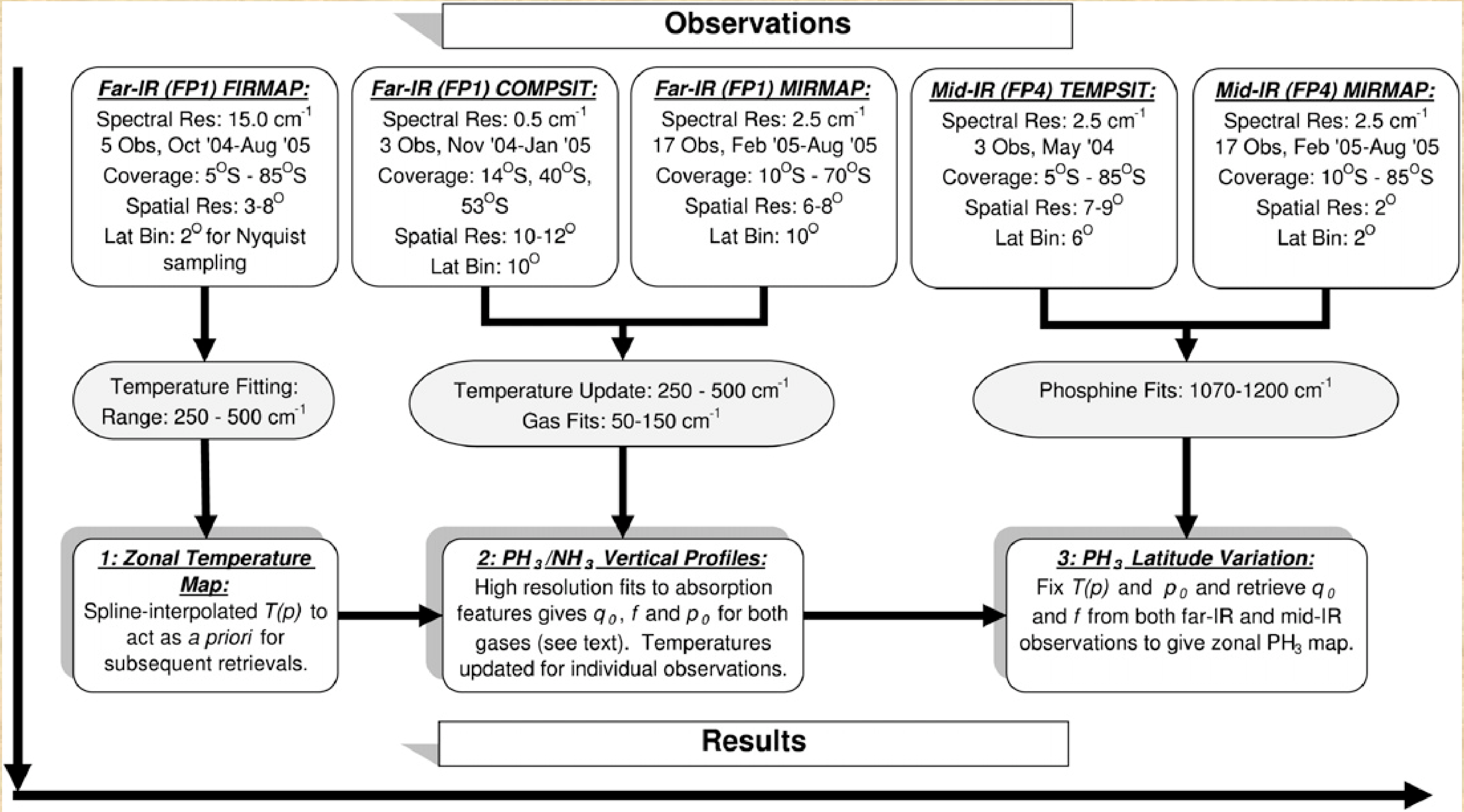


(b) Typical FP4 spectra

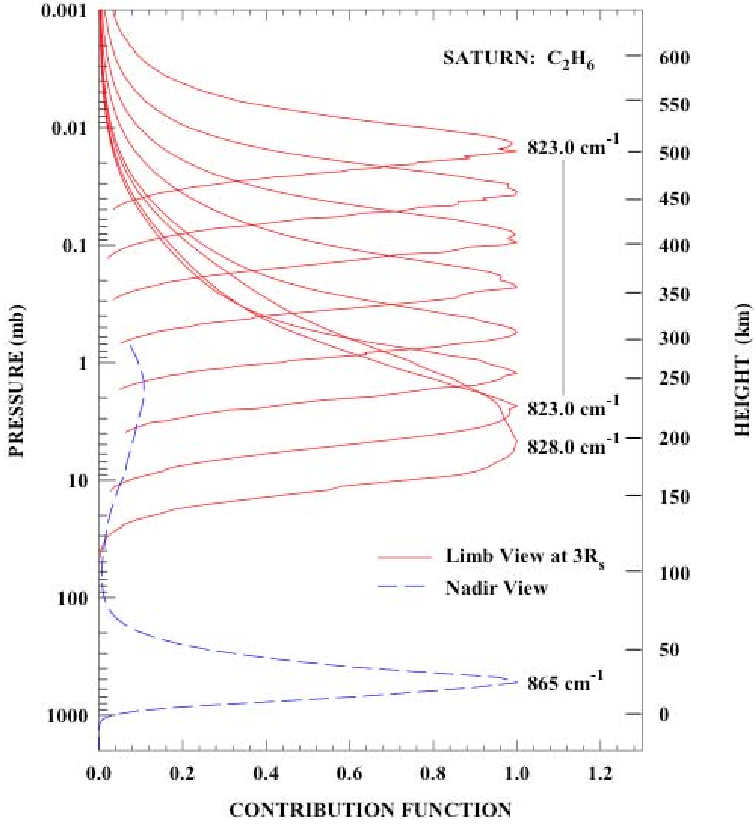


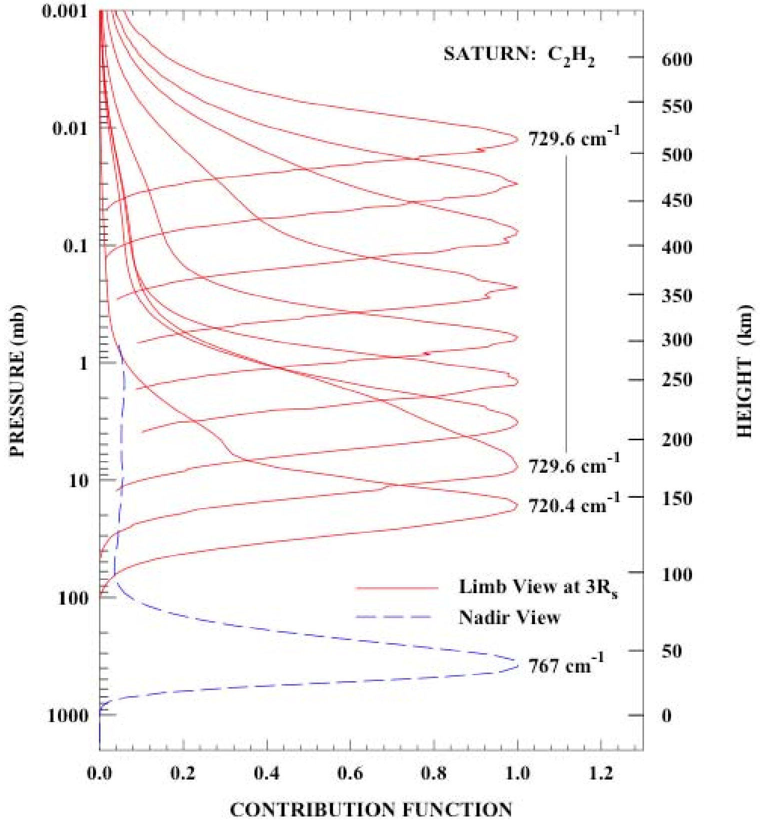
Saturn’s Composition

• This schematic from Fletcher, et al. 2007 illustrates how several types of data sets and modeling procedures are needed to extract the atmospheric composition.



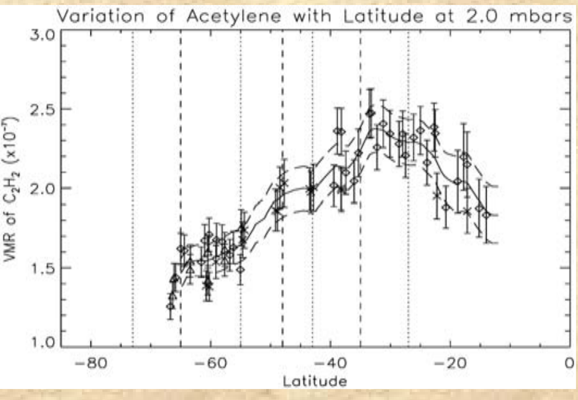
Saturn Composition-Inversion Kernels

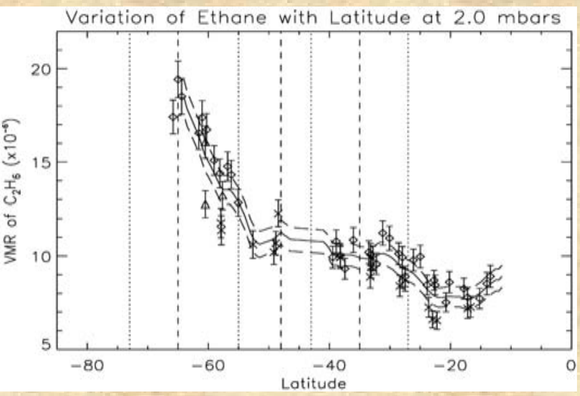


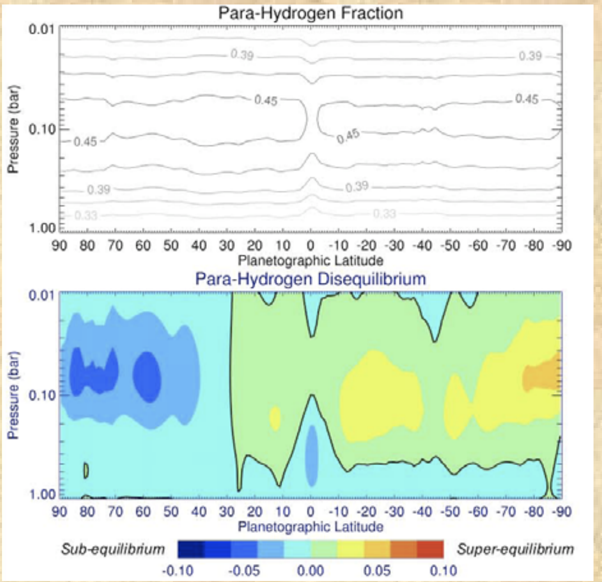


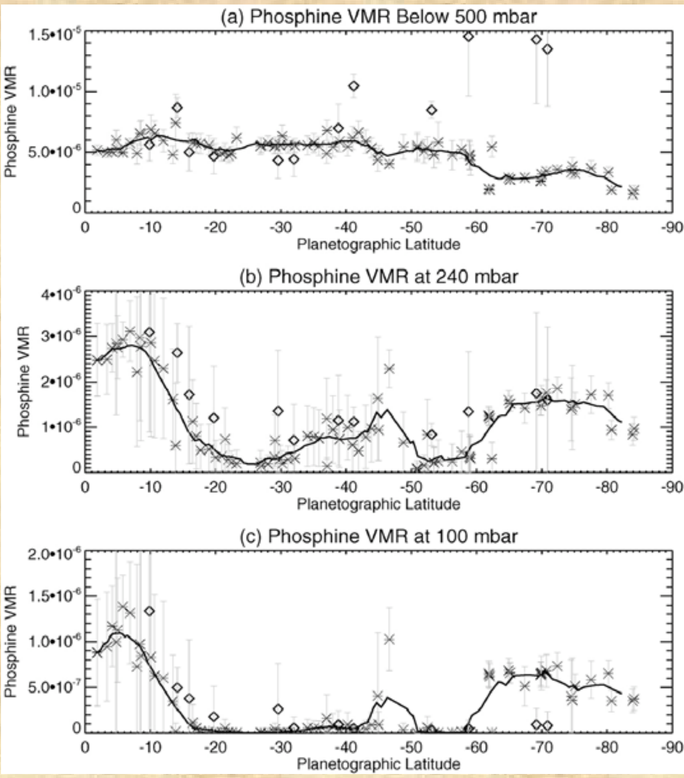
Saturn's Latitudinal Variations

•CIRS is revealing that the distribution of minor molecules vary strongly with both latitude and altitude.
• How will this change with season? Stay tuned!



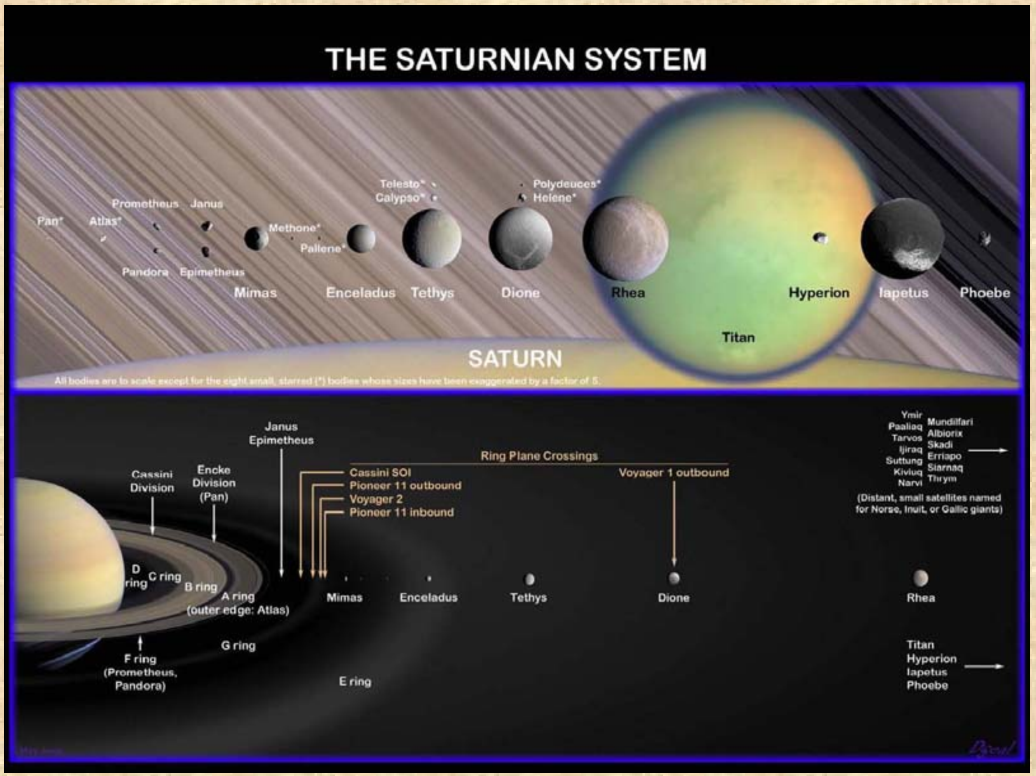






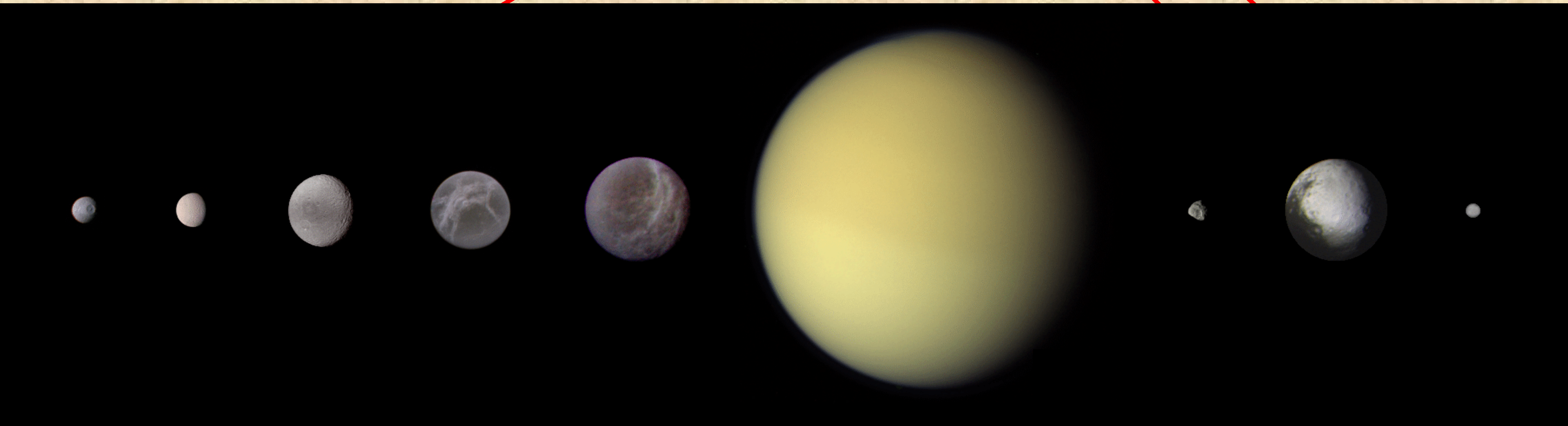
CIRS: The Science

The Icy Satellites



CIRS and Saturns's Mid-Sized Satellites

- Extensive data on all the medium-sized satellites
- Concentrate here on three of them:
  - Phoebe
  - Iapetus
  - Enceladus



