



## 16658 - Hunting for Black Holes with Astrometric Microlensing

Cycle: 29, Proposal Category: GO

(Availability Mode: SUPPORTED)

### INVESTIGATORS

<i>Name</i>	<i>Institution</i>
<b>Dr. Jessica Ryan Lu (PI) (Contact)</b>	<b>University of California - Berkeley</b>
Dr. William Anthony Dawson (CoI)	Lawrence Livermore National Laboratory
Casey Lam (CoI)	Carnegie Institution of Washington
Dr. Peter E. Nugent (CoI)	Lawrence Berkeley National Laboratory
Michael Medford (CoI)	University of California - Berkeley
Dr. Nathan Golovich (CoI)	Lawrence Livermore National Laboratory

### 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	(2) OB230215	WFC3/UVIS	1	20-Feb-2025 14:00:47.0	yes
02	(2) OB230215	WFC3/UVIS	1	20-Feb-2025 14:00:48.0	yes
52	(2) OB230215	WFC3/UVIS	1	20-Feb-2025 14:00:49.0	yes
03	(2) OB230215	WFC3/UVIS	1	20-Feb-2025 14:00:50.0	yes
04	(2) OB230215	WFC3/UVIS	1	20-Feb-2025 14:00:50.0	yes
05	(2) OB230215	WFC3/UVIS	1	20-Feb-2025 14:00:51.0	yes

6 Total Orbits Used

### ABSTRACT

Proposal 16658 (STScI Edit Number: 7, Created: Thursday, February 20, 2025, 2:00:51PM Eastern Standard Time) - Overview

Although there are likely  $10^7 - 10^9$  stellar mass black holes (BHs) in the Milky Way, only a handful have been detected in the Universe, all in X-ray binaries or BH-BH mergers; no isolated BHs have been definitively detected. A census of isolated BHs will provide important constraints on stellar evolution, the Milky Way BH mass function, supernovae physics, and BH/neutron star formation. Gravitational microlensing is ideal for finding isolated BHs, as properties of the lens can be inferred from changes in the brightness and position of a background star. By combining both the photometric and astrometric microlensing signal, we can directly determine the lens mass. We propose to use HST to measure the astrometric shift of 4 likely BH microlensing candidates. Combined with other ongoing measurements, this will allow us to constrain the number of BHs in the Milky Way to better than 50%, a major improvement over the current orders of magnitude uncertainty. This will also enable the first constraints on the Milky Way BH mass function, binarity, and kick velocities.

### **OBSERVING DESCRIPTION**

Four black hole candidates will be selected from photometric microlensing surveys for follow-up astrometric observations with HST WFC3-UVIS. The 4 targets will be non-disruptive ToOs and, once selected, 5 HST measurements will be obtained spread as evenly as possible over Cycle 29. The targets will be changing brightness, thus exposure times and number of exposures will be adjusted prior to each new observation. Further astrometric follow-up will be obtained in Cycles 30 and 31.

