15102 - The Super-Remnant of the Recurrent Nova M31N 2008-12a - A Signpost to Type Ia Supernovae?

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) RX-J0045.4+4154	WFC3/UVIS	1	26-Mar-2018 20:01:43.0	yes
02	(1) RX-J0045.4+4154	WFC3/UVIS	1	26-Mar-2018 20:01:44.0	yes
03	(1) RX-J0045.4+4154	WFC3/UVIS	1	26-Mar-2018 20:01:44.0	yes
04	(1) RX-J0045.4+4154	WFC3/UVIS	1	26-Mar-2018 20:01:45.0	yes
05	(1) RX-J0045.4+4154	WFC3/UVIS	1	26-Mar-2018 20:01:45.0	yes

Visit	*Targets used in Visit*	*Configurations used in Visit*	*Orbits Used*	*Last Orbit Planner Run*	*OP Current with Visit?*
06	(1) RX-J0045.4+4154	WFC3/UVIS	1	26-Mar-2018 20:01:46.0	yes
07	(1) RX-J0045.4+4154	WFC3/UVIS	1	26-Mar-2018 20:01:46.0	yes
08	(1) RX-J0045.4+4154	WFC3/UVIS	1	26-Mar-2018 20:01:47.0	yes

8 Total Orbits Used

ABSTRACT

M31N 2008-12a is the single most important nova system in M31. With an unprecedented 9 observed eruptions in just 9 years, an ultra-high mass white dwarf, a high accretion rate, and low ejected mass, it is the leading pre-explosion Supernova Type Ia progenitor candidate in any galaxy. Our team uncovered a vast elliptical nebula, centred on the nova - a recurrent nova 'super-remnant', the relic of many thousands of past eruptions. State-of-the-art 'multi-cycle' nova eruption models have shown that a CO WD in a short-recurrence period nova does indeed grow towards the Chandrasekhar mass. Such models predict frequent He-flashes, ejecting significantly more mass at higher velocities, every few-hundred eruptions. Our Cycle 24 Halpha observations confirmed the association between the recurrent nova and its super-remnant, enabled the mapping of the gas density, and provided the first possible evidence of the proposed recurrent He-flashes - large scale 'ripples' in the super-remnant. We propose to utilize the unique high-spatial resolution capabilities of HST at visible wavelengths to obtain a series of deep [S II] images to: (i) uniquely trace the remnant shock structure; (ii) confirm the detection of the signature ripples laid down in the super-remnant by the recurrent He-flashes, hence (iii) constrain models of the super-remnant, allowing extrapolation to other systems, and (iv) validate long-term nova eruption models, and also (v) explore shaping mechanisms both by the nova process and surrounding ISM. The relics of He-flashes within the super-remnant would confirm the new single-degenerate WD growth model, providing crucial evidence in support of the nova pathway to SNe Ia.

OBSERVING DESCRIPTION

To carry out the proposed programme of observations of the super-remnant surrounding M31N 2008-12a we will employ the WFC3/UVIS instrument due to its superior spatial resolution capabilities and charge transfer efficiency.

We will use the F673N ([S ii] 6717/6731) filter for these new observations of the super-remnant, and reutilise the F645N observations, taken as part of our successful Cycle 24 proposal, for continuum subtraction purposes. We plan to utilise the entire UVIS detector to maximise the archival usefulness of these data.

We have selected the wider F673N filter rather than the FQ672N ([S ii] 6717) or FQ674N ([S ii] 6731) filters for a number of reasons. Utilising the flux from both [S ii] lines will increase the remnant signal/noise (S/N). But, most importantly, with M31 approaching with a velocity of 300 km/s the peak of each [S ii] line will be shifted by at least 6.6 Angstroms, toward the edge of the 9 Angstrom half-width FQ672N/FQ674N filters where the throughput starts to diminish significantly.

Our exposure time calculations are based on determinations of the [S ii] (6717/6731) flux of the nebula (15 muJy per square arcsec determined from the ground-based data) and the background/continuum (3 Jy per square arcsec ; measured directly from the Cycle 24 F645N image).

