



# 12916 - Continuing a Successful Multiwavelength Campaign: Watching the AGN Outflow from Mrk 509 with COS

Cycle: 20, Proposal Category: GO

(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) MRK-509	COS/FUV	4	16-Jul-2012 21:50:39.0	yes
02	(1) MRK-509	COS/FUV	4	16-Jul-2012 21:51:01.0	yes

8 Total Orbits Used

## ABSTRACT

Measuring variations in UV absorption lines is an important tool for determining the location, the mass, and the kinetic flux in outflows from active galaxies. Our team has been carrying out a highly successful multiwavelength campaign using XMM-Newton, Swift, INTEGRAL, Chandra, and HST to characterize the physical properties of the outflow from the Seyfert 1 galaxy Mrk 509. Here we propose to continue that campaign and obtain HST/COS spectra of Mrk 509 covering the main absorption lines in O VI, Ly alpha, Ly beta, Ly gamma, N V, Si IV, and C IV for comparison to previous observations obtained with COS, STIS, and FUSE. We will coordinate these observations with already scheduled Chandra HETG grating spectra in the fall of 2012. The high throughput of COS down to 1000 Å allows us to observe several Lyman series lines for measuring accurate total H I column densities, as well as O VI. This gives a direct tie to our X-ray spectra for determining absolute abundances in the outflow. Our observations will sample intermediate-to-longer-term timescales for variations in the outflow, ranging from 3 years since our prior COS observations, to 12 years since the prior FUSE observations. These timescales will allow us to detect variations in more distant, lower density gas that may comprise more massive components of the outflow, and thus have greater cosmological influence on the host galaxy and its surroundings.

## OBSERVING DESCRIPTION

We propose to obtain medium-resolution far-UV spectra of Mrk 509 using COS. We will use grating G140L primarily to measure absorption in the high-ionization O VI 1032,1038 resonance doublet, but this grating will also permit us to simultaneously measure absorption in Lyg, Lyb, N V 1238,1242, and C IV 1548,1550. Although this grating only provides a resolving power of R2000, this is well matched to the 100 km s<sup>-1</sup> spacing of the UV absorption components in Mrk 509 (Kriss et al. 2000; Kraemer et al. 2003; Kriss et al. 2011). To make more detailed measurements of trough profiles, optical depths, and covering factors, higher resolution is necessary, so we will also use gratings G130M to cover the Ly $\alpha$ , N V region at R 15,000, and G160M for C IV. The far-UV flux of Mrk 509 has historically ranged from a low of  $4.1 \times 10^{14}$  erg cm<sup>-2</sup> s<sup>-1</sup> Å<sup>-1</sup> at 1401 Å to a high of  $1.4 \times 10^{13}$  erg cm<sup>-2</sup> s<sup>-1</sup> Å<sup>-1</sup> (Dunn et al. 2006), with a mean flux of  $7.0 \times 10^{14}$  erg cm<sup>-2</sup> s<sup>-1</sup> Å<sup>-1</sup>. A

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S/N of 20 per resolution element in G140L would permit us to detect unresolved O VI absorption features as weak as  $50 \text{ m}^\circ\text{A}$  in the far blue wing of O VI, corresponding to an optically thin column density of  $4.3 \times 10^{13} \text{ cm}^2$ . Using the COS ETC (v20.1.1), achieving a S/N=20 at the mean historical flux would require 12,200 s of exposure time. This calculation is optimized for O VI, but we will achieve comparable S/N in Lyb and Lyg. For the longer-wavelength lines S/N will exceed 100, in principle. With multiple exposures at different FP-POS positions, this is possible.

For the medium resolution gratings, we need to achieve a S/N significantly better than the

20:1 of the STIS 2001 observation so that as with our 2009 COS observations, errors in the comparison are dominated by the quality of the historical STIS data. This is possible for a S/N=30 per resolution element in COS, which is readily achievable with multiple FP-POS and central wavelength settings. Achieving S/N=30 in the continuum under Ly $\alpha$  and N V using G130M requires 1500 s; for C IV using G160M, we would need 3900 s. This S/N level would enable us to see variations in the transmission of the main absorption troughs of  $< 5\%$ , comparable to the results of our comparison of COS spectra in 2009 to STIS spectra from 2001 (Arav et al. 2012).

