Searching for New Horizons Targets in the Distant Kuiper Belt: Summary and Future Prospects

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Subaru Users Meeting, NAOJ, Mitaka Campus, 28 January 2025

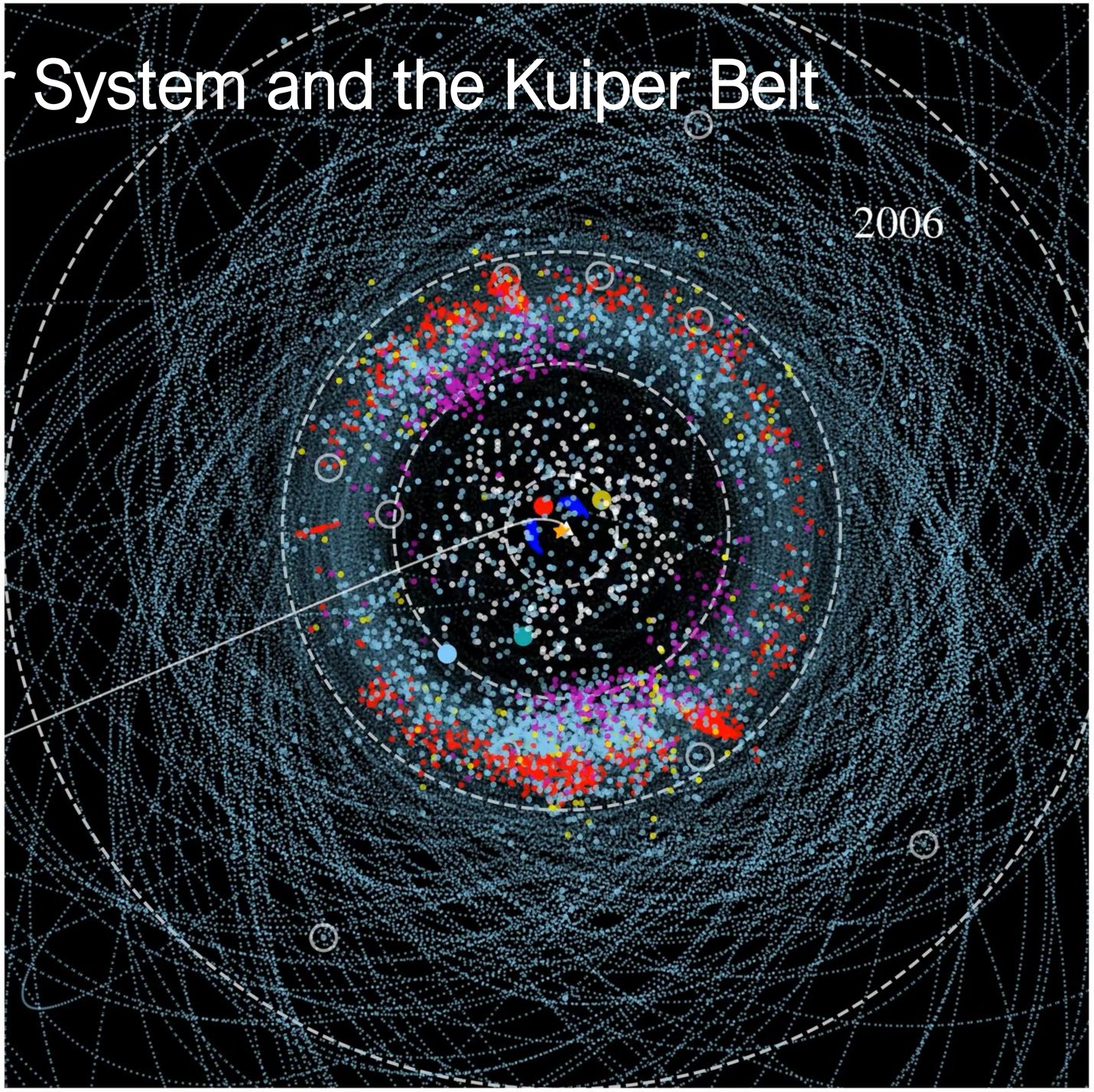
The Solar System and the Kuiper Belt

▲ New Horizons Spacecraft Location

★ Sun

○ Dwarf Planets, Large Kuiper Belt Objects (KBOs)

