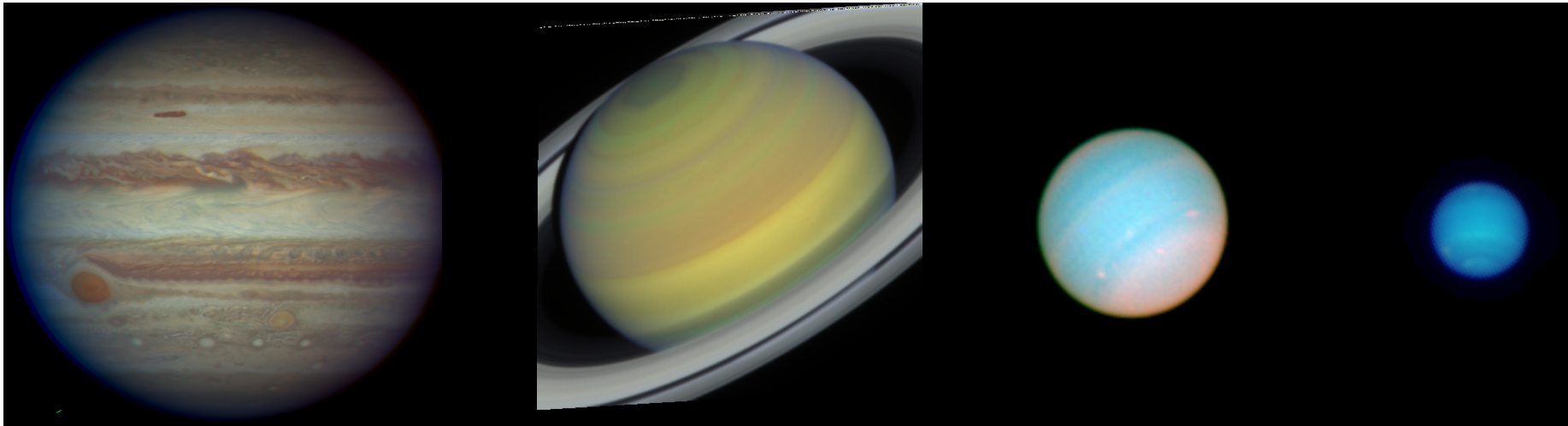


Observing the Solar System's Giant Planets in the UVOIR

Amy Simon (NASA GSFC)

ATLAST Seminar

12/9/2015

Outline

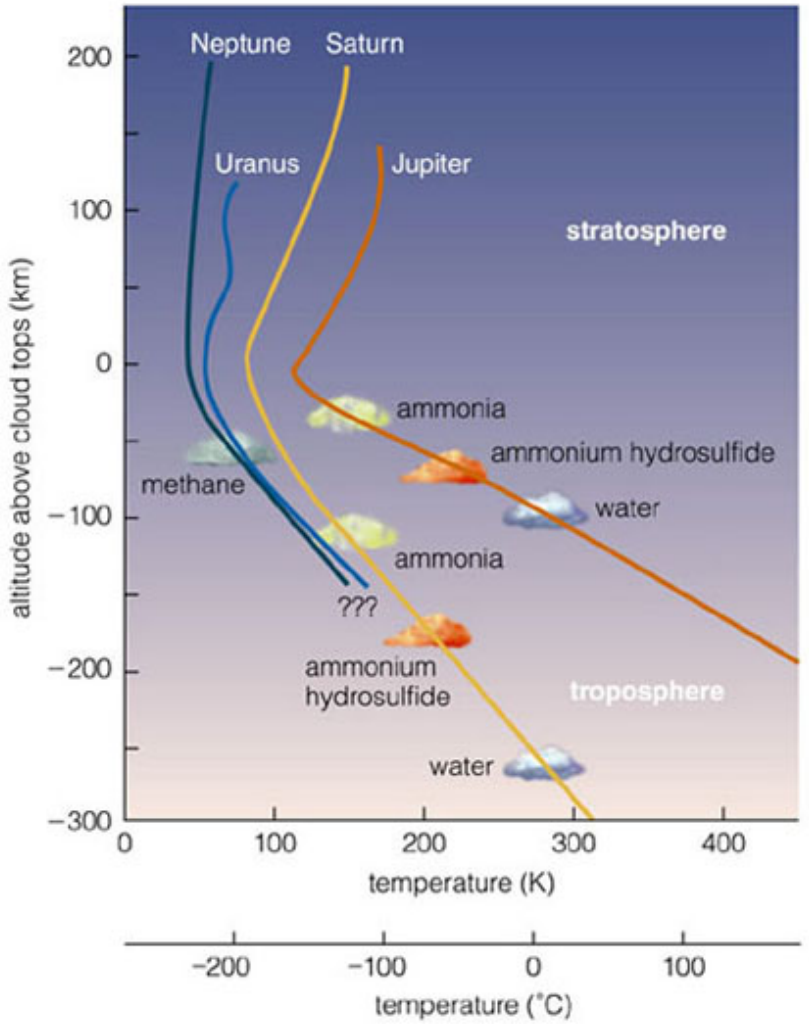
- What do we learn from the UVOIR?
- Types of observations
  - Light curves
  - Feature tracking/monitoring
  - Global mapping
- Why not other types of facilities?
  - Ground-based w/ AO
  - Target-driven deep space missions

Observing in the UVOIR

- Cloud pressures (and composition) vary by planet

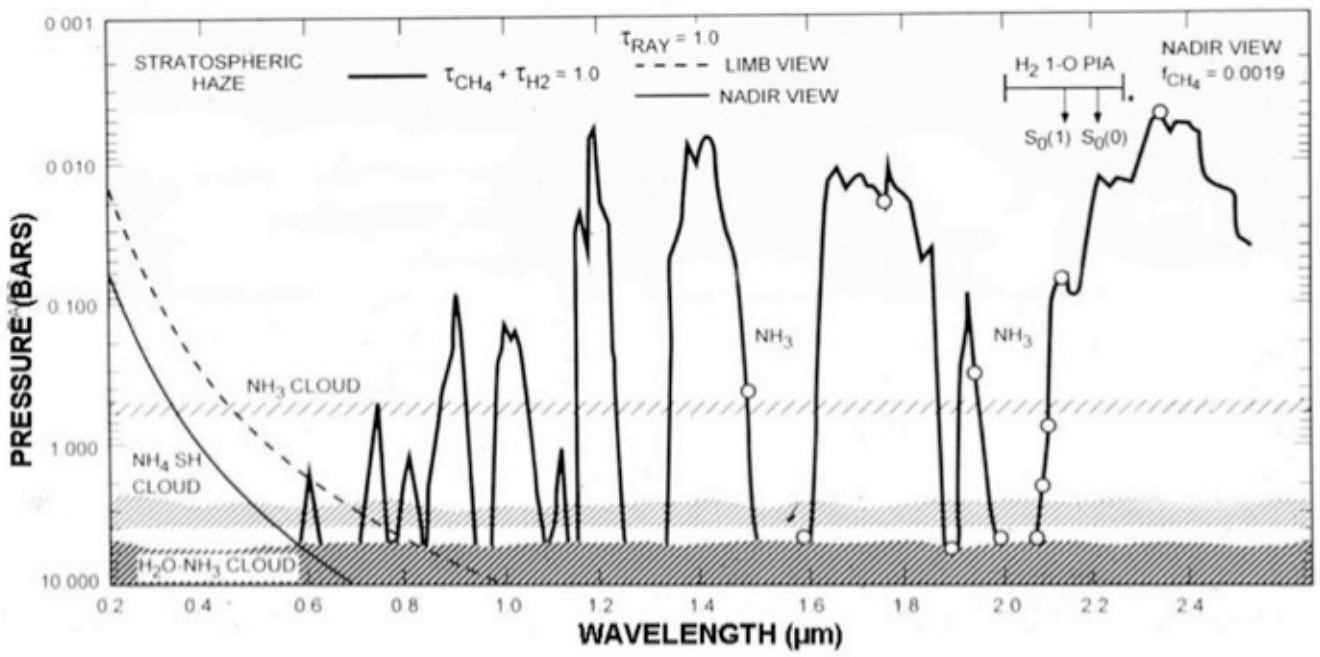
- Remote sensing can constrain
  - Cloud vertical structure
  - Dynamics
  - Composition
  - Seasonal effects
  - Interior structure

… and much more



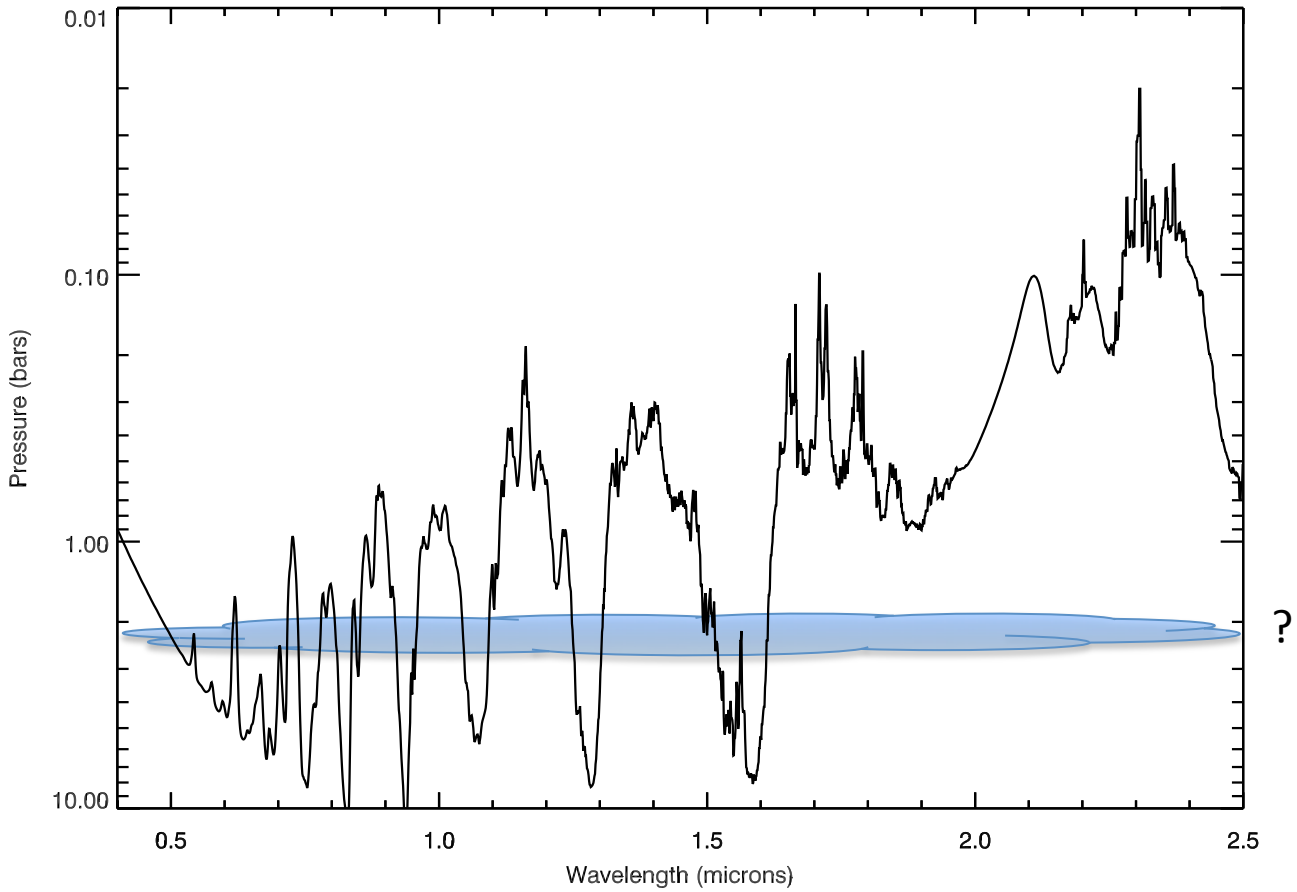
Different wavelengths sense different altitudes

Jupiter



Cloud-free transmission curve:
CH_4 absorption, H_2-H_2 and H_2-He collision induced absorption, Rayleigh scattering

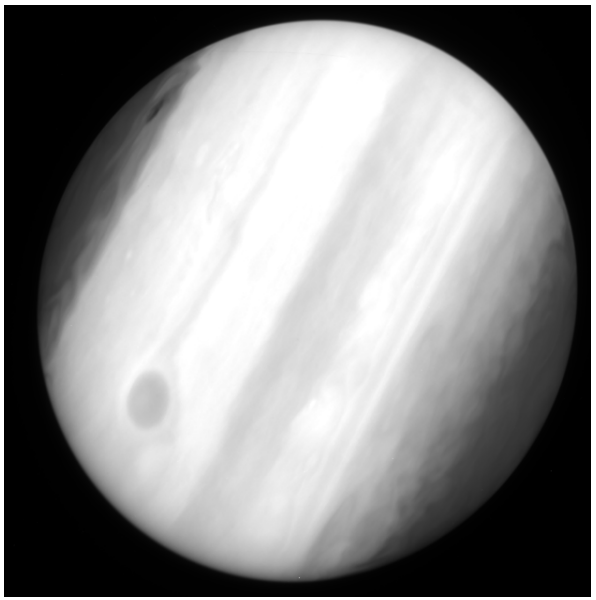
Uranus Transmission Curve



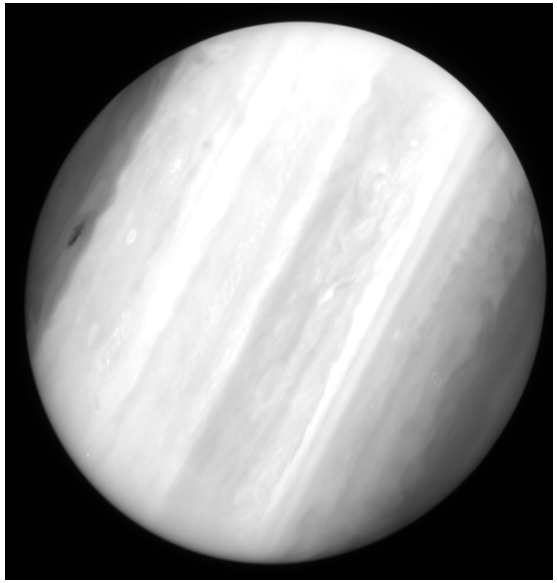
Cloud-free transmission curve:
CH_4 absorption, H_2-H_2 and H_2-He collision induced absorption, Rayleigh scattering

Can sense to higher pressures, but clouds are also deeper

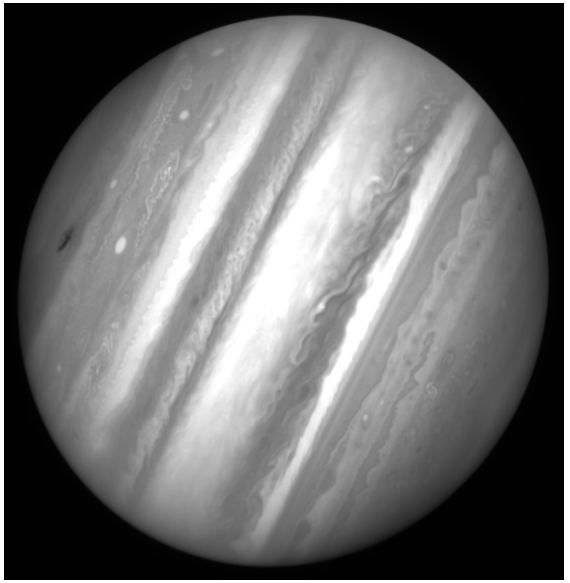
What does this look like?



