Subaru Telescope and New Horizons: A Decade of Discovery, Recovery, and Results

Anne Verbiscer, Simon Porter, J. J. Kavelaars, Wes Fraser, Susan Benecchi, Fumi Yoshida, Takashi Ito, Tsuyoshi Terai, David Gerdes, Marc Buie, Hsing Wen (Ed) Lin, Lowell Peltier, Alan Stern, Joel Parker, Kelsi Singer, Pontus Brandt, New Horizons KBO Search Team

SOUTHWEST RESEARCH INSTITUTE

Subaru Users Meeting, NAOJ, Mitaka Campus, 29 October 2025

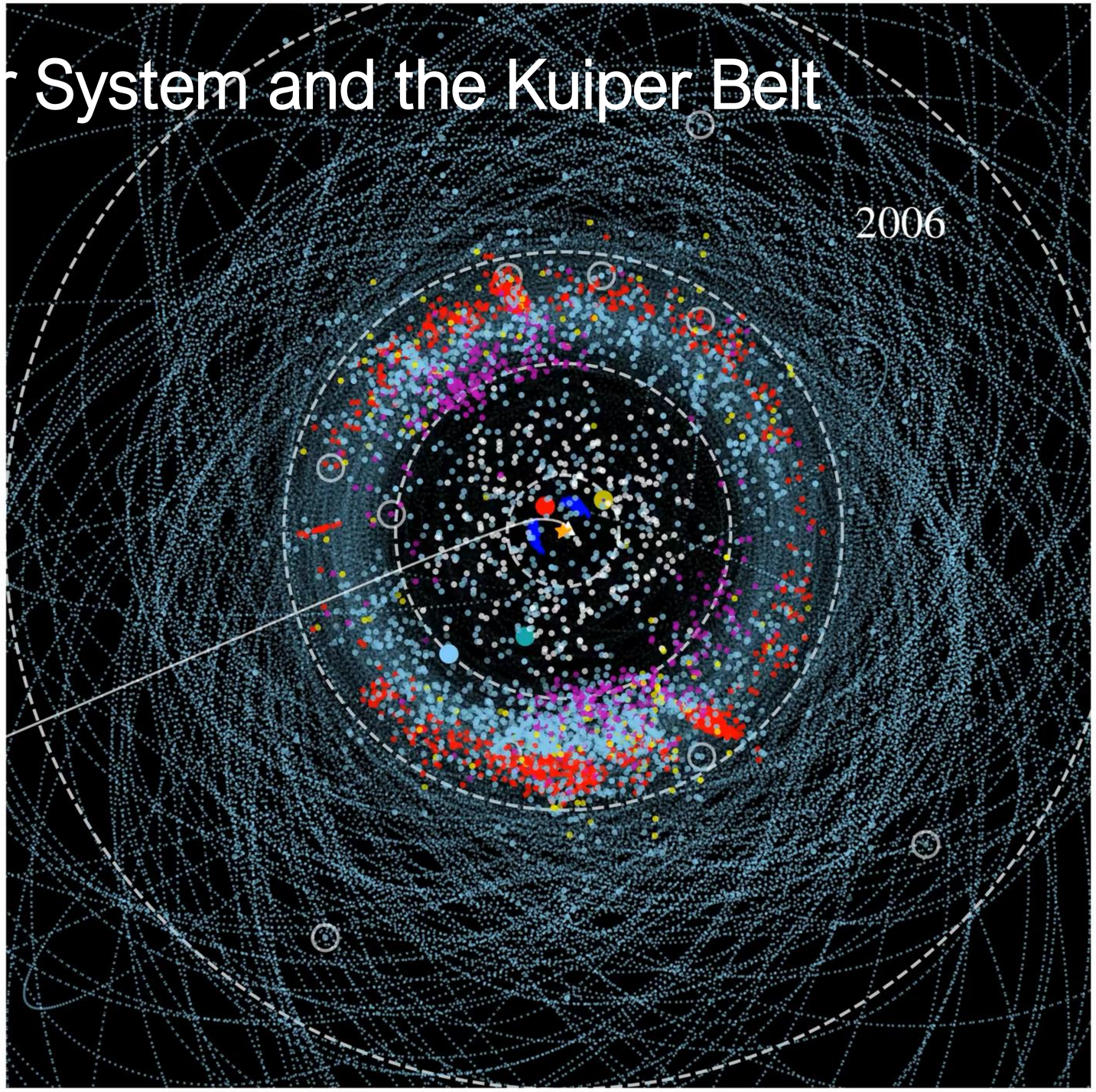
The Solar System and the Kuiper Belt

▲ New Horizons Spacecraft Location – Currently 63au hibernating until June 2026

★ Sun

○ Dwarf Planets, Large Kuiper Belt Objects (KBOs)