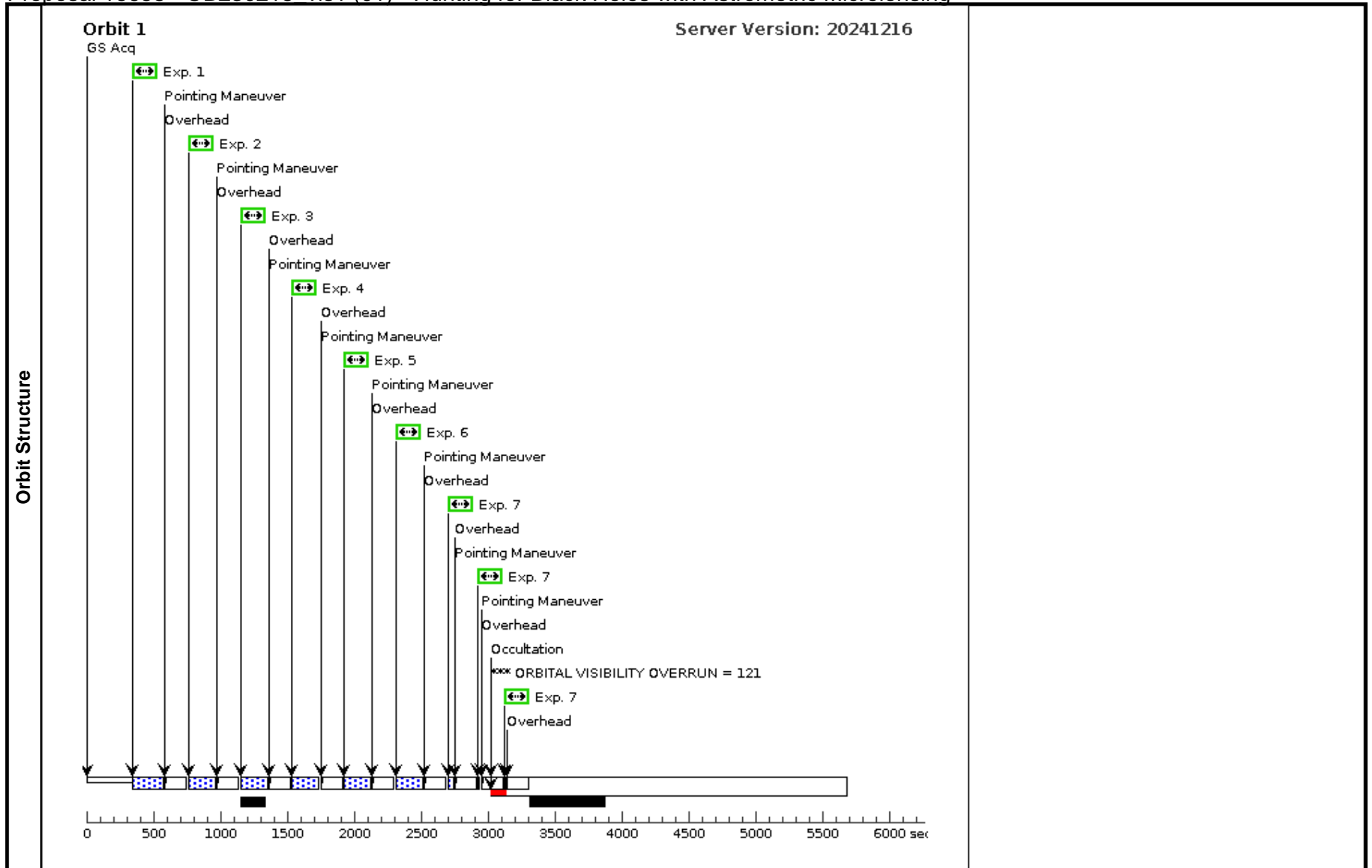
Each target observation consists of  $>5$  dither positions (to maximize pixel phase coverage and thus astrometric precision) in a single orbit. The exposure times will be chosen in order to not saturate the source star or any bright neighbor stars within a few arcseconds. We will observe using 2k x 2k sub-array mode as the astrometric reference stars are those closest to the target and we would like to minimize the astrometric impacts of CTE.

In order to maximize observability and time sampling throughout the year, we have placed no restrictions on roll angle.

Proposal 16658 - OB230215 vis1 (01) - Hunting for Black Holes with Astrometric Microlensing

