14933 - The accretion flow and evolutionary history of an intriguing short-period black hole X-ray binary

Cycle: 24, Proposal Category: GO/DD

(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) SWIFTJ1357.2-0933	COS/FUV COS/NUV	2	06-Jun-2017 21:03:04.0	yes
02	(1) SWIFTJ1357.2-0933	STIS/CCD STIS/NUV-MAMA	2	06-Jun-2017 21:03:06.0	yes

4 Total Orbits Used

ABSTRACT

The process of accretion via an accretion disk is a fundamental aspect of several areas of Astrophysics. Ultraviolet (UV) observations of sub-luminous X-ray binaries offer the unique opportunity to study cool, gaseous accretion disks around black holes in the poorly explored regime of low mass-accretion rates. The sub-luminous black hole Swift J1357.2-0933 just entered a new accretion outburst and shares a set of properties that make it one of the few X-ray binaries that can be studied at UV wavelengths: it is located relatively nearby (0.5-6 kpc) and at high Galactic latitude (b=+50 deg) with an unprecedented low reddening of E(B-V)=0.02 mag, causing it to be very UV bright despite its low mass-accretion rate (~14 mag at ~2000 A). We propose to take advantage of the unanticipated opportunity to study the accretion flow in this object using HST FUV and NUV spectroscopic observations with the COS and STIS, respectively. Using the shape of the UV continuum and line emission, we will uniquely test the theoretical predictions that the accretion disk is truncated and a wind outflow is present in the regime of low mass-accretion rates. Another prime reason to study the UV spectrum of Swift J1357.2-0933 is that its orbital period is only ~2.8 hr: such short-period black hole X-ray binaries are rare and their formation channels unknown. From the relative strength of the many ionised UV emission lines we can study chemical abundance patterns in the accreted material, which is a powerful tracer of the evolutionary stage of the binary.

OBSERVING DESCRIPTION

We will visit our target twice with the HST. One visit consists of 2 orbits of COS observations, the other visit of 2 orbits of STIS observations.

For the exposure time calculations we used the known reddening towards our target of E(B-V)=0.02 mag and always assumed average observing conditions. Our target is well monitored with Swift/UVOT using different filters, which provides an optical-UV SED of the accretio disk. To estimate the fluxes for the proposed HST observations, we fit the Swift optical-UV SED to a F_lambda propto lambda^-alpha function. We first perfom our SED fits and ETCs using Swift data obtained on 2017 May 28, which is representative for the current state of our target. We measure a NUV flux of 6.88E-15 erg/cm2/s/A at 2231A for this observation and the optica-UV SED can be fitted to a power law with an index of -2.5. We perform a second set of SED fits and ETCs for the maximum brightness ever observed for our target, i.e. during the peak of its 2011 outburst. Its maximum NUV flux was ~1.5E-14 erg/cm2/s/A at 2231 A (Armas Padilla+2013, MNRAS 428, 3083) and the optical-UV SED is described by a power law with an index of -2.7. This provides us with a worst-case scenario to address the safety of the UV detectors. Finally, to ensure sufficient S/N for target acquisition, we conservatively assume a flux of 2E-15 erg/cm2/s/A (at 2231 A) to account for the fact that our target continues to fade until the HST observations are performed.

During the first visit (2 orbits) we will carry out time-resolved NUV TIME-TAG spectroscopy with the STIS/NUVMAMA/G230L instrument/grating combination. We will use the 2376 A setting for these observations, allowing us to achieve continuous wavelength coverage between 1570 A and 3180 A, with the 52-0.2 slit. Our exposure time calculations (described above) indicate that there are no safety concerns for the STIS detectors, even when we assume the maximum brightness ever observed for our target (STIS.sp.996776). We will use an imaging target acquisition with Mirror B as the best compromise between efficiency and instrument safety. With this setup, a 3s ACQ/IMAGE target acquisition exposure with the CCD and the 50 CCD aperture yields S/N~100 (based on the most recent UVOT observations; STIS.ta.996793).

During the second visit (2 orbits) we will perform FUV TIME-TAG spectroscopy using the COS/G140L intrument/grating combination. The resolving power of the low-resolution grating is sufficient to resolve the expected ionized emission lines as these have typical widths of ~10 A in LMXBs. We will use the 1105 A setting that provides continuous coverage between 1118-2251 A in segment A, while segment B is switched off. With this setup, a 1100 s exposure for COS yields a S/N~30 at the current flux level (ECT ID COS.sp.997723). We will be using different FP-POS positions to reduce fixed-pattern noise and to minimize long-term gain sag. The source position is accurately known (to within 0.3 arcsec; ATel #3147), so target acquisition can be performed using ACQ/IMAGE. Since our object is relatively bright we use MIRRORB. With this setup, an exposure time of 67 s is required to reach a S/N>40 for target acquisition for all possible flux levels (COS.sa.997618).

