15833 - Recurrent Nova M31N 2008-12a: Neon and Jets - Determining the ultimate fate of a Chandrasekhar mass white dwarf

Cycle: 27, 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) M31N-2008-12A (2) AQUSTAR	STIS/CCD STIS/FUV-MAMA	3	25-Jul-2019 07:00:29.0	yes

Visit	*Targets used in Visit*	*Configurations used in Visit*	*Orbits Used*	*Last Orbit Planner Run*	*OP Current with Visit?*
02	(1) M31N-2008-12A (2) AQUSTAR	STIS/CCD STIS/FUV-MAMA	4	25-Jul-2019 07:00:31.0	yes
03	(1) M31N-2008-12A (2) AQUSTAR	STIS/CCD STIS/FUV-MAMA	5	25-Jul-2019 07:00:33.0	yes
04	(1) M31N-2008-12A (2) AQUSTAR	STIS/CCD STIS/FUV-MAMA	5	25-Jul-2019 07:00:35.0	yes

17 Total Orbits Used

ABSTRACT

M31N 2008-12a is the single most important nova system now known. With its one-year recurrence period, high-mass white dwarf, high mass accretion rate, low peak optical luminosity, and low ejecta mass, this system is the leading pre-explosion Supernova Type Ia single-degenerate candidate. The rapid decline from optical peak and the distance of M31 necessitate a request for disruptive target of opportunity observations. We propose a series of early eruption FUV spectroscopic observations to study the evolution of the composition of the ejecta, including probing the underlying composition of the white dwarf, CO vs. ONe, which is key to the ultimate fate of this system (SN Ia vs. accretion-induced collapse). A single Cycle 23 FUV spectrum taken just 3 days post-eruption found no evidence for neon, but the lack of other similarly high ionization lines suggests Ne lines may develop later in the evolution. That spectrum also presented evidence of a highly collimated - jet-like - ejecta. This new FUV series will take place on day 4, 5, 6, and 7, post-eruption, and will definitively explore the presense of Ne in the ejecta, provide key ejecta abundance information, and they will also probe the nature of the proposed outflows. The regularity of eruptions of M31N 2008-12a are unprecedented and this is the only thermonuclear nova system where we can accurately predict eruptions. The unique FUV capabilities of HST therefore allow us to study the physics of this vitally important system even at the great distance of M31, providing invaluable information about the ultimate fate of this remarkable system.

OBSERVING DESCRIPTION

STIS Spectroscopy: The spectroscopic observations proposed here are to obtain a series of four FUV eruption spectra of the recurrent nova M31N 2008-12a, with the science goals of confirming the ejecta abundances (absolutely ruling out Ne), computing ejecta abundances and their evolution with time, exploring continuum emission mechanisms, and exploring the ejecta morphology and its evolution. As such, the proposed observations require a good signal-to-noise ratio (SNR) in both the continuum and expected emission lines.

By employing STIS FUV MAMA G140L (1150-1737 Angstrom) grating utilising the 52" x 0.2" slit, we obtain coverage of the majority of the FUV regime, which is required, for e.g., to maximise the available lines for abundance calculations and to determine the continuum level. The 0.2" slit width provides a good compromise between resolution and throughput, allowing accurate absorption line measurements in the continuum. Additionally, the low-resolution grating selected generally provides the best throughput across the entire wavelength range.

MAMA safety: We can confirm that, based on the expected luminosity of 12a (even at peak luminosity as seen in the eleven previous eruptions), we do not approach the bright object limits for the STIS MAMA detectors. We have not identified any bright sources within the nearby field that are expected to cause problems with the observation (all UV sources within the field are fainter than the peak luminosity of the nova). The past FUV and NUV spectra (with identical setup), and NUV imaging, of this object also confirms this.

STIS target acquisition: The area around 12a is relatively uncrowded in the U-band and NUV, and even at the quiescence luminosity of 12a, the nearest brighter source is 3.5" away. As such, we intend to employ the STIS acquisition and peakup (ACQ / PEAK) to acquire and centre the target on the slit. We envisage no issues in acquiring 12a for STIS spectroscopy, and again note past successful acquisition of 12a by STIS.

Exposure time calculations: The SEDs from the 2013 - 2015 eruptions and the existing NUV spectrum indicates an optically thick free-free emission spectrum; we have based our continuum exposure time calculations upon such a spectrum, normalised to the Swift UVOT/UVW1 photometry at day 4, 5, 6, and 7 (m = 19;+1 mag/day) post-eruption. We also note that this is a conservative approach, as the light curves (UV included) enter a plateau-like phase at around day 4 post-eruption. We have also included a number of expected FUV emission lines in our exposure time calculations, N V, Si IV, and C IV. The lines fluxes and widths used are taken directly from the 2015 FUV spectrum of 12a, and the expected fluxes are reduced in line with the continuum as the eruption proceeds. Throughout our exposure time simulations, we have assumed a line-of-sight reddening towards 12a of E(B-V) = 0.1.

Based on the estimated orbital visibility (49 mins to maximise flexibility) and the above simulations, we require three, four, five, and five HST orbits for the first, second, third, and fourth visits, respectively (to account for the waning flux). The equates to exposure times of 7,087s, 9686s, 12,285s, and 12,285s for the four visits to allow us to achieve suitable SNRs for the continuum and selected emission lines.

STIS Dithering: In order to remove detector defect and hot pixels a 3, 4, and 5 point STIS-ALONG-SLIT dither pattern has been applied to the 1st, 2nd, and last two epochs of FUV observations respectively. The dither patterns have been created using a 7 pixel point spacing in epoch 1, 5.24 in

epoch 2, and 4.2 in the last two epochs to allow for an improved spatial resolution.

STIS TIME-TAG MODE: Using the ETC and expected values for the peak luminosity of the nova we have determined a total global count rate significantly below 20,000 c/s. We therefore wish to observe in the Time-tag mode for archival purposes and preservation of data. Buffer time for this mode has been calculated as 1/2 the exposure time for each observation.

Scheduling: We request scheduability of 100%. As we do not exactly know when this object will go off we require as large a visit window as possible. It is thought that the nova may erupt in as early as November 2019. We have adjusted our exposure times accordingly to take account of the shortest orbital visibility needed to obtain 100% scheduability (approximately a five minute reduction per orbit from the numbers stated in the Phase I case).

