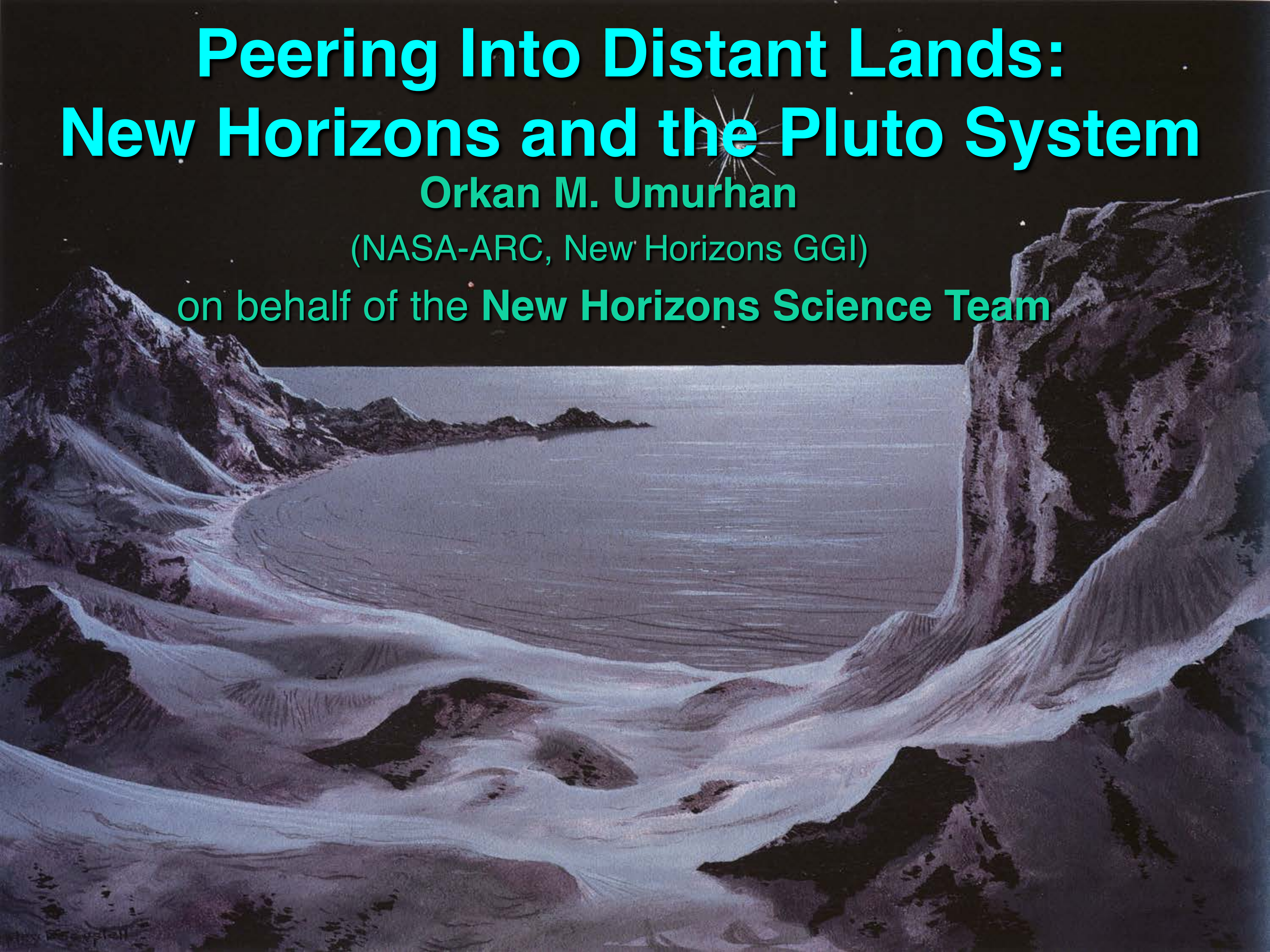
Peering Into Distant Lands: New Horizons and the Pluto System

Orkan M. Umurhan

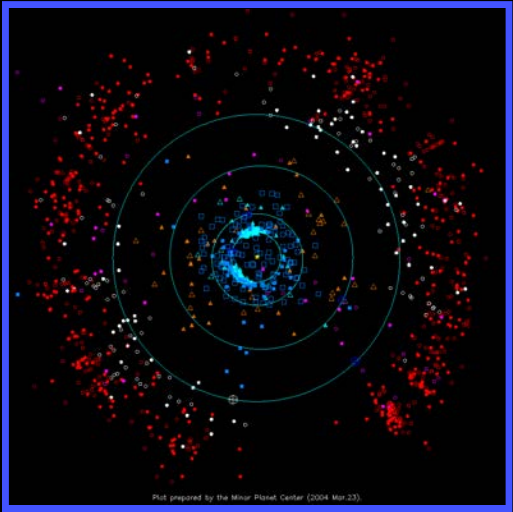
(NASA-ARC, New Horizons GGI)

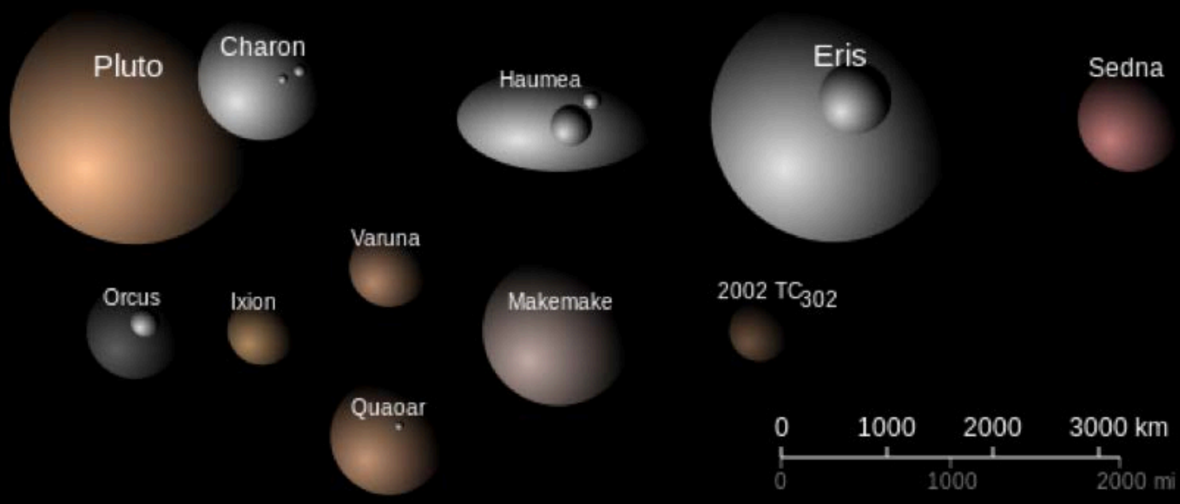
on behalf of the **New Horizons Science Team**



ENTER THE KUIPER BELT:

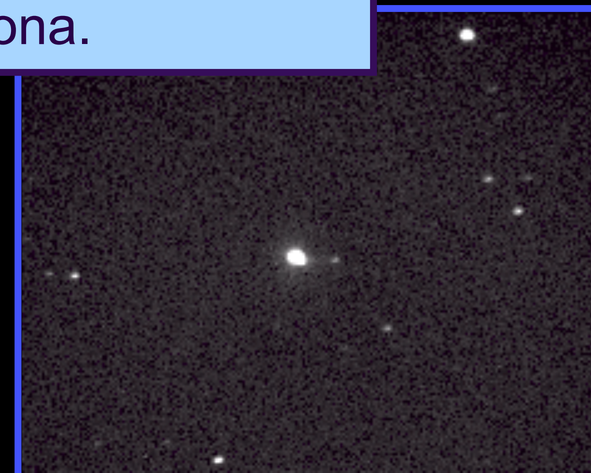
<u>New View of the Solar System:</u>
4 Terrestrial Planets
4 Giant Planets
Perhaps 1000 Dwarf Planets

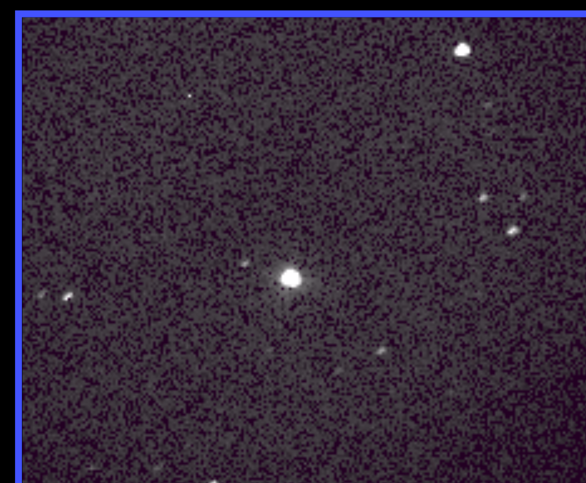




PLUTO'S DISCOVERY

Pluto was discovered in January-February 1930, by Clyde Tombaugh at Lowell Observatory, Arizona.



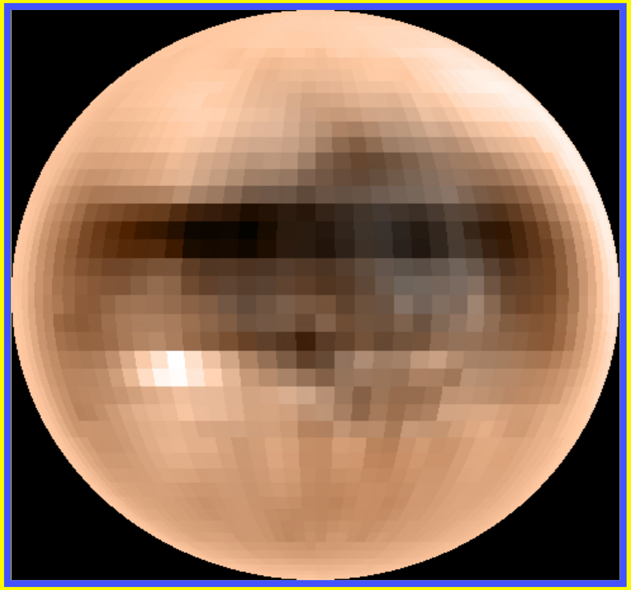


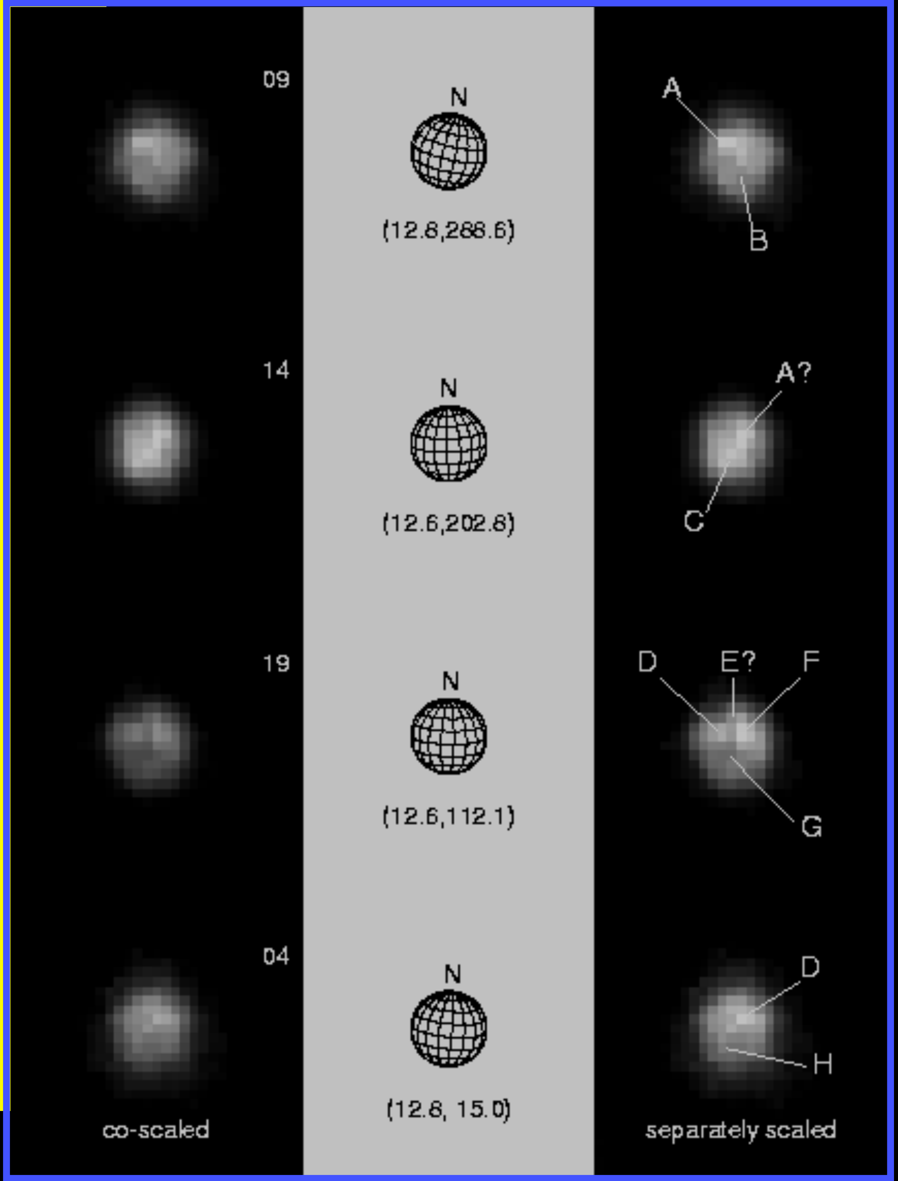
BEST HST IMAGES OF PLUTO

HST Observations (1994):

- **Strong Surface Variegation**
- **Polar Features**

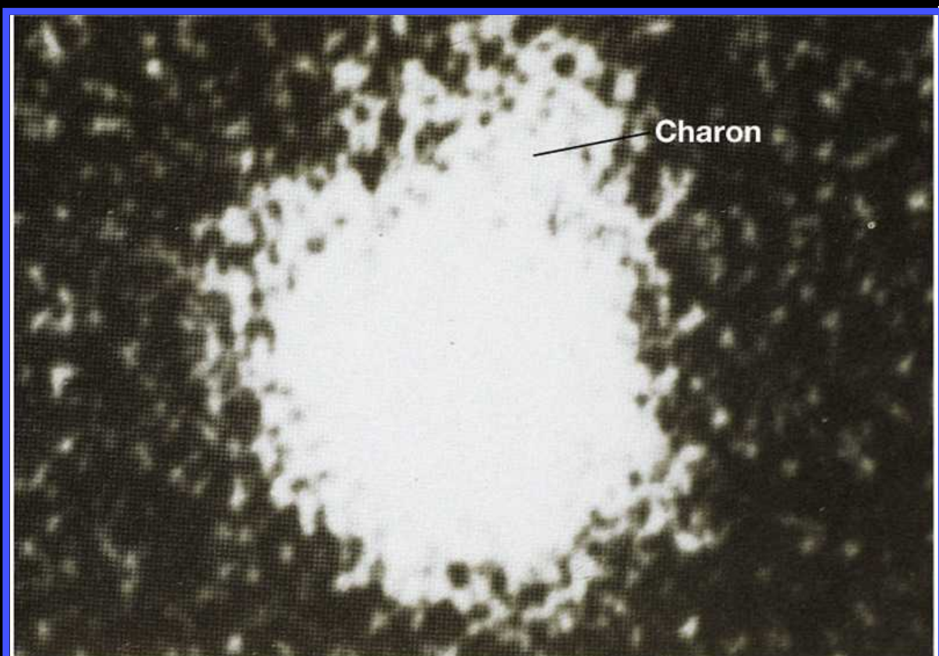
True Color Map

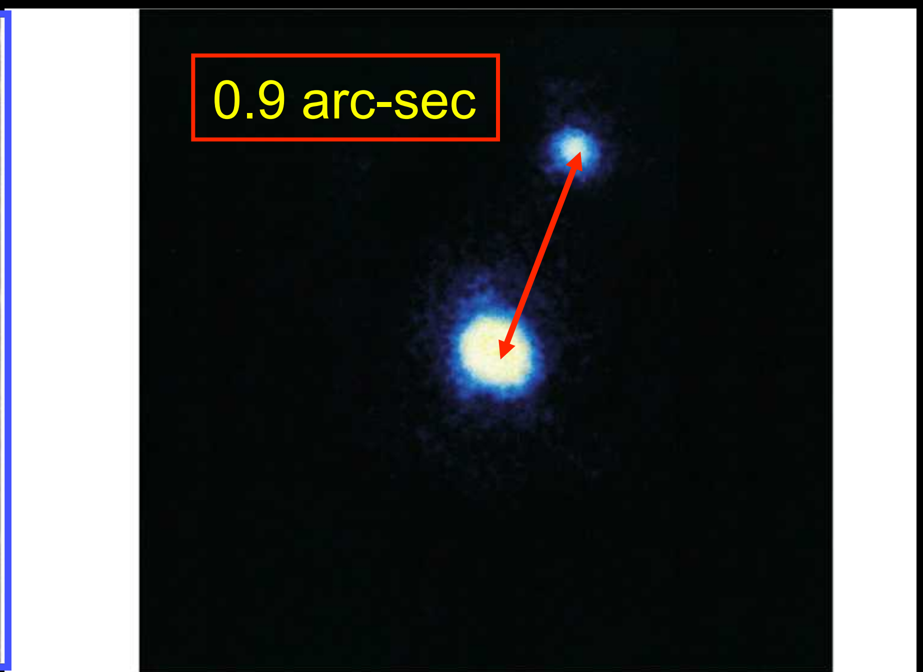




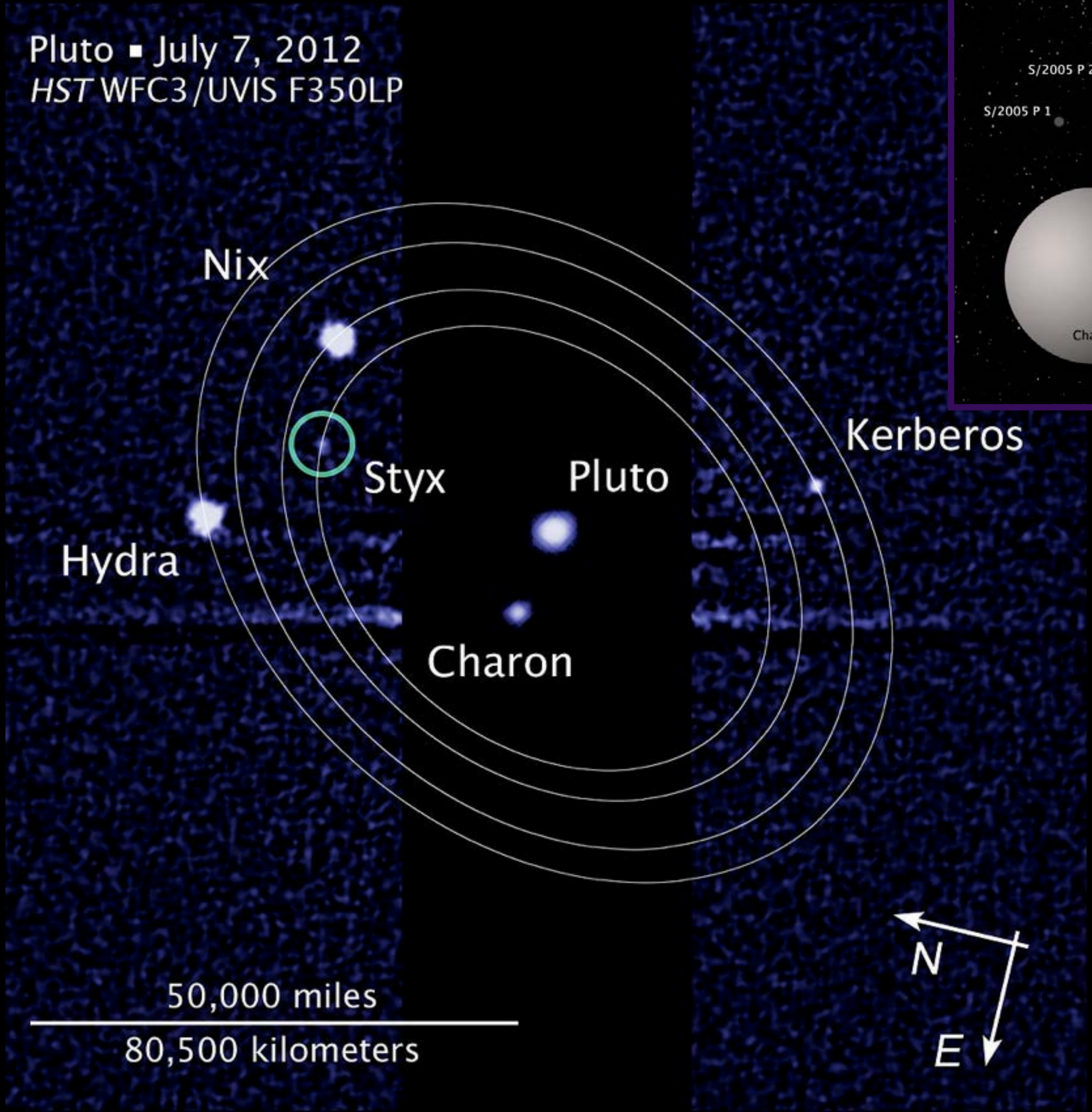
PLUTO'S LARGE MOON: CHARON

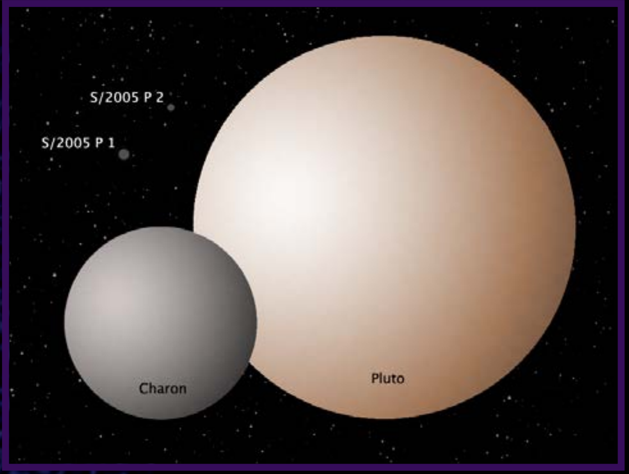
- Charon was discovered, by accident, in July 1978 by Jim Christy of the U.S. Naval Observatory.
- Charon is in synchronous orbit ~19,400 km from Pluto, and spin-spin-orbit locked with a 6.4 day period.
- Charon's surface is covered in H_2O-ice; there is as yet no detected atmosphere.





