Saturn's atmosphere and interior

CHARM presentation

July 27, 2010

Andrew Ingersoll

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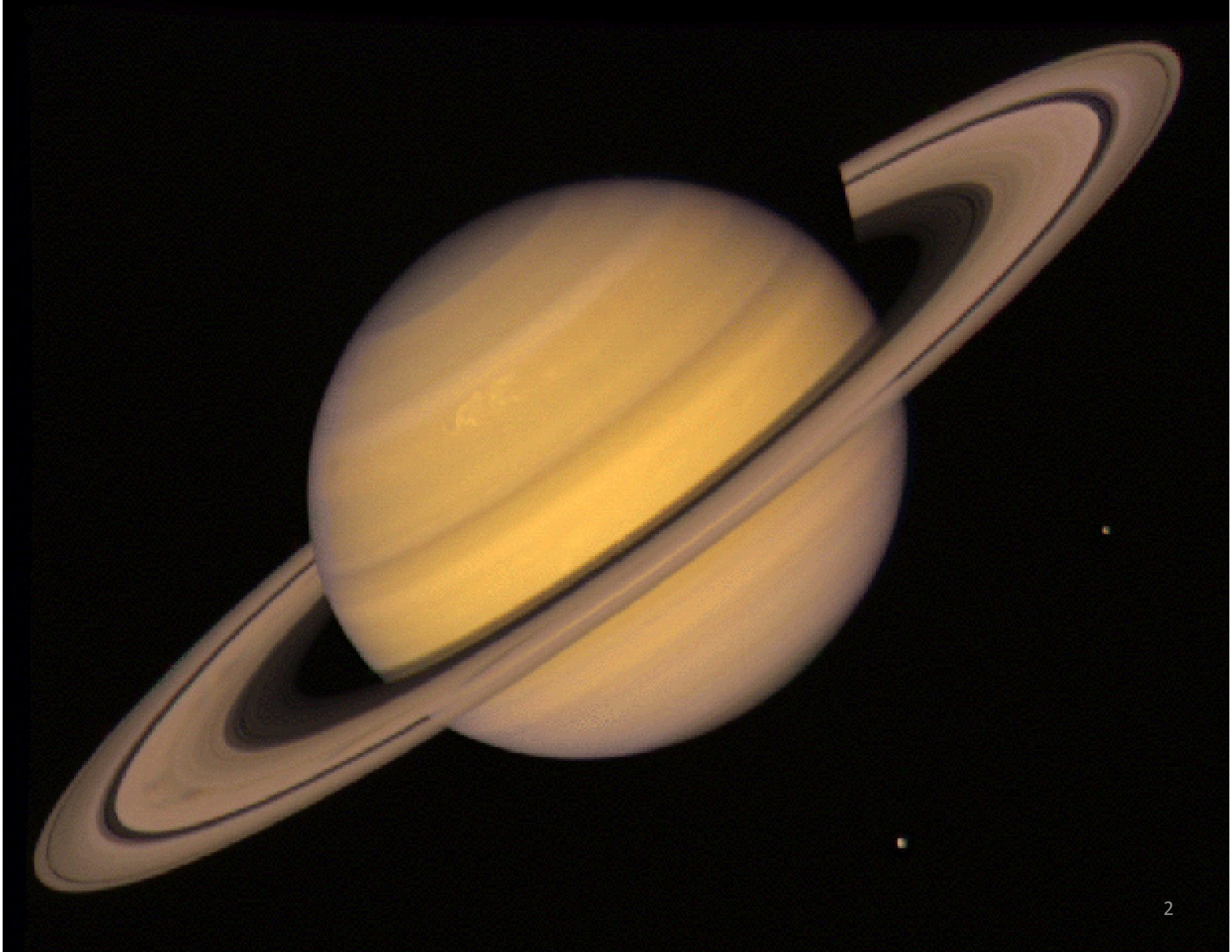
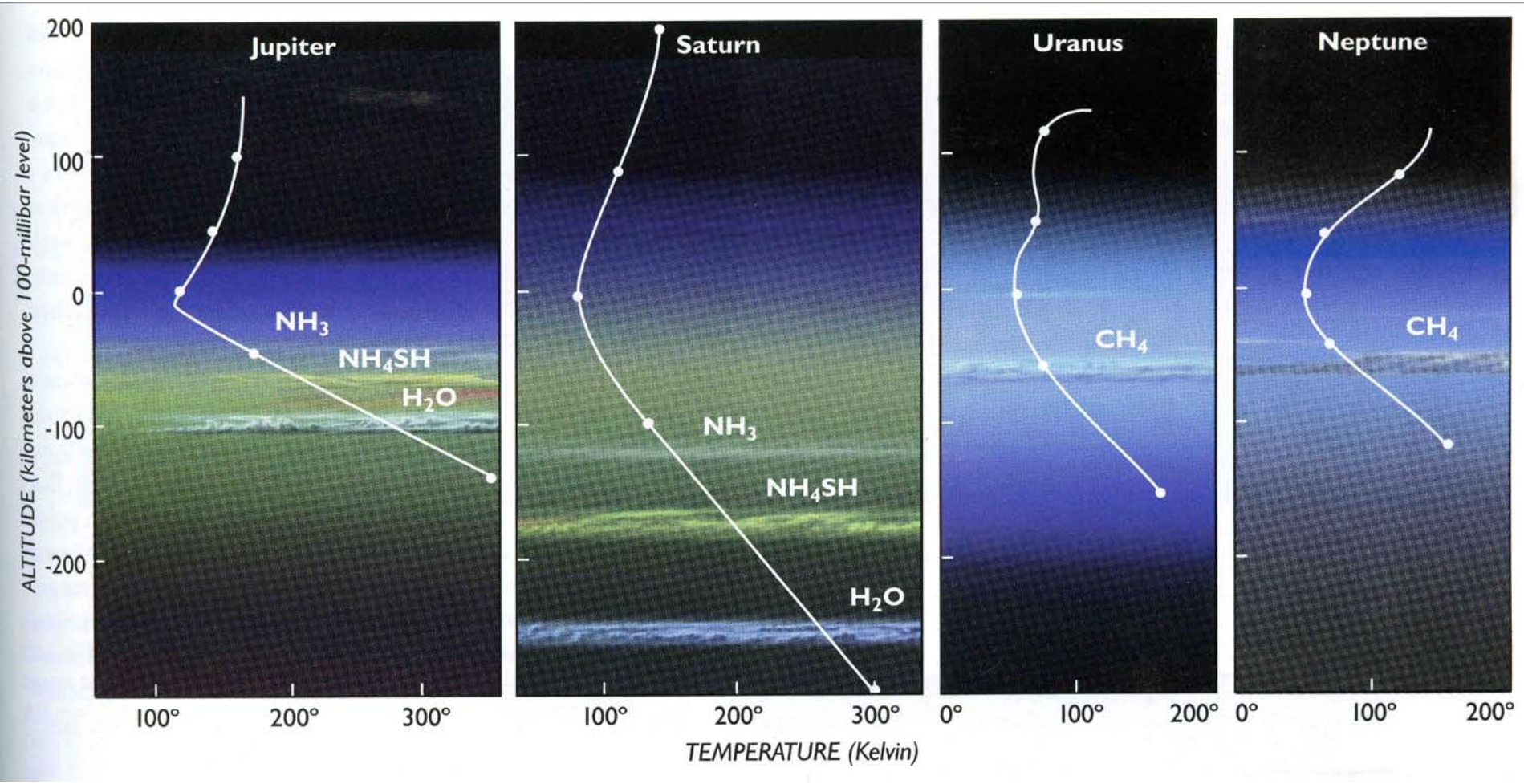
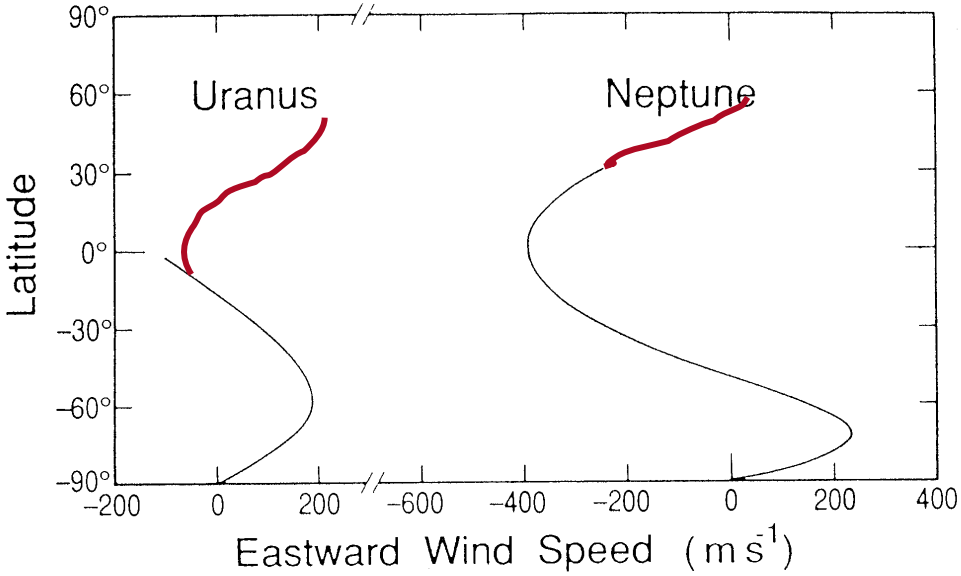


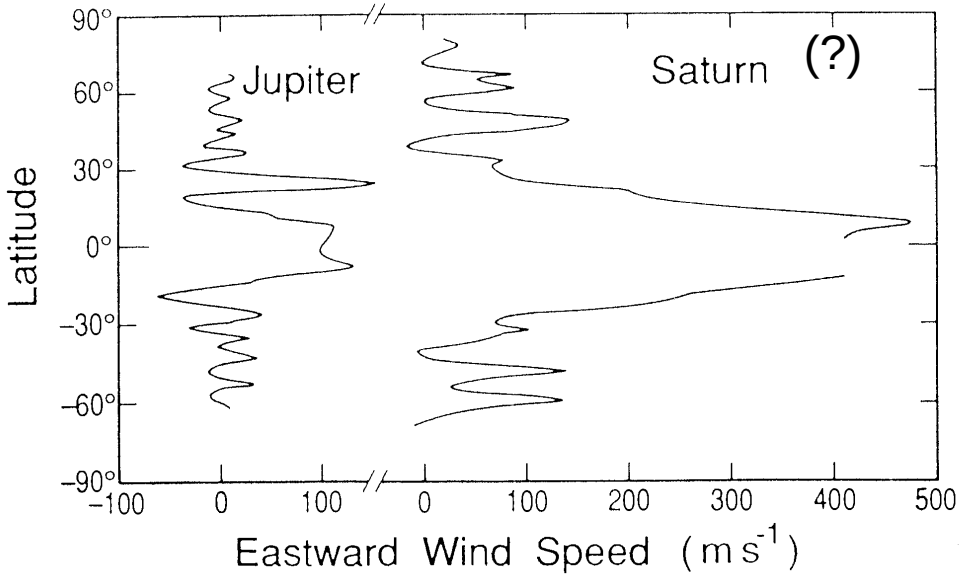


Ingersoll, A. in *The New Solar System, 4th Ed.*
(Sky Publishing Co. 1999)

Zonal winds relative to the internal rates of rotation: Voyager data

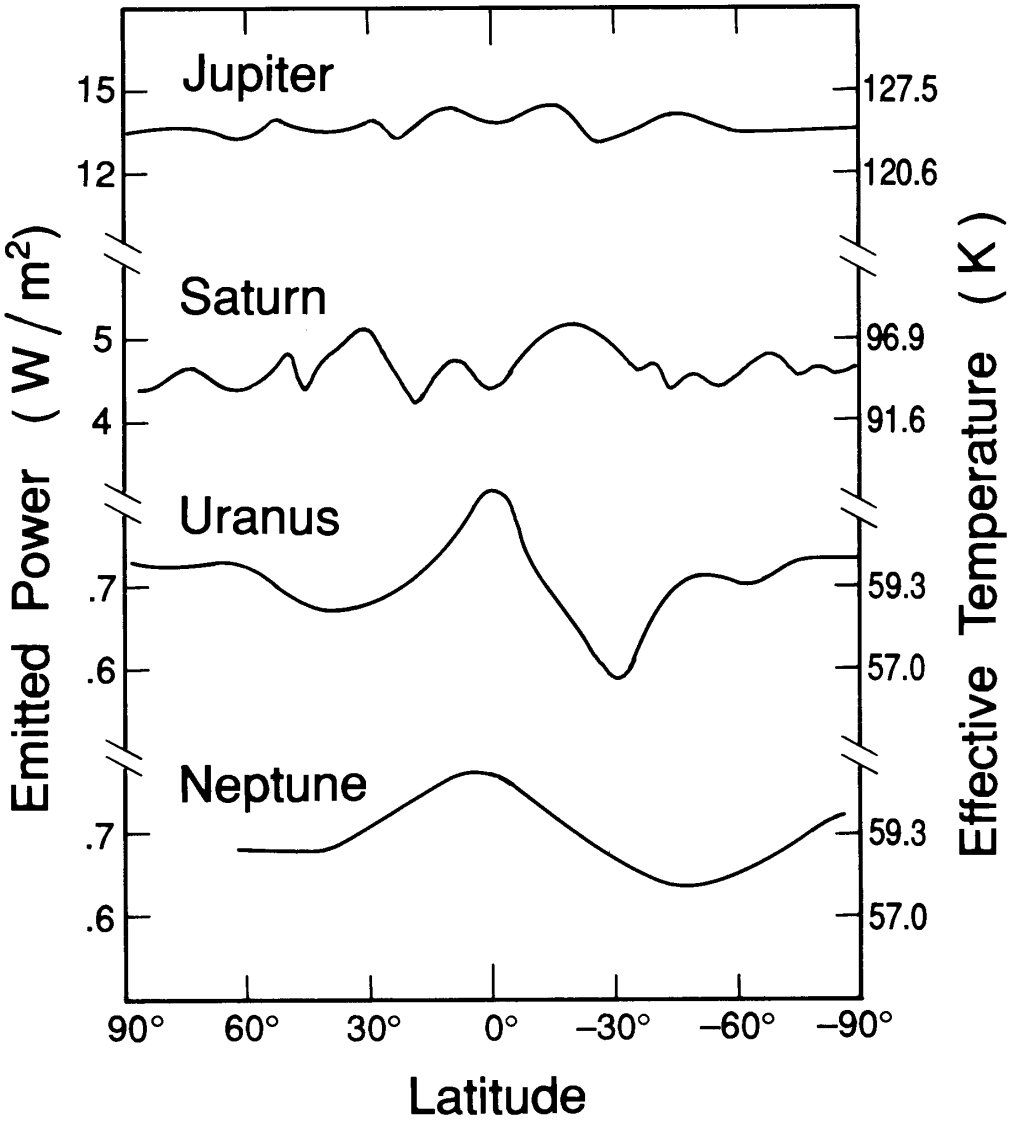


Red = recent data



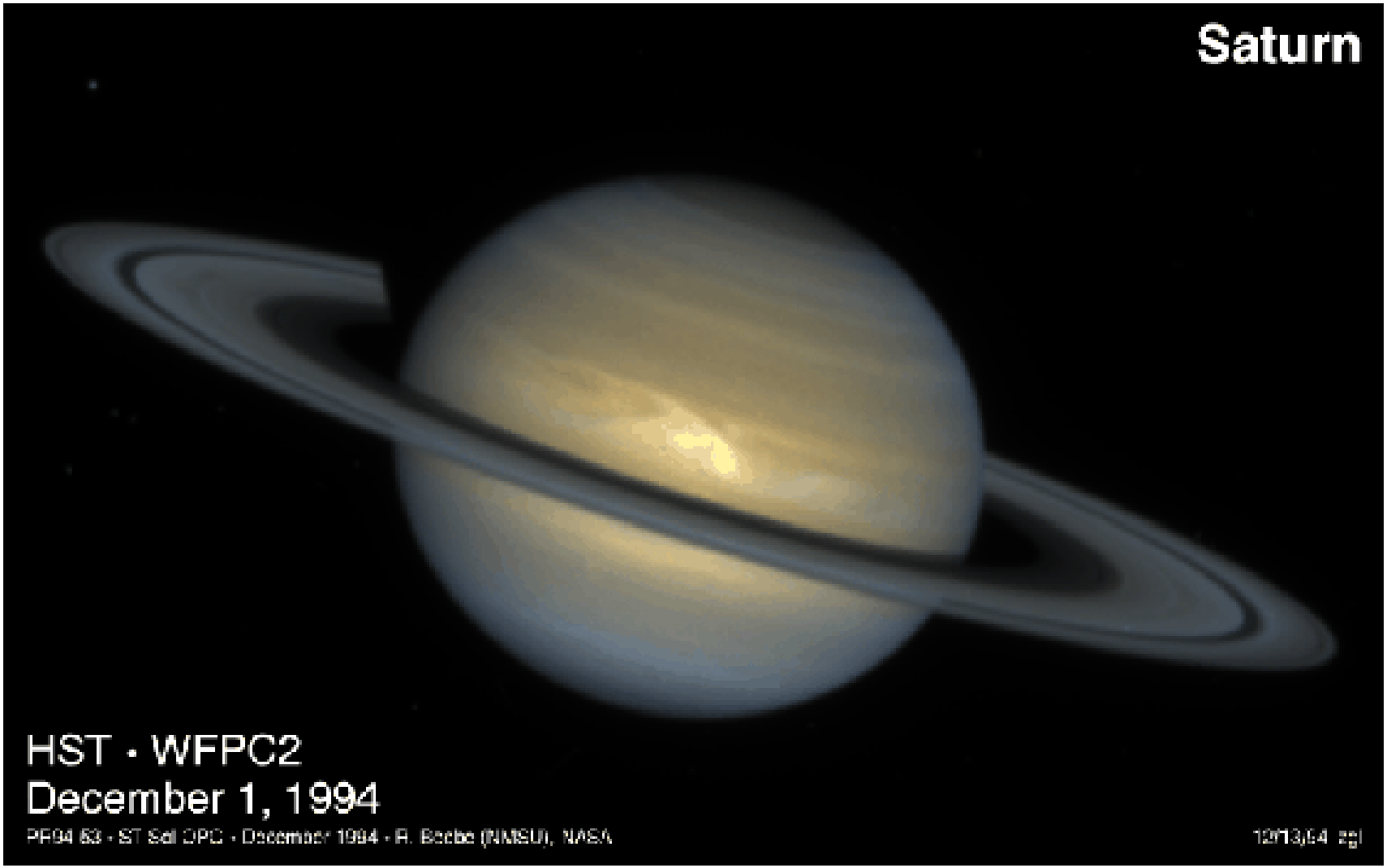
Saturn's internal rotation rate is unknown

Ingersoll, A. P. *Science* **208**, 308-315 (1990)



Ingersoll, A. P. *Science* **208**, 308-315 (1990)

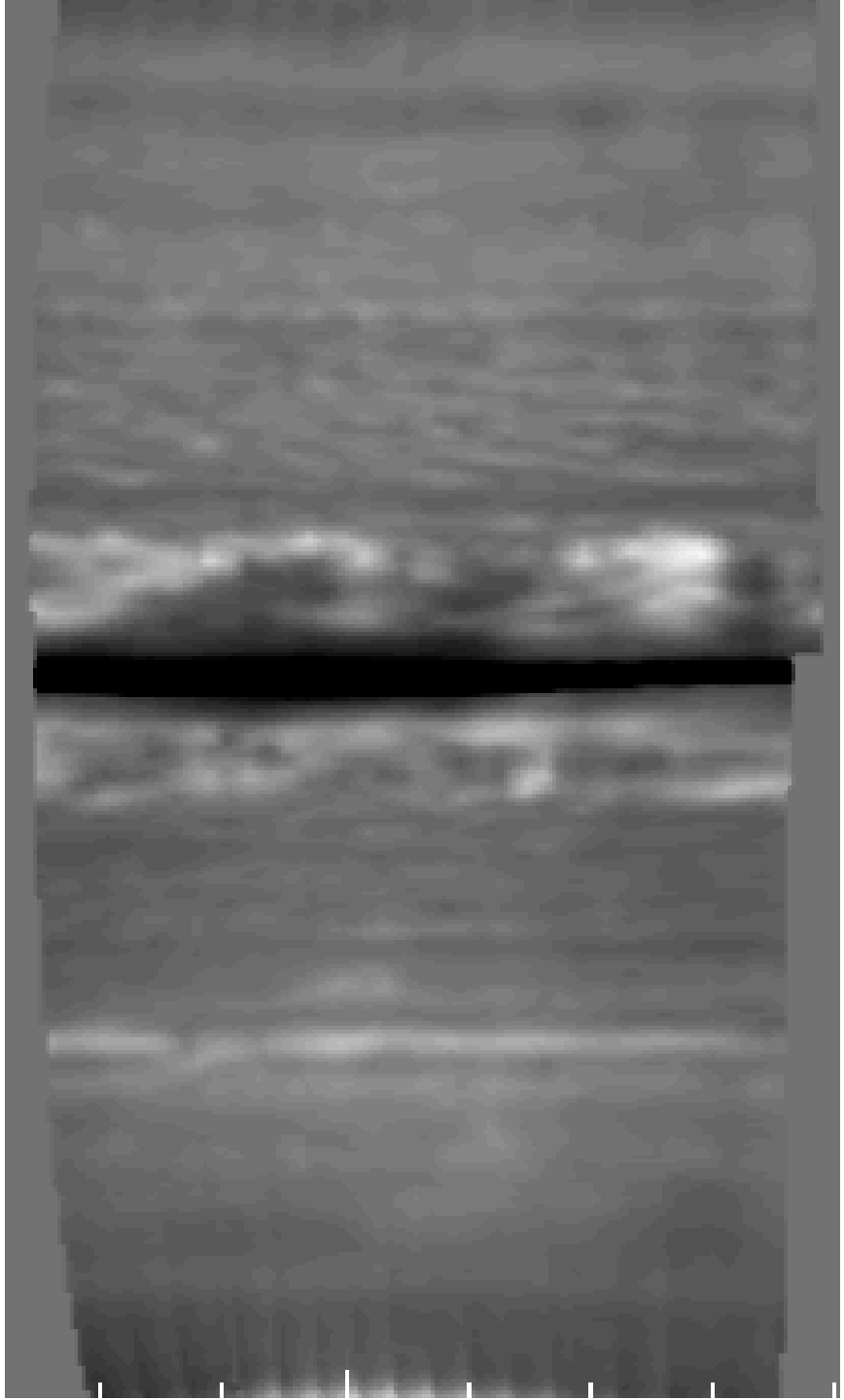
Ingersoll, A.P., and Porco, C.C. *Icarus* **35**, 27-43 (1978)


