Monitoring Neptune's atmosphere with a combination of small large telescopes

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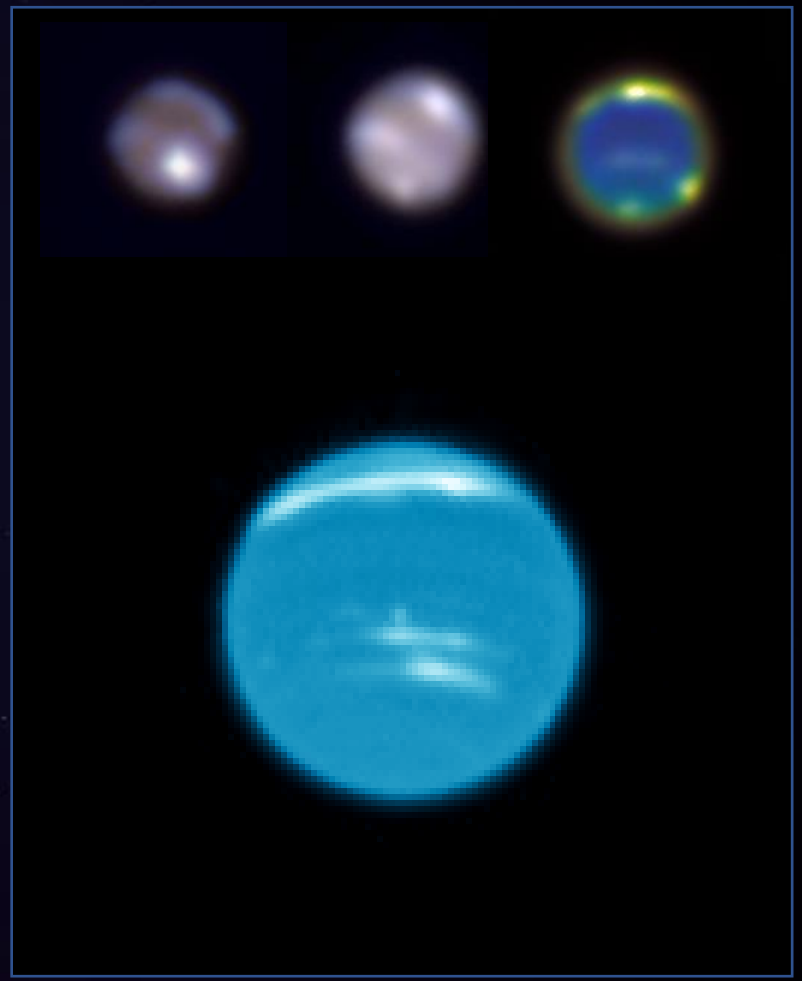


This online talk does not contain material under embargo.

This talk contains an audio description of the talk. Please activate sound

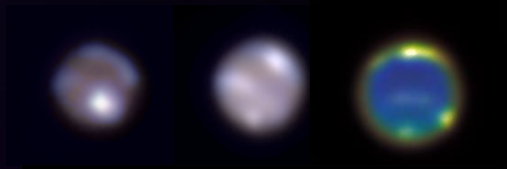
Outline of this talk

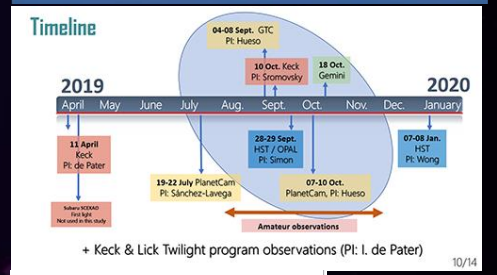
- Motivation for this study
- Neptune in 2019: Many different data sets

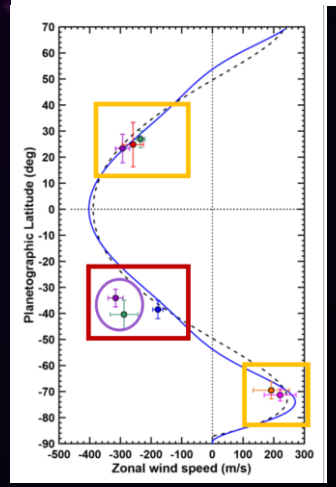
  (high-resolution and more frequent small-resolution images)
- Timeline of observations
- Tracking the long-lived systems in 2019:

  Results, winds & problems
- Conclusions

Due to the COVID-19 situation this report is only a "Work in progress" and we will have better results in the near future







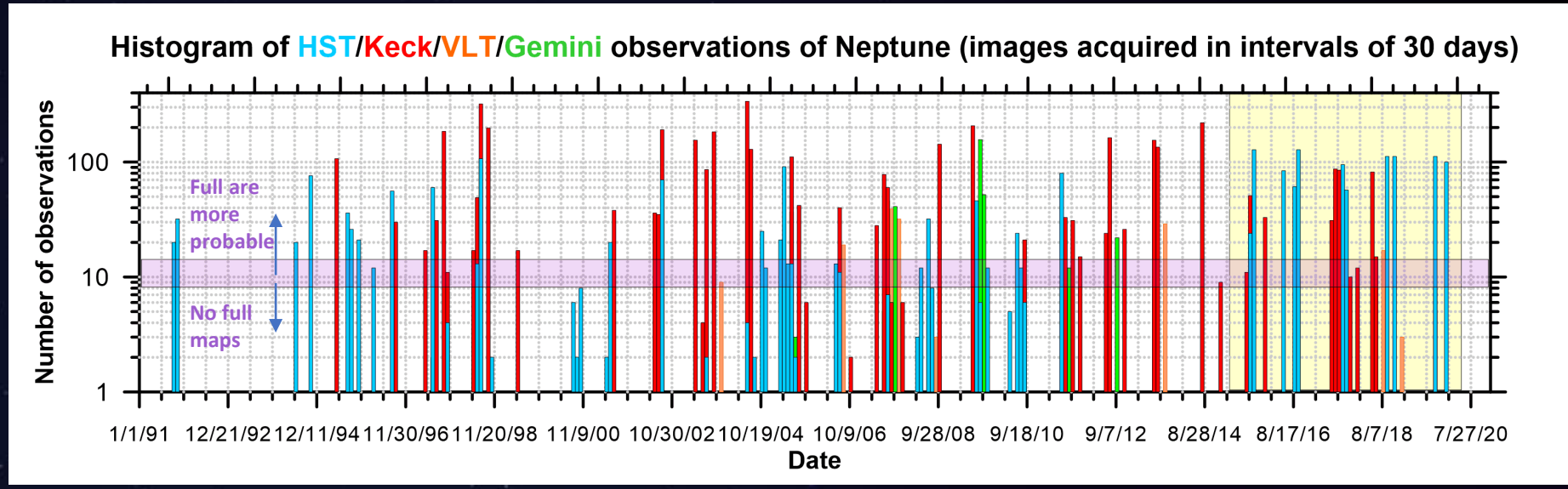
Motivation

Neptune is not observed enough to understand its global atmospheric activity

Small target
(2.3-2.35 arc sec at most)

Histogram

AO or HST observations able to resolve Neptune atmospheric features and study its dynamics



