14470 - AR Sco: the first white dwarf pulsar?

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) V-AR-SCO	COS/FUV	5	03-Dec-2015 21:15:49.0	yes

5 Total Orbits Used

ABSTRACT

AR Sco was mis-classified in 1971 as a pulsating delta-Scuti star, and has received little attention until now. In May this year, we became aware of the truly unique nature of this object: besides a two-magnitude modulation on the 3.56h orbital period, we detected a coherent 2min variability from the optical into the radio, and a spectacular infrared excess across the WISE bands. Our optical spectroscopy reveals a late-type companion star,

clearly identifying AR Sco as a compact binary. While most of its observational characteristics are reminiscent of neutron star or black hole binaries, the 2min modulation is archetypical of the spin period of a strongly magnetic white dwarf. We believe that AR Sco is the first white dwarf radio pulsar, where the combination of a large field and rapid rotation results in the acceleration of relativisitic particles that blast the inner hemisphere of the M-dwarf companion, akin to the well-known milli-second pulsars. The ultimate proof of our hypothesis relies on the unambiguous identification of the white dwarf, which will be achieved through the detection of Zeeman-split Ly alpha absorption in the requested COS/G140L observations.

OBSERVING DESCRIPTION

We believe that AR Sco is the first white dwarf pulsar, and these COS FUV G140L observations are designed to detect the white dwarf photoshere, in particular Zeeman-split Ly alpha, to confirm our hypothesis. We have obtained detailed ground-based photometry (ULTRACAM u, g, i bands) as well as many SWIFT UVW1observations. The u-band and UVW1 flux have nearly identical flux levels, and the same orbital modulation amplitude, and we assume for the Phase II a flat spectrum (in Flambda).

The target is acquired spectroscopically, assuming that HST hits the faintest (2e-14erg/cm2/s/AA) phase, any other phase will result in a S/N>40 in the target acq.

We need to observe the target for five consecutive orbits to achieve nearly-complete orbital phase coverage (the orbital period is 3.55h), see Fig. 4 in the Phase I proposal. Because of the large orbital variability, we decided to split every single HST orbit into four FP-POS settings, so that we get an optimally wavelength-sampled spectrum at five different orbital phases. To minimise the overheads, we set the BUFFER-TIME to Texp-110sec (which is significantly shorter than the maximum buffer time given by our ETC simulation).

The flux level at orbital maximum, 1.2e-14erg/cm2/s/AA (Fig. 1 in the Phase I proposal, middle panel), falls a factor ~30 below the maximum count rate of COS/G140L, so should pose no threat to the detector.

We have a decade worth of optical monitoring of AR Sco (from the Catalina Real Time Survey), which shows no variability besides the orbital modulation, i.e. no flares, no outbursts.

Visit

Proposal 14470, AR Sco (01) Fri Dec 04 02:15:52 GMT 2015

Diagnostic Status: Warning

Scientific Instruments: COS/FUV

Special Requirements: (none)

Comments: Because of the substantial orbital phase variation, we split every single orbit into four FP-POS settings, so that we get five fully-sampled FUV spectra across the binary orbit.

Diagnostics

(AR Sco (01)) Warning (Orbit Planner): INEFFICIENT ORDERING OF FP-POS POSITIONS

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Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	V-AR-SCO	RA: 16 21 47.2820 (245.4470083d)	Proper Motion RA: 17.0 mas/yr	V=16.5	Reference Frame: ICRS
		Dec: -22 53 10.31 (-22.88620d)	Proper Motion Dec: -31.6 mas/yr		
		Equinox: J2000	Epoch of Position: 2000		

