11684 - The First Proper Motion Measurement for M31: Dynamics and Mass of the Local Group

Cycle: 17, Proposal Category: GO

(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) M31-SPHEROID1 ANY	ACS/WFC WFC3/UVIS	2	24-Sep-2009 21:03:55.0	yes
02	(2) M31-OUTERDISK1 ANY	ACS/WFC WFC3/UVIS	2	24-Sep-2009 21:04:01.0	yes
03	(3) M31-TIDALSTREAM1 ANY	ACS/WFC WFC3/UVIS	2	24-Sep-2009 21:04:06.0	yes
04	(4) M31-SPHEROID2 ANY	ACS/WFC WFC3/UVIS	1	24-Sep-2009 21:04:12.0	yes

Visit	*Targets used in Visit*	*Configurations used in Visit*	*Orbits Used*	*Last Orbit Planner Run*	*OP Current with Visit?*
05	(5) M31-OUTERDISK2 ANY	ACS/WFC WFC3/UVIS	1	24-Sep-2009 21:04:15.0	yes
06	(6) M31-TIDALSTREAM2 ANY	ACS/WFC WFC3/UVIS	1	24-Sep-2009 21:04:17.0	yes

9 Total Orbits Used

ABSTRACT

We will perform observations to determine the proper motion of the Andromeda galaxy M31, which has been sought for almost a century without success. While challenging, this measurement has now become possible due to the availability of existing deep ACS/WFC images of several M31 fields. The requested second epoch images will yield the average shift of the M31 stars with respect to compact galaxies in the background. Our observing strategy uses six different fields (three primary and three coordinated parallel) with two different instruments (ACS and WFC3) to provide a maximum handle on possible systematic effects. The expected result will be sufficiently accurate to: (a) discriminate between different histories for the dynamics of the Local Group; (b) constrain the mass distribution of the Local Group; (c) determine the details of the expected future merger between M31 and the Milky Way; (d) infer the past interaction history between M31 and M33; (e) constrain the internal proper motion kinematics of the M31 spheroid, outer disk, and tidal stream; and (f) obtain a pilot estimate of the M31 distance through the method of rotational parallax.

OBSERVING DESCRIPTION

To measure absolute PMs we will use compact background galaxies in the field of view (FOV) of M31 as stationary reference sources. We will measure the average motion of stars in M31 between epochs 1 and 2, with respect to these reference sources. Our analysis techniques and expected accuracies were described in the Phase I proposal. First epoch data are available from previous observing programs by PI

T. Brown. The present project will obtain the second epoch data.

One could use all exposure time with a single field and instrument, but then there would be no internal consistency checks on the results. So instead, we will study three different M31 fields with two different instruments (WFC3 and ACS). This will yield more or less the same random error, but in addition will constrain possible systematic errors.

The target fields are the spheroid, disk, and tidal stream fields from Brown et al. (2003, 2006). These have similar stellar densities that provide acceptable crowding. The first epoch data were taken by Brown et al. in two filters, to make color magnitude diagrams that reach the M31 main sequence turn-off. These data are very deep (30--60 orbits per field per filter) so we already have excellent templates of all the usable reference background galaxies in the field. Moreover, the available broad-band colors and depth are sufficient for separating M31 stars, foreground stars, and background galaxies. For the second epoch it is therefore sufficient to take less deep data in only one of the filters.

We will observe each field for 2 orbits with WFC3 and 1 orbit with ACS, all in the F606W filter. Individual exposures will be sub-pixel dithered and will last half an orbit. Tests have shown that the F606W filter provides the best astrometric handle on the background galaxies. The compact source detection efficiencies (taking into

account pixel size, read noise, and throughput characteristics) of WFC3 and ACS are similar in this filter.

Brown et al. (2003, 2006) also observed fields with WFPC2 in parallel with their primary ACS fields. We will use coordinated parallel observations (with ACS when WFC3 is primary, and vice versa) to cover exactly these same fields. We do not expect the same astrometric accuracy as for the primary fields, because of the lower depth with WFPC2, the larger pixel size, and the larger CTE. Nonetheless, this will yield another handle on possible systematic errors, in addition to the ones discussed below.

For our primary ACS observations we request the same telescope orientation as for epoch 1. For our primary WFC3 observations we request the orientation that will align the parallel ACS field with the coordinated parallel WFPC2 fields of Brown et al. (2003, 2006).

Possible systematic errors are difficult to quantify a priori, but our multi-faceted observing strategy should provide a good handle both on such errors as well as on field-to-field variations in M31 internal kinematics. Using WFC3 in epoch 2 has the advantage of providing a new detector that is relatively free of Charge Transfer Efficiency (CTE) effects. The disadvantage is that we will have to calculate PMs by comparison of data from different instruments. While this has the potential to introduce low-level systematic errors, we have already performed studies that show that such cross-instrument comparisons can

be done to high accuracy. By contrast, using ACS in epoch 2 has the disadvantage that it now has significant CTE degradation, which affects astrometry at low but important levels. By comparing the second epoch ACS and WFC3 results, and their dependence on detector y-position, we will be able to perform a low-level correction for CTE effects in both the second and the first epoch data. The large number of M31 stars of different brightnesses will also constrain the differential CTE between the first and second epoch.

