Science Objectives of Joint Ice Giant – KBO Missions

Kunio M. Sayanagi (佐柳 邦男)
kunio.sayanagi@hamptonu.edu
Associate Professor, Atmospheric and Planetary Sciences Department, Hampton University

Amy A. Simon (NASA Goddard Space Flight Center)
Mark D. Hofstadter (JPL/Caltech)
Alan Stern (Southwest Research Institute)

Presented on February 17, 2019
Symposium on Planetary Science 2019, Tohoku University, Sendai, Japan

We discuss the current status of advocating for joint missions to Uranus, Neptune and Kuiper Belt Objects (KBOs) to prepare inputs to the next US Planetary Science Decadal Survey, which is expected to start in late 2019.

The 2013 US Planetary Science Decadal Survey recommended three large missions for the 2013-2022 decade, namely:

1. Start the Mars Sample Return Mission
2. Jupiter Europa Orbiter
3. Uranus Orbiter and Probe

The first and second recommendations are being implemented as Mars2020 and Europa Clipper missions, respectively. The next priority large mission for the current decade is a mission to an Ice Giant Planet, Uranus or Neptune.

In preparation for exploring the Ice Giant planets, NASA and ESA have organized study groups to define science goals and mission architecture options. NASA supported a Science Definition Team (SDT) team study in 2016-2017, and the final report and other documents from the study are available at:
https://www.lpi.usra.edu/icegiants/mission_study/
ESA also took part in the NASA SDT process. ESA is currently conducting a separate study to consider possible contributions to future NASA missions to Uranus and/or Neptune as M-Class mission. ESA planning documents can be found at:
https://www.cosmos.esa.int/web/ice-giant-study

In addition, considerable amount of new discoveries in KBOs make them compelling exploration targets for the next decade. The successful exploration of Pluto and MU_{69} "Ultima Thule" by NASA's New Horizons spacecraft demonstrates that KBOs, which harbor the most pristine building blocks of our solar system, are fruitful targets of further future planetary exploration.

Exploration of Ice Giant planets and KBOs benefit from significant synergistic cooperation. First, some moons of Uranus and Neptune are believed to be captured KBOs, and thus understanding of the Ice Giant satellite systems will benefit from improved understanding of KBOs. Second, many more KBOs could be reached through a gravity assist maneuver during a flyby at Uranus or Neptune.

From above, we advocate for a two-mission plan as a coherent vision to explore the outer solar system starting in the 2020s and into the 2040s. We envision two missions as part of a unified plan:

1. Orbiter to explore Neptune system with an atmospheric probe
2. Flyby of Uranus with final destination at multiple KBOs

These missions would benefit from significant international cooperation – we invite interested parties to contact Dr. Amy A. Simon at amy.simon@nasa.gov to coordinate potential international contributions.

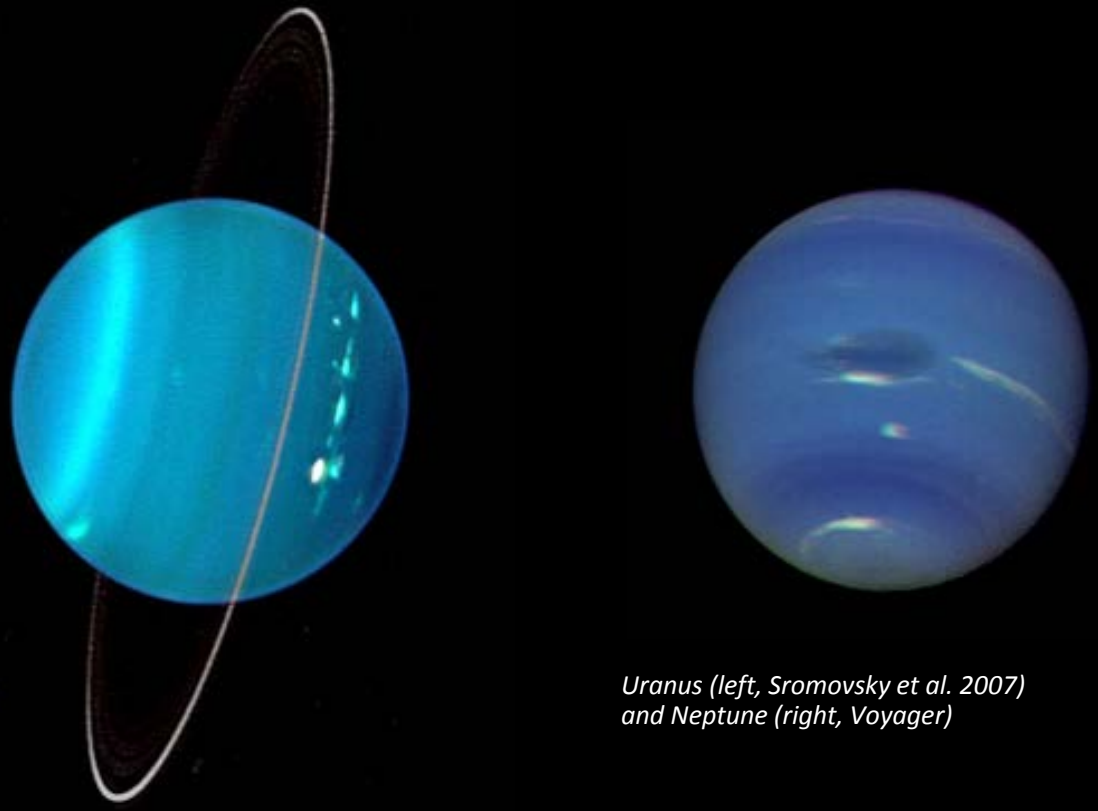
Science Objectives of Joint Ice Giant – KBO Missions

Kunio M. Sayanagi (Hampton University)

Amy A. Simon (NASA Goddard Space Flight Center)
Mark D. Hofstadter (JPL/Caltech)
Alan Stern (Southwest Research Institute)

Ice-Giant Exploration

The Ice Giant systems are unexplored and very different from the Gas Giant systems. They challenge our understanding of planet formation, evolution, and physics. An Ice Giant Flagship Mission would engage every discipline within planetary science, as well as the heliophysics and exoplanet communities.



