Exploring Our Solar System's Minor Body Populations with Roman

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The Roman Revolution

Despite not being required to support moving target tracking, the Nancy Grace Roman Space Telescope is still more than capable of revolutionizing the study of the minor body and irregular satellite populations within our own solar system. The large field-of-view and sensitivity of the Wide Field Instrument (WFI) will enable deeper, more efficient imaging than any previous survey, revealing smaller and more distant minor bodies.

Astrophysics > Earth and Planetary Astrophysics

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Solar system science with the Wide-Field InfraRed Survey Telescope (WFIRST)

B.J. Holler, S.N. Milam, J.M. Bauer, C. Alcock, M.T. Bannister, G.L. Bjoraker, D. Bodewits, A.S. Bosh, M.W. Buie, T.L. Farnham, N. Haghighipour, P.S. Hardersen, A.W. Harris, C.M. Hirata, H.H. Hsieh, M.S.P. Kelley, M.M. Knight, E.A. Kramer, A. Longobardo, C.A. Nixon, E. Palomba, S. Protopapa, L.C. Quick, D. Ragozzine, V. Reddy, J.D. Rhodes, A.S. Rivkin, G. Sarid, A.A. Sickafoose, A.A. Simon, C.A. Thomas, D.E. Trilling, R.A. West

We present a community-led assessment of the solar system investigations achievable with NASA's next-generation space telescope, the Wide Field InfraRed Survey Telescope (WFIRST). WFIRST will provide imaging, spectroscopic, and coronagraphic capabilities from 0.43-2.0 μm and will be a potential contemporary and eventual successor to JWST. Surveys of irregular satellites and minor bodies are where WFIRST will excel with its 0.28 deg^2 field of view Wide Field Instrument (WFI). Potential ground-breaking discoveries from WFIRST could include detection of the first minor bodies orbiting in the Inner Oort Cloud, identification of additional Earth Trojan asteroids, and the discovery and characterization of asteroid binary systems similar to Ida/Dactyl. Additional investigations into asteroids, giant planet satellites, Trojan asteroids, Centaurs, Kuiper Belt Objects, and comets are presented. Previous use of astrophysics assets for solar system science and synergies between WFIRST, LSST, JWST, and the proposed NEOCam mission are discussed. We also present the case for implementation of moving target tracking, a feature that will benefit from the heritage of JWST and enable a broader range of solar system observations.

