



12509 - Peering into the Cat's Eye with STIS

Cycle: 19, Proposal Category: GO

(Availability Mode: SUPPORTED)

INVESTIGATORS

<i>Name</i>	<i>Institution</i>	<i>E-Mail</i>
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VISITS

<i>Visit</i>	<i>Targets used in Visit</i>	<i>Configurations used in Visit</i>	<i>Orbits Used</i>	<i>Last Orbit Planner Run</i>	<i>OP Current with Visit?</i>
01	(1) NGC6543-MINOR	STIS/CCD STIS/FUV-MAMA	4	11-Jul-2011 22:21:41.0	yes
02	(2) NGC6543-MAJOR	STIS/CCD STIS/FUV-MAMA	4	11-Jul-2011 22:21:58.0	yes

8 Total Orbits Used

ABSTRACT

Planetary Nebulae (PNe) are formed by interactions of the current fast stellar wind and the previous slow AGB wind. In this scenario, the bright PN shell consists of the swept-up AGB wind, while the central cavity contains shocked fast wind. The structure and evolution of the so-called hot bubble is largely dependent on the physical processes occurring at the interface between the 10^4 K nebular shell and the $>10^6$ K interior gas. Among the PNe whose extended X-ray emission has been detected and analyzed in detail with Chandra or XMM data, the Cat's Eye Nebula (NGC 6543) is the best resolved and has the least non-uniform extinction, and thus provides the best laboratory to study the interaction of the fast stellar wind with the surrounding nebula, i.e. the interface between hot and cold media.

We request HST STIS UV and optical spectroscopic observations of the Cat's Eye Nebula to: (1) use N V and C IV lines to determine the precise location of the interface between the hot interior and the cool nebular shell, and (2) use nebular lines to determine the temperature and density structure of the adjacent nebular shell. These observations, together with our Chandra and FUSE observations, provide the first complete description of the interface and its boundary conditions that will allow us to investigate the underlying physical processes, such as heat conduction, turbulent mixing, and mass loading. Understanding the interface physics is important for a wide range of astronomical objects where hot gas is in contact with cooler gas, e.g. supernovae remnants, wind-blown bubbles, superbubbles, and interstellar/intergalactic medium.

OBSERVING DESCRIPTION

The goals of these observations are: 1) to probe the physical conditions of the interface region between the hot, X-ray-emitting gas in the central cavity and the surrounding cool nebular shell, and 2) the measurement of the optical nebular emission lines to establish the density and temperature of the surrounding nebular material. To this end we will use STIS/FUV slit spectroscopy to detect the N V and C IV emission lines from the interface region, and optical STIS slit spectroscopy to measure optical emission lines sensitive to density and temperature of the nebular shell.

The original proposed observations included the following setups:

- G140L in the range 1150–1730 Å (total exposure time of 4,500 sec).
- G750M in the range 6295–6867 Å (500 sec) and 5448–6020 Å (1,100 sec).
- G430L in the range 2900–5700 Å (200 sec).
- G430M in the range 3537–3823 Å (500 sec) and 4308–4594 Å (1,600 sec).

Ideally these optical and UV observations should share common slit positions to probe the conditions of the gas along exactly the same sight lines. For this study we proposed to obtain slit positions that are within 10 degrees of the nebular shell's major and minor axes (PA=25 and 115 degrees) using ORIENT constraints. To further ensure the observations have the same slit positions we request the optical and UV observations for each slit position to occur as part of a common 4-orbit visits. To investigate whether this request affects the schedulability of our program we have compared two APT "simulations" one with the CCD and MAMA observations in separate visits and one with the observations combined in a common visit. We found no noticeable impact on the schedulability as shown in the APT visit planner.

The proposed observations are complicated by the UV bright central star which will also be on the spectrographic slit. Initial estimates indicate the proposed STIS/FUV observations with the G140L grating would indeed violate the brightness limits (communications w/Massa). We have

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investigated the feasibility of other setups and find that observations with the G140M grating, the F52x0.2 aperture, and the central star offset 0.5" from the slit edge would still achieve our science goals and would not violate the STIS/FUV brightness limits. Therefore, in the request outlined in this APT submission we use two STIS/FUV configurations with the G140M grating to observe the N V and C IV line emission from NGC 6543. This change also makes our request to combine STIS UV and optical observations in a common visit more necessary as the time required for the necessary ACQ/PEAK exposures can take place in the optical orbits (orbits 1 and 2 of each visit) and allow longer exposure times for the subsequent FUV observations (during orbits 3 and 4 of each visit).

