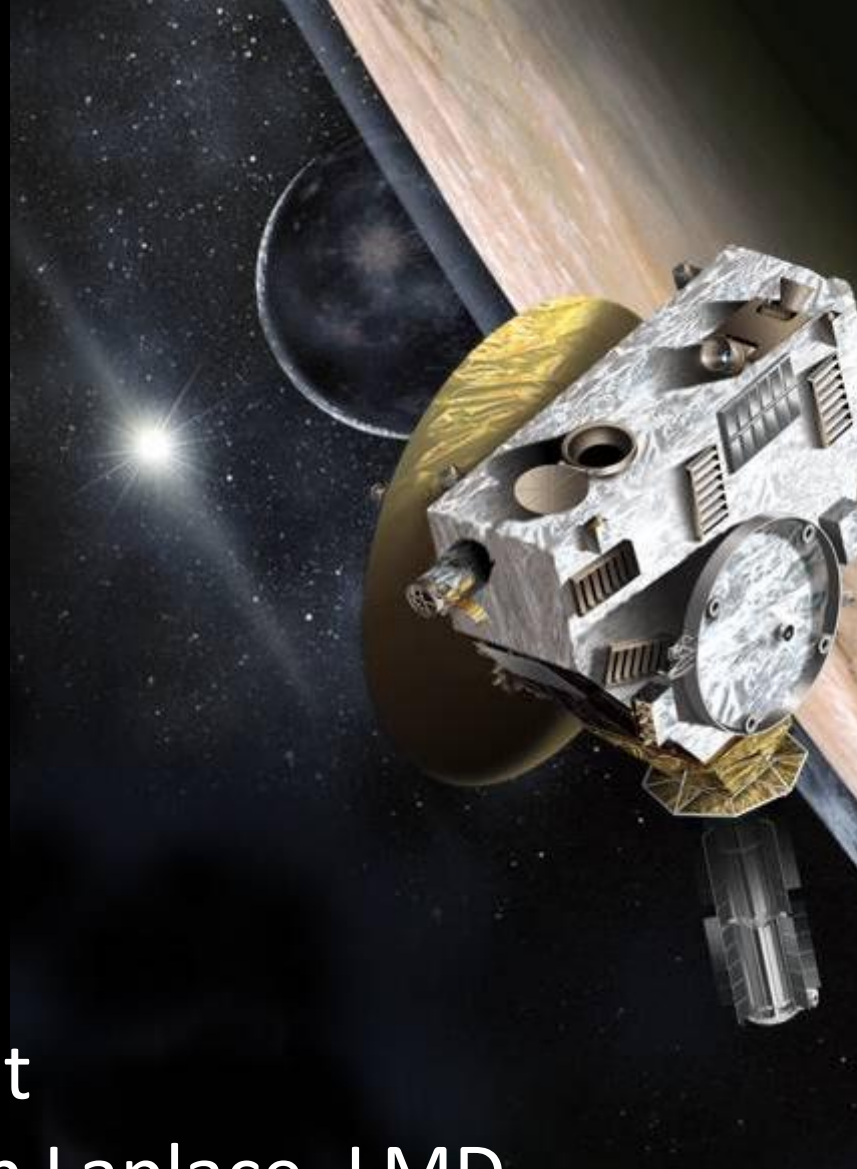


**NEW HORIZONS :
EXPLORATION DE
PLUTON EN JUILLET
2015**

François Forget
CNRS, Institut Pierre-Simon Laplace, LMD





Cap Canaveral, 19 janvier 2006

Lanceur Atlas V-551

Capacité: 20 Tonnes (en orbite basse)



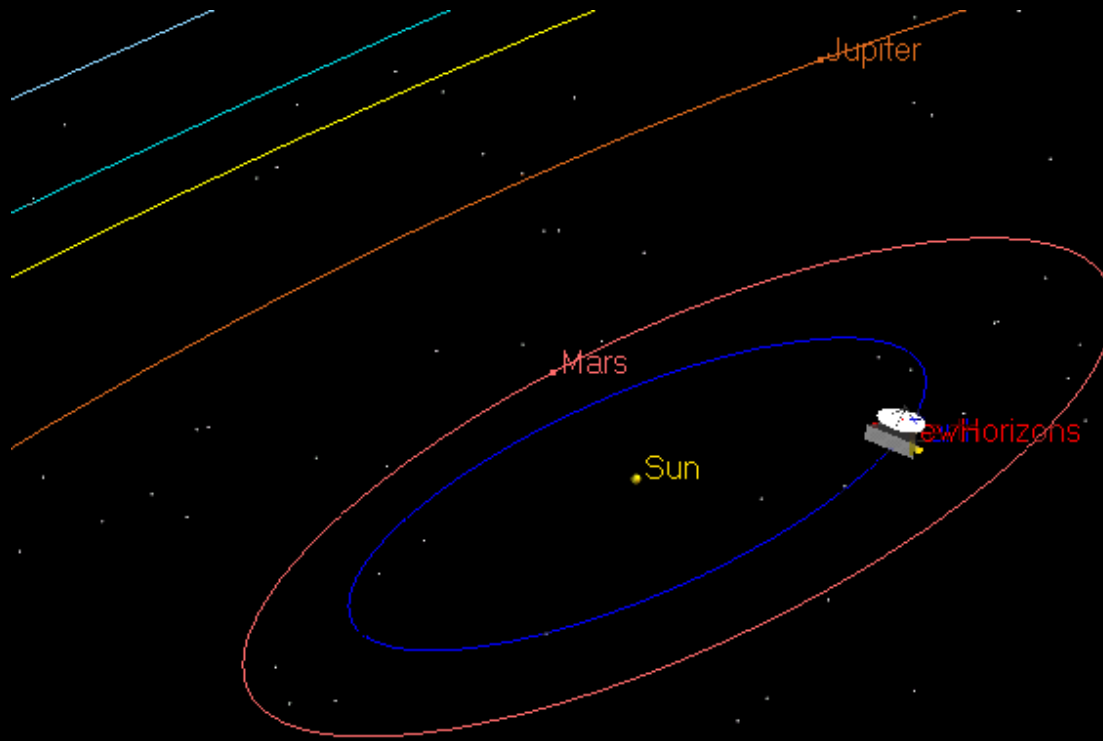
La sonde New Horizons

478 kg

Decembre 2005

New Horizons
478 kg
Novembre 2005





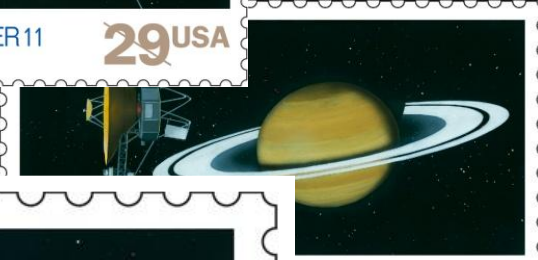
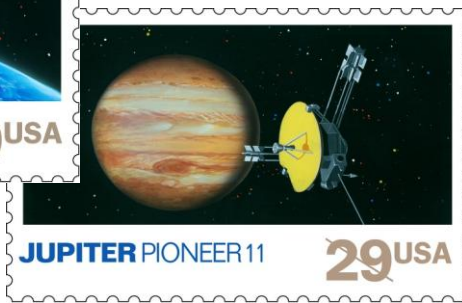
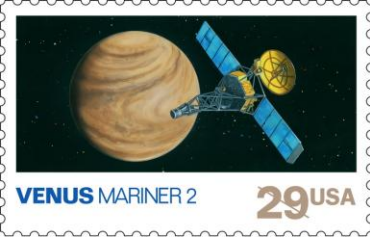
Lancement 19/01/2006

Jupiter : 28/02/2007

Pluton: 14/07/2015



PI: Alan Stern, 57 ans



Pluton:

Découverte en Janvier-Fevrier 1930, par Clyde Tombaugh (24 ans) au Lowell Observatory, Arizona.



- ❑ Pluton est difficile à observer
- ❑ 50,000 times moins lumineux que Mars ($V \sim 14$)

Pluton

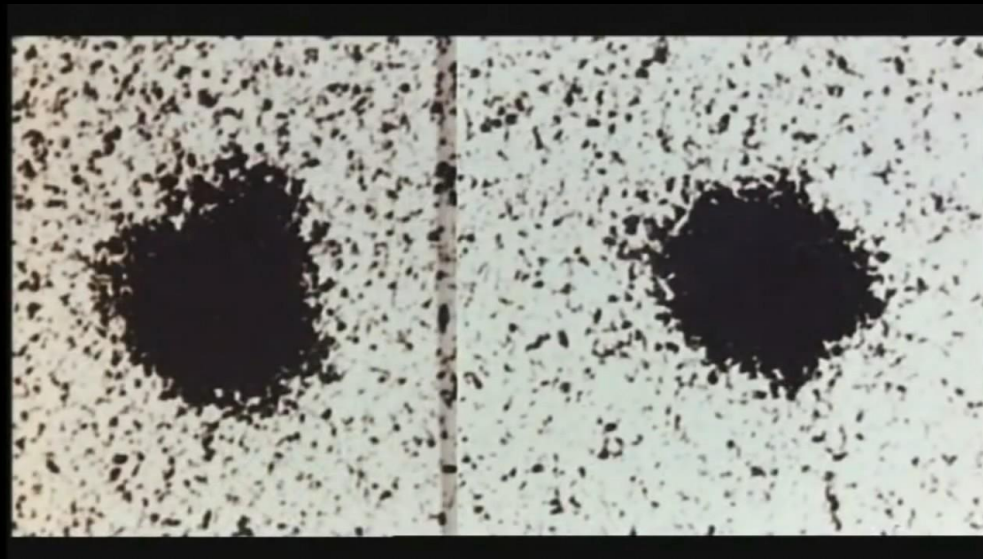
[JAN 23]



Pluton
[JAN 29]



Découverte de
Charon, Lune de
Pluton, 1978



James Christy
et Robert
Harrington,
1978

Le systeme Pluton-Charon

Pluton : $\varnothing \sim 2400$ km

Charon : $\varnothing \sim 1200$ km



1 jour Pluton & Charon
= 6,4 jours terrestres

1 an = 247.7 années terrestre

Obliquité = 122°

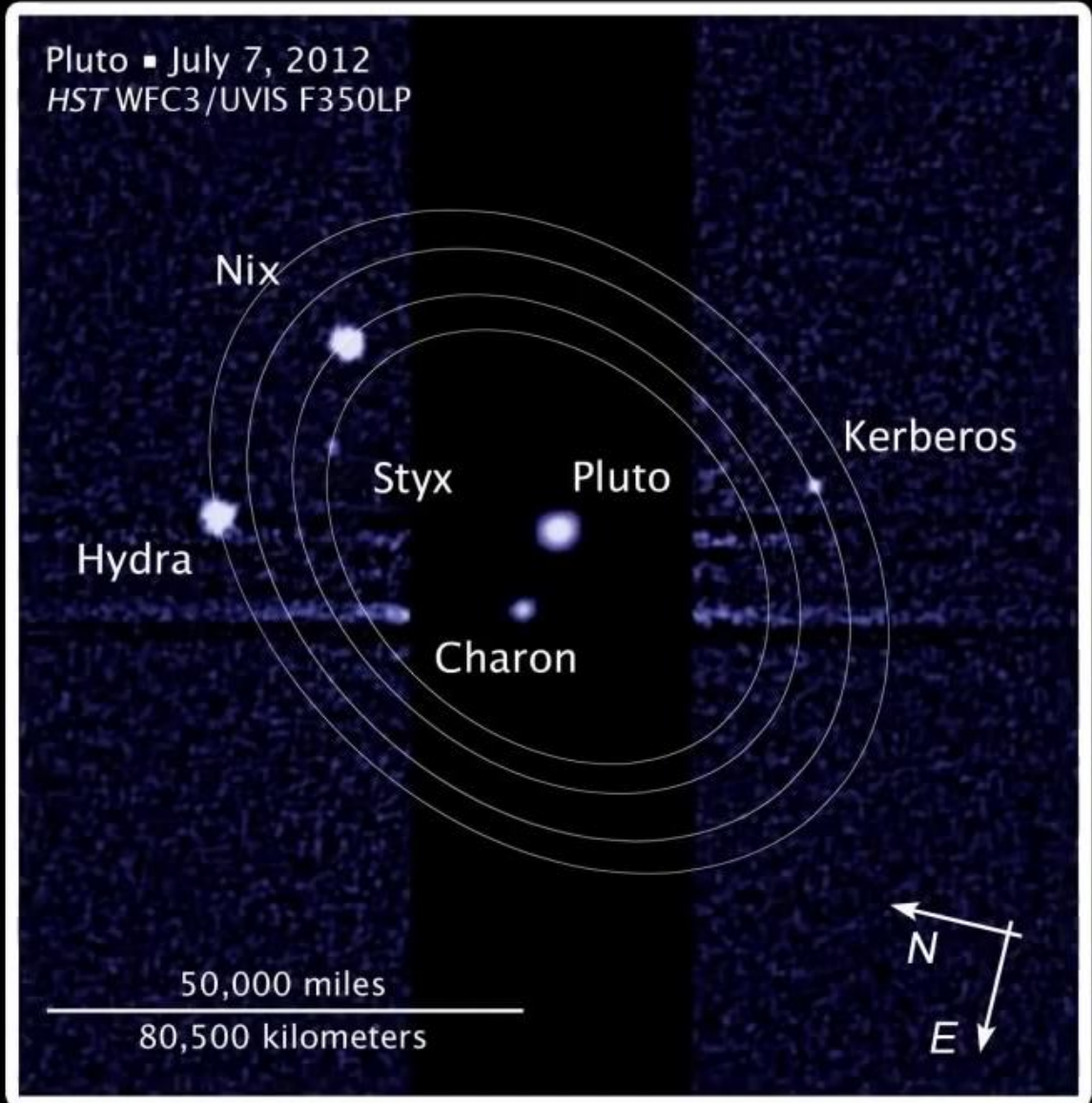
Perihelie = 29.6 UA

Aphelie=49.3 UA



Plusieurs petits satellites

- Hydra (2005) ~ 60 km
- Nix (2005) ~50 km
- Kerberos (2011) ~ 20 km
- Styx (2012) ~15 km

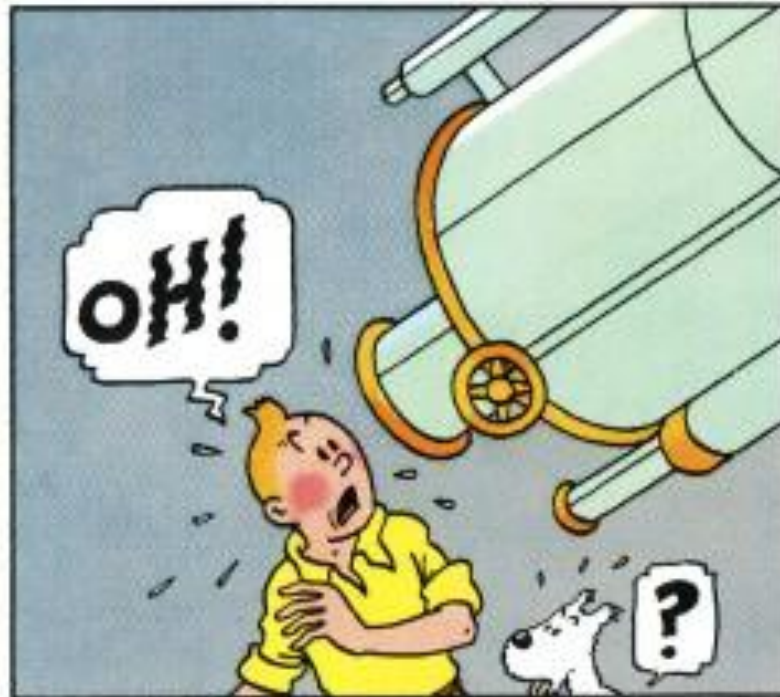


Pluton avant 2015 (*Hubble Space Telescope*)



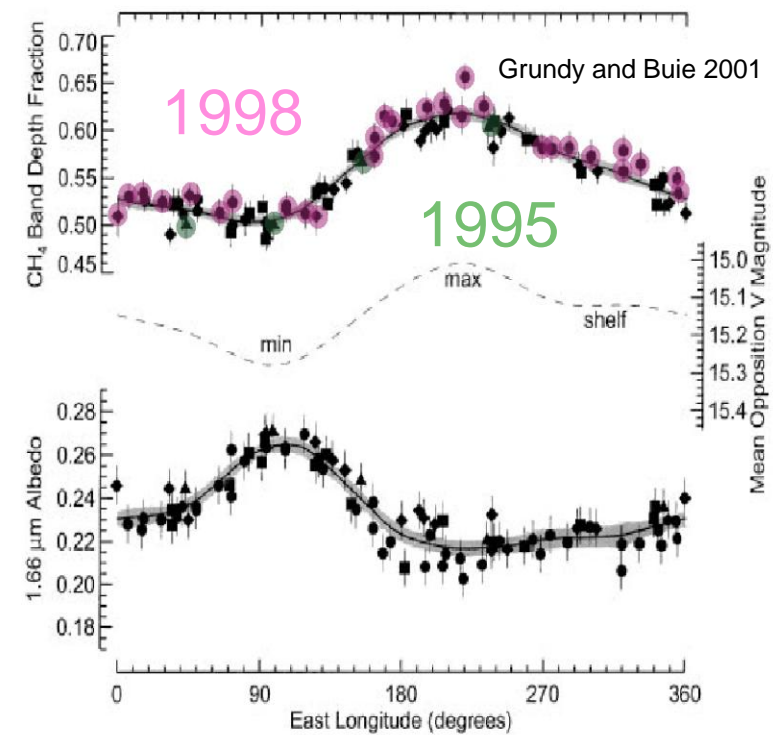
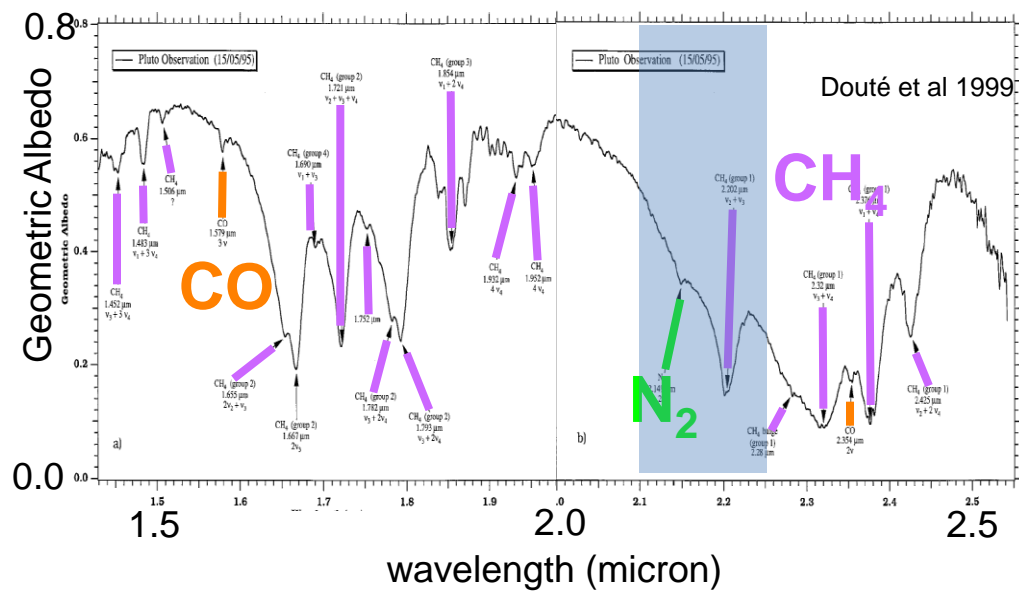
Explorer Pluton depuis la Terre:

- Spectroscopie de la surface
- Occultation stellaire
- Spectroscopie de l'atmosphère
- Modélisation