Saturn
HST • WFPC2
December 1, 1994

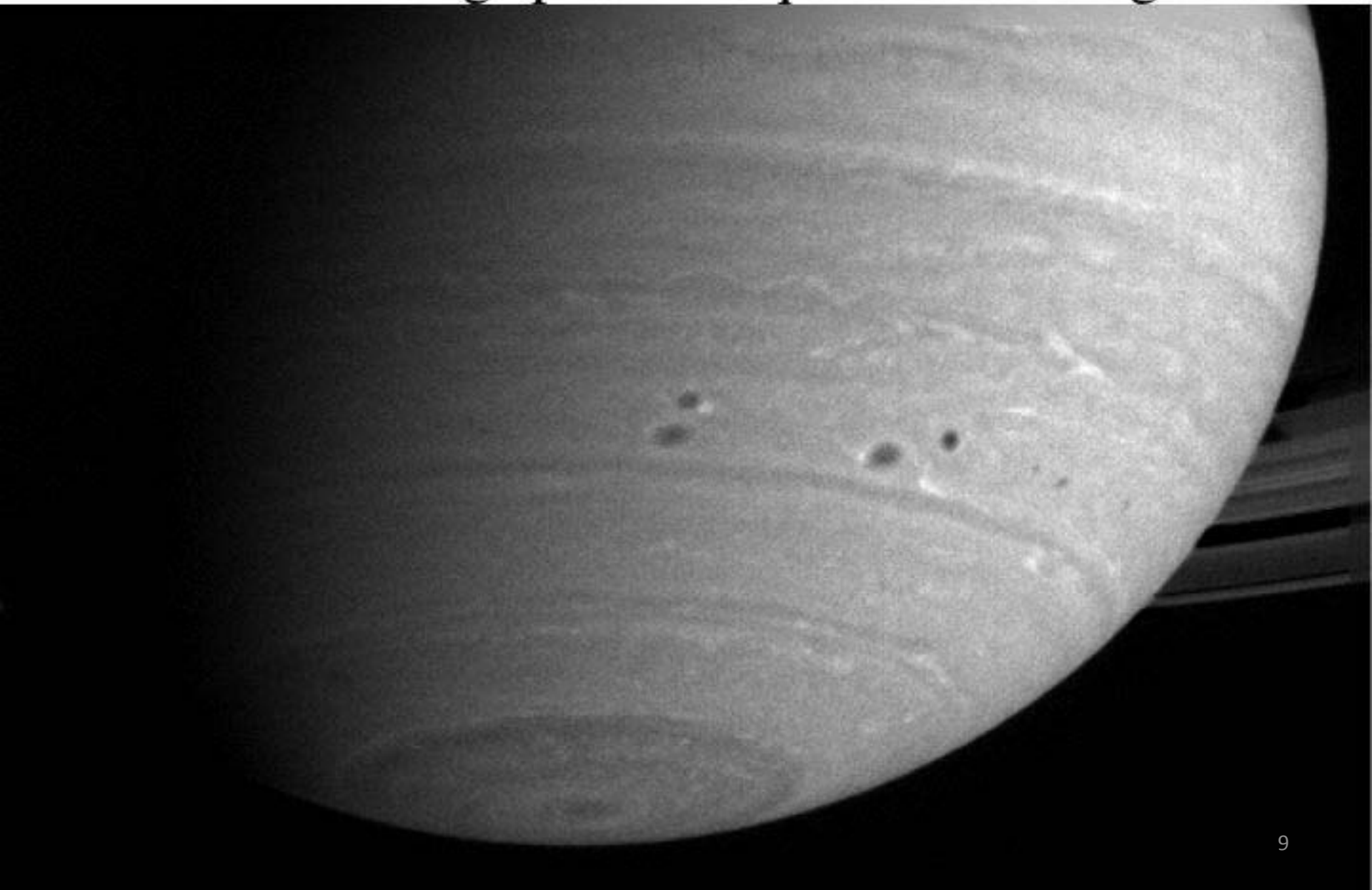
Cassini microwave radiometer

Relative brightness is where NH3 abundance is low. Dark band in middle is the ring. Bright bands out to $\pm 10^{\circ}$ from the equator have brightness temperatures up to 10° warmer than at higher latitudes.

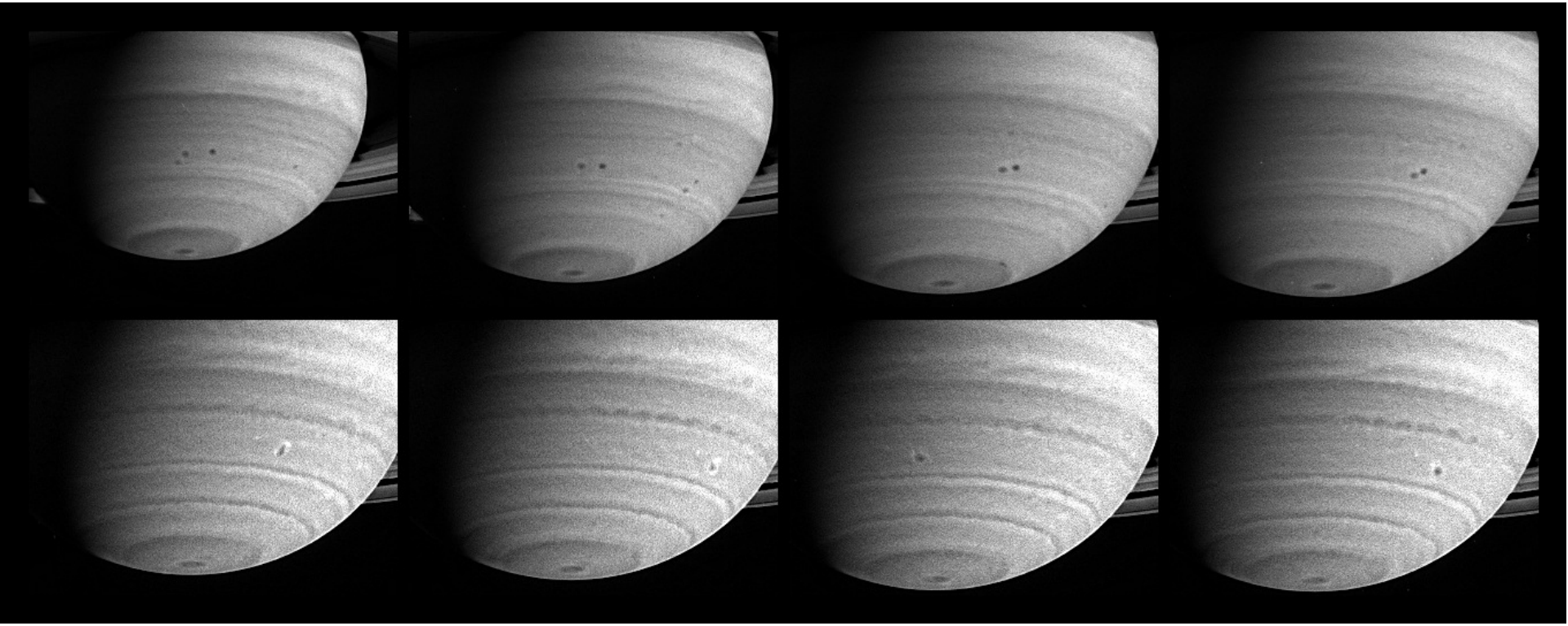
M. Janssen and the Cassini RADAR team (2010)

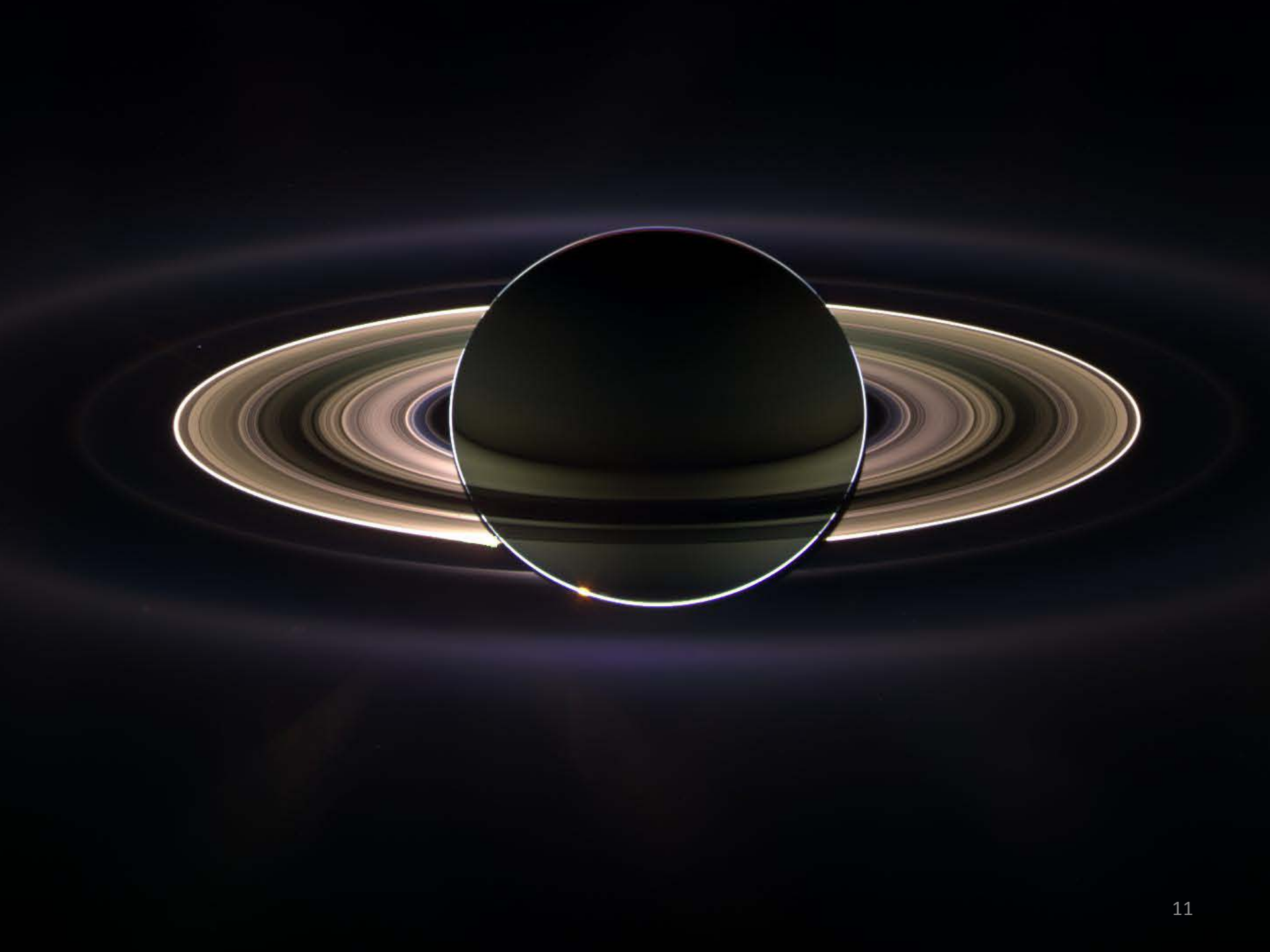


ISS: Tracking spots in sequences of images

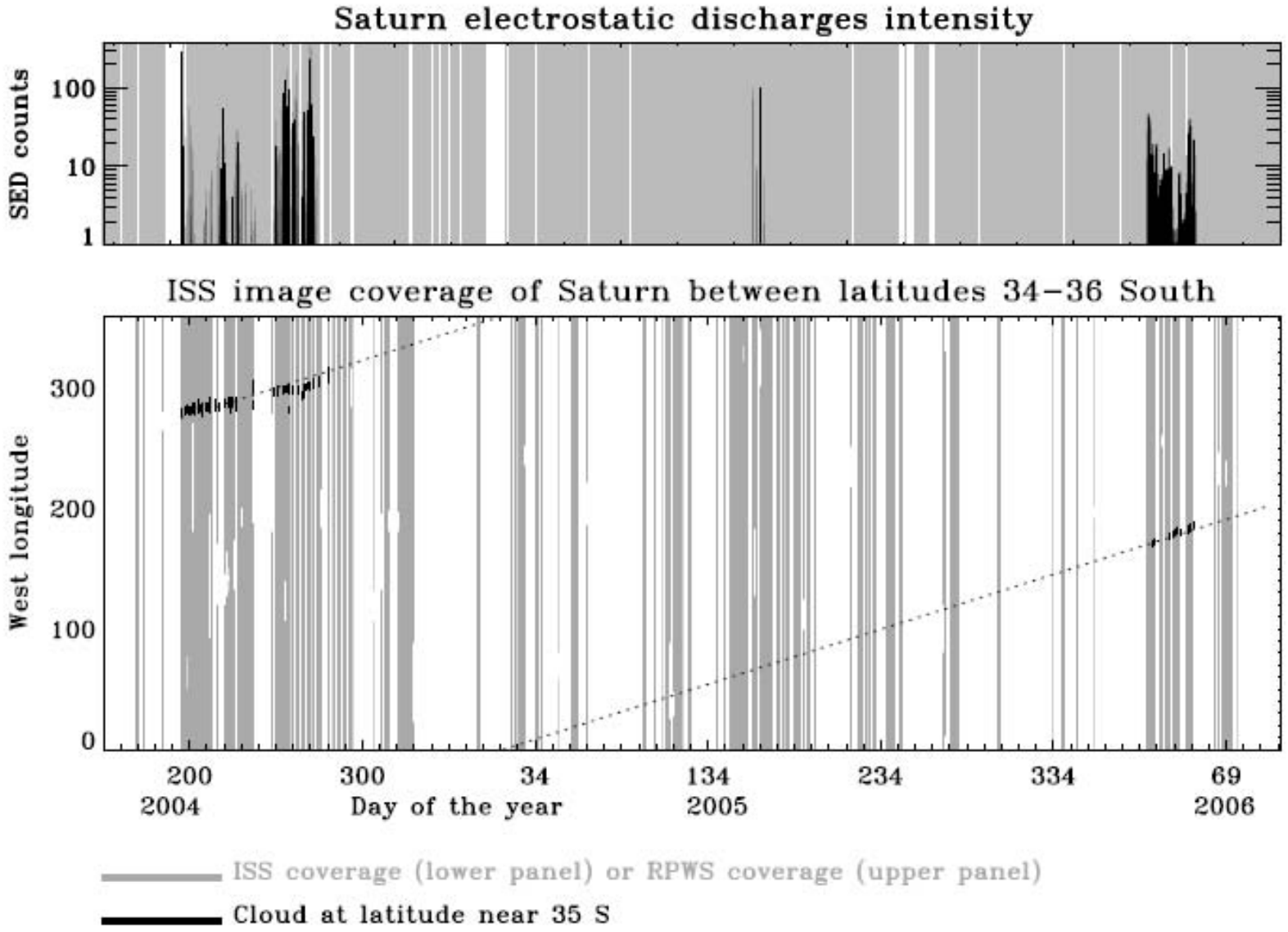


ISS: Merging of spots in an anticyclonic shear zone

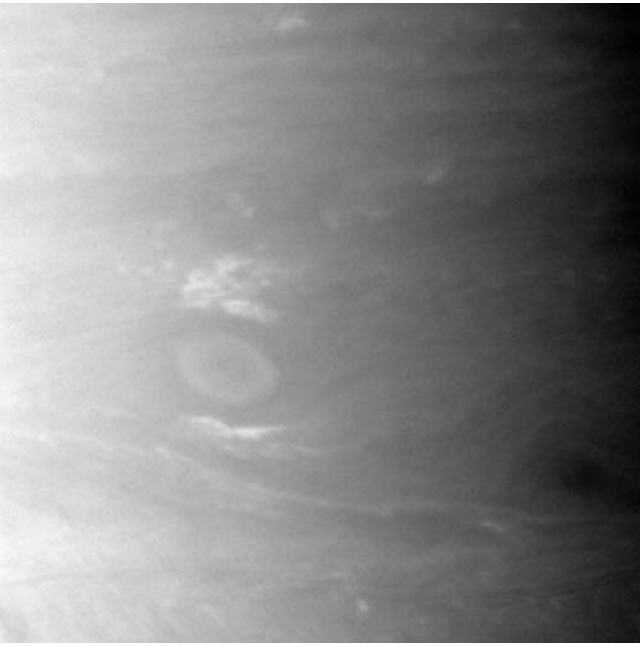




Cloud-SED correlation during 2 years.

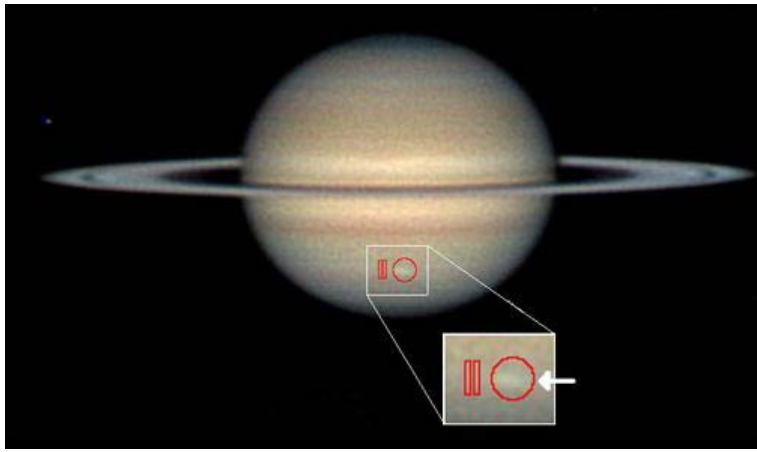


ISS v. Amateur Astronomers



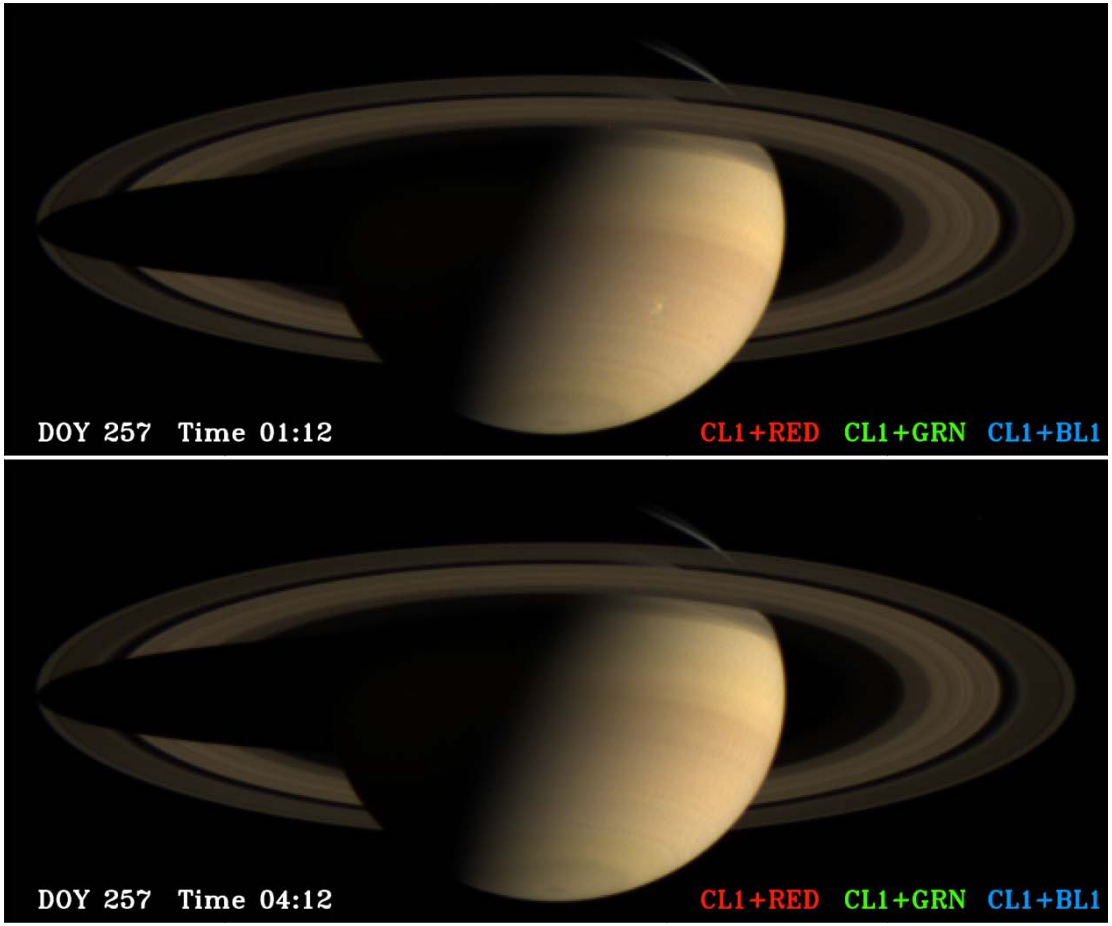
ISS captured this view of a similar storm on November 6, 2009. Modern technology makes keeping up with amateur astronomers challenging.

Amateur astronomer Anthony Wesley obtained this image of a storm on Saturn from his backyard telescope in Murrumbateman, Australia, on March 22, 2010. He sent it to scientists working with NASA's Cassini spacecraft the next day.



Amateur astronomer Christopher Go took this image of a storm on Saturn from his veranda in Cebu, Philippines, on March 13, 2010.

