



# 17267 - Gas content of a new class of stellar system in the Virgo cluster

Cycle: 30, Proposal Category: GO

(Availability Mode: SUPPORTED)

## INVESTIGATORS

| <i>Name</i>                                    | <i>Institution</i>                                     |
|------------------------------------------------|--------------------------------------------------------|
| <b>Dr. Michael Gordon Jones (PI) (Contact)</b> | <b>University of Arizona</b>                           |
| Prof. David J. Sand (CoI) (AdminUSPI)          | University of Arizona                                  |
| Dr. Ananthan Karunakaran (CoI) (CSA Member)    | University of Toronto                                  |
| Dr. Kristine Spekkens (CoI) (CSA Member)       | Royal Military College of Canada                       |
| Dr. Paul Bennet (CoI)                          | Space Telescope Science Institute                      |
| Burcin Mutlu Pakdil (CoI)                      | University of Minnesota - Twin Cities                  |
| Dr. Denija Crnojevic (CoI)                     | University of Tampa                                    |
| Dr. Elizabeth A. K. Adams (CoI) (ESA Member)   | Stichting Astronomisch Onderzoek in Nederland (ASTRON) |

## 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) BC6                      | ACS/WFC                             | 2                  | 16-May-2023 16:00:13.0        | yes                           |
| 02           | (2) BC7                      | ACS/WFC                             | 2                  | 16-May-2023 16:00:14.0        | yes                           |
| 03           | (3) BC8                      | ACS/WFC                             | 2                  | 16-May-2023 16:00:16.0        | yes                           |

6 Total Orbits Used

## ABSTRACT

A recently discovered class of isolated, tiny, blue stellar systems in the Virgo cluster present a challenge for our current models of ram pressure stripping, the process by which they are thought to have formed, and which is responsible for the quenching of galaxies in clusters. Owing to their miniscule stellar masses and unique, clumpy morphology these objects are very difficult to identify and thus far only 5 confirmed examples are

known. Here we propose GBT observations of a further 7 candidates to measure, or place tight constraints on, their HI masses. We also request HST observation of 3 of these candidates which span a slightly broader range of morphology than that of the known objects, in order to confirm these candidates and understand the full range of physical properties that these objects can exhibit. Although neutral gas is undoubtedly the principal component of these system upon formation, they appear to rapidly lose this gas after beginning to form stars. Thus, HI observations are key to understanding the evolutionary state of each object as well as providing constraints for models seeking to explain their formation via gas stripping of galaxies falling into the cluster.

## **OBSERVING DESCRIPTION**

**Overview and Sample:** We request 6 orbits of HST/ACS observations (F606W, F814W filters) in conjunction with our deep GBT HI request, to measure the stellar morphology, luminosity and star formation history of 3 newly discovered blue, isolated stellar systems in the Virgo cluster. As discussed in the science justification, our team has discovered a new class of systems whose properties are consistent with being unique remnants of interactions between gas-rich galaxies and the intracluster medium -- they a) have luminosities similar to faint dwarf galaxies but with metallicities consistent with much higher mass systems, suggesting their gas originated from stripped, massive galaxies; b) consist largely of young stars with bright UV emission, c) have a clumpy, sometimes disjointed morphology, d) reside far from any large galaxies, and e) have mixed HI properties suggesting they lose and/or consume their gas quickly after star formation begins. We have begun a citizen science project to uncover the full sample of such blue, isolated stellar systems in Virgo and are using this proposal to explore their general properties. It is key that we get multi-wavelength data spanning HI, optical spectroscopy (for metallicity measurements) and HST (for structure and star formation history). Some examples are similar to the initial sample, some have slightly redder colors and others are fainter but just as blue. This mix is represented in our HST targets, with an example of each.

**Camera choice, Filters, Depth:** We generally mimic our previous, successful HST observations of the initial set of blue stellar systems we identified (Sand et al. 2017, Jones et al. 2022a,b) and thus request a single orbit of ACS imaging in both the F606W and F814W bands for each of our 3 targets, yielding S/N~5 at 26.7-26.8 mag in both bands (according to the ETC). The similar depth and observing strategy across the larger sample will ensure that directly comparable data and conclusions can be drawn from this more expansive sample.