Uranus (left, Sromovsky et al. 2007) and Neptune (right, Voyager)

Decadal Context:
2003 Planetary Decadal Survey Recommendations (Last Decade)

Large Missions

Europa Geophysical Explorer (Clipper)

Medium Missions

KBO-Pluto Explorer (New Horizons)

South Pole Aitken Basin Sample Return

Jupiter Polar Orbiter with Probes (Juno)

Venus In-Situ Explorer

Comet Surface Sample Return (CAESAR in Phase A Competition)

Mars Missions

Mars Scout Series (e.g. Phoenix)

Mars Upper Atmosphere Orbiter (MAVEN)

Mars Science Lab (Curiosity)

Mars Long-Lived Lander Network (some obj's addressed by InSight)

Mars Sample Return (Mars 2020)

In Operation / Completed

In Development

Decadal Context
2011 Planetary Decadal Survey Recommendations (Current Decade)

Large Missions (in priority order):

1. *Mars Sample Return – Sample Cacher (Mars 2020)*
2. *Jupiter Europa Orbiter (Europa Clipper)*
3. Uranus Orbiter and Probe (!! Next Priority !!)

Medium Missions (in alphabetical Order):

Comet Sample Return (CAESAR in Phase A Competition)
Io Observer
Lunar Geophysical Network
Lunar South Pole Aitken Basin Sample Return
Ocean World (Dragonfly in Phase A Competition)
Saturn Probe
Trojan Tour and Rendezvous (Lucy)
Venus In-Situ Explorer

In Operation / Completed
In Development

More on Decadal Survey Discussion in the Future Plans Splinter Discussion, Feb 19 17:50-

Preparing for the Next: Ice-Giant Exploration

NASA Science Definition Team Study:

- Studied mission architecture options
- Recommended International collaborations to maximize the science return while minimizing the cost to each partner
- Recommended a second study for a more detailed point design of a specific architecture
- Report released in 2017

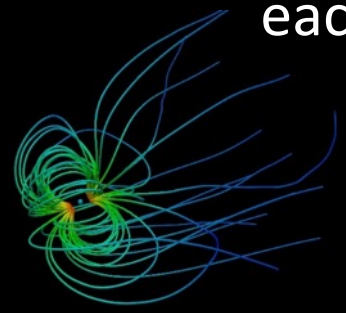
ESA Study:

- Considered options including:
  - Atmospheric Probe
  - Triton Lander
  - Second Spacecraft
- Final report to be released soon

Uranus (left, Sromovsky et al. 2007) and Neptune (right, Voyager)

NASA Ice Giants Study Recommendations

- An orbiter with an atmospheric probe be flown to an ice giant, launching near 2030.
- Two-planet, two-spacecraft mission options should be considered.
- There should be continued investments in ground-based research and instrumentation. Important areas for designing future missions include upper-atmospheric properties, ring-particle impact hazards, and giant-planet seismology.
- International collaborations should be leveraged to maximize the science return while minimizing the cost to each partner