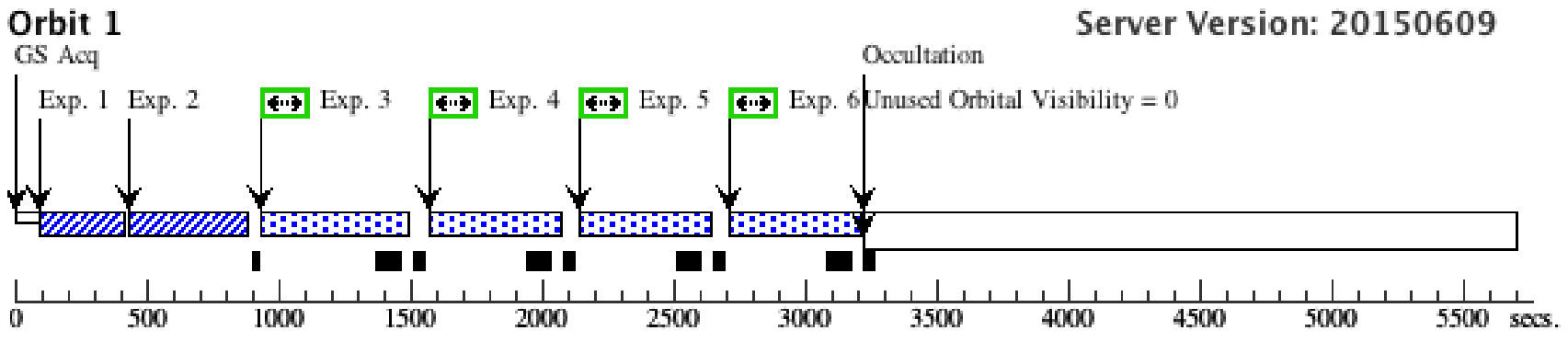
Comments: Extended=NO

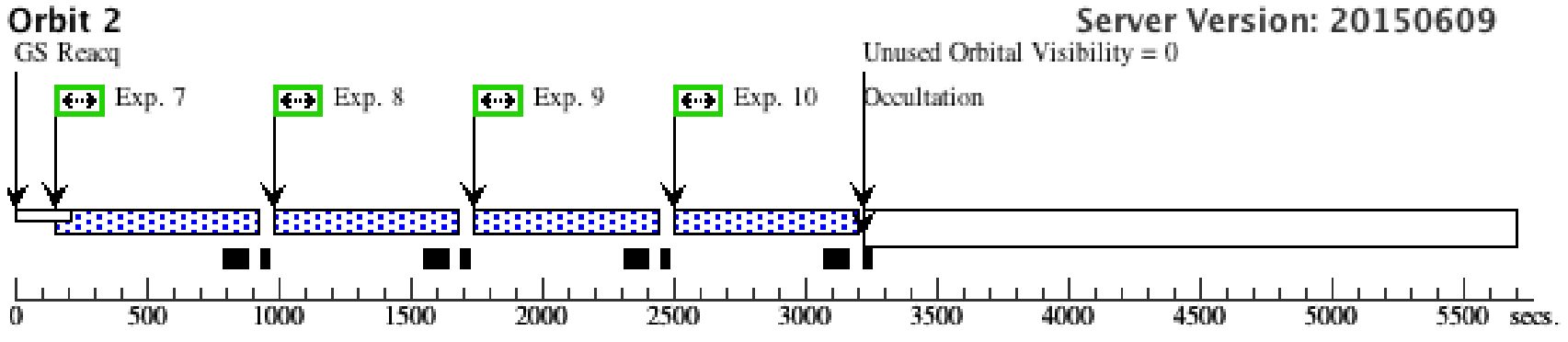
Exposures

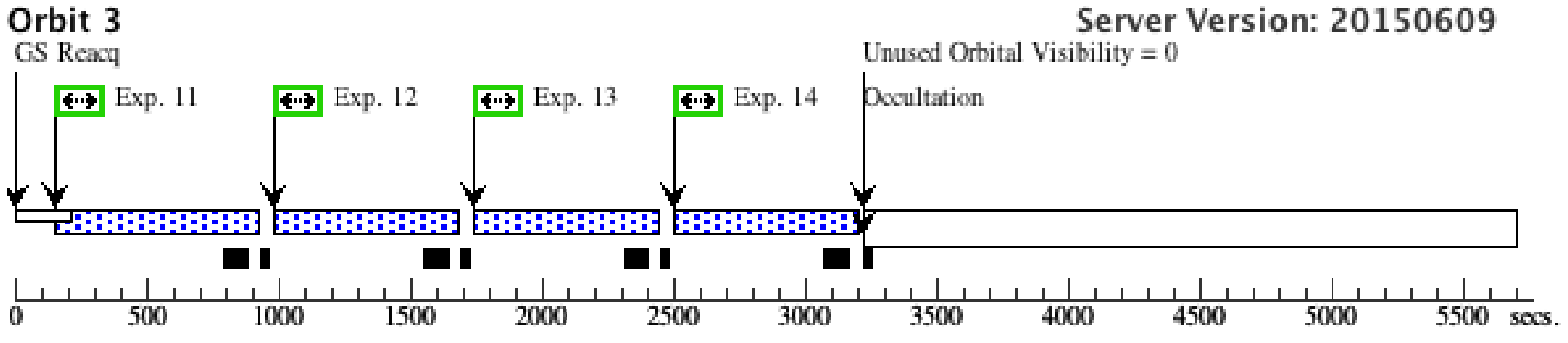
#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	AR Sco PE AKXD (COS.sa.755 453)	(1) V-AR-SCO	COS/FUV, ACQ/PEAKXD, PSA	G140L 1105 A				60 Secs (60 Secs) *[==>]*	***[1]***
	Comments: We have good orbital phase coverage with Swift UVW1 (2600A) and SDSS u (3650A), amplitude and flux in the two bands are identical, so we adopt a flat spectrum in Flambda. At orbital minimum, the flux in Swift UVW1 is 2e-15 erg/cm2/s/AA, and we set up the target acquisition to achieve a S/N of 40 at that faintest phase. At orbital maximum, the system reaches 1.2e-14 erg/cm2/s/AA. This is a factor ~30 below the COS bright limit for the chosen setup.								
2	AR Sco PE AKD (COS.sa.755 453)	(1) V-AR-SCO	COS/FUV, ACQ/PEAKD, PSA	G140L 1105 A	STEP-SIZE=0.9; CENTER=DEF; NUM-POS=5			60 Secs (60 Secs) *[==>]*	***[1]***
3	(COS.sp.755 475)	(1) V-AR-SCO	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=335; FP-POS=1			445 Secs (445 Secs) *[==>]*	***[1]***
	Comments: We have good orbital phase coverage with Swift UVW1 (2600A) and SDSS u (3650A), amplitude and flux in the two bands are identical, so we adopt a flat spectrum in Flambda. At orbital minimum, the flux in Swift UVW1 is 2e-15 erg/cm2/s/AA, at orbital maximum 1.2e-14 erg/cm2/s/AA. We adopt the max. flux for the ETC run given above. The bright phase is a factor ~30 below the COS maximum count rate.								
4	(COS.sp.755 475)	(1) V-AR-SCO	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=335; FP-POS=2			445 Secs (445 Secs) *[==>]*	***[1]***
5	(COS.sp.755 475)	(1) V-AR-SCO	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=335; FP-POS=3			445 Secs (445 Secs) *[==>]*	***[1]***
6	(COS.sp.755 475)	(1) V-AR-SCO	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=334; FP-POS=4			444 Secs (444 Secs) *[==>]*	***[1]***
