



# 17838 - Mass Measurement of a Candidate Balck Hole Microlens with Systematic Error Control

Cycle: 32, Proposal Category: GO  
(Availability Mode: SUPPORTED)

## INVESTIGATORS

<i>Name</i>	<i>Institution</i>
<b>Dr. David P. Bennett (PI) (Contact)</b>	<b>University of Maryland</b>
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Dr. Joshua Blackman (CoI) (ESA Member)	University of Bern
Dr. Aparna Bhattacharya (CoI)	University of Maryland
Dr. Ian Bond (CoI)	Massey University
Dr. Naoki Koshimoto (CoI)	Osaka University
Casey Lam (CoI)	Carnegie Institution of Washington
Dr. Jessica Ryan Lu (CoI)	University of California - Berkeley
Dr. Przemek Mroz (CoI) (ESA Member)	Warsaw University Observatory
Dr. Clement Ranc (CoI) (ESA Member)	CNRS, Institut d'Astrophysique de Paris
Jan Skowron (CoI) (ESA Member)	Warsaw University Observatory
Prof. Takahiro Sumi (CoI)	Osaka University
Dr. Sean Terry (CoI) (CoPI)	University of Maryland
Dr. Andrzej Udalski (CoI) (ESA Member)	Warsaw University Observatory
Dr. Aikaterini Vandenbroucke (CoI)	University of Maryland

## 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) MOA-2019-BLG-284	WFC3/UVIS	2	12-Aug-2024 14:01:02.0	yes

<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>
02	(1) MOA-2019-BLG-284	WFC3/UVIS	2	12-Aug-2024 14:01:05.0	yes

4 Total Orbits Used

## ABSTRACT

We propose Hubble imaging of the black hole candidate microlens system MOA-2019-BLG-284 in order to measure the astrometric microlensing signal and determine the lens system mass. Microlensing is the only method that can detect black holes that are isolated or in stable, non-accreting binary systems, so routine detection of black hole astrometric microlensing will provide a significant advance in our understanding of the formation of stellar mass black holes. Our proposed observations will determine if the MOA-2019-BLG-284 lens system is a rare stable binary system with a black hole primary or an isolated stellar mass black hole. This observing program is designed to address possible systematic errors in the astrometric measurements. We will also use the Hubble data to correct systematic errors in the ground-based photometry that determines the microlensing parallax. Since both astrometric microlensing and microlensing parallax measurements are needed to determine black hole masses, an understanding of systematic errors in both quantities is needed for reliable mass measurements. The novel systematic error correction methods that we propose may be used to increase the sensitivity of future black hole mass measurements from astrometric and photometric microlensing.

## OBSERVING DESCRIPTION

We request two visits per year of two orbits each, with one orbit to observe in each of the F814W and F606W passbands. This is 4 orbits per year for a total of 12 orbits over 3 years. We require a time series of data in both the F814W and F606W passbands for two reasons. First, we can get redundant astrometry measurements with two passband, and this will help to understand possible systematic astrometry errors. The two passbands will also provide a critical test of the possibility of models with binary source stars, since astrometric microlensing of binary source stars is generally color dependent. The spring and fall data are necessary in order to obtain a time series of observations with roll angles changing by 180 degrees every ~ 6 months. This will provide yearly imaging with PSF distortions due to CTE losses in nearly opposite directions in alternate visits. The roll angles used will be the same as two previous observing programs for this target (Bennett et al. 2020, Terry et al. 2021) in order to provide two long duration, independent data sets with nearly opposite directions of CCD charge transfer. The strongest astrometric microlensing signals are expected at twice the Einstein radius crossing time (~ 570 days) after the event peak, which will be in mid-2023 for MB19284. However, as Dominik & Sahu (2002) point out, it is necessary to make astrometric microlensing observations for a longer duration (at least 3 Einstein radius crossing times) to separate the astrometric microlensing signal from the linear proper motion of the source star. We propose observations over 3 cycles to obtain the last observation at 3.6 Einstein radius crossing times after the light curve peak. We request 18 exposures per orbit in the WFC3/UVIS F814W and F606W passbands

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to get good spatial sampling of the effective PSFs (Anderson and King 2000) and to avoid saturation. So, we select the UVIS2-C1K1C-SUB subarray to minimize PSF distortions due to the effects of CTE degradation.