Thu Feb 20 19:00:51 GMT 2025

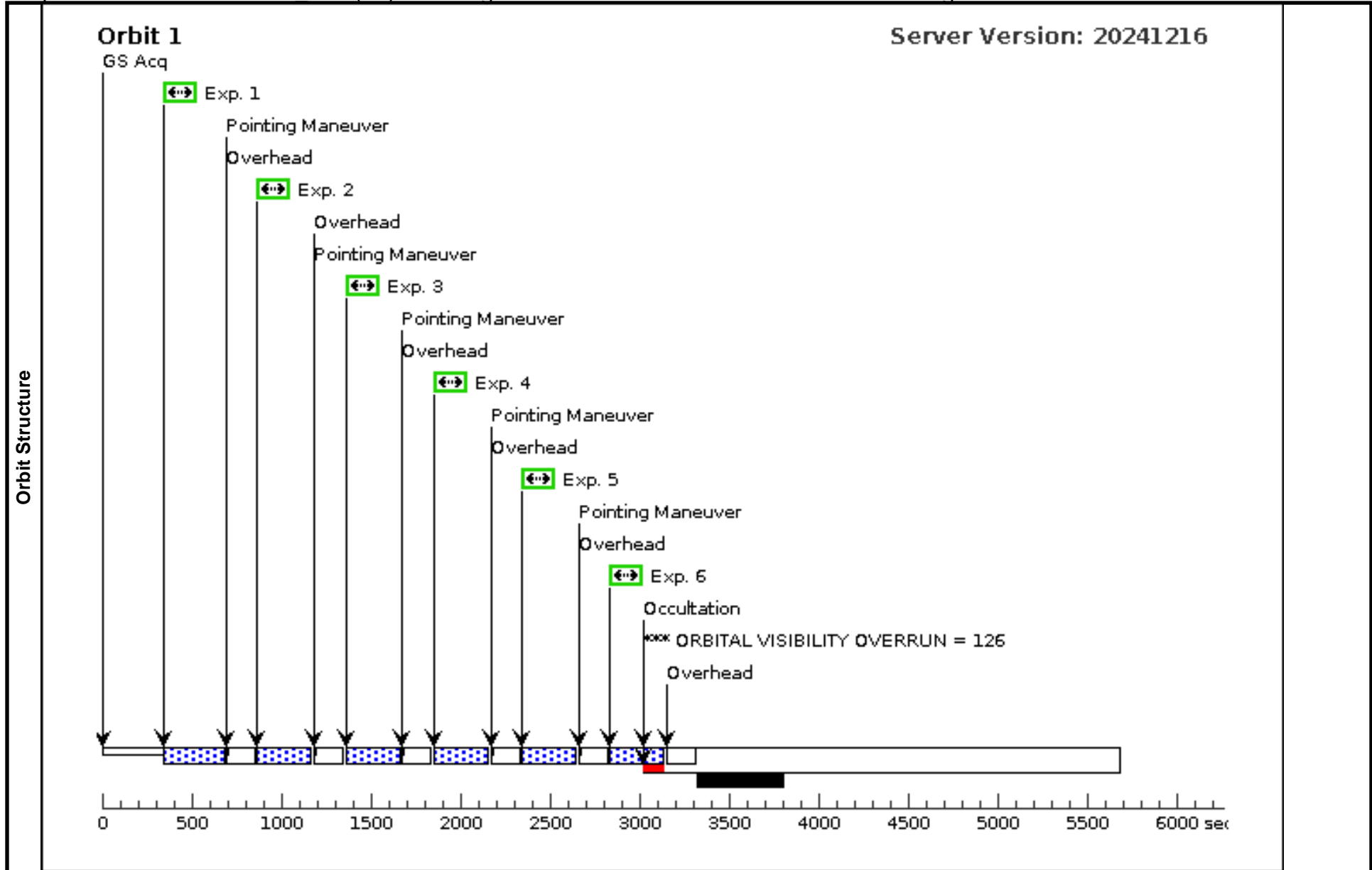
<b>Visit</b>	Proposal 16658, OB230215_vis1 (01), completed Diagnostic Status: Warning Scientific Instruments: WFC3/UVIS Special Requirements: ORIENT 83.25D TO 92.44 D; BETWEEN 19-JUL-2023:00:00:00 AND 23-JUL-2023:00:00:00; TOO RESPONSE TIME 14.0D									
	(OB230215_vis1 (01)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN (Exposure 7 (Pattern 3, Exps 7-7 in OB230215_vis1 (01))) Warning (Form): FLASH level may be too low for this exposure or a short subexposure. See extended explanation in the diagnostic browser									
<b>Diagnosics</b>										
<b>Patterns</b>	#	Primary Pattern	Secondary Pattern	Exposures						
	(3)	Pattern Type=WFC3-UVIS-DITHER- LINE-3PT Purpose=DITHER Number Of Points=3 Point Spacing=0.135 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=46.84 Angle Between Sides= Center Pattern=false		(7)					
<b>Fixed Targets</b>	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(2)	OB230215	RA: 18 20 20.3700 (275.0848750d) Dec: -21 35 14.90 (-21.58747d) Equinox: J2000		V=21.09+/-0.1 I-Mag 18.37	Reference Frame: ICRS				
	Comments: Category=STELLAR CLUSTER Description=[BULGE, GRAVITATIONAL LENS] Extended=NO									
<b>Exposures</b>	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1		(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.0000,0 .0000		198 Secs (198 Secs) [==>]	[1]
	2		(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.0927,0 .3376		198 Secs (198 Secs) [==>]	[1]
	3		(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.1851,0 .1978		198 Secs (198 Secs) [==>]	[1]
	4		(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.2382,0 .5130		198 Secs (198 Secs) [==>]	[1]
	5		(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.3305,0 .3732		198 Secs (198 Secs) [==>]	[1]
	6		(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.5024,0 .5171		198 Secs (198 Secs) [==>]	[1]
	7		(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F606W	FLASH=14		Pattern 3, Exps 7-7 in OB230215_vis1 (01) (3)	14 Secs (42 Secs) [==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)]	[1]



Proposal 16658 - OB230215\_vis2 (02) - Hunting for Black Holes with Astrometric Microlensing

