15135 - An exoplanet with a stratosphere: seeking the unknown absorber

Cycle: 25, Proposal Category: GO

(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) WASP-121	WFC3/IR	5	08-Nov-2017 10:05:04.0	yes
02	(1) WASP-121	WFC3/IR	5	08-Nov-2017 10:05:31.0	yes

10 Total Orbits Used

ABSTRACT

The extent to which significant stratospheres form in highly-irradiated gas giant exoplanets is still a major unresolved question in the field. Using WFC3 G141, we have recently measured a thermal emission spectrum for WASP-121b (T~2700K). The 1.4 micron water band is spectrally-resolved in emission, providing a clear detection of a thermal inversion in the atmosphere. From this measurement, we conclude that the most likely cause of the inversion is absorption of impinging stellar radiation by a high-altitude optical absorber, as other heating mechanisms are almost certainly insufficient. Intriguingly, the G141 spectrum also shows a flux excess at ~1.22 micron, which can be well-explained by vanadium oxide emission. Indeed, absorption by vanadium oxide and titanium oxide has been proposed as a possible means by which to generate stratospheres in the hottest exoplanets. However, we are currently unable to draw a confident conclusion on the presence of vanadium oxide in the atmosphere of WASP-121b with the available data. We propose here to rectify this situation, by extending the wavelength coverage of the measured thermal spectrum across the 0.9-1.1 micron wavelength range using WFC3 G102. This will allow us to target the prominent vanadium oxide and titanium oxide bands at these wavelengths, where the flux from the planet is still high. If observed, a long-theorized link would be established between these important chemical species and thermal inversions in highly-irradiated atmospheres.

OBSERVING DESCRIPTION

Our WFC3 observations will provide a thermal emission spectrum for the transiting exoplanet WASP-121b across the 0.9-1.1 micron wavelength range.

**Observing strategy:

To construct the emission spectrum, we will observe two secondary eclipses of WASP-121b with WFC3 G102. The observations will be made in slitless spectroscopic mode. Our observing setup is very similar to that used in previous successful programs, such as Prog 14468 (PI Evans; G141 primary transit of WASP-121b), Prog 14767 (PI Sing; G141 secondary eclipse of WASP-121b), and Prog 13467 (PI Bean; G102 transits for the somewhat fainter WASP-12b).

At the start of each HST visit, a standard phase-constrained acquisition image will be taken. The subsequent observing strategy for both visits consists of taking repeated exposures for the duration of the eclipse, plus time before and after the eclipse to establish the out-of-eclipse baseline flux. Different phase constraints have been specified for each visit to maximize the phase coverage of the eclipse itself. Indeed, the only difference between each visit is the phase constraint provided for the acquisition image in the first orbit.

We will use the forward spatial scanning mode with a scan rate of 0.08 arcsec/sec, using SPARS10 and NSAMP=15. We will read out a subarray size of 256 pixels to reduce overheads. Individual exposure times will be 103.1 sec, resulting in a scan across 8.25 arcsec = 68 pixels per exposure. We will apply an offset of -6 arcsec = -50 pixel along the cross-dispersion y-axis of the array at the start of each exposure. This will leave enough room on the detector above and below the scan to estimate the background flux.

Each eclipse of WASP-121b lasts 173 minutes. We therefore require 5 consecutive HST orbits for each visit. The first orbit serves to allow the telescope to thermally relax into its new pointing position and for the detector charge-traps to fill, which is a standard procedure adopted by all HST WFC3 transiting exoplanet observations. The remaining orbits will provide good phase coverage during eclipse, and allow for sufficient time (2 HST orbits - one before eclipse, one after eclipse) to establish the baseline stellar flux necessary to accurately measure the eclipse depth. We will obtain 17 science exposures per HST orbit, coming to a total of 34 in-eclipse and 34 out-of-eclipse science exposures per visit.

We choose not to use bi-directional spatial scanning, e.g. as has been done for WASP-12b in Program 13467 (PI Bean). This is because although bi-directional spatial scanning would allow an additional 2 exposures to be acquired per HST orbit (i.e. 19 per orbit), the instrumental systematics are different for each scan direction, which is likely more of a disadvantage.

**Signal-to-noise estimates:

WASP-121b is a bright target in the conventional sense (V=10.5mag, J=9.6mag). The challenge with exoplanet emission spectroscopy is to measure subtle changes in the system brightness across different wavelength channels, via variations in the transit depth. We used the HST Exposure Time Calculator with the observational setup described above to calculate a SNR of ~1800 per resolution element per exposure. Note that this flux will be spread over ~68 pixel columns due to the spatial scan (see above), so there is no risk of saturation. According to the HST Exposure Time Calculator, with this setup the brightest pixel per exposure will reach 24,700 electrons (see linked ETC Run #'s in the observing sequences).

Visit

Proposal 15135, WASP-121 WFC3 Eclipse 1 (01), implementation Wed Nov 08 15:05:35 GMT 2017

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/IR

Special Requirements: SCHED 70%; ORIENT 25D TO 50 D; ORIENT 125D TO 140 D; ORIENT 310D TO 325 D; ORIENT 200D TO 220 D; Period 1.2749255 D AND ZERO-PHASE HJD2457702.82133

Comments: It is essential that the five HST orbits be scheduled in a contiguous block. We have defined each HST orbit within a non-interruptible sequence, to ensure that all exposures defined within the sequence are taken during the same HST orbit.

We will use forward spatial scanning mode to avoid saturation on relatively long exposures and increase observing efficiency.