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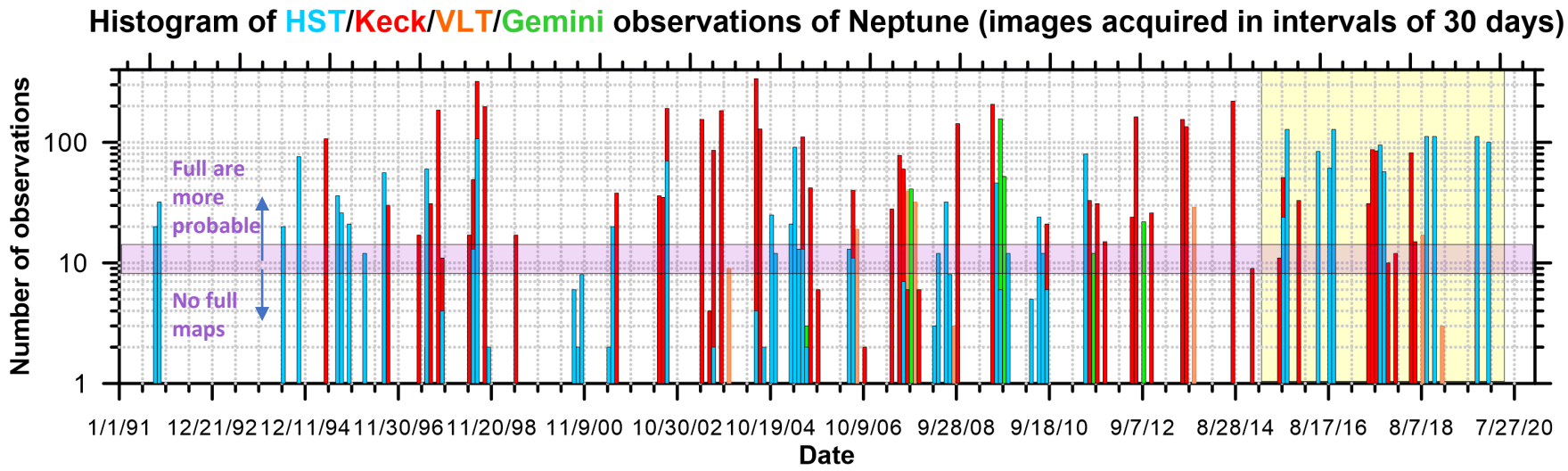
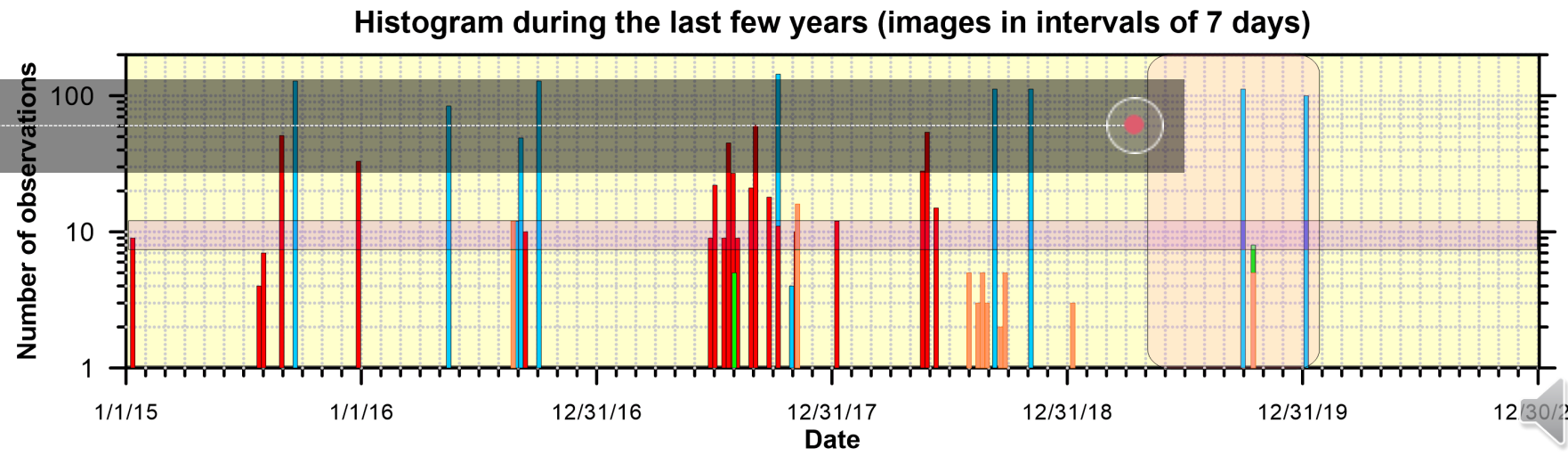
This work (2019)

Previously

2015: Hueso et al. Icarus, 2017

2017: Molter et al. Icarus, 2019



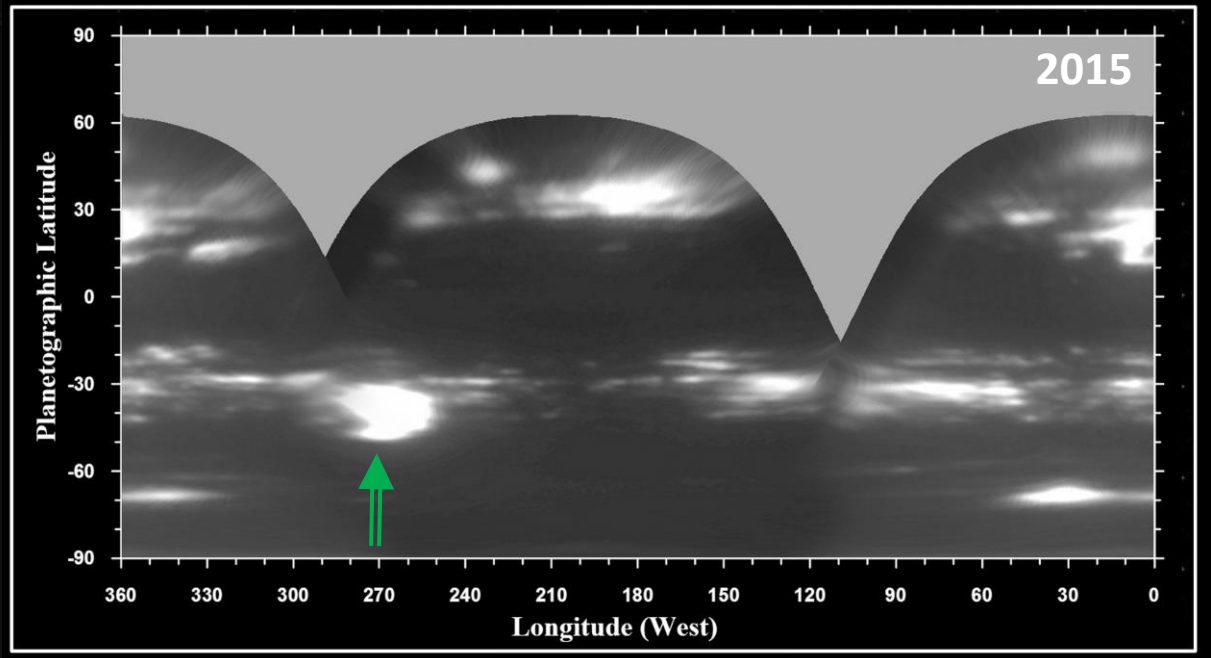


An extremely dynamic planet

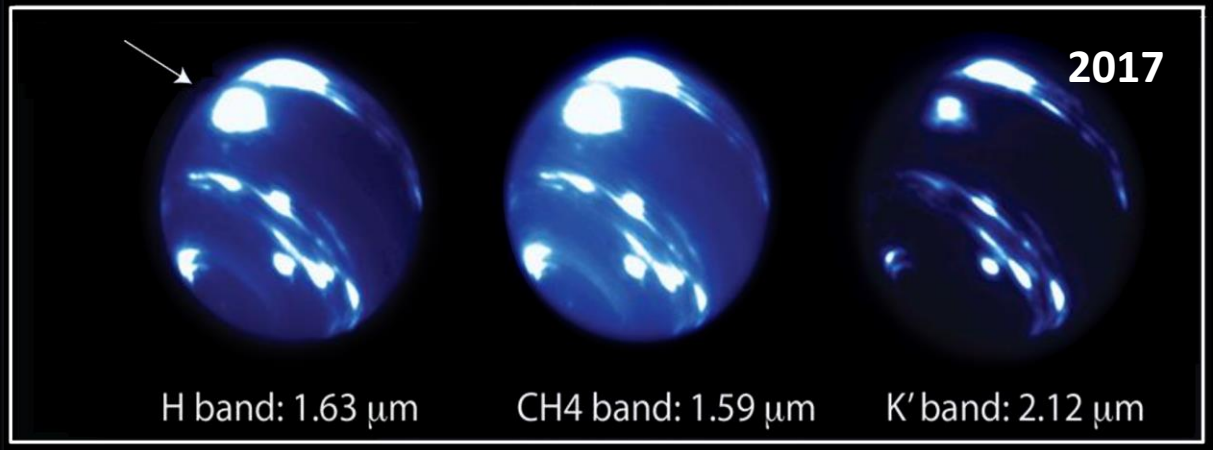
Neptune's cloud systems evolve in time-scales of years to days and a survey of its meteorology requires many more observations than those available to most observing programs or with most facilities.

