



# 2055 - Tracing Hot Jupiter Formation and Migration with Volatile and Refractory Element Ratios

Cycle: 1, Proposal Category: GO

## INVESTIGATORS

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## OBSERVATIONS

<i>Folder</i>	<i>Observation</i>	<i>Label</i>	<i>Observing Template</i>	<i>Science Target</i>
Observation Folder				
	1	Transit	NIRSpec Bright Object Time Series	(1) HD-134004

## ABSTRACT

A primary goal of exoplanet characterization is to use a planet's current composition to understand how that planet formed. For example, the C/O ratio has long been recognized as carrying important information on the enrichment via ices in the outer parts of the protoplanetary disk. JWST opens the door to characterization of the C/O ratio. However, the C/O ratio alone cannot unambiguously constrain the formation mechanism or location of an exoplanet. A new path forward is to measure both volatile (C, O) and refractory (Fe, Mg, Si) elemental abundances in ultra-hot Jupiters, which can remain hot enough to largely avoid the condensation of these elements. By measuring the refractory-to-volatile ratio, we can infer the rock-to-ice ratio of the atmosphere, which can distinguish various formation and migration scenarios. We propose to measure the 2.9-5.2 micron transmission

spectrum of ultra-hot Jupiter WASP-178b with JWST/NIRSpec/G395H to complement UV-NIR observations from HST. This exciting planet shows large short-wavelength transit depths from Fe and SiO, allowing us to measure refractory elemental abundances. Combined with our proposed JWST spectra, we will measure the planets O, C, and refractory content and be able to constrain whether the planet formed inside or outside the H<sub>2</sub>O iceline, whether the planet formed via planetesimal- or gas-dominated accretion, and whether the planet formed in a carbon-depleted disk. Such measurements would represent the beginning of a paradigm shift in our ability to connect the present-day composition of exoplanets to the processes and building blocks that formed them.

## **OBSERVING DESCRIPTION**

We will observe a single transit of WASP-178b with NIRSpec/G395H. Our time series observations will consist of observing a single transit event where WASP-178b passes in front of its host star, WASP-178, relative to Earth. Transits of WASP-178b are 3.47 hours long (Hellier et al. 2019). To gather sufficient baseline, we will start our observations in a 1 hour window between 4 and 3 hours before the center of the transit (i.e., 1.25 and 2.25 hours before ingress). We will then observe for 7 hours to observe ingress, the transit, egress, and the after-transit baseline.

We will use the SUB2048 subarray to readout the whole wavelength coverage of the instrument with NRSRAPID readout mode. Using the PandExo observing simulator, we determined the optimal number of groups per integration for our situation. This observing plan will gather 480 total integrations with 57 groups each for a total of nearly 26,880 frames. In each 52-second integration, we will reach a maximum S/N of 189 at shorter wavelength and a minimum S/N of 80 at longer wavelengths (ETC Calc ID 58029.1). We will reach a maximum of 80% saturation in the brightest pixel.

Due to the high saturation magnitude ( $J=11.2$ ) of even the fastest NIRSpec Wide Aperture Target Acquisition (WATA) sequence (SUB32+F110W+NRSRAPID), we cannot directly acquire on WASP-178 ( $J=9.78$ ) as this will fully saturate 2 pixels. We will instead use the nearest star that is in both the Gaia and 2MASS catalogues, as this will ensure an accurate position, proper motion, and IR magnitude. 15090619-4242069 is a nearby  $J=16.3$  star 17.867 arcsec away from WASP-178, well within the 70.0 arcsec visit splitting distance, that we will use for TA, after which we will offset to our science target. With SUB2048, F110W, and NRSRAPID, we will gain SNR of about 150 during WATA (ETC Calc ID 58029.3).

Our observations are phase constrained in order to observe the primary transit of WASP-178b in front of its host star WASP-178. These events occur about every 3.3 days with a 1 hour window to begin observations. Additionally, since we are using the NIRSpec Bright Object Time Series template, our observations are designated as "Time Series Observations" in APT with no parallel observations.

