



# 14922 - Probing the Nature of Dark Matter with Individual Stars Highly Magnified by a Galaxy Cluster

Cycle: 24, Proposal Category: GO

(Availability Mode: SUPPORTED)

## INVESTIGATORS

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Proposal 14922 (STScI Edit Number: 0, Created: Monday, March 27, 2017 8:05:19 PM EST) - Overview

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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) POSSIBLESTARCOUNTERIMAGE	WFC3/IR WFC3/UVIS	1	27-Mar-2017 21:05:14.0	yes
02	(1) POSSIBLESTARCOUNTERIMAGE	WFC3/IR WFC3/UVIS	1	27-Mar-2017 21:05:15.0	yes
03	(1) POSSIBLESTARCOUNTERIMAGE	WFC3/IR WFC3/UVIS	1	27-Mar-2017 21:05:16.0	yes
04	(1) POSSIBLESTARCOUNTERIMAGE	WFC3/IR WFC3/UVIS	1	27-Mar-2017 21:05:17.0	yes
05	(1) POSSIBLESTARCOUNTERIMAGE	WFC3/IR WFC3/UVIS	1	27-Mar-2017 21:05:18.0	yes

5 Total Orbits Used

**ABSTRACT**

A star highly magnified by a galaxy cluster should provide a powerful new tool for probing the composition of dark matter. We discovered the first-known such star (named "Icarus") close to the critical curve of the MACS J1149 galaxy cluster in April 2016. The star's spectral energy distribution (SED) shows no change over the last several years, including during its rise to peak brightness in May 2016. The SED is consistent with that of a mid-to-late B-type star at the redshift  $z=1.49$  of the background lensed galaxy, and our models suggest that the star became temporarily magnified by a factor of at least  $\sim 2000$  at peak. While continuing to monitor the field, we discovered a new, entirely unexpected source (dubbed "Chucky") with very high significance  $\sim 0.26$  arcseconds away from Icarus on October 30, 2016. If Chucky is a counterimage of Icarus, a population of massive

objects ( $>20$  solar masses) may be needed to hide it during the  $\sim 12$  years while the field has been observed. When a follow-up program was able to observe the field to measure its SED, Chucky had faded. However, in a subsequent visit, we detected an additional potential  $\sim 4$ -sigma source ("Perdix") offset from both Icarus and Chucky. If we continue to detect transients at large offsets, dark matter corresponding to an ultra-light scalar field (Hui et al. 2016) may be required to account for the rate of such events. An ultra-light scalar field would be granular instead of smoothly distributed, leading to microlensing events with large angular separations. The observations of the field, at an optimal cadence for finding microlensing events, will be able to identify distinct stars from their Balmer jumps.

