18019 - Gravitational lensing by a luminous satellite: a test of dark matter and galaxy formation models

Cycle: 33, Proposal Category: GO

(Availability Mode: SUPPORTED)

INVESTIGATORS

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VISITS

Visit	*Targets used in Visit*	*Configurations used in Visit*	*Orbits Used*	*Last Orbit Planner Run*	*OP Current with Visit?*
01	(1) J0040+2555	WFC3/IR WFC3/UVIS	2	14-Aug-2025 13:00:32.0	yes

2 Total Orbits Used

ABSTRACT

Strong gravitational lensing enables precise measurements of galaxy mass distributions, including both dark matter and baryonic components. In some systems, small satellites perturb the lensed arcs, allowing us to measure their masses independently. Recent lensing detections of low-mass satellites show anomalously high concentrations, inconsistent with predictions from the Cold Dark Matter (CDM) model. These outliers cannot be explained by baryonic effects alone, as simulations that reproduce the observed densities require stellar masses exceeding luminosity constraints.

This tension motivates the exploration of alternative dark matter models such as Self-Interacting Dark Matter (SIDM), which can alter central densities through particle interactions.

To test these scenarios, we propose deep HST observations of a newly discovered lens system with a luminous satellite visibly perturbing the arc. This rare configuration allows us to disentangle stellar and dark components of the satellite, measuring its mass, light, and dark matter density profile. Preliminary Keck-AO modeling indicates a steep satellite mass profile (gamma~2), deviating from NFW expectations. Multi-band HST imaging will enable accurate stellar mass and luminosity estimates for both the lens and satellite, allowing us to precisely constrain the density profile. These data are critical to determine whether the high concentrations observed are a general feature of lensing satellites or indicate new dark matter physics. This system, part of a growing sample our team is compiling, offers a timely and high-impact opportunity to address fundamental questions about dark matter on galactic scales.

OBSERVING DESCRIPTION

We propose to observe the system J0040+2555 with HST to complement the existing Keck AO data and add this system to the sample built on AGEL data. The K$^\prime$ band Keck data (2.1 μm) were obtained with the imager of the OSIRIS instrument, as a set of 8 dithered images for a total exposure time of 1440 seconds. This led to a peak signal-to-noise ratio of $\sim$50 for the luminous satellite. As mentioned above, the AO data were not photometric and do not provide the luminosities or stellar masses of the lens and satellite. However, based on our previous comparisons of AO and HST data, we can estimate the HST exposure times required for our science. We propose the following observations:

- one orbit in the F140W filter, which is close to Keck K$^\prime$ and thus should yield a similar morphology. Moreover, this is the same filter used for the available AGEL observations, allowing us to directly compare the systems. Given the low redshift of the lensing galaxy, we expect it to have a relatively smooth red continuum, bright in this filter. From this observation, we will calculate the luminosity and stellar mass of the lens and perturber, in addition to modelling the arc.
- one orbit in the F606W filter. Given the redshift of the source galaxy (z=0.4), we expect to see bright emission from the arc also in this band and the emergence of additional detail in the surface brightness distribution. It could also reveal additional angular structure in the lens galaxy to explain the multipoles required to correctly model this system and reconstruct the source.
- We will split each orbit into 4 exposures and use standard dithering patterns to improve PSF reconstruction and cosmic-ray rejection.

Proposal 18019 - Visit 01 - Gravitational lensing by a luminous satellite: a test of dark matter and galaxy formation models

Visit

Proposal 18019, Visit 01, implementation Thu Aug 14 17:00:32 GMT 2025

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/IR, WFC3/UVIS

Special Requirements: ORIENT 185D TO 255 D; ORIENT 5D TO 75 D

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=WFC3-UVIS-DITHER-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.173 Line Spacing=0.112	Coordinate Frame=POS-TARG Pattern Orientation=23.884 Angle Between Sides=81.785 Center Pattern=false		(1)
(2)	Pattern Type=WFC3-IR-DITHER-BOX-MIN Purpose=DITHER Number Of Points=4 Point Spacing=1.716 Line Spacing=1.095	Coordinate Frame=POS-TARG Pattern Orientation=18.528 Angle Between Sides=74.653 Center Pattern=false		(2)

