16168 - Stuck in the Middle with WASP-77Ab: Defining Transitions in Hot Jupiter Atmospheres

Cycle: 28, Proposal Category: GO

(Availability Mode: SUPPORTED)

INVESTIGATORS

Name	*Institution*	*E-Mail*
Megan Mansfield (PI) (Contact)	**University of Chicago**	**meganmansfield@uchicago.edu**
Jacob Arcangeli (CoI) (ESA Member)	Universiteit van Amsterdam	jarcangeli92@gmail.com
Prof. Jacob L. Bean (CoI)	University of Chicago	jbean@astro.uchicago.edu
Prof. Jean-Michel Desert (CoI) (ESA Member)	Universiteit van Amsterdam	desert@uva.nl
Prof. Jonathan Fortney (CoI)	University of California - Santa Cruz	jfortney@ucsc.edu
Prof. Eliza M.-R. Kempton (CoI)	University of Maryland	ekempton@astro.umd.edu
Dr. Michael Line (CoI)	Arizona State University	mrline@asu.edu
Dr. Brian Kilpatrick (CoI)	Space Telescope Science Institute	bkilpatrick@stsci.edu
Dr. Laura Kreidberg (CoI) (ESA Member)	Max Planck Institute for Astronomy	kreidberg@mpia.de
Matej Malik (CoI)	University of Maryland	malik@umd.edu
Dr. Vivien Parmentier (CoI) (ESA Member)	University of Oxford	vivien.parmentier@physics.ox.ac.uk
Dr. Kevin Stevenson (CoI)	The Johns Hopkins University Applied Physics Laboratory	kevin.stevenson@jhuapl.edu

VISITS

Visit	*Targets used in Visit*	*Configurations used in Visit*	*Orbits Used*	*Last Orbit Planner Run*	*OP Current with Visit?*
01	(1) WASP-77A	WFC3/IR	5	04-Dec-2020 16:02:17.0	yes
02	(1) WASP-77A	WFC3/IR	5	04-Dec-2020 16:02:37.0	yes

10 Total Orbits Used

ABSTRACT

Hot Jupiters are compelling targets for thermal emission observations because their high signal-to-noise allows precise atmospheric characterization. Theory predicts a continuum of thermal structures and resulting emission spectra for these objects. Planets with dayside temperatures (Tday) below ~2100 K are expected to have uninverted atmospheres and display absorption features in their spectra. Planets with Tday>2100 K should have inverted atmospheres, but only those with 2100<Tday<2500 are expected to show emission features, as those with Tday>2500 are expected to have featureless, blackbody-like spectra. While we have observed cooler planets with absorption features and warmer planets with blackbody-like spectra, we have not observed any intermediate-temperature planets at high enough precision to understand the transition between these regimes.

We propose to use the Hubble Space Telescope (HST)/WFC3+G141 grism to observe the thermal emission spectrum of the hot Jupiter WASP-77Ab. WASP-77Ab planet sits at a temperature where the models predict the widest range of potential atmospheric structures and resulting secondary eclipse spectra, and it is the only planet in this transition region whose spectrum can be measured precisely with only two eclipse observations. The resulting spectrum will be as precise as that of the benchmark hot Jupiter WASP-43b, and if it shows absorption or emission features we will place equally tight constraints on the water abundance of WASP-77Ab. Its high signal-to-noise means WASP-77Ab has the potential to become a new archetype hot Jupiter and will likely be targeted for extensive JWST observations if its spectrum shows interesting features.

OBSERVING DESCRIPTION

We will perform time-series spectroscopy using HST to measure two secondary eclipses of WASP-77Ab. We will use the WFC3/IR instrument with the G141 grism to measure the thermal emission spectra of WASP-77Ab from 1.1 to 1.7 microns.

We used PandExo to simulate the observations and predict the S/N values for each secondary eclipse (Batalha et al., 2017). The observations will be done with the 256 x 256 subarray. We will use the SPARS25, NSAMP=5 sampling sequence (total time per exposure of 89.7 s) and the spatial scan mode with bi-directional scans to maximize the duty cycle (expected to be 66%). We will use a scan rate of 0.195"/s, which will give peak counts of roughly 30k electrons/pixel and a scan height of 144 pixels. The scan will fit comfortably in the 256 subarray and leave plenty of empty detector space to estimate the background. We expect a photon-limited signal-to-noise ratio of about 3,200 per pixel in each extracted 1D spectrum. A total of 20 exposures will be obtained in each orbit, and 1 orbit during each visit will occur during the secondary eclipse. Each visit will consist of 5 orbits. Each orbit will begin with a direct image through the F126N filter for wavelength calibration.

WASP-77A has a companion star (WASP-77B) with a projected separation of 3.2". In order to correct for contamination from this companion star, the first orbit of each visit contains a single G141 stare mode spectrum to measure the relative flux of the two stars. We have placed orient constraints on each visit such that the spectra of WASP-77A and WASP-77B do not overlap in this stare mode image.

Visit

Proposal 16168, Visit 01, completed Fri Dec 04 21:02:39 GMT 2020

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/IR

Special Requirements: SCHED 30%; ORIENT 43.6D TO 173.6 D; ORIENT 223.6D TO 353.6 D; Period 1.36002854 D AND ZERO-PHASE HJD2457420.88439

Comments: The position angle from WASP-77A to WASP-77B is 153.6 degrees. This position angle must be >10 pixels (which corresponds to ~24.9 degrees) from the WFC3 IR x-axis. The WFC3 IR instrument has a y offset angle of 13.5 degrees, which we used to calculate the below allowable orient ranges.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	WASP-77A	RA: 02 28 37.3253 (37.1555221d) Dec: -07 03 38.40 (-7.06067d) Equinox: J2000	Proper Motion RA: 0.006307096188681314 sec of time/yr Proper Motion Dec: -0.0015670000721001998 arcsec/yr Epoch of Position: 2015.5	V=10.29+/-0.05	Reference Frame: SIMBAD

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=STAR
Description=[EXTRA-SOLAR PLANET]