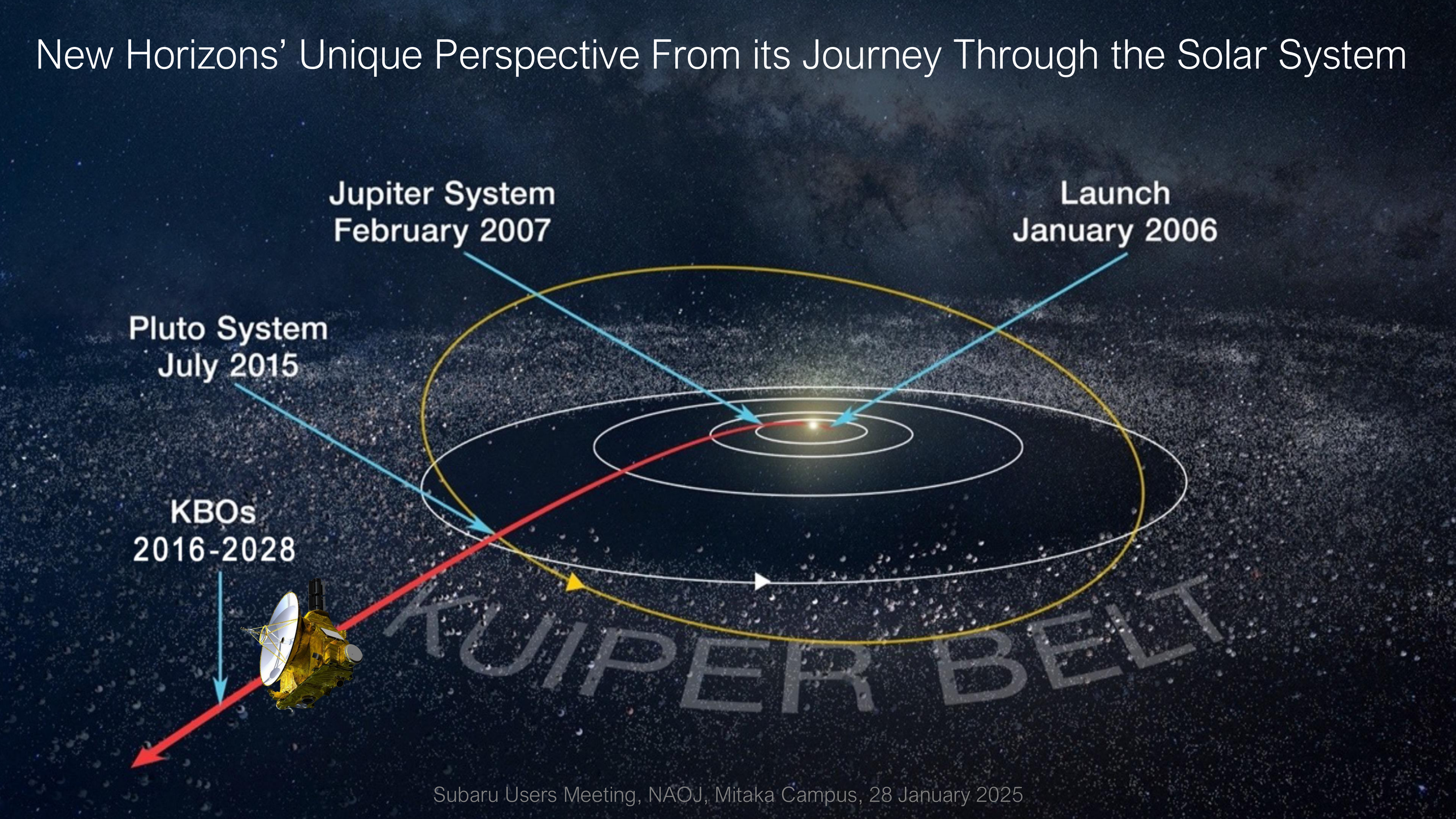
● Neptune



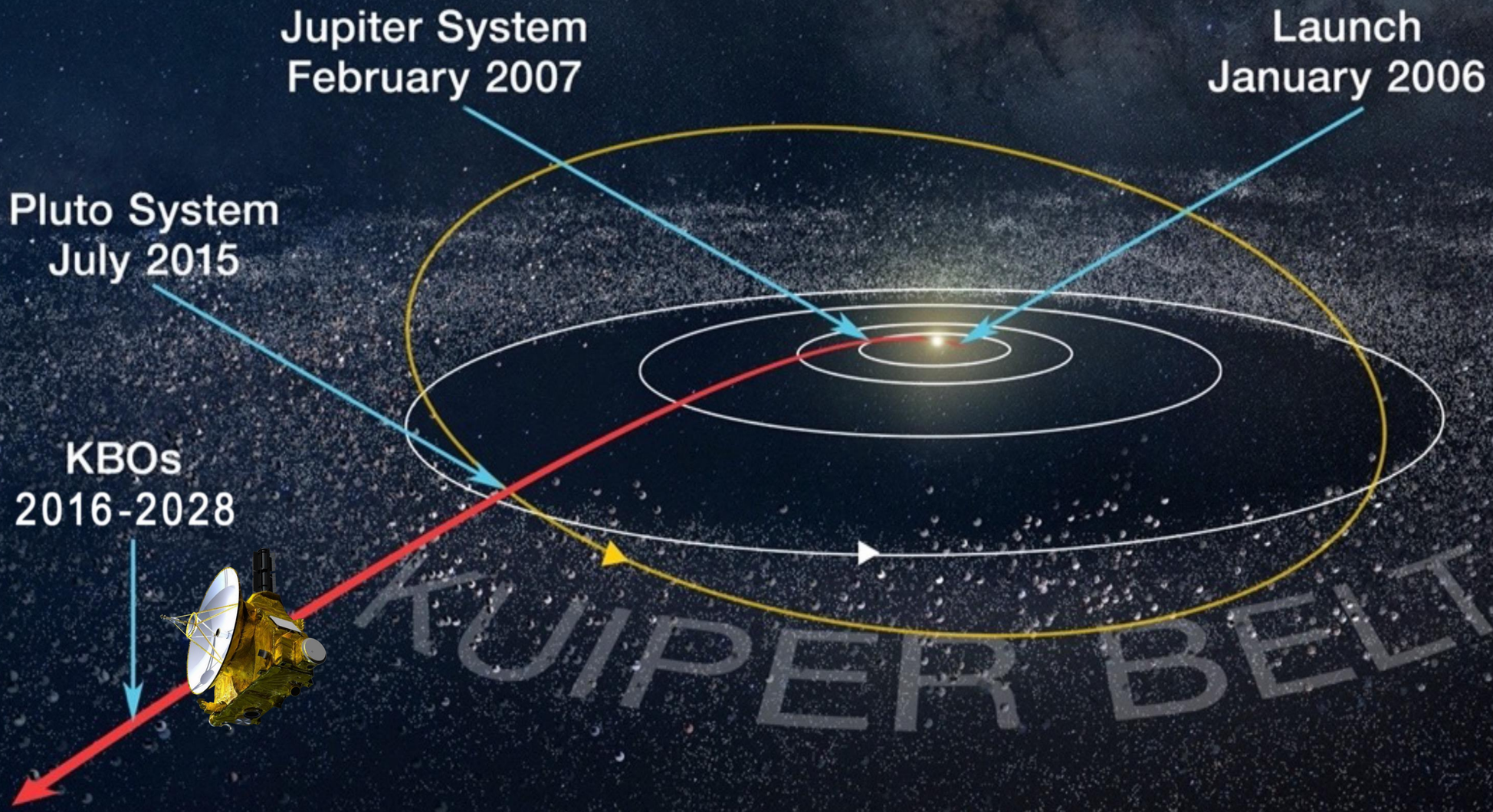
Cold Classical KBOs
Plutinos
Centaurs
Jupiter Trojans
Scattered Disk
(other) Resonant KBO

