

Hot Science Cool Talks

UT Environmental Science Institute

102

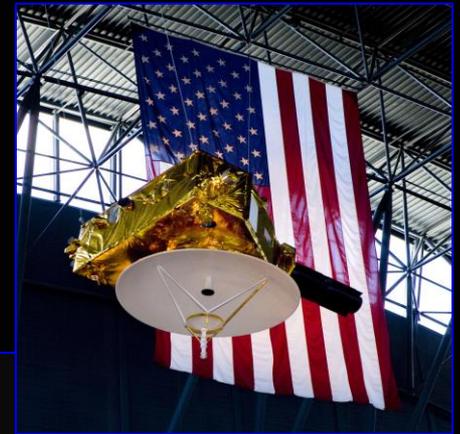
The Amazing Mission to Pluto: Three Billion Miles Away and We Made It!

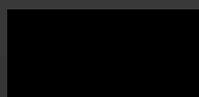
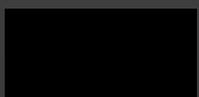
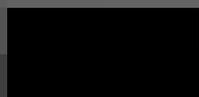
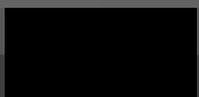
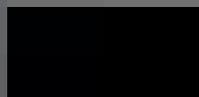
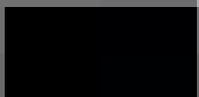
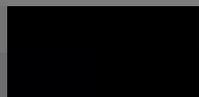
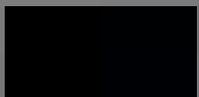
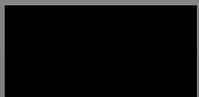
Dr. Alan Stern
September 16, 2016

Produced by and for *Hot Science - Cool Talks* by the Environmental Science Institute. We request that the use of these materials include an acknowledgement of the presenter and *Hot Science - Cool Talks* by the Environmental Science Institute at UT Austin. We hope you find these materials educational and enjoyable.

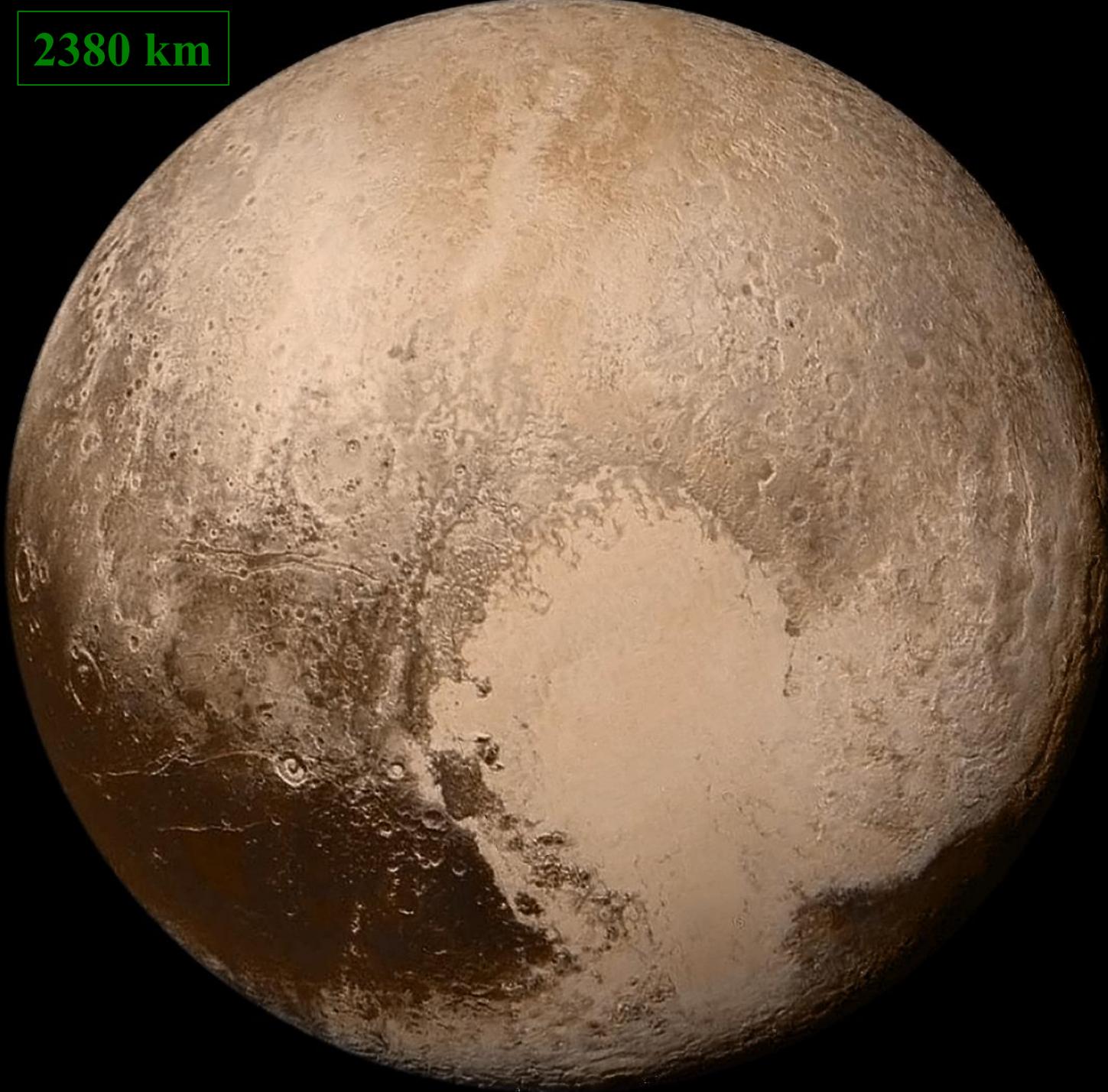
The Amazing Exploration of Pluto By New Horizons

Alan Stern

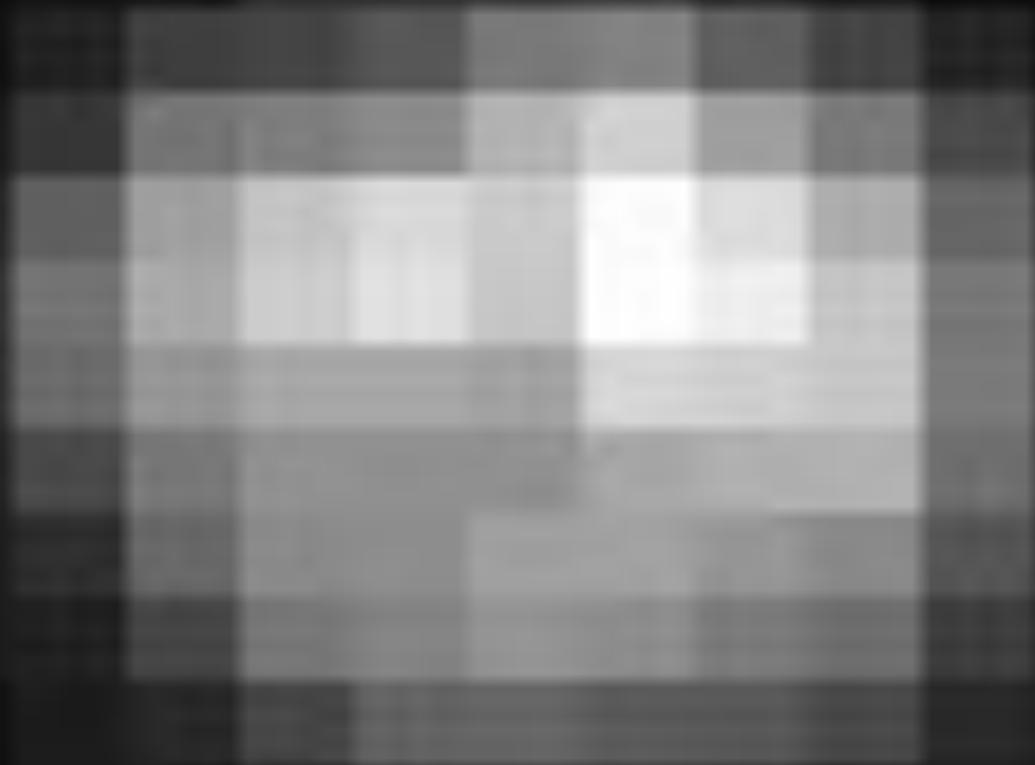




2380 km











**HOW DID WE GET TO DO
THIS?**



SKOAL



WAL-MART
ALWAYS LOW PRICES *Always*



Energizer

INTERSTATE BATTERIES



LOWE'S
Improving Home Improvement

Budweiser



WINN-DIXIE

BEEF 'O' BRAD'S



DUPONT
MOTORSPORTS

THE HOME DEPOT

GOODYEAR



VIAGRA
(sildenafil citrate) tablets

WAFFLE HOUSE

Goody's



Advance Auto Parts

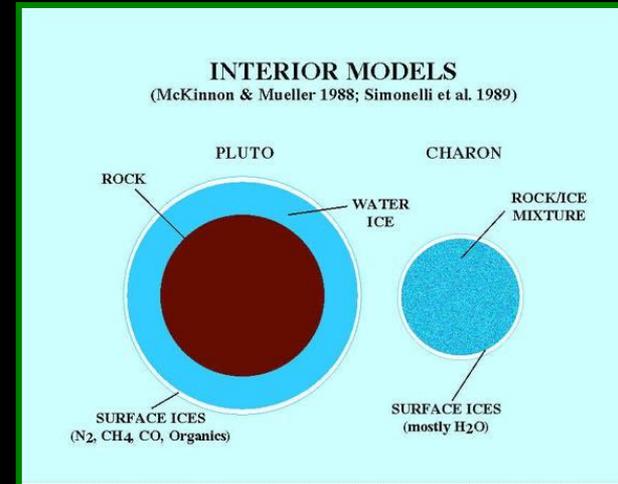
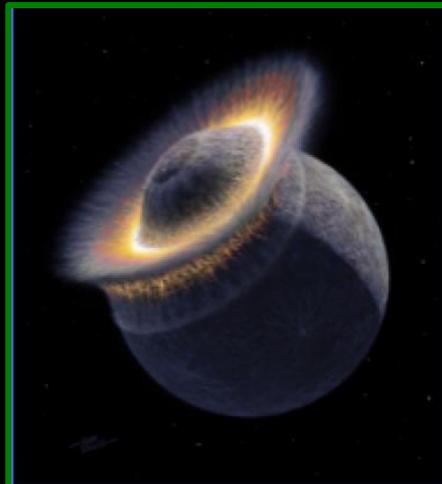
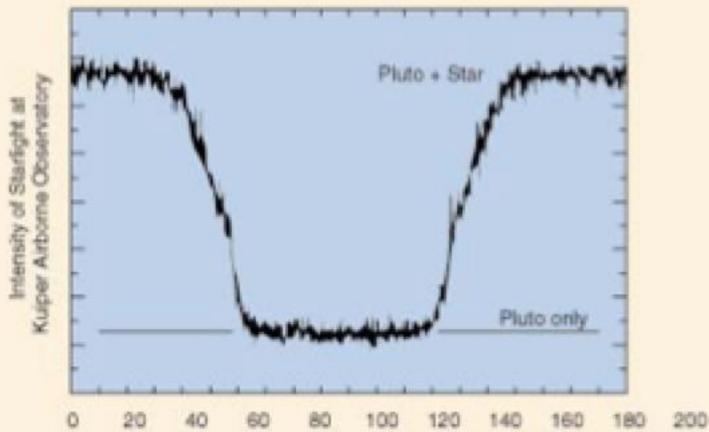
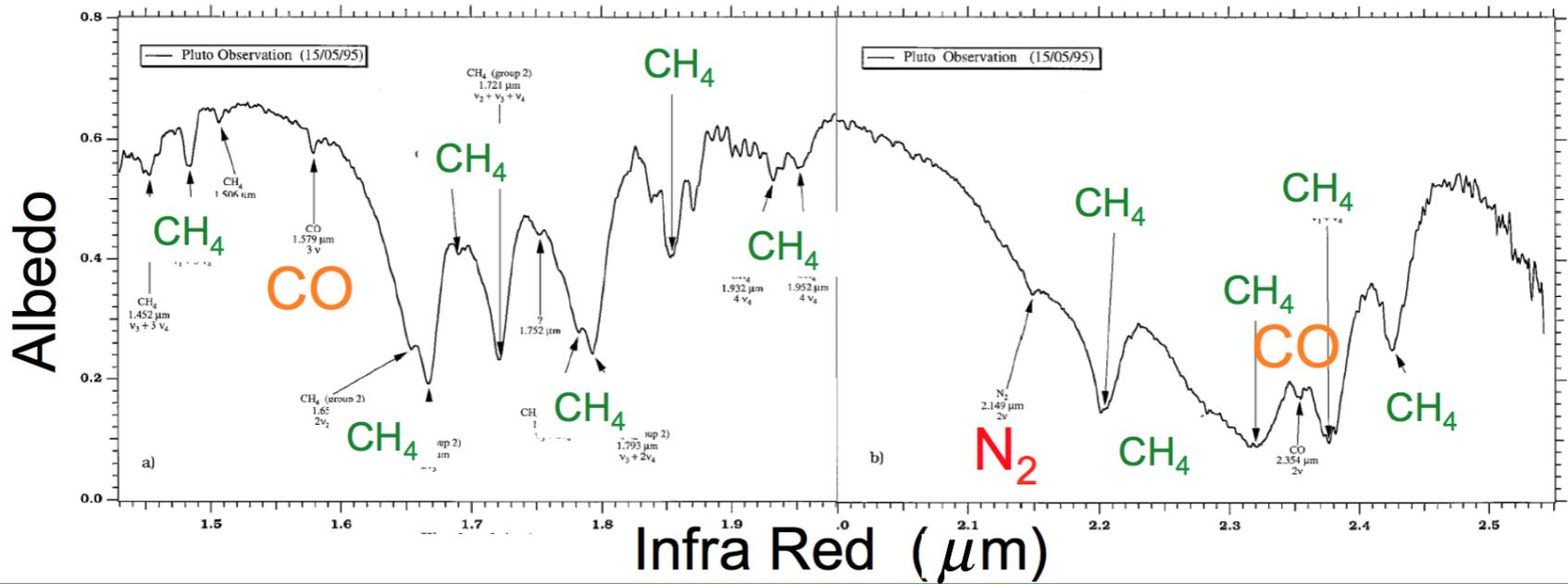
7399-1401

Mission History

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

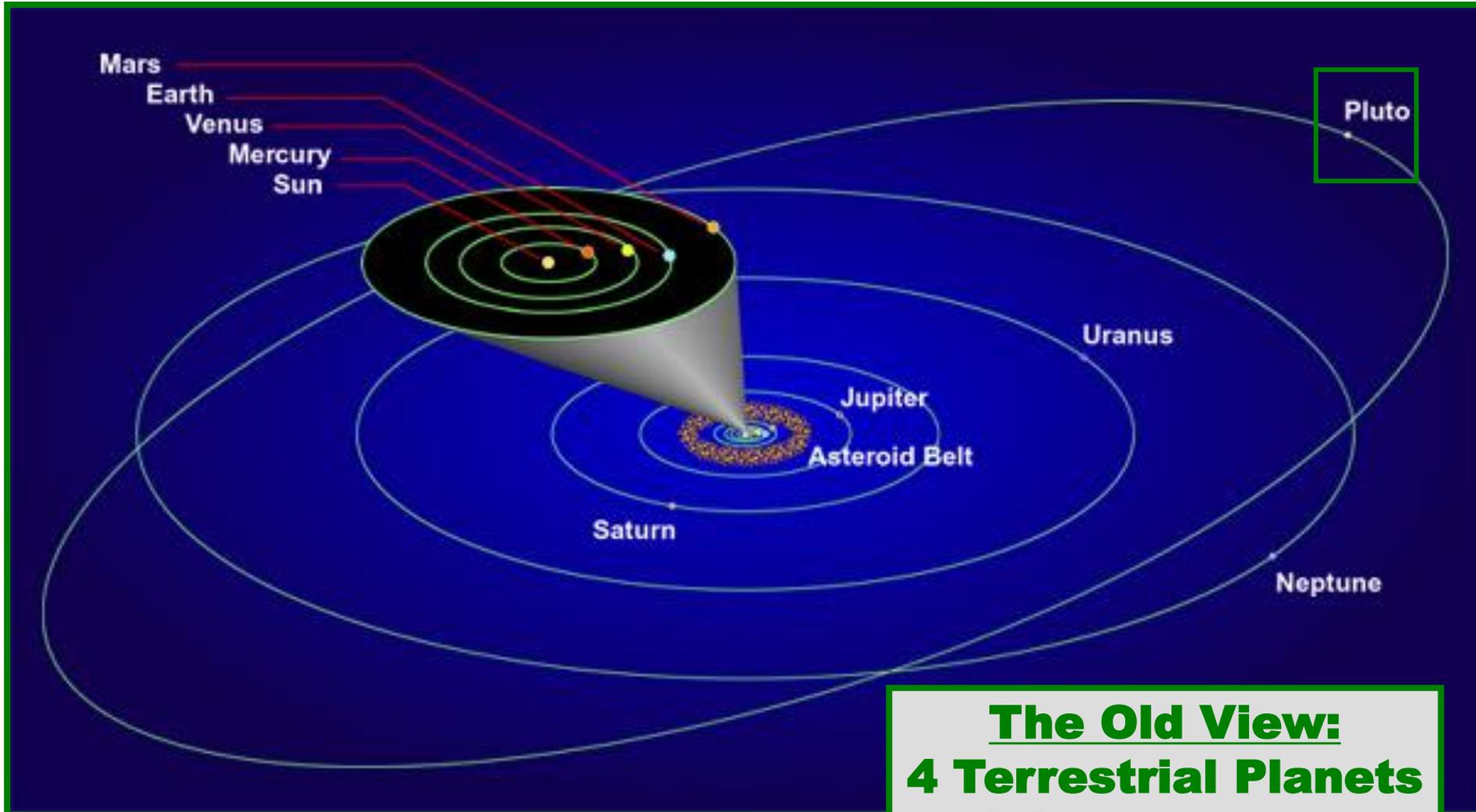


Pluto's Surface Composition Is Complex

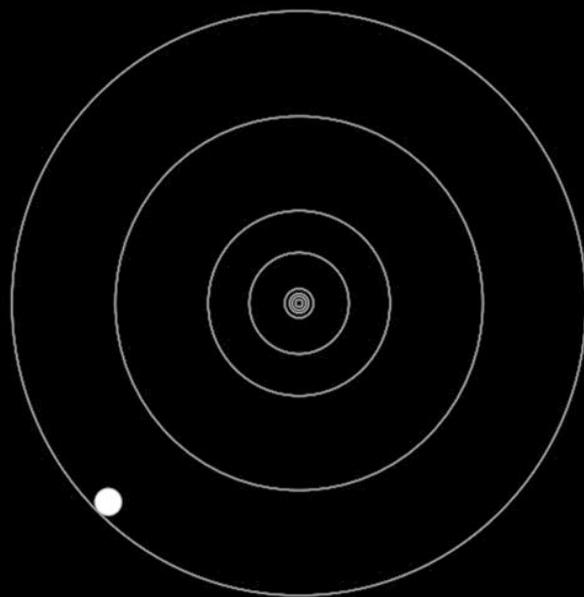




MISFIT PLUTO?



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



New View of the Solar System

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

Kuiper Belt



Asteroid Belt

Scale
1000 km



SO MANY PLANETS!

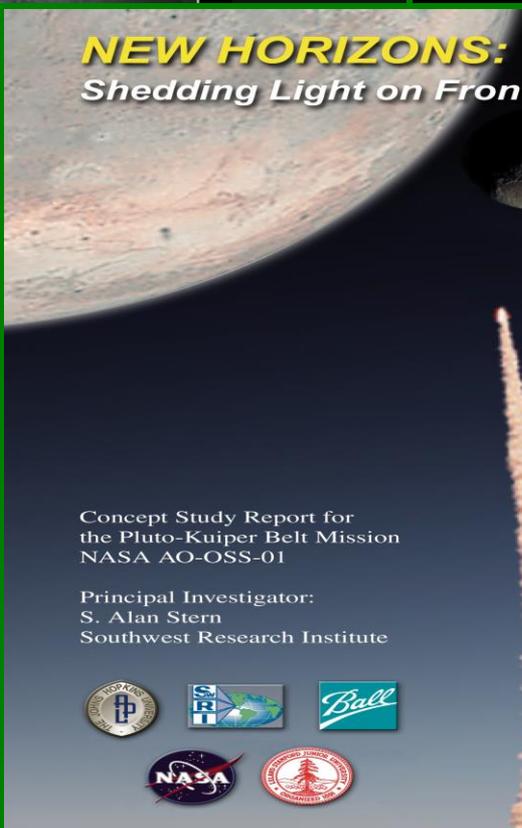


Highest Funding Priority Medium-Scale Mission
New Start of the 2003 Planetary Decadal Survey:

*A Reconnaissance Expedition
to Pluto-Charon & the Kuiper Belt*



NEW HORIZONS:
Shedding Light on Frontier Worlds

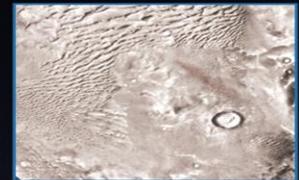


Concept Study Report for
the Pluto-Kuiper Belt Mission
NASA AO-OSS-01

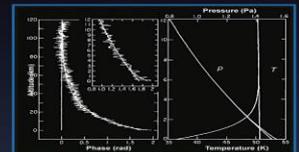
Principal Investigator:
S. Alan Stern
Southwest Research Institute



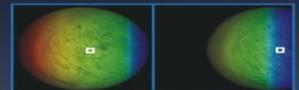
Global
Mapping &
High-Res
Imagery



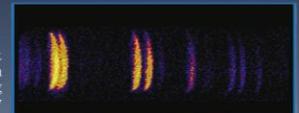
Radio Science
Occultation,
Gravity, &
Radiometry



IR Surface
Composition &
Temperature
Mapping



UV Airglow &
Occultation
Imaging
Spectroscopy



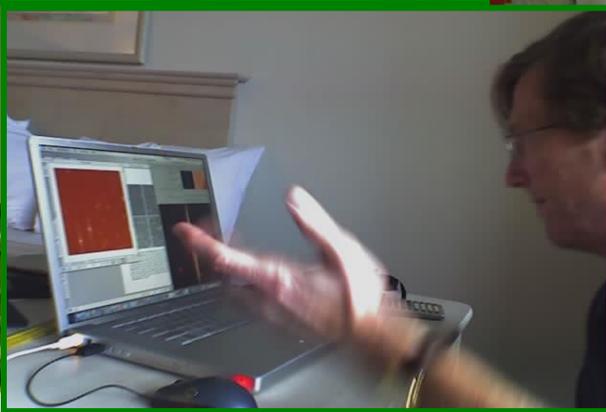
In Situ Particles
& Plasma
Measurements



THE BLUR: 2002-2005



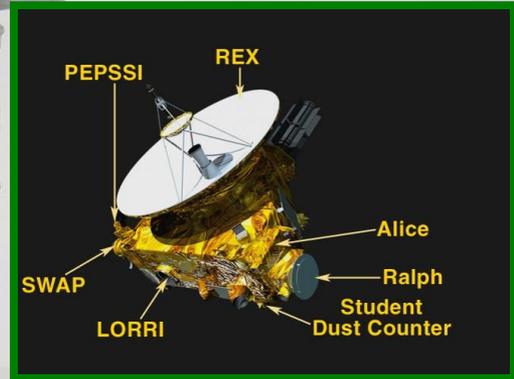
Science Objectives				
Observation	Science	Instrument	Details	New Leads
Stellar Occultation	Upper Atmosphere Composition	Alice	~30 minutes	yes Gladstone
Storms	Dynamics, lightning, haze & clouds	LEISA, MVIC, LORRI	Synoptic (every 10h)	yes Baines
"Best" Portrait	Small scale dynamics (e.g. of GRS) - EPOI	LEISA	C/A	yes Baines
Aurora & Airglow	Solar wind vs. activity	Alice, LORRI, MVIC, LEISA	Synoptic, Day & Night, H ₂ ⁺ , H ₂ quad.	yes Gladstone
	Aeronomy, composition, interaction	Alice, LEISA, MVIC	Mainly in eclipse	yes Gladstone



IT TAKES A TEAM



NEW HORIZONS



MOMENTOS



Clyde Tombaugh's Remains



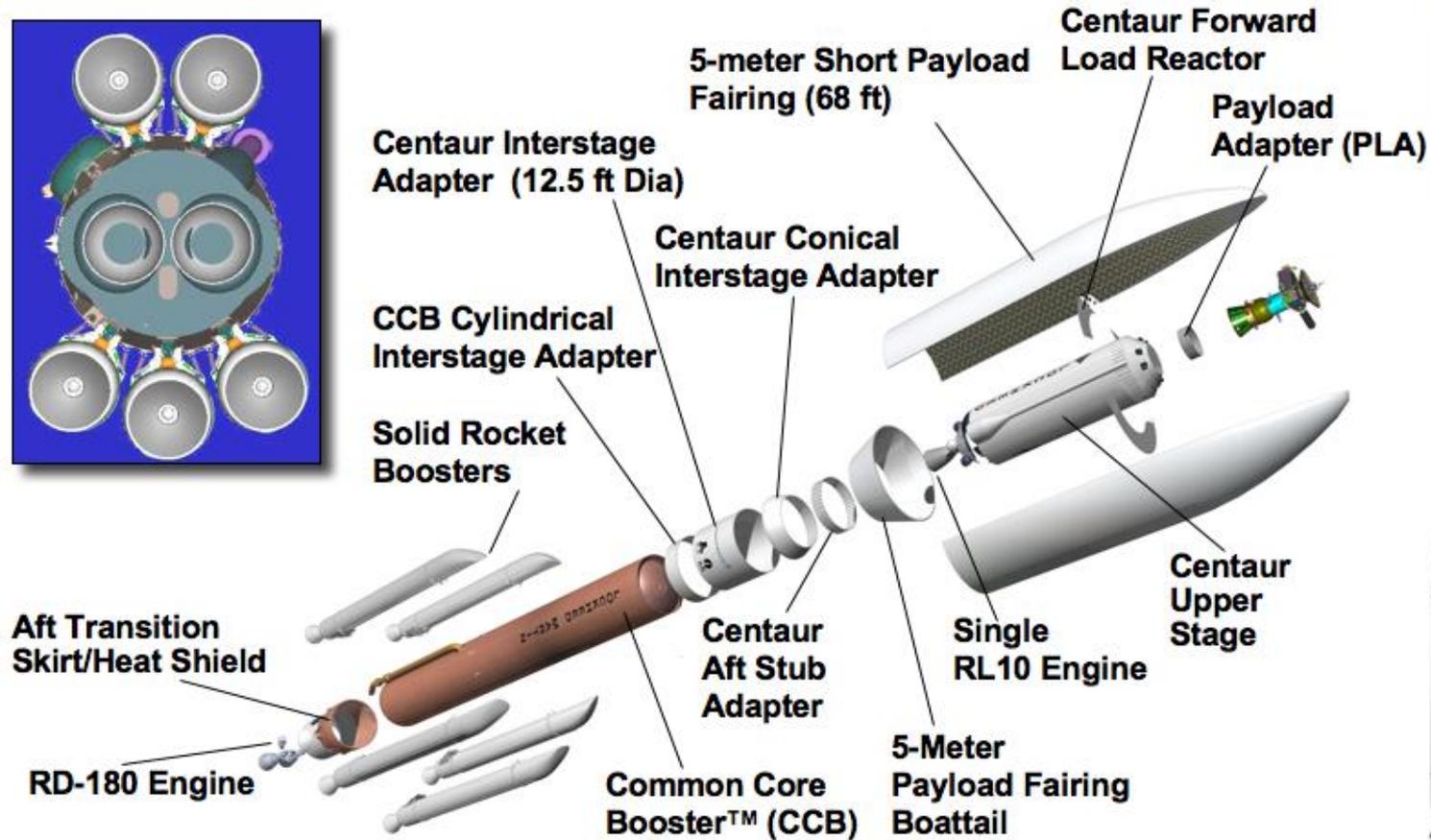
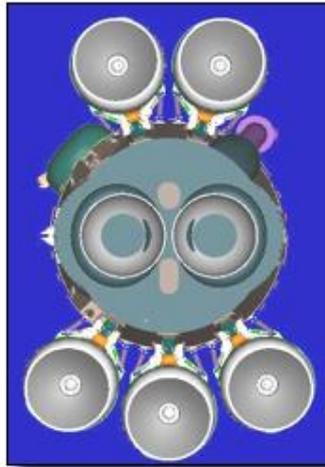
Interred herein are remains of American Clyde W. Tombaugh, discoverer of Pluto and the solar system's "third zone." Adelle and Muron's boy, Patricia's husband, Annette and Alden's father, astronomer, teacher, punster, and friend:
Clyde W. Tombaugh (1906-1997).