Notes with regard to scheduling:
Our target has been active for ~5 weeks at the time of submitting this phase 2 proposal (ATel #10314). It is regularly monitored by Swift at UV/optical and X-ray wavelengths, which shows that it follows a slow but steady decrease of its X-ray and UV flux similar to the behaviour during its 2011 outburst (Armas Padilla et al., 2013, MNRAS 428, 3083). Assuming that our target continues to follow the same flux evolution as during its 2011 outburst, we expect it to disappear into quiescence (fading >2 mag in the UV) within ~2 months from now. To avoid that it fades too much to obtain high-quality NUV/FUV spectra, hence loosing this target of opportunity, it would be highly desirable to schedule the observations as soon as can be accommodated within the HST constraints, preferably within ~1 month from now.

As mentioned in our phase-1 proposal, it would be preferred to schedule the two visits (one using the STIS, one using the COS) back to back. This is because black hole X-ray binaries can display significant intrinsic variability on a time scale of days-weeks.

Finally, we note after our phase-1 proposal submission, our target was scheduled to be observed with VLT/ULTRACAM on June 11. This will provide high time-resolution optical imaging and NuSTAR X-ray observations are coordinated to be able to study correlated rapid variability at optical and X-ray wavelenghts. We realize that it is a lot to ask, and it was not specified in our phase 1 proposal (because it was not known yet), but if

it is remotely possible within the HST scheduling constraints to have our COS visit overlap with the ULTRACAM/NuSTAR observations (UT00:30 to 03:30) that could provide a unique multi-wavelength data set at high time-resolution of a black hole X-ray binary that can even further enhance the outcome of our proposed HST observations.

Visit

Proposal 14933, COS (01), implementation Wed Jun 07 01:03:06 GMT 2017

Diagnostic Status: No Diagnostics

Scientific Instruments: COS/FUV, COS/NUV

Special Requirements: (none)

Fixed Targets

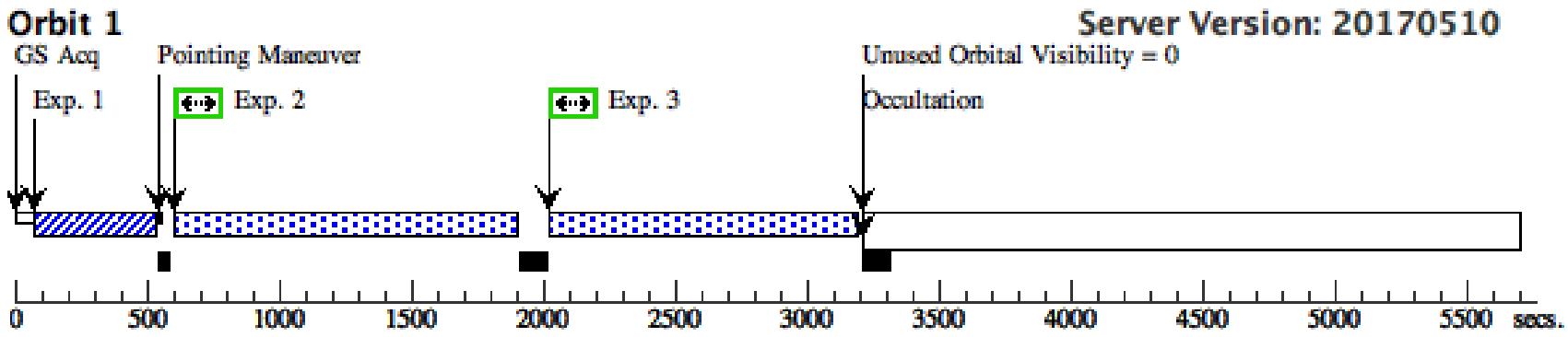
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	SWIFTJ1357.2-0933	RA: 13 57 16.8180 (209.3200750d) Dec: -09 32 38.55 (-9.54404d) Equinox: J2000		V=16.0+/-0.1	Reference Frame: ICRS

