National Aeronautics and Space Administration

Tracking Seasonal Changes on Titan with the Palomar Adaptive Optics System

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Program: FY21 R&TD **Strategic Focus Area: Innovative Spontaneous Concepts**

Objectives:
The objective of this study was to determine whether the Palomar Observatory's Adaptive Optics system on the Hale Telescope could be used for tracking cloud motion and more generally seasonal changes on Saturn's moon Titan. The objective involved determining whether the system could be used to capture data of sufficient spatial resolution and to determine whether the existing near-infrared filter system could identify surface features and track clouds and polar vortices.

Background:
The Palomar Mountain Hale telescope is equipped with a state-of-the-art adaptive optics system, the Palomar High Angular Resolution Observer (PHARO). Until recently, this instrument was used primarily for astrophysics applications, including the study of exoplanetary systems. This Proposal Team used PHARO to capture a once in 161-year event when the Pluto-Charon system went through true opposition – when the face of Pluto is fully illuminated [Buratti et al., 2021, *GRL*]. The purpose of this investigations is to explore the use of this system for other planetary applications. One that is ripe for investigation is the observation of seasonal changes on Titan, the largest moon of Saturn that was studied closely by *Cassini* and will be the target of *Dragonfly*.

Approach and Results:
In July, August, and September 2021, we successfully tested the feasibility of an innovative program to observe Titan and its temperate and polar cloud features, which were visible as a 30-pixel disk produced by the 25 arc-second PHARO field. We obtained images of Titan on three of the four assigned nights (with two nights yet to go), processing the data with the standard procedures (flatfielding, dark-subtraction, etc.). Subsequent image processing and experimentation with the filters available on PHARO brought out both surface and cloud features and enabled comparison with both cloud coverage during the *Cassini* mission and previous ground-based images. We used experimental procedures including the use of different filters at the telescope and innovative ways of image processing to optimally map features. The Figure shows an example of our work so far.

We were also able to successfully image Uranus and Neptune with PHARO. We followed on with a proposal to the Fellows program to experiment with the images and track cloud dynamics on these two planets. The purpose of this follow-on task is to bolster JPL's expertise in the area of Ice Giant science to prepare for the next outer planets Flagship Mission.

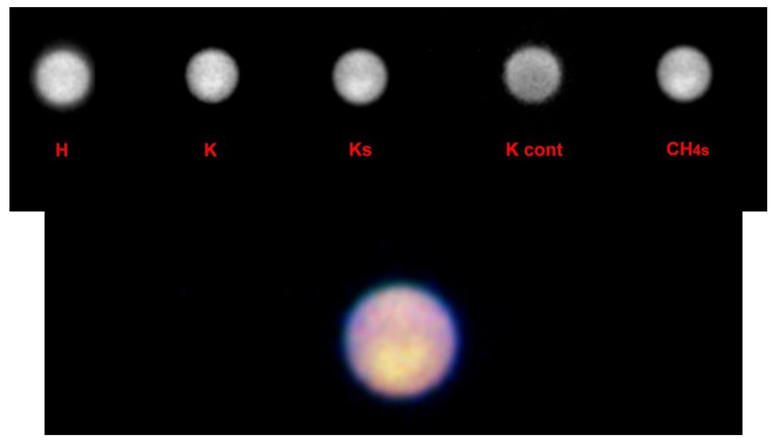
Significance/Benefits to JPL and NASA:
We have demonstrated that Palomar Observatory's adaptive optics system can be used to image Titan and to track clouds and other features such as polar vortices to understand seasonal changes. Changes in haze opacity with time will also be possible with this data. This work is sufficiently mature to secure ROSES funding and thus open up a new research area in outer planets and ocean worlds for JPL. It also enhances NASA's missions by extending through time the seasonal changes closely monitored by *Cassini* and by preparing the context and bigger picture for the *Dragonfly* mission. Seasonal landing conditions will be understood for the landing and operation of *Dragonfly*, mitigating risk to NASA

Publication:

Buratti, B. J., Hicks, M. D.; Momary, T.; Bauer, J. "Neptune and Uranus through the Eyes of the Palomar High Angular Resolution Observer (PHARO)", submitted as a talk at the AGU Fall Meeting, New Orleans, LA, December 2021.

Figure:

This Figure shows images of Titan obtained on July 19, 2021 in five filters of PHARO: H (1.6 microns, three K-filters (2.4 microns) and a methane filter. The bottom is an image with Kcont in the R channel, CH4s in the channel, and Kshort in the B channel. CH4s is the most likely to see to the surface as it is in the 1.58 transparent window for Titan. The K bands are sensitive to clouds and atmosphere, including haze and the polar vortices that develop during winter.



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