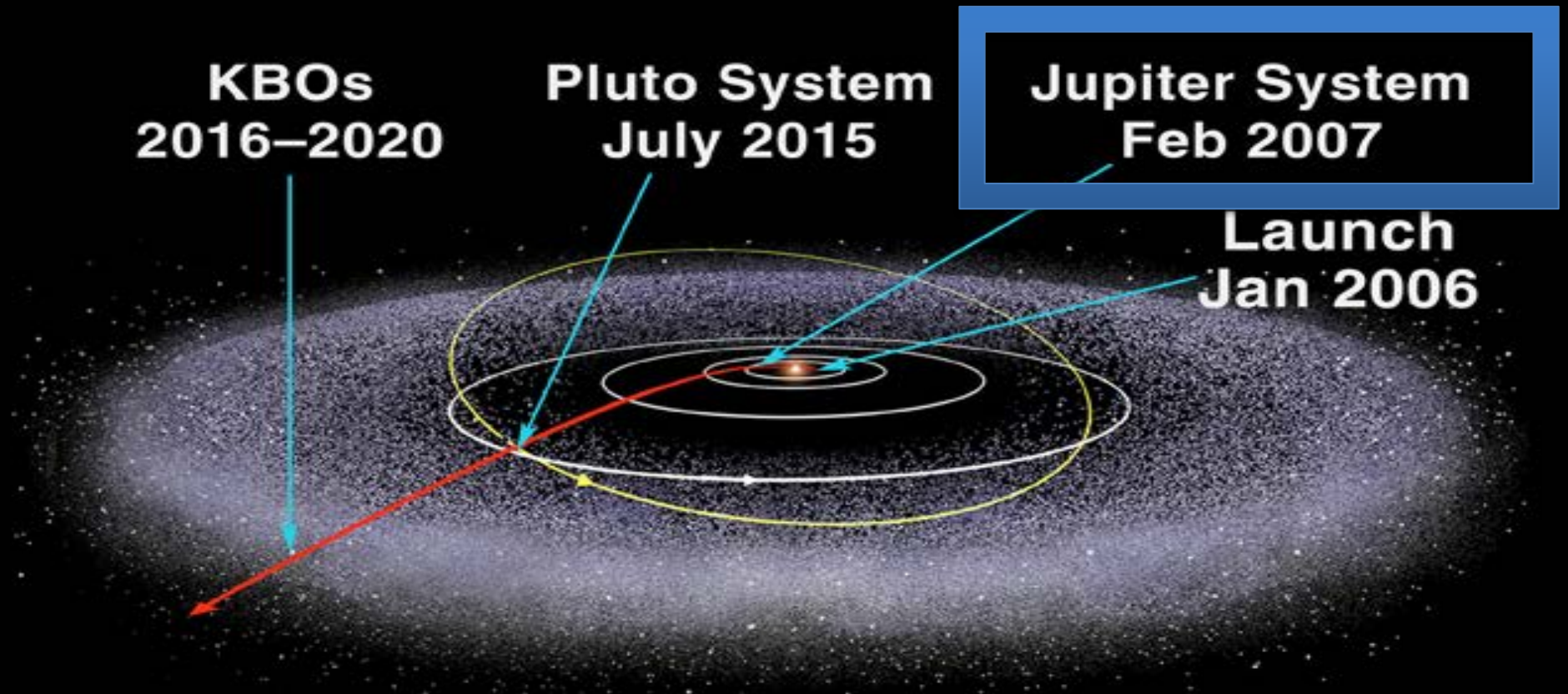
Giant Planet / Kuiper Belt Flyby

Amanda Zangari (SwRI)
Tiffany Finley (SwRI)
with Cecilia Leung (LPL/SwRI)
Simon Porter (SwRI)
OPAG: February 23, 2017

Take Away

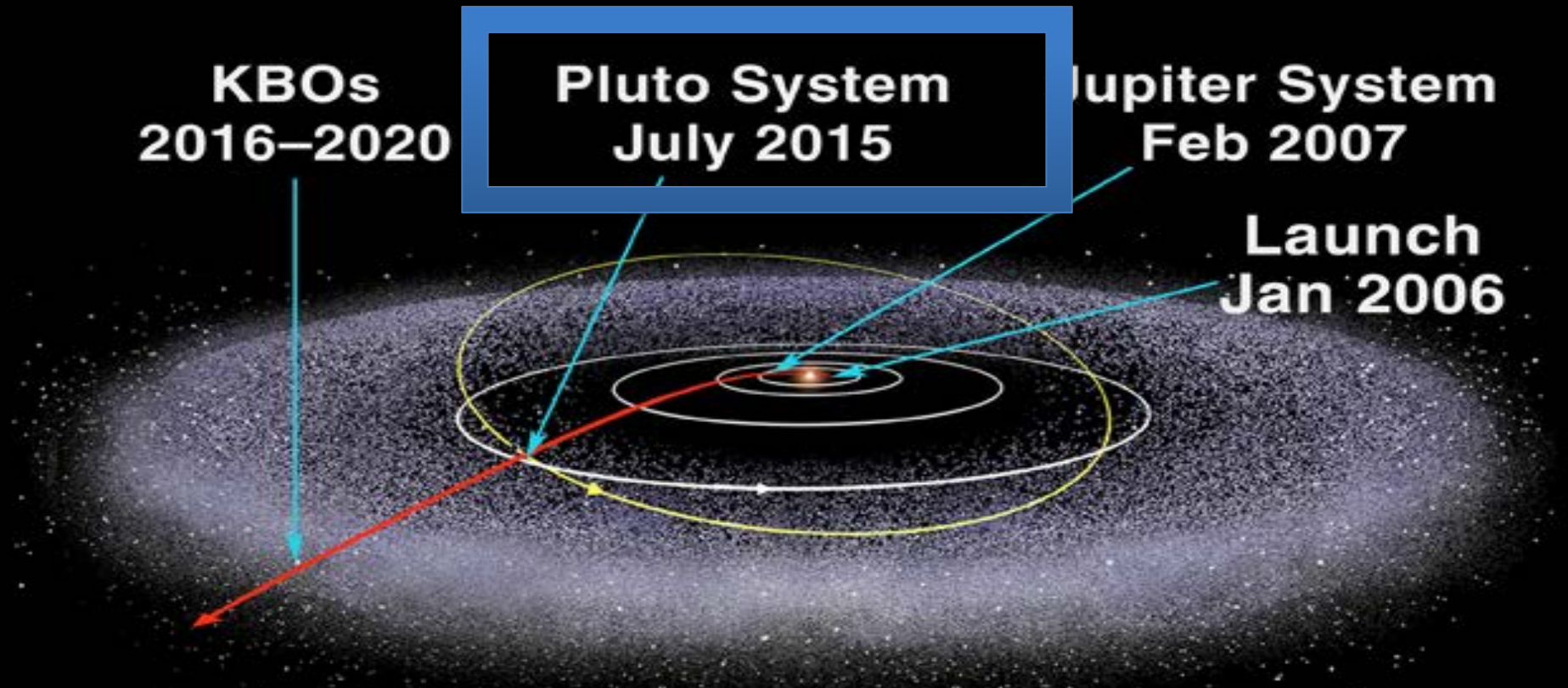
- New Horizons provided scientifically valuable exploration of the Kuiper Belt in the New Frontiers cost cap.
- The Kuiper Belt is full of objects with a diverse range of stories that go beyond what we learned from Pluto.
- Giant Planet flybys add scientific value to a Kuiper Belt mission
- Found **preliminary** trajectory examples for high interest KBOs--
  Haumea, Varuna, 2015 RR245 can be reached via Jupiter
  AND Saturn, Uranus or Neptune flyby in the 2030s.
- To be a candidate New Frontiers mission, a 2 Giant planet+KBO
  mission must be endorsed by a decadal survey
  according to current rules.

