



## 13317 - Infrared Grism Confirmation of a Strongly Lensed $z \sim 11$ Candidate:

### MACS0647-JD

Cycle: 21, Proposal Category: GO

(Availability Mode: SUPPORTED)

#### INVESTIGATORS

| <i>Name</i>                                    | <i>Institution</i>                             | <i>E-Mail</i>                  |
|--|--|--------------------------------|
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| Ms. Elizabeth Barker (CoI)                     | Space Telescope Science Institute              | ebarker@stsci.edu              |

#### 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) MACS0647+7015            | WFC3/IR                             | 4                  | 28-Aug-2014 21:00:40.0        | yes                           |
| 04           | (1) MACS0647+7015            | WFC3/IR                             | 4                  | 28-Aug-2014 21:00:42.0        | yes                           |
| 05           | (1) MACS0647+7015            | WFC3/IR                             | 4                  | 28-Aug-2014 21:00:44.0        | yes                           |

12 Total Orbits Used

## **ABSTRACT**

The first galaxies are the frontier of extragalactic astronomy. How and when did they form, and how did they contribute to reionization? Gravitational lensing has enabled efficient discovery of high-redshift galaxies including MACS0647-JD at  $z \sim 10.8$  (420 Myr after the Big Bang), a strong candidate for the most distant galaxy yet known. This discovery by the CLASH Multi-Cycle Treasury program is consistent with expectations extrapolated from lower redshifts ( $4 < z < 8$ ). The evolving luminosity function fit to these data includes sufficient numbers of faint galaxies at early times to reionize the universe. However, the discovery of MACS0647-JD is in tension with lower number densities of  $z > 9$  candidates identified in deep field observations including the UDF. These field studies suggest  $z > 9$  galaxies were building up in numbers much more rapidly than observed at later times. Confirmation of the  $z \sim 10.8$  candidate is therefore paramount to our understanding of early galaxy evolution and reionization. All three strongly lensed images of MACS0647-JD are significantly detected in two HST filters (F140W and F160W). Lower redshift objects have been ruled out with high confidence, and the redshift is corroborated by our lens modeling. The strong lensing magnification provides us with a rare opportunity to confirm such a high redshift. We propose to do so with ten orbits of WFC3/IR G141 grism observations. Two orbits of F140W imaging are also required for calibration. As the first ever HST IR grism observations of a  $z < 1$  cluster, this program will serve as an important pathfinder for future IR grism observations of lensed fields with HST and with the James Webb Space Telescope.

## **OBSERVING DESCRIPTION**

We will observe MACS0647+7015 for a total of 12 HST orbits (10 orbits G141 grism + 2 orbits F140W imaging) at 3 roll angles ( $U3 = 53, 165, 204$  degrees) carefully selected to minimize contamination of the high-redshift candidate spectra. At each of the 3 roll angles, we will observe for 4 orbits. Each of these 4 orbits will be obtained at a different dither position, following the optimal dither pattern described in Brammer12a. Each orbit will begin with a ~5-minute F140W "direct image" prior to the G141 observations.

All G141 observations will be NSAMP=15 SPARS100.

All F140W observations will be SPARS50.

Thus at each roll angle, we'll have time for the following sequences with exposure times given in seconds (and NSAMP x SPARS in parentheses):

Orbit 1) (initial guide star acquisition)

Proposal 13317 (STScI Edit Number: 1, Created: Thursday, August 28, 2014 8:00:45 PM EST) - Overview

F140W 353 ( 8 x 50)

G141 1403 (15 x 100)

G141 1403 (15 x 100)

Orbits 2-4) (guide star re-acquisitions)

F140W 503 (11 x 50)

G141 1403 (15 x 100)

