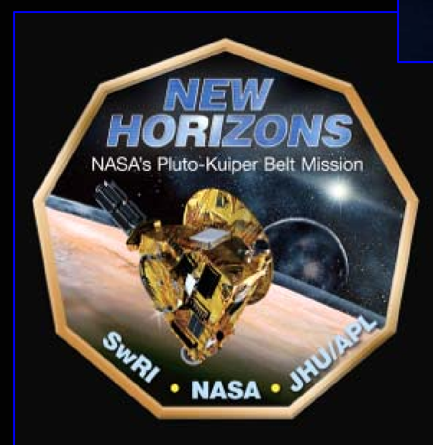
New Horizons Update

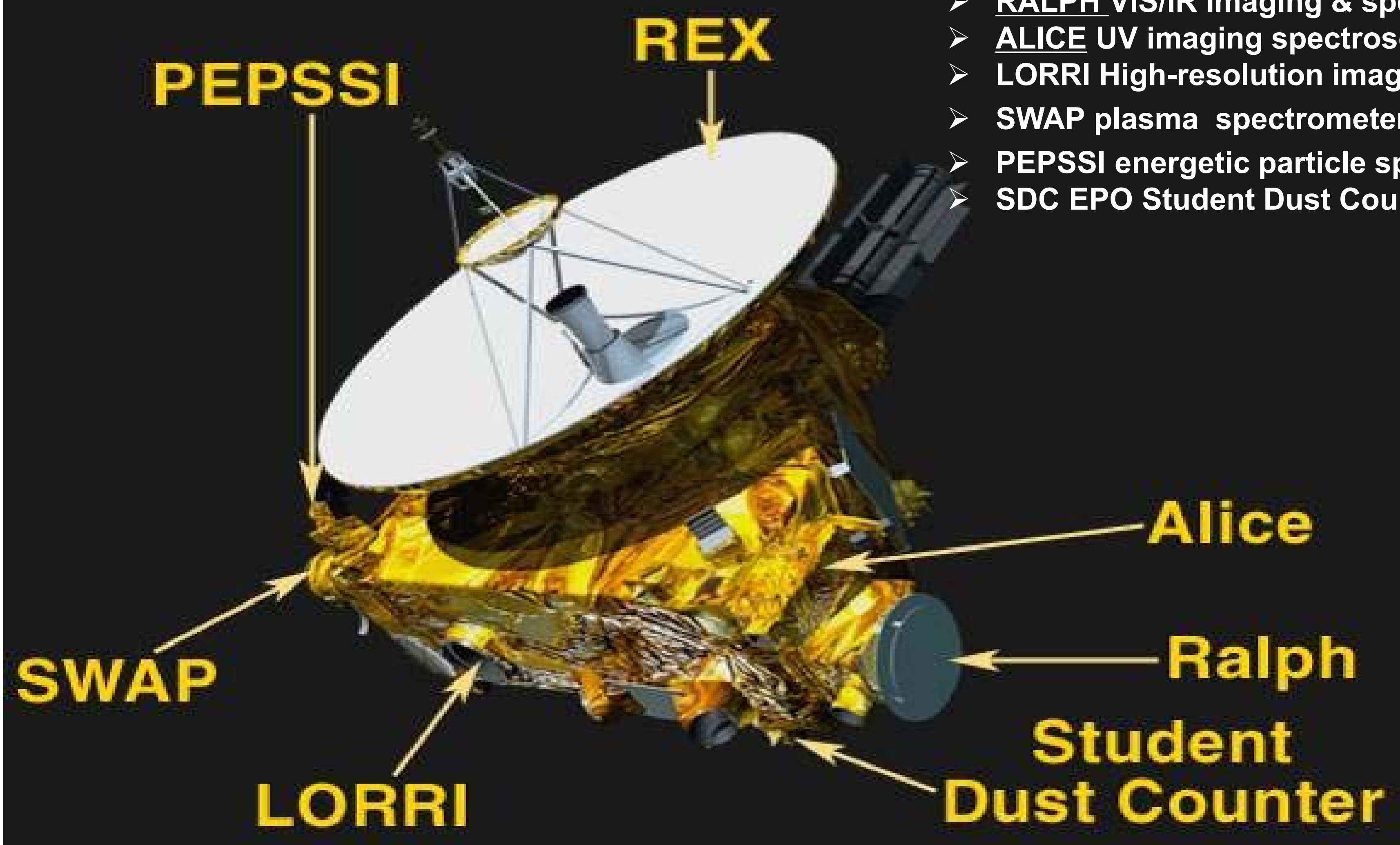
Alan Stern/Mission PI



THE SCIENTIFIC PAYLOAD

Instruments:

- REX radio science & radiometry
- RALPH VIS/IR imaging & spectroscopy
- ALICE UV imaging spectroscopy
- LORRI High-resolution imager
- SWAP plasma spectrometer
- PEPSSI energetic particle spectrometer
- SDC EPO Student Dust Counter



NEW HORIZONS:
MISSION OBJECTIVES

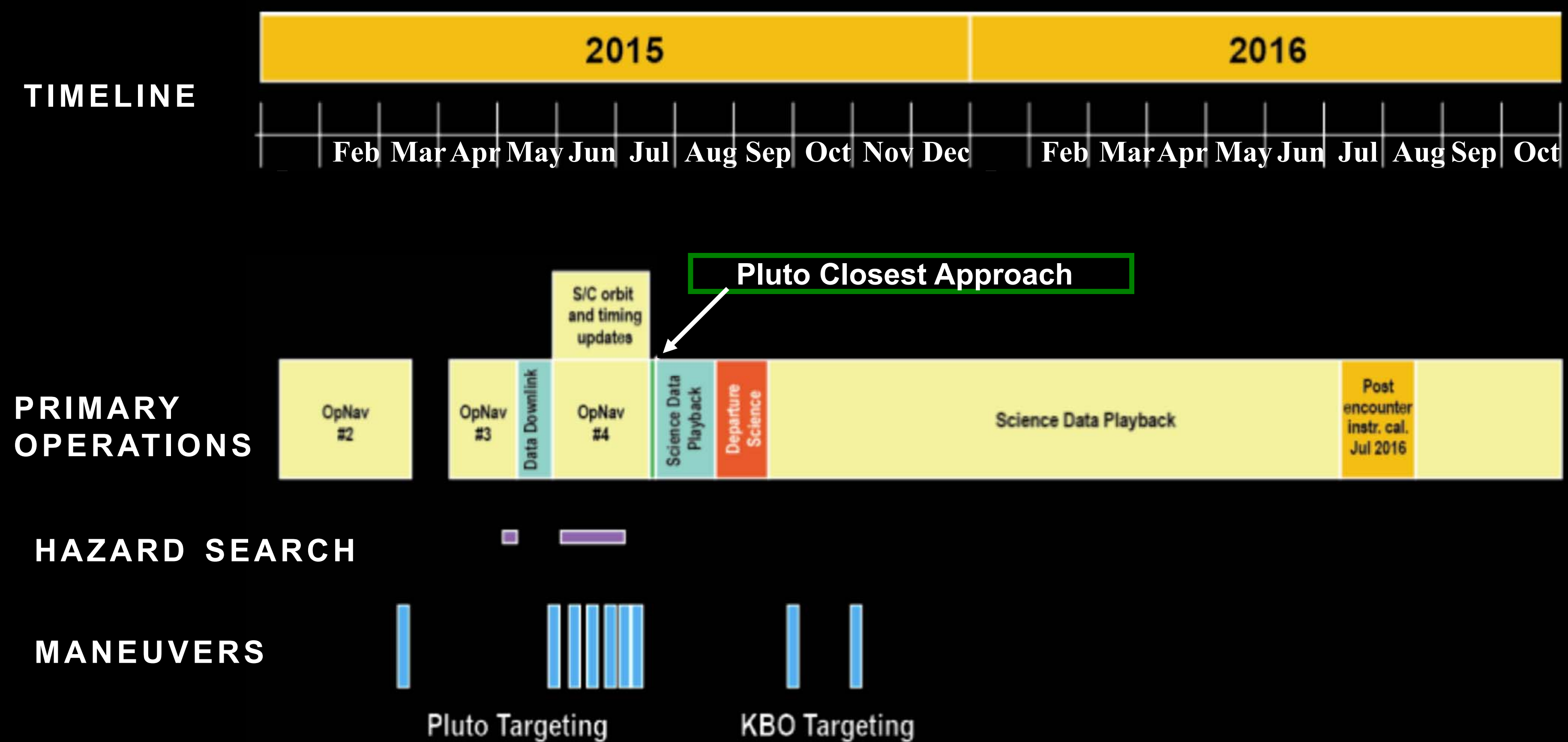
Primary objectives:

- Characterize global geology and morphology of Pluto and Charon
- Map surface composition of Pluto and Charon
- Characterize the neutral atmosphere of Pluto and its escape rate

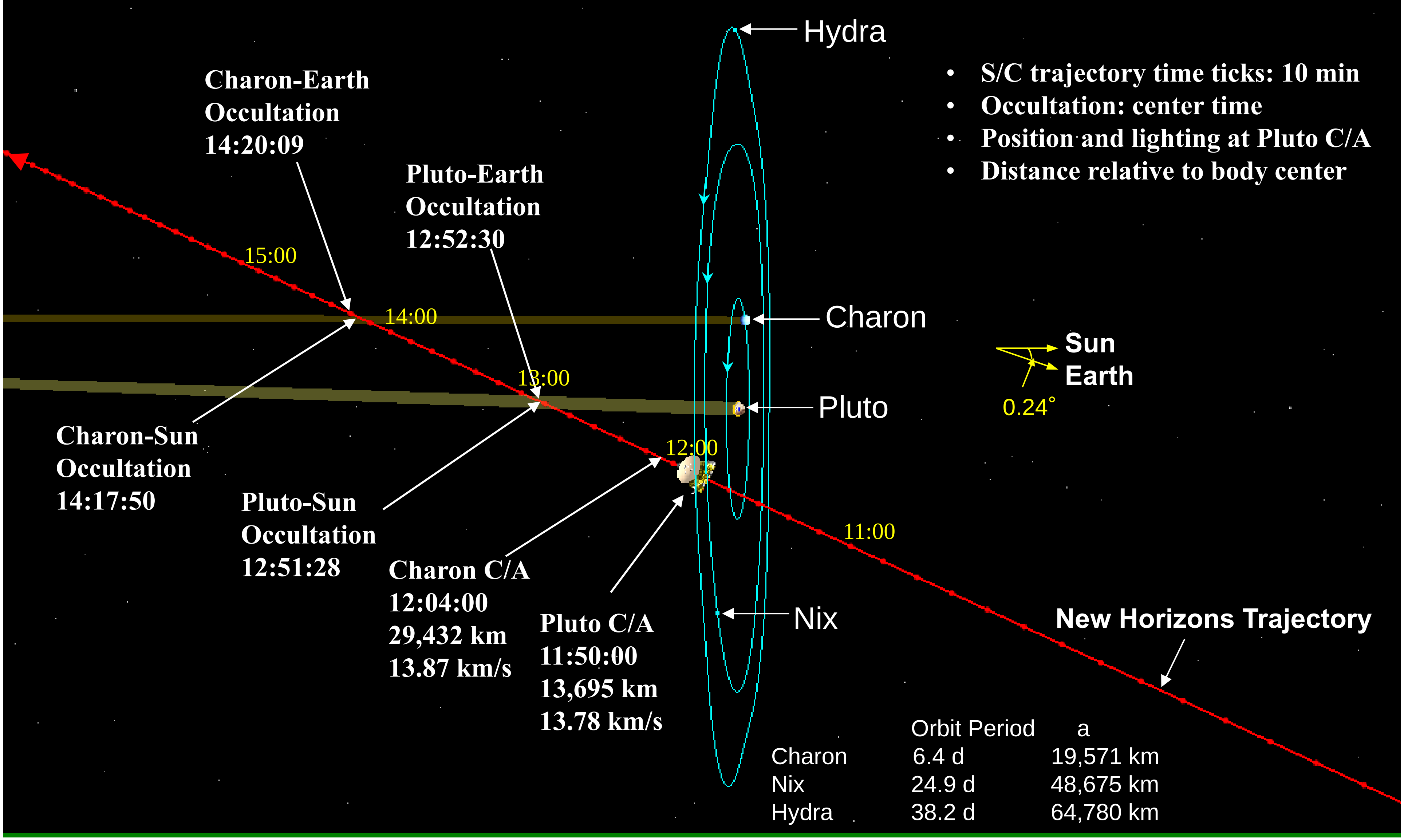
Earth's surface (New York City) at New Horizons' highest resolution
(70 meters / pixel)

