Saturn's Auroras from Cassini UVIS

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for the UVIS team
Presented at the Charm telecon
May 29, 2007

Topics

- Introduction to Auroras
- Comparison of Earth, Jupiter, and Saturn
- Cassini Saturn Aurora Results
- Effects: Polar Haze at Jupiter, and Saturn
- Time-dependence of solar wind and the aurora
- Hubble comparisons
- Recent high-latitude observations: hints of auroral patterns that repeat in longitude

Solar wind

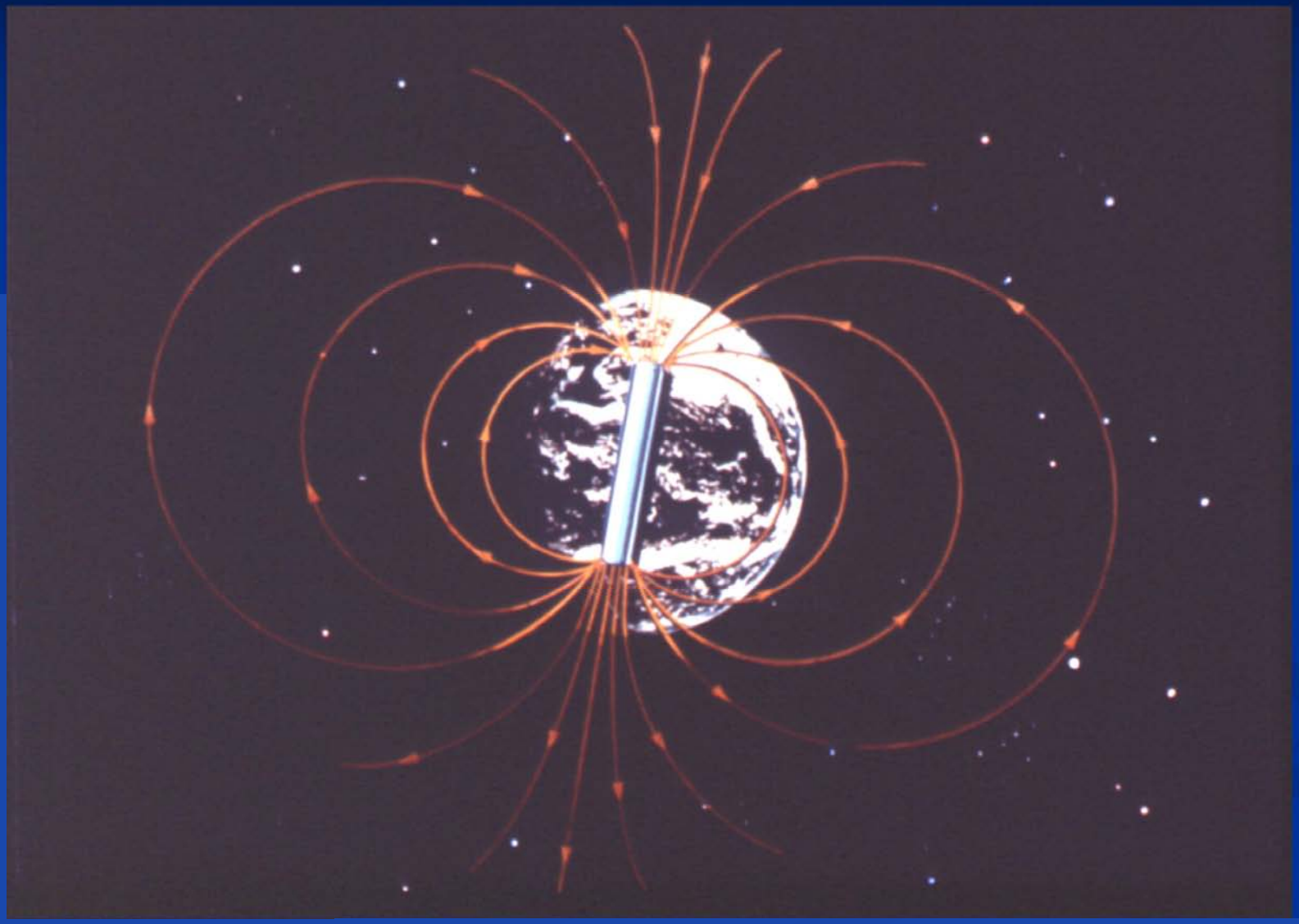
Solar wind is a flow of charged particles from the Sun

Density ~5 particles/cm^3 at Earth (TINY!!)

Mostly **protons** and **electrons**

Makes auroras when the particles hit planetary atmospheres

The Earth has a dipolar magnetic field



Earth's Magnetosphere and the Solar Wind

When solar wind nears a magnetized body, it is slowed and deflected

Region controlled by the Earth's magnetic field is called the *magnetosphere*

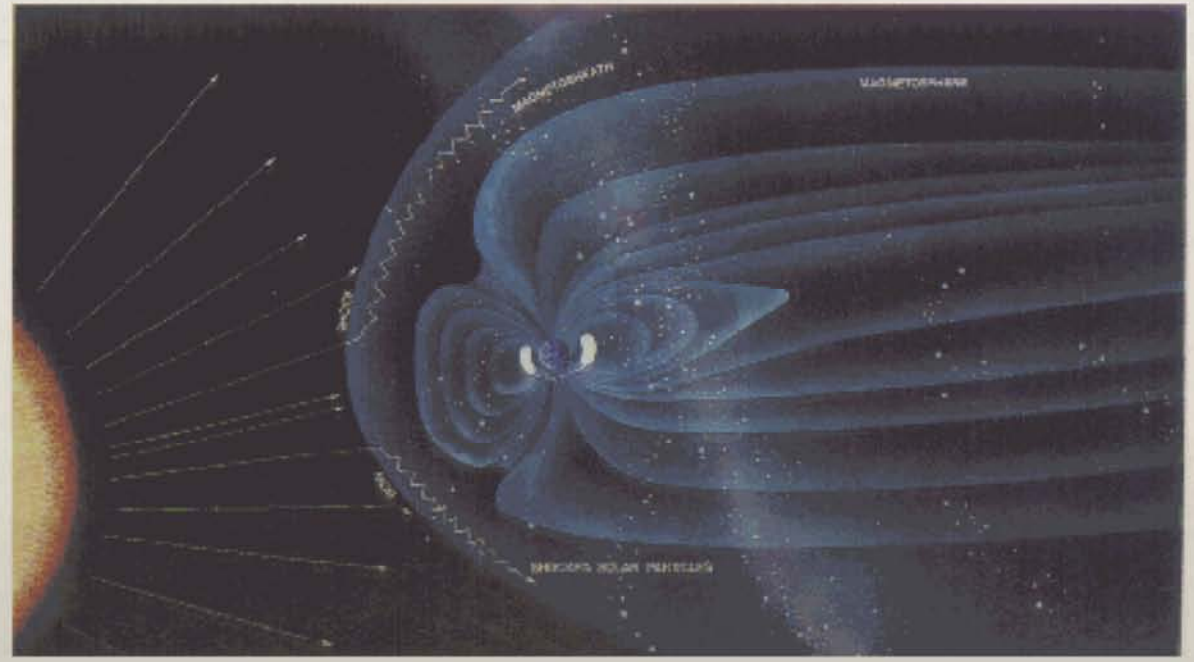
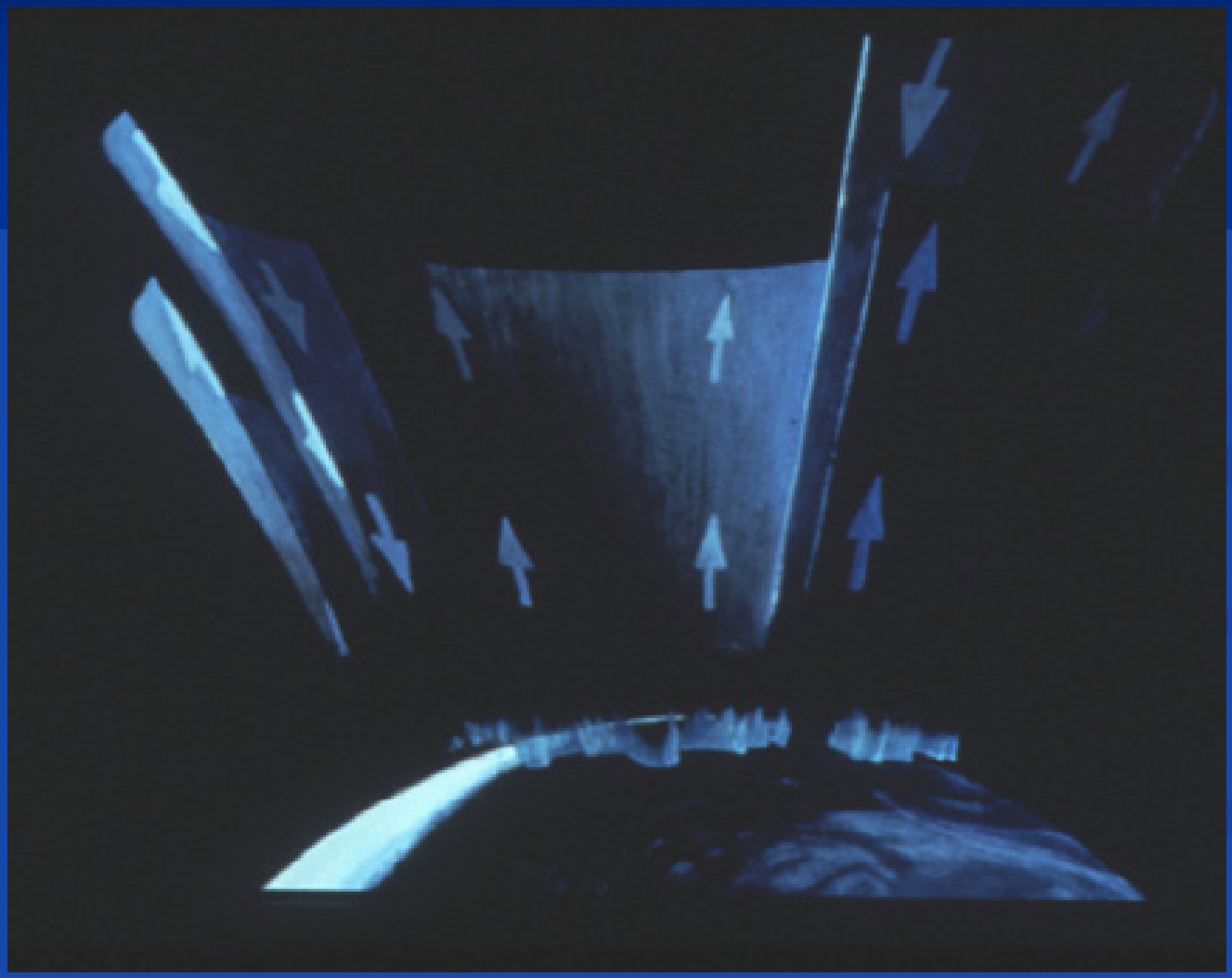


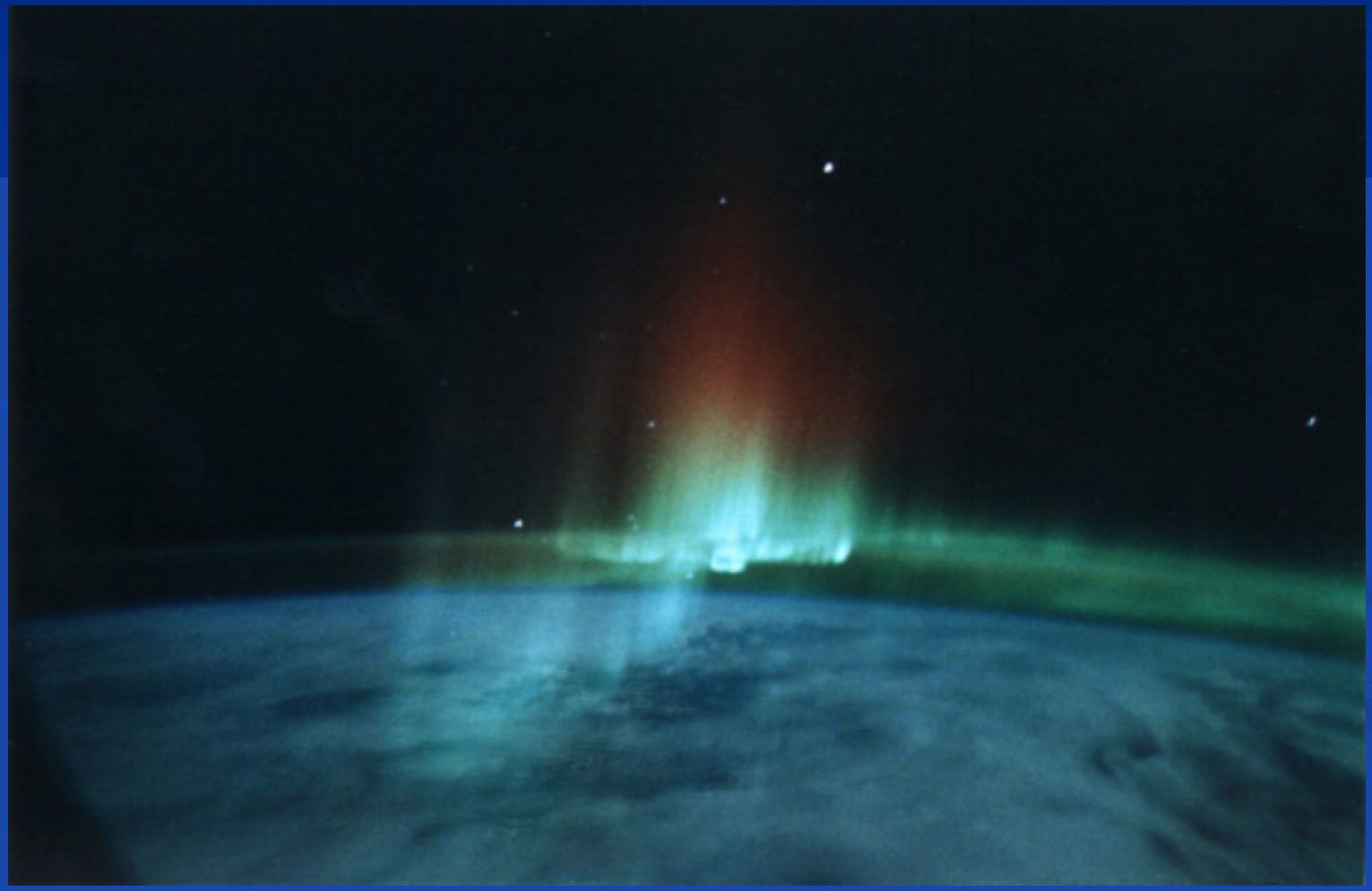
Fig. 4 The Earth's Magnetosphere

Currents flow along the magnetic field



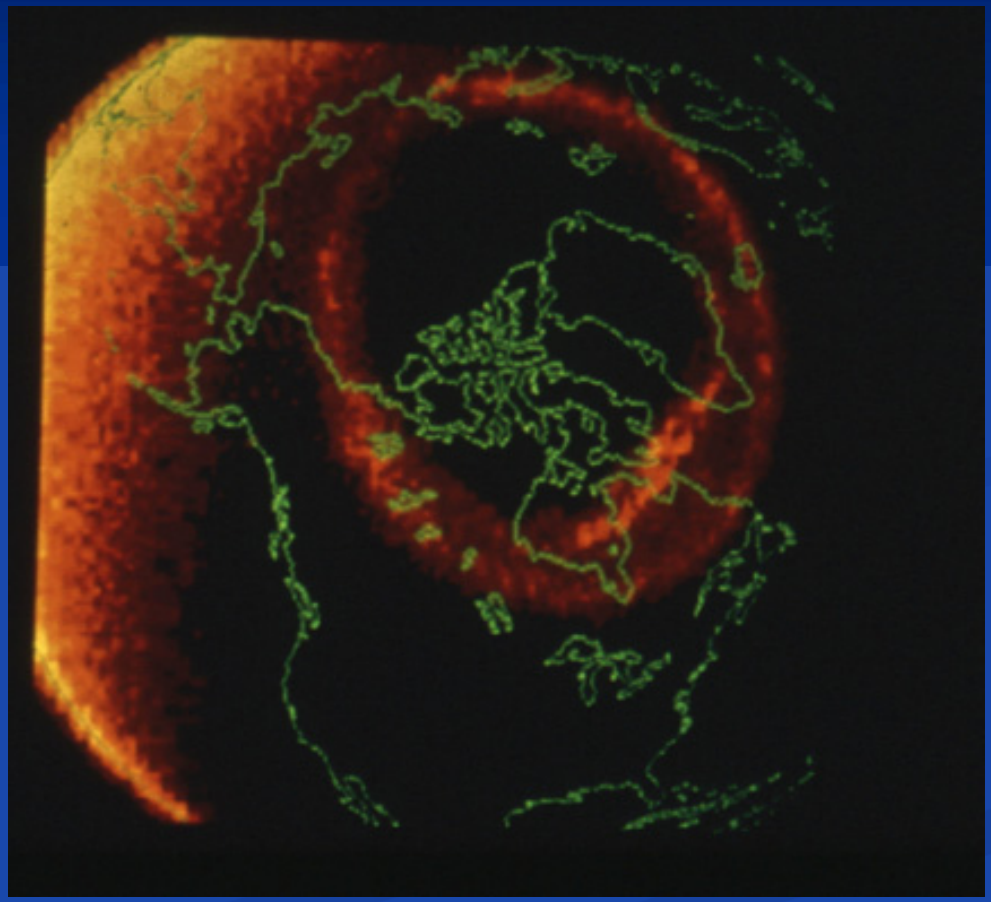
Field Aligned currents light up the sky- the Aurora

The aurora as seen by the Space Shuttle (300 km altitude)

