# 17712 - Elucidating the Nature of a 'Starless' Dark Matter Halo Near M94

Cycle: 32, Proposal Category: GO

(Availability Mode: SUPPORTED)

**INVESTIGATORS**

| *Name* | *Institution* |
|---|---|
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| Dr. Elena D'Onghia (CoI) | University of Wisconsin - Madison |
| Prof. Julio Navarro (CoI) (CSA Member) | University of Victoria |
| Dr. Gagandeep Singh Anand (CoI) (Contact) | Space Telescope Science Institute |

**VISITS**

| *Visit* | *Targets used in Visit* | *Configurations used in Visit* | *Orbits Used* | *Last Orbit Planner Run* | *OP Current with Visit?* |
|---|---|---|---|---|---|
| 01 | (1) M94-CL9<br>ANY | ACS/WFC<br>WFC3/UVIS | 2 | 08-Oct-2024 11:00:36.0 | yes |
| 02 | (1) M94-CL9<br>ANY | ACS/WFC<br>WFC3/UVIS | 2 | 08-Oct-2024 11:00:37.0 | yes |
| 03 | (1) M94-CL9<br>ANY | ACS/WFC<br>WFC3/UVIS | 2 | 08-Oct-2024 11:00:38.0 | yes |
| 04 | (1) M94-CL9<br>ANY | ACS/WFC<br>WFC3/UVIS | 2 | 08-Oct-2024 11:00:39.0 | yes |

8 Total Orbits Used

**ABSTRACT**

Observations with the FAST radio telescope recently detected a marginally resolved 21 cm HI cloud (named Cloud-9) near the M94 galaxy without an optical counterpart down to the surface brightness limit of the DESI Imaging Legacy Survey (~29.5 mag/arcsec^2 in the g band). Unlike previous candidate "dark" HI clouds, all known properties of Cloud-9 are consistent with RELHICs, namely starless dark matter halos filled with gas in hydrostatic equilibrium and thermal equilibrium with the cosmic ultraviolet background. However, the main doubts about its true nature concern the relatively poor angular resolution of the FAST data and the uncomfortably large upper limit in the stellar mass of any luminous stellar counterpart, M_* <= 10^5 Msun, a value comparable to the stellar mass of nearby HI-rich dwarfs. We thus propose to carry out deep photometric observations (8 orbits) with the HST/ACS instrument to bring down constraints to the stellar mass of this object to M_* < 10^4 Msun (and possibly 10^{3.5} Msun) and elucidate the true nature of Cloud-9. Either outcome will be important: (i) if we do not detect a stellar counterpart, we will reinforce the RELHIC interpretation for this system while confirming a cornerstone prediction of the LCDM model, namely the existence of starless collapsed dark matter structures on sub-galactic mass scales; (ii) if we do detect a stellar counterpart, we will have uncovered the faintest HI-rich dwarf galaxy known outside the Local Group.

**OBSERVING DESCRIPTION**

This program target a potential satellite galaxy of M94 for analysis of its resolved stellar populations. There is a chance the satellite is a LCDM RELHIC (a starless cloud containing just gas and dark matter), in which case there will be no stars seen in the images.

This 8-orbit program is broken up into 4 2-orbit visits, with equal amounts of time to F606W and F814W with both ACS/WFC (prime, main target) and WFC3/UVIS (parallel, for analysis of a background field). Orient constraints (specified in Phase I) are present to obtain an optimal background field and avoid a bright foreground star, but can be adjusted for scheduling if needed.

The dither pattern adopted is the 5x5 pixel ACS-WFC-DITHER-LINE pattern to optimize rejection of bad pixels/columns/artifacts in ACS/WFC. The dither patter is implemented via POS TARGs.