Due to the distance to M31N2008-12a, its intrinsic low peak luminosity, and rapid decline, the target is only accessible (feasible) for STIS spectroscopy for up to a week post-discovery. As such a Disruptive Target of Opportunity (dToO) status is required to achieve these science goals. With the lead-in time for a dToO typically 4 to 5 days, and the expected discovery at least one day pre-maximum, we have a 4 to 6 day window to obtain the four STIS FUV spectra (planned for days 4, 5, 6, and 7 post-eruption). As such a ToO of 3 days has been requested.

Visit

Proposal 15833, UV Spec T0 G140L (01) Thu Jul 25 11:00:36 GMT 2019

Diagnostic Status: No Diagnostics

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

Special Requirements: SCHED 100%; ORIENT 232D TO 28 D; ORIENT 47D TO 204 D; ON HOLD ; TOO RESPONSE TIME 3.0D

On Hold Comments: The dToO lead-in time is aproximatly 5 days, but we will detect the 2019 eruption at least 1 day before peak, so we will first observe 12a when the FUV light curve has decayed to 19 to 20 mag (AB system). The dToO lead-in time and the nova decay rate opens a small, 4 to 6 day, window (3 to7days post-eruption) during which FUV spectroscopy of this unique system is feasible. We therfore request a 3 day ToO.

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(2)	Pattern Type=STIS-ALONG-SLIT	Coordinate Frame=POS-TARG		(2)
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	Line Spacing=			

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	M31N-2008-12A	RA: 00 45 28.8200 (11.3700833d) Dec: +41 54 10.10 (41.90281d) Equinox: J2000		V=20.8+/-0.1 Maximum magnitudes obtained by this system within observing window (day 3 onwards): Sloan i'=20.8+/-0.1, Sloan r'=20.4+/-0.1, B=21.0+/-0.1, U=19.2+/-0.5	Reference Frame: ICRS
Comments: *Category=STAR* *Description=[INTERACTING BINARY, RECURRENT NOVA]*					
(2)	AQUSTAR	RA: 00 45 28.5265 (11.3688604d) Dec: +41 54 51.86 (41.91441d) Equinox: J2000	Epoch of Position: 1986.91	V=18.349+/-0.45	Reference Frame: ICRS
Comments: *Category=CALIBRATION* *Description=[APERTURE LOCATION]* *Extended=NO*					

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	AQUIRE TARGET	(2) AQUSTAR	STIS/CCD, ACQ, F28X50LP	MIRROR				30 Secs (30 Secs)	
								[==>]	***[1]***
2	Speactra G140L (STIS.sp.733005)	(1) M31N-2008-12A	STIS/FUV-MAMA, TIME-TAG, 52X0.2D1	G140L 1425 A	BUFFER-TIME=1812		Pattern 2, Exps 2-2 in UV Spec T0 G140L (01) (2)	2000 Secs (7087 Secs)	
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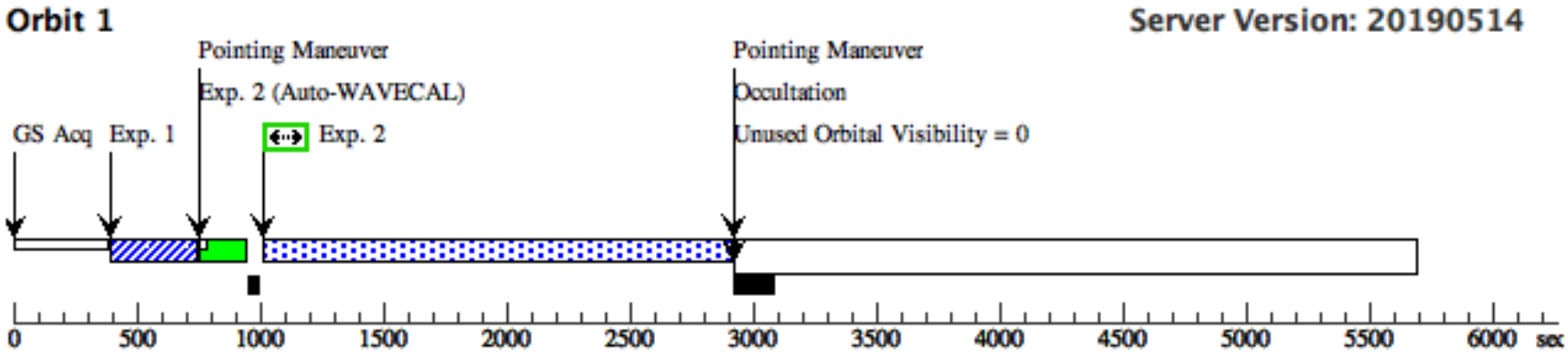
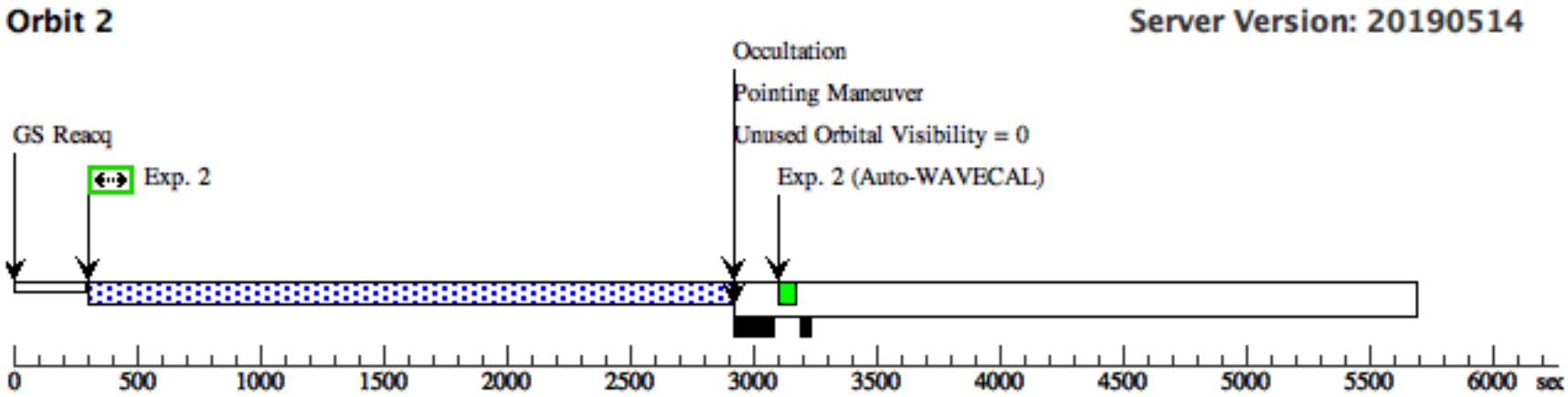
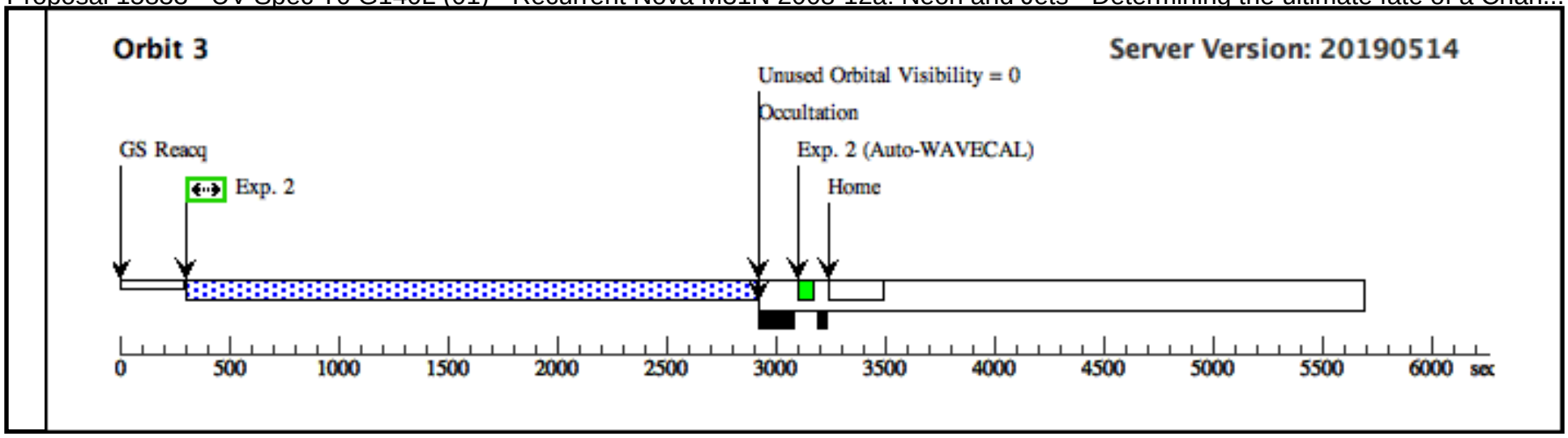
								[==>2599.0 Secs (Pattern 2)]	***[2]***
								[==>2599.0 Secs (Pattern 3)]	***[3]***

