



17715 - The curious case of SDSS J1000+2233: a recoiling SMBH, a sub-parsec SMBH binary, or an unusual disk emitter?

Cycle: 32, Proposal Category: GO

(UV Initiative)

(Availability Mode: SUPPORTED)

INVESTIGATORS

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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) SDSSJ1000+2233	WFC3/IR WFC3/UVIS	2	05-Nov-2024 18:00:17.0	yes
03	(1) SDSSJ1000+2233	STIS/CCD STIS/NUV-MAMA	3	05-Nov-2024 18:00:19.0	yes
04	(2) EGGR-26	WFC3/IR WFC3/UVIS	1	05-Nov-2024 18:00:20.0	yes

6 Total Orbits Used

ABSTRACT

SDSS J1000+2233 is a broad-line quasar at $z \sim 0.4$ with the peaks of its broad low-ionization lines blueshifted from the systemic velocity by ~ 8000 km/s, without obvious double-peaked broad line profiles characteristic of disk emitters. It represents one of the few best cases where a recoiling SMBH or a sub-parsec binary SMBH could be a viable interpretation of the blueshifted broad lines. We propose joint HST and Chandra observations to elucidate the nature of SDSS J1000+2233. HST WFC3 optical and IR imaging will potentially resolve spatially-offset nuclei supporting the scenario of a recoiling SMBH, and allow image decomposition to measure the properties of its host galaxy. HST STIS NUV spectroscopy will probe the broad UV emission line profiles to rule out (or confirm) the disk emitter scenario. Chandra X-ray imaging will pinpoint the location of the active SMBH to facilitate the HST imaging observations. The rejection or confirmation of the disk emitter hypothesis would provide valuable guidance for the searches of recoiling or binary SMBHs with kinematically-offset broad emission lines. Alternatively, detailed multi-wavelength coverage and host galaxy measurements will help understand the physical conditions leading to extreme broad line profiles that are rare even for disk emitters. The observations will have general implications for gravitational wave and multi-messenger astronomy, the understanding of galaxy evolution and SMBH formation, and/or astrophysical objects under extreme physical conditions. With a small investment of 6 HST hours and 25 ks of Chandra, the program could potentially confirm the general relativistic prediction of recoils from SMBH mergers.

OBSERVING DESCRIPTION

Overview:

1. We will use HST WFC3 to perform optical and near-IR imaging to potentially resolve close double nuclei at the 0.1" resolution, and to perform quasar-host imaging decomposition to derive host properties and stellar mass estimate from two-band color.
2. We will use HST STIS to obtain NUV spectroscopy to cover the UV broad emission lines from Ly to C III] to test the disk emitter scenario, and to facilitate photoionization modeling.

More specifically:

1. For the WFC3 imaging, we choose the UVIS channel with the F606W filter to cover the restframe ~ 4000 – 5000 Angstrom. This band roughly samples the rest-frame B band for our target and probes the young stellar population in the host. We also choose the IR channel with the F110W (wide J) filter, which roughly samples the rest-frame I band for our target and probes the old stellar population in the host (mostly the bulge). The quasar light is expected to be at a minimum at this wavelength to facilitate quasar-host decomposition. The two-band (UVIS+IR) observations, after proper quasar-host decomposition, provide rest-frame optical color for the host to allow an estimate of the mass-to-light ratio (M/L) and hence the

Proposal 17715 (STScI Edit Number: 1, Created: Tuesday, November 5, 2024, 6:00:20PM Eastern Standard Time) - Overview
host stellar mass, based on stellar population synthesis models. The choice of these two bands is such that complications with TP-AGB stars on host SED are not an issue for the M/L estimation.

For the F110W observation, we will use the subarray to minimize overhead and avoid buffer dump. We will use the 4-step BOX dither between exposures to facilitate cosmic-ray and bad-pixel rejection, to better sample the PSF, and to improve the effective image resolution.

For the F606W observations, we will use the full array to cover the largest field of view to include as many field stars as possible to register for absolute astrometry by comparing to deep ground based imaging from the DECaL Legacy Survey. To achieve the best PSF possible with HST, desirable for identifying close double nuclei, we will adopt a 4-point dither pattern to over-sample the PSF.

We use one orbit each in the WFC3 IR and UVIS bands to accommodate these dither patterns and to reach the depth desirable to detect faint extended host features.

