14678 - Whimper of a Bang: Documenting the Final Days of the Nearby Type Ia Supernova 2011fe

Cycle: 24, 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) SN-2011FE-UVIS ANY	ACS/WFC WFC3/UVIS	4	23-May-2017 21:06:12.0	yes
02	(1) SN-2011FE-UVIS (2) SN-2011FE-IR ANY	ACS/WFC WFC3/IR WFC3/UVIS	4	23-May-2017 21:06:17.0	yes

8 Total Orbits Used

ABSTRACT

Even though SNe Ia are crucial to cosmological studies as distance indicators, the exact nature of these systems remains theoreltically ambiguous and observationally elusive. However, there is a new hope. The very late-time light curves of SNe Ia harbor important clues to the natures of their

progenitor systems. First, the ejecta from the SN will shock heat a non-degenerate companion, leaving it luminous and visible at very late times after the SN has faded . Second, due to nucleosynthetic effects during the explosion, single and double degenerate SNe Ia models are predicted to produce vastly differing amounts of 57Co and 55Fe. 57Co and 55Fe dominate the power of the very late time light curves of SNe Ia after >1050 days after the initial explosion. Broadband observations of the bolometric luminosity at these epochs have the ability to measure the ratio of these two isotopes and thus discriminate between progenitor models. As the brightest SN Ia in nearly 40 years, SN 2011fe offers a prime opportunity to follow a SN Ia to such late epochs. Here we propose HST WFC3 optical and IR photometry of SN 2011fe to observe the transition from a 57Co to a 55Fe powered lightcurve and to constrain a possible shock-heated companion. These observations will place unique constraints on progenitor systems of SNe Ia. SN 2011fe, having been already observed for more than 1600 days and a factor of four million in flux. The observations proposed here would follow SN 2011fe to an epoch 2.5 times later than any other SNe Ia. SN 2011fe is likely to remain the best studied normal SN Ia of our generation and if these observations are not made now, they will likely never be done with Hubble.

OBSERVING DESCRIPTION

The observations proposed here continue a project from Cycles 22 and 23 with the goal of constructing a quasi-bolometric light curve to monitor the late-time evolution of SN 2011fe. We have already obtained four epochs and a fifth epoch is scheduled for September 2016. We propose obtaining two additional epochs during Cycles 24 and 25 at ~ 2100 and ~ 2500 days after tBmax to well-sample the transition to a dominantly 55Fe powered light curve and to constrain the existence of a shock-heated companion.

The very late-time spectra of SNe Ia predominantly consists of line emission over a very broad range of wavelengths longwards of the UV (where there is little emission). We selected the F438W (B), F555W (V) and F600LP (R+I) filters for WFC3/UVIS and F110W (Y J) and F160W (H) for WFC3/IR. There are a number of reasons this filter combination is ideal for this project: 1) These filters cover 4000 to 17000 A with no gaps and relatively uniform throughput. Our ground-based spectroscopy and photometry show there is little flux blueward of 4000 A so we forgo the F336W (U) and UV filters. 2) A single long pass filter would not be sufficient because the shape of the SN spectral energy distribution is known to be changing with ionization (McClelland et al. 2013; Graham et al 2015; Taubenberger et al. 2015, Shappee et al. in prep.). Computing the bolometric luminosity with a single F350LP observation would lead to large systematic uncertainties. However, using individual broad band filters retains some spectral information without the impossible expense of taking a spectrum. Without this information, we could mistake a change in ionization state for a change in the bolometric luminosity or interpret a light echo as a flattening of the bolometric light curve. 3) Finally, the optical filter combination also attempts to evenly partition the optical energy. In the spectrum obtained 850 days after tBmax, the wavelength ranges covered by B, V , R, and I, contained 48%, 37%, 21%, 19% of the optical energy. Thus we have kept B and V as separate filters but F600LP covers both the R and I wavelength

ranges.

We estimated the number of orbits and exposures needed for our program using the estimated magnitudes shown in Figure 1 and the recommendations in the HST Primer. We require a SNR of 7 and 5 for the 3 optical filters during Cycle 24 and 25, respectively. These SNRs will allow us to construct a quasi-bolometric light curve of SN 2011fe and distinguish between the Ropke et al. (2012) models by ~ 3 sigma at each epoch. Conveniently, these SNRs will also allow us to constrain the light from a possible 1Msun shock-heated companion at the 2 and 3-sigma level during each epoch in the F 555W and F 600LP filters, respectively.

The NIR, however, is not as simple because it appears that SN 2011fe is blended in the Cycle 22 and 23 F110W and F160W observations with nearby, faint, very-red stars.

There is also the concern that crowding and confusion may inhibit our measurement in the optical. Luckily, SN 2011fe exploded in a sparse region of the outer disk of M101 where archival pre-explosion HST images existed. Li et al. (2011) use these images and Keck AO observations of SN 2011fe to constrain the progenitor system. They detect no counter part at the location of the SN and place upper limits of F435W < 27.87, F555W < 27.49, and F814W < 26.81 at its position. These limits are fainter than SN 2011fe is expected to be during all of Cycle 24.

We then used the exposure time calculator to estimate the length of our required ob- servations. The exposure time calculations for all of the observations include both their dates and coordinates to ensure that our estimated times are accurate and that the correct contribution of zodiacal light is accounted for. The estimates are also based on the observed optical spectrum of SN 2011fe taken 850 days after tBmax which is calibrated to the expected broad-band magnitudes for each epoch. Finally, because no SN Ia has ever been observed at these epochs, changes in the ionization state of SN 2011fe are possible and can not be predicted. This could conceivably significantly change which filters receive the largest portion of the SN flux. Thus, we will use the Cycle 23/24 photometry to determine if the exposure time distribution needs to be adjusted for Cycle 24/25, respectively.

It is important to note that both of the proposed observations in Cycle 24 and Cycle 25 are critical to understanding the late-time evolution of SN 2011fe. Cycle 24 could unveil the existence of a shock-heated companion. But decisively determining if a flattening in the F600LP lightcurve is due to a companion (evolves on a time scale of ~ 1000 years), 55Fe becoming the dominate heating source (half-life of ~ 3 years), or a change in ionization state will be difficult without a latter epoch. If a shock-heated companion is not seen, then the observations in Cycle 25 will represent the first time we observe a SNe Ia light curve powered by 55Fe. Additionally, difference imaging with the later, deeper epoch will allow us to better deal with crowding, especially in the NIR filters. All of these reasons make late-time observations key.