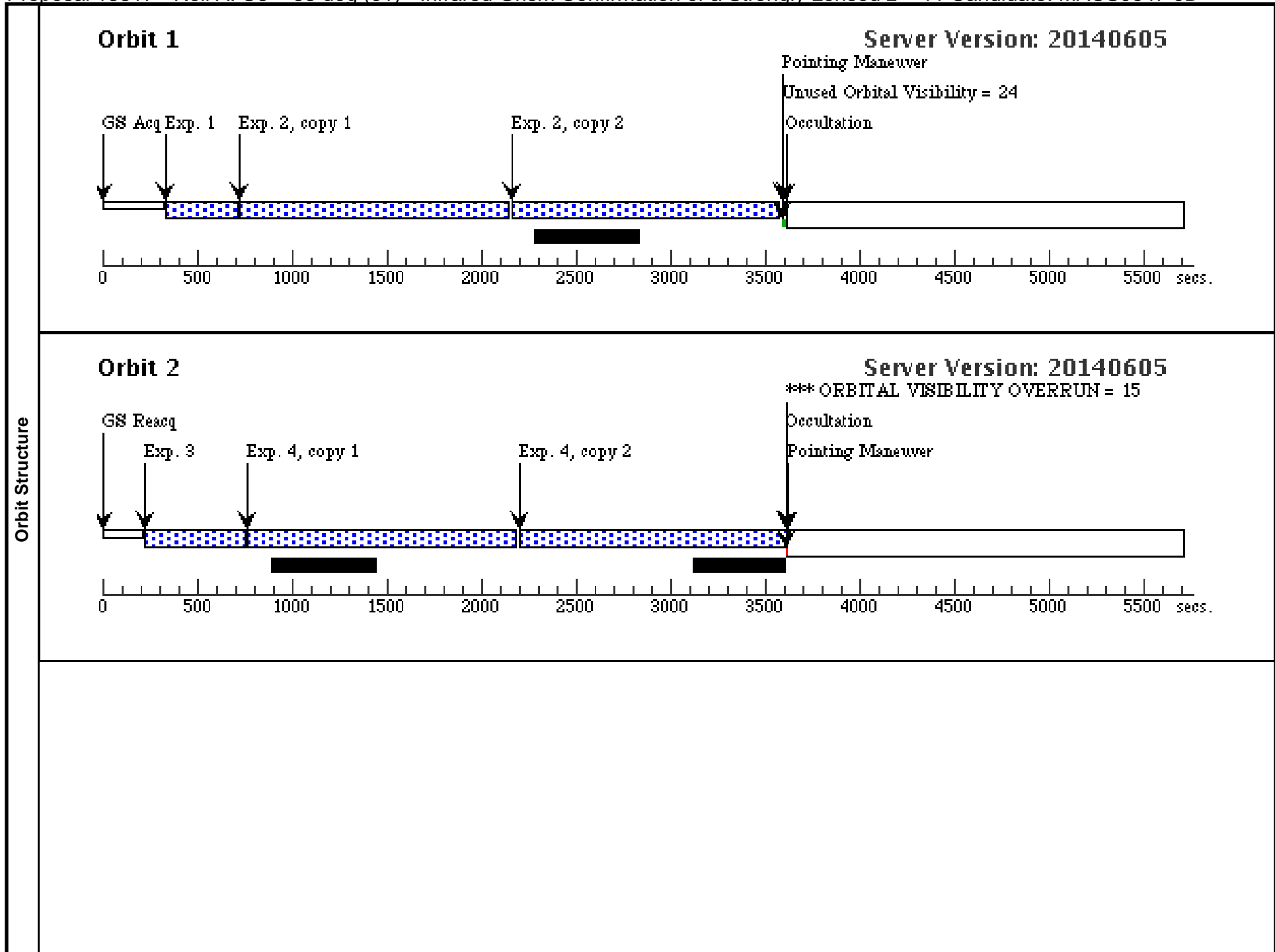
G141 1403 (15 x 100)

Proposal 13317 - Roll A: U3 = 53 deg (01) - Infrared Grism Confirmation of a Strongly Lensed z ~ 11 Candidate: MACS0647-JD

| <b>Visit</b>  | <p><b>Proposal 13317, Roll A: U3 = 53 deg (01), completed</b> <span style="float: right;">Fri Aug 29 01:00:46 GMT 2014</span></p> <p><b>Diagnostic Status: Warning</b></p> <p>Scientific Instruments: WFC3/IR</p> <p>Special Requirements: SCHED 30%; ORIENT 53D TO 53 D</p>  |   |                    |                          |                       |               |      |                    |                          |        |               |     |               |   |  |      |                       |
|---|---|---|--------------------|--------------------------|-----------------------|---------------|------|--------------------|--------------------------|--------|---------------|-----|---------------|---|--|------|-----------------------|
|   | <b>Diagnostics</b>  | (Roll A: U3 = 53 deg (01)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE |                    |                          |                       |               |      |                    |                          |        |               |     |               |   |  |      |                       |
| (Roll A: U3 = 53 deg (01)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE |   |   |                    |                          |                       |               |      |                    |                          |        |               |     |               |   |  |      |                       |
| (Roll A: U3 = 53 deg (01)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN      |   |   |                    |                          |                       |               |      |                    |                          |        |               |     |               |   |  |      |                       |
| (Roll A: U3 = 53 deg (01)) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN      |   |   |                    |                          |                       |               |      |                    |                          |        |               |     |               |   |  |      |                       |
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| (Roll A: U3 = 53 deg (01)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE |   |   |                    |                          |                       |               |      |                    |                          |        |               |     |               |   |  |      |                       |
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| <b>Fixed Targets</b>  | <table border="1"> <thead> <tr> <th>#</th> <th>Name</th> <th>Target Coordinates</th> <th>Targ. Coord. Corrections</th> <th>Fluxes</th> <th>Miscellaneous</th> </tr> </thead> <tbody> <tr> <td>(1)</td> <td>MACS0647+7015</td> <td>RA: 06 47 50.2700 (101.9594583d)<br/>Dec: +70 14 55.00 (70.24861d)<br/>Equinox: J2000</td> <td></td> <td>V=15</td> <td>Reference Frame: ICRS</td> </tr> </tbody> </table> |   |                    |                          |                       | #             | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous | (1) | MACS0647+7015 | RA: 06 47 50.2700 (101.9594583d)<br>Dec: +70 14 55.00 (70.24861d)<br>Equinox: J2000 |  | V=15 | Reference Frame: ICRS |
|   | #   | Name  | Target Coordinates | Targ. Coord. Corrections | Fluxes                | Miscellaneous |      |                    |                          |        |               |     |               |   |  |      |                       |
| (1)   | MACS0647+7015   | RA: 06 47 50.2700 (101.9594583d)<br>Dec: +70 14 55.00 (70.24861d)<br>Equinox: J2000 |                    | V=15                     | Reference Frame: ICRS |               |      |                    |                          |        |               |     |               |   |  |      |                       |
|   |   |   |                    |                          |                       |               |      |                    |                          |        |               |     |               |   |  |      |                       |

