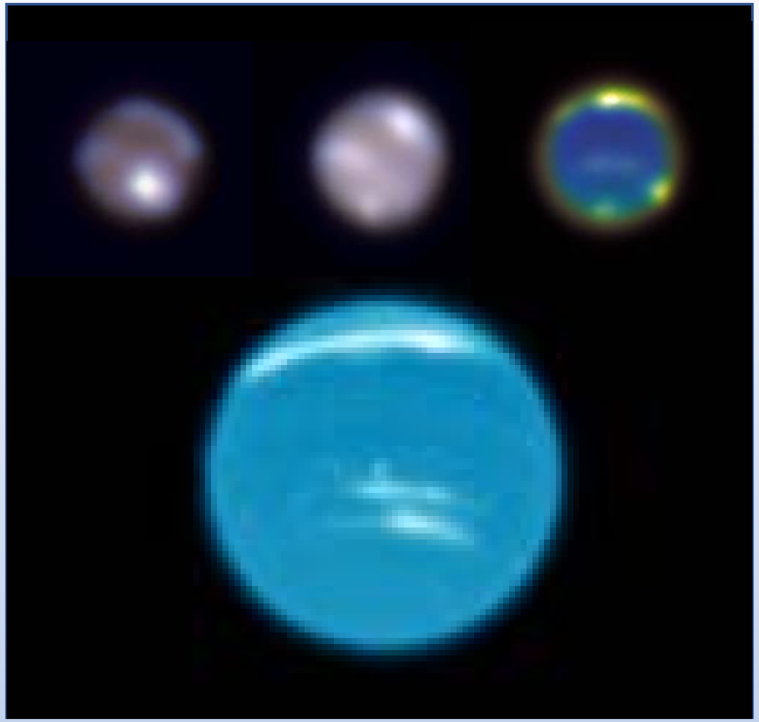
Monitoring Neptune's atmosphere with a combination of small and large telescopes: The role of Spanish Telescopes in a global international campaign



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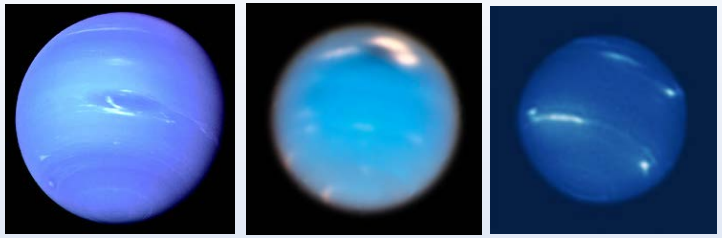
Neptune's atmosphere is covered by tropospheric clouds and hazes that evolve in timescales of days, months and years. Given the small apparent size of Neptune's disk (2.4"), there are outstanding difficulties in obtaining sufficient high-resolution data to trace Neptune's atmospheric dynamics and study its variability.

Here we present results of an international campaign to observe Neptune & we focus in the potential of Spanish Telescopes to advance in the knowledge of its atmosphere.

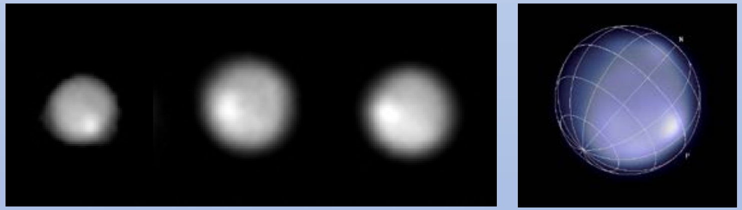
CONTEXT: *Conventional knowledge assumes that only Adaptive Optics and space telescopes such as HST, can provide data to study the atmospheric dynamics of Neptune with systems of clouds of 1,000-3,000 km observed at 40 AU (with apparent sizes of 0.03-0.1" over Neptune's disk of 2.35").*



We have used the ***PlanetCam*** *"lucky-imaging" dual camera on the 2.2m telescope at* ***Calar Alto*** *to monitor Neptune's activity since 2015 showing resolved features well bellow the seeing limit. Also from* ***OSIRIS*** *and* ***HiPERCAM*** *at* ***GTC*** *(next slide).*

The ***difficulty to access enough observational time on larger telescopes*** *suggests that a combination of data from several observing programs can help in understanding Neptune atmosphere dynamics.*