We have used the WFC3/UVIS ETC to compute the S/N for the expected [S ii] back-ground/continuum and also the [S ii] background+nebula signal. These results were suitably manipulated to give the following results for the pure (post-background/continuum subtraction) nebula signal. Given the extended nature of our source and fact that we will be looking for potentially small-scale and small-flux changes in nebula density/structure we require our observations to possess a relatively high S/N (> 20 within a discrete region). We also require that we match the sensitivity achieved by the Cycle 24 F657N observations, and the strategy employed for those.

The expected visibility of the target per orbit is 55 mins. Employing 8 HST orbits and the F673N filter gives a total integration time of 21600 s (2770 s per orbit; after allowing for the relevant overheads). In these data we would detect emission from the nebula (in a 5 x 5 pixel region, above the background, i.e. these are the S/N expected after continuum
subtraction using the existing F645N image) with a S/N of 25 (matching the 24 achieved for the Cycle 24 proposal. This corresponds to a flux sensitivity of ~4% over an angular size of just 0.75 pc (at the distance of M31). The flux sensitivity decreases to ~23% for a single (0.04") pixel, an angular size of 0.15 pc. For the fainter centre of the super-remnant (around 1/5 of the peak flux) the 5 x 5 pixel region sensitivity will still be ~8%. The predicted scale of the He-flash ripples (peak-to-peak) are expected to be in the range of 0.5 - 2.0 pc (3 - 13WFC3/UVIS pixels).

Each orbit will consist of two equal length exposures, giving 16 images in total (compared to the 15 for the Cycle 24 proposal). We will mitigate any CTE-losses by initiating a post-flash of 6 electrons (the S/N calculations above include such a flash, and the additional noise from splitting the exposure time into 16 images).

WFC3's 2 point line dither will be implemented for each orbit within each visit. This will allow for cosmic ray rejection. In addition, the dither pattern of each visit will be slightly offset from the last to allow for the creation of a finer dither pattern and as such enable the creation of higher resolution images via Drizzlepac's Astrodrizzle software. This higher resolution will be employed to obtain a better understanding of the structure of

the nebulosity in regions of particularly high S/N (e.g. the bright knot to the west).

We request that the orient of each visit be the same or a 90 degree equivalent angle, in order to preserve the dither pattern and to minimise the effect of geometric distortion. As we are observing a static system we have no additional scheduling constraints.

Interestingly, each visit will also provide [S ii] photometry of 12a this information (even if simply upper limits) may be useful for expanding our knowledge of the quiescent system. Finally, there are no bright targets in the field that will cause any problems with the detector. Should 12a actually erupt during one of these observations it will only reach an apparent magnitude of 18th (across all visible bands) and won't be the brightest object in the field.

Visit

Proposal 15102, Nebula (01), implementation Tue Mar 27 00:01:47 GMT 2018

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/UVIS

Special Requirements: ORIENT 91.8D TO 91.8 D; ORIENT 181.8D TO 181.8 D; ORIENT 271.8D TO 271.8 D; ORIENT 1.8D TO 1.8 D

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=WFC3-UVIS-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.145 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=46.84 Angle Between Sides= Center Pattern=false		(1)

