# 16504 - A Spectroscopically Confirmed Massively Star-forming Protocluster at z = 3.14

Cycle: 28, Proposal Category: GO

(Availability Mode: SUPPORTED)

**INVESTIGATORS**



| *Name* | *Institution* | *E-Mail* |
|---|---|---|
| **Mr. Michael Jacob Rosenthal (PI) (Contact)** | **University of Wisconsin - Madison** | **rosenthal@astro.wisc.edu** |
| Mr. Logan Houston Jones (CoI) | University of Wisconsin - Madison | ljones@astro.wisc.edu |
| Dr. Amy J. Barger (CoI) | University of Wisconsin - Madison | barger@astro.wisc.edu |
| Dr. Lennox L. Cowie (CoI) | University of Hawaii | cowie@ifa.hawaii.edu |



**VISITS**

| *Visit* | *Targets used in Visit* | *Configurations used in Visit* | *Orbits Used* | *Last Orbit Planner Run* | *OP Current with Visit?* |
|---|---|---|---|---|---|
| 01 | (1) GNCL-NORTH | WFC3/IR | 1 | 11-Aug-2021 17:01:13.0 | yes |
| 02 | (2) GNCL-SOUTH | WFC3/IR | 1 | 11-Aug-2021 17:01:14.0 | yes |
| 03 | (1) GNCL-NORTH | WFC3/IR | 1 | 11-Aug-2021 17:01:15.0 | yes |
| 04 | (2) GNCL-SOUTH | WFC3/IR | 2 | 11-Aug-2021 17:01:16.0 | yes |

5 Total Orbits Used

**ABSTRACT**

Dense protoclusters of bright submillimeter galaxies are the suspected progenitors of today's massive clusters, but the mechanisms that govern their triggering and transition to compact quiescent galaxies by z ~ 2 are not well understood. These processes are hinted at by millimeter spectral line profiles, but are only fully resolved at sub-arcsecond scales, which cannot be imaged efficiently with ground-based telescopes in the Northern

hemisphere. We propose to constrain the morphology of the stars in the two submillimeter-brightest galaxies in a newly identified, spectroscopically confirmed protocluster at z = 3.14. This requires 5 total orbits with WFC3-IR, with 3 orbits with F110W and 2 orbits with F160W. The protocluster lies in the GOODS-North and has extensive multi-wavelength coverage, but is just outside the coverage of HST/ACS and WFC3 from the original GOODS and CANDELS surveys, such that no sufficiently high-resolution imaging of this field currently exists. The two galaxies have spectroscopic redshifts from CO line scans with NOEMA, but their CO(5-4) line profiles are different, suggesting different stages or mechanisms of triggering. The 0.15" resolution of the proposed observations will resolve close mergers and/or compact stellar counterparts. Our ~9 square arminute coverage will also serendipitously detect the near-IR counterparts of many fainter submillimeter galaxies in this dense field. The identification of advanced mergers or compact stellar counterparts in these galaxies, which can trace ongoing triggering or quenching, respectively, will be used to prioritize targets for high-resolution millimeter interferometric follow-up.

**OBSERVING DESCRIPTION**

We will obtain deep images of the counterparts of the four brightest SMGs in the protocluster field with the infrared channel of WFC3 in the F110W and F160W filters, to identify the extent and morphology of their stellar populations. These include GN-CL-2 and GN-CL-3, the two spectroscopically confirmed protocluster members. These galaxies are separated by more than the size of the WFC3 IR channel FoV, so we request two pointings: a northern pointing containing GN-CL-2 alone, and a southern pointing containing GN-CL-3. Splitting the observations into two pointings is necessary to avoid a bright star (2MASS J=8.34, H=7.77) in the field, which has saturated a portion of the CFHT/WIRCam images near GN-CL-1 and GN-CL-2. Our specified pointings avoid this bright star, and our orientation ranges should prevent diffraction spikes from interfering with our imaging.

We estimated exposure times using the WFC3-IR imaging calculator in F110W and F160W. We assumed that GN-CL-2 and GN-CL-3 have half-light radii of ~2.8 kpc, or 0.36 arcsec at z = 3.14, and used existing CFHT/WIRCam J and H photometry to estimate their brightnesses.

We break our observations up into four visits, with each one observing a single pointing in a single filter. The visit containing the F110W imaging of GN-CL-3 will consist of two orbits, and each of the other three visits will consist of one orbit each. These are sufficient to reach a S/N of 5 per pixel.