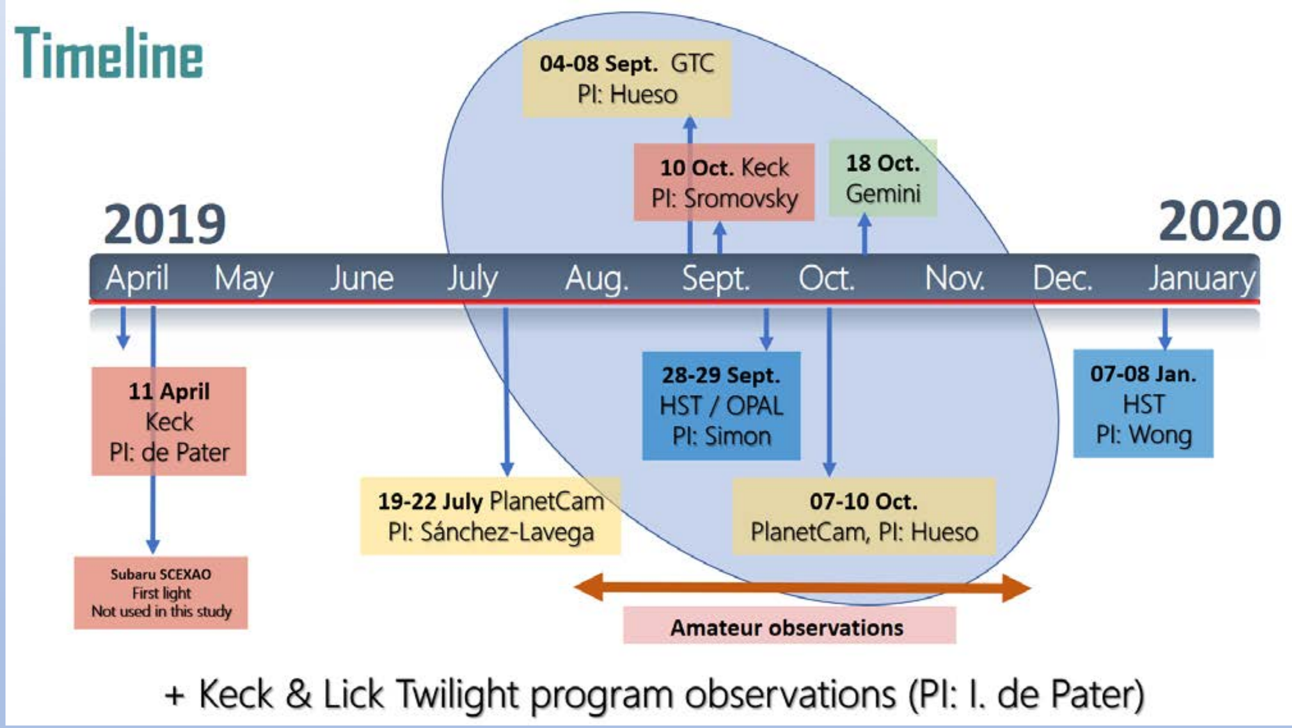
Smaller telescopes *can also play an important role to cover the gaps between observations obtained by the larger telescopes. See great examples of Neptune amateur images on the* ***PVOL database*** *at http://pvol2.ehu.eus*

