



# 15858 - The Satellite Luminosity Function of M101 into the Ultra-Faint Dwarf Galaxy Regime

Cycle: 27, Proposal Category: GO  
(Availability Mode: SUPPORTED)

## 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) M101-DW21 ANY	ACS/WFC WFC3/UVIS	1	24-Sep-2019 10:00:32.0	yes
02	(2) M101-DW22 ANY	ACS/WFC WFC3/UVIS	1	24-Sep-2019 10:00:34.0	yes
03	(3) M101-DW23 ANY	ACS/WFC WFC3/UVIS	1	24-Sep-2019 10:00:35.0	yes
04	(4) M101-DW35 ANY	ACS/WFC WFC3/UVIS	1	24-Sep-2019 10:00:36.0	yes

4 Total Orbits Used

## **ABSTRACT**

We request 4 orbits of HST/ACS to image, in resolved stellar light, four diffuse dwarf candidates that recent tentative distance measurements (using the surface brightness fluctuation technique) indicate may be associated with M101, a Milky Way analog at  $D=7$  Mpc. These four dwarfs are the only remaining viable satellites of M101 down to  $M_V \sim -7$  mag, out of a complete sample drawn from a semi-automated ground-based search which conducted extensive simulations to assess the efficiency in their detection. This dataset will allow us to measure tip of the red giant branch (TRGB) distances, luminosities and structural parameters for these dwarfs, and will result in a complete satellite luminosity function for M101 out to a galacocentric radius of 150 kpc and down to the ultra-faint dwarf galaxy regime ( $M_V \sim -7$  mag). Such a complete luminosity function has been only obtained for the Local Group to date. The current M101 satellite system is very sparse in comparison to the Milky Way, M31 and cosmological simulations, and a confirmation of its properties will provide additional constraints on Cold Dark Matter predictions at these small galaxy scales.

## **OBSERVING DESCRIPTION**

The observations are going to be performed with ACS/WFC (primary) and WFC3/UVIS (parallel). We request imaging in F606W and F814W filters (broad V and I) for both instruments, in order to compute accurate TRGB distances for our targets and characterize their stellar content (star formation histories and metallicities), while optimizing the exposure times. The parallel pointings will allow us to observe a field region next to our targets. We will thus be able to estimate more precisely the number of background/foreground contaminants present in our ACS fields.

Our goal is to obtain a SNR of  $\sim 5$  at  $\sim 1$  mag below the TRGB in I band, assuming that the TRGB is found at  $M_I = \sim -4.0$  and  $M_V = \sim -2.5$ , in order to derive precise distance measurements, structural properties and average metallicities. With the requested SNR, we will obtain distance uncertainties as low as  $\sim 0.2$  mag, corresponding to  $\sim 200$  kpc at the distance of M101. We stress that, even for the faintest of our targets we expect  $\sim 25$  stars in the upper 1 mag below the TRGB.

Since the exact distances for our targets are unknown, the candidate M101 satellites are assumed to be at the distance of M101 ( $\sim 7$  Mpc). Given their low masses, these are expected to be metal-poor objects, thus having average colours of  $V - I \sim 1.5$ . At this distance, the TRGB is found at a magnitude of  $I \sim 25.2$  and  $V \sim 25.9$ . The exposures to obtain the required SNR at 1 mag below the TRGB for both bands are  $\sim 1200$  sec in F606W and  $\sim 900$  sec in F814W (as computed with the latest version of the ACS ETC), which result in one orbit per target. Each exposure will be split in two with a dither pattern in order to subsequently remove detector defects and improve the PSF sampling. We have checked that the charge transfer

