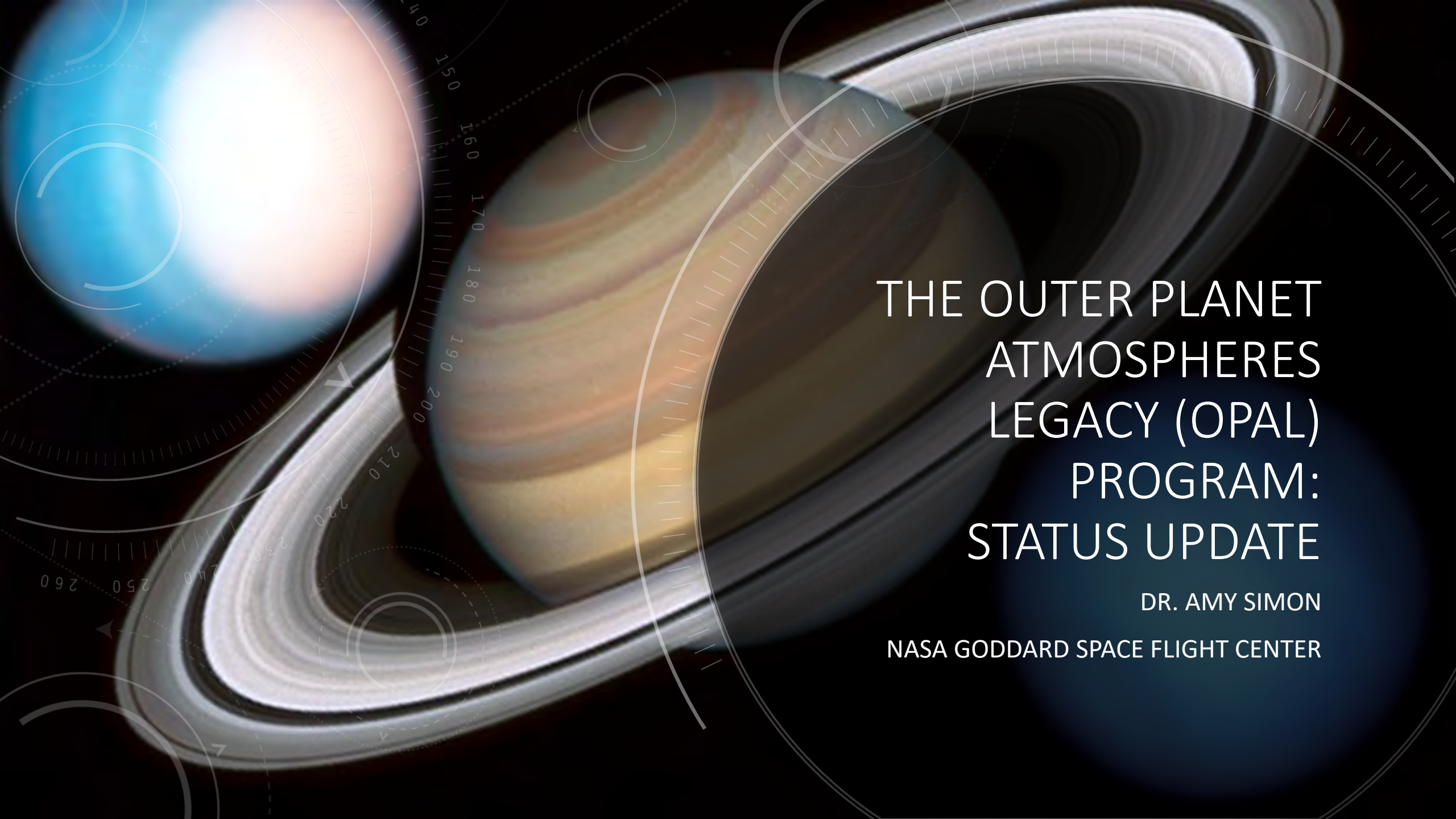

THE OUTER PLANET ATMOSPHERES LEGACY (OPAL) PROGRAM: STATUS UPDATE

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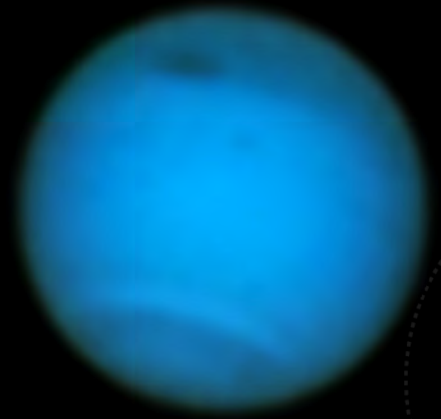
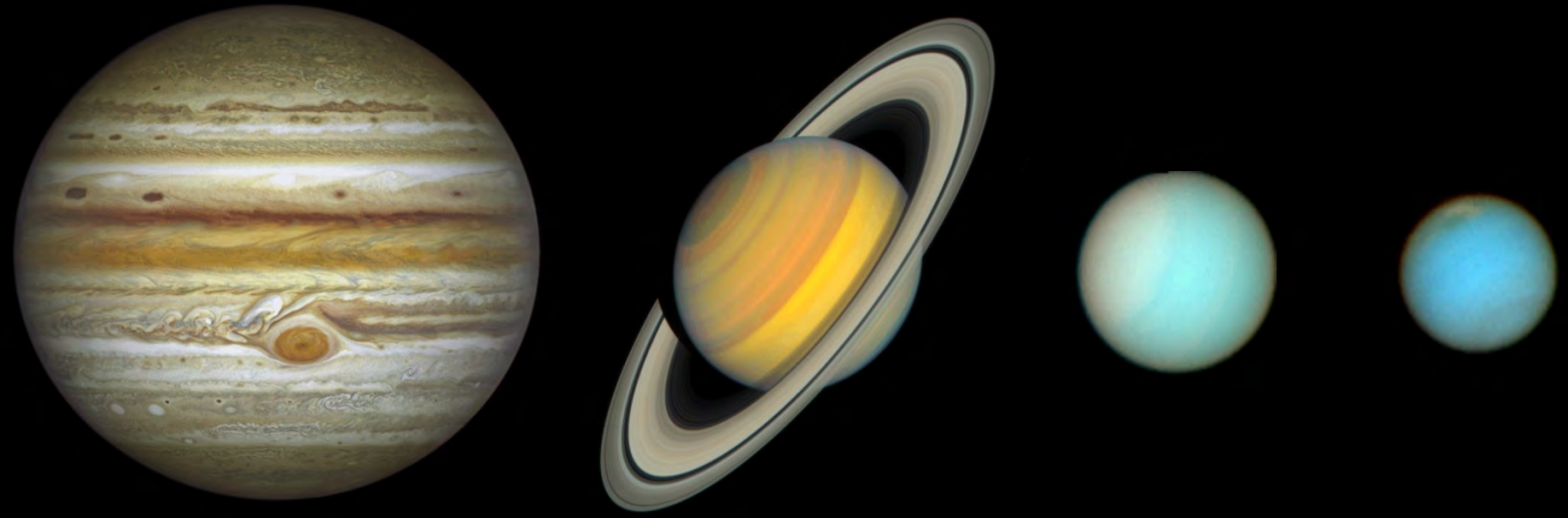
NASA GODDARD SPACE FLIGHT CENTER