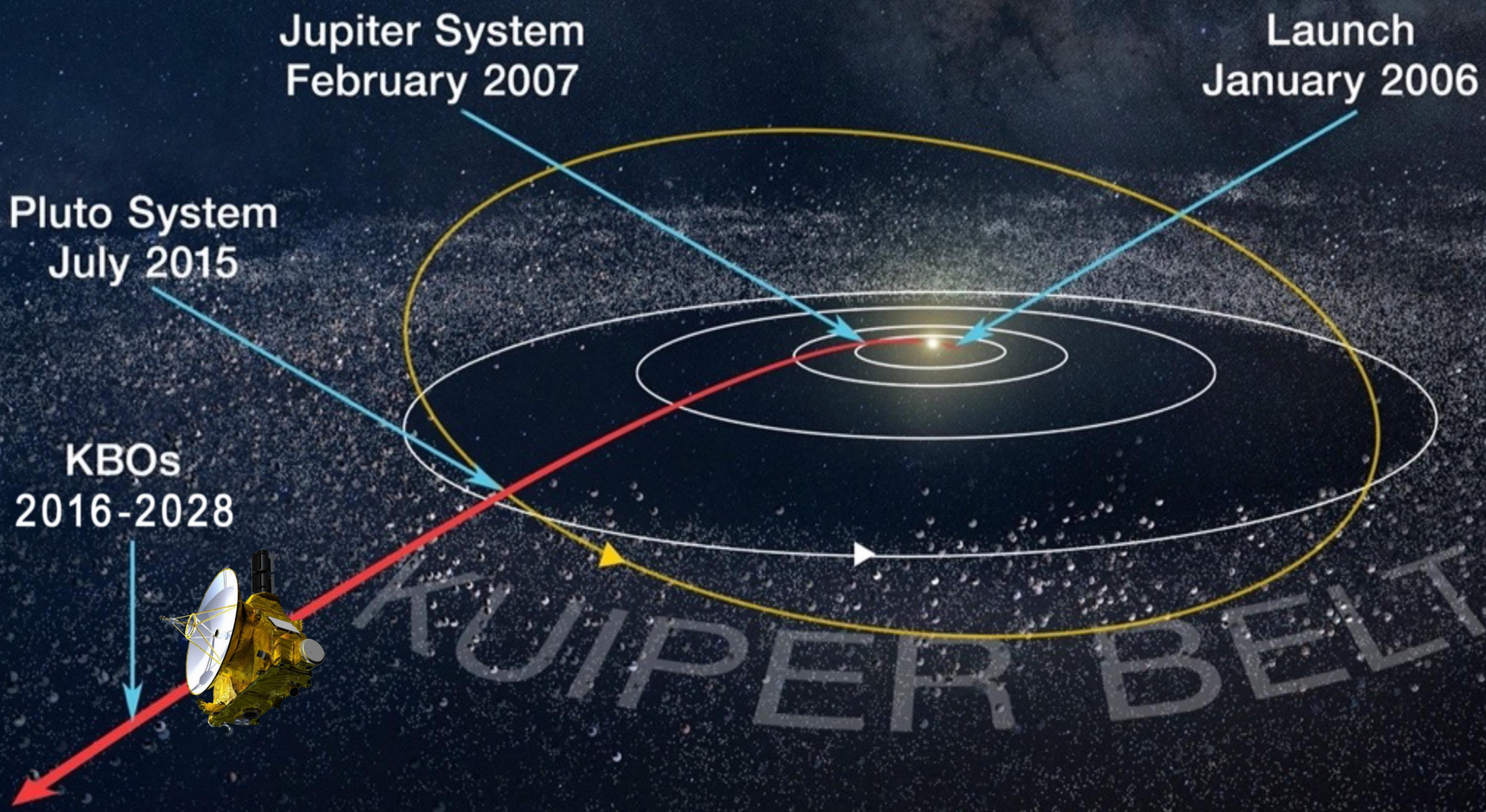
● Neptune



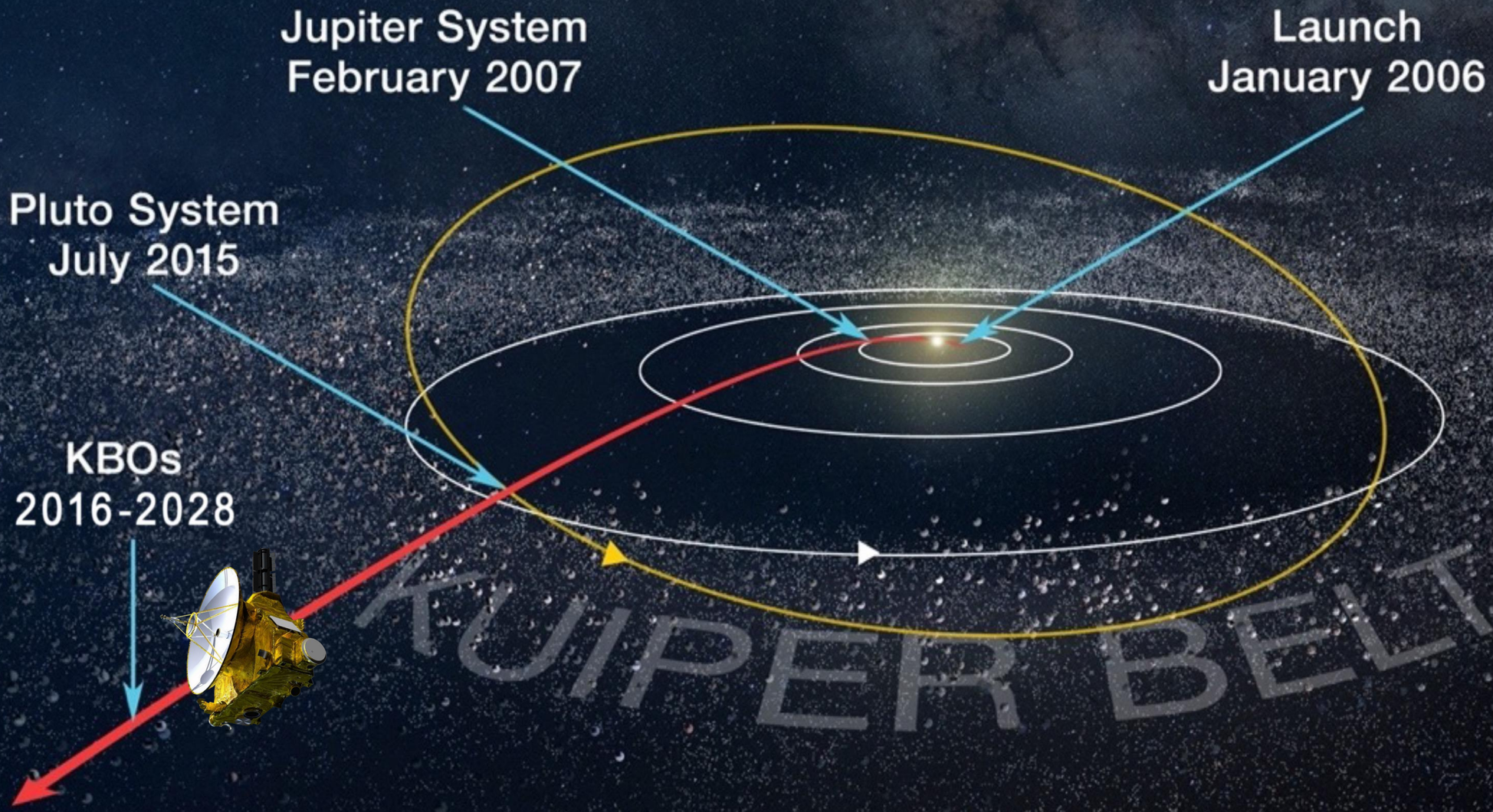
Cold Classical KBOs
Plutinos
Centaurs
Jupiter Trojans
Scattered Disk
(other) Resonant KBO