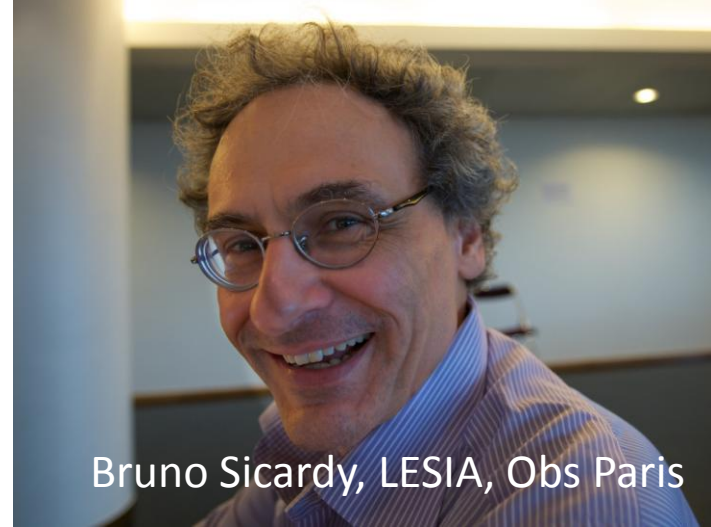


Spectroscopie de Pluton : Composition de la Surface

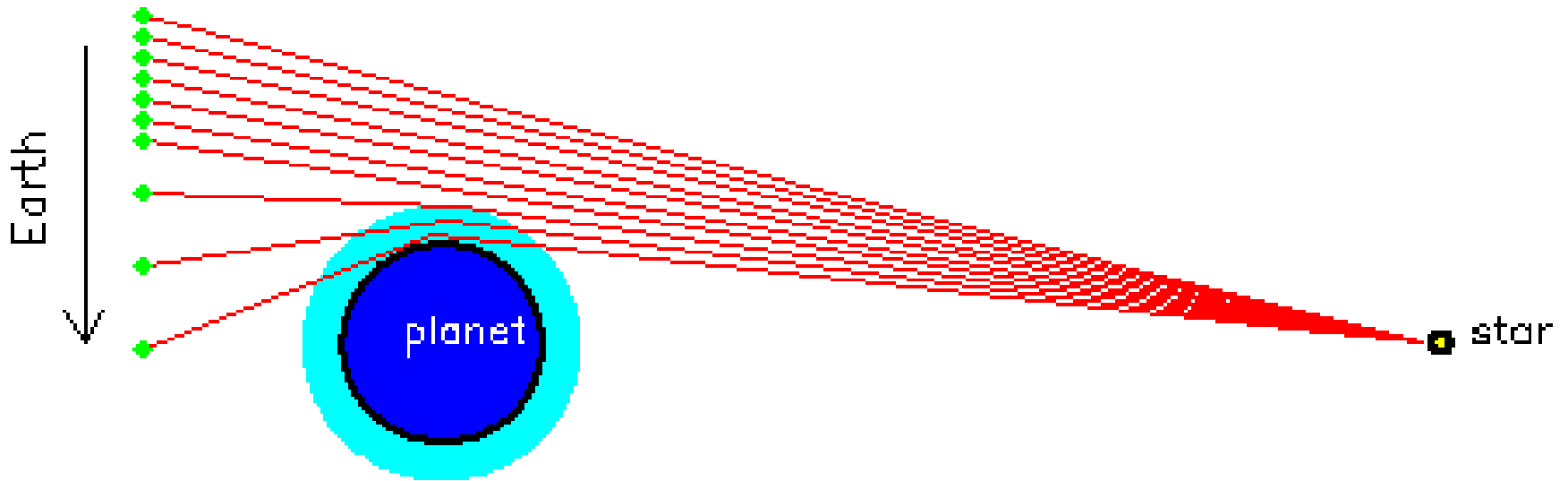
- Pluton est couverte de glace de N₂, CO, CH₄
- Temperature de la surface : ~38K (-235° C)
- Une atmosphère d'azote en équilibre solide gaze avec les glaces à la surface

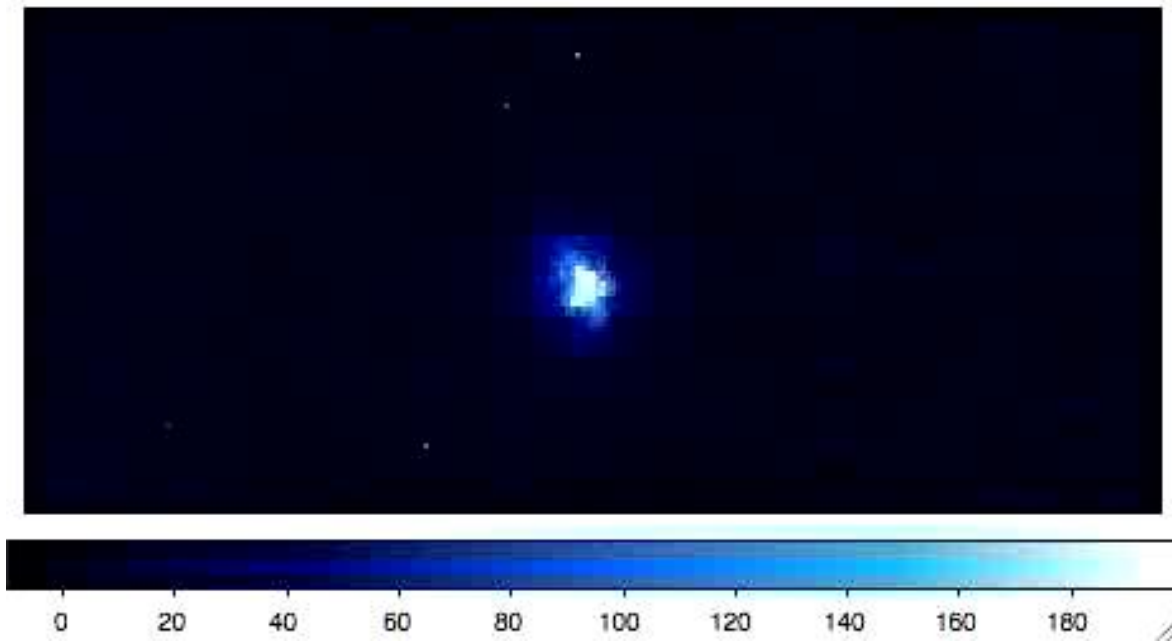


Occultation Stellaire



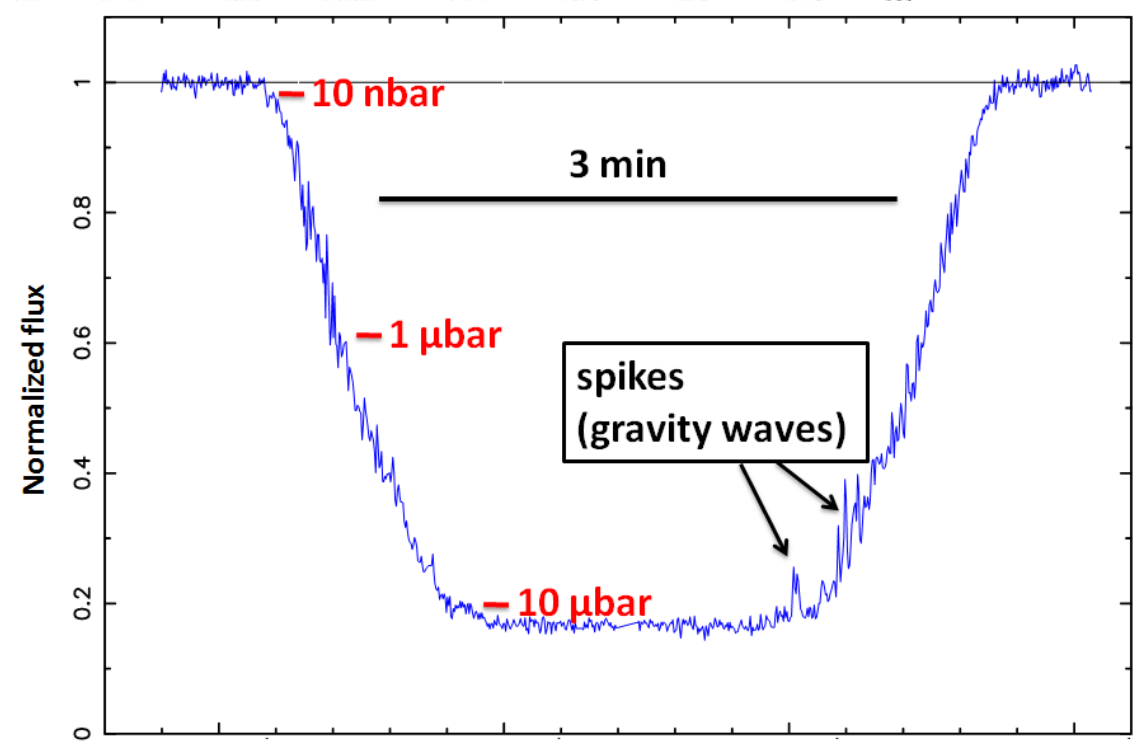
Découverte de l'atmosphère de Pluton: 1985





VLT
 18 July 2012
 Julien Girard
 Bruno Sicardy

Luminosité
 Etoile
 +
 Pluton
 +
 Charon

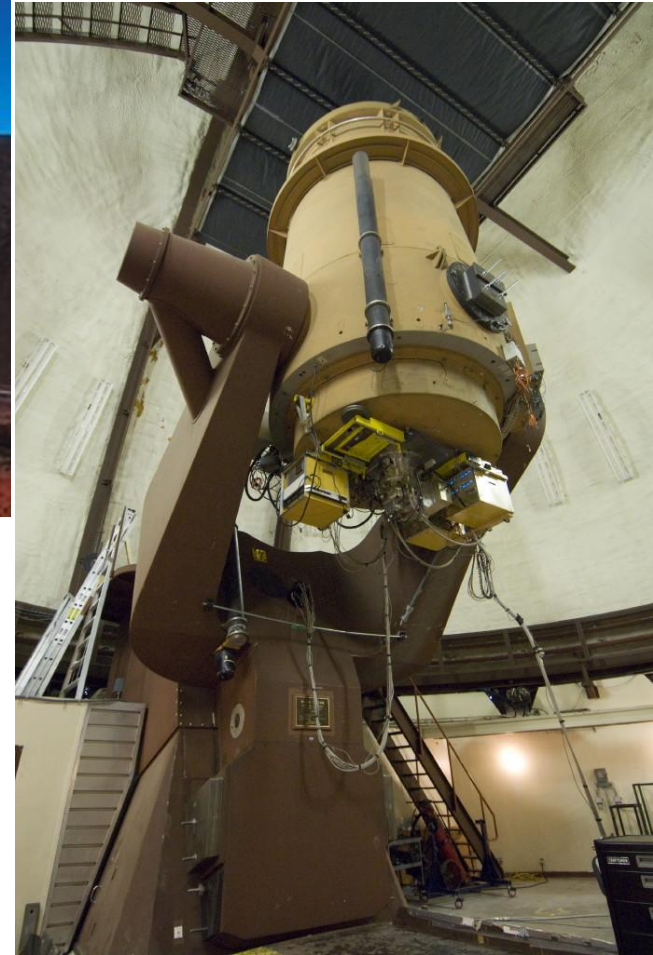


UT time (sec)

Occultations Stellaires:

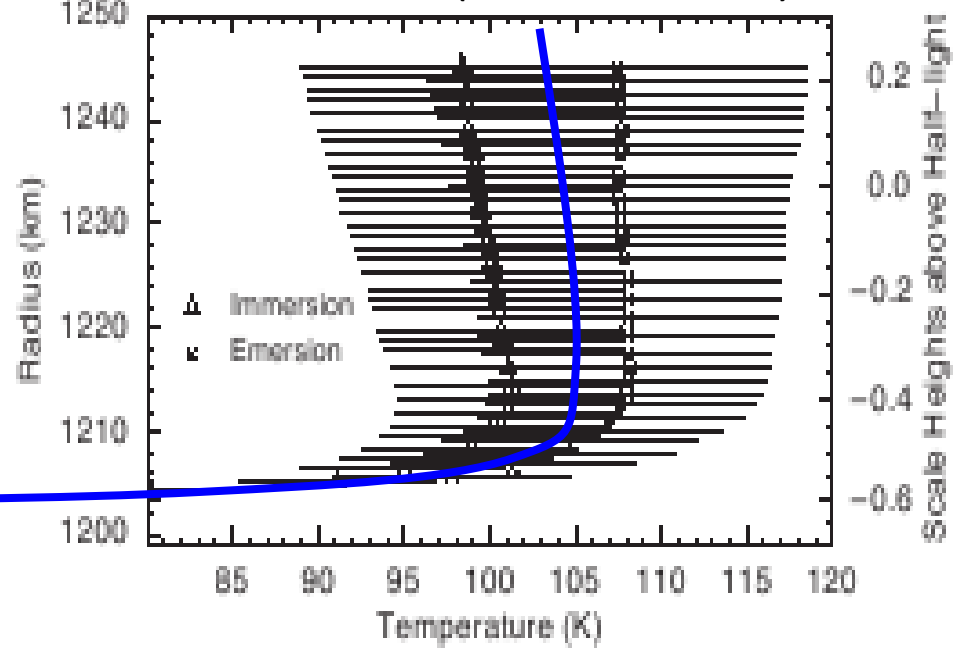
Mon expérience d'observateur-astronome...

Télescope de l'Université d'Hawaii, Mauna Kea, 7 Novembre 1997

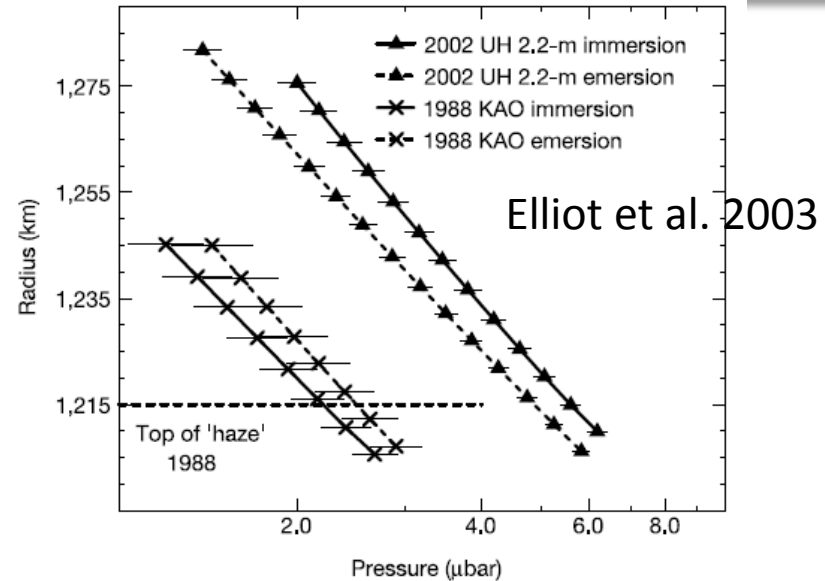
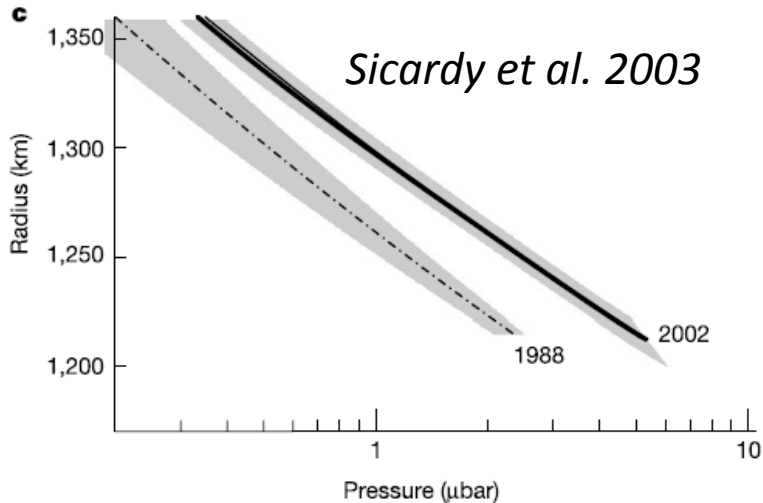


Structure Thermique

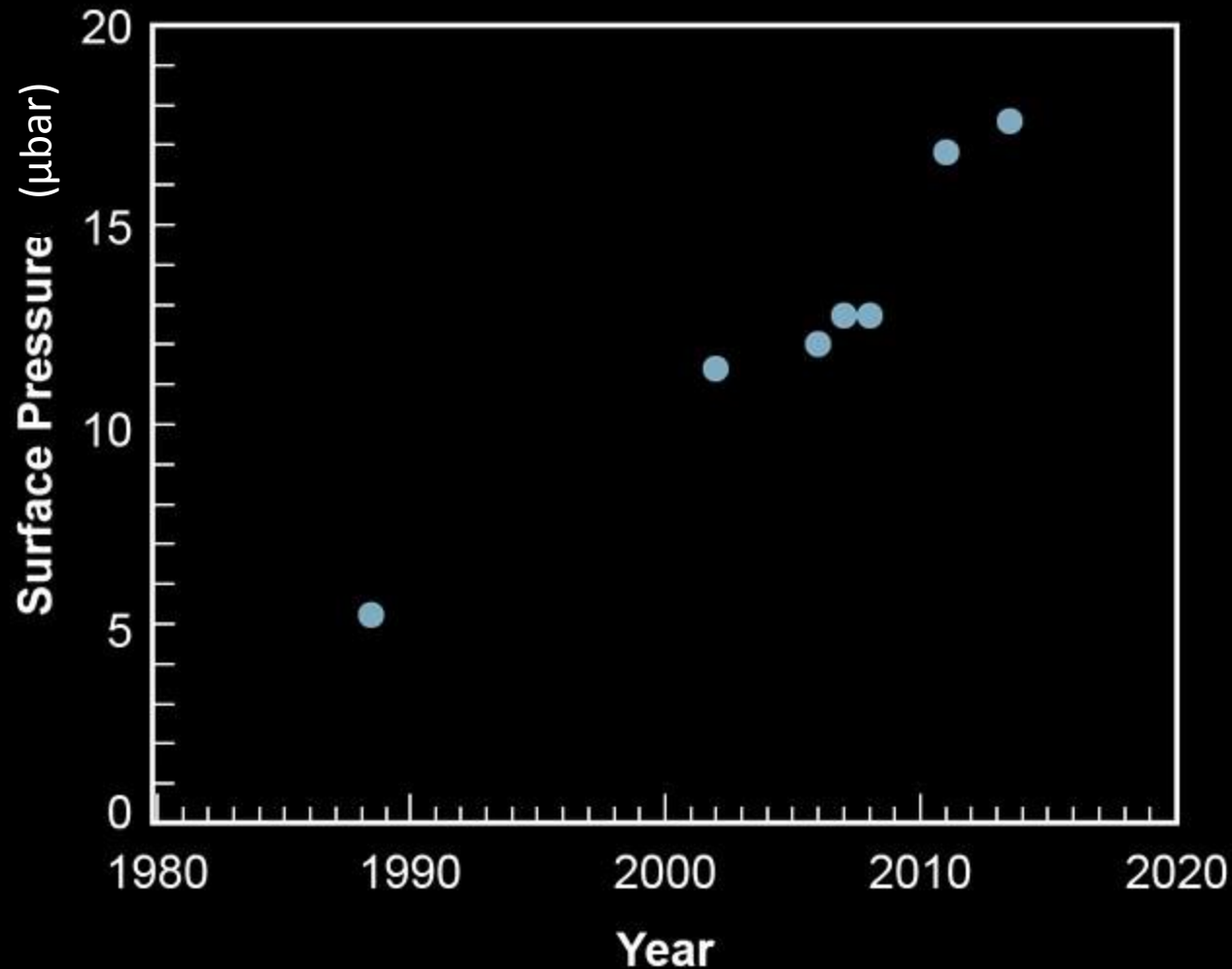
Occultation stellaire (*Elliot et al. 1989*)