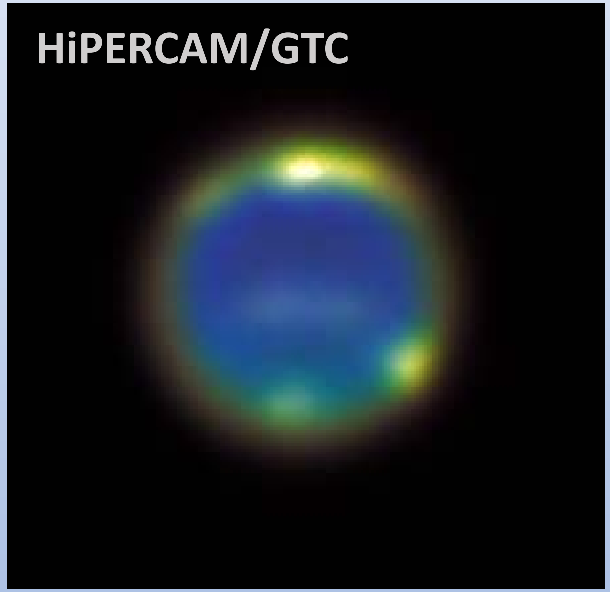


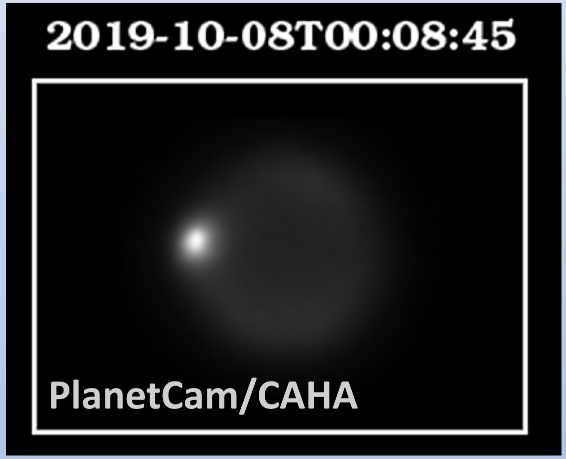
During the last few years we have combined observations obtained from a variety of telescopes to study the major cloud systems and understand their life-time and evolution including those of "companion" clouds linked to rare dark vortices that are only observable in blue wavelengths from space. In this work we present our data for 2019.

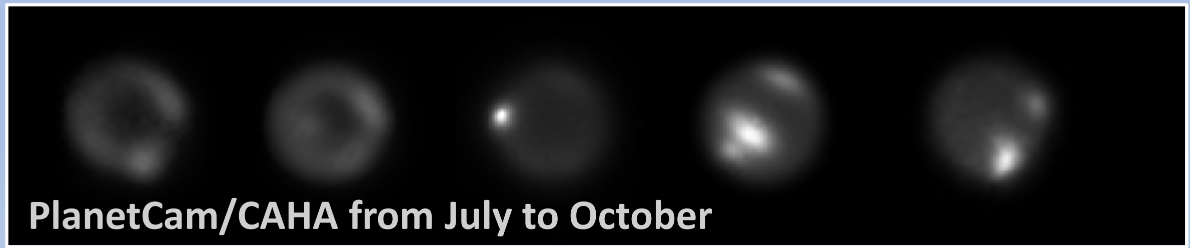
Our 2019 data:

- *HST observations from the Outer Planets Atmospheres Legacy program (OPAL).*
- *Several sets from Keck and Lick telescopes from different programs including the TWILIGHT program.*
- ***GTC observations with the HiperCam instrument doing lucky-imaging.***
- ***Calar Alto 2.2m telescope with the PlanetCam lucky-imaging instrument.***
- *One single observation from Gemini while testing an AO system.*
- *Additional observations from the Pic du Midi 1.05 m telescope.*
- *Images provided by amateur astronomers and available through the PVOL database.*