Thu Feb 20 19:00:51 GMT 2025

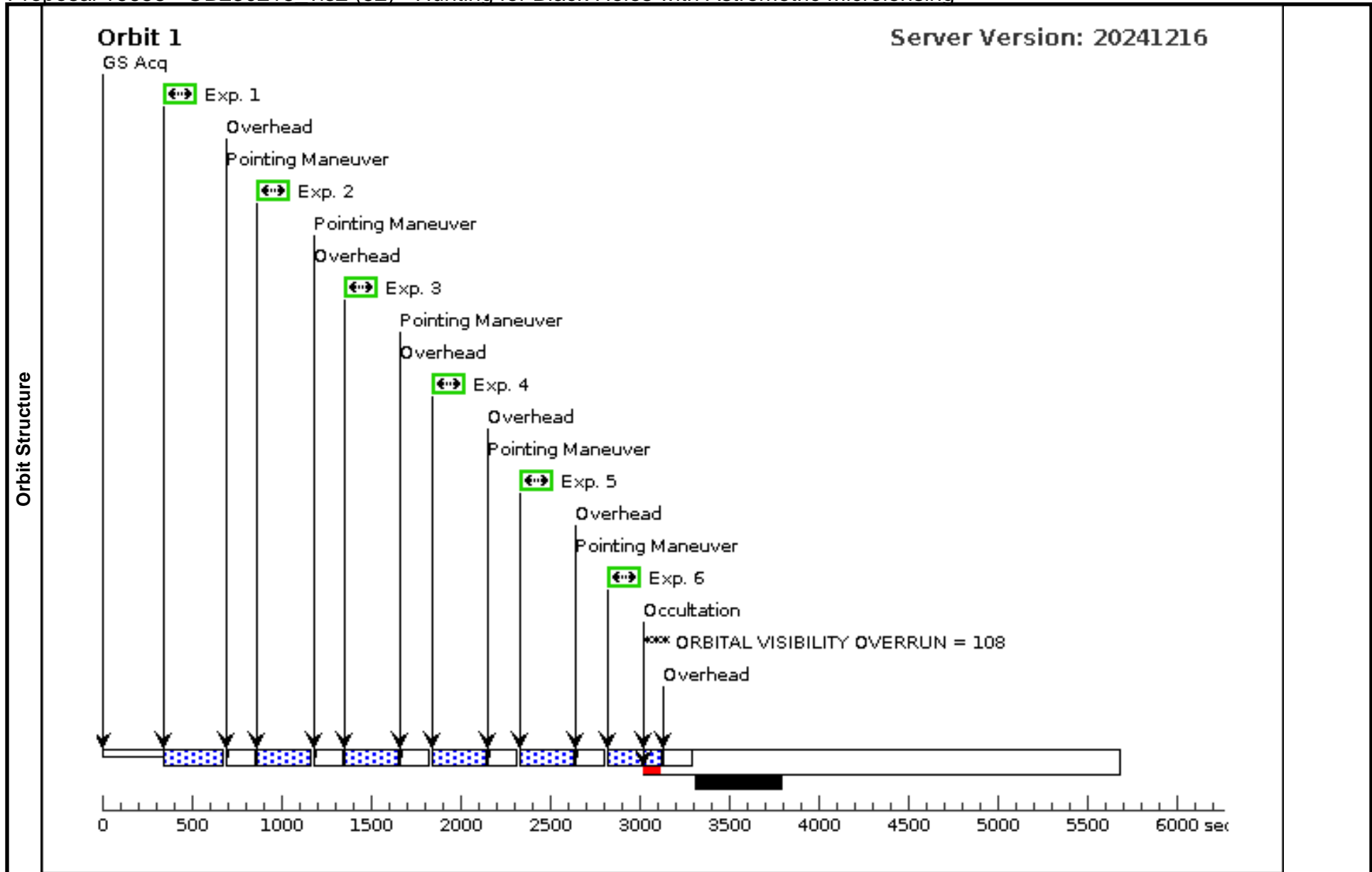
<b>Visit</b>	<b>Proposal 16658, OB230215_vis2 (02), failed</b> <b>Diagnostic Status: Warning</b> Scientific Instruments: WFC3/UVIS Special Requirements: SAME ORIENT AS 01; AFTER 01 BY 81 D TO 95 D																																																																										
	(OB230215_vis2 (02)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN (OB230215_vis2 (02)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.																																																																										
<b>Fixed Targets</b>	<table border="1"> <thead> <tr> <th>#</th> <th>Name</th> <th>Target Coordinates</th> <th>Targ. Coord. Corrections</th> <th>Fluxes</th> <th>Miscellaneous</th> </tr> </thead> <tbody> <tr> <td>(2)</td> <td>OB230215</td> <td>RA: 18 20 20.3700 (275.0848750d) Dec: -21 35 14.90 (-21.58747d) Equinox: J2000</td> <td></td> <td>V=21.09+/-0.1 I-Mag 18.37</td> <td>Reference Frame: ICRS</td> </tr> </tbody> </table>	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous	(2)	OB230215	RA: 18 20 20.3700 (275.0848750d) Dec: -21 35 14.90 (-21.58747d) Equinox: J2000		V=21.09+/-0.1 I-Mag 18.37	Reference Frame: ICRS	Comments: Category=STELLAR CLUSTER Description=[BULGE, GRAVITATIONAL LENS] Extended=NO																																																													
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<b>Exposures</b>	<table border="1"> <thead> <tr> <th>#</th> <th>Label</th> <th>Target</th> <th>Config,Mode,Aperture</th> <th>Spectral Els.</th> <th>Opt. Params.</th> <th>Special Reqs.</th> <th>Groups</th> <th>Exp. Time (Total)/[Actual Dur.]</th> <th>Orbit</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>(2) OB230215</td> <td>WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB</td> <td>F814W</td> <td>FLASH=15</td> <td>POS TARG 0.0000,0 .0000</td> <td></td> <td></td> <td>306 Secs (306 Secs) [==&gt;]</td> <td>[1]</td> </tr> <tr> <td>2</td> <td>(2) OB230215</td> <td>WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB</td> <td>F814W</td> <td>FLASH=15</td> <td>POS TARG 0.0927,0 .3376</td> <td></td> <td></td> <td>306 Secs (306 