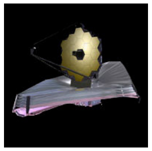

5268 - Around the world in less than two days: observing the spectral phase curve of an ultra-hot Jupiter with JWST/NIRSpec

Cycle: 3, Proposal Category: GO

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OBSERVATIONS

Folder	***Observation***	***Label***	***Observing Template***	***Science Target***
Observation Folder				
	1	WASP-76b Phase Curve	NIRSpec Bright Object Time Series	(1) BD+01-316

ABSTRACT

We propose to observe the full phase curve of the ultra-hot Jupiter (UHJ) WASP-76b with NIRSpec/G395H. WASP-76b is one of the best-characterized exoplanets to date, having been observed with at least 8 different ground-based instruments. To date, 22 different atoms and molecules have been detected in its atmosphere, while 13 optical species (i.e., refractories and alkalis) have measured abundances. This poses an exceptional opportunity: if we combine these data with infrared JWST measurements of the planet’s volatile content (C, O, H, etc.), we can compute robust volatile-to-refractory ratios and trace back the formation history of WASP-76b with unprecedented detail.

One aspect that complicates the spectral analysis of UHJs is their inherent 3D structure. The permanent dayside and nightside show extreme differences in temperature and chemical composition. Hence, interpreting observations of UHJs with 1D atmospheric models can lead to biased inferences of chemical abundances. To bypass this issue, we need to measure the full 3D temperature structure and cloud cover of the planet, which can then serve as a prior for a multi-dimensional retrieval framework. This will also allow us to re-interpret previous abundance measurements based on ground-based observations. Observing the full phase curve of WASP-76b with sufficient spectral resolution is the only way to obtain a complete picture of the 3D temperature structure and chemistry of its atmosphere. With NIRSpec/G395H on JWST, we will measure the spectroscopic phase curve of WASP-76b at hundreds of wavelength points across a wavelength range that contains the absorption bands of all prominent volatile-bearing molecules.

OBSERVING DESCRIPTION

We will observe a full phase curve of the keystone ultra-hot-Jupiter WASP-76b with NIRSpec/G395H in BOTS mode in order to obtain some of the tightest-ever constraints on the formation history of an exoplanet, and better understand its three-dimensional structure.
We use an observing setup of 11 groups per integration and 16676 total integrations. In order to remain below the observatory's maximum frame rate, we divide the total observation up into three exposures, and ensure that the exposure breaks do not occur near any of the rapidly-varying periods of

the phase curve (e.g., transit ingress/egress).

We are unable to perform the TA on the target itself, as this leads to saturation of three pixels, and therefore a strong risk that the TA will fail. WASP-76 resides in a sparse field, and the closest star ammenable to TA is located at a distance of ~84"; much further than the recommended splitting distance of 40" for NIRSpec. However, using this target for the TA does not adversely affect the schedulability of these observations, as verified with the visit planner.

In order to circumvent scheduling errors related to the length of the observations and short period of the target, we have doubled the published period of WASP-76b and halved the phases when entering scheduling phase constraints.

Two warnings remain in the APT. One concerns the splitting distance between the target and TA star, which was addressed above. The other concerns a possible high gain antenna move during the observations. This warning is expected and acceptable for exoplnet time series observations, and there is no evidence that high gain antenna moves have any negative effects on data quality.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	BD+01-316	RA: 01 46 31.9100 (26.6329583d) Dec: +02 42 1.38 (2.70038d) Equinox: J2000	Proper Motion RA: 45.531 mas/yr Proper Motion Dec: -40.593 mas/yr Parallax: 0.0052899" Epoch of Position: 2016.0	
Comments: This object was generated by the targetselector and retrieved from the SIMBAD database. RA, DEC updated to GAIA DR3 Category=Star Description=[Exoplanet Systems, F stars] Extended=NO				
(2)	01462736+0241115	RA: 01 46 27.3700 (26.6140417d) Dec: +02 41 11.58 (2.68655d) Equinox: J2000	Proper Motion RA: 7.324 mas/yr Proper Motion Dec: -1.996 mas/yr Parallax: 0.0006803" Epoch of Position: 2016.0	
Comments: This object was generated by the targetselector and retrieved from the 2MASS database. TA star for WASP-76. RA, DEC updated to GAIA DR3 Category=Calibration Description=[Target acquisition test] Extended=NO				

Observation

Proposal 5268, Observation 1: WASP-76b Phase Curve Thu Dec 19 22:00:29 GMT 2024

Diagnostic Status: Warning

Observing Template: NIRSpec Bright Object Time Series

Comments: Period and zero phase from Demangeon (2024).
Phase constraint start calculated as: 0.5 - T14/2/P - 1hr/P (- 1hr/P).
Period is doubled and phase ranges halved in order to avoid scheduling error.
Phase curve will give minimum 1 hour before first and after second eclipse.
Total phase curve (~51hrs) would be over the maximum frame limit for TSOs if done in single exposure. TSO is therefore broken up into three, ~17 hour exposures. Breaks would occur at phase ~-0.2 and ~0.2, so not effecting transit or eclipse.
TA is performed on a seperate 2MASS source as TA on the target will saturate 5/9 pixels and may fail. TA star is ~80" away from the target, which is not ideal, but the field is sparse. Schedulability is not adversely impacted after running the Visit Planner, despite the APT warning.
**Note*: PandExo predicts 11 groups for this target, whereas the ETC finds saturation after 8. I have gone with 8 as the ETC is more reliable, however this reduces the observation efficiency.*

Diagnostics

(WASP-76b Phase Curve (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.

(WASP-76b Phase Curve (Obs 1)) Warning (Form): The slew between the acquisition exposure and the farthest science exposure is 84.383 Arcsec (larger than the recommended limit of 40.000 Arcsec) and may result in reduced or no schedulability. See more information in the diagnostic browser.

(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)	BD+01-316	RA: 01 46 31.9100 (26.6329583d) Dec: +02 42 1.38 (2.70038d) Equinox: J2000	Proper Motion RA: 45.531 mas/yr Proper Motion Dec: -40.593 mas/yr Parallax: 0.0052899" Epoch of Position: 2016.0	

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
RA, DEC updated to GAIA DR3
Category=Star
Description=[Exoplanet Systems, F stars]
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 01462736+0241115	WATA	SUB32	F110W	NRSRAPID	3	1	1	0.08	178025.2

Template

Subarray
SUB2048

Spectral Elements

#	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	8	7405	3	1	22215	180796.333	178025.1

Special Requirements	
	Phase 0.20571759822201398 to 0.21722849028664888 with period 3.61976904 Days and zero-phase 2459371.070433 HJD Aperture PA Range 201.35295105 to 201.35295105 Degrees (V3 62.5 to 62.5) Time Series Observation No Parallel Attachments