The continuum variations of Mrk 509 in the ultraviolet are well characterized by a powerdensity spectrum with a spectral index of  $2.06 \pm 0.14$  with a fractional variation of  $F_{\text{var}} = 0.29$

(Collier & Peterson 2001). For a random observation time in the future, we can then expect continuum variations of 29%. As Arav et al. (2012) show, these translate roughly proportionately into column density variations in C IV and N V. With our ability to detect trough variations as small as  $< 5\%$ , the controlling factor in determining whether we see changes in the absorption troughs is the density of the medium. Thus, we will be sensitive to lower-density gas with recombination timescales as long as 12 years, 50% longer than sampled by previous observations.

These observations pose no bright object concerns. All historical flux levels for Mrk 509 lie below the bright object limits for COS. Since Mrk 509 has been observed successfully before, there are also no surrounding field objects that are too bright.

Mrk 509 has an orbital visibility of 54 m. Since the target is a bright point source, we will use dispersed light target acquisition as in past observations of Mrk 509 with COS. Using trial orbit layouts in APT, after target acquisition, 1900 s remains for science on the first orbit, and 2700 s in subsequent orbits. The required observing time detailed above will require a total of 7.6 orbits, which we round up to a total of 8 orbits. We break this up into 2 visits to facilitate coordination with Chandra.

Visit 1 should be coordinated with Chandra to within 4 days. For this visit we use exposures in all three gratings---G130M, G160M, and G140L, to cover all desired spectral features with a minimum S/N of 15. Visit 2 is identical in structure. Ideally, to obtain our target total S/N, it should be

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scheduled close in time to Visit 1 (within 4-8 days) so that variability would not preclude combining the two data sets. However, to give flexibility in scheduling, Visit 2 could be scheduled at any time in the fall observing season, which ends for Mrk 509 on ~December 11. Such a visit would have the scientific value of permitting monitoring of variability on short timescales.

