



# 18411 - Proper Motion Constraints on Dark Matter in Dwarf Galaxies: The Extreme Case of Leo I

Cycle: 34, Proposal Category: GO

(Availability Mode: SUPPORTED)

## INVESTIGATORS

| <i>Name</i>                                  | <i>Institution</i>                               |
|----------------------------------------------|--------------------------------------------------|
| <b>Dr. Sangmo Tony Sohn (PI) (Contact)</b>   | <b>Space Telescope Science Institute</b>         |
| Dr. Eduardo Vitral (CoI) (ESA Member)        | University of Edinburgh, Institute for Astronomy |
| Dr. Paul Bennet (CoI)                        | Space Telescope Science Institute                |
| Dr. Roeland P. van der Marel (CoI)           | Space Telescope Science Institute                |
| Dr. Laura L. Watkins (CoI) (ESA Member)      | Space Telescope Science Institute - ESA - JWST   |
| Dr. Ekta Patel (CoI)                         | Villanova University                             |
| Dr. Andrea Bellini (CoI)                     | Space Telescope Science Institute                |
| Dr. Mattia Libralato (CoI) (ESA Member)      | INAF - Osservatorio Astronomico di Padova        |
| Dr. Kevin Andrew McKinnon (CoI) (CSA Member) | University of Toronto                            |
| Dr. Mark Fardal (CoI)                        | Eureka Scientific Inc.                           |

## 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) LEO-I<br>ANY             | ACS/WFC<br>WFC3/UVIS                | 4                  | 29-Jul-2026 16:00:25.0        | yes                           |
| 02           | (1) LEO-I<br>ANY             | ACS/WFC<br>WFC3/UVIS                | 4                  | 29-Jul-2026 16:00:27.0        | yes                           |

8 Total Orbits Used

## **ABSTRACT**

Classical dwarf spheroidal galaxies (dSphs) are premier laboratories for testing dark matter (DM) physics, yet their mass profiles remain limited by the mass-anisotropy degeneracy in line-of-sight velocities. To break this degeneracy, internal proper motions are essential to yield 3D kinematics. We propose a GO-Archival Cycle 34 ACS/WFC program combining new observations with archival 2006 and 2011 epochs to study Leo I's internal kinematics.

Leo I is dynamically extreme, combining three properties that connect the core-cusp debate to orbital archaeology and black-hole demographics. First, its unusual orbit, including a recent first-infall pericenter passage, provides a clean testbed for how environmental factors shape dwarf-galaxy evolution. Second, recent dynamical analyses suggest that Leo I may host one of the highest central DM densities among classical Milky Way dSphs, making it a critical test of Cold Dark Matter cusps versus tidal compression. Third, it lies at the center of a controversy regarding a claimed 3.3 million solar mass central black hole, an extraordinary mass that challenges standard scaling relations.

By matching the footprint of archival HST observations from 2006 and 2011, our new data will extend the baseline to 21 years and deliver the sub-milliarcsecond proper-motion (PM) precision needed to map Leo I's internal 3D velocity dispersion and measure its bulk PM. We will perform dynamical modeling of the inferred kinematics to break the mass-anisotropy degeneracy. This will allow us to determine the origin of Leo I's extreme DM density, constrain the black-hole interpretation, and provide a lasting kinematic legacy for Local Group astrophysics.