Below we summarize the feasibility and safety considerations of the requested observations not already explicitly described in our phase 1 proposal.

ACQ and ACQ/Peak:

The central star of the Cat's Eye Nebula (NGC 6543) will be used for target acquisition. This star has $T_{\text{eff}}=45,000$ K with $B=9.8$ and $V=11.3$ mag. We have used the $V=11.3$ measurement for our ACQ ETC calculations that accompany the APT submission because this measurement comes from previous HST observations (PID: 6119) and is less likely affected by nebular line emission. In all cases we have also performed ETC calculations with the $B=9.8$ measurement as a sanity check and adjusted the observing configuration and exposure times so that the ACQ and ACQ/PEAK observations would be appropriate for either measurement.

The ACQ exposure will employ the F25ND3 filter and 3 s exposure time (as the $B=9.8$ measurement implied saturation could be an issue had the setup used the CLEAR(50CCD) filter). Similarly, the ACQ/PEAK exposures will employ the 0.2x0.05ND aperture and 3 s exposure times to accurately establish the position of the central star which will then be offset by (POSTARG X=0.6") such that it is 0.5" outside the slit.

Feasibility of Revised STIS/FUV Observations:

The expected surface brightness of the N V and C IV diffuse emission from our proposal remains $5.0E-14$ and $2.3E-13$ erg/cm²/s/arcsec². We further assume a line-width of 0.2 Å, similar to those in FUSE O VI observations (Gruendl, Chu, and Guerrero, 2004, ApJL, 612, 127). Using the G140M grating and the 52x0.2 aperture, the STIS ETC predicts our N V (wave=1222) observations with exposure time of 4,000 s would have $S/N=6.3$ in a single resolution element. Similarly, the STIS ETC predicts our C IV (wave=1550) observations with exposure time of 1,500 s would have $S/N=3.9$ in a single resolution element.

Brightness Limits for STIS/FUV Observations:

As mentioned the UV bright central star of NGC 6543 precludes use of the G140L grating. Analysis of IUE observations (e.g., SWP35504) show the typical flux density of the central star is generally less than $1.5E-11$ ergs/cm²/s/A in the 1150-1900 A range. The P-Cygni emission peaks for the N V and C IV lines do not exceed $3.0E-11$ ergs/cm²/s/A, all below the bright-object limits for the G140M ($9.4E-11$ ergs/cm²/s/A).

To further reduce the impact of the central star on our observations, prior to all observations we will offset 0.6" in the dispersion direction (POSTARG X=0.6). We estimate the maximum expected count rate from the scattered stellar UV light from the offset star as follows. In the STIS spectroscopic ETC we use the IUE spectrum (SWP35504) as input and simulate an observations with our G140M observing configurations (see ETC calculations STIS.sp.198664 and STIS.sp.198674 for examples). The expected global count-rates from the central star are 13,289 cts/s and 4,012 cts/s for the N V and C IV setups, respectively. Based on the spatial profiles for the G140M grating, less than 5% of the light should be present (1/2 the light outside a radius of 0.5"). Therefore, we expect the global count-rates from scattered stellar emission from the offset star to be less than 660 cts/s and 200 cts/s for the N V and C IV setups, respectively.