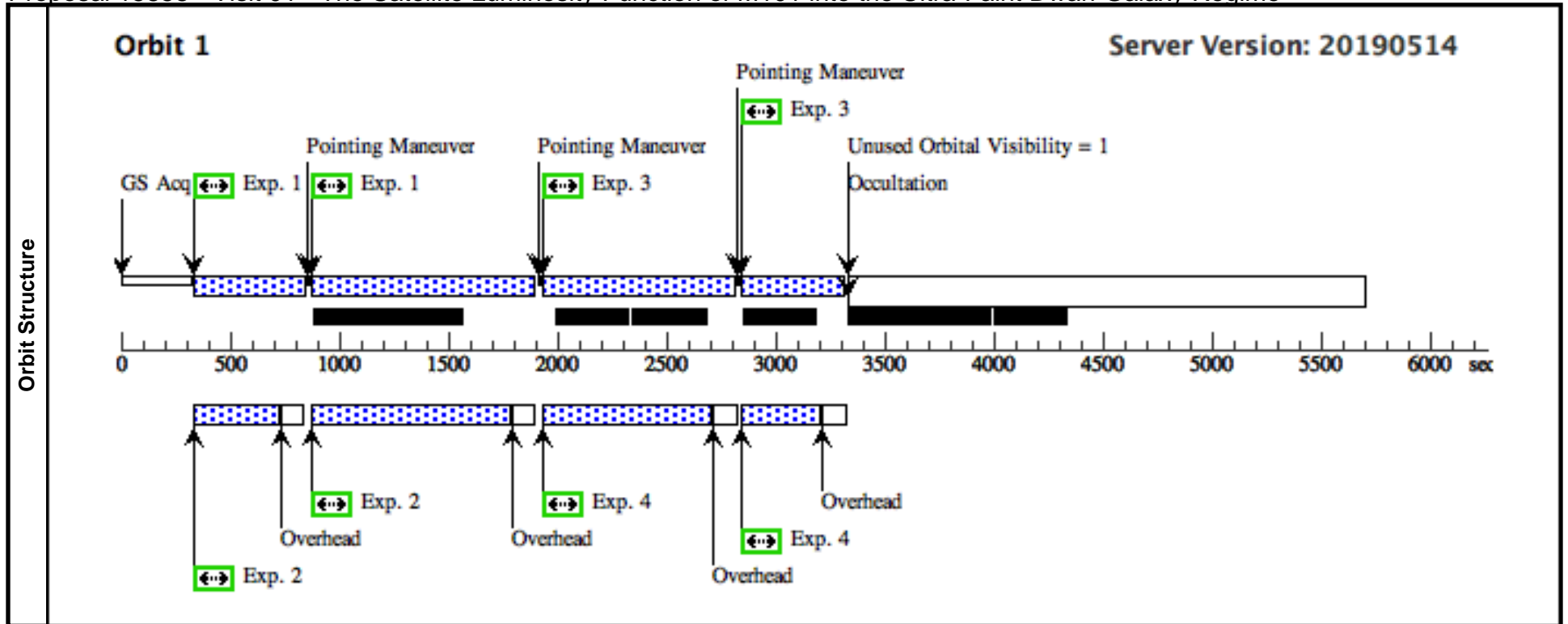
Proposal 15858 (STScI Edit Number: 0, Created: Tuesday, September 24, 2019 at 9:00:37 AM Eastern Standard Time) - Overview  
efficiency losses of ACS do not significantly affect our observations (at most 10% loss of flux).

This program is resilient to two-gyro mode, we believe. Our visits are 1-orbit, and we have no ORIENT requirements. Nor does this program have time constraints (other than the baseline excitement of the science!). We can also achieve our science goals with a longer acquisition time, if necessary.

Proposal 15858 - Visit 01 - The Satellite Luminosity Function of M101 into the Ultra-Faint Dwarf Galaxy Regime