New Horizons Heritage



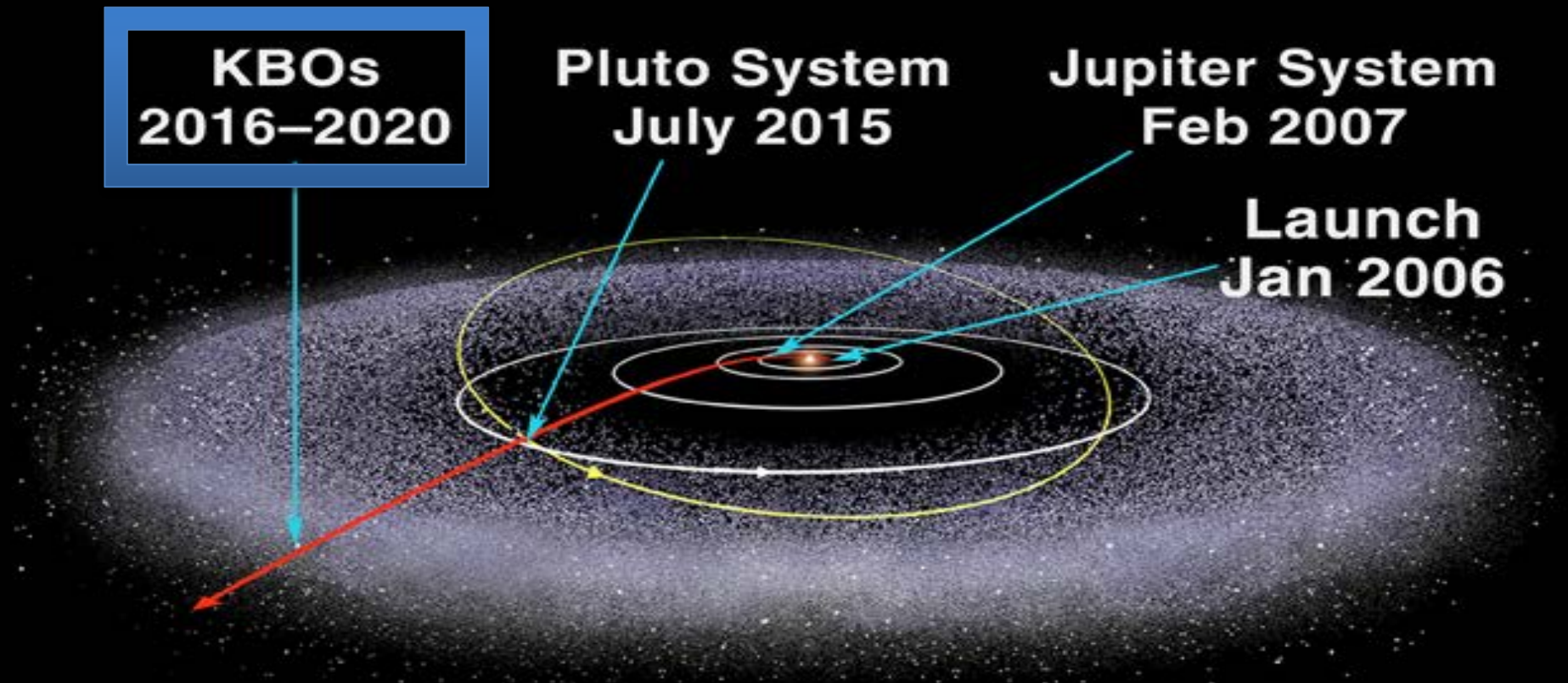
NH Jupiter Encounter planned around Pluto flyby timing, which was dominated by achieving quadruple occultations, “interesting” side up.

