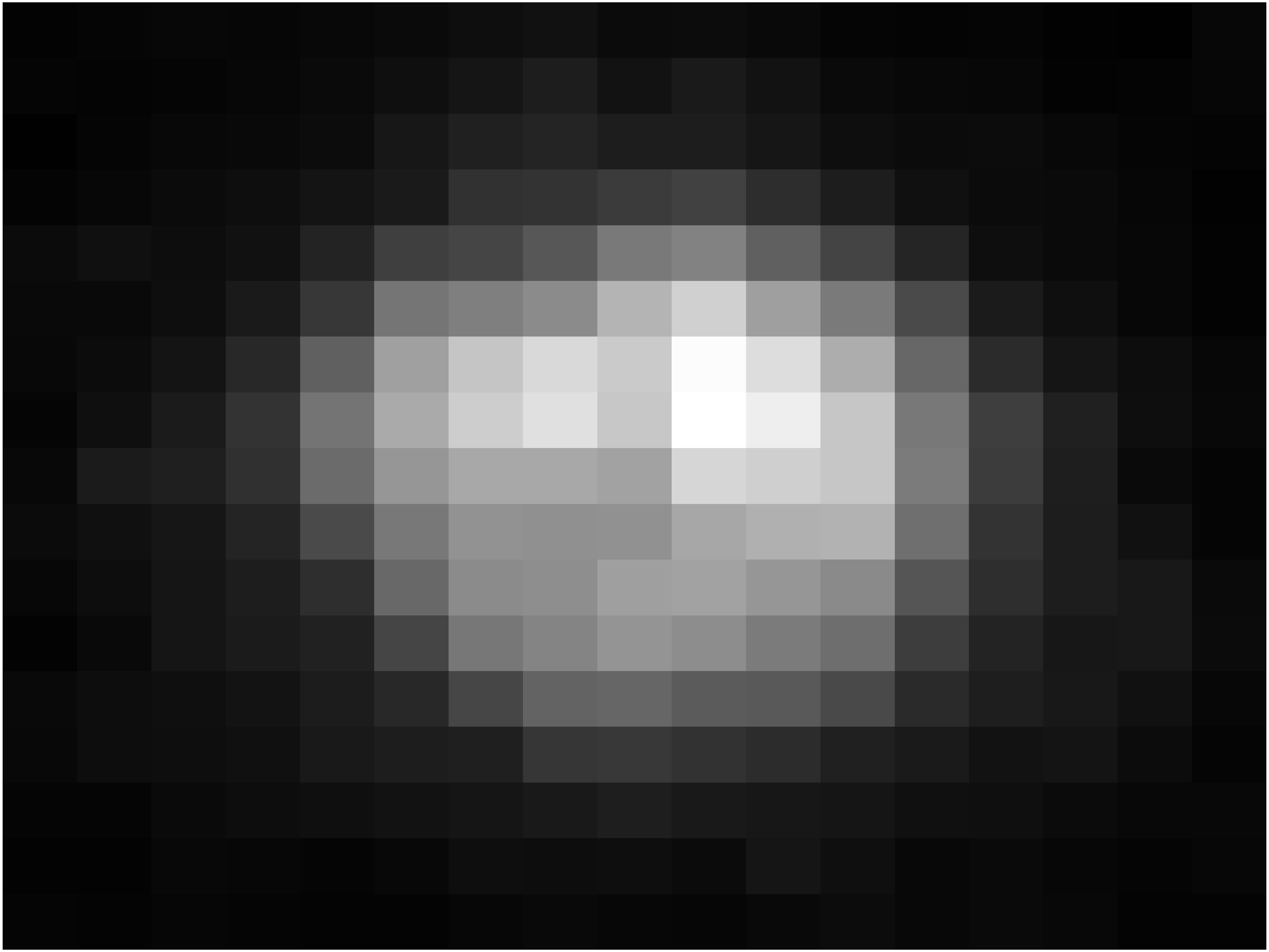
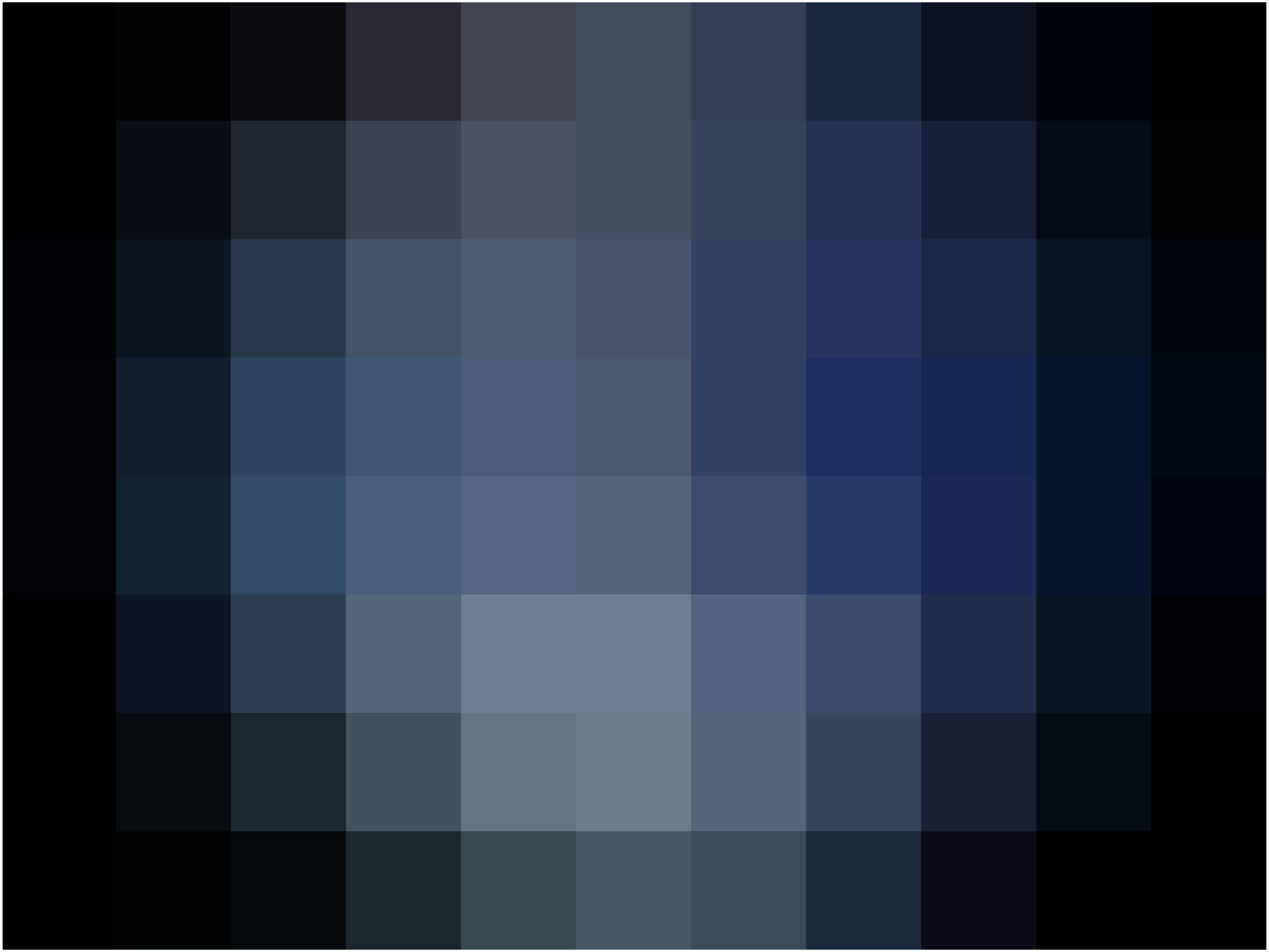
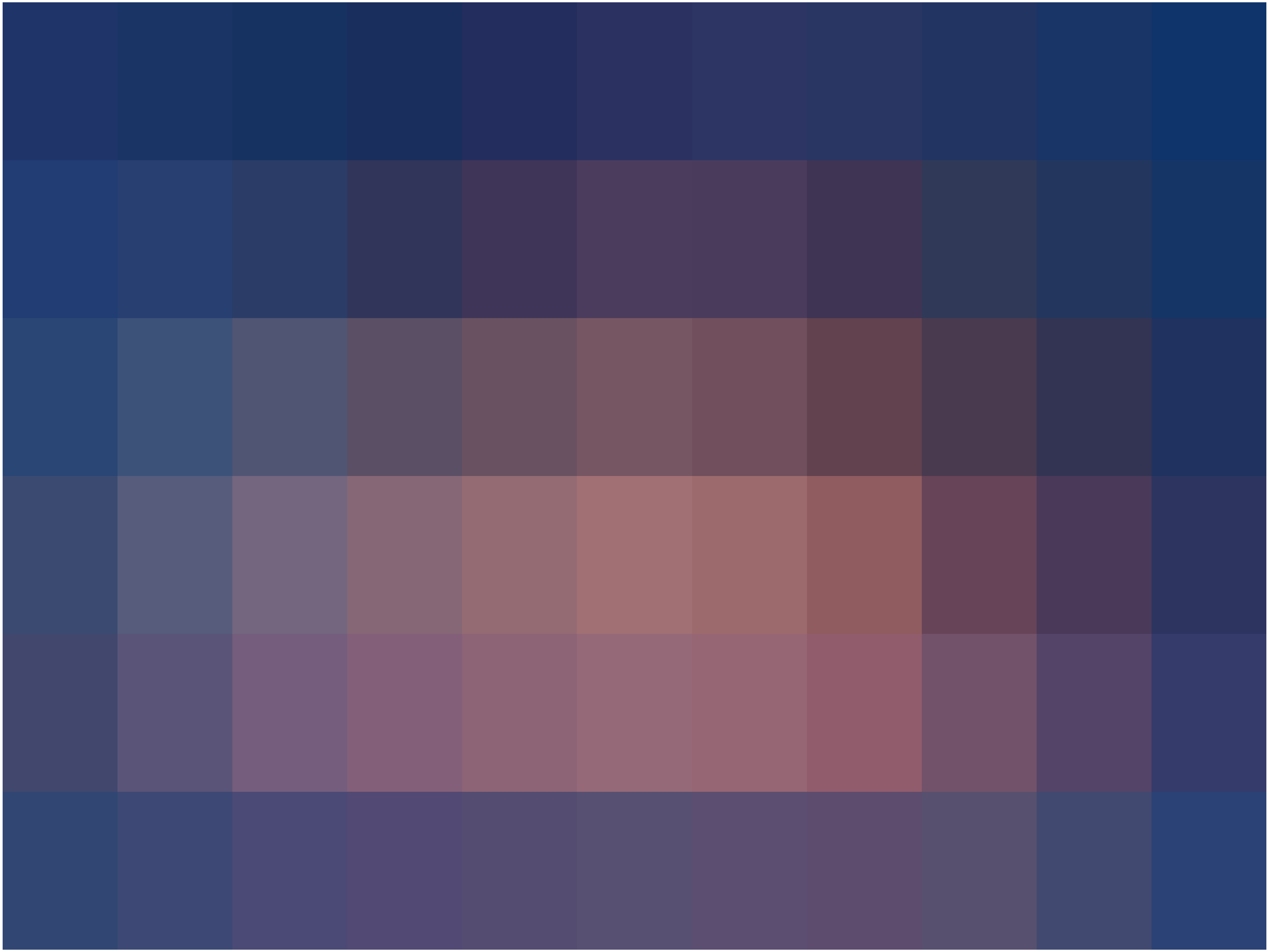
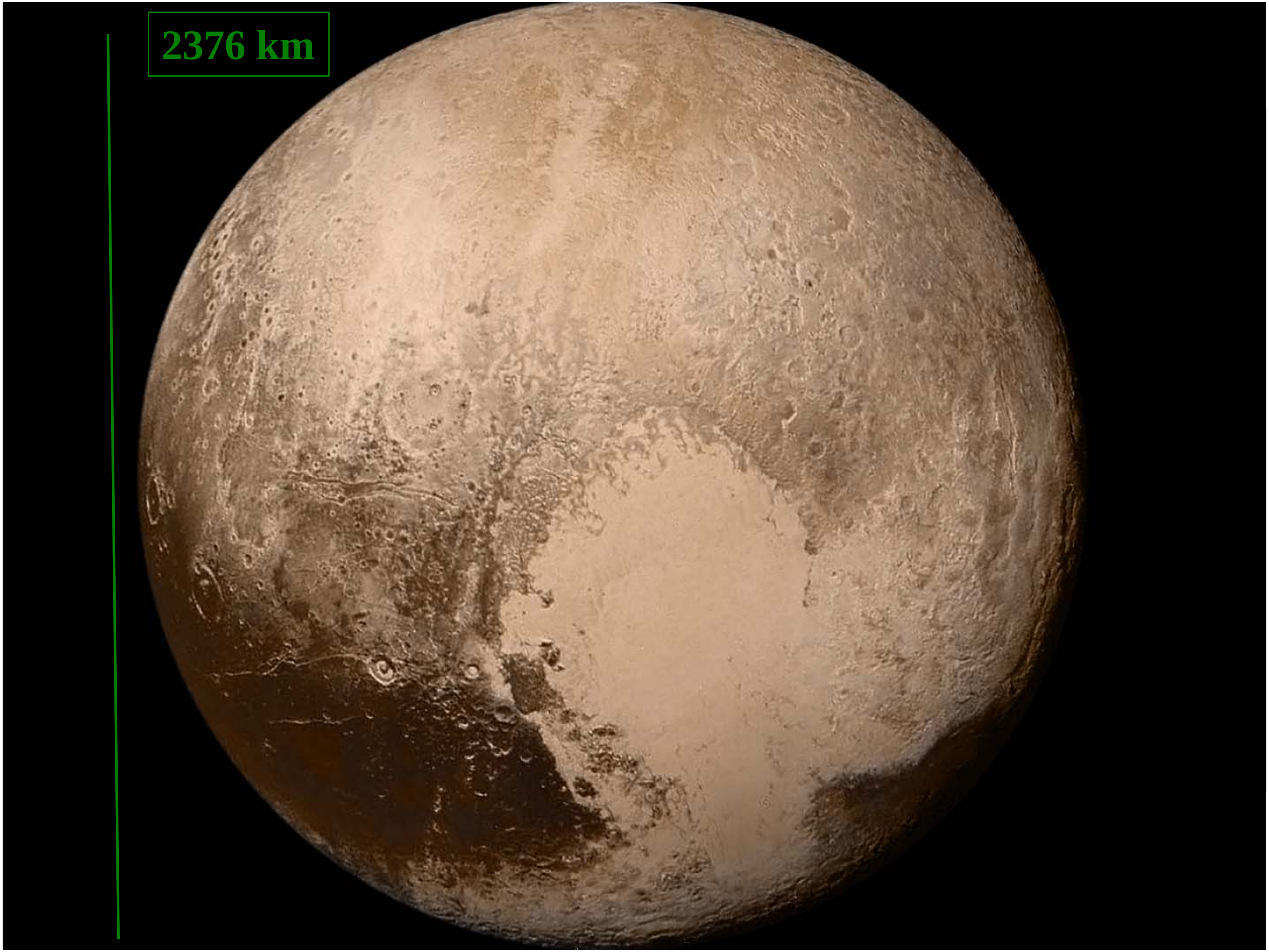
The Exploration of Pluto
By New Horizons

Alan Stern/SwRI

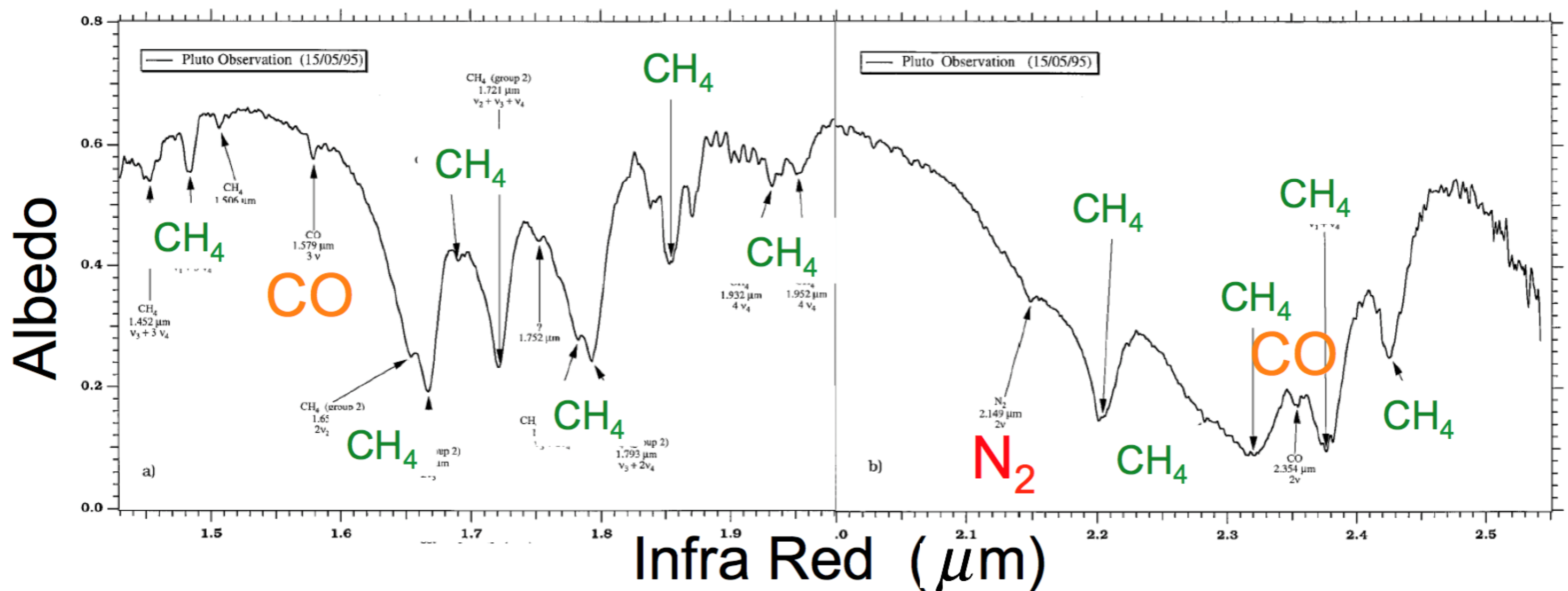


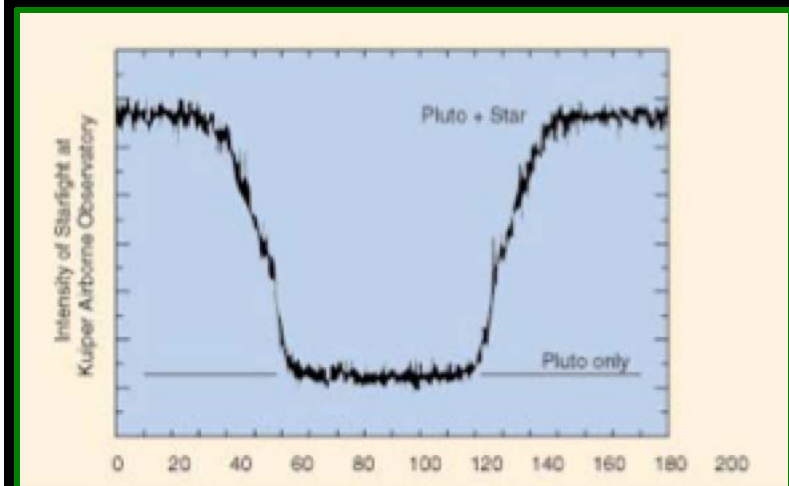


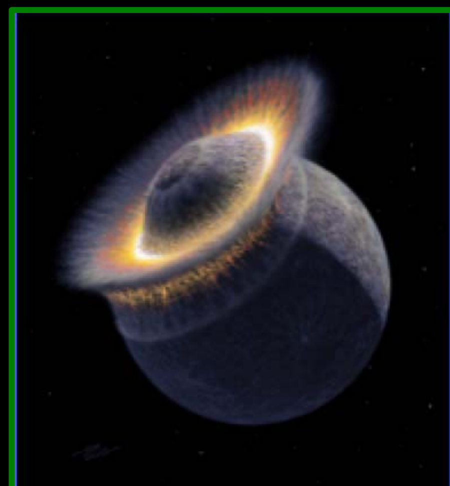


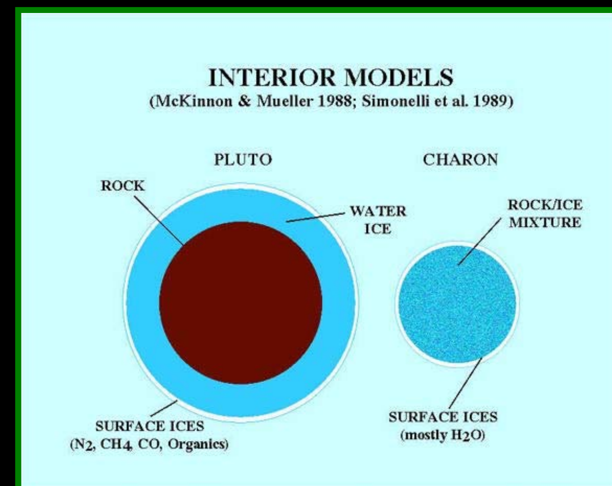

2376 km

Pluto's Surface Composition Is Complex



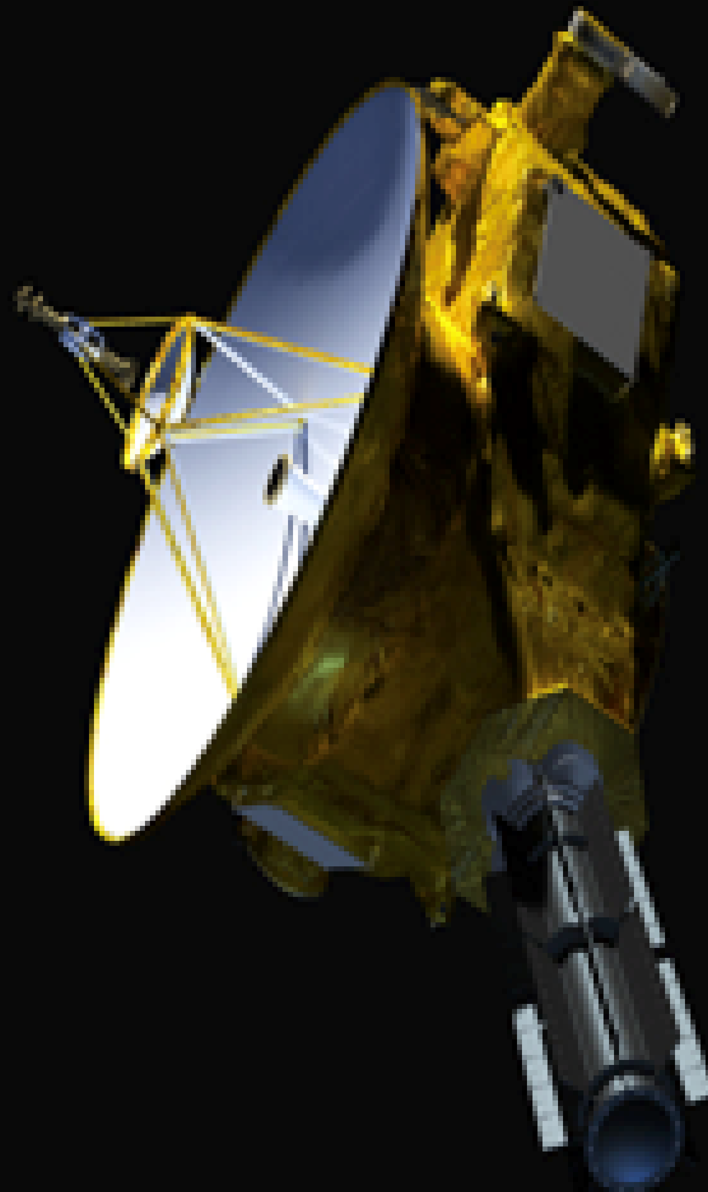


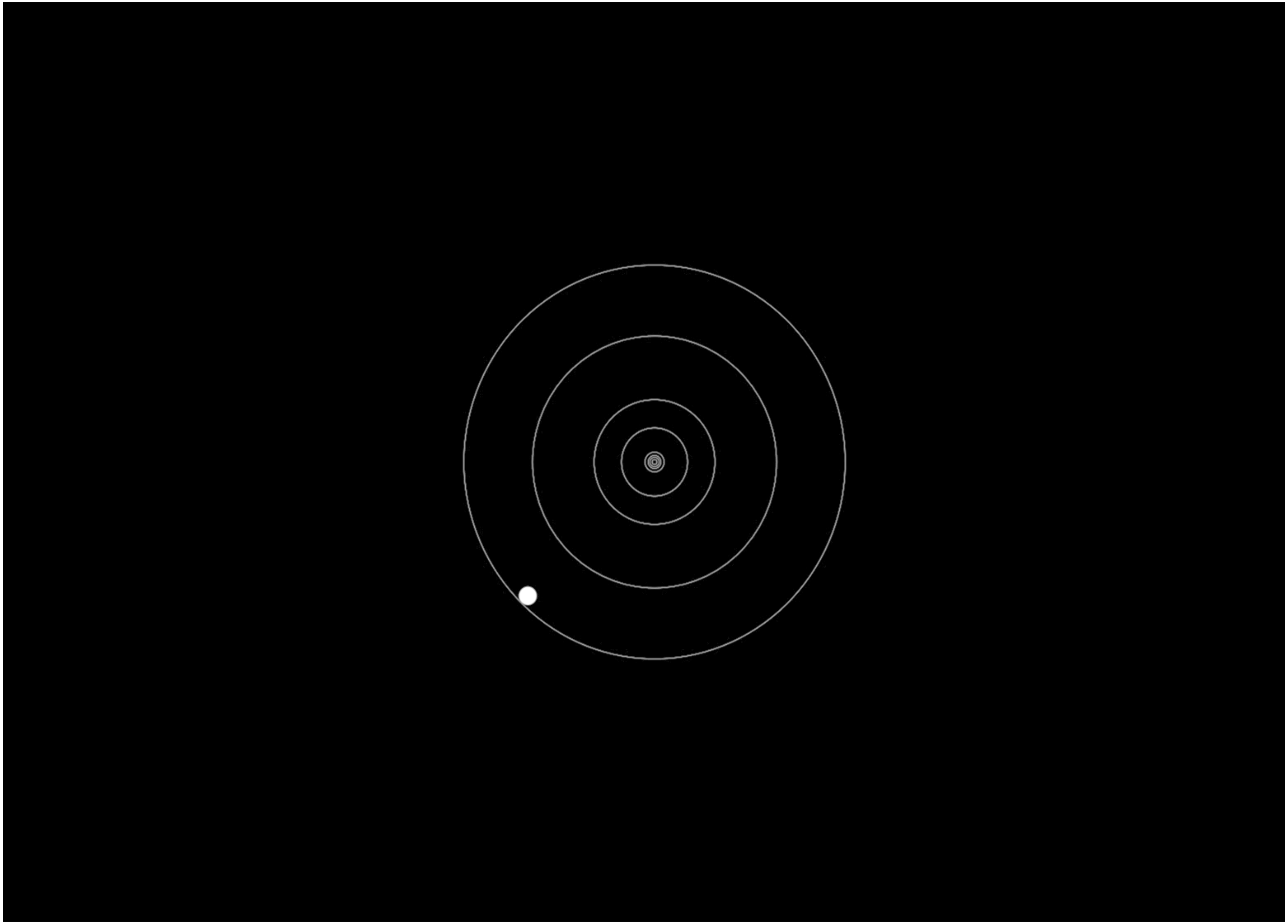




Mission History

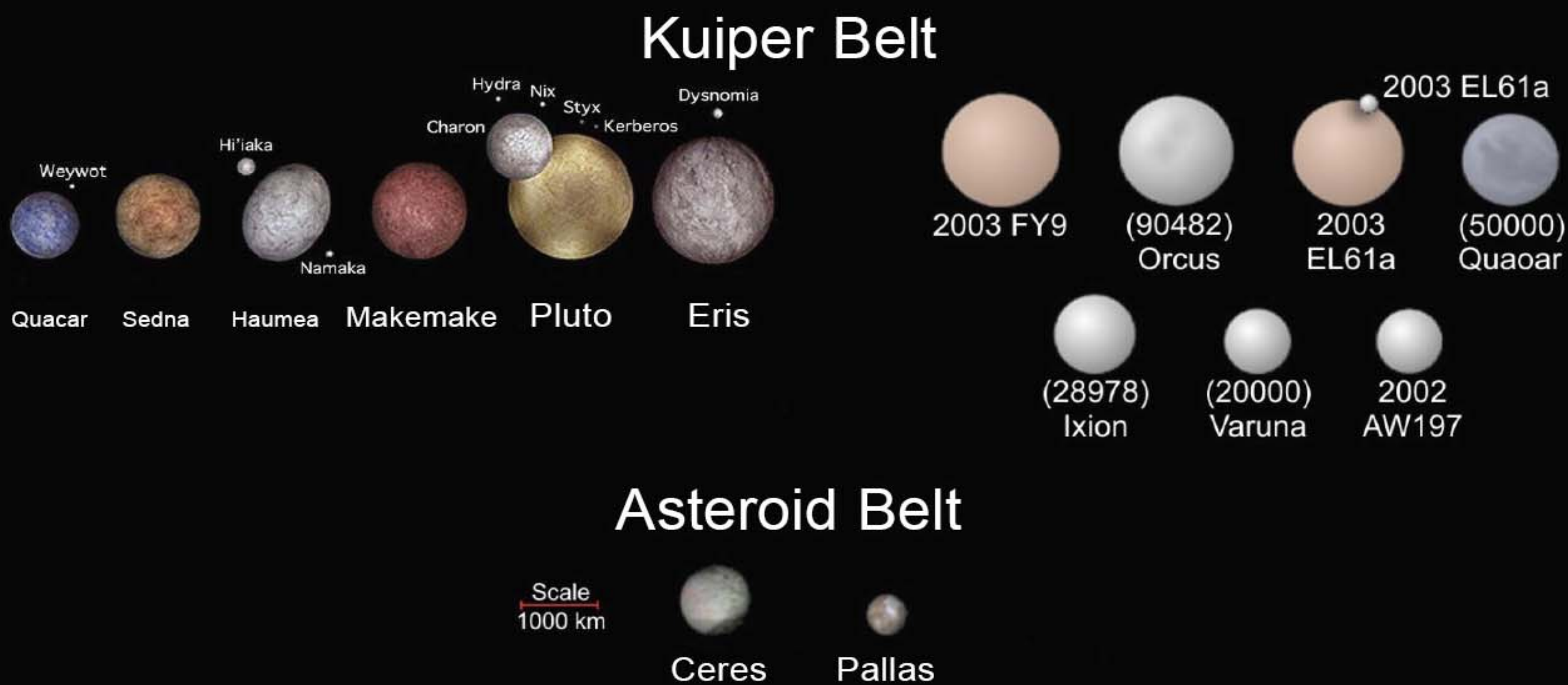
- 1990: Pluto 350
- 1991: Pluto Mariner Mark II
- 1992: Pluto Fast Flyby
- 1994: Pluto Express
- 1997: Pluto Kuiper Express
- 2001: New Horizons





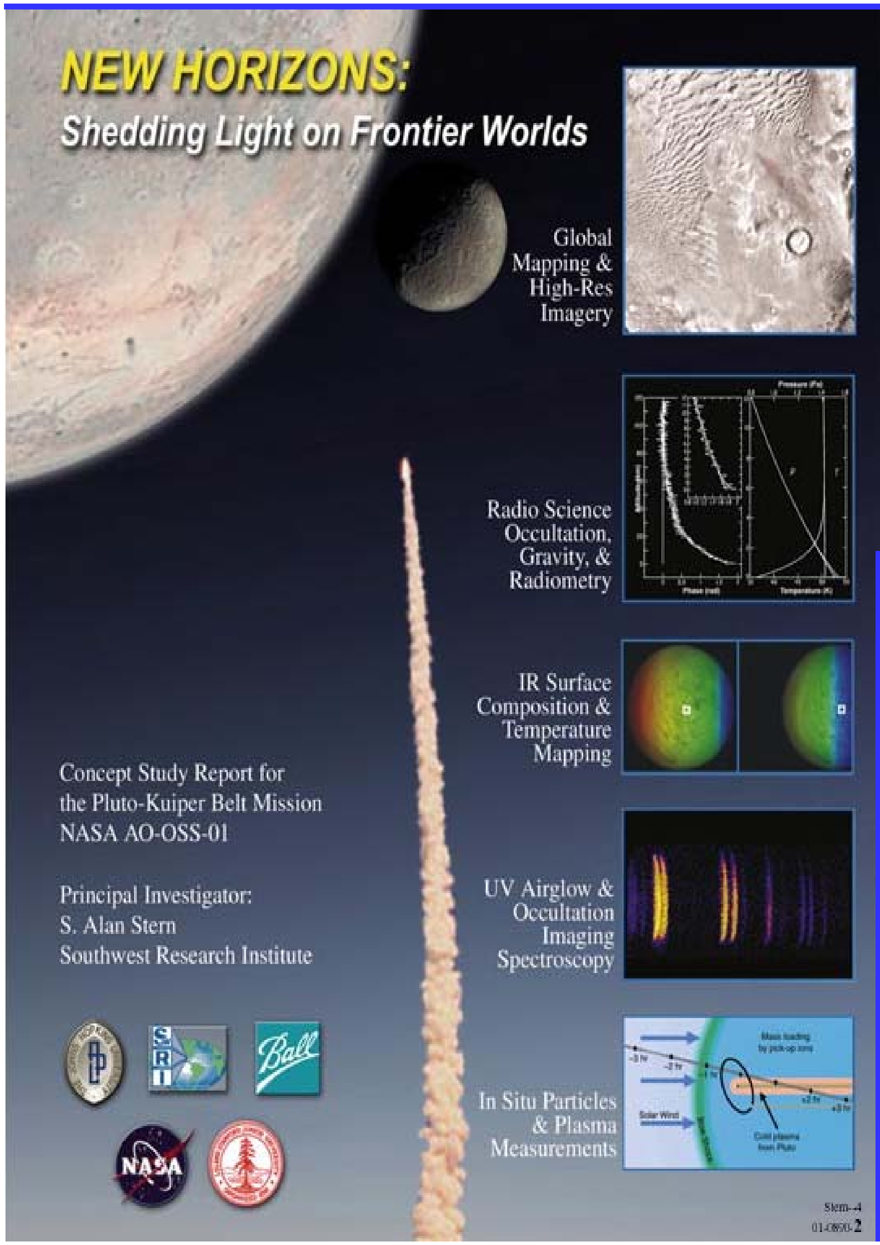
New View of the Solar System

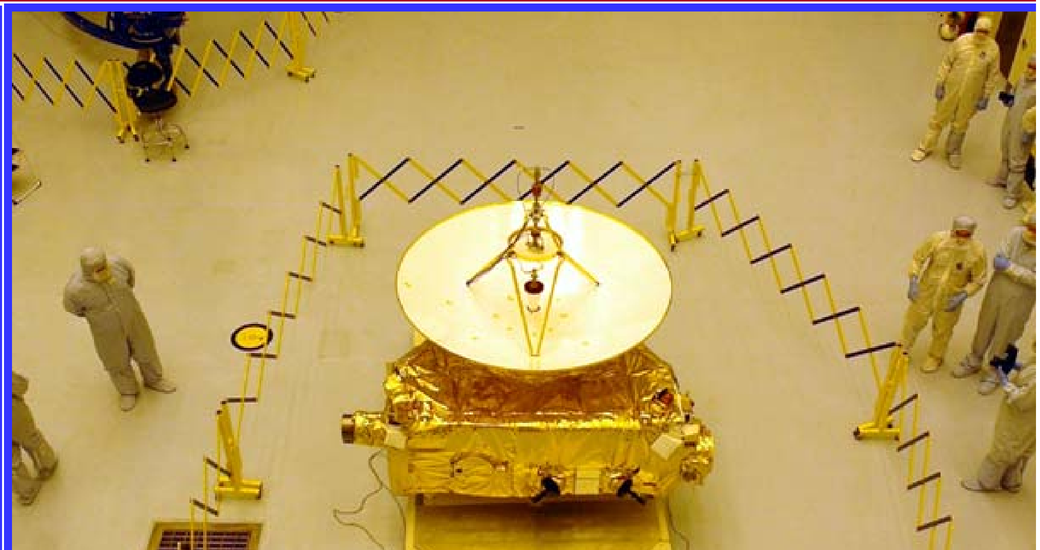
- Third class of planetary body
- Dwarf planets most common type