The data need to be corrected for geometric distortion. For ACS this is calibrated and stable with time to better than 0.005 pixels. However, any instabilities at this level would only affect our results to much lower levels. This is because we will compare the position of each galaxy only to its local neighboring stars. Therefore, we are sensitive only to the highest spatial frequencies of any geometric distortion uncertainty. Moreover, averaging of many galaxies at different positions in the FOV will further reduce these uncertainties. Being a new instrument, no distortion calibration exists yet for WFC3. However, calibration observations will be obtained soon after SM4 that should allow a calibration of similar accuracy as what we have obtained in the past for ACS.

We request that visit 4 be scheduled early in Cycle 17. This 1-orbit visit contains ACS observations of the M31 spheroid field. This is the only field for which we have already analyzed the epoch 1 data in some

detail. Early receipt and analysis of the visit 4 data will allow us to do a quick sanity check on the results, and identify possible problems, if any. If problems are identified then we will tweak the other visits if necessary.

REAL TIME JUSTIFICATION

N/A

CALIBRATION JUSTIFICATION

N/A

ADDITIONAL COMMENTS

N/A

Visit

Proposal 11684, Visit 01, implementation Fri Sep 25 01:04:20 GMT 2009

Diagnostic Status: No Diagnostics

Scientific Instruments: ACS/WFC, WFC3/UVIS

Special Requirements: SCHED 50%; ORIENT 255.070404D TO 255.070404 D

Patterns

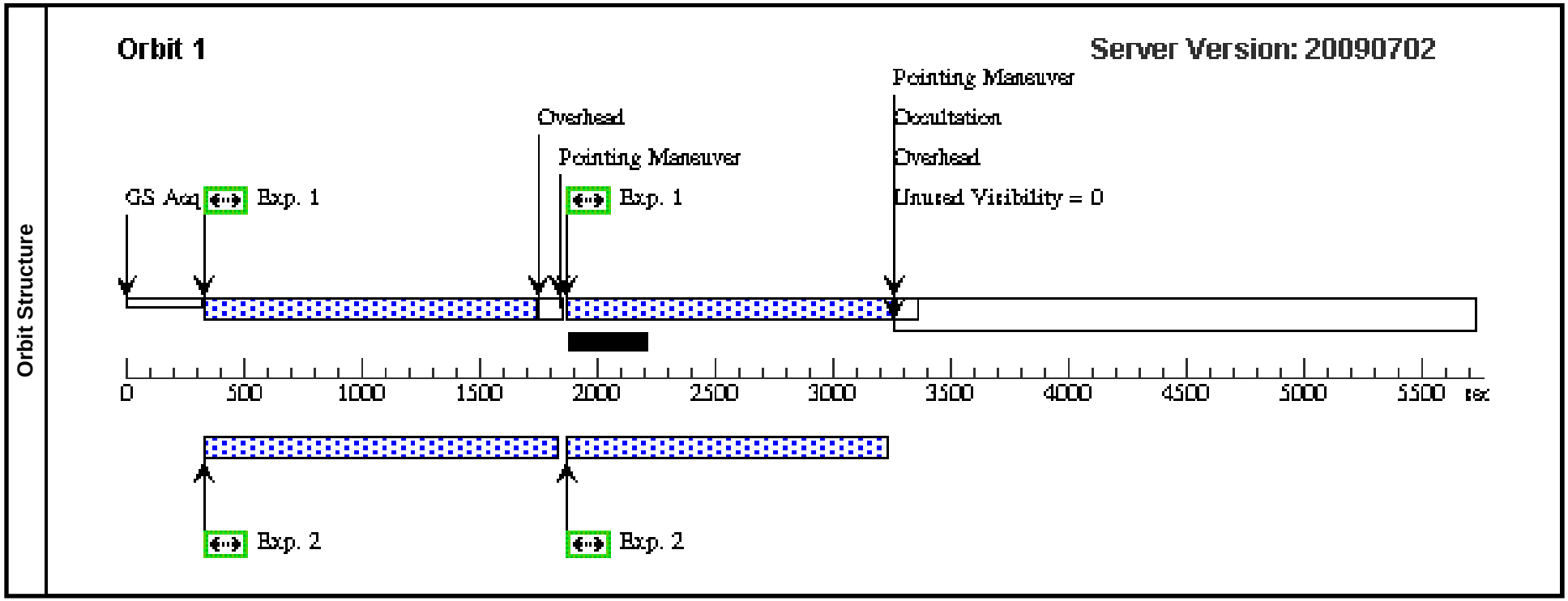
#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=WFC3-UVIS-DITHER-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.173 Line Spacing=0.112	Coordinate Frame=POS-TARG Pattern Orientation=23.884 Angle Between Sides=81.785 Center Pattern=false		(1-2)

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	M31-SPHEROID1	RA: 00 46 7.8020 (11.5325083d) Dec: +40 42 28.21 (40.70784d) Equinox: J2000	Radial Velocity: -301 km/sec	V=3.44+/-0.03	Reference Frame: ICRS

