



# 11100 - Two new 'bullets' for MOND: revealing the properties of dark matter in massive merging clusters

Cycle: 16, Proposal Category: GO

(Availability Mode: SUPPORTED)

## INVESTIGATORS

| <i>Name</i>                   | <i>Institution</i>                       | <i>E-Mail</i>                   |
|-------------------------------|------------------------------------------|---------------------------------|
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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) MACSJ0025.4-1222         | WFPC2                               | 5                  | 22-Aug-2007 21:00:55.0        | yes                           |
| 51           | (4) MACSJ0025.4-1222-COPY    | WFPC2                               | 5                  | 22-Aug-2007 21:01:03.0        | yes                           |
| 02           | (2) MACSJ2243.3-0935         | WFPC2                               | 5                  | 22-Aug-2007 21:01:11.0        | yes                           |
| 03           | (2) MACSJ2243.3-0935         | WFPC2                               | 6                  | 22-Aug-2007 21:01:18.0        | yes                           |
| 04           | (2) MACSJ2243.3-0935         | WFPC2                               | 6                  | 22-Aug-2007 21:01:25.0        | yes                           |
| 05           | (3) MESSIER-002              | WFPC2                               | 1                  | 22-Aug-2007 21:01:31.0        | yes                           |

28 Total Orbits Used

## **ABSTRACT**

The principal objective of this proposal is to study the physical nature of dark matter by using two, massive, newly-identified merging clusters of galaxies. As shown by the pioneering example of the "bullet cluster" (1E0657-56), such systems are ideal laboratories for detecting dark matter and distinguishing between cold dark matter (CDM) and other scenarios (e.g. self-interacting dark matter). Our limit on the self-interaction cross-section of dark matter relies on the assumption of a normal pre-merger mass-to-light ratios, and a small impact parameter during the collision of the two clusters. In order to mitigate any possible systematic effects, it is vital to extend this work to other, similar systems. With detailed observations of new systems, the systematic uncertainties in the dark matter cross section calculations can be improved substantially, allowing us to move from rough order of magnitude estimates to measurements with quantifiable uncertainties that can be compared usefully with the predictions from numerical simulations.

Our targets are two extraordinary, high-redshift, merging galaxy clusters recently discovered by the Massive Cluster Survey (MACS). This survey is by far the best matched to this study, since it selects medium redshift (optimal for gravitational lensing studies) and X-ray luminous (hence massive) objects. We have selected the best candidates with clear evidence for considerable offsets between the hot X-ray emitting gas and optically luminous stellar material. The two most striking examples are the targets of this proposal. To pin down the position of the dark matter component we require high resolution, absolutely calibrated mass maps. The combination of weak and strong lensing measurements is needed to attain this goal. This can only be achieved with the excellent resolving power of the HST (in combination with wide-field, multicolor Subaru data already in hand). We therefore request multicolor HST/WFPC2 observations of the two merging clusters. The combination of constraints from multiply lensed images (identified via morphology and color information) and high-resolution weak lensing data will allow us to construct, self-consistently, their mass distribution from the very centers to the outskirts. Gravitational lensing thus provides a unique tool transforming these clusters into dark matter laboratories. They will supply us with answers as to the nature and properties of dark matter, and how it shapes galaxies and galaxy clusters and their evolution through cosmic time.

## **OBSERVING DESCRIPTION**

The goal of this program is to identify strongly lensed sources, and measure distortions of background sources due to weak lensing by these two massive, intermediate redshift merging clusters. The resolution of HST is critical to this program for two reasons: (1) the search for and identification

of multiply imaged sources; and (2) shape measurements of background galaxies. The exquisite resolution will allow the morphological and color classification of multiple images, as well providing a high number-density of sources that can be used for weak lensing. Together, these will enable us to derive a high-fidelity strong+weak lensing mass map accurate on the small scales (angular separations  $\sim 45$  arcsec needed to unambiguously separate the contribution from baryons (derived from X-ray mass maps) and dark matter.

**Required Area:** This program requires one pointing per cluster. Due to the WF4 CCD anomaly, we prefer to use WF2 and WF3 for the purpose of weak lensing, therefore we request observations at a specific roll-angle (see special requirements). We still plan to use information from WF4 to study mass distribution on larger scale, we do not, however rely on those observations.

**Required Filters:** The main purpose of this program is to identify the strongly lensed sources, which requires color information. This will not only help us to identify the multiple images, but will also aid in determining photometric redshift estimates for the sources. To this end, we plan to perform careful point spread function (PSF) matched photometry using both ground- and space-based data. The color information is also needed for the weak lensing data, both for efficient subtraction of the cluster members from the catalogs, as well as for the estimate of the redshift distribution of the background population; knowledge of at least the average redshift for the ensemble of weak lensing sources is needed for the absolute calibration of the cluster mass reconstruction. To obtain this calibration we plan to match colors these sources to auxiliary data like the HDF-S photometric redshift catalog of Fontana et al 99. The main filter requirements are therefore broad wavelength coverage and high depth, achieved in relatively short exposure time.

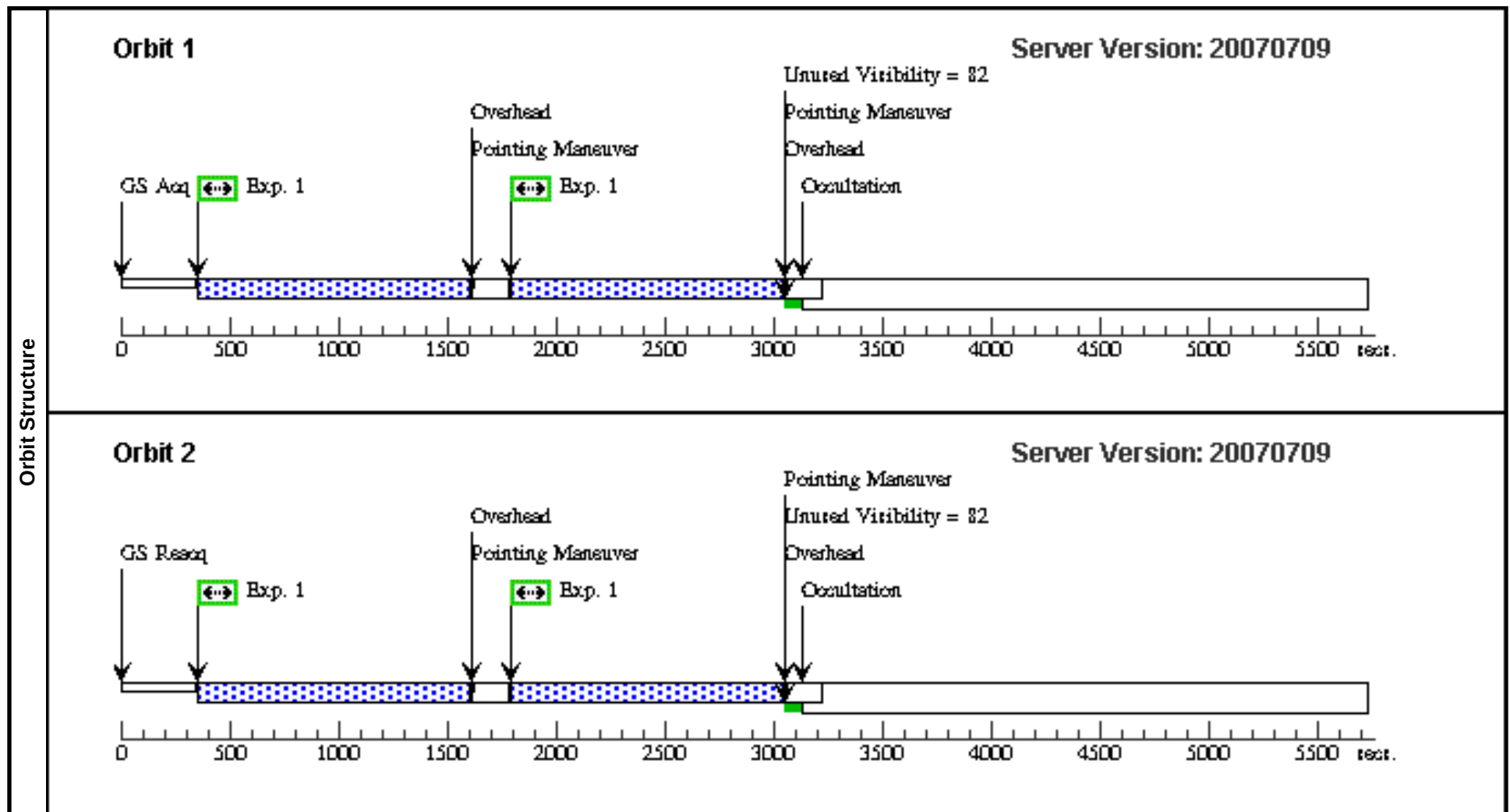
We therefore request observations in the following filters.

