15082 - Monsters on the move: Confirming gravitational wave recoiling supermassive black hole candidates

Cycle: 25, Proposal Category: GO

(Availability Mode: SUPPORTED)

INVESTIGATORS

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VISITS

Visit	*Targets used in Visit*	*Configurations used in Visit*	*Orbits Used*	*Last Orbit Planner Run*	*OP Current with Visit?*
01	(1) M-89	WFC3/IR	1	20-Jul-2017 15:04:54.0	yes
02	(5) NGC-3998	WFC3/IR	1	20-Jul-2017 15:04:55.0	yes
03	(2) NGC-5419	WFC3/IR	1	20-Jul-2017 15:04:56.0	yes
04	(3) NGC-5920	WFC3/IR	1	20-Jul-2017 15:04:57.0	yes
05	(4) NGC-4473	WFC3/IR	1	20-Jul-2017 15:04:58.0	yes

5 Total Orbits Used

ABSTRACT

There is compelling evidence that supermassive black holes (SMBH) reside at the centers of all large galaxies and are the gravitational 'engines' of Active Galactic Nuclei (AGN). Mergers between galaxies are thought to have played a fundamental role in the growth and evolution of the largest galaxies in the nearby universe. Galaxy mergers lead to the formation of an SMBH binary, which eventually coalescences through the emission of

gravitational waves and receives a recoil kick (~several 1000km/s). This recoil in turn causes the merged SMBH to oscillate (~1Gyr) in the gravitational potential well of the host galaxy. During this time, the recoiling SMBH may be observed as a 'displaced' AGN. These events are a strong test of gravitational physics and the merger frequency of binary SMBH. Due to the long damping time of the post recoil oscillations, displacements ~10-100pc may be expected even in nearby elliptical galaxies and can be measured as spatial offsets of AGN in high resolution optical or infrared images. In a preliminary study of 96 early type galaxies using archival HST/WFPC2 images we have identified 18 candidates that show a significant displacement between the SMBH (traced by the AGN) and the photocenter of the host galaxy, determined by isophotal analysis. However, it is necessary to confirm these displacements using IR images since diffuse galaxy scale and nuclear dust structures are common. Here we propose to obtain WFC3/IR F110W and F160W images of 6 of the 18 candidates for which no IR images are available in the HST archive. These observations will allow us to both confirm and improve the accuracy of the measured displacements.

OBSERVING DESCRIPTION

We propose to obtain WFC3/IR F110W and F160W images of 5 nearby elliptical galaxies known to host AGN. We have previously identified these galaxies as hosting candidate gravitationally recoiling supermassive black holes, based on measurements of significant spatial displacements between the galaxy photocenter and the position of the AGN in archival HST images (typically WFPC2 images). However, as diffuse galaxy scale and nuclear dust structures can produce spurious displacements, we will repeat the analysis (as described below) with the new WFC3/IR F110W and F160W images in order to confirm that comparable displacements are also present at these longer wavelengths.

Isophotal analysis of WFC3/IR images that are available in the archive for other candidate galaxies indicates that we require a SNR ~ 5-10 for accurate fitting of the outermost isophotes considered in the analysis. We will require one orbit for each object to obtain an exposure in each of the two filters. We will use a standard 2-point dither pattern to improve spatial sampling and mitigate the effects of hot pixels, cosmetic defects and cosmic rays.

Using available HST images of our 5 target galaxies, we have used the HST WCS ETC with an elliptical galaxy spectrum to estimate the exposure times required to reach an SNR of at least 5 in the filters WFC3/IR F110W and F160W for the outermost isophotes, that is, the faintest included in our photometric modelling of the existing optical images (WFPC2 or ACS). At larger distances from the galaxy center the surface brightness is either too low for reliable isophote fitting and/or becomes significantly irregular. For our 5 objects the outer isophotes have radii of 6.75 to 20 arcsecs from the center of the galaxy. The typical surface brightness at these distances ranges from 3.84E-18 erg cm-2 s-1 A-1 arcsec-2 (at 5439 A) to 2.68E-19 erg cm-2 s-1 A-1 arcsec-2 (at 6919 A).

We have also used the WFC3 ETC to make sure that the exposure times are well within the saturation limits for the center of the galaxy. The typical central flux of the galaxies ranges between 2.60E-16 erg cm-2 s-1 A-1 arcsec-2 (at 9054.8 A) and 1.27E-17 erg cm-2 s-1 A-1 arcsec-2 (at 6919 A).

