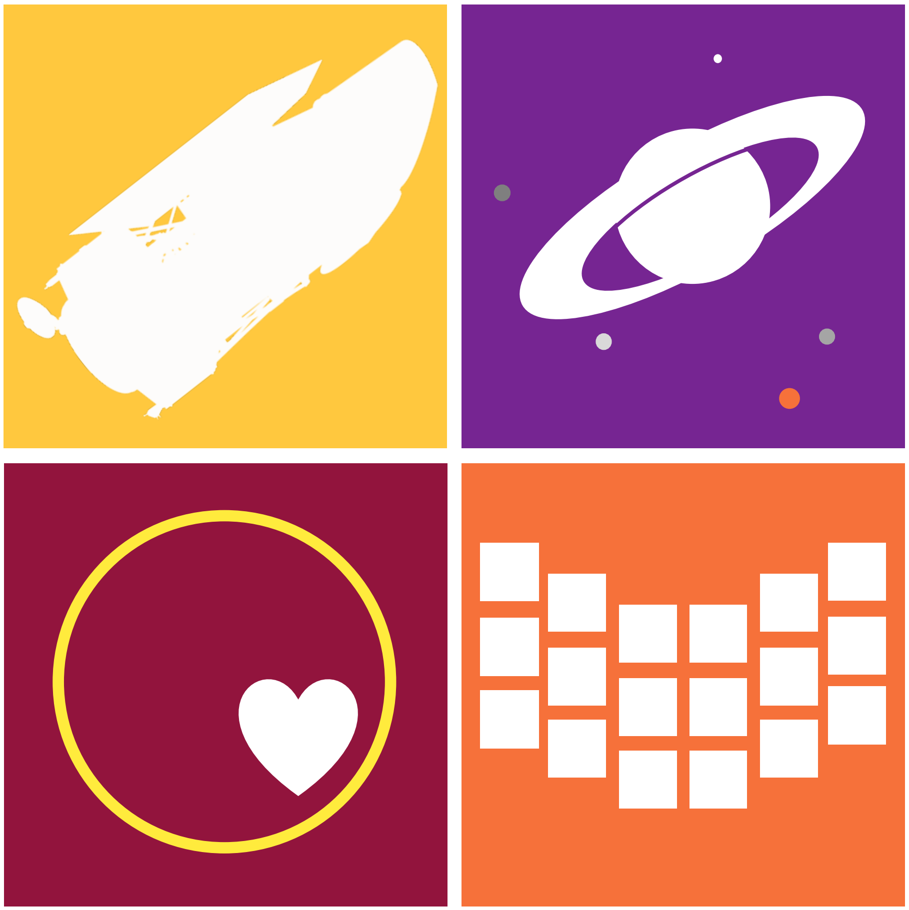

Revolutionizing Solar System Science with WFIRST

Bryan J. Holler

STScI | SPACE TELESCOPE SCIENCE INSTITUTE

WFIRST Solar System Working Group (SSWG)

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James Bauer
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Tony Farnham
Nader Haghighipour
Paul Harderson
Alan Harris
Henry Hsieh
Michael Kelley
Matthew Knight
Emily Kramer
Andrea Longobardo
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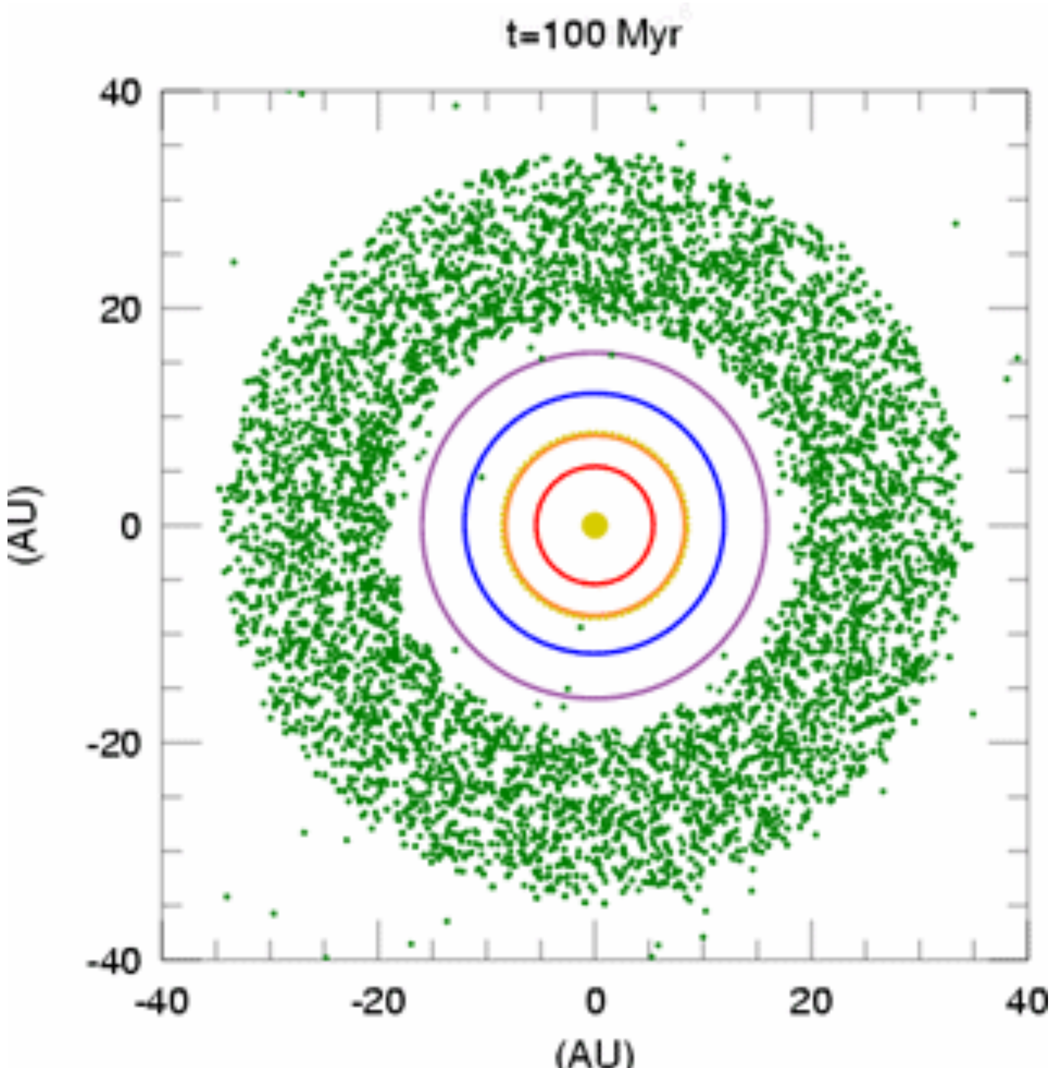
Ernesto Palomba
Silvia Protopapa
Lynnae Quick
Darin Ragozzine
Vishnu Reddy
Jason Rhodes
Andy Rivkin
Gal Sarid
Amanda Sickafoose
Amy Simon
Cristina Thomas
David Trilling
Robert West