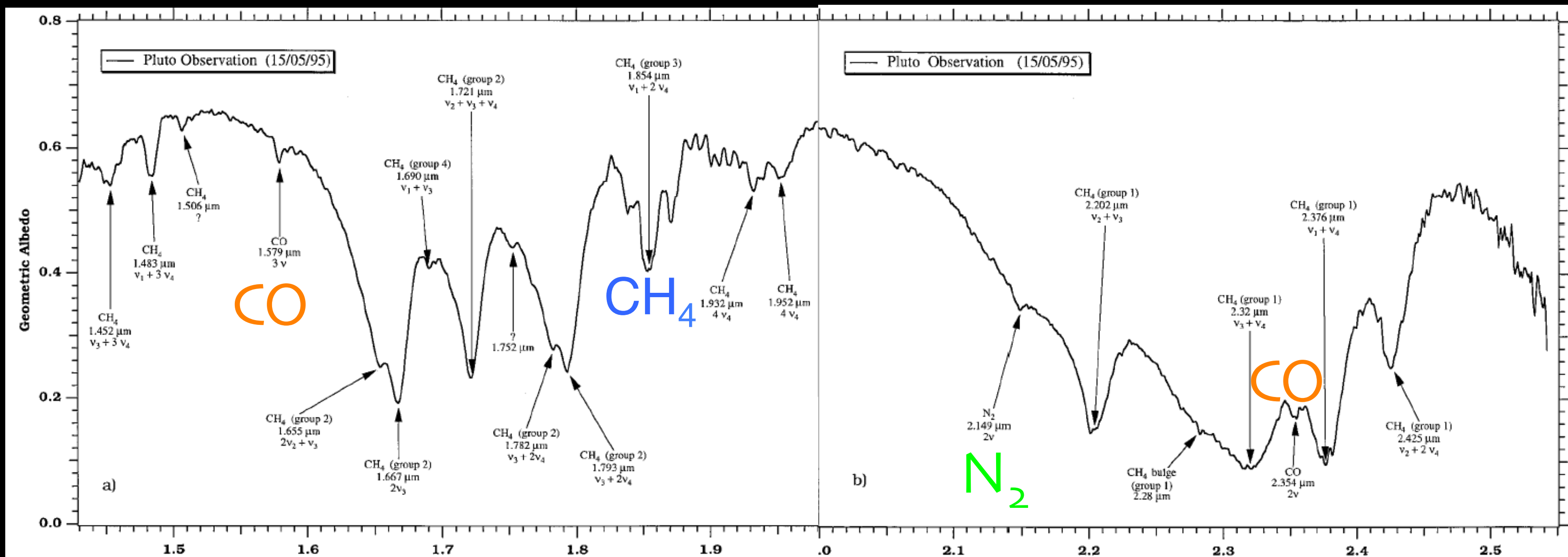
Four More Much Smaller Moons were Discovered over the Last Decade





SURFACE COMPOSITION

Douté et al 1999, Icarus 142



- CH_4 discovered 1976.
- N_2 and CO ices were discovered in the 1990s.
- The CH_4 and CO distribution is patchy.
- N_2 dominates ~10:1.

Pluto's surface contains at least three volatiles, each with different physiochemical properties.

ATMOSPHERE

- ❑ First detected in 1985 and 1988 by a clear refractive signature, seen in stellar occultations; the surface pressure is ~10 μbar.

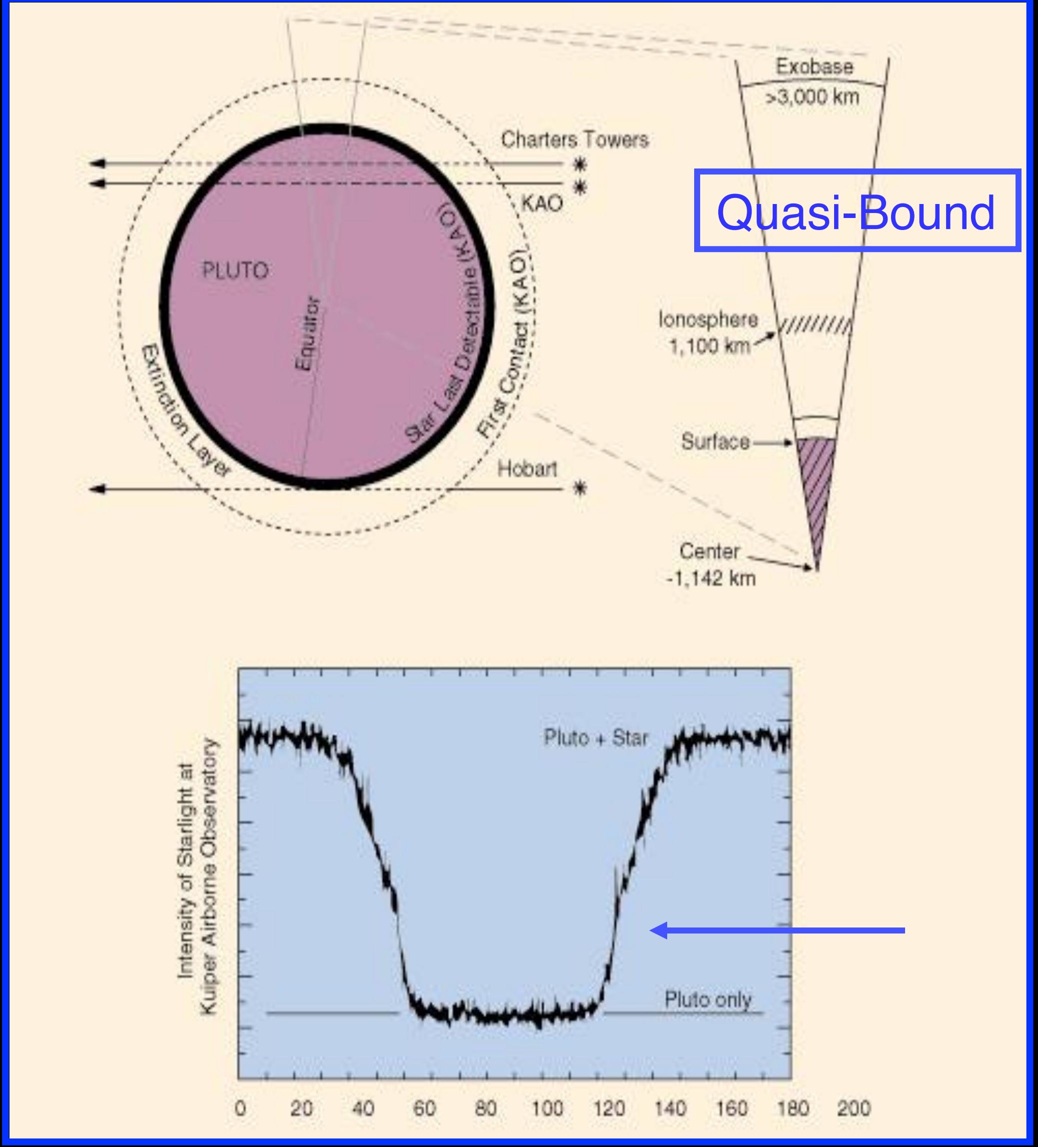
- ❑ N_2, CO, & CH_4, plus trace photo-chemical species.

- ❑ Evidence for haze and/or temperature T(z) structure.

- ❑ Strong seasonal effects are expected.

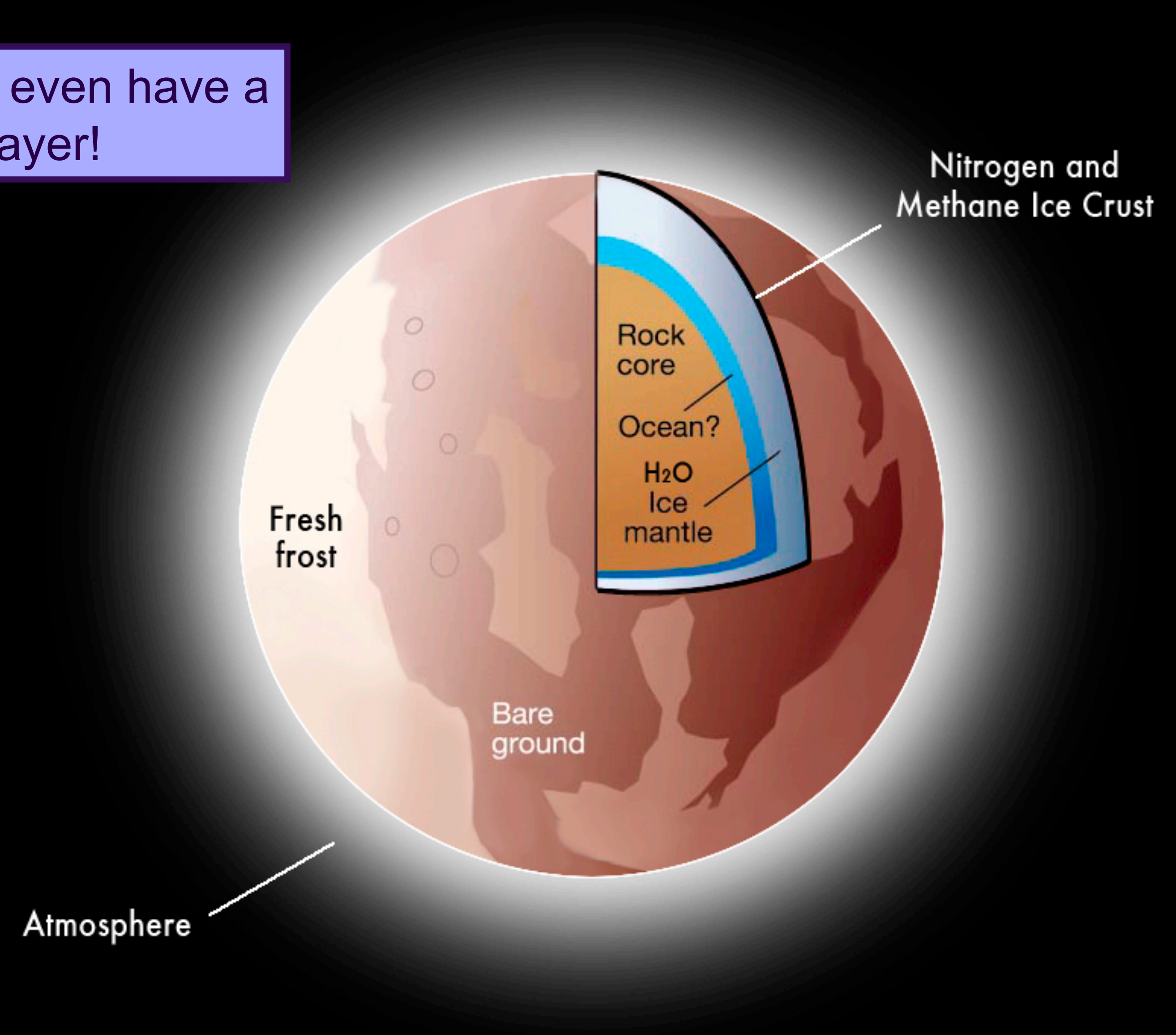
- ❑ <u>The atmosphere is likely hydrodynamically escaping, several km of ices lost in 4 Gyr.</u>

- ❑ Both the 2002 and 2006 occultations revealed distinct structural & pressure changes.



Pluto is a primarily rocky, *not* icy body!

Pluto might even have a liquid H_2O layer!



POSSIBLE SATELLITE ORIGIN

PREFERRED SCENARIO: GIANT IMPACT

is consistent with:

- *Pluto's orbit and obliquity*
- *The system mass ratio and angular momentum*
- *The densities of Pluto and Charon*

but is problemmatic in:

- *Retention of surface volatiles*
- *Collisional probabilities*

A giant impact origin for Pluto-Charon was first suggested in the 1980s (McKinnon 1984, 1989).

Numerical models seem incapable of plausibly producing Charon otherwise (Stern, McKinnon & Lunine 1997; Canup 2005).

The giant impact was further strengthened by the discoveries of the smaller satellites in co-planar orbits to Charon.


19 January 2006

SCIENTIFIC PAYLOAD

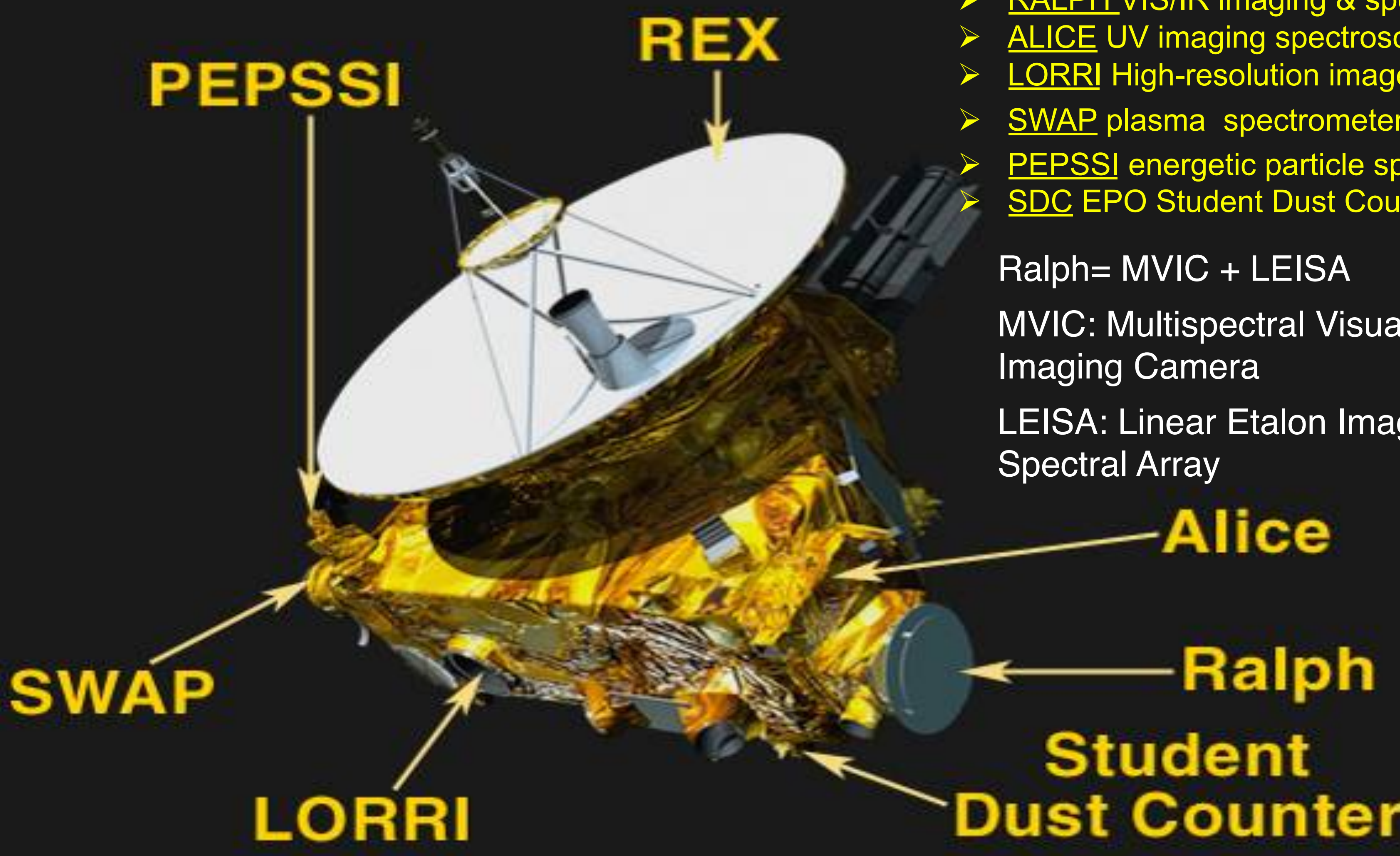
Instruments:

- 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

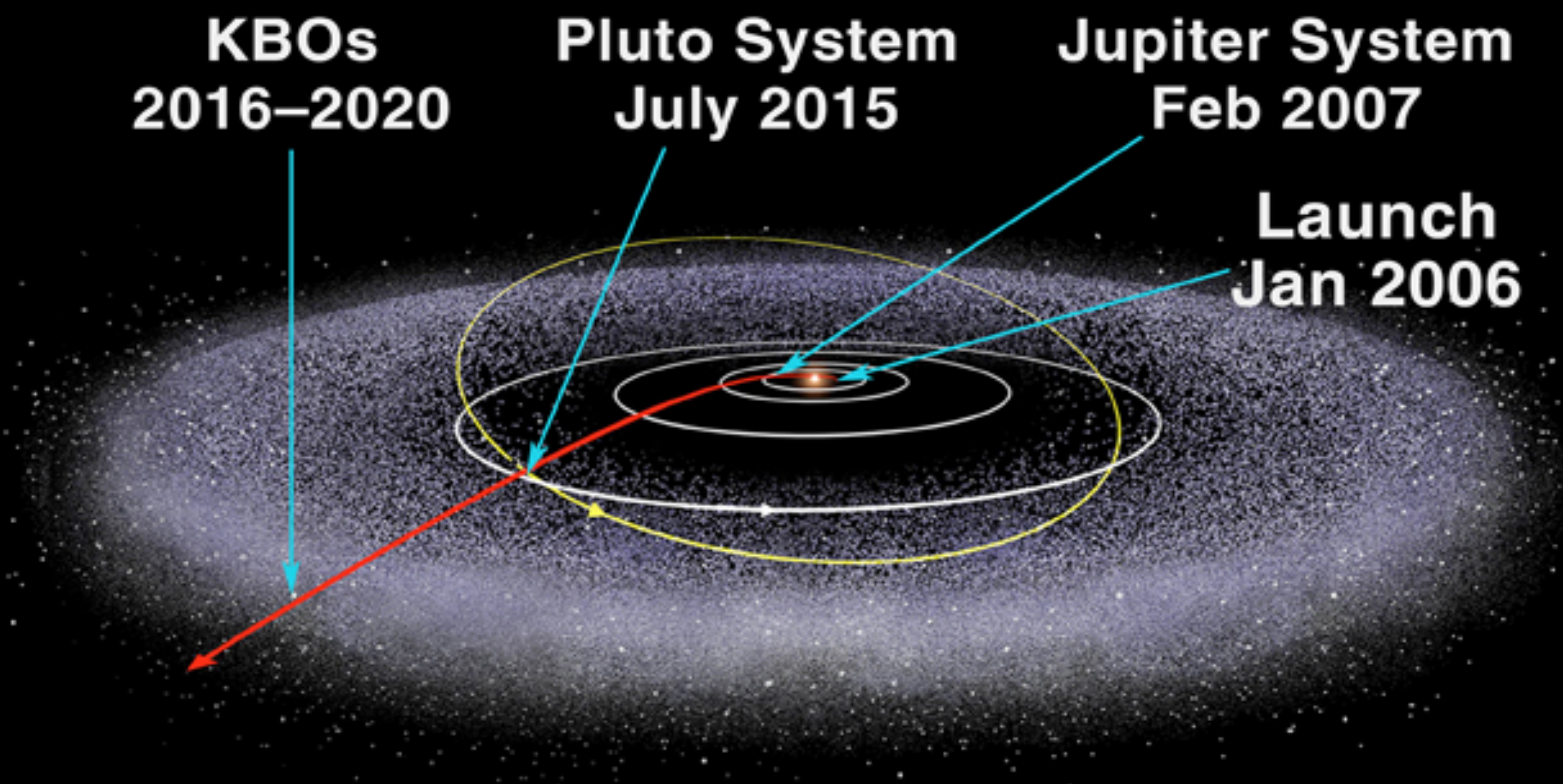
Ralph= MVIC + LEISA

MVIC: Multispectral Visual Imaging Camera

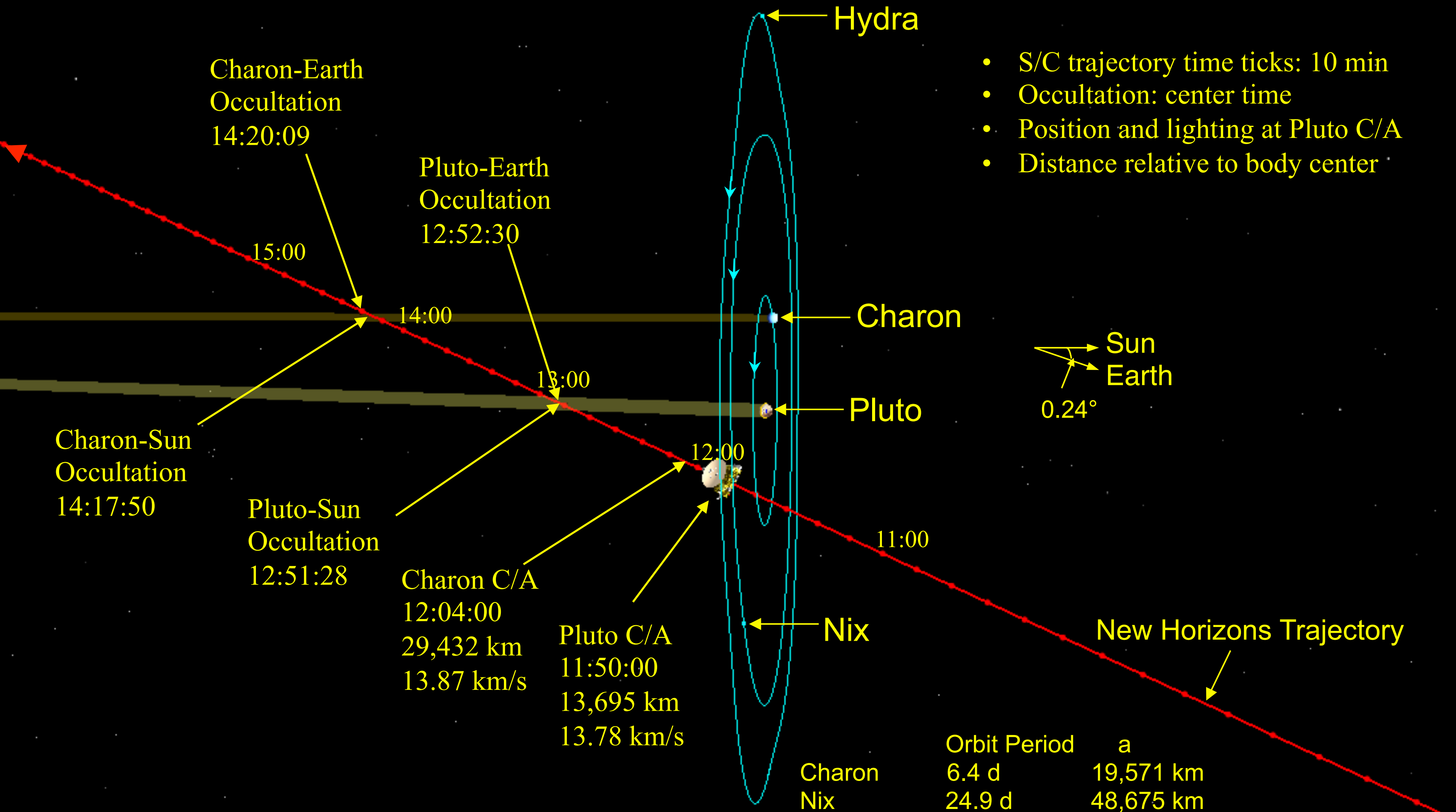
LEISA: Linear Etalon Imaging Spectral Array