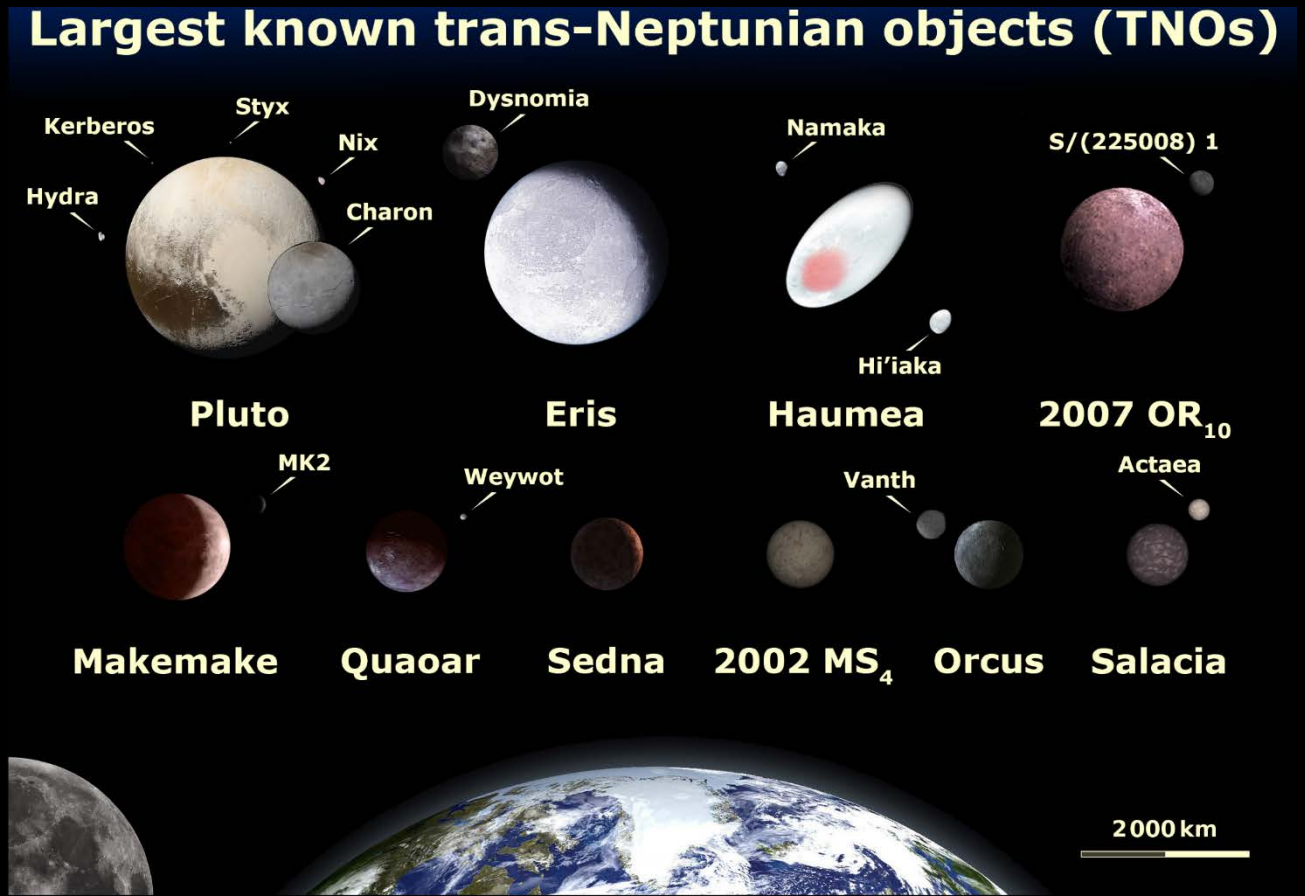


ESA Ice Giants Study

- ESA is considering potential M-class contributions to NASA's Ice Giant mission(s).
- Three options are being studied:
  - An atmospheric probe
  - A satellite lander (Triton)
  - Contributions that enable two spacecraft on a single launch, to allow exploration of both ice giants (entire spacecraft, subsystems, or probes)
  - Phase 0 (technical study) begun
    - Kickoff with NASA October 2018 (complete)
    - Concurrent design runs November–December 2018
    - Results briefed to NASA ~January 2019
- Would need to be approved for the next ESA Scientific Program (decision at end of 2019).
- Contingent on NASA and/or the Next Decadal Survey.

Dramatic Advances in KBO Science

- **New Horizons and Earth-based observations revealed rich diversity of pristine outer solar system bodies.**
- **Gravity Assist by Uranus or Neptune significantly expands the list of KBO targets within reach.**



Ice Giants – KBO Joint Mission

Unified Strategy to Explore Diverse Targets in Outer Solar System:

- **Ice Giant Planet Systems**
  - US Community Base: Outer Planets Assessment Group (OPAG)
  - Decadal Panel: Giant Planets Panel
  - Science Topics: Interior, Atmosphere, Magnetosphere, Rings, Connection to Exoplanets, …
- **Satellites**
  - US Community Base: Outer Planets Assessment Group (OPAG)
  - Decadal Panel: Giant Planet Satellites Panel
  - Some Ice Giant satellites are captured KBOs!
  - Science Topics: Solar System Origin & Formation, Geology & Geophysics, Astrobiology, …
- **KBOs and Centaurs**
  - US Community Base: Small Bodies Assessment Group (SBAG)
  - Decadal Panel: Primitive Bodies Panel
  - Science Topics: Solar System Origin & Formation, Geology & Geophysics, …

Creating a Compelling and Unified Strategy for Outer Solar System Exploration

Joint Ice Giants – KBO Mission:

- ✓ **Advocated in US Planetary Science Community**
- ✓ **Next Step: Study needed to inform the Decadal Survey**
- ✓ **This new strategy will have to be recommended by the next Planetary Science Decadal Survey**

Accomplished with two missions:

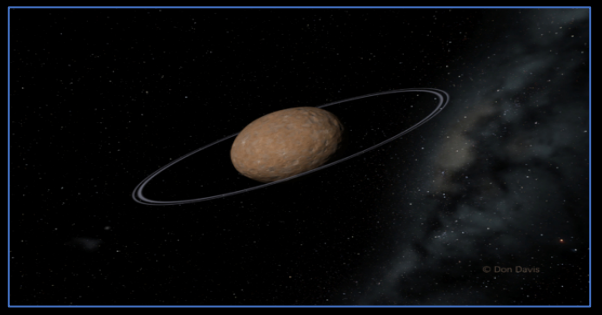
(1) an ice giant orbiter and
(2) an ice giant/multi-KBO Planet flyby mission.

These two missions will revolutionize scientific understanding of:

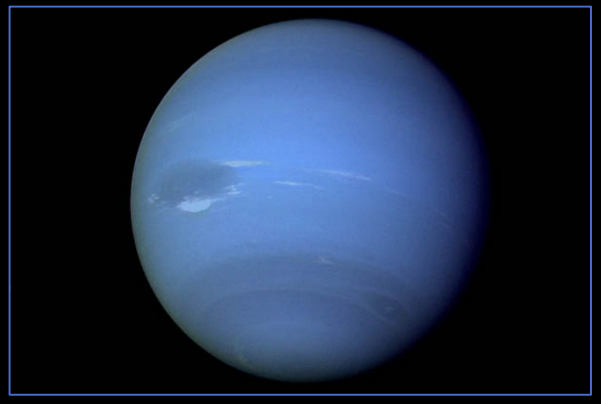
- ✓ **Solar system, ice giant, and origin of Planet-sized KBOs**
- ✓ **The processes that shape the evolution of planets, their satellites, rings, and magnetospheres**
- ✓ **KBOs -- Planet-sized as well as small ones**
- ✓ **And even shed new light on the nature of exoplanets.**

Mission 1:
Flagship Neptune Orbiter and Probe

1. Centaur flyby en route to Neptune.



2. Orbit Neptune.
   - 2-4 years
   - Many Triton flybys
     (Captured from the Kuiper Belt)
   - Satellite/magnetosphere tour
   - Neptune atmospheric probe



- Cost Based on 2017 NASA/JPL Ice Giant Study: ~$2.6B.

Mission 2:
New Frontiers Uranus-KBO Flyby Tour

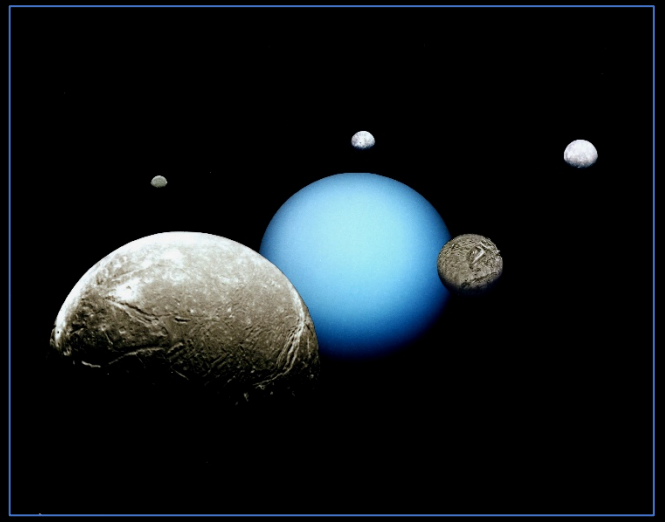
1. Centaur flyby en route to Uranus.