We will use a modified WFC3-IR-DITHER-BOX-MIN dithering pattern (pattern E4 in WFC3 IRS 2010-09) to sub-sample the PSF and step over IR blobs. Although none of our main science targets are positioned on IR blobs or the Death Star, we include this large step to maximize image quality over the whole field, given many galaxies in the WFC3 FoV may be protocluster members.

## Visit

**Proposal 16504, CL2 F160W (01), scheduling** Wed Aug 11 21:01:17 GMT 2021

**Diagnostic Status: No Diagnostics**

Scientific Instruments: WFC3/IR

Special Requirements: ORIENT 35D TO 55 D; ORIENT 215D TO 235 D

## Patterns

| # | Primary Pattern | | Secondary Pattern | Exposures |
|---|---|---|---|---|
| (1) | Pattern Type=WFC3-IR-DITHER-BOX-MIN<br>Purpose=DITHER<br>Number Of Points=4<br>Point Spacing=0.384<br>Line Spacing=4.793 | Coordinate Frame=POS-TARG<br>Pattern Orientation=331.798<br>Angle Between Sides=288.391<br>Center Pattern=false | | (1) |

## Fixed Targets

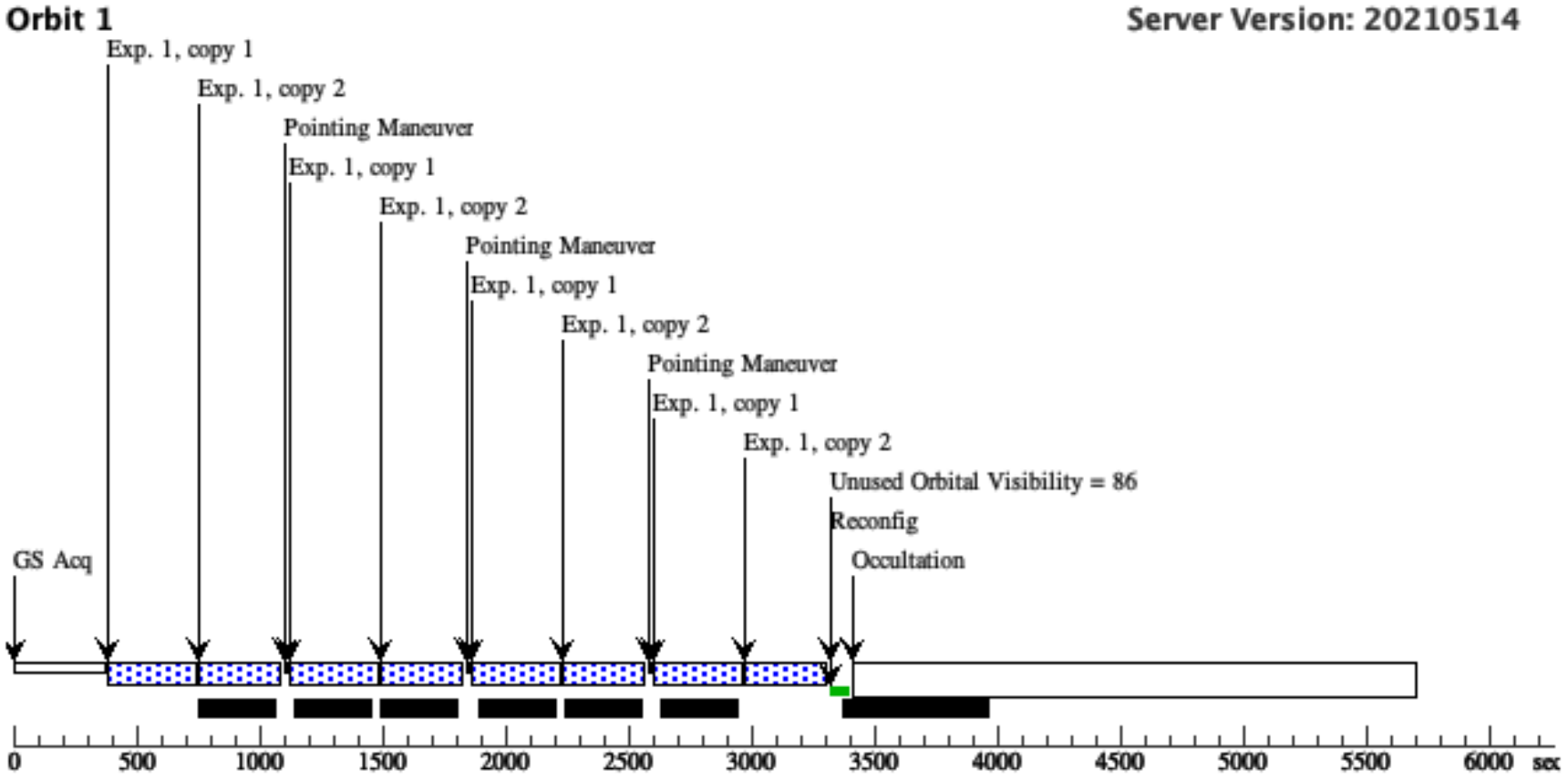
| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
|---|---|---|---|---|---|
| (1) | GNCL-NORTH<br>Alt Name1: GN-CL-2 | RA: 12 35 52.6550 (188.9693958d)<br>Dec: +62 23 22.73 (62.38965d)<br>Equinox: J2000 | Redshift: 3.148 | V=24.6+/-0.2<br>J=24.0,<br>H=23.4 (AB). | Reference Frame: ICRS |

