10703 - Life in the fast lane: The dark-matter distribution in the most massive galaxy clusters in the Universe at z>0.5

Cycle: 13, Proposal Category: GO/DD

(Availability Mode: SUPPORTED)

INVESTIGATORS

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VISITS

Visit	*Targets*	*Configurations*	*Orbits Used*	*Last Orbit Planner Run*	*OP Current with Visit?*
01	(1) MACSJ0025-1222	ACS/WFC	4	14-Dec-2005 21:23:46.0	yes
51	(1) MACSJ0025-1222	ACS/WFC	4	14-Dec-2005 21:24:02.0	yes

8 Total Orbits Used

ABSTRACT

We propose two-filter ACS observations of a complete sample of 12 very X-ray luminous galaxy clusters at 0.5<z<0.7 as a cornerstone of a comprehensive multi-wavelength study of the properties of the most massive clusters in the universe. Our sample includes the famous systems Cl0016+16 and MS0451-03; all other clusters are new discoveries from the MACS survey. Being the counterparts of the best-studied systems at lower and higher redshift and comprising ALL massive clusters at 0.5<z<0.7 observable from Mauna Kea this sample will become the ultimate reference for cluster studies at z>0.5. HST's unique capabilities will allow us to: 1) measure accurately the clusters' dark matter distribution on scales from tens to more than 500/h_50 kpc from observations of strong and weak gravitational lensing, 2) use galaxy-galaxy lensing to measure the shape, extent, and mass content of the dark-matter halos of both cluster and field galaxies, and 3) study the color morphology of mergers and the star formation history of galaxies in a high-density environment. The proposed observations are complemented by Chandra observations of all our targets (all 12 awarded, 11 executed to date) which provide independent constraints on the dark matter and gas distribution in the cluster cores, as well a by extensive groundbased observations of weak lensing on yet larger scales, galaxy dynamics, and the SZ effect.

OBSERVING DESCRIPTION

PROPOSED OBSERVATIONS

We propose moderately deep ACS observations in two passbands (two orbit in each of F555W and F814W) of a complete subsample of the 12 most distant MACS clusters at 0.5<z<0.7 as a cornerstone of our comprehensive, quantitative, multi-waveband study of the properties of massive distant clusters. The depth of the proposed observations is dictated by the requirement for an accurate measurement of the gravitational shear field; resolved color information is critical for secure identifications of all faint, multiply imaged background objects and thus an unambiguously determined lens model, as well as

for the proposed detailed study of the cluster galaxy population and its evolution.

We expect MACS to become the sample of choice for future studies of massive clusters at intermediate redshift $0.3<z<0.7$ and stress the heritage character of the observations proposed here which will prove useful to a wider community for cluster-related studies.

SUPPORTING OBSERVATIONS

X-ray

Thanks to an investment of several hundreds of ks of Chandra GTO time by Leon Van Speybroeck all 12 proposed clusters have been or will be observed with ACIS-I, yielding superb X-ray data for this best-defined sample of massive distant clusters ever (see Fig.~5).

Groundbased optical

The proposed HST observations are supported and complemented by observations with Subaru, Gemini, and Keck. We are obtaining multi-object spectroscopy (MOS) of the galaxies in MACS clusters to assess the prevalence of velocity substructure. MOS data for 9 of the 12 MACS clusters at $z>0.5$ are in hand, and yield velocity dispersions ranging from 820 to 1700 km/s, time to

complete the sample has been awarded on Gemini/GMOS. In addition, we are conducting a wide-field VRIz' imaging survey of MACS clusters with Subaru/SuprimeCam to constrain the large-scale mass distribution beyond the ACS field of view via weak lensing, and to obtain global colours for galaxies in these regions. SuprimeCam data for eight of our 12 most distant MACS clusters are in hand (e.g. Fig.~4); the full sample will be completed using three additional SuprimeCam nights in the coming semester.

Sub-mm and radio

We are collaborating with John Carlstrom's group to secure detections of the Sunyaev-Zel`dovich effect in MACS clusters with the OVRO and BIMA mm arrays. Strong detections have been obtained for all 8 clusters at z>0.5 observed so far (LaRoque et al. 2003).

