16303 - Fine-Tuned Search for Kilonova Emission in a Short Gamma-Ray Burst: Implications for the Progenitors, GW Sources, and r-Process Nucleosynthesis

Cycle: 28, Proposal Category: GO

(JWST Initative)

(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) SGRB211106A	ACS/WFC WFC3/IR	4	18-Nov-2021 16:00:15.0	yes
02	(1) SGRB211106A	WFC3/IR	2	18-Nov-2021 16:00:16.0	yes
03	(1) SGRB211106A	ACS/WFC WFC3/IR	4	18-Nov-2021 16:00:18.0	yes

10 Total Orbits Used

ABSTRACT

The joint gravitational wave and electromagnetic detections of the binary neutron star (BNS) merger GW170817 ushered in a new era of astrophysics. In the UV/optical/NIR the emission (a "kilonova") was powered by radioactive decay of nuclei produced via r-process nucleosynthesis. In the gamma-ray, X-ray, and radio the emission was instead powered by an off-axis jet typical of short gamma-ray bursts (SGRBs); this connection was previously supported by the HST detection of a kilonova in the short GRB130603B. With only a single joint GW-EM detection and a single kilonova detection in an SGRB, the key frontier is to begin to map the distribution of merger outcomes: ejecta mass, velocity, geometry, and nucleosynthetic yields. Here we propose to achieve this goal with HST observations of a kilonova associated with an SGRBs; observations of kilonovae in SGRBs are essential because the orientation is well known (face-on, along the binary's angular momentum axis) and the LIGO/Virgo Observing Run 3 has not yielded joint GW-EM detections. Such a study can only be achieved with the sensitivity and resolution of HST, and it matches one of the "special initiatives", namely deep NIR monitoring that is essential for informing future JWST follow-ups ("JWST Preparatory Observations"). We request 10 orbits for 1 SGRB event. The HST observations will be supported by approved programs at Chandra, VLA, ALMA, Gemini, Keck, Magellan, MMT that will provide the targets, cover optical and early NIR follow-up to establish the baseline behavior, and complete the multi-wavelength picture of the event. Given the broad interest in this topic we waive the proprietary period.

OBSERVING DESCRIPTION

Triggered target is GRB211106A at z=0.1, with observations for this redshift range as described below.

To determine the expected apparent brightness of the kilonova for the expected range of ejecta masses (0.01-0.1 Msun), and to inform the choice of filters, we convolve the kilonova models of Barnes & Kasen (2013) as a function of redshift with the ACS/F814W, WFC3/F110W, and WFC3/F160W filter response functions. We calculate the resulting apparent brightness in two rest-frame times of 4 days (peak) and 10 days (post-

maximum). The actual observer-frame times for the two HST epochs will therefore be 4x(1+z) days and 10x(1+z) days, where the redshift will be known prior to triggering the HST observations from rapid ground-based follow-up. The choice of filters is designed to straddle the break at 1 micron in the rest-frame, in order to capture the unusually red color of a kilonova.

We base our HST trigger criteria and time request on the model with 0.01 Msun so that we can probe the wide range of ejecta masses predicted by numerical simulations (rather than just the bright upper bound of 0.1sun); this will allow any non-detections to place meaningful constraints on the r-process yield.

Epoch 1 (4x(1+z) days): We find that at z<=0.2 it is advantageous to use the ACS/F814W and WFC3/F110W filters, which give the best combination of sensitivity (5sigma=27.7 and 27.5 AB mag in 2 orbits each, respectively, using the ACS and WFC3 ETCs) and color contrast (F814W-F110W=1.6-2 AB mag). The afterglow color in these filters will be much bluer, F814W-F110W=0.3 AB mag, so a kilonova origin can be robustly demonstrated. At z=0.2-0.4 we will instead use the WFC3/F110W and F160W filters to capture the spectral break (5sigma=26.3 AB mag for F160W in 2 orbits). The resulting
color is F110W-F160W=0.6-1.2 AB mag, compared to a bluer color for the afterglow, F110W-F160W=0.3 AB mag. The kilonova emission for 0.1 Msun can be detected to z=0.7, but we truncate our trigger criteria at z=0.4 to be able to detect the emission in the case of 0.01 Msun.