OUTER PLANET ATMOSPHERES LEGACY GOALS

- Yearly Hubble observations of all 4 giant planets
  - Global coverage over two planetary rotations
  - Consistent camera/filter set (WFC3/UVIS)
- Ability to observe trends in:
  - Zonal (latitude-averaged) and 2D winds
  - Cloud/haze color
  - Storm evolution
- Serendipitous capture of unique events (new storms, waves, other unpredictable features)



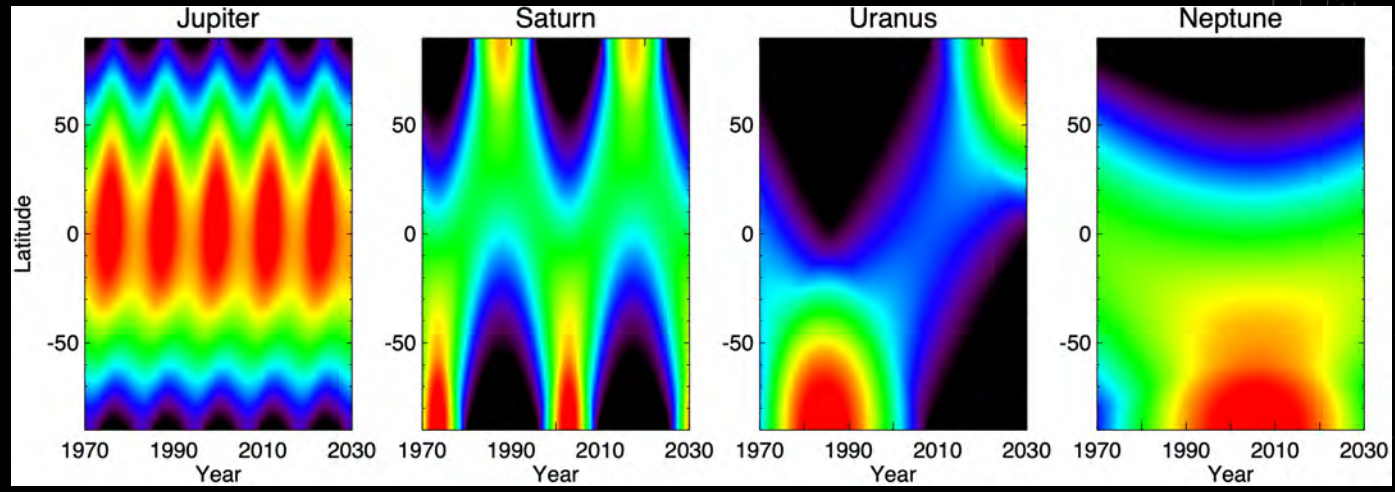
A LITTLE CONTEXT



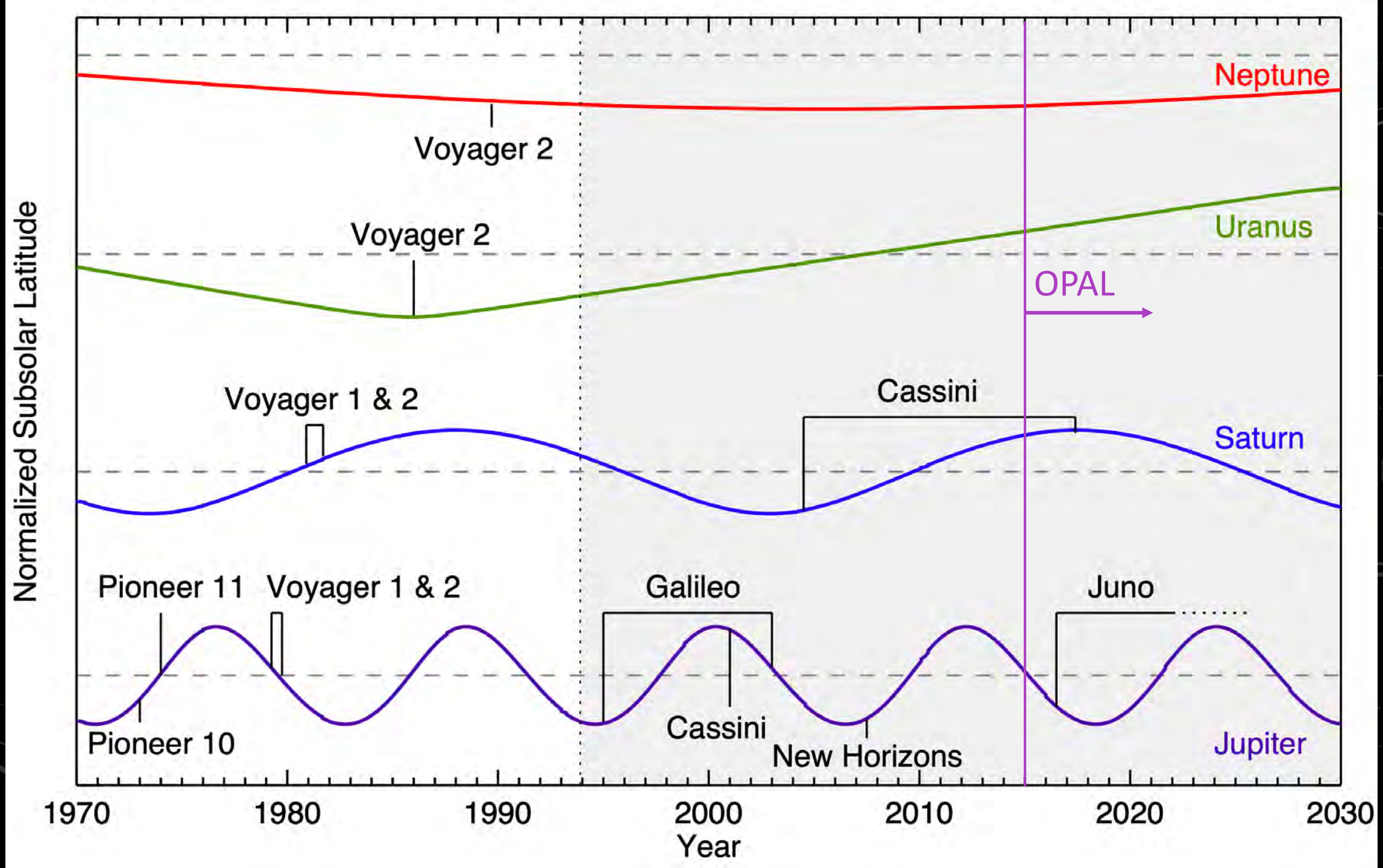
Outer planet atmospheres are dynamic and time variable…

and timescales are long….