Finally, because there is still a large and ongoing interest in SN 2011fe, we will waive our 1 year proprietary period and make the data immediately public.

Parallel Observations: As the closest face-on Milky Way analogue, M101 is an important nearby galaxy for many reasons. For example, Shara et al. (2013) have compiled a catalog of 10,000 Wolf- Rayet stars using extensive HST WFC3 He II optical narrow-band imaging. There are also F435W/F555W/F814W/F658N(Halpha) mosaics covering most of the galaxy (GO 9490, 9492, 9720). We have performed a study of Cepheids using archival ACS data that provides the distance which is commonly used for SN 2011fe (Shappee & Stanek 2011). M101 is an important galaxy for the recent 2.4% determination of the Hubble Constant (Riess et al. 2016). We are surveying the entire galaxy for new Cepheids with the LBT. We include ACS in parallel mode to broaden the archival data base. We have used APT and Aladin to confirm it is possible to place the ACS detector (given the roll restrictions created by the timing of the observations) on both of the two Cepheid fields used for published HST Cepheid distance measurements. Our parallel fields could add another, even deeper, epoch for each field and help to better constrain down Cepheid periods, magnitudes, and reddening in those fields. However, because M101 is such and interesting and large galaxy, an ACS parallel observation at any roll angle would be valuable.

Visit

Proposal 14678, Sixth Epoch (1st Visit) (01), implementation Wed May 24 01:06:19 GMT 2017

Diagnostic Status: Warning

Scientific Instruments: WFC3/UVIS, ACS/WFC

Special Requirements: ORIENT 115D TO 129 D; BETWEEN 12-JUN-2017:00:00:00 AND 30-JUN-2017:00:00:00; ON HOLD

Comments: 8 orbits were not schedulable together, so we had to split the thrid epoch into two visits.

Orientation angles are to put the parallels on the Cepheid fields like promised in the Phase I.

On Hold Comments: The exposure times for the sisth visit will be adjusted depending on the 5th visit's observations (from Cycle 23). It is not possible to know the SED at these times because no SN Ia has been observed this late.

Diagnostics

(Sixth Epoch (1st Visit) (01)) Warning (Orbit Planner): PATTERN AND COORDINATED PARALLEL MISMATCH

(Sixth Epoch (1st Visit) (01)) Warning (Orbit Planner): PATTERN AND COORDINATED PARALLEL MISMATCH

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=WFC3-UVIS-DITHER-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.173 Line Spacing=0.112	Coordinate Frame=POS-TARG Pattern Orientation=23.884 Angle Between Sides=81.785 Center Pattern=false		(1-4)

Fixed Targets

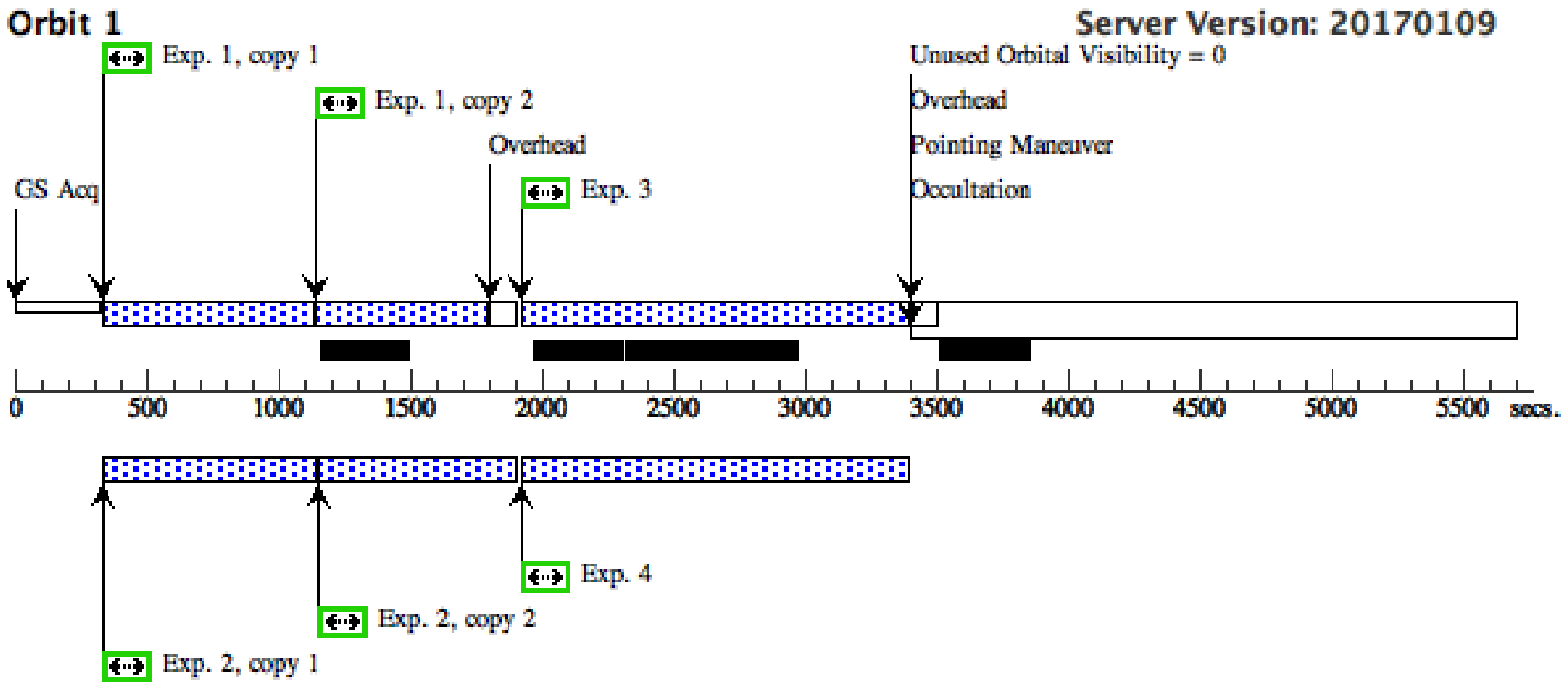
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	SN-2011FE-UVIS	RA: 14 03 7.6436 (210.7818483d) Dec: +54 15 29.72 (54.25826d) Equinox: J2000		V=27.5+/-1.0	Reference Frame: SIMBAD

