

Hubble OPAL Observations of Uranus and Neptune: 2014-2019

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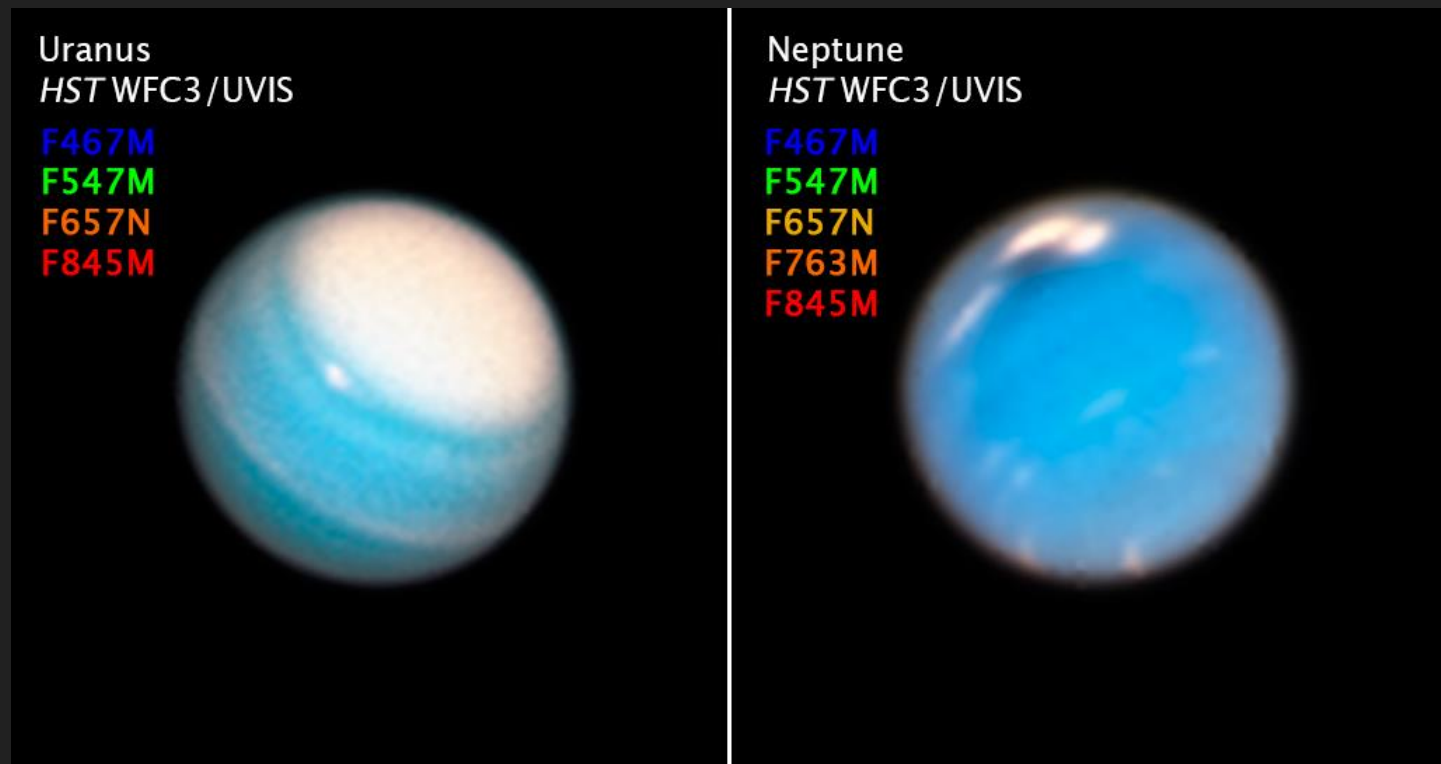
Hubble Outer Planets Atmospheres Legacy (OPAL) program