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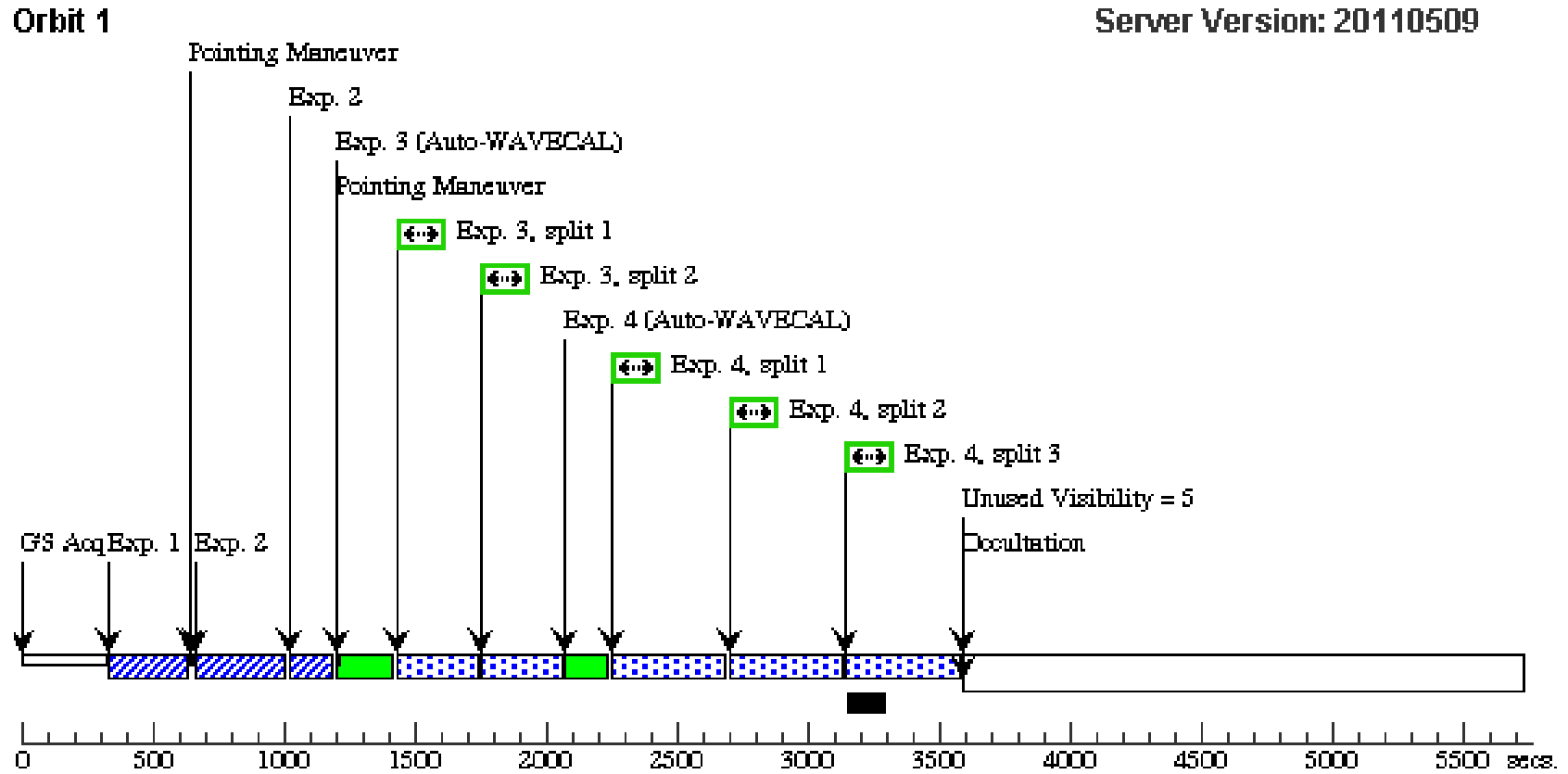
Tue Jul 12 02:22:05 GMT 2011

Visit	Proposal 12509, Visit 01 Diagnostic Status: Warning Scientific Instruments: STIS/CCD, STIS/FUV-MAMA Special Requirements: PCS MODE FINE; GUID TOL 0.02"; ORIENT 150D TO 170 D; ORIENT 330D TO 350 D <i>Comments: Optical and UV long-slit spectroscopy along the minor axis of NGC 6543.</i>				
	Diagnostics	(Visit 01) Warning (Orbit Planner): POS TARG OUTSIDE OF APERTURE			
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Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes
	(1)	NGC6543-MINOR	RA: 17 58 33.4200 (269.6392500d) Dec: +66 37 59.50 (66.63319d) Equinox: J2000		V=11.3 Johnson B=9.8
					Miscellaneous Reference Frame: ICRS

