



## 17787 - DELVE 1: The Least Massive Galaxy?

Cycle: 32, Proposal Category: GO

(Availability Mode: SUPPORTED)

### INVESTIGATORS

<i>Name</i>	<i>Institution</i>
<b>William Cerny (PI) (Contact)</b>	<b>Yale University</b>
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Dr. Andrew Pace (CoI)	Carnegie Mellon University
Dr. Ting Li (CoI) (CSA Member)	University of Toronto
Prof. Eric F. Bell (CoI)	University of Michigan
Dr. Burcin Mutlu-Pakdil (CoI)	Dartmouth College
Dr. Holger Baumgardt (CoI)	University of Queensland

### 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) DELVE1-NORTH ANY	ACS/WFC WFC3/UVIS	2	17-Oct-2024 12:00:55.0	yes
02	(1) DELVE1-SOUTHEAST ANY	ACS/WFC WFC3/UVIS	2	17-Oct-2024 12:00:56.0	yes
03	(3) DELVE1-SOUTHWEST ANY	ACS/WFC WFC3/UVIS	2	17-Oct-2024 12:00:56.0	yes
04	(2) DELVE1-NORTH ANY	ACS/WFC WFC3/UVIS	2	17-Oct-2024 12:00:57.0	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>
05	(1) DELVE1-SOUTHEAST ANY	ACS/WFC WFC3/UVIS	2	17-Oct-2024 12:00:58.0	yes
06	(3) DELVE1-SOUTHWEST ANY	ACS/WFC WFC3/UVIS	2	17-Oct-2024 12:00:59.0	yes

12 Total Orbits Used

## **ABSTRACT**

The Milky Way satellite DELVE 1 may be the faintest, smallest, and least-massive galaxy known. However, the alternative possibility that DELVE 1 is a chemically-peculiar, very metal poor star cluster has thus far proven impossible to rule out through spectroscopy; this is because the system has too few bright stars to enable definitive velocity or metallicity dispersion measurements capable of distinguishing between these scenarios. Classifying the system as a dwarf galaxy or star cluster will therefore require an independent avenue that does not rely on ground-based spectroscopy. Here, we request 12 orbits of HST/ACS F606W+F814W imaging to construct a deep color--magnitude diagram of DELVE 1 and test whether the system displays stellar mass segregation. The presence of mass segregation would imply short dynamical times in DELVE 1 consistent with a star cluster, while its absence would provide strong evidence that DELVE 1 is a dark matter dominated dwarf galaxy. Our proposed observations will either confirm DELVE 1 as the least-massive galaxy yet discovered or would suggest that DELVE 1 is the first known example of a uniformly carbon-enhanced star cluster formed directly out of gas enriched by Population III supernovae. Whatever the outcome, these results will have important implications for the nature of dark matter and the formation of the lowest mass galaxies and most metal-poor star clusters.

## **OBSERVING DESCRIPTION**

This 12-orbit, 6-visit program images the DELVE 1 stellar system with ACS in the F606W and F814W filters, with WFC3 UVIS coordinated parallels in the same filters. Three pointings (labeled NORTH, SOUTHEAST, SOUTHWEST) have been placed to cover the system contiguously out to at roughly twice its half-light radius for any possible ORIENT. Each of the three pointings is split into 2 visits at the SAME ORIENT: one visit consisting of two orbits of F606W imaging and the other visit consists of one orbit of F814W imaging and one orbit split between F606W and F814W. In other words, 3 pointings x 2 visits/pointing x 2 orbits/visit = 12 prime orbits. For each filter and pointing, we use a ACS-WFC-DITHER-LINE pattern to cover the chip gap. In practice, we use a 4-point LINE for the F606W exposures and a 3-point LINE for the F814W exposures. The single fifth exposure in F606W from the split F606W+F814W orbit is not part of this pattern and is placed at the center of each of the three main pointings. These LINE patterns favor filling the chip gaps and providing CR removal over perfect subpixel sampling. Lastly, we note that there are