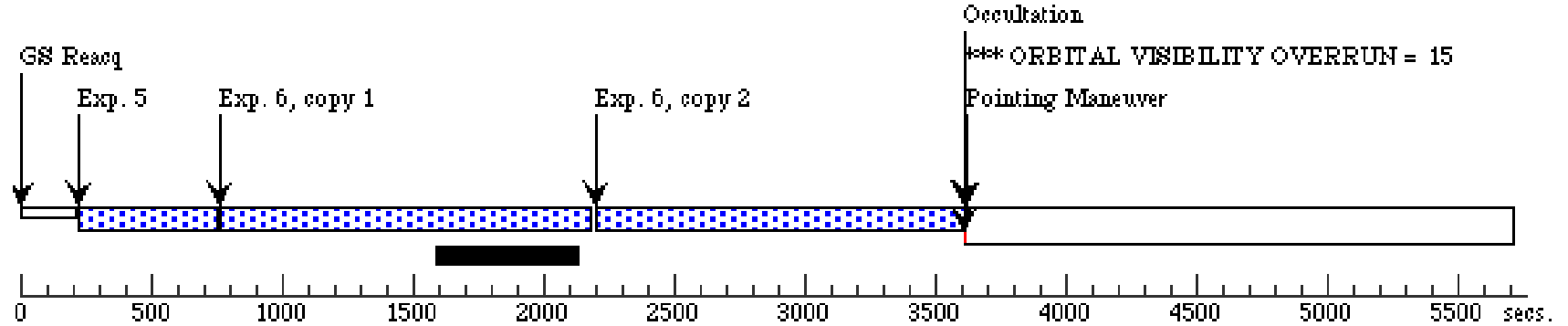
Proposal 13317 - Roll A: U3 = 53 deg (01) - Infrared Grism Confirmation of a Strongly Lensed z ~ 11 Candidate: MACS0647-JD

| Exposures | # | Label         | Target            | Config,Mode,Aperture           | Spectral Els. | Opt. Params.                       | Special Reqs.         | Groups   | Exp. Time (Total)/[Actual Dur.]  | Orbit |
|-----------|---|---------------|-------------------|--------------------------------|---------------|------------------------------------|-----------------------|--|--|-------|
|           | 1 | F140W imaging | (1) MACS0647+7015 | WFC3/IR, MULTIACCUM, GRISM1024 | F140W         | NSAMP=8;<br>SAMP-SEQ=SPAR<br>S50   | POS TARG 0,0          | Sequence 1-2 Non-Int in Roll A: U3 = 53 deg (01) | 352.935448 Secs (352.935 Secs)<br>[==>]                                | [1]   |
|           | 2 | G141 grism    | (1) MACS0647+7015 | WFC3/IR, MULTIACCUM, GRISM1024 | G141          | NSAMP=15;<br>SAMP-SEQ=SPAR<br>S100 | SAME POS AS 1         | Sequence 1-2 Non-Int in Roll A: U3 = 53 deg (01) | 1402.936813 Secs X 2 (2805.874 Secs)<br>[==>(Copy 1)]<br>[==>(Copy 2)] | [1]   |
|           | 3 | F140W imaging | (1) MACS0647+7015 | WFC3/IR, MULTIACCUM, GRISM1024 | F140W         | NSAMP=11;<br>SAMP-SEQ=SPAR<br>S50  | POS TARG 1.355,0.424  | Sequence 3-4 Non-Int in Roll A: U3 = 53 deg (01) | 502.936801 Secs (502.937 Secs)<br>[==>]                                | [2]   |
|           | 4 | G141 grism    | (1) MACS0647+7015 | WFC3/IR, MULTIACCUM, GRISM1024 | G141          | NSAMP=15;<br>SAMP-SEQ=SPAR<br>S100 | SAME POS AS 3         | Sequence 3-4 Non-Int in Roll A: U3 = 53 deg (01) | 1402.936813 Secs X 2 (2805.874 Secs)<br>[==>(Copy 1)]<br>[==>(Copy 2)] | [2]   |
|           | 5 | F140W imaging | (1) MACS0647+7015 | WFC3/IR, MULTIACCUM, GRISM1024 | F140W         | NSAMP=11;<br>SAMP-SEQ=SPAR<br>S50  | POS TARG 0.881,1.212  | Sequence 5-6 Non-Int in Roll A: U3 = 53 deg (01) | 502.936801 Secs (502.937 Secs)<br>[==>]                                | [3]   |
|           | 6 | G141 grism    | (1) MACS0647+7015 | WFC3/IR, MULTIACCUM, GRISM1024 | G141          | NSAMP=15;<br>SAMP-SEQ=SPAR<br>S100 | SAME POS AS 5         | Sequence 5-6 Non-Int in Roll A: U3 = 53 deg (01) | 1402.936813 Secs X 2 (2805.874 Secs)<br>[==>(Copy 1)]<br>[==>(Copy 2)] | [3]   |
|           | 7 | F140W imaging | (1) MACS0647+7015 | WFC3/IR, MULTIACCUM, GRISM1024 | F140W         | NSAMP=11;<br>SAMP-SEQ=SPAR<br>S50  | POS TARG -0.474,0.788 | Sequence 7-8 Non-Int in Roll A: U3 = 53 deg (01) | 502.936801 Secs (502.937 Secs)<br>[==>]                                | [4]   |
|           | 8 | G141 grism    | (1) MACS0647+7015 | WFC3/IR, MULTIACCUM, GRISM1024 | G141          | NSAMP=15;<br>SAMP-SEQ=SPAR<br>S100 | SAME POS AS 7         | Sequence 7-8 Non-Int in Roll A: U3 = 53 deg (01) | 1402.936813 Secs X 2 (2805.874 Secs)<br>[==>(Copy 1)]<br>[==>(Copy 2)] | [4]   |