New Horizons Heritage



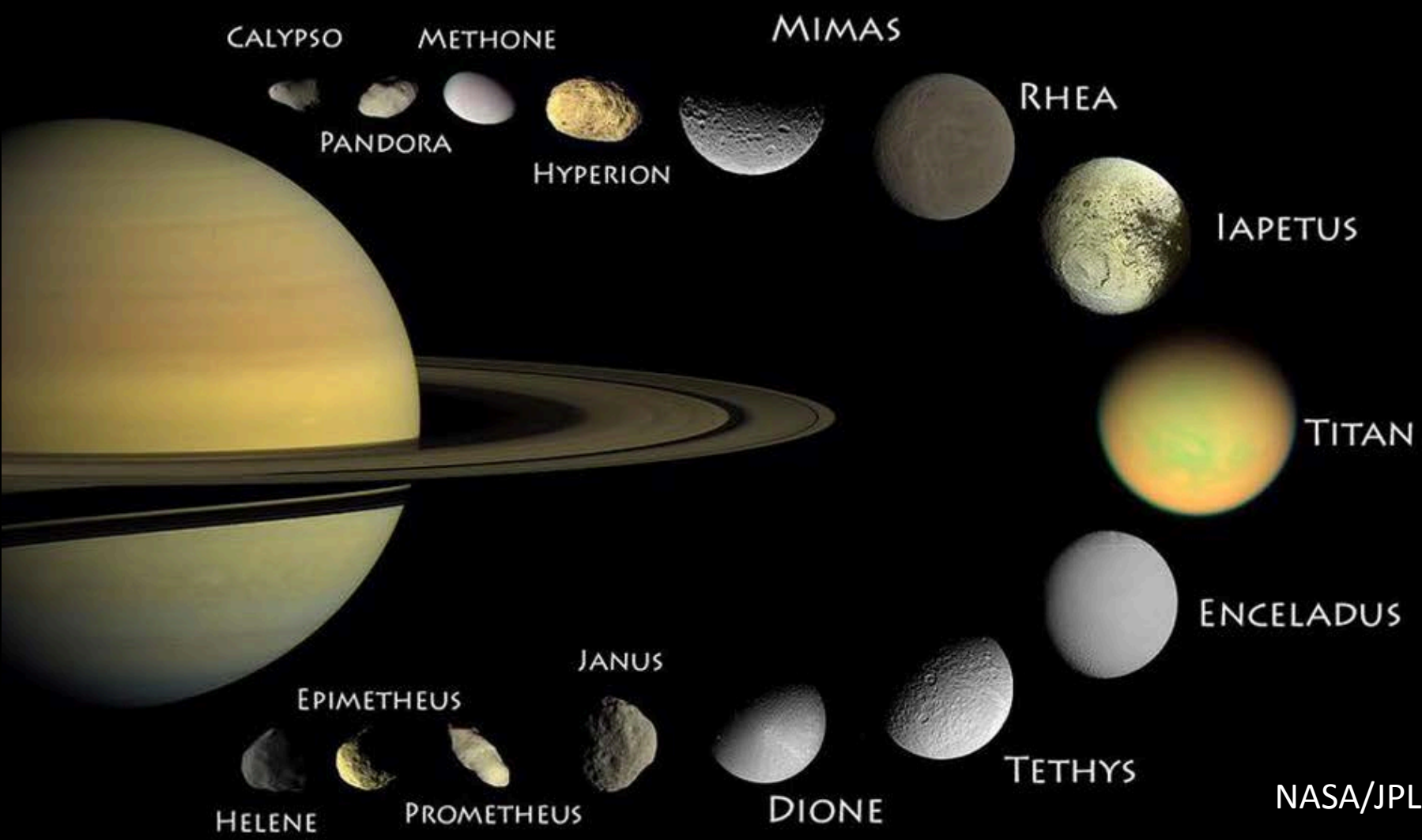
Pluto flyby took advantage of Ecliptic crossing, enabling access to the cold classical belt (where 2014 MU69 is located).

New Horizons Heritage

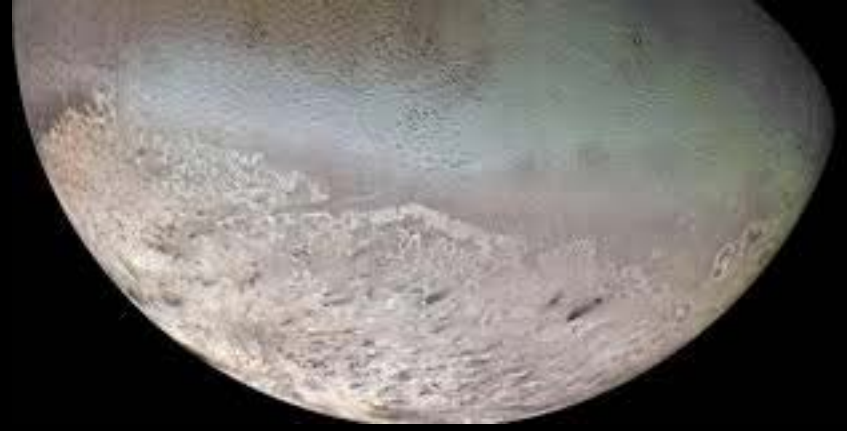


2014 MU69 discovered while in flight. Targeting was from spacecraft propulsion and took advantage of cold classical population density. Object is small, reddish ~40 km diameter.