TECHNICAL JUSTIFICATION

Our primary goal is to map in detail the dark matter distribution in these clusters. The ACS field extends to a median radius of 120" or ~0.9/h50 Mpc at z=0.5-0.7. The high masses expected for these X-ray luminous systems predict typical shears of 20% at this radius. Our analysis of our Subaru data imaging (see Fig.~4) confirm that ground-based data can measure the radially averaged shear on these scales, but can not provide the

high-resolution mass maps essential for comparing the dark matter and
intracluster gas on ~100 kpc scales in the cluster cores.

The limiting shear necessary per resolution element in our mass map
determines the required depth. The rms error of the shear
averaged over the shapes of galaxies in a patch of sky is
sigma_gamma ~ \sigma_epsilon/sqrt(N), where
sigma_epsilon ~ 0.25 is the rms intrinsic ellipticity
of field galaxies and N is the number per patch. A 3sigma
detection on 20" (~150 kpc) scales of the shear at the edge of
our field thus requires a sensitivity of sigma_gamma ~ 7%
(the systematic errors due to the HST optics can be removed to a
negligible level compared to this, Rhodes et al. 2000; Hoekstra et
al. 1998). This equates to a galaxy surface density of 150/arcmin^2, or a limiting magnitude of I=25.5, for clusters at z~0.5-0.7, after accounting for 30% of field galaxies lying
in front of the clusters (Kneib et al. 1996).

Based on our previous lensing work with HST we estimate that we need
to measure the shapes of individual galaxies to better than 20%
accuracy to be dominated by their intrinsic ellipticity distribution.
This requires that 10 pixels across the galaxy are detected above a
S/N=1 per pixel threshold. With 4 WFC pixels averaged to produce a
0.1"x 0.1" superpixel, and for galaxies at I=25.5, with
scale sizes of r_hl ~ 0.25", this corresponds to mu_F814W=25.7 mag/arcsec^2. For a 1sigma detection (per
2x2 WFC pixel) of this isophote using F814W, we calculate an
exposure time of 5000 s using the WWW exposure tool. This exposure

time translate into 2 orbits using LOW-SKY (to reduce Earth-shine) and hence a visibility of 2800 sec for a typical target. We will dither between exposures to cover the gaps between the WFC chips and also to reduce the effects of flatfield and hot pixel errors. Customized software (ImCat) designed to take into account the HST PSF (Kaiser 2000) is in place for a comprehensive analysis of the observed shear field.

The F814W observations will probe the restframe morphology of the cluster members longward of 4000A. Shortwards of 4000A we complement these with observations in F555W to study the internal color structure of the cluster members and most importantly to use colors to confirm the identity of multiply imaged background sources in the crowded cluster cores. To achieve the latter we require photometry to 20% precision at the limit of our arclet catalog, I=25.5, or V=26.5 using the typical color at this depth. For a 5-sigma detection of V=26.5 in F555W within a 1" aperture, this requires 5600 s and hence 2 orbits per cluster (again based on LOW-SKY).

Visit

Proposal 10703, Visit 01 Thu Dec 15 02:24:05 GMT 2005

Diagnostic Status: No Diagnostics

Scientific Instruments: ACS/WFC

Special Requirements: (none)

Patterns

#	Primary Pattern		Secondary Pattern		Exposures
(1)	Pattern Type=LINE Purpose=DITHER Number Of Points=2 Point Spacing=3.011 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=85.3 Angle Between Sides= Center Pattern=true	Pattern Type=ACS-WFC-DITHER-LINE Purpose=DITHER Number Of Points=3 Point Spacing=0.138 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=33 Angle Between Sides= Center Pattern=true	(1), (2)

