



17193 - WO-type Wolf-Rayet Stars: The Last Hurrah of Massive Stars

Cycle: 30, Proposal Category: GO

(UV Initiative)

(Availability Mode: AVAILABLE)

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) OFFSET-LH41-1040 (2) LH41-1042	STIS/CCD STIS/FUV-MAMA STIS/NUV-MAMA	4	20-Jun-2024 18:00:17.0	yes
02	(1) OFFSET-LH41-1040 (2) LH41-1042 CCDFLAT	STIS/CCD WFC3/UVIS	3	20-Jun-2024 18:00:21.0	yes

7 Total Orbits Used

ABSTRACT

The WO class of Wolf-Rayet (WR) stars represent the most evolved type of massive star: their last hurrah before they undergo core-collapse. Abundance determinations of WOs thus give us a glimpse of the nucleosynthesis of massive stars at the very end of their lives, providing an unprecedented test of stellar evolutionary theory. We have recently finished an analysis of two WOs in the Large Magellanic Cloud (LMC) in order to determine their physical properties, including their abundances. Our results imply that the nuclear reaction rate for $12\text{C}+4\text{He}\rightarrow 16\text{O}$ (long known to be uncertain) must be significantly lower than what is used in modern evolutionary models. This has enormous implications: among other things, it would eliminate the conflict between the theoretical black hole upper mass gap and the large black hole masses revealed by various gravitational wave events. Yet, our result hinges on the analysis of only two stars. WO-type WRs are rare: there are only three in the LMC, and the handful known in the Milky Way and in other galaxies are too reddened or distant to obtain the high-quality UV spectra necessary for their analysis. Unfortunately, the third LMC WO star, LH41-1042, has a companion only 0.1" away. However, by carefully aligning one of the narrow STIS slits, we can obtain a nearly uncontaminated spectrum of this third WO with just seven orbits. These data will provide an important test of our conclusion that the $12\text{C}+4\text{He}\rightarrow 16\text{O}$ nuclear reaction rate is too high. LH41-1042 is the only remaining WO star that can be observed in both the UV and optical; obtaining these data can only be done with HST.

OBSERVING DESCRIPTION

The WO-type Wolf-Rayet star LH41-1042 has a companion star located located 0.122" at a position angle of -10 degrees. We have previous observations of the star in the UV with COS and in the optical with Magellan, but these spectra are all contaminated by the companion; these data however, provided the means to estimate the S/N and exposure times and alleviate any safety concerns. Our goal in this program is to obtain a relatively uncontaminated spectra. We have an F225W WFC3 image which shows that the companion is about 1.8 mag fainter than the WR star in the UV; we also know that the companion is bound to be cooler than the WR and hence more of a problem as we go to longer wavelengths. We also know it doesn't dominate at optical wavelengths as there is no hint of absorption lines in our high S/N ground-based data. Exposure times and safety could be readily determined thanks to our combined COS and optical fluxed spectra.

Our primary goal, then, is to obtain good S/N UV spectra in the FUV and NUV using the G140L and G230L gratings using STIS/MAMA (Visit 1) and in the optical using the G430L and G750L gratings (Visit 2). The MAMA observations will be done with the 0.2x0.06" slit (available but unsupported with G140L), and the optical with the 52x0.05". (The use of the echelle slit for the UV observations removes safety concerns given other bright UV stars in the region.) In both cases we will require an orient angle (145+/- 20 or 325+/- 20) to place the companion star off to the side of the slit. [See below] (The alternative, of observing both stars on the slit and attempting to deblend them, was considered but rejected given the sampling.) Our acquisition will be done using a well-isolated O7V star located about 10" away; we will perform the ACQ/PEAK on this offset star

Proposal 17193 (STScI Edit Number: 3, Created: Thursday, June 20, 2024 at 5:00:23 PM Eastern Standard Time) - Overview

as well. Coordinates have been carefully measured from the WFC3 image, and converted to ICRS by comparison with Gaia DR3 values. (The position for our science target required PSF fitting to remove the influence of the companion.)