Saturn's moons show incredible diversity

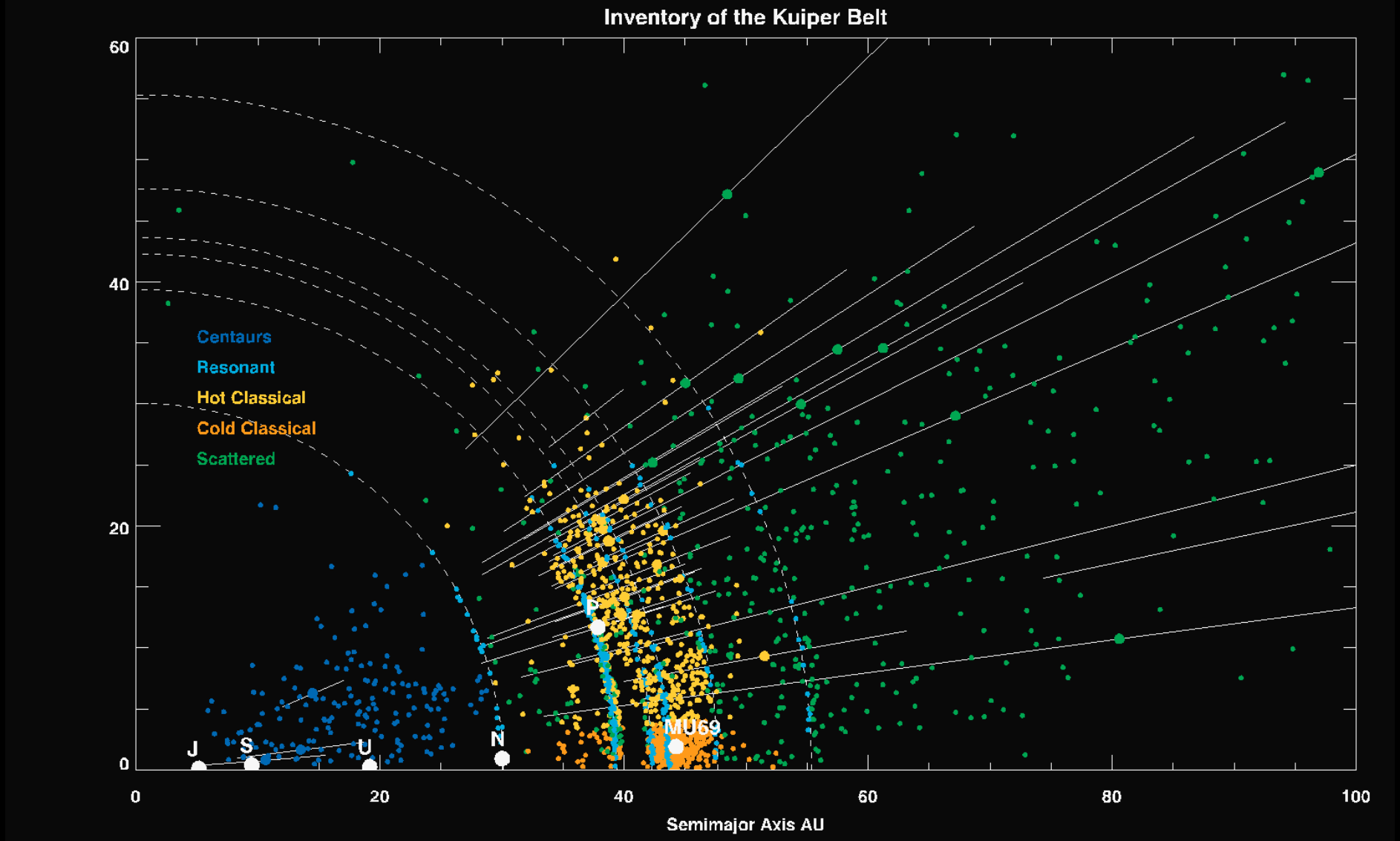


NASA/JPL

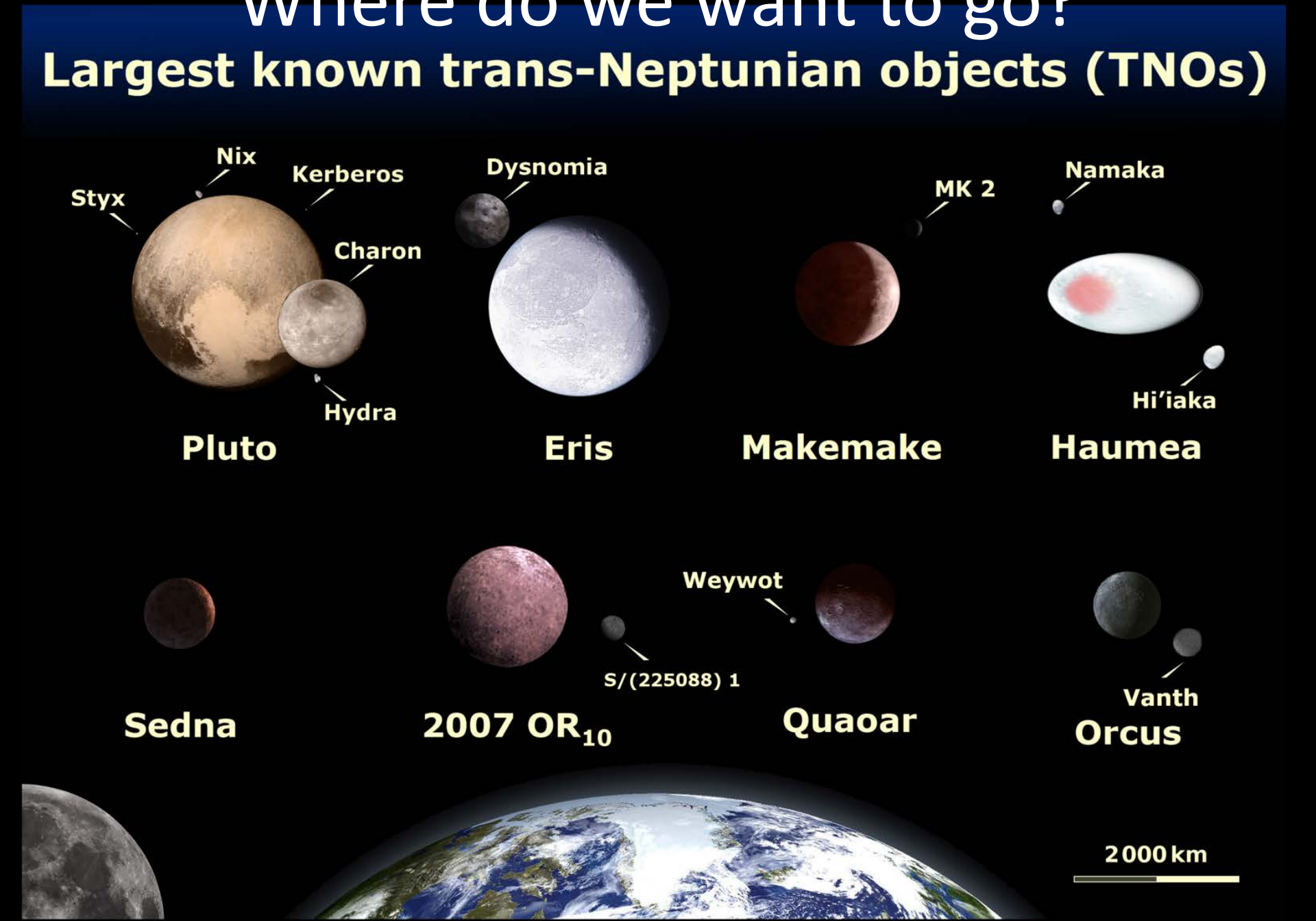


As do Uranus and Neptune

Some Kuiper Belt Geography



Where do we want to go?



Getting there- JGA “anytime”

New Horizons model: Fast Launch, Jupiter Flyby, Launch window every 11 years

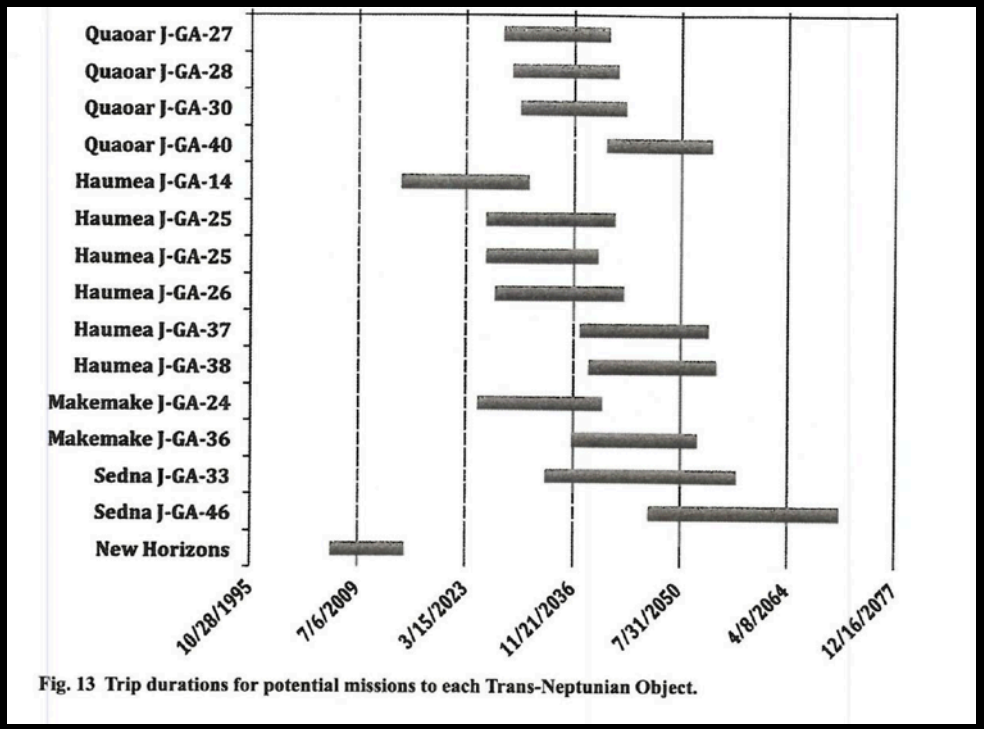


Fig. 13 Trip durations for potential missions to each Trans-Neptunian Object.