Credit: Wes Fraser

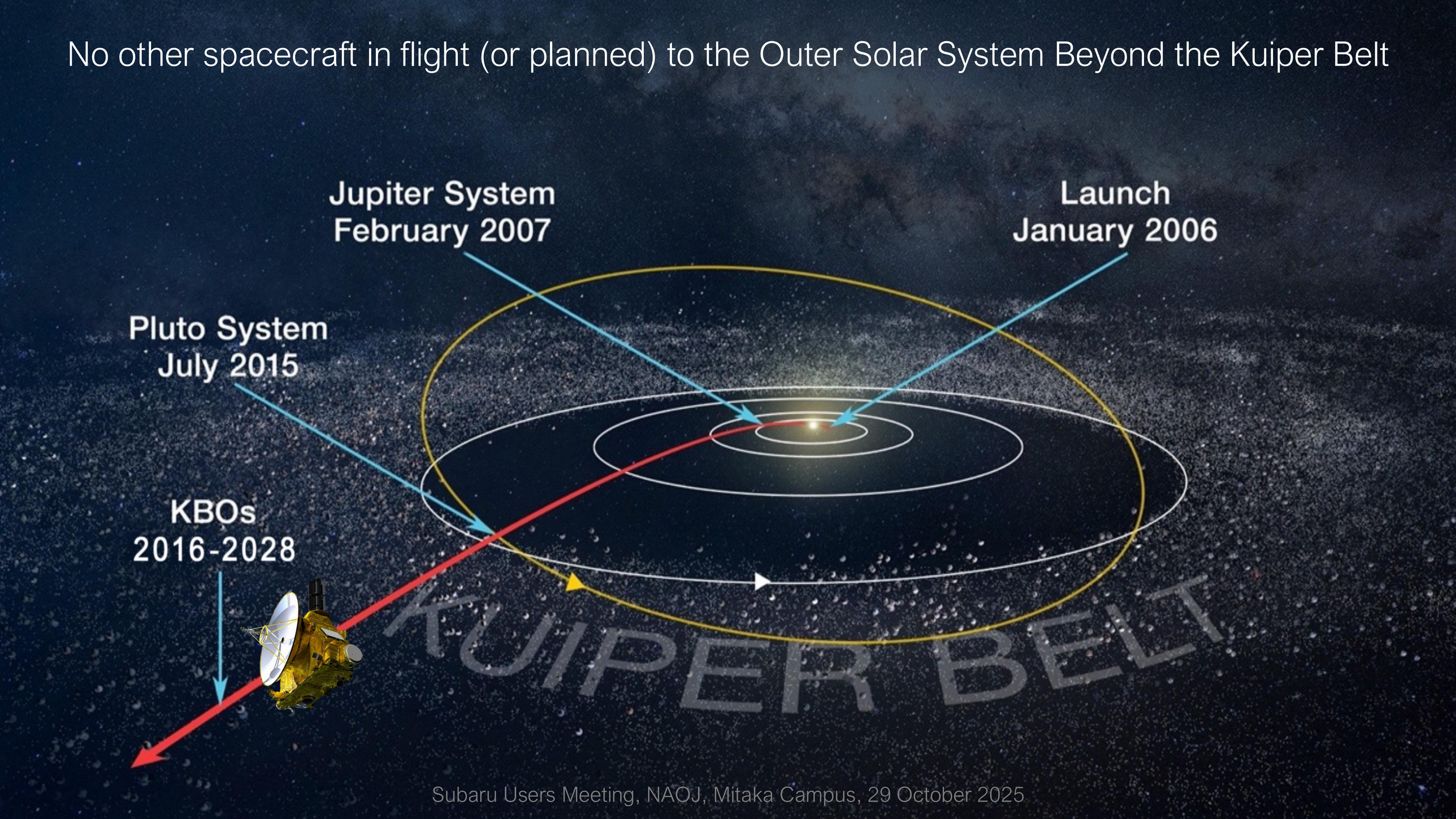
New Horizons' Unique Perspective From its Journey Through the Solar System



It’s all about the viewing geometry…

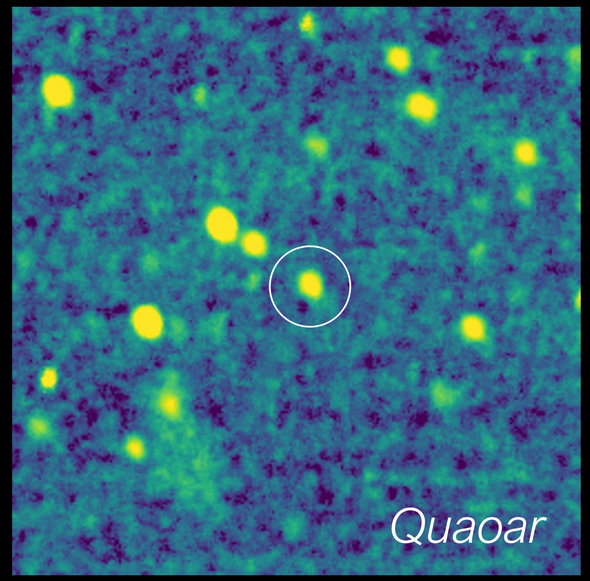


No other spacecraft in flight (or planned) to the Outer Solar System Beyond the Kuiper Belt



Two Types of New Horizons KBO Observations

Point-Source ‘Distant’ KBO (DKBO)

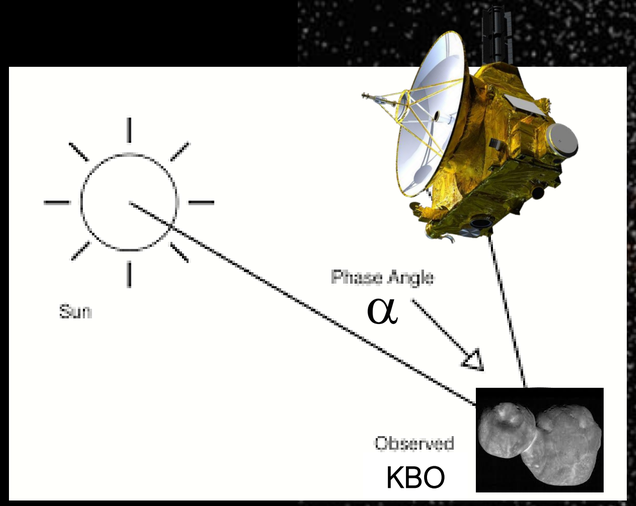


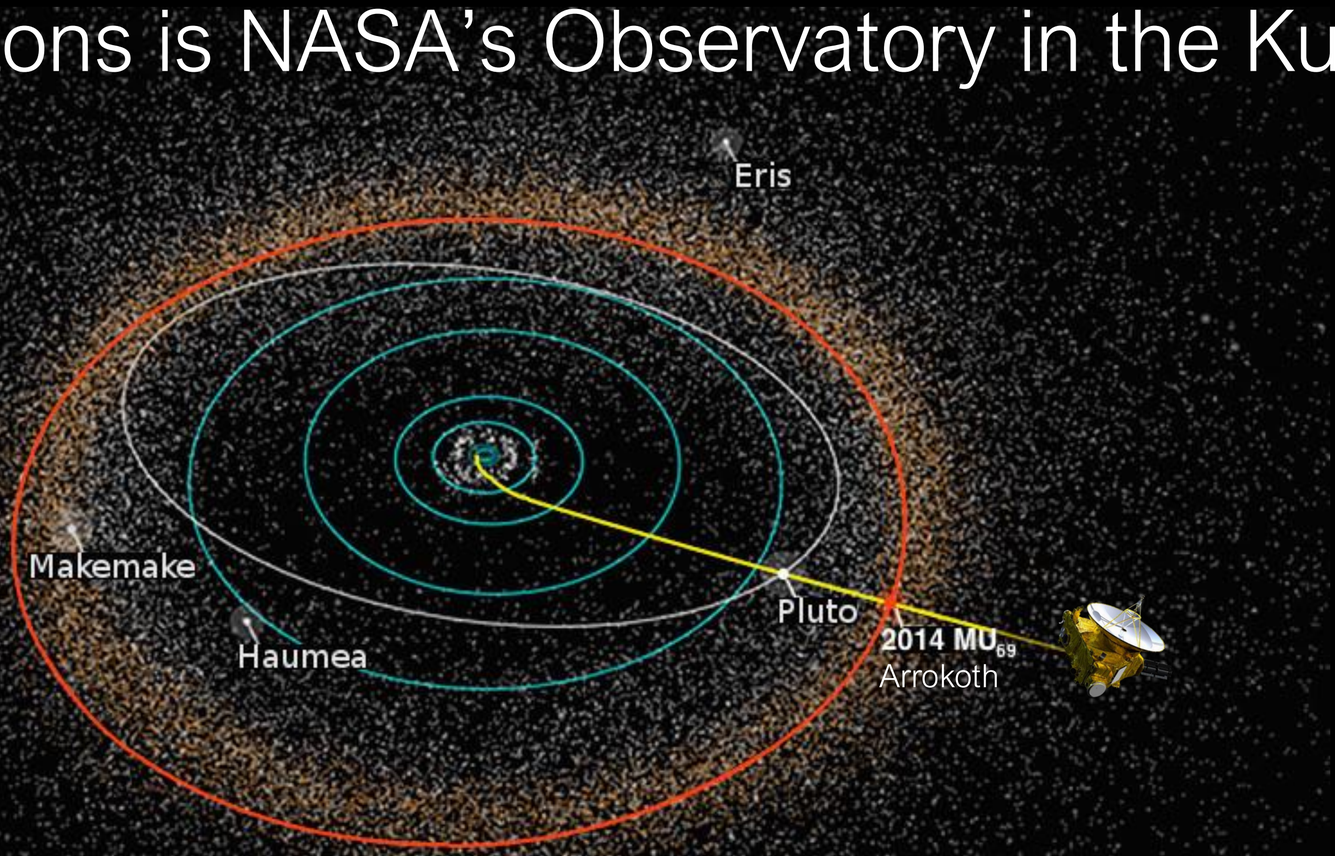
Spatially Resolved, Close ‘Flyby’

Arrokoth 2019

Goal from our searches with Subaru is to find targets for *both* types.

