# 13374 - Extremely faint, diffuse satellite systems in the M31 halo: exceptional star clusters or tiny dwarf galaxies?

Cycle: 21, 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-PANDAS-3<br>ANY | ACS/WFC<br>WFC3/UVIS | 2 | 18-Jun-2013 21:40:01.0 | yes |
| 02 | (2) M31-PANDAS-18<br>ANY | ACS/WFC<br>WFC3/UVIS | 2 | 18-Jun-2013 21:40:17.0 | yes |
| 03 | (3) M31-PANDAS-33<br>ANY | ACS/WFC<br>WFC3/UVIS | 2 | 18-Jun-2013 21:40:32.0 | yes |
| 04 | (4) M31-PANDAS-38<br>ANY | ACS/WFC<br>WFC3/UVIS | 2 | 18-Jun-2013 21:40:45.0 | yes |

8 Total Orbits Used

**ABSTRACT**

Recent years have seen the discovery of a variety of low surface brightness, diffuse stellar systems in the Local Group. Of particular prominence are the ultra-faint dwarf satellites of the Milky Way and the extended globular clusters seen in M31, M33, and NGC 6822. As part of the major Pan-Andromeda Archaeological Survey (PAndAS) we have discovered several very faint and diffuse stellar satellites in the M31 halo. In Cycle 19 we obtained ACS/WFC imaging for one of these, PAndAS-48, which has revealed it to be a puzzling and unusual object. On the size-luminosity plane it falls between the extended clusters and ultra-faint dwarfs; however, its characteristics do not allow us to unambiguously class it as either type of system. If PAndAS-48 is an extended cluster then it is the most elliptical, isolated, metal-poor, and lowest-luminosity example yet uncovered. Conversely, while its properties are generally consistent with those observed for the faint dwarf satellites of the Milky Way, it would be a factor ~2-3 smaller in spatial extent than its Galactic counterparts at comparable luminosity. Here we propose deep resolved imaging of the remaining five similar objects in our sample, with the aim of probing this hitherto poorly-explored region of parameter space in greater detail. If we are able to confirm any of these objects as faint dwarfs, they will provide the first insight into the behaviour of this class of object in a galaxy other than the Milky Way.

**OBSERVING DESCRIPTION**

The aim of this program is to conduct ACS/WFC resolved imaging of 5 satellite systems in the extreme outer reaches of the Andromeda galaxy (M31, NGC224). These may be extremely diffuse, low-luminosity globular clusters, or members of the class of ultra-faint dwarf galaxies similar to those seen around the Milky Way. Using our observations we will construct a colour-magnitude diagram for each target object, allowing us to study their constituent stellar populations, structures, and line-of-sight distances, and determine their identities.

ACS/WFC possesses a sufficiently wide field of view to fully cover each object and sample the surrounding halo field, while providing a suitably high pixel scale to completely resolve each target into its individual stars. It also possesses considerably higher throughput than WFC3/UVIS in the mid-optical passbands we will use. Although charge-transfer inefficiency is now a non-negligible issue for ACS/WFC photometry, we do not expect our science to be negatively impacted. CTE effects are somewhat mitigated because (i) we will be conducting deep broadband imaging, where the background is comparatively high, and (ii) our targets cover a rather small region on the camera (typically with radius ~500 pixels). In addition, sophisticated tools (such as that developed by Anderson & Bedin at STScI) enable CTE effects to be corrected with a high degree of precision.

We will observe using the F606W and F814W filters. These offer maximum throughput and match the vast majority of extant ACS/WFC imaging of

M31 and Galactic globular clusters.

In order to achieve our science goals we require our colour-magnitude diagrams to reach at least 2 magnitudes below the level of the horizontal branch, and cover the possibility that the horizontal branch may extend significantly to blue colours. The horizontal branch level in systems at the distance and and typical foreground extinction of M31 (D ~ 780 kpc, A_V ~ 0.2 mag) is V ~ 25. The ACS/WFC exposure time calculator shows that suitable signal-to-noise can be achieved with three ~800 s exposures in both F606W and F814W. With these exposure durations the ETC suggests we will reach S/N ~ 10 for red giant branch stars with V ~ 27.3 -- that is, more than 2 magnitudes below the horizontal branch level. On the horizontal branch at V ~ 25, we expect S/N ~ 60, which is excellent for an accurate assessment of horizontal branch morphology even if this feature extends far to the blue. In no individual exposure will the brightest cluster red giants (at V ~ 22) be saturated, meaning the upper parts of the red giant branch will be fully sampled at high signal-to-noise (> 350).