We request the ACS/WFC imager for its wider field of view than WFC3 and its better sensitivity in our chosen imaging bands. We will employ a standard 4-point dither strategy. If a given stellar system can safely fit on a single chip, we will position it accordingly so that we do not have to fill the chip gap.

Analysis Overview: At these depths, the resolved stellar populations will be sparse and predominantly young, but very informative (we will use the point source photometry code DOLPHOT, along with artificial star tests). If the original sample is a guide, the overall morphology of each system is likely to be clumpy with separate star forming clumps possibly spanning  $\sim 1$  arcmin on the sky. As in our previous work, we will do 'by-eye' matching of the color magnitude diagram with simulated stellar populations convolved with the measured uncertainties and completeness of the observations (Sand et al. 2017). At the distance of the Virgo cluster, standard features such as the extent of the red and blue helium burning sequences can directly constrain the age and duration of a relatively young star formation event ( $< 100$  Myr) and can roughly constrain the metallicity. Similarly the appearance of any resolved young main sequence and apparent turnoff would also indicate a stellar system's age. Ground-based observations are complementary here, as the appearance of HII regions indicate a very young ( $< 10$  Myr) stellar population. HI gas indicates that continuing star formation is possible.

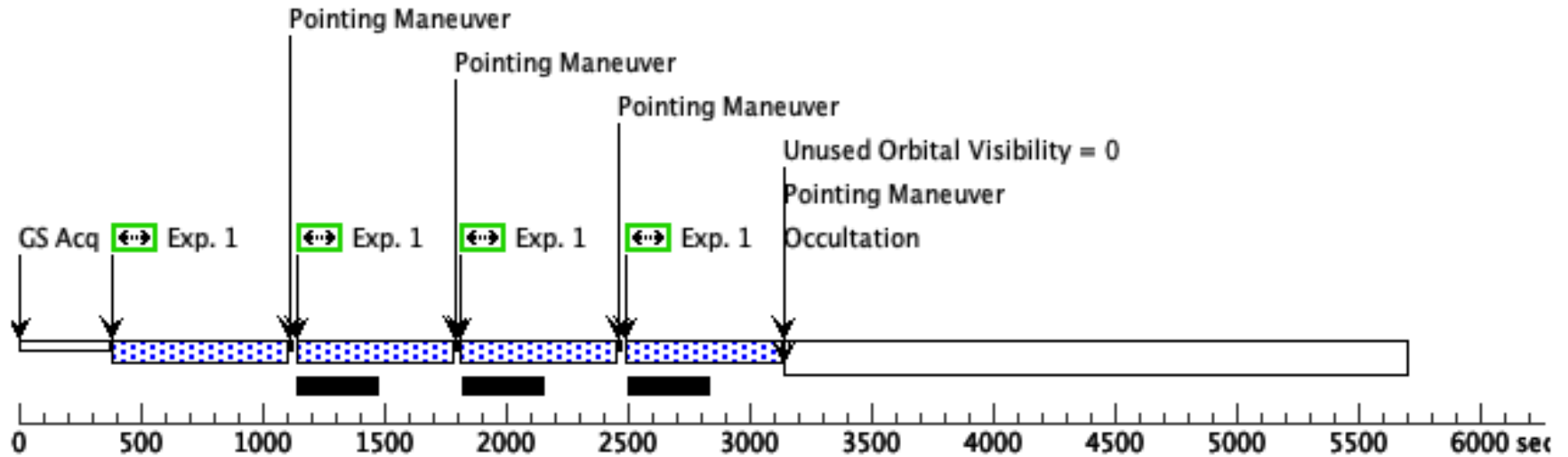
After removing the point sources from our images, we will also characterize the diffuse light from each stellar system. Using this, and comparing with available data on dwarf spheroidal galaxies in the Virgo cluster, we will also constrain the old stellar population associated with each target. Again, our past work indicates that few to no old stars will be present, but we will assess this anew as we expand the sample with our ongoing citizen science project.

