



3522 - Spectroscopic characterization of the smallest and coolest directly imaged exoplanet 51 Eridani b

Cycle: 2, Proposal Category: GO

INVESTIGATORS

| <i>Name</i> | <i>Institution</i> |
|---------------------------------------|---|
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| Mr. Alexander Bogdan Madurowicz (CoI) | Stanford University |
| Aneesh Baburaj (CoI) | University of California - San Diego |

OBSERVATIONS

| <i>Folder</i> | <i>Observation</i> | <i>Label</i> | <i>Observing Template</i> | <i>Science Target</i> |
|--------------------|--------------------|-------------------------------------|---------------------------------|---------------------------------|
| Observation Folder | | | | |
| | 7 | 51 Eri S200A1 (planet and speckles) | NIRSpec Fixed Slit Spectroscopy | (6) Group 51-Eri-b-and-speckles |
| | 8 | 51 Eri S200A2 (planet and speckles) | NIRSpec Fixed Slit Spectroscopy | (6) Group 51-Eri-b-and-speckles |

ABSTRACT

We propose to spectroscopically characterize the atmosphere of 51 Eridani b, the lowest-mass (2-4 MJup) and coolest (Teff~600-850 K) directly imaged exoplanet. We will obtain R~2,700 fixed-slit NIRSpec spectra between 3-5 um, targeting the peak flux of this young Jupiter and enabling the detection of molecular lines from species such as CH₄, CO, CO₂, and H₂O. These detections will be used to derive the metallicity, carbon-to-oxygen ratio, disequilibrium chemistry, and cloud properties of 51 Eri b. With its low temperature and partially cloudy or wholly cloud-free atmosphere, 51

Eri b is one of the most interesting directly imaged exoplanets for the purpose of comparative exoplanetology, representing a bridge between wide-orbit super-Jovian worlds and our own Jupiter.

OBSERVING DESCRIPTION

We propose to use NIRSpec 200mas wide fixed slits (S200A1 and S200A2) with the 2.9-5.1 filter (F290LP) at moderate resolution (G395H; R~2,700) to measure the composition of 51 Eridani b and inform the formation pathway of directly imaged exoplanets. In cycle 2, the planet will be 300mas away from the star and we require the slit to be oriented perpendicular to the planet-star axis to avoid saturation. The science observation will be dominated by the light from the stellar halo and therefore requires reference observation of the speckle field on the other side of the star. This reference spectra will be used to model and/or subtract the stellar light in the science data that includes the planet signal. The observations will be split into otherwise identical sequences between the two 200mas slits. The host star (51 Eridani) being too bright for target acquisition, an offset star with Gaia astrometry will be used.

Proposal 3522 - Targets - Spectroscopic characterization of the smallest and coolest directly imaged exoplanet 51 Eridani b

| # | Name | Target Coordinates | Targ. Coord. Corrections | Miscellaneous |
|--|-----------------------------|--|--|---------------|
| (1) | 51-ERI-B | RA: 04 37 36.1986 (69.4008275d) Dec: -02 28 25.88 (-2.47386d) Equinox: J2000 | Proper Motion RA: 44.04884090373149 mas/yr Proper Motion Dec: -64.02842203088811 mas/yr Parallax: 0.0334390324822182" Epoch of Position: 2016.0 | |
| <p><i>Comments: Position of the planet (not the star). The stellar position was retrieved from Gaia DR3 and the offset of the planet was retrieved from http://whereistheplanet.com/.</i> Category=Star Description=[Exoplanets]</p> | | | | |
| (2) | 51-ERI-SPECKLES | RA: 04 37 36.1606 (69.4006692d) Dec: -02 28 25.72 (-2.47381d) Equinox: J2000 | Proper Motion RA: 44.04884090373149 mas/yr Proper Motion Dec: -64.02842203088811 mas/yr Parallax: 0.0334390324822182" Epoch of Position: 2016.0 | |
| <p><i>Comments: Reference position to sample the speckle field, diametrically opposed to the planet (but still not the on axis star). The stellar position was retrieved from Gaia DR3 and the offset of the planet was retrieved from http://whereistheplanet.com/.</i> Category=Star Description=[Exoplanets]</p> | | | | |
| (3) | 04373380-0228391 | RA: 04 37 33.8140 (69.3908917d) Dec: -02 28 39.19 (-2.47755d) Equinox: J2000 | Proper Motion RA: 2.895599158727207 mas/yr Proper Motion Dec: 1.5343560607306668 mas/yr Parallax: 0.0003955" Epoch of Position: 2016 | |
| <p><i>Comments: Data from Gaia DR3 3205095194041180160 2MASS 04373380-0228391 Offset star. Category=Star Description=[F stars]</i></p> | | | | |
| (6) | Group 51-Eri-b-and-speckles | | | |
| <p><i>Comments: Including both the planet and the reference position (i.e., speckles), these positions are situated diametrically opposite on each side of the star 51 Eri. Target Selection=[1 51-ERI-B, 2 51-ERI-SPECKLES]</i></p> | | | | |