We require observations within two weeks of one of our May and September 2020 and 2021 observations in order to minimize the effect of parallax motion of our astrometric reference stars between visits in different years.

# Proposal 17838 - Visit 01 - Mass Measurement of a Candidate Balck Hole Microlens with Systematic Error Control

<b>Visit</b>	<b>Proposal 17838, Visit 01, implementation</b> <span style="float: right;">Mon Aug 12 18:01:06 GMT 2024</span> <b>Diagnostic Status: No Diagnostics</b> Scientific Instruments: WFC3/UVIS Special Requirements: ORIENT 269D TO 269 D; BETWEEN 15-FEB-2025:00:00:00 AND 07-MAR-2025:00:00:00					
	<b>Fixed Targets</b>	<b>#</b>	<b>Name</b>	<b>Target Coordinates</b>	<b>Targ. Coord. Corrections</b>	<b>Fluxes</b>
(1)		MOA-2019-BLG-284	RA: 18 05 55.0600 (271.4794167d) Dec: -30 20 12.94 (-30.33693d) Equinox: J2000		V=17.65+/-0.05 I = 15.97 +- 0.05	Reference Frame: ICRS
<i>Comments:</i> Category=STAR Description=[BULGE, GRAVITATIONAL LENS, K V-IV]						

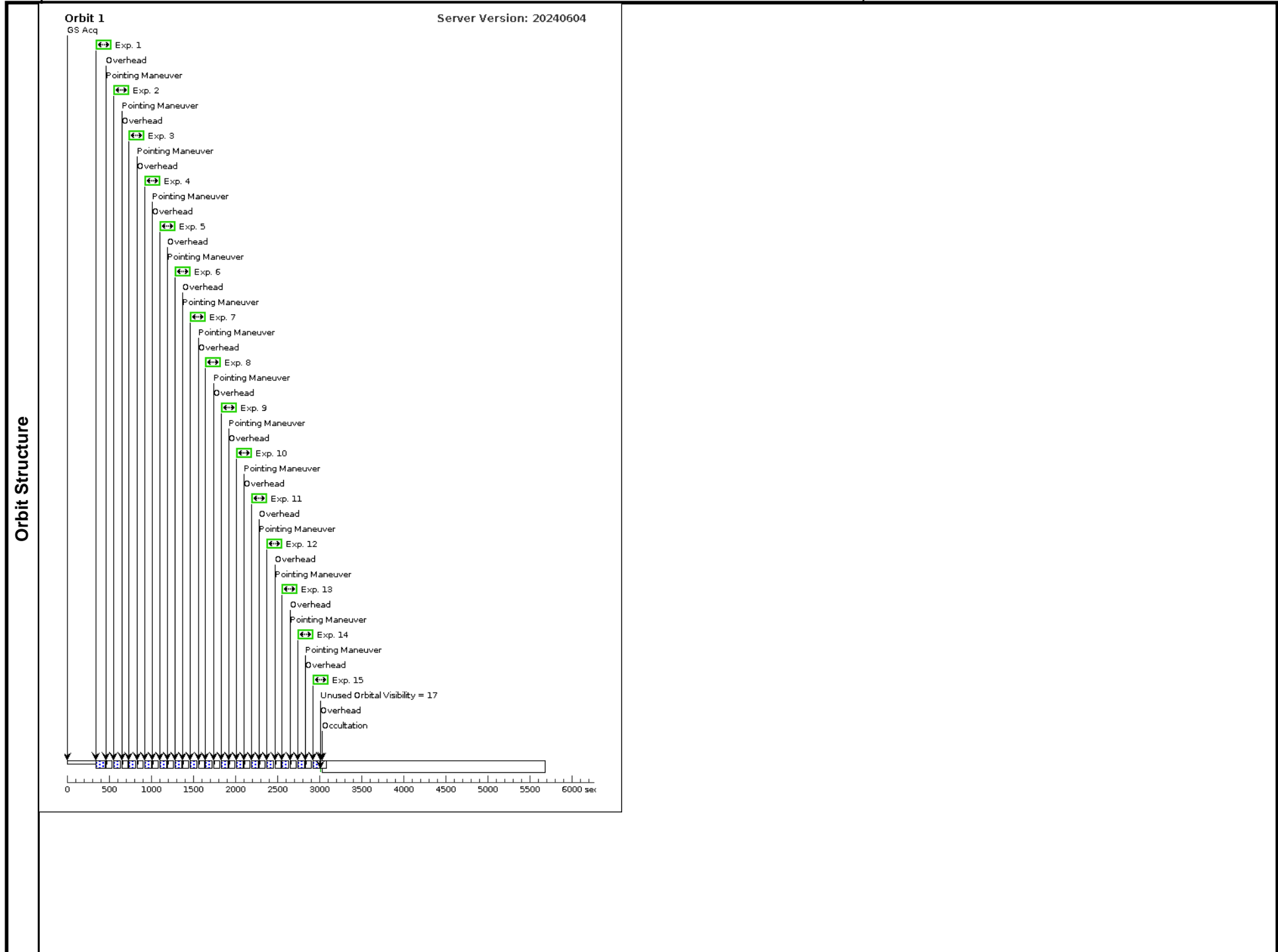
Proposal 17838 - Visit 01 - Mass Measurement of a Candidate Balck Hole Microlens with Systematic Error Control