New Horizons is NASA's Observatory in the Kuiper Belt





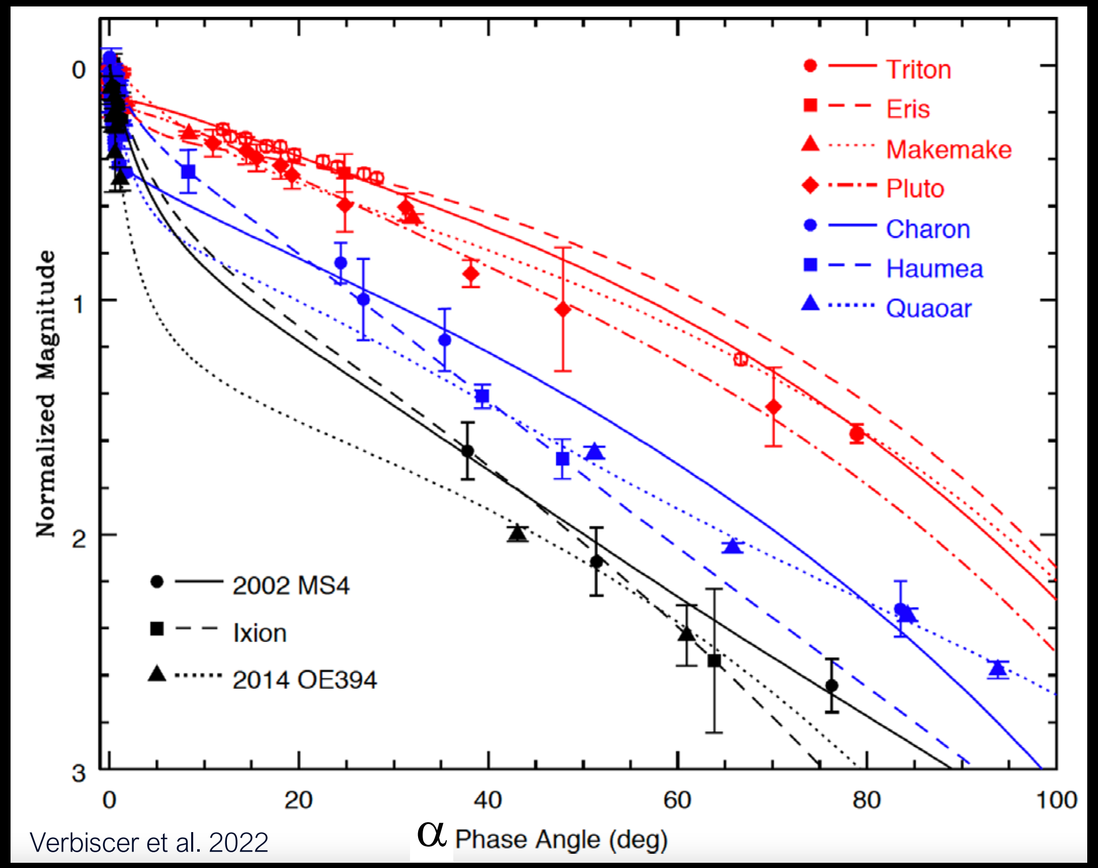
Since 2007, New Horizons has observed dwarf planets and other KBOs at unique viewing geometries only possible from a spacecraft in the outer solar system in addition to conducting heliophysics and astrophysics studies.

‘Distant’ KBOs & Dwarf Planets Observable by New Horizons by Dynamical Class (all point source observations)

Cold Classical	Hot Classical	Scattered Disk	Resonant	Large KBO ($H_V < 5$)	Dwarf Planet	Centaur
2004 LW_{31}	2012 HZ_{84}	2011 HK_{103}	2012 HE_{85}	Quaoar	Eris	Chiron
2011 HF_{103}	2011 HJ_{103}	2014 OJ_{394}	2018 MG_{13}	Ixion	Makemake	2010 JJ_{124}
2011 HZ_{102}		2020 KV_{11}	2020 KS_{11}	2014 OE_{394}	Haumea	
2011 JA_{32}		2020 KP_{11}		2002 KX_{14}		
2011 JW_{31}		2020 KH_{42}		2002 MS_4		
2011 JX_{31}		2020 KT_{11}				
2011 JY_{31}						
2014 OS_{393}						
2014 PN_{70}						
2018 MF_{13}						
2020 KR_{11}						