Fixed Targets

Proposal 3522 - Observation 7 - Spectroscopic characterization of the smallest and coolest directly imaged exoplanet 51 Eridani b

Tue Dec 05 17:00:48 GMT 2023

| | | | | | | | | | | | | |
|--------------------------|--|-----------------------------|---|-----------------|------------|--------------------------|-------------------|------------------|--------------------|---------------------|---------------------|------------------|
| Observation | Proposal 3522, Observation 7: 51 Eri S200A1 (planet and speckles) Diagnostic Status: Warning Observing Template: NIRSpec Fixed Slit Spectroscopy | | | | | | | | | | | |
| | (Visit 7:1) Warning (Form): Overheads are provisional until the Visit Planner has been run. | | | | | | | | | | | |
| Fixed Targets | # | Name | Target Coordinates | | | Targ. Coord. Corrections | | | Miscellaneous | | | |
| | (6) | Group 51-Eri-b-and-speckles | Comments: Including both the planet and the reference position (i.e., speckles), these positions are situated diametrically opposite on each side of the star 51 Eri. Target Selection=[1 51-ERI-B, 2 51-ERI-SPECKLES] | | | | | | | | | |
| Acquisition | # | Target | TA Method | Subarray | Filter | Readout Pattern | Groups/Int | Integrations/Exp | Total Integrations | Total Exposure Time | ETC Wkbk.Calc ID | |
| | 1 | 3 04373380-0228391 | WATA | SUB32 | F140X | NRSRAPID | 3 | 1 | 1 | 0.08 | 146792.37 | |
| Template | Slit | | | | Subarray | | | | | | | |
| | S200A1 | | | | SUBS200A1 | | | | | | | |
| Dithers | # | Primary Dither Positions | | | | | Sub-Pixel Pattern | | | | | |
| | 1 | 5 | | | | | BOTH | | | | | |
| Spectral Elements | # | Grating/Filter | Slit | Readout Pattern | Groups/Int | Integrations/Exp | # | Autocal | Total Dithers | Total Integrations | Total Exposure Time | ETC Wkbk.Calc ID |
| | 1 | G395H/F290LP | S200A1 | NRSRAPID | 4 | 40 | 1 | NONE | 20 | 800 | 6248.384 | 146792.38 |

Proposal 3522 - Observation 7 - Spectroscopic characterization of the smallest and coolest directly imaged exoplanet 51 Eridani b

Special Requirements

Aperture PA Range 188 to 205 Degrees (V3 49.15809631 to 66.15809631)

Proposal 3522 - Observation 8 - Spectroscopic characterization of the smallest and coolest directly imaged exoplanet 51 Eridani b