Epoch 2 (10x(1 + z) days): In the second epoch we will only observe in a single filter redward of the 1 micron break since we are only concerned with demonstrating a rapid decline that will help to robustly determine the ejecta mass (i.e., the unusually red color will already be established with the first epoch near peak). This will require 2 orbits in F110W (z<=0.2) or F160W (z=0.2-0.4). In this case, if the ejecta mass is 0.01 Msun we will obtain a deep upper limit that will establish the expected rapid fading, while in the case of 0.1 Msun we will have a second detection.

Templates (>1 month): We will acquire template images after the kilonova emission has faded away that match the exposure time and filters of the earlier epochs. This will therefore require a total of 4 orbits (2 orbits in each filter). We note, however, that in the case of 0.01 Msun a non-detection in the second epoch could be used as a template in one of the two filters (F110W or F160W depending on the redshift), meaning that the final observation will require only 2 orbits. Since we do not know the ejecta mass in advance we request 4 orbits for the final epoch, but may use only 2 orbits. This will be known following epoch 2.

Visit

Proposal 16303, SRGB211106A-EP1 (01), implementation Thu Nov 18 21:00:18 GMT 2021

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/IR, ACS/WFC

Special Requirements: ON HOLD ; TOO RESPONSE TIME 3.0D

On Hold Comments: This visit is a target of opportunity triggered on a Short GRB of z < 0.2. This is our first epoch and should be triggered at 4 x (1+z) days after the GRB detection.

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=ACS-WFC-DITHER-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.262 Line Spacing=0.192	Coordinate Frame=POS-TARG Pattern Orientation=18.39 Angle Between Sides=68.14 Center Pattern=false		(1-2)
(2)	Pattern Type=WFC3-IR-DITHER-BOX-MIN Purpose=DITHER Number Of Points=4 Point Spacing=0.572 Line Spacing=0.365	Coordinate Frame=POS-TARG Pattern Orientation=18.528 Angle Between Sides=74.653 Center Pattern=false		(3-4)

Fixed Targets

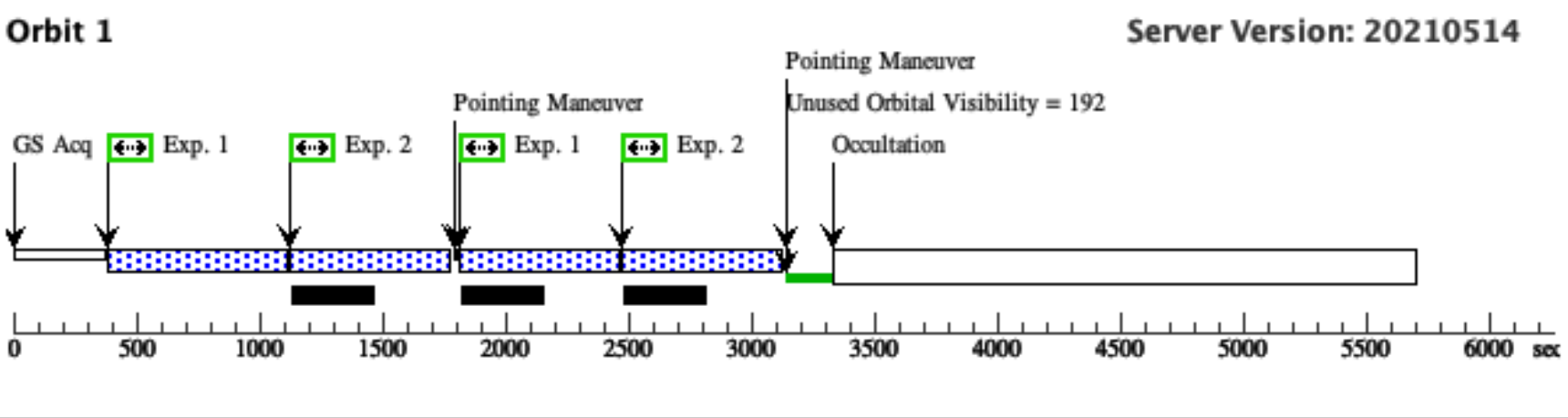
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	SGRB211106A	RA: 22 54 20.5000 (343.5854167d) Dec: -53 13 50.90 (-53.23081d) Equinox: J2000	Redshift: 0.1	V=26	Reference Frame: ICRS