7	(COS.sp.755 475)	(1) V-AR-SCO	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=537; FP-POS=1			647 Secs (647 Secs) *[==>]*	***[2]***
	Comments: We have good orbital phase coverage with Swift UVW1 (2600A) and SDSS u (3650A), amplitude and flux in the two bands are identical, so we adopt a flat spectrum in Flambda. At orbital minimum, the flux in Swift UVW1 is 2e-15 erg/cm2/s/AA, at orbital maximum 1.2e-14 erg/cm2/s/AA. We adopt the max. flux for the ETC run given above. The bright phase is a factor ~30 below the COS maximum count rate.								
8	(COS.sp.755 475)	(1) V-AR-SCO	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=537; FP-POS=2			647 Secs (647 Secs) *[==>]*	***[2]***
9	(COS.sp.755 475)	(1) V-AR-SCO	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=537; FP-POS=3			647 Secs (647 Secs) *[==>]*	***[2]***
10	(COS.sp.755 475)	(1) V-AR-SCO	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=537; FP-POS=4			650 Secs (650 Secs) *[==>]*	***[2]***
11	(COS.sp.755 475)	(1) V-AR-SCO	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=537; FP-POS=1			647 Secs (647 Secs) *[==>]*	***[3]***
	Comments: We have good orbital phase coverage with Swift UVW1 (2600A) and SDSS u (3650A), amplitude and flux in the two bands are identical, so we adopt a flat spectrum in Flambda. At orbital minimum, the flux in Swift UVW1 is 2e-15 erg/cm2/s/AA, at orbital maximum 1.2e-14 erg/cm2/s/AA. We adopt the max. flux for the ETC run given above. The bright phase is a factor ~30 below the COS maximum count rate.								
12	(COS.sp.755 475)	(1) V-AR-SCO	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=537; FP-POS=2			647 Secs (647 Secs) *[==>]*	***[3]***
13	(COS.sp.755 475)	(1) V-AR-SCO	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=537; FP-POS=3			647 Secs (647 Secs) *[==>]*	***[3]***