ROUTE OF FLIGHT



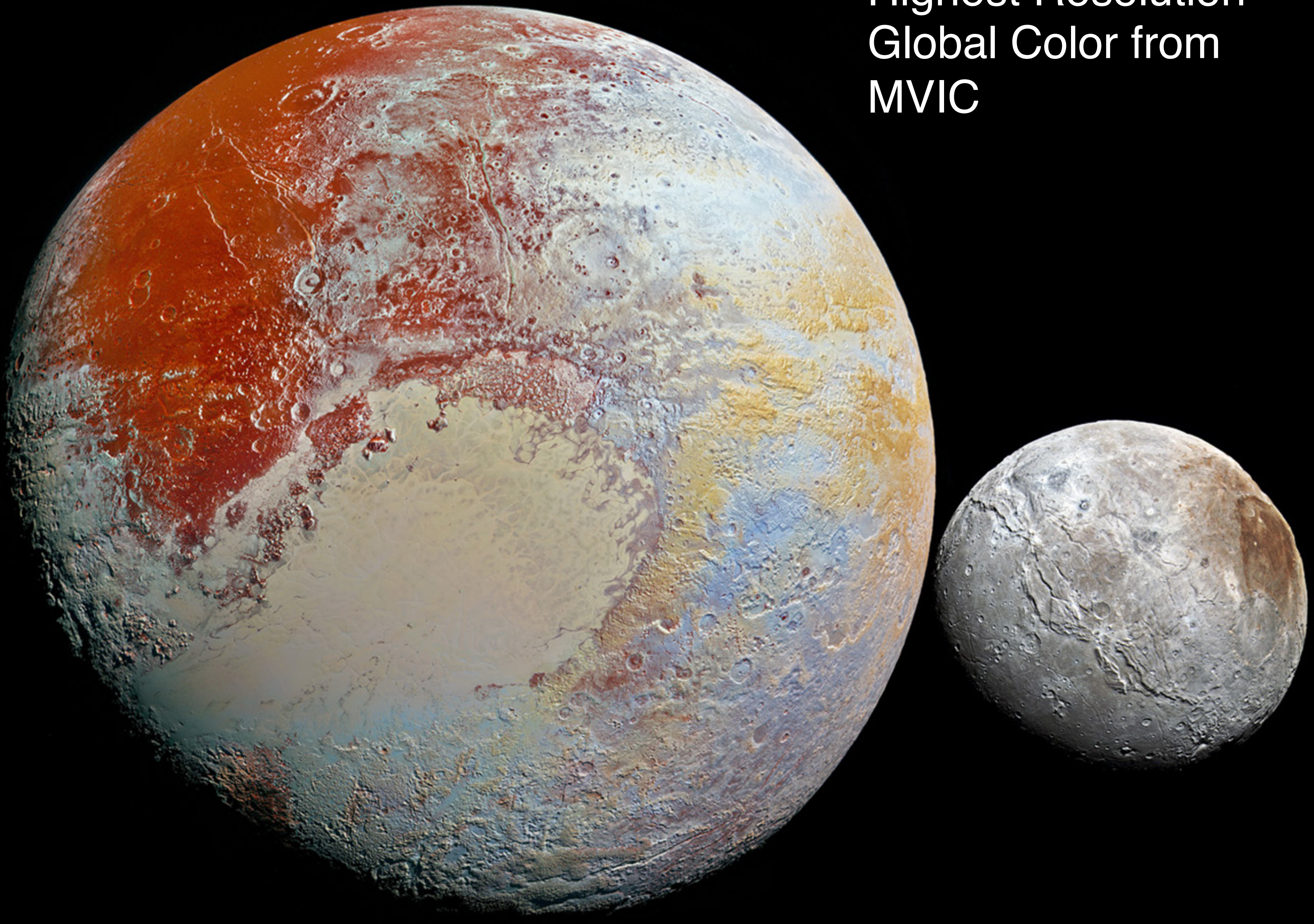
C/A GEOMETRY

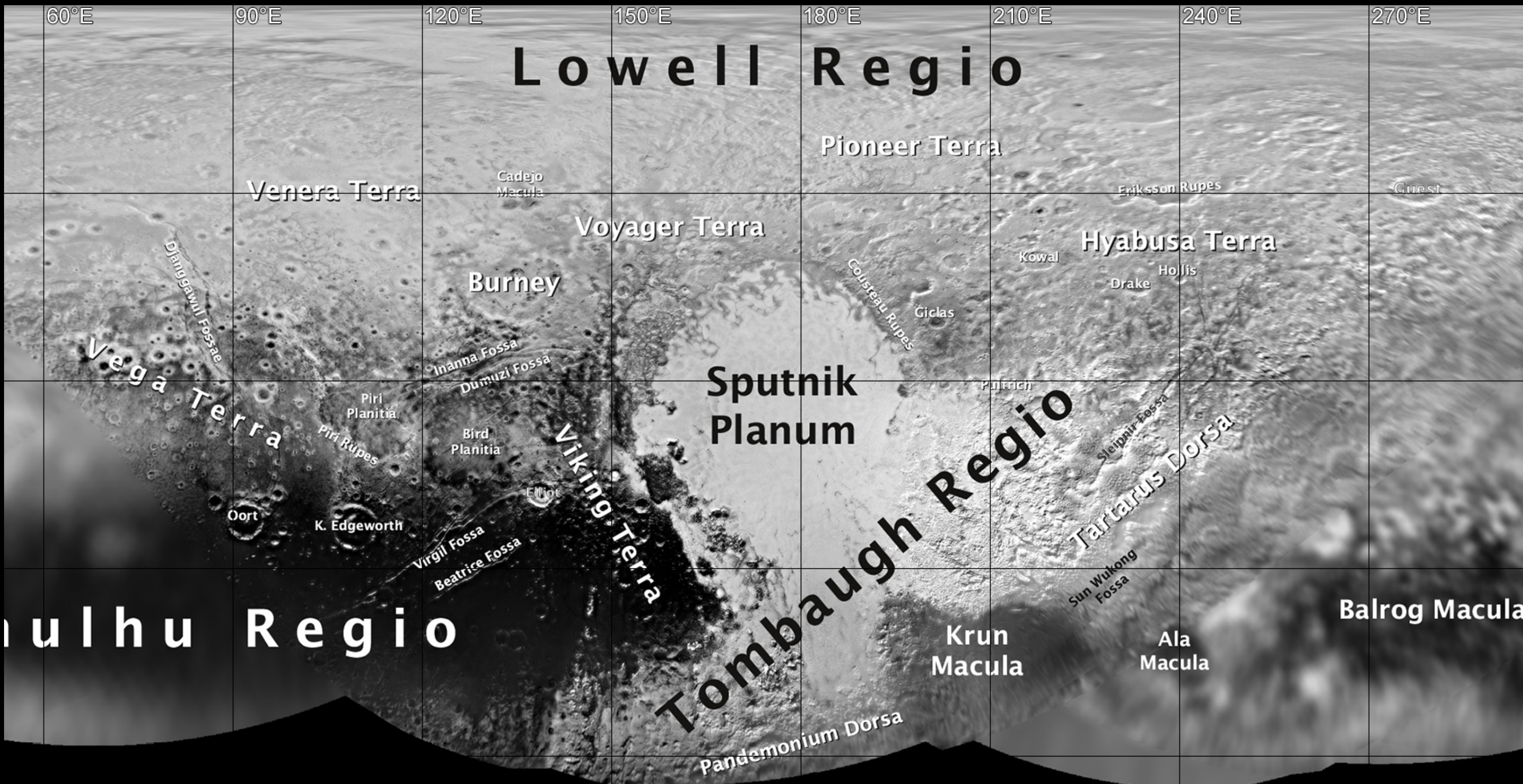


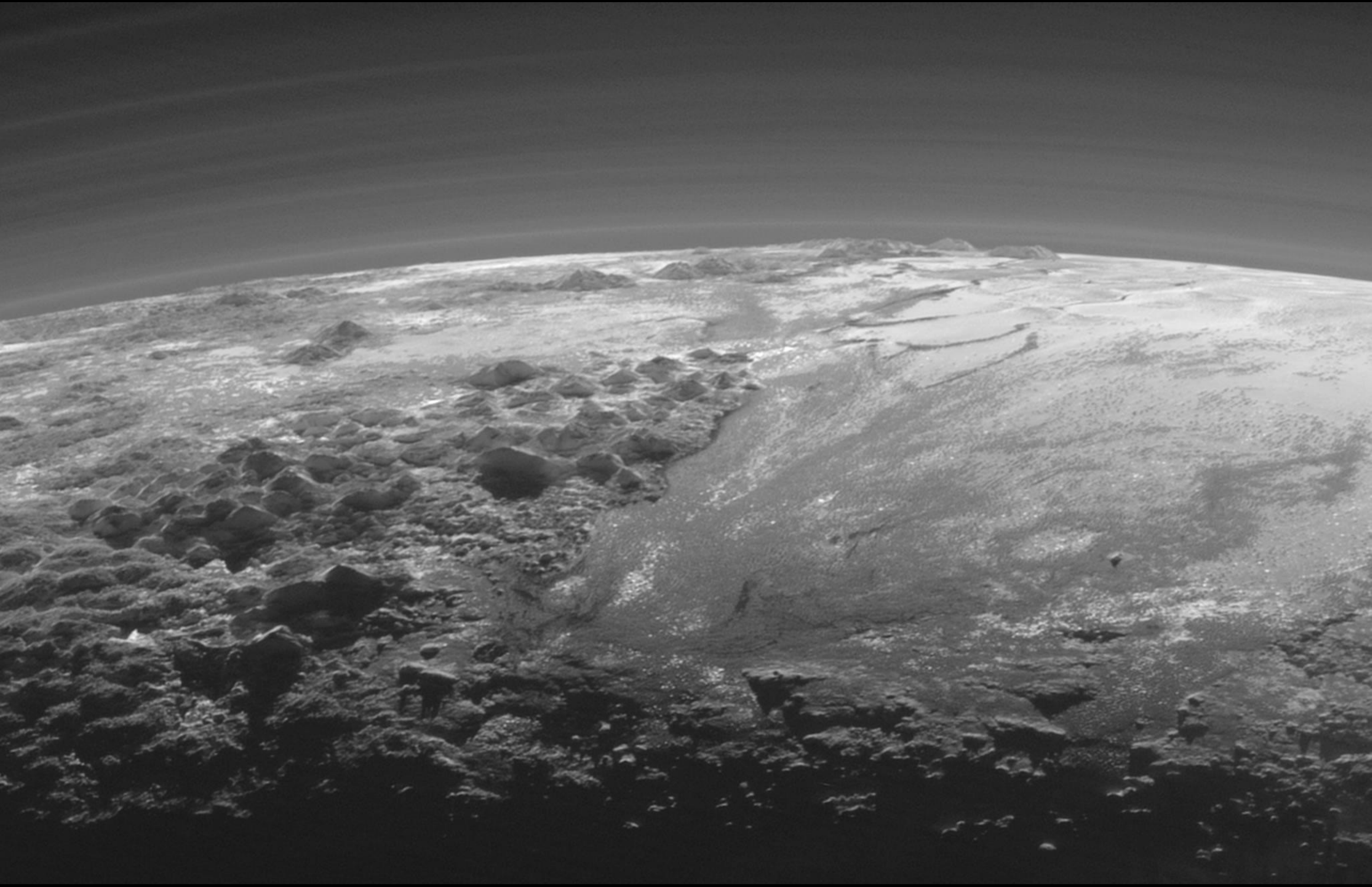
- S/C trajectory time ticks: 10 min
- Occultation: center time
- Position and lighting at Pluto C/A
- Distance relative to body center

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

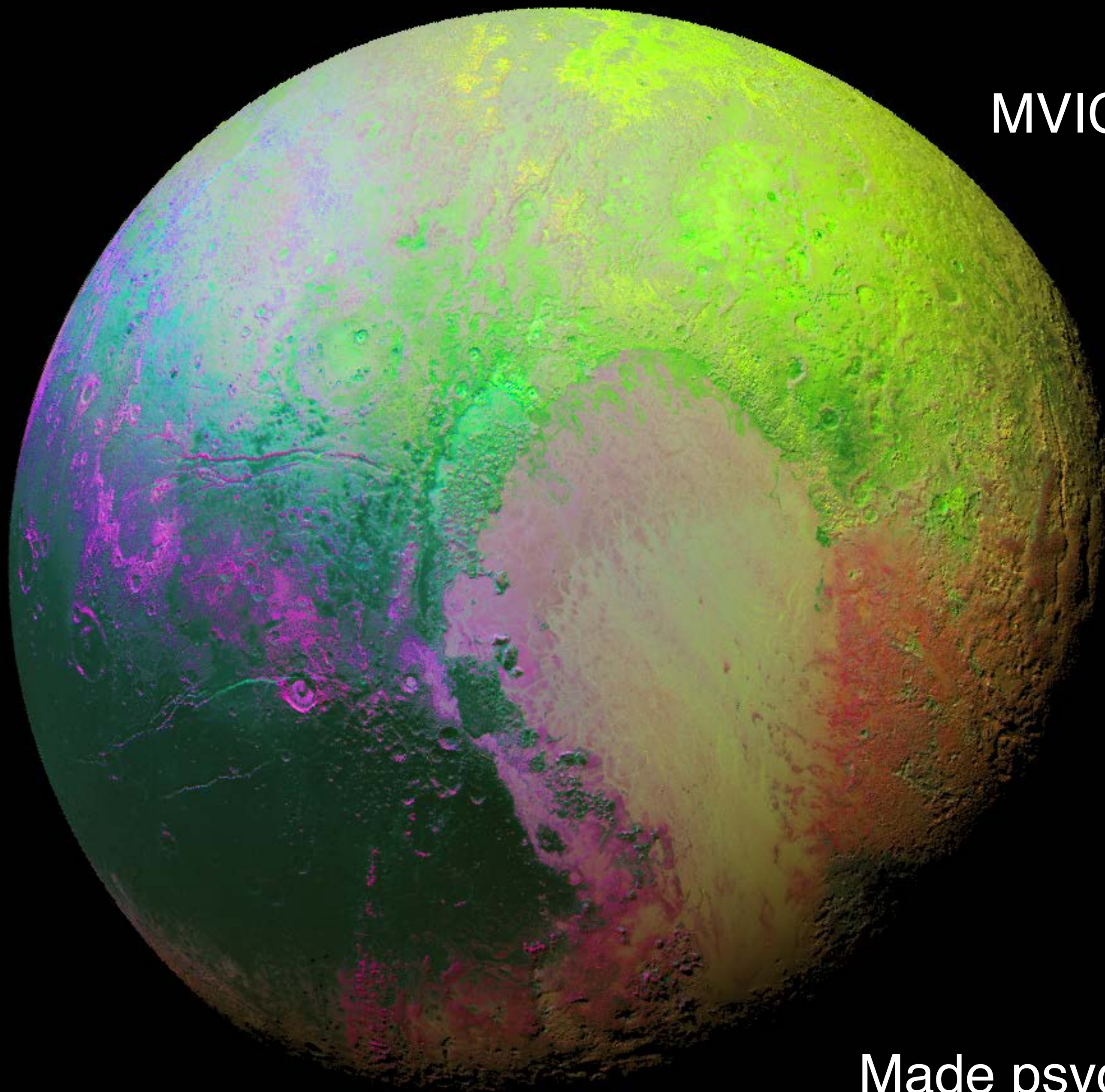
Highest Resolution Global Color from MVIC




60°E
90°E
120°E
150°E
180°E
210°E
240°E
270°E
Lowell Regio
Pioneer Terra
Venera Terra
Cadejo Macula
Voyager Terra
Eriksson Rupes
Guest
Hyabusa Terra
Kowal
Hollis
Drake
Burney
Djanggawul Fossae
Cousteau Rupes
Giclas
Vega Terra
Inanna Fossa
Dumuzi Fossa
Sputnik Planum
Pulfrich
Piri Planitia
Piri Rupes
Bird Planitia
Viking Terra
Tombaugh Regio
Sleipnir Fossa
Tartarus Dorsa
Elliot
Oort
K. Edgeworth
Virgil Fossa
Beatrice Fossa
Sun Wukong Fossa
ulhu Regio
Balrog Macula
Krun Macula
Ala Macula
Pandemonium Dorsa



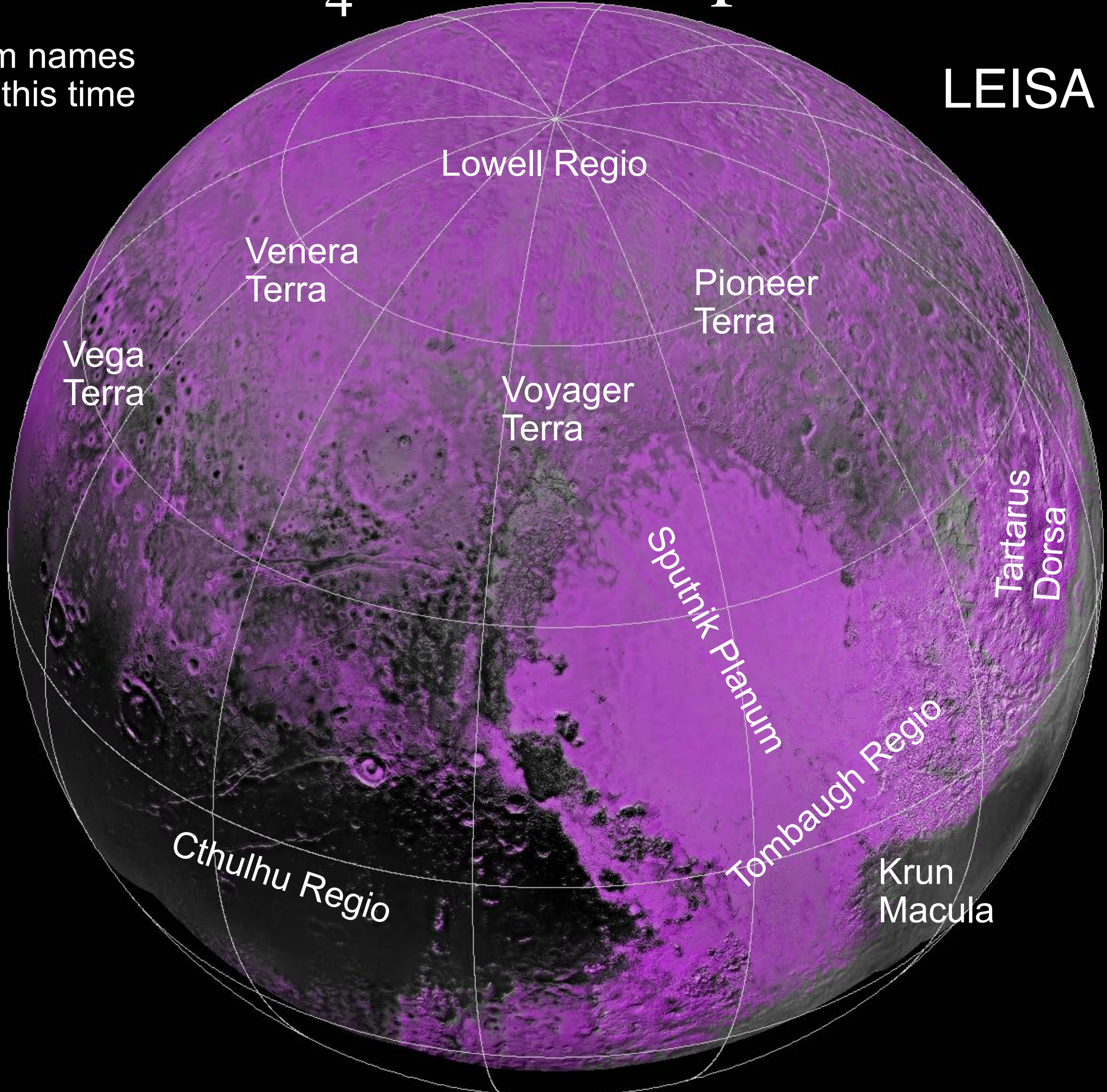
MVIC



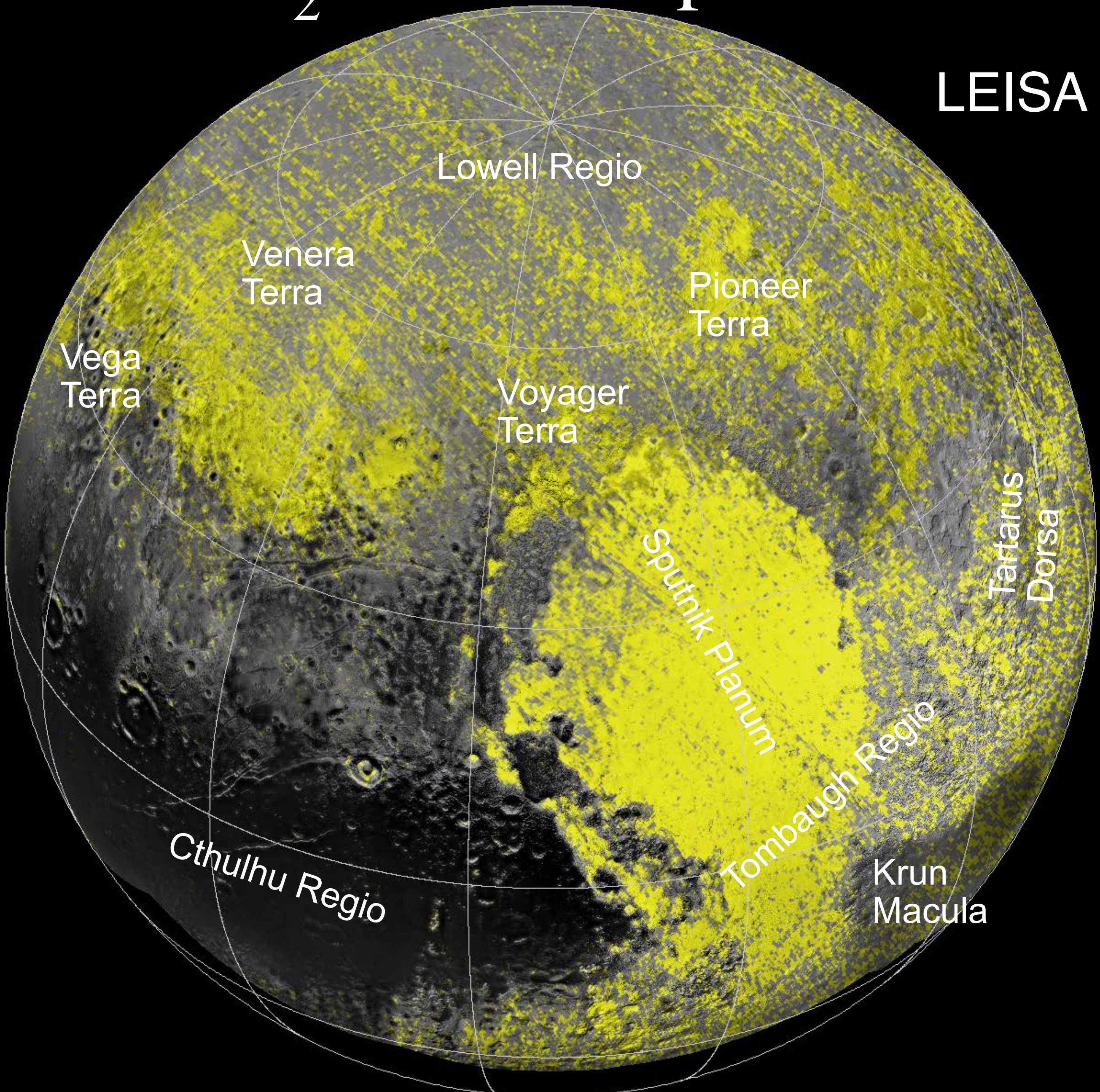
Made psychedelic via
Principal Components Analysis