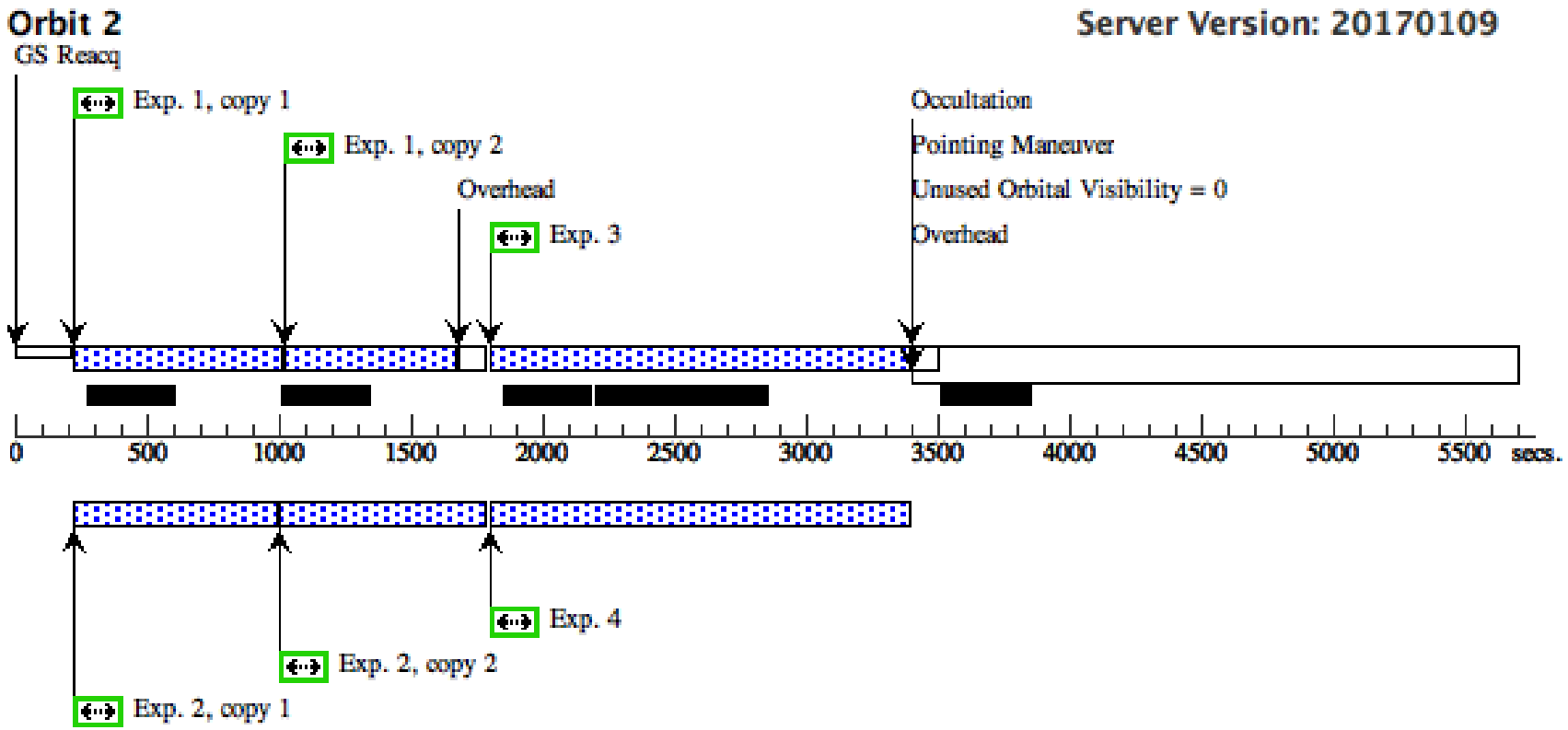
Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	WFC3_F555W	(1) SN-2011FE-UVIS	WFC3/UVIS, ACCUM, UVIS	F555W			Pattern 1, Exps 1-4 in Sixth Epoch (1st Visit) (01) (1) Prime + Parallel Group 1-2 in Pattern 1, Exps 1-4 in Sixth Epoch (1st Visit) (01)	650 Secs X 2 (5200 Secs)	
								[==>(Pattern 1, Copy 1)] *[==>(Pattern 1, Copy 2)]*	***[1]***
								[==>(Pattern 2, Copy 1)] *[==>(Pattern 2, Copy 2)]*	***[2]***
								[==>(Pattern 3, Copy 1)] *[==>(Pattern 3, Copy 2)]*	***[3]***
								[==>(Pattern 4, Copy 1)] *[==>(Pattern 4, Copy 2)]*	***[4]***
2	ACS_F555W	ANY	ACS/WFC, ACCUM, WFC	F555W			Pattern 1, Exps 1-4 in Sixth Epoch (1st Visit) (01) (1) Prime + Parallel Group 1-2 in Pattern 1, Exps 1-4 in Sixth Epoch (1st Visit) (01)	600 Secs X 2 (4994 Secs)	
								[==>(Pattern 1, Copy 1)] *[==>630.0 Secs (Pattern 1, Copy 2)]*	***[1]***
								[==>(Pattern 2, Copy 1)] *[==>655.0 Secs (Pattern 2, Copy 2)]*	***[2]***
								[==>(Pattern 3, Copy 1)] *[==>655.0 Secs (Pattern 3, Copy 2)]*	***[3]***
								[==>627.0 Secs (Pattern 4, Copy 1)] *[==>627.0 Secs (Pattern 4, Copy 2)]*	***[4]***
3	WFC3_F438W	(1) SN-2011FE-UVIS	WFC3/UVIS, ACCUM, UVIS	F438W			Pattern 1, Exps 1-4 in Sixth Epoch (1st Visit) (01) (1) Prime + Parallel Group 3-4 in Pattern 1, Exps 1-4 in Sixth Epoch (1st Visit) (01)	1350 Secs (6148 Secs)	
								[==>1447.0 Secs (Pattern 1)]	***[1]***
								[==>1567.0 Secs (Pattern 2)]	***[2]***
								[==>1567.0 Secs (Pattern 3)]	***[3]***
								[==>1567.0 Secs (Pattern 4)]	***[4]***
4	ACS_F435W	ANY	ACS/WFC, ACCUM, WFC	F435W			Pattern 1, Exps 1-4 in Sixth Epoch (1st Visit) (01) (1) Prime + Parallel Group 3-4 in Pattern 1, Exps 1-4 in Sixth Epoch (1st Visit) (01)	1000 Secs (5548 Secs)	
								[==>1297.0 Secs (Pattern 1)]	***[1]***
								[==>1417.0 Secs (Pattern 2)]	***[2]***
								[==>1417.0 Secs (Pattern 3)]	***[3]***
								[==>1417.0 Secs (Pattern 4)]	***[4]***