Proposal 12509 - Visit 01 - Peering into the Cat's Eye with STIS

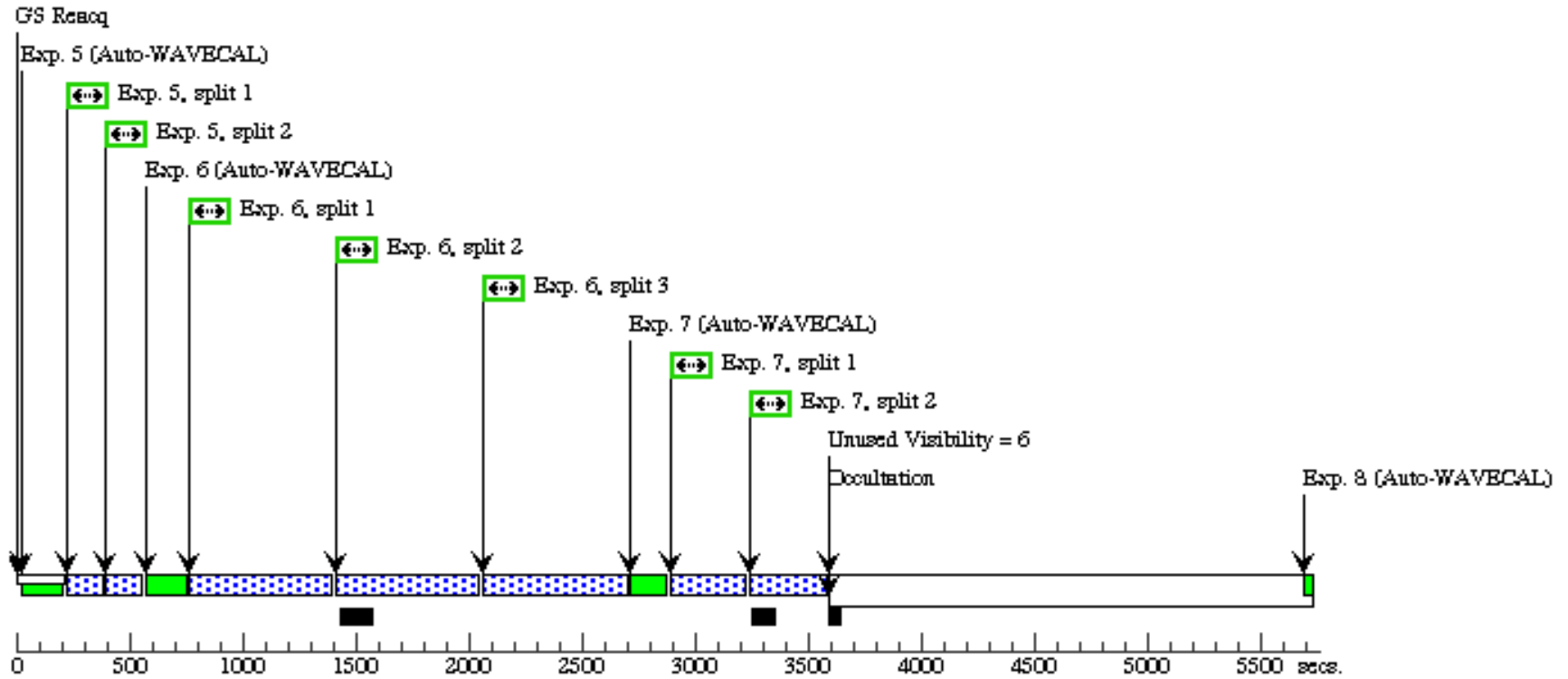
Exposures	#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit	
	1	ACQ (STIS.ta.198 604)	(1) NGC6543-MINO R	STIS/CCD, ACQ, F25ND3	MIRROR					3 Secs [==>]	[1]
	2	ACQ/PEAK (STIS.ta.198 617)	(1) NGC6543-MINO R	STIS/CCD, ACQ/PEAK, 0.2X0.05ND	MIRROR					3 Secs [==>]	[1]
	3	Minor axis CCD	(1) NGC6543-MINO R	STIS/CCD, ACCUM, 52X0.2	G750M 6581 A	CR-SPLIT=2	POS TARG 0.6,null			550 Secs [==>(Split 1)] [==>(Split 2)]	[1]
	4	Minor axis CCD	(1) NGC6543-MINO R	STIS/CCD, ACCUM, 52X0.2	G750M 5734 A	CR-SPLIT=3	POS TARG 0.6,null			1200 Secs [==>(Split 1)] [==>(Split 2)] [==>(Split 3)]	[1]
	5	Minor axis CCD	(1) NGC6543-MINO R	STIS/CCD, ACCUM, 52X0.2	G430L 4300 A	CR-SPLIT=2	POS TARG 0.6,null			250 Secs [==>127.0 Secs (Split 1)] [==>127.0 Secs (Split 2)]	[2]
	6	Minor axis CCD	(1) NGC6543-MINO R	STIS/CCD, ACCUM, 52X0.2	G430M 4451 A	CR-SPLIT=3	POS TARG 0.6,null			1800 Secs [==>602.0 Secs (Split 1)] [==>602.0 Secs (Split 2)] [==>602.0 Secs (Split 3)]	[2]
	7	Minor axis CCD	(1) NGC6543-MINO R	STIS/CCD, ACCUM, 52X0.2	G430M 3680 A	CR-SPLIT=2	POS TARG 0.6,null			600 Secs [==>302.0 Secs (Split 1)] [==>302.0 Secs (Split 2)]	[2]
	8	Minor axis F UV NVa (STIS.sp.19 8724)	(1) NGC6543-MINO R	STIS/FUV-MAMA, ACCUM, 52X0.2	G140M 1222 A		POS TARG 0.6,null			3000 Secs [==>3347.0 Secs]	[3]
	9	Minor axis F UV NVb (STIS.sp.19 8724)	(1) NGC6543-MINO R	STIS/FUV-MAMA, ACCUM, 52X0.2	G140M 1222 A		POS TARG 0.6,null			1000 Secs [==>1223.0 Secs]	[4]
10	Minor axis F UV CIV (STIS.sp.19 8741)	(1) NGC6543-MINO R	STIS/FUV-MAMA, ACCUM, 52X0.2	G140M 1550 A		POS TARG 0.6,null			1500 Secs [==>1723.0 Secs]	[4]	