Secs) [==&gt;]</td> <td>[1]</td> </tr> <tr> <td>3</td> <td>(2) OB230215</td> <td>WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB</td> <td>F814W</td> <td>FLASH=15</td> <td>POS TARG 0.1851,0 .1978</td> <td></td> <td></td> <td>306 Secs (306 Secs) [==&gt;]</td> <td>[1]</td> </tr> <tr> <td>4</td> <td>(2) OB230215</td> <td>WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB</td> <td>F814W</td> <td>FLASH=15</td> <td>POS TARG 0.2382,0 .5130</td> <td></td> <td></td> <td>306 Secs (306 Secs) [==&gt;]</td> <td>[1]</td> </tr> <tr> <td>5</td> <td>(2) OB230215</td> <td>WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB</td> <td>F814W</td> <td>FLASH=15</td> <td>POS TARG 0.3305,0 .3732</td> <td></td> <td></td> <td>306 Secs (306 Secs) [==&gt;]</td> <td>[1]</td> </tr> <tr> <td>6</td> <td>(2) OB230215</td> <td>WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB</td> <td>F814W</td> <td>FLASH=15</td> <td>POS TARG 0.5024,0 .5171</td> <td></td> <td></td> <td>306 Secs (306 Secs) [==&gt;]</td> <td>[1]</td> </tr> </tbody> </table>	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit	1	(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.0000,0 .0000			306 Secs (306 Secs) [==>]	[1]	2	(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.0927,0 .3376			306 Secs (306 Secs) [==>]	[1]	3	(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.1851,0 .1978			306 Secs (306 Secs) [==>]	[1]	4	(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.2382,0 .5130			306 Secs (306 Secs) [==>]	[1]	5	(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.3305,0 .3732			306 Secs (306 Secs) [==>]	[1]	6	(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.5024,0 .5171			306 Secs (306 Secs) [==>]	[1]				
	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit																																																																	
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	5	(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.3305,0 .3732			306 Secs (306 Secs) [==>]	[1]																																																																	
6	(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.5024,0 .5171			306 Secs (306 Secs) [==>]	[1]																																																																		