Fixed Targets

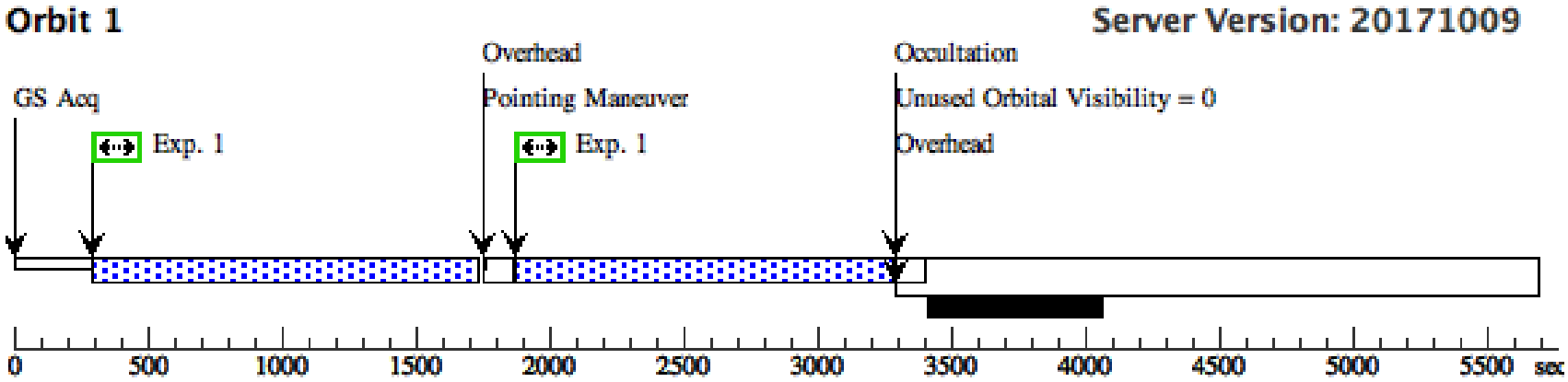
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	RX-J0045.4+4154	RA: 00 45 28.8000 (11.3700000d) Dec: +41 54 10.10 (41.90281d) Equinox: J2000		V=23+/-1	Reference Frame: SIMBAD

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=STAR
Description=[EJECTA, RECURRENT NOVA]
Extended=YES

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	S II	(1) RX-J0045.4+4154	WFC3/UVIS, ACCUM, UVIS2-FIX	F673N	FLASH=7		Pattern 1, Exps 1-1 in Nebula (01) (1)	1412 Secs (2824 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]*	*[1]*

Orbit Structure



Visit

Proposal 15102, Nebula (02), implementation Tue Mar 27 00:01:48 GMT 2018

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/UVIS

Special Requirements: SAME ORIENT AS 01

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=WFC3-UVIS-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.145 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=46.84 Angle Between Sides= Center Pattern=false		(1)

Fixed Targets

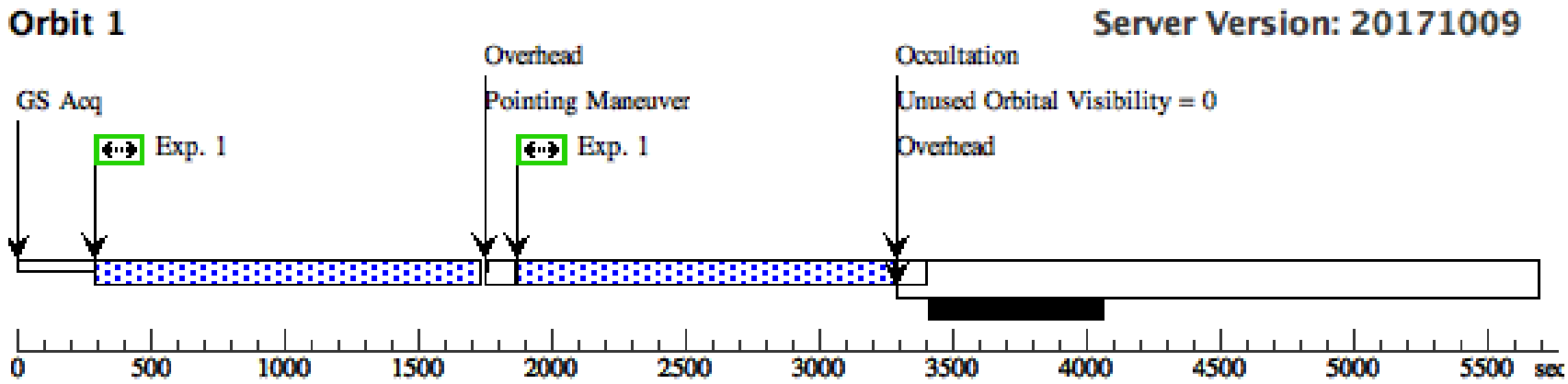
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	RX-J0045.4+4154	RA: 00 45 28.8000 (11.3700000d) Dec: +41 54 10.10 (41.90281d) Equinox: J2000		V=23+/-1	Reference Frame: SIMBAD