### **OBSERVING DESCRIPTION**

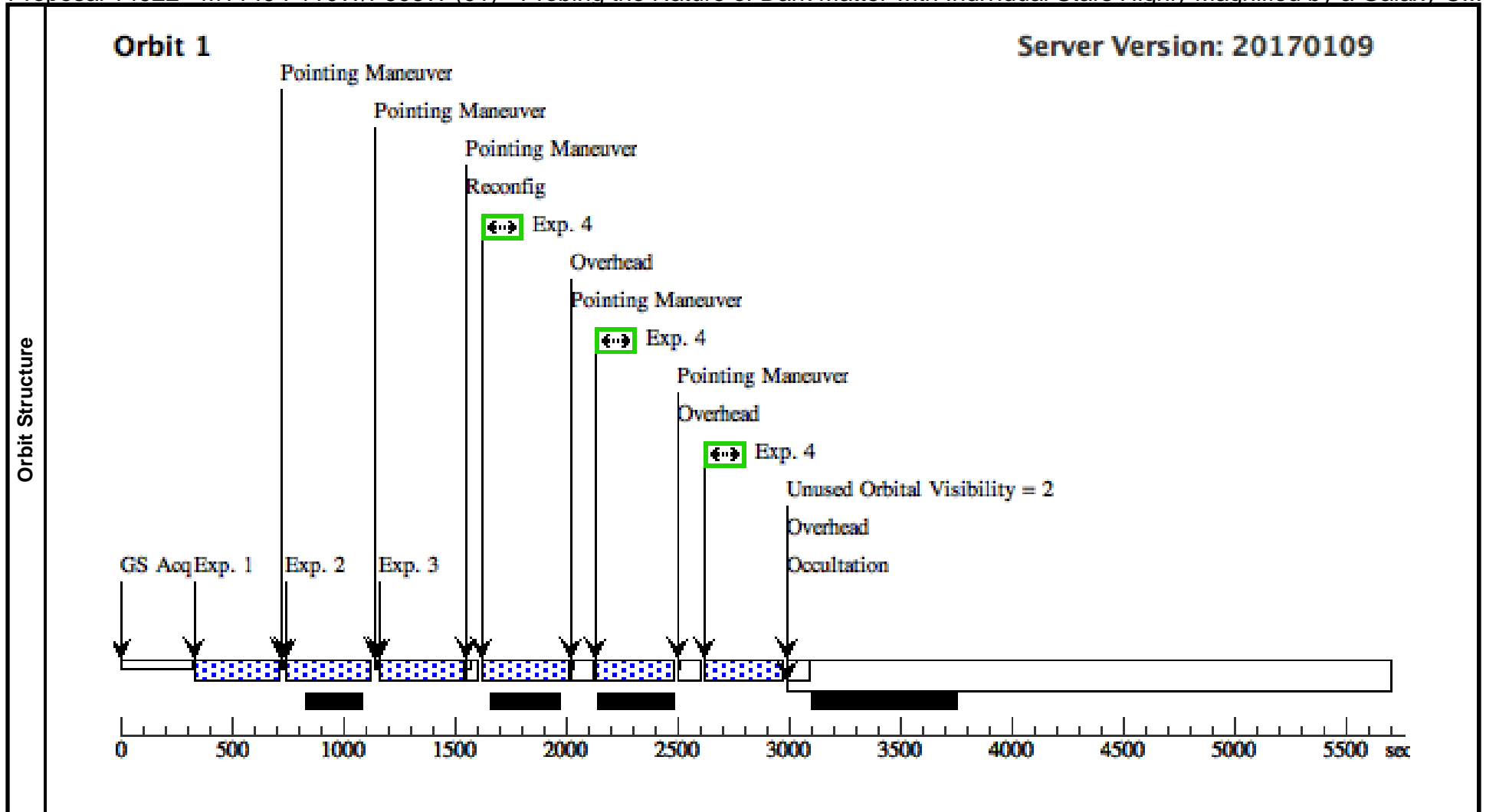
Two transients that we understand to be individual magnified stars have appeared close ( $<0.1''$ ) to the critical curve of the MACS J1149 galaxy cluster in HST observations that we acquired during Cycle 23 and Cycle 24. As part of this program, we will continue to monitor the field for similar events, which should help us to understand the lens system and place constraints on dark matter in the form of compact objects.

This program will consist of five separate one-orbit visits each split between integrations in the WFC3-UVIS F606W and WFC3-IR F125W wideband filters. These observer-frame optical and near-IR filters span the Balmer jump of stars at the redshift ( $z=1.49$ ) of the lensed background galaxy. The observations will therefore make it possible to place constraints on the photospheric temperatures of lensed stars and distinguish between the images of distinct stars.

Proposal 14922 - M1149 F110W/F606W (01) - Probing the Nature of Dark Matter with Individual Stars Highly Magnified by a Galaxy C...