*Comments: Coordinates are for the center of the field, which contains several submillimeter galaxies. The brightest target galaxy GN-CL-2 is at 12:35:55.88 +62:22:39.0 (+/- 2 arcsec in both RA and Dec). J and H magnitudes are for this galaxy.*
*Category=CLUSTER OF GALAXIES*
*Description=[HIGH REDSHIFT CLUSTER]*

## Exposures

| # | Label | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 01-F160W | (1) GNCL-NORTH | WFC3/IR, MULTIACCUM, IR-FIX | F160W | NSAMP=14;<br>SAMP-SEQ=SPARS25 | | Pattern 1, Exps 1-1 in CL2 F160W (01) (1) | 327.938986 Secs X 2 (2623.512 Secs) | |
| | | | | | | | | *[==>(Pattern 1, Copy 1)]*<br>*[==>(Pattern 1, Copy 2)]*<br>*[==>(Pattern 2, Copy 1)]*<br>*[==>(Pattern 2, Copy 2)]*<br>*[==>(Pattern 3, Copy 1)]*<br>*[==>(Pattern 3, Copy 2)]*<br>*[==>(Pattern 4, Copy 1)]*<br>*[==>(Pattern 4, Copy 2)]* | ***[1]*** |

Orbit Structure



## Visit

**Proposal 16504, CL3 F160W (02), implementation** Wed Aug 11 21:01:17 GMT 2021

**Diagnostic Status: No Diagnostics**

Scientific Instruments: WFC3/IR

Special Requirements: ORIENT 75D TO 95 D; ORIENT 255D TO 275 D

## Patterns

| # | Primary Pattern | | Secondary Pattern | Exposures |
|---|---|---|---|---|
| (1) | Pattern Type=WFC3-IR-DITHER-BOX-MIN<br>Purpose=DITHER<br>Number Of Points=4<br>Point Spacing=0.384<br>Line Spacing=4.793 | Coordinate Frame=POS-TARG<br>Pattern Orientation=331.798<br>Angle Between Sides=288.391<br>Center Pattern=false | | (1) |