A combined analysis of several sources is needed just to understand the dynamical history of the features observed.

Karkoschka 2011



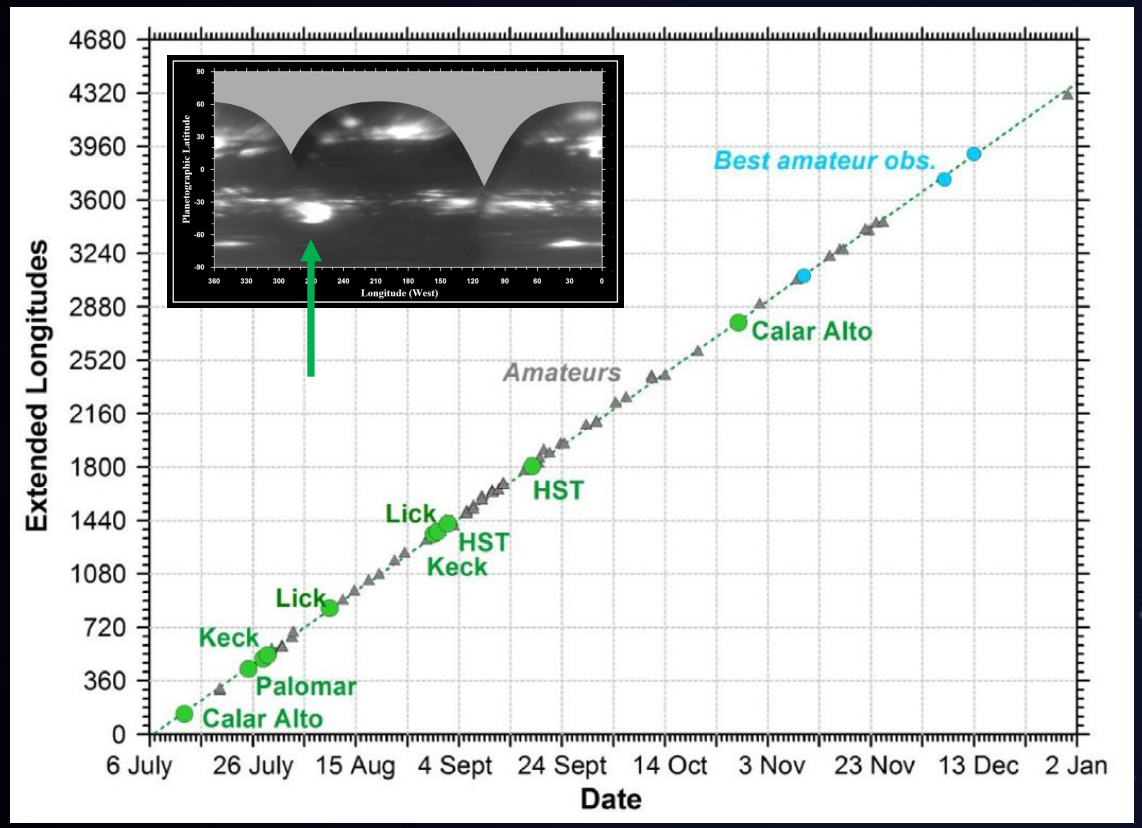
Hueso et al. 2017



Molter et al. 2019

Long-term studies

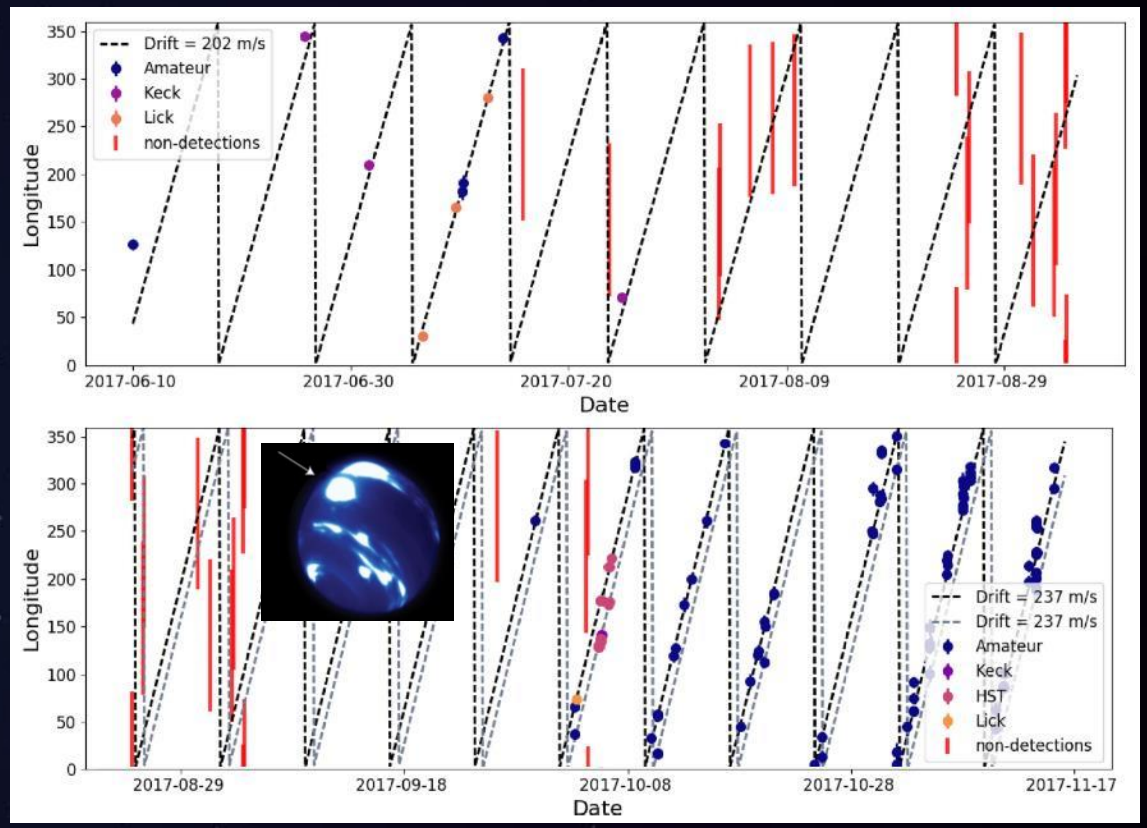
Fill the gaps with small telescopes including amateur observations. Study motions & changes



Hueso et al. 2017

Tracking the bright mid-latitude feature in 2013-2015 and other long-lived features in 2015.