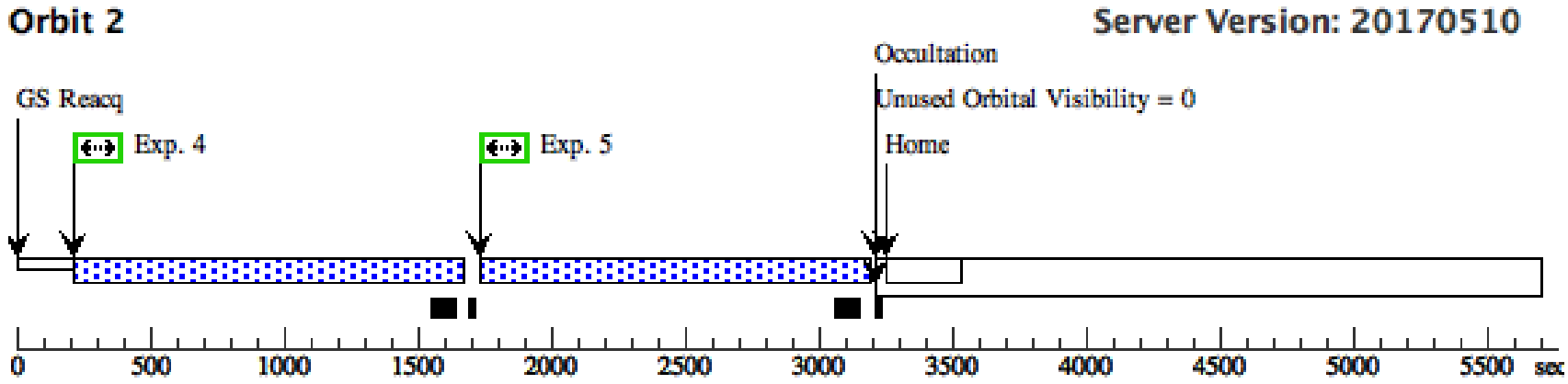
Comments: Extended=NO

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	TA1 (COS.ta.997618)	(1) SWIFTJ1357.2-0933	COS/NUV, ACQ/IMAGE, PSA	MIRRORB				70 Secs (70 Secs) *[==>]*	*[1]*
2	Science1 (COS.sp.997723)	(1) SWIFTJ1357.2-0933	COS/FUV, TIME-TAG, PSA	G140L 1105 A	FP-POS=1; BUFFER-TIME=1116			1116 Secs (1116 Secs) *[==>]*	*[1]*
3	Science2 (COS.sp.997723)	(1) SWIFTJ1357.2-0933	COS/FUV, TIME-TAG, PSA	G140L 1105 A	FP-POS=2; BUFFER-TIME=1117			1117 Secs (1117 Secs) *[==>]*	*[1]*
4	Science3 (517864)	(1) SWIFTJ1357.2-0933	COS/FUV, TIME-TAG, PSA	G140L 1105 A	FP-POS=3; BUFFER-TIME=1296			1411 Secs (1411 Secs) *[==>]*	*[2]*
5	Science4 (517864)	(1) SWIFTJ1357.2-0933	COS/FUV, TIME-TAG, PSA	G140L 1105 A	FP-POS=4; BUFFER-TIME=1296			1411 Secs (1411 Secs) *[==>]*	*[2]*