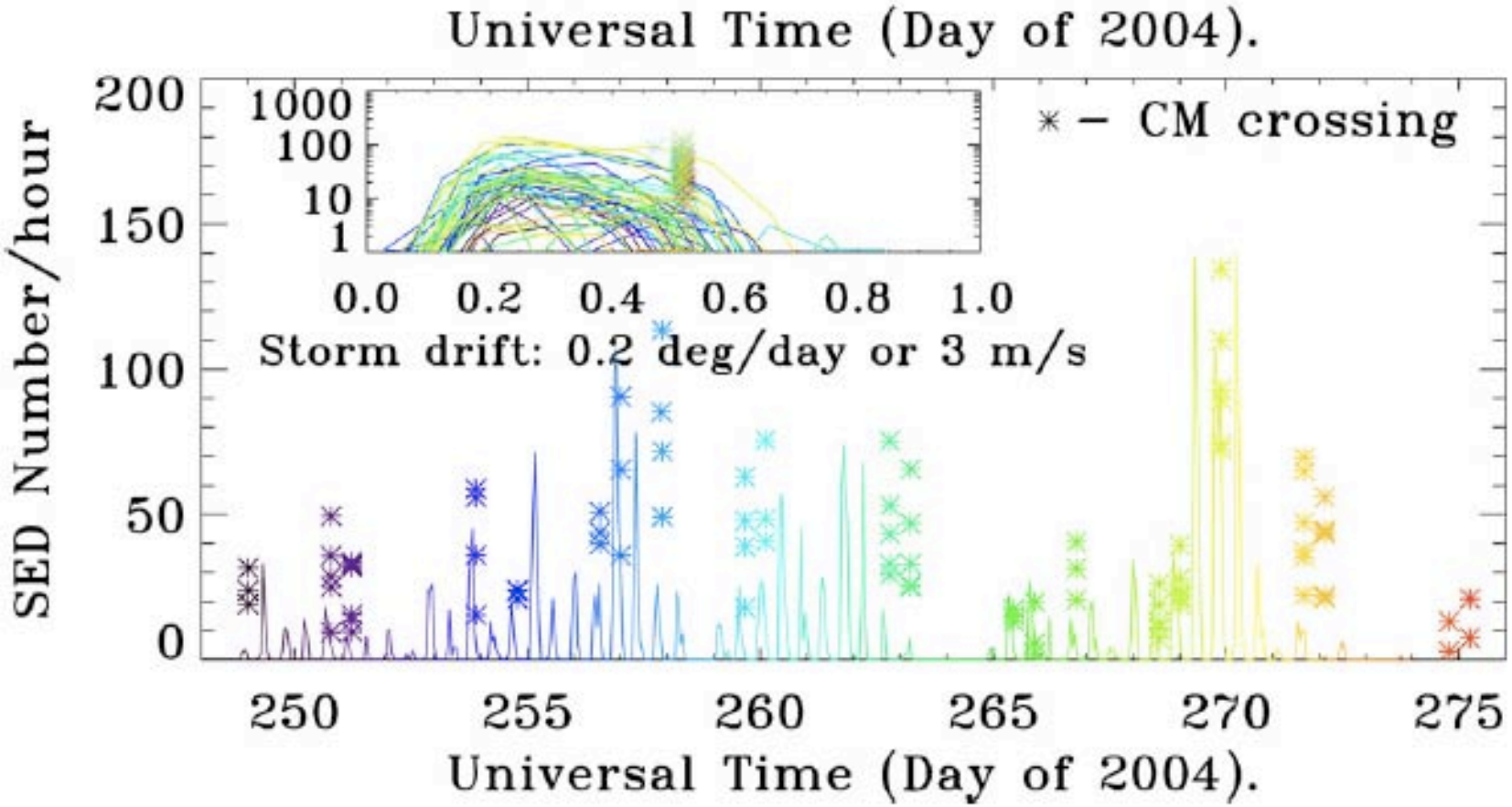
Lightning on Saturn observed by Cassini ISS and RPWS during 2004-2006.

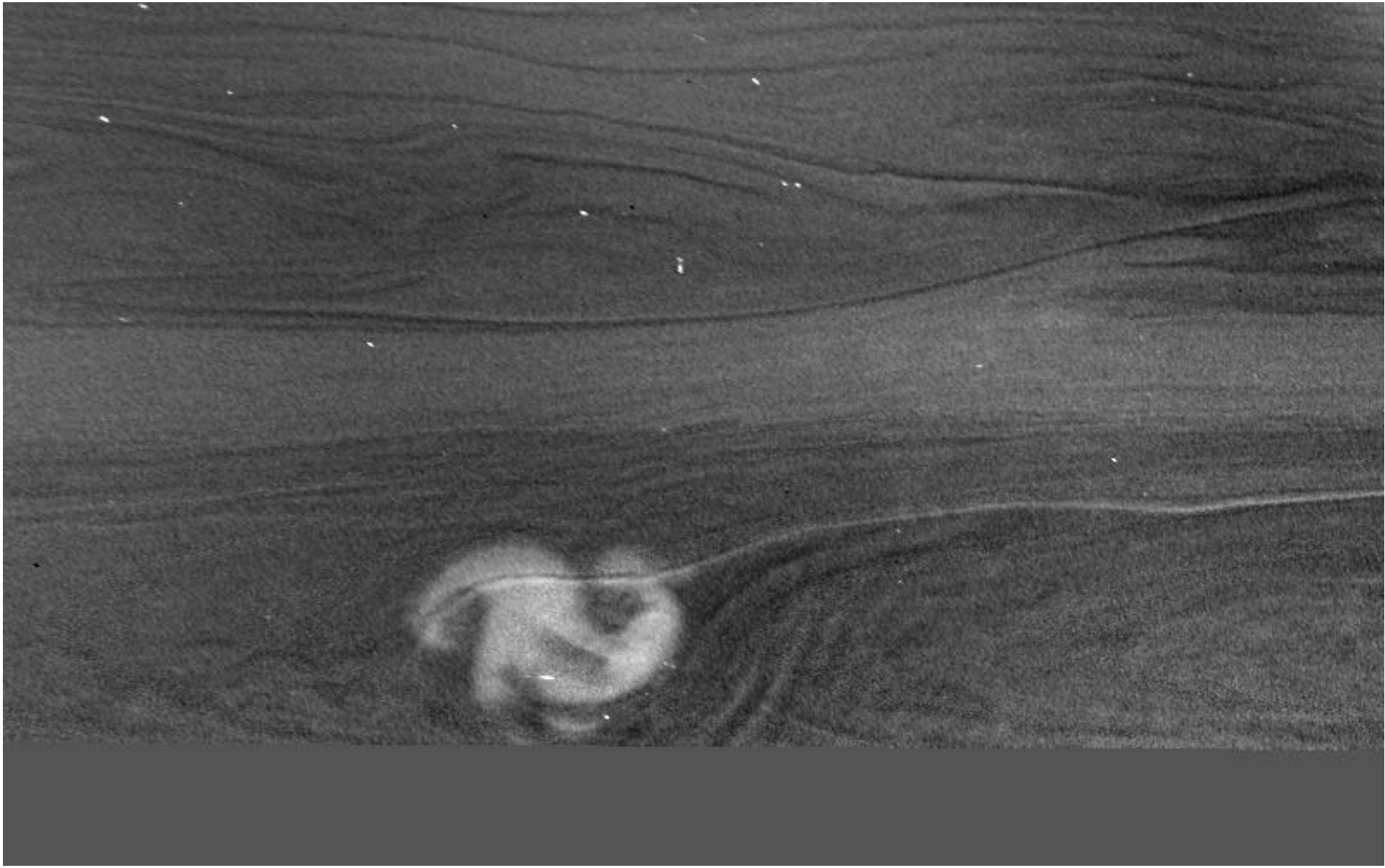


U. A. Dyudina, A. P. Ingersoll, S. P. Ewald (Caltech)

C. C. Porco (CICLOPS/Space Science Institute)

G. Fischer and W. Kurth (University of Iowa)


Universal Time (Day of 2004).
SED Number/hour
200
150
100
50
0
1000
100
10
1
0.0
0.2
0.4
0.6
0.8
1.0
Storm drift: 0.2 deg/day or 3 m/s
* – CM crossing
250
255
260
265
270
275
Universal Time (Day of 2004).



Cassini ISS image of Dragon Storm on the night side of Saturn

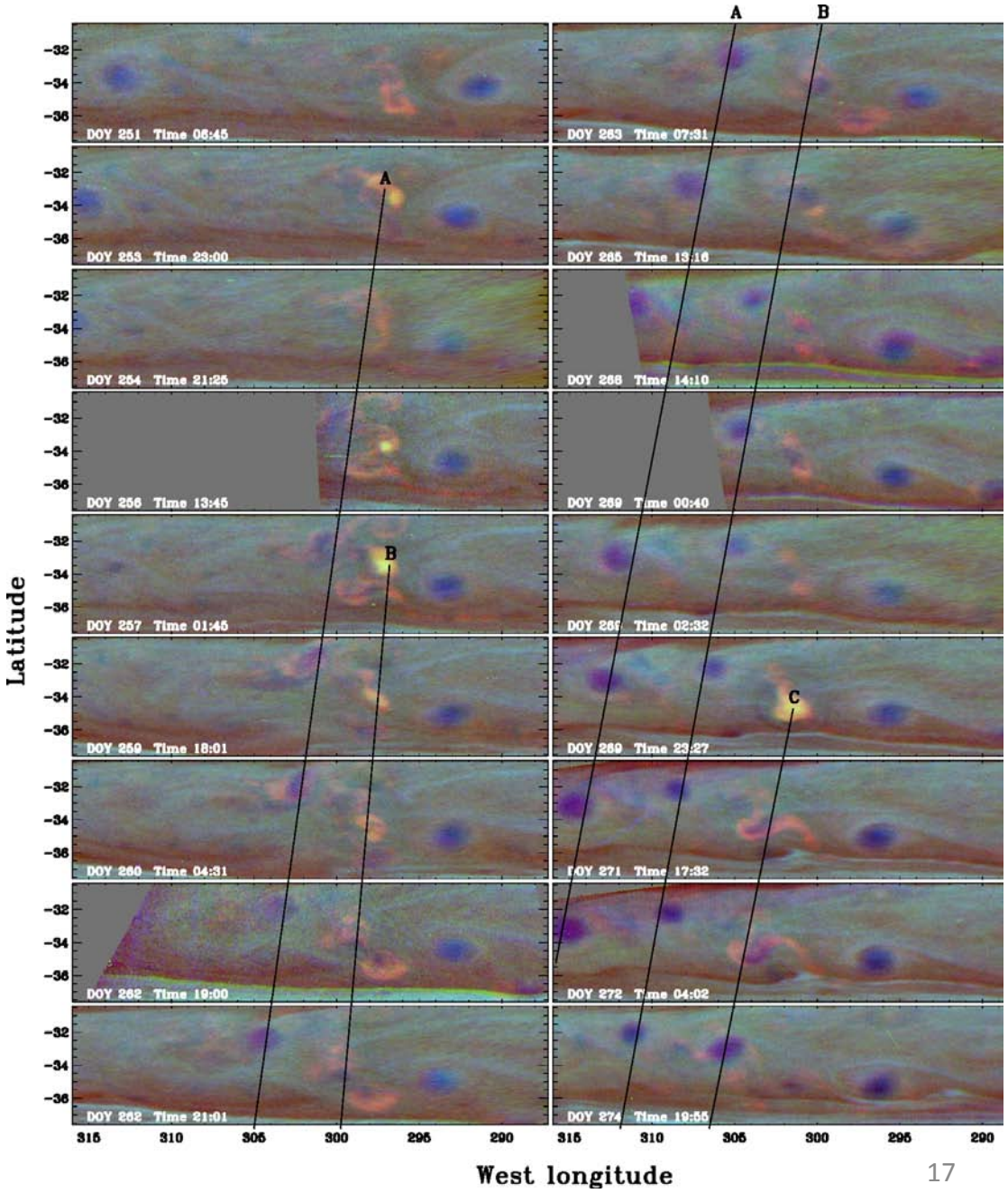
Dragon storm

Sep. 2004

see also Porco et al., Science 307, 2005

Colors are combined from images in different filters

- tall thick cloud
- deep cloud
- middle cloud
- -Hole or absorber
  In the low cloud
  covered by high haze

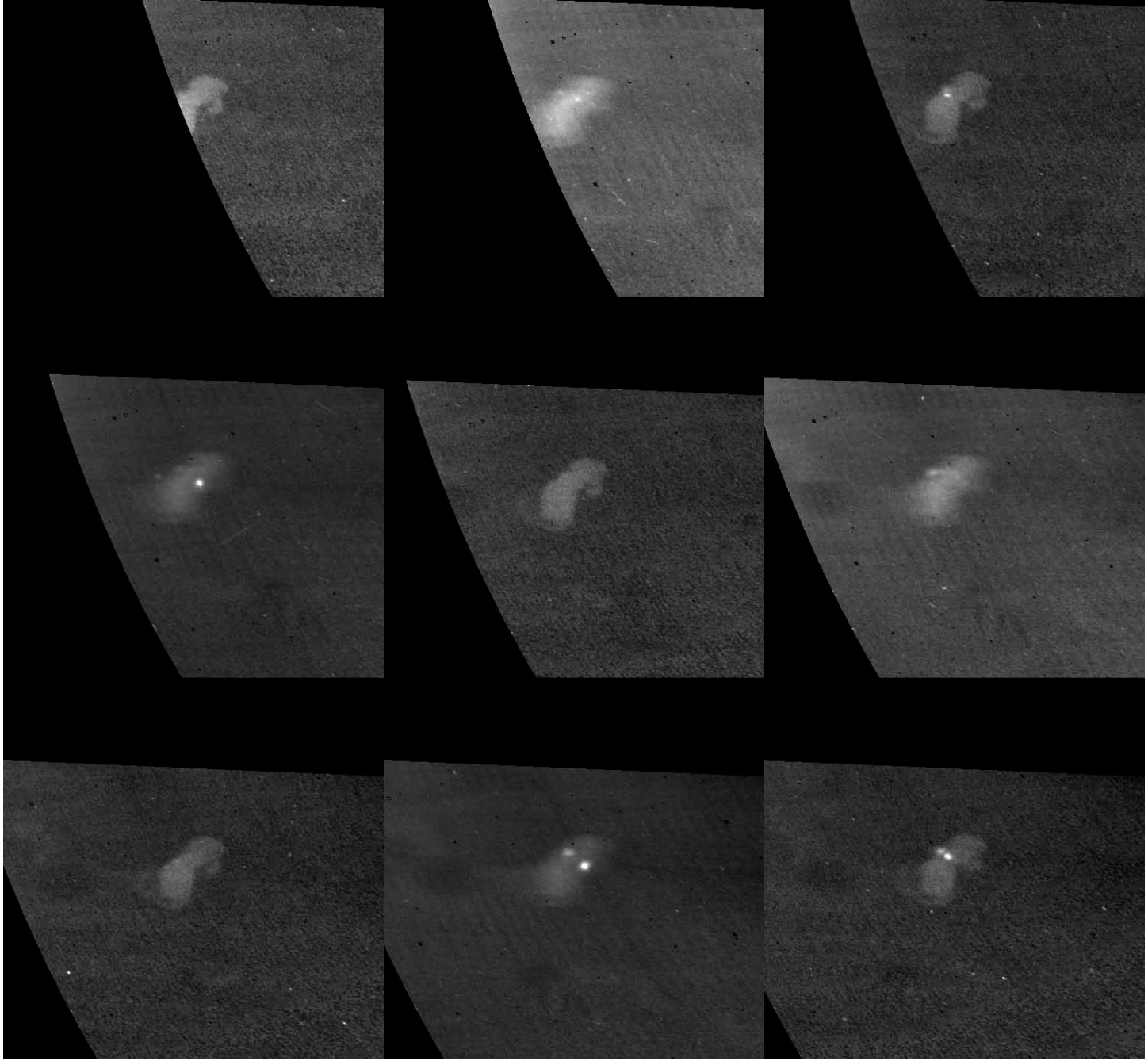


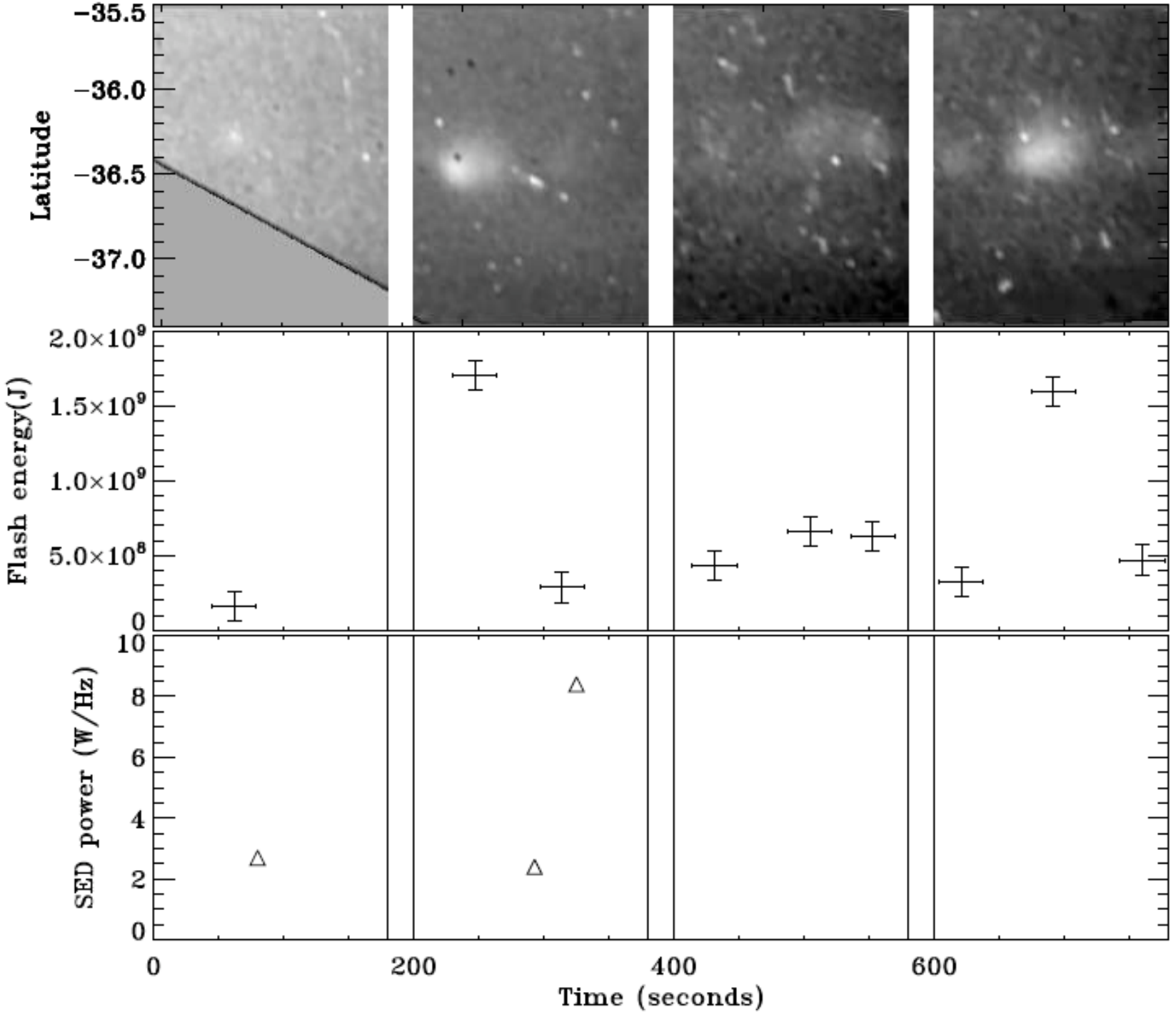
Dyudina, U, et al.