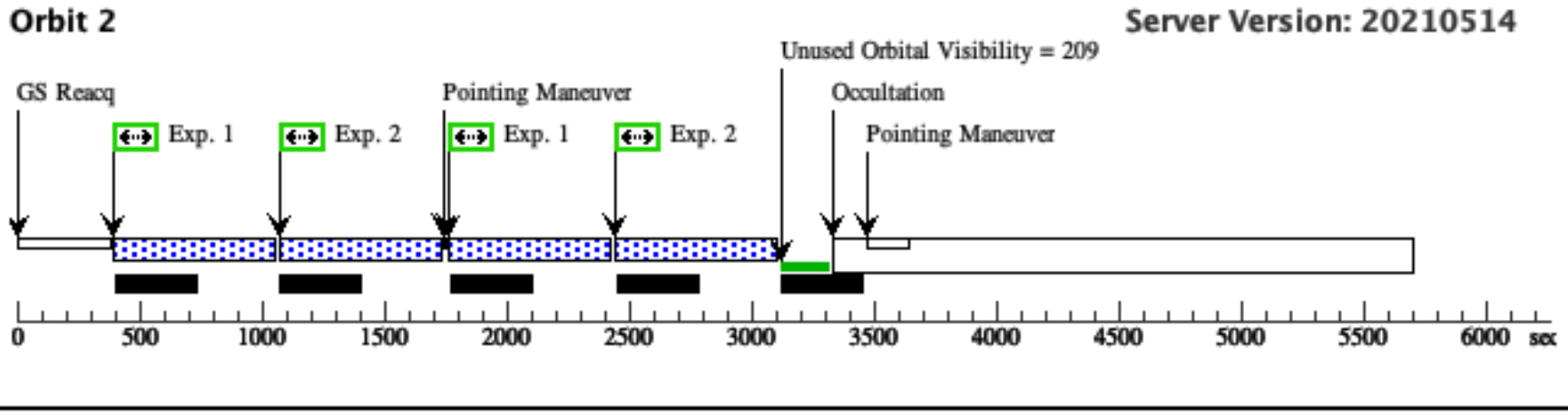
Comments: Short GRB at z~0.1; observations in ACS/F814W and WFC3/F110W as planned in the original proposal.
Category=UNIDENTIFIED
Description=[GAMMA RAY EMITTER]
Extended=NO