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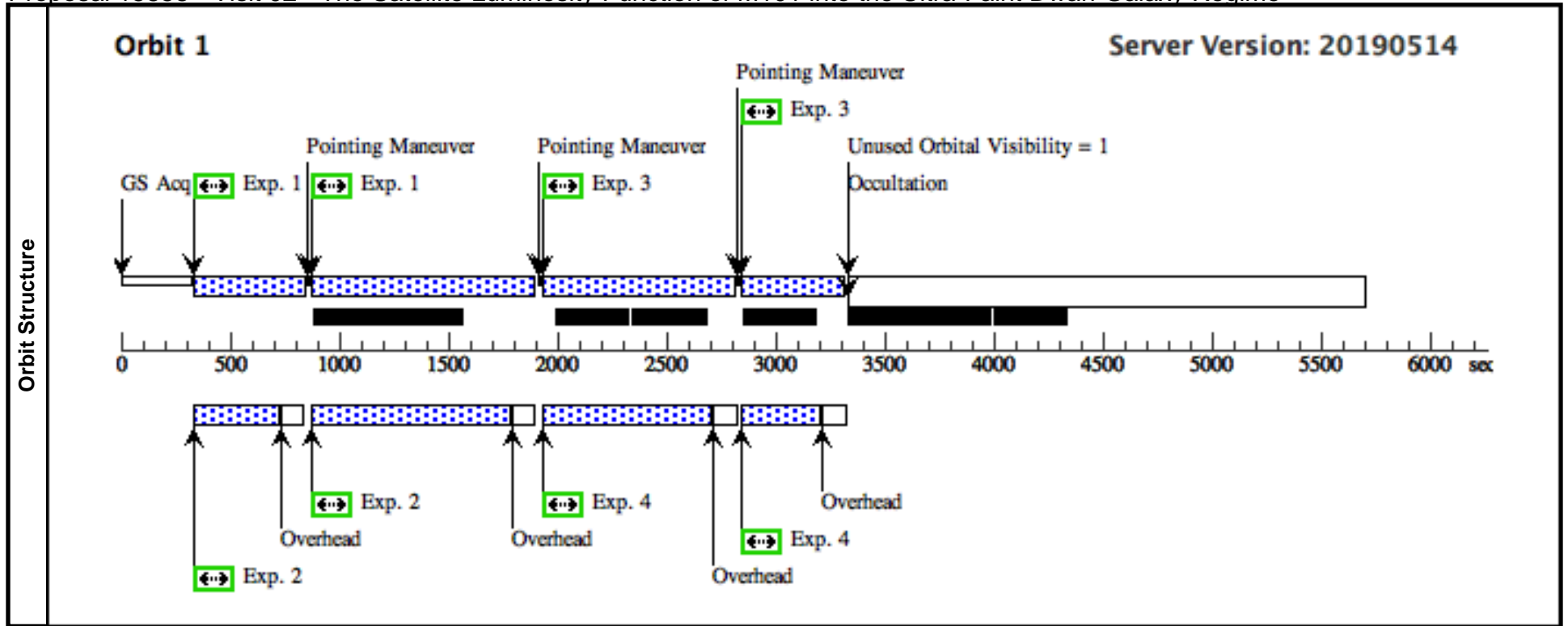
<b>Visit</b>	<b>Proposal 15858, Visit 01, implementation</b> <b>Diagnostic Status: Warning</b> Scientific Instruments: WFC3/UVIS, ACS/WFC Special Requirements: (none)									
	(Parallel Exposure 4 (Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 in Visit 01)) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser									
<b>Diagnosics</b>										
<b>Patterns</b>	<b>#</b>	<b>Primary Pattern</b>	<b>Secondary Pattern</b>	<b>Exposures</b>						
	(1)	Pattern Type=ACS-WFC-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.364 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=47.23 Angle Between Sides= Center Pattern=false		(1-2), (3-4)					
<b>Fixed Targets</b>	<b>#</b>	<b>Name</b>	<b>Target Coordinates</b>	<b>Targ. Coord. Corrections</b>	<b>Fluxes</b>	<b>Miscellaneous</b>				
	(1)	M101-DW21	RA: 14 07 56.5000 (211.9854167d) Dec: +54 56 3.00 (54.93417d) Equinox: J2000		V=21.3+/-0.2	Reference Frame: ICRS				
<i>Comments:</i> Category=GALAXY Description=[DWARF SPHEROIDAL] Extended=YES										
<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		(1) M101-DW21	ACS/WFC, ACCUM, WFC1	F606W			Pattern 1, Exps 1-2 in Visit 01 (1) Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in Visit 01	650 Secs (1200 Secs) [==>300.0 Secs (Pattern 1)] [==>900.0 Secs (Pattern 2)]	[1]
	2		ANY	WFC3/UVIS, ACCUM, UVIS1	F606W			Pattern 1, Exps 1-2 in Visit 01 (1) Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in Visit 01	200 Secs (1270 Secs) [==>360.0 Secs (Pattern 1)] [==>910.0 Secs (Pattern 2)]	[1]
	3		(1) M101-DW21	ACS/WFC, ACCUM, WFC1	F814W			Pattern 1, Exps 3-4 in Visit 01 (1) Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 in Visit 01	450 Secs (1050 Secs) [==>700.0 Secs (Pattern 1)] [==>350.0 Secs (Pattern 2)]	[1]
	4		ANY	WFC3/UVIS, ACCUM, UVIS1	F814W	FLASH=3.0		Pattern 1, Exps 3-4 in Visit 01 (1) Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 in Visit 01	200 Secs (1112 Secs) [==>752.0 Secs (Pattern 1)] [==>360.0 Secs (Pattern 2)]	[1]