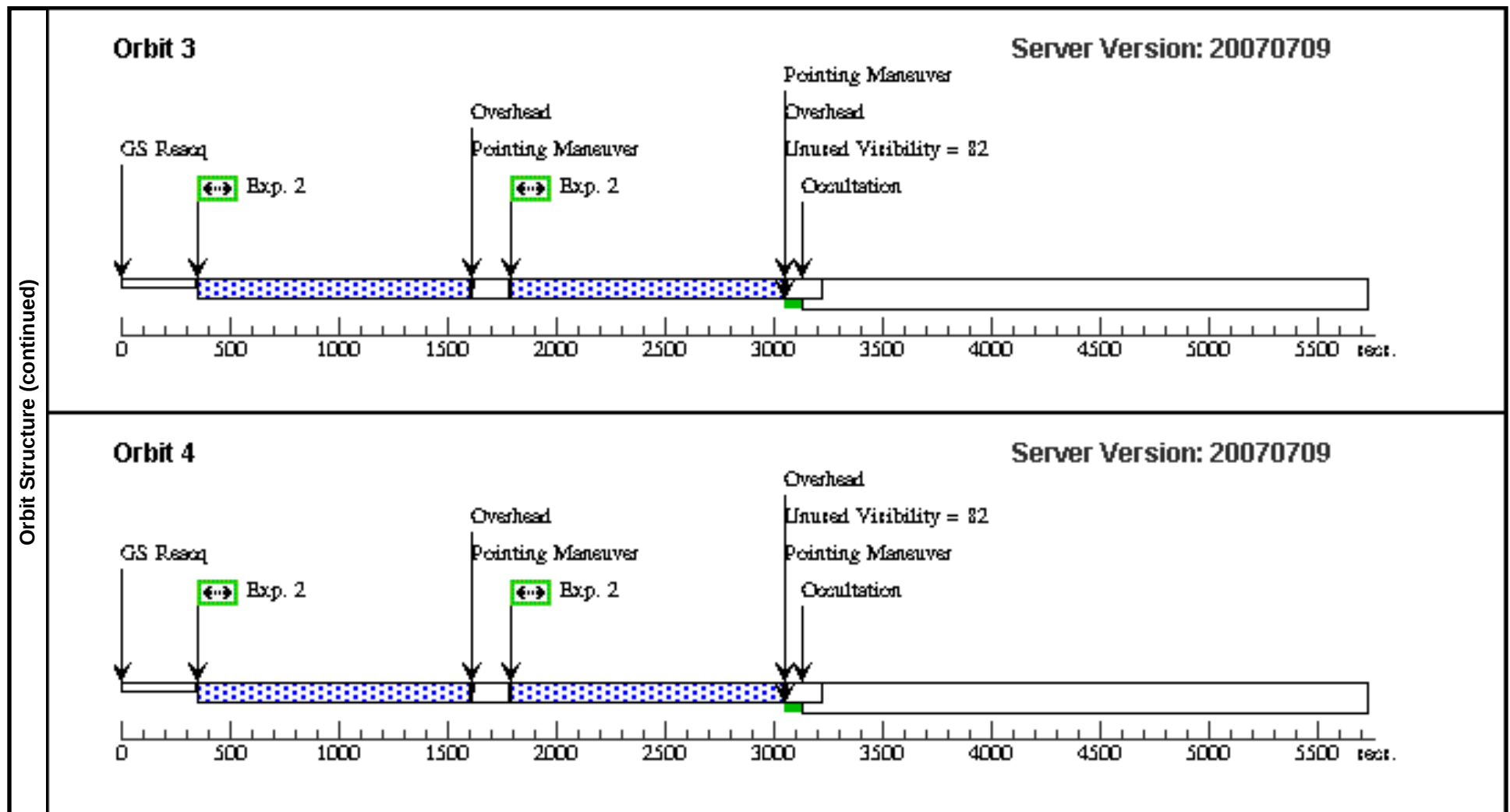
- For MACSJ2243.3-0935 we request complementary observations in WFPC2/F450W, WFPC2/F606W, and WFPC2/F814W.
- For MACSJ0025.4-1222 we request WFPC2/F450W data to allow the unambiguous determination of strong lensing systems.

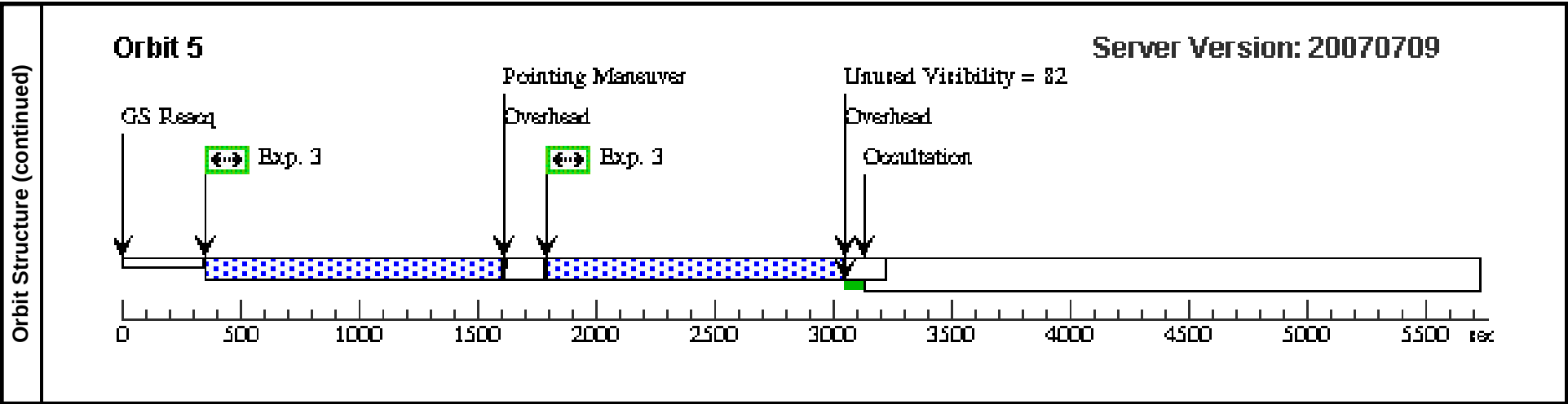
**Dither Pattern:**

For all observations we will use 2 exposures per orbit. We are using standard WFPC2 dither pattern (17) to cover the chip gap and remove artifacts. Each time 4 point dither is completed we shift the pattern by  $(2+1/4\text{pix}, 2+1/4\text{pix})$  first and  $(4+1/4\text{pix}, 0\text{pix})$  next and repeat the pattern.

|               |                                                                        |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                  |                         |     |                              |
|---------------|------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|----------------------|--------------------------------------------------------------------------------------------------------------|--------------|-------------------------|------------------|-------------------------|-----|------------------------------|
| Visit         | Proposal 11100, Visit 01, failed                                       |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                  |                         |     | Thu Aug 23 01:01:34 GMT 2007 |
|               | Diagnostic Status: No Diagnostics                                      |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                  |                         |     |                              |
|               | Scientific Instruments: WFPC2                                          |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                  |                         |     |                              |
|               | Special Requirements: ORIENT 67.0D TO 87.0 D; ORIENT 247.0D TO 267.0 D |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                  |                         |     |                              |
| Patterns      | #                                                                      | Primary Pattern                                                                                       |                                                                                    |                      |                                                                                                              |              | Secondary Pattern       |                  |                         |     | Exposures                    |
|               | (1)                                                                    | Pattern Type=BOX<br>Purpose=DITHER<br>Number Of Points=4<br>Point Spacing=2.349<br>Line Spacing=2.349 |                                                                                    |                      | Coordinate Frame=POS-TARG<br>Pattern Orientation=32.01<br>Angle Between Sides=154.01<br>Center Pattern=false |              |                         |                  |                         |     | (1), (2)                     |
|               | (2)                                                                    | Pattern Type=LINE<br>Purpose=DITHER<br>Number Of Points=2<br>Point Spacing=2.349<br>Line Spacing=     |                                                                                    |                      | Coordinate Frame=POS-TARG<br>Pattern Orientation=32.01<br>Angle Between Sides=<br>Center Pattern=false       |              |                         |                  |                         |     | (3)                          |
| Fixed Targets | #                                                                      | Name                                                                                                  | Target Coordinates                                                                 |                      | Targ. Coord. Corrections                                                                                     |              | Fluxes                  |                  | Miscellaneous           |     |                              |
|               | (1)                                                                    | MACSJ0025.4-1222                                                                                      | RA: 00 25 30.8324 (6.3784683d)<br>Dec: -12 22 15.84 (-12.37107d)<br>Equinox: J2000 |                      |                                                                                                              |              | V=25.0                  |                  | Reference Frame: ICRS   |     |                              |
| Exposures     | #                                                                      | Label                                                                                                 | Target                                                                             | Config,Mode,Aperture | Spectral Els.                                                                                                | Opt. Params. | Special Reqs.           | Groups           | Exp. Time/[Actual Dur.] |     | Orbit                        |
|               | 1                                                                      |                                                                                                       | (1) MACSJ0025.4-1222                                                               | WFPC2, IMAGE, WFALL  | F450W                                                                                                        | CR-SPLIT=NO  |                         | Pattern 1-1 (1)  | 1100.0 Secs             |     |                              |
|               |                                                                        |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                  | [==>(Pattern 1)]        |     | [1]                          |
|               |                                                                        |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                  | [==>(Pattern 2)]        |     |                              |
|               |                                                                        |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                  | [==>(Pattern 3)]        |     |                              |
|               |                                                                        |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                  | [==>(Pattern 4)]        |     | [2]                          |
|               | 2                                                                      |                                                                                                       | (1) MACSJ0025.4-1222                                                               | WFPC2, IMAGE, WFALL  | F450W                                                                                                        | CR-SPLIT=NO  | POS TARG 0.2241,0 .2241 | Pattern 2-2 (1)  | 1100.0 Secs             |     |                              |
|               |                                                                        |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                  | [==>(Pattern 1)]        |     | [3]                          |
|               |                                                                        |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                  | [==>(Pattern 2)]        |     |                              |
|               |                                                                        |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                  | [==>(Pattern 3)]        |     |                              |
|               |                                                                        |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         | [==>(Pattern 4)] |                         | [4] |                              |
|               | 3                                                                      |                                                                                                       | (1) MACSJ0025.4-1222                                                               | WFPC2, IMAGE, WFALL  | F450W                                                                                                        | CR-SPLIT=NO  | POS TARG 0.4233,0       | Pattern 3-3 (2)  | 1100.0 Secs             |     |                              |
|               |                                                                        |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                  | [==>(Pattern 1)]        |     |                              |
|               |                                                                        |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                  | [==>(Pattern 2)]        |     | [5]                          |