MOMENTOS



PLUTO NOT YET EXPLORED **29** USA

LAUNCHER



224 ft

ON THE PAD



ALL ABOARD!



LAUNCH 19 JANUARY 2006

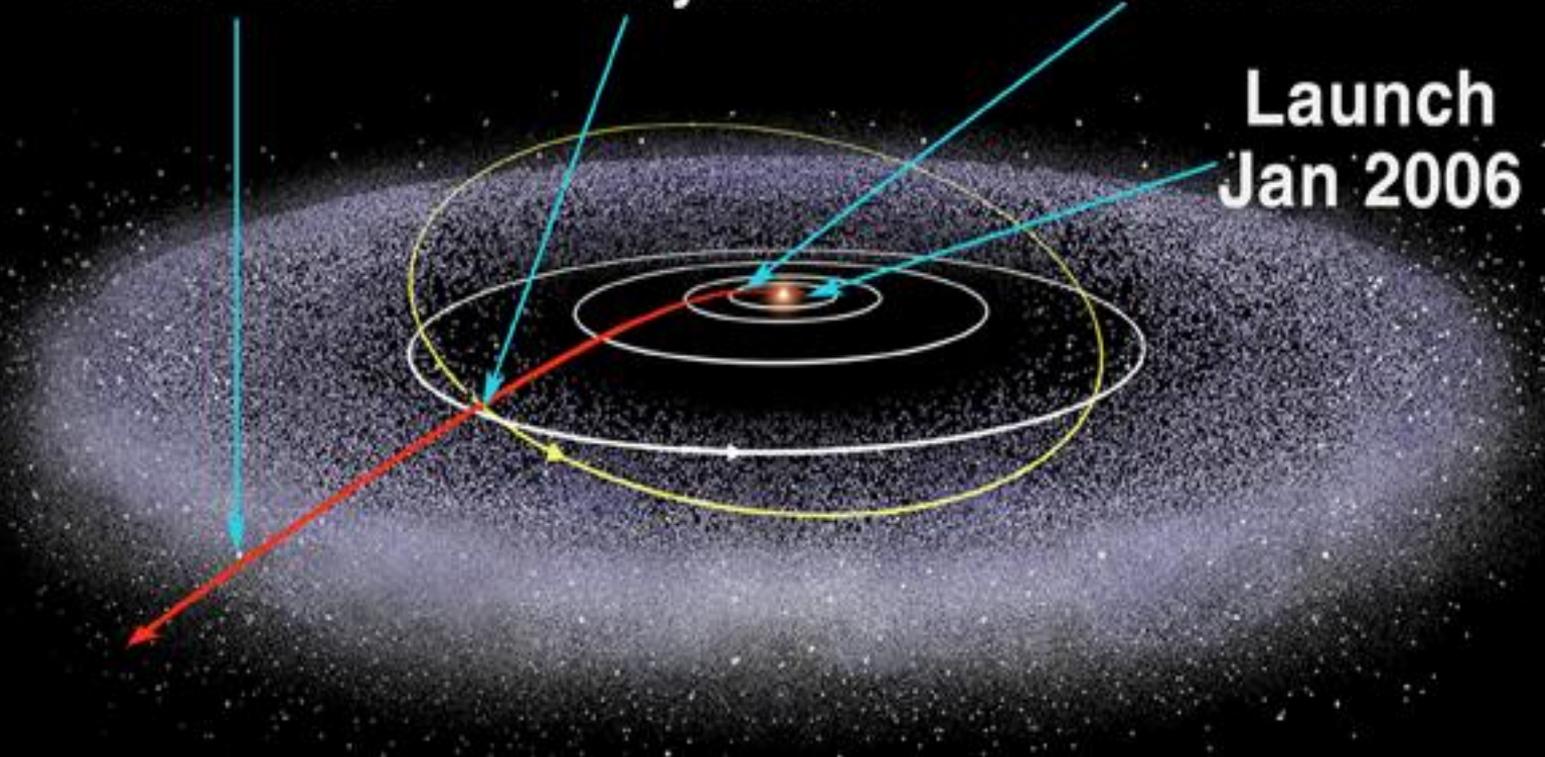


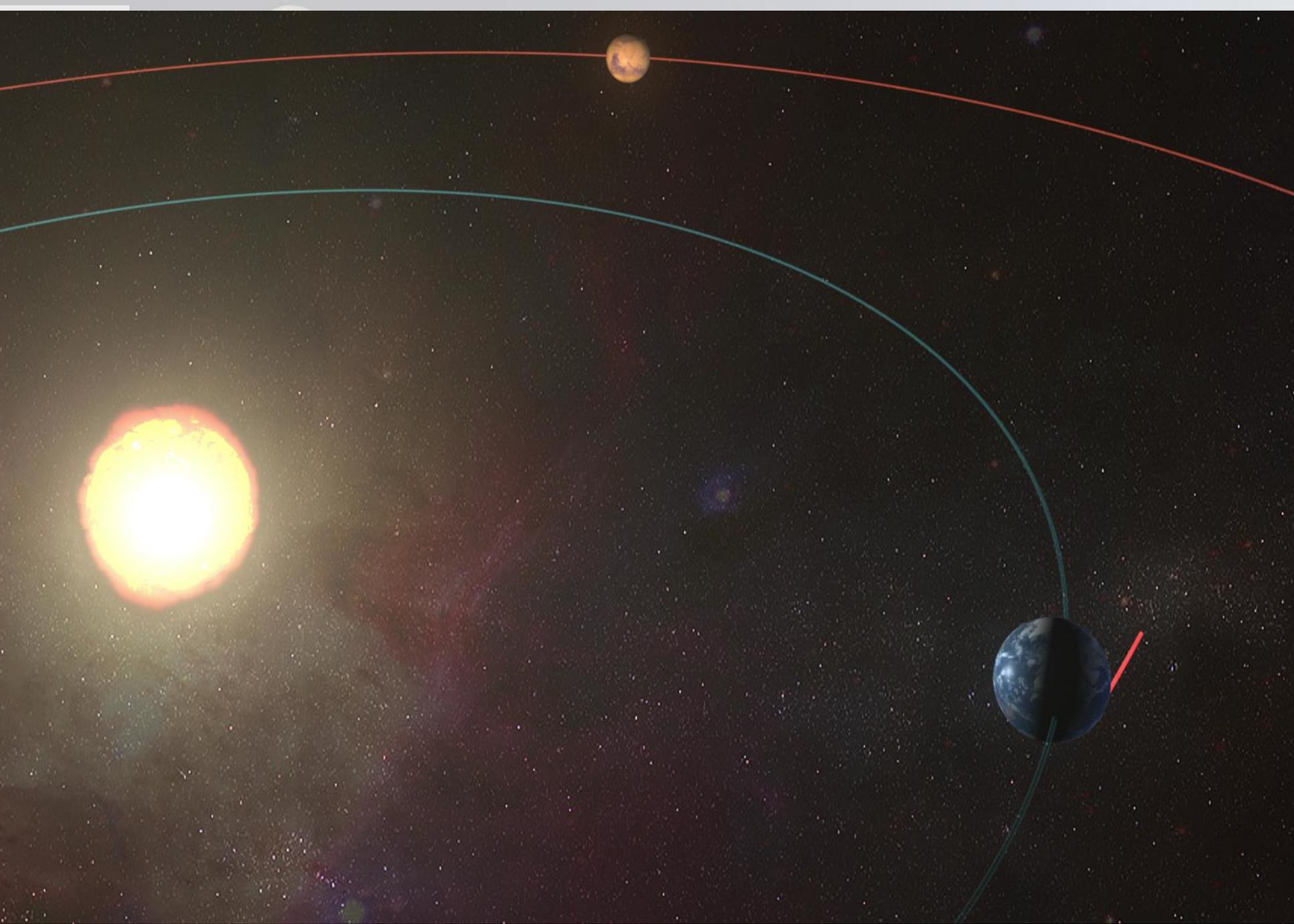
KBOs
2016–2020

Pluto System
July 2015

Jupiter System
Feb 2007

Launch
Jan 2006

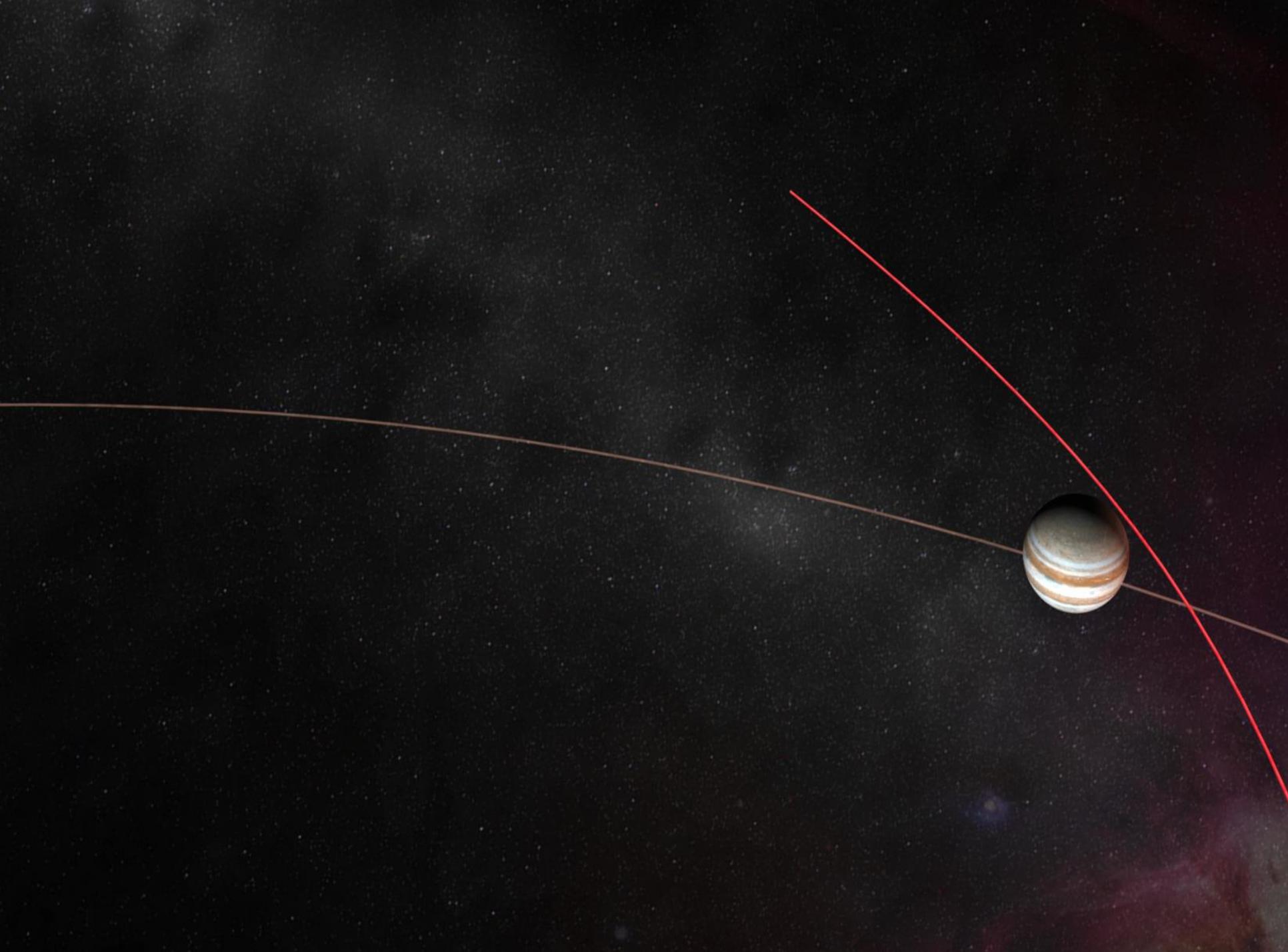




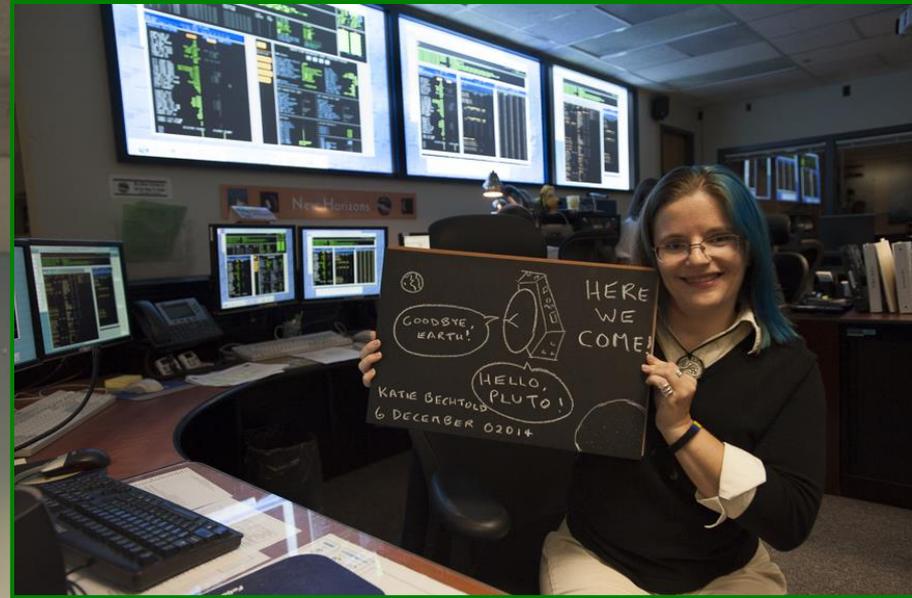
Science



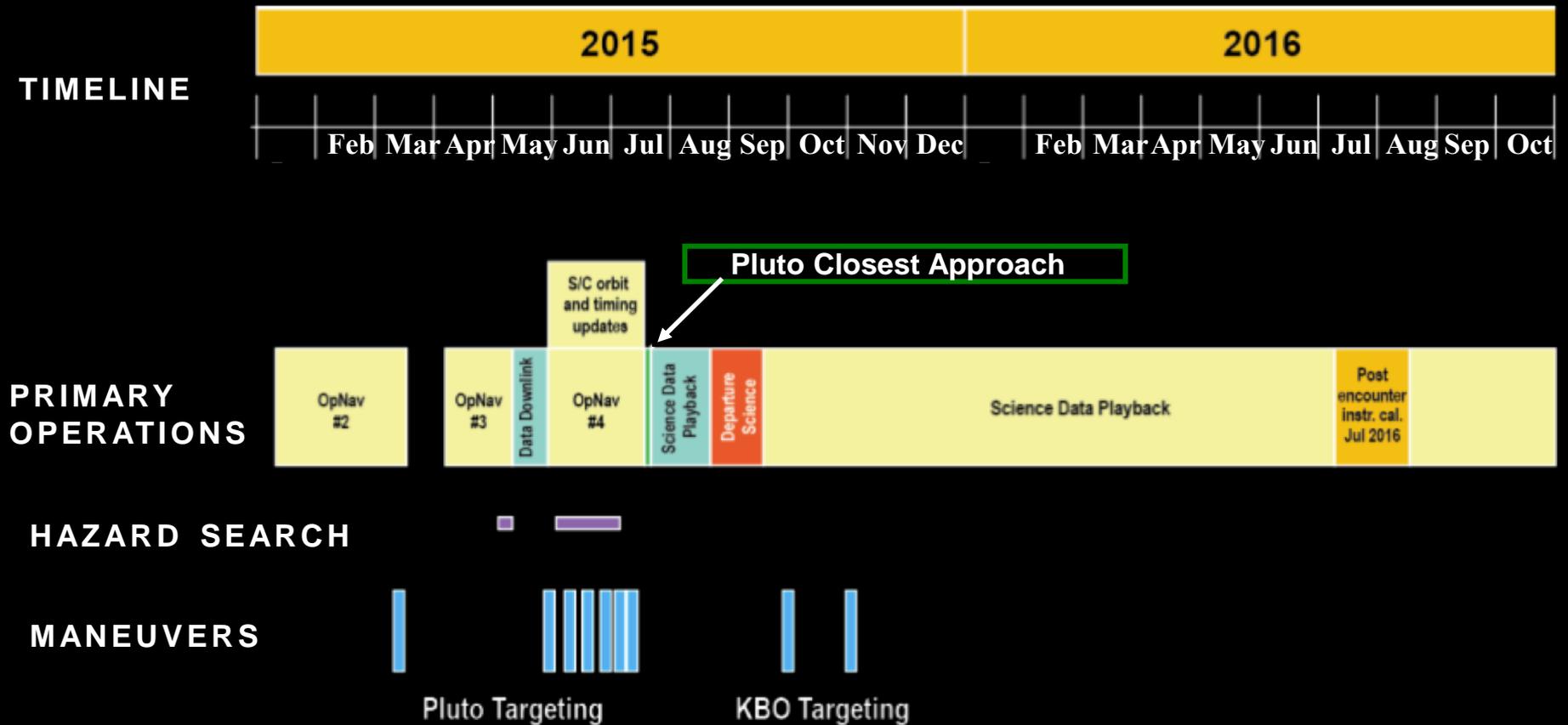
NEW HORIZONS
at Jupiter



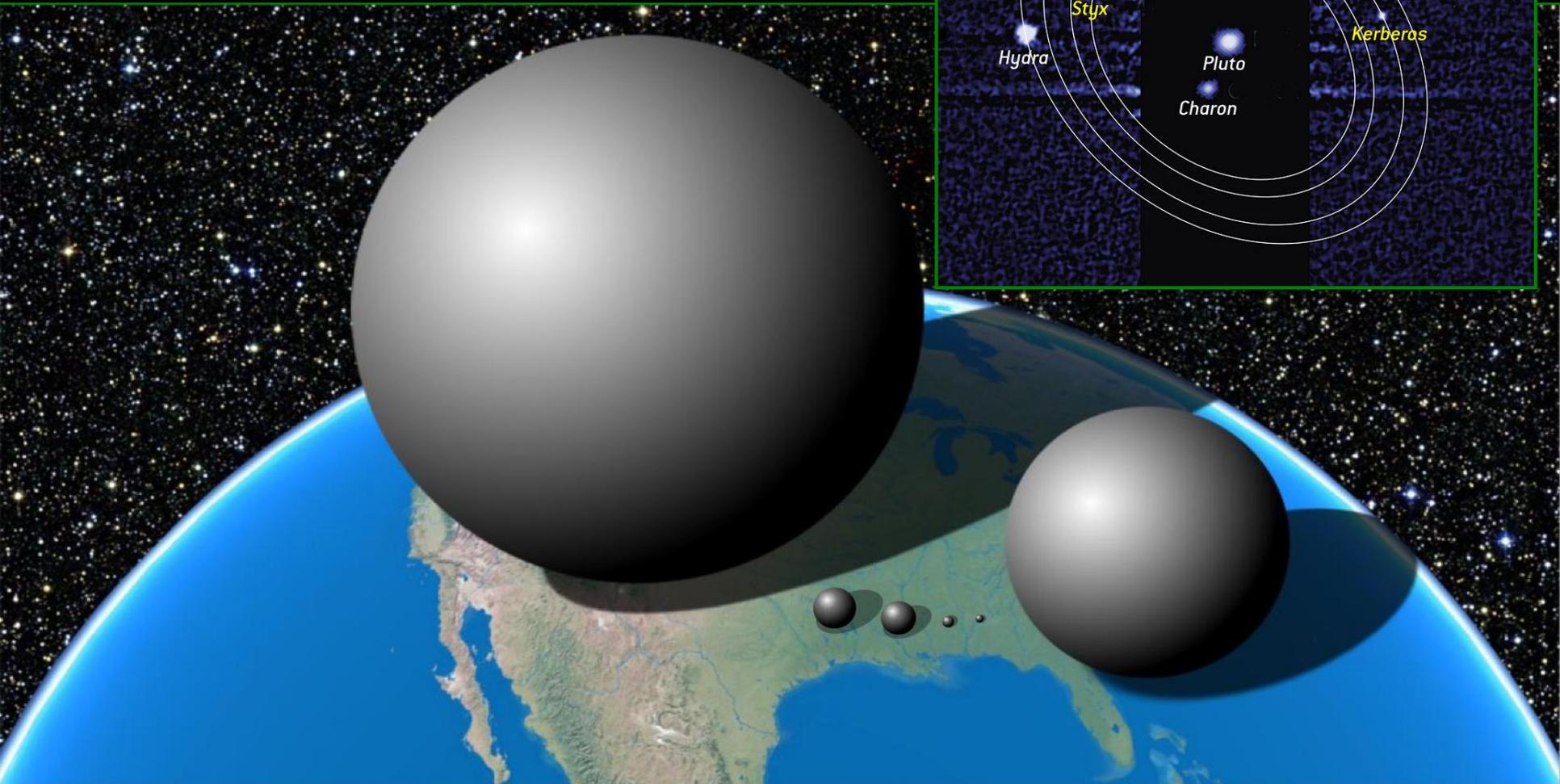
WELCOME TO PLUTO!