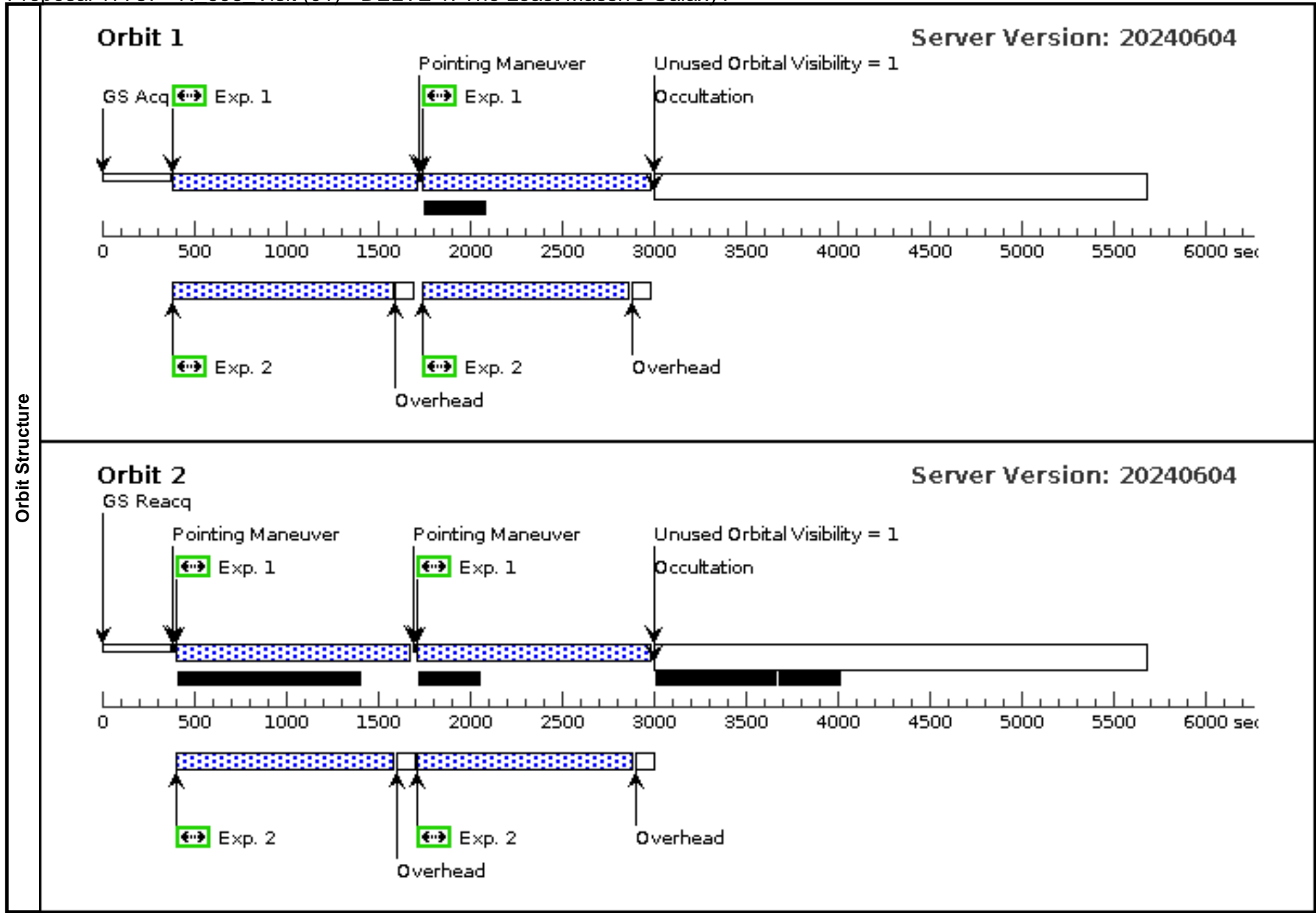
Proposal 17787 (STScI Edit Number: 0, Created: Thursday, October 17, 2024, 11:00:59AM Eastern Standard Time) - Overview

two bright ( $G \sim 12$ ) stars covered by our fields. These two stars will certainly saturate but we expect this will not be a major issue (based on similar ACS observations in the archive). However, "glint" artifacts may also occur; the SAME ORIENT restriction will help ensure that any possible glints are localized to the same region of the detector within a given pointing, allowing them to be masked at the analysis stage.

Proposal 17787 - N\_606\_Visit (01) - DELVE 1: The Least Massive Galaxy?