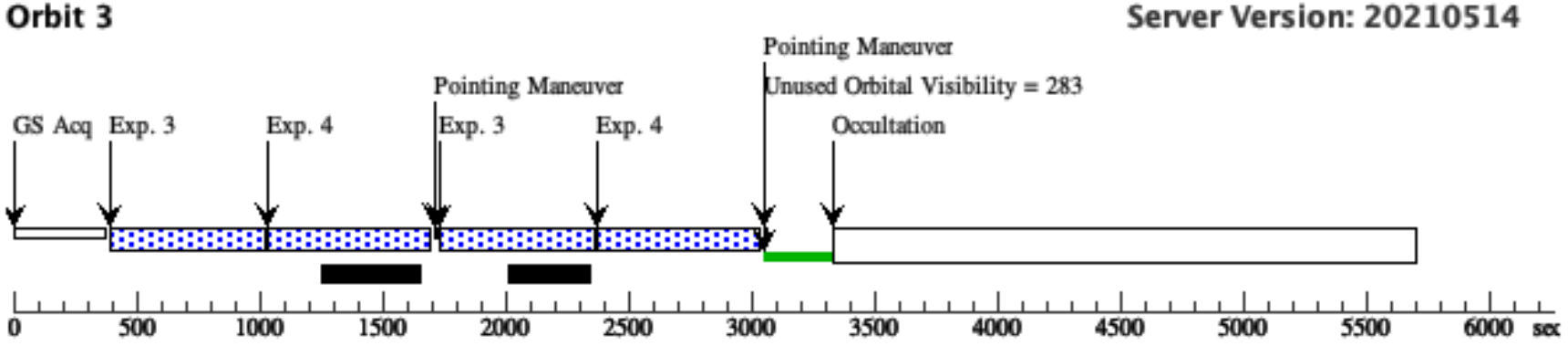
Exposures

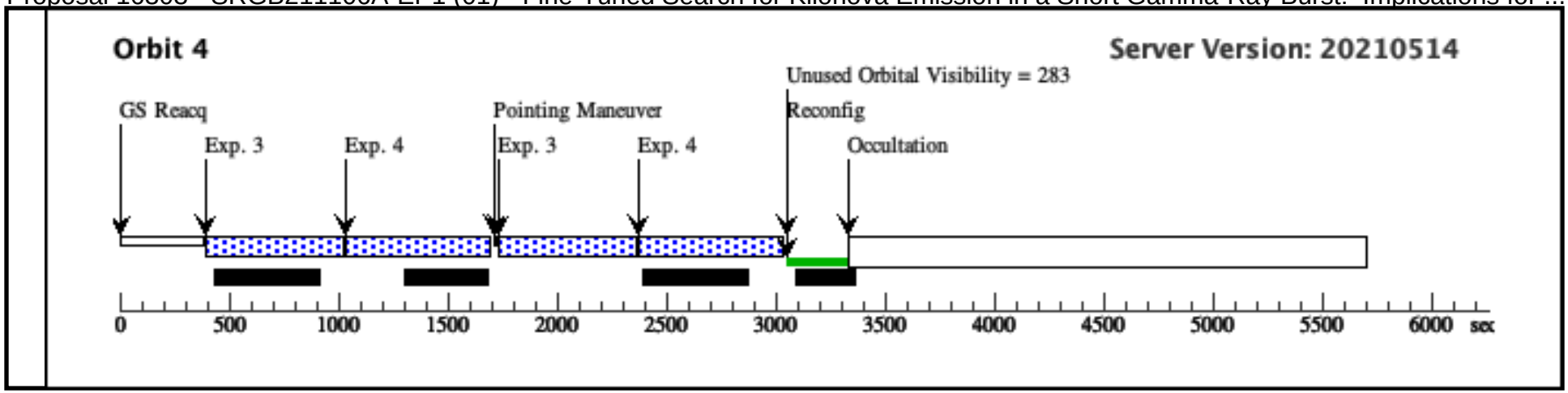
#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	SGRB-KILONOVA-DAY4-ORBIT1	(1) SGRB211106A	ACS/WFC, ACCUM, WFC	F814W			Pattern 1, Exps 1-2 in SRGB211106A-EP1 (01) (1)	500 Secs (2132 Secs)	
								[==>526.0 Secs (Pattern 1)] *[==>526.0 Secs (Pattern 2)]*	***[1]***
								[==>540.0 Secs (Pattern 3)] *[==>540.0 Secs (Pattern 4)]*	***[2]***
2	SGRB-KILONOVA-DAY4-ORBIT2	(1) SGRB211106A	ACS/WFC, ACCUM, WFC	F814W			Pattern 1, Exps 1-2 in SRGB211106A-EP1 (01) (1)	500 Secs (2132 Secs)	
								[==>526.0 Secs (Pattern 1)] *[==>526.0 Secs (Pattern 2)]*	***[1]***
								[==>540.0 Secs (Pattern 3)] *[==>540.0 Secs (Pattern 4)]*	***[2]***
3	SGRB-KILONOVA-DAY4-ORBIT3	(1) SGRB211106A	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=13; SAMP-SEQ=SPARS50		Pattern 2, Exps 3-4 in SRGB211106A-EP1 (01) (2)	602.937703 Secs (2411.751 Secs)	
								[==>(Pattern 1)] *[==>(Pattern 2)]*	***[3]***
								[==>(Pattern 3)] *[==>(Pattern 4)]*	***[4]***
4	SGRB-KILONOVA-DAY4-ORBIT4	(1) SGRB211106A	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=14; SAMP-SEQ=SPARS50		Pattern 2, Exps 3-4 in SRGB211106A-EP1 (01) (2)	652.938154 Secs (2611.753 Secs)	
								[==>(Pattern 1)] *[==>(Pattern 2)]*	***[3]***
								[==>(Pattern 3)] *[==>(Pattern 4)]*	***[4]***