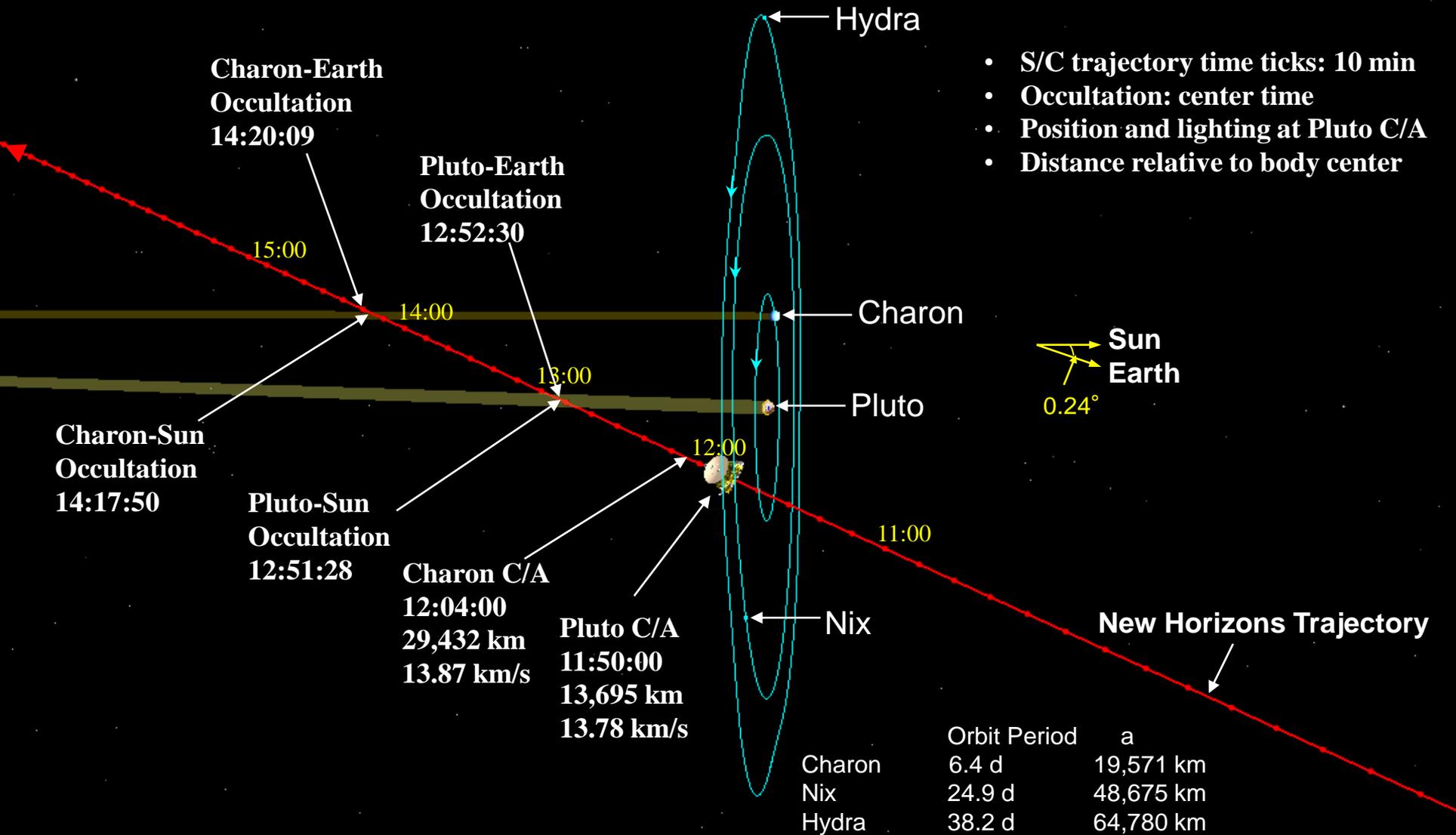
PLUTO FLYBY OVERVIEW

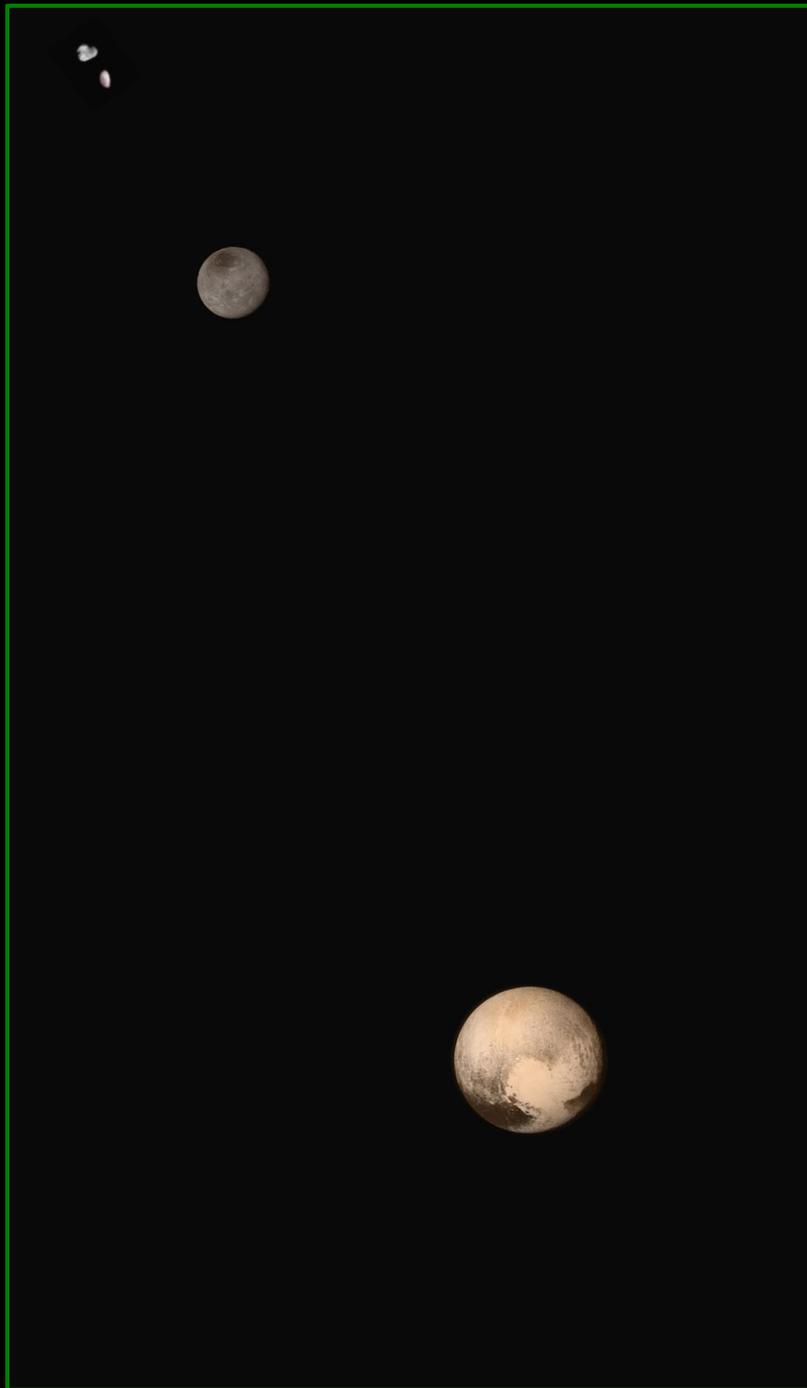


SIX BODIES TO STUDY



AND NEEDLES TO THREAD





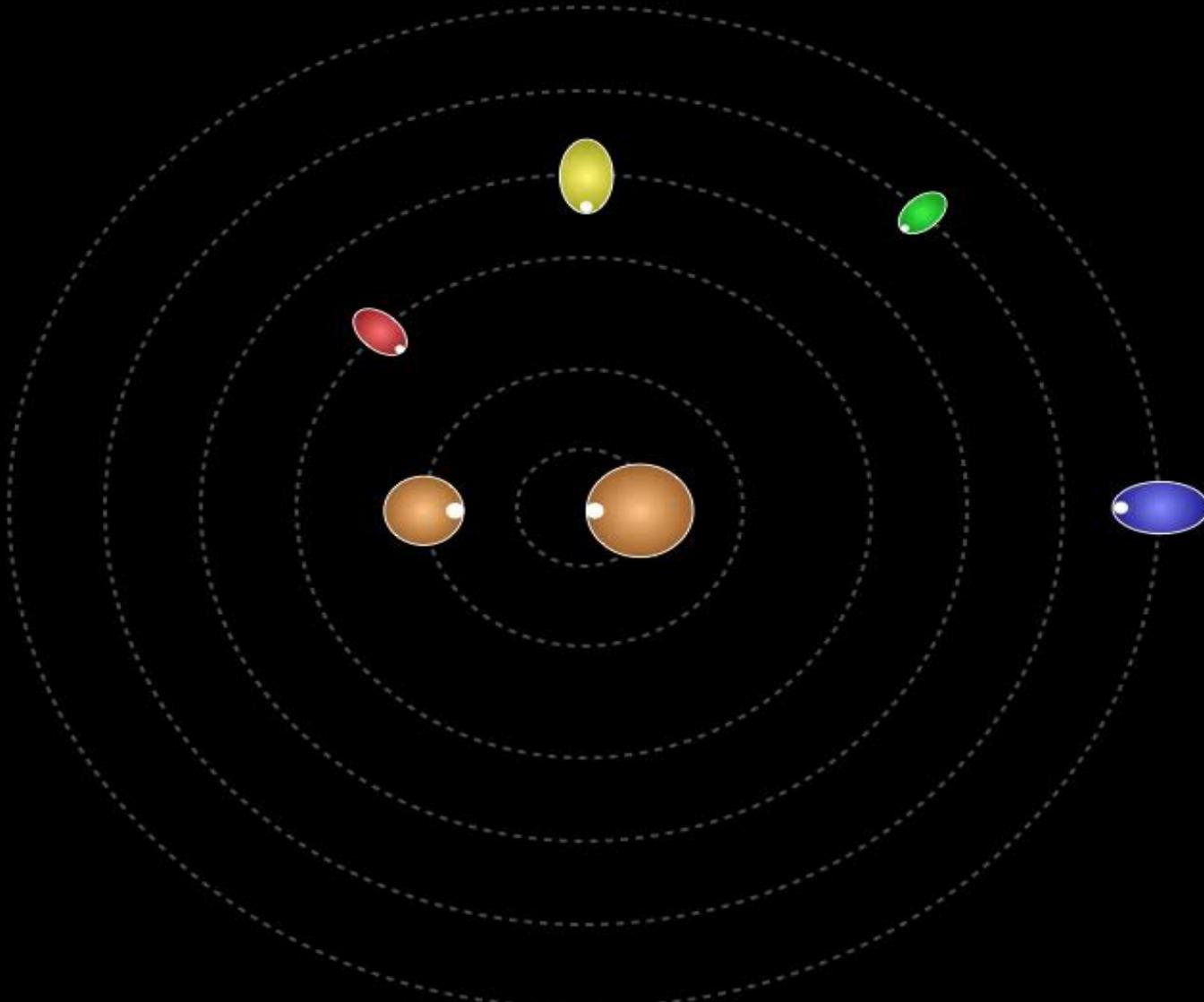


Charon



10 miles
10 km

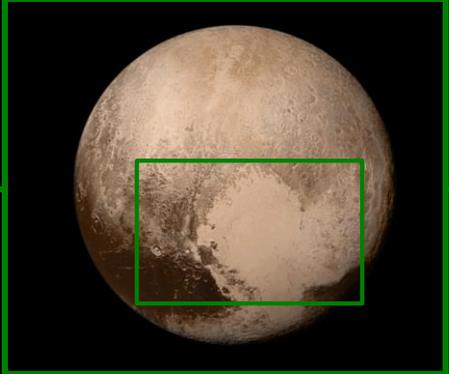
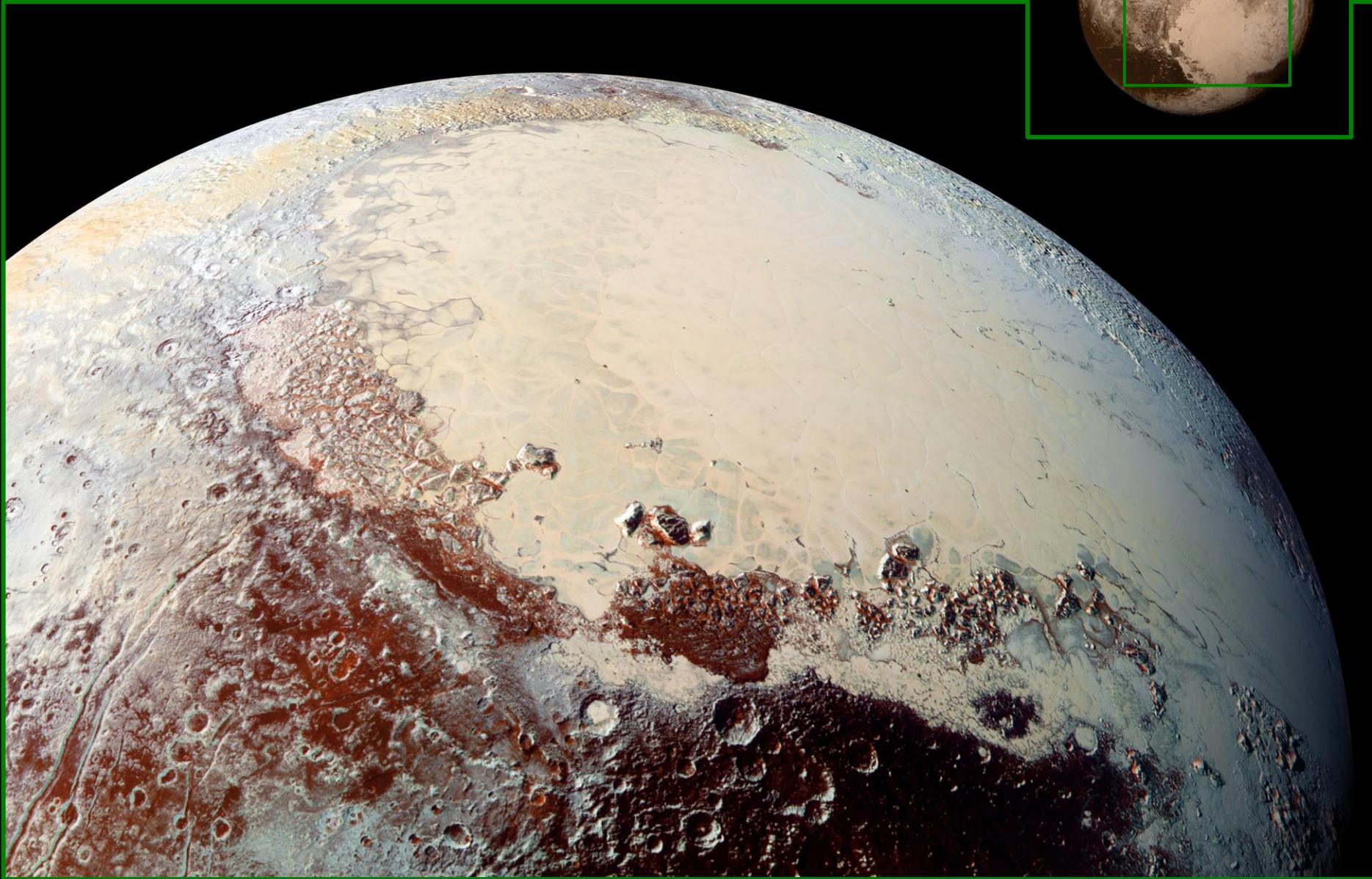


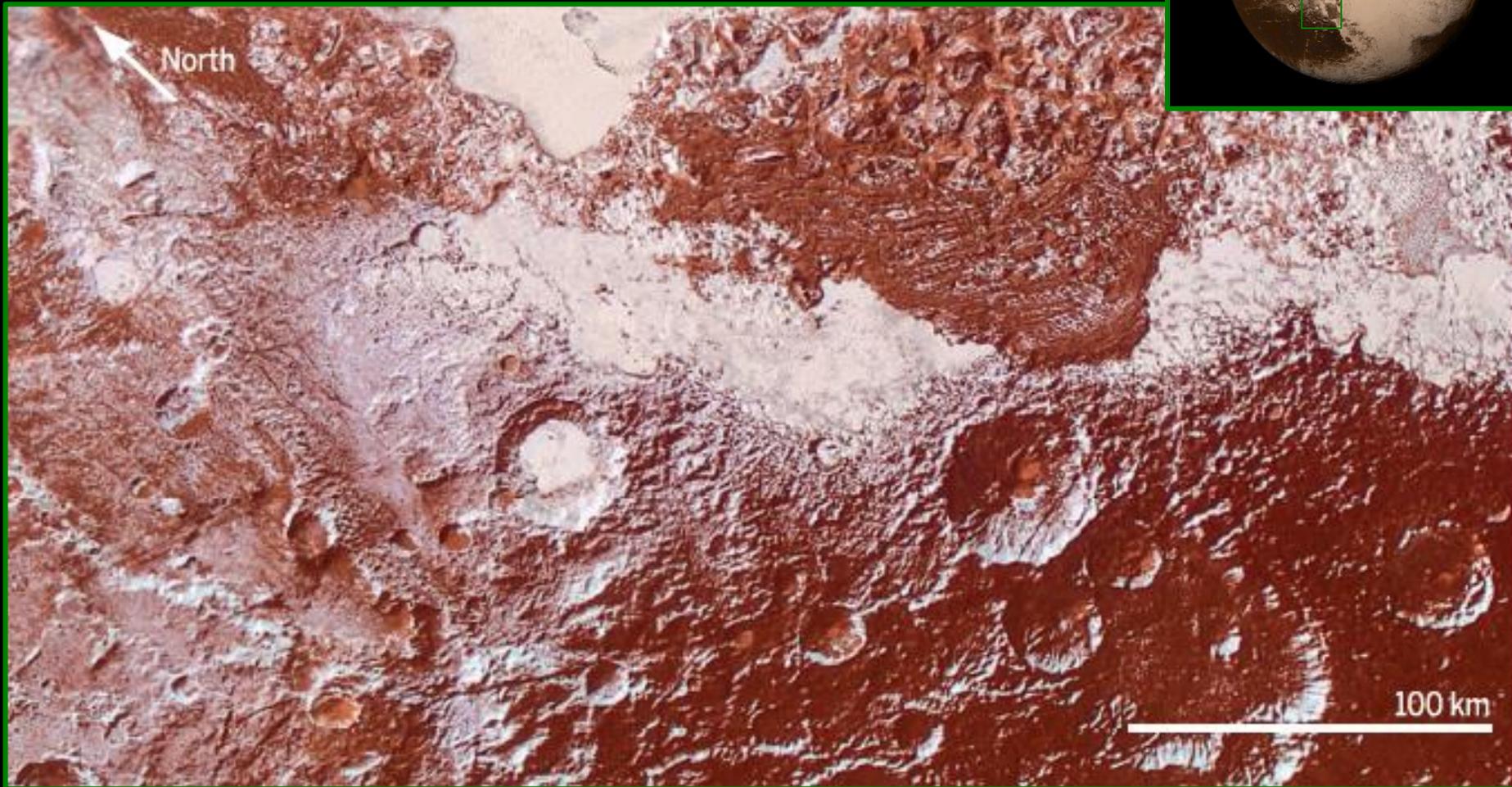
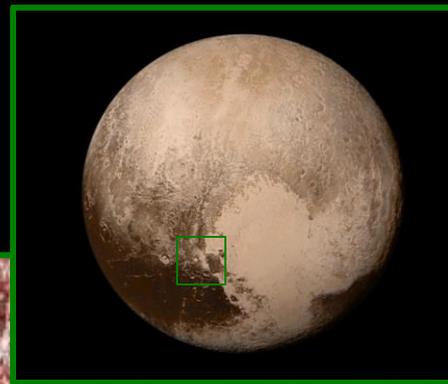


**PLUTO'S SMALL SATELLITES
ARE ALL RAPIDLY TUMBLING**

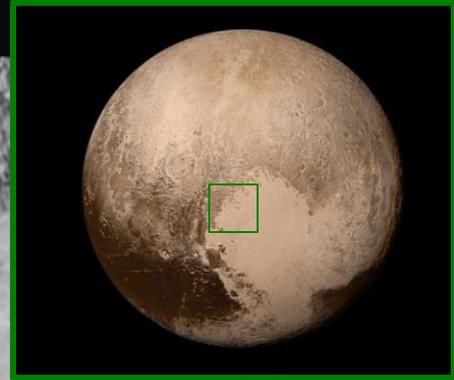
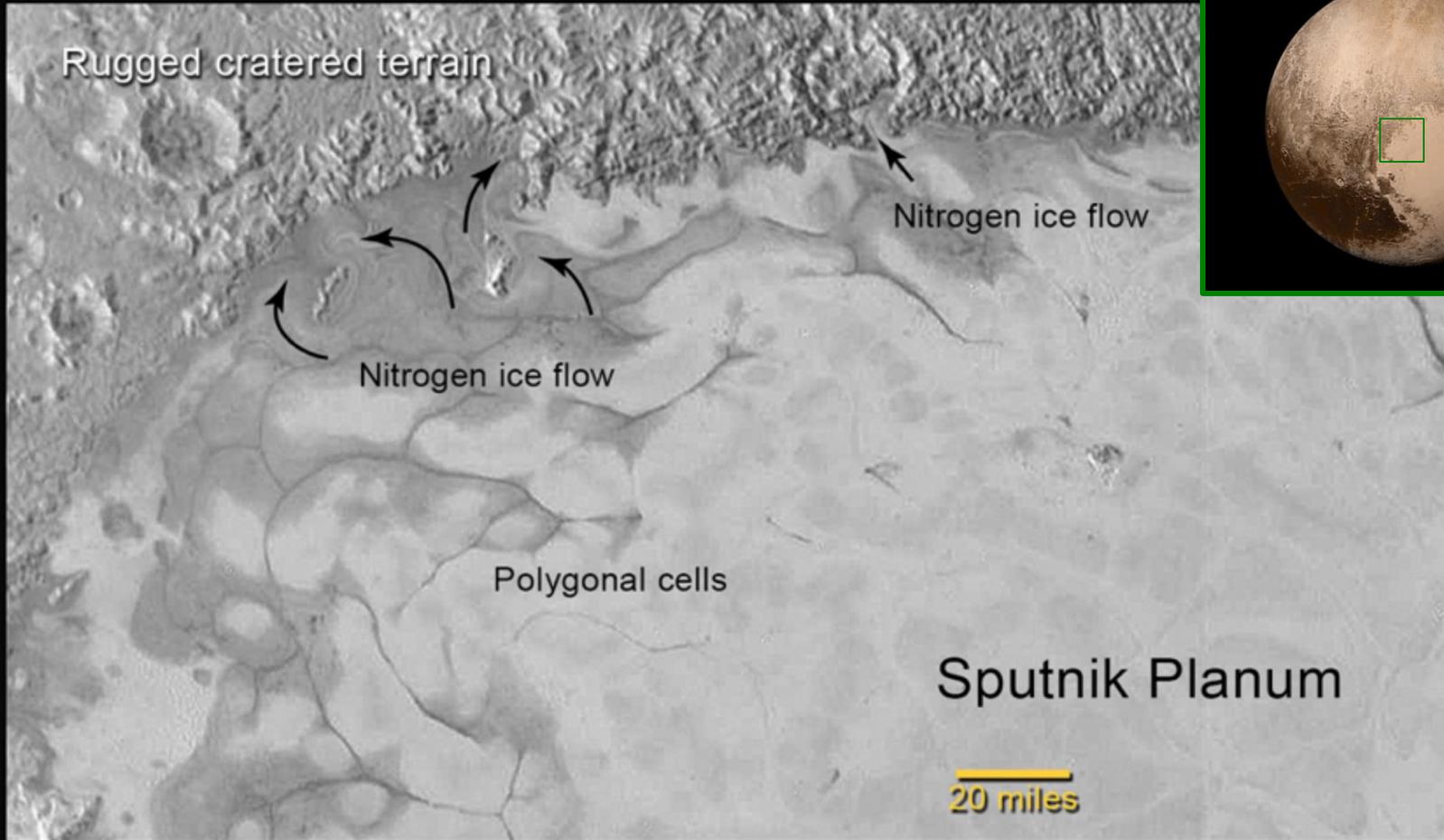


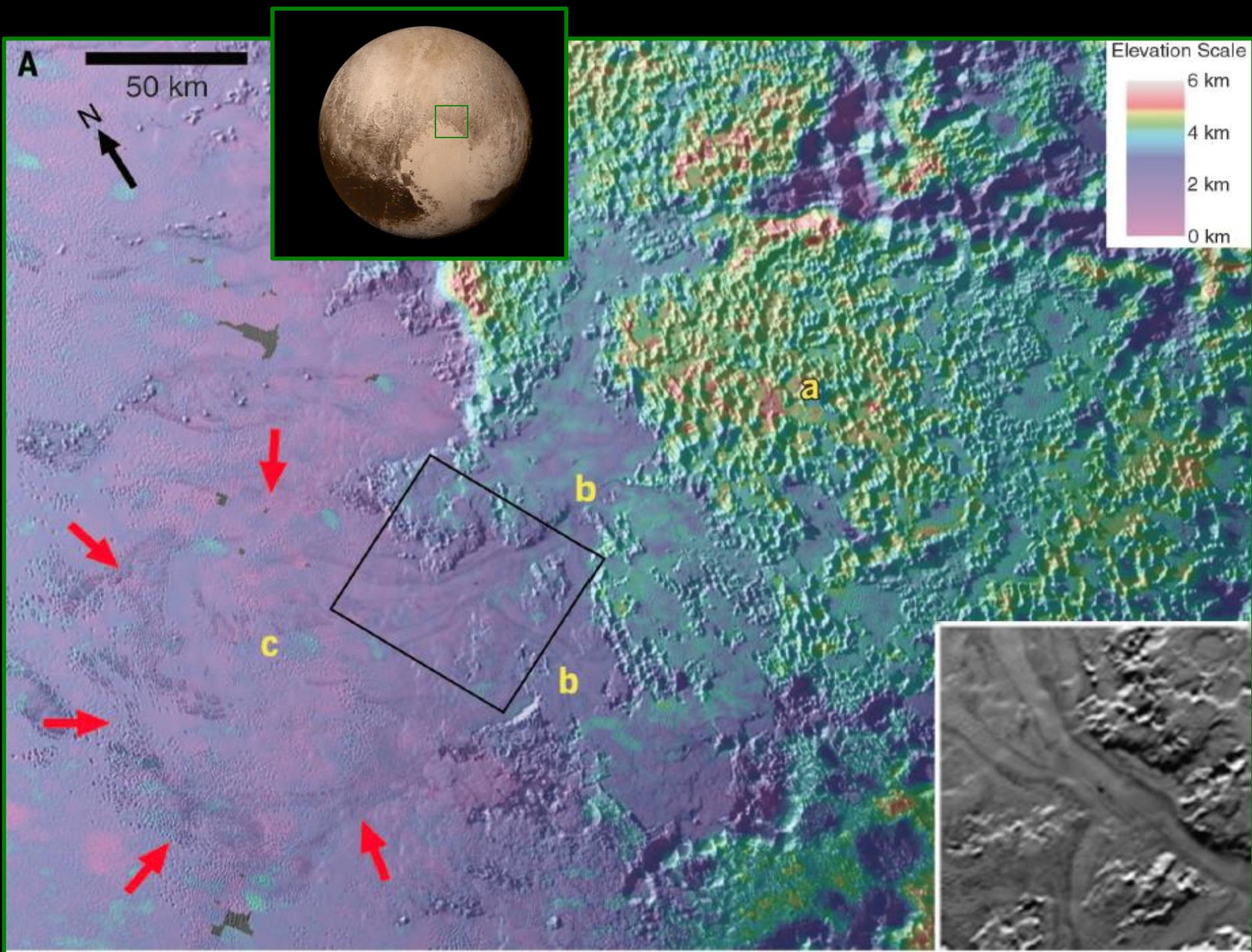


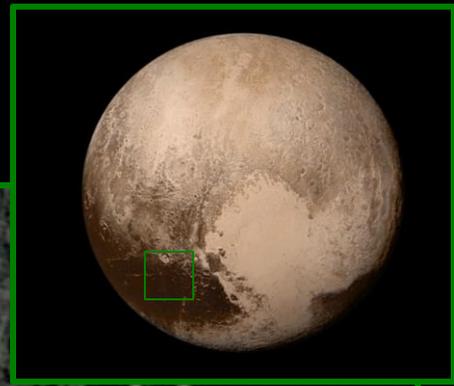
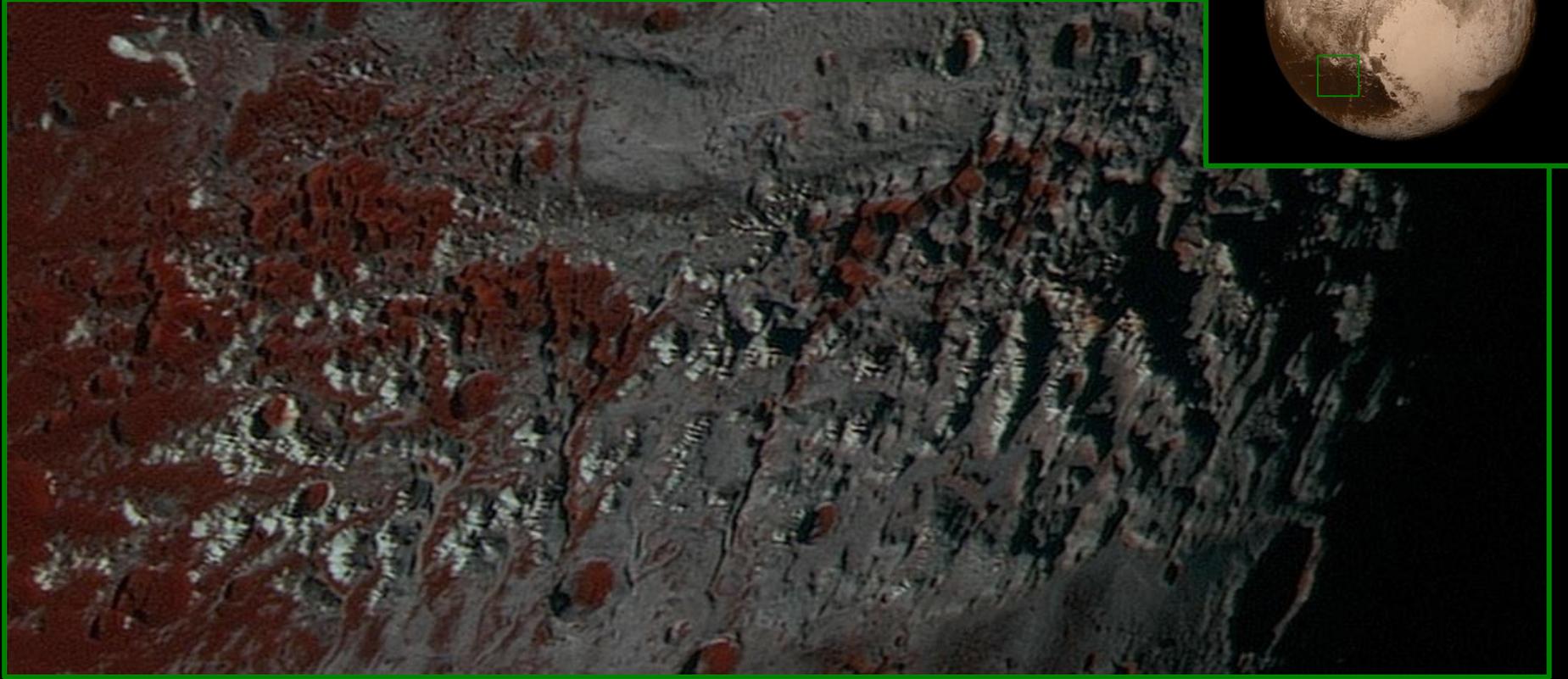