Orbit Structure



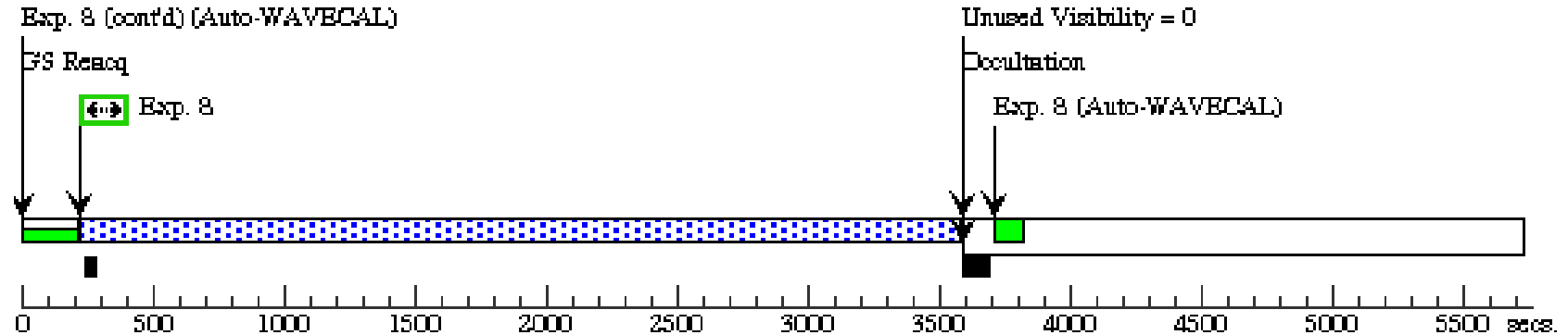
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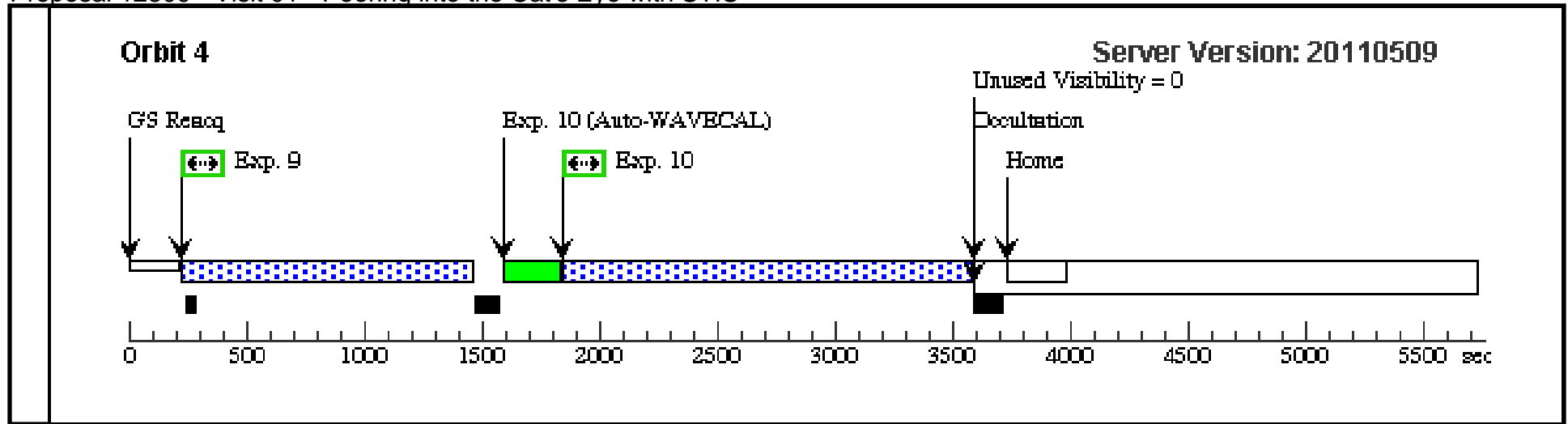
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Orbit 3