Proposal 15858 - Visit 02 - The Satellite Luminosity Function of M101 into the Ultra-Faint Dwarf Galaxy Regime

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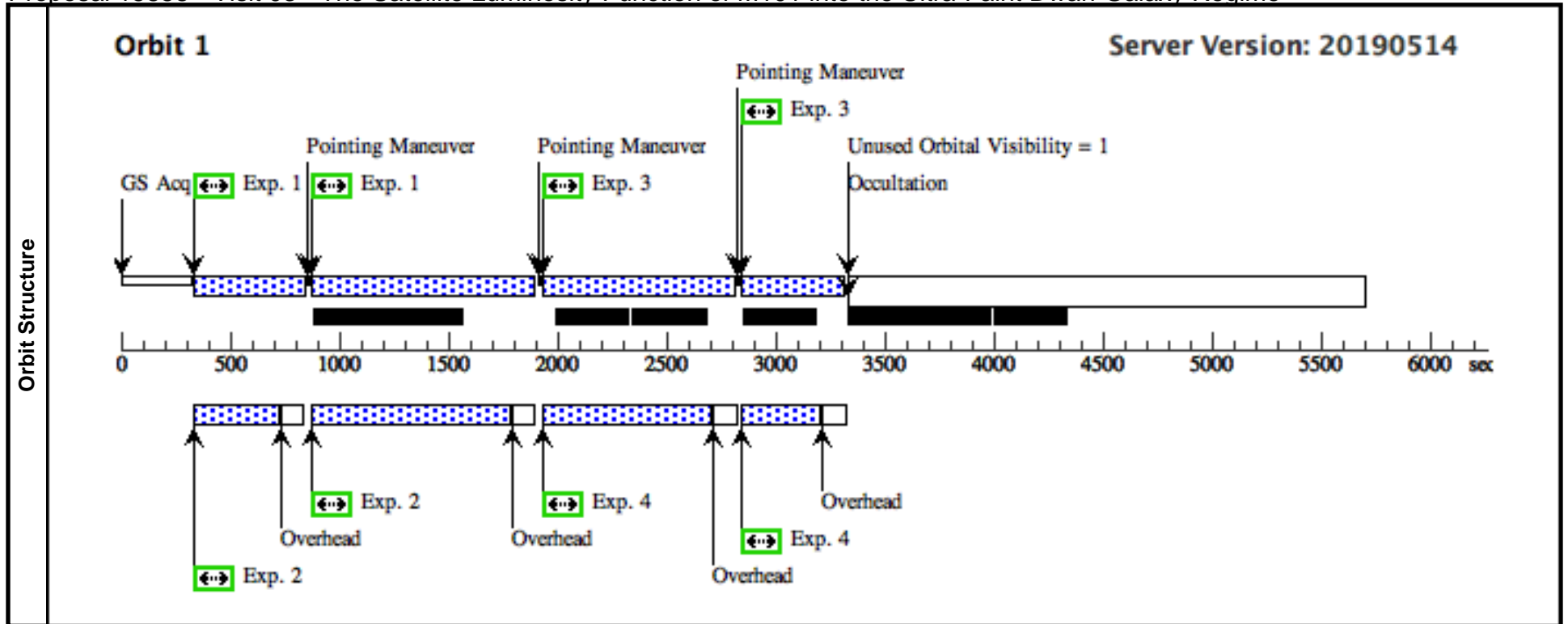
<b>Visit</b>	<b>Proposal 15858, Visit 02, implementation</b> <b>Diagnostic Status: Warning</b> Scientific Instruments: WFC3/UVIS, ACS/WFC Special Requirements: (none)									
	(Parallel Exposure 4 (Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 in Visit 02)) Warning (Form): FLASH level may be too high for this exposure or a long subexposure. See extended explanation in the diagnostic browser									
<b>Diagnosics</b>										
<b>Patterns</b>	<b>#</b>	<b>Primary Pattern</b>	<b>Secondary Pattern</b>	<b>Exposures</b>						
	(1)	Pattern Type=ACS-WFC-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.364 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=47.23 Angle Between Sides= Center Pattern=false		(1-2), (3-4)					
<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)	M101-DW22	RA: 14 03 3.3000 (210.7637500d) Dec: +54 47 12.00 (54.78667d) Equinox: J2000  <i>Comments:</i> Category=GALAXY Description=[DWARF SPHEROIDAL] Extended=YES		V=21.0+/-0.1	Reference Frame: ICRS				