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]		Orbit
Exposures	1	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.0,0.0		81 Secs (81 Secs)	[=>]	[1]
	2	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.21981, 0.01893		81 Secs (81 Secs)	[=>]	[1]
	3	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.08573, 0.22678		81 Secs (81 Secs)	[=>]	[1]
	4	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.30554, 0.24572		81 Secs (81 Secs)	[=>]	[1]
	5	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.56707, 0.11780		81 Secs (81 Secs)	[=>]	[1]
	6	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.78688, 0.13673		81 Secs (81 Secs)	[=>]	[1]
	7	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.65279, 0.34459		81 Secs (81 Secs)	[=>]	[1]
	8	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.91230, 0.36598		81 Secs (81 Secs)	[=>]	[1]
	9	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.08446, 0.53624		81 Secs (81 Secs)	[=>]	[1]
	10	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.30427, 0.55517		81 Secs (81 Secs)	[=>]	[1]
	11	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.20990, 0.76546		81 Secs (81 Secs)	[=>]	[1]
	12	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.38999, 0.78195		81 Secs (81 Secs)	[=>]	[1]
	13	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.65150, 0.65404		81 Secs (81 Secs)	[=>]	[1]
	14	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.87130, 0.67303		81 Secs (81 Secs)	[=>]	[1]
	15	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.73722, 0.88083		81 Secs (81 Secs)	[=>]	[1]
	16	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F814W	FLASH=20	POS TARG 0.0,0.0		80 Secs (80 Secs)	[=>]	[2]
	17	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F814W	FLASH=20	POS TARG 0.21981, 0.01893		80 Secs (80 Secs)	[=>]	[2]
	18	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F814W	FLASH=20	POS TARG 0.08573, 0.22678		80 Secs (80 Secs)	[=>]	[2]
	19	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F814W	FLASH=20	POS TARG 0.30554, 0.24572		80 Secs (80 Secs)	[=>]	[2]
	20	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F814W	FLASH=20	POS TARG 0.56707, 0.11780		80 Secs (80 Secs)	[=>]	[2]
	21	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F814W	FLASH=20	POS TARG 0.78688, 0.13673		80 Secs (80 Secs)	[=>]	[2]
	22	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F814W	FLASH=20	POS TARG 0.65279, 0.34459		80 Secs (80 Secs)	[=>]	[2]

