



16163 - Planetary mass loss and the high-energy spectrum of V1298 Tau

Cycle: 28, Proposal Category: GO

(UV Initiative)

(Availability Mode: SUPPORTED)

INVESTIGATORS

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VISITS

<i>Visit</i>	<i>Targets used in Visit</i>	<i>Configurations used in Visit</i>	<i>Orbits Used</i>	<i>Last Orbit Planner Run</i>	<i>OP Current with Visit?</i>
01	(1) V-V1298-TAU	STIS/CCD STIS/NUV-MAMA	1	12-May-2022 11:00:13.0	yes
02	(1) V-V1298-TAU	COS/FUV COS/NUV	1	12-May-2022 11:00:14.0	yes
03	(1) V-V1298-TAU	COS/FUV COS/NUV	5	12-May-2022 11:00:15.0	yes
04	(1) V-V1298-TAU	COS/FUV COS/NUV	5	12-May-2022 11:00:16.0	yes

<i>Visit</i>	<i>Targets used in Visit</i>	<i>Configurations used in Visit</i>	<i>Orbits Used</i>	<i>Last Orbit Planner Run</i>	<i>OP Current with Visit?</i>
54	(1) V-V1298-TAU	COS/FUV COS/NUV	5	12-May-2022 11:00:17.0	yes
05	(1) V-V1298-TAU	COS/FUV COS/NUV	5	12-May-2022 11:00:19.0	yes

22 Total Orbits Used

ABSTRACT

The origin of the radius distribution gap for short-period Kepler planets has become a priority investigation in exoplanet science. The current leading explanation is the photoevaporation of H/He envelopes during the first 100 million years of a planet's lifetime, where the gap is created when planets below some initial envelope mass fraction lose their atmospheres entirely. The star's high-energy spectrum is the main driver of atmospheric loss in short-period planets. Spectral information on the X-ray, EUV, and FUV flux is crucial for accurate modeling of the photoevaporation process in specific systems. The recently-discovered multi-transiting planet system V1298 Tau offers a unique opportunity to investigate atmospheric evaporation in young systems. V1298 Tau is a ~24 million year old star with multiple gas giants in short period orbits. Furthermore, the brightness of V1298 Tau and the transiting nature of its close-in planets make this system ripe for atmospheric characterization via transmission spectroscopy. We propose to use HST observations to characterize the FUV and NUV flux of V1298 Tau which, combined with scheduled NICER X-ray observations, will allow us to perform a differential emission analysis and approximate the EUV spectrum. We will also perform transit observations to search for absorption by metals in escaping planetary material of the innermost planet and estimate its mass loss rate. Our observations of this incredible star will provide a high-energy spectrum for one of the few <100 Myr old systems with a transiting short-period planet that is amenable to mass loss measurements with current facilities.

OBSERVING DESCRIPTION

We will observe the FUV and NUV spectrum of our only target, V1298 Tau, using COS (FUV) and STIS (NUV). In order to observe as much of the UV spectrum as possible, we will utilize two COS settings and a single STIS setting: 1 orbit with STIS G230L (1570 - 3180 angstroms), 1 orbit with COS G160M/1533 angstroms (1340 - 1700 angstroms), and 15 orbits with COS G130M/1291 angstroms (1130 - 1430 angstroms) to observe three transits of planet c. Both the G130M/1291 and G160M/1533 exposures will measure the FUV flux that is critical to He I 10830 angstrom models. The COS settings also cover all of the high temperature emission lines that will be used in the DEM analysis. The NUV flux, which is also essential to the He I 10830 angstrom models, will be observed with the STIS G230L setting. The wavelength coverage of these combined observations will ensure

that the entire UV spectrum of V1298 Tau is characterized. This includes all of the flux important for modeling planetary evaporation and will allow the EUV flux to be calculated from our DEM analysis.

V1298 Tau is visible for 3100 seconds per orbit. Based on the instrument overheads, this leaves 2800 seconds of usable visibility per orbit for STIS and 2000 s of exposure time for the first COS orbit and 2800 seconds for consecutive orbits in a visit. We will break these orbits into consecutive exposures of 1000 - 2400 s depending on the available visibility after overheads. Variability due to flaring will be addressed by analyzing the data in time-tagged mode and flagging any flare events (e.g., Loyd & France 2014).

V1298 Tau is similar in UV brightness, spectral type, and evolutionary status to the weak-lined T Tauri star LkCa 19, which has been previously observed with HST STIS and COS (Program ID 11616). Using the NUV flux of LkCa 19, and the on-line STIS ETC, we estimate being able to achieve a signal-to-noise in the continuum near 2720 angstroms of 44 per resolution element with an exposure time of 1400 s for the STIS G230L setting and the 52x0.2 arc-second slit. Two exposures will be taken for the STIS G230L orbit, resulting in a final S/N of 50. We will use 1 orbit for this setting.

Most of the FUV flux from young K-type stars is in high-temperature transition region emission lines, such as N V (1238,1242 angstroms), Si IV (1393,1402 angstroms), and C IV (1548, 1550 angstroms); there is little to no continuum emission. The coronal model fluxes for V1298 Tau are similar to those observed for LkCa 19 so, as a check, we compared our S/N estimates with the values obtained for LkCa 19 for a $t=970$ s exposure. We find similar S/N values in the strong emission lines in LkCa 19's spectrum, confirming our estimates for V1298 Tau. This suggests that our V1298 Tau coronal model is representative of LkCa 19's coronal emission.

The G160M/1533 angstrom setting will be used to characterize the spectrum from 1340-1700 angstrom, which contains, for example, the strong transition region lines C IV 1548, 1550 angstroms and He II 1640 angstroms. Using the C IV 1548 angstrom line from LkCa 19, we estimate $S/N=12$ per resolution element for a single exposure of $t=1400$ s. The He II 1640 angstrom flux is similar to that of C IV 1548 angstrom so we will detect all of the important emission lines. We will use 1 orbit for this setting.

