13709 - Constraining the Cosmic-ray Acceleration and Gamma-ray Emission Processes in IC 443

Cycle: 22, 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) HD-43582	STIS/CCD STIS/FUV-MAMA	5	17-Jul-2014 21:05:52.0	yes
02	(2) HD-254755	STIS/CCD STIS/FUV-MAMA	5	17-Jul-2014 21:05:55.0	yes

10 Total Orbits Used

ABSTRACT

Supernova remnants are widely believed to be the sources responsible for the acceleration of Galactic cosmic rays. Over the last few years, observations made with the Fermi Gamma-ray Space Telescope have confirmed that cosmic-ray nuclei are indeed accelerated in some supernova

remnants, including IC 443, which is a prototype for supernova remnants interacting with molecular clouds. Still, while cosmic-ray acceleration has been confirmed for IC 443, through the detection of the characteristic pion-decay signature, the acceleration processes are not fully understood, in part because the basic model parameters are not always well constrained. Here, we propose FUV observations of two stars probing diffuse molecular gas in IC 443. One star probes the interior region of the supernova remnant, while the other is located just outside the visible edge of IC 443. This arrangement will allow us to evaluate the physical conditions in pre-shock and post-shock gas through a comprehensive analysis of interstellar absorption lines. A major component of the analysis will involve the derivation of gas densities and kinetic temperatures from the relative populations of collisionally-excited fine-structure levels in C I and O I. A determination of the post-shock temperature will yield the shock velocity, which will constrain not only the age of IC 443, but also the cosmic-ray acceleration efficiency. The observed B/O ratio will also help to constrain the cosmic-ray content in the gas. These results will be of primary importance in accessing the role of supernova remnants as sources of Galactic cosmic rays.

OBSERVING DESCRIPTION

We plan to obtain high-resolution (~2.8 km/s), moderately-high S/N ratio (~35-45) far-UV STIS spectra of two stars behind the supernova remnant IC 443. These data will allow us to determine the physical conditions in neutral gas clumps positioned both ahead of and behind the supernova shock front. Such measurements are needed to constrain models of the cosmic-ray acceleration and gamma-ray emission processes in IC 443.

The selected targets are the only early-type stars probing IC 443 that are bright enough for high-resolution UV spectroscopy. Both are rapidly rotating, so that interstellar lines will be easily distinguished from stellar features, and are at distances that place them well behind the SNR. In addition, both stars have been observed with the HET at McDonald Observatory at high S/N and at a resolution comparable to what will be achieved with the planned STIS observations. The ground-based data provide absorption profiles for the atomic species Ca II, Ca I, Na I, K I, and Li I, and the molecules CH and CH+, which will be useful in interpreting the UV data.

Both stars will be observed using the 1307 A central wavelength setting of the STIS/E140H grating, which provides continuous wavelength coverage in the range 1197-1397 A. Of primary importance are the many C I multiplets in this wavelength range, which will yield information on the thermal pressures in the neutral gas clumps surrounding IC 443. In highly compressed clouds, the absorption lines arising from the excited fine-structure levels of neutral oxygen (i.e., O I* 1304 and O I** 1306) are also expected to be present. Having observations of the excited fine-structure levels in both C I and O I will allow us to derive unique solutions for both the gas densities and kinetic temperatures. The column density of O I in the ground level will be determined from the weak inter-system line at 1355 A, since the O I 1302 transition will be much too heavily saturated.

The chosen wavelength setting will also cover the absorption features arising from the excited fine-structure level of Si II (i.e., Si II* 1264), which is a useful probe of the electron density if the column density of Si II in the ground level is also known. We will use the weak Mg II doublet near 1240 A as a proxy for Si II, because the weakest Si II line in this wavelength range (Si II 1304) will be heavily saturated. The derived electron densities, in conjunction with the previously obtained densities and temperatures, will allow us to estimate the strength of the local radiation field from a consideration of the ionization balance between neutral and singly-ionized carbon. Here, the column density of O I will serve as a proxy for that of C II, since the C II 1334 transition will also be heavily saturated.

Our wavelength coverage will also include the high-ion lines of N V 1238, 1242 and Si IV 1393, which are important probes of hot shocked gas, and will help us to estimate the temperature in the post-shock region. (The Si IV 1402 line may or may not be covered by our observations depending on the exact placement of the grating.) Our observations will also cover several of the CO A-X bands, which (if present) will provide additional constraints on the physical conditions in the molecular material.