## **OBSERVING DESCRIPTION**

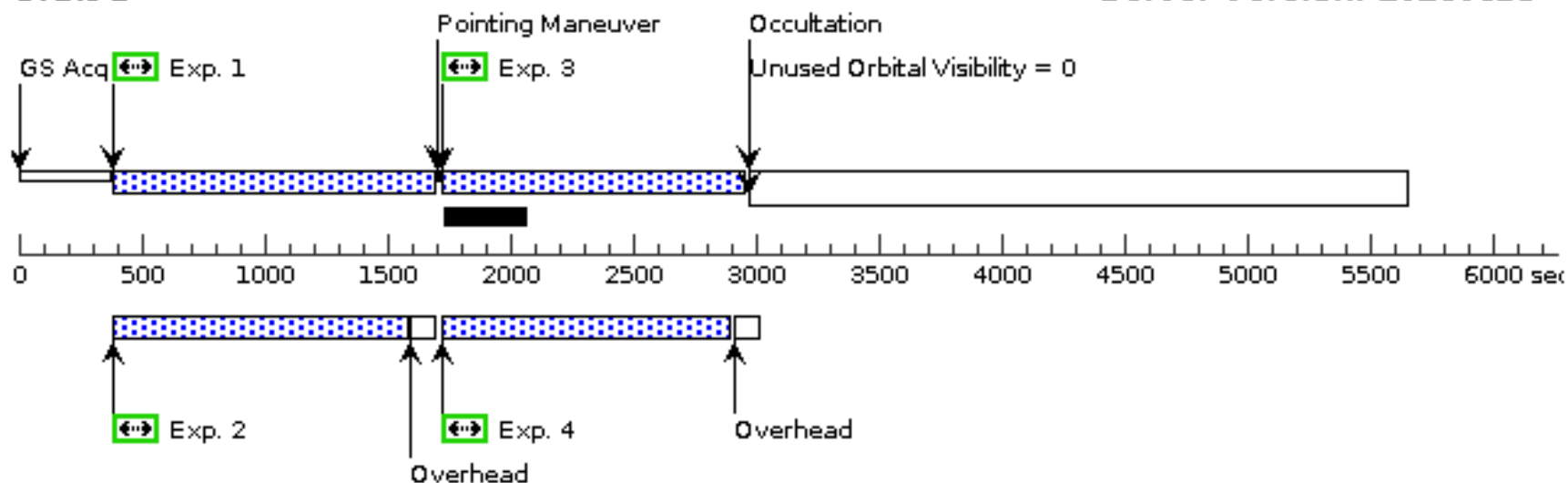
The primary goal of this program is to measure the internal proper motion kinematics of the Leo I dwarf spheroidal galaxy using multi-epoch HST imaging data. We will observe a single primary ACS/WFC field + a single parallel WFC3/UVIS field for 8 orbits with the same telescope pointing and orientation as older epoch observations. The telescope orientation conditions are added as special requirements for each visit to match the filed coverages between the pre-existing data. Individual exposures will be sub-pixel dithered and will last half an orbit.