CH_4 Ice Absorption

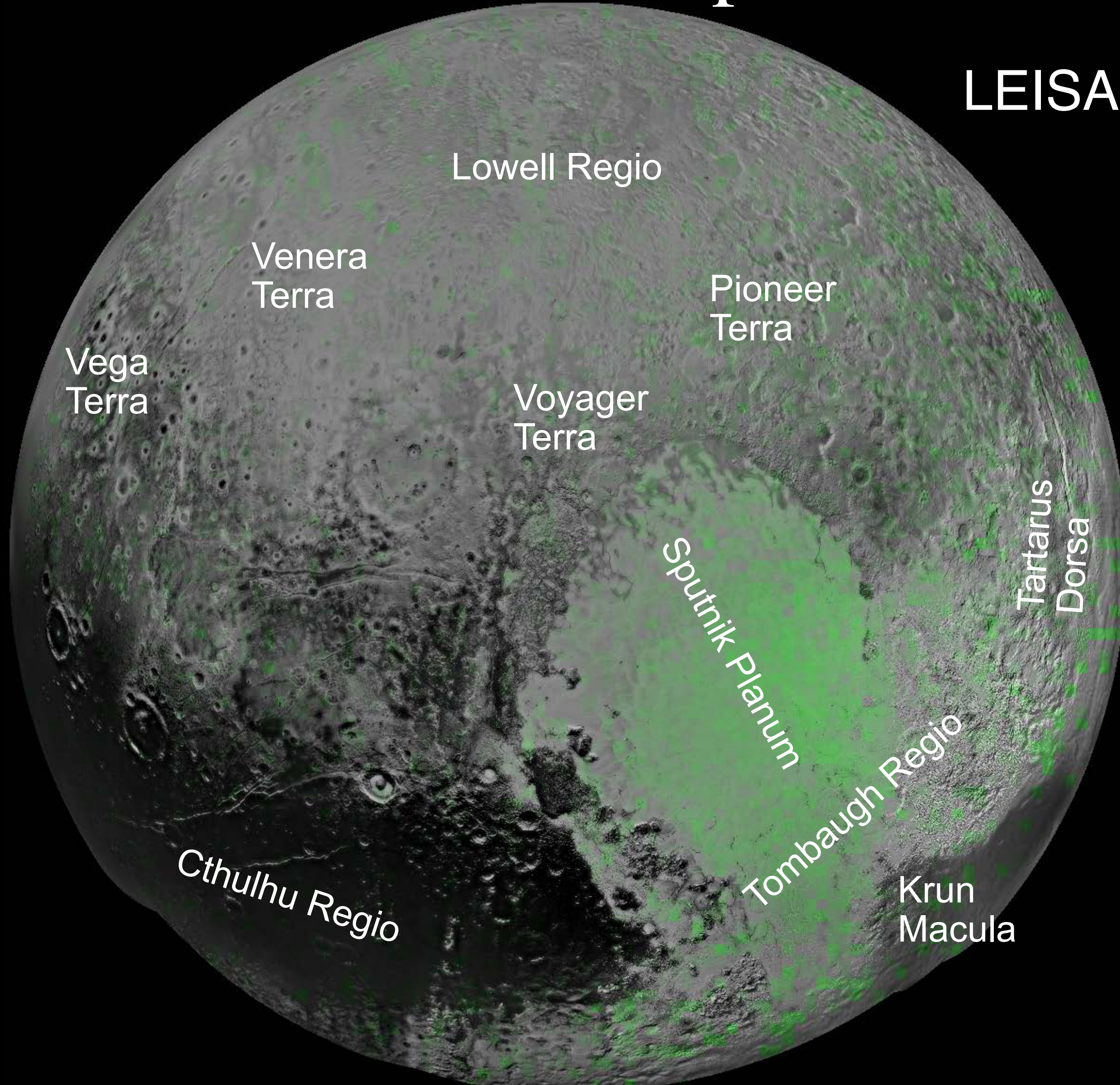
All Pluto system names are informal at this time



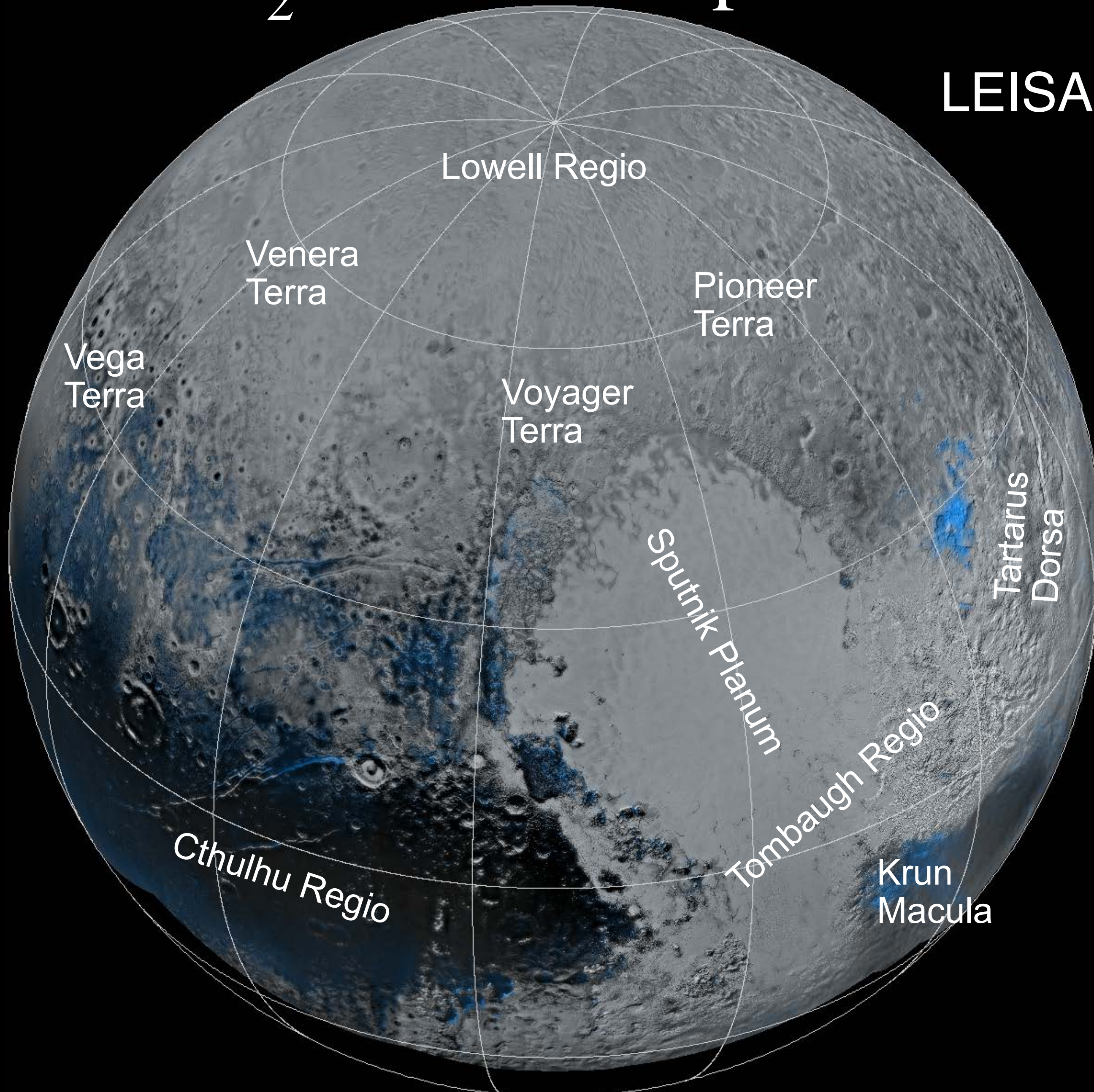
N_2 Ice Absorption



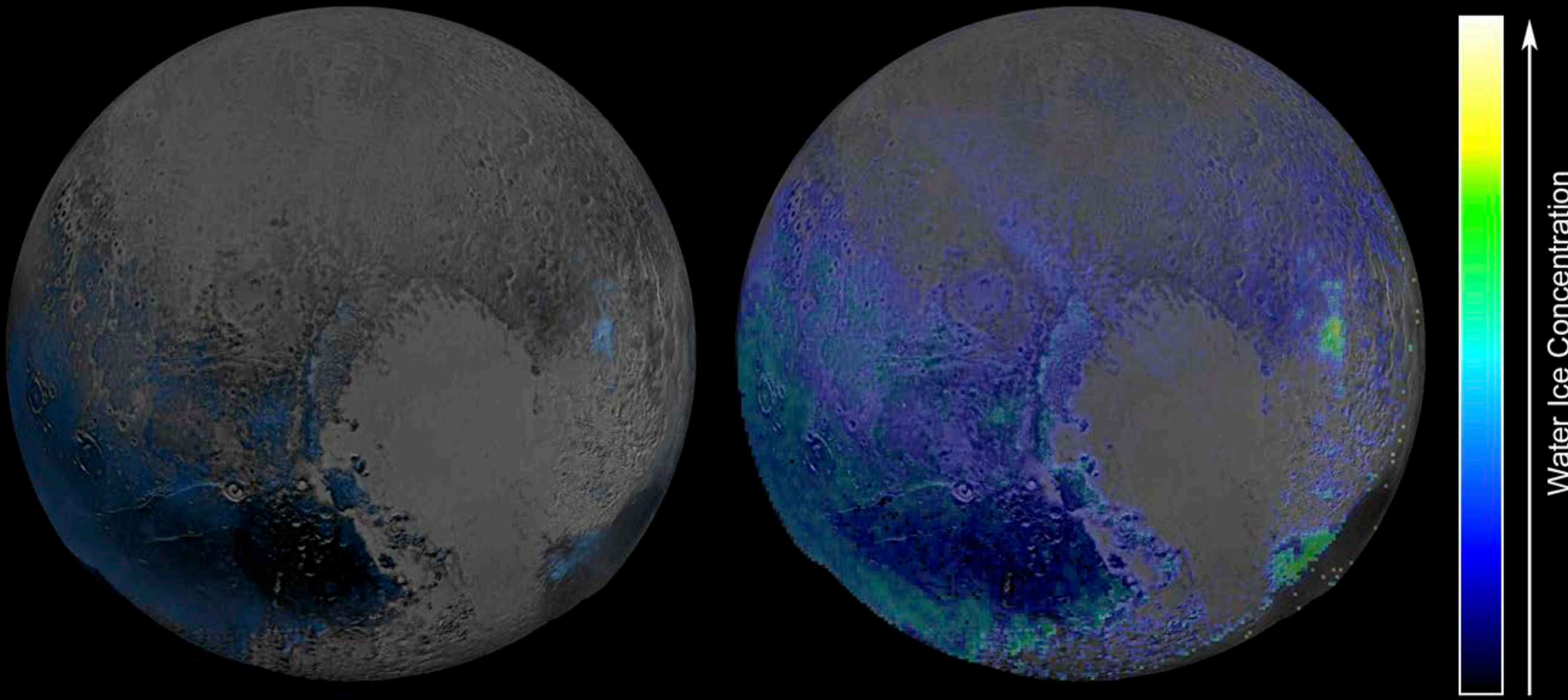
CO Ice Absorption



H_2O Ice Absorption



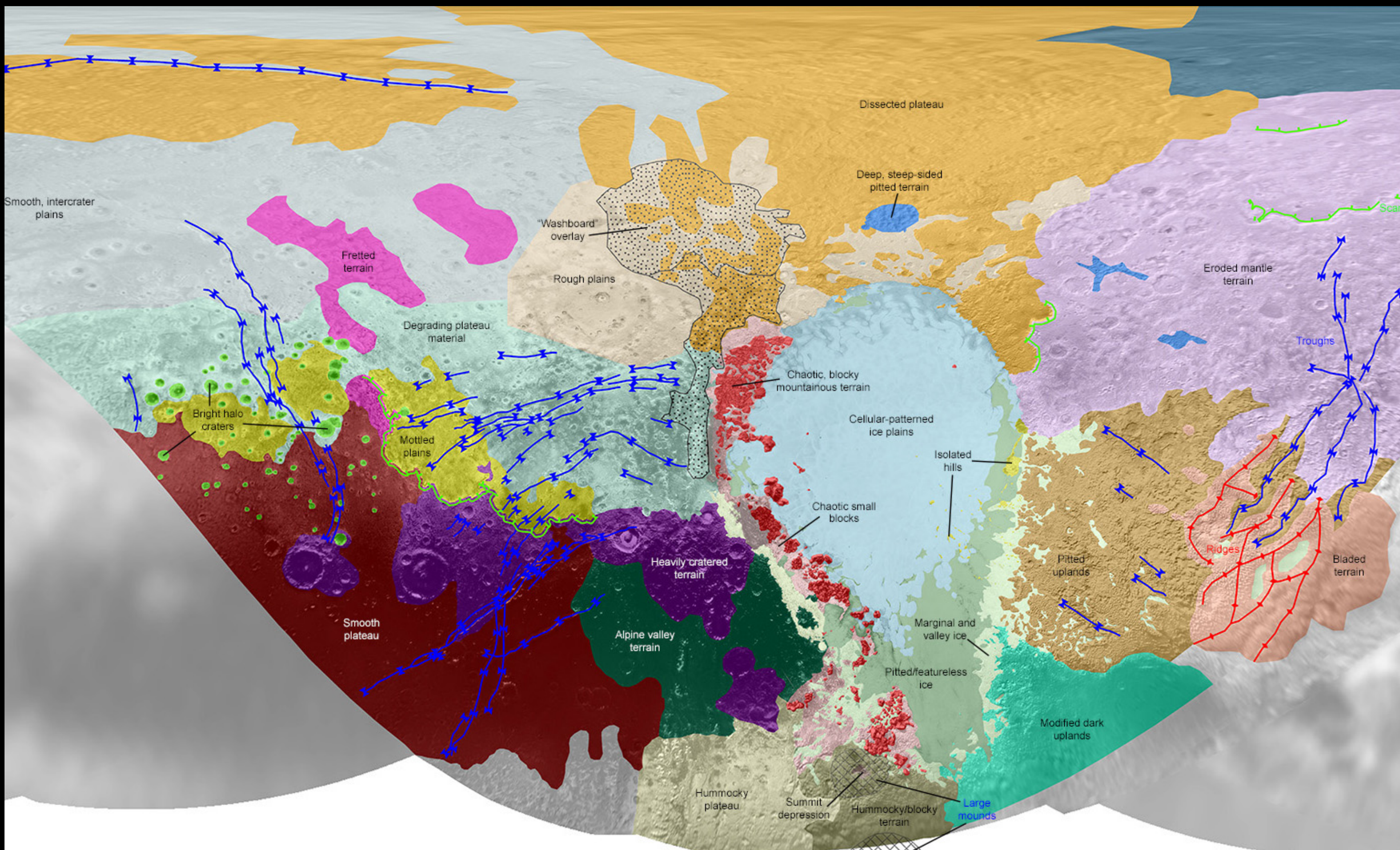
Updated water absorption map



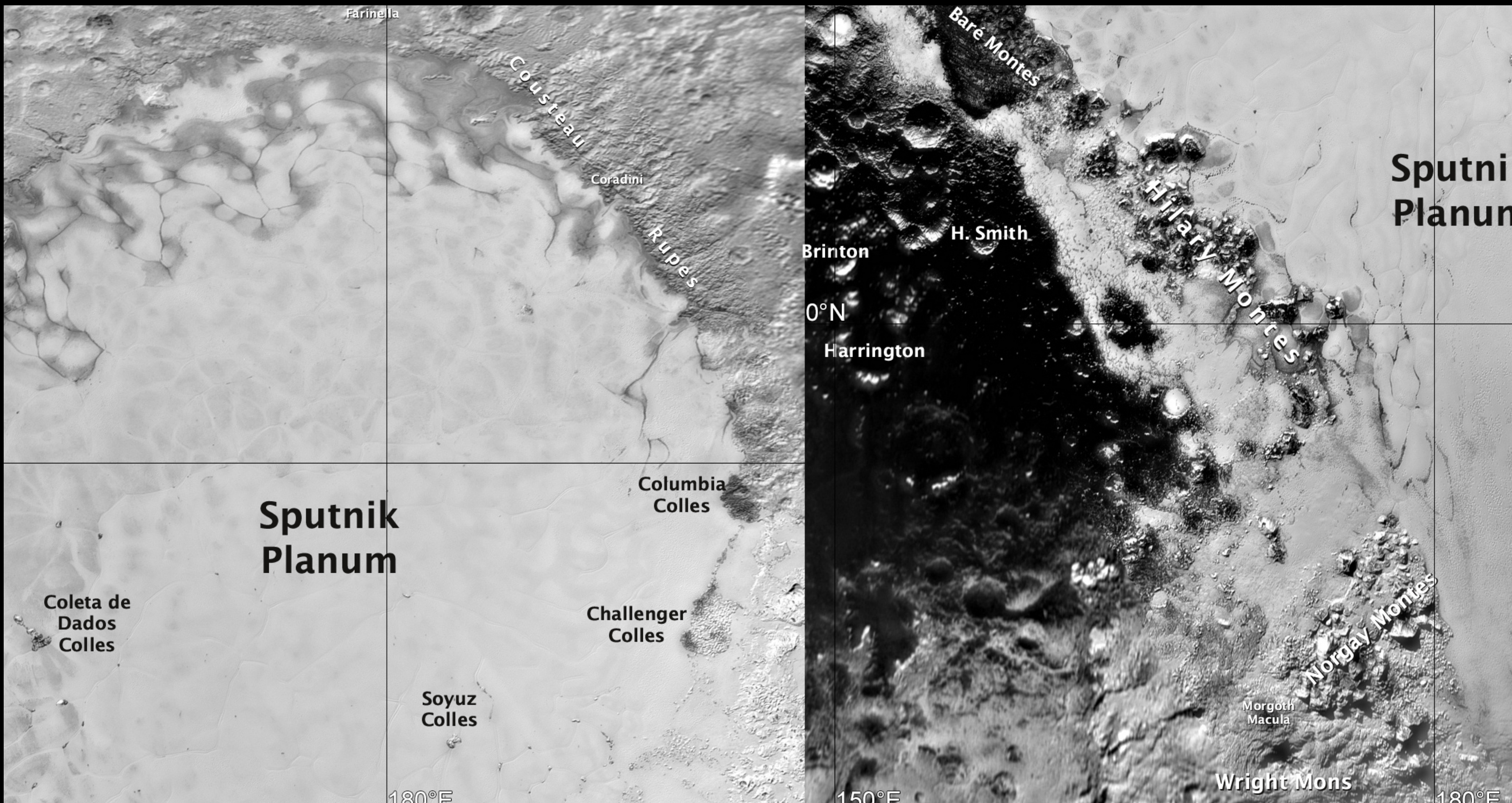
HOW DO WE START DOING GEOLOGY?

Step 1: Identify and Locate the Occurrences of the different Landform Classes and Terrain Types and then Describe them