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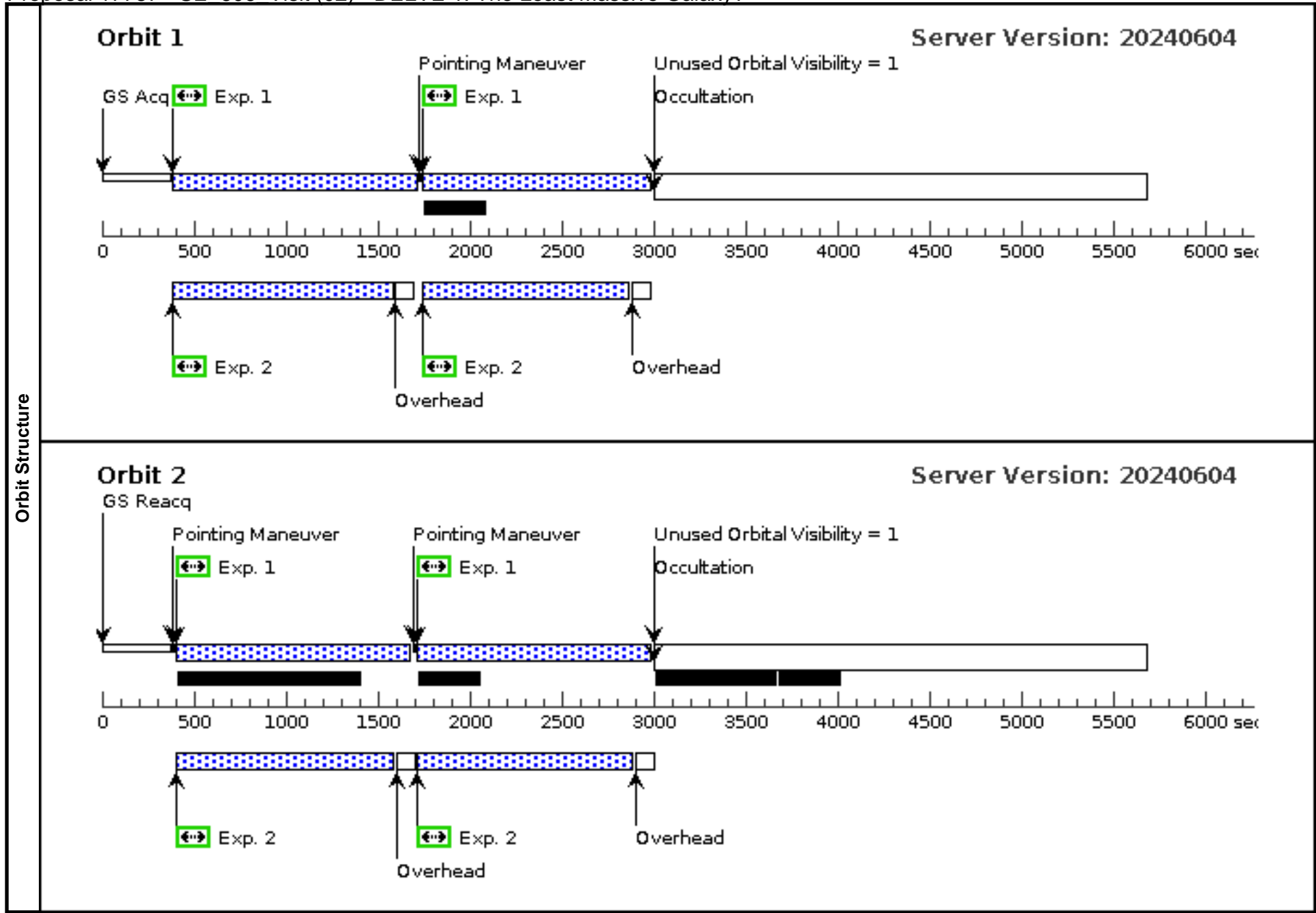
<b>Visit</b>	<b>Proposal 17787, N_606_Visit (01), implementation</b> <b>Diagnostic Status: No Diagnostics</b> Scientific Instruments: WFC3/UVIS, ACS/WFC Special Requirements: (none) <i>Comments: 2 orbits of F606W imaging on the northern pointing; 4 point DITHER-LINE                  Cpar with F606W imaging</i>										
	<b>Patterns</b>	#	<b>Primary Pattern</b>				<b>Secondary Pattern</b>			<b>Exposures</b>	
(1)		Pattern Type=ACS-WFC-DITHER-LINE Purpose=DITHER Number Of Points=4 Point Spacing=3.034 Line Spacing=		Coordinate Frame=POS-TARG Pattern Orientation=85.29 Angle Between Sides= Center Pattern=true					(1-2)		
<b>Fixed Targets</b>	#	<b>Name</b>	<b>Target Coordinates</b>		<b>Targ. Coord. Corrections</b>		<b>Fluxes</b>	<b>Miscellaneous</b>			
	(2)	DELVE1-NORTH Alt Name1: NORTHPOINTING	RA: 16 30 53.7378 (247.7239075d) Dec: -00 57 17.98 (-.95499d) Equinox: J2000		Proper Motion RA: 0 mas/yr Proper Motion Dec: 0 mas/yr Parallax: 0"		V=16	Reference Frame: ICRS			
<i>Comments:</i> Category=STELLAR CLUSTER Description=[GLOBULAR CLUSTER]											
<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	N606	(2) DELVE1-NORTH	ACS/WFC, ACCUM, WFC	F606W			Pattern 1, Exps 1-2 in N_606_Visit (01) (1)	1100 Secs (4542 Secs)		
			H						[==>1121.0 Secs (Pattern 1)]		[1]
								Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in N_606_Visit (01)	[==>1121.0 Secs (Pattern 2)]		
									[==>1150.0 Secs (Pattern 3)]		[2]
									[==>1150.0 Secs (Pattern 4)]		
2	ParN606	ANY	WFC3/UVIS, ACCUM, UVIS	F606W				Pattern 1, Exps 1-2 in N_606_Visit (01) (1)	1100 Secs (4654 Secs)		
									[==>1173.0 Secs (Pattern 1)]		[1]
								Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in N_606_Visit (01)	[==>1123.0 Secs (Pattern 2)]		
									[==>1184.0 Secs (Pattern 3)]		[2]
									[==>1174.0 Secs (Pattern 4)]		



Proposal 17787 - SE 606 Visit (02) - DELVE 1: The Least Massive Galaxy?