Visit orientation requirements have been defined to avoid spectra from nearby stars overlapping the target spectrum.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	WASP-121	RA: 07 10 24.0580 (107.6002417d)	Proper Motion RA: -2.993 mas/yr	V=10.51	Reference Frame: SIMBAD
		Dec: -39 05 50.55 (-39.09737d)	Proper Motion Dec: 25.086 mas/yr		
		Equinox: J2000	Epoch of Position: 2000		

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	Acquisition 1	(1) WASP-121	WFC3/IR, MULTIACCUM, GRISM256	F130N	NSAMP=3; SAMP-SEQ=RAPID	PHASE 0.340 TO 0.346	Sequence 1-2 Non-Int in WASP-121 WFC3 Eclipse 1 (01)	0.833445 Secs (0.833 Secs) *[==>]*	*[1]*
Comments: Phase-constrained									
2	Science 1 (WFC3IR.ss.1009660)	(1) WASP-121	WFC3/IR, MULTIACCUM, GRISM256	G102	NSAMP=15; SAMP-SEQ=SPARS10	POS TARG null,-6; SPATIAL SCAN 0.062,90.0 Degrees,Forward	Sequence 1-2 Non-Int in WASP-121 WFC3 Eclipse 1 (01)	103.128633 Secs X 14 (1443.801 Secs) *[==>(Copy 1)] [==>(Copy 2)] [==>(Copy 3)] [==>(Copy 4)] [==>(Copy 5)] [==>(Copy 6)] [==>(Copy 7)] [==>(Copy 8)] [==>(Copy 9)] [==>(Copy 10)] [==>(Copy 11)] [==>(Copy 12)] [==>(Copy 13)] [==>(Copy 14)]*	*[1]*
3	Science 2 (WFC3IR.ss.1009660)	(1) WASP-121	WFC3/IR, MULTIACCUM, GRISM256	G102	NSAMP=15; SAMP-SEQ=SPARS10	POS TARG null,-6; SPATIAL SCAN 0.062,90.0 Degrees,Forward	Sequence 3-3 Non-Int in WASP-121 WFC3 Eclipse 1 (01)	103.128633 Secs X 16 (1650.058 Secs) *[==>(Copy 1)] [==>(Copy 2)] [==>(Copy 3)] [==>(Copy 4)] [==>(Copy 5)] [==>(Copy 6)] [==>(Copy 7)] [==>(Copy 8)] [==>(Copy 9)] [==>(Copy 10)] [==>(Copy 11)] [==>(Copy 12)] [==>(Copy 13)] [==>(Copy 14)] [==>(Copy 15)] [==>(Copy 16)]*	*[2]*

4	Science 3 (WFC3IR.ss .1009660)	(1) WASP-121	WFC3/IR, MULTIACCUM, GRISM256	G102	NSAMP=15; SAMP-SEQ=SPARS10	POS TARG null,-6; SPATIAL SCAN 0.062,90.0 Degrees,Forward	Sequence 4-4 Non-Int in WASP-121 WFC3 Eclipse 1 (01)	103.128633 Secs X 16 (1650.058 Secs)	
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5	Science 4 (WFC3IR.ss .1009660)	(1) WASP-121	WFC3/IR, MULTIACCUM, GRISM256	G102	NSAMP=15; SAMP-SEQ=SPARS10	POS TARG null,-6; SPATIAL SCAN 0.062,90.0 Degrees,Forward	Sequence 5-5 Non-Int in WASP-121 WFC3 Eclipse 1 (01)	103.128633 Secs X 16 (1650.058 Secs)	
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	6	Science 5 (WFC3IR.ss .1009660)	(1) WASP-121	WFC3/IR, MULTIACCUM, GRISM256	G102	NSAMP=15; SAMP-SEQ=SPARS10	POS TARG null,-6; SPATIAL SCAN 0.062,90.0 Degrees,Forward	Sequence 6-6 Non-Int in WASP-121 WFC3 Eclipse 1 (01)	103.128633 Secs X 16 (1650.058 Secs)	
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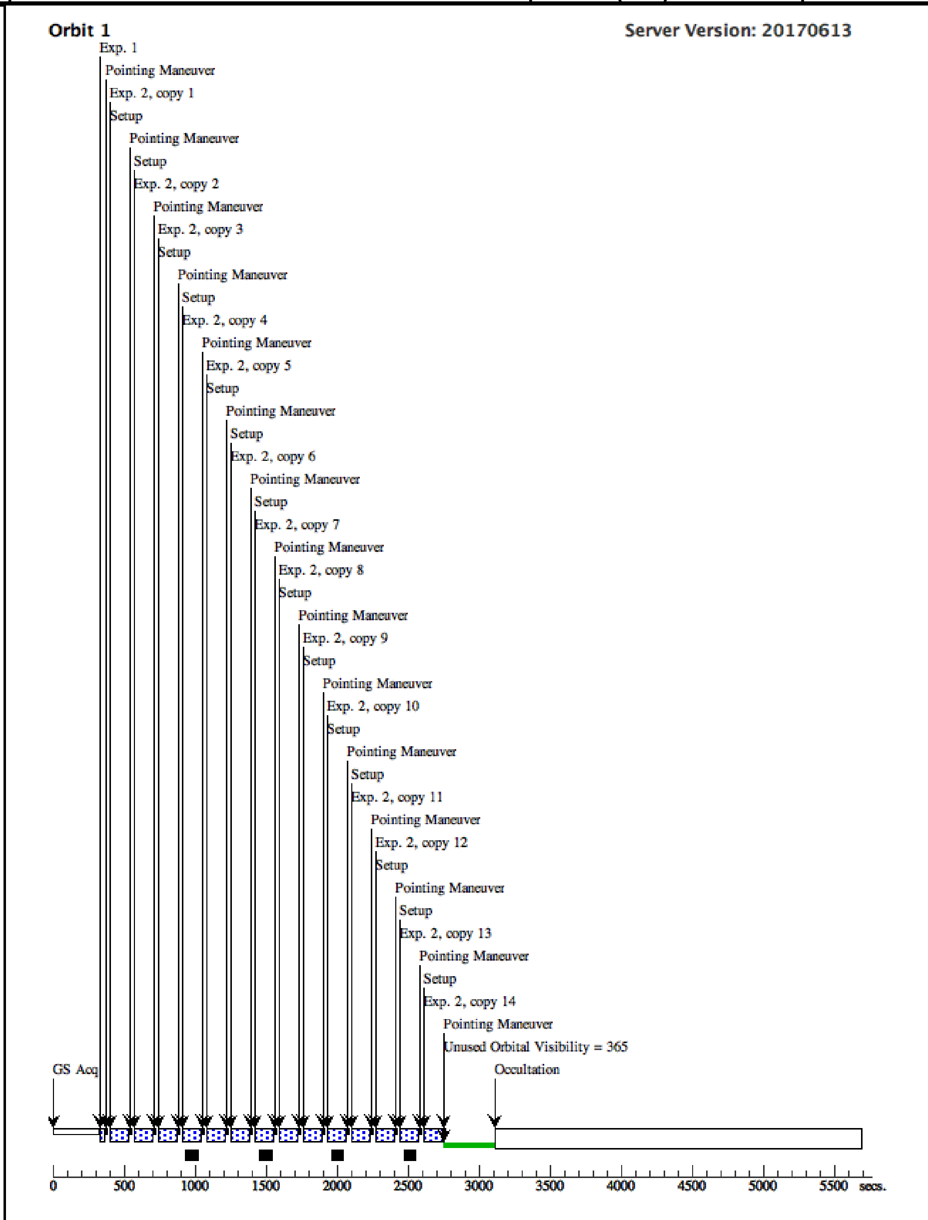