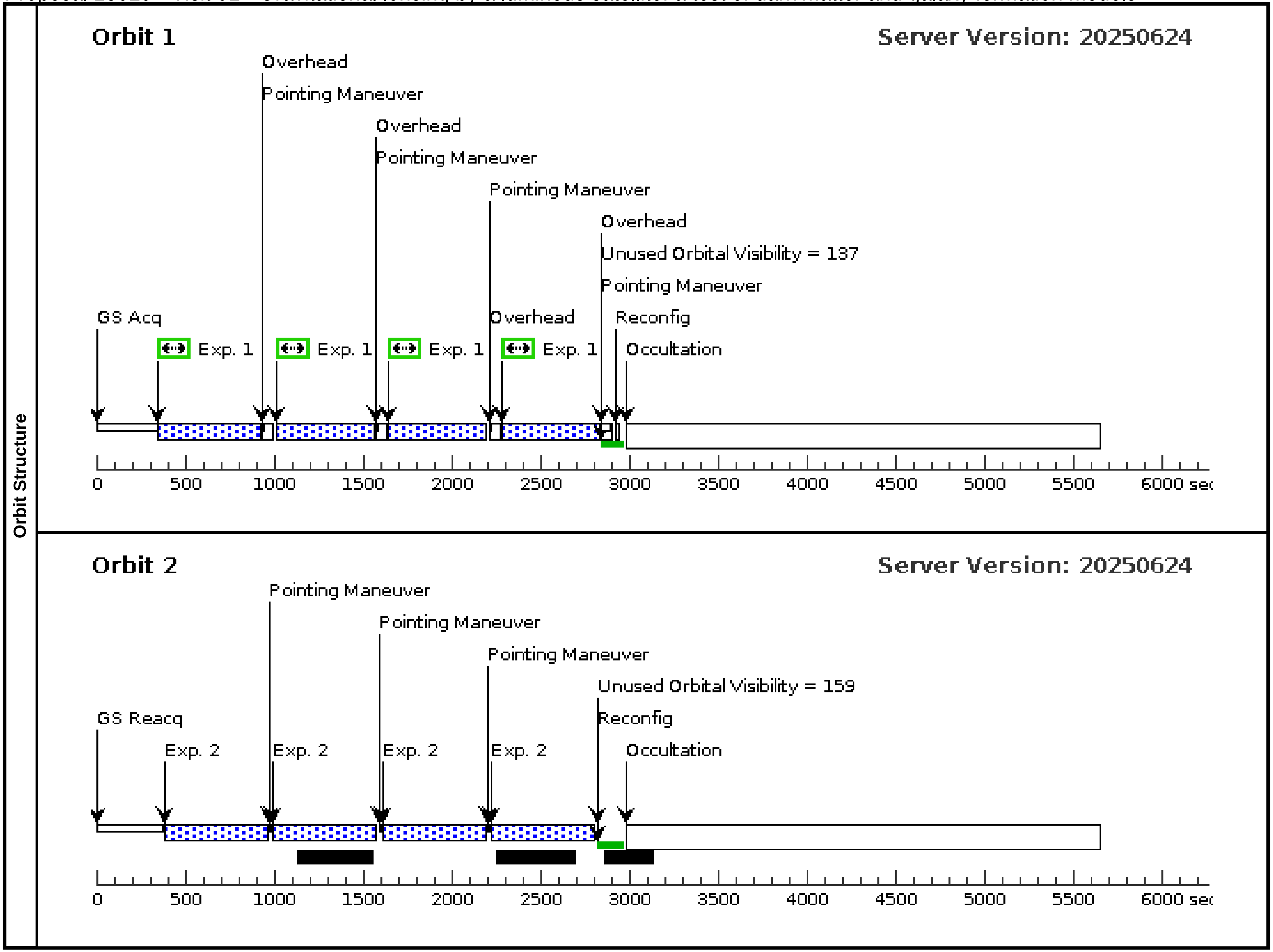
Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	J0040+2555	RA: 00 40 18.2600 (10.0760833d) Dec: +25 55 35.88 (25.92663d) Equinox: J2000	Redshift: 0.143	V=19	Reference Frame: ICRS

Comments:
Category=GALAXY
Description=[EINSTEIN RING, GRAVITATIONAL LENS]
Extended=YES

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1		(1) J0040+2555	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F606W			Pattern 1, Exps 1-1 in Visit 01 (1)	550 Secs (2200 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]* *[==>(Pattern 3)]* *[==>(Pattern 4)]*	***[1]***
2		(1) J0040+2555	WFC3/IR, MULTIACCUM, IR	F140W	NSAMP=12; SAMP-SEQ=SPARS50		Pattern 2, Exps 2-2 in Visit 01 (2)	552.937252 Secs (2211.749 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]* *[==>(Pattern 3)]* *[==>(Pattern 4)]*	***[2]***


Orbit Structure
Orbit 1
Server Version: 20250624
Overhead
Pointing Maneuver
Overhead
Pointing Maneuver
Pointing Maneuver
Overhead
Unused Orbital Visibility = 137
Pointing Maneuver
GS Acq
Overhead
Reconfig
Exp. 1
Exp. 1
Exp. 1
Exp. 1
Occultation
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000 sec
Orbit 2
Server Version: 20250624
Pointing Maneuver
Pointing Maneuver
Pointing Maneuver
Unused Orbital Visibility = 159
GS Reacq
Reconfig
Exp. 2
Exp. 2
Exp. 2
Exp. 2
Occultation
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000 sec