There are no field stars in the same field-of-view that are bright enough to use as PSF templates. For robust PSF modeling, we thus use a separate orbit to observe a bright white dwarf in addition to the WFC3 observations of the science target. We will combine the UVIS and IR observations in the same orbit, with the same filter configurations and dither patterns as for our science target. It is important to observe the PSF star in the same cycle to minimize the impact of instrument PSF variations across cycles.

2. NUV spectroscopy is used to explore the UV broad lines to test the disk emitter hypothesis. We choose STIS NUV-MAMA with the G230L grating for the broad spectral coverage from Ly α to C III] in one setting. The moderate spectral resolution $R \sim 500$ is sufficient to resolve the broad UV emission lines and their potential offset of ~ 8000 km/s.

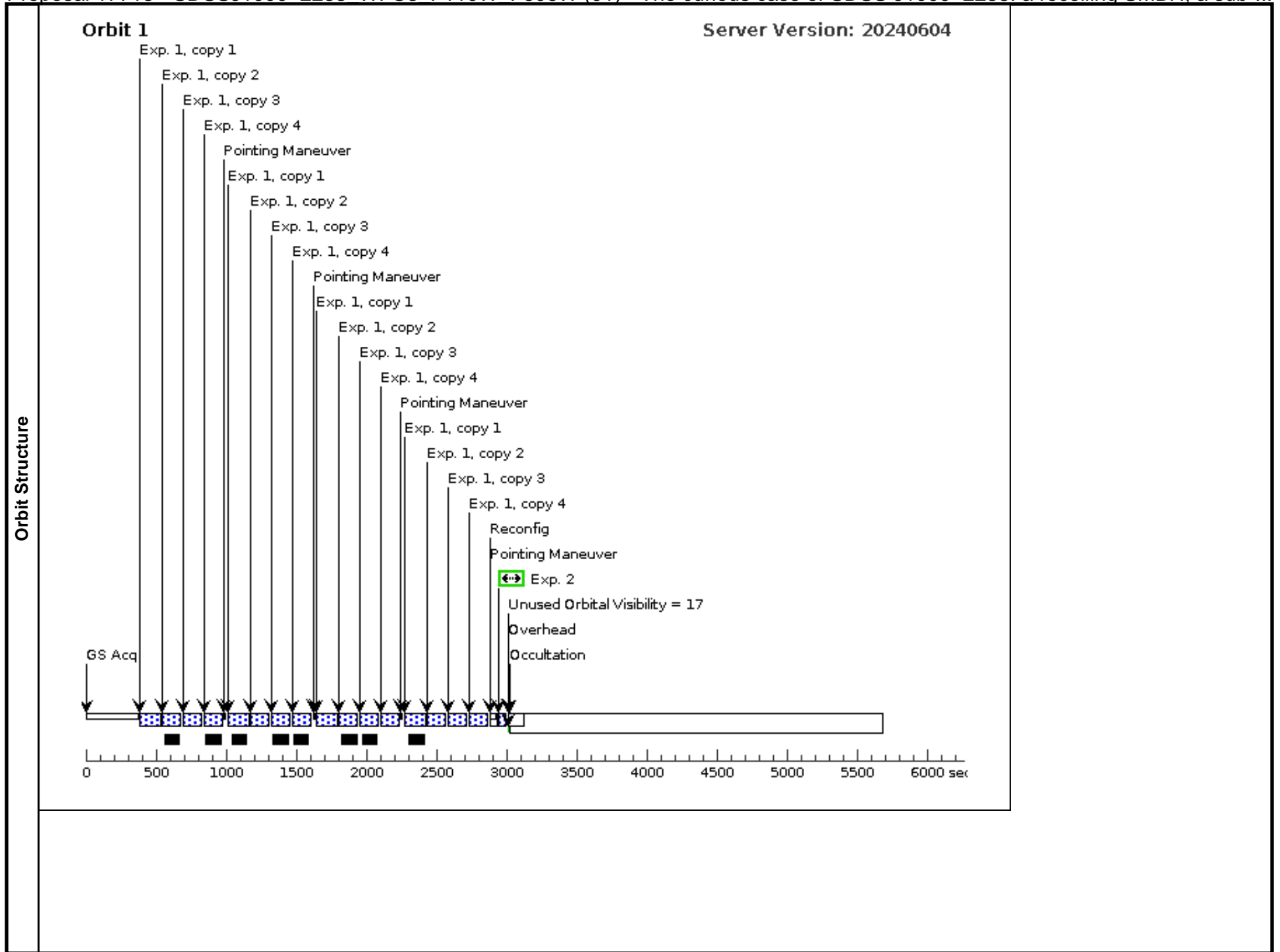
We will orient the 52"x0.2" slit to cover both nuclei should they be discovered from the WFC3 imaging, and therefore request the NUV spectroscopy to be taken at least 17 days (to allow time for analysis and resubmission of the observation and to be non-disruptive) after the WFC3 imaging for us to properly set up the slit position.