We do not have simulated V1298 Tau spectra for the wavelength range covered by the G130M/1291 angstrom setting, which will be utilized for the transit observations for planet c. However, the previous comparison between LkCa 19 and V1298 Tau demonstrates that the FUV emission lines for V1298 Tau should be observable at comparable S/N with similar integration times. Using the C II 1336 angstrom emission line from LkCa 19 we used the COS ETC to estimate a $S/N \sim 10$ in the line core for a $t=1400$ s exposure. We will integrate any absorption measurements across both C II

lines at 1334.5 angstroms and 1335.7 angstroms increasing the S/N of the transmission spectrum by a factor of 1.4.

The transit duration of V1298 Tau c is 4.66 hours. This means that a minimum of 5 orbits is required to obtain the necessary pre- and post-transit comparison observations. Based on the individual exposure calculation above, we estimate $S/N \sim 109$ for the final in-transit C II 1334, 1335 angstrom flux by co-adding the in-transit exposures and summing across both lines. Our threshold for detecting absorption will be 1.5% when also accounting for the S/N of the out-of-transit spectra. Planet c was specifically chosen over planet d because its ephemeris is more precisely known, it receives a higher level of high energy stellar radiation, it transits more frequently ($P_{orb}=8.24958$ days versus $P_{orb}=12.4$ days for planet d), and it currently resides closer to the radius valley. The recent Spitzer observations of planet c's transit have reduced the uncertainty in the transit midpoint to 1.4 minutes, guaranteeing that any scheduled transits in Cycle 28 will occur within ~ 10 minutes of the predicted transit time.

Proposal 16163 - Visit 01 - Planetary mass loss and the high-energy spectrum of V1298 Tau

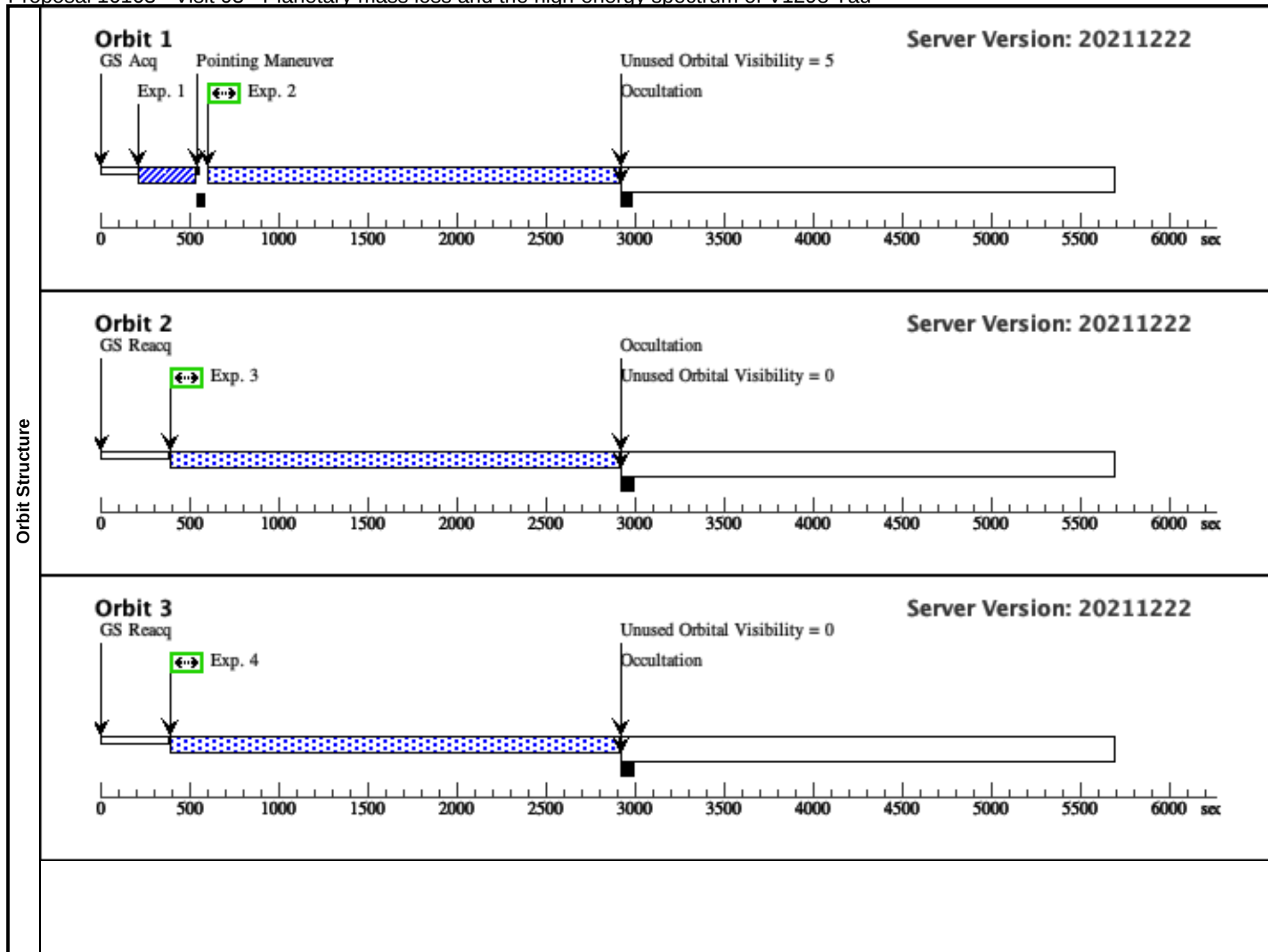
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	Scientific Instruments: STIS/NUV-MAMA, STIS/CCD										
	Special Requirements: (none)										
Fixed Targets	#	Name	Target Coordinates		Targ. Coord. Corrections		Fluxes		Miscellaneous		
	(1)	V-V1298-TAU	RA: 04 05 19.5970 (61.3316542d) Dec: +20 09 25.31 (20.15703d) Equinox: J2000		Proper Motion RA: 3.712731804600008E-4 sec of time/yr Proper Motion Dec: -0.016077000032055366 arcsec/yr Epoch of Position: 2015.5		V=10.12		Reference Frame: ICRS		
	Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.										
	Category=STAR Description=[T TAURI STAR] Extended=NO										
Exposures	#	Label (ETC Run)	Target	Config,Mode,Aperture		Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	(STIS.ta.145 0264)	(1) V-V1298-TAU	STIS/CCD, ACQ, F28X500II		MIRROR				1.9 Secs (1.9 Secs)	
										[==>]	[1]
	2	(STIS.sp.14 50301)	(1) V-V1298-TAU	STIS/NUV-MAMA, TIME-TAG, 52X0.2		G230L 2376 A	BUFFER-TIME=46 0			2200 Secs (2200 Secs)	
										[==>]	[1]
Orbit Structure	Orbit 1 Server Version: 20211222 GS Acq Exp. 1 Pointing Maneuver Exp. 2 (Auto-WAVECAL) Exp. 2 Unused Orbital Visibility = 0 Occultation Home <										