Credit: Wes Fraser

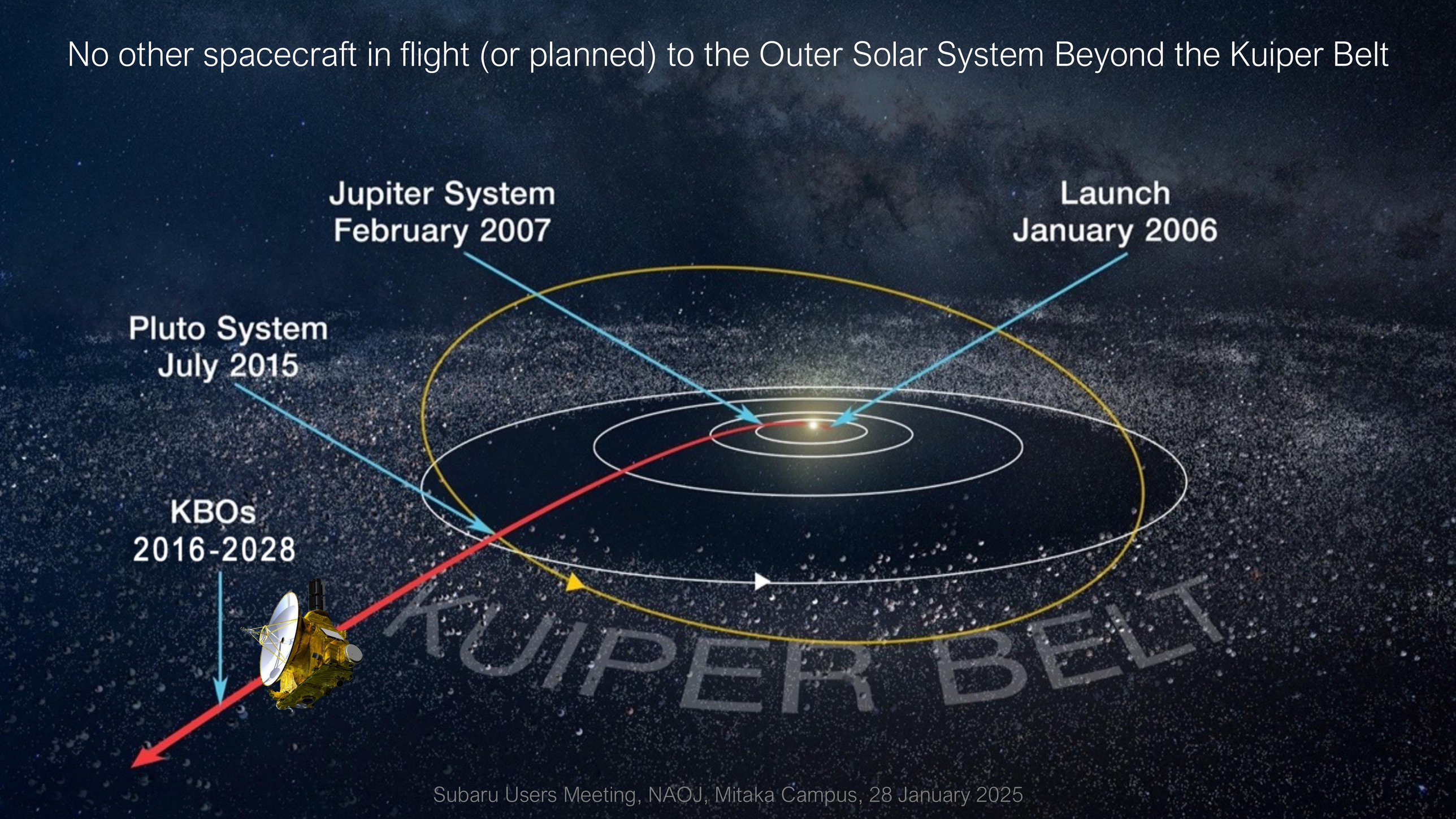
New Horizons' Unique Perspective From its Journey Through the Solar System



It’s all about the viewing geometry…

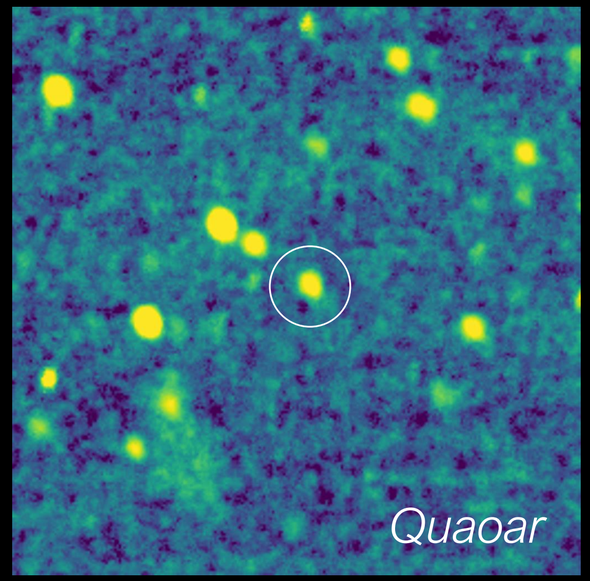


No other spacecraft in flight (or planned) to the Outer Solar System Beyond the Kuiper Belt



Two Types of New Horizons KBO Observations

Point-Source ‘Distant’ KBO (DKBO)

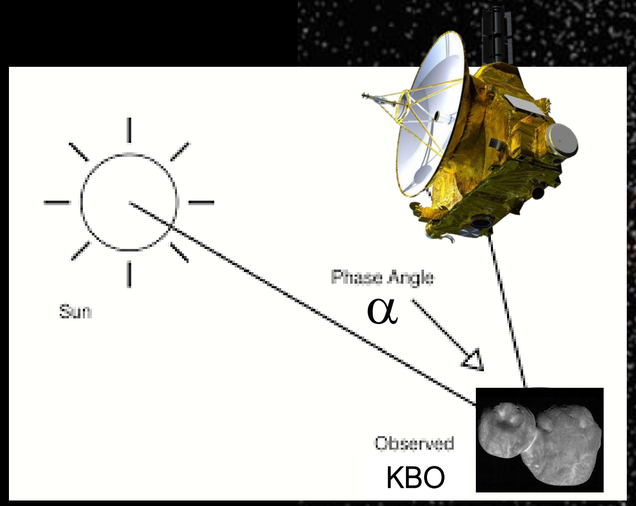


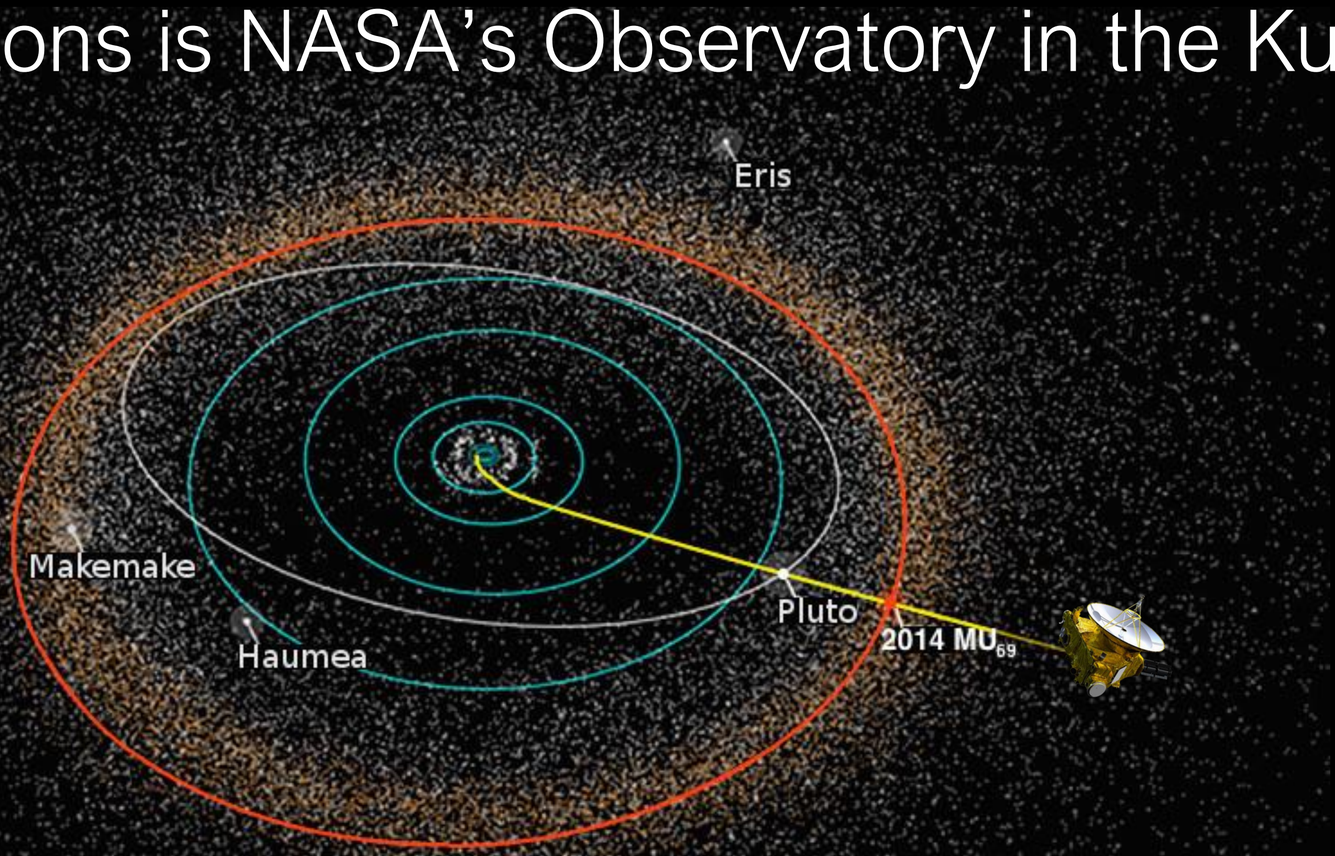
Spatially Resolved, Close ‘Flyby’