For NGC 3998, NGC5419 and NGC5920 we use one exposure in each filter to obtain an SNR of ~5 for NGC5920, ~13 for NGC3998 and ~57 for NGC5419 in the outer isophotes, without reaching saturation in the center.

Since M89 and NGC4473 are relatively bright sources, similar exposures would result in saturation at the center of the galaxy as the exposure ramps up. Therefore, to avoid persistence effects we will use 2 iterations of shorter exposures in each filter to obtain an SNR of ~24 for M89 and SNR of ~26 for NGC4473.

For optimal utilization of each orbit, we have used SPARS100 and NSAMP = 9 (for F160W) and NSAMP = 6 (for F110W) for NGC5419 and NGC5920. We use SPARS50 and NSAMP = 9 for F160W, and SPARS25 and NSAMP = 10 for F110W for each of the 2 iterations for both M89 and NGC4473. We use SPARS100 and NSAMP = 10 (for F160W), and SPARS50 and NSAMP = 12 (for F110W) for NGC3998.

These images will allow us to conduct isophotal analysis to confirm the photocenter-AGN displacements measured in the initial study. Measurements from both WFC3/IR images will be combined to obtain a robust weighted average displacement.

The analysis methodology has been developed and tested during the preliminary study. Each galaxy was modelled by fitting elliptical isophotes to the HST image, outside the break radius at which the surface brightness profile flattens off. Within this core the ellipse fits are likely to be distorted by the nuclear PSF and possibly by intrinsic asymmetries. The global photocenter position is then computed as the mean value of the ellipse centers, weighted by the surface brightness. The position of the AGN was obtained by fitting the nuclear point source after applying an unsharp mask to the same image. The two positions are then compared to determine a displacement vector for spatial offsets. The interpercentile range of the distribution of individual isophote centers gives a conservative estimate of the uncertainty of the photocenter position. This method shall be applied for the obtained WFC3 images to confirm and study the displacements between the photocenter and the AGN.

Visit

Proposal 15082, M-89 (01) Thu Jul 20 19:04:59 GMT 2017

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/IR

Special Requirements: (none)

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=WFC3-IR-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.636 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=41.788 Angle Between Sides= Center Pattern=false		(1-2)

Fixed Targets

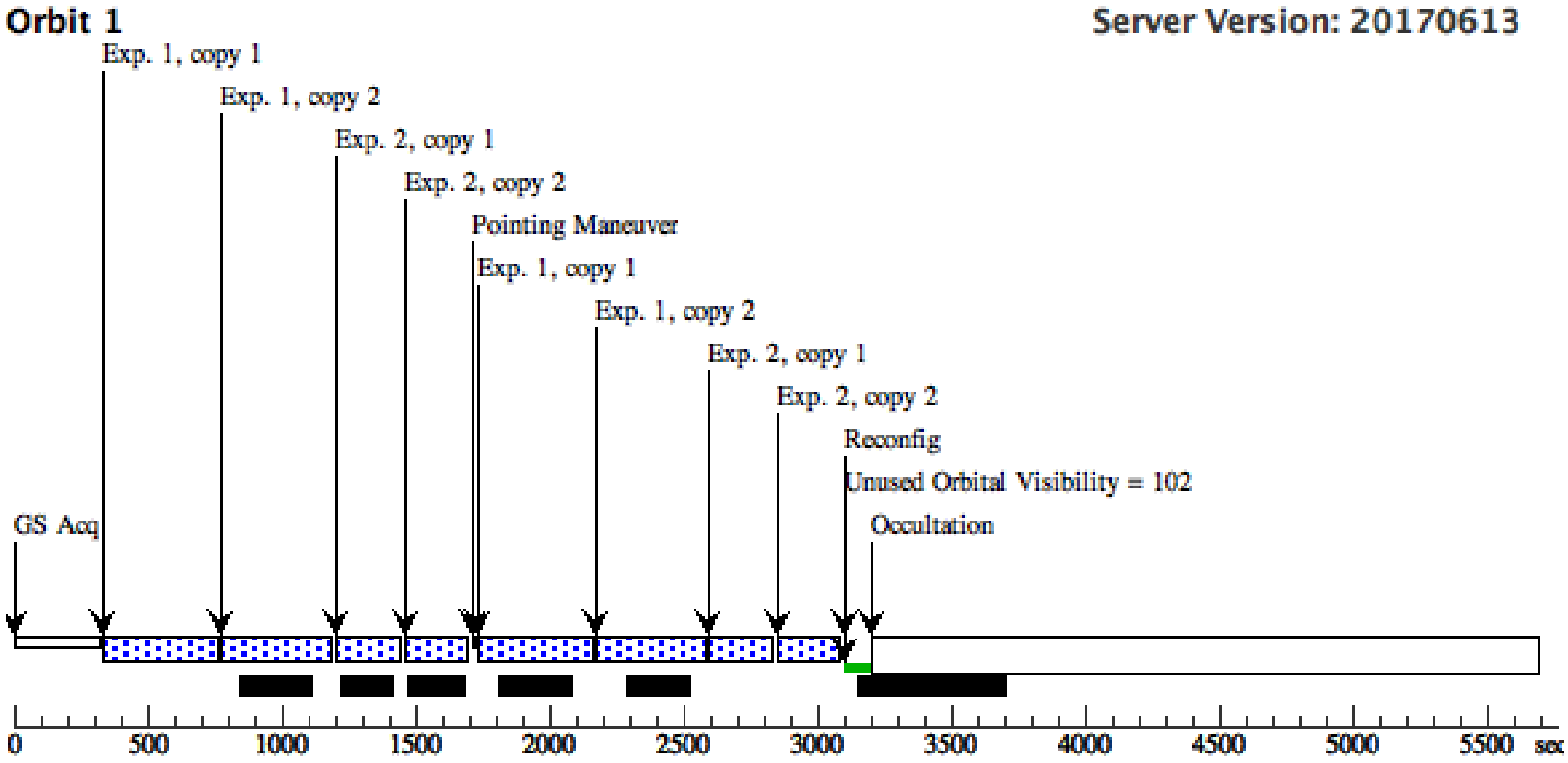
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	M-89	RA: 12 35 39.8000 (188.9158333d) Dec: +12 33 23.00 (12.55639d) Equinox: J2000		V=9.75	Reference Frame: SIMBAD