Tue Mar 28 01:05:19 GMT 2017

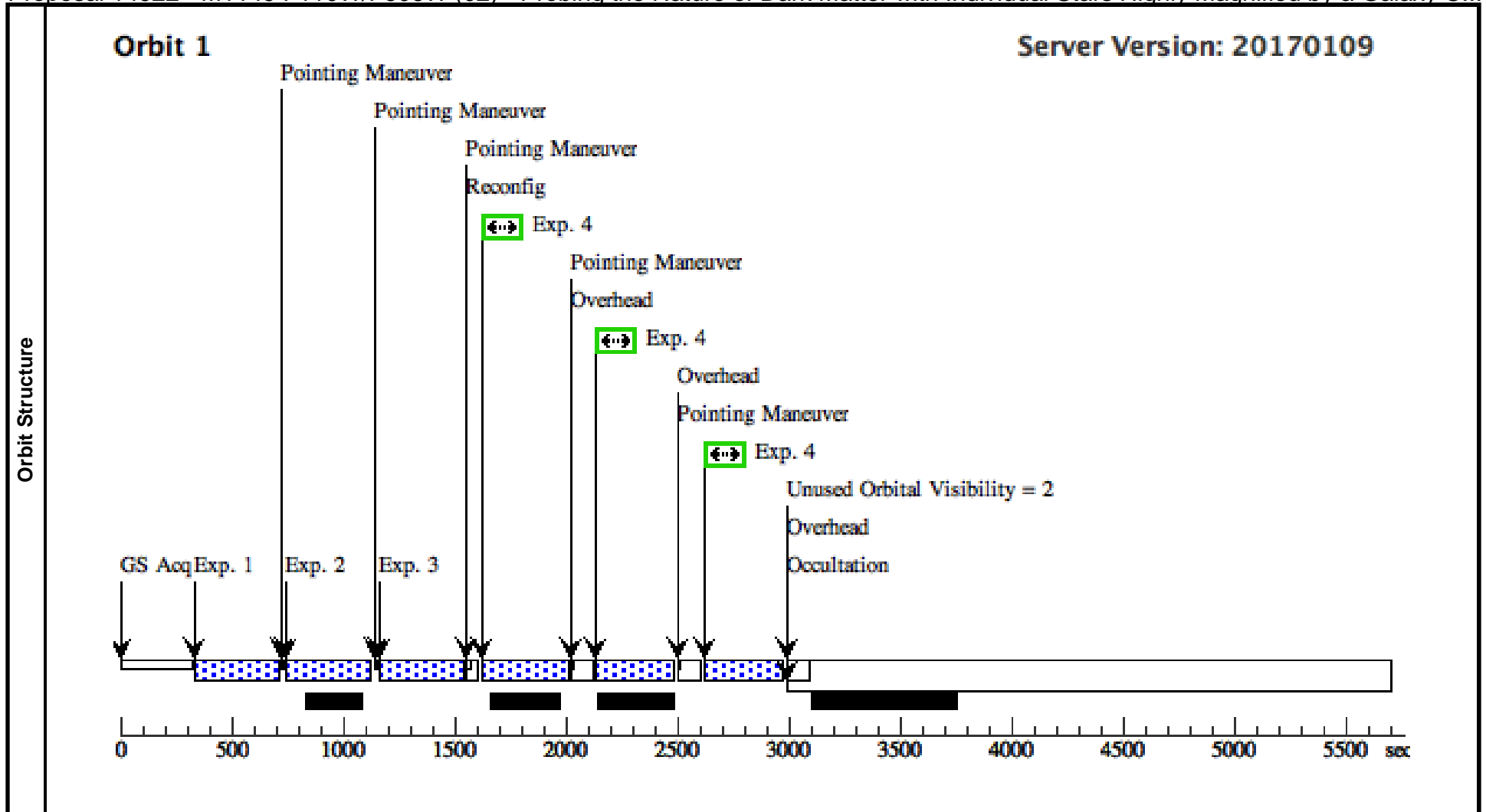
Visit	<b>Proposal 14922, M1149 F110W/F606W (01), implementation</b> <b>Diagnostic Status: No Diagnostics</b> Scientific Instruments: WFC3/IR, WFC3/UVIS Special Requirements: SCHED 100%; ORIENT 123D TO 175 D; BETWEEN 01-APR-2017:00:00:00 AND 21-APR-2017:00:00:00 Comments: 3 short WFC3-IR F110W and 3 short WFC3-UVIS F606W exposures of source in the MACS1149 field.									
	Patterns	#	Primary Pattern	Secondary Pattern	Exposures					
	(1)	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		(4)					
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	POSSIBLESTAR COUNTERIMAGE	RA: 11 49 35.6720 (177.3986333d) Dec: +22 23 48.15 (22.39671d) Equinox: J2000		V=27+/-1	Reference Frame: ICRS				
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	F110W	(1) POSSIBLESTAR COUNTERIMAGE	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=8; SAMP-SEQ=SPAR S50	POS TARG 0,0		352.935448 Secs (352.935 Secs)	
									[==>]	[1]
	2	F110W	(1) POSSIBLESTAR COUNTERIMAGE	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=8; SAMP-SEQ=SPAR S50	POS TARG 0.451,0. 403		352.935448 Secs (352.935 Secs)	
								[==>]	[1]	
3	F110W	(1) POSSIBLESTAR COUNTERIMAGE	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=8; SAMP-SEQ=SPAR S50	POS TARG 0.902,0. 806		352.935448 Secs (352.935 Secs)		
								[==>]	[1]	
4		(1) POSSIBLESTAR COUNTERIMAGE	WFC3/UVIS, ACCUM, UVIS	F606W				Pattern 1, Exps 4-4 i n M1149 F110W/F6 06W (01) (1)	370 Secs (1068 Secs) [==>356.0 Secs (Pattern 1)] [==>356.0 Secs (Pattern 2)] [==>356.0 Secs (Pattern 3)]	[1]