Evolution de la Pression

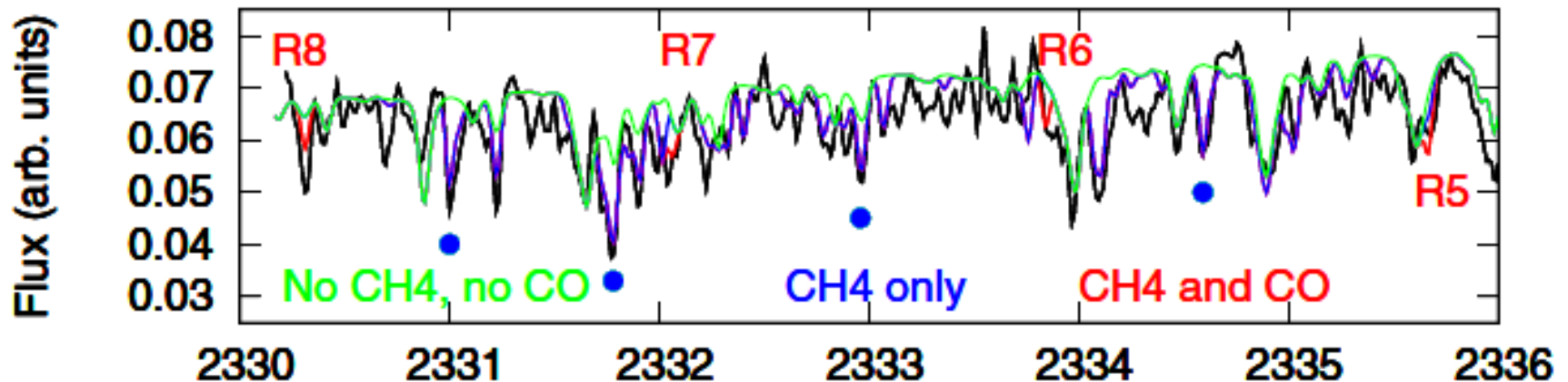


Variation de la pression à la surface



Composition de l'atmosphère par spectroscopie

Emmanuel Lellouch
(LESIA,
Obs. de Paris)

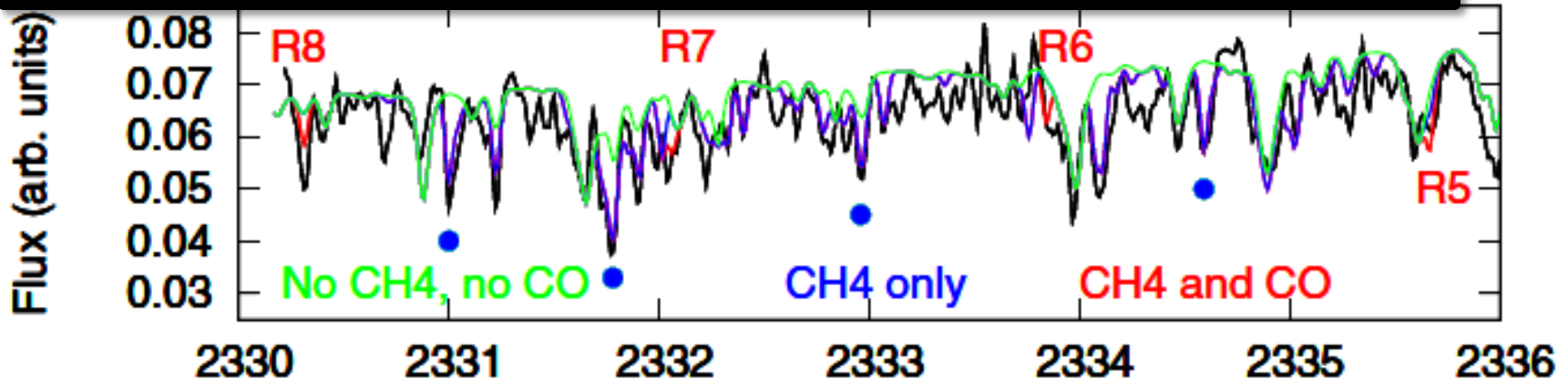


Composition de l'atmosphère par spectroscopie

Emmanuel Lellouch
(LESIA,
Obs. de Paris)

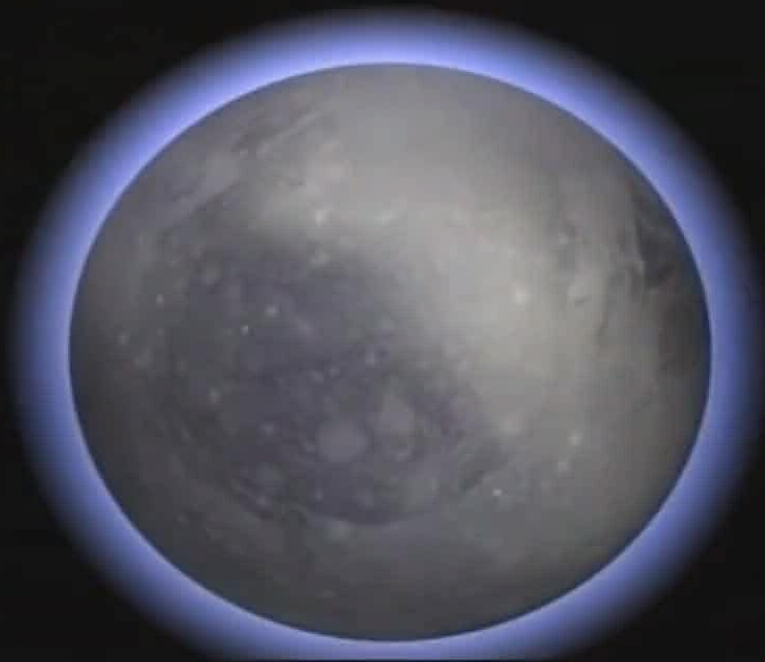
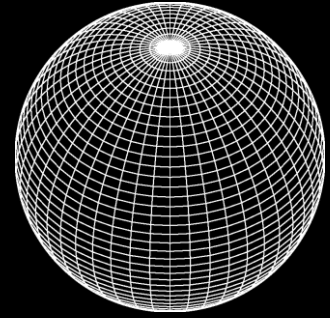


- Une fine atmosphère d'azote. Actuellement :
 - Pression ~ 2 Pa
 - $\sim 0.5\%$ de Methane (CH_4)
 - 0.04% de CO (*Lellouch et al. 2009, 2011, 2014*)



Modélisation Numérique de l'atmosphère de Pluton

(au LMD, Paris)

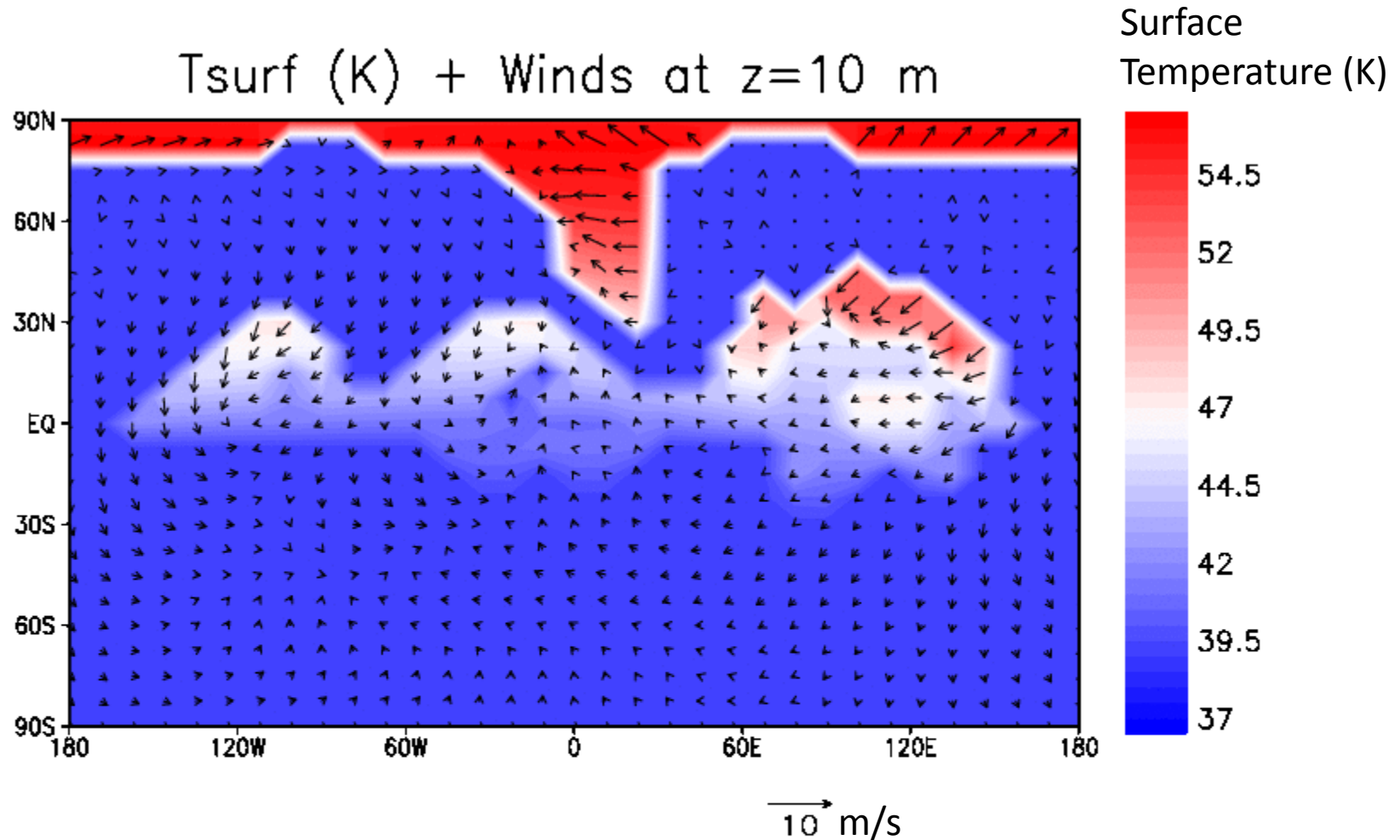


Tanguy
Bertrand
Doctorant au
LMD

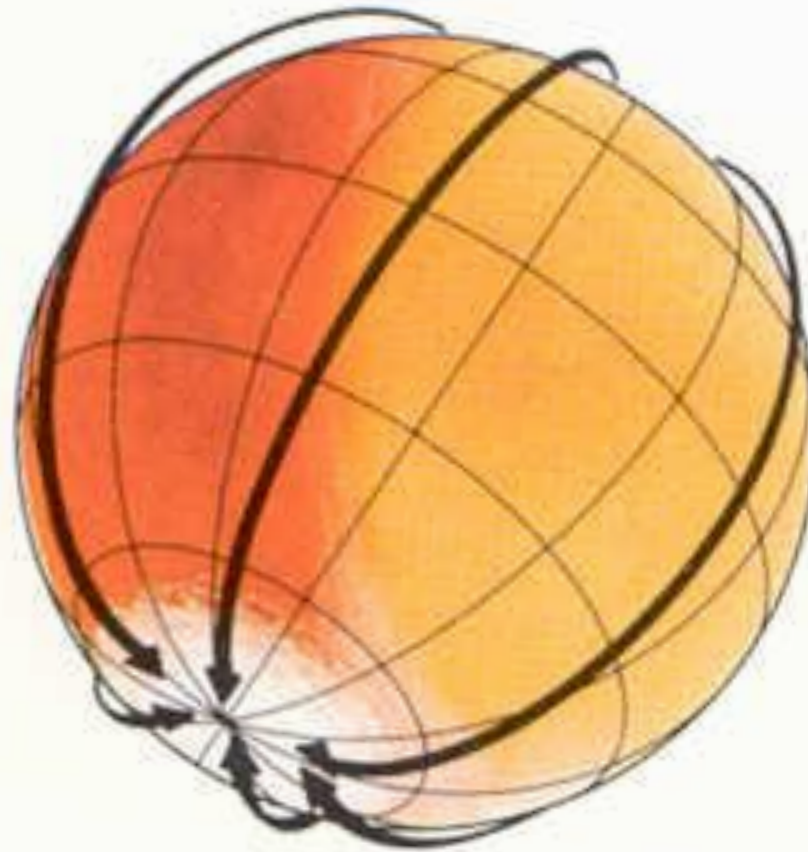
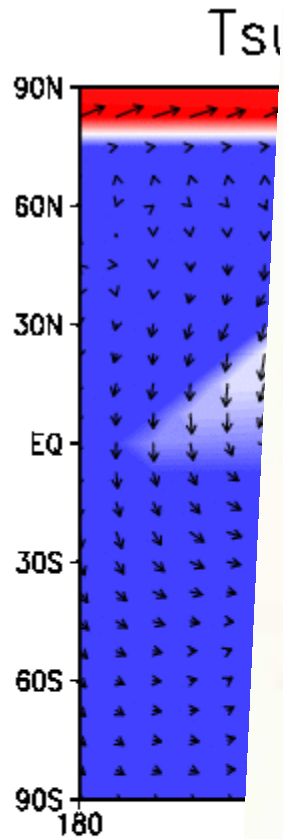


Mélanie
Vangvichith
(These en2013)

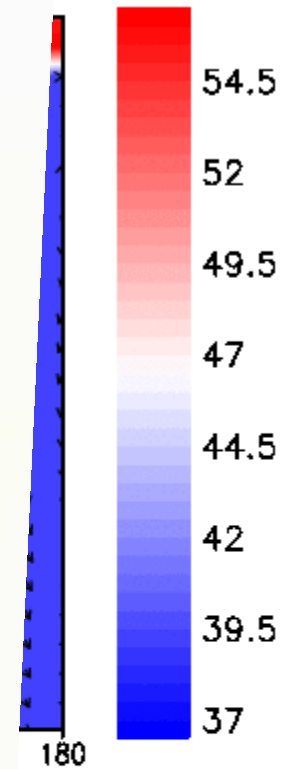
Simulation de la Temperature et de vents à a la surface



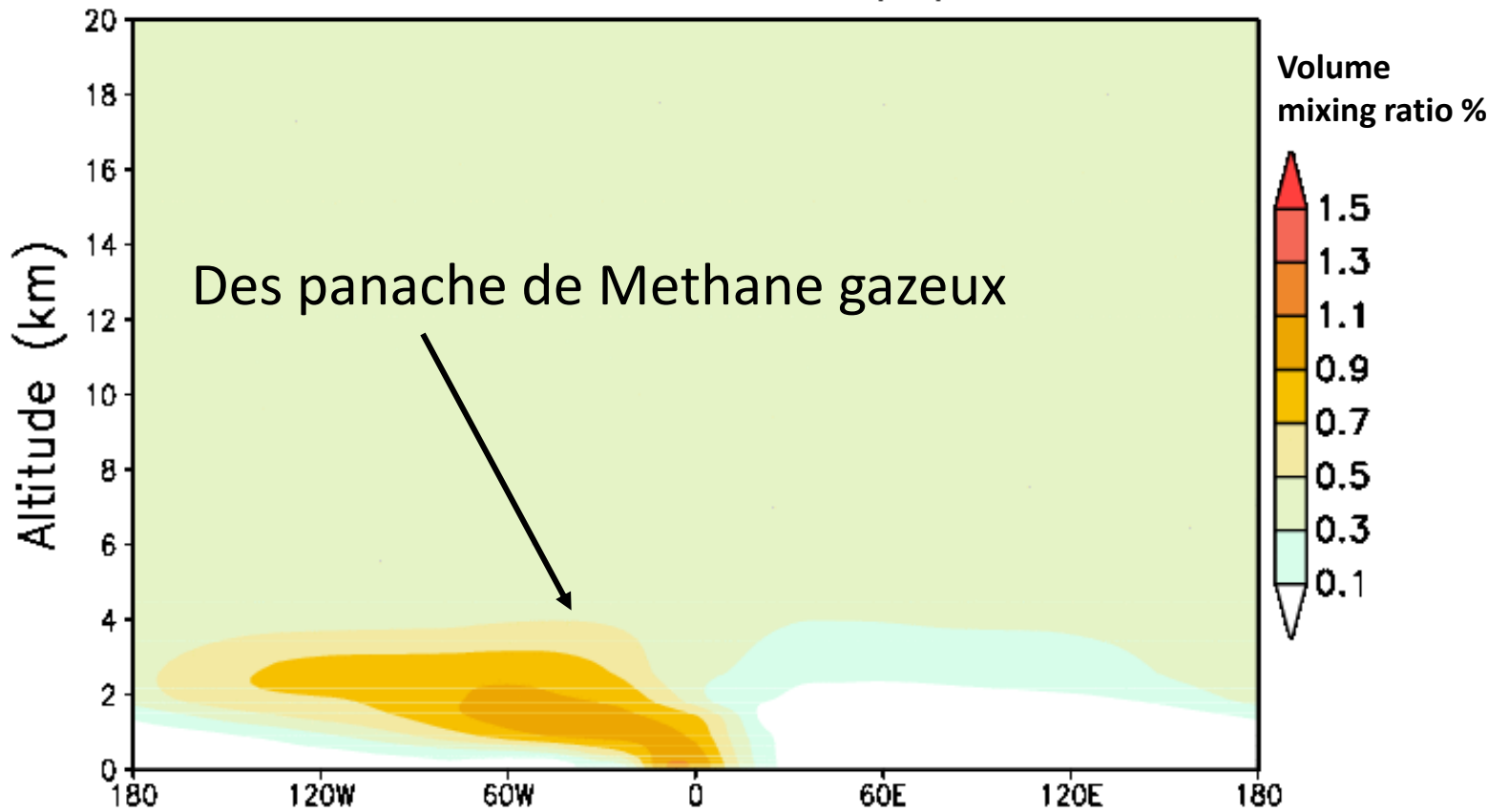
Simulation de la Temperature et de vents à la surface



