



17820 - First mass measurement of black holes in a globular cluster

Cycle: 32, Proposal Category: GO

(Availability Mode: SUPPORTED)

INVESTIGATORS

<i>Name</i>	<i>Institution</i>
Casey Lam (PI) (Contact)	Carnegie Institution of Washington
Dr. Kyle Kremer (CoI) (CoPI) (Contact)	University of California - San Diego
Dr. Andrea Bellini (CoI)	Space Telescope Science Institute
Dr. Mattia Libralato (CoI) (ESA Member)	INAF - Istituto di Astrofisica Spaziale e Fisica
Dr. Kareem El-Badry (CoI)	California Institute of Technology

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) NGC-3201	WFC3/UVIS	1	23-Sep-2024 17:00:41.0	yes
02	(1) NGC-3201	WFC3/UVIS	1	23-Sep-2024 17:00:42.0	yes
03	(1) NGC-3201	WFC3/UVIS	1	23-Sep-2024 17:00:43.0	yes
04	(1) NGC-3201	WFC3/UVIS	1	23-Sep-2024 17:00:43.0	yes
05	(1) NGC-3201	WFC3/UVIS	1	23-Sep-2024 17:00:44.0	yes
06	(1) NGC-3201	WFC3/UVIS	1	23-Sep-2024 17:00:45.0	yes
07	(1) NGC-3201	WFC3/UVIS	1	23-Sep-2024 17:00:45.0	yes
08	(1) NGC-3201	WFC3/UVIS	1	23-Sep-2024 17:00:46.0	yes
09	(1) NGC-3201	WFC3/UVIS	1	23-Sep-2024 17:00:46.0	yes
10	(1) NGC-3201	WFC3/UVIS	1	23-Sep-2024 17:00:47.0	yes

10 Total Orbits Used

ABSTRACT

We propose to perform astrometric follow-up of two black hole candidates in the Galactic globular cluster NGC 3201. Globular clusters are dense and dynamic stellar systems that are expected to harbor populations of stellar mass black holes. These black holes play an important role in the evolution of the cluster, as well as sourcing a variety of high-energy phenomena, such as binary black hole mergers. Two black hole candidates were identified through a radial velocity survey of the nearby globular cluster NGC 3201. However, because of a degeneracy between the orbital inclination and mass, only a lower limit on the black hole candidate masses can be derived from the existing radial velocities. In contrast, an astrometric orbit can break this degeneracy and enable a direct mass measurement of these black holes. We propose to use HST WFC3-UVIS imaging to obtain 10 measurements with an astrometric precision of 0.1 - 0.2 mas in order to map out the orbits of the two black hole candidates, measure their orbital inclinations, and most importantly, their masses. This will lead to the first mass measurement of black holes in a globular cluster, which will enable comparisons to the properties of black holes in field environments, insight into gravitational wave sources, and the dynamical evolution of globular clusters.