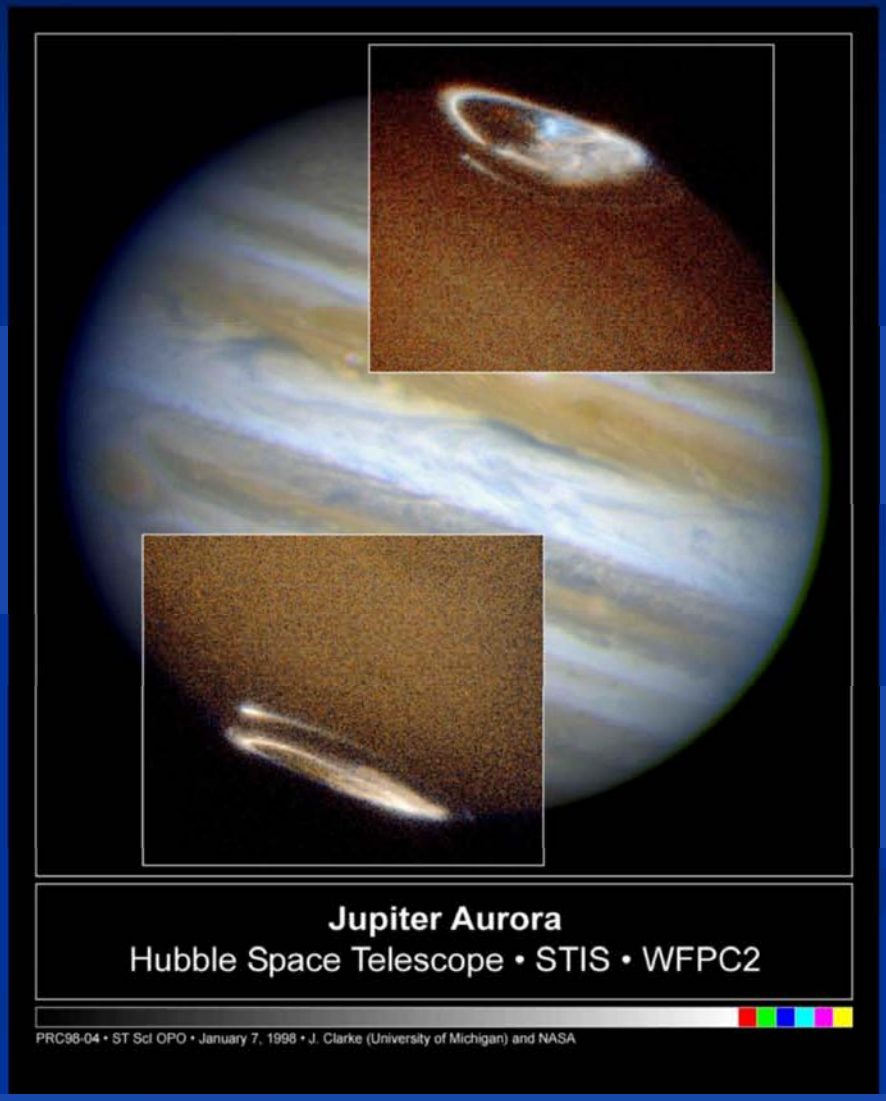


Global Aurora

UV (ultraviolet) image from the Dynamics Explorer satellite shows the northern auroral oval



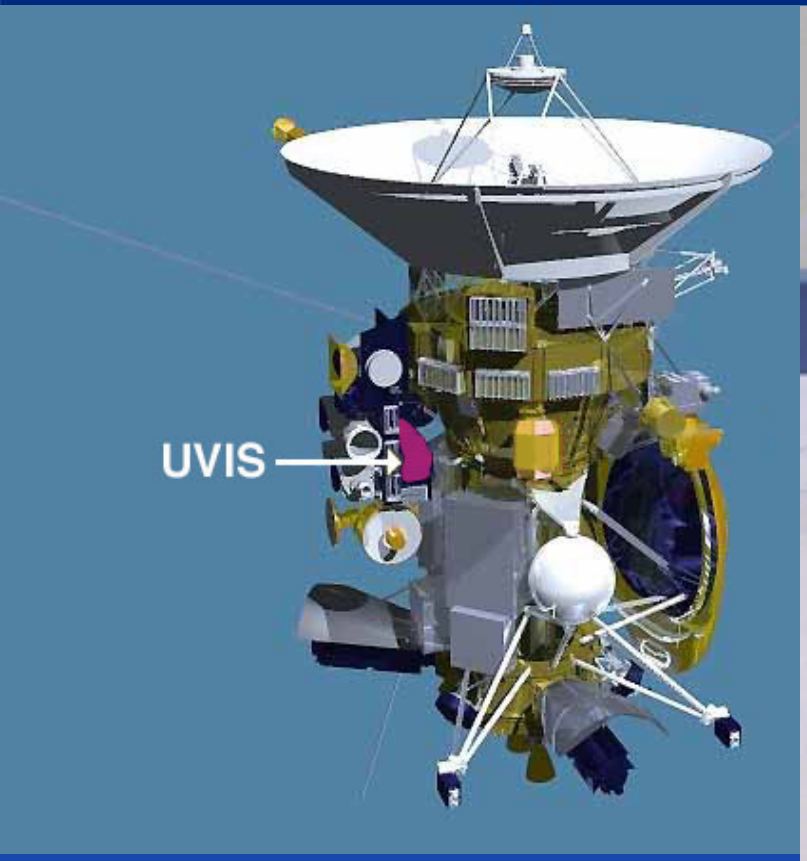
Other planets have auroras too!

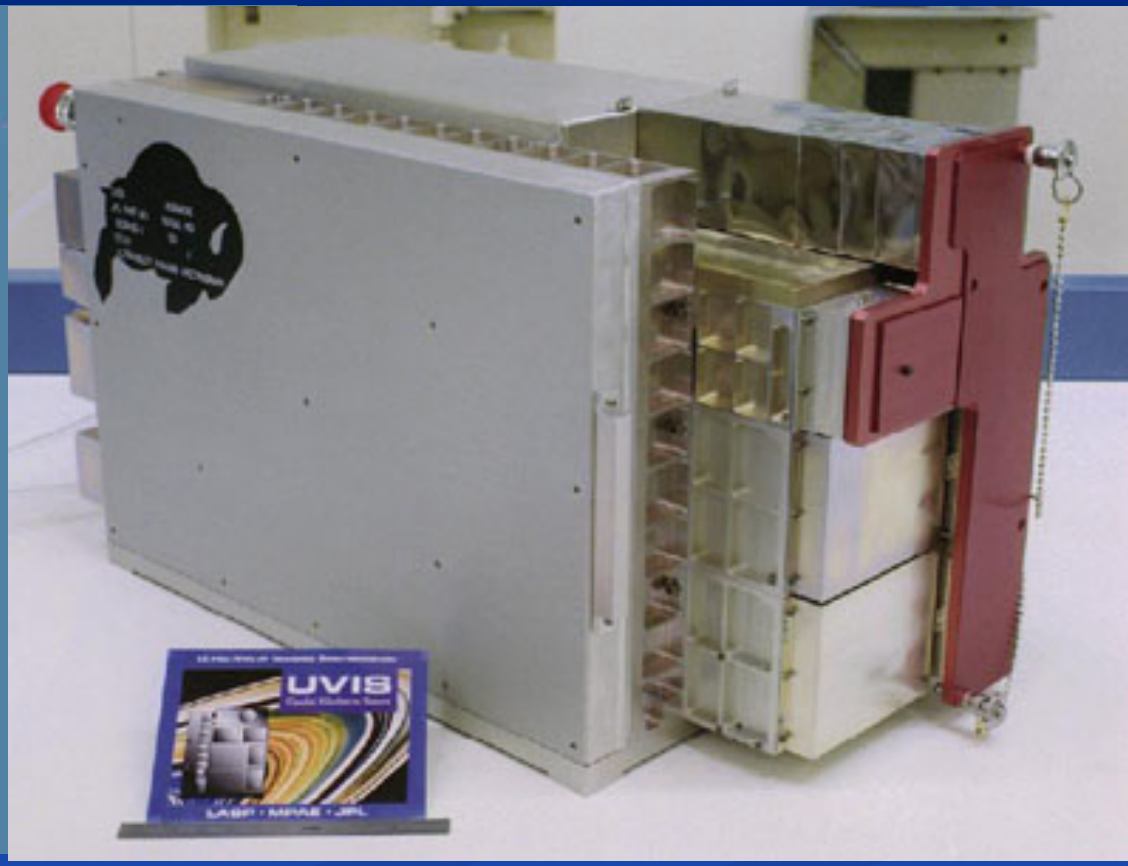


Processes by planet

- Earth: solar-wind driven auroras
- Jupiter: auroras dominated by sulfur, oxygen plasma from the moon Io's volcanoes. Main aurora is due to "co-rotation breakdown"
- Saturn: mixture of solar wind driven and internal stuff from magnetospheric plasmas rich in water products from the rings and the moon Enceladus

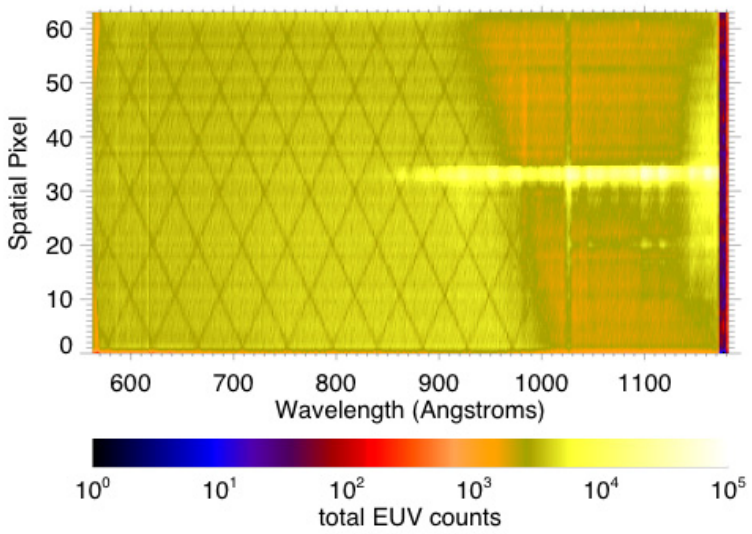
UVIS and VIMS are on the Cassini Orbiter



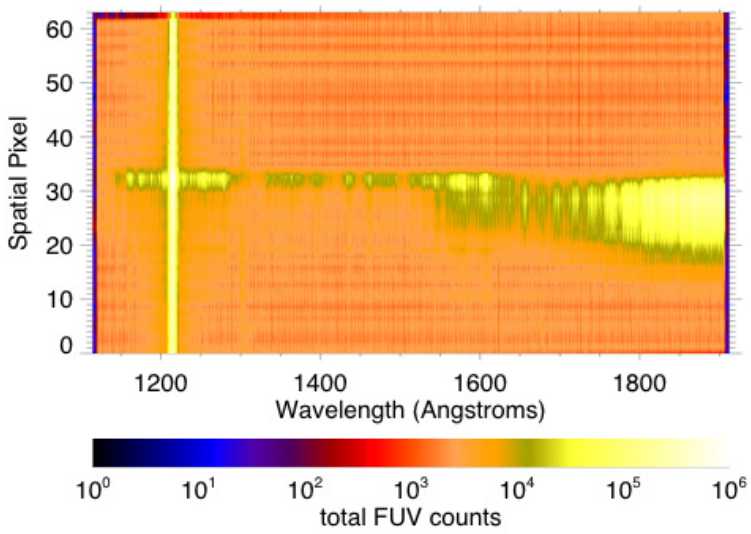


Sample Saturn Spectral Images

EUV



FUV



UVIS long-slit spectroscopy

EUV channel 56.3-118. 2 nm

FUV channel 111.5-191.3 nm

64 spatial x 1024 spectral pixels

Spectral imaging is done

by spacecraft slews

<u>Saturn's emissions</u>:

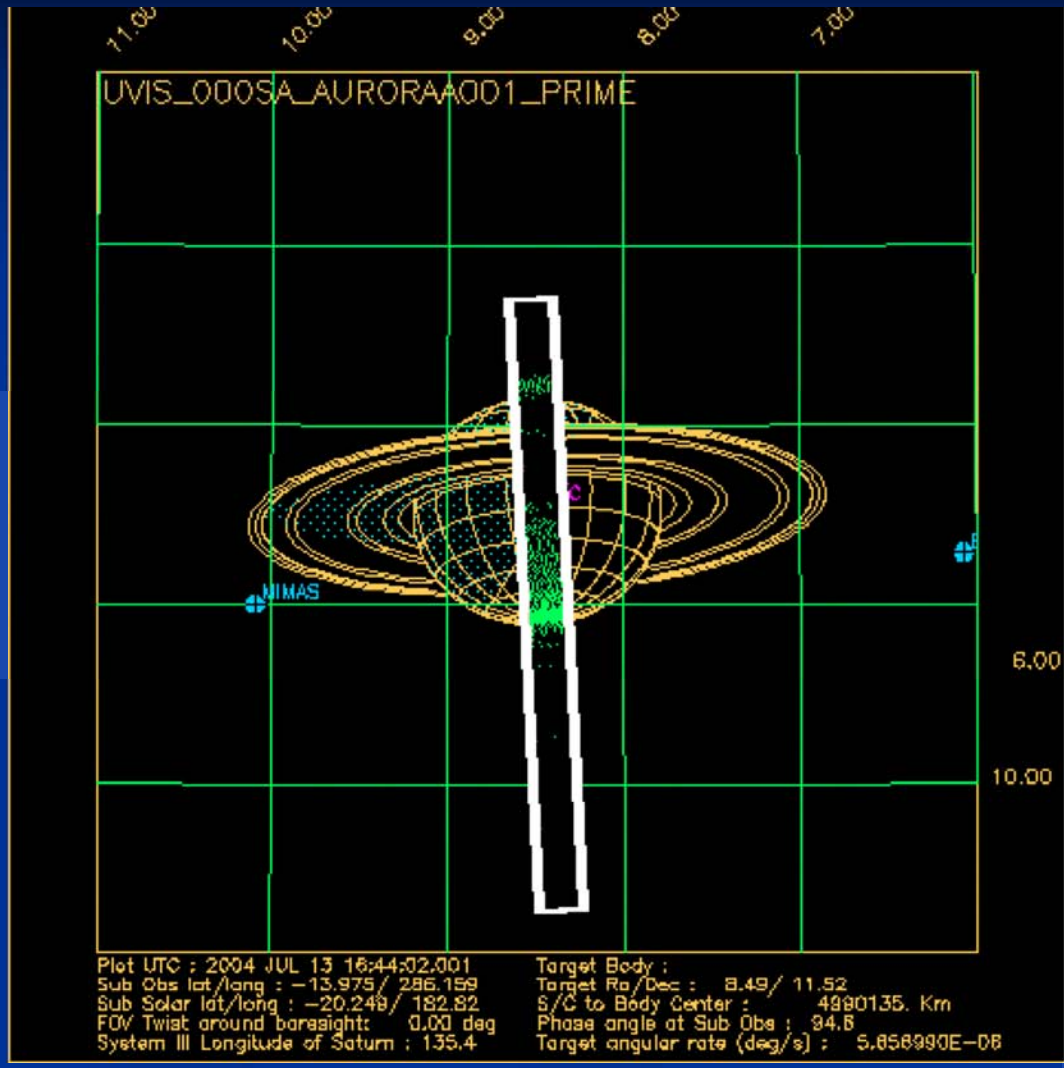
H Lyman-a and H_2 bands

from auroras and dayglow.

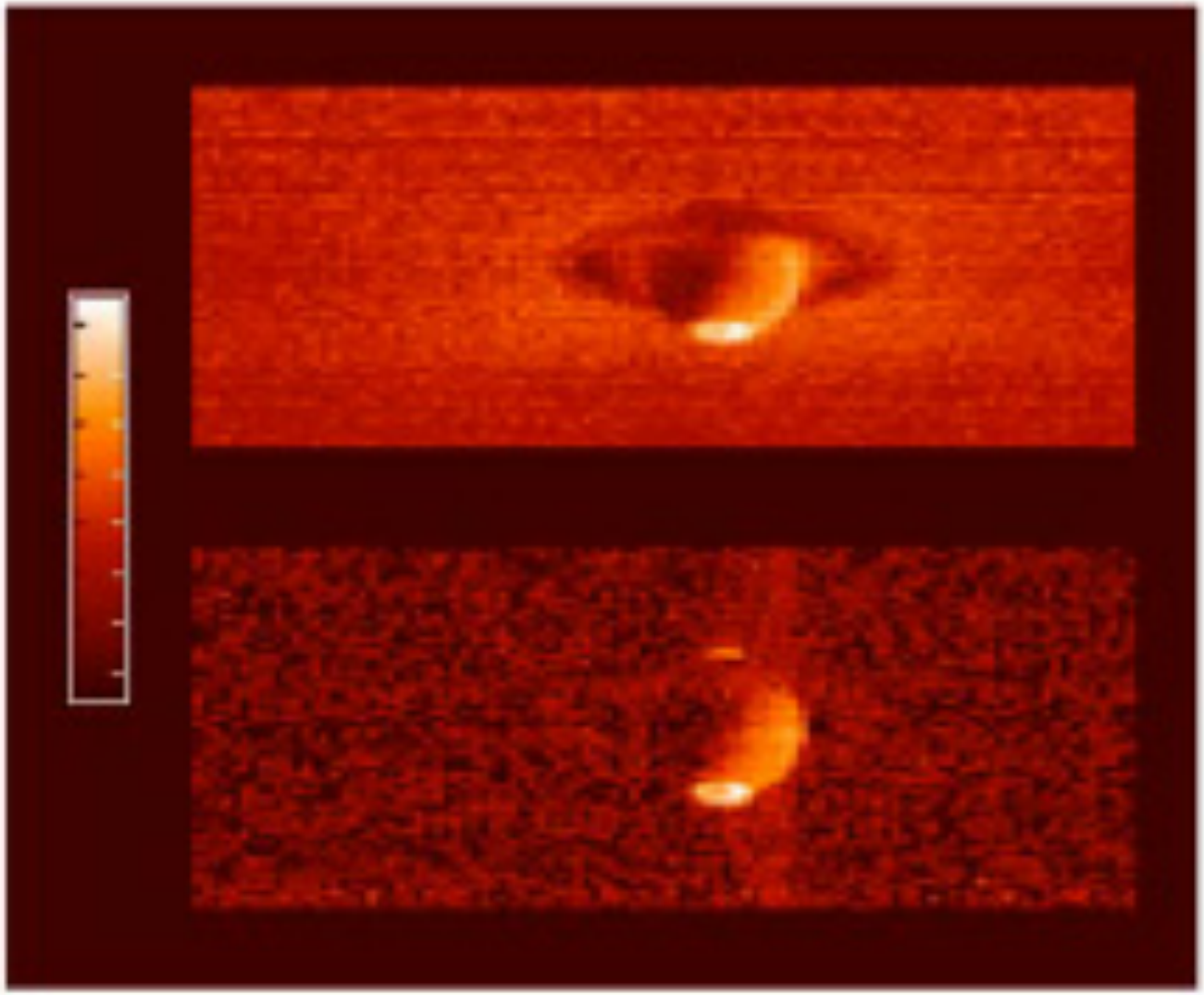
<u>Reflected sunlight spectrum</u>:

Rayleigh scattering in H_2

and acetylene absorption bands



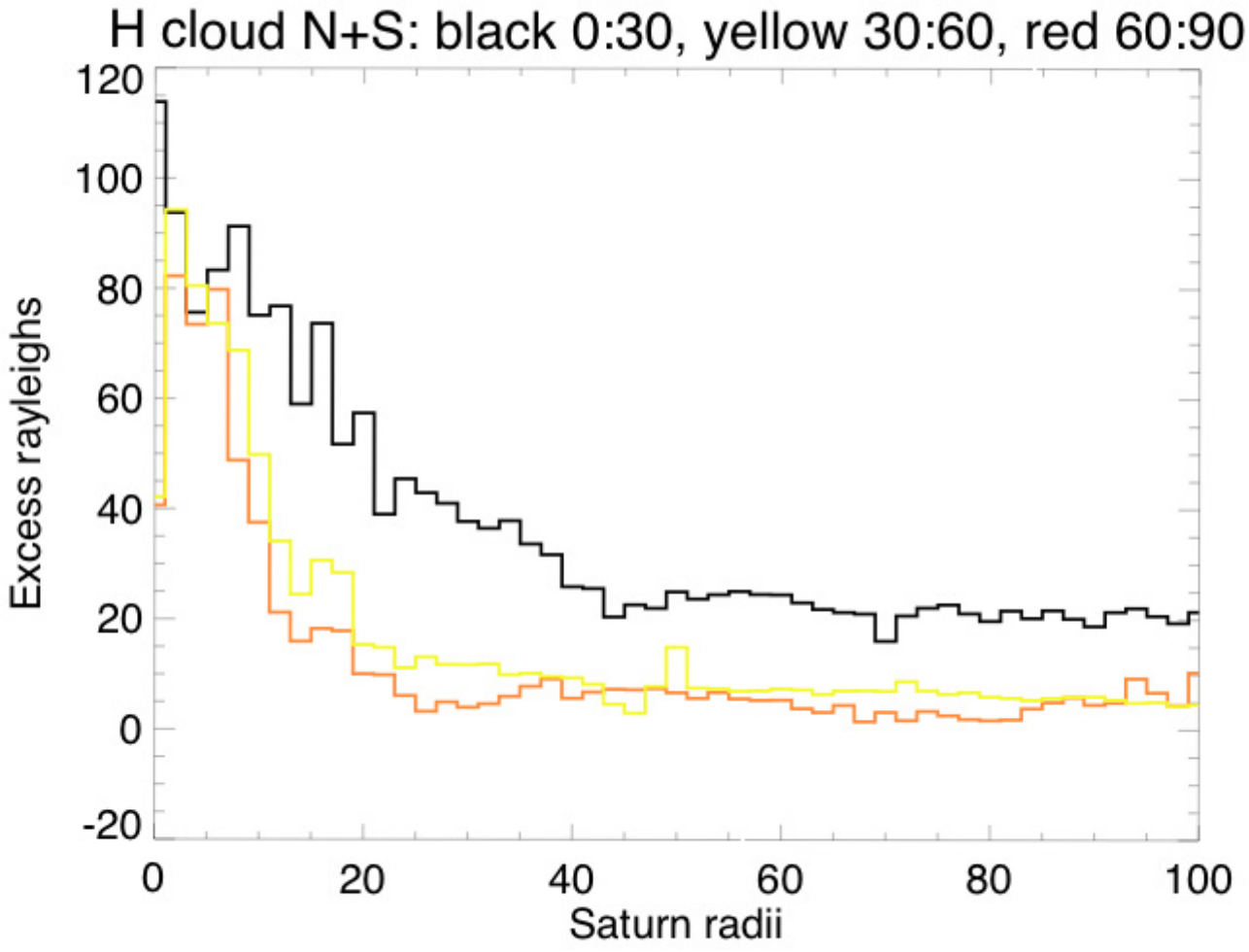
Saturn in ultraviolet (July 13, 2004): auroras!



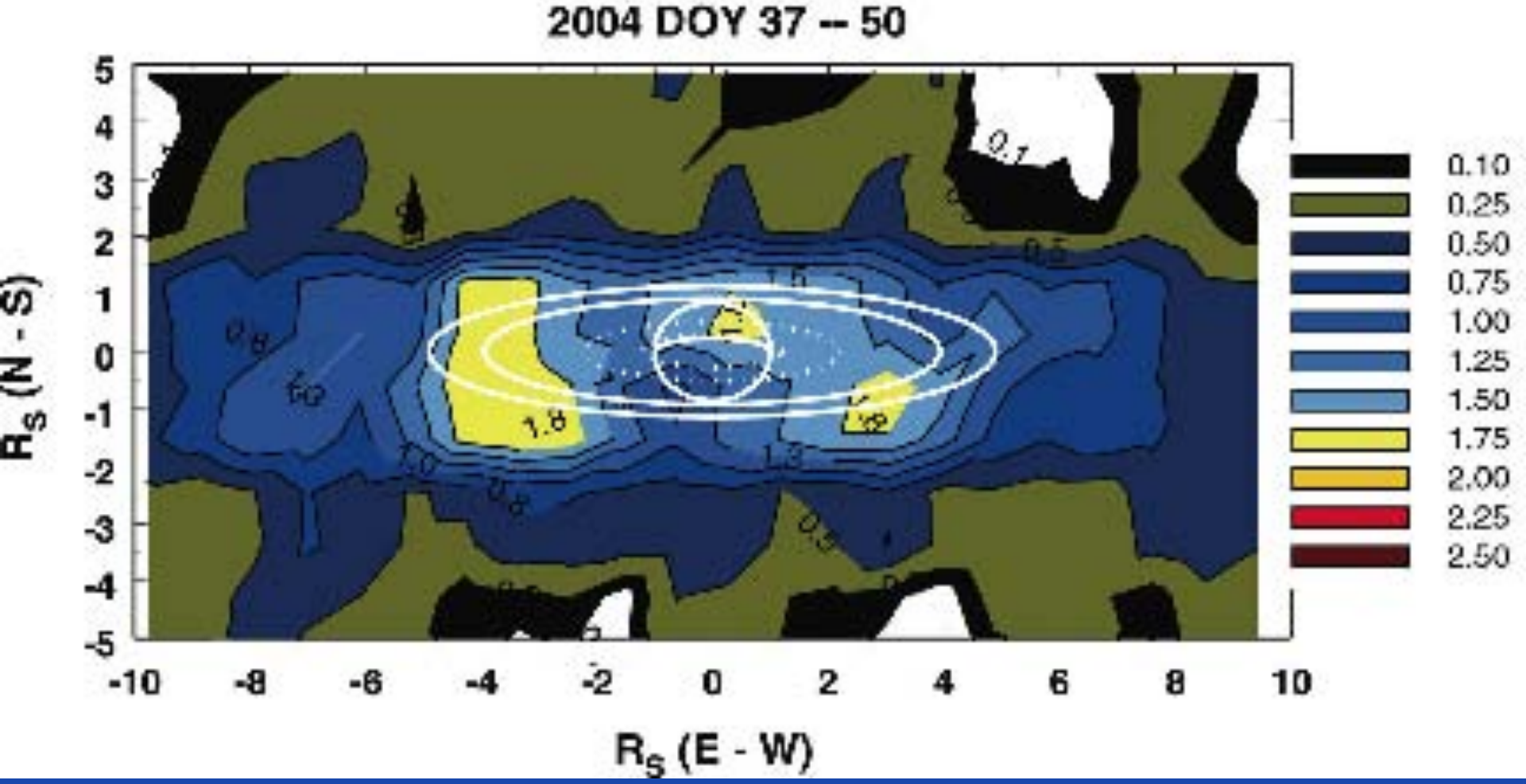
H Lyman-alpha

H_2 band emission

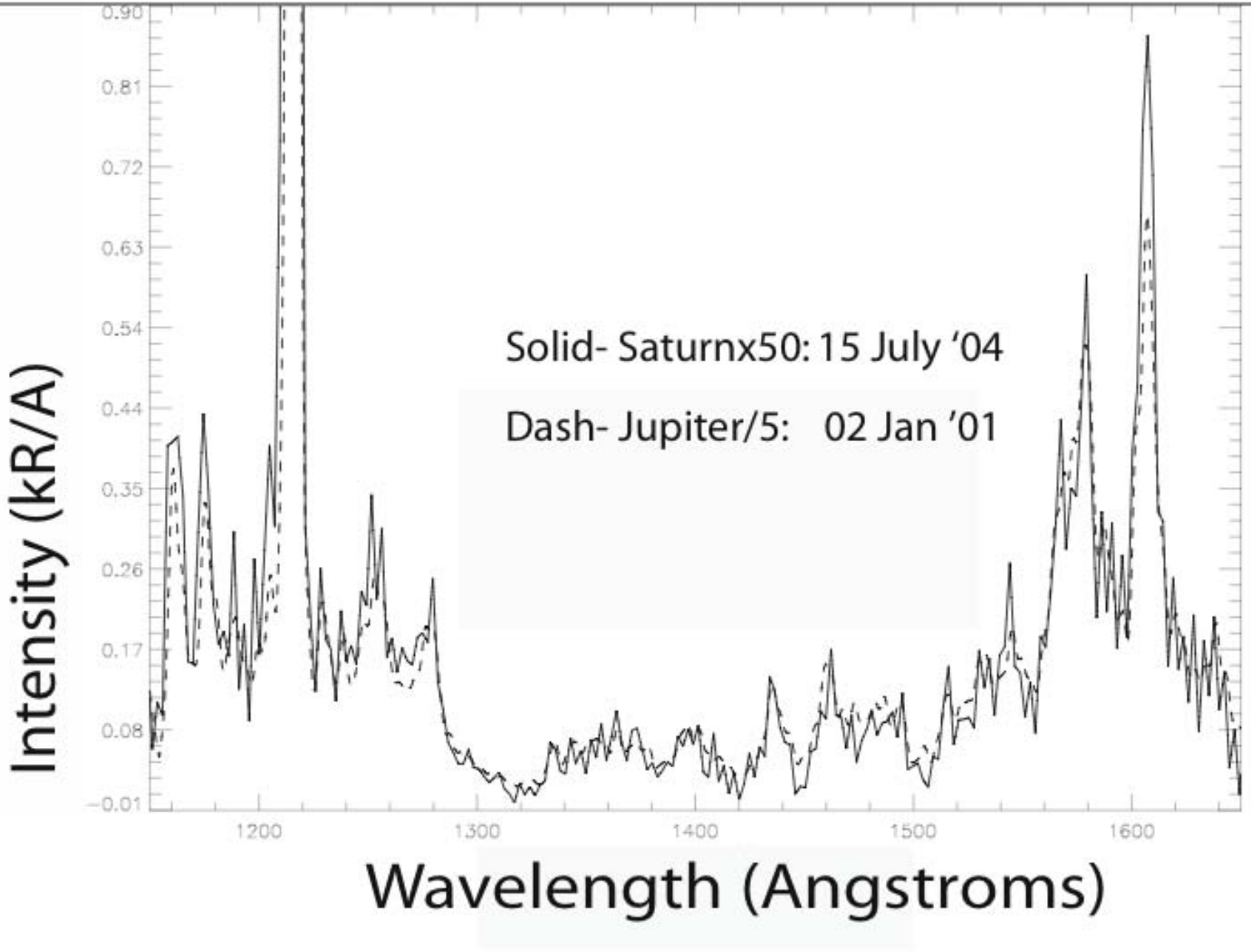
Saturn H Lyman-a



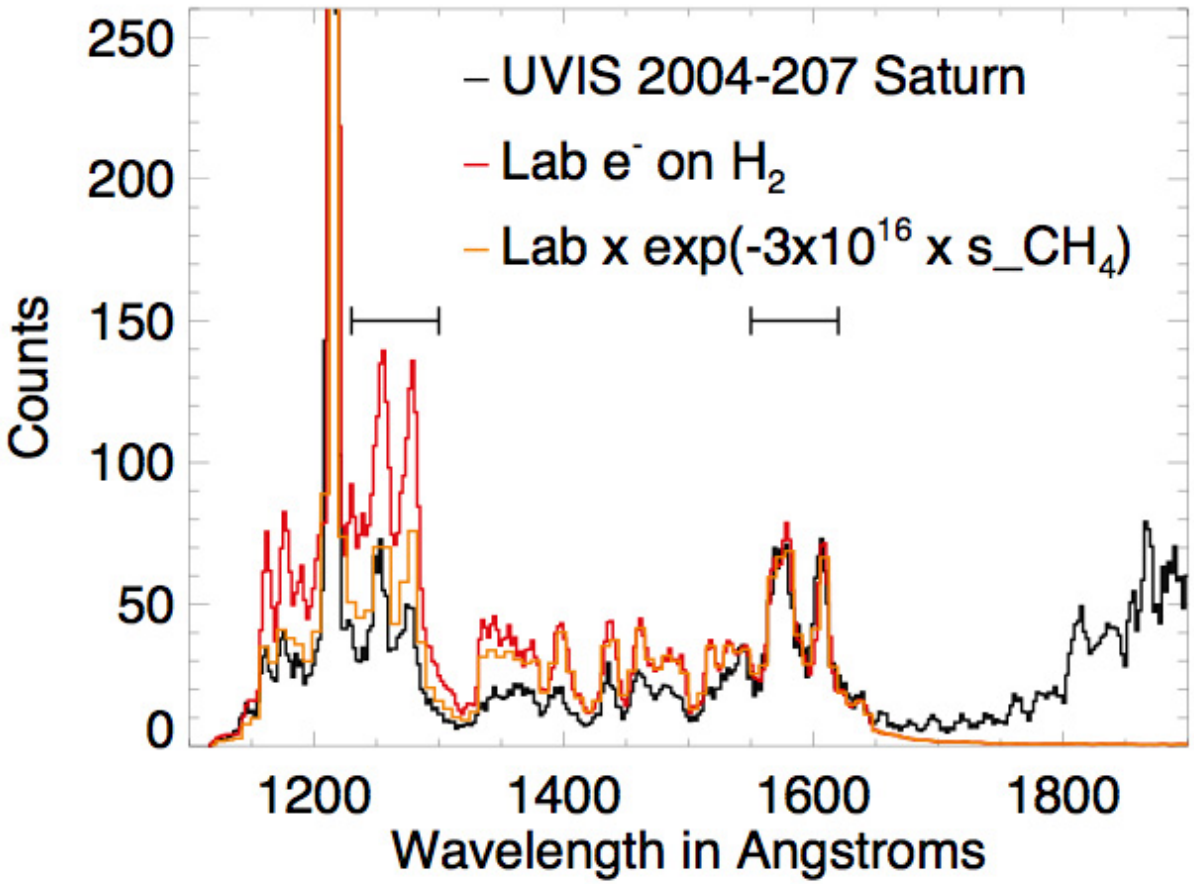
Saturn Oxygen image 130 nm
(peaks ~2 Rayleighs, cloud has 10^{12} grams of O)