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=STAR
Description=[EJECTA, RECURRENT NOVA]
Extended=YES

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	S II	(1) RX-J0045.4+4154	WFC3/UVIS, ACCUM, UVIS2-FIX	F673N	FLASH=7	POS TARG 0.1125,0.1125	Pattern 1, Exps 1-1 in Nebula (02) (1)	1412 Secs (2824 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]*	*[1]*

Orbit Structure



Visit

Proposal 15102, Nebula (03), implementation Tue Mar 27 00:01:48 GMT 2018

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/UVIS

Special Requirements: SAME ORIENT AS 01

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=WFC3-UVIS-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.145 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=46.84 Angle Between Sides= Center Pattern=false		(1)

Fixed Targets

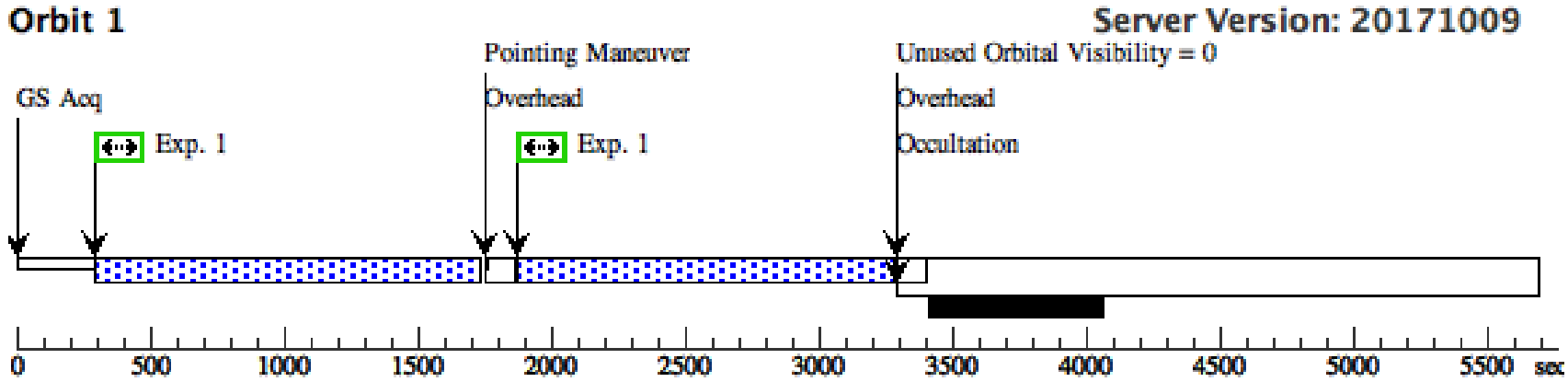
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	RX-J0045.4+4154	RA: 00 45 28.8000 (11.3700000d) Dec: +41 54 10.10 (41.90281d) Equinox: J2000		V=23+/-1	Reference Frame: SIMBAD

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=STAR
Description=[EJECTA, RECURRENT NOVA]
Extended=YES

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	S II	(1) RX-J0045.4+4154	WFC3/UVIS, ACCUM, UVIS2-FIX	F673N	FLASH=7	POS TARG -0.1125, -0.1125	Pattern 1, Exps 1-1 in Nebula (03) (1)	1412 Secs (2824 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]*	*[1]*

Orbit Structure



Visit

Proposal 15102, Nebula (04), implementation Tue Mar 27 00:01:48 GMT 2018

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/UVIS

Special Requirements: SAME ORIENT AS 01

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=WFC3-UVIS-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.145 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=46.84 Angle Between Sides= Center Pattern=false		(1)