Orbit Structure





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Exp. 3
Exp. 4
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1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
sec

Visit

Proposal 16303, SRGB211106A-EP2 (02), implementation Thu Nov 18 21:00:19 GMT 2021

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/IR

Special Requirements: AFTER 01 BY 6 D TO 9 D; ON HOLD

On Hold Comments: This visit is a target of opportunity triggered on a Short GRB of z < 0.2. This is our second epoch and should be triggered at 10 x (1+z) days after the GRB detection.

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(2)	Pattern Type=WFC3-IR-DITHER-BOX-MIN Purpose=DITHER Number Of Points=4 Point Spacing=0.572 Line Spacing=0.365	Coordinate Frame=POS-TARG Pattern Orientation=18.528 Angle Between Sides=74.653 Center Pattern=false		(1-2)

Fixed Targets

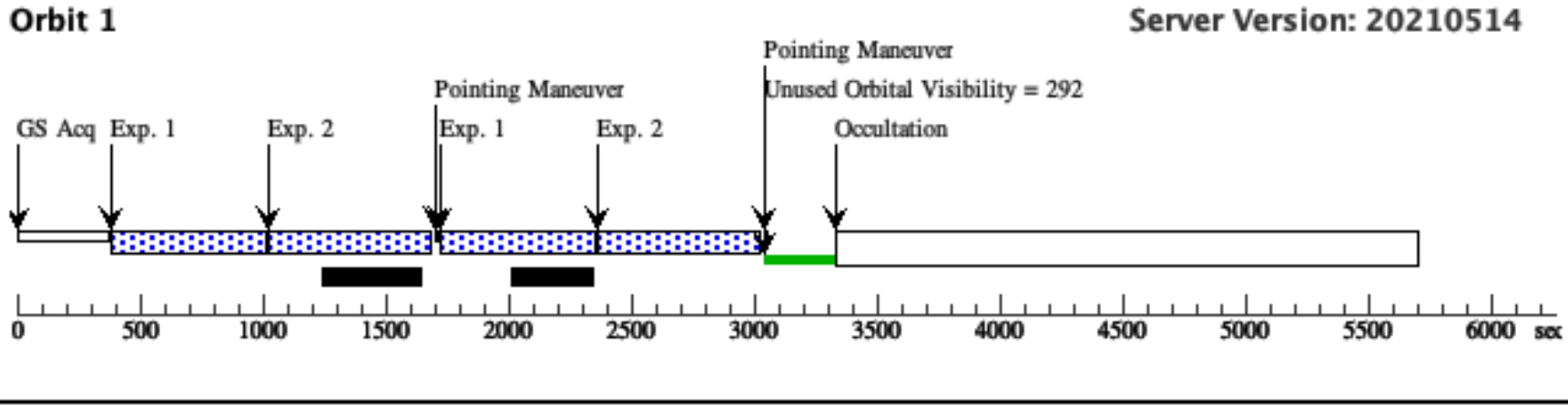
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	SGRB211106A	RA: 22 54 20.5000 (343.5854167d) Dec: -53 13 50.90 (-53.23081d) Equinox: J2000	Redshift: 0.1	V=26	Reference Frame: ICRS