Viz: Dr. Amanda Zangari

ENCOUNTER OVERVIEW

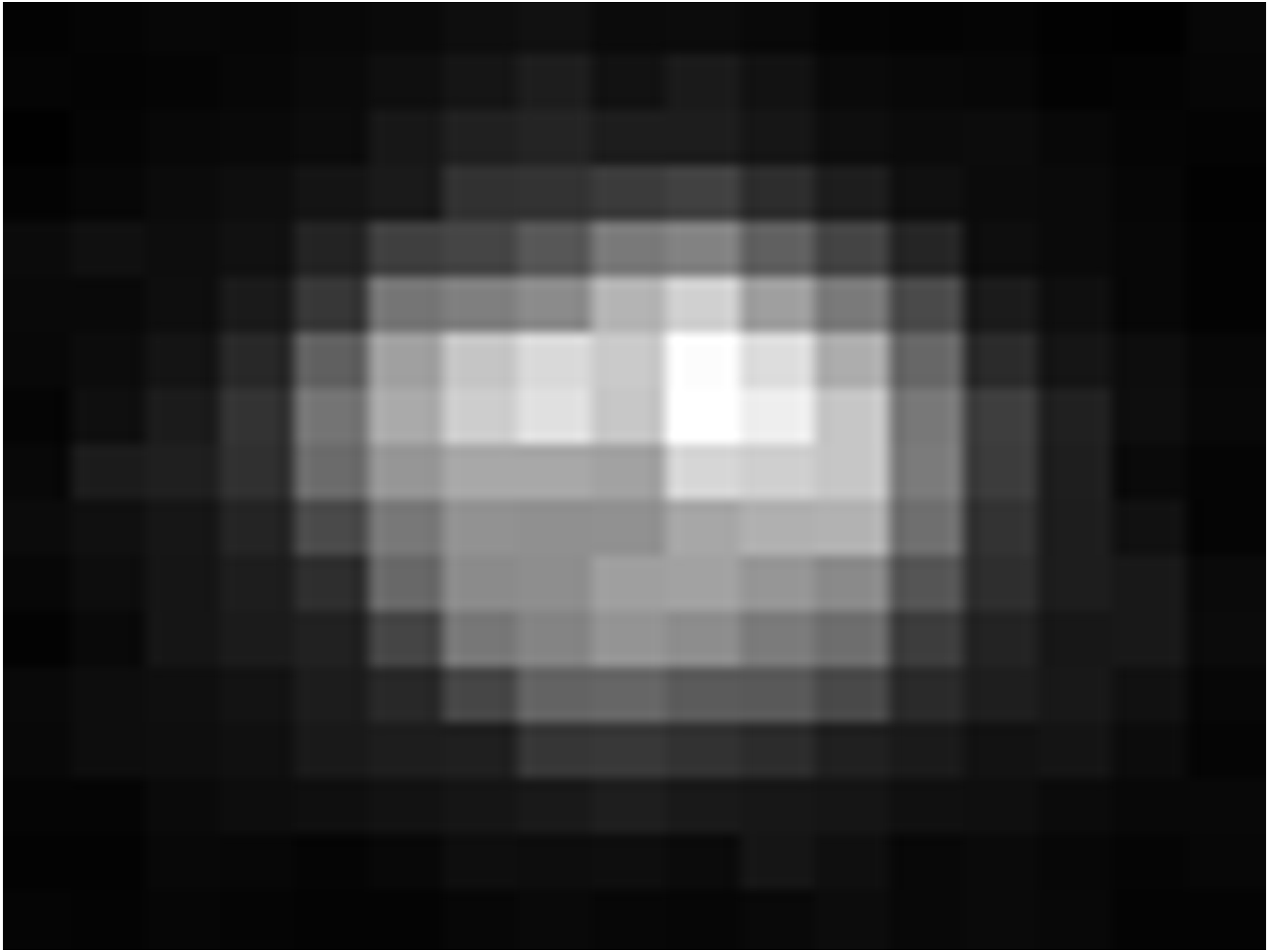


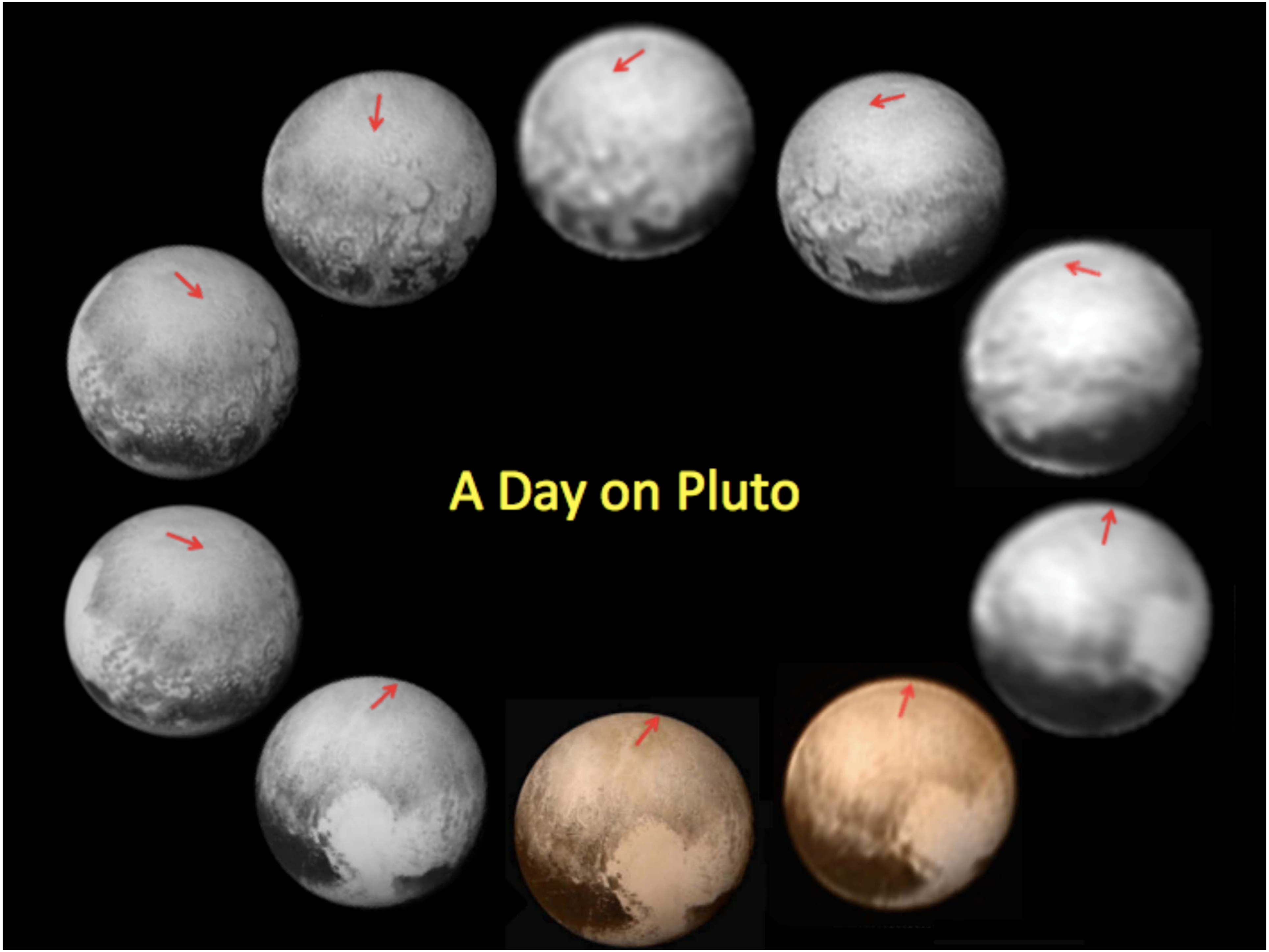
AND NEEDLES TO THREAD

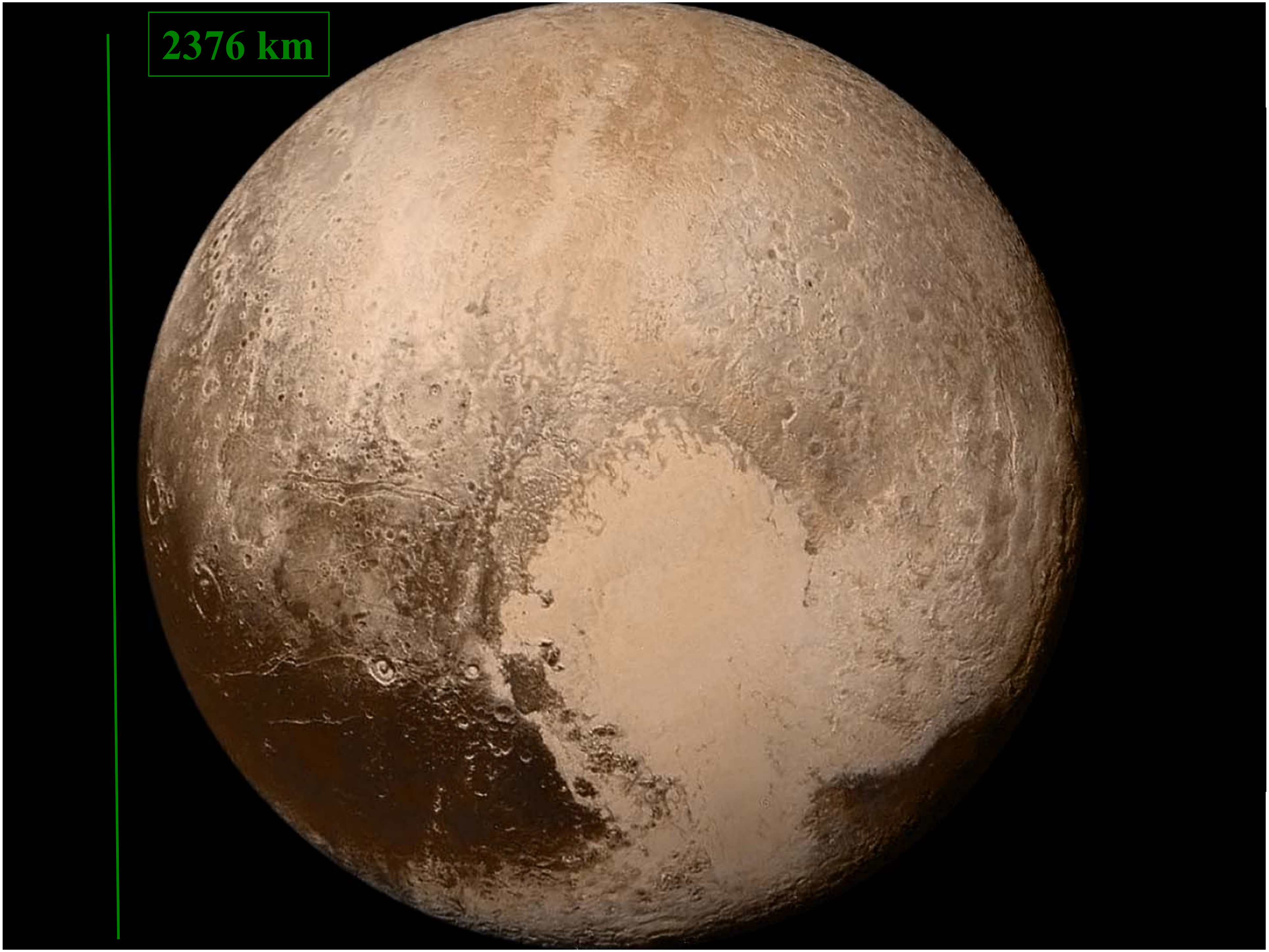


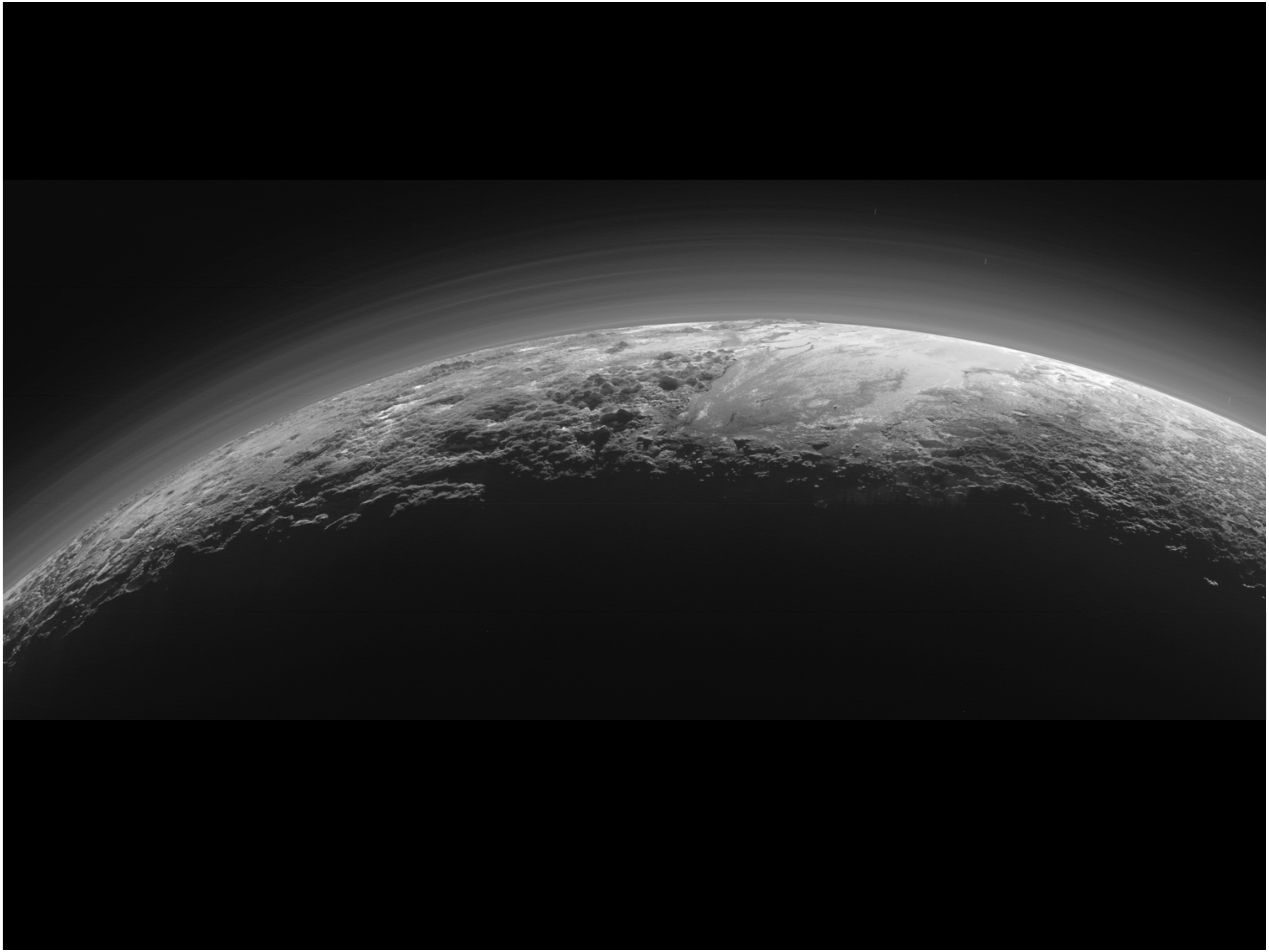
- S/C trajectory time ticks: 10 min
- Occultation: center time
- Position and lighting at Pluto C/A
- Distance relative to body center

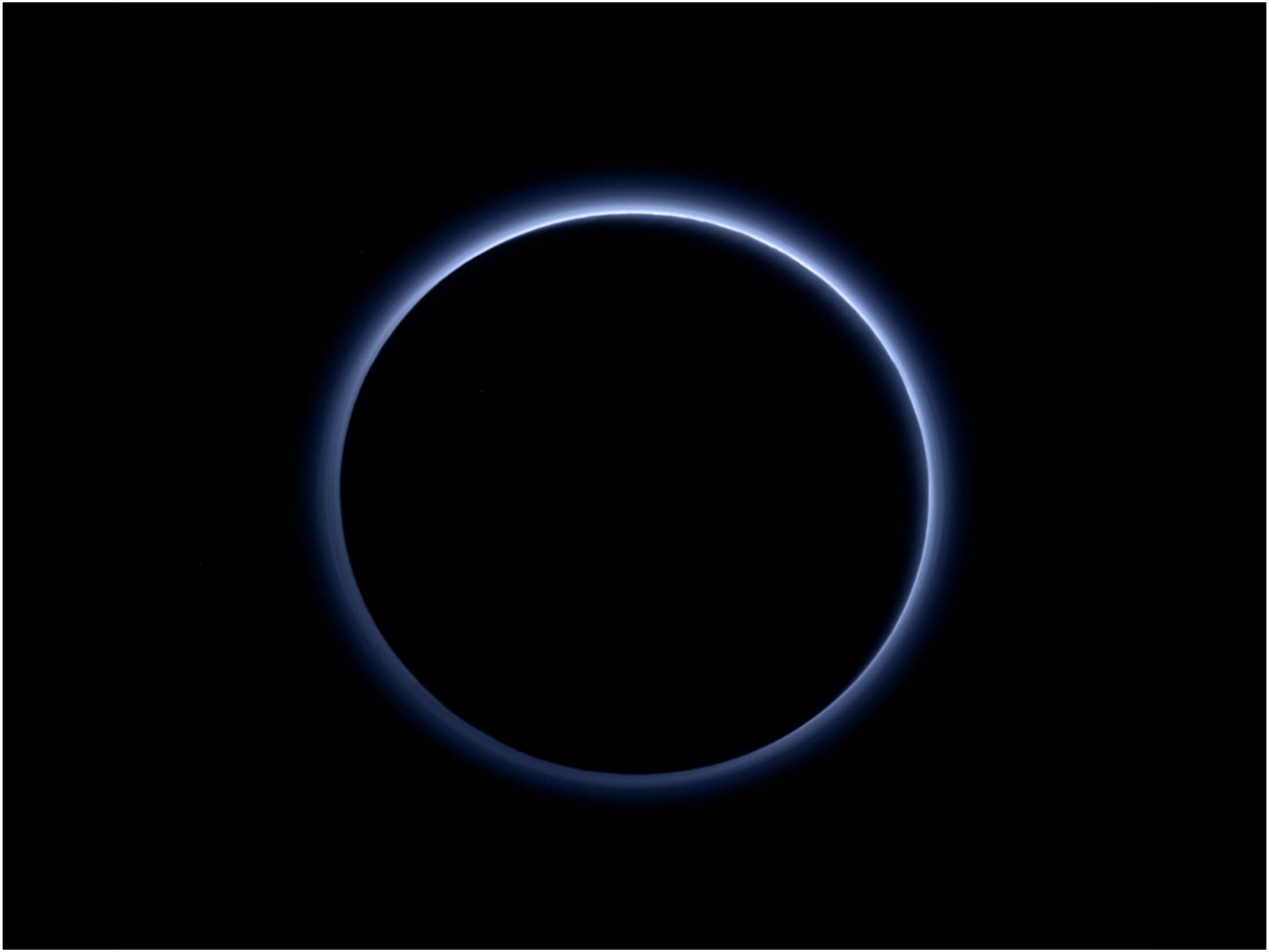
	Orbit Period	a
Charon	6.4 d	19,571 km
Nix	24.9 d	48,675 km
Hydra	38.2 d	64,780 km