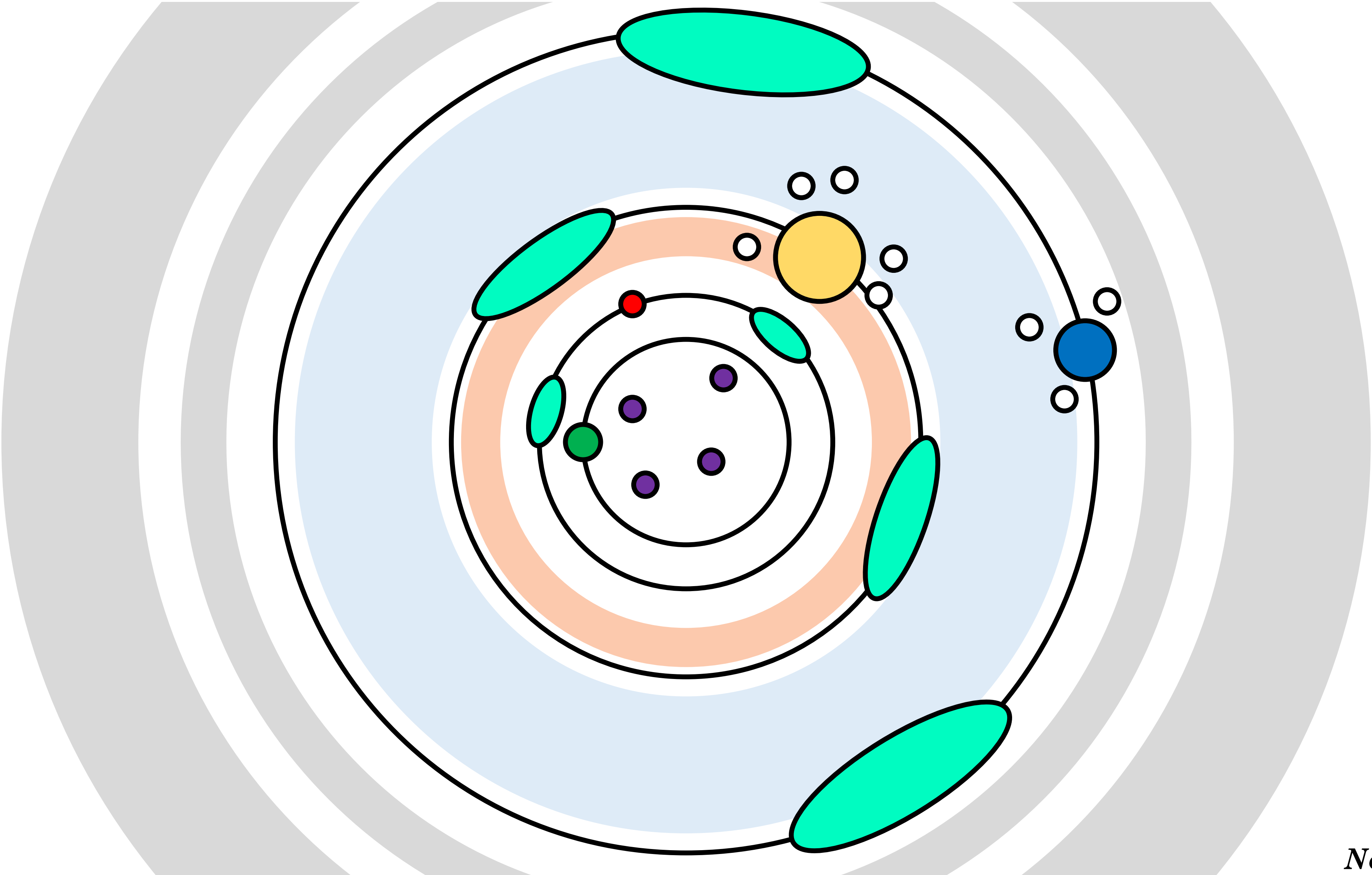
With thanks to:
Christopher Hirata
Jason Kalirai
Jeff Kruk
Ed Nelan

“Observations of XYZ will provide valuable information for understanding the origin and evolution of the solar system.”

-Every solar system proposal



(From Gomes, *et al.*, 2005, *Nature*, v. 435, p. 466-469.)



Not to scale!

