14176 - Measuring Absolute Abundances in NGC 5548 and Definitively Linking the UV and X-ray Outflows

Cycle: 23, Proposal Category: GO

(UV Initiative)

(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) NGC-5548	COS/FUV	4	01-Jul-2015 21:11:25.0	yes
02	(1) NGC-5548	COS/FUV	5	01-Jul-2015 21:11:31.0	yes

9 Total Orbits Used

ABSTRACT

We propose to obtain HST/COS spectra of the Seyfert 1 galaxy NGC 5548 with 9 orbits covering the Lyman lines, O VI, P V, N V, and C IV in conjunction with 60 ks of XMM-Newton time. Our observations will measure absolute abundances anchored by accurate H I column densities for both the narrow and broad UV absorption lines. These will add fidelity to our measurements of the outflowing mass flux and kinetic energy obtained in our 2013 campaign using XMM-Newton and COS, and solve discrepancies between the UV and X-ray absorbers in NGC 5548. Due to the profound influence of the new soft X-ray obscurer in NGC 5548 discovered during our 2013 campaign, simultaneous X-ray spectra are essential for determining the ionizing spectral energy distribution. Outflows from active galactic nuclei (AGN) may play a crucial role in feedback processes that control galaxy evolution, the growth of central black holes in galaxies, and the chemical enrichment of the surrounding environment. The high throughput and resolution (R > 12,000) of COS at wavelengths below 1150 A make it possible to observe O VI and the Lyman lines in nearby bright AGN and link high-resolution X-ray spectroscopy of O VI and higher ions with longer-wavelength UV observations. Observations of the resonance doublets of O VI, N V, and C IV enable robust photoionization solutions as a function of outflow velocity that include the determination of absolute abundances relative to hydrogen. Observations of unsaturated Lyman lines are the only way to measure hydrogen column densities for absolute abundances. This provides crucial information on the physical conditions in AGN outflows and their chemistry.

OBSERVING DESCRIPTION

We will obtain medium-resolution far-UV spectra of NGC 5548 using COS. Our 9-orbit allocation will be divided into 2 visits, which will be coordinated with two 30 ks observations using XMM-Newton.

We will use COS and grating G130M/1096 primarily to measure absorption in the higher-order Lyman series lines Lyβ, Lyγ, and Lyδ, and in the high-ionization O VI 1032,1038 resonance doublet. The R~12,000 resolving power of the G130M/1096 grating setting fully resolves the ~100 km~s^{-1} widths of the UV absorption components in NGC 5548 (Crenshaw09). This resolution enables detailed measurements of trough profiles, optical depths, and covering factors in all the observed troughs. The far-UV flux of NGC 5548 has historically ranged from a low of
0.66e-14 erg~cm^{-2}~s^{-1}~\AA^{-1} at 1360 A, to a high of
8.6e-14 erg~cm^{-2}~s^{-1}~\AA^{-1} (Dunn06),
with a mean flux of 4.4e-14 erg~cm^{-2}~s^{-1}~\AA^{-1}.
A S/N of 10 per resolution element in the continuum at 1040 A suffices to measure covering fractions to a level of 10% in the absorption troughs. Using the COS ETC (v23.2.1) and the FOS QSO composite spectrum at z=0.017175 with E(B - V)=0.019 to match NGC 5548, this requires 17,500 s of exposure time. This calculation is optimized for O VI, but we will achieve comparable S/N in Ly beta, gamma, and delta, and S/N>50 for P V. The combined coverage of Ly alpha through Ly delta will allow us to obtain the real H I column density even if Ly alpha is very heavily saturated since the optical depth ratio between Ly alpha and Ly delta is 38.

We note that the high resolution afforded by COS makes our proposed observations robust to flux variations to fainter levels. The 100 km/s troughs are spanned by 4 COS resolution elements. If NGC 5548 were half as bright, we could bin our spectrum up by a factor of two and still oversample the absorption troughs at the same S/N.

