New Horizons Kuiper Extended Mission 1 Science Overview and Distant KBO Campaign

FOUR+ YEARS OF DISCOVERY

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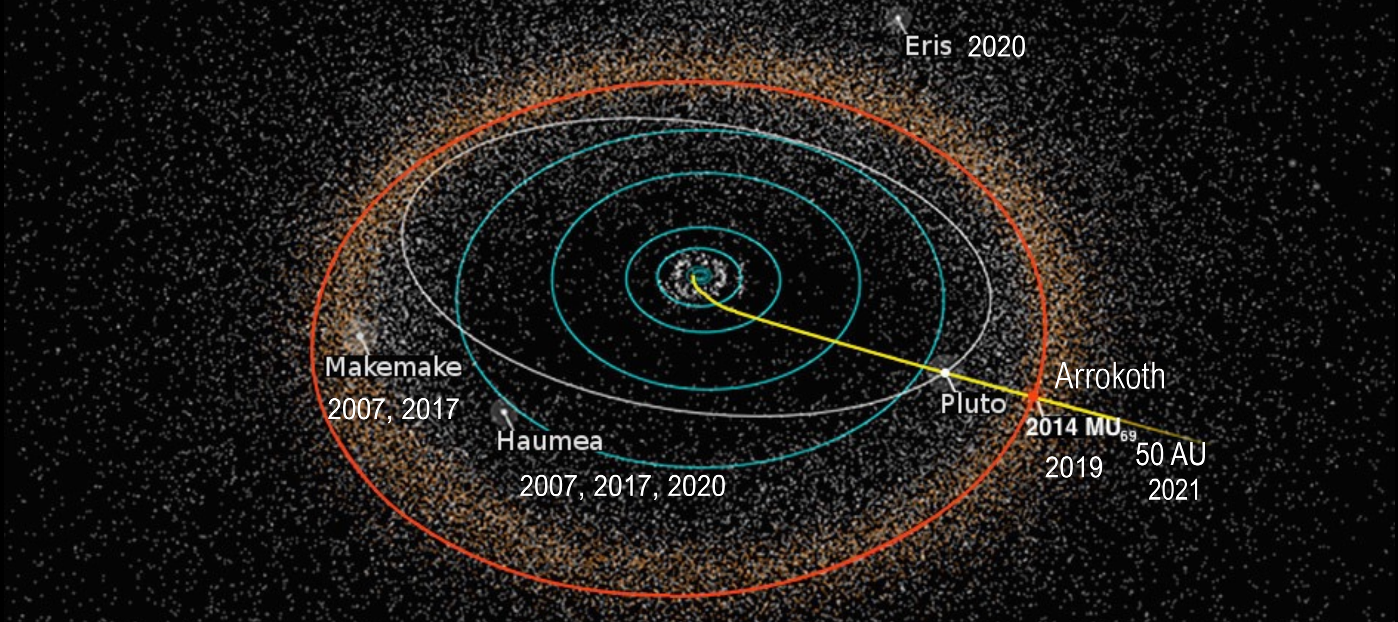
New Horizons is NASA's Observatory in the Kuiper Belt