For each target our observations are most efficiently arranged over a two orbit visit -- one orbit per filter. Even though our targets span a range of declinations and therefore have a range of orbital visibility periods, at minimum we will obtain 3x800s exposures in F606W and F814W. We have used the "auto-adjust" feature in APT to deliver maximum on-target exposure time per orbit. We place the F814W exposures, for which ACS/WFC has slightly lower throughput, on the second orbit of each visit as the available exposure time is slightly longer than on the first orbit.

Our overall allocation is 5x2 = 10 orbits.

We place each target at the WFC1 aperture. This will ensure full coverage of the majority of each, while avoiding the ACS/WFC inter-chip gap. In order to minimise the effect of this gap on our imaging we will employ a 3-point dither in each filter using the ACS-WFC-DITHER-LINE pattern. This will enable cosmic ray and hot pixel rejection across the field of view.

All but one of our visits are unconstrained in orientation. The exception is visit 02, for target M31-PAndAS-18 which lies relatively near a bright star. To keep this star from falling within the field of view we have imposed an orientation constraint. This renders the visit considerably more difficult to schedule than the other, unconstrained, visits. If this is a problem then I expect the constraint could probably be lifted without degrading our images too badly (but it is not optimal).

We will conduct coordinated parallel observations using WFC3/UVIS to sample the M31 halo near each target. The aim is to construct colour-magnitude diagrams for field halo stars at large distances from the centre of M31. We will utilise the F606W and F814W filters, which offer

maximum thoughput. Exposure times are similar to those employed for our primary observations, but again maximised using the "auto-adjust" feature in APT. Since we are not imaging a specific target with any of these parallels, it does not matter whether the dither pattern we have selected for the primary imaging ends up covering the WFC3/UVIS inter-chip gap or not.

Each of our visits, apart from visit 02, is schedulable on numerous occasions throughout Cycle 21. Visit 02 is more constrained but there are still around 5 weeks available in total. If the orientation constraint on this visit is lifted, there will be no scheduling difficulties.

**REAL TIME JUSTIFICATION**

N/A

**CALIBRATION JUSTIFICATION**

N/A

**ADDITIONAL COMMENTS**

As noted in the "Observing Description", we have imposed an orientation constraint on visit 02 to avoid placing a bright star in the ACS/WFC field of view. This is the optimal scenario; if the constraint renders the visit too difficult to schedule, I expect it could probably be lifted without degrading the images too badly.

## Visit

**Proposal 13374, Visit 01, implementation** Wed Jun 19 01:40:54 GMT 2013

**Diagnostic Status: No Diagnostics**

Scientific Instruments: WFC3/UVIS, ACS/WFC

Special Requirements: (none)

## Patterns

| # | Primary Pattern | | Secondary Pattern | Exposures |
|---|---|---|---|---|
| (1) | Pattern Type=ACS-WFC-DITHER-LINE<br>Purpose=DITHER<br>Number Of Points=3<br>Point Spacing=3.011<br>Line Spacing= | Coordinate Frame=POS-TARG<br>Pattern Orientation=85.28<br>Angle Between Sides=<br>Center Pattern=false | | (1-2), (3-4) |