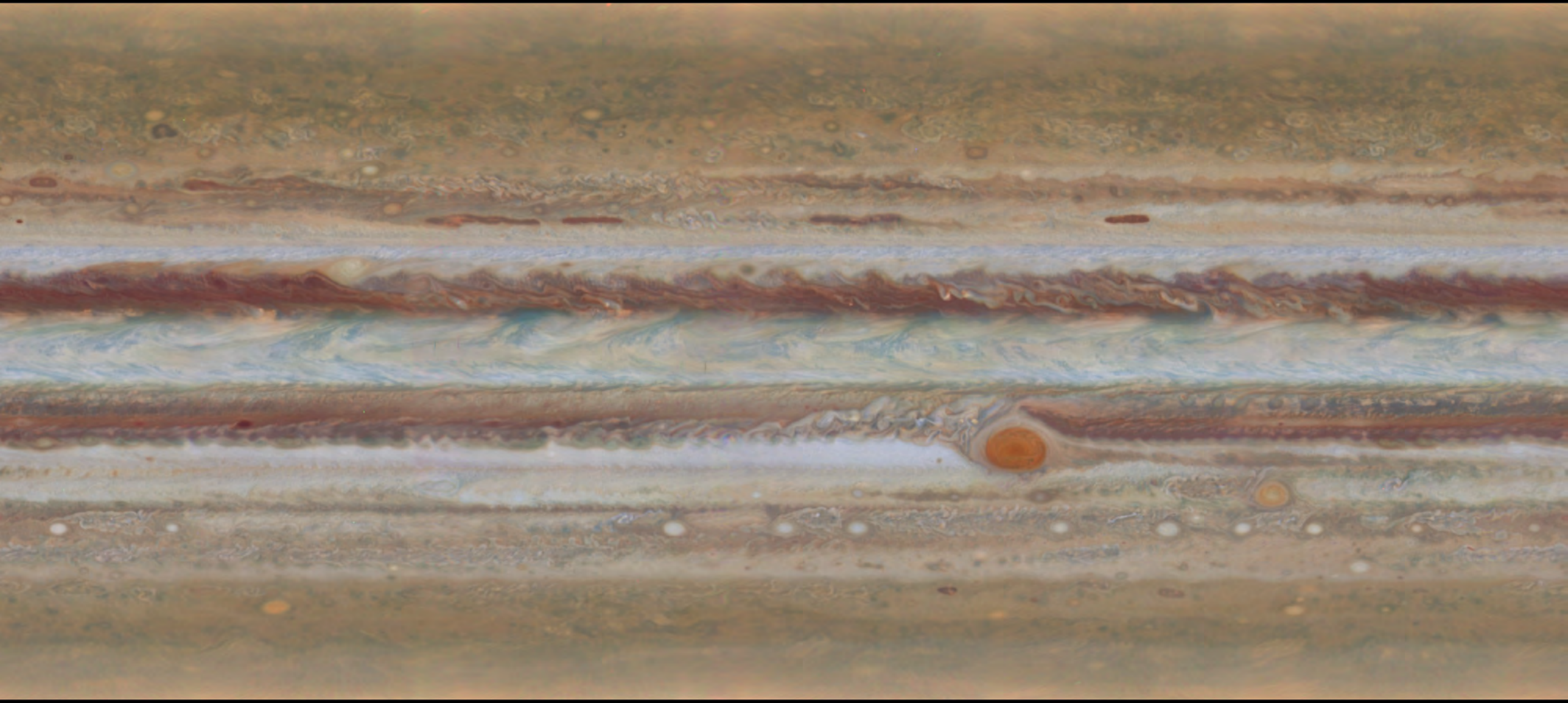
Planet	Orbital Period	Orbital Inclination	Orbital Eccentricity	Axial Tilt
Jupiter	11.9 yr	1.3°	0.049	3.1°
Saturn	29.5 yr	2.5°	0.052	26.7°
Uranus	84.0 yr	0.8°	0.047	97.8°
Neptune	164.8 yr	1.8°	0.010	28.3°



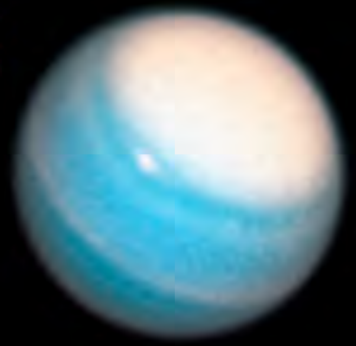
Simon et al. 2022 *Remote Sensing* **14**, 1518


Neptune
Voyager 2
Uranus
Voyager 2
OPAL
Voyager 1 & 2
Cassini
Saturn
Pioneer 11
Voyager 1 & 2
Galileo
Juno
Pioneer 10
Cassini
New Horizons
Jupiter
Normalized Subsolar Latitude
1970
1980
1990
2000
2010
2020
2030
Year

