15434 - Searching for Atmospheric Loss Signatures In the Newly Discovered Super-Earth GJ9827b

Cycle: 25, Proposal Category: GO

(UV Initiative)

(Availability Mode: SUPPORTED)

INVESTIGATORS

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VISITS

Visit	*Targets used in Visit*	*Configurations used in Visit*	*Orbits Used*	*Last Orbit Planner Run*	*OP Current with Visit?*
01	(1) BD-02D5958 WAVE	STIS/CCD STIS/FUV-MAMA	4	23-Sep-2020 12:00:22.0	yes
02	(1) BD-02D5958 WAVE	STIS/CCD STIS/FUV-MAMA	4	23-Sep-2020 12:00:25.0	yes
03	(1) BD-02D5958	STIS/CCD STIS/NUV-MAMA	1	23-Sep-2020 12:00:26.0	yes

9 Total Orbits Used

ABSTRACT

Super-Earth characterization continues to be a particular focus of the field given that it is the interface between terrestrial planets and gas-dominated planets. The implications of this division reverberate in planet formation, planetary interiors, and the origins and evolution of planetary atmospheres. Our team recently announced the detection of three super-Earth planets in 1:3:5 commensurability, with the innermost planet having a period of 1.2 days. At 30 pc, GJ9827 is the nearest planetary system that Kepler or K2 has ever found. Given its brightness, it is one of the top systems for follow-up characterization. GJ9827b has a relatively hot atmosphere, which makes it an ideal target for measuring atmospheric hydrogen escape, particularly given the high activity of its host star. Measurements of hydrogen escape provides constraints on the evolution of the planetary atmosphere including the photodissociation of water. We propose spectroscopic observations of two planetary transits to measure the stellar Lyman-alpha emission line and search for signatures of an extended hydrogen atmosphere. The Lyman-alpha line is also the dominant source of UV emission for cool stars, and thereby has a tremendous impact on planetary atmospheres. These observations, along with a short near-UV observation of MgII, the second most dominant emission line, will provide a vital characterization of the stellar inputs into all of the planetary atmospheres in this system. Observations of hot and cloud-free atmospheres, like the one requested in this proposal, are an important step in planning future observations of temperate planetary atmospheres.

OBSERVING DESCRIPTION

We plan to use STIS with the G140M grating and 52" x 0.1" aperture in order to observe R ~ 10,000 spectra of Lyman-alpha at 1215.67 A in time-tag mode for two transits of GJ9827b. The target is the newly discovered planetary system transiting GJ~9827. Of the thousands of planetary systems that Kepler and K2 have discovered, this is the nearest system to the Earth that telescope has found, at only a distance of 30 pc. Therefore, it is quite bright, and among the very best super-Earths with which to do these atmospheric follow-up observations. Observing two transits will allow the pre-,

in-, and post-transit phases to be fully sampled. Due to Hubble's visibility restrictions, a single HST visit composed of 4 orbits will include 79% of the 1.12 hour transit, and 1 or 2 pre- or post-transit observations depending on the chosen schedule. Observations far from first and fourth contact is important in case the escaping material is very extended. A NUV E230H exposure is also planned in order to observe the second strongest UV stellar emission line in cool stars, MgII at 2796 and 2803 A. These observations are important in reconstructing the ISM absorption that dominates the Lyman-alpha profile.

This visit has no scheduling constraints and can be taken at any time. The narrow slits and spectral resolution capabilities of STIS are necessary to observe the Lyman-alpha profile without overwhelming contamination by geocoronal emission. The resolving power of the G140M grating has been demonstrated to be sufficient to resolve the line and detect extended atmospheres of small exoplanets. Depending on the time of year, the Earth's motion can Doppler shift the geocoronal line into the stellar emission and contaminate our measurement. Our target will require a timing constraint to ensure that the geocoronal line is in the core of the ISM absorption. For this reason, observations are limited between 4 Feb and 28 Apr, as well as 29 July and 24 Oct. Additional between limits are included to avoid transits which overlap with the other two planets in the system. This is not an uncommon occurance as the planets are in a 1:3:5 commensurability.

Because cool stars (even late-A and early-F stars) are emission line sources in the far-UV, estimating expected S/N for our planned spectra requires first estimating Lyman-alpha and MgII fluxes, which we can do by extrapolating from previously observed stars. Chromospheric line fluxes (such as MgII and Lyman-alpha) are related to X-ray fluxes. Wood et al. (2005) provide Lyman-alpha spectra for many stars, which serve as the comparison stars for our purposes here.