Orbit Structure

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Exp. 3
Occultation
Pointing Maneuver
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Overhead
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4000
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secs.
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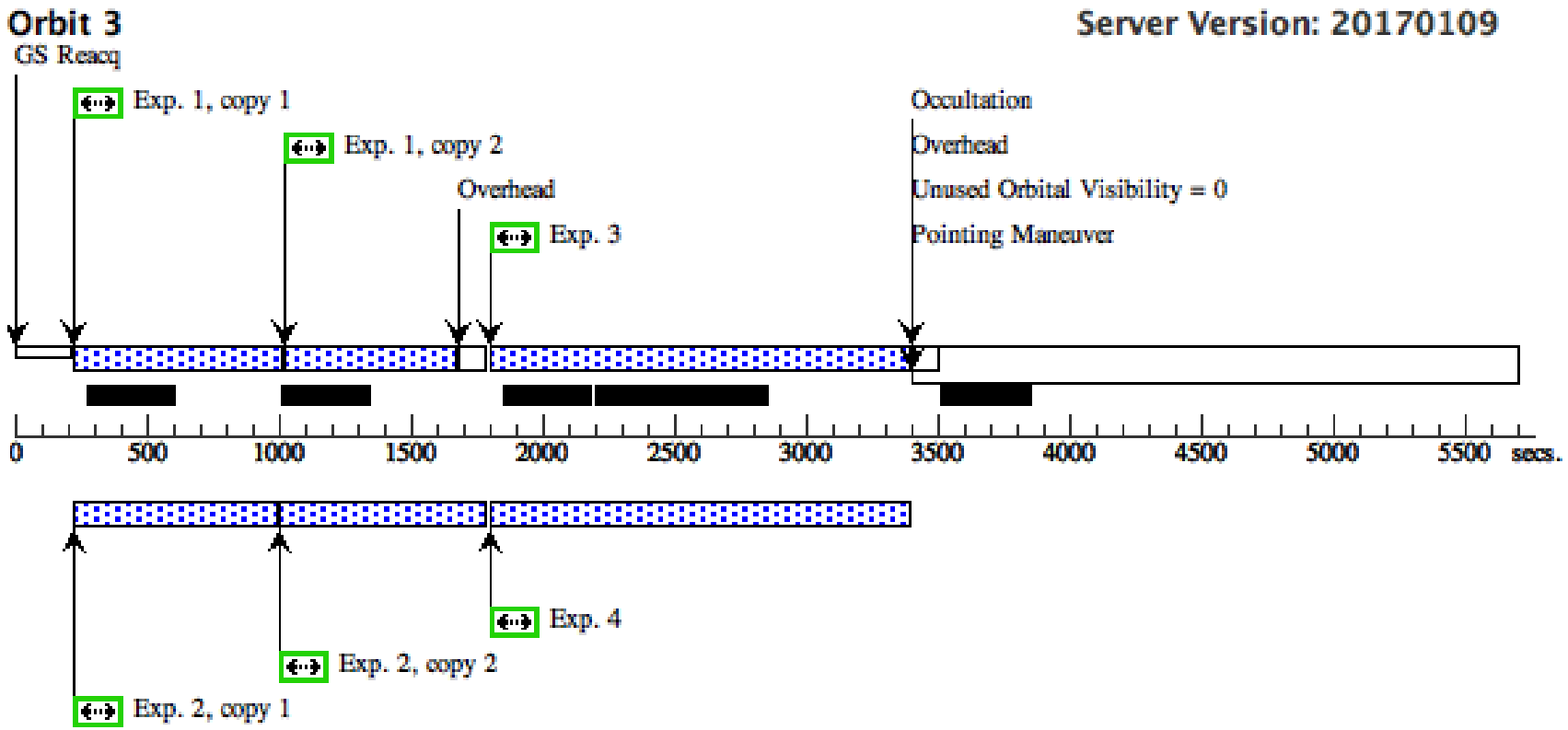
Exp. 2, copy 2
Exp. 2, copy 1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Server Version: 20170109
GS Reacq
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Exp. 1, copy 2
Overhead
Exp. 3
Occultation
Overhead
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Pointing Maneuver
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secs.
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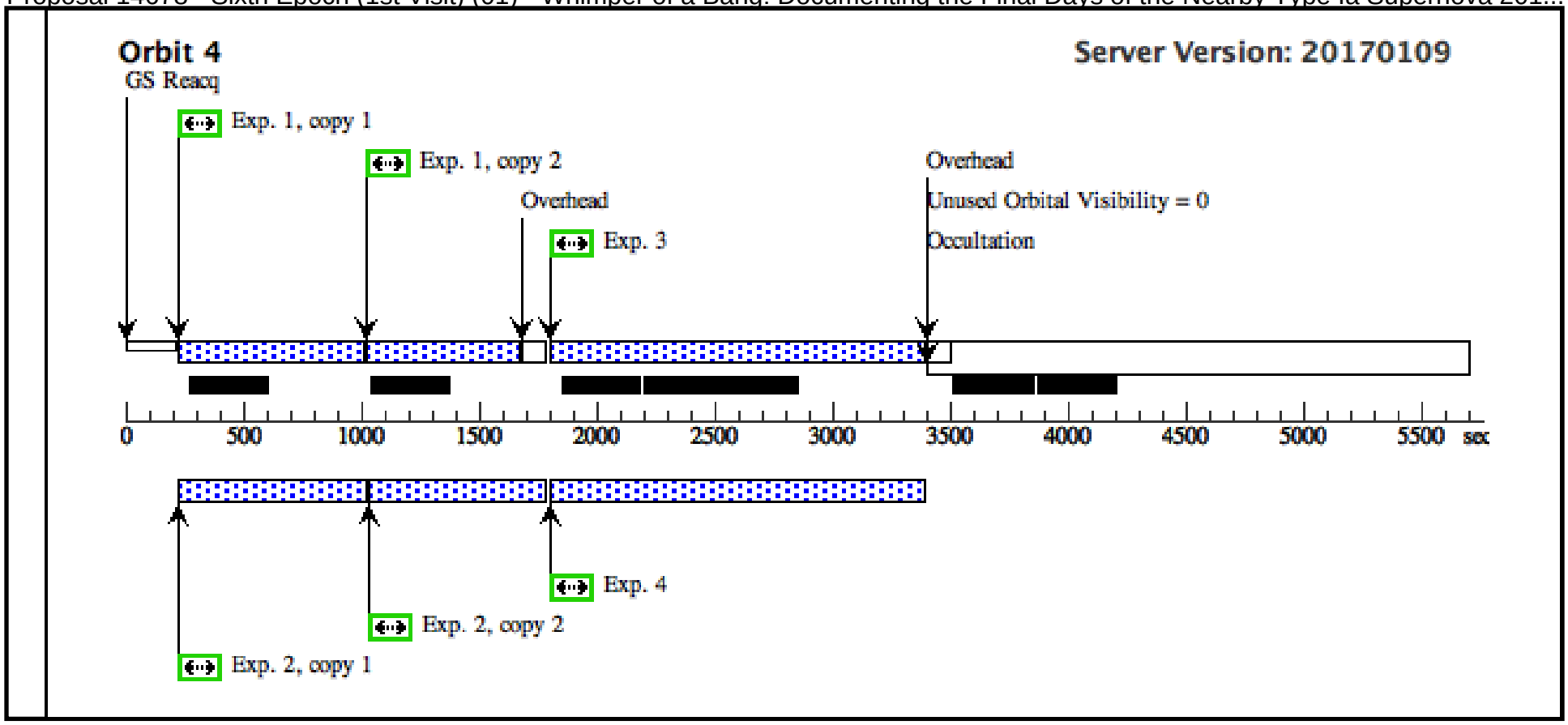
Orbit 4
Server Version: 20170109
GS Reacq
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Exp. 1, copy 2
Overhead
Exp. 3
Overhead
Unused Orbital Visibility = 0
Occultation
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
sec
Exp. 4
Exp. 2, copy 2
Exp. 2, copy 1