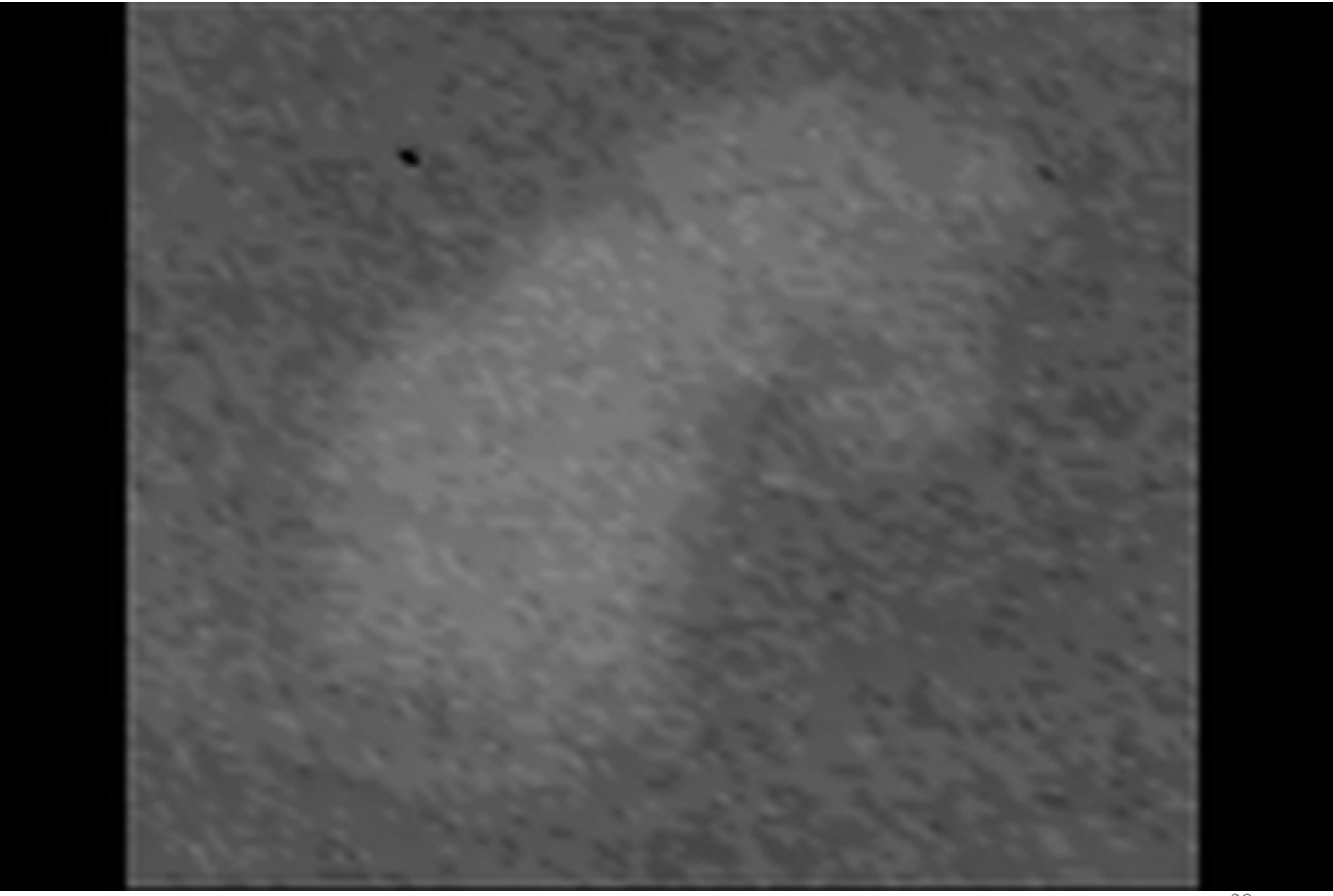
Lightning on Saturn

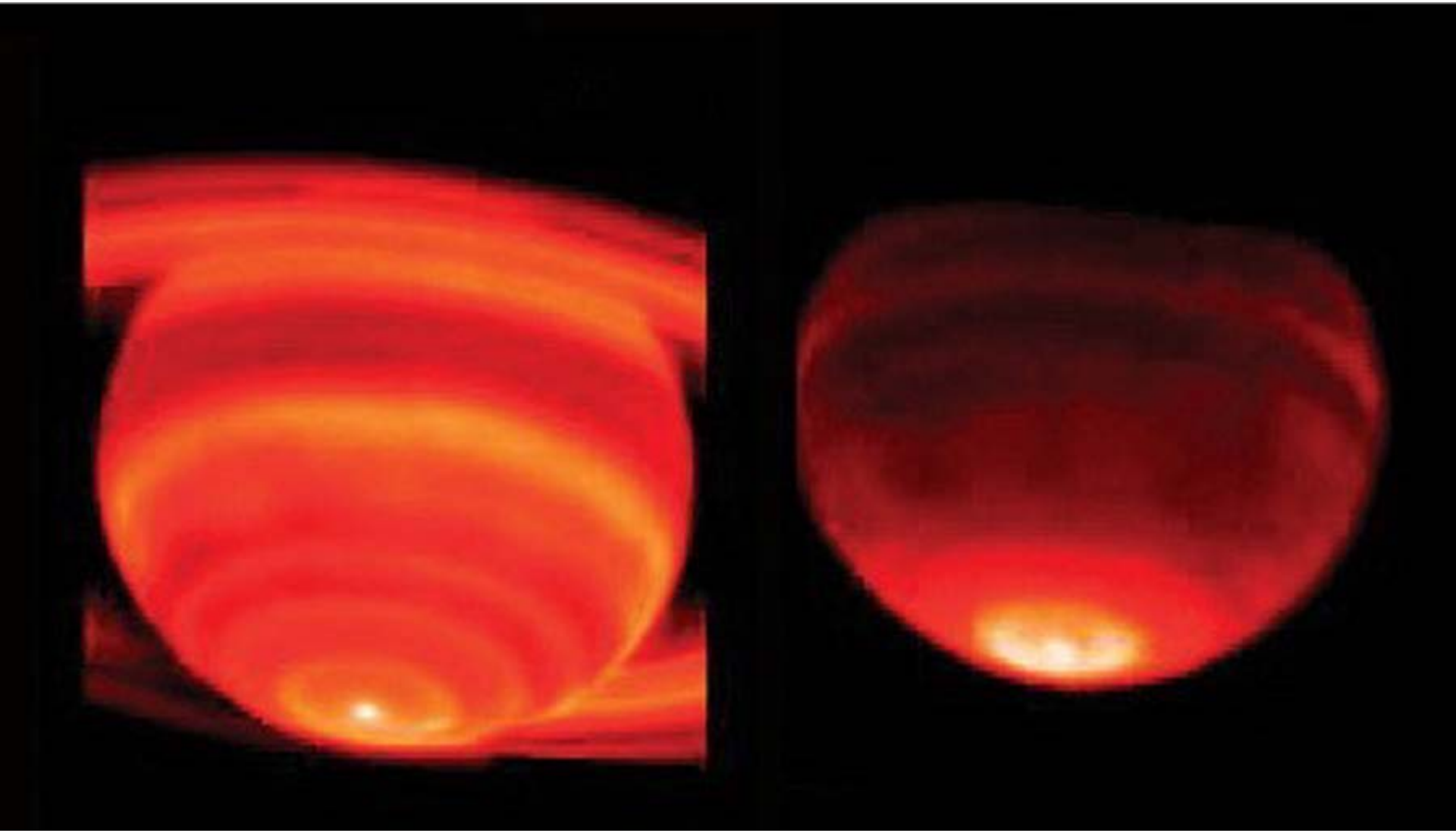
GRL 37, L09205

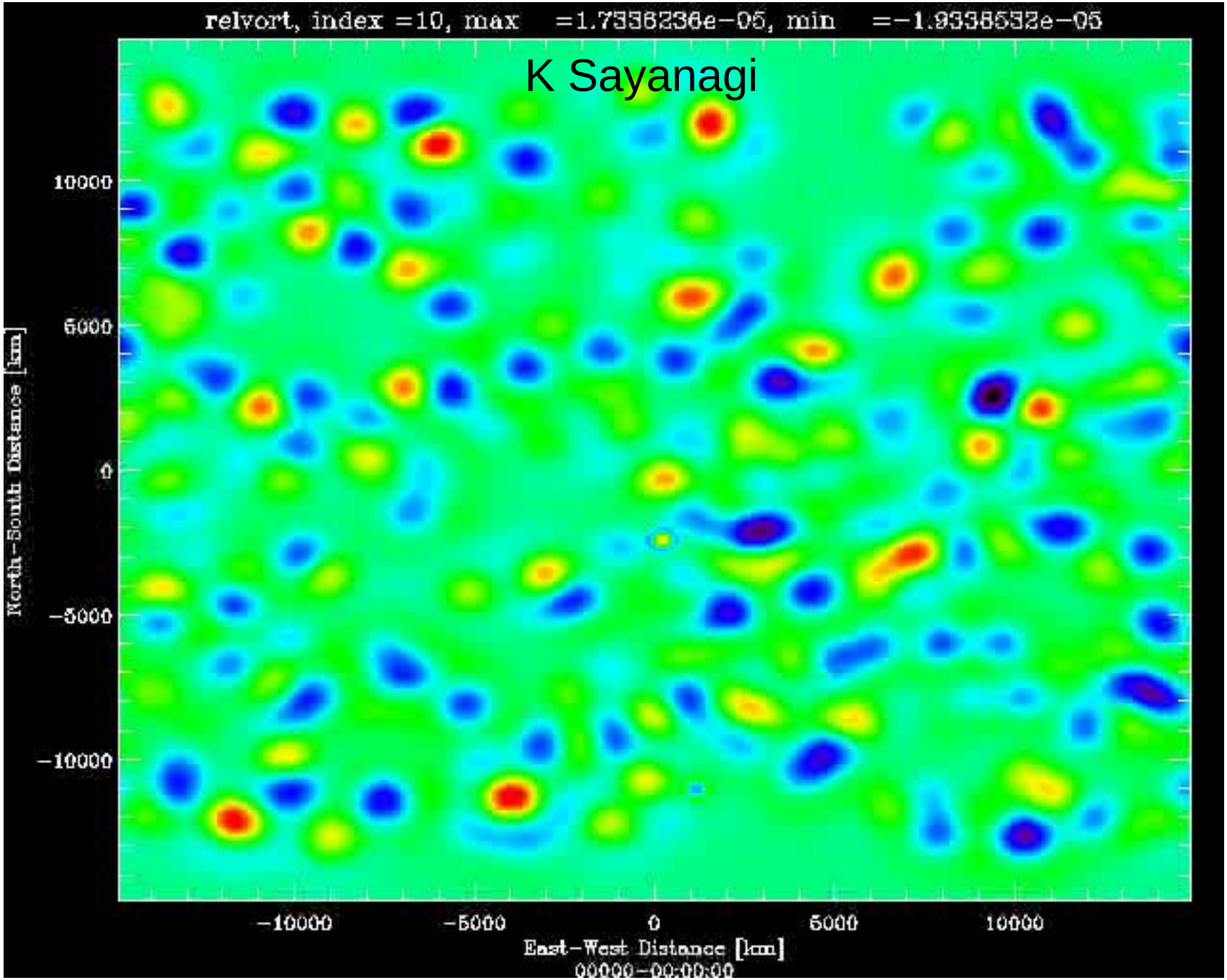
(2010)




Latitude
−35.5
−36.0
−36.5
−37.0
Flash energy(J)
2.0×10⁹
1.5×10⁹
1.0×10⁹
5.0×10⁸
0
SED power (W/Hz)
10
8
6
4
2
0
0
200
400
600
Time (seconds)






relvort, index =10, max =1.7336236e-05, min =-1.9338532e-05
K Sayanagi
10000
5000
0
-5000
-10000
North-South Distance [km]
-10000
-5000
0
5000
10000
East-West Distance [km]
00000-00:00:00

Dyudina, U., et al.

Science 319 (2008)

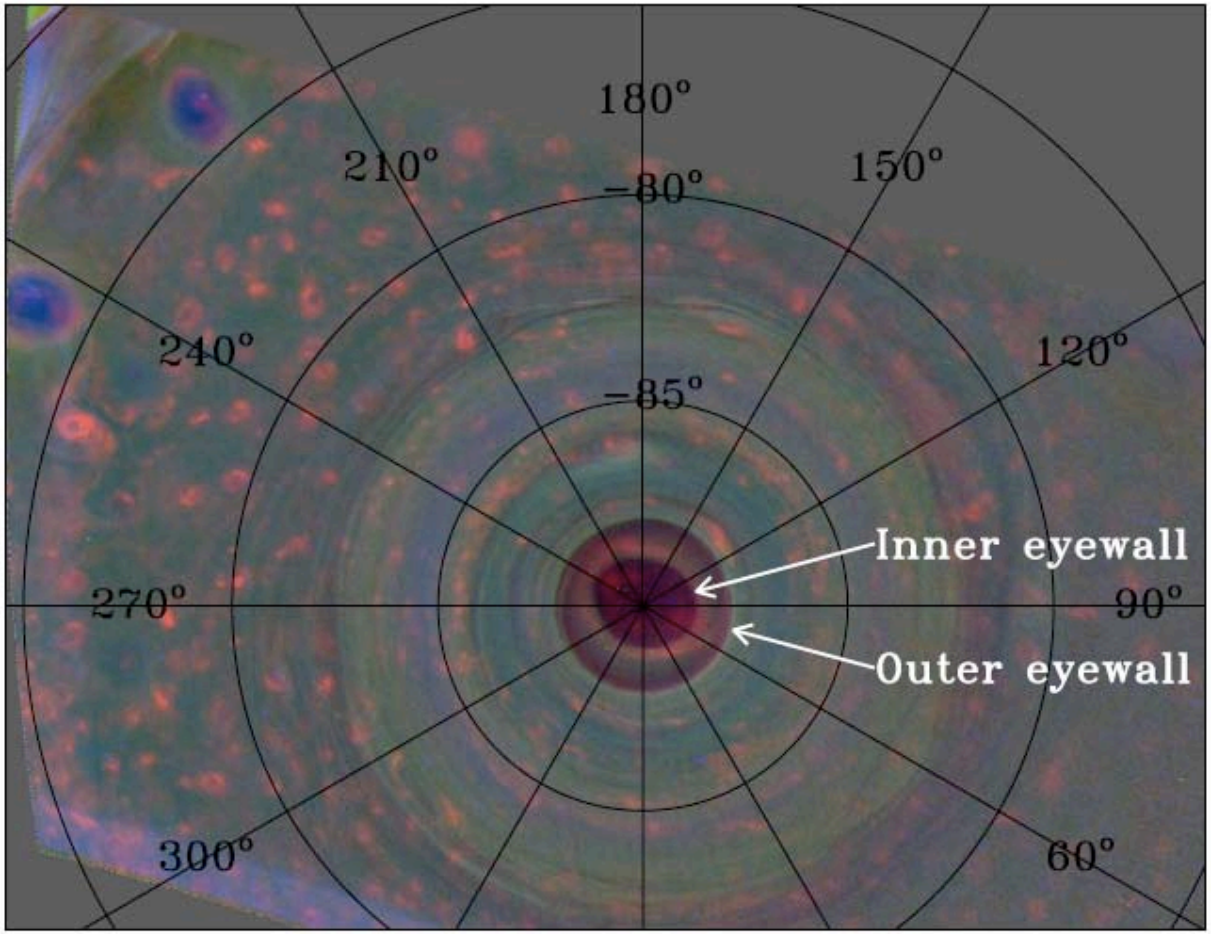
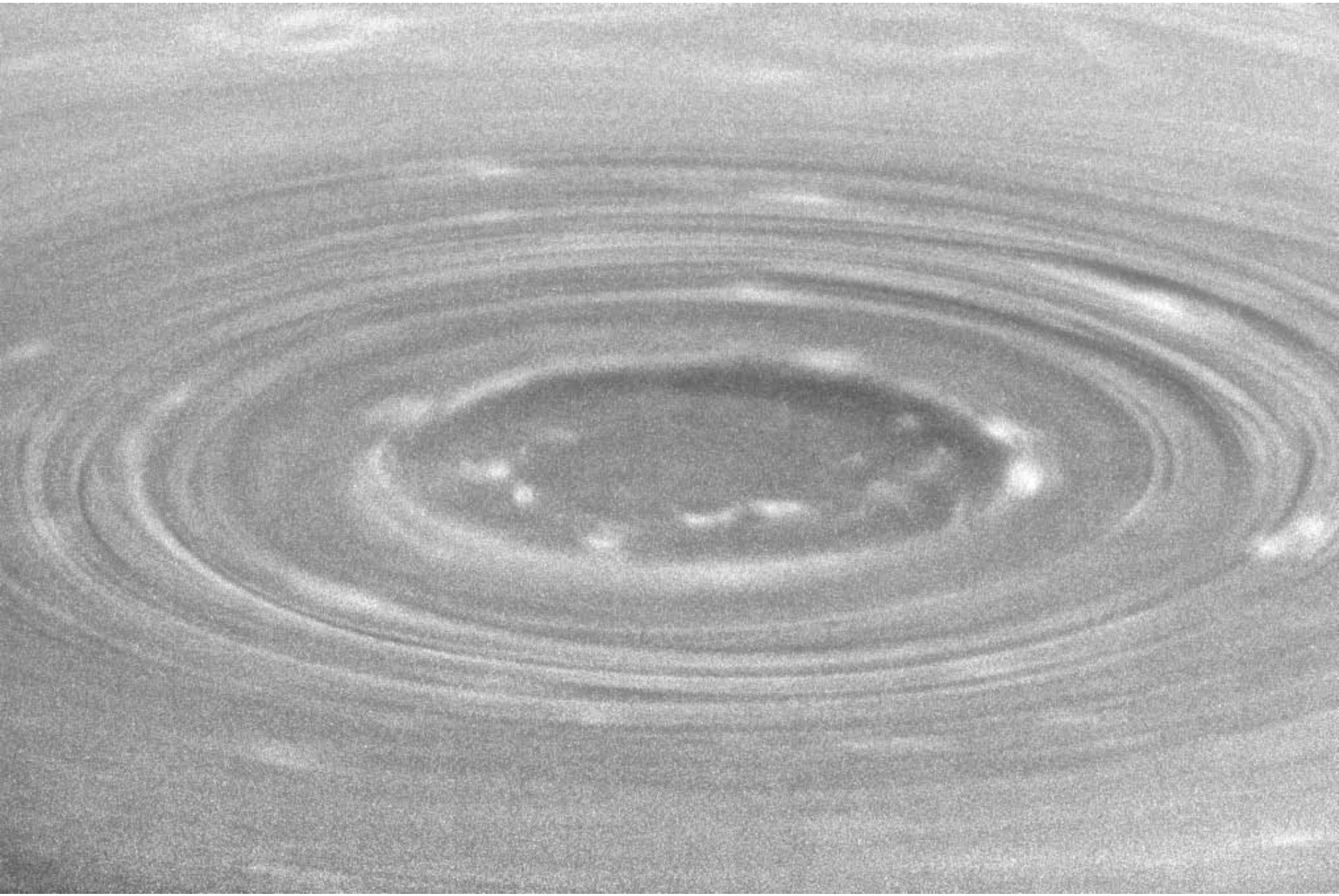
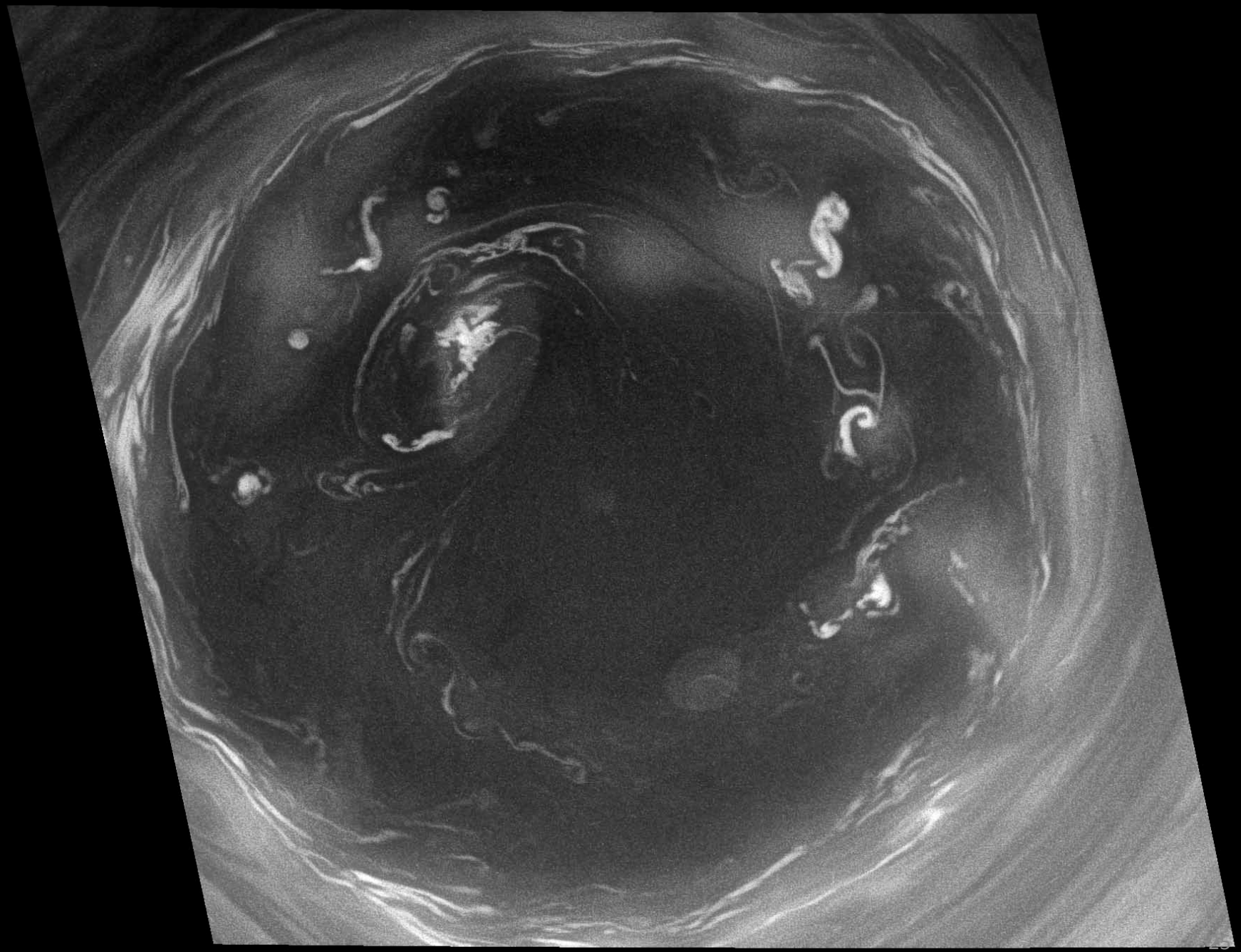
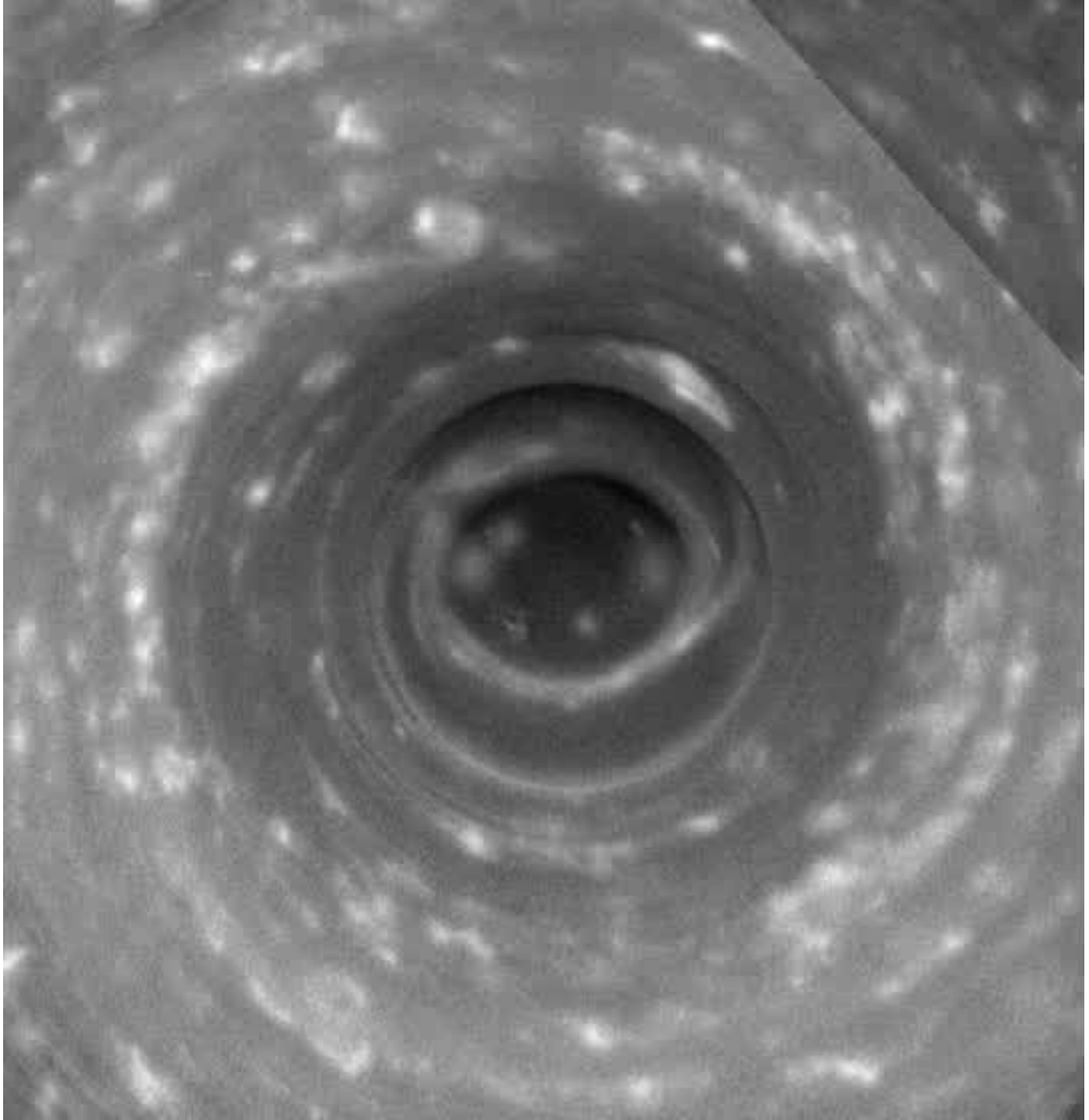