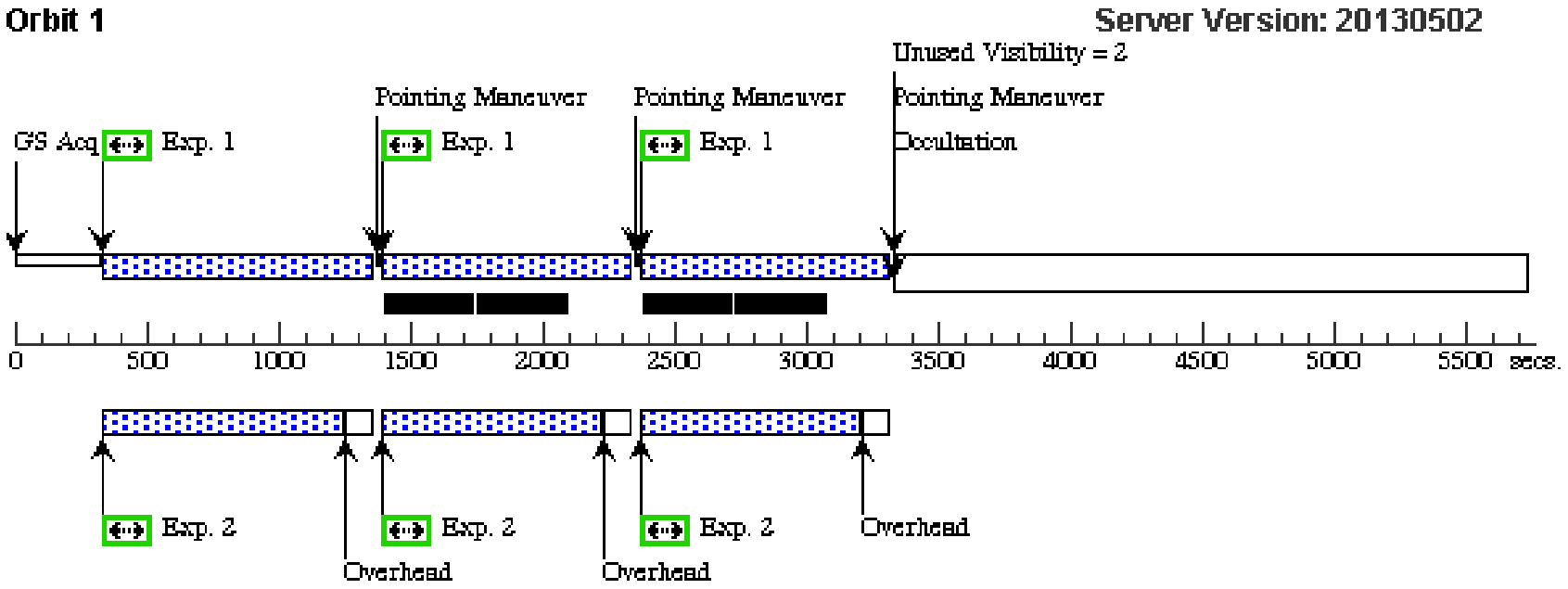
## Fixed Targets

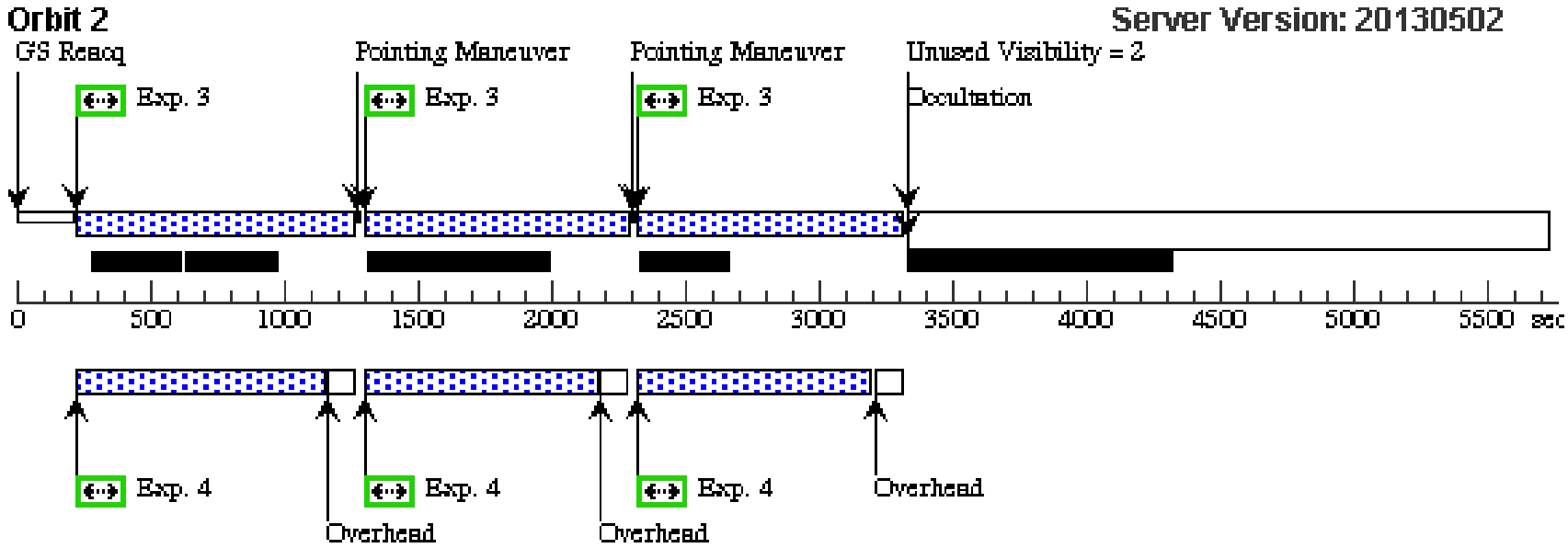
| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
|---|---|---|---|---|---|
| (1) | M31-PANDAS-3 | RA: 00 03 56.4100 (.9850417d)<br>Dec: +40 53 19.20 (40.88867d)<br>Equinox: J2000 | | V=20.6+/-0.3<br>SURF(V) = 26.3 +/- 0.3,<br>(V-I) = 1.0 +/- 0.3,<br>E(B-V) = 0.09 +/- 0.01 | Reference Frame: ICRS |