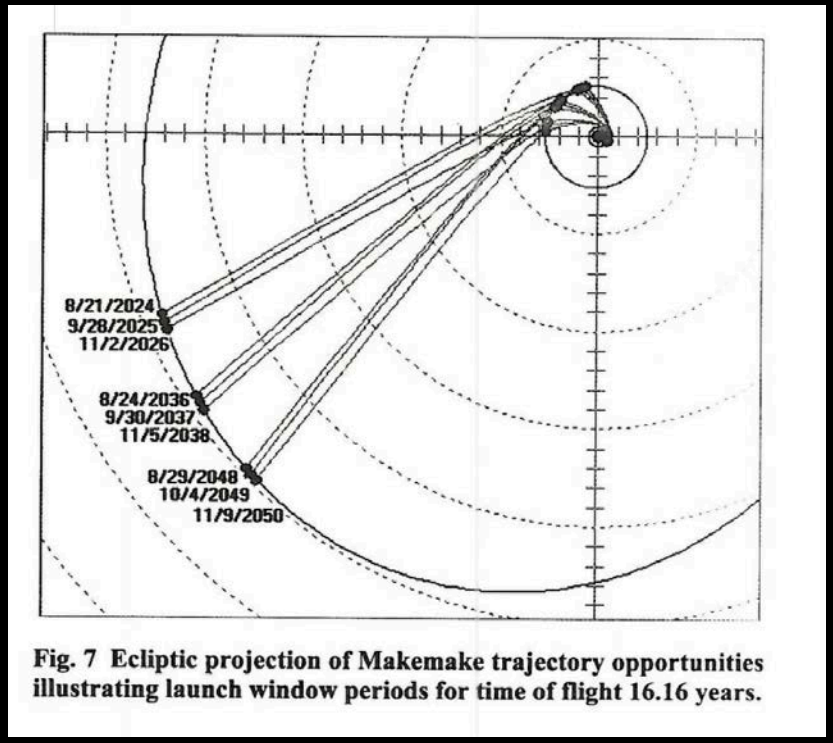


Fig. 7 Ecliptic projection of Makemake trajectory opportunities illustrating launch window periods for time of flight 16.16 years.

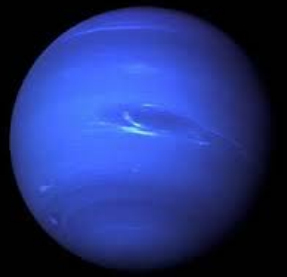
McGranaghan et al 2011

Can we go to more than just Jupiter?
If so, where, what?

New Horizons 2

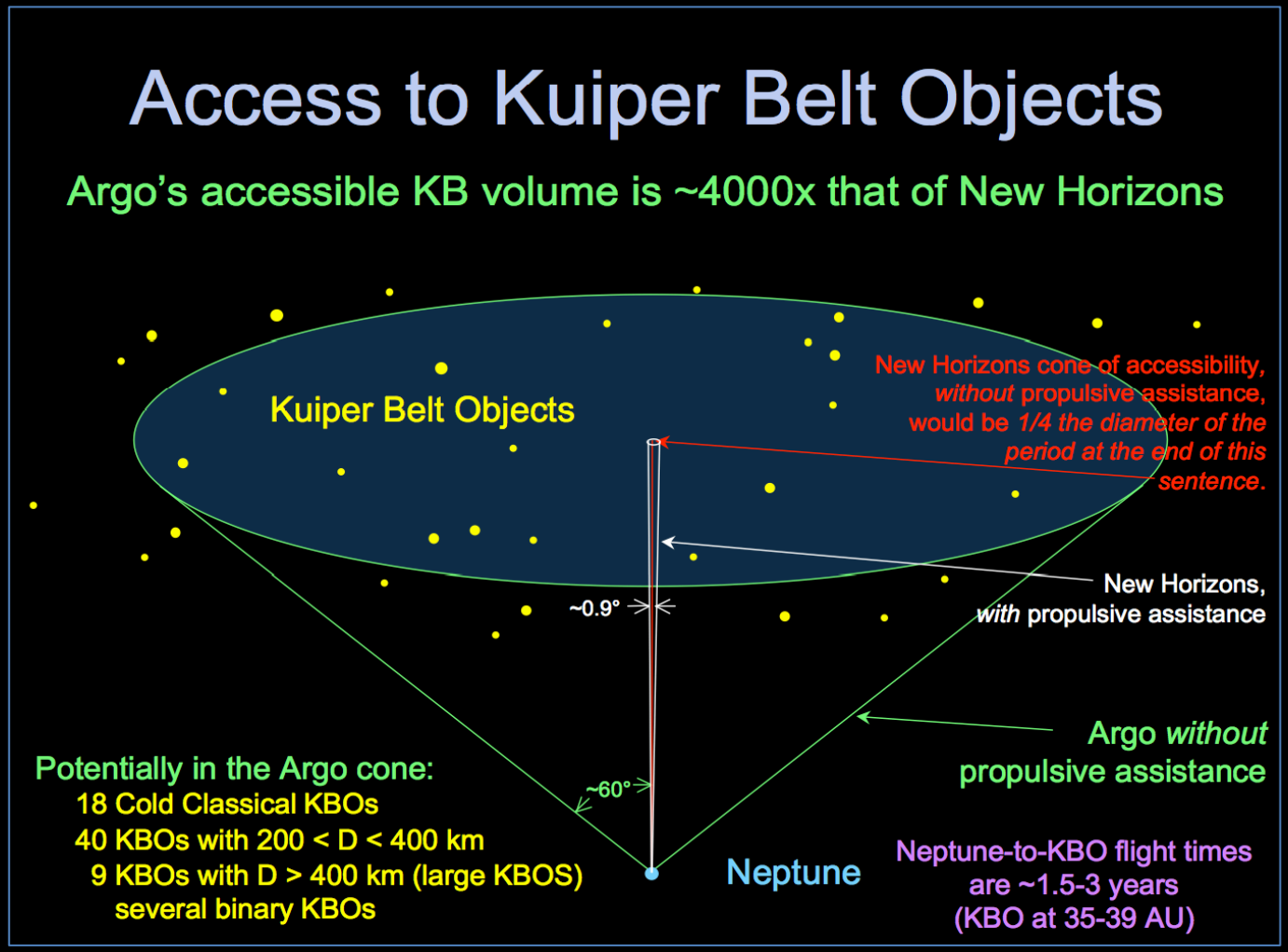
- 2008 launch using New Horizons flight spares
- Proposed Jupiter flyby, equinox flyby of Uranus, and flyby of (47171) 1999 TC36 (now know to be trinary).