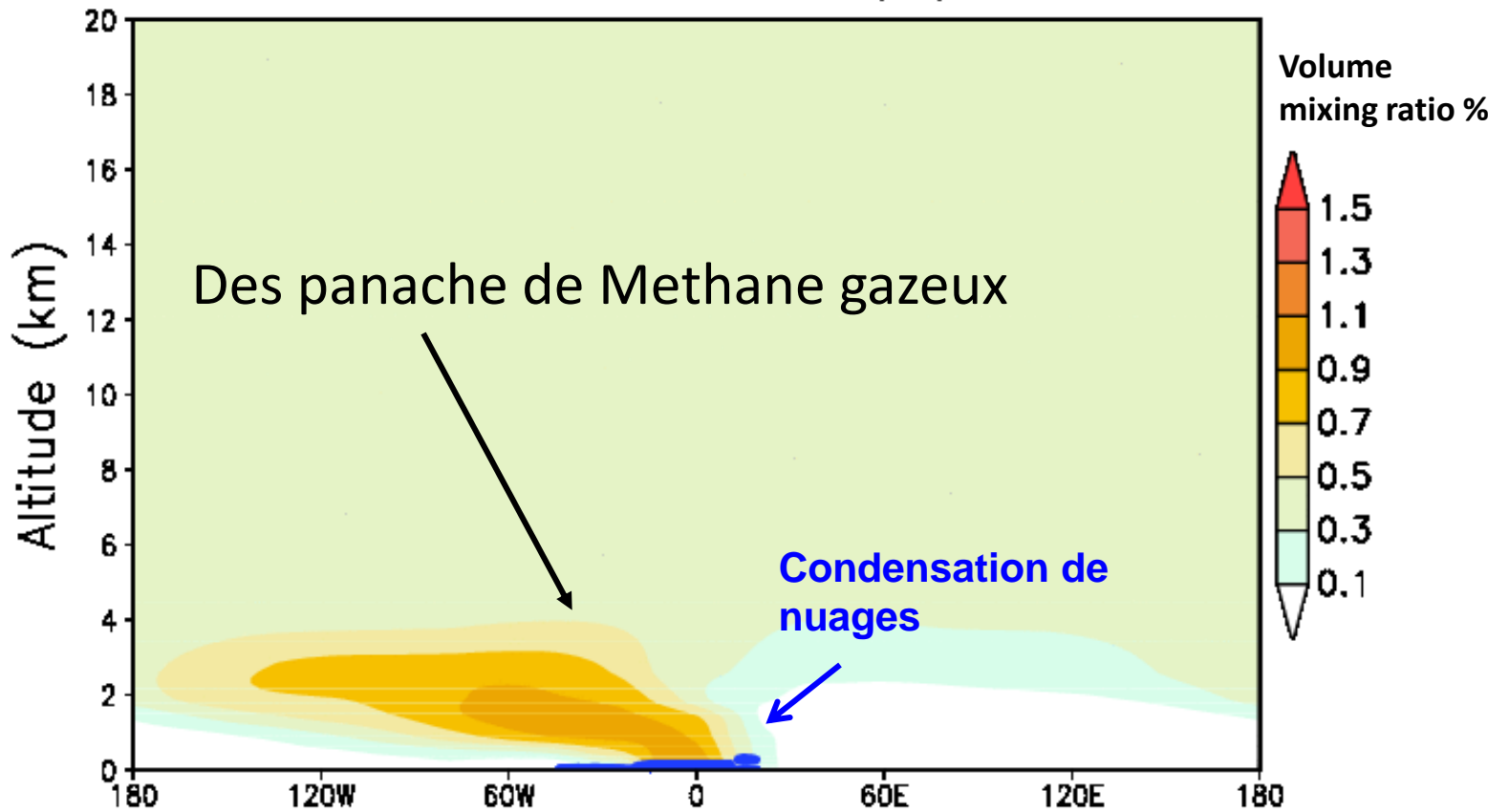
Surface
Temperature (K)



CH4 at 60N (%)



CH4 at 60N (%)

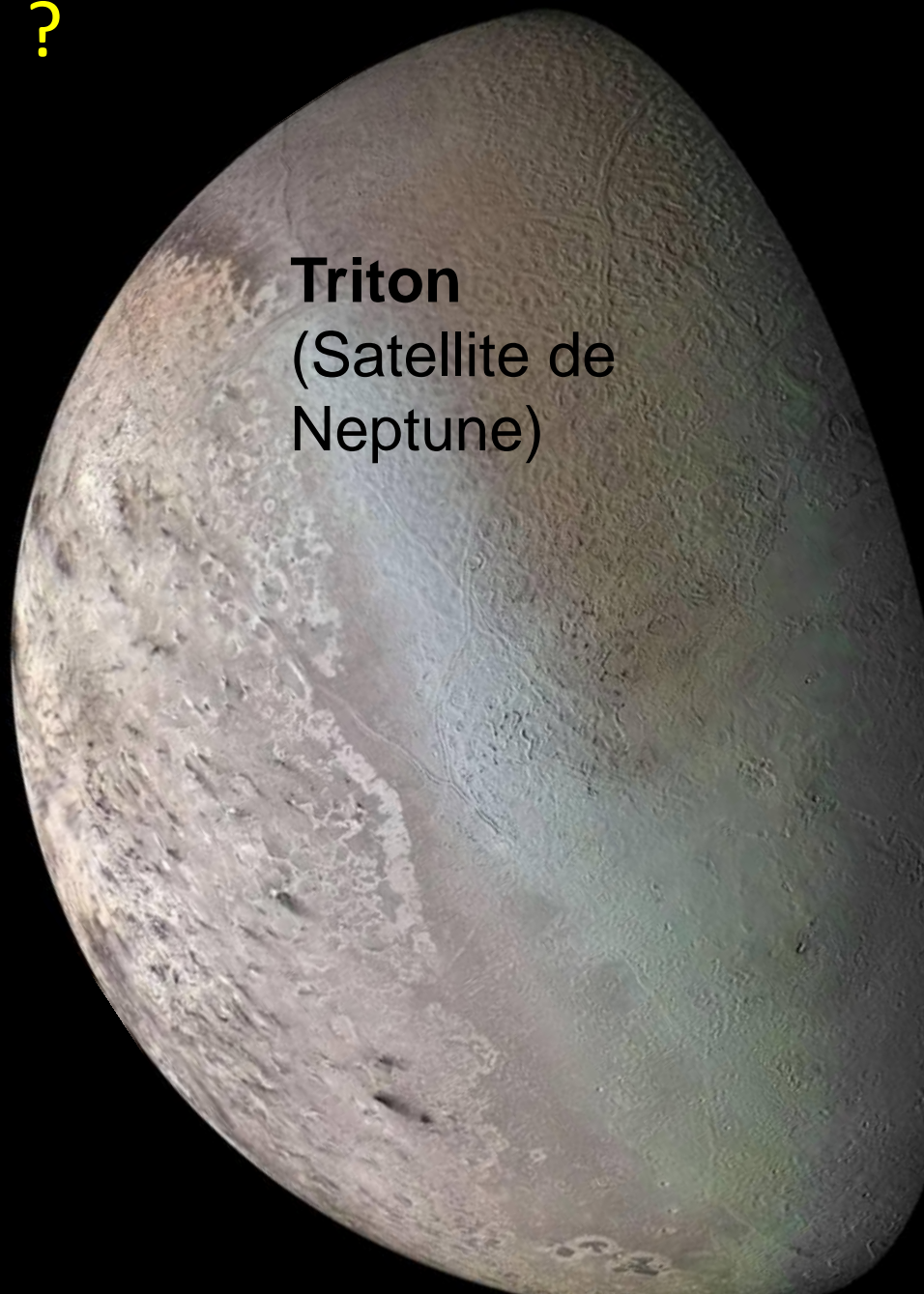


Géologie ?

Rhea,
(Satellite de
Saturne)



Triton
(Satellite de
Neptune)



L'Exploration de Pluton par New Horizons



New Horizons

(Observations de l'atmosphère)

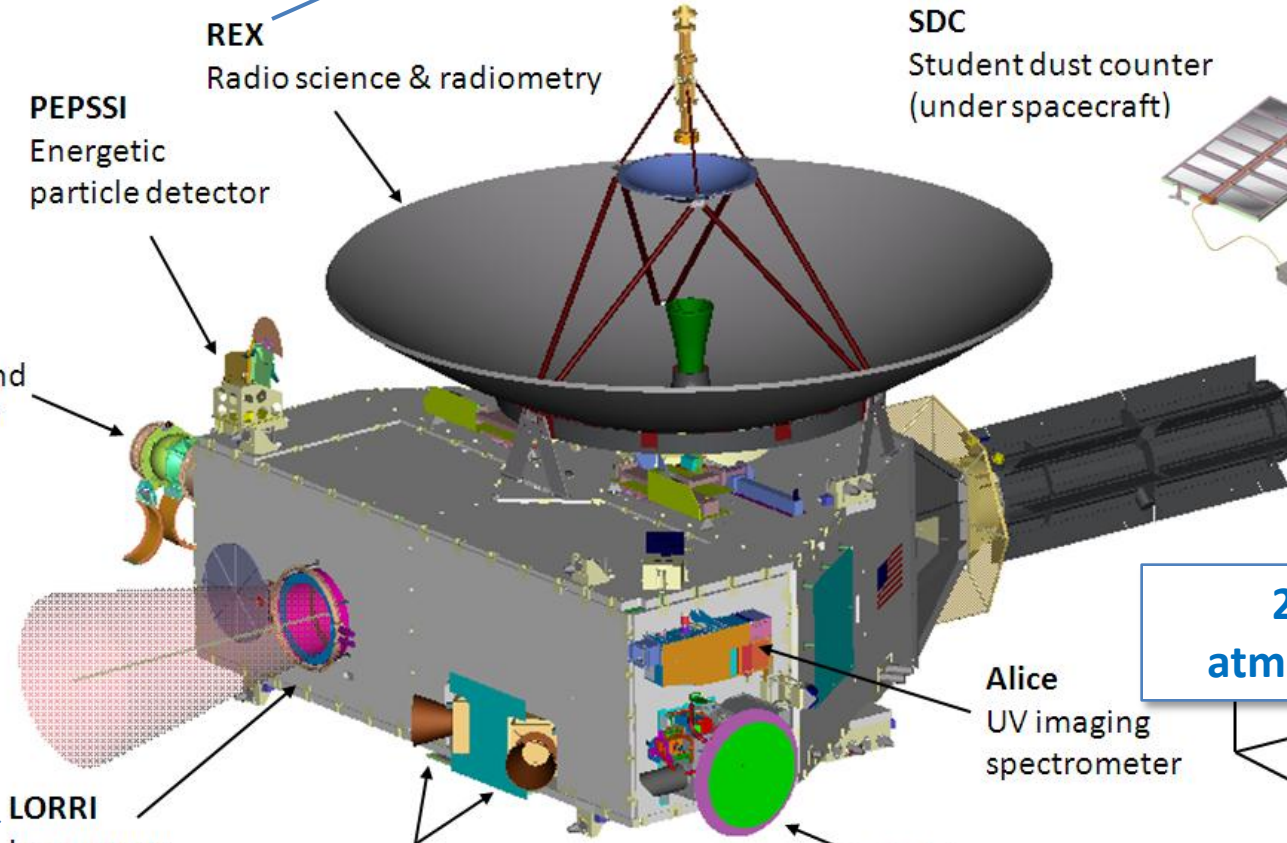
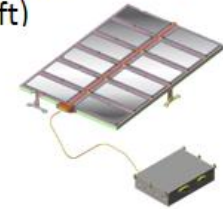
2 x Profils
atmosphériques

REX
Radio science & radiometry

SDC
Student dust counter
(underspacecraft)

PEPSSI
Energetic
particle detector

SWAP
Solar wind
analyzer



2 x Profils
atmosphériques

Alice
UV imaging
spectrometer

+X
+Z

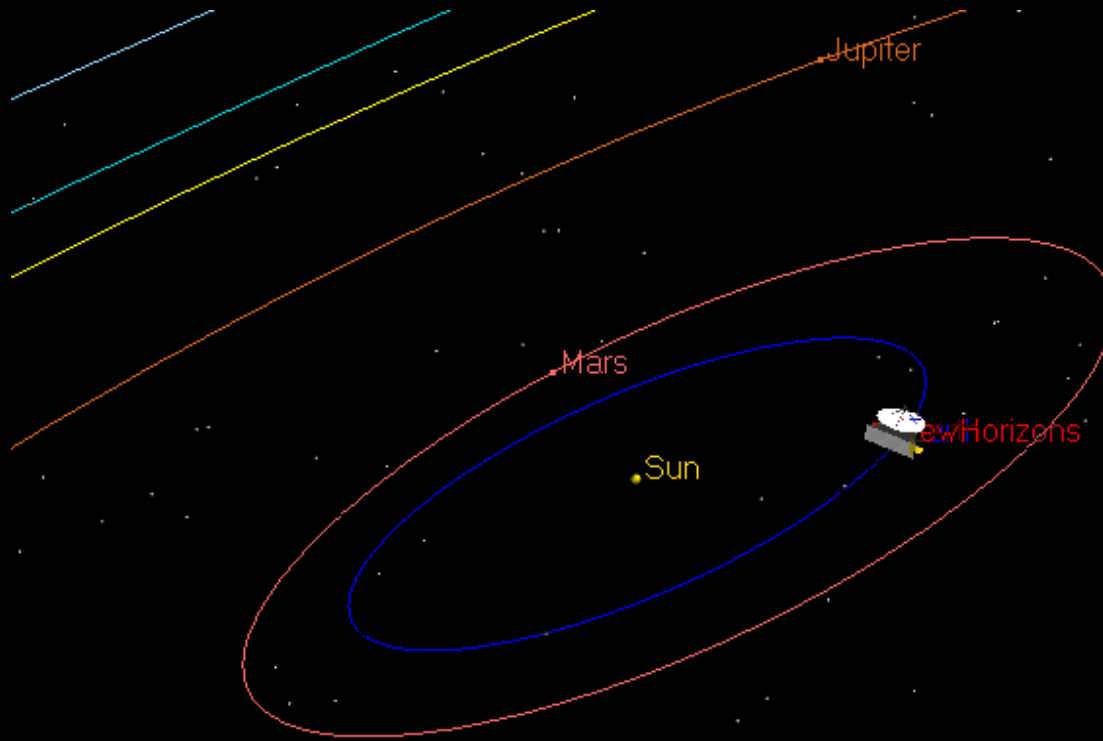
LORRI
Long-range
visible imager

Star Trackers
Guidance and control

Ralph
visible pan. and color imager, (MVIC: 5000x5000)
IR spectrometer (LEISA)

Images de la surface.
Brumes au limbe

Cartes des glaces et des
températures



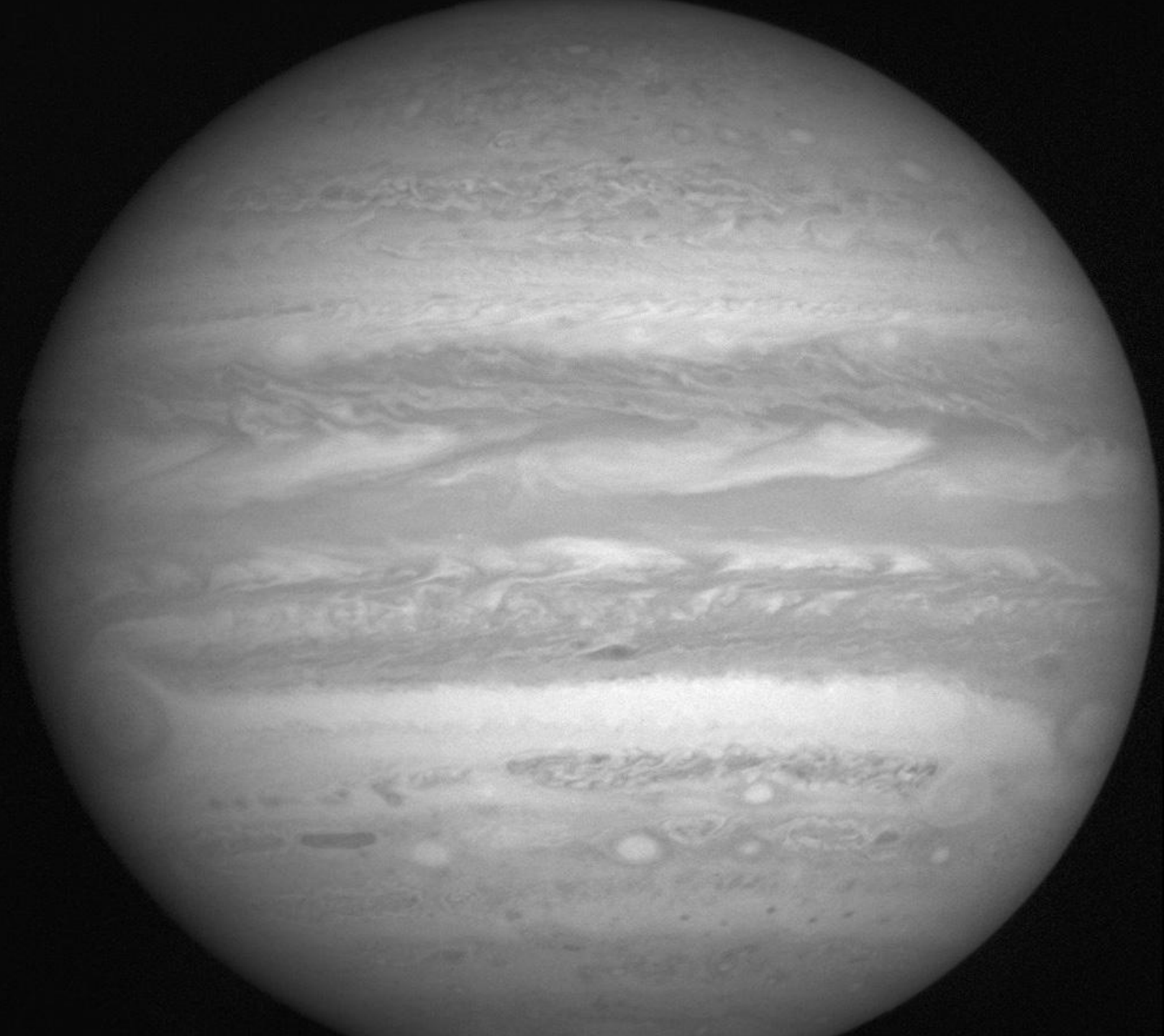
Lancement 19/01/2006

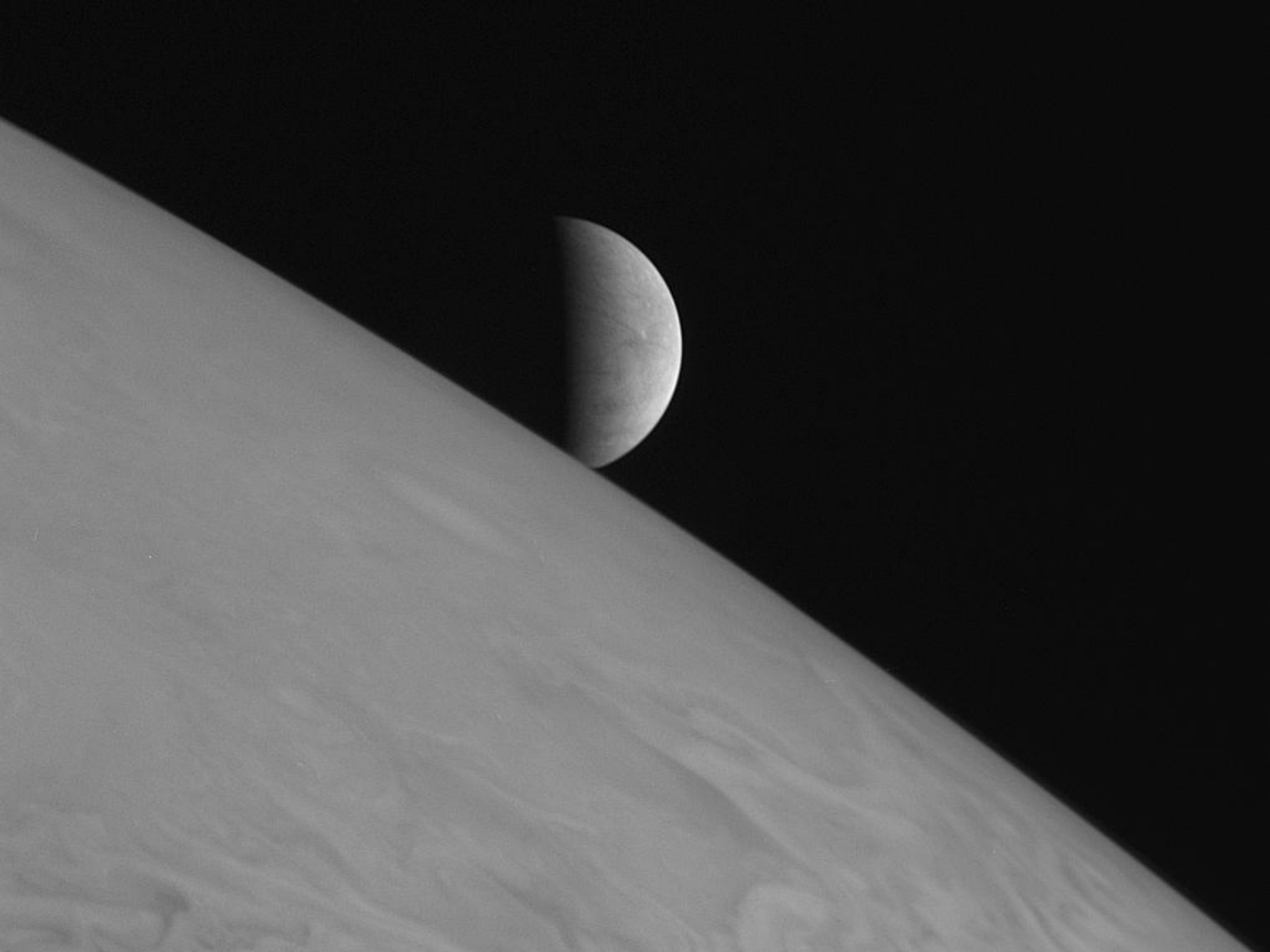
Jupiter : 28/02/2007

Pluton: 14/07/2015



Survol du système de Jupiter par
new Horizons (assistance
gravitationnelle)
Février-Mars 2007