Arrokoth

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

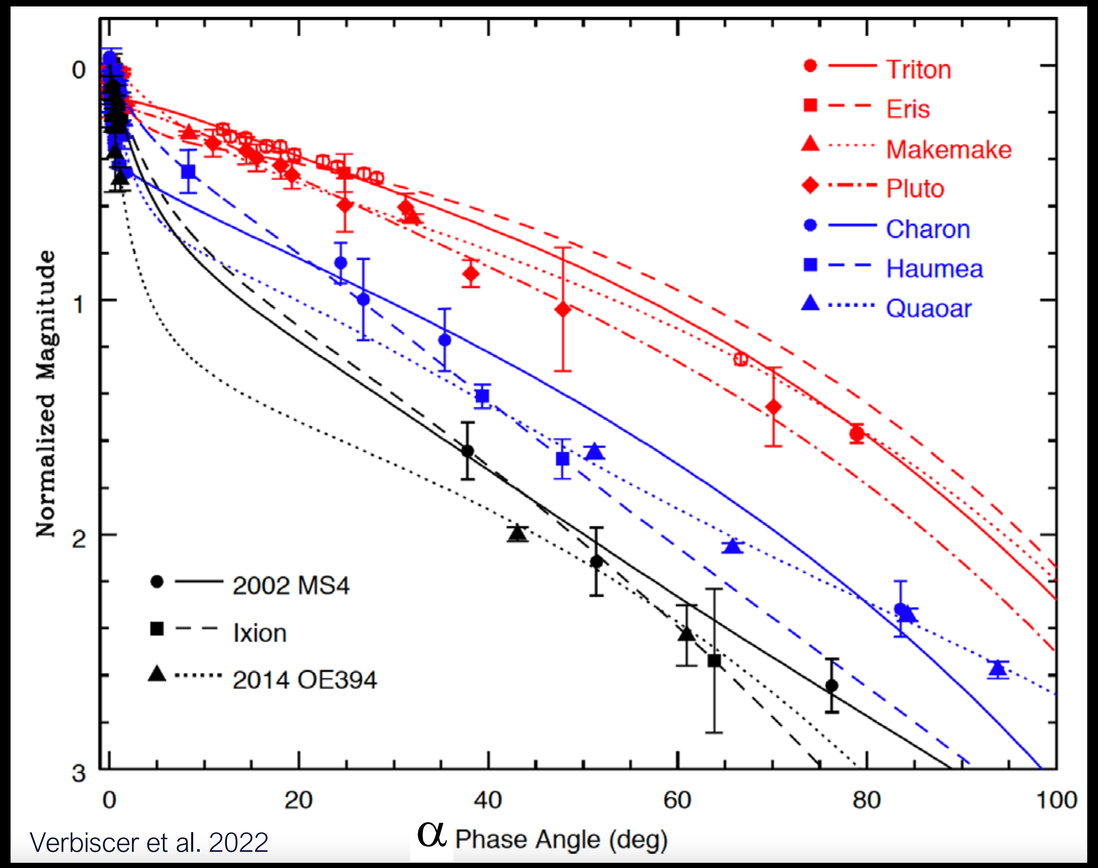
New Horizons is NASA's Observatory in the Kuiper Belt

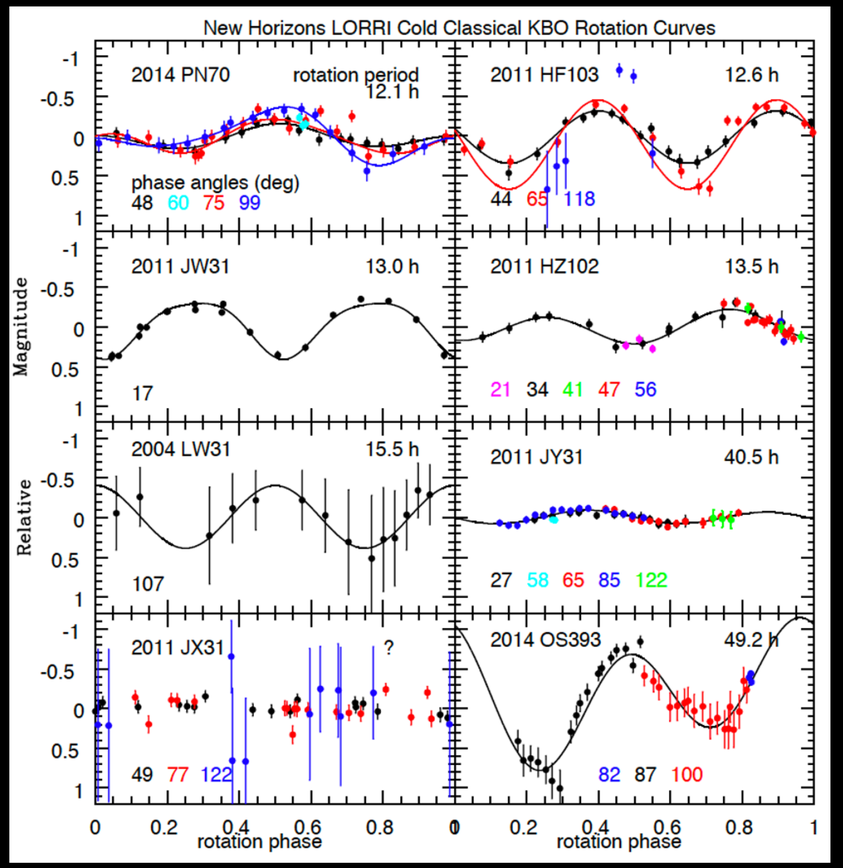




Since 2007, New Horizons has observed dwarf planets and other KBOs at unique viewing geometries only possible from a spacecraft in the outer solar system in addition to conducting heliophysics and astrophysics studies.