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
1	WFCspheroid	(1) M31-SPHEROID1	WFC3/UVIS, ACCUM, UVIS	F606W	CR-SPLIT=NO		Pattern 1, Exps 1-2 (1) Prime + Parallel Group 1-2	1360 Secs	
								[==>1379.0 Secs (Pattern 1)] *[==>1379.0 Secs (Pattern 2)]*	***[1]***
								[==>1450.0 Secs (Pattern 3)] *[==>1450.0 Secs (Pattern 4)]*	***[2]***
2	PARwWFCspheroid	ANY	ACS/WFC, ACCUM, WFC	F606W	CR-SPLIT=NO		Pattern 1, Exps 1-2 (1) Prime + Parallel Group 1-2	1200 Secs	
								[==>1290.0 Secs (Pattern 1)] *[==>1240.0 Secs (Pattern 2)]*	***[1]***
								[==>1420.0 Secs (Pattern 3)] *[==>1320.0 Secs (Pattern 4)]*	***[2]***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Pointing Maneuver
Occultation
Overhead
Unused Visibility = 0
Overhead
Pointing Maneuver
GS Acq
Exp. 1
Exp. 1
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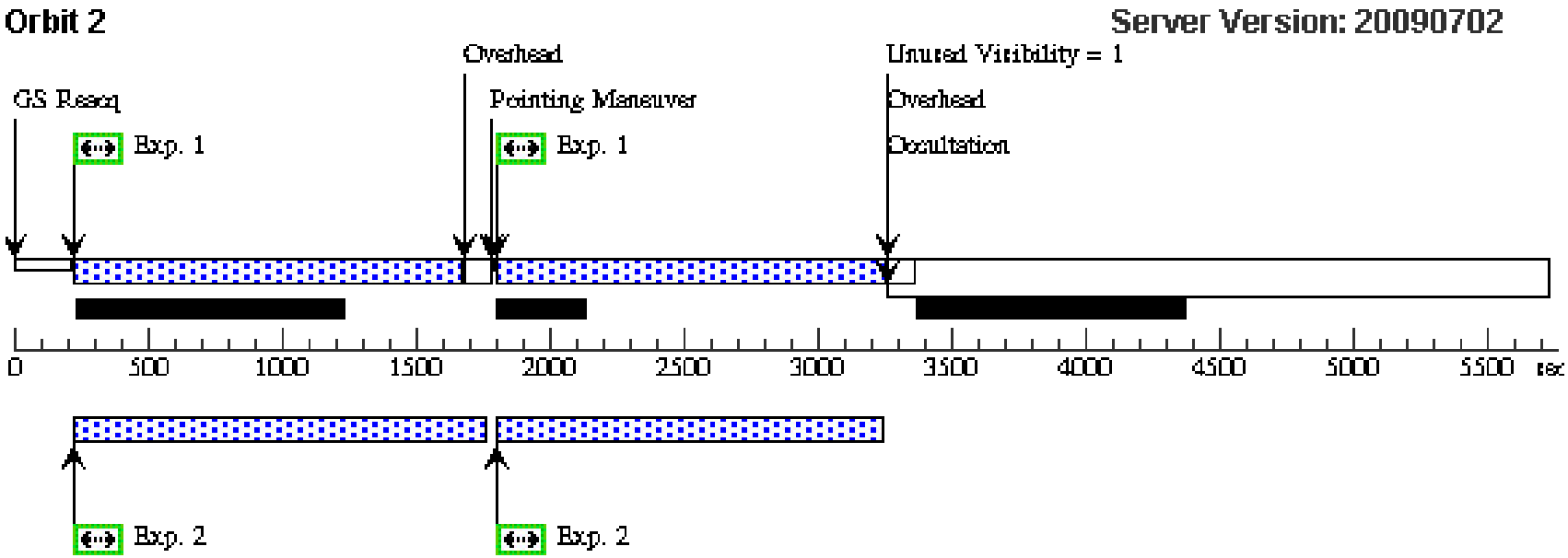
2000
2500
3000
3500
4000
4500
5000
5500
sec
Exp. 2
Exp. 2

Orbit Structure (continued)



Visit

Proposal 11684, Visit 02, implementation Fri Sep 25 01:04:21 GMT 2009

Diagnostic Status: No Diagnostics

Scientific Instruments: ACS/WFC, WFC3/UVIS

Special Requirements: ORIENT 247.085007D TO 247.085007 D

Patterns

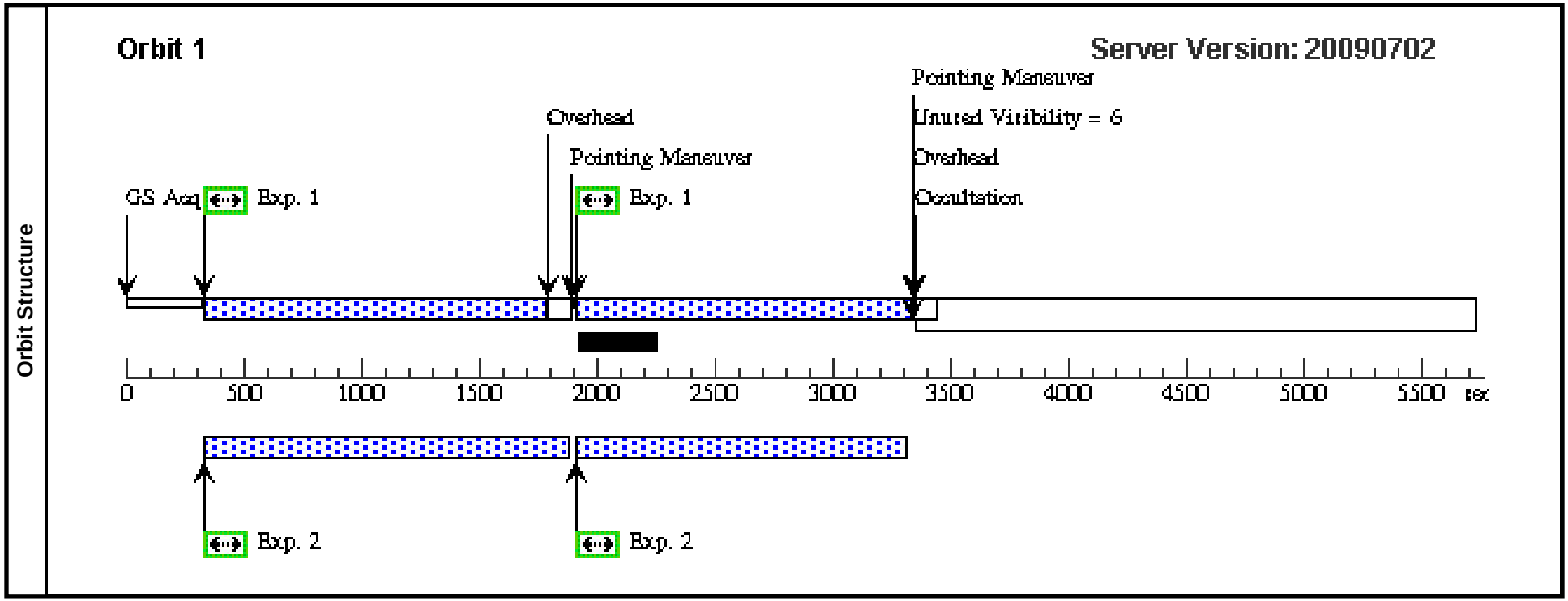
#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=WFC3-UVIS-DITHER-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.173 Line Spacing=0.112	Coordinate Frame=POS-TARG Pattern Orientation=23.884 Angle Between Sides=81.785 Center Pattern=false		(1-2)