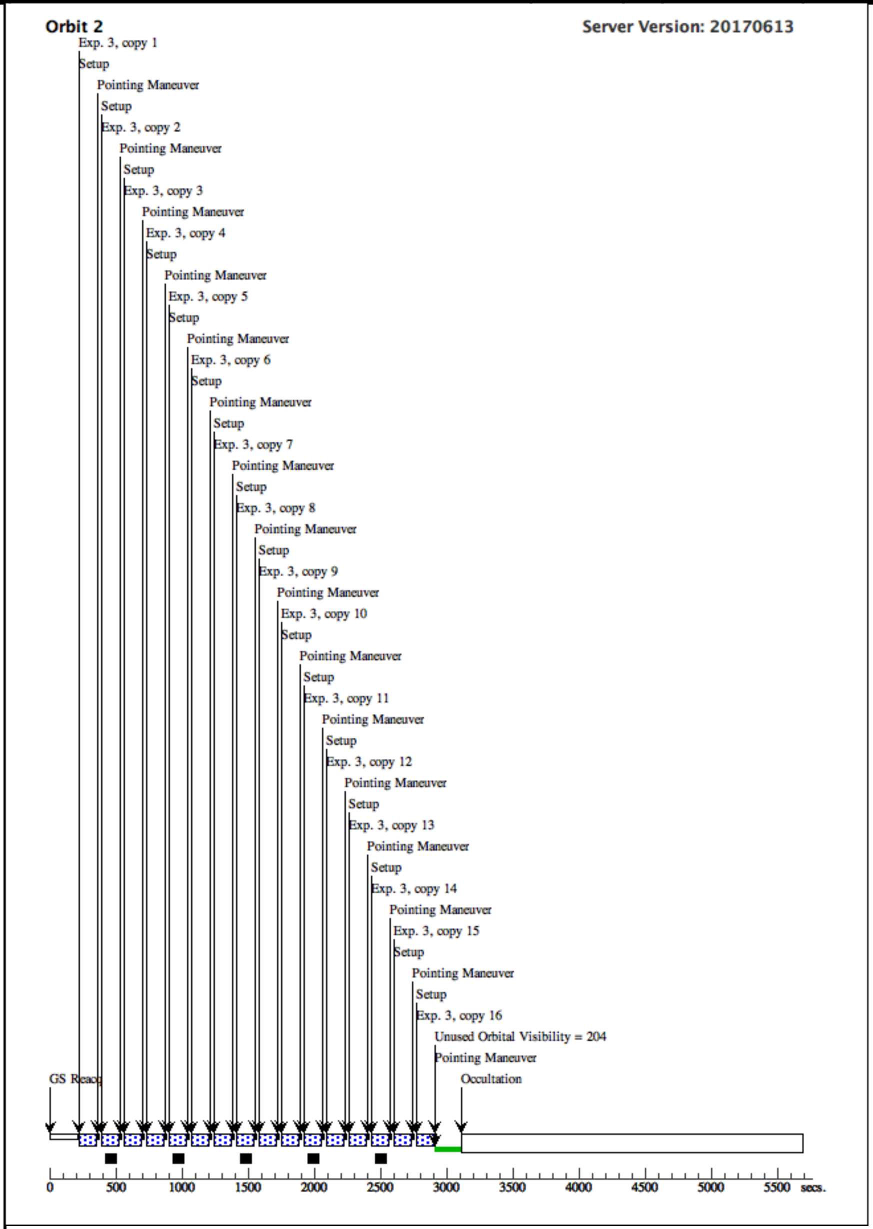
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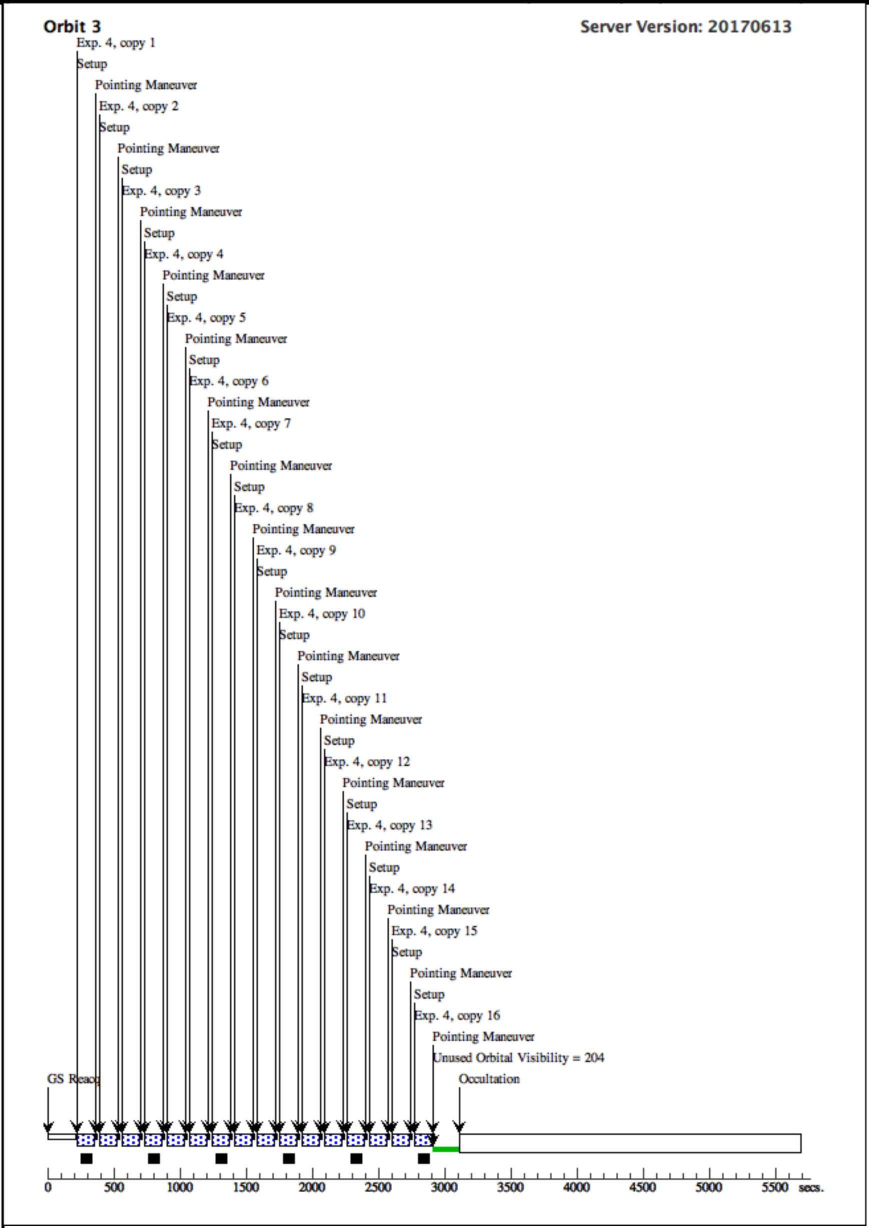