KBOs at High Solar Phase Angles

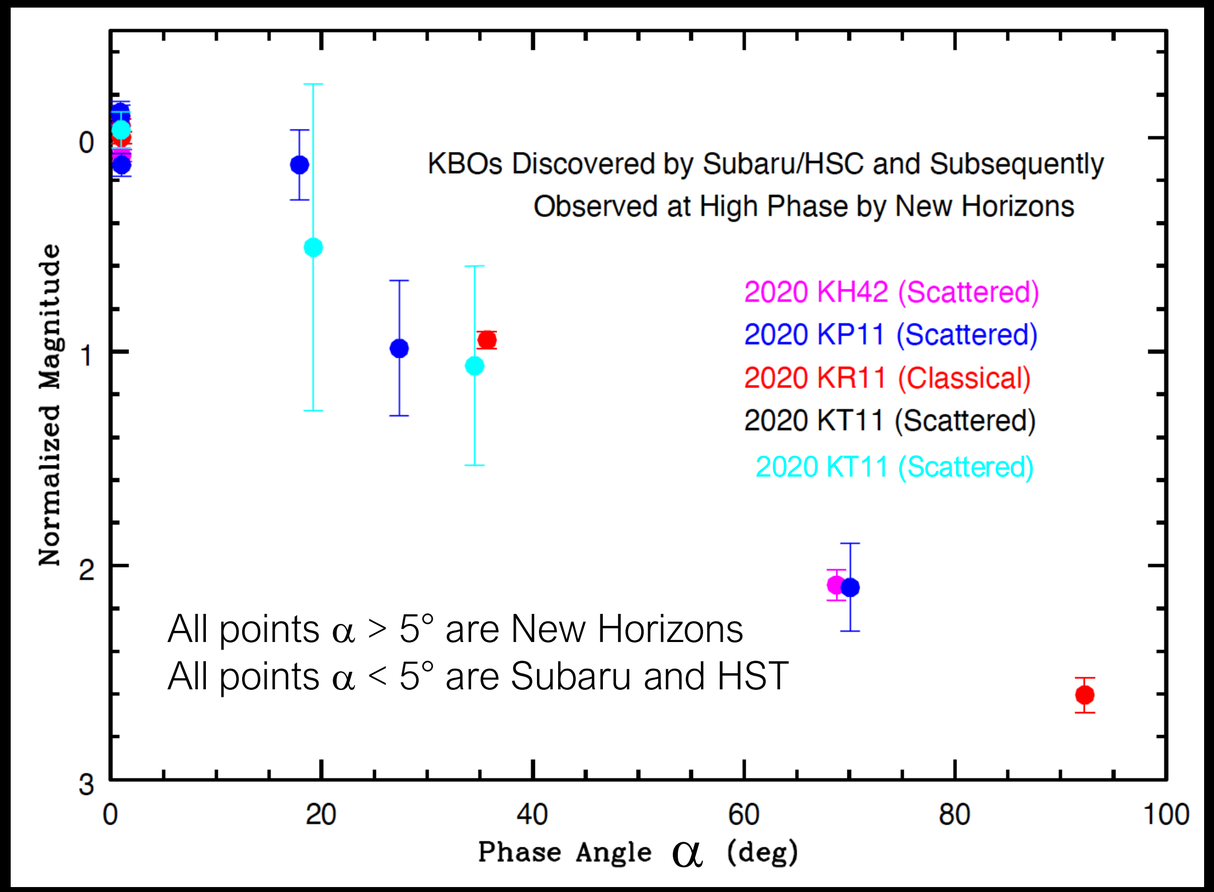




Solar phase curves → surface microtexture

Rotation phase curves → shapes and poles

NH Subaru/HSC DKBO Solar Phase Curves



- Most Subaru DKBOs have steep phase curves relative to other SS objects
  - strongly backscattering
  - volatile-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°
- Compare properties of small, outer KBOs:
  - space weathering via phase curve modeling
  - shape, pole analyses via rotation curves

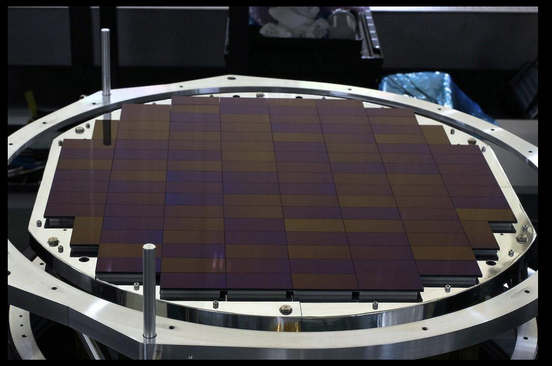
New Horizons 'Distant' KBOs & Dwarf Planets by Dynamical Class (all point source observations)

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}						

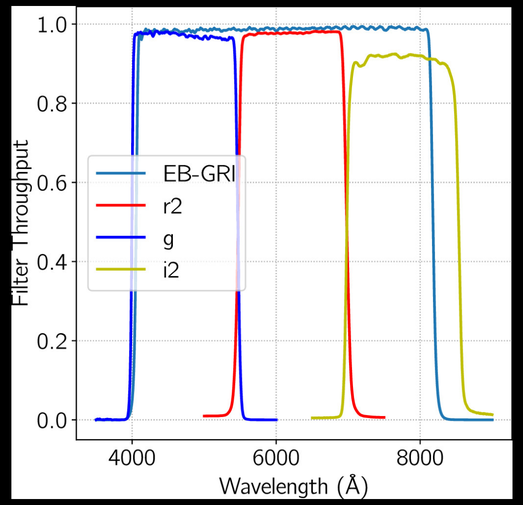
KBOs Discovered by Subaru HSC

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

- Began in 2020
  with Japanese collaborators added
- 42 half nights to date
- Magnitude limit (thru 2023) r ~ 26.5
- 7 new targets for New Horizons:
  - 5 observed in 2020
  - 1 observed in 2023
  - 1 best observed in 2027
- 241 new KBOs (thru 2023)
  - 239 Fraser et al. (2024) *PSJ*
  - 2 Yoshida et al. (2024) *PASJ*



