6978 - The dayside of the coolest ultra-hot Jupiter, KELT-20b, resolved with eclipse mapping

Cycle: 4, Proposal Category: GO

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OBSERVATIONS

Folder	Observation	Label	Observing Template	Science Target
KELT-20b eclipse				
	1	KELT-20b eclipse	NIRSpec Bright Object Time Series	(1) KELT-20

ABSTRACT

With the advent of JWST, one-dimensional atmospheric models of hot gas giants are no longer sufficient to capture the complexity of their spectra. 3D models are now required to correctly interpret the atmospheric signals of these planets. However, these models need a new kind of observable to be properly benchmarked: the planet's 3D temperature structure. Eclipse mapping is the only technique that can directly resolve the dayside temperature structure of hot gas giants, both in latitude and longitude.

We propose to create the most precise 3D temperature map of an exoplanet to date. Our selected target, the ultra-hot Jupiter (UHJ) KELT-20b, offers the highest expected signal-to-noise ratio for eclipse mapping and exhibits prominent water and CO emission features, owing to a strong dayside thermal inversion. Thanks to its sensitivity to these two molecules, NIRSpec-BOTS/G395H will allow us to probe different pressures and measure the temperature structure horizontally and vertically. Eclipse mapping provides crucial measurements to understand how the energy from the host star is redistributed globally across the atmosphere of UHJs. Moreover, simulations predict a large range of temperatures on KELT-20b's dayside (1000-3500K), including the limit where molecules such as water and H2 will dissociate (around 2200K). This will cause important temperature heterogeneities on the dayside that will be measured by our eclipse map, allowing us to put constraints on these phenomena. From the disk integrated emission spectrum, we will be able to constrain the C/O ratio and improve the refractory-to-volatiles ratios, which are tracers of giant planet formation/migration mechanisms.

OBSERVING DESCRIPTION

We plan to observe the eclipse of KELT-20b and obtain a partial phase curve centered around its peak. The partial phase curve will allow to accurately measure the hotspot offset expected in KELT-20b's dayside and will lift some degeneracies inherent to the eclipse mapping method. This will result in a better latitudinal and longitudinal accuracy in the map of the planet's dayside. We will use NIRSpec/G395H with the Bright Object Time Series (BOTS) mode.

We request a total of 11 hours (charged time 16 hours) to observe the secondary eclipse of KELT-20b, including the partial phase curve before eclipse, in a single continuous sequence (i.e. one exposure) with NIRSPEC/G395H. The time duration corresponds to a total of 9000 integrations of 5 groups. The selected number of group is a conservative choice (one group less than the maximum number of groups before saturation returned by the ETC = 6 groups) to make sure that there are no systematic related to partial saturation. There should be at least 6h30min of observations before the

eclipse (phase at least 0.42) to target the expected peak of the phase curve and measure the disk-integrated dayside emission spectrum of KELT-20b. This also gives a window of 1h30min to start the observation.

We are not able to use the target acquisition (WATA) on KELT-20b since it is too bright, with 6 pixels fully saturated according to ETC, and no suitable offset stars are available for this system. However, the 1.6"x1.6" square aperture is large enough to minimize the effect of FGS pointing errors, with in-flight precision around 0.1". This will slightly increase the uncertainty in the wavelength solution. However, this will not affect the primary science objective of the proposal, as we will use 2-3 wavelength bins for eclipse mapping.

Proposal 6978 - Targets - The dayside of the coolest ultra-hot Jupiter, KELT-20b, resolved with eclipse mapping

<table>
<tr><th></th><th>#</th><th>Name</th><th>Target Coordinates</th><th>Targ. Coord. Corrections</th><th>Miscellaneous</th></tr>
<tr><td rowspan="4">Fixed Targets</td><td>(1)</td><td>KELT-20</td><td>RA: 19 38 38.7400 (294.6614167d)</td><td>Proper Motion RA: 3.151 mas/yr</td><td></td></tr>
<tr><td></td><td></td><td>Dec: +31 13 9.12 (31.21920d)</td><td>Proper Motion Dec: -6.265 mas/yr</td><td></td></tr>
<tr><td></td><td></td><td>Equinox: J2000</td><td>Parallax: 0.0073"</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Epoch of Position: 2016</td><td></td></tr>
<tr><td></td><td colspan="4">Comments: This object was generated by the targetselector and retrieved from the SIMBAD database. Updated target coordinates to the Gaia DR3 values.
Category=Star
Description=[A stars, Exoplanets]
Extended=NO</td></tr>
<tr><td></td><td>(2)</td><td>TA-star</td><td>RA: 19 38 35.7600 (294.6490000d)</td><td>Proper Motion RA: -4.541 mas/yr</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Dec: +31 13 15.89 (31.22108d)</td><td>Proper Motion Dec: -12.881 mas/yr</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Equinox: J2000</td><td>Parallax: 0.0006664"</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Epoch of Position: 2016</td><td></td></tr>
<tr><td></td><td colspan="4">Comments: TA star selected using the 2MASS database. Coordinates taken from Gaia DR3. J mag = 13.6. The field around the target is crowded but the TA star is at least 2 magnitudes brighter than its direct neighbours.
Category=Star
Description=[Exoplanets]
Extended=NO</td></tr>
</table>

Proposal 6978 - Observation 1 - The dayside of the coolest ultra-hot Jupiter, KELT-20b, resolved with eclipse mapping

Observation

Proposal 6978, Observation 1: KELT-20b eclipse   Wed Jul 16 22:00:18 GMT 2025

Diagnostic Status: Warning

Observing Template: NIRSpec Bright Object Time Series

Diagnostics

(KELT-20b eclipse (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.

(KELT-20b eclipse (Obs 1)) Warning (Form): Record ETC Wkbk.Calc ID used to verify target acquisition.

(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)	KELT-20	RA: 19 38 38.7400 (294.6614167d)	Proper Motion RA: 3.151 mas/yr	
		Dec: +31 13 9.12 (31.21920d)	Proper Motion Dec: -6.265 mas/yr	
		Equinox: J2000	Parallax: 0.0073"	
			Epoch of Position: 2016	

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database. Updated target coordinates to the Gaia DR3 values.
Category=Star
Description=[A stars, Exoplanets]
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 TA-star	WATA	SUB32	F110W	NRSRAPID	3	1	1	0.08	

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	5	8987	1	1	8987	48821.698	178865

Special Requirements

Phase 0.4042 to 0.4222 with period 3.474100 Days and zero-phase 2458694.73670 HJD
Time Series Observation
No Parallel Attachments