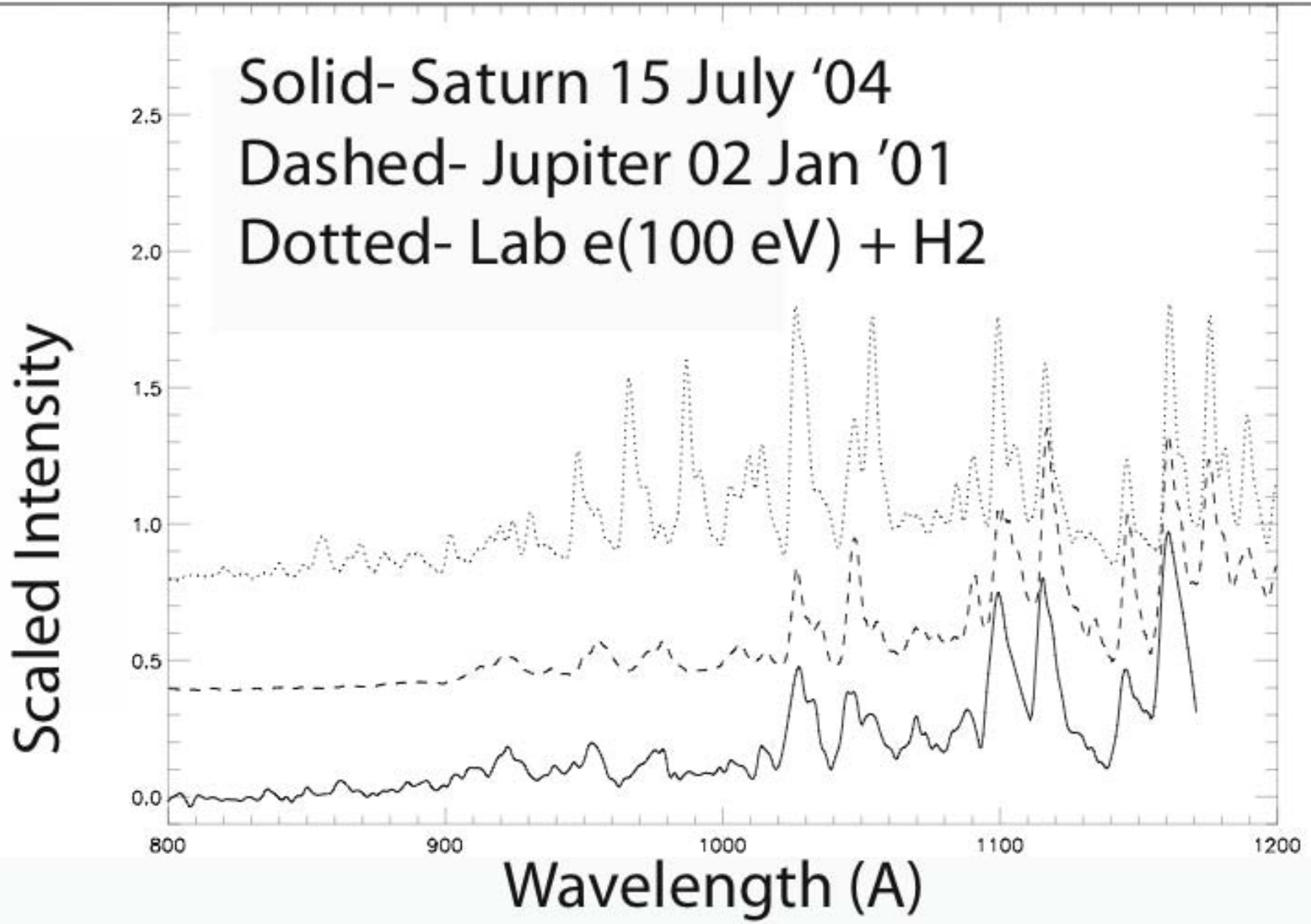
UVIS FUV Saturn and Jupiter Aurora



Saturn Auroral Spectrum

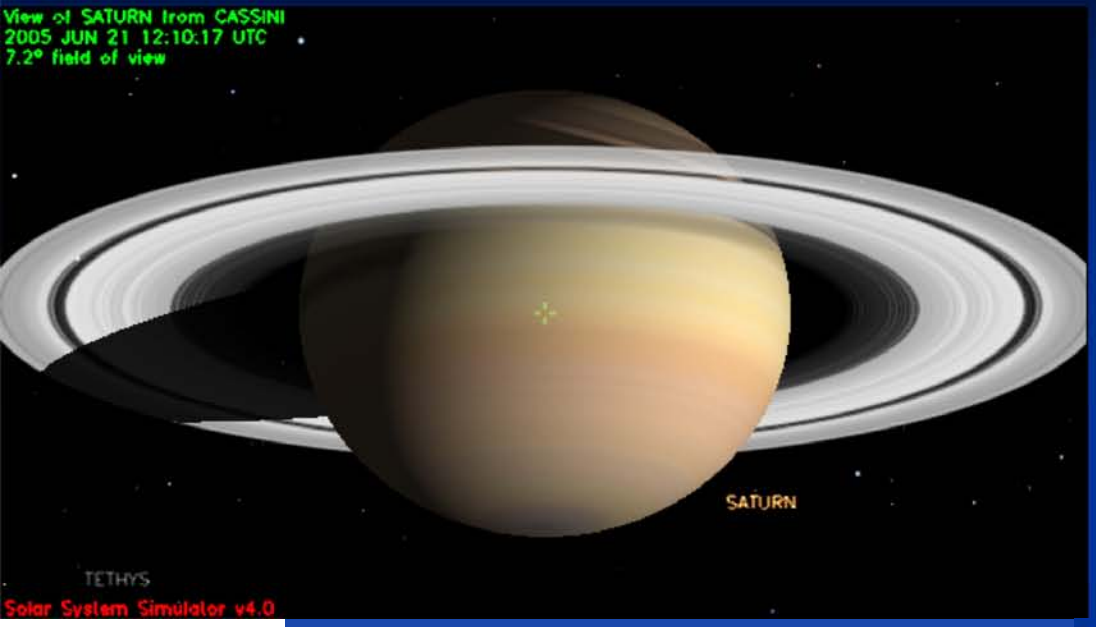


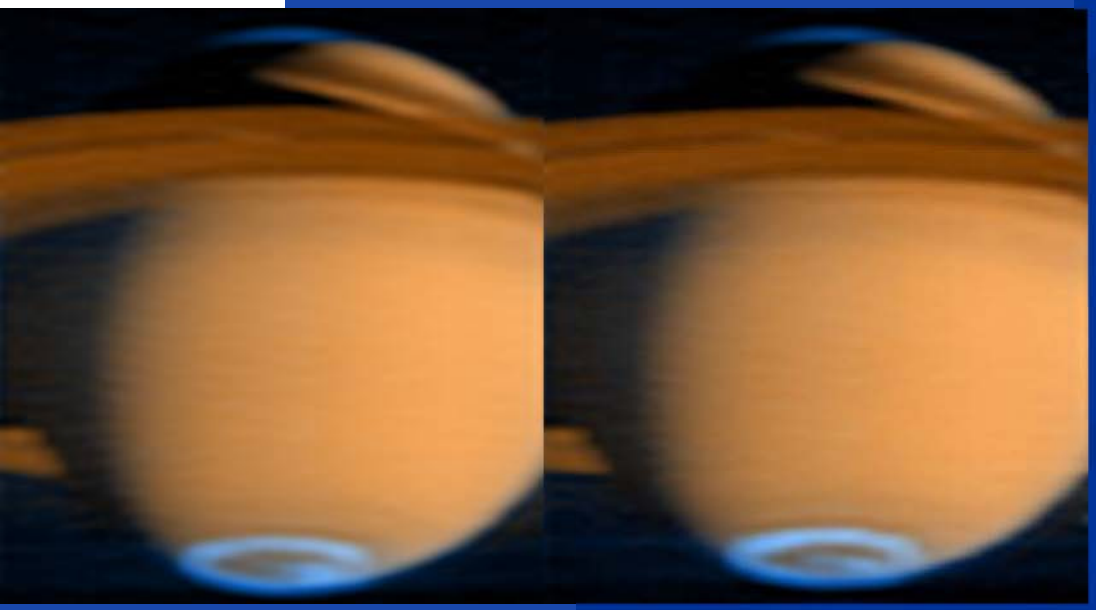
UVIS EUV Aurora



June 21 (Day 172), 2005 03:30-14:30

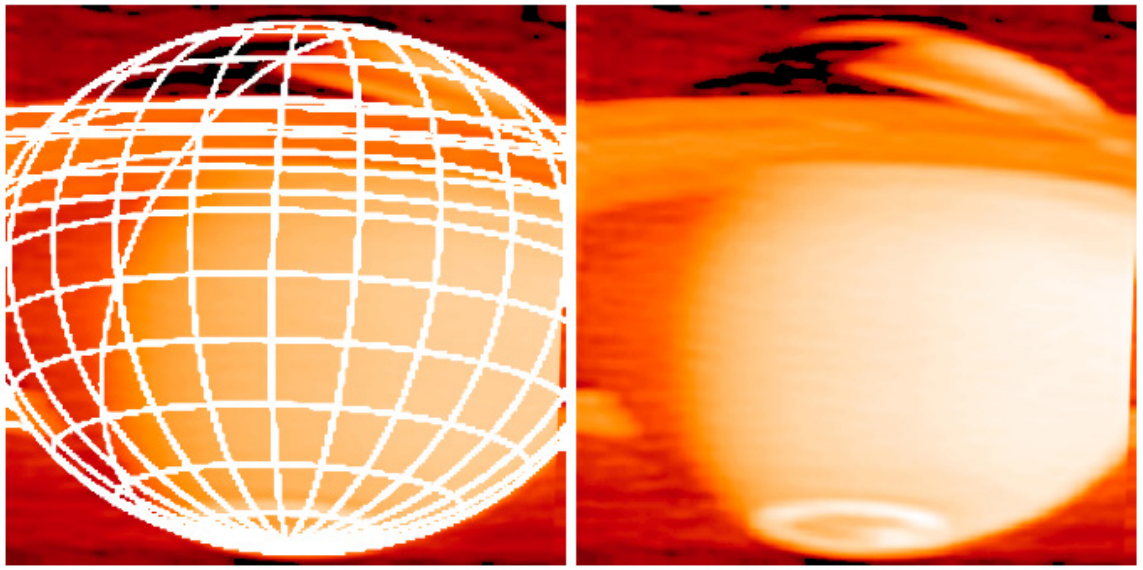
"EUVFUV" from 35 Rs





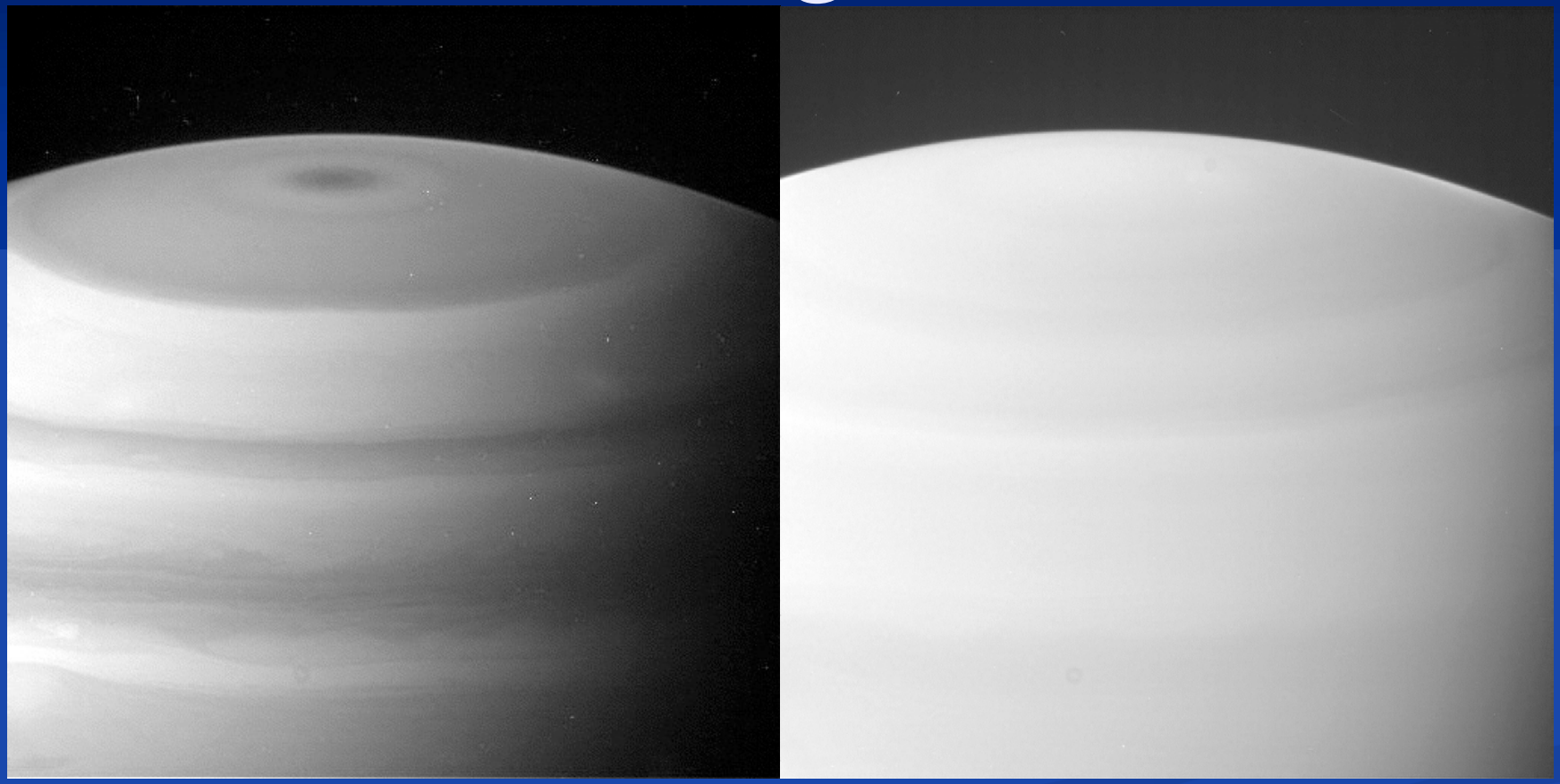
- N-S-N UVIS scan
- Slit E-W
- Auroral oval imaged twice
- Images deconvolved
- Blue H_2, H emission
- Orange reflected sunlight
- Aurora changes over ~1 hour
- Oval 70-75S

Saturn Day 172, 2005

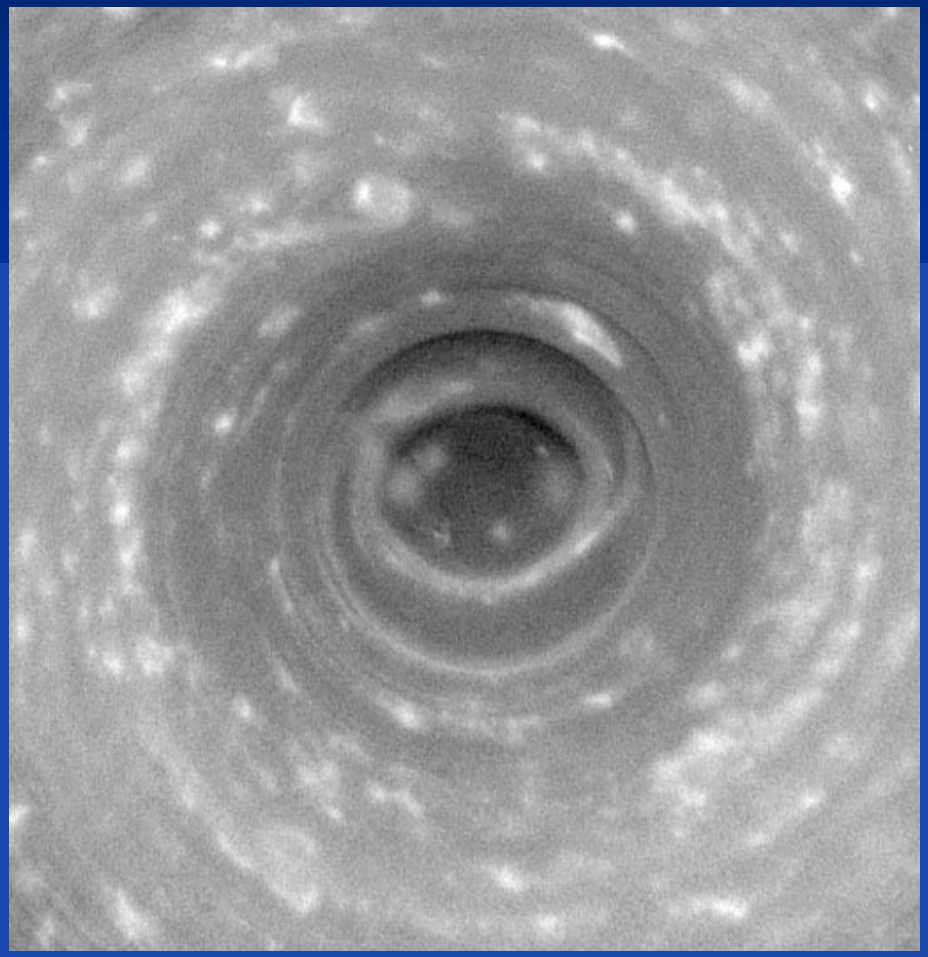


- Limb-fitting puts auroral oval in 70-75 S range

ISS south pole methane, uv3 images

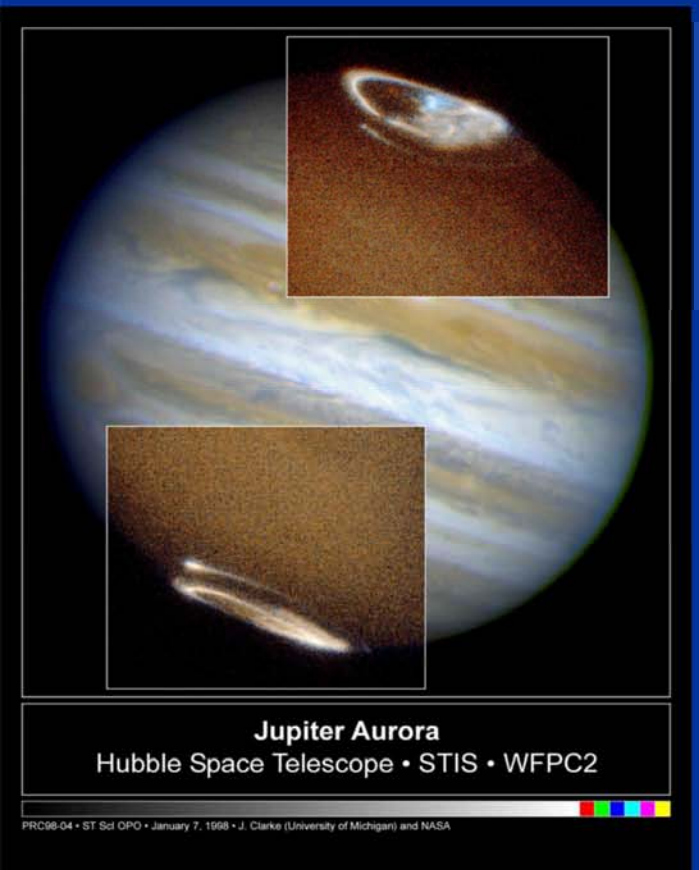


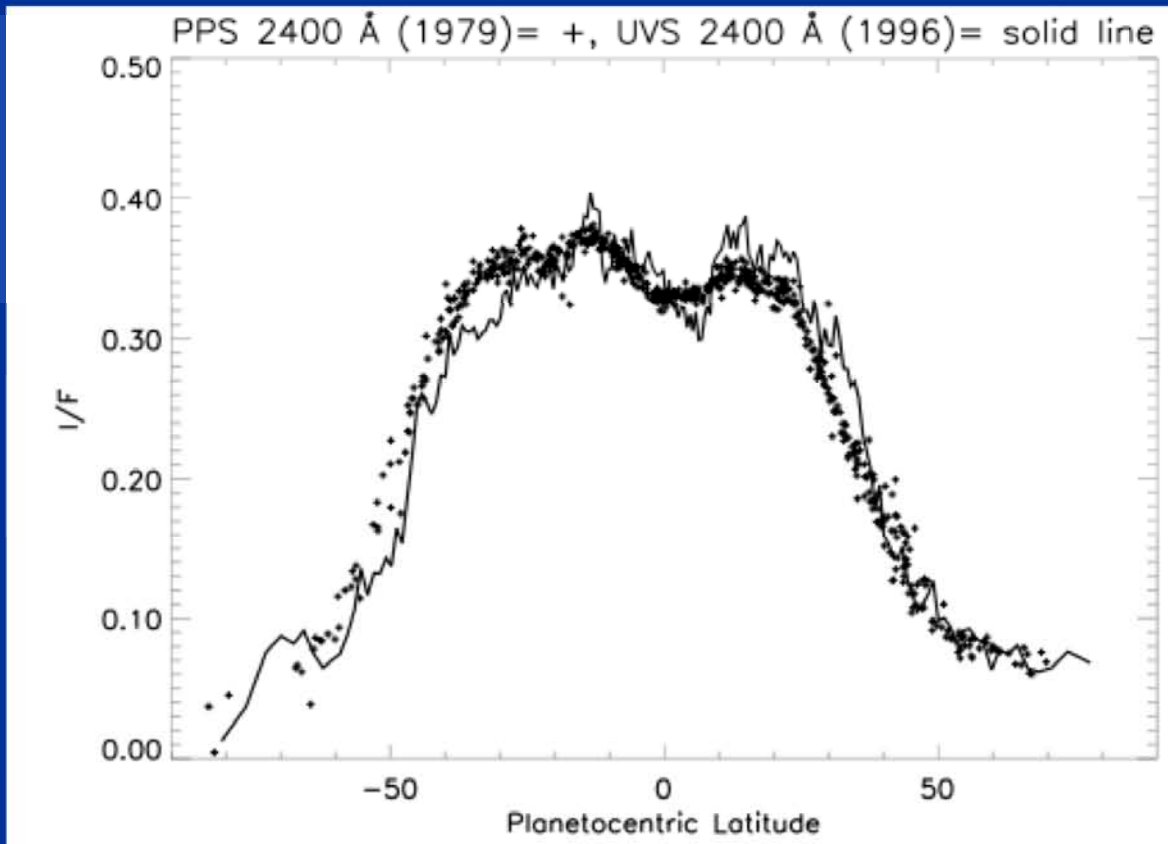
Recent Cassini Camera S Polar Image



- Intense storm at the site of an unusual UV spectrum

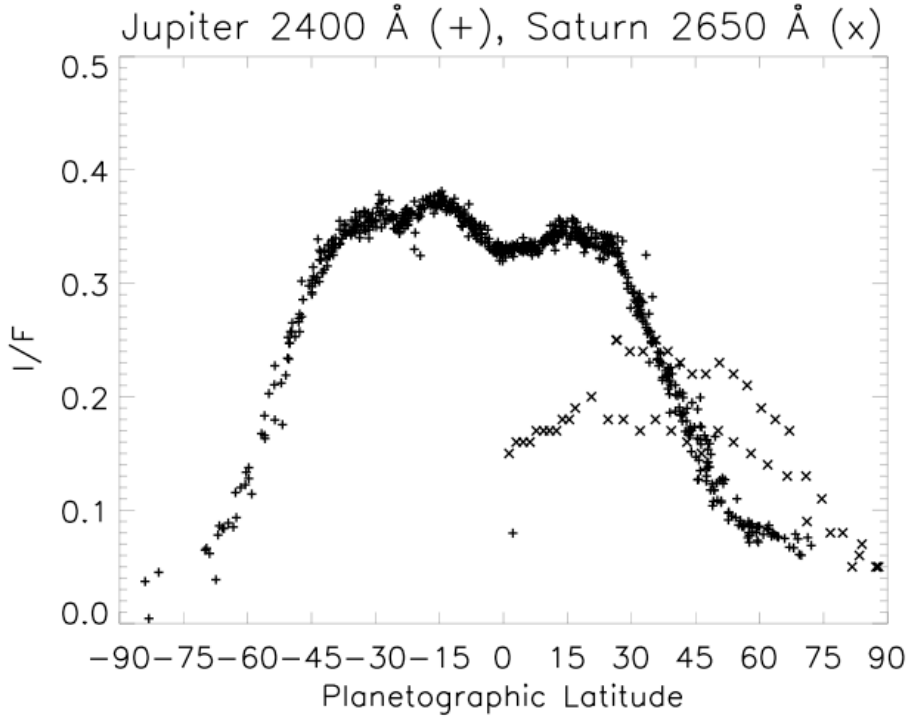
Jupiter's UV-dark Polar Haze: persistent N-S asymmetry, like the auroral asymmetry: do the auroras make dark haze?