Proposal 14922 - M1149 F110W/F606W (02) - Probing the Nature of Dark Matter with Individual Stars Highly Magnified by a Galaxy C...

Tue Mar 28 01:05:20 GMT 2017

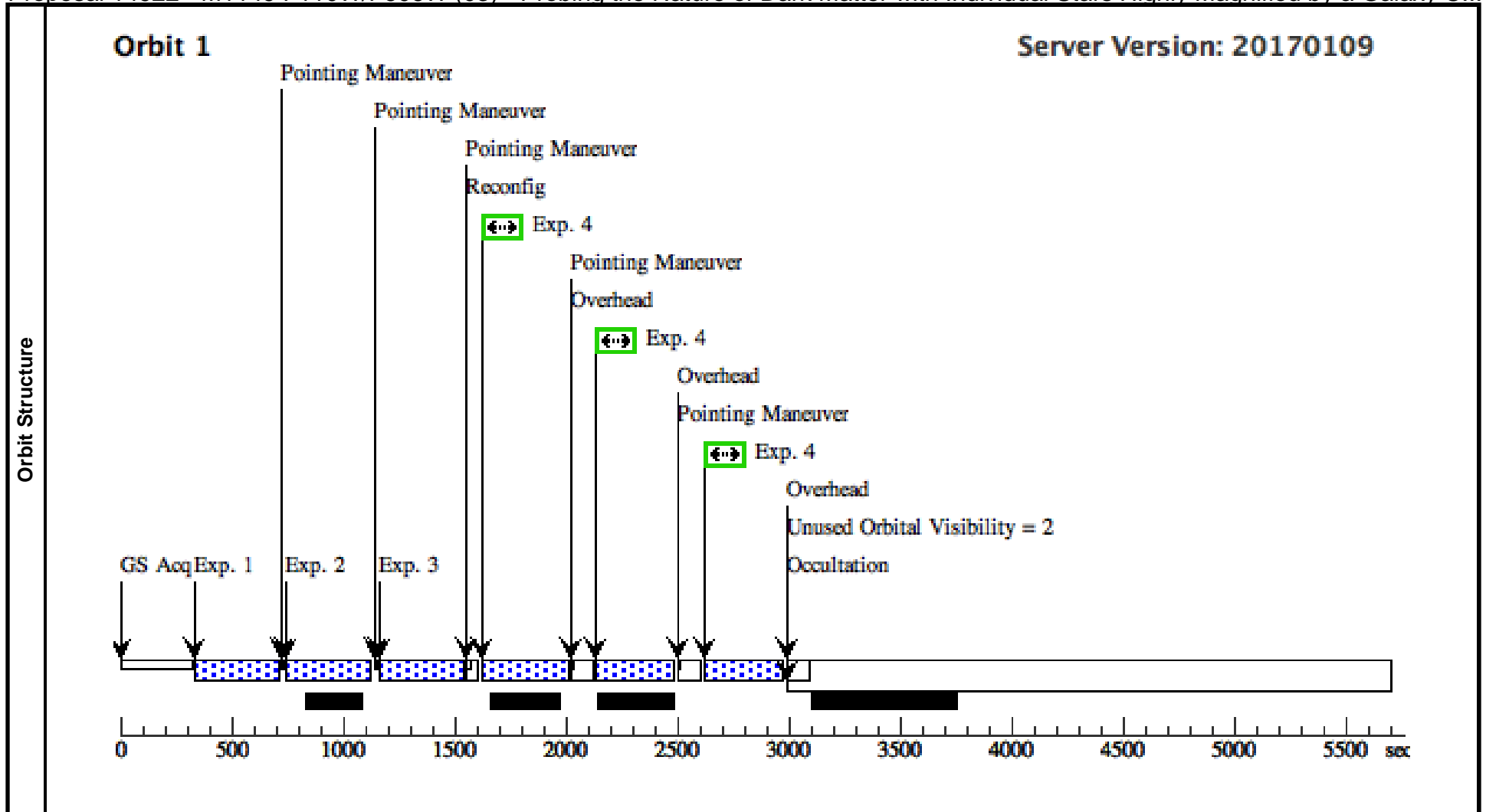
Visit	<b>Proposal 14922, M1149 F110W/F606W (02), implementation</b> <b>Diagnostic Status: No Diagnostics</b> Scientific Instruments: WFC3/IR, WFC3/UVIS Special Requirements: SCHED 100%; ORIENT 123D TO 153 D; AFTER 01 BY 18 D TO 25 D; BETWEEN 22-APR-2017:00:00:00 AND 13-MAY-2017:00:00:00 Comments: 3 short WFC3-IR F110W and 3 short WFC3-UVIS F606W exposures of source in the MACS1149 field.									
	Patterns	#	Primary Pattern	Secondary Pattern	Exposures					
		(1)	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	(4)					
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	POSSIBLESTAR COUNTERIMAGE	RA: 11 49 35.6720 (177.3986333d) Dec: +22 23 48.15 (22.39671d) Equinox: J2000		V=27+/-1	Reference Frame: ICRS				
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	F110W	(1) POSSIBLESTAR COUNTERIMAGE	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=8; SAMP-SEQ=SPAR S50	POS TARG 0,0		352.935448 Secs (352.935 Secs) [==>]	[1]
	2	F110W	(1) POSSIBLESTAR COUNTERIMAGE	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=8; SAMP-SEQ=SPAR S50	POS TARG 0.451,0. 403		352.935448 Secs (352.935 Secs) [==>]	[1]
	3	F110W	(1) POSSIBLESTAR COUNTERIMAGE	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=8; SAMP-SEQ=SPAR S50	POS TARG 0.902,0. 806		352.935448 Secs (352.935 Secs) [==>]	[1]
4		(1) POSSIBLESTAR COUNTERIMAGE	WFC3/UVIS, ACCUM, UVIS	F606W			Pattern 1, Exps 4-4 i n M1149 F110W/F6 06W (02) (1)	370 Secs (1068 Secs) [==>356.0 Secs (Pattern 1)] [==>356.0 Secs (Pattern 2)] [==>356.0 Secs (Pattern 3)]	[1]	