## Fixed Targets

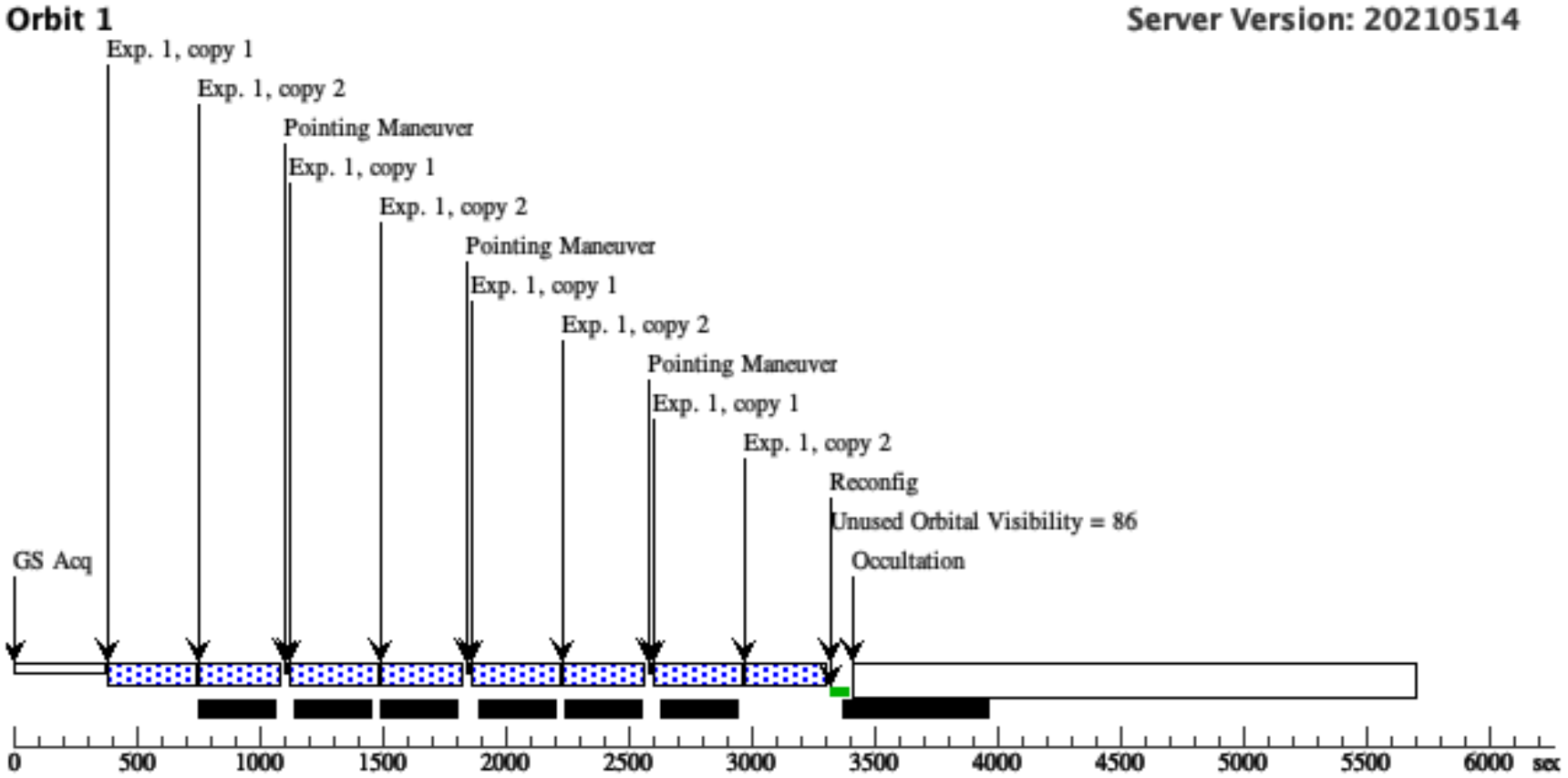
| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
|---|---|---|---|---|---|
| (2) | GNCL-SOUTH<br>Alt Name1: GN-CL-3 | RA: 12 35 46.6158 (188.9442325d)<br>Dec: +62 21 8.91 (62.35247d)<br>Equinox: J2000 | Redshift: 3.133 | V=26.1+/-0.4<br>J=25.0,<br>H=24.0 (AB) | Reference Frame: ICRS |

*Comments: Coordinates are for the center of the field, which contains several submillimeter galaxies. The brightest target galaxy GN-CL-3 is at 12:35:46.64 +62:20:13.3 (+/- 2 arcsec in both RA and Dec). J and H magnitudes are for this galaxy. Also contains GN-CL-1 at 12:35:51.37 +62:21:47.2 (z=4.422) and GN-CL-4 at 12:35:39.9 +62:21:29 (z unknown).*
*Category=CLUSTER OF GALAXIES*
*Description=[HIGH REDSHIFT CLUSTER]*

## Exposures

| # | Label | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 02-F160W | (2) GNCL-SOUTH | WFC3/IR, MULTIACCUM, IR | F160W | NSAMP=14;<br>SAMP-SEQ=SPARS25 | | Pattern 1, Exps 1-1 in CL3 F160W (02) (1) | 327.938986 Secs X 2 (2623.512 Secs) | |
| | | | | | | | | *[==>(Pattern 1, Copy 1)]*<br>*[==>(Pattern 1, Copy 2)]*<br>*[==>(Pattern 2, Copy 1)]*<br>*[==>(Pattern 2, Copy 2)]*<br>*[==>(Pattern 3, Copy 1)]*<br>*[==>(Pattern 3, Copy 2)]*<br>*[==>(Pattern 4, Copy 1)]*<br>*[==>(Pattern 4, Copy 2)]* | ***[1]*** |