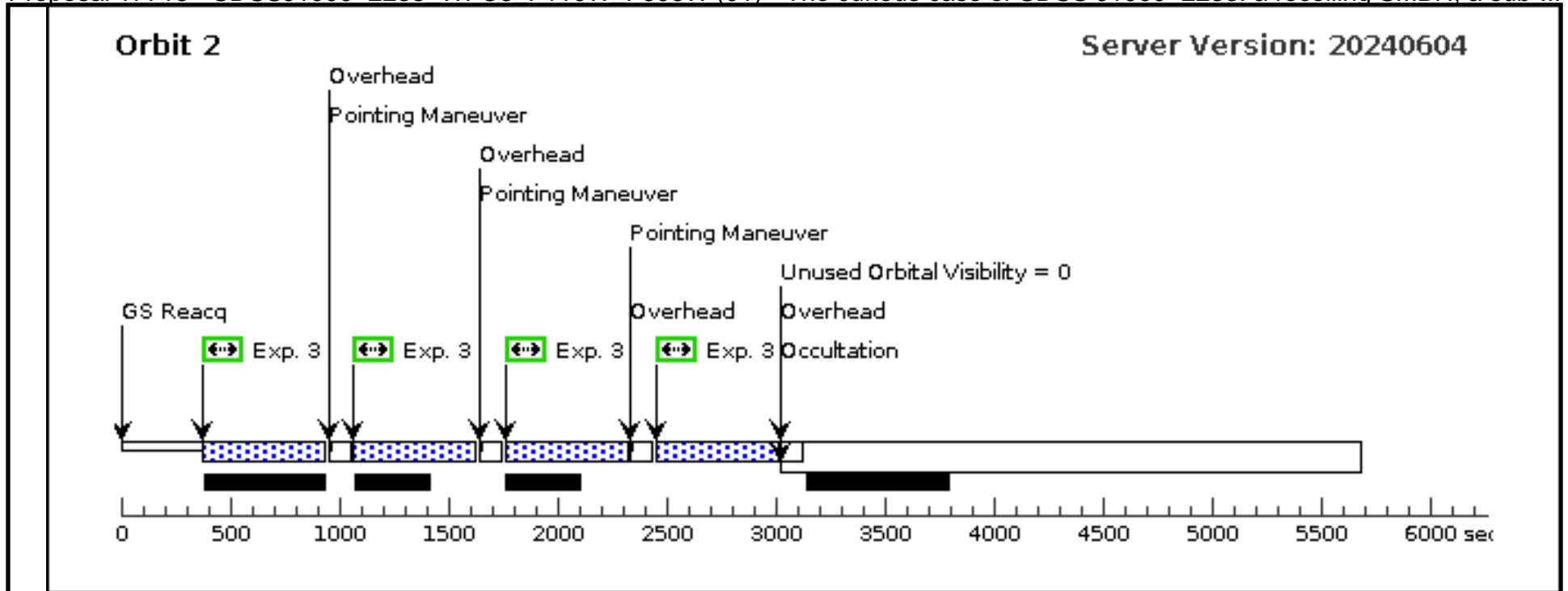
We use 3 orbits for the NUV spectroscopy taking into account an estimated overhead of 35 min (including initial guide-star acquisition 5.6 min, target acquisition 6.0 min, two additional automatic wavecal for series of identical exposures extending more than 40 min at 4.0 min each, and two guide-star reacquisitions at 3.7 min each, and additional overhead such as CR-split/buffer dump).