Discovery → **Characterization**

WIDE-FIELD INFRARED SURVEY TELESCOPE
WFIRST
ASTROPHYSICS • DARK ENERGY • EXOPLANETS

LSST
Large Synoptic Survey Telescope

James Webb Space Telescope
JWST
NASA • ESA • CSA

TMT

GMT

NASA

WFIRST mission assumptions

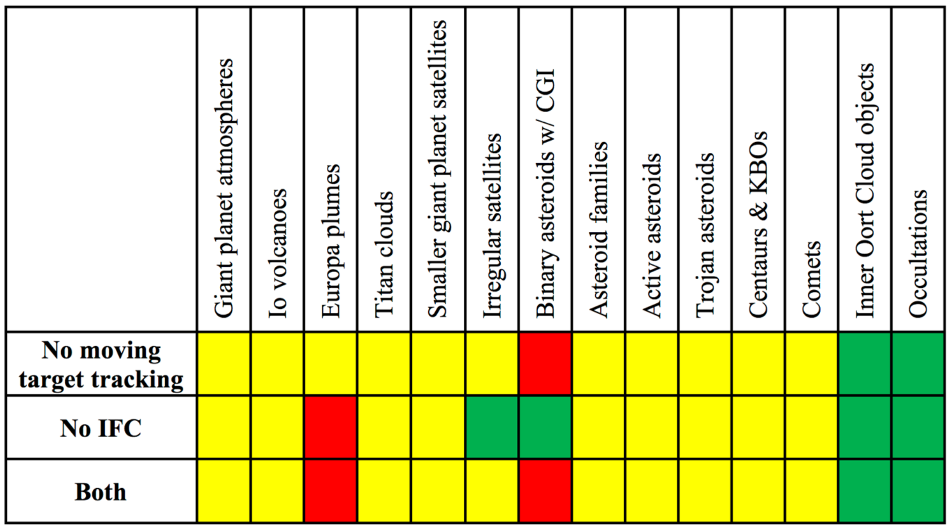
No IFC

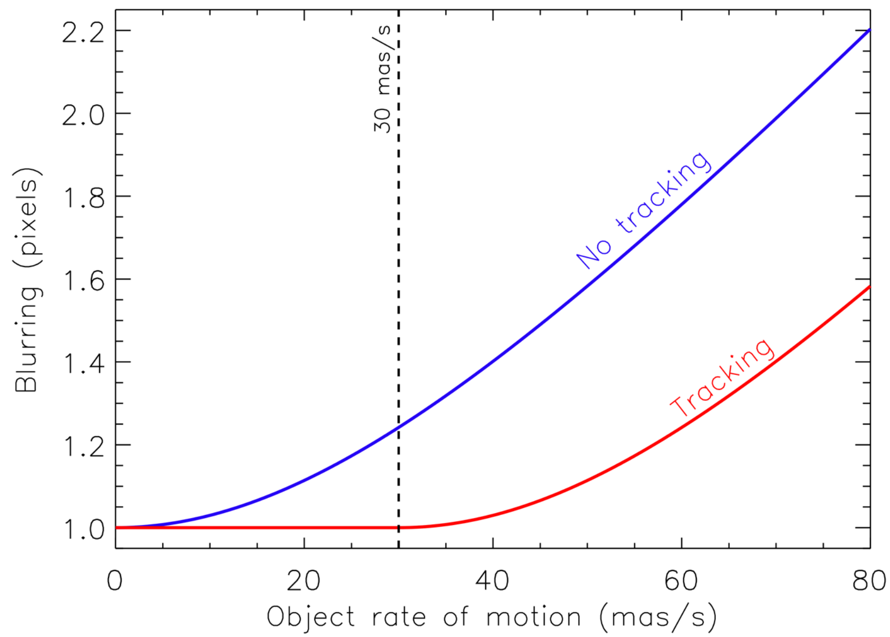
No moving target tracking

Passive cooling

Surveys not yet finalized

Descope effects on solar system science

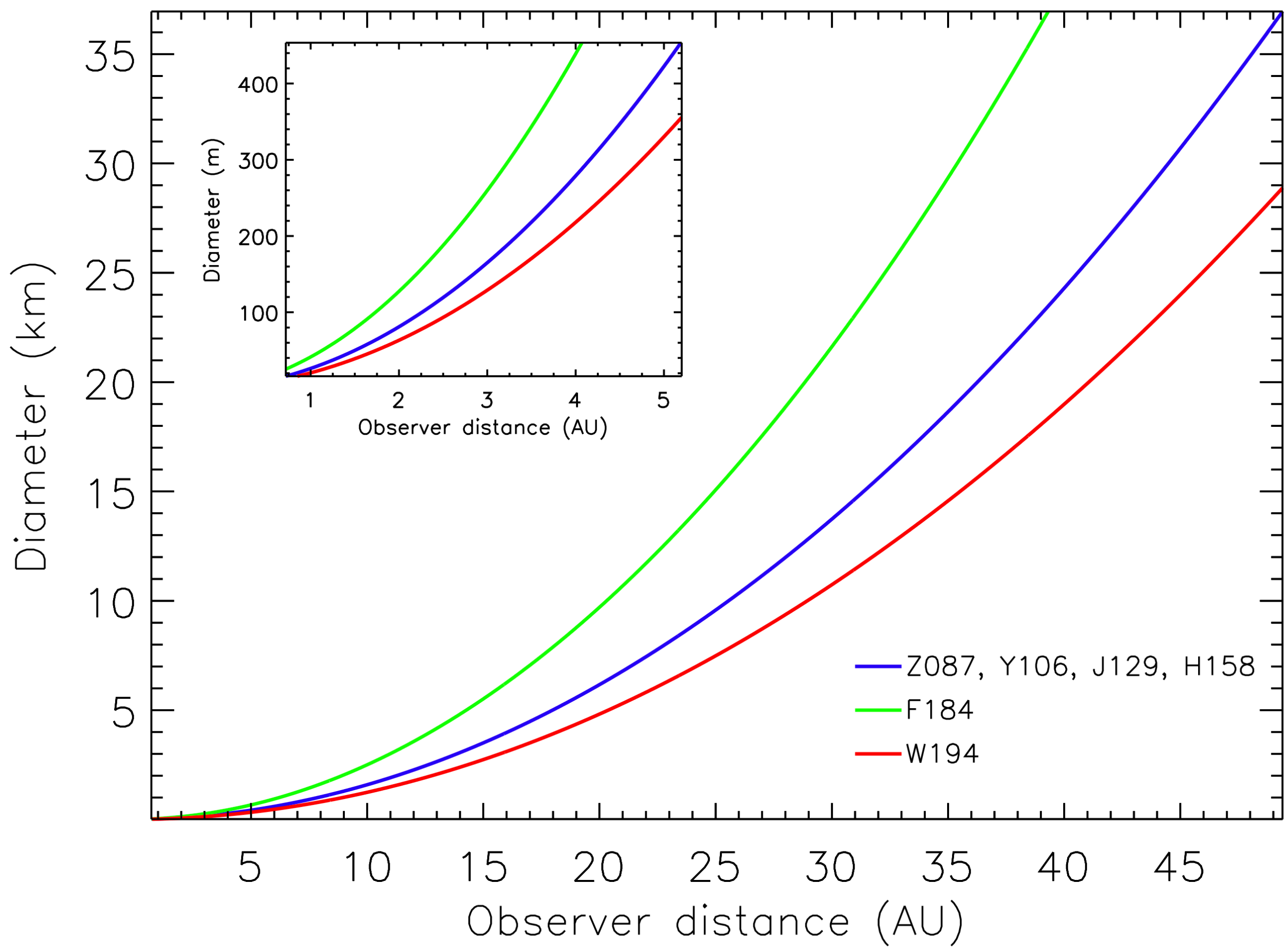




Holler et al. (2018)


NASA/JPL/K. McGill

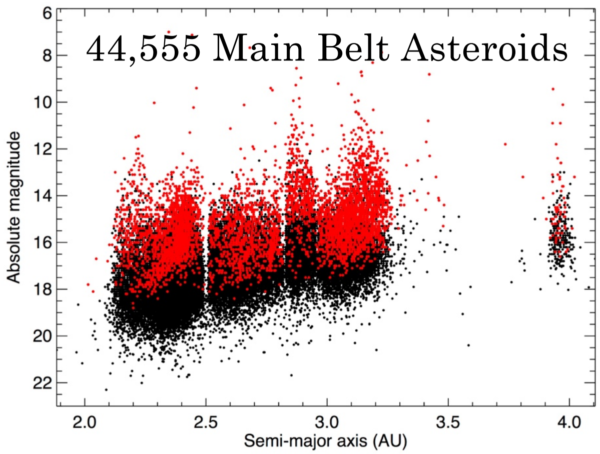
Estimated detection limits (1000 sec, 5-σ)