Orbit Structure



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Visit

Proposal 15833, UV Spec T0 G140L (02) Thu Jul 25 11:00:36 GMT 2019

Diagnostic Status: No Diagnostics

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

Special Requirements: SCHED 100%; ORIENT 232D TO 28 D; ORIENT 47D TO 204 D; AFTER 01 BY 0.75 D TO 1.25 D

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=STIS-ALONG-SLIT	Coordinate Frame=POS-TARG		(2)
	Purpose=DITHER	Pattern Orientation=90.0		
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	Point Spacing=0.131	Center Pattern=false		
	Line Spacing=			

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	M31N-2008-12A	RA: 00 45 28.8200 (11.3700833d) Dec: +41 54 10.10 (41.90281d) Equinox: J2000		V=20.8+/-0.1 Maximum magnitudes obtained by this system within observing window (day 3 onwards): Sloan i'=20.8+/-0.1, Sloan r'=20.4+/-0.1, B=21.0+/-0.1, U=19.2+/-0.5	Reference Frame: ICRS
Comments: *Category=STAR* *Description=[INTERACTING BINARY, RECURRENT NOVA]*					
(2)	AQUSTAR	RA: 00 45 28.5265 (11.3688604d) Dec: +41 54 51.86 (41.91441d) Equinox: J2000	Epoch of Position: 1986.91	V=18.349+/-0.45	Reference Frame: ICRS
Comments: *Category=CALIBRATION* *Description=[APERTURE LOCATION]* *Extended=NO*					