# Proposal 17267 - BC6 visit (01) - Gas content of a new class of stellar system in the Virgo cluster

|               |                                                                                                                                     |                                                                                                                  |        |                                  |                                                                                                        |                          |                   |               |                                               |                                                                                                                          |                              |       |
|---------------|-------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|--------|----------------------------------|--------------------------------------------------------------------------------------------------------|--------------------------|-------------------|---------------|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|------------------------------|-------|
| Visit         | Proposal 17267, BC6_visit (01), completed                                                                                           |                                                                                                                  |        |                                  |                                                                                                        |                          |                   |               |                                               |                                                                                                                          | Tue May 16 20:00:16 GMT 2023 |       |
|               | Diagnostic Status: No Diagnostics                                                                                                   |                                                                                                                  |        |                                  |                                                                                                        |                          |                   |               |                                               |                                                                                                                          |                              |       |
|               | Scientific Instruments: ACS/WFC                                                                                                     |                                                                                                                  |        |                                  |                                                                                                        |                          |                   |               |                                               |                                                                                                                          |                              |       |
|               | Special Requirements: (none)                                                                                                        |                                                                                                                  |        |                                  |                                                                                                        |                          |                   |               |                                               |                                                                                                                          |                              |       |
| Patterns      | #                                                                                                                                   | Primary Pattern                                                                                                  |        |                                  |                                                                                                        |                          | Secondary Pattern |               |                                               |                                                                                                                          | Exposures                    |       |
|               | (2)                                                                                                                                 | Pattern Type=ACS-WFC-DITHER-LINE<br>Purpose=DITHER<br>Number Of Points=4<br>Point Spacing=3.034<br>Line Spacing= |        |                                  | Coordinate Frame=POS-TARG<br>Pattern Orientation=85.29<br>Angle Between Sides=<br>Center Pattern=false |                          |                   |               |                                               |                                                                                                                          | (1), (2)                     |       |
| Fixed Targets | #                                                                                                                                   | Name                                                                                                             |        | Target Coordinates               |                                                                                                        | Targ. Coord. Corrections |                   | Fluxes        |                                               | Miscellaneous                                                                                                            |                              |       |
|               | (1)                                                                                                                                 | BC6                                                                                                              |        | RA: 12 29 34.5922 (187.3941342d) |                                                                                                        |                          |                   | V=22.0        |                                               | Reference Frame: ICRS                                                                                                    |                              |       |
|               |                                                                                                                                     | Alt Name1: 423223779                                                                                             |        | Dec: +09 44 27.64 (9.74101d)     |                                                                                                        |                          |                   |               |                                               |                                                                                                                          |                              |       |
|               |                                                                                                                                     |                                                                                                                  |        | Equinox: J2000                   |                                                                                                        |                          |                   |               |                                               |                                                                                                                          |                              |       |
|               | Comments:<br>Category=UNIDENTIFIED<br>Description=[KNOT, OPTICAL EMITTER, STAR FORMING REGION, ULTRAVIOLET EMITTER]<br>Extended=YES |                                                                                                                  |        |                                  |                                                                                                        |                          |                   |               |                                               |                                                                                                                          |                              |       |
| Exposures     | #                                                                                                                                   | Label                                                                                                            | Target | Config,Mode,Aperture             |                                                                                                        | Spectral Els.            | Opt. Params.      | Special Reqs. | Groups                                        | Exp. Time (Total)/[Actual Dur.]                                                                                          |                              | Orbit |
|               | 1                                                                                                                                   | ACS F606W (1) BC6                                                                                                |        | ACS/WFC, ACCUM, WFC              |                                                                                                        | F606W                    |                   |               | Pattern 2, Exps 1-1 i<br>n BC6_visit (01) (2) | 450 Secs (2056 Secs)                                                                                                     |                              |       |
|               |                                                                                                                                     |                                                                                                                  |        |                                  |                                                                                                        |                          |                   |               |                                               | [==>514.0 Secs (Pattern 1)]<br>[==>514.0 Secs (Pattern 2)]<br>[==>514.0 Secs (Pattern 3)]<br>[==>514.0 Secs (Pattern 4)] |                              | [1]   |
|               | 2                                                                                                                                   | ACS F814W (1) BC6                                                                                                |        | ACS/WFC, ACCUM, WFC              |                                                                                                        | F814W                    |                   |               | Pattern 2, Exps 2-2 i<br>n BC6_visit (01) (2) | 450 Secs (2072 Secs)                                                                                                     |                              |       |
|               |                                                                                                                                     |                                                                                                                  |        |                                  |                                                                                                        |                          |                   |               |                                               | [==>518.0 Secs (Pattern 1)]<br>[==>518.0 Secs (Pattern 2)]<br>[==>518.0 Secs (Pattern 3)]<br>[==>518.0 Secs (Pattern 4)] |                              | [2]   |
|               |                                                                                                                                     |                                                                                                                  |        |                                  |                                                                                                        |                          |                   |               |                                               |                                                                                                                          |                              |       |