While we do not have a direct X-ray observation of GJ9827, Houldebine et al. (2017) provide a comprehensive activity and rotation study of a large sample of cool stars, including GJ9827. Using their scaling relationships, log L_X is estimated to be 27.48. This is comparable to other moderately active nearby stars such as 61 Cyg A and epsilon Ind whose stellar Lyman-alpha line has been successfully observed by HST. We use these observed targets to estimate the Lyman-α flux. We estimate that over a single transit, approximately 2,880 seconds after accounting for overheads, that a S/N in the blue wing of the Lyman-alpha profile at 1215.3 A will be 37.6 per resolution element. Across the entire observed Lyman-alpha profile, the S/N will be ~180, and capable of detecting levels of 10%-50% seen for GJ436~b, even accounting for the difference in planetary and stellar size.

We plan observations of two transits for several reasons. First, to fully sample the transit curve and the pre- and post-transit periods. Second, to increase the S/N in order to be sensitive to small Lyman-alpha planetary absorption levels. With two transits we will be sensitive to extended atmosphere absorption of ~1% at the 3sigma level. Finally, two transits will enable a test of variability on the planetary absorption (as was found for

HD189733b taken in a similar observing mode; Lecavelier des Etangs et al. 2012), any variability in the pre- or post-transit absorption, or variability in the stellar flux.

We plan to correct for telescope ``breathing'' which can generally be modeled as a low order polynomial by using time-tagged data to create a time series of exposures for each individual orbit (Ehrenreich et al. 2012, Bourrier et al. 2013). This effect is important at the 20\% level, well above the expected pre-transit absorption level. Four orbits per visit should allow us to adequately model the breathing effect and remove it from each orbit. Another potentially important systematic effect is the ramp-up in measured flux seen for some STIS observations (Sing et al. 2011, Bourrier et al. 2013). The ramp-up effect tends to produce systematically lower flux values for the first orbit of a visit. However, it is not clear that this effect is always important for the instrument setup we have chosen. Ehrenreich et al. (2012) do not observe this effect in either of their two visits. In fact, even the breathing effect seems not to be present in the data form their second visit. Bourrier et al. (2013) do observe the ramp-up effect in the first orbit of their observations.

The E230H MgII exposure is expected to obtain a S/N of 12.6 per resolution element on wing at half-maximum of the stellar emission profile. This is sufficient to characterize the stellar emission line profile shape (used to help estimate the intrinsic Lyman-alpha profile shape), and even measure the ISM absorption (used to help characterize the ISM absorption in the Lyman-alpha profile). This has been demonstrated on several nearby targets observed with comparable S/N (e.g., Redfield & Linsky 2002, 2004).

GJ9827, as a cool star, has a UV spectrum characterized by minimal continuum, but strong emission lines. For this reason, it falls far short of the global brightness limit. The emission lines for our target also falls far short of the local brightness limit. The two emission lines of interest in this proposal (Lyman-alpha and MgII) are also the brightest, and therefore, the procedure given above for estimating the S/N near their peaks is also utilized to test for brightness limit violations.