We will also make observations using the same G130M and G160M configurations we
used in the 2014 reverberation campaign on NGC 5548 (HST PID 13330), in order to observe the longer wavelength absorption troughs that are not covered by G130M/1096. These include N V, Si II, Si III*, Si IV, C II, C III*, C IV, and Al II. All these lines are seen in the COS 2013 and 2014 data and are crucial for deriving a complete ionization solution of the outflow, which is necessary for absolute abundance determinations. Since NGC 5548 is highly variable in ionizing flux, we need near-simultaneous observations of these grating configurations with our main G130M/1096 observation in order to derive the ionization equilibrium for that epoch. Our experience with the 2014 data show that 1 orbits per visit for these

G130M and G160M settings will yield sufficient S/N for our analysis, even if the object dims by half.

In the separate visits comprising this proposal, we do not use four grating positions (either central wavelength or FPPOS) for each grating in the individual observations so that we minimze overheads. We use two central wavelengths in each visit for G130M and G160M to make sure we span the gap between segments A and B, and we use different FPPOS positions for each of those in the two separate visits. So, across both visits we have a 4-fold diversity of grating settings for each grating. This strategy worked well in the 2014 reverberation campaign (13330).

These observations pose no bright object concerns. All historical flux levels for NGC 5548 lie below the bright object limits for COS. Since NGC 5548 has been observed successfully before (see HST PIDs 12212, 13814, and 13330), there are also no surrounding field objects that are too bright. Our ETC calculations use the ETC FOS quasar spectrum redshifted to z=0.017175 with foreground extinction of E(B-V)=0.019 and normalized to the historical minimum and maximum flux at 1360 A (flam_min=0.66e-14, flam_max=8.6e-14, Dunn et al. 2006) in order to get our limiting cases:

- ACQUISITION -

Configuration	Flux	EXP time	Max cts/s/pix	Total rate	Buffer Time	COS ETC ID
G130M/1291	0.66e-14	25 s	0.10	767	3076	COS.sa.715069
G130M/1291	8.60e-14	25 s	0.13	4618	510	COS.sa.715068

- EXPOSURES -

Configuration	Flux	EXP time	Max cts/s/pix	Total rate	Buffer Time	COS ETC ID
G130M/1096	8.6e-14	1000	0.08	1621	1455	COS.sp.715065
G130M/1291	8.6e-14	1000	0.13	4533	520	COS.sp.715066
G160M/1600	8.6e-14	1000	0.02	1947	1211	COS.sp.715067

XMM-Newton Observations

Our HST observations will be coordinated with 2x30 ks XMM-Newton RGS, pn, MOS and OM observations near-simultaneously with the proposed HST/COS observations. NGC 5548 has >30 ks visibility for all XMM revolutions between 2015-12-20 and 2016-02-04, giving >6 weeks of scheduling opportunities during HST Cycle 23. These observations replicate the successful visits that comprised our 2013 campaign. Average background-subtracted count rates in the summer of 2013 were 0.1 cts/s in the RGS, and 4.63 cts/s for the pn. With OM, we would get excellent fluxes using all filters and the optical grism. Recent Swift observations (2015 Feb 4) show that NGC 5548 is still obscured, and with an X-ray intensity comparable to that during the summer of 2013.

Two 30 ks visits scheduled on consecutive 2-day XMM orbits will ensure
near simultaneity between our X-ray spectra of NGC 5548 and our two HST visits, which presumably will take place at least one day apart in order to satisfy SAA constratints. Each HST visit should overlap, or be within 1 day of the scheduled XMM observation time.

Visit

Proposal 14176, Visit 01 Thu Jul 02 01:11:33 GMT 2015

Diagnostic Status: Warning

Scientific Instruments: COS/FUV

Special Requirements: SCHED 100%

Diagnostics

(Visit 01) Warning (Form): For the best data quality, it is strongly recommended that all four FP-POS positions be used when observing at a given COS CENWAVE setting.