GLOBAL MAPS



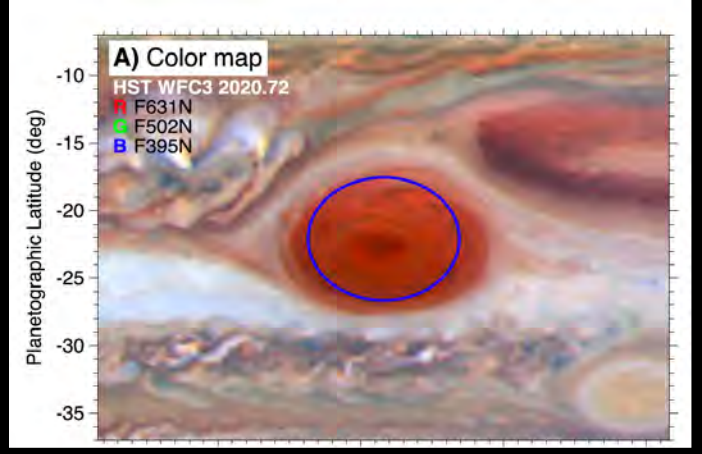
OPAL BY THE NUMBERS



- 41 orbits per year
  - 7 to 10 filters per planet
  - 2 global maps per filter[+] per planet, all archived at https://archive.stsci.edu/prepds/opal/
- 48 publications (as of 6 May 2022)
- 6 news releases* in 2020 and 2021:
  - HUBBLE'S GRAND TOUR OF THE OUTER SOLAR SYSTEM (2021-047)
  - HUBBLE SHOWS WINDS IN JUPITER'S GREAT RED SPOT ARE SPEEDING UP (2021-055)
  - DARK STORM ON NEPTUNE REVERSES DIRECTION, POSSIBLY SHEDDING A FRAGMENT (2020-059)
  - HUBBLE CAPTURES CRISP NEW PORTRAIT OF JUPITER'S STORMS (2020-042)
  - HUBBLE SEES SUMMERTIME ON SATURN (2020-043)
  - TELESCOPES AND SPACECRAFT JOIN FORCES TO PROBE DEEP INTO JUPITER'S ATMOSPHERE (2020-021)

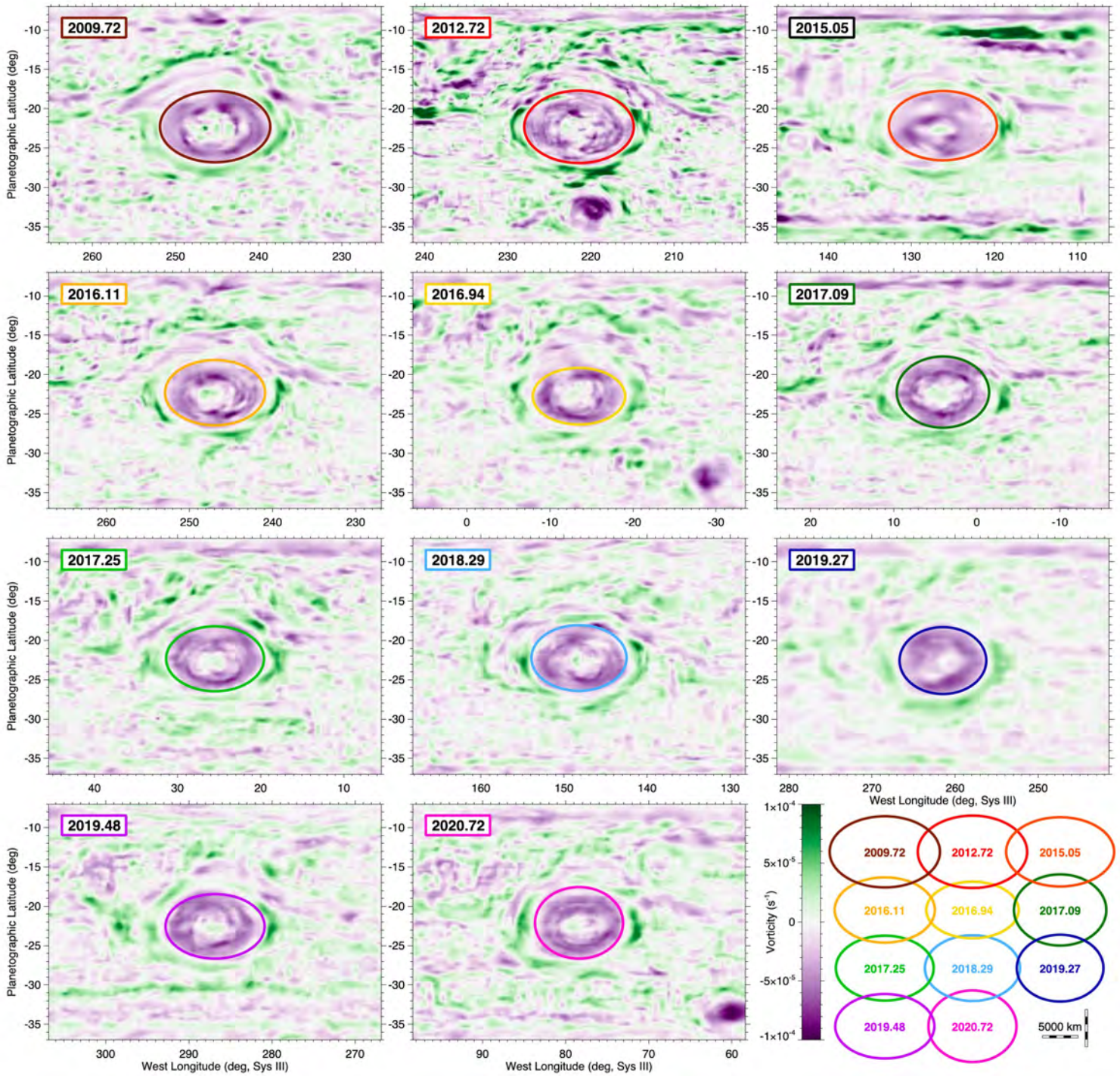
+ some filters only have one map, and sometimes gaps occur
* Several included data from other programs, as well