Saturn also has UV-dark polar haze tied to the auroras

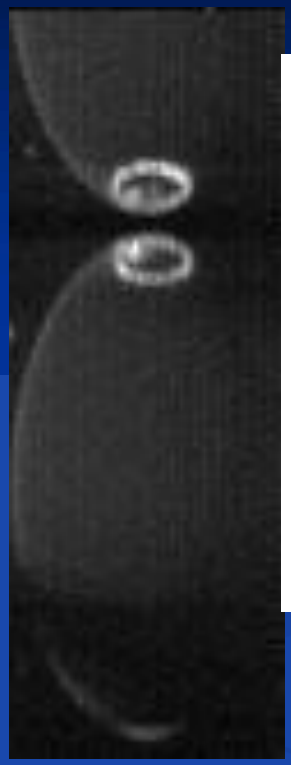
Polar Haze from Voyager PPS

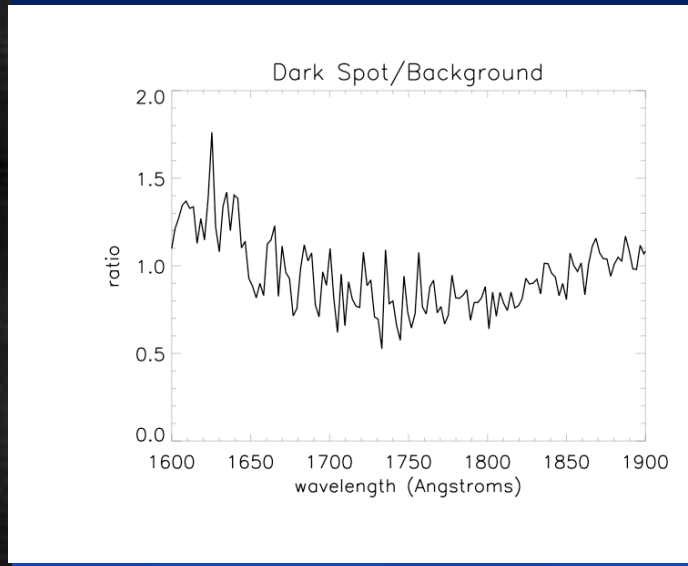


Polar Haze Chemistry

- Several theoretical and laboratory studies suggest methane (CH_4) chemistry after irradiation by the auroral electrons makes UV-dark hydrocarbon haze
- Benzene (C_6H_6) is an important step in this haze formation process
- We've looked for benzene in the UVIS data from 2005 day 172

Polar Dark Spot (2005 day 172)





wavelengths (A)

1738-1816

1816-1894

ratio 1st/2nd

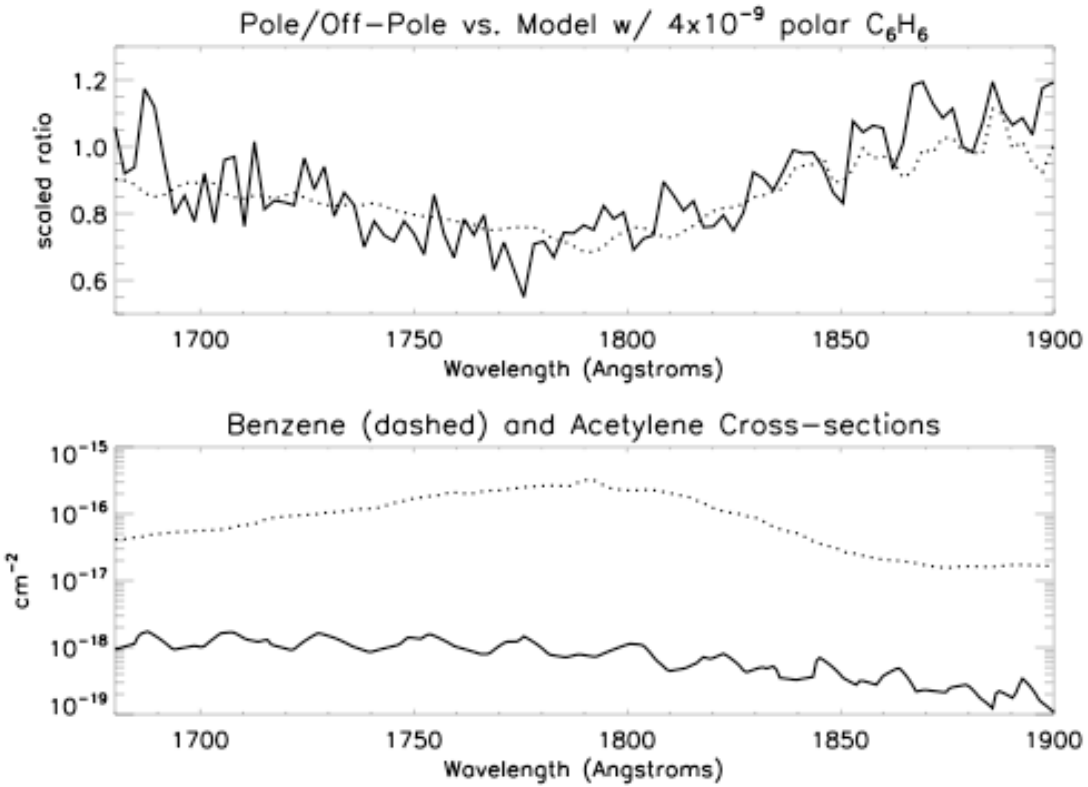
1328-1426

Spot in 1st image is gone at longer wavelengths (2nd image)

Localized small hydrocarbons? (spectrum is noisy)

Polar convergence & downwelling?

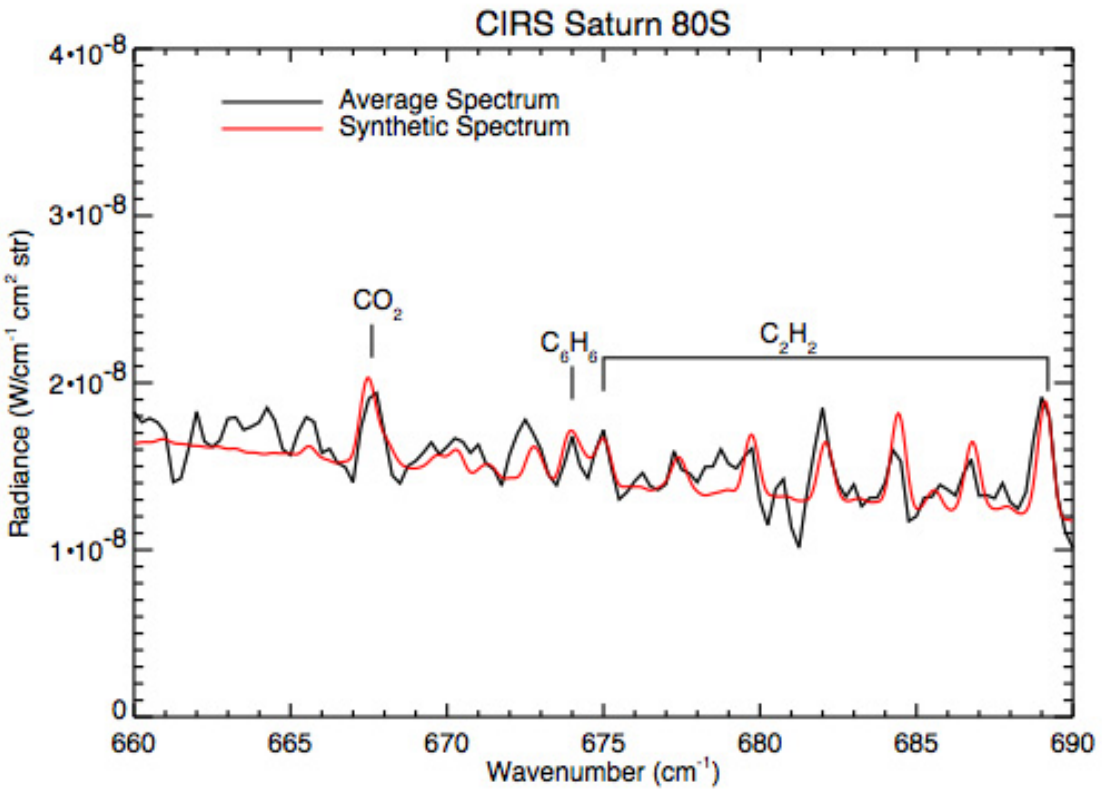
UVIS polar benzene feature? Pantos et al., 1978: broad benzene feature peaks at cross-section of ~2.7×10^{-16} cm^2



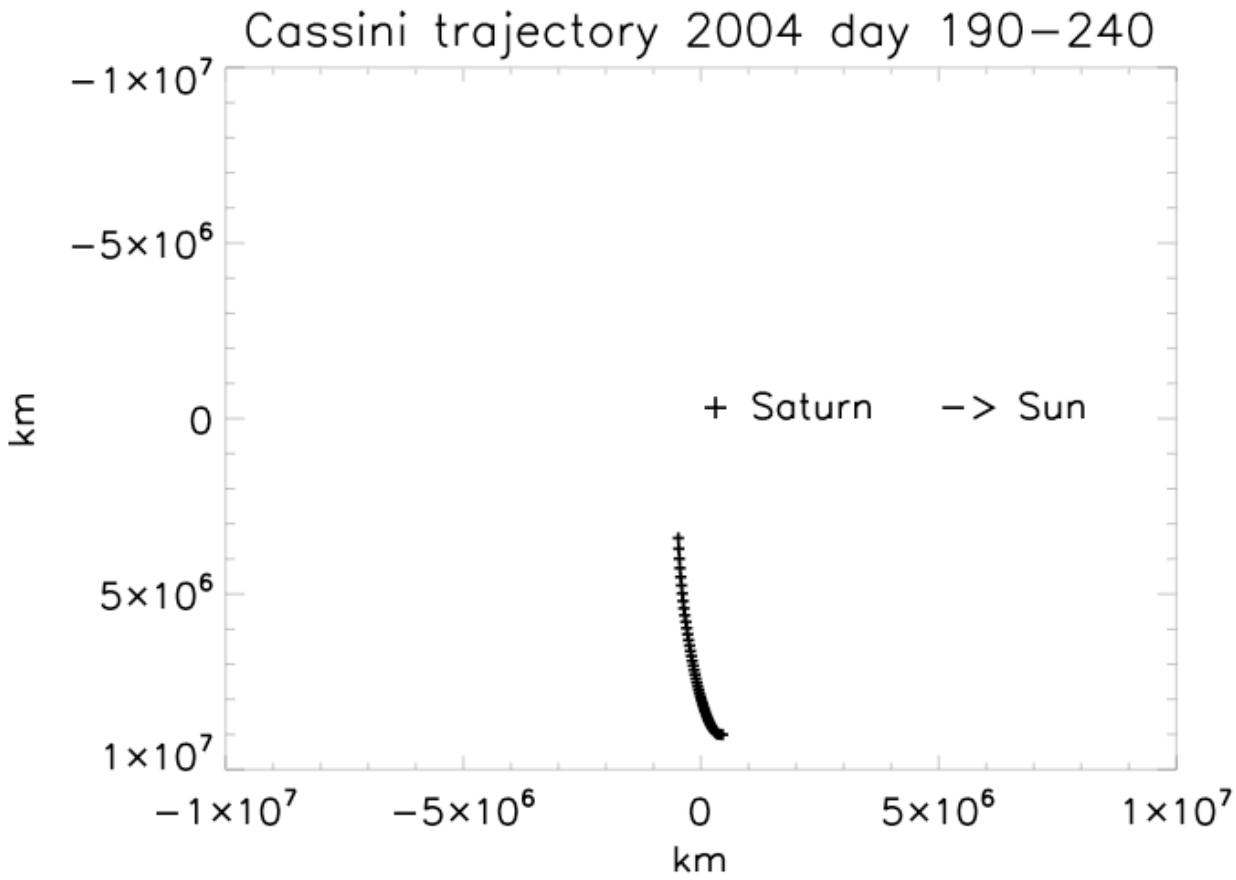
Model at left has C_2H_2 mixing ratio=10^{-6} off spot, 5×10^{-6} on spot, with C_6H_6 of 4×10^{-9} on spot

Cassini CIRS sees enhanced benzene at 14.8 μm at 80S (no 90S report yet)

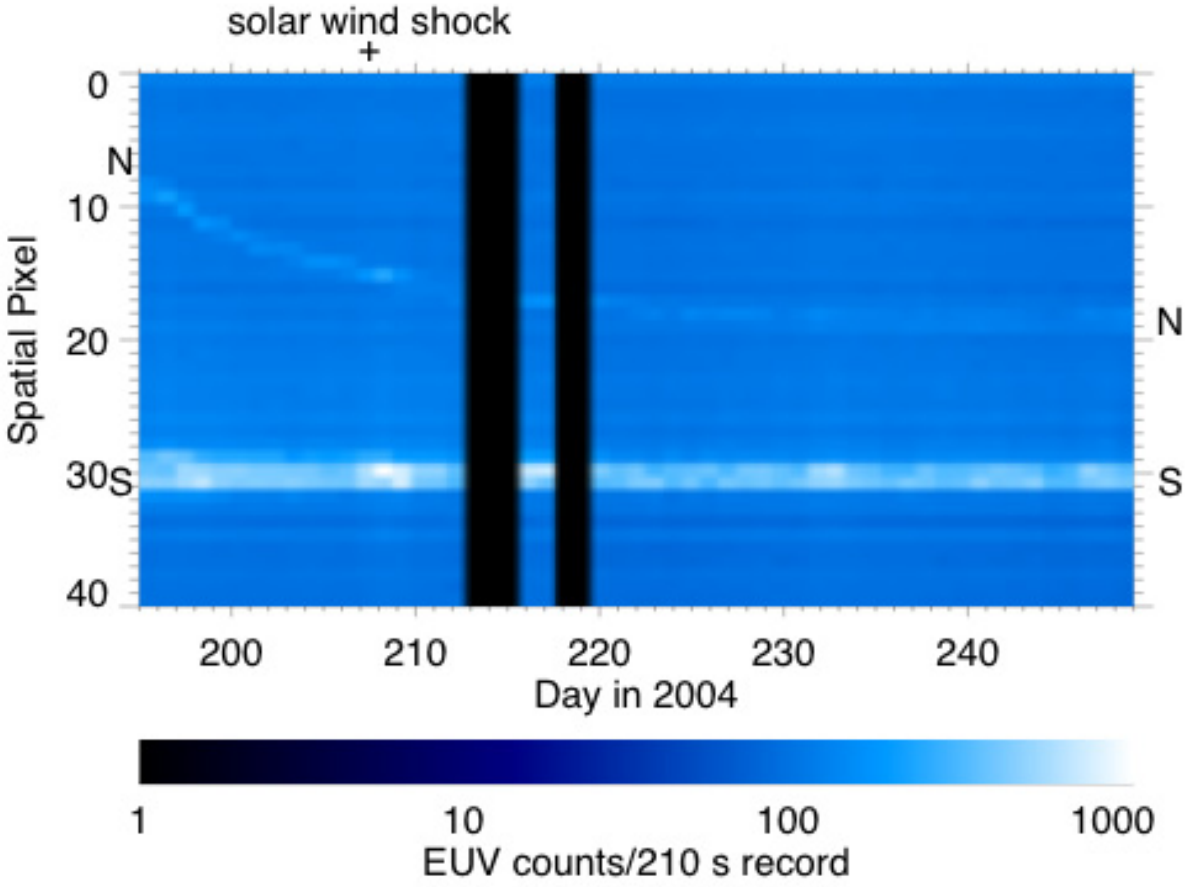
	column above 10 mb (cm^{-2})	10 mb mixing ratio
37S	1.1×10^{14}	0.98×10^{-13}
80S	2.2×10^{14}	8.73×10^{-13}

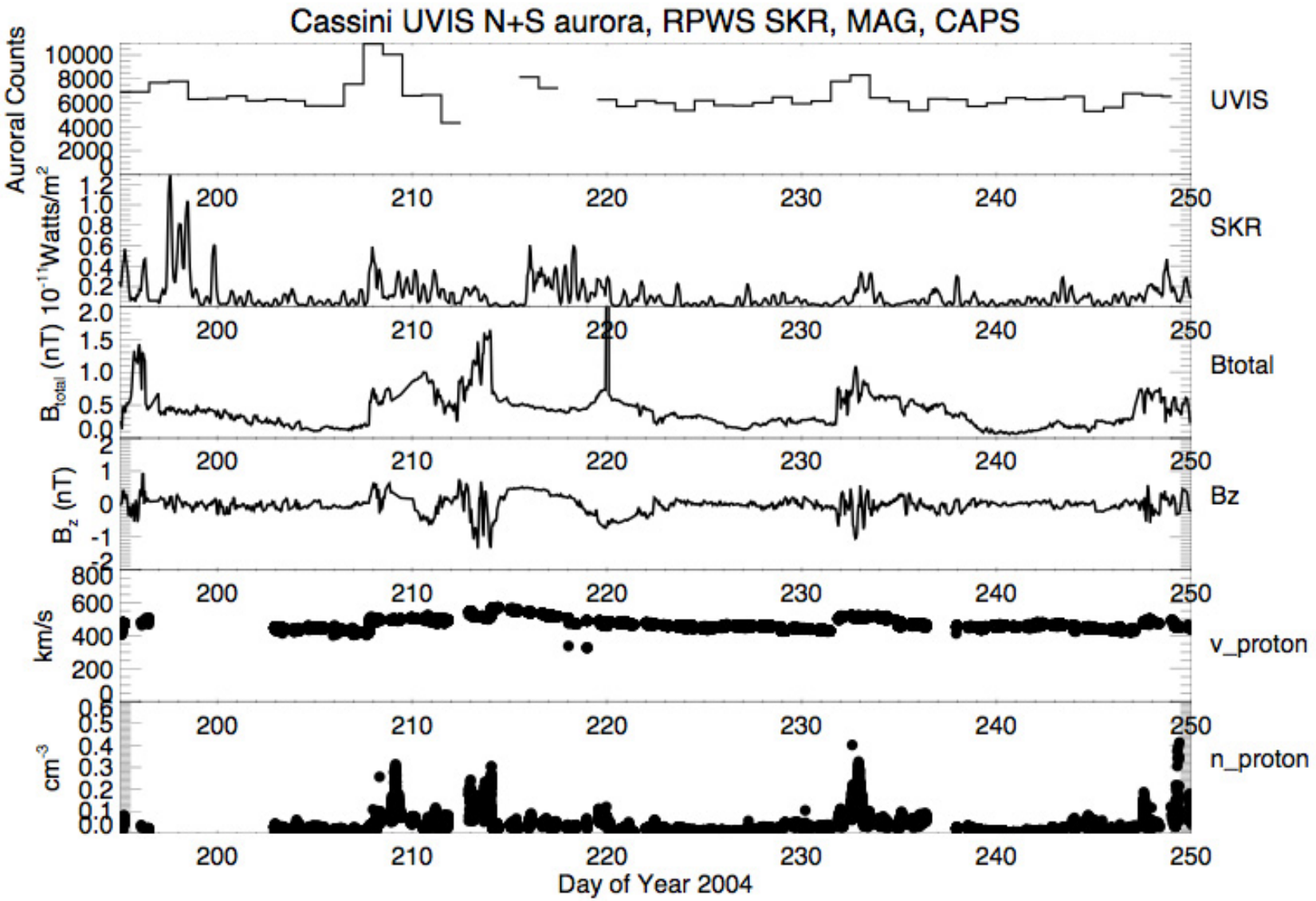


Auroral Time-Dependence: 50 day time-series moving away from Saturn near phase angle 90 with the spacecraft in the solar wind