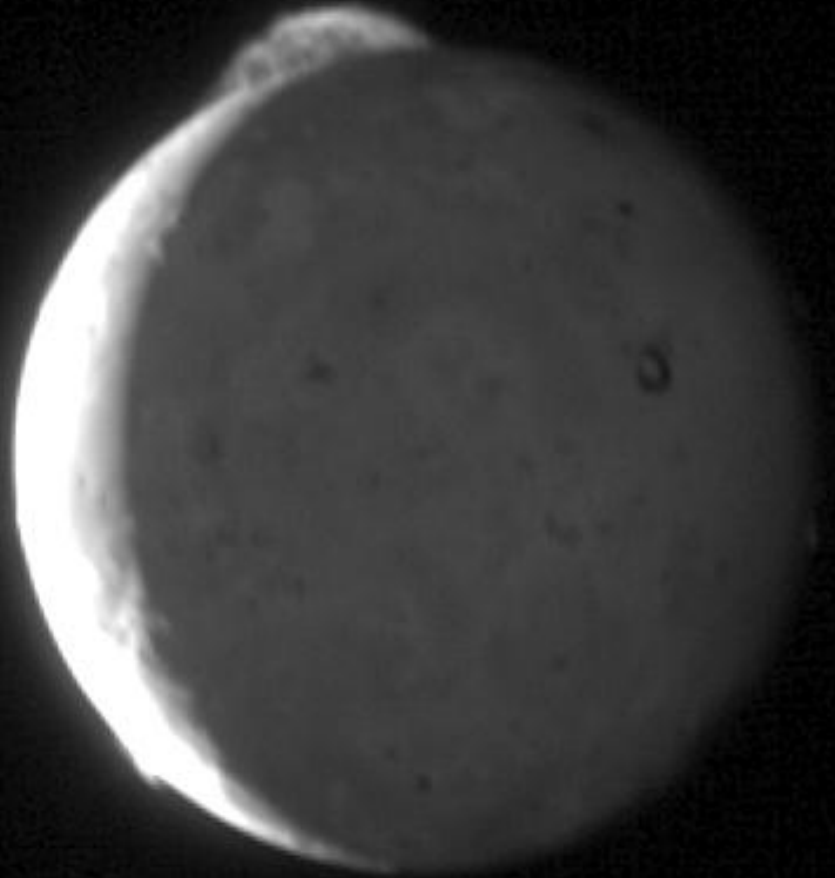




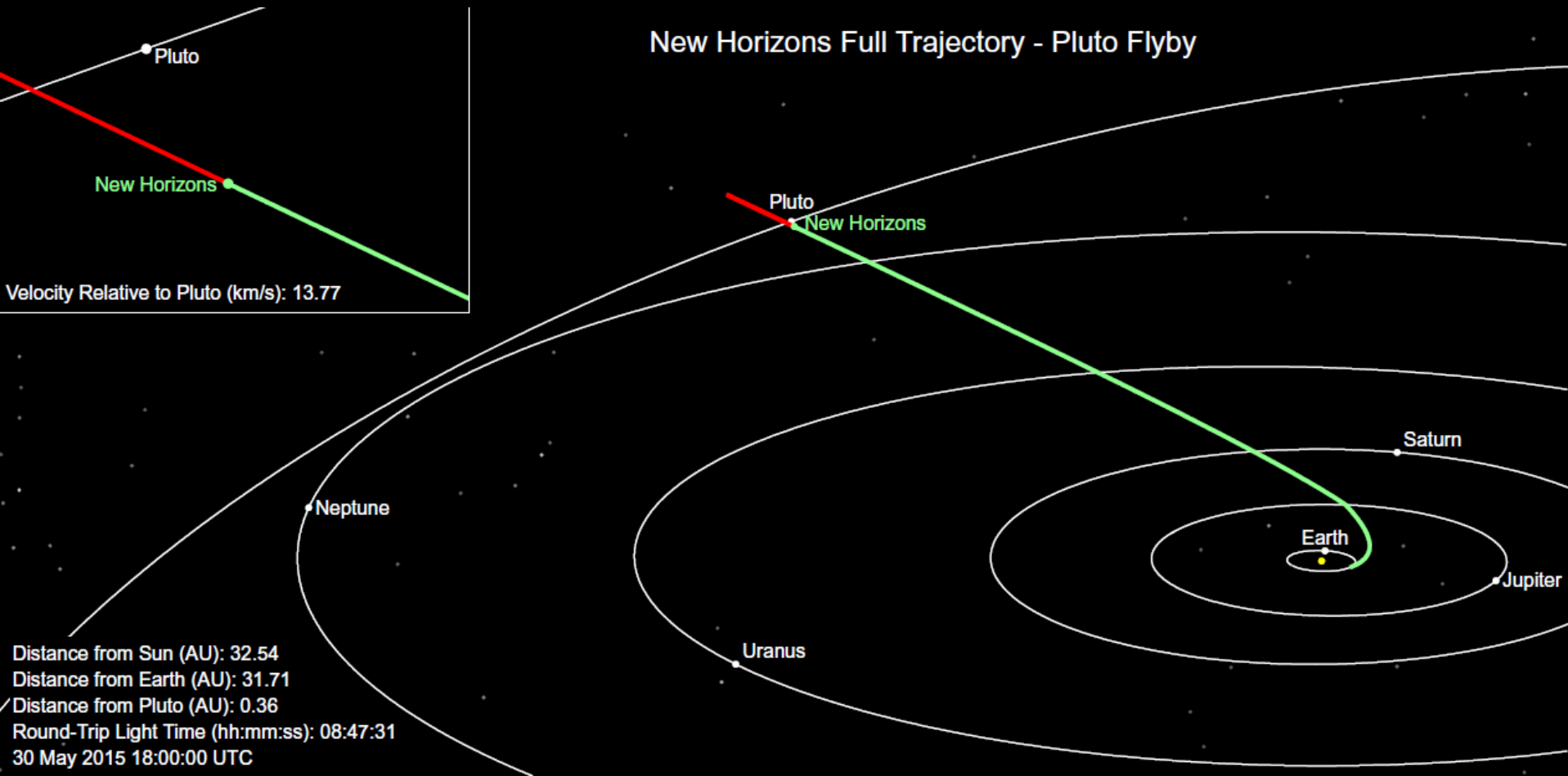


2 Mars 2007

Eruption du Volcan **Tvashtar**
(Pôle Nord de Io)



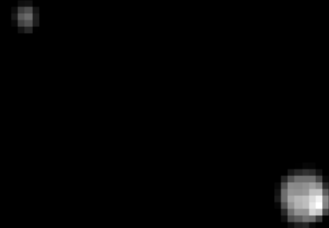
Mai 2015: New Horizons s'approche de Pluton



Premières images de New Horizons

Pluton – Charon

LORRI, 12-18 avril
(à ~105 millions km)



Premières
images de
New Horizons

Pluton



LORRI, 8-12 mai 2015

(à ~75 millions km)



JUNE 8, 2015

**PLUTO CENTRAL
LONGITUDE: 39°**



JUNE 13, 2015

**PLUTO CENTRAL
LONGITUDE: 79°**



JUNE 15, 2015

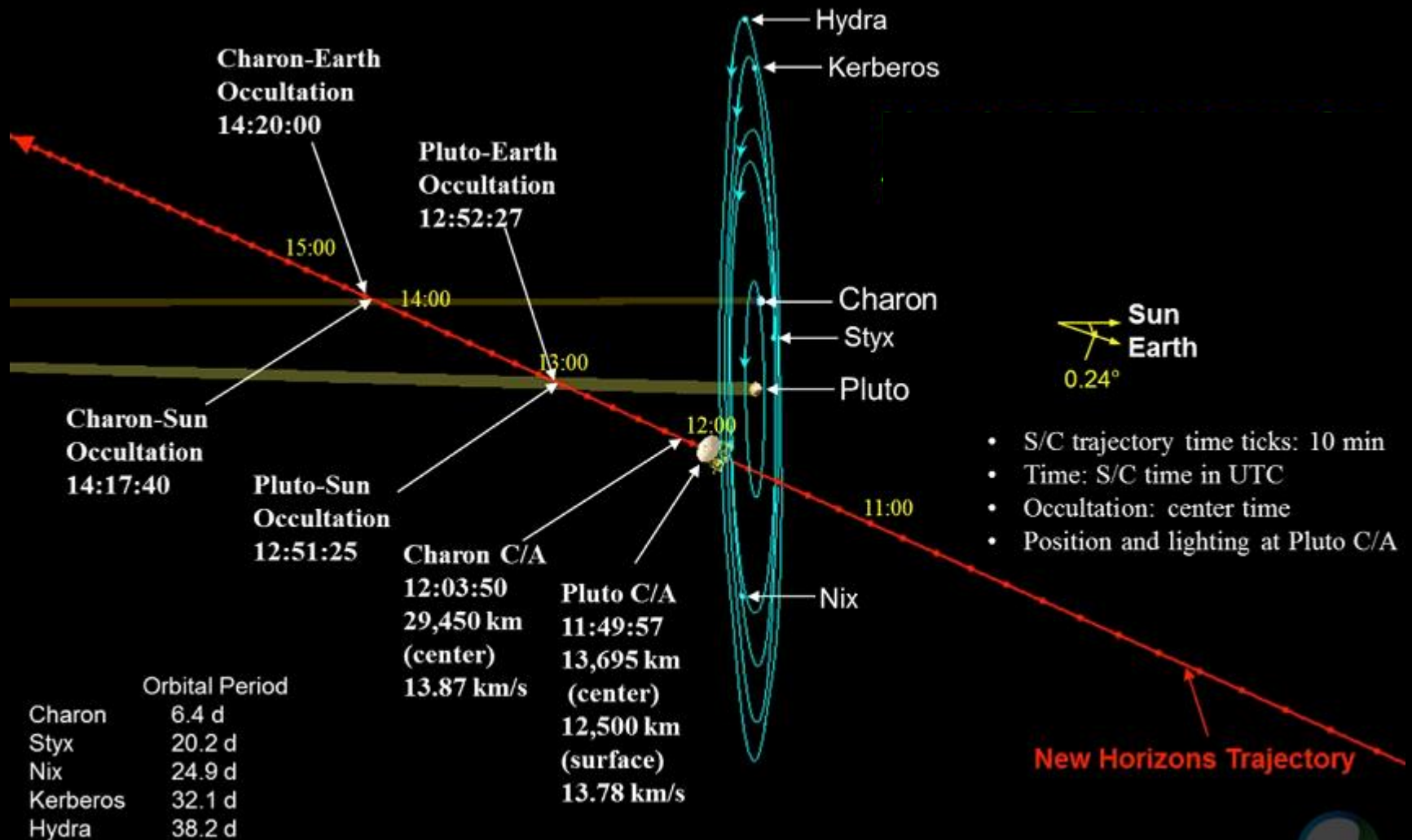
**PLUTO CENTRAL
LONGITUDE: 356°**

3 juillet 2015
(12.5 million km)



14 Juillet: survol de Pluton

Vitesse relative 13.78 km/s (49,600 km/h) ~10,000 km de Pluton. ~27000 km de Charon



4 juillet 2014 (J-9) : New Horizons tombe en panne !

- **New Horizons cesse de fonctionner et interroge la Terre**
- Il faut 9h pour interroger New Horizons et recevoir la réponse !
- On comprend rapidement que l'ordinateur de bord a reçu une nouvelle commande alors qu'il n'avait pas terminé la tâche précédente (compression de données): Il a rebooté par sécurité...