Visit

Proposal 15434, Visit 01, completed Wed Sep 23 16:00:26 GMT 2020

Diagnostic Status: Warning

Scientific Instruments: STIS/CCD, STIS/FUV-MAMA

Special Requirements: SCHED 40%; BETWEEN 2018.235:12:00:00 AND 2018.235:13:00:00

Diagnostics

(Visit 01) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

(Visit 01) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

(Visit 01) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

(Visit 01) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

Fixed Targets

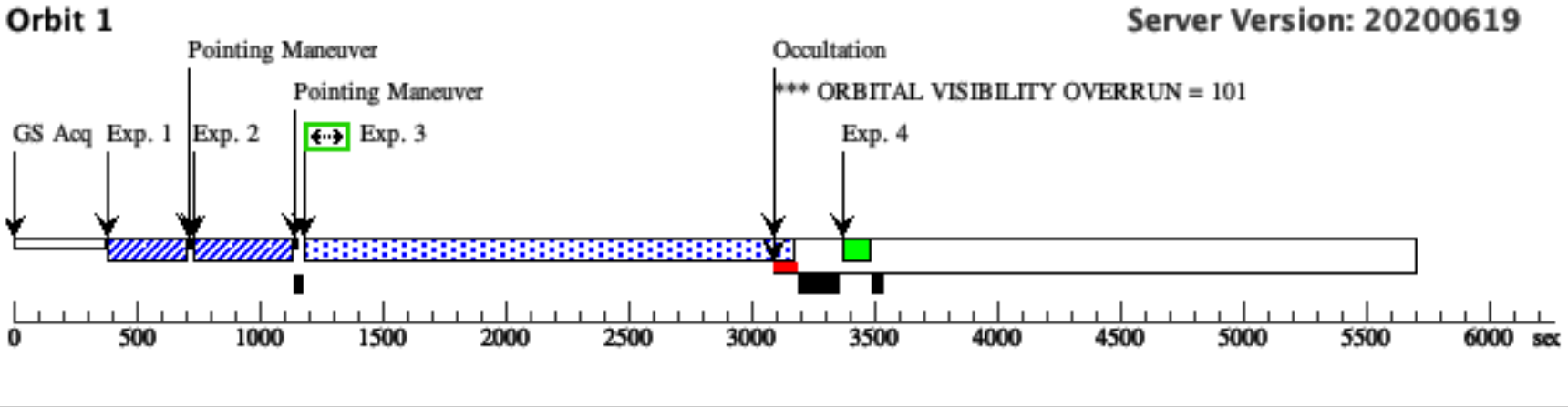
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	BD-02D5958	RA: 23 27 4.8365 (351.7701521d)	Proper Motion RA: +0.02490 sec of time/yr	V=10.101	Reference Frame: ICRS
	Alt Name1: GJ9827	Dec: -01 17 10.58 (-1.28627d)	Proper Motion Dec: +0.21604 arcsec/yr	TYPE=K6V,	
	Alt Name2: K2-135	Equinox: J2000	Parallax: 0.03298"	B-V=1.47,	
			Epoch of Position: 2000	E(B-V)=0,	
			Radial Velocity: 27.00 km/sec	F-LINE(2796)=0.20e-12,	
				W-LINE(2796)=0.5,	
				F-LINE(1215)=0.34e-12,	
				W-LINE(1215)=0.65	

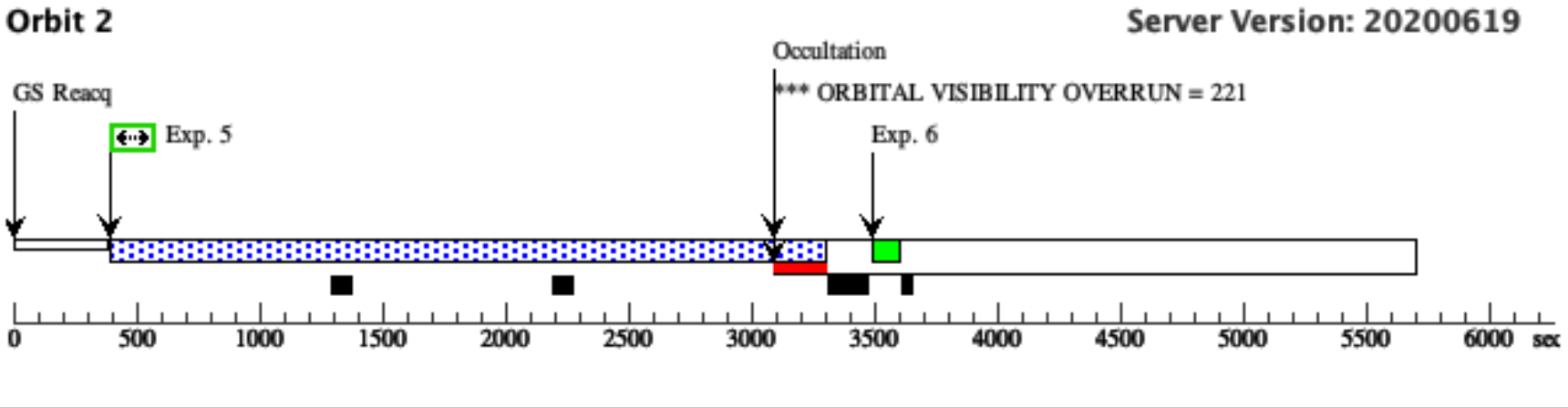
Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=STAR
Description=[EXTRA-SOLAR PLANETARY SYSTEM, K V-IV]
Extended=NO