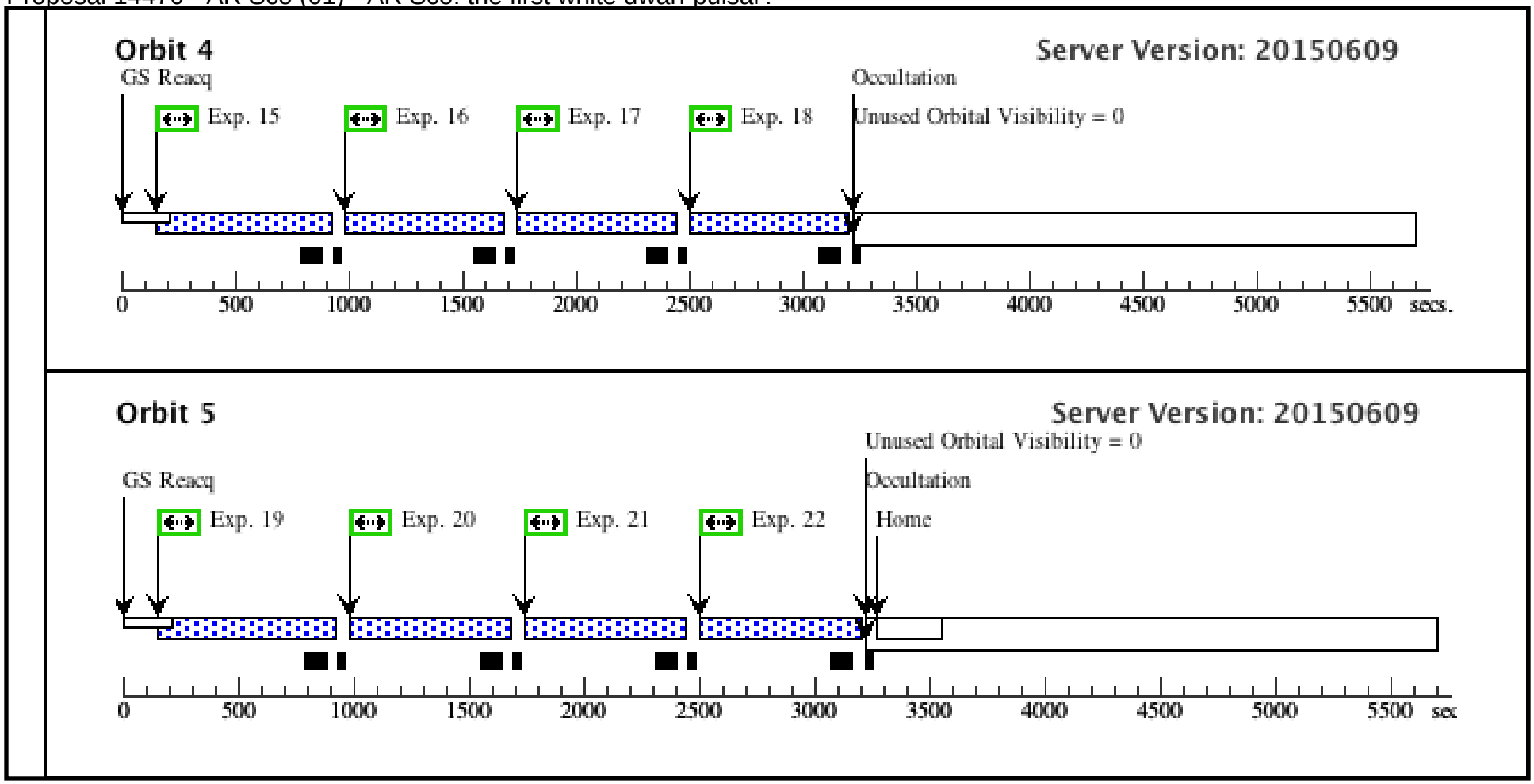
	14	(COS.sp.755 (1) V-AR-SCO 475)	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=537; FP-POS=4	650 Secs (650 Secs) *[==>]*	***[3]***
	15	(COS.sp.755 (1) V-AR-SCO 475)	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=537; FP-POS=1	647 Secs (647 Secs) *[==>]*	***[4]***
	Comments: We have good orbital phase coverage with Swift UVW1 (2600A) and SDSS u (3650A), amplitude and flux in the two bands are identical, so we adopt a flat spectrum in Flambda. At orbital minimum, the flux in Swift UVW1 is 2e-15 erg/cm2/s/AA, at orbital maximum 1.2e-14 erg/cm2/s/AA. We adopt the max. flux for the ETC run given above. The bright phase is a factor ~30 below the COS maximum count rate.						
	16	(COS.sp.755 (1) V-AR-SCO 475)	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=537; FP-POS=2	647 Secs (647 Secs) *[==>]*	***[4]***
	17	(COS.sp.755 (1) V-AR-SCO 475)	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=537; FP-POS=3	647 Secs (647 Secs) *[==>]*	***[4]***
	18	(COS.sp.755 (1) V-AR-SCO 475)	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=537; FP-POS=4	650 Secs (650 Secs) *[==>]*	***[4]***
	19	(COS.sp.755 (1) V-AR-SCO 475)	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=537; FP-POS=1	647 Secs (647 Secs) *[==>]*	***[5]***
