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Uranus in Mid-Spring: Persistent Temperatures and Atmospheric Circulations Inferred from Thermal Imaging

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Abstract

With the Voyager flyby and southern summer-era observations now more than 33 years behind us, we take a fresh look at Uranus in the thermal infrared $\sim$ 1.5 Uranian seasons later. Using the VISIR instrument at the Very Large Telescope, we acquired and analyzed spatially-resolved, mid-infrared images of Uranus' atmosphere and rings (marking the first-ever detection of Uranus' rings in the mid-IR) in two filters, Q2 (18.7μm) and NeII_2 (13.0 μm), sensitive to the upper troposphere and stratosphere, respectively. Employing a combination of radiative-transfer forward modelling and retrievals, we develop atmospheric temperature models consistent with these observations. We then compare these results with archival data, including similar VLT observations dating from near northern spring equinox (2007-2009) and synthetic models of emission based on Voyager era temperatures. We find that the Q2 emission in 2018 is consistent with the observations at equinox and the modelled emission from Voyager IRIS, suggesting little change in the tropospheric temperatures despite the passing of seasons. Likewise, the pattern of stratospheric emission revealed equinoctial observations [1] also persists, though we measure significant variation in longitude consistent with the inferred variation in disk-integrated Spitzer observations [2]. From the retrieved temperatures, we infer the presence of persistent stratospheric circulation cells perhaps associated with an unseen, tropical stratospheric jet.

1. Introduction

Uranus, with its extreme obliquity, long orbital period, and negligible internal heat source, experiences arguably the most unusual seasonal forcing in the solar system or of any planetary atmosphere yet observed. Yet, due to Uranus' lengthy orbital period, compounded by the challenges of measuring temperatures on this distant, frigid world, inferences of seasonal changes and stratospheric circulation are only now becoming feasible.

Our best constraints on upper-tropospheric temperature as a function of latitude (and the dynamical circulations these imply) still come from the Voyager 2 IRIS measurements in 1986, which observed Uranus near solstice. These measurements suggested cold mid-latitudes (indicating upwelling) and warm equator and poles (indicating subsidence) [3]. By the late 2000's, ground-based thermal imaging revealed that the same basic upper-tropospheric pattern had persisted, despite the passage of an entire season on Uranus and visible changes in its polar cloud cover. However, ground-based thermal imaging sensitive to stratospheric hydrocarbons revealed an unexpectedly different pattern with strongly enhanced emission poleward of about 25° latitude. This suggested heating associated with a distinct stratospheric circulation and/or a polar enhancement of acetylene unexplained by the current leading photochemical seasonal model [4].

Now, a decade later, we present and analyse new observations of Uranus to examine changes in the temperatures and implied circulations relative to previous observations at equinox and solstice.

2. Observations

Uranus was observed at mid-infrared wavelengths using the Very Large Telescope (VLT) VISIR instrument. Images (Fig. 1) were acquired over five nights between September 4th and October 20th, 2018 in the two filters: the Q2 filter (18.7 μm), sensitive to upper tropospheric temperatures, and the NeII_2 (13.0 μm) filter, sensitive to emission from stratospheric acetylene. These images were compared to previous archival VISIR observations from 2008 and 2009, just following equinox [3, 1].

3. Analysis

Observations were absolutely calibrated, navigated, and compared to models to evaluate seasonal changes. We used the NEMESIS radiative-transfer suite [5] to simulate equivalent emission from Voyager era temperatures (following Orton et al. [3]) and to perform retrievals from the filtered images. Best-fitting temperature models were retrieved from our observations and then forward-modelled to viewing geometries at previous epochs for direct comparison (see Figs. 2, 3) assuming seasonal models of hydrocarbon abundances [4]. Finally, we investigated the circulations implied by the retrieved temperatures.

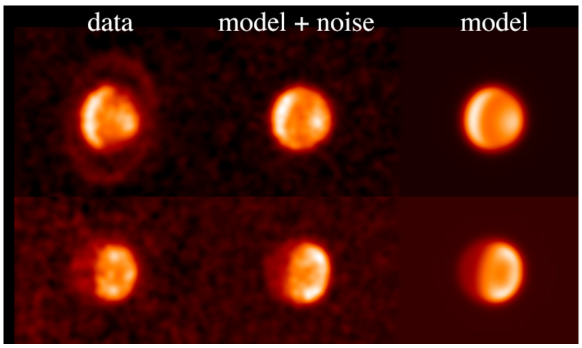

Figure 1: Uranus in Q2 (18.7 μm) (top row) and NeII_2 (13.0 μm) (bottom row) from September and October 2018. Real images are on the left, followed by synthetic images (convolved model+noise), and corresponding models convolved with an appropriate point spread function on the right. This Q2 image provides the first-ever detection of the rings in the mid-IR.

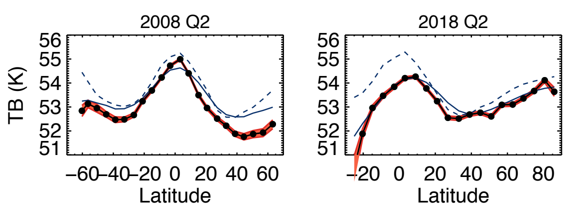

Figure 2: Comparison of data to Voyager-era model for Q2 (18.7 μm) images from 2008 and 2018. The lines represent the zonally averaged disk brightness temperature as a function of latitude. The data are shown as black circles within a red 1-sigma error envelope; the dashed blue line is the raw model based on the Voyager IRIS temperature field [3], and the solid blue line is that model convolved with an appropriate PSF to simulate the effect of atmospheric blurring.

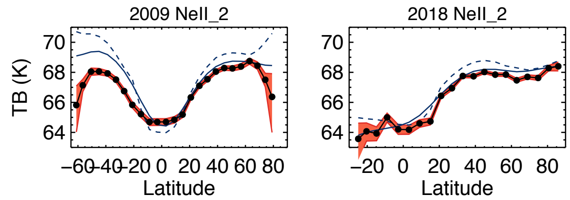

Figure 3: As Fig. 2, but with NeII_2 (13.0 μm) images from 2009 and 2018 and a model developed by retrievals from the 2018 data. We find significant asymmetry between the northern and southern hemispheres.

4. Summary and Conclusions

Recent mid-IR images of Uranus at mid-spring display temperature distributions largely consistent with solstitial and equinoctial observations, despite theoretical expectations and observed changes at near-infrared wavelengths. While this conclusion confirms and extends findings from the previous investigation of equinoctial observations [3], analysis of our new 13.0 μm data provides new insights into Uranus' stratosphere. We show that the pattern of stratospheric emission can be explained by enhanced temperatures at mid-to-polar latitudes, implying a circulation possibly associated with a tropical stratospheric jet. We also find longitudinal and variation and north-south asymmetry indicative of additional dynamical processes.

Acknowledgements

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References

[1] Orton, G., et al. Spatial Variability in the Stratosphere of Uranus. 42nd COSPAR Sci. Assembly (Vol. 42), 2018

[2] Orton, G., et al. Mid-infrared spectroscopy of Uranus... Icarus, 243, pp.471-493. 2014.

[3] Orton GS, et al., Thermal imaging of Uranus: Upper-tropospheric temp... Icarus. Nov 1;260:94-102. 2015

[4] Moses, J.I., et al., Seasonal stratospheric photochemistry on Uranus... Icarus, 307, pp.124-145. 2018

[5] Irwin et al., The NEMESIS planetary atmosphere radiative..., JQSRT, v. 109, issue. 6, p. 1136-1150. , 2008