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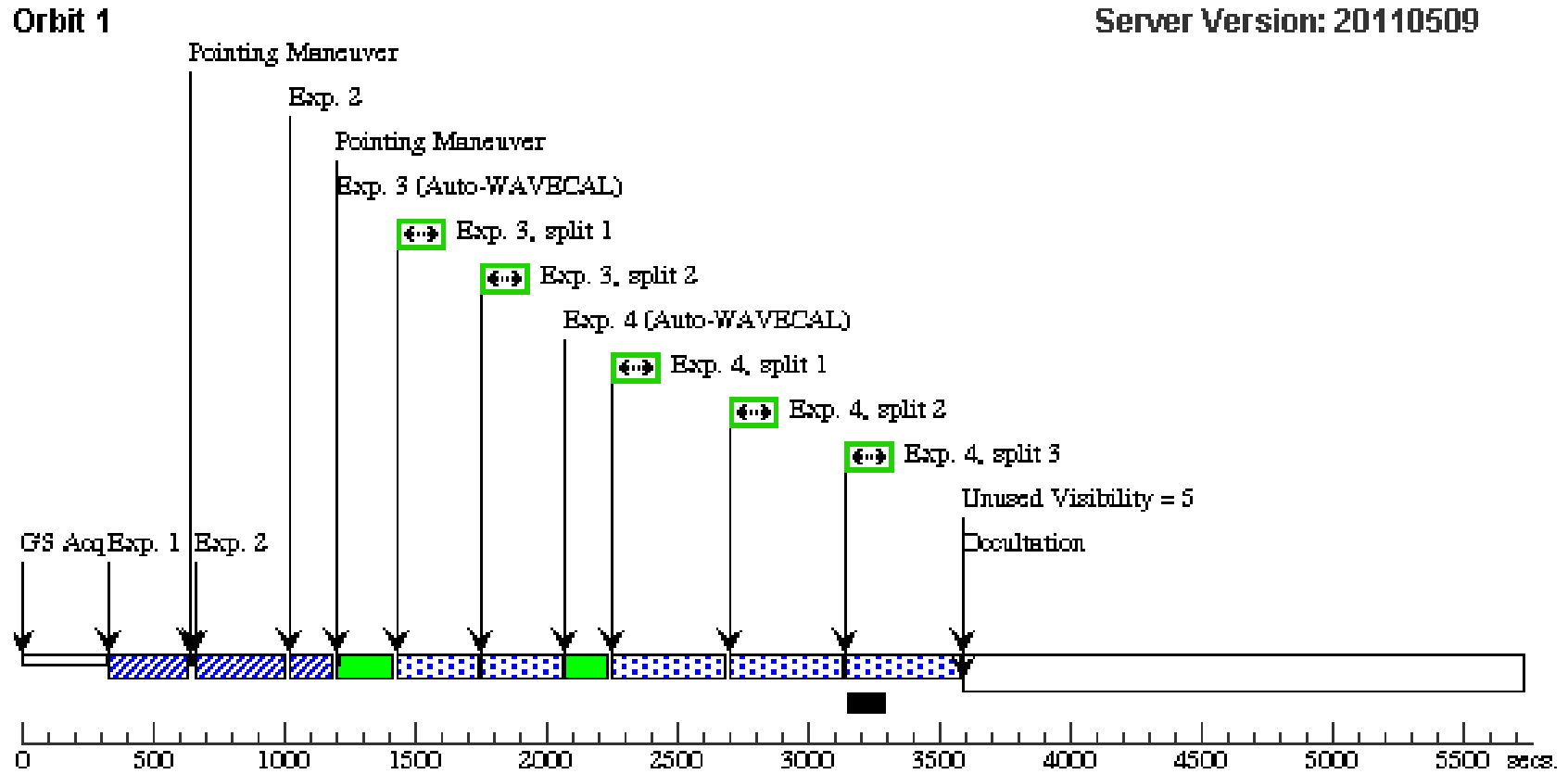
Tue Jul 12 02:22:08 GMT 2011