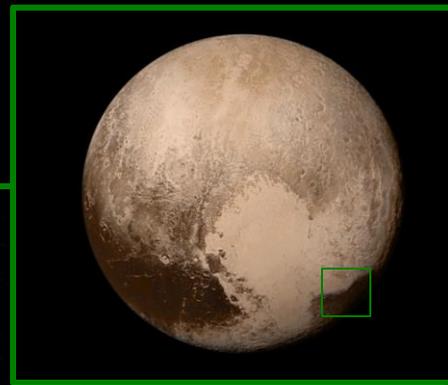
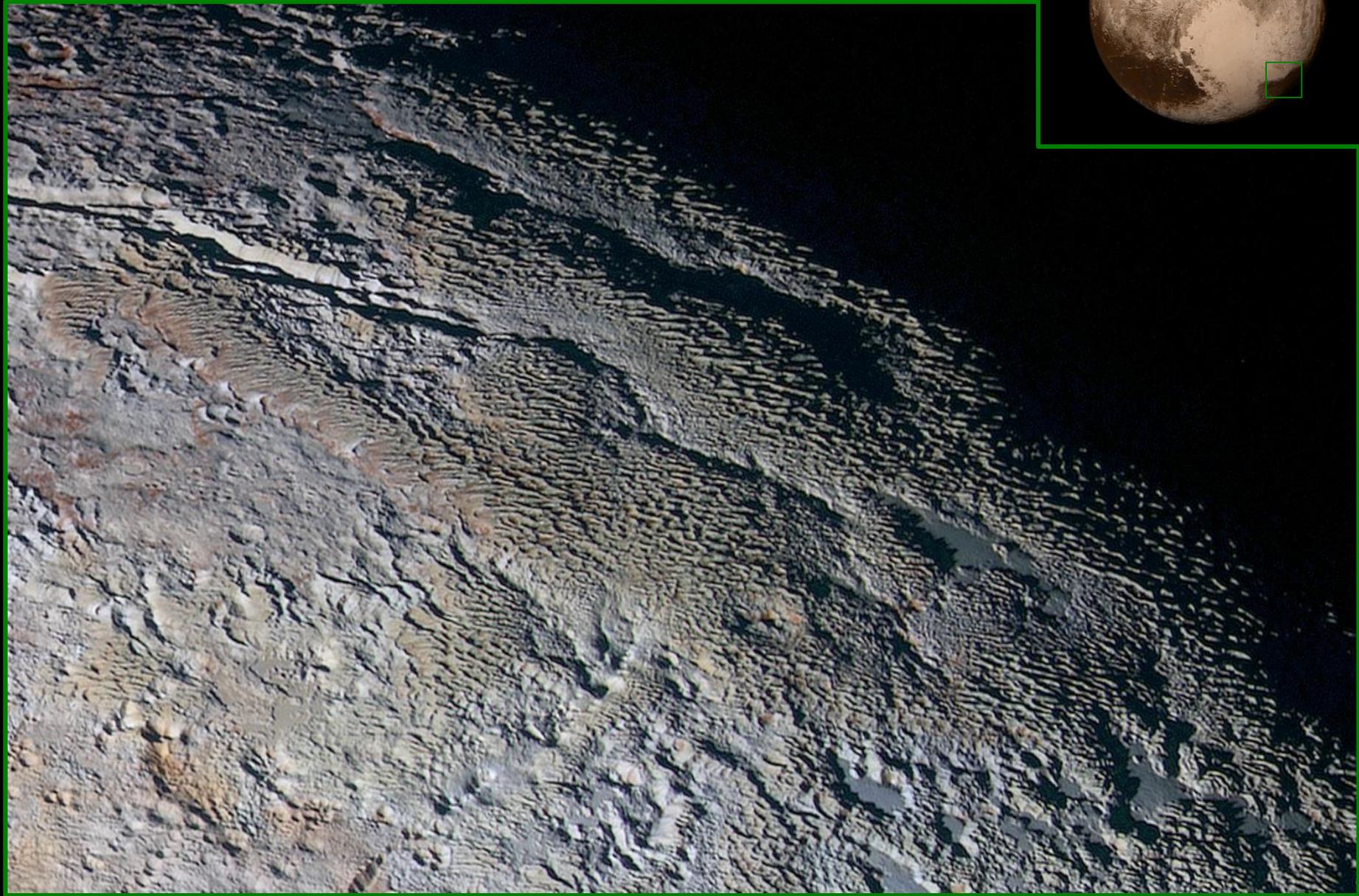


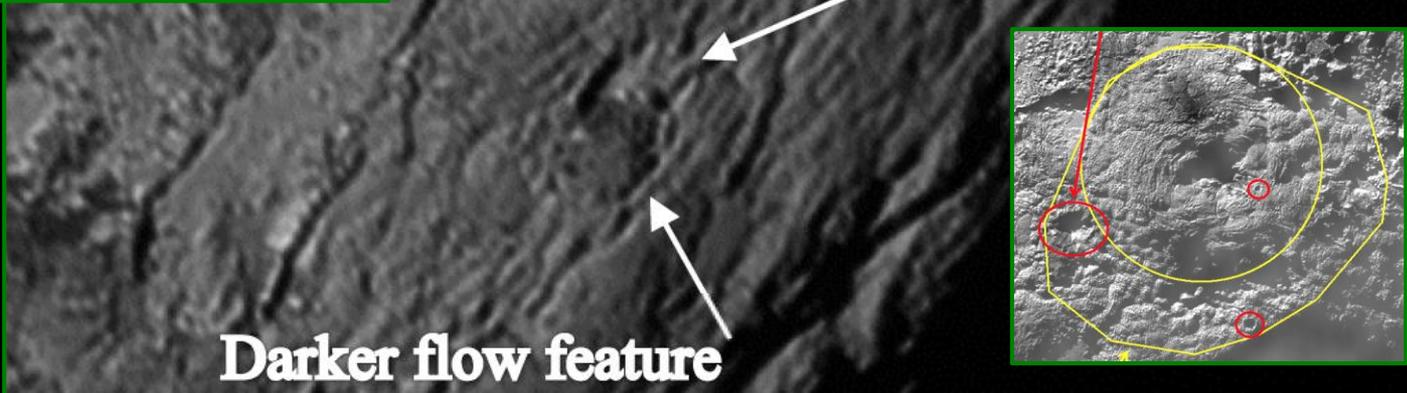
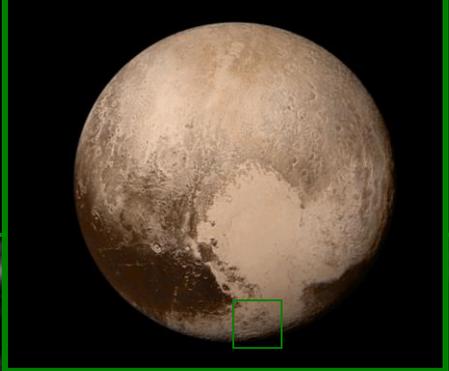
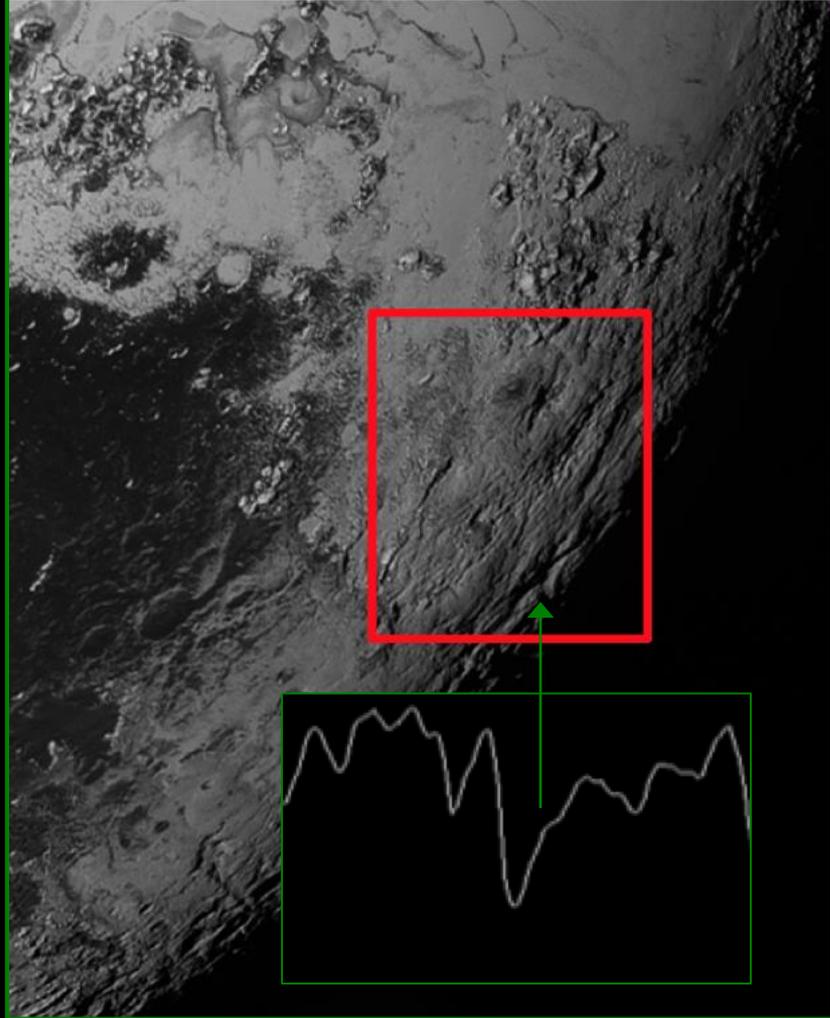
NEW HORIZONS: GLACIAL FLOW ON PLUTO

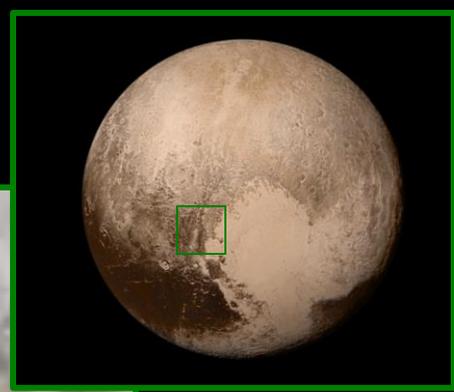




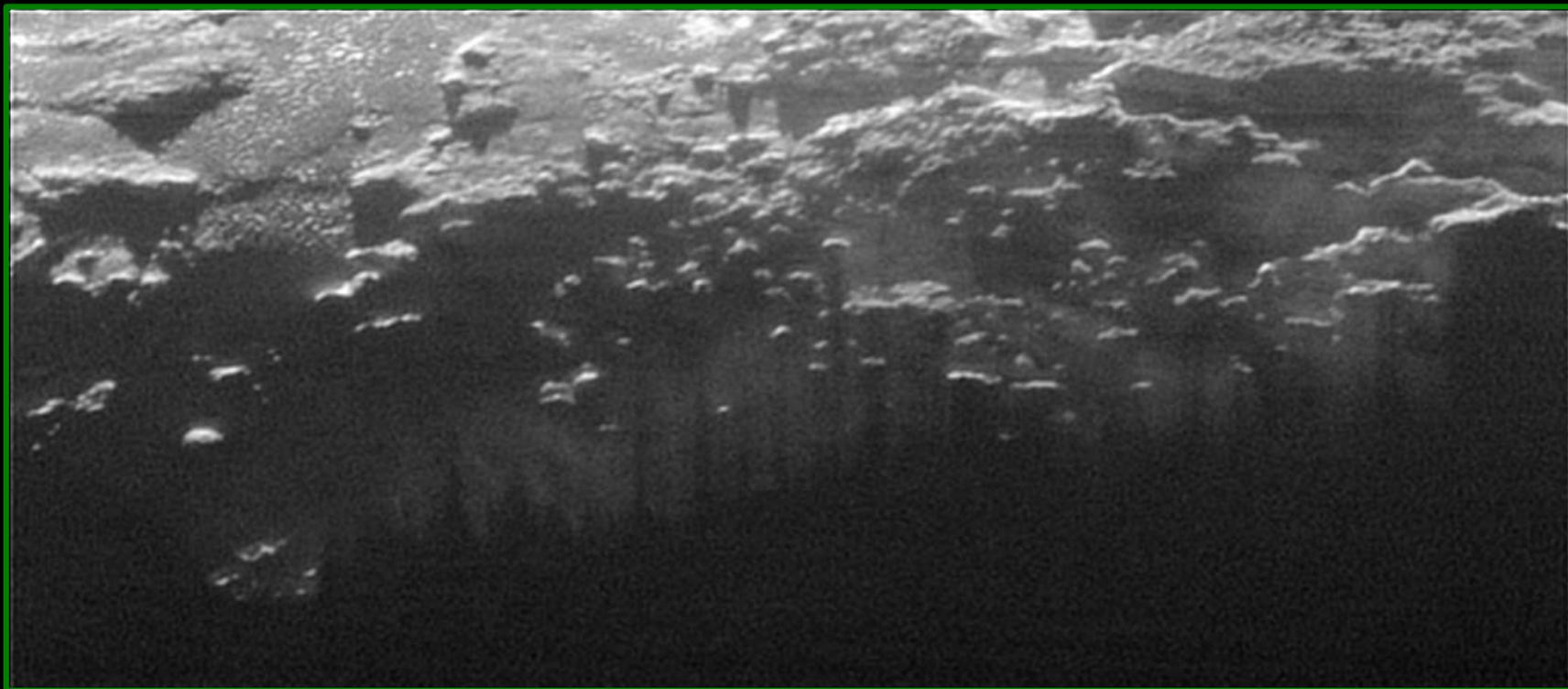


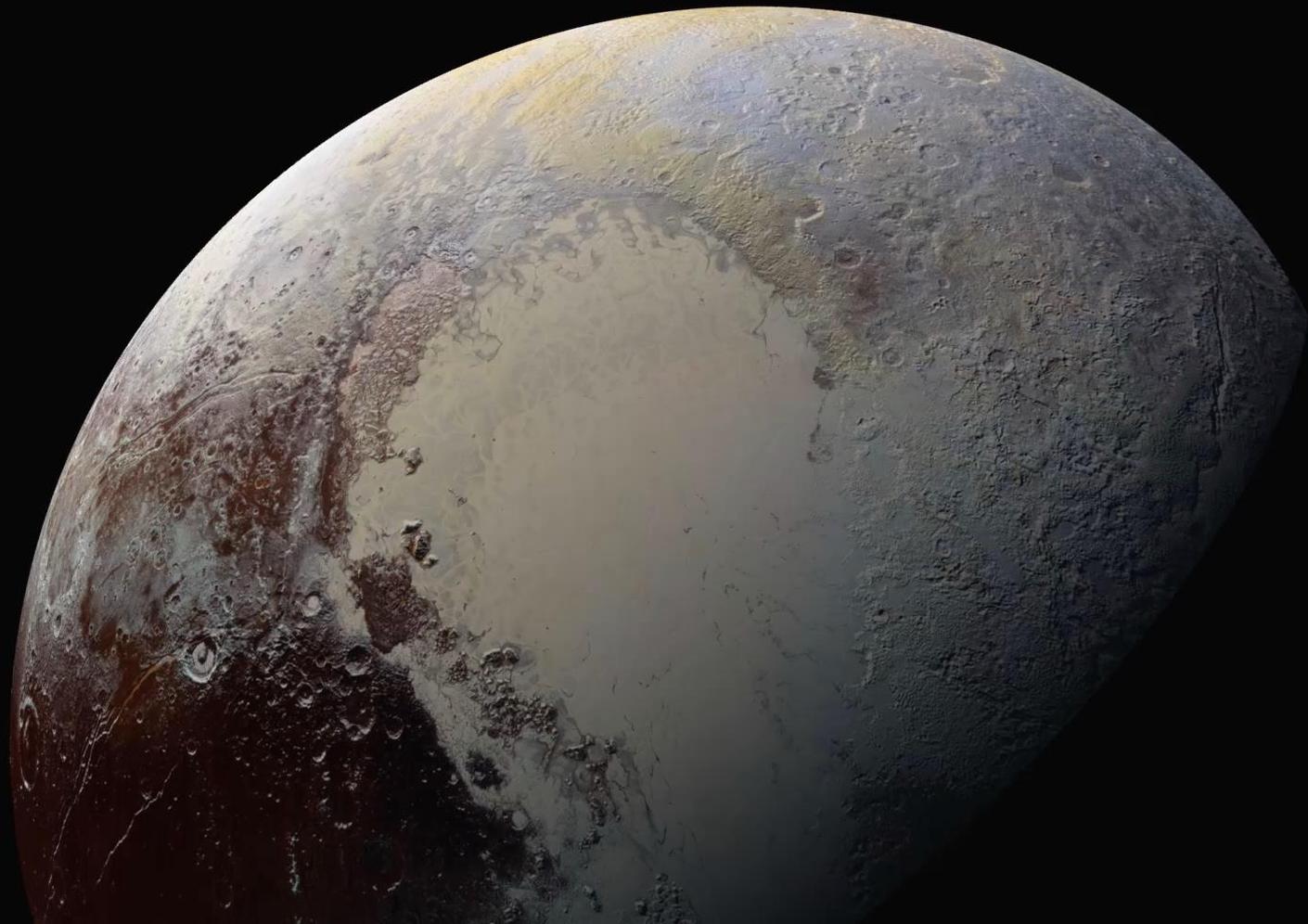














Pluto—Explored!

Pluto



Forever
USA

2016

New Horizons



Forever
USA

2016

New Horizons



Forever
USA

2016

Pluto



Forever
USA

2016



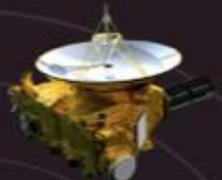


A PEEK INSIDE THE PLUTO PUBLIC RELATIONS MACHINE

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

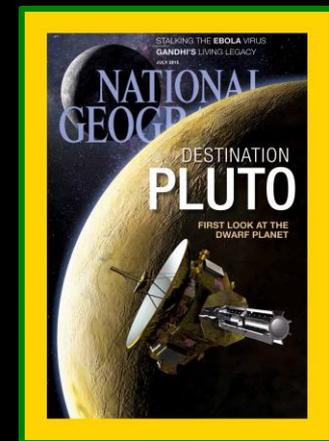
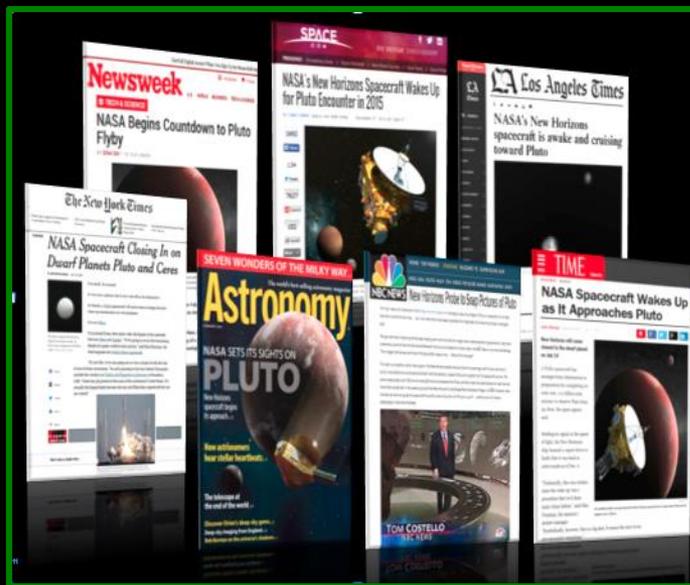
Number of web stream plays on NASA TV. The normal average is 10K plays per day.

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.



Late Edition
This page, along with the
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daily, except on
Sundays, except on
holidays, except on
the dates of July 1st
and 2nd, and on July 31st.

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\$2.50

12-4. Another News Service (The NY Times)
Daily and Sunday Edition: This, with
nightly, Sunday, and Saturday.
(See Page 1 for details)
(See Page 1 for details)
(See Page 1 for details)

TEN CENTS

NEW YORK, FRIDAY, JULY 19, 1965



Pluto's Portrait: Ice Mountains, No Craters and, for Scientists, a 'Toy Store'

SCIENTISTS' CLAIM
LANSING, Mich. — The first photograph of Pluto has revealed mountains as tall as the Rockies, and an absence of craters — discoveries that, to three delightfully speculative scientists on NASA's New Horizons mission, led to a preliminary conclusion for a journey now well a half-way to the ending.
"It's 12 years after the Wright brothers could barely get their airplane off the ground, a continent later, Earth has around the solar system to a small, icy world whose future is bright. The fact is, it's Sunday, when New Horizons is about 40 million miles from the distant, rocky planet, and it's only a few days after NASA's Mariner 10 spacecraft made a similar first pass by Venus."

Pluto was a few weeks ago was a mystery. Within the past couple of days, a few items (mountains) that a distance would make a good photograph demonstrate that Pluto is the presence of an icy world and a distant, rocky planet. All of the new information would provide clues to how planets form and even to the origin of life on the budding planets of the solar system.
"Scientists say one of the most interesting things they might have seen is a new way of life. A. Alan, says, the scientists' preliminary conclusion, and being a very tentative one."
"Without a doubt, an enormous amount of work is still to be done. The scientists are looking to explore the entire composition of Pluto, which is: "This is what we know."
"The mission will be to see the planet's surface and atmosphere, and the data they will collect will be the first step in understanding Pluto's true nature."



Area of view of Pluto shown in the photograph above is high as the Rockies.

Earlier in the day, three scientists had also taken the first photo of a spherical planet of the size that had captured the attention of the public. The photo was taken from the New Horizons mission, which is now on its way to Pluto. The scientists said that the photo was "the first step in understanding Pluto's true nature."
"The first step was to see the planet's surface and atmosphere, and the data they will collect will be the first step in understanding Pluto's true nature."
"The first step was to see the planet's surface and atmosphere, and the data they will collect will be the first step in understanding Pluto's true nature."

YEARS OF TRADING AND COMPROMISE SEALED IRAN DEAL

ASSIST FROM A SUITAN

Concluding That Halting
Beard Development
Exposed All Else

By JAMES R. HANCOCK
and MICHAEL S. GREENBERG

WASHINGTON — The 10-year search for a nuclear deal between the United States and Iran has ended in a triumph for the United States, but the deal is far from perfect. The deal, which was announced today, is a landmark in the history of U.S.-Iran relations. It is the first time that the United States has agreed to a nuclear deal with Iran. The deal is a landmark in the history of U.S.-Iran relations. It is the first time that the United States has agreed to a nuclear deal with Iran.

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Year-Long Boom in Spending

Administration Forces Deal
to Kill 'Mexicans'

By MARGARET DUTCHER
Special to The New York Times

WASHINGTON, July 18 — Administration forces, concerned by a long-term decline in U.S. savings, have passed a bill to increase the savings rate. The bill is a landmark in the history of U.S.-Iran relations. It is the first time that the United States has agreed to a nuclear deal with Iran.

WASHINGTON, July 18 — Administration forces, concerned by a long-term decline in U.S. savings, have passed a bill to increase the savings rate. The bill is a landmark in the history of U.S.-Iran relations. It is the first time that the United States has agreed to a nuclear deal with Iran.

SENATE APPROVES HOUSING MEASURE WITH RENT SUBSIDY

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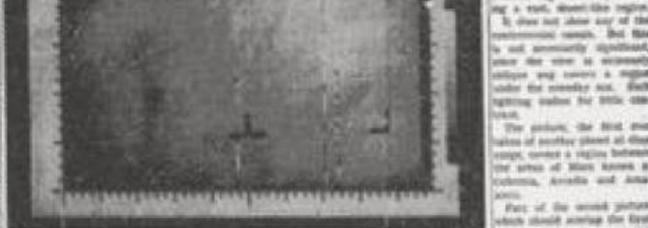
FIRST MARS PHOTO IS TRANSMITTED; MARINER SIGNALS INDICATE PLANET LACKS A LIQUID CORE LIKE EARTH'S

Administration Forces Deal
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FIRST CLOSE-UP OF MARS: Photograph was by Mariner 4 of the planet and sent back to earth. The area covered along edge of planet is about 200 miles. Most was taken at about 10,000 miles. It is expected to add greatly to scientists' knowledge of Mars.

OTHER DATA SENT

Sensors Find Scant
Radiation Belt and
Thin Atmosphere

By HELEN GARDNER
Special to The New York Times

WASHINGTON, July 18 — Mariner 4 has sent back the first close-up photograph of Mars. The planet, transmitted today in an eight-hour broadcast, is a distance of 120 million miles from the "Red Planet," as the planet is known. The data is not immediately significant, but the first is extremely important, and the rest is extremely interesting. The data is not immediately significant, but the first is extremely important, and the rest is extremely interesting.