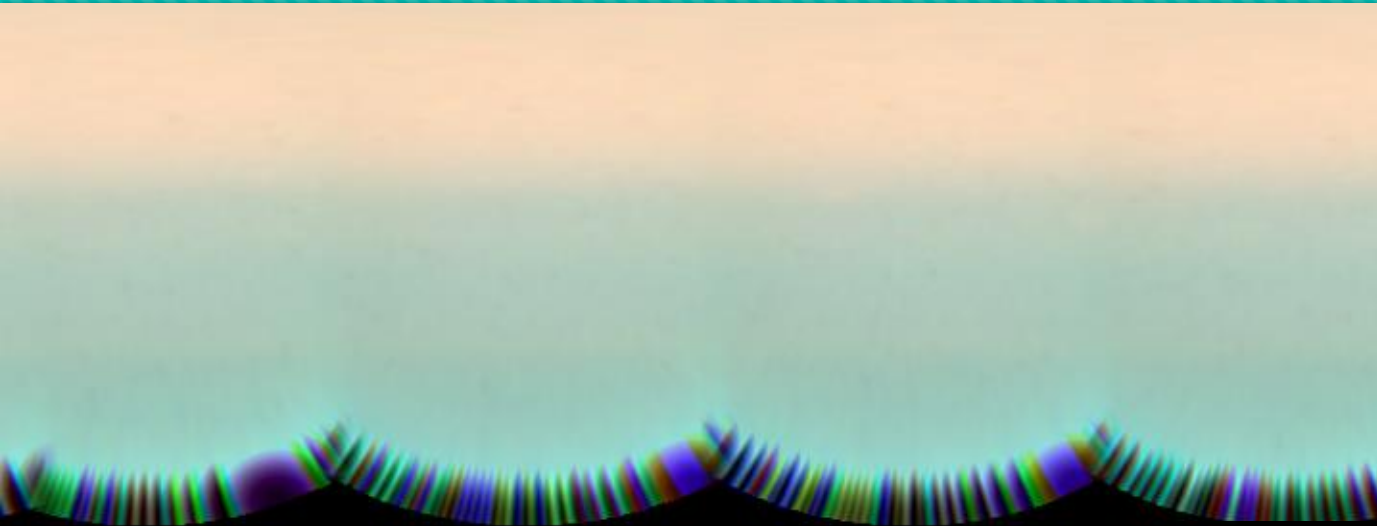
- Yearly Hubble (UV-Vis) imaging of the outer planets; two global maps per planet, began in 2014 with Uranus, 2015 for Neptune and Jupiter, 2018 for Saturn
- Trend changes in:
 - brightness,
 - cloud activity,
 - 2D and zonal wind fields,
 - storm size, color, other changes
 - Serendipitous events
- All data are public,
- Maps are posted at STScI