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(2)	M31-OUTERDISK1	RA: 00 49 9.6070 (12.2900292d) Dec: +42 44 51.15 (42.74754d) Equinox: J2000	Radial Velocity: -301 km/sec	V=3.44+/-0.03	Reference Frame: ICRS

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
1	WFCdisk	(2) M31-OUTERDISK1	WFC3/UVIS, ACCUM, UVIS	F606W	CR-SPLIT=NO		Pattern 1, Exps 1-2 (1) Prime + Parallel Group 1-2	1400 Secs	
								[==>1420.0 Secs (Pattern 1)] *[==>1420.0 Secs (Pattern 2)]*	***[1]***
								[==>1491.0 Secs (Pattern 3)] *[==>1491.0 Secs (Pattern 4)]*	***[2]***
2	PARwWFCdisk	ANY	ACS/WFC, ACCUM, WFC	F606W	CR-SPLIT=NO		Pattern 1, Exps 1-2 (1) Prime + Parallel Group 1-2	1280 Secs	
								[==>1340.0 Secs (Pattern 1)] *[==>1280.0 Secs (Pattern 2)]*	***[1]***
								[==>1460.0 Secs (Pattern 3)] *[==>1340.0 Secs (Pattern 4)]*	***[2]***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Pointing Maneuver
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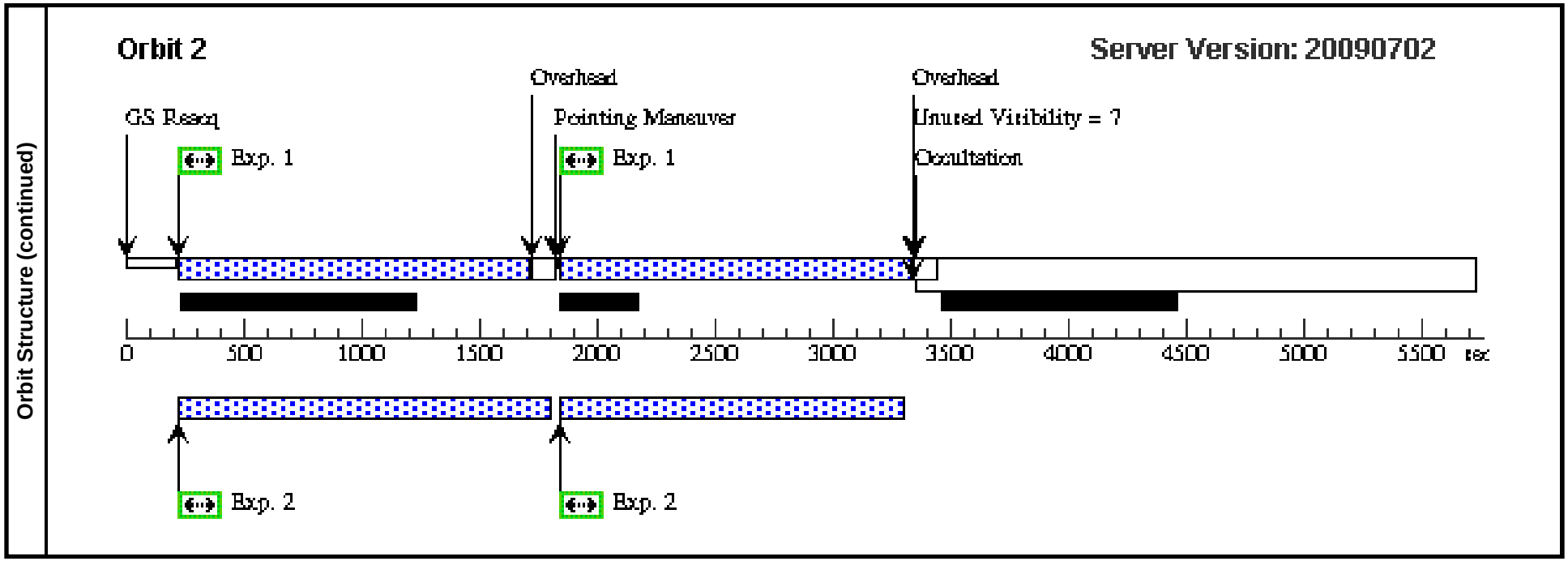
sec
Exp. 2
Exp. 2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sec
Exp. 2
Exp. 2