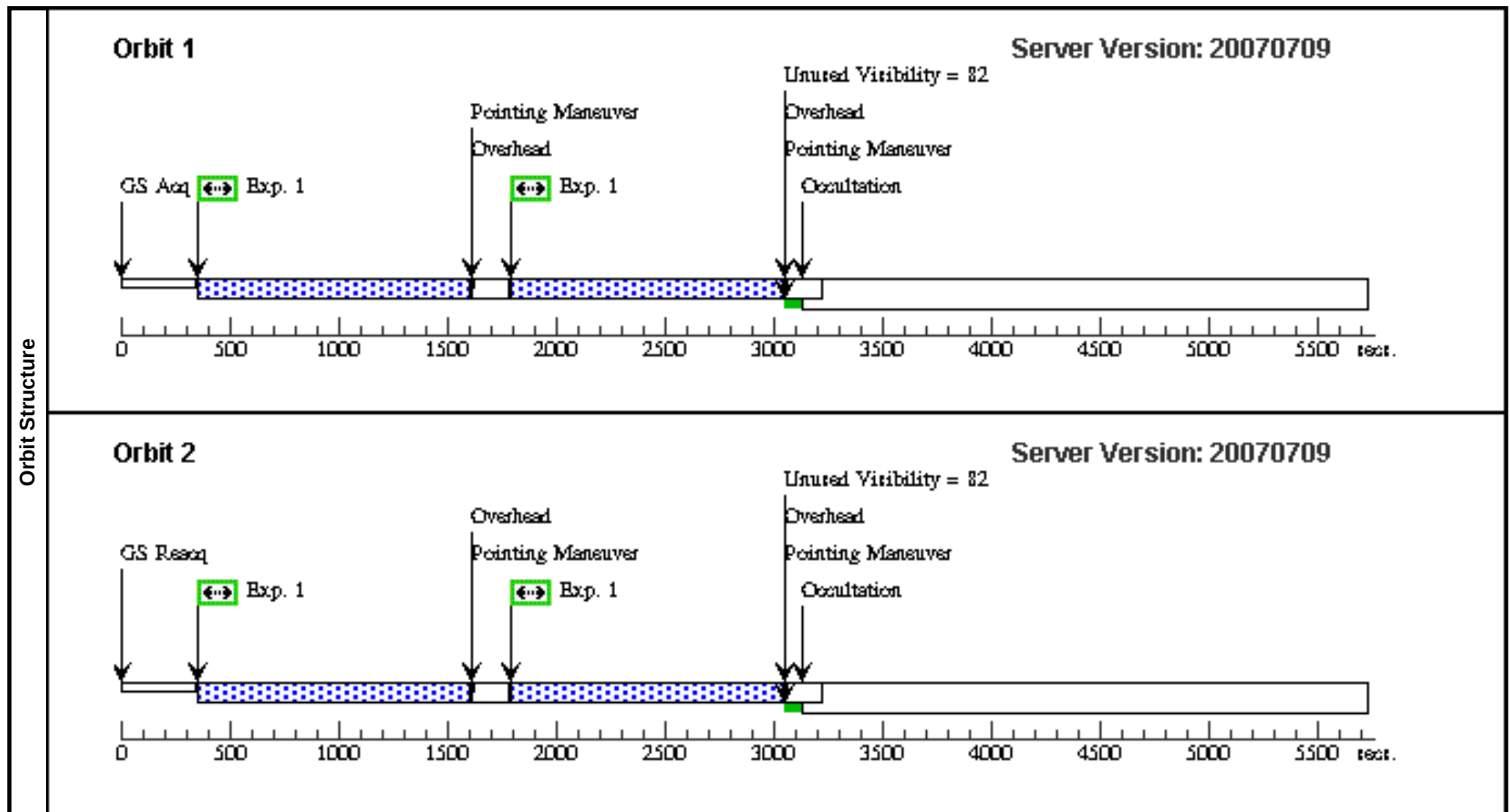


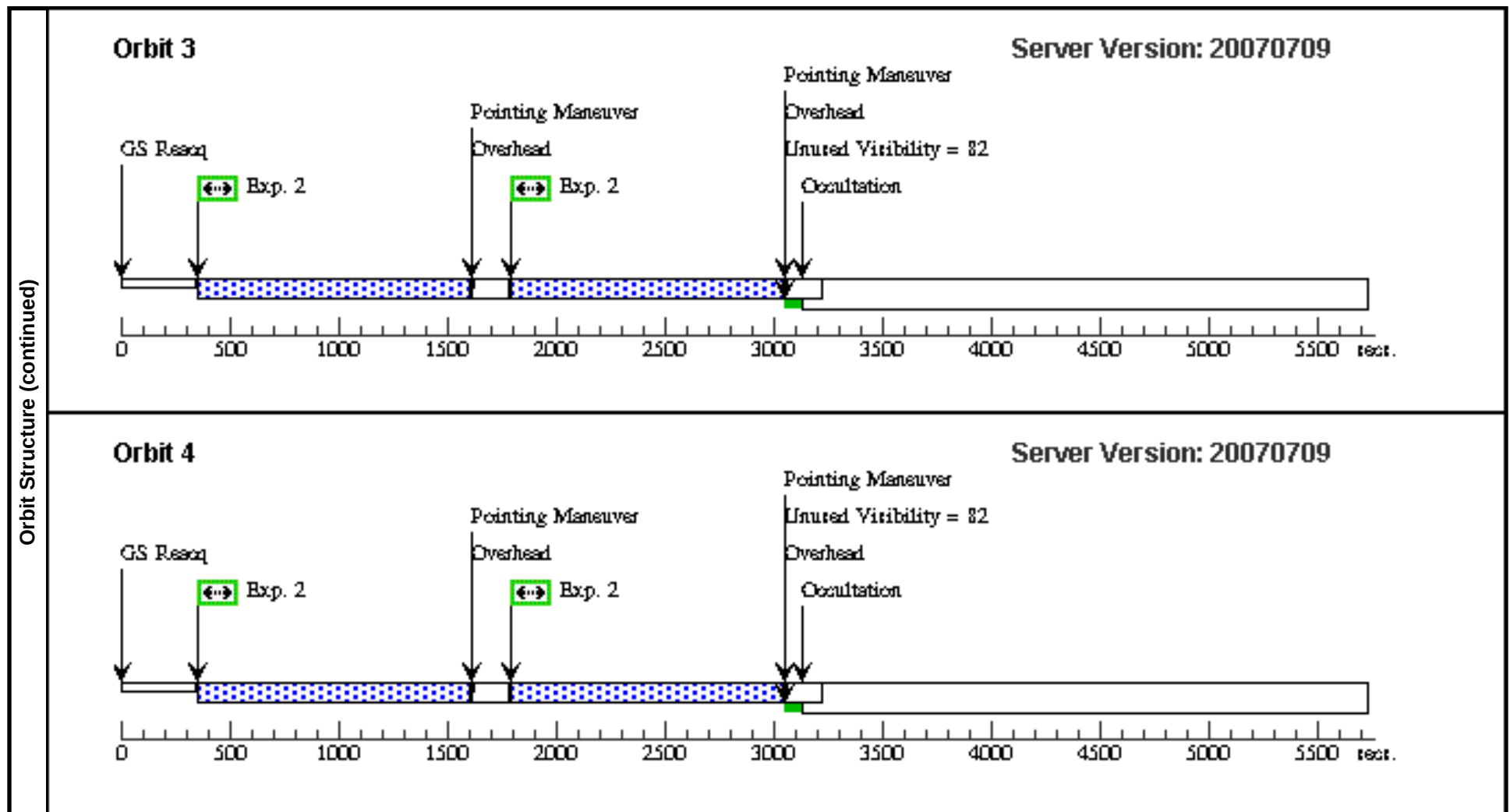


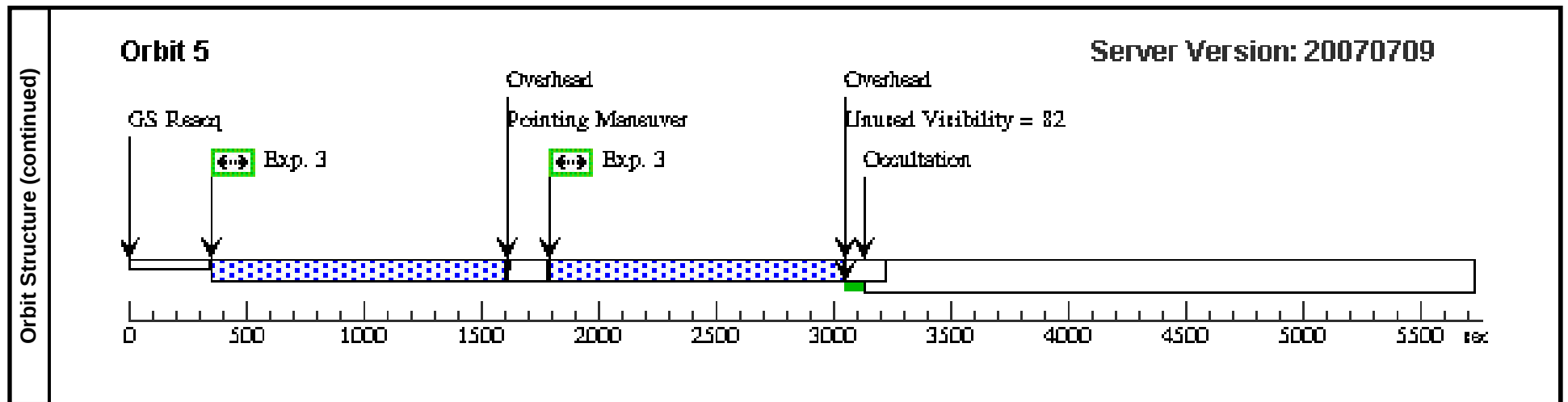


Proposal 11100 - Visit 51 - Two new `bullets' for MOND: revealing the properties of dark matter in massive merging cl...

|               |                                                |                                                                                                       |                                                                                   |                                                                                                              |                          |                              |                         |                  |                         |           |       |
|---------------|------------------------------------------------|-------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|--------------------------|------------------------------|-------------------------|------------------|-------------------------|-----------|-------|
| Visit         | Proposal 11100, Visit 51, implementation       |                                                                                                       |                                                                                   |                                                                                                              |                          | Thu Aug 23 01:01:36 GMT 2007 |                         |                  |                         |           |       |
|               | Diagnostic Status: No Diagnostics              |                                                                                                       |                                                                                   |                                                                                                              |                          |                              |                         |                  |                         |           |       |
|               | Scientific Instruments: WFPC2                  |                                                                                                       |                                                                                   |                                                                                                              |                          |                              |                         |                  |                         |           |       |
|               | Special Requirements: ORIENT 267.0D TO 267.0 D |                                                                                                       |                                                                                   |                                                                                                              |                          |                              |                         |                  |                         |           |       |
| Patterns      | #                                              | Primary Pattern                                                                                       |                                                                                   |                                                                                                              |                          | Secondary Pattern            |                         |                  |                         | Exposures |       |
|               | (1)                                            | Pattern Type=BOX<br>Purpose=DITHER<br>Number Of Points=4<br>Point Spacing=2.349<br>Line Spacing=2.349 |                                                                                   | Coordinate Frame=POS-TARG<br>Pattern Orientation=32.01<br>Angle Between Sides=154.01<br>Center Pattern=false |                          |                              |                         |                  |                         | (1), (2)  |       |
|               | (2)                                            | Pattern Type=LINE<br>Purpose=DITHER<br>Number Of Points=2<br>Point Spacing=2.349<br>Line Spacing=     |                                                                                   | Coordinate Frame=POS-TARG<br>Pattern Orientation=32.01<br>Angle Between Sides=<br>Center Pattern=false       |                          |                              |                         |                  |                         | (3)       |       |
| Fixed Targets | #                                              | Name                                                                                                  | Target Coordinates                                                                |                                                                                                              | Targ. Coord. Corrections |                              | Fluxes                  |                  | Miscellaneous           |           |       |
|               | (4)                                            | MACSJ0025.4-1222-COPY                                                                                 | RA: 00 25 29.4696 (6.3727900d)<br>Dec: -12 23 4.49 (-12.38458d)<br>Equinox: J2000 |                                                                                                              |                          |                              | V=25.0                  |                  | Reference Frame: ICRS   |           |       |
| Exposures     | #                                              | Label                                                                                                 | Target                                                                            | Config,Mode,Aperture                                                                                         | Spectral Els.            | Opt. Params.                 | Special Reqs.           | Groups           | Exp. Time/[Actual Dur.] |           | Orbit |
|               | 1                                              |                                                                                                       | (4) MACSJ0025.4-1222-COPY                                                         | WFPC2, IMAGE, WFALL                                                                                          | F450W                    | CR-SPLIT=NO                  |                         | Pattern 1-1 (1)  | 1100.0 Secs             |           |       |
|               |                                                |                                                                                                       |                                                                                   |                                                                                                              |                          |                              |                         |                  | [==>(Pattern 1)]        |           | [1]   |
|               |                                                |                                                                                                       |                                                                                   |                                                                                                              |                          |                              |                         |                  | [==>(Pattern 2)]        |           |       |
|               |                                                |                                                                                                       |                                                                                   |                                                                                                              |                          |                              |                         |                  | [==>(Pattern 3)]        |           | [2]   |
|               |                                                |                                                                                                       |                                                                                   |                                                                                                              |                          |                              |                         |                  | [==>(Pattern 4)]        |           |       |
|               | 2                                              |                                                                                                       | (4) MACSJ0025.4-1222-COPY                                                         | WFPC2, IMAGE, WFALL                                                                                          | F450W                    | CR-SPLIT=NO                  | POS TARG 0.2241,0 .2241 | Pattern 2-2 (1)  | 1100.0 Secs             |           |       |
|               |                                                |                                                                                                       |                                                                                   |                                                                                                              |                          |                              |                         |                  | [==>(Pattern 1)]        |           | [3]   |
|               |                                                |                                                                                                       |                                                                                   |                                                                                                              |                          |                              |                         |                  | [==>(Pattern 2)]        |           |       |
|               |                                                |                                                                                                       |                                                                                   |                                                                                                              |                          |                              |                         |                  | [==>(Pattern 3)]        |           | [4]   |
|               |                                                |                                                                                                       |                                                                                   |                                                                                                              |                          |                              |                         | [==>(Pattern 4)] |                         |           |       |
| 3             |                                                | (4) MACSJ0025.4-1222-COPY                                                                             | WFPC2, IMAGE, WFALL                                                               | F450W                                                                                                        | CR-SPLIT=NO              | POS TARG 0.4233,0            | Pattern 3-3 (2)         | 1100.0 Secs      |                         |           |       |
|               |                                                |                                                                                                       |                                                                                   |                                                                                                              |                          |                              |                         | [==>(Pattern 1)] |                         | [5]       |       |
|               |                                                |                                                                                                       |                                                                                   |                                                                                                              |                          |                              |                         | [==>(Pattern 2)] |                         |           |       |