Proposal 16163 - Visit 02 - Planetary mass loss and the high-energy spectrum of V1298 Tau

Visit	Proposal 16163, Visit 02, completed										Thu May 12 15:00:19 GMT 2022
	Diagnostic Status: No Diagnostics										
	Scientific Instruments: COS/FUV, COS/NUV										
	Special Requirements: (none)										
Fixed Targets	#	Name	Target Coordinates		Targ. Coord. Corrections		Fluxes		Miscellaneous		
	(1)	V-V1298-TAU	RA: 04 05 19.5970 (61.3316542d) Dec: +20 09 25.31 (20.15703d) Equinox: J2000		Proper Motion RA: 3.712731804600008E-4 sec of time/yr Proper Motion Dec: -0.016077000032055366 arcsec/yr Epoch of Position: 2015.5		V=10.12		Reference Frame: ICRS		
	Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.										
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Exposures	#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]		Orbit
	1	(COS.ta.146 7066)	(1) V-V1298-TAU	COS/NUV, ACQ/IMAGE, BOA	MIRRORA				40 Secs (40 Secs)		
									[==>]		[1]
	2	(COS.sp.146 7070)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA	G160M 1533 A	FP-POS=1; BUFFER-TIME=20 078			499 Secs (499 Secs)		
									[==>]		[1]
	3	(COS.sp.146 7070)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA	G160M 1533 A	FP-POS=2; BUFFER-TIME=20 078			499 Secs (499 Secs)		
									[==>]		[1]
	4	(COS.sp.146 7070)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA	G160M 1533 A	FP-POS=3; BUFFER-TIME=20 078			500 Secs (500 Secs)		
									[==>]		[1]
	5	(COS.sp.146 7070)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA	G160M 1533 A	FP-POS=4; BUFFER-TIME=20 078			500 Secs (500 Secs)		
									[==>]		[1]
Orbit Structure	Orbit 1 Server Version: 20211222 GS Acq Exp. 1 Pointing Maneuver Exp. 2 Exp. 3 Exp. 4 Exp. 5 Home Occultation Unused Orbital Visibility = 0										

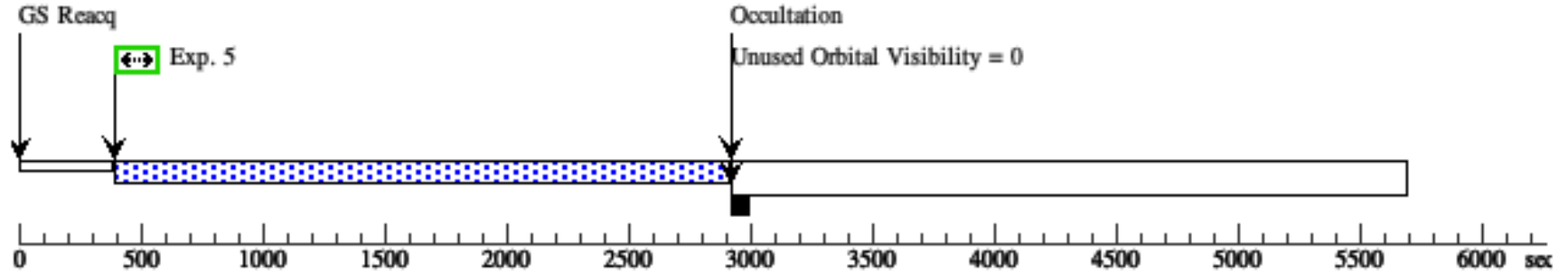
Proposal 16163 - Visit 03 - Planetary mass loss and the high-energy spectrum of V1298 Tau