Orbit Structure



## Visit

**Proposal 16504, CL2 F110W (03), implementation** Wed Aug 11 21:01:17 GMT 2021

**Diagnostic Status: No Diagnostics**

Scientific Instruments: WFC3/IR

Special Requirements: ORIENT 35D TO 55 D; ORIENT 215D TO 235 D

## Patterns

| # | Primary Pattern | | Secondary Pattern | Exposures |
|---|---|---|---|---|
| (1) | Pattern Type=WFC3-IR-DITHER-BOX-MIN<br>Purpose=DITHER<br>Number Of Points=4<br>Point Spacing=0.384<br>Line Spacing=4.793 | Coordinate Frame=POS-TARG<br>Pattern Orientation=331.798<br>Angle Between Sides=288.391<br>Center Pattern=false | | (1) |

## Fixed Targets

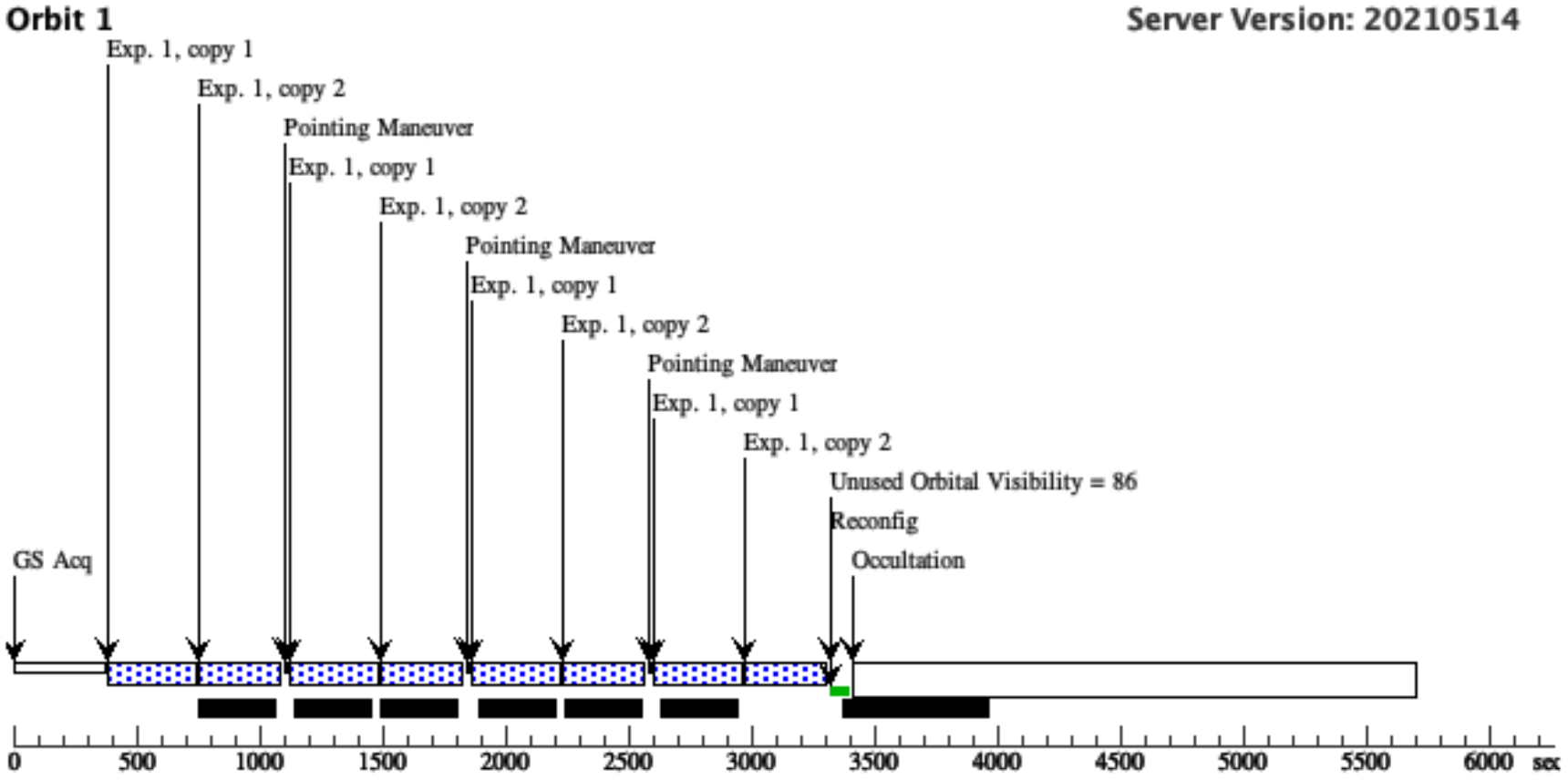
| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
|---|---|---|---|---|---|
| (1) | GNCL-NORTH<br>Alt Name1: GN-CL-2 | RA: 12 35 52.6550 (188.9693958d)<br>Dec: +62 23 22.73 (62.38965d)<br>Equinox: J2000 | Redshift: 3.148 | V=24.6+/-0.2<br>J=24.0,<br>H=23.4 (AB). | Reference Frame: ICRS |