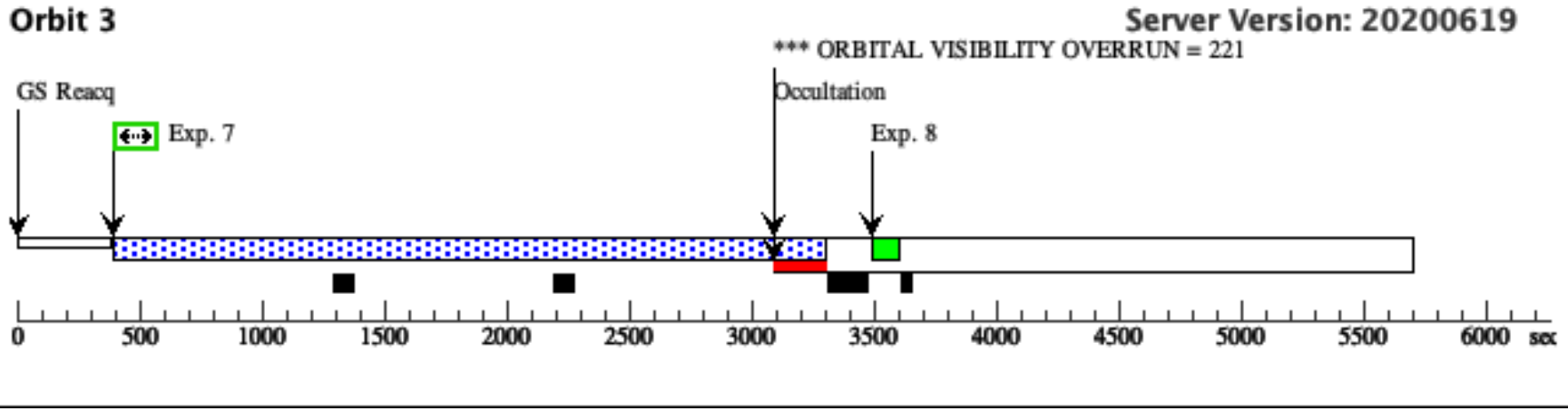
Exposures

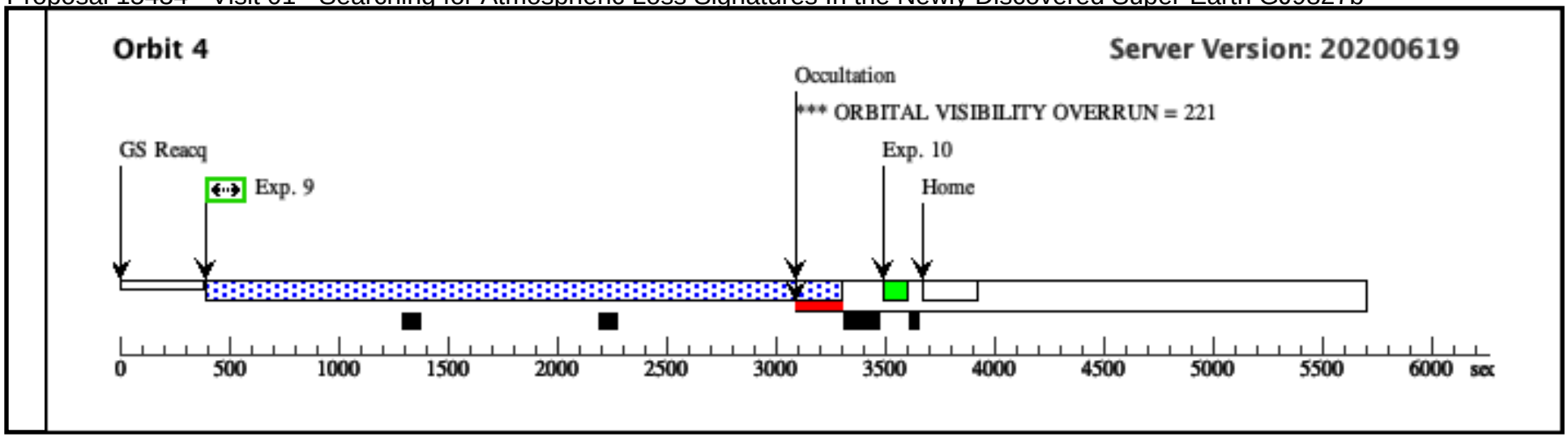
#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	ACQ (STIS.ta.1040017)	(1) BD-02D5958	STIS/CCD, ACQ, F25ND3	MIRROR	ACQTYPE=POINT	GS ACQ SCENARIO BASE1B3	Sequence 1-4 Non-Int in Visit 01	6.6 Secs (6.6 Secs) *[==>]*	*[1]*
	Comments: SNR = 150.5348 *Brightest Pixel = 8,557.96 e*								
2	ACQ/PEAK (STIS.sp.1040054)	(1) BD-02D5958	STIS/CCD, ACQ/PEAK, 31X0.05NDC	G430L 4300 A			Sequence 1-4 Non-Int in Visit 01	1.0 Secs (1 Secs) *[==>]*	*[1]*
	Comments: SNR = 21.6692 *Brightest Pixel = 193.09 e* *Global Source Counts = 426,975.924 e*								
3	SCIENCE (STIS.sp.1040055)	(1) BD-02D5958	STIS/FUV-MAMA, TIME-TAG, 52X0.1D1	G140M 1222 A	BUFFER-TIME=900; WAVECAL=NO		Sequence 1-4 Non-Int in Visit 01	1786 Secs (1786 Secs) *[==>]*	*[1]*
	Comments: SNR = 38.0752 *Brightest Pixel = 240.89 e*								
4	GO WAVE CAL	WAVE	STIS/FUV-MAMA, ACCUM, 52X0.1	G140M 1222 A			Sequence 1-4 Non-Int in Visit 01	*[==>]*	*[1]*
5	SCIENCE (STIS.sp.1040057)	(1) BD-02D5958	STIS/FUV-MAMA, TIME-TAG, 52X0.1D1	G140M 1222 A	BUFFER-TIME=900; WAVECAL=NO		Sequence 5-6 Non-Int in Visit 01	2890 Secs (2890 Secs) *[==>]*	*[2]*
	Comments: SNR = 48.1324 *Brightest Pixel = 384.95 e*								
6	GO WAVE CAL	WAVE	STIS/FUV-MAMA, ACCUM, 52X0.1	G140M 1222 A			Sequence 5-6 Non-Int in Visit 01	*[==>]*	*[2]*
7	SCIENCE (STIS.sp.1040057)	(1) BD-02D5958	STIS/FUV-MAMA, TIME-TAG, 52X0.1D1	G140M 1222 A	BUFFER-TIME=900; WAVECAL=NO		Sequence 7-8 Non-Int in Visit 01	2890 Secs (2890 Secs) *[==>]*	*[3]*
	Comments: SNR = 48.1324 *Brightest Pixel = 384.95 e*								
8	GO WAVE CAL	WAVE	STIS/FUV-MAMA, ACCUM, 52X0.1	G140M 1222 A			Sequence 7-8 Non-Int in Visit 01	*[==>]*	*[3]*
9	SCIENCE (STIS.sp.1040057)	(1) BD-02D5958	STIS/FUV-MAMA, TIME-TAG, 52X0.1D1	G140M 1222 A	BUFFER-TIME=900; WAVECAL=NO		Sequence 9-10 Non-Int in Visit 01	2890 Secs (2890 Secs) *[==>]*	*[4]*
	Comments: SNR = 48.1324 *Brightest Pixel = 384.95 e*								
10	GO WAVE CAL	WAVE	STIS/FUV-MAMA, ACCUM, 52X0.1	G140M 1222 A			Sequence 9-10 Non-Int in Visit 01	*[==>]*	*[4]*

