15121 - Does Globular Cluster Formation Precede Galaxy Formation?

Cycle: 25, Proposal Category: GO

(Availability Mode: SUPPORTED)

INVESTIGATORS

Name	*Institution*	*E-Mail*
Prof. Dennis Zaritsky (PI) (Contact)	**University of Arizona**	**dzaritsky@as.arizona.edu**
Dr. Nicola Amorisco (CoI)	Harvard University	nicola.amorisco@cfa.harvard.edu
Jennifer Kadowaki (CoI)	University of Arizona	jkadowaki@email.arizona.edu
Richard Donnerstein (CoI)	University of Arizona	donnerst@email.arizona.edu

VISITS

Visit	*Targets used in Visit*	*Configurations used in Visit*	*Orbits Used*	*Last Orbit Planner Run*	*OP Current with Visit?*
01	(1) DF07	ACS/WFC	2	14-Dec-2018 11:00:34.0	yes
02	(1) DF07	ACS/WFC	2	14-Dec-2018 11:00:35.0	yes
03	(2) DF08	ACS/WFC	2	14-Dec-2018 11:00:36.0	yes
04	(2) DF08	ACS/WFC	2	14-Dec-2018 11:00:36.0	yes
05	(3) DF44	ACS/WFC	2	14-Dec-2018 11:00:37.0	yes
06	(3) DF44	ACS/WFC	2	14-Dec-2018 11:00:38.0	yes
07	(4) PU1251013	ACS/WFC	2	14-Dec-2018 11:00:38.0	yes
08	(4) PU1251013	ACS/WFC	2	14-Dec-2018 11:00:39.0	yes

16 Total Orbits Used

ABSTRACT

The recent findings that the number, or total mass, of a galaxy's globular clusters tracks the galaxy's total mass much more closely than it tracks the stellar mass suggest a decoupling of "early-phase" star formation (the globular clusters and perhaps halo stellar population) and the "late-phase" star formation (the central disk, bulge, and/or spheroid). Although these suggestive findings come from the study of normal, or high-surface brightness galaxies, the extreme example of this phenomenon is found in the ultradiffuse galaxy (UDG) DF 44. This galaxy is estimated to contain nearly 100 globular clusters, a similar number as in the Milky Way, but only 1% as many stars as the Milky Way. We propose to test this result with definitive data for DF44 and expand the sample of such galaxies by observing three other, spectroscopically-confirmed, physically similar galaxies at the same distance. These observations will confirm or refute the hypothesis that globular cluster formation is decoupled from galaxy formation as we envision it and that it precedes the formation of the central galaxy.

OBSERVING DESCRIPTION

We have a single fundamental goal: to obtain a pure and complete census of globular cluster candidates in the largest UDGs. To do this, we need to count unresolved objects down to and fainter than the turnover of the globular cluster luminosity function (GCLF). Fortunately, we are in an excellent situation to define our observational plan because archival data (GO 12476, PI Cook; Macri et al. 2013) has already been used (by two independent groups) to measure the GC population of the Coma cluster UDG DF17 (Peng & Lim 2016; Beasley & Trujillo 2016). DF17 is not a galaxy that is expected to host as many clusters as DF44 or its analogs because it is not as large (and so is not in our sample). Indeed the published measurements (28 +-14 and 27 +- 5, respectively) are substantially below the number of clusters in DF44 and do not provide a strong constraint for our problem. Nevertheless, the agreement between the two teams shows that when the completeness and contamination corrections are low, thanks to the depth and resolution of the HST imaging, then high fidelity measurements of the GC populations of Coma cluster UDGs can be achieved.

The archival imaging of DF17 includes total exposure times of 5100s in F475W and 5100s in F814W. This exposure time enabled Peng and Lim to reach 50% completeness one magnitude fainter than the peak of the GCLF. This is exactly what is needed to moderate completeness corrections. In both studies, the majority of the contamination was removed by using HST's angular resolution to resolve and identify the majority of background galaxies. Color then helped the investigators reject about half of the remaining sample (Beasley & Trujillo 2016). Given the success of the previous observation for our purpose, we propose to obtain the same set of data for our sample of UDGs as is available in the archive for DF17. If our final measurement uncertainty for the DF44 cluster population is comparable to that obtained for DF17, then our uncertainty when placing DF44 in Figure 1 will be smaller than the plotted star. It is critical to reach at least the expected turnover in the GCLF because we have no constraints on the GCLF in UDGs. Assuming that it is the same Gaussian distribution in UDGs as in "normal" galaxies (same peak absolute magnitude and same dispersion) is completely unjustified. Only by confirming a population to and below the peak can one keep the completeness corrections below a factor of two. P.

van Dokkum (priv. communication) has confirmed that in one example (not DF44) there are a number of bright clusters that are not accompanied by fainter clusters in deeper imaging.