Visit

Proposal 14678, Sixth Epoch (2nd Visit) (02), implementation Wed May 24 01:06:19 GMT 2017

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/IR, WFC3/UVIS, ACS/WFC

Special Requirements: ORIENT 115D TO 129 D; BETWEEN 12-JUN-2017:00:00:00 AND 30-JUN-2017:00:00:00; ON HOLD

Comments: 8 orbits were not schedulable together, so we had to split the thrid epoch into two visits.

On Hold Comments: The exposure times for the third visit will be adjusted depending on the 1st visit's observations. It is not possible to know the SED at these times because no SN Ia has been observed this late.

Patterns

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Fixed Targets

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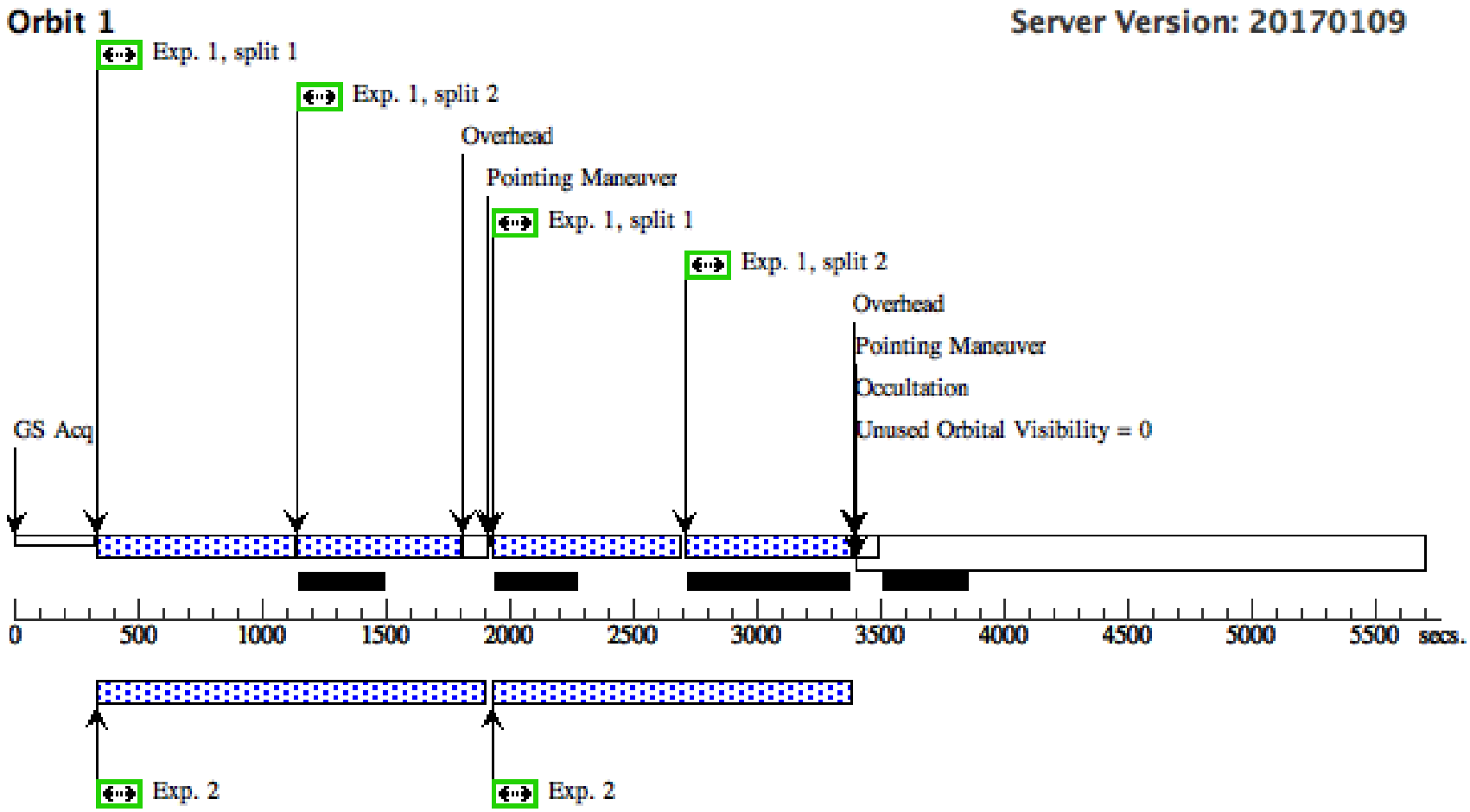
Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.					
(2)	SN-2011FE-IR	RA: 14 03 6.1271 (210.7755296d) Dec: +54 16 22.98 (54.27305d) Equinox: J2000		V=27.5+/-1.0	Reference Frame: SIMBAD
Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.					