# Proposal 17712 - Visit 01 - Elucidating the Nature of a 'Starless' Dark Matter Halo Near M94

## Visit

**Proposal 17712, Visit 01, implementation** Tue Oct 08 15:00:40 GMT 2024

**Diagnostic Status: No Diagnostics**

Scientific Instruments: WFC3/UVIS, ACS/WFC

Special Requirements: ORIENT 223D TO 227 D

## Fixed Targets

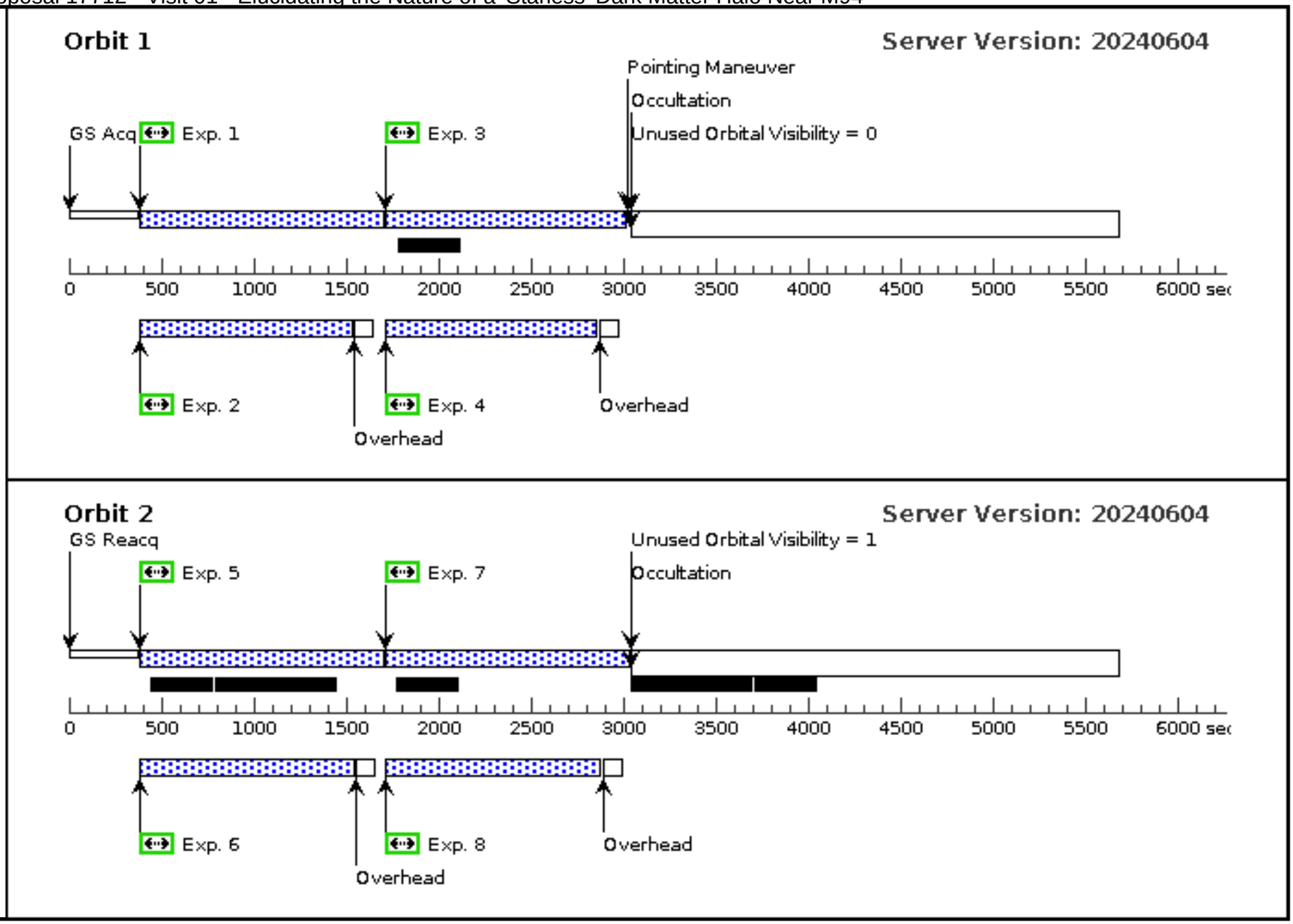
| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
|---|---|---|---|---|---|
| (1) | M94-CL9 | RA: 12 51 51.3000 (192.9637500d)<br>Dec: +40 18 5.00 (40.30139d)<br>Equinox: J2000 | | V=25 | Reference Frame: ICRS |