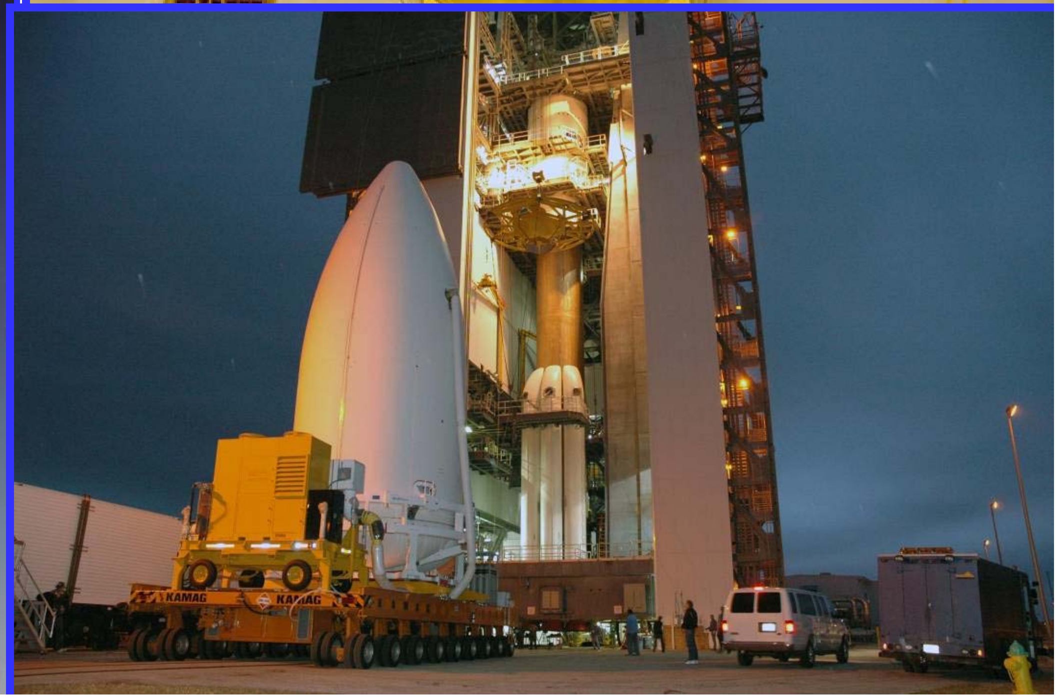



Highest Funding Priority Medium-Scale Mission
New Start of the 2003 Planetary Decadal Survey:
A Reconnaissance Expedition
to Pluto-Charon & the Kuiper Belt
NEW HORIZONS:
Shedding Light on Frontier Worlds
Global Mapping & High-Res Imagery
Radio Science Occultation, Gravity, & Radiometry
IR Surface Composition & Temperature Mapping
UV Airglow & Occultation Imaging Spectroscopy
In Situ Particles & Plasma Measurements
Concept Study Report for
the Pluto-Kuiper Belt Mission
NASA AO-OSS-01
Principal Investigator:
S. Alan Stern
Southwest Research Institute
Ball
NASA

2002-2005: DESIGN, BUILD, TEST

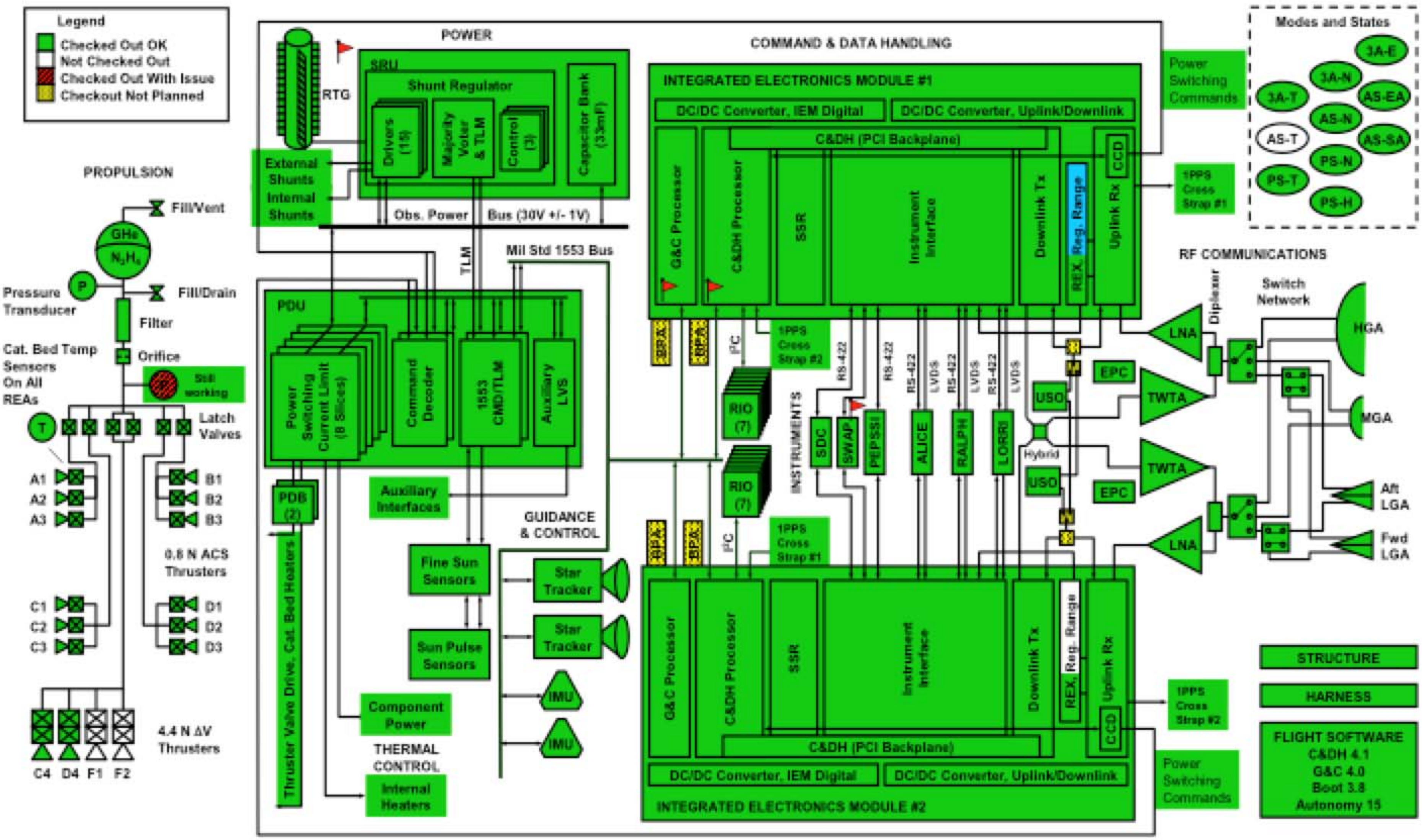






AT THE CAPE: NOV 2005

INSIDE NEW HORIZONS

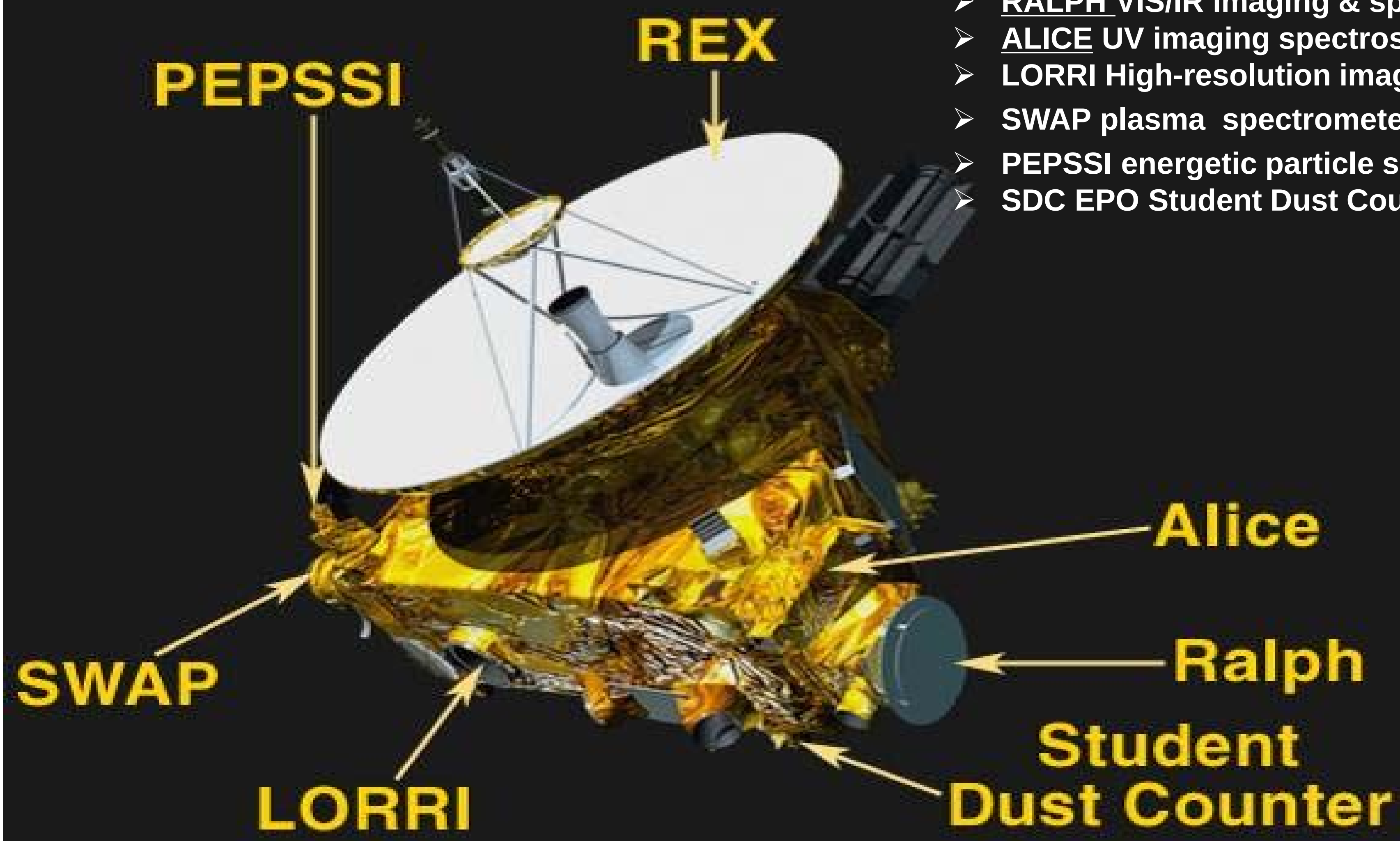


As of 9/28/07

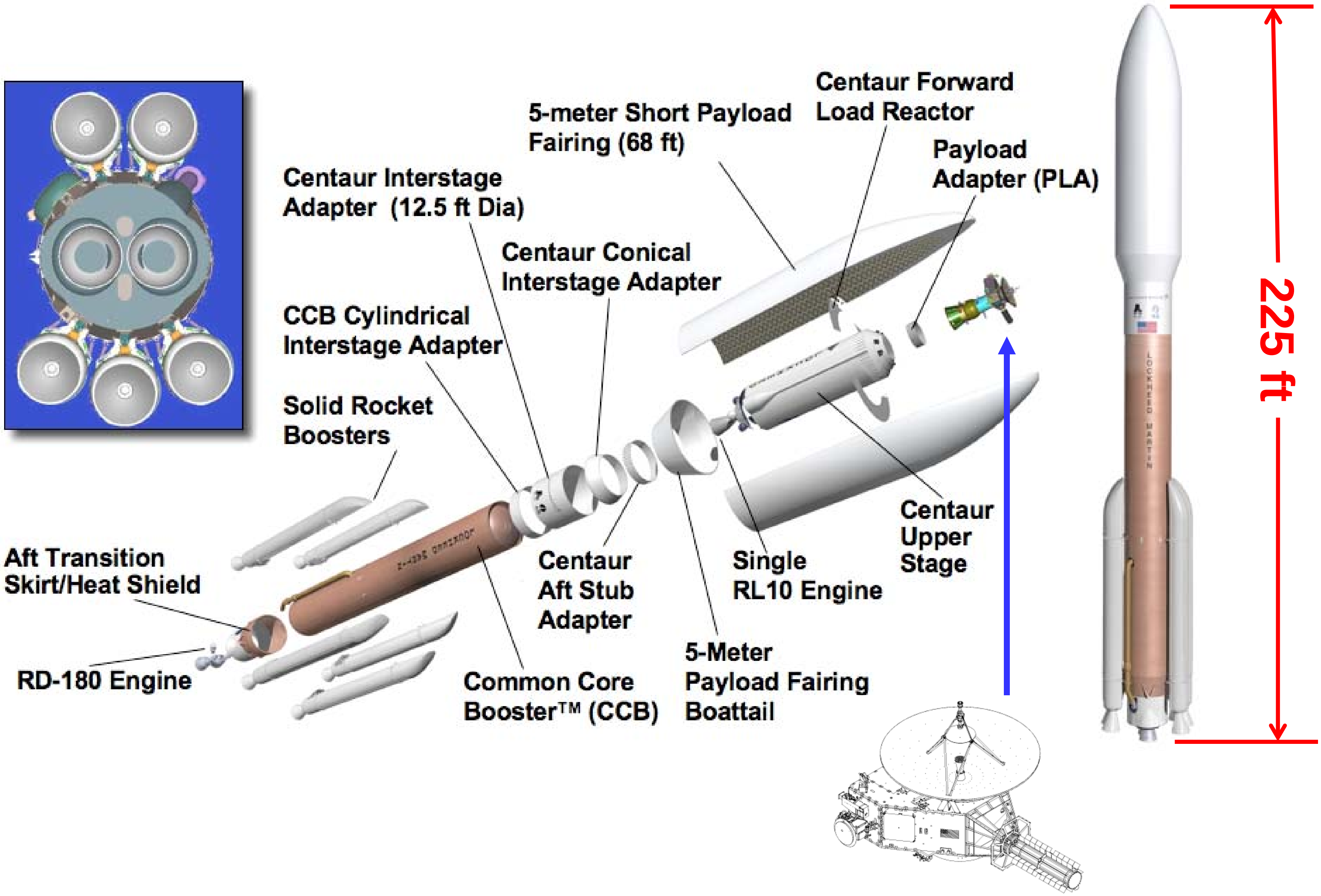
THE SCIENTIFIC PAYLOAD

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

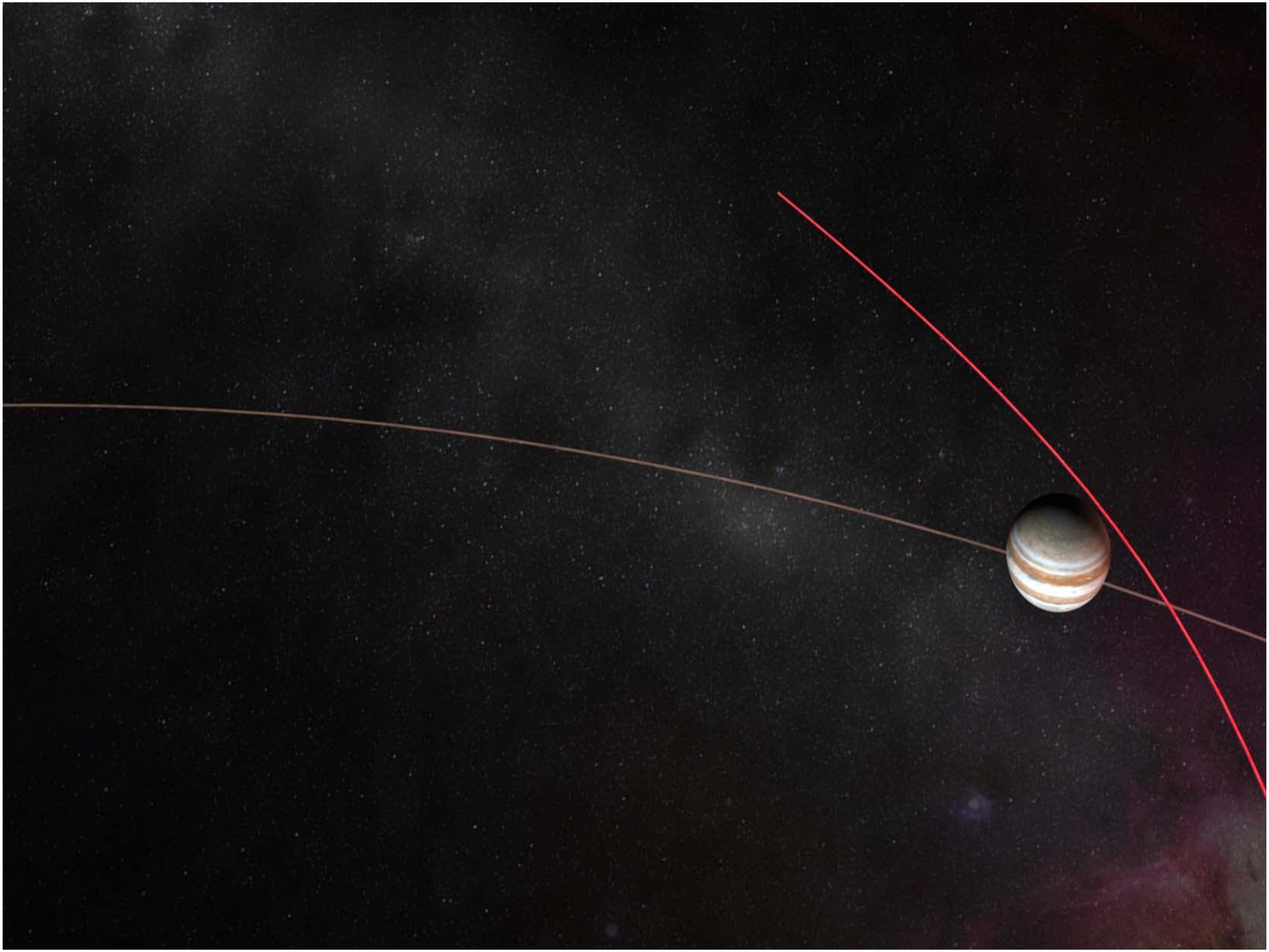


LAUNCH VEHICLE



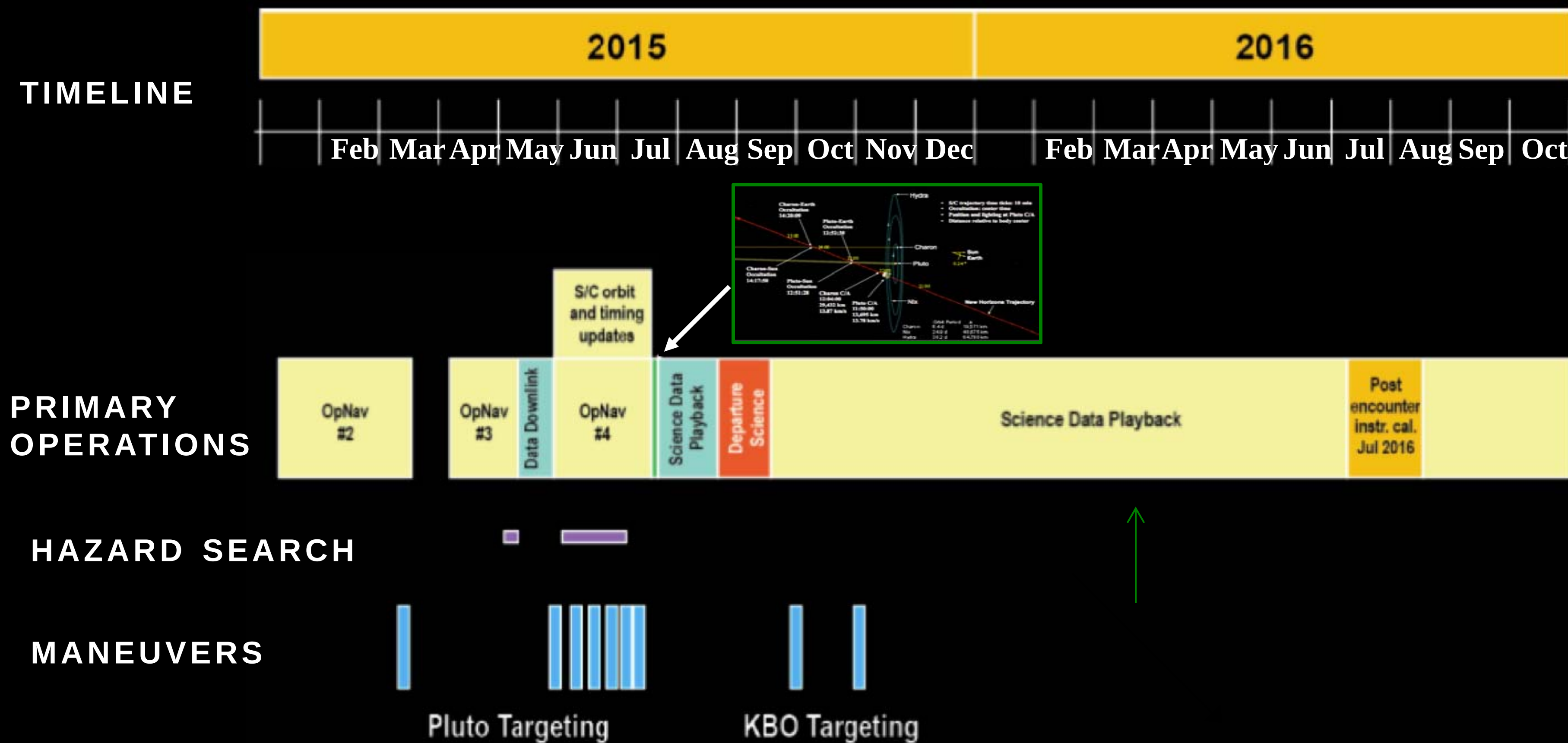
LAUNCH
19 JANUARY 2006


Science
NEW HORIZONS
at Jupiter

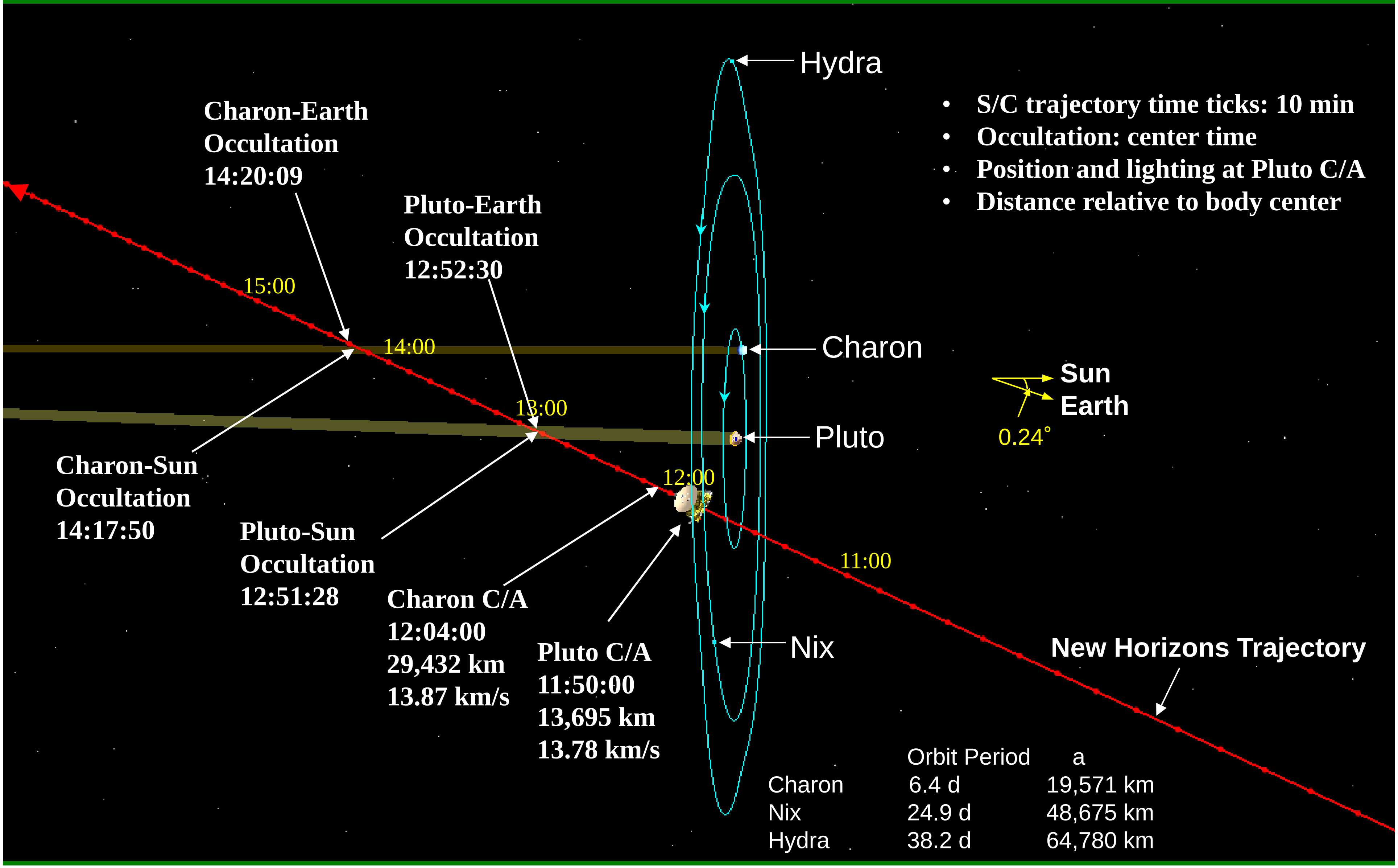


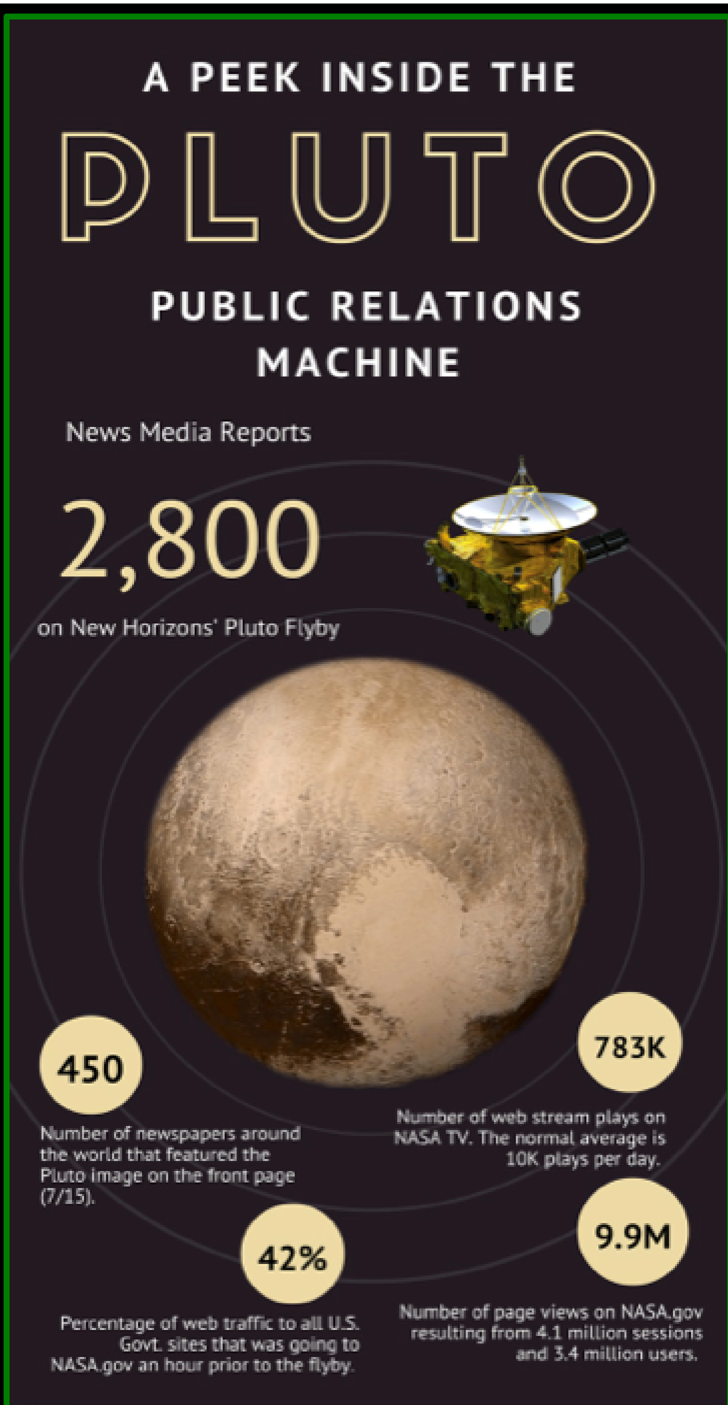
WELCOME TO ENCOUNTER!

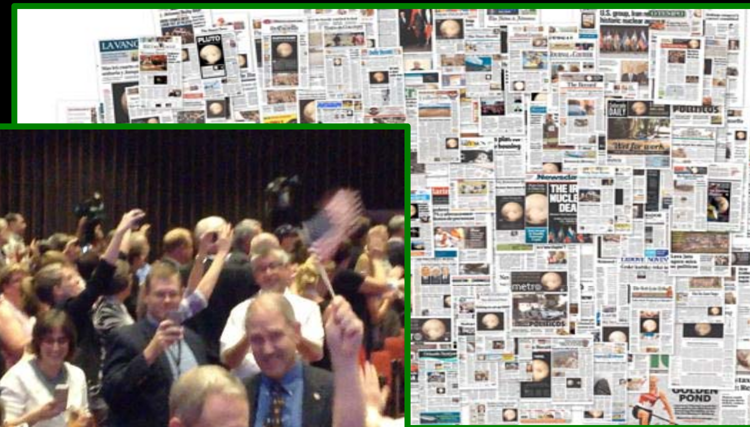
ENCOUNTER OVERVIEW



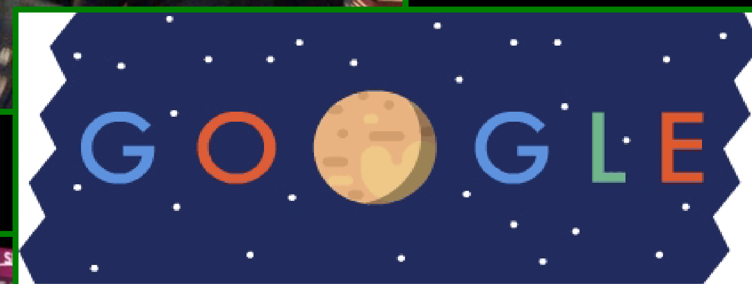
AND NEEDLES TO THREAD

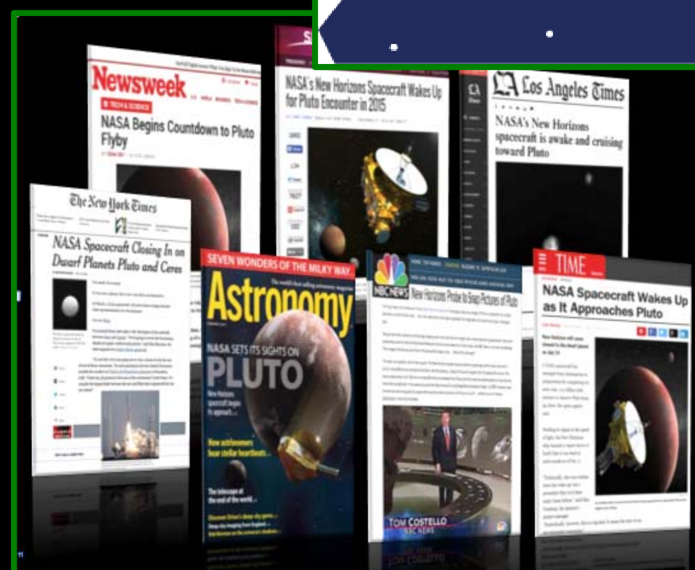


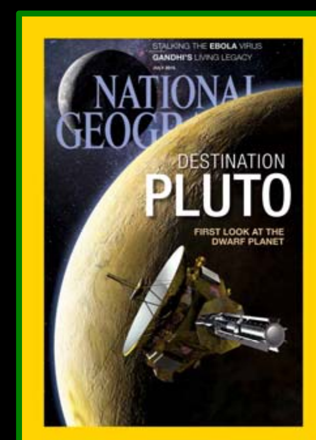

A PEEK INSIDE THE
PLUTO
PUBLIC RELATIONS MACHINE
News Media Reports
2,800
on New Horizons' Pluto Flyby
450
Number of newspapers around the world that featured the Pluto image on the front page (7/15).
783K
Number of web stream plays on NASA TV. The normal average is 10K plays per day.
42%
Percentage of web traffic to all U.S. Govt. sites that was going to NASA.gov an hour prior to the flyby.
9.9M
Number of page views on NASA.gov resulting from 4.1 million sessions and 3.4 million users.