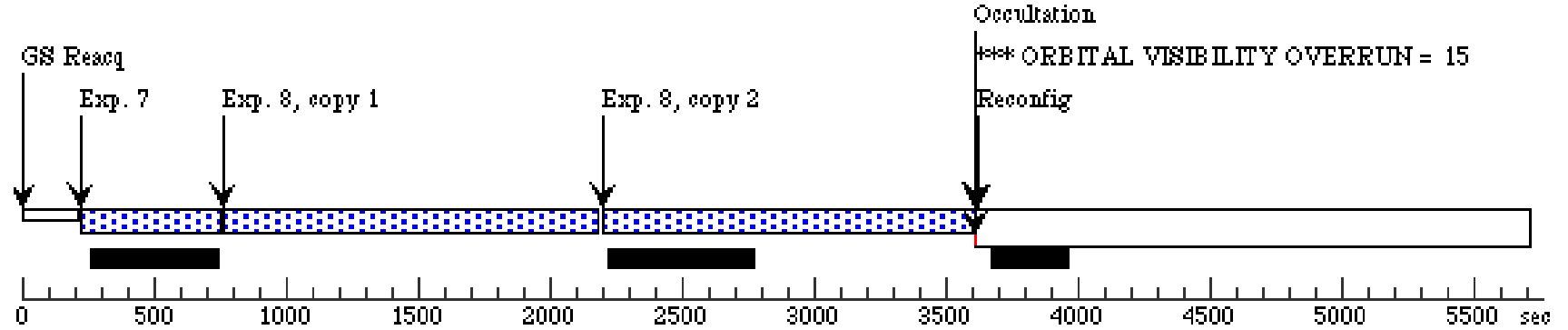
### Orbit 3

Server Version: 20140605



### Orbit 4

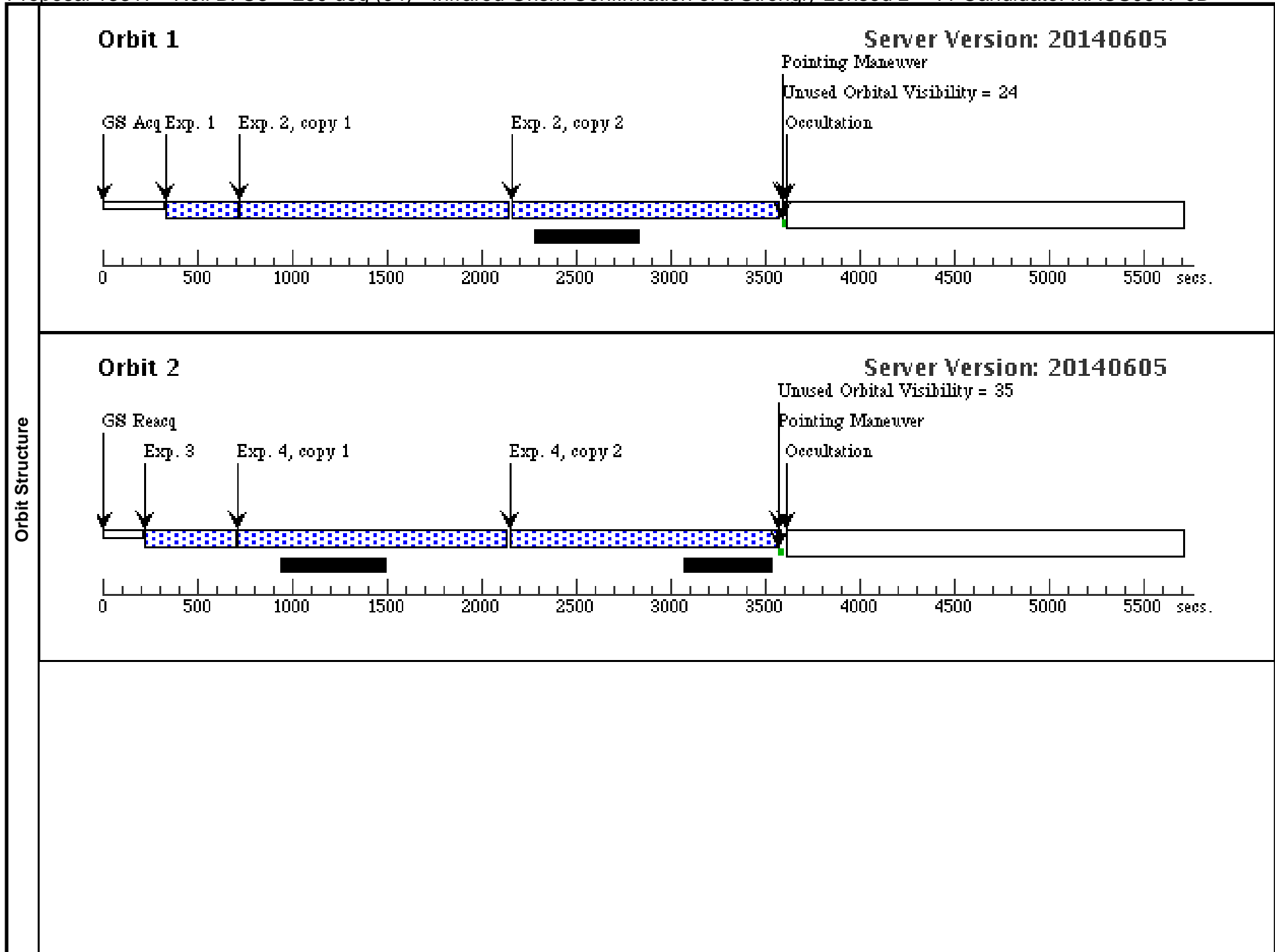
Server Version: 20140605



Proposal 13317 - Roll B: U3 = 289 deg (04) - Infrared Grism Confirmation of a Strongly Lensed z ~ 11 Candidate: MACS0647-JD

Fri Aug 29 01:00:46 GMT 2014

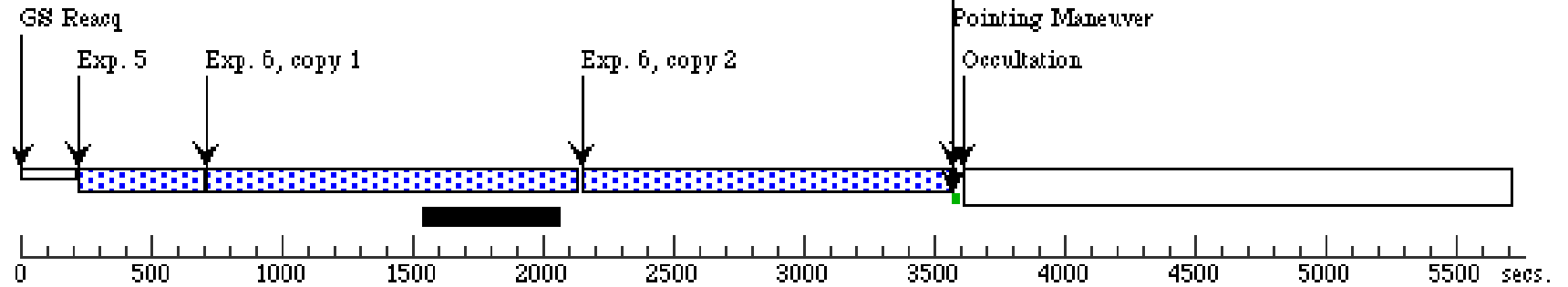
| Visit         | <b>Proposal 13317, Roll B: U3 = 289 deg (04)</b><br><b>Diagnostic Status: Warning</b><br>Scientific Instruments: WFC3/IR<br>Special Requirements: SCHED 30%; ORIENT 289D TO 289 D |  |                                |   |                                 |                                 |   |  |  |  |       |
|---------------|---|--|--------------------------------|---|---------------------------------|---------------------------------|---|--|--|--|-------|
|               | Diagnostics   | (Roll B: U3 = 289 deg (04)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE<br>(Roll B: U3 = 289 deg (04)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE<br>(Roll B: U3 = 289 deg (04)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE<br>(Roll B: U3 = 289 deg (04)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE<br>(Roll B: U3 = 289 deg (04)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE<br>(Roll B: U3 = 289 deg (04)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE<br>(Roll B: U3 = 289 deg (04)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE |                                |   |                                 |                                 |   |  |  |  |       |
| Fixed Targets |   | #  | Name                           | Target Coordinates  | Targ. Coord. Corrections        | Fluxes                          | Miscellaneous                                     |  |  |  |       |