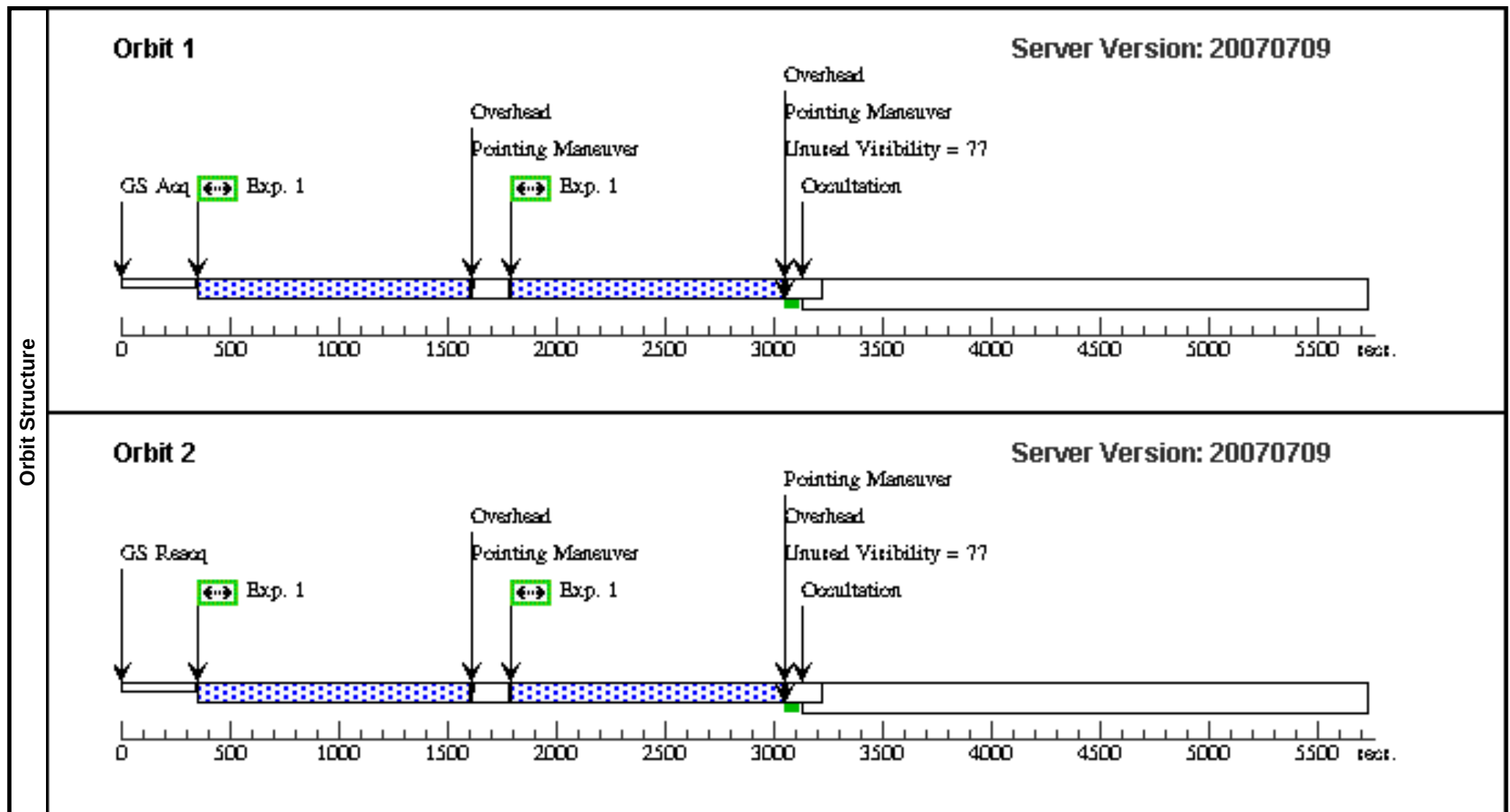


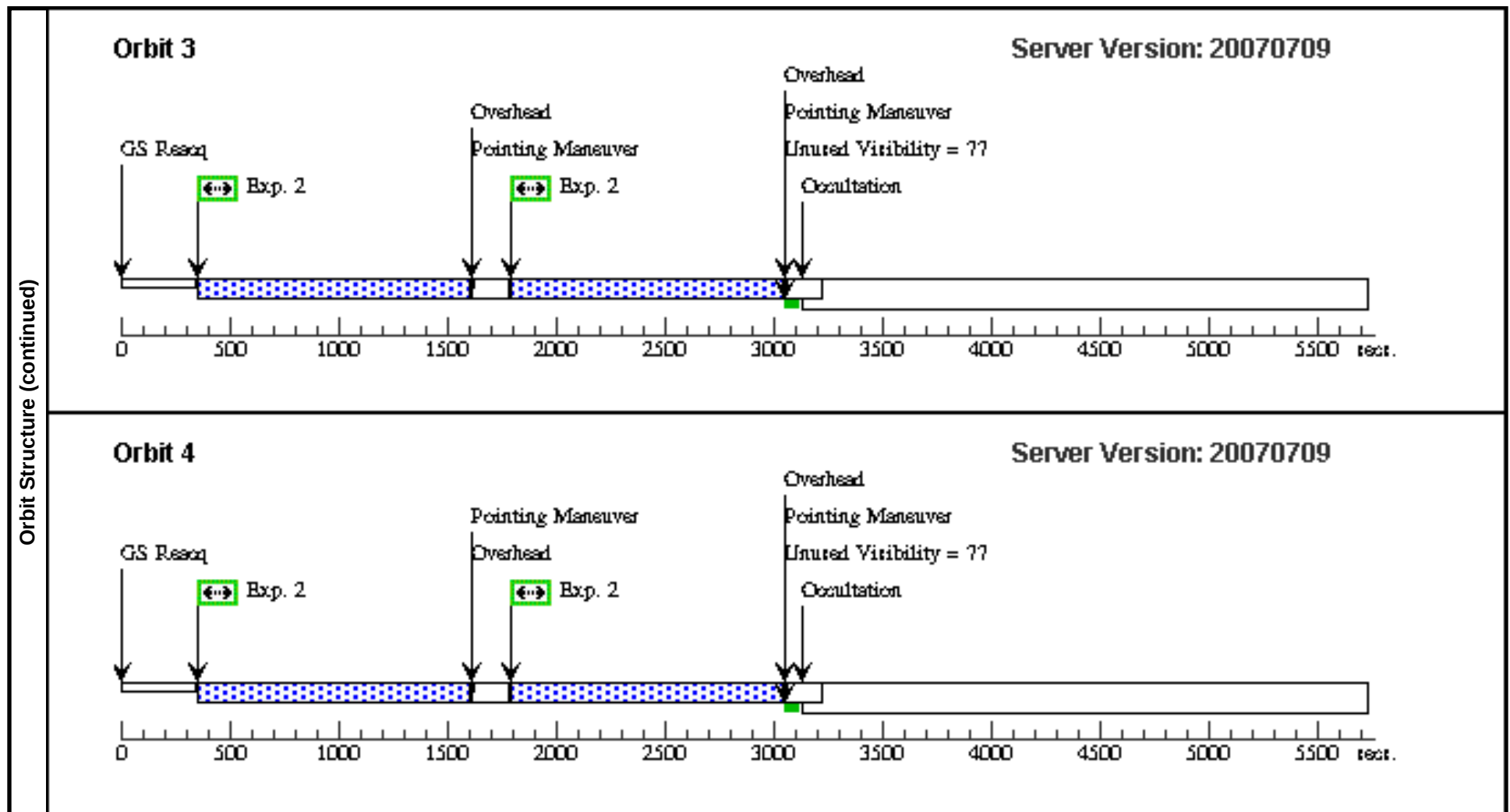


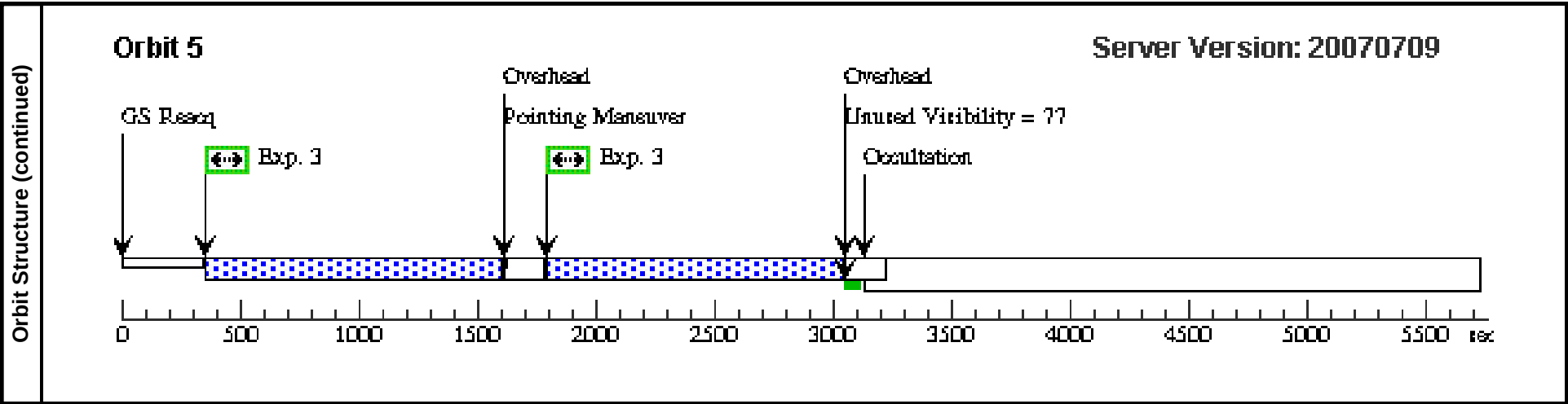


Proposal 11100 - Visit 02 - Two new `bullets' for MOND: revealing the properties of dark matter in massive merging cl...