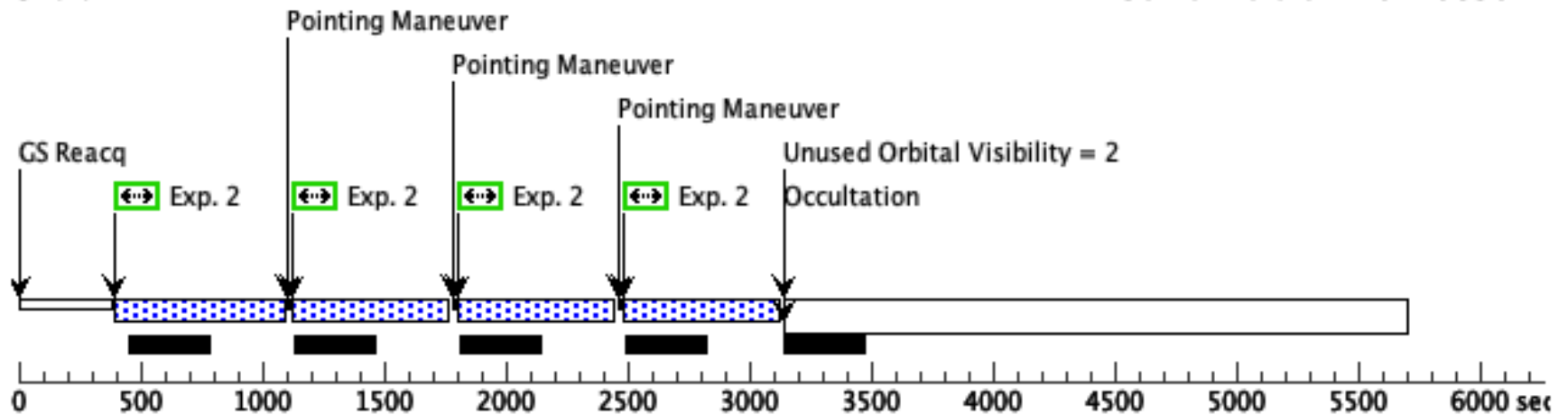
### Orbit 1

Server Version: 20220630



### Orbit 2

Server Version: 20220630

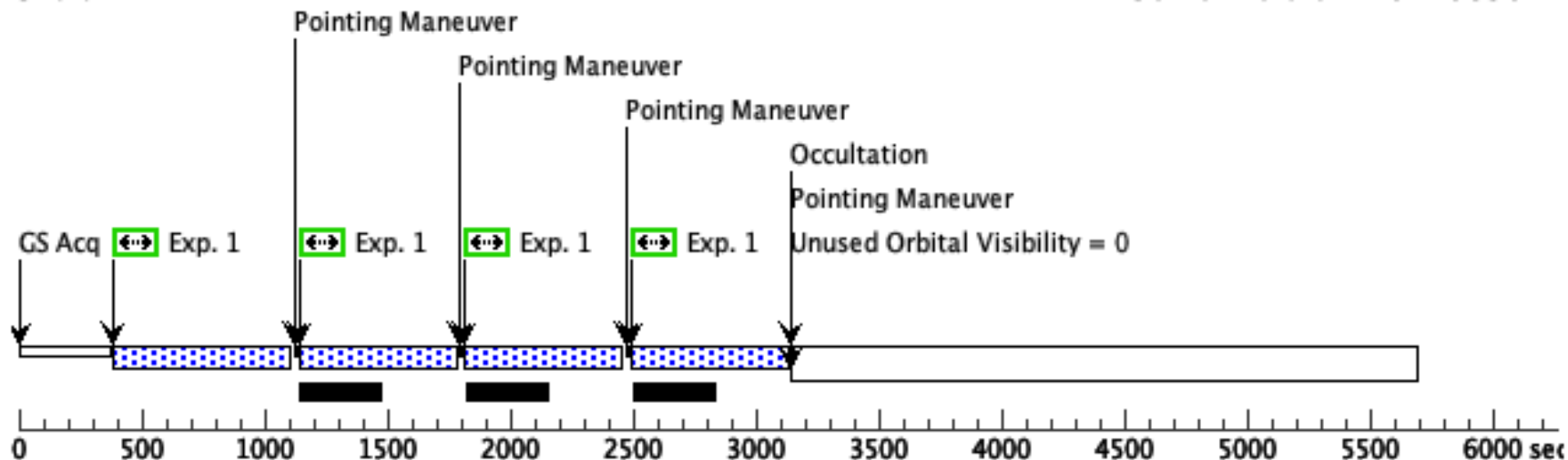


# Proposal 17267 - BC7 visit (02) - Gas content of a new class of stellar system in the Virgo cluster

|               |                                                                                                                                     |                                                                                                                        |                                  |                                                                                                            |                          |                   |              |                                           |                                           |                                 |                              |       |
|---------------|-------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|----------------------------------|------------------------------------------------------------------------------------------------------------|--------------------------|-------------------|--------------|-------------------------------------------|-------------------------------------------|---------------------------------|------------------------------|-------|
| Visit         | Proposal 17267, BC7_visit (02), scheduled                                                                                           |                                                                                                                        |                                  |                                                                                                            |                          |                   |              |                                           |                                           |                                 | Tue May 16 20:00:16 GMT 2023 |       |
|               | Diagnostic Status: No Diagnostics                                                                                                   |                                                                                                                        |                                  |                                                                                                            |                          |                   |              |                                           |                                           |                                 |                              |       |
|               | Scientific Instruments: ACS/WFC                                                                                                     |                                                                                                                        |                                  |                                                                                                            |                          |                   |              |                                           |                                           |                                 |                              |       |
|               | Special Requirements: (none)                                                                                                        |                                                                                                                        |                                  |                                                                                                            |                          |                   |              |                                           |                                           |                                 |                              |       |
| Patterns      | #                                                                                                                                   | Primary Pattern                                                                                                        |                                  |                                                                                                            |                          | Secondary Pattern |              |                                           |                                           | Exposures                       |                              |       |
|               | (1)                                                                                                                                 | Pattern Type=ACS-WFC-DITHER-BOX<br>Purpose=DITHER<br>Number Of Points=4<br>Point Spacing=0.2637<br>Line Spacing=0.1856 |                                  | Coordinate Frame=POS-TARG<br>Pattern Orientation=20.7<br>Angle Between Sides=69.02<br>Center Pattern=false |                          |                   |              |                                           |                                           | (1), (2)                        |                              |       |
| Fixed Targets | #                                                                                                                                   | Name                                                                                                                   | Target Coordinates               |                                                                                                            | Targ. Coord. Corrections |                   | Fluxes       |                                           | Miscellaneous                             |                                 |                              |       |
|               | (2)                                                                                                                                 | BC7                                                                                                                    | RA: 12 24 30.6695 (186.1277896d) |                                                                                                            |                          |                   | V=23.0       |                                           | Reference Frame: ICRS                     |                                 |                              |       |
|               |                                                                                                                                     | Alt Name1: 425805902                                                                                                   | Dec: +11 48 34.40 (11.80956d)    |                                                                                                            |                          |                   |              |                                           |                                           |                                 |                              |       |
|               |                                                                                                                                     |                                                                                                                        | Equinox: J2000                   |                                                                                                            |                          |                   |              |                                           |                                           |                                 |                              |       |