# Proposal 18411 - Visit 01 - Proper Motion Constraints on Dark Matter in Dwarf Galaxies: The Extreme Case of Leo I

| Visit         | Proposal 18411, Visit 01                                       |       |                                                                                    |                          |               |                       |                            |                                              |                                 |       | Wed Jul 29 20:00:27 GMT 2026 |  |
|---------------|----------------------------------------------------------------|-------|------------------------------------------------------------------------------------|--------------------------|---------------|-----------------------|----------------------------|----------------------------------------------|---------------------------------|-------|------------------------------|--|
|               | Diagnostic Status: No Diagnostics                              |       |                                                                                    |                          |               |                       |                            |                                              |                                 |       |                              |  |
|               | Scientific Instruments: WFC3/UVIS, ACS/WFC                     |       |                                                                                    |                          |               |                       |                            |                                              |                                 |       |                              |  |
|               | Special Requirements: ORIENT 315D TO 315 D                     |       |                                                                                    |                          |               |                       |                            |                                              |                                 |       |                              |  |
| Fixed Targets | #                                                              | Name  | Target Coordinates                                                                 | Targ. Coord. Corrections | Fluxes        | Miscellaneous         |                            |                                              |                                 |       |                              |  |
|               | (1)                                                            | LEO-I | RA: 10 08 22.5000 (152.0937500d)<br>Dec: +12 18 5.90 (12.30164d)<br>Equinox: J2000 |                          | V=12          | Reference Frame: ICRS |                            |                                              |                                 |       |                              |  |
|               | Comments:<br>Category=GALAXY<br>Description=[DWARF SPHEROIDAL] |       |                                                                                    |                          |               |                       |                            |                                              |                                 |       |                              |  |
| Exposures     | #                                                              | Label | Target                                                                             | Config,Mode,Aperture     | Spectral Els. | Opt. Params.          | Special Reqs.              | Groups                                       | Exp. Time (Total)/[Actual Dur.] | Orbit |                              |  |
|               | 1                                                              |       | (1) LEO-I                                                                          | ACS/WFC, ACCUM, WFCENTER | F814W         |                       |                            | Prime + Parallel Gro<br>up 1-2 in Visit 01   | 1108 Secs (1108 Secs)<br>[==>]  | [1]   |                              |  |
|               | 2                                                              |       | ANY                                                                                | WFC3/UVIS, ACCUM, UVIS   | F814W         |                       |                            | Prime + Parallel Gro<br>up 1-2 in Visit 01   | 1170 Secs (1170 Secs)<br>[==>]  | [1]   |                              |  |
|               | 3                                                              |       | (1) LEO-I                                                                          | ACS/WFC, ACCUM, WFCENTER | F814W         |                       | POS TARG 0.2228,0<br>.1158 | Prime + Parallel Gro<br>up 3-4 in Visit 01   | 1108 Secs (1108 Secs)<br>[==>]  | [1]   |                              |  |
|               | 4                                                              |       | ANY                                                                                | WFC3/UVIS, ACCUM, UVIS   | F814W         |                       |                            | Prime + Parallel Gro<br>up 3-4 in Visit 01   | 1170 Secs (1170 Secs)<br>[==>]  | [1]   |                              |  |
|               | 5                                                              |       | (1) LEO-I                                                                          | ACS/WFC, ACCUM, WFCENTER | F814W         |                       | POS TARG 0.0998,0<br>.2303 | Prime + Parallel Gro<br>up 5-6 in Visit 01   | 1108 Secs (1108 Secs)<br>[==>]  | [2]   |                              |  |
|               | 6                                                              |       | ANY                                                                                | WFC3/UVIS, ACCUM, UVIS   | F814W         |                       |                            | Prime + Parallel Gro<br>up 5-6 in Visit 01   | 1170 Secs (1170 Secs)<br>[==>]  | [2]   |                              |  |
|               | 7                                                              |       | (1) LEO-I                                                                          | ACS/WFC, ACCUM, WFCENTER | F814W         |                       | POS TARG 0.3225,0<br>.3460 | Prime + Parallel Gro<br>up 7-8 in Visit 01   | 1108 Secs (1108 Secs)<br>[==>]  | [2]   |                              |  |
|               | 8                                                              |       | ANY                                                                                | WFC3/UVIS, ACCUM, UVIS   | F814W         |                       |                            | Prime + Parallel Gro<br>up 7-8 in Visit 01   | 1170 Secs (1170 Secs)<br>[==>]  | [2]   |                              |  |
|               | 9                                                              |       | (1) LEO-I                                                                          | ACS/WFC, ACCUM, WFCENTER | F814W         |                       | POS TARG 0.4075,0<br>.0306 | Prime + Parallel Gro<br>up 9-10 in Visit 01  | 1108 Secs (1108 Secs)<br>[==>]  | [3]   |                              |  |
|               | 10                                                             |       | ANY                                                                                | WFC3/UVIS, ACCUM, UVIS   | F814W         |                       |                            | Prime + Parallel Gro<br>up 9-10 in Visit 01  | 1170 Secs (1170 Secs)<br>[==>]  | [3]   |                              |  |
|               | 11                                                             |       | (1) LEO-I                                                                          | ACS/WFC, ACCUM, WFCENTER | F814W         |                       | POS TARG 0.6304,0<br>.1464 | Prime + Parallel Gro<br>up 11-12 in Visit 01 | 1108 Secs (1108 Secs)<br>[==>]  | [3]   |                              |  |
|               | 12                                                             |       | ANY                                                                                | WFC3/UVIS, ACCUM, UVIS   | F814W         |                       |                            | Prime + Parallel Gro<br>up 11-12 in Visit 01 | 1170 Secs (1170 Secs)<br>[==>]  | [3]   |                              |  |
|               | 13                                                             |       | (1) LEO-I                                                                          | ACS/WFC, ACCUM, WFCENTER | F814W         |                       | POS TARG 0.5073,0<br>.2609 | Prime + Parallel Gro<br>up 13-14 in Visit 01 | 1108 Secs (1108 Secs)<br>[==>]  | [4]   |                              |  |
|               | 14                                                             |       | ANY                                                                                | WFC3/UVIS, ACCUM, UVIS   | F814W         |                       |                            | Prime + Parallel Gro<br>up 13-14 in Visit 01 | 1170 Secs (1170 Secs)<br>[==>]  | [4]   |                              |  |
|               | 15                                                             |       | (1) LEO-I                                                                          | ACS/WFC, ACCUM, WFCENTER | F814W         |                       | POS TARG 0.7302,0<br>.3767 | Prime + Parallel Gro<br>up 15-16 in Visit 01 | 1108 Secs (1108 Secs)<br>[==>]  | [4]   |                              |  |
|               | 16                                                             |       | ANY                                                                                | WFC3/UVIS, ACCUM, UVIS   | F814W         |                       |                            | Prime + Parallel Gro<br>up 15-16 in Visit 01 | 1170 Secs (1170 Secs)<br>[==>]  | [4]   |                              |  |