The central wavelength setting at 1307 A was deliberately chosen (over the more commonly used setting at 1271 A) so that the weak B II line at 1362 A would be covered by the observations. Absorption from B II 1362 is expected to be fairly strong toward our targets (W > 10 mA), based on comparisons with the line of sight to HD 43818, which is a member of the Gem OB1 association (like our target stars and the progenitor of IC 443), and has STIS/E140H data (covering the B II line) in the MAST archive. In order to obtain B abundances that are accurate enough to adequately constrain the amount of spallation driven by newly-accelerated cosmic rays (as opposed to background GCRs), we require equivalent width uncertainties of 1.0-1.5 mA. To achieve this, a S/N ratio of approximately 30-50 is needed with our chosen instrumental setup.

The observations will be obtained using the 0.2x0.09 arcsec slit, which will provide a resolution of ~2.8 km/s. The high resolution is necessary to disentangle the various overlapping absorption features of the C I multiplets, and also to facilitate the detection of weak features, such as the B II 1362 line. Only HST/STIS can cover all of the UV lines of interest at the required resolution.

Exposure times were calculated based on the spectral type, V magnitude, and E(B-V) of each target, assuming an average Galactic extinction curve. The ETC outputs indicate that our observations will not violate any count rate restrictions with the STIS FUV MAMA. Furthermore, the input spectrum adopted in the ETC for HD 43582 has a flux at 1300 A of ~1x10^{-12} ergs cm^{-2} s^{-1} A^{-1}, in very good agreement with the actual flux determined from existing IUE spectra of this star.

The required S/N can be achieved in 5 orbits (1 visit) for each target. At a declination of +23 degrees, the visibility period for our targets is 54 minutes per orbit. Because we are using a narrow slit, the targets will be aquired with an ACQ followed by an ACQ/PEAK. An additional ACQ/PEAK will be performed at the beginning of the 4th orbit of each visit. Taking into account the visibility period, the guide star acquisition times, the target acquisition and peakup times, and the instrument overheads, the total science exposure time per target for the 5 orbits will be 12,807 seconds. This will result in a S/N at 1362 A of ~45 for HD 43582 and ~35 for HD 254755.

Visit

Proposal 13709, HD-43582 (01) Fri Jul 18 01:05:56 GMT 2014

Diagnostic Status: No Diagnostics

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

Special Requirements: (none)

Fixed Targets

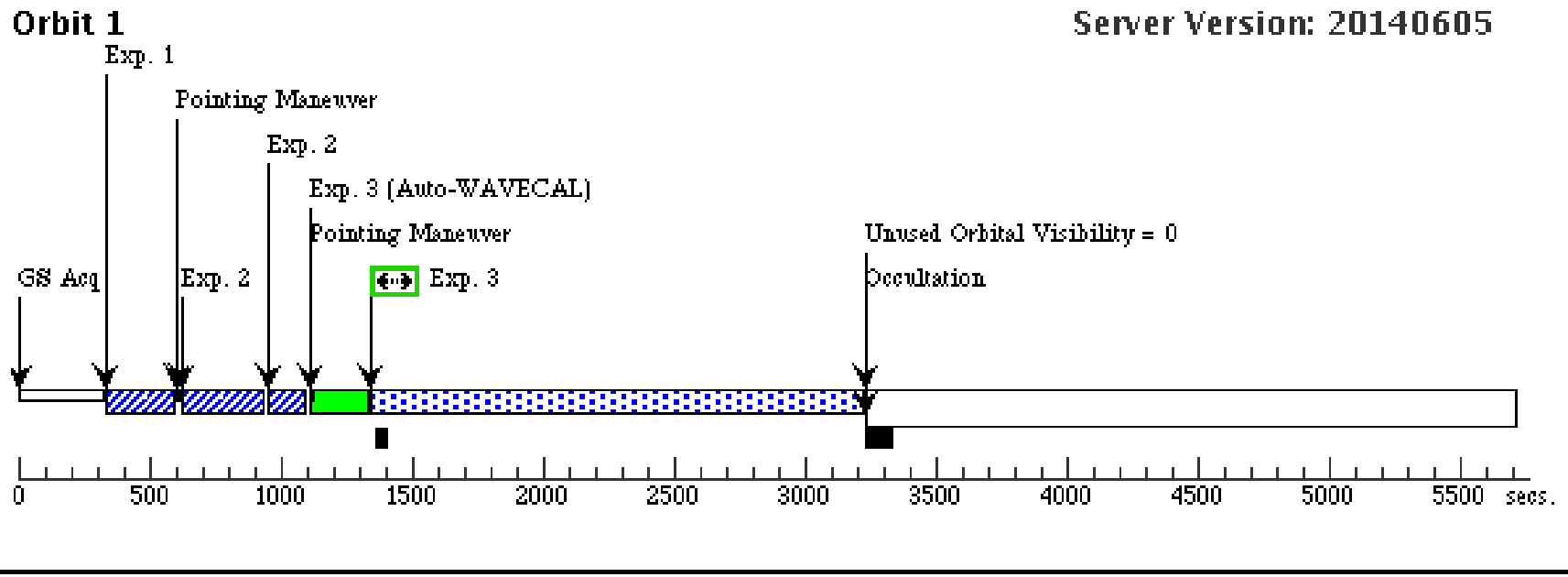
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	HD-43582	RA: 06 18 0.3459 (94.5014412d)	Proper Motion RA: -1.2 mas/yr	V=8.79+/-0.02	Reference Frame: ICRS
		Dec: +22 39 29.99 (22.65833d)	Proper Motion Dec: -3.6 mas/yr	B-V = 0.32; F(1300) = 1.0E-12	
		Equinox: J2000	Epoch of Position: 2000.0		