We select UDGs from our analysis of DECaLS data (a public preimaging survey for DESI). We have surveyed a 10 degree radius region centered on the Coma cluster for large UDGs. We have confirmed that we recover the previously known large UDGs in the central regions of the Coma cluster (eg. the DF galaxies). Therefore, our new survey provides targets selected homogeneously from the center of the Coma cluster to well outside the cluster (10 degrees corresponds to approximately 17 Mpc or alternatively almost 6 times the virial radius). The practical difficulty in identifying large UDGs well outside the cluster is that statistics alone cannot be used to argue against dominant foreground contamination. In particular, the large angular size candidates are the most likely to be foreground. Spectroscopic confirmation is therefore essential, particularly before expending precious HST time. We have been using the Large Binocular Telescope to measure redshifts of apparently large UDGs both in the center of Coma and in the outskirts. In Kadowaki et al. (2017) we added four spectroscopic confirmations to the list of large Coma UDGs, which previous consisted of only one UDG (DF44; van Dokkum et al. 2015), and we also found one interloper. We recently completed our second observing run and now have additional spectra to tap. Here we propose to target all of the extreme systems (re > 4 kpc) in the Coma region for which we have a spectroscopic redshift confirmation (DF07, DF08, DF44, and a new system currently named PU1251013).
In addition to confirming the globular cluster population in DF44 with deeper observations, we select three other systems to mitigate against statistical errors and varying systematic errors, such as highly variable field-to-field contamination rates, in our determination of the globular cluster populations. There may also be intrinsic variations that a sample of more than one or two galaxies will highlight. These possibilities lead us to propose to observe all four of the currently known objects that satisfy all of our criteria. To reach a total of about 5000 sec in each band, we require 2 orbits per band after accounting for overheads. Therefore, we request a total of 16 orbits (4 per UDG, with 2 spent in each of the two passbands). This type of observation and data analysis of globular cluster populations has been done for other galaxies and so we anticipate a straightforward path to science.

During Phase II, we have decided to dither each observation (a single, line dither) and to effectively CR split the observations within an orbit by iterating on the initial exposure. This will allow us to mitigate both CRs and hot pixels. Additionally, for three of the systems we can use that shallower archival images to further assist in the identification of hot pixels.

Visit

Proposal 15121, DF07 - 475W (01), implementation Fri Dec 14 16:00:39 GMT 2018

Diagnostic Status: No Diagnostics

Scientific Instruments: ACS/WFC

Special Requirements: (none)

Patterns

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(1)	Pattern Type=ACS-WFC-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=3.034 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=85.29 Angle Between Sides= Center Pattern=false	Pattern Type=ACS-WFC-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=3.034 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=85.29 Angle Between Sides= Center Pattern=false	(1)

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	DF07	RA: 12 57 1.7424 (194.2572600d) Dec: +28 23 6.10 (28.38503d) Equinox: J2000		V=18.8	Reference Frame: ICRS

Comments:
Category=GALAXY
Description=[UNDESIGNATED]
Extended=YES

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
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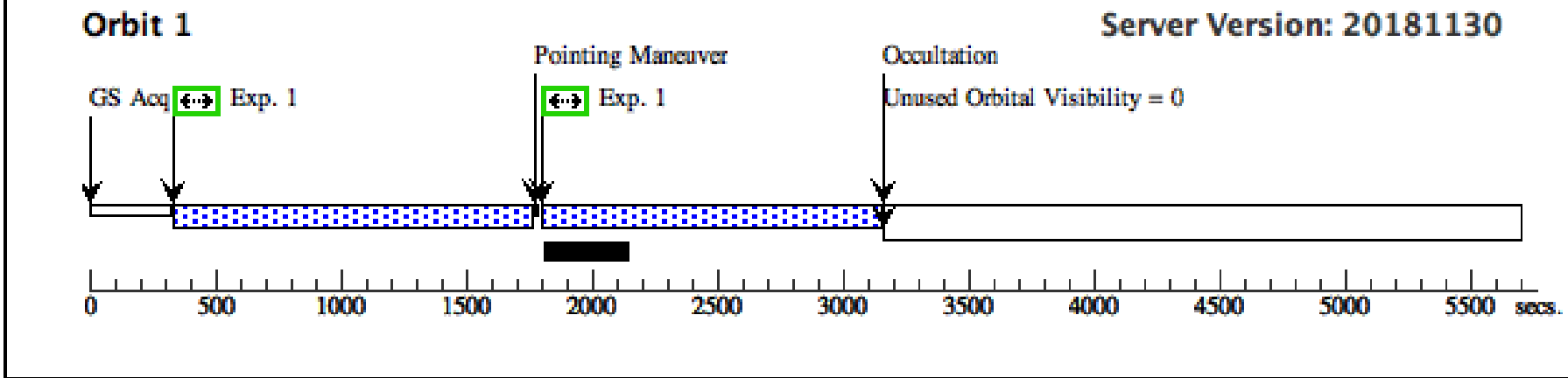
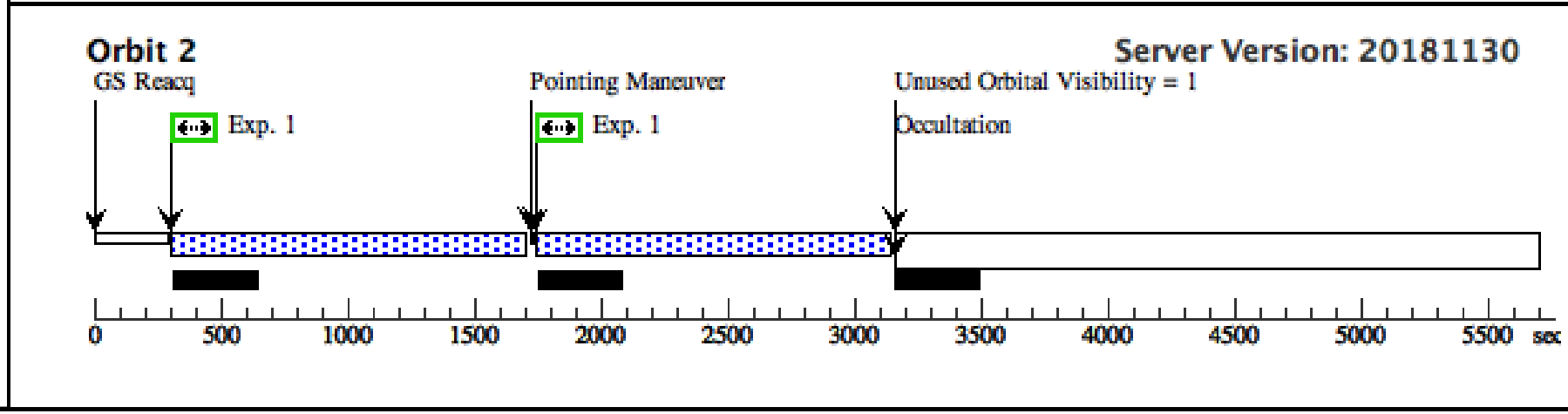
Orbit Structure