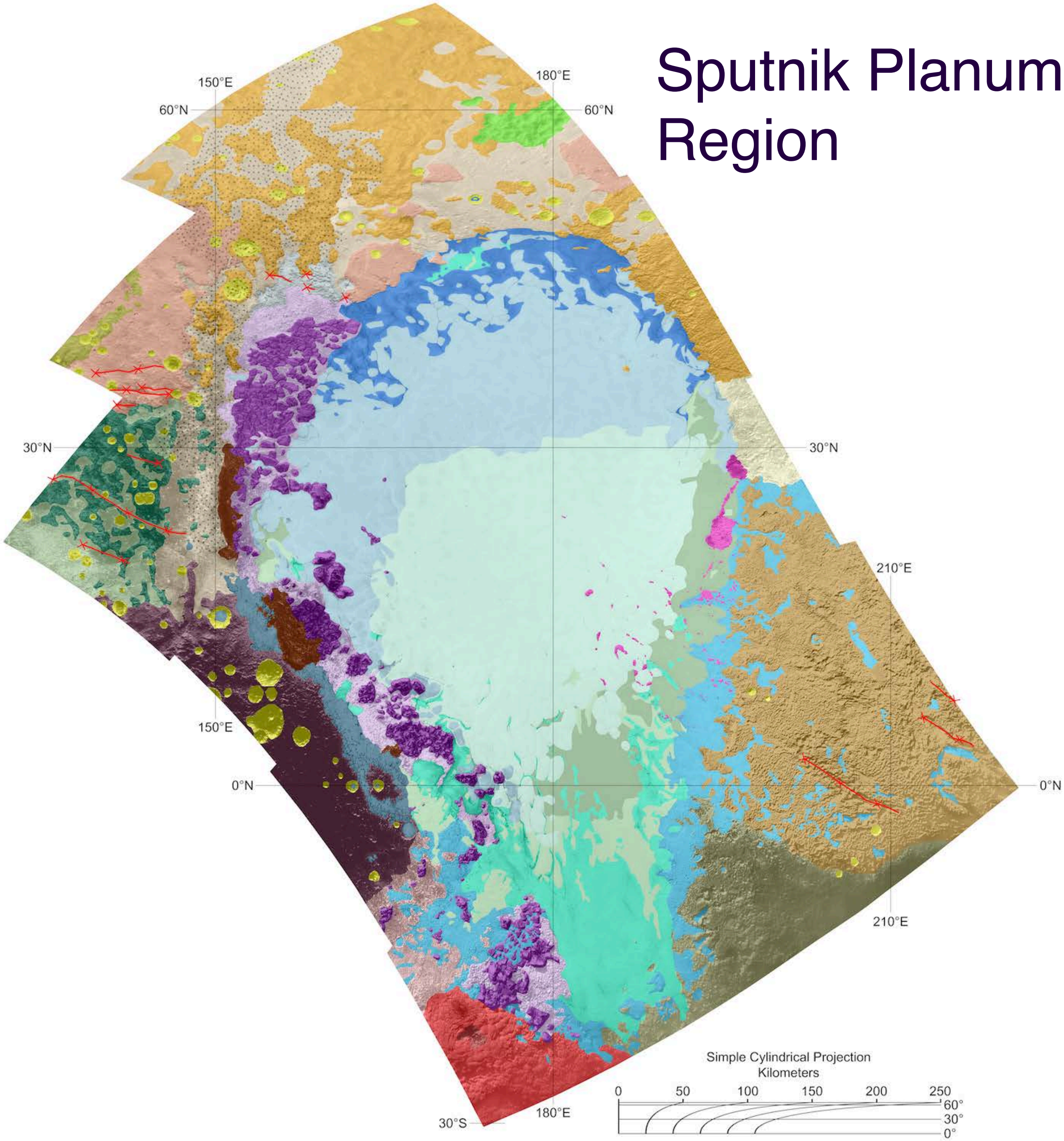
WARNING: This is NOT a Geological Map



Place Names on/around Sputnik Planum

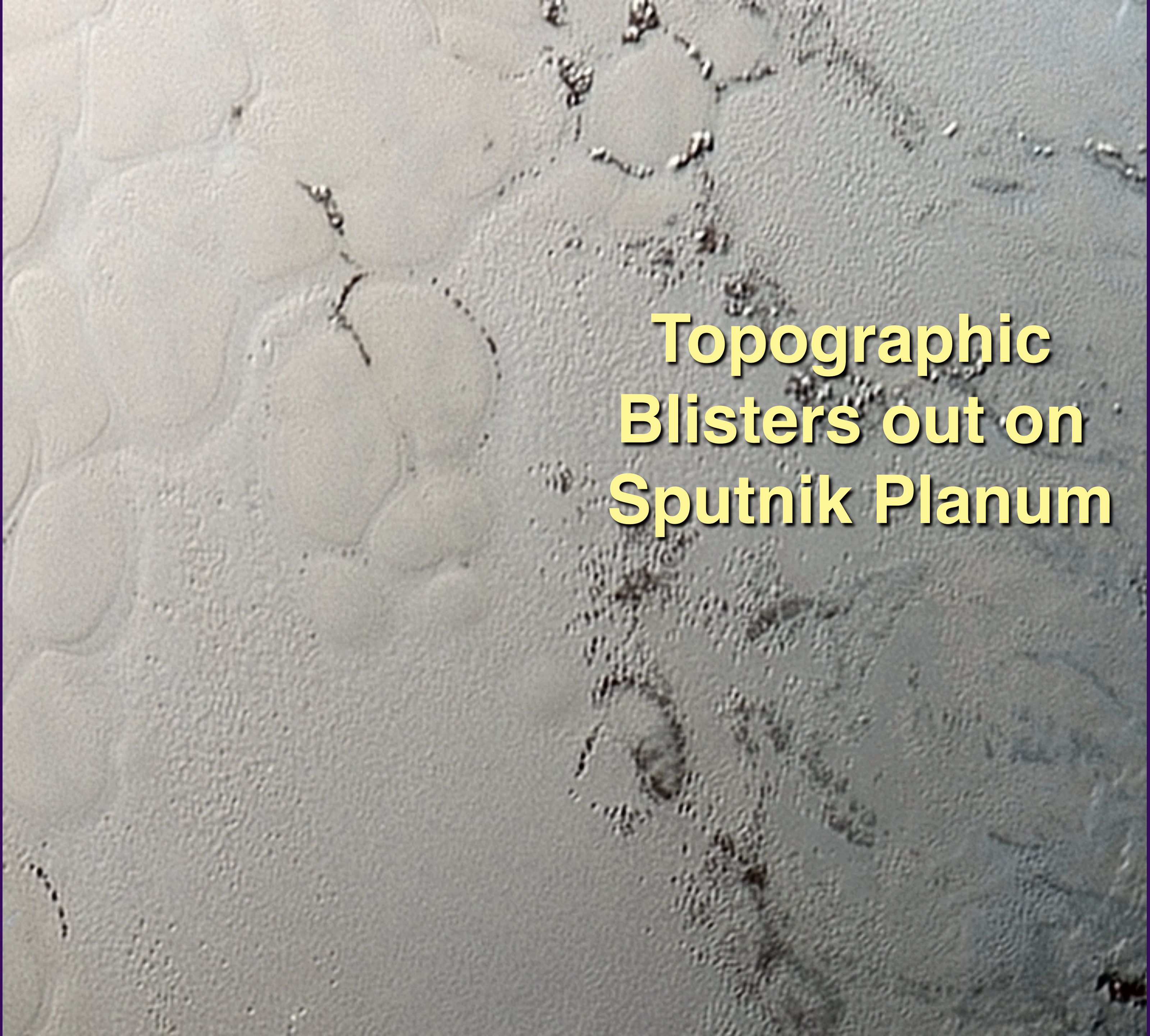


Sputnik Planum Region

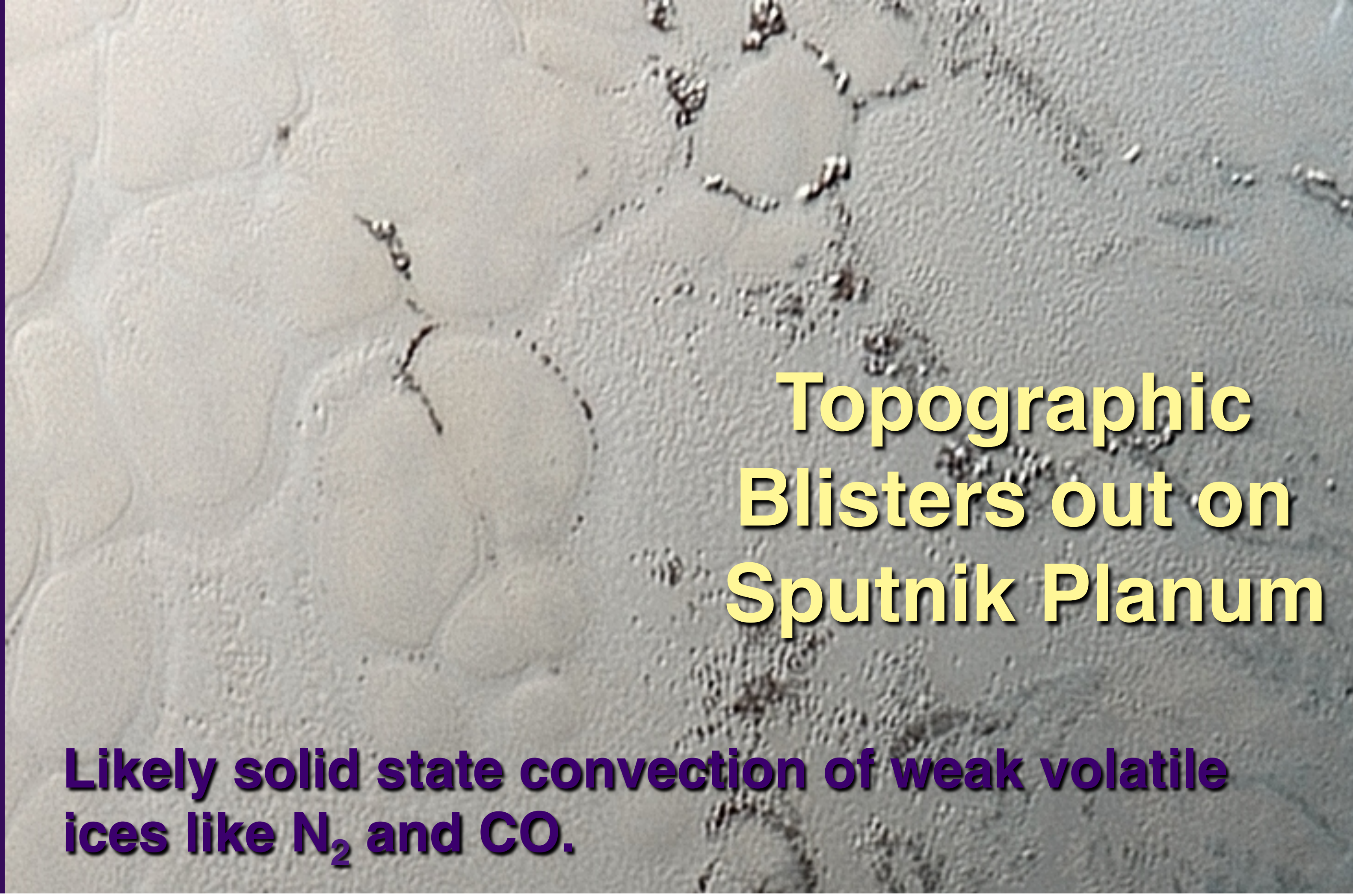


Separate geomorphological units in and around Sputnik Planum have been mapped and defined, with preliminary interpretations.

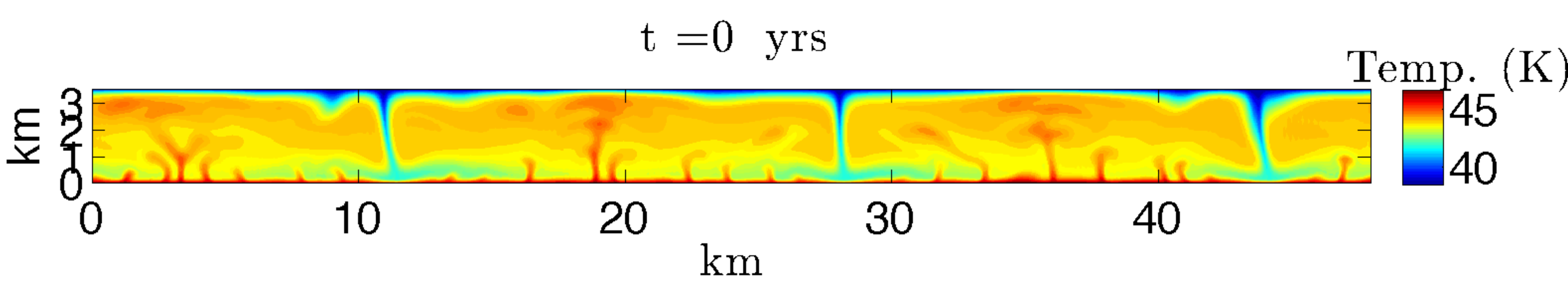
This region of Pluto is highly complex, with a multitude of landform-modifying processes having occurred (or occurring) within it.

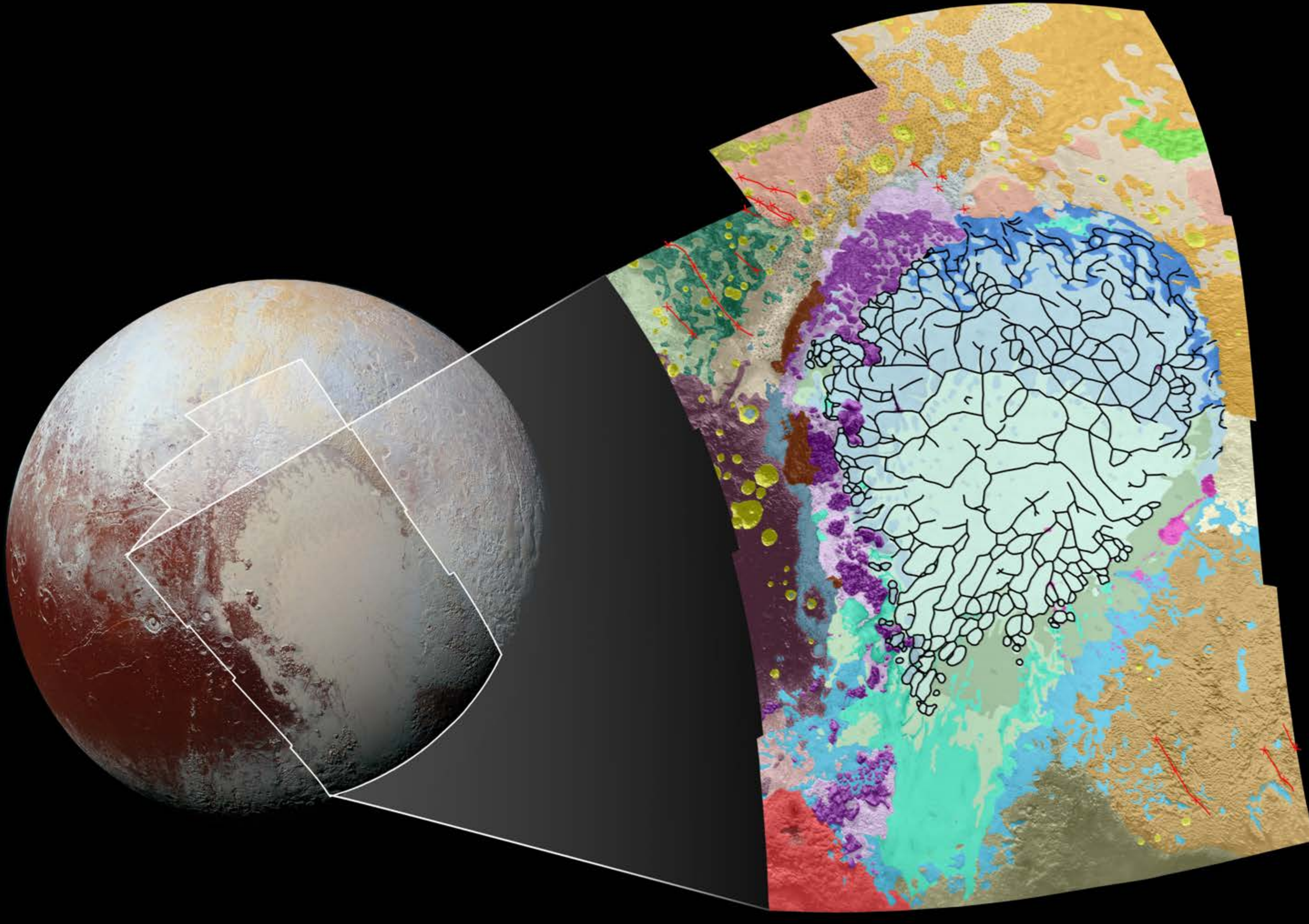

Topographic
Blisters out on
Sputnik Planum

Topographic Blisters out on Sputnik Planum



Likely solid state convection of weak volatile ices like N_2 and CO.





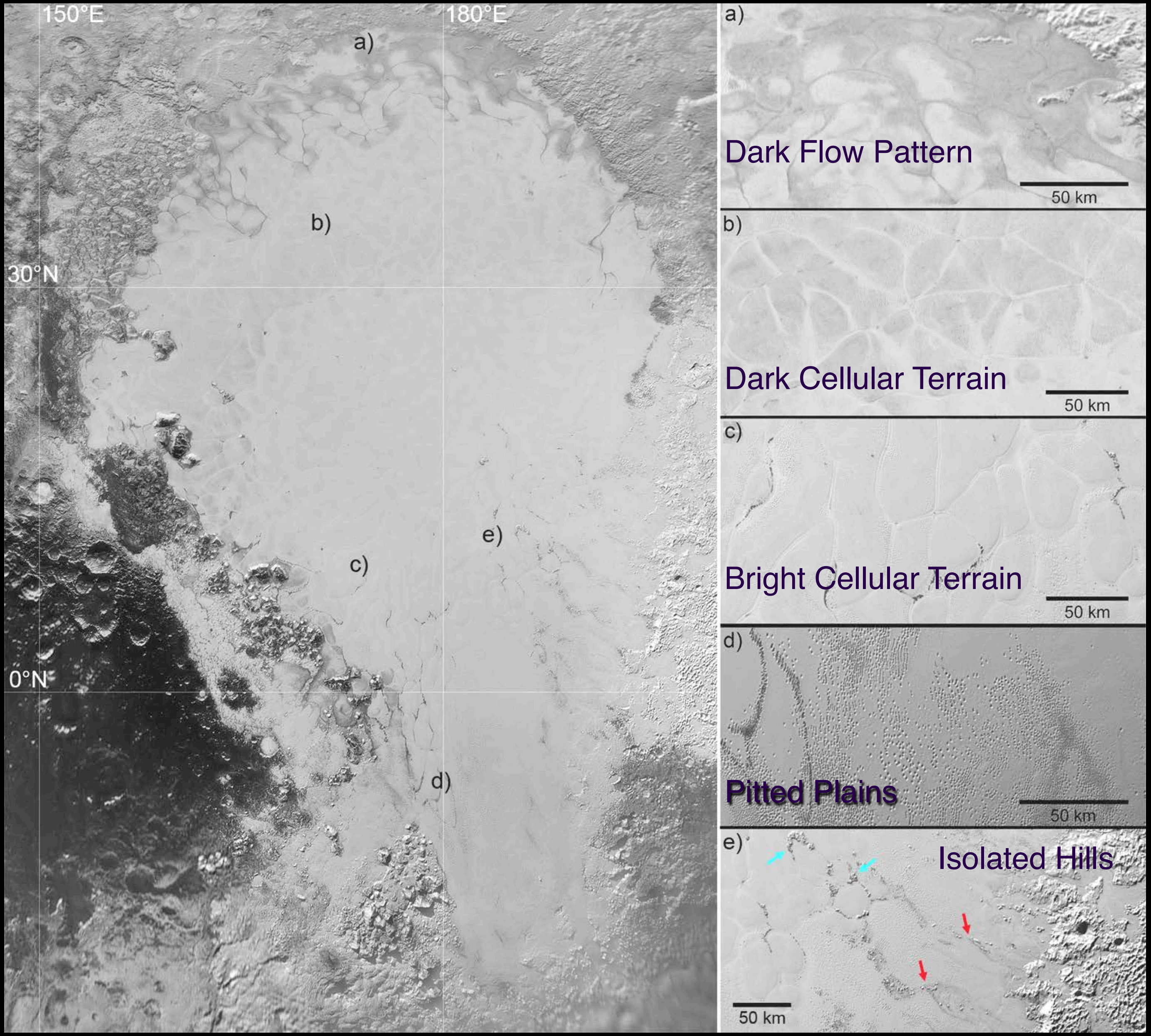
Variety of Cell & Other Textures in Sputnik Plaum

Cells (30-50 km) are bounded by troughs that typically reach a few kilometers across and around a hundred meters deep,

In some instances, dark material and even small blocks collects within these troughs.

Southern portion of SP, does not display cellular morphology, instead surface appears featureless or shows dense concentrations of pits (Fig. d).

Individual pits reach a few kilometers across, and some form strings resembling bacilli



CHAOS & ANARCHY IN SPUTNIK PLANUM!

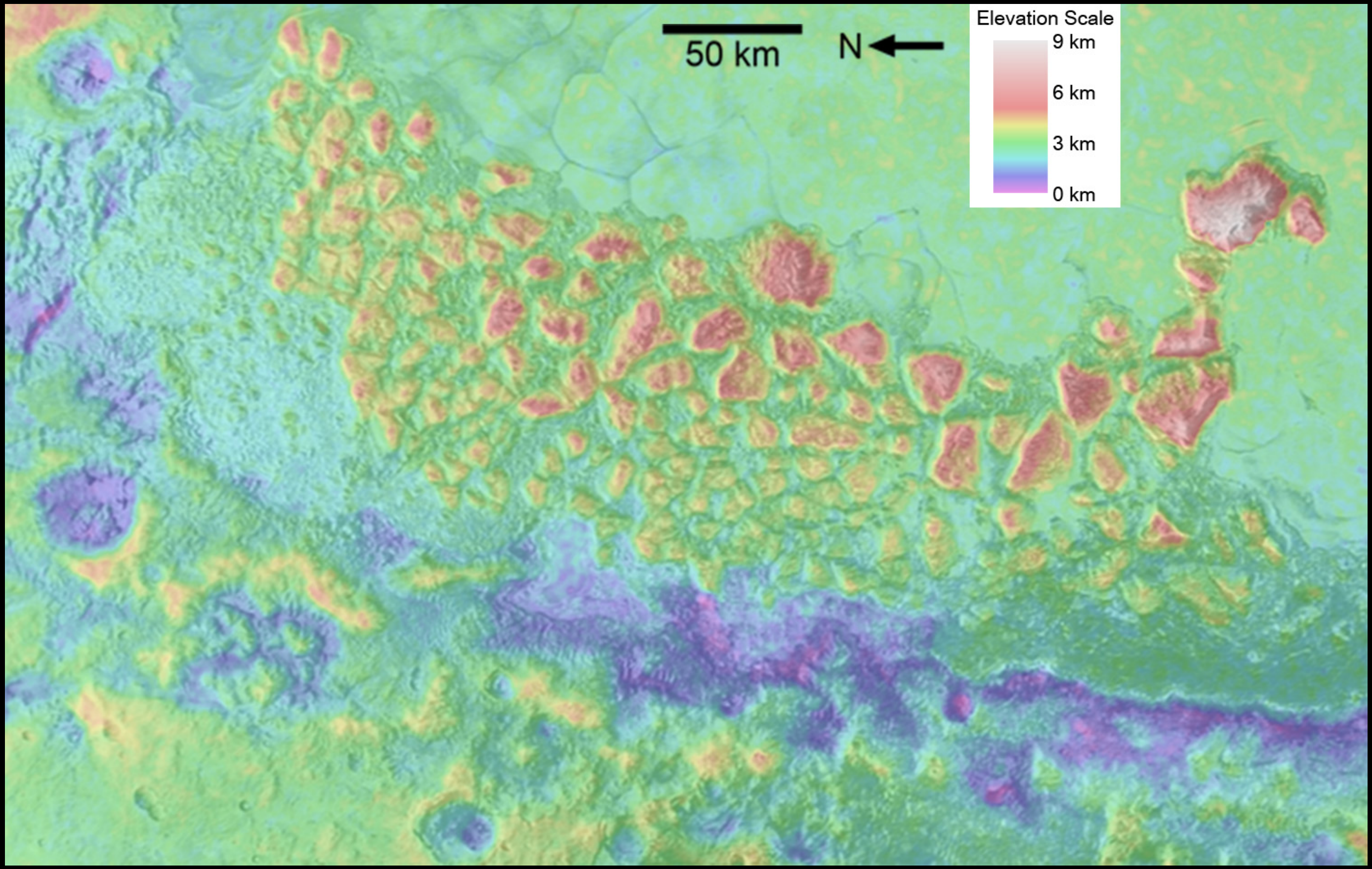
Discontinuous chains of mountains with apparently random orientations and sizes up to 40 km across and 5 km high, extend for hundreds of km along the west margin of SP.

Here, blocks are closely packed, and many blocks have flat or gently sloping upper surfaces with linear textures similar to some of the surrounding highland terrain, indicating breakup of a preexisting surface.

Water ice is buoyant with respect to N_2 & CO ice, and blocks of water ice embedded or buried in solid N_2/CO will seek to "float"

Small blocks can be carried along essentially as icebergs, and large blocks may be undermined, shifted, and rotated.

Even the largest mountains on Pluto could be floating.