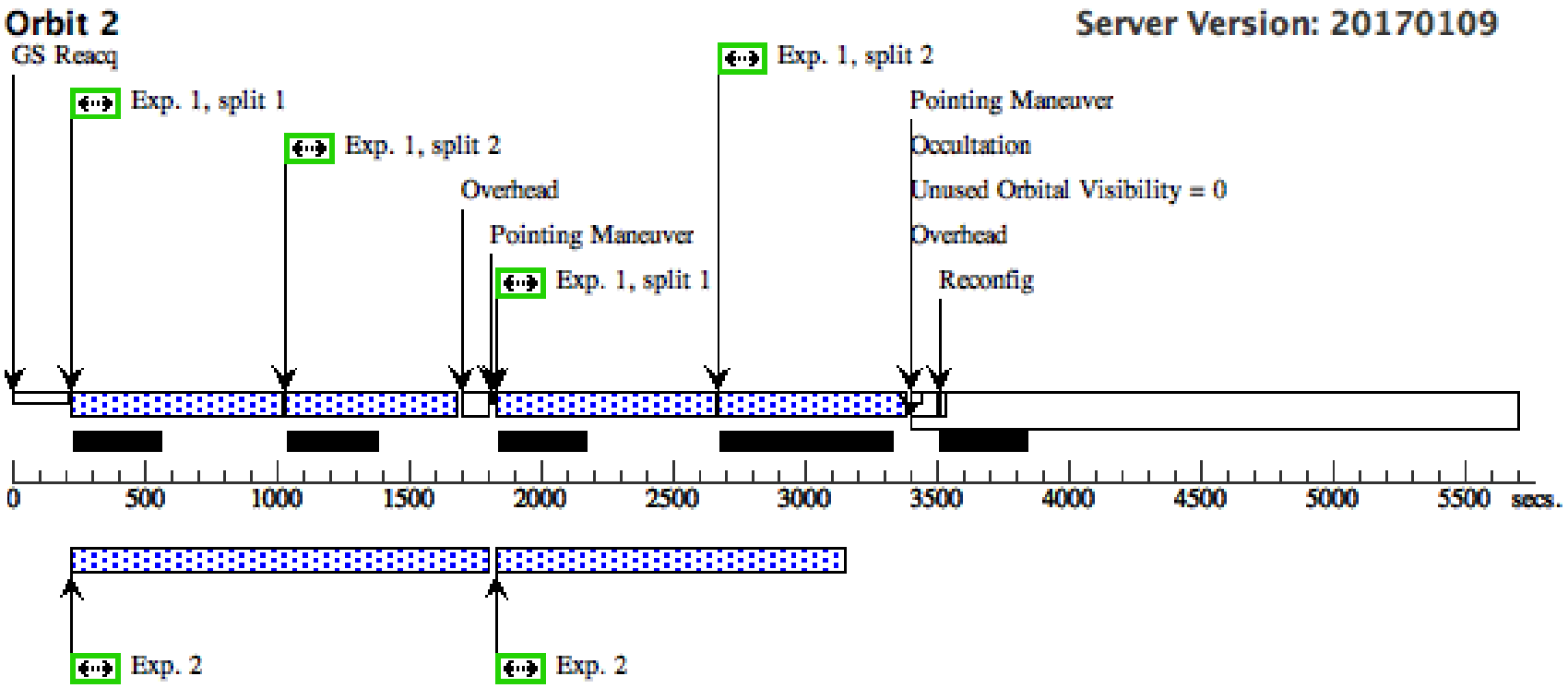
Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	WFC3-F600LP	(1) SN-2011FE-UVIS	WFC3/UVIS, ACCUM, UVIS	F600LP	CR-SPLIT=2		Pattern 1, Exps 1-2 in Sixth Epoch (2nd Visit) (02) (1) Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in Sixth Epoch (2nd Visit) (02)	1000 Secs (5402 Secs) *[==>651.0 Secs (Pattern 1, Split 1)]* *[==>661.0 Secs (Pattern 1, Split 2)]* *[==>651.0 Secs (Pattern 2, Split 1)]* *[==>671.0 Secs (Pattern 2, Split 2)]* *[==>687.0 Secs (Pattern 3, Split 1)]* *[==>651.0 Secs (Pattern 3, Split 2)]* *[==>715.0 Secs (Pattern 4, Split 1)]* *[==>715.0 Secs (Pattern 4, Split 2)]*	 ***[1]*** ***[2]***
2	ACS_F658N	ANY	ACS/WFC, ACCUM, WFC	F658N	FLASH=8		Pattern 1, Exps 1-2 in Sixth Epoch (2nd Visit) (02) (1) Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in Sixth Epoch (2nd Visit) (02)	100 Secs (5325 Secs) *[==>1357.0 Secs (Pattern 1)]* *[==>1325.0 Secs (Pattern 2)]* *[==>1448.0 Secs (Pattern 3)]* *[==>1195.0 Secs (Pattern 4)]*	 ***[1]*** ***[2]***
3	WFC3-F160W	(2) SN-2011FE-IR	WFC3/IR, MULTIACCUM, IR	F160W	SAMP-SEQ=SPARS50; NSAMP=10	POS TARG 0.0,0.0	Prime + Parallel Group 3-4 in Sixth Epoch (2nd Visit) (02)	452.93635 Secs (452.936 Secs) *[==>]*	 ***[3]***
4	ACS_F814W	ANY	ACS/WFC, ACCUM, WFC	F814W			Prime + Parallel Group 3-4 in Sixth Epoch (2nd Visit) (02)	300 Secs (314 Secs) *[==>314.0 Secs]*	 ***[3]***
5	WFC3-F160W	(2) SN-2011FE-IR	WFC3/IR, MULTIACCUM, IR	F160W	SAMP-SEQ=SPARS50; NSAMP=11	POS TARG 0.542,0.182	Prime + Parallel Group 5-6 in Sixth Epoch (2nd Visit) (02)	502.936801 Secs (502.937 Secs) *[==>]*	 ***[3]***
6	ACS_F814W	ANY	ACS/WFC, ACCUM, WFC	F814W			Prime + Parallel Group 5-6 in Sixth Epoch (2nd Visit) (02)	350 Secs (418 Secs) *[==>418.0 Secs]*	 ***[3]***
7	WFC3-F110W	(2) SN-2011FE-IR	WFC3/IR, MULTIACCUM, IR	F110W	SAMP-SEQ=SPARS100; NSAMP=11	SAME POS AS 5	Prime + Parallel Group 7-8 in Sixth Epoch (2nd Visit) (02)	1002.935521 Secs (1002.936 Secs) *[==>]*	 ***[3]***
8	ACS_F814W	ANY	ACS/WFC, ACCUM, WFC	F814W			Prime + Parallel Group 7-8 in Sixth Epoch (2nd Visit) (02)	640 Secs (907 Secs) *[==>907.0 Secs]*	 ***[3]***
9	WFC3-F110W	(2) SN-2011FE-IR	WFC3/IR, MULTIACCUM, IR	F110W	SAMP-SEQ=SPARS100; NSAMP=11	SAME POS AS 3	Prime + Parallel Group 9-10 in Sixth Epoch (2nd Visit) (02)	1002.935521 Secs (1002.936 Secs) *[==>]*	 ***[3]***
10	ACS_F814W	ANY	ACS/WFC, ACCUM, WFC	F814W			Prime + Parallel Group 9-10 in Sixth Epoch (2nd Visit) (02)	640 Secs (907 Secs) *[==>907.0 Secs]*	 ***[3]***
11	WFC3-F160W	(2) SN-2011FE-IR	WFC3/IR, MULTIACCUM, IR	F160W	SAMP-SEQ=SPARS50; NSAMP=10	POS TARG 0.0,0.0	Prime + Parallel Group 11-12 in Sixth Epoch (2nd Visit) (02)	452.93635 Secs (452.936 Secs) *[==>]*	 ***[4]***
12	ACS_F814W	ANY	ACS/WFC, ACCUM, WFC	F814W			Prime + Parallel Group 11-12 in Sixth Epoch (2nd Visit) (02)	300 Secs (335 Secs) *[==>335.0 Secs]*	 ***[4]***
13	WFC3-F160W	(2) SN-2011FE-IR	WFC3/IR, MULTIACCUM, IR	F160W	SAMP-SEQ=SPARS50; NSAMP=11	POS TARG 0.542,0.182	Prime + Parallel Group 13-14 in Sixth Epoch (2nd Visit) (02)	502.936801 Secs (502.937 Secs) *[==>]*	 ***[4]***