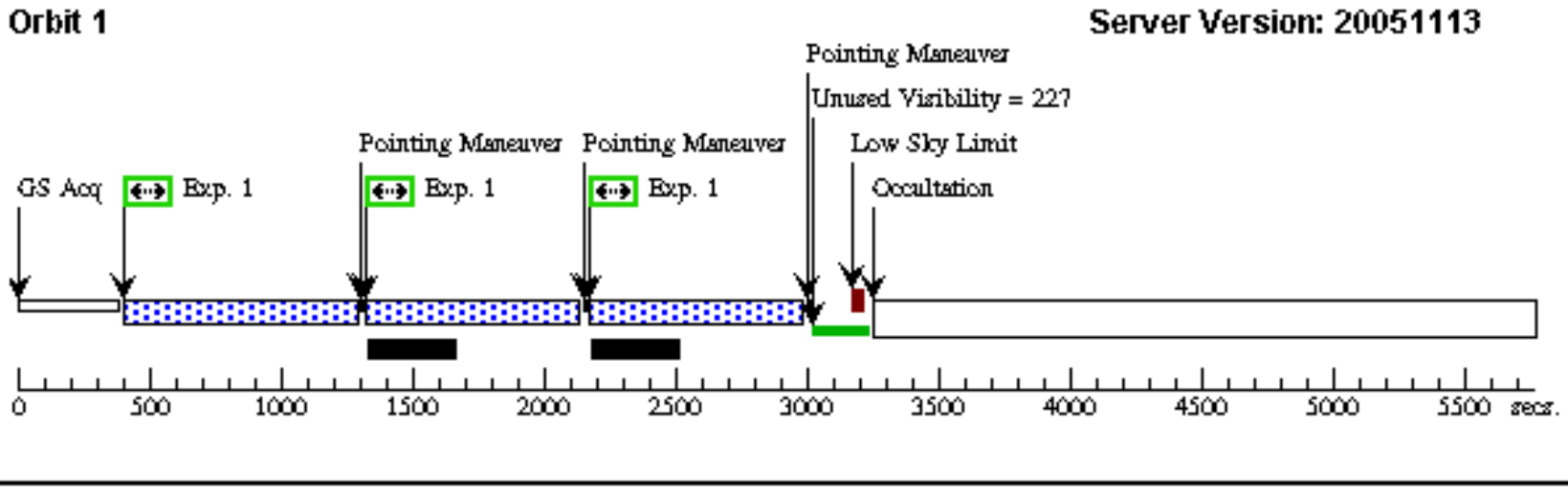
Fixed Targets

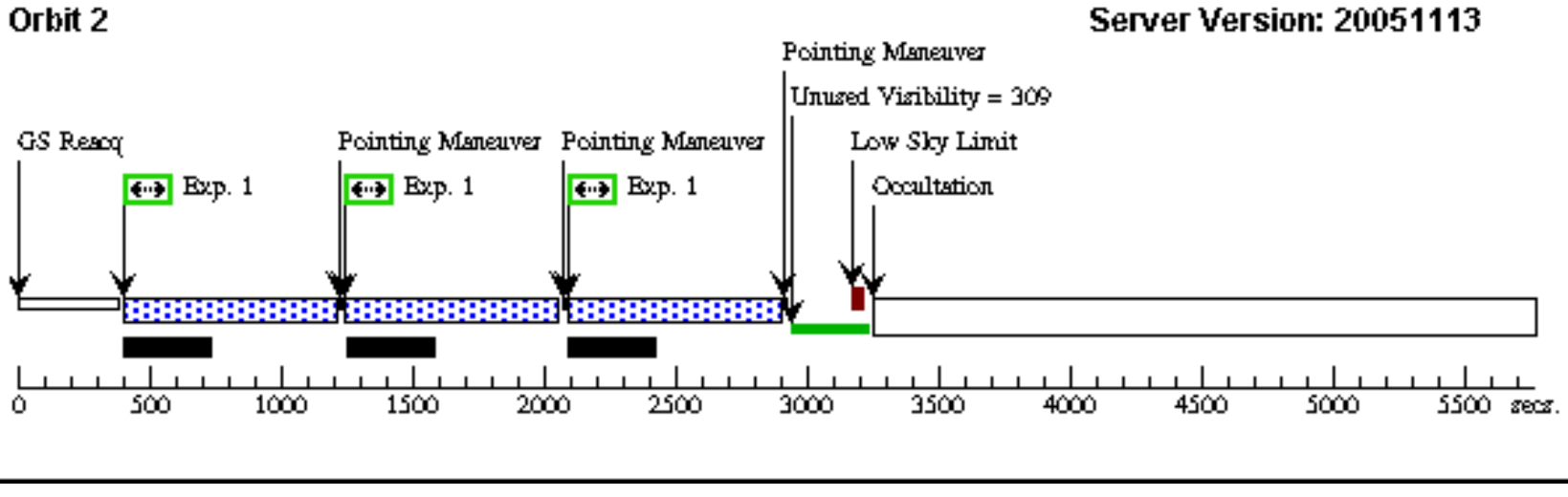
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	MACSJ0025-1222	RA: 00 25 30.2300 (6.3759583d) Dec: -12 22 43.00 (-12.37861d) Equinox: J2000 Plate Id: (?)	Proper Motion RA: 0.0s/yr Proper Motion Dec: 0.0"/yr Parallax: 0.0" Epoch of Position:	V=18.0	Coordinate Source: Chandra

