



10827 - Imaging Polarimetry of the Seyfert 1 MCG-6-30-15: Clues to the Structure of Warm Absorbers

Cycle: 15, 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) MCG-6-30-15	WFPC2	2	17-Jan-2008 14:41:42.0	yes
02	(1) MCG-6-30-15	WFPC2	2	17-Jan-2008 14:41:48.0	yes
52	(1) MCG-6-30-15	WFPC2	2	17-Jan-2008 14:41:52.0	yes
03	(1) MCG-6-30-15	WFPC2	2	17-Jan-2008 14:41:58.0	yes

8 Total Orbits Used

ABSTRACT

Imaging polarimetry at high spatial resolution, which is only possible with HST, offers a potentially powerful new tool for determining the orientation and geometry of AGN containing warm absorbers. These absorbed AGN tend to be more highly polarized than unabsorbed Type 1s, but less polarized than Type 2s. If the polarized flux is due to a polar scattering region as seen in polarized flux images of Seyfert 2s, imaging polarimetry of nearby absorbed Type 1 objects using HST can detect and resolve these scattering regions. We propose to make the first HST imaging polarimetry study of an absorbed Seyfert 1 by obtaining broad-band polarization images with WFPC2 of the prototypical "dusty warm absorber" in MCG-6-30-15 ($z=0.0077$, $D\sim 33$ Mpc). We will measure the wavelength dependence of the polarized light free from dilution by the host galaxy starlight in order to assess whether the polarization is due to a nuclear scattering region or dichroic transmission through the absorbing dust. These observations will enable us to (1) use the wavelength dependence of unresolved polarized flux to understand the properties of the absorbing dust suggested by X-ray spectral features attributed to Fe~I absorption, and (2) test whether polarization in warm absorbers is due to resolved polar scattering regions. Resolving the scattering region in a moderately polarized Seyfert 1 such as MCG-6-30-15 will let us answer the question of whether line-of-sight inclination can be directly linked to observed outflow characteristics, as suggested by the most recent unified models of AGN outflows.

OBSERVING DESCRIPTION

We will use WFPC2 with the broad-band filters F555W and F675W to obtain imaging polarimetry of the Seyfert 1 galaxy MCG-6-30-15. We divide our 6-orbit allocation into 3 visits of 2 orbits each. To obtain the requisite minimum observations through a polarization filter at three different angles, we must rely on spacecraft roll to provide the different orientations on the sky of the polarizing filter that works best with chip PC1 (POLQ; Biretta & Sparks 1995, ISR WFPC2 95-01). The proposed broadband filters have the highest throughput and the lowest systematic calibration errors, $\sim 1\%$ (Biretta & McMaster 1997, ISR WFPC2 97-11). At $z=0.0077$ (33 Mpc for $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$), the PC's 0.046 arc-second scale will provide us with 7.4 pc per pixel. The flux of the unresolved nuclear source in the WFPC2/F606W image of MCG--6-30-15 obtained by Malkan et al (1998) is $1.53 \times 10^{-15} \text{ ergs cm}^{-2} \text{ s}^{-1} \text{ \AA}^{-1}$ at 6060 \AA. We use this flux to normalize the spectrum, which we assume is a powerlaw $f_\nu \sim \nu^{-2}$ reddened by $E(B-V)=0.8$, following Reynolds et al (1997). We also include the stellar background light within 1 arc sec of the nucleus, which we measure to have a surface brightness in the V band of $18.5 \text{ mag arcsec}^{-2}$. The polarization of MCG--6-30-15, as measured through 4--6 arc second apertures using ground-based telescopes, ranges from 3.1--5.1% from the I band to the B band (Thompson & Martin 1988; Brindle et al 1990a). Naturally, this is

diluted by host-galaxy starlight in these large apertures. Our analysis of the WFPC2/F606W image of \mcb6\ shows that only 25\% of the flux in the 4--6"\$ apertures used for the ground-based polarimetry comes from the active nucleus. Thus, if the diluting starlight is unpolarized, we expect to see polarizations as high as 12--20\% in our HST images.