# Proposal 2055 - Targets - Tracing Hot Jupiter Formation and Migration with Volatile and Refractory Element Ratios

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	HD-134004	RA: 15 09 4.8930 (227.2703875d) Dec: -42 42 17.79 (-42.70494d) Equinox: J2000	Proper Motion RA: -9.082050149195317E-4 sec of time/yr Proper Motion Dec: -0.005653000039274048 arcsec/yr Epoch of Position: 2015.5	
<p><i>Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.</i></p> <p>Category=Star Description=[A stars, Exoplanet Systems, Exoplanets] Extended=NO</p>				
(2)	15090619-4242069	RA: 15 09 6.1968 (227.2758200d) Dec: -42 42 6.91 (-42.70192d) Equinox: J2000	Proper Motion RA: 1.535 mas/yr Proper Motion Dec: -1.588 mas/yr Parallax: 0.0006068" Epoch of Position: 2015.5	
<p><i>Comments: This object was generated by the targetselector and retrieved from the 2MASS database. Not sure for the star description... just a 2MASS source.</i></p> <p>2MASS: 15090619-4242069, J=16.3 15 09 6.1934 -42 42 6.92 Gaia: 6003809992814697216 FK5, Eq=J2000.0, Epoch=2000.0: 15 09 06.19468 -42 42 06.881997 Category=Star Description=[F stars, G stars, K stars] Extended=NO</p>				
(3)	15090619-4242069-DR3UPDATE	RA: 15 09 6.1969 (227.2758204d) Dec: -42 42 6.91 (-42.70192d) Equinox: J2000	Proper Motion RA: 1.936 mas/yr Proper Motion Dec: -1.440 mas/yr Parallax: 0.0006556" Epoch of Position: 2016	
<p><i>Comments: This object was generated by the targetselector and retrieved from the 2MASS database. Teff estimate from Gaia: 3971.7K</i></p> <p>2MASS: 15090619-4242069, J=16.3 15 09 6.1934 -42 42 6.92 Gaia: 6003809992814697216 FK5, Eq=J2000.0, Epoch=2000.0: 15 09 06.19468 -42 42 06.881997 Updated with Gaia DR 3 RA, DEC, proper motion, and parallax. <a href="https://vizier.cds.unistra.fr/viz-bin/VizieR-5?-ref=VIZ63ebd74236e783&amp;-out.add=.&amp;-source=1/355/gaiadr3&amp;-c=227.27582049586%20-42.70191872460,eq=ICRS,rs=2&amp;-out.orig=o">https://vizier.cds.unistra.fr/viz-bin/VizieR-5?-ref=VIZ63ebd74236e783&amp;-out.add=.&amp;-source=1/355/gaiadr3&amp;-c=227.27582049586%20-42.70191872460,eq=ICRS,rs=2&amp;-out.orig=o</a> Category=Star Description=[K stars, M stars] Extended=NO</p>				

Fixed Targets

# Proposal 2055 - Observation 1 - Tracing Hot Jupiter Formation and Migration with Volatile and Refractory Element Ratios

Thu Feb 16 00:00:55 GMT 2023

<b>Observation</b>	<p><b>Proposal 2055, Observation 1: Transit</b></p> <p><b>Diagnostic Status: Warning</b></p> <p>Observing Template: NIRSpec Bright Object Time Series</p>																															
<b>Diagnostics</b>	<p>(Transit (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>Targ. Coord. Corrections</th> <th>Miscellaneous</th> </tr> </thead> <tbody> <tr> <td>(1)</td> <td>HD-134004</td> <td>RA: 15 09 4.8930 (227.2703875d) Dec: -42 42 17.79 (-42.70494d) Equinox: J2000</td> <td>Proper Motion RA: -9.082050149195317E-4 sec of time/yr Proper Motion Dec: -0.005653000039274048 arcsec/yr Epoch of Position: 2015.5</td> <td></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 Description=[A stars, Exoplanet Systems, Exoplanets] Extended=NO</p>										#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous	(1)	HD-134004	RA: 15 09 4.8930 (227.2703875d) Dec: -42 42 17.79 (-42.70494d) Equinox: J2000	Proper Motion RA: -9.082050149195317E-4 sec of time/yr Proper Motion Dec: -0.005653000039274048 arcsec/yr Epoch of Position: 2015.5													
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<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>45</td> <td>605</td> <td>1</td> <td>1</td> <td>605</td> <td>25115.05</td> <td>149142.1</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	45	605	1	1	605	25115.05	149142.1		
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<b>Special Requirements</b>	<p>Phase 0.95 to 0.9625 with period 3.3448285 Days and zero-phase 2456927.06839 HJD</p> <p>Time Series Observation</p> <p>No Parallel Attachments</p>																															