|               |   | (1)  | MACS0647+7015                  | RA: 06 47 50.2700 (101.9594583d)<br>Dec: +70 14 55.00 (70.24861d)<br>Equinox: J2000 |                                 | V=15                            | Reference Frame: ICRS                             |  |  |  |       |
| Exposures     |   | #  | Label                          | Target  | Config,Mode,Aperture            | Spectral Els.                   | Opt. Params.                                      | Special Reqs.  | Groups   | Exp. Time (Total)/[Actual Dur.]  | Orbit |
|               |   | 1  | F140W imaging                  | (1) MACS0647+7015   | WFC3/IR, MULTIACCUM, GRISM1024  | F140W                           | NSAMP=8;<br>SAMP-SEQ=SPAR S50                     | POS TARG 0,0   | Sequence 1-2 Non-Int in Roll B: U3 = 289 deg (04)                      | 352.935448 Secs (352.935 Secs)<br>[==>]                                | [1]   |
|               |   | 2  | G141 grism                     | (1) MACS0647+7015   | WFC3/IR, MULTIACCUM, GRISM1024  | G141                            | NSAMP=15;<br>SAMP-SEQ=SPAR S100                   | SAME POS AS 1  | Sequence 1-2 Non-Int in Roll B: U3 = 289 deg (04)                      | 1402.936813 Secs X 2 (2805.874 Secs)<br>[==>(Copy 1)]<br>[==>(Copy 2)] | [1]   |
|               |   | 3  | F140W imaging                  | (1) MACS0647+7015   | WFC3/IR, MULTIACCUM, GRISM1024  | F140W                           | NSAMP=10;<br>SAMP-SEQ=SPAR S50                    | POS TARG 1.355,0.424   | Sequence 3-4 Non-Int in Roll B: U3 = 289 deg (04)                      | 452.93635 Secs (452.936 Secs)<br>[==>]                                 | [2]   |