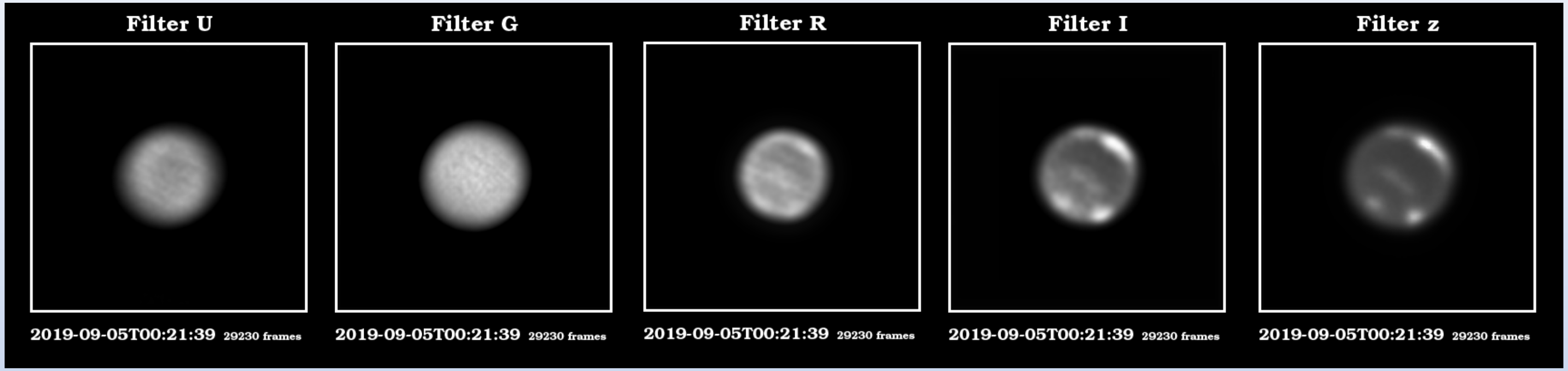


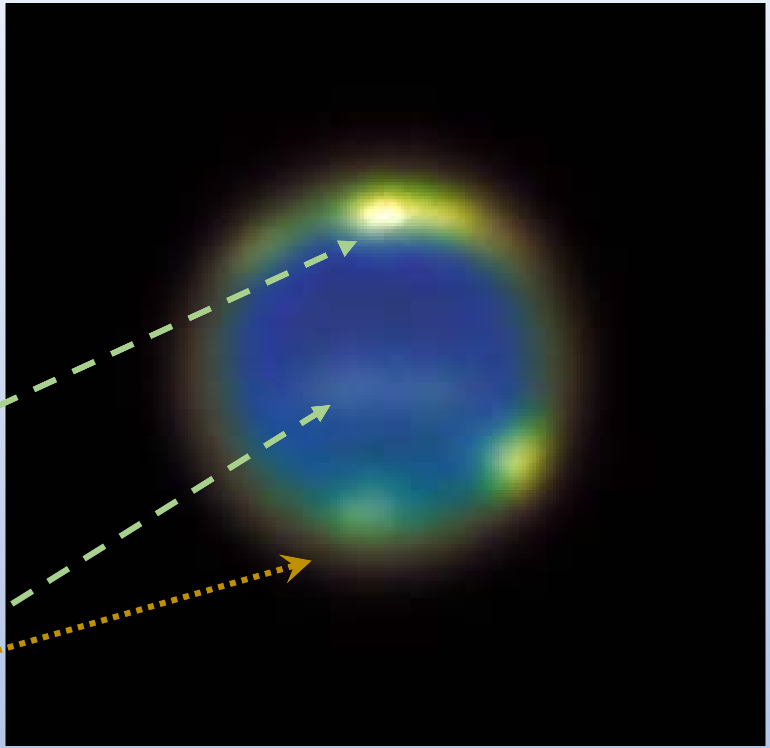




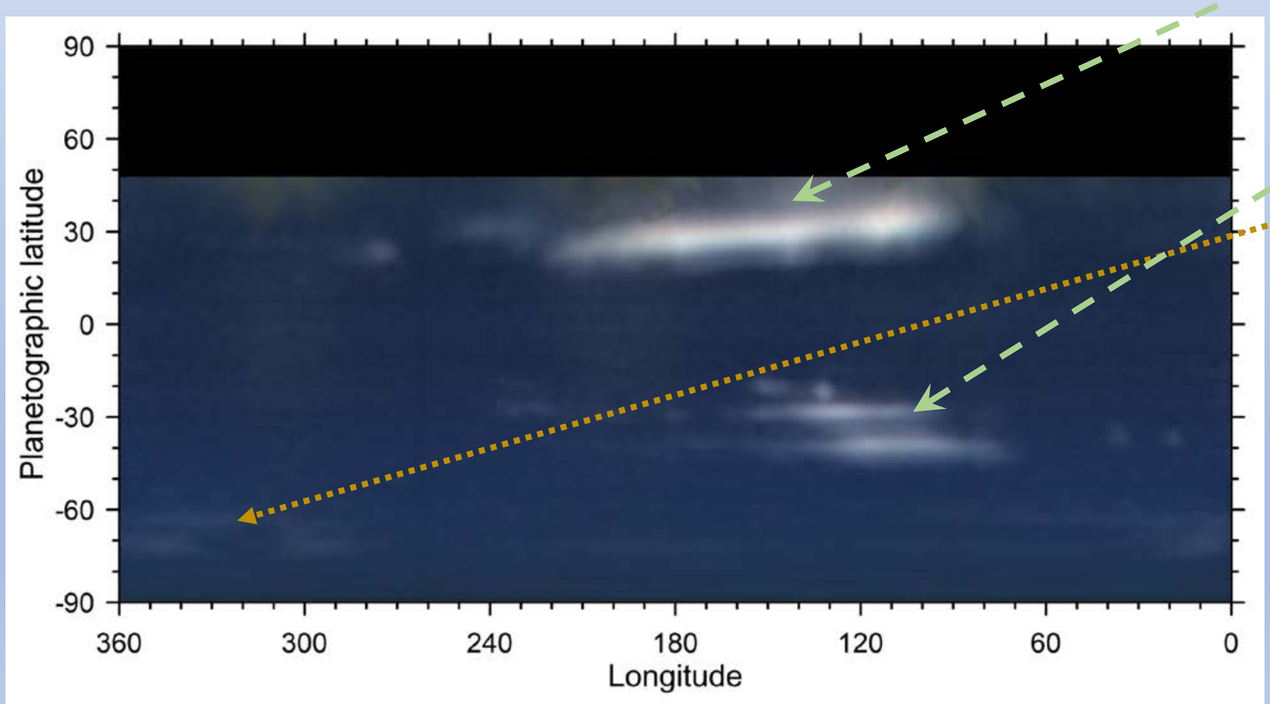
GTC data: Lucky-imaging with Hipercam on 05-08 Sept.