|               |                                                                        |                                                                                                       |                                                                                     |                                                                                                              |                          |                   |                         |                  |                         |     |                              |
|---------------|------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|--------------------------|-------------------|-------------------------|------------------|-------------------------|-----|------------------------------|
| Visit         | Proposal 11100, Visit 02, completed                                    |                                                                                                       |                                                                                     |                                                                                                              |                          |                   |                         |                  |                         |     | Thu Aug 23 01:01:37 GMT 2007 |
|               | Diagnostic Status: No Diagnostics                                      |                                                                                                       |                                                                                     |                                                                                                              |                          |                   |                         |                  |                         |     |                              |
|               | Scientific Instruments: WFPC2                                          |                                                                                                       |                                                                                     |                                                                                                              |                          |                   |                         |                  |                         |     |                              |
|               | Special Requirements: ORIENT 15.0D TO 45.0 D; ORIENT 195.0D TO 227.0 D |                                                                                                       |                                                                                     |                                                                                                              |                          |                   |                         |                  |                         |     |                              |
| Patterns      | #                                                                      | Primary Pattern                                                                                       |                                                                                     |                                                                                                              |                          |                   | Secondary Pattern       |                  |                         |     | Exposures                    |
|               | (1)                                                                    | Pattern Type=BOX<br>Purpose=DITHER<br>Number Of Points=4<br>Point Spacing=2.349<br>Line Spacing=2.349 |                                                                                     | Coordinate Frame=POS-TARG<br>Pattern Orientation=32.01<br>Angle Between Sides=154.01<br>Center Pattern=false |                          |                   |                         |                  |                         |     | (1), (2)                     |
|               | (2)                                                                    | Pattern Type=LINE<br>Purpose=DITHER<br>Number Of Points=2<br>Point Spacing=2.349<br>Line Spacing=     |                                                                                     | Coordinate Frame=POS-TARG<br>Pattern Orientation=32.01<br>Angle Between Sides=<br>Center Pattern=false       |                          |                   |                         |                  |                         |     | (3)                          |
| Fixed Targets | #                                                                      | Name                                                                                                  | Target Coordinates                                                                  |                                                                                                              | Targ. Coord. Corrections |                   | Fluxes                  |                  | Miscellaneous           |     |                              |
|               | (2)                                                                    | MACSJ2243.3-0935                                                                                      | RA: 22 43 23.3576 (340.8473233d)<br>Dec: -09 35 42.11 (-9.59503d)<br>Equinox: J2000 |                                                                                                              |                          |                   | V=25.0                  |                  | Reference Frame: ICRS   |     |                              |
| Exposures     | #                                                                      | Label                                                                                                 | Target                                                                              | Config,Mode,Aperture                                                                                         | Spectral Els.            | Opt. Params.      | Special Reqs.           | Groups           | Exp. Time/[Actual Dur.] |     | Orbit                        |
|               | 1                                                                      |                                                                                                       | (2) MACSJ2243.3-0935                                                                | WFPC2, IMAGE, WFALL                                                                                          | F450W                    | CR-SPLIT=NO       |                         | Pattern 1-1 (1)  | 1100.0 Secs             |     |                              |
|               |                                                                        |                                                                                                       |                                                                                     |                                                                                                              |                          |                   |                         |                  | [==>(Pattern 1)]        |     |                              |
|               |                                                                        |                                                                                                       |                                                                                     |                                                                                                              |                          |                   |                         |                  | [==>(Pattern 2)]        | [1] |                              |
|               |                                                                        |                                                                                                       |                                                                                     |                                                                                                              |                          |                   |                         |                  | [==>(Pattern 3)]        |     |                              |
|               |                                                                        |                                                                                                       |                                                                                     |                                                                                                              |                          |                   |                         |                  | [==>(Pattern 4)]        | [2] |                              |
|               | 2                                                                      |                                                                                                       | (2) MACSJ2243.3-0935                                                                | WFPC2, IMAGE, WFALL                                                                                          | F450W                    | CR-SPLIT=NO       | POS TARG 0.2241,0 .2241 | Pattern 2-2 (1)  | 1100.0 Secs             |     |                              |
|               |                                                                        |                                                                                                       |                                                                                     |                                                                                                              |                          |                   |                         |                  | [==>(Pattern 1)]        |     |                              |
|               |                                                                        |                                                                                                       |                                                                                     |                                                                                                              |                          |                   |                         |                  | [==>(Pattern 2)]        | [3] |                              |
|               |                                                                        |                                                                                                       |                                                                                     |                                                                                                              |                          |                   |                         |                  | [==>(Pattern 3)]        |     |                              |
|               |                                                                        |                                                                                                       |                                                                                     |                                                                                                              |                          |                   |                         | [==>(Pattern 4)] | [4]                     |     |                              |
| 3             |                                                                        | (2) MACSJ2243.3-0935                                                                                  | WFPC2, IMAGE, WFALL                                                                 | F450W                                                                                                        | CR-SPLIT=NO              | POS TARG 0.4233,0 | Pattern 3-3 (2)         | 1100.0 Secs      |                         |     |                              |
|               |                                                                        |                                                                                                       |                                                                                     |                                                                                                              |                          |                   |                         | [==>(Pattern 1)] |                         |     |                              |
|               |                                                                        |                                                                                                       |                                                                                     |                                                                                                              |                          |                   |                         | [==>(Pattern 2)] | [5]                     |     |                              |