The polarization properties of the nucleus in MCG--6-30-15 are well known and well studied. It is the potential faint, extended scattering regions that we are searching for. To show that we can easily detect a polarized extended source that may represent the scattering region in MCG--6-30-15 we calculate the expected S/N and polarization error σ_p using the approximation $\sigma_p = \sqrt{2} / (S/N)$ (where the S/N is for $\{i\}$ of the three observations) with results in Table 1. We assume that the scattering region is a 2×2 pixel region (15×15 pc) containing 1\% of the nuclear flux with an intrinsic polarization of 25\% (typical of dust scattering regions seen in other AGN, e.g., the NE dust knot in NGC 1068, Miller \etal 1991). Since the scattering cone in NGC~1068 is visible to projected distances of ~ 1 --3 arc sec, we would expect comparable structures in MCG--6-30-15 to lie at distances of ~ 0.3 --1.0 arc sec. We must also subtract the bright nuclear source from this region. The wings of the PSF at radii of ~ 0.3 arcsec (0.2\% of peak at 0.3 arcsec) are comparable to the surface brightness of the host galaxy for a source as bright as MCG--6-30-15 Section 7.3 of the WFPC2 Instrument Handbook shows that sources as faint as $\Delta m = 6.4 - 7.3$ relative to the nuclear source can be detected at the 3σ level in the region $0.25 - 0.40$ arcsec. Our hypothetical scattering region has $\Delta m = 5.0$, so PSF subtraction should pose little difficulty, even with the blooming and saturation

expected in our individual exposures. This will affect only the central 5 pixels.

Table 1. S/N Results for Imaging Polarimetry of MCG--6-30-15

Filter	P(%)	S/N(pt src)	σ_p	S/N(ext src)	σ_p
F555W	4%	1121	0.14%	112	1.2%
F675W	2%	1086	0.14%	111	1.2%

Integration times are 4 x 260 s in all filters, with GAIN=7, no CR-SPLIT, and average backgrounds. Columns 3 and 4 give the S/N and σ_p for an unresolved point source. Columns 5 and 6 give the same for a 2×2 pixel extended region with 1% of the flux of the nuclear source and an intrinsic polarization of 25% superposed on the stellar background of MCG--6-30-15 and the PSF of the nuclear point source (0.2% of peak at 0.3 arcsec). The bright source and the background provided by the host galaxy light make CTE losses negligible ($< 10\%$).

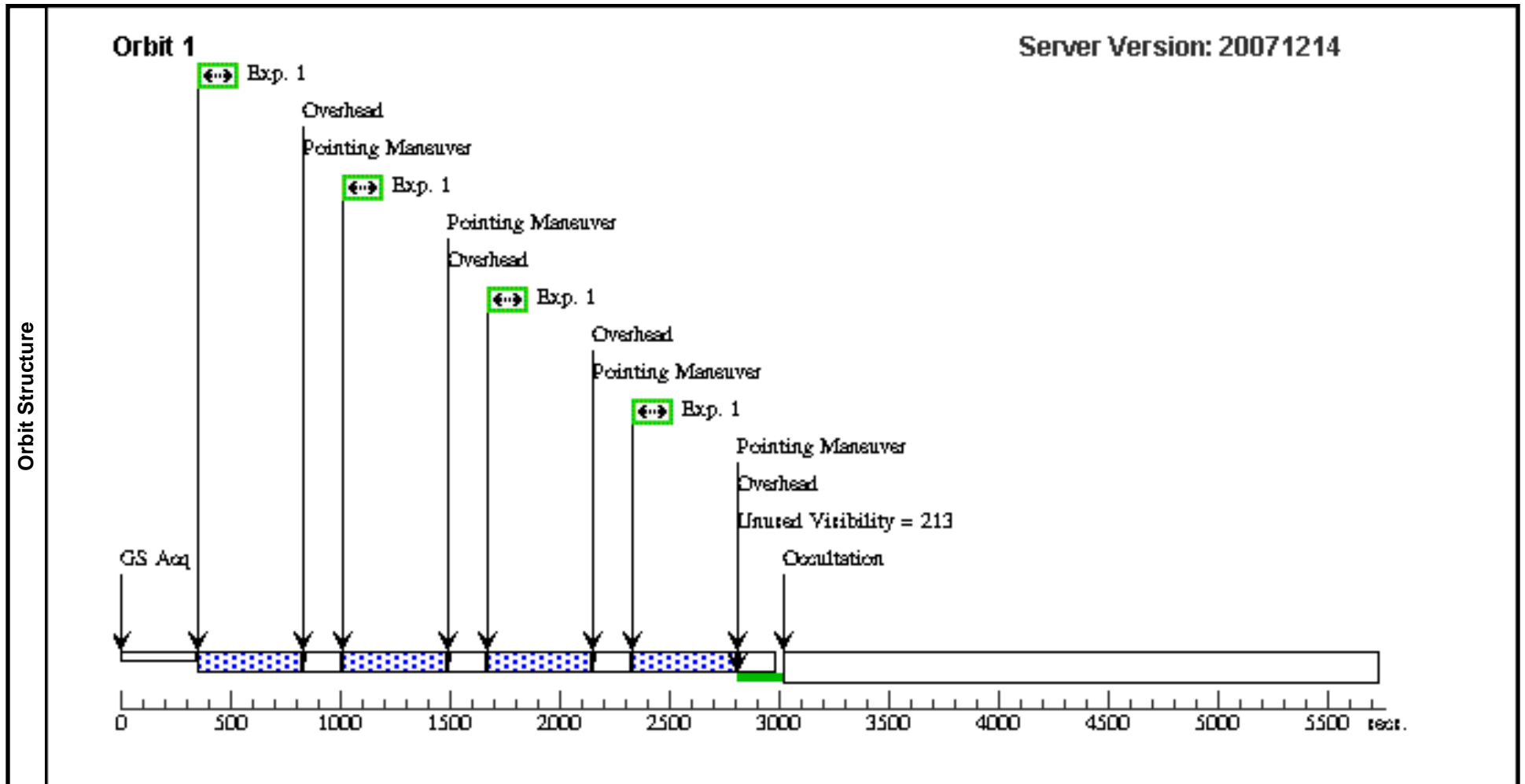
Therefore, we propose observations that will consist of three 2-orbit visits.