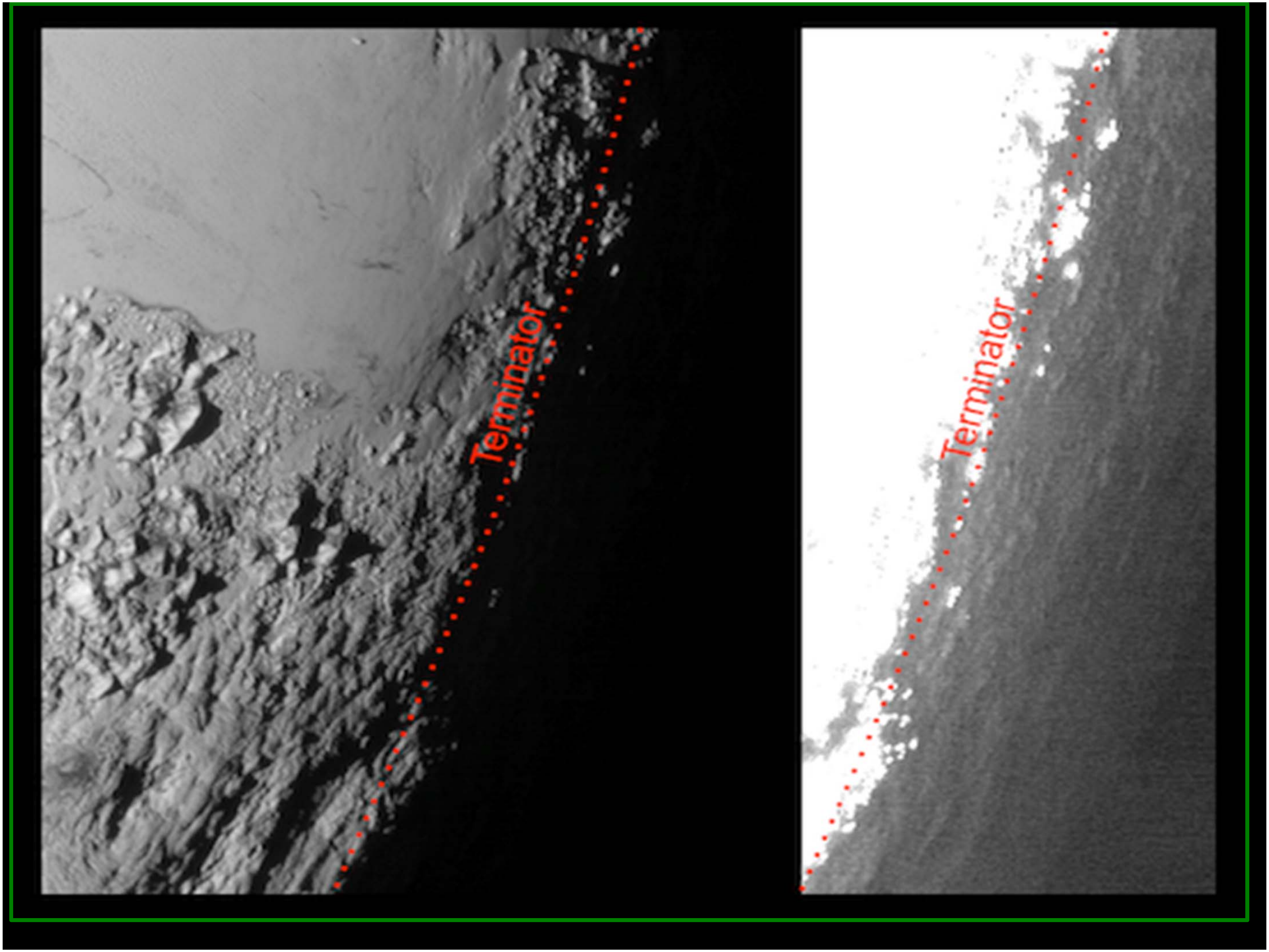



A Day on Pluto

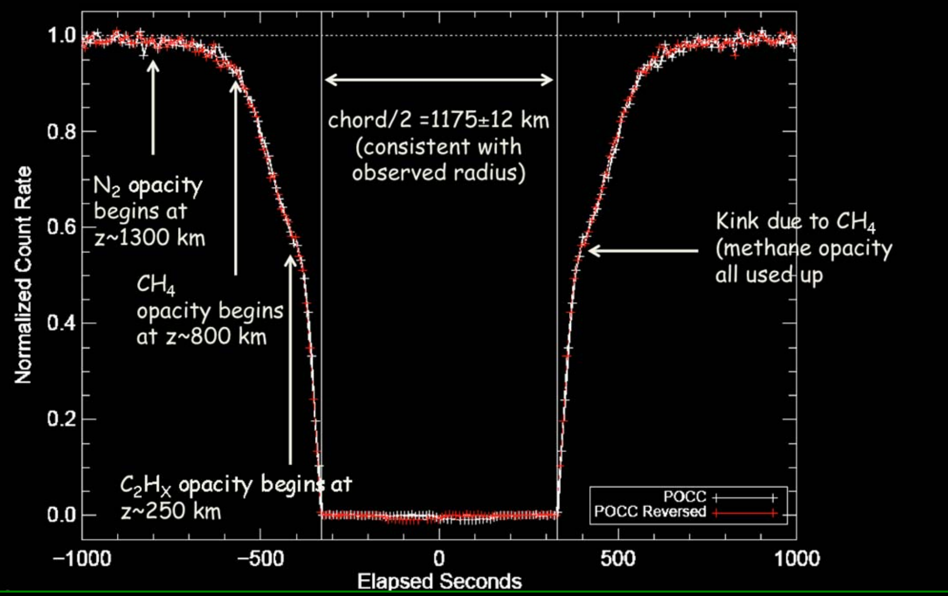

2376 km



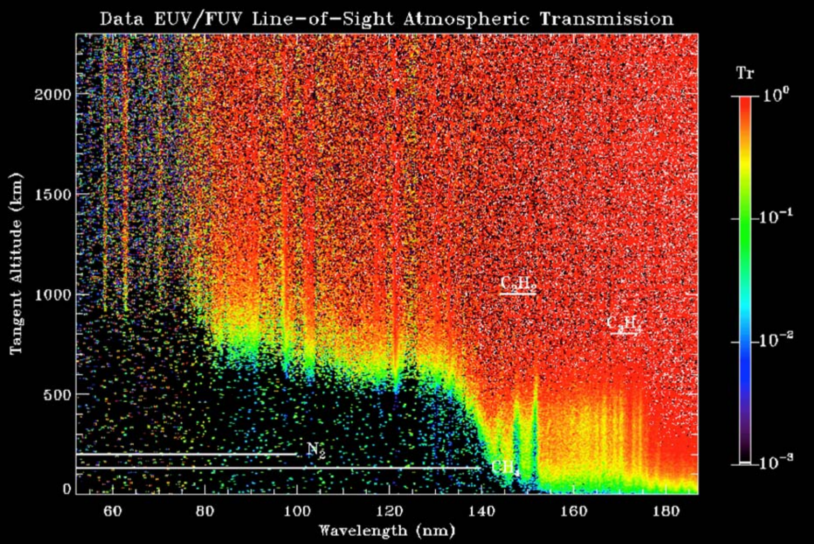


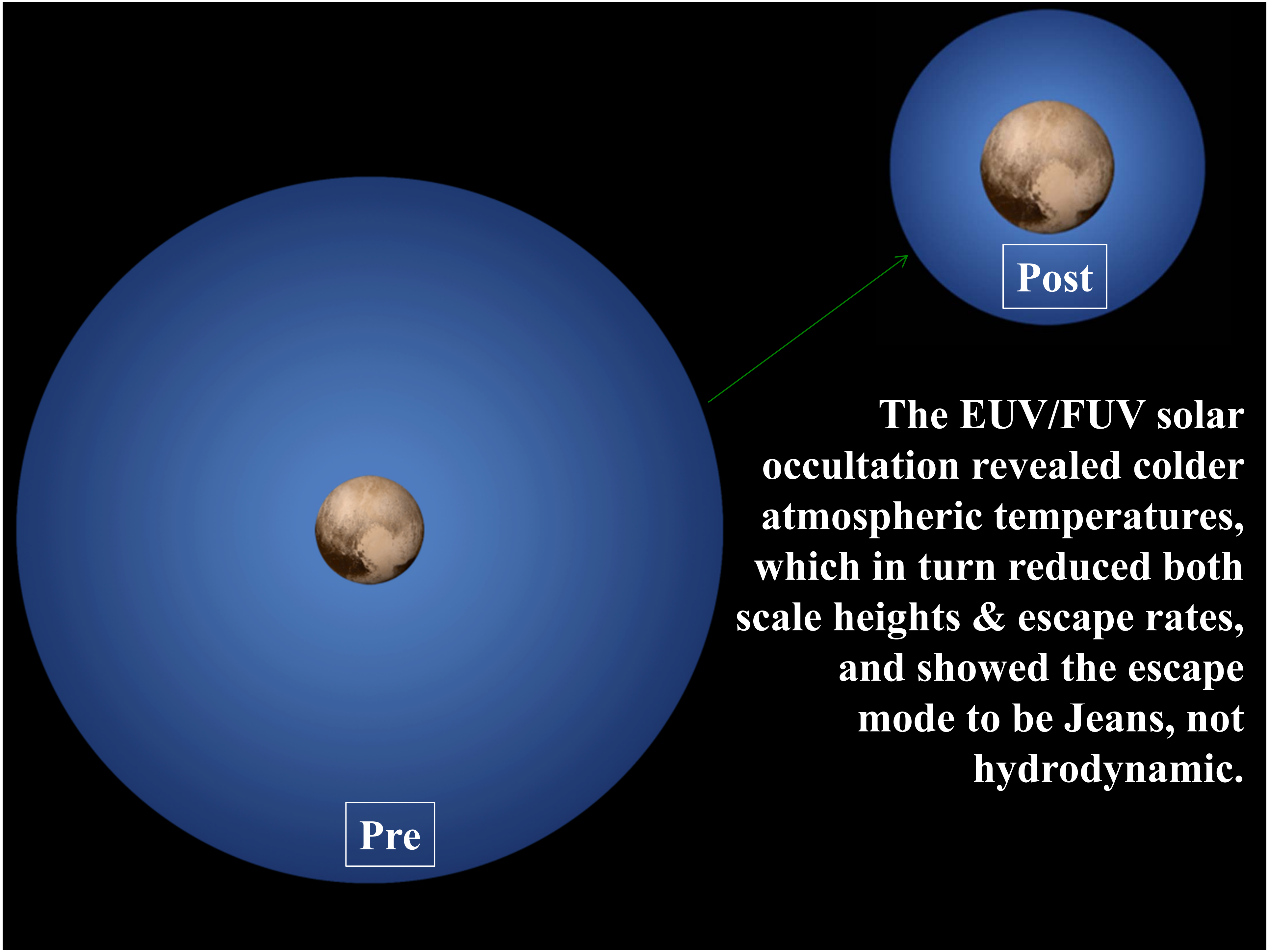

Terminator
Terminator

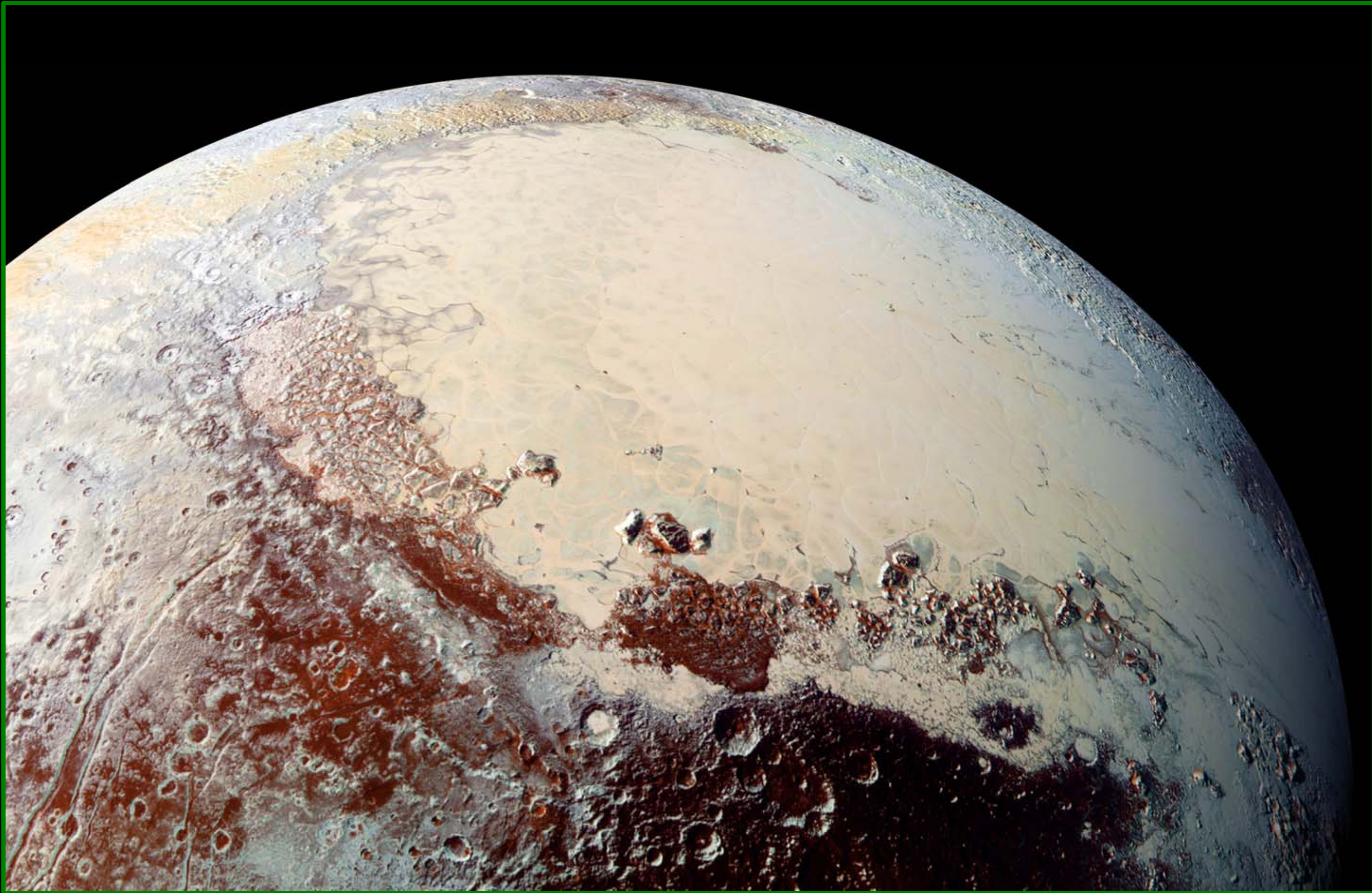
Alice Pocc Total Count Rates

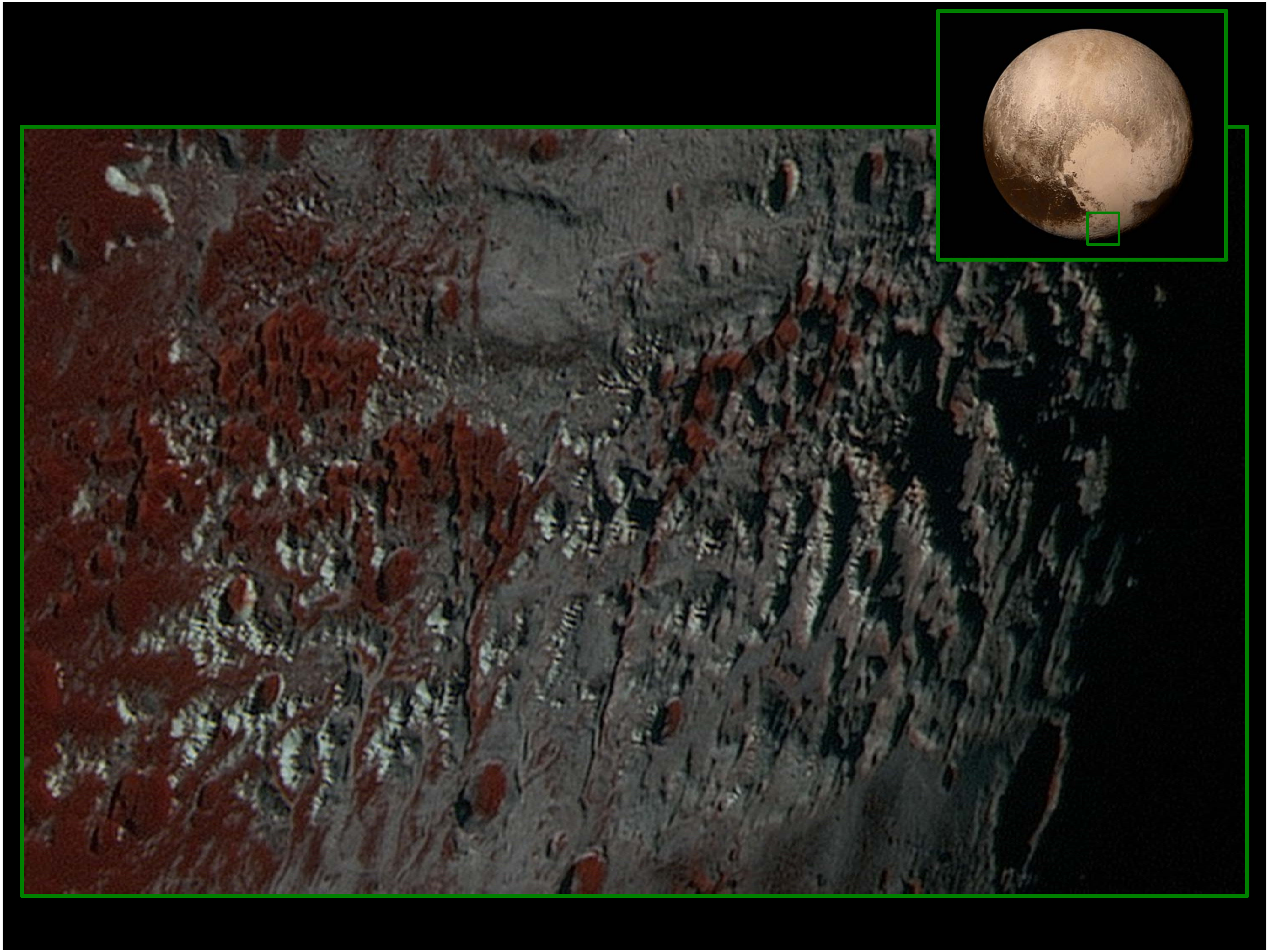


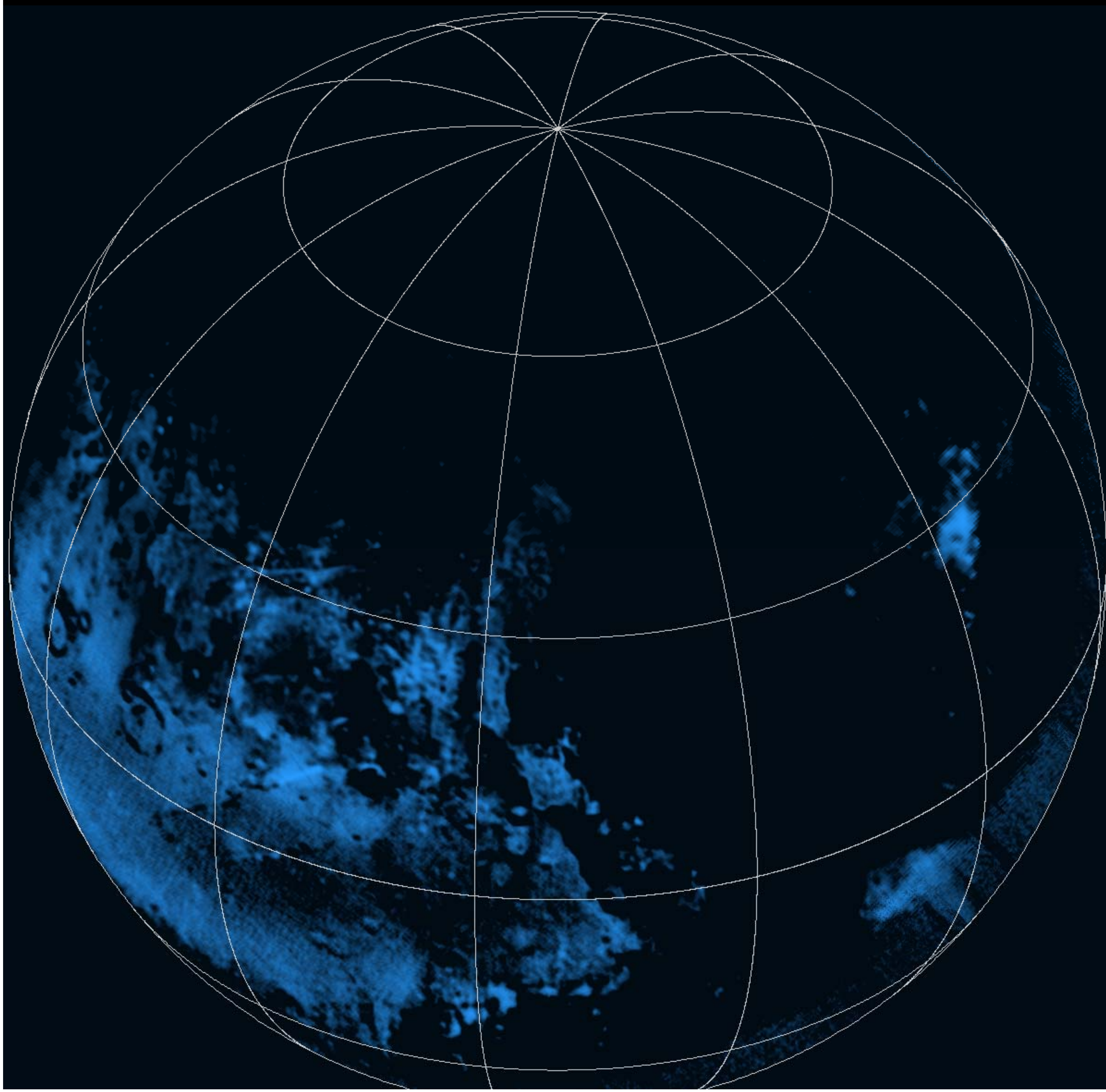
Pluto's FUV Opacity



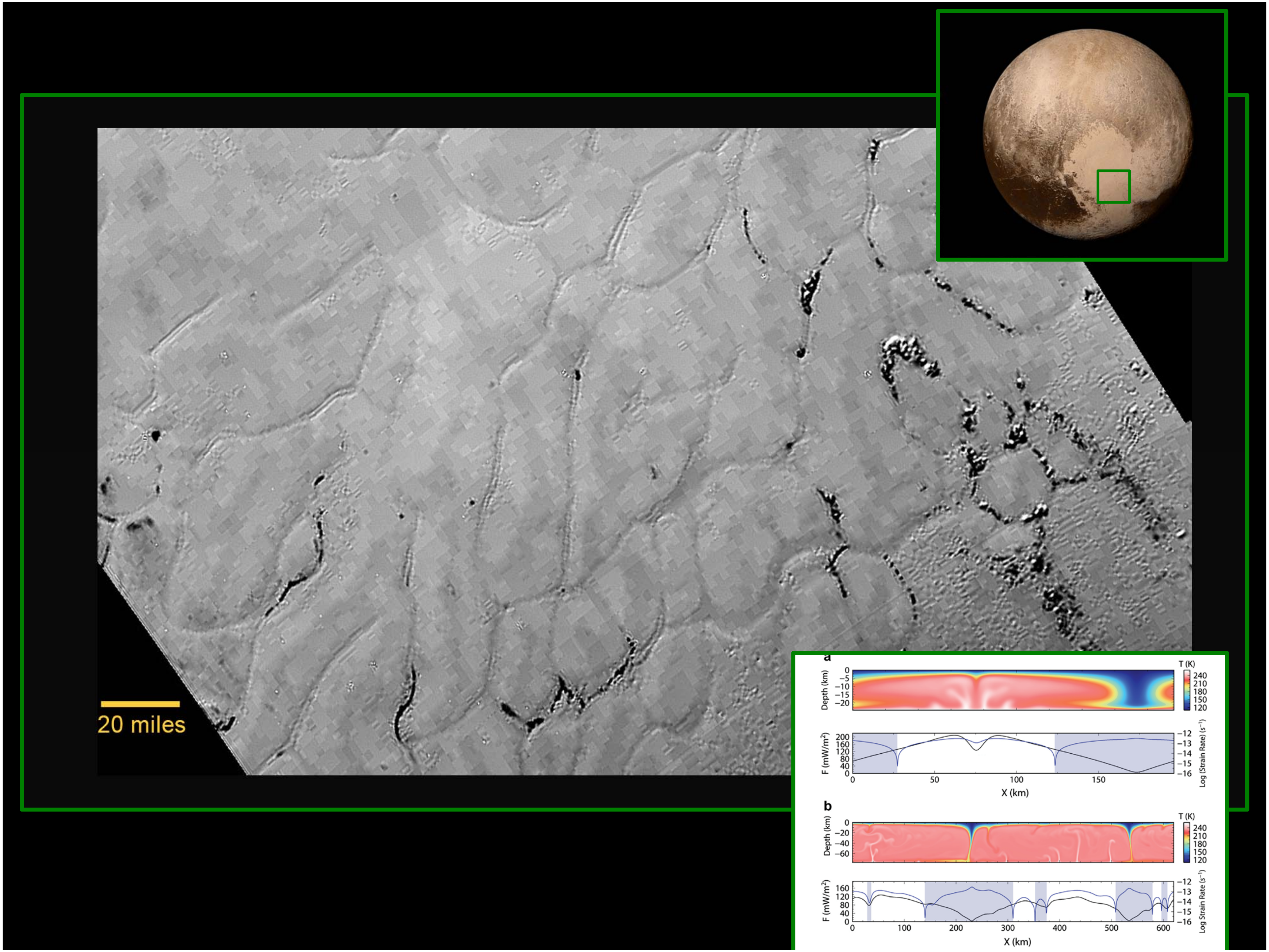

Post
The EUV/FUV solar occultation revealed colder atmospheric temperatures, which in turn reduced both scale heights & escape rates, and showed the escape mode to be Jeans, not hydrodynamic.
Pre