Similar motions to Voyager but the mid-latitude features displaced in latitude and companions to the NDS-2015 (Wong et al., 2017)



Molter et al. 2019

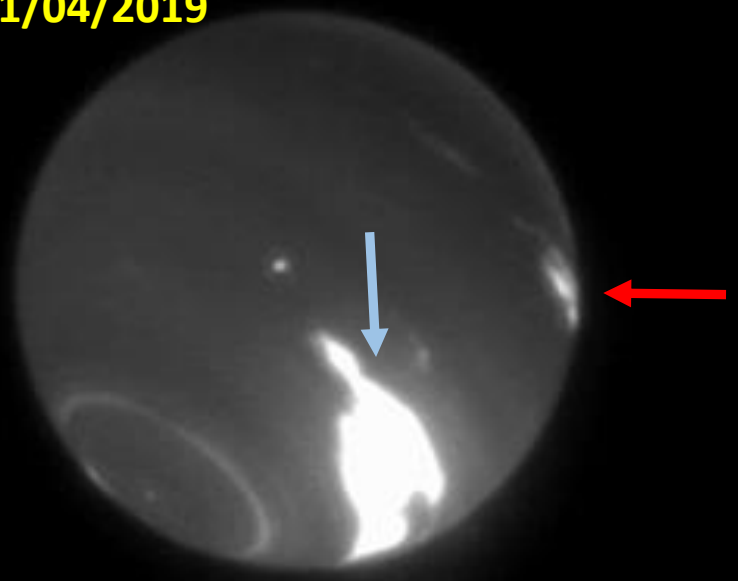
Systematic study of the Bright Equatorial Storm in 2017

No dark vortex companion, several cases of storm splitting
Detailed radiative transfer models & posible convective system
Equatorial vertical wind shear required

Neptune in 2019

Outstanding individual images (but not long-term data sets)

H Band
11/04/2019

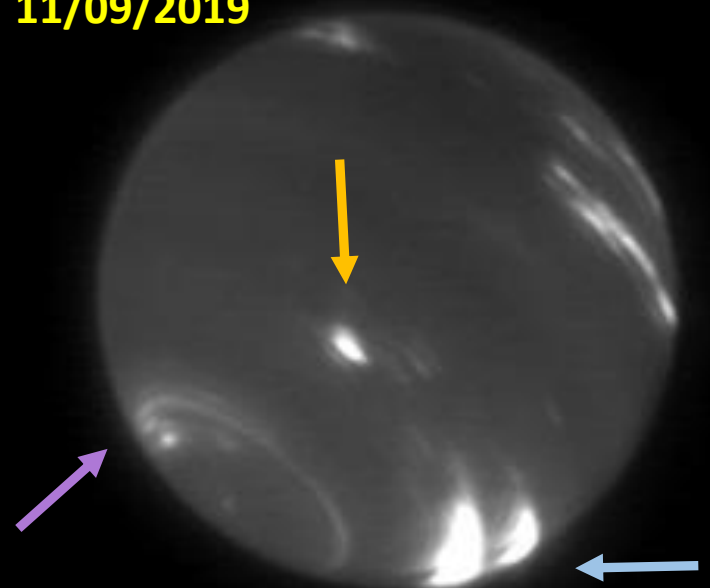


PI: Imke de Pater

H Band
10/09/2019

PI: Larry Sromovsky

H Band
11/09/2019



PI: Larry Sromovsky

Outstanding data sets

HST/OPAL images in 28-29 September
PI: Simon
Two full maps in several filters

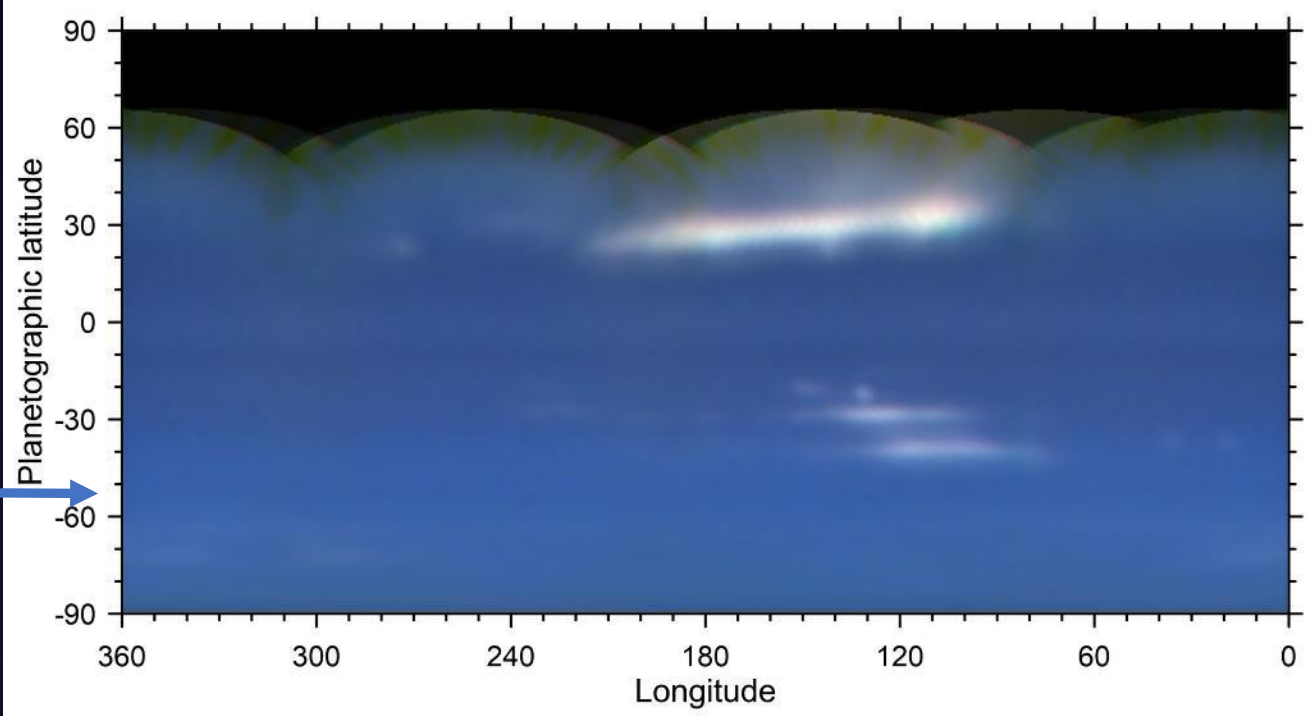
False color composition in methane-band filters
- R F845M
- G F657M
- B F763M
- Luminosity: 727N+F845M