## Exposures

| # | Label | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | (1) M31-PANDAS-3 | ACS/WFC, ACCUM, WFC1 | F606W | | | Pattern 1, Exps 1-2 in Visit 01 (1)<br>Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in Visit 01 | 780 Secs (2454 Secs)<br>*[==>818.0 Secs (Pattern 1)]*<br>*[==>818.0 Secs (Pattern 2)]*<br>*[==>818.0 Secs (Pattern 3)]* | ***[1]*** |
| 2 | | ANY | WFC3/UVIS, ACCUM, UVIS-CENTER | F606W | | | Pattern 1, Exps 1-2 in Visit 01 (1)<br>Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in Visit 01 | 780 Secs (2534 Secs)<br>*[==>878.0 Secs (Pattern 1)]*<br>*[==>828.0 Secs (Pattern 2)]*<br>*[==>828.0 Secs (Pattern 3)]* | ***[1]*** |
| 3 | | (1) M31-PANDAS-3 | ACS/WFC, ACCUM, WFC1 | F814W | | | Pattern 1, Exps 3-4 in Visit 01 (1)<br>Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 in Visit 01 | 820 Secs (2592 Secs)<br>*[==>864.0 Secs (Pattern 1)]*<br>*[==>864.0 Secs (Pattern 2)]*<br>*[==>864.0 Secs (Pattern 3)]* | ***[2]*** |
| 4 | | ANY | WFC3/UVIS, ACCUM, UVIS-CENTER | F814W | | | Pattern 1, Exps 3-4 in Visit 01 (1)<br>Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 in Visit 01 | 820 Secs (2654 Secs)<br>*[==>906.0 Secs (Pattern 1)]*<br>*[==>874.0 Secs (Pattern 2)]*<br>*[==>874.0 Secs (Pattern 3)]* | ***[2]*** |

Orbit Structure



## Visit

**Proposal 13374, Visit 02, implementation** Wed Jun 19 01:40:57 GMT 2013

**Diagnostic Status: No Diagnostics**

Scientific Instruments: WFC3/UVIS, ACS/WFC

Special Requirements: ORIENT 153D TO 227 D

## Patterns

| # | Primary Pattern | | Secondary Pattern | Exposures |
|---|---|---|---|---|
| (1) | Pattern Type=ACS-WFC-DITHER-LINE<br>Purpose=DITHER<br>Number Of Points=3<br>Point Spacing=3.011<br>Line Spacing= | Coordinate Frame=POS-TARG<br>Pattern Orientation=85.28<br>Angle Between Sides=<br>Center Pattern=false | | (1-2), (3-4) |