|               | 4   | G141 grism   | (1) MACS0647+7015              | WFC3/IR, MULTIACCUM, GRISM1024  | G141                            | NSAMP=15;<br>SAMP-SEQ=SPAR S100 | SAME POS AS 3                                     | Sequence 3-4 Non-Int in Roll B: U3 = 289 deg (04)                      | 1402.936813 Secs X 2 (2805.874 Secs)<br>[==>(Copy 1)]<br>[==>(Copy 2)] | [2]  |       |
|               | 5   | F140W imaging  | (1) MACS0647+7015              | WFC3/IR, MULTIACCUM, GRISM1024  | F140W                           | NSAMP=10;<br>SAMP-SEQ=SPAR S50  | POS TARG 0.881,1.212                              | Sequence 5-6 Non-Int in Roll B: U3 = 289 deg (04)                      | 452.93635 Secs (452.936 Secs)<br>[==>]                                 | [3]  |       |
|               | 6   | G141 grism   | (1) MACS0647+7015              | WFC3/IR, MULTIACCUM, GRISM1024  | G141                            | NSAMP=15;<br>SAMP-SEQ=SPAR S100 | SAME POS AS 5                                     | Sequence 5-6 Non-Int in Roll B: U3 = 289 deg (04)                      | 1402.936813 Secs X 2 (2805.874 Secs)<br>[==>(Copy 1)]<br>[==>(Copy 2)] | [3]  |       |
|               | 7   | F140W imaging  | (1) MACS0647+7015              | WFC3/IR, MULTIACCUM, GRISM1024  | F140W                           | NSAMP=10;<br>SAMP-SEQ=SPAR S50  | POS TARG -0.474,0.788                             | Sequence 7-8 Non-Int in Roll B: U3 = 289 deg (04)                      | 452.93635 Secs (452.936 Secs)<br>[==>]                                 | [4]  |       |
| 8             | G141 grism  | (1) MACS0647+7015  | WFC3/IR, MULTIACCUM, GRISM1024 | G141  | NSAMP=15;<br>SAMP-SEQ=SPAR S100 | SAME POS AS 7                   | Sequence 7-8 Non-Int in Roll B: U3 = 289 deg (04) | 1402.936813 Secs X 2 (2805.874 Secs)<br>[==>(Copy 1)]<br>[==>(Copy 2)] | [4]  |  |       |