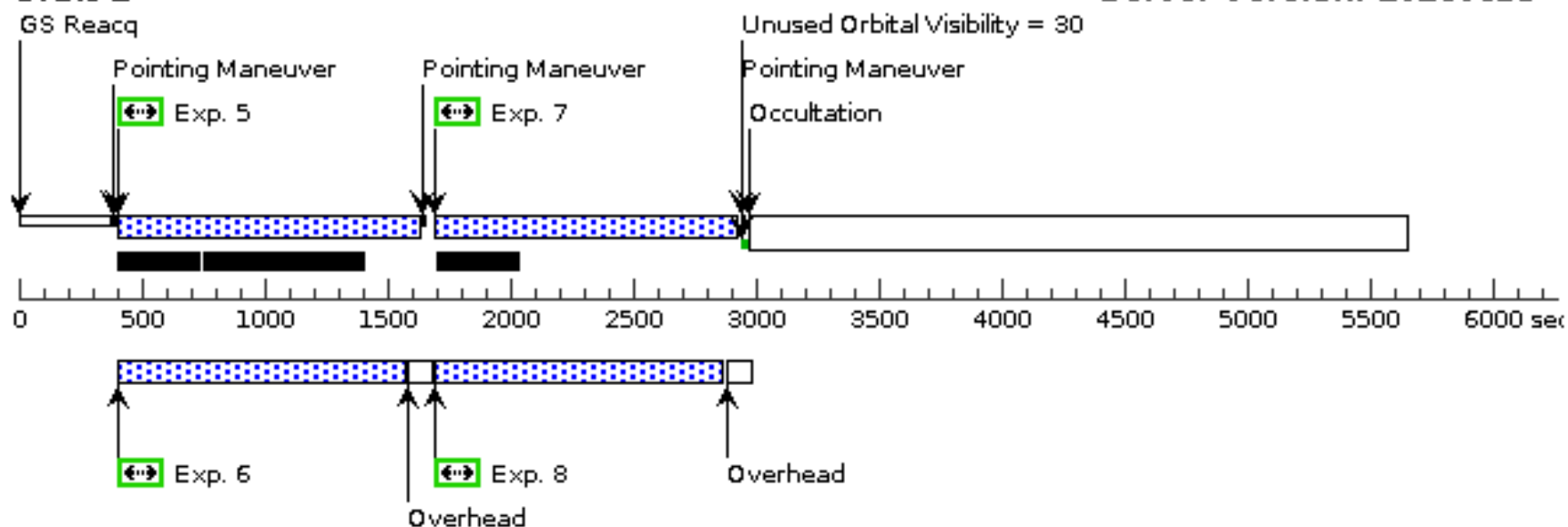
### Orbit 1

Server Version: 20260618



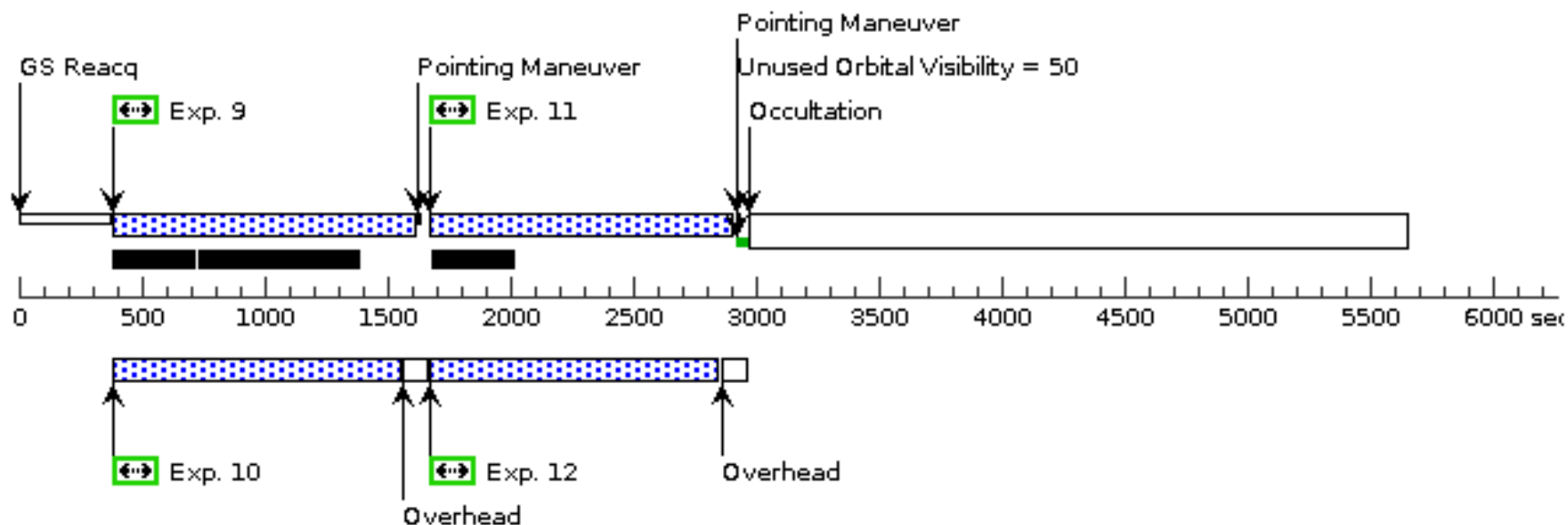
### Orbit 2

Server Version: 20260618



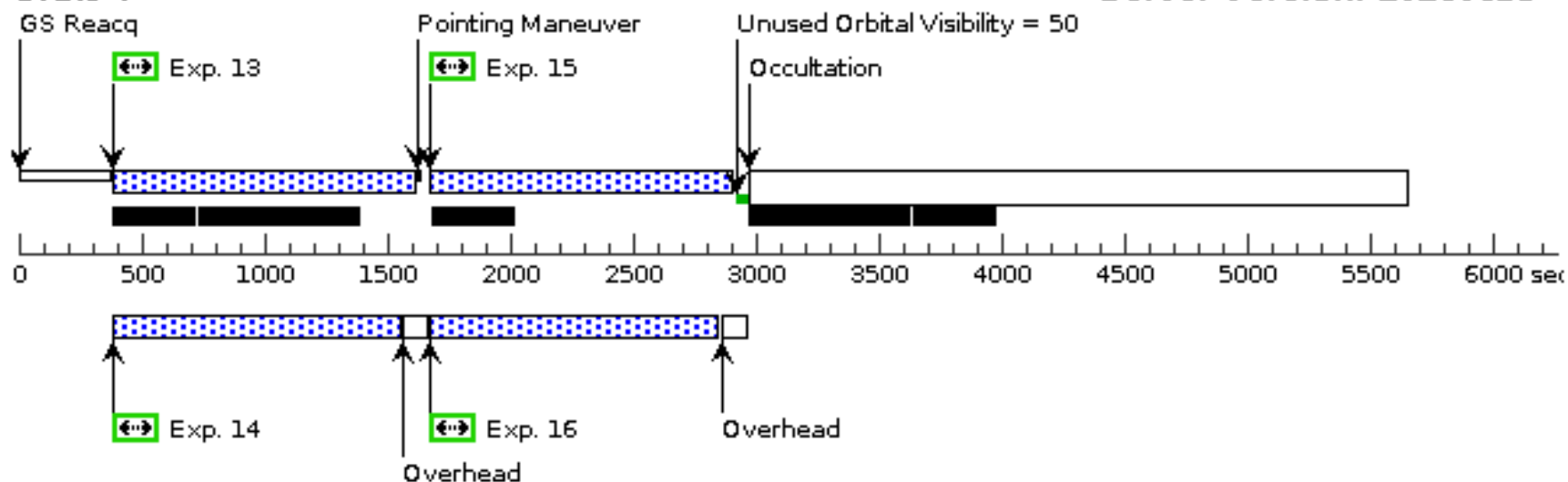
### Orbit 3

Server Version: 20260618



### Orbit 4

Server Version: 20260618

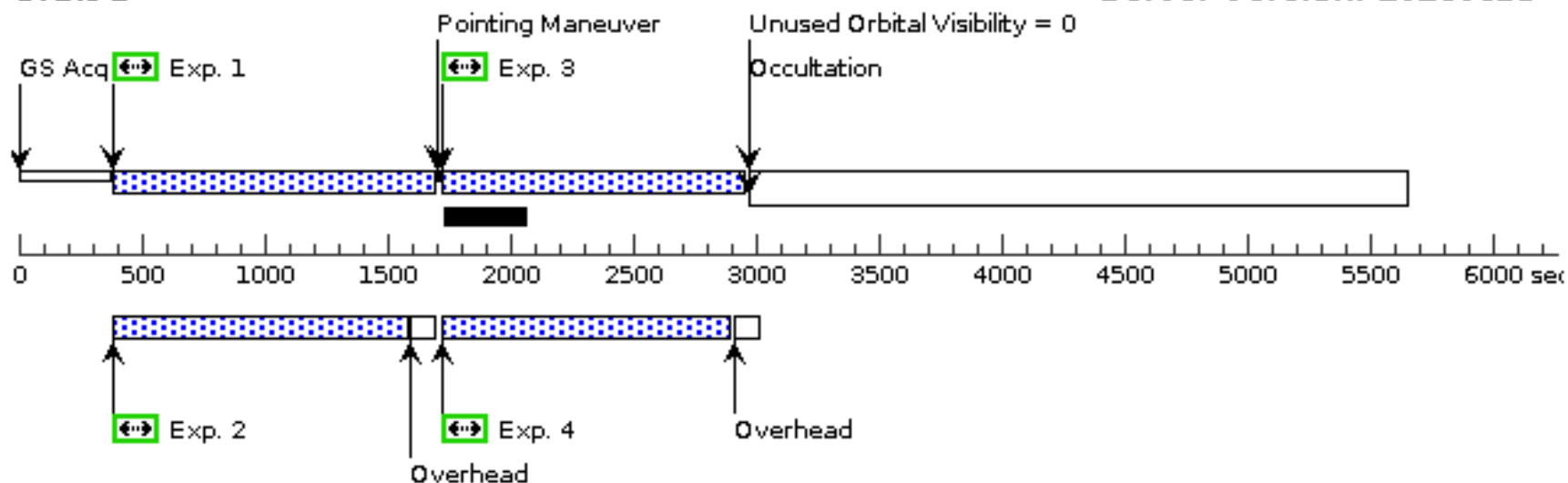


# Proposal 18411 - Visit 02 - Proper Motion Constraints on Dark Matter in Dwarf Galaxies: The Extreme Case of Leo I

| Visit         | Proposal 18411, Visit 02                                       |           |                                                                                    |                          |                          |                         |                                          |                                         |                                 |     | Wed Jul 29 20:00:27 GMT 2026 |  |
|---------------|----------------------------------------------------------------|-----------|------------------------------------------------------------------------------------|--------------------------|--------------------------|-------------------------|------------------------------------------|-----------------------------------------|---------------------------------|-----|------------------------------|--|
|               | Diagnostic Status: No Diagnostics                              |           |                                                                                    |                          |                          |                         |                                          |                                         |                                 |     |                              |  |
|               | Scientific Instruments: WFC3/UVIS, ACS/WFC                     |           |                                                                                    |                          |                          |                         |                                          |                                         |                                 |     |                              |  |
|               | Special Requirements: ORIENT 315D TO 315 D                     |           |                                                                                    |                          |                          |                         |                                          |                                         |                                 |     |                              |  |
| Fixed Targets | #                                                              | Name      | Target Coordinates                                                                 |                          | Targ. Coord. Corrections |                         | Fluxes                                   |                                         | Miscellaneous                   |     |                              |  |
|               | (1)                                                            | LEO-I     | RA: 10 08 22.5000 (152.0937500d)<br>Dec: +12 18 5.90 (12.30164d)<br>Equinox: J2000 |                          |                          |                         | V=12                                     |                                         | Reference Frame: ICRS           |     |                              |  |
|               | Comments:<br>Category=GALAXY<br>Description=[DWARF SPHEROIDAL] |           |                                                                                    |                          |                          |                         |                                          |                                         |                                 |     |                              |  |
| Exposures     | #                                                              | Label     | Target                                                                             | Config,Mode,Aperture     | Spectral Els.            | Opt. Params.            | Special Reqs.                            | Groups                                  | Exp. Time (Total)/[Actual Dur.] |     | Orbit                        |  |