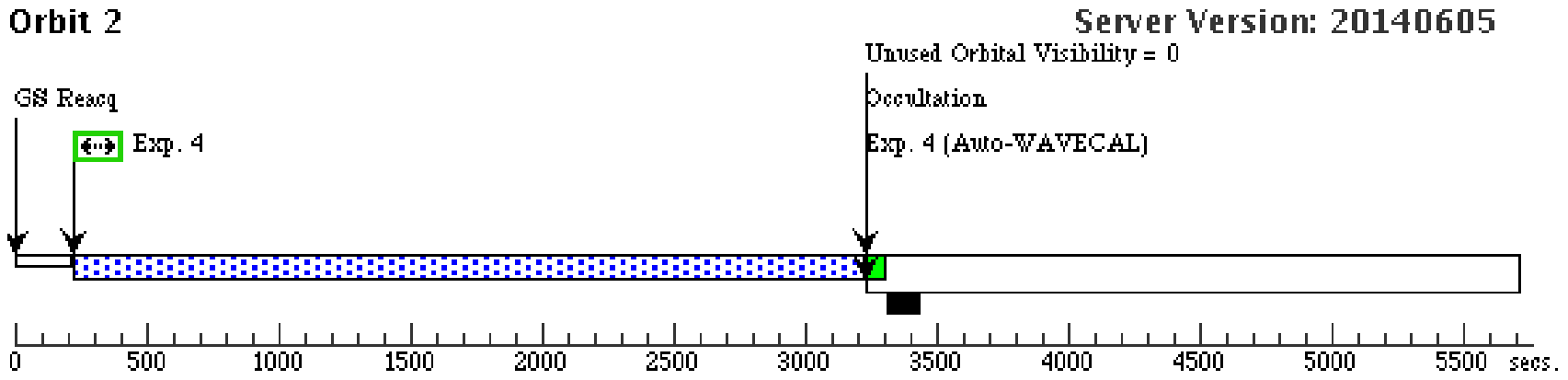
Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