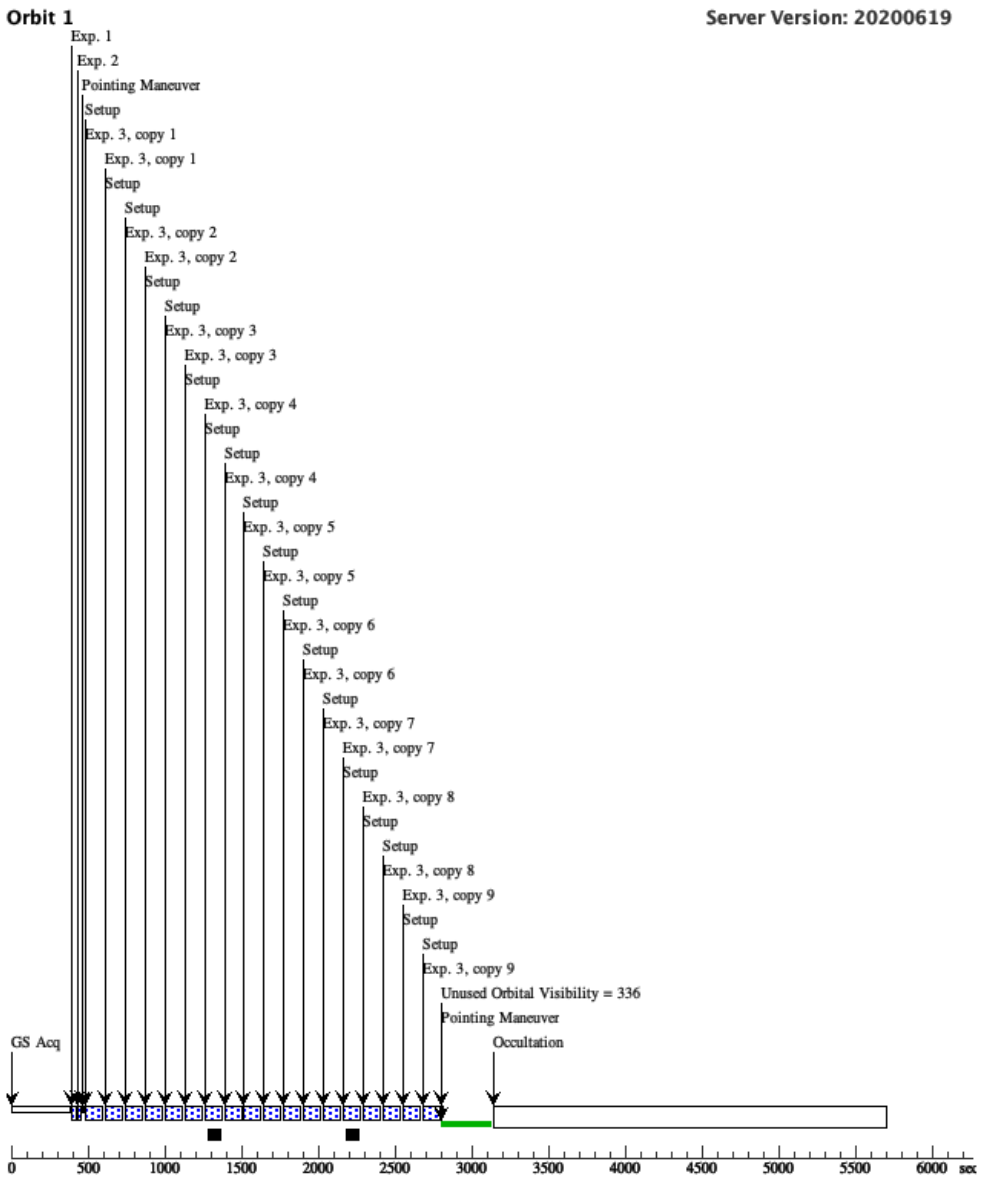
Exposures

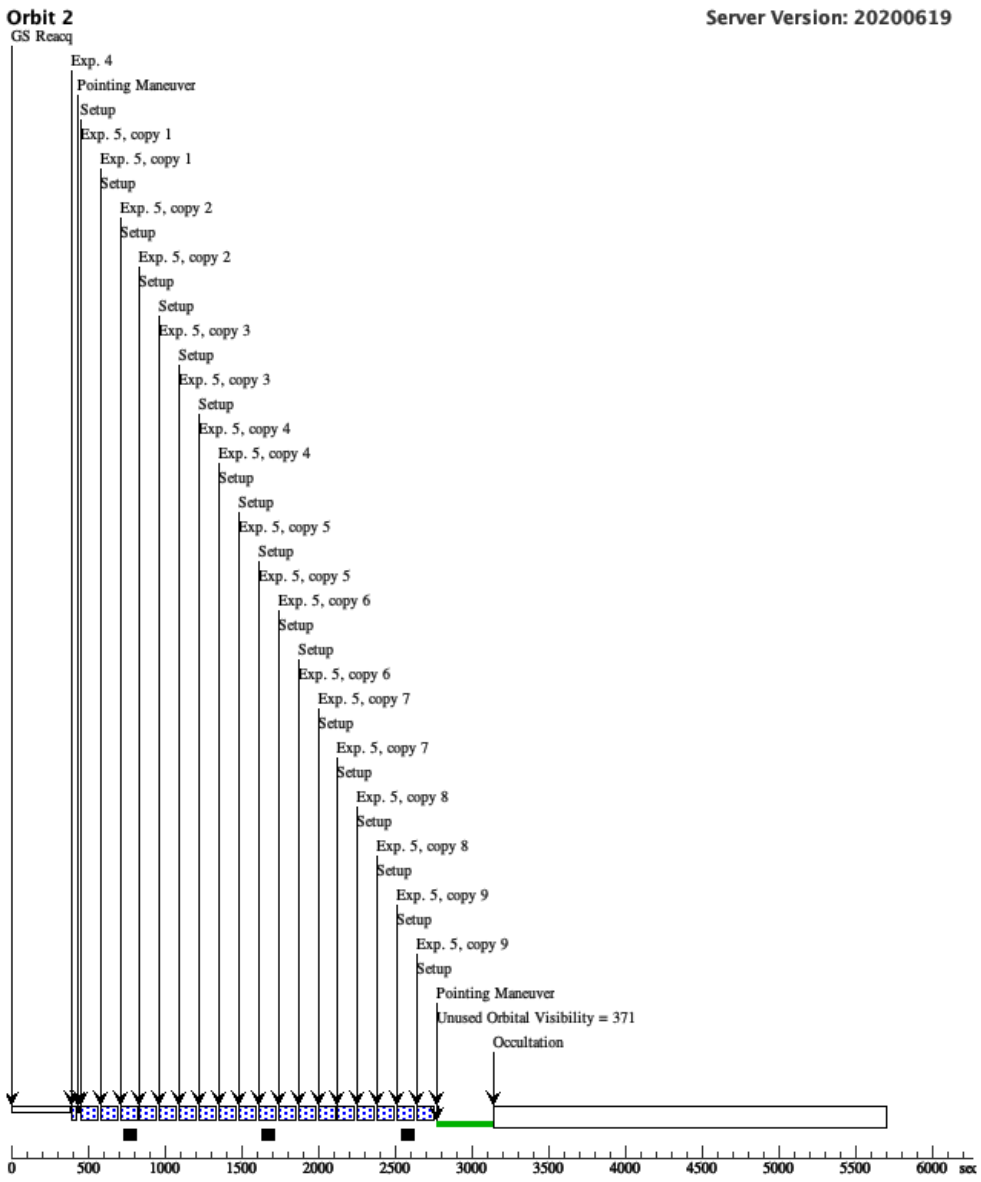
#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1		(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	F126N	SAMP-SEQ=RAPID; NSAMP=2	POS TARG null,-11.5; PHASE 0.34239 TO 0.35771	Sequence 1-3 Non-Int in Visit 01	0.55563 Secs (0.556 Secs) *[==>]*	***[1]***
2		(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	G141	SAMP-SEQ=RAPID; NSAMP=2	POS TARG null,-11.5	Sequence 1-3 Non-Int in Visit 01	0.55563 Secs (0.556 Secs) *[==>]*	***[1]***
3		(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	G141	SAMP-SEQ=SPARS25; NSAMP=5	POS TARG null,-11.5; SPATIAL SCAN 0.1 95,90.0 Degrees,Round trip	Sequence 1-3 Non-Int in Visit 01	89.661971 Secs X 9 (1613.915 Secs) *[==>(Copy 1, Forward)]* *[==>(Copy 1, Reverse)]* *[==>(Copy 2, Forward)]* *[==>(Copy 2, Reverse)]* *[==>(Copy 3, Forward)]* *[==>(Copy 3, Reverse)]* *[==>(Copy 4, Forward)]* *[==>(Copy 4, Reverse)]* *[==>(Copy 5, Forward)]* *[==>(Copy 5, Reverse)]* *[==>(Copy 6, Forward)]* *[==>(Copy 6, Reverse)]* *[==>(Copy 7, Forward)]* *[==>(Copy 7, Reverse)]* *[==>(Copy 8, Forward)]* *[==>(Copy 8, Reverse)]* *[==>(Copy 9, Forward)]* *[==>(Copy 9, Reverse)]*	***[1]***
4		(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	F126N	SAMP-SEQ=RAPID; NSAMP=2	POS TARG null,-11.5	Sequence 4-5 Non-Int in Visit 01	0.55563 Secs (0.556 Secs) *[==>]*	***[2]***