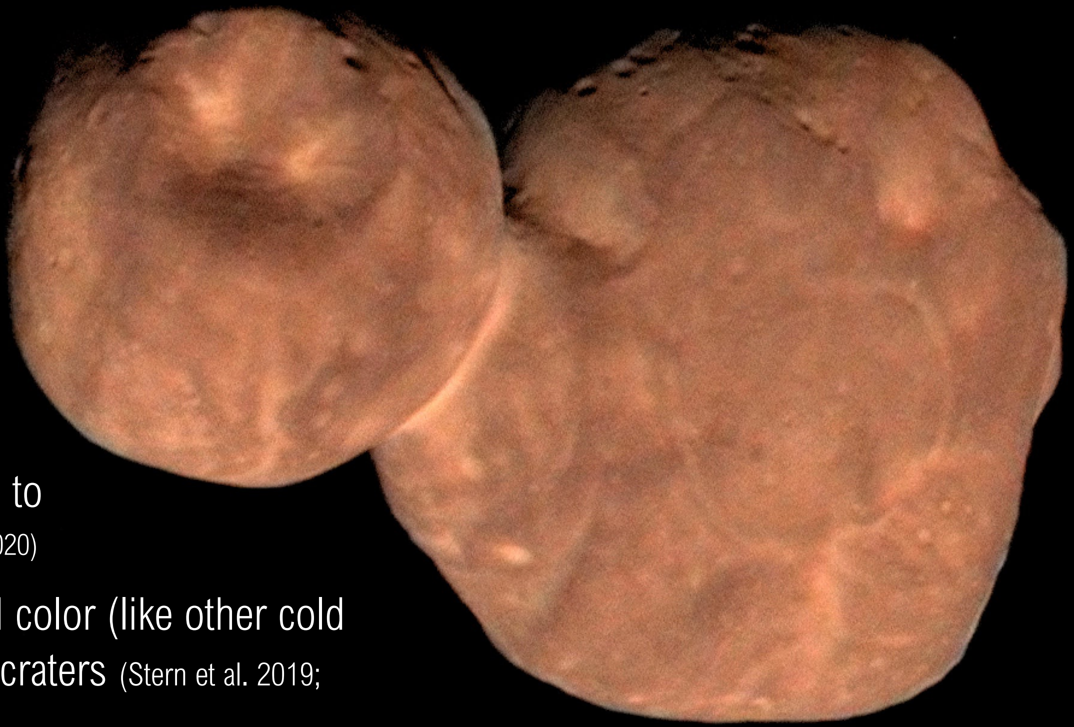
Since its Pluto flyby in July 2015, New Horizons' journey through the Kuiper Belt (KB) has conducted:

- the first close flyby of a Cold Classical KBO, Arrokoth (2014 MU69) in 2019
- unique observations of dozens of "Distant" KBOs (DKBOs) & dwarf planets, Pluto, Uranus, and Neptune
- searches for tight binary KBO systems beyond the reach of Hubble (HST)
- a plasma, dust, and neutral H gas transect of the KB and its space weathering environment

New Horizons Spacecraft Status

- Spacecraft is healthy
  - 15+ years in flight and no backup instruments or systems needed
- Lifetime presently limited only by fuel and power
- New Horizons is ready to continue to return science, make discoveries, until the mid-2030s, pending successful PMSRs in 2022 and beyond

First Look at A Cold Classical KBO



(486958) Arrokoth
Some Major Takeaways:

- Contact binary 36 x 20 x 10 km (Stern et al. 2019)
- Formed by streaming instability pebble cloud collapse (Stern et al. 2019; McKinnon et al. 2020)
- Two lobes – with similar composition, color, & albedo – formed separately then slowly merged to create bilobate shape (Grundy et al. 2019; McKinnon et al. 2020)
- Smooth surface of methanol ice (little H_2O), red color (like other cold classical KBOs), visible albedo ~0.2, paucity of craters (Stern et al. 2019; Grundy et al. 2019; Hofgartner et al. 2021)
- Most pristine surface ever viewed by a spacecraft