Orbit Structure





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Exp. 10
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5500
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sec

Visit

Proposal 15434, Visit 02, implementation Wed Sep 23 16:00:26 GMT 2020

Diagnostic Status: Warning

Scientific Instruments: STIS/CCD, STIS/FUV-MAMA

Special Requirements: BETWEEN 04-FEB-2018:00:00:00 AND 28-APR-2018:00:00:00; BETWEEN 04-FEB-2019:00:00:00 AND 28-APR-2019:00:00:00; BETWEEN 29-JUL-2018:00:00:00 AND 30-JUL-2018:04:27:09; BETWEEN 30-JUL-2018:20:27:09 AND 05-AUG-2018:05:31:49; BETWEEN 05-AUG-2018:21:31:49 AND 24-AUG-2018:13:46:46; BETWEEN 25-AUG-2018:05:46:46 AND 28-AUG-2018:04:49:33; BETWEEN 28-AUG-2018:20:49:33 AND 31-AUG-2018:19:52:22; BETWEEN 01-SEP-2018:11:52:22 AND 04-SEP-2018:10:55:10; BETWEEN 05-SEP-2018:02:55:10 AND 05-SEP-2018:15:56:06; BETWEEN 06-SEP-2018:07:56:06 AND 08-SEP-2018:01:57:58; BETWEEN 08-SEP-2018:17:57:58 AND 11-SEP-2018:17:00:46; BETWEEN 12-SEP-2018:09:00:46 AND 15-SEP-2018:08:03:34; BETWEEN 16-SEP-2018:00:03:34 AND 17-SEP-2018:18:05:27; BETWEEN 18-SEP-2018:10:05:27 AND 18-SEP-2018:23:06:23; BETWEEN 19-SEP-2018:15:06:23 AND 22-SEP-2018:14:09:10; BETWEEN 23-SEP-2018:06:09:10 AND 23-SEP-2018:19:10:07; BETWEEN 24-SEP-2018:11:10:07 AND 26-SEP-2018:05:11:59; BETWEEN 26-SEP-2018:21:11:59 AND 24-OCT-2018:00:00:00; BETWEEN 02-AUG-2019:00:00:00 AND 06-AUG-2019:00:00:00; BETWEEN 14-OCT-2019:00:00:00 AND 24-OCT-2019:00:00:00; BETWEEN 04-FEB-2020:00:00:00 AND 28-APR-2020:00:00:00; BETWEEN 29-JUL-2020:00:00:00 AND 24-OCT-2020:00:00:00; BETWEEN 04-FEB-2021:00:00:00 AND 28-APR-2021:00:00:00; BETWEEN 29-JUL-2021:00:00:00 AND 24-OCT-2021:00:00:00; Period 1.208957 D AND ZERO-PHASE HJD2457738.82671