Black-body Radiation

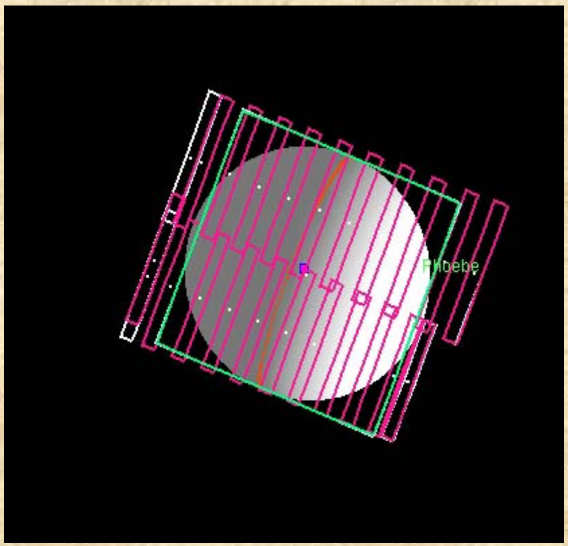
- Any object warmer than absolute zero emits heat radiation
- The hotter the surface, the shorter the wavelength of the radiated light
  - Brightness and wavelength of the radiation gives the temperature
- Objects as cold as those in the Saturn system emit their radiation at long infrared wavelengths

Hot lava emits red and yellow light

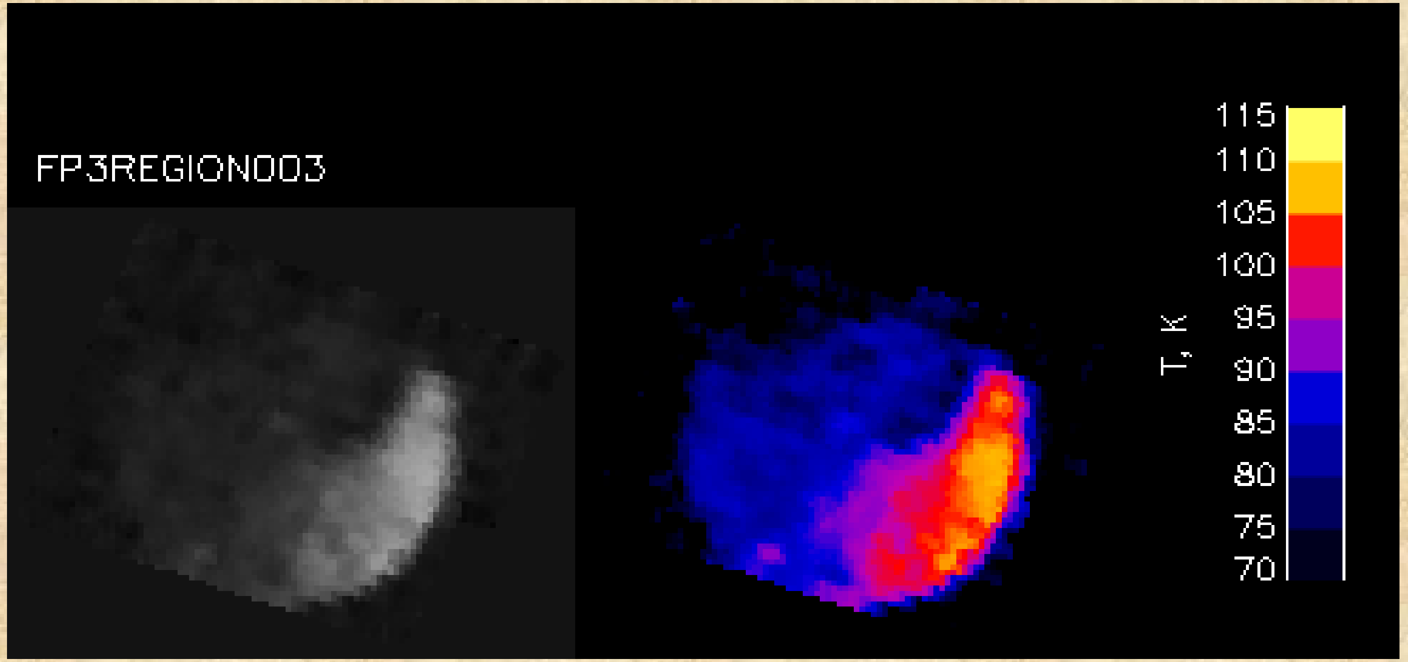
Cooler lava emits red light

Even cooler lava emits only infrared light

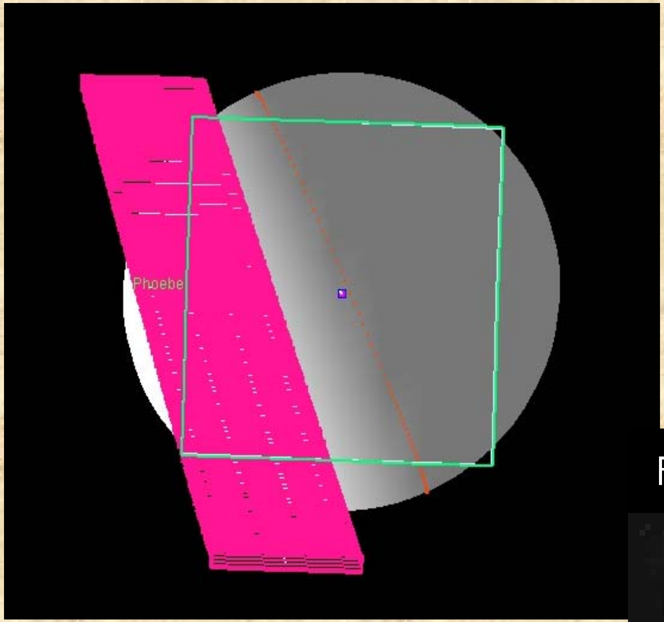
Phoebe: June 2004

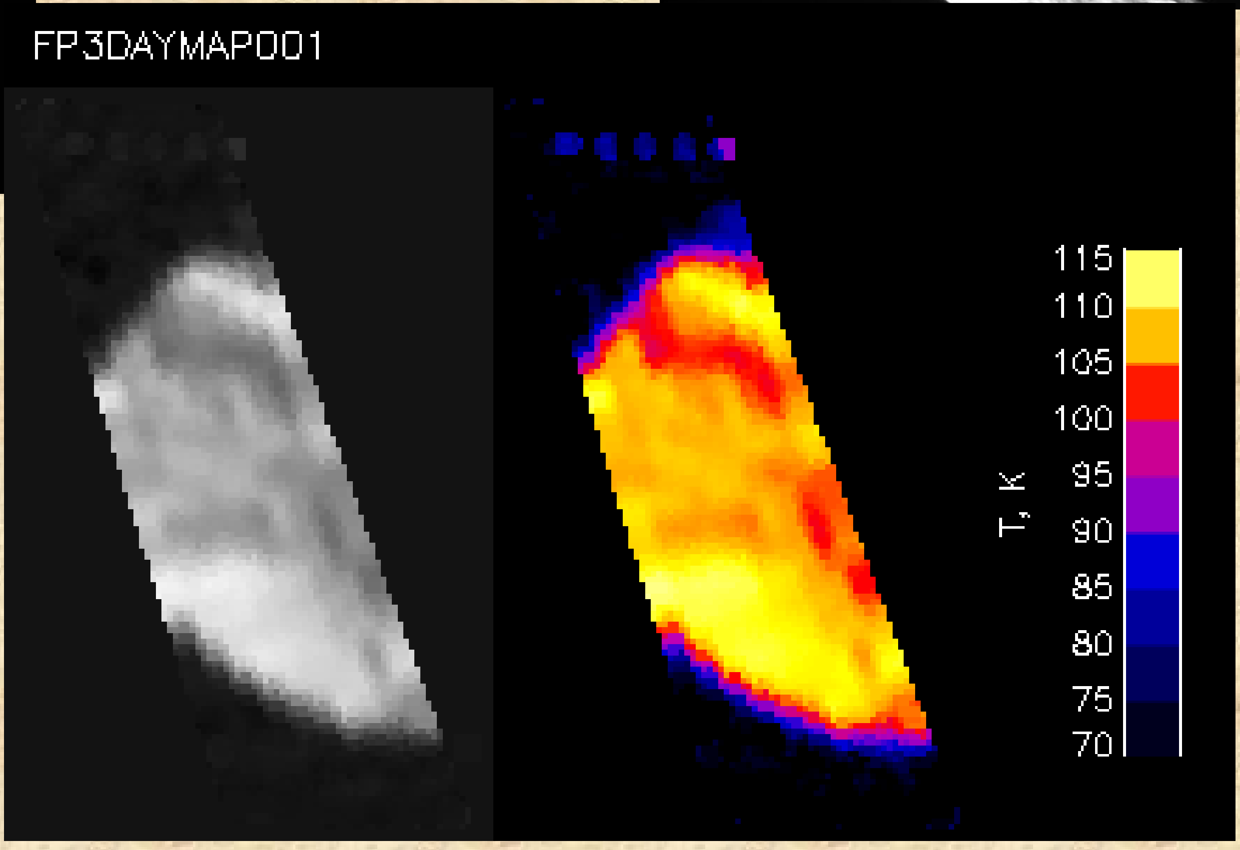


Sunrise on the big crater Jason



Phoebe Departure





0:55h after close approach

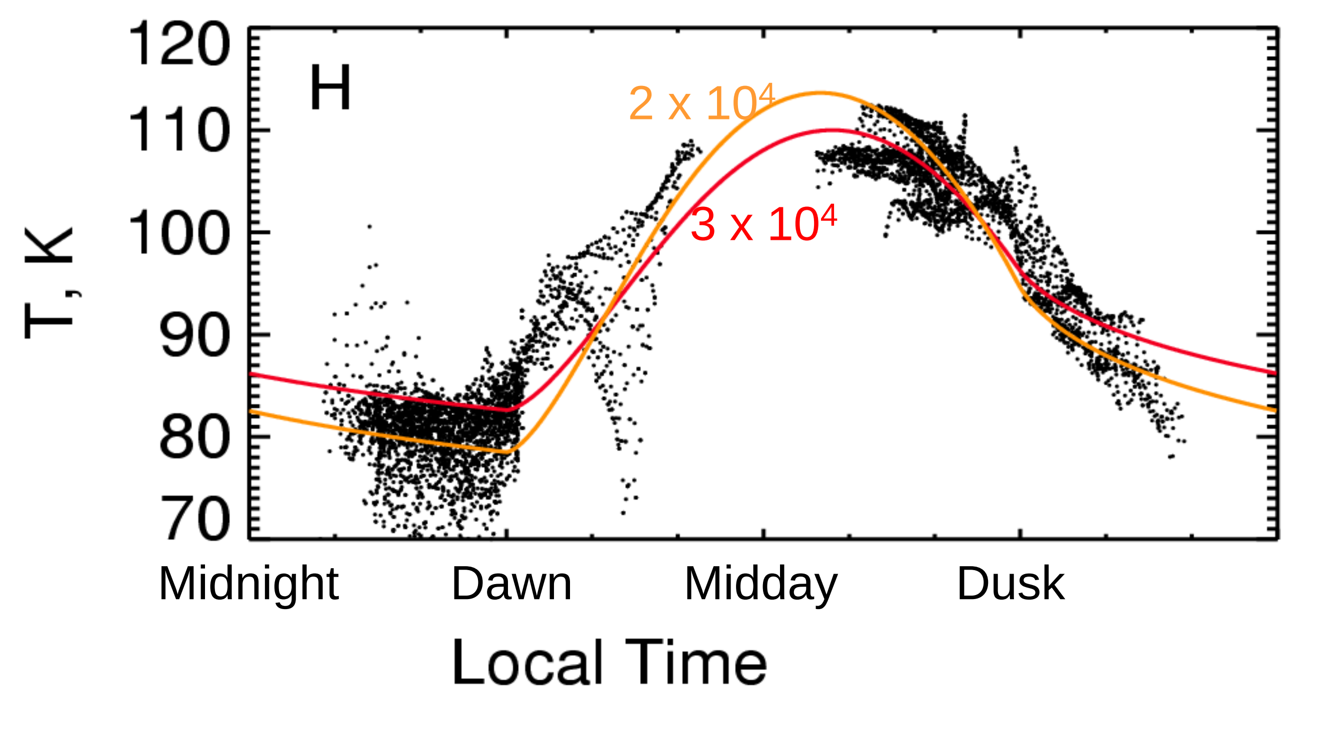
Range: 21,500 km

Early afternoon is the warmest time of day, ~112 K

Warmer than most Saturn satellites because Phoebe is dark and absorbs most of the available sunlight

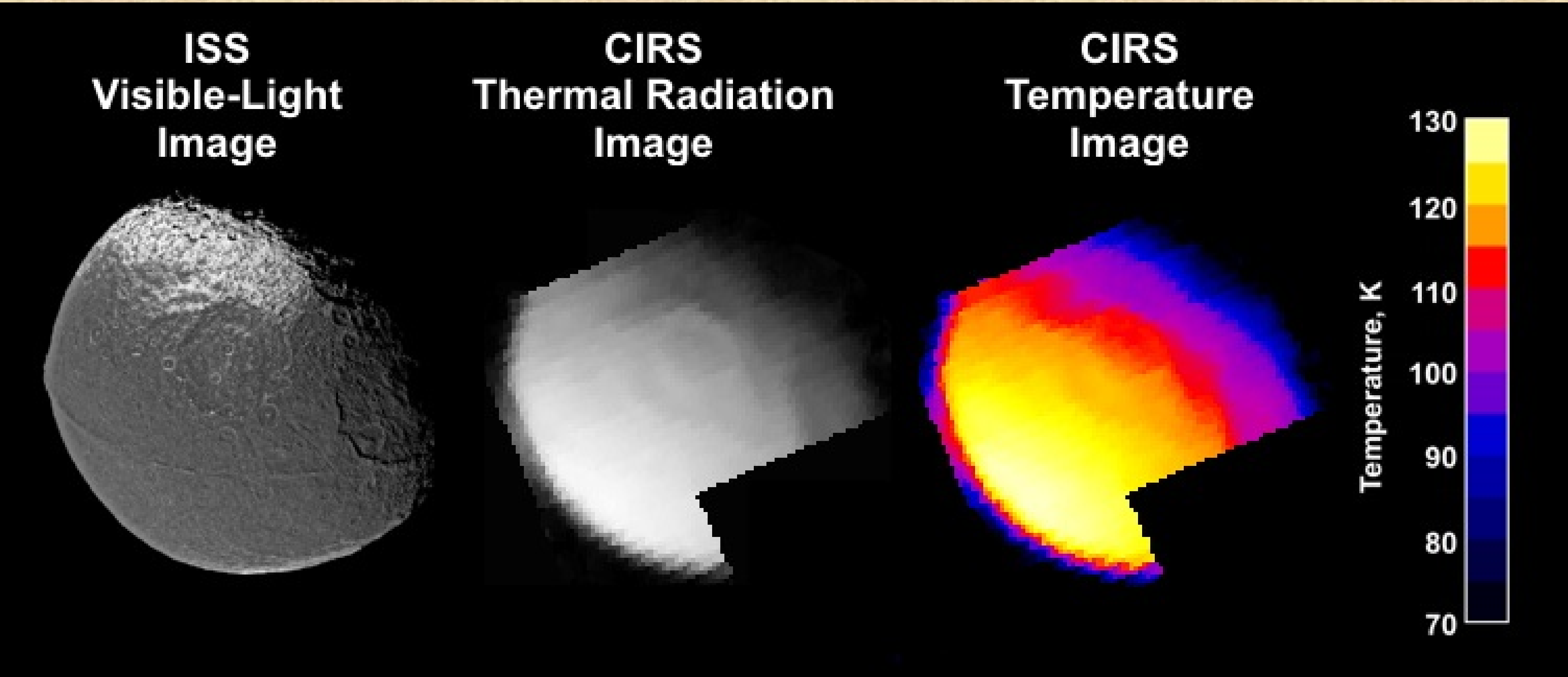
Phoebe Diurnal Temperature Curve

- Allows determination of thermal inertia: how well the surface retains heat at night.
  - Solid rock and ice store heat efficiently, change temperature slowly (think of warm stone walls at the end of a summer day)
  - Fluffy, dusty, surfaces change temperature quickly when the heat source (sunlight here) goes away.
- Large diurnal variations in temperature on Phoebe mean that its surface is very dusty or fluffy: thermal inertia is 100x lower than for solid rock or ice.
- Pulverized by billions of years of impacts