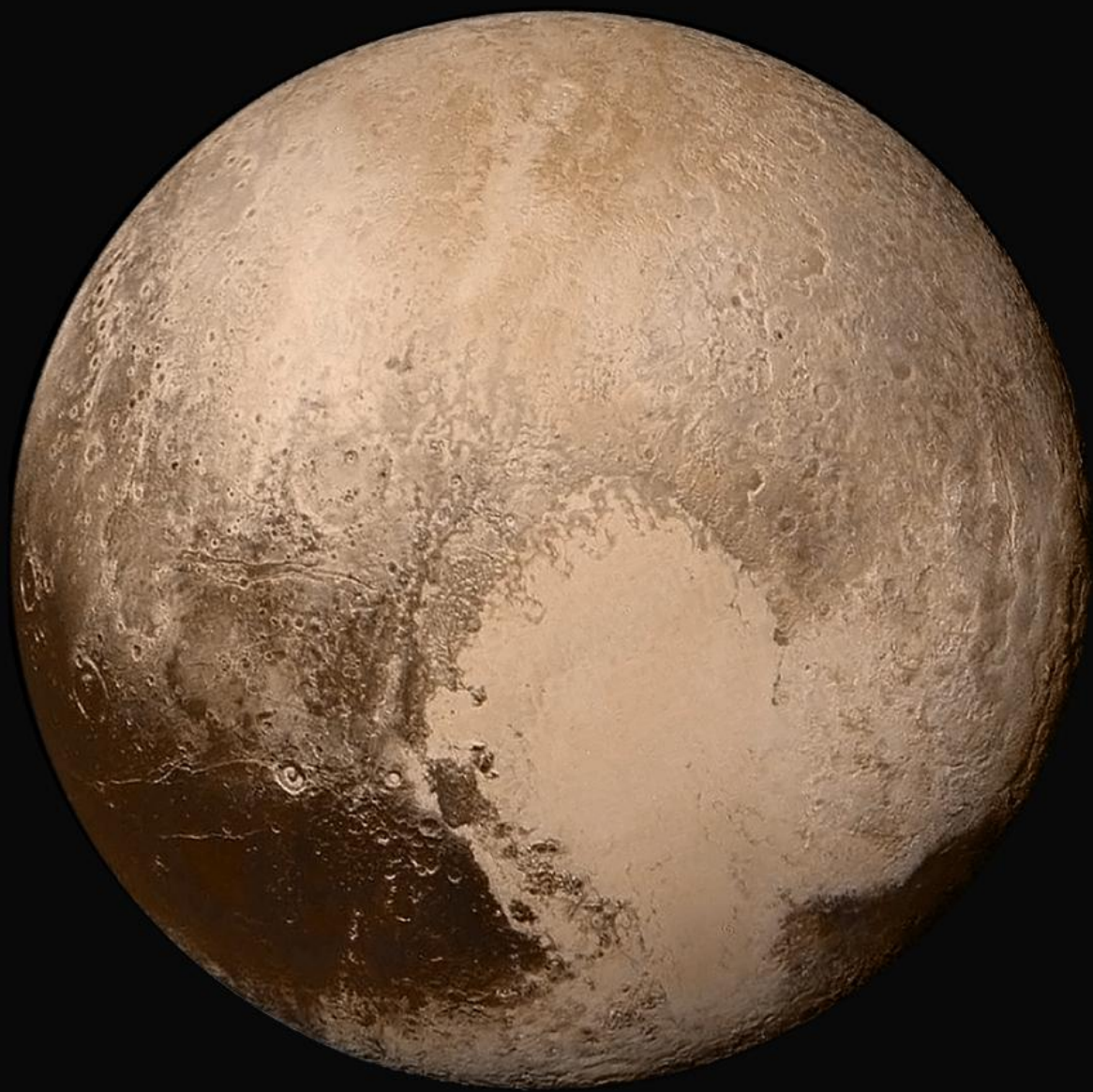


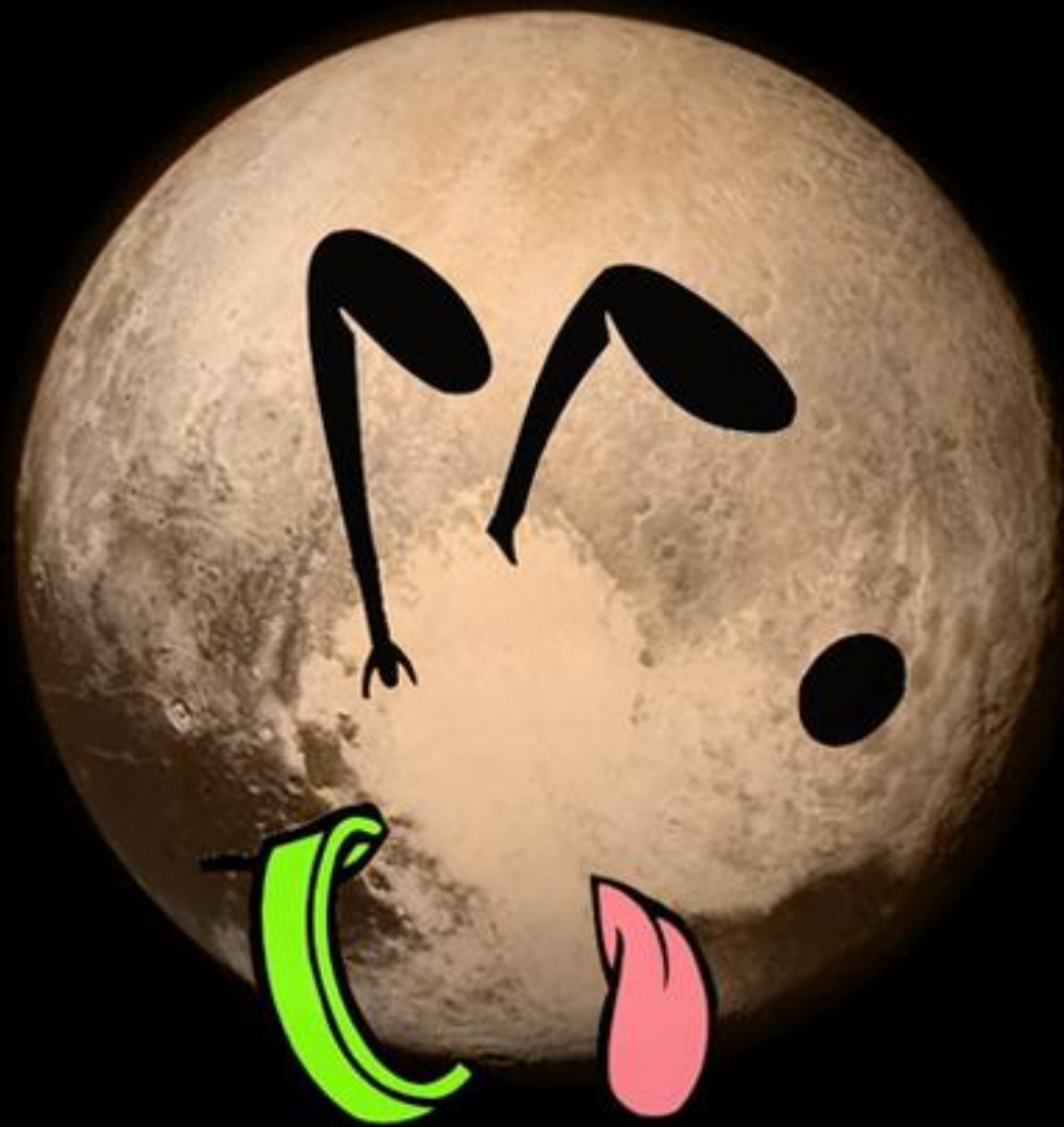
14 Juillet 2015

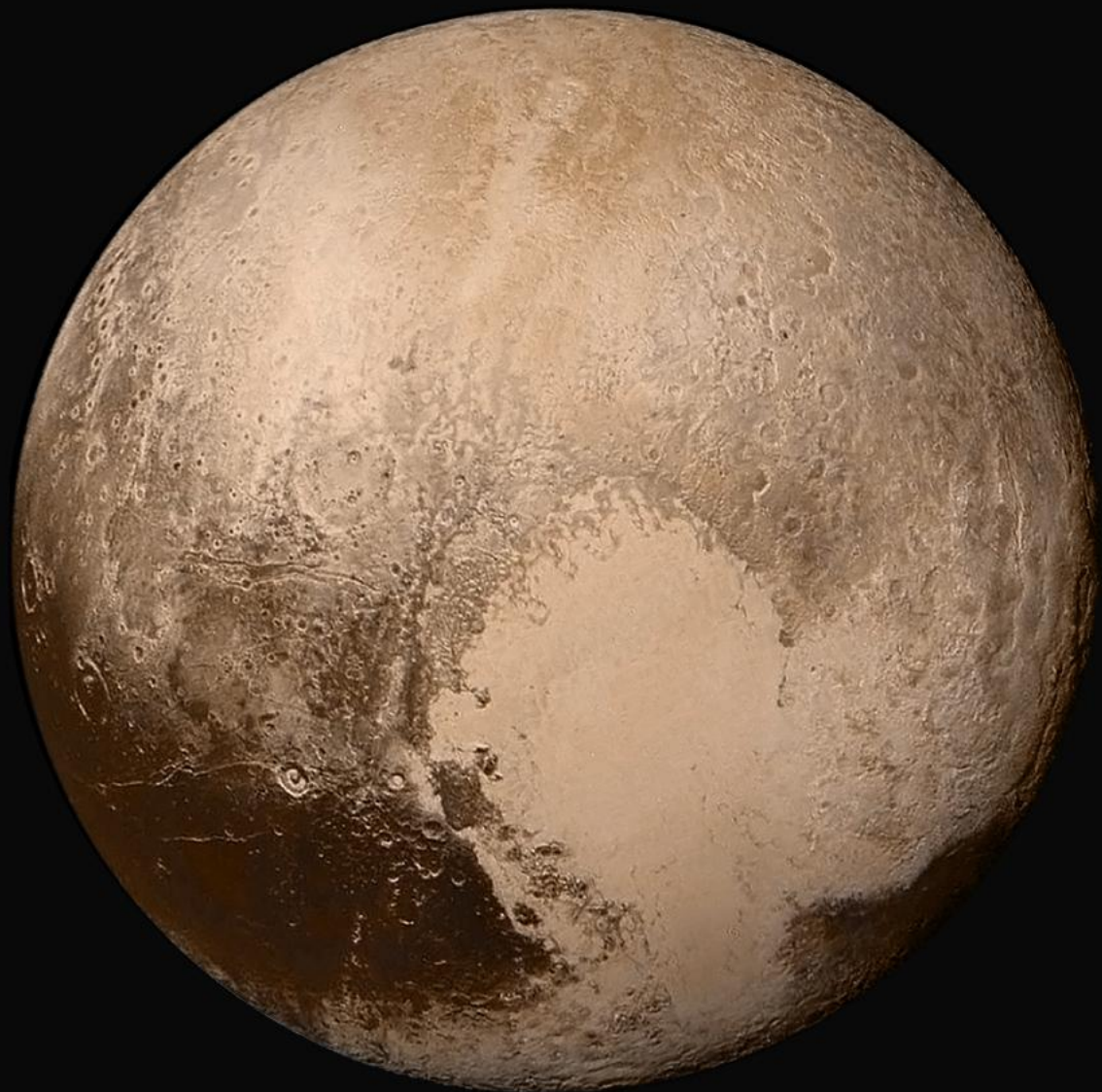


15 juillet, 2h10 du matin (Heure française):
« New Horizons call home »



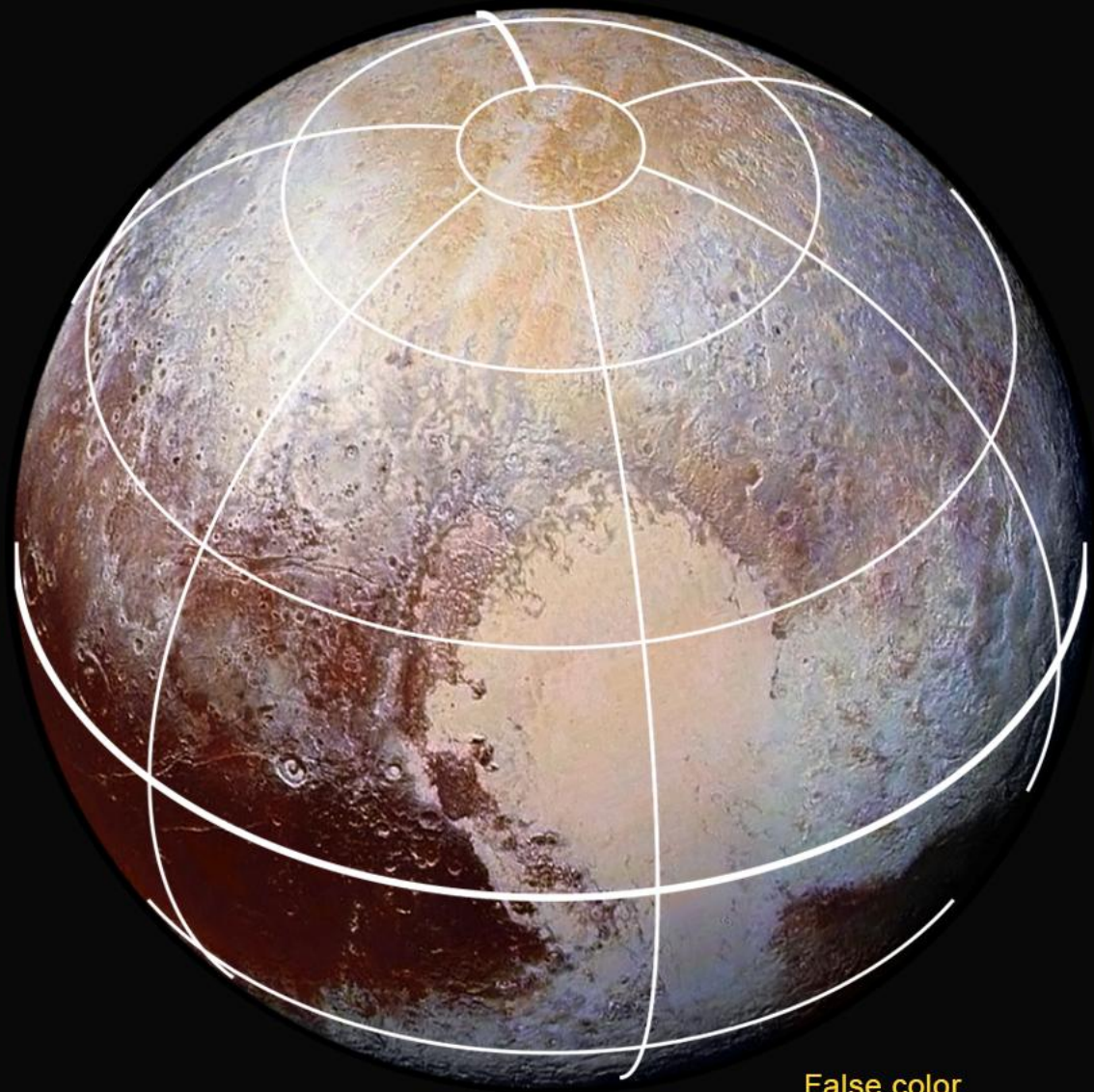




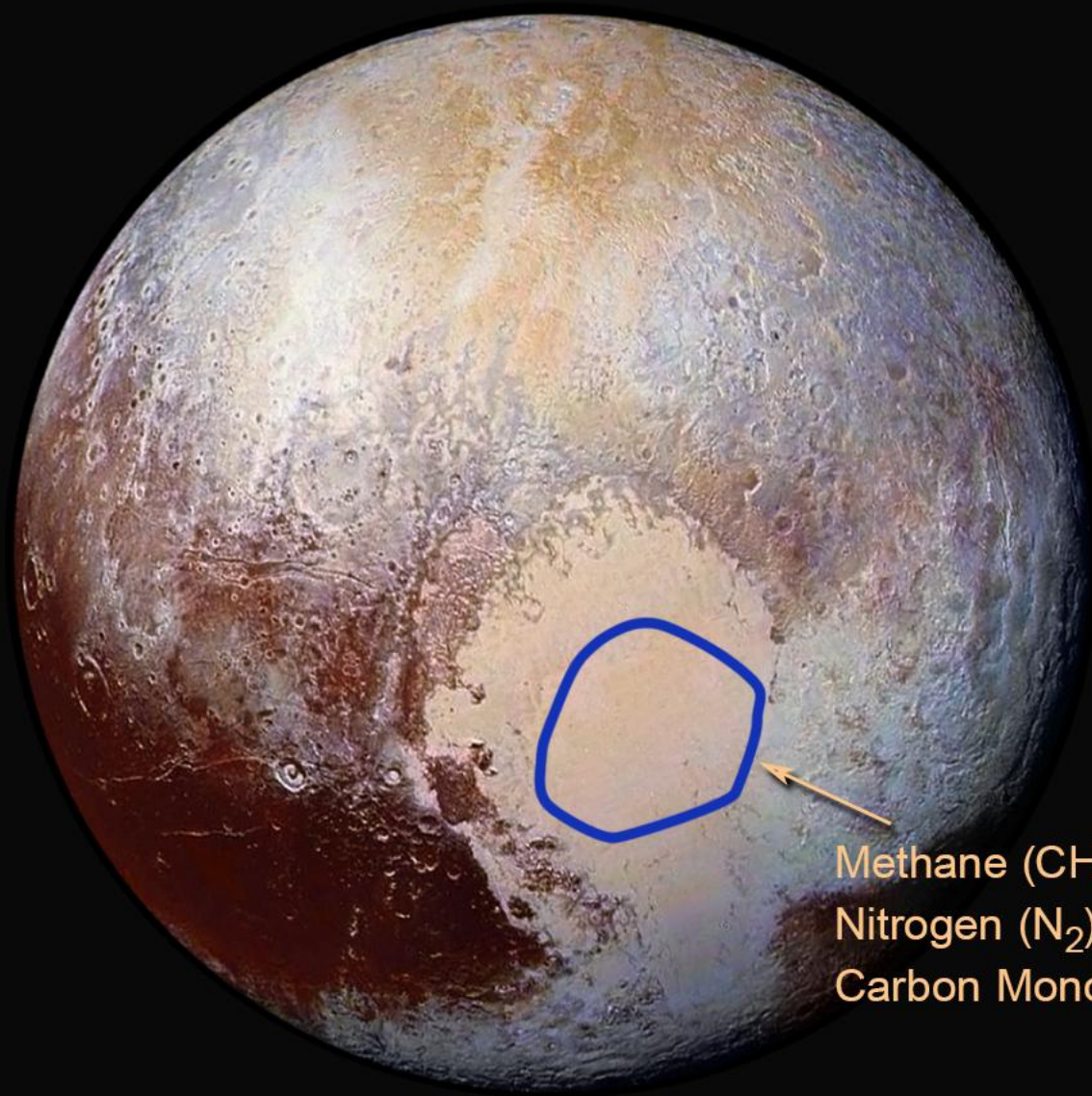




False Color

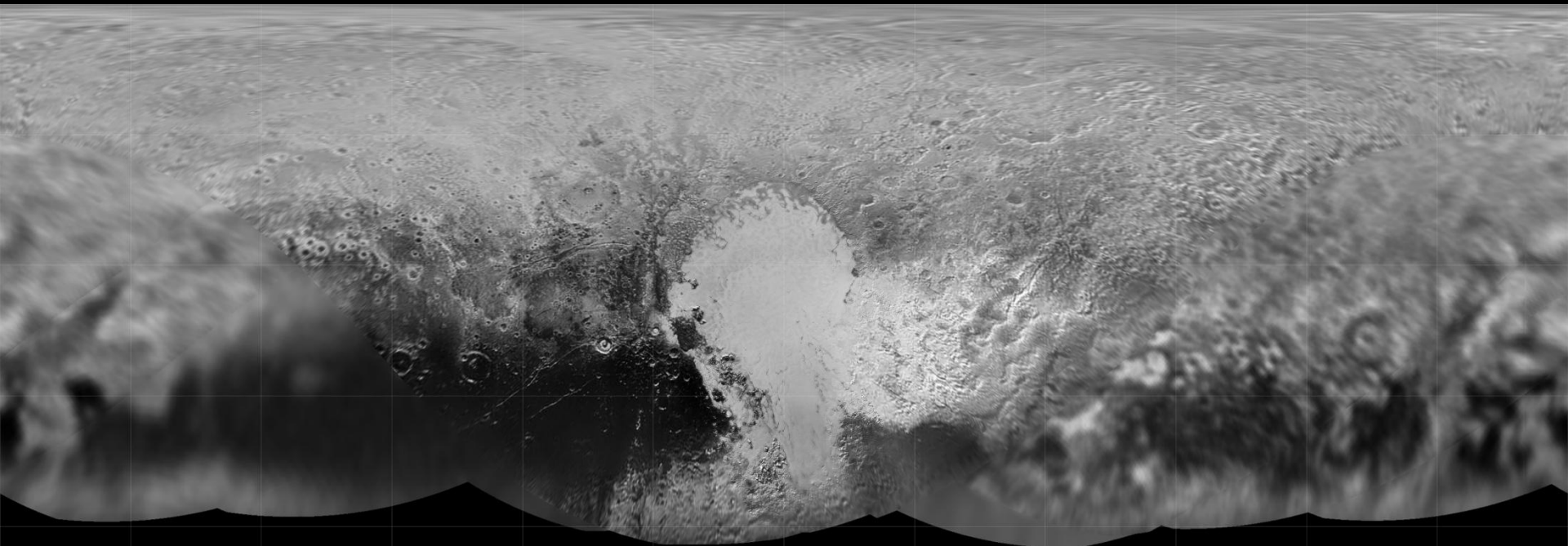


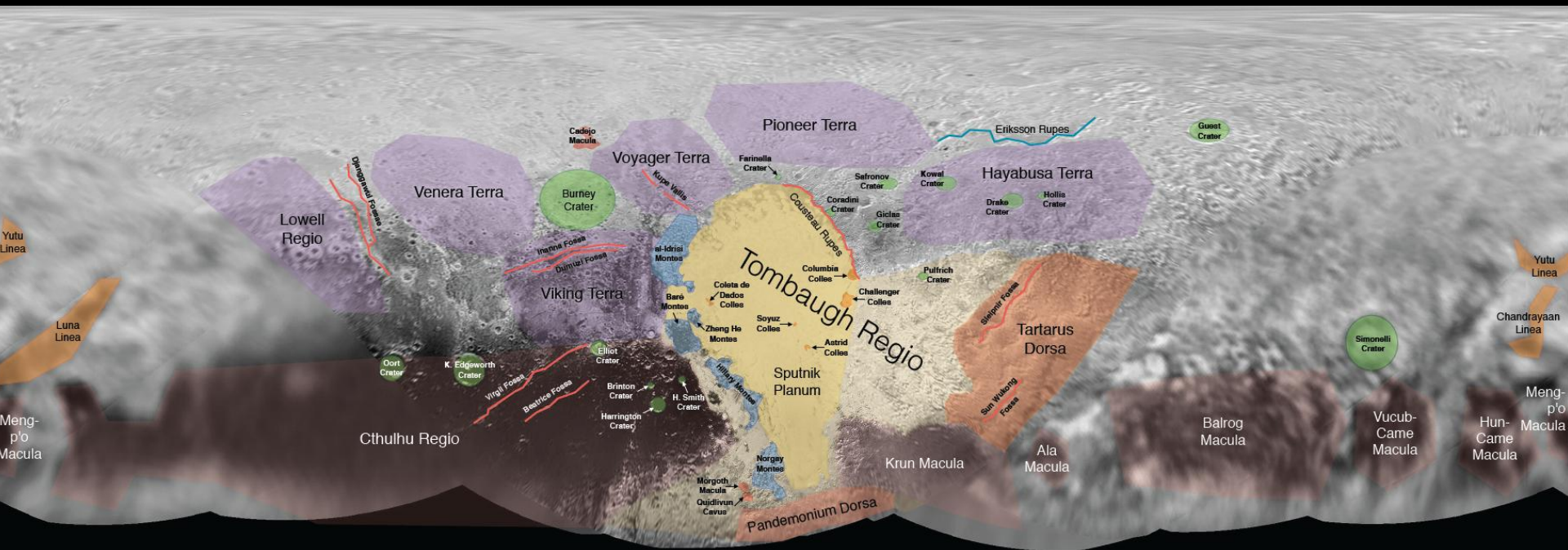
False color



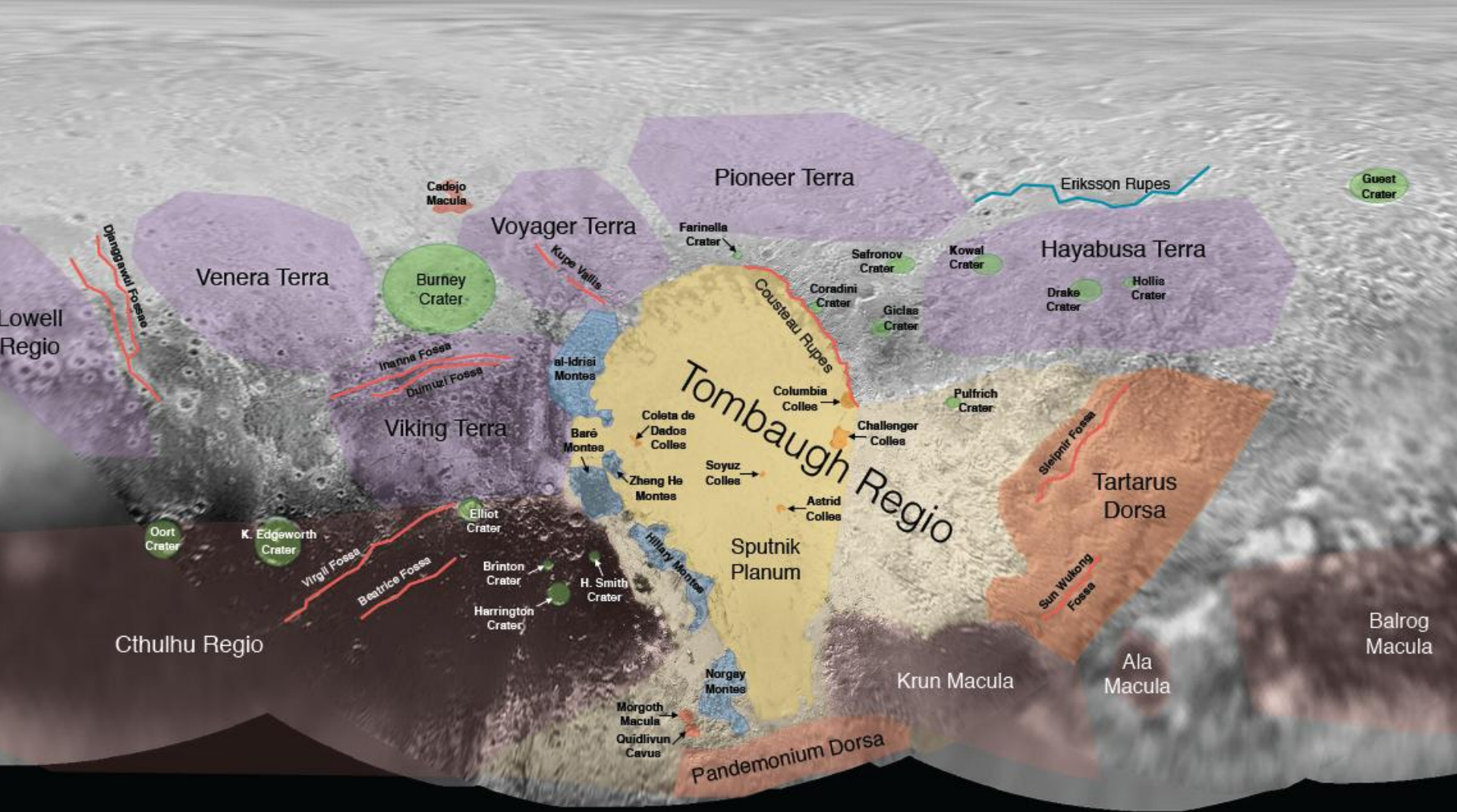
Methane (CH₄) ice
Nitrogen (N₂) ice
Carbon Monoxide (CO) ice