Exposures

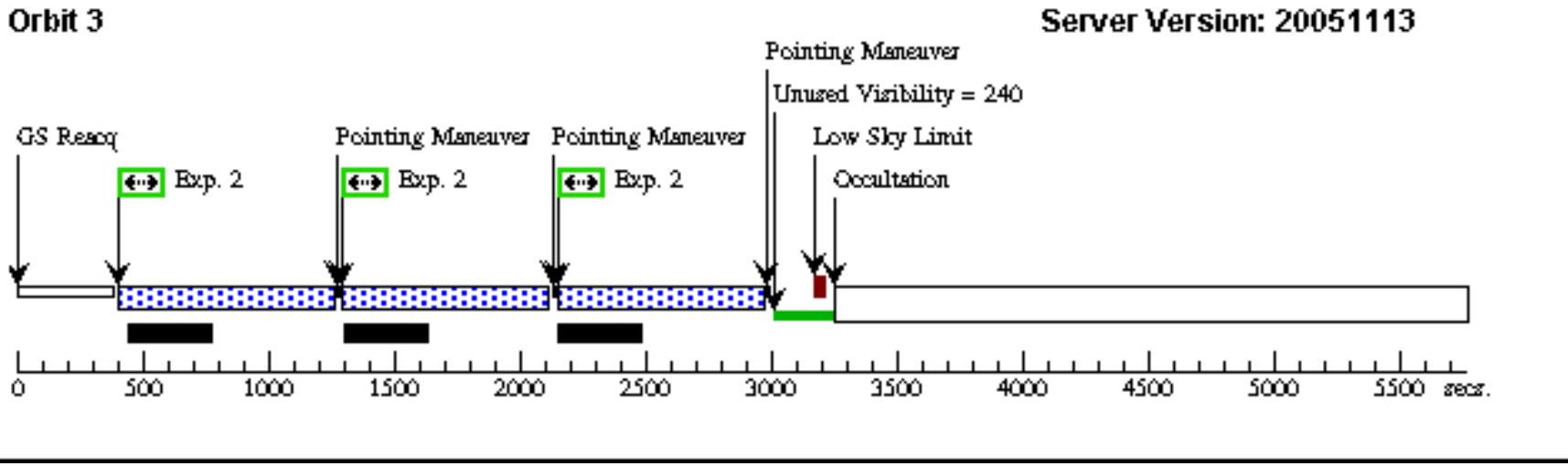
#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
1	0025-F555	(1) MACSJ0025-1222	ACS/WFC, ACCUM, WFC	F555W	CR-SPLIT=NO	LOW-SKY	Pattern 1-1 (1)	690.0 Secs	
								[==>(Pattern 1,1)] *[==>(Pattern 1,2)]* *[==>(Pattern 1,3)]*	***[1]***
								[==>(Pattern 2,1)] *[==>(Pattern 2,2)]* *[==>(Pattern 2,3)]*	***[2]***
2	0025-F814	(1) MACSJ0025-1222	ACS/WFC, ACCUM, WFC	F814W	CR-SPLIT=NO	LOW-SKY	Pattern 2-2 (1)	700.0 Secs	
								[==>(Pattern 1,1)] *[==>(Pattern 1,2)]* *[==>(Pattern 1,3)]*	***[3]***
								[==>(Pattern 2,1)] *[==>(Pattern 2,2)]* *[==>(Pattern 2,3)]*	***[4]***