UVIS auroral time-series as Cassini recedes from Saturn…



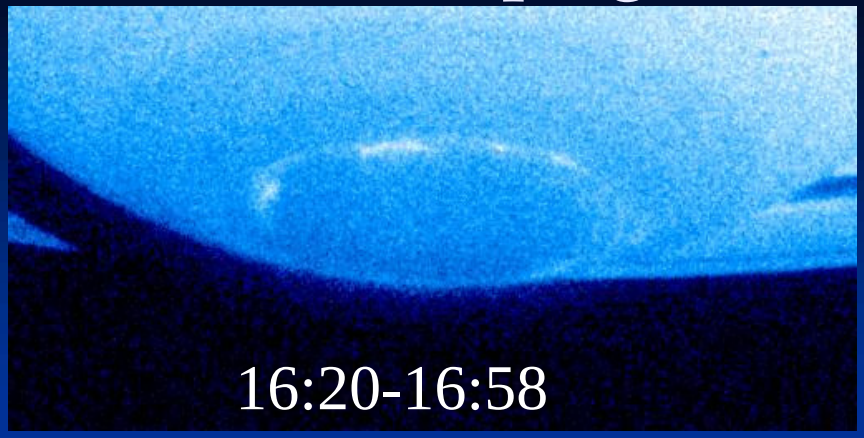

Cassini UVIS N+S aurora, RPWS SKR, MAG, CAPS
Auroral Counts
UVIS
SKR
Watts/m²
Btotal
Btotal (nT)
Bz
Bz (nT)
v_proton
km/s
n_proton
cm⁻³
Day of Year 2004

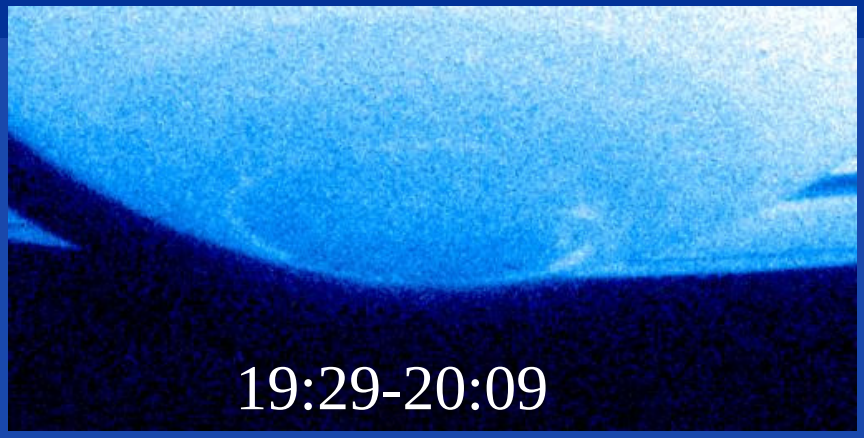
^ shock ^ shock

Hubble Auroral Campaign Feb 17, 2005

- J. Clarke, J.-C. Gerard PI's:
- Day-side S auroras by HST ACS in UV (5 orbits)
- Night-side N auroras by Cassini VIMS and UVIS
- Cassini VIMS_003SA_THRCYLMAP001_UVIS_FOV
- Started 2005-048 T23:08:00 GMT, ran 8 h 22 m
- Cassini at ~800,000 km range
- Aurora was weak that day

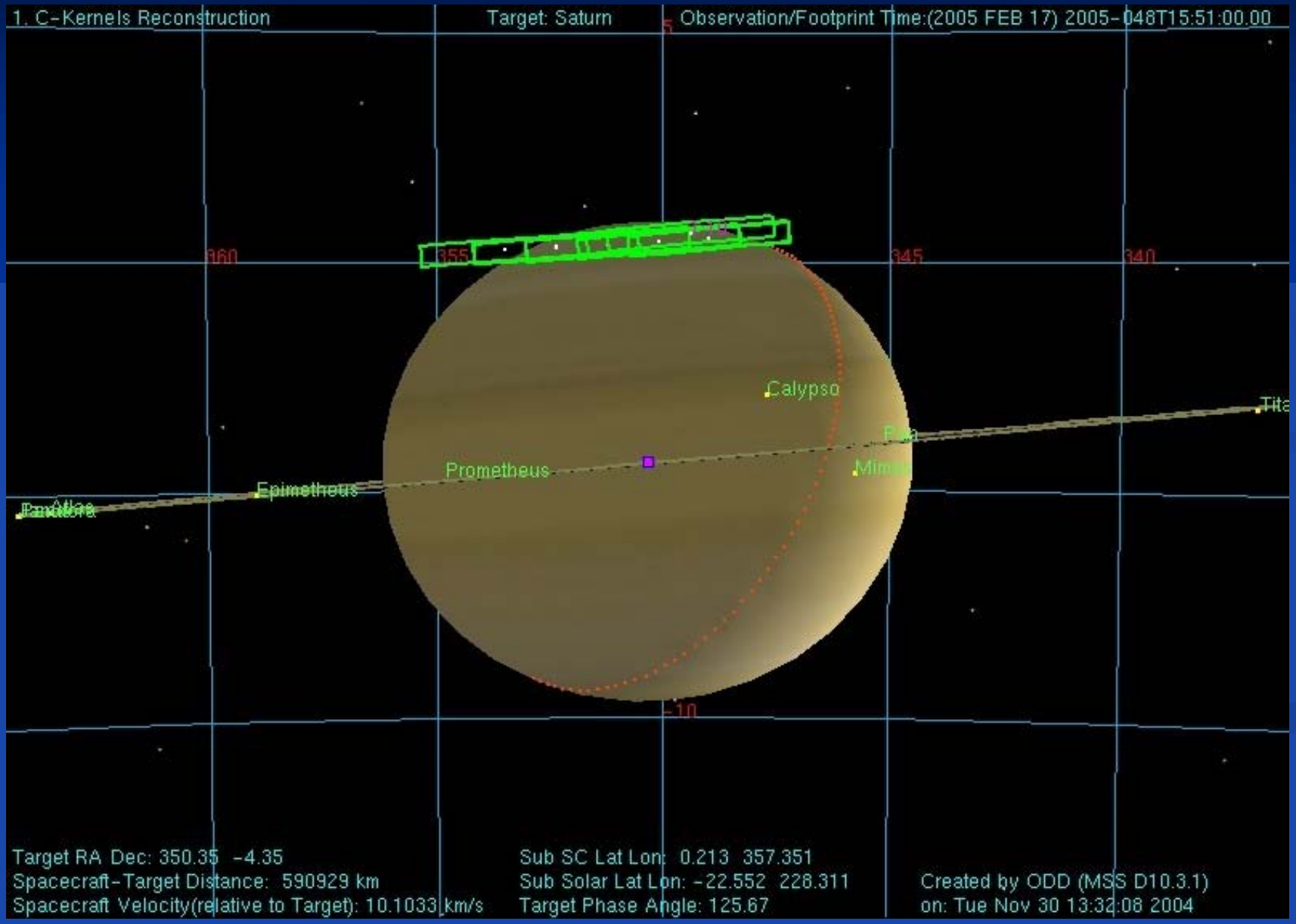
HST Campaign ACS Images: Feb 17, 2005



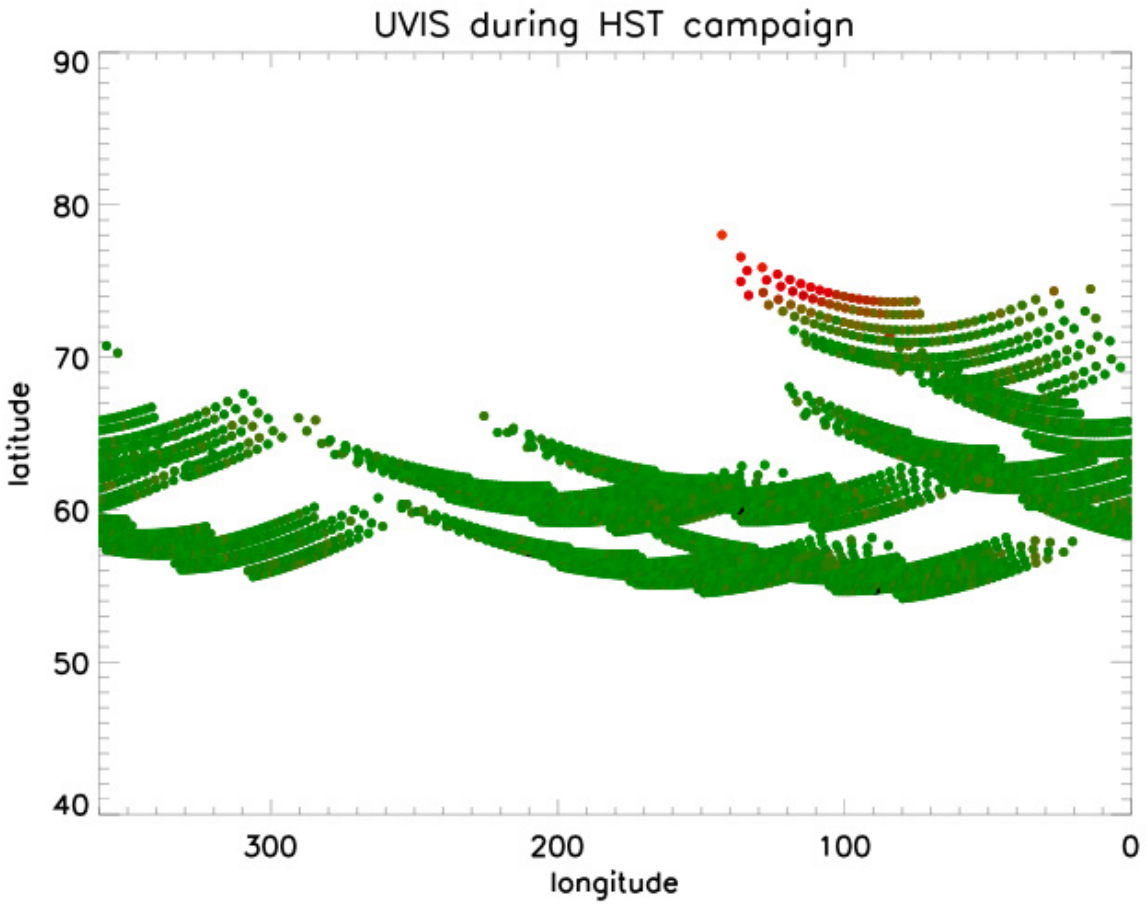


HST Campaign UVIS Geometry

VIMS_003SA_THRCYLMAP001



HST campaign UVIS map projection



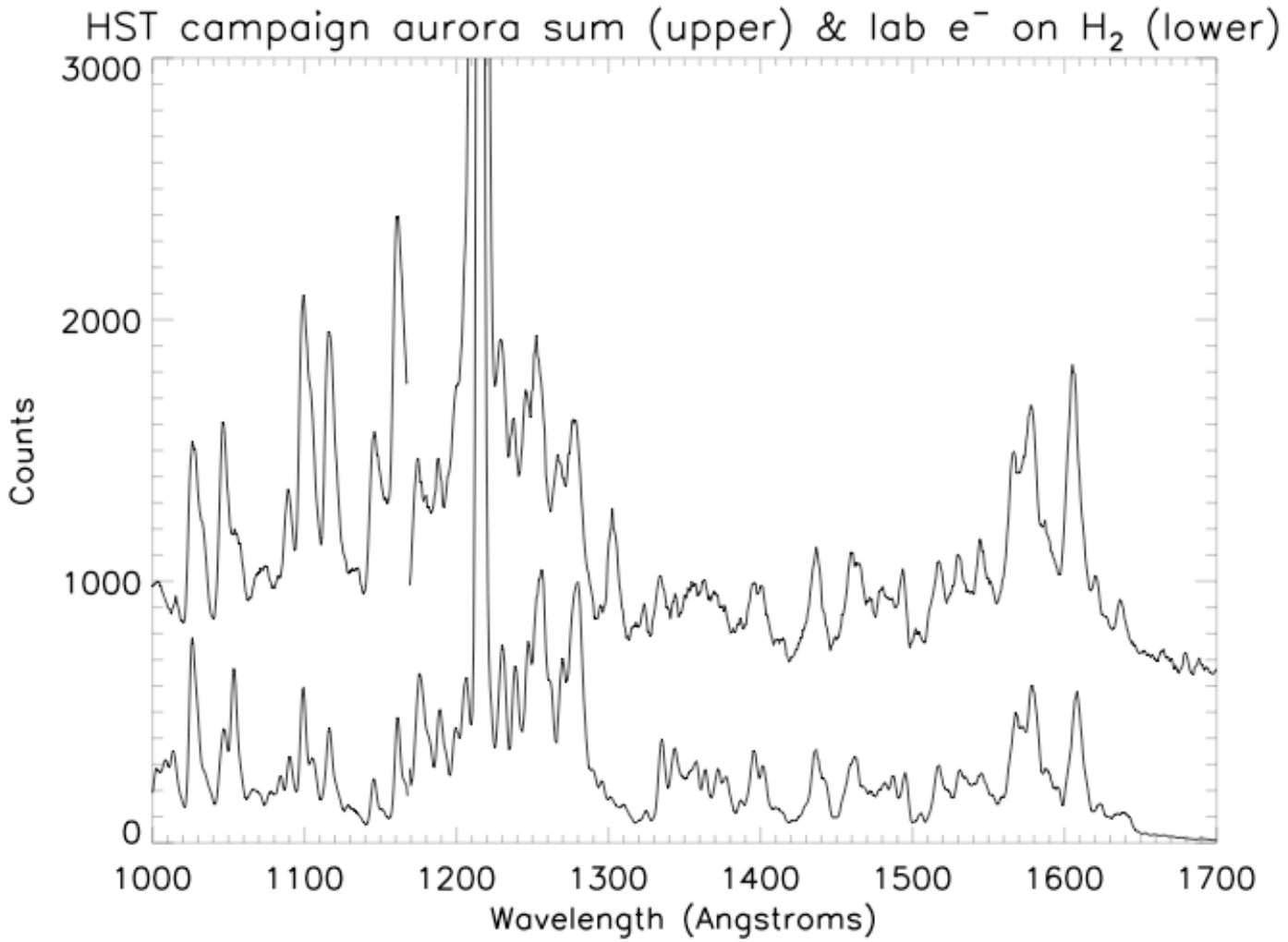
Red=aurora

Green=no aurora

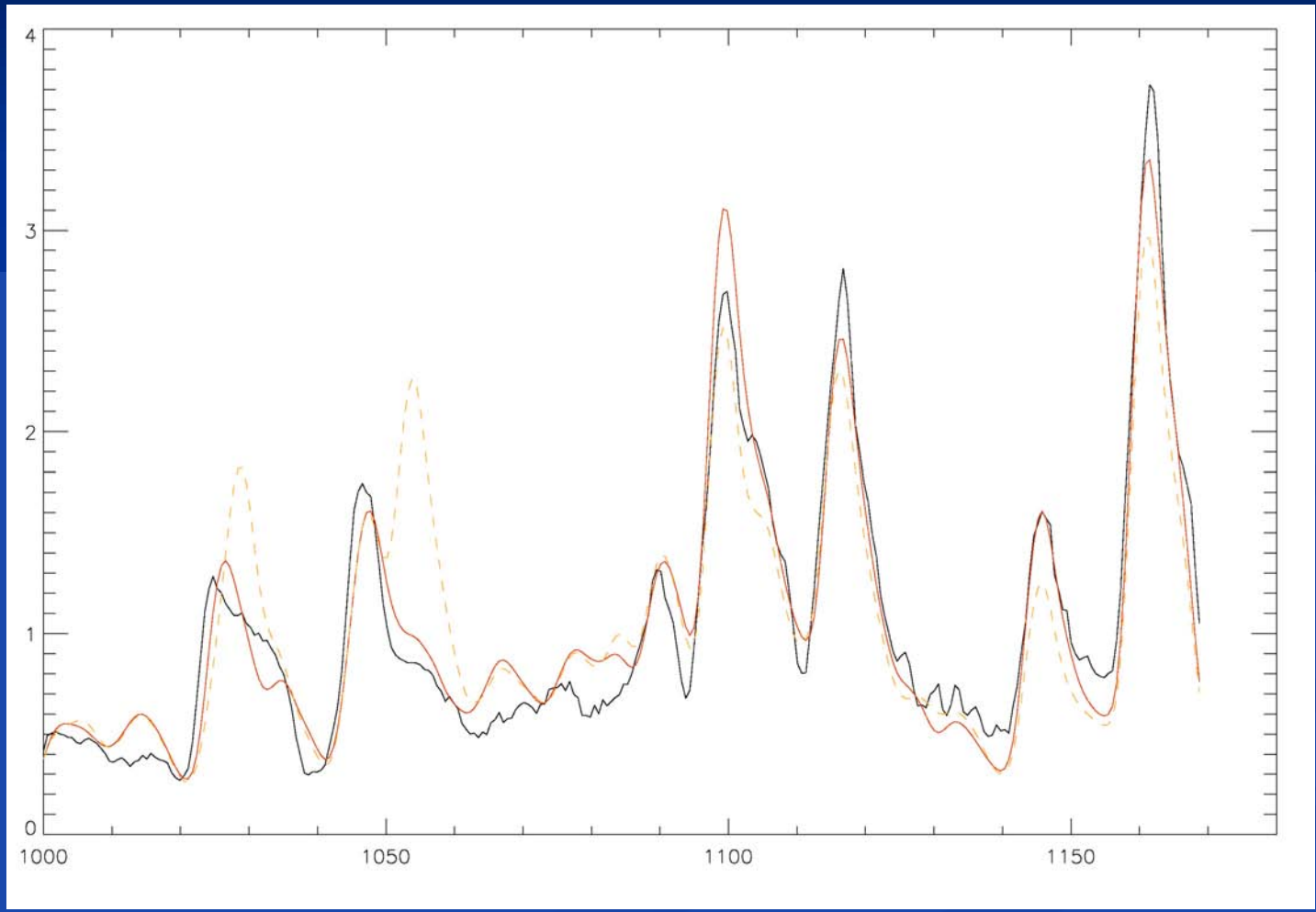
Auroras ~75 N

- Mostly UVIS slit was too far south, but…

UVIS dark-side spectrum

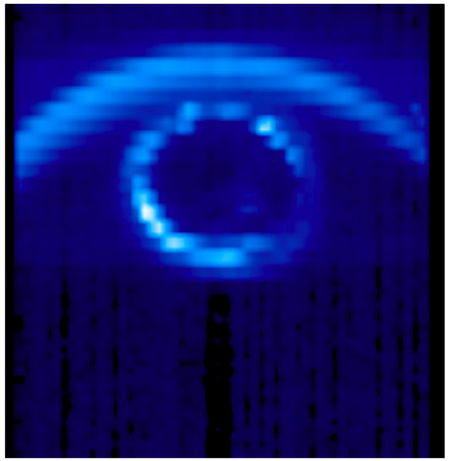


EUV aurora data Feb 17, 2005 (black)
Model w/o self-absorption (dashed brown)
Model fit (solid brown) for H_2 = 5x10^{20} cm^{-2} & T=500K