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	AQUIRE TARGET	(2) AQUSTAR	STIS/CCD, ACQ, F28X50LP	MIRROR				30 Secs (30 Secs)	
								[==>]	***[1]***
2	Speactra G140L (STIS.sp.733005)	(1) M31N-2008-12A	STIS/FUV-MAMA, TIME-TAG, 52X0.2D1	G140L 1425 A	BUFFER-TIME=1211		Pattern 1, Exps 2-2 in UV Spec T0 G140L (02) (1)	2000 Secs (9686 Secs)	
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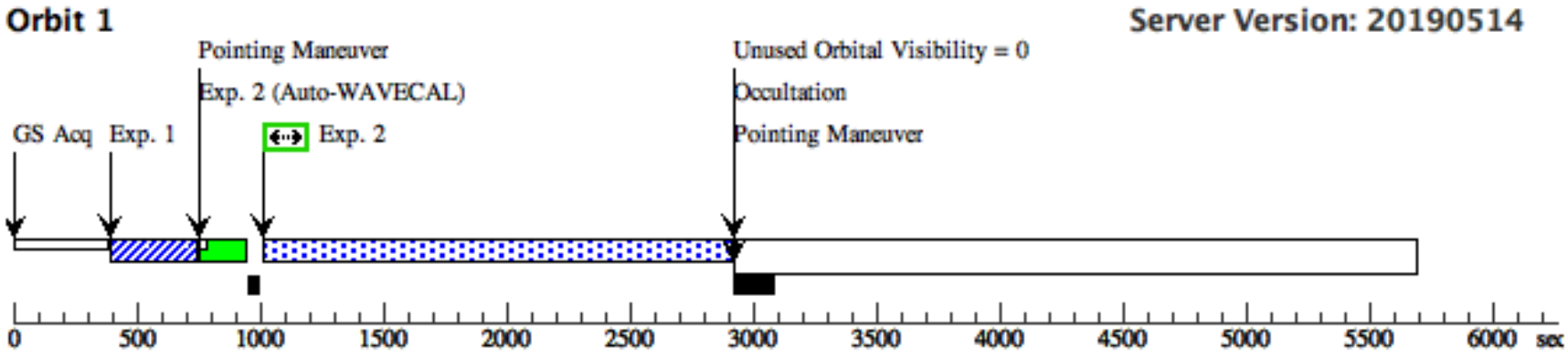
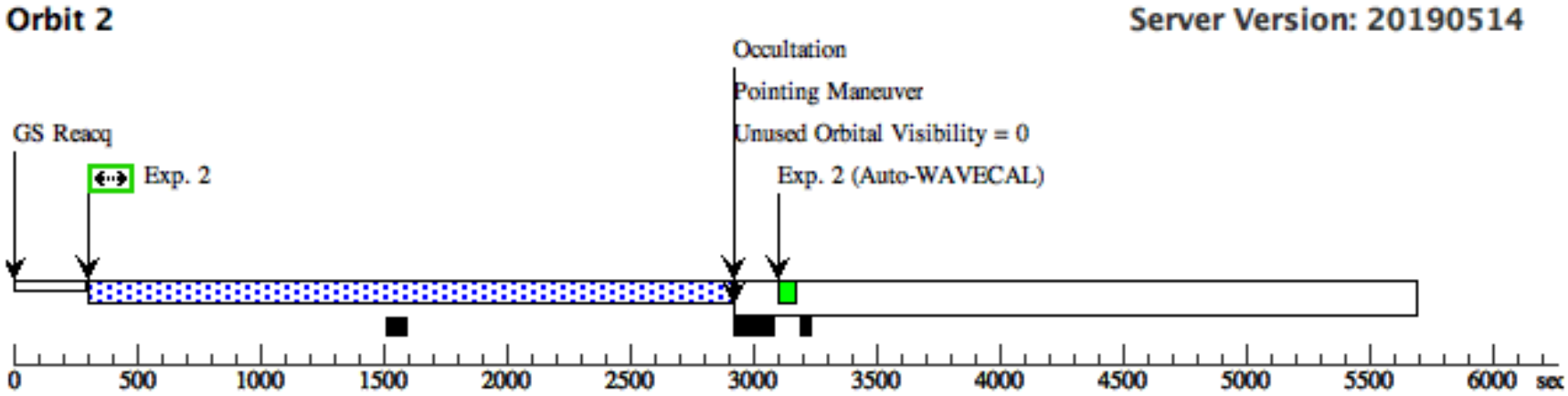
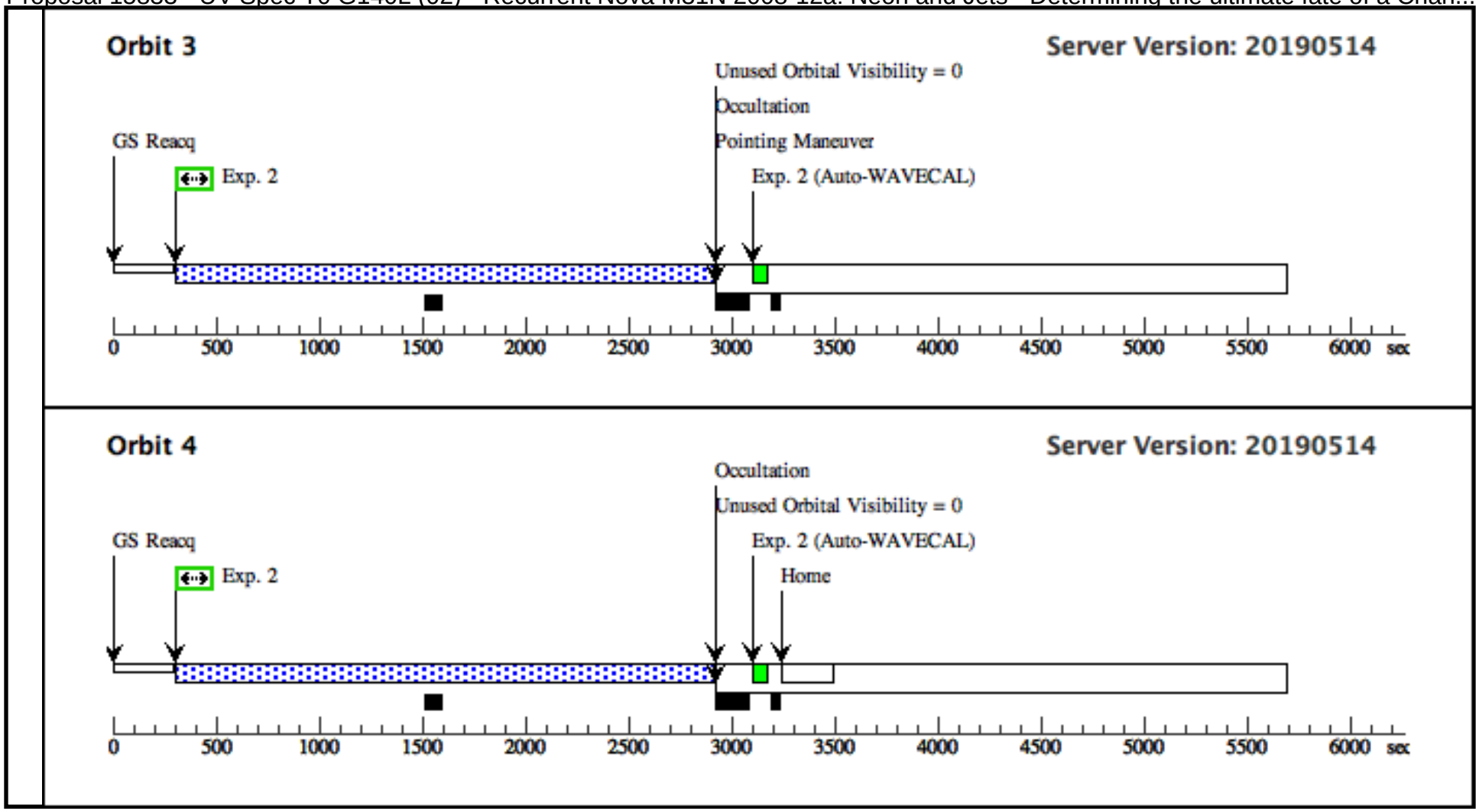
								[==>2599.0 Secs (Pattern 2)]	***[2]***
								[==>2599.0 Secs (Pattern 3)]	***[3]***
								[==>2599.0 Secs (Pattern 4)]	***[4]***

Orbit Structure



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Orbit 4
Server Version: 20190514
Occultation
Unused Orbital Visibility = 0
GS Reacq
Exp. 2
Exp. 2 (Auto-WAVECAL)
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Visit

Proposal 15833, UV Spec T0 G140L (03) Thu Jul 25 11:00:36 GMT 2019

Diagnostic Status: No Diagnostics

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

Special Requirements: SCHED 100%; ORIENT 232D TO 28 D; ORIENT 47D TO 204 D; AFTER 01 BY 1.75 D TO 2.25 D

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(3)	Pattern Type=STIS-ALONG-SLIT	Coordinate Frame=POS-TARG		(2)
	Purpose=DITHER	Pattern Orientation=90.0		
	Number Of Points=5	Angle Between Sides=		
	Point Spacing=0.105	Center Pattern=false		
	Line Spacing=			