	14	ACS_F814W	ANY	ACS/WFC, ACCUM, WFC	F814W		Prime + Parallel Group 13-14 in Sixth Epoch (2nd Visit) (02)	350 Secs (418 Secs) *[==>418.0 Secs]*	 ***[4]***
	15	WFC3-F110W	(2) SN-2011FE-IR	WFC3/IR, MULTIACCUM, IR	F110W	SAMP-SEQ=SPARS 100; SAME POS AS 5 NSAMP=11	Prime + Parallel Group 15-16 in Sixth Epoch (2nd Visit) (02)	1002.935521 Secs (1002.936 Secs) *[==>]*	 ***[4]***
	16	ACS_F814W	ANY	ACS/WFC, ACCUM, WFC	F814W		Prime + Parallel Group 15-16 in Sixth Epoch (2nd Visit) (02)	640 Secs (907 Secs) *[==>907.0 Secs]*	 ***[4]***
	17	WFC3-F110W	(2) SN-2011FE-IR	WFC3/IR, MULTIACCUM, IR	F110W	SAMP-SEQ=SPARS 100; SAME POS AS 3 NSAMP=11	Prime + Parallel Group 17-18 in Sixth Epoch (2nd Visit) (02)	1002.935521 Secs (1002.936 Secs) *[==>]*	 ***[4]***
	18	ACS_F814W	ANY	ACS/WFC, ACCUM, WFC	F814W		Prime + Parallel Group 17-18 in Sixth Epoch (2nd Visit) (02)	640 Secs (907 Secs) *[==>907.0 Secs]*	 ***[4]***