Visit	Proposal 16163, Visit 03, completed										Thu May 12 15:00:19 GMT 2022	
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	Scientific Instruments: COS/FUV, COS/NUV											
	Special Requirements: SCHED 100%; Period 8.249141 D AND ZERO-PHASE HJD2457064.281634											
Fixed Targets	#	Name	Target Coordinates			Targ. Coord. Corrections		Fluxes		Miscellaneous		
	(1)	V-V1298-TAU	RA: 04 05 19.5970 (61.3316542d) Dec: +20 09 25.31 (20.15703d) Equinox: J2000			Proper Motion RA: 3.712731804600008E-4 sec of time/yr Proper Motion Dec: -0.016077000032055366 arcsec/yr Epoch of Position: 2015.5		V=10.12		Reference Frame: ICRS		
	Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.											
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Exposures	#	Label (ETC Run)	Target	Config,Mode,Aperture		Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]		Orbit
	1	(COS.ta.146 7066)	(1) V-V1298-TAU	COS/NUV, ACQ/IMAGE, BOA		MIRRORA		PHASE .982 TO .99 0; GS ACQ SCENARI O BASE1BE		40 Secs (40 Secs) [==>]		[1]
	2	(COS.sp.145 0355)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA		G130M 1291 A	BUFFER-TIME=41 34; FP-POS=4			2138 Secs (2138 Secs) [==>]		[1]
	3	(COS.sp.145 0357)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA		G130M 1291 A	BUFFER-TIME=41 33; FP-POS=4			2473 Secs (2473 Secs) [==>]		[2]
	4	(COS.sp.145 0357)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA		G130M 1291 A	BUFFER-TIME=41 33; FP-POS=4			2473 Secs (2473 Secs) [==>]		[3]
	5	(COS.sp.145 0357)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA		G130M 1291 A	BUFFER-TIME=41 33; FP-POS=4			2473 Secs (2473 Secs) [==>]		[4]
	6	(COS.sp.145 0357)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA		G130M 1291 A	BUFFER-TIME=41 33; FP-POS=4			2473 Secs (2473 Secs) [==>]		[5]