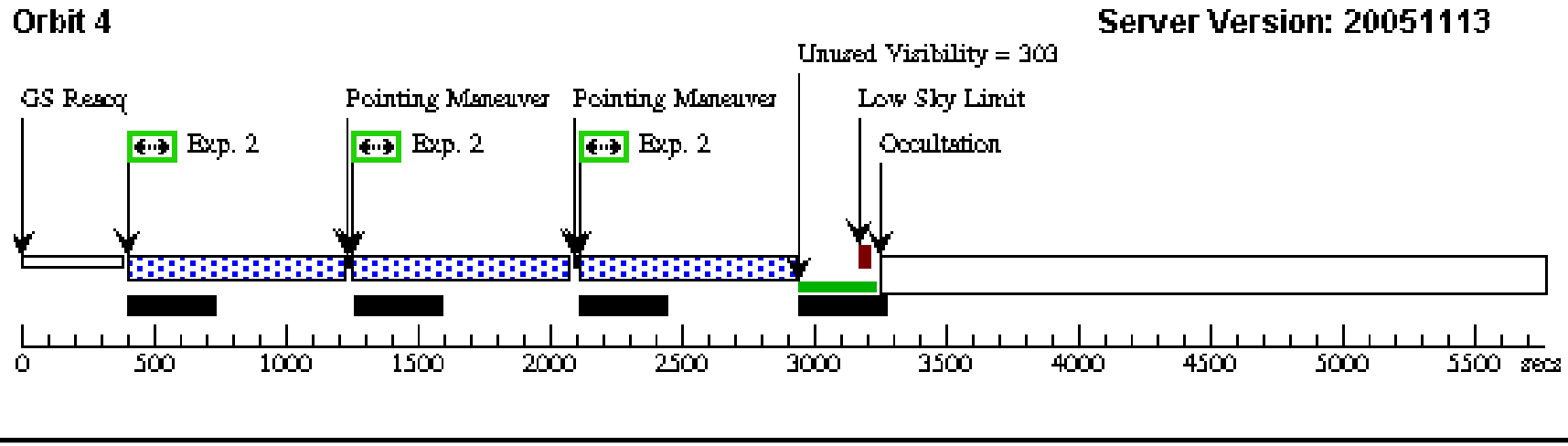
Orbit Structure





Orbit Structure (continued)





Visit

Proposal 10703, Visit 51 Thu Dec 15 02:24:06 GMT 2005

Diagnostic Status: No Diagnostics

Scientific Instruments: ACS/WFC

Special Requirements: (none)

Patterns

#	Primary Pattern		Secondary Pattern		Exposures
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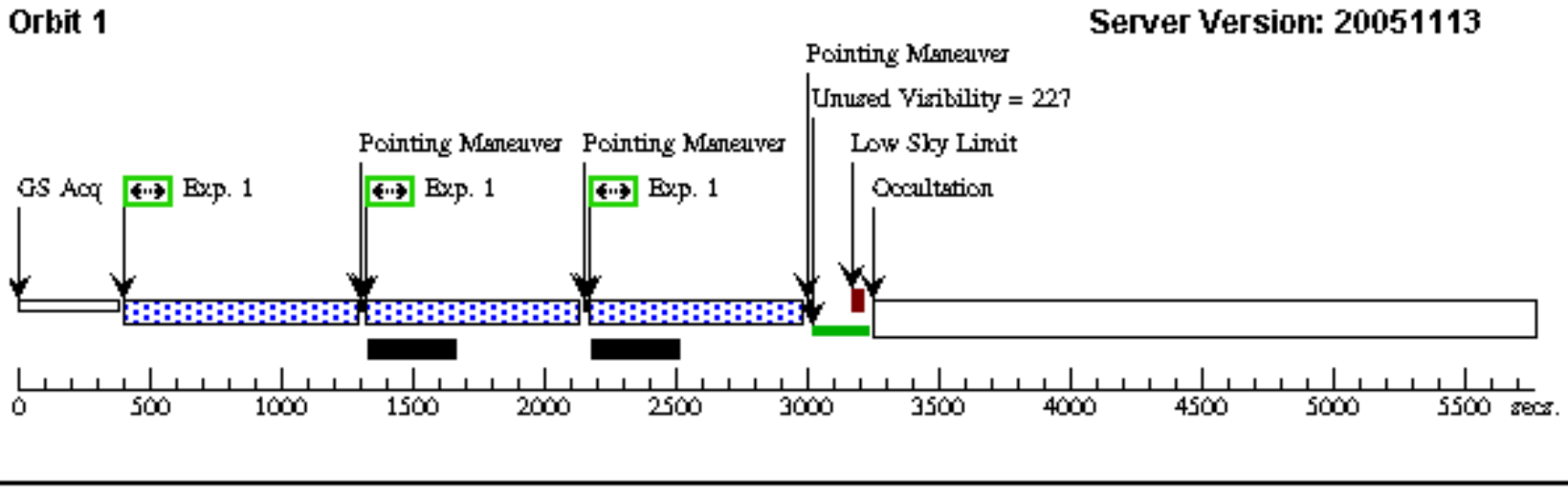
Fixed Targets