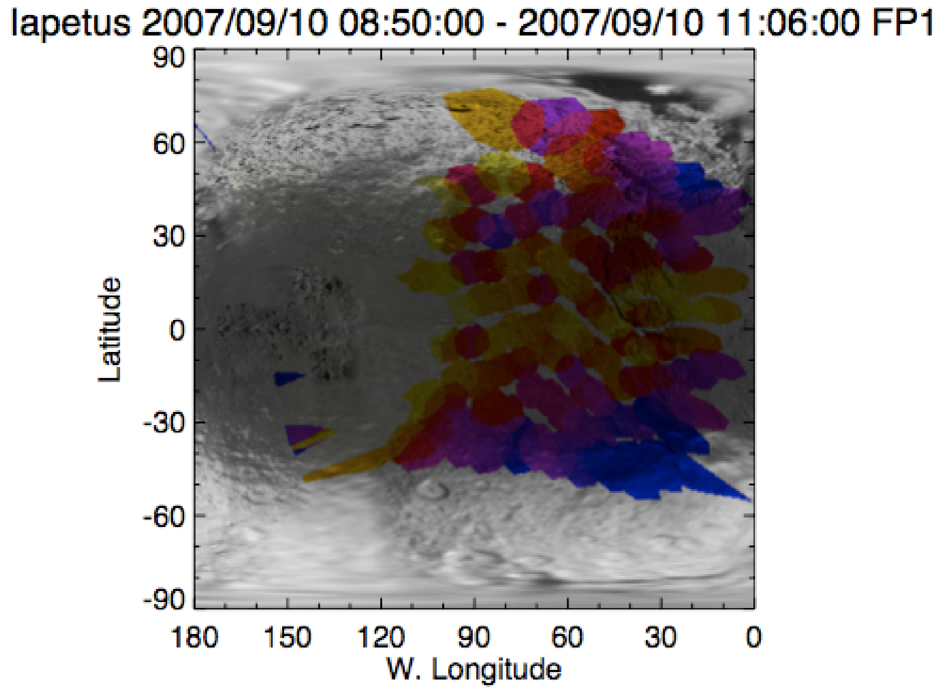
Iapetus New Year 2005 Flyby: Daytime Temperatures

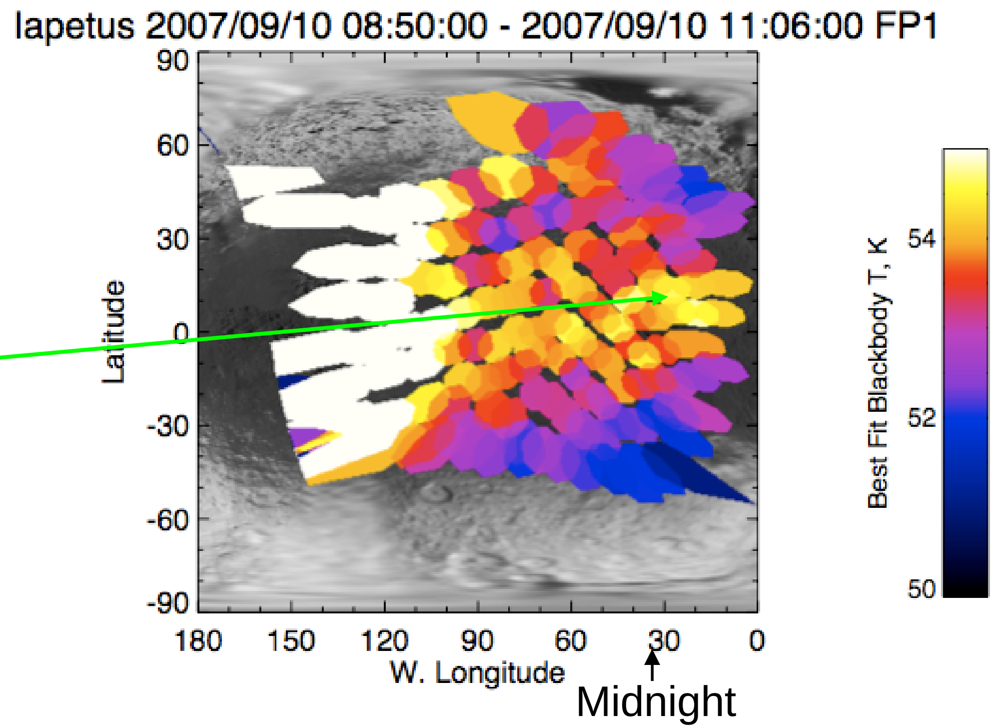
- Best resolution ~35 km
- Peak dark side noon temperatures ~130 K (-225 F)
- Poor sampling of nighttime temperatures
- No sampling of daytime bright-hemisphere temperatures



Sept. 2007 Nighttime Map

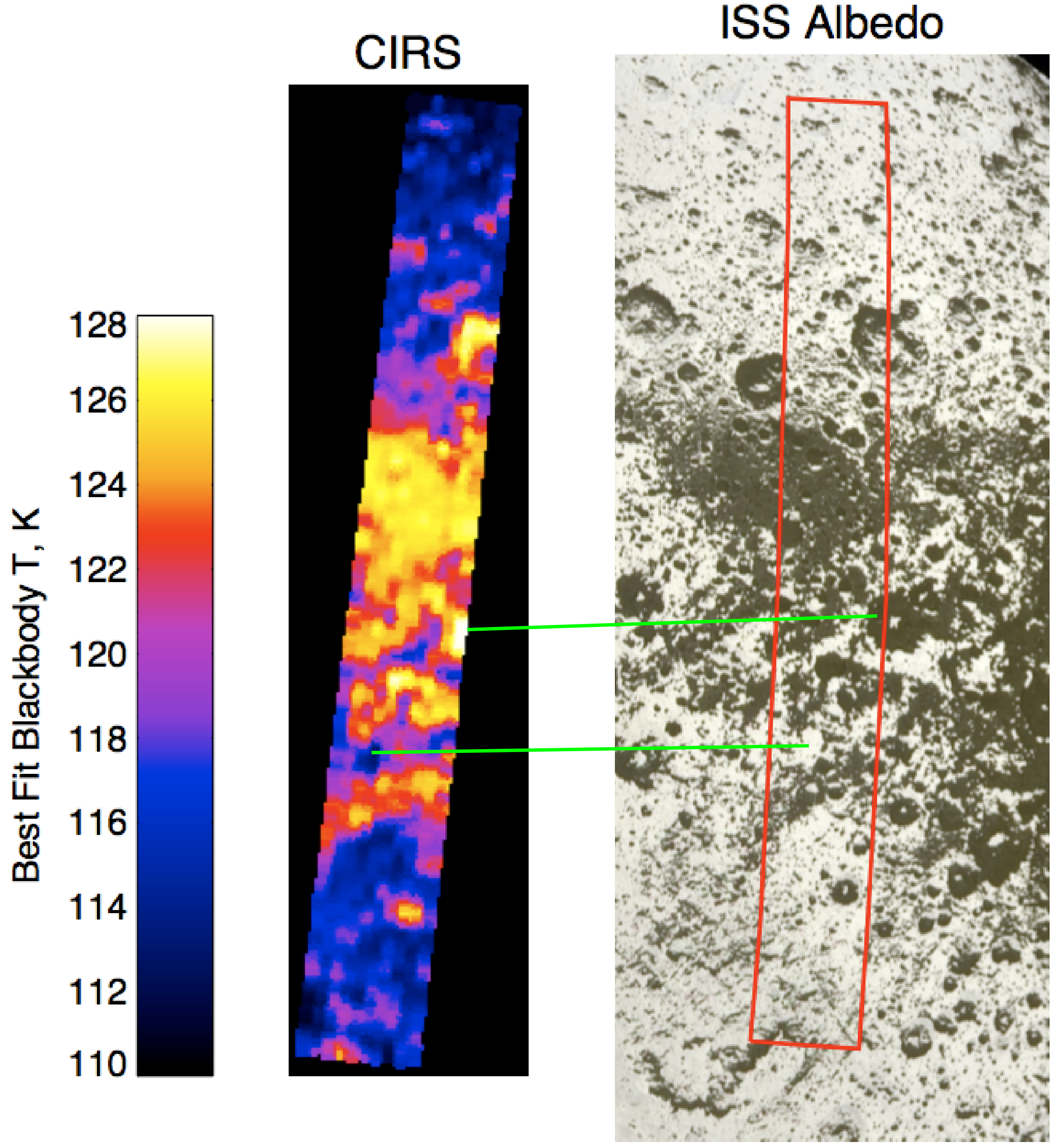
- Dark side at night
- Wavelength 20 - 200 microns
- 50-55 K (-369 - -360 F) nighttime temperatures
  - Rapid nightside cooling implies a very fluffy surface, similar to other Saturn moons
- Warm region near 0 N, 20 W
  - Less fluffy?





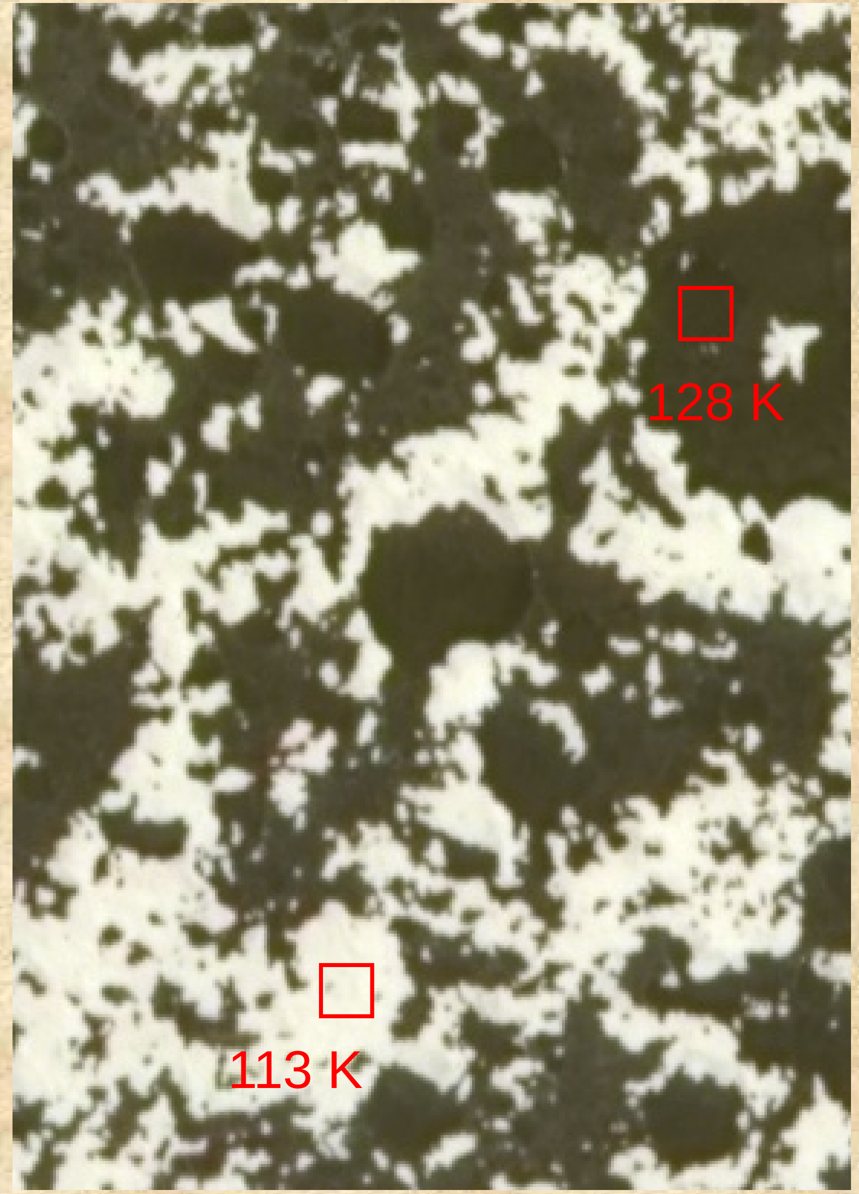
Hi-Res Noontime Scan

- Resolution = 8 km
- Dark regions are warm, bright regions are cold
- Peak temperature = 128 K (-229 F)
- Minimum equatorial temperature = 113 K (-256 F)



Hi-Res Daytime Scan

- 8 km resolution is sufficient to sample ~pure bright and dark material



H_2O Ice Sublimation Rates

- Temperature allows calculation of how fast ice should sublime (evaporate) from Iapetus' surface
  - Bright terrain: ~10 cm per billion years Impacts will remix material on similar timescales
  - Dark terrain: ~20 m per billion years - fast!
  - Dark ice is unstable and will evaporate
- Consistent with
  - Presence of thermal segregation
  - Bright pole-facing slopes
  - The shape of the bright/dark boundary