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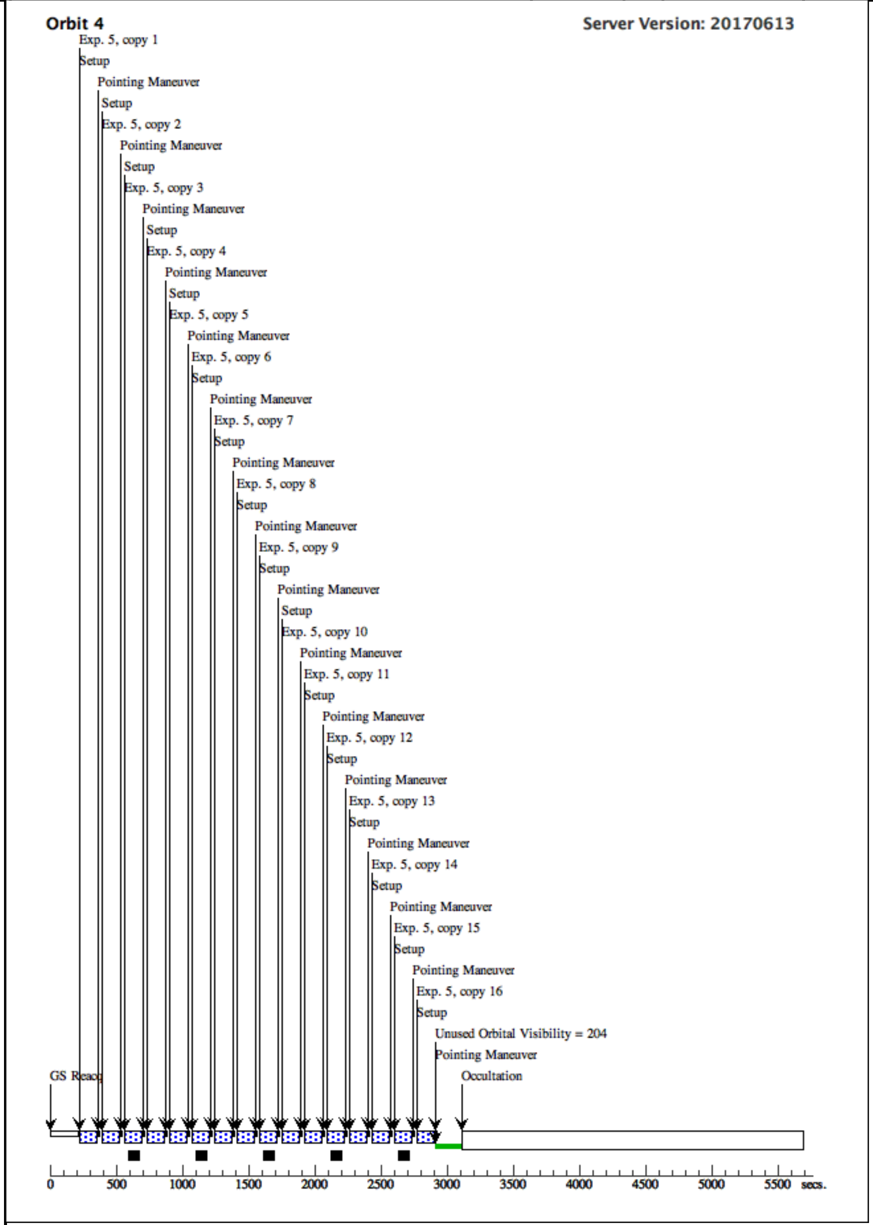