Only a few hours of data over 4 nights 3 images in 5 channels from U to Z





Compared with an HST map on 28-29 spt.



Absence of large meteorological systems like those observed in Neptune at least in 2013-2018. This is a major change in Neptune.

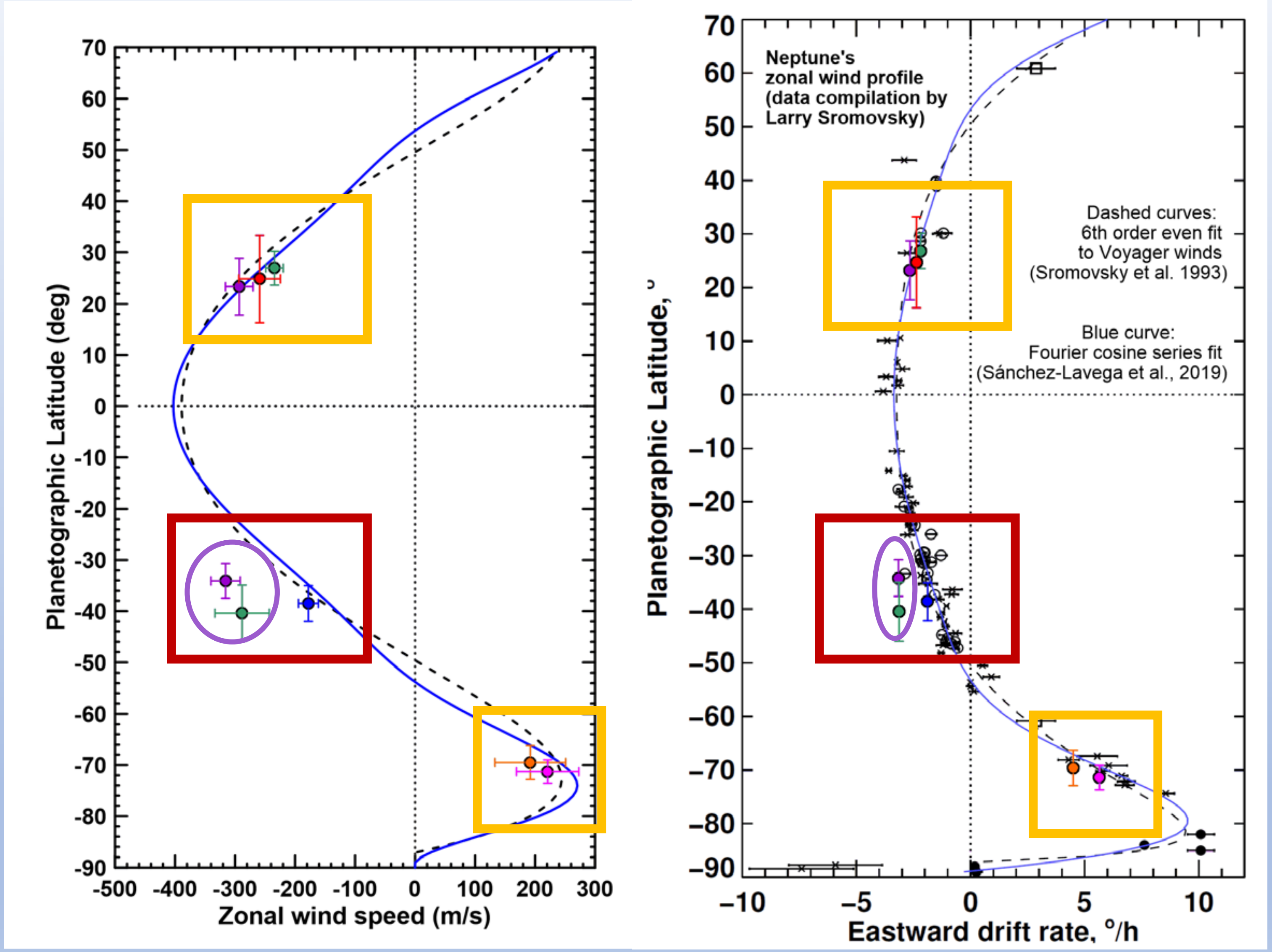
Results

We have obtained the drift rate of several atmospheric features from the ensemble of data (figure on the right)

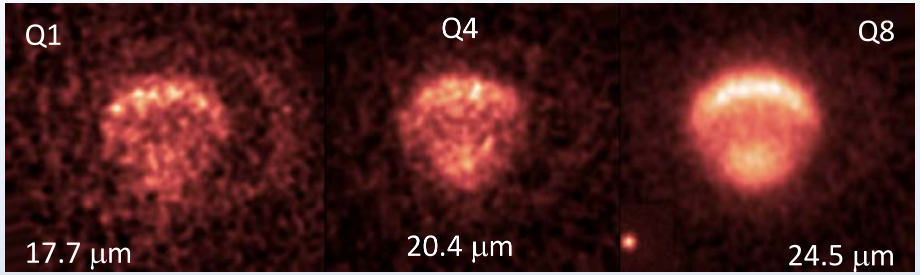
The Double Cloud System does not fit the Voyager winds suggesting vertical wind shear, or a change in the dynamical regime at the mid-latitudes.

Features in the South Polar Bright Feature and in the North Tropical Bright cloud can also be tracked and fit the Voyager zonal winds. Our analysis is ongoing and several more features will be added to this plot.

Atmospheric features in this work (points) compared with Voyager zonal winds



Impact & prospects for the future



A parallel program by our team in Uranus including GTC/CanariCam data shows promising results and the analysis of the data is on going.

Current analysis: Observations in 2019 show an unexpected lack of atmospheric cloud systems very different to 2013-2018. This situation seems to continue in 2020. Our current analysis is not finished and we will soon incorporate the analysis of observations gathered by the TWILIGHT programs at Keck and Lick observatories **should be able to fully resolve the inconsistencies in drift rates here shown**. Uranus.