*Comments:*
*Category=GALAXY*
*Description=[DWARF COMPACT]*

## Exposures

| # | Label | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | (1) M94-CL9 | ACS/WFC, ACCUM, WFC1-FIX | F606W | | | Prime + Parallel Group 1-2 in Visit 01 | 1118 Secs (1118 Secs)<br>*[==>]* | *[1]* |
| 2 | | ANY | WFC3/UVIS, ACCUM, UVIS | F606W | | | Prime + Parallel Group 1-2 in Visit 01 | 1118 Secs (1118 Secs)<br>*[==>]* | *[1]* |
| 3 | | (1) M94-CL9 | ACS/WFC, ACCUM, WFC1-FIX | F814W | | | Prime + Parallel Group 3-4 in Visit 01 | 1118 Secs (1118 Secs)<br>*[==>]* | *[1]* |
| 4 | | ANY | WFC3/UVIS, ACCUM, UVIS | F814W | | | Prime + Parallel Group 3-4 in Visit 01 | 1118 Secs (1118 Secs)<br>*[==>]* | *[1]* |
| 5 | | (1) M94-CL9 | ACS/WFC, ACCUM, WFC1-FIX | F606W | | POS TARG 0.247,0.267 | Prime + Parallel Group 5-6 in Visit 01 | 1141 Secs (1141 Secs)<br>*[==>]* | *[2]* |
| 6 | | ANY | WFC3/UVIS, ACCUM, UVIS | F606W | | | Prime + Parallel Group 5-6 in Visit 01 | 1141 Secs (1141 Secs)<br>*[==>]* | *[2]* |
| 7 | | (1) M94-CL9 | ACS/WFC, ACCUM, WFC1-FIX | F814W | | SAME POS AS 5 | Prime + Parallel Group 7-8 in Visit 01 | 1141 Secs (1141 Secs)<br>*[==>]* | *[2]* |
| 8 | | ANY | WFC3/UVIS, ACCUM, UVIS | F814W | | | Prime + Parallel Group 7-8 in Visit 01 | 1141 Secs (1141 Secs)<br>*[==>]* | *[2]* |