Fixed Targets

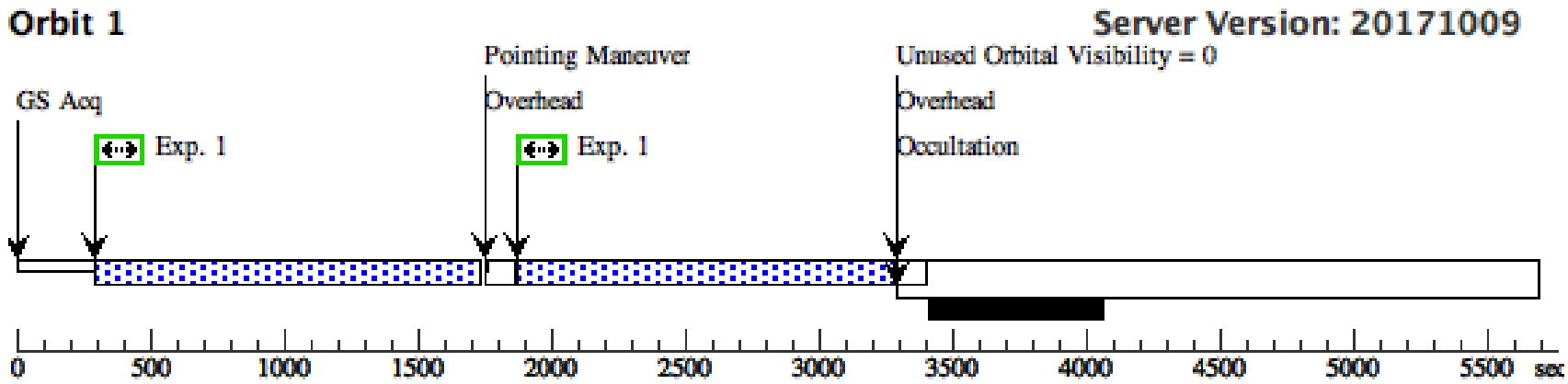
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	RX-J0045.4+4154	RA: 00 45 28.8000 (11.3700000d) Dec: +41 54 10.10 (41.90281d) Equinox: J2000		V=23+/-1	Reference Frame: SIMBAD

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=STAR
Description=[EJECTA, RECURRENT NOVA]
Extended=YES

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	S II	(1) RX-J0045.4+4154	WFC3/UVIS, ACCUM, UVIS2-FIX	F673N	FLASH=7	POS TARG -0.1125, 0.1125	Pattern 1, Exps 1-1 in Nebula (04) (1)	1412 Secs (2824 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]*	*[1]*

Orbit Structure



Visit

Proposal 15102, Nebula (05), implementation Tue Mar 27 00:01:48 GMT 2018

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/UVIS

Special Requirements: SAME ORIENT AS 01

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=WFC3-UVIS-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.145 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=46.84 Angle Between Sides= Center Pattern=false		(1)

Fixed Targets

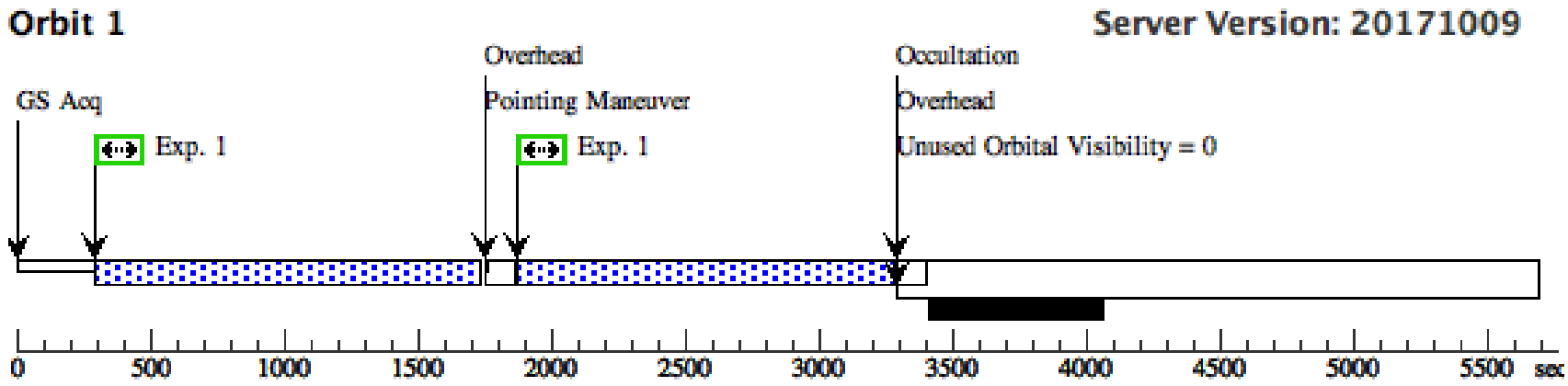
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	RX-J0045.4+4154	RA: 00 45 28.8000 (11.3700000d) Dec: +41 54 10.10 (41.90281d) Equinox: J2000		V=23+/-1	Reference Frame: SIMBAD