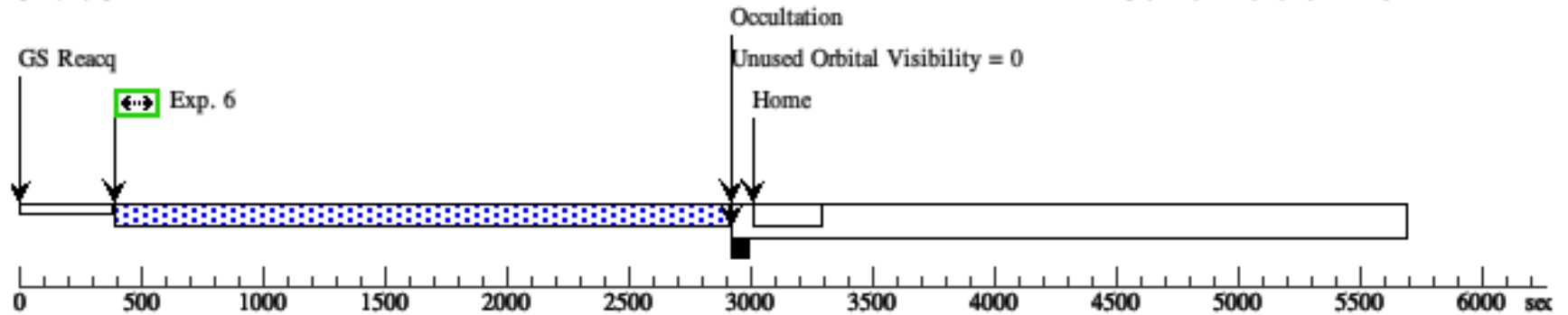
Orbit 4

Server Version: 20211222



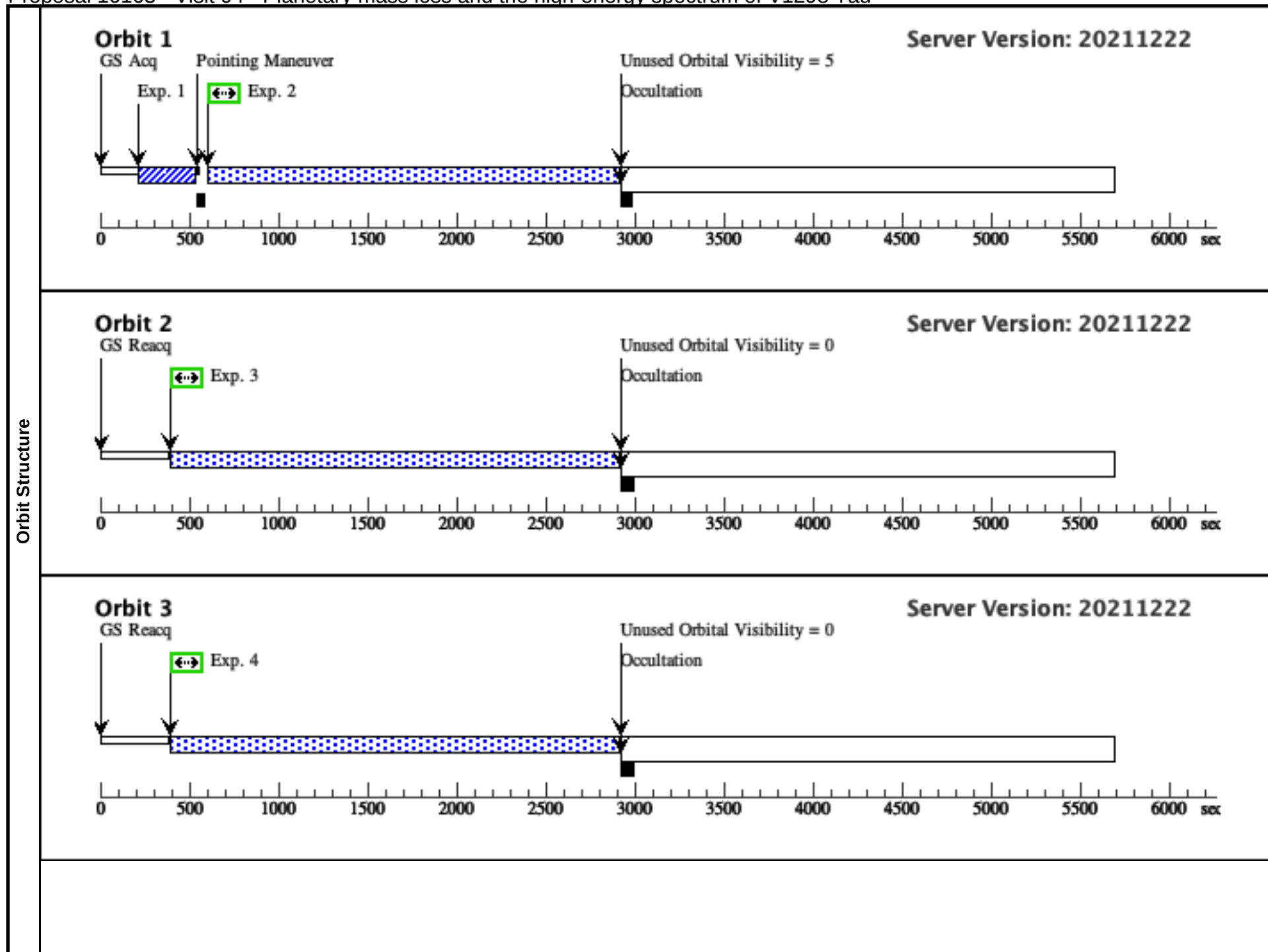
Orbit 5

Server Version: 20211222



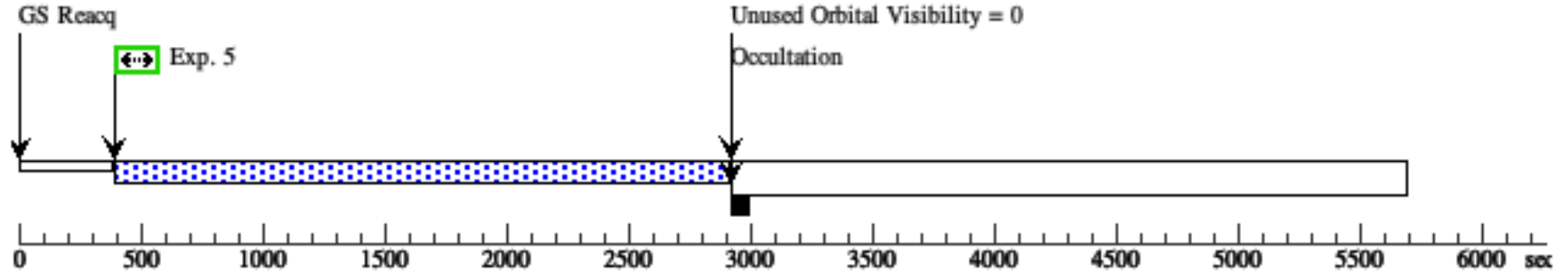
Proposal 16163 - Visit 04 - Planetary mass loss and the high-energy spectrum of V1298 Tau

Visit	Proposal 16163, Visit 04, failed										Thu May 12 15:00:19 GMT 2022	
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	Scientific Instruments: COS/FUV, COS/NUV											
	Special Requirements: SCHED 100%; Period 8.249141 D AND ZERO-PHASE HJD2457064.281634											
Fixed Targets	#	Name	Target Coordinates			Targ. Coord. Corrections			Fluxes		Miscellaneous	
	(1)	V-V1298-TAU	RA: 04 05 19.5970 (61.3316542d) Dec: +20 09 25.31 (20.15703d) Equinox: J2000			Proper Motion RA: 3.712731804600008E-4 sec of time/yr Proper Motion Dec: -0.016077000032055366 arcsec/yr Epoch of Position: 2015.5			V=10.12		Reference Frame: ICRS	
	Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.											
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Exposures	#	Label (ETC Run)	Target	Config,Mode,Aperture		Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]		Orbit
	1	(COS.ta.146 7066)	(1) V-V1298-TAU	COS/NUV, ACQ/IMAGE, BOA		MIRRORA		PHASE .987 TO .995; GS ACQ SCENARI O BASE1BE		40 Secs (40 Secs)		
										[==>]		
											[1]	
	2	(COS.sp.145 0355)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA		G130M 1291 A	BUFFER-TIME=4134; FP-POS=4			2138 Secs (2138 Secs)		
										[==>]		
											[1]	
	3	(COS.sp.145 0357)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA		G130M 1291 A	BUFFER-TIME=4133; FP-POS=4			2473 Secs (2473 Secs)		
										[==>]		
											[2]	
4	(COS.sp.145 0357)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA		G130M 1291 A	BUFFER-TIME=4133; FP-POS=4			2473 Secs (2473 Secs)			
									[==>]			
											[3]	
5	(COS.sp.145 0357)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA		G130M 1291 A	BUFFER-TIME=4133; FP-POS=4			2473 Secs (2473 Secs)			
									[==>]			
											[4]	
6	(COS.sp.145 0357)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA		G130M 1291 A	BUFFER-TIME=4133; FP-POS=4			2473 Secs (2473 Secs)			
									[==>]			
											[5]	