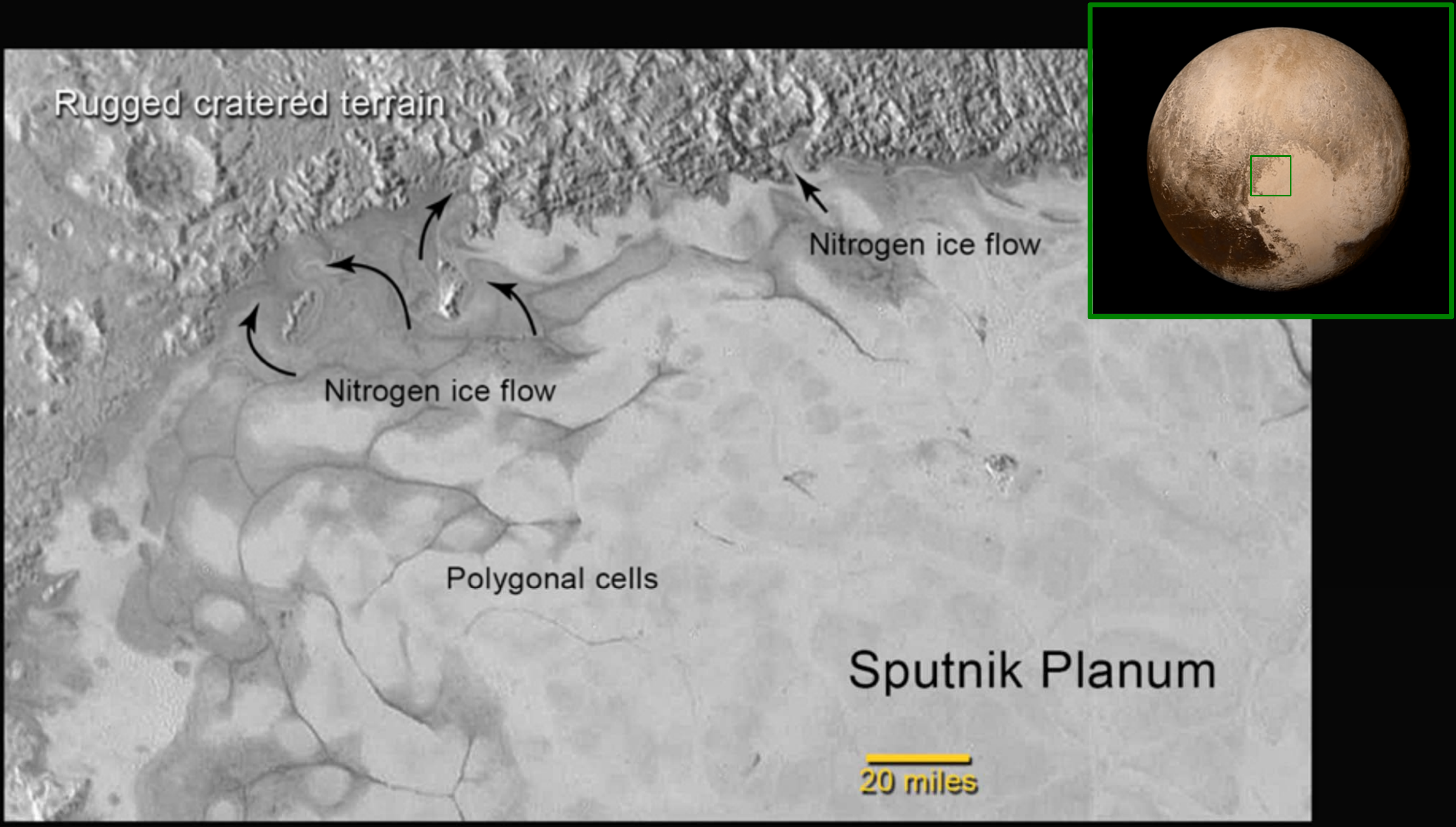


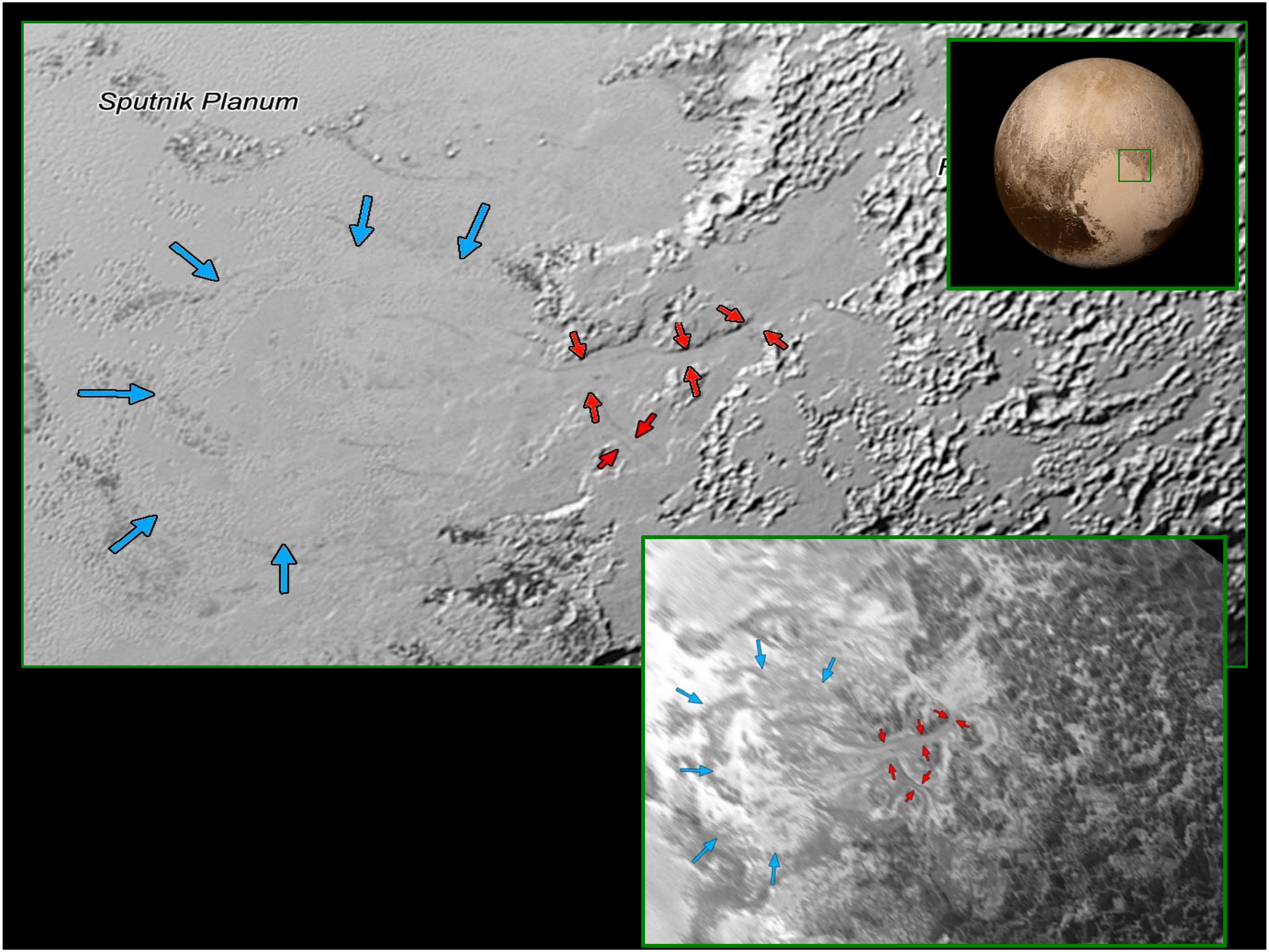


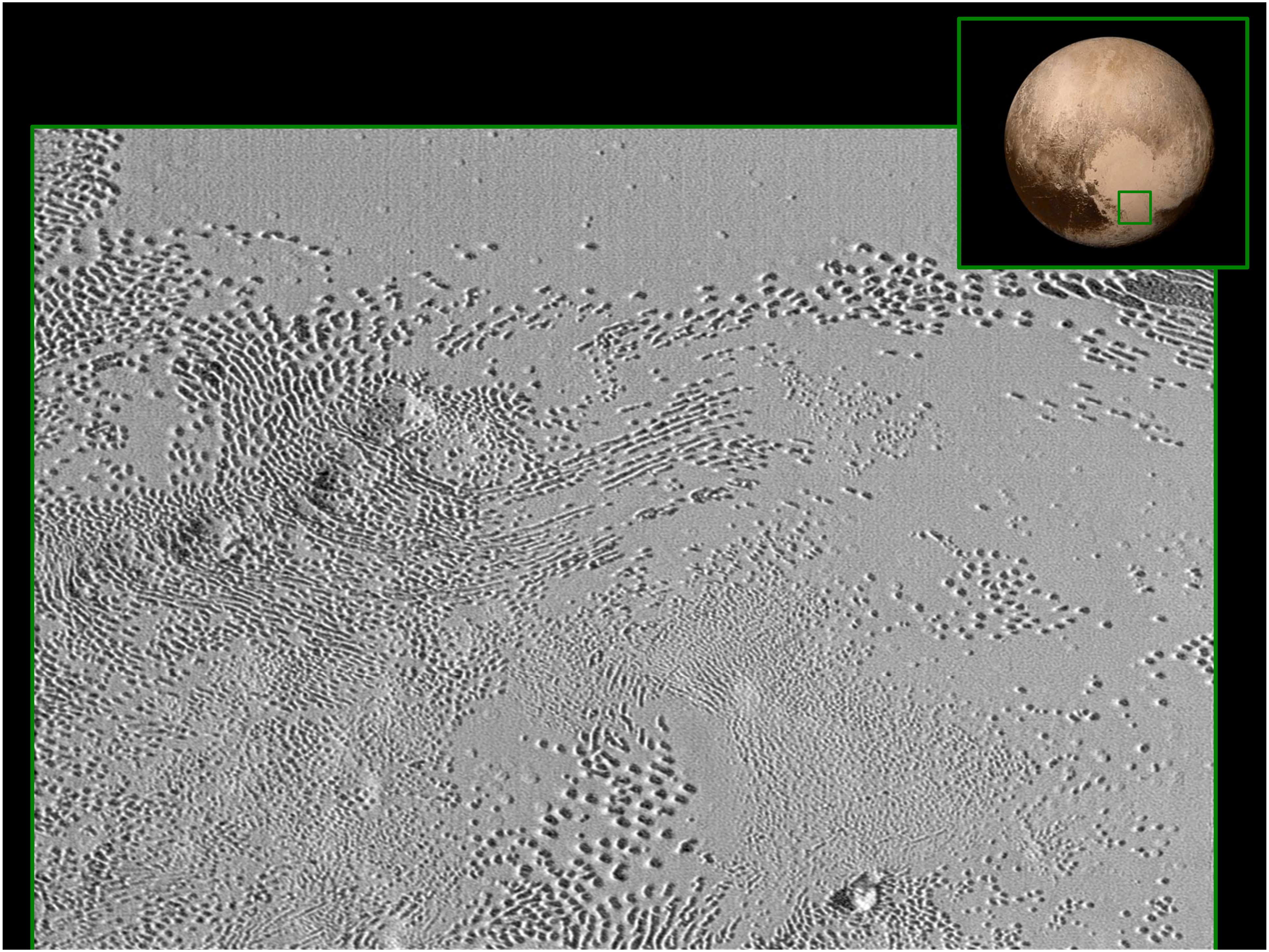
H2O

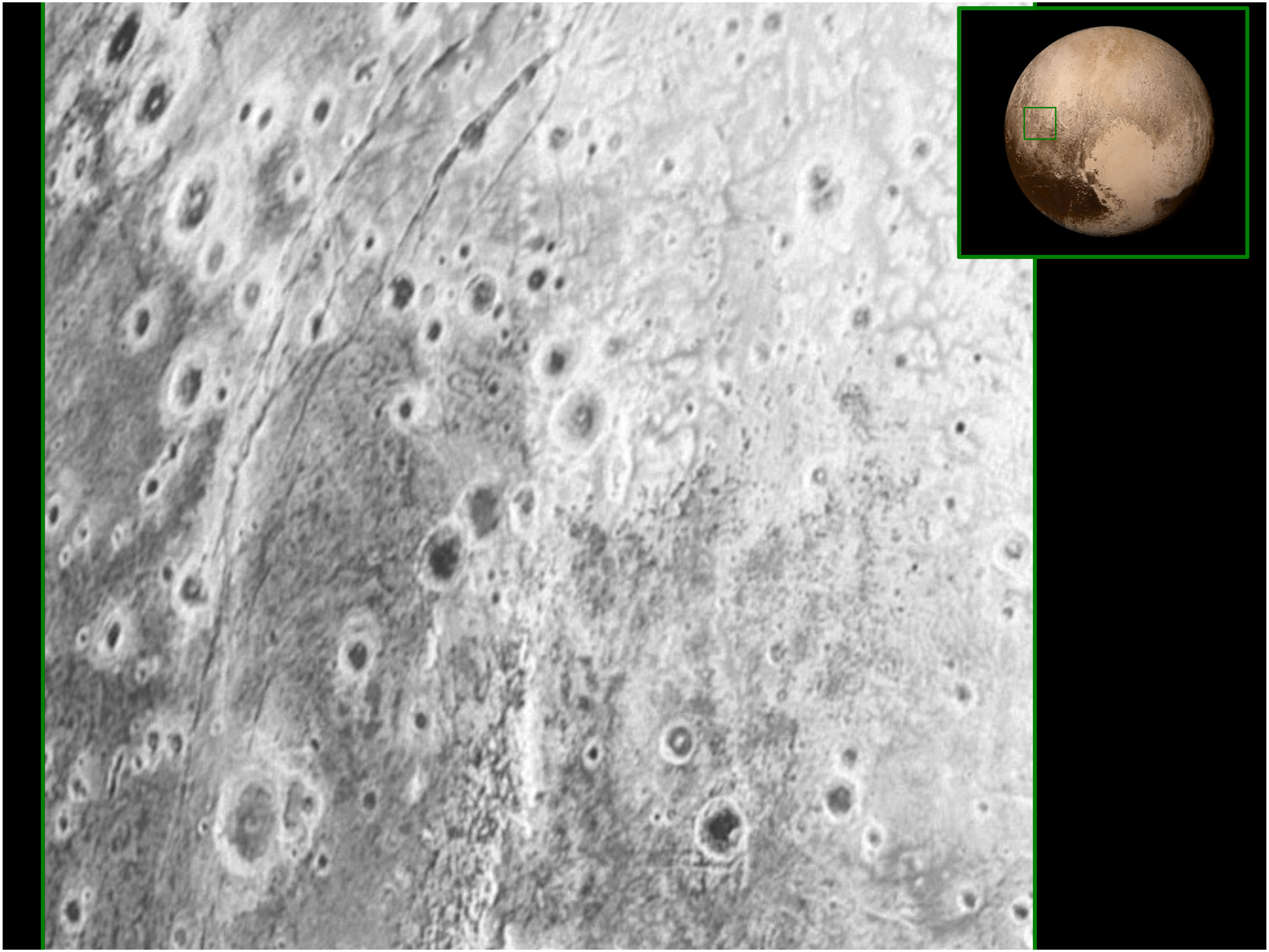

20 miles
a
Depth (km)
T (K)
F (mW/m²)
Log (Strain Rate) (s⁻¹)
X (km)
b
Depth (km)
T (K)
F (mW/m²)
Log Strain Rate (s⁻¹)
X (km)