Figure 1: False-color image of Saturn's south polar clouds taken by the Cassini imaging science subsystem (ISS) in three filters (*4*). An image at 889 nm, where methane gas is a strong absorber, is projected onto the blue plane. An image at 727 nm, where methane is a moderate absorber, is projected onto the green plane. An image at 750 nm, where the gases of Saturn's atmosphere are transparent, is projected onto the red plane. The images have been map projected using polar stereographic projection with planetocentric latitudes. In the original images the sun was 15° above the horizon at the pole, and attenuation by a factor of e (2.71...) occurs at the 80 mbar and 300 mbar levels for light at 889 nm and 727 nm, respectively. Clouds below 300 mbars appear red, and high thin clouds appear blue or green (see also modeling results in (*3*)). The eyewalls can be seen in all three color planes, and thus extend to ~80 mbar. To reduce the effect of varying solar illumination across the image, each color plane is high-pass filtered at the spatial scale of ~300 km, or ~0.3° of latitude.







Dyudina, U., et al.

Icarus 202 (2009)

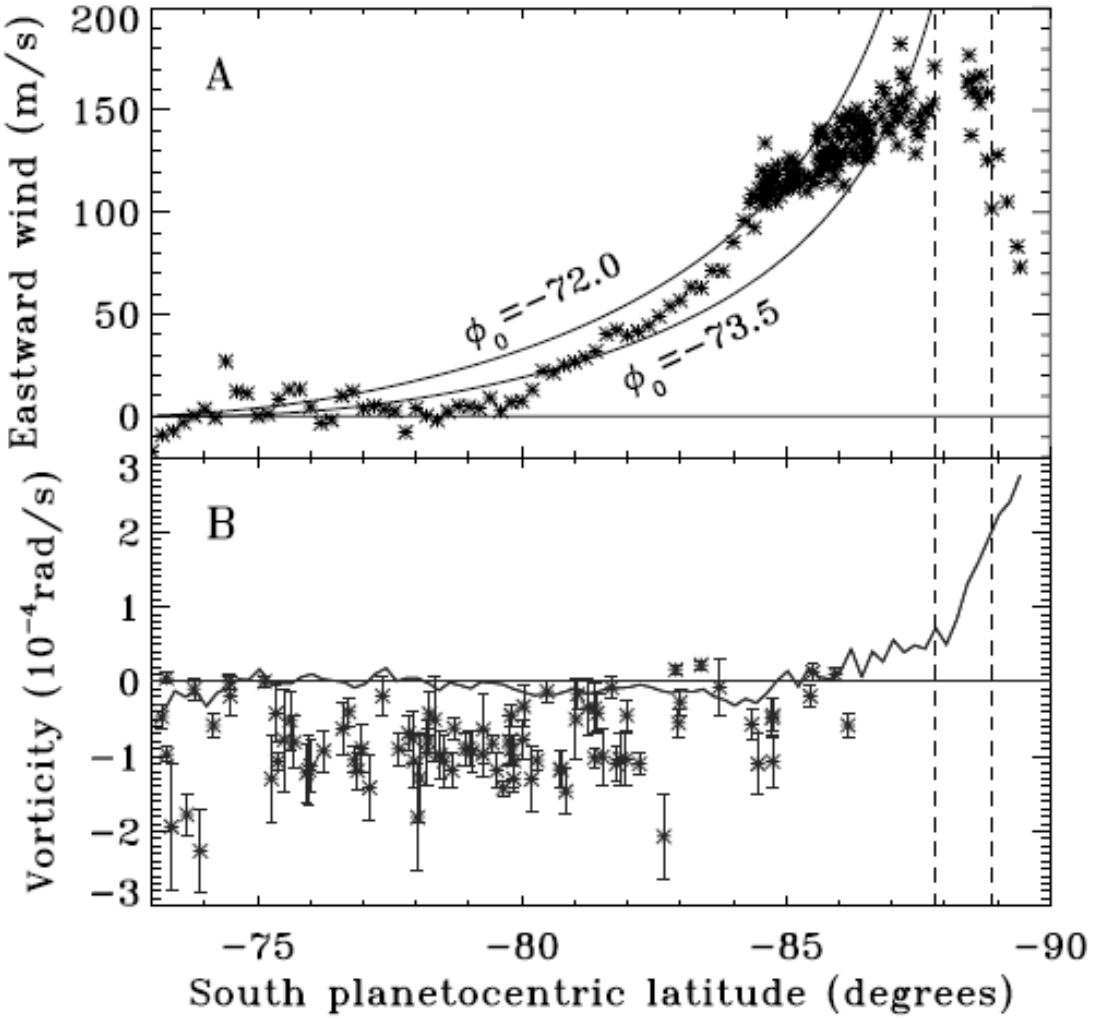


Figure 3: Profiles of zonal velocity (eastward) and cyclonic vorticity (clockwise) around Saturn's south pole. The dashed vertical lines indicate the inner and outer eyewalls. (A) Zonal velocity measured by tracking clouds in a sequence of images over a 3-hour period. The solid curves are for constant absolute vorticity $\zeta + f$ starting at latitude ϕ_0 (values labeled on the curves) with $a = 0$ and $\zeta = 0$ at that point. (B) Relative vorticity ζ. The solid curve is a spline fit to the velocity data of Fig. 3A (7). The points are the puffy red clouds of Fig. 1. To determine the relative vorticity of a puffy red cloud, we track it over the 3-hour time interval and measure its angular velocity of rotation relative to the rotating planet. Twice this angular velocity is the vorticity of the cloud. We repeated the procedure three to four times for each cloud and assigned error bars from the residuals (7).

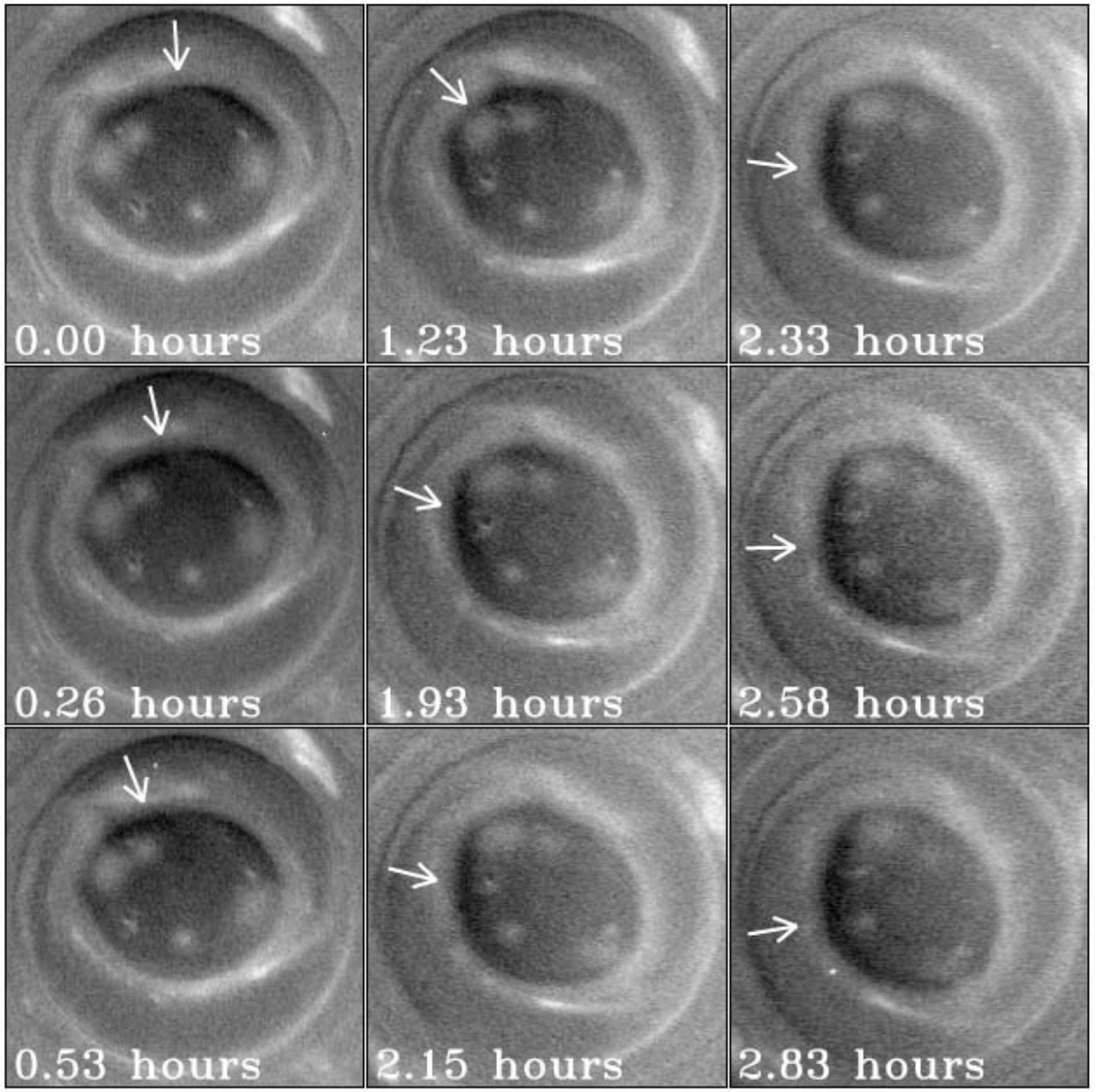
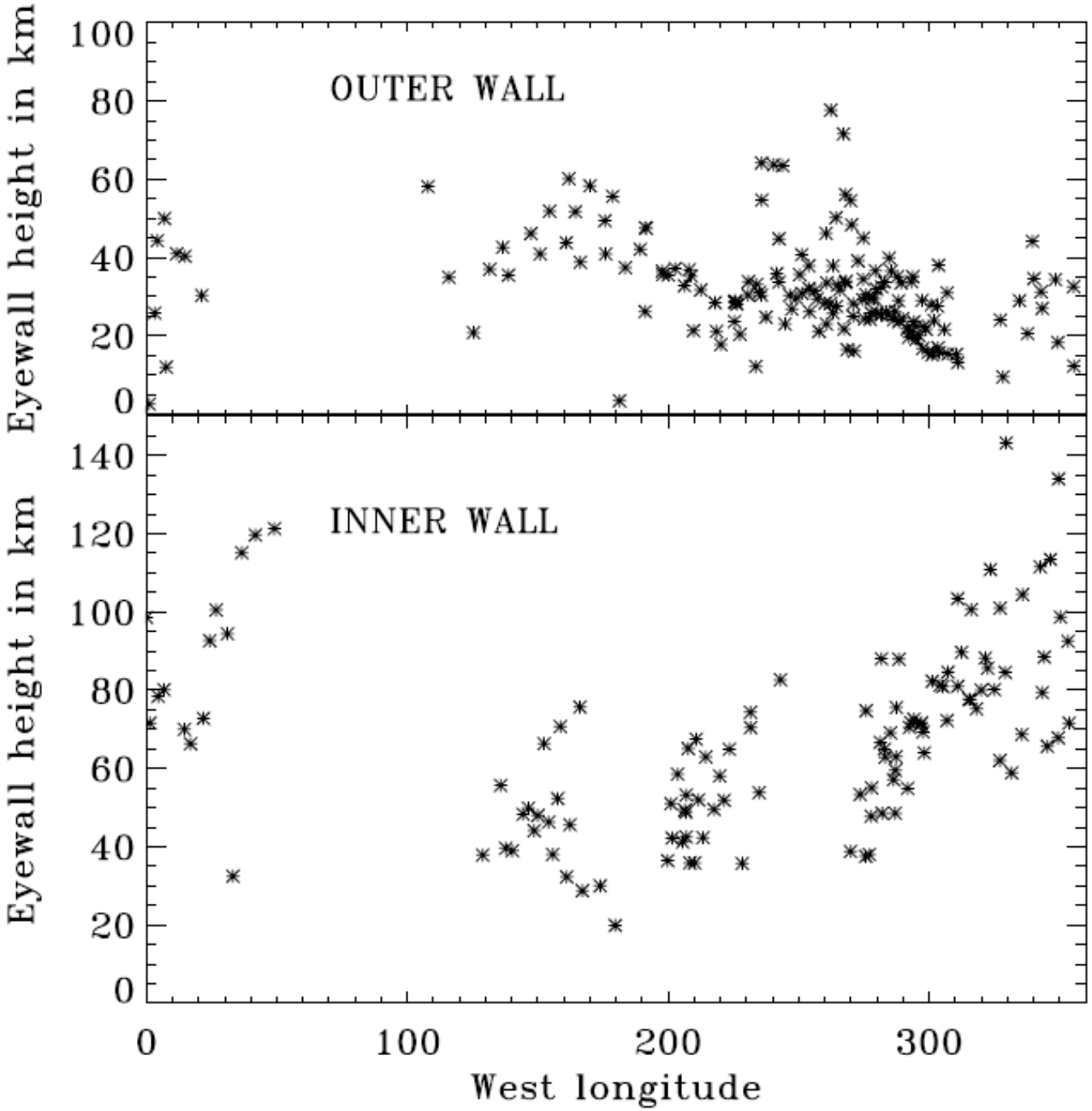


Figure 2: A time sequence showing how the shadows (the dark crescent-shaped areas inside the walls) follow the Sun. The first map is taken on October 11 (DOY 284), 2006 at 19 hr 42 min. The maps are labeled by the time lapsed since the first map. The white arrow shows the direction of propagation of the incident sunlight.


OUTER WALL
INNER WALL
Eyewall height in km
Eyewall height in km
West longitude
0
20
40
60
80
100
120
140
0
100
200
300

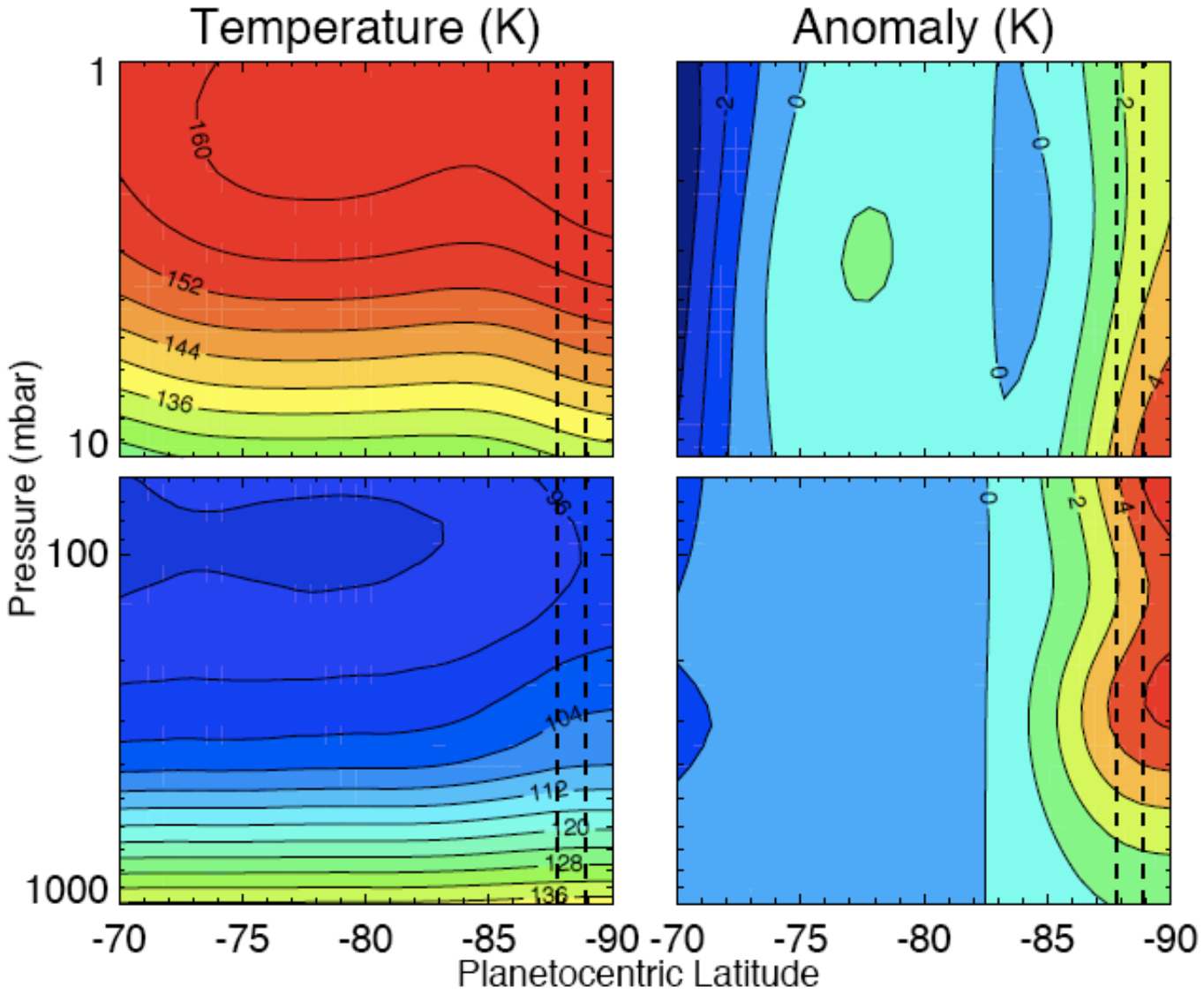
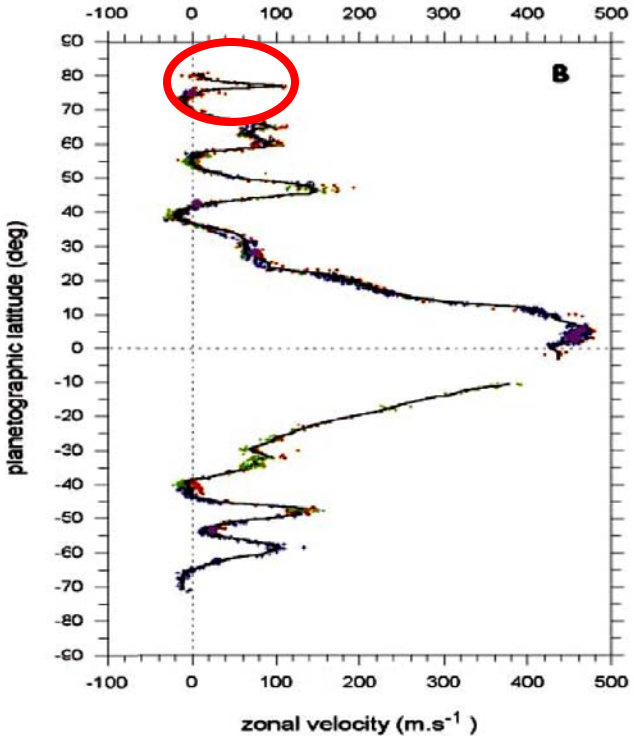
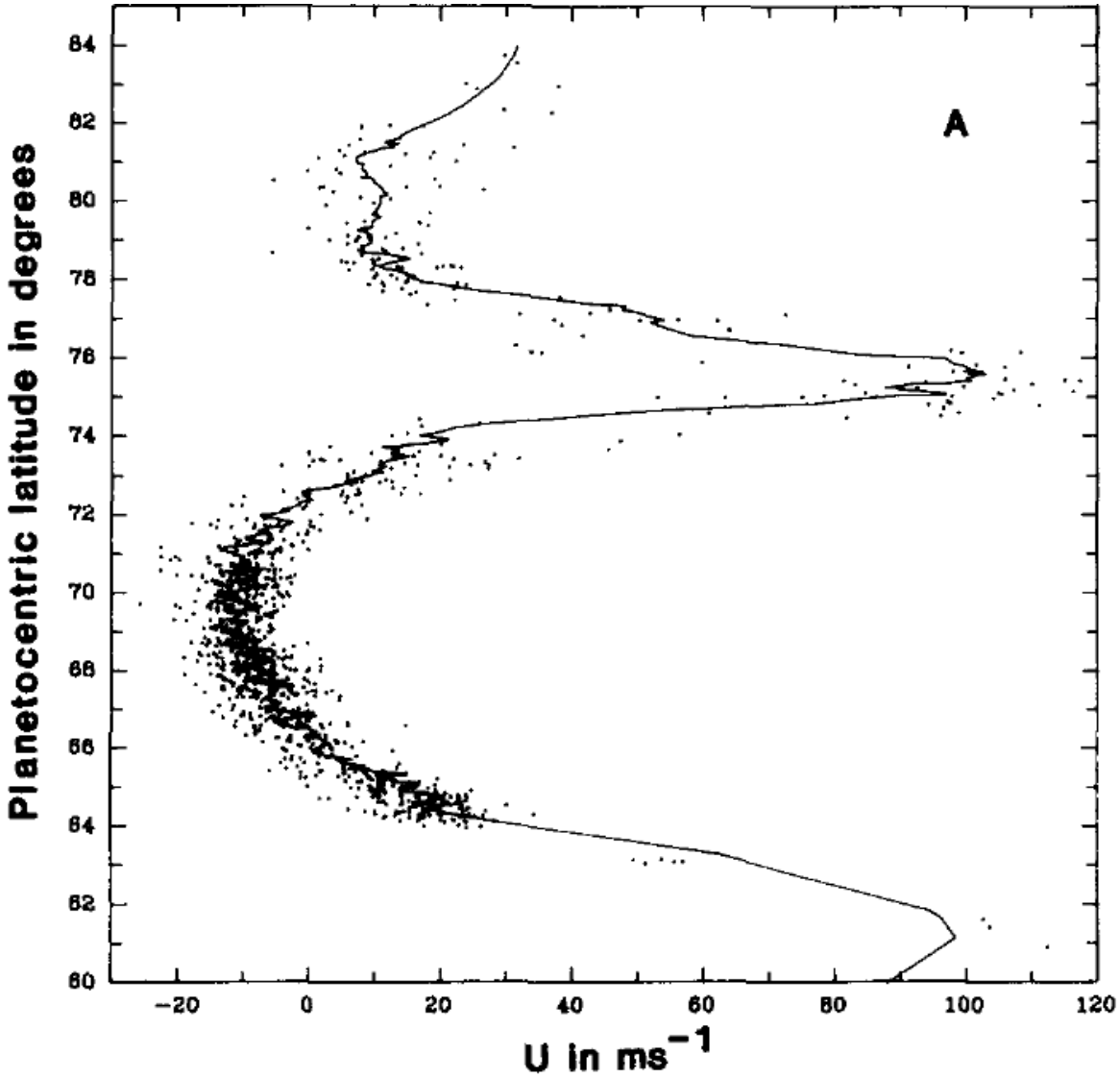