|               | 1                                                              |           | (1) LEO-I                                                                          | ACS/WFC, ACCUM, WFCENTER | F814W                    |                         | POS TARG 0.0018,0 .4085                  | Prime + Parallel Group 1-2 in Visit 02  | 1108 Secs (1108 Secs)           |     |                              |  |
|               |                                                                |           |                                                                                    |                          |                          |                         |                                          |                                         | [==>]                           |     | [1]                          |  |
|               | 2                                                              |           | ANY                                                                                | WFC3/UVIS, ACCUM, UVIS   | F814W                    |                         |                                          | Prime + Parallel Group 1-2 in Visit 02  | 1170 Secs (1170 Secs)           |     |                              |  |
|               |                                                                |           |                                                                                    |                          |                          |                         |                                          |                                         | [==>]                           |     | [1]                          |  |
|               | 3                                                              |           | (1) LEO-I                                                                          | ACS/WFC, ACCUM, WFCENTER | F814W                    |                         | POS TARG 0.2246,0 .5243                  | Prime + Parallel Group 3-4 in Visit 02  | 1108 Secs (1108 Secs)           |     |                              |  |
|               |                                                                |           |                                                                                    |                          |                          |                         |                                          |                                         | [==>]                           |     | [1]                          |  |
|               | 4                                                              |           | ANY                                                                                | WFC3/UVIS, ACCUM, UVIS   | F814W                    |                         |                                          | Prime + Parallel Group 3-4 in Visit 02  | 1170 Secs (1170 Secs)           |     |                              |  |
|               |                                                                |           |                                                                                    |                          |                          |                         |                                          |                                         | [==>]                           |     | [1]                          |  |
|               | 5                                                              |           | (1) LEO-I                                                                          | ACS/WFC, ACCUM, WFCENTER | F814W                    |                         | POS TARG 0.1017,0 .6388                  | Prime + Parallel Group 5-6 in Visit 02  | 1108 Secs (1108 Secs)           |     |                              |  |
|               |                                                                |           |                                                                                    |                          |                          |                         |                                          |                                         | [==>]                           |     | [2]                          |  |
|               | 6                                                              |           | ANY                                                                                | WFC3/UVIS, ACCUM, UVIS   | F814W                    |                         |                                          | Prime + Parallel Group 5-6 in Visit 02  | 1170 Secs (1170 Secs)           |     |                              |  |