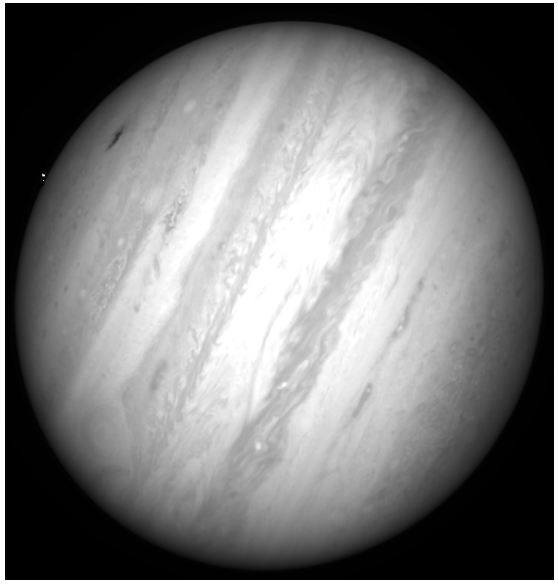
225 nm



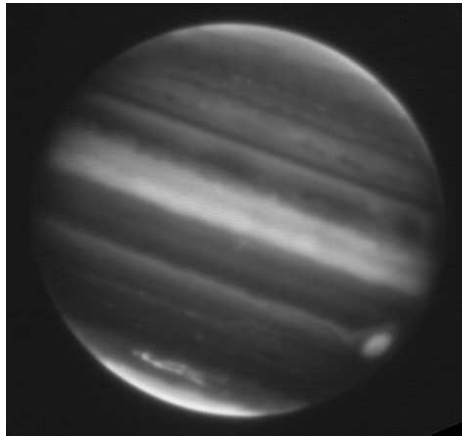
275 nm



378 nm

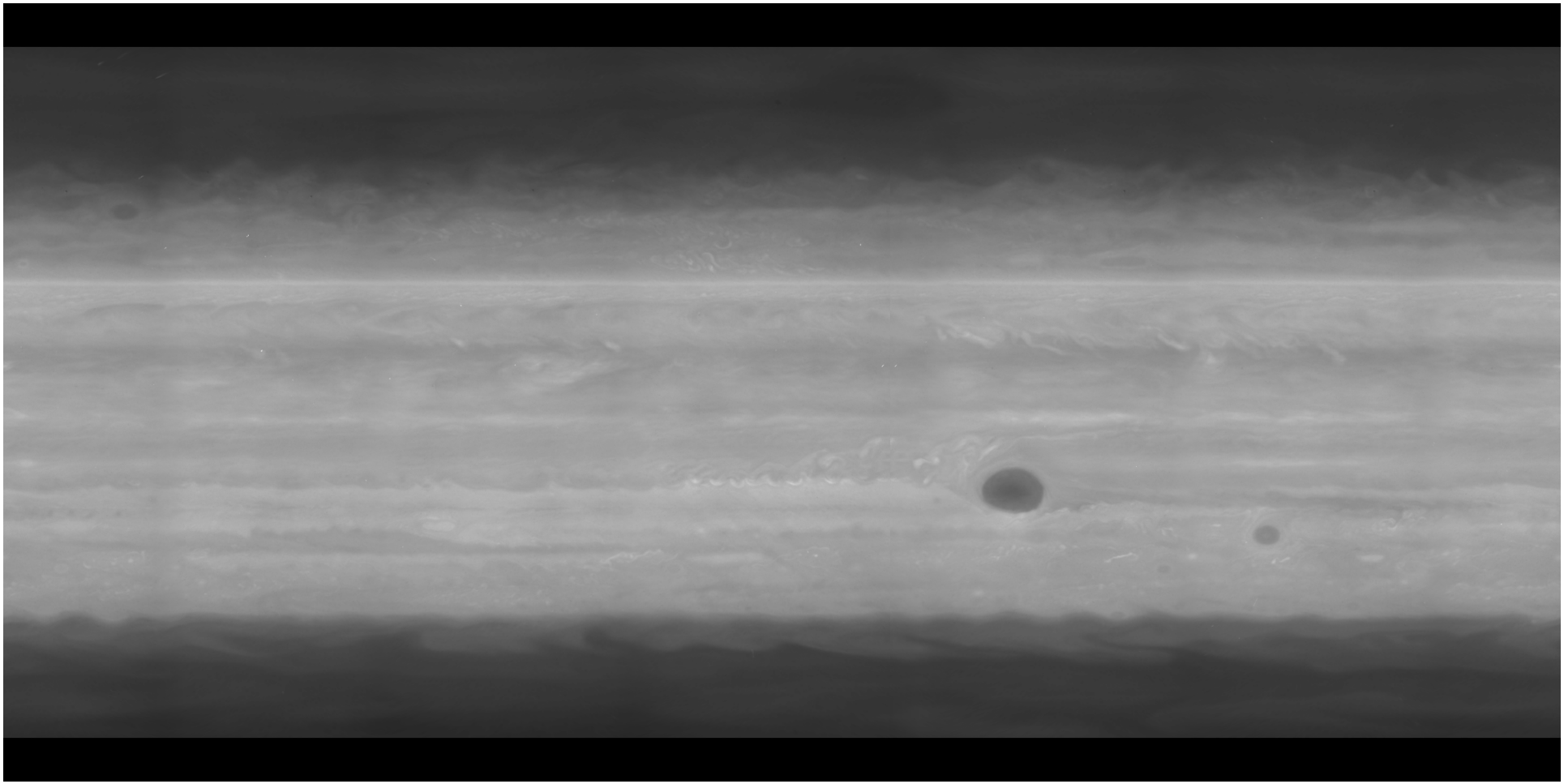


634 nm

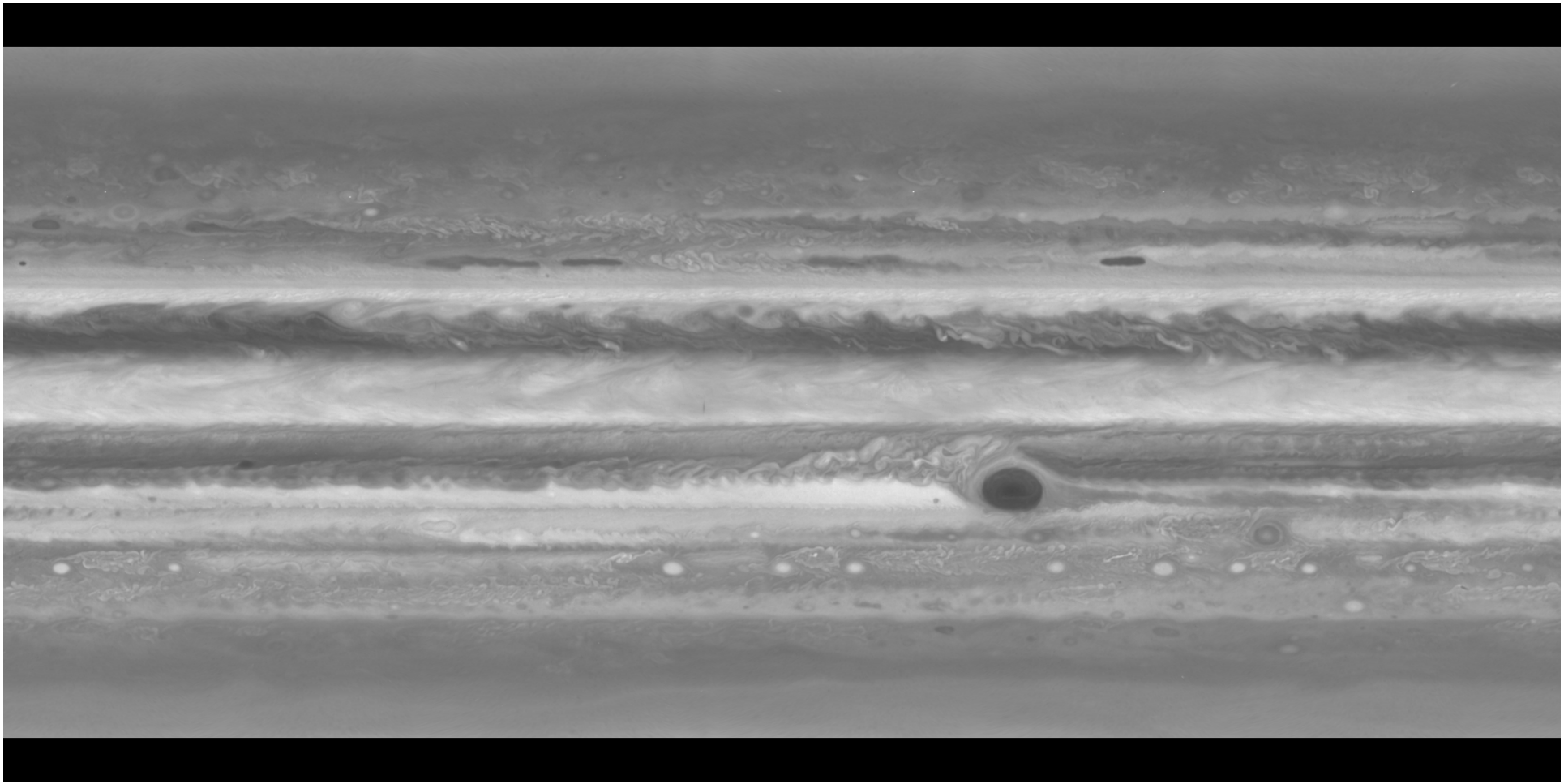


2.12 µm

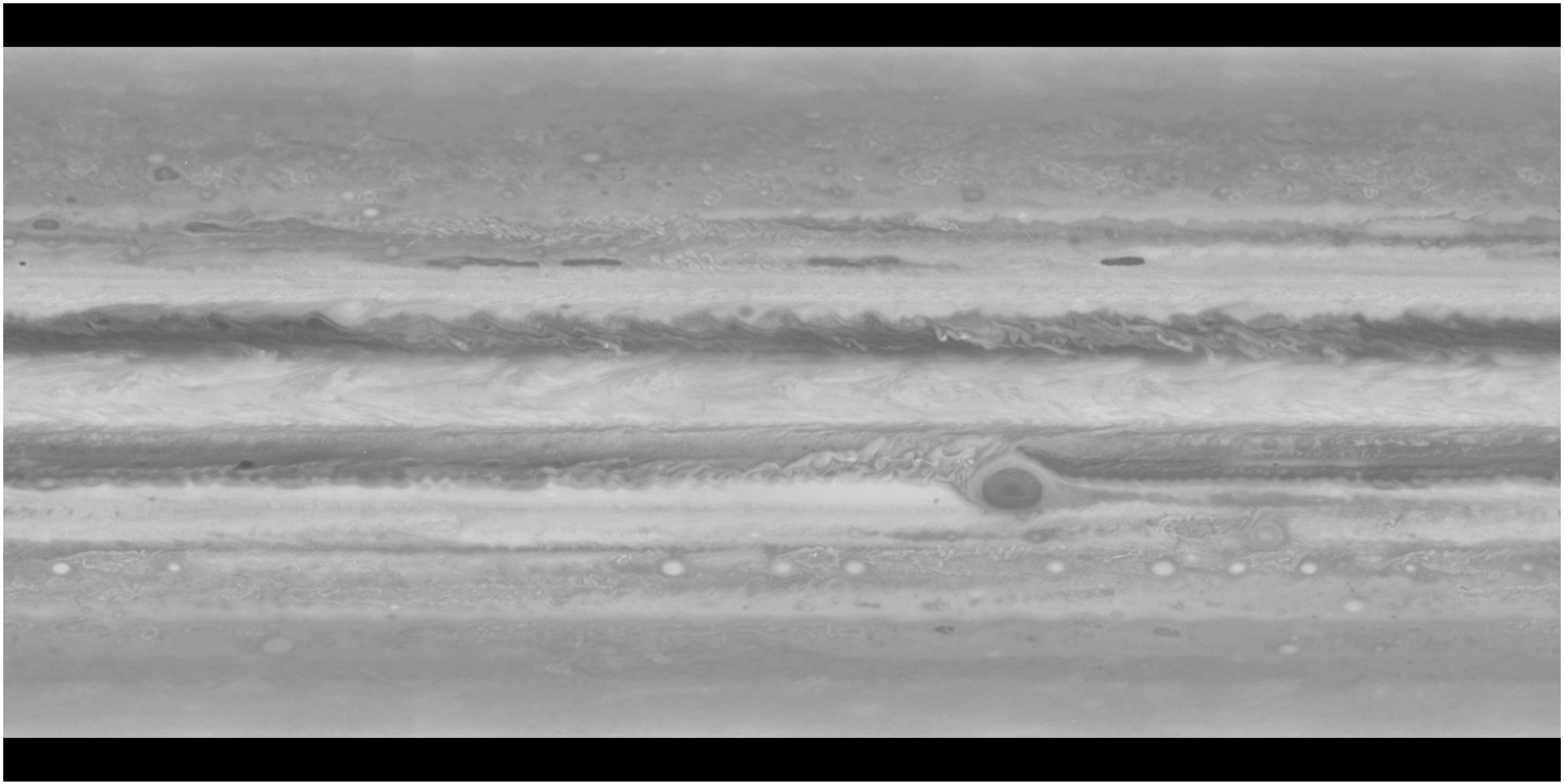
Near UV (275 nm)