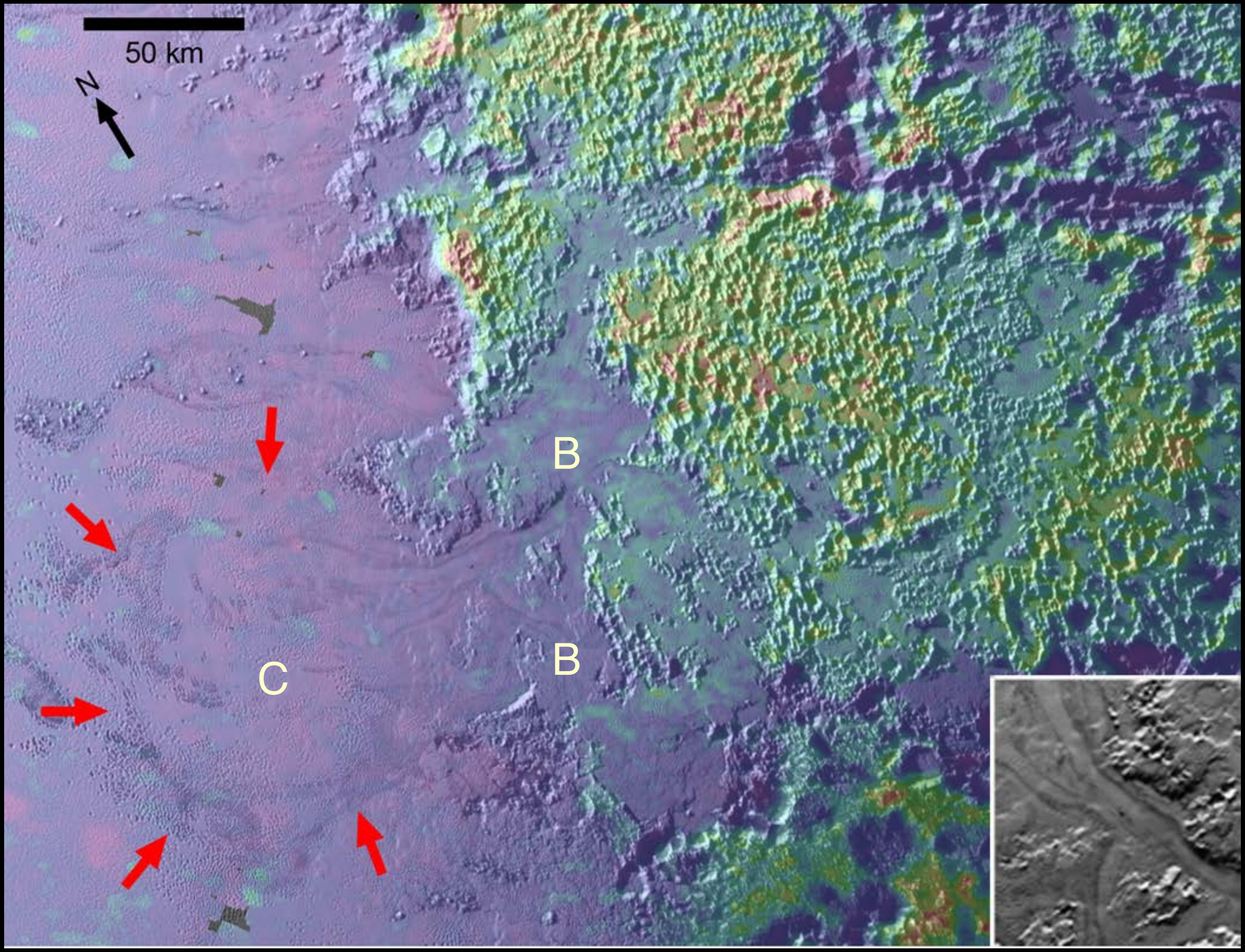


Pitted Uplands and Valley Glaciers East of Sputnik Planum

Densely pitted uplands, with smooth material covering the floors of the pits.

(B) Smooth material flowing glacially through notches in the pitted uplands towards SP. (see high phase view at bottom)

(C) Entry of a valley glacier into SP. Possible outer flow edges are indicated by red arrows.



VOLCANIC MOUNTAINS ON PLUTO?

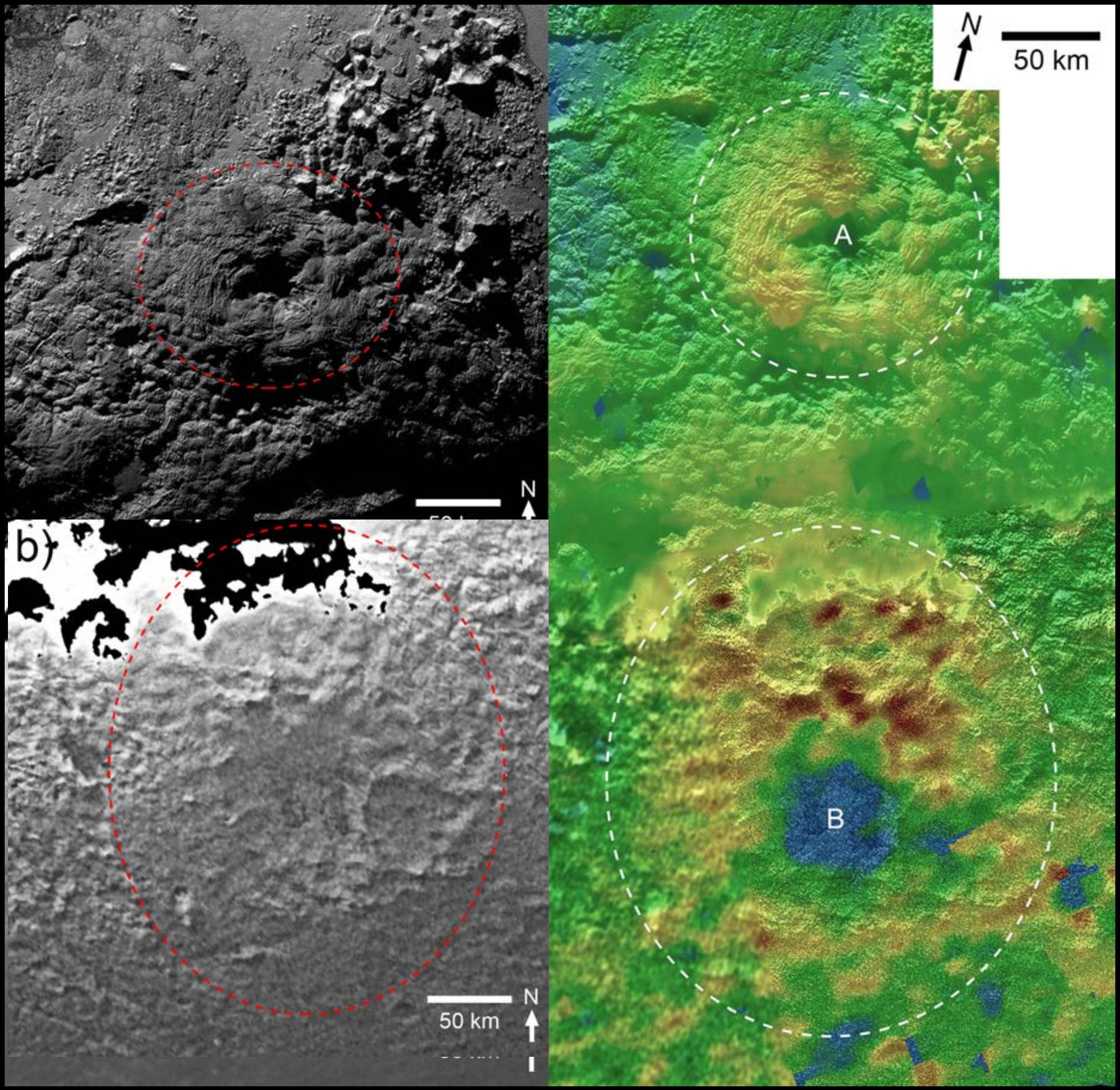
Wright Mons 3-5 km high (north) and Picard Mons ~6 km high (South).

Quasi-circular mounds south of SP, both with depressions at their summits. Dashed lines mark their approximate boundaries.

Wright Mons summit has a 5-km-deep central depression that has a rim showing a concentric fabric

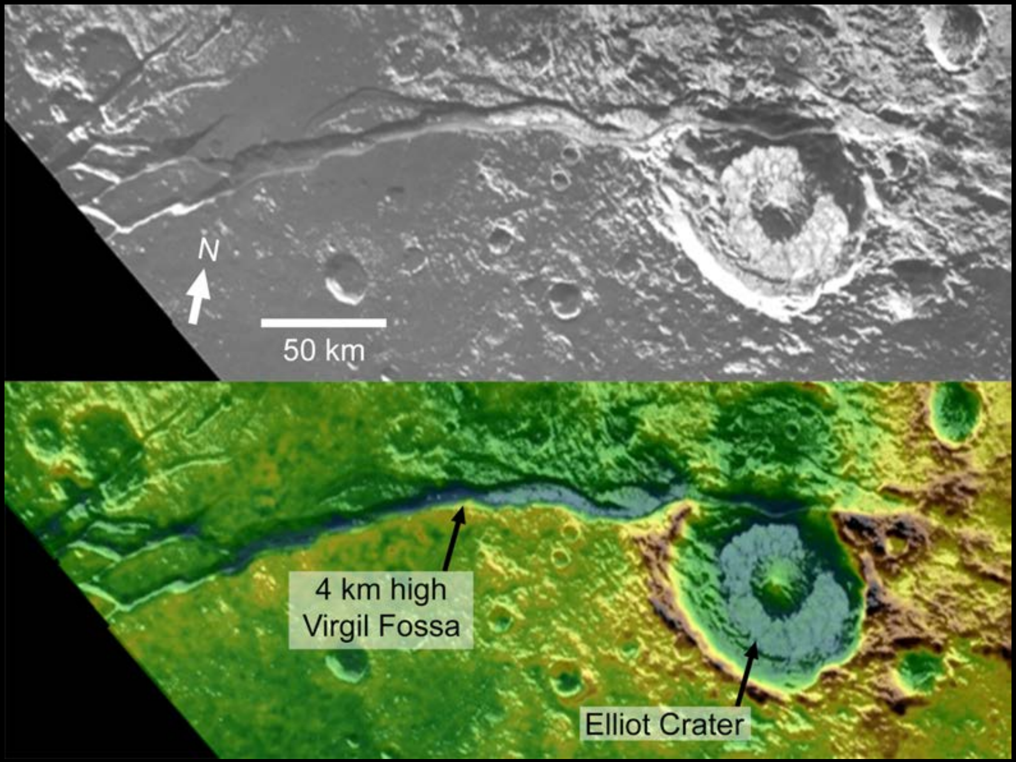
The mounds have blocky or hummocky surface textures, and are very lightly cratered.

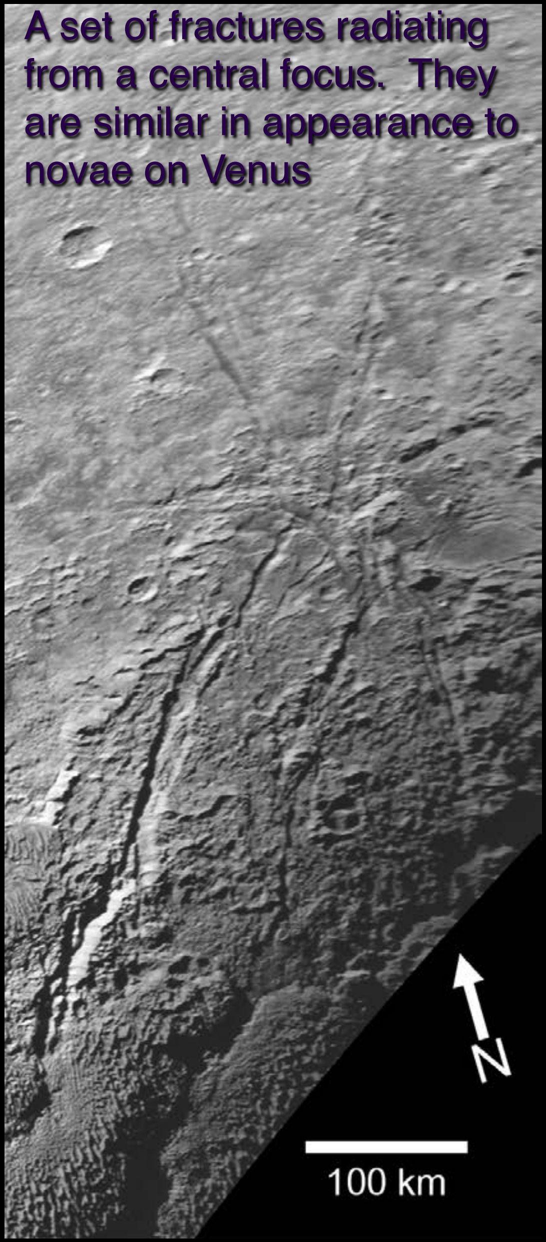
The general shapes of these edifices and associated structures appear to be constructional. Their origin could involve icy-volcanism and/or tectonism.



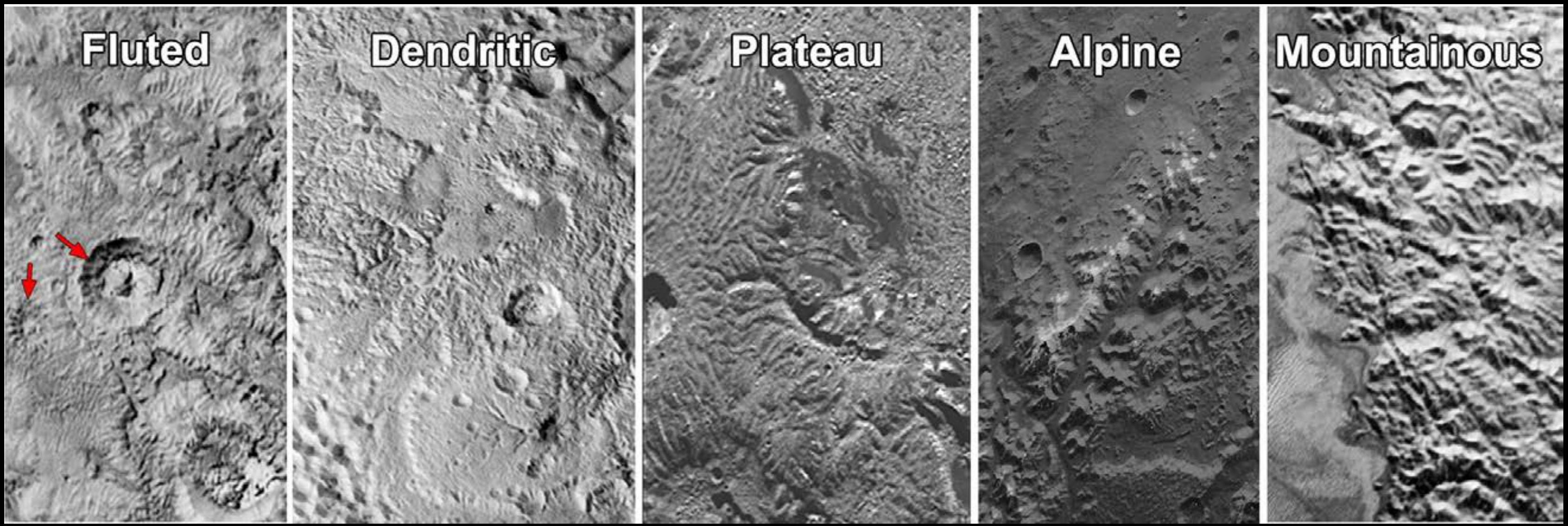
WIDESPREAD EXTENIONAL TECTONISM ON PLUTO

The differing fault orientations and states of preservation suggest multiple fracturing episodes and prolonged tectonic activity. The great length of individual faults, their steepness, and the absence of flank uplift suggest a thick H_2O-ice basement crust.





The Variety of Dissected Terrains

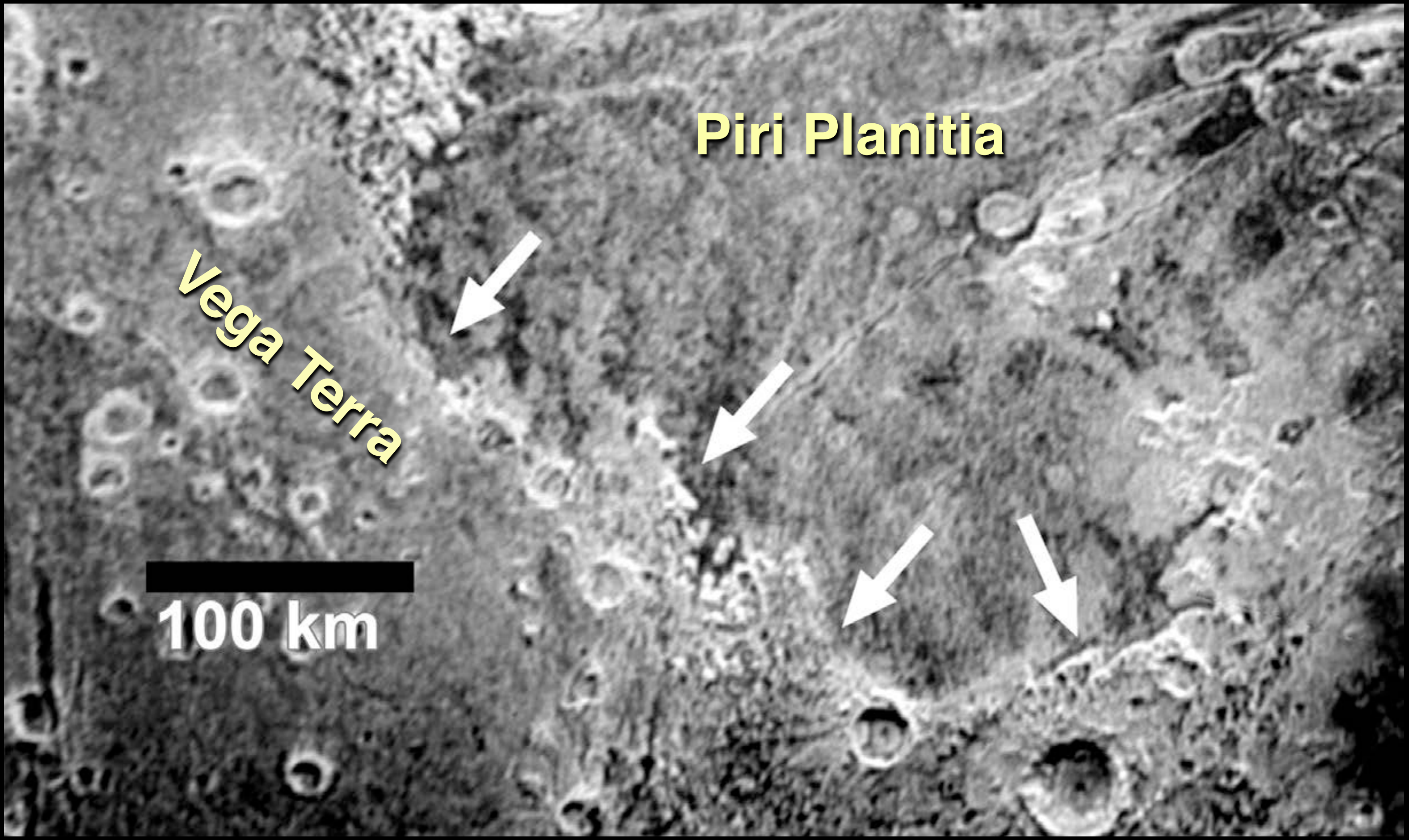


Both the fluted slopes and the valley networks probably result from the flow of nitrogen-rich ice, possibly accompanied by basal melting, involving surface ice accumulation, glacial flow, and erosion. This is the dominant mechanism for erosion by valley glaciers on Earth. Two possible variants are:

1. Erosion beneath thick ice sheets, such as ice streams at the margins of terrestrial plateau glaciers, such as at Greenland and Antarctica.

2. The precipitation of volatiles such as snow on slopes, followed by erosion by alpine glacial flow.

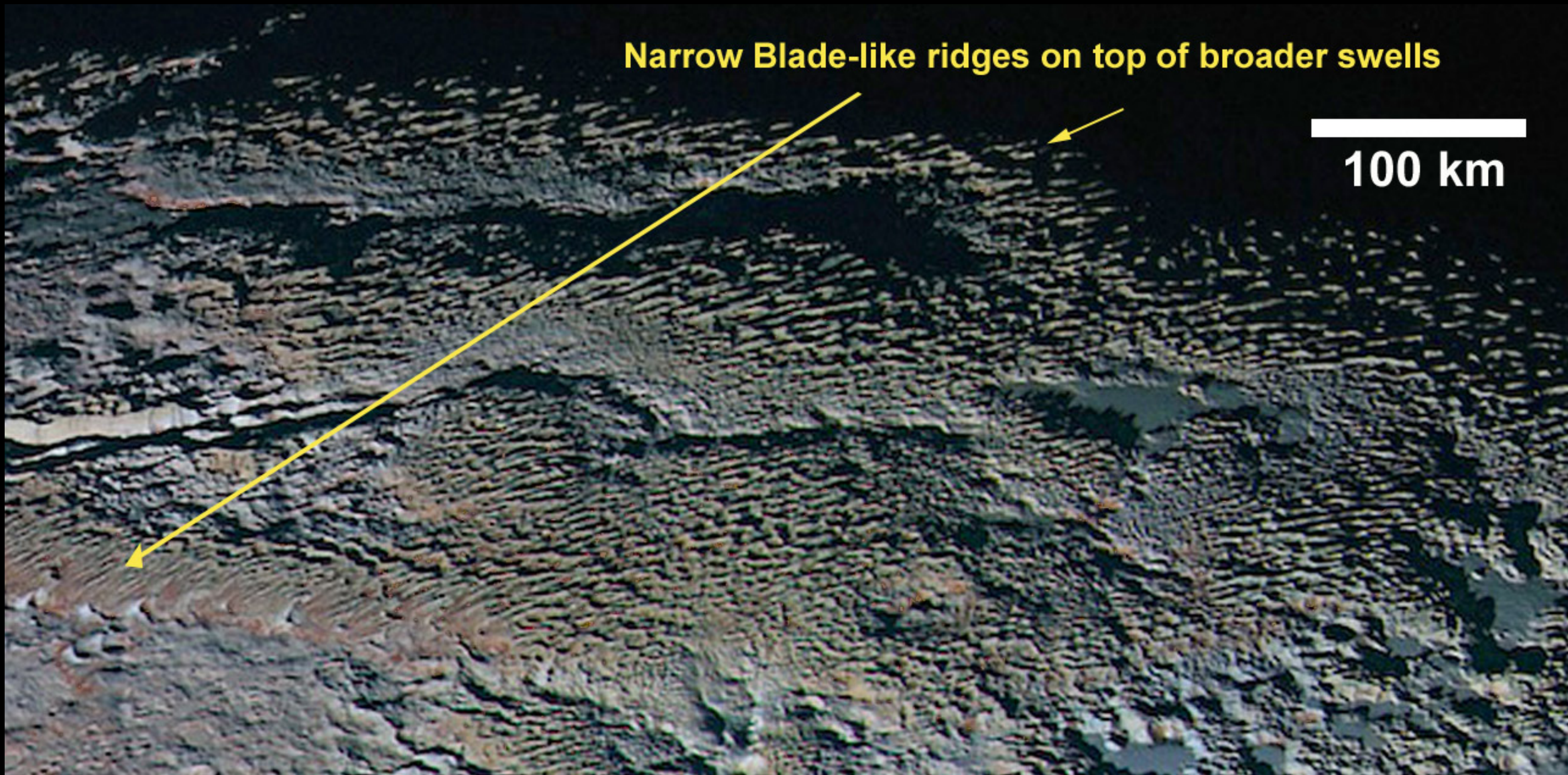
CLIFF RETREAT



The mottled plains in the center of the figure are surrounded to the W and S by a cliffs (white arrows) that may have retreated back, exhuming this relatively low-crater surface.

The plains unit below the cliffs contains H_2O, while the edge of plateau above the cliffs contains CH_4 which may be the sublimating volatile causing cliff retreat.

Bladed Terrain on Top and Flanks of Tartarus Dorsa



Maybe they are the result of sublimation. Maybe formed by widening and deepening of pre-existing parallel tectonic fractures.