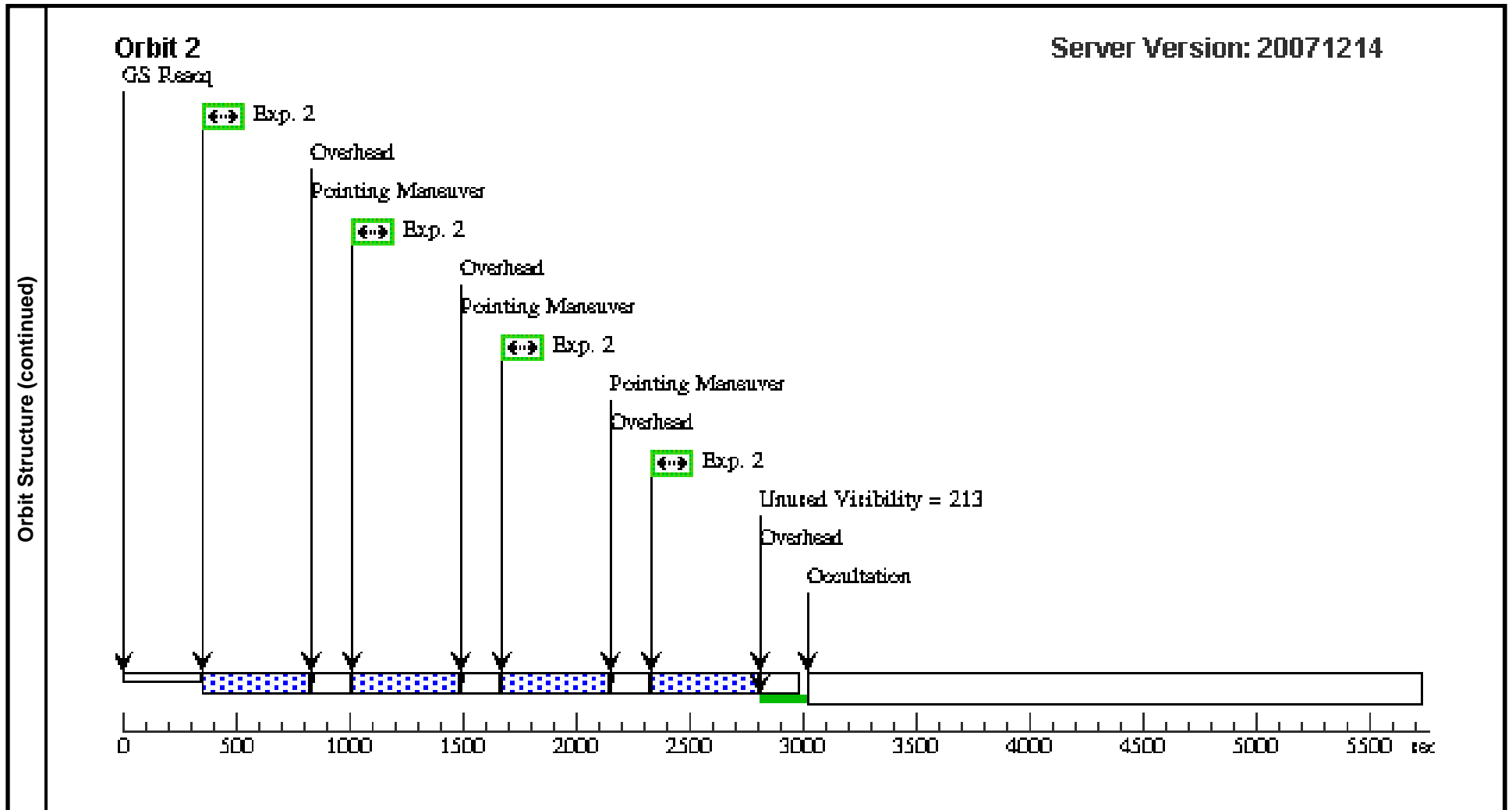
Each visit will have a different roll angle to appropriately sample the Stokes parameters through the polarized filter. On each visit we will use one orbit each to observe through the filters POLQ plus F555W and F675W. We will execute a 4-point dither pattern in each filter to optimally sample the PSF and to reject bad pixels and cosmic rays. Since individual exposures are no more than 260 s, we do not CR-SPLIT the individual exposures. The four dithered images will suffice to reject both hot pixels and cosmic rays.