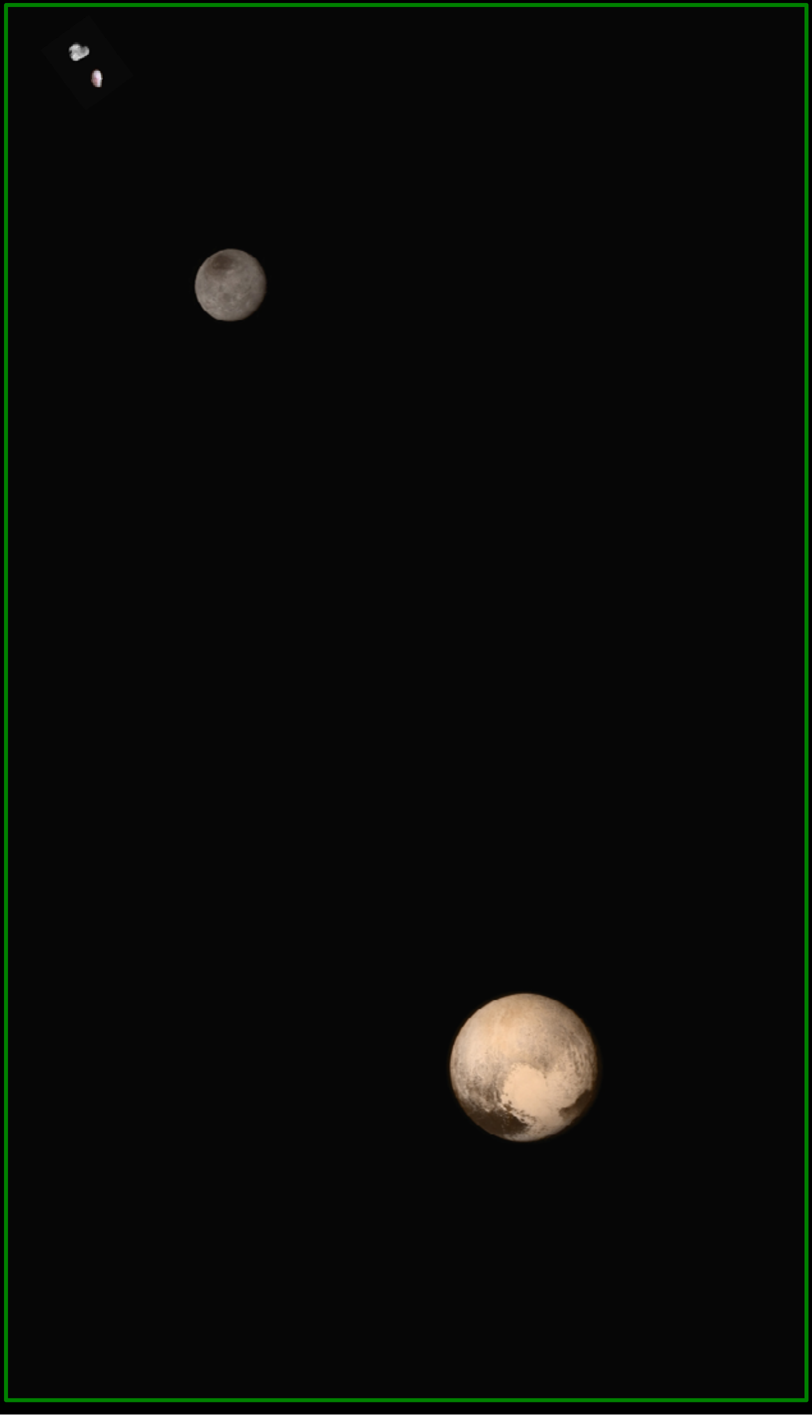



© Don Davis

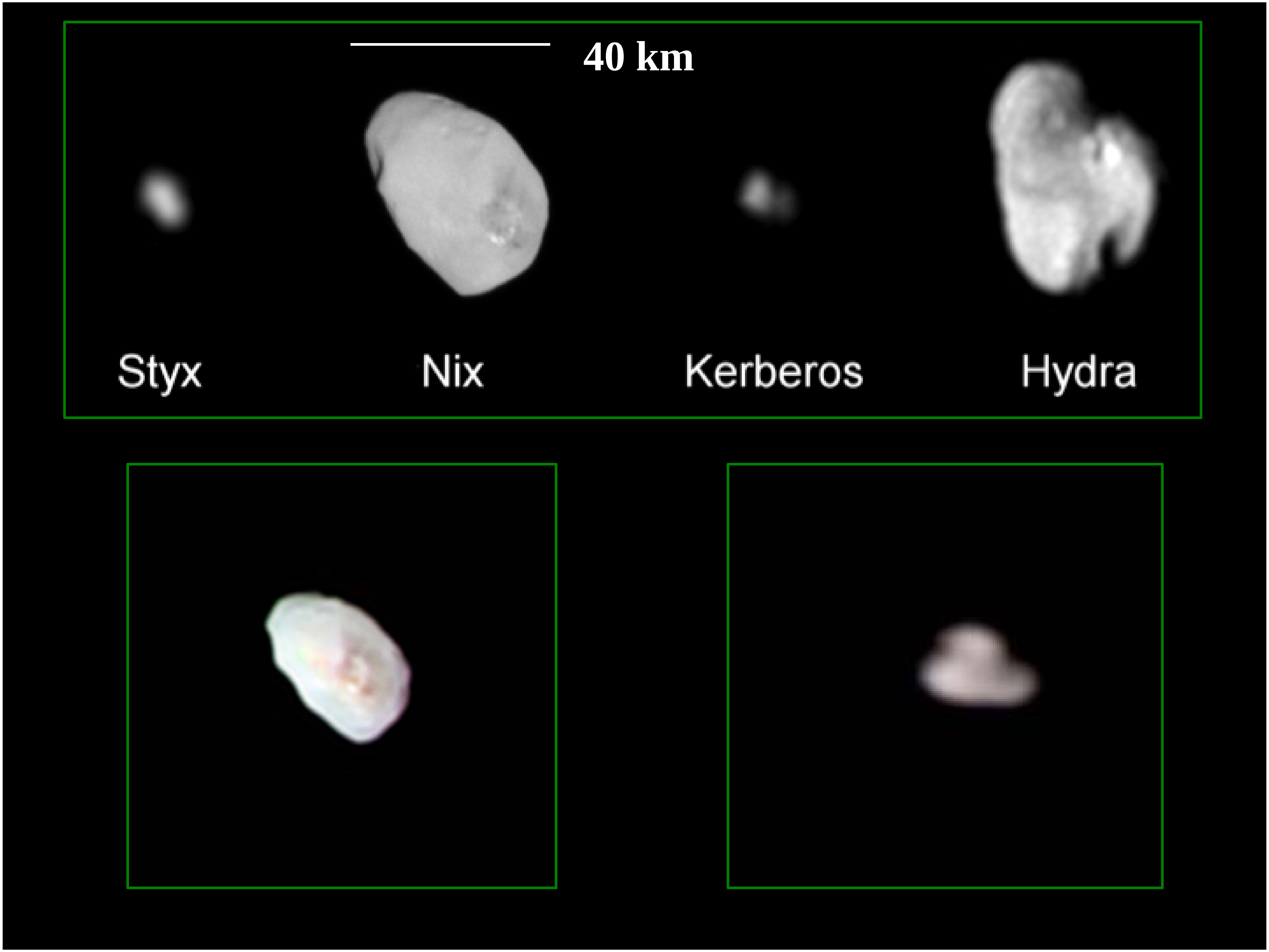



Newsweek
NASA Begins Countdown to Pluto Flyby
NASA's New Horizons Spacecraft Wakes Up for Pluto Encounter in 2015
Los Angeles Times
NASA's New Horizons spacecraft is awake and cruising toward Pluto
The New York Times
NASA Spacecraft Closing In on Dwarf Planets Pluto and Ceres
SEVEN WONDERS OF THE MILKY WAY
Astronomy
NASA SETS ITS SIGHTS ON PLUTO
NBC NEWS
TOM COSTELLO
TIME
NASA Spacecraft Wakes Up as It Approaches Pluto

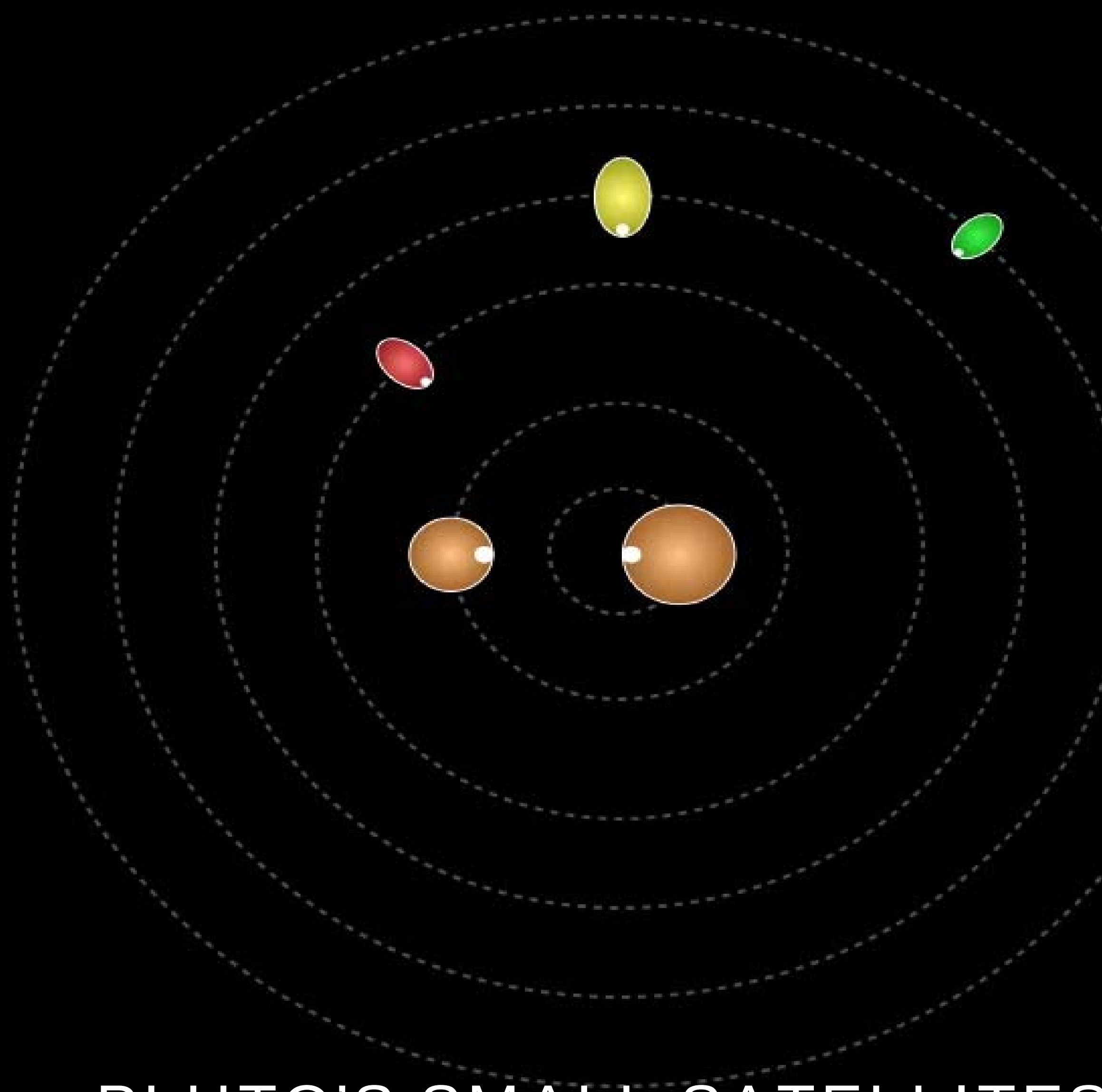

STALKING THE EBOLA VIRUS
GANDHI'S LIVING LEGACY
DESTINATION
PLUTO
FIRST LOOK AT THE DWARF PLANET

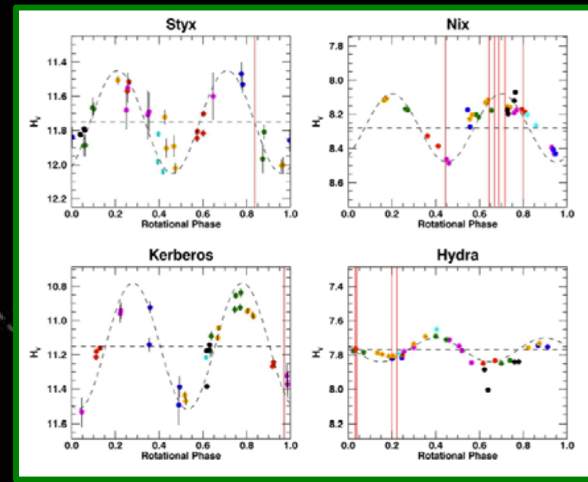


All surface feature names in this talk are informal.



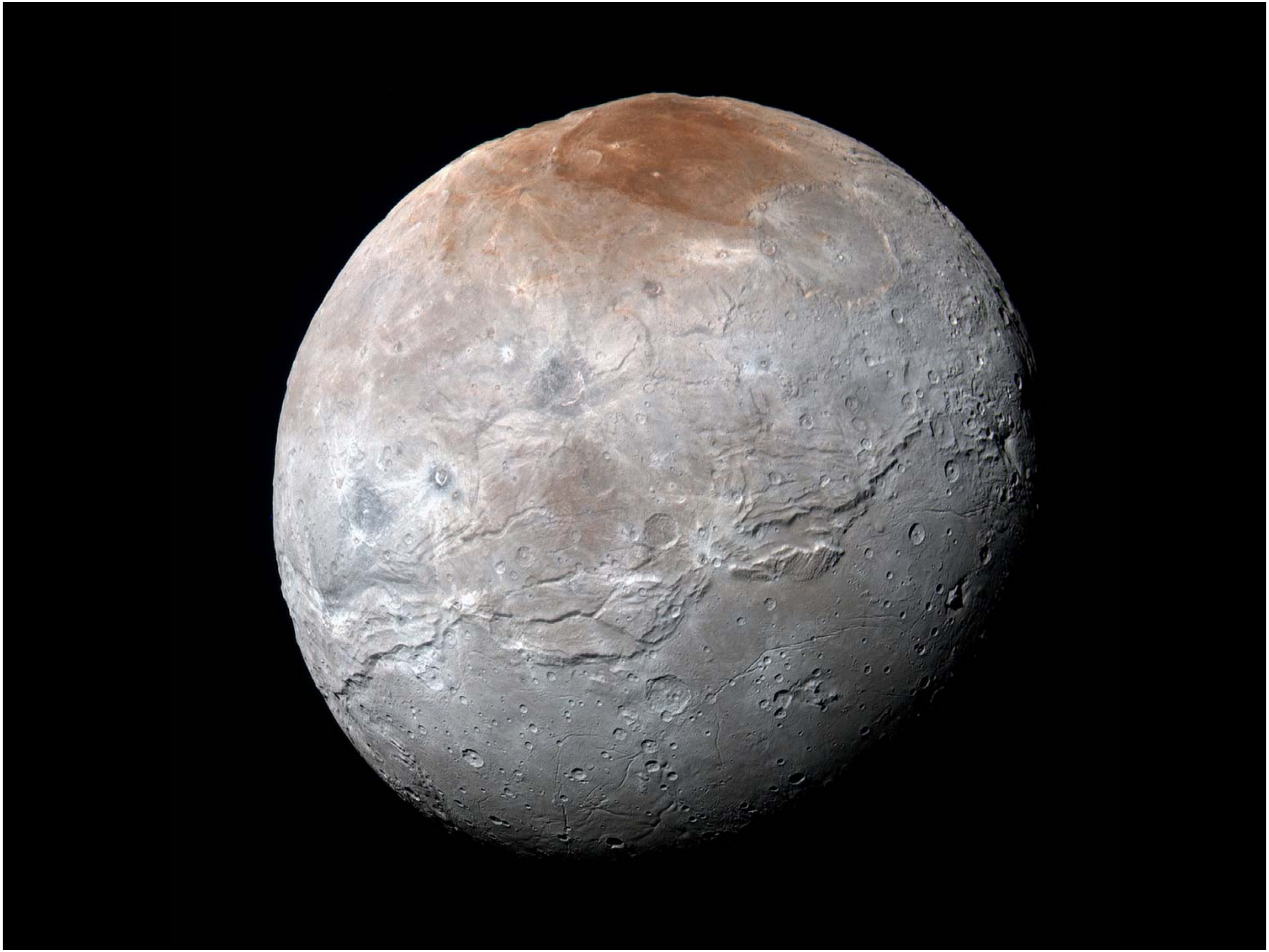
40 km
Styx
Nix
Kerberos
Hydra

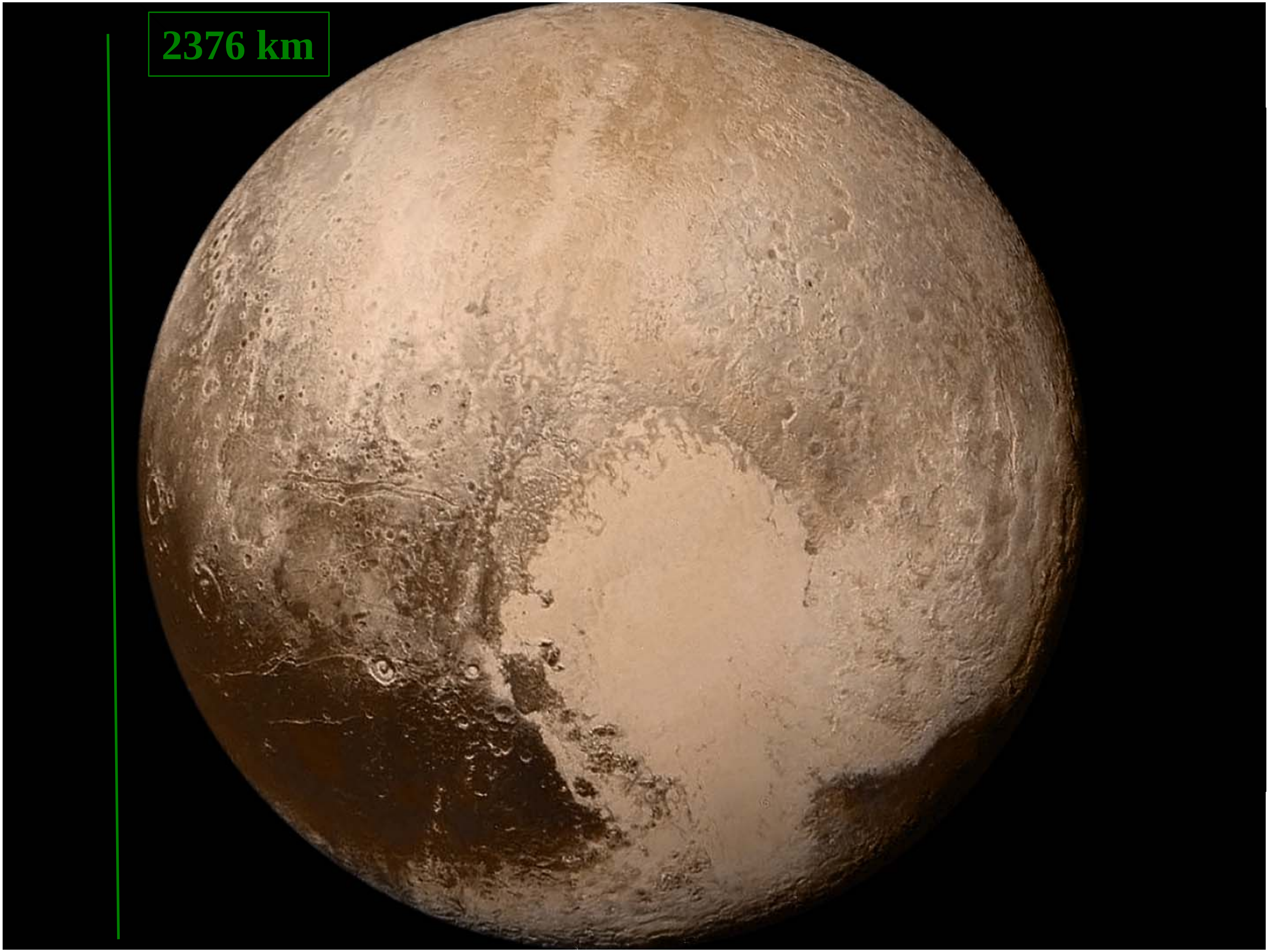


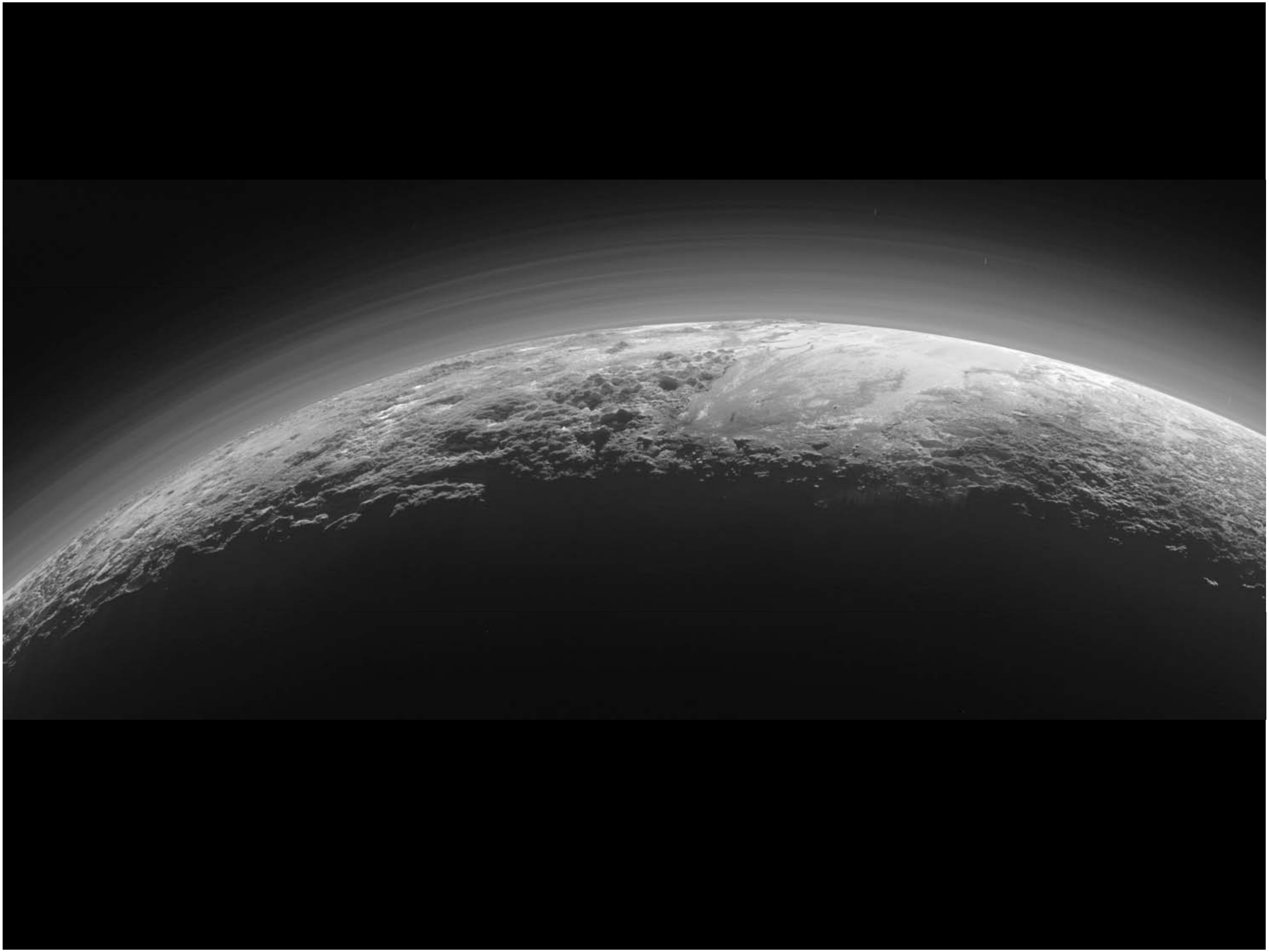


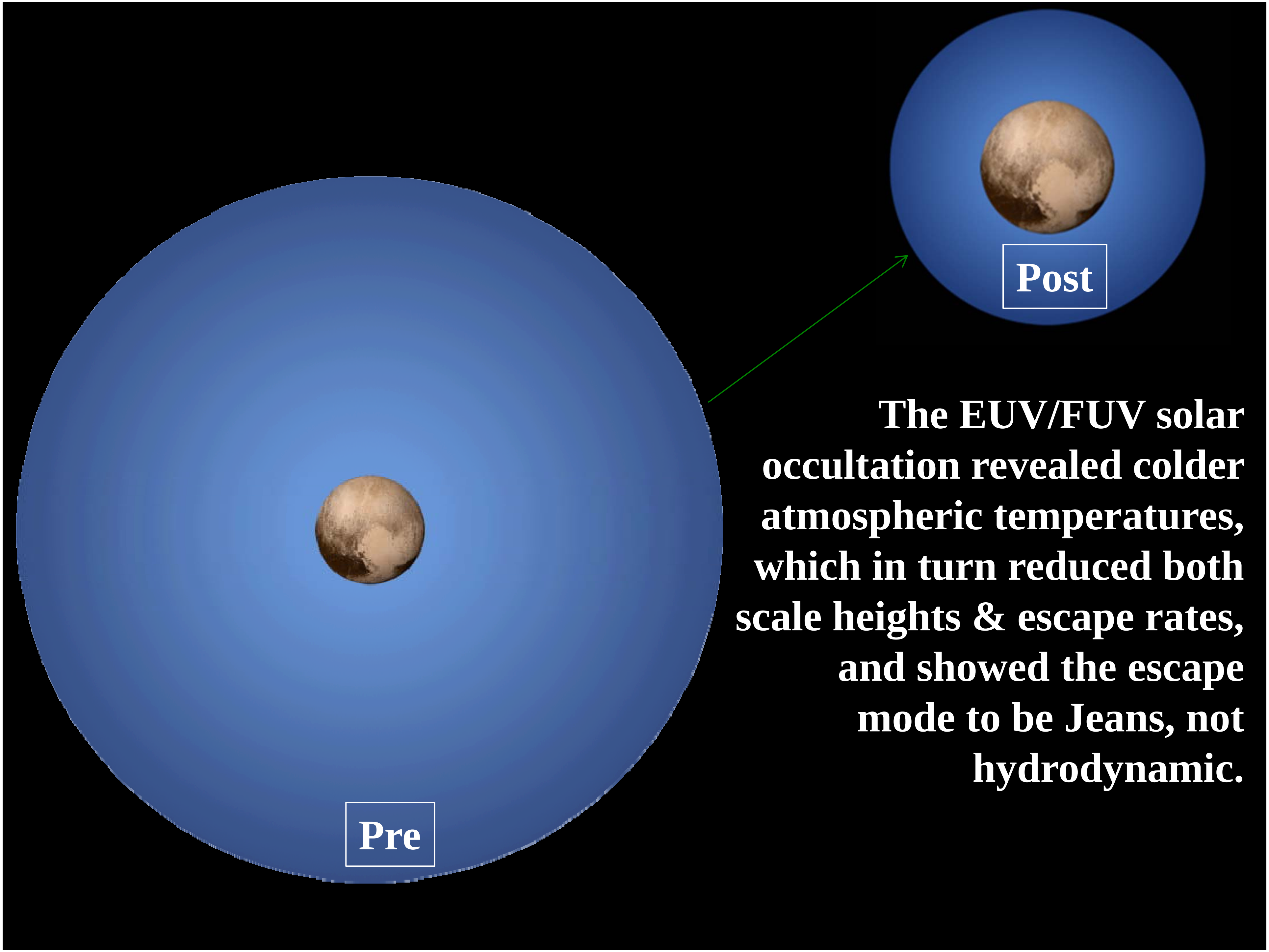
Body	Spin Period	
	Days	Orbits
Pluto	6.387	1
Charon	6.387	1
Styx	3.239	6.22
Nix	1.829	13.6
Kerberos	5.33	6.04
Hydra	0.4295	88.9