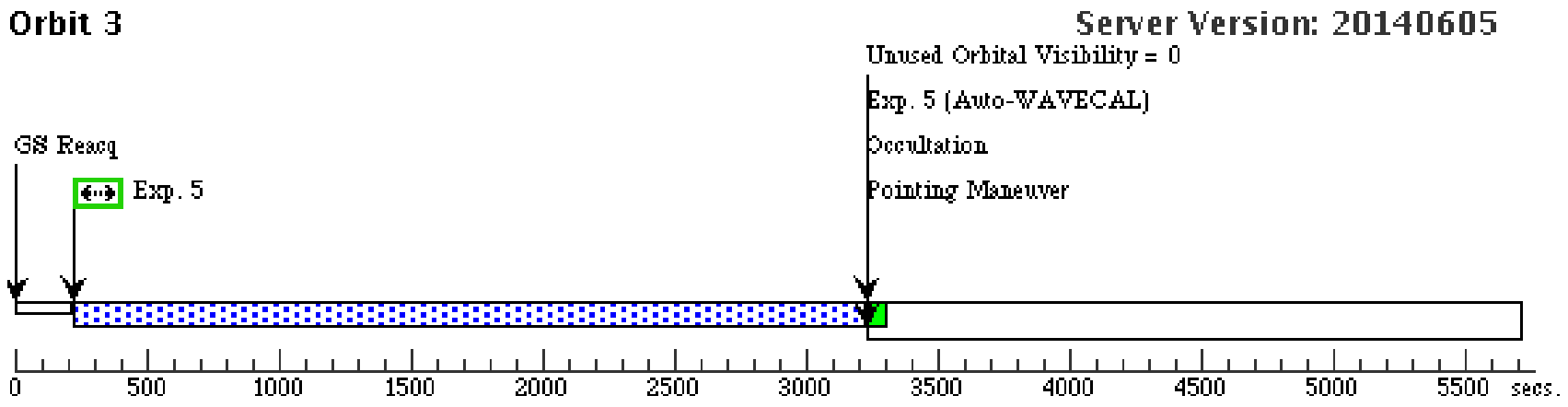
Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	ACQ-HD-43582 (STIS.ta.617708)	(1) HD-43582	STIS/CCD, ACQ, F28X50OII	MIRROR				1 Secs (1 Secs) *[==>]*	***[1]***
2	PEAK1-HD-43582 (STIS.ta.617711)	(1) HD-43582	STIS/CCD, ACQ/PEAK, 0.2X0.05ND	MIRROR				1 Secs (1 Secs) *[==>]*	***[1]***
3	SCI1-HD-43582 (STIS.sp.617735)	(1) HD-43582	STIS/FUV-MAMA, ACCUM, 0.2X0.09	E140H 1307 A				1860 Secs (1860 Secs) *[==>]*	***[1]***
4	SCI2-HD-43582 (STIS.sp.617736)	(1) HD-43582	STIS/FUV-MAMA, ACCUM, 0.2X0.09	E140H 1307 A				2980 Secs (2980 Secs) *[==>]*	***[2]***
5	SCI3-HD-43582 (STIS.sp.617736)	(1) HD-43582	STIS/FUV-MAMA, ACCUM, 0.2X0.09	E140H 1307 A				2980 Secs (2980 Secs) *[==>]*	***[3]***
6	PEAK2-HD-43582 (STIS.ta.617711)	(1) HD-43582	STIS/CCD, ACQ/PEAK, 0.2X0.05ND	MIRROR				1 Secs (1 Secs) *[==>]*	***[4]***
7	SCI4-HD-43582 (STIS.sp.619440)	(1) HD-43582	STIS/FUV-MAMA, ACCUM, 0.2X0.09	E140H 1307 A				2007 Secs (2007 Secs) *[==>]*	***[4]***
8	SCI5-HD-43582 (STIS.sp.617736)	(1) HD-43582	STIS/FUV-MAMA, ACCUM, 0.2X0.09	E140H 1307 A				2980 Secs (2980 Secs) *[==>]*	***[5]***