Proposal 10827 - Visit 01 - Imaging Polarimetry of the Seyfert 1 MCG-6-30-15: Clues to the Structure of Warm Absorbers

Thu Jan 17 19:42:02 GMT 2008

Visit	Proposal 10827, Visit 01, scheduling Diagnostic Status: No Diagnostics Scientific Instruments: WFPC2 Special Requirements: SCHED 100%; ORIENT 270.0D TO 285.0 D <i>Comments: First of three visits at different orientations to fully sample the polarization Stokes parameters.</i>									
	Patterns	#	Primary Pattern				Secondary Pattern			Exposures
(1)		Pattern Type=WFPC2-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.559017 Line Spacing=0.559017	Coordinate Frame=POS-TARG Pattern Orientation=26.56505 Angle Between Sides=143.1301 Center Pattern=false						(1), (2)	
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	MCG-6-30-15	RA: 13 35 53.8000 (203.9741667d) Dec: -34 17 44.00 (-34.29556d) Equinox: J2000	Radial Velocity: 2323 km/sec	V=16+/-0.2 1.5e-15 erg/cm2/s/A at 6060 A	Reference Frame: NED				
<i>Comments: This object was generated by the targetselector and retrieved from the NED database.</i>										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
	1	(1) MCG-6-30-15	WFPC2, IMAGE, PC1	F555W POLQ	POS TARG 8.0,8.0	Pattern 1-1 (1)	260.0 Secs		[1]	
										[=>(Pattern 1)]
										[=>(Pattern 2)]
								[=>(Pattern 3)]		
								[=>(Pattern 4)]		
2	(1) MCG-6-30-15	WFPC2, IMAGE, PC1	F675W POLQ	POS TARG 8.0,8.0	Pattern 2-2 (1)	260.0 Secs		[2]		
									[=>(Pattern 1)]	
									[=>(Pattern 2)]	
									[=>(Pattern 3)]	
								[=>(Pattern 4)]		