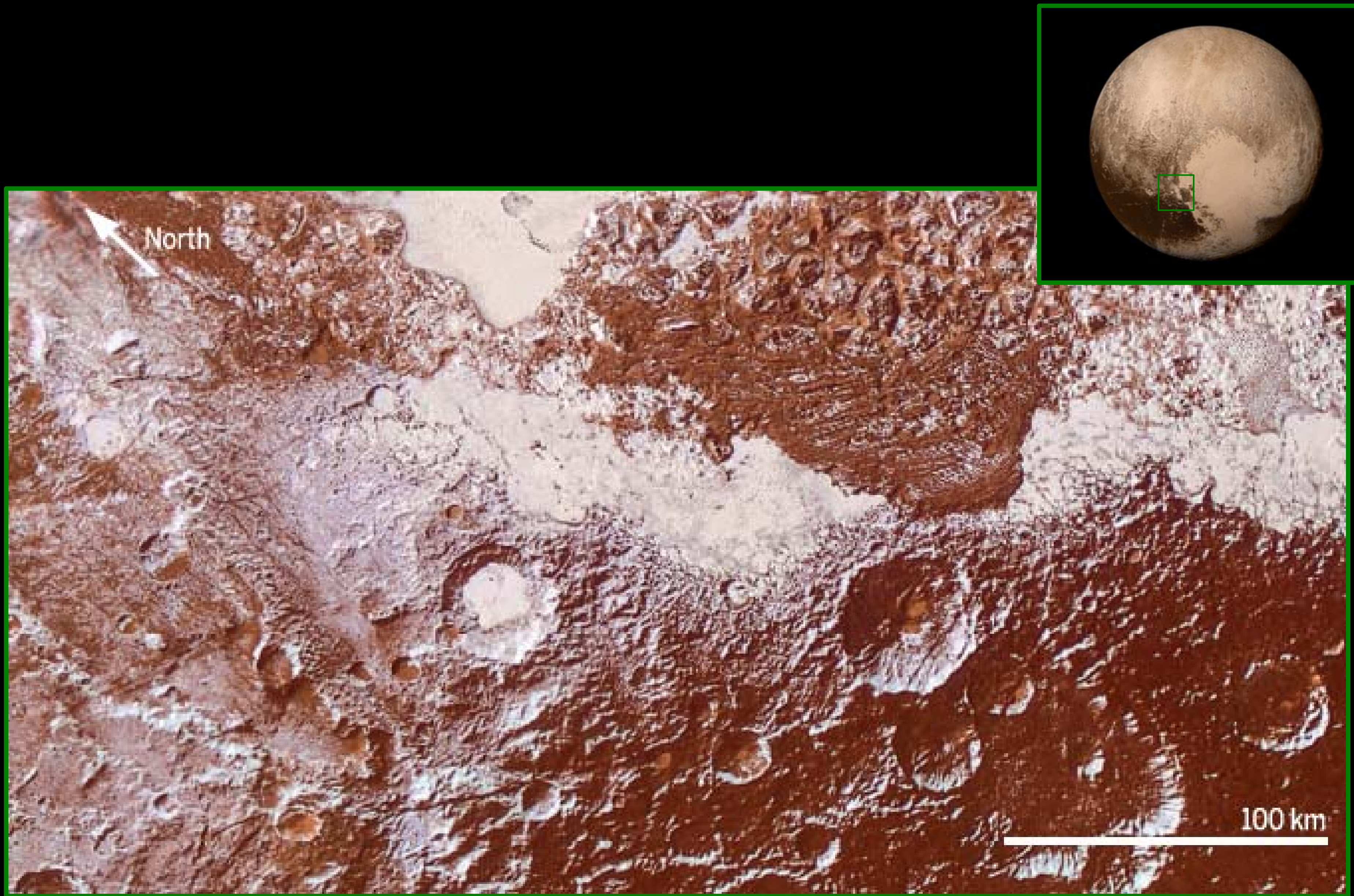
PLUTO'S SMALL SATELLITES ARE ALL NON-SYNCHRONOUS ROTATORS

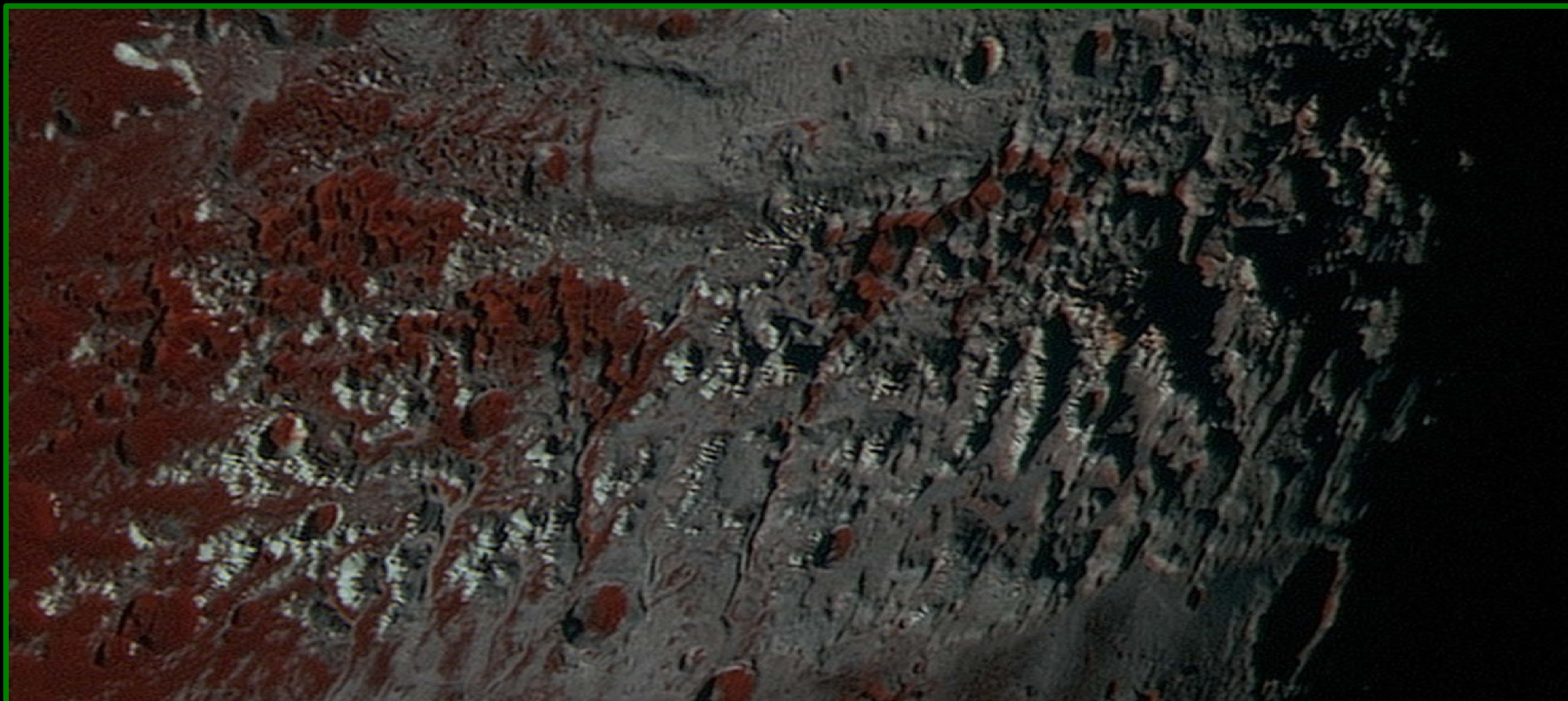


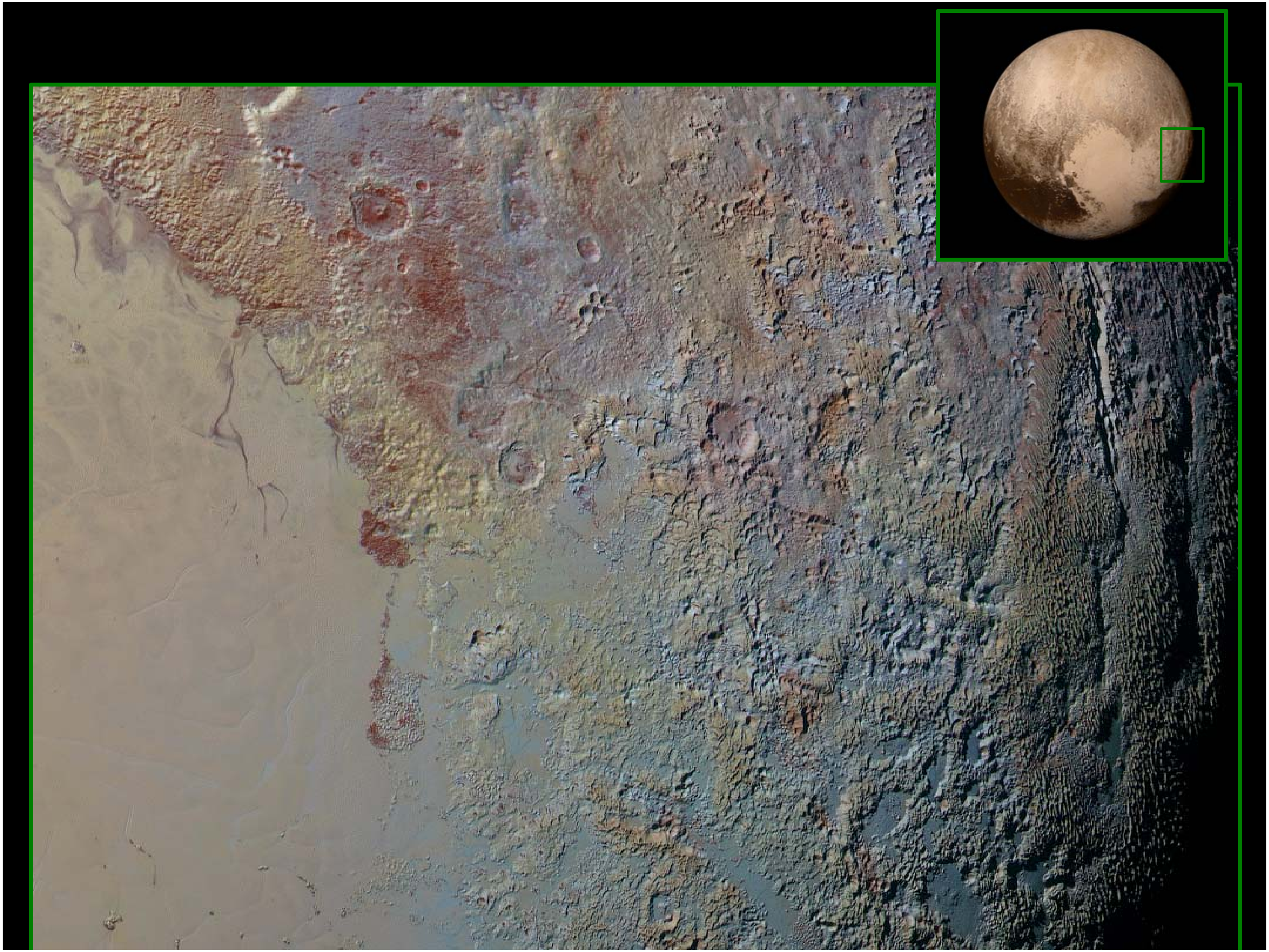

2376 km

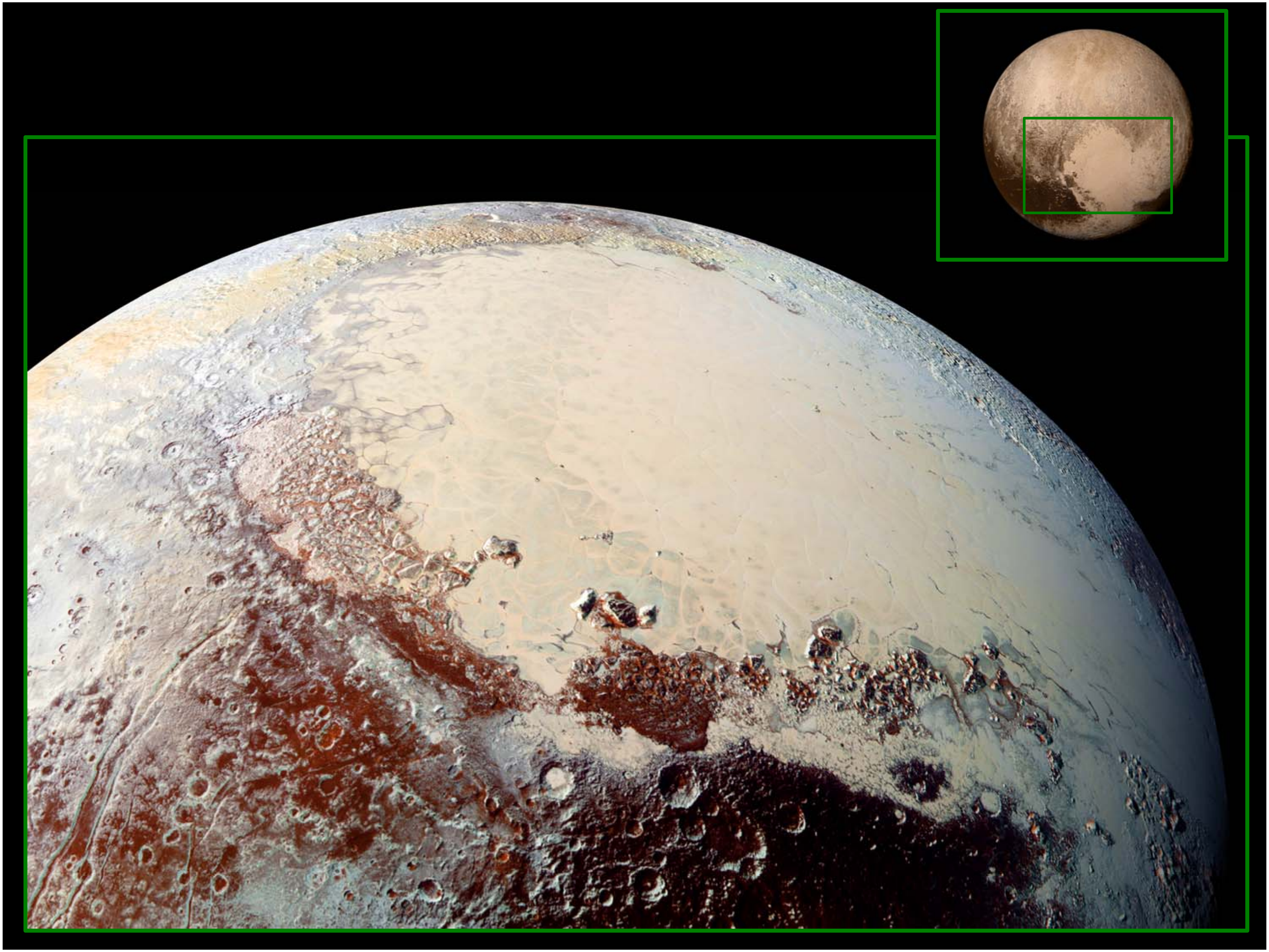


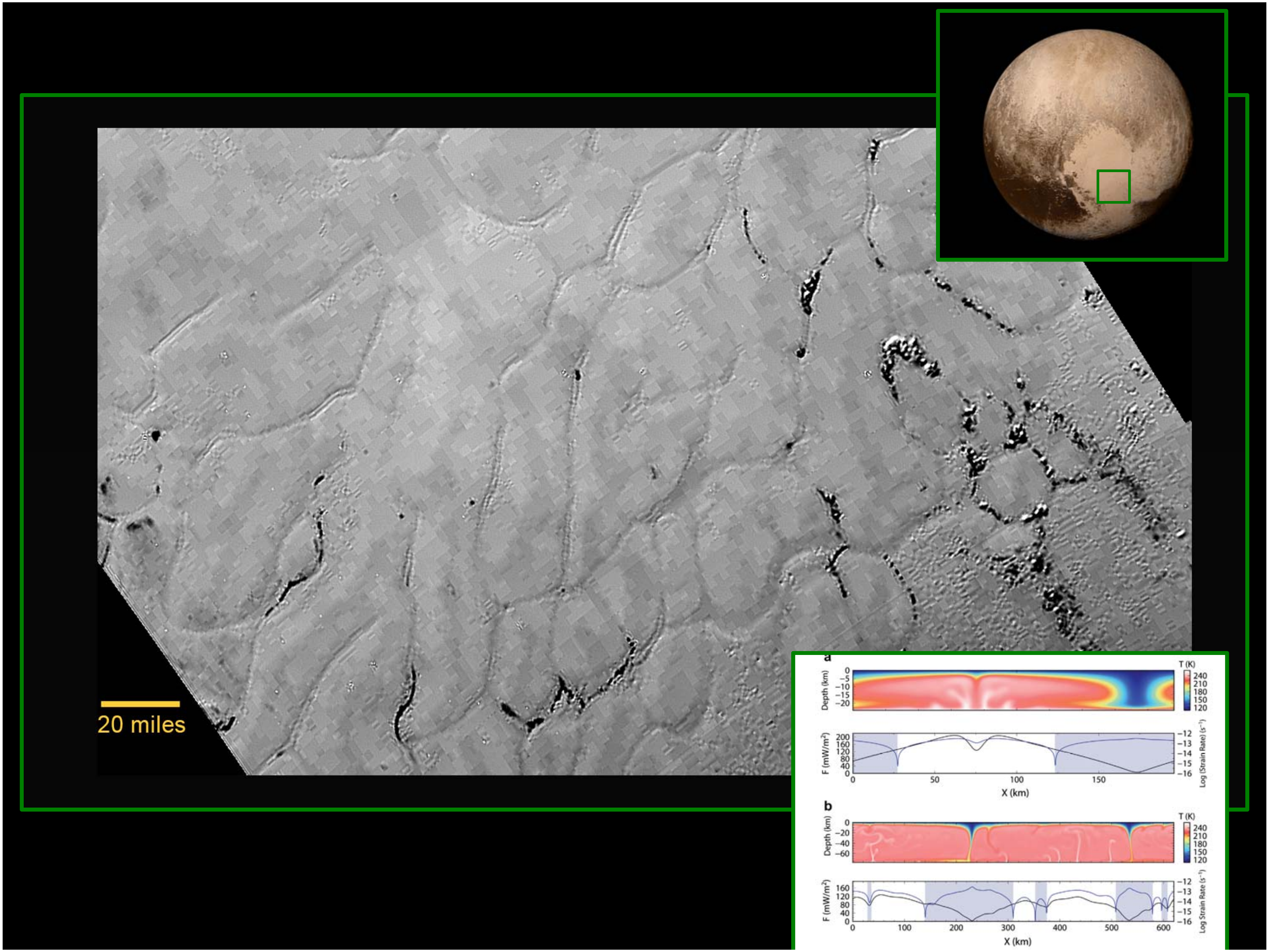

Post
Pre
The EUV/FUV solar occultation revealed colder atmospheric temperatures, which in turn reduced both scale heights & escape rates, and showed the escape mode to be Jeans, not hydrodynamic.


North
100 km

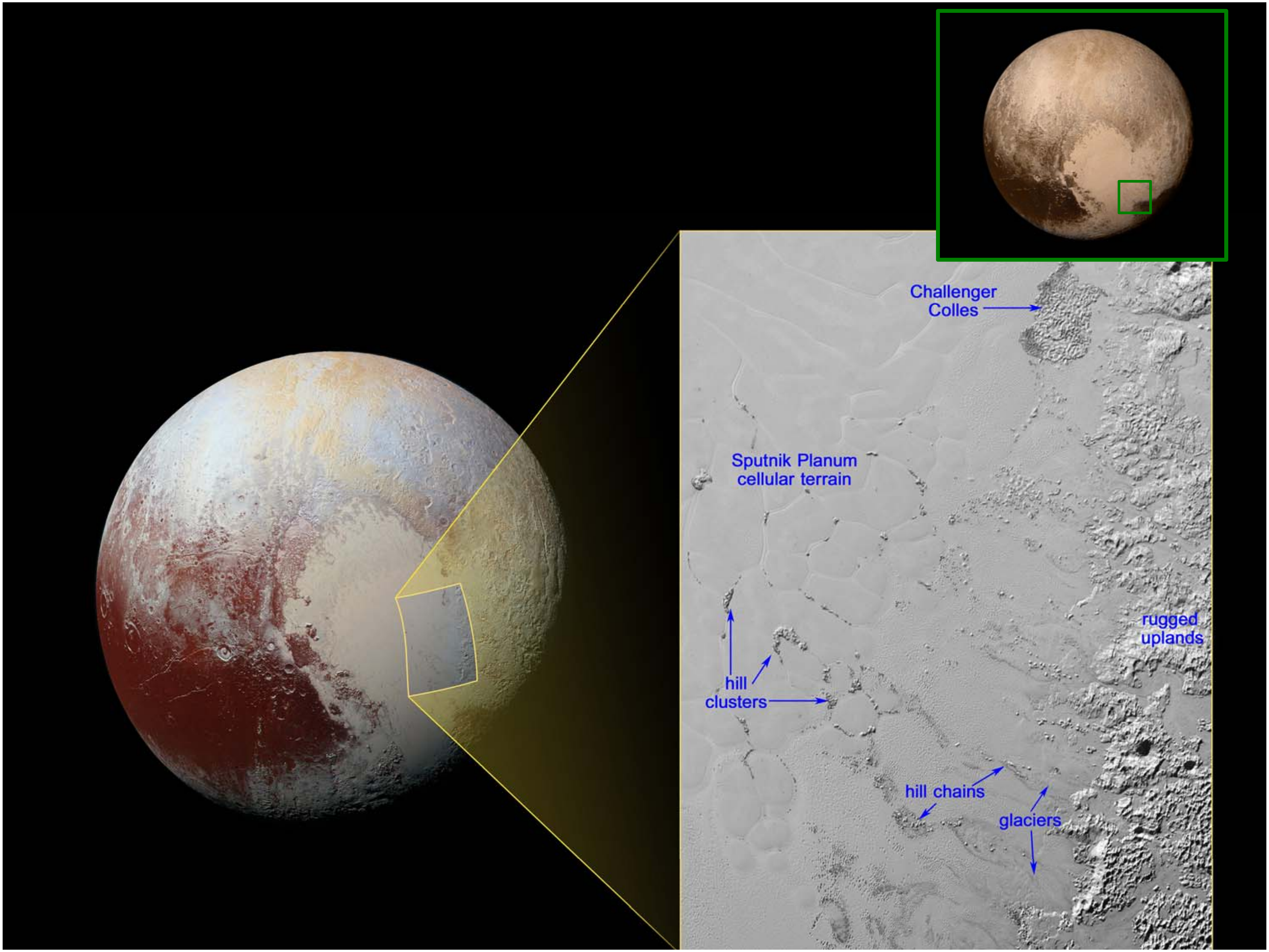




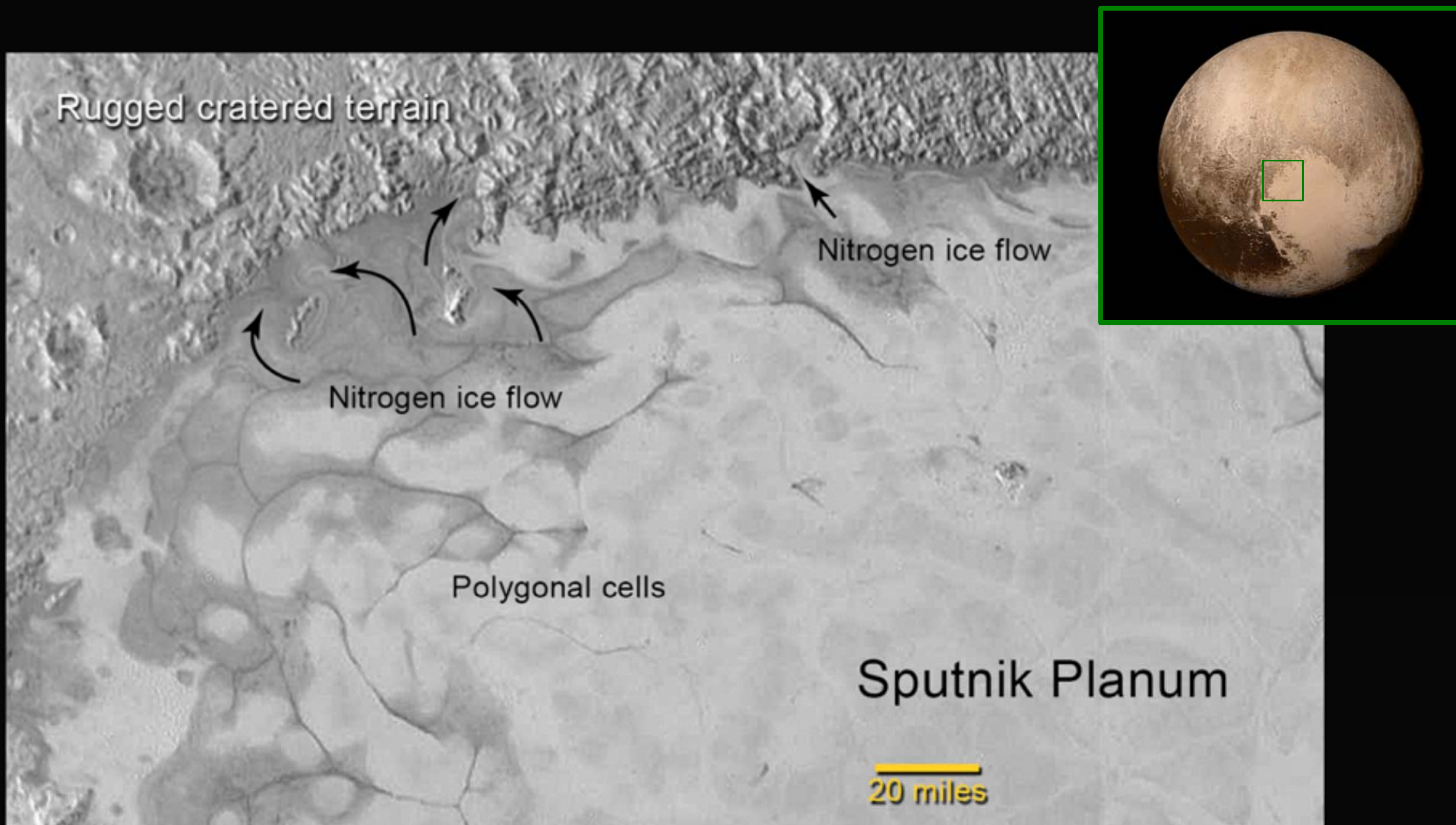


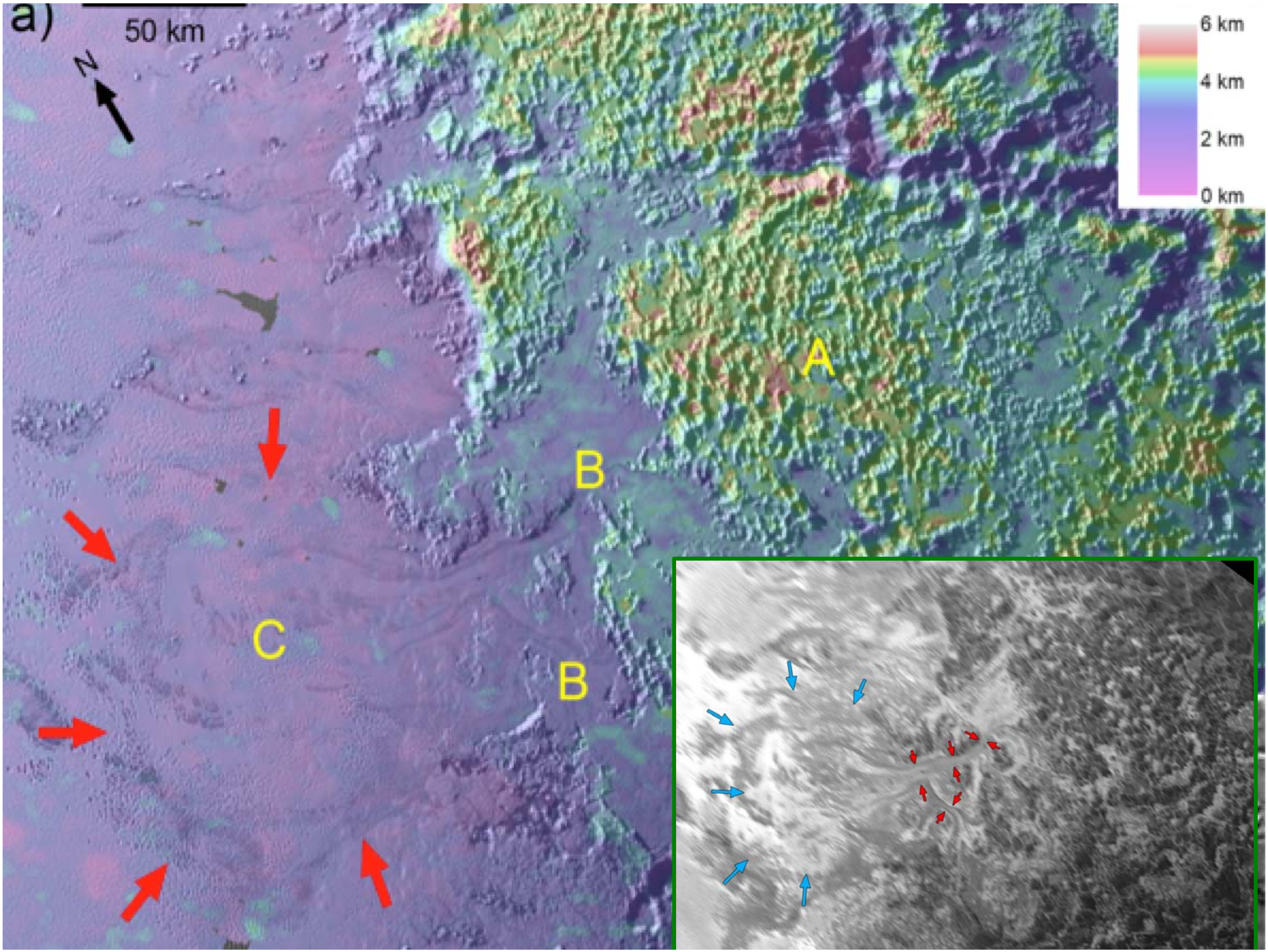


20 miles
a
Depth (km)
T (K)
240
210
180
150
120
F (mW/m²)
Log (Strain Rate) (s⁻¹)
X (km)
b

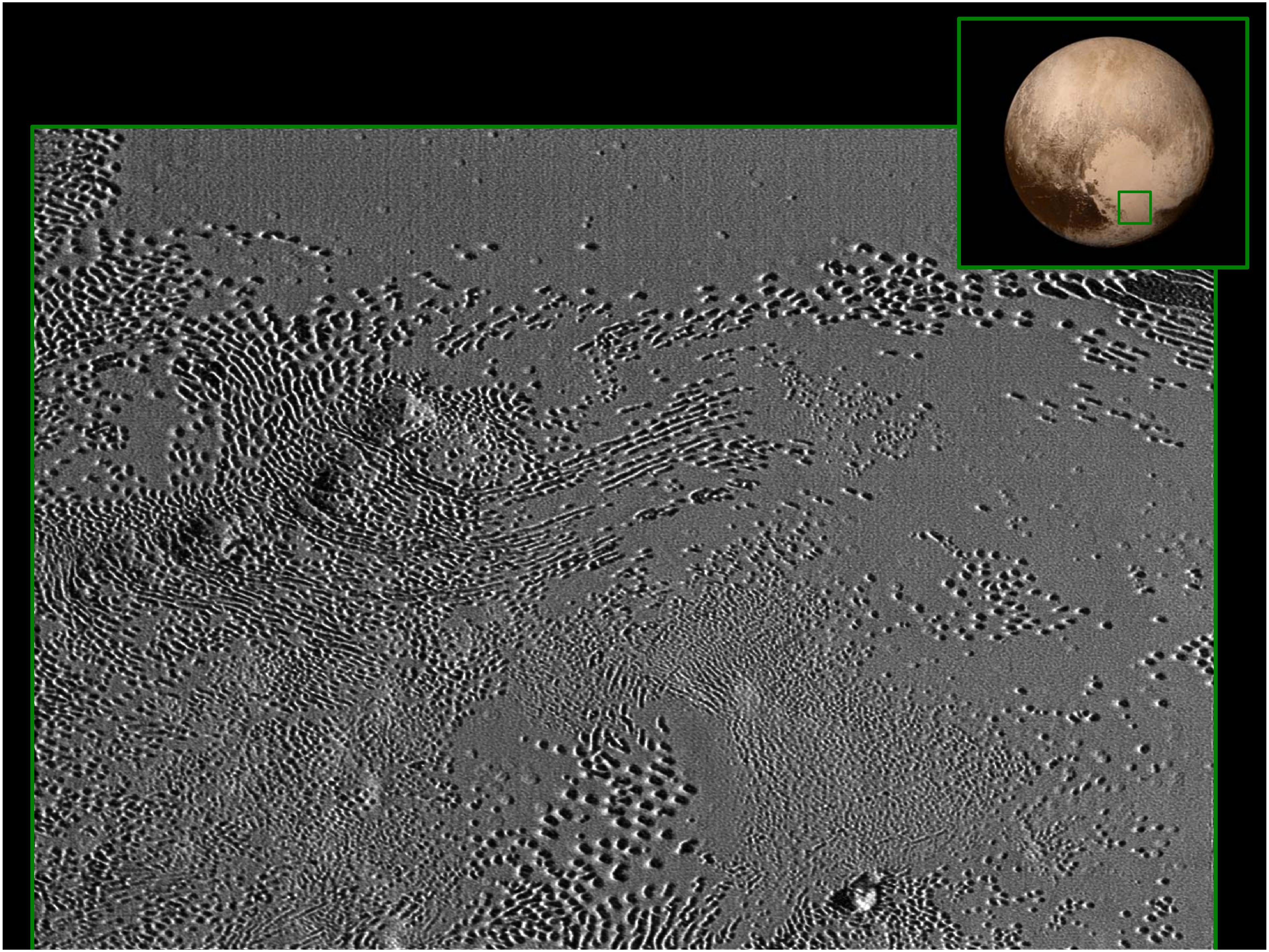

Challenger Colles
Sputnik Planum cellular terrain
hill clusters
rugged uplands
hill chains
glaciers

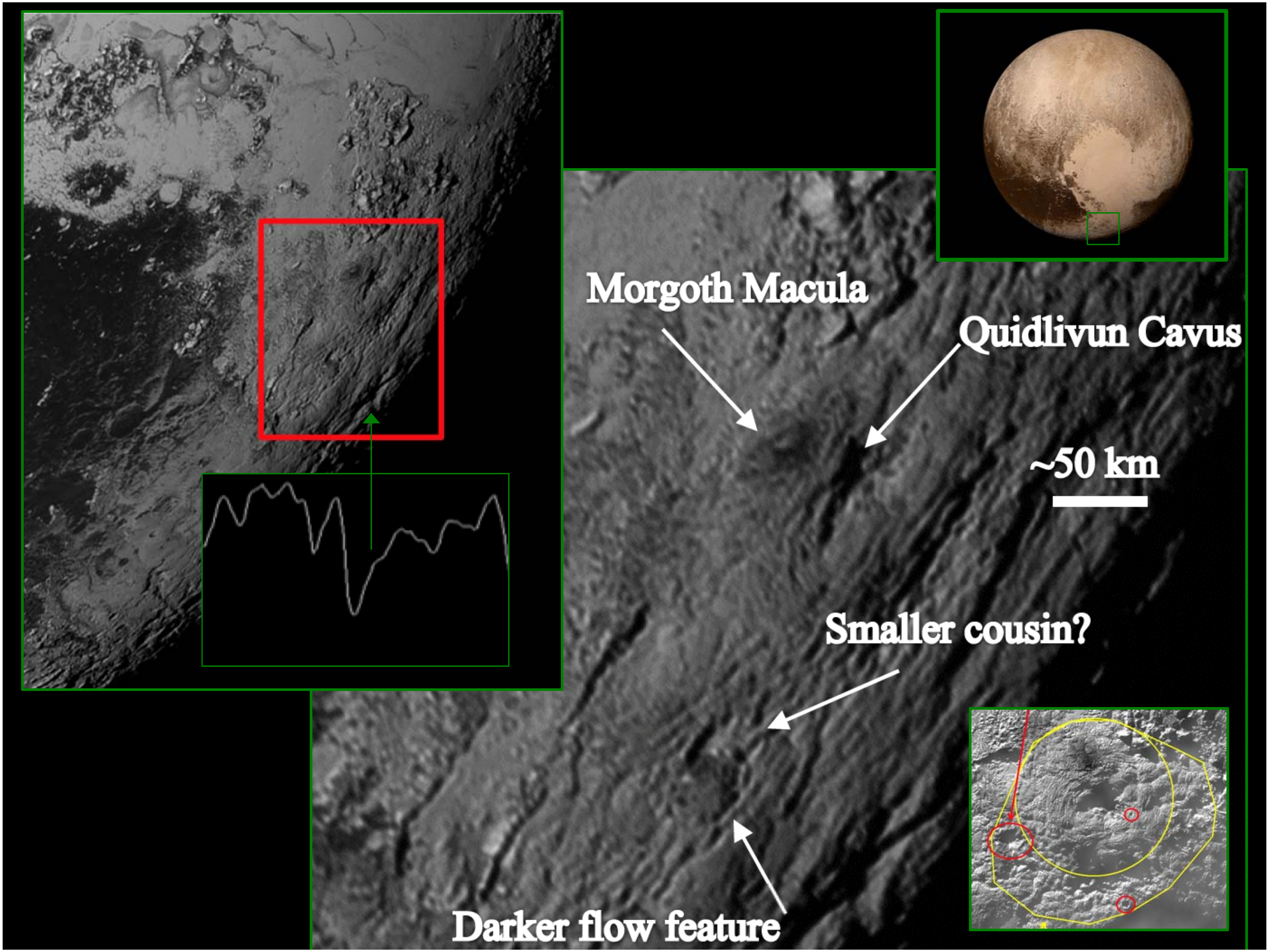
NEW HORIZONS:
GLACIAL FLOW ON PLUTO



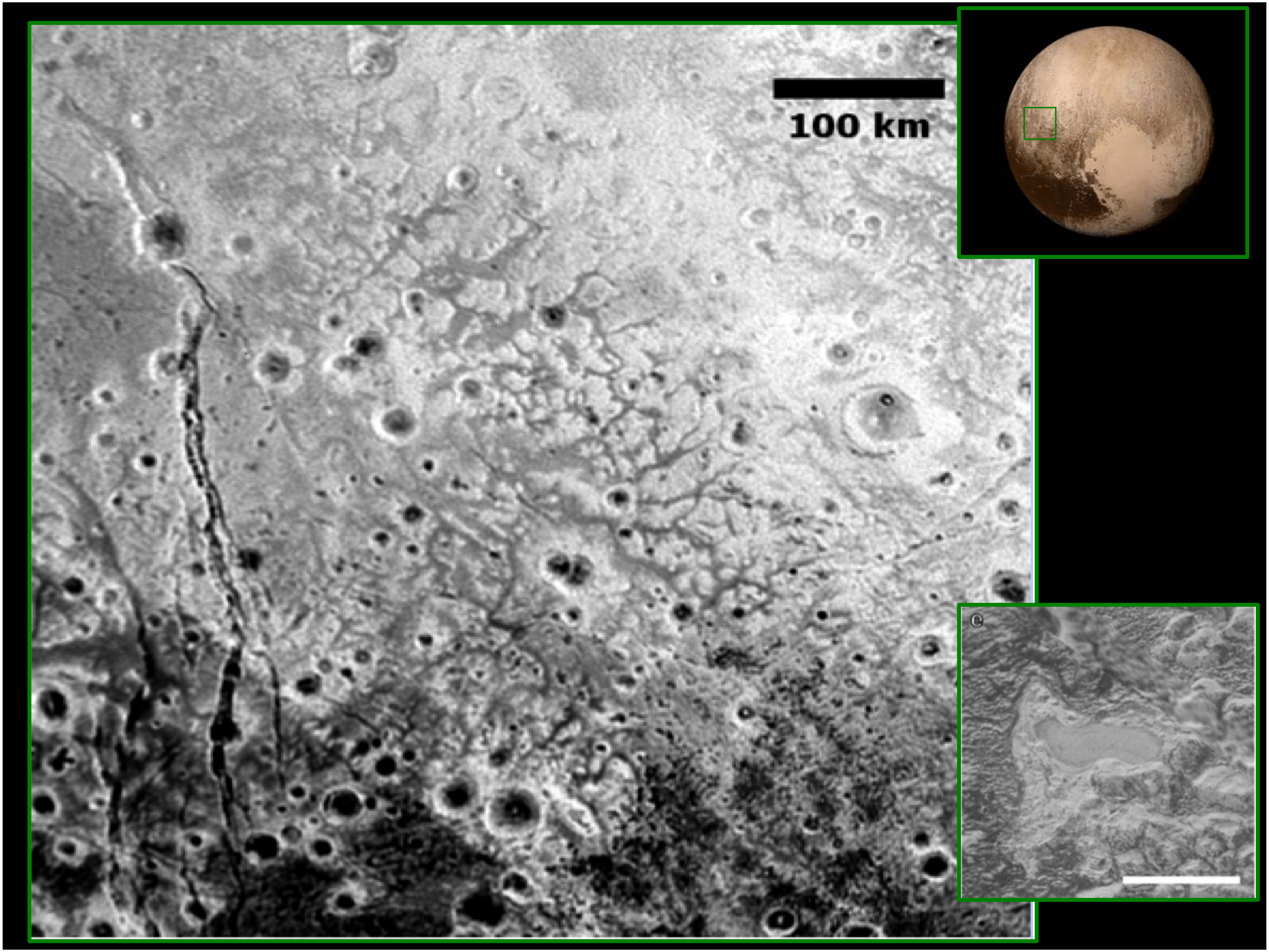


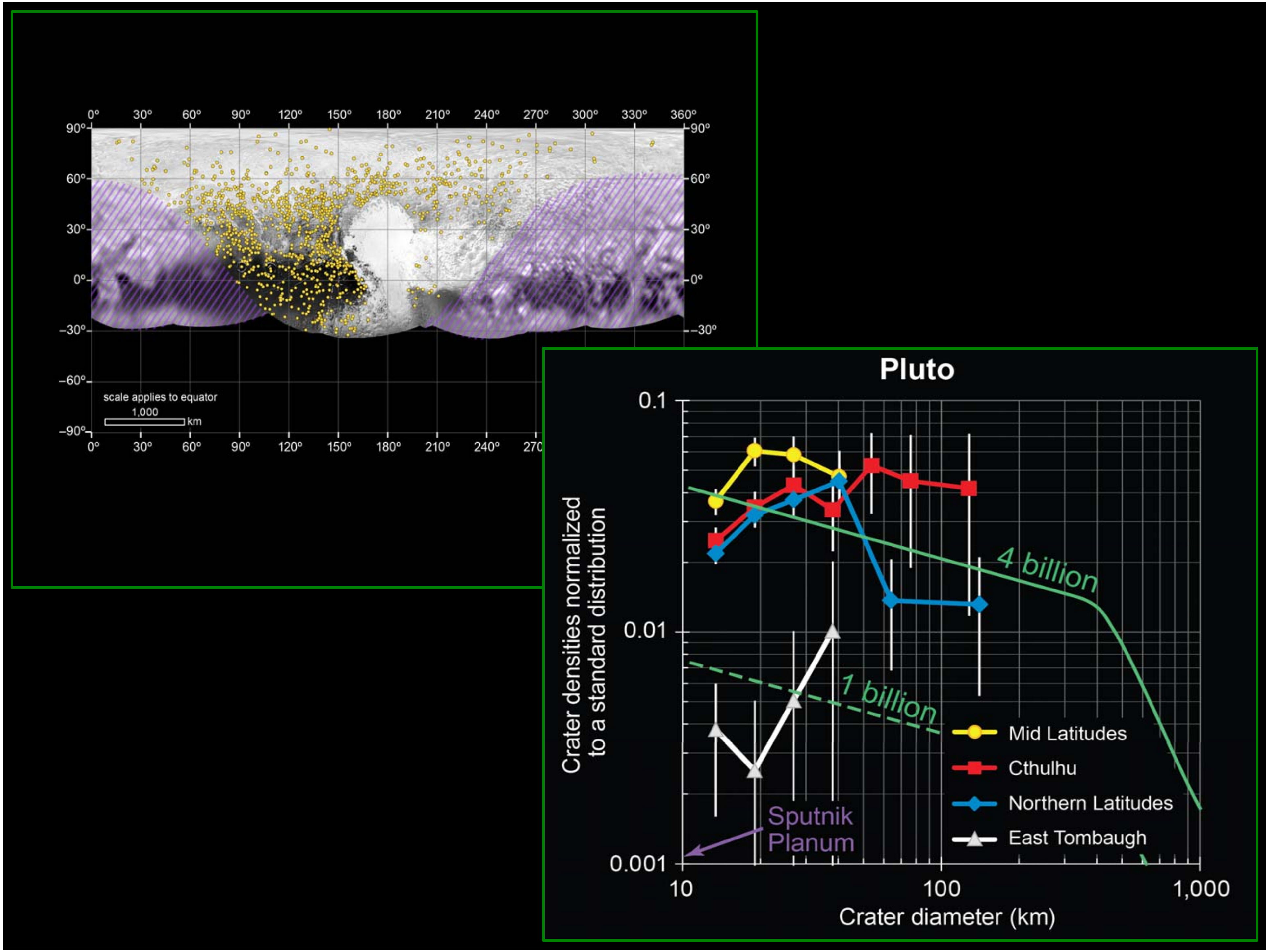
a)
50 km
N
6 km
4 km
2 km
0 km
A
B
B
C





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


100 km
e


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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sciencemag.org
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Flying past Pluto
New Horizons finds surprises at Pluto and Charon pp. 260 & 292


