



# 2044 - Direct Imaging Spectroscopy of two Jovian Exoplanets: Characterization of the TYC 8998-760-1 Multi-Planetary System

Cycle: 1, Proposal Category: GO

## INVESTIGATORS

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Dr. Kimberly Ward-Duong (CoI)	Smith College

**OBSERVATIONS**

<i>Folder</i>	<i>Observation</i>	<i>Label</i>	<i>Observing Template</i>	<i>Science Target</i>
Observation Folder				
	1	NIRSpec IFU: G395H and Prism	NIRSpec IFU Spectroscopy	(4) TYC-8998-760-1-B-AND-C
	5	MIRI LRS: b	MIRI Low Resolution Spectroscopy	(2) TYC-8998-760-1-B
	6	MIRI LRS: c	MIRI Low Resolution Spectroscopy	(3) TYC-8998-760-1-C

**ABSTRACT**

TYC 8988-760-1 is the most recently discovered imaged multi-planetary system, containing two young Jovian exoplanets seen at ~160 and 320 au (1.7" and 3" projected separations). We propose a comprehensive spectroscopic characterization of these two worlds using the NIRSpec IFU and MIRI LRS to obtain complete spectra of both planets spanning 1-12 microns at low resolution, for high fidelity measurements of fundamental planetary properties through atmospheric retrievals, and at high-resolution across 3-5 microns to measure elemental abundances, non-equilibrium chemistry, and cloud properties using forward modeling. Together these spectral datasets, spanning a wealth of molecular and atomic lines, will yield measurements of planetary temperatures, radii, atmospheric C/O ratio, metallicity, vertical mixing, clouds, and more. The combination of low- and high-resolution data will break degeneracies of these parameters with properties such as non-equilibrium chemistry and surface gravity. These observations will enable detailed comparative planetology assessing the atmospheres and formation pathways of these worlds against one another, other directly imaged planets, and young field brown dwarfs. The presence of two imaged planets in this system, and their brightness and wide separation from the host star, makes this system an extraordinarily favorable target for JWST exoplanet spectroscopy, and will efficiently yield exquisitely precise spectra for comparative study of their atmospheres to an unprecedented level.

**OBSERVING DESCRIPTION**

Our program will obtain complete spectra of both planets in this multi-planet system from 1-12 microns using NIRSpec and MIRI at low resolution, plus higher resolution (R~2700) spectra from 3-5 microns using NIRSpec.

NIRSpec observations:

An IFU pointing centered on the planets will obtain high-SNR spectra of both simultaneously, while keeping the host star out of the IFU aperture. We observe in Clear/Prism and G395H/F290LP modes. The IFU target location is the point midway between the two planets. Target acquisition is

not needed; the expected pointing precision without TA is more than sufficient to place both planets well within the IFU field. We use NIRSpec's 4-POINT-DITHER pattern to improve sampling and mitigate instrumental and detector artifacts. Total exposure times are 3560 s (G359H/F290LP) and 1050 s (Clear/Prism).

MIRI observations:

MIRI LRS slit spectra will be taken for each planet. To minimize stellar light entering the slit, we will observe each planet with the slit oriented approximately perpendicular to the vector between planet and star. To ensure accurate pointings for the LRS observations, we will perform offset target acquisitions, using the host star itself as the acquisition target with the ND filter, and then offsetting the small distance to each planet. We use the Nod Along Slit dither pattern for background subtraction and detector artifact mitigation. Total exposure times are 5000 s (for planet c) and 500 s (for planet b).

Proposal 2044 - Targets - Direct Imaging Spectroscopy of two Jovian Exoplanets: Characterization of the TYC 8998-760-1 Multi-Plane...