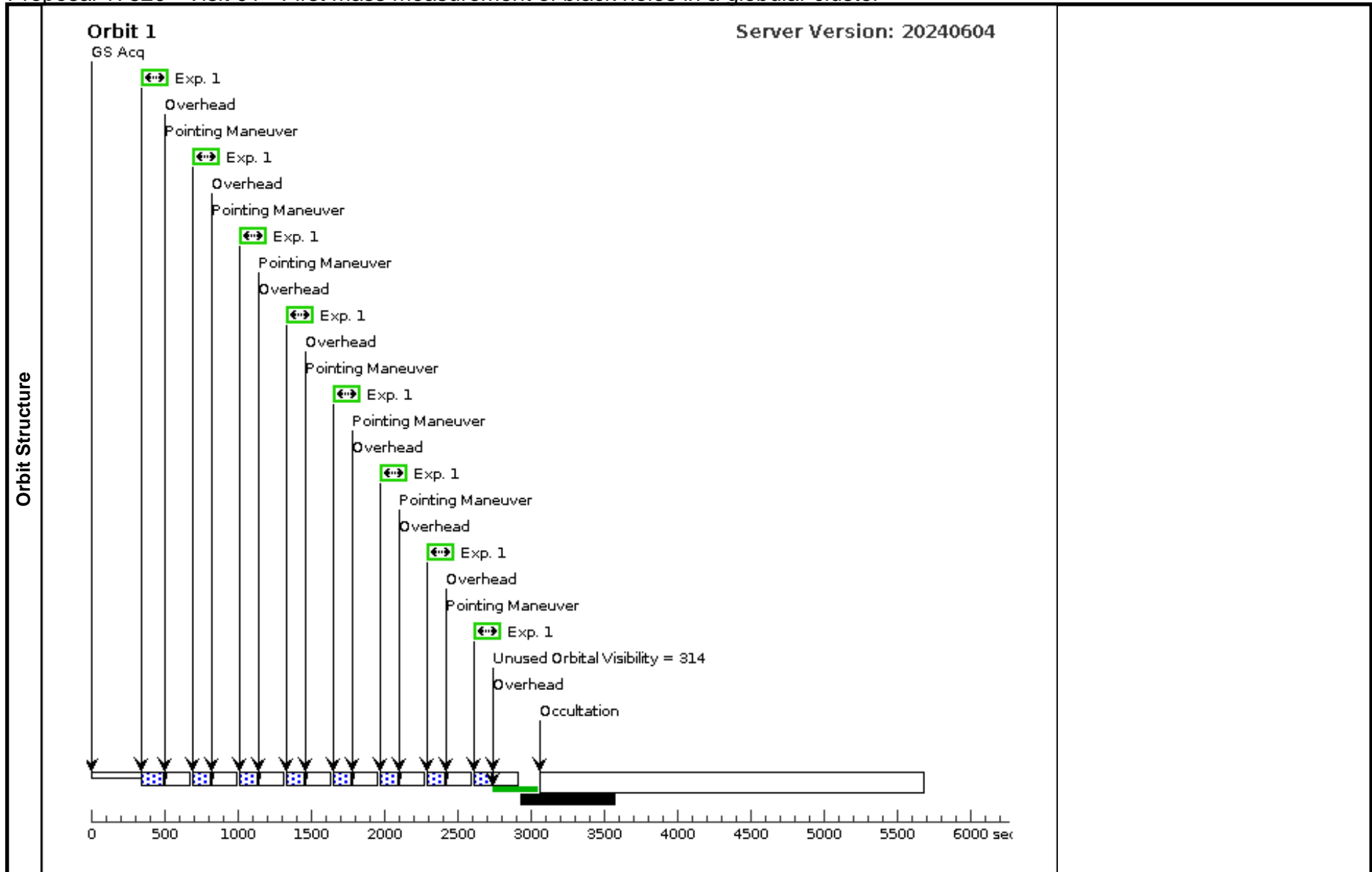
OBSERVING DESCRIPTION

We will obtain 10 epochs of WFC3-UVIS imaging of NGC 3201 BH1 and BH2 in order to measure their orbital motions and their masses. We will use the F606W filter and the UVIS2-2K2C-SUB subarray. For the observations, we will dither small amounts (approximately 10 pixels) to sample the pixel phase, mitigate the effect of bad pixels, and maximize the SNR without saturating our brighter target ($F606W = 17.57$).

Proposal 17820 - Visit 01 - First mass measurement of black holes in a globular cluster

Mon Sep 23 21:00:48 GMT 2024

Visit	Proposal 17820, Visit 01, implementation Diagnostic Status: Warning Scientific Instruments: WFC3/UVIS Special Requirements: BETWEEN 15-NOV-2024:00:00:00 AND 30-NOV-2024:00:00:00									
	(Exposure 1 (Pattern 1, Exps 1-1 in Visit 01)) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser									
Diagnosics										
Patterns	#	Primary Pattern	Secondary Pattern		Exposures					
	(1)	Pattern Type=SPIRAL Purpose=DITHER Number Of Points=8 Point Spacing=0.38 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=45 Angle Between Sides= Center Pattern=false		(1)					
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	NGC-3201	RA: 10 17 36.5856 (154.4024400d) Dec: -46 25 14.20 (-46.42061d) Equinox: J2000	Parallax: 2.22E-4" Epoch of Position: 2000	V=18.6	Reference Frame: ICRS				
<i>Comments:</i> Category=STELLAR CLUSTER Description=[GLOBULAR CLUSTER]										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	(1) NGC-3201	(1) NGC-3201	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F606W	FLASH=40		Pattern 1, Exps 1-1 i n Visit 01 (1)	120 Secs (960 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)] [=>(Pattern 5)] [=>(Pattern 6)] [=>(Pattern 7)] [=>(Pattern 8)]	[1]



Proposal 17820 - Visit 02 - First mass measurement of black holes in a globular cluster