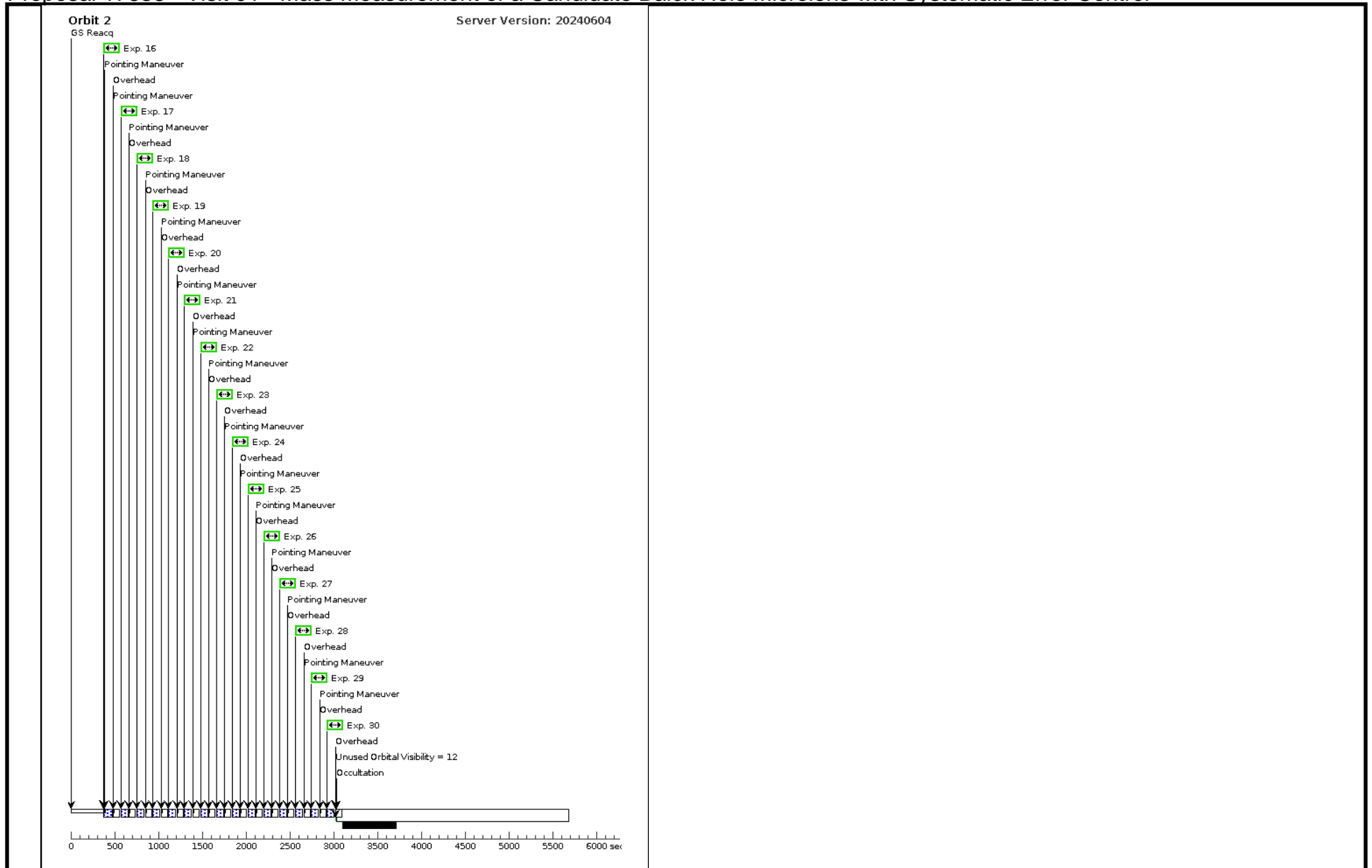
Proposal 17838 - Visit 01 - Mass Measurement of a Candidate Balck Hole Microlens with Systematic Error Control