<https://archive.stsci.edu/prepds/opal/>

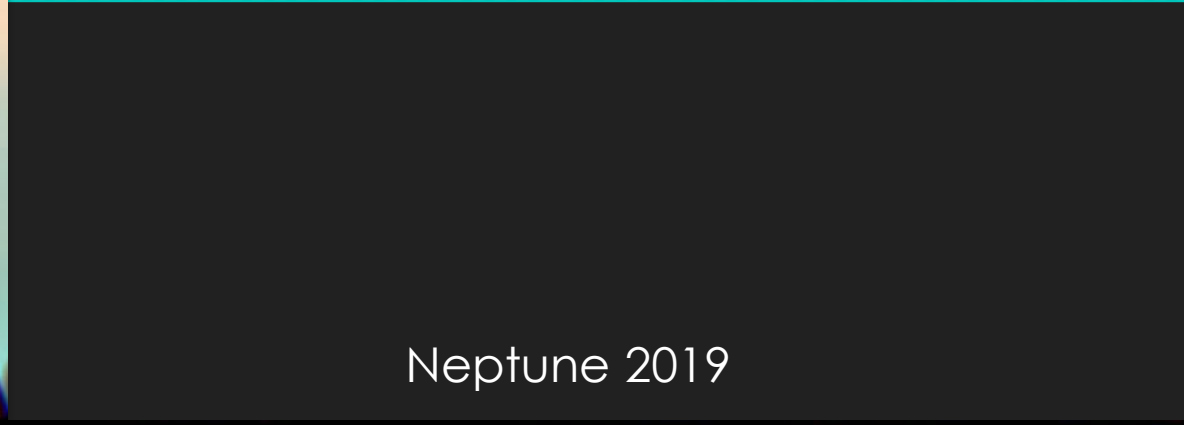
Simon et al. 2015 *ApJ* 812, 55



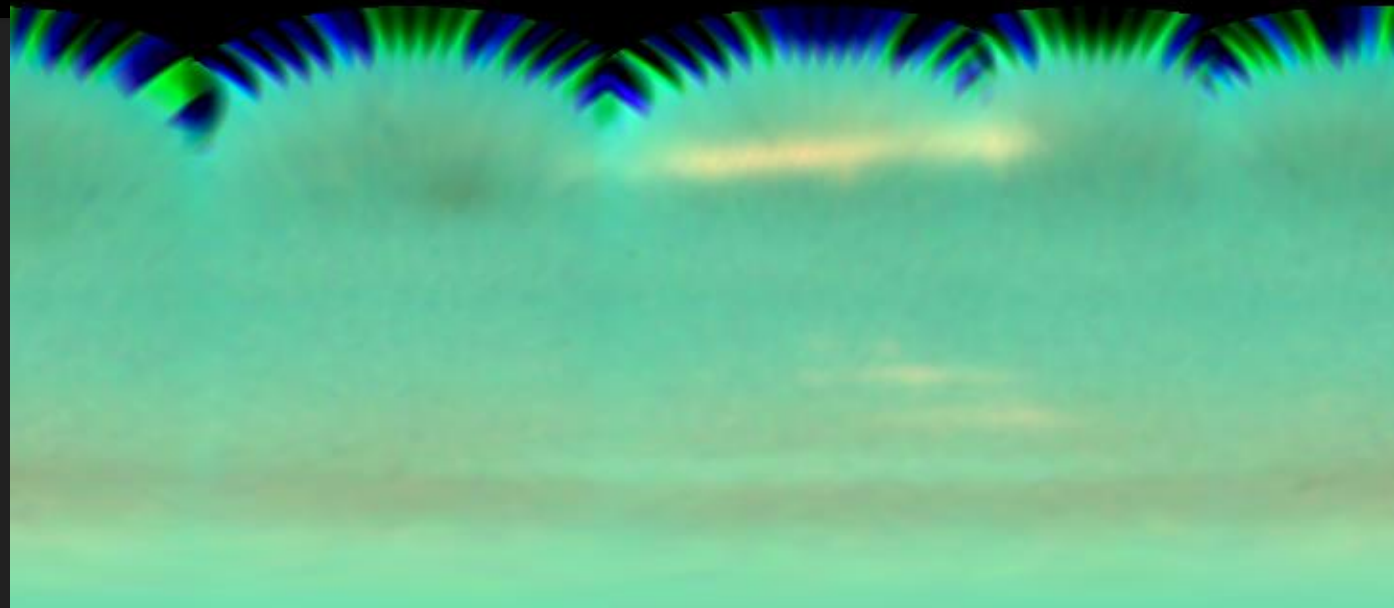
MAPS



Uranus 2019



Neptune 2019



Generated in 5 continuum filters:

- F467, F547, F657, F763, F845

2 methane absorption bands:

- F619, F727

2014

Uranus

- Polar haze has continued to brighten
- Small storm activity

2017

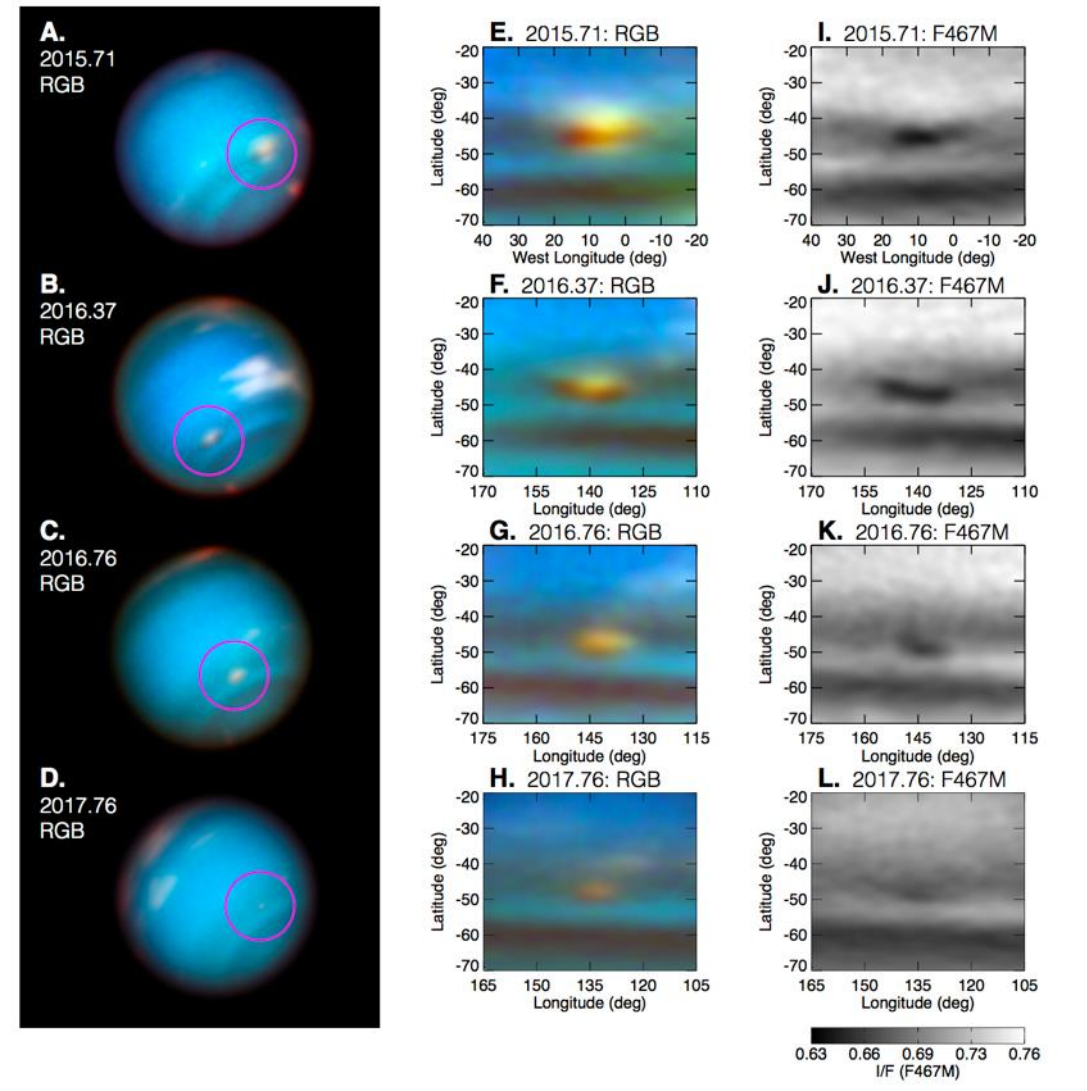
2019

Toledo et al. 2019 *Icarus* 333, 1-11

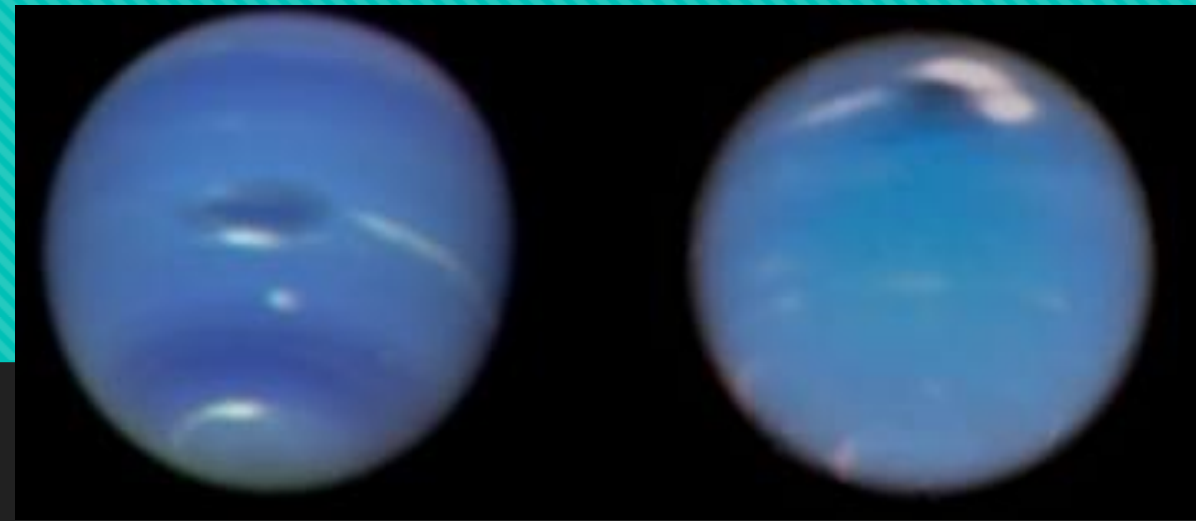
Toledo et al. 2018 *Geophys. Res. Letters* 45, 5329-5335