Our secondary goal is to obtain good fluxes for the WR component, and for this we will use a series of very short WFC3 exposures at the end of Visit 2.

The FUV/NUV observations are straightforward and will require four orbits to obtain the required S/N; we will use time-tag and obtain 2100 sec (orbit 1) + 3000 sec (orbit 2) + 500 sec (orbit 3) in FUV/G140L. During orbit 3 we switch to NUV/G230L and obtain 500 sec (remainder of orbit 3) and 3000 sec (orbit 4).

In visit 2 we acquire and peakup on the offset star as before (exposures 1 and 2), and begin with observing with the G430L grating (exposure 3). There is essentially no background in our exposures, and so to alleviate CTE effects we will be using the E1 position. We will dither along the slit to 7 positions with the 52x0.05" slit. At each position we will do a CR=3 slit; thus the individual exposure times of these 2 sub-exposures will be 33 seconds. Each of these will reach a continuum counts of about 2000 electrons/resolution element; i.e., these are low counts in the spectrum, only in the background. Using CR=3 not only helps eliminate CRs but also keeps the exposure times short enough to avoid saturation of the strong emission lines (the intensity of which are known from our ground-based data). This occupies most of orbit 1. Near the end of orbit 1 we switch to the G750L grating and begin a similar series of exposures (exposure 4). Again we will do a CR=3 and dither along the slit to 7 positions; each of the 21 exposure components will be 104 sec in length. Again, this will reach about 2000 e counts in the continuum per sub-exposure, and avoid saturating the strongest emission lines. At the end of the visibility period of orbit 2 we then take a fringe frame (exposure 5).

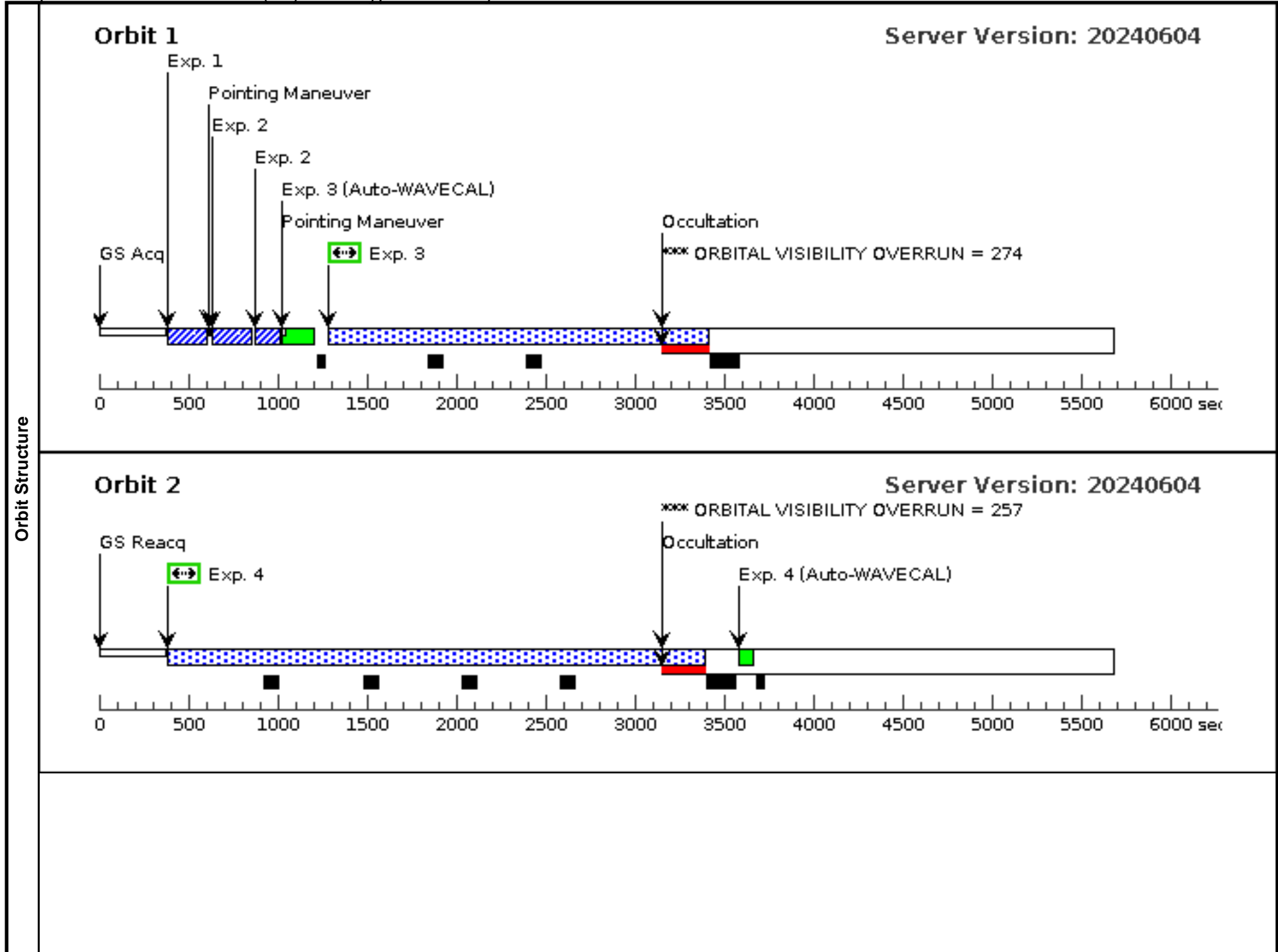
We then switch to WFC3 and take 0.5 sec exposures in F275W, F336W, F438W, F555W, F625W, and F814W. We use a subarray to reduce CTE effects, and use the standard 4-point dither pattern for each exposure.