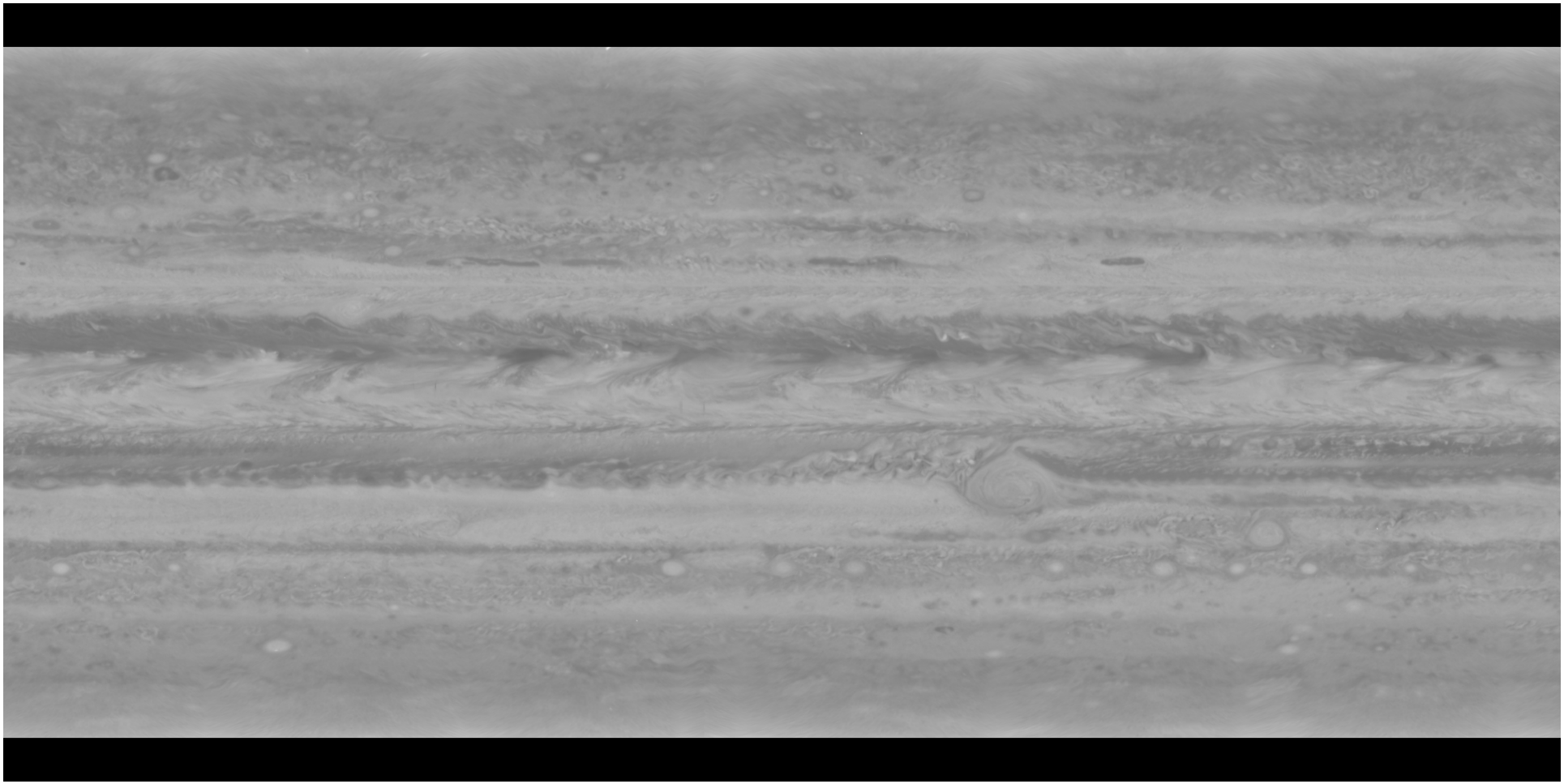
Blue/Violet (395 nm)



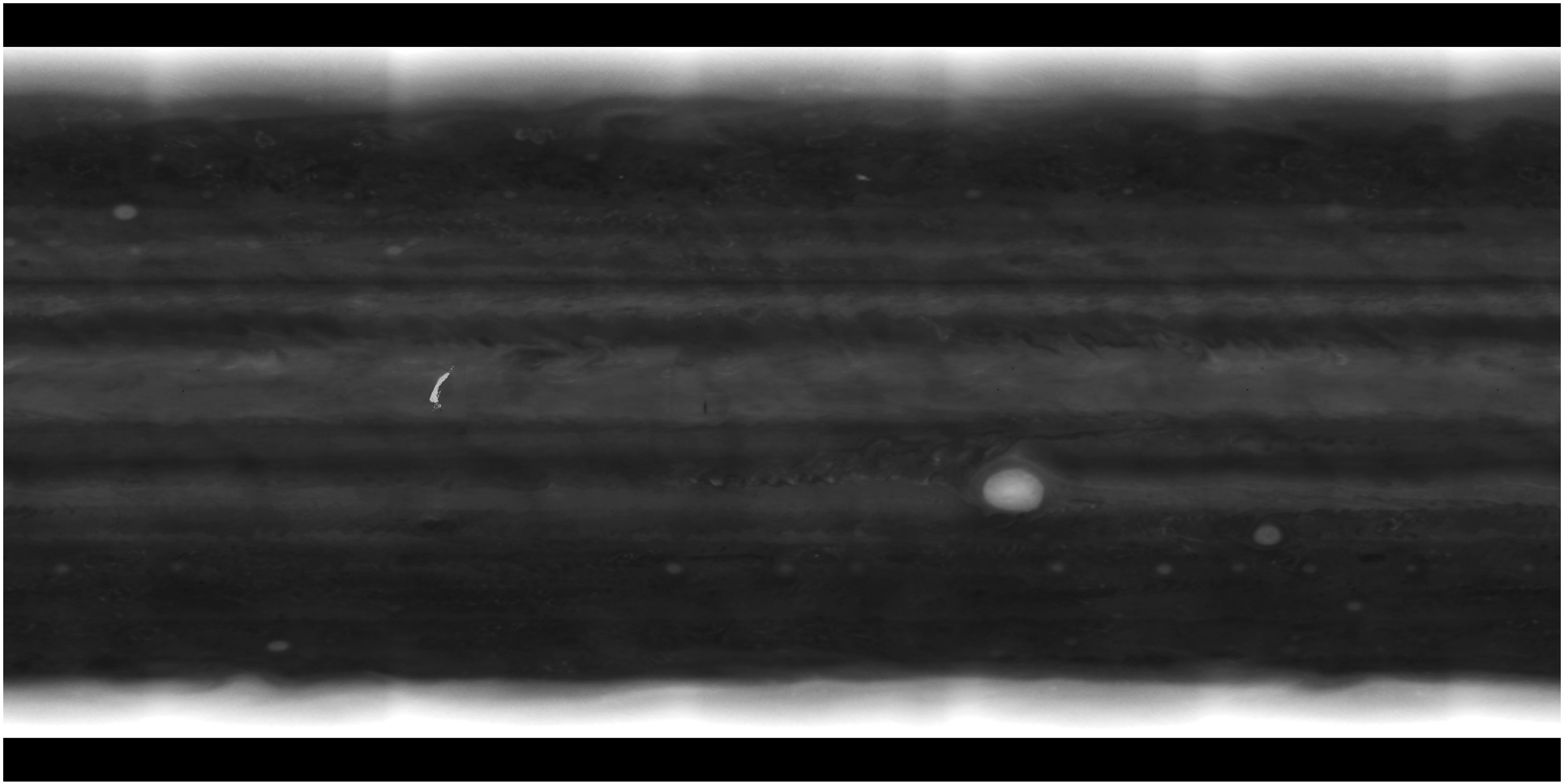
Green (502 nm)



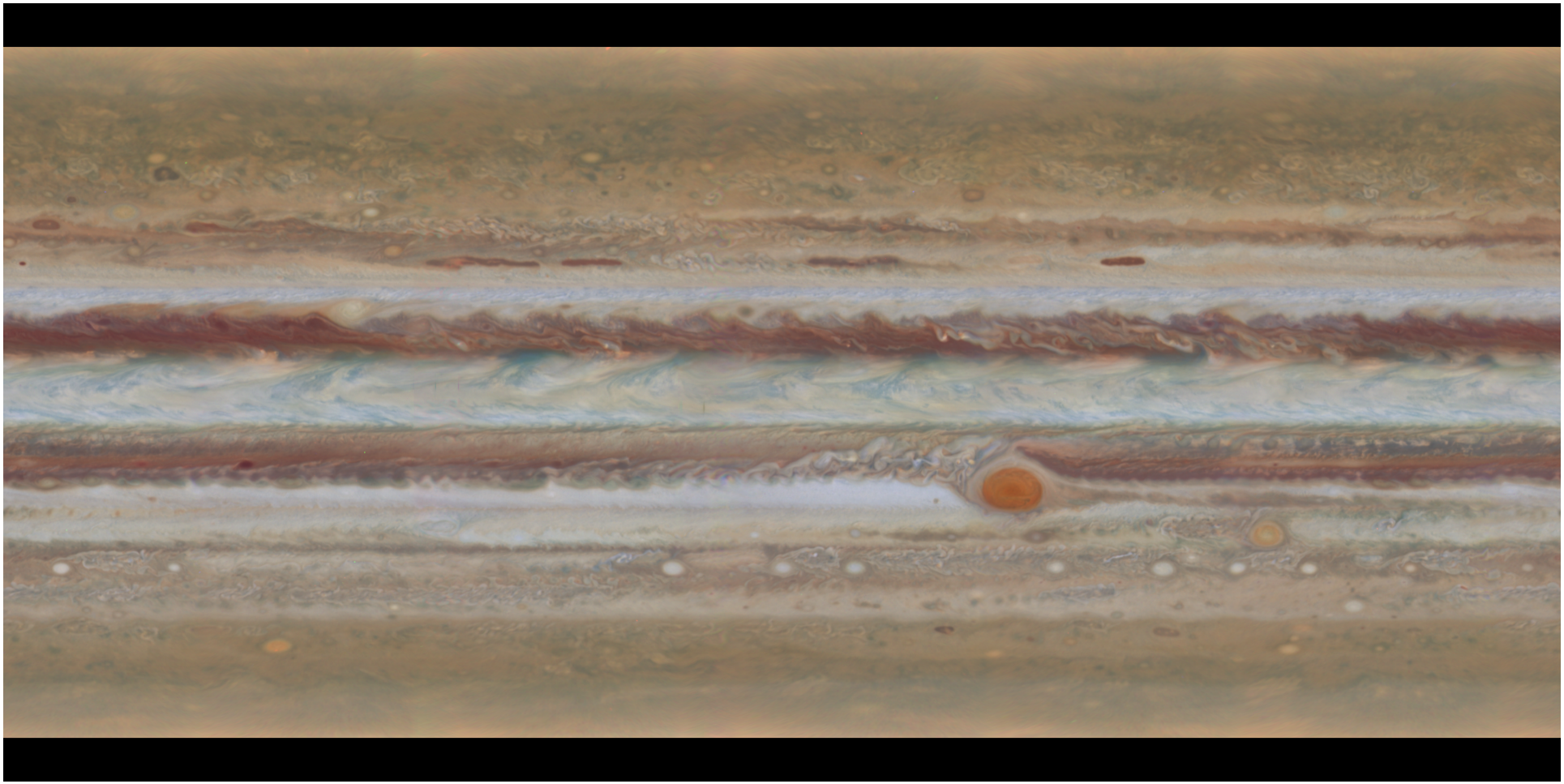
Red (631 nm)



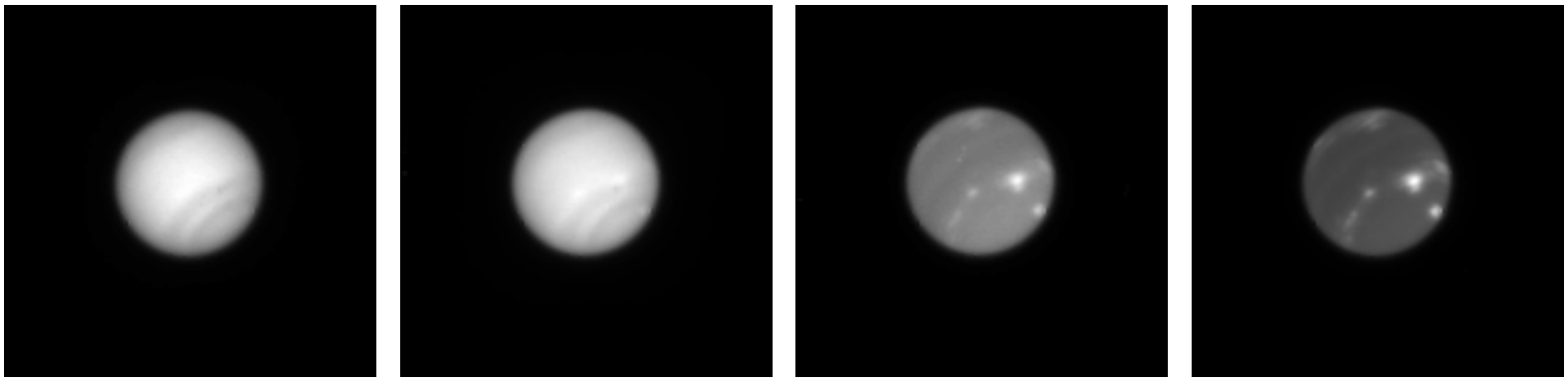
Methane band (889 nm)



“True” Color



Neptune



467 547 657 763

Types of Observations

Light curves

- Generate a light curve to observe brightness oscillations
  - Planetary Rotation Period + Differential Rotation - Clouds
  - Solar Oscillations
  - Planetary Oscillations – the holy grail!