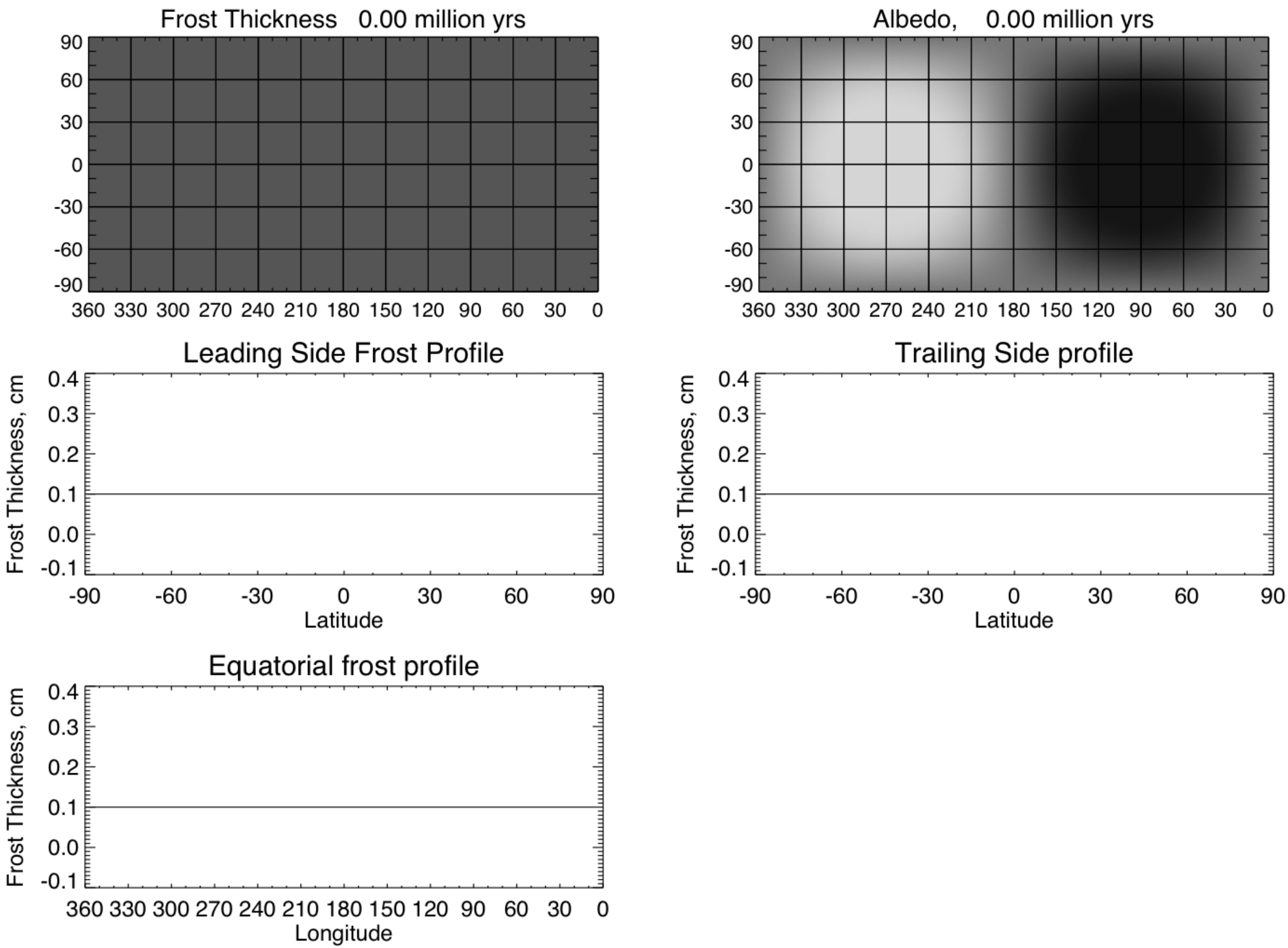
Global Ice Movement

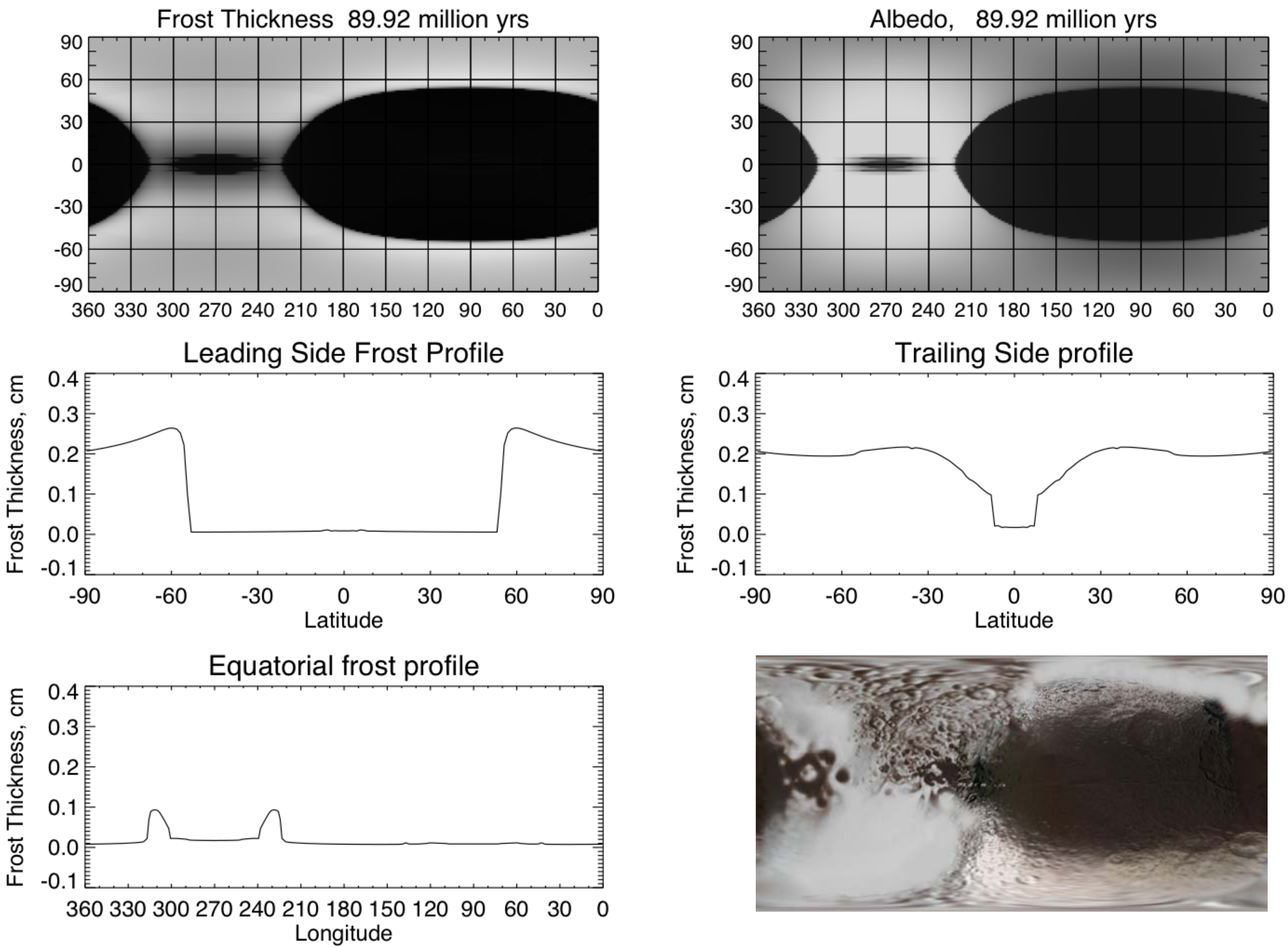
- Simple models of dark material infall darken the leading hemisphere, but Iapetus is not so simple
  - Iapetus' bright material extends over the poles
  - Dark material extends around the equator
- Thermal ice migration can explain this…
  - Originally proposed by Mendis and Axford in 1974

Iapetus map by Steve Albers

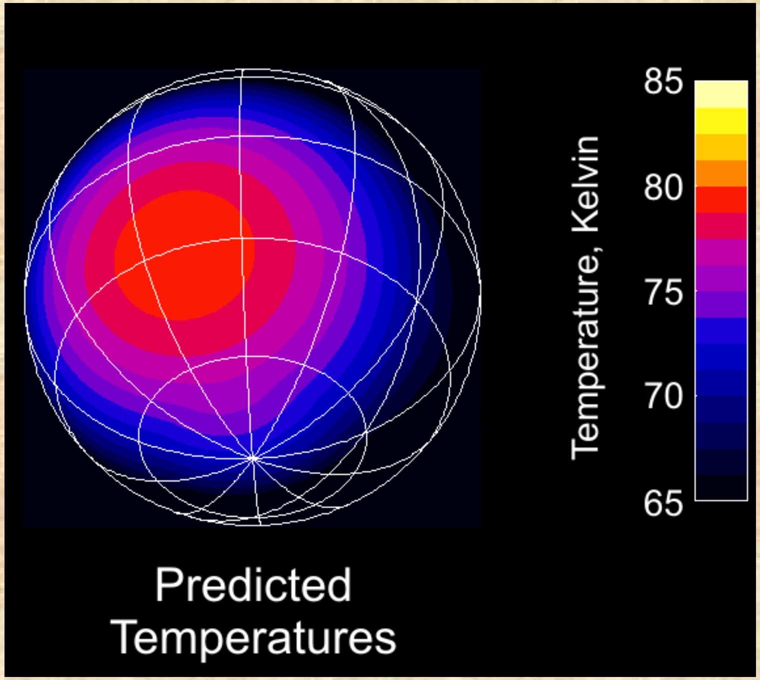
Frost Migration Model

- Assume Iapetus is covered in ice
- Infalling material darkens the leading side
- Dark, warm, ice evaporates and recondenses elsewhere
- Evaporation shuts off when 1mm of ice has been lost
  - Ice layer is exhausted
  - Or lag deposit forms

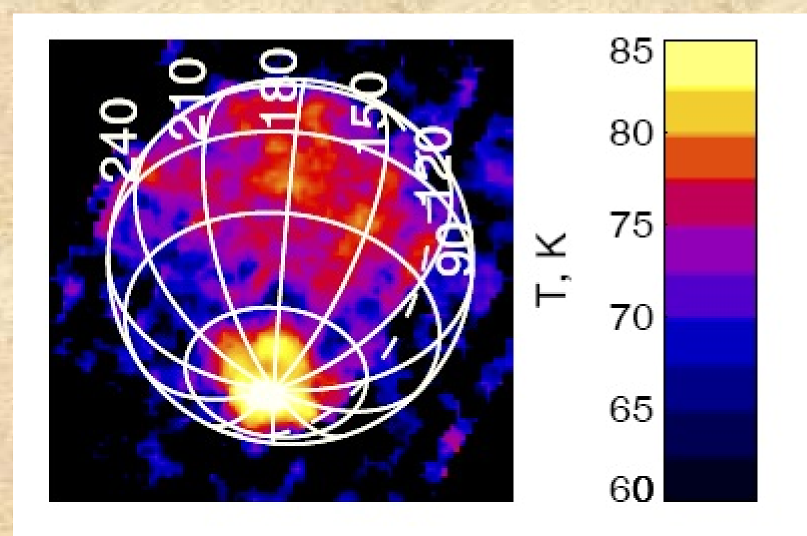

Frost Thickness 0.00 million yrs
Albedo, 0.00 million yrs
Leading Side Frost Profile
Trailing Side profile
Equatorial frost profile
Frost Thickness, cm
Latitude
Longitude
90 60 30 0 -30 -60 -90
360 330 300 270 240 210 180 150 120 90 60 30 0
0.4 0.3 0.2 0.1 0.0 -0.1
-90 -60 -30 0 30 60 90


Frost Thickness 89.92 million yrs
Albedo, 89.92 million yrs
90 60 30 0 -30 -60 -90
360 330 300 270 240 210 180 150 120 90 60 30 0
Leading Side Frost Profile
Trailing Side profile
Frost Thickness, cm
0.4 0.3 0.2 0.1 0.0 -0.1
-90 -60 -30 0 30 60 90
Latitude
Equatorial frost profile
Longitude

Enceladus: The Big Surprise



Best-fit blackbody temperature

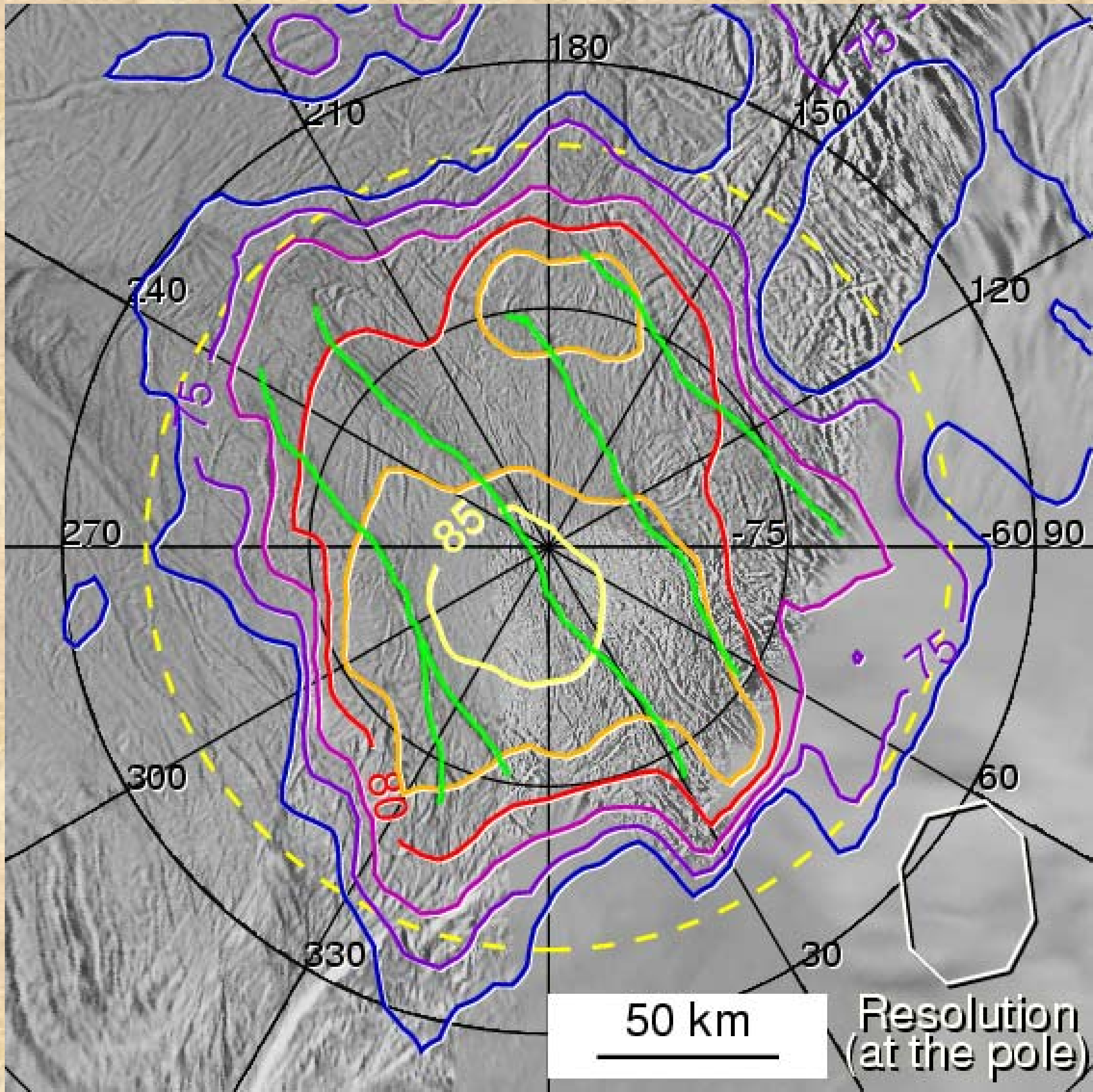


South polar hot spot!

- Simple passive model cannot produce a warm pole

Location of Warm Region

- Centered on the south pole
- Corresponds closely to the "tiger stripe" fractures (rather than the larger south polar terrain)

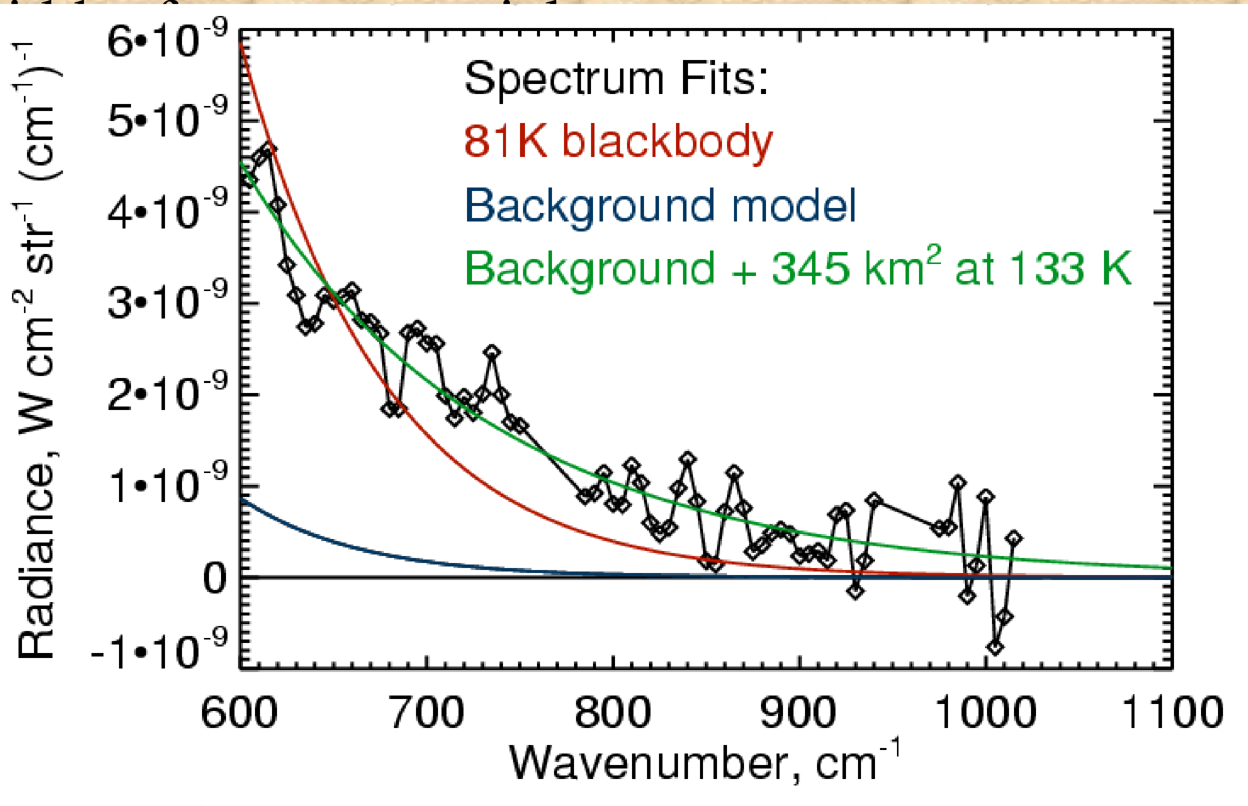


Brightness Temperature Contours
(Spencer et al. 2006)

Spectrum of South Polar Warm Region

Average spectrum south of 65 S

- Not consistent with a blackbody
- Best fit after subtracting expected background:
  - 345 km^2 (~1% of the surface) at 133 K
  - 6 GW of radiated power!
- Average ~660 m w
  tiger stripes