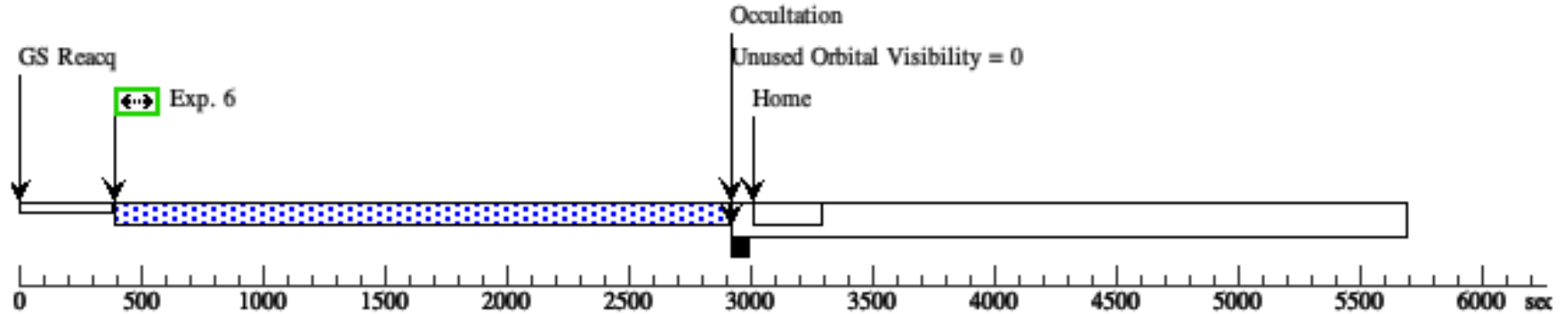
Orbit 4

Server Version: 20211222



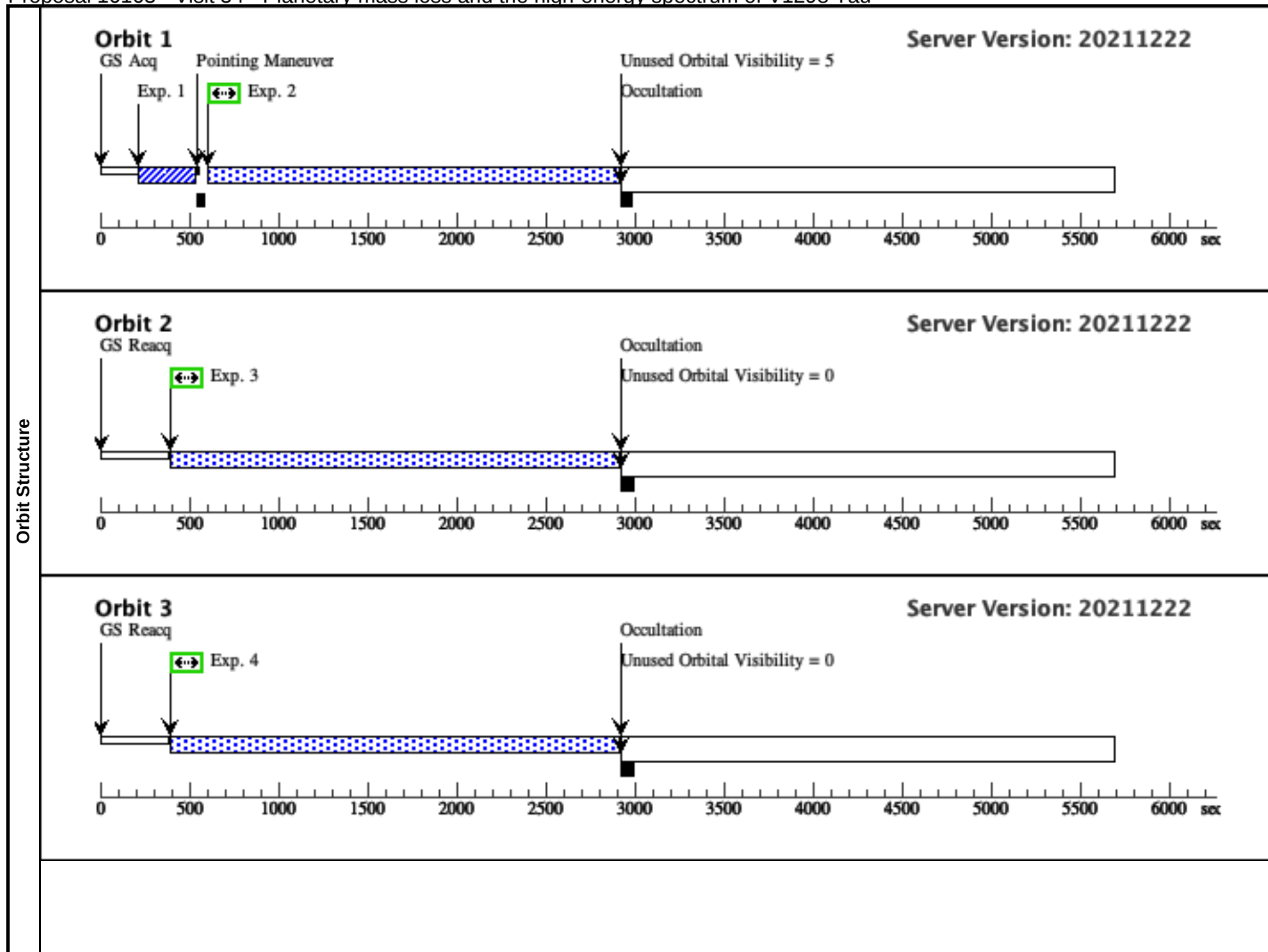
Orbit 5

Server Version: 20211222



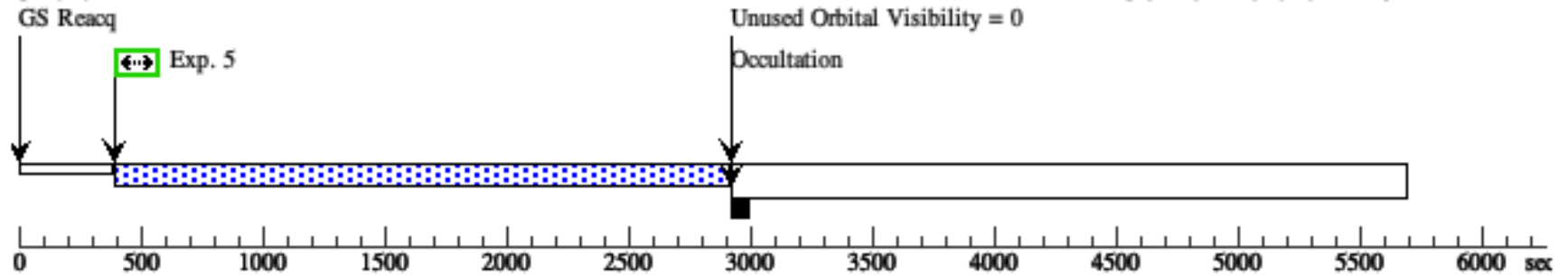
Proposal 16163 - Visit 54 - Planetary mass loss and the high-energy spectrum of V1298 Tau