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	F160W	(1) M-89	WFC3/IR, MULTIACCUM, IR	F160W	SAMP-SEQ=SPARS50; NSAMP=9		Pattern 1, Exps 1-2 in M-89 (01) (1)	402.935899 Secs X 2 (1611.744 Secs) *[==>(Pattern 1, Copy 1)]* *[==>(Pattern 1, Copy 2)]* *[==>(Pattern 2, Copy 1)]* *[==>(Pattern 2, Copy 2)]*	***[1]***
2	F110W	(1) M-89	WFC3/IR, MULTIACCUM, IR	F110W	SAMP-SEQ=SPARS25; NSAMP=10		Pattern 1, Exps 1-2 in M-89 (01) (1)	227.936926 Secs X 2 (911.748 Secs) *[==>(Pattern 1, Copy 1)]* *[==>(Pattern 1, Copy 2)]* *[==>(Pattern 2, Copy 1)]* *[==>(Pattern 2, Copy 2)]*	***[1]***

Orbit Structure



Visit

Proposal 15082, NGC-3998 (02) Thu Jul 20 19:04:59 GMT 2017

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/IR

Special Requirements: (none)

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=WFC3-IR-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.636 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=41.788 Angle Between Sides= Center Pattern=false		(1-2)

Fixed Targets

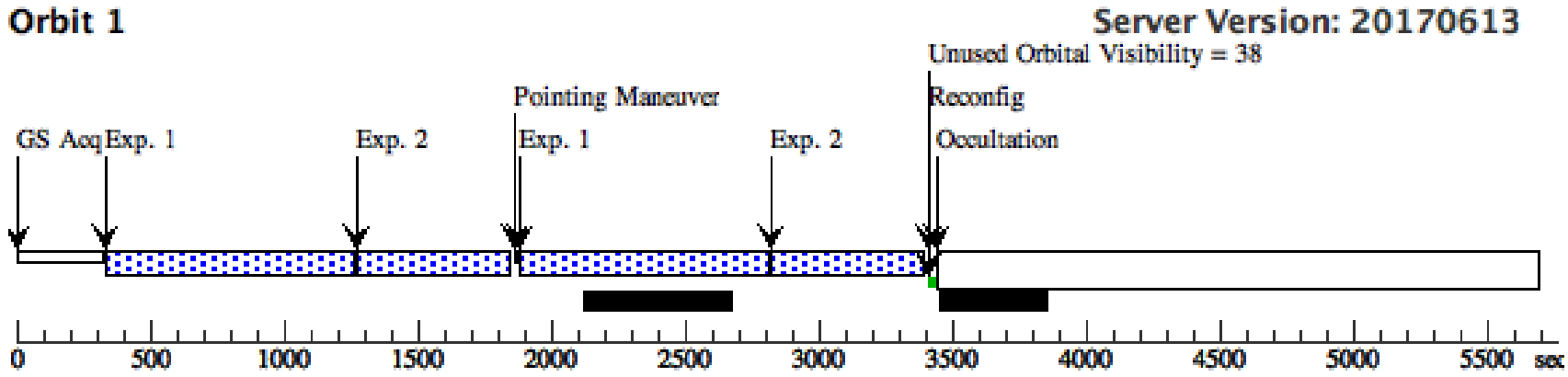
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(5)	NGC-3998	RA: 11 57 56.1333 (179.4838888d) Dec: +55 27 12.92 (55.45359d) Equinox: J2000		V=12.1	Reference Frame: SIMBAD