Orbit Structure



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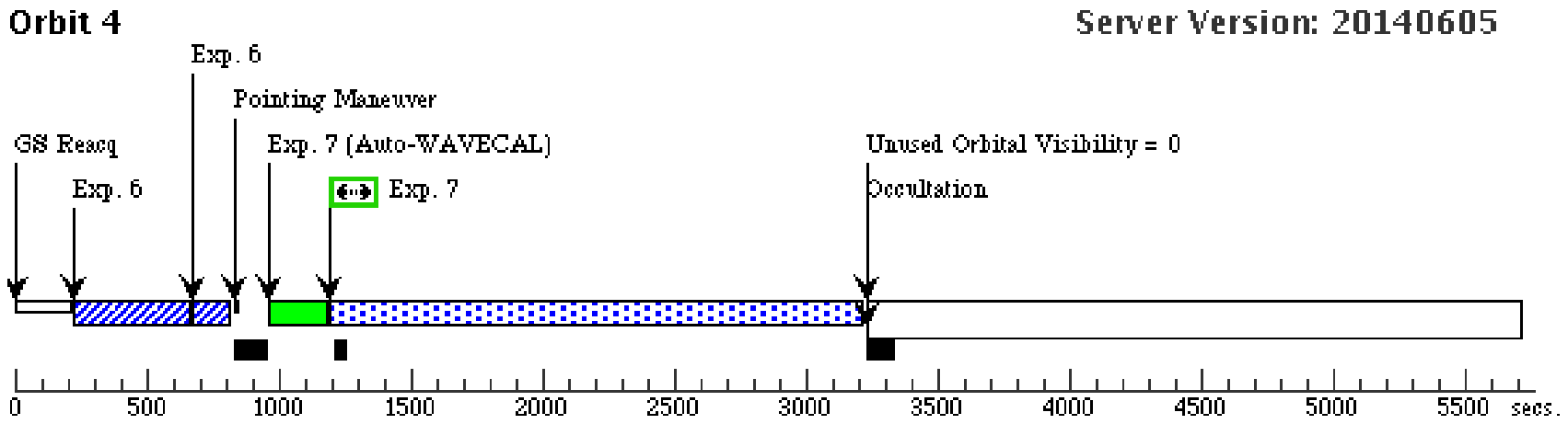
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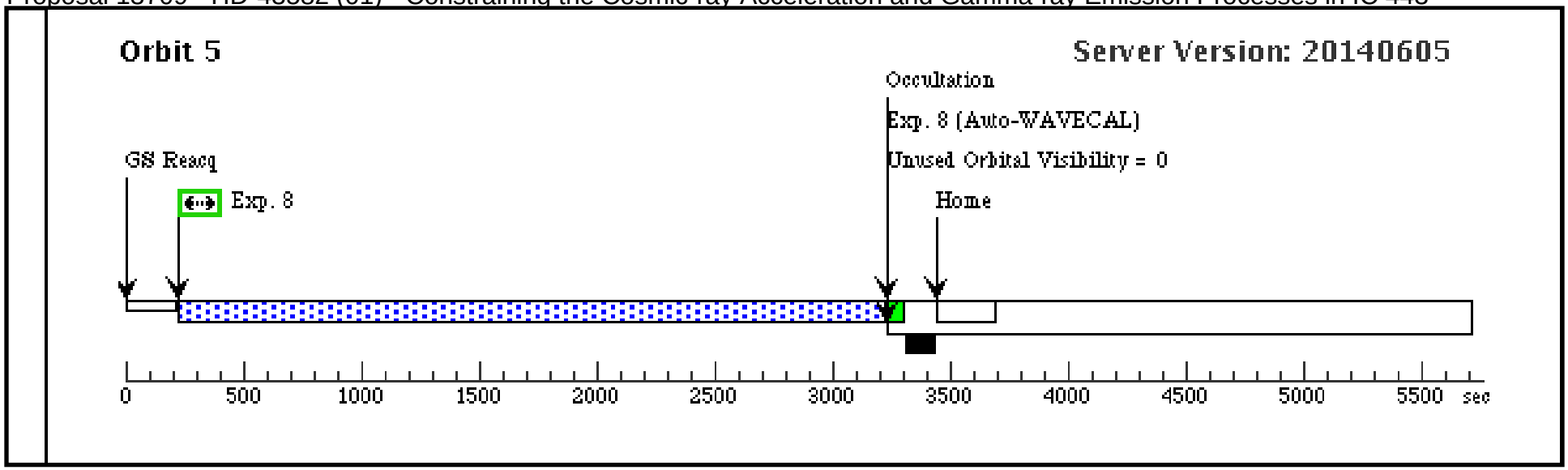
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Visit

Proposal 13709, HD-254755 (02) Fri Jul 18 01:05:57 GMT 2014

Diagnostic Status: No Diagnostics

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

Special Requirements: (none)