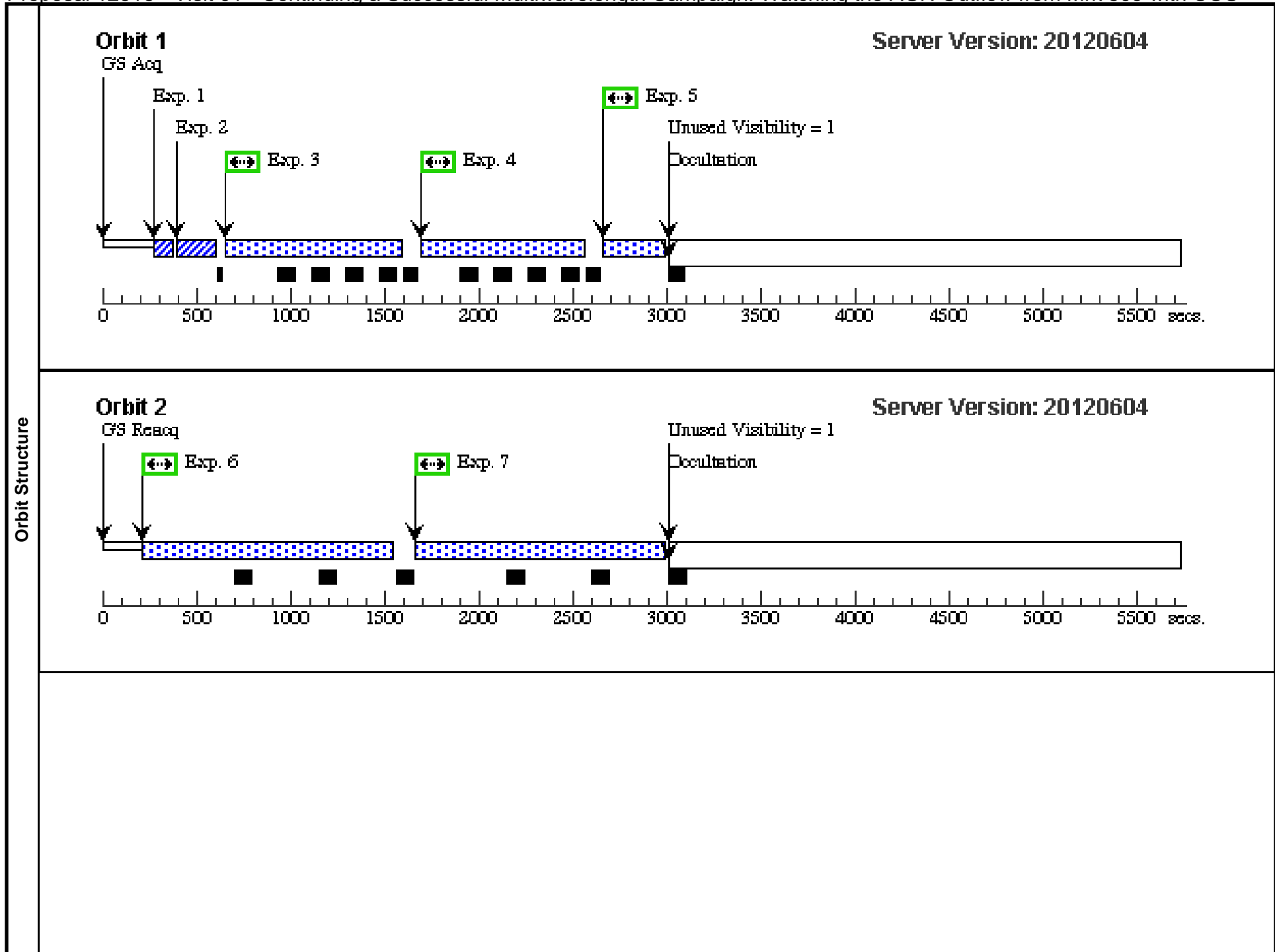
#### **ADDITIONAL COMMENTS**

Visit 1 is to be coordinated to within 4 days with Chandra observations, currently in their long-range plan for September 3-9.

Proposal 12916 - Visit 01 - Continuing a Successful Multiwavelength Campaign: Watching the AGN Outflow from Mrk 509 with COS

