



# 8877 - The Core of the Matter: Constraining the Formation History of a Super-Jupiter

Cycle: 4, Proposal Category: GO

## INVESTIGATORS

| <i>Name</i>                             | <i>Institution</i>                        |
|---|---|
| <b>Dr. Nicole L. Wallack (PI)</b>       | <b>Carnegie Institution of Washington</b> |
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| Dr. Heather A. Knutson (CoI)            | California Institute of Technology        |
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| Dr. Ian Wong (CoI)                      | Space Telescope Science Institute         |
| Dr. Yayaati Chachan (CoI)               | University of California - Santa Cruz     |
| Dr. Shreyas Vissapragada (CoI)          | Carnegie Institution of Washington        |
| Dr. Tiffany Kataria (CoI)               | Jet Propulsion Laboratory                 |
| Mr. Michael Greklek-McKeon (CoI)        | California Institute of Technology        |
| Prof. Fei Dai (CoI)                     | University of Hawaii                      |
| Daniel Peter Thorngren (CoI)            | The Johns Hopkins University              |
| Dr. Jerry Xuan (CoI)                    | University of California - Los Angeles    |

## OBSERVATIONS

| <i>Folder</i>      | <i>Observation</i> | <i>Label</i>        | <i>Observing Template</i>         | <i>Science Target</i> |
|--------------------|--------------------|---------------------|-----------------------------------|-----------------------|
| Observation Folder |                    |                     |                                   |                       |
|                    | 1                  | TOI2109b_PhaseCurve | NIRSpec Bright Object Time Series | (1) BD+16-3058        |

## ABSTRACT

We propose to observe the ultra-hot super-Jupiter TOI-2109b over its full orbit in order to study its core mass fraction and its atmospheric composition. A phase curve using NIRSpec G395H will provide the first constraint on the core mass fraction of a super-Jupiter, allowing for

unprecedented insights into the otherwise ambiguous formation mechanism of these giant planets. This planet is the most promising target for such an investigation, meaning that it may be the only chance that we have to understand the formation of super-Jupiters. Constraints on the core mass fraction coupled with a careful investigation of its atmospheric composition with the same data will allow for the best understanding of a super-Jupiter to date.

### **OBSERVING DESCRIPTION**

We will observe a full orbit phase curve of the ultra-hot super-Jupiter TOI-2109b using NIRSpec BOTS G395H/F290LP (2.87-5.27 microns) with SUB2048. We will use 26 groups per observation, which ensures that the observation will fall under 80% saturation and out of nonlinearity. TOI-2109 is too bright to be used for NIRSpec BOTS target acquisition, so we utilize a target acquisition star to avoid saturation. We will observe TOI-2109b over its full orbit (~16 hours) plus a second eclipse and adequate time for settling of the telescope, for a total science time of 20.6 hours. Including overheads this is a total of 25.8 hours. The observation will begin prior to the first eclipse with the one hour observing window for flexible scheduling and enough pre-eclipse baseline to both discard an initial maximum of 0.5 hours for settling and determine an accurate out of eclipse baseline. This planet has an ultra-short period, allowing for many scheduling opportunities throughout Cycle 4.

# Proposal 8877 - Targets - The Core of the Matter: Constraining the Formation History of a Super-Jupiter

| Fixed Targets   | #      | Name   | Target Coordinates   | Targ. Coord. Corrections   | Miscellaneous |
|---|--------|--|--|--|---------------|
|   | (1)    | BD+16-3058   | RA: 16 52 44.7203 (253.1863346d)<br>Dec: +16 34 47.84 (16.57996d)<br>Equinox: J2000                                      | Proper Motion RA: -8.314 mas/yr<br>Proper Motion Dec: -9.350999948765093 mas/yr<br>Parallax: 0.0037367"<br>Epoch of Position: 2000 |               |
| <i>Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.</i><br>Category=Star<br>Description=[Exoplanets] |        |  |  |  |               |
| (2)   | TAStar | RA: 16 52 42.8300 (253.1784583d)<br>Dec: +16 35 6.92 (16.58526d)<br>Equinox: J2000 | Proper Motion RA: -1.802 mas/yr<br>Proper Motion Dec: -0.377 mas/yr<br>Parallax: 0.0014690"<br>Epoch of Position: 2016.0 |  |               |
| <i>Comments: Data for Gaia DR3 4558178186282579328 from Vizier I/355/gaiadr3.</i><br>Category=Star<br>Description=[G stars]                           |        |  |  |  |               |