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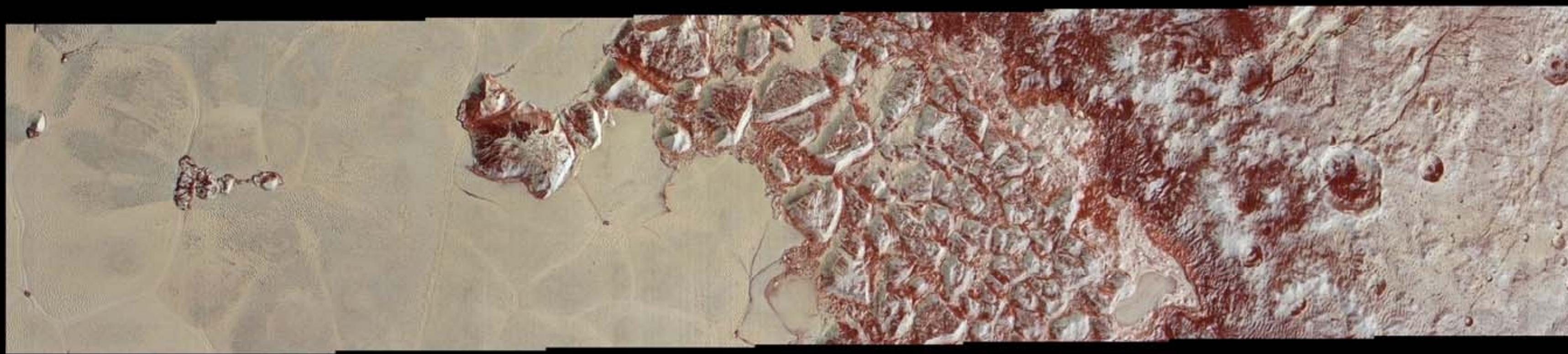
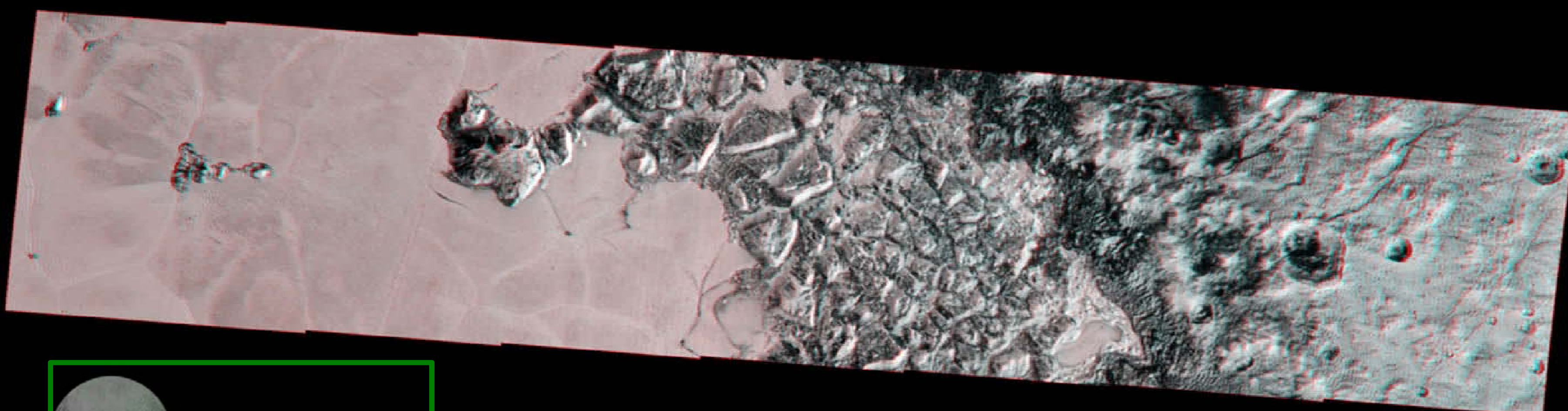
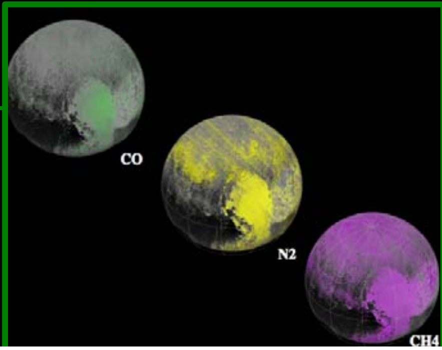
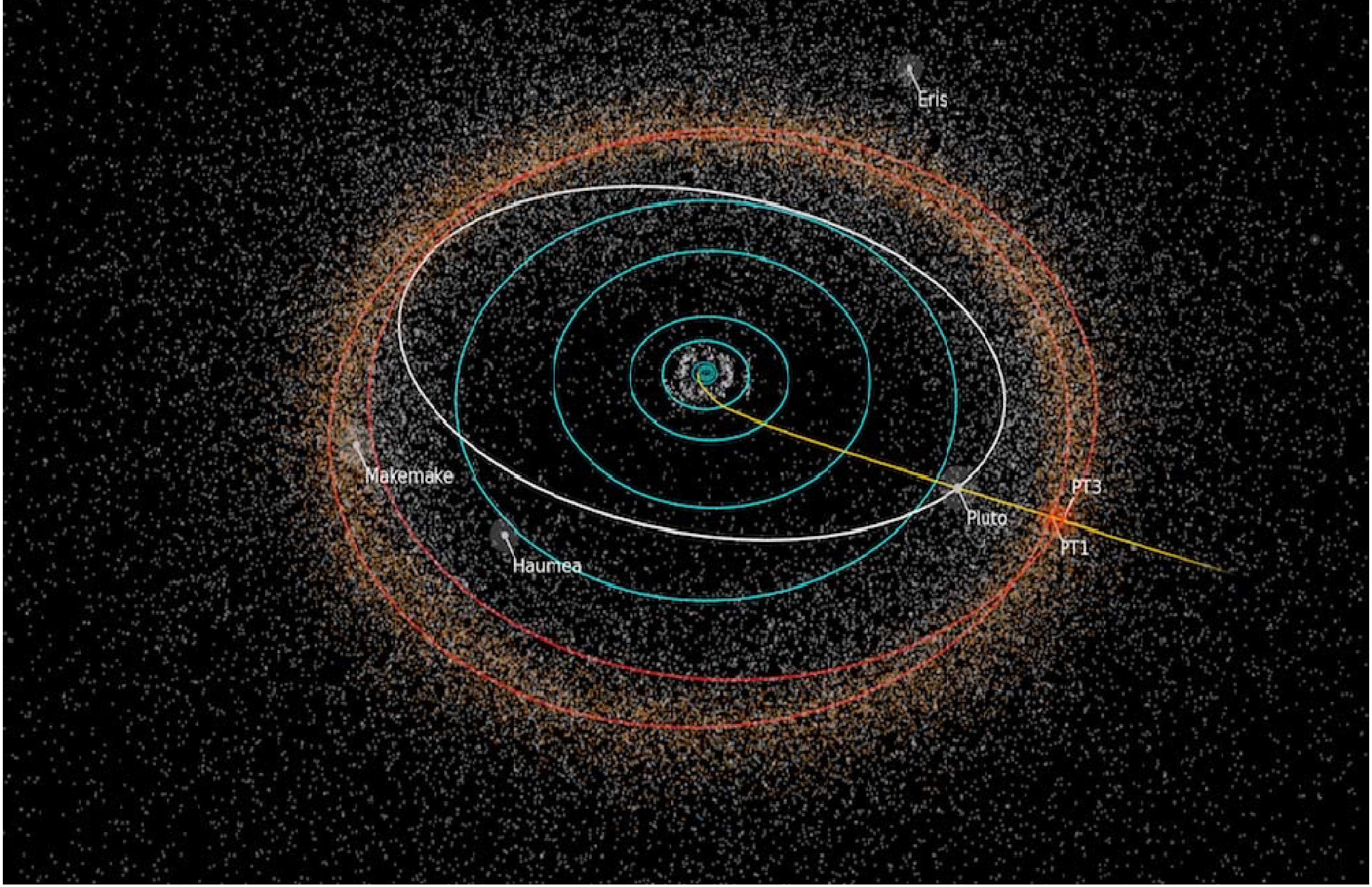
18 MARCH 2016
sciencemag.org
AAAS
A new horizon
The Pluto system seen up close
pp. 1280–1293





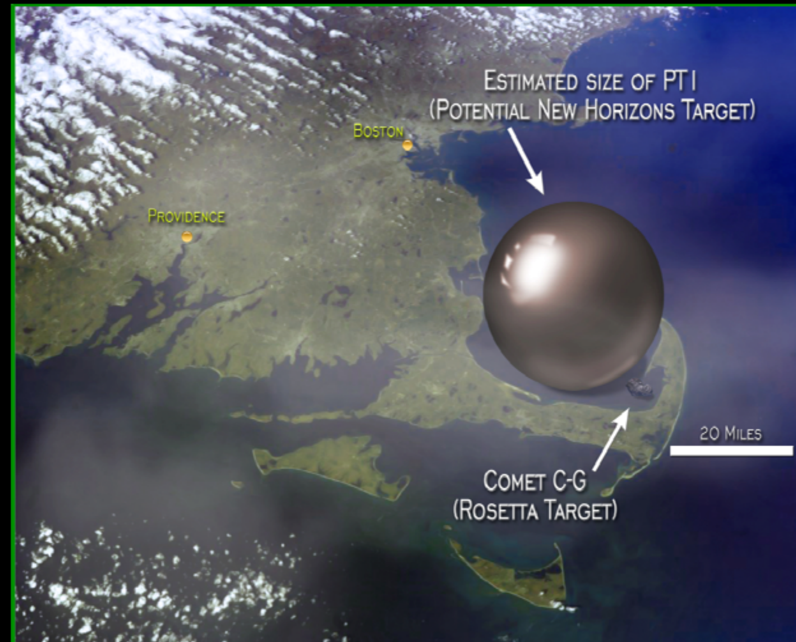

CO
N2
CH4

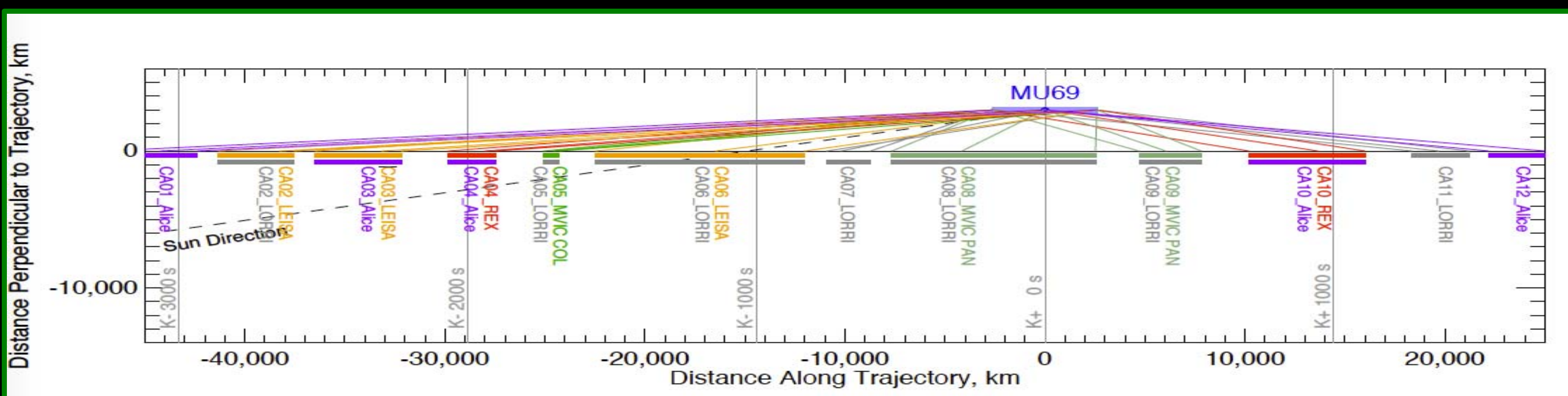
EXTENDED MISSION: 2016-2021



KBO CLOSE (3,000 KM) FLYBY

	PT1
MPC Designator	2014 MU69
Diameter Range	21-40 km
Orbital Semi-major Axis	44.2 AU
Orbital Eccentricity	0.036
Orbital Inclination	1.9 deg
KBO Type	Cold Classical
Encounter Date	1 Jan 2019





KBO EXTENDED MISSION SCIENCE OBJECTIVES

- **Close flyby of a primordial KBO planetesimal: 2019.**
- **Distant flyby observations of ~20 other KBOs: 2016-2020.**
- **Search for Centaur and KBO Rings: 2016-2020.**
- **Heliospheric transect of the Kuiper Belt—plasma, dust, and neutral gas observations: 2016-2021.**
- **Potentially conduct astrophysical cruise science: 2020-2021.**

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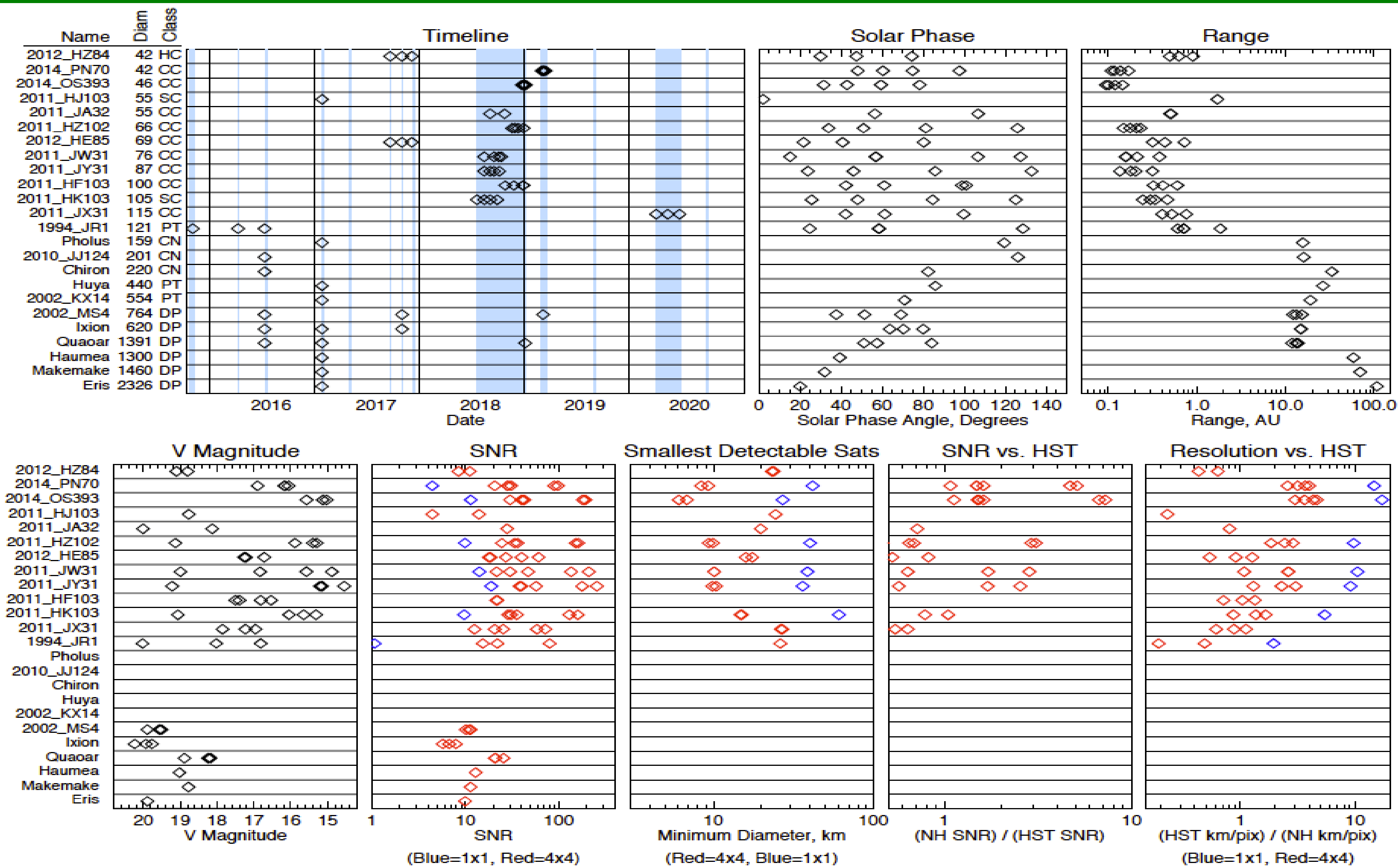
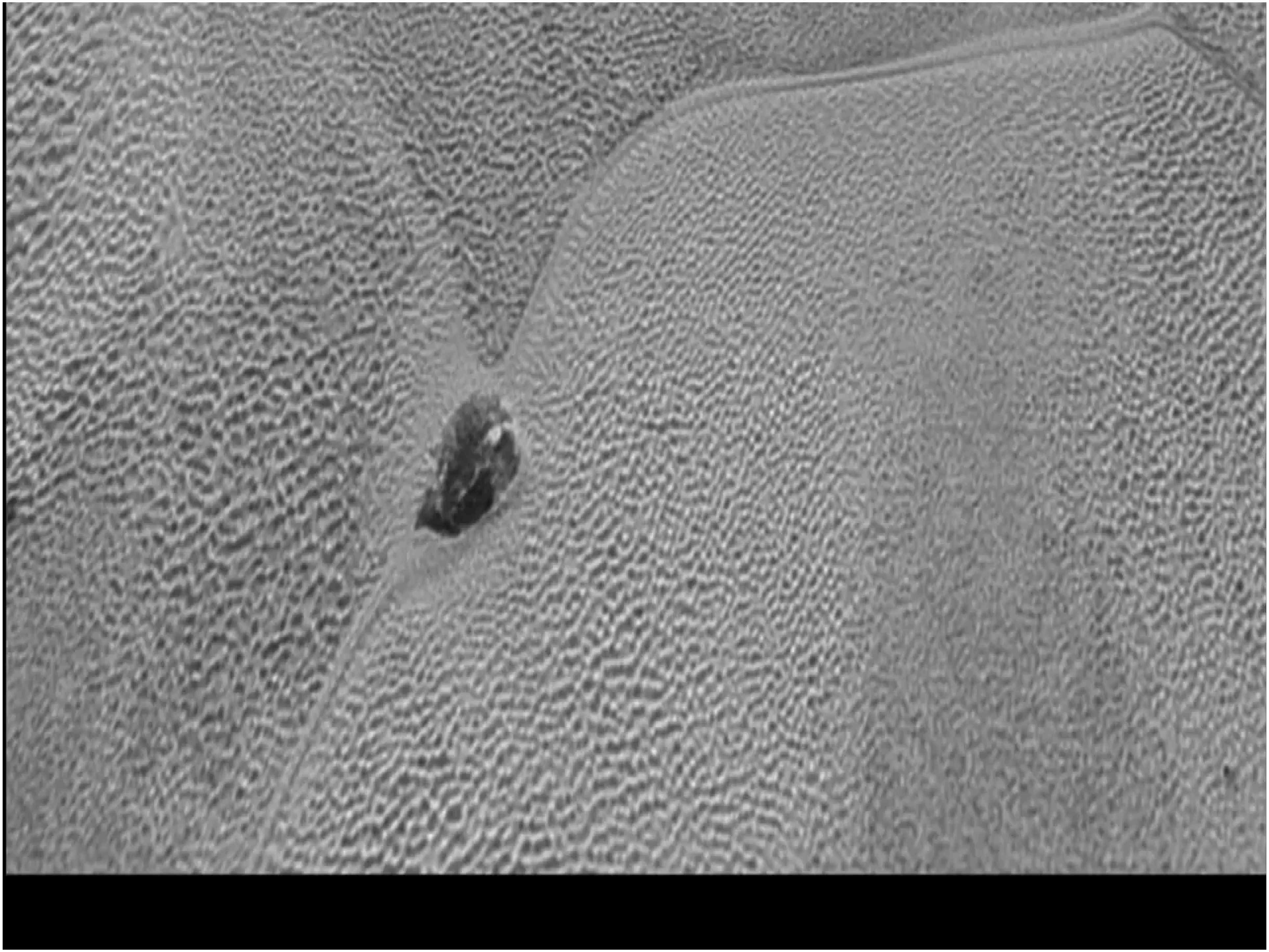
KBO EXTENDED MISSION
KBO SURVEY SCIENCE



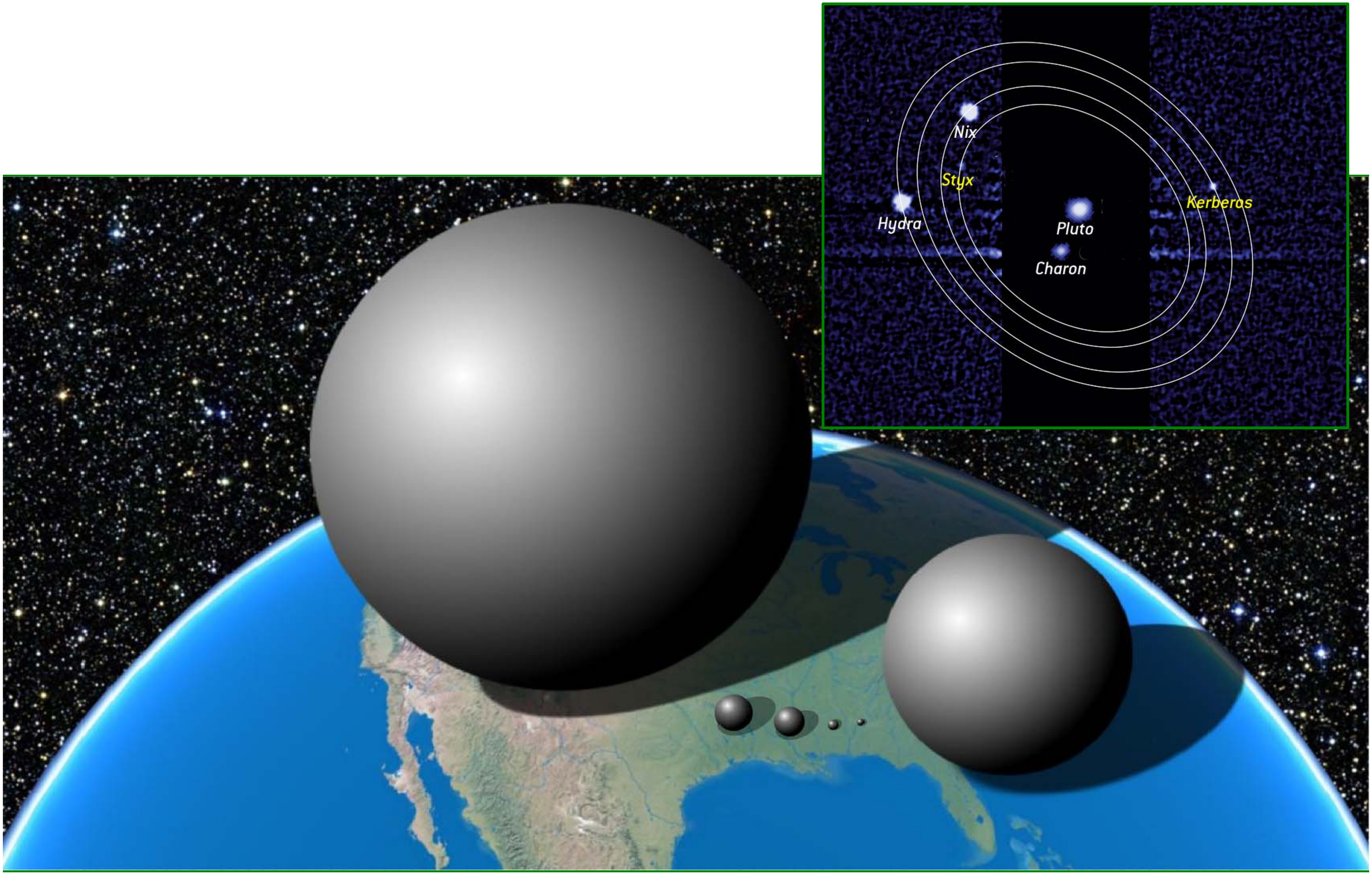



NEW HORIZONS
NASA's Pluto-Kuiper Belt Mission
SwRI • NASA • JHU/APL

Backups

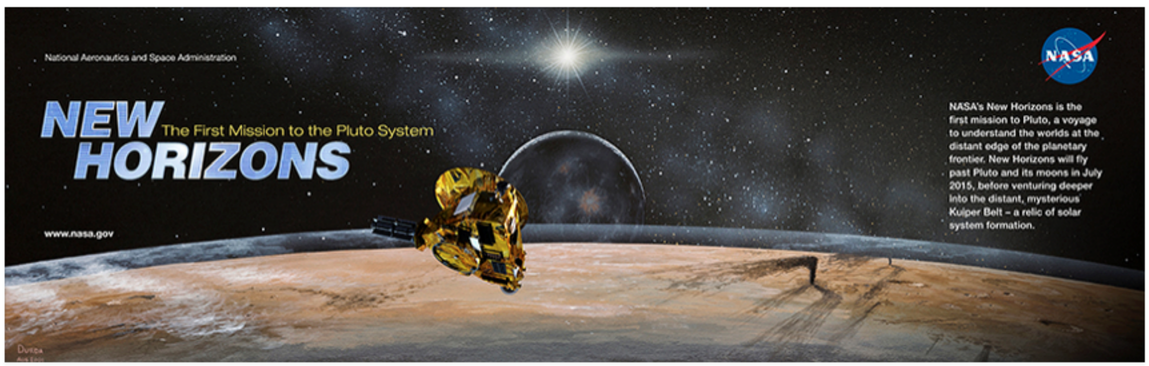
Is It Really So Hard?

WITH SIX BODIES TO STUDY



Stephen Hawking
April 30 at 8:00am ·

The New Horizons pioneering, decade-long mission is to travel to the outer reaches of our solar system, in order that we can discover more about our most distant planet, Pluto, and the Kuiper belt in which it is located. This July, NASA - National Aeronautics and Space Administration's New Horizons probe will fly by Pluto at 14km/s, using instruments to examine its atmosphere and surface and then transmit this information back 3 billion miles by X band for us to interpret and view. This would have been the subject of science fiction when I was at school, but is now science fact. I feel proud and honoured for such a momentous scientific mission to be completed within my lifetime, and plan to celebrate in my own way, with a Pluto party in July. My congratulations to everyone on the New Horizons team. With imagination and determination, it is humbling to see what we are capable of. -SH



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Cindy Conrad, Carole Jones Stern, Joel Parker and 5,606 others like this.

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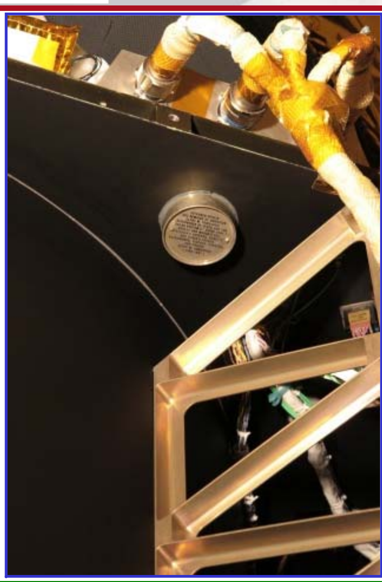
2005: TESTING

June 2005 – GSFC Spin Balance

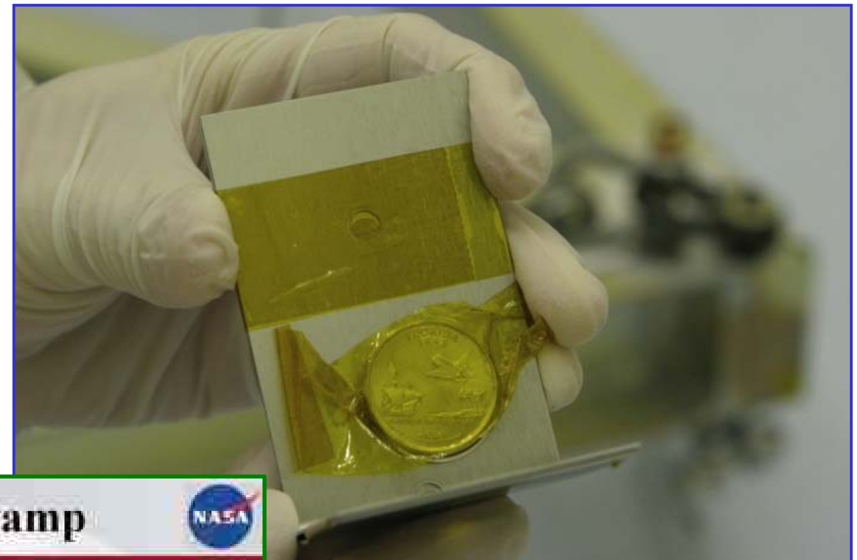
MOMENTOS

Clyde Tombaugh's Remains

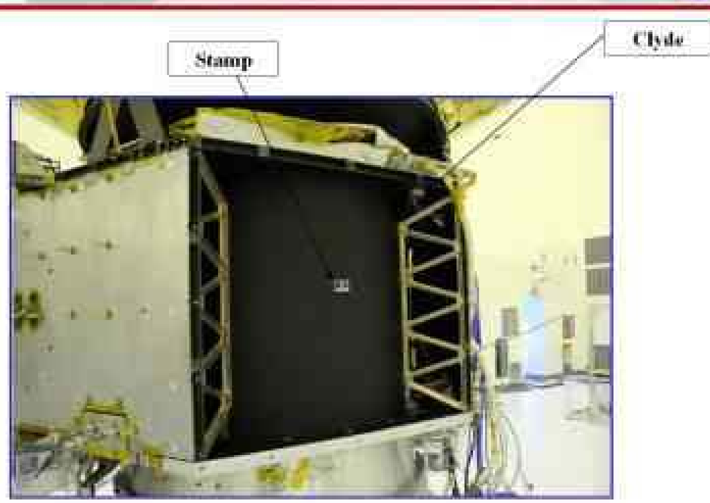


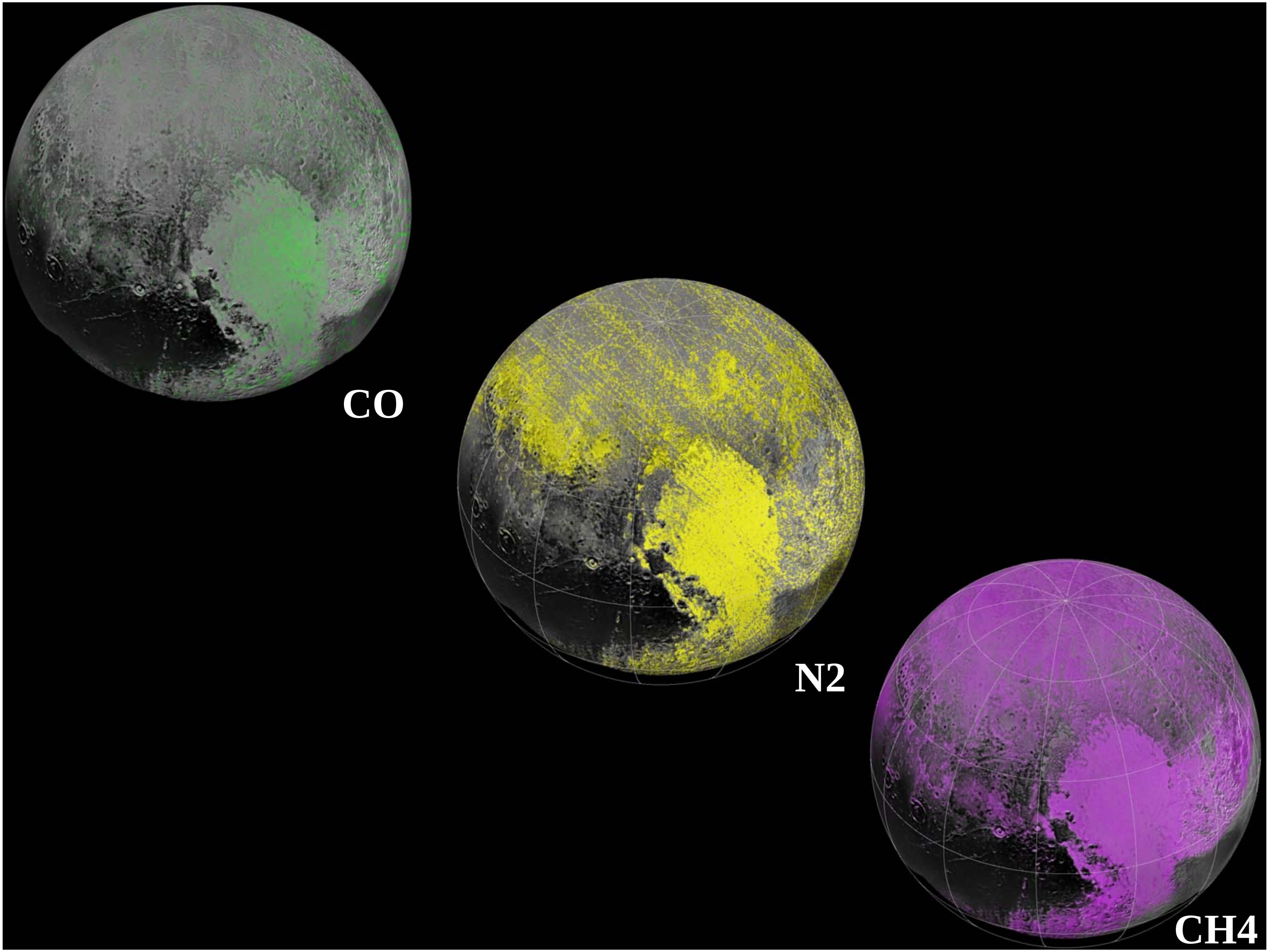
Interned herein are remains of American Clyde W. Tombaugh, discoverer of Pluto and the solar system's "third zone." Adelle and Muron's boy, Patricia's husband, Annette and Alden's father, astronomer, teacher, punster, and friend:
Clyde W. Tombaugh (1906-1997).