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Spyder Webb @Spyder_Webb · 4h

Front page of The New York Times as it appeared on 16 July 2015 and 16 July 1965 #PlutoFlyBy

#NewHorizons #Mariner

You, Pluto, NASA New Horizons and 7 others



NEW HORIZONS

NASA's Pluto-Kuiper Belt Mission



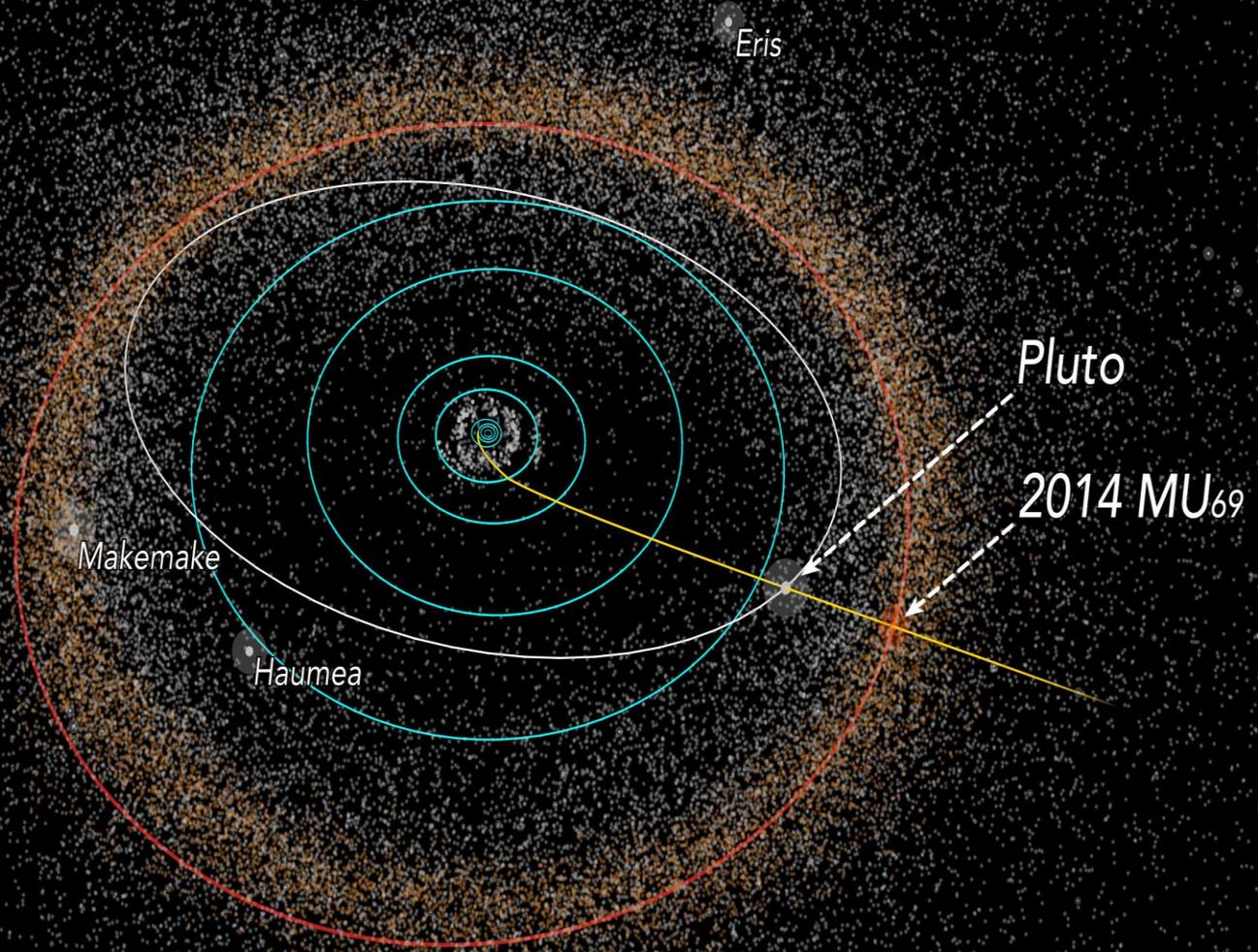
SWRI

• NASA

• JHU/APL

Backups

EXTENDED MISSION: 2016-2021



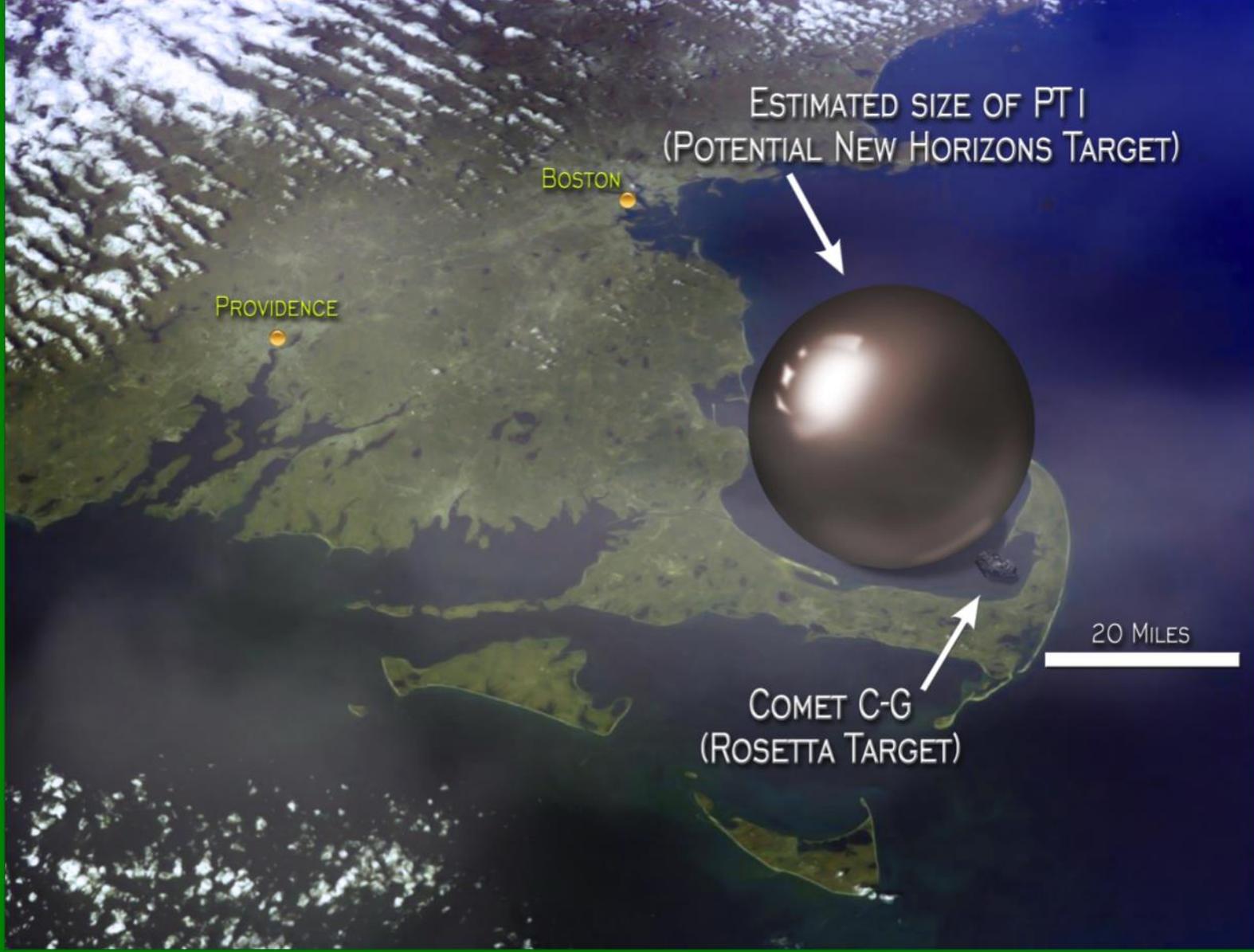
ESTIMATED SIZE OF PT I
(POTENTIAL NEW HORIZONS TARGET)

BOSTON

PROVIDENCE

COMET C-G
(ROSETTA TARGET)

20 MILES



MOMENTOS



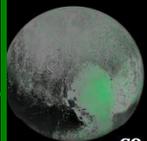
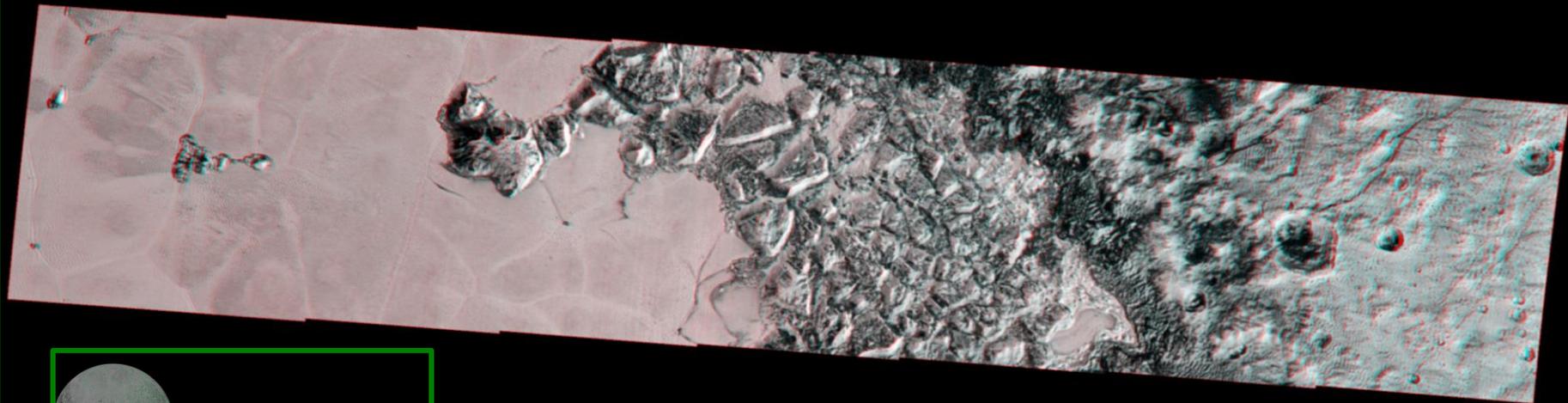
Clyde and the Stamp



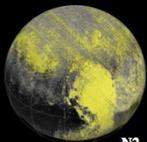
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Clyde





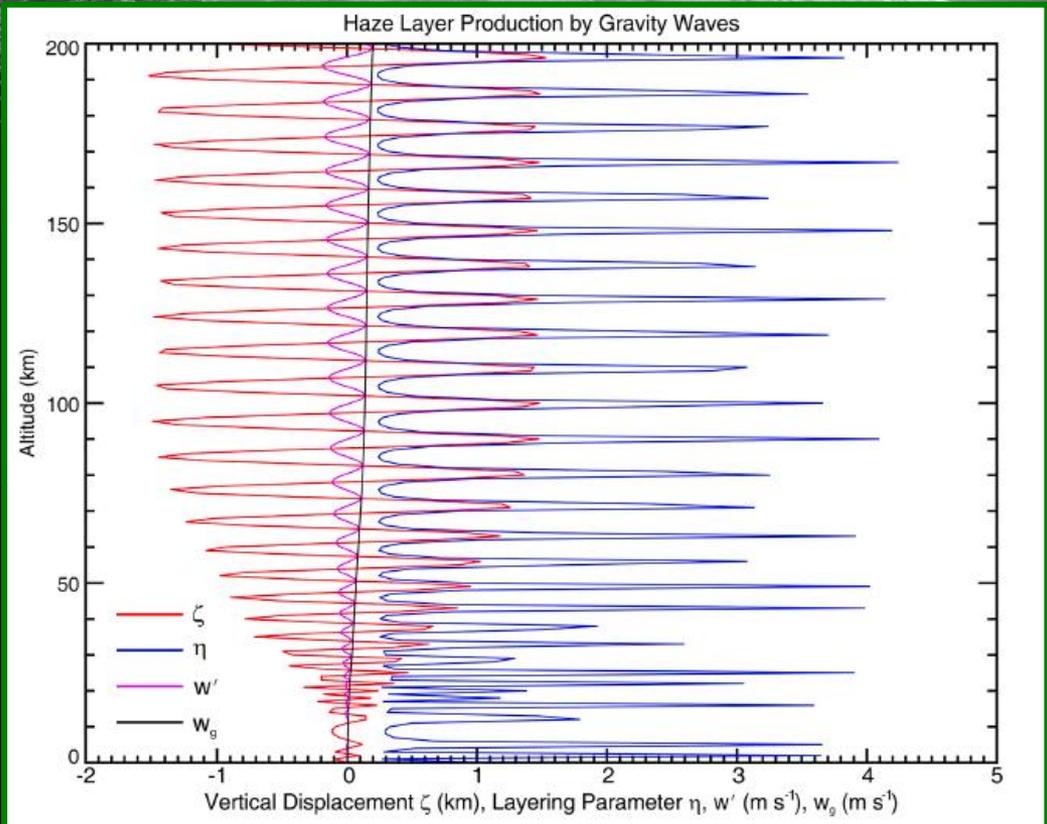
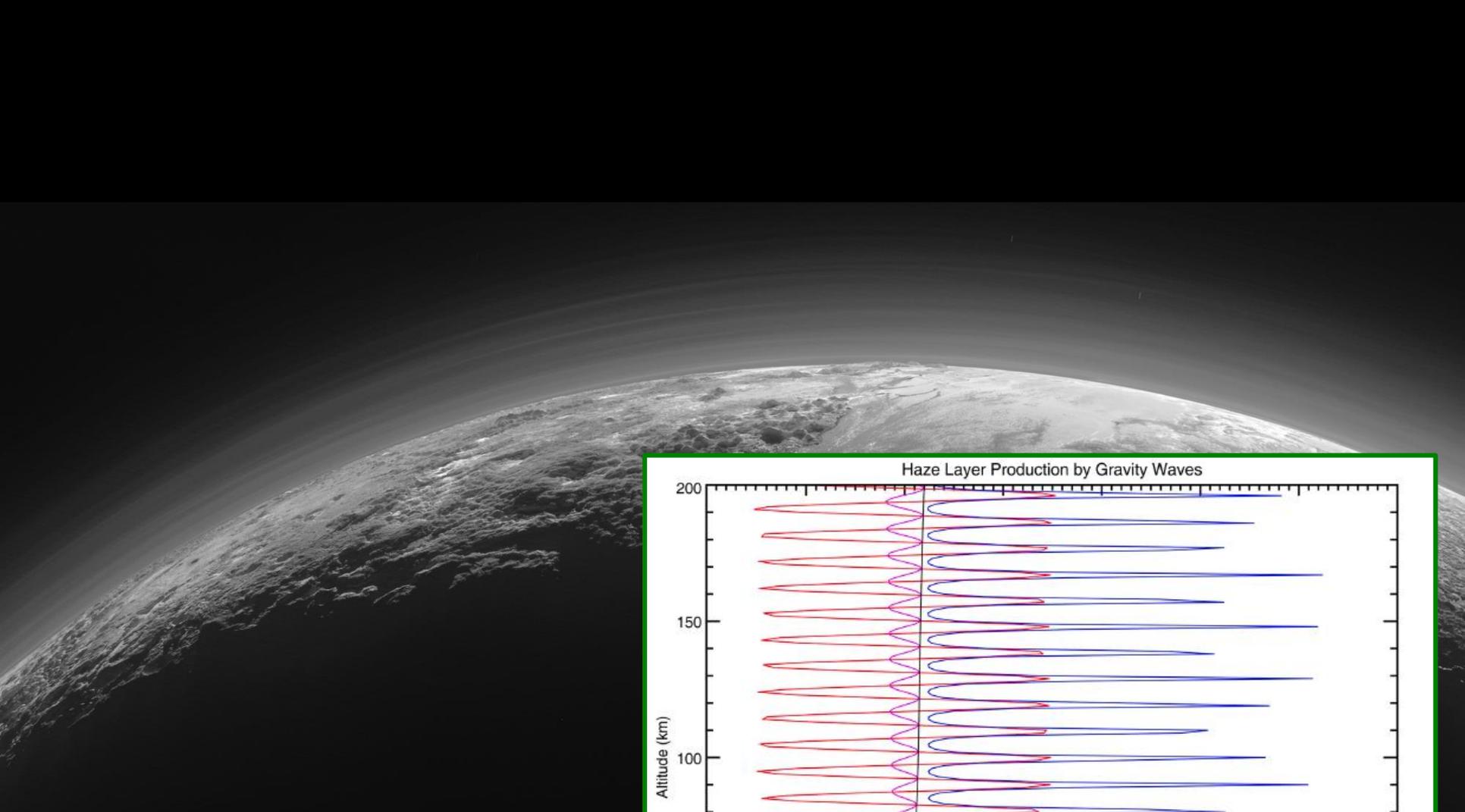
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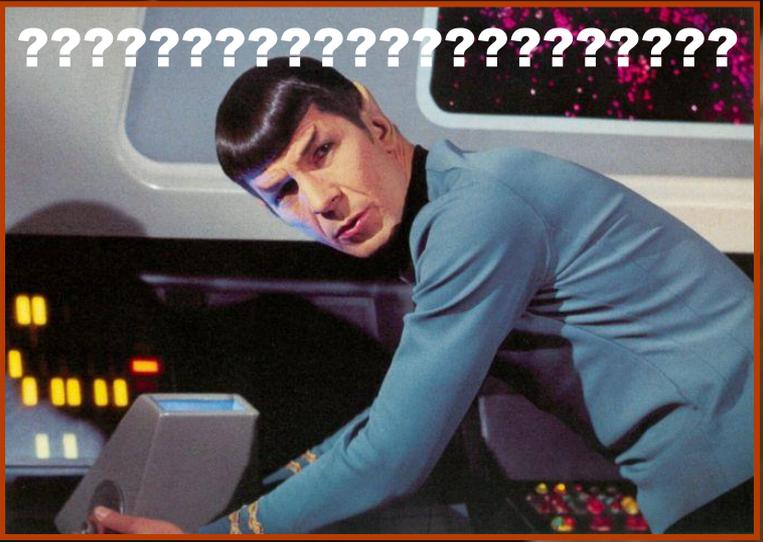
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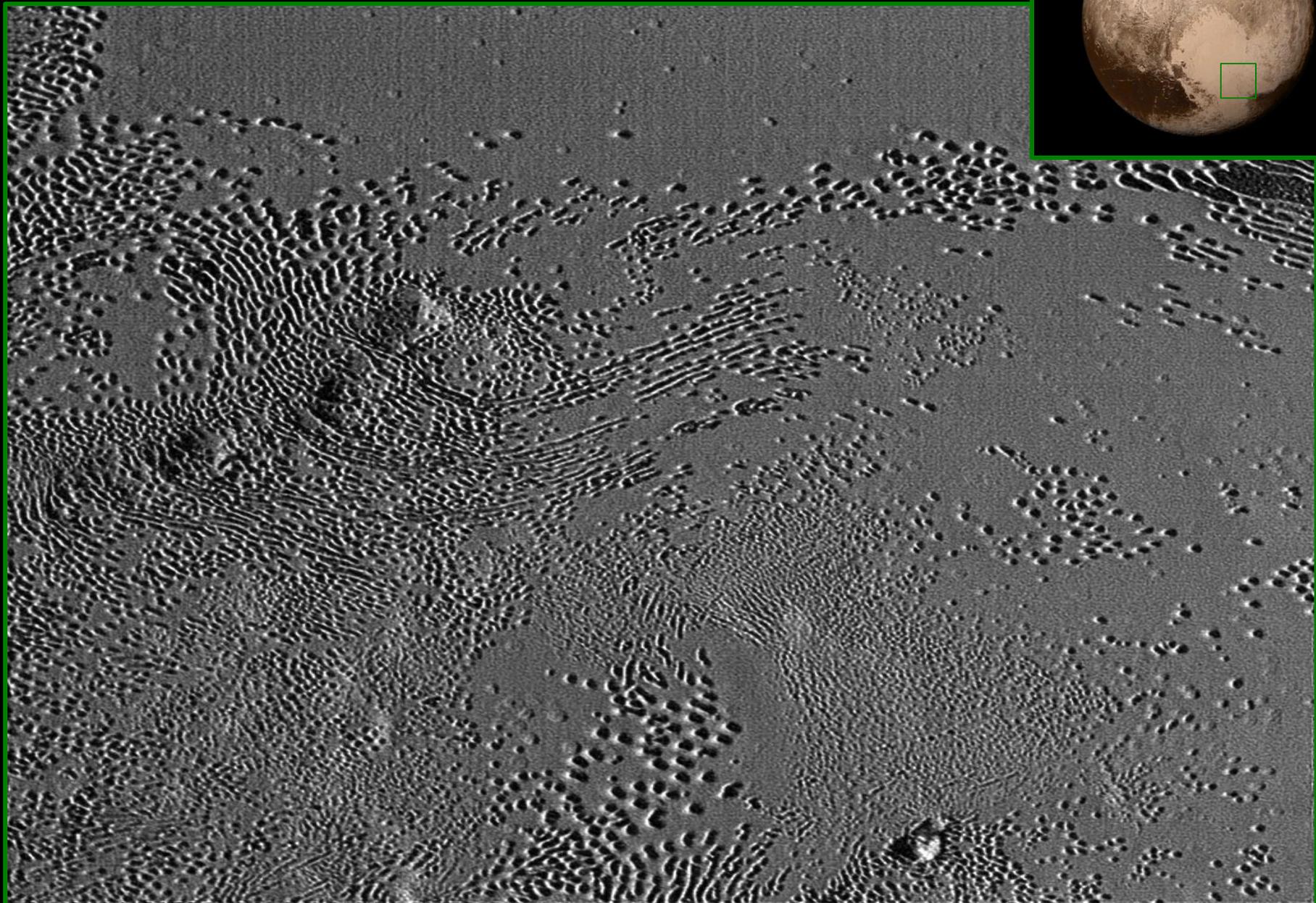
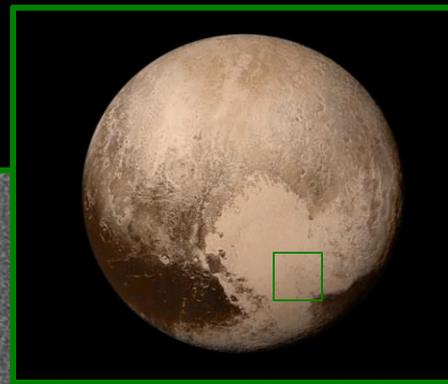
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Is It Really So Hard?



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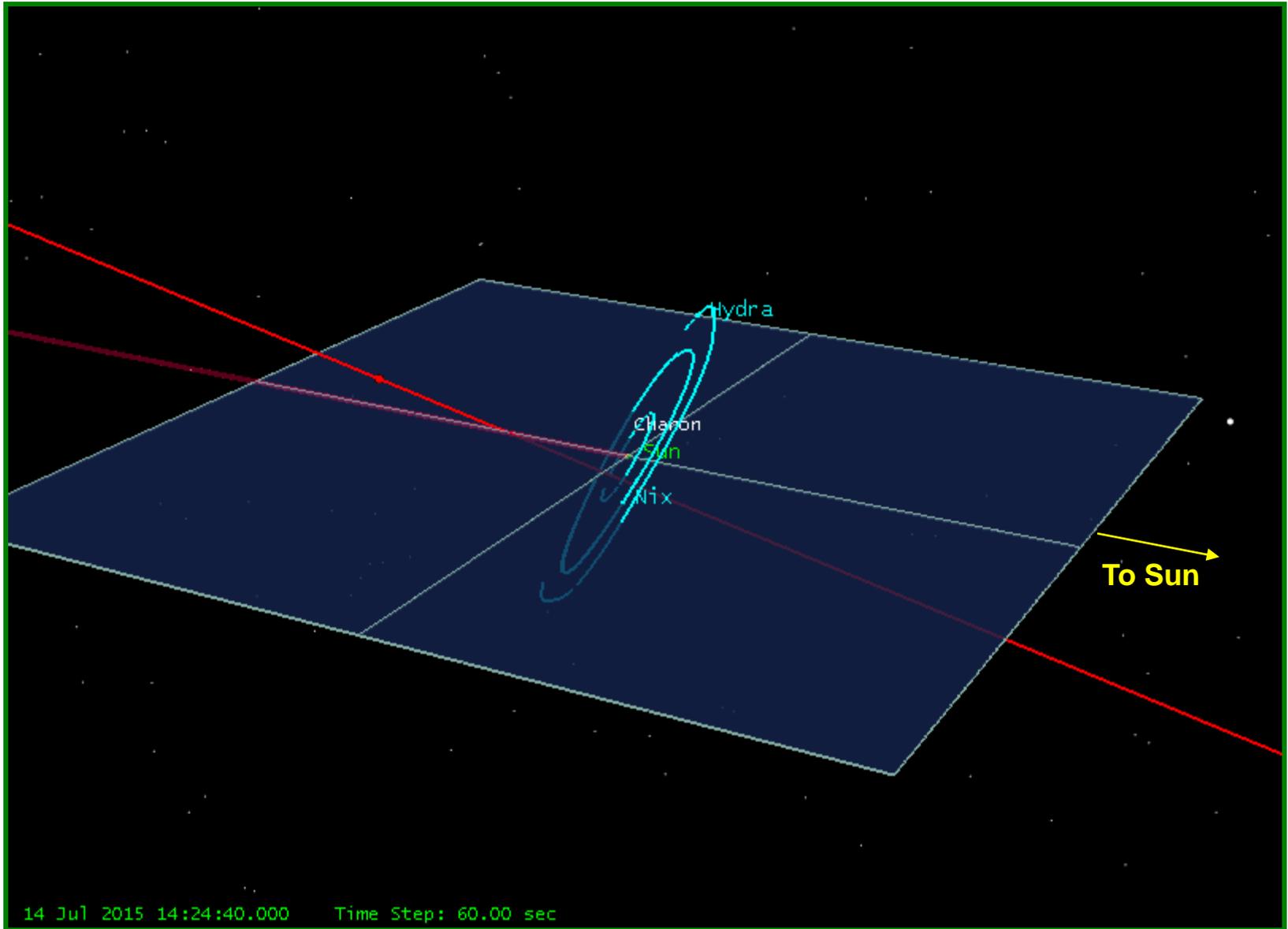
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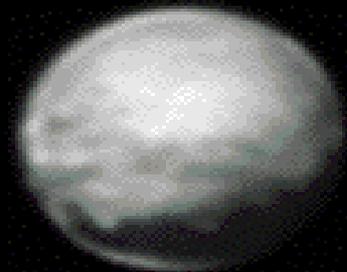
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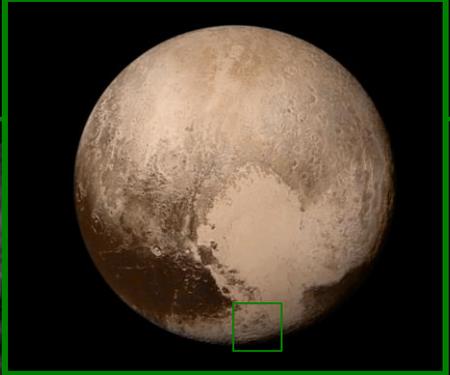
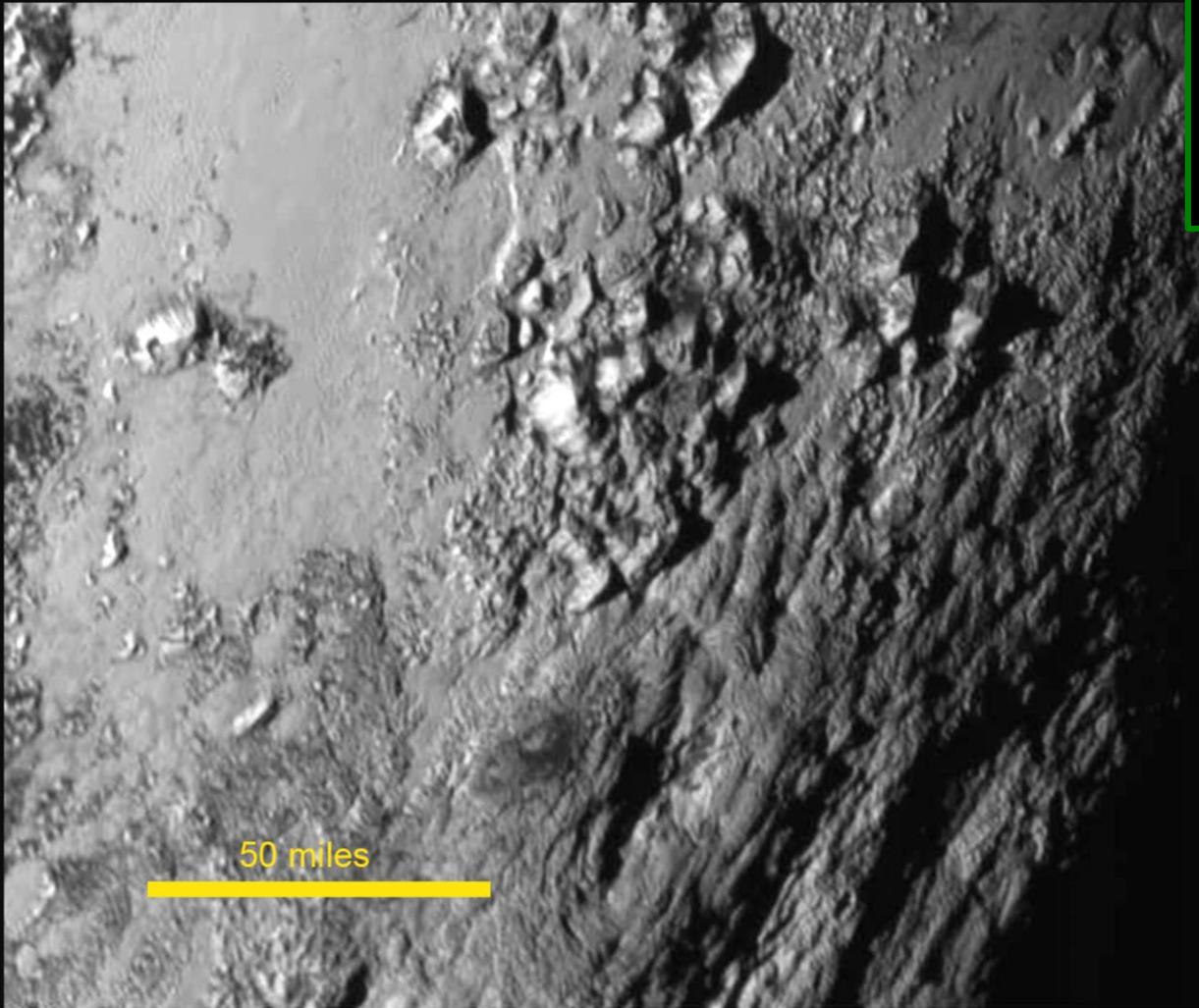