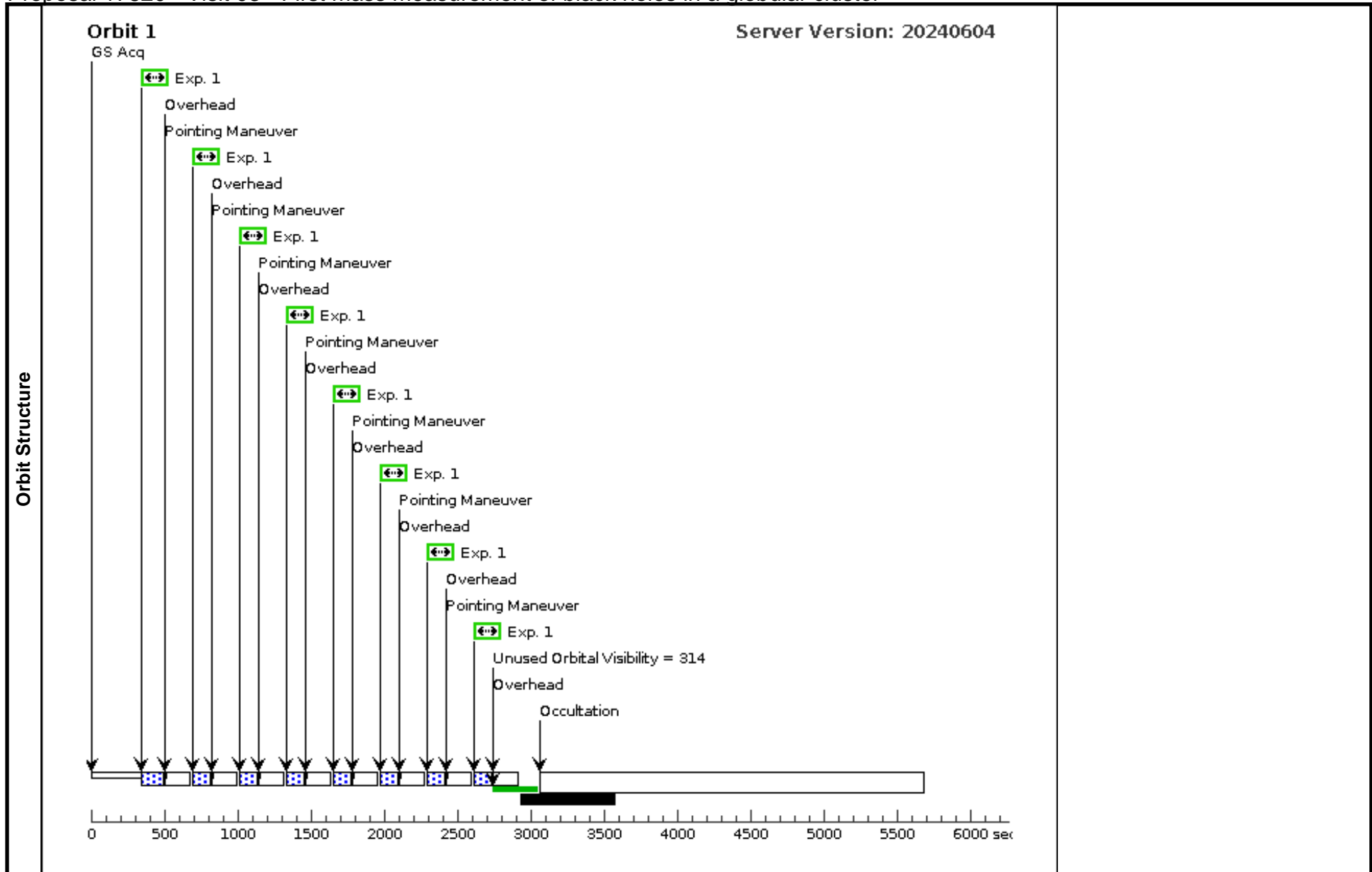
Mon Sep 23 21:00:48 GMT 2024

Visit	Proposal 17820, Visit 02, implementation Diagnostic Status: Warning Scientific Instruments: WFC3/UVIS Special Requirements: BETWEEN 12-DEC-2024:00:00:00 AND 16-DEC-2024:00:00:00									
	(Exposure 1 (Pattern 1, Exps 1-1 in Visit 02)) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser									
Diagnosics										
Patterns	#	Primary Pattern		Secondary Pattern		Exposures				
	(1)	Pattern Type=SPIRAL Purpose=DITHER Number Of Points=8 Point Spacing=0.38 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=45 Angle Between Sides= Center Pattern=false			(1)				
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	NGC-3201	RA: 10 17 36.5856 (154.4024400d) Dec: -46 25 14.20 (-46.42061d) Equinox: J2000	Parallax: 2.22E-4" Epoch of Position: 2000	V=18.6	Reference Frame: ICRS				
Comments: Category=STELLAR CLUSTER Description=[GLOBULAR CLUSTER]										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	(1) NGC-3201	(1) NGC-3201	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F606W	FLASH=40		Pattern 1, Exps 1-1 i n Visit 02 (1)	120 Secs (960 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)] [=>(Pattern 5)] [=>(Pattern 6)] [=>(Pattern 7)] [=>(Pattern 8)]	[1]

Proposal 17820 - Visit 03 - First mass measurement of black holes in a globular cluster

Mon Sep 23 21:00:48 GMT 2024

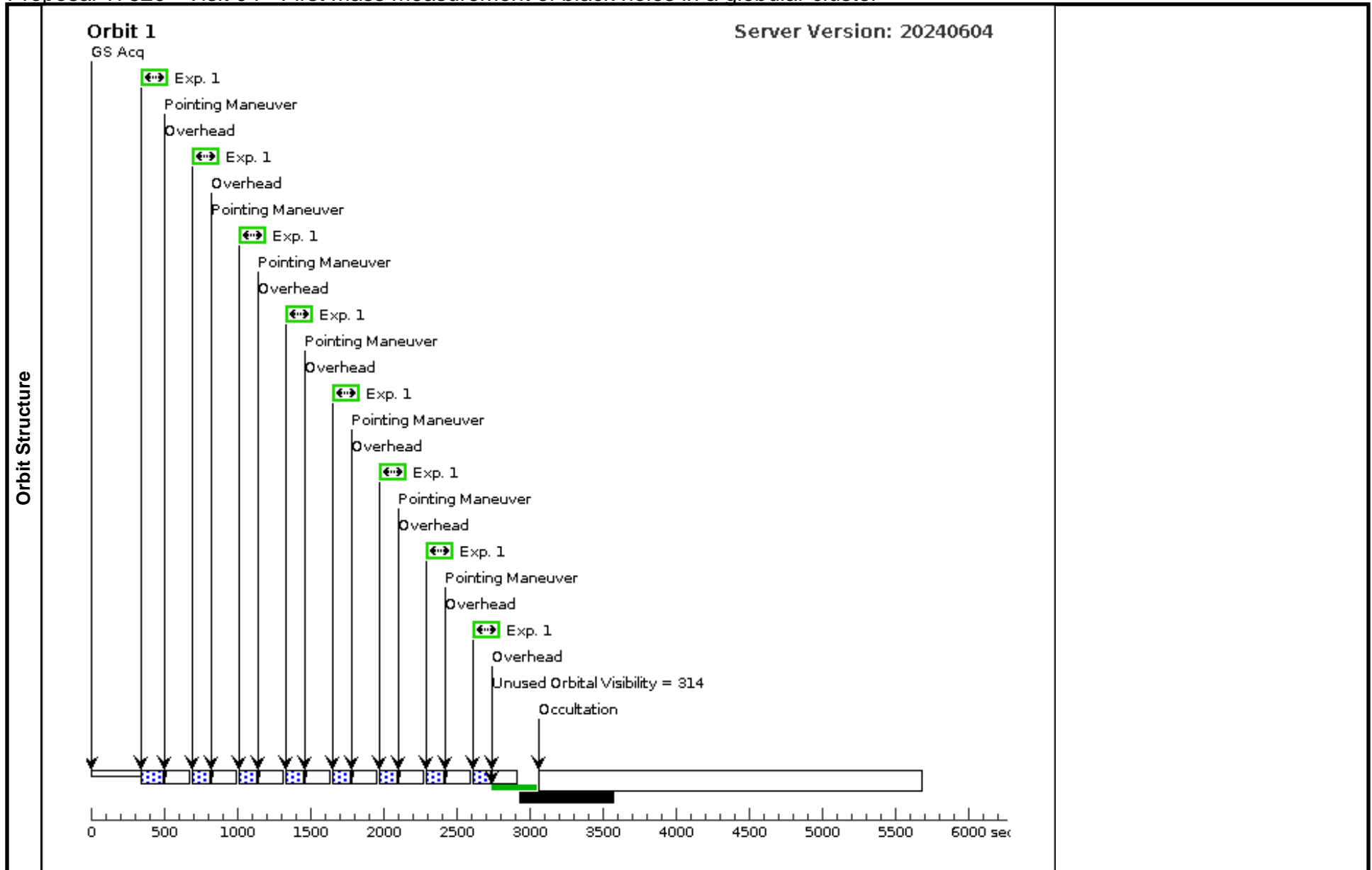
Visit	Proposal 17820, Visit 03, implementation Diagnostic Status: Warning Scientific Instruments: WFC3/UVIS Special Requirements: BETWEEN 07-JAN-2025:00:00:00 AND 11-JAN-2025:00:00:00									
	(Exposure 1 (Pattern 1, Exps 1-1 in Visit 03)) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser									
Diagnosics										
Patterns	#	Primary Pattern	Secondary Pattern		Exposures					
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Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	NGC-3201	RA: 10 17 36.5856 (154.4024400d) Dec: -46 25 14.20 (-46.42061d) Equinox: J2000	Parallax: 2.22E-4" Epoch of Position: 2000	V=18.6	Reference Frame: ICRS				
<i>Comments:</i> Category=STELLAR CLUSTER Description=[GLOBULAR CLUSTER]										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	(1) NGC-3201	(1) NGC-3201	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F606W	FLASH=40		Pattern 1, Exps 1-1 i n Visit 03 (1)	120 Secs (960 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)] [=>(Pattern 5)] [=>(Pattern 6)] [=>(Pattern 7)] [=>(Pattern 8)]	[1]