Proposal 16658 - OB230215\_vis2 (52) - Hunting for Black Holes with Astrometric Microlensing

Thu Feb 20 19:00:51 GMT 2025

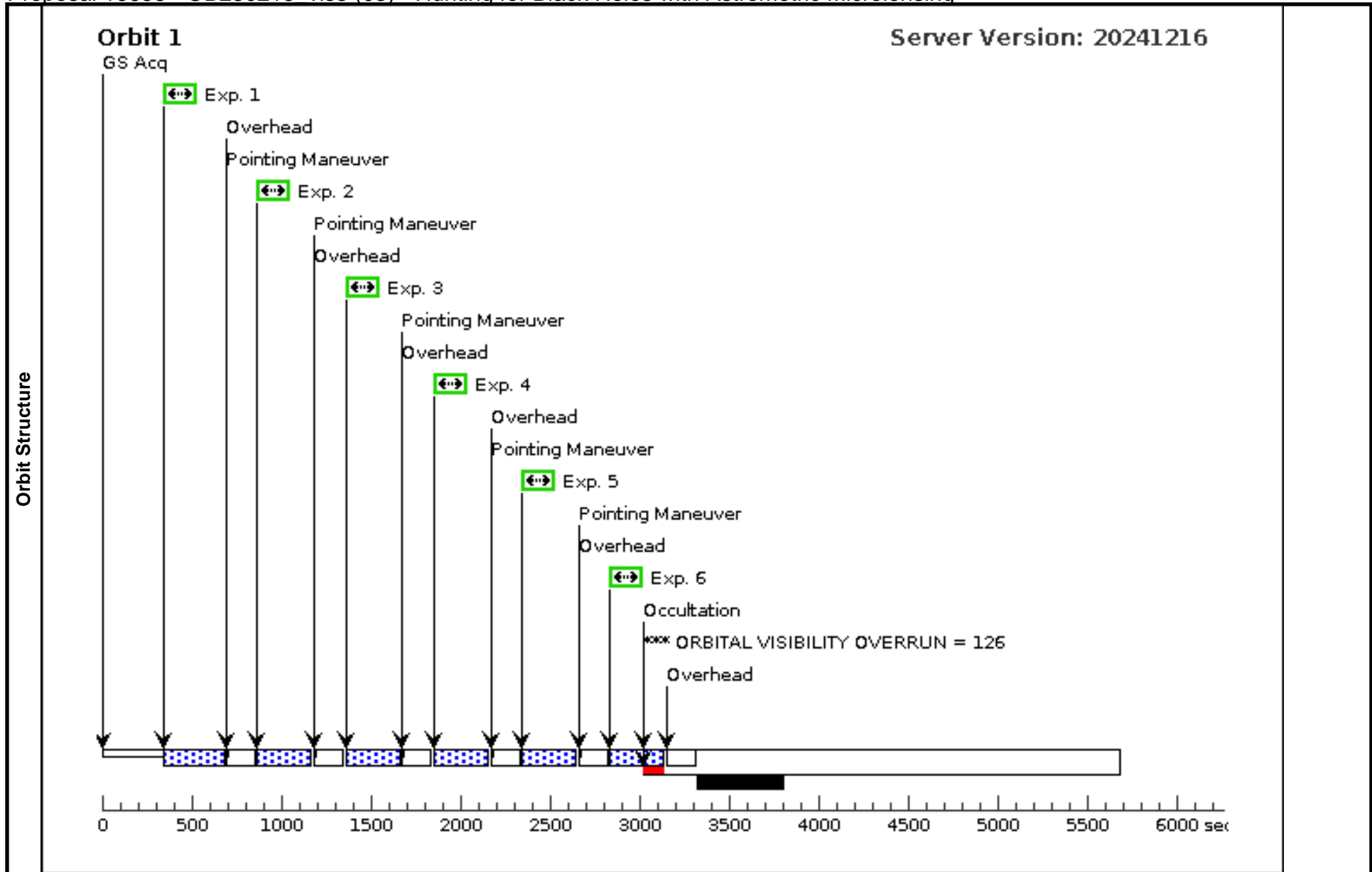
<b>Visit</b>	<b>Proposal 16658, OB230215_vis2 (52), completed</b> <b>Diagnostic Status: Warning</b> Scientific Instruments: WFC3/UVIS Special Requirements: (none) <i>Comments: Repeat of failed visit 02</i>						
	(OB230215_vis2 (52)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN						
<b>Fixed Targets</b>	# <b>Name</b> <b>Target Coordinates</b> <b>Targ. Coord. Corrections</b> <b>Fluxes</b> <b>Miscellaneous</b>	(2)      OB230215      RA: 18 20 20.3700 (275.0848750d) Dec: -21 35 14.90 (-21.58747d) Equinox: J2000	V=21.09+/-0.1 I-Mag 18.37	Reference Frame: ICRS			
	<i>Comments:</i> Category=STELLAR CLUSTER Description=[BULGE, GRAVITATIONAL LENS] Extended=NO						
<b>Exposures</b>	# <b>Label</b> <b>Target</b> <b>Config,Mode,Aperture</b> <b>Spectral Els.</b> <b>Opt. Params.</b> <b>Special Reqs.</b> <b>Groups</b> <b>Exp. Time (Total)/[Actual Dur.]</b> <b>Orbit</b>	1      (2) OB230215      WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB      F814W      FLASH=15      POS TARG 0.0000,0.0000      [==>]      [1]	2      (2) OB230215      WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB      F814W      FLASH=15      POS TARG 0.0927,0.3376      [==>]      [1]	3      (2) OB230215      WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB      F814W      FLASH=15      POS TARG 0.1851,0.1978      [==>]      [1]	4      (2) OB230215      WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB      F814W      FLASH=15      POS TARG 0.2382,0.5130      [==>]      [1]	5      (2) OB230215      WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB      F814W      FLASH=15      POS TARG 0.3305,0.3732      [==>]      [1]	6      (2) OB230215      WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB      F814W      FLASH=15      POS TARG 0.5024,0.5171      [==>]      [1]



Proposal 16658 - OB230215 vis3 (03) - Hunting for Black Holes with Astrometric Microlensing