PLUS A SPECIAL ENCOUNTER GEOMETRY



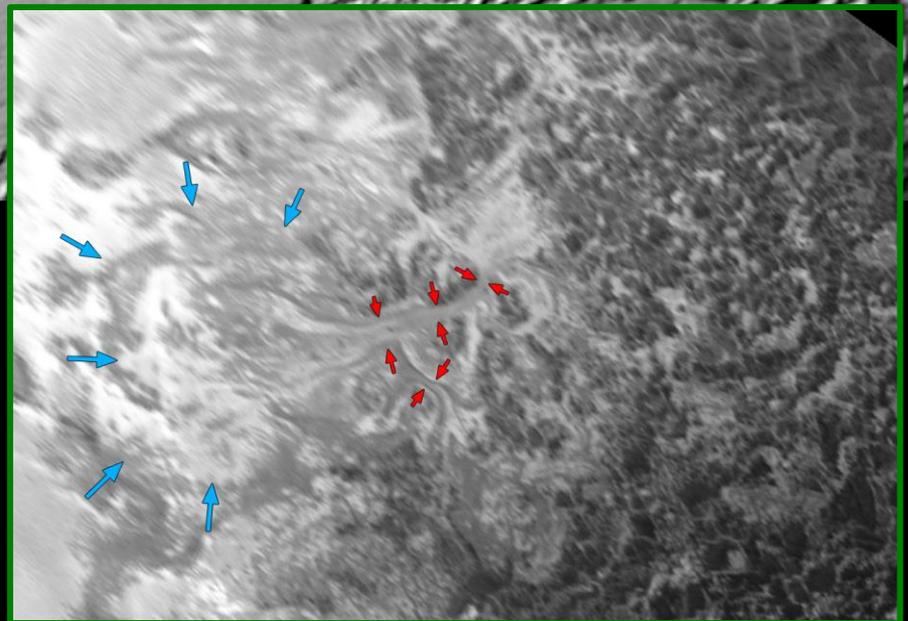
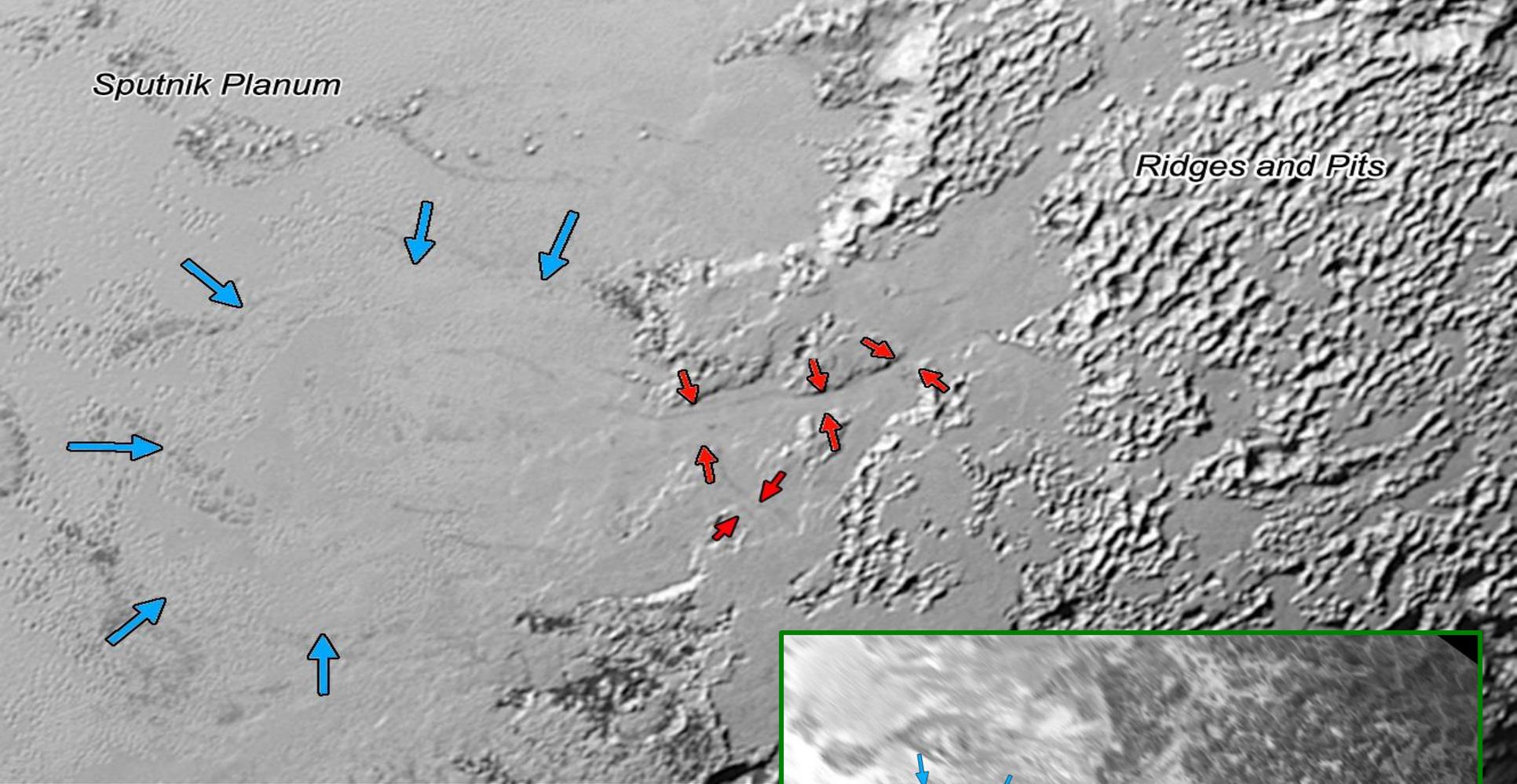


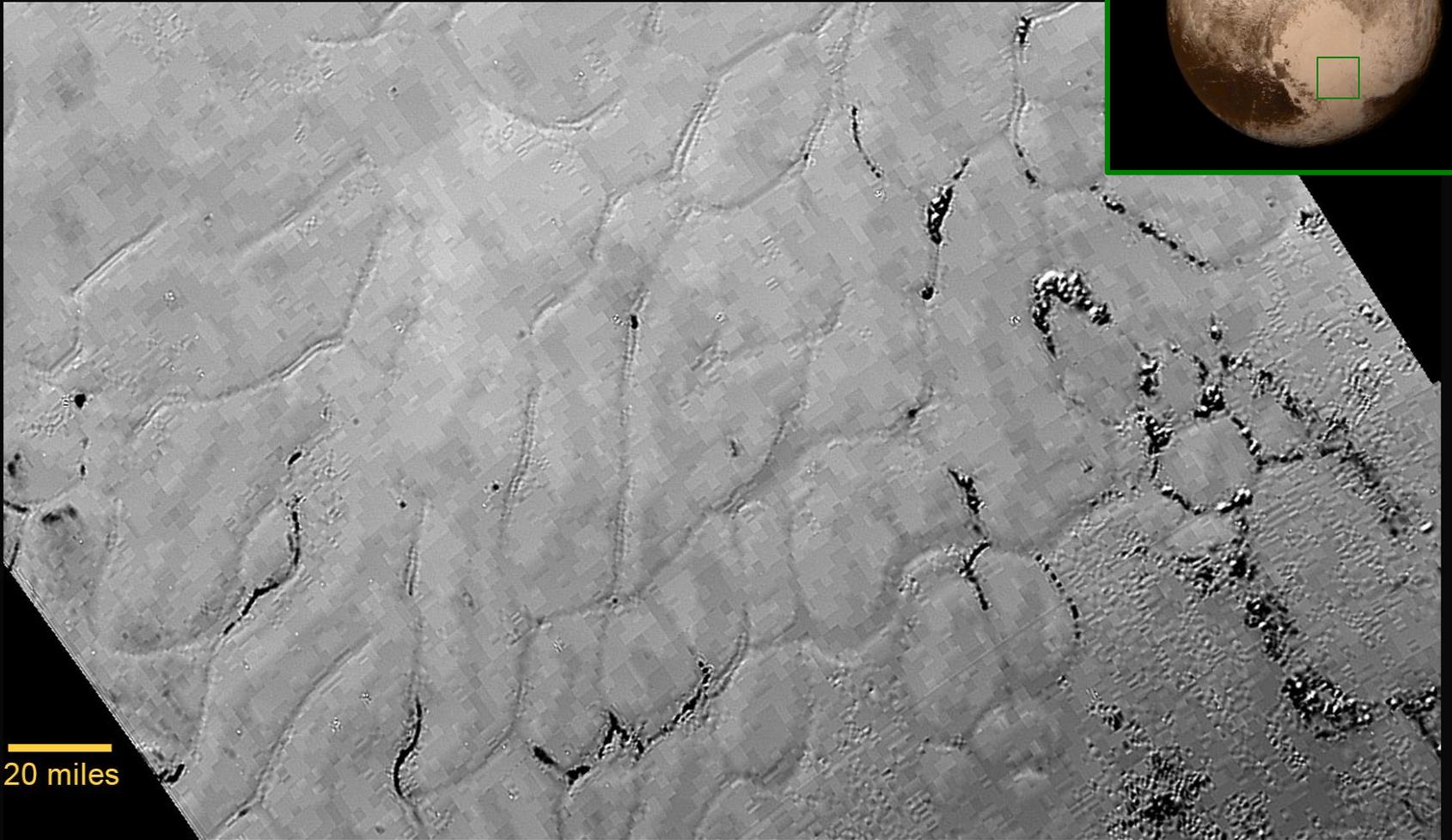




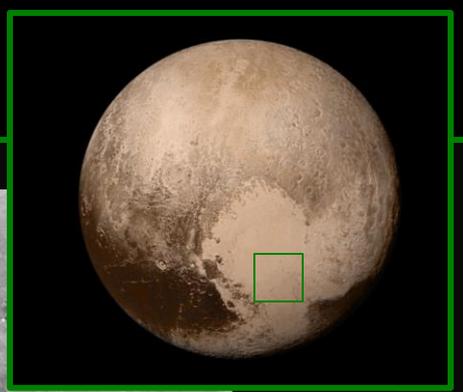
Sputnik Planum

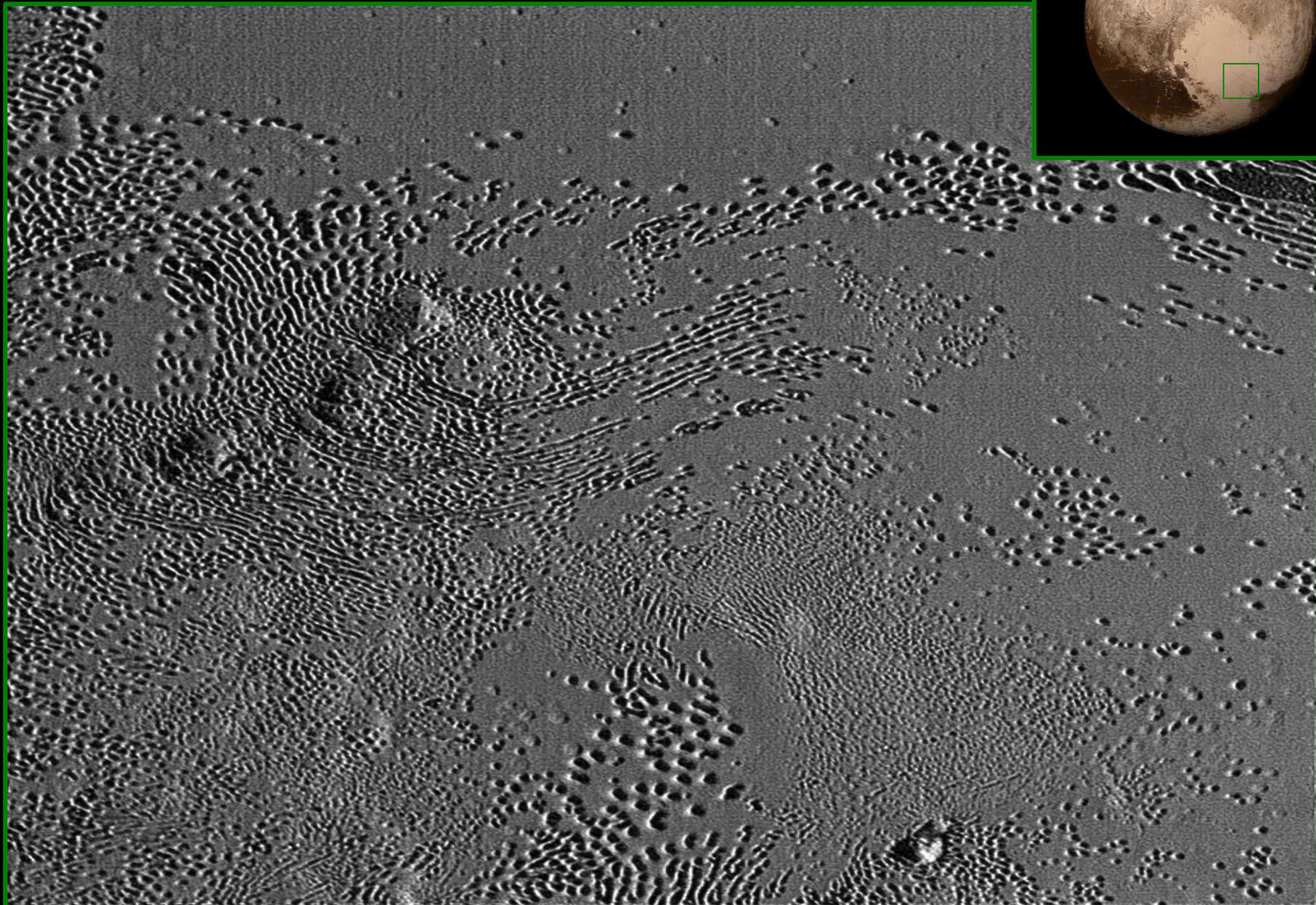
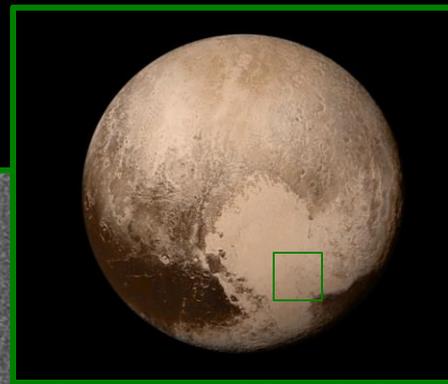
Ridges and Pits



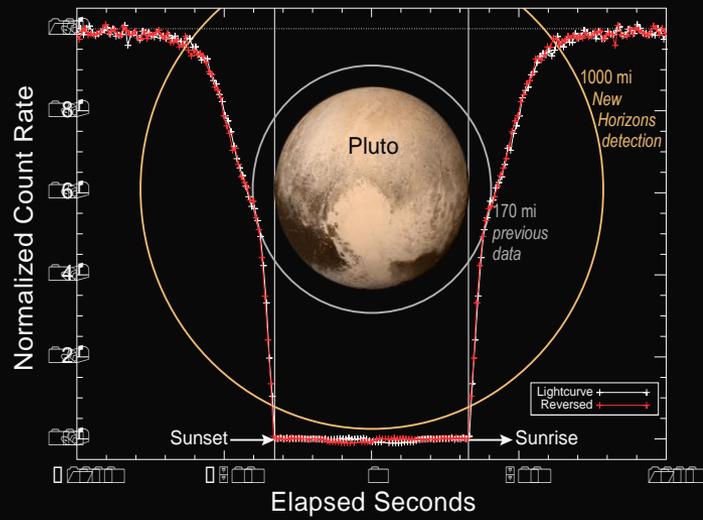


20 miles

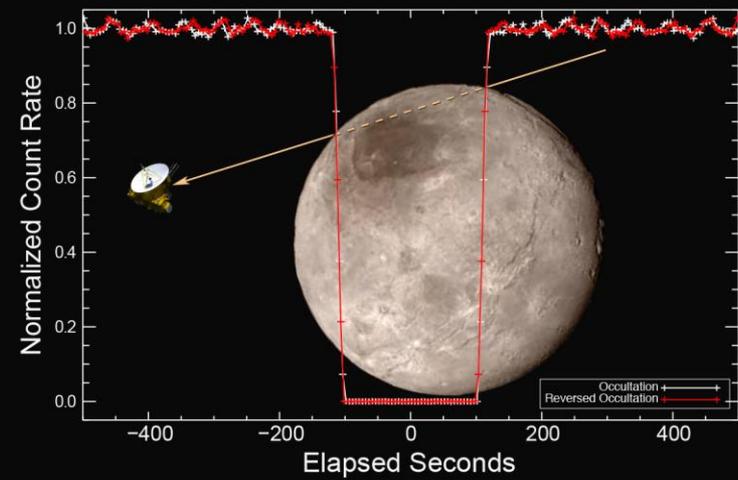


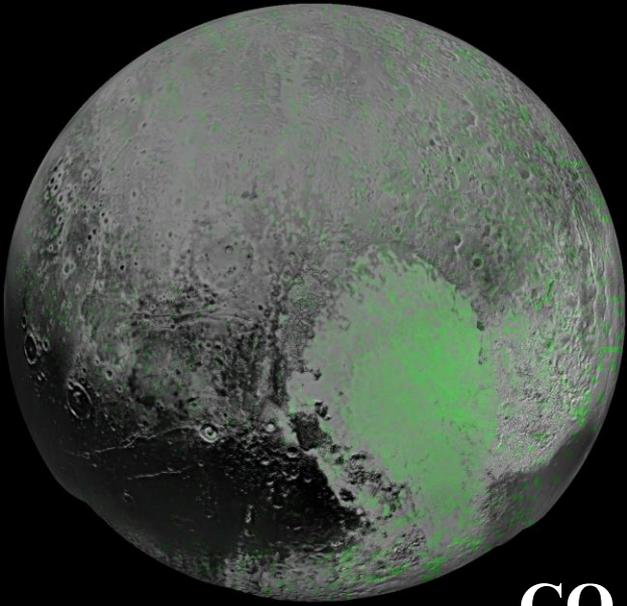


Alice Solar Occultation

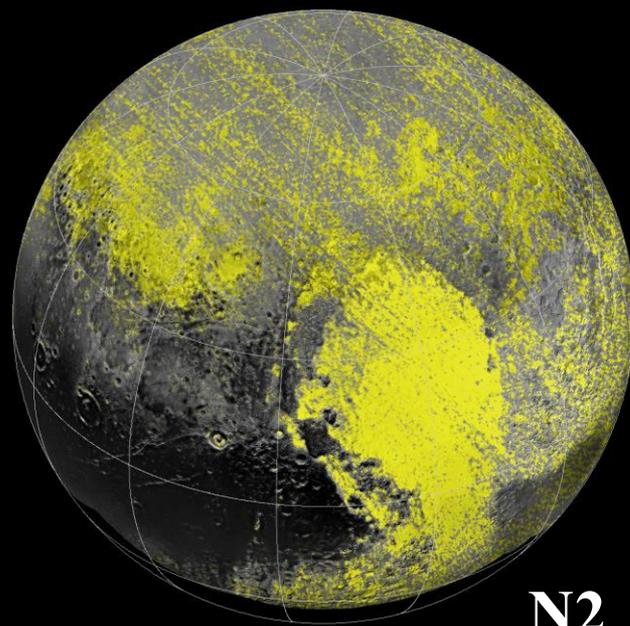


Alice Solar Occultation of Charon

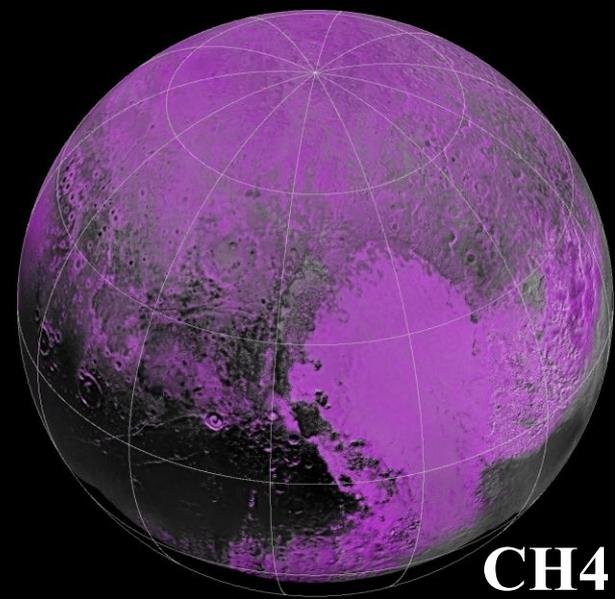




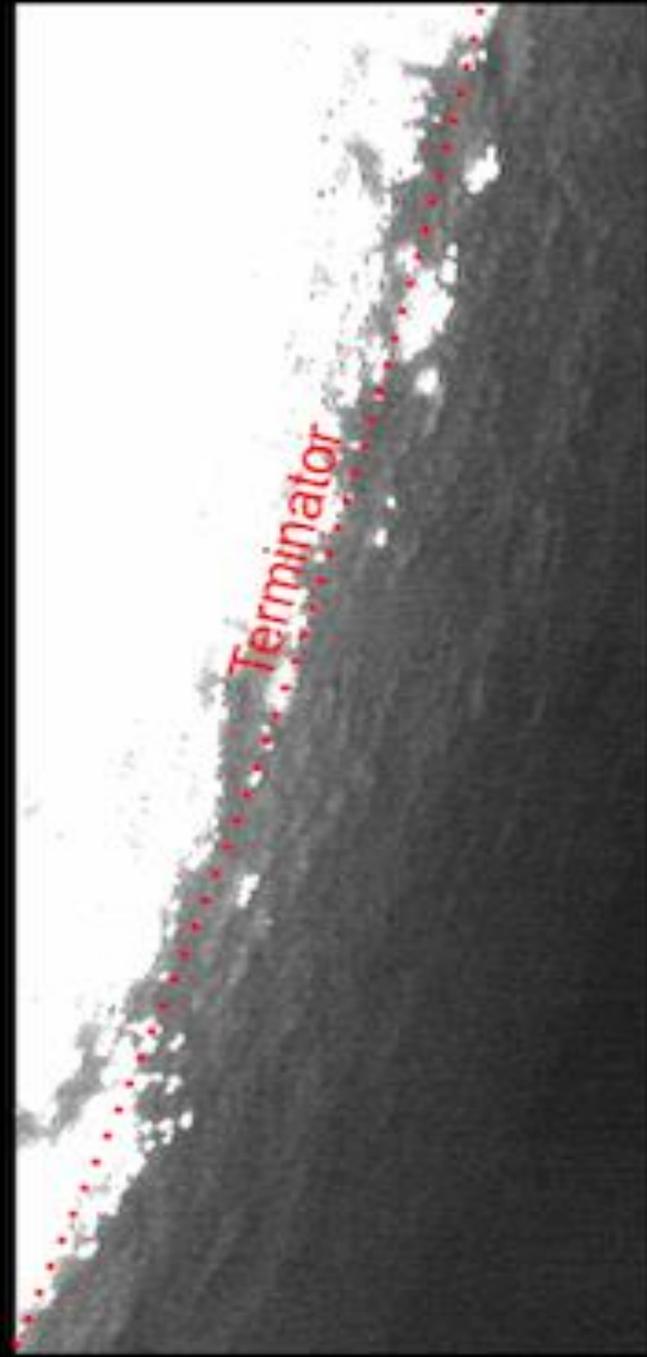
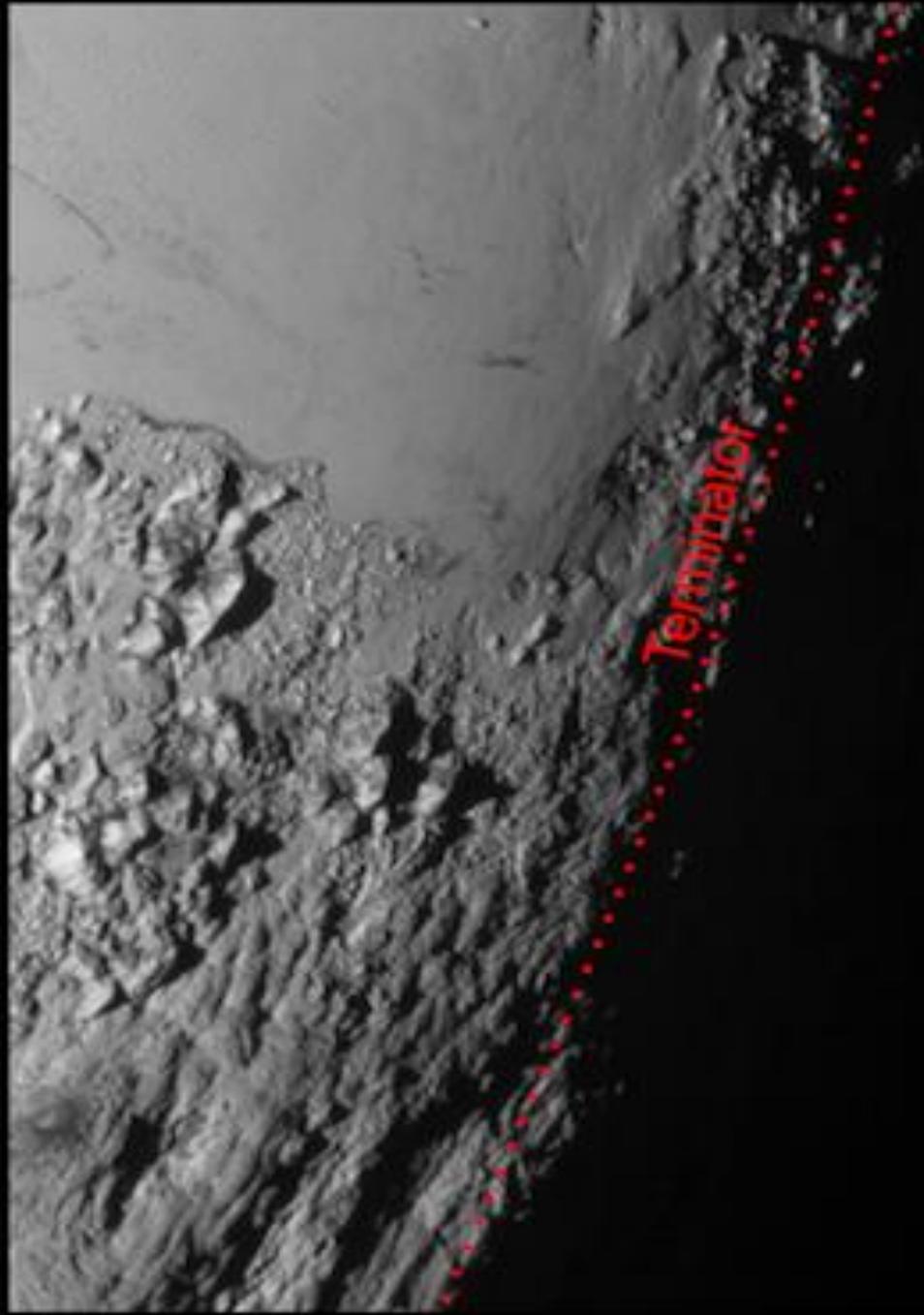
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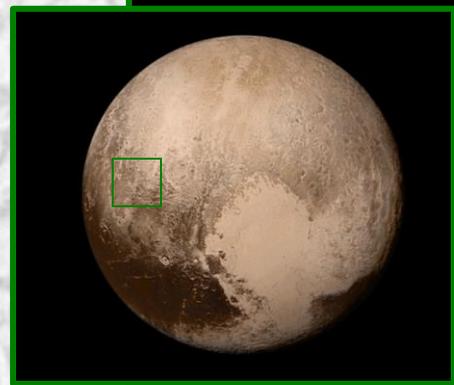
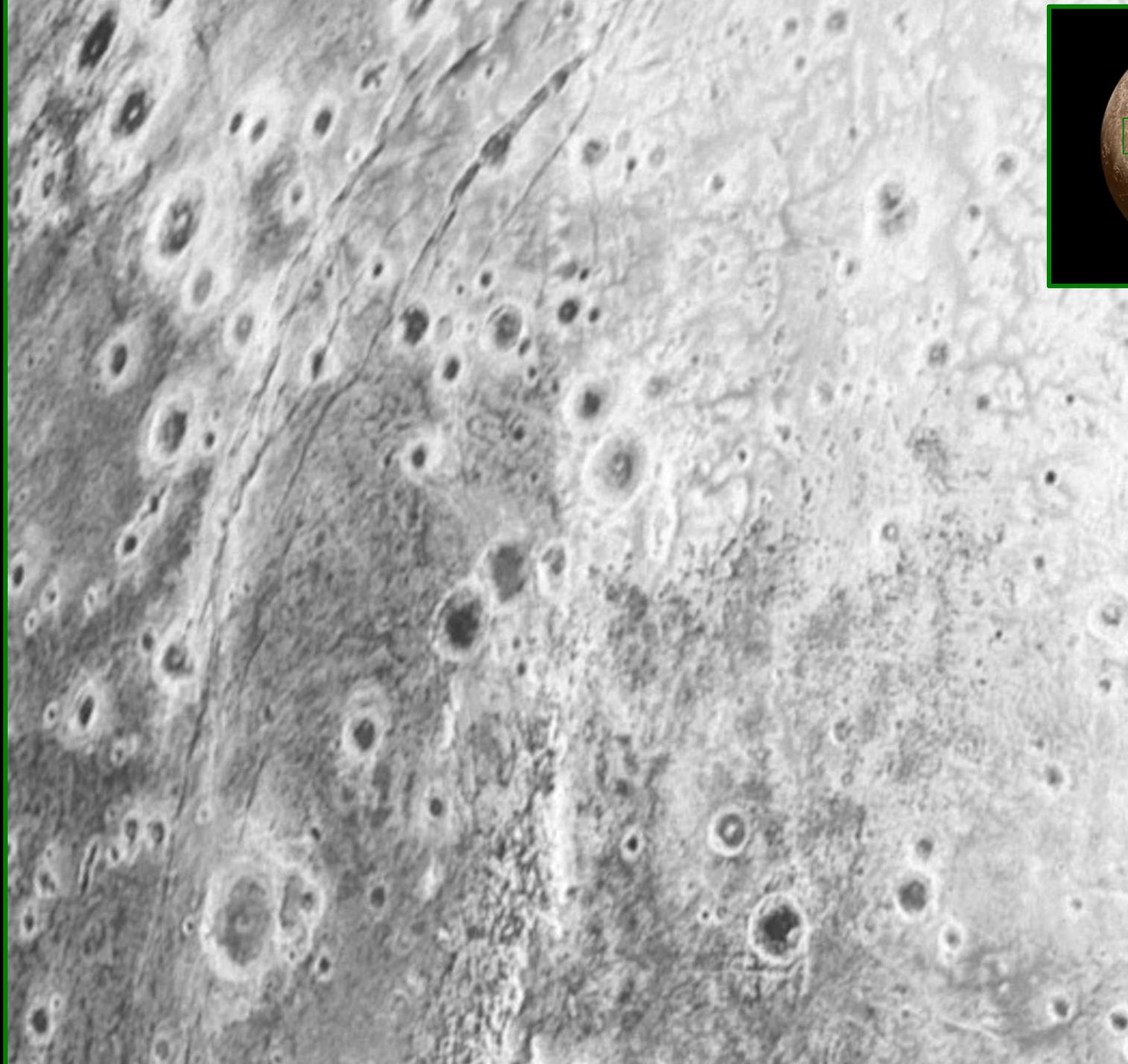