Visit

Proposal 11684, Visit 03, implementation Fri Sep 25 01:04:21 GMT 2009

Diagnostic Status: No Diagnostics

Scientific Instruments: ACS/WFC, WFC3/UVIS

Special Requirements: SCHED 40%; ORIENT 21.922609D TO 36.922609 D

Patterns

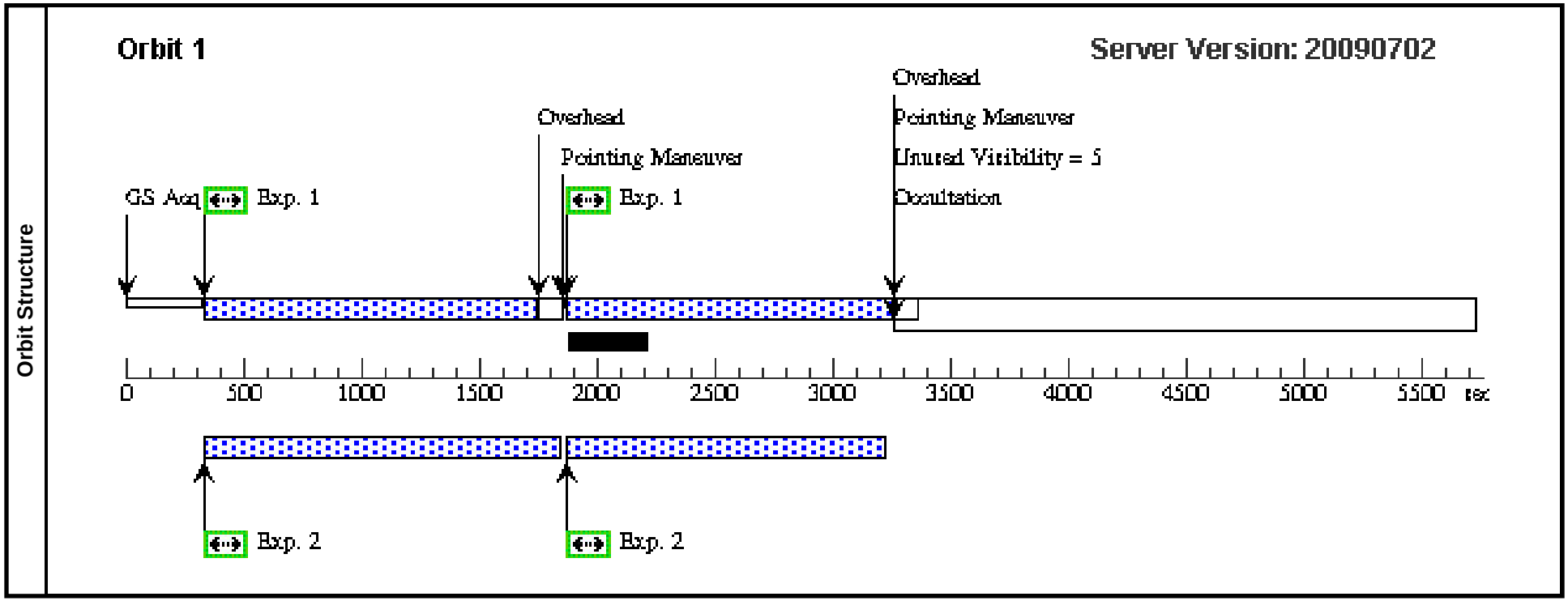
#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=WFC3-UVIS-DITHER-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.173 Line Spacing=0.112	Coordinate Frame=POS-TARG Pattern Orientation=23.884 Angle Between Sides=81.785 Center Pattern=false		(1-2)

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(3)	M31-TIDALSTREAM1	RA: 00 44 16.9601 (11.0706671d) Dec: +39 47 31.63 (39.79212d) Equinox: J2000	Radial Velocity: -301 km/sec	V=3.44+/-0.03	Reference Frame: ICRS