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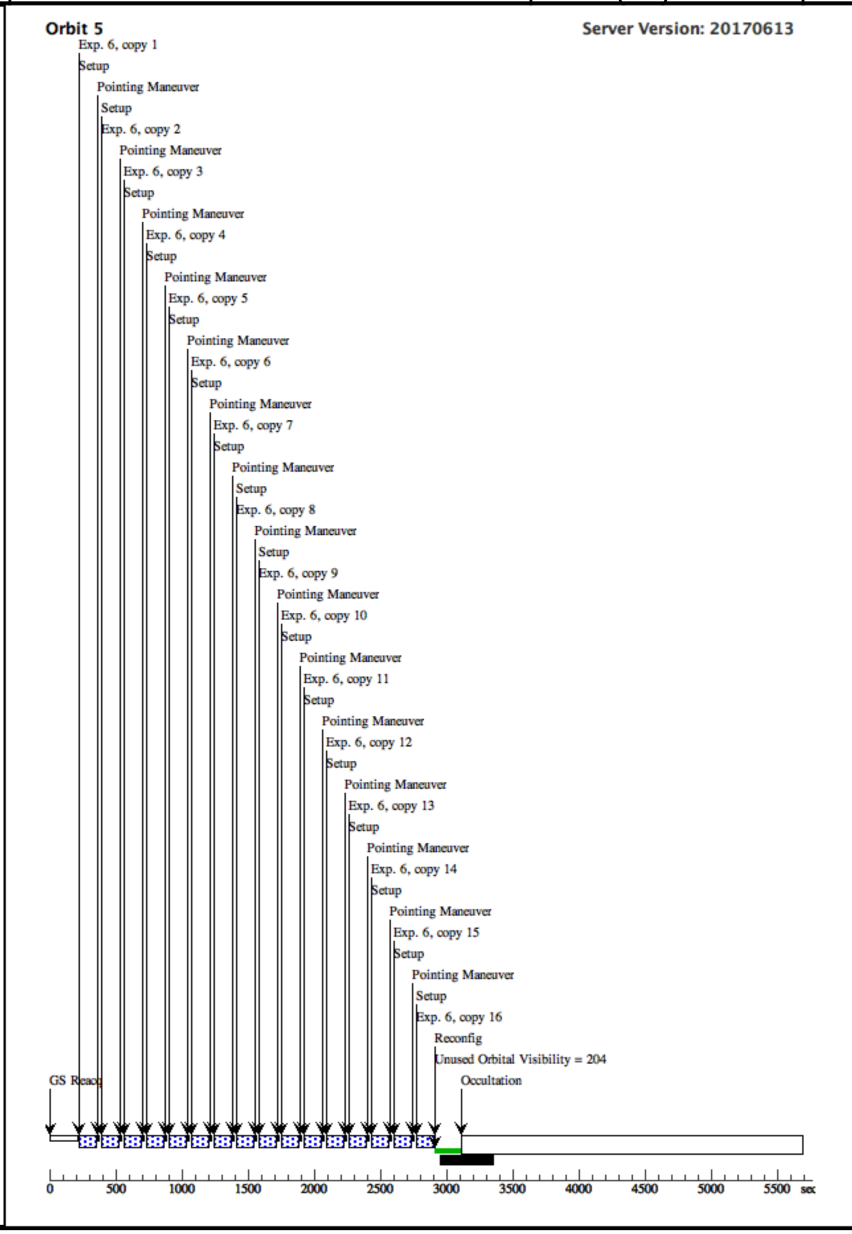
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Visit