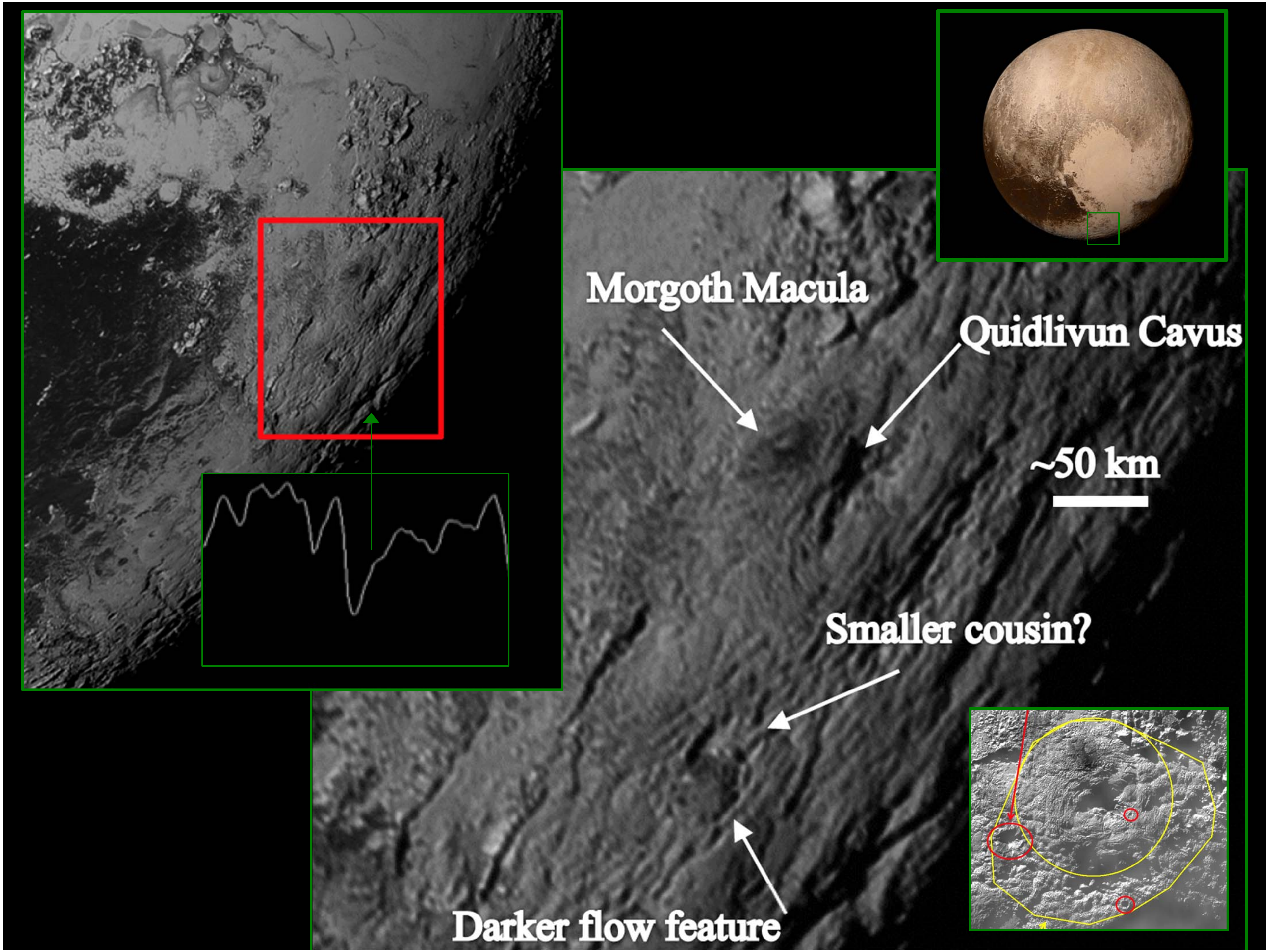
NEW HORIZONS:
GLACIAL FLOW ON PLUTO

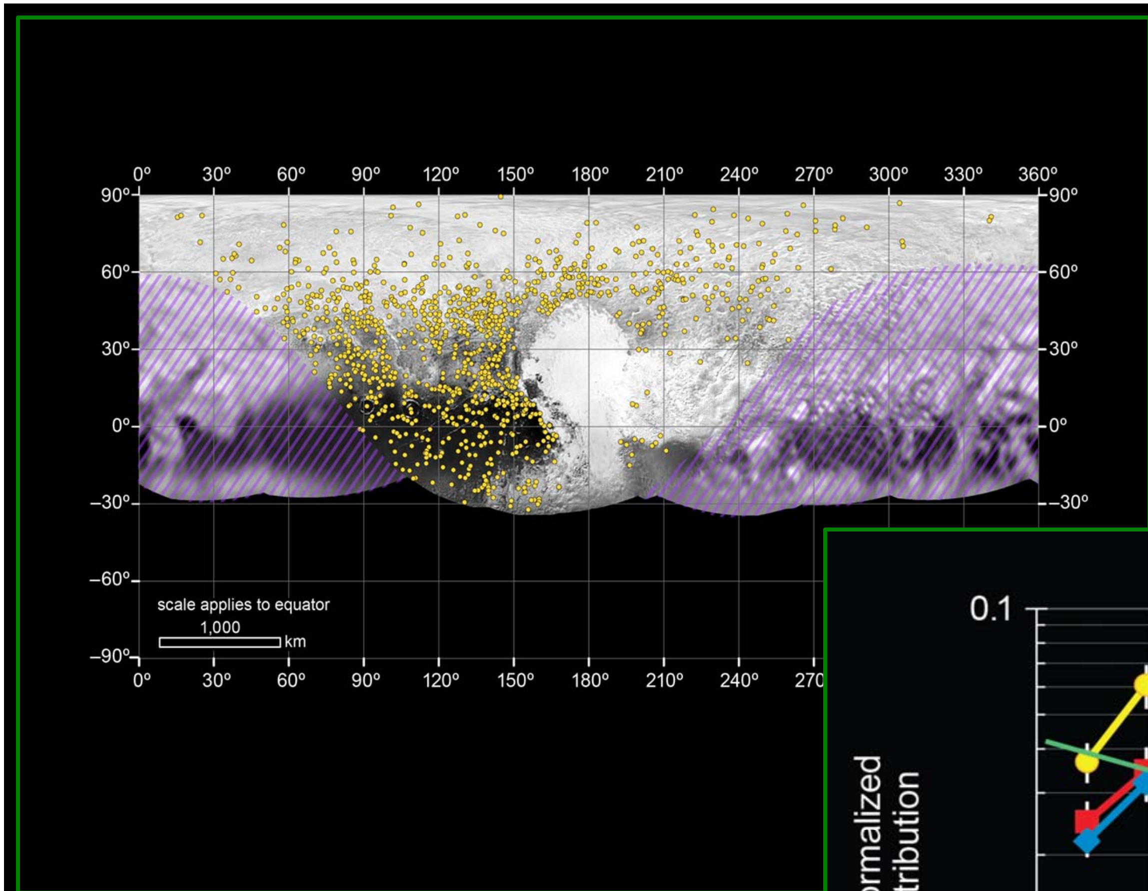


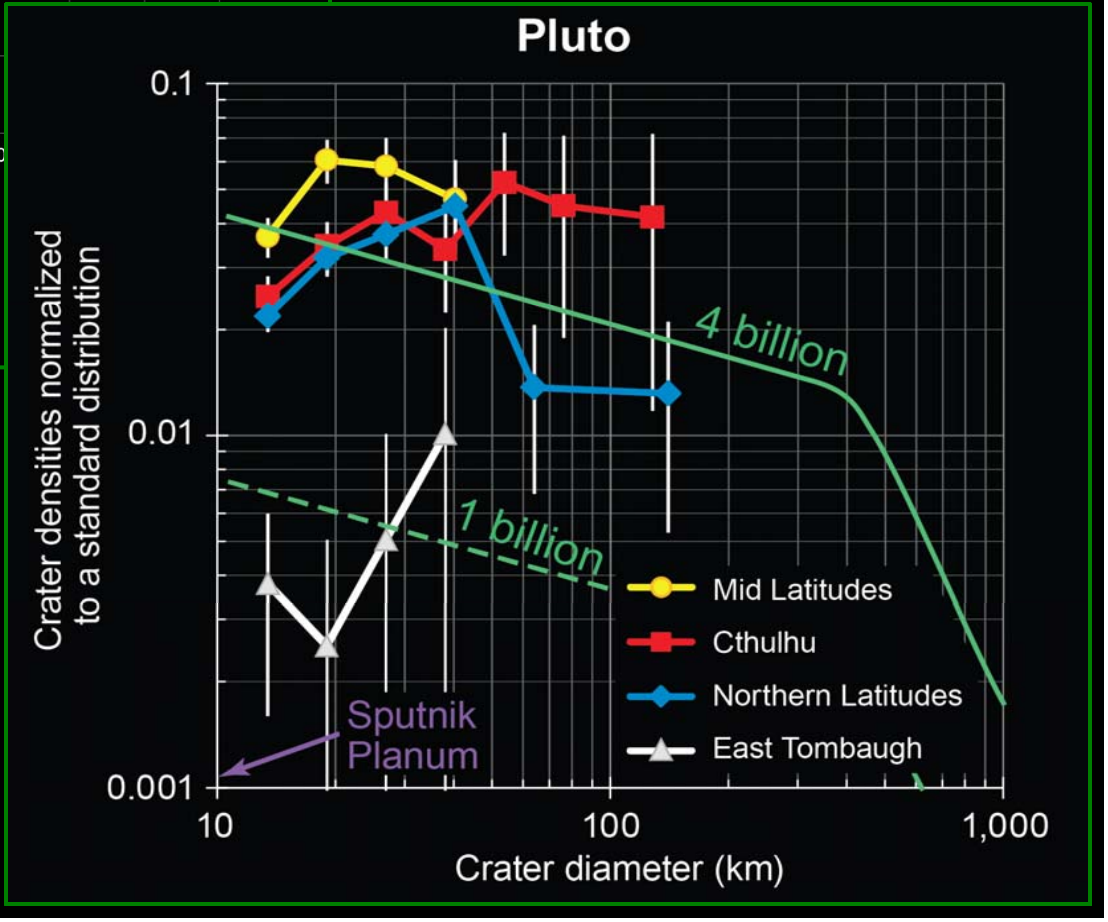

Sputnik Planum

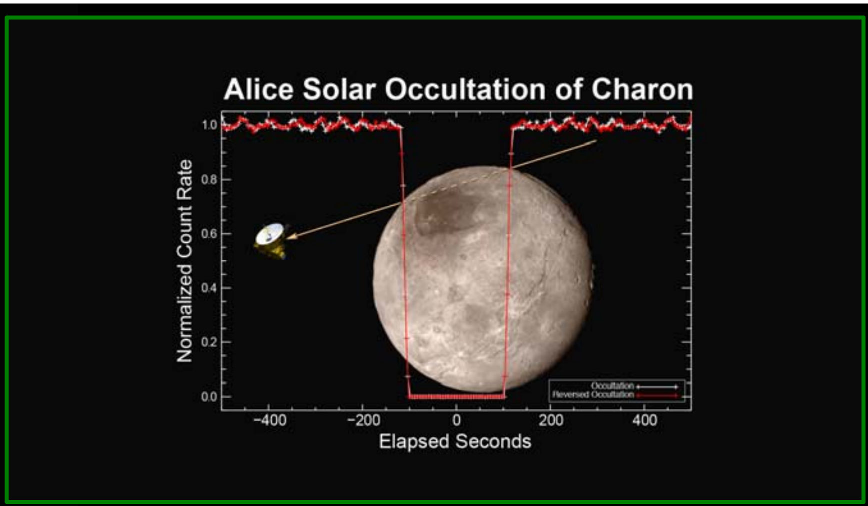


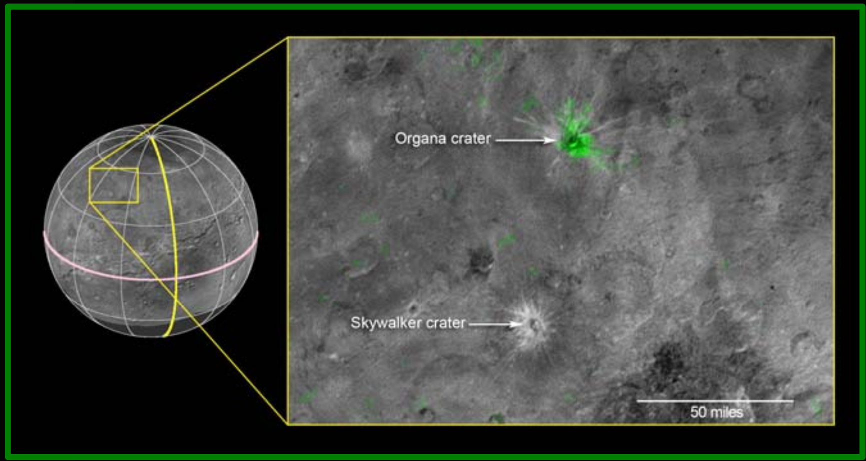


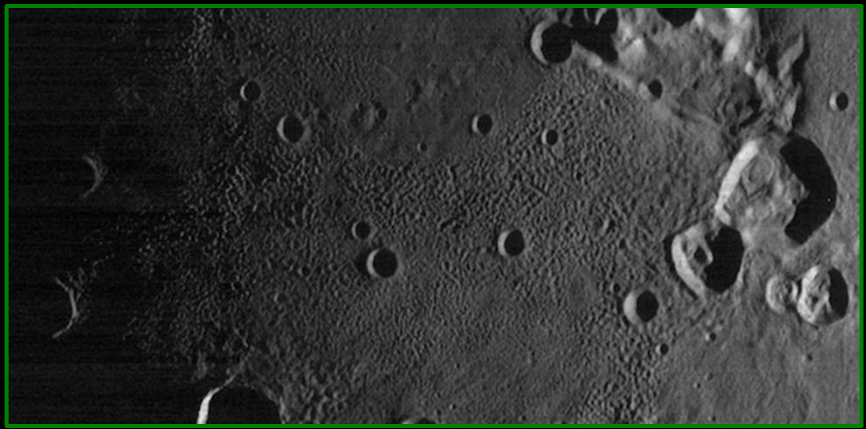

Morgoth Macula
Quidlivun Cavus
~50 km
Smaller cousin?
Darker flow feature

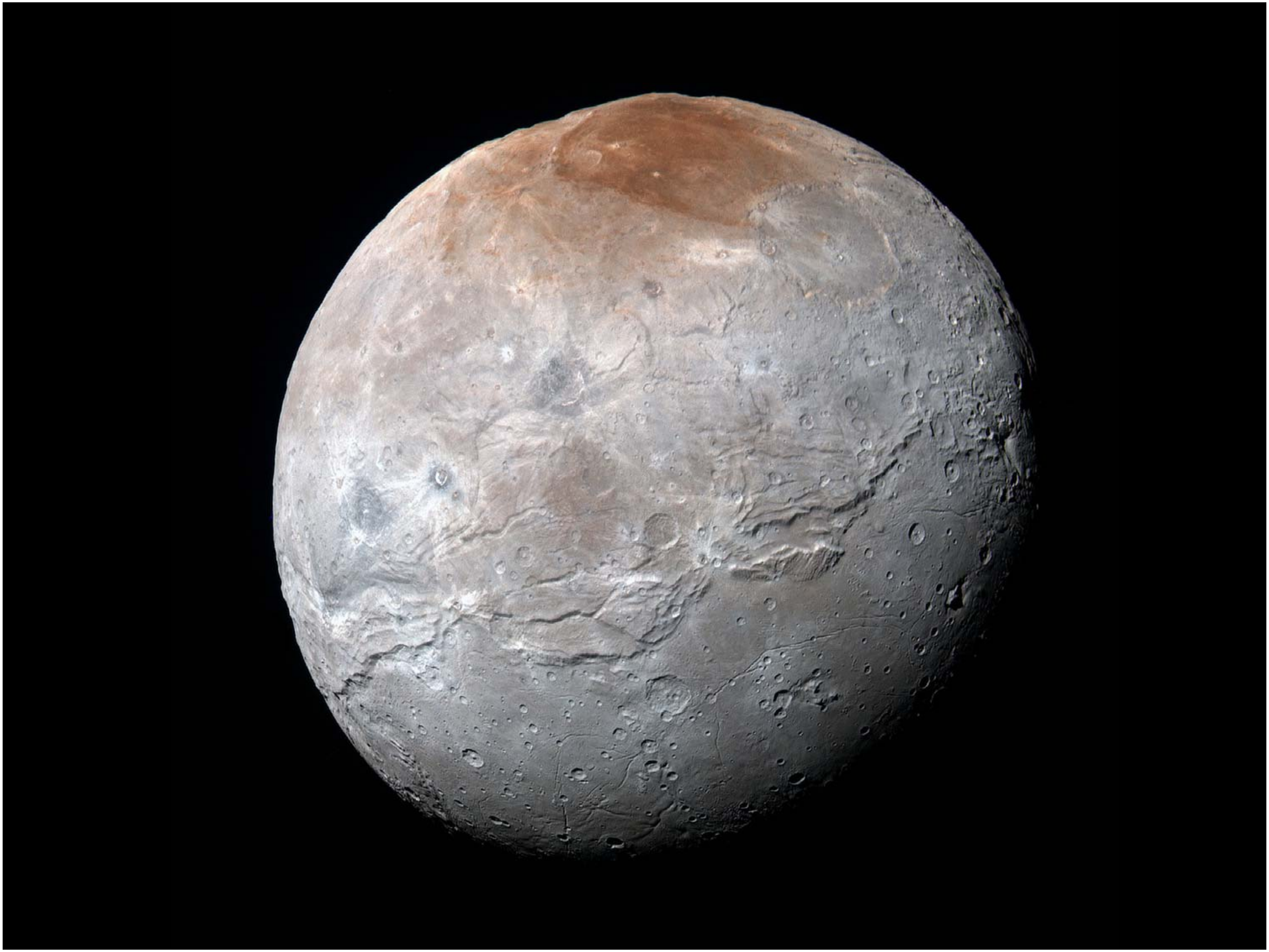

0° 30° 60° 90° 120° 150° 180° 210° 240° 270° 300° 330° 360°
90° 60° 30° 0° −30° −60° −90°
scale applies to equator
1,000
km

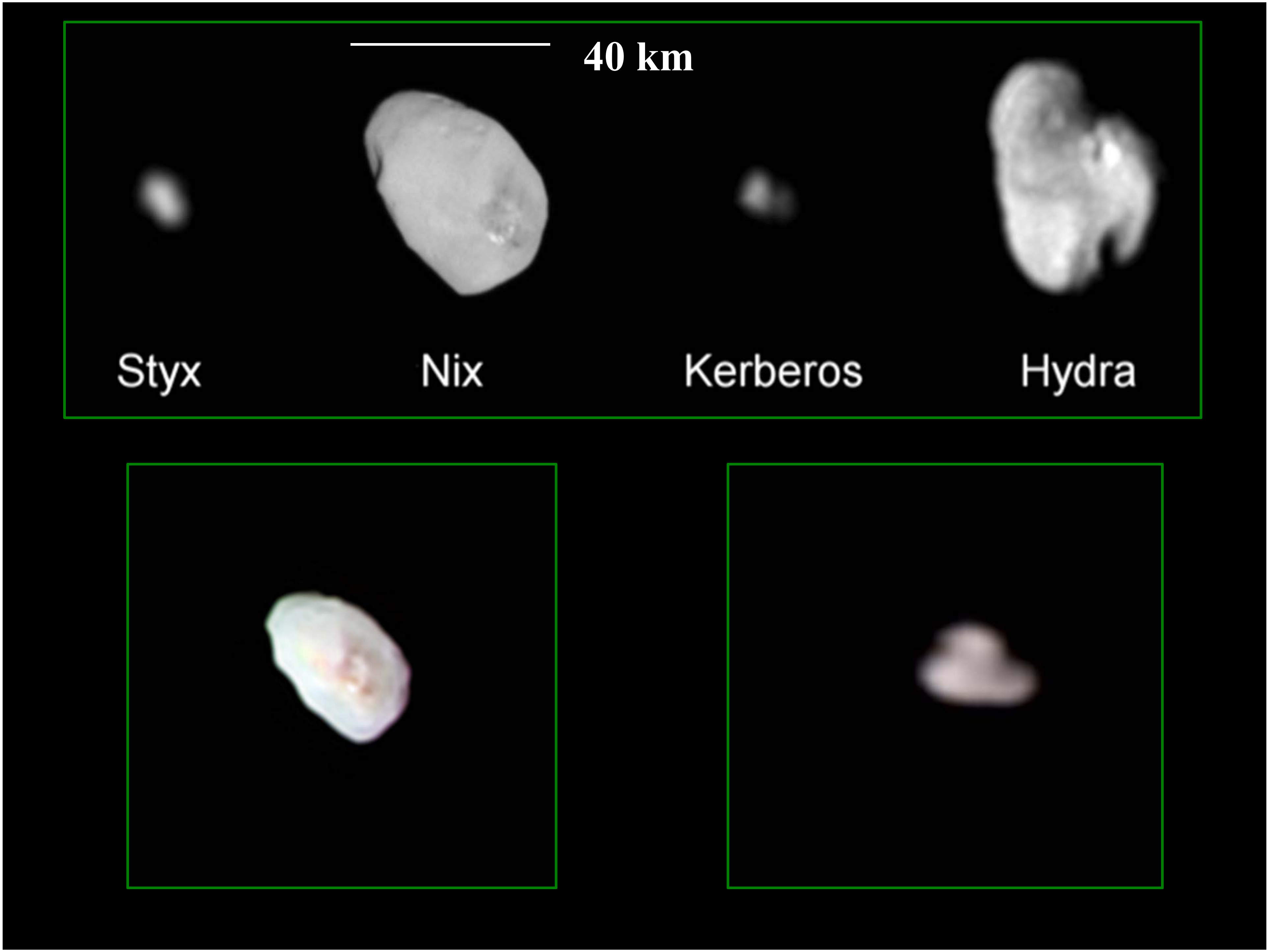

Pluto