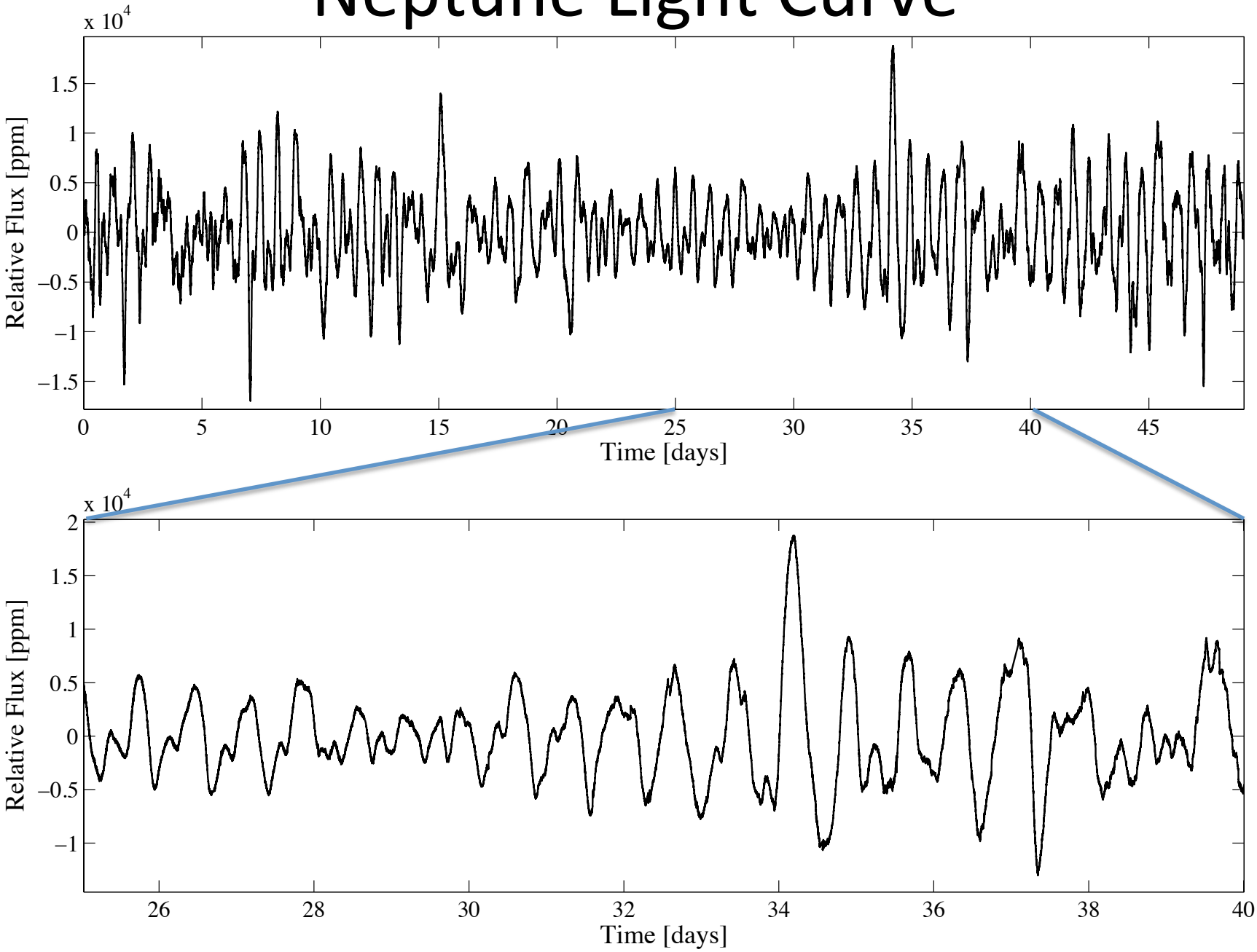
- We expect the planets to have spherical harmonic oscillations
  - Predicted by Vorontsov 1976, Bercovici & Schubert 1987
  - Change in radius should change the reflected solar flux (Mosser 1995) and ring structures (Marley & Porco 1993)

- Original attempts for Jupiter failed, however
  - Detected acoustic modes in Doppler observations of Jupiter (Gaulme 2011)
  - Possibly detected via waves observed in Saturn's C-ring (Hedman & Nicholson 2013)

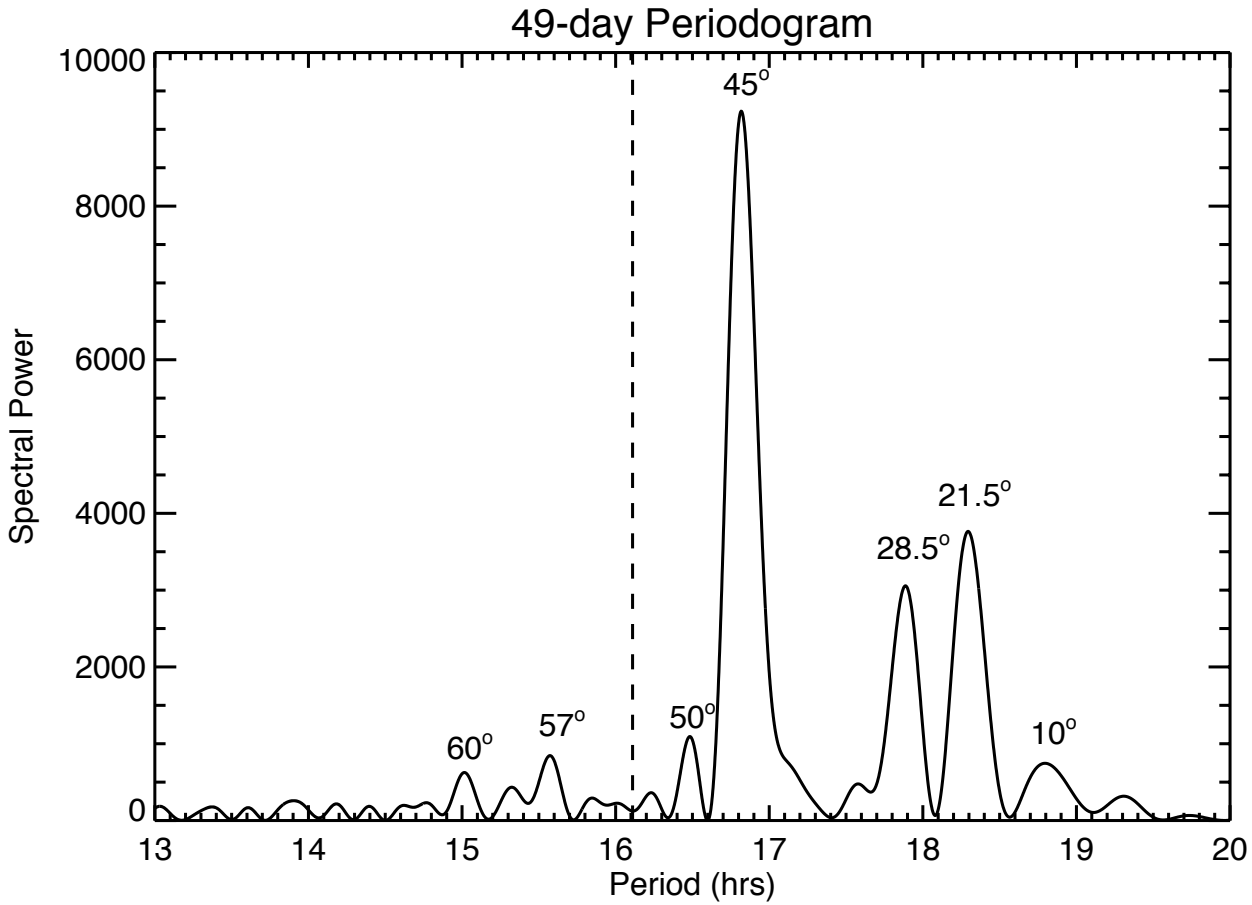
Kepler – visible panchrom curve of Neptune

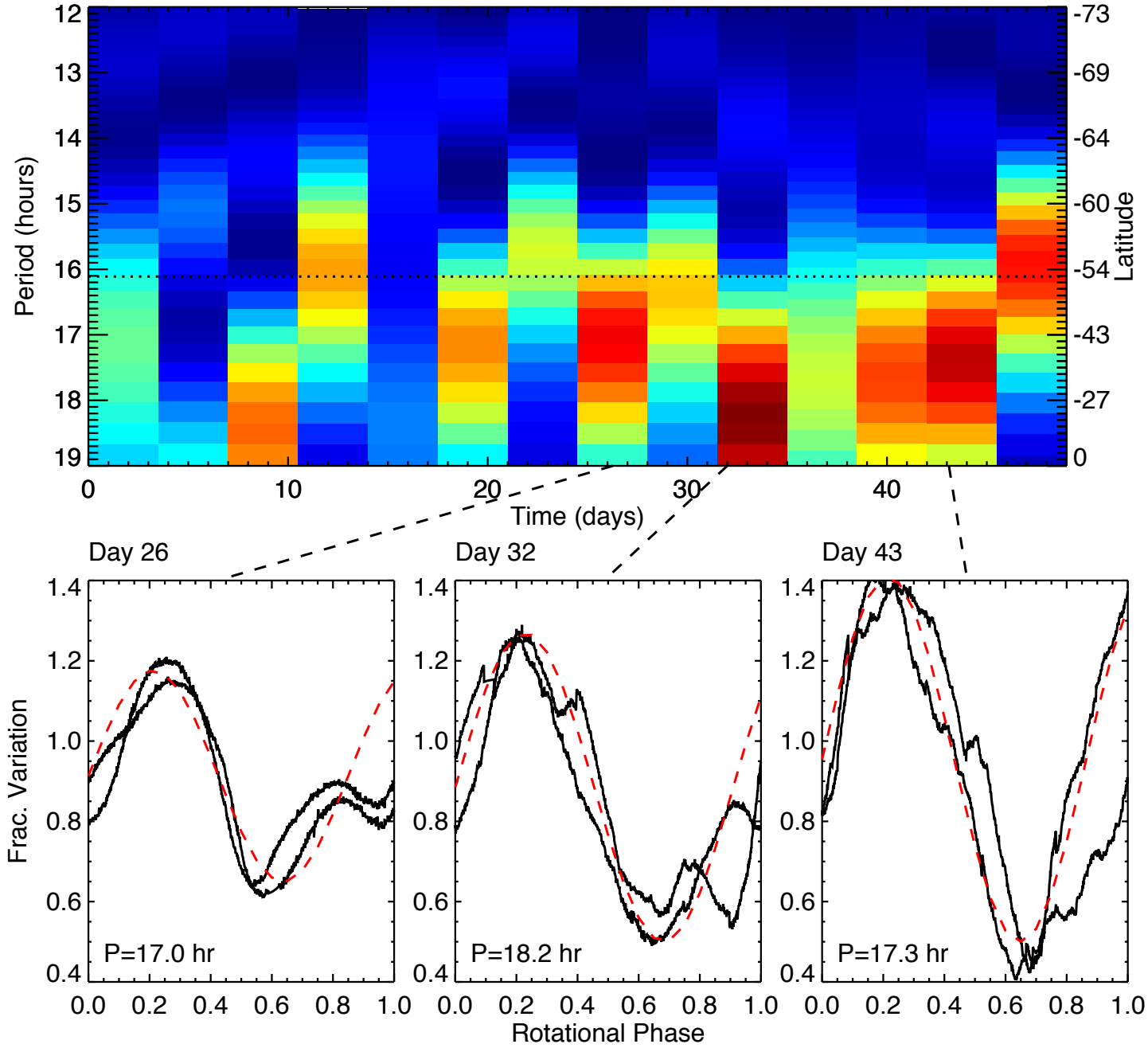
- 49-day observation with 98% coverage, 1-min cadence