Visit	Proposal 16163, Visit 54, implementation										Thu May 12 15:00:20 GMT 2022	
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	Scientific Instruments: COS/FUV, COS/NUV											
	Special Requirements: SCHED 100%; Period 8.249141 D AND ZERO-PHASE HJD2457064.281634											
Fixed Targets	#	Name	Target Coordinates		Targ. Coord. Corrections		Fluxes		Miscellaneous			
	(1)	V-V1298-TAU	RA: 04 05 19.5970 (61.3316542d) Dec: +20 09 25.31 (20.15703d) Equinox: J2000		Proper Motion RA: 3.712731804600008E-4 sec of time/yr Proper Motion Dec: -0.016077000032055366 arcsec/yr Epoch of Position: 2015.5		V=10.12		Reference Frame: ICRS			
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	1	(COS.ta.146 7066)	(1) V-V1298-TAU	COS/NUV, ACQ/IMAGE, BOA		MIRRORA		PHASE .987 TO .99 5		40 Secs (40 Secs) [==>]		[1]
	2	(COS.sp.145 0355)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA		G130M 1291 A	BUFFER-TIME=41 34; FP-POS=4			2138 Secs (2138 Secs) [==>]		[1]
	3	(COS.sp.145 0357)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA		G130M 1291 A	BUFFER-TIME=41 33; FP-POS=4			2473 Secs (2473 Secs) [==>]		[2]
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	5	(COS.sp.145 0357)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA		G130M 1291 A	BUFFER-TIME=41 33; FP-POS=4			2473 Secs (2473 Secs) [==>]		[4]
	6	(COS.sp.145 0357)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA		G130M 1291 A	BUFFER-TIME=41 33; FP-POS=4			2473 Secs (2473 Secs) [==>]		[5]