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	M31N-2008-12A	RA: 00 45 28.8200 (11.3700833d) Dec: +41 54 10.10 (41.90281d) Equinox: J2000		V=20.8+/-0.1 Maximum magnitudes obtained by this system within observing window (day 3 onwards): Sloan i'=20.8+/-0.1, Sloan r'=20.4+/-0.1, B=21.0+/-0.1, U=19.2+/-0.5	Reference Frame: ICRS
Comments: *Category=STAR* *Description=[INTERACTING BINARY, RECURRENT NOVA]*					
(2)	AQUSTAR	RA: 00 45 28.5265 (11.3688604d) Dec: +41 54 51.86 (41.91441d) Equinox: J2000	Epoch of Position: 1986.91	V=18.349+/-0.45	Reference Frame: ICRS
Comments: *Category=CALIBRATION* *Description=[APERTURE LOCATION]* *Extended=NO*					

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	AQUIRE TARGET	(2) AQUSTAR	STIS/CCD, ACQ, F28X50LP	MIRROR				30 Secs (30 Secs)	
								[==>]	***[1]***
2	Speactra G140L (STIS.sp.733005)	(1) M31N-2008-12A	STIS/FUV-MAMA, TIME-TAG, 52X0.2D1	G140L 1425 A	BUFFER-TIME=1229		Pattern 3, Exps 2-2 in UV Spec T0 G140L (03) (3)	2000 Secs (12285 Secs)	
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								[==>2599.0 Secs (Pattern 2)]	***[2]***
								[==>2599.0 Secs (Pattern 3)]	***[3]***
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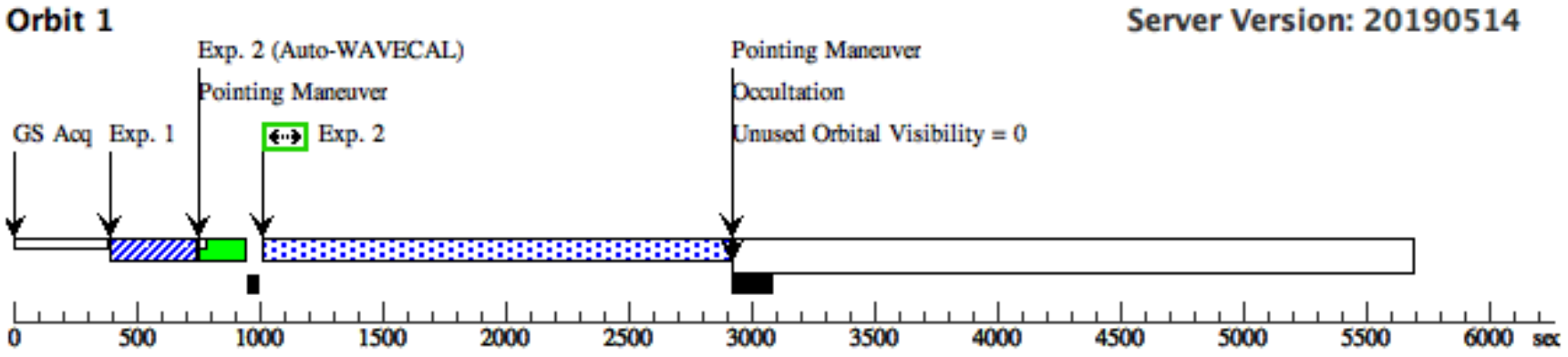
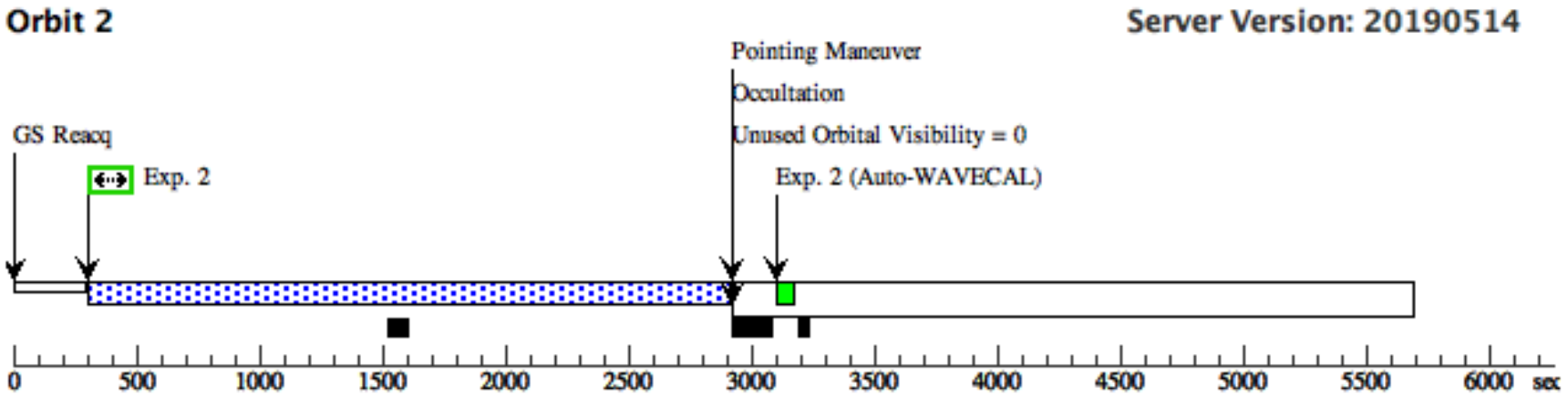
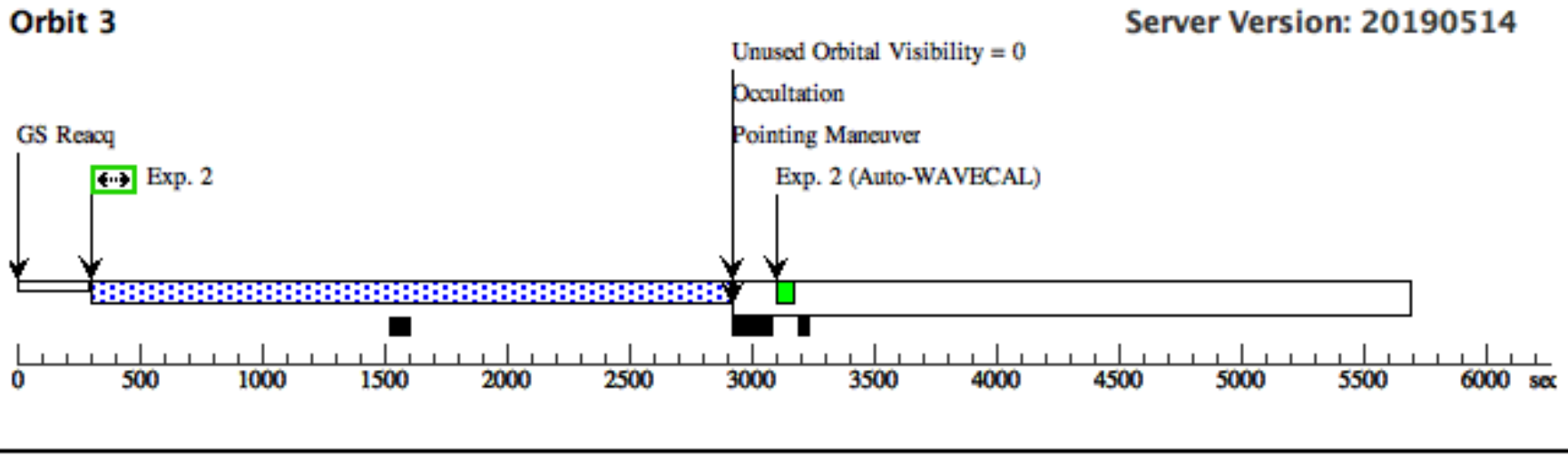
Orbit Structure