Diagnostics

(Visit 02) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

(Visit 02) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

(Visit 02) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

Fixed Targets

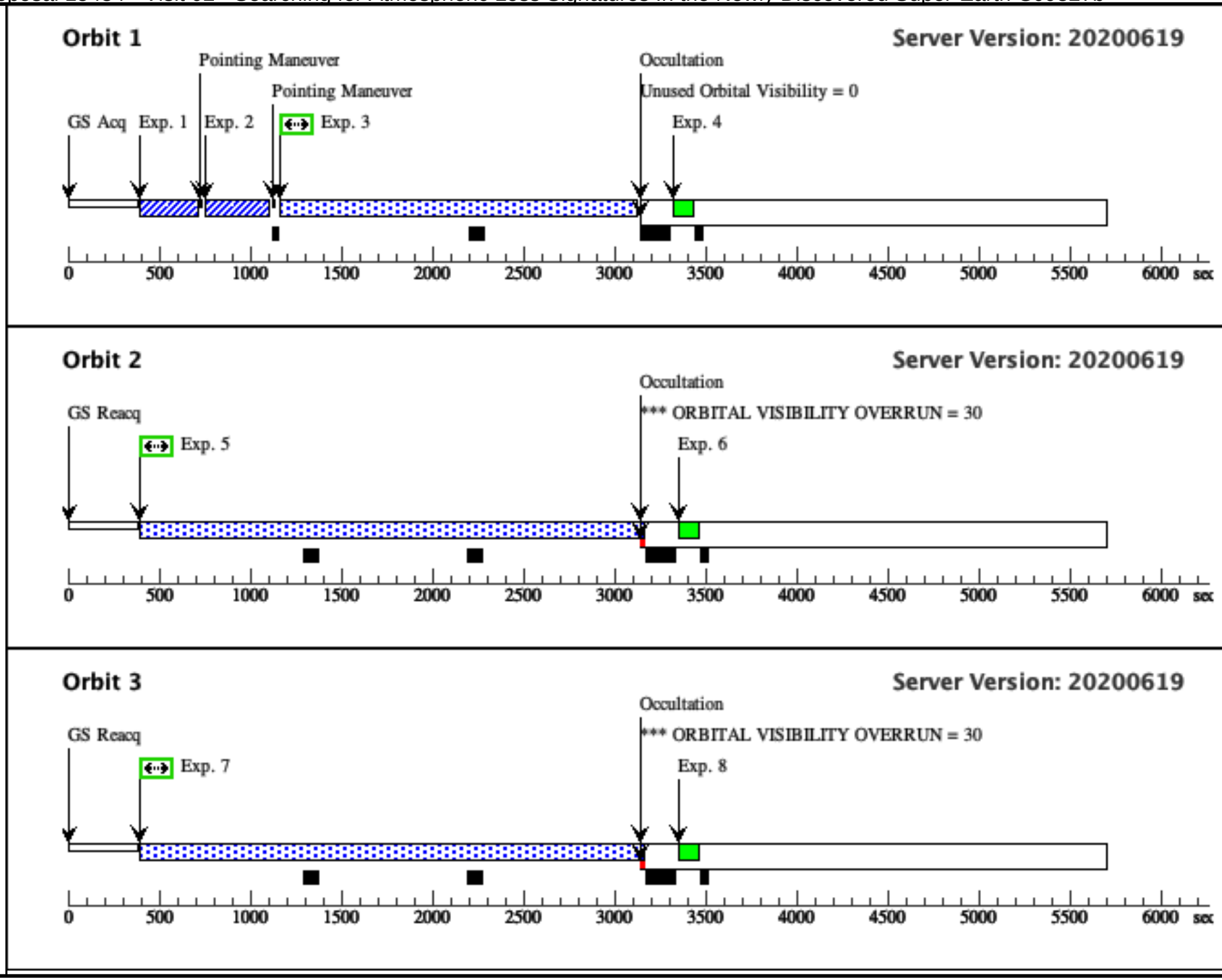
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	BD-02D5958	RA: 23 27 4.8365 (351.7701521d)	Proper Motion RA: +0.02490 sec of time/yr	V=10.101	Reference Frame: ICRS
	Alt Name1: GJ9827	Dec: -01 17 10.58 (-1.28627d)	Proper Motion Dec: +0.21604 arcsec/yr	TYPE=K6V,	
	Alt Name2: K2-135	Equinox: J2000	Parallax: 0.03298"	B-V=1.47,	
			Epoch of Position: 2000	E(B-V)=0,	
			Radial Velocity: 27.00 km/sec	F-LINE(2796)=0.20e-12,	
				W-LINE(2796)=0.5,	
				F-LINE(1215)=0.34e-12,	
				W-LINE(1215)=0.65	