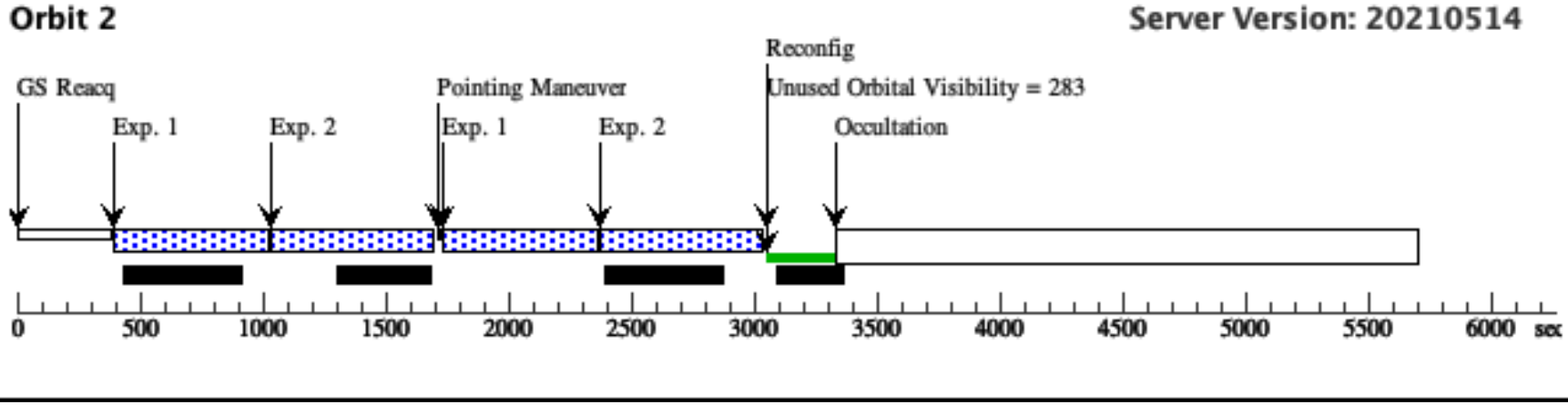
Comments: Short GRB at z~0.1; observations in ACS/F814W and WFC3/F110W as planned in the original proposal.
Category=UNIDENTIFIED
Description=[GAMMA RAY EMITTER]
Extended=NO

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	SGRB-KILONOVA-DAY10-ORBIT1	(1) SGRB211106A	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=13; SAMP-SEQ=SPARS50		Pattern 2, Exps 1-2 in SRGB211106A-EP2 (02) (2)	602.937703 Secs (2411.751 Secs)	
								[==>(Pattern 1)] *[==>(Pattern 2)]*	***[1]***
								[==>(Pattern 3)] *[==>(Pattern 4)]*	***[2]***
2	SGRB-KILONOVA-DAY10-ORBIT2	(1) SGRB211106A	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=14; SAMP-SEQ=SPARS50		Pattern 2, Exps 1-2 in SRGB211106A-EP2 (02) (2)	652.938154 Secs (2611.753 Secs)	
								[==>(Pattern 1)] *[==>(Pattern 2)]*	***[1]***
								[==>(Pattern 3)] *[==>(Pattern 4)]*	***[2]***

Orbit Structure





Visit

Proposal 16303, SRGB211106A-TEMPLATE (03), implementation Thu Nov 18 21:00:19 GMT 2021

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/IR, ACS/WFC

Special Requirements: AFTER 02 BY 20 D TO 30 D; ON HOLD

On Hold Comments: This visit is a target of opportunity triggered on a Short GRB of z < 0.2. This is our template epoch and should be triggered at >1 month after the GRB detection.

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=ACS-WFC-DITHER-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.262 Line Spacing=0.192	Coordinate Frame=POS-TARG Pattern Orientation=18.39 Angle Between Sides=68.14 Center Pattern=false		(1-2)
(2)	Pattern Type=WFC3-IR-DITHER-BOX-MIN Purpose=DITHER Number Of Points=4 Point Spacing=0.572 Line Spacing=0.365	Coordinate Frame=POS-TARG Pattern Orientation=18.528 Angle Between Sides=74.653 Center Pattern=false		(3-4)