Proposal 17820 - Visit 04 - First mass measurement of black holes in a globular cluster

Mon Sep 23 21:00:48 GMT 2024

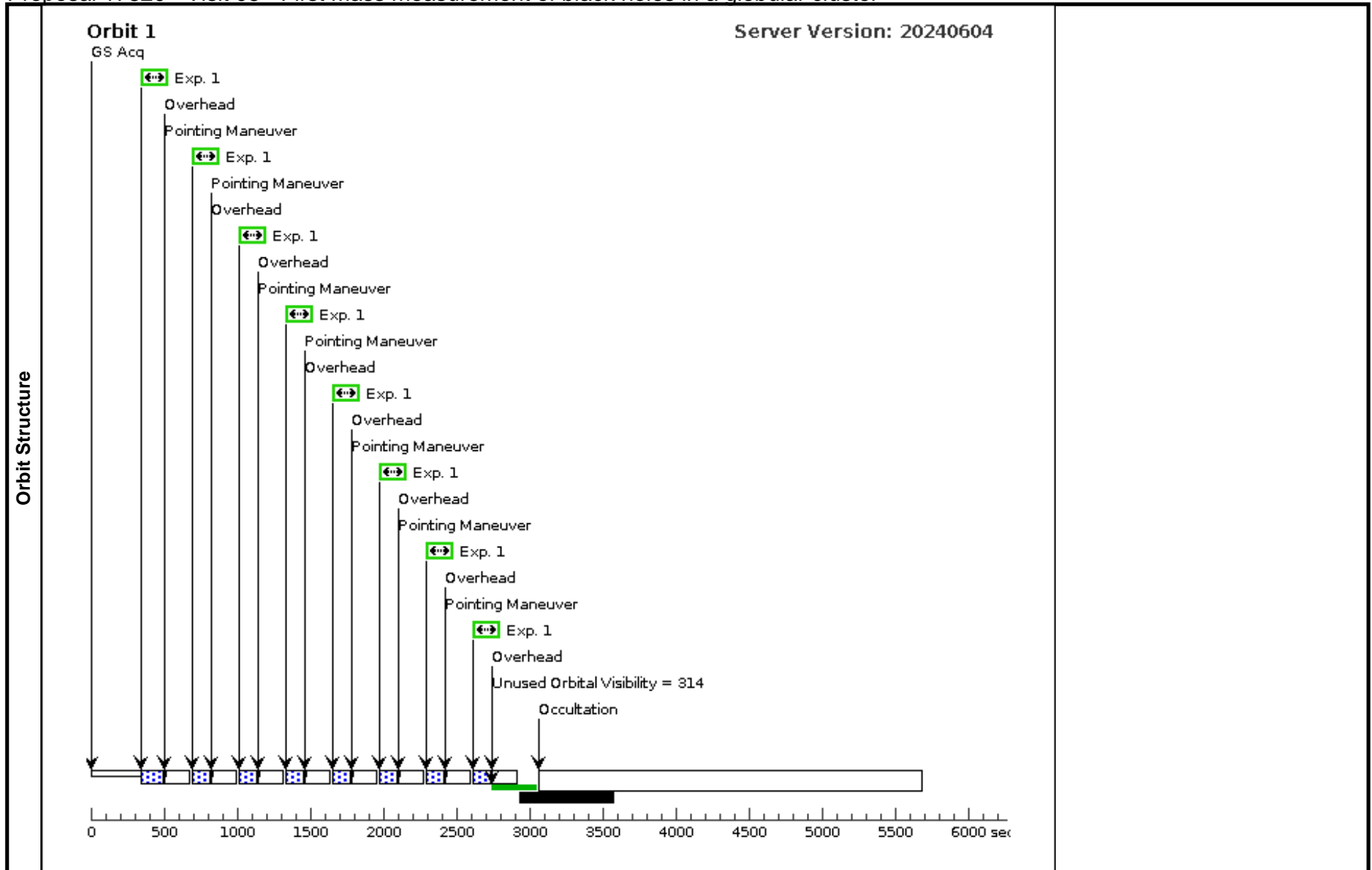
Visit	Proposal 17820, Visit 04, implementation Diagnostic Status: Warning Scientific Instruments: WFC3/UVIS Special Requirements: BETWEEN 31-JAN-2025:00:00:00 AND 04-FEB-2025:00:00:00									
	(Exposure 1 (Pattern 1, Exps 1-1 in Visit 04)) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser									
Diagnosics										
Patterns	#	Primary Pattern		Secondary Pattern		Exposures				
	(1)	Pattern Type=SPIRAL Purpose=DITHER Number Of Points=8 Point Spacing=0.38 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=45 Angle Between Sides= Center Pattern=false			(1)				
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	NGC-3201	RA: 10 17 36.5856 (154.4024400d) Dec: -46 25 14.20 (-46.42061d) Equinox: J2000	Parallax: 2.22E-4" Epoch of Position: 2000	V=18.6	Reference Frame: ICRS				
Comments: Category=STELLAR CLUSTER Description=[GLOBULAR CLUSTER]										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	(1) NGC-3201	(1) NGC-3201	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F606W	FLASH=40		Pattern 1, Exps 1-1 in Visit 04 (1)	120 Secs (960 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)] [=>(Pattern 5)] [=>(Pattern 6)] [=>(Pattern 7)] [=>(Pattern 8)]	[1]