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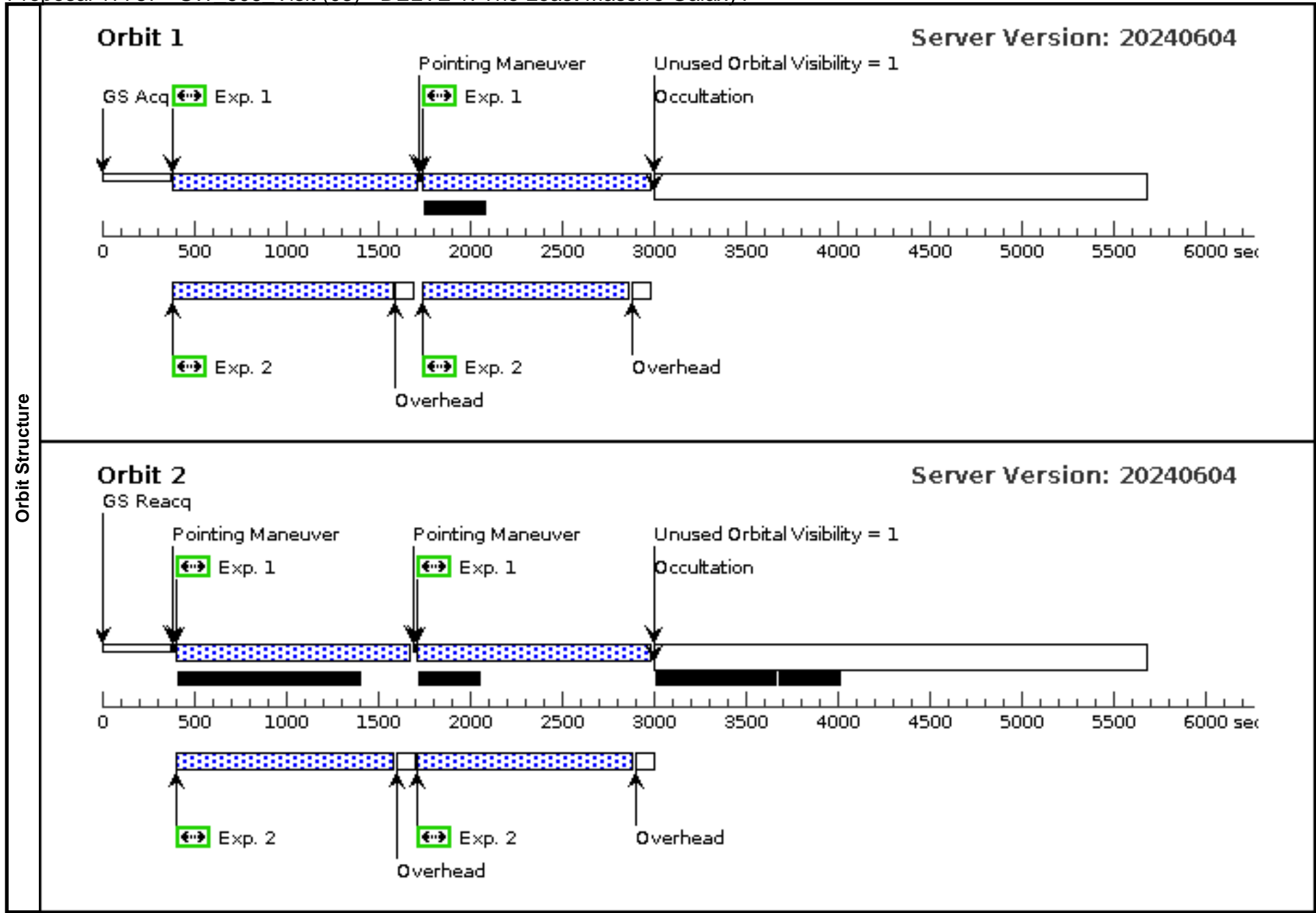
<b>Visit</b>	<b>Proposal 17787, SE_606_Visit (02), implementation</b> <b>Diagnostic Status: No Diagnostics</b> Scientific Instruments: WFC3/UVIS, ACS/WFC Special Requirements: (none) <i>Comments: 2 orbits of F606W imaging on the southeastern pointing; 4 point DITHER-LINE                  Cpar with F606W imaging</i>									
	<b>Patterns</b>	#	<b>Primary Pattern</b>	<b>Secondary Pattern</b>	<b>Exposures</b>					
	(1)	Pattern Type=ACS-WFC-DITHER-LINE Purpose=DITHER Number Of Points=4 Point Spacing=3.034 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=85.29 Angle Between Sides= Center Pattern=true		(1-2)					
<b>Fixed Targets</b>	#	<b>Name</b>	<b>Target Coordinates</b>	<b>Targ. Coord. Corrections</b>	<b>Fluxes</b>	<b>Miscellaneous</b>				
	(1)	DELVE1-SOUTHEAST Alt Name1: SEPOINTING	RA: 16 30 58.0230 (247.7417625d) Dec: -00 58 56.95 (-.98249d) Equinox: J2000	Proper Motion RA: 0 mas/yr Proper Motion Dec: 0 mas/yr Parallax: 0"	V=16	Reference Frame: ICRS				
	<i>Comments:                  Category=STELLAR CLUSTER                  Description=[GLOBULAR CLUSTER]</i>									
<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	SE606	(1) DELVE1-SOUTHEAST	ACS/WFC, ACCUM, WFC	F606W			Pattern 1, Exps 1-2 in SE_606_Visit (02) (1)	1100 Secs (4542 Secs)	
								Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in SE_606_Visit (02)	[==>1121.0 Secs (Pattern 1)] [==>1121.0 Secs (Pattern 2)]	[1]
									[==>1150.0 Secs (Pattern 3)] [==>1150.0 Secs (Pattern 4)]	[2]
	2	ParSE606	ANY	WFC3/UVIS, ACCUM, UVIS	F606W			Pattern 1, Exps 1-2 in SE_606_Visit (02) (1)	1100 Secs (4654 Secs)	
								Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in SE_606_Visit (02)	[==>1173.0 Secs (Pattern 1)] [==>1123.0 Secs (Pattern 2)] [==>1184.0 Secs (Pattern 3)] [==>1174.0 Secs (Pattern 4)]	[1] [2]