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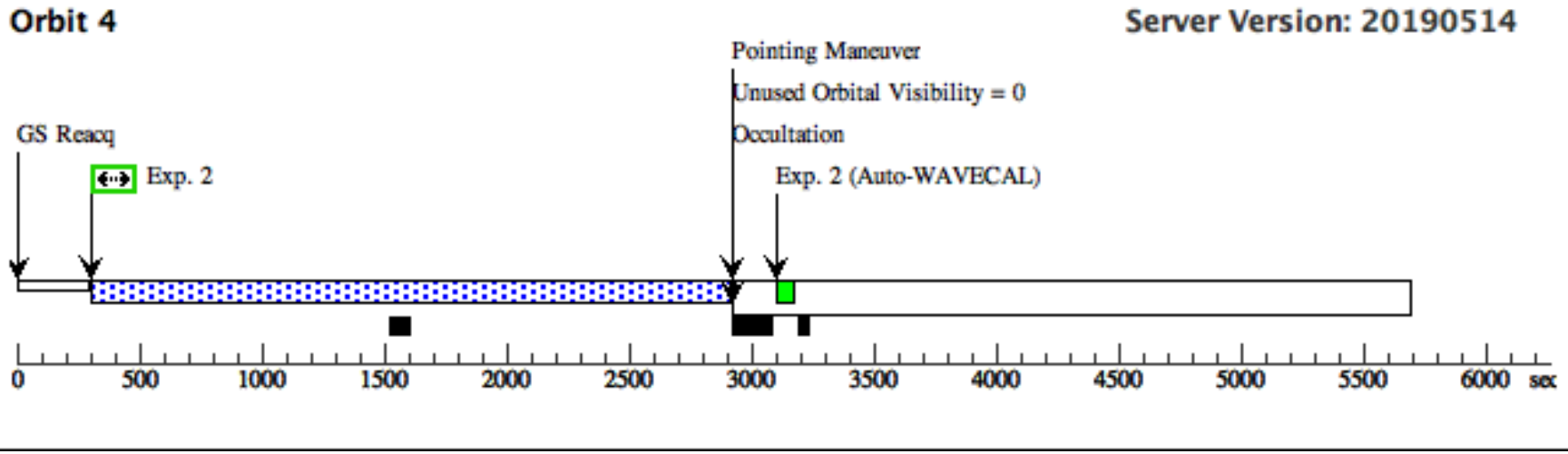
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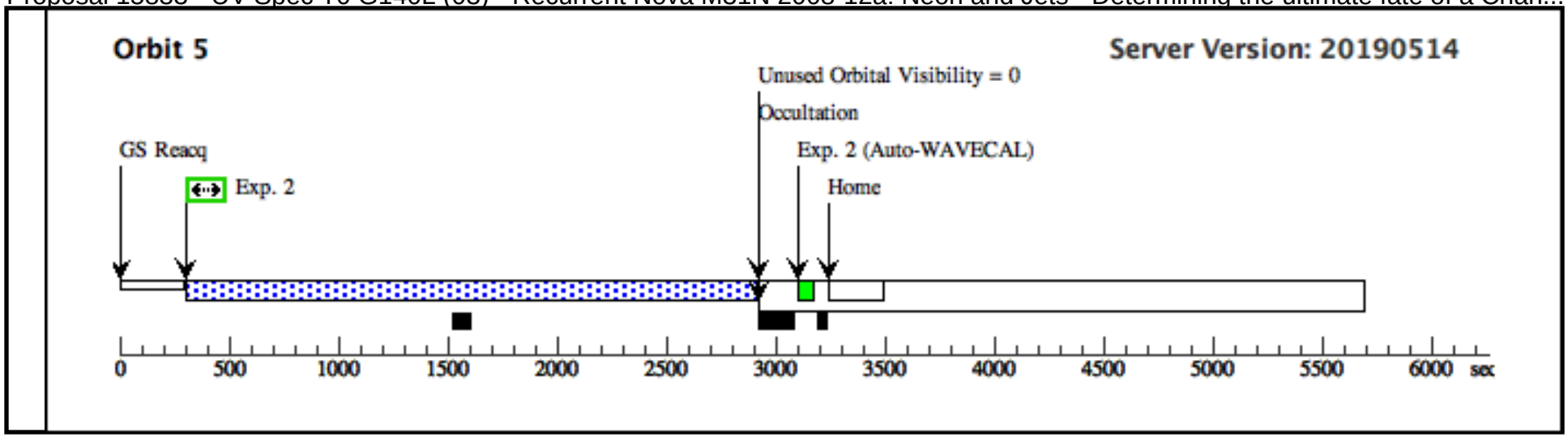
Orbit 5
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Visit

Proposal 15833, UV Spec T0 G140L (04) Thu Jul 25 11:00:37 GMT 2019

Diagnostic Status: No Diagnostics

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

Special Requirements: SCHED 100%; ORIENT 232D TO 28 D; ORIENT 47D TO 204 D; AFTER 01 BY 2.75 D TO 3.25 D