Proposal 17820 - Visit 05 - First mass measurement of black holes in a globular cluster

Mon Sep 23 21:00:48 GMT 2024

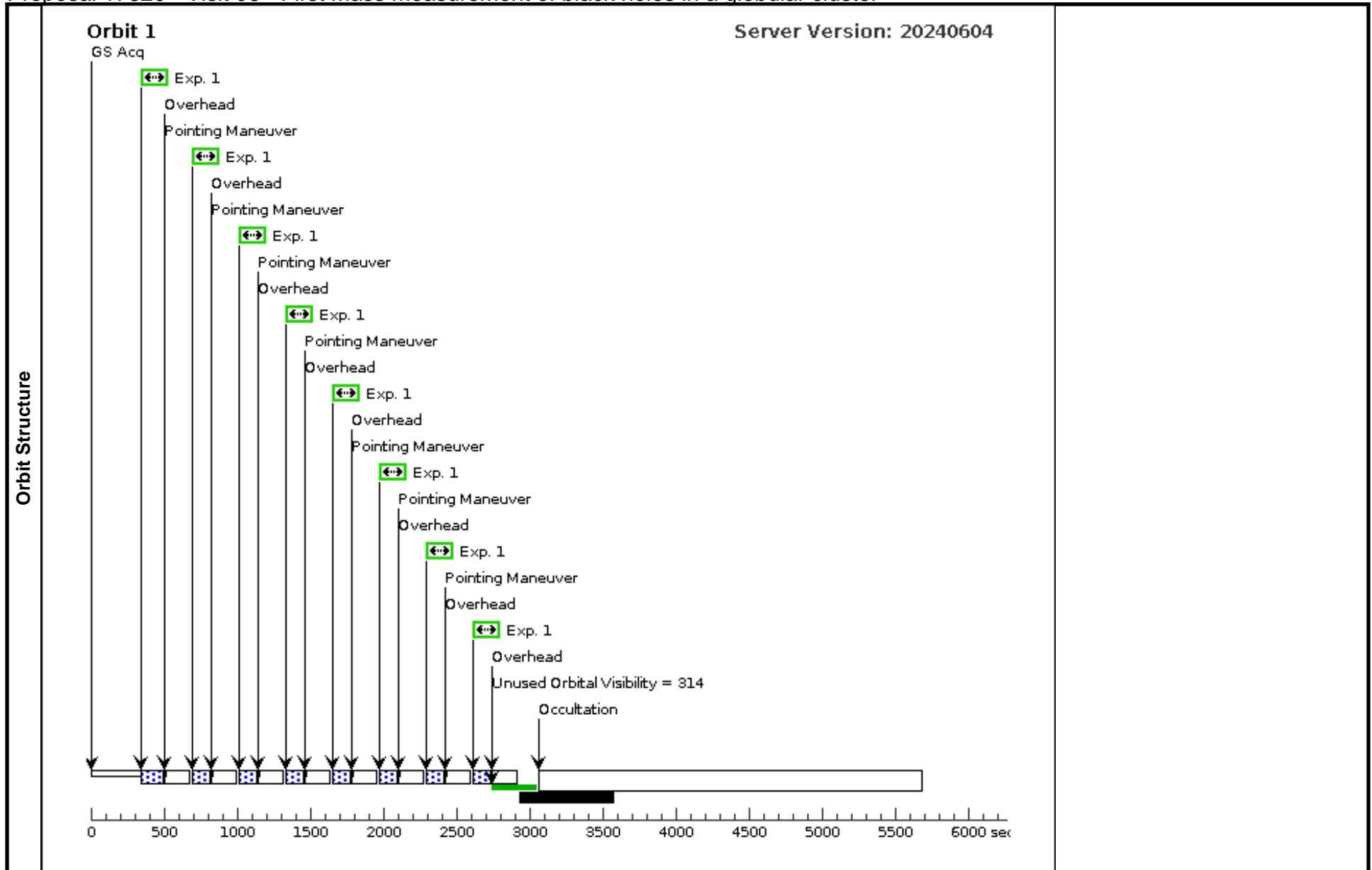
Visit	Proposal 17820, Visit 05, implementation Diagnostic Status: Warning Scientific Instruments: WFC3/UVIS Special Requirements: BETWEEN 20-MAR-2025:00:00:00 AND 24-MAR-2025:00:00:00									
	(Exposure 1 (Pattern 1, Exps 1-1 in Visit 05)) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser									
Diagnosics										
Patterns	#	Primary Pattern	Secondary Pattern		Exposures					
	(1)	Pattern Type=SPIRAL Purpose=DITHER Number Of Points=8 Point Spacing=0.38 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=45 Angle Between Sides= Center Pattern=false		(1)					
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	NGC-3201	RA: 10 17 36.5856 (154.4024400d) Dec: -46 25 14.20 (-46.42061d) Equinox: J2000	Parallax: 2.22E-4" Epoch of Position: 2000	V=18.6	Reference Frame: ICRS				
<i>Comments:</i> Category=STELLAR CLUSTER Description=[GLOBULAR CLUSTER]										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	(1) NGC-3201	(1) NGC-3201	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F606W	FLASH=40		Pattern 1, Exps 1-1 i n Visit 05 (1)	120 Secs (960 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)] [=>(Pattern 5)] [=>(Pattern 6)] [=>(Pattern 7)] [=>(Pattern 8)]	[1]



Proposal 17820 - Visit 06 - First mass measurement of black holes in a globular cluster