Note about the orient angle. The companion is at a PA of -10 degrees relative to the WR companion. Thus to keep it off the slit, we want the slit to be at a PA of 80 degrees (-10+90). Our understanding from the documentation is thus that we want the orient angle to be PA + 45 or PA + 225. Thus we are requesting an orient angle near 125 or near 305. We allow +/- 20 deg slop around these optimal angles.

Proposal 17193 - STIS UV (01) - WO-type Wolf-Rayet Stars: The Last Hurrah of Massive Stars

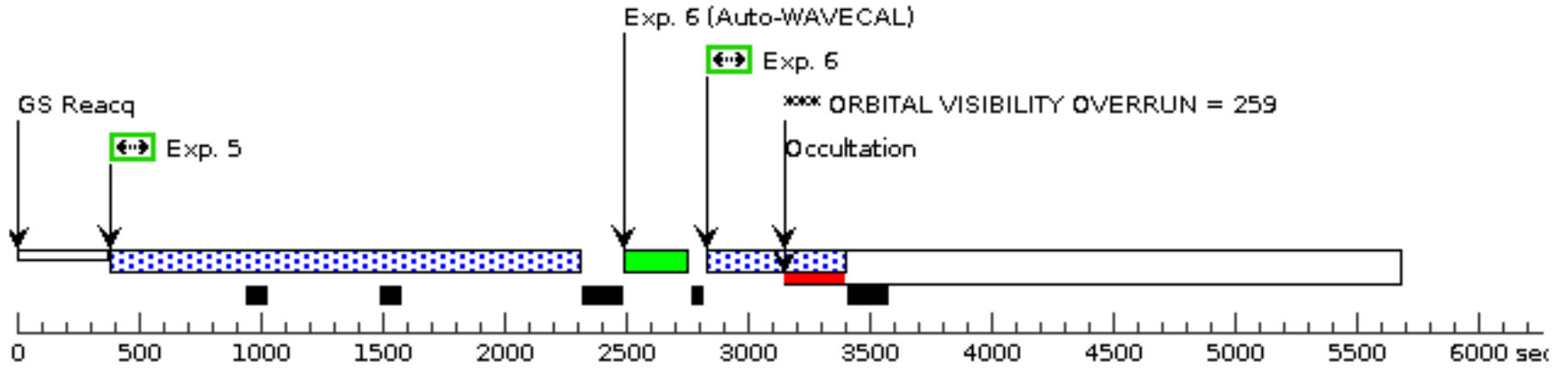
Thu Jun 20 22:00:23 GMT 2024

Visit	Proposal 17193, STIS UV (01), completed Diagnostic Status: Warning Scientific Instruments: STIS/NUV-MAMA, STIS/CCD, STIS/FUV-MAMA Special Requirements: ORIENT 105D TO 145 D; ORIENT 285D TO 325 D										
	Diagnostics	(STIS UV (01)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN									
(STIS UV (01)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN											
(STIS UV (01)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN											
(STIS UV (01)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN											
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections			Fluxes	Miscellaneous			
	(1)	OFFSET-LH41-1040	RA: 05 18 13.2670 (79.5552792d) Dec: -69 13 21.36 (-69.22260d) Equinox: J2000				V=13.79+/-0.02 B-V=-0.12, G=13.9	Reference Frame: ICRS			
	<i>Comments:</i> Category=EXT-STAR Description=[B0-B2 III-I] Extended=NO										
	(2)	LH41-1042	RA: 05 18 10.8910 (79.5453792d) Dec: -69 13 11.42 (-69.21984d) Equinox: J2000				V=14.10+/-0.05 B-V=+0.07	Reference Frame: ICRS			
<i>Comments:</i> Category=EXT-STAR Description=[WOLF RAYET - WC] Extended=NO											
Exposures	#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit	
	1	(1808637)	(1) OFFSET-LH41-1040	STIS/CCD, ACQ, F28X50LP	MIRROR	ACQTYPE=POINT			0.4 Secs (0.4 Secs) [==>]	[1]	
	2	(1808638)	(1) OFFSET-LH41-1040	STIS/CCD, ACQ/PEAK, 0.2X0.06	MIRROR				0.6 Secs (0.6 Secs) [==>]	[1]	
	3	(1724746)	(2) LH41-1042	STIS/FUV-MAMA, TIME-TAG, 0.2X0.06	G140L 1425 A	BUFFER-TIME=55 0			2100 Secs (2100 Secs) [==>]	[1]	
	4	(1724746)	(2) LH41-1042	STIS/FUV-MAMA, TIME-TAG, 0.2X0.06	G140L 1425 A	BUFFER-TIME=55 0			3000 Secs (3000 Secs) [==>]	[2]	
	5	(1724746)	(2) LH41-1042	STIS/FUV-MAMA, TIME-TAG, 0.2X0.06	G140L 1425 A	BUFFER-TIME=55 0			1900 Secs (1900 Secs) [==>]	[3]	
	6	(1724747)	(2) LH41-1042	STIS/NUV-MAMA, TIME-TAG, 0.2X0.06	G230L 2376 A	BUFFER-TIME=32 0			500 Secs (500 Secs) [==>]	[3]	
	7	(1724747)	(2) LH41-1042	STIS/NUV-MAMA, TIME-TAG, 0.2X0.06	G230L 2376 A	BUFFER-TIME=32 0			3000 Secs (3000 Secs) [==>]	[4]	