Visit	Proposal 17715, SDSSJ1000+2233_WFC3_F110W_F606W (01), implementation Diagnostic Status: No Diagnostics Scientific Instruments: WFC3/IR, WFC3/UVIS Special Requirements: (none)					
Patterns	#	Primary Pattern	Secondary Pattern	Exposures		
	(1)	Pattern Type=WFC3-IR-DITHER-BOX-MIN Purpose=DITHER Number Of Points=4 Point Spacing=1.716 Line Spacing=1.095	Coordinate Frame=POS-TARG Pattern Orientation=18.528 Angle Between Sides=74.653 Center Pattern=false		(1)	
	(2)	Pattern Type=WFC3-UVIS-DITHER-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.173 Line Spacing=0.112	Coordinate Frame=POS-TARG Pattern Orientation=23.884 Angle Between Sides=81.785 Center Pattern=false		(3)	
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
	(1)	SDSSJ1000+2233	RA: 10 00 21.8000 (150.0908333d) Dec: +22 33 18.60 (22.55517d) Equinox: J2000	Redshift: 0.4189	V=18 NUV=19.72, r=18.44, H=15.8	Reference Frame: ICRS
Comments: Category=GALAXY Description=[QSO]						

Proposal 17715 - SDSSJ1000+2233 WFC3 F110W F606W (01) - The curious case of SDSS J1000+2233: a recoiling SMBH, a sub-...

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1		(1) SDSSJ1000+2233 3	WFC3/IR, MULTIACCUM, IRSUB512	F110W	NSAMP=10; SAMP-SEQ=STEP2 5		Pattern 1, Exps 1-1 i n SDSSJ1000+2233_ WFC3_F110W_F60 6W (01) (1)	128.439646 Secs X 4 (2055.034 Sec s)	
								[==>(Pattern 1, Copy 1)]	
								[==>(Pattern 1, Copy 2)]	
								[1]	
2		(1) SDSSJ1000+2233 3	WFC3/UVIS, ACCUM, UVIS2-C1K1C-CTE	F606W	FLASH=20			20 Secs (20 Secs)	
								[==>]	[1]
<i>Comments: short exposure to help reconstruct the bright nucleus in case of saturation</i>									
3		(1) SDSSJ1000+2233 3	WFC3/UVIS, ACCUM, UVIS2-C1K1C-CTE	F606W			Pattern 2, Exps 3-3 i n SDSSJ1000+2233_ WFC3_F110W_F60 6W (01) (2)	564 Secs (2256 Secs)	
								[==>(Pattern 1)]	[2]
								[==>(Pattern 2)]	
								[==>(Pattern 3)]	
								[==>(Pattern 4)]	

