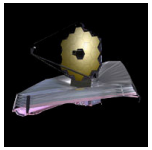

5894 - Comparative Atmospheric Planetology With the Three Large, Close-in Planets of TOI-4010

Cycle: 3, Proposal Category: GO

INVESTIGATORS

Name	*Institution*
Dr. Michelle Kunimoto (PI)	**Massachusetts Institute of Technology**
Dr. Ian Crossfield (CoI)	University of Kansas Center for Research, Inc.
Dr. Tansu Daylan (CoI)	Washington University in St. Louis
Dr. Daniel Huber (CoI)	University of Hawaii
Dr. Mercedes Lopez-Morales (CoI)	Space Telescope Science Institute
Sarah Millholland (CoI)	Massachusetts Institute of Technology
Dr. Alessandro Sozzetti (CoI) (ESA Member)	INAF- Osservatorio Astrofisico di Torino
Dr. Andrew Vanderburg (CoI)	Massachusetts Institute of Technology
Dr. Shreyas Vissapragada (CoI)	Carnegie Institution of Washington
Dr. Thomas G. Wilson (CoI) (ESA Member)	University of Warwick
Dr. George R. Ricker (CoI)	Massachusetts Institute of Technology
David W Latham (CoI)	Smithsonian Institution Astrophysical Observatory

OBSERVATIONS

Folder	*Observation*	*Label*	*Observing Template*	*Science Target*
TOI-4010				
	1	TOI-4010b	NIRSpec Bright Object Time Series	(1) TOI-4010
	2	TOI-4010c	NIRSpec Bright Object Time Series	(1) TOI-4010
	3	TOI-4010d	NIRSpec Bright Object Time Series	(1) TOI-4010

ABSTRACT

Comparing the atmospheres of multiple planets within a single system offers unique insights into their formation and evolution. As one of the only systems for which we can characterize the atmospheres of three planets, TOI-4010 offers an incredible opportunity for comparative planetology. We propose to use JWST/NIRSpec-Prism to observe single transits of TOI-4010 b, c, and d. By measuring planetary C/O ratios we will test predictions from multiple planet formation models, and by measuring atmospheric metallicity we will test predictions from photoevaporation theory. Atmospheric characterization of TOI-4010 with JWST will help answer where and how a rare hot Neptune desert-dweller and multiple close-in large planets could have formed around the same star, for the first time.

OBSERVING DESCRIPTION

We propose a small program of 24.62 hours to obtain single transits of TOI-4010 b, c, and d with NIRSpec in Bright Object Time Series (BOTS) mode. This requires the S1600A1 aperture with a fixed 1.6"x1.6" field of view. Because TOI-4010 is relatively faint (J = 10.649 mag), we are able to use the Prism/CLEAR disperser-filter combination with the SUB512 subarray. This provides broad wavelength coverage over 0.6 - 5.3 microns at a resolving power of R ~ 100.

To obtain the total dwell time needed for each planet, we start with a base requirement of 1.8 times the transit duration and add a 1 hour window for flexible scheduling. This additional hour also increases the observing baselines to 2.4, 2.2, and 2.1 times the transit durations of TOI-4010 b, c, and d, respectively, providing sufficient out-of-transit baseline to correct for systematics and measure transit depths. We also add 0.25 hours of padding at the beginning of each observation to account for the thermal settling time of the detectors. Respectively, TOI-4010 b, c, and d have transit durations of 1.768, 2.769, and 3.604 hours, resulting in total dwell times of 4.432, 6.235, and 7.737 hours. Using 5 groups per integration and the NRSRAPID readout pattern, our dwell times correspond to 11583, 16295, and 20220 integrations per exposure. Based on PandExo simulations of NIRSpec-Prism observations under this observing strategy, we will have transit depth precisions of 100ppm, 82ppm, and 73ppm at 2.95 microns when binned to R = 100 for TOI-4010 b, c, and d, respectively.

The spectra will fully or partially saturate over 0.8 - 2.1 microns. This is similar to what occurred for the NIRSpec-Prism Early Release Science (ERS) observations of the comparably-bright WASP-39 (J = 10.663 mag), for which data over the saturated region was still able to be recovered. We will follow the strategy taken for WASP-39 to recover the saturated region for TOI-4010. Our mock retrievals of PandExo-simulated observations show that we are able to measure atmospheric C/O and metallicity sufficiently for our science goals even without any data over fully saturated wavelengths.

Because our science target is too bright for target acquisition, we will utilize the Wide Aperture Target Acquisition (WATA) mode on a nearby star with the F110W filter.

