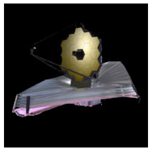

2594 - The twin paradox: assessing planetary radius evolution with a CH4 thermometer

Cycle: 1, Proposal Category: GO

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OBSERVATIONS

Folder	*Observation*	*Label*	*Observing Template*	*Science Target*
HATS-72				
	1	G395M Transit	NIRSpec Bright Object Time Series	(1) HATS-72
	2	SOSS Transit	NIRISS Single-Object Slitless Spectroscopy	(1) HATS-72

ABSTRACT

What sets the radius of a planet? Even at a given mass and equilibrium temperature, gas giants have a broad spread in radius, and it is unclear under which circumstances thermal evolution; migrational and mass-loss history; or composition is the dominant controller of a planet’s radius. Studies of

individual planet atmospheres can help. Recently, Fortney et al. (2020) showed that atmospheric CH4/H2O and CH4/CO2 abundance ratios are probes of interior temperatures of moderately-irradiated exoplanets (Teq~750K). This “CH4 thermometer” can be used to infer whether a hot interior is responsible for an inflated planet, and it can also measure vertical atmospheric mixing - which is currently unconstrained for most exoplanets. We propose to test these theories for the first time on the only two appropriate planetary twins available: WASP-107b and HATS-72b. They both have the same mass (0.12MJ), stellar type (K5/6), and equilibrium temperatures (750K), but HATS-72b’s radius is significantly smaller, making it twice as dense as WASP-107b. With only two transit observations of HATS-72b with NIRISS and NIRSpec, we can measure CH4, H2O, CO and CO2 abundances to 0.2 dex, which we would compare to GTO observations of WASP-107b, implying a colder interior. As HATS-72b is significantly older, it is expected to show stronger CH4 features and so comparing the CH4/H2O and CH4/CO abundance ratios between these two planets will give direct insight into their internal temperatures and the evolutionary history of exoplanets.

OBSERVING DESCRIPTION

We calculated the optimal detector readout patters and groups per integration using STScI’s ExoCTK (https://exoctk.stsci.edu) and the official JWST ETC (https://jwst.etc.stsci.edu/). The integrations per exposure required to cover both transit events and the and signal-to-noise ratios achieved on the exoplanet transmission spectra were calculated using PandEXO (https://exoctk.stsci.edu/pandexo/).

HATS-72 is a high proper motion star. We cross-checked the Simbad proper motions against the Gaia DR2 values.

NIRSpec G395H SNR: we will use the NIRSpec G395H/F290LP, using the 1.6”×1.6” fixed slit aperture with the Bright Object Time Series (BOTS) mode optimized for transit exoplanets enabling high photometric precision time-series spectroscopy. The SUB2048 subarray will be used to improve duty cycles and capture the full 2.8 to 5.1 µm range at a resolution of R~3000. We will use the NRSRAPID readout pattern, with the groups and integrations optimized using PandEXO. HATS-72b is moderately bright (J=10.4), so we will use 50 groups/integration and 500 integrations, which results in a transmission-spectrum precision of 30ppm per 0.02microns.

NIRISS SOSS SNR: we will use the NIRISS GR700XD with the SUBSTRIP256 subarray, which provides broad 0.6-2.8 µm coverage at a R~700. NISRAPID with 5 groups and 350 integrations.
For our target (J=10.4) we will reach a transmission-spectrum precision of 30ppm per 0.01m for NIRISS. The ExoCTK tool (https://exoctk.stsci.edu/contam_visibility) indicates that our target will be observable free of contamination.

We calculate the SNR of the acquisition image using ETC approximating the F480M bandpass magnitude as the ALLWISE W2 magnitude (9.4) and find an SNR > 100 for 19 groups per integration.

We request an accompanying GR700XD+F277W observation in order to decontaminate the overlapping orders along the trace.
We use the NIRISS SOSS recommended strategy of 5 integrations per group (the same as the GR700XD/CLEAR observations), and 10 integrations total (as recommended by the User Documentation).