Neptune Light Curve

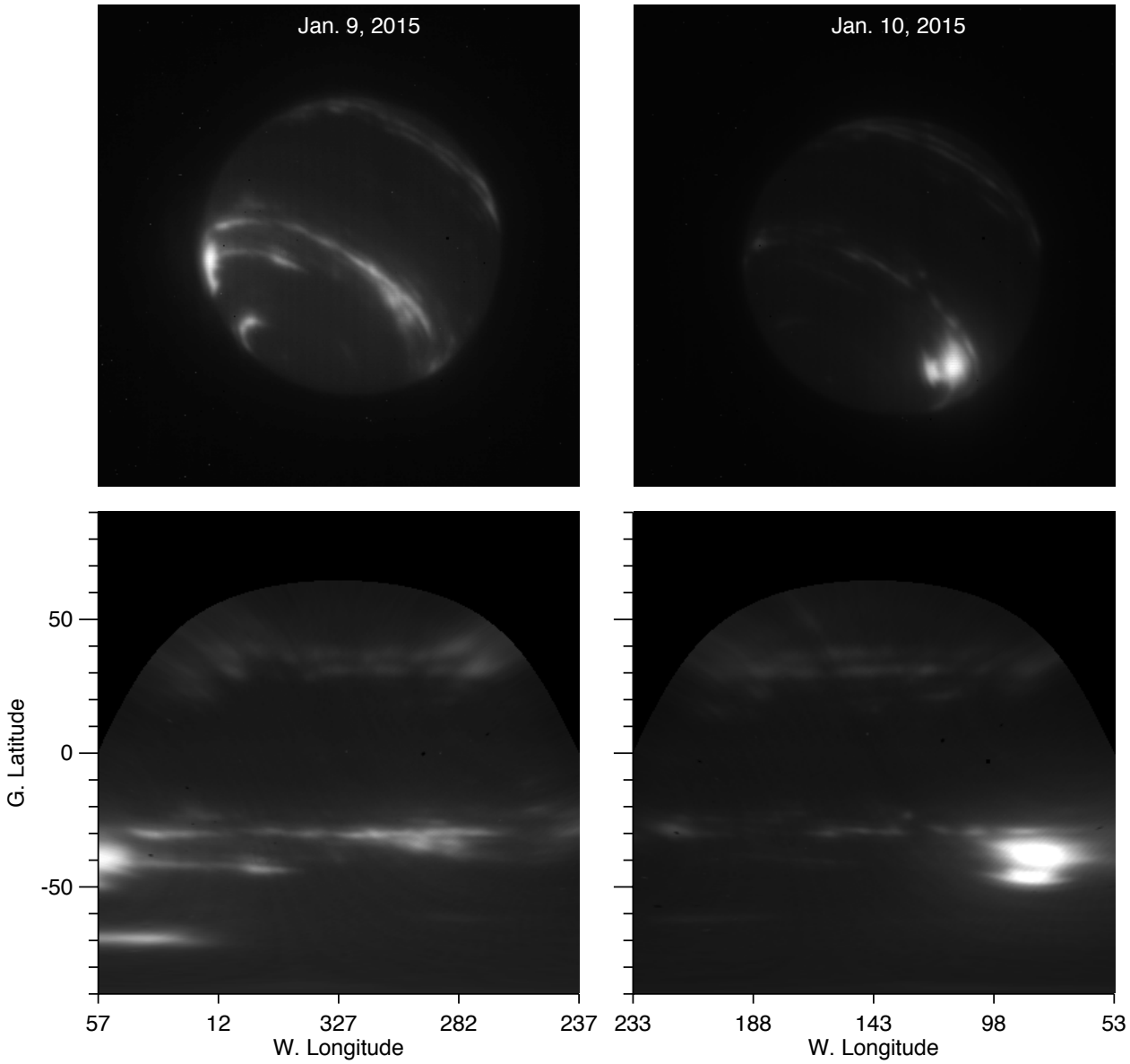


Periodograms




Period (hours)
12
13
14
15
16
17
18
19
Latitude
-73
-69
-64
-60
-54
-43
-27
0
0
10
20
30
40
Time (days)
Day 26
Day 32
Day 43
Frac. Variation
1.4
1.2
1.0
0.8
0.6
0.4
P=17.0 hr
P=18.2 hr
P=17.3 hr
0.0
0.2
0.4
0.6
0.8
1.0
Rotational Phase

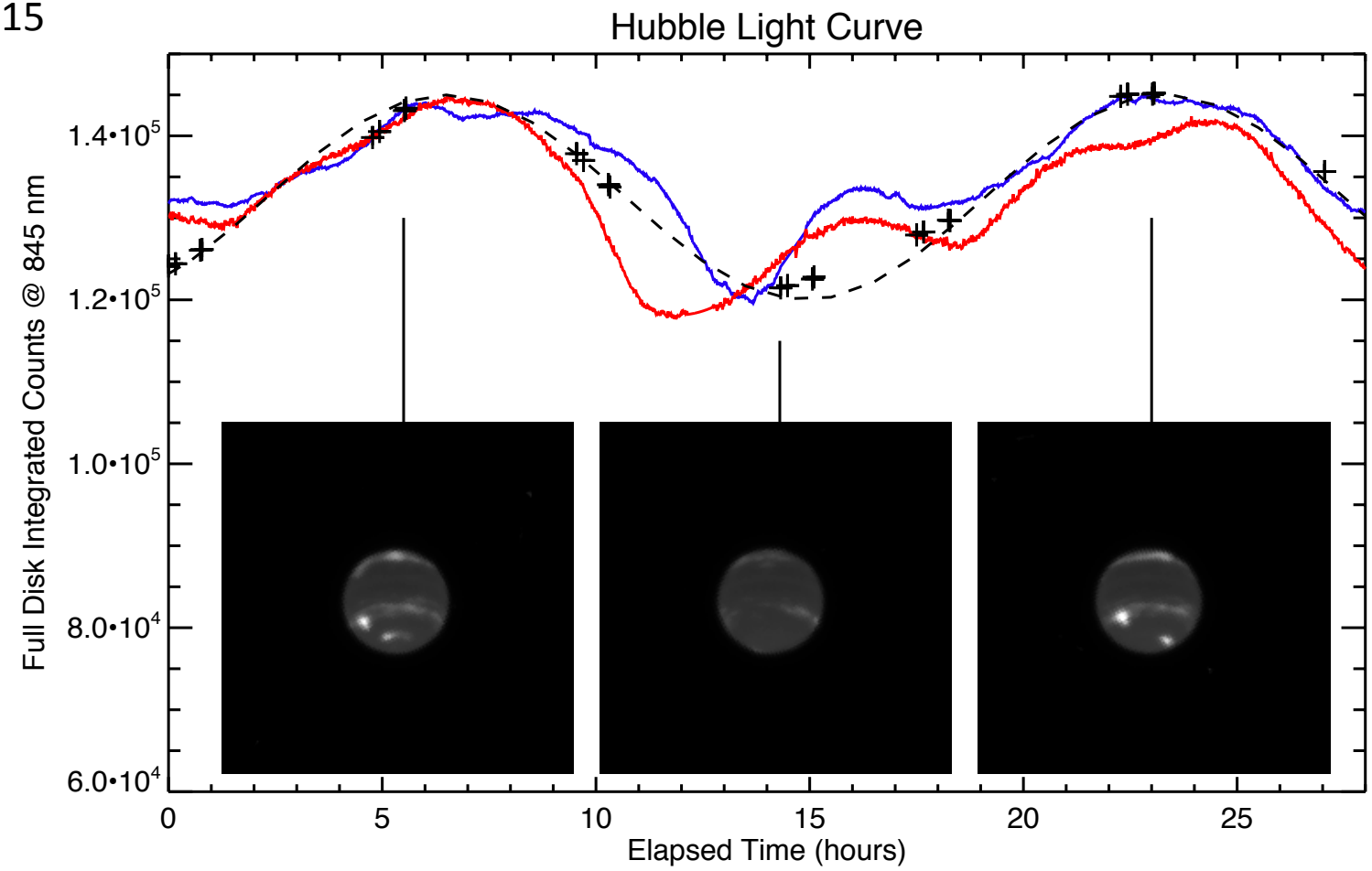
Keck for Context



H-band
1.6 µm

Hubble for Context

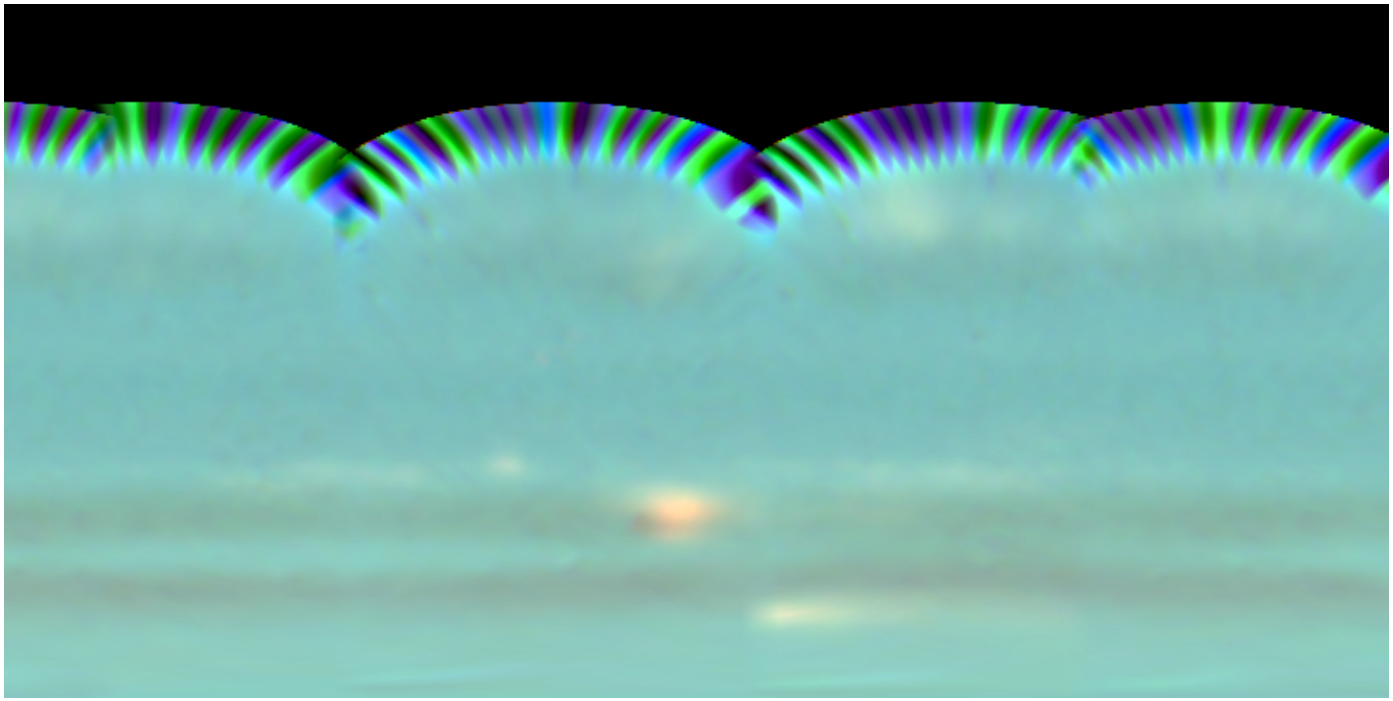
Sept. 2015



Use Neptune's variability to inform brown dwarf and directly imaged exoplanet analysis

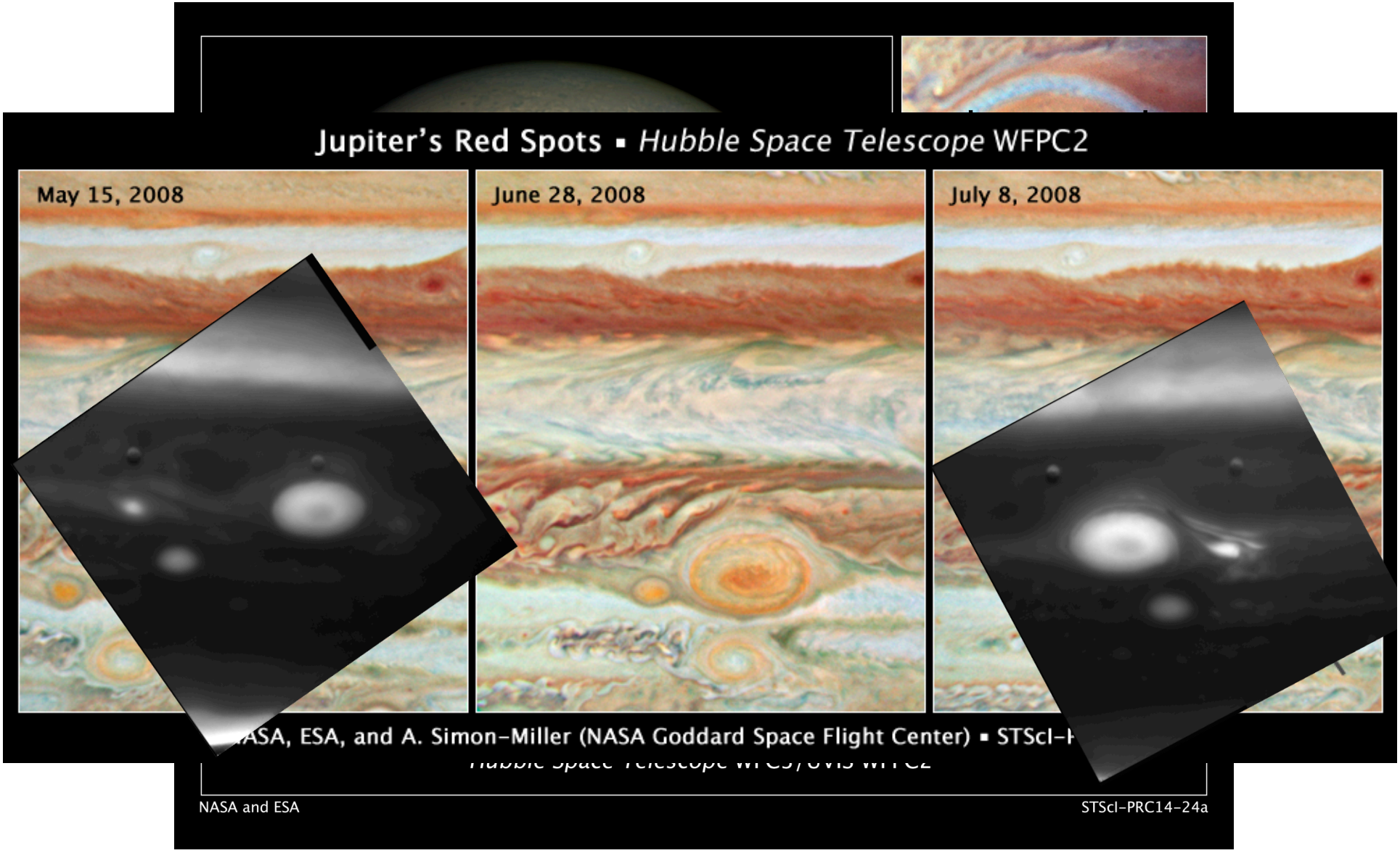
Large storm persists for >12 months, although smaller clouds come and go