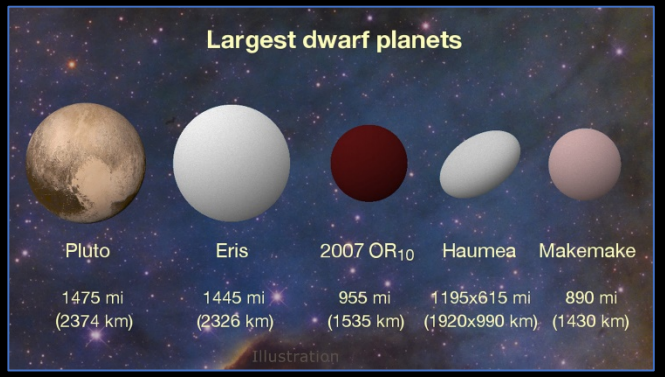
2. Uranus science flyby and gravity assist.

3. KB Exploration:
   - A large KBO is the prime target to explore Kuiper Belt diversity relative to Pluto system.
   - Additional small-intermediate sized KBO flybys pre- and/or post this flyby.

- New Frontiers cost class: ~$1B.

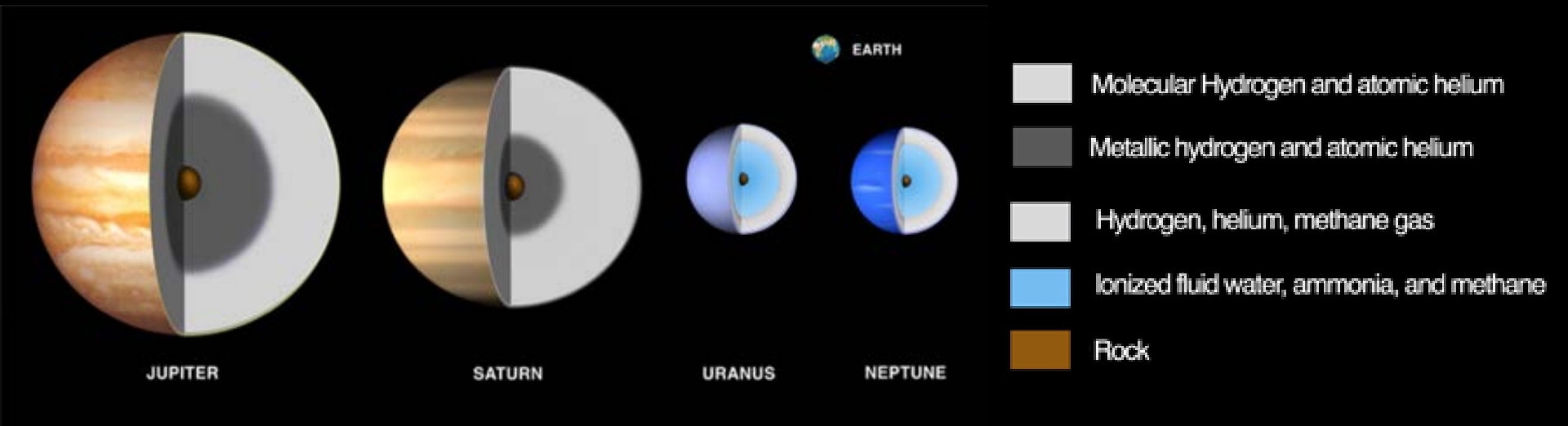
- Enhanced Goal: Uranus entry probe as a foreign (e.g., ESA) contribution.





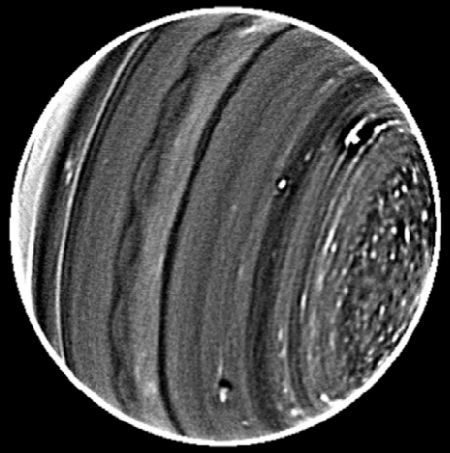
IG Priority Science Objectives (1 of 5)

- Twelve science objectives, spanning all elements of an ice-giant system: interior, atmosphere, rings, satellites, and magnetosphere.
- The two highest-priority objectives address fundamental questions regarding ice giants as a class of planet:
  - Constrain the structure and characteristics of the planet's interior, including layering, locations of convective and stable regions, internal dynamics.
  - Determine the planet's bulk composition, including abundances and isotopes of heavy elements, He and heavier noble gases.

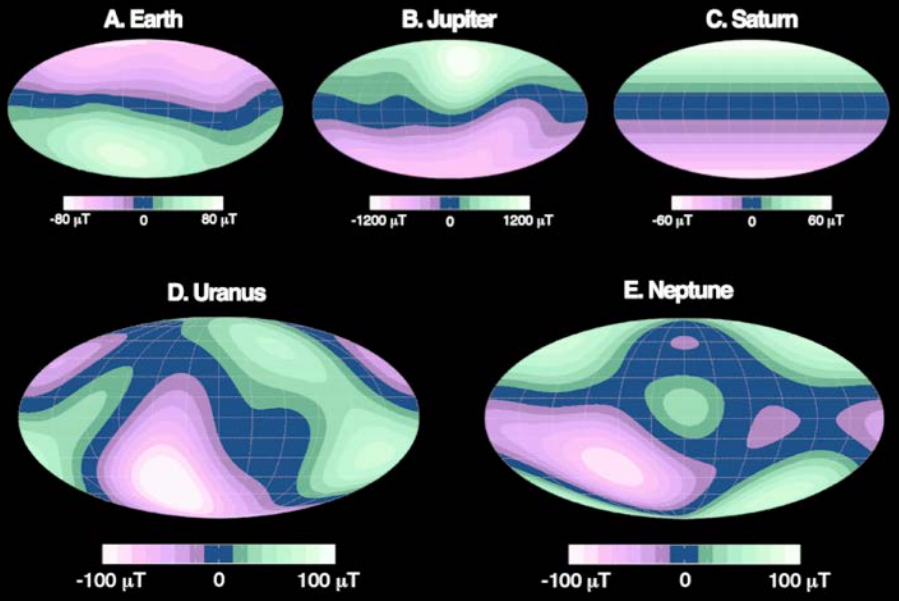


IG Science Objectives (2 of 5)