|               |                                                                |           |                                                                                    |                          |                          |                         |                                          |                                         | [==>]                           |     | [2]                          |  |
|               | 7                                                              |           | (1) LEO-I                                                                          | ACS/WFC, ACCUM, WFCENTER | F814W                    |                         | POS TARG 0.3244,0 .7545                  | Prime + Parallel Group 7-8 in Visit 02  | 1108 Secs (1108 Secs)           |     |                              |  |
|               |                                                                |           |                                                                                    |                          |                          |                         |                                          |                                         | [==>]                           |     | [2]                          |  |
|               | 8                                                              |           | ANY                                                                                | WFC3/UVIS, ACCUM, UVIS   | F814W                    |                         |                                          | Prime + Parallel Group 7-8 in Visit 02  | 1170 Secs (1170 Secs)           |     |                              |  |
|               |                                                                |           |                                                                                    |                          |                          |                         |                                          |                                         | [==>]                           |     | [2]                          |  |
|               | 9                                                              |           | (1) LEO-I                                                                          | ACS/WFC, ACCUM, WFCENTER | F814W                    |                         | POS TARG 0.4093,0 .4392                  | Prime + Parallel Group 9-10 in Visit 02 | 1108 Secs (1108 Secs)           |     |                              |  |
|               |                                                                |           |                                                                                    |                          |                          |                         |                                          |                                         | [==>]                           |     | [3]                          |  |
|               | 10                                                             |           | ANY                                                                                | WFC3/UVIS, ACCUM, UVIS   | F814W                    |                         |                                          | Prime + Parallel Group 9-10 in Visit 02 | 1170 Secs (1170 Secs)           |     |                              |  |
|               |                                                                |           |                                                                                    |                          |                          |                         |                                          | [==>]                                   |                                 | [3] |                              |  |
| 11            |                                                                | (1) LEO-I | ACS/WFC, ACCUM, WFCENTER                                                           | F814W                    |                          | POS TARG 0.6322,0 .5550 | Prime + Parallel Group 11-12 in Visit 02 | 1108 Secs (1108 Secs)                   |                                 |     |                              |  |