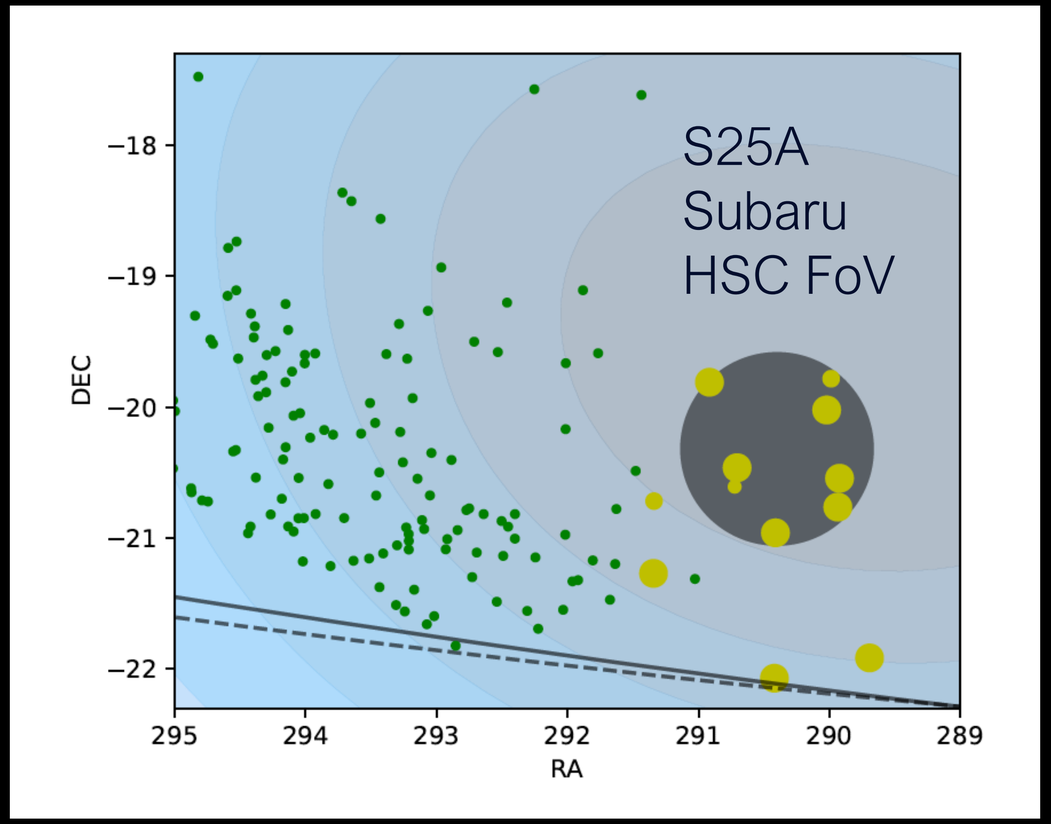
HSC 116 CCDs



Extreme wide-Band EB-GRI Filter (since 2023)
Provided by New Horizons Project

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

- Observation Planning
  July 20, 21 half nights in S25A
  using NASA/Keck exchange time
- Reductions and subtractions
  using the latest LSST pipeline
- Shift and stack search
- Machine learning source rejection



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 – Process

- Observation Planning
- Reductions and subtractions
  using the latest LSST pipeline
- Shift and stack search
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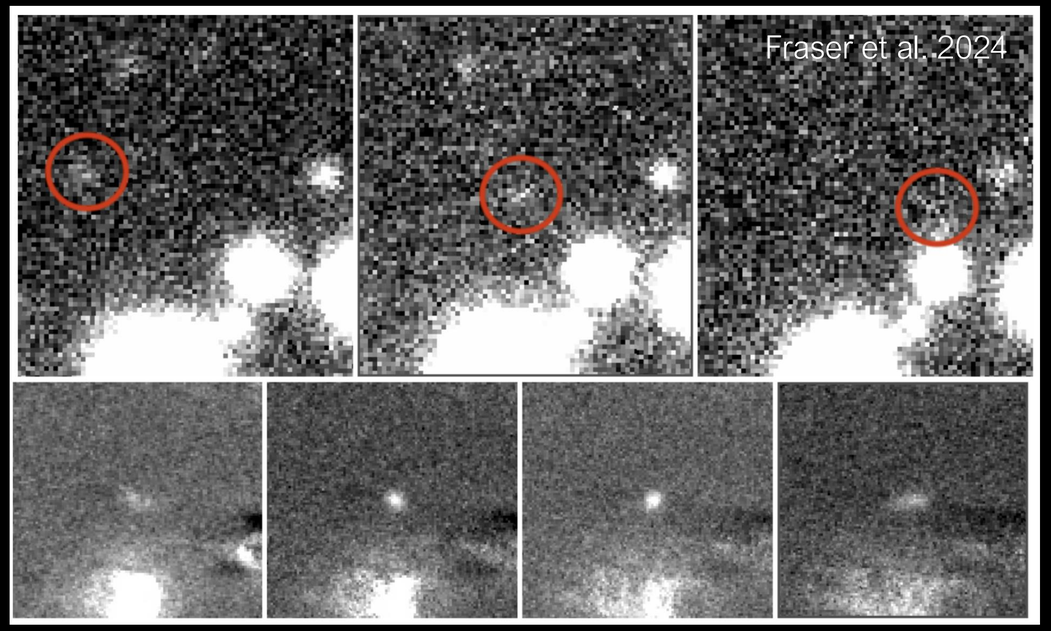
Detection of real KBO via shift & stack search