- Improve knowledge of the planetary dynamo.
- Determine the planet's atmospheric heat balance.
- Measure planet’s tropospheric 3-D flow (zonal, meridional, vertical) including winds, waves, storms and their lifecycles, and deep convective activity



Uranus (Sromovsky et al. 2015)



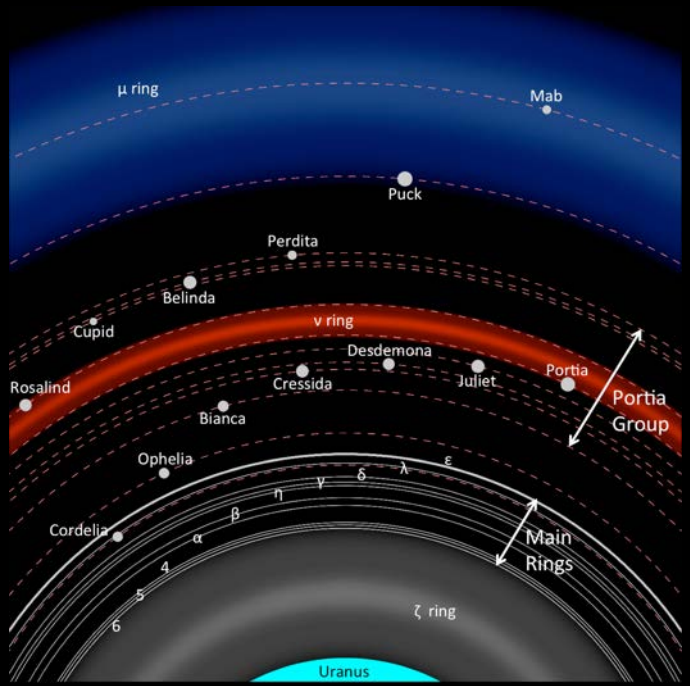
Planetary Magnetic Fields, from Schubert and Soderlund (2011)

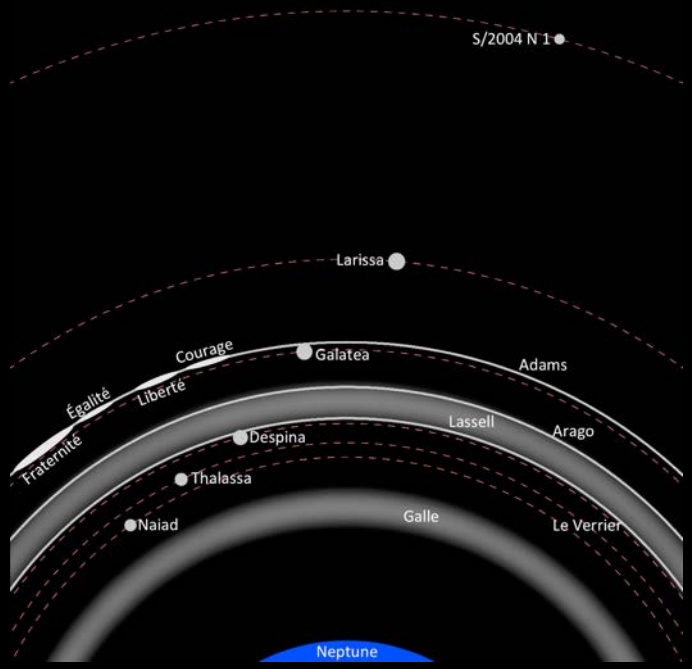
IG Science Objectives (3 of 5)

- Determine the composition, density, structure, source, spatial and temporal variability, and dynamics of Triton's atmosphere.
- Map the shape and surface geology of major and minor satellites.
- Determine the density, mass distribution, internal structure of major satellites and, where possible, small inner satellites and irregular satellites.

IG Science Objectives (4 of 5)

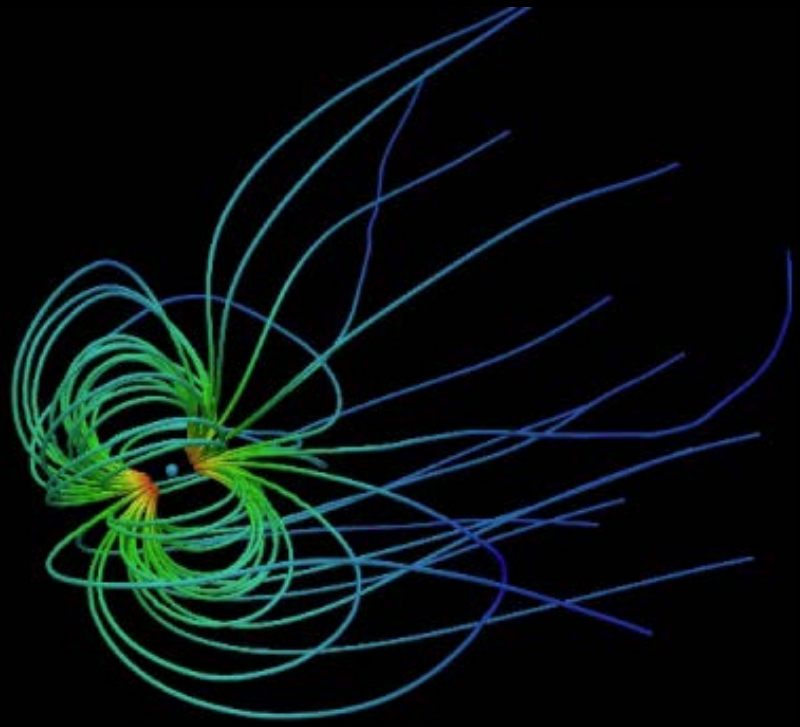
- Determine surface composition of rings and moons; search for evidence of modifications and evidence of long-term mass exchange/volatile transport.
- Characterize the structures and temporal changes in the rings.
- Obtain a complete inventory of small moons, including embedded source bodies in dusty rings.