Proposal 15135, WASP-121 WFC3 Eclipse 2 (02), completed Wed Nov 08 15:05:35 GMT 2017

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/IR

Special Requirements: SCHED 70%; ORIENT 25D TO 50 D; ORIENT 125D TO 140 D; ORIENT 310D TO 325 D; ORIENT 200D TO 220 D; Period 1.2749255 D AND ZERO-PHASE HJD2457702.82133

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We will use forward spatial scanning mode to avoid saturation on relatively long exposures and increase observing efficiency.

Visit orientation requirements have been defined to avoid spectra from nearby stars overlapping the target spectrum.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	WASP-121	RA: 07 10 24.0580 (107.6002417d)	Proper Motion RA: -2.993 mas/yr	V=10.51	Reference Frame: SIMBAD
		Dec: -39 05 50.55 (-39.09737d)	Proper Motion Dec: 25.086 mas/yr		
		Equinox: J2000	Epoch of Position: 2000		

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	Acquisition 1	(1) WASP-121	WFC3/IR, MULTIACCUM, GRISM256	F130N	NSAMP=3; SAMP-SEQ=RAPID	PHASE 0.363 TO 0.369	Sequence 1-2 Non-Int in WASP-121 WFC3 Eclipse 2 (02)	0.833445 Secs (0.833 Secs) *[==>]*	*[1]*
Comments: *Phase-constrained*									
2	Science 1 (WFC3IR.ss.1009660)	(1) WASP-121	WFC3/IR, MULTIACCUM, GRISM256	G102	NSAMP=15; SAMP-SEQ=SPARS10	POS TARG null,-6; SPATIAL SCAN 0.062,90.0 Degrees,Forward	Sequence 1-2 Non-Int in WASP-121 WFC3 Eclipse 2 (02)	103.128633 Secs X 14 (1443.801 Secs) *[==>(Copy 1)]* *[==>(Copy 2)]* *[==>(Copy 3)]* *[==>(Copy 4)]* *[==>(Copy 5)]* *[==>(Copy 6)]* *[==>(Copy 7)]* *[==>(Copy 8)]* *[==>(Copy 9)]* *[==>(Copy 10)]* *[==>(Copy 11)]* *[==>(Copy 12)]* *[==>(Copy 13)]* *[==>(Copy 14)]*	*[1]*