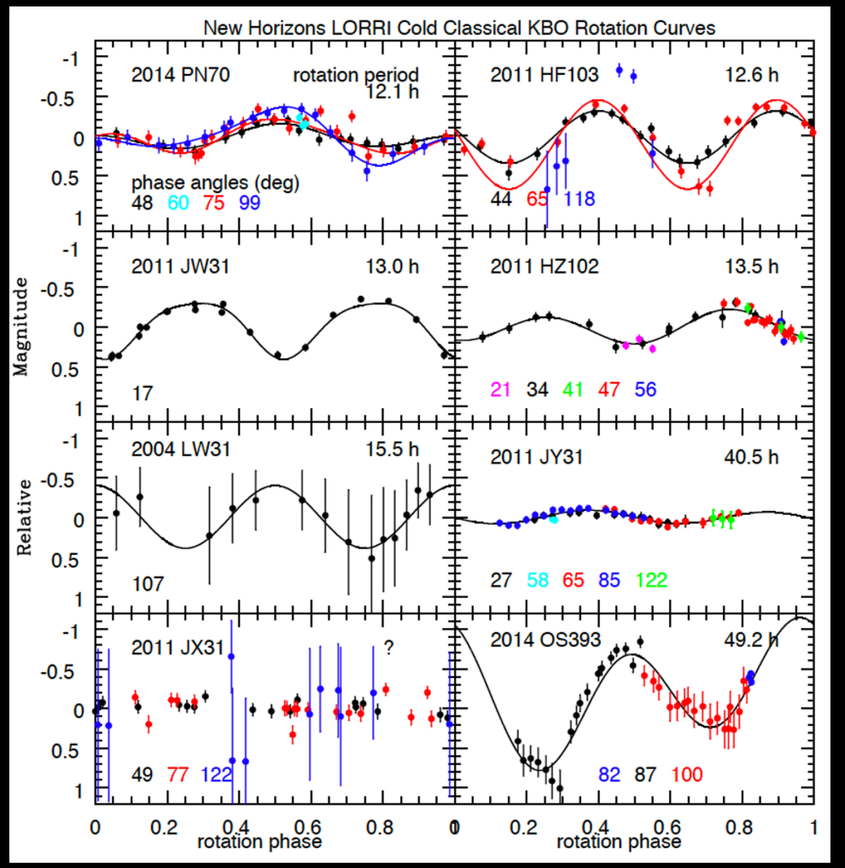
KBOs Discovered by Subaru HSC

KBOs at High Solar Phase Angles



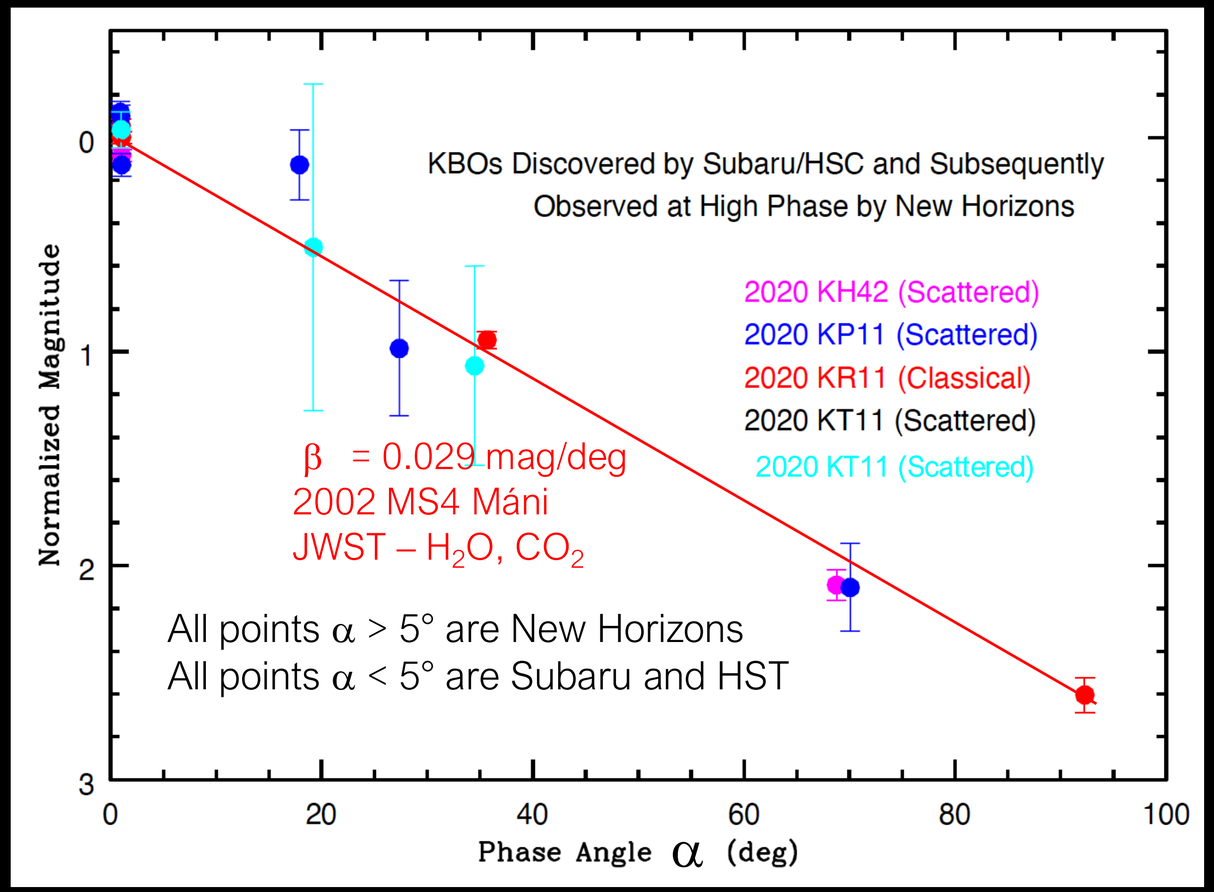
Verbiscer et al. 2022

Solar phase curves → surface microtexture



Rotation phase curves → shapes and poles

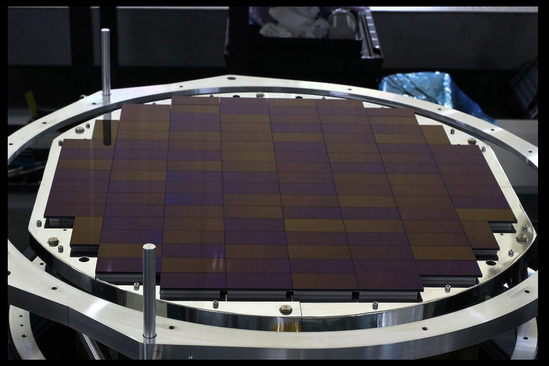
NH Subaru/HSC KBO Solar Phase Curves



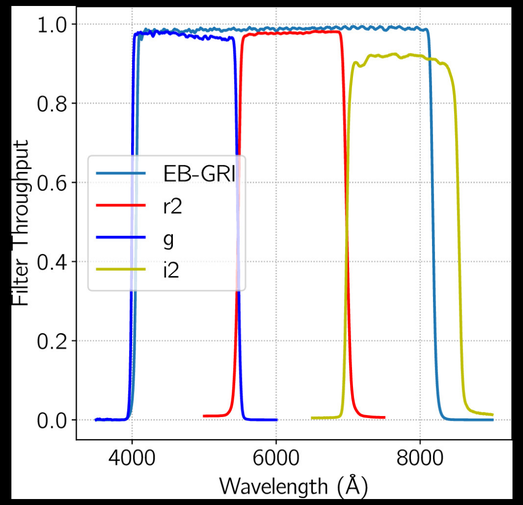
- Most Subaru KBOs have steep phase curves relative to other SS objects
  - strongly backscattering
  - hypervolatile-poor surfaces
- NH has not yet observed 2020 KV11:
  - scattered disk object
  - aphelion 154 au, beyond heliopause
  - observable (V<20.5) 2025 – 2028, α = 1°-98°
  - brightest (V=18.9) July 2027 α = 41°
  - NH observation planning started
- Compare properties of small, outer KBOs:
  - space weathering via phase curve modeling
  - shape, pole analyses via rotation curves

Searching for KBO Targets for New Horizons with Subaru Telescope – Summary

- 2014 Suprime-Cam follow-up observations
- 2020 HSC discovery observations
  - Japanese collaborators added
- 45 HSC half nights
  - Magnitude limit (thru 2023) r ~ 26.5
- 7 new New Horizons targets:
  - 5 observed in 2020
  - 1 observed in 2023
  - 1 best observed in 2027
- 294 new KBOs (thru 2025)
  - 51 new in 2024, follow up in 2025
  - 239 Fraser et al. (2024) *PSJ*
  - 2 Yoshida et al. (2024) *PASJ*
  - *2 More Just Added (2025) See Yamashita P7 & Shibukawa P10 Posters!!*