Tue Dec 05 17:00:48 GMT 2023

| Observation | Proposal 3522, Observation 8: 51 Eri S200A2 (planet and speckles) Diagnostic Status: Warning Observing Template: NIRSpec Fixed Slit Spectroscopy | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------------------------|---|--------------------------|--------------------|--------------------------|---------------|--------------------|------------|------------------|--------------------|---------------------|------------------|------|--------------------------|--------------------|--------------------------|---------------|--------------------|-----------------------------|------------------|--------------------|---------------------|------------------|---|--------------------|--------|----------|-------|----------|---|------|----|------|-----------|-----------|
| | (51 Eri S200A2 (planet and speckles) (Obs 8)) Warning (Form): The slew between the acquisition exposure and the farthest science exposure is 55.834 Arcsec (larger than the recommended limit of 55.000 Arcsec) and may result in reduced or no schedulability. See more information in the diagnostic browser. (Visit 8:1) Warning (Form): Overheads are provisional until the Visit Planner has been run. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Diagnosics | <table border="1"> <thead> <tr> <th>#</th> <th>Name</th> <th>Target Coordinates</th> <th>Targ. Coord. Corrections</th> <th>Miscellaneous</th> </tr> </thead> <tbody> <tr> <td>(6)</td> <td>Group 51-Eri-b-and-speckles</td> <td></td> <td></td> <td></td> </tr> </tbody> </table> Comments: Including both the planet and the reference position (i.e., speckles), these positions are situated diametrically opposite on each side of the star 51 Eri. Target Selection=[1 51-ERI-B, 2 51-ERI-SPECKLES] | | | | | | | | | | | # | Name | Target Coordinates | Targ. Coord. Corrections | Miscellaneous | (6) | Group 51-Eri-b-and-speckles | | | | | | | | | | | | | | | | |
| | # | Name | Target Coordinates | Targ. Coord. Corrections | Miscellaneous | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| (6) | Group 51-Eri-b-and-speckles | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Fixed Targets | <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>3 04373380-0228391</td> <td>WATA</td> <td>SUB32</td> <td>F140X</td> <td>NRSRAPID</td> <td>3</td> <td>1</td> <td>1</td> <td>0.08</td> <td>146792.37</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 | 3 04373380-0228391 | WATA | SUB32 | F140X | NRSRAPID | 3 | 1 | 1 | 0.08 | 146792.37 | |
| | # | Target | TA Method | Subarray | Filter | Readout Pattern | Groups/Int | Integrations/Exp | Total Integrations | Total Exposure Time | ETC Wkbk.Calc ID | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 3 04373380-0228391 | WATA | SUB32 | F140X | NRSRAPID | 3 | 1 | 1 | 0.08 | 146792.37 | | | | | | | | | | | | | | | | | | | | | | | | |
| Acquisition | <table border="1"> <thead> <tr> <th>Slit</th> <th>Subarray</th> </tr> </thead> <tbody> <tr> <td>S200A2</td> <td>SUBS200A2</td> </tr> </tbody> </table> | | | | | | | | | | | Slit | Subarray | S200A2 | SUBS200A2 | | | | | | | | | | | | | | | | | | | |
| | Slit | Subarray | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| S200A2 | SUBS200A2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Template | <table border="1"> <thead> <tr> <th>#</th> <th>Primary Dither Positions</th> <th>Sub-Pixel Pattern</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>5</td> <td>BOTH</td> </tr> </tbody> </table> | | | | | | | | | | | # | Primary Dither Positions | Sub-Pixel Pattern | 1 | 5 | BOTH | | | | | | | | | | | | | | | | | |
| | # | Primary Dither Positions | Sub-Pixel Pattern | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Dithers | <table border="1"> <thead> <tr> <th>#</th> <th>Grating/Filter</th> <th>Slit</th> <th>Readout Pattern</th> <th>Groups/Int</th> <th>Integrations/Exp #</th> <th>Autocal</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>S200A2</td> <td>NRSRAPID</td> <td>4</td> <td>39</td> <td>1</td> <td>NONE</td> <td>20</td> <td>780</td> <td>6092.174</td> <td>146792.38</td> </tr> </tbody> </table> | | | | | | | | | | | # | Grating/Filter | Slit | Readout Pattern | Groups/Int | Integrations/Exp # | Autocal | Total Dithers | Total Integrations | Total Exposure Time | ETC Wkbk.Calc ID | 1 | G395H/F290LP | S200A2 | NRSRAPID | 4 | 39 | 1 | NONE | 20 | 780 | 6092.174 | 146792.38 |
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| 1 | G395H/F290LP | S200A2 | NRSRAPID | 4 | 39 | 1 | NONE | 20 | 780 | 6092.174 | 146792.38 | | | | | | | | | | | | | | | | | | | | | | | |
| Spectral Elements | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Proposal 3522 - Observation 8 - Spectroscopic characterization of the smallest and coolest directly imaged exoplanet 51 Eridani b

Special Requirements

Aperture PA Range 188 to 205 Degrees (V3 49.08631897 to 66.08631897)