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	TYC-8998-760-1	RA: 13 25 12.1263 (201.3005262d) Dec: -64 56 20.69 (-64.93908d) Equinox: J2000	Proper Motion RA: -40.996 mas/yr Proper Motion Dec: -17.734 mas/yr Parallax: 0.0106124" Epoch of Position: 2016.0	
<p><i>Comments: This is the coordinates of the actual star. In this program, this is used only for the offset Target Acquisitions for the LRS observations.</i></p> <p><i>Coordinates updated to use Gaia EDR3 as best available astrometry, consistent with the current values shown in SIMBAD for this object.</i>  <i>(Only a small change relative to prior DR2 values)</i>                      Category=Star                      Description=[Exoplanet Systems]</p>				
(2)	TYC-8998-760-1-B	RA: 13 25 11.9834 (201.2999308d) Dec: -64 56 22.14 (-64.93948d) Equinox: J2000	Proper Motion RA: -40.996 mas/yr Proper Motion Dec: -17.734 mas/yr Parallax: 0.0106124" Epoch of Position: 2016.0	
<p><i>Comments: Coordinates for the planet TYC 8998 b. ICRS coordinates for the planet were computed from the stellar coordinates, plus the relative astrometry of the planet as given in Bohn et al. 2020a.</i></p> <p><i>Calculation of the offset coords was updated using stellar coordinates from EDR3, consistent with target star setup.</i></p> <p><i>Proper motion and epoch are copied from the stellar coordinates (based on Gaia EDR3).</i>                      Category=Star                      Description=[Exoplanet Systems]</p>				
(3)	TYC-8998-760-1-C	RA: 13 25 11.7777 (201.2990737d) Dec: -64 56 23.23 (-64.93979d) Equinox: J2000	Proper Motion RA: -40.996 mas/yr Proper Motion Dec: -17.734 mas/yr Parallax: 0.0106124" Epoch of Position: 2016.0	
<p><i>Comments: Coordinates for the planet TYC 8998 c. ICRS coordinates for the planet were computed from the stellar coordinates, plus the relative astrometry of the planet as given in Bohn et al. 2020b.</i></p> <p><i>Calculation of the offset coords was updated using stellar coordinates from EDR3, consistent with target star setup.</i></p> <p><i>Proper motion and epoch are copied from the stellar coordinates (based on Gaia EDR3).</i>                      Category=Star                      Description=[Exoplanet Systems]</p>				
(4)	TYC-8998-760-1-B-AND-C	RA: 13 25 11.8806 (201.2995025d) Dec: -64 56 22.68 (-64.93963d) Equinox: J2000	Proper Motion RA: -40.996 mas/yr Proper Motion Dec: -17.734 mas/yr Parallax: 0.0106124" Epoch of Position: 2016.0	
<p><i>Comments: These coordinates are the midpoint location between both planets Tyc 8998-760-1 b and c. By targeting this location with the NIRSspec IFU, both planets will be within the NIRSspec field of view.</i></p> <p><i>Calculation was performed similarly to the target setup for B and C, using EDR3 values.</i>                      Category=Star                      Description=[Exoplanet Systems]</p>				

Fixed Targets

Proposal 2044 - Observation 1 - Direct Imaging Spectroscopy of two Jovian Exoplanets: Characterization of the TYC 8998-760-1 Multi...

Fri Apr 07 23:01:19 GMT 2023

<b>Observation</b>	<p><b>Proposal 2044, Observation 1: NIRSpec IFU: G395H and Prism</b></p> <p><b>Diagnostic Status: Warning</b></p> <p>Observing Template: NIRSpec IFU Spectroscopy</p>											
<b>Diagnostics</b>	(Visit 1:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.											
<b>Fixed Targets</b>	#	Name	Target Coordinates			Targ. Coord. Corrections			Miscellaneous			
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	<p><i>Comments: These coordinates are the midpoint location between both planets Tyc 8998-760-1 b and c. By targeting this location with the NIRSpec IFU, both planets will be within the NIRSpec field of view.</i></p> <p><i>Calculation was performed similarly to the target setup for B and C, using EDR3 values.</i></p> <p><i>Category=Star</i></p> <p><i>Description=[Exoplanet Systems]</i></p>											
<b>Template</b>	<p><b>TA Method</b></p> <p>NONE</p>											
<b>Dithers</b>	#	Dither Type		Size	Starting Point		Number of Points		Points			
	1	CYCLING		SMALL	1		4					
<b>Spectral Elements</b>	#	Grating/Filter	Readout Pattern	Groups/Int	Integrations/Exp	Leakcal	Dither	Autocal	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
	1	G395H/F290LP	NRSIRS2RAPI D	60	1	false	true	NONE	4	4	3559.689	52441.14
	2	PRISM/CLEAR	NRSIRS2RAPI D	17	1	false	true	NONE	4	4	1050.4	52441.23