Orbit Structure



# Proposal 17712 - Visit 02 - Elucidating the Nature of a 'Starless' Dark Matter Halo Near M94

## Visit

**Proposal 17712, Visit 02, implementation** Tue Oct 08 15:00:40 GMT 2024

**Diagnostic Status: No Diagnostics**

Scientific Instruments: WFC3/UVIS, ACS/WFC

Special Requirements: ORIENT 223D TO 227 D

## Fixed Targets

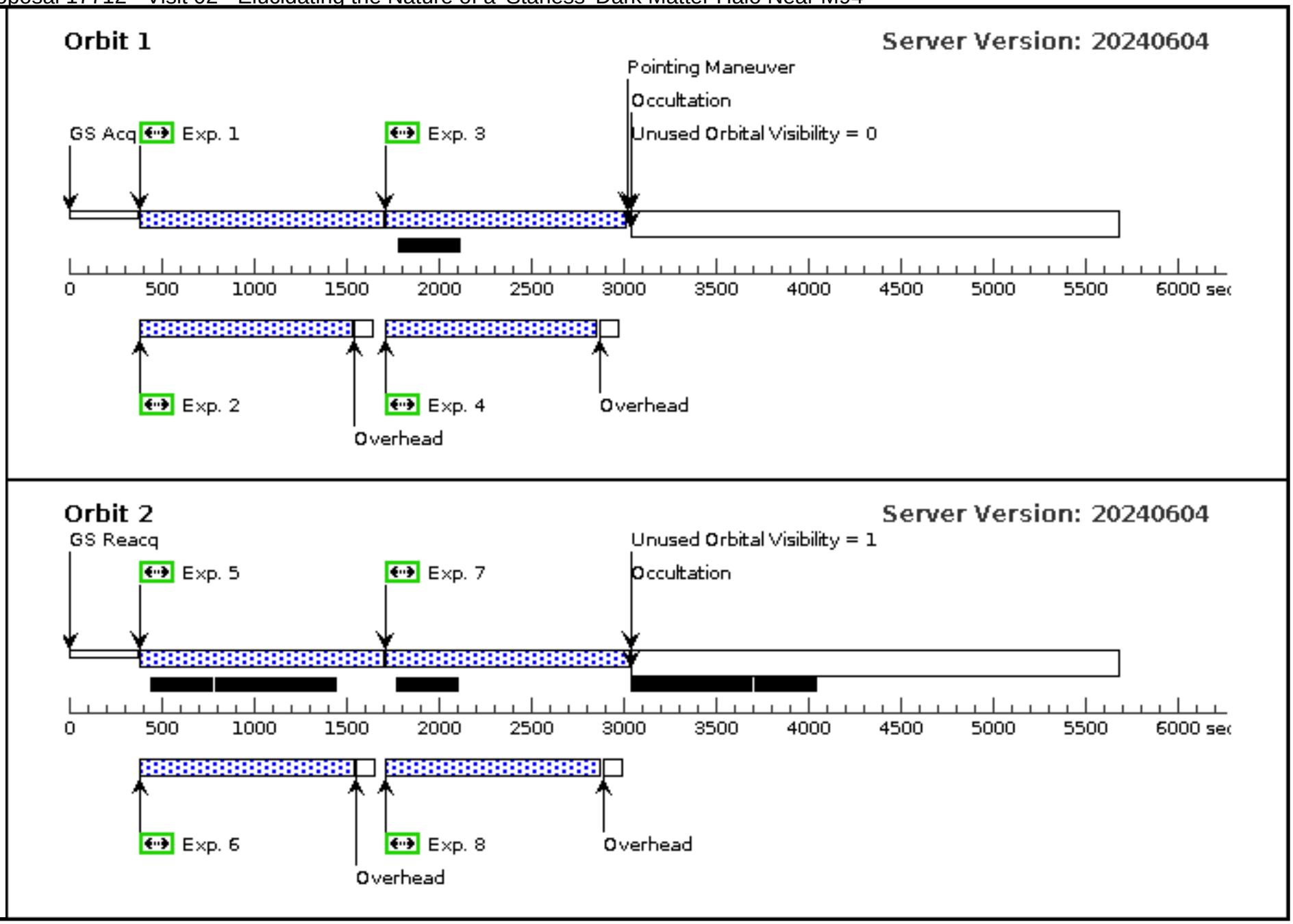
| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
|---|---|---|---|---|---|
| (1) | M94-CL9 | RA: 12 51 51.3000 (192.9637500d)<br>Dec: +40 18 5.00 (40.30139d)<br>Equinox: J2000 | | V=25 | Reference Frame: ICRS |

*Comments:*
*Category=GALAXY*
*Description=[DWARF COMPACT]*

## Exposures

| # | Label | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | (1) M94-CL9 | ACS/WFC, ACCUM, WFC1-FIX | F606W | | | Prime + Parallel Group 1-2 in Visit 02 | 1118 Secs (1118 Secs)<br>*[==>]* | *[1]* |
| 2 | | ANY | WFC3/UVIS, ACCUM, UVIS | F606W | | | Prime + Parallel Group 1-2 in Visit 02 | 1118 Secs (1118 Secs)<br>*[==>]* | *[1]* |
| 3 | | (1) M94-CL9 | ACS/WFC, ACCUM, WFC1-FIX | F814W | | | Prime + Parallel Group 3-4 in Visit 02 | 1118 Secs (1118 Secs)<br>*[==>]* | *[1]* |
| 4 | | ANY | WFC3/UVIS, ACCUM, UVIS | F814W | | | Prime + Parallel Group 3-4 in Visit 02 | 1118 Secs (1118 Secs)<br>*[==>]* | *[1]* |
| 5 | | (1) M94-CL9 | ACS/WFC, ACCUM, WFC1-FIX | F606W | | POS TARG 0.247,0.267 | Prime + Parallel Group 5-6 in Visit 02 | 1141 Secs (1141 Secs)<br>*[==>]* | *[2]* |
| 6 | | ANY | WFC3/UVIS, ACCUM, UVIS | F606W | | | Prime + Parallel Group 5-6 in Visit 02 | 1141 Secs (1141 Secs)<br>*[==>]* | *[2]* |
| 7 | | (1) M94-CL9 | ACS/WFC, ACCUM, WFC1-FIX | F814W | | SAME POS AS 5 | Prime + Parallel Group 7-8 in Visit 02 | 1141 Secs (1141 Secs)<br>*[==>]* | *[2]* |
| 8 | | ANY | WFC3/UVIS, ACCUM, UVIS | F814W | | | Prime + Parallel Group 7-8 in Visit 02 | 1141 Secs (1141 Secs)<br>*[==>]* | *[2]* |