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(3)	Pattern Type=STIS-ALONG-SLIT	Coordinate Frame=POS-TARG		(2)
	Purpose=DITHER	Pattern Orientation=90.0		
	Number Of Points=5	Angle Between Sides=		
	Point Spacing=0.105	Center Pattern=false		
	Line Spacing=			

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	M31N-2008-12A	RA: 00 45 28.8200 (11.3700833d) Dec: +41 54 10.10 (41.90281d) Equinox: J2000		V=20.8+/-0.1 Maximum magnitudes obtained by this system within observing window (day 3 onwards): Sloan i'=20.8+/-0.1, Sloan r'=20.4+/-0.1, B=21.0+/-0.1, U=19.2+/-0.5	Reference Frame: ICRS
Comments: *Category=STAR* *Description=[INTERACTING BINARY, RECURRENT NOVA]*					
(2)	AQUSTAR	RA: 00 45 28.5265 (11.3688604d) Dec: +41 54 51.86 (41.91441d) Equinox: J2000	Epoch of Position: 1986.91	V=18.349+/-0.45	Reference Frame: ICRS
Comments: *Category=CALIBRATION* *Description=[APERTURE LOCATION]* *Extended=NO*					

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	AQUIRE TARGET	(2) AQUSTAR	STIS/CCD, ACQ, F28X50LP	MIRROR				30 Secs (30 Secs)	
								[==>]	***[1]***