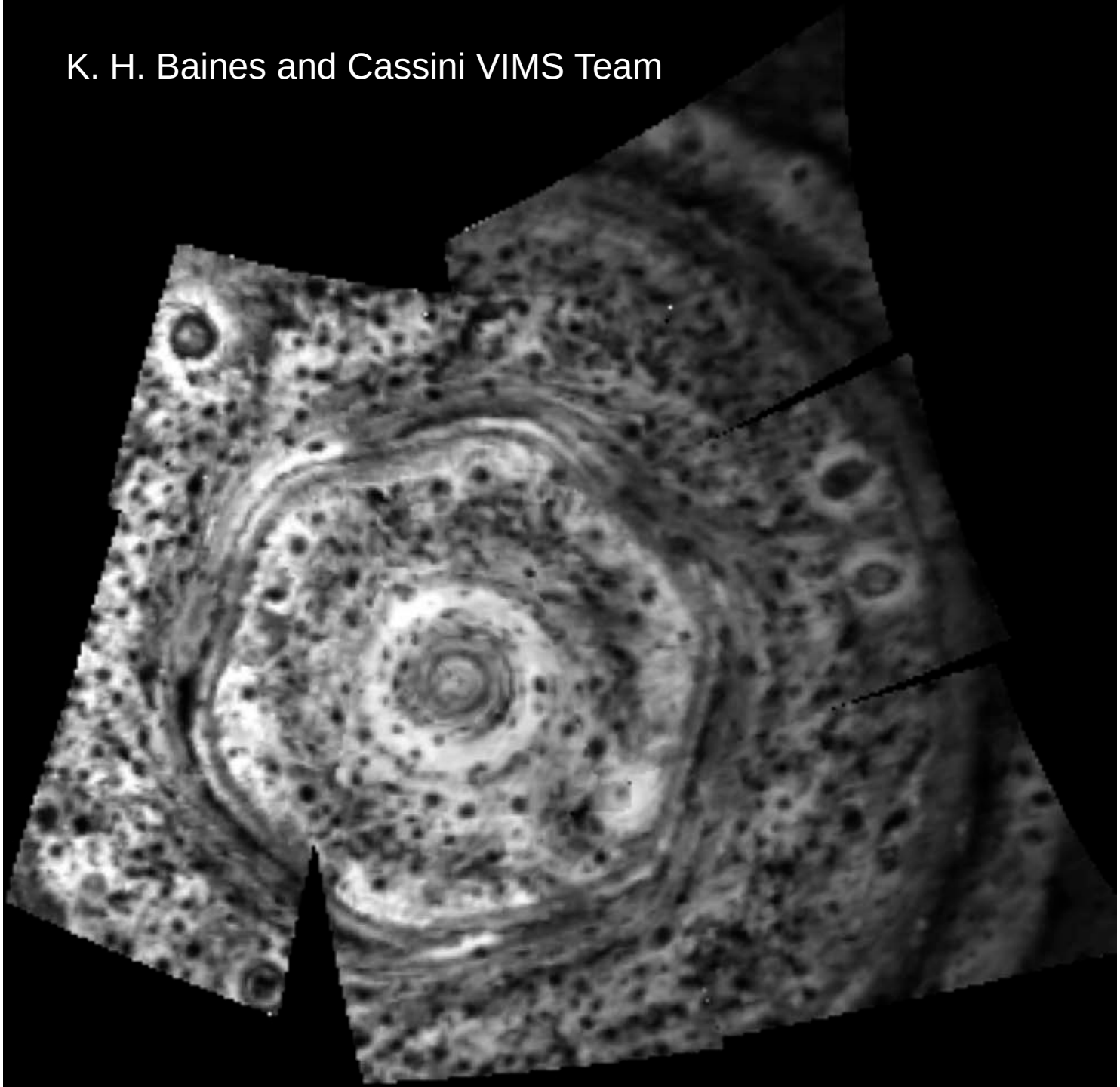
Figure 4: Zonal mean temperatures in Saturn's south polar region derived from the Cassini composite infrared spectrometer (CIRS) spectra (left panels) (*10, 11, 19*). The gap between the upper and lower panels arises because the CIRS instrument is not sensitive to the 6-70 mbar region. Temperature anomalies (right panels) are calculated by subtracting the zonal mean temperatures at -84° latitude. The dashed vertical lines indicate the inner and outer eyewalls.

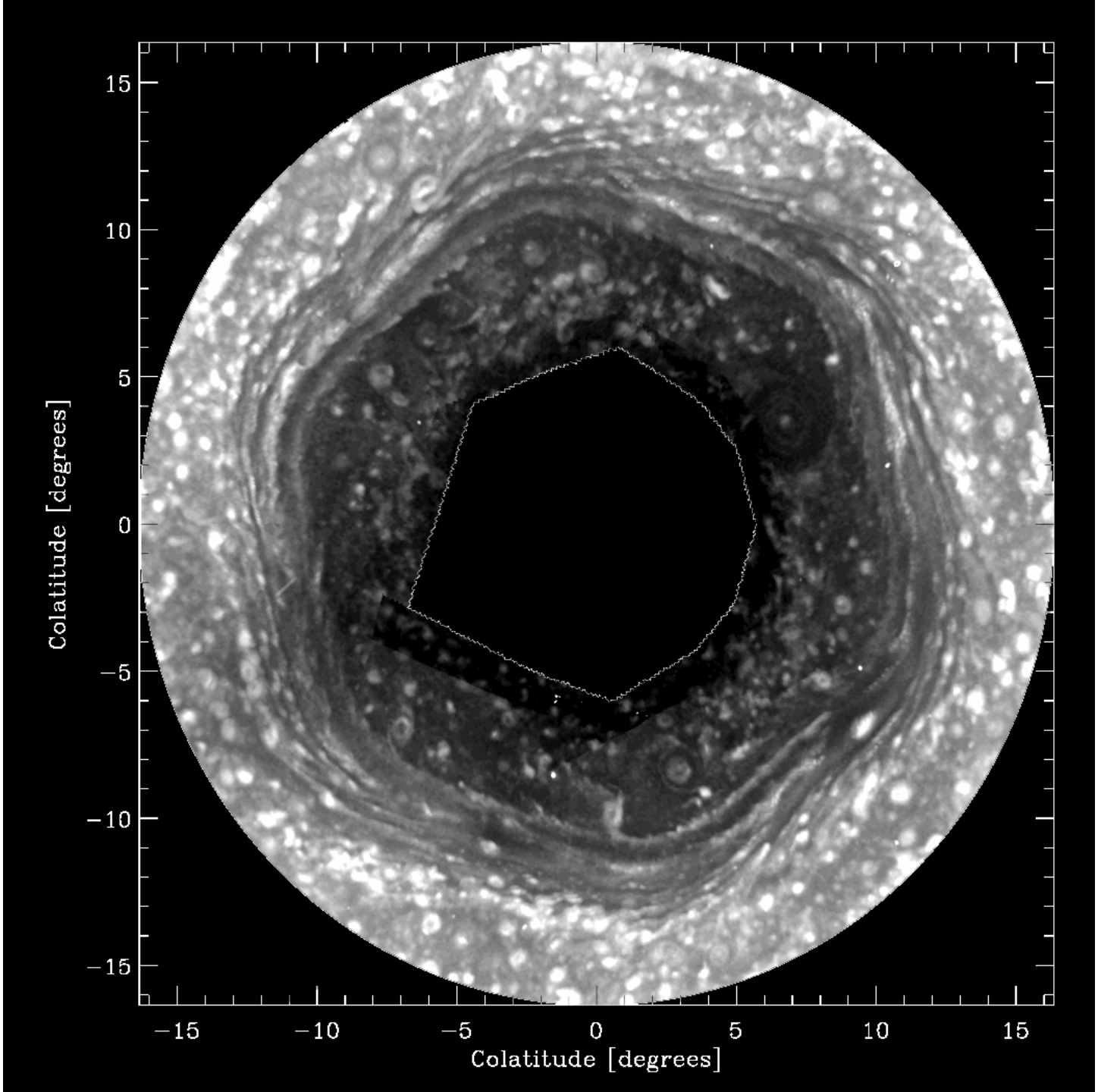
Northern Jet Stream

The hexagon is a feature in the 77degN Jet:



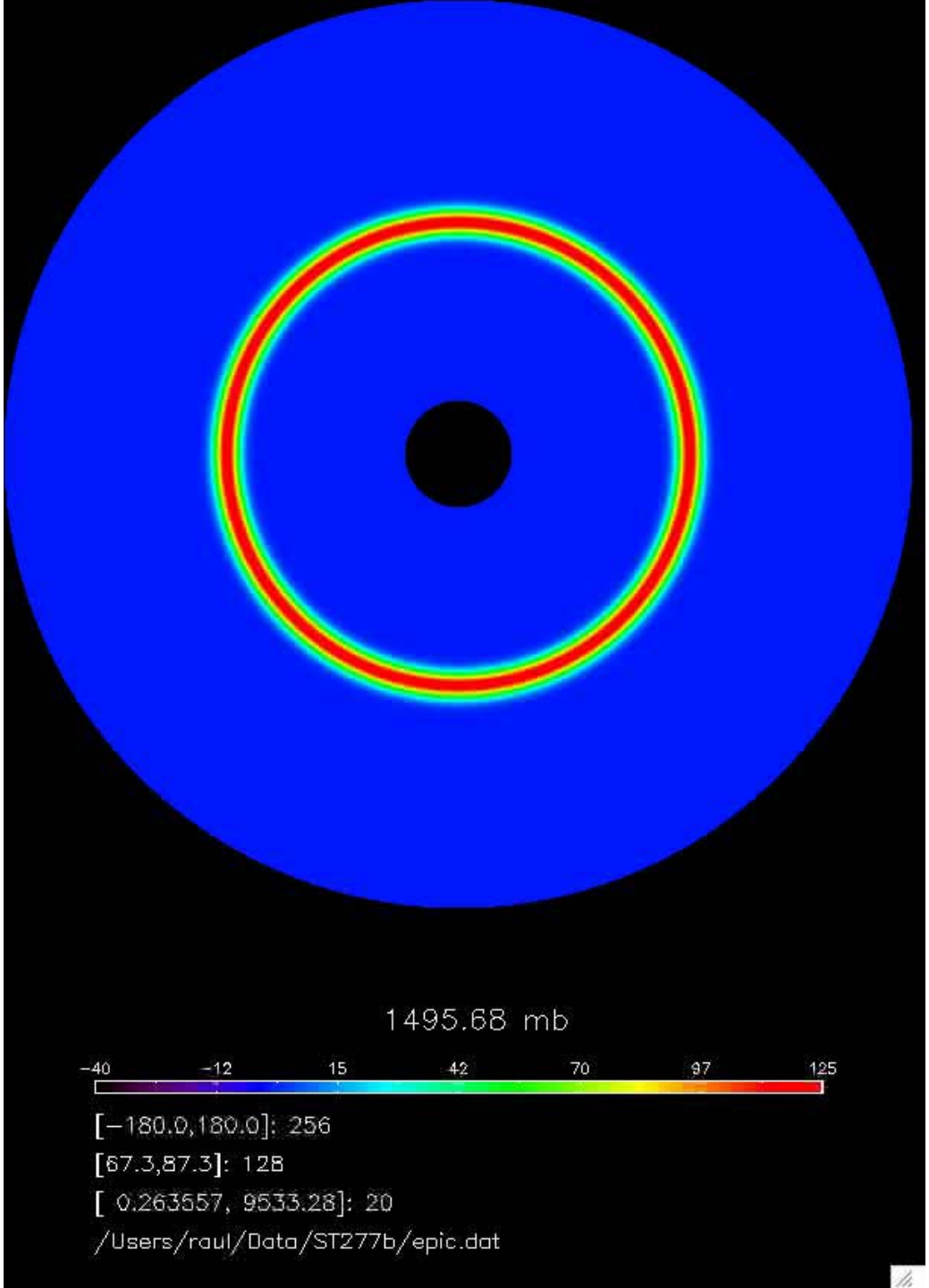



K. H. Baines and Cassini VIMS Team

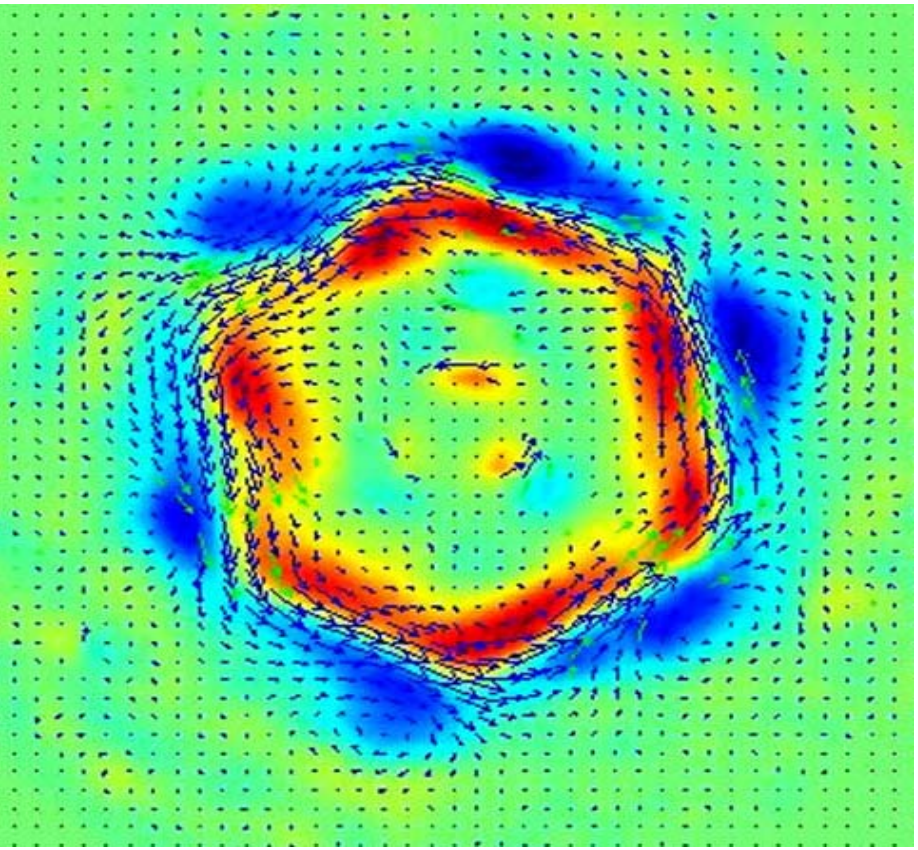

15
10
5
0
−5
−10
−15
Colatitude [degrees]
−15
−10
−5
0
5
10
15
Colatitude [degrees]

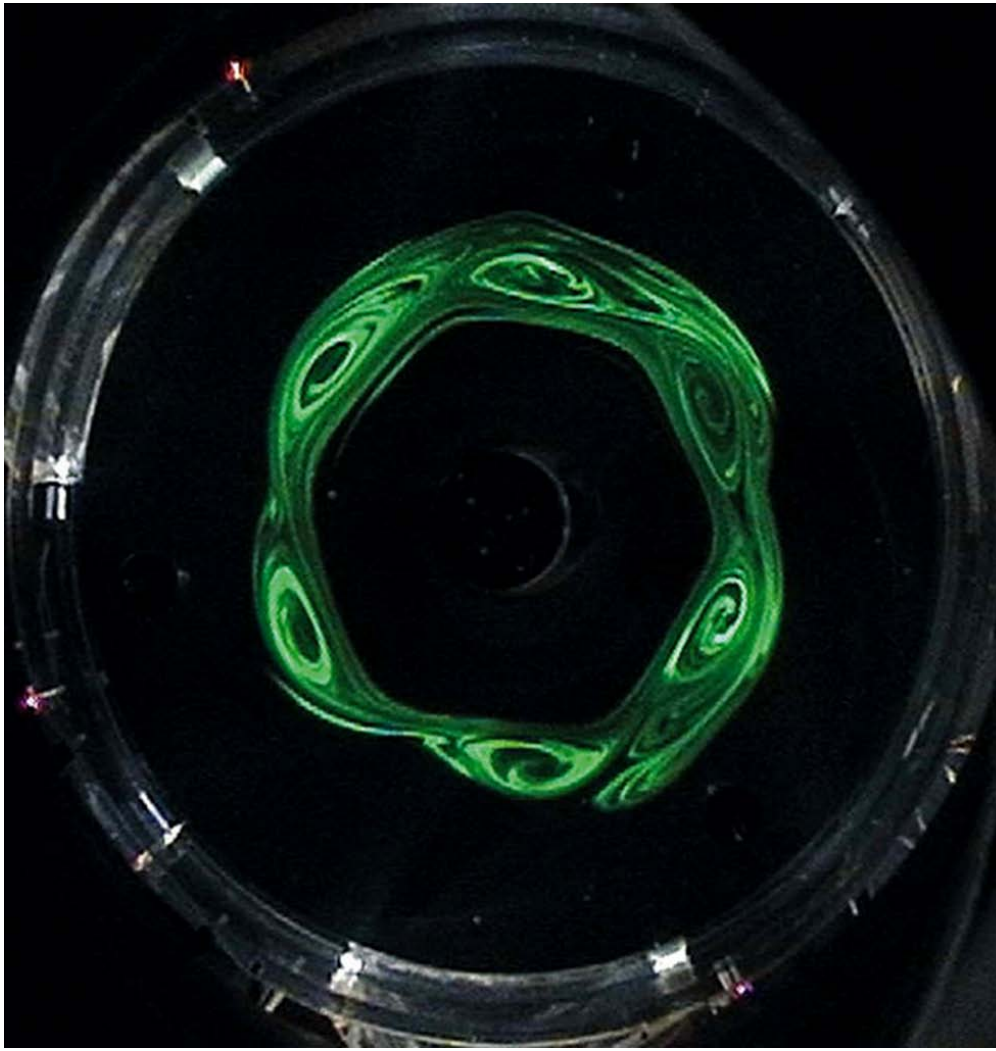
Sayanagi et al.
J. Atmos. Sci., in press (2010)

Morales-Juberas et al., J. Atmos. Sci. submitted (2010)