Orbit Structure



# Proposal 17712 - Visit 03 - Elucidating the Nature of a 'Starless' Dark Matter Halo Near M94

## Visit

**Proposal 17712, Visit 03, implementation** Tue Oct 08 15:00:40 GMT 2024

**Diagnostic Status: No Diagnostics**

Scientific Instruments: WFC3/UVIS, ACS/WFC

Special Requirements: ORIENT 223D TO 227 D

## Fixed Targets

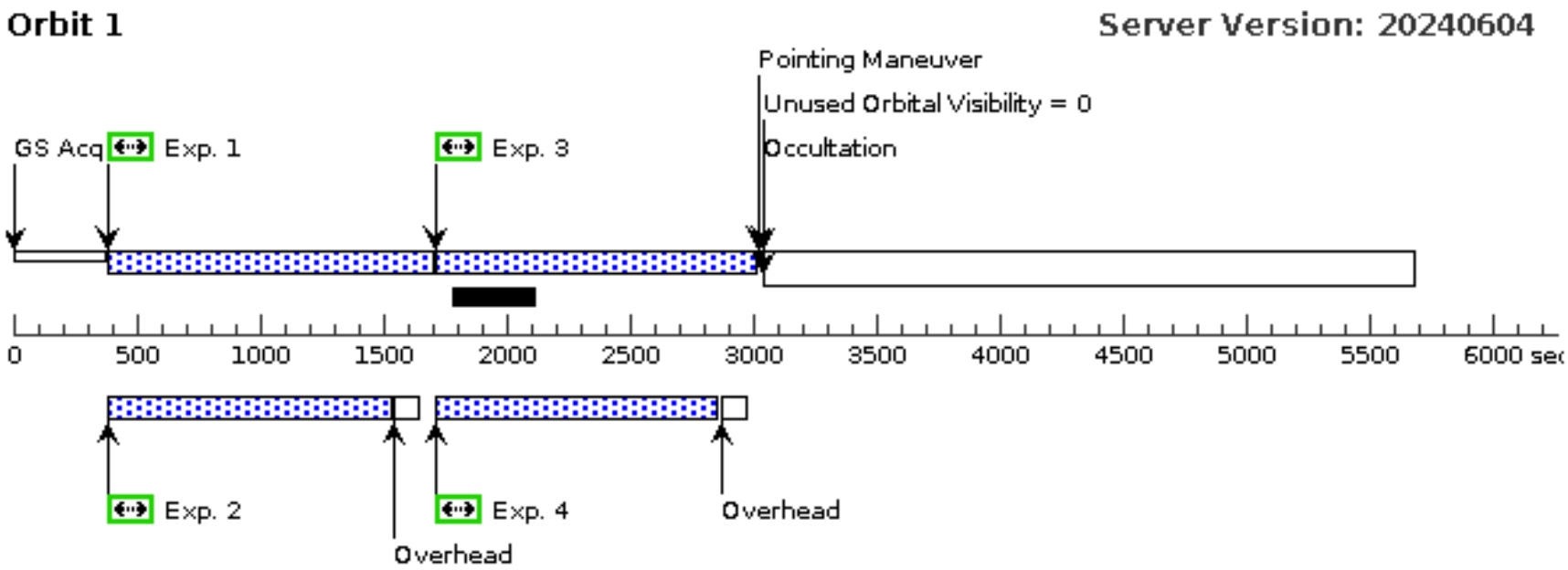
| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
|---|---|---|---|---|---|
| (1) | M94-CL9 | RA: 12 51 51.3000 (192.9637500d)<br>Dec: +40 18 5.00 (40.30139d)<br>Equinox: J2000 | | V=25 | Reference Frame: ICRS |