|               | Comments:<br>Category=UNIDENTIFIED<br>Description=[KNOT, OPTICAL EMITTER, STAR FORMING REGION, ULTRAVIOLET EMITTER]<br>Extended=YES |                                                                                                                        |                                  |                                                                                                            |                          |                   |              |                                           |                                           |                                 |                              |       |
| Exposures     | #                                                                                                                                   | Label                                                                                                                  | Target                           | Config,Mode,Aperture                                                                                       |                          | Spectral Els.     | Opt. Params. | Special Reqs.                             | Groups                                    | Exp. Time (Total)/[Actual Dur.] |                              | Orbit |
|               | 1                                                                                                                                   | ACS F606W                                                                                                              | (2) BC7                          | ACS/WFC, ACCUM, WFC1                                                                                       |                          | F606W             |              |                                           | Pattern 1, Exps 1-1 in BC7_visit (02) (1) | 450 Secs (2072 Secs)            |                              |       |
|               |                                                                                                                                     |                                                                                                                        |                                  |                                                                                                            |                          |                   |              |                                           |                                           | [==>518.0 Secs (Pattern 1)]     |                              | [1]   |
|               |                                                                                                                                     |                                                                                                                        |                                  |                                                                                                            |                          |                   |              |                                           |                                           | [==>518.0 Secs (Pattern 2)]     |                              |       |
|               |                                                                                                                                     |                                                                                                                        |                                  |                                                                                                            |                          |                   |              |                                           |                                           | [==>518.0 Secs (Pattern 3)]     |                              |       |
|               |                                                                                                                                     |                                                                                                                        |                                  |                                                                                                            |                          |                   |              |                                           |                                           | [==>518.0 Secs (Pattern 4)]     |                              |       |
| 2             | ACS F814W                                                                                                                           | (2) BC7                                                                                                                | ACS/WFC, ACCUM, WFC1             |                                                                                                            | F814W                    |                   |              | Pattern 1, Exps 2-2 in BC7_visit (02) (1) | 450 Secs (2088 Secs)                      |                                 |                              |       |
|               |                                                                                                                                     |                                                                                                                        |                                  |                                                                                                            |                          |                   |              |                                           | [==>522.0 Secs (Pattern 1)]               |                                 | [2]                          |       |
|               |                                                                                                                                     |                                                                                                                        |                                  |                                                                                                            |                          |                   |              |                                           | [==>522.0 Secs (Pattern 2)]               |                                 |                              |       |
|               |                                                                                                                                     |                                                                                                                        |                                  |                                                                                                            |                          |                   |              |                                           | [==>522.0 Secs (Pattern 3)]               |                                 |                              |       |
|               |                                                                                                                                     |                                                                                                                        |                                  |                                                                                                            |                          |                   |              |                                           | [==>522.0 Secs (Pattern 4)]               |                                 |                              |       |