<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) M101-DW22	ACS/WFC, ACCUM, WFC1	F606W			Pattern 1, Exps 1-2 in Visit 02 (1) Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in Visit 02	650 Secs (1200 Secs) [==>300.0 Secs (Pattern 1)] [==>900.0 Secs (Pattern 2)]	[1]
	2		ANY	WFC3/UVIS, ACCUM, UVIS1	F606W			Pattern 1, Exps 1-2 in Visit 02 (1) Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in Visit 02	200 Secs (1270 Secs) [==>360.0 Secs (Pattern 1)] [==>910.0 Secs (Pattern 2)]	[1]
	3		(2) M101-DW22	ACS/WFC, ACCUM, WFC1	F814W			Pattern 1, Exps 3-4 in Visit 02 (1) Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 in Visit 02	450 Secs (1050 Secs) [==>700.0 Secs (Pattern 1)] [==>350.0 Secs (Pattern 2)]	[1]
	4		ANY	WFC3/UVIS, ACCUM, UVIS1	F814W	FLASH=3.0		Pattern 1, Exps 3-4 in Visit 02 (1) Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 in Visit 02	200 Secs (1112 Secs) [==>752.0 Secs (Pattern 1)] [==>360.0 Secs (Pattern 2)]	[1]



Proposal 15858 - Visit 03 - The Satellite Luminosity Function of M101 into the Ultra-Faint Dwarf Galaxy Regime