2	Speactra G140L (STIS.sp.733005)	(1) M31N-2008-12A	STIS/FUV-MAMA, TIME-TAG, 52X0.2D1	G140L 1425 A	BUFFER-TIME=1229		Pattern 3, Exps 2-2 in UV Spec T0 G140L (04) (3)	2000 Secs (12285 Secs)	
								[==>1889.0 Secs (Pattern 1)]	***[1]***
								[==>2599.0 Secs (Pattern 2)]	***[2]***
								[==>2599.0 Secs (Pattern 3)]	***[3]***
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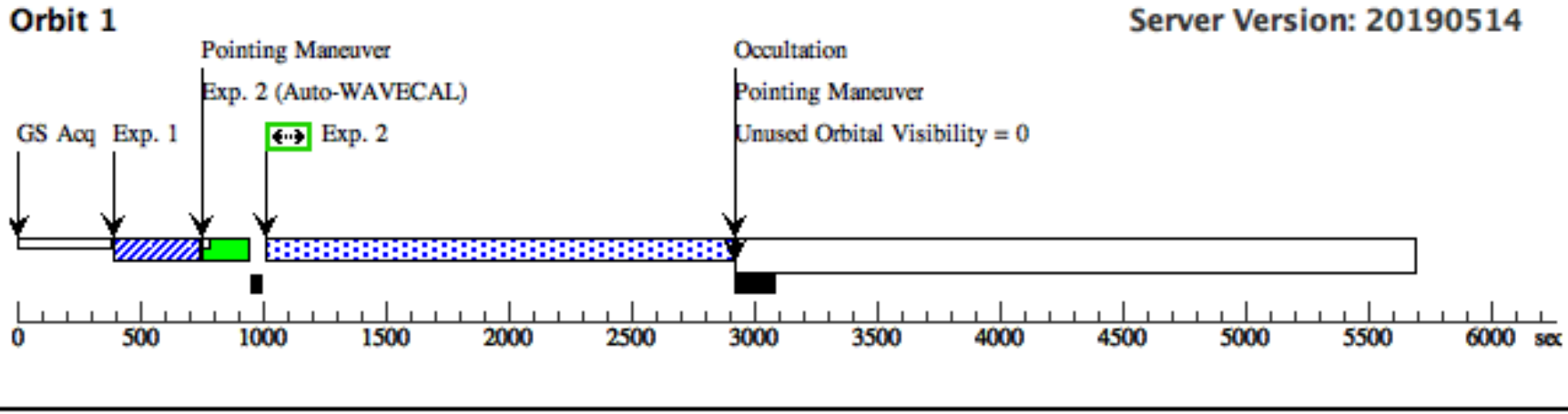
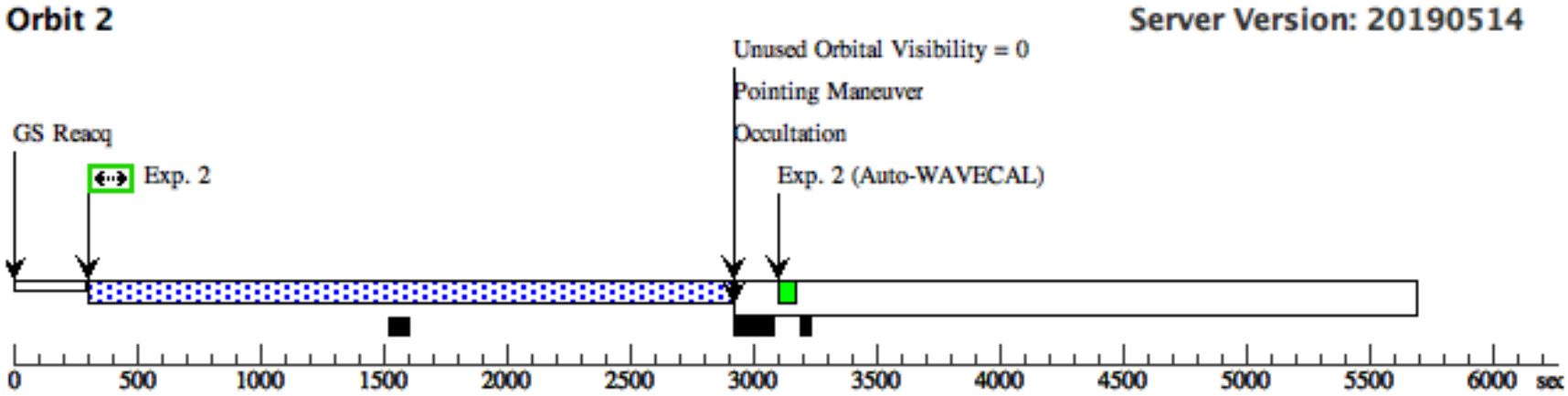
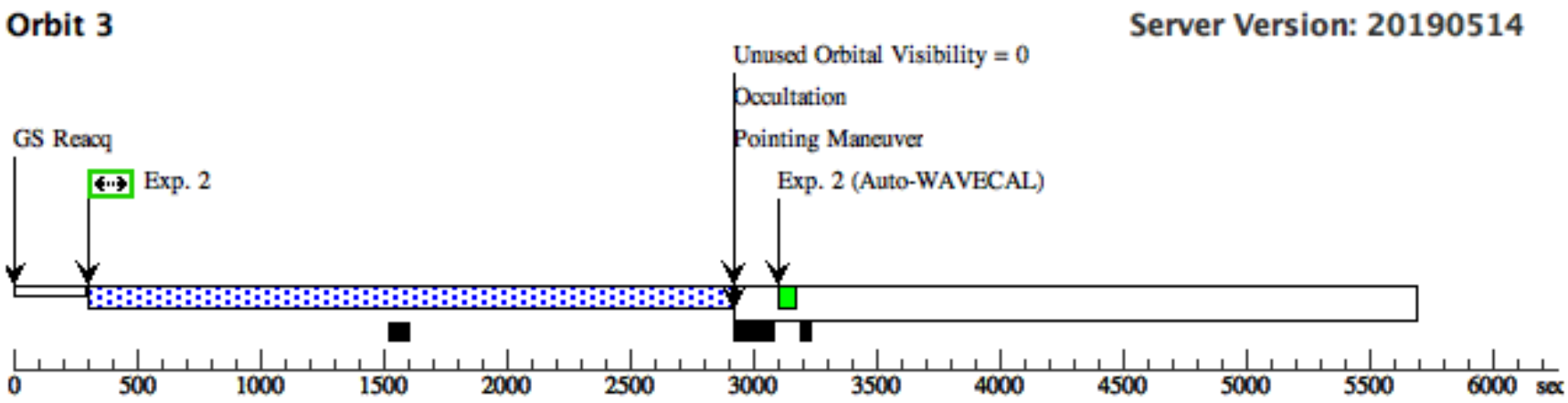
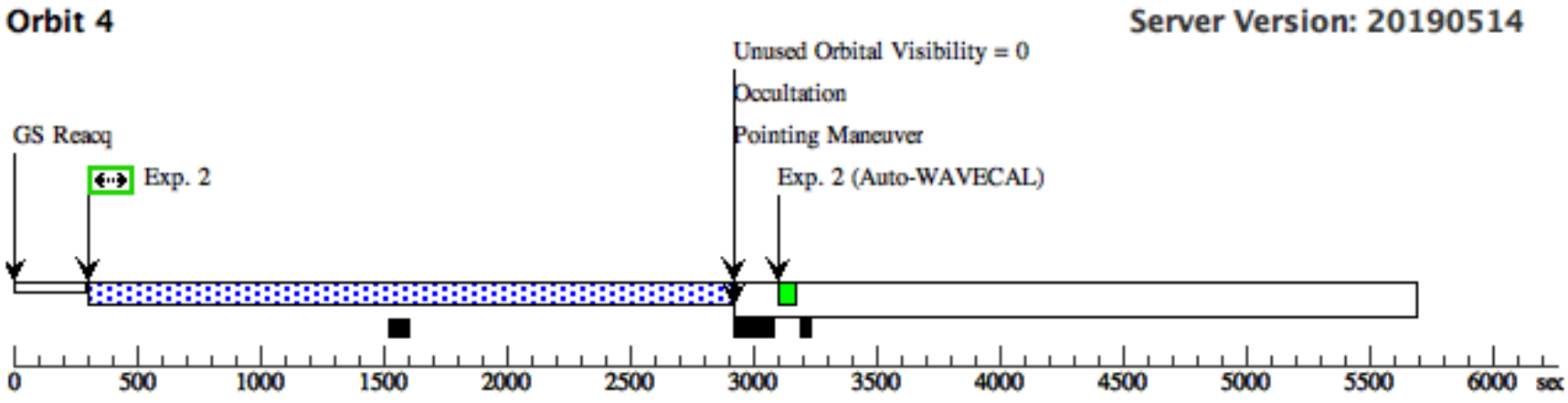
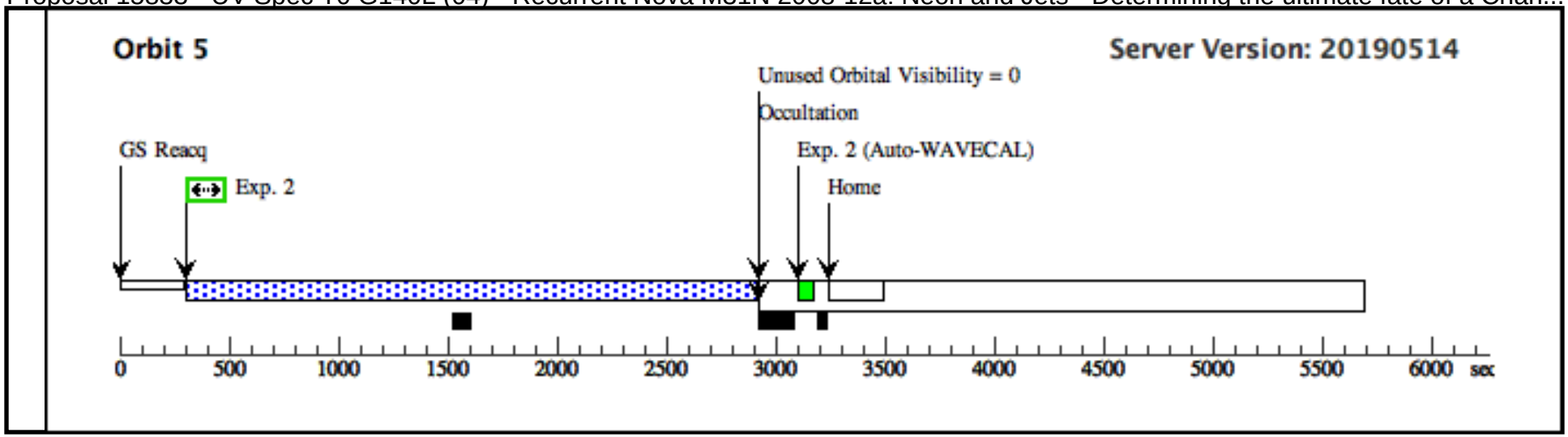
Orbit Structure






Orbit 3
Server Version: 20190514
Unused Orbital Visibility = 0
Occultation
Pointing Maneuver
GS Reacq
Exp. 2
Exp. 2 (Auto-WAVECAL)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
sec


Orbit 4
Server Version: 20190514
Unused Orbital Visibility = 0
Occultation
Pointing Maneuver
GS Reacq
Exp. 2
Exp. 2 (Auto-WAVECAL)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
sec


Orbit 5
Server Version: 20190514
Unused Orbital Visibility = 0
Occultation
GS Reacq
Exp. 2
Exp. 2 (Auto-WAVECAL)
Home
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
sec