*Comments: Coordinates are for the center of the field, which contains several submillimeter galaxies. The brightest target galaxy GN-CL-2 is at 12:35:55.88 +62:22:39.0 (+/- 2 arcsec in both RA and Dec). J and H magnitudes are for this galaxy.*
*Category=CLUSTER OF GALAXIES*
*Description=[HIGH REDSHIFT CLUSTER]*

## Exposures

| # | Label | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 01-F110W | (1) GNCL-NORTH | WFC3/IR, MULTIACCUM, IR | F110W | NSAMP=14;<br>SAMP-SEQ=SPARS25 | GS ACQ SCENARIO BASE1B3 | Pattern 1, Exps 1-1 in CL2 F110W (03) (1) | 327.938986 Secs X 2 (2623.512 Secs) | |
| | | | | | | | | *[==>(Pattern 1, Copy 1)]*<br>*[==>(Pattern 1, Copy 2)]*<br>*[==>(Pattern 2, Copy 1)]*<br>*[==>(Pattern 2, Copy 2)]*<br>*[==>(Pattern 3, Copy 1)]*<br>*[==>(Pattern 3, Copy 2)]*<br>*[==>(Pattern 4, Copy 1)]*<br>*[==>(Pattern 4, Copy 2)]* | ***[1]*** |

Orbit Structure



## Visit

**Proposal 16504, CL3 F110W (04), implementation** Wed Aug 11 21:01:17 GMT 2021

**Diagnostic Status: No Diagnostics**

Scientific Instruments: WFC3/IR

Special Requirements: ORIENT 75D TO 95 D; ORIENT 255D TO 275 D

## Patterns

| # | Primary Pattern | | Secondary Pattern | Exposures |
|---|---|---|---|---|
| (1) | Pattern Type=WFC3-IR-DITHER-BOX-MIN<br>Purpose=DITHER<br>Number Of Points=4<br>Point Spacing=0.384<br>Line Spacing=4.793 | Coordinate Frame=POS-TARG<br>Pattern Orientation=331.798<br>Angle Between Sides=288.391<br>Center Pattern=false | | (1) |