Neptune

- It's all about the storms!
- Hubble's high spatial resolution at short wavelengths allows us to see dark vortices not otherwise visible
- New storm first seen in 2015 (SDS-2015)
- Moved poleward and dissipated by 2018



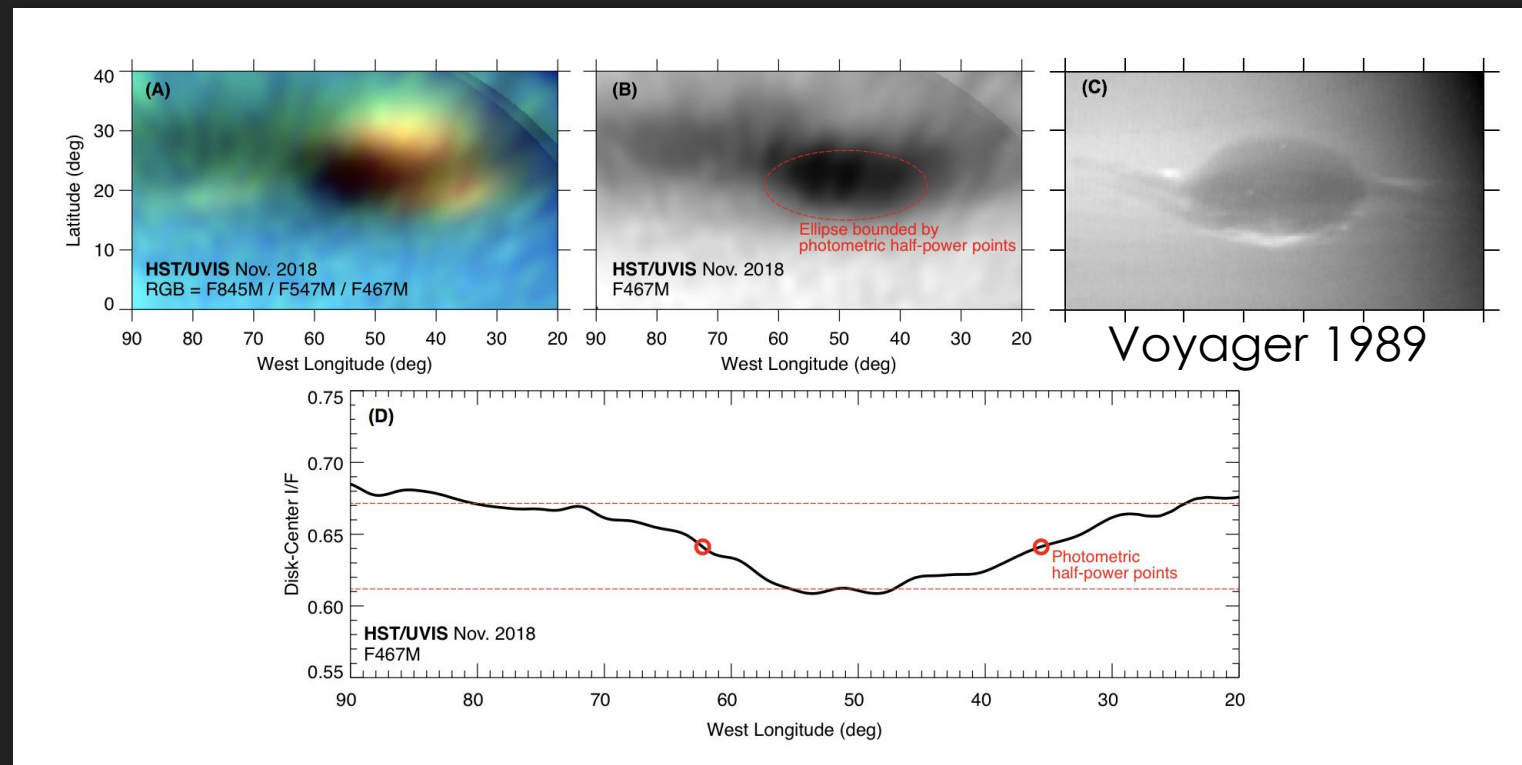
Neptune, cont.