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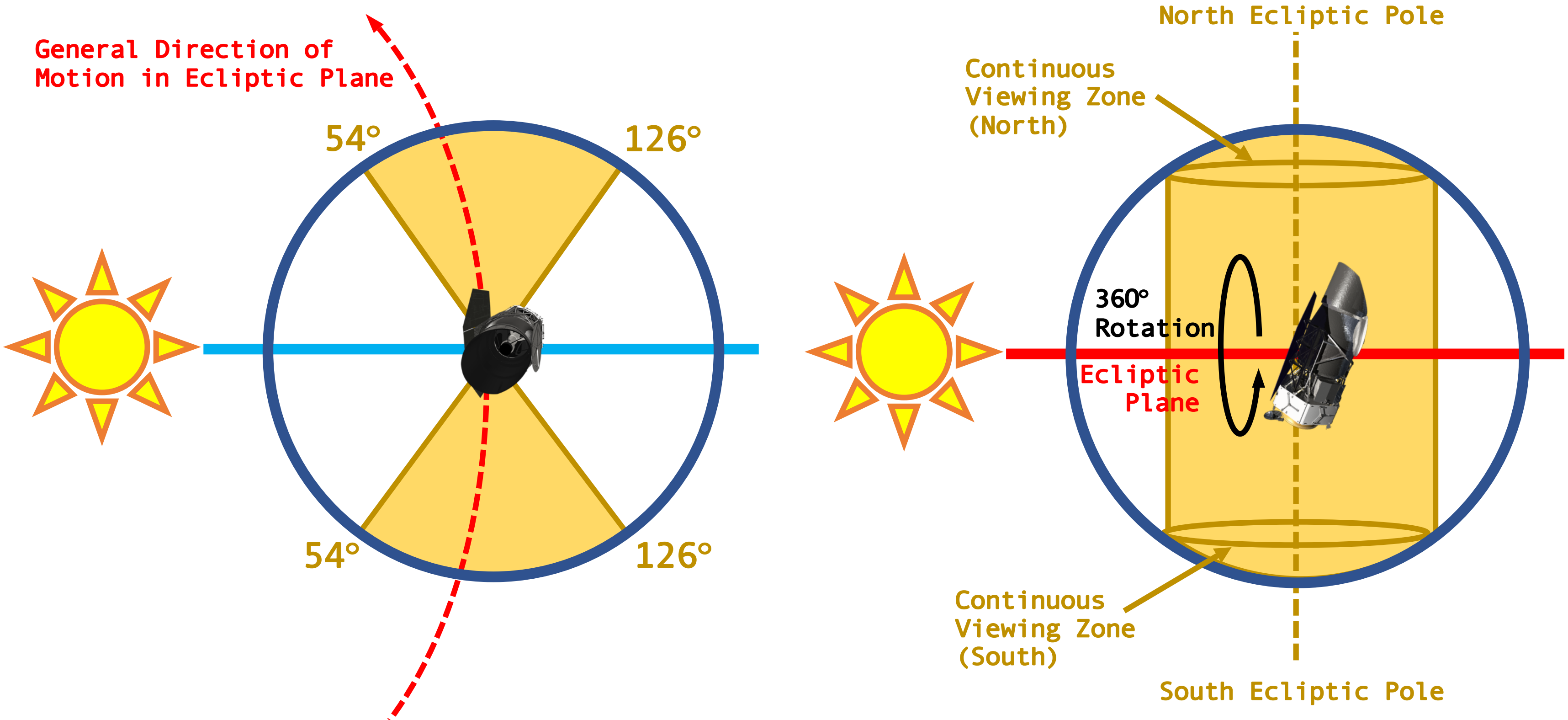
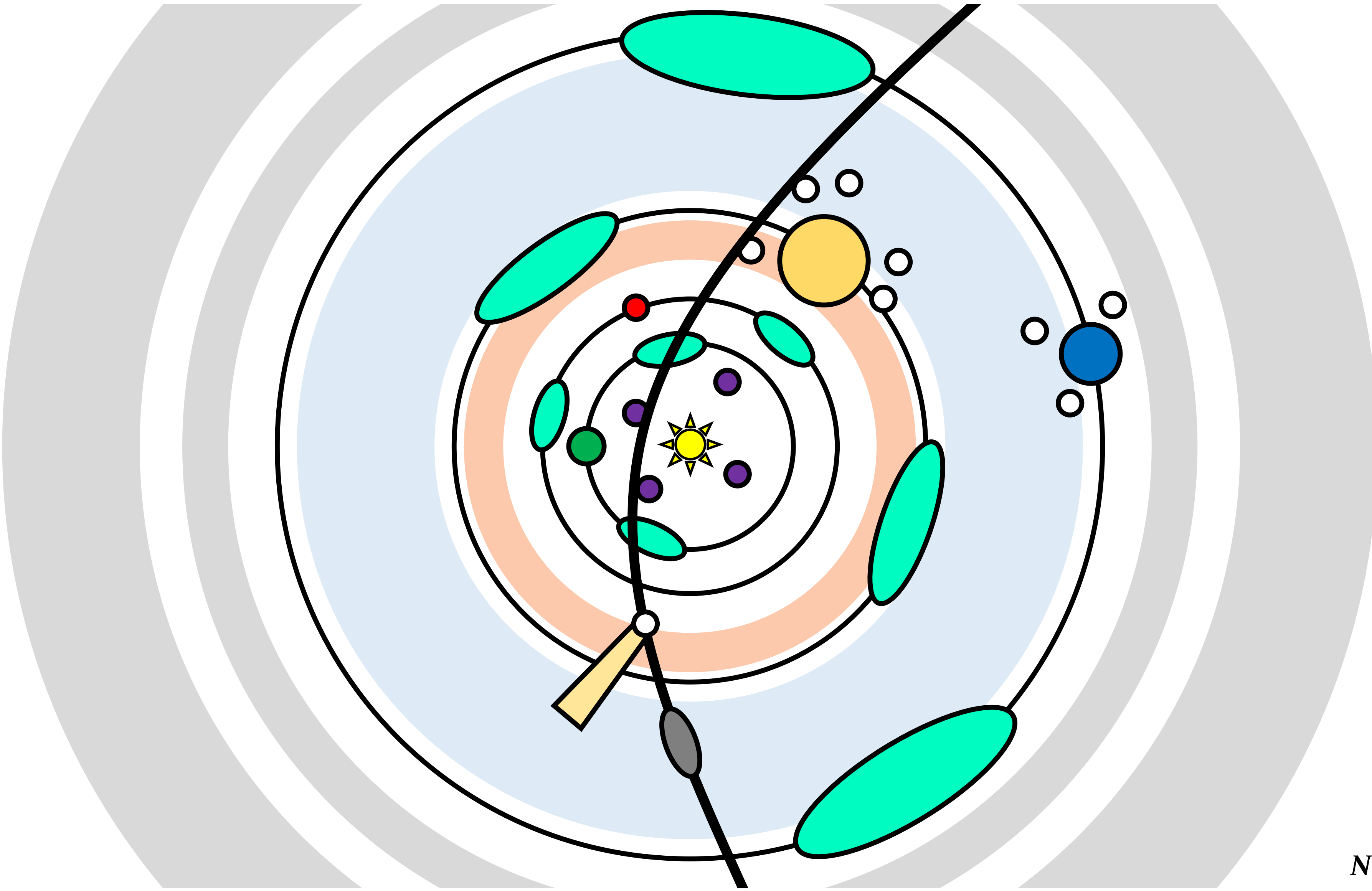
(or arXiv:1709.02763v3 **[astro-ph.EP]** for this version)

https://arxiv.org/abs/1709.02763

Field of regard (FOR)



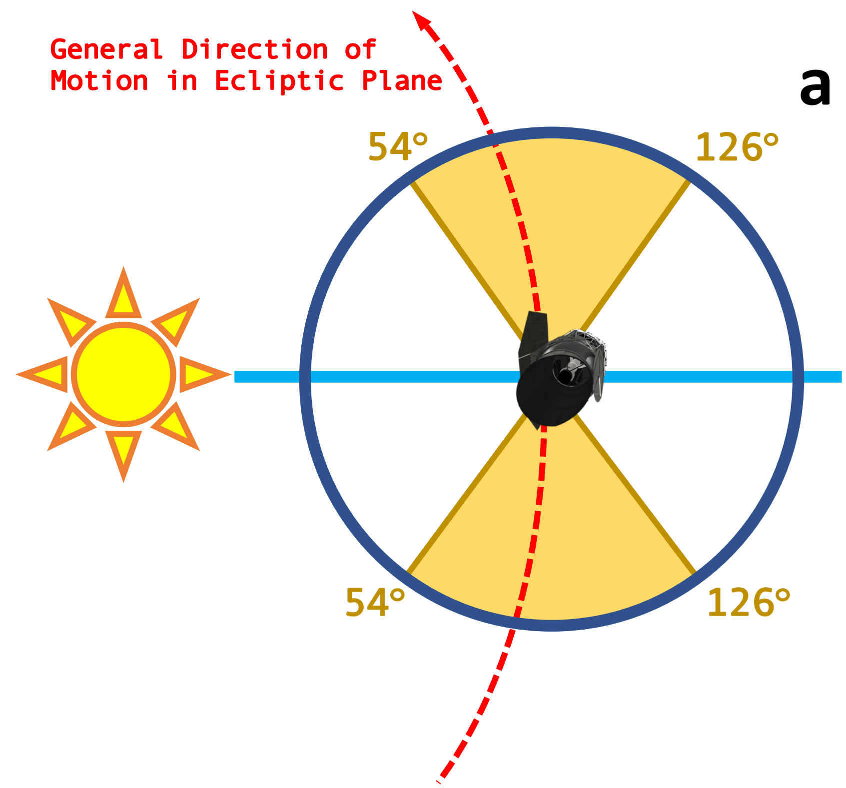
Holler et al. (2018); spacecraft images from NASA/GSFC