	5	(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	G141	SAMP-SEQ=SPARS25; NSAMP=5	POS TARG null,-11.5; SPATIAL SCAN 0.195,90.0 Degrees,Round trip	Sequence 4-5 Non-Int in Visit 01	89.661971 Secs X 9 (1613.915 Secs) *[==>(Copy 1, Forward)]* *[==>(Copy 1, Reverse)]* *[==>(Copy 2, Forward)]* *[==>(Copy 2, Reverse)]* *[==>(Copy 3, Forward)]* *[==>(Copy 3, Reverse)]* *[==>(Copy 4, Forward)]* *[==>(Copy 4, Reverse)]* *[==>(Copy 5, Forward)]* *[==>(Copy 5, Reverse)]* *[==>(Copy 6, Forward)]* *[==>(Copy 6, Reverse)]* *[==>(Copy 7, Forward)]* *[==>(Copy 7, Reverse)]* *[==>(Copy 8, Forward)]* *[==>(Copy 8, Reverse)]* *[==>(Copy 9, Forward)]* *[==>(Copy 9, Reverse)]*	***[2]***
	6	(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	F126N	SAMP-SEQ=RAPID; NSAMP=2	POS TARG null,-11.5	Sequence 6-7 Non-Int in Visit 01	0.55563 Secs (0.556 Secs) *[==>]*	***[3]***
	7	(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	G141	SAMP-SEQ=SPARS25; NSAMP=5	POS TARG null,-11.5; SPATIAL SCAN 0.195,90.0 Degrees,Round trip	Sequence 6-7 Non-Int in Visit 01	89.661971 Secs X 9 (1613.915 Secs) *[==>(Copy 1, Forward)]* *[==>(Copy 1, Reverse)]* *[==>(Copy 2, Forward)]* *[==>(Copy 2, Reverse)]* *[==>(Copy 3, Forward)]* *[==>(Copy 3, Reverse)]* *[==>(Copy 4, Forward)]* *[==>(Copy 4, Reverse)]* *[==>(Copy 5, Forward)]* *[==>(Copy 5, Reverse)]* *[==>(Copy 6, Forward)]* *[==>(Copy 6, Reverse)]* *[==>(Copy 7, Forward)]* *[==>(Copy 7, Reverse)]* *[==>(Copy 8, Forward)]* *[==>(Copy 8, Reverse)]* *[==>(Copy 9, Forward)]* *[==>(Copy 9, Reverse)]*	***[3]***
	8	(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	F126N	SAMP-SEQ=RAPID; NSAMP=2	POS TARG null,-11.5	Sequence 8-9 Non-Int in Visit 01	0.55563 Secs (0.556 Secs) *[==>]*	***[4]***

	9	(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	G141	SAMP-SEQ=SPARS25; NSAMP=5	POS TARG null,-11.5; SPATIAL SCAN 0.195,90.0 Degrees,Round trip	Sequence 8-9 Non-Int in Visit 01	89.661971 Secs X 9 (1613.915 Secs) *[==>(Copy 1, Forward)]* *[==>(Copy 1, Reverse)]* *[==>(Copy 2, Forward)]* *[==>(Copy 2, Reverse)]* *[==>(Copy 3, Forward)]* *[==>(Copy 3, Reverse)]* *[==>(Copy 4, Forward)]* *[==>(Copy 4, Reverse)]* *[==>(Copy 5, Forward)]* *[==>(Copy 5, Reverse)]* *[==>(Copy 6, Forward)]* *[==>(Copy 6, Reverse)]* *[==>(Copy 7, Forward)]* *[==>(Copy 7, Reverse)]* *[==>(Copy 8, Forward)]* *[==>(Copy 8, Reverse)]* *[==>(Copy 9, Forward)]* *[==>(Copy 9, Reverse)]*	***[4]***
	10	(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	F126N	SAMP-SEQ=RAPID; NSAMP=2	POS TARG null,-11.5	Sequence 10-11 Non-Int in Visit 01	0.55563 Secs (0.556 Secs) *[==>]*	***[5]***
	11	(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	G141	SAMP-SEQ=SPARS25; NSAMP=5	POS TARG null,-11.5; SPATIAL SCAN 0.195,90.0 Degrees,Round trip	Sequence 10-11 Non-Int in Visit 01	89.661971 Secs X 9 (1613.915 Secs) *[==>(Copy 1, Forward)]* *[==>(Copy 1, Reverse)]* *[==>(Copy 2, Forward)]* *[==>(Copy 2, Reverse)]* *[==>(Copy 3, Forward)]* *[==>(Copy 3, Reverse)]* *[==>(Copy 4, Forward)]* *[==>(Copy 4, Reverse)]* *[==>(Copy 5, Forward)]* *[==>(Copy 5, Reverse)]* *[==>(Copy 6, Forward)]* *[==>(Copy 6, Reverse)]* *[==>(Copy 7, Forward)]* *[==>(Copy 7, Reverse)]* *[==>(Copy 8, Forward)]* *[==>(Copy 8, Reverse)]* *[==>(Copy 9, Forward)]* *[==>(Copy 9, Reverse)]*	***[5]***

