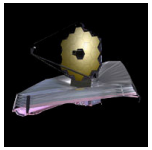

# 5177 - Detailed Atmospheric Characterization of a Unique Low-Temperature Exo-Saturn

Cycle: 3, Proposal Category: GO

**INVESTIGATORS**



| *Name* | *Institution* |
|---|---|
| **Dr. Renyu Hu (PI)** | **Jet Propulsion Laboratory** |
| Dr. Mario Damiano (CoI) | Jet Propulsion Laboratory |
| Dr. Aaron Bello-Arufe (CoI) | Jet Propulsion Laboratory |
| Dr. Heather A. Knutson (CoI) | California Institute of Technology |
| Dr. Jeehyun Yang (CoI) | Jet Propulsion Laboratory |
| Dr. Armen Tokadjian (CoI) | Jet Propulsion Laboratory |
| Prof. Xi Zhang (CoI) | University of California - Santa Cruz |



**OBSERVATIONS**

| *Folder* | *Observation* | *Label* | *Observing Template* | *Science Target* |
|---|---|---|---|---|
| Observation Folder | | | | |
| | 1 | | NIRSpec Bright Object Time Series | (1) CD-60-1144 |

**ABSTRACT**

Astronomers have learned a great deal about the atmospheres of hot extrasolar Jupiters and Saturns using ground-based, HST, Spitzer, and JWST observations. These planets are however in very different atmospheric circulation and chemistry regimes than their solar-system counterparts, and so far, there lacks an extrasolar analog of Jupiter or Saturn where we could test the basic theories of giant planet atmospheres. Here we identify TOI-199 b, a 350-K, Saturn-sized planet orbiting a G star, as a highly favorable target for detailed atmospheric characterization via transmission spectroscopy. We propose to observe one transit of the planet using NIRSpec/G395M. With a TSM of >100 and a long transit duration of nearly 8 hours, the observation will result in exquisite photometric precision and precisely constrain the abundances of H2O, CH4, NH3, HCN, CO2, and CO in the

planet's atmosphere. This unprecedented information will not only determine the atmospheric metallicity and C/O ratio, but also assess whether the vertical mixing in the planet's atmosphere is closer to the Jupiter regime or the hot Jupiter regime, and if the planet has a Jupiter-like vertical mixing, constrain the photochemical production mechanisms of HCN. The constraints on the metallicity and vertical mixing will also determine the fraction of nitrogen as NH3 (or indirectly as HCN), leading to a comprehensive picture of the planet's C, N, and O inventories. This program pushes the frontier of exoplanet characterization to low-temperature planets and advances the understanding of atmospheric physics and chemistry in unique planetary environments.

**OBSERVING DESCRIPTION**

We will observe one transit of TOI-199 b using NIRSpec/BOTS/G395M, acquiring the planet's transmission spectrum in 2.8 – 5.2 microns. We choose the number of groups (Ngroup=7) to avoid saturation and maximize the efficiency of the observations. Due to the brightness of the star, we perform target acquisition (TA) on a nearby infrared source with precise position and proper motion from Gaia DR3.

As is recommended for exoplanet transit observations, we include an out-of-transit portion of the light curve that lasts 1.5 times the transit duration (7.9 hours) and splits evenly before and after the transit. The out-of-transit observation is necessary to establish a baseline from which the transit depth can be determined and using which instrumental systematics can be modeled. Additionally, since any timing constraint narrower than 1 hour is considered "tight" and incurs a 1-hour scheduling overhead penalty, we use a timing window of exactly 1 hour, centered at 30 min (scheduling flexibility) + out-of-transit-duration/2 minutes before the predicted start of the transit. The exposure time is 2.5 times the transit duration plus 1 hour, which totals 20.8 hours.

The planet has an orbital period of 105 days and we have confirmed with APT that there are 3 schedulable events during Cycle 3. The planet has a transit timing variation of up to ~30 minutes, possibly caused by a non-transiting outer planet. We choose to not specify additional scheduling constraints, and the 30-min uncertainty in the transit timing has no impact on achieving the proposed science given the total exposure time of 20.8 hours.

# Proposal 5177 - Targets - Detailed Atmospheric Characterization of a Unique Low-Temperature Exo-Saturn

**Fixed Targets**

| # | Name | Target Coordinates | Targ. Coord. Corrections | Miscellaneous |
|---|---|---|---|---|
| (1) | CD-60-1144 | RA: 05 20 25.3152 (80.1054800d) | Proper Motion RA: 45.864 mas/yr | |
| | | Dec: -59 53 44.46 (-59.89568d) | Proper Motion Dec: 58.44499999999999 mas/yr | |
| | | Equinox: J2000 | Epoch of Position: 2000 | |
| *Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.*<br>*Category=Star*<br>*Description=[G dwarfs]* | | | | |
| (2) | 05202457-5953526 | RA: 05 20 24.5758 (80.1023992d) | | |
| | | Dec: -59 53 52.70 (-59.89797d) | | |
| | | Equinox: J2000 | | |
| *Comments: This object was generated by the targetselector and retrieved from the 2MASS database.*<br>*Category=Unidentified*<br>*Description=[Infrared sources]* | | | | |

## Observation

**Proposal 5177, Observation 1**

Thu Oct 17 19:00:10 GMT 2024

**Diagnostic Status: Warning**

Observing Template: NIRSpec Bright Object Time Series

*Comments: The planet has substantial transit timing variation. The timing constraint in "Special Requirements" is provided for the next observable event in December, 2024.*
*There are two additional events in 2025, and the mid-transit time for those are (JD):*
*2460773.06501296*
*2460877.93700206*

## Diagnostics

(Observation 1) Warning (Form): Exposure Duration exceeds the limit of 10000.0 seconds. Above this limit it is possible that a High Gain Antenna move may occur during the exposure.

(Visit 1:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

## Fixed Targets

| # | Name | Target Coordinates | Targ. Coord. Corrections | Miscellaneous |
|---|---|---|---|---|
| (1) | CD-60-1144 | RA: 05 20 25.3152 (80.1054800d) | Proper Motion RA: 45.864 mas/yr | |
| | | Dec: -59 53 44.46 (-59.89568d) | Proper Motion Dec: 58.44499999999999 mas/yr | |
| | | Equinox: J2000 | Epoch of Position: 2000 | |

*Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.*
*Category=Star*
*Description=[G dwarfs]*

## Acquisition

| # | Target | TA Method | Subarray | Filter | Readout Pattern | Groups/Int | Integrations/Exp | Total Integrations | Total Exposure Time | ETC Wkbk.Calc ID |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 05202457-5953526 | WATA | SUB32 | CLEAR | NRSRAPID | 3 | 1 | 1 | 0.08 | 173816.1 |

## Template

| Subarray |
|---|
| SUB2048 |

## Spectral Elements

| # | Grating/Filter | Readout Pattern | Groups/Int | Integrations/Exp | Exposures/Dith | Total Dithers | Total Integrations | Total Exposure Time | ETC Wkbk.Calc ID |
|---|---|---|---|---|---|---|---|---|---|
| 1 | G395M/F290LP | NRSRAPID | 7 | 10280 | 1 | 1 | 10280 | 74391.014 | 173544.1 |

## Special Requirements

Between Dates 23-DEC-2024:06:22:34 and 23-DEC-2024:07:22:34
Time Series Observation
No Parallel Attachments