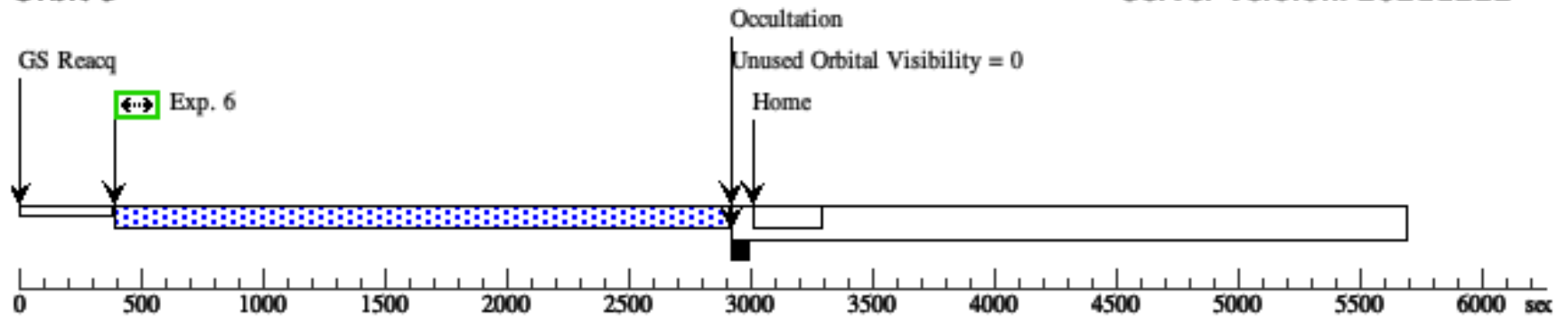
Orbit 4

Server Version: 20211222



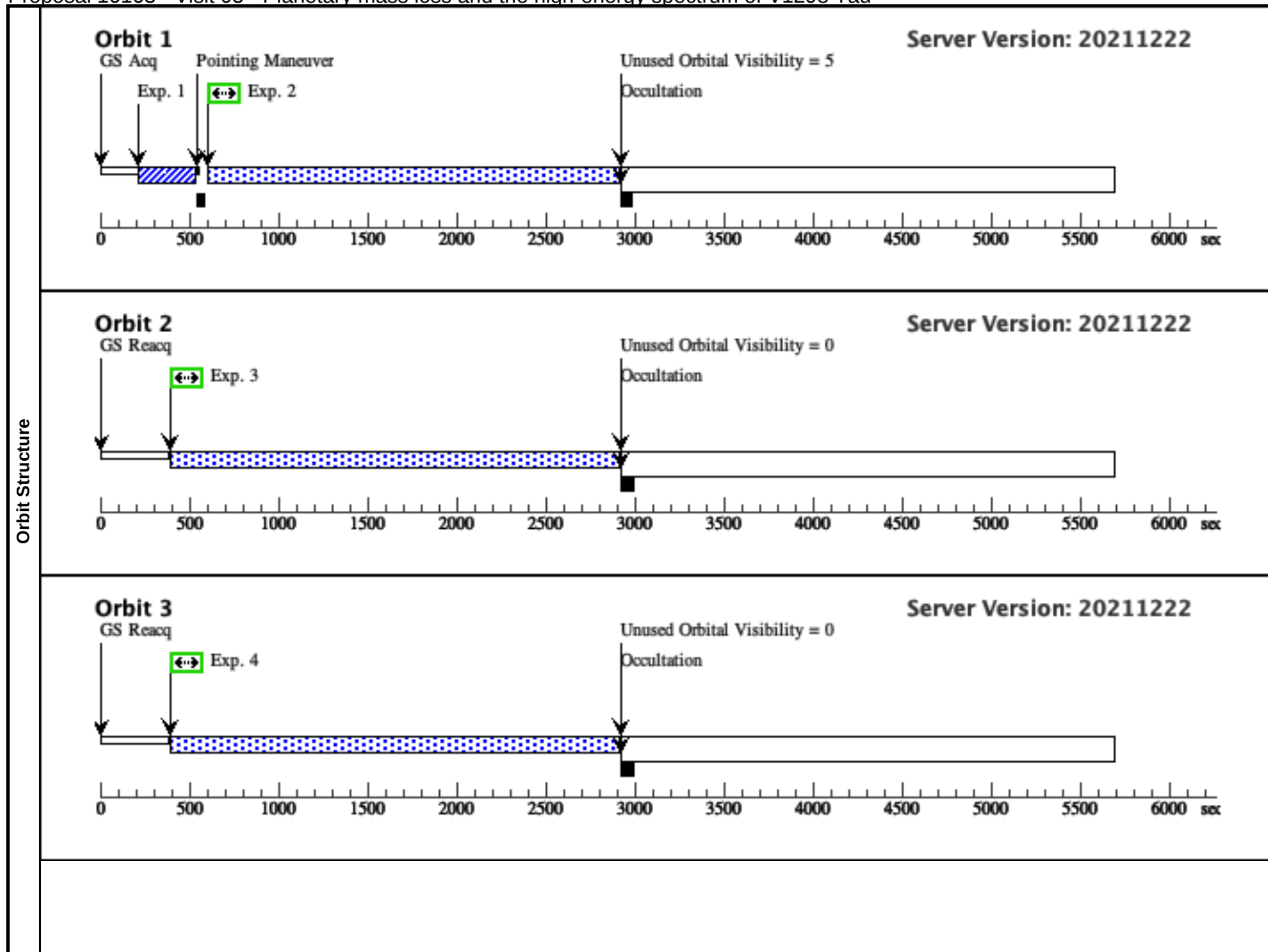
Orbit 5

Server Version: 20211222



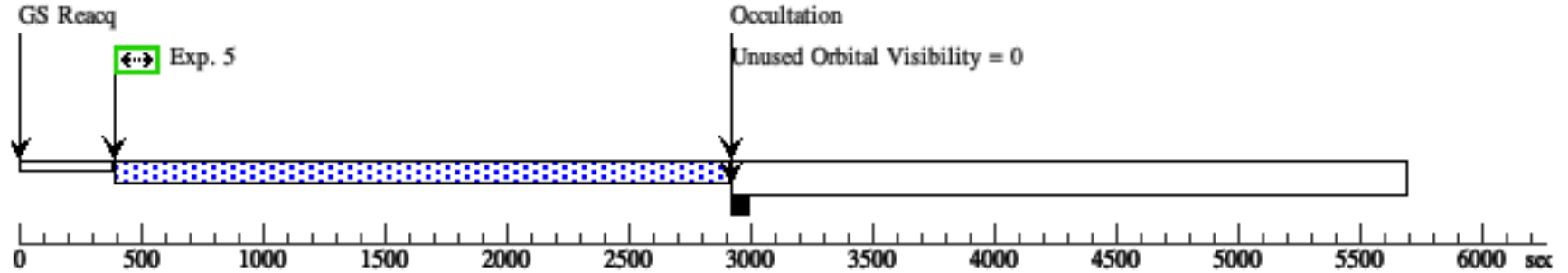
Proposal 16163 - Visit 05 - Planetary mass loss and the high-energy spectrum of V1298 Tau

Visit	Proposal 16163, Visit 05, completed										Thu May 12 15:00:20 GMT 2022	
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	Scientific Instruments: COS/FUV, COS/NUV											
	Special Requirements: SCHED 100%; Period 8.249141 D AND ZERO-PHASE HJD2457064.281634											
Fixed Targets	#	Name	Target Coordinates		Targ. Coord. Corrections		Fluxes		Miscellaneous			
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Exposures	#	Label (ETC Run)	Target	Config,Mode,Aperture		Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]		Orbit
	1	(COS.ta.146 7066)	(1) V-V1298-TAU	COS/NUV, ACQ/IMAGE, BOA		MIRRORA		PHASE .974 TO .98 2; GS ACQ SCENARI O BASE1BE		40 Secs (40 Secs) [==>]		 [1]
	2	(COS.sp.145 0355)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA		G130M 1291 A	BUFFER-TIME=41 34; FP-POS=4			2138 Secs (2138 Secs) [==>]		 [1]
	3	(COS.sp.145 0357)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA		G130M 1291 A	BUFFER-TIME=41 33; FP-POS=4			2473 Secs (2473 Secs) [==>]		 [2]
	4	(COS.sp.145 0357)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA		G130M 1291 A	BUFFER-TIME=41 33; FP-POS=4			2473 Secs (2473 Secs) [==>]		 [3]
	5	(COS.sp.145 0357)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA		G130M 1291 A	BUFFER-TIME=41 33; FP-POS=4			2473 Secs (2473 Secs) [==>]		 [4]
	6	(COS.sp.145 0357)	(1) V-V1298-TAU	COS/FUV, TIME-TAG, PSA		G130M 1291 A	BUFFER-TIME=41 33; FP-POS=4			2473 Secs (2473 Secs) [==>]		 [5]



Orbit 4

Server Version: 20211222



Orbit 5

Server Version: 20211222