Not to scale!

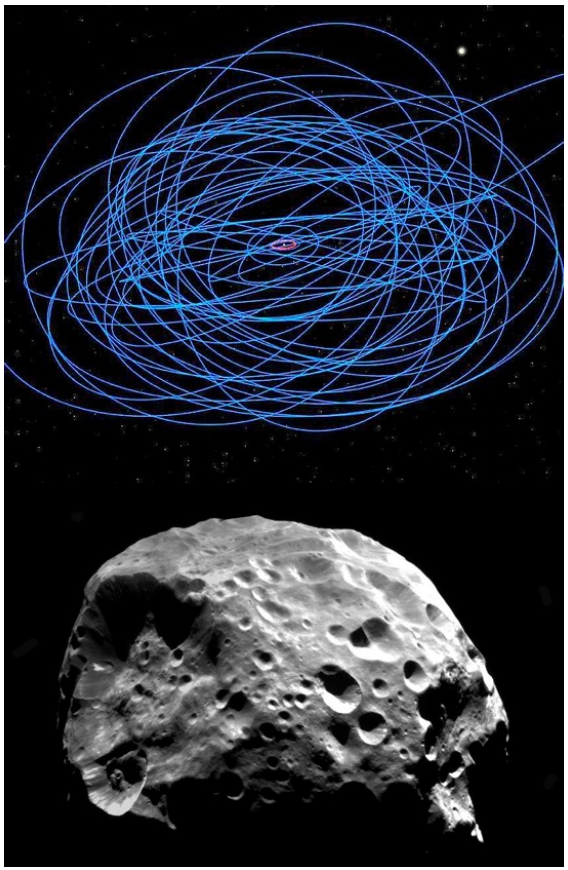
Earth Trojans

- Two Earth Trojans known: 2010 TK_7 (Connors et al., 2011) & 2020 XL_5 (Hui et al., 2021)
- Important to detect and study due to proximity to Earth
  - Potential for future robotic and manned space missions
- Difficult to detect due to:
  - Small solar elongation angles as seen from Earth
  - Inability for space telescopes to observe in the direction of the Sun
- Object exactly at L4 or L5 would be at a solar elongation angle of 59°
  - 5° above minimum solar elongation angle observable by Roman