Visit

Proposal 15121, DF07 - 814W (02), implementation Fri Dec 14 16:00:40 GMT 2018

Diagnostic Status: No Diagnostics

Scientific Instruments: ACS/WFC

Special Requirements: (none)

Patterns

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Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	DF07	RA: 12 57 1.7424 (194.2572600d) Dec: +28 23 6.10 (28.38503d) Equinox: J2000		V=18.8	Reference Frame: ICRS

Comments:
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Description=[UNDESIGNATED]
Extended=YES

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	DF07 - 814W	(1) DF07	ACS/WFC, ACCUM, WFC	F814W			Pattern 1, Exps 1-1 in DF07 - 814W (02) (1)	1200 Secs (5012 Secs)	
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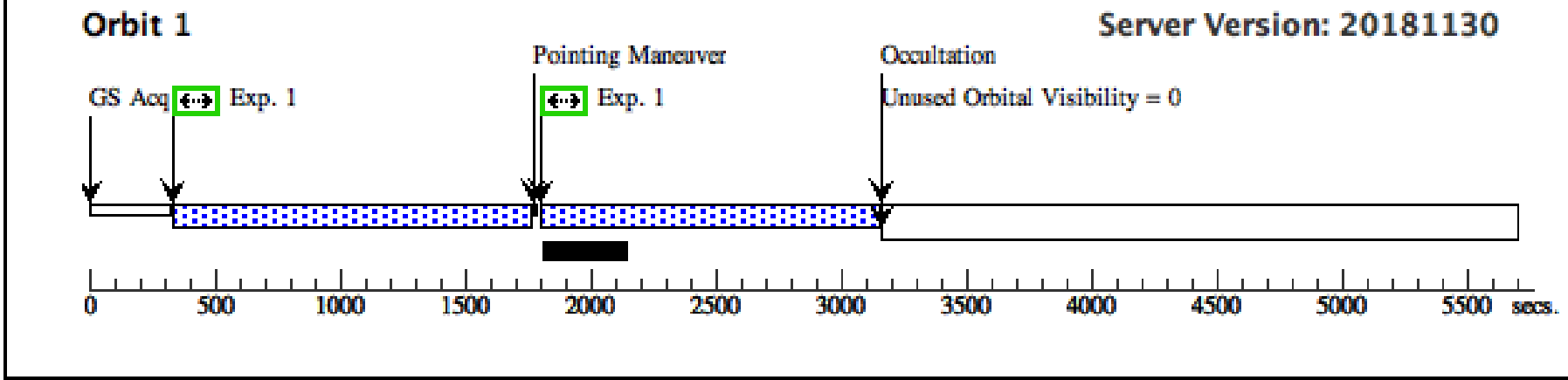
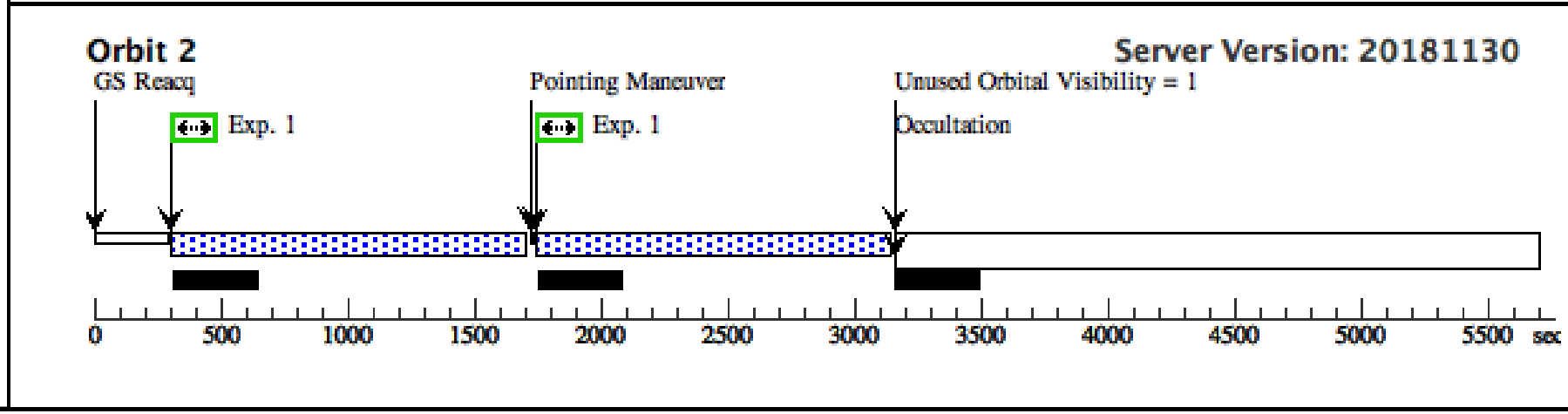
Orbit Structure