RECENT JUPITER RESULTS



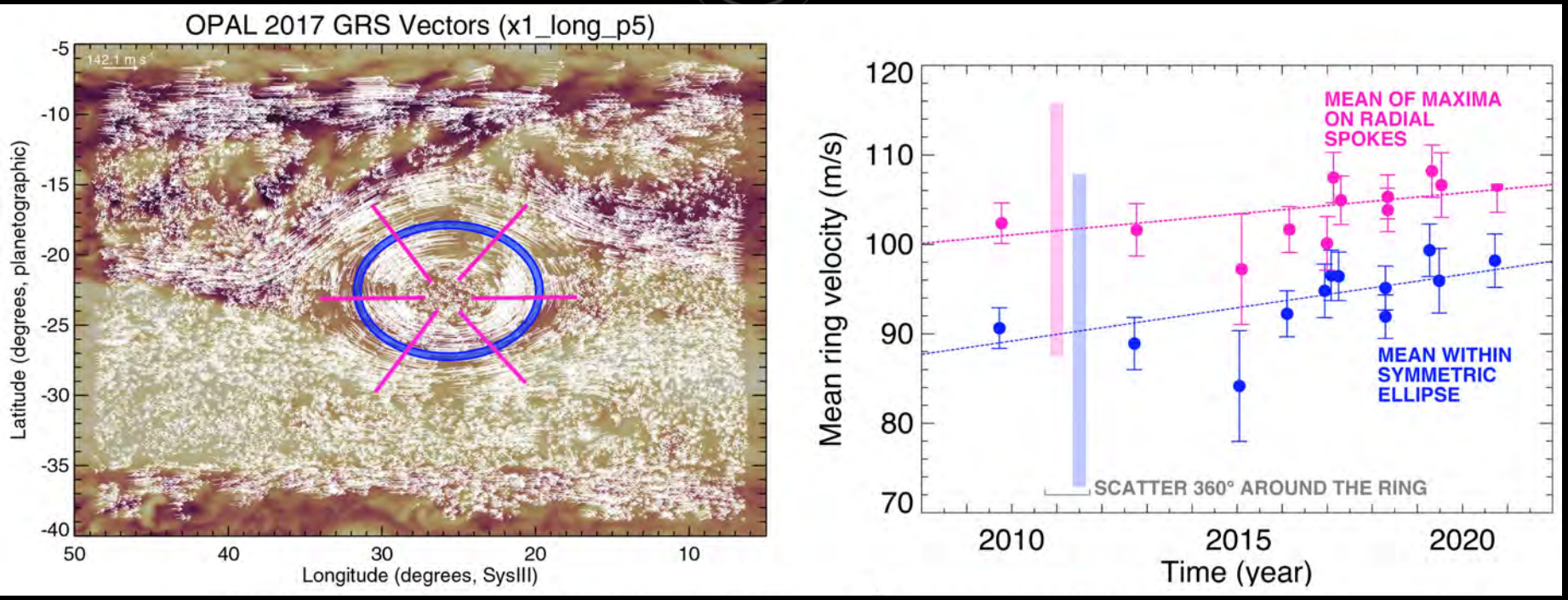
- Study of Jupiter's Great Red Spot winds over 2009-2020
  - Prior studies used mixed methods (manual and automated) for winds, size, color
  - Decreasing size was confirmed, but internal velocity trends remained unclear
  - This study used advances in velocimetry techniques across a longer time period

Wong et al. *Geophys. Res. Let*. 2021



The dynamical field is a better measure of the GRS size, rather than colored clouds, because it doesn't depend on contrast or other subjective measures.

Decrease in size is still apparent, but see some temporal variability



With 11 years of data, an increase in velocity is now apparent

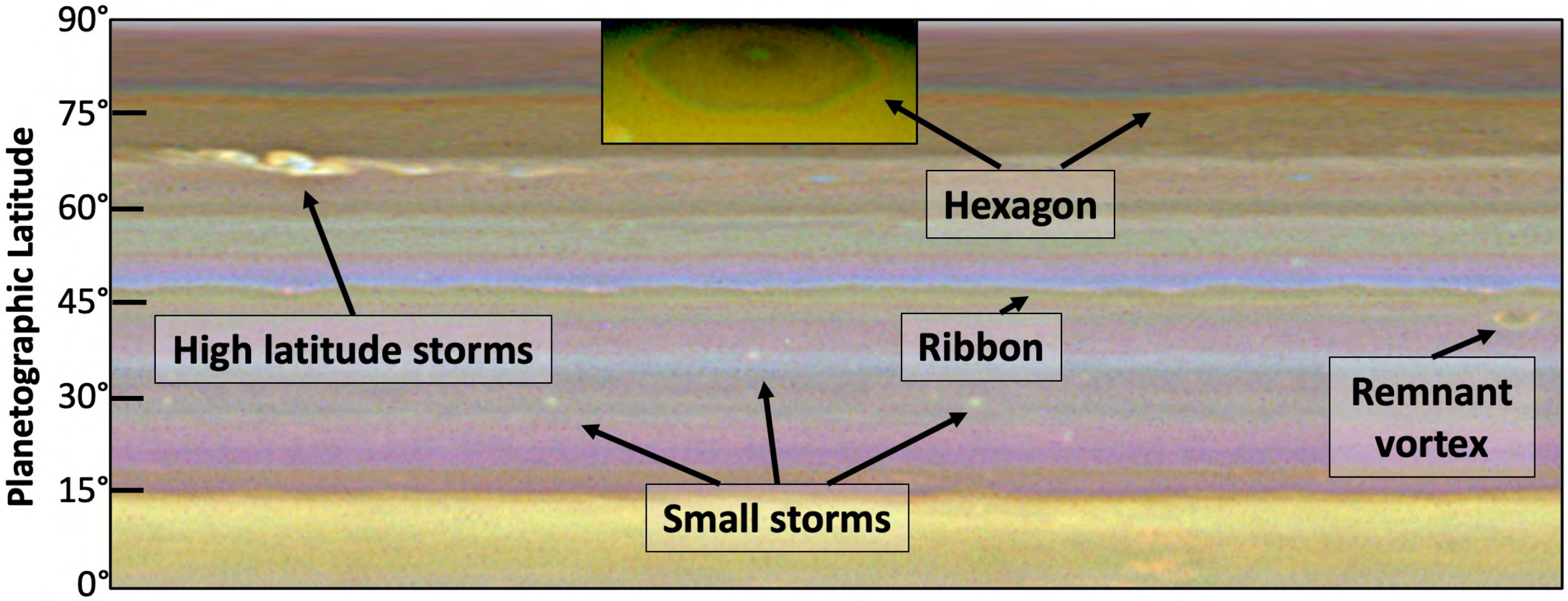
- Part of the overall dynamical balance of the shrinking spot
- Short-term disruptions happen, however, on time scales of days to months