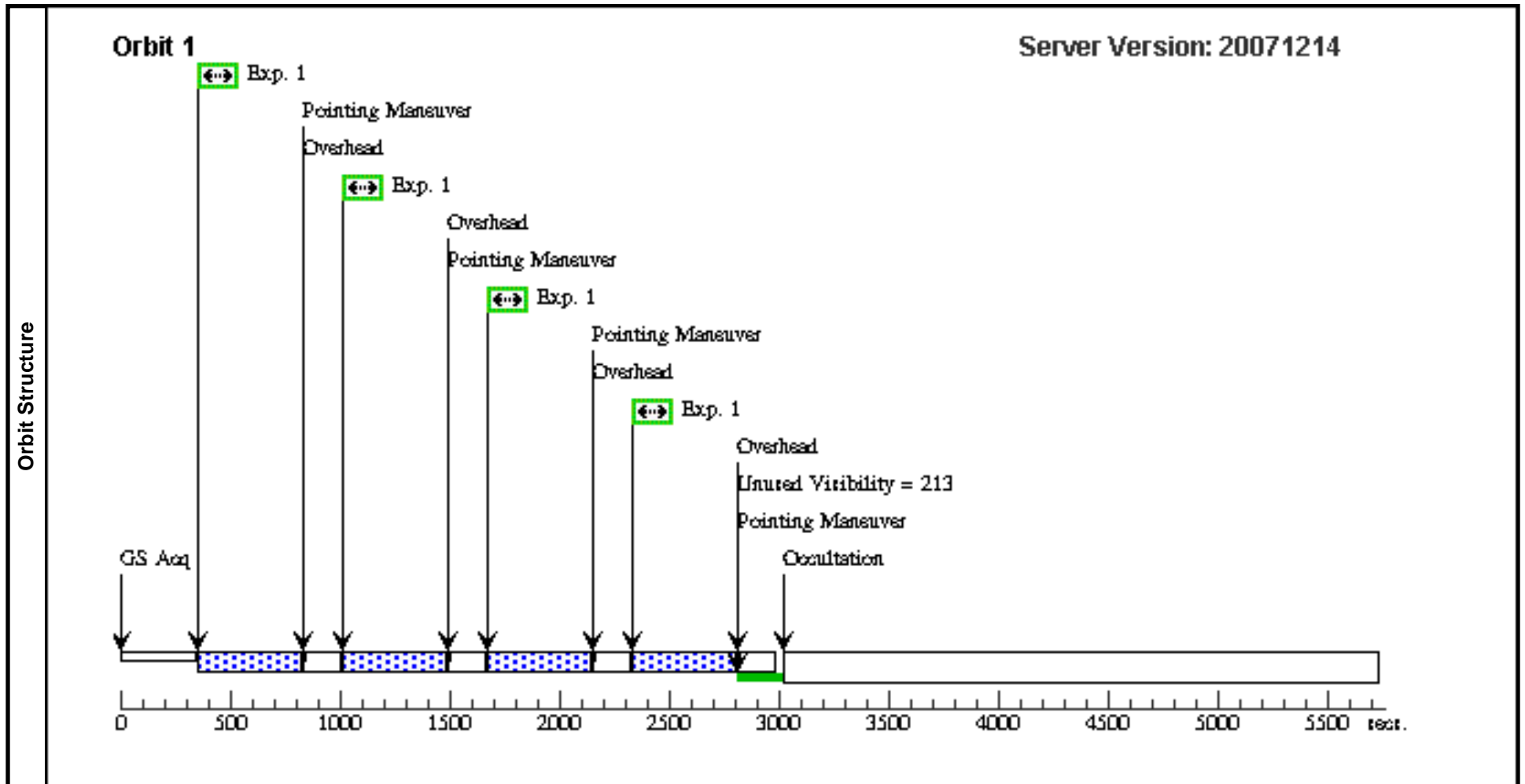


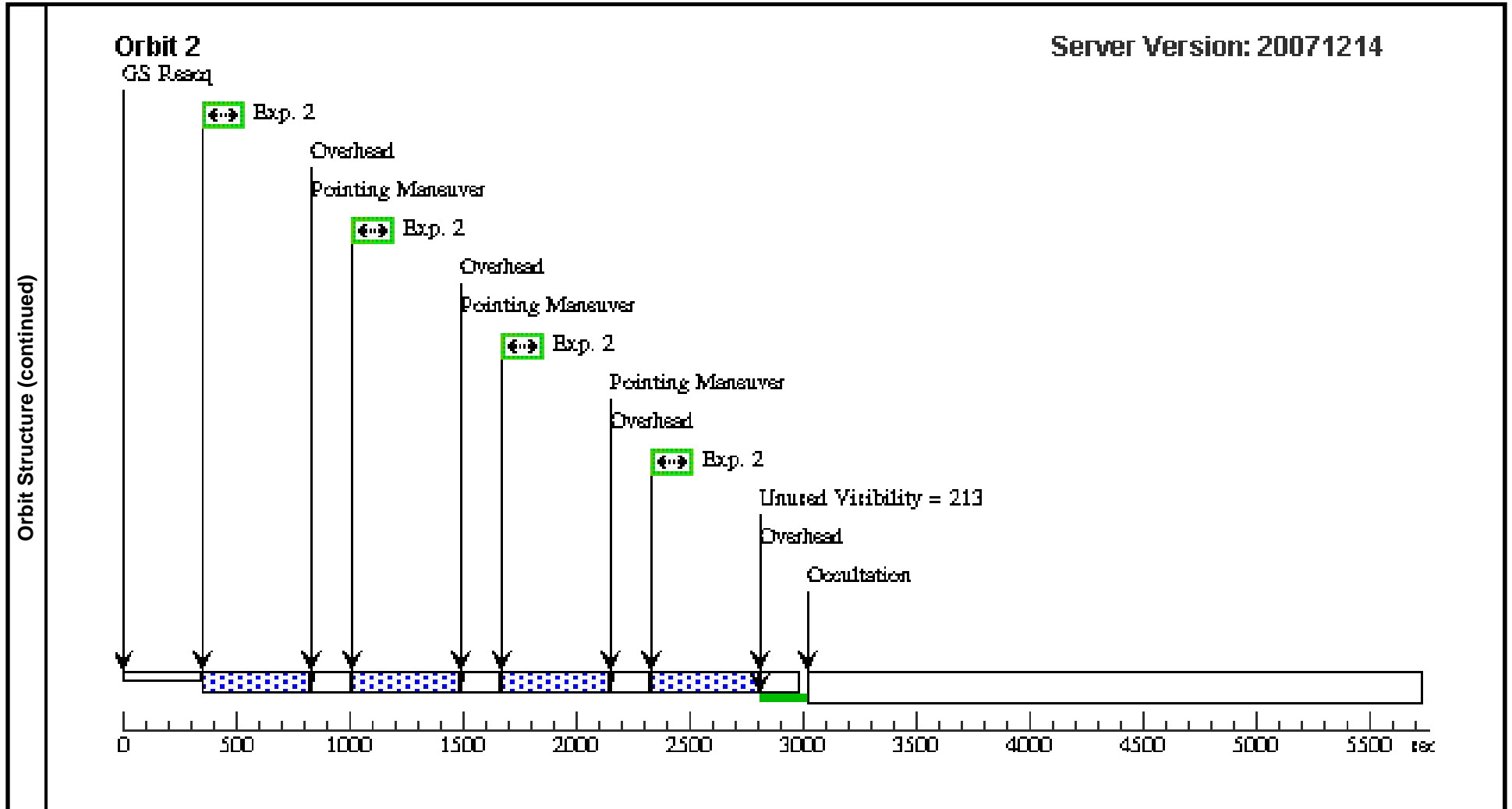


Proposal 10827 - Visit 02 - Imaging Polarimetry of the Seyfert 1 MCG-6-30-15: Clues to the Structure of Warm Absorbers

Thu Jan 17 19:42:03 GMT 2008

Visit	Proposal 10827, Visit 02, completed Diagnostic Status: No Diagnostics Scientific Instruments: WFPC2 Special Requirements: SCHED 100%; ORIENT 330.0D TO 359.9 D <i>Comments: Second of three visits at different orientations to fully sample the polarization Stokes parameters.</i>									
	Patterns	#	Primary Pattern				Secondary Pattern			Exposures
(1)		Pattern Type=WFPC2-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.559017 Line Spacing=0.559017	Coordinate Frame=POS-TARG Pattern Orientation=26.56505 Angle Between Sides=143.1301 Center Pattern=false						(1), (2)	
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	MCG-6-30-15	RA: 13 35 53.8000 (203.9741667d) Dec: -34 17 44.00 (-34.29556d) Equinox: J2000	Radial Velocity: 2323 km/sec	V=16+/-0.2 1.5e-15 erg/cm2/s/A at 6060 A	Reference Frame: NED <i>Comments: This object was generated by the targetselector and retrieved from the NED database.</i>				
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
	1	(1) MCG-6-30-15	WFPC2, IMAGE, PC1	F555W POLQ	POS TARG 8.0,8.0	Pattern 1-1 (1)	260.0 Secs	[=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)]	[1]	
	2	(1) MCG-6-30-15	WFPC2, IMAGE, PC1	F675W POLQ	POS TARG 8.0,8.0	Pattern 2-2 (1)	260.0 Secs	[=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)]	[2]	