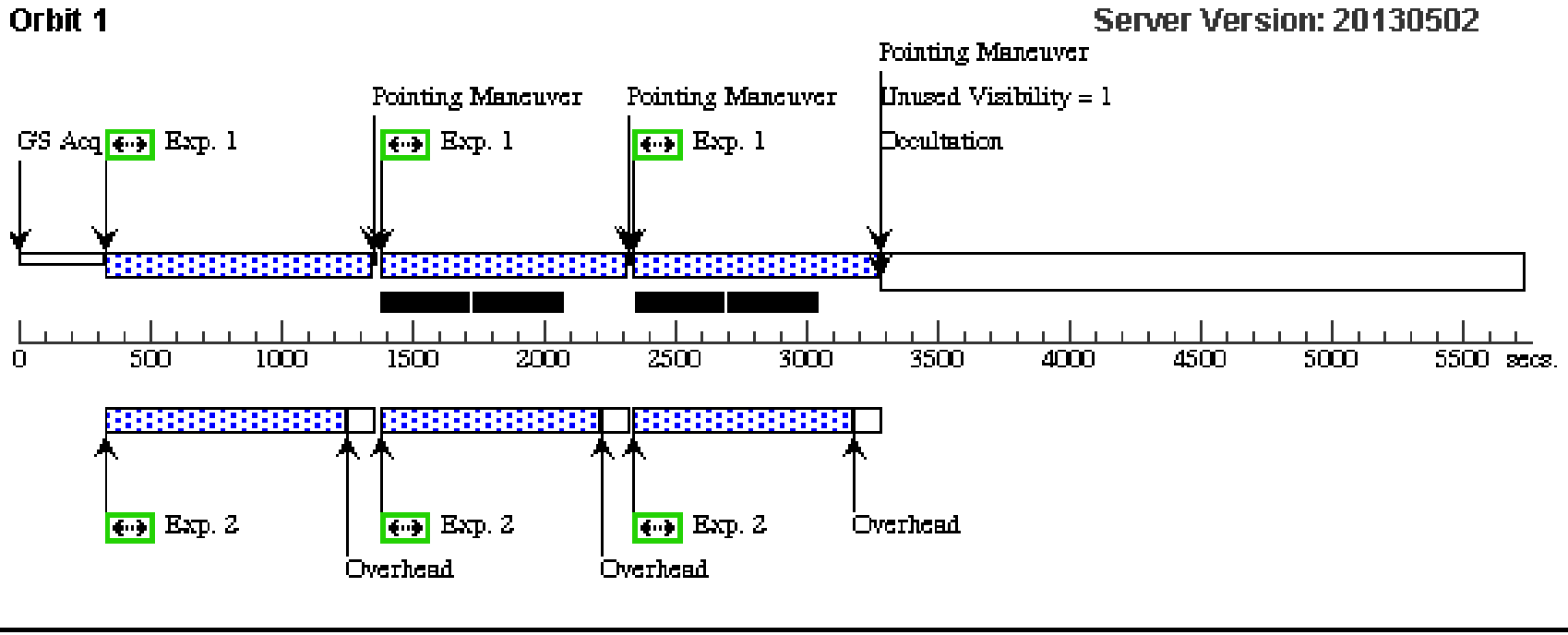
## Fixed Targets

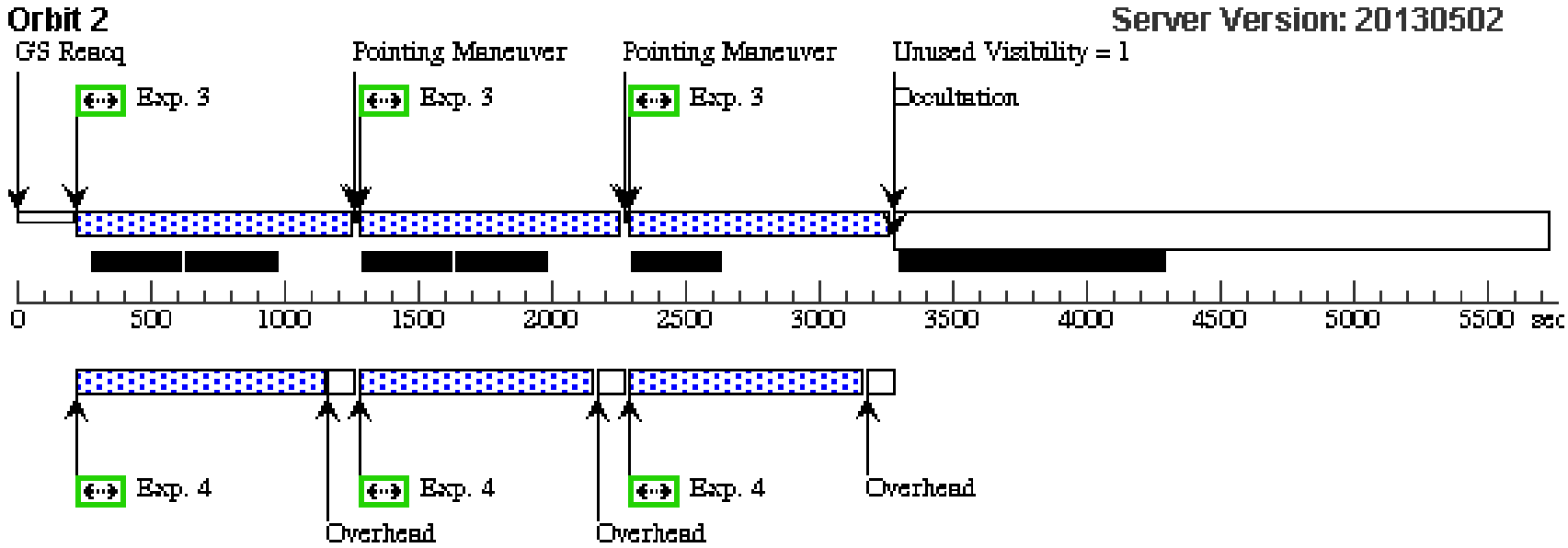
| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
|---|---|---|---|---|---|
| (2) | M31-PANDAS-18 | RA: 00 28 23.2600 (7.0969167d)<br>Dec: +39 55 4.86 (39.91802d)<br>Equinox: J2000 | | V=19.3+/-0.3<br>SURF(V) = 24.1 +/- 0.3,<br>(V-I) = 1.0 +/- 0.3,<br>E(B-V) = 0.06 +/- 0.01 | Reference Frame: ICRS |