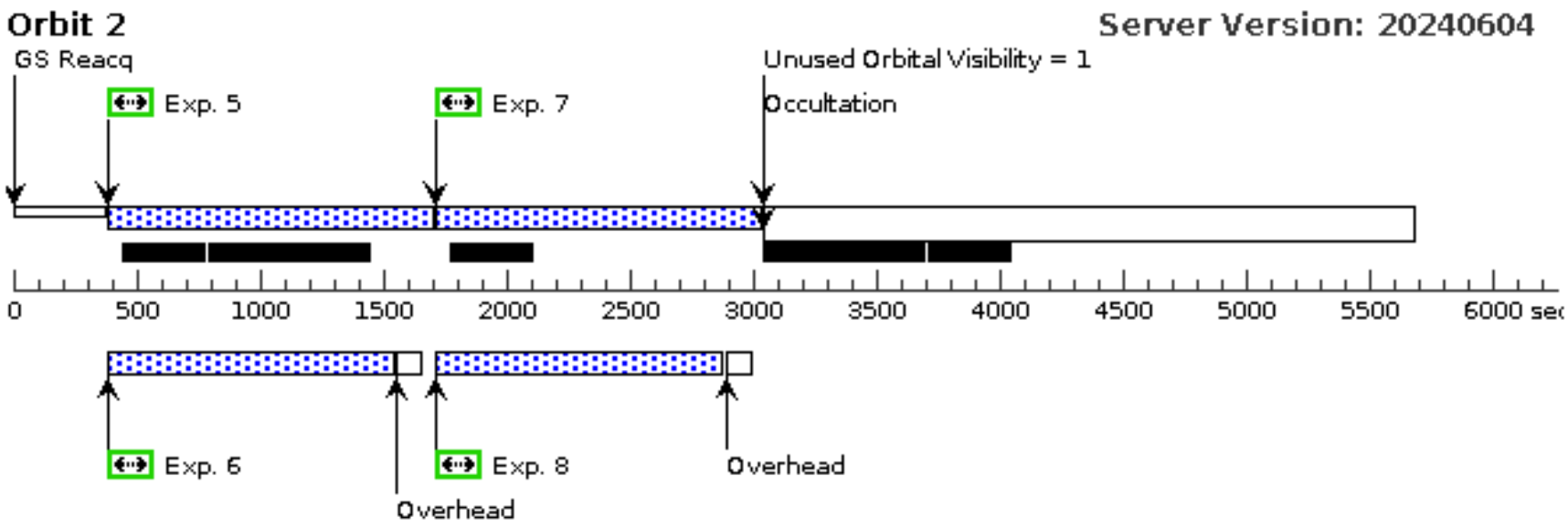
*Comments:*
*Category=GALAXY*
*Description=[DWARF COMPACT]*