### Orbit 3

Server Version: 20140605

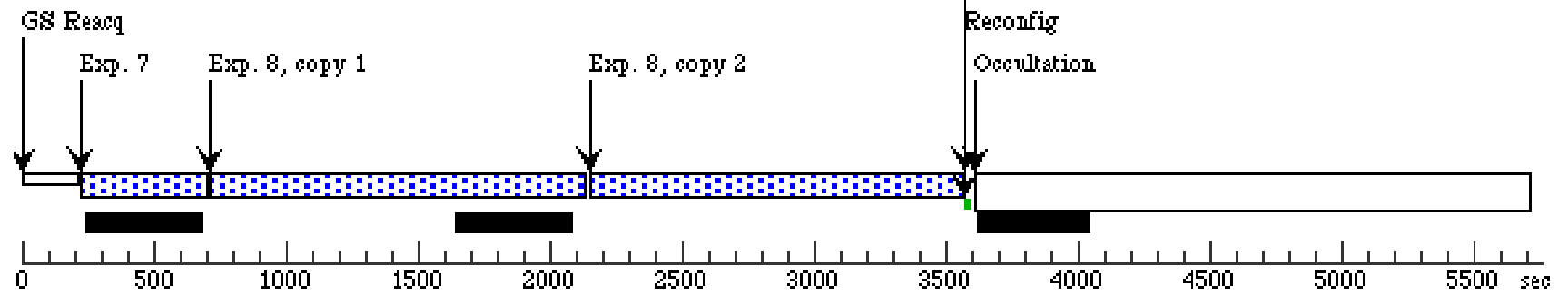
Unused Orbital Visibility = 35



### Orbit 4

Server Version: 20140605

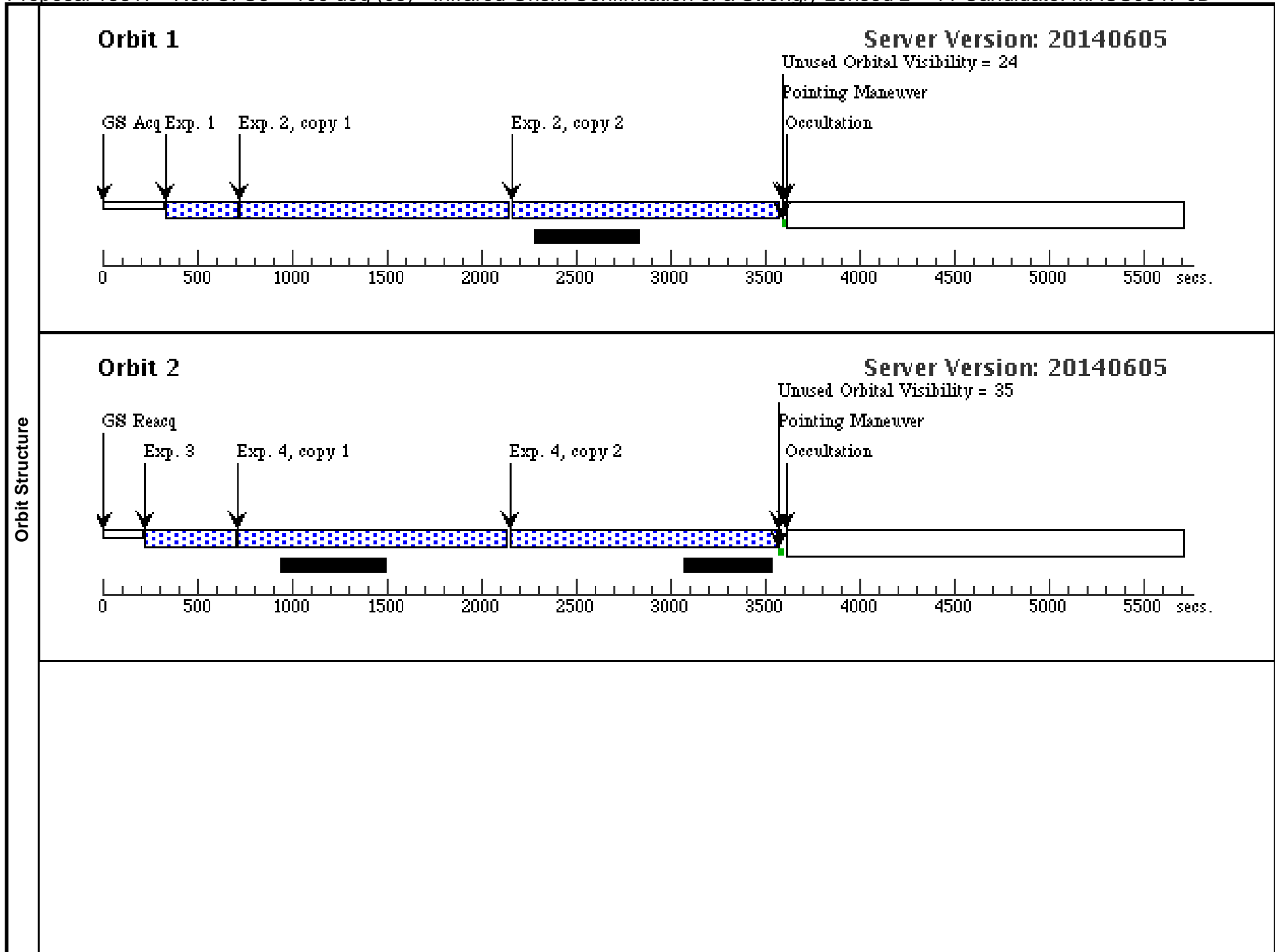
Unused Orbital Visibility = 35



Proposal 13317 - Roll C: U3 = 109 deg (05) - Infrared Grism Confirmation of a Strongly Lensed z ~ 11 Candidate: MACS0647-JD