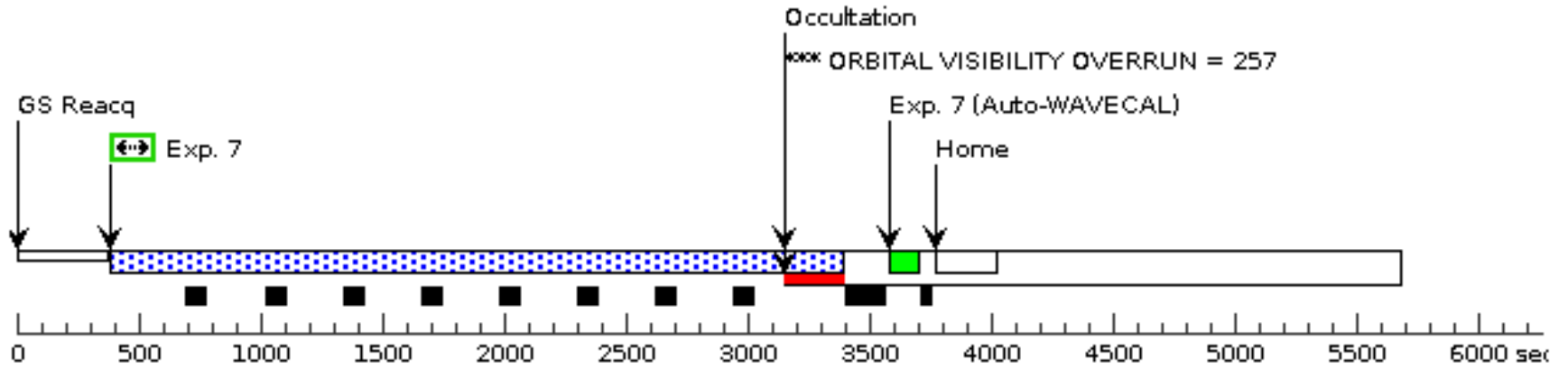
Orbit 3

Server Version: 20240604



Orbit 4

Server Version: 20240604



Proposal 17193 - Optical CCD (02) - WO-type Wolf-Rayet Stars: The Last Hurrah of Massive Stars

Thu Jun 20 22:00:23 GMT 2024

Visit	Proposal 17193, Optical CCD (02), implementation Diagnostic Status: Warning Scientific Instruments: WFC3/UVIS, STIS/CCD Special Requirements: ORIENT 105D TO 145 D; ORIENT 285D TO 325 D					
	Diagnosics (Optical CCD (02)) Warning (Orbit Planner): WFC3 EXPOSURE TIME ADJUSTED (Optical CCD (02)) Warning (Orbit Planner): WFC3 EXPOSURE TIME ADJUSTED (Optical CCD (02)) Warning (Orbit Planner): WFC3 EXPOSURE TIME ADJUSTED (Optical CCD (02)) Warning (Orbit Planner): WFC3 EXPOSURE TIME ADJUSTED					
Patterns	#	Primary Pattern	Secondary Pattern	Exposures		
	(1)	Pattern Type=STIS-ALONG-SLIT Coordinate Frame=POS-TARG Purpose=DITHER Pattern Orientation=90.0 Number Of Points=7 Angle Between Sides= Point Spacing=0.15 Center Pattern=false Line Spacing=		(3), (4)		
(2)	Pattern Type=WFC3-UVIS-DITHER-BOX Coordinate Frame=POS-TARG Purpose=DITHER Pattern Orientation=23.884 Number Of Points=4 Angle Between Sides=81.785 Point Spacing=0.173 Center Pattern=false Line Spacing=0.112		(6-10)			
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
	(1)	OFFSET-LH41-1040	RA: 05 18 13.2670 (79.5552792d) Dec: -69 13 21.36 (-69.22260d) Equinox: J2000		V=13.79+/-0.02 B-V=-0.12, G=13.9	Reference Frame: ICRS
	<i>Comments:</i> Category=EXT-STAR Description=[B0-B2 III-I] Extended=NO					
(2)	LH41-1042	RA: 05 18 10.8910 (79.5453792d) Dec: -69 13 11.42 (-69.21984d) Equinox: J2000		V=14.10+/-0.05 B-V=+0.07	Reference Frame: ICRS	
	<i>Comments:</i> Category=EXT-STAR Description=[WOLF RAYET - WC] Extended=NO					

Proposal 17193 - Optical CCD (02) - WO-type Wolf-Rayet Stars: The Last Hurrah of Massive Stars