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	F160W	(5) NGC-3998	WFC3/IR, MULTIACCUM, IR	F160W	SAMP-SEQ=SPARS100; NSAMP=10		Pattern 1, Exps 1-2 in NGC-3998 (02) (1)	902.935198 Secs (1805.87 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]*	***[1]***
2	F110W	(5) NGC-3998	WFC3/IR, MULTIACCUM, IR	F110W	SAMP-SEQ=SPARS50; NSAMP=12		Pattern 1, Exps 1-2 in NGC-3998 (02) (1)	552.937252 Secs (1105.875 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]*	***[1]***

Orbit Structure



Visit

Proposal 15082, NGC-5419 (03) Thu Jul 20 19:04:59 GMT 2017

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/IR

Special Requirements: (none)

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=WFC3-IR-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.636 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=41.788 Angle Between Sides= Center Pattern=false		(1-2)

Fixed Targets

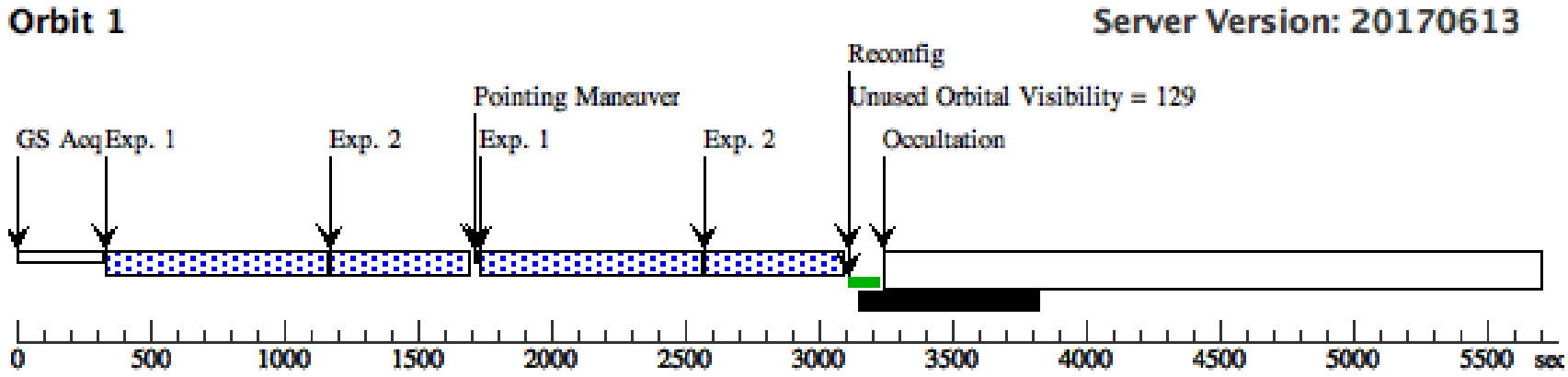
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(2)	NGC-5419	RA: 14 03 38.7710 (210.9115458d) Dec: -33 58 42.20 (-33.97839d) Equinox: J2000		V=11.33	Reference Frame: SIMBAD

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	F160W	(2) NGC-5419	WFC3/IR, MULTIACCUM, IR	F160W	SAMP-SEQ=SPARS100; NSAMP=9		Pattern 1, Exps 1-2 in NGC-5419 (03) (1)	802.934875 Secs (1605.87 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]*	*[1]*
2	F110W	(2) NGC-5419	WFC3/IR, MULTIACCUM, IR	F110W	SAMP-SEQ=SPARS100; NSAMP=6		Pattern 1, Exps 1-2 in NGC-5419 (03) (1)	502.933906 Secs (1005.868 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]*	*[1]*

Orbit Structure



Visit

Proposal 15082, NGC-5920 (04) Thu Jul 20 19:04:59 GMT 2017

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/IR

Special Requirements: (none)