Hubble Visible View



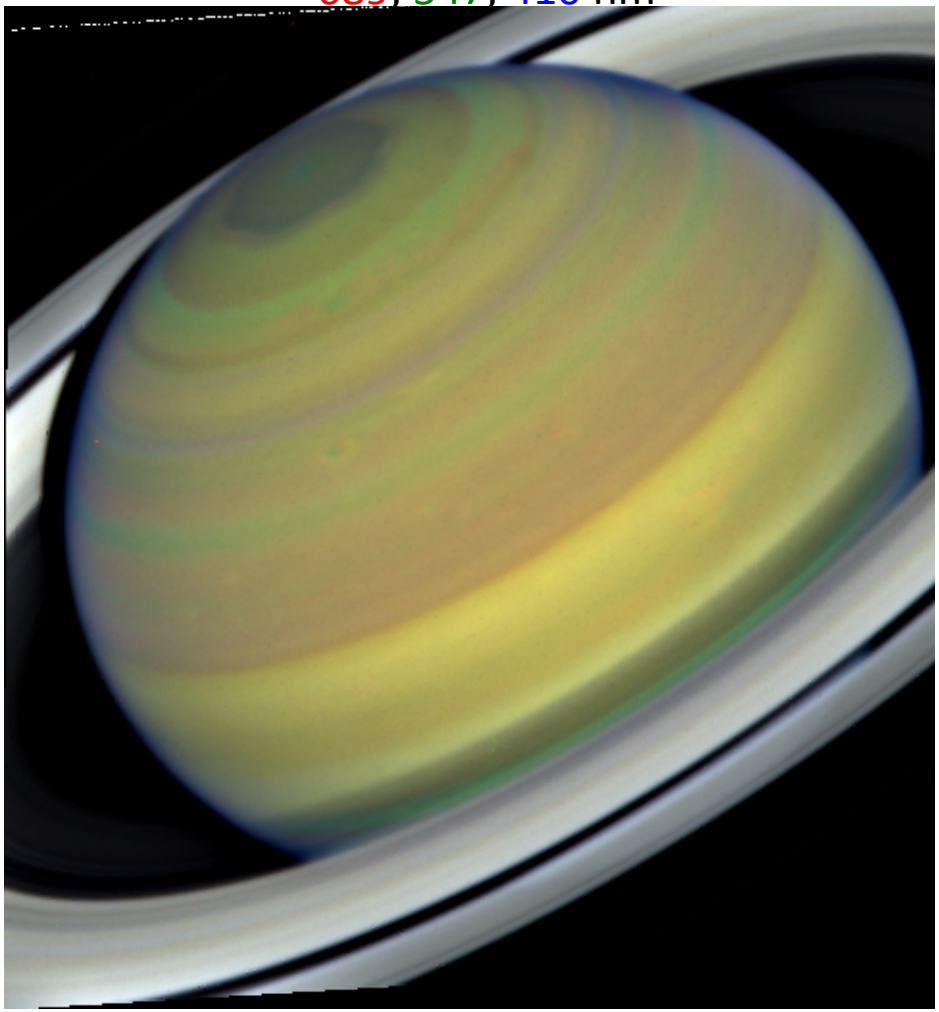
Slightly sharpened, with an unsharp mask