# Proposal 8877 - Observation 1 - The Core of the Matter: Constraining the Formation History of a Super-Jupiter

Wed Jul 02 20:00:19 GMT 2025

| <b>Observation</b>          | <p><b>Proposal 8877, Observation 1: TOI2109b_PhaseCurve</b></p> <p><b>Diagnostic Status: Warning</b></p> <p>Observing Template: NIRSspec Bright Object Time Series</p>   |   |  |                  |                 |               |                    |                     |                     |                  |   |                |                    |                          |                  |                 |               |                    |                     |                     |                  |              |   |  |       |       |          |      |           |        |      |        |
|-----------------------------|--|---|--|------------------|-----------------|---------------|--------------------|---------------------|---------------------|------------------|---|----------------|--------------------|--------------------------|------------------|-----------------|---------------|--------------------|---------------------|---------------------|------------------|--------------|---|--|-------|-------|----------|------|-----------|--------|------|--------|
| <b>Diagnostics</b>          | <p>(TOI2109b_PhaseCurve (Obs 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.</p> <p>(Visit 1:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.</p>   |   |  |                  |                 |               |                    |                     |                     |                  |   |                |                    |                          |                  |                 |               |                    |                     |                     |                  |              |   |  |       |       |          |      |           |        |      |        |
| <b>Fixed Targets</b>        | <table border="1"> <thead> <tr> <th>#</th> <th>Name</th> <th>Target Coordinates</th> <th colspan="3">Targ. Coord. Corrections</th> <th colspan="4">Miscellaneous</th> </tr> </thead> <tbody> <tr> <td>(1)</td> <td>BD+16-3058</td> <td>RA: 16 52 44.7203 (253.1863346d)<br/>Dec: +16 34 47.84 (16.57996d)<br/>Equinox: J2000</td> <td colspan="3">Proper Motion RA: -8.314 mas/yr<br/>Proper Motion Dec: -9.350999948765093 mas/yr<br/>Parallax: 0.0037367"<br/>Epoch of Position: 2000</td> <td colspan="4"></td> </tr> </tbody> </table> <p><i>Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.</i></p> <p>Category=Star<br/>Description=[Exoplanets]</p> |   |  |                  |                 |               |                    |                     |                     |                  | # | Name           | Target Coordinates | Targ. Coord. Corrections |                  |                 | Miscellaneous |                    |                     |                     | (1)              | BD+16-3058   | RA: 16 52 44.7203 (253.1863346d)<br>Dec: +16 34 47.84 (16.57996d)<br>Equinox: J2000 | Proper Motion RA: -8.314 mas/yr<br>Proper Motion Dec: -9.350999948765093 mas/yr<br>Parallax: 0.0037367"<br>Epoch of Position: 2000 |       |       |          |      |           |        |      |        |
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| <b>Acquisition</b>          | <table border="1"> <thead> <tr> <th>#</th> <th>Target</th> <th>TA Method</th> <th>Subarray</th> <th>Filter</th> <th>Readout Pattern</th> <th>Groups/Int</th> <th>Integrations/Exp</th> <th>Total Integrations</th> <th>Total Exposure Time</th> <th>ETC Wkbk.Calc ID</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>2 TASTar</td> <td>WATA</td> <td>SUB32</td> <td>CLEAR</td> <td>NRSRAPID</td> <td>3</td> <td>1</td> <td>1</td> <td>0.08</td> <td>256683</td> </tr> </tbody> </table>  |   |  |                  |                 |               |                    |                     |                     |                  | # | Target         | TA Method          | Subarray                 | Filter           | Readout Pattern | Groups/Int    | Integrations/Exp   | Total Integrations  | Total Exposure Time | ETC Wkbk.Calc ID | 1            | 2 TASTar  | WATA   | SUB32 | CLEAR | NRSRAPID | 3    | 1         | 1      | 0.08 | 256683 |
| #                           | Target   | TA Method   | Subarray   | Filter           | Readout Pattern | Groups/Int    | Integrations/Exp   | Total Integrations  | Total Exposure Time | ETC Wkbk.Calc ID |   |                |                    |                          |                  |                 |               |                    |                     |                     |                  |              |   |  |       |       |          |      |           |        |      |        |
| 1                           | 2 TASTar   | WATA  | SUB32  | CLEAR            | NRSRAPID        | 3             | 1                  | 1                   | 0.08                | 256683           |   |                |                    |                          |                  |                 |               |                    |                     |                     |                  |              |   |  |       |       |          |      |           |        |      |        |
| <b>Template</b>             | <p><b>Subarray</b></p> <p>SUB2048</p>  |   |  |                  |                 |               |                    |                     |                     |                  |   |                |                    |                          |                  |                 |               |                    |                     |                     |                  |              |   |  |       |       |          |      |           |        |      |        |
| <b>Spectral Elements</b>    | <table border="1"> <thead> <tr> <th>#</th> <th>Grating/Filter</th> <th>Readout Pattern</th> <th>Groups/Int</th> <th>Integrations/Exp</th> <th>Exposures/Dith</th> <th>Total Dithers</th> <th>Total Integrations</th> <th>Total Exposure Time</th> <th>ETC Wkbk.Calc ID</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>G395H/F290LP</td> <td>NRSRAPID</td> <td>26</td> <td>3150</td> <td>1</td> <td>1</td> <td>3150</td> <td>76779.612</td> <td>178406</td> </tr> </tbody> </table>  |   |  |                  |                 |               |                    |                     |                     |                  | # | Grating/Filter | Readout Pattern    | Groups/Int               | Integrations/Exp | Exposures/Dith  | Total Dithers | Total Integrations | Total Exposure Time | ETC Wkbk.Calc ID    | 1                | G395H/F290LP | NRSRAPID  | 26   | 3150  | 1     | 1        | 3150 | 76779.612 | 178406 |      |        |
| #                           | Grating/Filter   | Readout Pattern   | Groups/Int   | Integrations/Exp | Exposures/Dith  | Total Dithers | Total Integrations | Total Exposure Time | ETC Wkbk.Calc ID    |                  |   |                |                    |                          |                  |                 |               |                    |                     |                     |                  |              |   |  |       |       |          |      |           |        |      |        |
| 1                           | G395H/F290LP   | NRSRAPID  | 26   | 3150             | 1               | 1             | 3150               | 76779.612           | 178406              |                  |   |                |                    |                          |                  |                 |               |                    |                     |                     |                  |              |   |  |       |       |          |      |           |        |      |        |
| <b>Special Requirements</b> | <p>Phase 0.147734605 to 0.178714731 with period 1.34494828 Days and zero-phase 2459378.459370 HJD</p> <p>Time Series Observation</p> <p>No Parallel Attachments</p>  |   |  |                  |                 |               |                    |                     |                     |                  |   |                |                    |                          |                  |                 |               |                    |                     |                     |                  |              |   |  |       |       |          |      |           |        |      |        |