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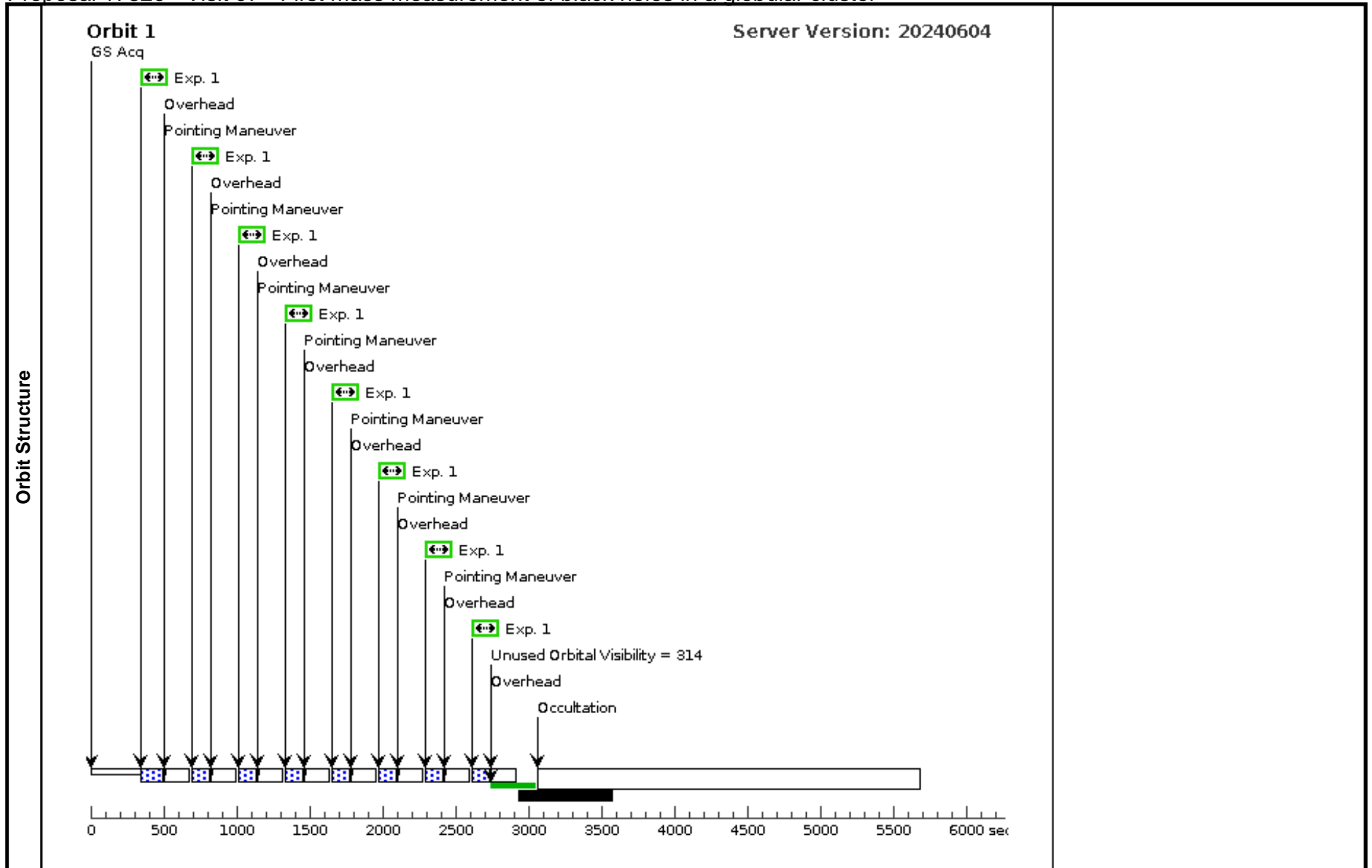
Visit	Proposal 17820, Visit 06, implementation Diagnostic Status: Warning Scientific Instruments: WFC3/UVIS Special Requirements: BETWEEN 03-JUN-2025:00:00:00 AND 07-JUN-2025:00:00:00									
	(Exposure 1 (Pattern 1, Exps 1-1 in Visit 06)) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser									
Diagnosics										
Patterns	#	Primary Pattern	Secondary Pattern		Exposures					
	(1)	Pattern Type=SPIRAL Purpose=DITHER Number Of Points=8 Point Spacing=0.38 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=45 Angle Between Sides= Center Pattern=false		(1)					
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	NGC-3201	RA: 10 17 36.5856 (154.4024400d) Dec: -46 25 14.20 (-46.42061d) Equinox: J2000	Parallax: 2.22E-4" Epoch of Position: 2000	V=18.6	Reference Frame: ICRS				
<i>Comments:</i> Category=STELLAR CLUSTER Description=[GLOBULAR CLUSTER]										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	(1) NGC-3201	(1) NGC-3201	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F606W	FLASH=40		Pattern 1, Exps 1-1 i n Visit 06 (1)	120 Secs (960 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)] [=>(Pattern 5)] [=>(Pattern 6)] [=>(Pattern 7)] [=>(Pattern 8)]	[1]



Proposal 17820 - Visit 07 - First mass measurement of black holes in a globular cluster