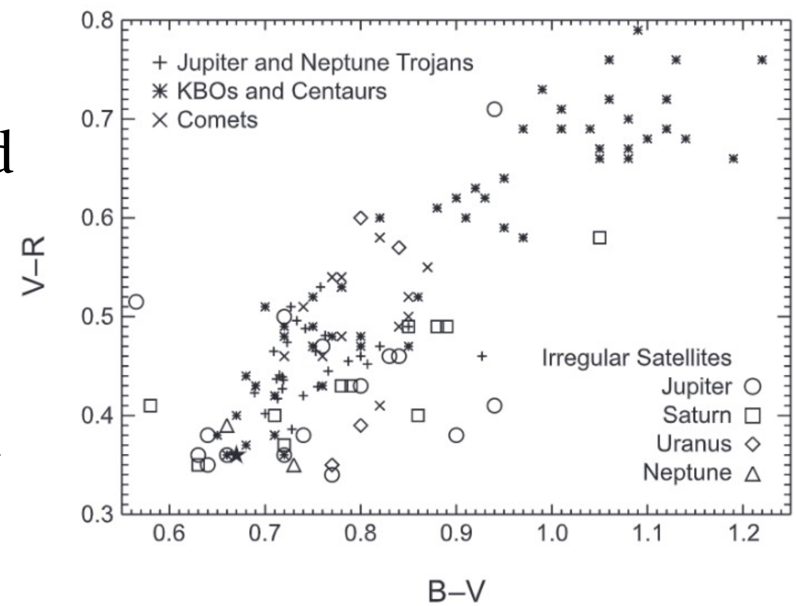


Holler et al. (2018); spacecraft image from NASA/GSFC

Irregular satellites of the giant planets

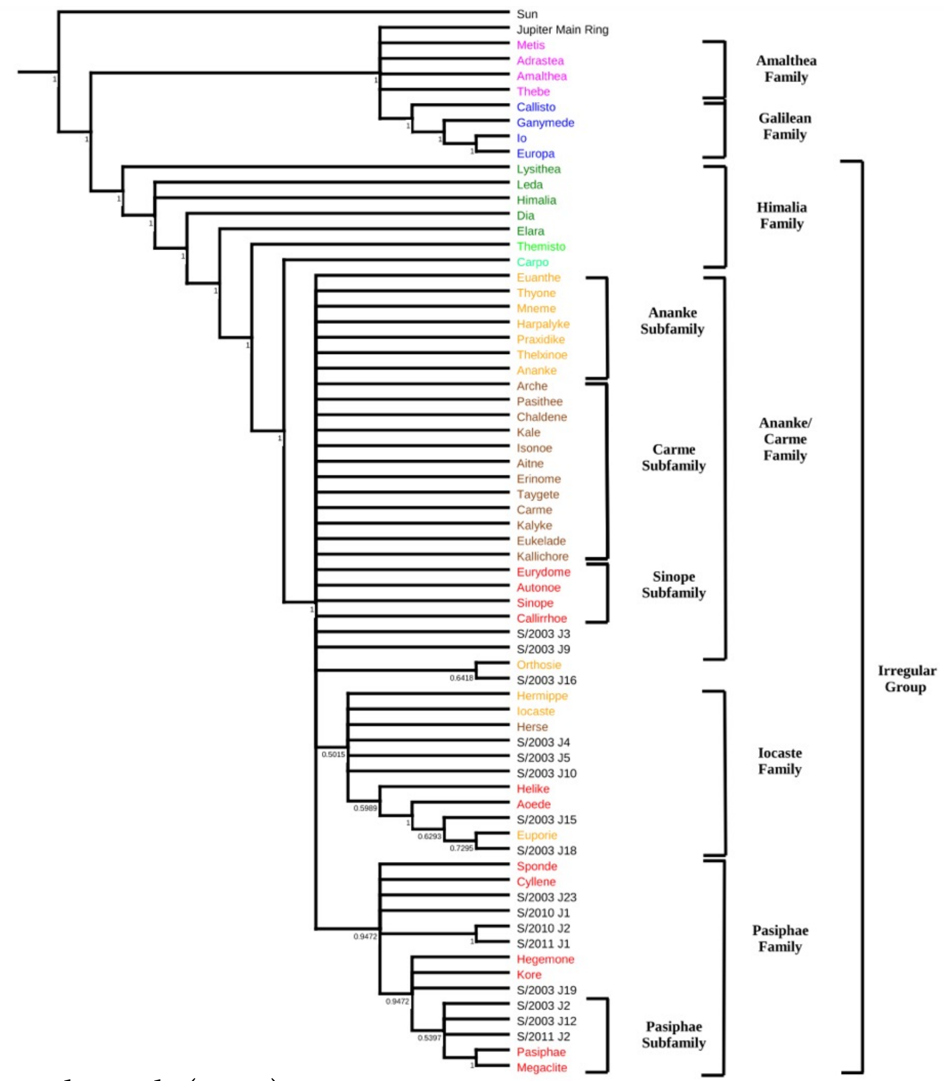


- Populations of minor bodies captured from heliocentric orbit and collisionally processed
- Phoebe (Saturn) and Triton (Neptune) provide best evidence of a Kuiper belt origin
- Unclear if other existing or primordial populations are also sources



Nicholson et al. (2008)

Irregular satellite families

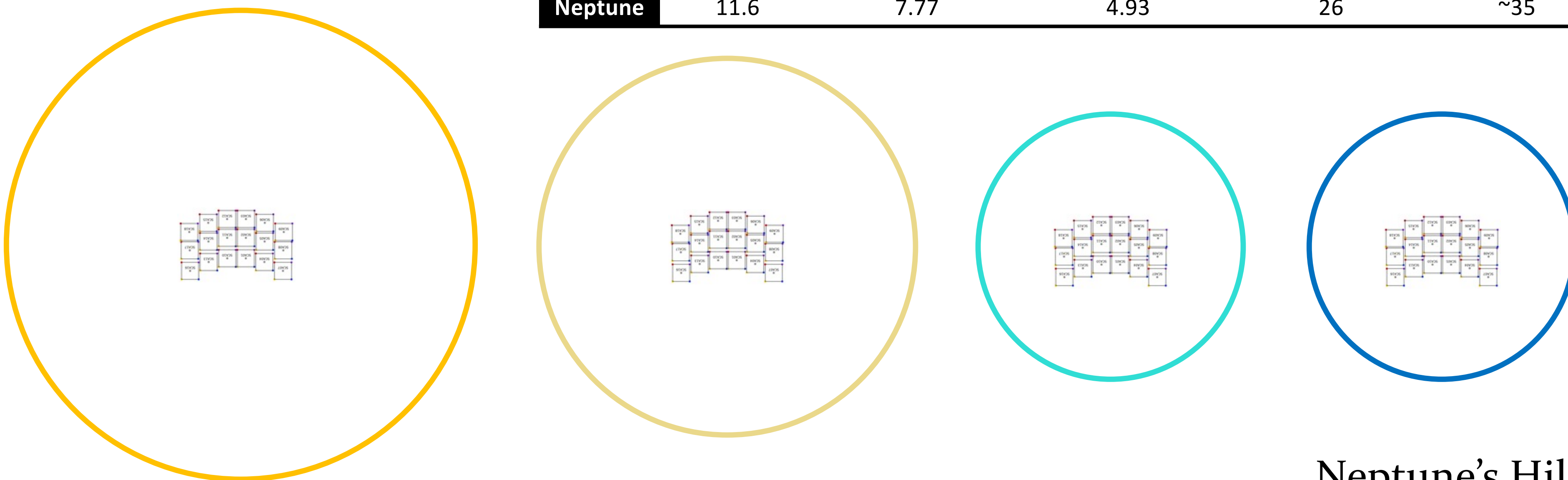


Holt et al. (2018)

- Capture onto high-inclination, eccentric orbits can result in collisions
- Collisional families exist in the irregular satellite populations
- How do these collisional processes compare to those in other populations, such as main belt asteroids?

Irregular satellites (cont.)