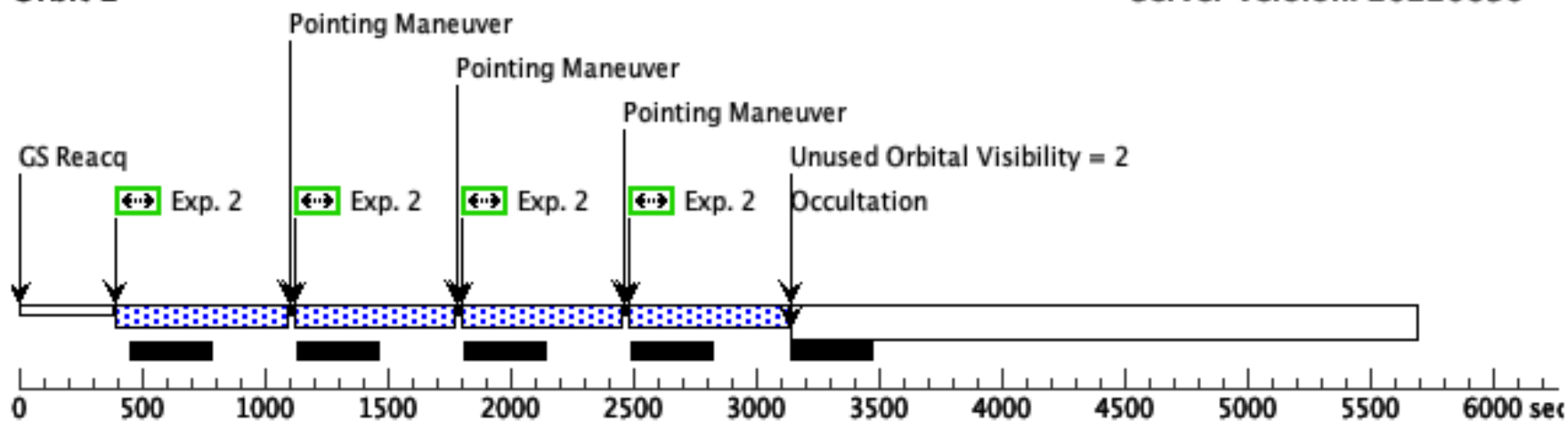
### Orbit 1

Server Version: 20220630



### Orbit 2

Server Version: 20220630

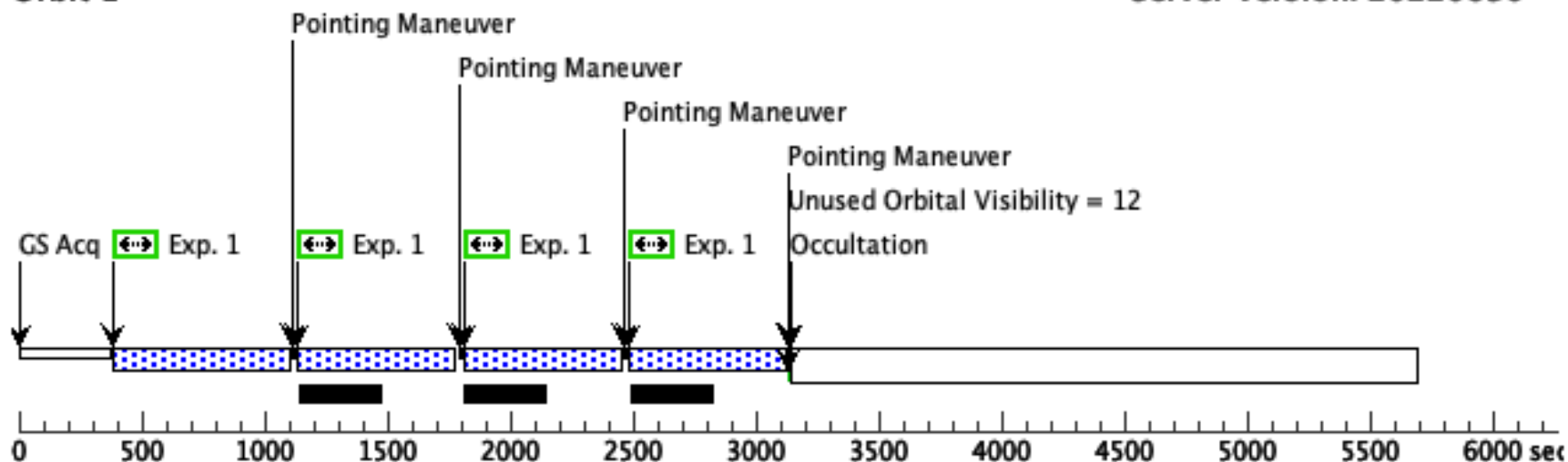


# Proposal 17267 - BC8 visit (03) - Gas content of a new class of stellar system in the Virgo cluster

|                                                                               |                                            |                                 |                               |                                  |                           |                          |                                                   |                                                   |                                            |                                 |                              |           |  |
|-------------------------------------------------------------------------------|--------------------------------------------|---------------------------------|-------------------------------|----------------------------------|---------------------------|--------------------------|---------------------------------------------------|---------------------------------------------------|--------------------------------------------|---------------------------------|------------------------------|-----------|--|
| Visit                                                                         | Proposal 17267, BC8_visit (03), scheduling |                                 |                               |                                  |                           |                          |                                                   |                                                   |                                            |                                 | Tue May 16 20:00:16 GMT 2023 |           |  |
|                                                                               | Diagnostic Status: No Diagnostics          |                                 |                               |                                  |                           |                          |                                                   |                                                   |                                            |                                 |                              |           |  |
|                                                                               | Scientific Instruments: ACS/WFC            |                                 |                               |                                  |                           |                          |                                                   |                                                   |                                            |                                 |                              |           |  |
|                                                                               | Special Requirements: (none)               |                                 |                               |                                  |                           |                          |                                                   |                                                   |                                            |                                 |                              |           |  |
| Patterns                                                                      | #                                          | Primary Pattern                 |                               |                                  |                           |                          | Secondary Pattern                                 |                                                   |                                            |                                 |                              | Exposures |  |
|                                                                               | (1)                                        | Pattern Type=ACS-WFC-DITHER-BOX |                               |                                  | Coordinate Frame=POS-TARG |                          |                                                   |                                                   |                                            |                                 |                              | (1), (2)  |  |
|                                                                               | Purpose=DITHER                             |                                 |                               | Pattern Orientation=20.7         |                           |                          |                                                   |                                                   |                                            |                                 |                              |           |  |
|                                                                               | Number Of Points=4                         |                                 |                               | Angle Between Sides=69.02        |                           |                          |                                                   |                                                   |                                            |                                 |                              |           |  |