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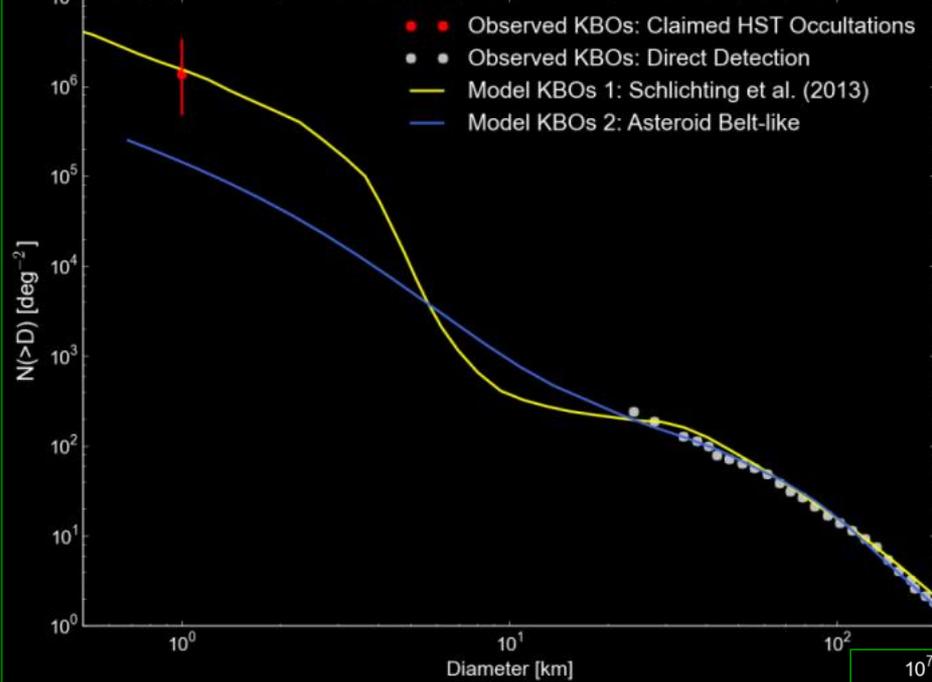


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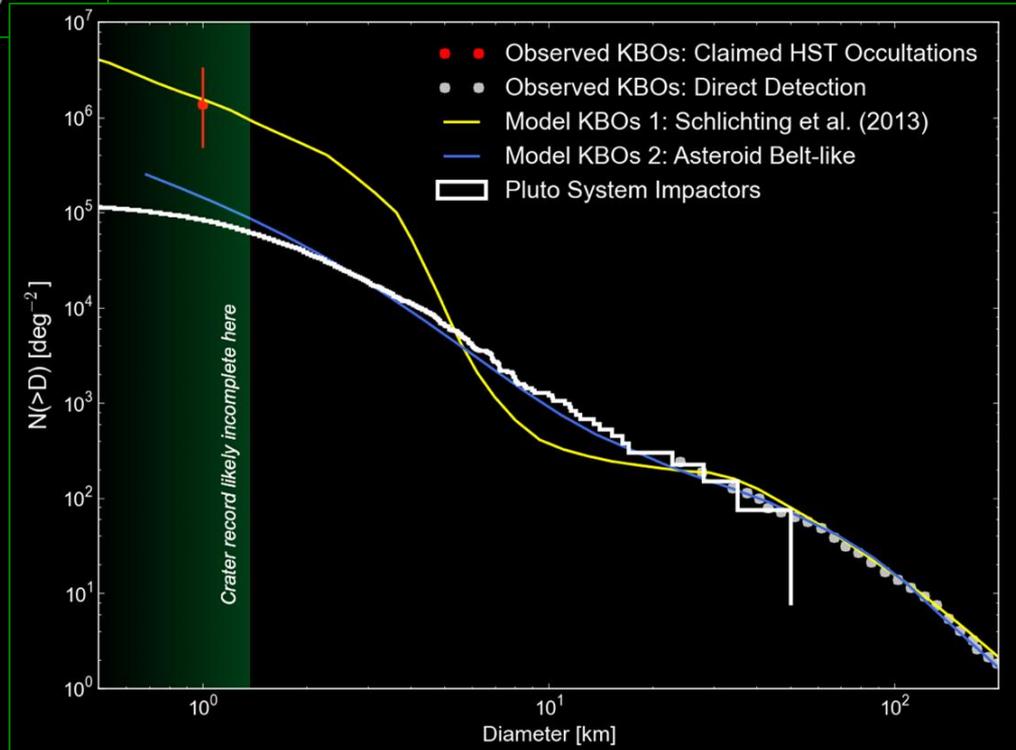


Probing the Kuiper Belt

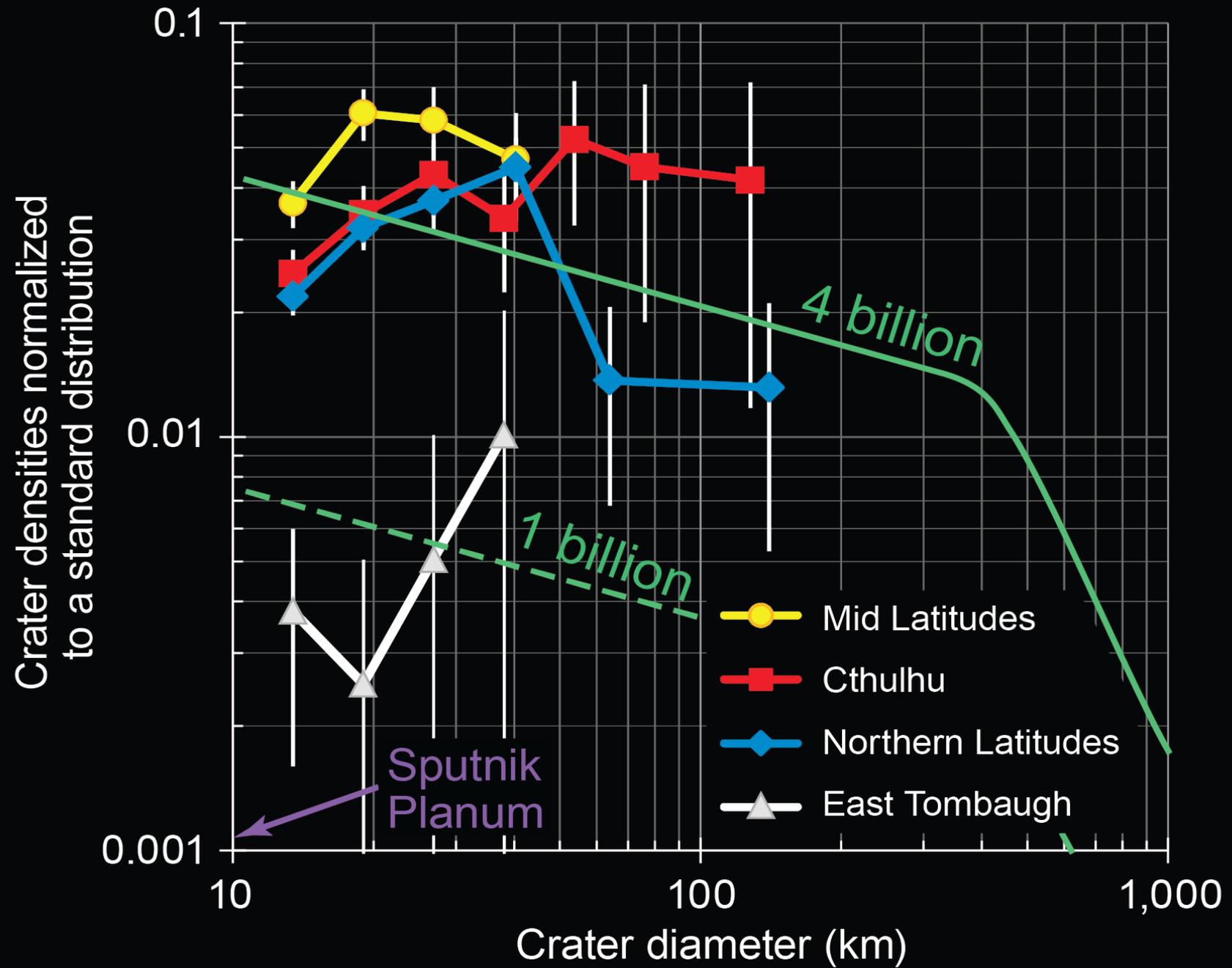


Before New Horizons

After New Horizons



Pluto



Ultimate bodybuilding: The quest for exoskeletons p. 270

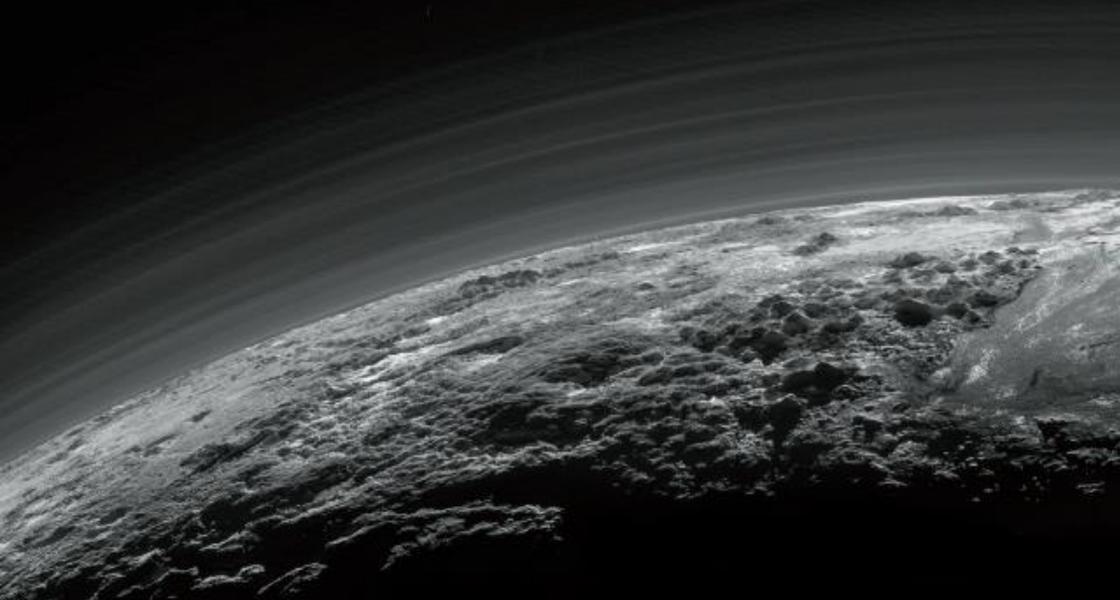
Giving a boost to quantum electronics pp. 280 & 307

Engineering remote-controlled T cells p. 293

Science

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Flying past Pluto

New Horizons finds surprises at Pluto and Charon pp. 260 & 292

RESEARCH ARTICLE SUMMARY

PLANETARY SCIENCE

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

S. A. Stern* and the New Horizons team†

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 color composition spectrometer; the LORRI long-focal-length panchromatic visible imager; the Alice extreme/far ultraviolet mapping spectrometer; twin REX radio science experiments; the SWAP solar wind detector; the PEPSSI high-energy charged particle spec-

trimeter; 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, volcanic transport, and glacial flow.

Pluto's atmosphere is highly extended, with trace hydrocarbons, a global haze layer, and a surface pressure near 10 micrometers. The bulk densities of Pluto and Charon were found to differ by less than 1%, 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. ■

The list of authors and affiliations is available in the full article online.
*Corresponding author. E-mail: adam@boisduval.swri.edu
†See this article as S. A. Stern et al., *Science* 300, aa1815 (2015); DOI:10.1126/science.aa1815



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.

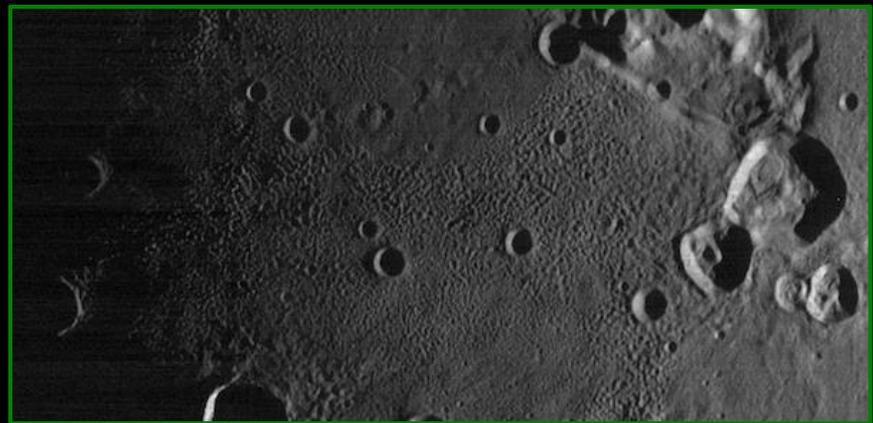
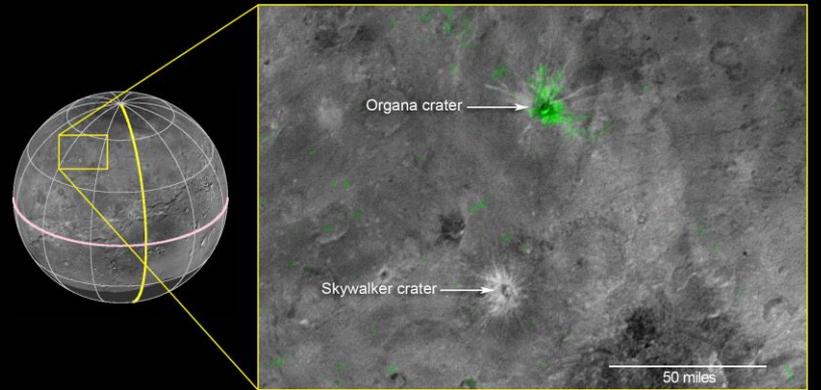
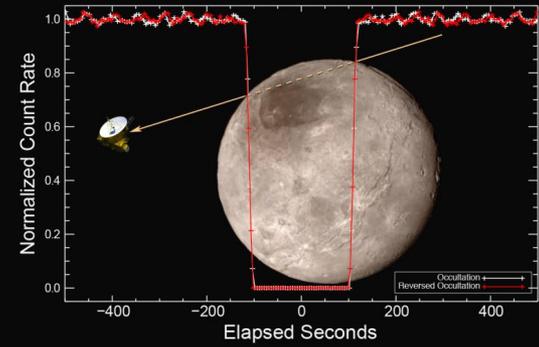
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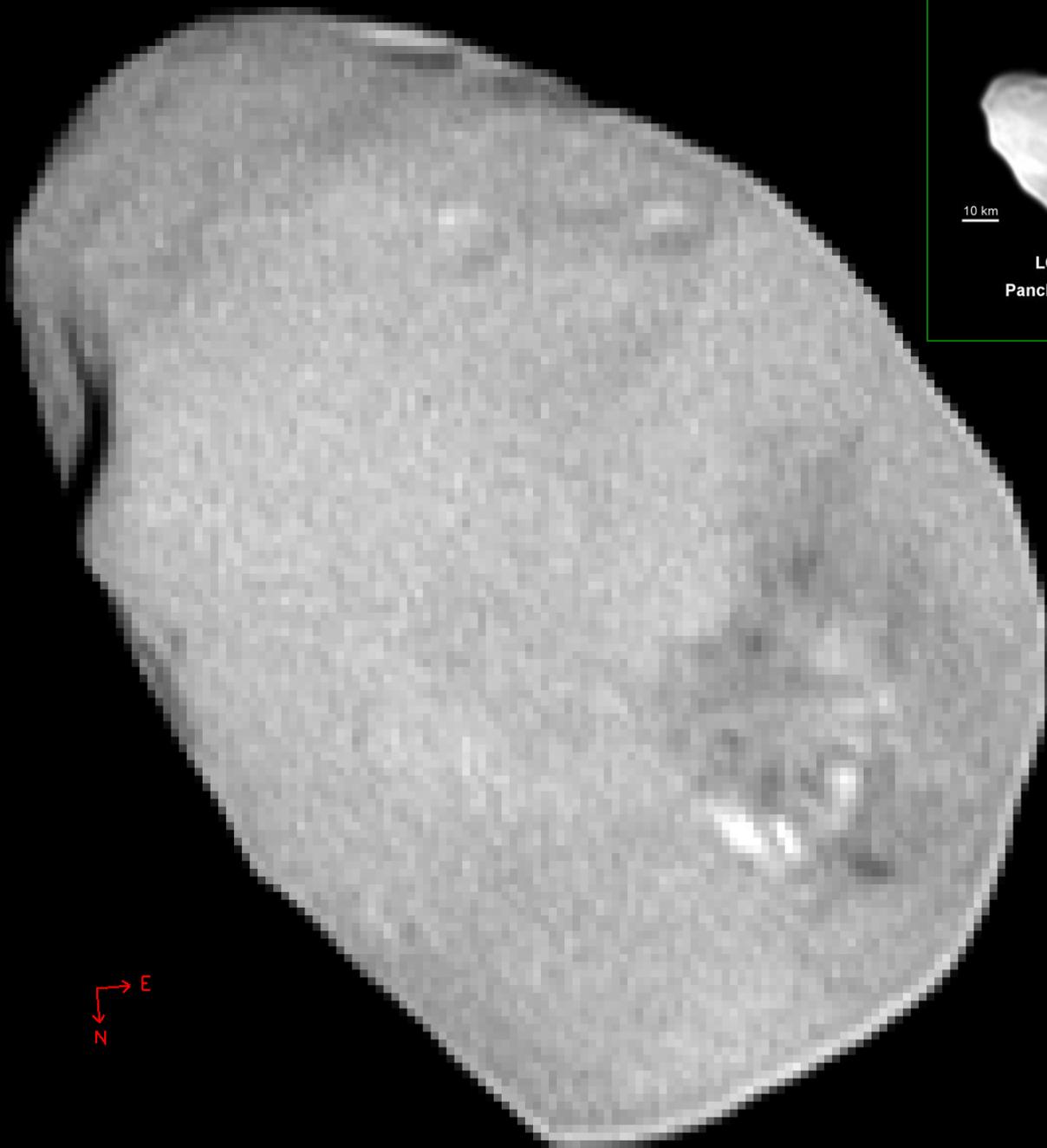
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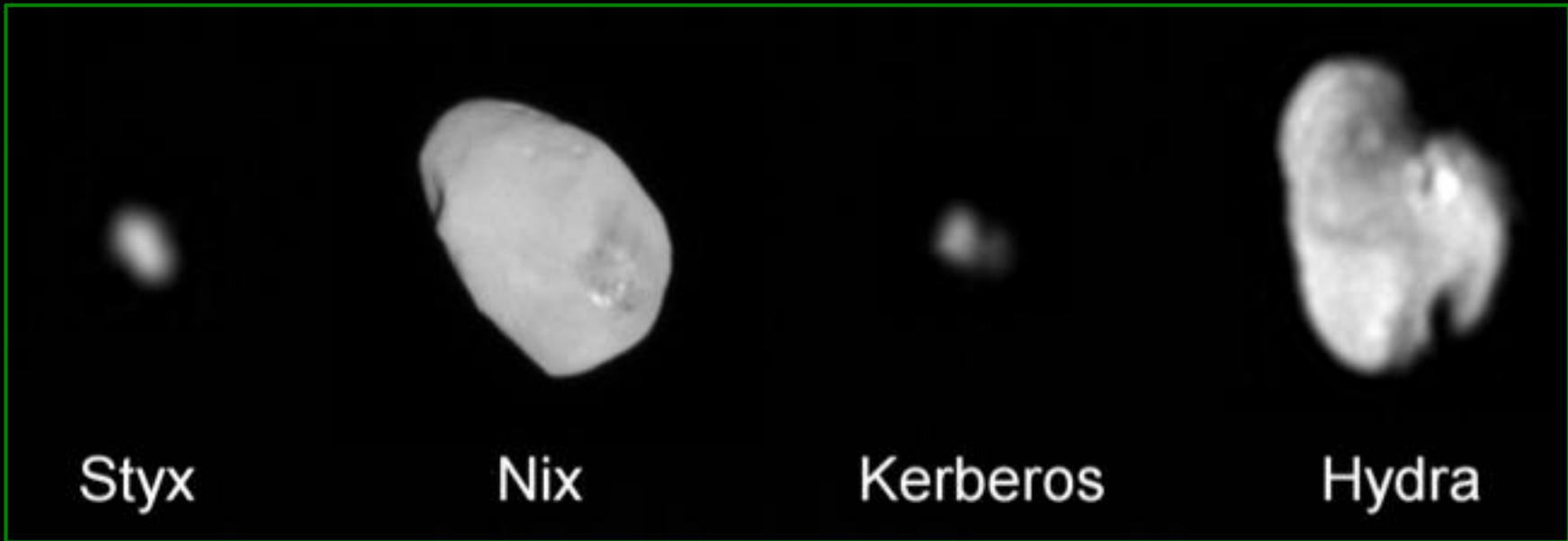
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Alice Solar Occultation of Charon



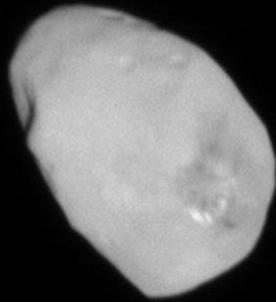




At least two and possibly all four moons are the result of mergers between smaller bodies. Pluto may have had many more moons in the past.