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=STAR
Description=[EJECTA, RECURRENT NOVA]
Extended=YES

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	S II	(1) RX-J0045.4+4154	WFC3/UVIS, ACCUM, UVIS2-FIX	F673N	FLASH=7	POS TARG 0.1125,-0.1125	Pattern 1, Exps 1-1 in Nebula (05) (1)	1412 Secs (2824 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]*	*[1]*

Orbit Structure



Visit

Proposal 15102, Nebula (06), implementation Tue Mar 27 00:01:48 GMT 2018

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/UVIS

Special Requirements: SAME ORIENT AS 01

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=WFC3-UVIS-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.145 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=46.84 Angle Between Sides= Center Pattern=false		(1)

Fixed Targets

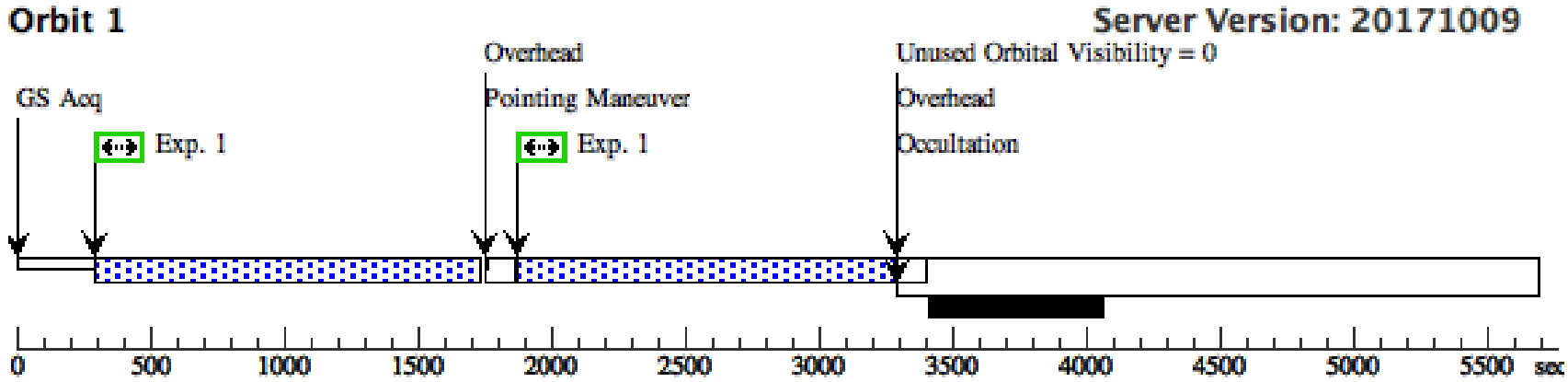
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	RX-J0045.4+4154	RA: 00 45 28.8000 (11.3700000d) Dec: +41 54 10.10 (41.90281d) Equinox: J2000		V=23+/-1	Reference Frame: SIMBAD

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=STAR
Description=[EJECTA, RECURRENT NOVA]
Extended=YES