Thu Feb 20 19:00:51 GMT 2025

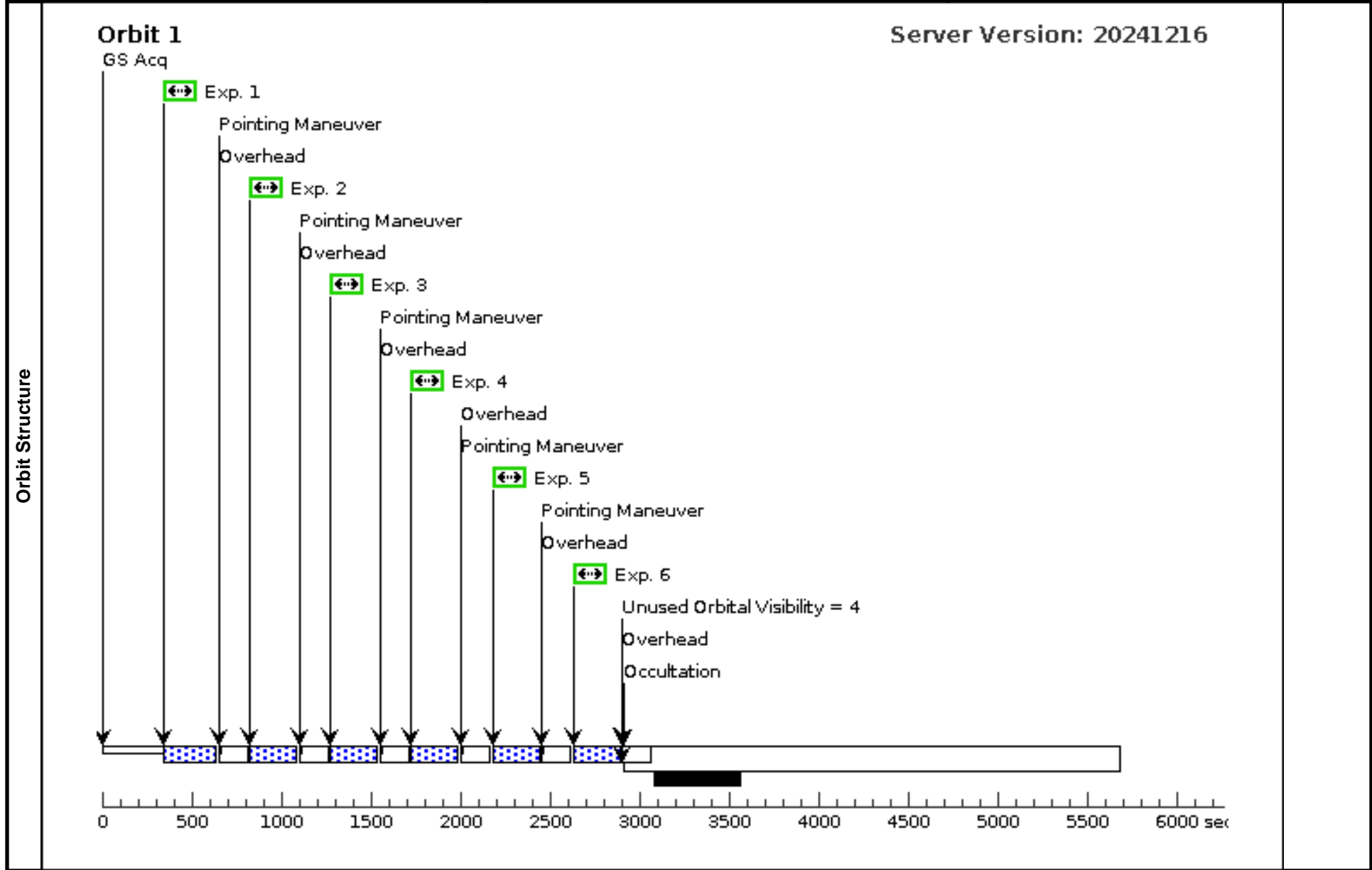
<b>Visit</b>	Proposal 16658, OB230215_vis3 (03), completed <b>Diagnostic Status: Warning</b> Scientific Instruments: WFC3/UVIS Special Requirements: ORIENT 180D TO 180D FROM 01: AFTER 02 BY 146 D TO 160 D				
	(OB230215_vis3 (03)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN (OB230215_vis3 (03)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.				
<b>Fixed Targets</b>	#      Name      Target Coordinates      Targ. Coord. Corrections      Fluxes      Miscellaneous				
	(2)      OB230215      RA: 18 20 20.3700 (275.0848750d) Dec: -21 35 14.90 (-21.58747d) Equinox: J2000 V=21.09+/-0.1 I-Mag 18.37 Reference Frame: ICRS Comments: Category=STELLAR CLUSTER Description=[BULGE, GRAVITATIONAL LENS] Extended=NO				
<b>Exposures</b>	#      Label      Target      Config,Mode,Aperture      Spectral Els.      Opt. Params.      Special Reqs.      Groups      Exp. Time (Total)/[Actual Dur.]      Orbit				
	1      (2) OB230215      WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB      F814W      FLASH=15      POS TARG 0.0000,0 .0000      306 Secs (306 Secs)      [1]				
	2      (2) OB230215      WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB      F814W      FLASH=15      POS TARG 0.0927,0 .3376      306 Secs (306 Secs)      [1]				
	3      (2) OB230215      WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB      F814W      FLASH=15      POS TARG 0.1851,0 .1978      306 Secs (306 Secs)      [1]				
	4      (2) OB230215      WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB      F814W      FLASH=15      POS TARG 0.2382,0 .5130      306 Secs (306 Secs)      [1]				
	5      (2) OB230215      WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB      F814W      FLASH=15      POS TARG 0.3305,0 .3732      306 Secs (306 Secs)      [1]				
	6      (2) OB230215      WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB      F814W      FLASH=15      POS TARG 0.5024,0 .5171      306 Secs (306 Secs)      [1]				