Proposal 14922 - M1149 F110W/F606W (03) - Probing the Nature of Dark Matter with Individual Stars Highly Magnified by a Galaxy C...

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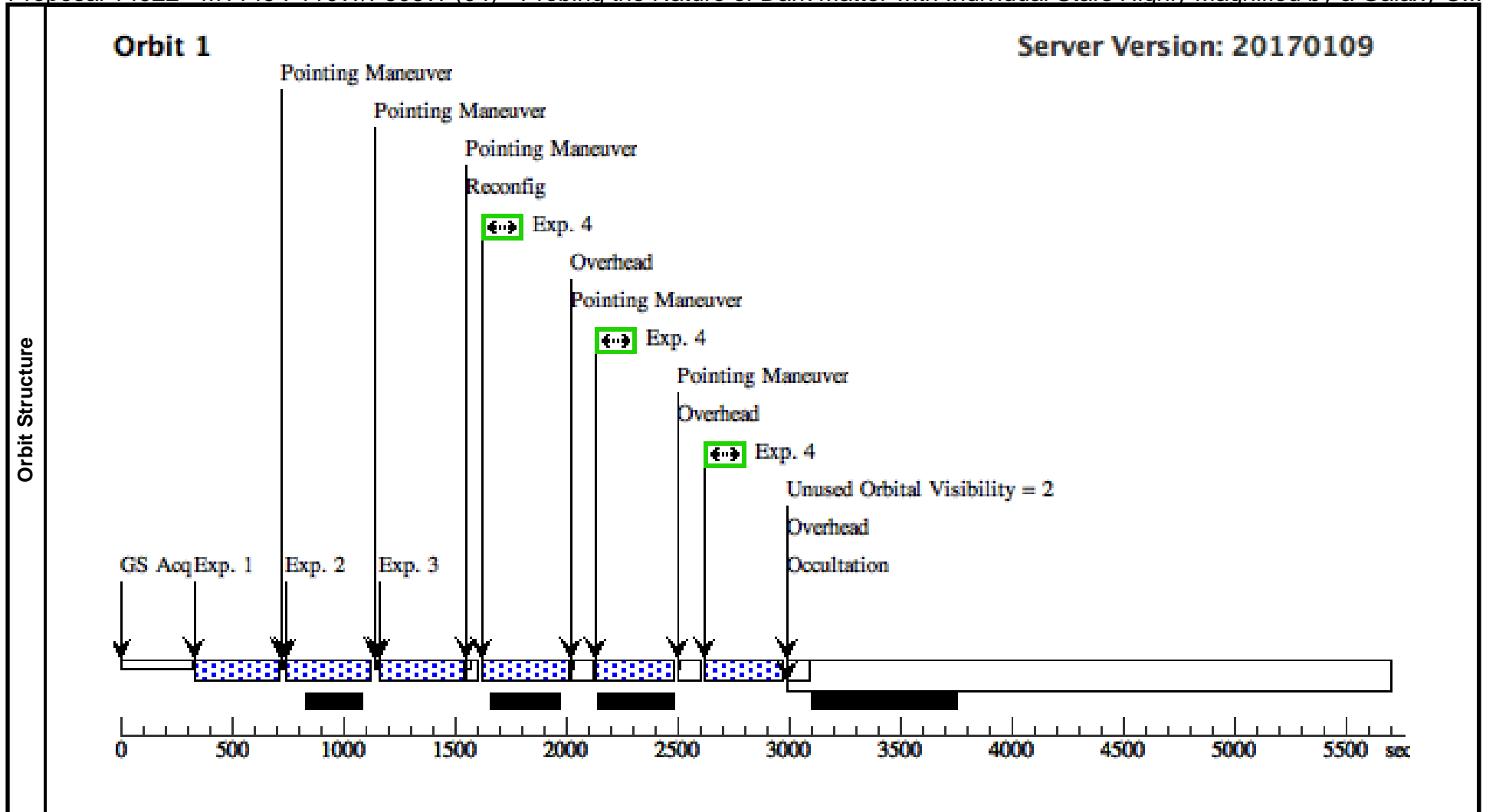
Visit	<b>Proposal 14922, M1149 F110W/F606W (03), implementation</b> <b>Diagnostic Status: No Diagnostics</b> Scientific Instruments: WFC3/IR, WFC3/UVIS Special Requirements: SCHED 100%; ORIENT 123D TO 148 D; AFTER 02 BY 18 D TO 25 D; BETWEEN 14-MAY-2017:00:00:00 AND 04-JUN-2017:00:00:00 Comments: 3 short WFC3-IR F110W and 3 short WFC3-UVIS F606W exposures of source in the MACS1149 field.									
	Patterns	#	Primary Pattern	Secondary Pattern	Exposures					
	(1)	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		(4)					
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	POSSIBLESTAR COUNTERIMAGE	RA: 11 49 35.6720 (177.3986333d) Dec: +22 23 48.15 (22.39671d) Equinox: J2000		V=27+/-1	Reference Frame: ICRS				
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	F110W	(1) POSSIBLESTAR COUNTERIMAGE	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=8; SAMP-SEQ=SPAR S50	POS TARG 0,0		352.935448 Secs (352.935 Secs) [==>]	[1]
	2	F110W	(1) POSSIBLESTAR COUNTERIMAGE	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=8; SAMP-SEQ=SPAR S50	POS TARG 0.451,0. 403		352.935448 Secs (352.935 Secs) [==>]	[1]
	3	F110W	(1) POSSIBLESTAR COUNTERIMAGE	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=8; SAMP-SEQ=SPAR S50	POS TARG 0.902,0. 806		352.935448 Secs (352.935 Secs) [==>]	[1]
4		(1) POSSIBLESTAR COUNTERIMAGE	WFC3/UVIS, ACCUM, UVIS	F606W			Pattern 1, Exps 4-4 i n M1149 F110W/F6 06W (03) (1)	370 Secs (1068 Secs) [==>356.0 Secs (Pattern 1)] [==>356.0 Secs (Pattern 2)] [==>356.0 Secs (Pattern 3)]	[1]	



Proposal 14922 - M1149 F110W/F606W (04) - Probing the Nature of Dark Matter with Individual Stars Highly Magnified by a Galaxy C...