Visit	Proposal 12509, Visit 02 Diagnostic Status: Warning Scientific Instruments: STIS/CCD, STIS/FUV-MAMA Special Requirements: PCS MODE FINE; GUID TOL 0.02"; ORIENT 60D TO 80 D; ORIENT 240D TO 260 D <i>Comments: Optical and UV long-slit spectroscopy along the major axis of NGC 6543.</i>				
	Diagnostics	(Visit 02) Warning (Orbit Planner): POS TARG OUTSIDE OF APERTURE			
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Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes
	(2)	NGC6543-MAJOR	RA: 17 58 33.4200 (269.6392500d) Dec: +66 37 59.50 (66.63319d) Equinox: J2000		V=11.3 Johnson B=9.8
					Miscellaneous Reference Frame: ICRS

Proposal 12509 - Visit 02 - Peering into the Cat's Eye with STIS

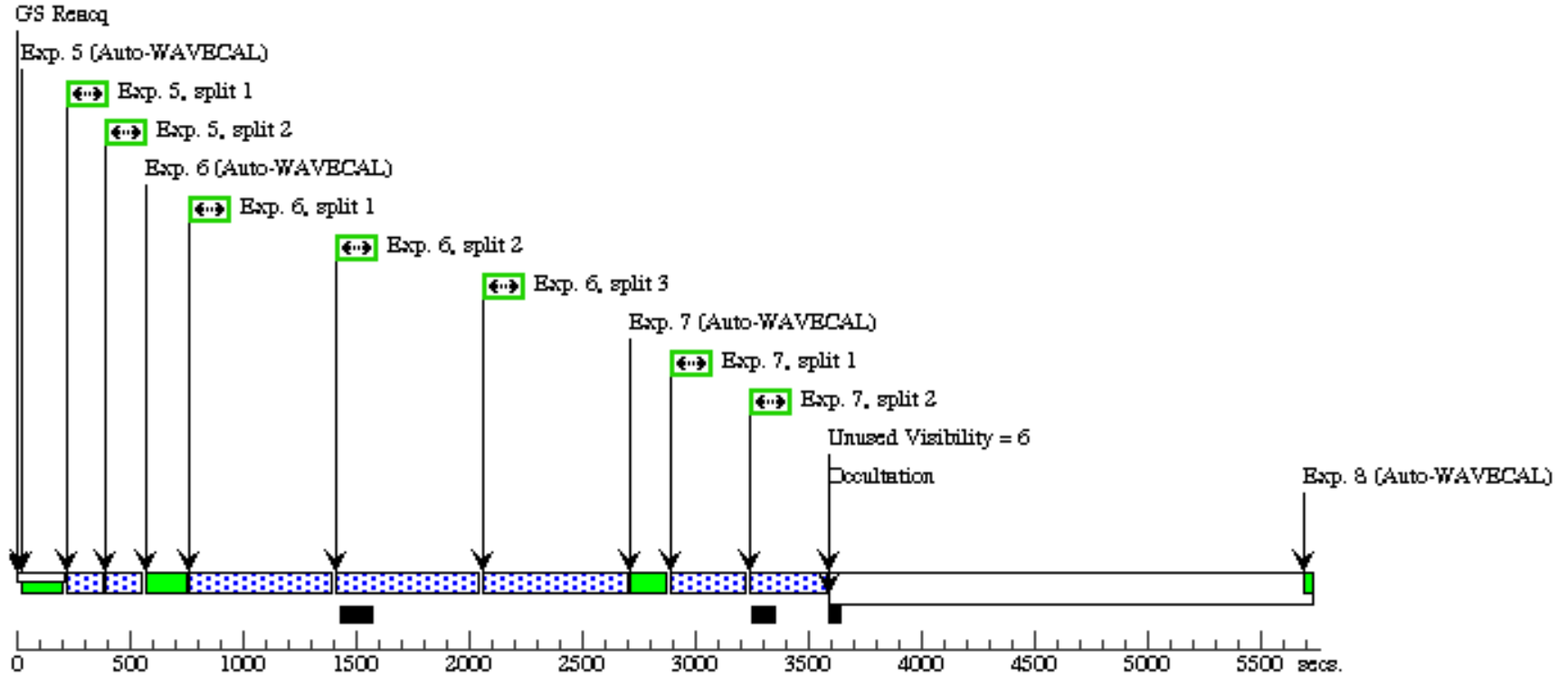
Exposures	#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit	
	1	ACQ (STIS.ta.198 604)	(2) NGC6543-MAJO R	STIS/CCD, ACQ, F25ND3	MIRROR					3 Secs [==>]	[1]
	2	ACQ/PEAK (STIS.ta.198 617)	(2) NGC6543-MAJO R	STIS/CCD, ACQ/PEAK, 0.2X0.05ND	MIRROR					3 Secs [==>]	[1]