RECENT SATURN RESULTS: YEARLY COLOR CHANGES

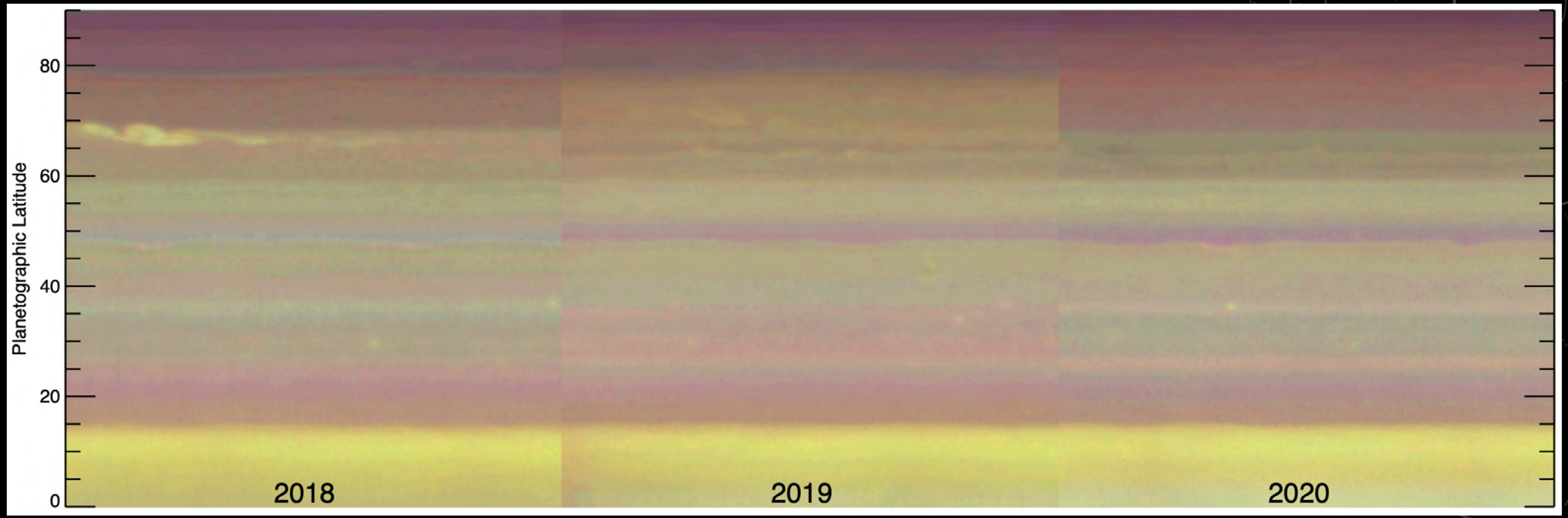
2018

2019

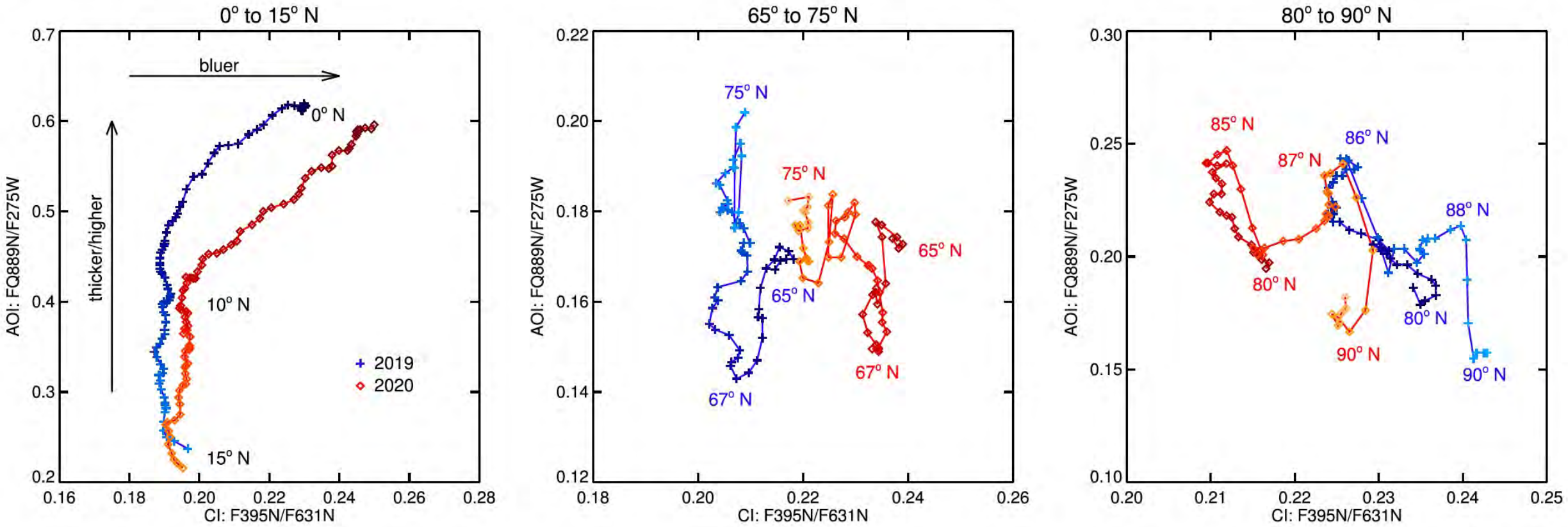
2020



Simon et al. *Remote Sensing* 2022


Planetographic Latitude
80
60
40
20
0
2018
2019
2020

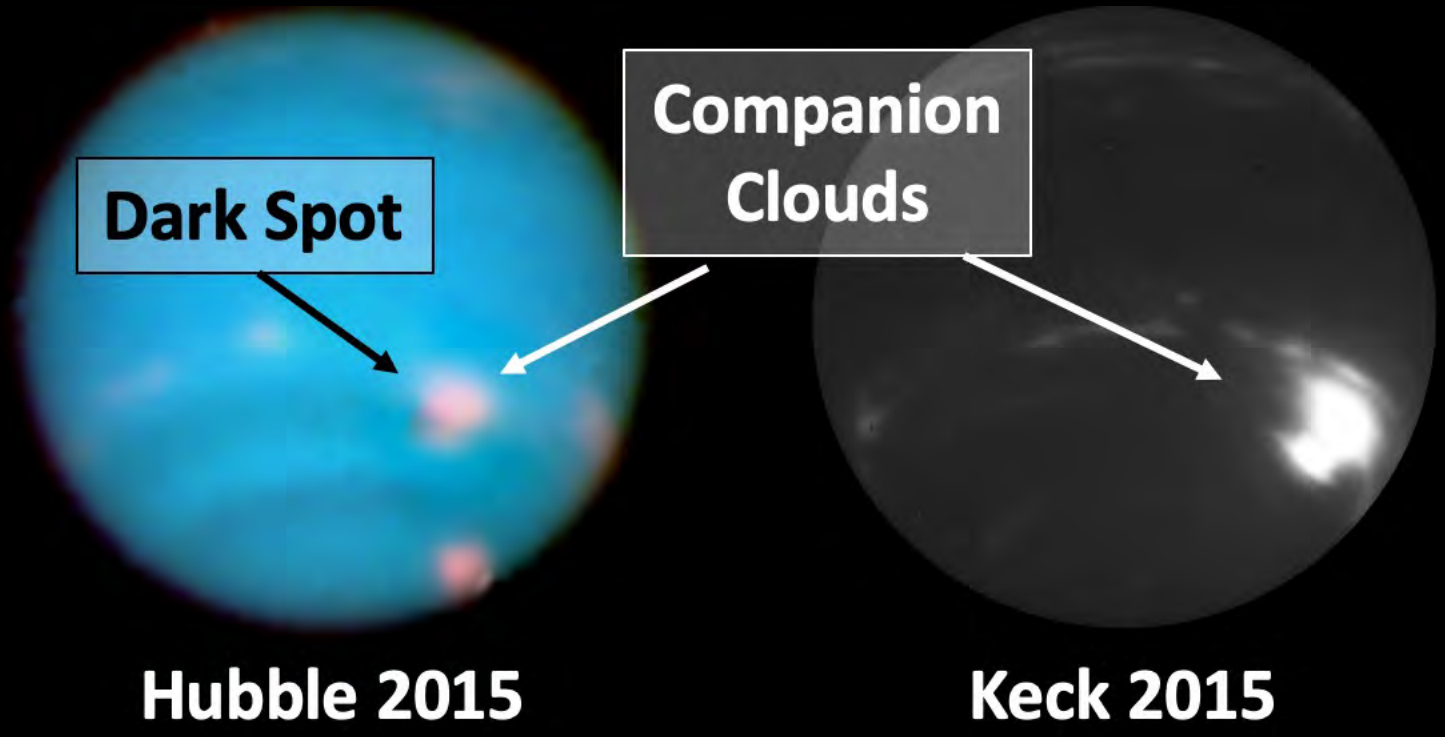
WAVELENGTH INDICES



Filter ratios highlight rapid changes in color (CI) and cloud height/thickness (AOI), as