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
1	WFCstream	(3) M31-TIDALSTREAM1	WFC3/UVIS, ACCUM, UVIS	F606W	CR-SPLIT=NO		Pattern 1, Exps 1-2 (1) Prime + Parallel Group 1-2	1350 Secs	
								[==>1379.0 Secs (Pattern 1)] *[==>1379.0 Secs (Pattern 2)]*	***[1]***
								[==>1450.0 Secs (Pattern 3)] *[==>1450.0 Secs (Pattern 4)]*	***[2]***
2	PARwWFCstream	ANY	ACS/WFC, ACCUM, WFC	F606W	CR-SPLIT=NO		Pattern 1, Exps 1-2 (1) Prime + Parallel Group 1-2	1230 Secs	
								[==>1300.0 Secs (Pattern 1)] *[==>1230.0 Secs (Pattern 2)]*	***[1]***
								[==>1420.0 Secs (Pattern 3)] *[==>1290.0 Secs (Pattern 4)]*	***[2]***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Pointing Maneuver
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Overhead
Pointing Maneuver
GS Acq
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4500
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5500
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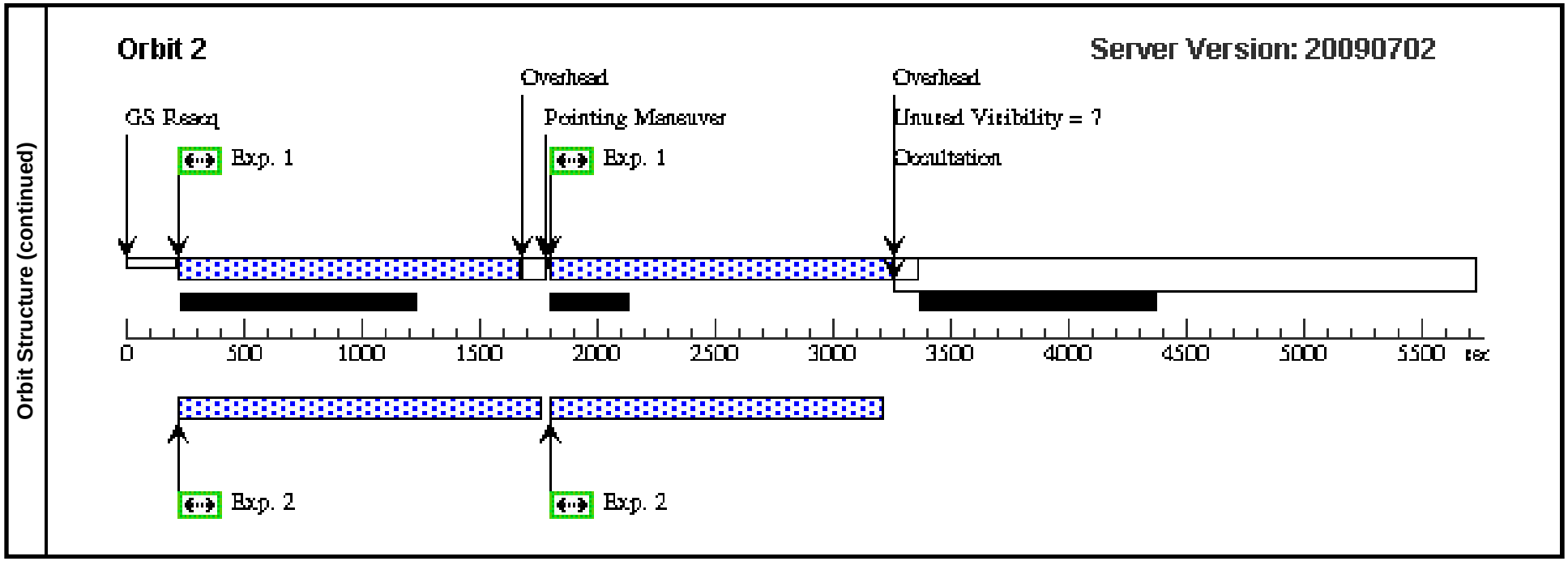
Exp. 2
Exp. 2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Overhead
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Pointing Maneuver
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Exp. 1
Occultation
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sec
Exp. 2
Exp. 2

Visit

Proposal 11684, Visit 04, implementation Fri Sep 25 01:04:23 GMT 2009

Diagnostic Status: No Diagnostics

Scientific Instruments: ACS/WFC, WFC3/UVIS

Special Requirements: SCHED 40%; ORIENT 75.070404D TO 75.070404 D

Patterns

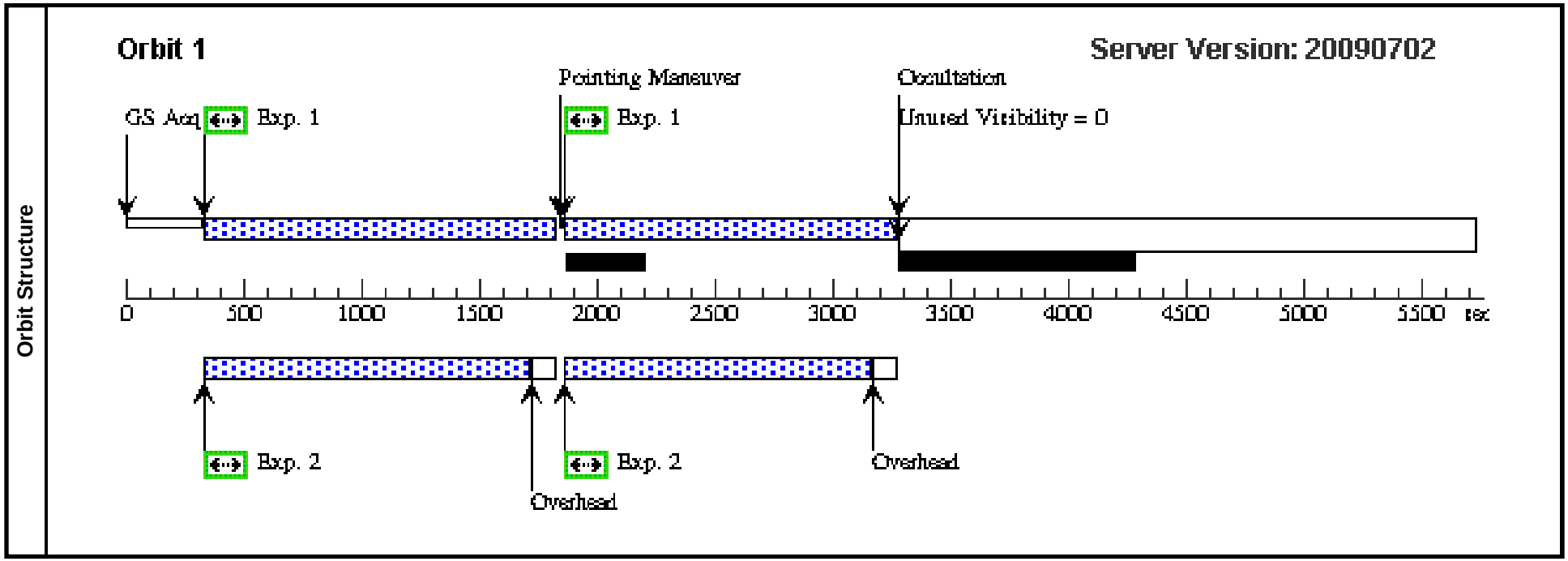
#	Primary Pattern		Secondary Pattern	Exposures
(2)	Pattern Type=ACS-WFC-DITHER-LINE Purpose=DITHER Number Of Points=2 Point Spacing=0.149 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=34.25 Angle Between Sides= Center Pattern=false		(1-2)