Florida & Maryland Quarters

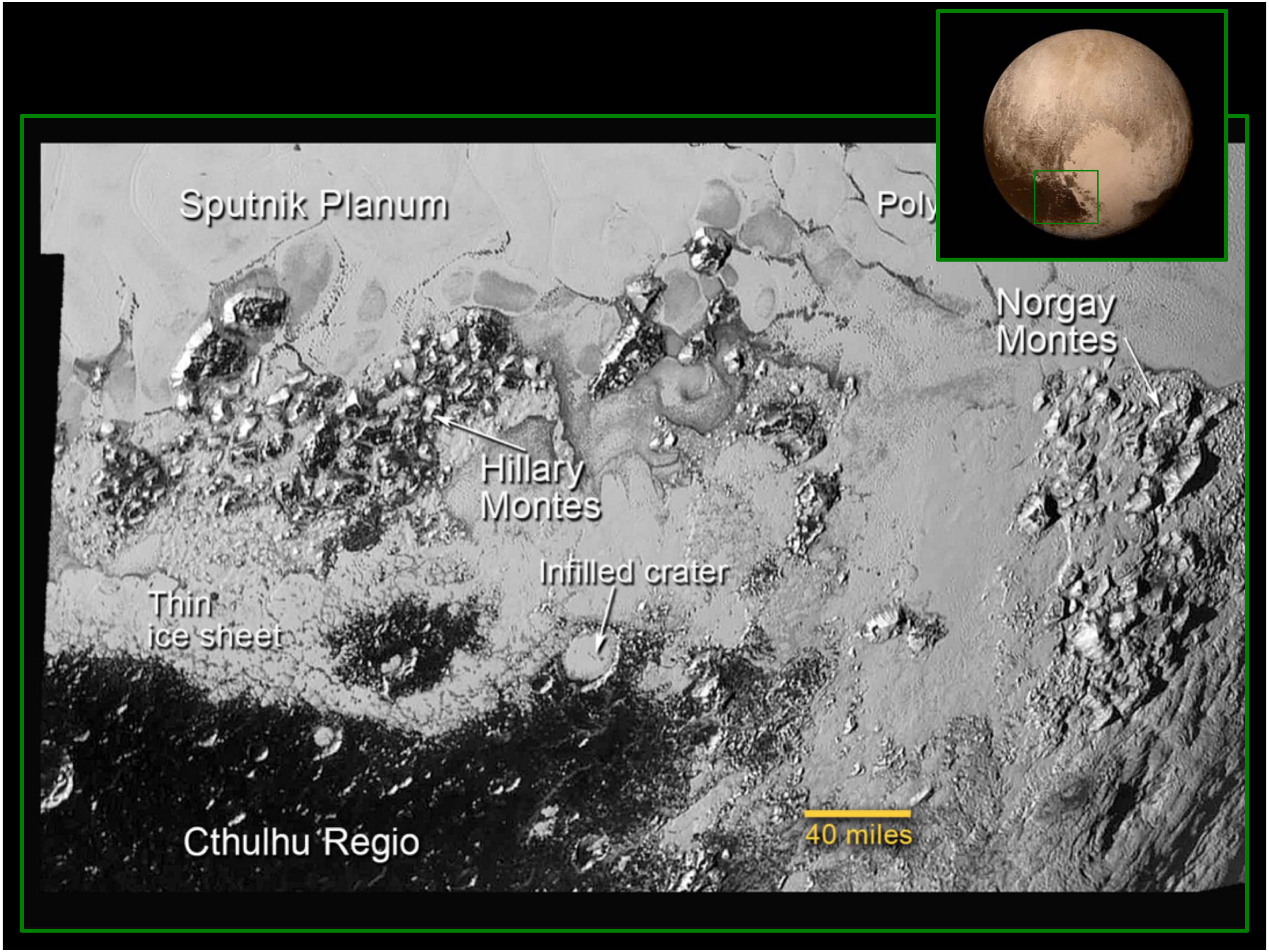


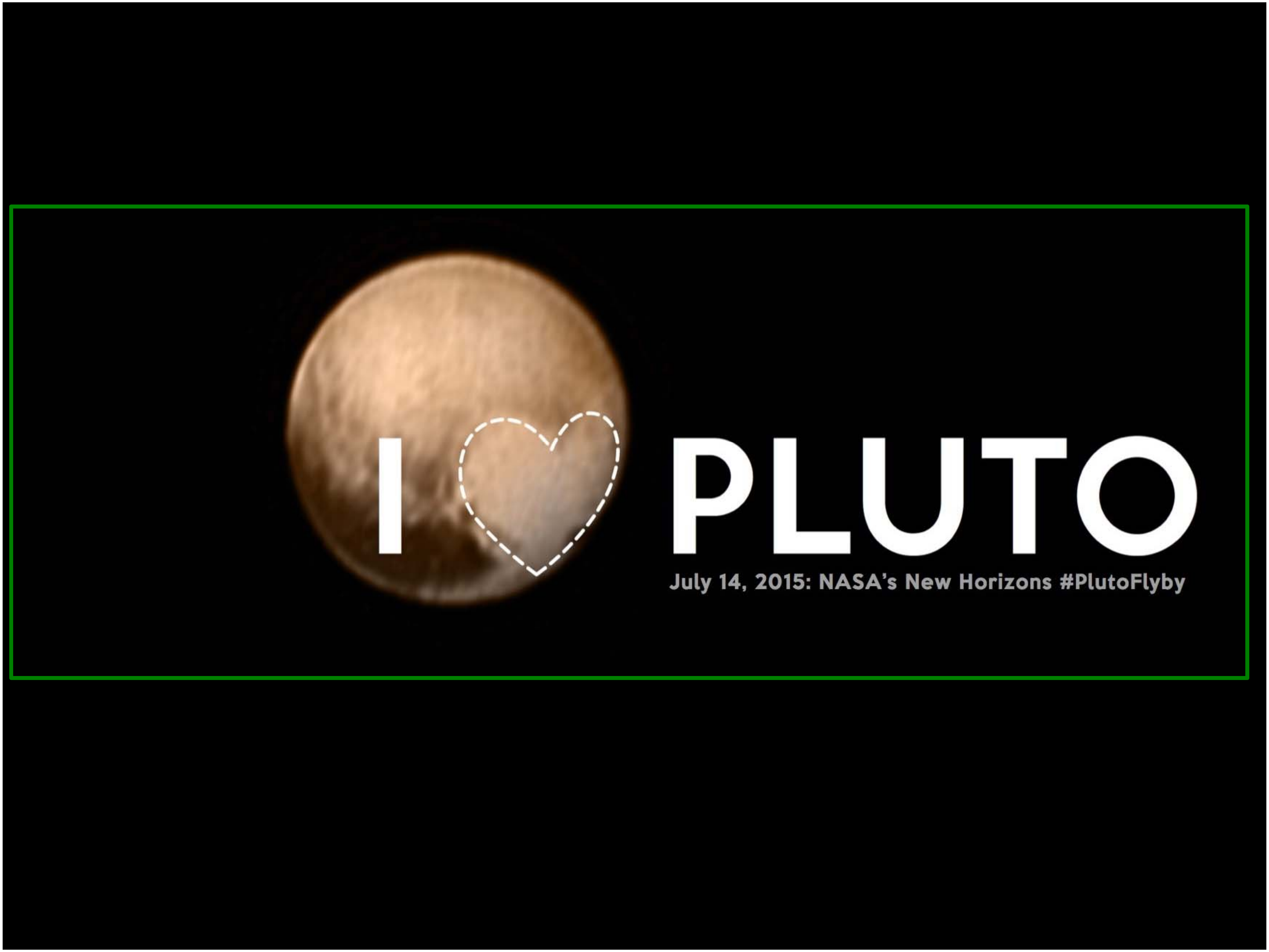
Clyde and the Stamp



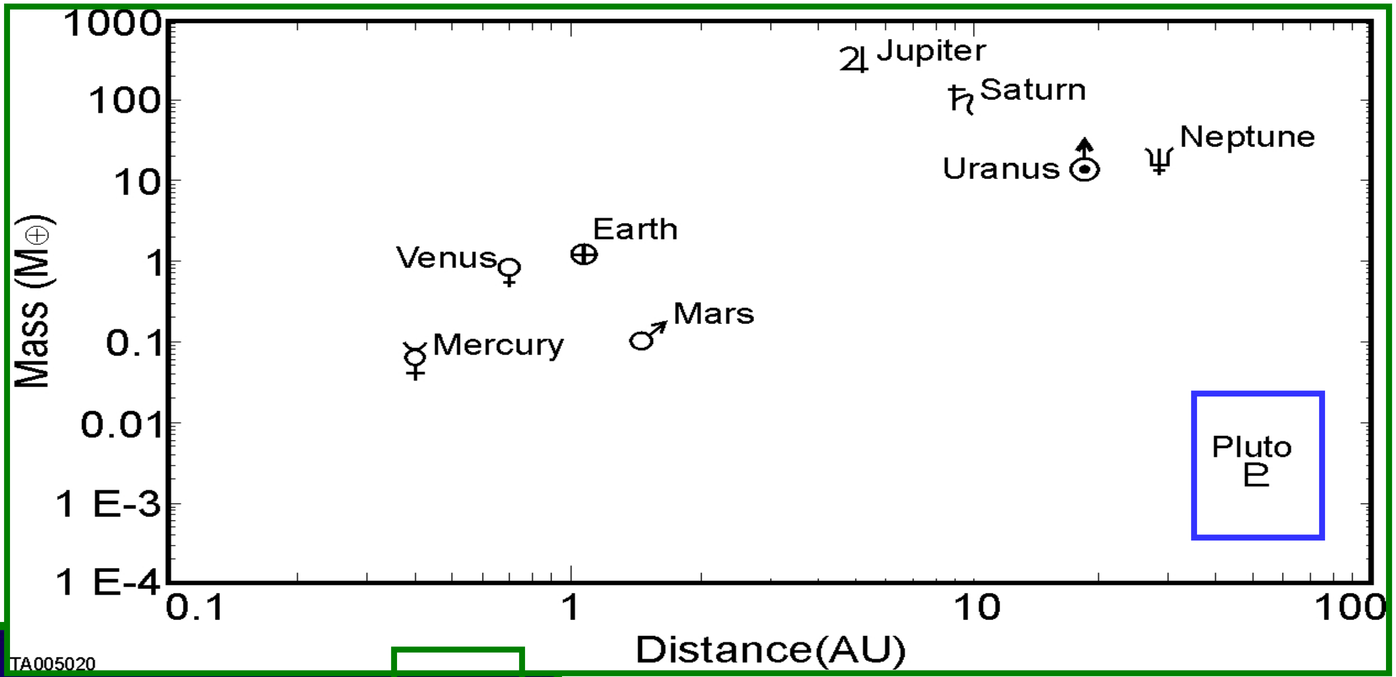

CO
N2
CH4

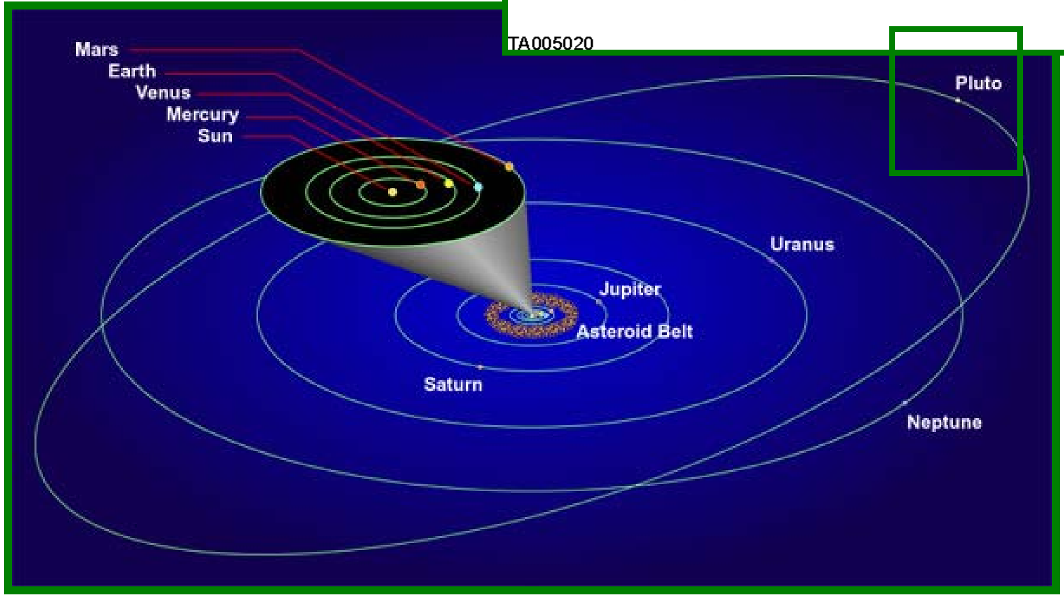

Pluto's moon Nix
as seen by *New Horizons*
10 km
LORRI
Panchromatic
MVIC
Enhanced Color
LORRI/MVIC
Composite
E
N


Sputnik Planum
Poly
Norgay
Montes
Hillary
Montes
Infilled crater
Thin
ice sheet
Cthulhu Regio
40 miles


I ♥ PLUTO
July 14, 2015: NASA's New Horizons #PlutoFlyby

LONE MISFIT?





The Old View:
4 Terrestrial Planets
4 Giant Planets
1 Misfit Pluto

PLUTO SYSTEM MEASUREMENT OBJECTIVES

Group 1 Objectives: Required	
Characterize the 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	
Group 2 Objectives: Important	
Characterize the time variability of Pluto's surface and atmosphere	
Image Pluto and Charon in stereo	
Map the terminators of Pluto and Charon with high resolution	
Map the composition of selected areas of Pluto & Charon at high resolution	
Characterize Pluto's ionosphere and solar wind interaction	
Search for neutral species including H, H_2, HCN, and C_xH_y, and other hydrocarbons and nitriles in Pluto's upper atmosphere	
Search for an atmosphere around Charon	
Determine bolometric Bond albedos for Pluto and Charon	
Map the surface temperatures of Pluto and Charon	
Group 3 Objectives: Desired	
Characterize the energetic particle environment of Pluto and Charon	
Refine bulk parameters (radii, masses, densities) and orbits of Pluto & Charon	
Search for magnetic fields of Pluto and Charon	
Search for additional satellites and rings	

PAYLOAD DETAILS

Alice	UV Spectrometer	➢ 46.5-188.0 nm, 0.3 nm resolution ➢ FOV 4° x 0.1° "slot" and 2° x 2° "box", 5 mrad/pixel ➢ Airglow & occultation capabilities
Ralph/ MVIC	Multispectral Visible Imaging Camera (Pan/Color Imager)	➢ Panchromatic (350-850 nm) & 4-color (Blue, Red, CH_4, Near-IR) ➢ FOV 5.7° x 0.15° or 5.7° x scan length, 20 microrad resolution
Ralph/ LEISA	Linear Etalon Imaging Spectral Array (IR Imaging spectrometer)	➢ 1.25-2.50 micron at R=240 and 2.10-2.25 micron at R = 550 ➢ FOV 0.9° x 0.9° (scanned), 62 microrad/pixel
LORRI	LOng-Range Reconnaissance Imager (High-Resolution Imager)	➢ Panchromatic (350-850 nm) ➢ FOV 0.29° x 0.29° , 5 microrad/pixel
REX	Radio Experiment (Uplink, Radiometery)	➢ Part of telecommunications systems, with 2.1 m antenna ➢ X-band (7.182 GHz uplink, 8.438 GHz downlink)
SWAP	Solar WInd at Pluto (Solar Wind Detector)	➢ 0.25-7.5 KeV. RPA: 0.5V (<1.5 keV), ESA: $\Delta E/E=0.4$ (>1.4 keV) ➢ FOV 200° x 10°
PEPSSI	Pluto Energetic Particle Spectrometer Science Investigation (Particle Detector)	➢ e^-: 25-500 KeV, Protons: 40-500 KeV, CNO: 150-1000 KeV ➢ FOV 160° x 12° , 25° x 12° resolution
SDC	Situ Dust Counter	➢ 0.10 m^2 active area, ➢ Threshold Mass ~10^{-12} gram (~1 micron)

HIGH PAYLOAD FUNCTIONAL REDUNDANCY

AO Objective		Primary Sensor(s)	Fallback	Supporting	Fidelity of Fallback + Supporting
Group 1					
Geology/ Geophysics	pan	MVIC pan	LORRI, MVIC color	LEISA	High
	color	MVIC 4-color	MVIC 2-color	LEISA	High
Surface composition		LEISA 4 quadrants	LEISA 2 of 4 quadrants	MVIC CH4 mapping	High
Neutral atmosphere		Both ALICE and REX	Either ALICE or REX	SWAP, PEPSSI, MVIC	Medium
Group 2					
Surface and atmospheric variability		MVIC, LORRI, LEISA, ALICE, REX	Any of MVIC, LORRI, LEISA, ALICE, or REX	SWAP, PEPSSI	High
Stereo		MVIC pan	MVIC color, LORRI		High
Hi-res terminator maps		MVIC pan	MVIC color, LORRI		High
Hi-res composition maps		LEISA 4 quadrants	LEISA 2 of 4 quadrants	MVIC CH4 mapping	High
Ionosphere/solar wind		Both REX and SWAP	Either REX or SWAP	ALICE	High
Other atmospheric species		ALICE		SWAP, PEPSSI, [LEISA]	Low
Charon atmosphere		ALICE		REX , LEISA	High
Bond albedos		MVIC pan	MVIC color	LORRI, LEISA	Medium
Surface temperatures		REX and LEISA 4 quadrants	LEISA 2 of 4 quadrants or REX		High
Group 3					
Energetic particles		PEPSSI		SWAP	Low
Bulk parameters		MVIC, LORRI, LEISA, REX	Any of MVIC, LORRI, LEISA, or REX		High
Satellite and ring search		MVIC pan	MVIC color, LORRI	ALICE, REX	High

[ ] implies indirect measurement requiring modeling

ENCOUNTER GOALS

- MEET/EXCEED ALL PROPOSED SCIENCE
- INCLUDE SMALL SATELLITE OBSERVATIONS
- INCLUDE PAYLOAD CAL CAMPAIGN
- BE ROBUST TO ANOMALIES
- INCLUDE "PROGRESS" DOWNLINKS FOR HEALTH & SAFETY, EPO, SCIENCE, FAIL SAFE
- LEAVE >40% OF LAUNCH LOAD PROPELLANTS FOR KBO EXTENDED MISSION

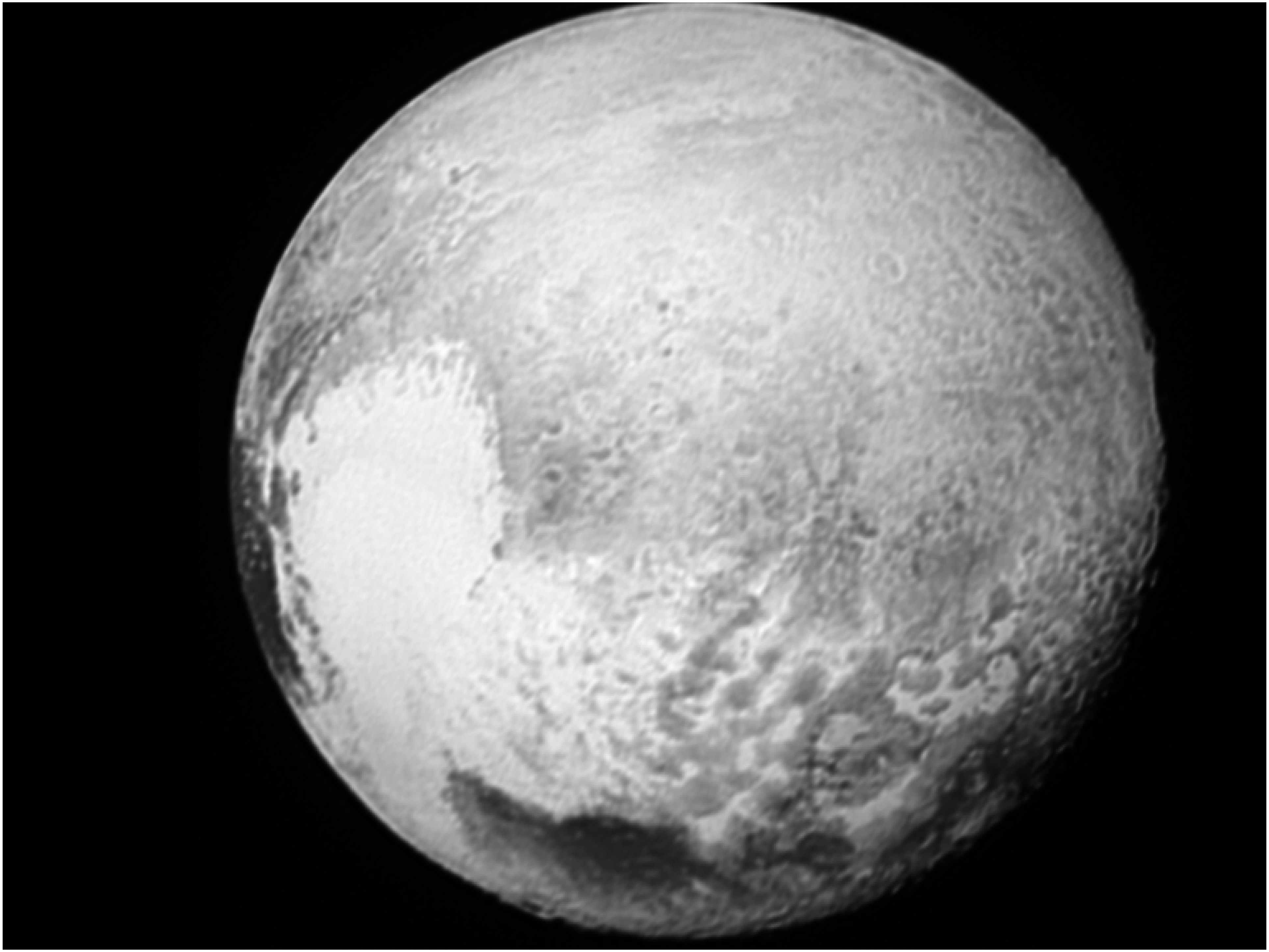
ENCOUNTER DESIGN SCORECARD

ENCOUNTER FULLFILLMENT

	Group 1 Objectives: REQUIRED	Pluto	Charon
PROP	Characterize the global geology and morphology of Pluto and Charon	Exceed	Exceed
	Map surface composition of Pluto and Charon	Meet	Meet
	Characterize the neutral atmosphere of Pluto and its escape rate	Exceed	n/a

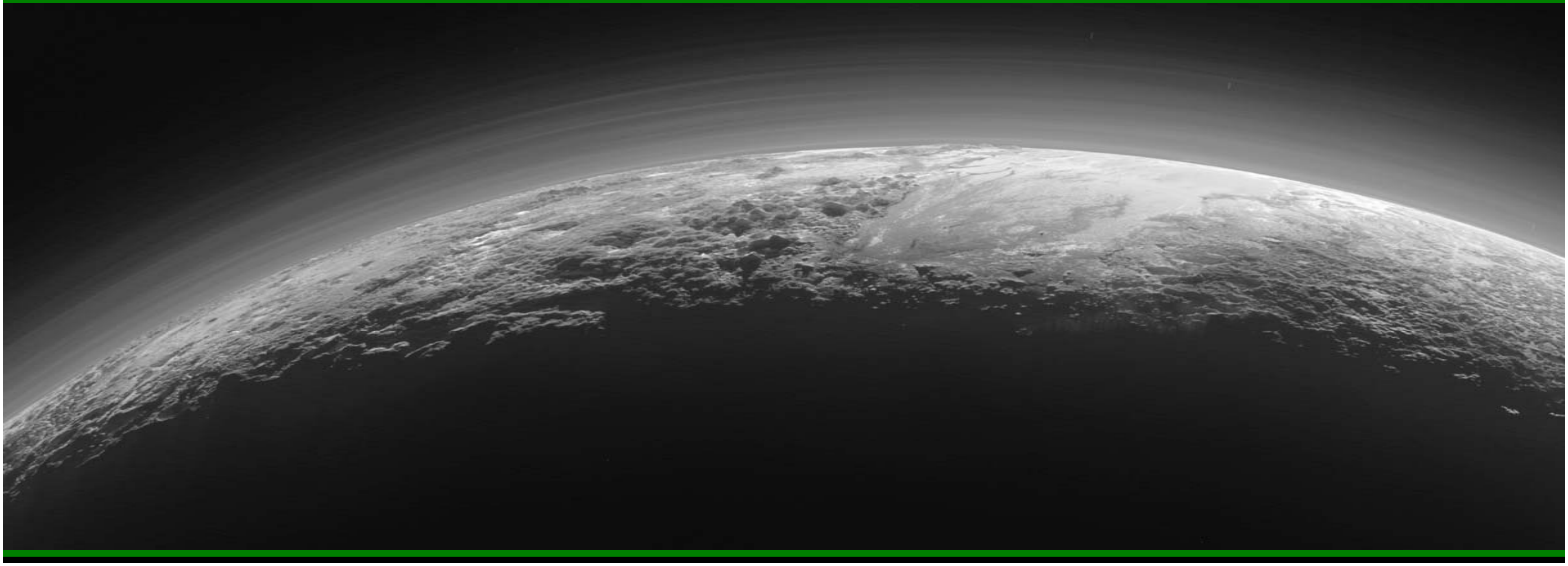
	Group 2 Objectives: STRONGLY DESIRED	Pluto	Charon	Nix	Hydra	P4 etc.
PROPOSED	Characterize the time variability of Pluto's surface and atmosphere	Meet	n/a	n/a	n/a	n/a
	Image Pluto and Charon in Stereo	Meet	Meet			
	Map the terminators of Pluto and Charon with high resolution	Meet	Meet	n/a	n/a	n/a
	Map the surface composition of Pluto and Charon with high resolution	Meet	Meet	n/a	n/a	n/a
	Characterize Pluto's ionosphere and solar wind interaction	Meet	n/a	n/a	n/a	n/a
	Search for neutral species in Pluto's upper atmosphere	Meet	n/a	n/a	n/a	n/a
	Search for an atmosphere around Charon	n/a	Meet	n/a	n/a	n/a
	Determine bolometric Bond albedos for Pluto and Charon	Meet	Meet	n/a	n/a	n/a
	Map the surface temperatures of Pluto and Charon	Meet	Meet	n/a	n/a	n/a
NEW	Composition of dark surfaces on Pluto	Exceed	n/a	n/a	n/a	n/a
	"Far-side" imaging of Pluto and Charon	Exceed	Exceed	n/a	n/a	n/a
	"Far-side" color and composition of Pluto and Charon	Exceed	Exceed	n/a	n/a	n/a
	High resolution imaging of Nix and Hydra	n/a	n/a	Exceed	Exceed	Exceed
	Composition of Nix and Hydra	n/a	n/a	Exceed	Exceed	Exceed
	Shapes of Nix and Hydra	n/a	n/a	Exceed	Exceed	Exceed

	Group 3 Objectives: DESIRED	Pluto	Charon	Nix	Hydra	P4 etc.
PROP	Characterize the energetic particle environment of Pluto and Charon	Meet	Meet	n/a	n/a	n/a
	Refine bulk parameters (radii, masses, densities) and orbits of Pluto & Char	Meet	Meet	n/a	n/a	n/a
	Search for magnetic fields of Pluto and Charon	Indirect	Indirect	n/a	n/a	n/a
	Search for additional satellites and rings	Meet	Meet	n/a	n/a	n/a
NEW	Surface microphysics of Pluto and Charon	Exceed	Exceed	n/a	n/a	n/a
	Measure the surface temperatures of Nix and Hydra	n/a	n/a	Exceed	Exceed	Exceed
	Measure the phase curve of Nix and Hydra	n/a	n/a	Exceed	Exceed	Exceed
	Image Nix and Hydra in stereo	n/a	n/a	Exceed	Exceed	Exceed
	Education/Public Outreach	Exceed	Exceed	Exceed	Exceed	Exceed



PLUTO SYSTEM FLYBY RECAP

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



RESEARCH ARTICLE SUMMARY

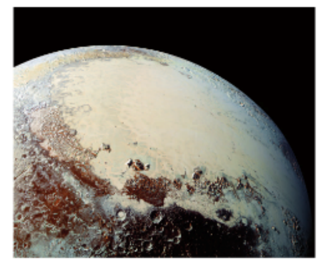
PLANETARY SCIENCE

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.



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.

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

The list of affiliations is available in the full article online.
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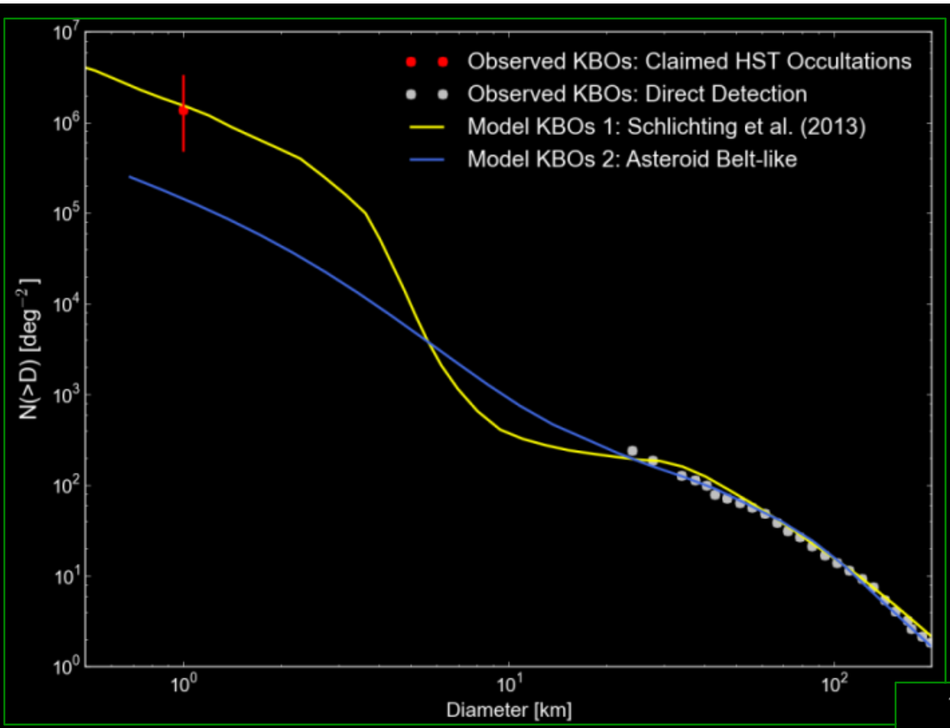
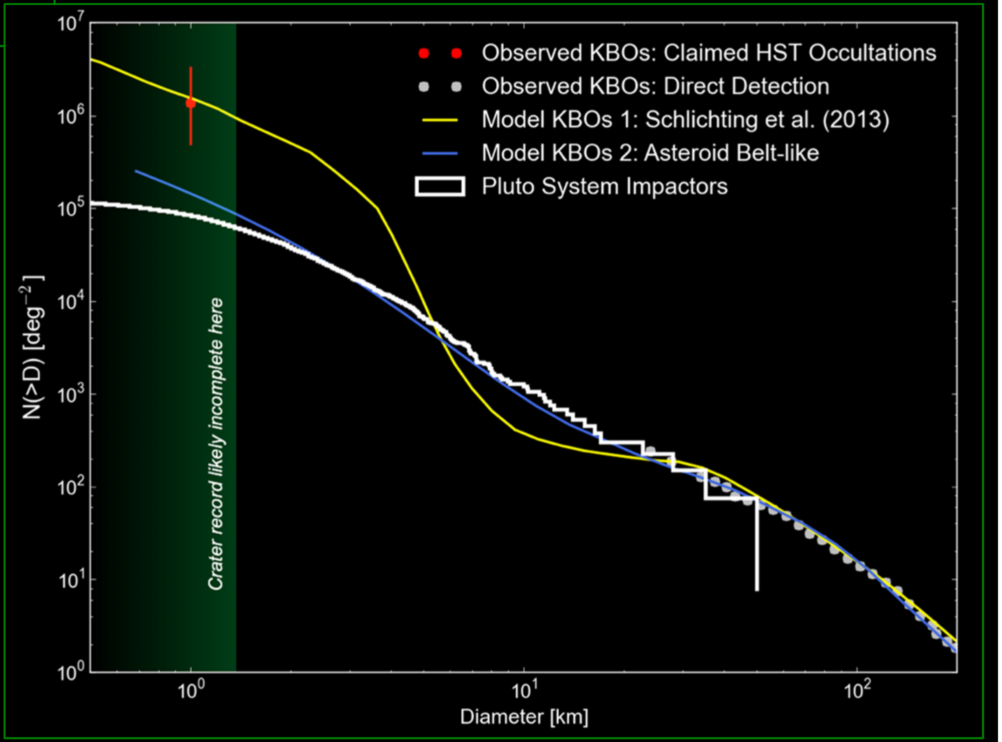
Cite this article as S. A. Stern et al., Science 350, aad1815 (2015). DOI: 10.1126/science.aad1815

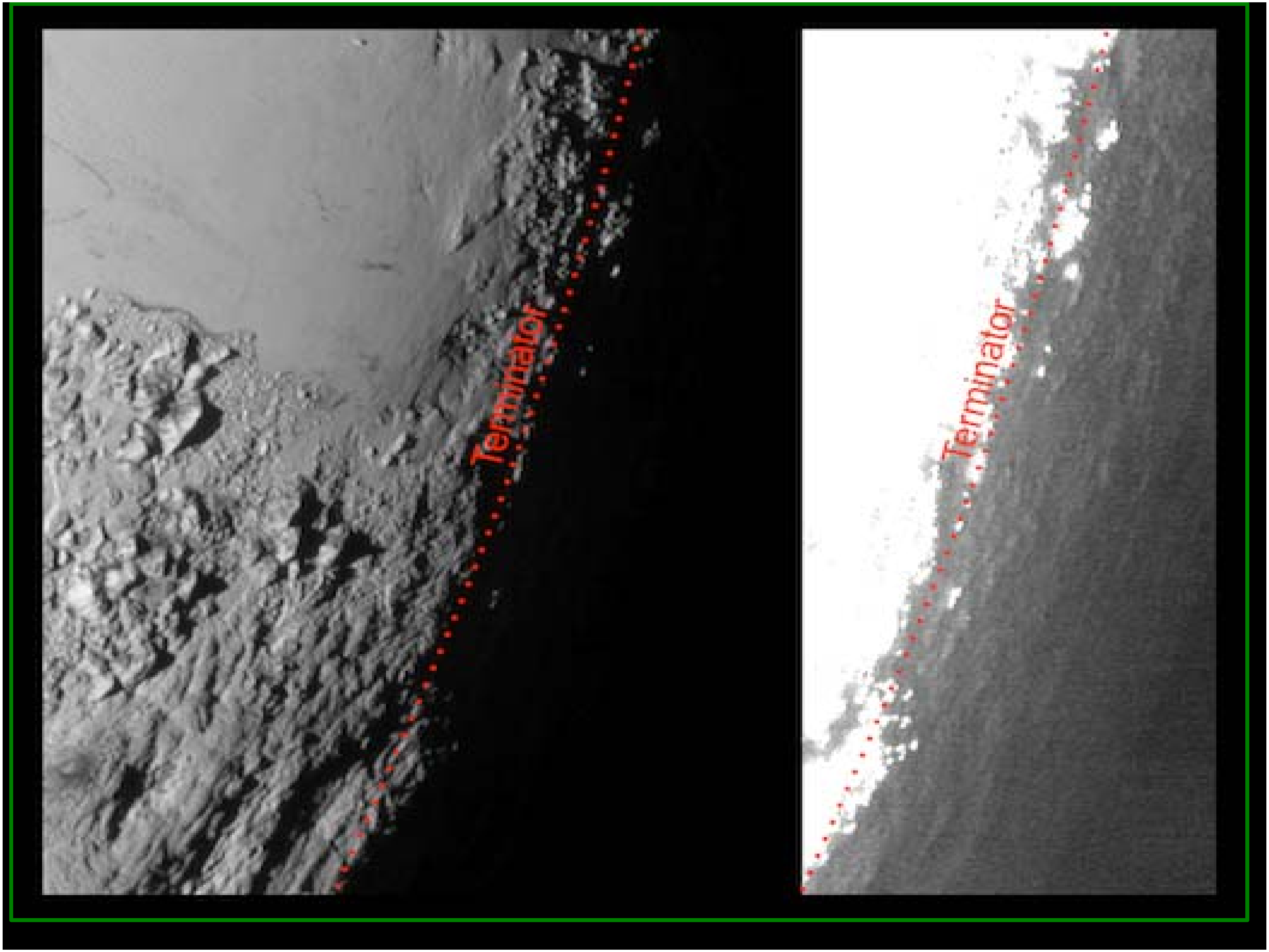
Probing the Kuiper Belt Population Structure