Crater densities normalized to a standard distribution
0.1
0.01
0.001
10
100
1,000
Crater diameter (km)
4 billion
1 billion
Sputnik Planum
Mid Latitudes
Cthulhu
Northern Latitudes
East Tombaugh

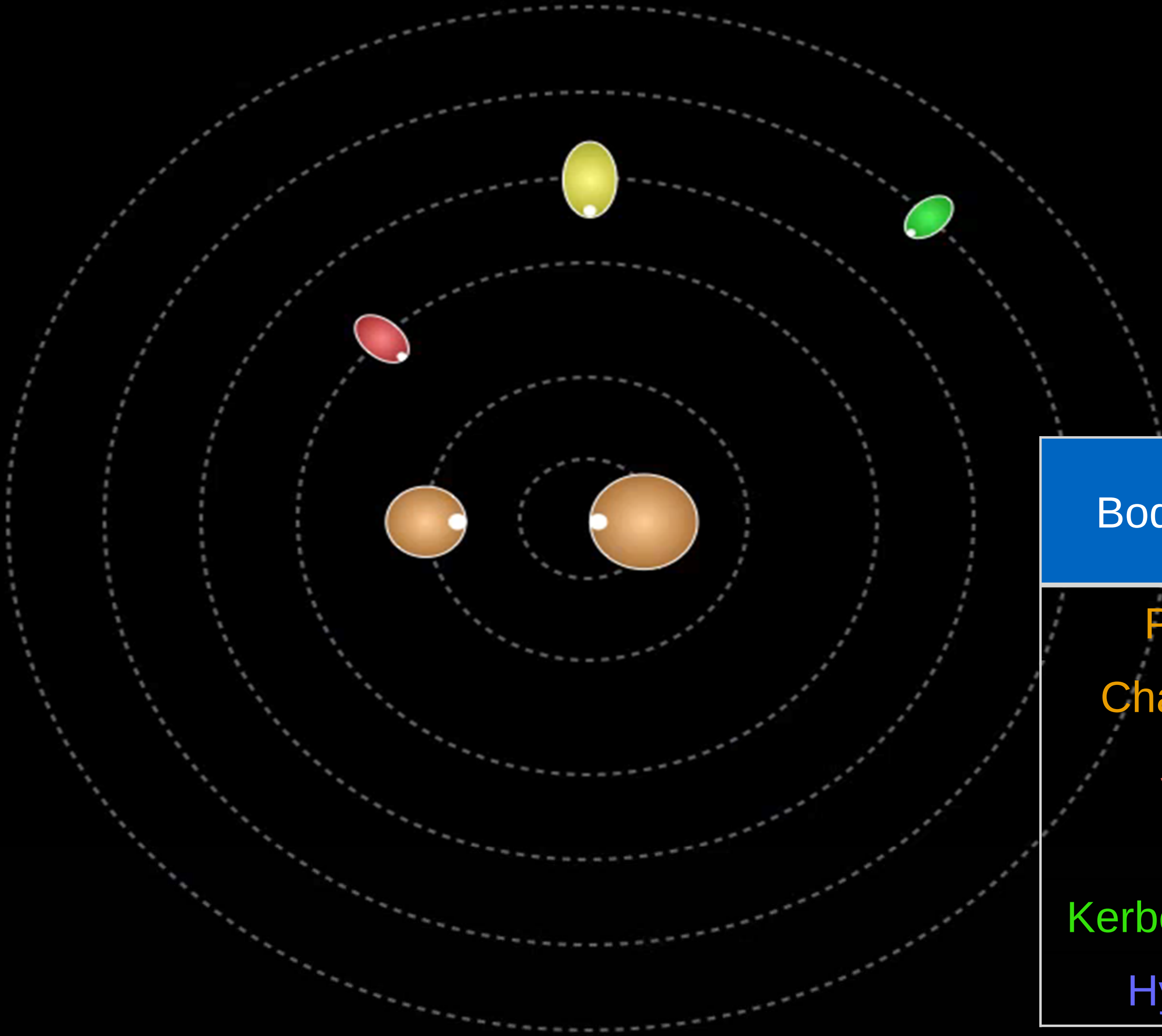

Alice Solar Occultation of Charon
Normalized Count Rate
1.0
0.8
0.6
0.4
0.2
0.0
-400
-200
0
200
400
Elapsed Seconds
Occultation
Reversed Occultation


Organa crater
Skywalker crater
50 miles



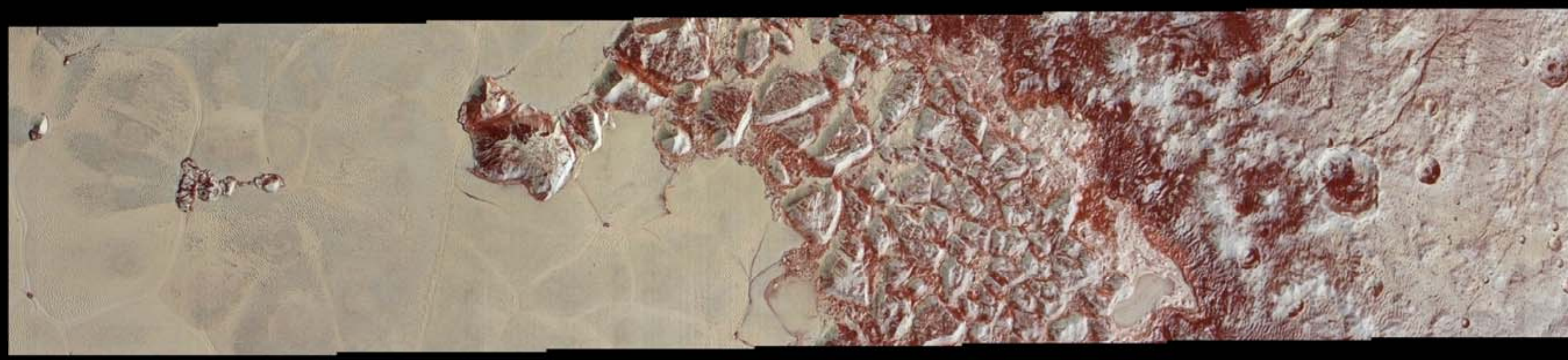


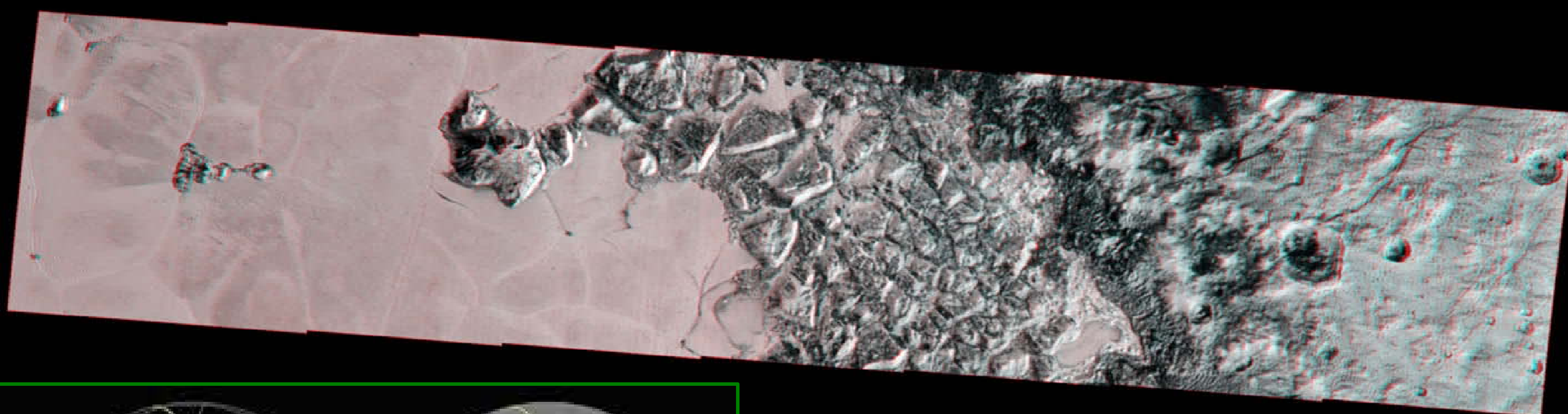

40 km
Styx
Nix
Kerberos
Hydra

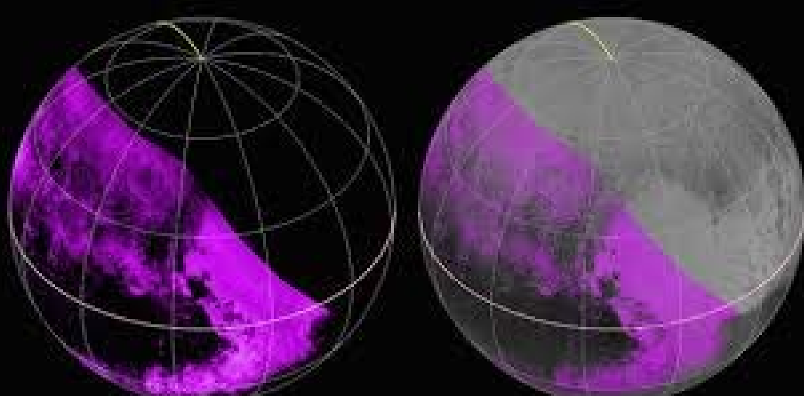


...NOT synchronous!