Orbit Structure

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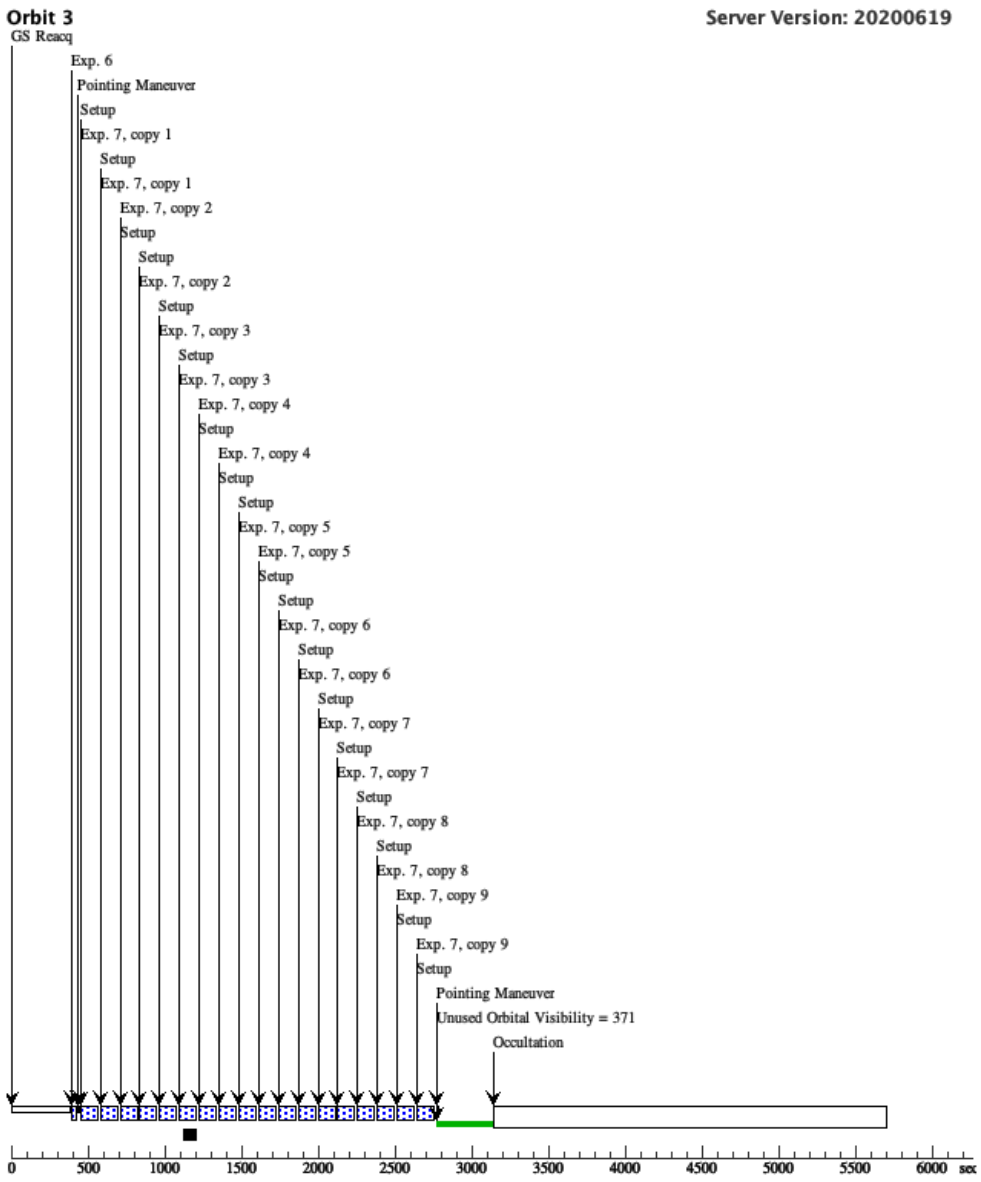
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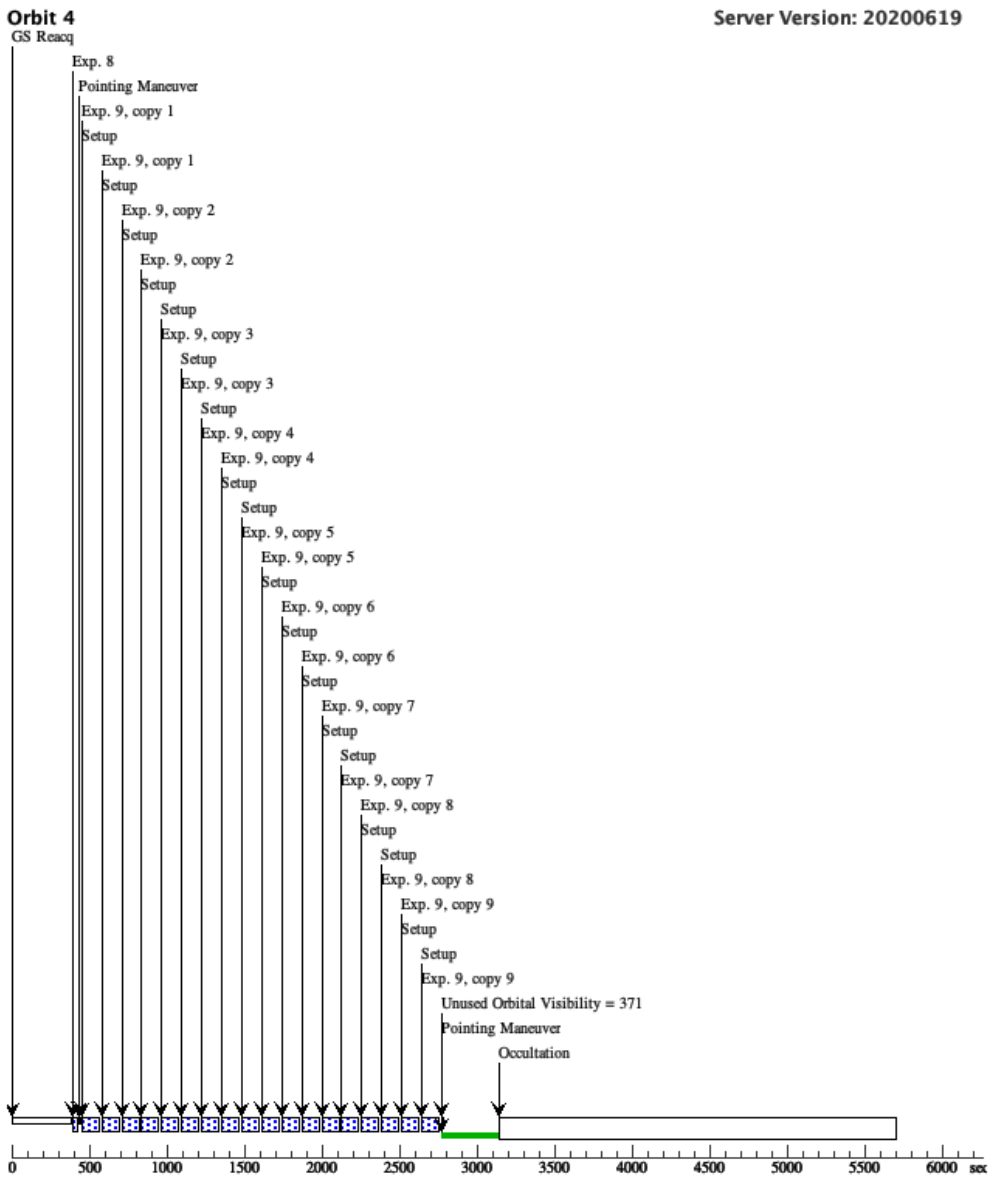
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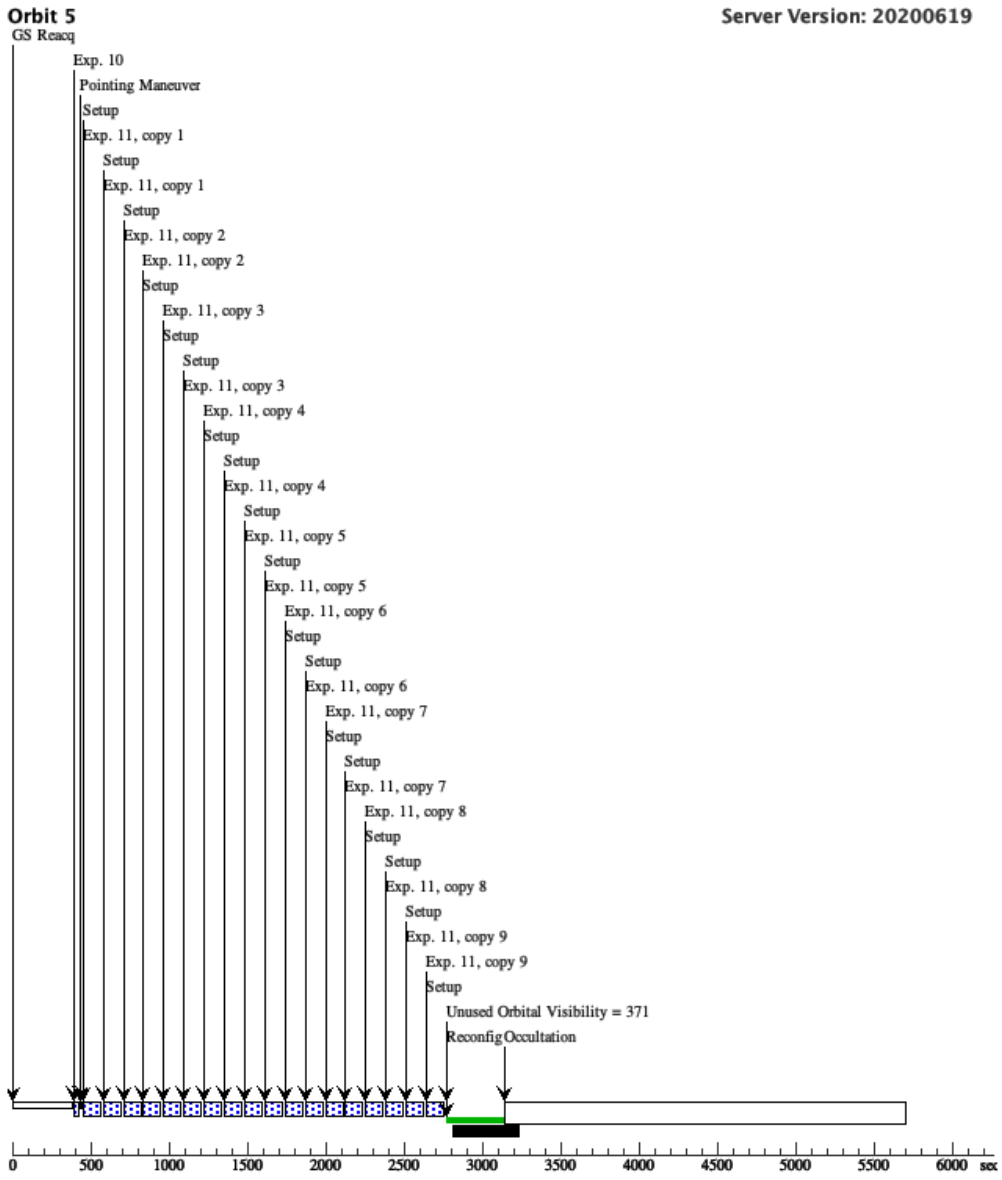
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Unused Orbital Visibility = 371
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Visit