Carte globale de Pluton

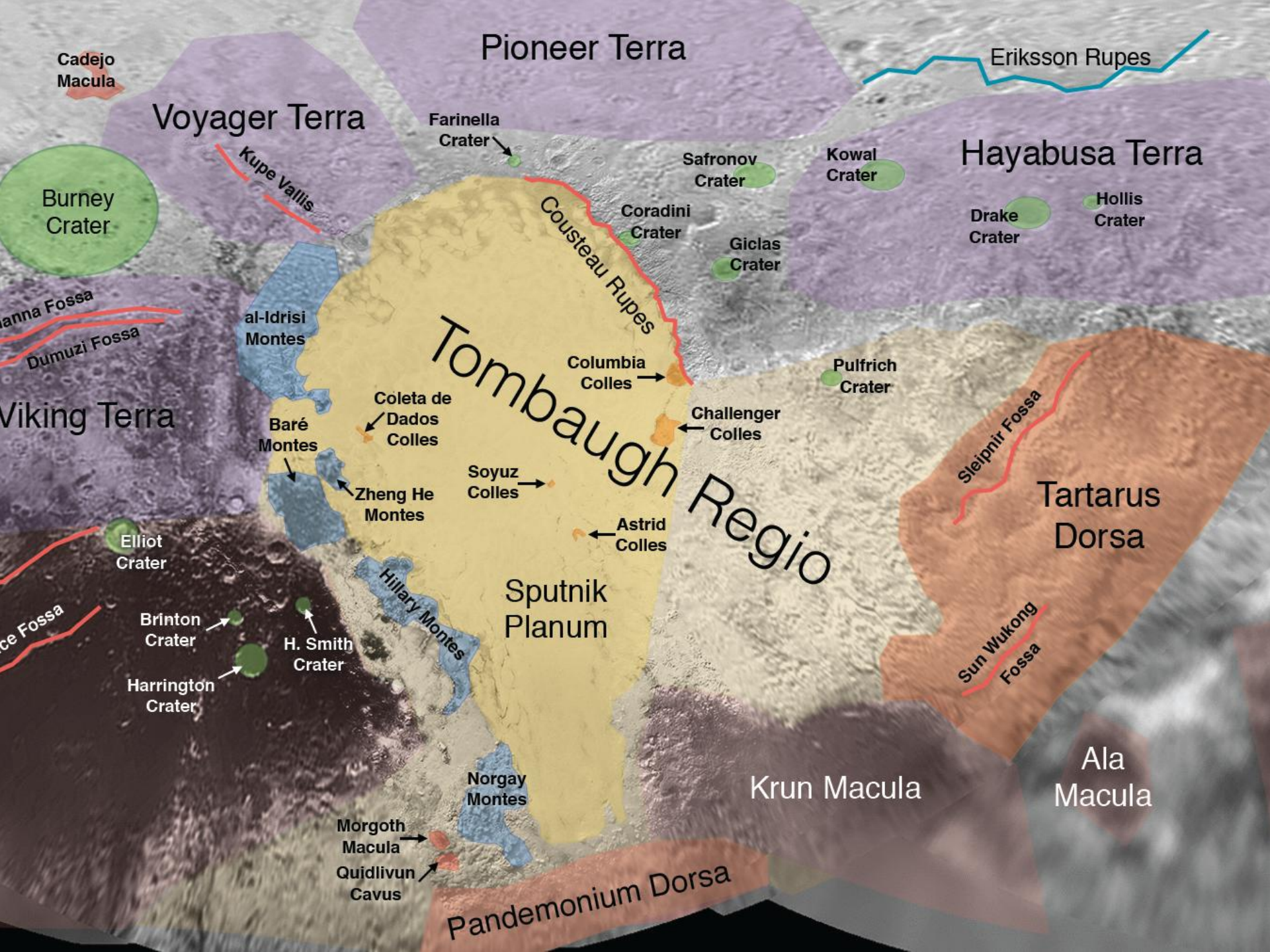




Informal Names for Features on Pluto



Informal Names for Features on Pluto



Pioneer Terra

Eriksson Rupes

Cadejo Macula

Voyager Terra

Farinella Crater

Safronov Crater

Kowal Crater

Hayabusa Terra

Burney Crater

Kupe Vallis

Coradini Crater

Giclas Crater

Drake Crater

Hollis Crater

Lanna Fossa

Dumuzi Fossa

al-Idrisi Montes

Cousteau Rupes

Columbia Colles

Challenger Colles

Pulfrich Crater

Viking Terra

Baré Montes

Coleta de Dados Colles

Soyuz Colles

Astrid Colles

Sleipnir Fossa

Tartarus Dorsa

Elliot Crater

Zheng He Montes

Sputnik Planum

Ice Fossa

Brinton Crater

H. Smith Crater

Hillary Montes