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=WFC3-IR-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.636 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=41.788 Angle Between Sides= Center Pattern=false		(1-2)

Fixed Targets

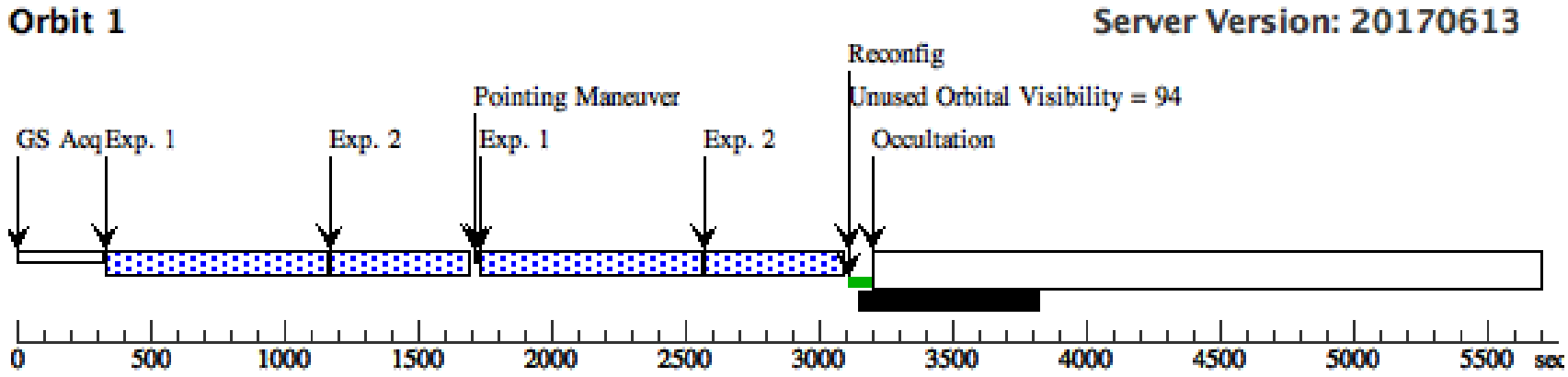
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(3)	NGC-5920	RA: 15 21 51.8700 (230.4661250d) Dec: +07 42 31.97 (7.70888d) Equinox: J2000		V=14.7	Reference Frame: SIMBAD

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	F160W	(3) NGC-5920	WFC3/IR, MULTIACCUM, IR	F160W	SAMP-SEQ=SPARS100; NSAMP=9		Pattern 1, Exps 1-2 in NGC-5920 (04) (1)	802.934875 Secs (1605.87 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]*	*[1]*
2	F110W	(3) NGC-5920	WFC3/IR, MULTIACCUM, IR	F110W	SAMP-SEQ=SPARS100; NSAMP=6		Pattern 1, Exps 1-2 in NGC-5920 (04) (1)	502.933906 Secs (1005.868 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]*	*[1]*

Orbit Structure



Visit

Proposal 15082, NGC-4473 (05) Thu Jul 20 19:04:59 GMT 2017

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/IR

Special Requirements: (none)

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=WFC3-IR-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.636 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=41.788 Angle Between Sides= Center Pattern=false		(1-2)

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(4)	NGC-4473	RA: 12 29 48.8780 (187.4536583d) Dec: +13 25 45.55 (13.42932d) Equinox: J2000		V=10.2	Reference Frame: SIMBAD

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	F160W	(4) NGC-4473	WFC3/IR, MULTIACCUM, IR	F160W	SAMP-SEQ=SPARS50; NSAMP=9		Pattern 1, Exps 1-2 in NGC-4473 (05) (1)	402.935899 Secs X 2 (1611.744 Secs) *[==>(Pattern 1, Copy 1)]* *[==>(Pattern 1, Copy 2)]* *[==>(Pattern 2, Copy 1)]* *[==>(Pattern 2, Copy 2)]*	 ***[1]***
2	F110W	(4) NGC-4473	WFC3/IR, MULTIACCUM, IR	F110W	SAMP-SEQ=SPARS25; NSAMP=10		Pattern 1, Exps 1-2 in NGC-4473 (05) (1)	227.936926 Secs X 2 (911.748 Secs) *[==>(Pattern 1, Copy 1)]* *[==>(Pattern 1, Copy 2)]* *[==>(Pattern 2, Copy 1)]* *[==>(Pattern 2, Copy 2)]*	 ***[1]***

Orbit Structure