|                                                                               | Point Spacing=0.2637                       |                                 |                               | Center Pattern=false             |                           |                          |                                                   |                                                   |                                            |                                 |                              |           |  |
| Line Spacing=0.1856                                                           |                                            |                                 |                               |                                  |                           |                          |                                                   |                                                   |                                            |                                 |                              |           |  |
| Fixed Targets                                                                 | #                                          | Name                            |                               | Target Coordinates               |                           | Targ. Coord. Corrections |                                                   |                                                   | Fluxes                                     |                                 | Miscellaneous                |           |  |
|                                                                               | (3)                                        | BC8                             |                               | RA: 12 23 14.6400 (185.8110000d) |                           |                          |                                                   |                                                   | V=20.7                                     |                                 | Reference Frame: ICRS        |           |  |
|                                                                               | Alt Name1: 423284472                       |                                 | Dec: +11 33 23.76 (11.55660d) |                                  |                           |                          |                                                   |                                                   |                                            |                                 |                              |           |  |
|                                                                               |                                            |                                 | Equinox: J2000                |                                  |                           |                          |                                                   |                                                   |                                            |                                 |                              |           |  |
|                                                                               | Comments:                                  |                                 |                               |                                  |                           |                          |                                                   |                                                   |                                            |                                 |                              |           |  |
| Category=UNIDENTIFIED                                                         |                                            |                                 |                               |                                  |                           |                          |                                                   |                                                   |                                            |                                 |                              |           |  |
| Description=[KNOT, OPTICAL EMITTER, STAR FORMING REGION, ULTRAVIOLET EMITTER] |                                            |                                 |                               |                                  |                           |                          |                                                   |                                                   |                                            |                                 |                              |           |  |
| Extended=YES                                                                  |                                            |                                 |                               |                                  |                           |                          |                                                   |                                                   |                                            |                                 |                              |           |  |
| Exposures                                                                     | #                                          | Label                           | Target                        | Config,Mode,Aperture             |                           | Spectral Els.            | Opt. Params.                                      | Special Reqs.                                     | Groups                                     | Exp. Time (Total)/[Actual Dur.] |                              | Orbit     |  |