## Fixed Targets

| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
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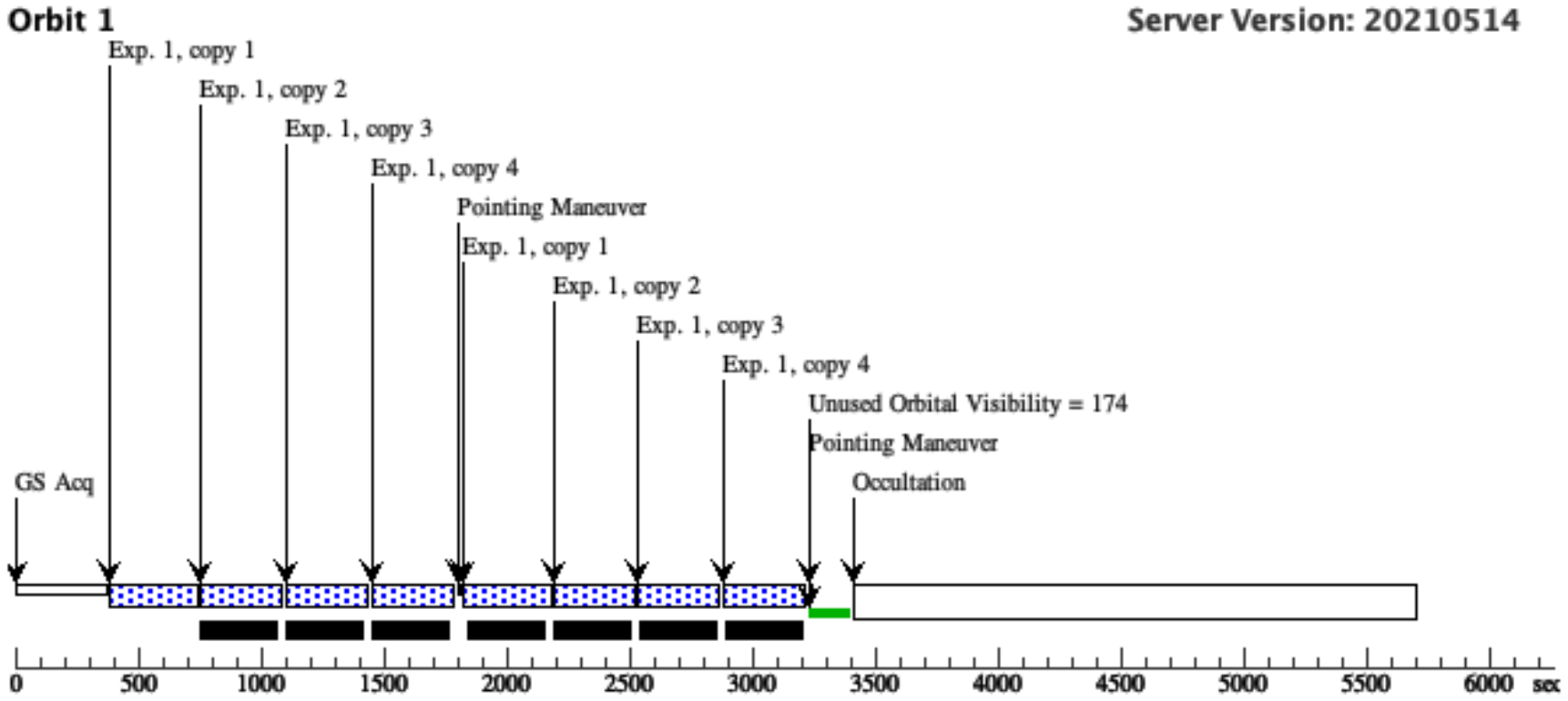
| (2) | GNCL-SOUTH<br>Alt Name1: GN-CL-3 | RA: 12 35 46.6158 (188.9442325d)<br>Dec: +62 21 8.91 (62.35247d)<br>Equinox: J2000 | Redshift: 3.133 | V=26.1+/-0.4<br>J=25.0,<br>H=24.0 (AB) | Reference Frame: ICRS |