Orbit Structure





Visit

Proposal 14933, STIS (02), implementation Wed Jun 07 01:03:07 GMT 2017

Diagnostic Status: No Diagnostics

Scientific Instruments: STIS/NUV-MAMA, STIS/CCD

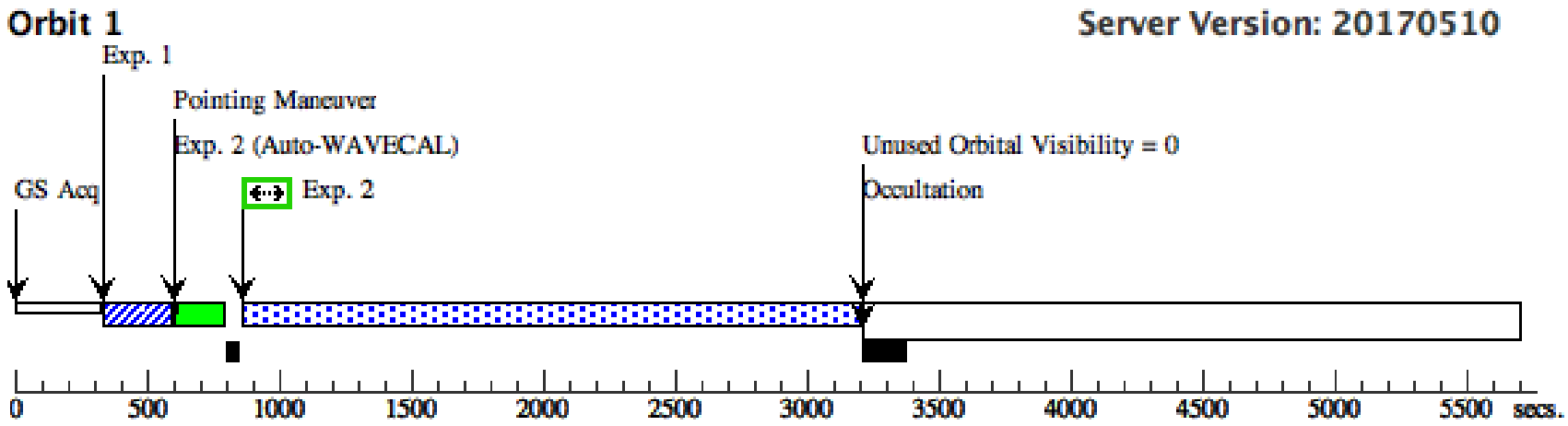
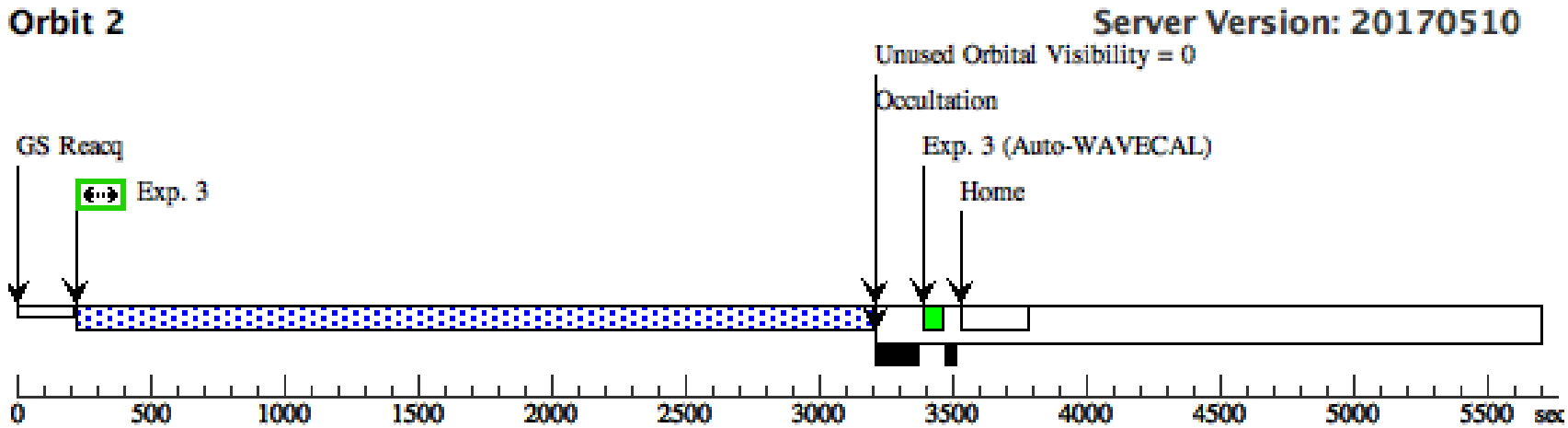
Special Requirements: (none)

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	SWIFTJ1357.2-0933	RA: 13 57 16.8180 (209.3200750d) Dec: -09 32 38.55 (-9.54404d) Equinox: J2000		V=16.0+/-0.1	Reference Frame: ICRS

Comments: Extended=NO

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	TA1 (STIS.ta.996462)	(1) SWIFTJ1357.2-0933	STIS/CCD, ACQ, 50CCD	MIRROR				3 Secs (3 Secs) *[==>]*	***[1]***
2	Science1 (STIS.sp.996459)	(1) SWIFTJ1357.2-0933	STIS/NUV-MAMA, TIME-TAG, 52X0.2	G230L 2376 A	BUFFER-TIME=1500			2324 Secs (2324 Secs) *[==>]*	***[1]***
3	Science2 (STIS.sp.996459)	(1) SWIFTJ1357.2-0933	STIS/NUV-MAMA, TIME-TAG, 52X0.2	G230L 2376 A	BUFFER-TIME=1500			2963 Secs (2963 Secs) *[==>]*	***[2]***

Orbit Structure