Visit

Proposal 15121, DF08 - 475W (03), implementation Fri Dec 14 16:00:40 GMT 2018

Diagnostic Status: No Diagnostics

Scientific Instruments: ACS/WFC

Special Requirements: (none)

Patterns

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Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(2)	DF08	RA: 13 01 28.7191 (195.3696629d) Dec: +28 22 26.81 (28.37411d) Equinox: J2000		V=19.9	Reference Frame: ICRS

Comments:
Category=GALAXY
Description=[UNDESIGNATED]
Extended=YES

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	DF08 - 475 W	(2) DF08	ACS/WFC, ACCUM, WFC	F475W			Pattern 1, Exps 1-1 in DF08 - 475W (03) (1)	1200 Secs (5011 Secs)	
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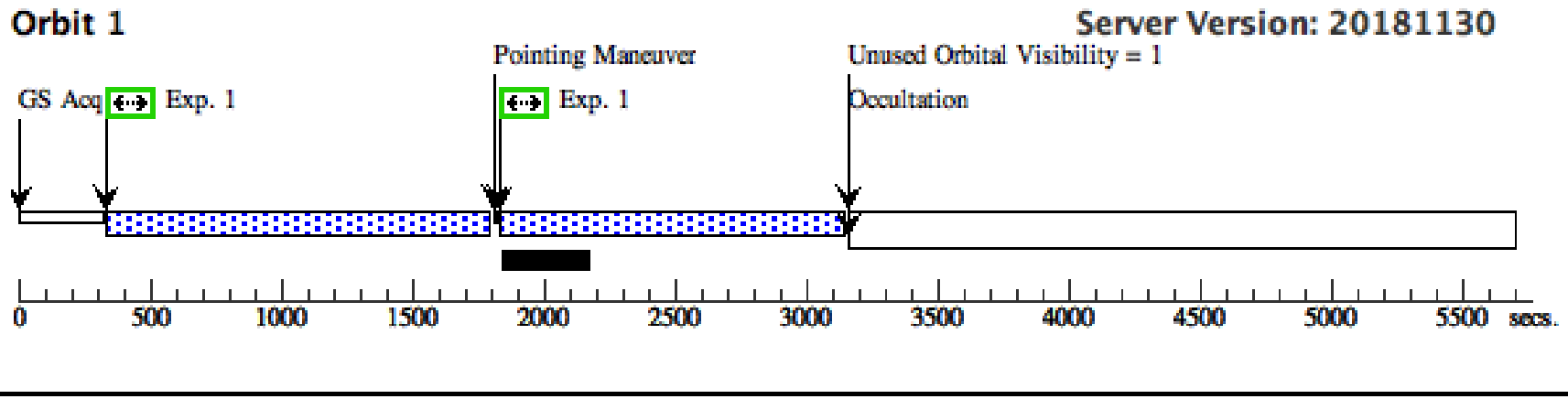
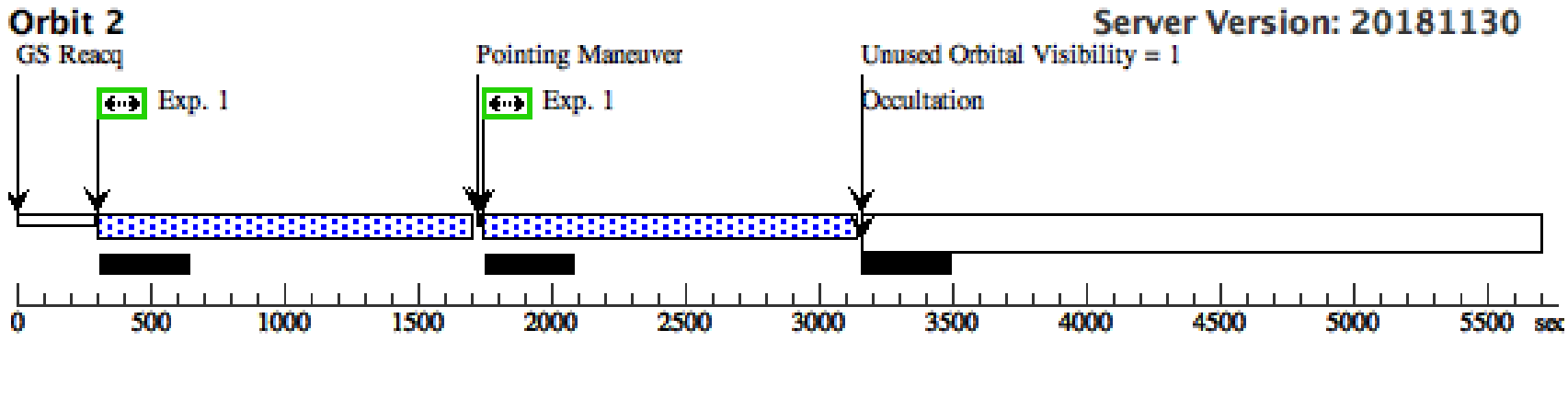
Orbit Structure