New Horizons Distant, Non-Flyby KBO Science

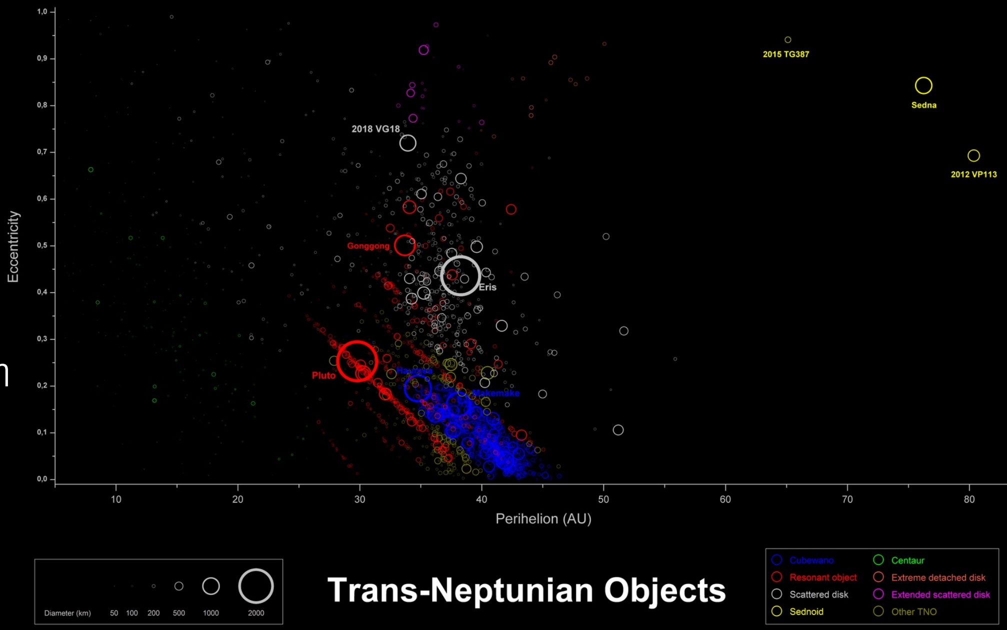
New Horizons is uniquely positioned to return valuable science from within the Kuiper Belt itself by acquiring data sets not readily obtainable by other means:

– 36 KBOs & Dwarf Planets observed to date, sample diverse populations:

- Classical KBOs
- Centaurs
- Resonant objects
- Scattered Disk Objects

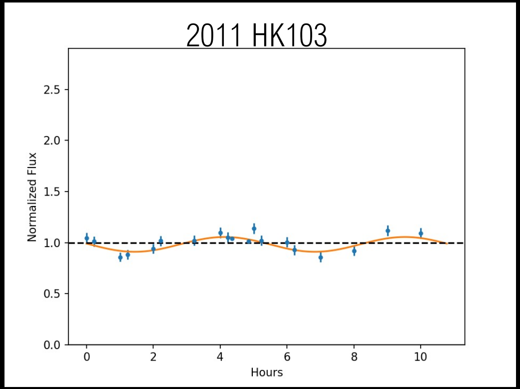
- Light curves of distant KBOs constrain shapes and rotation periods (e.g. Porter et al. 2016; Verbiscer et al. 2019, 2021)
- Searches for tight KBO binaries at high spatial resolution (e.g. Porter et al. 2019, 2020; Weaver et al. 2021)
- Extending solar phase functions from the $\alpha < 2°$ seen from Earth to $\alpha < 131°$

  (Porter et al. 2016; Verbiscer et al. 2019, 2021)
- Probing new populations farther out in future years