Fixed Targets

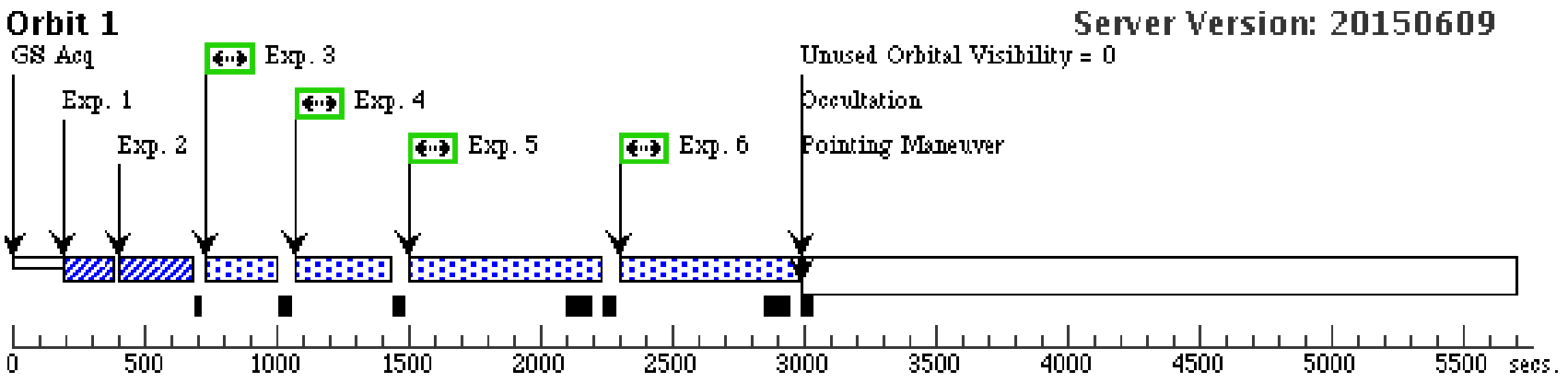
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	NGC-5548	RA: 14 17 59.5130 (214.4979708d) Dec: +25 08 12.45 (25.13679d) Equinox: J2000		V=13.73+/-0.3 4.39e-14 at 1360 A	Reference Frame: ICRS

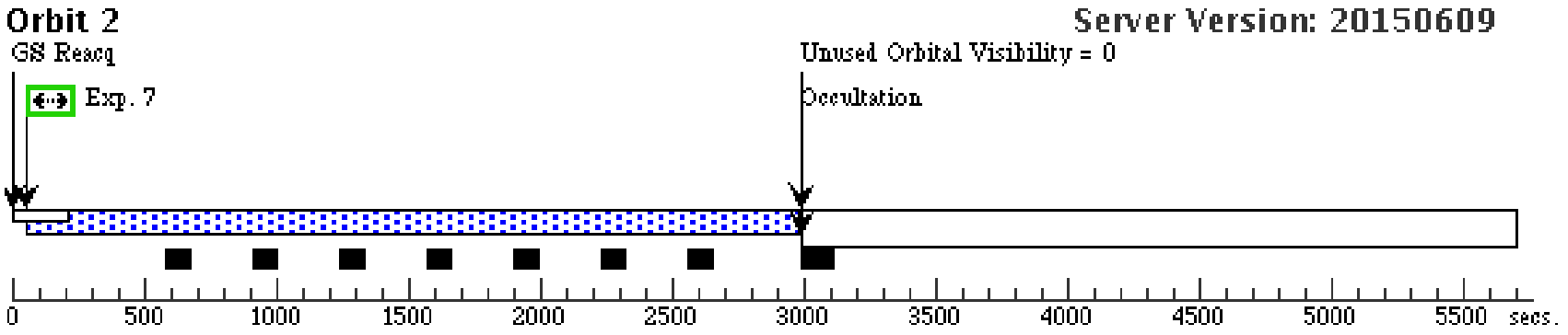
Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
UV flux is the historical mean.
Extended=NO