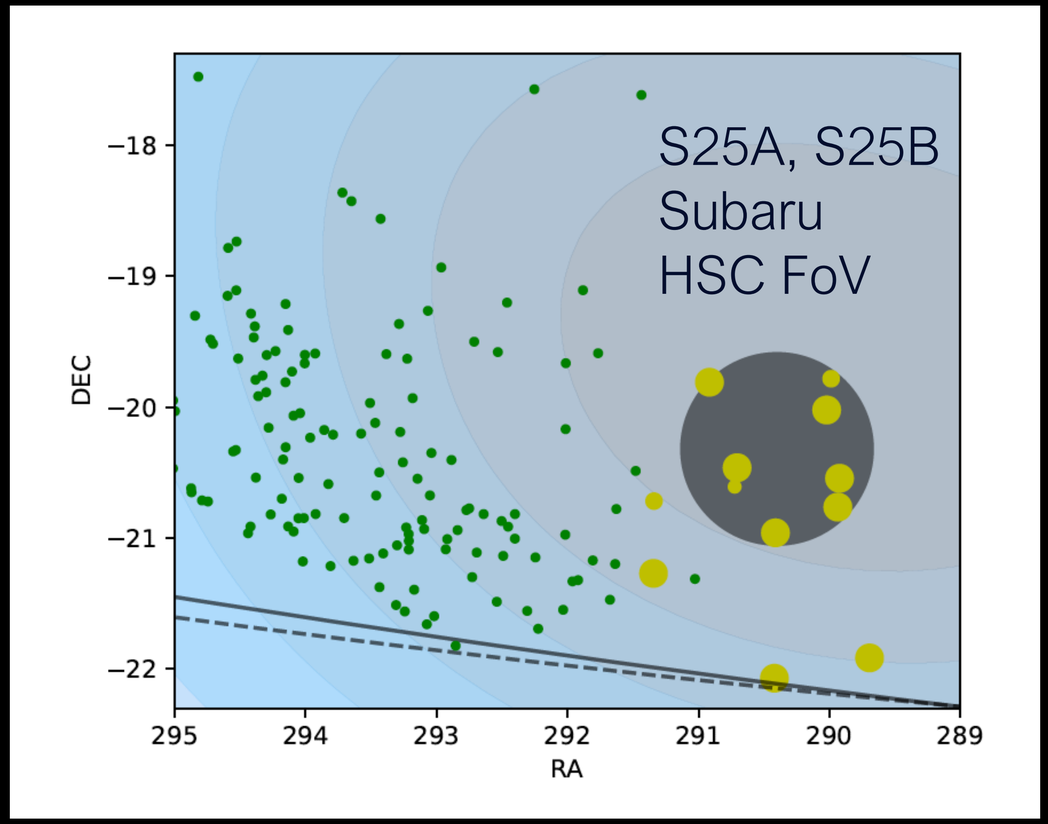
HSC 116 CCDs



Extreme wide-Band EB-*gri* filter (since 2023)
Provided by New Horizons Project

Searching for KBO Targets for New Horizons with Subaru Telescope – Summary

- 2025 Observations
  - July 20, 21 half nights in S25A
  - August 21 half night in S25B
- Reductions and subtractions
  - using the latest LSST pipeline
- Shift and stack search
- Machine learning source rejection
  - see poster P10 Shibukawa et al.



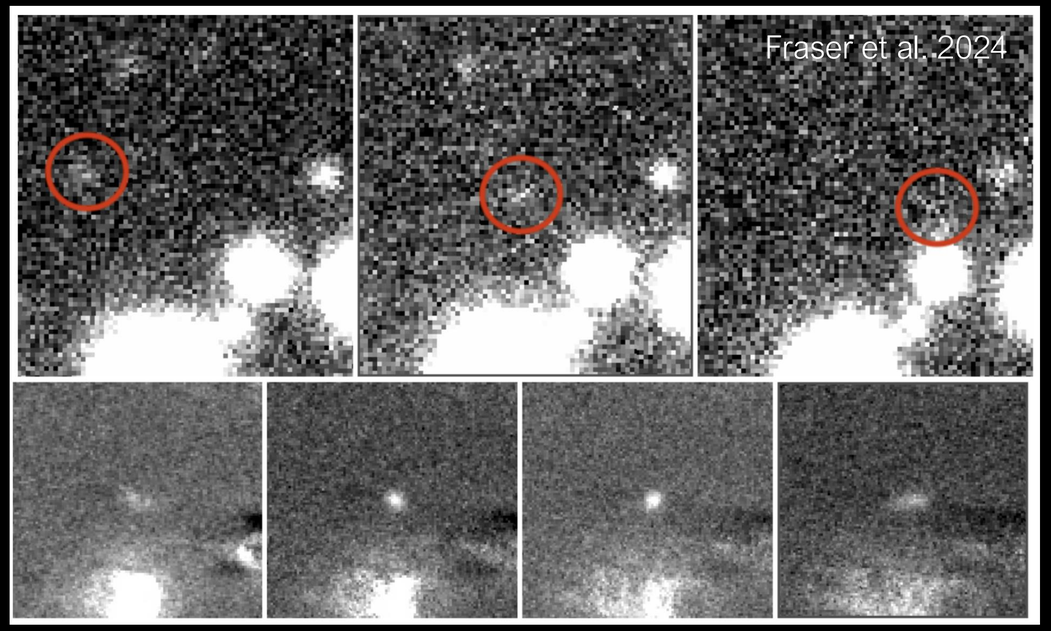
Green dots – all KBOs discovered by Subaru, no longer observable by NH
Yellow dots – locations of KBOs >60 au discovered by Subaru; size:orbit arc length

Searching for KBO Targets for New Horizons with Subaru Telescope – Summary

- Observations S25A, S25B
- Reductions and subtractions
  using the latest LSST pipeline
- Shift and stack search
- Machine learning source rejection

- See Poster P10 Shibukawa et al. Convolutional Neural Network (CNN) technique.