Proposal 16168, Visit 02, scheduling Fri Dec 04 21:02:40 GMT 2020

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/IR

Special Requirements: SCHED 30%; ORIENT 43.6D TO 173.6 D; ORIENT 223.6D TO 353.6 D; Period 1.36002854 D AND ZERO-PHASE HJD2457420.88439

Comments: The position angle from WASP-77A to WASP-77B is 153.6 degrees. This position angle must be >10 pixels (which corresponds to ~24.9 degrees) from the WFC3 IR x-axis. The WFC3 IR instrument has a y offset angle of 13.5 degrees, which we used to calculate the below allowable orient ranges.

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(1)	WASP-77A	RA: 02 28 37.3253 (37.1555221d) Dec: -07 03 38.40 (-7.06067d) Equinox: J2000	Proper Motion RA: 0.006307096188681314 sec of time/yr Proper Motion Dec: -0.0015670000721001998 arcsec/yr Epoch of Position: 2015.5	V=10.29+/-0.05	Reference Frame: SIMBAD

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=STAR
Description=[EXTRA-SOLAR PLANET]

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
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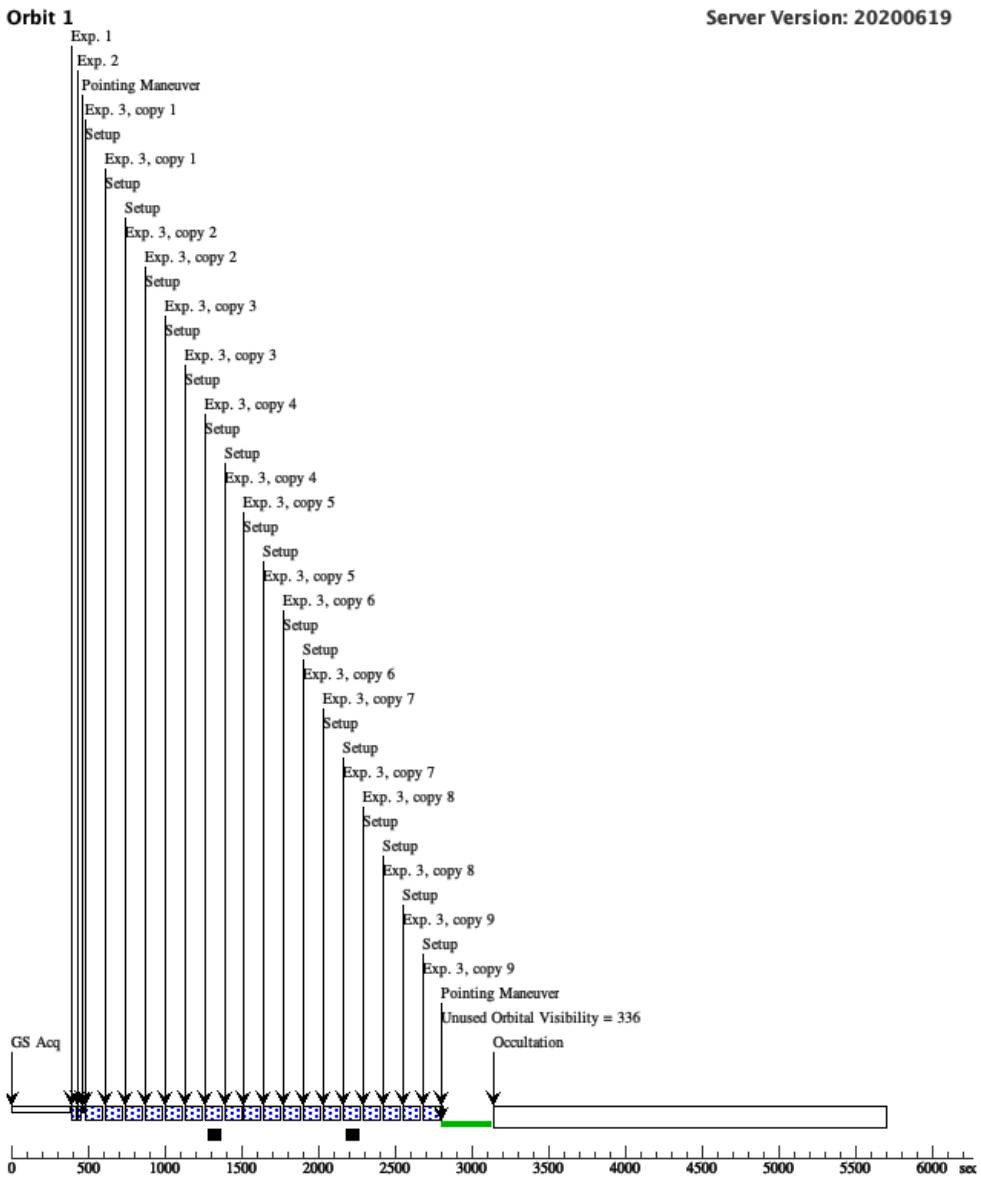
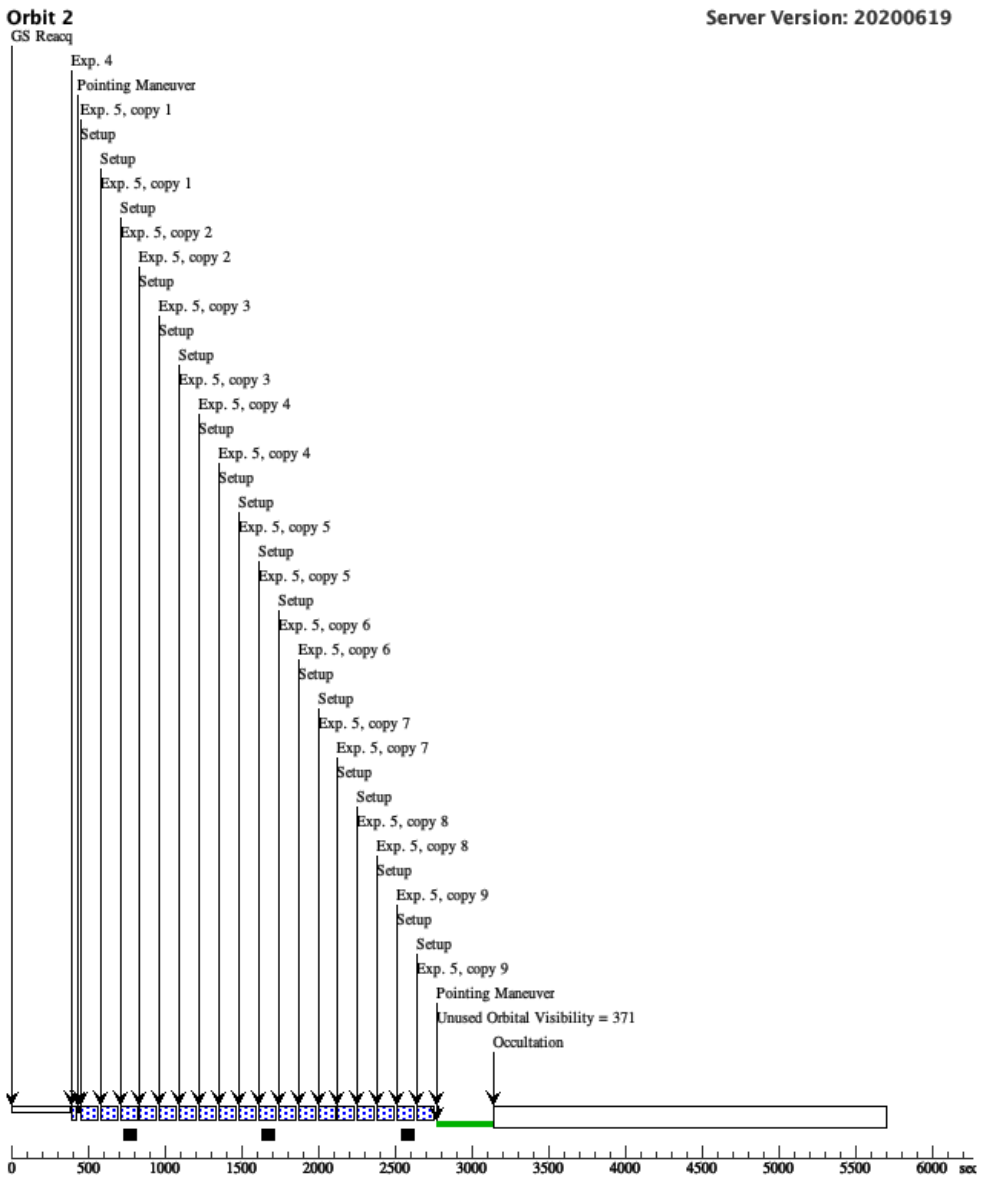
2		(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	G141	SAMP-SEQ=RAPID; NSAMP=2	POS TARG null,-11.5	Sequence 1-3 Non-Int in Visit 02	0.55563 Secs (0.556 Secs) *[==>]*	 ***[1]***
3		(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	G141	SAMP-SEQ=SPARS25; NSAMP=5	POS TARG null,-11.5; SPATIAL SCAN 0.1 95,90.0 Degrees,Round trip	Sequence 1-3 Non-Int in Visit 02	89.661971 Secs X 9 (1613.915 Secs) *[==>(Copy 1, Forward)]* *[==>(Copy 1, Reverse)]* *[==>(Copy 2, Forward)]* *[==>(Copy 2, Reverse)]* *[==>(Copy 3, Forward)]* *[==>(Copy 3, Reverse)]* *[==>(Copy 4, Forward)]* *[==>(Copy 4, Reverse)]* *[==>(Copy 5, Forward)]* *[==>(Copy 5, Reverse)]* *[==>(Copy 6, Forward)]* *[==>(Copy 6, Reverse)]* *[==>(Copy 7, Forward)]* *[==>(Copy 7, Reverse)]* *[==>(Copy 8, Forward)]* *[==>(Copy 8, Reverse)]* *[==>(Copy 9, Forward)]* *[==>(Copy 9, Reverse)]*	 ***[1]***
4		(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	F126N	SAMP-SEQ=RAPID; NSAMP=2	POS TARG null,-11.5	Sequence 4-5 Non-Int in Visit 02	0.55563 Secs (0.556 Secs) *[==>]*	 ***[2]***