IG Science Objectives (5 of 5)

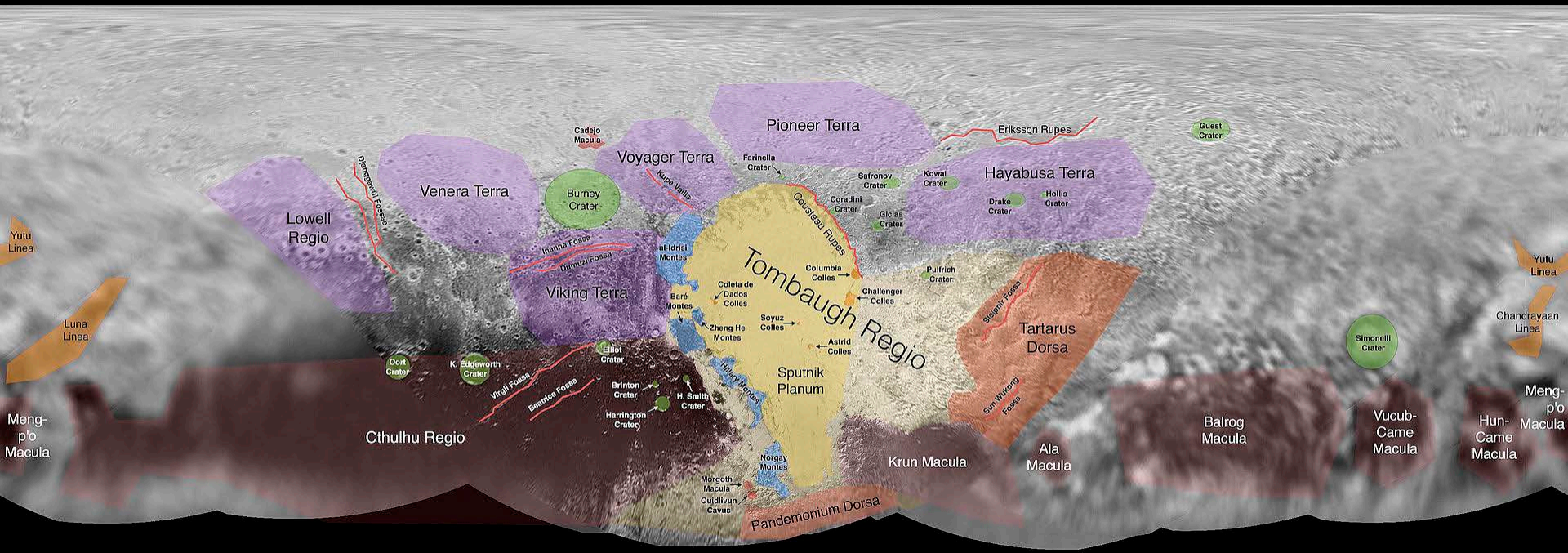
- Investigate solar wind-magnetosphere-ionosphere interactions and constrain plasma transport in the magnetosphere.



Lars Majnertsen, Imperial College London

KBO Science Objectives (1 of 5)

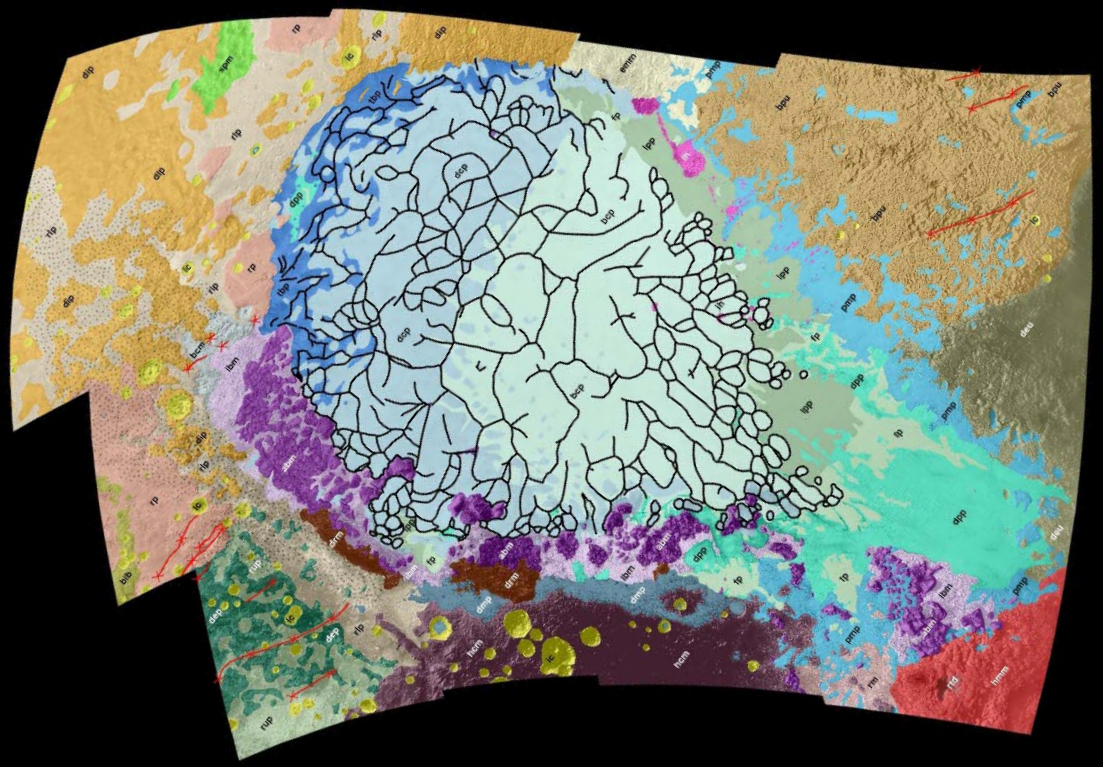
- Map the surfaces of these bodies in three dimensions to determine their photometric properties, geologies, and geophysical expressions.