23	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F814W	FLASH=20	POS TARG 0.91230, 0.36598	80 Secs (80 Secs)	
						[==>]	[2]
24	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F814W	FLASH=20	POS TARG 0.08446, 0.53624	80 Secs (80 Secs)	
						[==>]	[2]
25	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F814W	FLASH=20	POS TARG 0.30427, 0.55517	80 Secs (80 Secs)	
						[==>]	[2]
26	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F814W	FLASH=20	POS TARG 0.20990, 0.76546	80 Secs (80 Secs)	
						[==>]	[2]
27	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F814W	FLASH=20	POS TARG 0.38999, 0.78195	80 Secs (80 Secs)	
						[==>]	[2]
28	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F814W	FLASH=20	POS TARG 0.65150, 0.65404	80 Secs (80 Secs)	
						[==>]	[2]
29	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F814W	FLASH=20	POS TARG 0.87130, 0.67303	80 Secs (80 Secs)	
						[==>]	[2]
30	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F814W	FLASH=20	POS TARG 0.73722, 0.88083	80 Secs (80 Secs)	
						[==>]	[2]

# Proposal 17838 - Visit 01 - Mass Measurement of a Candidate Balck Hole Microlens with Systematic Error Control



# Proposal 17838 - Visit 01 - Mass Measurement of a Candidate Balck Hole Microlens with Systematic Error Control



Proposal 17838 - Visit 02 - Mass Measurement of a Candidate Balck Hole Microlens with Systematic Error Control

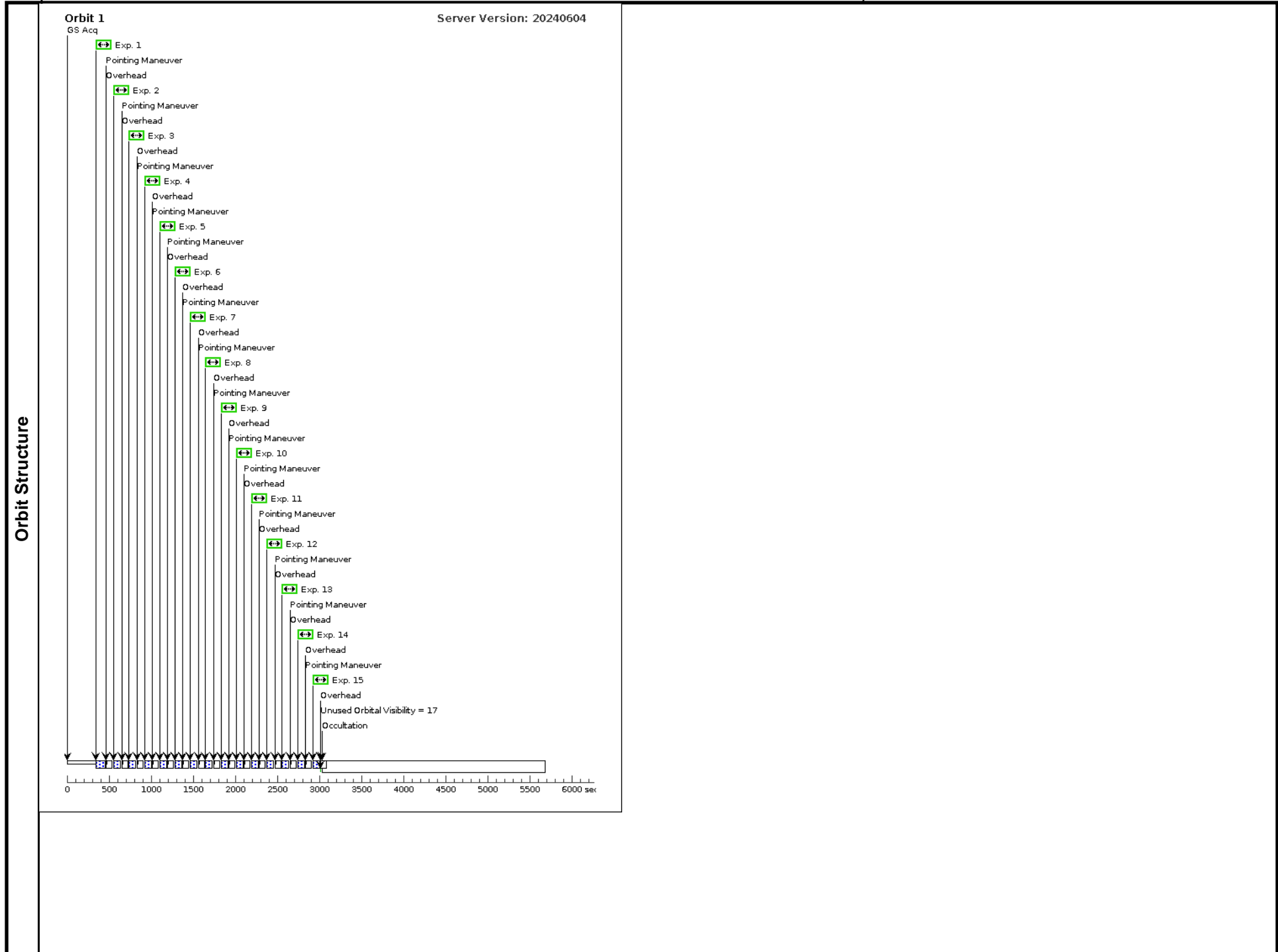
<b>Visit</b>	<b>Proposal 17838, Visit 02, implementation</b> <span style="float: right;">Mon Aug 12 18:01:06 GMT 2024</span> <b>Diagnostic Status: No Diagnostics</b> Scientific Instruments: WFC3/UVIS Special Requirements: ORIENT 269D TO 269 D; BETWEEN 01-JUN-2025:00:00:00 AND 12-JUN-2025:00:00:00					
	<b>Fixed Targets</b>	<b>#</b>	<b>Name</b>	<b>Target Coordinates</b>	<b>Targ. Coord. Corrections</b>	<b>Fluxes</b>
(1)		MOA-2019-BLG-284	RA: 18 05 55.0600 (271.4794167d) Dec: -30 20 12.94 (-30.33693d) Equinox: J2000		V=17.65+/-0.05 I = 15.97 +- 0.05	Reference Frame: ICRS
<i>Comments:</i> Category=STAR Description=[BULGE, GRAVITATIONAL LENS, K V-IV]						