N_2 ice too soft to retain topography. A possible candidate is CH_4 ice.

Deep Depressions in the Eroded Mantled Terrain of the Arctic

A variety of formation mechanisms are under investigation.

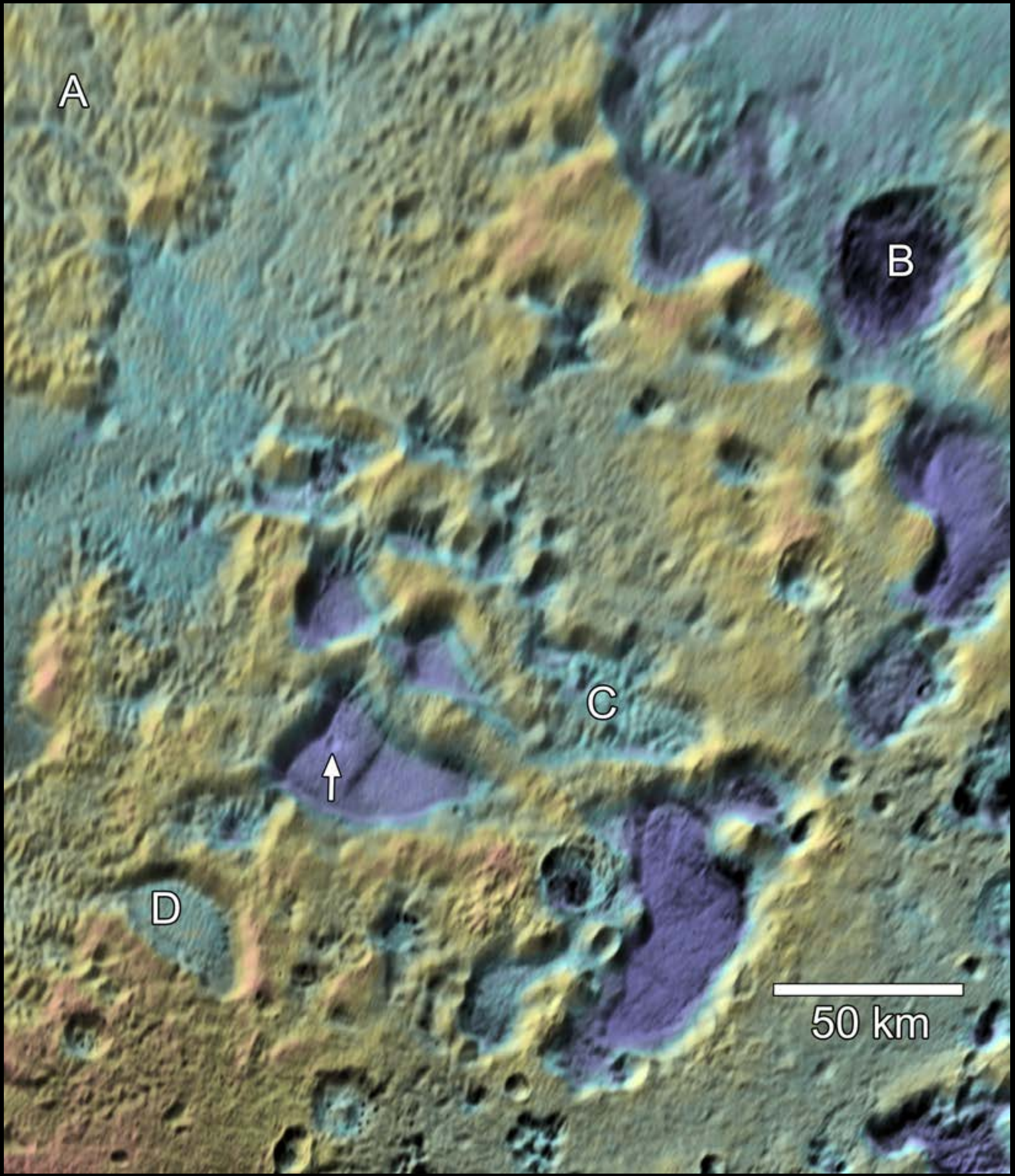
•Icy Flats – N_2 rich

•Rugged higher terrain CH_4

•Local removal of upland deposits through selective sublimation is one possibility

• As are resurfacing and associated erosion by icy-volcanic flows or accumulation of ices from condensation within pre-existing depressions.

• The depression floors range over a vertical elevation range of about 3 km. Smaller, pit-like depressions also occur at scattered locations.

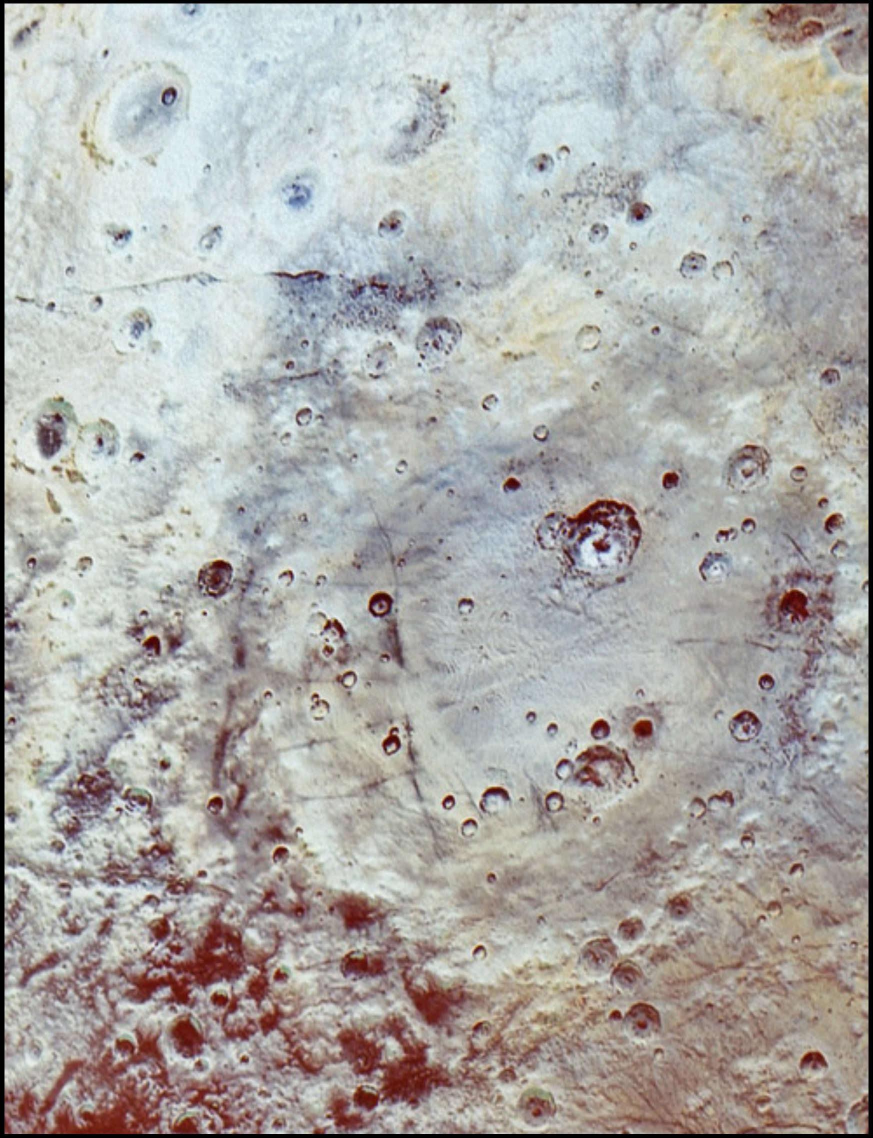


Implications of Crater Statistics

There is a range of ages on Pluto: There is either ongoing activity or very recent resurfacing

Charon did see early resurfacing (e.g., Vulcan Planum) But the age of this "younger" plain is on the order of ~4 Gyr.

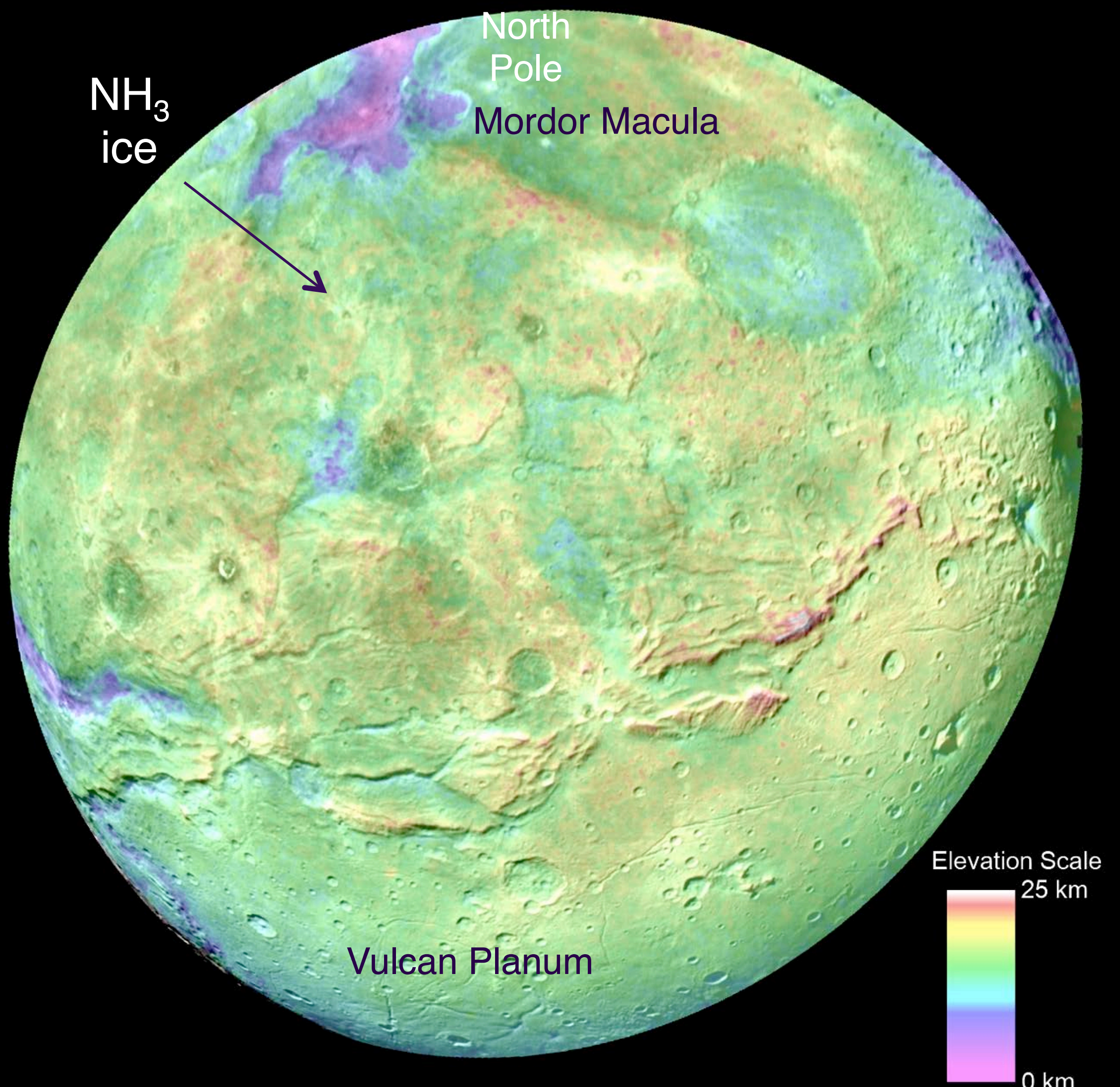
Measured cratered populations do NOT support large numbers of small KBO impactors.



CHARON

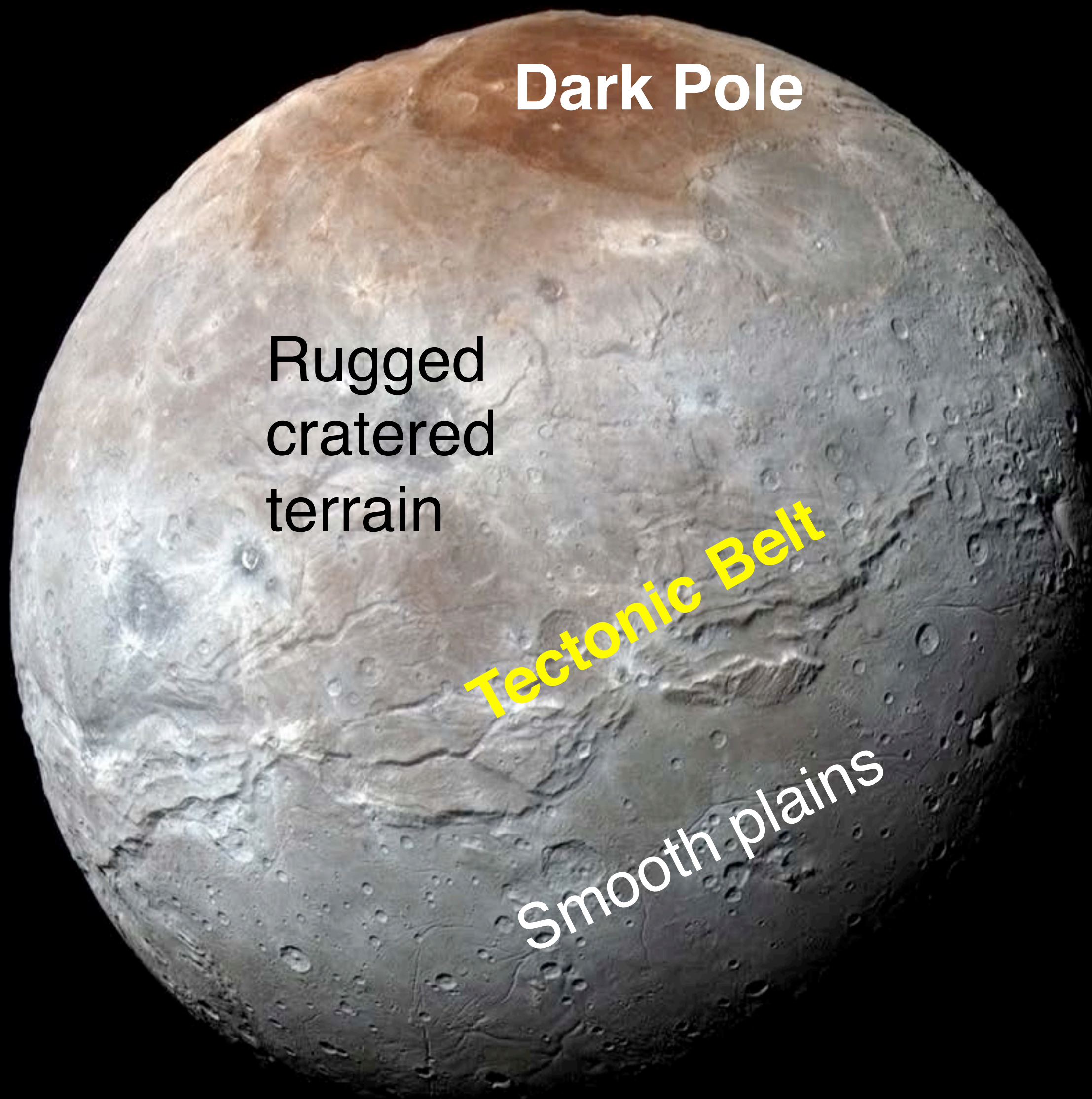
It is divided into two broad provinces separated by an assemblage of ridges and canyons, which span the encounter hemisphere from E to W.

North of this tectonic belt is rugged, cratered terrain. South of it is smoother but geologically complex plains, perhaps formed by icy-volcanism.



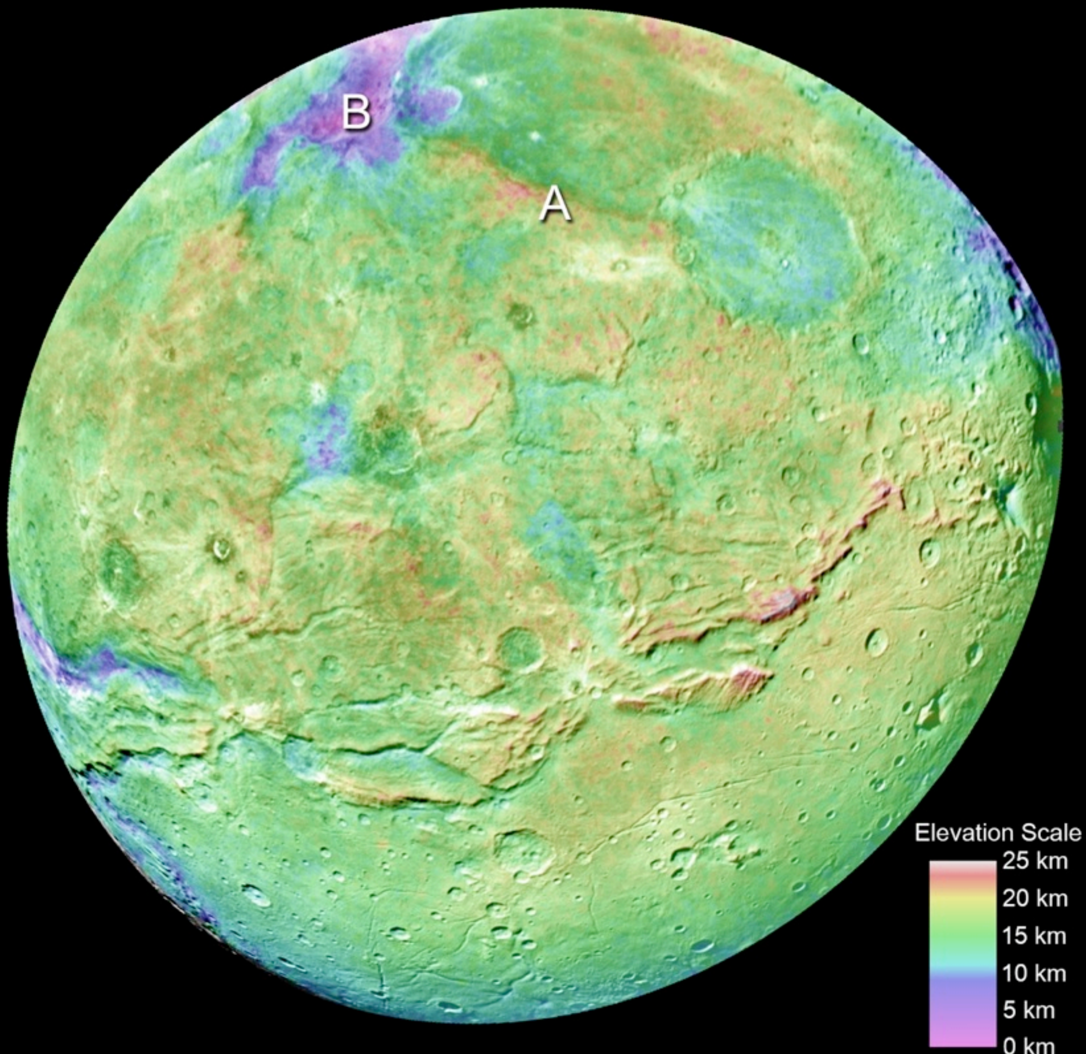
Major Features

Dark pole due to winter cold-trapping and photolysis/ radiolysis of escaping hydrocarbons from Pluto? (Stern et al. 2015, Cruikshank, Olkin 2016)



Topography

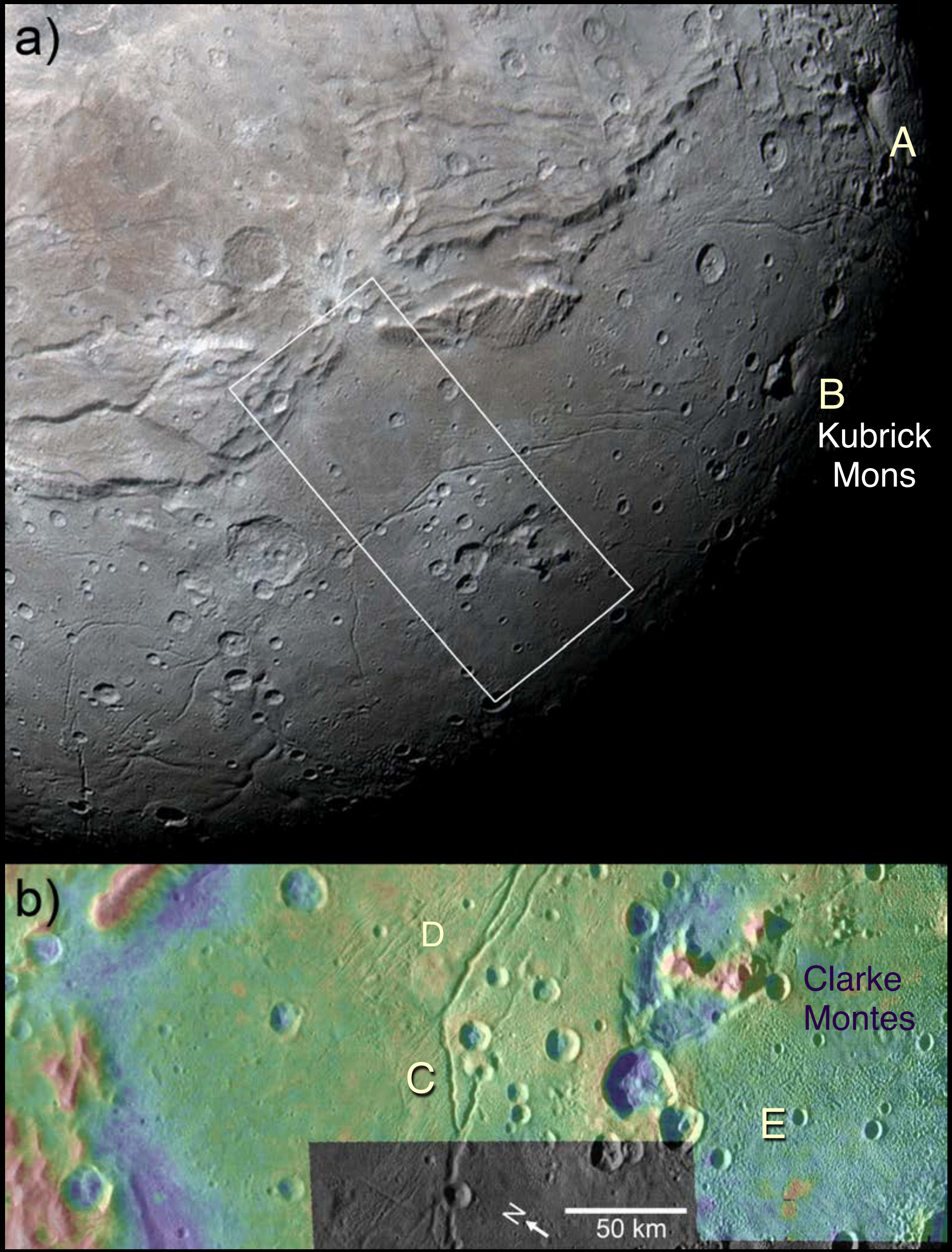
- Very high relief, esp. in the cratered terrain
- Complex polygonal network of troughs 3 – 10 km deep
- Extensional graben separating cratered and smooth plains provinces
  - ~1% extension, perhaps from freezing of subsurface ocean?