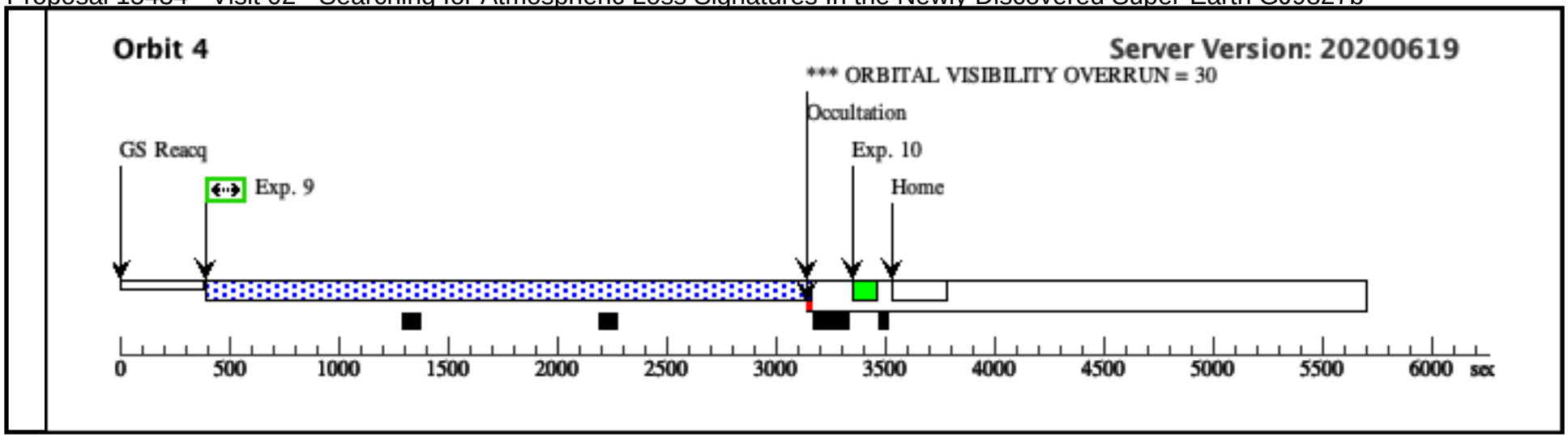
Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=STAR
Description=[EXTRA-SOLAR PLANETARY SYSTEM, K V-IV]
Extended=NO