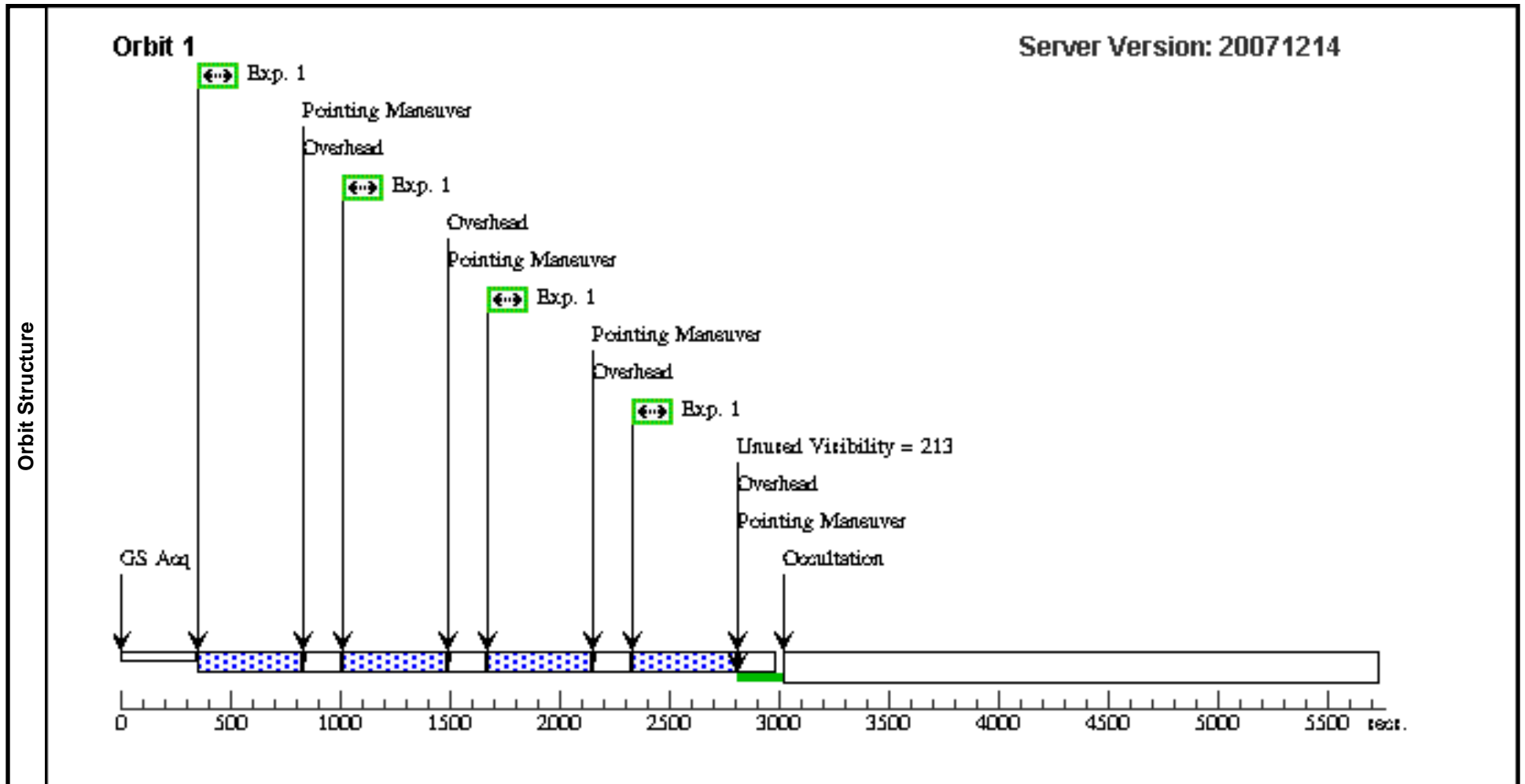


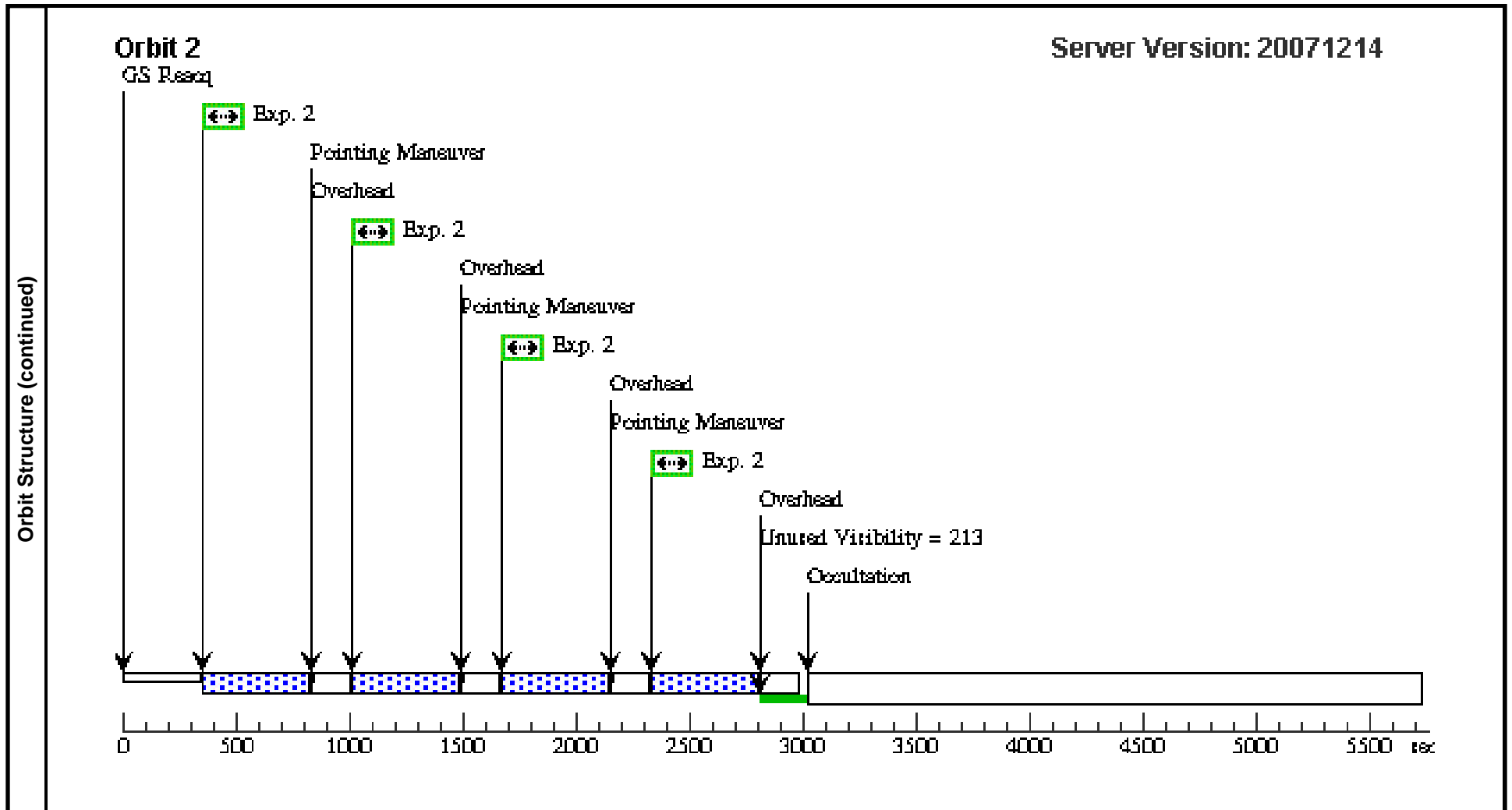


Proposal 10827 - Visit 52 - Imaging Polarimetry of the Seyfert 1 MCG-6-30-15: Clues to the Structure of Warm Absorbers

Thu Jan 17 19:42:04 GMT 2008

Visit	Proposal 10827, Visit 52 Diagnostic Status: No Diagnostics Scientific Instruments: WFPC2 Special Requirements: SCHED 100%; ORIENT 330.0D TO 359.9 D <i>Comments: Second of three visits at different orientations to fully sample the polarization Stokes parameters.</i>									
	Patterns	#	Primary Pattern				Secondary Pattern			Exposures
(1)		Pattern Type=WFPC2-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.559017 Line Spacing=0.559017	Coordinate Frame=POS-TARG Pattern Orientation=26.56505 Angle Between Sides=143.1301 Center Pattern=false						(1), (2)	
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	MCG-6-30-15	RA: 13 35 53.8000 (203.9741667d) Dec: -34 17 44.00 (-34.29556d) Equinox: J2000	Radial Velocity: 2323 km/sec	V=16+/-0.2 1.5e-15 erg/cm2/s/A at 6060 A	Reference Frame: NED				
<i>Comments: This object was generated by the targetselector and retrieved from the NED database.</i>										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
	1	(1) MCG-6-30-15	WFPC2, IMAGE, PC1	F555W POLQ	POS TARG 8.0,8.0	Pattern 1-1 (1)	260.0 Secs	[=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)]	[1]	
	2	(1) MCG-6-30-15	WFPC2, IMAGE, PC1	F675W POLQ	POS TARG 8.0,8.0	Pattern 2-2 (1)	260.0 Secs	[=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)]	[2]	