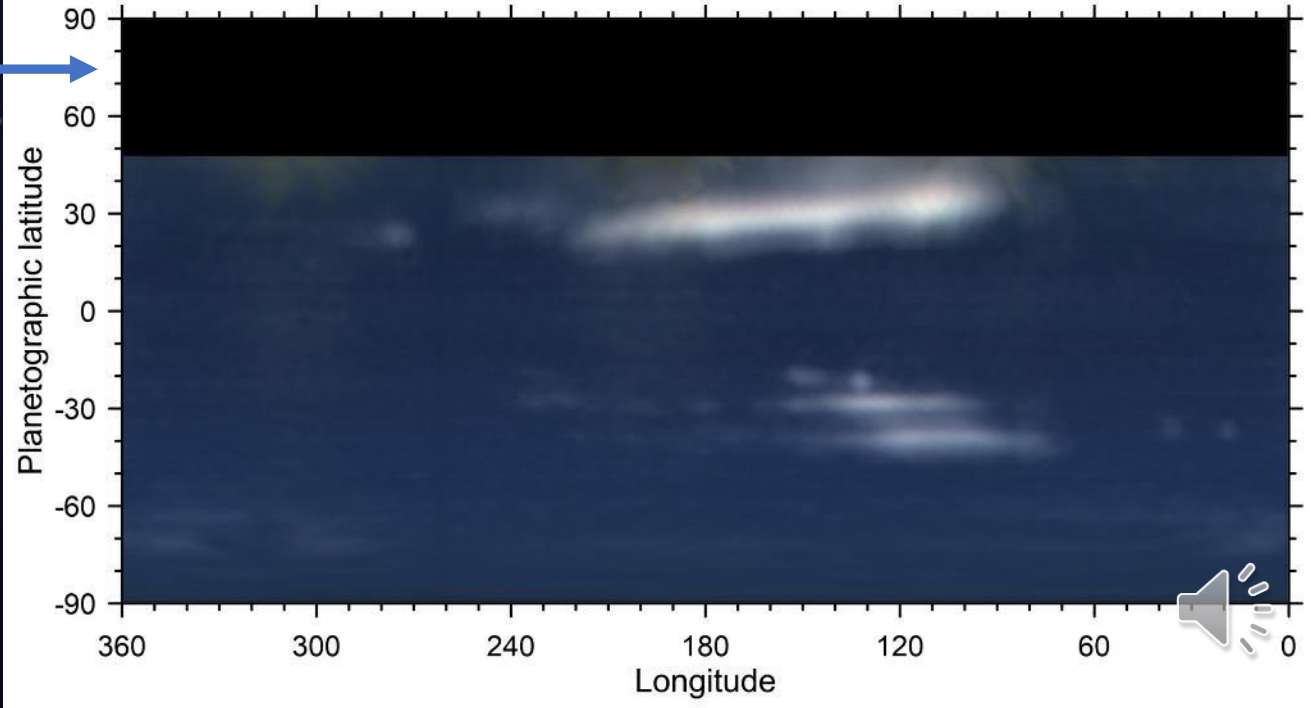
Differential image

Highlighting cloud systems

Additional HST maps in January 2020
(PI: Wong)

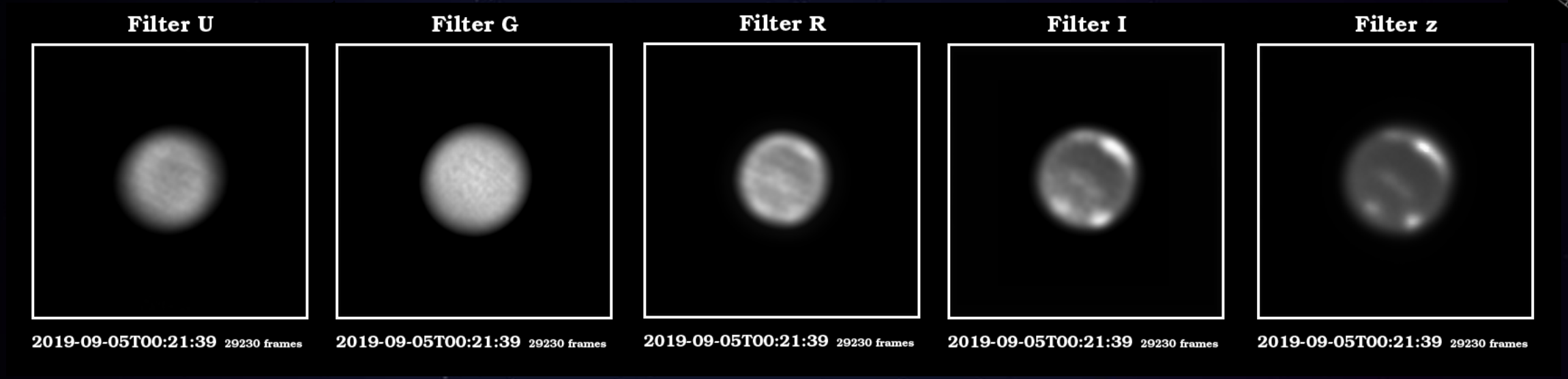
CAVEAT: None of these cloud ystems is very bright (except the North tropical cloud system) making difficult their observation with small telescopes



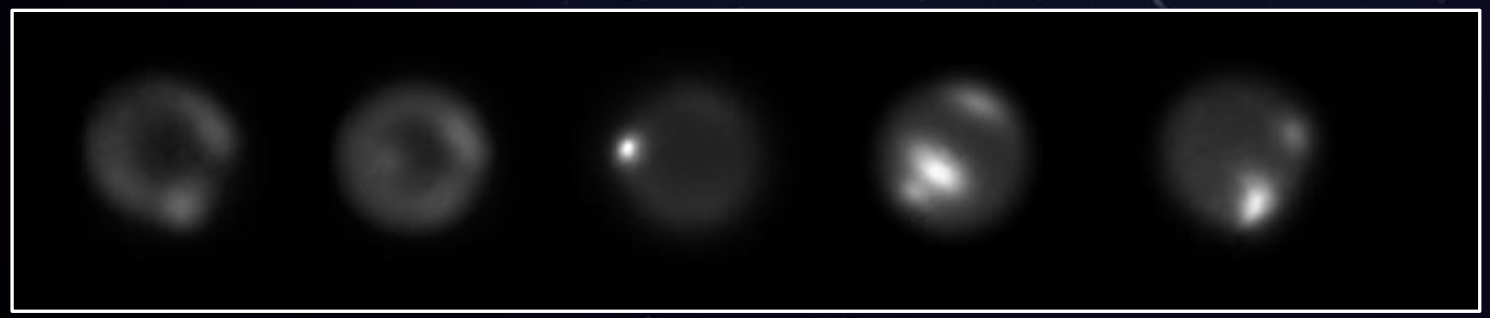


GTC 10.4m doing lucky-imaging with HyperCam

1 hour each night in 4-8 September: 5 cameras running in parelel from U (365 nm) to z (900 nm)



Calar Alto 2.2-m telescope with PlanetCam (VIS & SWIR: 0.4-1.7 μm)

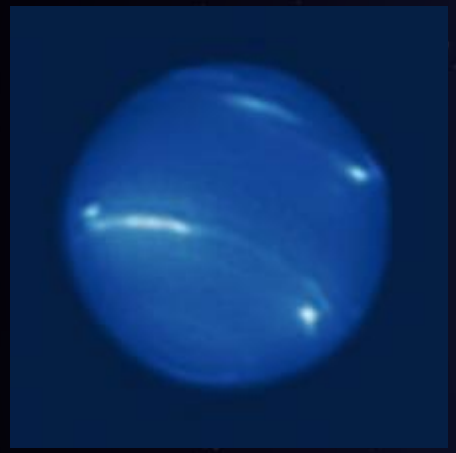


All "small" images navigated with the position of Triton

Low spatial resolution but only data set with sustained observations over several hours each night for 4 consecutive nights in 2 rounds (July & October). Sensitivity to different absorption bands

An additional Gemini AO image

Ks band (only sensitive to the brightest cloud systems at highest elevations)