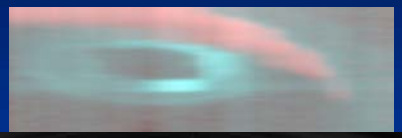
Recent UVIS N Auroral Image: 2006 Day 303

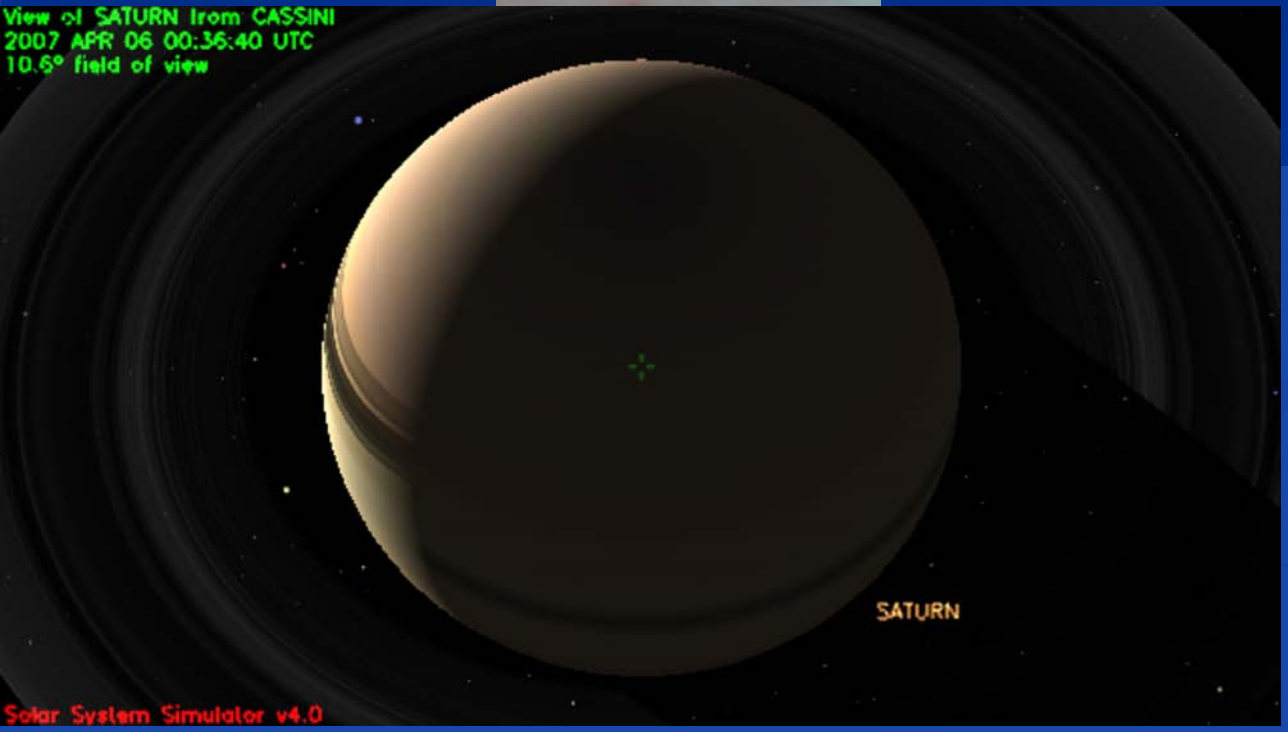
- Emission on a complete oval
- Generally brighter pre-midnight
- Emission spot visible inside the oval after midnight



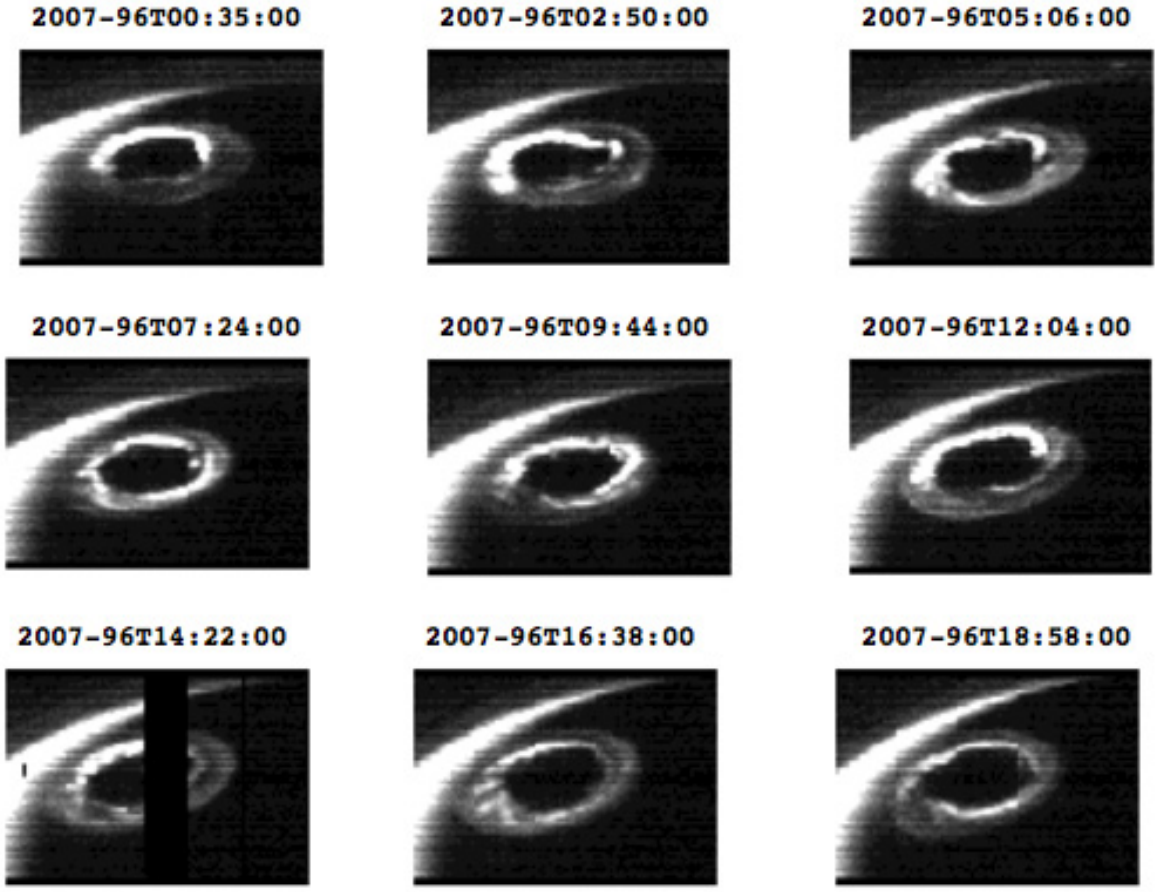
- Sub-spacecraft lat. 45 N
- Range 22.6 Rs

2007 day 96 high-latitude N auroras



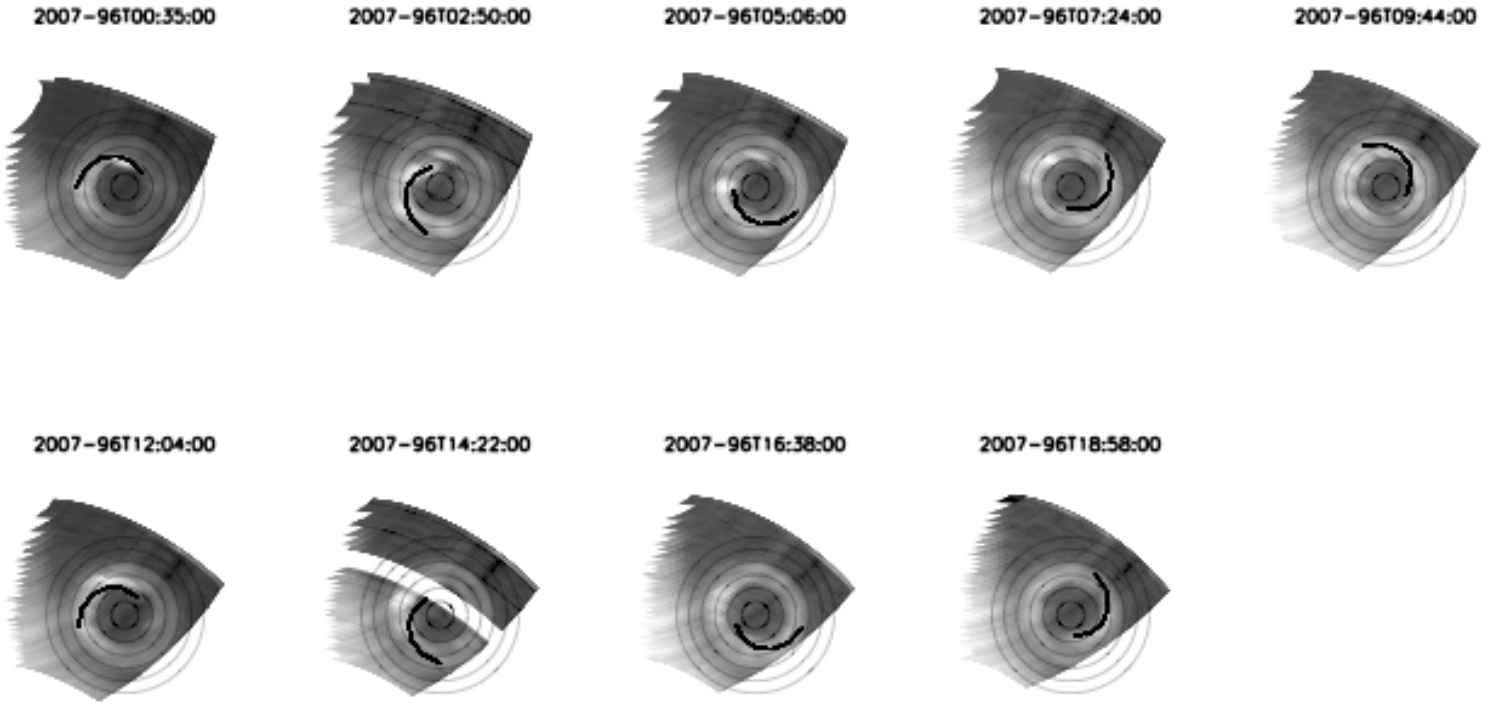


- Sub-s/c lat=51°
- Range=21.6 Rs
- Phase=125.4°
- Nine ~2 hour images
- First image shown: reflected sunlight=red
- aurora=blue

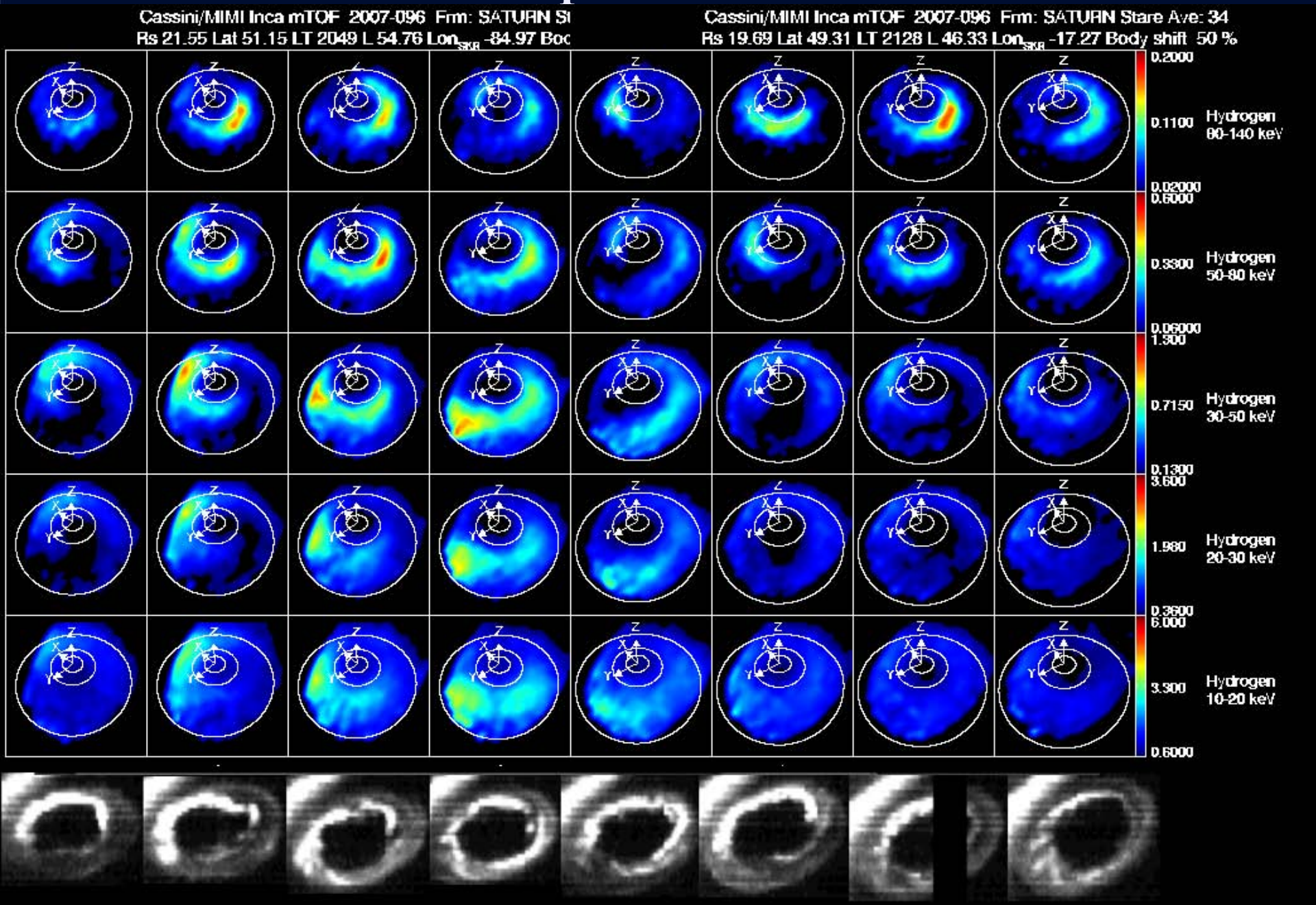


EVOLUTION OF SATURN NORTHERN AURORA
2007-96 (Sequence 29)

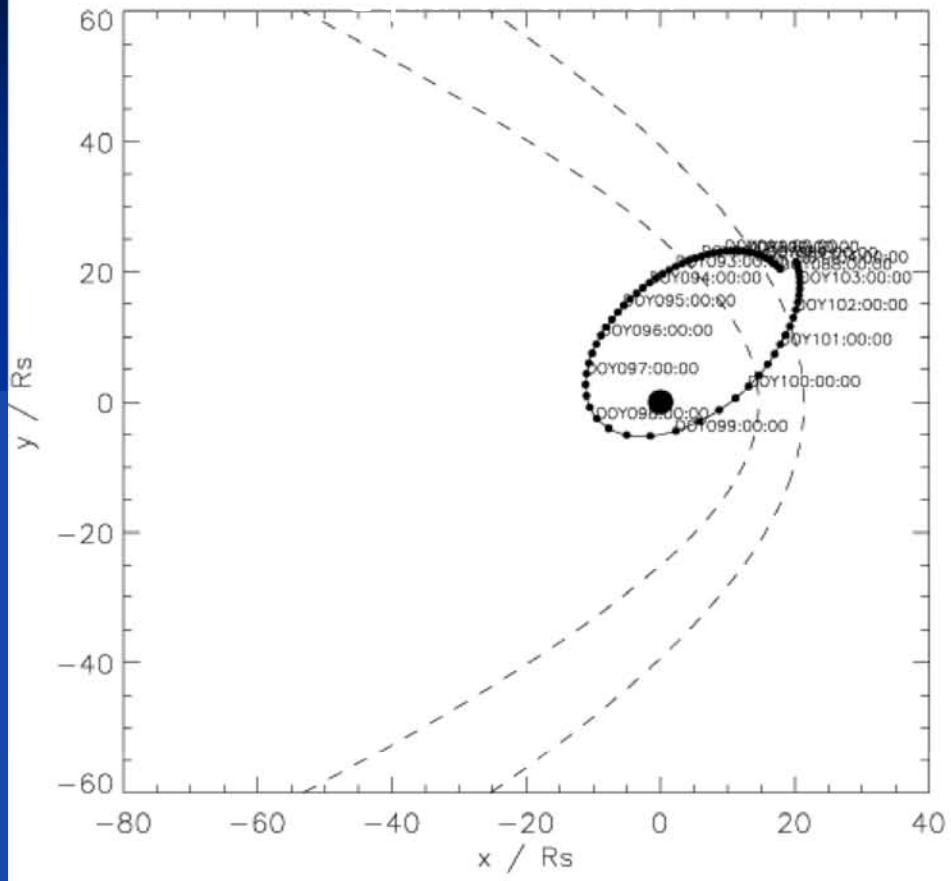
Polar projected, 5° grid in lat
sun at lower left, auroras 70-85N

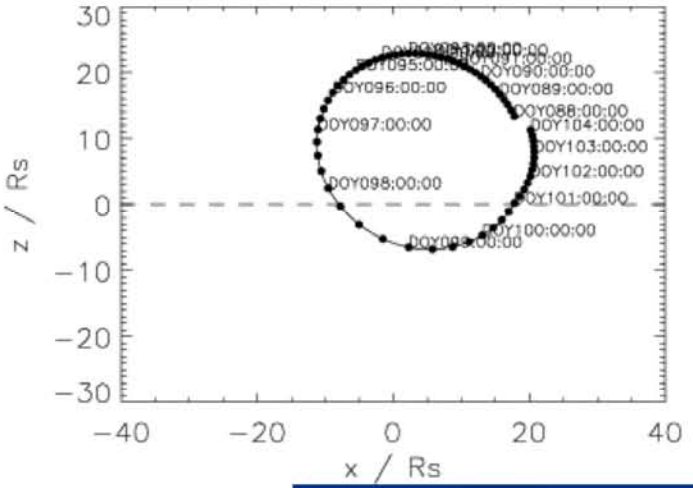


INCA-UVIS comparisons from Don Mitchell



Cassini Revolution 42 KGS trajectory





During Revolution 42 Cassini moves from the dayside (day 90), through dusk to midnight between day 95 and day 98. The spacecraft moves through dawn towards noon between day 98 and 103. The spacecraft crosses the equator on day 98 –midnight (N to S), and from S to N on day 101 post-noon.