Detection of real KBO via shift & stack search



1.5”/hr 2.0”/hr 2.5”/hr 3.0”/hr

Actual = 1.9”/hr

Searching for KBO Targets for New Horizons with Subaru Telescope – Summary

- Observations S25A, S25B
- Reductions and subtractions
  using the latest LSST pipeline
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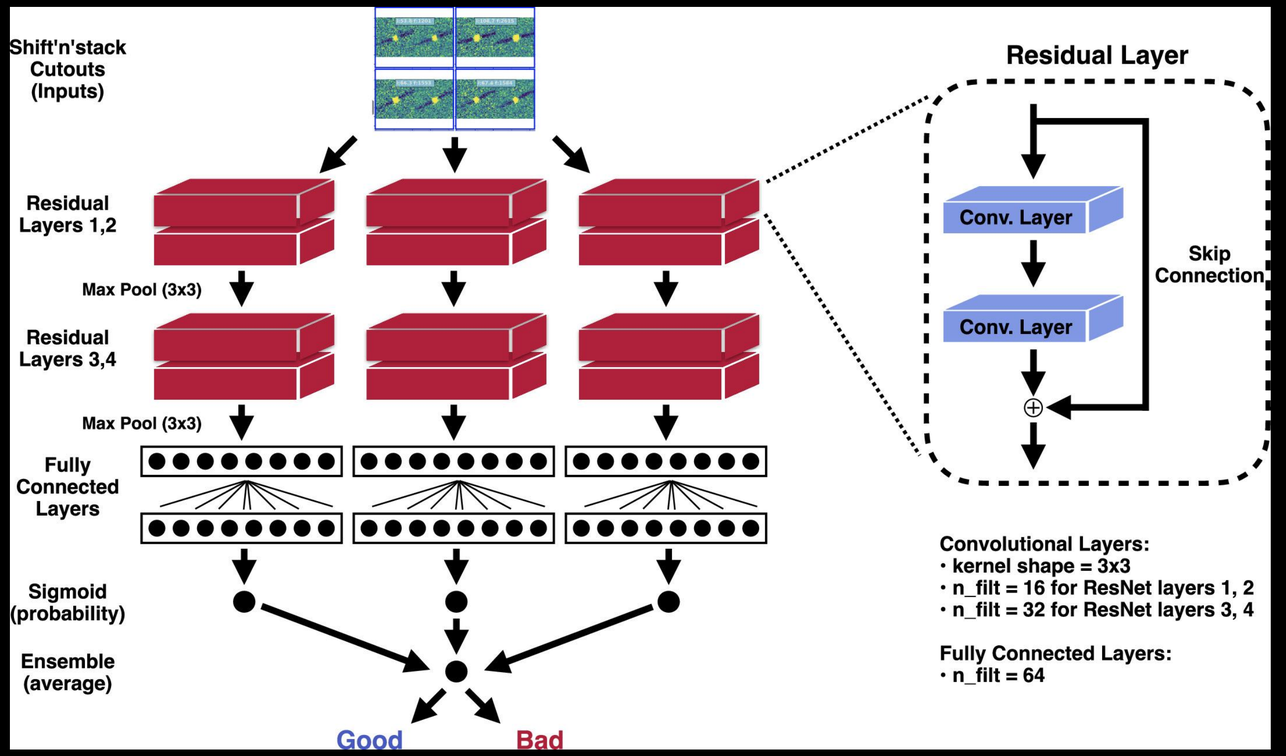
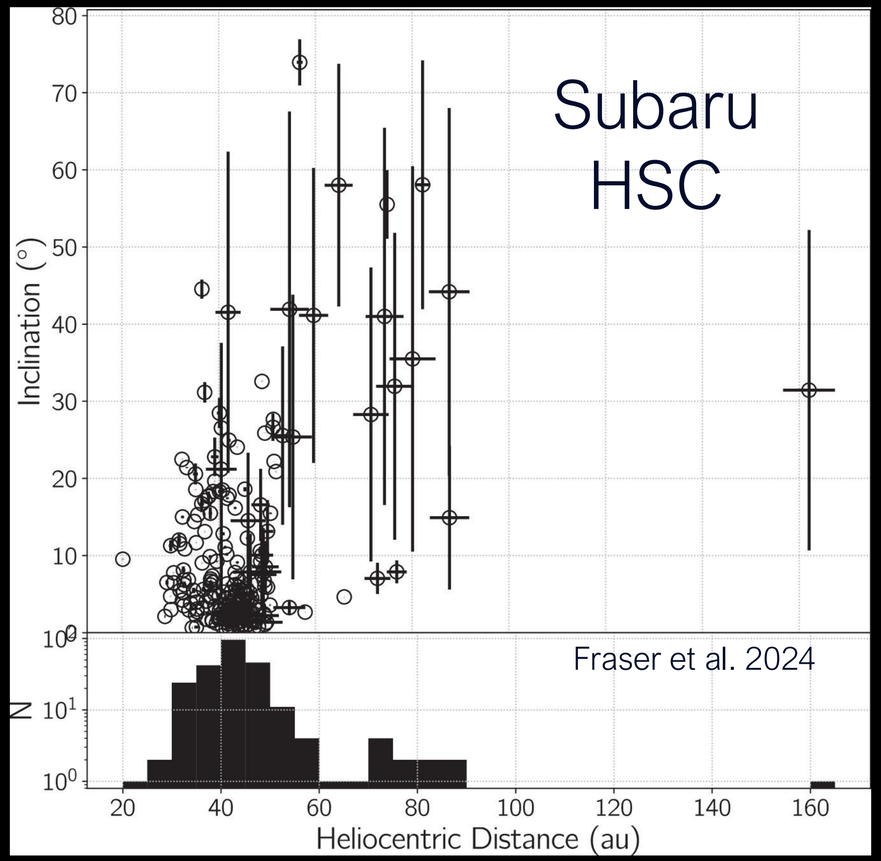
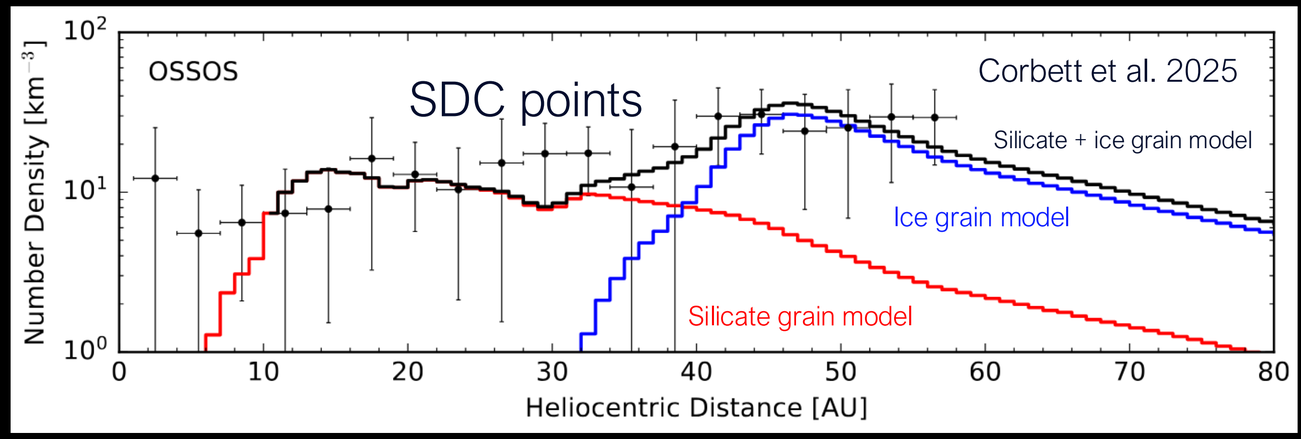


Fraser et al. 2024

Searching for KBO Targets for New Horizons with Subaru Telescope – Results



Evidence for an extended Kuiper Belt?
Potential for a major discovery!