Proposal 16658 - OB230215 vis4 (04) - Hunting for Black Holes with Astrometric Microlensing

Thu Feb 20 19:00:51 GMT 2025

Visit	Proposal 16658, OB230215_vis4 (04), scheduled Diagnostic Status: No Diagnostics Scientific Instruments: WFC3/UVIS Special Requirements: SCHED 100%; ORIENT 180D TO 180D FROM 01; BETWEEN 24-FEB-2025:00:00:00 AND 08-MAR-2025:00:00:00									
	Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous			
	(2)	OB230215	RA: 18 20 20.3700 (275.0848750d) Dec: -21 35 14.90 (-21.58747d) Equinox: J2000		V=21.09+/-0.1 I-Mag 18.37	Reference Frame: ICRS				
	Comments: Category=STELLAR CLUSTER Description=[BULGE, GRAVITATIONAL LENS] Extended=NO									
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1		(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.0000,0 .0000		285 Secs (265 Secs) [=>265.0 Secs ]	[1]
	2		(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.0927,0 .3376		285 Secs (265 Secs) [=>265.0 Secs ]	[1]
	3		(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.1851,0 .1978		285 Secs (265 Secs) [=>265.0 Secs ]	[1]
	4		(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.2382,0 .5130		285 Secs (265 Secs) [=>265.0 Secs ]	[1]
	5		(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.3305,0 .3732		285 Secs (265 Secs) [=>265.0 Secs ]	[1]
	6		(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.5024,0 .5171		285 Secs (265 Secs) [=>265.0 Secs ]	[1]



Proposal 16658 - OB230215 vis5 (05) - Hunting for Black Holes with Astrometric Microlensing

Thu Feb 20 19:00:52 GMT 2025

<b>Visit</b>	Proposal 16658, OB230215_vis5 (05), scheduling <b>Diagnostic Status: Informational</b> Scientific Instruments: WFC3/UVIS Special Requirements: ORIENT 180D TO 180D FROM 01: AFTER 04 BY 30 D TO 180 D; BETWEEN 03-APR-2025:00:00:00 AND 07-JUN-2025:00:00:00									
	(OB230215_vis5 (05)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.									
<b>Fixed Targets</b>	<b>#</b>	<b>Name</b>	<b>Target Coordinates</b>	<b>Targ. Coord. Corrections</b>			<b>Fluxes</b>	<b>Miscellaneous</b>		
	(2)	OB230215	RA: 18 20 20.3700 (275.0848750d) Dec: -21 35 14.90 (-21.58747d) Equinox: J2000				V=21.09+/-0.1 I-Mag 18.37	Reference Frame: ICRS		
Comments: Category=STELLAR CLUSTER Description=[BULGE, GRAVITATIONAL LENS] Extended=NO										
<b>Exposures</b>	<b>#</b>	<b>Label</b>	<b>Target</b>	<b>Config,Mode,Aperture</b>	<b>Spectral Els.</b>	<b>Opt. Params.</b>	<b>Special Reqs.</b>	<b>Groups</b>	<b>Exp. Time (Total)/[Actual Dur.]</b>	<b>Orbit</b>
	1	(2) OB230215	(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.0000,0 .0000		285 Secs (285 Secs) [==>]	[1]
	2	(2) OB230215	(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.0927,0 .3376		285 Secs (285 Secs) [==>]	[1]
	3	(2) OB230215	(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.1851,0 .1978		285 Secs (285 Secs) [==>]	[1]
	4	(2) OB230215	(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.2382,0 .5130		285 Secs (285 Secs) [==>]	[1]
	5	(2) OB230215	(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.3305,0 .3732		285 Secs (285 Secs) [==>]	[1]
	6	(2) OB230215	(2) OB230215	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F814W	FLASH=15	POS TARG 0.5024,0 .5171		285 Secs (285 Secs) [==>]	[1]