	5	(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	G141	SAMP-SEQ=SPARS25; NSAMP=5	POS TARG null,-11.5; SPATIAL SCAN 0.195,90.0 Degrees,Round trip	Sequence 4-5 Non-Int in Visit 02	89.661971 Secs X 9 (1613.915 Secs) *[==>(Copy 1, Forward)]* *[==>(Copy 1, Reverse)]* *[==>(Copy 2, Forward)]* *[==>(Copy 2, Reverse)]* *[==>(Copy 3, Forward)]* *[==>(Copy 3, Reverse)]* *[==>(Copy 4, Forward)]* *[==>(Copy 4, Reverse)]* *[==>(Copy 5, Forward)]* *[==>(Copy 5, Reverse)]* *[==>(Copy 6, Forward)]* *[==>(Copy 6, Reverse)]* *[==>(Copy 7, Forward)]* *[==>(Copy 7, Reverse)]* *[==>(Copy 8, Forward)]* *[==>(Copy 8, Reverse)]* *[==>(Copy 9, Forward)]* *[==>(Copy 9, Reverse)]*	***[2]***
	6	(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	F126N	SAMP-SEQ=RAPID; NSAMP=2	POS TARG null,-11.5	Sequence 6-7 Non-Int in Visit 02	0.55563 Secs (0.556 Secs) *[==>]*	***[3]***
	7	(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	G141	SAMP-SEQ=SPARS25; NSAMP=5	POS TARG null,-11.5; SPATIAL SCAN 0.195,90.0 Degrees,Round trip	Sequence 6-7 Non-Int in Visit 02	89.661971 Secs X 9 (1613.915 Secs) *[==>(Copy 1, Forward)]* *[==>(Copy 1, Reverse)]* *[==>(Copy 2, Forward)]* *[==>(Copy 2, Reverse)]* *[==>(Copy 3, Forward)]* *[==>(Copy 3, Reverse)]* *[==>(Copy 4, Forward)]* *[==>(Copy 4, Reverse)]* *[==>(Copy 5, Forward)]* *[==>(Copy 5, Reverse)]* *[==>(Copy 6, Forward)]* *[==>(Copy 6, Reverse)]* *[==>(Copy 7, Forward)]* *[==>(Copy 7, Reverse)]* *[==>(Copy 8, Forward)]* *[==>(Copy 8, Reverse)]* *[==>(Copy 9, Forward)]* *[==>(Copy 9, Reverse)]*	***[3]***
	8	(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	F126N	SAMP-SEQ=RAPID; NSAMP=2	POS TARG null,-11.5	Sequence 8-9 Non-Int in Visit 02	0.55563 Secs (0.556 Secs) *[==>]*	***[4]***

	9	(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	G141	SAMP-SEQ=SPARS25; NSAMP=5	POS TARG null,-11.5; SPATIAL SCAN 0.195,90.0 Degrees,Round trip	Sequence 8-9 Non-Int in Visit 02	89.661971 Secs X 9 (1613.915 Secs) *[==>(Copy 1, Forward)]* *[==>(Copy 1, Reverse)]* *[==>(Copy 2, Forward)]* *[==>(Copy 2, Reverse)]* *[==>(Copy 3, Forward)]* *[==>(Copy 3, Reverse)]* *[==>(Copy 4, Forward)]* *[==>(Copy 4, Reverse)]* *[==>(Copy 5, Forward)]* *[==>(Copy 5, Reverse)]* *[==>(Copy 6, Forward)]* *[==>(Copy 6, Reverse)]* *[==>(Copy 7, Forward)]* *[==>(Copy 7, Reverse)]* *[==>(Copy 8, Forward)]* *[==>(Copy 8, Reverse)]* *[==>(Copy 9, Forward)]* *[==>(Copy 9, Reverse)]*	***[4]***
	10	(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	F126N	SAMP-SEQ=RAPID; NSAMP=2	POS TARG null,-11.5	Sequence 10-11 Non-Int in Visit 02	0.55563 Secs (0.556 Secs) *[==>]*	***[5]***
	11	(1) WASP-77A	WFC3/IR, MULTIACCUM, GRISM256	G141	SAMP-SEQ=SPARS25; NSAMP=5	POS TARG null,-11.5; SPATIAL SCAN 0.195,90.0 Degrees,Round trip	Sequence 10-11 Non-Int in Visit 02	89.661971 Secs X 9 (1613.915 Secs) *[==>(Copy 1, Forward)]* *[==>(Copy 1, Reverse)]* *[==>(Copy 2, Forward)]* *[==>(Copy 2, Reverse)]* *[==>(Copy 3, Forward)]* *[==>(Copy 3, Reverse)]* *[==>(Copy 4, Forward)]* *[==>(Copy 4, Reverse)]* *[==>(Copy 5, Forward)]* *[==>(Copy 5, Reverse)]* *[==>(Copy 6, Forward)]* *[==>(Copy 6, Reverse)]* *[==>(Copy 7, Forward)]* *[==>(Copy 7, Reverse)]* *[==>(Copy 8, Forward)]* *[==>(Copy 8, Reverse)]* *[==>(Copy 9, Forward)]* *[==>(Copy 9, Reverse)]*	***[5]***