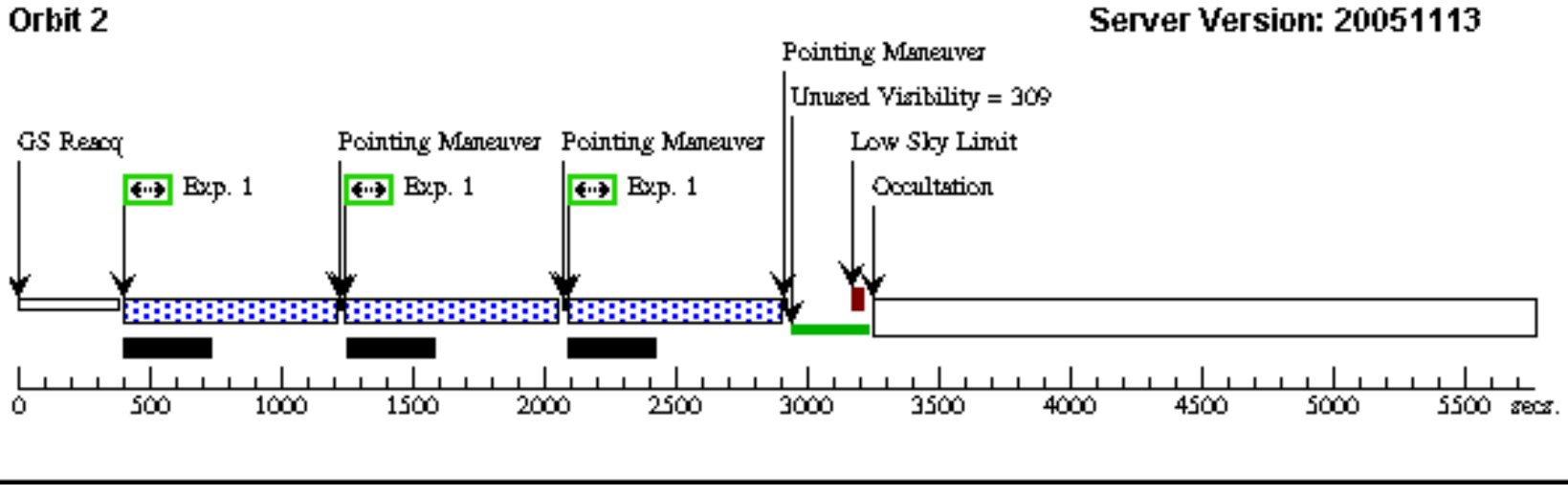
#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	MACSJ0025-1222	RA: 00 25 30.2300 (6.3759583d) Dec: -12 22 43.00 (-12.37861d) Equinox: J2000 Plate Id: (?)	Proper Motion RA: 0.0s/yr Proper Motion Dec: 0.0"/yr Parallax: 0.0" Epoch of Position:	V=18.0	Coordinate Source: Chandra

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
1	0025-F555	(1) MACSJ0025-1222	ACS/WFC, ACCUM, WFC	F555W	CR-SPLIT=NO	LOW-SKY	Pattern 1-1 (1)	690.0 Secs	
								[==>(Pattern 1,1)] *[==>(Pattern 1,2)]* *[==>(Pattern 1,3)]*	***[1]***
								[==>(Pattern 2,1)] *[==>(Pattern 2,2)]* *[==>(Pattern 2,3)]*	***[2]***
2	0025-F814	(1) MACSJ0025-1222	ACS/WFC, ACCUM, WFC	F814W	CR-SPLIT=NO	LOW-SKY	Pattern 2-2 (1)	700.0 Secs	
								[==>(Pattern 1,1)] *[==>(Pattern 1,2)]* *[==>(Pattern 1,3)]*	***[3]***
								[==>(Pattern 2,1)] *[==>(Pattern 2,2)]* *[==>(Pattern 2,3)]*	***[4]***

Orbit Structure





Orbit Structure (continued)