Fixed Targets

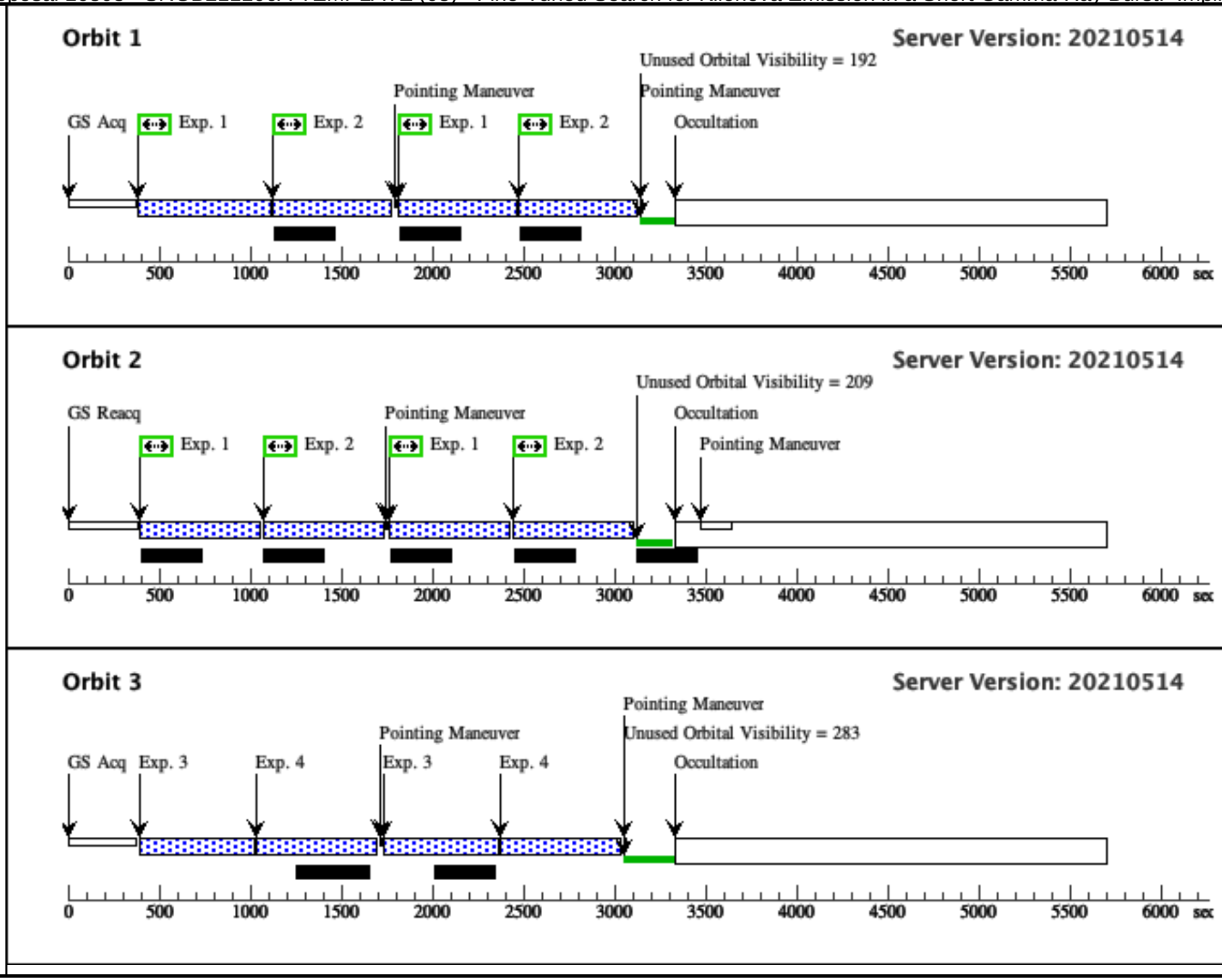
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	SGRB211106A	RA: 22 54 20.5000 (343.5854167d) Dec: -53 13 50.90 (-53.23081d) Equinox: J2000	Redshift: 0.1	V=26	Reference Frame: ICRS