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(4)	M31-SPHEROID2	RA: 00 46 8.1358 (11.5338992d) Dec: +40 42 38.37 (40.71066d) Equinox: J2000	Radial Velocity: -301 km/sec	V=3.44+/-0.03	Reference Frame: ICRS

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
1	ACSspheroid	(4) M31-SPHEROID2	ACS/WFC, ACCUM, WFC	F606W	CR-SPLIT=NO		Pattern 2, Exps 1-2 (2) Prime + Parallel Group 1-2	1200 Secs *[==>1289.0 Secs (Pattern 1)]* *[==>1289.0 Secs (Pattern 2)]*	***[1]***
2	PARwACSspheroid	ANY	WFC3/UVIS, ACCUM, UVIS	F606W	CR-SPLIT=NO		Pattern 2, Exps 1-2 (2) Prime + Parallel Group 1-2	1200 Secs *[==>1349.0 Secs (Pattern 1)]* *[==>1299.0 Secs (Pattern 2)]*	***[1]***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Exp. 1
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sec
Exp. 2
Overhead
Exp. 2
Overhead

Visit

Proposal 11684, Visit 05, implementation Fri Sep 25 01:04:23 GMT 2009

Diagnostic Status: No Diagnostics

Scientific Instruments: ACS/WFC, WFC3/UVIS

Special Requirements: SCHED 40%; ORIENT 67.085007D TO 67.085007 D

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
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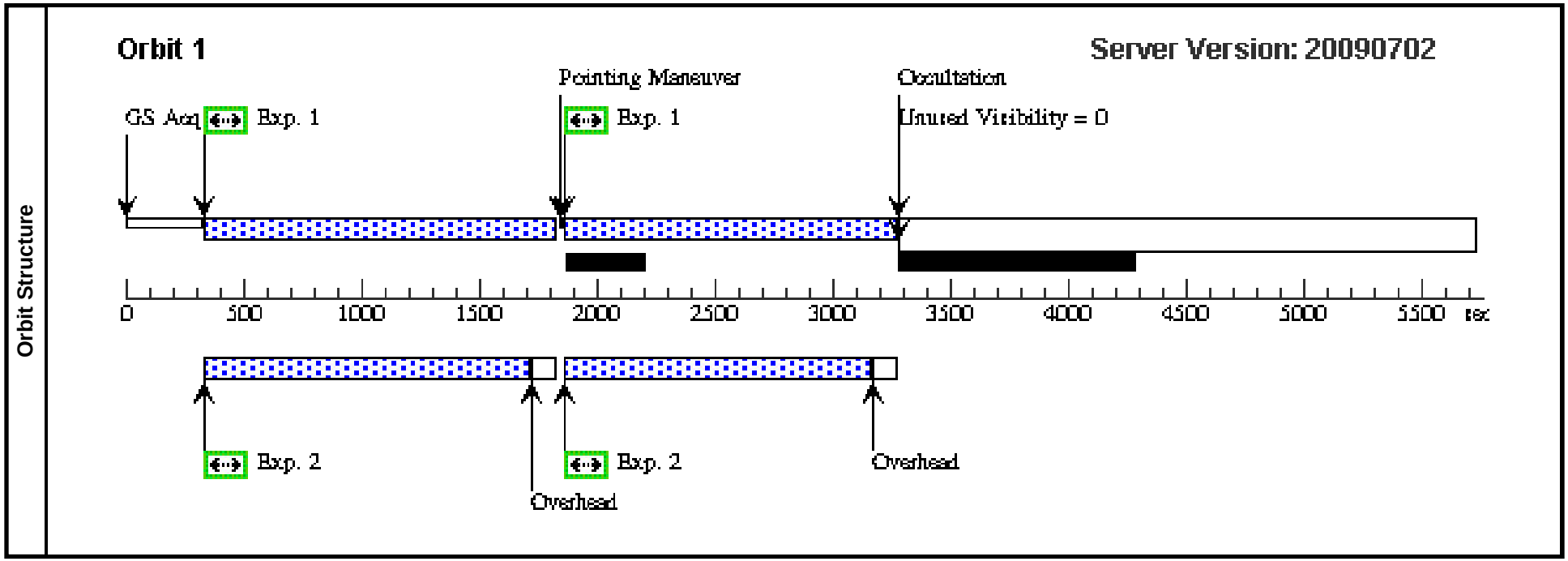
Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(5)	M31-OUTERDISK2	RA: 00 49 9.7732 (12.2907217d) Dec: +42 45 3.26 (42.75091d) Equinox: J2000	Radial Velocity: -301 km/sec	V=3.44+/-0.03	Reference Frame: ICRS