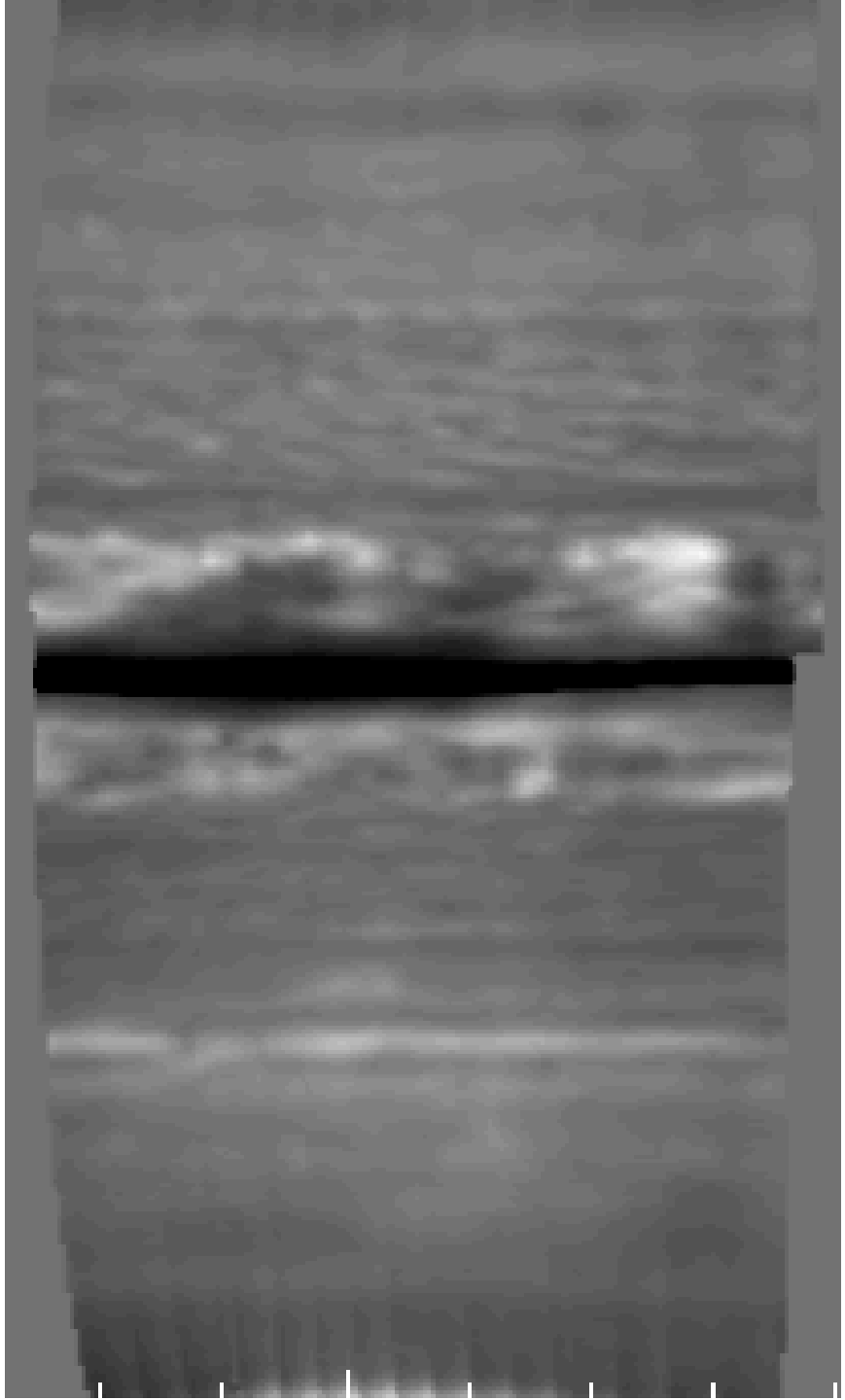


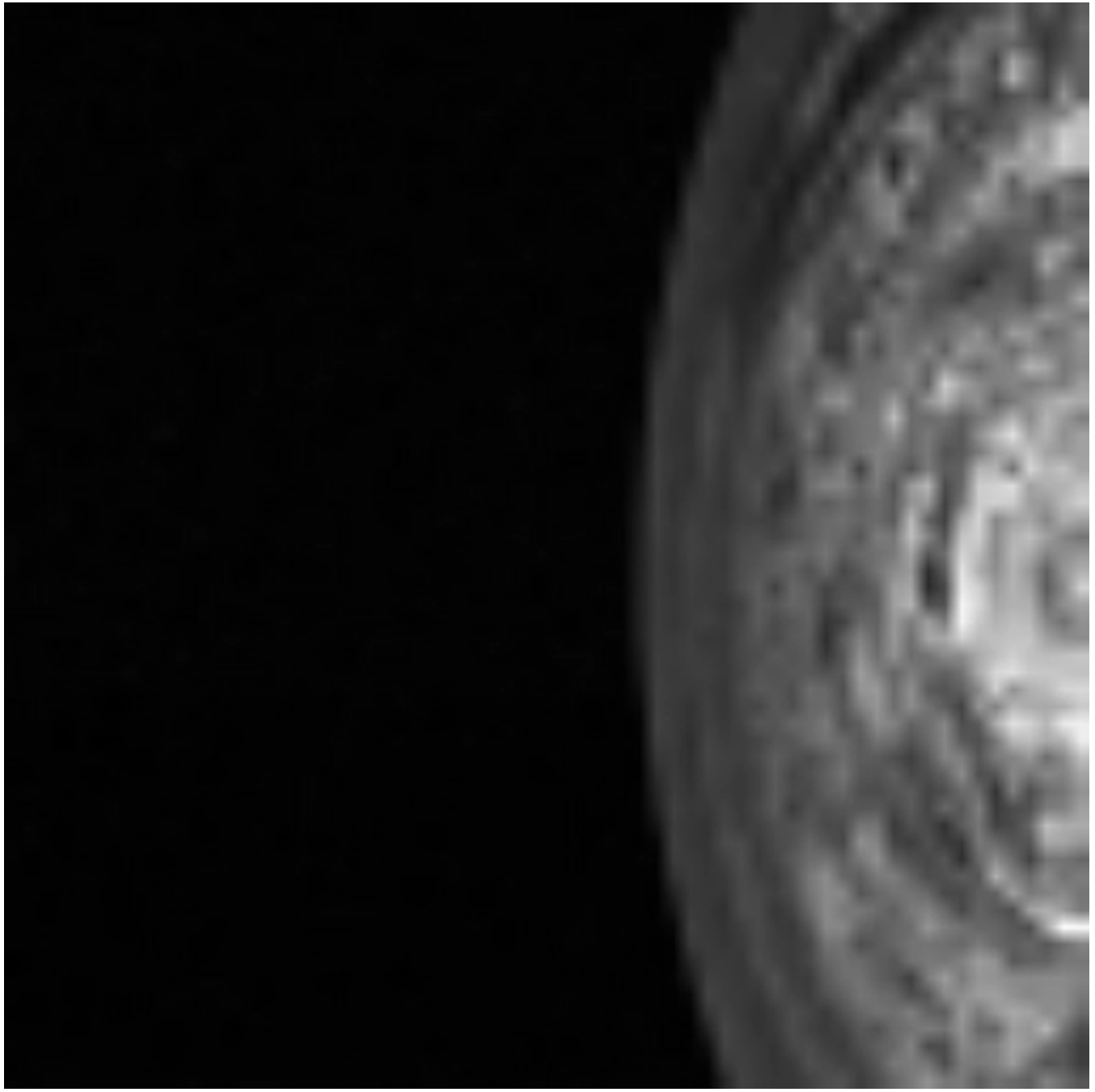
Comparison to Lab Experiment Study

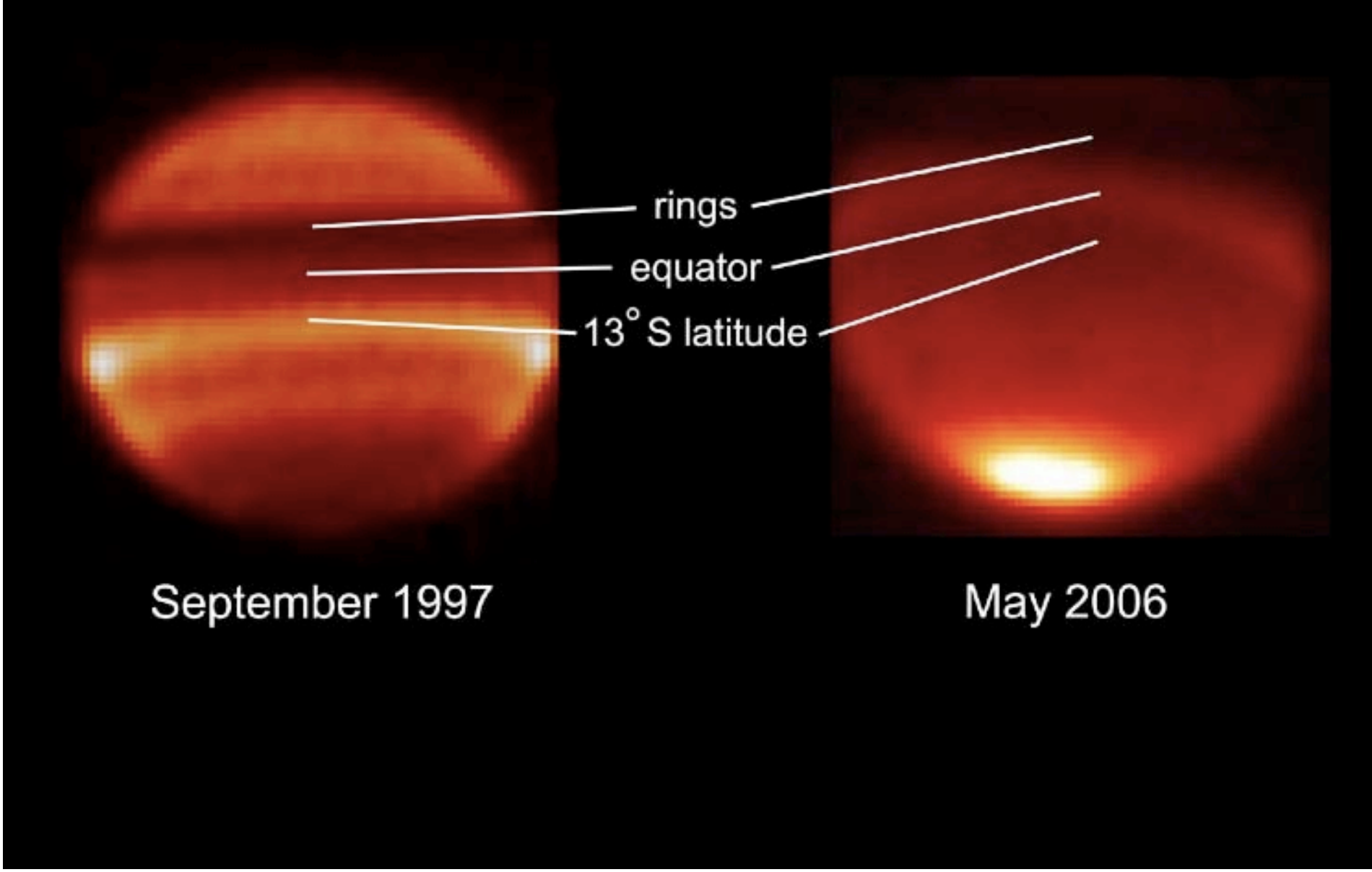




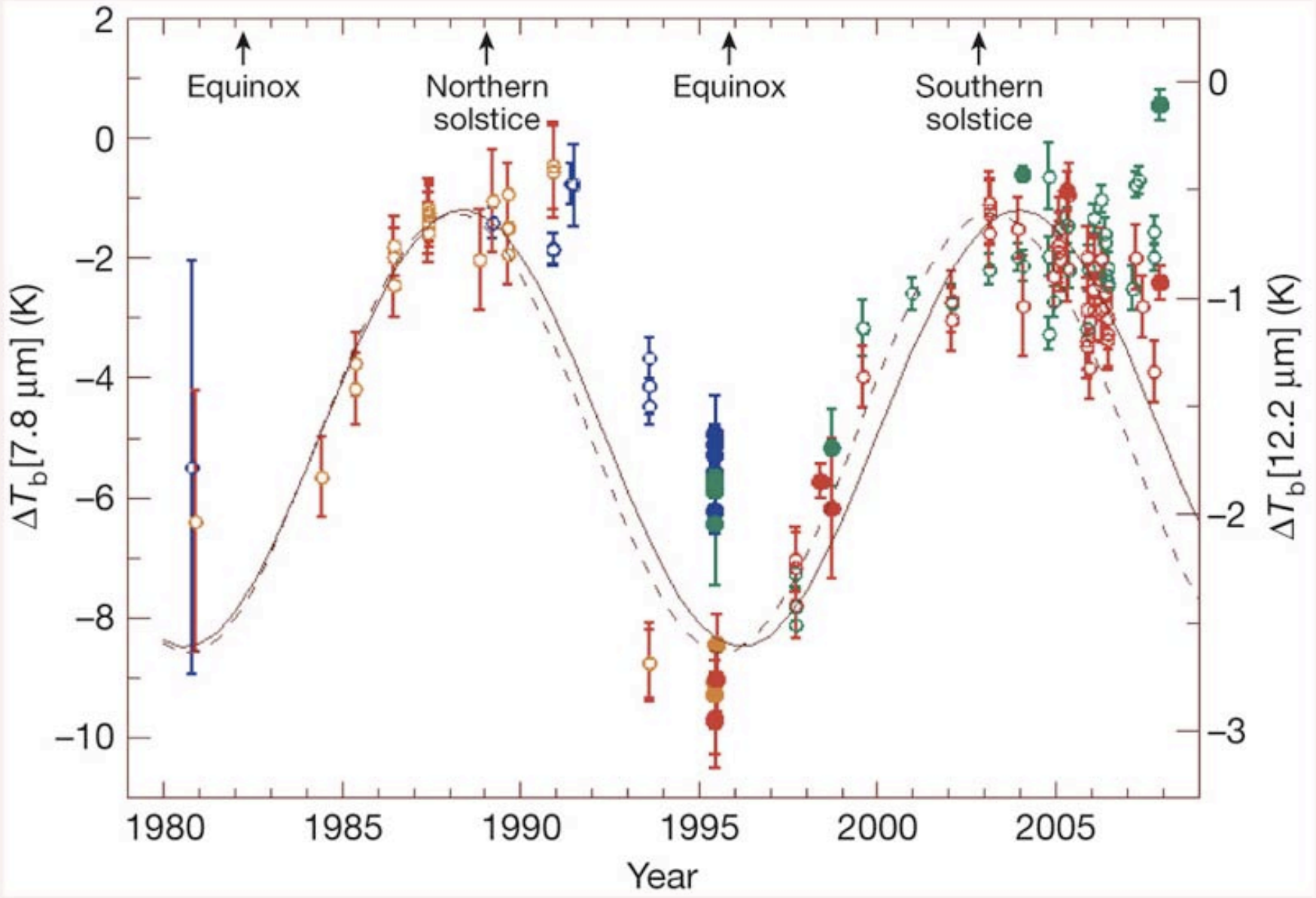
Barbosa-Aguiar et al. (2010)

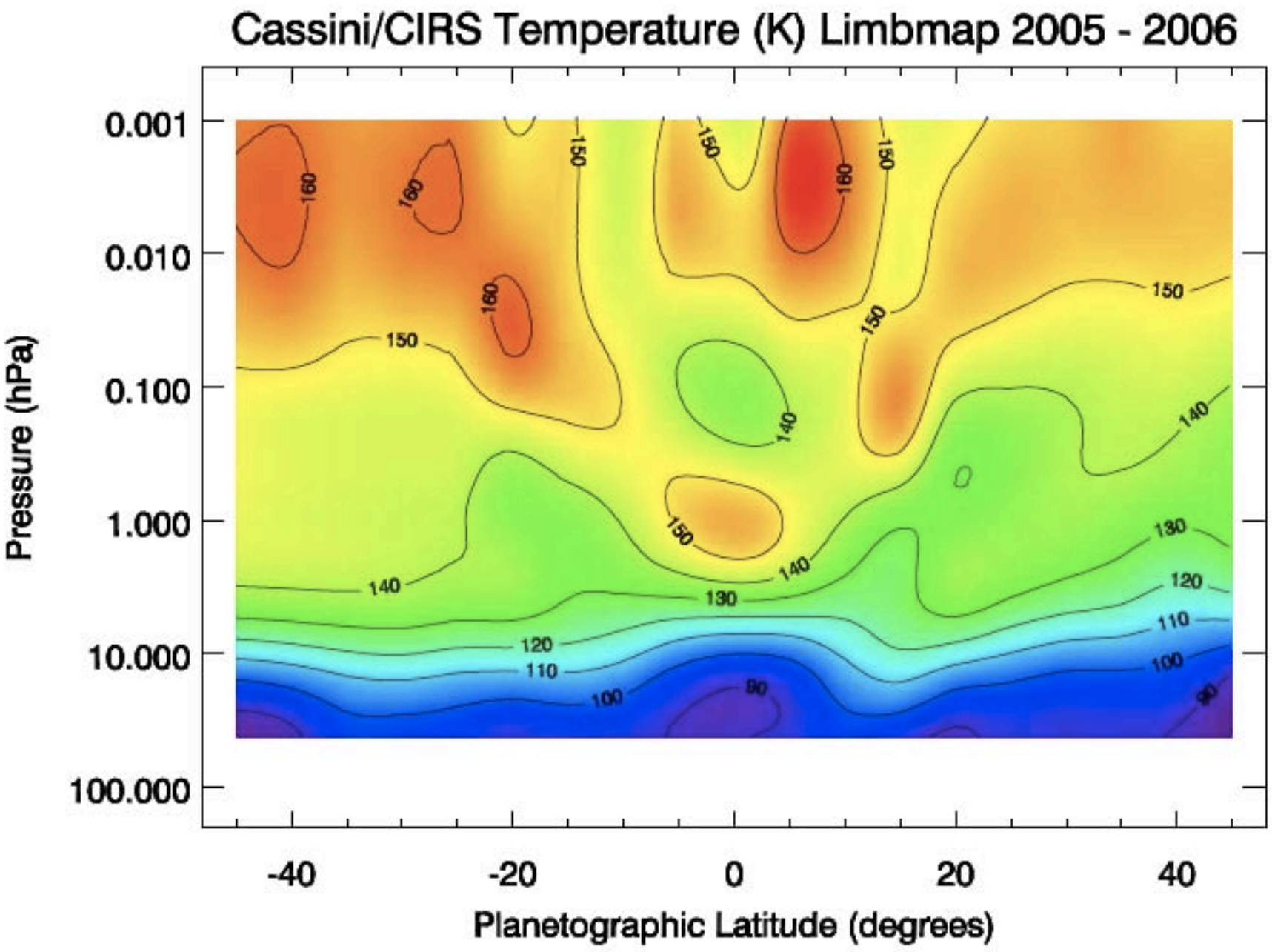


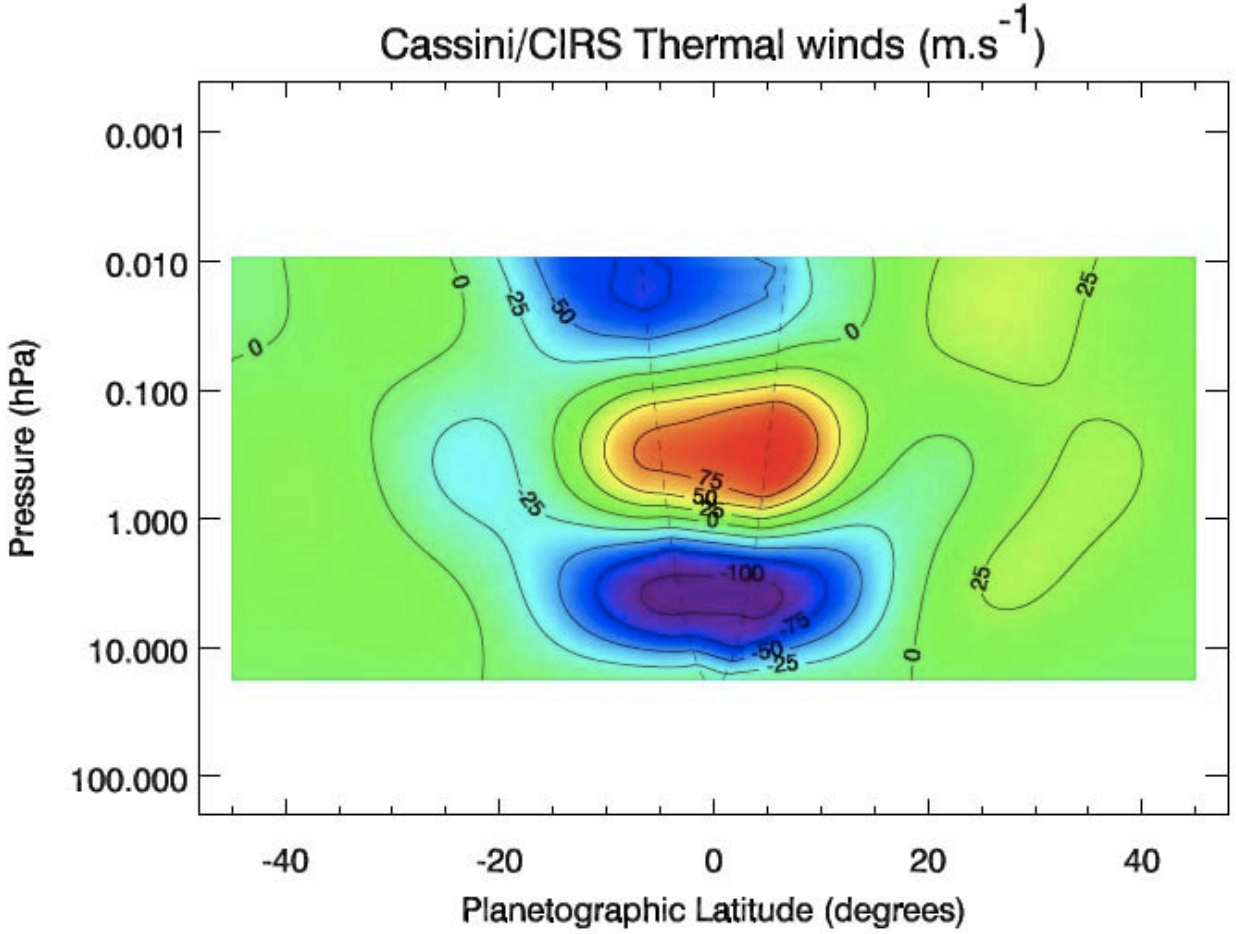


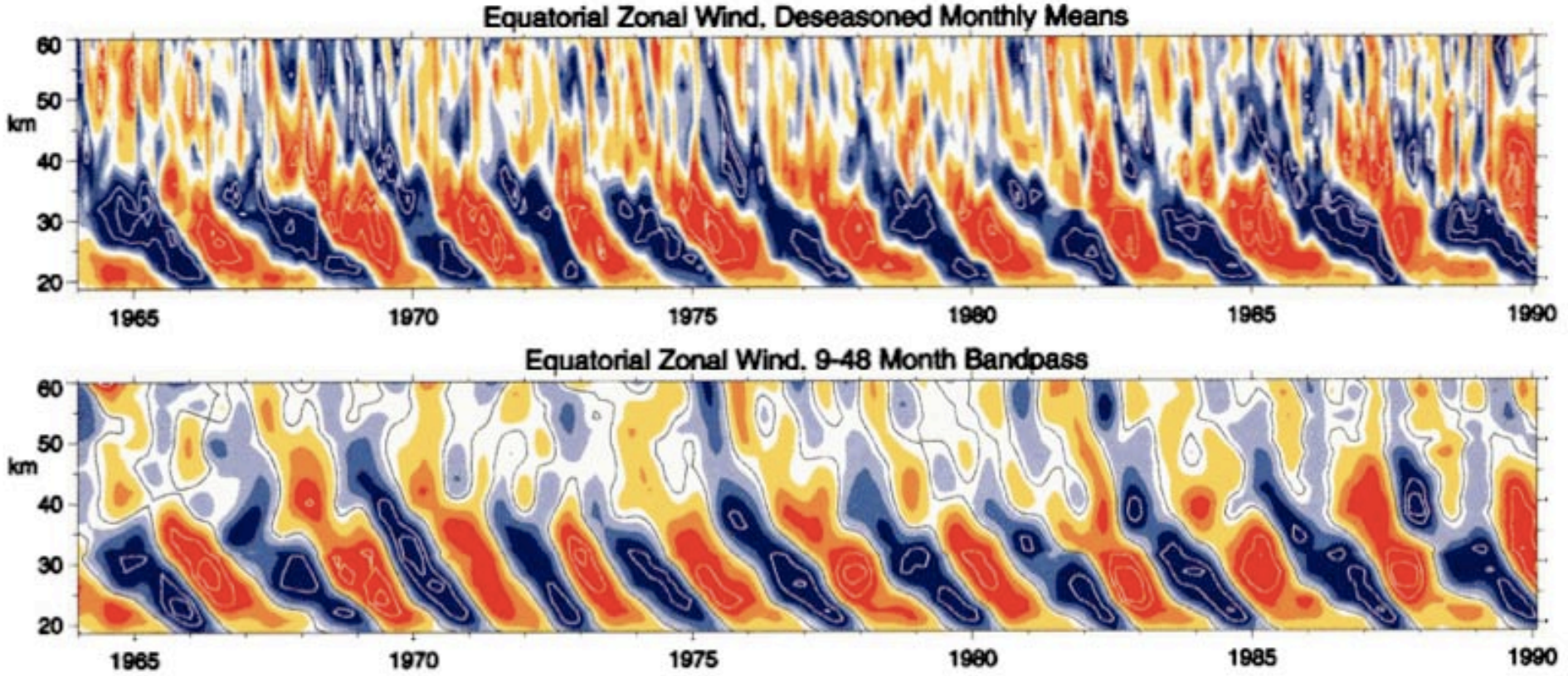


Orton et al. (Nature, 2008). Earth-based infrared images showing stratospheric temperatures in 1997 and 2006