Planet	Hill radius (10^7 km)	Stability region (10^7 km)	Semi-major axis of furthest known satellite (10^7 km)	% vol. of Hill sphere known to be occupied	Smallest satellite discovered (km)
Jupiter	5.32	3.56	2.86	52	~1
Saturn	6.53	4.38	2.45	18	~0.3
Uranus	7.00	4.69	2.09	9	~18
Neptune	11.6	7.77	4.93	26	~35



Jupiter's Hill sphere
17 pointings
0.3 km in 1000s

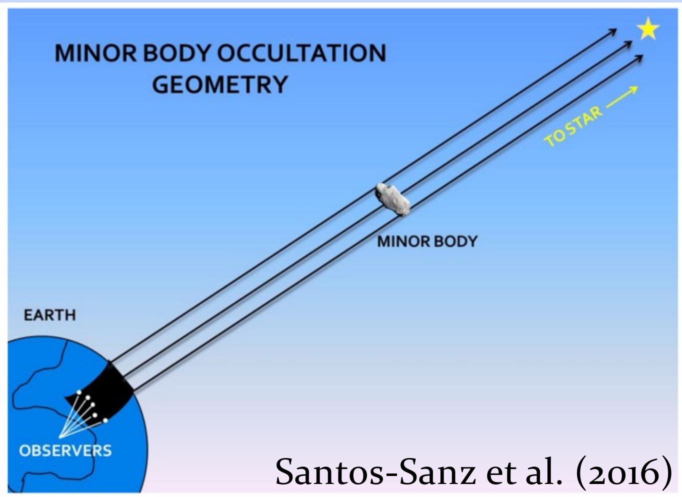
Saturn's Hill sphere
11 pointings
1.0 km in 1000s

Uranus' Hill sphere
6 pointings
4.5 km in 1000s

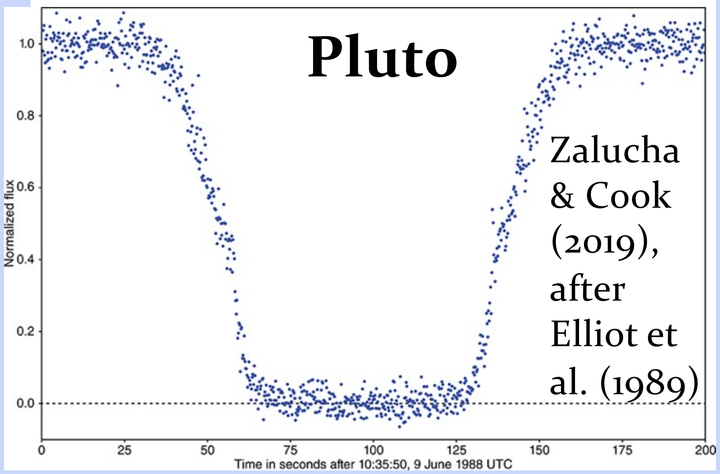
Neptune's Hill sphere
6 pointings
11.4 km in 1000s

The Roman WFI will enable deep, efficient searches for new irregular satellites of the giant planets.

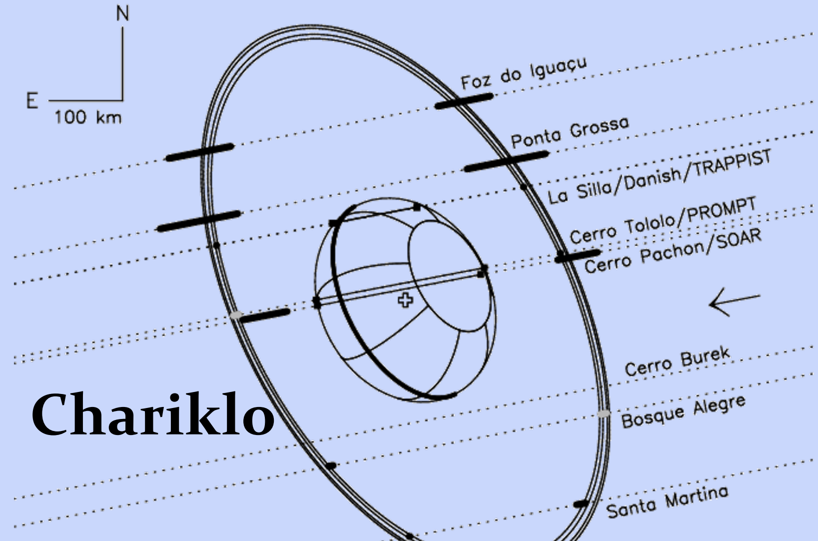
Stellar occultations



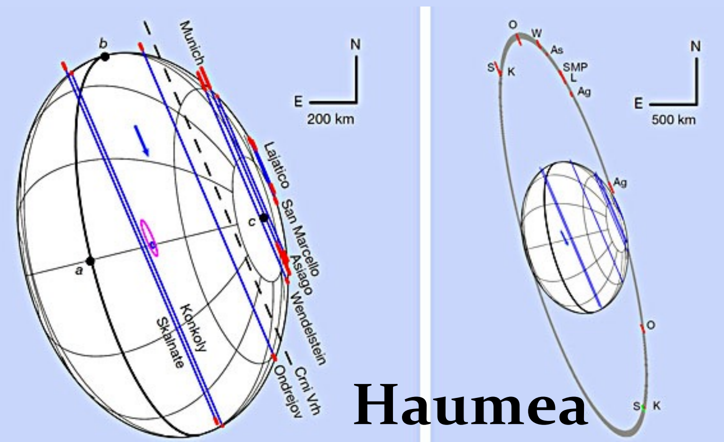
Santos-Sanz et al. (2016)



Zalucha & Cook (2019), after Elliot et al. (1989)