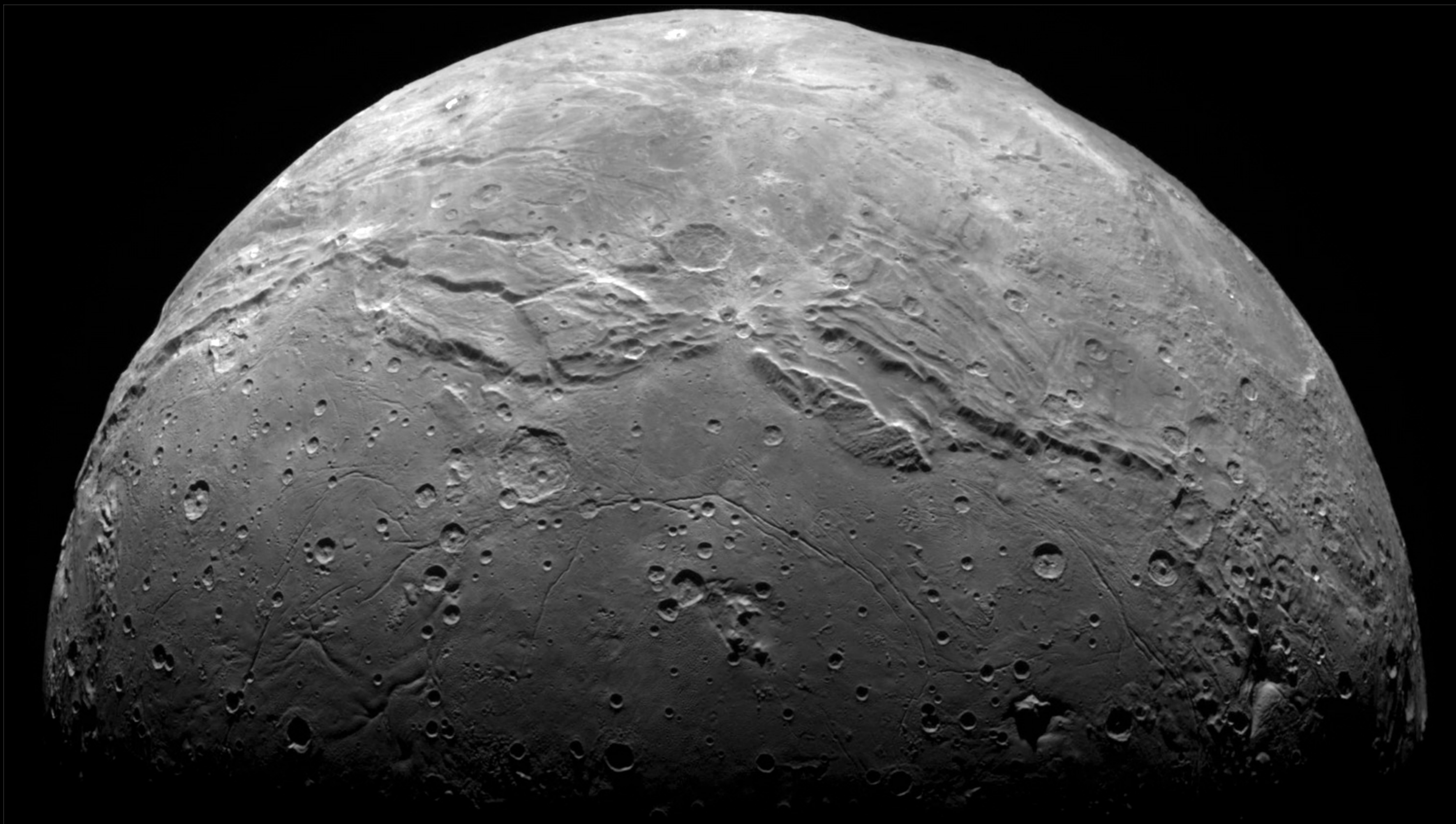
CHARON

This slide shows details of Vulcan Planum. White outline indicates high-resolution image below.

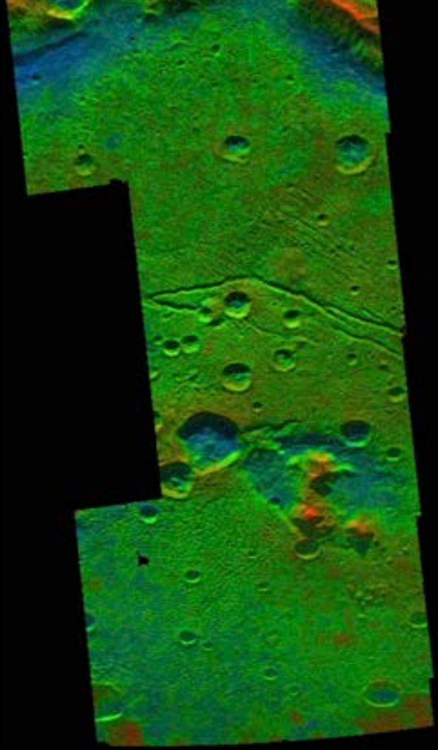
Note the depressions with lobate margins (A) ; mountains surrounded by moat-like depressions (B); deep, rille-like troughs (C), and a pancake-shaped deposit(D); and an unusual textured terrain (E) .



Charon at 620 meters per pixel

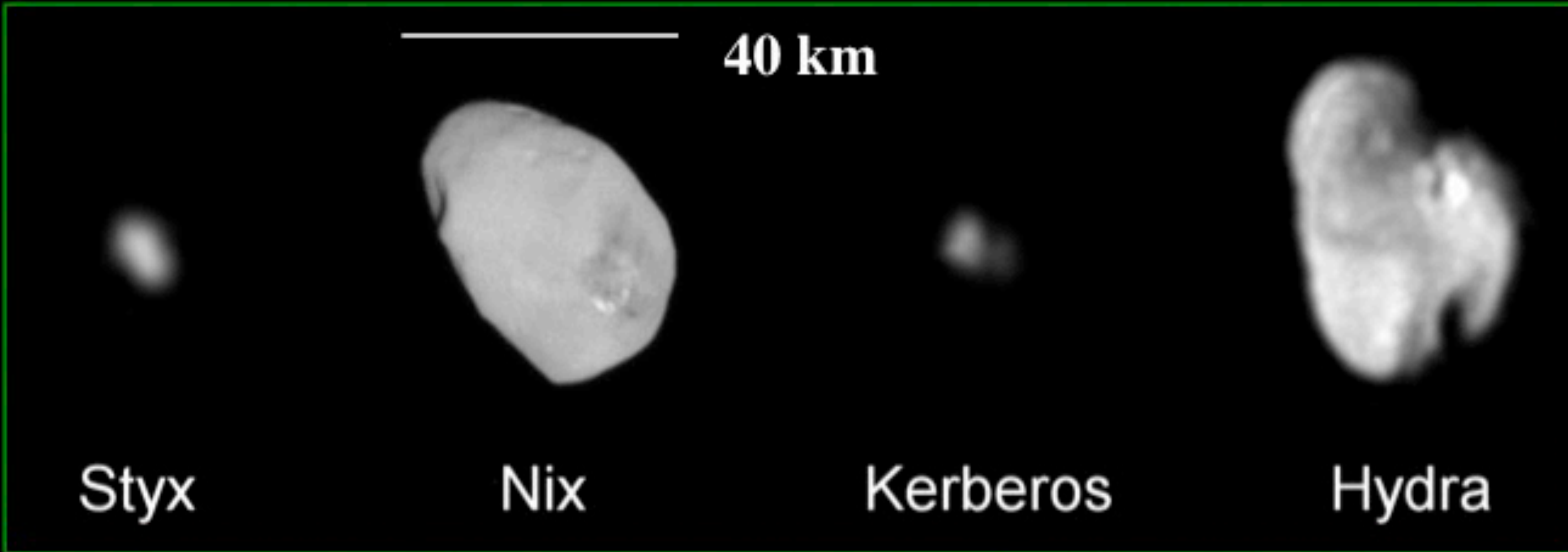


Evidence for Viscous Flow in Vulcan Planum



- Convex "flow fronts" several km high
- Possible H_2O - NH_3 eutectic fluid? (Kargel, etc.)





40 km
Styx
Nix
Kerberos
Hydra


Nix in color


Nix close up

Properties of Small Moons

Object	Size (km)	Orbital Period (days)	Rotation Rate (days)	Rotation Pole [RA,DEC] (deg)	Geometric Albedo
Styx	16 x 9 x 9	20.16155 ± 0.00027	3.24 ± 0.07	[196,61]	0.65 ± 0.07
Nix	50 x 34 x 32	24.85463 ± 0.00003	1.829 ± 0.009	[350, 42]	0.56 ± 0.05
Kerberos	17 x 10 x 9	32.16756 ± 0.00014	5.31 ± 0.10	[222,72]	0.56 ± 0.05
Hydra	52 x 39 x 10	38.20177 ± 0.00003	0.4295 ± 0.0008	[257,-24]	0.83 ± 0.08

Craters on Nix

Same image as on previous slide

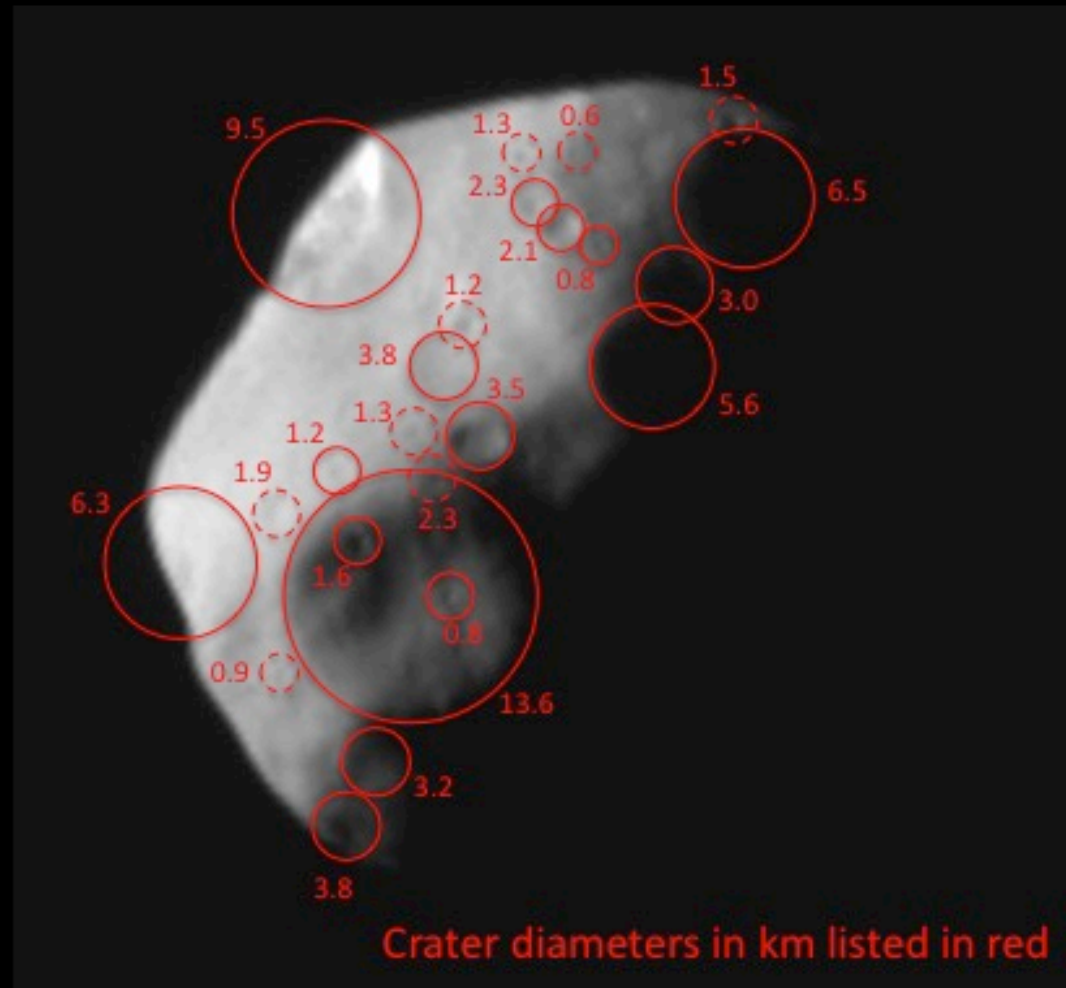
Solid red circles mark features identified with impact events (i.e., craters) with high confidence (16 total)

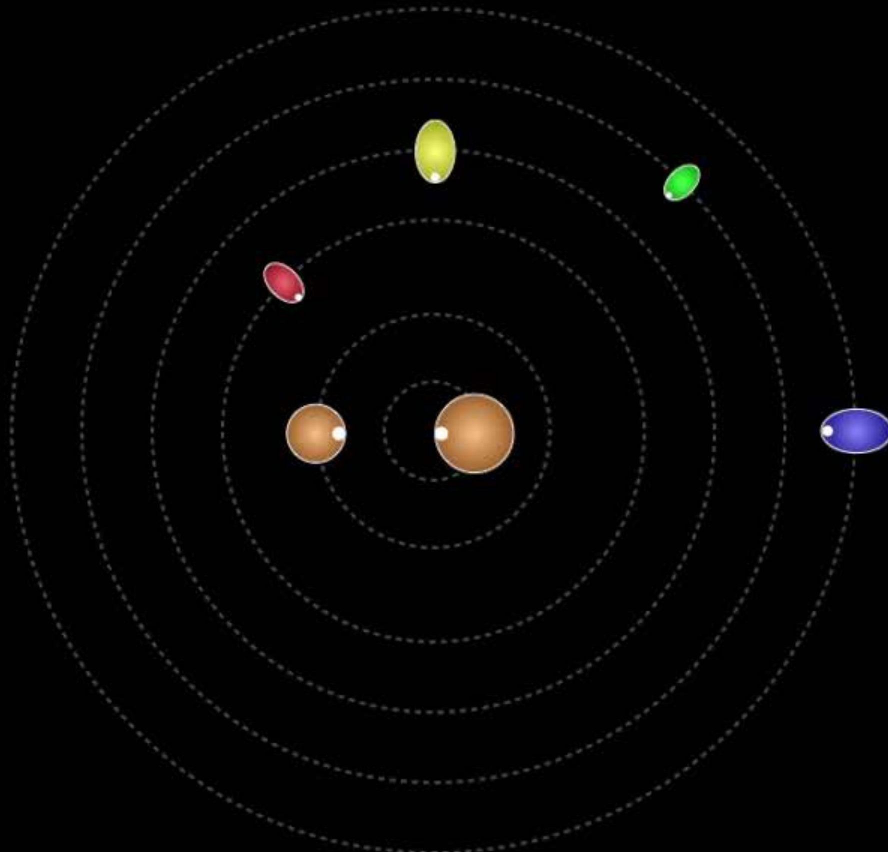
Dashed red circles mark features tentatively identified as craters (8 total)

Visible area ≈ 740 km^2

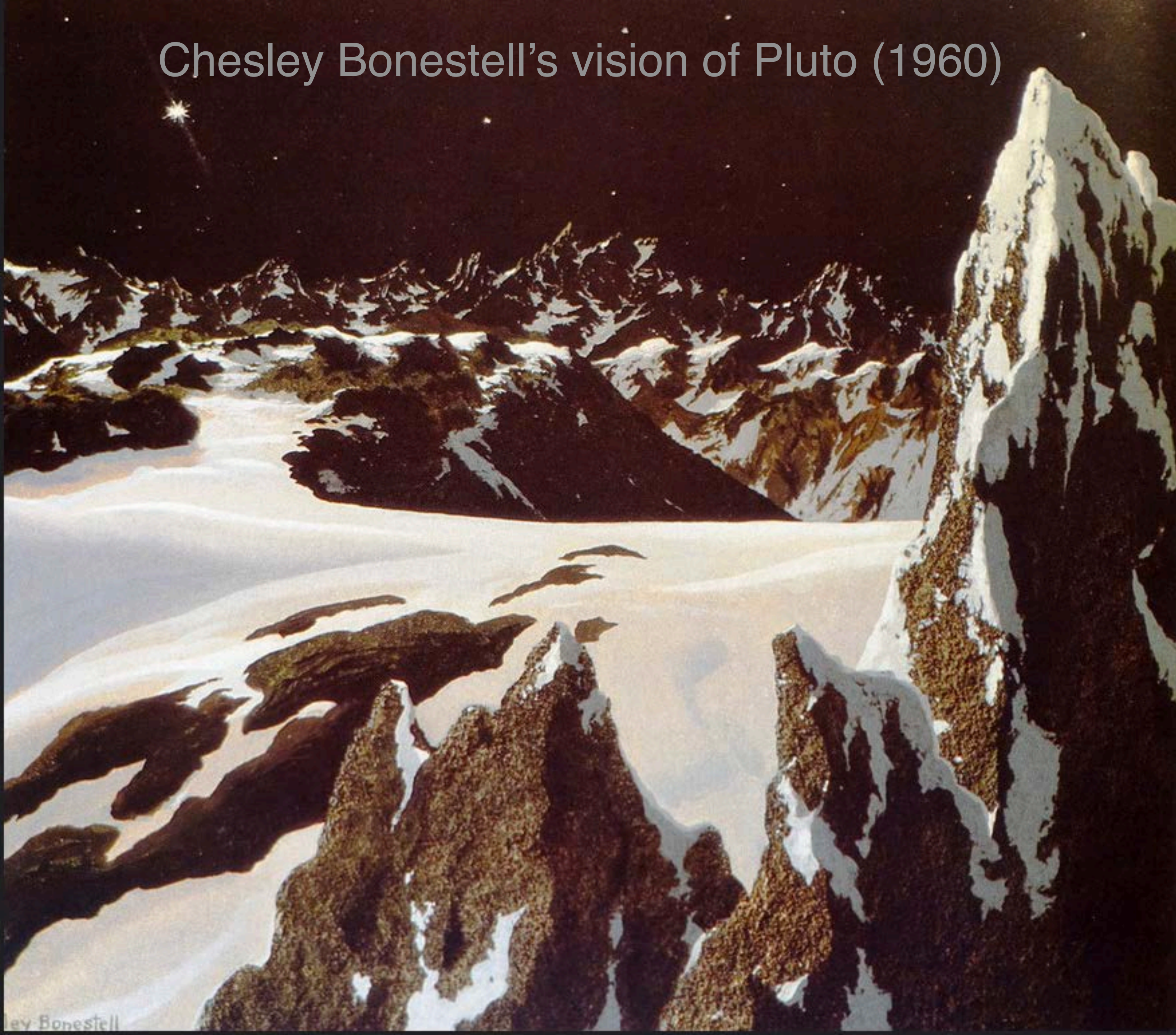
Crater density ≈ 2–3 x 10^{-2} km^{-2}
Cumulative for d ≥ 1 km

Crater retention age ≥ 4 Ga



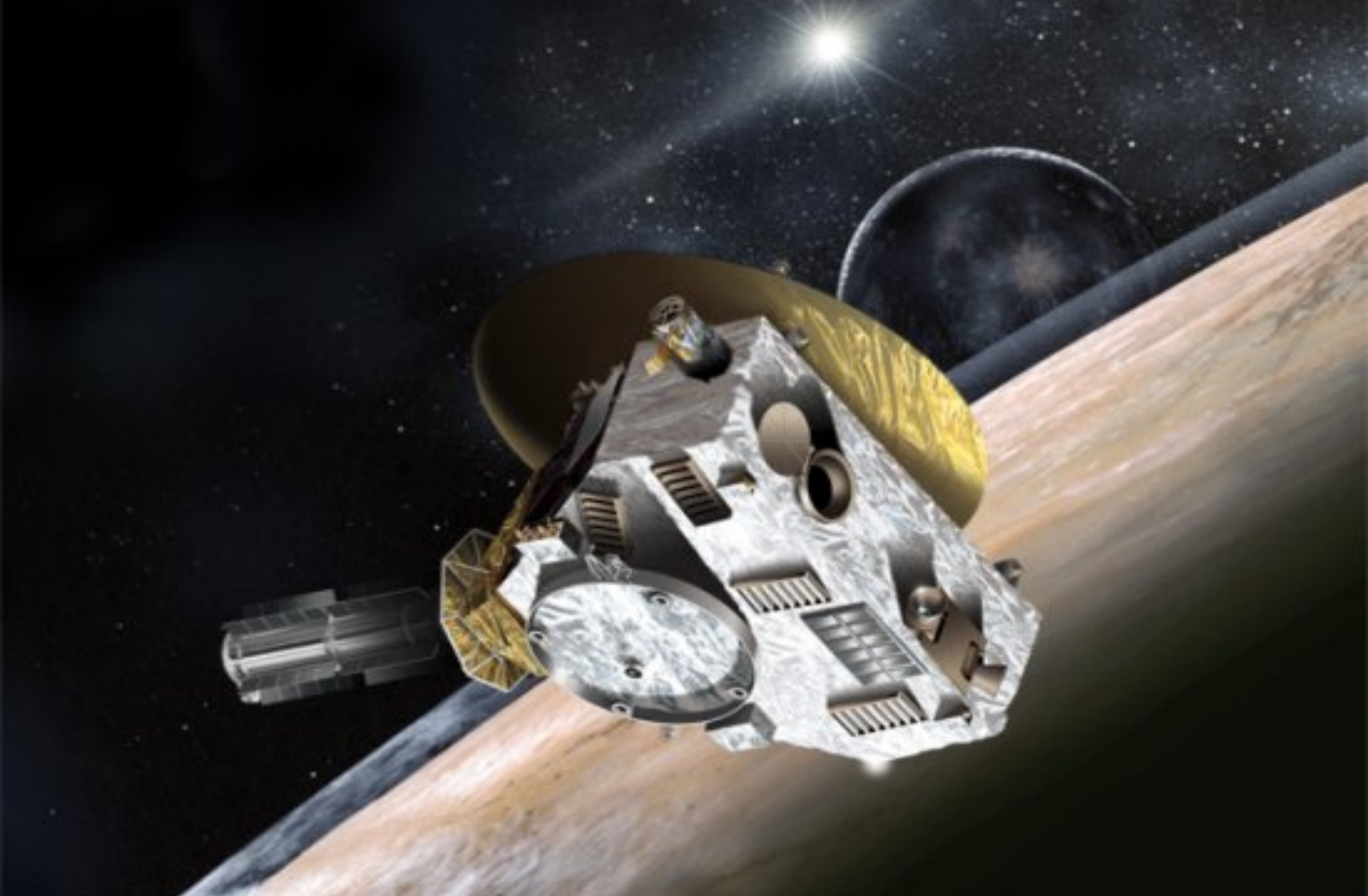


Chesley Bonestell’s vision of Pluto (1960)



Chesley Bonestell’s vision of Pluto (1960)

On to our next Kuiper Belt Object target!
Closest Approach: 1 January 2019



End

3-D Glasses Time!