Tue Mar 28 01:05:20 GMT 2017

<b>Visit</b>	<b>Proposal 14922, M1149 F110W/F606W (04), implementation</b> <b>Diagnostic Status: No Diagnostics</b> Scientific Instruments: WFC3/IR, WFC3/UVIS Special Requirements: SCHED 100%; ORIENT 123D TO 148 D; ORIENT 90D TO 98 D; AFTER 03 BY 18 D TO 25 D; BETWEEN 05-JUN-2017:00:00:00 AND 27-JUN-2017:00:00:00 Comments: 3 short WFC3-IR F110W and 3 short WFC3-UVIS F606W exposures of source in the MACS1149 field. preferred orients > 123									
	<b>Patterns</b>	<b>#</b>	<b>Primary Pattern</b>				<b>Secondary Pattern</b>			
(1)		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					(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)	POSSIBLESTARCOUNTERIMAGE	RA: 11 49 35.6720 (177.3986333d) Dec: +22 23 48.15 (22.39671d) Equinox: J2000		V=27+/-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	F110W	(1) POSSIBLESTAR COUNTERIMAGE	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=8; SAMP-SEQ=SPAR S50	POS TARG 0,0		352.935448 Secs (352.935 Secs) [==>]	[1]
	2	F110W	(1) POSSIBLESTAR COUNTERIMAGE	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=8; SAMP-SEQ=SPAR S50	POS TARG 0.451,0. 403		352.935448 Secs (352.935 Secs) [==>]	[1]
	3	F110W	(1) POSSIBLESTAR COUNTERIMAGE	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=8; SAMP-SEQ=SPAR S50	POS TARG 0.902,0. 806		352.935448 Secs (352.935 Secs) [==>]	[1]
	4		(1) POSSIBLESTAR COUNTERIMAGE	WFC3/UVIS, ACCUM, UVIS	F606W			Pattern 1, Exps 4-4 in M1149 F110W/F606W (04) (1)	370 Secs (1068 Secs) [==>356.0 Secs (Pattern 1)] [==>356.0 Secs (Pattern 2)] [==>356.0 Secs (Pattern 3)]	[1]



Proposal 14922 - M1149 F110W/F606W (05) - Probing the Nature of Dark Matter with Individual Stars Highly Magnified by a Galaxy C...

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<b>Visit</b>	<b>Proposal 14922, M1149 F110W/F606W (05), implementation</b> <b>Diagnostic Status: No Diagnostics</b> Scientific Instruments: WFC3/IR, WFC3/UVIS Special Requirements: SCHED 100%; ORIENT 90D TO 104 D; AFTER 04 BY 18 D TO 45 D; BETWEEN 08-JUL-2017:00:00:00 AND 23-JUL-2017:00:00:00 Comments: 3 short WFC3-IR F110W and 3 short WFC3-UVIS F606W exposures of source in the MACS1149 field. preferred orients <= 104									
	<b>Patterns</b>	<b>#</b>	<b>Primary Pattern</b>				<b>Secondary Pattern</b>			
(1)		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				(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)	POSSIBLESTAR COUNTERIMAGE	RA: 11 49 35.6720 (177.3986333d) Dec: +22 23 48.15 (22.39671d) Equinox: J2000				V=27+/-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	F110W	(1) POSSIBLESTAR COUNTERIMAGE	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=8; SAMP-SEQ=SPAR S50	POS TARG 0,0		352.935448 Secs (352.935 Secs) [==>]	[1]
	2	F110W	(1) POSSIBLESTAR COUNTERIMAGE	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=8; SAMP-SEQ=SPAR S50	POS TARG 0.451,0. 403		352.935448 Secs (352.935 Secs) [==>]	[1]
	3	F110W	(1) POSSIBLESTAR COUNTERIMAGE	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=8; SAMP-SEQ=SPAR S50	POS TARG 0.902,0. 806		352.935448 Secs (352.935 Secs) [==>]	[1]
4		(1) POSSIBLESTAR COUNTERIMAGE	WFC3/UVIS, ACCUM, UVIS	F606W			Pattern 1, Exps 4-4 i n M1149 F110W/F6 06W (05) (1)	370 Secs (1068 Secs) [==>356.0 Secs (Pattern 1)] [==>356.0 Secs (Pattern 2)] [==>356.0 Secs (Pattern 3)]	[1]	