	3	Major axis CCD	(2) NGC6543-MAJO R	STIS/CCD, ACCUM, 52X0.2	G750M 6581 A	CR-SPLIT=2	POS TARG -0.6,null			550 Secs [==>(Split 1)] [==>(Split 2)]	[1]
	4	Major axis CCD	(2) NGC6543-MAJO R	STIS/CCD, ACCUM, 52X0.2	G750M 5734 A	CR-SPLIT=3	POS TARG -0.6,null			1200 Secs [==>(Split 1)] [==>(Split 2)] [==>(Split 3)]	[1]
	5	Major axis CCD	(2) NGC6543-MAJO R	STIS/CCD, ACCUM, 52X0.2	G430L 4300 A	CR-SPLIT=2	POS TARG -0.6,null			250 Secs [==>127.0 Secs (Split 1)] [==>127.0 Secs (Split 2)]	[2]
	6	Major axis CCD	(2) NGC6543-MAJO R	STIS/CCD, ACCUM, 52X0.2	G430M 4451 A	CR-SPLIT=3	POS TARG -0.6,null			1800 Secs [==>602.0 Secs (Split 1)] [==>602.0 Secs (Split 2)] [==>602.0 Secs (Split 3)]	[2]
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	9	Major axis F UV NVb (STIS.sp.19 8724)	(2) NGC6543-MAJO R	STIS/FUV-MAMA, ACCUM, 52X0.2	G140M 1222 A		POS TARG -0.6,null			1000 Secs [==>1223.0 Secs]	[4]
10	Major axis F UV CIV (STIS.sp.19 8741)	(2) NGC6543-MAJO R	STIS/FUV-MAMA, ACCUM, 52X0.2	G140M 1550 A		POS TARG -0.6,null			1500 Secs [==>1723.0 Secs]	[4]	

Orbit Structure



Orbit 2

Server Version: 20110509



Orbit 3

Server Version: 20110509