Styx



Nix



Kerberos



Hydra



I

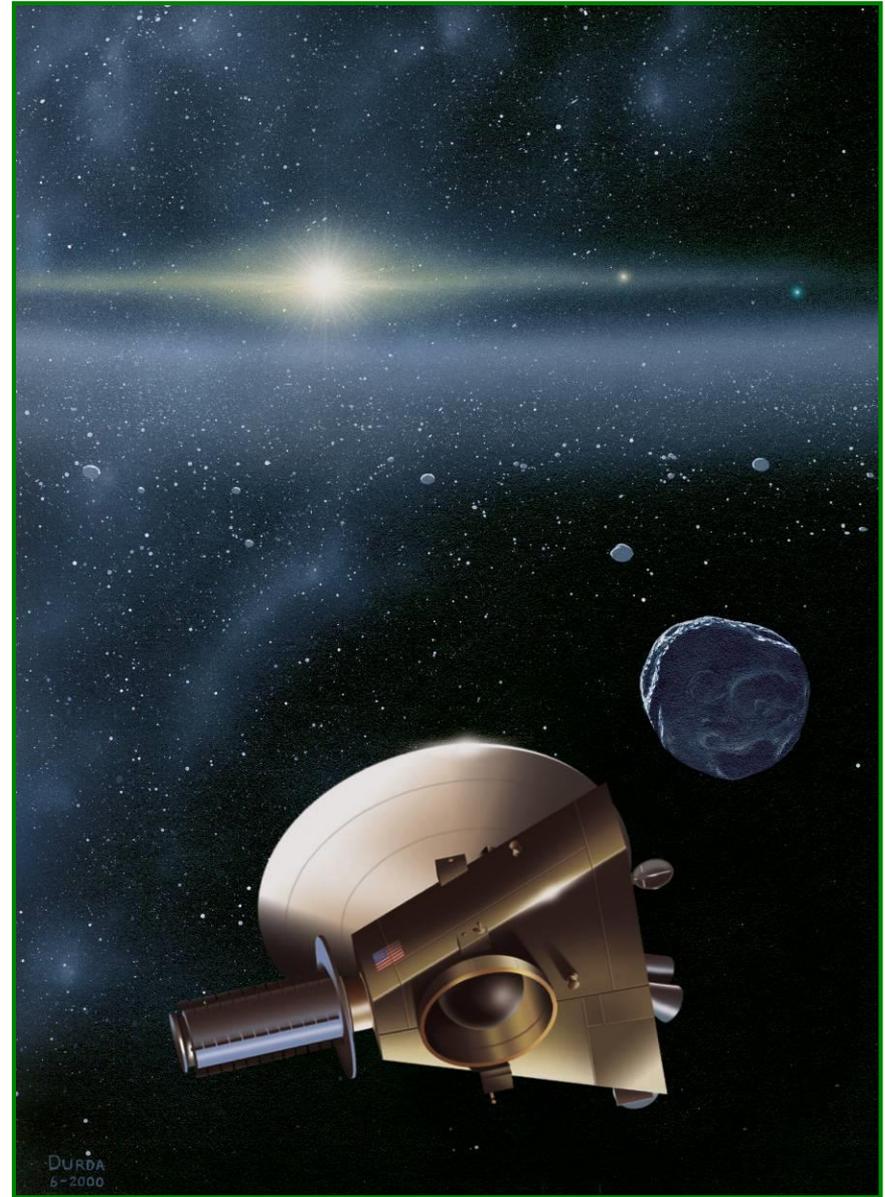
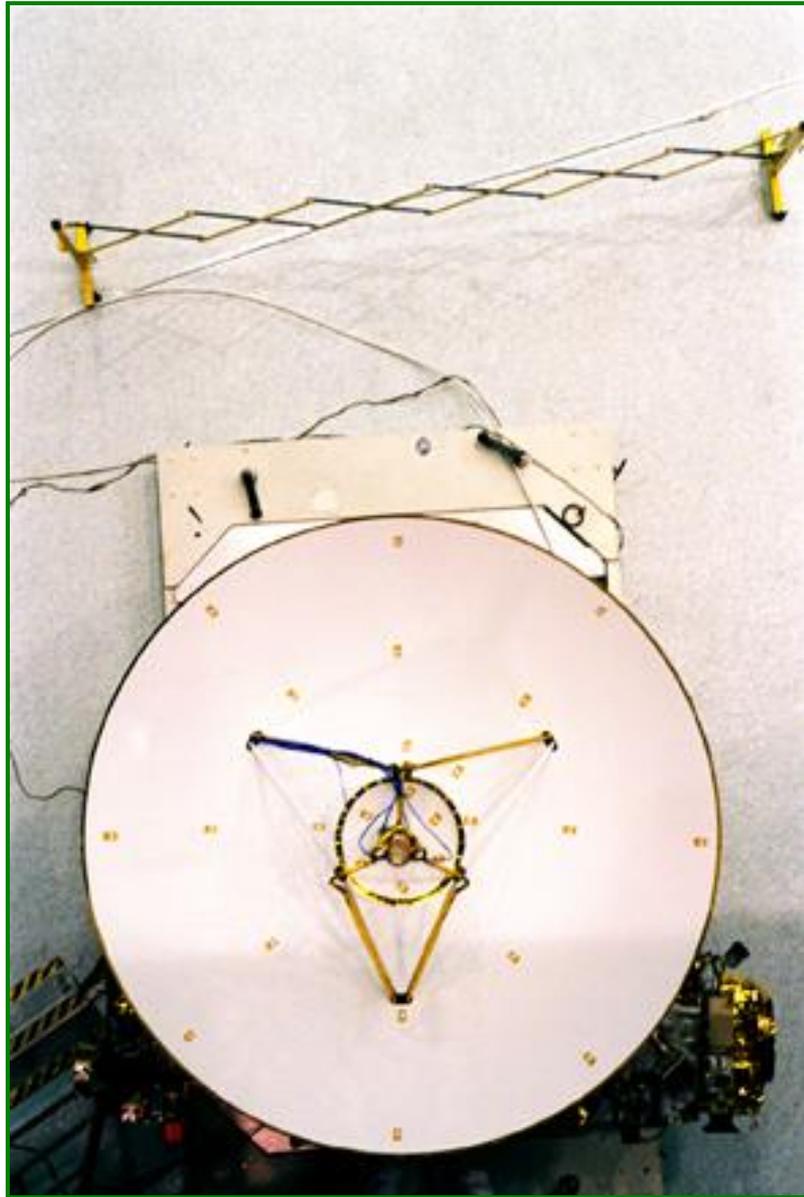


PLUTO

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



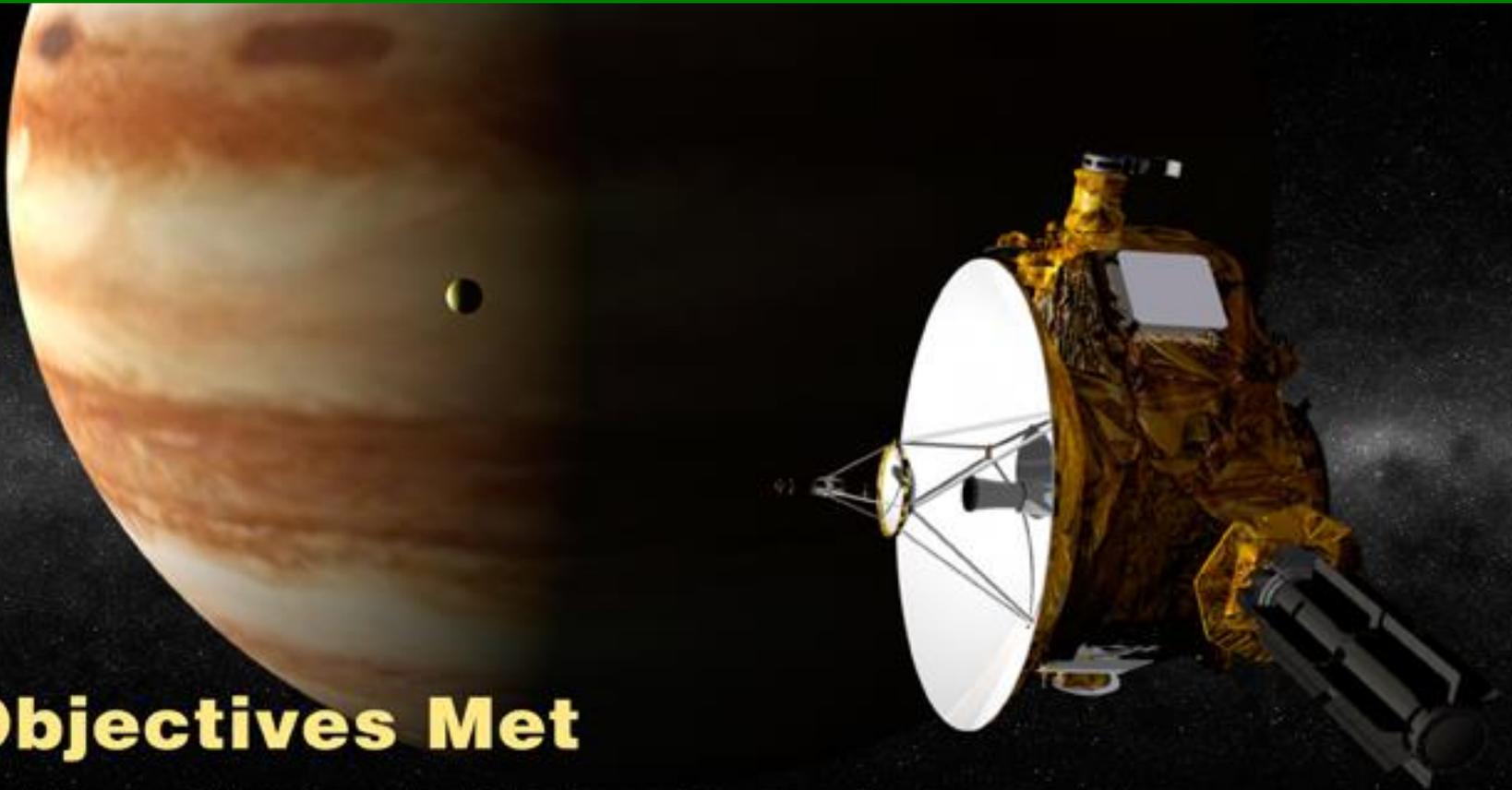
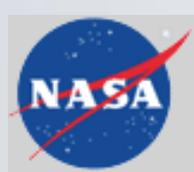
NOW ON TO THE KUIPER BELT 2019



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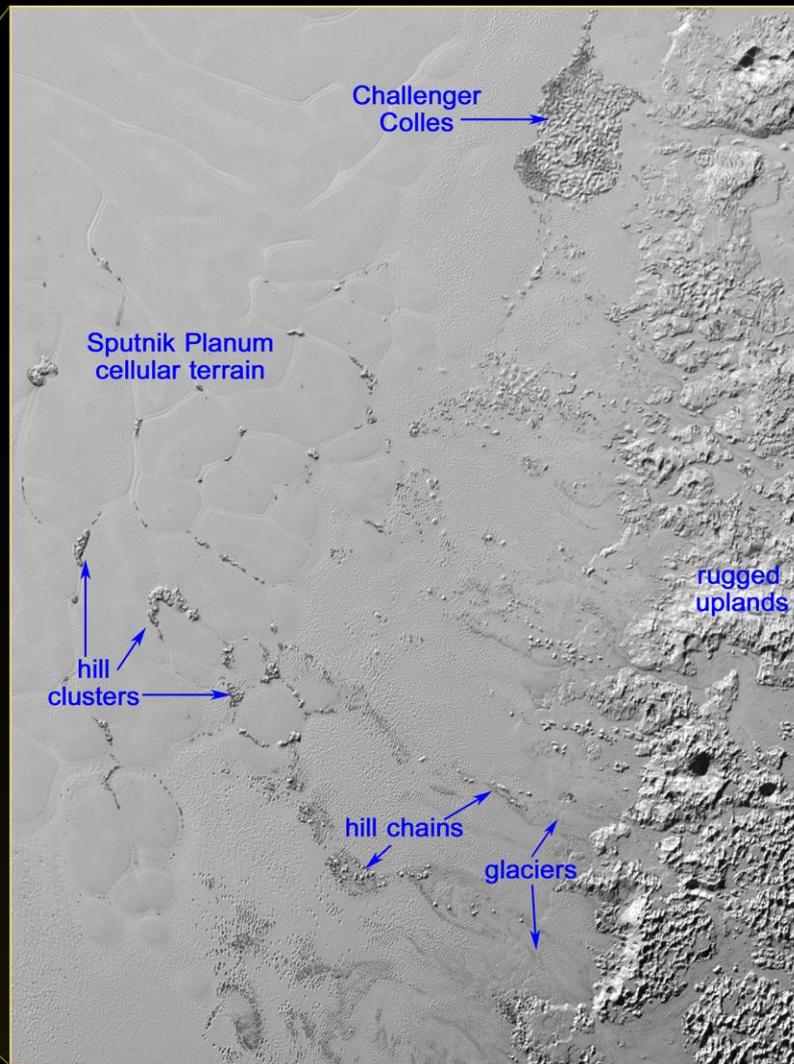
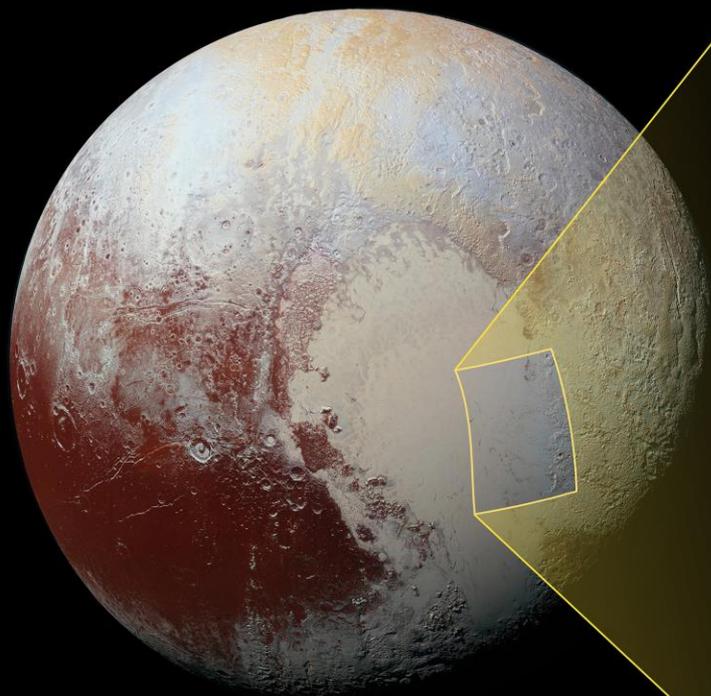


JUPITER OBJECTIVES



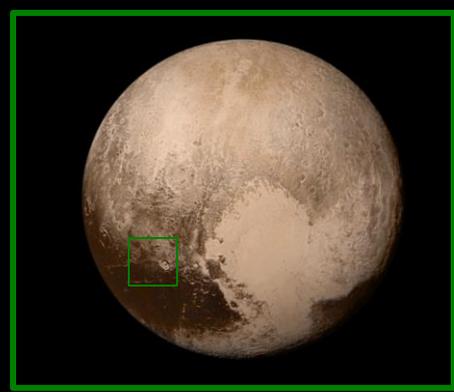
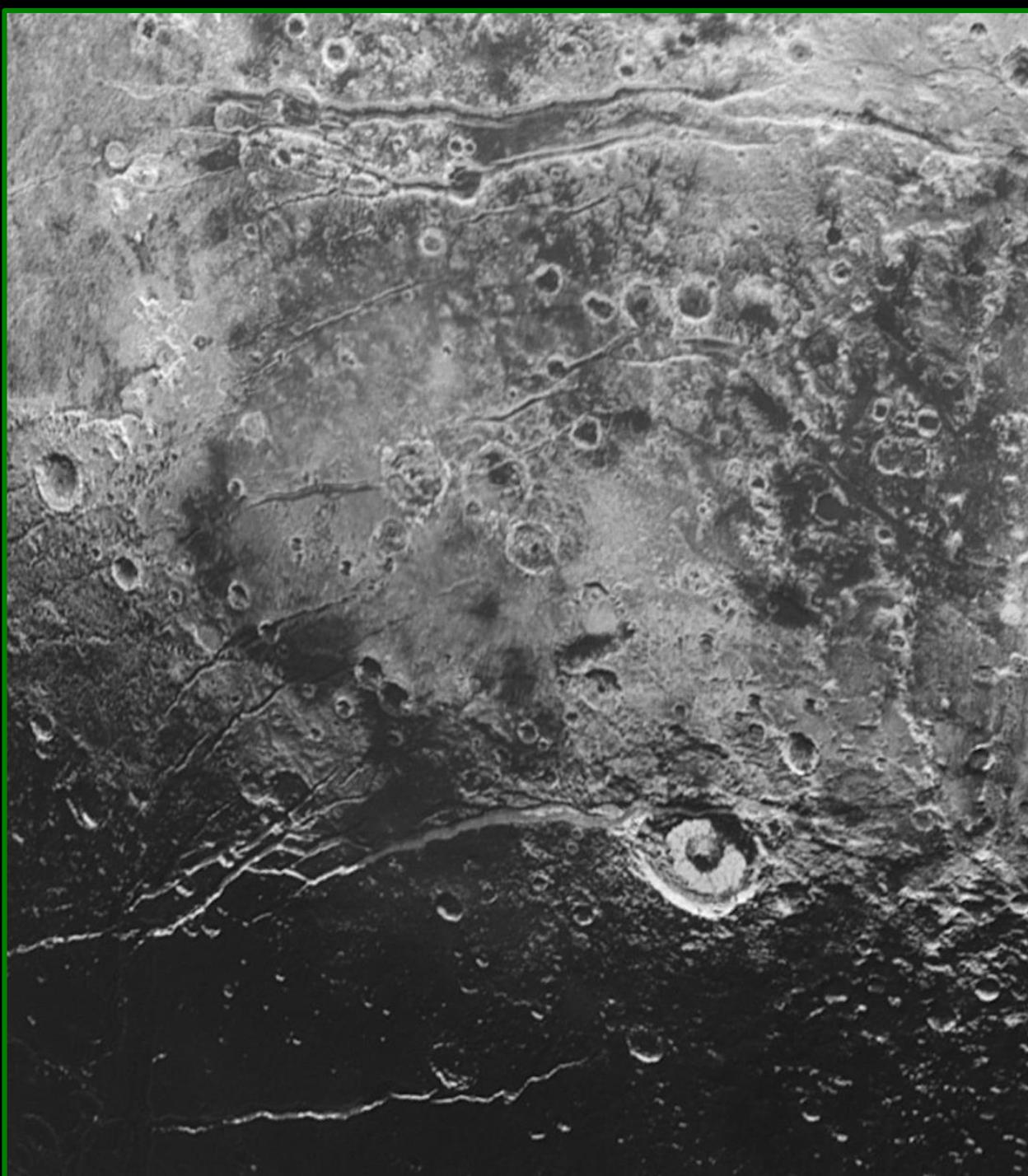
Objectives Met

- 1. Flew through Pluto aim point**
- 2. Served as flyby/encounter pathfinder**
- 3. Collected diverse scientific data**

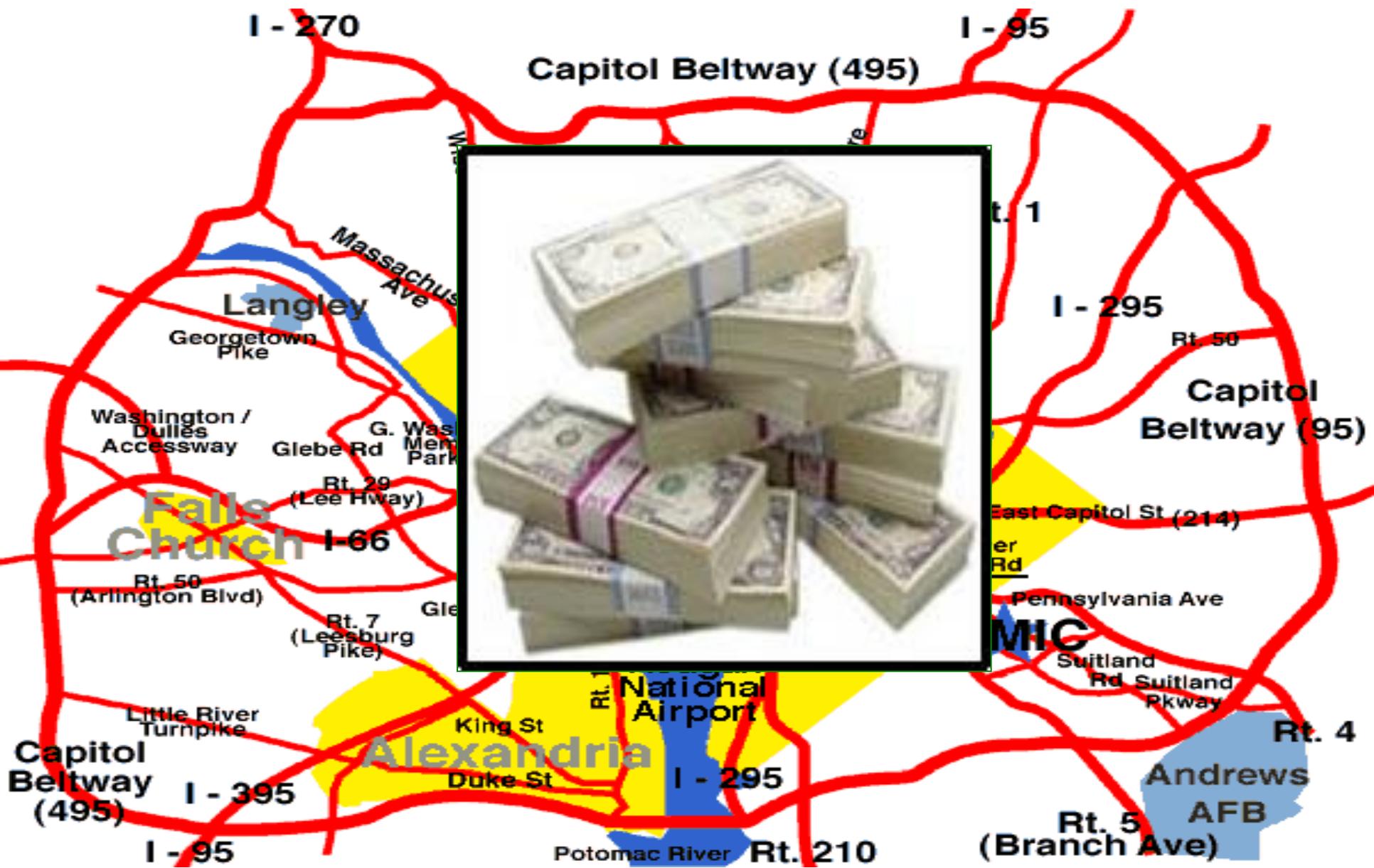








IT TOOK 14 YEARS JUST TO GET FUNDED





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NASA Begins Countdown to Pluto Flyby

BY STAV ZIV 1/15/15 AT 4:59 PM



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NASA's New Horizons Spacecraft Wakes Up for Pluto Encounter in 2015

by Caitla Coffield Space.com Staff Writer | December 07, 2014 09:12am ET

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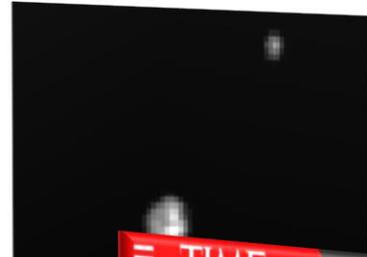
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LA Los Angeles Times

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

By KENNETH ORLAND JAN. 18, 2015



It is small. It is round. It was once a planet, but is now cast off as too diminutive. In March, a NASA spacecraft will arrive there to begin the first close-up examination of a dwarf planet. It is not Pluto. It is instead Ceres, 600 miles wide, the largest of the asteroids between Mars and Jupiter. "We're going to reveal the fascinating details of a giant world of rock and ice," said Marc Rayman, the chief engineer for NASA's Dawn spacecraft. "It's not like we're just going out to visit a chunk of rock the size of one of those mountains," he said, pointing to the San Gabriel Mountains outside the windows at NASA's Jet Propulsion Laboratory in Pasadena, Calif. "Ceres has 98 percent of the area of the continental United States. It's actually the largest body between the sun and Pluto that a spacecraft has not yet visited."



SEVEN WONDERS OF THE MILKY WAY

Astronomy

The world's best-selling astronomy magazine

FEBRUARY 2015

NASA SETS ITS SIGHTS ON PLUTO

New Horizons spacecraft begins its approach

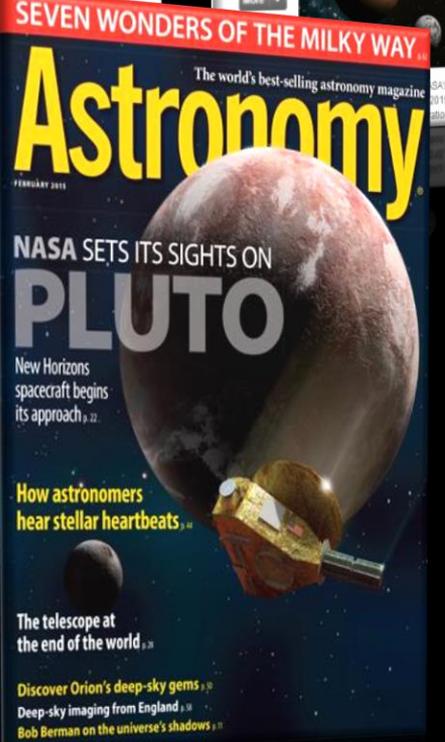
How astronomers hear stellar heartbeats

The telescope at the end of the world

Discover Orion's deep-sky gems

Deep-sky imaging from England

Bob Berman on the universe's shadows



NBC NEWS

New Horizons Probe to Snap Pictures of Pluto

The high-resolution camera on NASA's New Horizons spacecraft has begun capturing images of Pluto in preparation for its flyby less than 3 1/2 months from now... but it will take a few more days to process the image data, the mission's principal investigator said.

"We got telemetry indicating the Sunday imaging went well and that the images have 'normal engineering parameters,'" Allan Stern, a planetary scientist from the Southwest Research Institute who heads the mission team, told NBC News in an e-mail late Monday. "The images themselves won't be on the ground for a day or two... We're off to the races!"

This race is a marathon rather than a sprint. The New Horizons probe was launched nine years ago, and it's now more than 3 billion miles (4.8 billion kilometers) from Earth. At that distance, it takes 4 1/2 hours for signals from the spacecraft to arrive. The piano-sized probe is still 125 million miles (200 million kilometers) from Pluto, and that means the dwarf planet will look like little more than a bright dot in this week's pictures from New Horizons' Long Range Reconnaissance Imager, or LORRI. However, even that dot can serve to guide the spacecraft toward its close encounter with Pluto on July 14... and the view will improve dramatically in the months ahead.



TOM COSTELLO
NBC NEWS

TIME

NASA Spacecraft Wakes Up as It Approaches Pluto

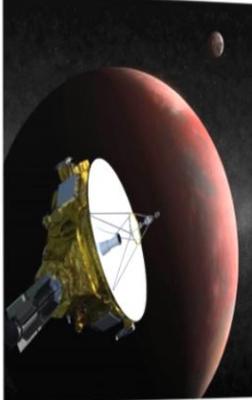
Justin Workland | Space.com | Dec. 8, 2014

New Horizons will come closest to the dwarf planet on July 14

A NASA spacecraft has emerged from hibernation in preparation for completing its nine-year, 2.9-billion-mile journey to observe Pluto from up close, the space agency said.

Sending its signal at the speed of light, the New Horizons ship beamed a report down to Earth that it was back in active mode as of Dec. 6.

"Technically, this was routine, since the wake-up was a procedure that we'd done many times before," said Glen Fountain, the mission's project manager. "Symbolically, however, this is a big deal. It means the start of our pre-encounter operations."





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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