Feature tracking and monitoring

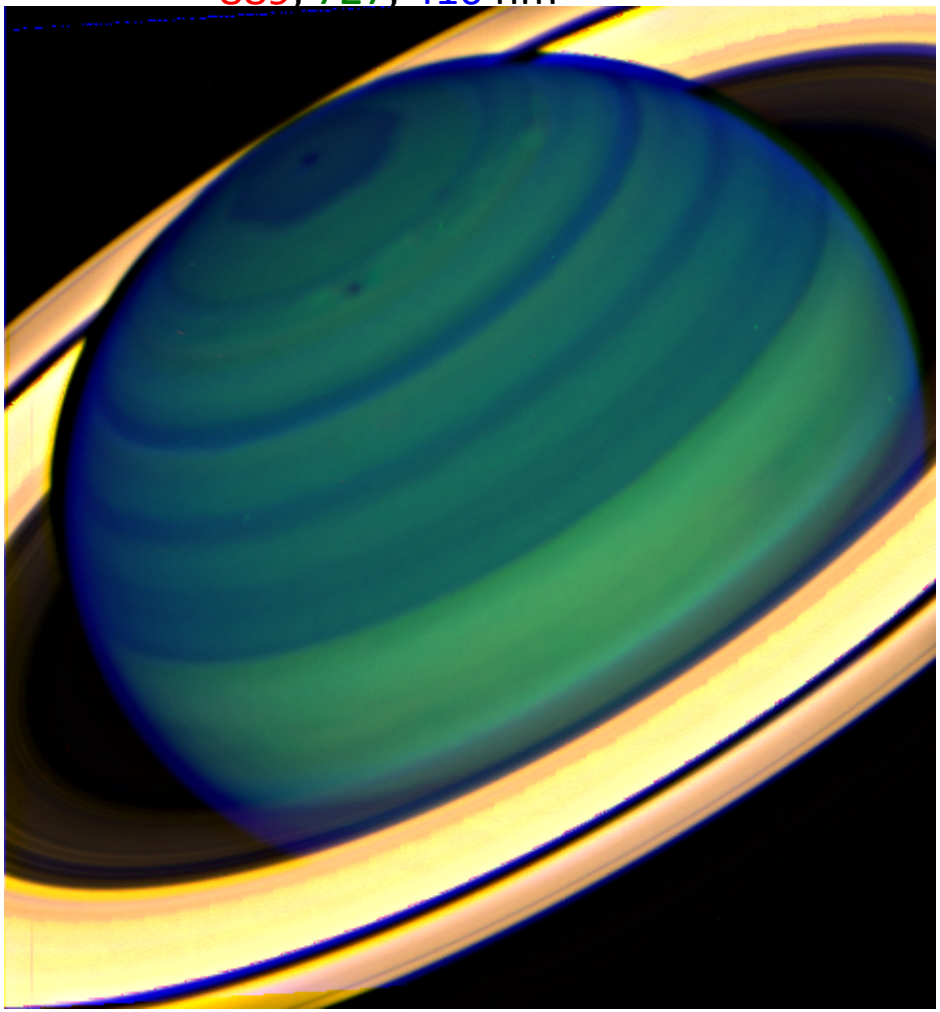


Saturn storms

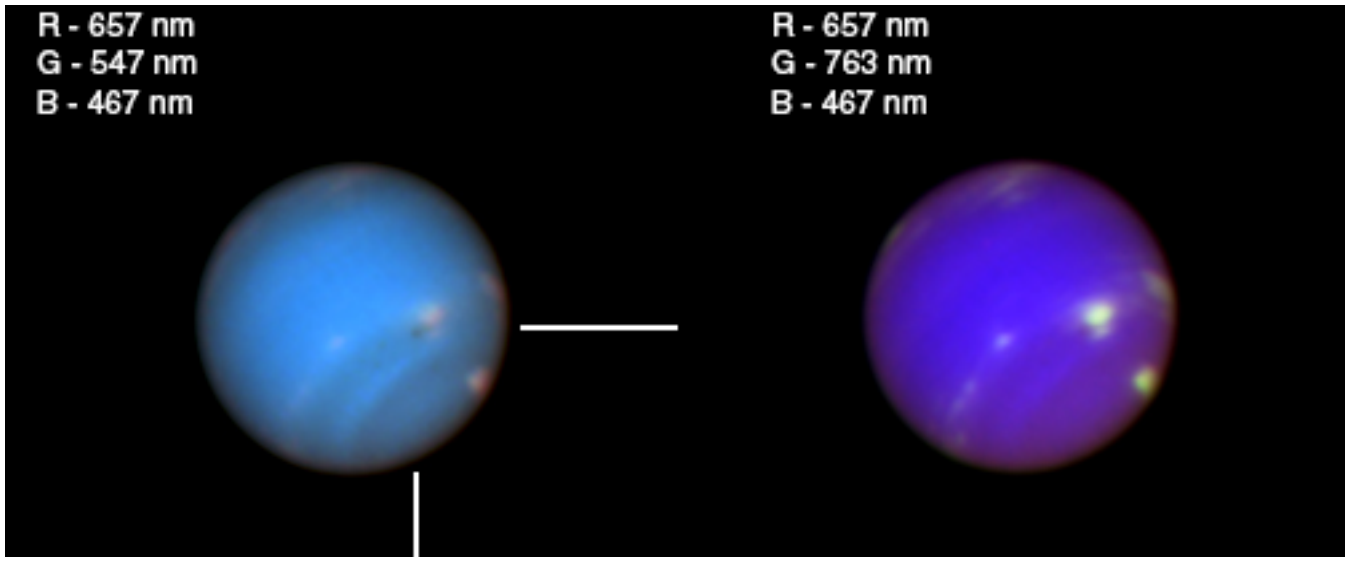
689, 547, 410 nm



889, 727, 410 nm

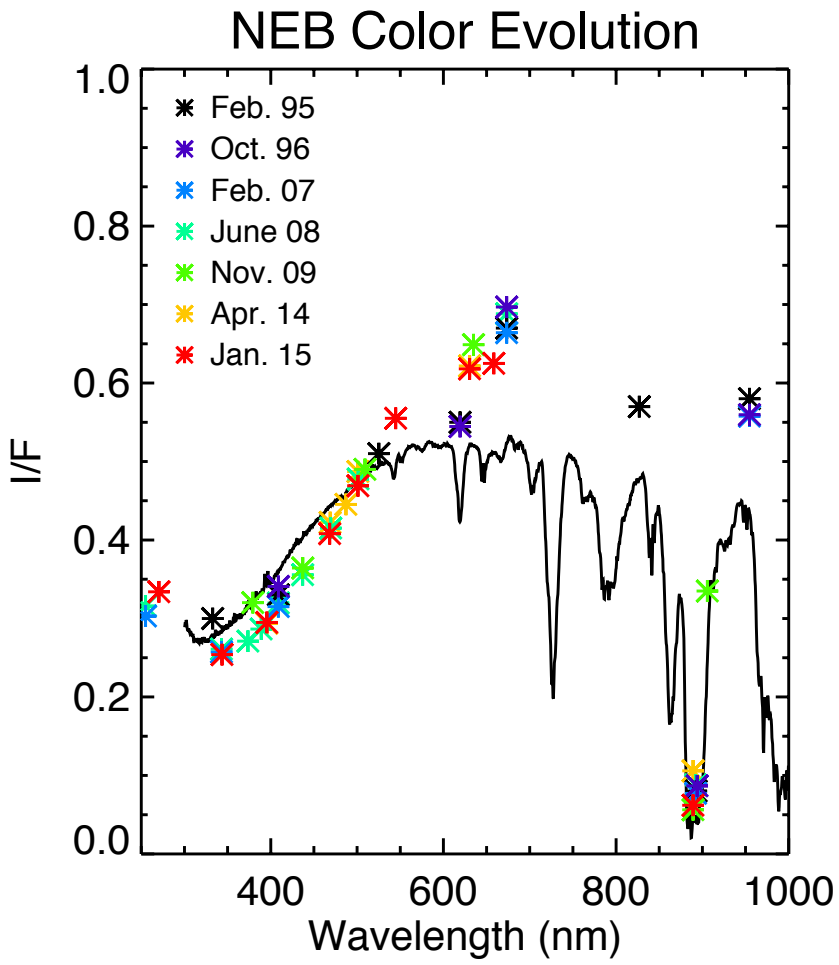


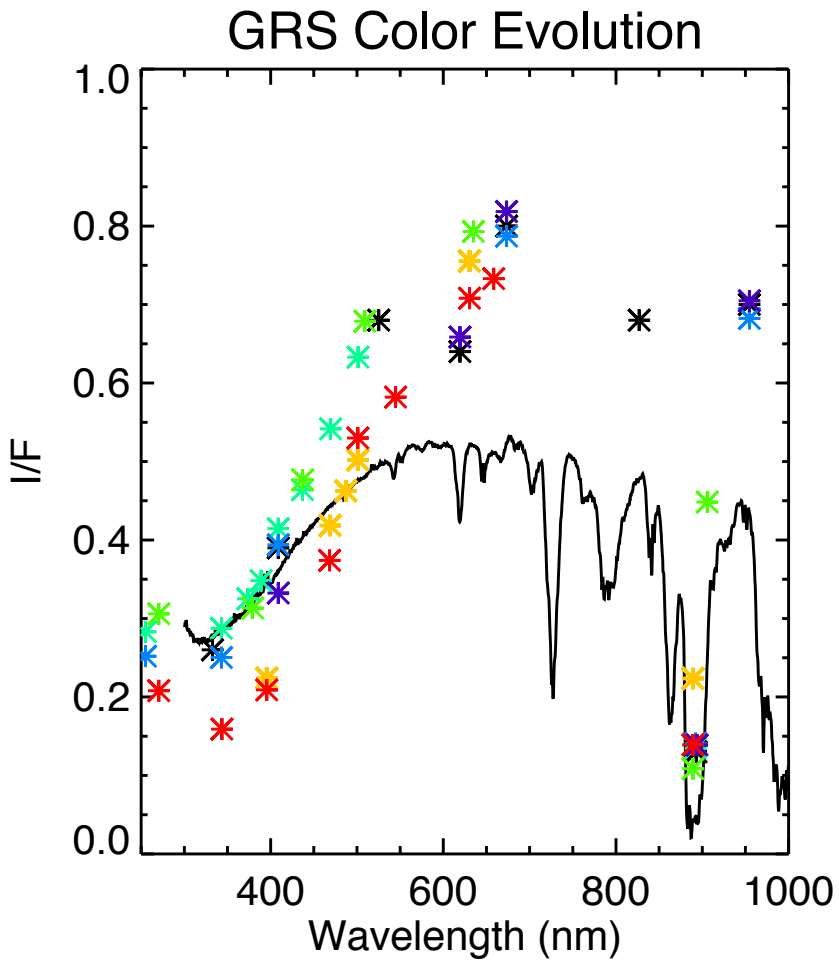
Neptune storms



A new Great Dark Spot?? The Voyager 2 GDS was gone by 1995

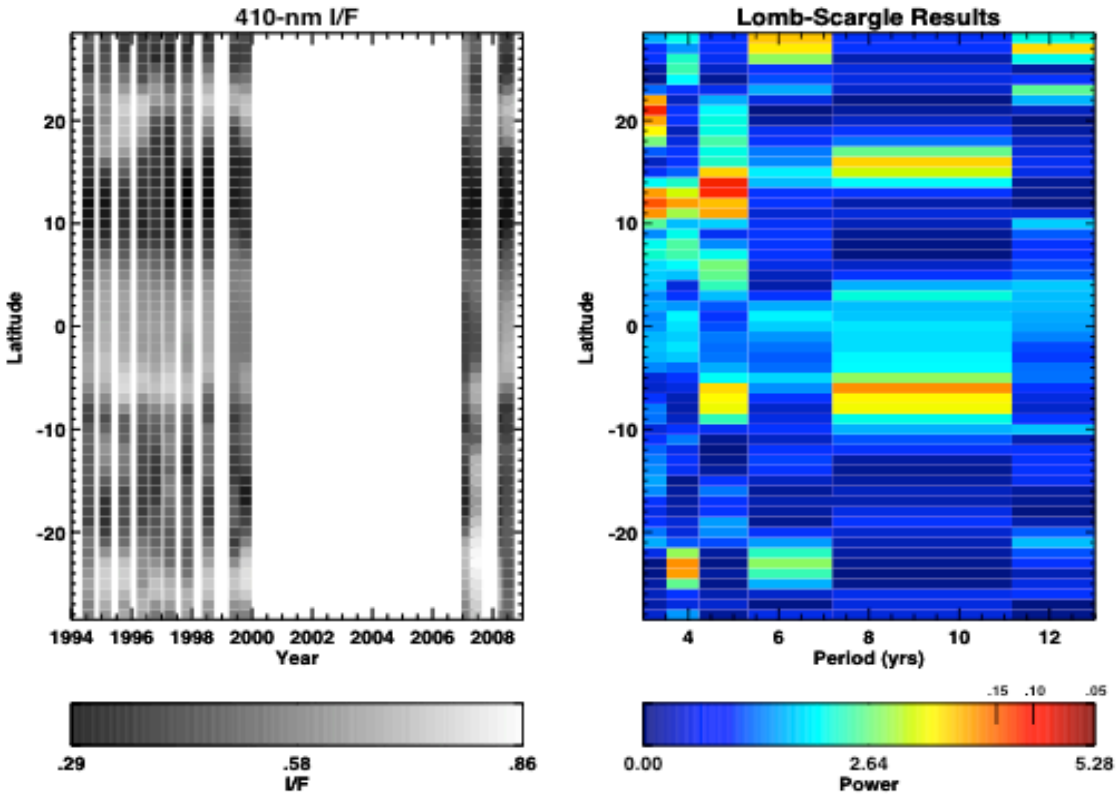
Color





Same areas relatively constant, others, not so much…

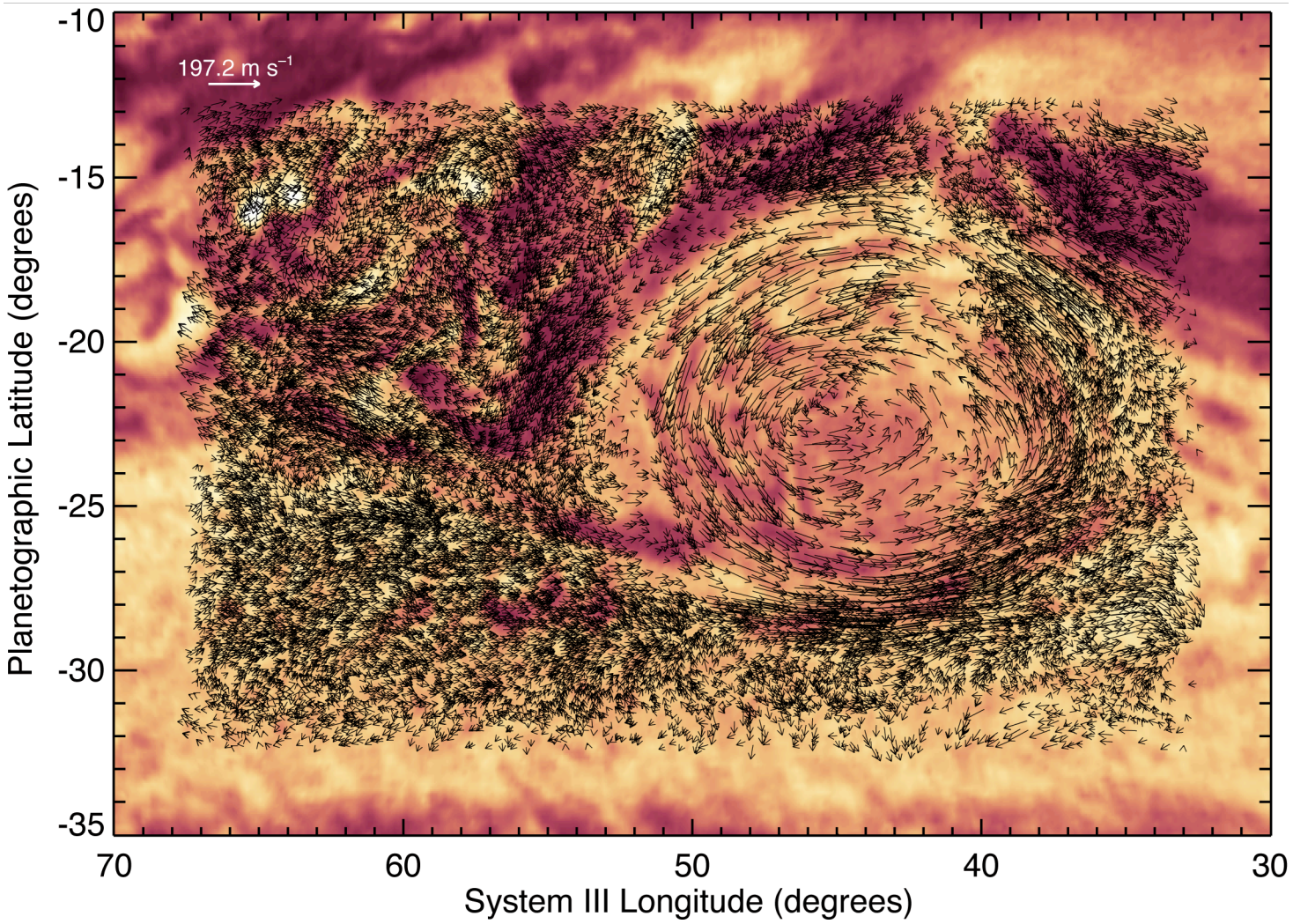
Zonal Brightness and Zonal Winds



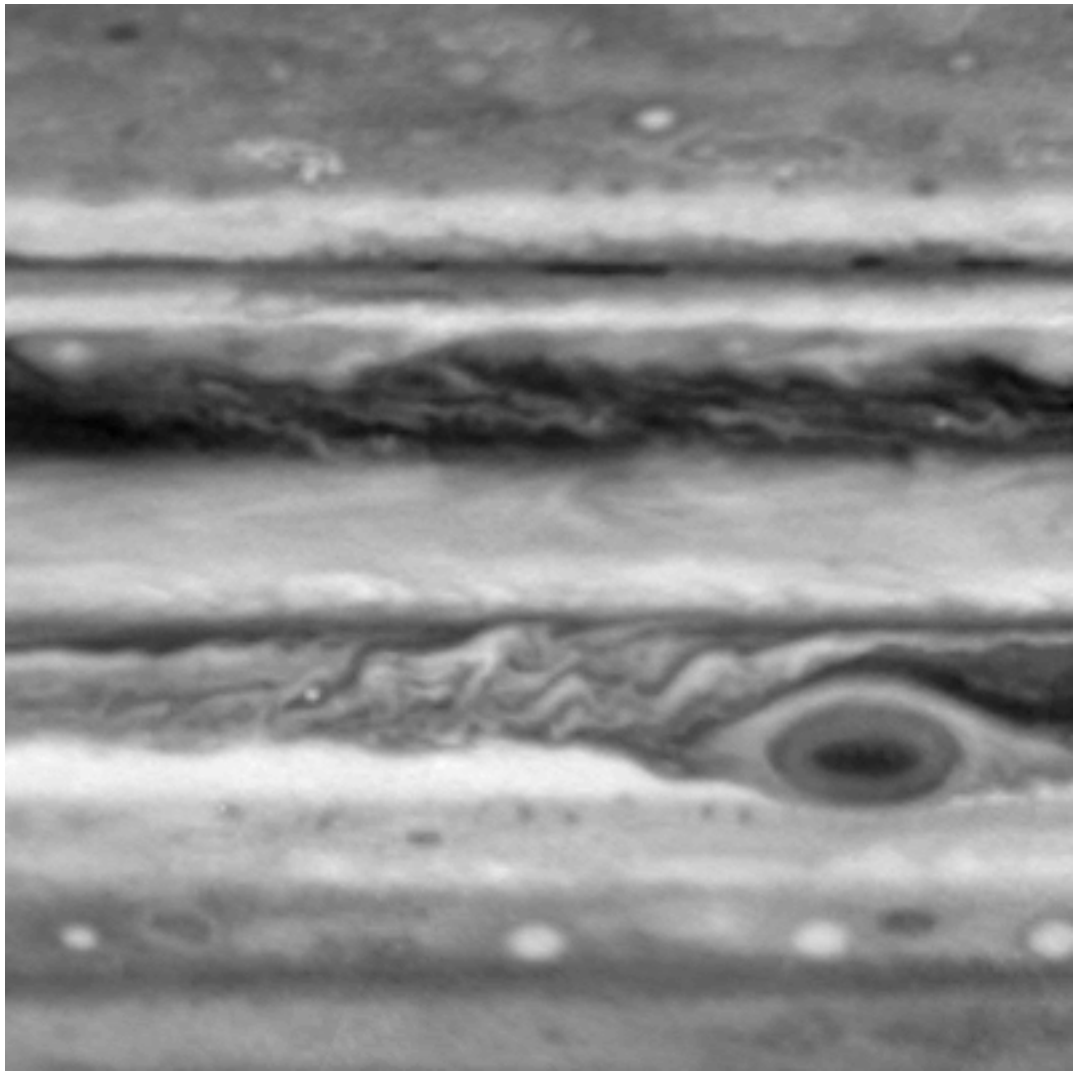
- Looking for periodic variations in brightness and winds tied to seasonal insolation or wave propagation (known to occur in Jup/Sat stratosphere from IR)
- Hampered by limited longitude coverage, time gaps, calibration

OPAL program to partly address this for all 4 giant planets with Hubble through ~2020