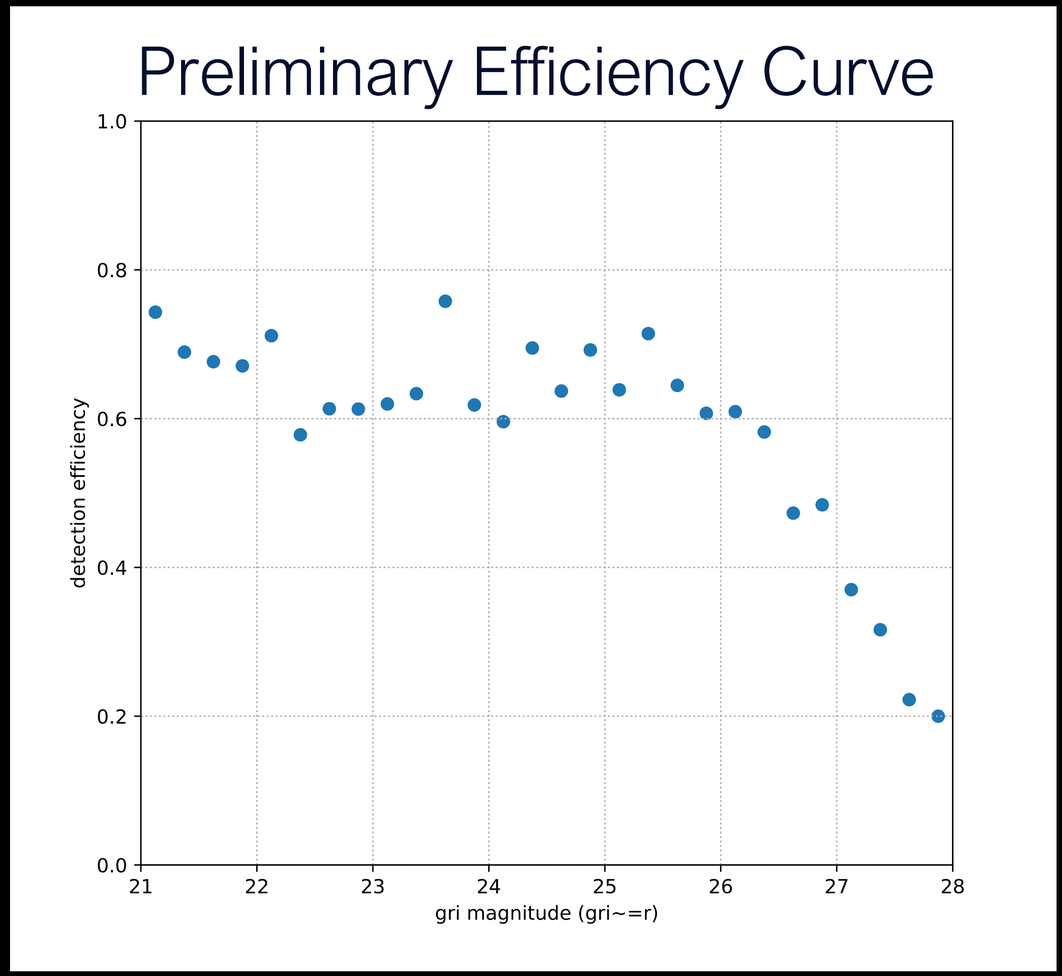
New Horizons Student Dust Counter (SDC) Flux

294 new KBOs, including 11 with R > 70 au (5x more than OSSOS++ model predicts)

Searching for KBO Targets for New Horizons with Subaru Telescope in 2024-2025

- 8.5 half nights 2024
  - 51 discoveries, so far
- 3 half nights in 2025
  - follow up 2024 discoveries
  - extend orbit arcs

- Analysis ongoing
- Magnitude limit r ~ 27



Wes Fraser

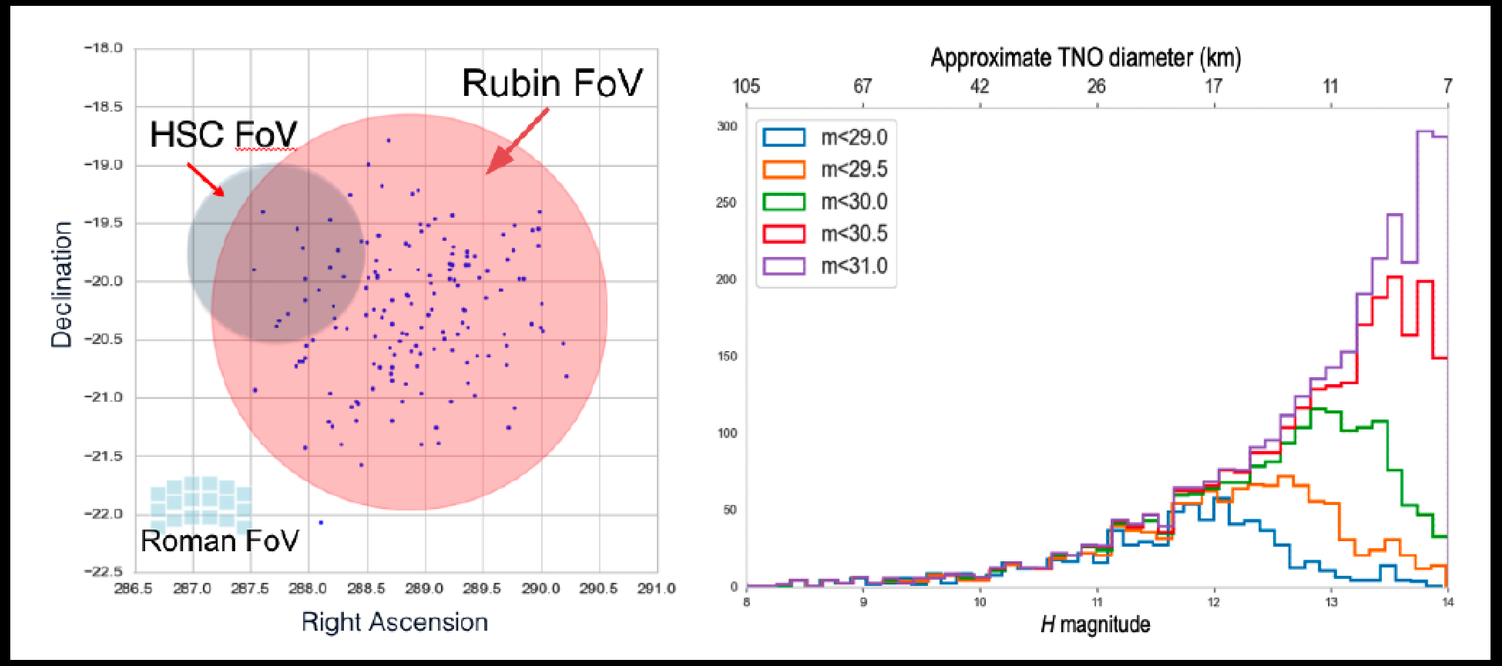
Searching for KBO Targets for New Horizons with Rubin Observatory

- Proposed a 30-hr ‘micro-survey’
  Kavelaars et al. 2025, *ApJS*
- Magnitude limit r ~ 27.5
- Expect ~730 new KBOs
  ~12 observable by NH
  ~1 within 1 au of NH
  → may resolve ‘tight’ binaries
- Magnitude limit r ~ 28 with 75 hrs

- Commissioning observations May-August
  results TBD

Searching for KBO Targets for New Horizons with Roman Space Telescope

- Cycle 1 Call for General Astrophysics Survey Proposals
  release date: November 2025 deadline: early March 2026
- Magnitude limit r ~ 30
- Expect ~900 new KBOs



Searching for KBO Targets for New Horizons with Subaru Telescope – Summary

- Complete 2024-25 Data Analysis
  - report discoveries (at least 51) to MPC
  - still more objects R>70 au than expected?
  - potential for a major discovery!
- Proposals going forward (S26A →)
  - led by Japanese collaborators (Ito, Yoshida, et al.)
- Use of Rubin, Roman Telescopes
  - reach magnitudes r~27.5, r ~30
- Observe new KBOs with New Horizons
  - can accommodate close flyby for at least a decade
    - power available until ~2050
    - limited remaining fuel for ΔV, flyby activities