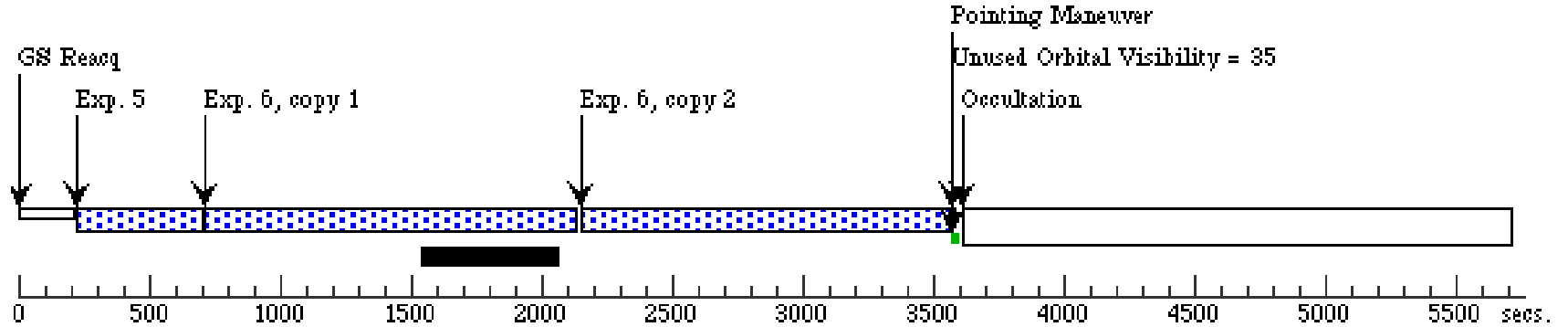
Fri Aug 29 01:00:46 GMT 2014

| Visit         | <b>Proposal 13317, Roll C: U3 = 109 deg (05)</b><br><b>Diagnostic Status: Warning</b><br>Scientific Instruments: WFC3/IR<br>Special Requirements: SCHED 30%; ORIENT 109D TO 109 D |  |                                |   |                                 |                                 |   |  |  |  |       |
|---------------|---|--|--------------------------------|---|---------------------------------|---------------------------------|---|--|--|--|-------|
|               | Diagnostics   | (Roll C: U3 = 109 deg (05)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE<br>(Roll C: U3 = 109 deg (05)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE<br>(Roll C: U3 = 109 deg (05)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE<br>(Roll C: U3 = 109 deg (05)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE<br>(Roll C: U3 = 109 deg (05)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE<br>(Roll C: U3 = 109 deg (05)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE<br>(Roll C: U3 = 109 deg (05)) Warning (Orbit Planner): SAME POS MAY NOT BE APPROPRIATE |                                |   |                                 |                                 |   |  |  |  |       |
| Fixed Targets |   | #  | Name                           | Target Coordinates  | Targ. Coord. Corrections        | Fluxes                          | Miscellaneous                                     |  |  |  |       |
|               |   | (1)  | MACS0647+7015                  | RA: 06 47 50.2700 (101.9594583d)<br>Dec: +70 14 55.00 (70.24861d)<br>Equinox: J2000 |                                 | V=15                            | Reference Frame: ICRS                             |  |  |  |       |
| Exposures     |   | #  | Label                          | Target  | Config,Mode,Aperture            | Spectral Els.                   | Opt. Params.                                      | Special Reqs.  | Groups   | Exp. Time (Total)/[Actual Dur.]  | Orbit |
|               |   | 1  | F140W imaging                  | (1) MACS0647+7015   | WFC3/IR, MULTIACCUM, GRISM1024  | F140W                           | NSAMP=8;<br>SAMP-SEQ=SPAR S50                     | POS TARG 0,0   | Sequence 1-2 Non-Int in Roll C: U3 = 109 deg (05)                      | 352.935448 Secs (352.935 Secs)<br>[==>]                                | [1]   |
|               |   | 2  | G141 grism                     | (1) MACS0647+7015   | WFC3/IR, MULTIACCUM, GRISM1024  | G141                            | NSAMP=15;<br>SAMP-SEQ=SPAR S100                   | SAME POS AS 1  | Sequence 1-2 Non-Int in Roll C: U3 = 109 deg (05)                      | 1402.936813 Secs X 2 (2805.874 Secs)<br>[==>(Copy 1)]<br>[==>(Copy 2)] | [1]   |
|               |   | 3  | F140W imaging                  | (1) MACS0647+7015   | WFC3/IR, MULTIACCUM, GRISM1024  | F140W                           | NSAMP=10;<br>SAMP-SEQ=SPAR S50                    | POS TARG 1.355,0.424   | Sequence 3-4 Non-Int in Roll C: U3 = 109 deg (05)                      | 452.93635 Secs (452.936 Secs)<br>[==>]                                 | [2]   |
|               | 4   | G141 grism   | (1) MACS0647+7015              | WFC3/IR, MULTIACCUM, GRISM1024  | G141                            | NSAMP=15;<br>SAMP-SEQ=SPAR S100 | SAME POS AS 3                                     | Sequence 3-4 Non-Int in Roll C: U3 = 109 deg (05)                      | 1402.936813 Secs X 2 (2805.874 Secs)<br>[==>(Copy 1)]<br>[==>(Copy 2)] | [2]  |       |
|               | 5   | F140W imaging  | (1) MACS0647+7015              | WFC3/IR, MULTIACCUM, GRISM1024  | F140W                           | NSAMP=10;<br>SAMP-SEQ=SPAR S50  | POS TARG 0.881,1.212                              | Sequence 5-6 Non-Int in Roll C: U3 = 109 deg (05)                      | 452.93635 Secs (452.936 Secs)<br>[==>]                                 | [3]  |       |
|               | 6   | G141 grism   | (1) MACS0647+7015              | WFC3/IR, MULTIACCUM, GRISM1024  | G141                            | NSAMP=15;<br>SAMP-SEQ=SPAR S100 | SAME POS AS 5                                     | Sequence 5-6 Non-Int in Roll C: U3 = 109 deg (05)                      | 1402.936813 Secs X 2 (2805.874 Secs)<br>[==>(Copy 1)]<br>[==>(Copy 2)] | [3]  |       |
|               | 7   | F140W imaging  | (1) MACS0647+7015              | WFC3/IR, MULTIACCUM, GRISM1024  | F140W                           | NSAMP=10;<br>SAMP-SEQ=SPAR S50  | POS TARG -0.474,0.788                             | Sequence 7-8 Non-Int in Roll C: U3 = 109 deg (05)                      | 452.93635 Secs (452.936 Secs)<br>[==>]                                 | [4]  |       |
| 8             | G141 grism  | (1) MACS0647+7015  | WFC3/IR, MULTIACCUM, GRISM1024 | G141  | NSAMP=15;<br>SAMP-SEQ=SPAR S100 | SAME POS AS 7                   | Sequence 7-8 Non-Int in Roll C: U3 = 109 deg (05) | 1402.936813 Secs X 2 (2805.874 Secs)<br>[==>(Copy 1)]<br>[==>(Copy 2)] | [4]  |  |       |



### Orbit 3

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### Orbit 4

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