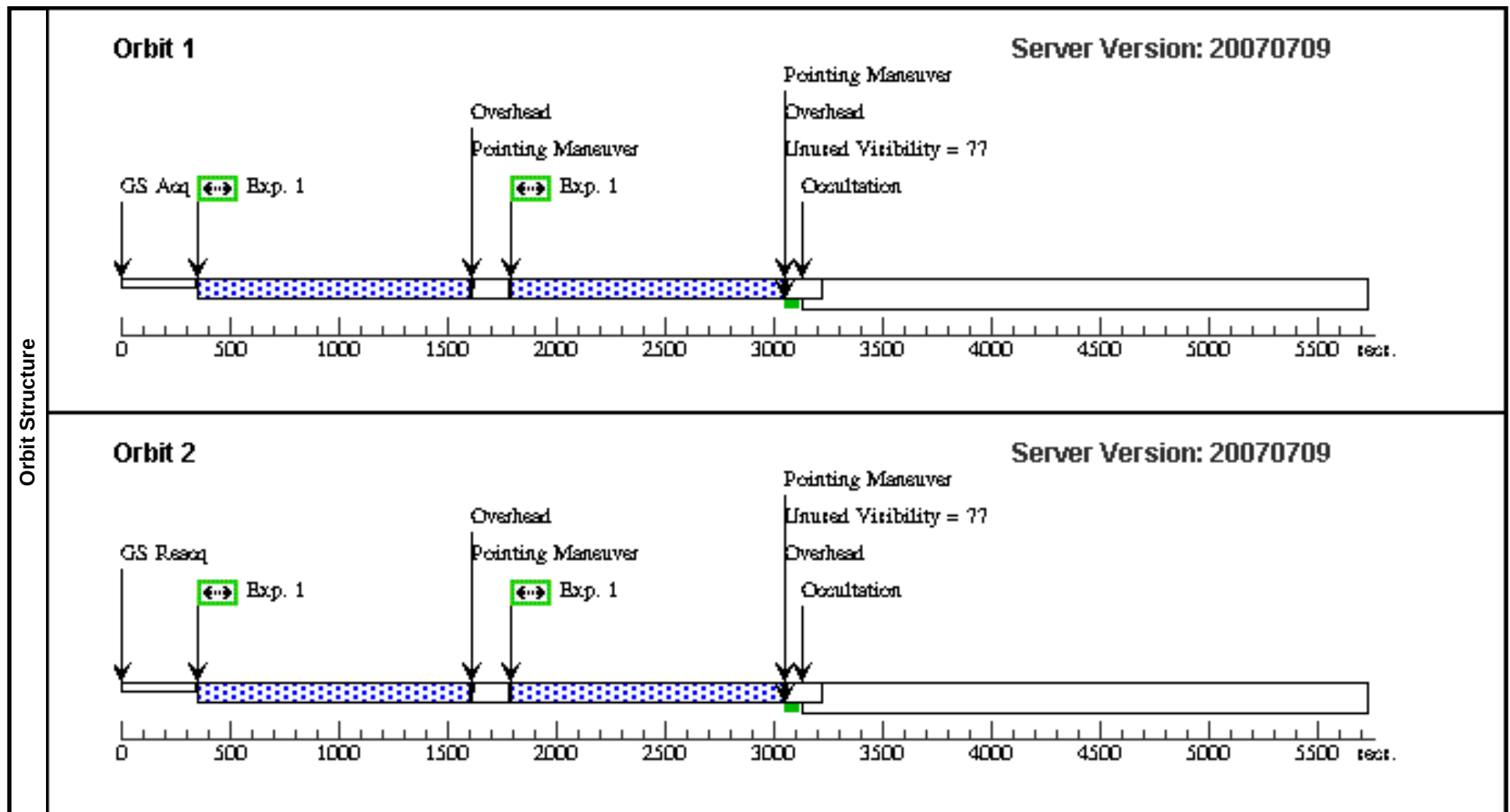


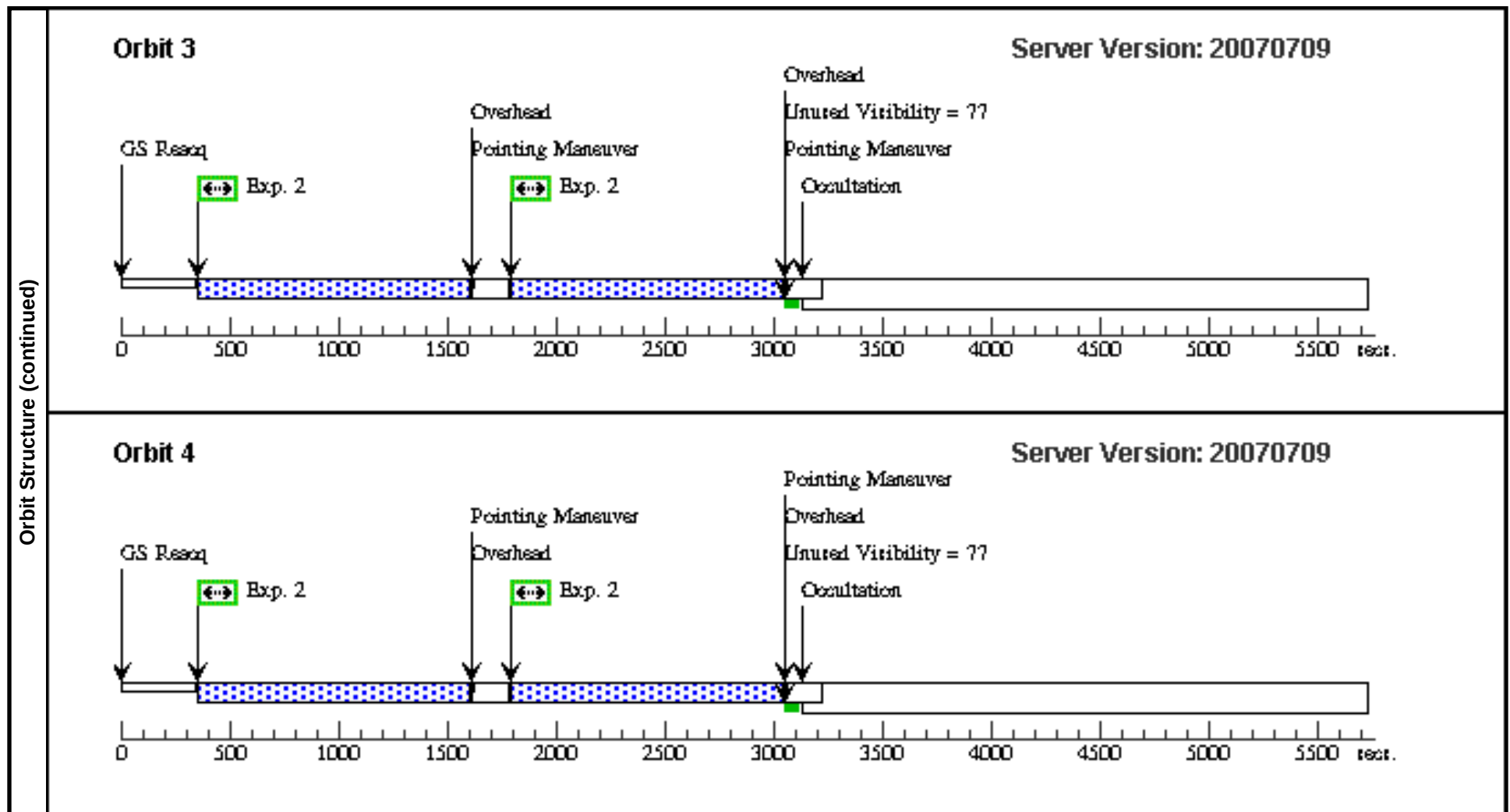


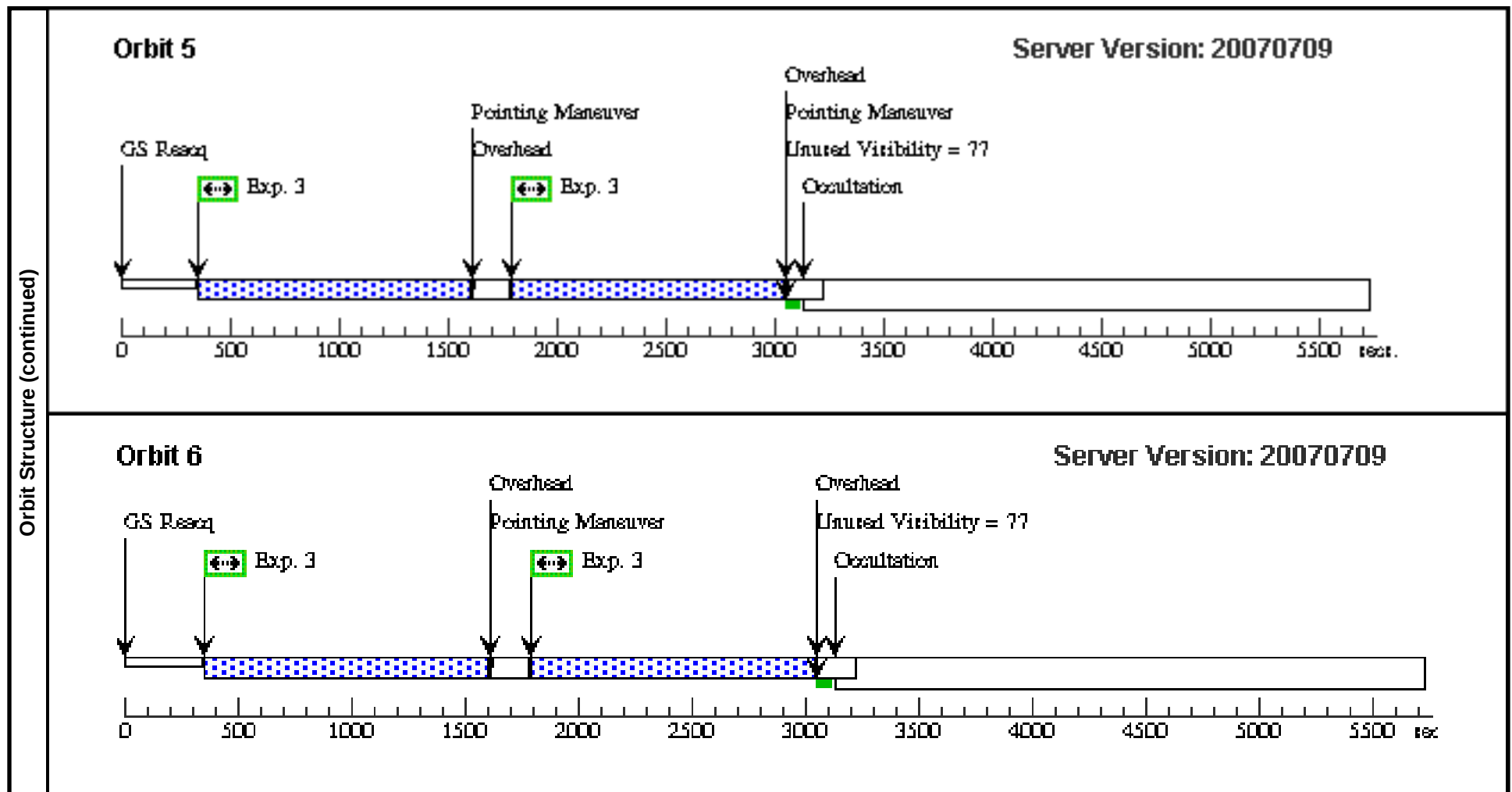


Proposal 11100 - Visit 03 - Two new `bullets' for MOND: revealing the properties of dark matter in massive merging cl...

|                  |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         |                         |                              |               |  |
|------------------|------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|----------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|--------------------------|-------------------|------------------|-------------------------|-------------------------|------------------------------|---------------|--|
| Visit            | Proposal 11100, Visit 03, completed                                    |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         |                         | Thu Aug 23 01:01:38 GMT 2007 |               |  |
|                  | Diagnostic Status: No Diagnostics                                      |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         |                         |                              |               |  |
|                  | Scientific Instruments: WFPC2                                          |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         |                         |                              |               |  |
|                  | Special Requirements: ORIENT 15.0D TO 45.0 D; ORIENT 195.0D TO 227.0 D |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         |                         |                              |               |  |
| Patterns         | #                                                                      | Primary Pattern                                                                                       |                      |                                                                                     |                                                                                                              |                          | Secondary Pattern |                  |                         |                         |                              | Exposures     |  |
|                  | (1)                                                                    | Pattern Type=BOX<br>Purpose=DITHER<br>Number Of Points=4<br>Point Spacing=2.349<br>Line Spacing=2.349 |                      |                                                                                     | Coordinate Frame=POS-TARG<br>Pattern Orientation=32.01<br>Angle Between Sides=154.01<br>Center Pattern=false |                          |                   |                  |                         |                         |                              | (1), (2), (3) |  |
| Fixed Targets    | #                                                                      | Name                                                                                                  |                      | Target Coordinates                                                                  |                                                                                                              | Targ. Coord. Corrections |                   | Fluxes           |                         | Miscellaneous           |                              |               |  |
|                  | (2)                                                                    | MACSJ2243.3-0935                                                                                      |                      | RA: 22 43 23.3576 (340.8473233d)<br>Dec: -09 35 42.11 (-9.59503d)<br>Equinox: J2000 |                                                                                                              |                          |                   | V=25.0           |                         | Reference Frame: ICRS   |                              |               |  |
| Exposures        | #                                                                      | Label                                                                                                 | Target               | Config,Mode,Aperture                                                                |                                                                                                              | Spectral Els.            | Opt. Params.      | Special Reqs.    | Groups                  | Exp. Time/[Actual Dur.] |                              | Orbit         |  |
|                  | 1                                                                      |                                                                                                       | (2) MACSJ2243.3-0935 | WFPC2, IMAGE, WFALL                                                                 |                                                                                                              | F606W                    | CR-SPLIT=NO       |                  | Pattern 1-1 (1)         | 1100.0 Secs             |                              |               |  |
|                  |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         | [==>(Pattern 1)]        |                              | [1]           |  |
|                  |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         | [==>(Pattern 2)]        |                              |               |  |
|                  |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         | [==>(Pattern 3)]        |                              |               |  |
|                  |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   | [==>(Pattern 4)] |                         | [2]                     |                              |               |  |
|                  |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         |                         |                              |               |  |
|                  |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         |                         |                              |               |  |
|                  |                                                                        | 2                                                                                                     |                      | (2) MACSJ2243.3-0935                                                                | WFPC2, IMAGE, WFALL                                                                                          |                          | F606W             | CR-SPLIT=NO      | POS TARG 0.2241,0 .2241 | Pattern 2-2 (1)         | 1100.0 Secs                  |               |  |
|                  | [==>(Pattern 1)]                                                       |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         |                         | [3]                          |               |  |
|                  | [==>(Pattern 2)]                                                       |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         |                         |                              |               |  |
|                  | [==>(Pattern 3)]                                                       |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         |                         |                              |               |  |
|                  |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   | [==>(Pattern 4)] |                         | [4]                     |                              |               |  |
|                  |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         |                         |                              |               |  |
|                  |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         |                         |                              |               |  |
|                  |                                                                        | 3                                                                                                     |                      | (2) MACSJ2243.3-0935                                                                | WFPC2, IMAGE, WFALL                                                                                          |                          | F606W             | CR-SPLIT=NO      | POS TARG 0.4233,0       | Pattern 3-3 (1)         | 1100.0 Secs                  |               |  |
| [==>(Pattern 1)] |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         |                         | [5]                          |               |  |
| [==>(Pattern 2)] |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         |                         |                              |               |  |
| [==>(Pattern 3)] |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         |                         |                              |               |  |
|                  |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          | [==>(Pattern 4)]  |                  | [6]                     |                         |                              |               |  |
|                  |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         |                         |                              |               |  |
|                  |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |                  |                         |                         |                              |               |  |