## Exposures

| # | Label | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | (2) M31-PANDAS-18 | ACS/WFC, ACCUM, WFC1 | F606W | | | Pattern 1, Exps 1-2 in Visit 02 (1)<br>Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in Visit 02 | 780 Secs (2409 Secs)<br>*[==>803.0 Secs (Pattern 1)]*<br>*[==>803.0 Secs (Pattern 2)]*<br>*[==>803.0 Secs (Pattern 3)]* | ***[1]*** |
| 2 | | ANY | WFC3/UVIS, ACCUM, UVIS-CENTER | F606W | | | Pattern 1, Exps 1-2 in Visit 02 (1)<br>Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in Visit 02 | 780 Secs (2534 Secs)<br>*[==>878.0 Secs (Pattern 1)]*<br>*[==>828.0 Secs (Pattern 2)]*<br>*[==>828.0 Secs (Pattern 3)]* | ***[1]*** |
| 3 | | (2) M31-PANDAS-18 | ACS/WFC, ACCUM, WFC1 | F814W | | | Pattern 1, Exps 3-4 in Visit 02 (1)<br>Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 in Visit 02 | 820 Secs (2547 Secs)<br>*[==>849.0 Secs (Pattern 1)]*<br>*[==>849.0 Secs (Pattern 2)]*<br>*[==>849.0 Secs (Pattern 3)]* | ***[2]*** |
| 4 | | ANY | WFC3/UVIS, ACCUM, UVIS-CENTER | F814W | | | Pattern 1, Exps 3-4 in Visit 02 (1)<br>Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 in Visit 02 | 820 Secs (2654 Secs)<br>*[==>906.0 Secs (Pattern 1)]*<br>*[==>874.0 Secs (Pattern 2)]*<br>*[==>874.0 Secs (Pattern 3)]* | ***[2]*** |

Orbit Structure



## Visit

**Proposal 13374, Visit 03, implementation** Wed Jun 19 01:41:01 GMT 2013

**Diagnostic Status: No Diagnostics**

Scientific Instruments: WFC3/UVIS, ACS/WFC

Special Requirements: (none)

## Patterns

| # | Primary Pattern | | Secondary Pattern | Exposures |
|---|---|---|---|---|
| (1) | Pattern Type=ACS-WFC-DITHER-LINE<br>Purpose=DITHER<br>Number Of Points=3<br>Point Spacing=3.011<br>Line Spacing= | Coordinate Frame=POS-TARG<br>Pattern Orientation=85.28<br>Angle Between Sides=<br>Center Pattern=false | | (1-2), (3-4) |