## Exposures

| # | Label | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | (1) M94-CL9 | ACS/WFC, ACCUM, WFC1-FIX | F606W | | | Prime + Parallel Group 1-2 in Visit 03 | 1118 Secs (1118 Secs)<br>*[==>]* | *[1]* |
| 2 | | ANY | WFC3/UVIS, ACCUM, UVIS | F606W | | | Prime + Parallel Group 1-2 in Visit 03 | 1118 Secs (1118 Secs)<br>*[==>]* | *[1]* |
| 3 | | (1) M94-CL9 | ACS/WFC, ACCUM, WFC1-FIX | F814W | | | Prime + Parallel Group 3-4 in Visit 03 | 1118 Secs (1118 Secs)<br>*[==>]* | *[1]* |
| 4 | | ANY | WFC3/UVIS, ACCUM, UVIS | F814W | | | Prime + Parallel Group 3-4 in Visit 03 | 1118 Secs (1118 Secs)<br>*[==>]* | *[1]* |
| 5 | | (1) M94-CL9 | ACS/WFC, ACCUM, WFC1-FIX | F606W | | POS TARG 0.247,0.267 | Prime + Parallel Group 5-6 in Visit 03 | 1141 Secs (1141 Secs)<br>*[==>]* | *[2]* |
| 6 | | ANY | WFC3/UVIS, ACCUM, UVIS | F606W | | | Prime + Parallel Group 5-6 in Visit 03 | 1141 Secs (1141 Secs)<br>*[==>]* | *[2]* |
| 7 | | (1) M94-CL9 | ACS/WFC, ACCUM, WFC1-FIX | F814W | | SAME POS AS 5 | Prime + Parallel Group 7-8 in Visit 03 | 1141 Secs (1141 Secs)<br>*[==>]* | *[2]* |
| 8 | | ANY | WFC3/UVIS, ACCUM, UVIS | F814W | | | Prime + Parallel Group 7-8 in Visit 03 | 1141 Secs (1141 Secs)<br>*[==>]* | *[2]* |

Orbit Structure



# Proposal 17712 - Visit 04 - Elucidating the Nature of a 'Starless' Dark Matter Halo Near M94

## Visit

**Proposal 17712, Visit 04, implementation** Tue Oct 08 15:00:40 GMT 2024

**Diagnostic Status: No Diagnostics**

Scientific Instruments: WFC3/UVIS, ACS/WFC

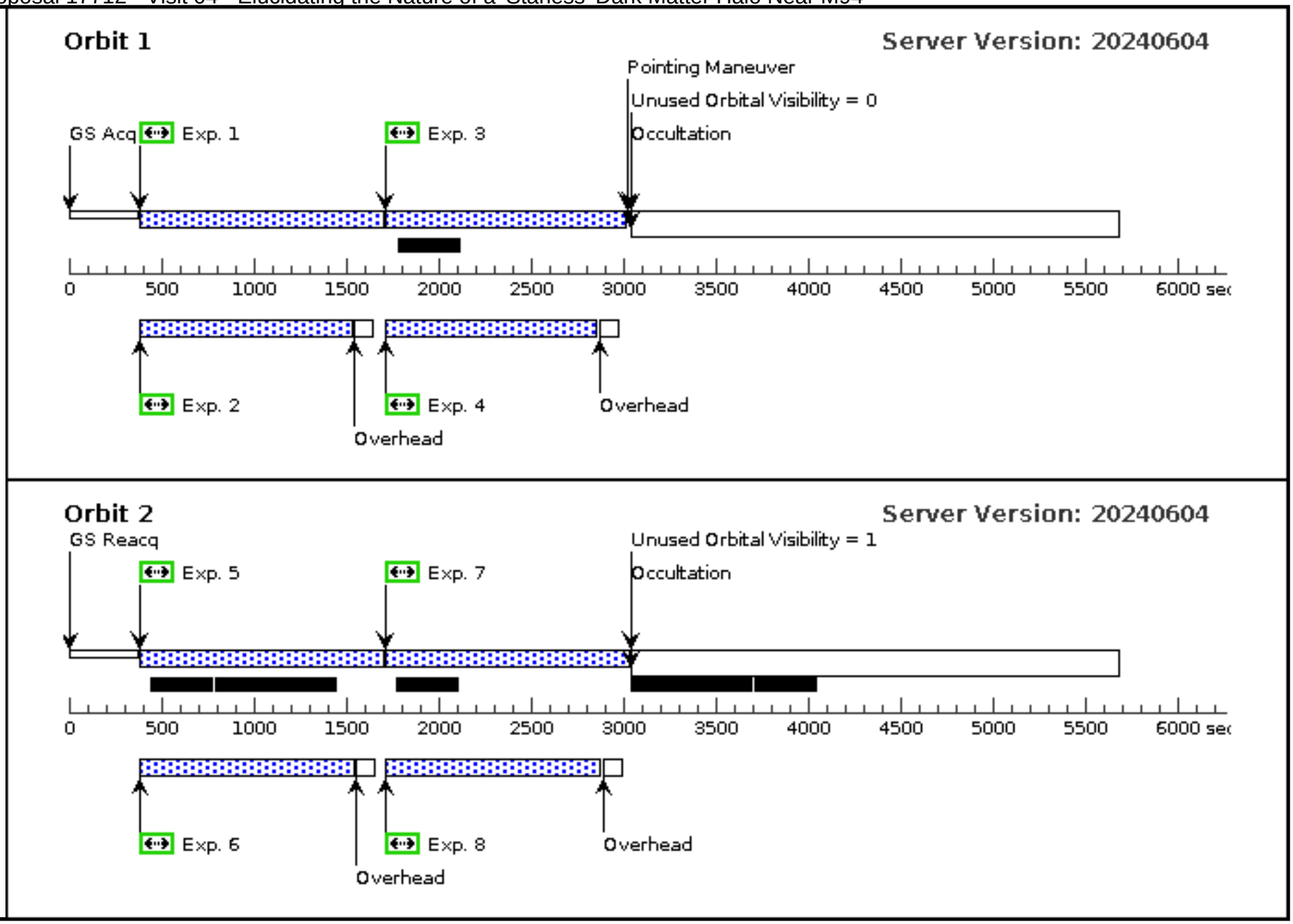
Special Requirements: ORIENT 223D TO 227 D