Proposal 17787 - SW 606 Visit (03) - DELVE 1: The Least Massive Galaxy?

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<b>Visit</b>	<b>Proposal 17787, SW_606_Visit (03), implementation</b> <b>Diagnostic Status: No Diagnostics</b> Scientific Instruments: WFC3/UVIS, ACS/WFC Special Requirements: (none) <i>Comments: 2 orbits of F606W imaging on the southwestern pointing; 4 point DITHER-LINE</i> <i>Cpar with F606W imaging</i>										
	<b>Patterns</b>	#	<b>Primary Pattern</b>				<b>Secondary Pattern</b>			<b>Exposures</b>	
(1)		Pattern Type=ACS-WFC-DITHER-LINE Purpose=DITHER Number Of Points=4 Point Spacing=3.034 Line Spacing=		Coordinate Frame=POS-TARG Pattern Orientation=85.29 Angle Between Sides= Center Pattern=true					(1-2)		
<b>Fixed Targets</b>	#	<b>Name</b>	<b>Target Coordinates</b>		<b>Targ. Coord. Corrections</b>		<b>Fluxes</b>	<b>Miscellaneous</b>			
	(3)	DELVE1-SOUTHWEST	RA: 16 30 49.7445 (247.7072688d)		Proper Motion RA: 0 mas/yr		V=16	Reference Frame: ICRS			
<i>Alt Name1: SWPOINTING</i> <i>Dec: -00 58 52.38 (-.98122d)</i> <i>Equinox: J2000</i> <i>Parallax: 0"</i> <i>Comments: STELLAR CLUSTER</i> <i>Description=[GLOBULAR CLUSTER]</i>											
<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	SW606	(3) DELVE1-SOUTHWEST	ACS/WFC, ACCUM, WFC	F606W			Pattern 1, Exps 1-2 in SW_606_Visit (03) (1)	1100 Secs (4542 Secs)		
									[==>1121.0 Secs (Pattern 1)]		[1]
									[==>1121.0 Secs (Pattern 2)]		
								Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in SW_606_Visit (03)	[==>1150.0 Secs (Pattern 3)]		[2]
									[==>1150.0 Secs (Pattern 4)]		
2	ParSW606	ANY	WFC3/UVIS, ACCUM, UVIS	F606W				Pattern 1, Exps 1-2 in SW_606_Visit (03) (1)	1100 Secs (4654 Secs)		
									[==>1173.0 Secs (Pattern 1)]		[1]
									[==>1123.0 Secs (Pattern 2)]		
								Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in SW_606_Visit (03)	[==>1184.0 Secs (Pattern 3)]		[2]
									[==>1174.0 Secs (Pattern 4)]		