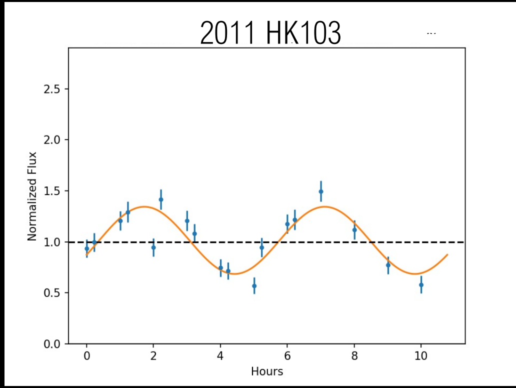


Light Curves of KBOs at High Solar Phase Angles

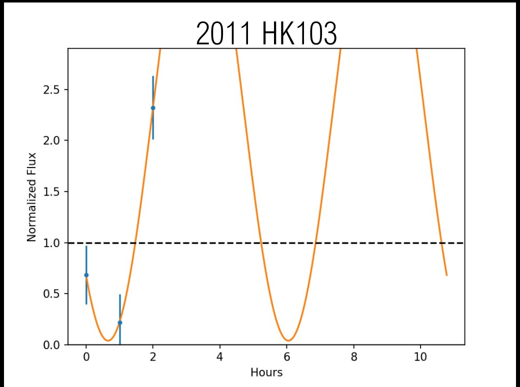
- Multiple New Horizons visits enable construction of rotation (light) curves at several high phase angles
  - Measure rotation periods (Porter et al. 2016; Verbiscer et al. 2019, 2021; Weaver et al. 2021)
  - Constrain DKBO shapes (assuming surface has uniform albedo)
    - Increasing peak-to-peak amplitude with increasing α ➡ non-spherical shape
    - Example: Scattered Disk KBO 2011 HK103, period ~10.8 hrs



Amplitude 0.3 mag α = 51°



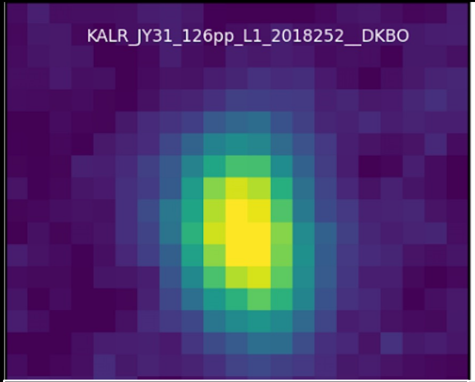
Amplitude 1 mag α = 96°



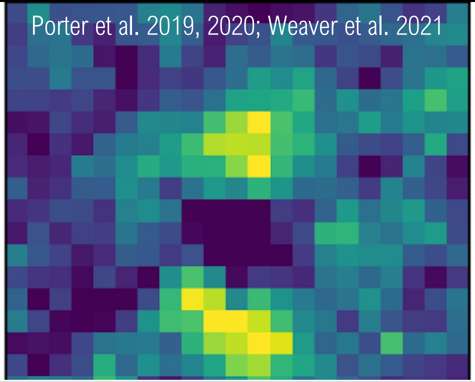
Amplitude 4 mag α = 124°

New Horizons Discovers The Tightest KBO Binary System

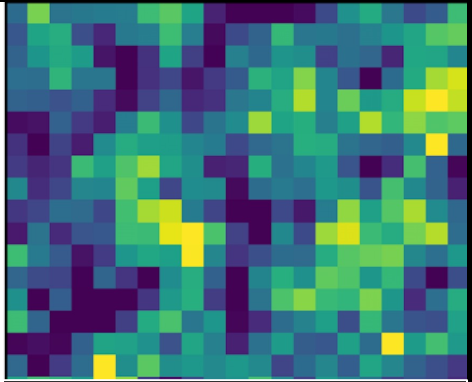
High spatial resolution search with LORRI 1x1 images included five DKBOs: 4 cold classicals, 1 scattered disk object



Stack of 125 NH LORRI images of cold classical KBO 2011 JY31

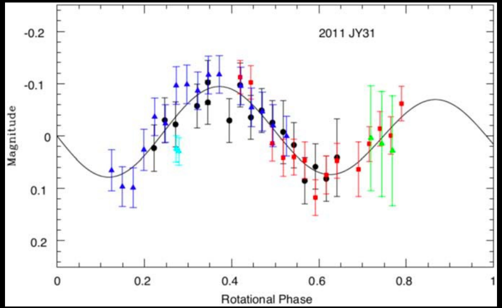


Residuals after subtracting a single PSF



Higher quality residuals after subtracting two PSFs indicates that 2011 JY31 is likely a binary KBO