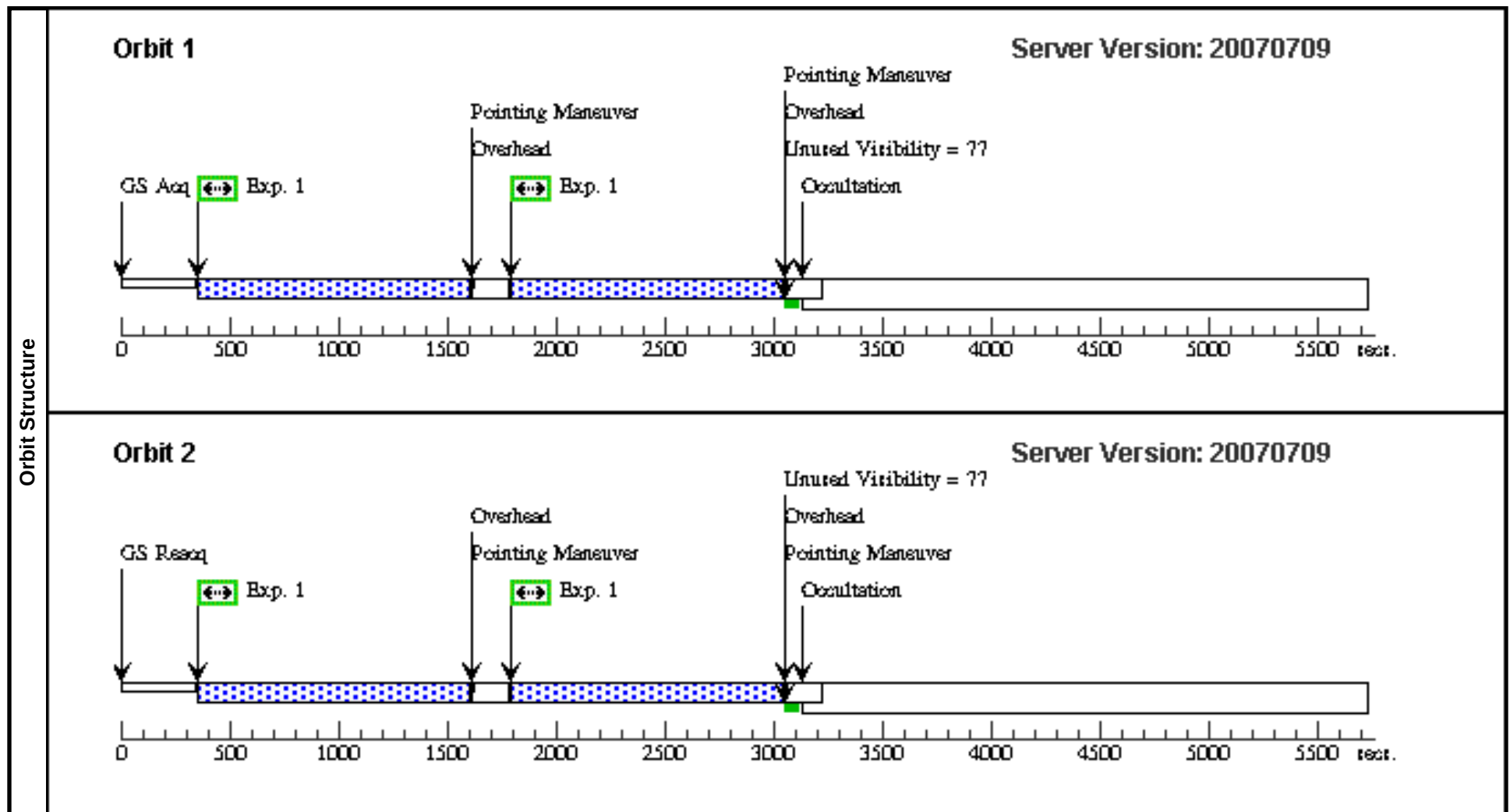


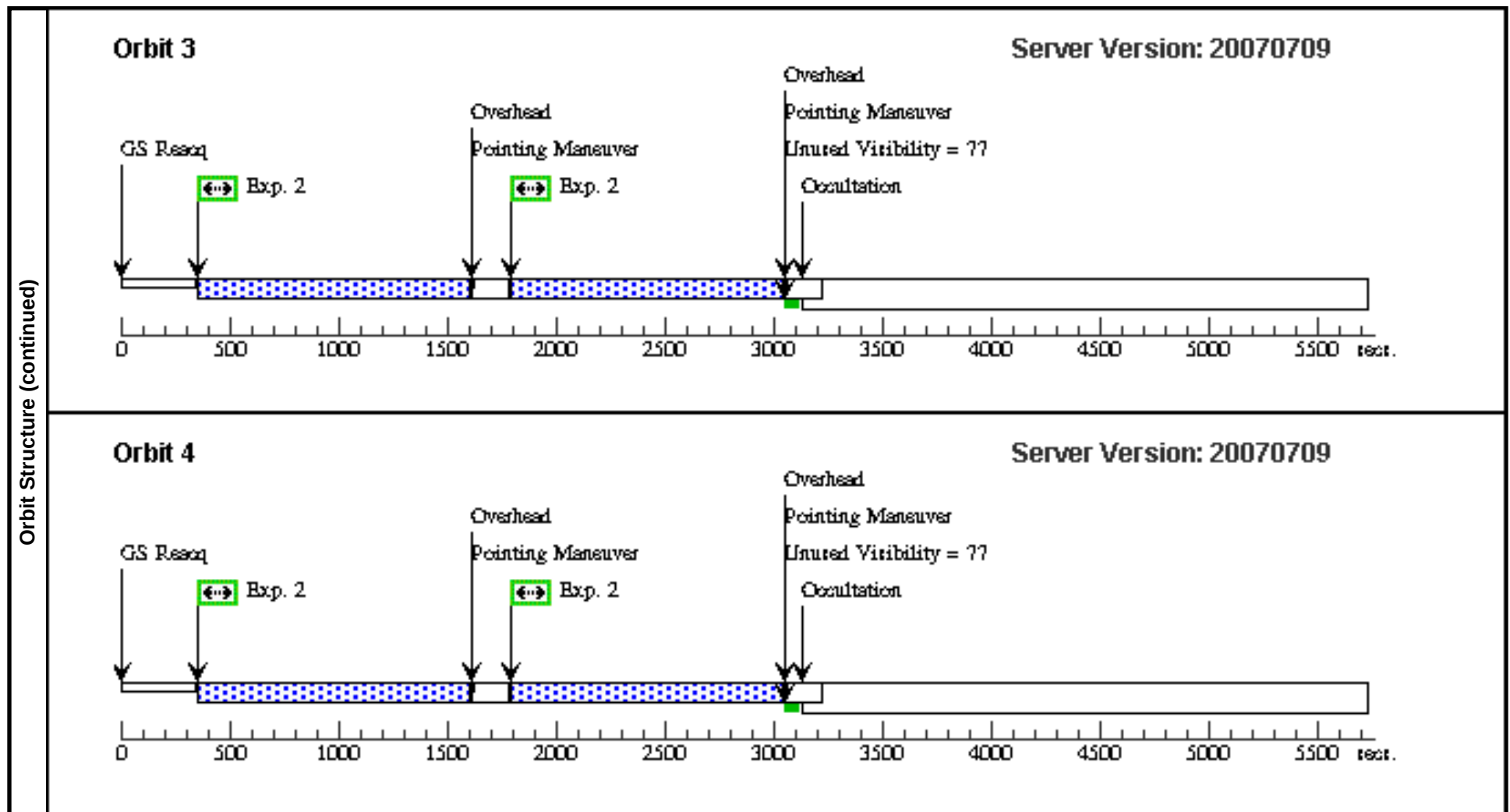


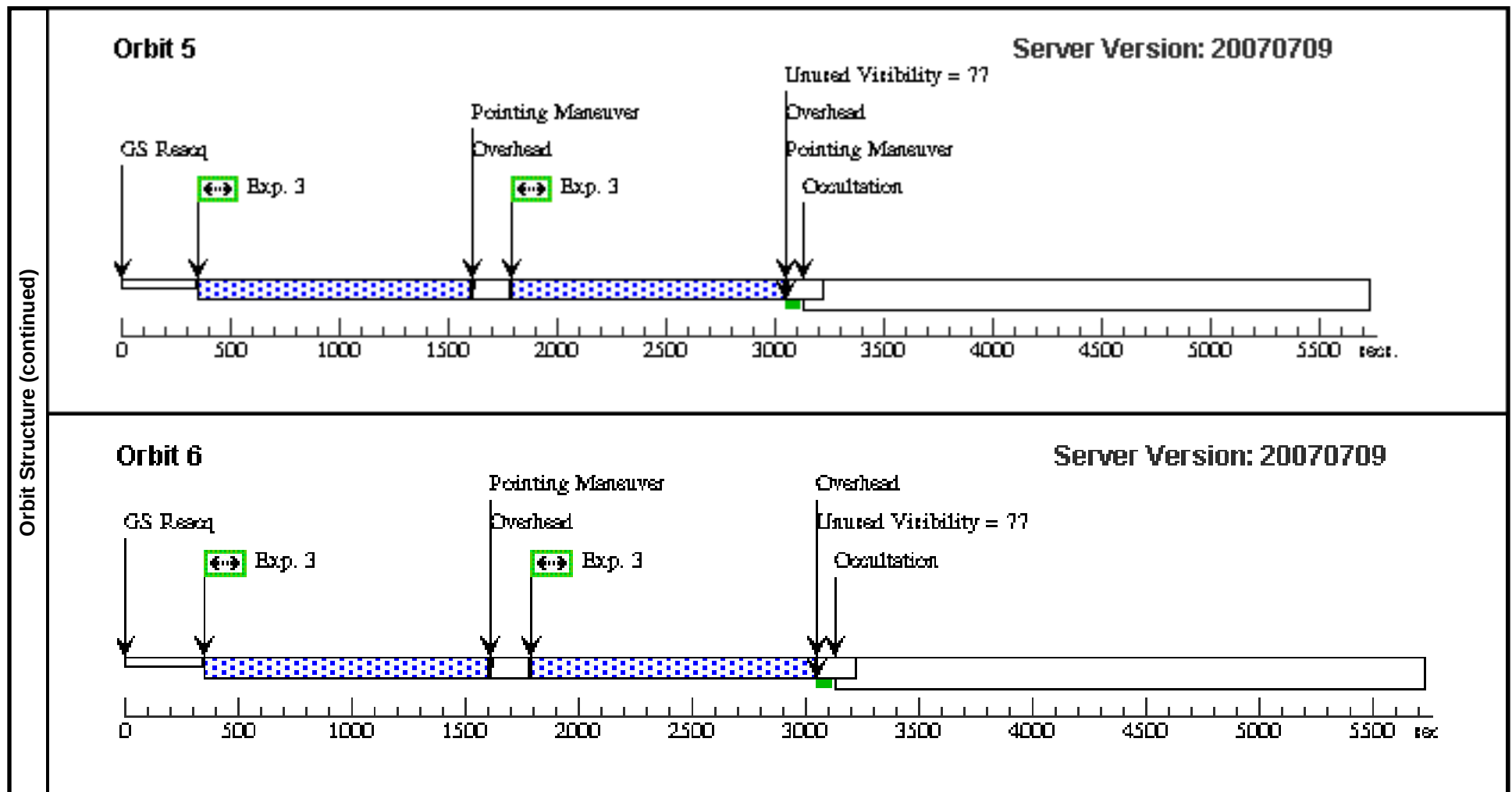


Proposal 11100 - Visit 04 - Two new `bullets' for MOND: revealing the properties of dark matter in massive merging cl...