Proposal 10827 - Visit 03 - Imaging Polarimetry of the Seyfert 1 MCG-6-30-15: Clues to the Structure of Warm Absorbers

Thu Jan 17 19:42:05 GMT 2008

Visit	Proposal 10827, Visit 03, scheduling Diagnostic Status: No Diagnostics Scientific Instruments: WFPC2 Special Requirements: SCHED 100%; ORIENT 300.0D TO 315.0 D <i>Comments: Third of three visits at different orientations to fully sample the polarization Stokes parameters.</i>									
	Patterns	#	Primary Pattern				Secondary Pattern			Exposures
(1)		Pattern Type=WFPC2-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.559017 Line Spacing=0.559017	Coordinate Frame=POS-TARG Pattern Orientation=26.56505 Angle Between Sides=143.1301 Center Pattern=false						(1), (2)	
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	MCG-6-30-15	RA: 13 35 53.8000 (203.9741667d) Dec: -34 17 44.00 (-34.29556d) Equinox: J2000	Radial Velocity: 2323 km/sec	V=16+/-0.2 1.5e-15 erg/cm2/s/A at 6060 A	Reference Frame: NED <i>Comments: This object was generated by the targetselector and retrieved from the NED database.</i>				
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
	1	(1) MCG-6-30-15	WFPC2, IMAGE, PC1	F555W POLQ	POS TARG 8.0,8.0	Pattern 1-1 (1)	260.0 Secs	[=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)]	[1]	
	2	(1) MCG-6-30-15	WFPC2, IMAGE, PC1	F675W POLQ	POS TARG 8.0,8.0	Pattern 2-2 (1)	260.0 Secs	[=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)]	[2]	