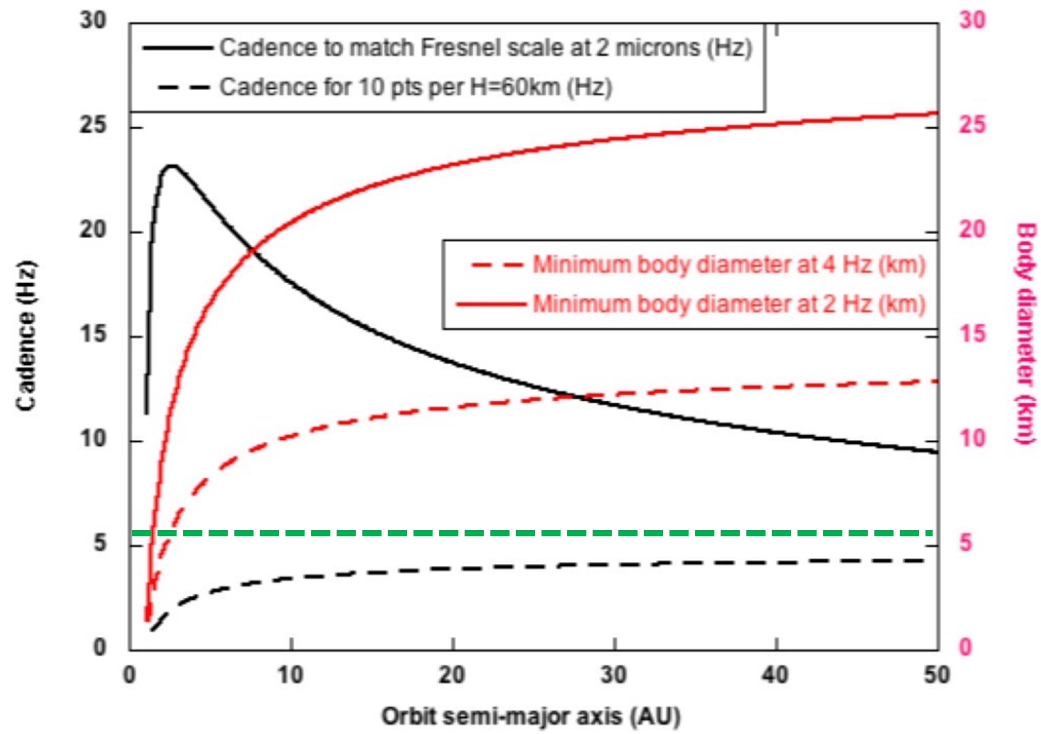
Braga-Ribas et al. (2013)



Ortiz et al. (2017)

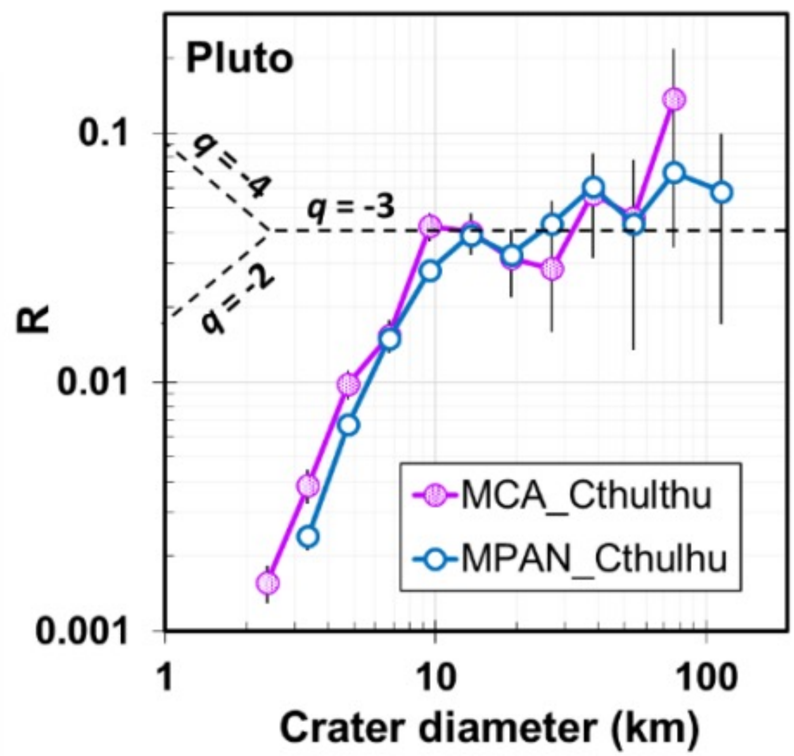
Serendipitous occultations

- Each of the 18 WFI detectors can obtain a guide star
- In practice, an observation will not require all 18, or guide stars will not be available
- Readout of guide star subarrays will be 5.8 Hz