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	(1808637)	(1) OFFSET-LH41-1 040	STIS/CCD, ACQ, F28X50LP	MIRROR				0.4 Secs (0.4 Secs)	
								[==>]	[1]
2	(1808644)	(1) OFFSET-LH41-1 040	STIS/CCD, ACQ/PEAK, 52X0.05	MIRROR				0.6 Secs (0.6 Secs)	
								[==>]	[1]
3	(1724762)	(2) LH41-1042	STIS/CCD, ACCUM, 52X0.05E1	G430L 4300 A	CR-SPLIT=3		Pattern 1, Exps 3-3 i n Optical CCD (02) (1)	75 Secs (525 Secs)	
								[==>(Pattern 1, Split 1)]	
								[==>(Pattern 1, Split 2)]	
								[==>(Pattern 1, Split 3)]	
								[==>(Pattern 2, Split 1)]	
								[==>(Pattern 2, Split 2)]	
								[==>(Pattern 2, Split 3)]	
								[==>(Pattern 3, Split 1)]	
								[==>(Pattern 3, Split 2)]	
								[==>(Pattern 3, Split 3)]	
								[==>(Pattern 4, Split 1)]	
								[==>(Pattern 4, Split 2)]	
								[==>(Pattern 4, Split 3)]	
								[==>(Pattern 5, Split 1)]	
								[==>(Pattern 5, Split 2)]	
								[==>(Pattern 5, Split 3)]	
								[==>(Pattern 6, Split 1)]	
								[==>(Pattern 6, Split 2)]	
								[==>(Pattern 6, Split 3)]	
								[==>(Pattern 7, Split 1)]	
[==>(Pattern 7, Split 2)]									
[==>(Pattern 7, Split 3)]									
								[1]	

Exposures

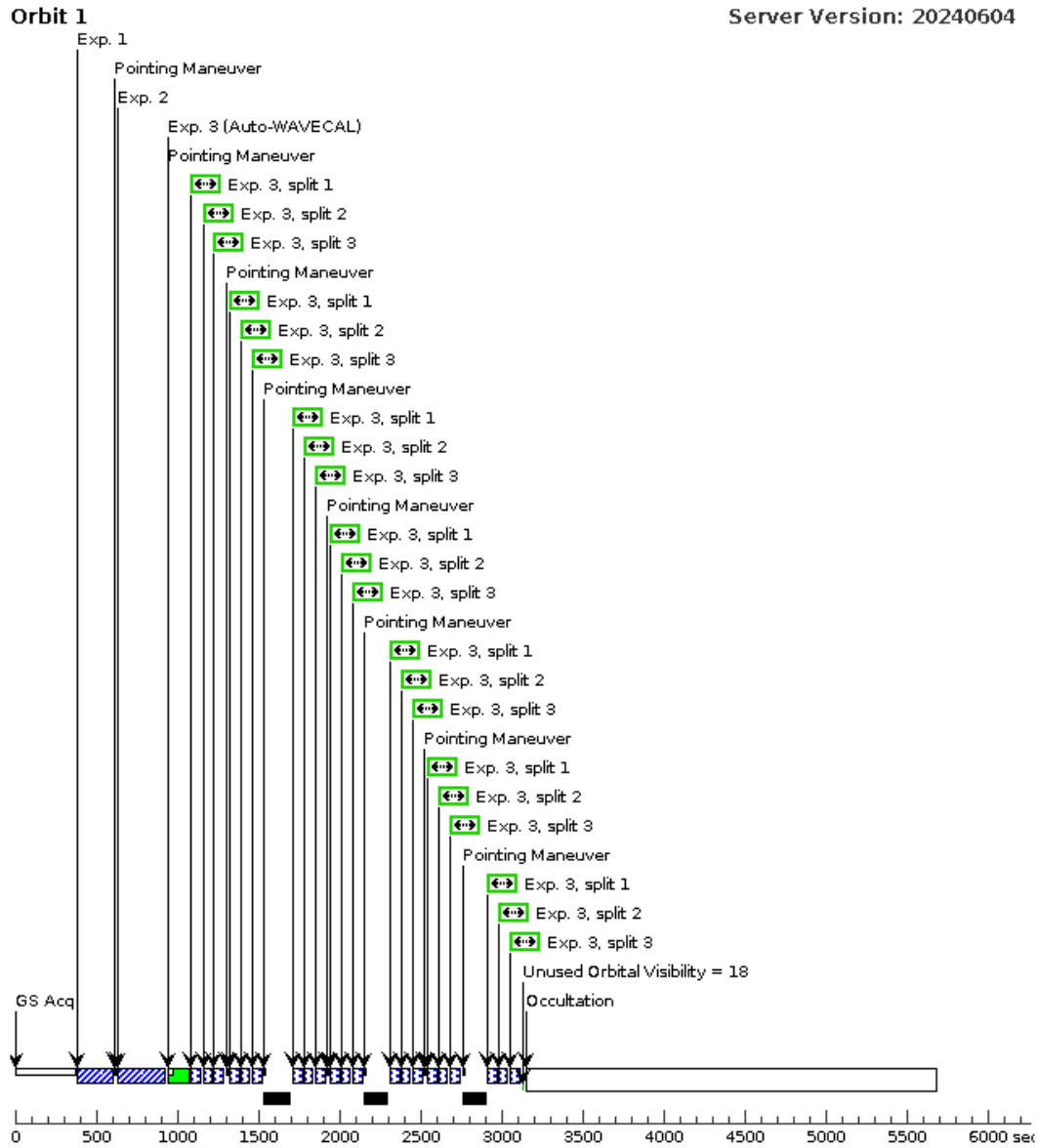
Proposal 17193 - Optical CCD (02) - WO-type Wolf-Rayet Stars: The Last Hurrah of Massive Stars