Local “Snapshot” Dynamics

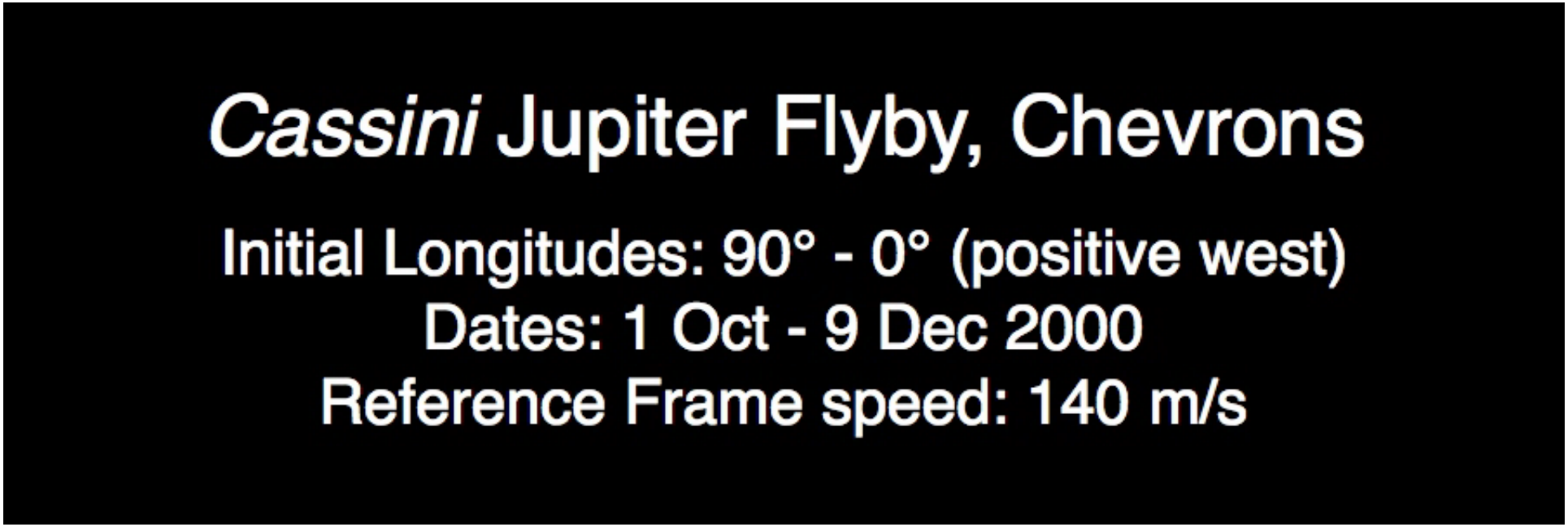


Localized Dynamics

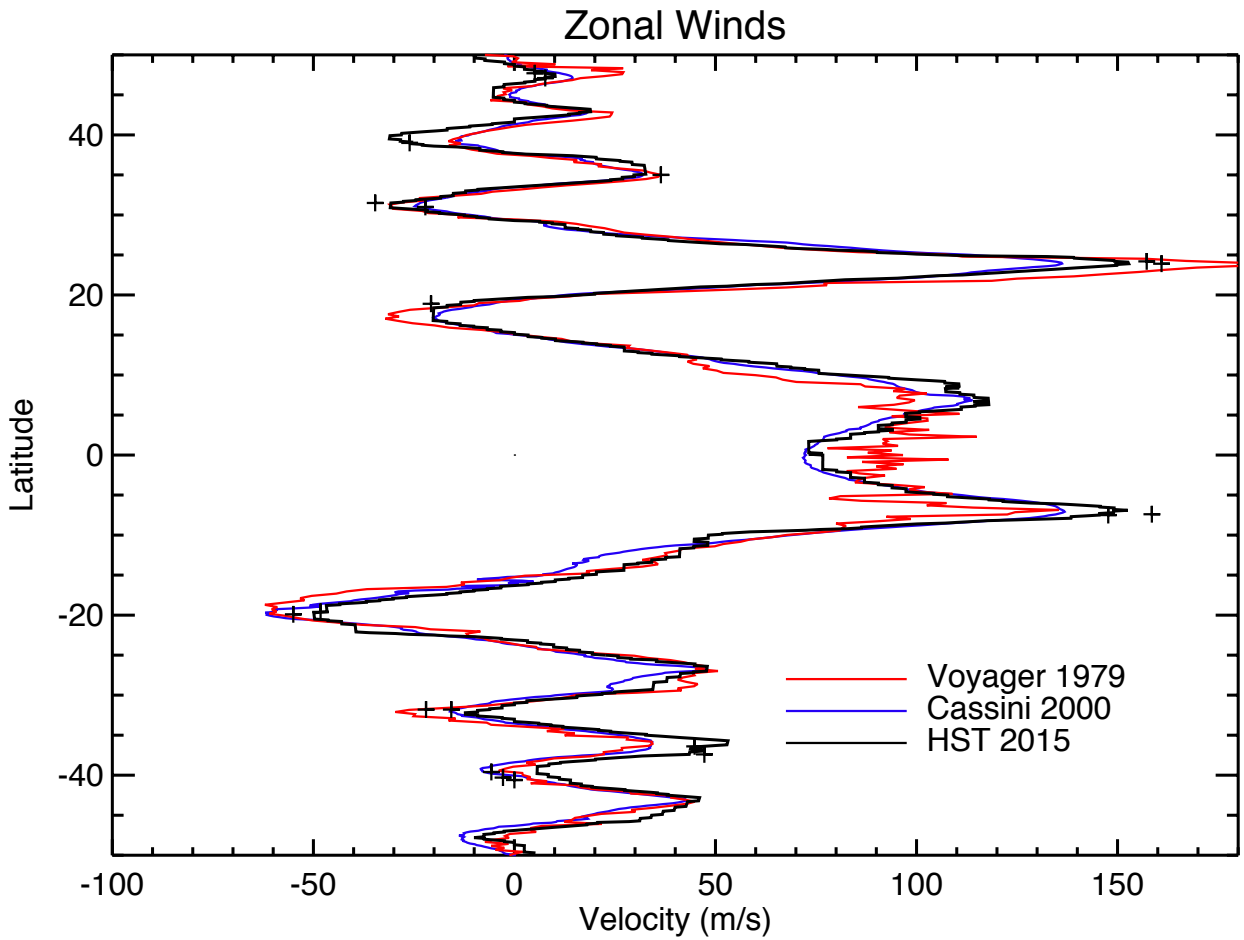


Global mapping and movies

- Long “movies” by Voyager 1 & 2 and Cassini
  - Flyby approach to Jupiter (all 3)
  - In orbit at Saturn (Cassini)
- Many rotations to watch feature evolution



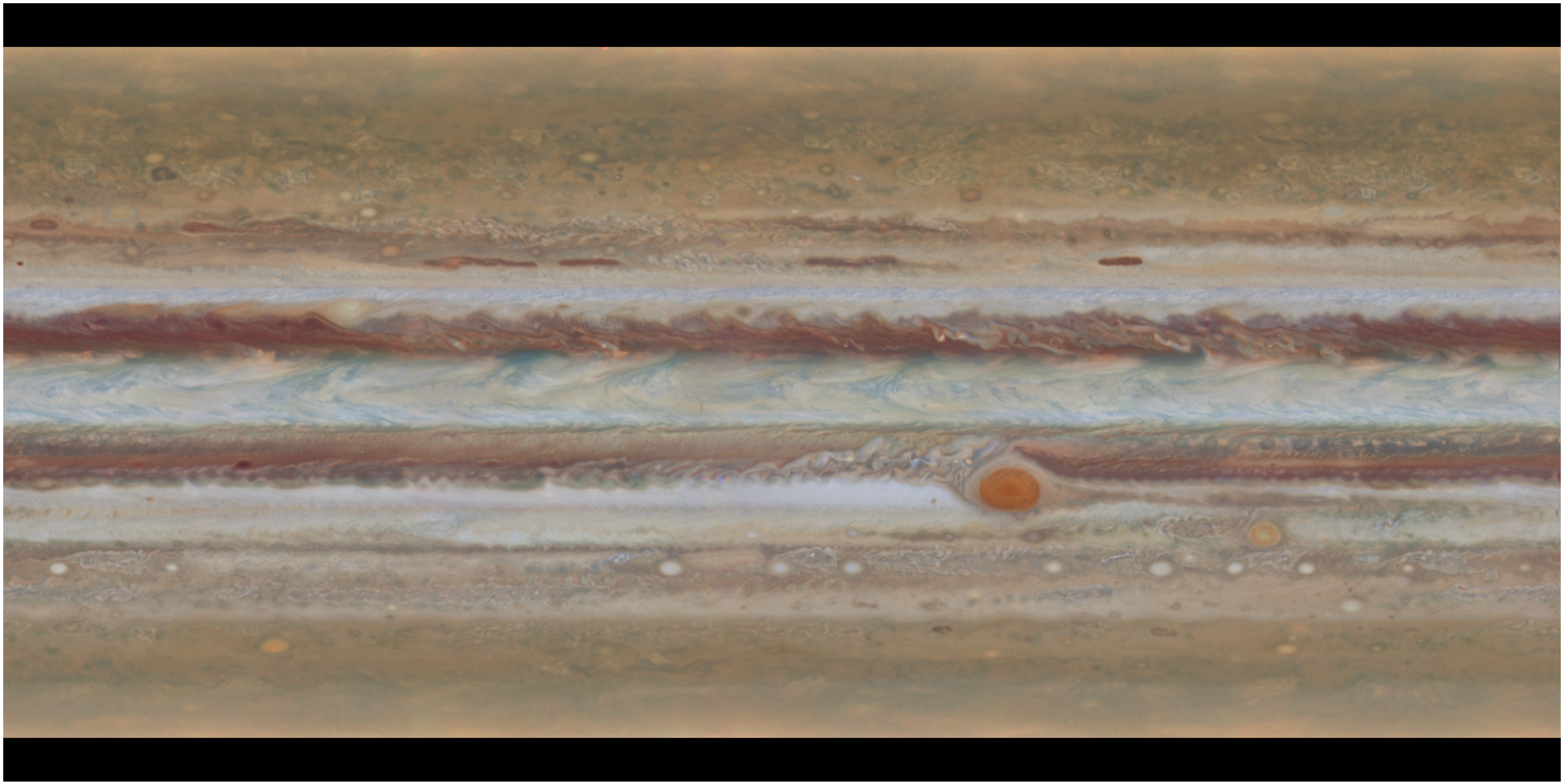
Zonal Winds from Full Maps



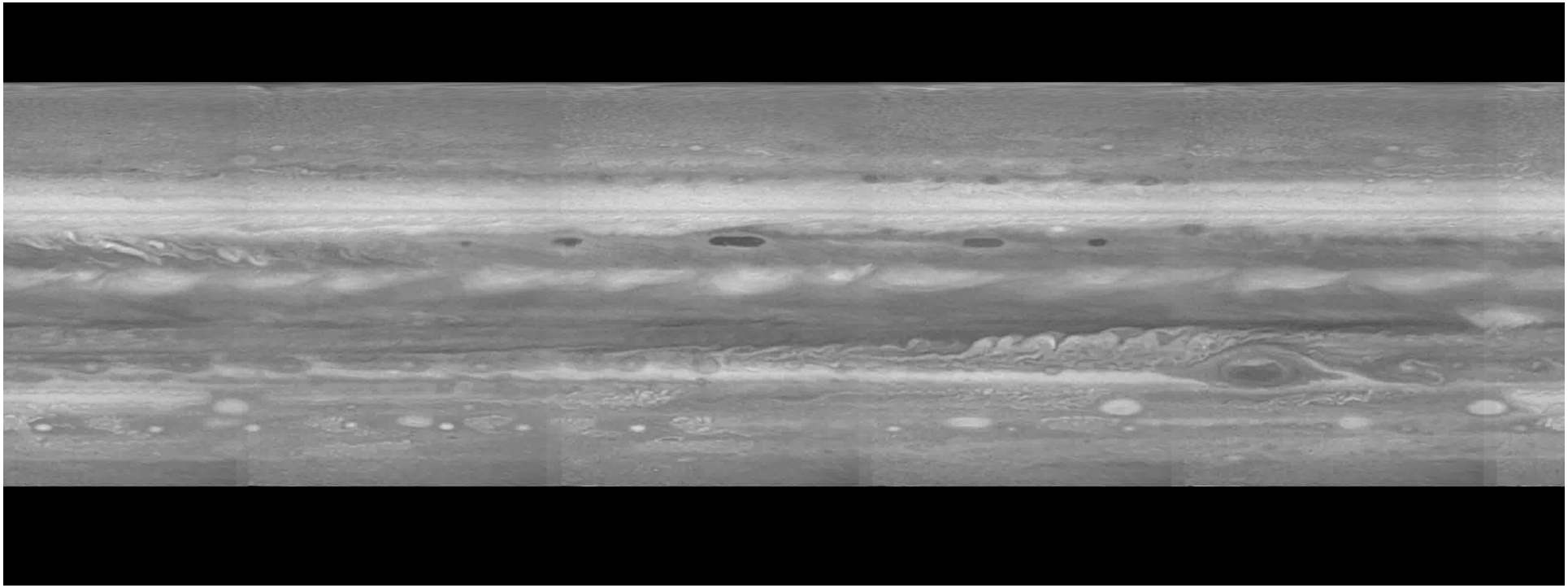
Less chance for storm biases, better measure of temporal changes

Hubble Global Maps

Enable many more types of study, including 2-D wind fields, but still as a snapshot



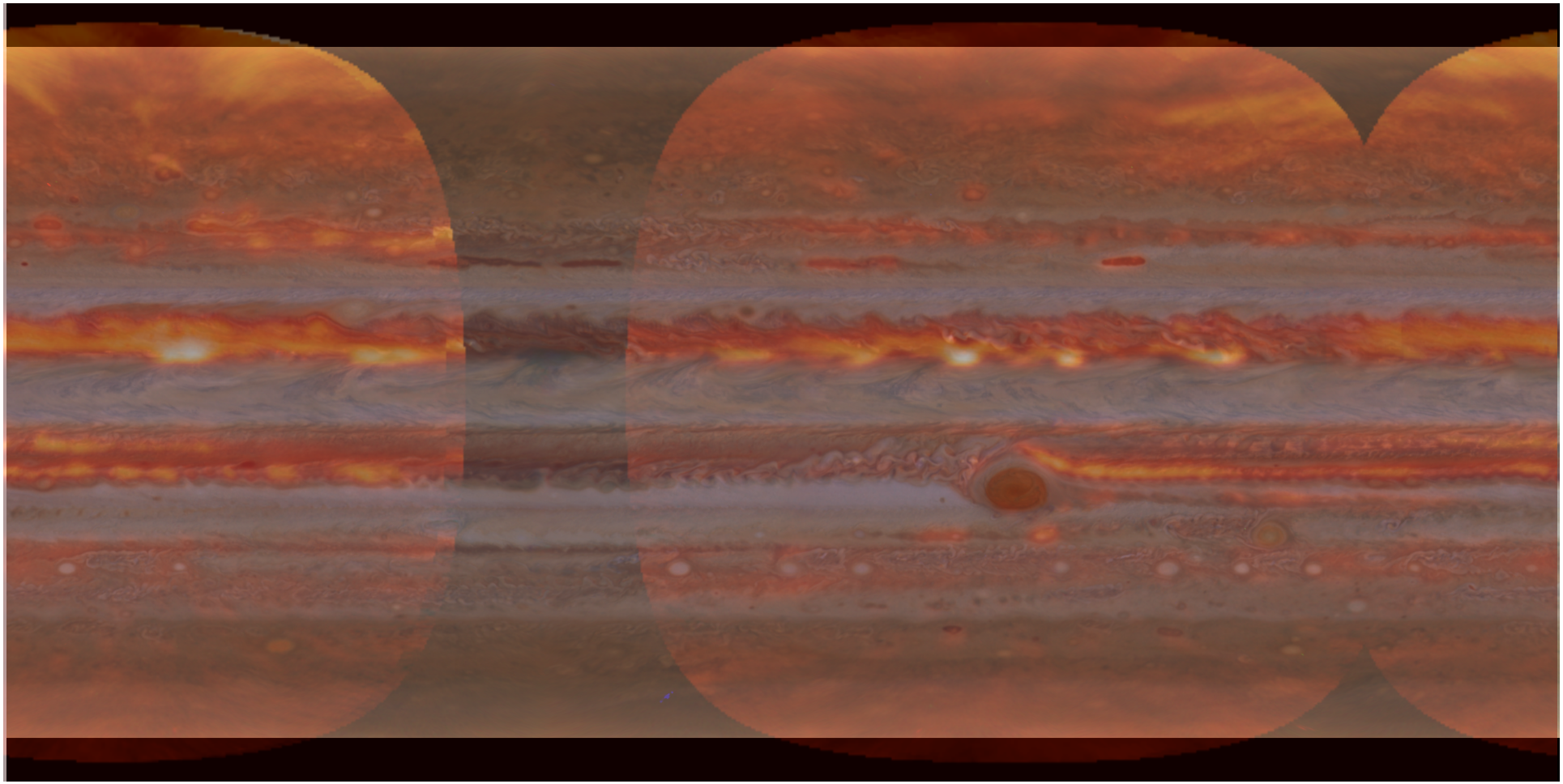
Voyager 2 Global Movie



Why can't we do this other ways?

- Ground-based
  - Time coverage driven by Earth's rotation
  - Spatial resolution without AO is low, can't do AO for visible wavelengths
  - Lose UV capability (and some IR in atmospheric telluric water bands)
- Target-driven deep space missions
  - Money (missions are expensive!!)
  - Too close for global monitoring
  - Time still limited given other objectives/targets

Value in combined observations from multiple facilities



Hubble visible and IRTF 5-micron

Summary

- Full wavelength range is valuable
  - Atmospheric diagnostics (vertical structure)
- Time coverage is valuable
  - Long term monitoring, feature evolution, detailed dynamics
  - Time-domain science!
- Would love a dedicated observatory
  - Happy to get frequent coverage in any form!