Fixed Targets

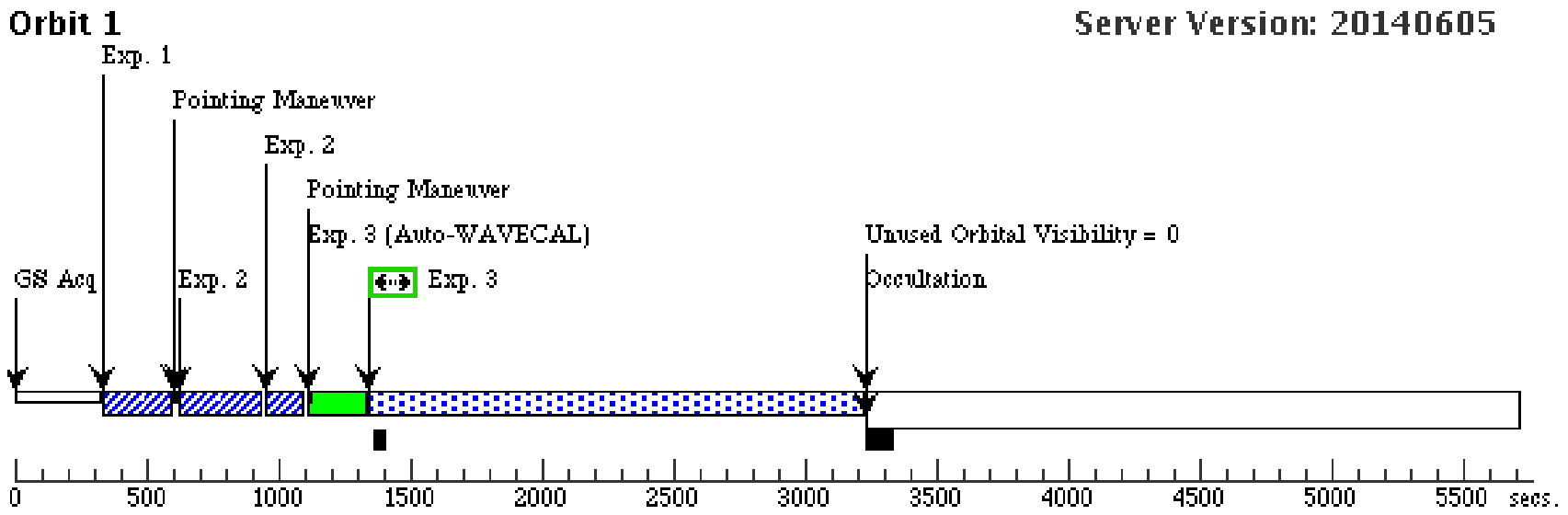
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(2)	HD-254755	RA: 06 18 31.7728 (94.6323867d) Dec: +22 40 45.12 (22.67920d) Equinox: J2000	Proper Motion RA: -0.61 mas/yr Proper Motion Dec: -1.36 mas/yr Epoch of Position: 2000.0	V=8.91+/-0.03 B-V = 0.42	Reference Frame: ICRS

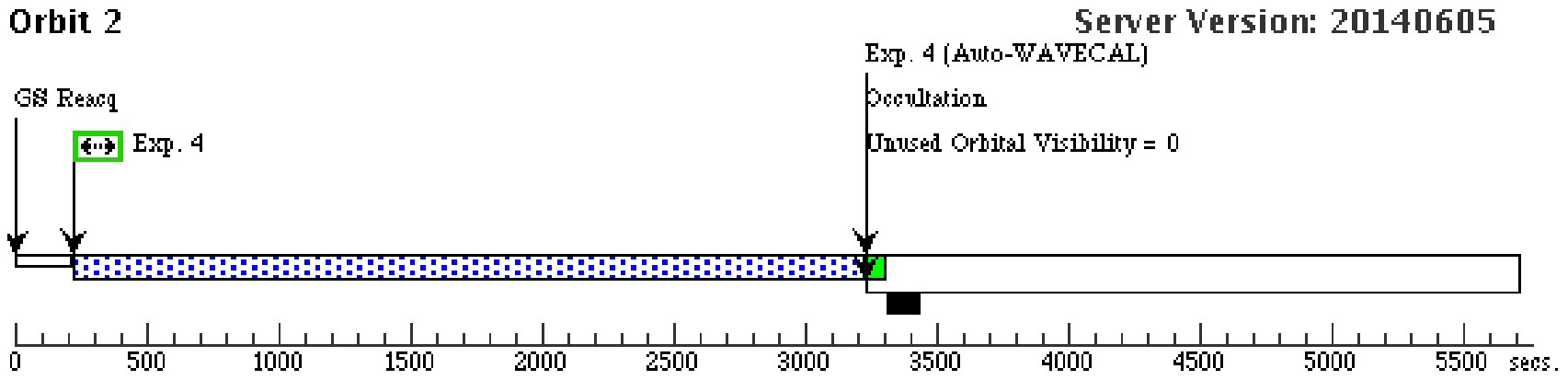
Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.