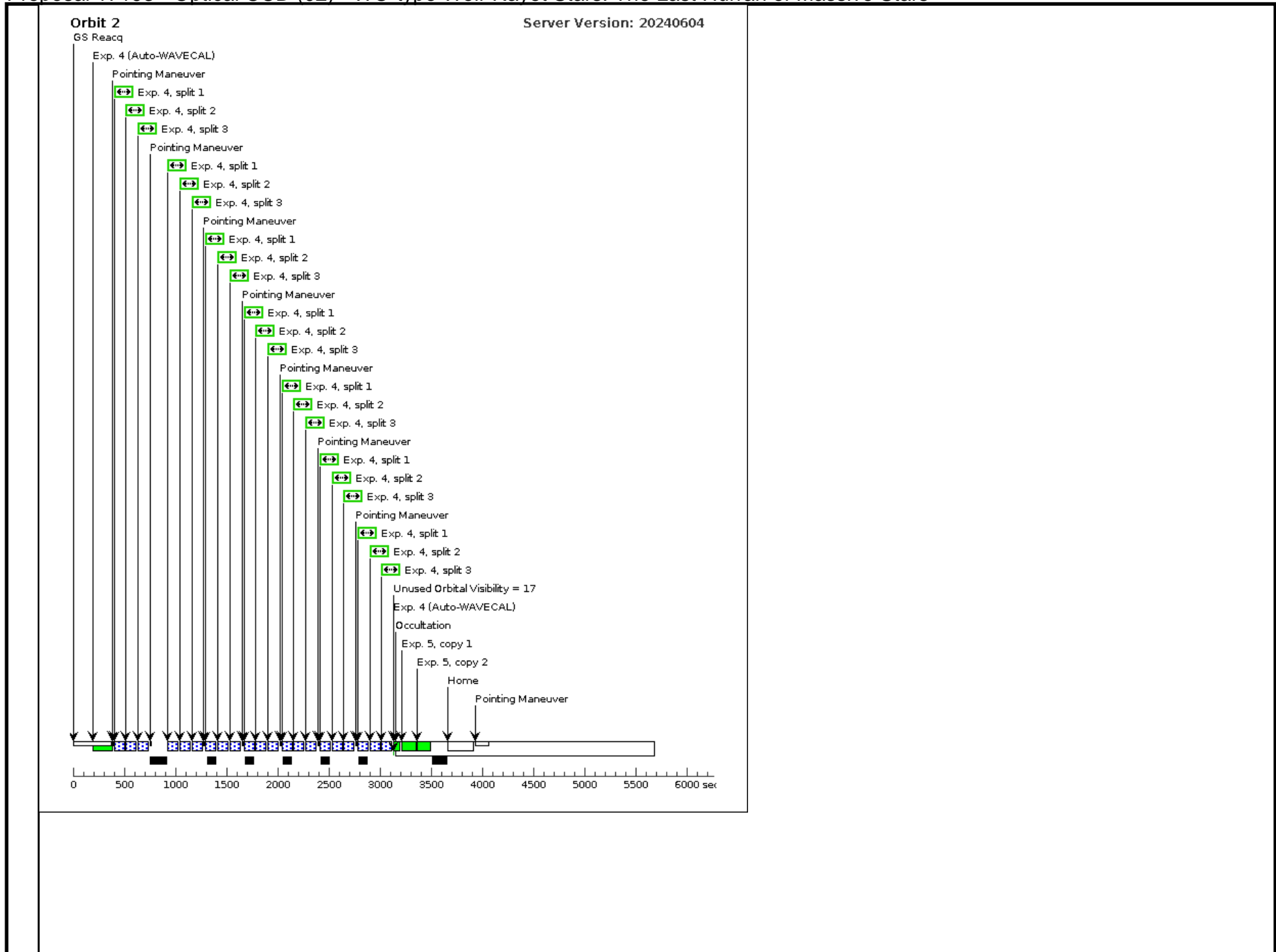
4	(1724767) (2) LH41-1042	STIS/CCD, ACCUM, 52X0.05E1	G750L 7751 A	CR-SPLIT=3	Pattern 1, Exps 4-4 in Optical CCD (02) (1)	213 Secs (1491 Secs) [==>(Pattern 1, Split 1)] [==>(Pattern 1, Split 2)] [==>(Pattern 1, Split 3)] [==>(Pattern 2, Split 1)] [==>(Pattern 2, Split 2)] [==>(Pattern 2, Split 3)] [==>(Pattern 3, Split 1)] [==>(Pattern 3, Split 2)] [==>(Pattern 3, Split 3)] [==>(Pattern 4, Split 1)] [==>(Pattern 4, Split 2)] [==>(Pattern 4, Split 3)] [==>(Pattern 5, Split 1)] [==>(Pattern 5, Split 2)] [==>(Pattern 5, Split 3)] [==>(Pattern 6, Split 1)] [==>(Pattern 6, Split 2)] [==>(Pattern 6, Split 3)] [==>(Pattern 7, Split 1)] [==>(Pattern 7, Split 2)] [==>(Pattern 7, Split 3)]	[2]
5		CCDFLAT	STIS/CCD, ACCUM, 52X0.05 7751 A			[==>(Copy 1)] [==>(Copy 2)]	[2]
6	(2) LH41-1042	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F275W	CR-SPLIT=NO; FLASH=20	Pattern 2, Exps 6-10 in Optical CCD (02) (2)	5 Secs (20 Secs) [==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)] [==>(Pattern 4)]	[3]
7	(2) LH41-1042	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F336W	FLASH=20; CR-SPLIT=NO	Pattern 2, Exps 6-10 in Optical CCD (02) (2)	0.7 Secs (2.8 Secs) [==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)] [==>(Pattern 4)]	[3]
8	(2) LH41-1042	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F438W	FLASH=20; CR-SPLIT=NO	Pattern 2, Exps 6-10 in Optical CCD (02) (2)	0.5 Secs (2 Secs) [==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)] [==>(Pattern 4)]	[3]
9	(2) LH41-1042	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F555W	FLASH=20; CR-SPLIT=NO	Pattern 2, Exps 6-10 in Optical CCD (02) (2)	0.5 Secs (2 Secs) [==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)] [==>(Pattern 4)]	[3]

Proposal 17193 - Optical CCD (02) - WO-type Wolf-Rayet Stars: The Last Hurrah of Massive Stars

	10	(2) LH41-1042	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F814W	FLASH=20; CR-SPLIT=NO	Pattern 2, Exps 6-10 in Optical CCD (02) (2)	0.5 Secs (2 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)]	[3]
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Orbit Structure





Proposal 17193 - Optical CCD (02) - WO-type Wolf-Rayet Stars: The Last Hurrah of Massive Stars