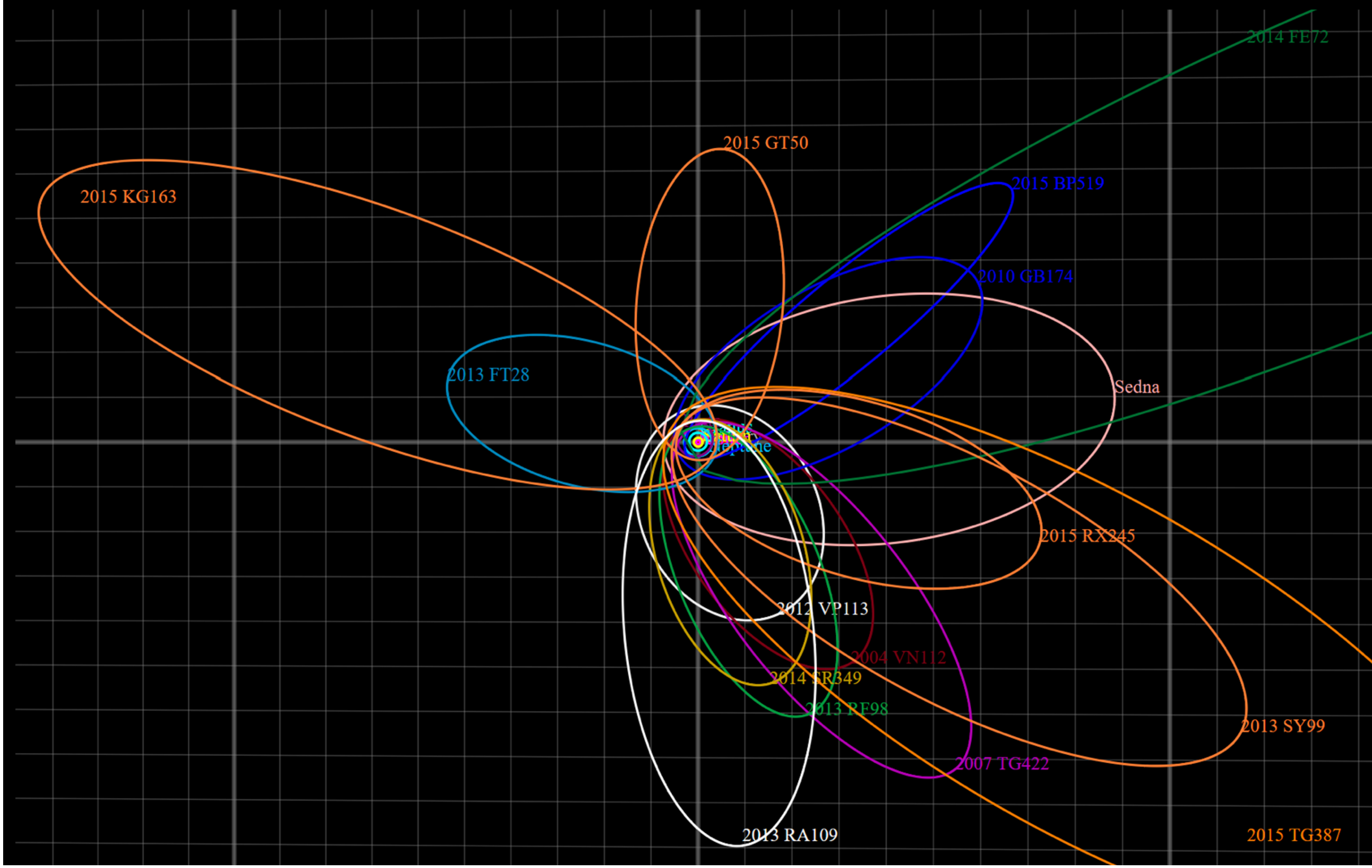
Holler et al. (2018)

Detection of small TNOs



Singer et al. (2021)

- The smallest TNOs are too faint to be observed directly
- Crater diameters on Pluto, Charon, and Arrokoth provide an indirect view of the size of the impactor population
- Knee at 10-15 km points to a dearth of small TNOs, compared to the asteroid belt
  - Different collisional history?
- Serendipitous occultations are one means of studying the population in a more direct way

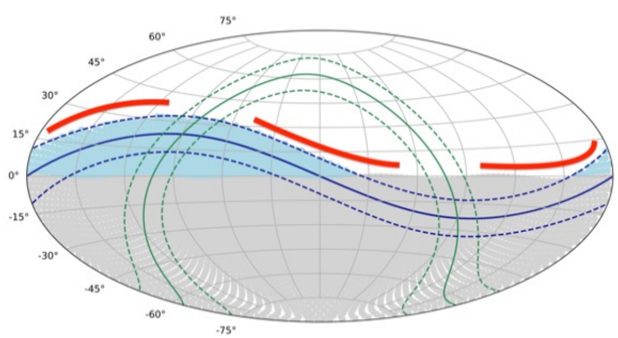


Batygin & Brown (2016)

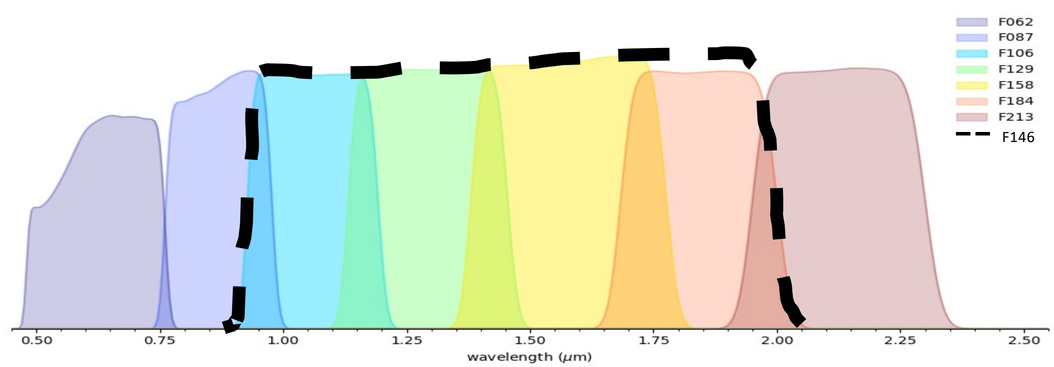
wikipedia.org

Roman Survey for Extreme TNOs (RoSET)

- ***The major goal of RoSET is to meaningfully increase the sample size of known ETNOs, specifically those further from perihelion, in order to remove any observational biases in the distribution of ETNO orbital parameters and re-evaluate the possibility of a distant planet.***
- A secondary goal of RoSET is to detect objects currently even further from the Sun than the ETNOs, beyond the “Kuiper cliff.”