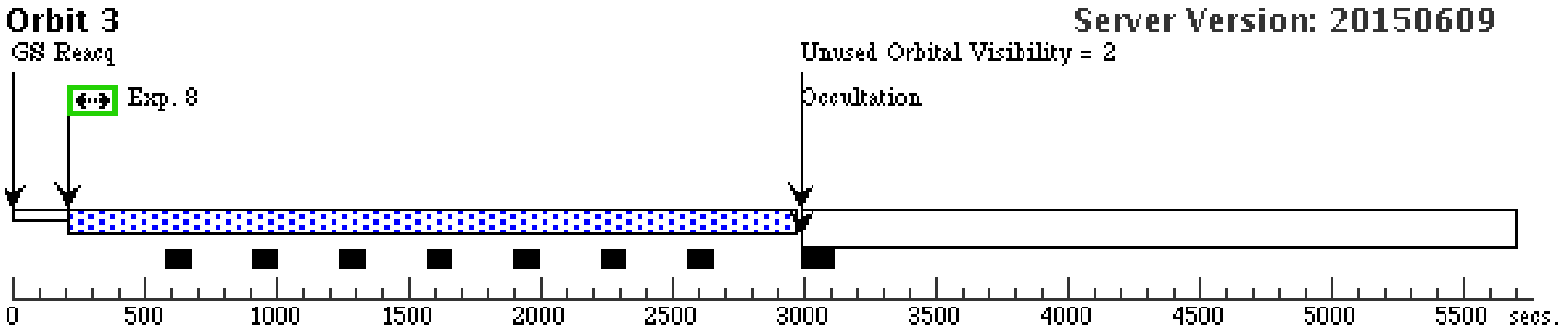
Exposures

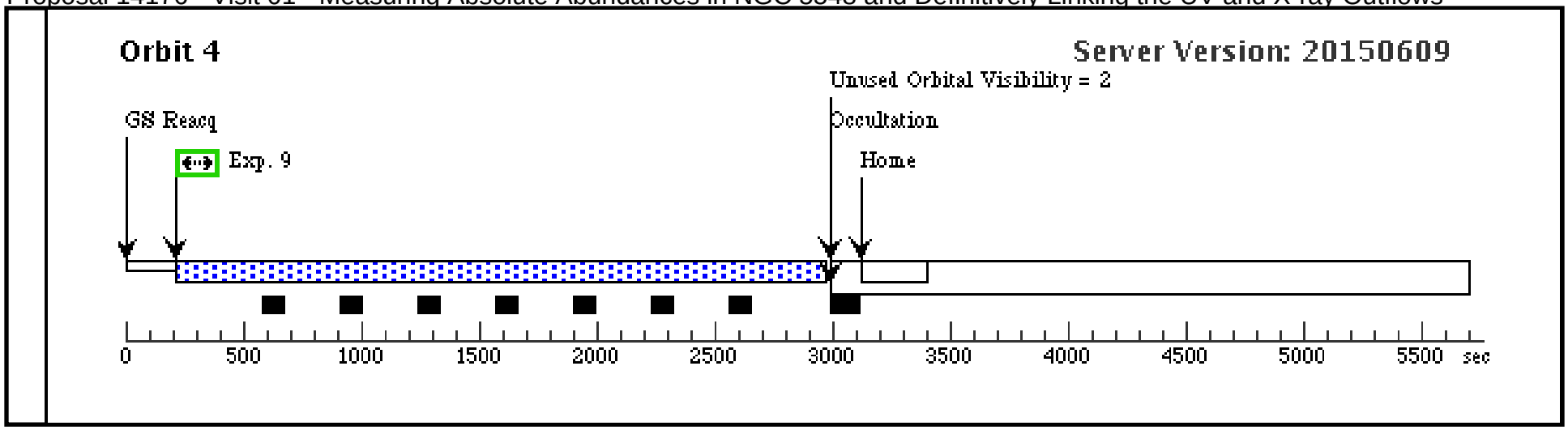
#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	(COS.sa.715 068)	(1) NGC-5548	COS/FUV, ACQ/PEAKXD, PSA	G130M 1291 A				25 Secs (25 Secs) *[==>]*	*[1]*
2	(COS.sa.715 068)	(1) NGC-5548	COS/FUV, ACQ/PEAKD, PSA	G130M 1291 A	NUM-POS=5; STEP-SIZE=0.9; CENTER=FLUX-WT-FLR			25 Secs (25 Secs) *[==>]*	*[1]*
3	(COS.sp.715 066)	(1) NGC-5548	COS/FUV, TIME-TAG, PSA	G130M 1291 A	BUFFER-TIME=700; FP-POS=4			220 Secs (220 Secs) *[==>]*	*[1]*
4	(COS.sp.715 066)	(1) NGC-5548	COS/FUV, TIME-TAG, PSA	G130M 1327 A	BUFFER-TIME=700; FP-POS=1			220 Secs (220 Secs) *[==>]*	*[1]*
5	(COS.sp.715 067)	(1) NGC-5548	COS/FUV, TIME-TAG, PSA	G160M 1600 A	BUFFER-TIME=440; FP-POS=1			550 Secs (550 Secs) *[==>]*	*[1]*
6	(COS.sp.715 067)	(1) NGC-5548	COS/FUV, TIME-TAG, PSA	G160M 1623 A	BUFFER-TIME=440; FP-POS=1			550 Secs (550 Secs) *[==>]*	*[1]*
7	(COS.sp.715 065)	(1) NGC-5548	COS/FUV, TIME-TAG, PSA	G130M 1096 A	BUFFER-TIME=330; FP-POS=2			2705 Secs (2705 Secs) *[==>]*	*[2]*
8	(COS.sp.715 065)	(1) NGC-5548	COS/FUV, TIME-TAG, PSA	G130M 1096 A	BUFFER-TIME=330; FP-POS=3			2705 Secs (2705 Secs) *[==>]*	*[3]*
9	(COS.sp.715 065)	(1) NGC-5548	COS/FUV, TIME-TAG, PSA	G130M 1096 A	BUFFER-TIME=330; FP-POS=4			2705 Secs (2705 Secs) *[==>]*	*[4]*