|               |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |               |                         |                         |                              |               |     |
|---------------|------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|----------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|--------------------------|-------------------|---------------|-------------------------|-------------------------|------------------------------|---------------|-----|
| Visit         | Proposal 11100, Visit 04, completed                                    |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |               |                         |                         | Thu Aug 23 01:01:39 GMT 2007 |               |     |
|               | Diagnostic Status: No Diagnostics                                      |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |               |                         |                         |                              |               |     |
|               | Scientific Instruments: WFPC2                                          |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |               |                         |                         |                              |               |     |
|               | Special Requirements: ORIENT 15.0D TO 45.0 D; ORIENT 195.0D TO 227.0 D |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |               |                         |                         |                              |               |     |
| Patterns      | #                                                                      | Primary Pattern                                                                                       |                      |                                                                                     |                                                                                                              |                          | Secondary Pattern |               |                         |                         |                              | Exposures     |     |
|               | (1)                                                                    | Pattern Type=BOX<br>Purpose=DITHER<br>Number Of Points=4<br>Point Spacing=2.349<br>Line Spacing=2.349 |                      |                                                                                     | Coordinate Frame=POS-TARG<br>Pattern Orientation=32.01<br>Angle Between Sides=154.01<br>Center Pattern=false |                          |                   |               |                         |                         |                              | (1), (2), (3) |     |
| Fixed Targets | #                                                                      | Name                                                                                                  |                      | Target Coordinates                                                                  |                                                                                                              | Targ. Coord. Corrections |                   | Fluxes        |                         | Miscellaneous           |                              |               |     |
|               | (2)                                                                    | MACSJ2243.3-0935                                                                                      |                      | RA: 22 43 23.3576 (340.8473233d)<br>Dec: -09 35 42.11 (-9.59503d)<br>Equinox: J2000 |                                                                                                              |                          |                   | V=25.0        |                         | Reference Frame: ICRS   |                              |               |     |
| Exposures     | #                                                                      | Label                                                                                                 | Target               | Config,Mode,Aperture                                                                |                                                                                                              | Spectral Els.            | Opt. Params.      | Special Reqs. | Groups                  | Exp. Time/[Actual Dur.] |                              | Orbit         |     |
|               | 1                                                                      |                                                                                                       | (2) MACSJ2243.3-0935 | WFPC2, IMAGE, WFALL                                                                 |                                                                                                              | F814W                    | CR-SPLIT=NO       |               | Pattern 1-1 (1)         | 1100.0 Secs             |                              |               |     |
|               |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |               |                         | [==>(Pattern 1)]        |                              | [1]           |     |
|               |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |               |                         | [==>(Pattern 2)]        |                              |               |     |
|               |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |               |                         | [==>(Pattern 3)]        |                              |               |     |
|               |                                                                        | [==>(Pattern 4)]                                                                                      |                      | [2]                                                                                 |                                                                                                              |                          |                   |               |                         |                         |                              |               |     |
|               |                                                                        | 2                                                                                                     | (2) MACSJ2243.3-0935 |                                                                                     | WFPC2, IMAGE, WFALL                                                                                          |                          | F814W             | CR-SPLIT=NO   | POS TARG 0.2241,0 .2241 | Pattern 2-2 (1)         | 1100.0 Secs                  |               |     |
|               |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |               |                         |                         | [==>(Pattern 1)]             |               | [3] |
|               |                                                                        |                                                                                                       |                      | [==>(Pattern 2)]                                                                    |                                                                                                              |                          |                   |               |                         |                         |                              |               |     |
|               | [==>(Pattern 3)]                                                       |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |               |                         |                         |                              |               |     |
|               |                                                                        | [==>(Pattern 4)]                                                                                      |                      | [4]                                                                                 |                                                                                                              |                          |                   |               |                         |                         |                              |               |     |
|               |                                                                        | 3                                                                                                     | (2) MACSJ2243.3-0935 |                                                                                     | WFPC2, IMAGE, WFALL                                                                                          |                          | F814W             | CR-SPLIT=NO   | POS TARG 0.4233,0       | Pattern 3-3 (1)         | 1100.0 Secs                  |               |     |
|               |                                                                        |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |               |                         |                         | [==>(Pattern 1)]             |               | [5] |
|               |                                                                        |                                                                                                       |                      | [==>(Pattern 2)]                                                                    |                                                                                                              |                          |                   |               |                         |                         |                              |               |     |
|               | [==>(Pattern 3)]                                                       |                                                                                                       |                      |                                                                                     |                                                                                                              |                          |                   |               |                         |                         |                              |               |     |
|               |                                                                        | [==>(Pattern 4)]                                                                                      |                      | [6]                                                                                 |                                                                                                              |                          |                   |               |                         |                         |                              |               |     |







Proposal 11100 - Visit 05 - Two new `bullets' for MOND: revealing the properties of dark matter in massive merging cl...

|               |                                                                                                |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                 |                                                                              |  |                              |
|---------------|------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|----------------------|--------------------------------------------------------------------------------------------------------------|--------------|-------------------------|-----------------|------------------------------------------------------------------------------|--|------------------------------|
| Visit         | Proposal 11100, Visit 05, completed                                                            |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                 |                                                                              |  | Thu Aug 23 01:01:40 GMT 2007 |
|               | Diagnostic Status: No Diagnostics                                                              |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                 |                                                                              |  |                              |
|               | Scientific Instruments: WFPC2                                                                  |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                 |                                                                              |  |                              |
|               | Special Requirements: (none)                                                                   |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                 |                                                                              |  |                              |
| Patterns      | #                                                                                              | Primary Pattern                                                                                       |                                                                                    |                      |                                                                                                              |              | Secondary Pattern       |                 |                                                                              |  | Exposures                    |
|               | (1)                                                                                            | Pattern Type=BOX<br>Purpose=DITHER<br>Number Of Points=4<br>Point Spacing=2.349<br>Line Spacing=2.349 |                                                                                    |                      | Coordinate Frame=POS-TARG<br>Pattern Orientation=32.01<br>Angle Between Sides=154.01<br>Center Pattern=false |              |                         |                 |                                                                              |  | (1-2)                        |
|               | (2)                                                                                            | Pattern Type=LINE<br>Purpose=DITHER<br>Number Of Points=2<br>Point Spacing=2.349<br>Line Spacing=     |                                                                                    |                      | Coordinate Frame=POS-TARG<br>Pattern Orientation=32.01<br>Angle Between Sides=<br>Center Pattern=false       |              |                         |                 |                                                                              |  | (3-4)                        |
| Fixed Targets | #                                                                                              | Name                                                                                                  | Target Coordinates                                                                 |                      | Targ. Coord. Corrections                                                                                     |              | Fluxes                  |                 | Miscellaneous                                                                |  |                              |
|               | (3)                                                                                            | MESSIER-002                                                                                           | RA: 21 33 16.9361 (323.3205671d)<br>Dec: -00 51 43.83 (-.86217d)<br>Equinox: J2000 |                      |                                                                                                              |              | V=7.5                   |                 | Reference Frame: ICRS                                                        |  |                              |
|               | Comments: This object was generated by the targetselector and retrieved from the NED database. |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                 |                                                                              |  |                              |
| Exposures     | #                                                                                              | Label                                                                                                 | Target                                                                             | Config,Mode,Aperture | Spectral Els.                                                                                                | Opt. Params. | Special Reqs.           | Groups          | Exp. Time/[Actual Dur.]                                                      |  | Orbit                        |
|               | 1                                                                                              |                                                                                                       | (3) MESSIER-002                                                                    | WFPC2, IMAGE, WFALL  | F606W                                                                                                        | CR-SPLIT=NO  |                         | Pattern 1-2 (1) | 10.0 Secs                                                                    |  |                              |
|               |                                                                                                |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                 | [==>(Pattern 1)]<br>[==>(Pattern 2)]<br>[==>(Pattern 3)]<br>[==>(Pattern 4)] |  | [1]                          |
|               | 2                                                                                              |                                                                                                       | (3) MESSIER-002                                                                    | WFPC2, IMAGE, WFALL  | F814W                                                                                                        | CR-SPLIT=NO  |                         | Pattern 1-2 (1) | 10.0 Secs                                                                    |  |                              |
|               |                                                                                                |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                 | [==>(Pattern 1)]<br>[==>(Pattern 2)]<br>[==>(Pattern 3)]<br>[==>(Pattern 4)] |  | [1]                          |
|               | 3                                                                                              |                                                                                                       | (3) MESSIER-002                                                                    | WFPC2, IMAGE, WFALL  | F606W                                                                                                        | CR-SPLIT=NO  | POS TARG 0.2241,0 .2241 | Pattern 3-4 (2) | 10.0 Secs                                                                    |  |                              |
|               |                                                                                                |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                 | [==>(Pattern 1)]<br>[==>(Pattern 2)]                                         |  | [1]                          |
|               | 4                                                                                              |                                                                                                       | (3) MESSIER-002                                                                    | WFPC2, IMAGE, WFALL  | F814W                                                                                                        | CR-SPLIT=NO  | POS TARG 0.2241,0 .2241 | Pattern 3-4 (2) | 10.0 Secs                                                                    |  |                              |
|               |                                                                                                |                                                                                                       |                                                                                    |                      |                                                                                                              |              |                         |                 | [==>(Pattern 1)]<br>[==>(Pattern 2)]                                         |  | [1]                          |