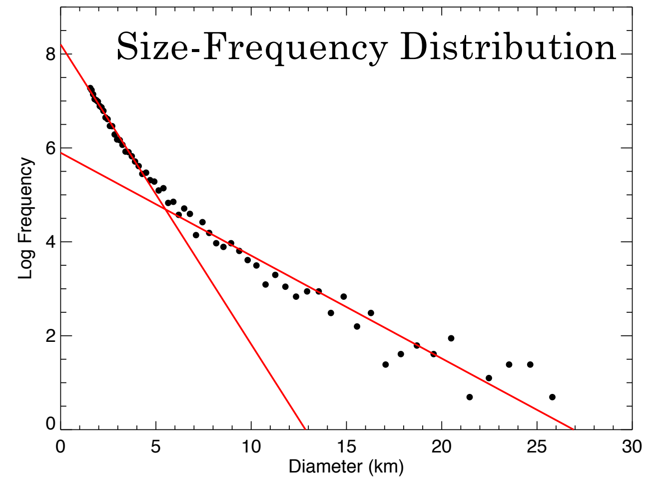


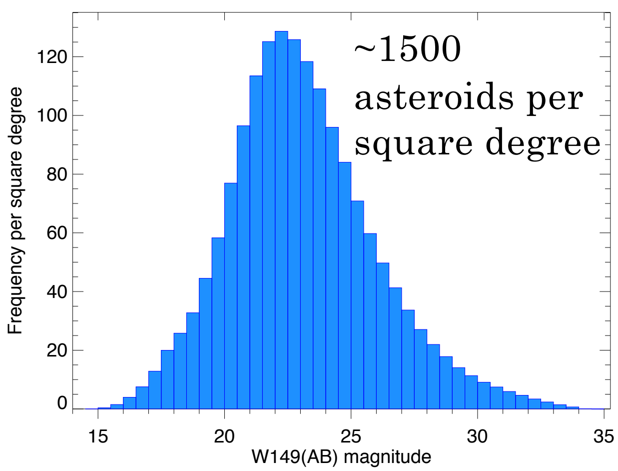
Holler et al. (2018)

Mining the astrophysics surveys

Microlensing survey







W149 AB mag

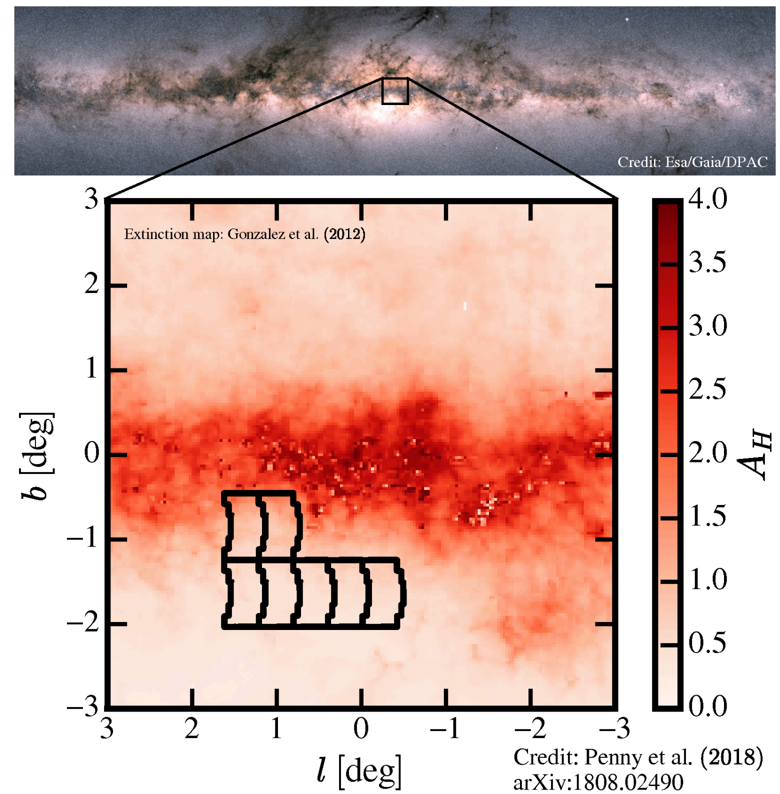
≈

Johnson V Vega mag

Microlensing survey (cont.)

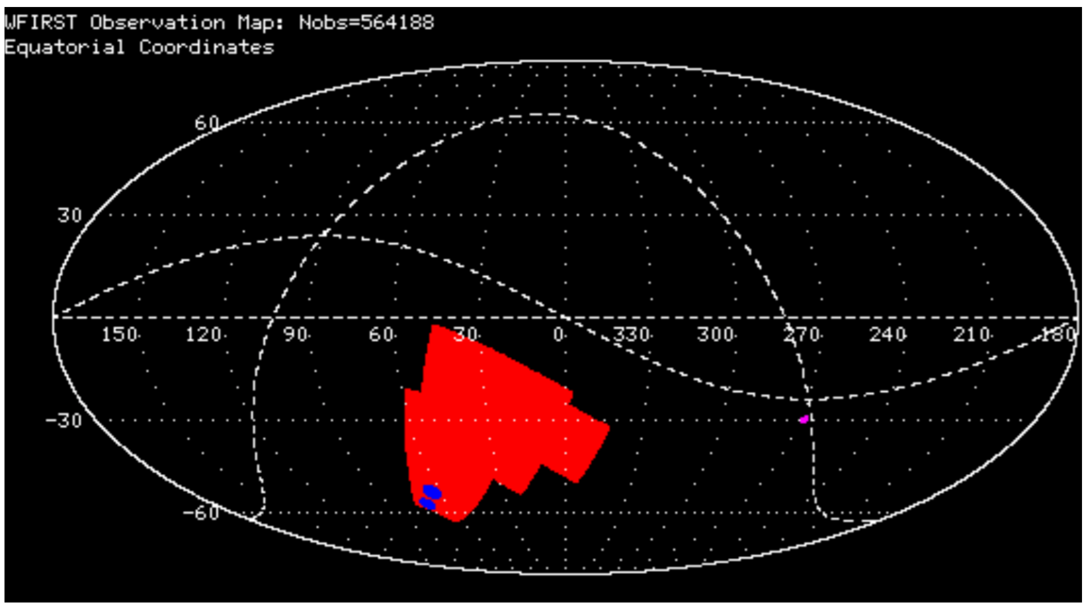
- Gould (2014) claims:
  - Detection of KBOs down to V=30.2
  - Detection of KBO satellites w/n 10 mas of primary down to V=31.0