Body	Spin Period	
	Days	Orbits
Pluto	6.387	1
Charon	6.387	1
Styx	3.239	6.22
Nix	1.829	13.6
Kerberos	5.33	6.04
Hydra	0.4295	88.9







RESEARCH ARTICLE SUMMARY

PLANETARY SCIENCE

The Pluto system: Initial results from its exploration by New Horizons

S. A. Stern,* F. Bagenal, K. Ennico, G. R. Gladstone, W. M. Grundy, W. B. McKinnon, J. M. Moore, C. B. Olkin, J. R. Spencer, H. A. Weaver, L. A. Young, T. Andert, J. Andrews, M. Banks, B. Bauer, J. Bauman, O. S. Barnouin, P. Bedini, K. Beisser, R. A. Beyer, S. Bhaskaran, R. P. Binzel, E. Birath, M. Bird, D. J. Bogan, A. Bowman, V. J. Bray, M. Brozovic, C. Bryan, M. R. Buckley, M. W. Buie, B. J. Buratti, S. S. Bushman, A. Calloway, B. Carcich, A. F. Cheng, S. Conard, C. A. Conrad, J. C. Cook, D. P. Cruikshank, O. S. Custodio, C. M. Dalle Ore, C. Deboy, Z. J. B. Dischner, P. Dumont, A. M. Earle, H. A. Elliott, J. Ercol, C. M. Ernst, T. Finley, S. H. Flanigan, G. Fountain, M. J. Freeze, T. Greathouse, J. L. Green, Y. Guo, M. Hahn, D. P. Hamilton, S. A. Hamilton, J. Hanley, A. Harch, H. M. Hart, C. B. Hersman, A. Hill, M. E. Hill, D. P. Hinson, M. E. Holdridge, M. Horanyi, A. D. Howard, C. J. A. Howett, C. Jackman, R. A. Jacobson, D. E. Jennings, J. A. Kammer, H. K. Kang, D. E. Kaufmann, P. Kollmann, S. M. Krimigis, D. Kusnierkiewicz, T. R. Lauer, J. E. Lee, K. L. Lindstrom, I. R. Linscott, C. M. Lisse, A. W. Lunsford, V. A. Mallder, N. Martin, D. J. McComas, R. L. McNutt Jr., D. Mehoke, T. Mehoke, E. D. Melin, M. Mutchler, D. Nelson, F. Nimmo, J. I. Nunez, A. Ocampo, W. M. Owen, M. Paetzold, B. Page, A. H. Parker, J. W. Parker, F. Pelletier, J. Peterson, N. Pinkine, M. Piquette, S. B. Porter, S. Protopapa, J. Redfern, H. J. Reitsema, D. C. Reuter, J. H. Roberts, S. J. Robbins, G. Rogers, D. Rose, K. Runyon, K. D. Retherford, M. G. Ryschkewitsch, P. Schenk, E. Schindhelm, B. Sepan, M. R. Showalter, K. N. Singer, M. Soluri, D. Stanbridge, A. J. Steffl, D. F. Strobel, T. Stryk, M. E. Summers, J. R. Szalay, M. Tapley, A. Taylor, H. Taylor, H. B. Throop, C. C. C. Tsang, G. L. Tyler, O. M. Umurhan, A. J. Verbiscer, M. H. Versteeg, M. Vincent, R. Webbert, S. Weidner, G. E. Weigle II, O. L. White, K. Whittenburg, B. G. Williams, K. Williams, S. Williams, W. W. Woods, A. M. Zangari, E. Zirnstein

INTRODUCTION: Pluto was discovered in 1930 and was long thought to be a misfit or anomaly in the solar system. However, the 1992 discovery of the Kuiper Belt—a torus-shaped region beyond Neptune's orbit, and the largest structure in our three-zoned planetary system—provided new context, showing Pluto to be the largest of a new class of small planets formed in the outer solar system during the ancient era of planetary accretion ~4.5 billion years ago. NASA's New Horizons spacecraft made the first exploration of Pluto, culminating on 14 July 2015; it collected numerous remote sensing and in situ measurements of Pluto and its system of five moons. We report the first scientific results and interpretations of that flyby.

RATIONALE: The New Horizons spacecraft completed a close approach to the Pluto system at a distance of 13,691 km from Pluto's center. The spacecraft carries a sophisticated suite of scientific instruments, including the Ralph multicolor/panchromatic mapper and mapping infrared composition spectrometer; the LORRI long-focal-length panchromatic visible imager; the Alice extreme/far ultraviolet mapping spectrograph; twin REX radio science experiments; the SWAP solar wind detector; the PEPSSI high-energy charged particle spectrometer; and VBSDC, a dust impact detector. Together these instruments collected more than 50 gigabits of data on the Pluto system near the time of the spacecraft's closest approach.

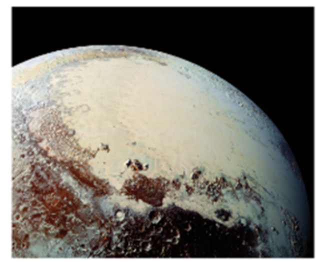
RESULTS: We found that Pluto's surface displays a wide variety of landforms and terrain ages, as well as substantial albedo, color, and compositional variation. Evidence was also found for a water ice-rich crust, geologically young surface units, tectonic extension, surface volatile ice convection, possible wind streaks, volatile transport, and glacial flow. Pluto's atmosphere is highly extended, with trace hydrocarbons, a global haze layer, and a surface pressure near 10 microbars. The bulk densities of Pluto and Charon were found to differ by less than 10%, which is consistent with bulk rock contents for the two bodies that are likewise similar. This could imply that both precursor bodies were undifferentiated (or only modestly differentiated) prior to their collision—which would have profound implications for the timing, the duration, and even the mechanism of accretion in the ancestral Kuiper Belt.

Pluto's large moon Charon displays extensional tectonics and extensive resurfacing, as well as possible evidence for a heterogeneous crustal composition; its north pole displays puzzling dark terrain. The sizes of Pluto's small satellites Nix and Hydra were measured for the first time, as were their surface reflectivities, which are puzzlingly higher than Charon's. No new satellites were detected.

CONCLUSION: The New Horizons encounter revealed that Pluto displays a surprisingly wide variety of geological landforms, including those resulting from glaciological and surface-atmosphere interactions as well as impact, tectonic, possible cryovolcanic, and mass-wasting processes. This suggests that other small planets of the Kuiper Belt, such as Eris, Makemake, and Haumea, could express similarly complex histories that rival those of terrestrial planets. Pluto's diverse surface geology and long-term activity also raise fundamental questions about how it has remained active many billions of years after its formation. ■

ON OUR WEB SITE

Read the full article at http://dx.doi.org/10.1126/science.aad1815

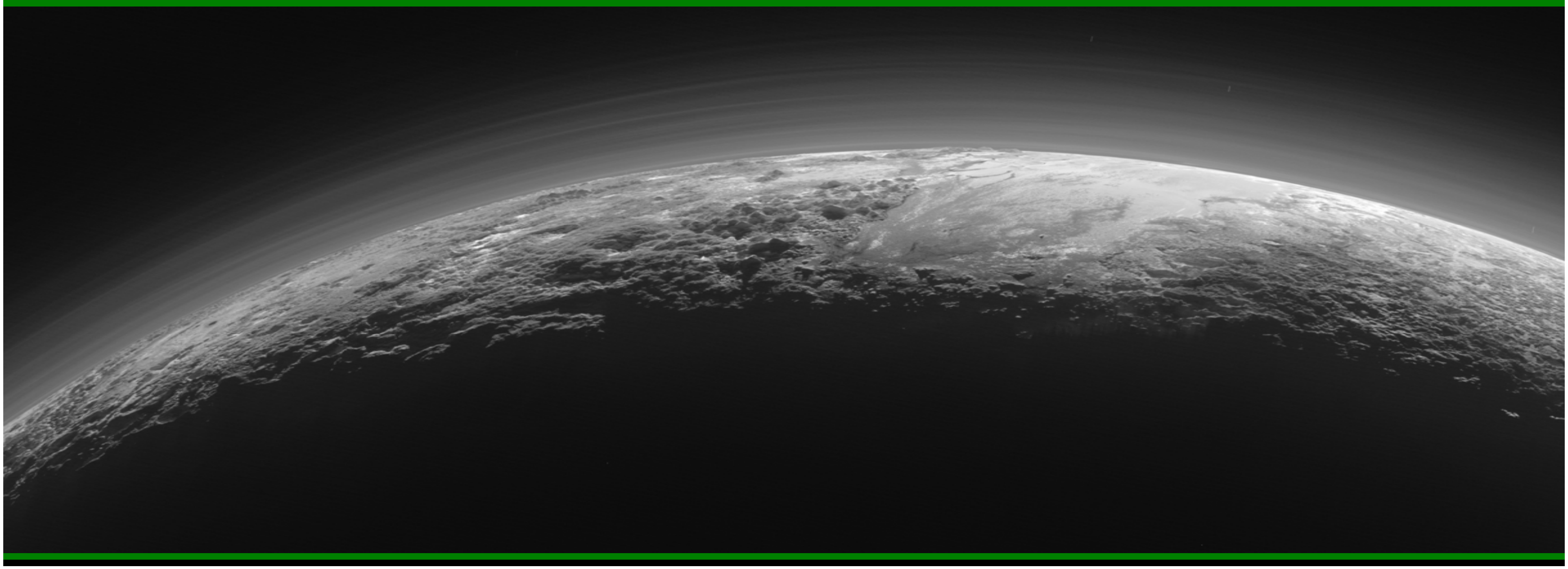


Pluto mosaic made from New Horizons LORRI images taken 14 July 2015 from a distance of 80,000 km. This view is projected from a point 1800 km above Pluto's equator, looking northeast over the dark, cratered, informally named Cthulhu Regio toward the bright, smooth expanse of icy plains informally called Sputnik Planum. Pluto's north pole is off the image to the left. This image mosaic was produced with panchromatic images from the New Horizons LORRI camera, with color overlaid from the Ralph color mapper onboard New Horizons.

The list of affiliations is available in the full article online.
*Corresponding author. Email: astern@boulder.swri.edu
Cite this article as S. A. Stern et al., Science 350, aad1815 (2015). DOI: 10.1126/science.aad1815

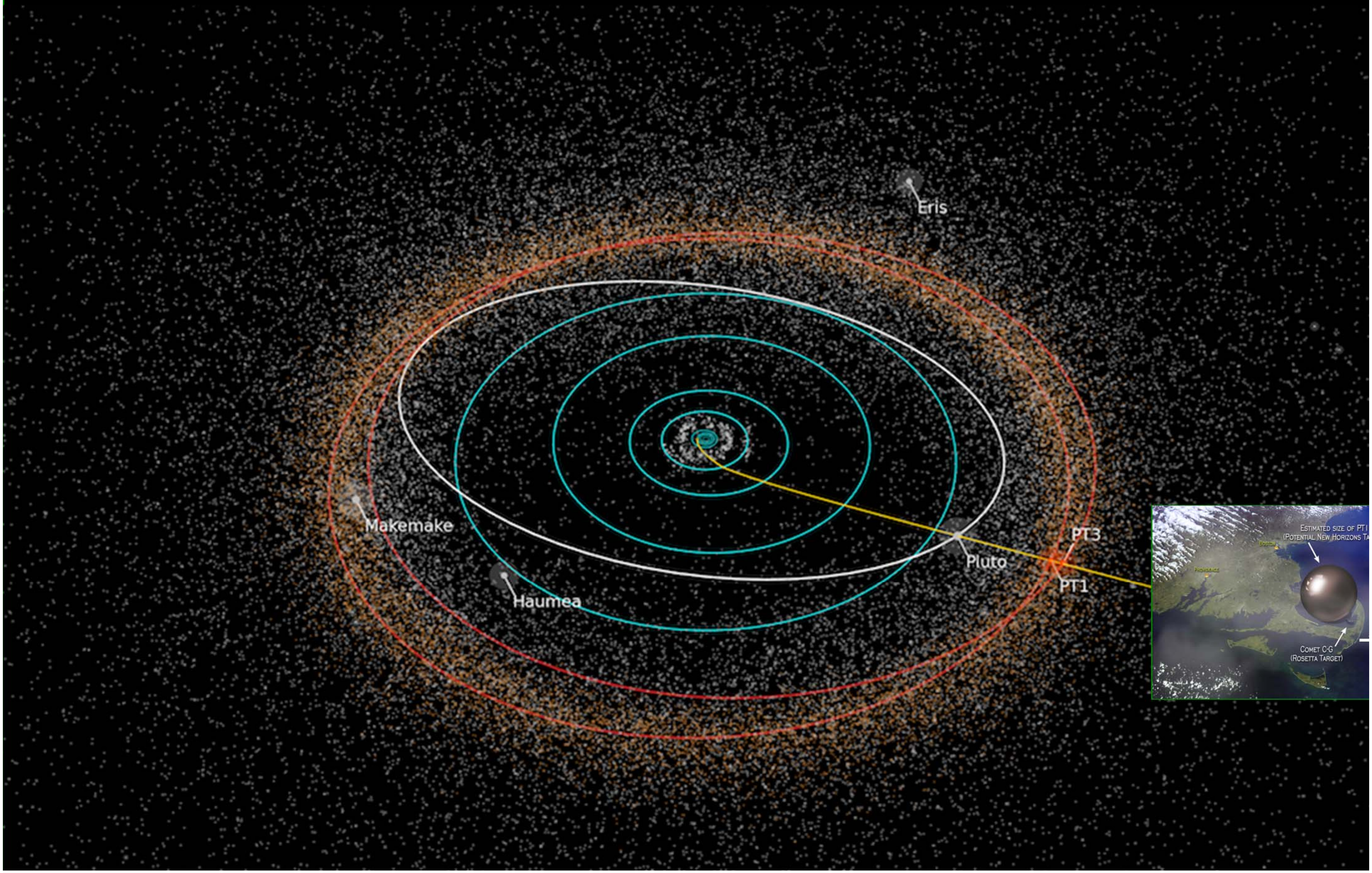
SIX MONTHS SINCE FLYBY

- **All flyby objectives met or exceeded.**
- **Flyby Archiving Begins April 2016, Complete October 2017.**
- **ROSES NF-DAP Call This Year.**
- **Over 25 Publications Will Have Been Submitted by Next Month.**




NEW HORIZONS
2019

EXTENDED MISSION: 2017-2021
PROPOSAL DUE APRIL 15



KBO EXTENDED MISSION CONTEX

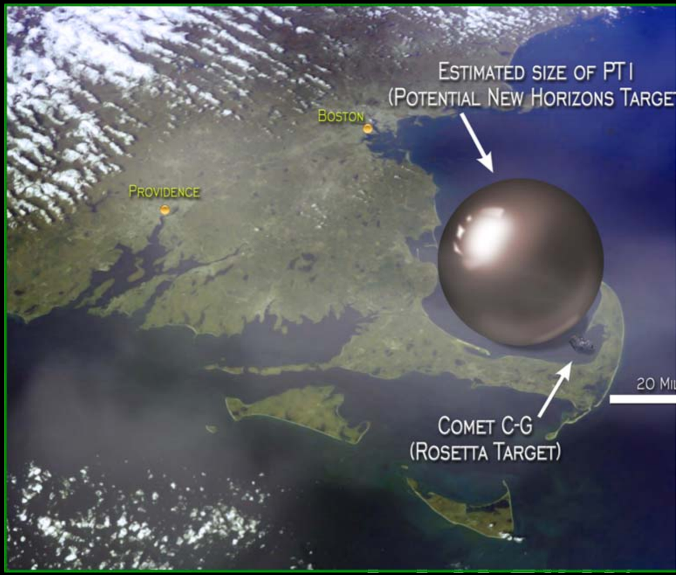
- **The 2003 Planetary Decadal Survey that enabled New Horizons called for a Kuiper Belt-Pluto Mission to explore both the Pluto System <u>and</u> small KBOs.**
- **New Horizons and its payload were explicitly designed to carry out this KBO mission in response to the NASA PKB AO.**
- **New Horizons is healthy and has more fuel and ΔV capability th originally planned for use after Pluto.**
- **In 2014 HST identified 5 potential CCKBO targets; in August 2015 New Horizons and NASA/SMD selected 2014 MU69.**
- **In October/November 2015, with NASA/SMD concurrence, New Horizons burned to target this flyby on 1 Jan 2019.**