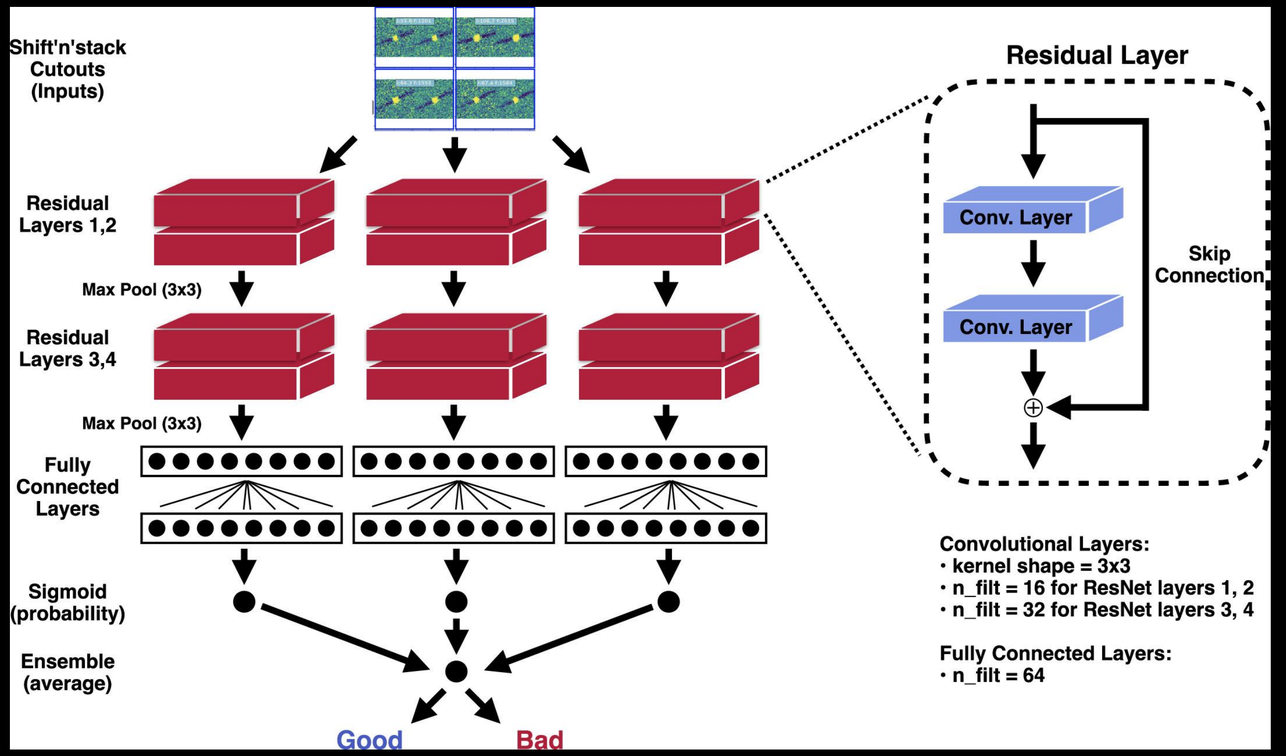


1.5”/hr 2.0”/hr 2.5”/hr 3.0”/hr

Actual = 1.9”/hr

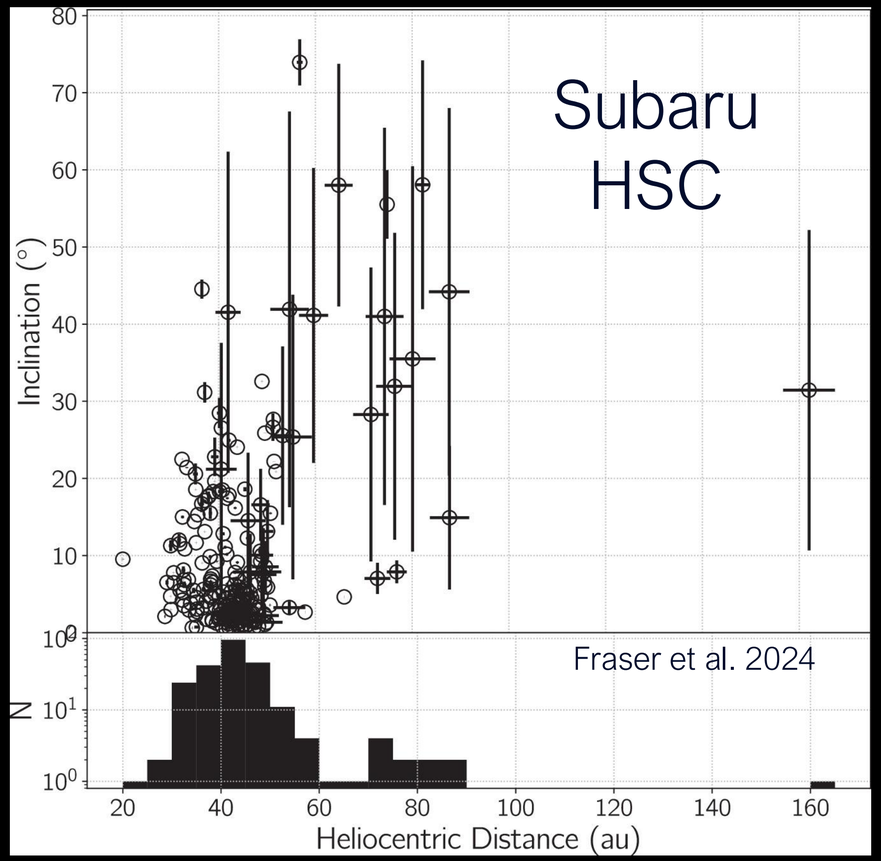
Searching for KBO Targets for New Horizons with Subaru Telescope – Process

- Observation Planning
- Reductions and subtractions
  using the latest LSST pipeline
- Shift and stack search
- Machine learning source rejection
  See Sibukawa-San talk on Friday