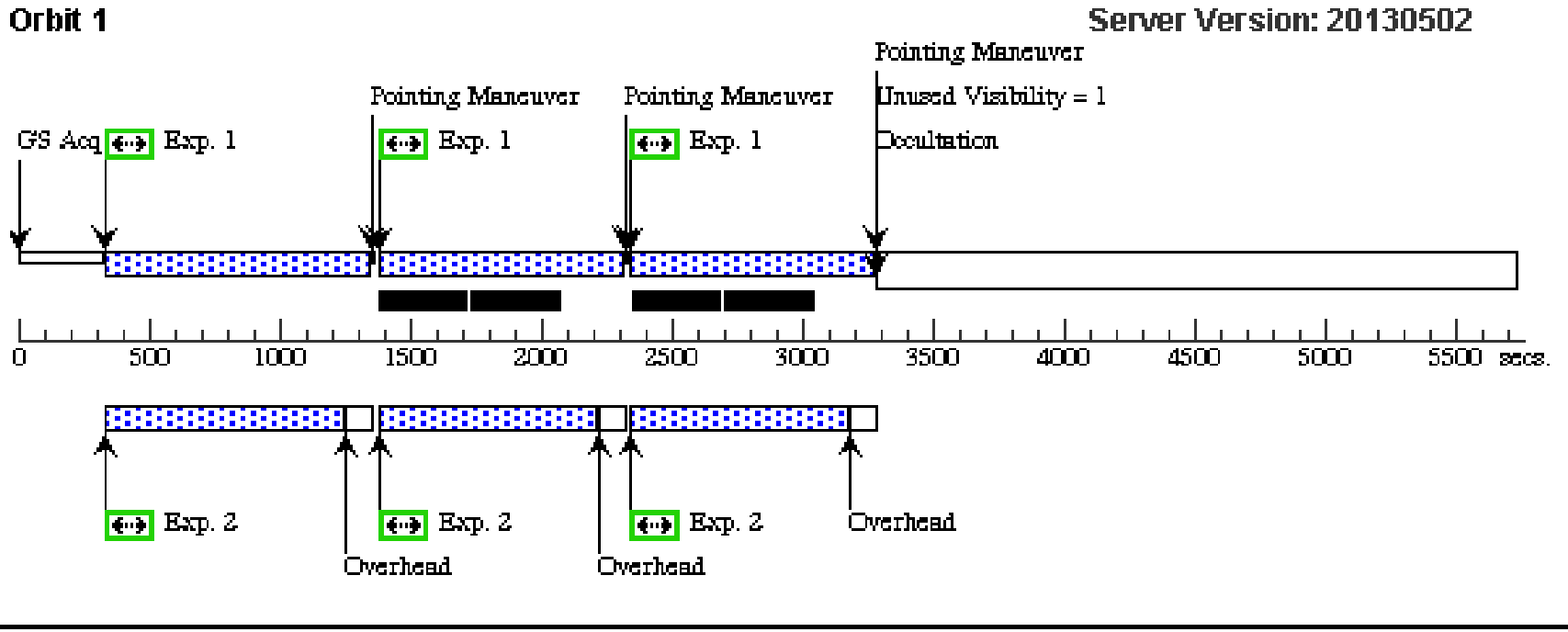
## Fixed Targets

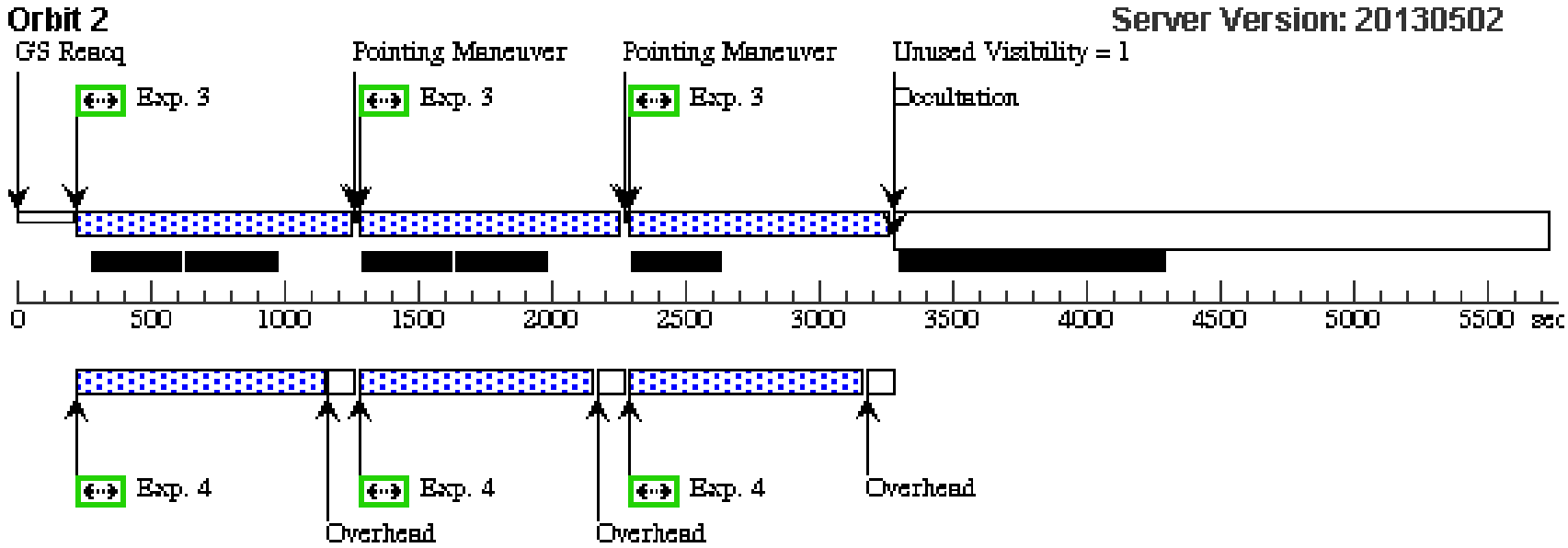
| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
|---|---|---|---|---|---|
| (3) | M31-PANDAS-33 | RA: 00 40 57.3500 (10.2389583d)<br>Dec: +38 38 10.24 (38.63618d)<br>Equinox: J2000 | | V=19.3+/-0.3<br>SURF(V) = 25.8 +/- 0.3,<br>(V-I) = 1.0 +/- 0.3,<br>E(B-V) = 0.06 +/- 0.01 | Reference Frame: ICRS |