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
1	ACSdisk	(5) M31-OUTERDISK2	ACS/WFC, ACCUM, WFC	F606W	CR-SPLIT=NO		Pattern 2, Exps 1-2 (2) Prime + Parallel Group 1-2	1200 Secs *[==>1289.0 Secs (Pattern 1)]* *[==>1289.0 Secs (Pattern 2)]*	***[1]***
2	PARwACSdisk	ANY	WFC3/UVIS, ACCUM, UVIS	F606W	CR-SPLIT=NO		Pattern 2, Exps 1-2 (2) Prime + Parallel Group 1-2	1200 Secs *[==>1349.0 Secs (Pattern 1)]* *[==>1299.0 Secs (Pattern 2)]*	***[1]***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Exp. 1
Exp. 1
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Exp. 2
Overhead
Exp. 2
Overhead

Visit

Proposal 11684, Visit 06, implementation Fri Sep 25 01:04:23 GMT 2009

Diagnostic Status: No Diagnostics

Scientific Instruments: ACS/WFC, WFC3/UVIS

Special Requirements: ORIENT 201.922609D TO 201.922609 D

Patterns

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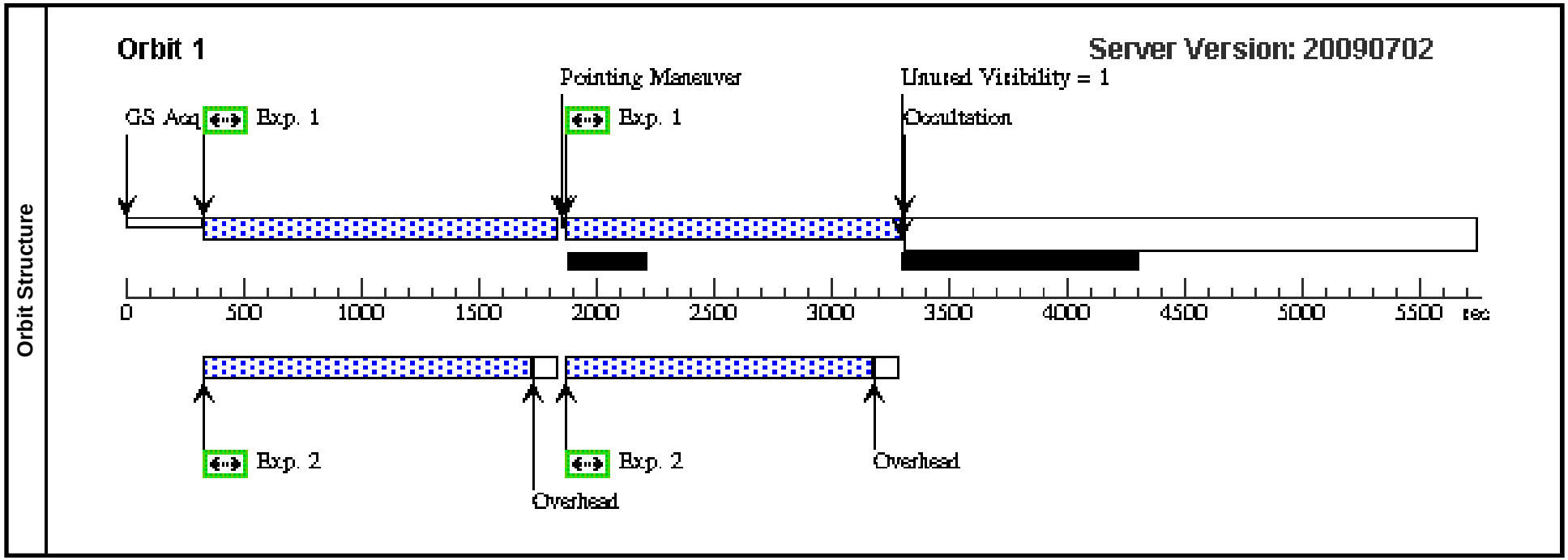
Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(6)	M31-TIDALSTREAM2	RA: 00 44 17.5102 (11.0729592d) Dec: +39 47 21.74 (39.78937d) Equinox: J2000	Radial Velocity: -301 km/sec	V=3.44+/-0.03	Reference Frame: ICRS

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
1	ACSstream	(6) M31-TIDALSTREAM2	ACS/WFC, ACCUM, WFC	F606W	CR-SPLIT=NO		Pattern 2, Exps 1-2 (2) Prime + Parallel Group 1-2	1290 Secs *[==>1299.0 Secs (Pattern 1)]* *[==>1299.0 Secs (Pattern 2)]*	***[1]***
2	PARwACSstream	ANY	WFC3/UVIS, ACCUM, UVIS	F606W	CR-SPLIT=NO		Pattern 2, Exps 1-2 (2) Prime + Parallel Group 1-2	1300 Secs *[==>1359.0 Secs (Pattern 1)]* *[==>(Pattern 2)]*	***[1]***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Pointing Maneuver
Unused Visibility = 1
GS Acq
Exp. 1
Exp. 1
Occultation
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1500
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3500
4000
4500
5000
5500
sec
Exp. 2
Overhead
Exp. 2
Overhead