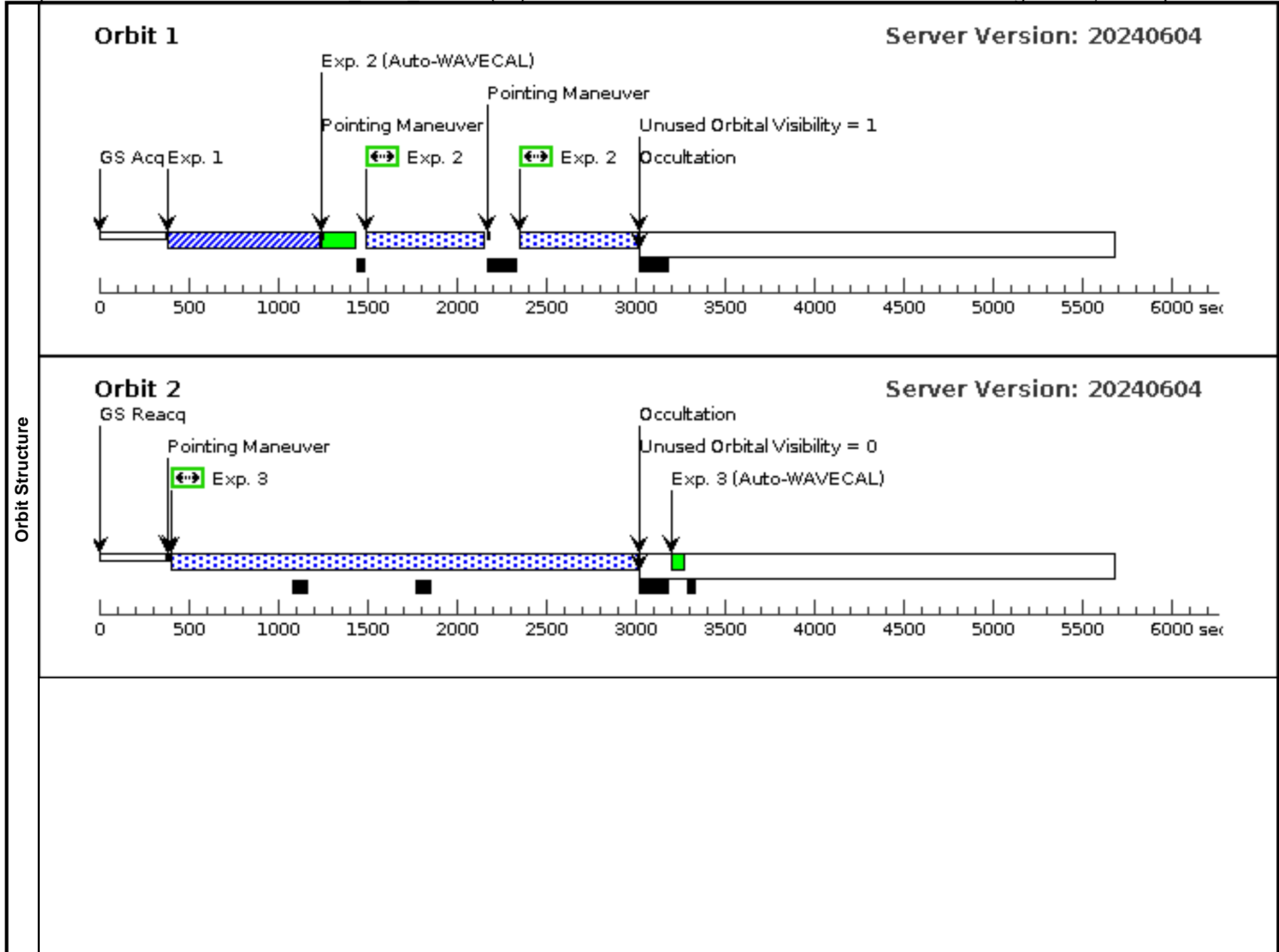


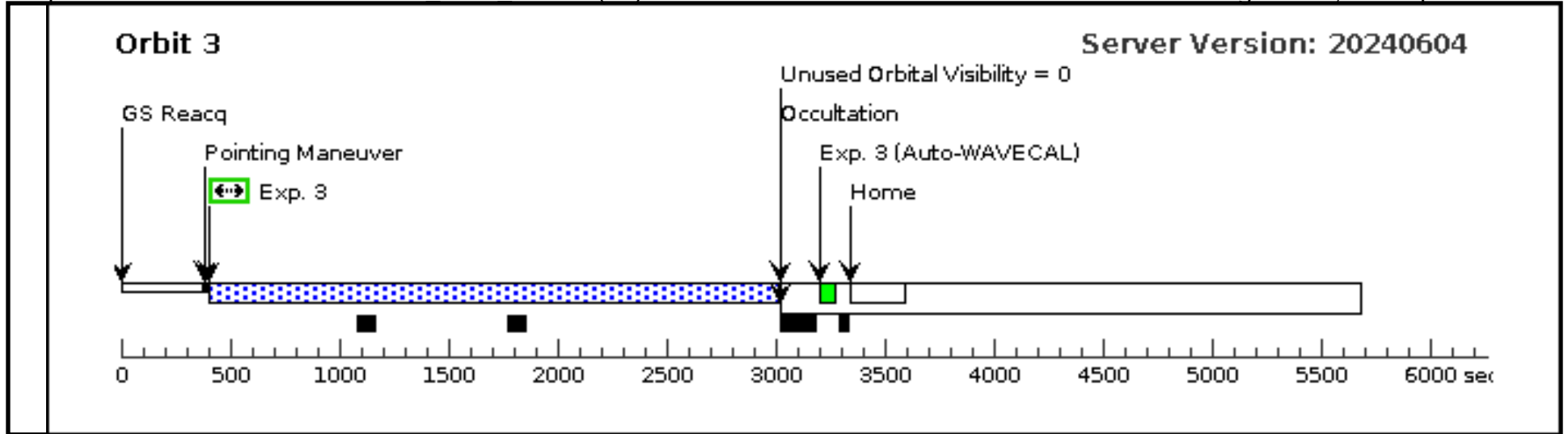


Proposal 17715 - SDSSJ1000+2233 STIS G230L (03) - The curious case of SDSS J1000+2233: a recoiling SMBH, a sub-parsec SM...