	Comments: We have good orbital phase coverage with Swift UVW1 (2600A) and SDSS u (3650A), amplitude and flux in the two bands are identical, so we adopt a flat spectrum in Flambda. At orbital minimum, the flux in Swift UVW1 is 2e-15 erg/cm2/s/AA, at orbital maximum 1.2e-14 erg/cm2/s/AA. We adopt the max. flux for the ETC run given above. The bright phase is a factor ~30 below the COS maximum count rate.						
	20	(COS.sp.755 (1) V-AR-SCO 475)	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=537; FP-POS=2	647 Secs (647 Secs) *[==>]*	***[5]***
	21	(COS.sp.755 (1) V-AR-SCO 475)	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=537; FP-POS=3	647 Secs (647 Secs) *[==>]*	***[5]***
	22	(COS.sp.755 (1) V-AR-SCO 475)	COS/FUV, TIME-TAG, PSA	G140L 1105 A	BUFFER-TIME=537; FP-POS=4	650 Secs (650 Secs) *[==>]*	***[5]***

Orbit Structure





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GS Reacq
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Exp. 16
Exp. 17
Exp. 18
Occultation
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2000
2500
3000
3500
4000
4500
5000
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secs.
Orbit 5
Server Version: 20150609
Unused Orbital Visibility = 0
GS Reacq
Exp. 19
Exp. 20
Exp. 21
Exp. 22
Occultation
Home
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sec