Future: We keep doing yearly observations of Uranus and Neptune with PlanetCam @ the 2.2m telescope in Calar Alto. More observations from small-telescopes will be helpful in years where Neptune presents bright cloud systems. We have developed an alert system for amateur observers is being developed through the Europlanet 2024 Research Infrastructure, so that we can communicate efficiently with amateurs when Neptune observations will be most helpful. Observations with new facilities (AO instrument like FRIDA@GTC, the James Webb Space Telescope & ELT) will be rare and they will benefit from similar global campaigns like the one shown. Results from previous campaigns have been published in the accompanying references.

Our research group has initiated a research line based in modeling and theory of Uranus and Neptune atmospheres to advance in this field for the near future when new observational facilities will revolutionize our knowledge of these planets..

REFERENCES: Results from our previous campaigns since 2015

[1] Hueso et al., Neptune long-lived atmospheric features in 2013-2015 from small (28-cm) to large (10-m) telescopes. Icarus, 2017.

[2] Wong et al., A New Dark vortex on Neptune, The Astronomical Journal, 2018.

[3] Molter et al., Analysis of Neptune's 2017 Bright Equatorial Storm, Icarus, 2019.

REFERENCES: Modeling & Theory

[1] Hueso & Sánchez-Lavega, Atmospheric Dynamics and Vertical structure of Uranus and Neptunes' weather layers, Space Science Reviews, 2019.

[2] Hueso, Guillot & Sánchez-Lavega, Vertical structure and convective storms in Uranus and Neptune: Observations and unknowns, Phil.Transactions A, 2020 (under review)