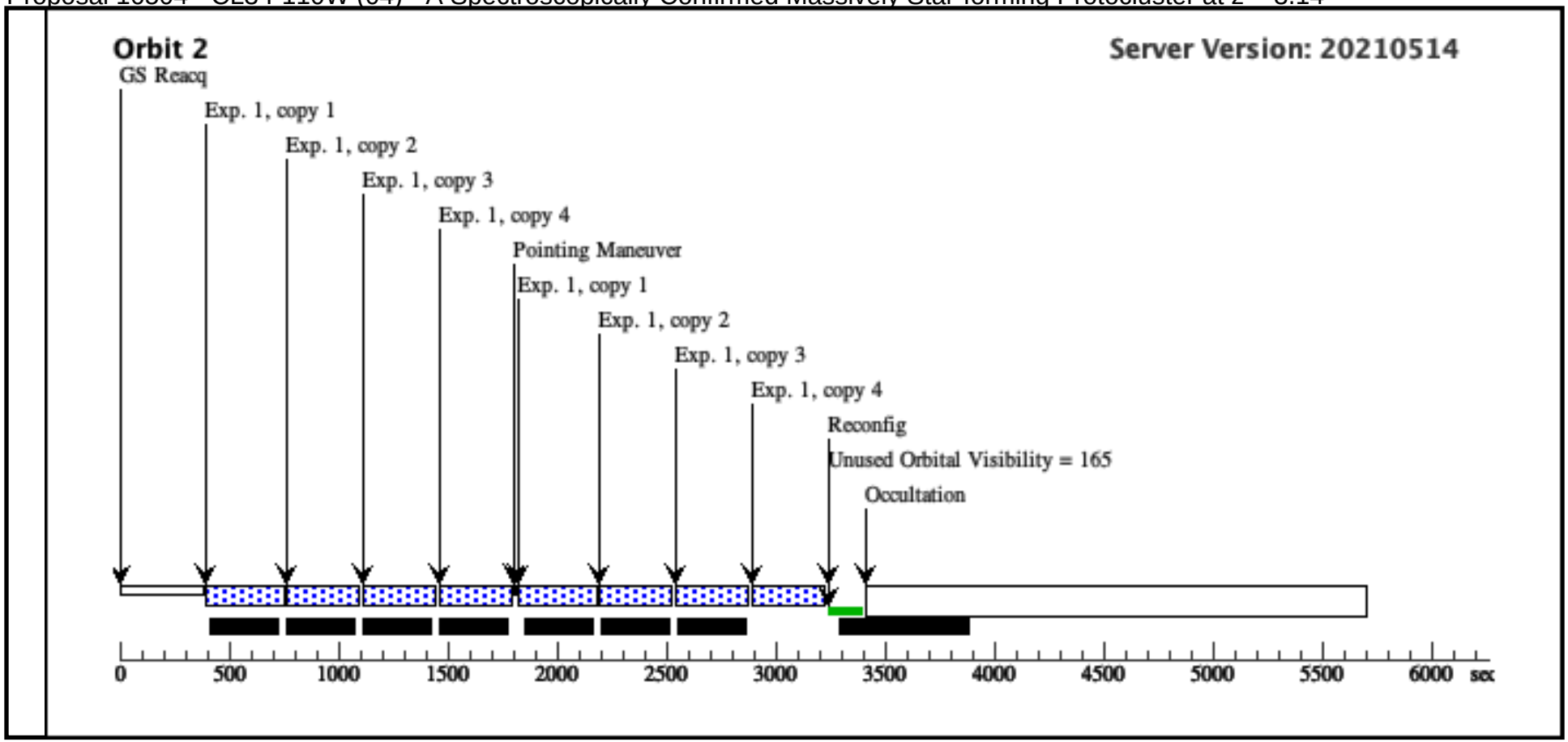
*Comments: Coordinates are for the center of the field, which contains several submillimeter galaxies. The brightest target galaxy GN-CL-3 is at 12:35:46.64 +62:20:13.3 (+/- 2 arcsec in both RA and Dec). J and H magnitudes are for this galaxy. Also contains GN-CL-1 at 12:35:51.37 +62:21:47.2 (z=4.422) and GN-CL-4 at 12:35:39.9 +62:21:29 (z unknown).*
*Category=CLUSTER OF GALAXIES*
*Description=[HIGH REDSHIFT CLUSTER]*

## Exposures

| # | Label | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 02-F110W | (2) GNCL-SOUTH | WFC3/IR, MULTIACCUM, IR | F110W | NSAMP=14;<br>SAMP-SEQ=SPARS25 | | Pattern 1, Exps 1-1 in CL3 F110W (04) (1) | 327.938986 Secs X 4 (5247.024 Secs) | |
| | | | | | | | | *[==>(Pattern 1, Copy 1)]*<br>*[==>(Pattern 1, Copy 2)]*<br>*[==>(Pattern 1, Copy 3)]*<br>*[==>(Pattern 1, Copy 4)]*<br>*[==>(Pattern 2, Copy 1)]*<br>*[==>(Pattern 2, Copy 2)]*<br>*[==>(Pattern 2, Copy 3)]*<br>*[==>(Pattern 2, Copy 4)]* | ***[1]*** |
| | | | | | | | | *[==>(Pattern 3, Copy 1)]*<br>*[==>(Pattern 3, Copy 2)]*<br>*[==>(Pattern 3, Copy 3)]*<br>*[==>(Pattern 3, Copy 4)]*<br>*[==>(Pattern 4, Copy 1)]*<br>*[==>(Pattern 4, Copy 2)]*<br>*[==>(Pattern 4, Copy 3)]*<br>*[==>(Pattern 4, Copy 4)]* | ***[2]*** |

Orbit Structure

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