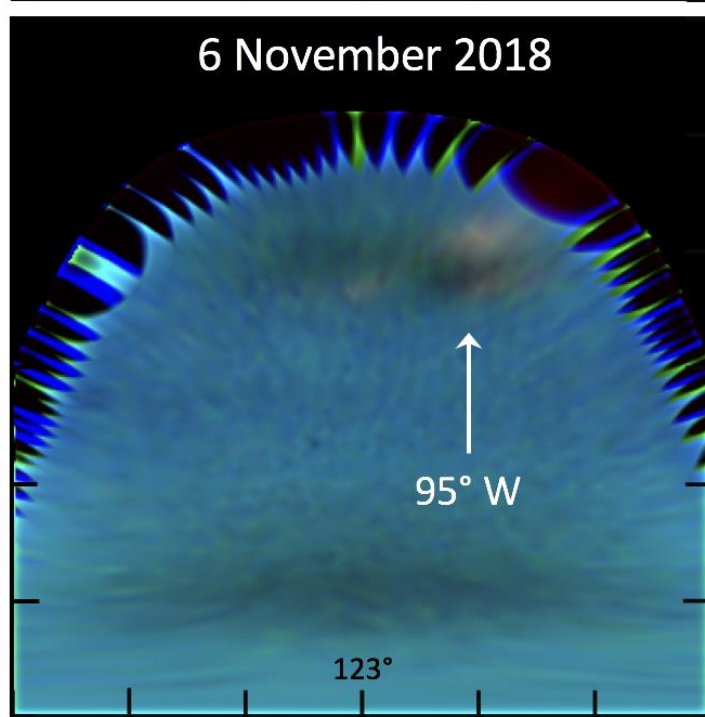
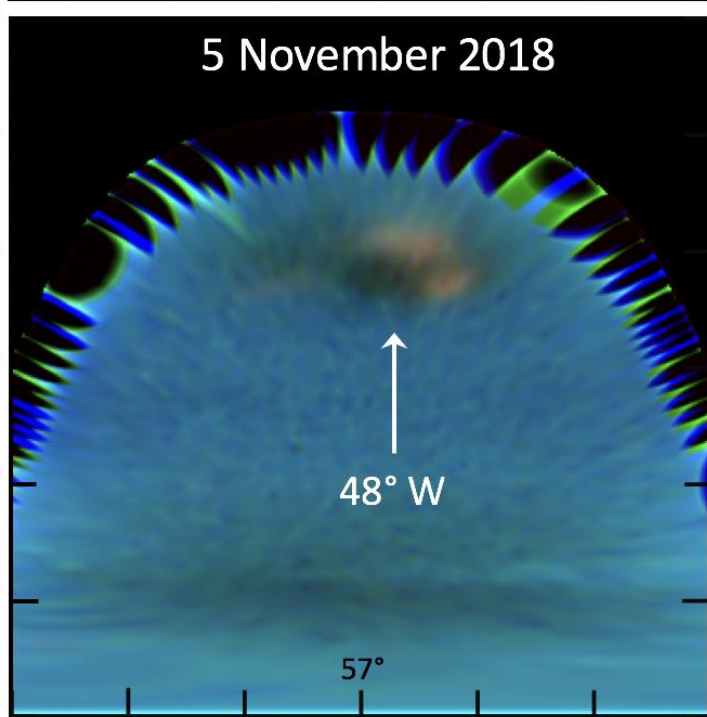
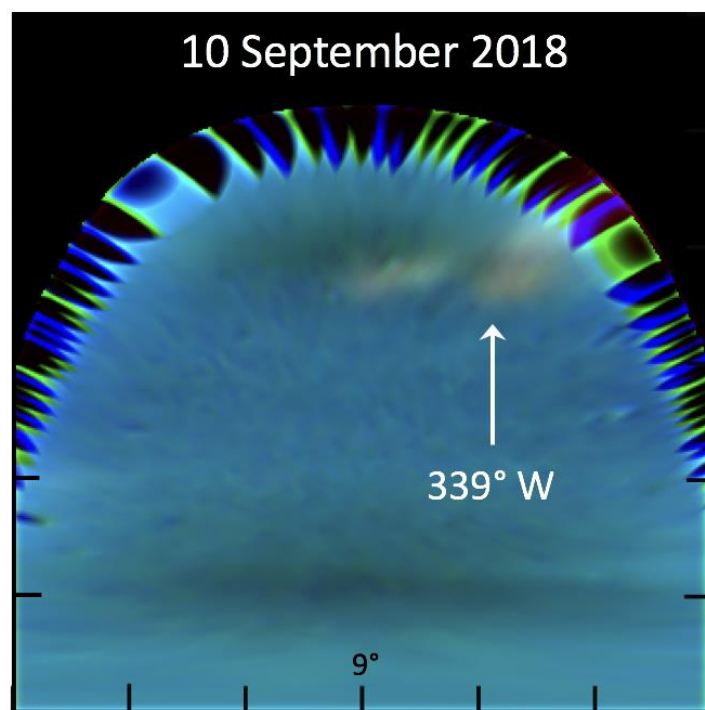
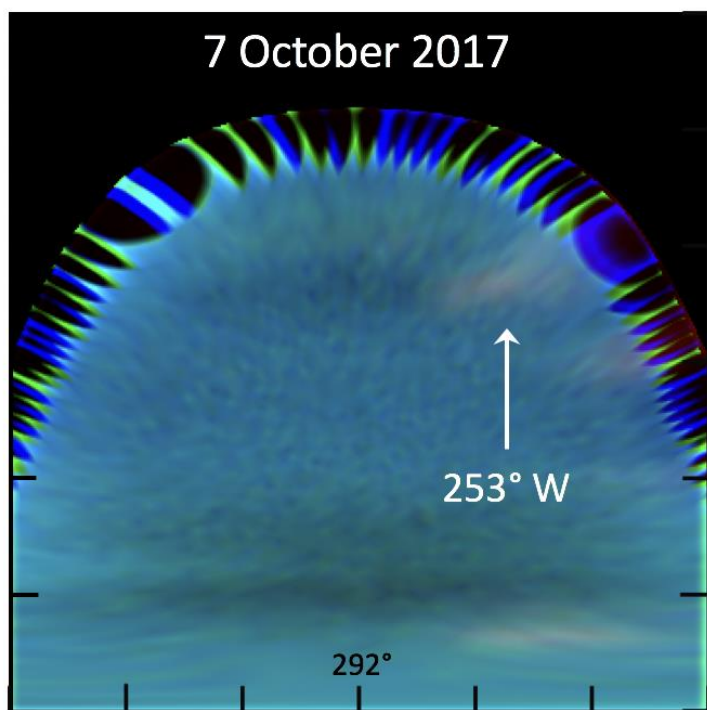