|                                                                               | 1                                          | ACS F606W                       | (3) BC8                       | ACS/WFC, ACCUM, WFC              |                           | F606W                    |                                                   | POS TARG -2.4428 344552439474,31.86 6420409380492 | Pattern 1, Exps 1-1 i n BC8_visit (03) (1) | 450 Secs (2060 Secs)            |                              |           |  |
|                                                                               |                                            |                                 |                               |                                  |                           |                          |                                                   |                                                   |                                            | [==>515.0 Secs (Pattern 1)]     |                              | [1]       |  |
|                                                                               |                                            |                                 |                               |                                  |                           |                          |                                                   |                                                   |                                            | [==>515.0 Secs (Pattern 2)]     |                              |           |  |
|                                                                               |                                            |                                 |                               |                                  |                           |                          |                                                   |                                                   |                                            | [==>515.0 Secs (Pattern 3)]     |                              |           |  |
|                                                                               |                                            |                                 |                               |                                  |                           |                          |                                                   |                                                   | [==>515.0 Secs (Pattern 4)]                |                                 |                              |           |  |
| 2                                                                             | ACS F814W                                  | (3) BC8                         | ACS/WFC, ACCUM, WFC           |                                  | F814W                     |                          | POS TARG -2.4428 344552439474,31.86 6420409380492 | Pattern 1, Exps 2-2 i n BC8_visit (03) (1)        | 450 Secs (2088 Secs)                       |                                 |                              |           |  |
|                                                                               |                                            |                                 |                               |                                  |                           |                          |                                                   |                                                   | [==>522.0 Secs (Pattern 1)]                |                                 | [2]                          |           |  |
|                                                                               |                                            |                                 |                               |                                  |                           |                          |                                                   |                                                   | [==>522.0 Secs (Pattern 2)]                |                                 |                              |           |  |
|                                                                               |                                            |                                 |                               |                                  |                           |                          |                                                   |                                                   | [==>522.0 Secs (Pattern 3)]                |                                 |                              |           |  |
|                                                                               |                                            |                                 |                               |                                  |                           |                          |                                                   |                                                   | [==>522.0 Secs (Pattern 4)]                |                                 |                              |           |  |

### Orbit 1

Server Version: 20220630



### Orbit 2

Server Version: 20220630