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	S II	(1) RX-J0045.4+4154	WFC3/UVIS, ACCUM, UVIS2-FIX	F673N	FLASH=7	POS TARG 0.225,0.225	Pattern 1, Exps 1-1 in Nebula (06) (1)	1412 Secs (2824 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]*	*[1]*

Orbit Structure



Visit

Proposal 15102, Nebula (07), implementation Tue Mar 27 00:01:48 GMT 2018

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/UVIS

Special Requirements: SAME ORIENT AS 01

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=WFC3-UVIS-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.145 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=46.84 Angle Between Sides= Center Pattern=false		(1)

Fixed Targets

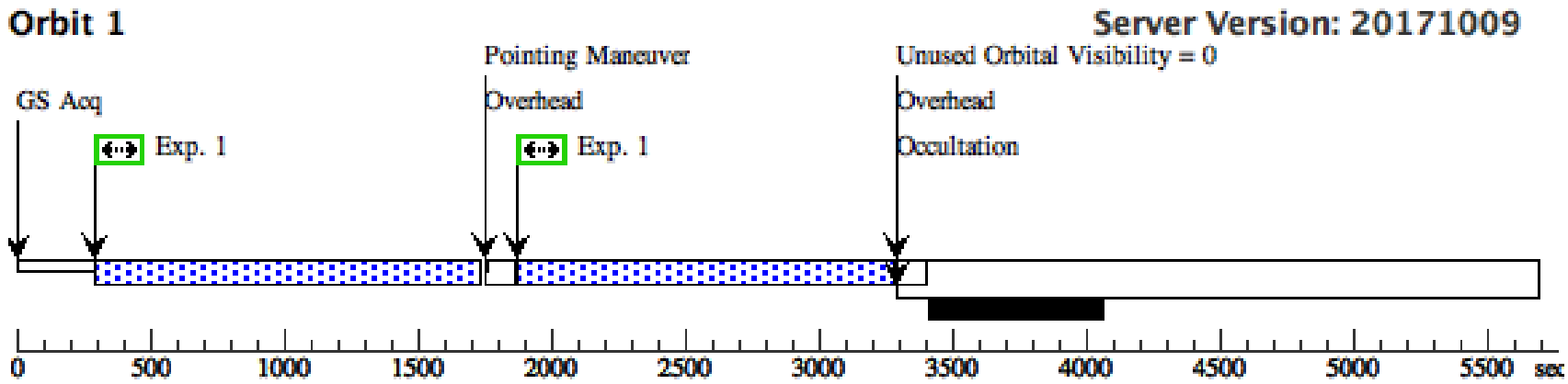
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	RX-J0045.4+4154	RA: 00 45 28.8000 (11.3700000d) Dec: +41 54 10.10 (41.90281d) Equinox: J2000		V=23+/-1	Reference Frame: SIMBAD

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=STAR
Description=[EJECTA, RECURRENT NOVA]
Extended=YES

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	S II	(1) RX-J0045.4+4154	WFC3/UVIS, ACCUM, UVIS2-FIX	F673N	FLASH=7	POS TARG -0.225,-0.225	Pattern 1, Exps 1-1 in Nebula (07) (1)	1412 Secs (2824 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]*	*[1]*

Orbit Structure



Visit

Proposal 15102, Nebula (08), implementation Tue Mar 27 00:01:48 GMT 2018

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/UVIS

Special Requirements: SAME ORIENT AS 01

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=WFC3-UVIS-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.145 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=46.84 Angle Between Sides= Center Pattern=false		(1)

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	RX-J0045.4+4154	RA: 00 45 28.8000 (11.3700000d) Dec: +41 54 10.10 (41.90281d) Equinox: J2000		V=23+/-1	Reference Frame: SIMBAD

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=STAR
Description=[EJECTA, RECURRENT NOVA]
Extended=YES

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	S II	(1) RX-J0045.4+4154	WFC3/UVIS, ACCUM, UVIS2-FIX	F673N	FLASH=7	POS TARG -0.225,0.225	Pattern 1, Exps 1-1 in Nebula (08) (1)	1412 Secs (2824 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]*	*[1]*

Orbit Structure