Saturn moves away from northern summer solstice. More trending will show if there is a long-term, latitudinal, pattern to the changes

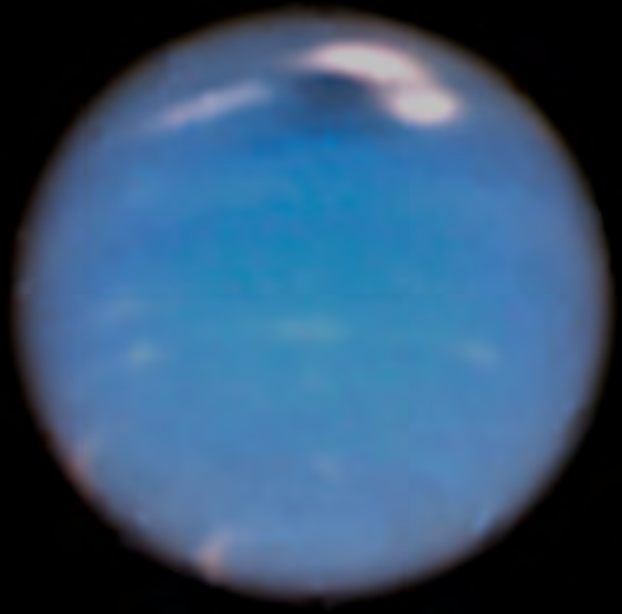
Simon et al. *Planetary Sci. Journal* 2021

RECENT NEPTUNE RESULTS: NEW DARK SPOTS

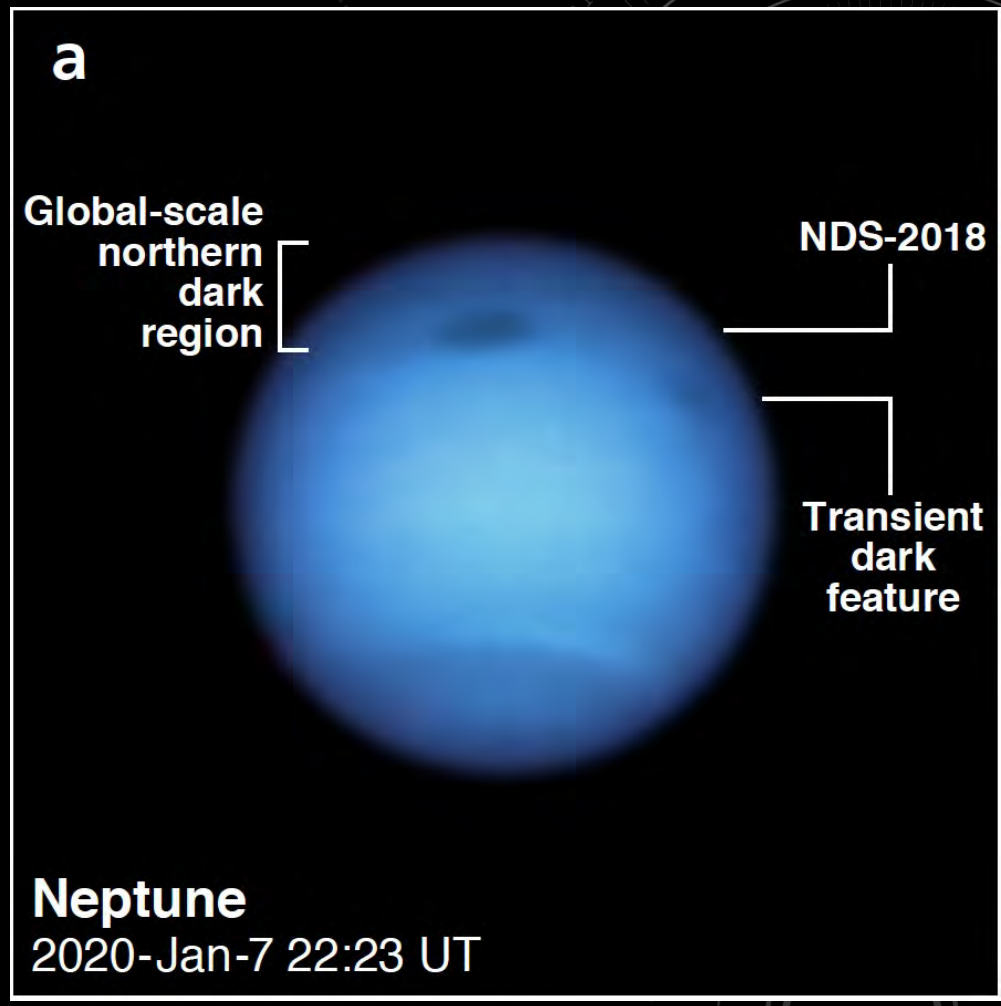


Only Hubble can detect dark spots, because of the high resolution needed at blue wavelengths