Proposal 17838 - Visit 02 - Mass Measurement of a Candidate Balck Hole Microlens with Systematic Error Control

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]		Orbit
Exposures	1	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.0,0.0		81 Secs (81 Secs)	[=>]	[1]
	2	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.21981, 0.01893		81 Secs (81 Secs)	[=>]	[1]
	3	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.08573, 0.22678		81 Secs (81 Secs)	[=>]	[1]
	4	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.30554, 0.24572		81 Secs (81 Secs)	[=>]	[1]
	5	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.56707, 0.11780		81 Secs (81 Secs)	[=>]	[1]
	6	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.78688, 0.13673		81 Secs (81 Secs)	[=>]	[1]
	7	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.65279, 0.34459		81 Secs (81 Secs)	[=>]	[1]
	8	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.91230, 0.36598		81 Secs (81 Secs)	[=>]	[1]
	9	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.08446, 0.53624		81 Secs (81 Secs)	[=>]	[1]
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	15	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W	FLASH=20	POS TARG 0.73722, 0.88083		81 Secs (81 Secs)	[=>]	[1]
	16	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F814W	FLASH=20	POS TARG 0.0,0.0		80 Secs (80 Secs)	[=>]	[2]
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						[==>]	[2]
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						[==>]	[2]
30	(1) MOA-2019-BLG-284	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F814W	FLASH=20	POS TARG 0.73722, 0.88083	80 Secs (80 Secs)	
						[==>]	[2]



# Proposal 17838 - Visit O2 - Mass Measurement of a Candidate Balck Hole Microlens with Systematic Error Control