3	Science 2 (WFC3IR.ss.1009660)	(1) WASP-121	WFC3/IR, MULTIACCUM, GRISM256	G102	NSAMP=15; SAMP-SEQ=SPARS10	POS TARG null,-6; SPATIAL SCAN 0.062,90.0 Degrees,Forward	Sequence 3-3 Non-Int in WASP-121 WFC3 Eclipse 2 (02)	103.128633 Secs X 16 (1650.058 Secs) *[==>(Copy 1)]* *[==>(Copy 2)]* *[==>(Copy 3)]* *[==>(Copy 4)]* *[==>(Copy 5)]* *[==>(Copy 6)]* *[==>(Copy 7)]* *[==>(Copy 8)]* *[==>(Copy 9)]* *[==>(Copy 10)]* *[==>(Copy 11)]* *[==>(Copy 12)]* *[==>(Copy 13)]* *[==>(Copy 14)]* *[==>(Copy 15)]* *[==>(Copy 16)]*	*[2]*

4	Science 3 (WFC3IR.ss .1009660)	(1) WASP-121	WFC3/IR, MULTIACCUM, GRISM256	G102	NSAMP=15; SAMP-SEQ=SPARS10	POS TARG null,-6; SPATIAL SCAN 0.062,90.0 Degrees,Forward	Sequence 4-4 Non-Int in WASP-121 WFC3 Eclipse 2 (02)	103.128633 Secs X 16 (1650.058 Secs)	
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5	Science 4 (WFC3IR.ss .1009660)	(1) WASP-121	WFC3/IR, MULTIACCUM, GRISM256	G102	NSAMP=15; SAMP-SEQ=SPARS10	POS TARG null,-6; SPATIAL SCAN 0.062,90.0 Degrees,Forward	Sequence 5-5 Non-Int in WASP-121 WFC3 Eclipse 2 (02)	103.128633 Secs X 16 (1650.058 Secs)	
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	6	Science 5 (WFC3IR.ss .1009660)	(1) WASP-121	WFC3/IR, MULTIACCUM, GRISM256	G102	NSAMP=15; SAMP-SEQ=SPARS10	POS TARG null,-6; SPATIAL SCAN 0.062,90.0 Degrees,Forward	Sequence 6-6 Non-Int in WASP-121 WFC3 Eclipse 2 (02)	103.128633 Secs X 16 (1650.058 Secs)	
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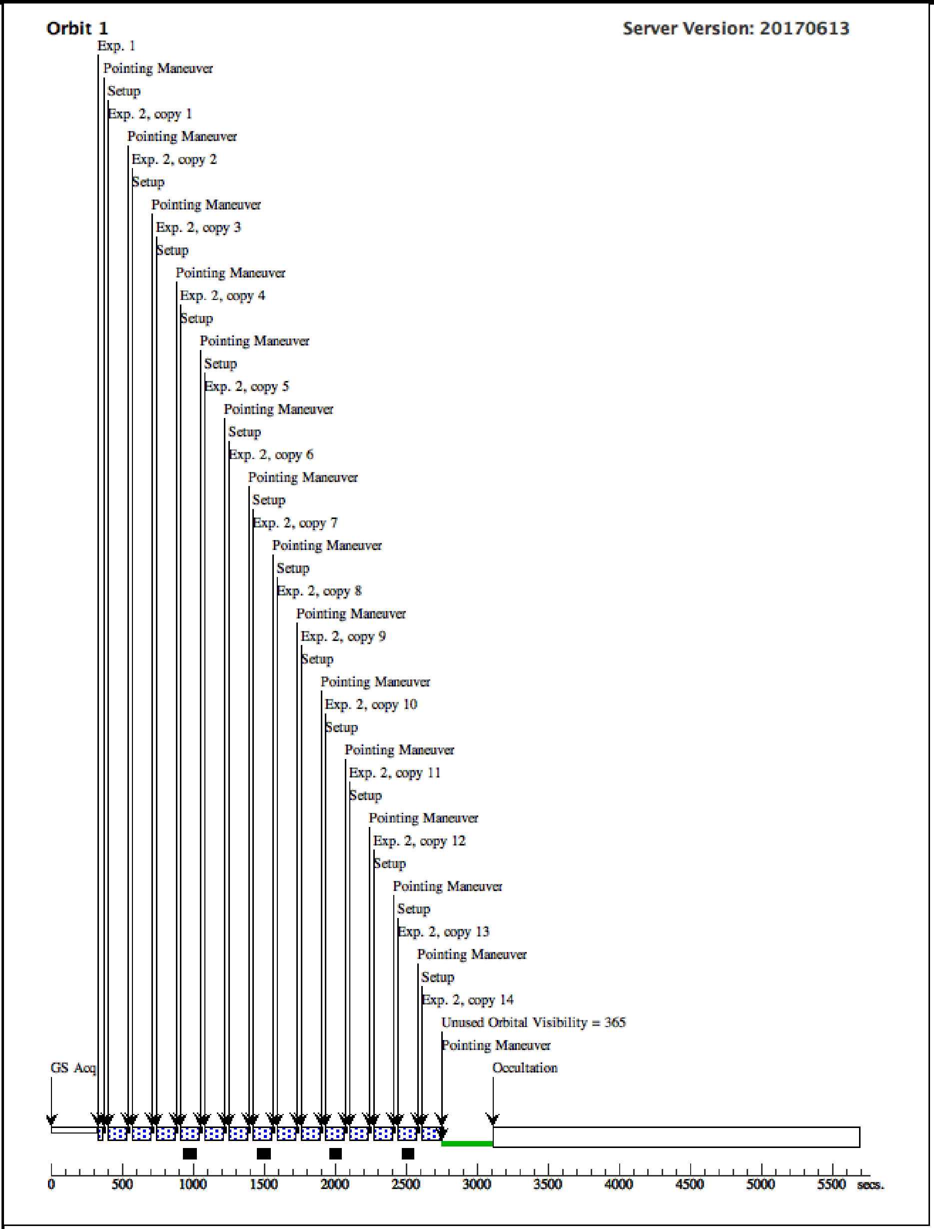
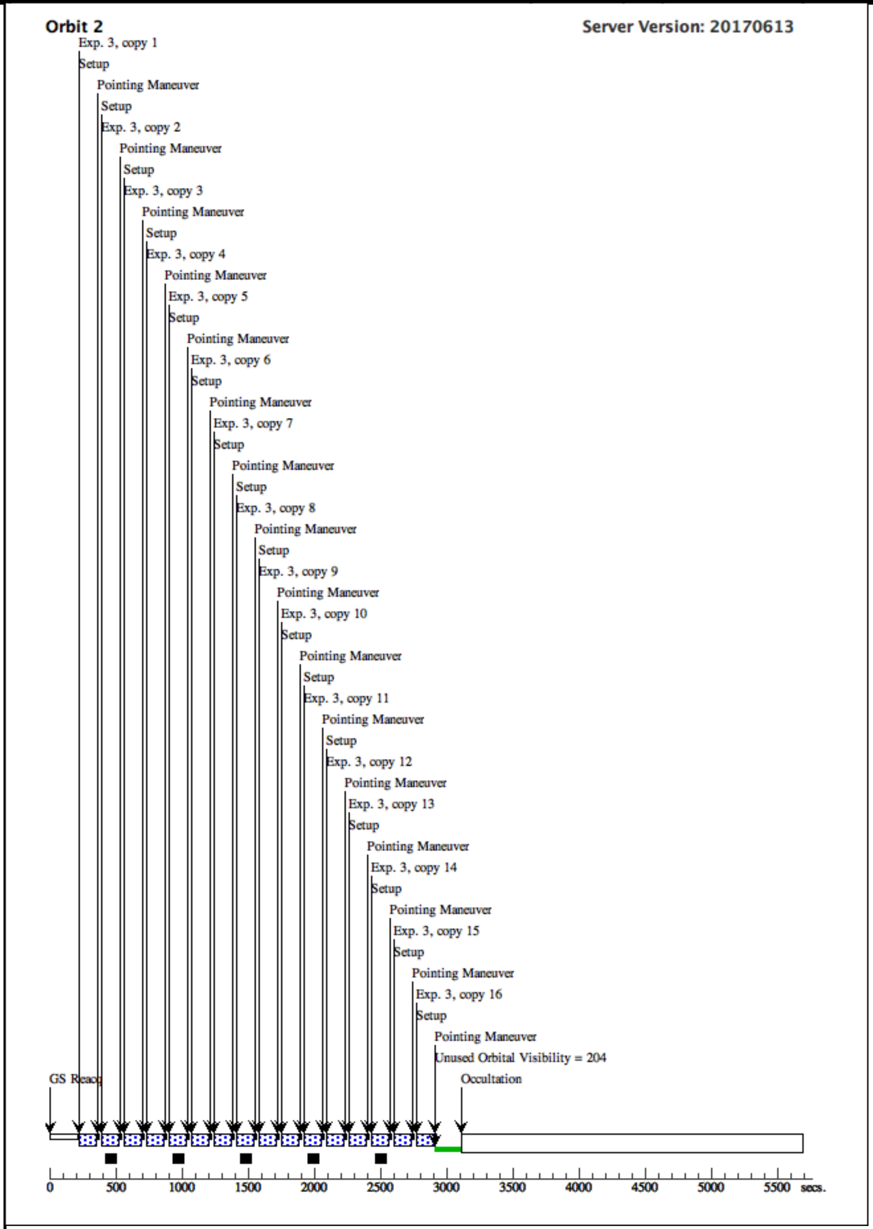
Orbit Structure