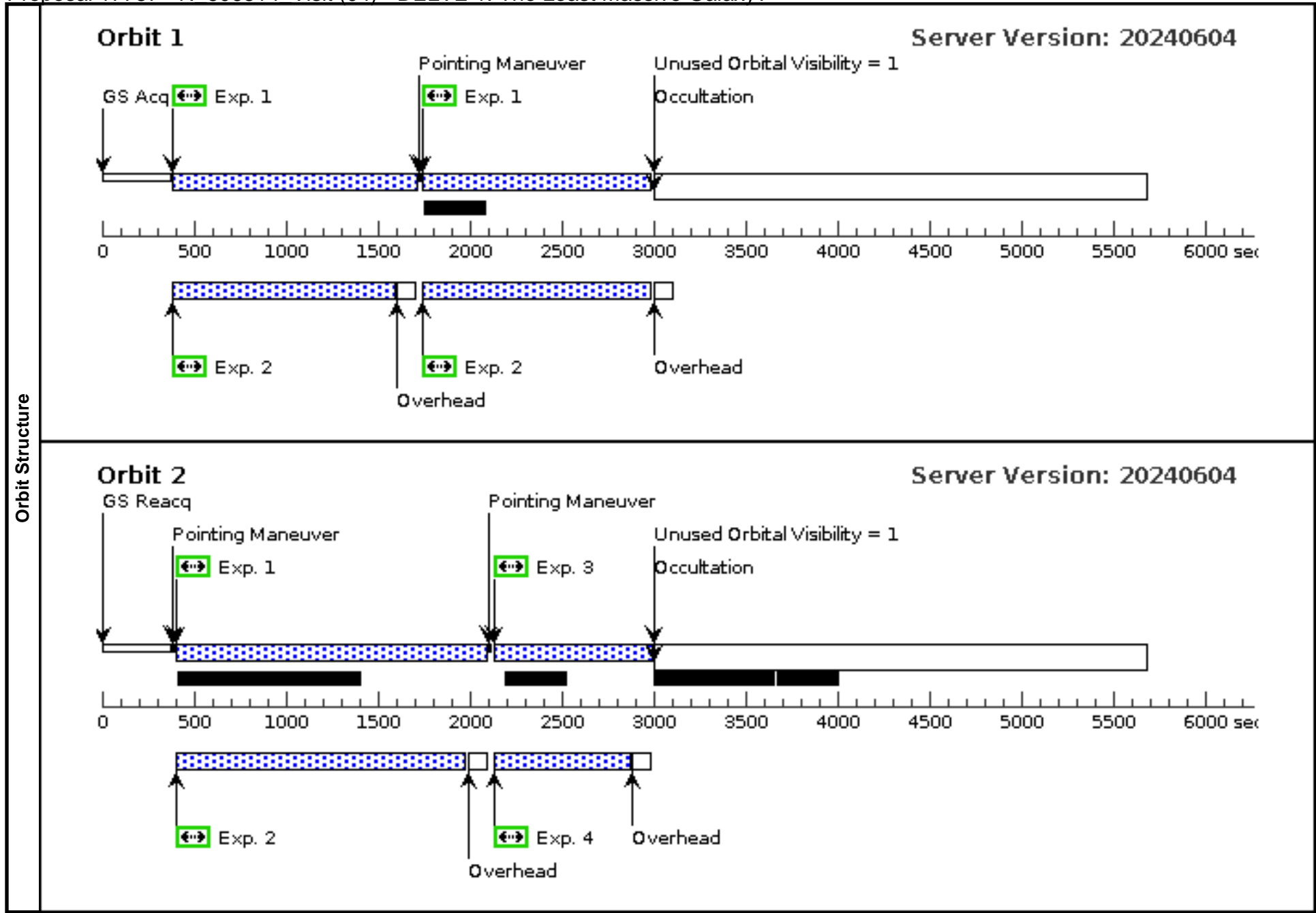


Orbit Structure

Proposal 17787 - N\_606814\_Visit (04) - DELVE 1: The Least Massive Galaxy?