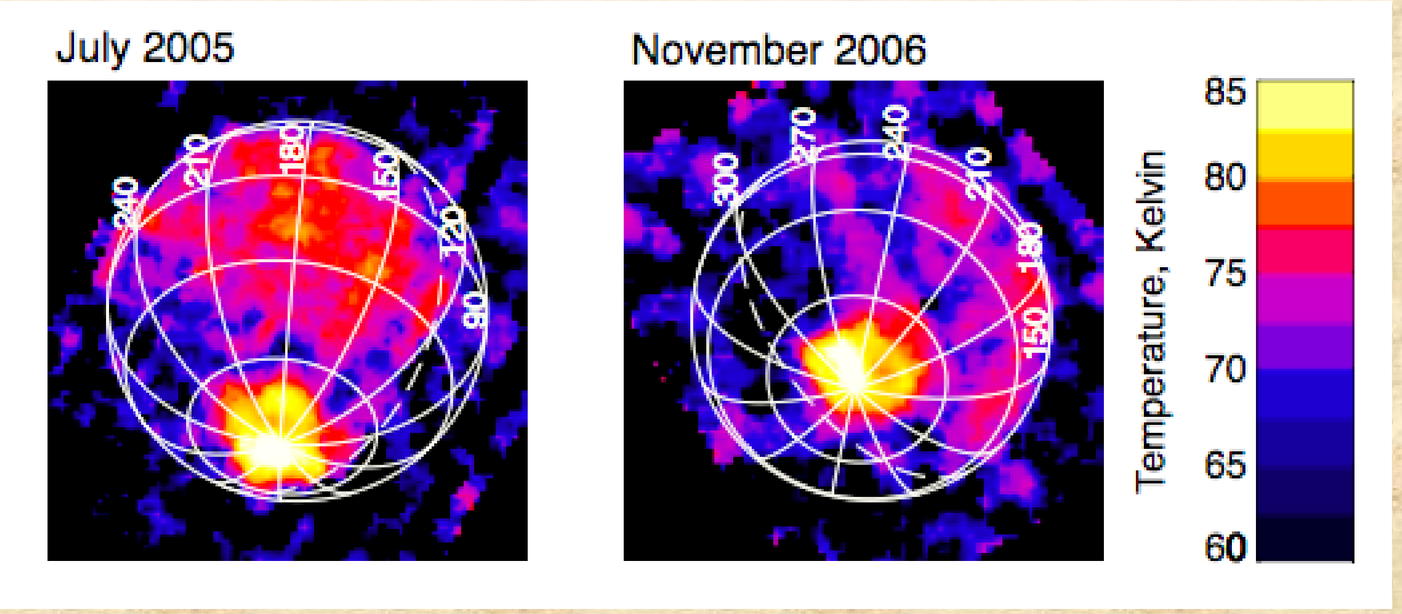


Spencer et al. (2006)

Repeat View in November 2006

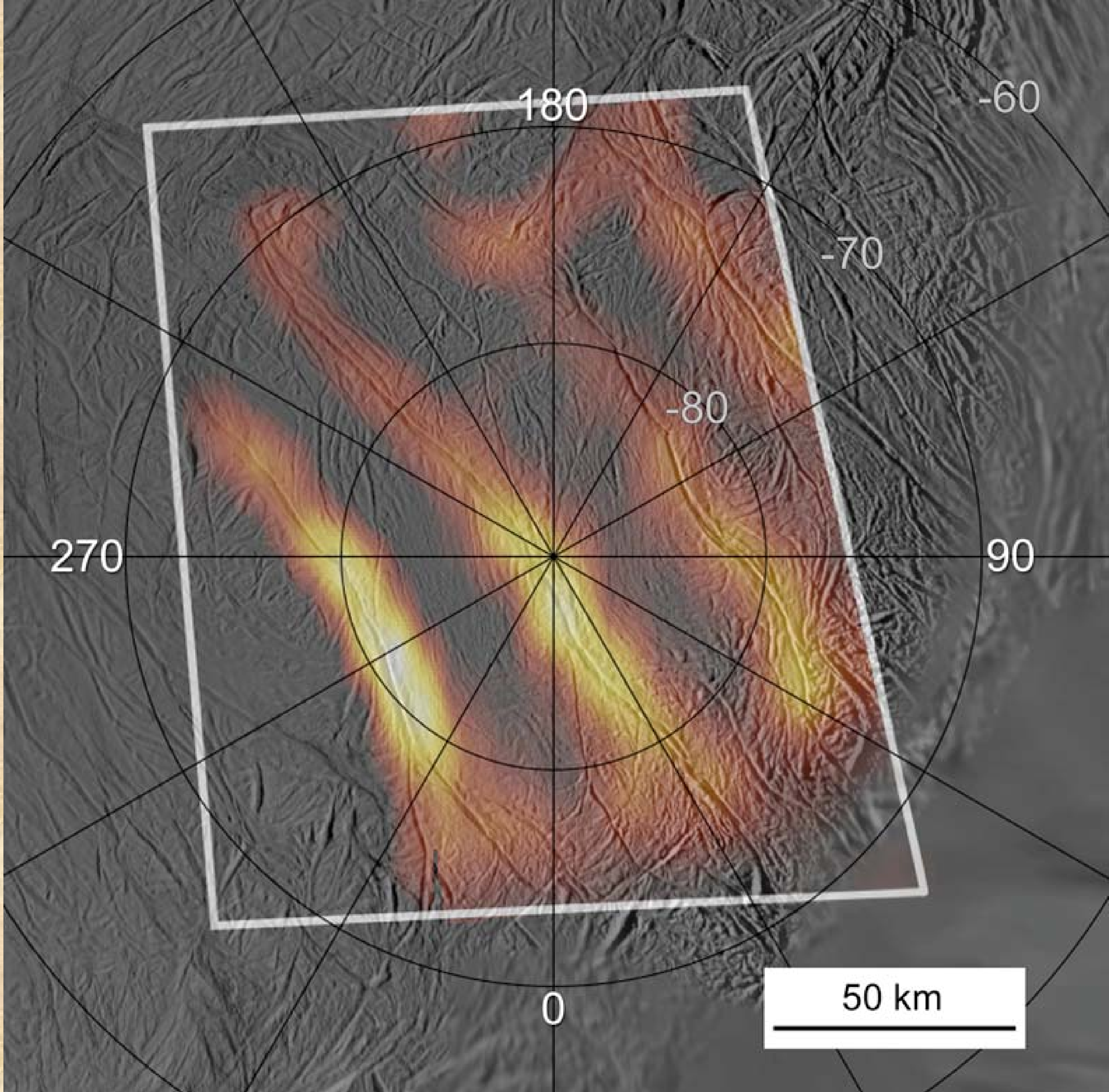
Distribution of temperatures unchanged since July 2005

Brightness the same to within ~10%



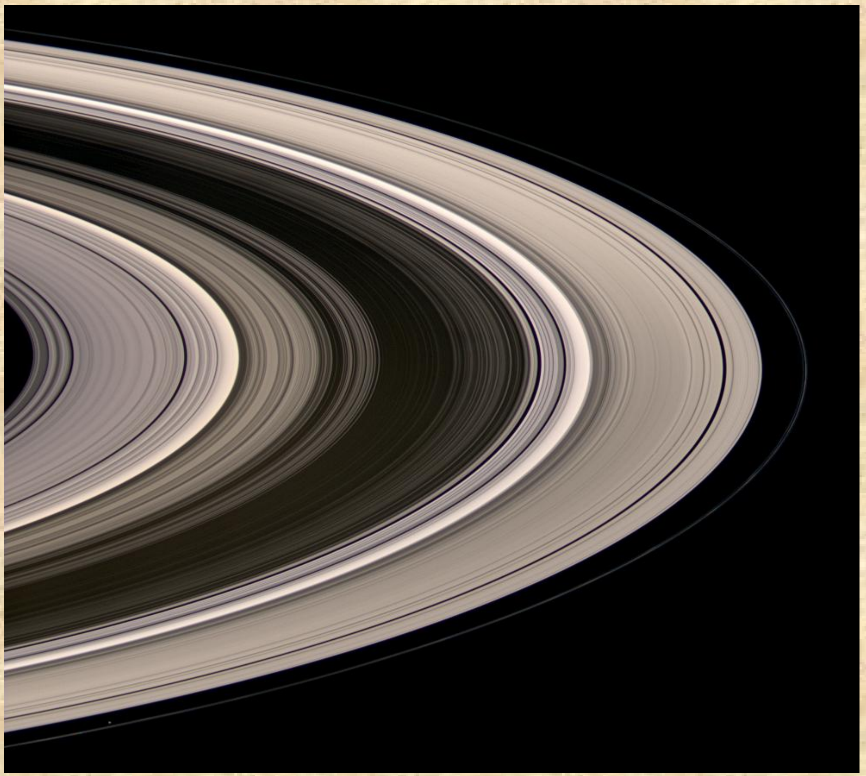
March 2008: A Closer Look

- Temper-atures of at least 180 K



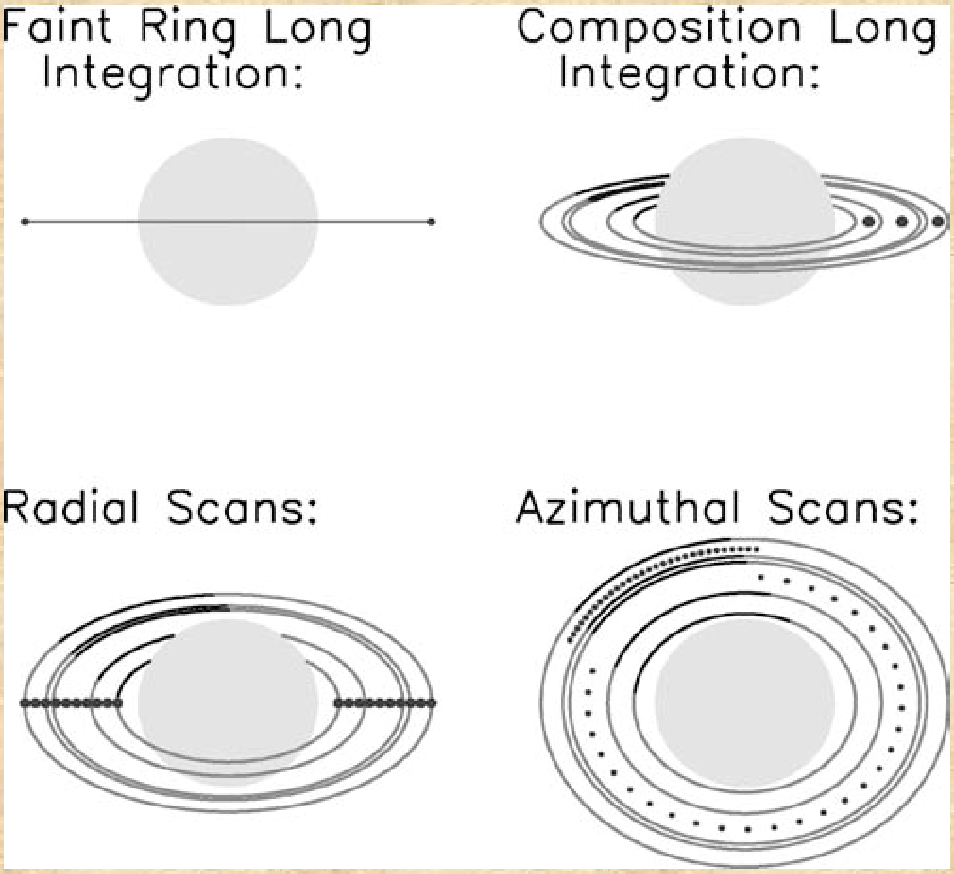
CIRS: The Science

The Rings

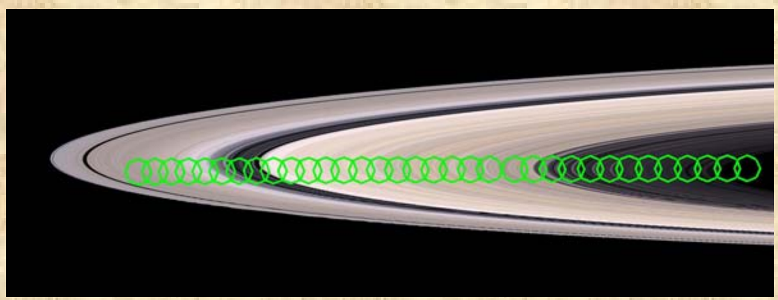


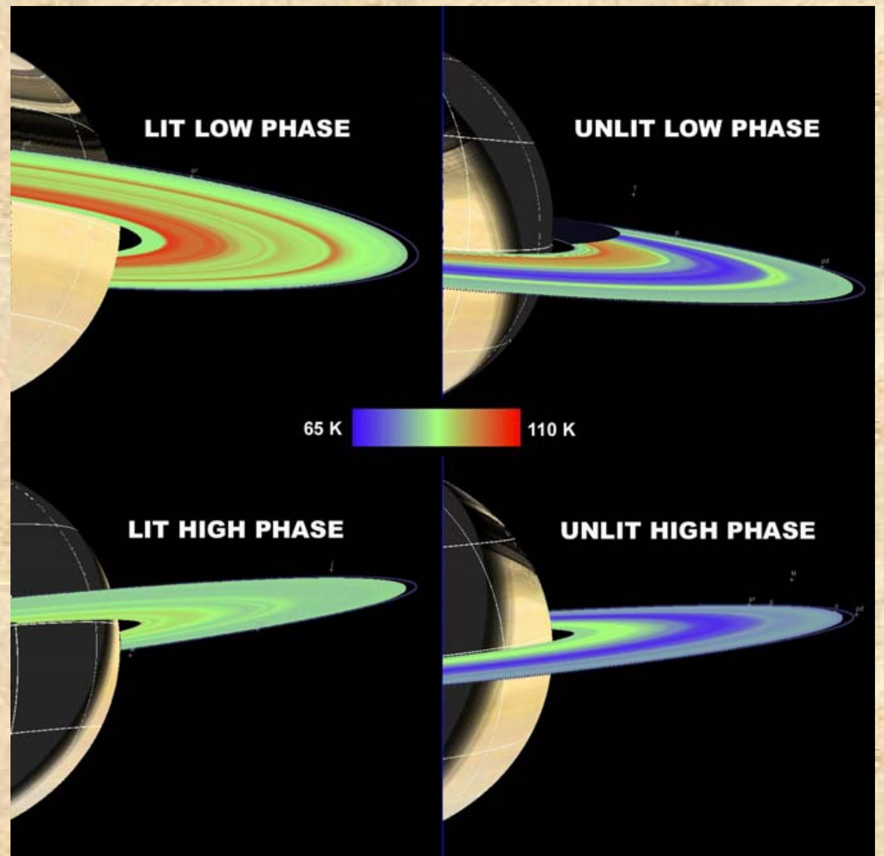
Types of Ring Observations

- Four basic types of observations conducted by CIRS depending on geometry and goal
- Thermal Characterization: Scans at a variety of phase angles, local hour angles, and inclinations. Requires low spectral resolution
- Composition: Long sit and stares. Requires high spectral resolution

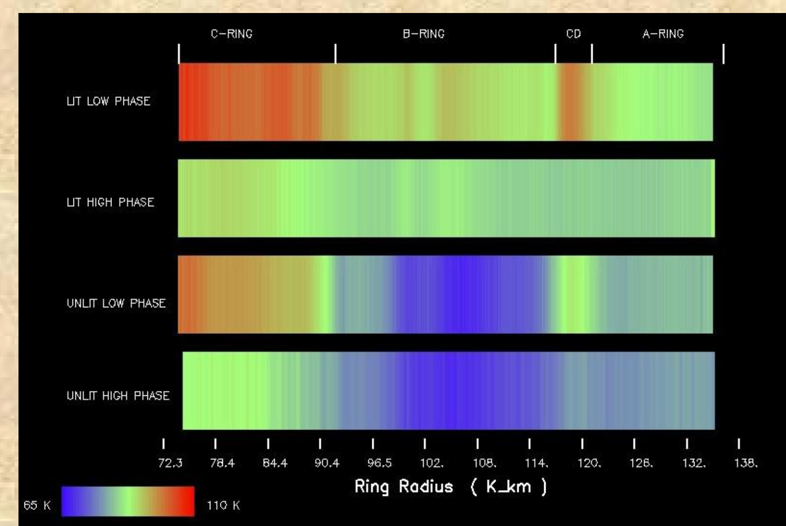


CIRS Radial Ring Scans





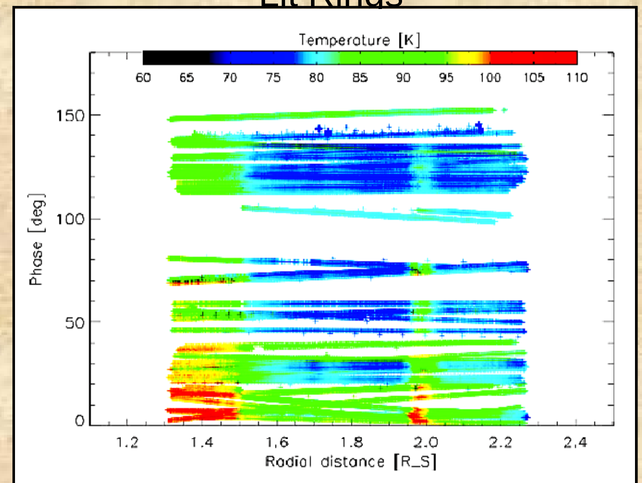
- Temperature variations with phase angle are present in A, B, C rings and Cassini Division
  - Ring temperatures decrease with increasing phase angle
- These variations are indicative of a population of slowly rotating ring particles