Proposal 5894 - Targets - Comparative Atmospheric Planetology With the Three Large, Close-in Planets of TOI-4010

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	TOI-4010	RA: 01 20 51.5598 (20.2148325d) Dec: +66 04 19.91 (66.07220d) Equinox: J2000	Proper Motion RA: 38.48439554536057 mas/yr Proper Motion Dec: -20.556200187601434 mas/yr Parallax: 0.005664557788519008" Epoch of Position: 2016	
Comments: This object has coordinates provided by Gaia DR3. *Category=Star* *Description=[Exoplanet Systems, Exoplanets, K dwarfs]* *Extended=NO*				
(2)	TIC352520831	RA: 01 20 44.8602 (20.1869175d) Dec: +66 04 46.01 (66.07945d) Equinox: J2000	Proper Motion RA: -0.8705024077055876 mas/yr Proper Motion Dec: 0.09614161181693365 mas/yr Parallax: 0.0002618734115388542 " Epoch of Position: 2016	
Comments: This is the fainter target needed for WATA Target Acquisition. Coordinates are from Gaia DR3. *Category=Star* *Description=[A subgiants]* *Extended=NO*				

Observation

Proposal 5894, Observation 1: TOI-4010b

Wed Aug 28 17:00:20 GMT 2024

Diagnostic Status: Warning

Observing Template: NIRSpec Bright Object Time Series

Diagnostics

(TOI-4010b (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.

(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)	TOI-4010	RA: 01 20 51.5598 (20.2148325d) Dec: +66 04 19.91 (66.07220d) Equinox: J2000	Proper Motion RA: 38.48439554536057 mas/yr Proper Motion Dec: -20.556200187601434 mas/yr Parallax: 0.005664557788519008" Epoch of Position: 2016	

Comments: This object has coordinates provided by Gaia DR3.
Category=Star
Description=[Exoplanet Systems, Exoplanets, K dwarfs]
Extended=NO

Acquisition

#	Target	TA Method	Subarray	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	2 TIC352520831	WATA	SUB32	F110W	NRSRAPID	3	1	1	0.08	212767

Template

Subarray
SUB512

Spectral Elements

#	Grating/Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	PRISM/CLEAR	NRSRAPID	5	11583	1	1	11583	15954.888	212768

Special Requirements

Phase 0.9122002296746221 to 0.9431025844280284 with period 1.3483330639091156 Days and zero-phase 2459007.549134722 HJD
Time Series Observation
No Parallel Attachments

Observation

Proposal 5894, Observation 2: TOI-4010c

Wed Aug 28 17:00:20 GMT 2024

Diagnostic Status: Warning

Observing Template: NIRSpec Bright Object Time Series

Diagnostics

(TOI-4010c (Obs 2)) 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 2:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	TOI-4010	RA: 01 20 51.5598 (20.2148325d) Dec: +66 04 19.91 (66.07220d) Equinox: J2000	Proper Motion RA: 38.48439554536057 mas/yr Proper Motion Dec: -20.556200187601434 mas/yr Parallax: 0.005664557788519008" Epoch of Position: 2016	

Comments: This object has coordinates provided by Gaia DR3.
Category=Star
Description=[Exoplanet Systems, Exoplanets, K dwarfs]
Extended=NO

Acquisition

#	Target	TA Method	Subarray	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	2 TIC352520831	WATA	SUB32	F110W	NRSRAPID	3	1	1	0.08	212767

Template

Subarray
SUB512

Spectral Elements

#	Grating/Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	PRISM/CLEAR	NRSRAPID	5	16295	1	1	16295	22445.385	212769

Special Requirements

Phase 0.9712038896808587 to 0.9788990635990173 with period 5.414649117720943 Days and zero-phase 2459000.0526590105 HJD
Time Series Observation
No Parallel Attachments

Observation

Proposal 5894, Observation 3: TOI-4010d

Wed Aug 28 17:00:20 GMT 2024

Diagnostic Status: Warning

Observing Template: NIRSpec Bright Object Time Series

Diagnostics

(TOI-4010d (Obs 3)) 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 3:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	TOI-4010	RA: 01 20 51.5598 (20.2148325d) Dec: +66 04 19.91 (66.07220d) Equinox: J2000	Proper Motion RA: 38.48439554536057 mas/yr Proper Motion Dec: -20.556200187601434 mas/yr Parallax: 0.005664557788519008" Epoch of Position: 2016	

Comments: This object has coordinates provided by Gaia DR3.
Category=Star
Description=[Exoplanet Systems, Exoplanets, K dwarfs]
Extended=NO

Acquisition

#	Target	TA Method	Subarray	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	2 TIC352520831	WATA	SUB32	F110W	NRSRAPID	3	1	1	0.08	212767

Template

Subarray
SUB512

Spectral Elements

#	Grating/Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	PRISM/CLEAR	NRSRAPID	5	20220	1	1	20220	27851.837	212770

Special Requirements

Phase 0.9872707417501616 to 0.9901034946097482 with period 14.708895809833232 Days and zero-phase 2458985.9838572093 HJD
Time Series Observation
No Parallel Attachments