Orbit Structure





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Visit

Proposal 14176, Visit 02 Thu Jul 02 01:11:34 GMT 2015

Diagnostic Status: Warning

Scientific Instruments: COS/FUV

Special Requirements: SCHED 100%

Diagnostics

(Visit 02) Warning (Form): For the best data quality, it is strongly recommended that all four FP-POS positions be used when observing at a given COS CENWAVE setting.

Fixed Targets

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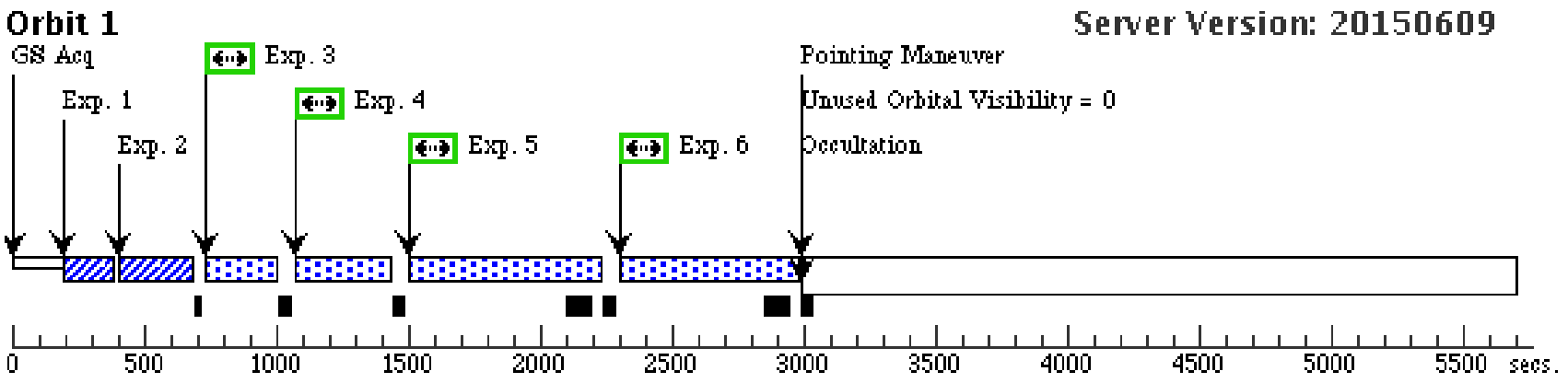
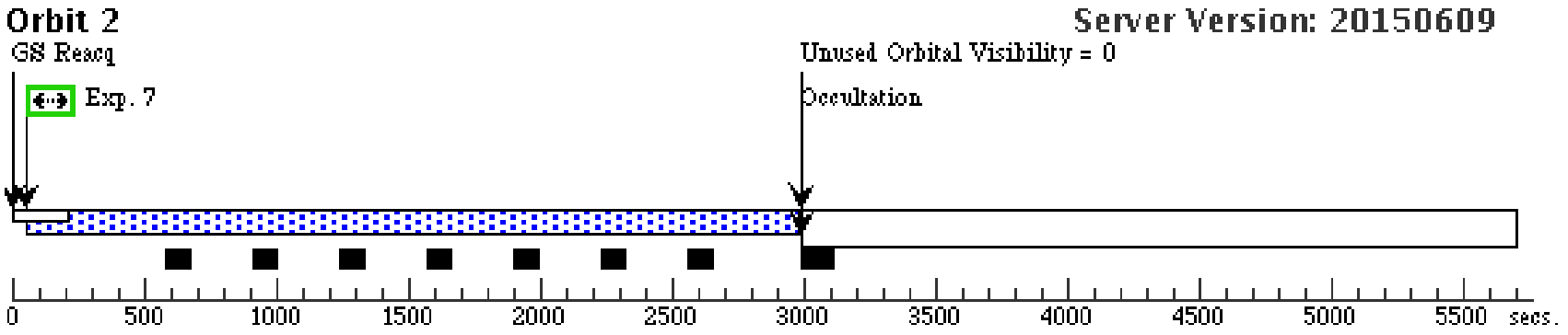
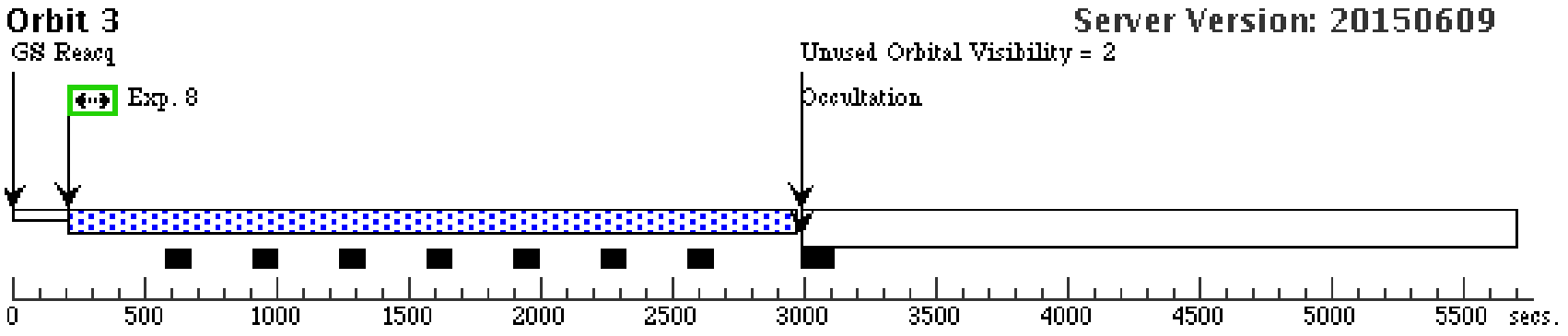
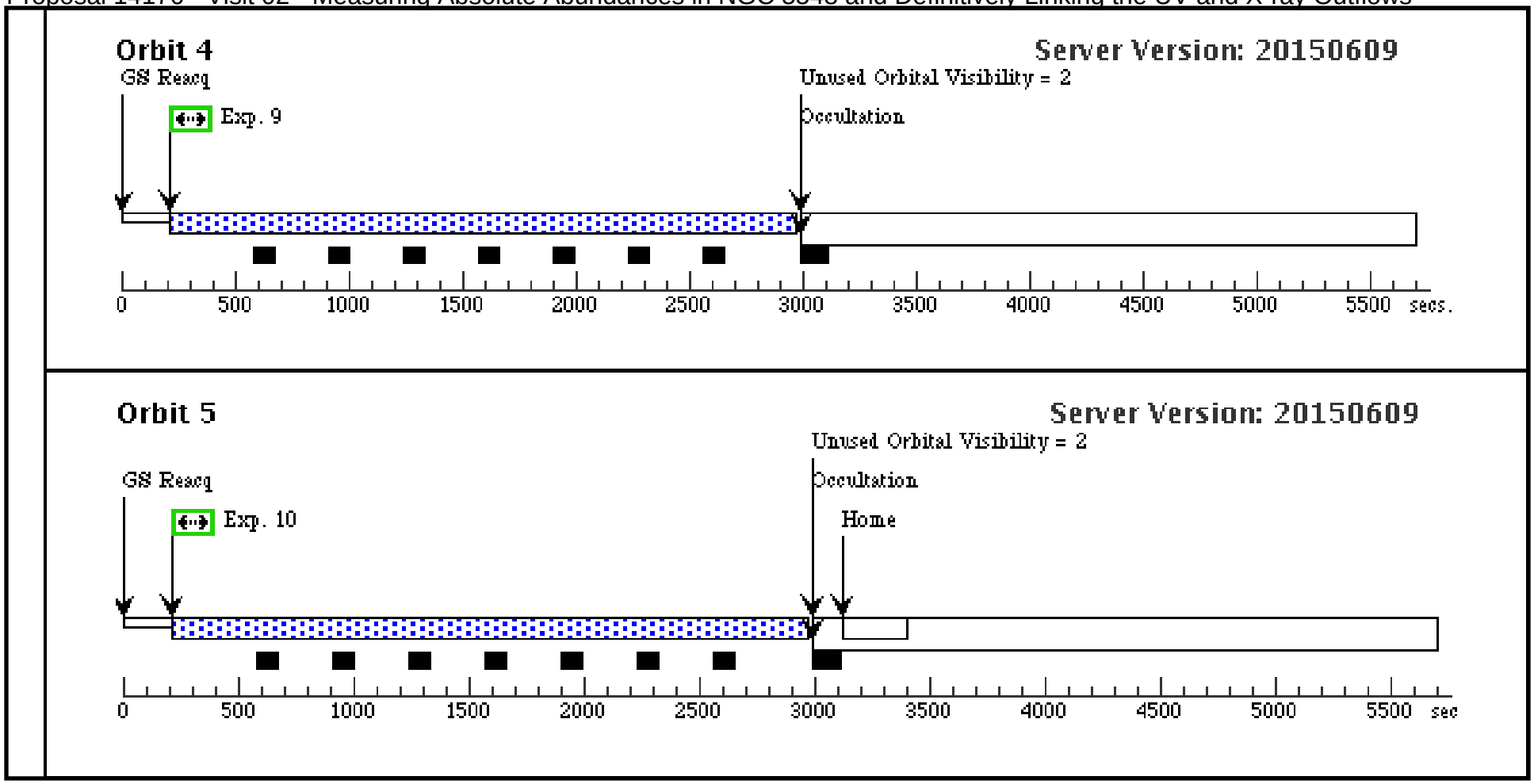