Visit

Proposal 15121, DF08 - 814W (04), implementation Fri Dec 14 16:00:40 GMT 2018

Diagnostic Status: No Diagnostics

Scientific Instruments: ACS/WFC

Special Requirements: (none)

Patterns

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Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(2)	DF08	RA: 13 01 28.7191 (195.3696629d) Dec: +28 22 26.81 (28.37411d) Equinox: J2000		V=19.9	Reference Frame: ICRS

Comments:
Category=GALAXY
Description=[UNDESIGNATED]
Extended=YES

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	DF08 - 814W	(2) DF08	ACS/WFC, ACCUM, WFC	F814W			Pattern 1, Exps 1-1 in DF08 - 814W (04) (1)	1200 Secs (5011 Secs)	
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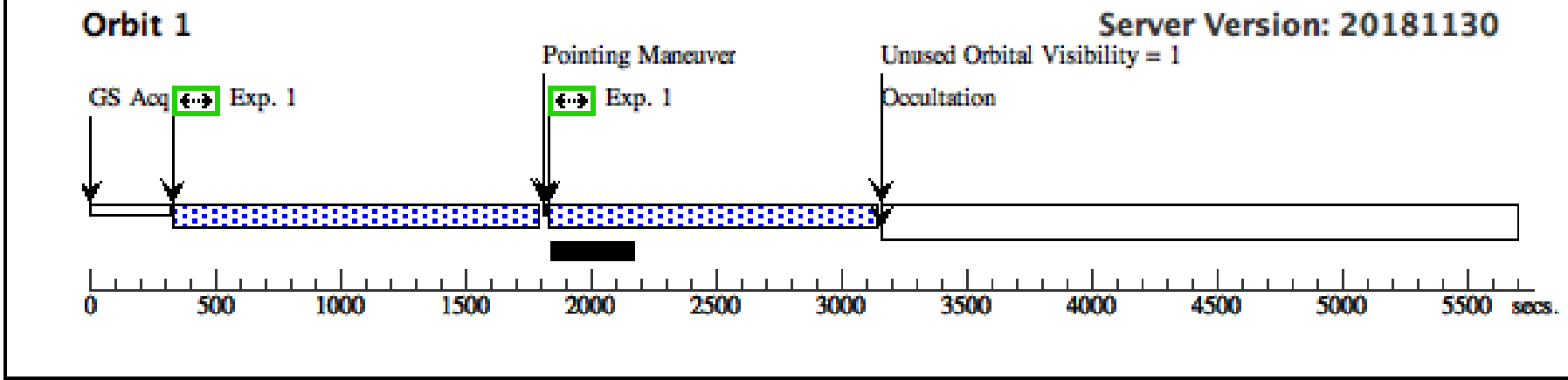
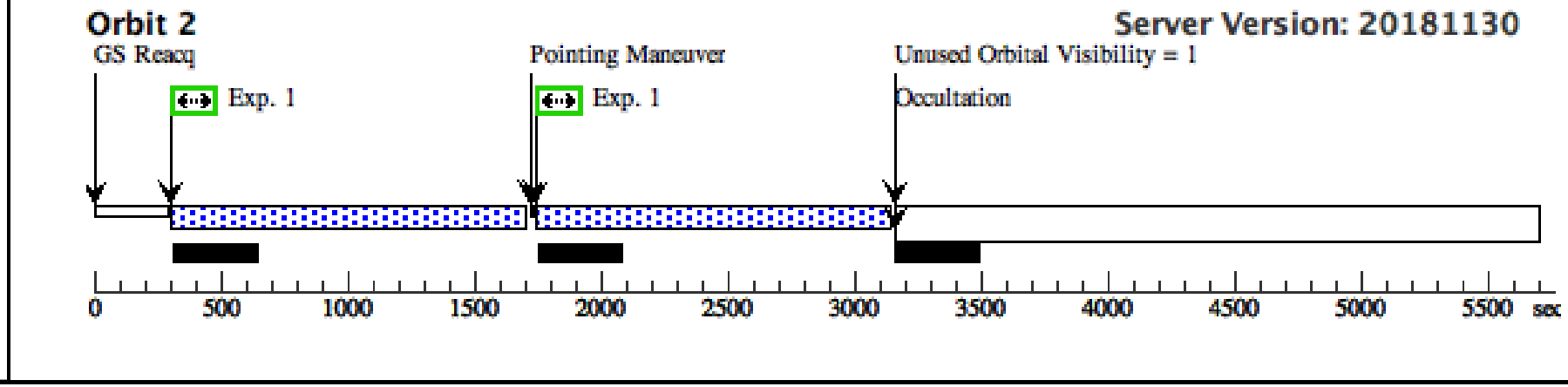
Orbit Structure