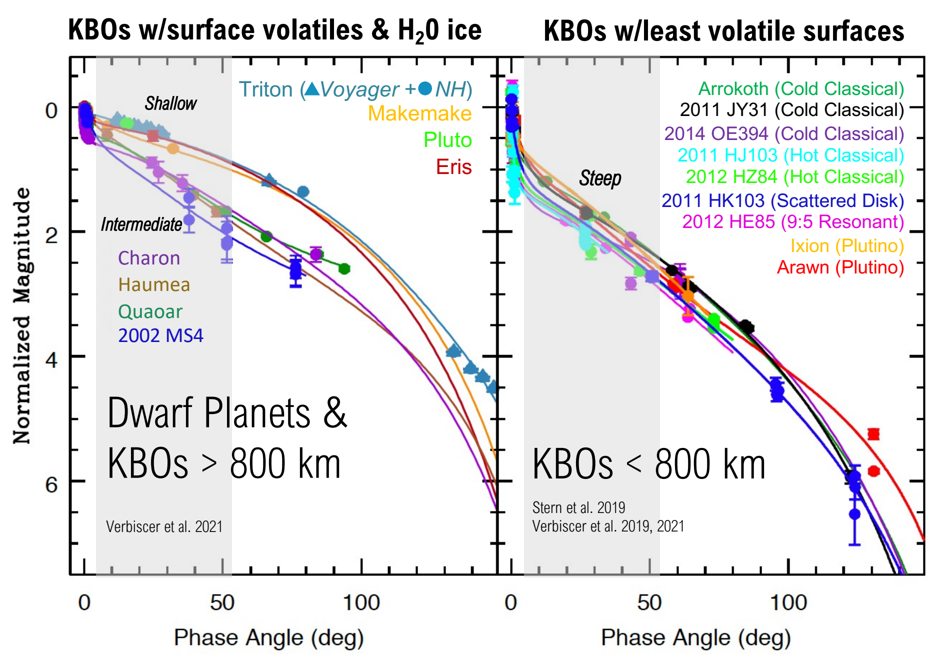
- Semi-major axis 198.6 ± 2.9 km (next closest 349 ± 26 km)
  - ~6mas from Earth, 0.16 HST WFC3 pixels
- Rotation period 1.942 ± 0.002 d
- Most likely tidally locked
- Constraint on formation:
  - Implies many slow rotators in KB are tight binaries



Verbiscer et al. 2019

Cold classical 2011 JY31 has a low (0.2 mag) amplitude, double-peaked rotation curve at multiple phase angles: 27°, 65°, & 85° (different colors in figure at left)

New Horizons Finds Diversity in Dwarf Planet and DKBO Solar Phase Curves



Solid lines are fits to the Hapke (2012) photometric model, normalized to 0 mag at opposition to enable shape comparisons.

All circles at α > 2° are New Horizons LORRI observations.

Phase curve shapes fall into three groupings based on *surface composition* (Verbiscer et al. 2021):

Shallow: "Hypervolatile" (N_2, CH_4, CO) surfaces

(Eris, Makemake, Pluto, Triton)

- Highest geometric albedos, phase integrals, Bond albedos

Intermediate: less volatile (H_2O, NH_3, tholins) surfaces

(Haumea, Charon, Quaoar, 2002 MS4?)

- Intermediate phase integrals, Bond albedos

Steep: least volatile (tholins, amorphous carbon) surfaces

(Ixion, other smaller, dark DKBOs)

- Lowest geometric albedos, phase integrals, Bond albedos
- Phase curve shapes match those of other small, dark bodies (asteroids, comet nuclei, satellites)

Searching for New KBO Targets

Using Subaru Telescope's Hyper Suprime-Cam (1.5 deg fov)

Discovered 87 new KBOs in the direction of the NH trajectory in Summer 2020, 7 observable by NH LORRI, several @ 60 au

- Observed 5 with NH LORRI in December 2020 & 3 of these in May 2021
  - Measure phase function, rotation periods, light curves
  - Others are for future NH observations
- Applying machine learning to this data set to discover *even more* KBOs
- Will observe multiple DKBOs with NH LORRI again in September 2021

2021 Campaign Begins Tonight!:

Approved Subaru/HSC time on June 8, 16; July 7; Sept. 3, 4; Oct. 3-10

Approved Keck time Aug. 30, Sept. 6, 7; CTIO 4-m (DECam) June 11-15

Next Flyby Target?

Searching for a needle in a haystack, but stay tuned!