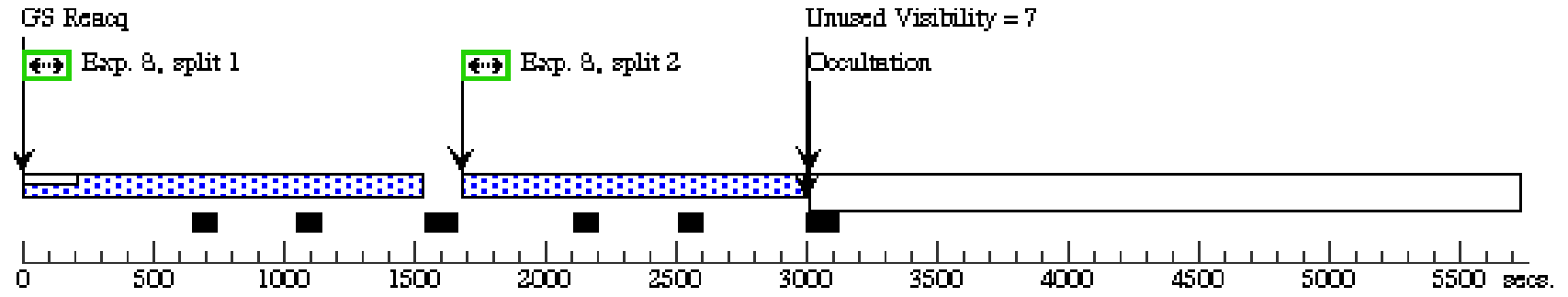
Tue Jul 17 01:51:12 GMT 2012

<b>Visit</b>	<b>Proposal 12916, Visit 01, implementation</b> <b>Diagnostic Status: Warning</b> Scientific Instruments: COS/FUV Special Requirements: SCHED 100%; BETWEEN 03-SEP-2012:00:00:00 AND 10-SEP-2012:23:59:59 <i>Comments: This visit to be coordinated to within 4 days with Chandra observations, currently in the long-range plan for September 3-10.</i>									
	(Visit 01) Warning (Form): If the target coordinates are not known to 0.4" (or better) an ACQ/SEARCH should precede the ACQ/PEAKXD. (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.									
<b>Diagnosics</b>										
<b>Fixed Targets</b>	<b>#</b>	<b>Name</b>	<b>Target Coordinates</b>	<b>Targ. Coord. Corrections</b>	<b>Fluxes</b>	<b>Miscellaneous</b>				
	(1)	MRK-509 Alt Name1: S3310133907	RA: 20 44 9.7483 (311.0406179d) Dec: -10 43 24.63 (-10.72351d) Equinox: J2000		V=13.12	Reference Frame: ICRS				
<i>Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.</i>										
<b>Exposures</b>	<b>#</b>	<b>Label (ETC Run)</b>	<b>Target</b>	<b>Config,Mode,Aperture</b>	<b>Spectral Els.</b>	<b>Opt. Params.</b>	<b>Special Reqs.</b>	<b>Groups</b>	<b>Exp. Time/[Actual Dur.]</b>	<b>Orbit</b>
	1	(COS.sa.412 190)	(1) MRK-509	COS/FUV, ACQ/PEAKXD, PSA	G130M 1309 A				11.5 Secs [==>]	[1]
	2	(COS.sa.412 190)	(1) MRK-509	COS/FUV, ACQ/PEAKD, PSA	G130M 1309 A	NUM-POS=5; STEP-SIZE=0.85			11.5 Secs [==>]	[1]
	3	(COS.sp.412 204)	(1) MRK-509	COS/FUV, TIME-TAG, PSA	G130M 1309 A	FP-POS=1; BUFFER-TIME=18 0			820 Secs [==>821.0 Secs ]	[1]
	4	(COS.sp.412 204)	(1) MRK-509	COS/FUV, TIME-TAG, PSA	G130M 1309 A	FP-POS=2; BUFFER-TIME=18 0			820 Secs [==>821.0 Secs ]	[1]
	5	(COS.sp.412 208)	(1) MRK-509	COS/FUV, TIME-TAG, PSA	G160M 1577 A	FP-POS=1; BUFFER-TIME=20 0			150 Secs [==>151.0 Secs ]	[1]
	6	(COS.sp.412 208)	(1) MRK-509	COS/FUV, TIME-TAG, PSA	G160M 1577 A	FP-POS=2; BUFFER-TIME=45 0			1270 Secs [==>1278.0 Secs ]	[2]
	7	(COS.sp.412 208)	(1) MRK-509	COS/FUV, TIME-TAG, PSA	G160M 1577 A	FP-POS=3; BUFFER-TIME=45 0			1270 Secs [==>1278.0 Secs ]	[2]
	8	(COS.sp.412 214)	(1) MRK-509	COS/FUV, TIME-TAG, PSA	G140L 1280 A	FP-POS=ALL; BUFFER-TIME=40 0			1260 Secs [==>(Split 1)] [==>(Split 2)] [==>(Split 3)] [==>(Split 4)]	[3] [4]