Visit

Proposal 15121, DF44 - 475W (05), implementation Fri Dec 14 16:00:40 GMT 2018

Diagnostic Status: No Diagnostics

Scientific Instruments: ACS/WFC

Special Requirements: (none)

Patterns

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Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(3)	DF44	RA: 13 00 58.0000 (195.2416667d) Dec: +26 58 35.00 (26.97639d) Equinox: J2000		V=19.1	Reference Frame: ICRS

Comments:
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Description=[UNDESIGNATED]
Extended=YES

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	DF44 - 475 W	(3) DF44	ACS/WFC, ACCUM, WFC	F475W			Pattern 1, Exps 1-1 in DF44 - 475W (05) (1)	1200 Secs (5011 Secs)	
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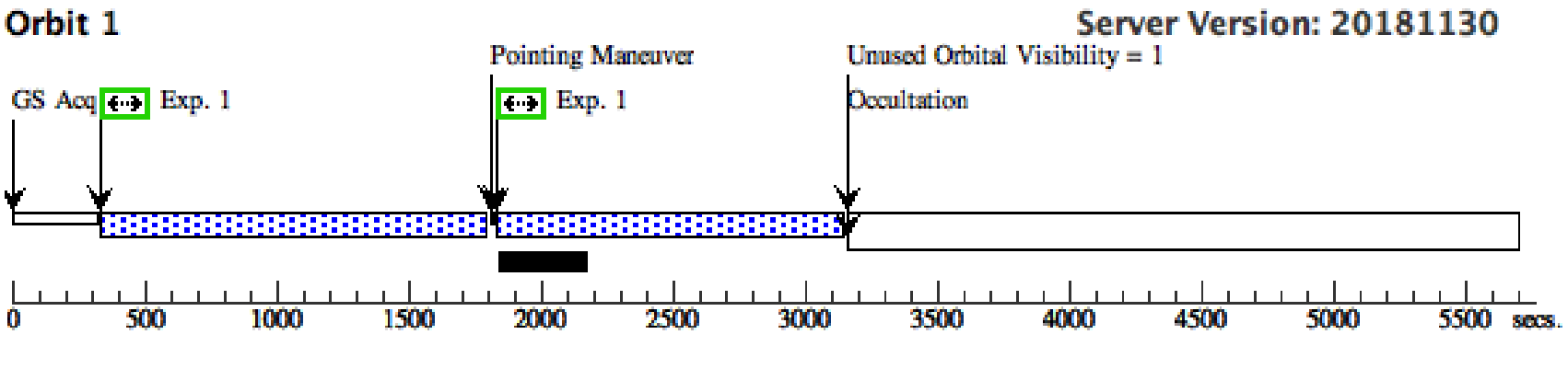
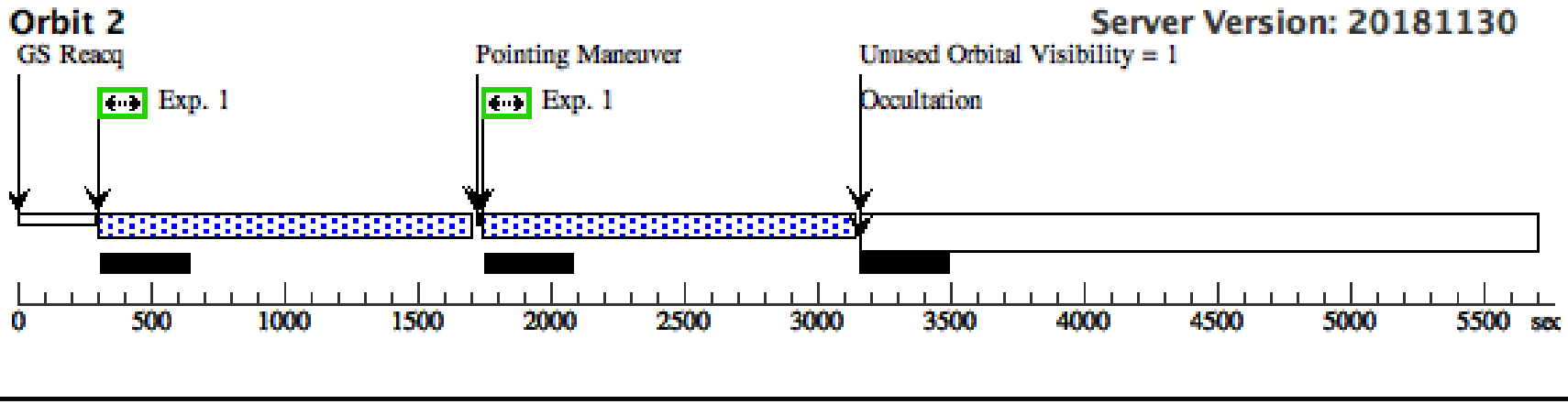
Orbit Structure