Cassini Revolution 42 KGS trajectory

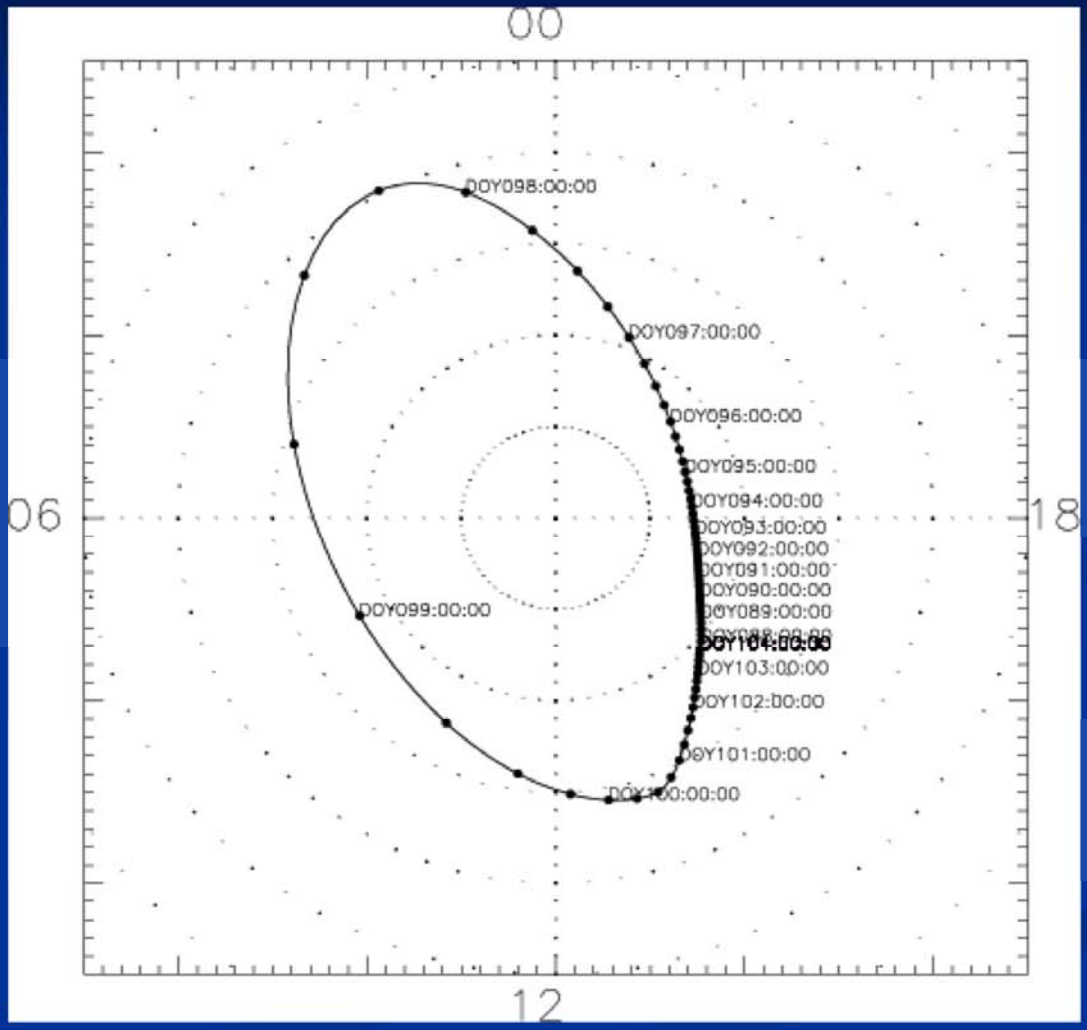
The spacecraft trajectory is mapped using dipole plus ring current magnetic field model

Dotted lines show ionospheric co-latitude in 5º multiples from the pole.

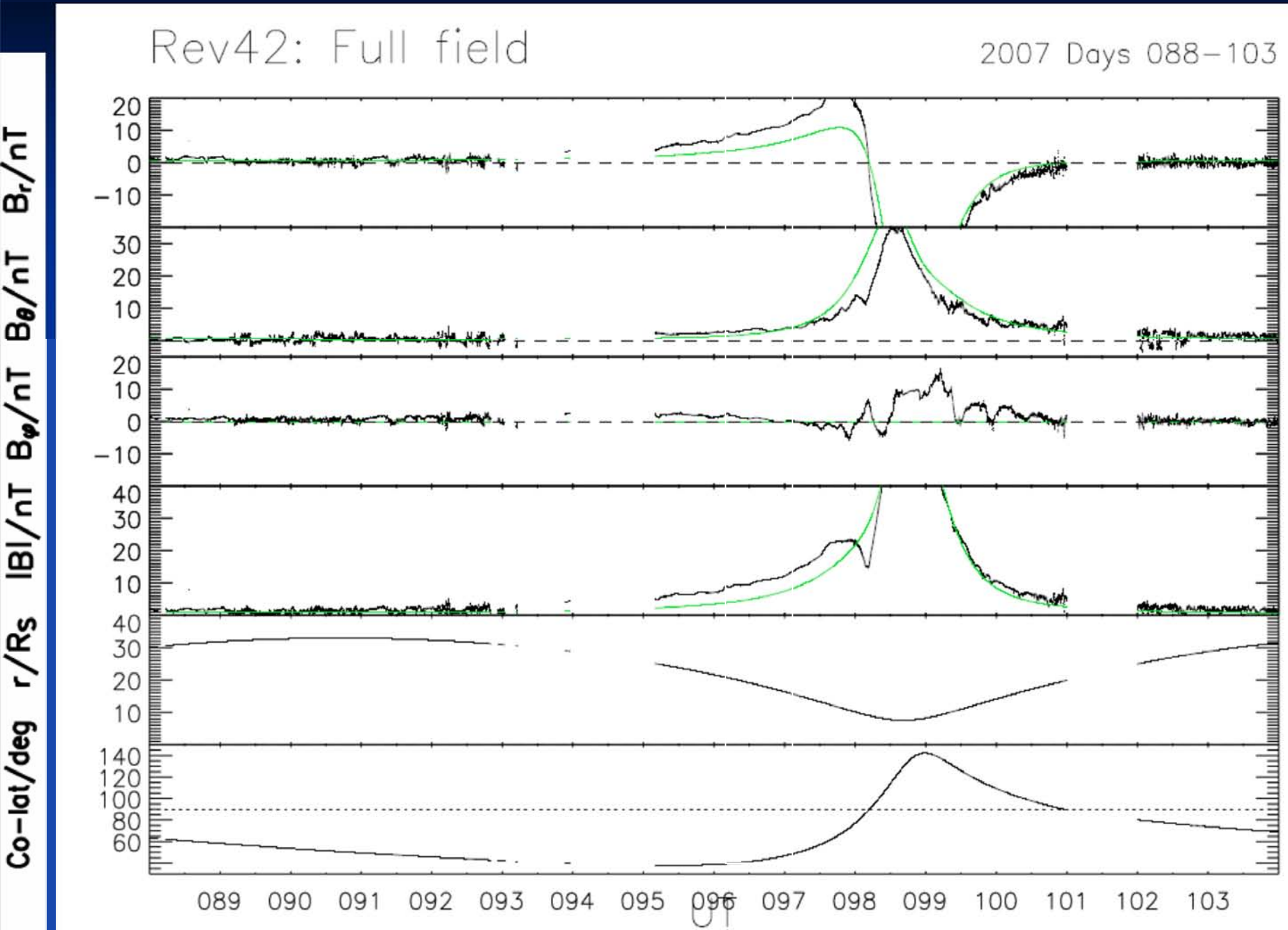
Cassini probably crosses field lines connecting to the statistical location (in the south) of the auroral oval during day 98-99 near dawn, day 100 near noon, and day 97 near midnight.

On day 96, the UVIS observations the s/c is at highest latitudes (mapping to **~8-11º** in the ionosphere), at a local time near to **dusk.** (Just inside the UVIS Oval!)

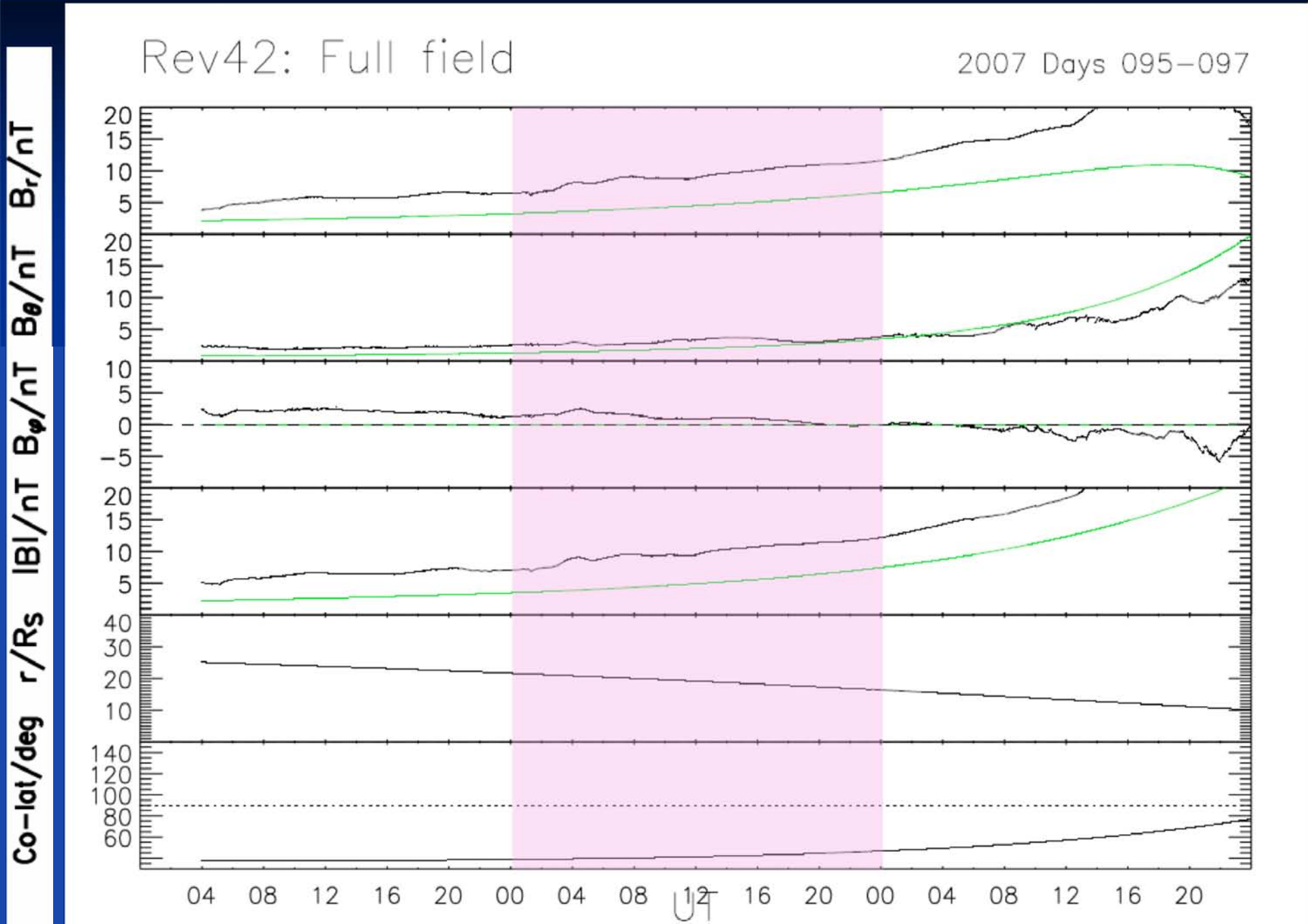
Northern ionosphere footprint of Cassini



UVIS observations on 96



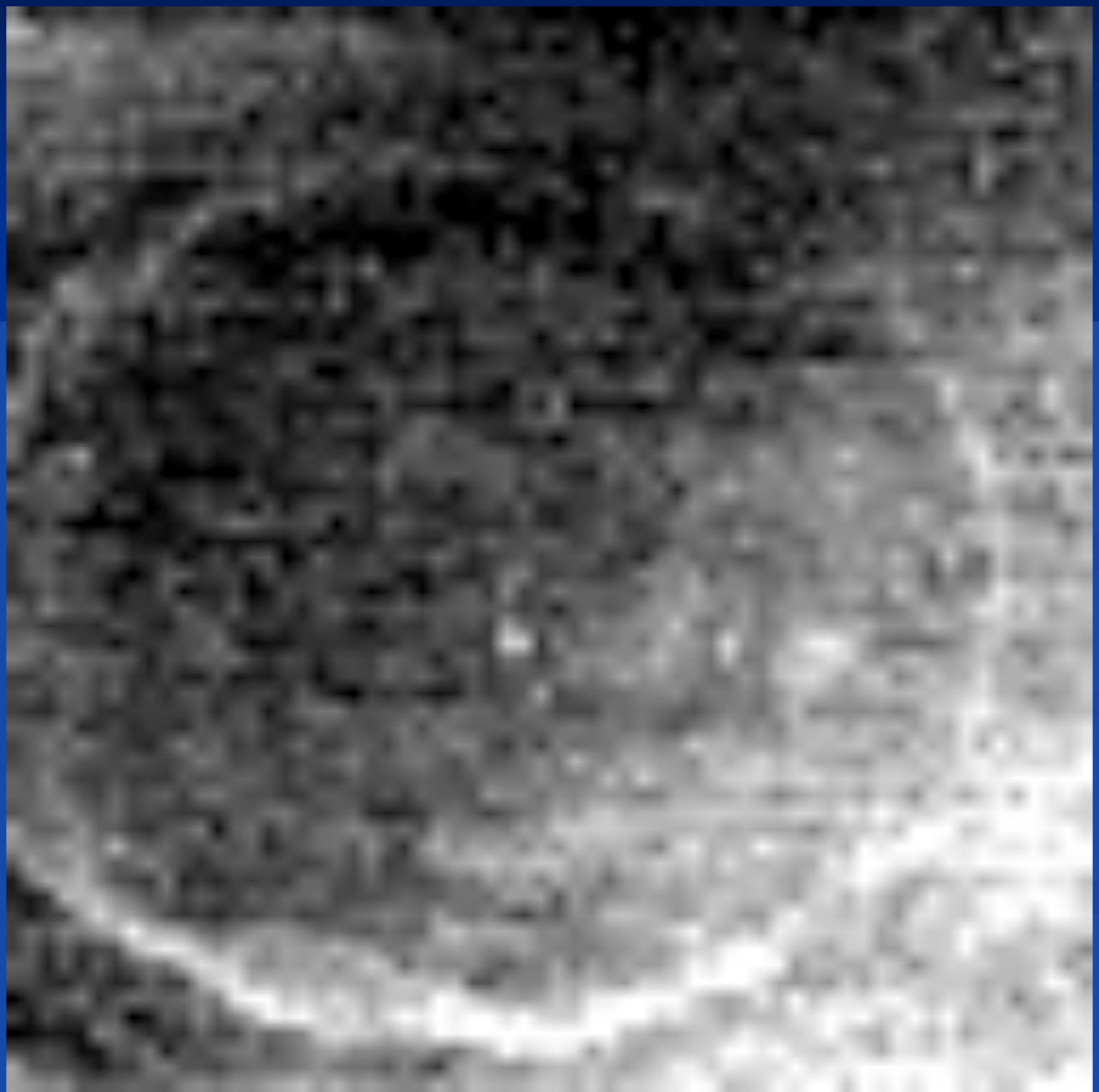
UVIS interval



Auroral Movie 2007-096 Results

- 2007-096: 9-frame movie in H_2 band emission
- Shows multiple arcs at times, spiral stuff
- Auroras mostly 70-80 N
- Generally brighter on dawn side
- MAG comparisons don't show much action: spacecraft field line passed *inside* the oval
- Intriguing comparisons with INCA energetic neutrals underway:
- INCA equatorial spirals spiral out (going clockwise)
- UVIS auroral spirals spiral in (going clockwise)
- Suggests mapping of patterns onto the ionosphere (larger L-shell goes to smaller co-latitude)
- Suggests oval shape primarily not solar wind controlled on that day
- Color ratios available-> electron energy estimates

VIMS S25 H_3^+ image from Tom Momary/Kevin Baines (S25NorthPoleAuroraSumCube8053THRCLMAP002)



Very Recent Good Stuff

- Auroral Movies Days 145-146 (May 25-26) 2007
- UVIS_045SA_NAURMOV001_PRIME:
- 2007-145T10:39:00 to 2007 -145T18:54:00.
- UVIS_045SA_AURORA001_PRIME:
- 2007-146T04:30:00 to 2007-146T09:30:00

UVIS Summary Saturn Conclusions

Saturn auroral oval has been imaged by UVIS (and VIMS)

Auroral modeling with self-absorption in H_2 and hydrocarbon absorption has been performed

Variations have been seen in response to solar wind changes

Small south polar dark spot (enhanced acetylene, and maybe benzene?) seen in reflected sunlight near 1750 ± 75 Å and not other wavelengths

Now getting auroral views from over the poles-with implications for what is causing the auroras: internally or externally driven?

(probably both)

UVIS Auroral References

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- Ajello, J. M., *et al.*, The Cassini Campaign Observations of the Jupiter Aurora by the Ultraviolet Imaging Spectrograph and the Space Telescope Imaging Spectrograph, *Icarus* 178, 327-345, 2005.
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- Nichols, J. D., *et al.*, Response of Jupiter's UV auroras to interplanetary conditions as observed by the Hubble Space Telescope during the Cassini fly-by campaign, *J. Geophys. Res.* 112, A02203, doi:10.1029/2006JA012005, 2007.