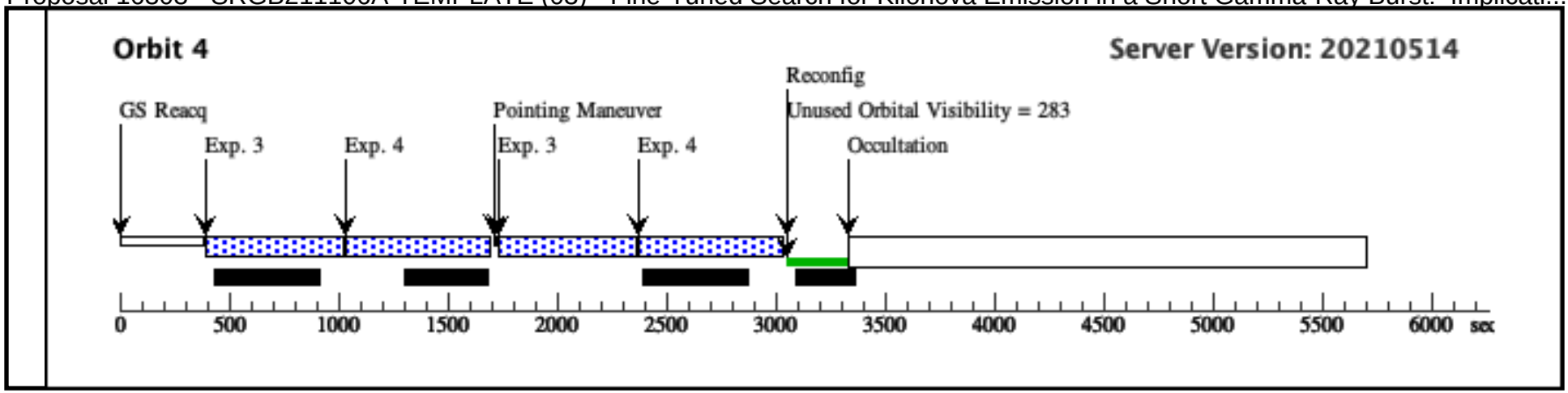
Comments: Short GRB at z~0.1; observations in ACS/F814W and WFC3/F110W as planned in the original proposal.
Category=UNIDENTIFIED
Description=[GAMMA RAY EMITTER]
Extended=NO

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	SGRB-KILONOVA-TEMPLATE-ORBIT1	(1) SGRB211106A	ACS/WFC, ACCUM, WFC	F814W			Pattern 1, Exps 1-2 in SRGB211106A-TEMPLATE (03) (1)	500 Secs (2132 Secs)	
								[==>526 Secs (Pattern 1)] *[==>526 Secs (Pattern 2)]*	***[1]***
								[==>540 Secs (Pattern 3)] *[==>540 Secs (Pattern 4)]*	***[2]***
2	SGRB-KILONOVA-TEMPLATE-ORBIT2	(1) SGRB211106A	ACS/WFC, ACCUM, WFC	F814W			Pattern 1, Exps 1-2 in SRGB211106A-TEMPLATE (03) (1)	500 Secs (2132 Secs)	
								[==>526 Secs (Pattern 1)] *[==>526 Secs (Pattern 2)]*	***[1]***
								[==>540 Secs (Pattern 3)] *[==>540 Secs (Pattern 4)]*	***[2]***
3	SGRB-KILONOVA-TEMPLATE-ORBIT3	(1) SGRB211106A	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=13; SAMP-SEQ=SPARS50		Pattern 2, Exps 3-4 in SRGB211106A-TEMPLATE (03) (2)	602.937703 Secs (2411.751 Secs)	
								[==>(Pattern 1)] *[==>(Pattern 2)]*	***[3]***
								[==>(Pattern 3)] *[==>(Pattern 4)]*	***[4]***
4	SGRB-KILONOVA-TEMPLATE-ORBIT4	(1) SGRB211106A	WFC3/IR, MULTIACCUM, IR	F110W	NSAMP=14; SAMP-SEQ=SPARS50		Pattern 2, Exps 3-4 in SRGB211106A-TEMPLATE (03) (2)	652.938154 Secs (2611.753 Secs)	
								[==>(Pattern 1)] *[==>(Pattern 2)]*	***[3]***
								[==>(Pattern 3)] *[==>(Pattern 4)]*	***[4]***

Orbit Structure

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