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<b>Visit</b>	<b>Proposal 15858, Visit 03, implementation</b> <b>Diagnostic Status: Warning</b> Scientific Instruments: WFC3/UVIS, ACS/WFC Special Requirements: (none)									
	(Parallel Exposure 4 (Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 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									
<b>Diagnosics</b>										
<b>Patterns</b>	<b>#</b>	<b>Primary Pattern</b>	<b>Secondary Pattern</b>		<b>Exposures</b>					
	(1)	Pattern Type=ACS-WFC-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.364 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=47.23 Angle Between Sides= Center Pattern=false		(1-2), (3-4)					
<b>Fixed Targets</b>	<b>#</b>	<b>Name</b>	<b>Target Coordinates</b>	<b>Targ. Coord. Corrections</b>	<b>Fluxes</b>	<b>Miscellaneous</b>				
	(3)	M101-DW23	RA: 14 07 8.4000 (211.7850000d) Dec: +54 33 49.00 (54.56361d) Equinox: J2000  <i>Comments:</i> Category=GALAXY Description=[DWARF SPHEROIDAL] Extended=YES		V=21.2+/-0.5	Reference Frame: ICRS				
<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		(3) M101-DW23	ACS/WFC, ACCUM, WFC1	F606W			Pattern 1, Exps 1-2 in Visit 03 (1) Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in Visit 03	650 Secs (1200 Secs) [==>300.0 Secs (Pattern 1)] [==>900.0 Secs (Pattern 2)]	[1]
	2		ANY	WFC3/UVIS, ACCUM, UVIS1	F606W			Pattern 1, Exps 1-2 in Visit 03 (1) Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in Visit 03	200 Secs (1270 Secs) [==>360.0 Secs (Pattern 1)] [==>910.0 Secs (Pattern 2)]	[1]
	3		(3) M101-DW23	ACS/WFC, ACCUM, WFC1	F814W			Pattern 1, Exps 3-4 in Visit 03 (1) Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 in Visit 03	450 Secs (1050 Secs) [==>700.0 Secs (Pattern 1)] [==>350.0 Secs (Pattern 2)]	[1]
	4		ANY	WFC3/UVIS, ACCUM, UVIS1	F814W	FLASH=3.0		Pattern 1, Exps 3-4 in Visit 03 (1) Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 in Visit 03	200 Secs (1112 Secs) [==>752.0 Secs (Pattern 1)] [==>360.0 Secs (Pattern 2)]	[1]



Proposal 15858 - Visit 04 - The Satellite Luminosity Function of M101 into the Ultra-Faint Dwarf Galaxy Regime

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<b>Visit</b>	<b>Proposal 15858, Visit 04, implementation</b> <b>Diagnostic Status: Warning</b> Scientific Instruments: WFC3/UVIS, ACS/WFC Special Requirements: (none)									
	(Parallel Exposure 4 (Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 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									
<b>Diagnosics</b>										
<b>Patterns</b>	<b>#</b>	<b>Primary Pattern</b>	<b>Secondary Pattern</b>	<b>Exposures</b>						
	(1)	Pattern Type=ACS-WFC-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.364 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=47.23 Angle Between Sides= Center Pattern=false		(1-2), (3-4)					
<b>Fixed Targets</b>	<b>#</b>	<b>Name</b>	<b>Target Coordinates</b>	<b>Targ. Coord. Corrections</b>	<b>Fluxes</b>	<b>Miscellaneous</b>				
	(4)	M101-DW35	RA: 14 05 36.2000 (211.4008333d) Dec: +54 49 2.00 (54.81722d) Equinox: J2000  <i>Comments:</i> Category=GALAXY Description=[DWARF SPHEROIDAL]		V=21.8+/-0.2	Reference Frame: ICRS				
<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	(4) M101-DW35		ACS/WFC, ACCUM, WFC1	F606W			Pattern 1, Exps 1-2 in Visit 04 (1) Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in Visit 04	650 Secs (1200 Secs) [==>300.0 Secs (Pattern 1)] [==>900.0 Secs (Pattern 2)]	[1]
	2	ANY		WFC3/UVIS, ACCUM, UVIS1	F606W			Pattern 1, Exps 1-2 in Visit 04 (1) Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in Visit 04	200 Secs (1270 Secs) [==>360.0 Secs (Pattern 1)] [==>910.0 Secs (Pattern 2)]	[1]
	3	(4) M101-DW35		ACS/WFC, ACCUM, WFC1	F814W			Pattern 1, Exps 3-4 in Visit 04 (1) Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 in Visit 04	450 Secs (1050 Secs) [==>700.0 Secs (Pattern 1)] [==>350.0 Secs (Pattern 2)]	[1]
	4	ANY		WFC3/UVIS, ACCUM, UVIS1	F814W	FLASH=3.0		Pattern 1, Exps 3-4 in Visit 04 (1) Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 in Visit 04	200 Secs (1112 Secs) [==>752.0 Secs (Pattern 1)] [==>360.0 Secs (Pattern 2)]	[1]