Subaru SCExAO

April 2019

First light images, not yet used in this study

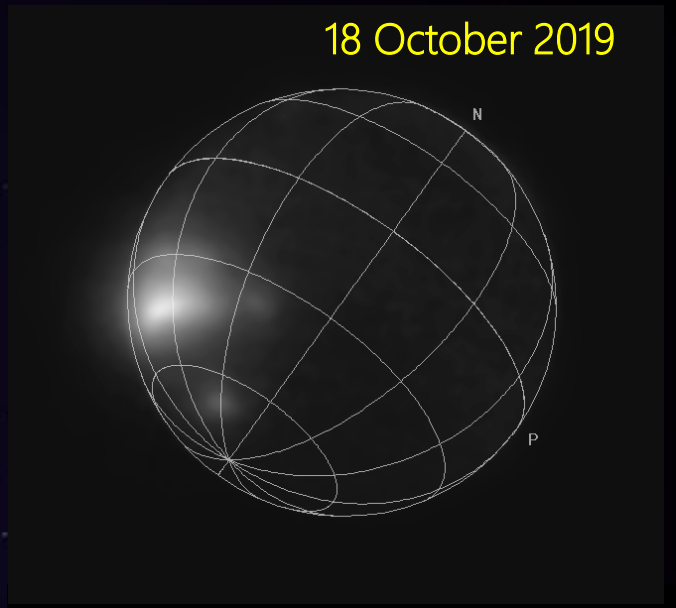


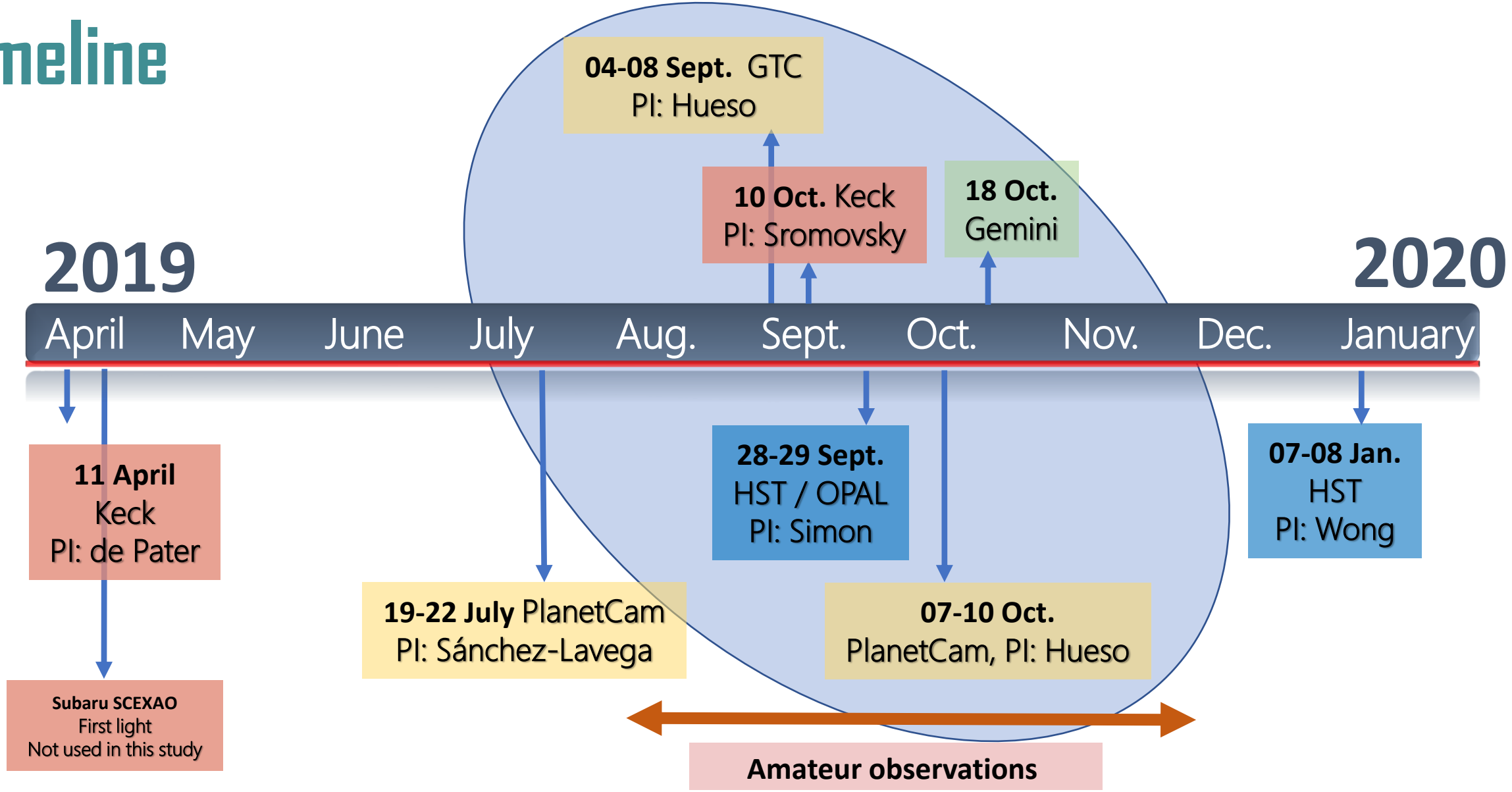
Image by Anthony Wesley (Australia)

And many observations with small telescopes!

provided by many amateur astronomers: Martin Vinicius, John Sussenbach, Marc Delcroix, Luigi Morrone, Roberto Sedrani, Anthony Wesley, Richard Christensen, Walter Martins, Darryl Milika, Pat Nicholas, Tiziano Olivetti

(images available at http://pvol2.ehu.es/ and/or ALPO Japan)

Timeline



+ Keck & Lick Twilight program observations (PI: I. de Pater)

Results

Only 2 well-defined long-lived systems matching linear drift rates with some confidence & consistent with the linear drift rates of other features observed with PlanetCam & HiperCam on 2.2m and 10.5 m telescopes.

Keck
10-Sept.

HST
28-29 Sept.

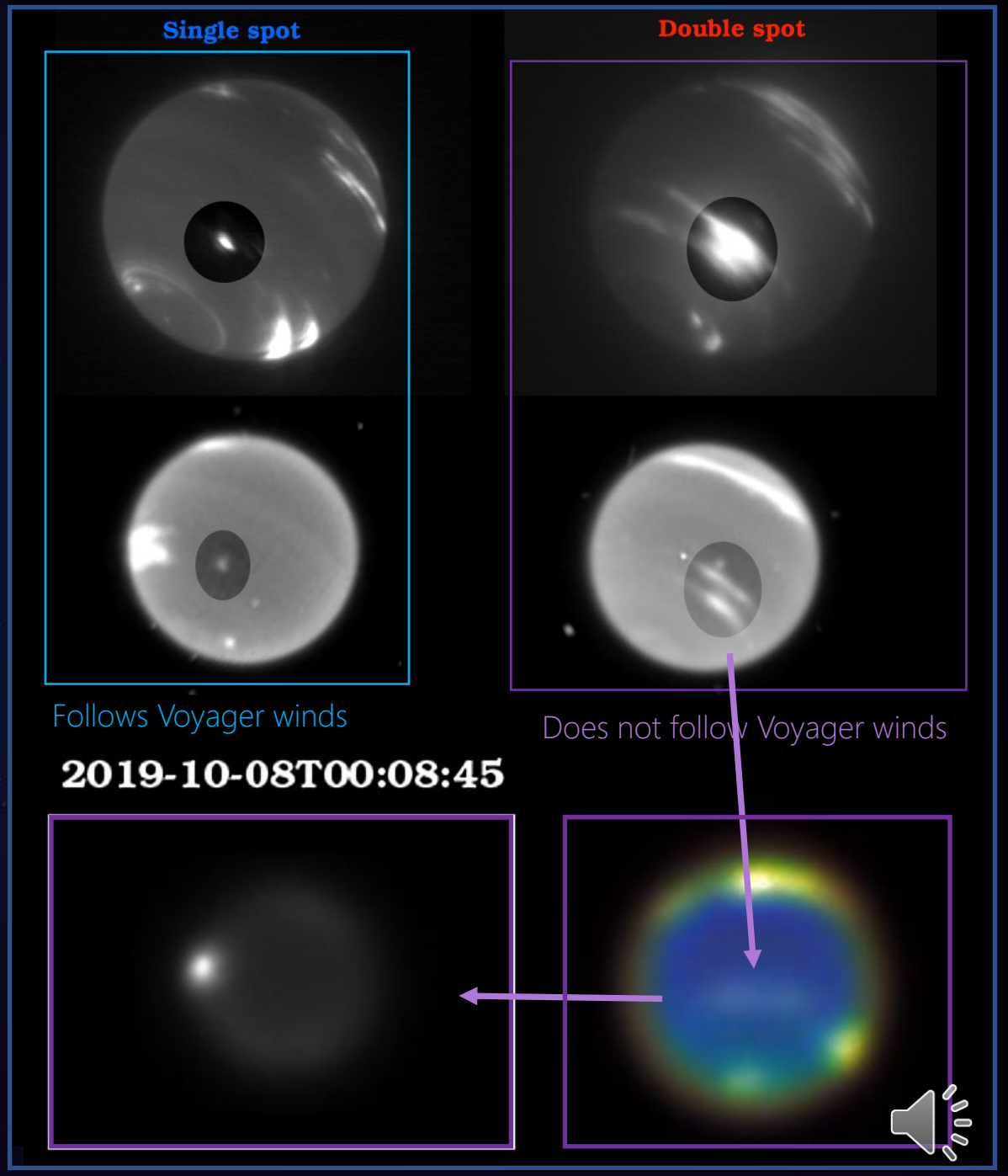
The double system may have altered its brightness and drift rate transforming into a possible third cloud system or they might drift at different speeds