Visit

Proposal 15121, DF44 - 814W (06), implementation Fri Dec 14 16:00:40 GMT 2018

Diagnostic Status: No Diagnostics

Scientific Instruments: ACS/WFC

Special Requirements: (none)

Patterns

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Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(3)	DF44	RA: 13 00 58.0000 (195.2416667d) Dec: +26 58 35.00 (26.97639d) Equinox: J2000		V=19.1	Reference Frame: ICRS

Comments:
Category=GALAXY
Description=[UNDESIGNATED]
Extended=YES

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	DF44 - 814 W	(3) DF44	ACS/WFC, ACCUM, WFC	F814W			Pattern 1, Exps 1-1 in DF44 - 814W (06) (1)	1200 Secs (5011 Secs)	
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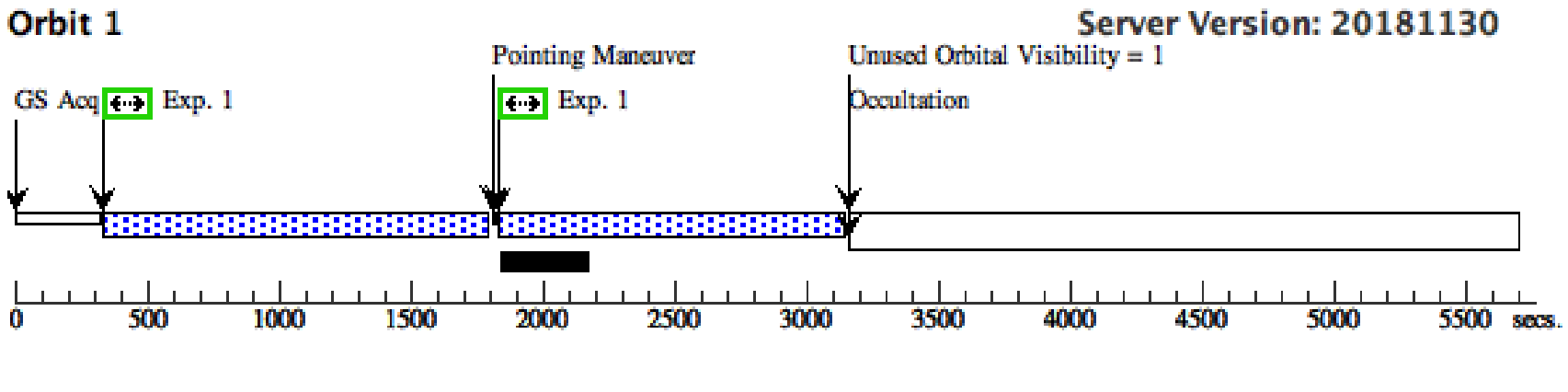
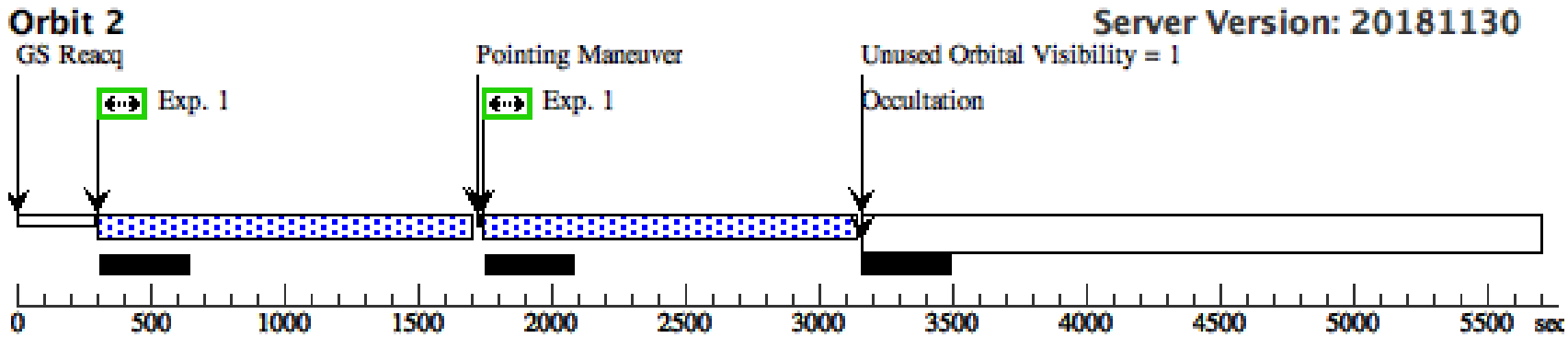
Orbit Structure





Visit

Proposal 15121, PU125 - 475W (07), implementation Fri Dec 14 16:00:40 GMT 2018

Diagnostic Status: No Diagnostics

Scientific Instruments: ACS/WFC

Special Requirements: (none)