Voyager 2: 1989



Hubble: 2018

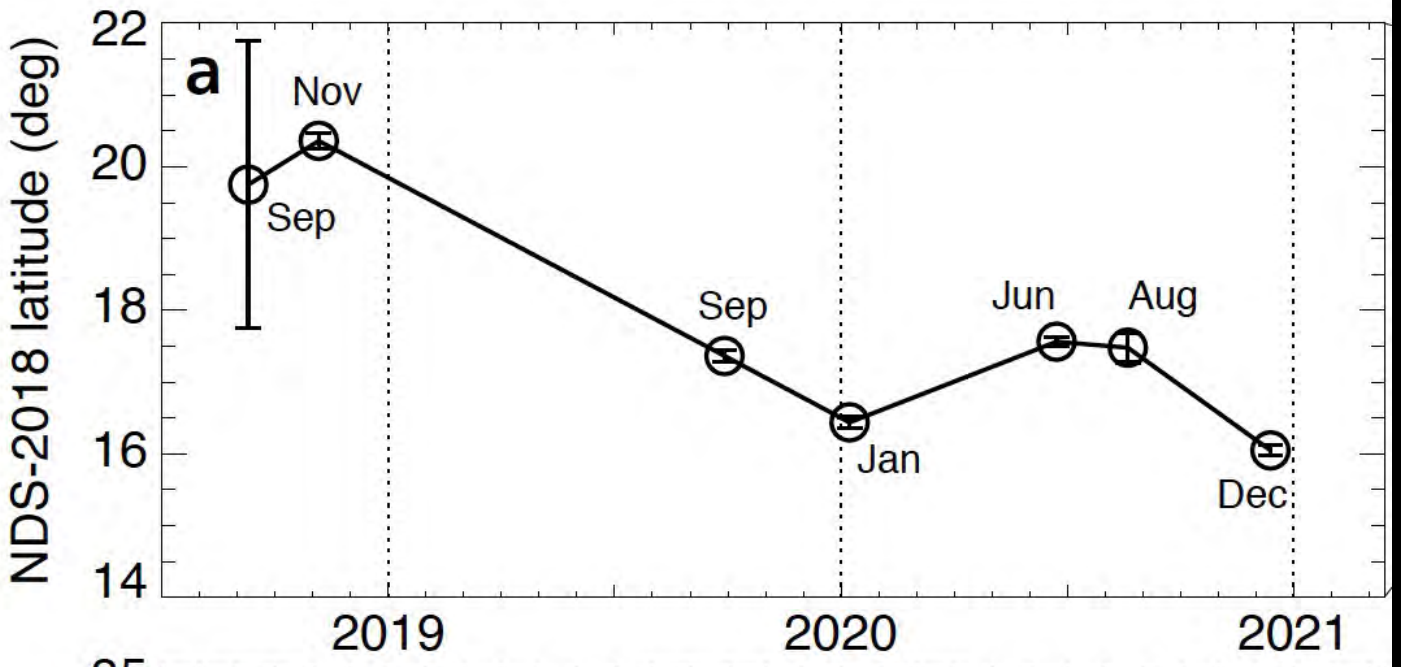


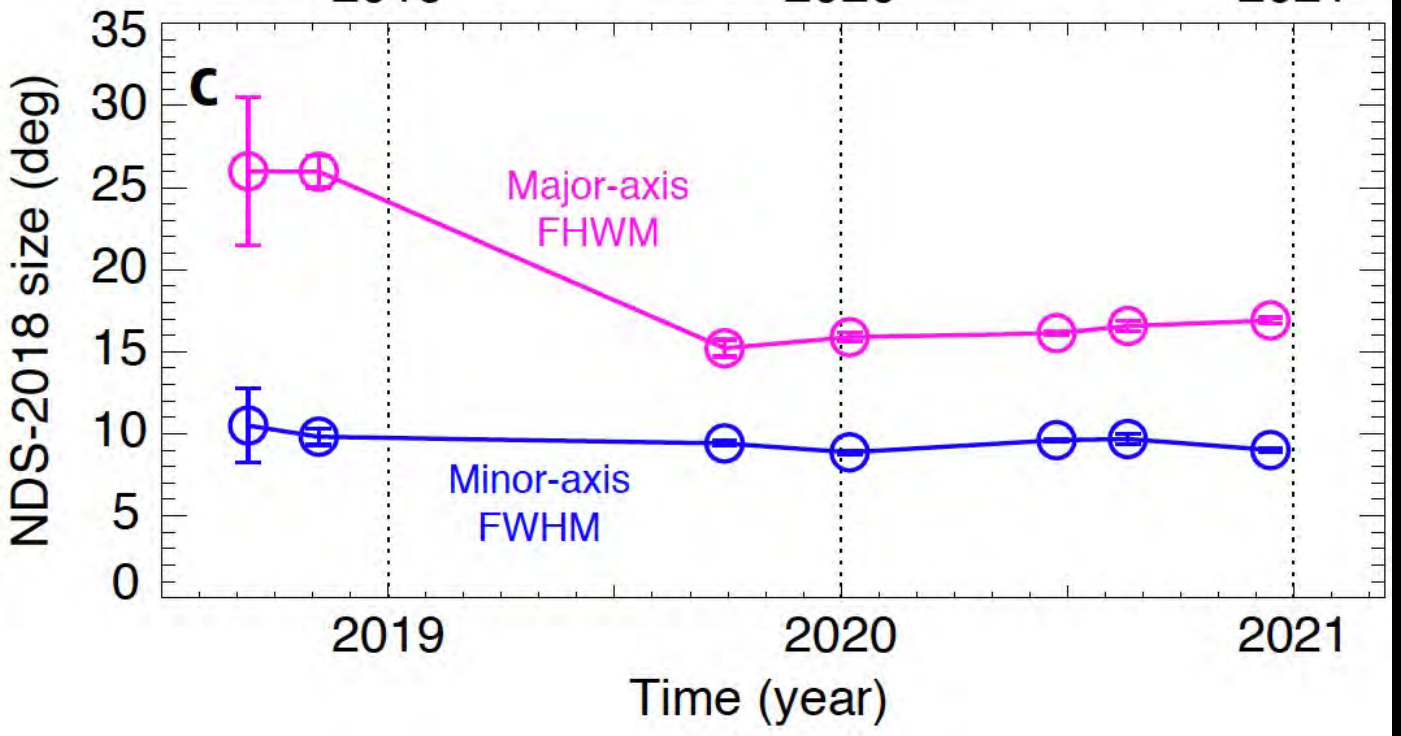
New, very large spot found in 2018 OPAL data, rivalling size of Voyager GDS

Transient secondary features may also be present

Simon et al. *Geophys. Res. Lett* 2019, Hsu et al. *AJ* 2019

Wong et al. *Icarus* 2022 (in revision)





Further observations showed the spot drifting in latitude.

Was predicted that if trend continued, it would pass into a critical dynamical boundary (~15° latitude), and disrupt, but it was still present in early 2022.

Initially, it also got smaller, but has since stabilized

SUMMARY

- Giant planet studies are challenging owing to long seasonal timescales (decades)
  - Variability is seen on timescales of hours to months
- OPAL is filling in the otherwise missing coverage
- OPAL data are complementary to JWST observations
- OPAL data will help set the stage for the Decadal-recommended Uranus Flagship mission

ANY QUESTIONS?