|               |                                                                |           |                                                                                    |                          |                          |                         |                                          | [==>]                                   |                                 | [3] |                              |  |
| 12            |                                                                | ANY       | WFC3/UVIS, ACCUM, UVIS                                                             | F814W                    |                          |                         | Prime + Parallel Group 11-12 in Visit 02 | 1170 Secs (1170 Secs)                   |                                 |     |                              |  |
|               |                                                                |           |                                                                                    |                          |                          |                         |                                          | [==>]                                   |                                 | [3] |                              |  |
| 13            |                                                                | (1) LEO-I | ACS/WFC, ACCUM, WFCENTER                                                           | F814W                    |                          | POS TARG 0.5091,0 .6695 | Prime + Parallel Group 13-14 in Visit 02 | 1108 Secs (1108 Secs)                   |                                 |     |                              |  |
|               |                                                                |           |                                                                                    |                          |                          |                         |                                          | [==>]                                   |                                 | [4] |                              |  |
| 14            |                                                                | ANY       | WFC3/UVIS, ACCUM, UVIS                                                             | F814W                    |                          |                         | Prime + Parallel Group 13-14 in Visit 02 | 1170 Secs (1170 Secs)                   |                                 |     |                              |  |
|               |                                                                |           |                                                                                    |                          |                          |                         |                                          | [==>]                                   |                                 | [4] |                              |  |
| 15            |                                                                | (1) LEO-I | ACS/WFC, ACCUM, WFCENTER                                                           | F814W                    |                          | POS TARG 0.7320,0 .7852 | Prime + Parallel Group 15-16 in Visit 02 | 1108 Secs (1108 Secs)                   |                                 |     |                              |  |
|               |                                                                |           |                                                                                    |                          |                          |                         |                                          | [==>]                                   |                                 | [4] |                              |  |
| 16            |                                                                | ANY       | WFC3/UVIS, ACCUM, UVIS                                                             | F814W                    |                          |                         | Prime + Parallel Group 15-16 in Visit 02 | 1170 Secs (1170 Secs)                   |                                 |     |                              |  |
|               |                                                                |           |                                                                                    |                          |                          |                         |                                          | [==>]                                   |                                 | [4] |                              |  |