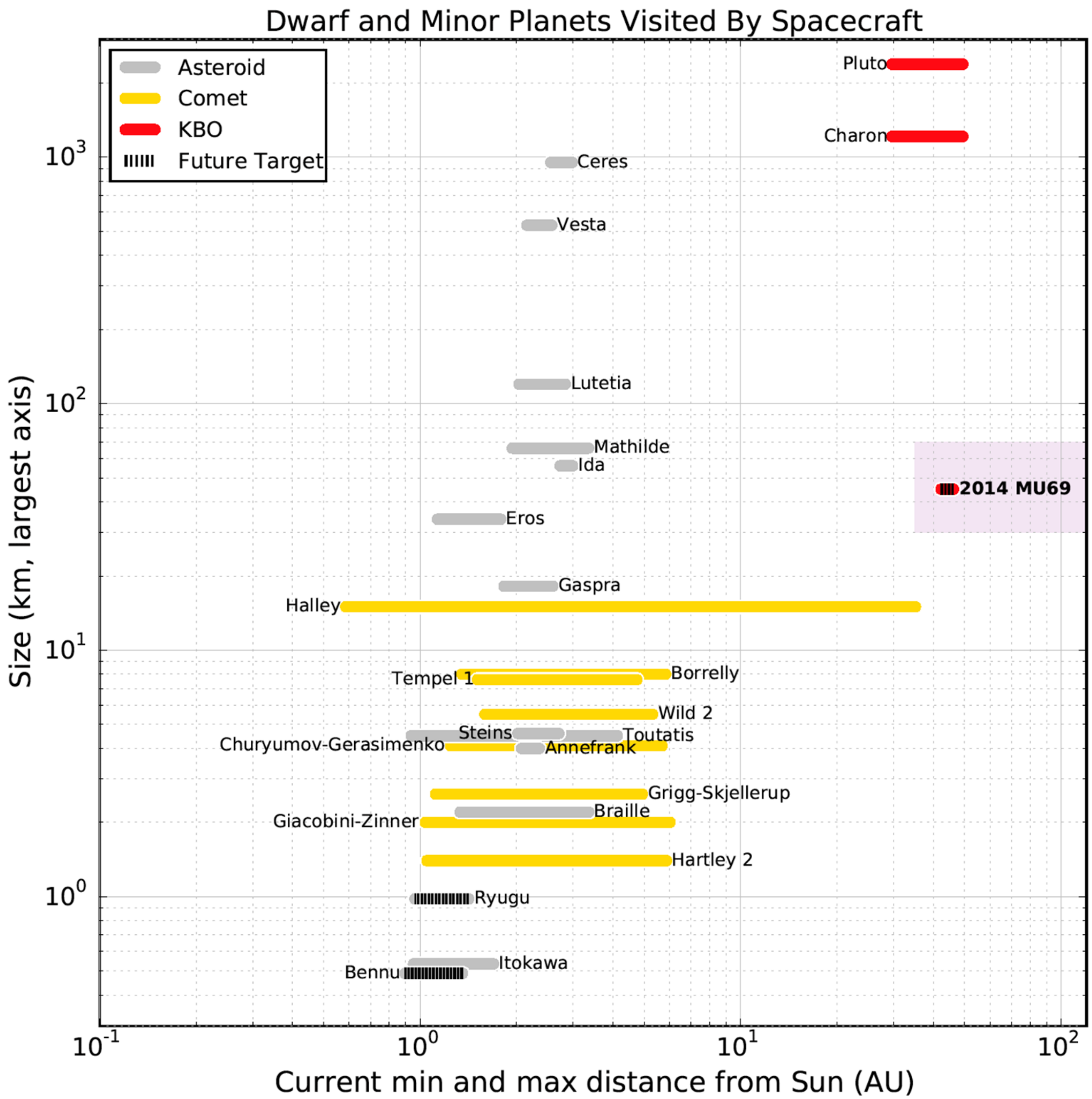
KBO EXTENDED MISSION SCIENCE OBJECTIVES

- **Conduct a close flyby of a primordial KBO.**
- **Conduct distant science flyby observations of ~20 other KBOs.**
- **Conduct heliospheric cruise science in the Kuiper Belt; specifically heliospheric plasma, dust, and neutral H/He observations.**
- **Observe Centaurs, Trojans, and Giant Planets at High Phase.**
- **Search for KBO Mutual Event and Stellar Occultation Targets of Opportunity.**
- **Potentially: Search for sub-km KBOs.**
- **Potentially: Conduct astrophysical cruise science.**

2014 MU69 OVERVIEW

	PT1
MPC Designator	2014 MU69
Diameter (p=0.04, smaller if higher albedo)	**45 km**
Orbital Semi-major Axis	44.2 AU
Orbital Eccentricity	0.036
Orbital Inclination	1.9 deg
Cold Classical	**Yes (96.5%)**
ΔV to Target	**56.5 m/s**
Encounter Date	**2019 Jan 01**

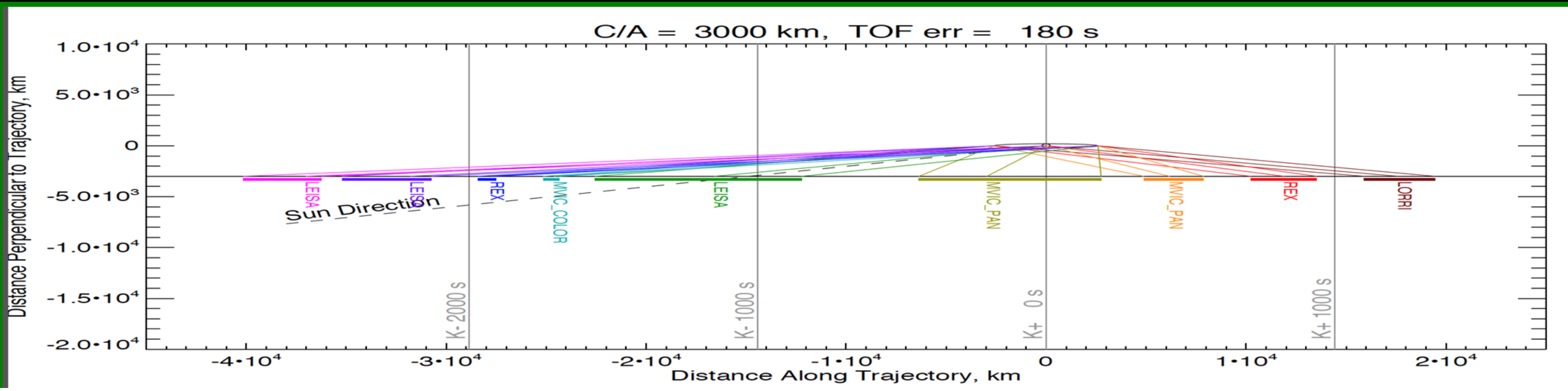




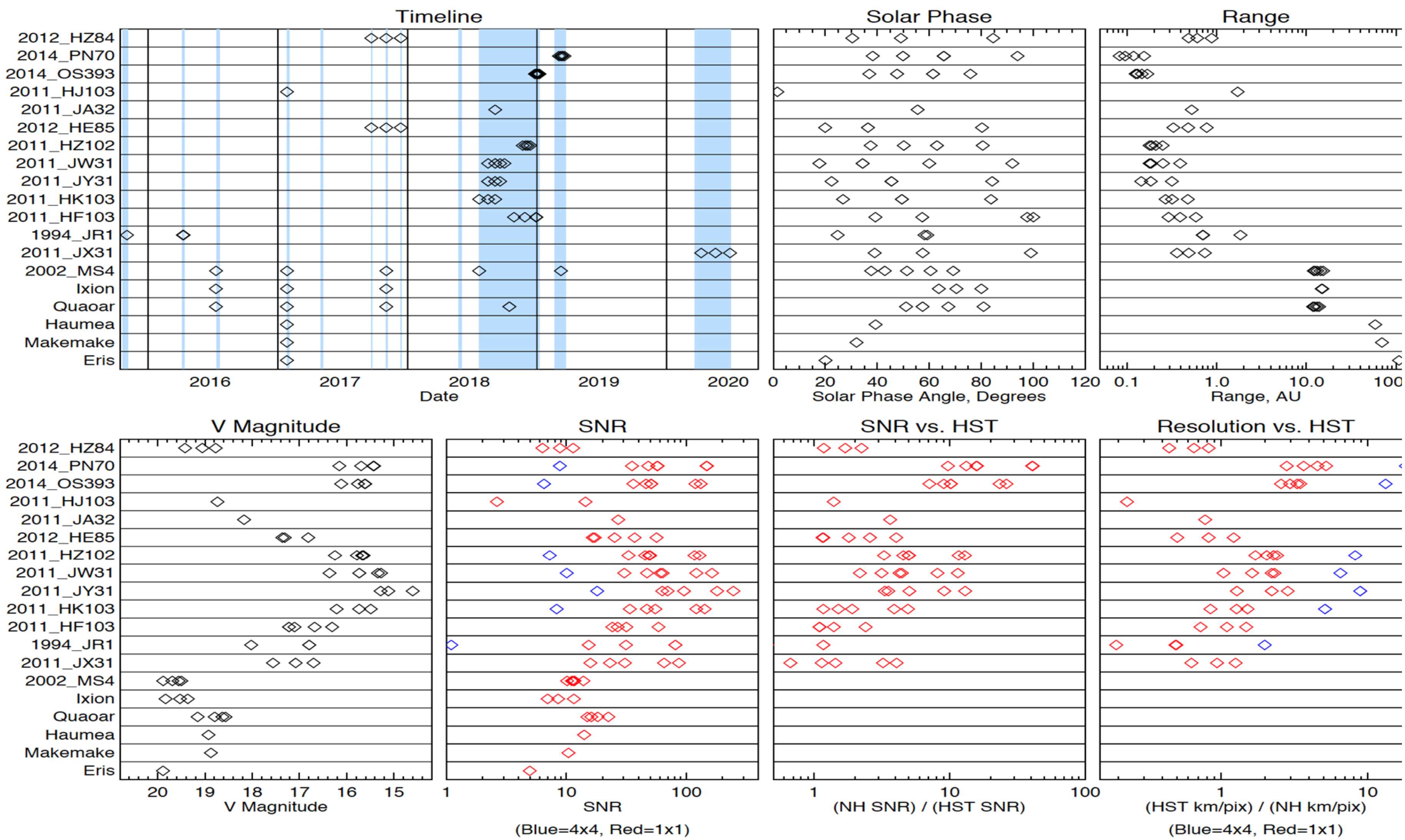
Dwarf and Minor Planets Visited By Spacecraft
Asteroid
Comet
KBO
Future Target
Pluto
Charon
Ceres
Vesta
Lutetia
Mathilde
Ida
2014 MU69
Eros
Gaspra
Halley
Tempel 1
Borrelly
Wild 2
Steins
Toutatis
Churyumov-Gerasimenko
Annefrank
Grigg-Skjellerup
Braille
Giacobini-Zinner
Hartley 2
Ryugu
Itokawa
Bennu
Size (km, largest axis)
Current min and max distance from Sun (AU)

KBO EXTENDED MISSION PRELIMINARY SCIENCE OBJECTIVES

Group	Science Objective	Mapping to specific measurement objectives	Comments [internal use only]
1	Characterize the global geology and morphology of MU69	G1, G5, G6, G2	
1	Map surface composition of MU69	G3, G4, C1, C2, C3	
1	Search for and characterize any satellites and rings of MU69	G7, G11, G12, G13, G14, G15	Included goal for distant KBOs- possibly separate?
2	Characterize composition and magnitude of any volatile escape from and coma around MU69	A1, A2, A3, A4, A5	Removed "neutral atmosphere" as MU69 will not have a bound atmosphere
2	Characterize near-surface day and night temperatures and bolometric albedo of MU69	G11, C1, G6	Should maybe be "day and night surface temperatures"
2	Characterize photometric properties of MU69	G1, G2, G3, G4, G5, G6	
3	Characterize the energetic particle environment and search for a solar wind interaction of MU69	P1, P2, P3	
3	Determine bulk parameters (mass, density) of MU69	G1, G2, G5	Group 3 because mass and density unlikely unless we find satellite(s)
4	Characterize the dust and solar wind environment across the Kuiper Belt	P4, P5, P6, P7	
4	Characterize shape of a range of KBOs	G9	Justification for lightcurves of distant KBOs
4	Characterize photometric properties of a range of KBOs	G9	Justification for photometric studies of distant KBOs
4	Search for satellites and rings of a range of KBOs	G8	Included goal for distant KBOs- possibly separate?

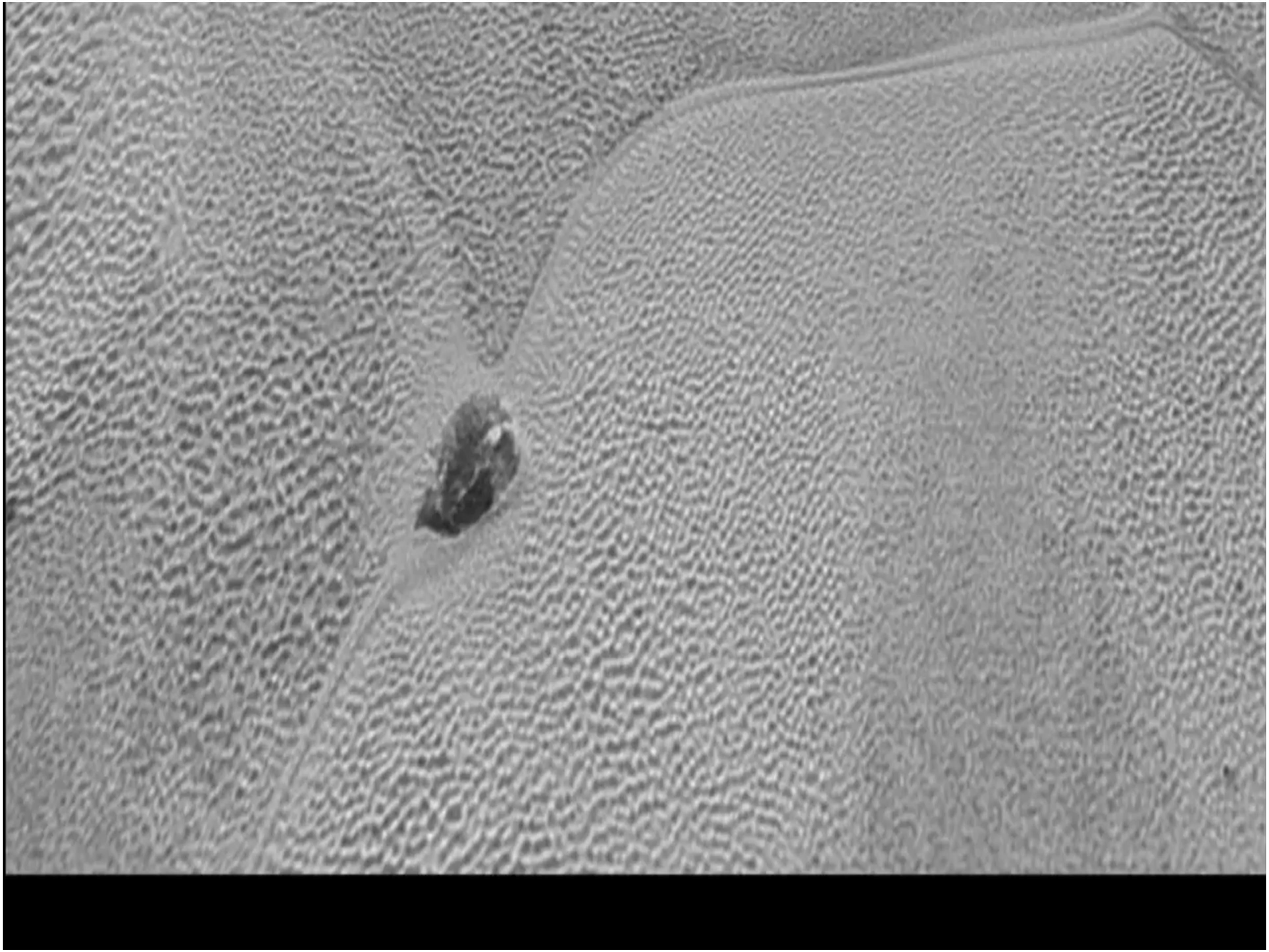


KBO EXTENDED MISSION SCIENCE OBJECTIVES



KBO EXTENDED MISSION PRELIMINARY SCIENCE TIMELINE

- **KB Surveys Science: 2016-2020**
- **<u>MU69 Close Flyby: 1 Jan 2019</u>**
- **<u>MU69 Data Return: 2019-2020.5</u>**
- **Astrophysics Option: 2019-2020**
- **50 AU Heliospheric Milestone: Early 2021**
- **PDS Archiving Complete: 30 Sep 2021**




NEW HORIZONS
NASA's Pluto-Kuiper Belt Mission
SwRI • NASA • JHU/APL