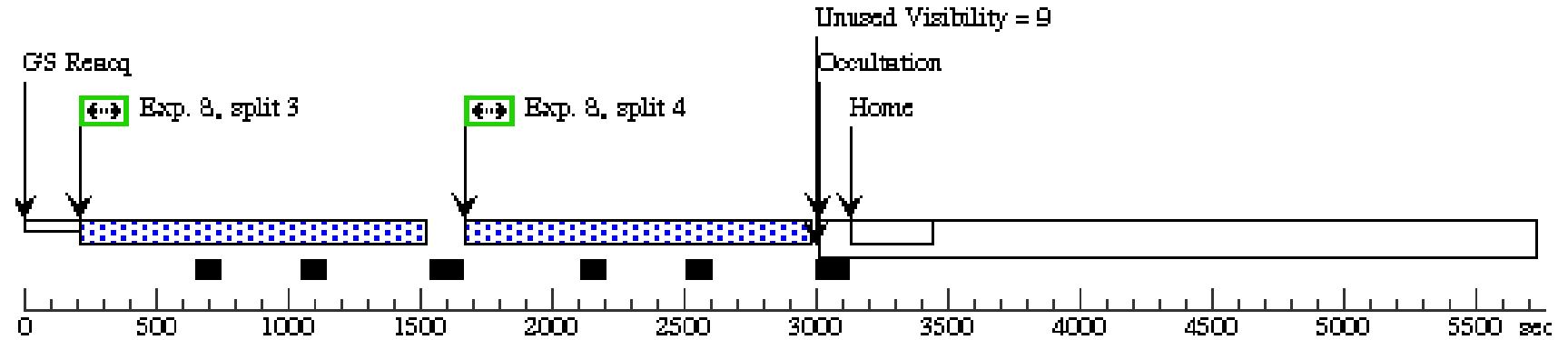
### Orbit 3

Server Version: 20120604



### Orbit 4

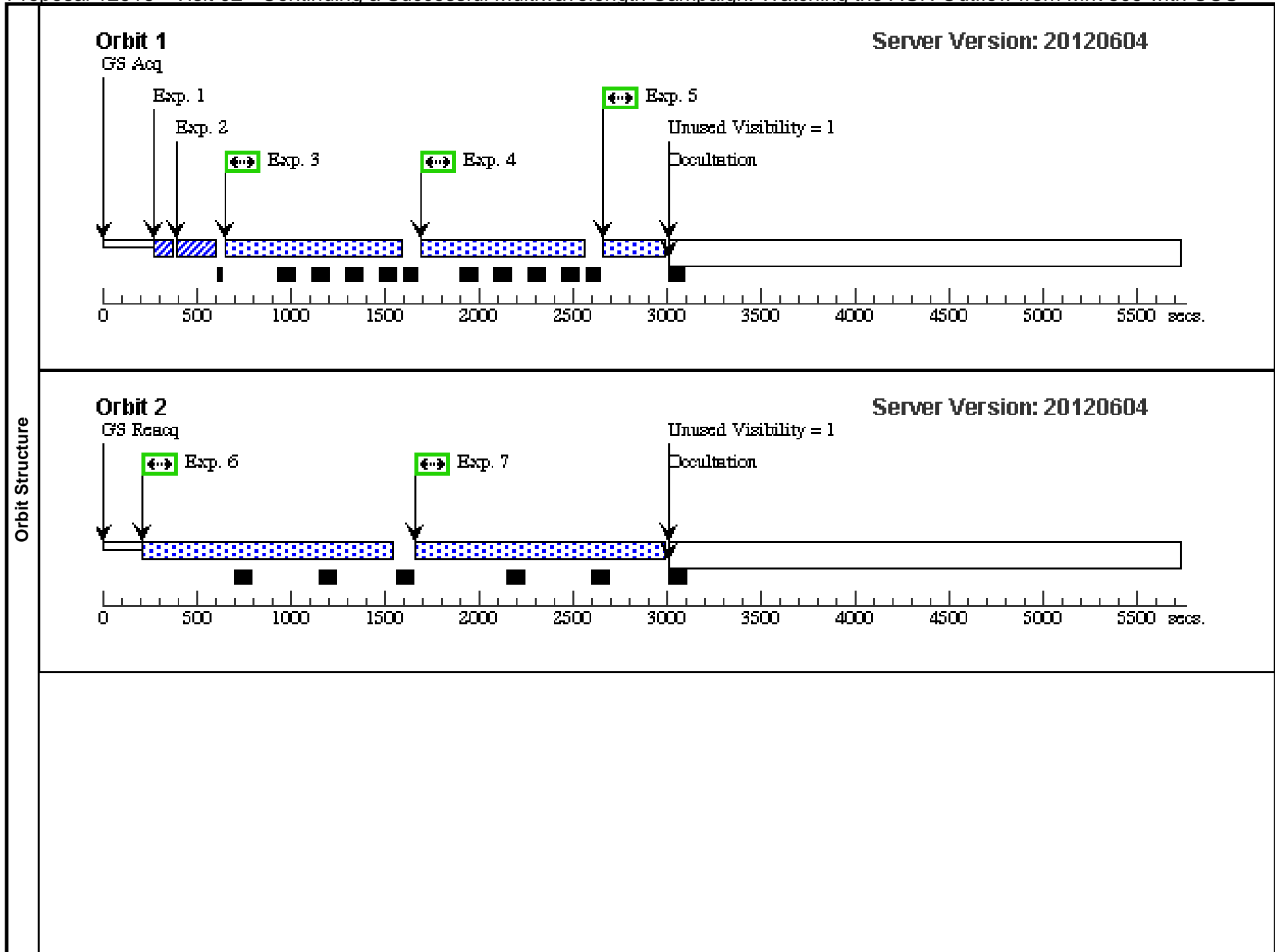
Server Version: 20120604



Proposal 12916 - Visit 02 - Continuing a Successful Multiwavelength Campaign: Watching the AGN Outflow from Mrk 509 with COS

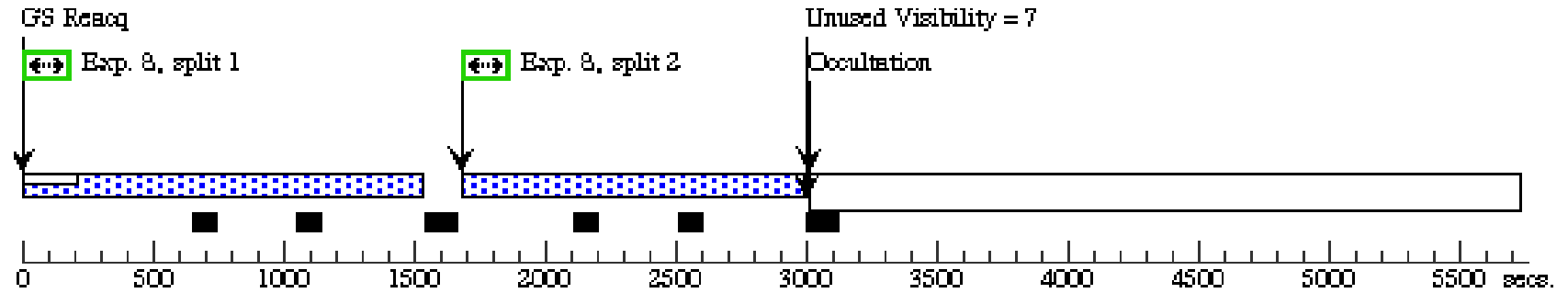
Tue Jul 17 01:51:17 GMT 2012

<b>Visit</b>	<b>Proposal 12916, Visit 02, implementation</b> <b>Diagnostic Status: Warning</b> Scientific Instruments: COS/FUV Special Requirements: SCHED 100% <i>Comments: This visit should ideally take place in close proximity to Visit 1, but we have not put any time constraints on it as to give flexibility in the scheduling. It is more important that Visit 1 be coordinated with Chandra. However, Visit 2 should be scheduled during this fall's observing season, which ends around December 11, 2012.</i>																	
	(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. (Visit 02) Warning (Form): If the target coordinates are not known to 0.4" (or better) an ACQ/SEARCH should precede the ACQ/PEAKXD.																	
<b>Fixed Targets</b>	<table border="1"> <thead> <tr> <th>#</th> <th>Name</th> <th>Target Coordinates</th> <th>Targ. Coord. Corrections</th> <th>Fluxes</th> <th>Miscellaneous</th> </tr> </thead> <tbody> <tr> <td>(1)</td> <td>MRK-509</td> <td>RA: 20 44 9.7483 (311.0406179d) Alt Name1: S3310133907 Dec: -10 43 24.63 (-10.72351d) Equinox: J2000</td> <td></td> <td>V=13.12</td> <td>Reference Frame: ICRS</td> </tr> </tbody> </table>						#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous	(1)	MRK-509	RA: 20 44 9.7483 (311.0406179d) Alt Name1: S3310133907 Dec: -10 43 24.63 (-10.72351d) Equinox: J2000		V=13.12	Reference Frame: ICRS
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### Orbit 3

Server Version: 20120604



### Orbit 4

Server Version: 20120604