Orbit Structure

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GS Reacq
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Exp. 5, copy 5
Setup
Exp. 5, copy 6
Exp. 5, copy 6
Setup
Setup
Exp. 5, copy 7
Exp. 5, copy 7
Setup
Setup
Exp. 5, copy 8
Exp. 5, copy 8
Setup
Exp. 5, copy 9
Setup
Setup
Exp. 5, copy 9
Pointing Maneuver
Unused Orbital Visibility = 371
Occultation
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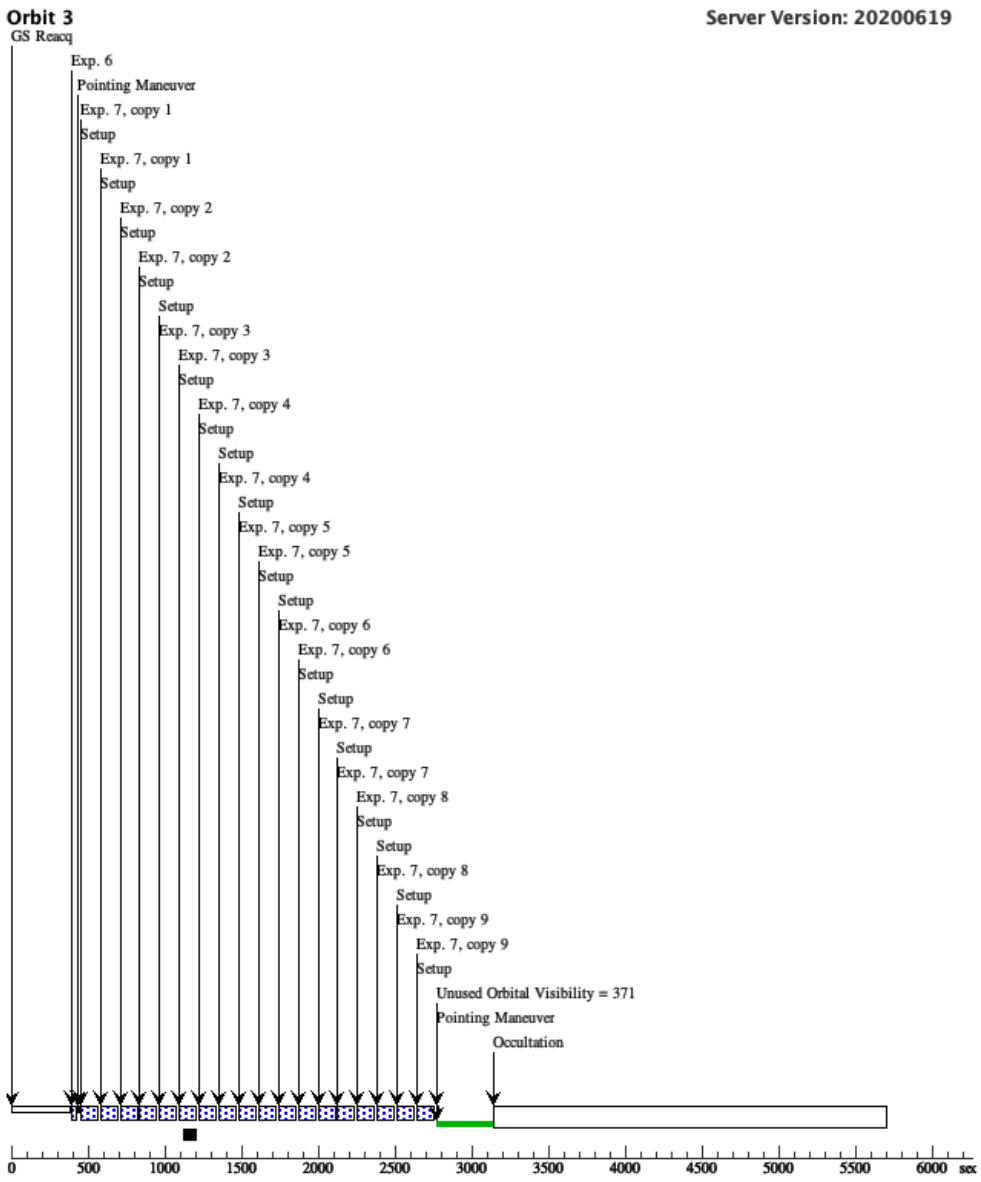
Orbit 3
Server Version: 20200619
GS Reacq
Exp. 6
Pointing Maneuver
Exp. 7, copy 1
Setup
Exp. 7, copy 1
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Exp. 7, copy 2
Setup
Exp. 7, copy 2
Setup
Setup
Exp. 7, copy 3
Exp. 7, copy 3
Setup
Exp. 7, copy 4
Setup
Setup
Exp. 7, copy 4
Setup
Exp. 7, copy 5
Exp. 7, copy 5
Setup
Setup
Exp. 7, copy 6
Exp. 7, copy 6
Setup
Setup
Exp. 7, copy 7
Setup
Exp. 7, copy 7
Exp. 7, copy 8
Setup
Setup
Exp. 7, copy 8
Setup
Exp. 7, copy 9
Exp. 7, copy 9
Setup
Unused Orbital Visibility = 371
Pointing Maneuver
Occultation
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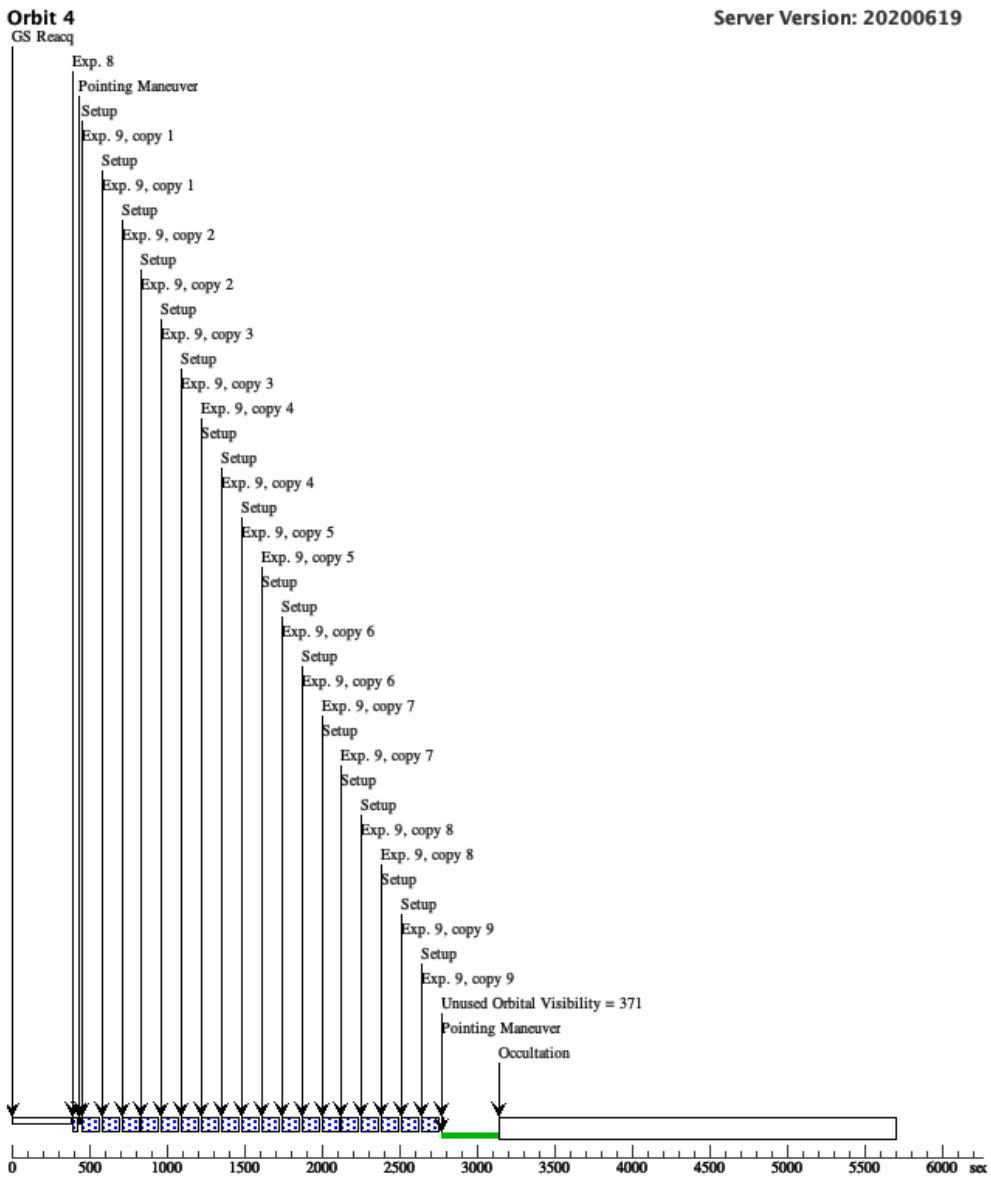
Orbit 4
Server Version: 20200619
GS Reacq
Exp. 8
Pointing Maneuver
Setup
Exp. 9, copy 1