Tue Nov 05 23:00:21 GMT 2024

Visit	Proposal 17715, SDSSJ1000+2233_STIS_G230L (03), implementation Diagnostic Status: No Diagnostics Scientific Instruments: STIS/NUV-MAMA, STIS/CCD Special Requirements: AFTER 01 BY 60.0 D TO 365.0 D; ON HOLD FOR 01 <i>On Hold Comments: We will need to determine the slit position angle (to be specified in the visit orientation requirements) should two close nuclei were to be discovered from the WFC3 F606W imaging.</i>									
	Patterns	#	Primary Pattern	Secondary Pattern	Exposures					
	(3)	Pattern Type=STIS-ALONG-SLIT Purpose=DITHER Number Of Points=2 Point Spacing=0.15 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=90.0 Angle Between Sides= Center Pattern=false		(2), (3)					
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	SDSSJ1000+2233	RA: 10 00 21.8000 (150.0908333d) Dec: +22 33 18.60 (22.55517d) Equinox: J2000	Redshift: 0.4189	V=18 NUV=19.72, r=18.44, H=15.8	Reference Frame: ICRS				
	<i>Comments:</i> Category=GALAXY Description=[QSO]									
Exposures	#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	acq	(1) SDSSJ1000+2233 3	STIS/CCD, ACQ, F28X50LP	MIRROR	ACQTYPE=DIFFUSE; SE;			20 Secs (20 Secs) [==>]	[1]
	2	(STIS.sp.19 30948)	(1) SDSSJ1000+2233 3	STIS/NUV-MAMA, TIME-TAG, 52X0.2	G230L 2376 A	BUFFER-TIME=68 5		Pattern 3, Exps 2-2 in SDSSJ1000+2233_ STIS_G230L (03) (3)	647 Secs (1294 Secs) [==>(Pattern 1)] [==>(Pattern 2)]	[1]
	3	(STIS.sp.19 30948)	(1) SDSSJ1000+2233 3	STIS/NUV-MAMA, TIME-TAG, 52X0.2	G230L 2376 A	BUFFER-TIME=68 5		Pattern 3, Exps 3-3 in SDSSJ1000+2233_ STIS_G230L (03) (3)	2600 Secs (5200 Secs) [==>(Pattern 1)] [==>(Pattern 2)]	[2] [3]





Proposal 17715 - PSF-EGGR26 (04) - The curious case of SDSS J1000+2233: a recoiling SMBH, a sub-parsec SMBH binary, or an u...

Tue Nov 05 23:00:21 GMT 2024

Visit	Proposal 17715, PSF-EGGR26 (04), implementation Diagnostic Status: No Diagnostics Scientific Instruments: WFC3/IR, WFC3/UVIS Special Requirements: (none)									
	#	Primary Pattern	Secondary Pattern	Exposures						
Patterns	(1)	Pattern Type=WFC3-IR-DITHER-BOX-MIN Purpose=DITHER Number Of Points=4 Point Spacing=1.716 Line Spacing=1.095 Coordinate Frame=POS-TARG Pattern Orientation=18.528 Angle Between Sides=74.653 Center Pattern=false		(2)						
	(2)	Pattern Type=WFC3-UVIS-DITHER-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.173 Line Spacing=0.112 Coordinate Frame=POS-TARG Pattern Orientation=23.884 Angle Between Sides=81.785 Center Pattern=false		(1)						
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(2)	EGGR-26	RA: 03 55 21.9900 (58.8416250d) Dec: +09 47 18.14 (9.78837d) Equinox: J2000	Proper Motion RA: 173.274 mas/yr Proper Motion Dec: -5.569 mas/yr Epoch of Position: 2000	V=14.506 J=14.831	Reference Frame: ICRS				
<i>Comments:</i> Category=CALIBRATION Description=[POINT SPREAD FUNCTION]										
Exposures	#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	(WFC3UVI S.im.193097 1)	(2) EGGR-26	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F606W	FLASH=20			Pattern 2, Exps 1-1 in PSF-EGGR26 (04) (2)	7 Secs (28 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)]
2		(2) EGGR-26	WFC3/IR, MULTIACCUM, IRSUB512	F110W	NSAMP=10; SAMP-SEQ=STEP2 5			Pattern 1, Exps 2-2 in PSF-EGGR26 (04) (1)	128.439646 Secs X 3 (1541.276 Secs) [=>(Pattern 1, Copy 1)] [=>(Pattern 1, Copy 2)] [=>(Pattern 1, Copy 3)] [=>(Pattern 2, Copy 1)] [=>(Pattern 2, Copy 2)] [=>(Pattern 2, Copy 3)] [=>(Pattern 3, Copy 1)] [=>(Pattern 3, Copy 2)] [=>(Pattern 3, Copy 3)] [=>(Pattern 4, Copy 1)] [=>(Pattern 4, Copy 2)] [=>(Pattern 4, Copy 3)]	[1]