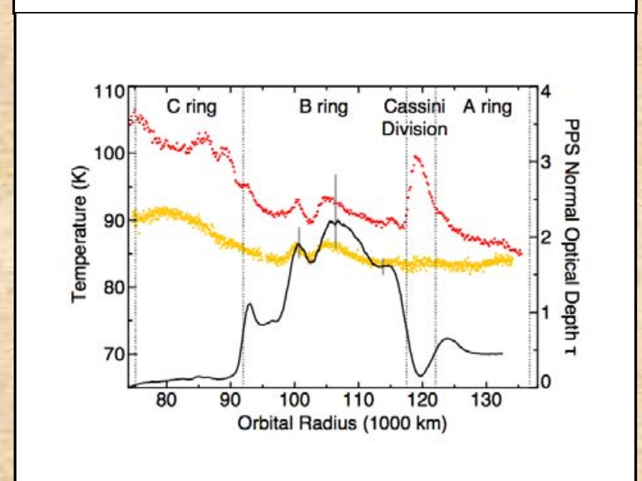


Ring Temperature vs. Phase Angle

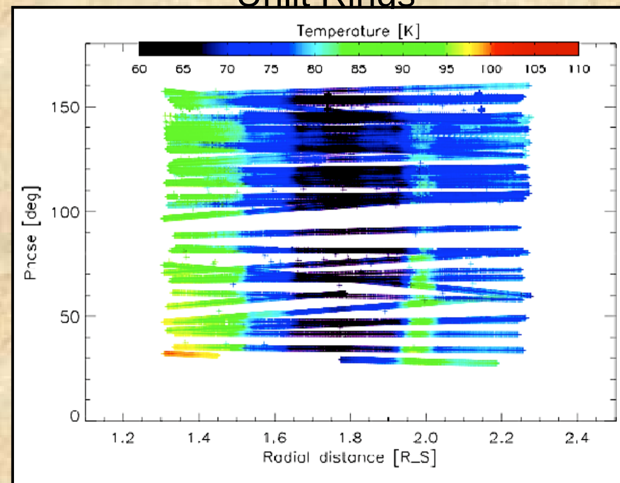
- Temperatures decrease with increasing phase angle and ring optical depth
- The Lit A and B rings warmer than the unlit A and B rings due to the ring thickness
- Both Lit and unlit C and CD exhibit similar temperatures implying that the thickness approach a single layer structure

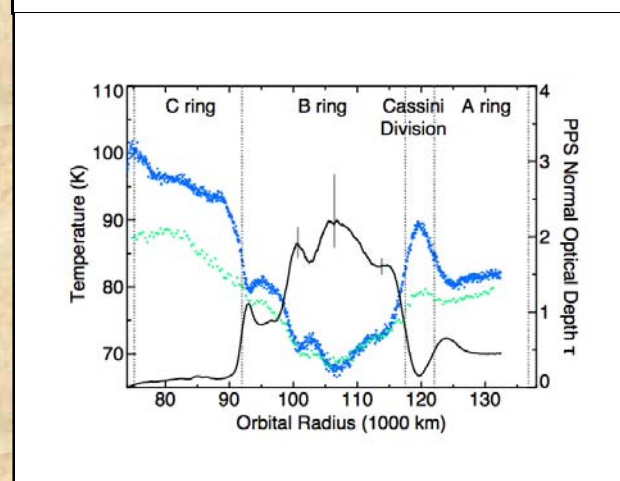
Lit Rings





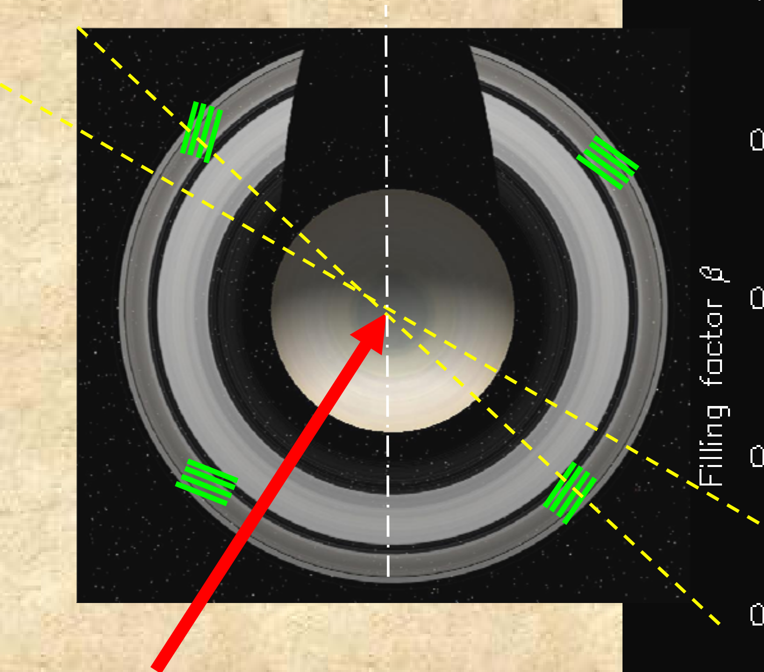
Unlit Rings



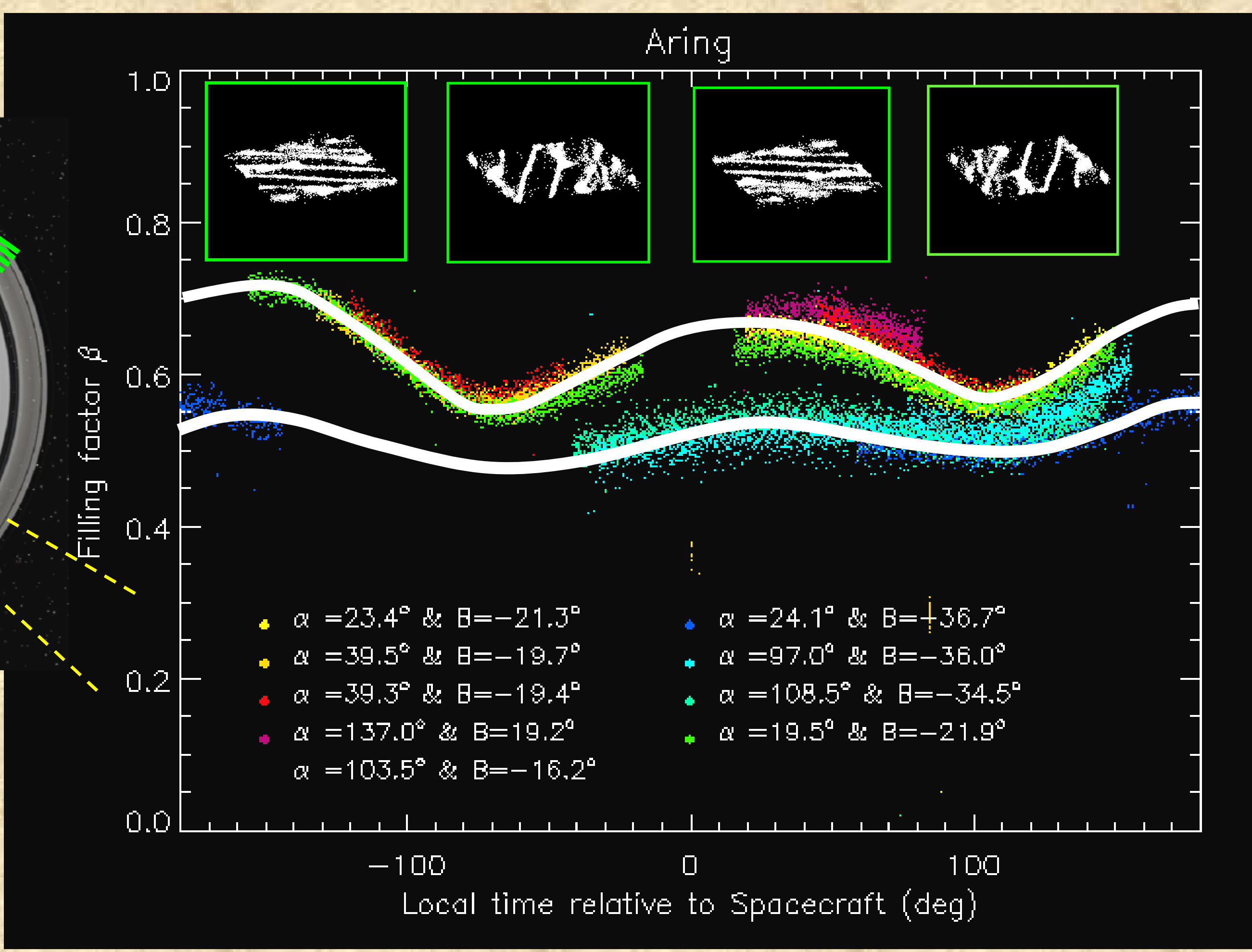


From Spilker et al. 2006 and Altobelli et al., 2007

Azimuthal Variations In The A-Ring



Cassini



Collisions
Shearing

Self Gravitation

Coherent motion of particles ⇨ Variation of τ

From Leyrat et al, 2007

Ring Sub-Millimeter Roll-off

- Brightness temperatures decrease with increasing wavelength (decreasing wavenumber)
- Each Ring system (A-, B-, and C-) exhibit a different roll-off
- Emissivity can give clues about the structure of ring particles, regolith properties, and composition.

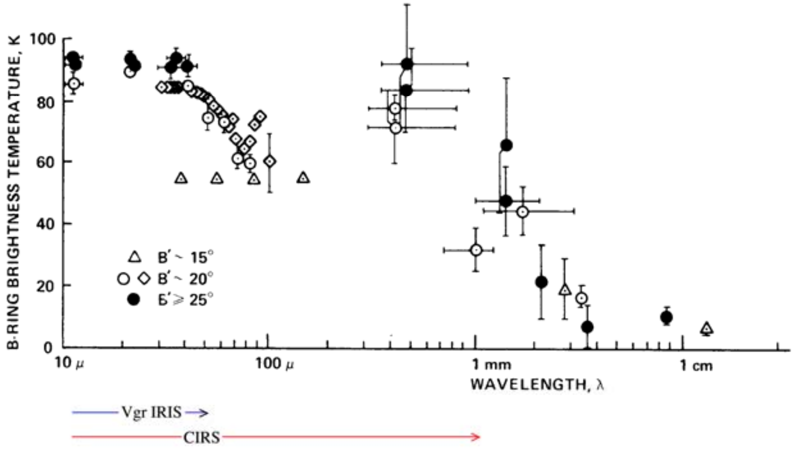
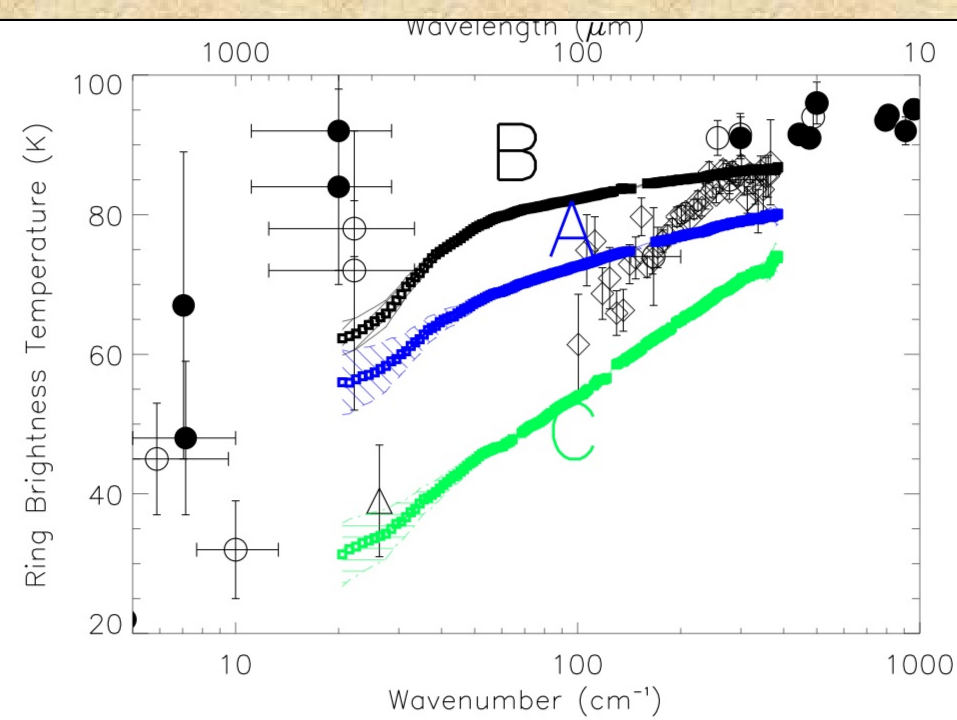


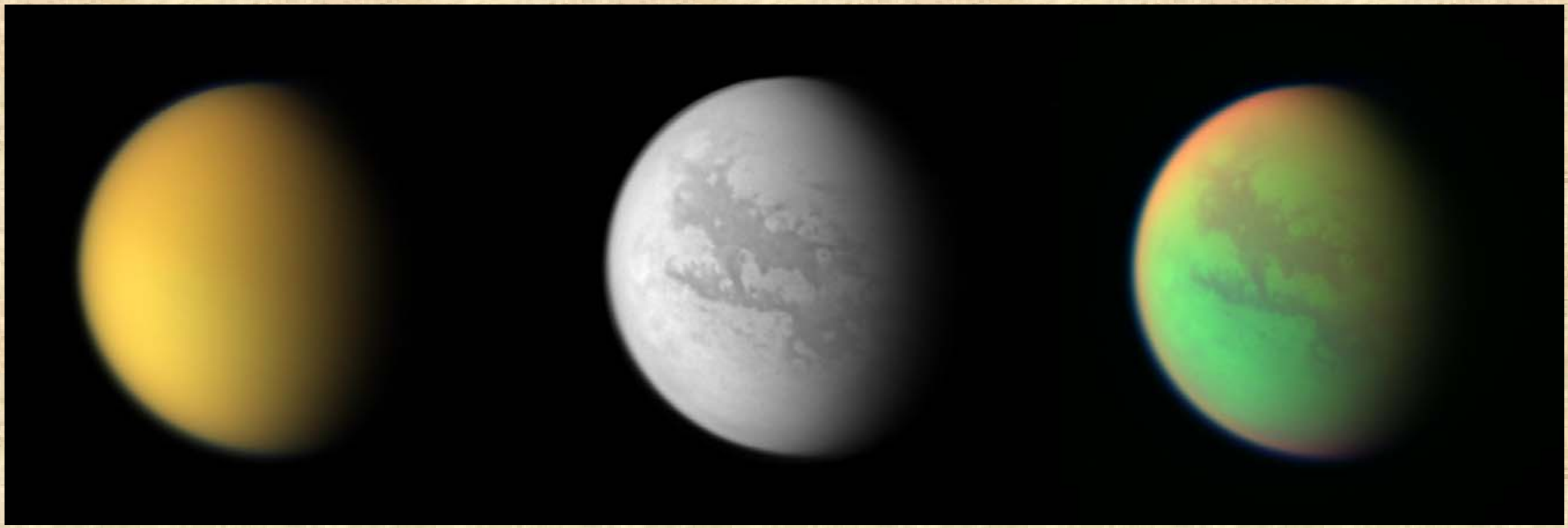
Fig. 8 Brightness temperatures of Saturn's B ring (Esposito *et al.*, 1984). B′ is the ring tilt angle relative to the sun. Between wavelengths 50 μm and 1 mm (200 cm⁻¹ and 10 cm⁻¹), the absorption coefficient for water ice at 100 K decreases by a factor ~10⁴, making the material progressively more transparent. This gives CIRS the ability to probe icy material to various depths, providing a powerful tool for the investigation of the composition and physical properties of this material. The reality of the unidentified emission feature near 400 μm, which interrupts the expected smooth decrease attributable to water ice, has recently been called into question.