Voyager 1989

Hubble 2018

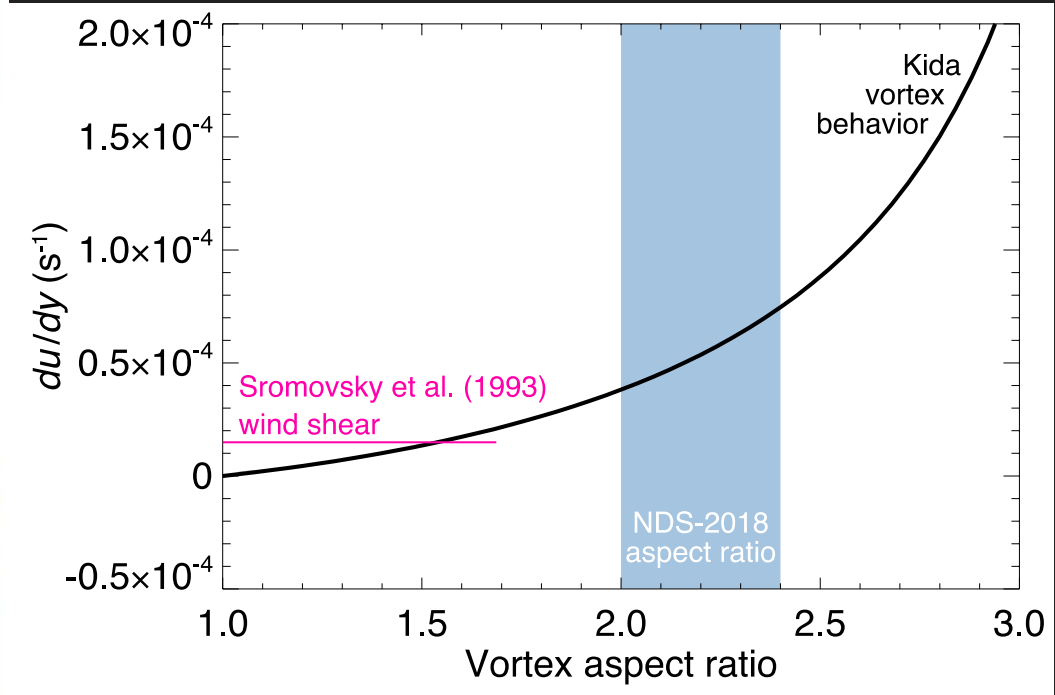
- Another large storm found in 2018 (NDS-2018)
 - Similar in size and drift rate as the Voyager Great Dark Spot, even though opposite hemispheres
 - Data from prior years allows a look at cloud activity in the region over the preceding years