PlanetCam (left)

July, October (8 nights)

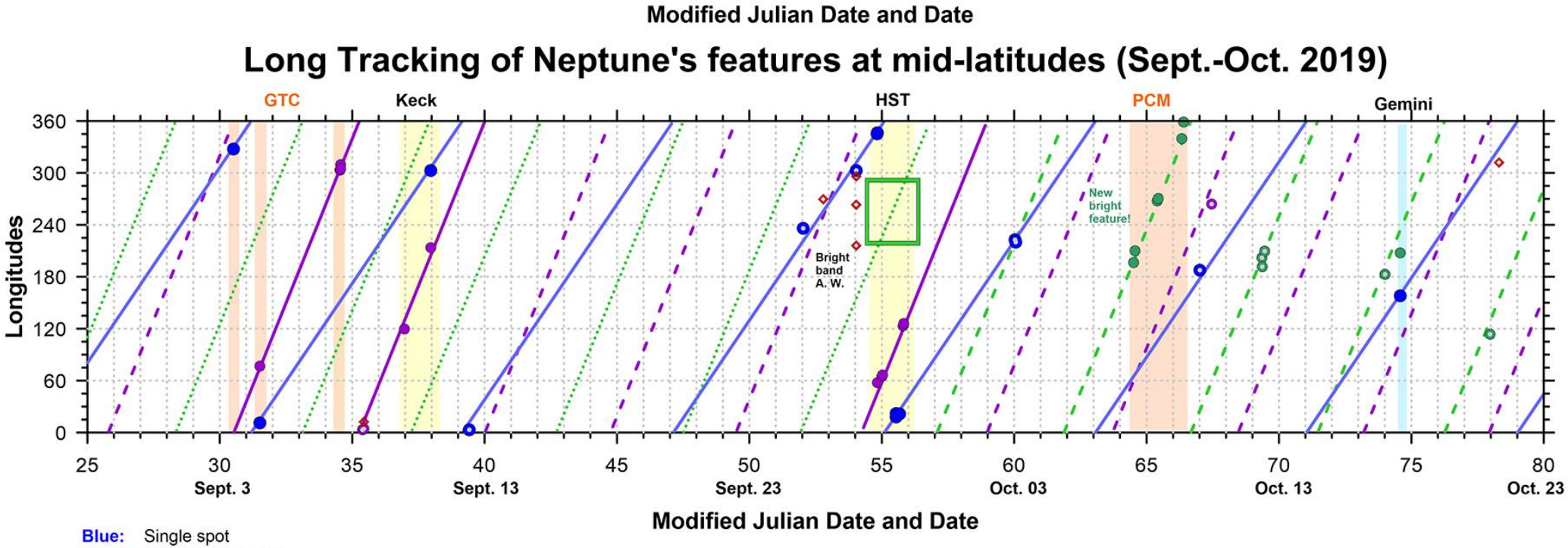
GTC/HiperCam (right)

04-08 September



Results

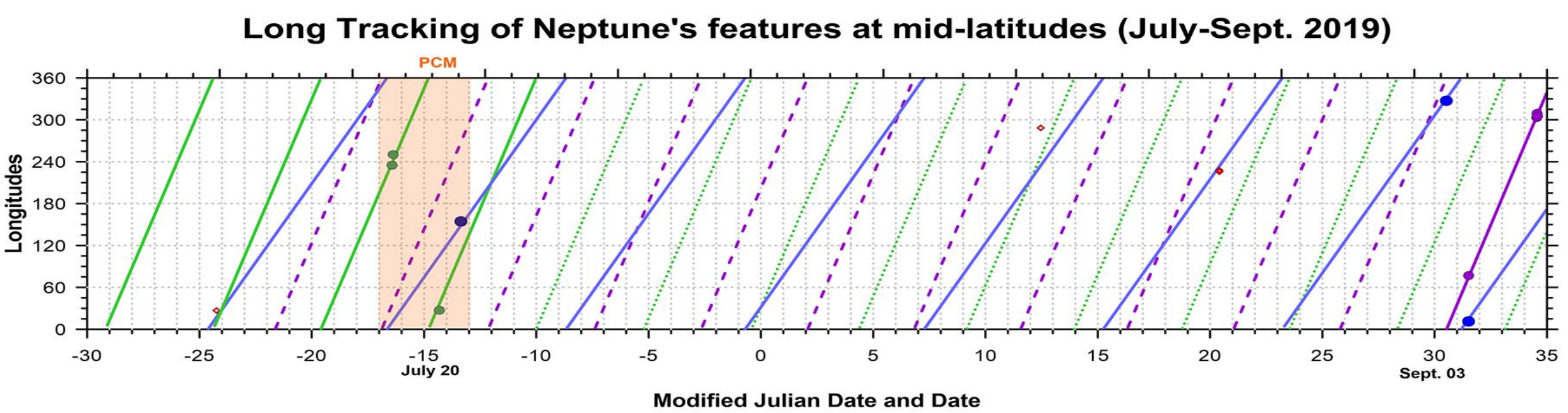
An extremely complex tracking.