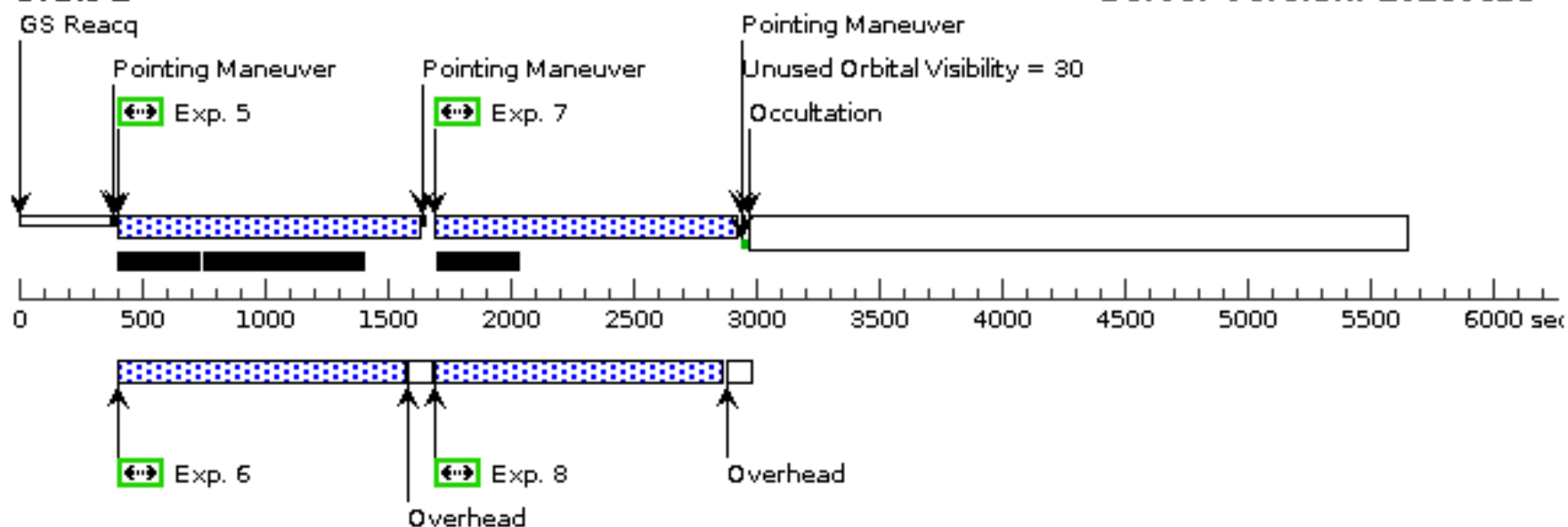
### Orbit 1

Server Version: 20260618



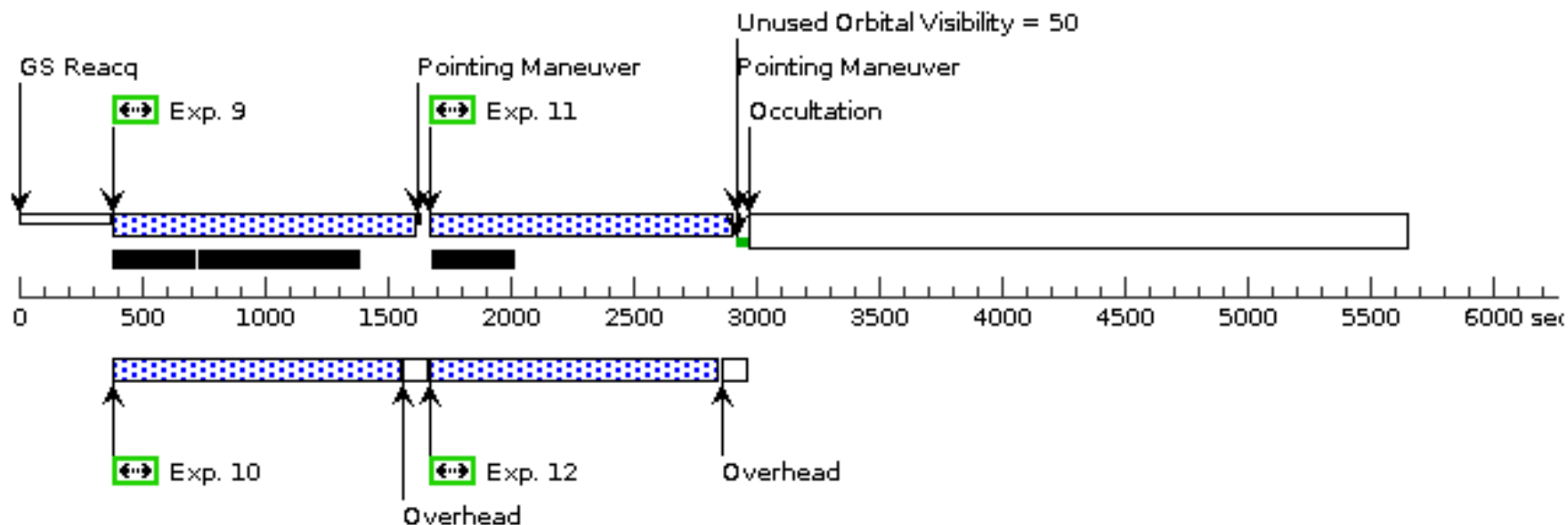
### Orbit 2

Server Version: 20260618



### Orbit 3

Server Version: 20260618



### Orbit 4

Server Version: 20260618