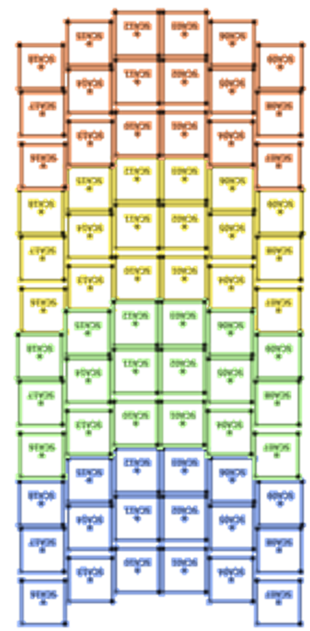


Schwamb et al. (2018)

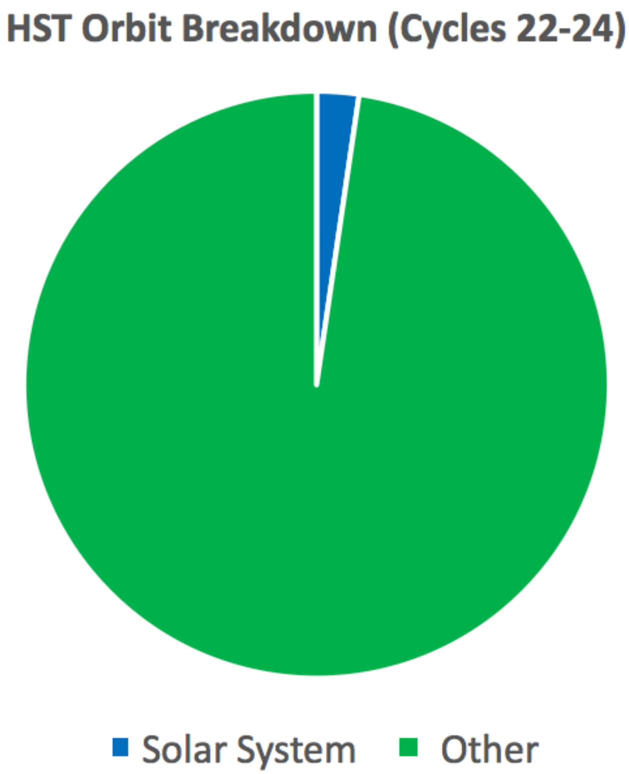


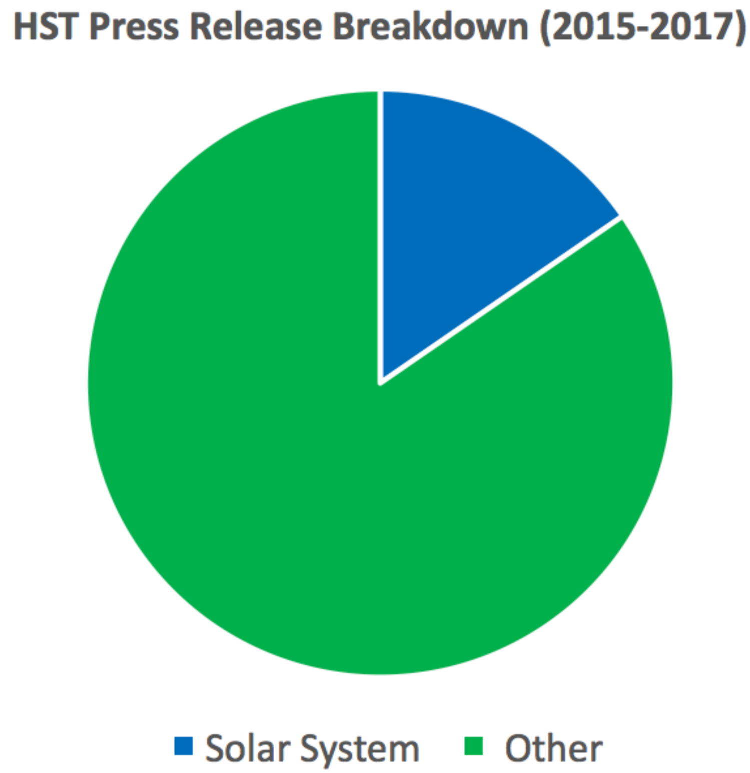
RoSET (cont.)

- 10 1000-s exposures with wide F146 filter
- 4 WFI fields = 1 sq. deg., 95% efficiency
- Same sky coverage would require 100 JWST/NIRCam mosaic tiles & multiple days of exposure time, reaching max 50% efficiency
- 3 visits to look for movement of distant targets
- Avoid galactic plane, cover ~20 sq. deg. over 700 hours (~1 month)
- Reach a depth of $r = 28.5$ to identify >100 new ETNOs
  - OSSOS: $r = 25$
  - LSST: $r = 24.5$



Astrophysics resources & solar system press releases

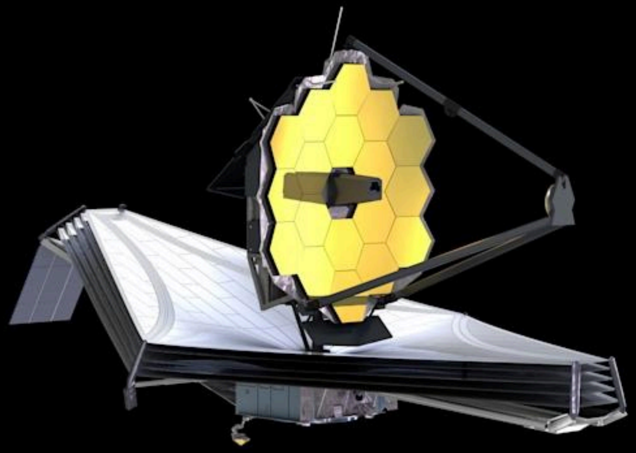




2.3% x 6.7 = 15.3%

Holler et al. (2018)

Synergies with other observatories



https://arxiv.org/abs/1709.02763