## Exposures

| # | Label | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | (3) M31-PANDAS-33 | ACS/WFC, ACCUM, WFC1 | F606W | | | Pattern 1, Exps 1-2 in Visit 03 (1)<br>Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in Visit 03 | 780 Secs (2409 Secs)<br>*[==>803.0 Secs (Pattern 1)]*<br>*[==>803.0 Secs (Pattern 2)]*<br>*[==>803.0 Secs (Pattern 3)]* | ***[1]*** |
| 2 | | ANY | WFC3/UVIS, ACCUM, UVIS-CENTER | F606W | | | Pattern 1, Exps 1-2 in Visit 03 (1)<br>Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in Visit 03 | 780 Secs (2534 Secs)<br>*[==>878.0 Secs (Pattern 1)]*<br>*[==>828.0 Secs (Pattern 2)]*<br>*[==>828.0 Secs (Pattern 3)]* | ***[1]*** |
| 3 | | (3) M31-PANDAS-33 | ACS/WFC, ACCUM, WFC1 | F814W | | | Pattern 1, Exps 3-4 in Visit 03 (1)<br>Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 in Visit 03 | 820 Secs (2547 Secs)<br>*[==>849.0 Secs (Pattern 1)]*<br>*[==>849.0 Secs (Pattern 2)]*<br>*[==>849.0 Secs (Pattern 3)]* | ***[2]*** |
| 4 | | ANY | WFC3/UVIS, ACCUM, UVIS-CENTER | F814W | | | Pattern 1, Exps 3-4 in Visit 03 (1)<br>Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 in Visit 03 | 820 Secs (2654 Secs)<br>*[==>906.0 Secs (Pattern 1)]*<br>*[==>874.0 Secs (Pattern 2)]*<br>*[==>874.0 Secs (Pattern 3)]* | ***[2]*** |

Orbit Structure



## Visit

**Proposal 13374, Visit 04, implementation** Wed Jun 19 01:41:04 GMT 2013

**Diagnostic Status: No Diagnostics**

Scientific Instruments: WFC3/UVIS, ACS/WFC

Special Requirements: (none)

## Patterns

| # | Primary Pattern | | Secondary Pattern | Exposures |
|---|---|---|---|---|
| (1) | Pattern Type=ACS-WFC-DITHER-LINE<br>Purpose=DITHER<br>Number Of Points=3<br>Point Spacing=3.011<br>Line Spacing= | Coordinate Frame=POS-TARG<br>Pattern Orientation=85.28<br>Angle Between Sides=<br>Center Pattern=false | | (1-2), (3-4) |

## Fixed Targets

| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
|---|---|---|---|---|---|
| (4) | M31-PANDAS-38 | RA: 00 49 45.6700 (12.4402917d)<br>Dec: +47 54 33.12 (47.90920d)<br>Equinox: J2000 | | V=20.5+/-0.3<br>SURF(V) = 25.7 +/- 0.3,<br>(V-I) = 1.1 +/- 0.3,<br>E(B-V) = 0.16 +/- 0.01 | Reference Frame: ICRS |

## Exposures

| # | Label | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | (4) M31-PANDAS-38 | ACS/WFC, ACCUM, WFC1 | F606W | | | Pattern 1, Exps 1-2 in Visit 04 (1)<br>Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in Visit 04 | 780 Secs (2499 Secs)<br>*[==>833.0 Secs (Pattern 1)]*<br>*[==>833.0 Secs (Pattern 2)]*<br>*[==>833.0 Secs (Pattern 3)]* | ***[1]*** |
| 2 | | ANY | WFC3/UVIS, ACCUM, UVIS-CENTER | F606W | | | Pattern 1, Exps 1-2 in Visit 04 (1)<br>Prime + Parallel Group 1-2 in Pattern 1, Exps 1-2 in Visit 04 | 780 Secs (2579 Secs)<br>*[==>893.0 Secs (Pattern 1)]*<br>*[==>843.0 Secs (Pattern 2)]*<br>*[==>843.0 Secs (Pattern 3)]* | ***[1]*** |
| 3 | | (4) M31-PANDAS-38 | ACS/WFC, ACCUM, WFC1 | F814W | | | Pattern 1, Exps 3-4 in Visit 04 (1)<br>Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 in Visit 04 | 820 Secs (2637 Secs)<br>*[==>879.0 Secs (Pattern 1)]*<br>*[==>879.0 Secs (Pattern 2)]*<br>*[==>879.0 Secs (Pattern 3)]* | ***[2]*** |
| 4 | | ANY | WFC3/UVIS, ACCUM, UVIS-CENTER | F814W | | | Pattern 1, Exps 3-4 in Visit 04 (1)<br>Prime + Parallel Group 3-4 in Pattern 1, Exps 3-4 in Visit 04 | 820 Secs (2699 Secs)<br>*[==>921.0 Secs (Pattern 1)]*<br>*[==>889.0 Secs (Pattern 2)]*<br>*[==>889.0 Secs (Pattern 3)]* | ***[2]*** |

Orbit Structure