- Cadence of microlensing survey could result in the construction of rotation light curves



High-Latitude Survey (HLS)

- DES and LSST can reach *r*<24.5
- WFIRST will be able to reach *r*<27
  - Observe targets 3x smaller at a particular distance or 3x farther away for a particular size



Spergel et al. (2015)

Potential solar system surveys

Earth Trojans

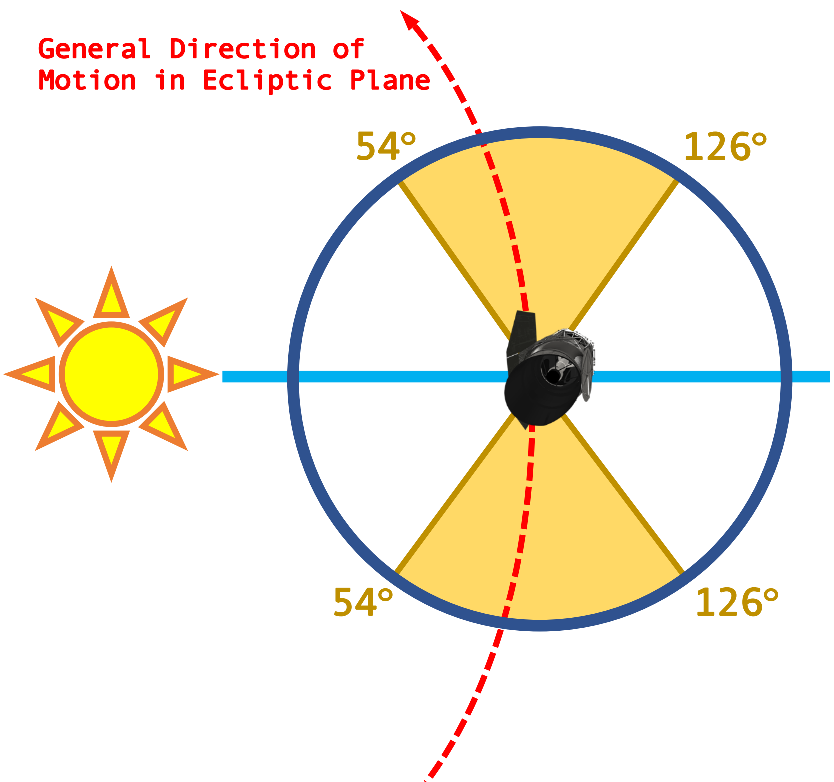
- One Earth Trojan known: 2010 TK_7 (Connors et al., 2011)

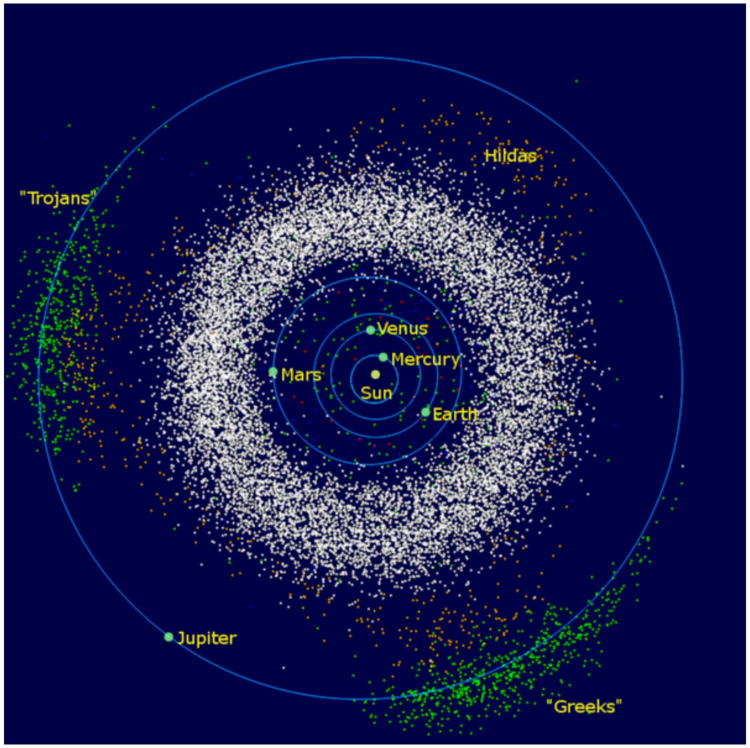
- Important to detect and study due to proximity to Earth
  - Potential for future robotic and manned space missions

- 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 WFIRST

Field of regard and Trojan orbits

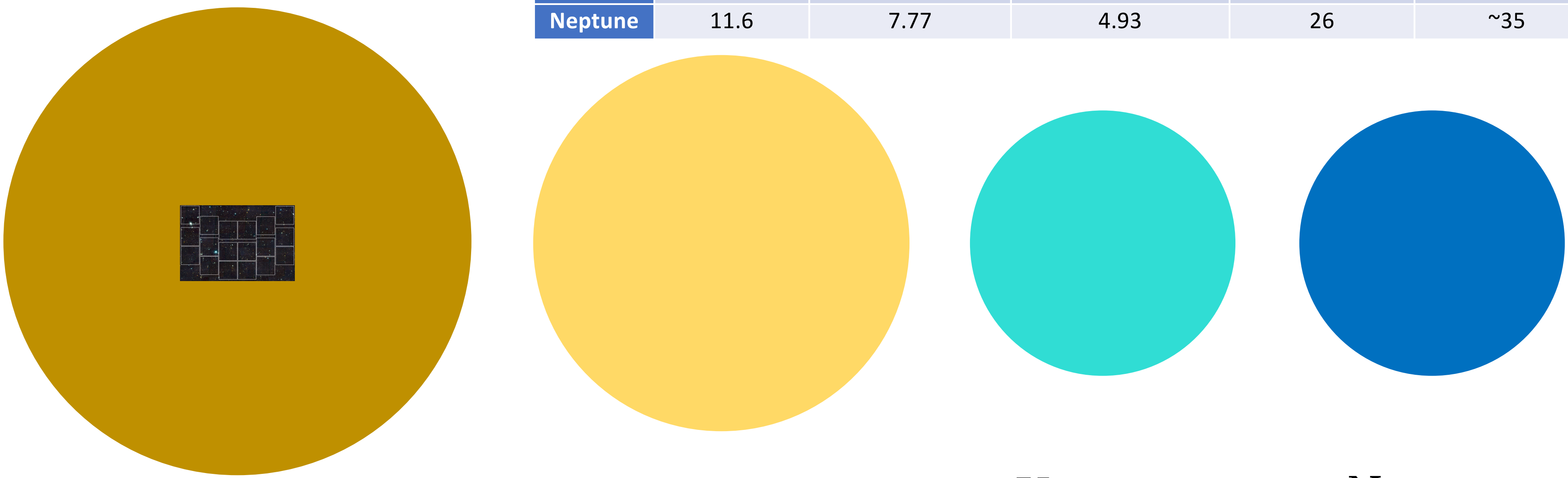




Holler et al. (2018); spacecraft image from NASA/GSFC

Irregular satellites

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
17 pointings
0.3 km in 1000s