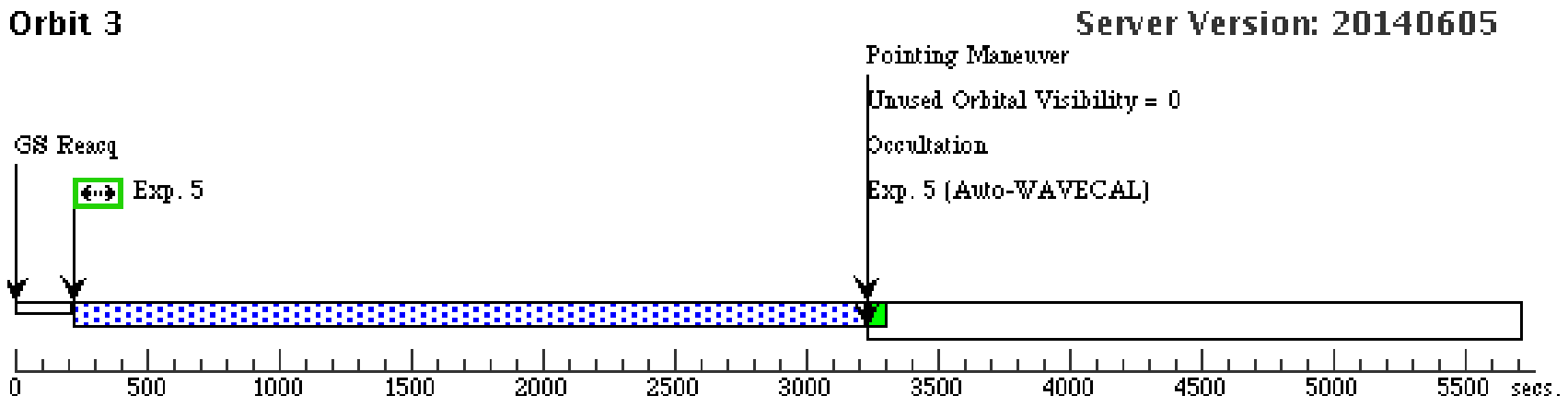
Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	ACQ-HD-254755 (STIS.ta.617714)	(2) HD-254755	STIS/CCD, ACQ, F28X50OII	MIRROR				1 Secs (1 Secs) *[==>]*	***[1]***
2	PEAK1-HD-254755 (STIS.ta.617716)	(2) HD-254755	STIS/CCD, ACQ/PEAK, 0.2X0.05ND	MIRROR				1 Secs (1 Secs) *[==>]*	***[1]***
3	SCI1-HD-254755 (STIS.sp.617733)	(2) HD-254755	STIS/FUV-MAMA, ACCUM, 0.2X0.09	E140H 1307 A				1860 Secs (1860 Secs) *[==>]*	***[1]***
4	SCI2-HD-254755 (STIS.sp.617734)	(2) HD-254755	STIS/FUV-MAMA, ACCUM, 0.2X0.09	E140H 1307 A				2980 Secs (2980 Secs) *[==>]*	***[2]***
5	SCI3-HD-254755 (STIS.sp.617734)	(2) HD-254755	STIS/FUV-MAMA, ACCUM, 0.2X0.09	E140H 1307 A				2980 Secs (2980 Secs) *[==>]*	***[3]***
6	PEAK2-HD-254755 (STIS.ta.617716)	(2) HD-254755	STIS/CCD, ACQ/PEAK, 0.2X0.05ND	MIRROR				1 Secs (1 Secs) *[==>]*	***[4]***
7	SCI4-HD-254755 (STIS.sp.619441)	(2) HD-254755	STIS/FUV-MAMA, ACCUM, 0.2X0.09	E140H 1307 A				2007 Secs (2007 Secs) *[==>]*	***[4]***
8	SCI5-HD-254755 (STIS.sp.617734)	(2) HD-254755	STIS/FUV-MAMA, ACCUM, 0.2X0.09	E140H 1307 A				2980 Secs (2980 Secs) *[==>]*	***[5]***