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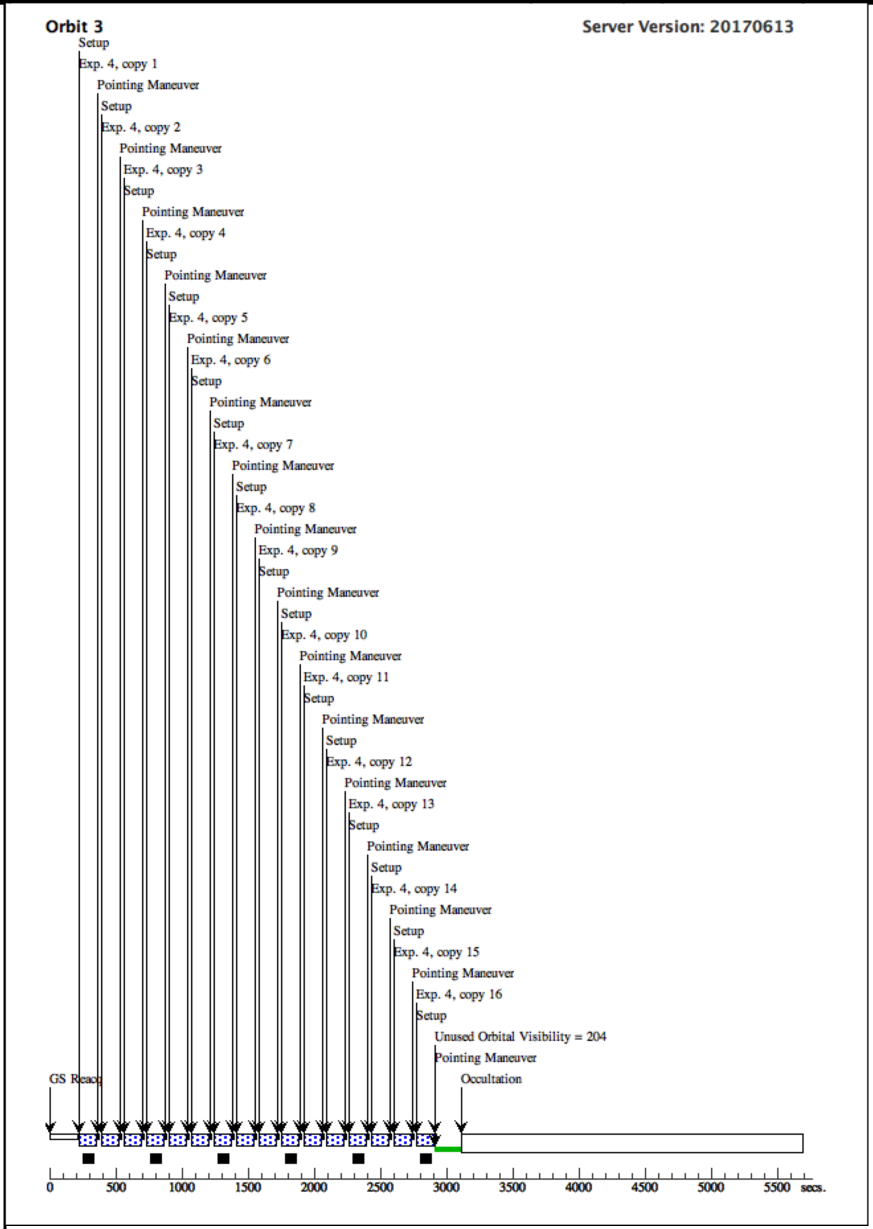
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1500
2000
2500
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3500
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4500
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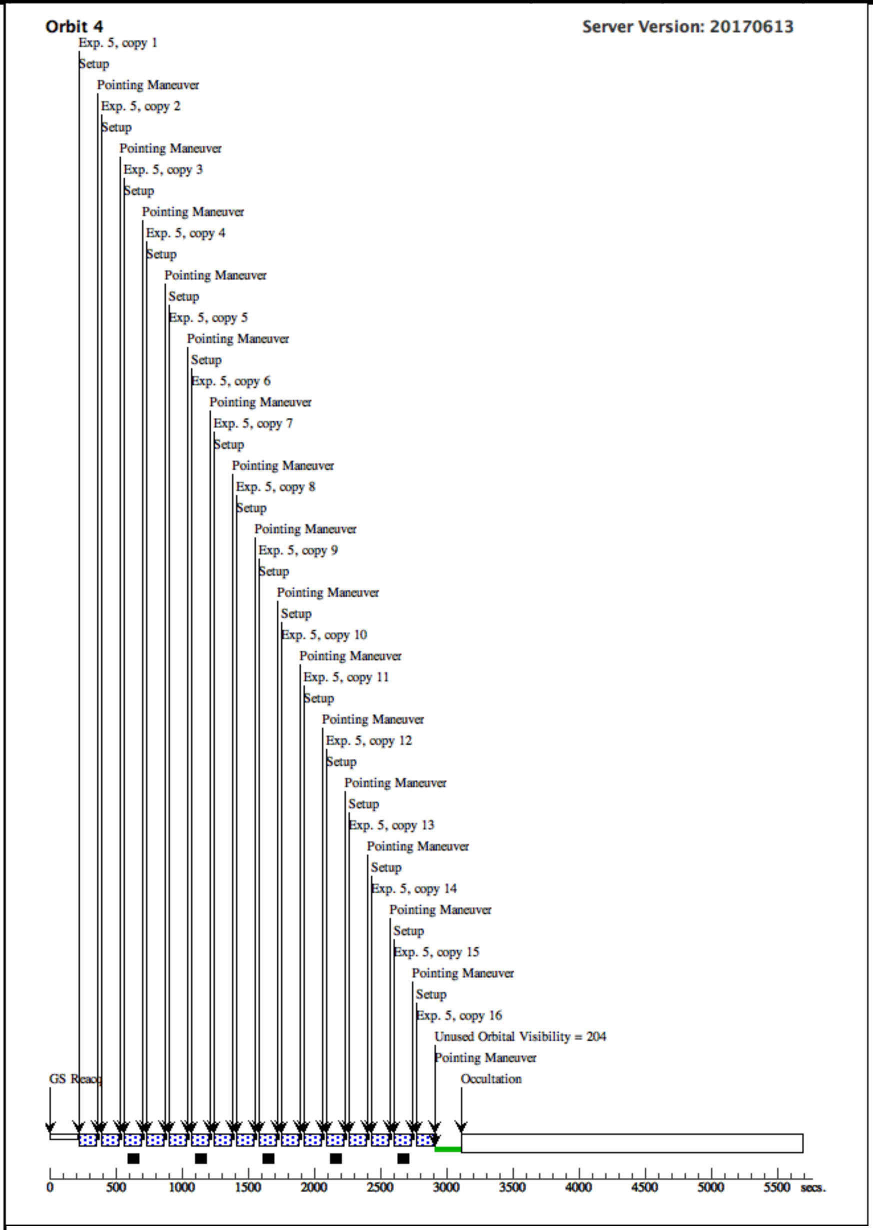
secs.


Orbit 4
Server Version: 20170613
Exp. 5, copy 1
Setup
Pointing Maneuver
Exp. 5, copy 2
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Exp. 5, copy 3
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Exp. 5, copy 5
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Exp. 5, copy 12
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Exp. 5, copy 13
Pointing Maneuver
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Exp. 5, copy 14
Pointing Maneuver
Setup
Exp. 5, copy 15
Pointing Maneuver
Setup
Exp. 5, copy 16
Unused Orbital Visibility = 204
Pointing Maneuver
Occultation
GS Reacq
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
secs.

Proposal 15135 - WASP-121 WFC3 Eclipse 2 (02) - An exoplanet with a stratosphere: seeking the unknown absorber