Saturn
11 pointings
1.0 km in 1000s

Uranus
6 pointings
4.5 km in 1000s

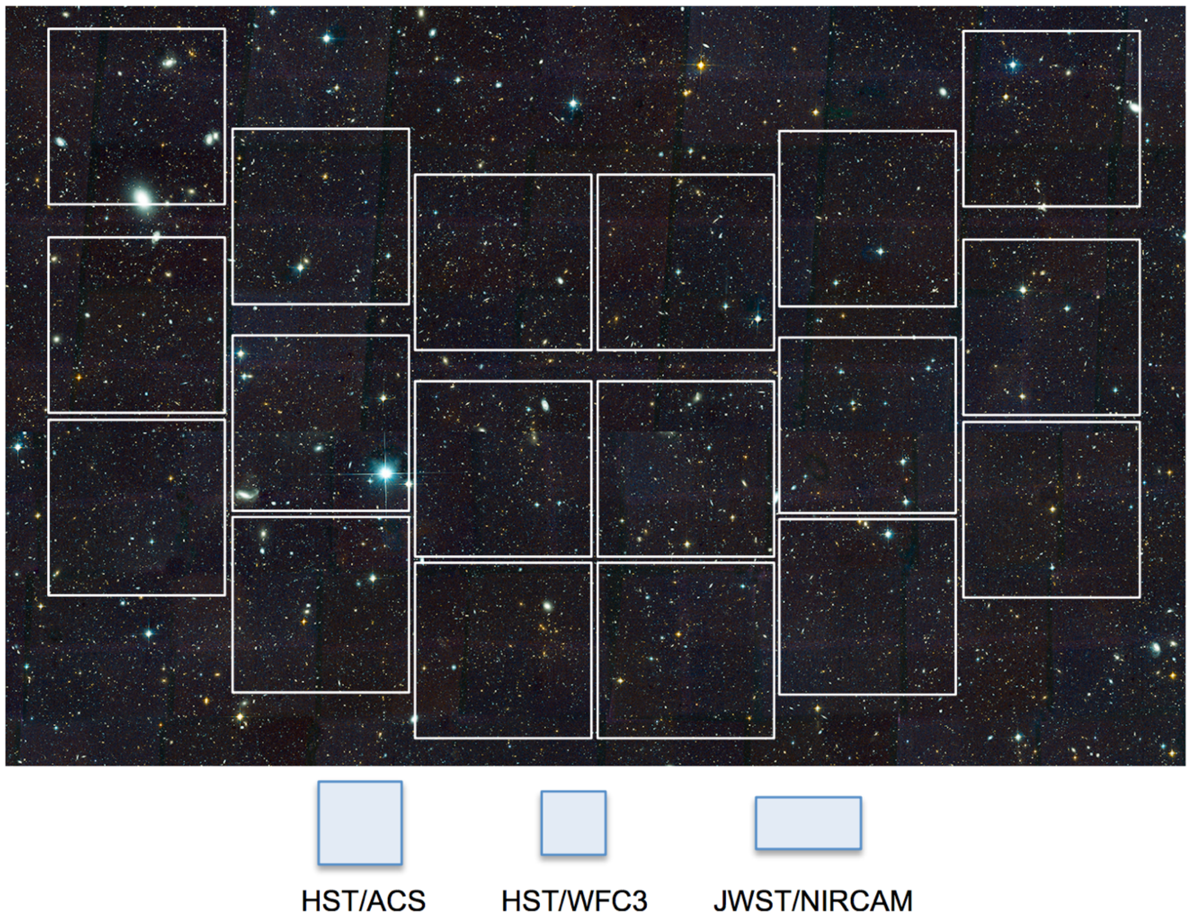
Neptune
6 pointings
11.4 km in 1000s

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

Field of view

WFIRST/WFI:
0.281 deg^2

Subaru/HSC:
1.8 deg^2

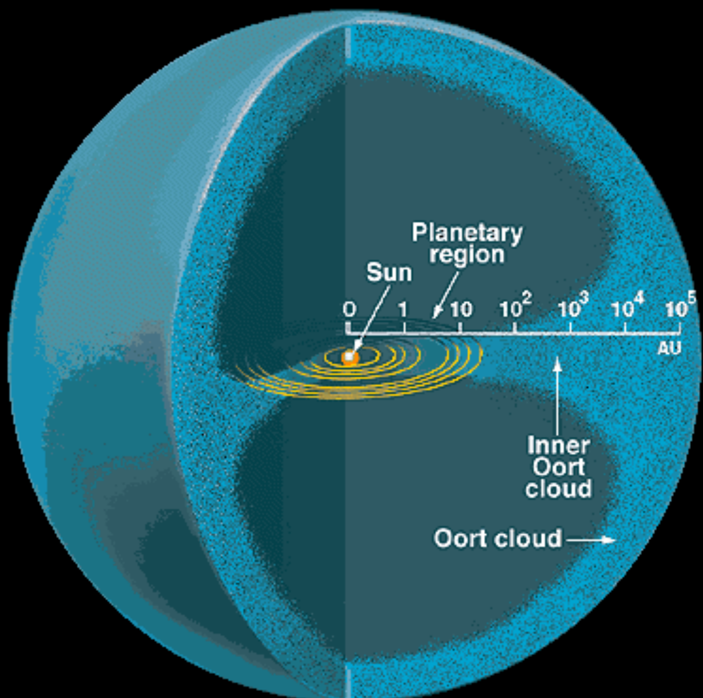


HST/ACS:
0.0031 deg^2

HST/WFC3/UVIS:
0.0020 deg^2

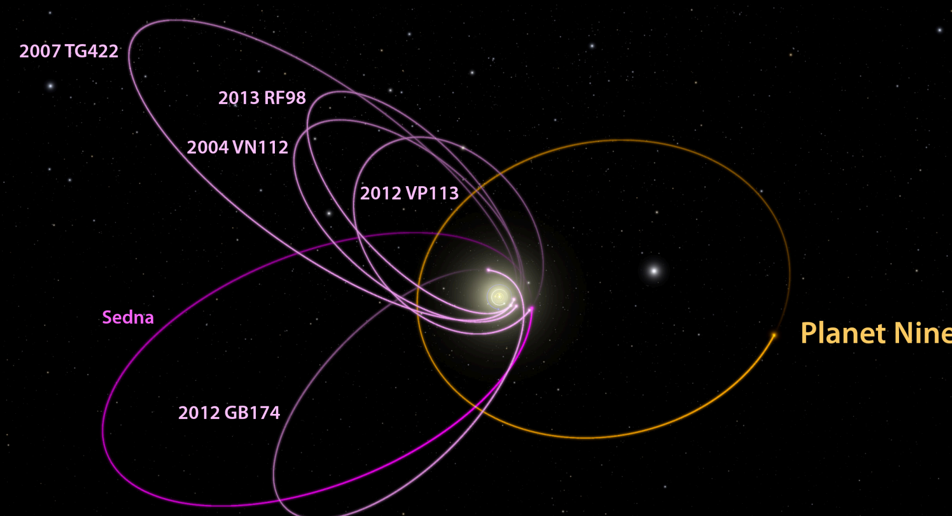
JWST/NIRCam:
0.0027 deg^2

Spergel et al. (2015)



Planetary region
Sun
0
1
10
10^2
10^3
10^4
10^5
AU
Inner Oort cloud
Oort cloud

Mercury
Earth
Venus
Mars
Jupiter
Saturn
Uranus
Neptune
34 AU
Pluto
80 AU
"The Goblin" 2015 TG387
"Biden" 2012 VP113
Sedna
96 AU
Eris
120 AU
"Farout" 2018 VG18