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Exp. 9, copy 1
Setup
Exp. 9, copy 2
Setup
Exp. 9, copy 2
Setup
Exp. 9, copy 3
Setup
Exp. 9, copy 3
Exp. 9, copy 4
Setup
Setup
Exp. 9, copy 4
Setup
Exp. 9, copy 5
Exp. 9, copy 5
Setup
Setup
Exp. 9, copy 6
Setup
Exp. 9, copy 6
Exp. 9, copy 7
Setup
Exp. 9, copy 7
Setup
Setup
Exp. 9, copy 8
Exp. 9, copy 8
Setup
Setup
Exp. 9, copy 9
Setup
Exp. 9, copy 9
Unused Orbital Visibility = 371
Pointing Maneuver
Occultation
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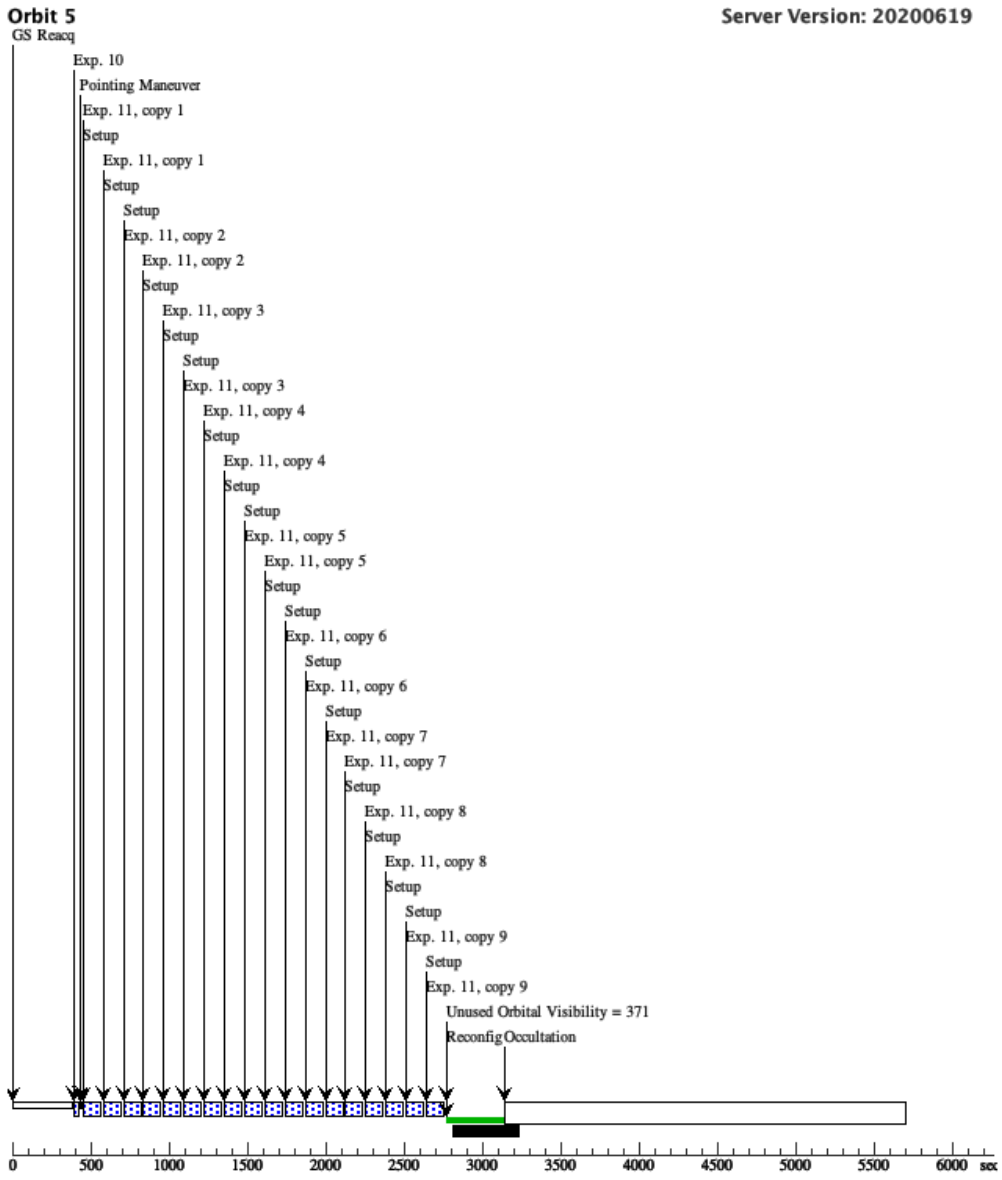
Orbit 5
Server Version: 20200619
GS Reacq
Exp. 10
Pointing Maneuver
Exp. 11, copy 1
Setup
Exp. 11, copy 1
Setup
Setup
Exp. 11, copy 2
Exp. 11, copy 2
Setup
Exp. 11, copy 3
Setup
Setup
Exp. 11, copy 3
Exp. 11, copy 4
Setup
Exp. 11, copy 4
Setup
Setup
Exp. 11, copy 5
Exp. 11, copy 5
Setup
Setup
Exp. 11, copy 6
Setup
Exp. 11, copy 6
Setup
Exp. 11, copy 7
Exp. 11, copy 7
Setup
Exp. 11, copy 8
Setup
Exp. 11, copy 8
Setup
Setup
Exp. 11, copy 9
Setup
Exp. 11, copy 9
Unused Orbital Visibility = 371
Reconfig
Occultation
0
500
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2000
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sec