Argo



- Proposed Jupiter flyby, Saturn flyby, Neptune flyby and flyby of 2001 QS322 with 2019 launch

Giant planet flyby accessibility bonus



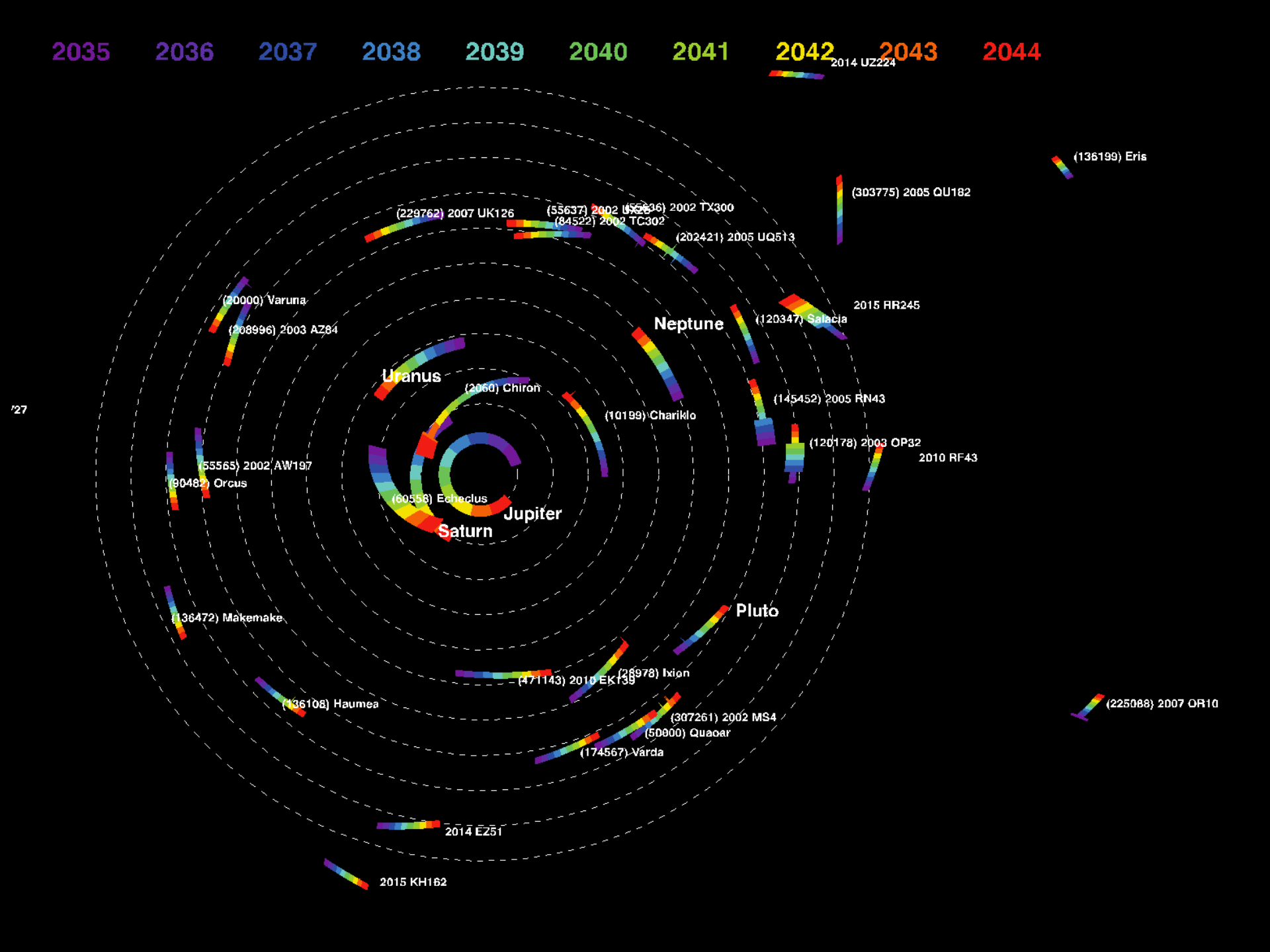
Hansen & Hammel , OPAG 2008

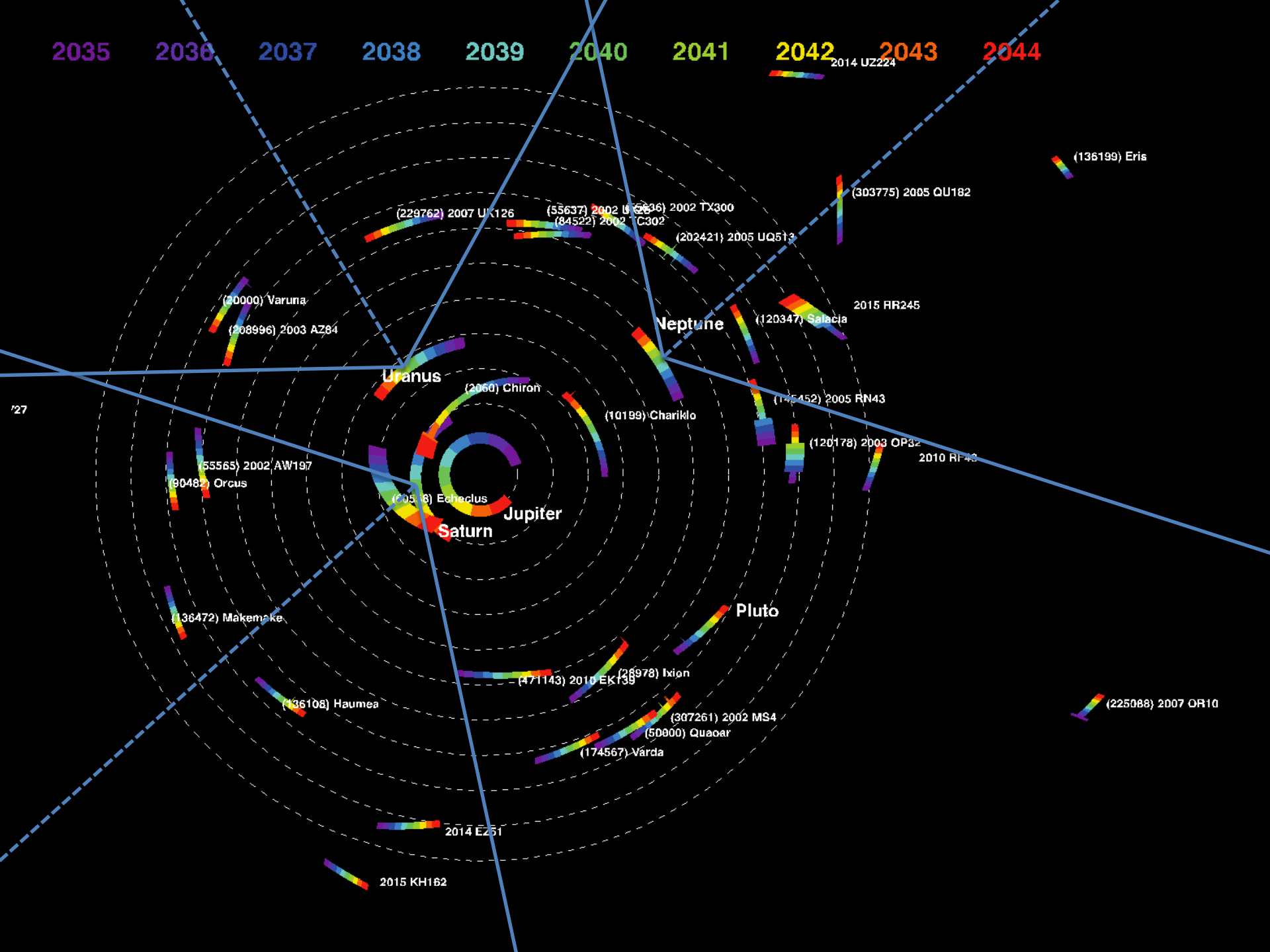
Methods

- Identified 32 brightest KBOs and Centaurs:

  $H < 4.0$, $V < 19.0$
- Identified possible EJS, EJU and EJN opportunities via NASA Ames Research Center Trajectory browser from 2020-2040:
  - trajbrowser.arc.nasa.gov/traj_browser.php
- Identified KBOs in 60° region at planet flyby time.
- Identified **preliminary** trajectories via

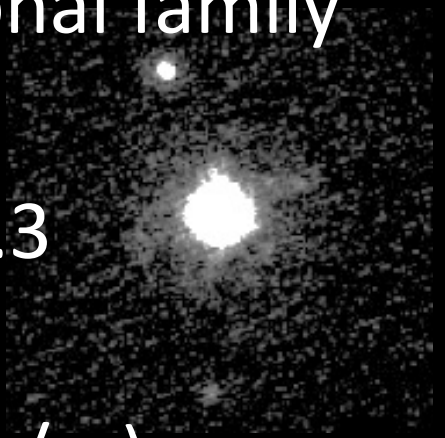
  Systems Tool Kit / Astrogator (STK)


2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2014 UZ224
(136199) Eris
(303775) 2005 QU182
(229762) 2007 UK126
(55637) 2002 UX25
(55636) 2002 TX300
(84522) 2002 TC302
(202421) 2005 UQ513
2015 RR245
(120347) Salacia
(20000) Varuna
(208996) 2003 AZ84
Neptune
Uranus
(2060) Chiron
(10199) Chariklo
(145452) 2005 RN43
(120178) 2003 OP32
2010 RF43
(55565) 2002 AW197
(90482) Orcus
(60558) Echeclus
Jupiter
Saturn
Pluto
(136472) Makemake
(471143) 2010 EK139
(28978) Ixion
(136108) Haumea
(225088) 2007 OR10
(307261) 2002 MS4
(50000) Quaoar
(174567) Varda
2014 EZ51
2015 KH162


2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2014 UZ224
(136199) Eris