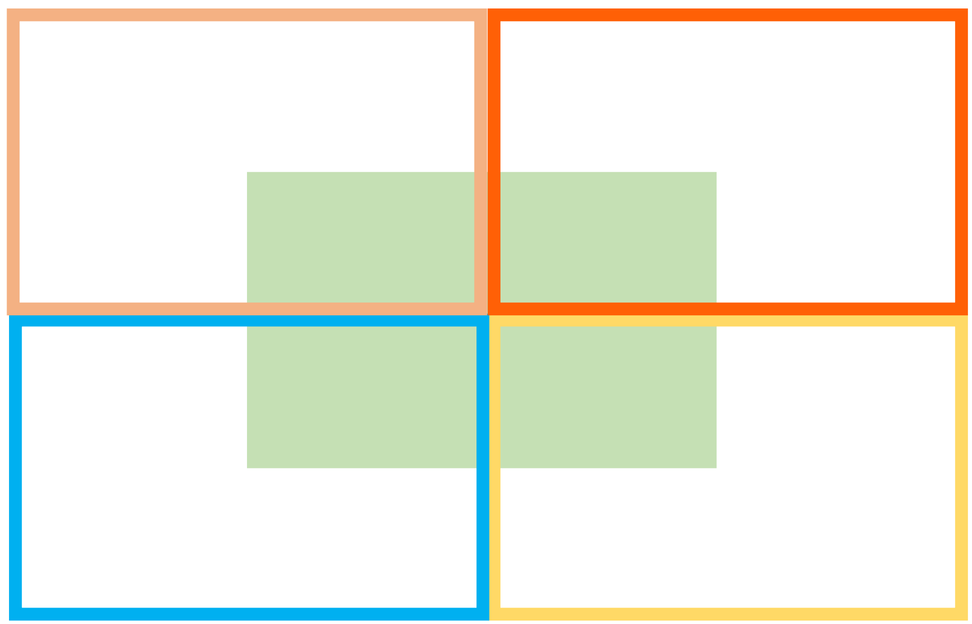


2007 TG422
2013 RF98
2004 VN112
2012 VP113
Sedna
2012 GB174
Planet Nine

Inner Oort Cloud search

10 1000-second exposures at each pointing

Longer exposures subject to cosmic ray double-strikes

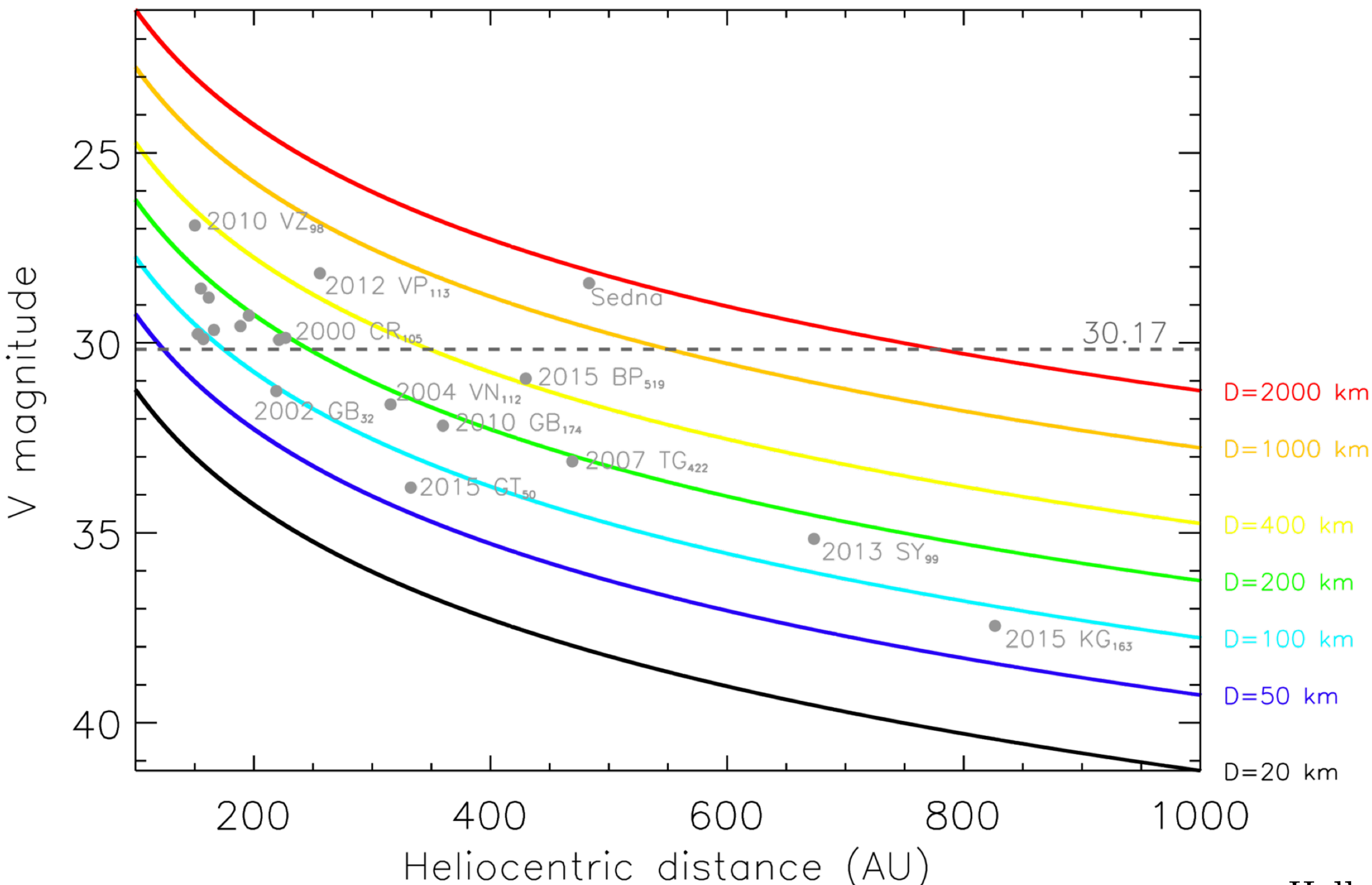


Overlap of fields enables detection of target movement

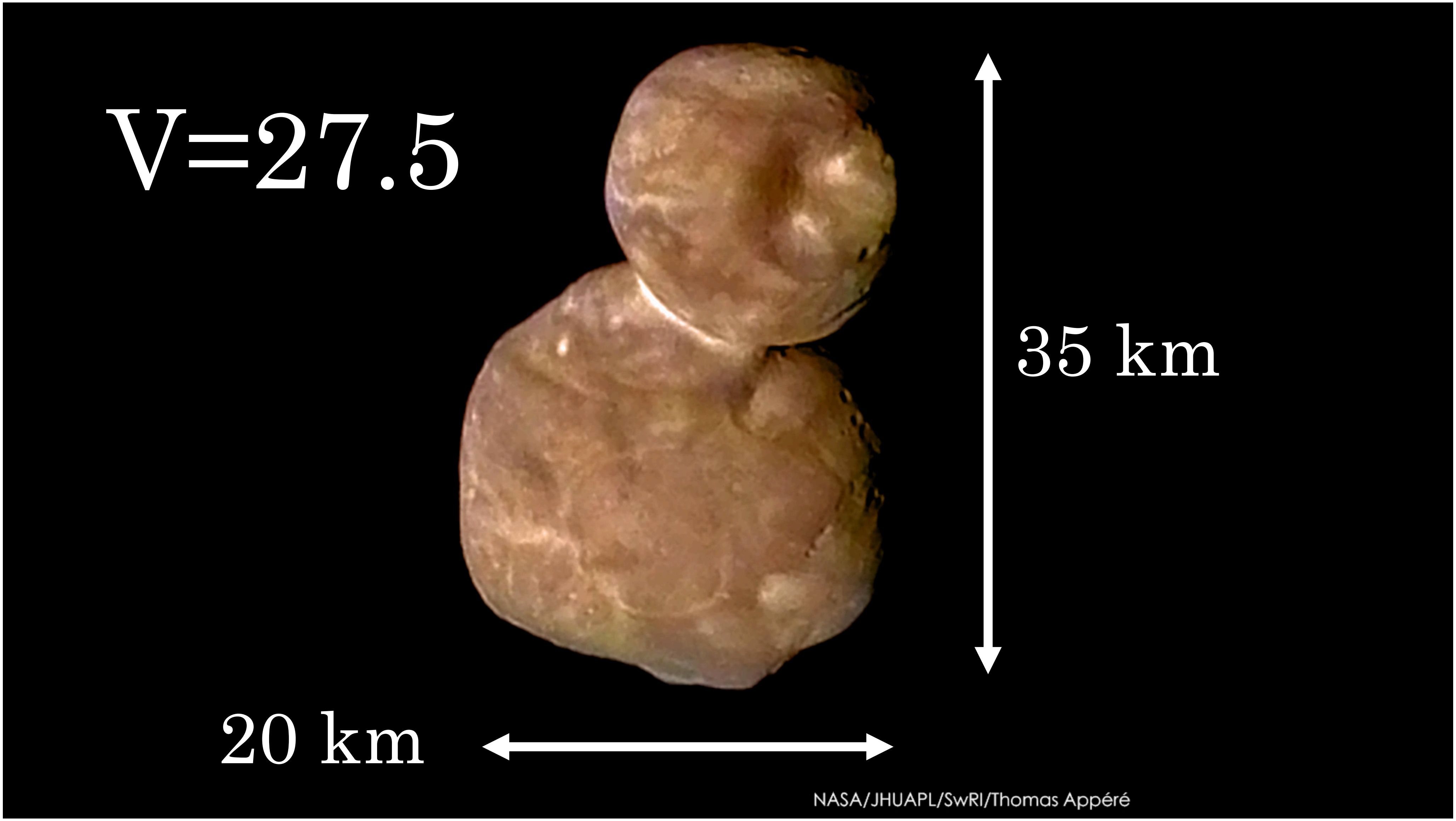
Deep imaging potentially of interest to astrophysics community

Object at 100 AU will move 4 pixels in 10,000 seconds
Object at 600 AU will move 2 pixels in 24 hours

Inner Oort Cloud detection limit



Holler et al. (2018)


V=27.5
35 km
20 km
NASA/JHUAPL/SwRI/Thomas Appéré

Serendipitous occultations

- Guide boxes:
  - 16 x 16 pixels (~1.8” x 1.8”)
  - 5.8 Hz cadence
  - Additional subarray options?

- Potential for all 18 WFI detectors to be tracking stars at once
  - Unlikely, but possible
  - More likely that a few detectors will be tracking at once
  - Currently unsure if these guide images would be saved and transmitted to the ground
  - Would result in 18 “star-hours” per hour on-target

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

(Submitted on 8 Sep 2017 (v1), last revised 27 Jul 2018 (this version, v3))

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.

https://arxiv.org/abs/1709.02763

CliffsNotes™

"It's full of asteroids!": Solar system science with a large field of view

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Thematic area: Planetary Systems

https://baas.aas.org/wp-content/uploads/2019/05/068_holler.pdf

Questions?

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