Proposal 2044 - Observation 5 - Direct Imaging Spectroscopy of two Jovian Exoplanets: Characterization of the TYC 8998-760-1 Multi...

Fri Apr 07 23:01:19 GMT 2023

<b>Observation</b>	<p><b>Proposal 2044, Observation 5: MIRI LRS: b</b></p> <p><b>Diagnostic Status: Warning</b></p> <p>Observing Template: MIRI Low Resolution Spectroscopy</p> <p><i>Comments: Pointing verification image ETC calc is 153509.48</i></p>																												
	<p>(Visit 5:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.</p>																												
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<b>Fixed Targets</b>	<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>(2)</td> <td>TYC-8998-760-1-B</td> <td>RA: 13 25 11.9834 (201.2999308d) Dec: -64 56 22.14 (-64.93948d) Equinox: J2000</td> <td>Proper Motion RA: -40.996 mas/yr Proper Motion Dec: -17.734 mas/yr Parallax: 0.0106124" Epoch of Position: 2016.0</td> <td></td> </tr> </tbody> </table>	#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous	(2)	TYC-8998-760-1-B	RA: 13 25 11.9834 (201.2999308d) Dec: -64 56 22.14 (-64.93948d) Equinox: J2000	Proper Motion RA: -40.996 mas/yr Proper Motion Dec: -17.734 mas/yr Parallax: 0.0106124" Epoch of Position: 2016.0		<p><i>Comments: Coordinates for the planet TYC 8998 b. ICRS coordinates for the planet were computed from the stellar coordinates, plus the relative astrometry of the planet as given in Bohn et al. 2020a.</i></p> <p><i>Calculation of the offset coords was updated using stellar coordinates from EDR3, consistent with target star setup.</i></p> <p><i>Proper motion and epoch are copied from the stellar coordinates (based on Gaia EDR3).</i></p> <p><i>Category=Star</i></p> <p><i>Description=[Exoplanet Systems]</i></p>																	
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Proposal 2044 - Observation 5 - Direct Imaging Spectroscopy of two Jovian Exoplanets: Characterization of the TYC 8998-760-1 Multi...

Spectral Elements	#	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Exposures/Dith	Total Dithers	Total Exposure Time	ETC Wkbk.Calc ID
	1	FASTR1	90	1	2	1	2	499.507	52441.31
Special Requirements	Aperture PA Range 12 to 42 Degrees (V3 7.24203 to 37.24203) Same Aperture PA 5, 6								

Proposal 2044 - Observation 6 - Direct Imaging Spectroscopy of two Jovian Exoplanets: Characterization of the TYC 8998-760-1 Multi...

Fri Apr 07 23:01:19 GMT 2023

<b>Observation</b>	<p><b>Proposal 2044, Observation 6: MIRI LRS: c</b></p> <p><b>Diagnostic Status: Warning</b></p> <p>Observing Template: MIRI Low Resolution Spectroscopy</p> <p><i>Comments: Pointing verification image ETC calc is 153509.49</i></p>																												
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Proposal 2044 - Observation 6 - Direct Imaging Spectroscopy of two Jovian Exoplanets: Characterization of the TYC 8998-760-1 Multi...

Spectral Elements	#	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Exposures/Dith	Total Dithers	Total Exposure Time	ETC Wkbk.Calc ID
	Special Requirements	1	FASTR1	300	3	6	1	2	5006.172
	Same Aperture PA 5, 6								