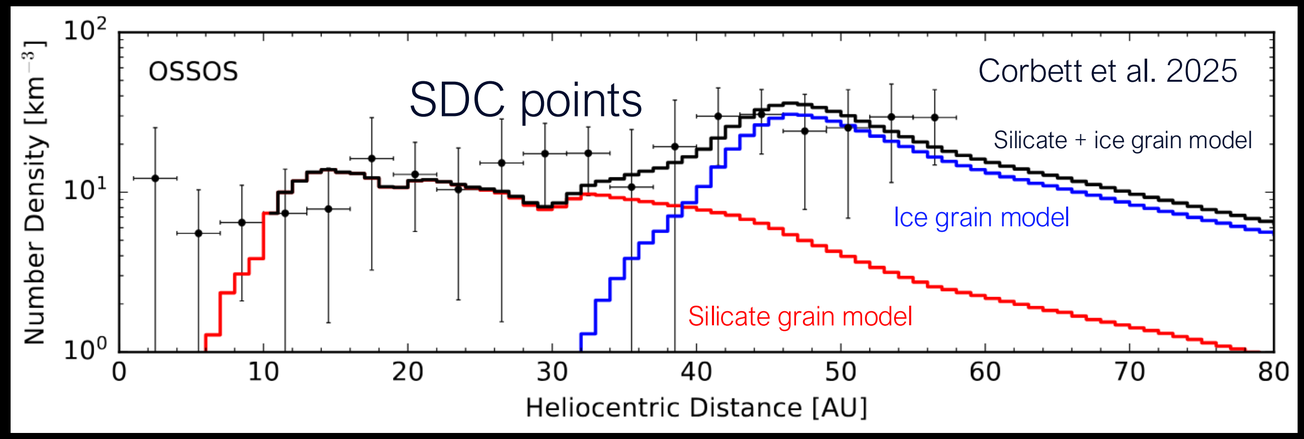


Fraser et al. 2024

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



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

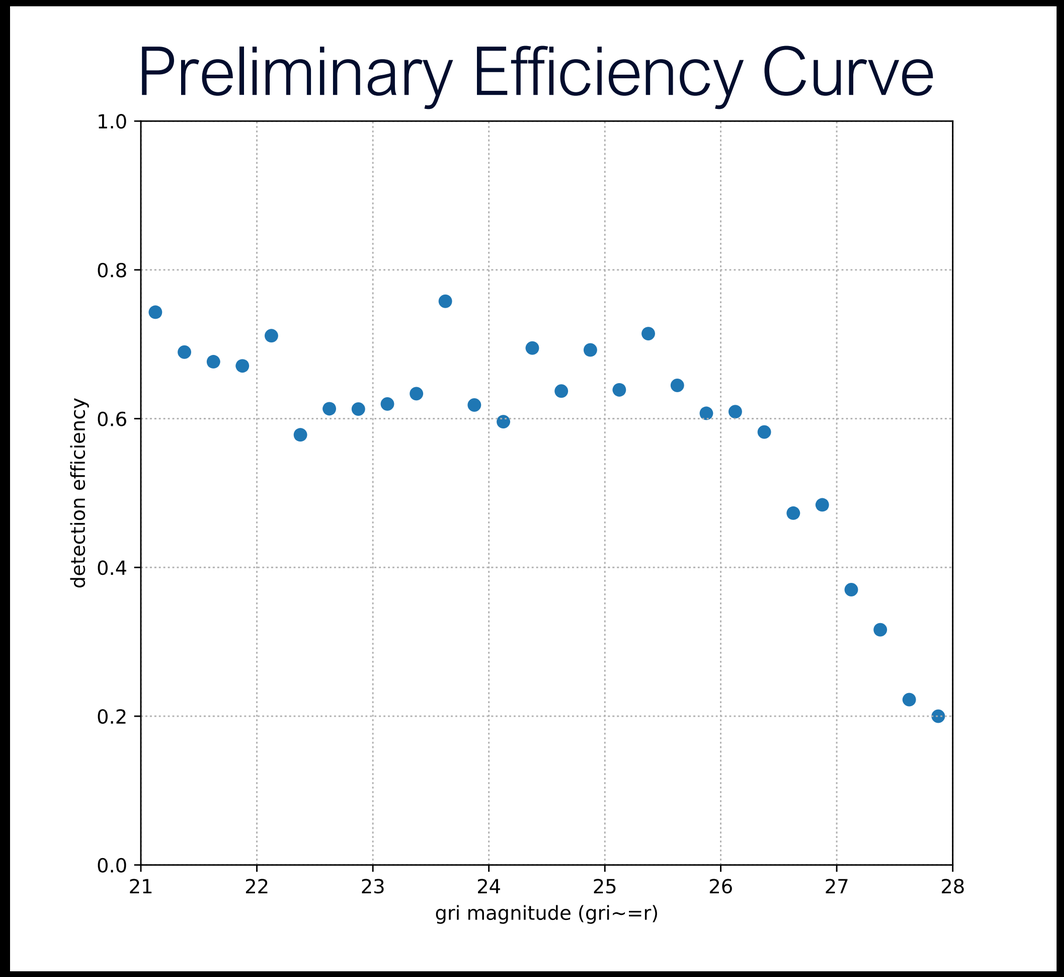


New Horizons Student Dust Counter (SDC) Flux

241 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

- 8 half nights in 2024
- Analysis ongoing
- Magnitude limit r ~ 27



Wes Fraser

Searching for KBO Targets for New Horizons with Rubin Observatory

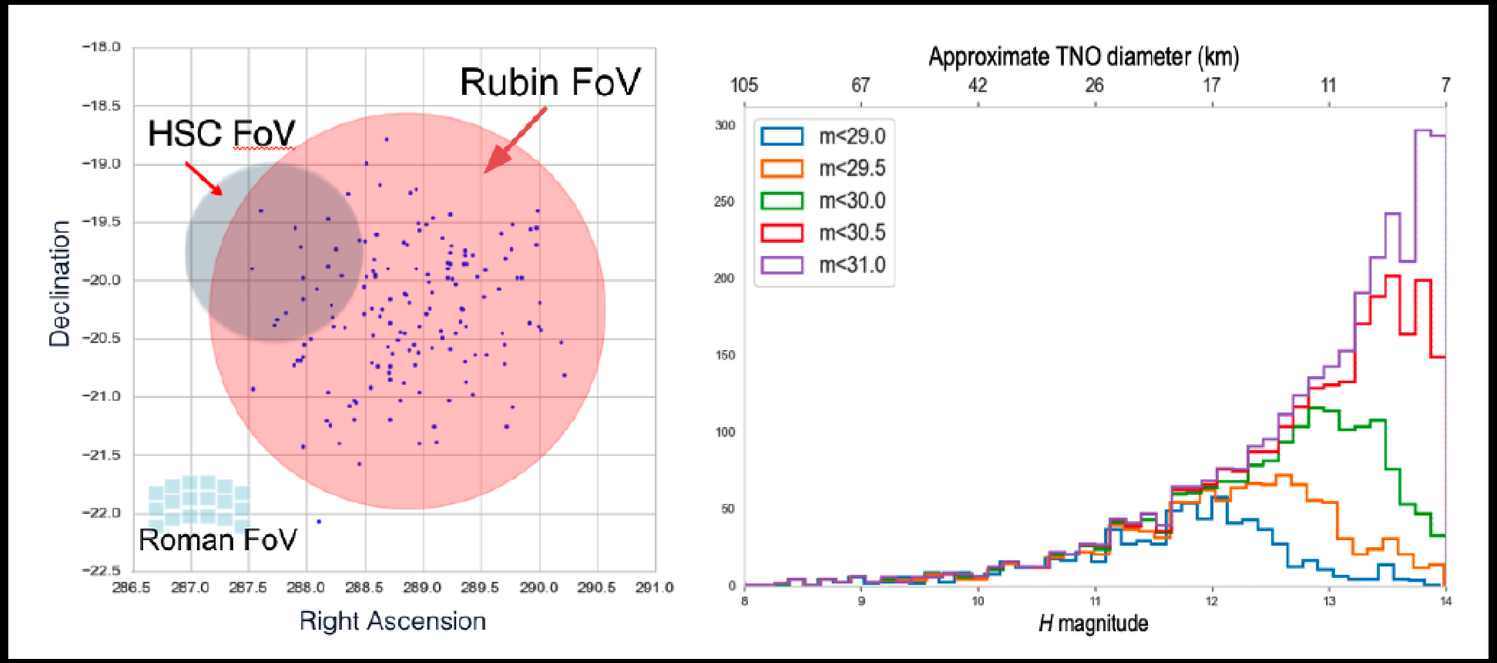
- Proposed a 30-hr ‘micro-survey’
  Kavelaars et al. 2025, *ApJS*
- Magnitude limit r ~ 27.5
- Expect ~730 new KBOs
  ~12 observable by NH
  ~1 within 1 au of NH
  → may resolve ‘tight’ binaries

- Magnitude limit r ~ 28 with 75 hrs

Searching for KBO Targets for New Horizons with Roman Space Telescope

- White paper submitted to Galactic Plane Community Survey Benecchi et al. 2024
- Magnitude limit r ~ 30
- Expect ~900 new KBOs

Preliminary Efficiency Curve



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

- Follow Up Observation Planning
  July 20, 21 S25A half nights
- Complete 2024 Data Analysis
  more objects R>70 au than expected?
- 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