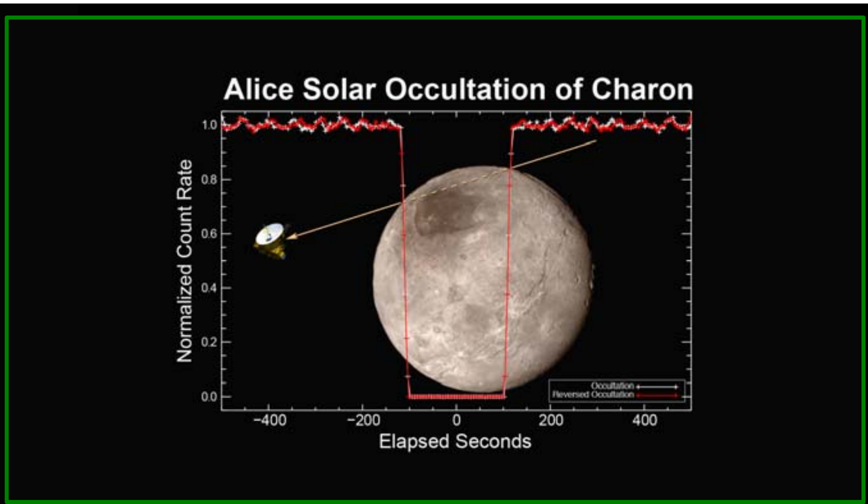
Before NH

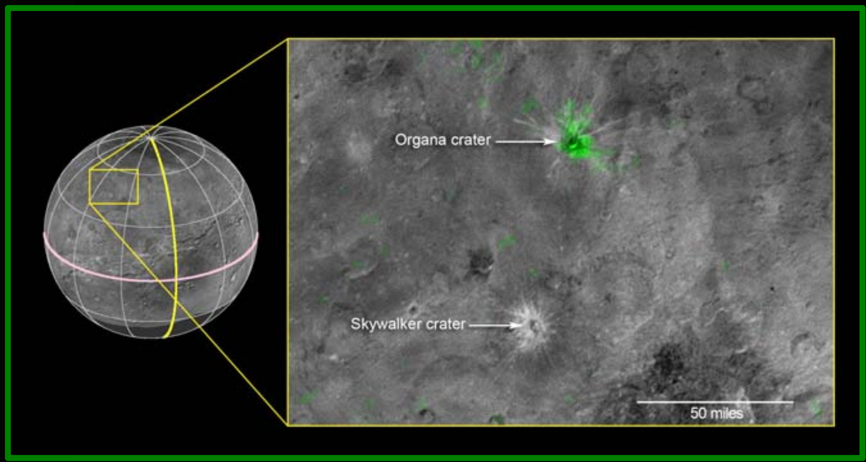
After NH

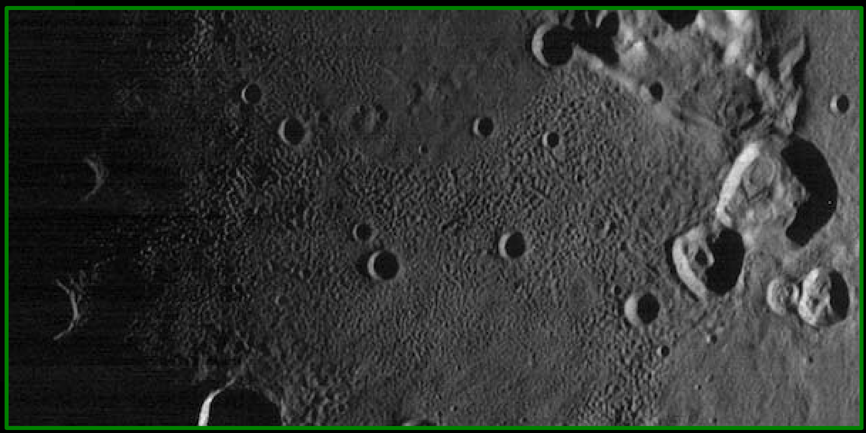


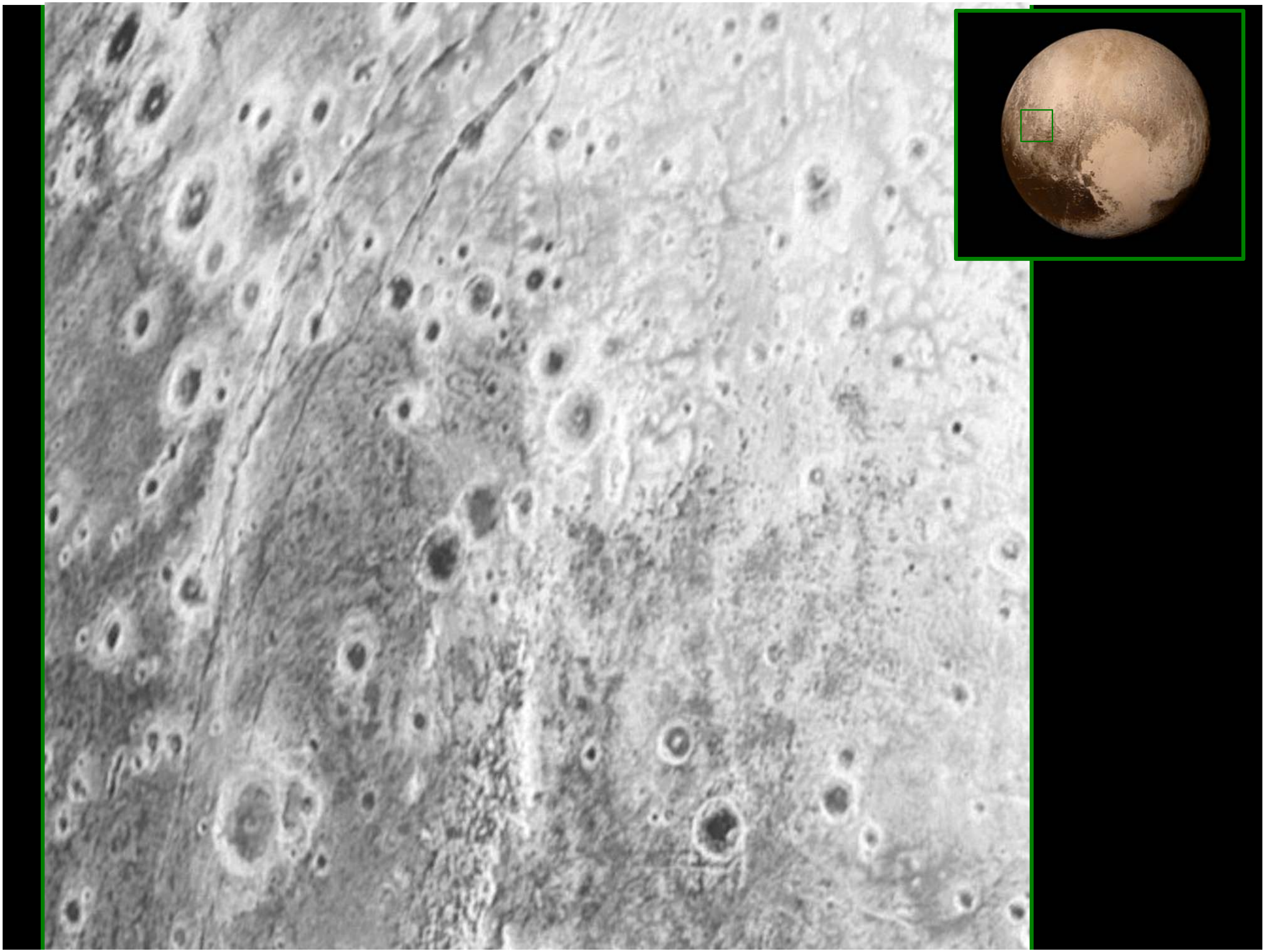


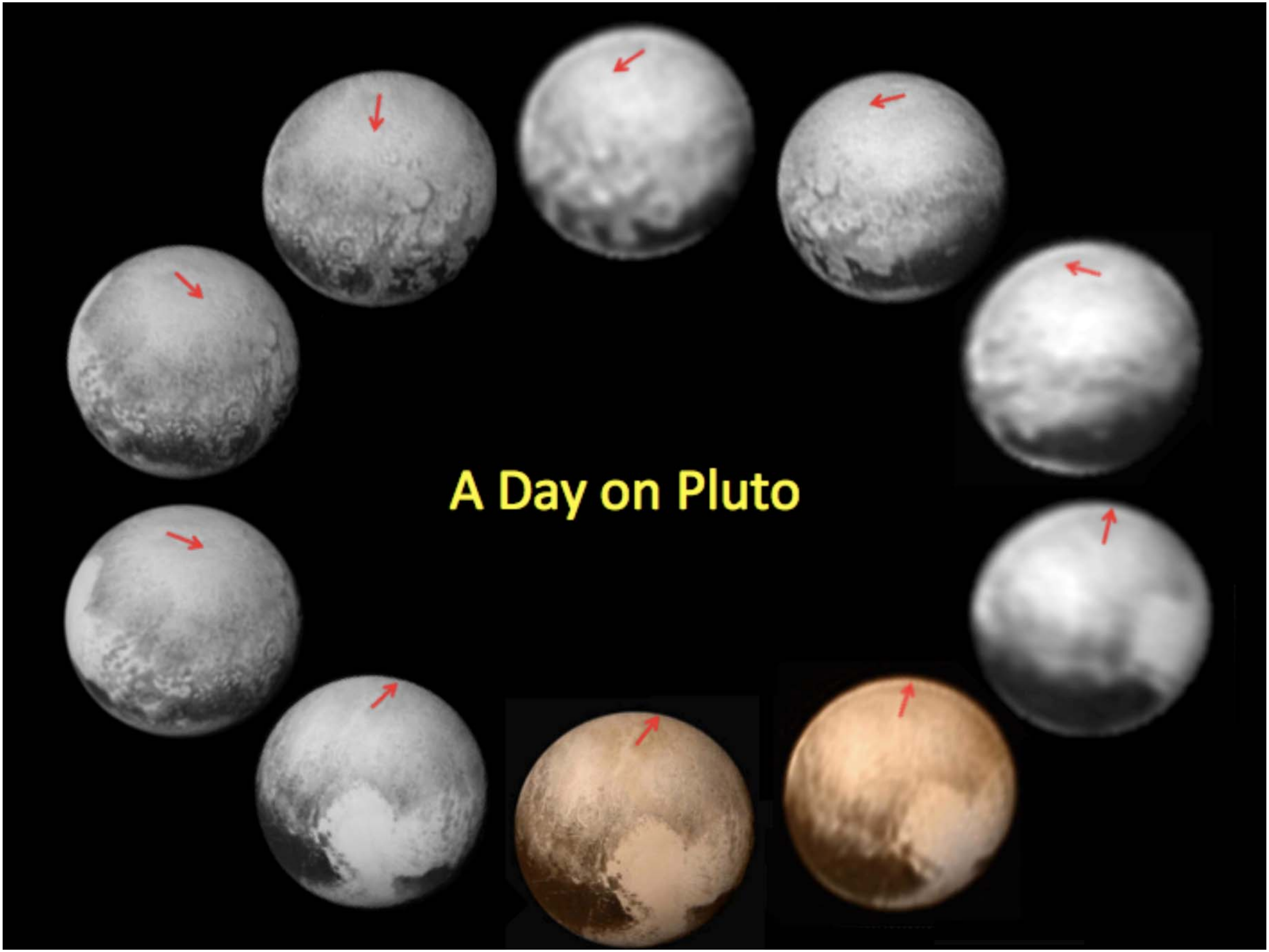
Terminator
Terminator

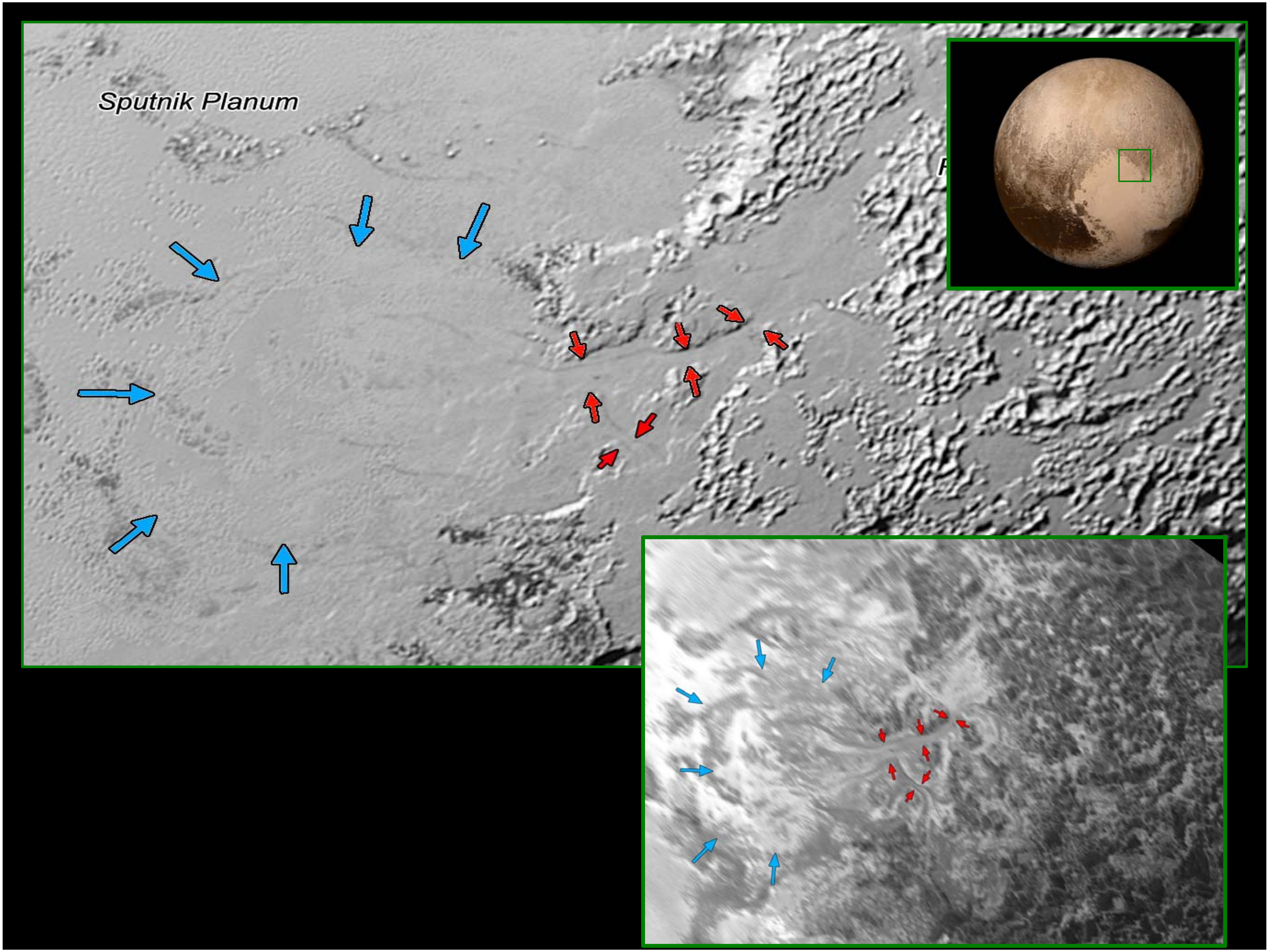

Alice Solar Occultation of Charon
Normalized Count Rate
1.0
0.8
0.6
0.4
0.2
0.0
-400
-200
0
200
400
Elapsed Seconds
Occultation
Reversed Occultation


Organa crater
Skywalker crater
50 miles



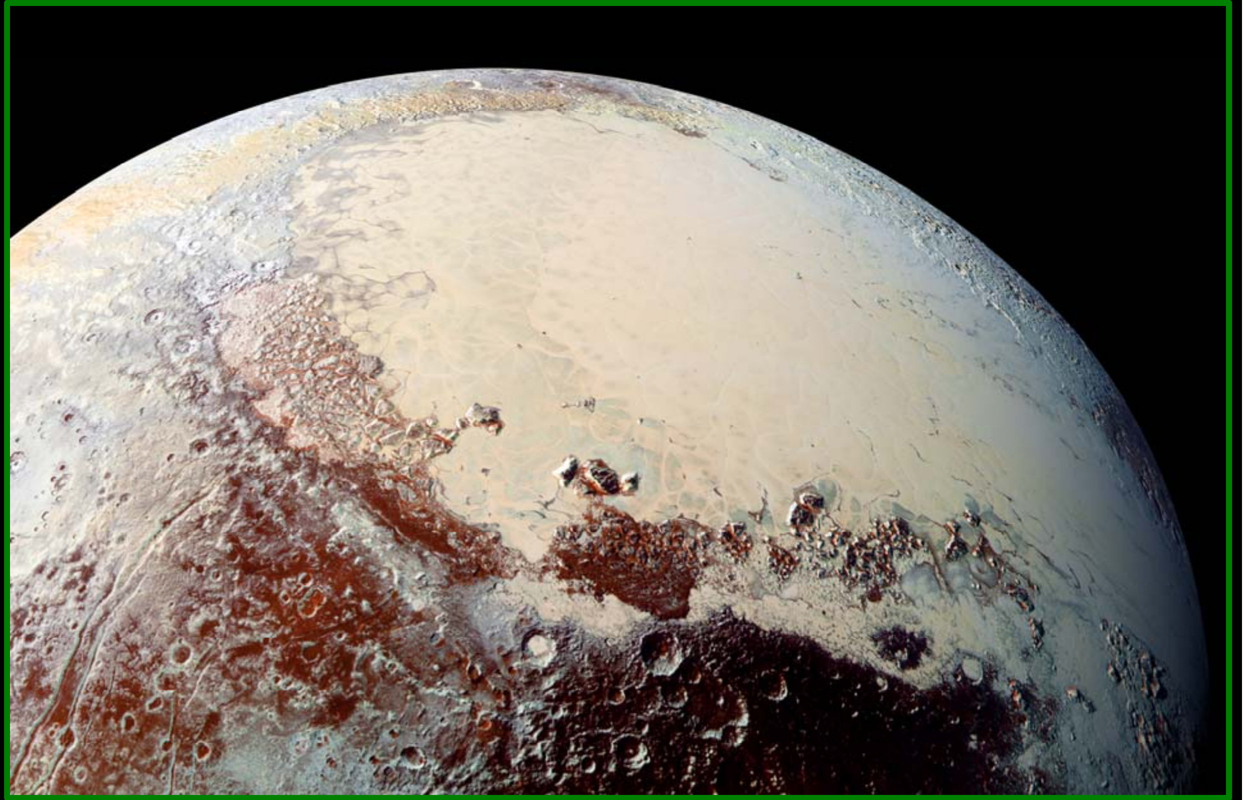


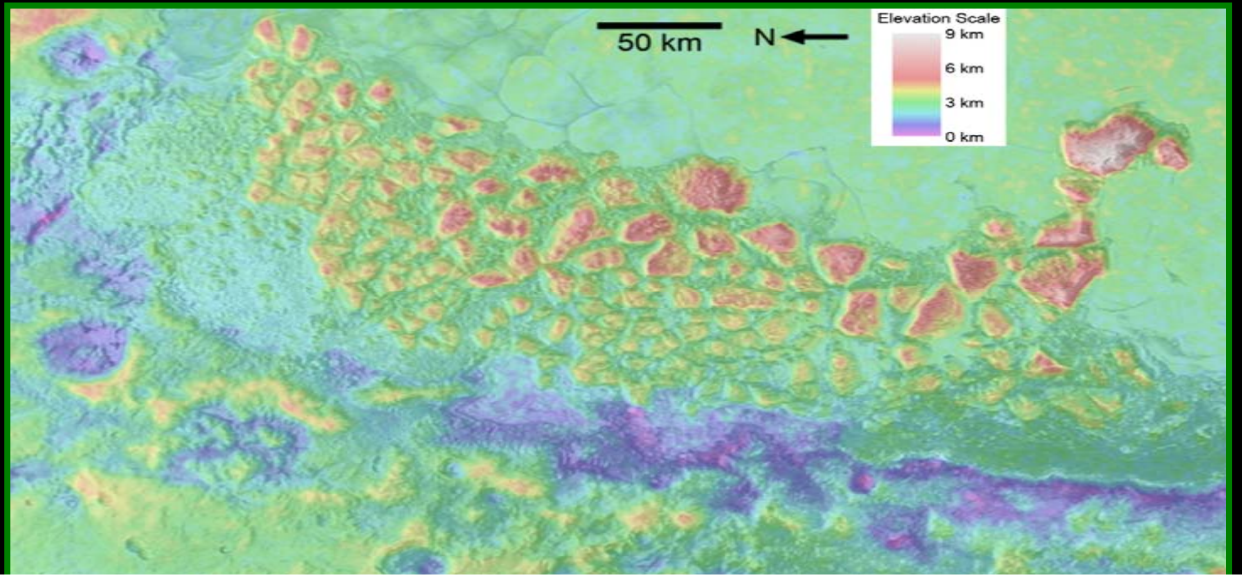

A Day on Pluto

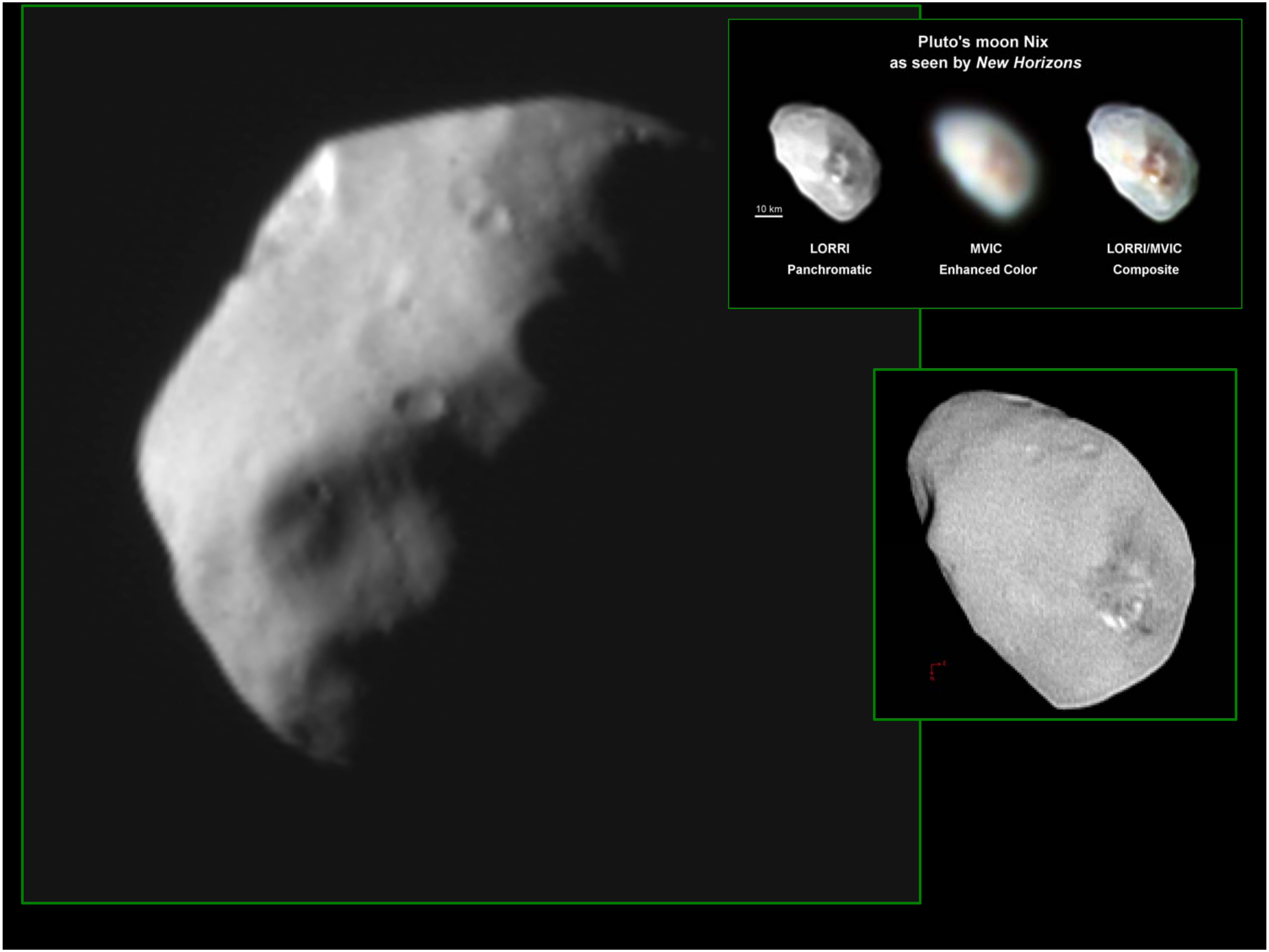

Sputnik Planum

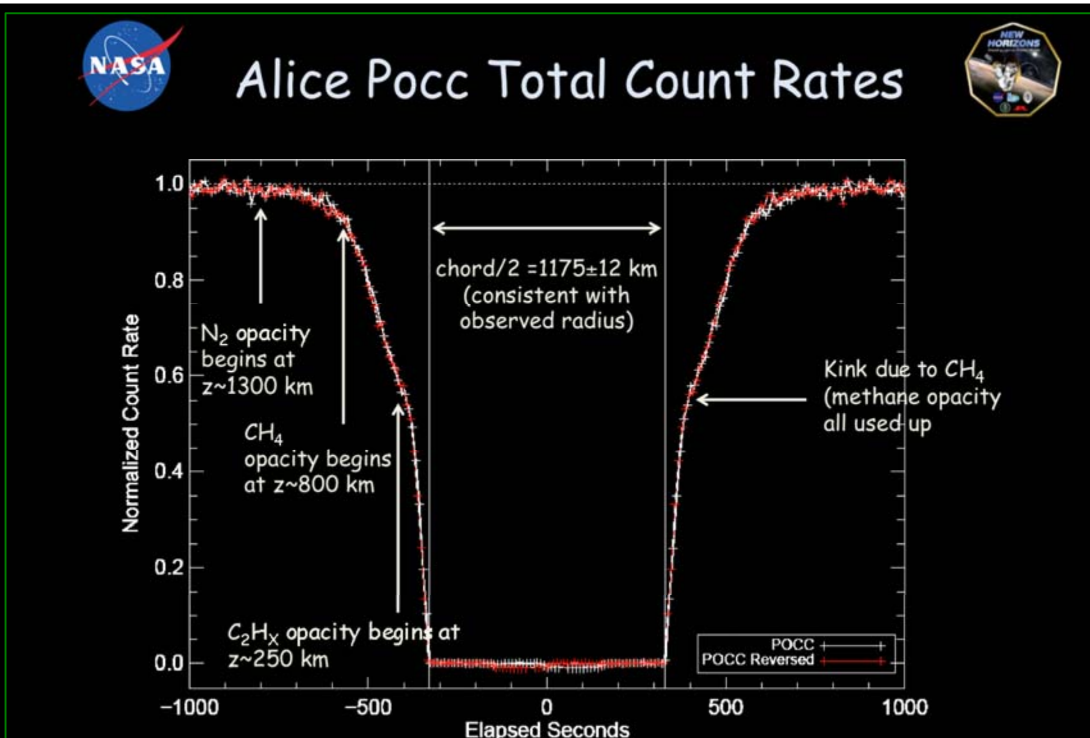
Water ice is buoyant in either N_2 or CO ice, soblocks of water ice embedded or buried in solid N_2/CO will seek to rise isostatically.

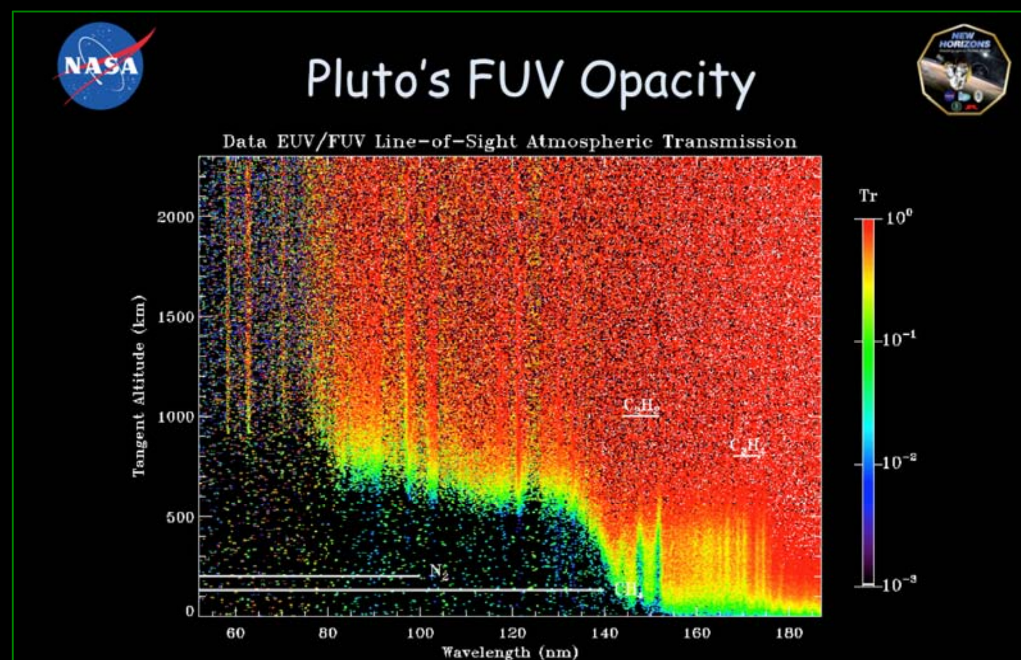
Numerous mountains on Pluto appear to be be floating.



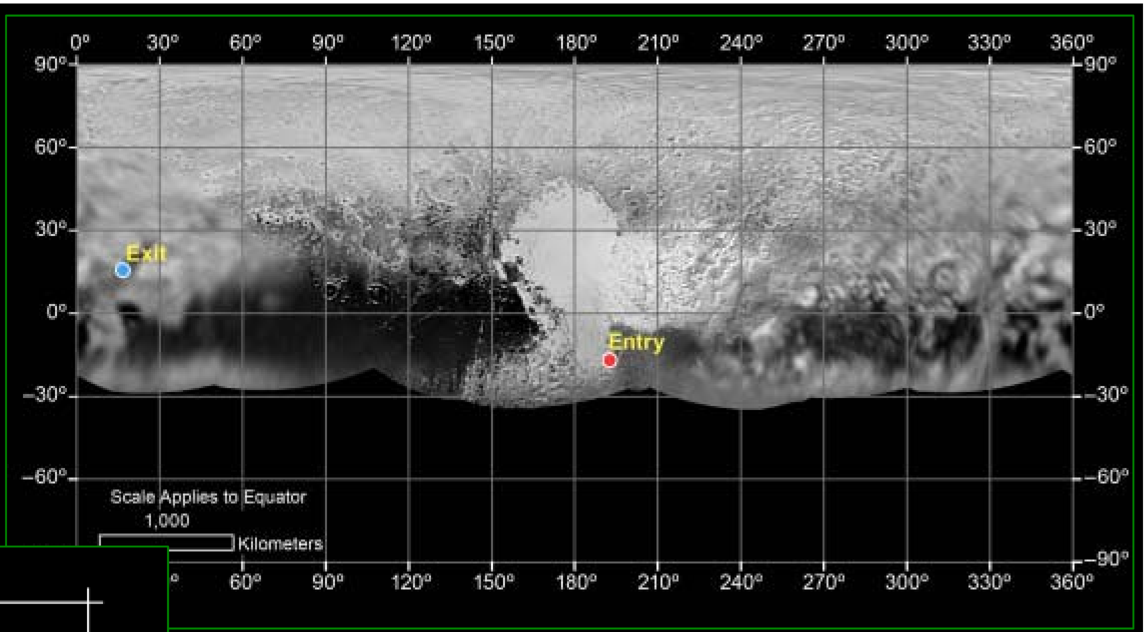


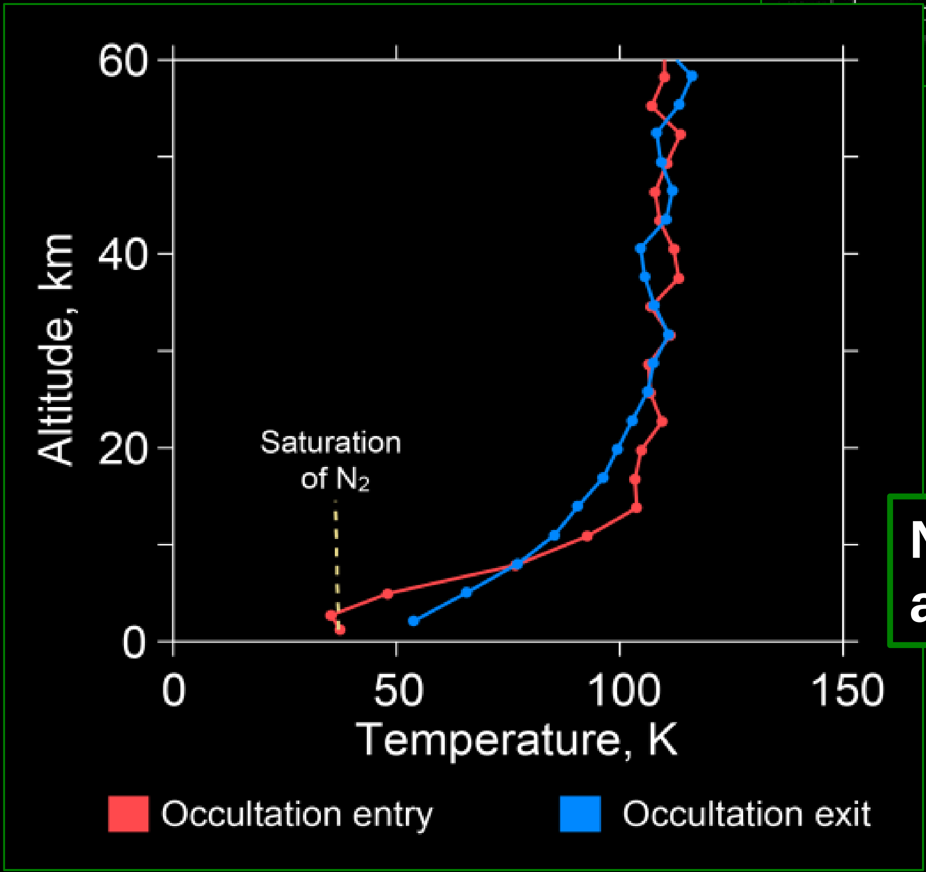

Pluto's moon Nix
as seen by New Horizons
10 km
LORRI
Panchromatic
MVIC
Enhanced Color
LORRI/MVIC
Composite


Alice Pocc Total Count Rates
Normalized Count Rate
Elapsed Seconds
N2 opacity begins at z~1300 km
CH4 opacity begins at z~800 km
C2HX opacity begins at z~250 km
chord/2 =1175±12 km (consistent with observed radius)
Kink due to CH4 (methane opacity all used up
POCC
POCC Reversed

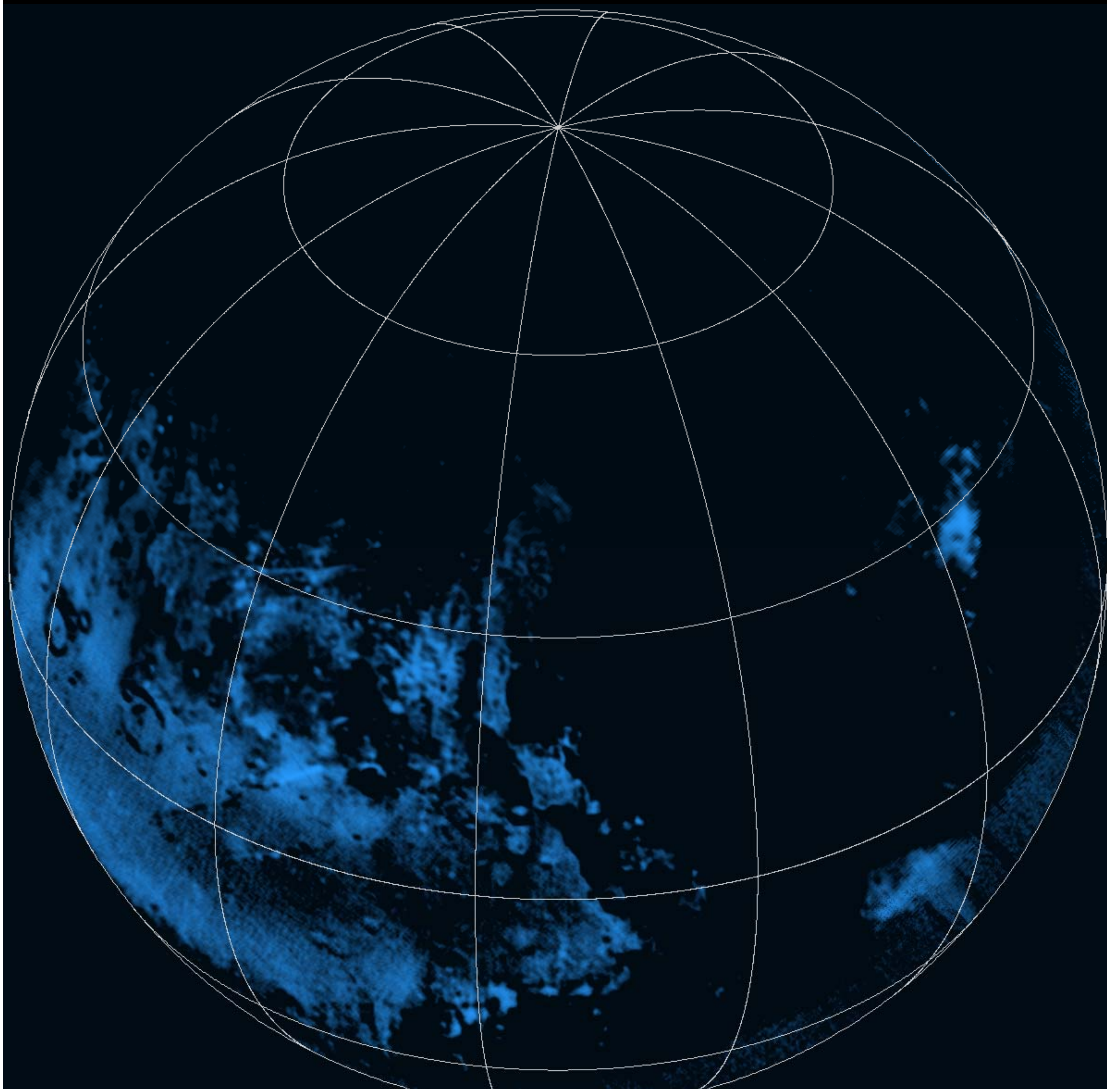

Pluto's FUV Opacity
Data EUV/FUV Line-of-Sight Atmospheric Transmission
Tangent Altitude (km)
Wavelength (nm)
Tr
N2