2	(COS.sa.715 068)	(1) NGC-5548	COS/FUV, ACQ/PEAKD, PSA	G130M 1291 A	NUM-POS=5; STEP-SIZE=0.9; CENTER=FLUX-WT-FLR			25 Secs (25 Secs) *[==>]*	*[1]*
3	(COS.sp.715 067)	(1) NGC-5548	COS/FUV, TIME-TAG, PSA	G130M 1291 A	BUFFER-TIME=700; FP-POS=4			220 Secs (220 Secs) *[==>]*	*[1]*
4	(COS.sp.715 067)	(1) NGC-5548	COS/FUV, TIME-TAG, PSA	G130M 1327 A	BUFFER-TIME=700; FP-POS=1			220 Secs (220 Secs) *[==>]*	*[1]*
5	(COS.sp.715 066)	(1) NGC-5548	COS/FUV, TIME-TAG, PSA	G160M 1600 A	BUFFER-TIME=440; FP-POS=1			550 Secs (550 Secs) *[==>]*	*[1]*
6	(COS.sp.715 066)	(1) NGC-5548	COS/FUV, TIME-TAG, PSA	G160M 1623 A	BUFFER-TIME=440; FP-POS=1			550 Secs (550 Secs) *[==>]*	*[1]*
7	(COS.sp.715 065)	(1) NGC-5548	COS/FUV, TIME-TAG, PSA	G130M 1096 A	BUFFER-TIME=330; FP-POS=1			2705 Secs (2705 Secs) *[==>]*	*[2]*
8	(COS.sp.715 065)	(1) NGC-5548	COS/FUV, TIME-TAG, PSA	G130M 1096 A	BUFFER-TIME=330; FP-POS=2			2705 Secs (2705 Secs) *[==>]*	*[3]*
9	(COS.sp.715 065)	(1) NGC-5548	COS/FUV, TIME-TAG, PSA	G130M 1096 A	BUFFER-TIME=330; FP-POS=3			2705 Secs (2705 Secs) *[==>]*	*[4]*
10	(COS.sp.715 065)	(1) NGC-5548	COS/FUV, TIME-TAG, PSA	G130M 1096 A	BUFFER-TIME=330; FP-POS=4			2705 Secs (2705 Secs) *[==>]*	*[5]*

Orbit Structure





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