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	HATS-72	RA: 22 36 6.2016 (339.0258400d) Dec: -17 00 1.10 (-17.00031d) Equinox: J2000	Proper Motion RA: -108.621 mas/yr Proper Motion Dec: -84.412 mas/yr Epoch of Position: 2015.5	
Comments: This object was generated by the targetselector and retrieved from the SIMBAD database. The star has a high proper motion. *Category=Star* *Description=[Exoplanet Systems, Exoplanets, K dwarfs]* *Extended=NO*				
(2)	ACQ-STAR	RA: 22 36 6.0561 (339.0252338d) Dec: -16 59 54.49 (-16.99847d) Equinox: J2000		
Comments: Faint nearby Gaia EDR3 source for target acquisition. Gaia magnitude 21.1. A few arcseconds from science target. *Category=Star* *Description=[Exoplanet Systems]*				
(3)	ACQ_STAR_NEW	RA: 22 36 0.4119 (339.0017163d) Dec: -17 00 20.05 (-17.00557d) Equinox: J2000	Proper Motion RA: -24.18 mas/yr Proper Motion Dec: -10.76 mas/yr Parallax: .0012865" Epoch of Position: 2016.0	
Comments: 2MASS 22360042-1700199 *Gaia DR3 2594869534863570048* *The best star for target acquisition, assuming it's not outside the visit splitting distance. Gaia color and absolute J mag point to a distant K7V star.* *Standard WATA with CLEAR and NRSRAPIDD6 at 3 groups/int gives SNR = 184.* *Please double check my coordinates and proper motions.* *Category=Star* *Description=[K dwarfs]*				

Observation

Proposal 2594, Observation 1: G395M Transit

Thu Nov 02 18:00:31 GMT 2023

Diagnostic Status: Warning

Observing Template: NIRSpec Bright Object Time Series

Comments: ~exptime = 33647.040 s = 3600([4.4232]+[4.4232]) + 60*([30])*
inttime = 6.360 s = [0.15900]([40]+[0])*
nint = 5290 = round(33647.040/6.360)
*exptime = 33644.400 s = [0.15900] * ([40]+[0]) * ([5290])*
time_start = -17722.2 s = -0.5(33644.400) - 0.5*60*[30]*
*time_earlist = -18022.2 s = -17722.2 - 0.5*60*[10]*
*time_latest = -17422.2 s = -17722.2 + 0.5*60*[10]*
*phase_earlist = 0.944160 = 1 -18022.2/(3600*24*[3.7354845])*
*phase_latest = 0.946019 = 1 -17422.2/(3600*24*[3.7354845])*

Diagnostics

(G395M 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.

(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)	HATS-72	RA: 22 36 6.2016 (339.0258400d)	Proper Motion RA: -108.621 mas/yr	
		Dec: -17 00 1.10 (-17.00031d)	Proper Motion Dec: -84.412 mas/yr	
		Equinox: J2000	Epoch of Position: 2015.5	

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database. The star has a high proper motion.
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	1 HATS-72	WATA	SUB32	F110W	NRSRAPID	3	1	1	0.08	179157

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	G395M/F290LP	NRSRAPID	18	1336	1	1	1336	22923.729	119954

Special Requirements	
	Phase 0.94106 to 0.95221 with period 7.3279474 Days and zero-phase 2458087.54782 HJD Time Series Observation No Parallel Attachments

Observation

Proposal 2594, Observation 2: SOSS Transit

Thu Nov 02 18:00:31 GMT 2023

Diagnostic Status: Warning

Observing Template: NIRISS Single-Object Slitless Spectroscopy

Comments: ~exptime = 33647.040 s = 3600([4.4232]+[4.4232]) + 60*([30])*
inttime = 60.401 s = [5.49100]([10]+[1])*
nint = 557 = round(33647.040/60.401)
*exptime = 33643.357 s = [5.49100] * ([10]+[1]) * ([557])*
time_start = -17721.7 s = -0.5(33643.357) - 0.5*60*[30]*
*time_earlist = -18021.7 s = -17721.7 - 0.5*60*[10]*
*time_latest = -17421.7 s = -17721.7 + 0.5*60*[10]*
*phase_earlist = 0.944161 = 1 -18021.7/(3600*24*[3.7354845])*
*phase_latest = 0.946020 = 1 -17421.7/(3600*24*[3.7354845])*

Diagnostics

(SOSS Transit (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.

(Exposure) 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)	HATS-72	RA: 22 36 6.2016 (339.0258400d)	Proper Motion RA: -108.621 mas/yr	
		Dec: -17 00 1.10 (-17.00031d)	Proper Motion Dec: -84.412 mas/yr	
		Equinox: J2000	Epoch of Position: 2015.5	

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database. The star has a high proper motion.
Category=Star
Description=[Exoplanet Systems, Exoplanets, K dwarfs]
Extended=NO

Acquisition

#	Target	Acquisition Mode	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	2 ACQ-STAR	SOSSFAINT	F480M	NISRAPID	19	1	1	0.93	92556

Template

Subarray	Include Short First Exposure and F277W Exposure?
FULL	true

Spectral Elements

#	Readout Pattern	Groups/Int	Integrations/Exp	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	NISRAPID	4	405	1	405	21741.959	119333
2	NISRAPID	5	10	1	10	644.206	59860

Special Requirements	
Special Requirements	Phase 0.94106 to 0.95221 with period 7.3279474 Days and zero-phase 2458087.54782 HJD Time Series Observation No Parallel Attachments