Informal Names for Features on Pluto

KBO Science Objectives (2 of 5)

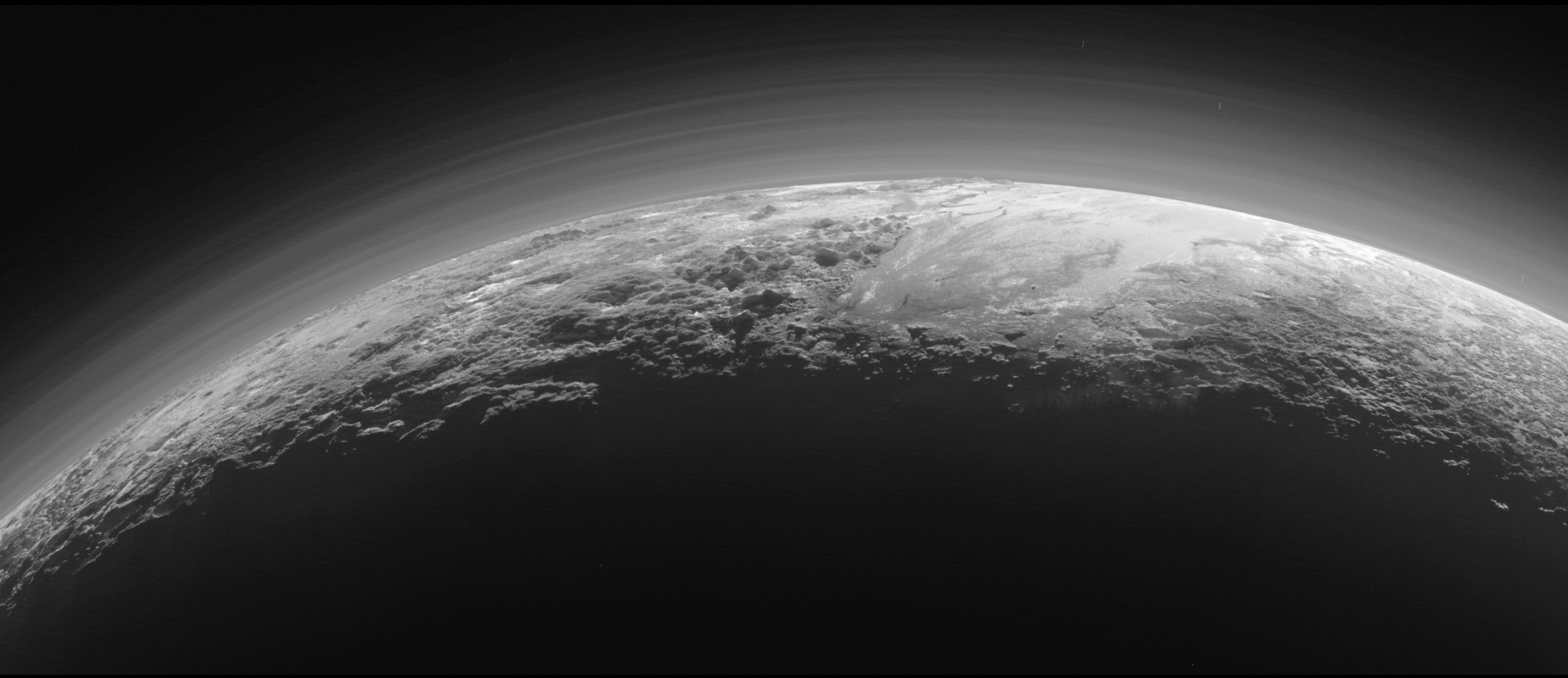
- Map the surface compositions of these bodies to determine their surface and interior compositions and compositional variation.



Geologic map of Pluto's Sputnik Planitia and surroundings

KBO Science Objectives (3 of 5)

- Assess their atmospheric compositions, vertical structures, escape rates, and solar wind interactions.



Haze with multiple layers in the atmosphere of Pluto.

KBO Science Objectives (4 of 5)

- Search for and study satellites and rings of KBO targets.

  Ground-based stellar occultation measurements show that Centaur 10199 Chariklo has rings.