Equinox
Northern solstice
Equinox
Southern solstice
2
0
−2
−4
−6
−8
−10
0
−1
−2
−3
ΔTb[7.8 μm] (K)
ΔTb[12.2 μm] (K)
1980
1985
1990
1995
2000
2005
Year


Cassini/CIRS Temperature (K) Limbmap 2005 - 2006
Pressure (hPa)
0.001
0.010
0.100
1.000
10.000
100.000
-40
-20
0
20
40
Planetographic Latitude (degrees)
160
150
140
130
120
110
100
90


Cassini/CIRS Thermal winds (m.s-1)
Pressure (hPa)
0.001
0.010
0.100
1.000
10.000
100.000
-40
-20
0
20
40
Planetographic Latitude (degrees)
0
25
50
75
-25
-50
-75
-100



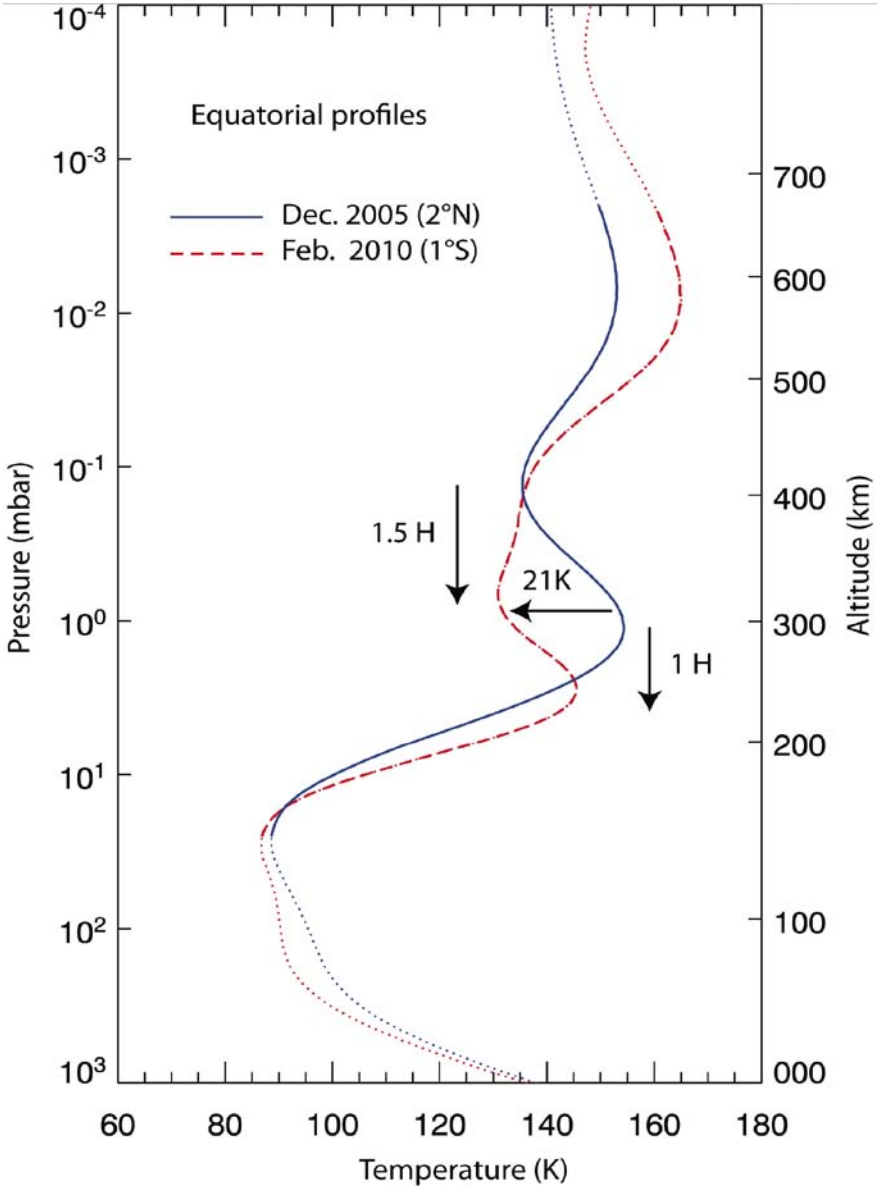
Earth's quasi-biennial oscillation (QBO). The pattern circles the Earth and varies with time. Equator is warmer than neighboring latitudes when westerly wind (red) is increasing with height

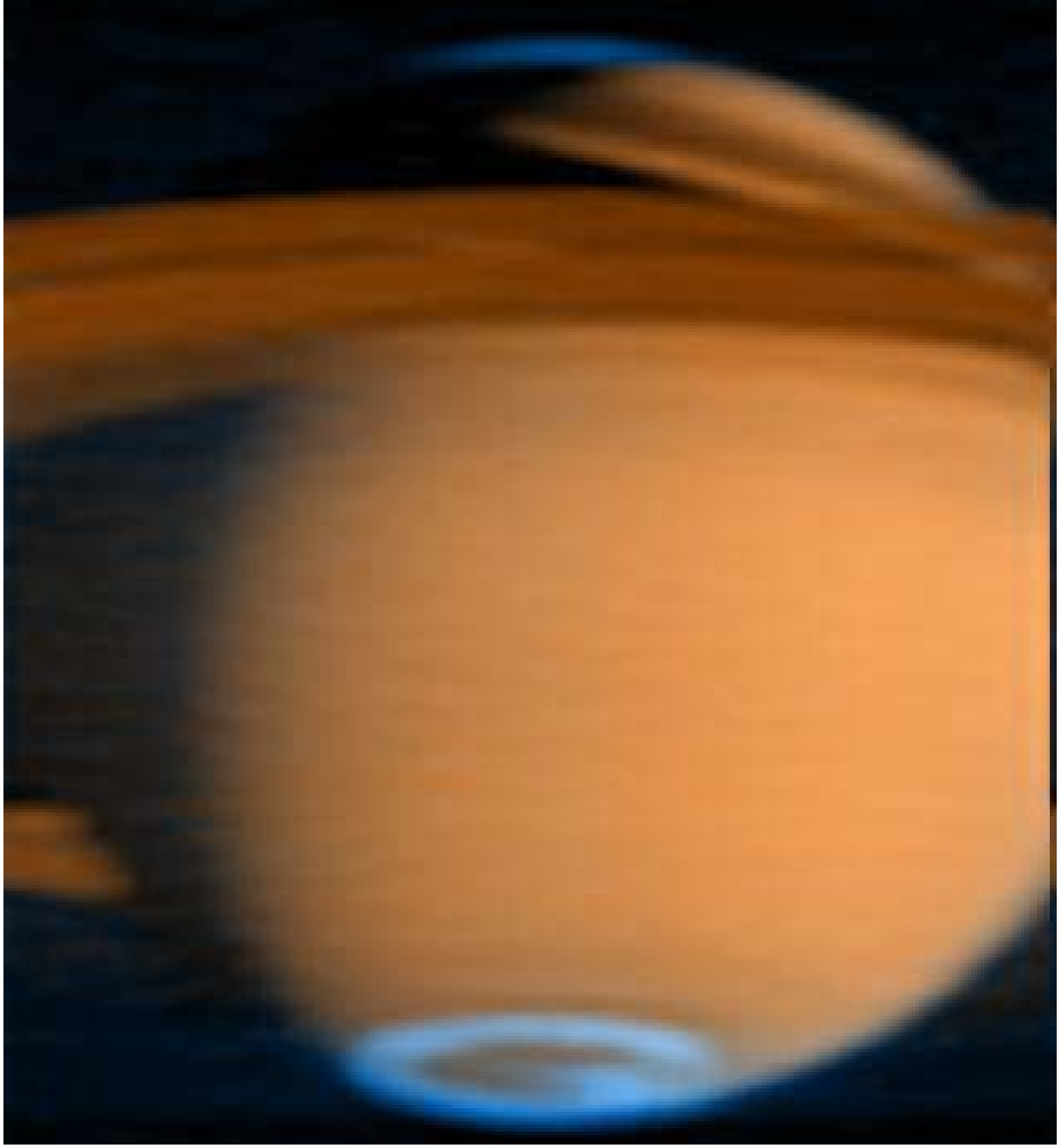
CIRS: Saturn's Equatorial Oscillation (cont.)

Observed temporal behavior from CIRS mid-IR limb sounding: Guerlet *et al.* (2010)

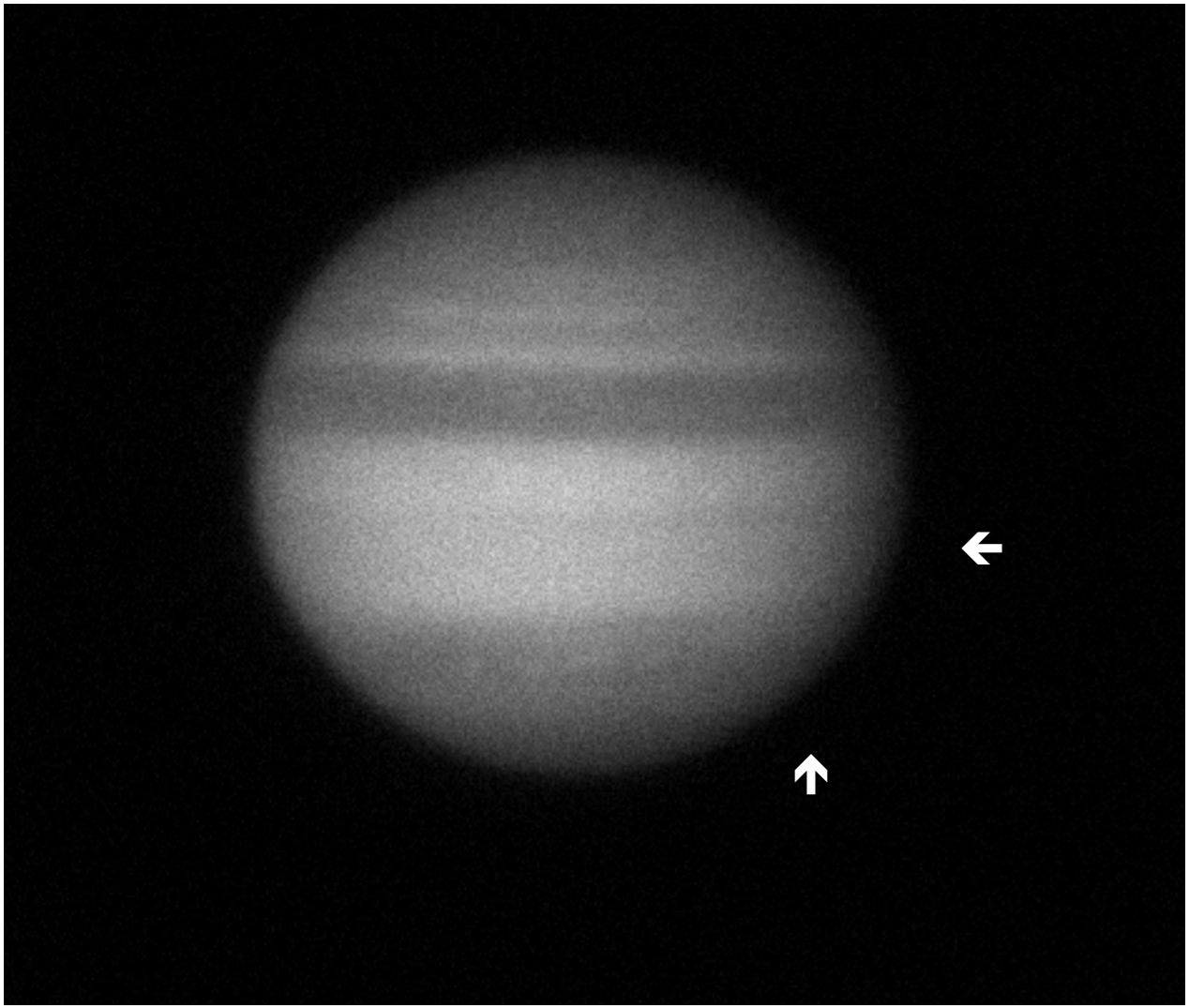
•Descending pattern reminiscent of terrestrial quasi-biennial and semi-annual oscillations in Earth's equatorial middle atmosphere.
•Descent of ~ 1 H (scale height) over 4 years is roughly consistent with 4-5 H descent over 15 years needed to produce cyclic pattern inferred from ground-based observations (previous slide).
•Radio occultation soundings show similar behavior extending to lower altitudes.

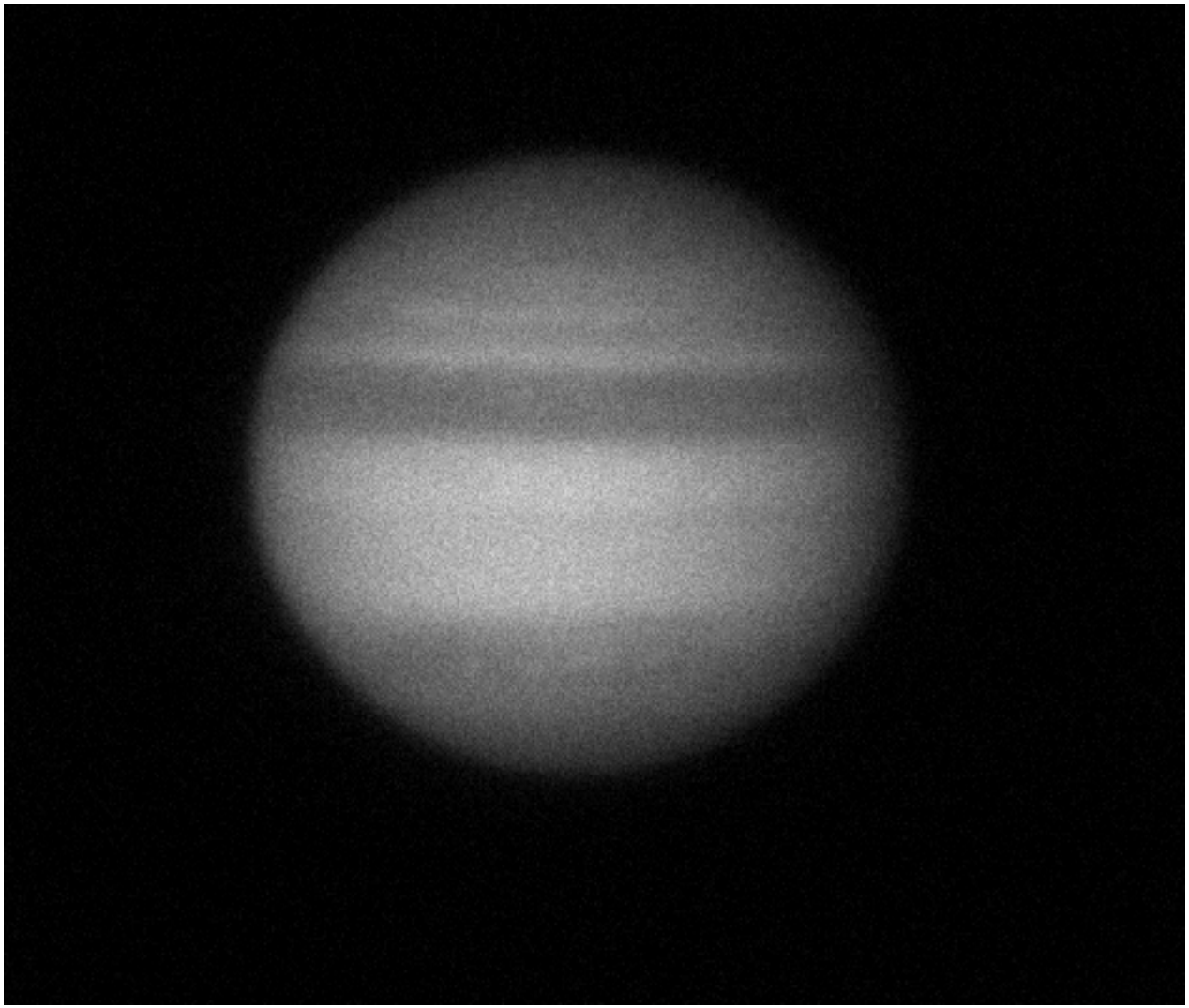
Saturn's equatorial oscillation: another Earth analog.



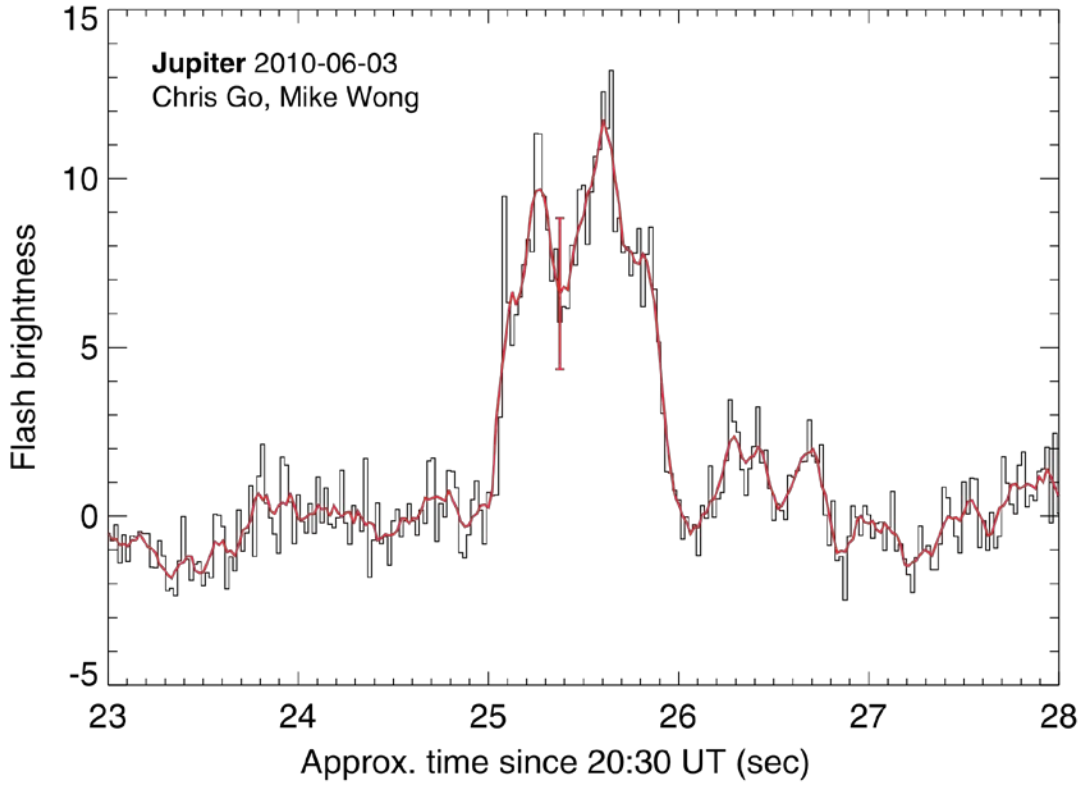


80-hour aurora movie in false color





Impact Lightcurves



Earth 2008-07-25
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