(303775) 2005 QU182
(229762) 2007 UK126
(55637) 2002 UX25
(55636) 2002 TX300
(84522) 2002 TC302
(202421) 2005 UQ513
2015 RR245
(120347) Salacia
Neptune
(20000) Varuna
(208996) 2003 AZ84
Uranus
(2060) Chiron
(10199) Chariklo
(145452) 2005 RN43
(120178) 2003 OP32
2010 RF43
(55565) 2002 AW197
(90482) Orcus
(52872) Echeclus
Jupiter
Saturn
Pluto
(136472) Makemake
(471143) 2010 EK139
(28978) Ixion
(136108) Haumea
(307261) 2002 MS4
(50000) Quaoar
(174567) Varda
(225088) 2007 OR10
2014 EZ51
2015 KH162

Why Haumea?

- Fastest rotation period (3.9h) of any object > 100 km
- Odd egg shape but in hydrostatic equilibrium
- Parent body of only known TNO collisional family
- Two small moons
- Dwarf planet - Fourth largest KBO. H=0.3
- Bright surface, albedo = 0.8
- Deep water ice, but rocky density (2.6 g/cc)



Why Varuna?

- Occultation suggests unusual shape: 1000+ km chord, but complete miss about 250 km south.
- Dark albedo, roughly 0.12
- Hot classical, probable dwarf planet
- H=3.7, but largest KBO at discovery
- Density of about 1 g/cc

Why 2015 RR245?

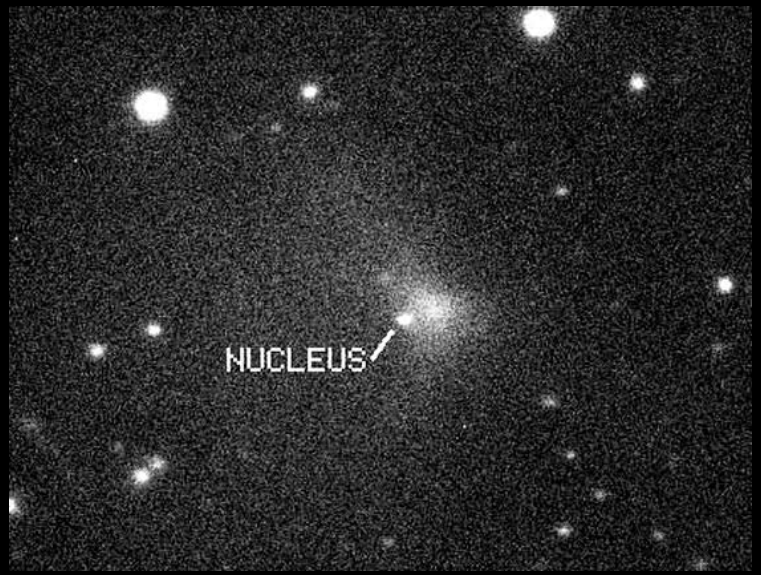
- Recent Dwarf Planet discovery, H_r=3.6±0.1, diam= 670 km (albedo = 0.12)
- Scattered object in 9:2 resonance with Neptune; Orbit ranges from 34 to 130 AU!
- Will be within 1 AU of the plane in 2044– potential for further classical KBO exploration