## Fixed Targets

| # | Name | Target Coordinates | Targ. Coord. Corrections | Fluxes | Miscellaneous |
|---|---|---|---|---|---|
| (1) | M94-CL9 | RA: 12 51 51.3000 (192.9637500d)<br>Dec: +40 18 5.00 (40.30139d)<br>Equinox: J2000 | | V=25 | Reference Frame: ICRS |

*Comments:*
*Category=GALAXY*
*Description=[DWARF COMPACT]*

## Exposures

| # | Label | Target | Config,Mode,Aperture | Spectral Els. | Opt. Params. | Special Reqs. | Groups | Exp. Time (Total)/[Actual Dur.] | Orbit |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | (1) M94-CL9 | ACS/WFC, ACCUM, WFC1-FIX | F606W | | | Prime + Parallel Group 1-2 in Visit 04 | 1118 Secs (1118 Secs)<br>*[==>]* | *[1]* |
| 2 | | ANY | WFC3/UVIS, ACCUM, UVIS | F606W | | | Prime + Parallel Group 1-2 in Visit 04 | 1118 Secs (1118 Secs)<br>*[==>]* | *[1]* |
| 3 | | (1) M94-CL9 | ACS/WFC, ACCUM, WFC1-FIX | F814W | | | Prime + Parallel Group 3-4 in Visit 04 | 1118 Secs (1118 Secs)<br>*[==>]* | *[1]* |
| 4 | | ANY | WFC3/UVIS, ACCUM, UVIS | F814W | | | Prime + Parallel Group 3-4 in Visit 04 | 1118 Secs (1118 Secs)<br>*[==>]* | *[1]* |
| 5 | | (1) M94-CL9 | ACS/WFC, ACCUM, WFC1-FIX | F606W | | POS TARG 0.247,0.267 | Prime + Parallel Group 5-6 in Visit 04 | 1141 Secs (1141 Secs)<br>*[==>]* | *[2]* |
| 6 | | ANY | WFC3/UVIS, ACCUM, UVIS | F606W | | | Prime + Parallel Group 5-6 in Visit 04 | 1141 Secs (1141 Secs)<br>*[==>]* | *[2]* |
| 7 | | (1) M94-CL9 | ACS/WFC, ACCUM, WFC1-FIX | F814W | | SAME POS AS 5 | Prime + Parallel Group 7-8 in Visit 04 | 1141 Secs (1141 Secs)<br>*[==>]* | *[2]* |
| 8 | | ANY | WFC3/UVIS, ACCUM, UVIS | F814W | | | Prime + Parallel Group 7-8 in Visit 04 | 1141 Secs (1141 Secs)<br>*[==>]* | *[2]* |

Orbit Structure