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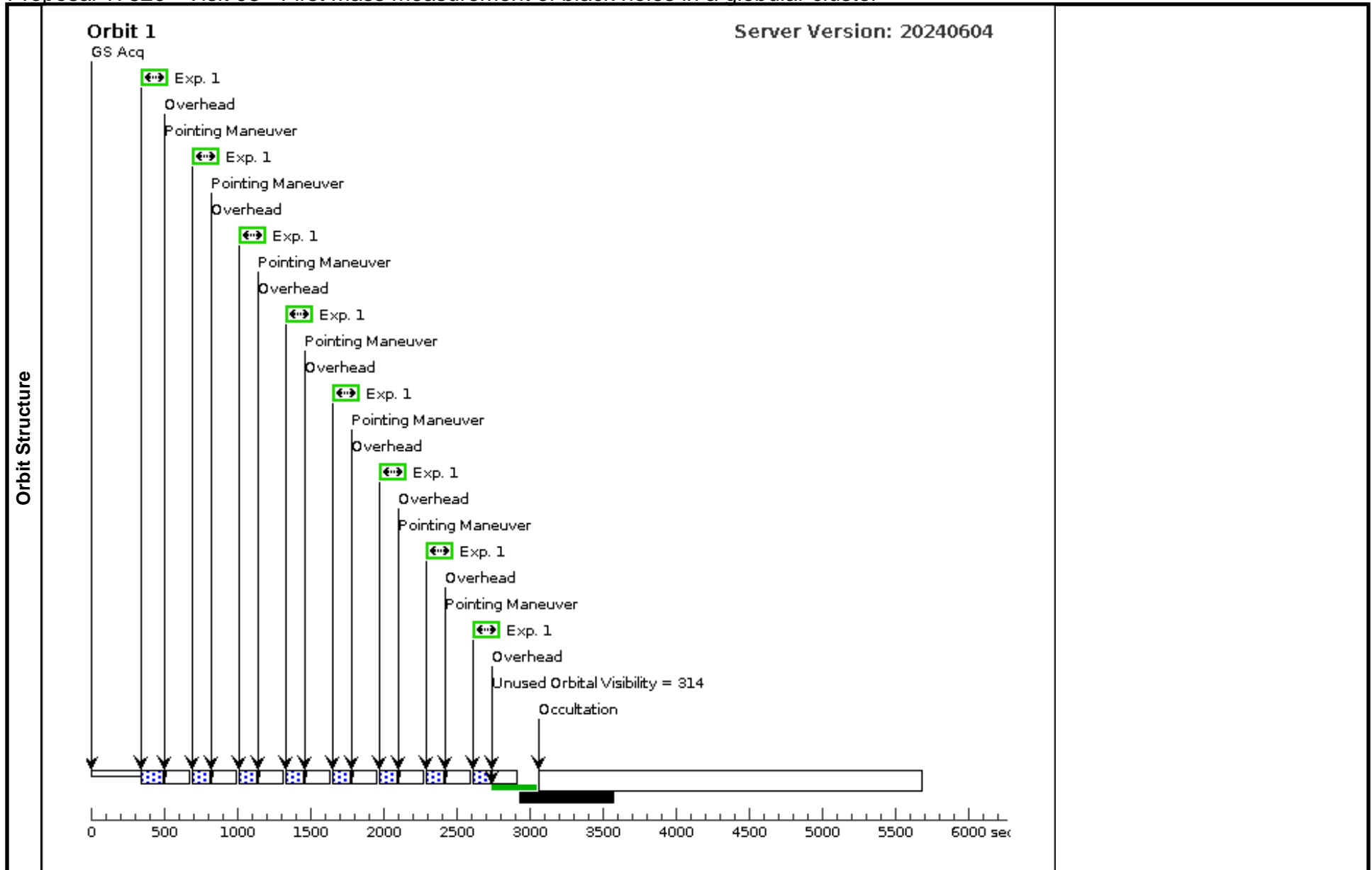
Visit	Proposal 17820, Visit 07, implementation Diagnostic Status: Warning Scientific Instruments: WFC3/UVIS Special Requirements: BETWEEN 20-JUL-2025:00:00:00 AND 24-JUL-2025:00:00:00									
	(Exposure 1 (Pattern 1, Exps 1-1 in Visit 07)) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser									
Diagnosics										
Patterns	#	Primary Pattern	Secondary Pattern		Exposures					
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Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	NGC-3201	RA: 10 17 36.5856 (154.4024400d) Dec: -46 25 14.20 (-46.42061d) Equinox: J2000	Parallax: 2.22E-4" Epoch of Position: 2000	V=18.6	Reference Frame: ICRS				
Comments: Category=STELLAR CLUSTER Description=[GLOBULAR CLUSTER]										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	(1) NGC-3201	(1) NGC-3201	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F606W	FLASH=40		Pattern 1, Exps 1-1 i n Visit 07 (1)	120 Secs (960 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)] [=>(Pattern 5)] [=>(Pattern 6)] [=>(Pattern 7)] [=>(Pattern 8)]	[1]



Proposal 17820 - Visit 08 - First mass measurement of black holes in a globular cluster