Preliminary Mission Design

Earth	2/24/2031	C3:106
Jupiter	7/11/3032	Vh:26
Neptune	3/31/2039	Vh:19.9
2015 RR245	8/11/2044	Vh:17.7

Don’t forget the centaurs!

- Chariklo – Centaur with rings, out of plane
- Echeclus – Centaur with coma, in plane, near Saturn
- Chiron – Evidence of coma from occultations



University of Oklahoma

Why fly by when you can orbit?

- Because you can still get an amazing amount of information when you fly by.
- Flyby can get to second ice giant if number of flagships are limited.
- Delivery of entry probe with short lifetime.
- Payload can be complimentary to orbiter, using different instruments.
- Allows for direct comparison of satellites with Kuiper Belt Objects based on measurements from the same instrument

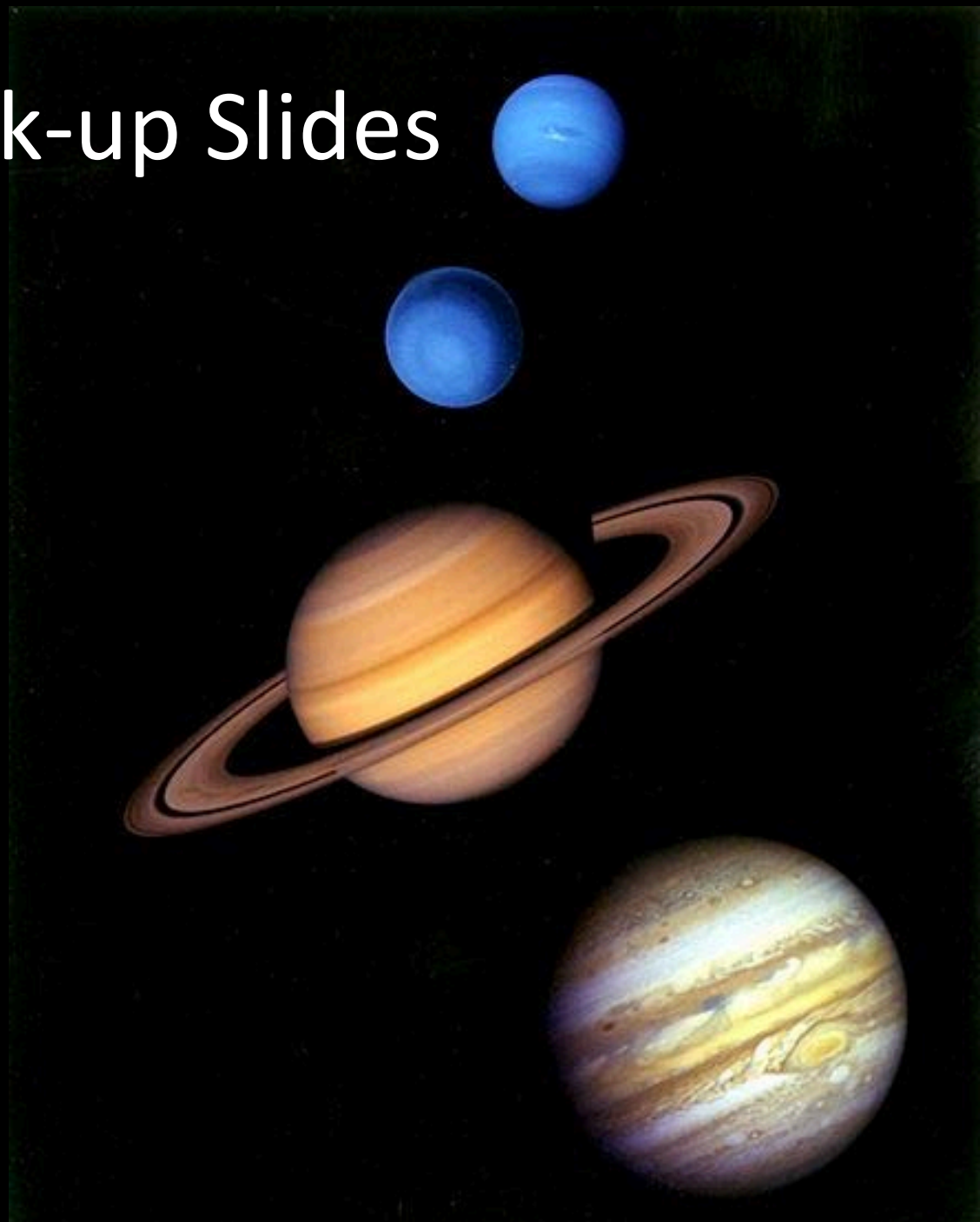
What next?

- Complete analysis of proper trajectories and reachable KBOs for potential targets.
- Submit paper detailing trajectories and mission.
- Looking for interested people! azangari@boulder.swri.edu
- Advocate for inclusion of KBO/Giant Planet flyby in Decadal Survey

Take Away

- New Horizons provided scientifically valuable exploration of the Kuiper Belt in the New Frontiers cost cap.
- The Kuiper Belt is full of objects with a diverse range of stories that go beyond what we learned from Pluto.
- Giant Planet flybys add scientific value to a Kuiper Belt mission
- Found **preliminary** trajectory examples for high interest KBOs--
  Haumea, Varuna, 2015 RR245 can be reached via Jupiter
  AND Saturn, Uranus or Neptune flyby in the 2030s.
- To be a candidate New Frontiers mission, a 2 Giant planet+KBO
  mission must be endorsed by a decadal survey
  according to current rules.

Back-up Slides



Why Makemake?

- Brightest KBO in sky after Pluto , H=-0.3
- Third largest (after Pluto and Eris KBO
- Large enough for volatiles like $N_{2,}$ CH_4 and CO to be retained.
- “Hot” classical.
- Surface is reddish, uniform, but bright, albedo =0.8.
- One satellite recently discovered.