Patterns

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Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(4)	PU1251013	RA: 12 51 1.3000 (192.7554167d) Dec: +27 47 53.00 (27.79806d) Equinox: J2000		V=19	Reference Frame: ICRS

Comments:
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Description=[UNDESIGNATED]
Extended=YES

Exposures

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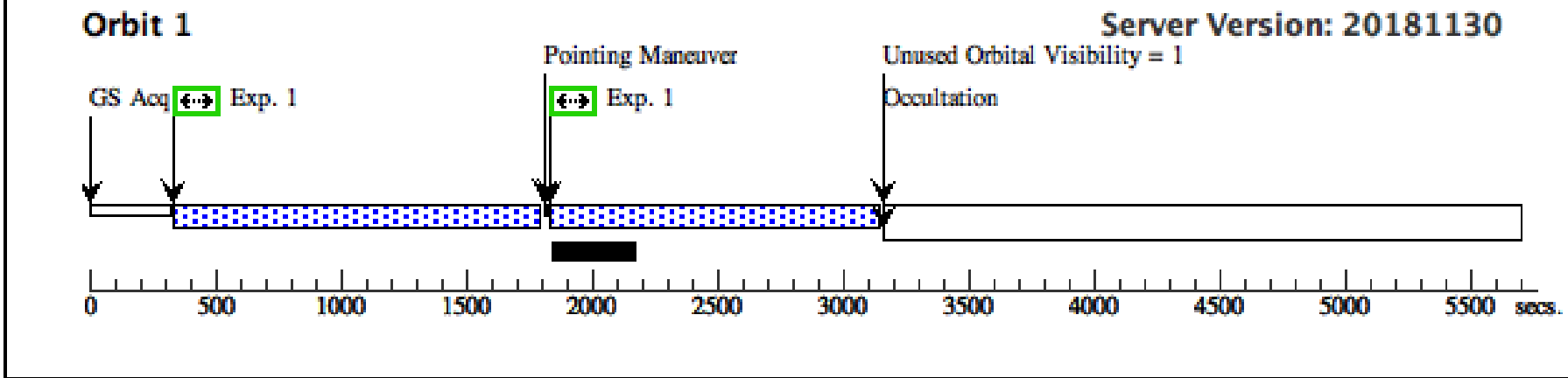
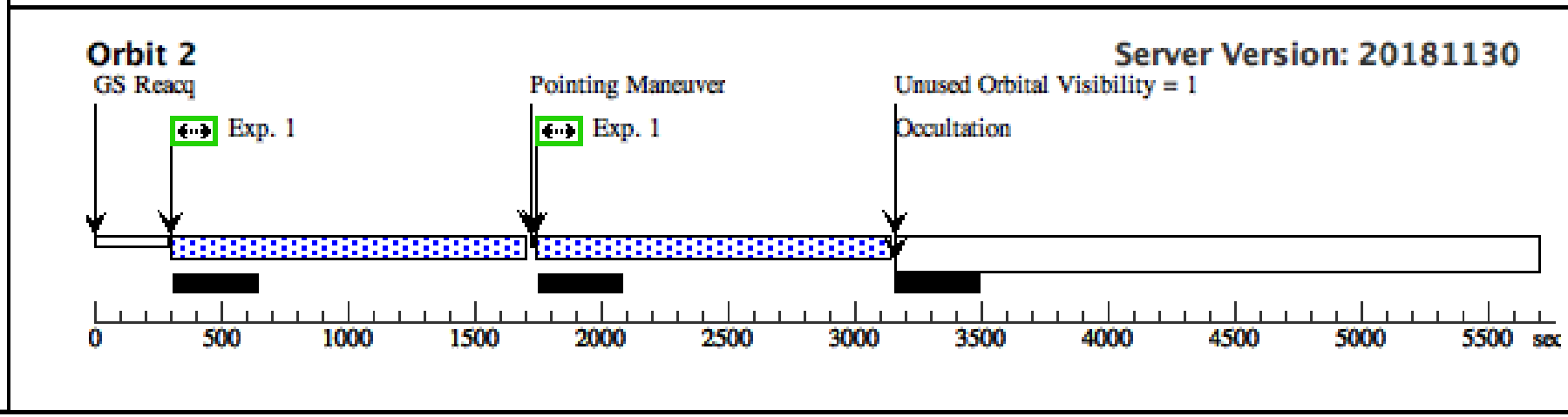
Orbit Structure





Visit

Proposal 15121, PU125 - 814W (08), implementation Fri Dec 14 16:00:40 GMT 2018

Diagnostic Status: No Diagnostics

Scientific Instruments: ACS/WFC

Special Requirements: (none)

Patterns

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Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(4)	PU1251013	RA: 12 51 1.3000 (192.7554167d) Dec: +27 47 53.00 (27.79806d) Equinox: J2000		V=19	Reference Frame: ICRS

Comments:
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Description=[UNDESIGNATED]
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Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	PU125 - 814W	(4) PU1251013	ACS/WFC, ACCUM, WFC	F814W			Pattern 1, Exps 1-1 in PU125 - 814W (08) (1)	1200 Secs (5011 Secs)	
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								[==>1281.0 Secs (Pattern 2,1)] *[==>1281.0 Secs (Pattern 2,2)]*	***[2]***

Orbit Structure