Mon Sep 23 21:00:48 GMT 2024

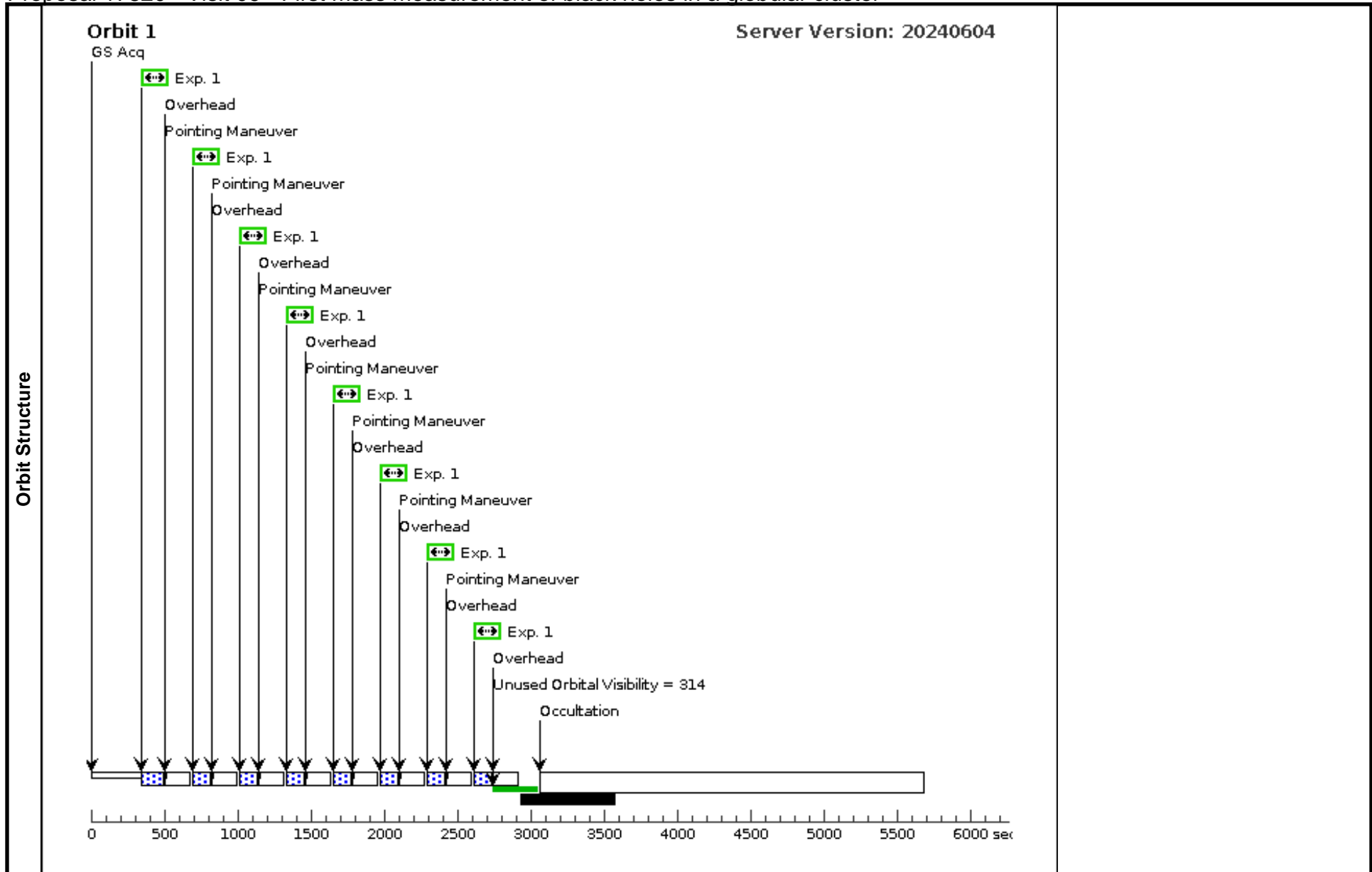
Visit	Proposal 17820, Visit 08, implementation Diagnostic Status: Warning Scientific Instruments: WFC3/UVIS Special Requirements: BETWEEN 04-AUG-2025:00:00:00 AND 09-AUG-2025:00:00:00									
	(Exposure 1 (Pattern 1, Exps 1-1 in Visit 08)) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser									
Diagnosics										
Patterns	#	Primary Pattern	Secondary Pattern		Exposures					
	(1)	Pattern Type=SPIRAL Purpose=DITHER Number Of Points=8 Point Spacing=0.38 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=45 Angle Between Sides= Center Pattern=false		(1)					
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	NGC-3201	RA: 10 17 36.5856 (154.4024400d) Dec: -46 25 14.20 (-46.42061d) Equinox: J2000	Parallax: 2.22E-4" Epoch of Position: 2000	V=18.6	Reference Frame: ICRS				
<i>Comments:</i> Category=STELLAR CLUSTER Description=[GLOBULAR CLUSTER]										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	(1) NGC-3201	(1) NGC-3201	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F606W	FLASH=40		Pattern 1, Exps 1-1 i n Visit 08 (1)	120 Secs (960 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)] [=>(Pattern 5)] [=>(Pattern 6)] [=>(Pattern 7)] [=>(Pattern 8)]	[1]



Proposal 17820 - Visit 09 - First mass measurement of black holes in a globular cluster

Mon Sep 23 21:00:48 GMT 2024

Visit	Proposal 17820, Visit 09, implementation Diagnostic Status: Warning Scientific Instruments: WFC3/UVIS Special Requirements: BETWEEN 01-NOV-2025:00:00:00 AND 04-NOV-2025:00:00:00									
	(Exposure 1 (Pattern 1, Exps 1-1 in Visit 09)) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser									
Diagnosics										
Patterns	#	Primary Pattern	Secondary Pattern		Exposures					
	(1)	Pattern Type=SPIRAL Purpose=DITHER Number Of Points=8 Point Spacing=0.38 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=45 Angle Between Sides= Center Pattern=false		(1)					
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	NGC-3201	RA: 10 17 36.5856 (154.4024400d) Dec: -46 25 14.20 (-46.42061d) Equinox: J2000	Parallax: 2.22E-4" Epoch of Position: 2000	V=18.6	Reference Frame: ICRS				
<i>Comments:</i> Category=STELLAR CLUSTER Description=[GLOBULAR CLUSTER]										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	(1) NGC-3201	(1) NGC-3201	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F606W	FLASH=40		Pattern 1, Exps 1-1 i n Visit 09 (1)	120 Secs (960 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)] [=>(Pattern 5)] [=>(Pattern 6)] [=>(Pattern 7)] [=>(Pattern 8)]	[1]



Proposal 17820 - Visit 10 - First mass measurement of black holes in a globular cluster

Mon Sep 23 21:00:48 GMT 2024

Visit	Proposal 17820, Visit 10, implementation Diagnostic Status: Warning Scientific Instruments: WFC3/UVIS Special Requirements: BETWEEN 10-NOV-2025:00:00:00 AND 14-NOV-2025:00:00:00									
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Diagnosics										
Patterns	#	Primary Pattern	Secondary Pattern		Exposures					
	(1)	Pattern Type=SPIRAL Purpose=DITHER Number Of Points=8 Point Spacing=0.38 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=45 Angle Between Sides= Center Pattern=false		(1)					
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	NGC-3201	RA: 10 17 36.5856 (154.4024400d) Dec: -46 25 14.20 (-46.42061d) Equinox: J2000	Parallax: 2.22E-4" Epoch of Position: 2000	V=18.6	Reference Frame: ICRS				
<i>Comments:</i> Category=STELLAR CLUSTER Description=[GLOBULAR CLUSTER]										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	(1) NGC-3201	(1) NGC-3201	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F606W	FLASH=40		Pattern 1, Exps 1-1 in Visit 10 (1)	120 Secs (960 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)] [=>(Pattern 5)] [=>(Pattern 6)] [=>(Pattern 7)] [=>(Pattern 8)]	[1]