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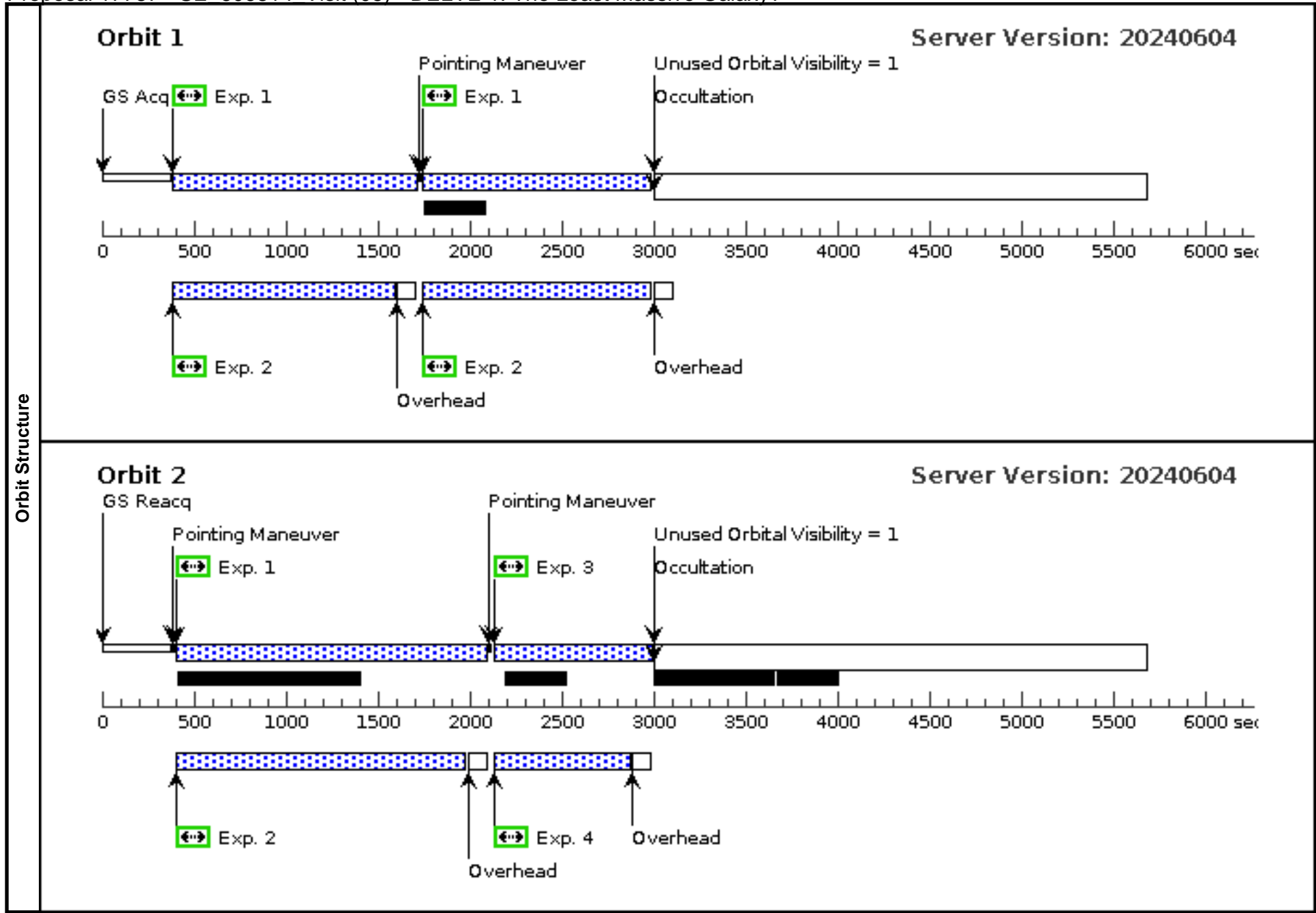
Visit	<b>Proposal 17787, N_606814_Visit (04), implementation</b> <b>Diagnostic Status: No Diagnostics</b> Scientific Instruments: WFC3/UVIS, ACS/WFC Special Requirements: SAME ORIENT AS 01 <i>Comments: Northern pointing; one orbit of entirely F814W imaging with UVIS F814 cpar; one orbit of F606W +F814W with UVIS cpar on both filters</i>										
	Patterns	#	Primary Pattern	Secondary Pattern	Exposures						
		(2)	Pattern Type=ACS-WFC-DITHER-LINE Purpose=DITHER Number Of Points=3 Point Spacing=3.034 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=85.29 Angle Between Sides= Center Pattern=true		(1-2)					
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous					
	(2)	DELVE1-NORTH	RA: 16 30 53.7378 (247.7239075d)	Proper Motion RA: 0 mas/yr	V=16	Reference Frame: ICRS					
		Alt Name1: NORTHPOINTING	Dec: -00 57 17.98 (-95499d) Equinox: J2000	Proper Motion Dec: 0 mas/yr Parallax: 0"							
	<i>Comments: Category=STELLAR CLUSTER Description=[GLOBULAR CLUSTER]</i>										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit	
	1	N814	(2) DELVE1-NORTH	ACS/WFC, ACCUM, WFC	F814W			Pattern 2, Exps 1-2 in N_606814_Visit (04) (2) Prime + Parallel Group 1-2 in Pattern 2, Exps 1-2 in N_606814_Visit (04)	1181 Secs (3806 Secs) [==>1121.0 Secs (Pattern 1)] [==>1121.0 Secs (Pattern 2)] [==>1564.0 Secs (Pattern 3)]	[1] [2]	
	2	ParN814	ANY	WFC3/UVIS, ACCUM, UVIS	F814W			Pattern 2, Exps 1-2 in N_606814_Visit (04) (2) Prime + Parallel Group 1-2 in Pattern 2, Exps 1-2 in N_606814_Visit (04)	1181 Secs (4002 Secs) [==>(Pattern 1)] [==>1247.0 Secs (Pattern 2)] [==>1574.0 Secs (Pattern 3)]	[1] [2]	
	3	N606_short	(2) DELVE1-NORTH	ACS/WFC, ACCUM, WFC	F606W			Prime + Parallel Group 3-4 in N_606814_Visit (04)	570 Secs (681 Secs) [==>681.0 Secs ]	[2]	
	<i>Comments: Single 606 exposure to complement the other four from the first visit</i>										
	4	ParN606_short	ANY	WFC3/UVIS, ACCUM, UVIS	F606W			Prime + Parallel Group 3-4 in N_606814_Visit (04)	688 Secs (723 Secs) [==>723.0 Secs ]	[2]	



Proposal 17787 - SE\_606814\_Visit (05) - DELVE 1: The Least Massive Galaxy?