Long coverage allowed us to track likely pre-cursor clouds to this storm forming

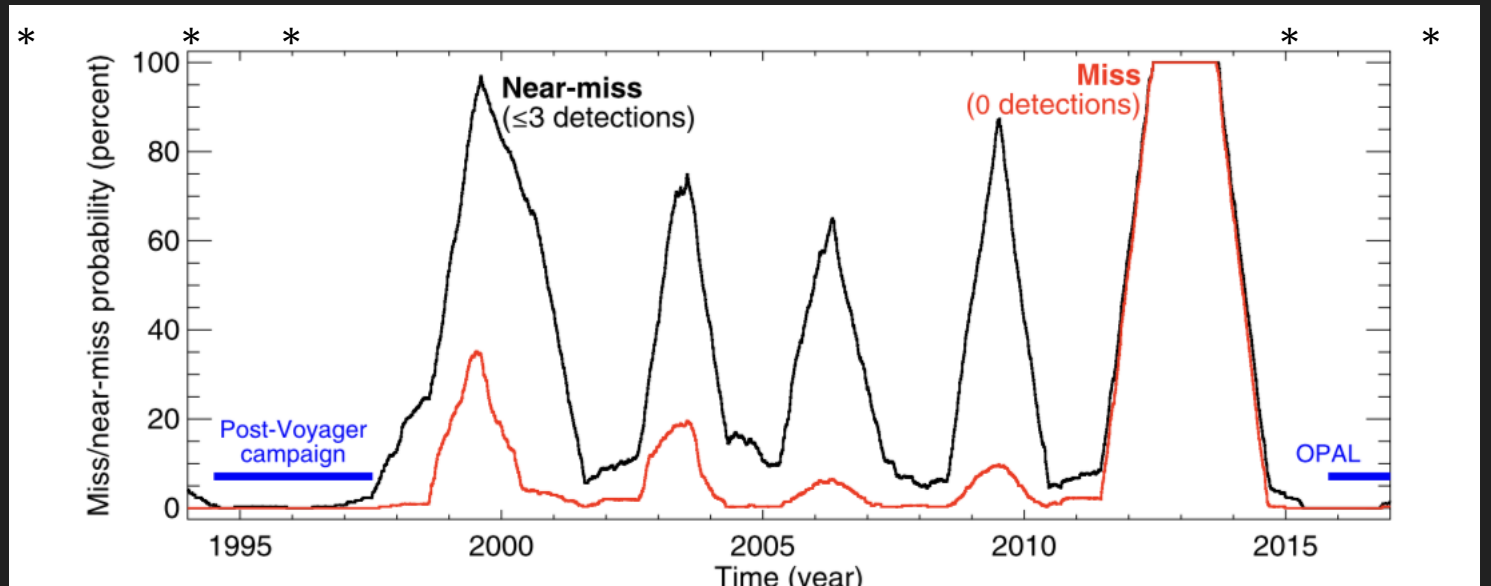
May be able to use shape to determine deeper atmosphere structure



Simon, Wong & Hsu 2019 *GRL* **46**, 3108-3113

Frequency and Lifetime of Dark Spots

- Counted dark spots seen by Voyager (2) and Hubble (4)
 - Time coverage is sparse, but maximum lifetimes could be constrained to 1 - 6 years
- Also looked at time coverage and how many observations had no spots detected
- Monte Carlo simulations then run to determine the likelihood of a spot forming, and of failing to detect it, based on these observing statistics
 - Can't see a spot, if not observing!



Summary

- Seeing a lot of activity on both Ice Giants
- Uranus
 - Smaller, high latitude, storms persist
 - Polar haze continues to brighten over time
- Neptune
 - Two new dark vortices detected
 - Occurrence of a spot every 4-6 years, with lifetimes from 1 to 6 years
- Frequent observations are invaluable, but any future mission will see interesting atmospheric activity, regardless of timing
 - A Neptune orbiter with a lifetime of 6 years would be ideal for ensuring a dark vortex is observed