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	ACQ (STIS.ta.1040017)	(1) BD-02D5958	STIS/CCD, ACQ, F25ND3	MIRROR	ACQTYPE=POINT	PHASE 0.8208 TO 0.9310; GS ACQ SCENARIO BASE1BE	Sequence 1-4 Non-Int in Visit 02	6.6 Secs (6.6 Secs) *[==>]*	***[1]***
	Comments: SNR = 150.5348 *Brightest Pixel = 8,557.96 e*								
2	ACQ/PEAK (STIS.sp.1040054)	(1) BD-02D5958	STIS/CCD, ACQ/PEAK, 52X0.05D1	G430L 4300 A			Sequence 1-4 Non-Int in Visit 02	1.0 Secs (1 Secs) *[==>]*	***[1]***
	Comments: SNR = 21.6692 *Brightest Pixel = 193.09 e* *Global Source Counts = 426,975.924 e*								
3	SCIENCE (STIS.sp.1040056)	(1) BD-02D5958	STIS/FUV-MAMA, TIME-TAG, 52X0.1D1	G140M 1222 A	BUFFER-TIME=900; WAVECAL=NO		Sequence 1-4 Non-Int in Visit 02	1802 Secs (1802 Secs) *[==>]*	***[1]***
	Comments: SNR = 38.8511 *Brightest Pixel = 250.81 e*								
4	GO WAVE CAL	WAVE	STIS/FUV-MAMA, ACCUM, 52X0.1	G140M 1222 A			Sequence 1-4 Non-Int in Visit 02	*[==>]*	***[1]***
5	SCIENCE (STIS.sp.1040057)	(1) BD-02D5958	STIS/FUV-MAMA, TIME-TAG, 52X0.1D1	G140M 1222 A	BUFFER-TIME=900; WAVECAL=NO		Sequence 5-6 Non-Int in Visit 02	2750 Secs (2750 Secs) *[==>]*	***[2]***
	Comments: SNR = 48.1324 *Brightest Pixel = 384.95 e*								
6	GO WAVE CAL	WAVE	STIS/FUV-MAMA, ACCUM, 52X0.1	G140M 1222 A			Sequence 5-6 Non-Int in Visit 02	*[==>]*	***[2]***
7	SCIENCE (STIS.sp.1040057)	(1) BD-02D5958	STIS/FUV-MAMA, TIME-TAG, 52X0.1D1	G140M 1222 A	BUFFER-TIME=900; WAVECAL=NO		Sequence 7-8 Non-Int in Visit 02	2750 Secs (2750 Secs) *[==>]*	***[3]***
	Comments: SNR = 48.1324 *Brightest Pixel = 384.95 e*								
8	GO WAVE CAL	WAVE	STIS/FUV-MAMA, ACCUM, 52X0.1	G140M 1222 A			Sequence 7-8 Non-Int in Visit 02	*[==>]*	***[3]***
9	SCIENCE (STIS.sp.1040057)	(1) BD-02D5958	STIS/FUV-MAMA, TIME-TAG, 52X0.1D1	G140M 1222 A	BUFFER-TIME=900; WAVECAL=NO		Sequence 9-10 Non-Int in Visit 02	2750 Secs (2750 Secs) *[==>]*	***[4]***
	Comments: SNR = 48.1324 *Brightest Pixel = 384.95 e*								
10	GO WAVE CAL	WAVE	STIS/FUV-MAMA, ACCUM, 52X0.1	G140M 1222 A			Sequence 9-10 Non-Int in Visit 02	*[==>]*	***[4]***

Orbit Structure

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Visit

Proposal 15434, Visit 03, completed Wed Sep 23 16:00:26 GMT 2020

Diagnostic Status: Warning

Scientific Instruments: STIS/NUV-MAMA, STIS/CCD

Special Requirements: (none)

Diagnostics

(Visit 03) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	BD-02D5958 Alt Name1: GJ9827 Alt Name2: K2-135	RA: 23 27 4.8365 (351.7701521d) Dec: -01 17 10.58 (-1.28627d) Equinox: J2000	Proper Motion RA: +0.02490 sec of time/yr Proper Motion Dec: +0.21604 arcsec/yr Parallax: 0.03298" Epoch of Position: 2000 Radial Velocity: 27.00 km/sec	V=10.101 TYPE=K6V, B-V=1.47, E(B-V)=0, F-LINE(2796)=0.20e-12, W-LINE(2796)=0.5, F-LINE(1215)=0.34e-12, W-LINE(1215)=0.65	Reference Frame: ICRS

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=STAR
Description=[EXTRA-SOLAR PLANETARY SYSTEM, K V-IV]
Extended=NO

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	ACQ (STIS.ta.1040017)	(1) BD-02D5958	STIS/CCD, ACQ, F25ND3	MIRROR	ACQTYPE=POINT	GS ACQ SCENARIO BASE1B3		6.6 Secs (6.6 Secs) *[==>]*	 ***[1]***
	Comments: SNR = 150.5348 *Brightest Pixel = 8,557.96 e*								
2	ACQ/PEAK (STIS.sp.1040050)	(1) BD-02D5958	STIS/CCD, ACQ/PEAK, 0.2X0.09	G430L 4300 A				1.3 Secs (1.3 Secs) *[==>]*	 ***[1]***
	Comments: SNR = 20.9060 *Brightest Pixel = 179.99 e* *Global Source Counts = 401,477.290 e*								
3	SCIENCE (STIS.sp.1040058)	(1) BD-02D5958	STIS/NUV-MAMA, ACCUM, 0.2X0.09	E230H 2713 A				1821 Secs (1821 Secs) *[==>]*	 ***[1]***
	Comments: SNR = 11.1559 *Brightest Pixel = 60.46 e*								

Orbit Structure