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Visit	<b>Proposal 17787, SE_606814_Visit (05), implementation</b> <b>Diagnostic Status: No Diagnostics</b> Scientific Instruments: WFC3/UVIS, ACS/WFC Special Requirements: SAME ORIENT AS 02 <i>Comments: Southeastern pointing; one orbit of entirely F814W imaging with UVIS F814 cpar; one orbit of F606W +F814W with UVIS cpar on both filters</i>									
	Patterns	#	Primary Pattern	Secondary Pattern	Exposures					
		(2)	Pattern Type=ACS-WFC-DITHER-LINE Purpose=DITHER Number Of Points=3 Point Spacing=3.034 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=85.29 Angle Between Sides= Center Pattern=true		(1-2)				
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	DELVE1-SOUTHEAST	RA: 16 30 58.0230 (247.7417625d)	Proper Motion RA: 0 mas/yr	V=16	Reference Frame: ICRS				
		Alt Name1: SEPOINTING	Dec: -00 58 56.95 (-.98249d) Equinox: J2000	Proper Motion Dec: 0 mas/yr Parallax: 0"						
	<i>Comments: Category=STELLAR CLUSTER Description=[GLOBULAR CLUSTER]</i>									
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	SE814	(1) DELVE1-SOUTH HEAST	ACS/WFC, ACCUM, WFC	F814W			Pattern 2, Exps 1-2 in SE_606814_Visit (05) (2) Prime + Parallel Group 1-2 in Pattern 2, Exps 1-2 in SE_606814_Visit (05)	1181 Secs (3806 Secs) [==>1121.0 Secs (Pattern 1)] [==>1121.0 Secs (Pattern 2)] [==>1564.0 Secs (Pattern 3)]	[1] [2]
	2	ParSE814	ANY	WFC3/UVIS, ACCUM, UVIS	F814W			Pattern 2, Exps 1-2 in SE_606814_Visit (05) (2) Prime + Parallel Group 1-2 in Pattern 2, Exps 1-2 in SE_606814_Visit (05)	1181 Secs (4002 Secs) [==>(Pattern 1)] [==>1247.0 Secs (Pattern 2)] [==>1574.0 Secs (Pattern 3)]	[1] [2]
	3	SE606_short	(1) DELVE1-SOUTH HEAST	ACS/WFC, ACCUM, WFC	F606W			Prime + Parallel Group 3-4 in SE_606814_Visit (05)	570 Secs (681 Secs) [==>681.0 Secs ]	[2]
	<i>Comments: Single 606 exposure to complement the other four from the first visit</i>									
	4	ParSE606	ANY	WFC3/UVIS, ACCUM, UVIS	F606W			Prime + Parallel Group 3-4 in SE_606814_Visit (05)	688 Secs (723 Secs) [==>723.0 Secs ]	[2]



Proposal 17787 - SW 606814 Visit (06) - DELVE 1: The Least Massive Galaxy?

Thu Oct 17 16:01:00 GMT 2024

Visit	<b>Proposal 17787, SW_606814_Visit (06), implementation</b> <b>Diagnostic Status: No Diagnostics</b> Scientific Instruments: WFC3/UVIS, ACS/WFC Special Requirements: SAME ORIENT AS 03 <i>Comments: Southwestern pointing; one orbit of entirely F814W imaging with UVIS F814 cpar; one orbit of F606W +F814W with UVIS cpar on both filters</i>									
	Patterns	#	Primary Pattern	Secondary Pattern	Exposures					
		(2)	Pattern Type=ACS-WFC-DITHER-LINE Purpose=DITHER Number Of Points=3 Point Spacing=3.034 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=85.29 Angle Between Sides= Center Pattern=true		(1-2)				
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(3)	DELVE1-SOUTHWEST	RA: 16 30 49.7445 (247.7072688d) Alt Name1: SWPOINTING Equinox: J2000	Proper Motion RA: 0 mas/yr Proper Motion Dec: 0 mas/yr Parallax: 0"	V=16	Reference Frame: ICRS				
<i>Comments: Category=STELLAR CLUSTER Description=[GLOBULAR CLUSTER]</i>										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	SW814	(3) DELVE1-SOUTHWEST	ACS/WFC, ACCUM, WFC	F814W				Pattern 2, Exps 1-2 in SW_606814_Visit (06) (2) Prime + Parallel Group 1-2 in Pattern 2, Exps 1-2 in SW_606814_Visit (06)	1181 Secs (3806 Secs) [==>1121.0 Secs (Pattern 1)] [==>1121.0 Secs (Pattern 2)] [==>1564.0 Secs (Pattern 3)]
2	ParSW814	ANY	WFC3/UVIS, ACCUM, UVIS	F814W				Pattern 2, Exps 1-2 in SW_606814_Visit (06) (2) Prime + Parallel Group 1-2 in Pattern 2, Exps 1-2 in SW_606814_Visit (06)	1181 Secs (4002 Secs) [==>(Pattern 1)] [==>1247.0 Secs (Pattern 2)] [==>1574.0 Secs (Pattern 3)]	[1] [2]
3	SW606_short	(3) DELVE1-SOUTHWEST	ACS/WFC, ACCUM, WFC	F606W				Prime + Parallel Group 3-4 in SW_606814_Visit (06)	570 Secs (681 Secs) [==>681.0 Secs ]	[2]
<i>Comments: Single 606 exposure to complement the other four from the first visit</i>										
4	ParSW606	ANY	WFC3/UVIS, ACCUM, UVIS	F606W				Prime + Parallel Group 3-4 in SW_606814_Visit (06)	688 Secs (723 Secs) [==>723.0 Secs ]	[2]