From Spilker et al, 2005

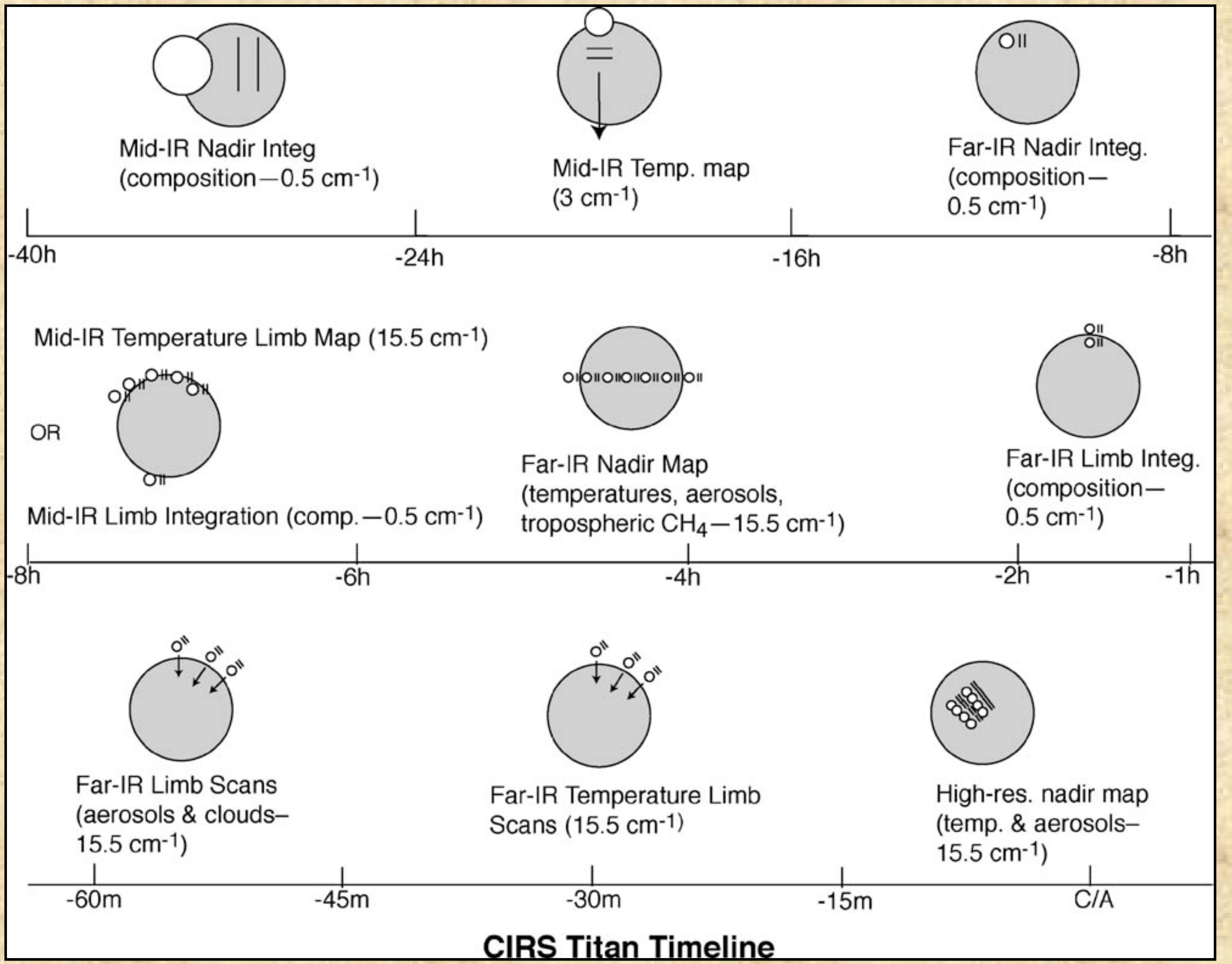
CIRS: The Science

Titan



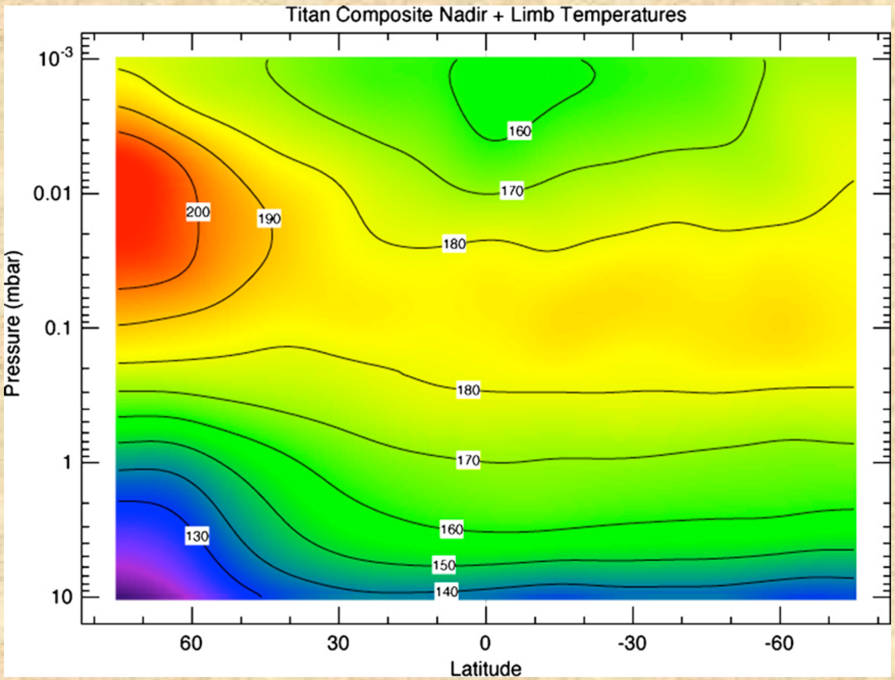
Titan Observations by Range

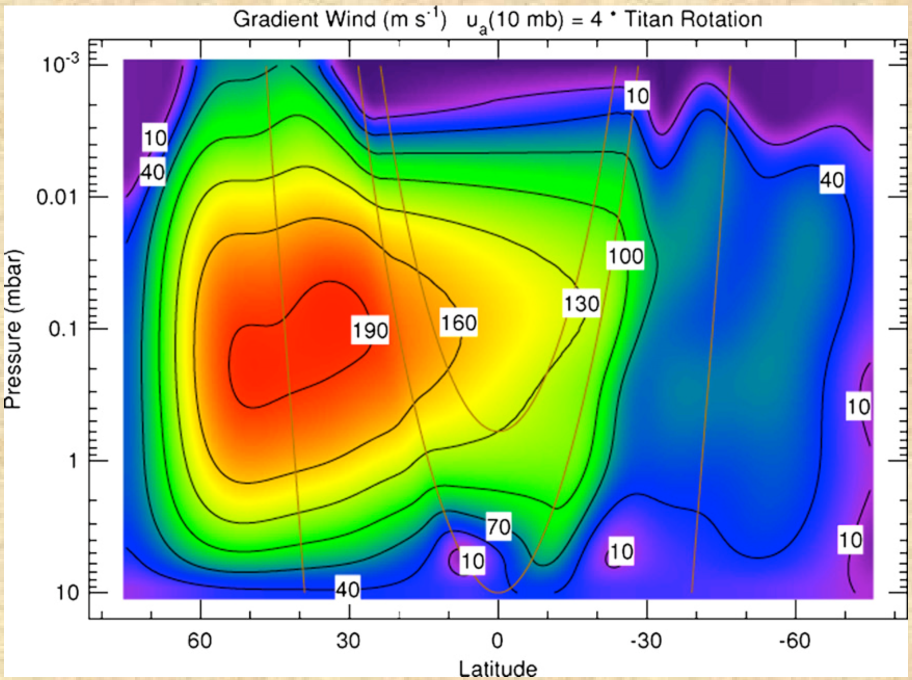
- Nine basic types of observations conducted by CIRS depending on range and goal
- Thermal Characterization: Mosaics across the disc. Requires low spectral resolution.
- Composition: Long long sit and stares. Requires high spectral resolution.



Titan’s Temperatures and Winds

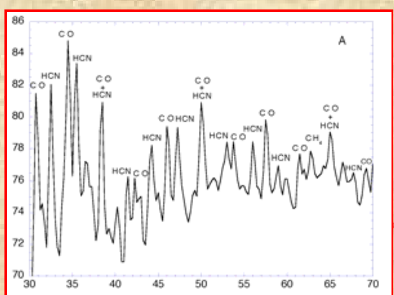
• Zonal mean temperatures from all limb and nadir maps. Retrieved temperatures were averaged in 5° latitude bins. Contours are labeled in K.
• Zonal winds calculated from the mean temperatures with the gradient wind equation. Wind speed contours (black lines) are labeled in m/s.
• From Achterberg, et al. 2008



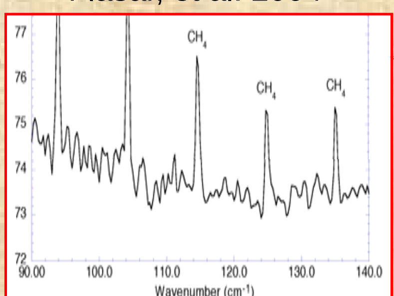


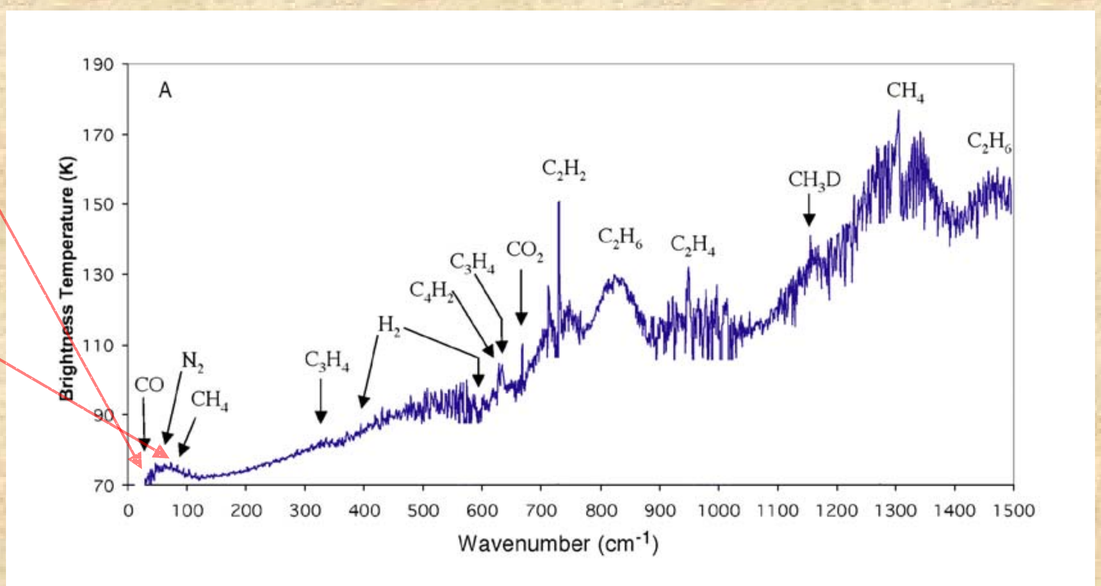
CIRS Titan Spectrum

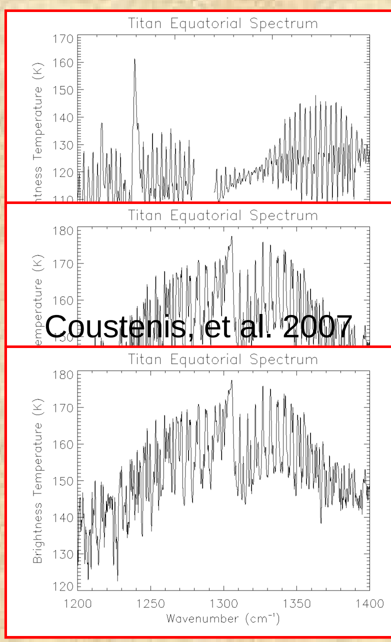
- ***Temperatures*** from CH_4 ν_4 band
- ***Abundances*** from emission bands of $^{13}CH_4$, C_2H_2, $^{13}C^{12}CH_2$, C_2H_6, $^{13}C^{12}CH_6$
  - allows calculation of $^{12}C/^{13}C$ ratios
- ***Spatial variations***
  - CIRS can trace the global stratospheric circulation by observing species of different chemical lifetimes.
- ***Isotopes***
  - CIRS has the ability to measure D/H, $^{12}C/^{13}C$, $^{14}N/^{15}N$ and $^{16}O/^{18}O$, which can provide constraints on formation and evolution (atmospheric chemistry scenarios).



Flasar, et al. 2004





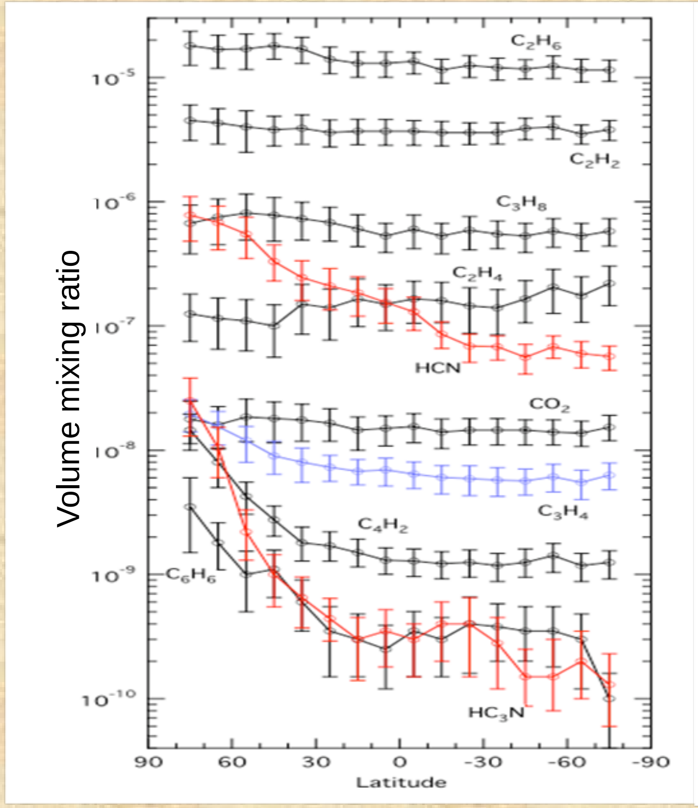


Coustenis, et al. 2007

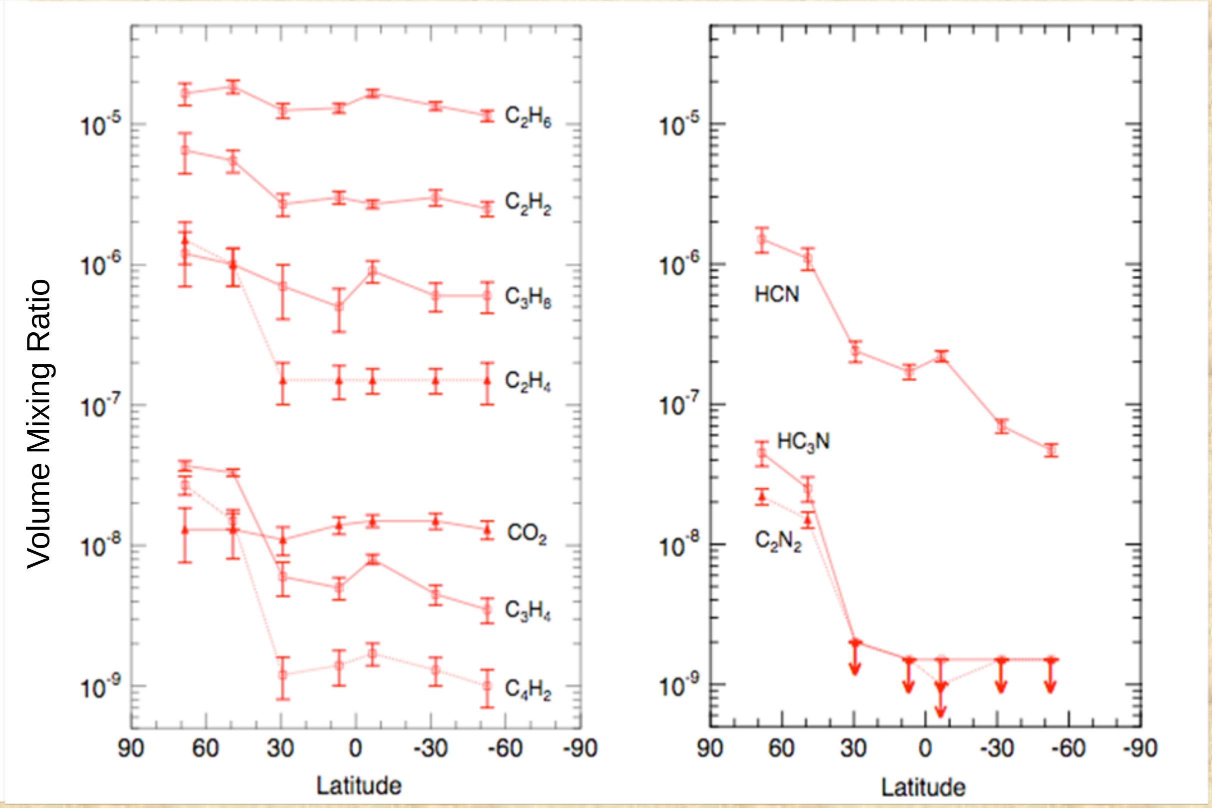
Titan’s Latitudinal Variations

• ***The enhancement at the North pole is currently a factor of 1.5-2 smaller than at the time of the Voyager encounter for all molecules***