Orbit Structure



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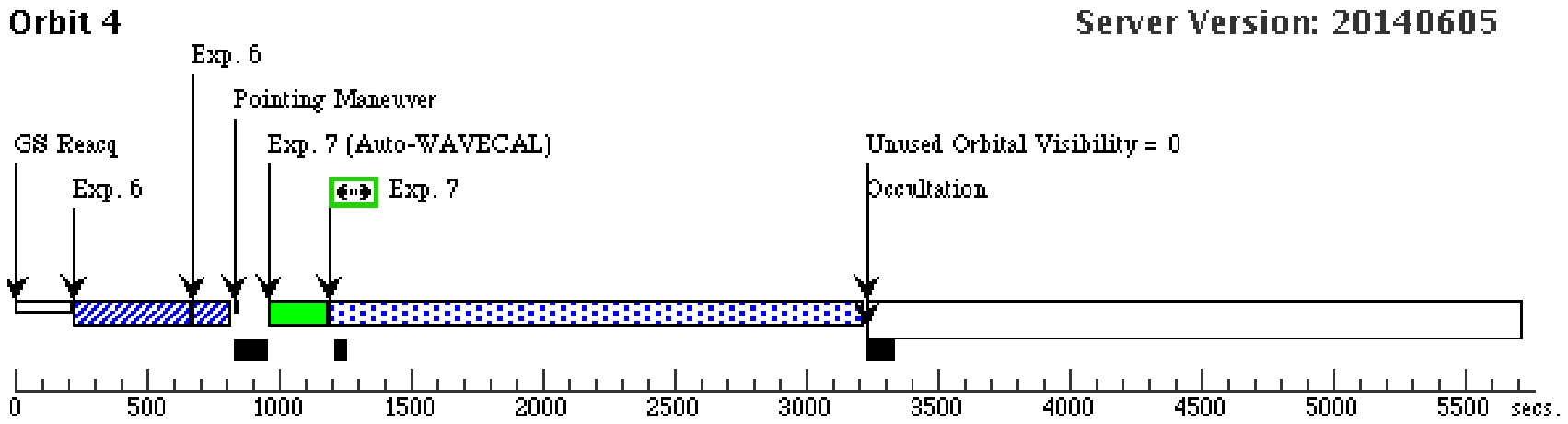
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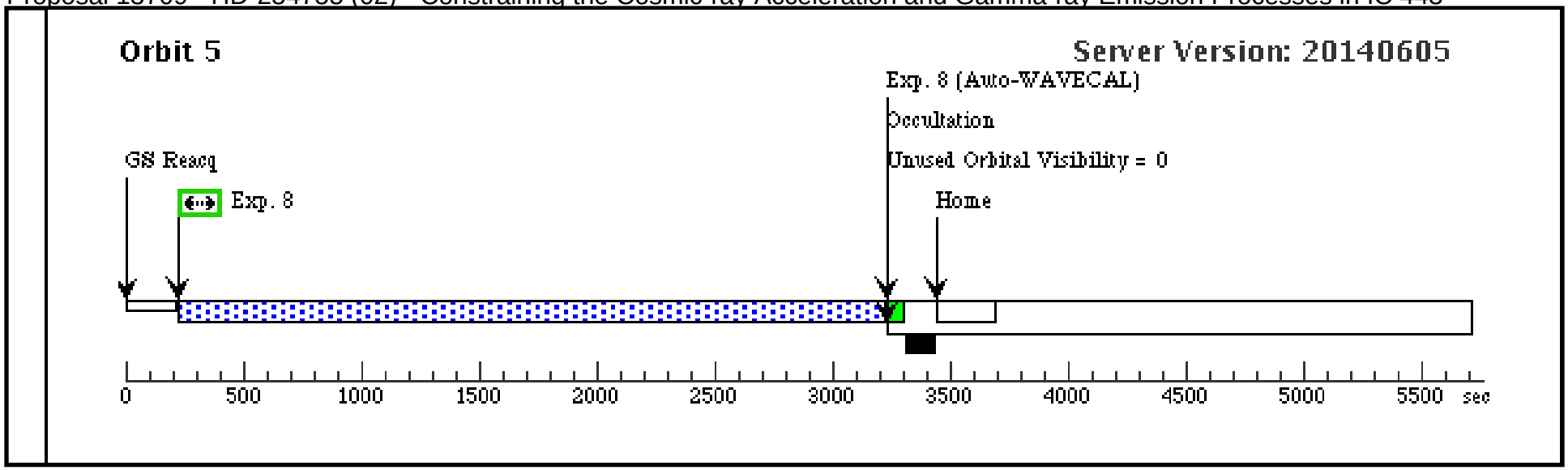
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