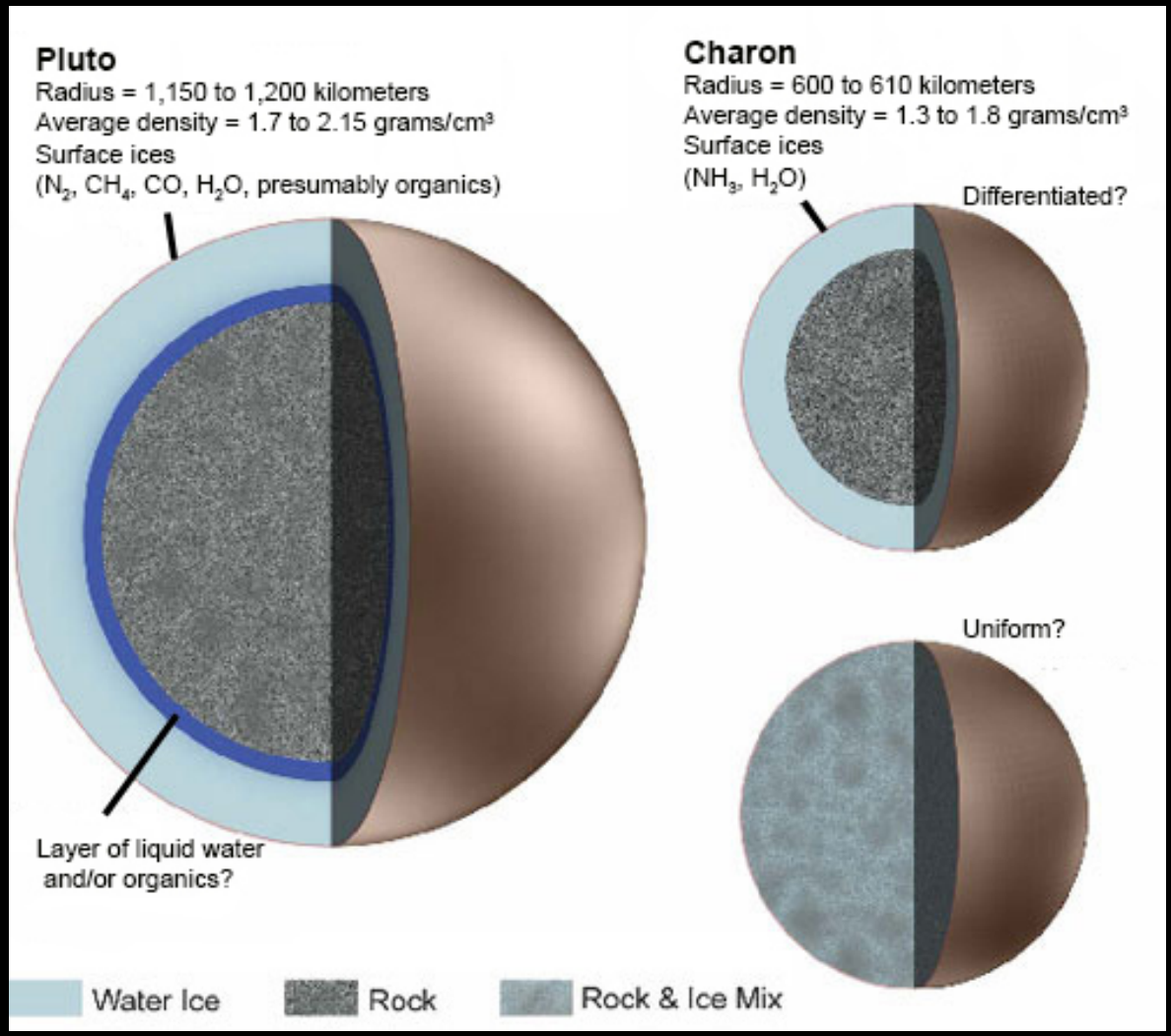
Styx Nix Kerberos Hydra

10 miles
10 km

Charon

KBO Science Objectives (5 of 5)

- Study the interior structure of Planet-sized KBOs through gravity and magnetic fields.



2014 MU_{69} “Ultima Thule”

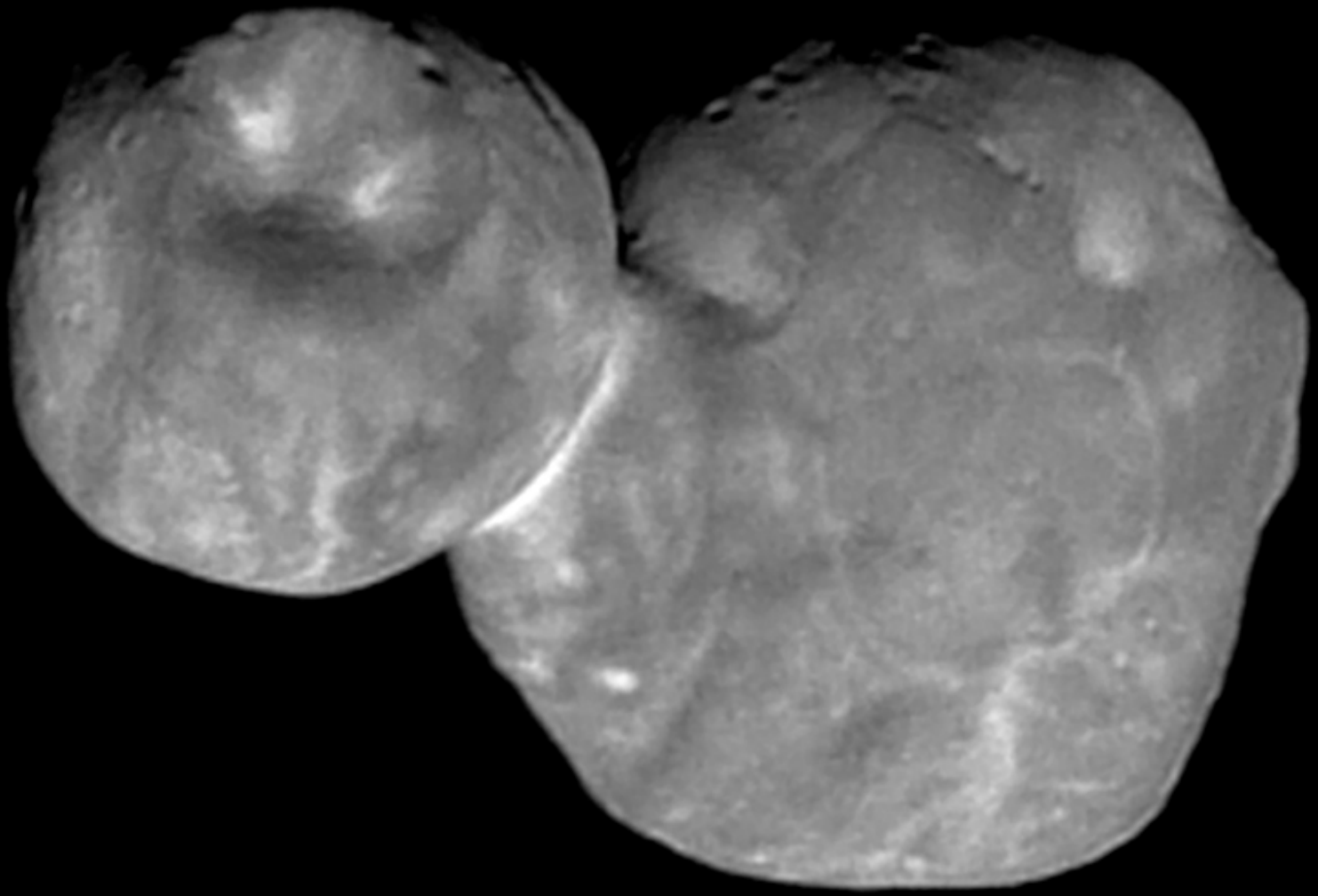


Image captured by New Horizons on January 1, 2019

What is Needed Next:

- **The Next Steps:**
  1. **A Uranus-KBO Pre-Decadal Study.**
  2. **A Neptune Orbiter+Probe Pre-Decadal Study.**

- **We ask your help urging these two studies, and also by signing on to the IG-KB Missions White Paper (contact Amy Simon at amy.simon@nasa.gov)**