Orbit Structure

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Pointing Maneuver
Exp. 1, split 1
Exp. 1, split 2
Pointing Maneuver
Occultation
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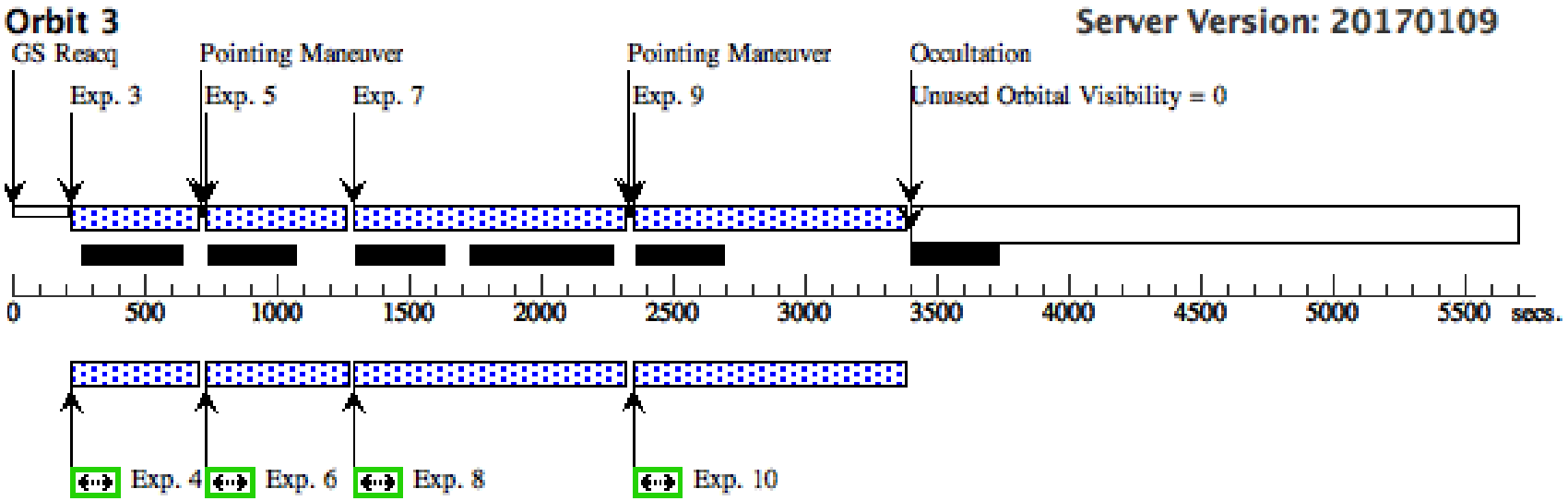
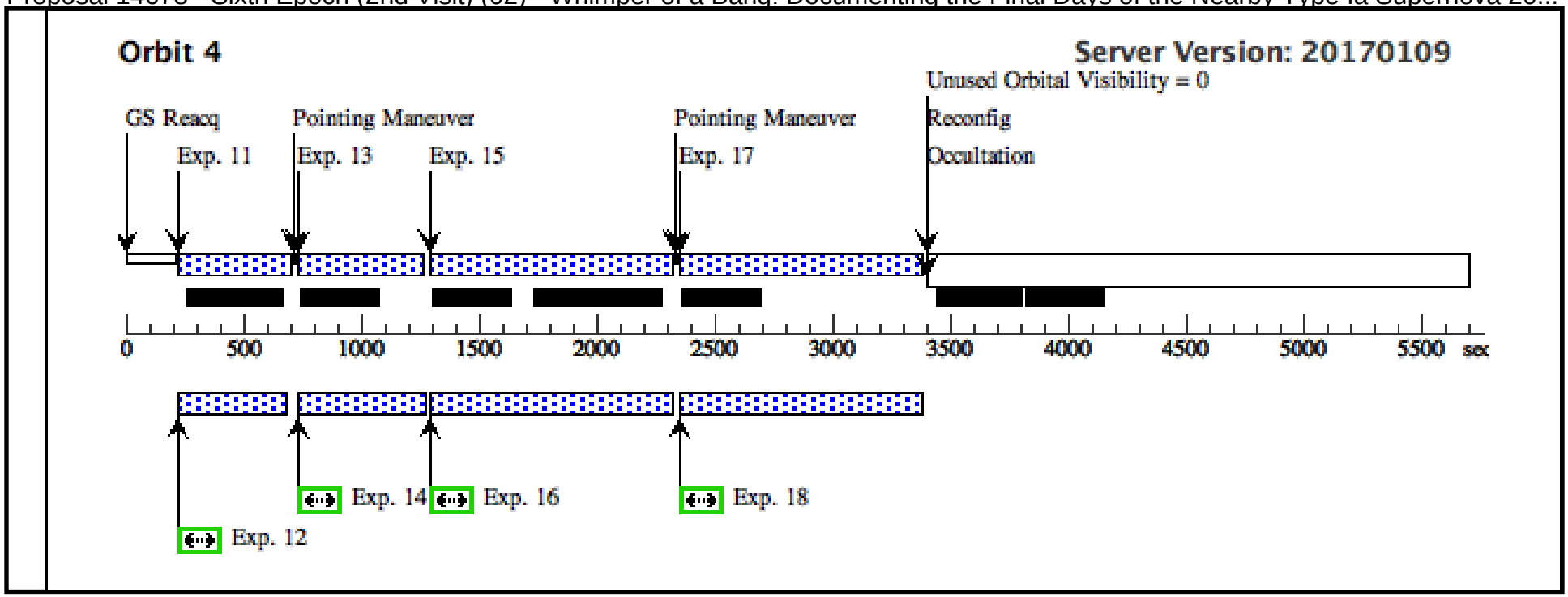
secs.
Exp. 2
Exp. 2


Orbit 3
Server Version: 20170109
GS Reacq
Exp. 3
Pointing Maneuver
Exp. 5
Exp. 7
Pointing Maneuver
Exp. 9
Occultation
Unused Orbital Visibility = 0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
secs.
Exp. 4
Exp. 6
Exp. 8
Exp. 10


Orbit 4
Server Version: 20170109
Unused Orbital Visibility = 0
GS Reacq
Exp. 11
Pointing Maneuver
Exp. 13
Exp. 15
Pointing Maneuver
Exp. 17
Reconfig
Occultation
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1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
sec
Exp. 14
Exp. 16
Exp. 18
Exp. 12