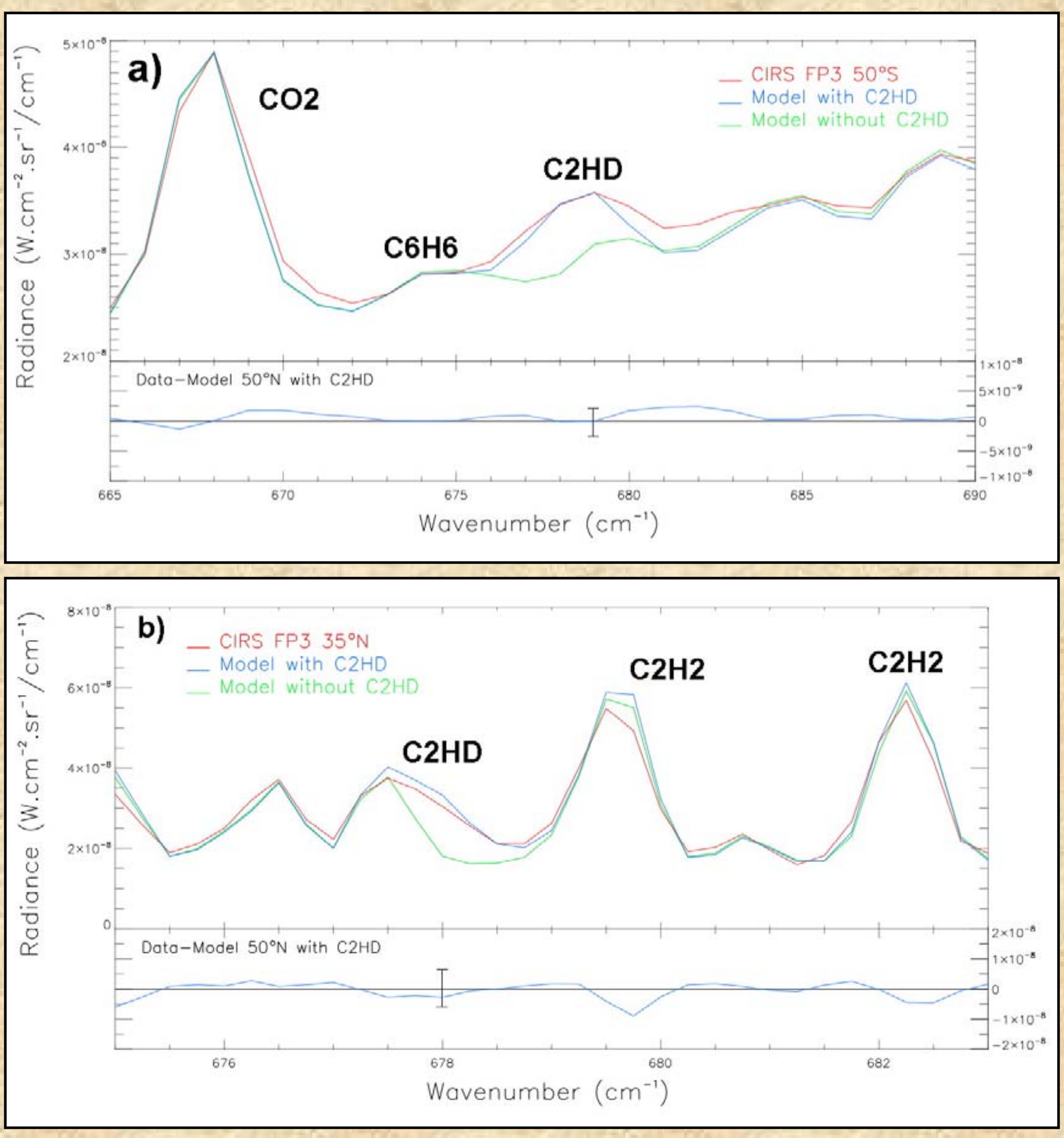
Cassini CIRS (2004-5):
Coustenis *et al.* (2007)
(N. winter)



Voyager IRIS (1980):
Coustenis & Bézard (1995)
(early N. spring)



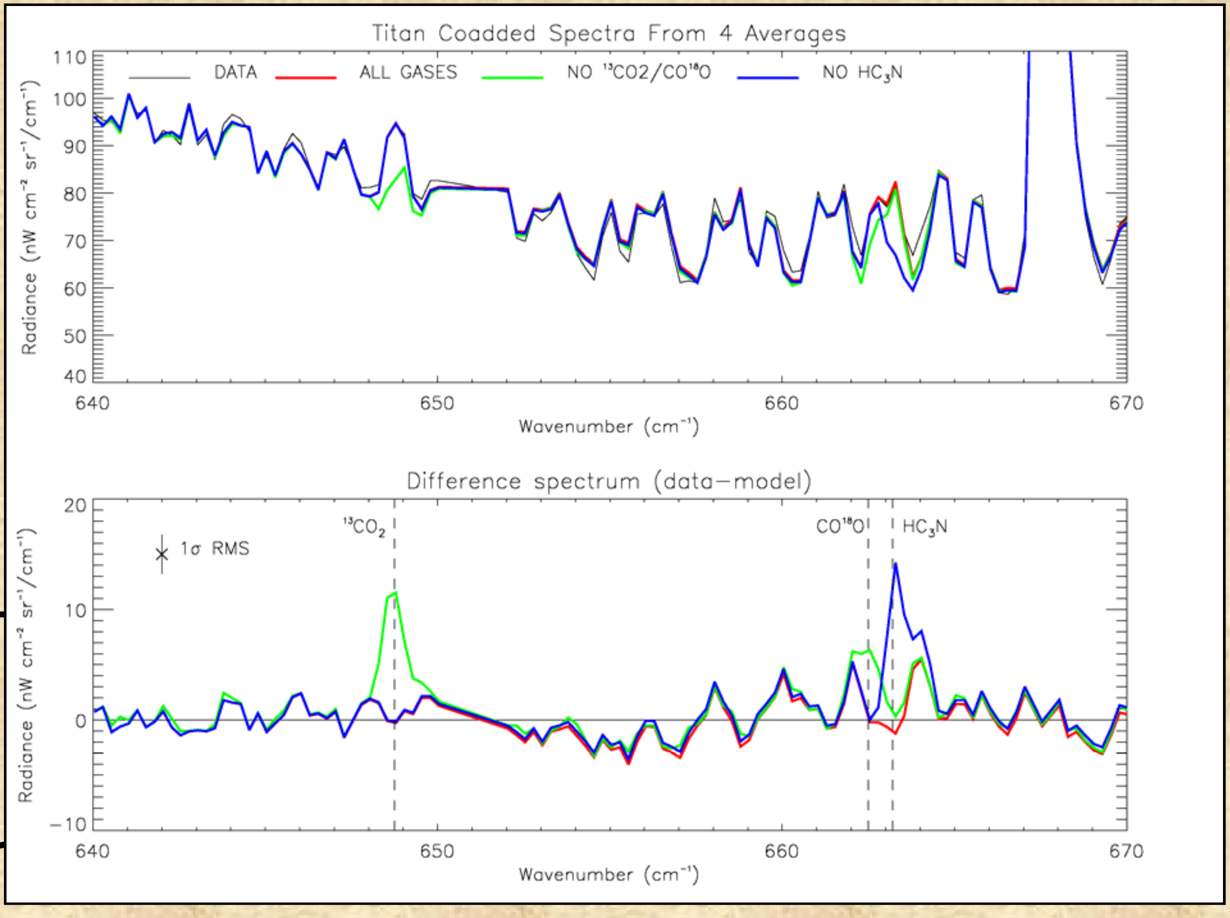
New Detection of C2HD



Coustenis et al., 2008

Isotopes of CO_2

- CO_2 has been mapped via ν_2 band @ 667 cm^{-1}.
- Stratospheric abundance ~ 10^{-8}.
- Recently we have detected the isotopic emission of $^{13}CO_2$ @ 648.5 cm^{-1} (6-σ detection).
- … and *probably* the $C^{18}O^{16}O$ emission at 662.5 cm^{-1} (3-σ detection, σ = NESR only).



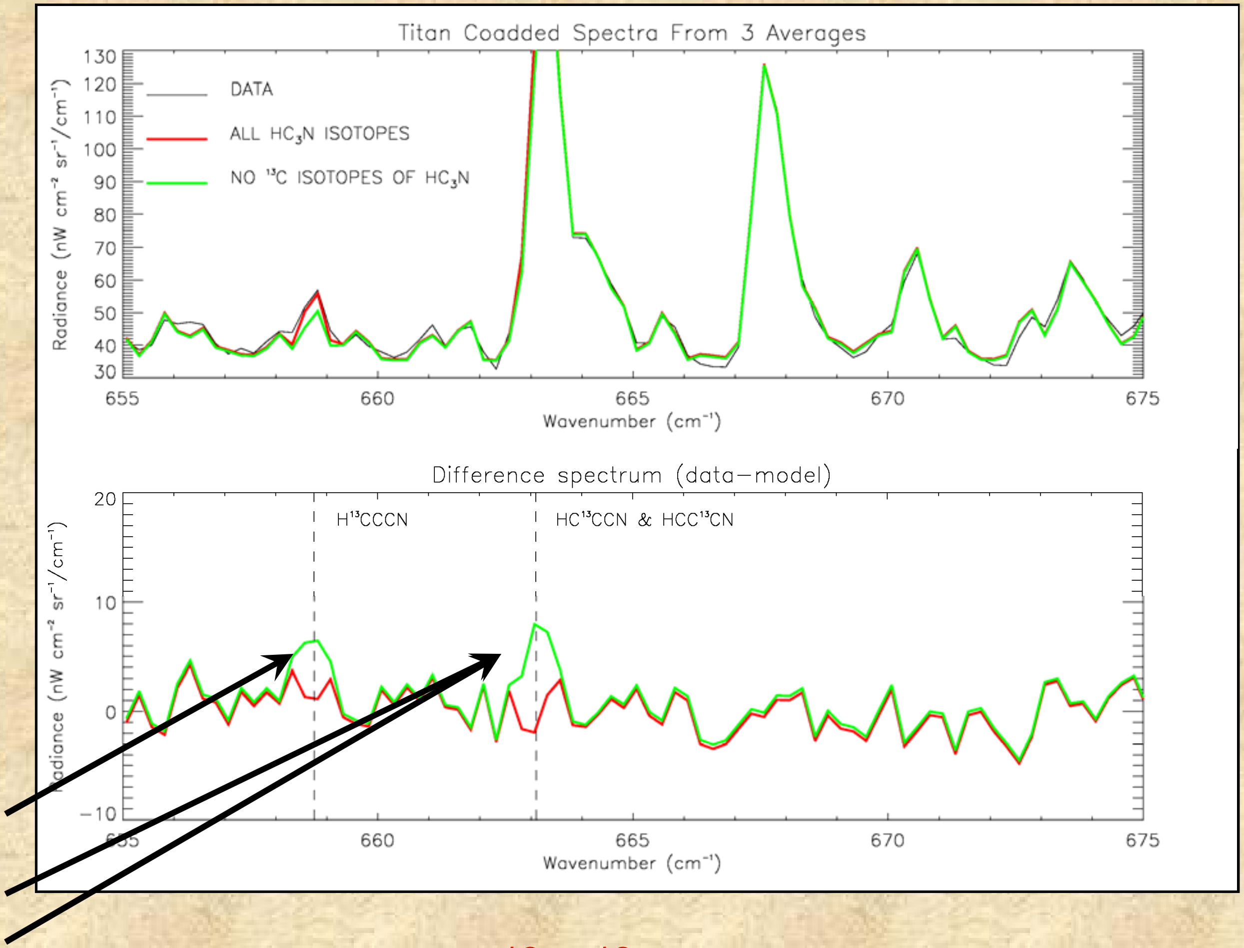
Retrieved isotopic ratios are $^{12}C/^{13}C$ ~ 84 ± 17, in line with Huygens GCMS (82.3 ± 1), and $^{16}O/^{18}O$ ~ 346 ± 110, perhaps 1.5x enriched versus terra

Nixon et al., 2008

^{13}C in HC_3N: H-C≡C-C≡N

- Cyanoacetylene formed by substitution of -CN (from HCN) into C_2H_2 and C_2H_4.
- HC_3N has a strong ν_5 band @ 663.4 cm^{-1} due to bending of CH.
- Replace $^{12}C \rightarrow {}^{13}C$ changes frequency:
  - $H^{13}CCCN$ = 658.7 cm^{-1}
  - $HC^{13}CCN$ = 663.1 cm^{-1}
  - $HCC^{13}CN$ = 663.1 cm^{-1}

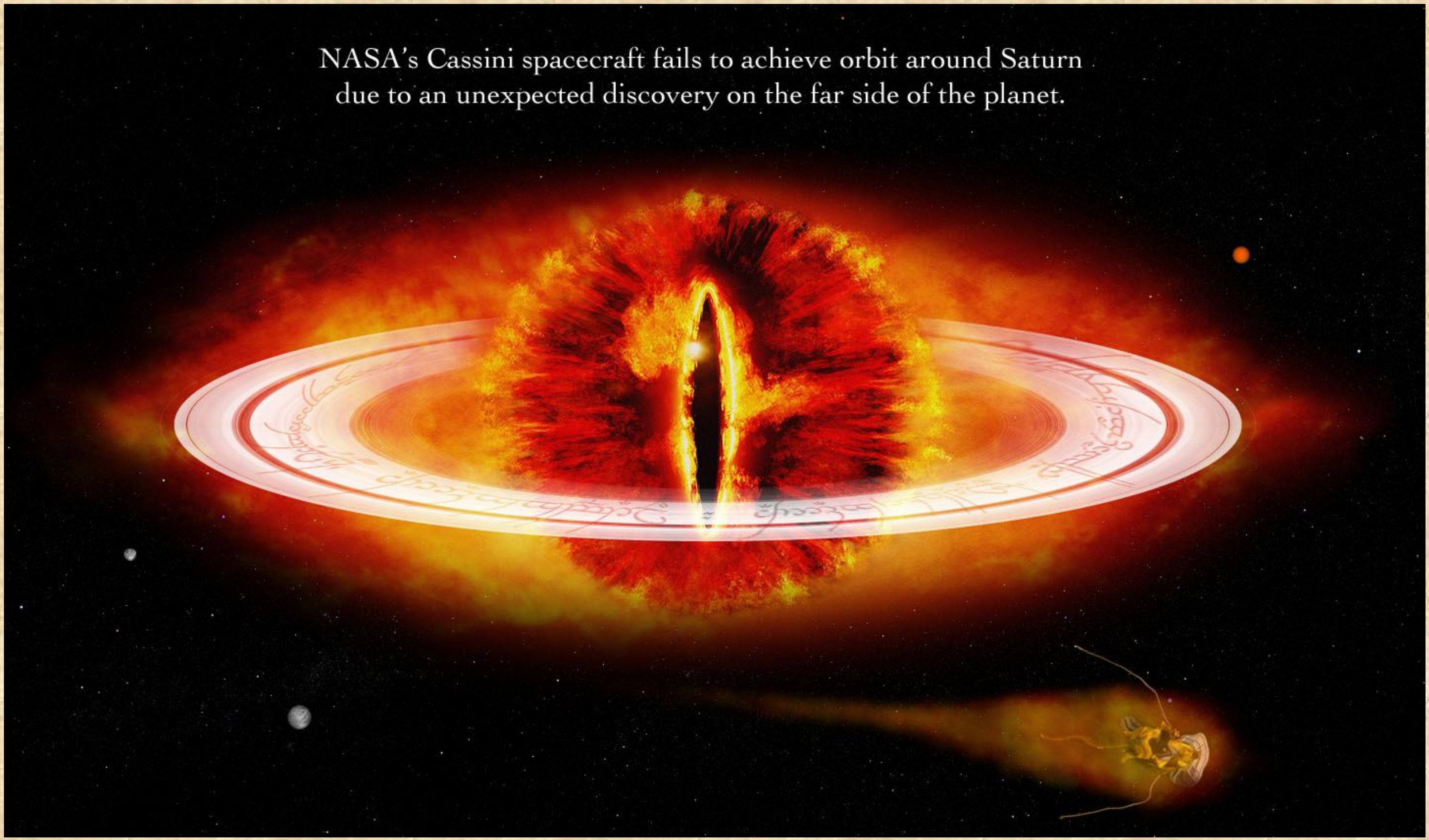
(Jolly et al. JMS, 242, 46-54, 2007)



Modeling implies $^{12}C/^{13}C$ ~ 78 ± 12, in line with Huygens GCMS (82.3 ± 1). *Potential* to discriminate between C from HCN and C_2H_2.

Jennings et al., 2008

CIRS: What's Next?



Acknowledgements

We would like to thank the following persons for their contributions to this presentation:

F.M. Flasar (PI)

N. Altobelli

A. Coustenis

L. Fletcher

C. Leyrat

The rest of the CIRS Team for their hard work

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