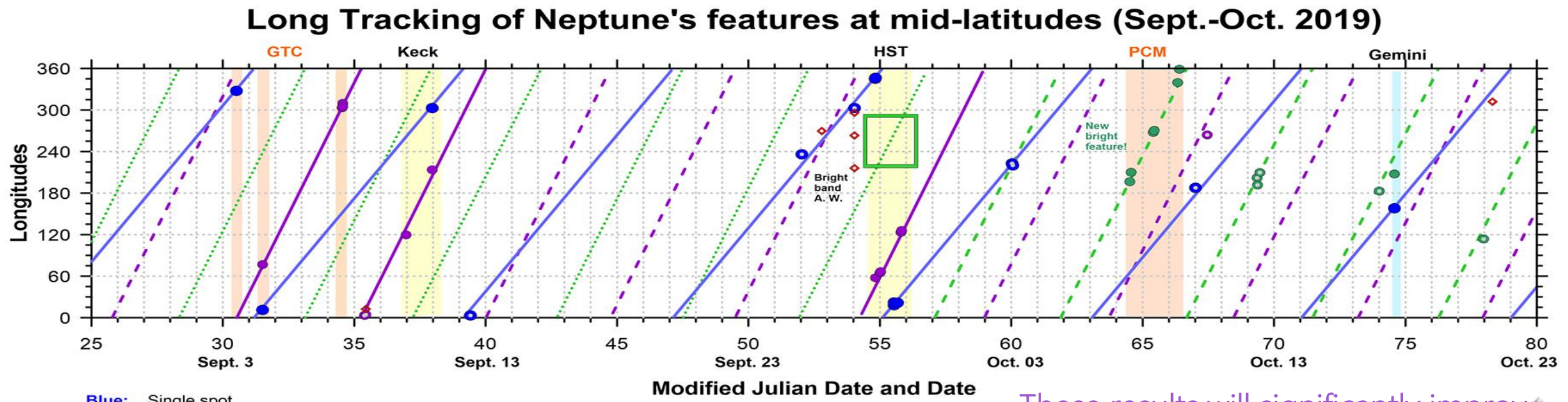


HST, GTC & Keck fit well

HST/& PlanetCam do not fit well

Changes in the single or the double system in October





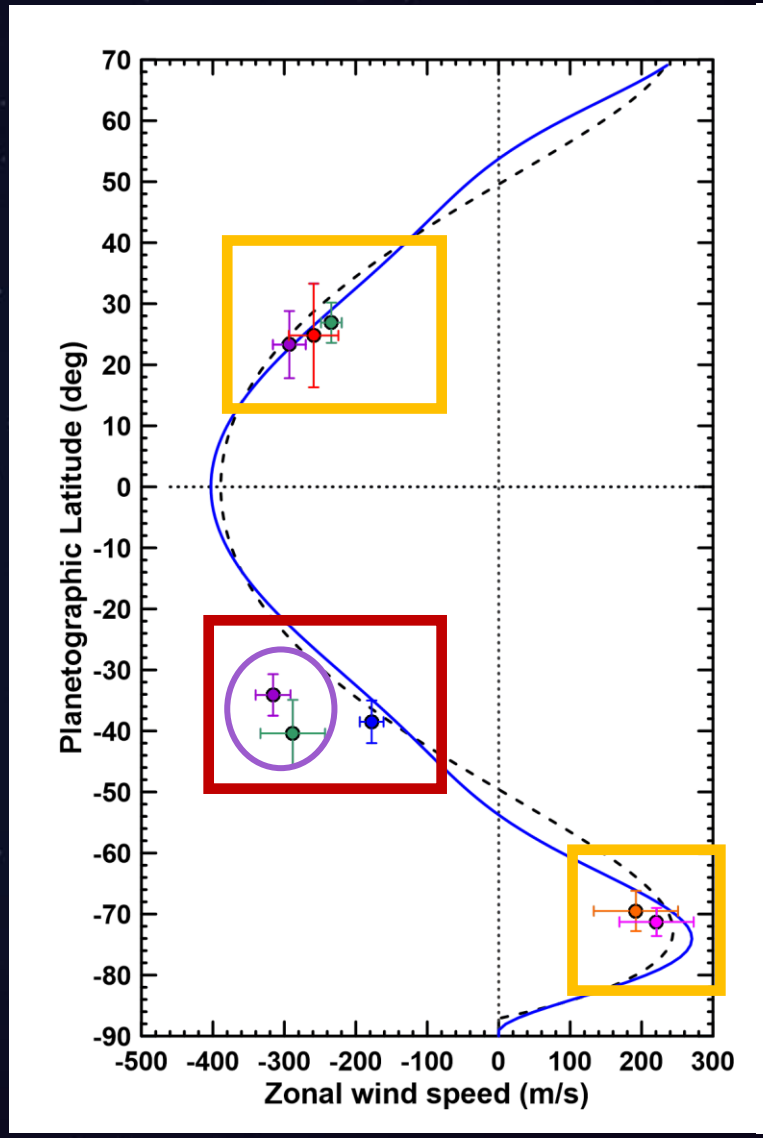
Blue: Single spot
Purple: Bright double spot
Green: Single bright spot
Grey: Features identified in amateur images
Red: Features observed in amateur images but not identified in the trackings

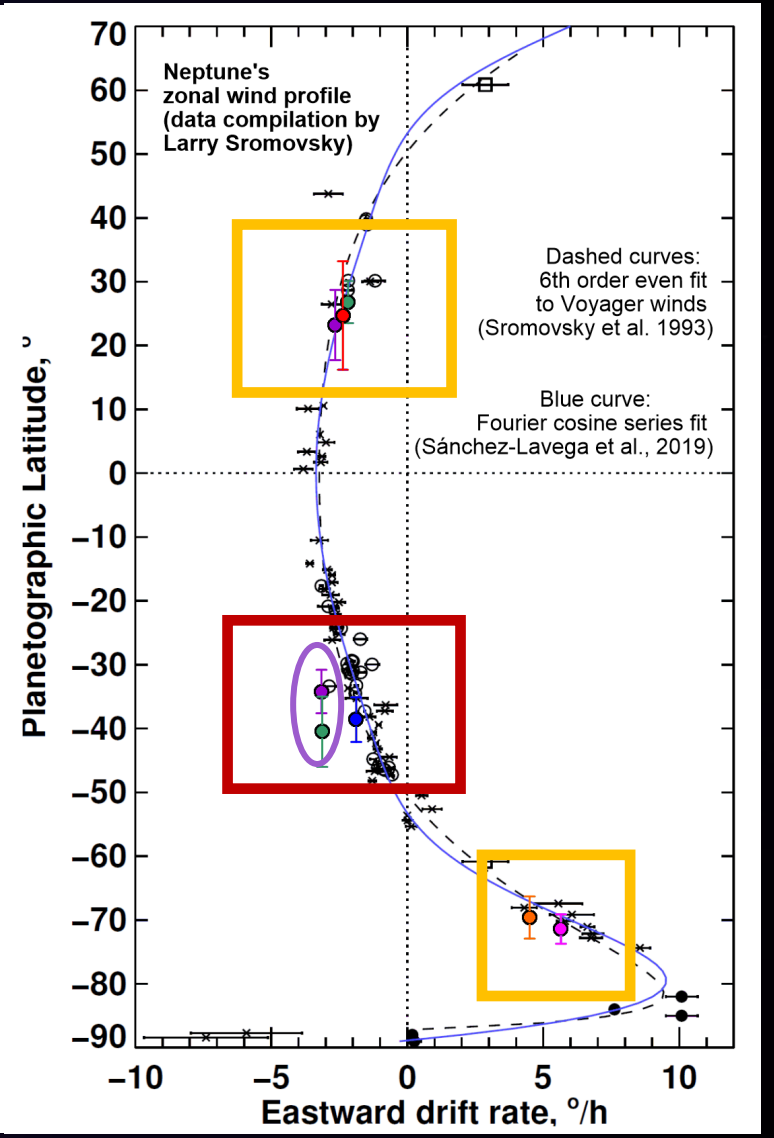
These results will significantly improve once we add more data to the analysis.

Results

These three main systems have drift rates that when compared with Voyager zonal winds only match for one of them
(the single bright & small spot)

The Double Cloud System with changes in time does not fit the Voyager winds by a long distance. It might be the manifestation of a deeper feature (a dark vortex not visible in HST image).
A slower drift rate is expected contrarily to what this analysis suggests.





Features in the South Polar Bright Feature and in the North Tropical Bright cloud can also be tracked (tracks not shown in this presentation) and fit the Voyager zonal winds.

Conclusions

- The current analysis of observations in 2019 does not solve the motions of the main cloud systems as successfully as in previous years. More work is needed.
- A comparison with observations gathered by the TWILIGHT programs at Keck and Lick observatories should be able to fully resolve the inconsistencies in drift rates here shown.
- **Future:** More observations from small-telescopes will be helpful in years where Neptune presents bright cloud systems but the 2019 campaign did not contain these "easy targets". An alert system for observers is being developed through the **Europlanet 2024 Research Infrastructure**, so that we can communicate efficiently with them when Neptune observations will be most helpful.
- **Future:** Observations with new facilities (**James Webb Space Telescope, ELT,...**) will only be obtained once or a few times per year. Advancing in the study of Neptune's dynamic atmosphere will benefit more coordinated analysis of observations from many different observatories and groups.