Selected REX Radio Occultation Results

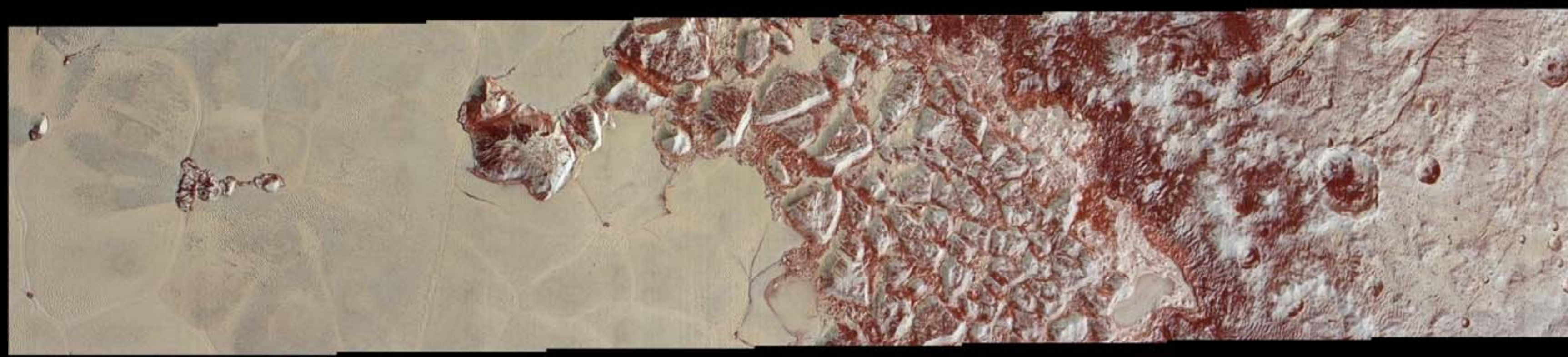


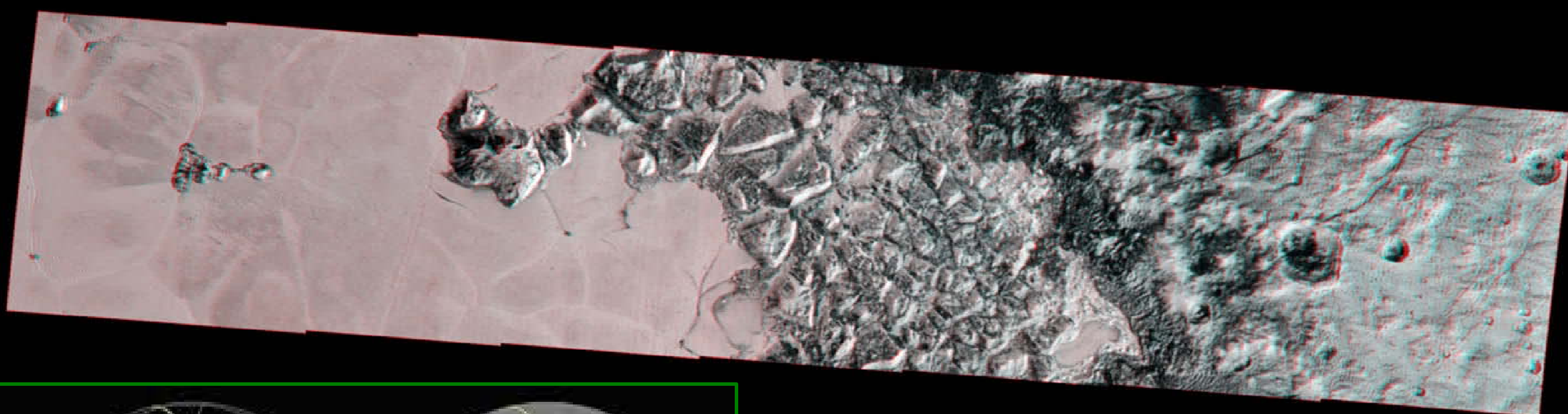


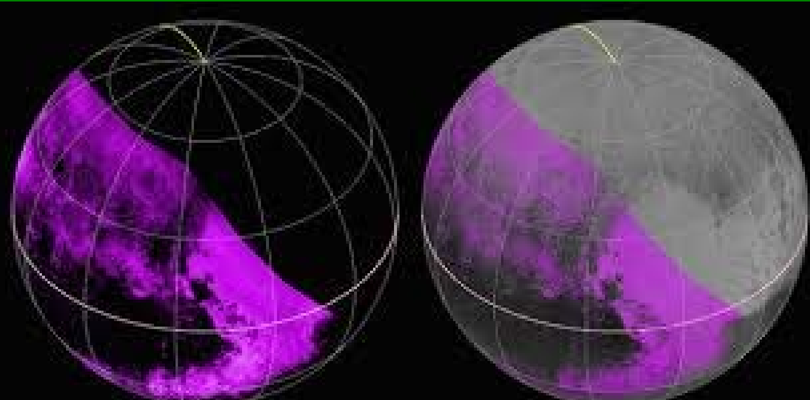
Note differening temperatures at entry and exit occultations.



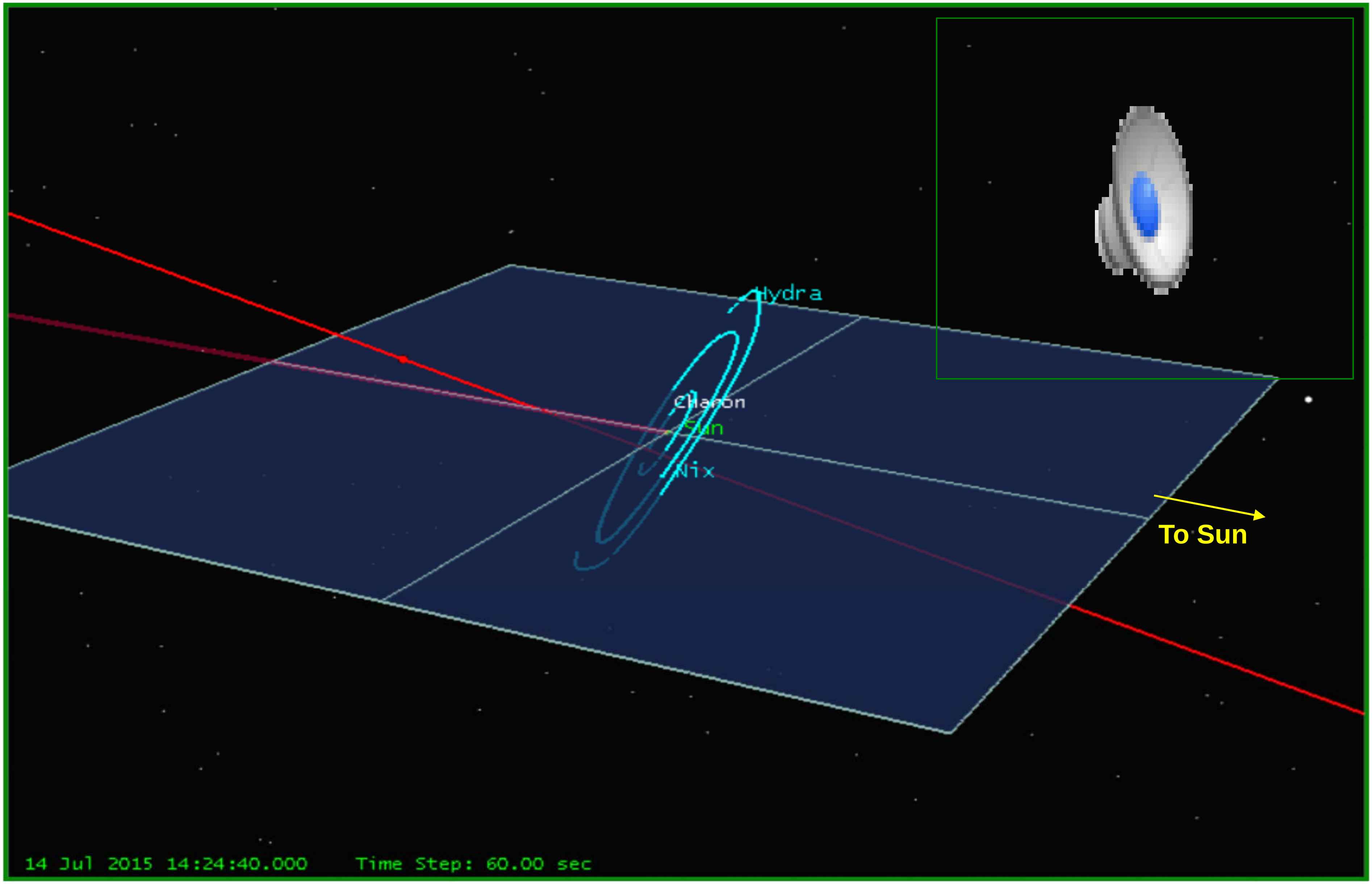
H2O

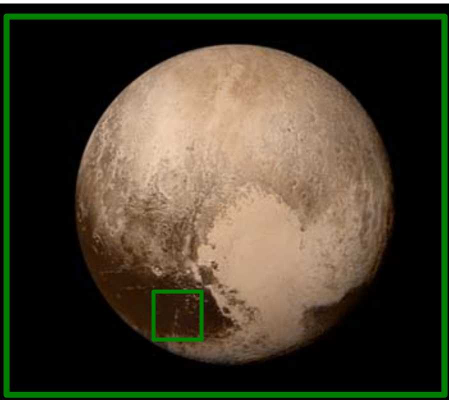


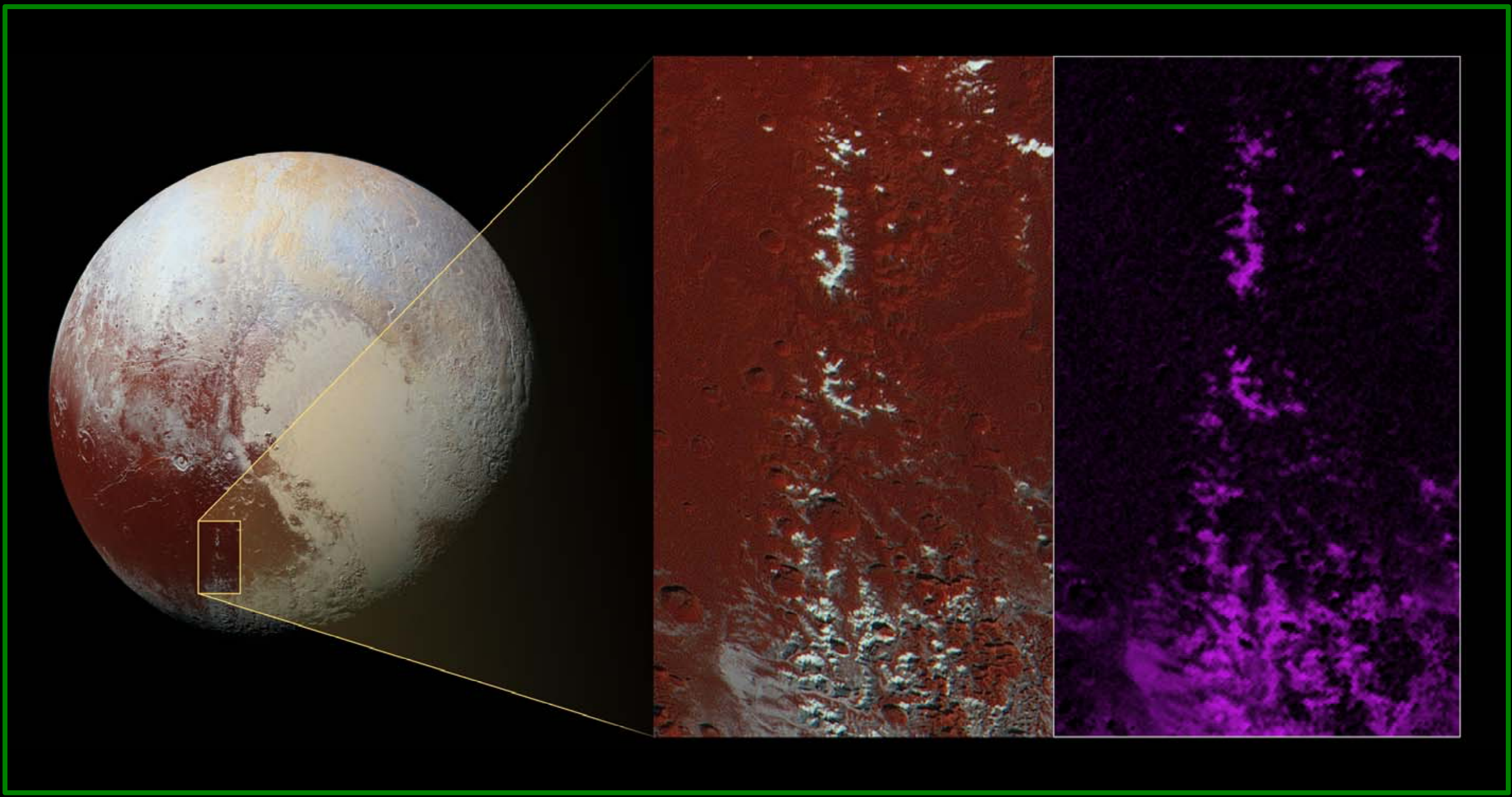


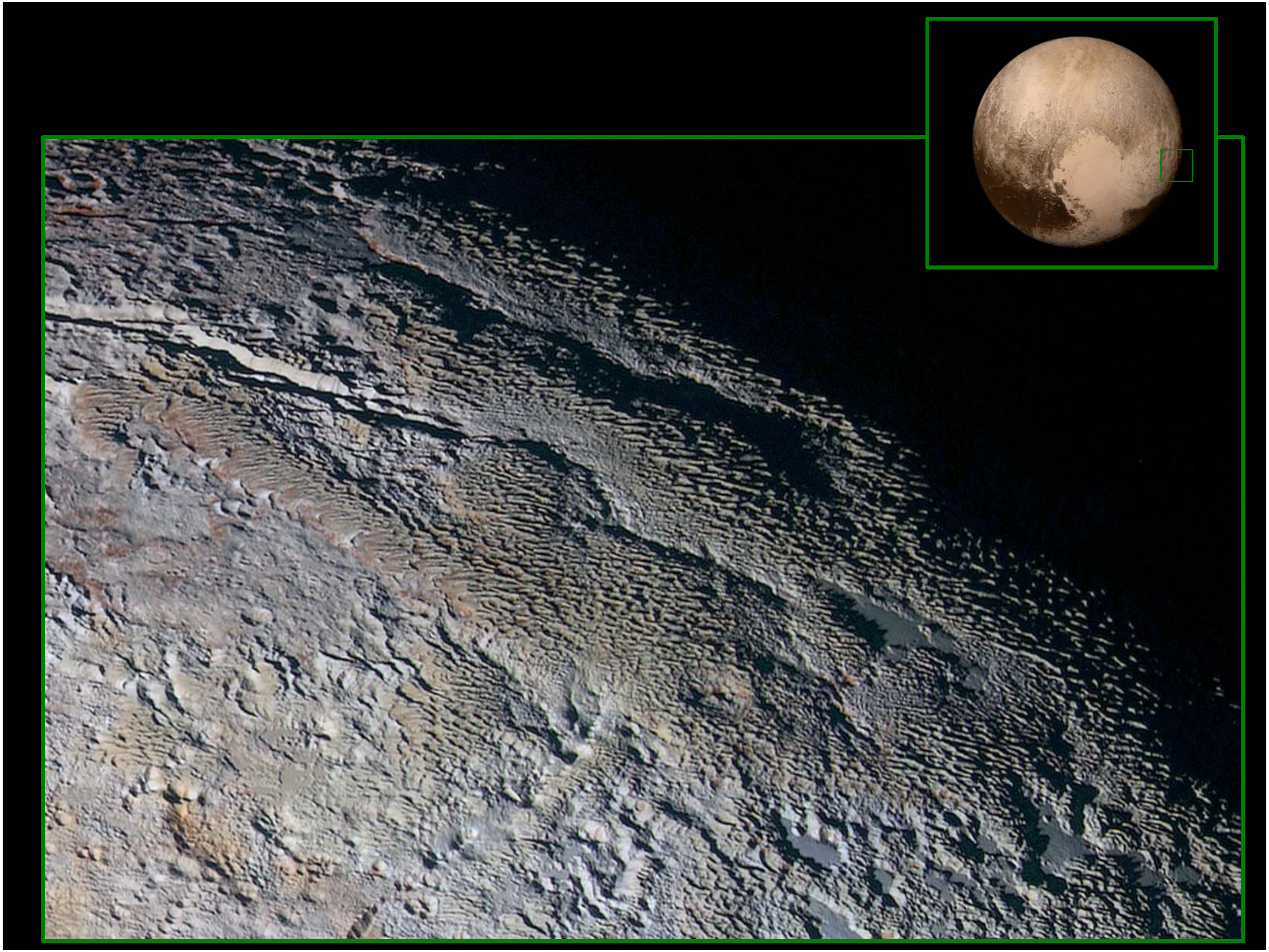


A SPECIAL ENCOUNTER GEOMETRY









[redacted]

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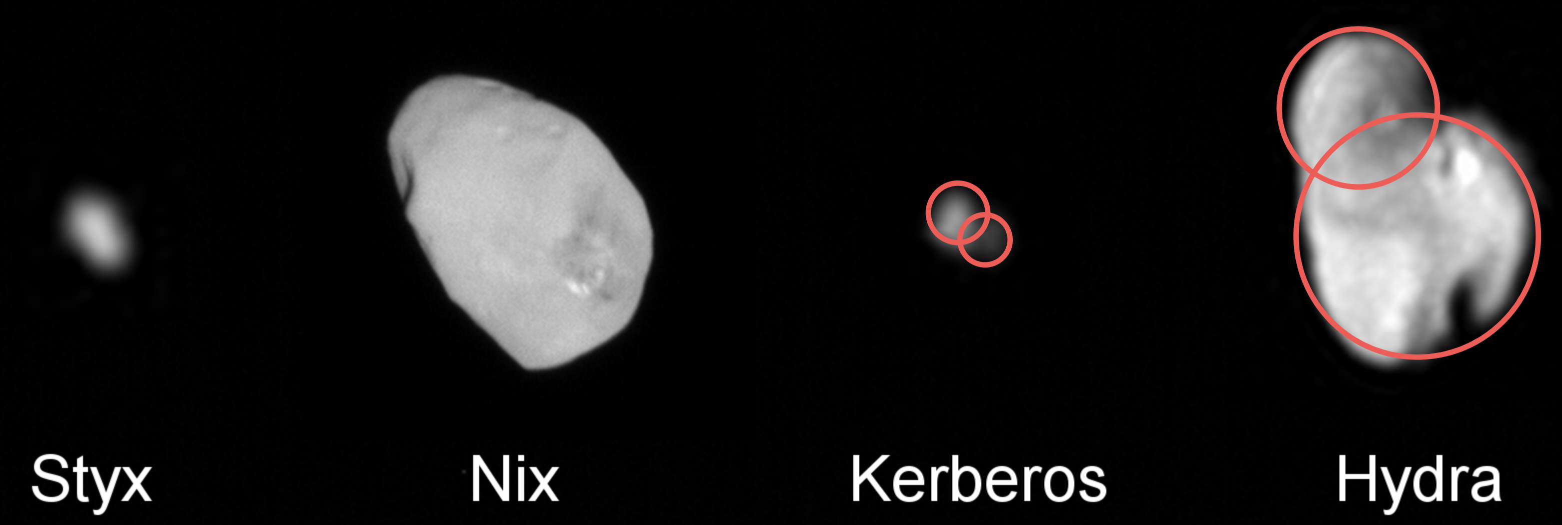
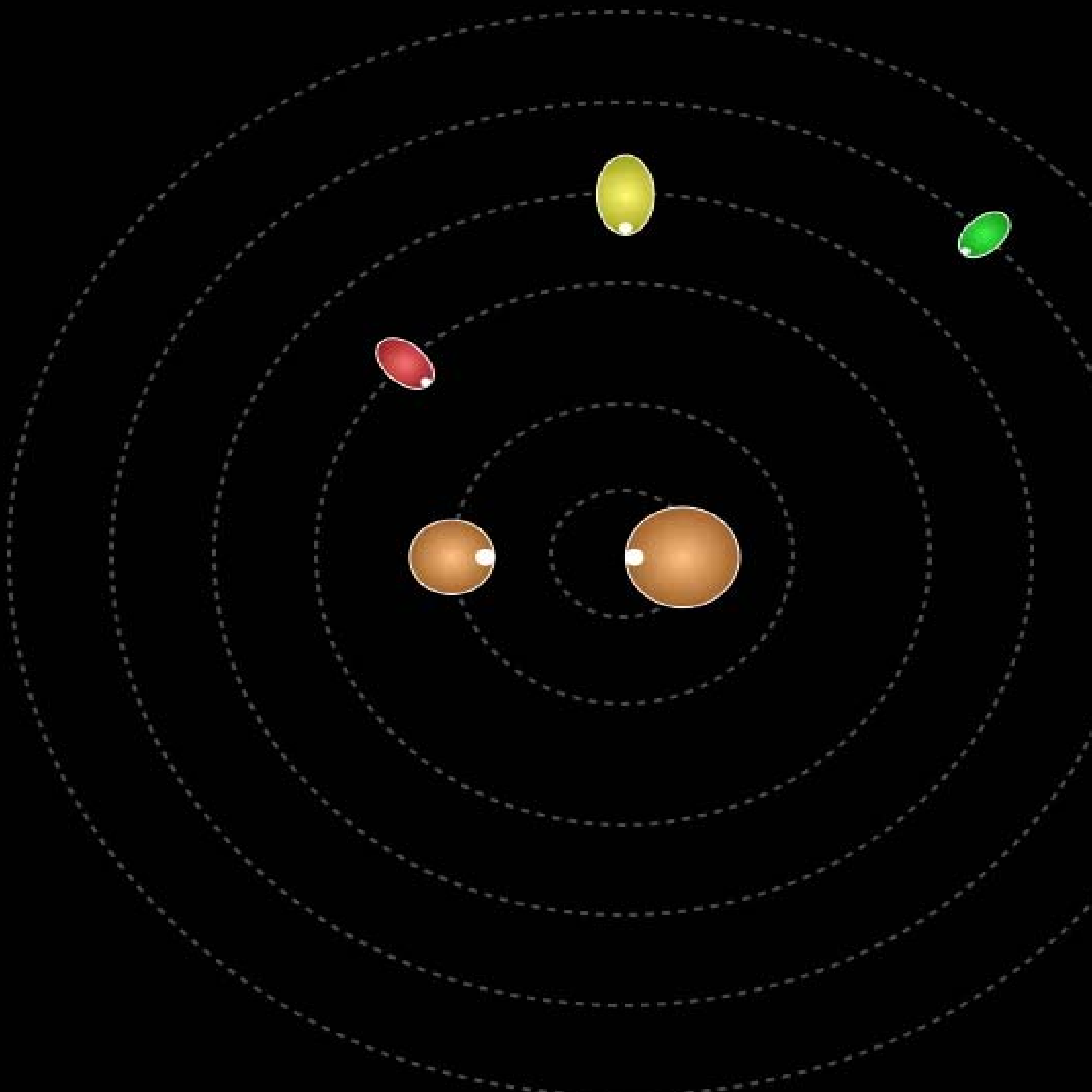
You, Pluto, NASA New Horizons and 7 others

3 3

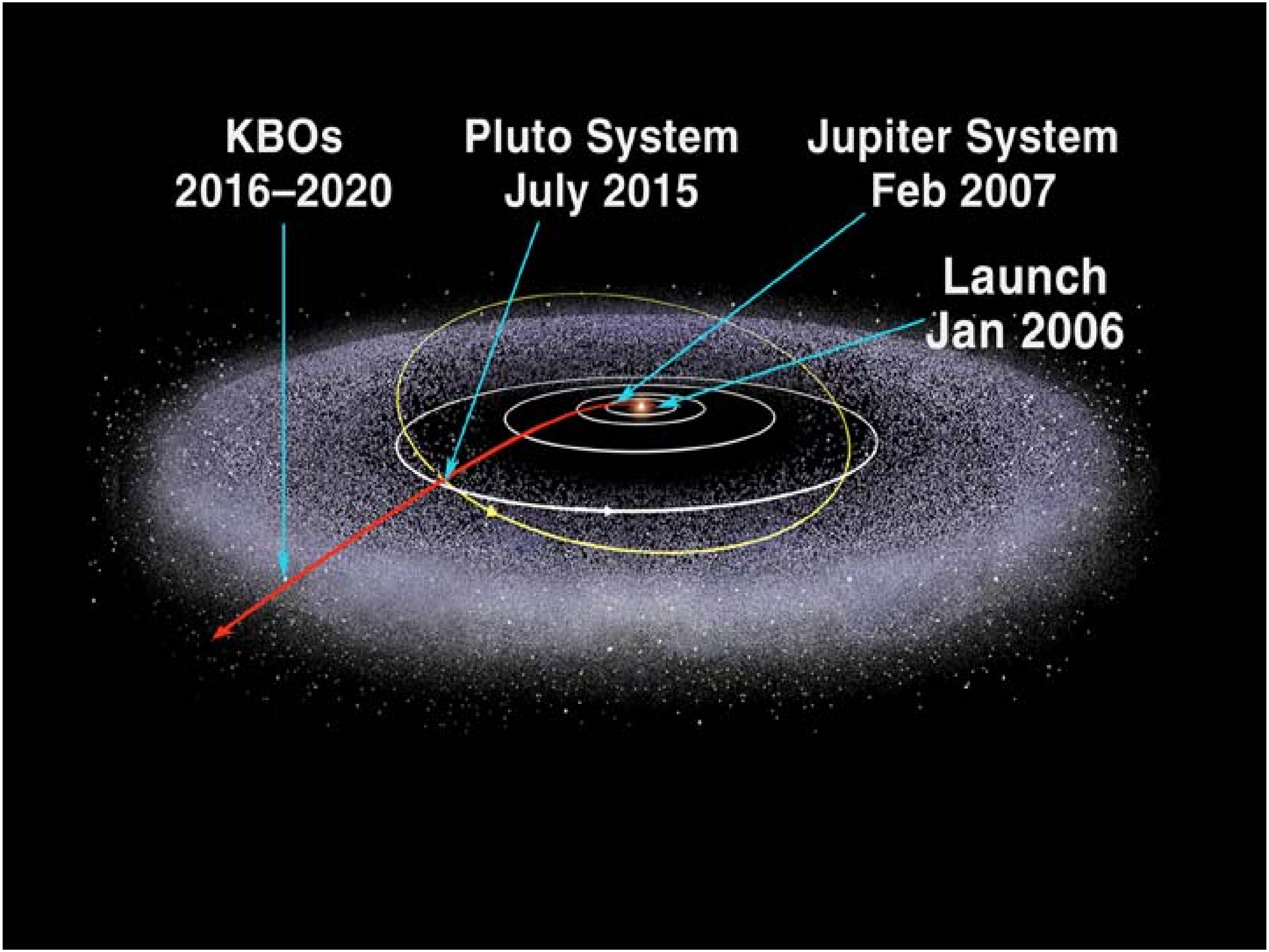
At least two and possibly all four moons are the result of mergers between smaller bodies. Pluto may have had many more moons in the past.



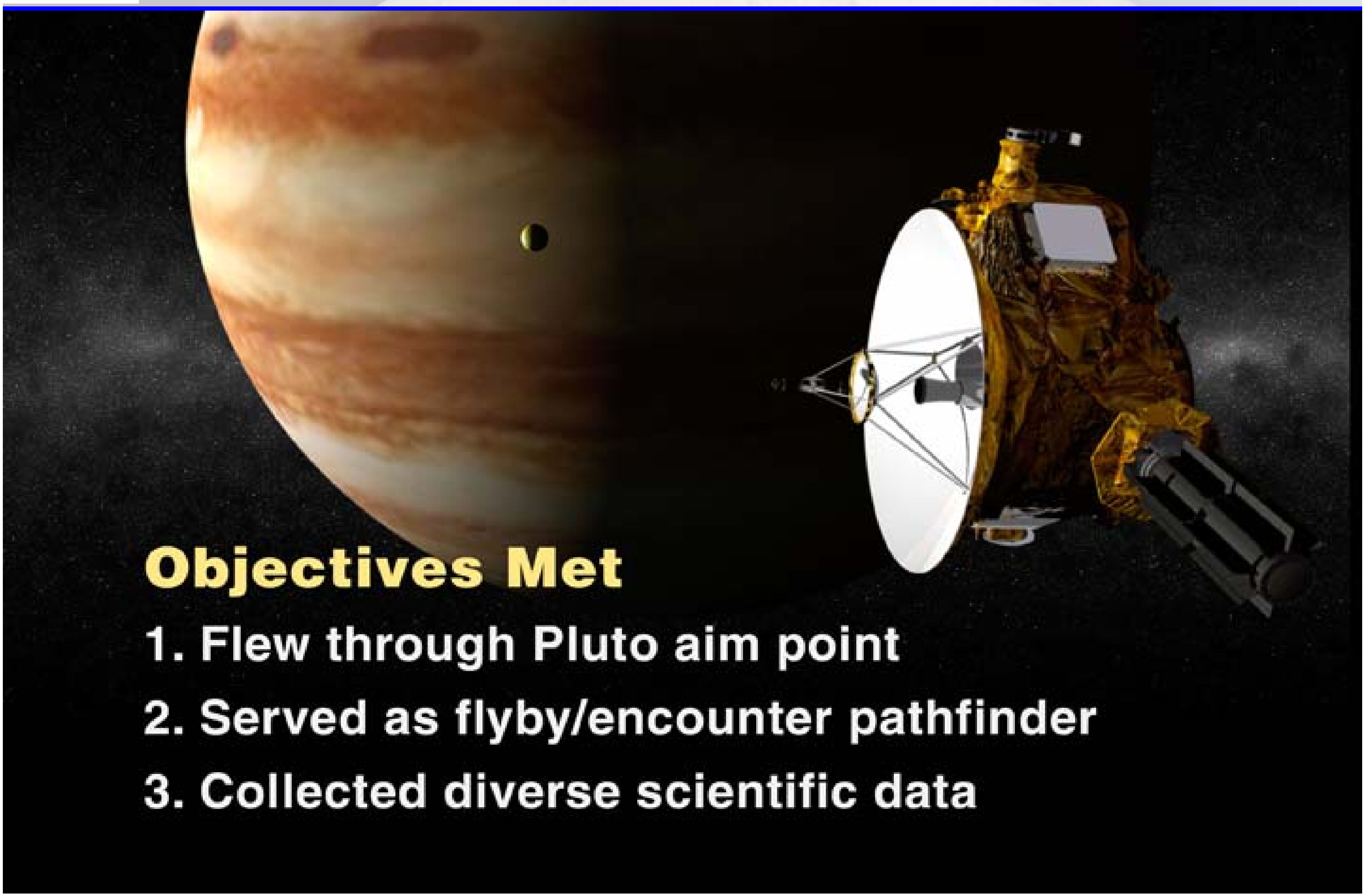


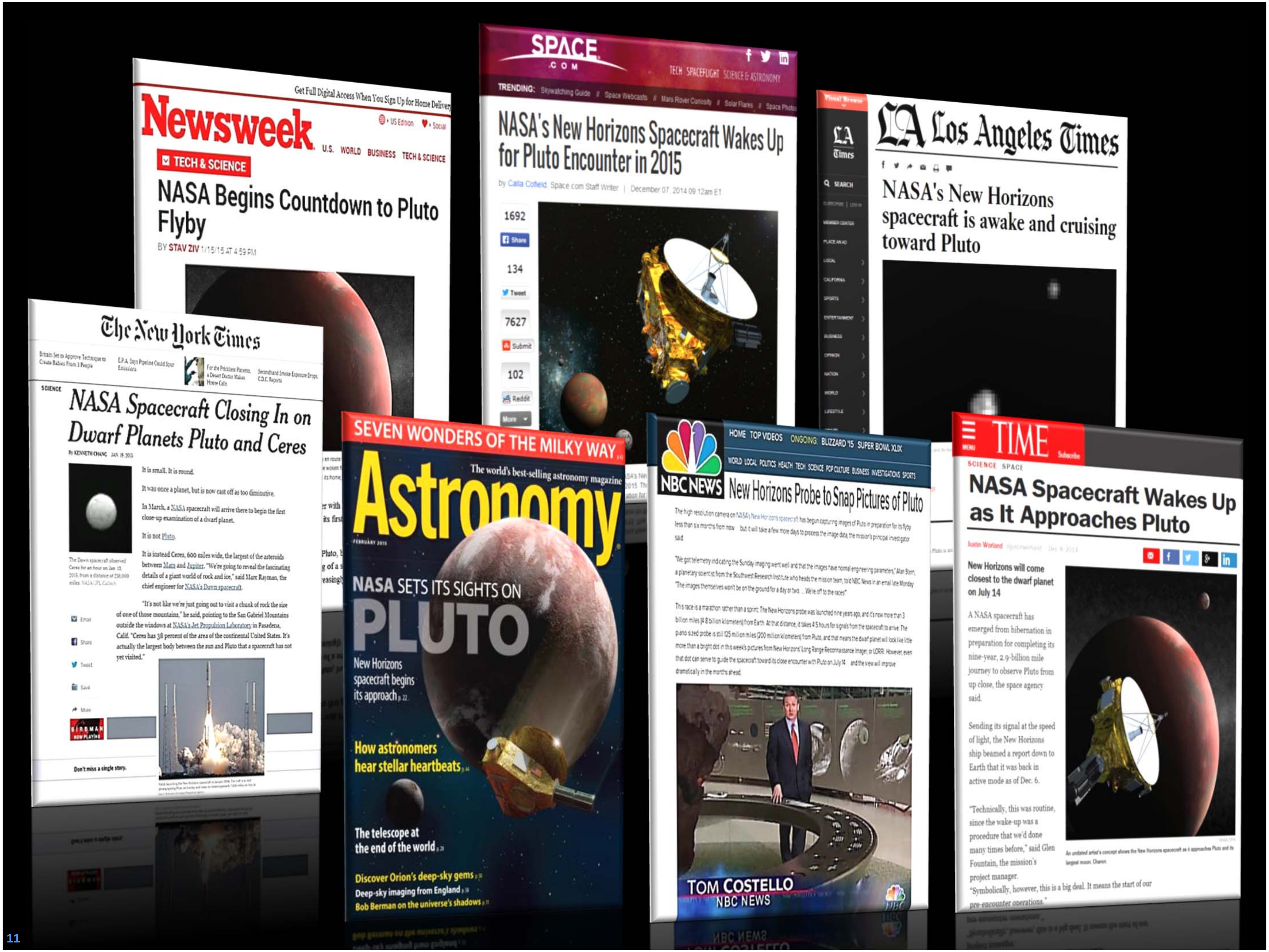
...NOT synchronous!

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


KBOs
2016–2020
Pluto System
July 2015
Jupiter System
Feb 2007
Launch
Jan 2006

JUPITER OBJECTIVES

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