Sputnik Planum

Sun Wukong Fossa

Harrington Crater

Norgay Montes

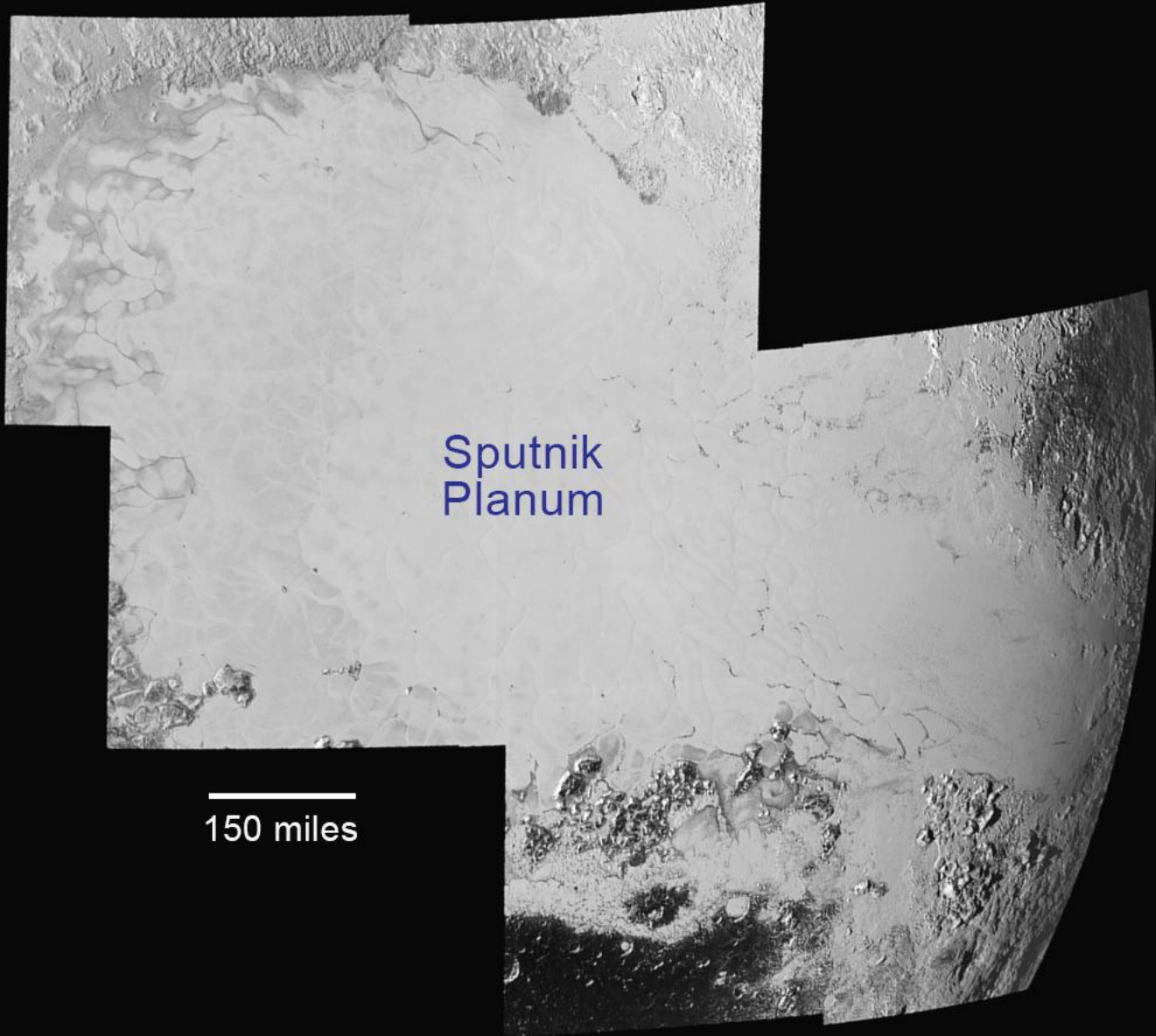
Krun Macula

Ala Macula

Morgoth Macula

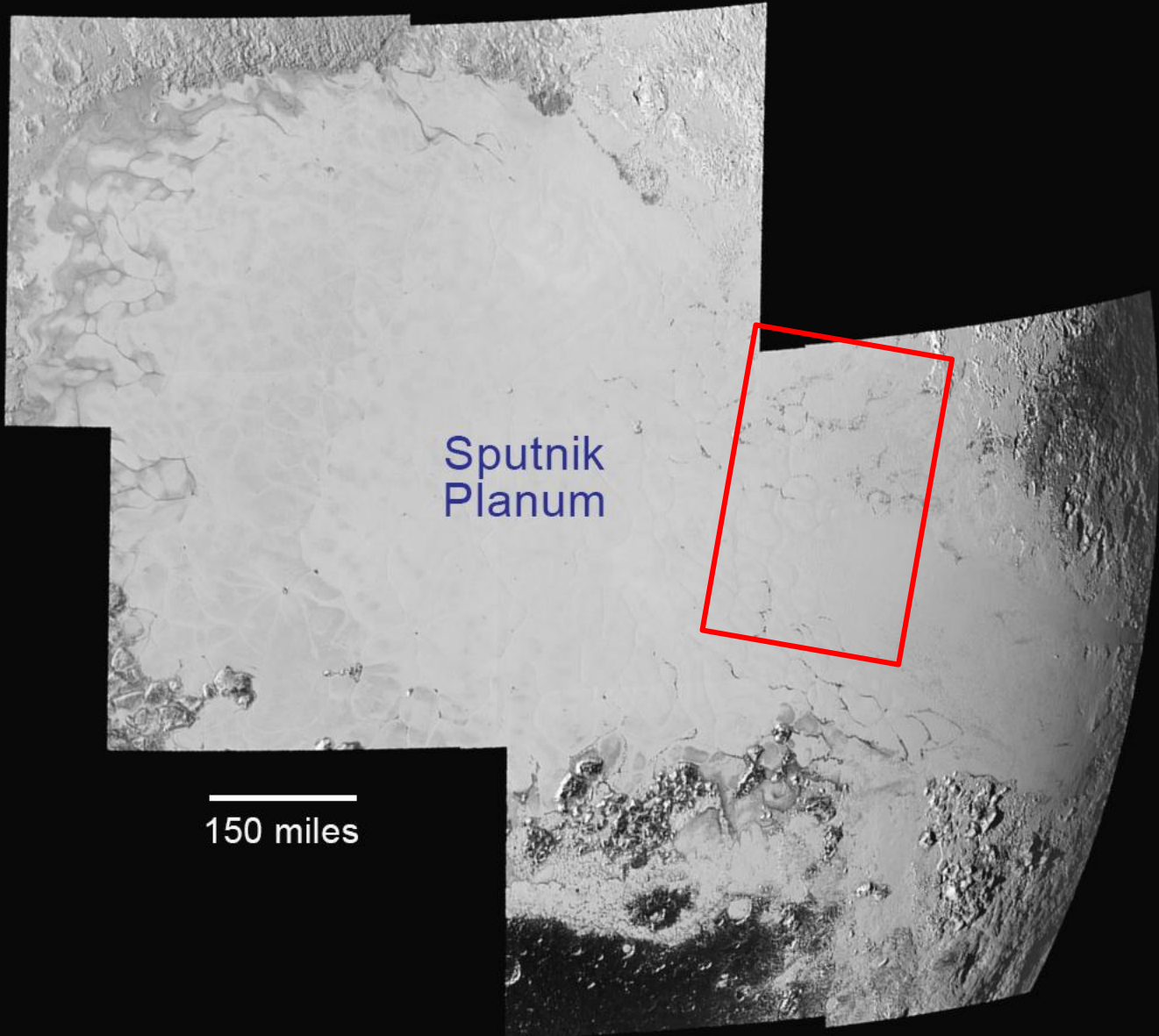
Quidlivun Cavus

Pandemonium Dorsa



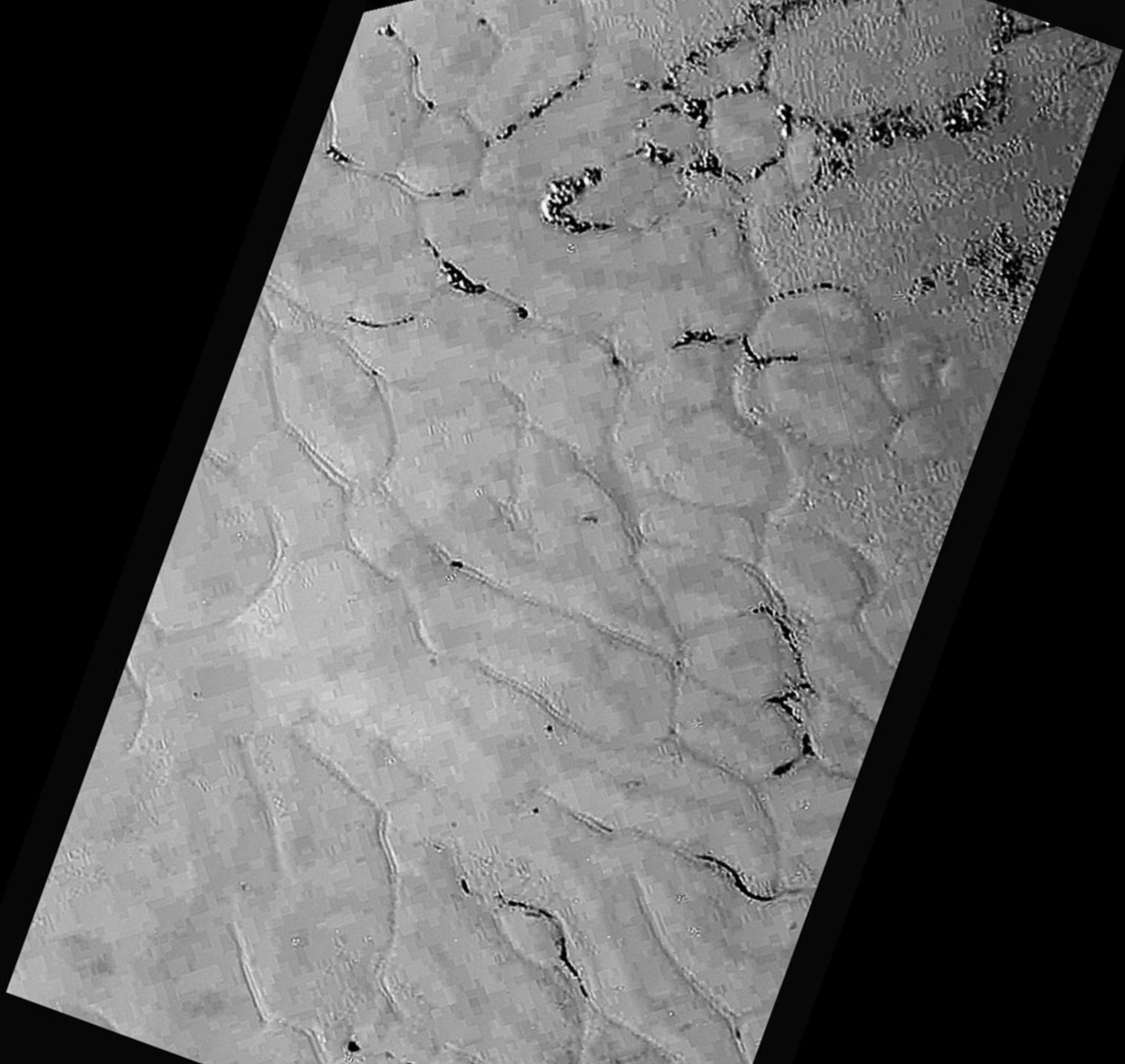
Sputnik
Planum

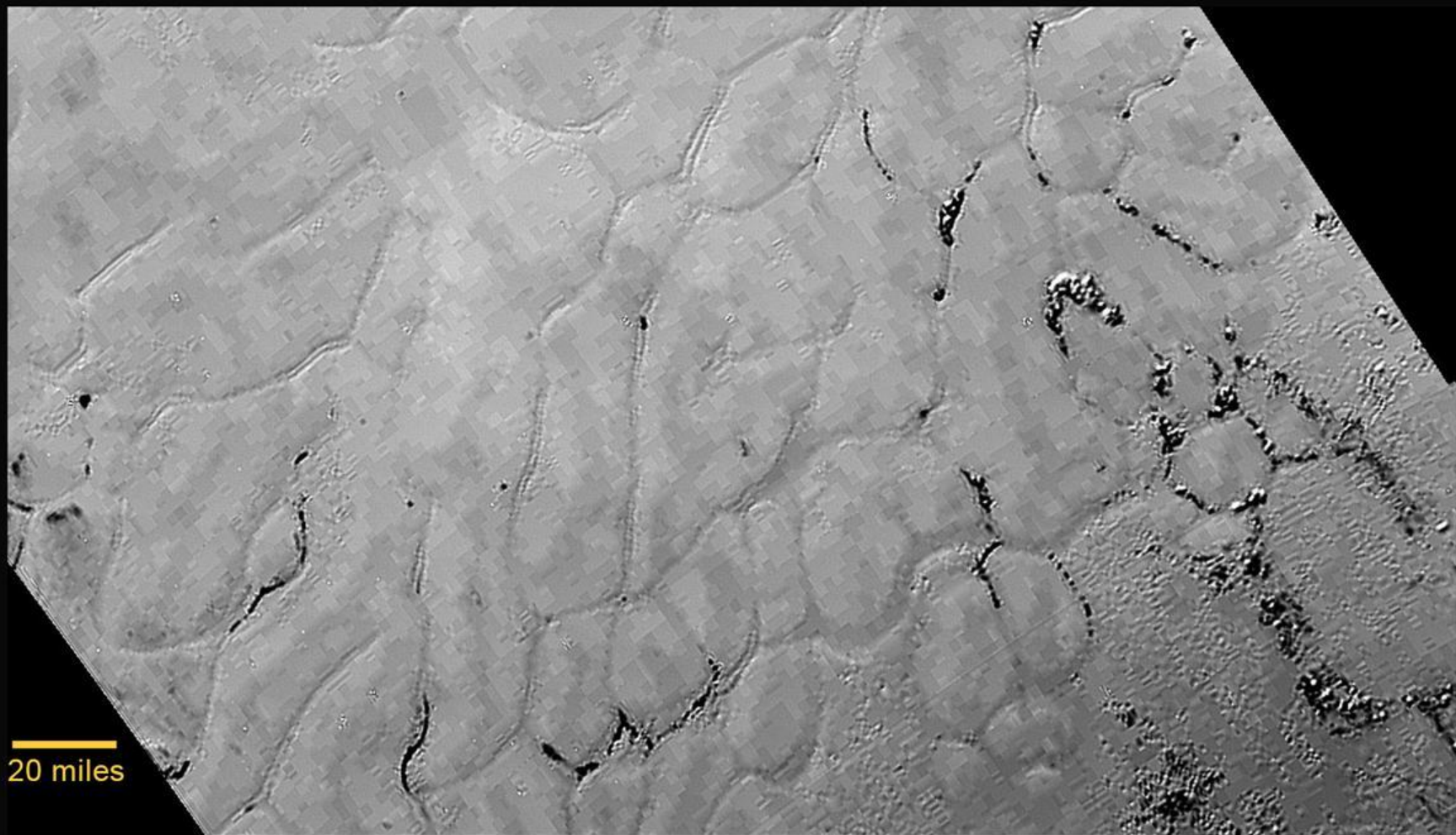
150 miles



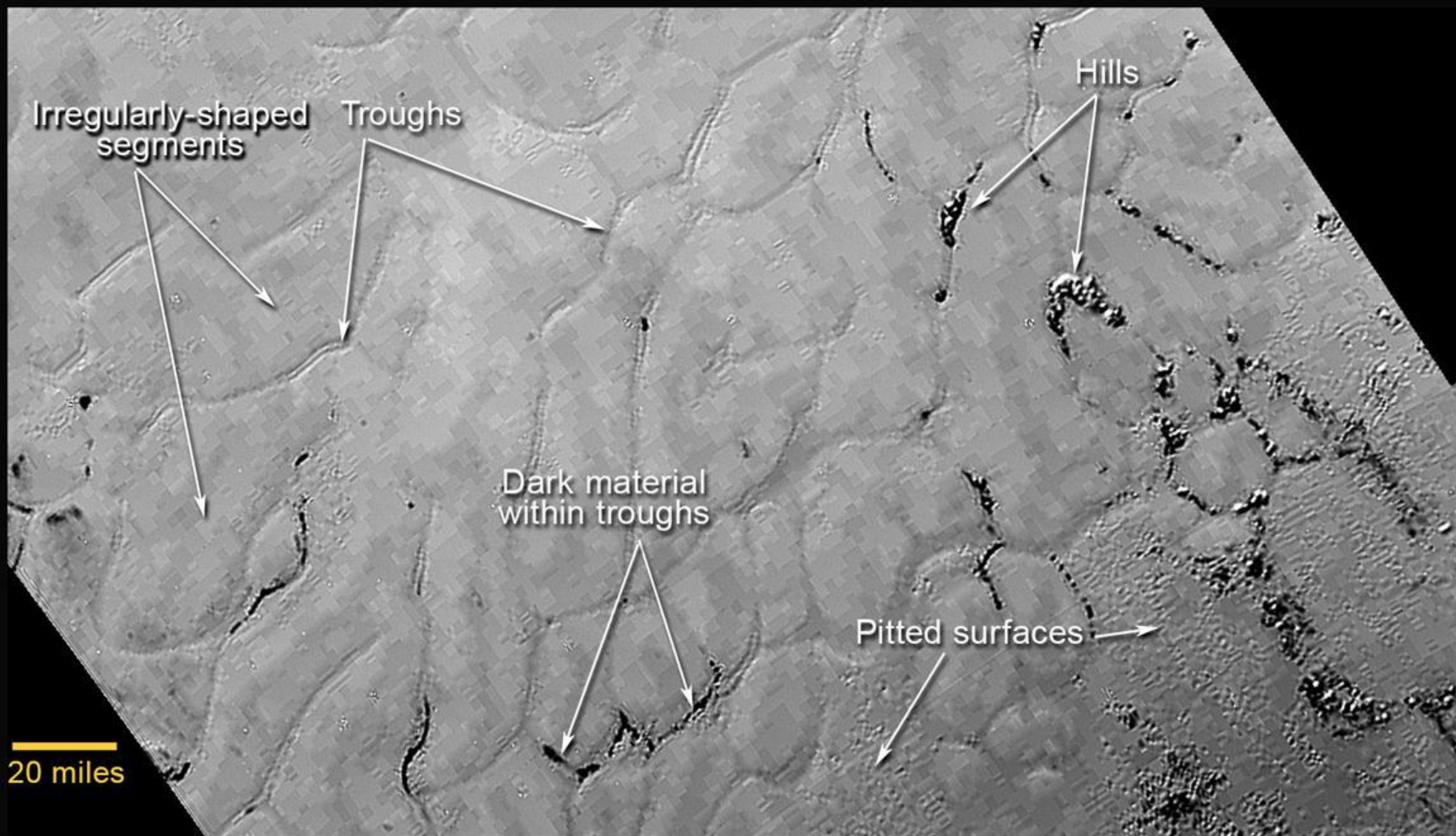
Sputnik
Planum

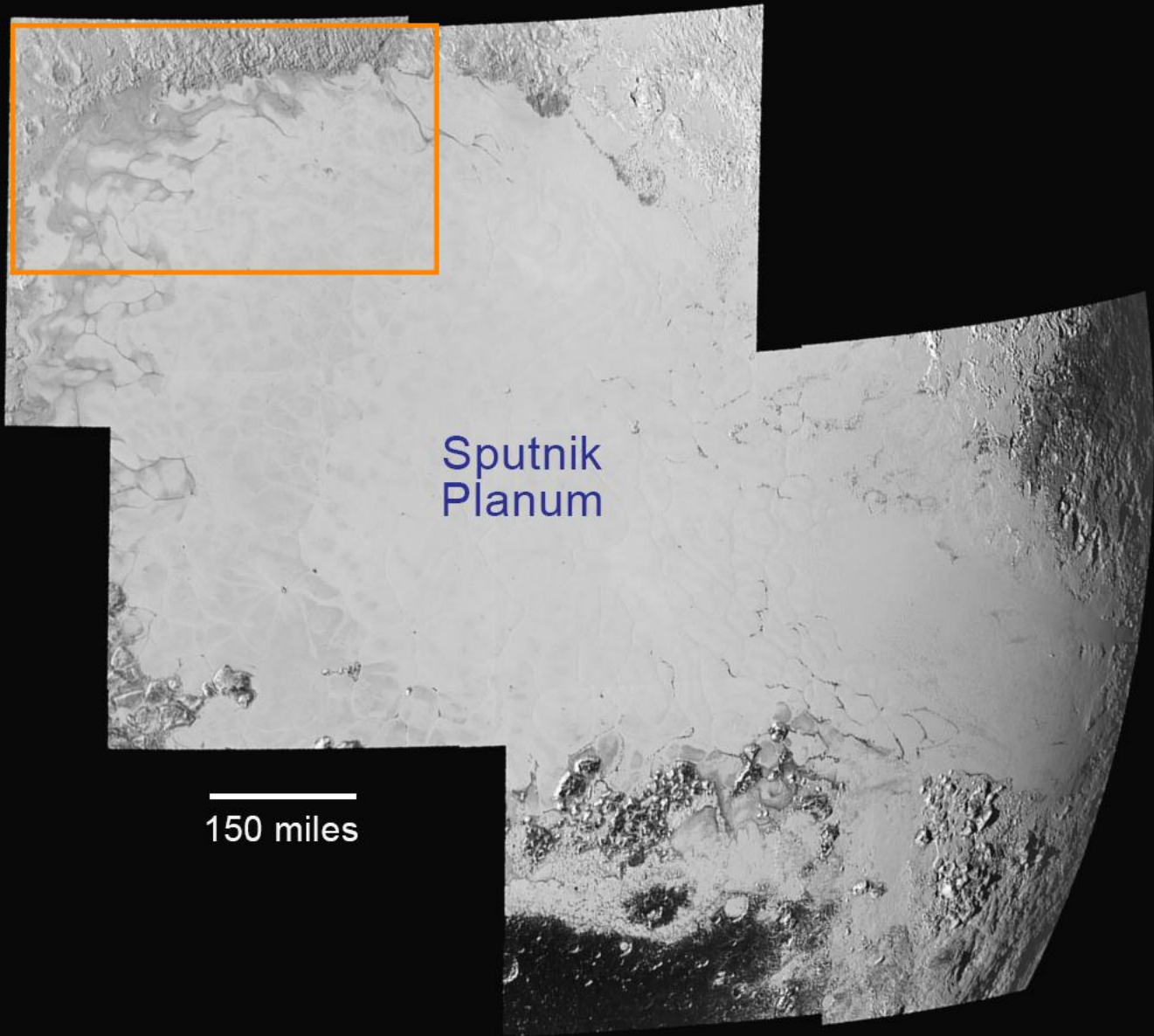
150 miles





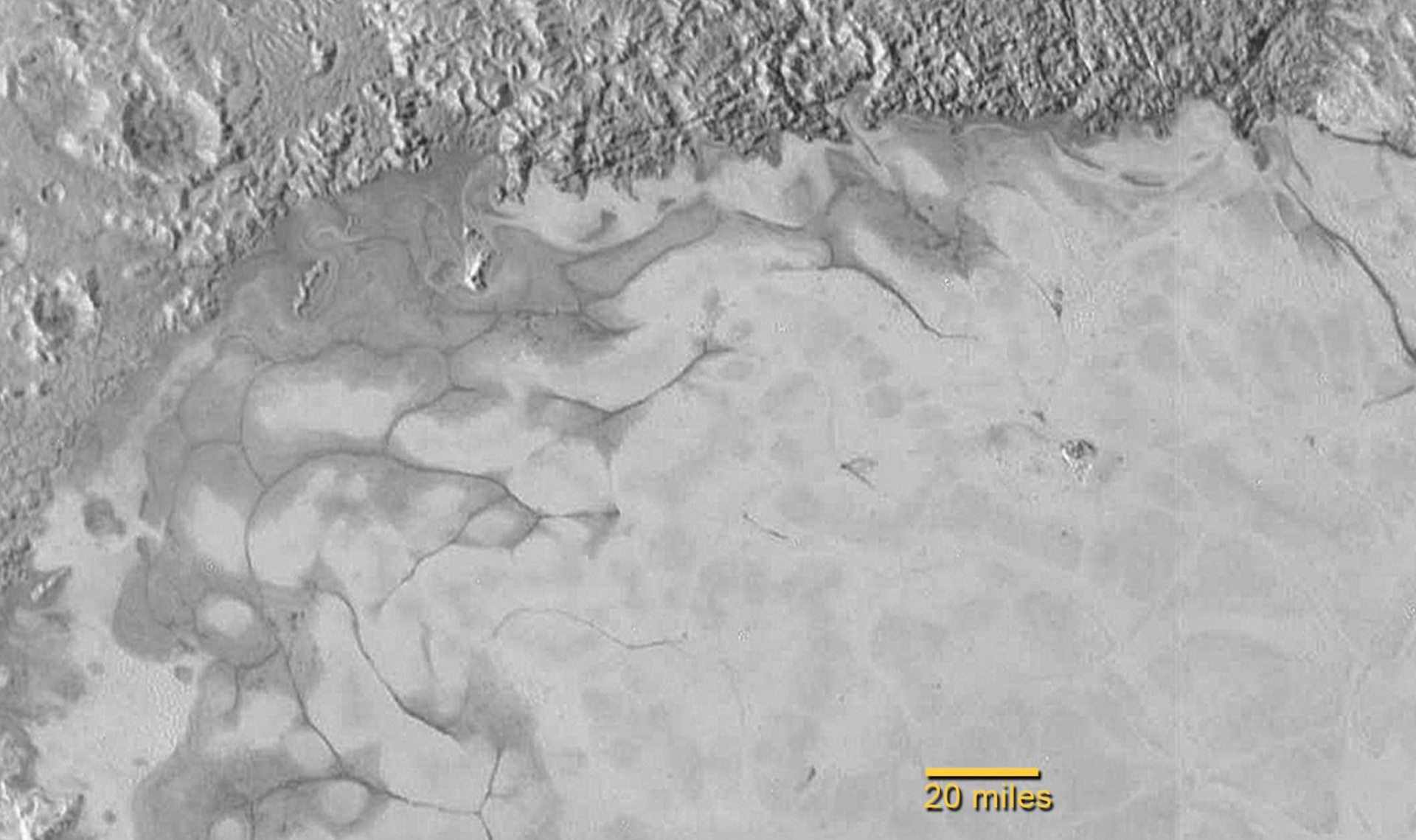
20 miles





Sputnik
Planum

150 miles



20 miles

Rugged cratered terrain

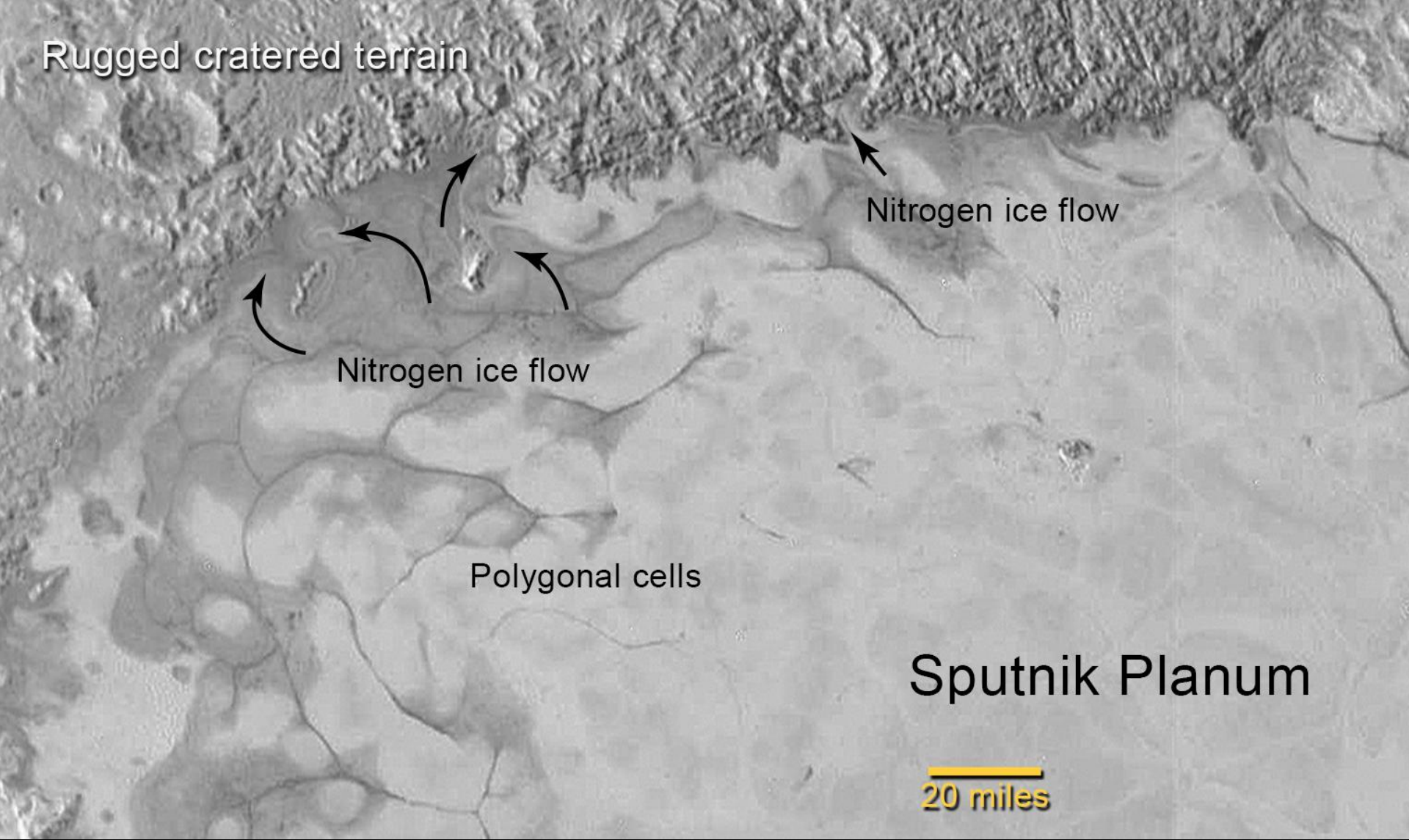
Nitrogen ice flow

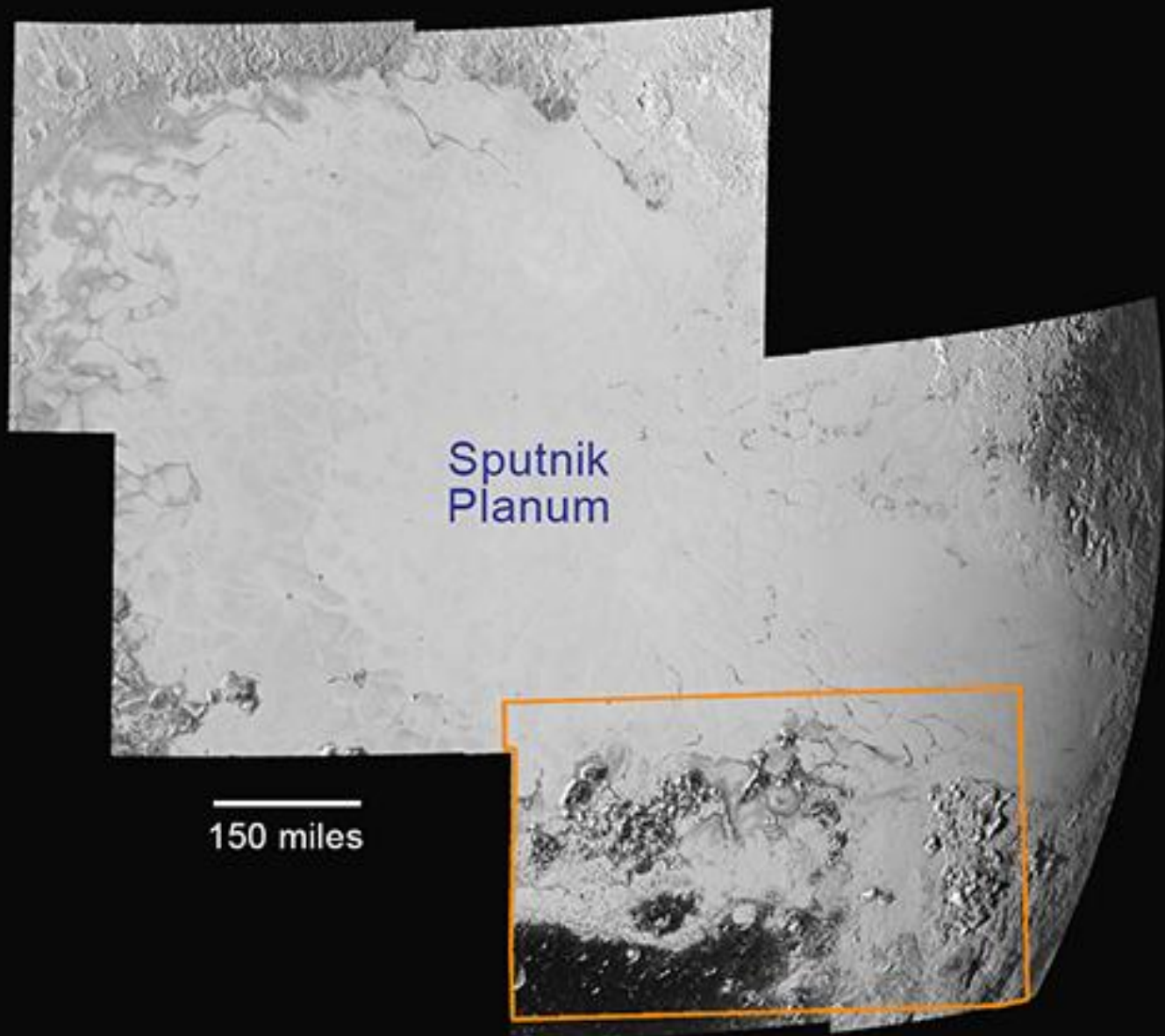
Nitrogen ice flow

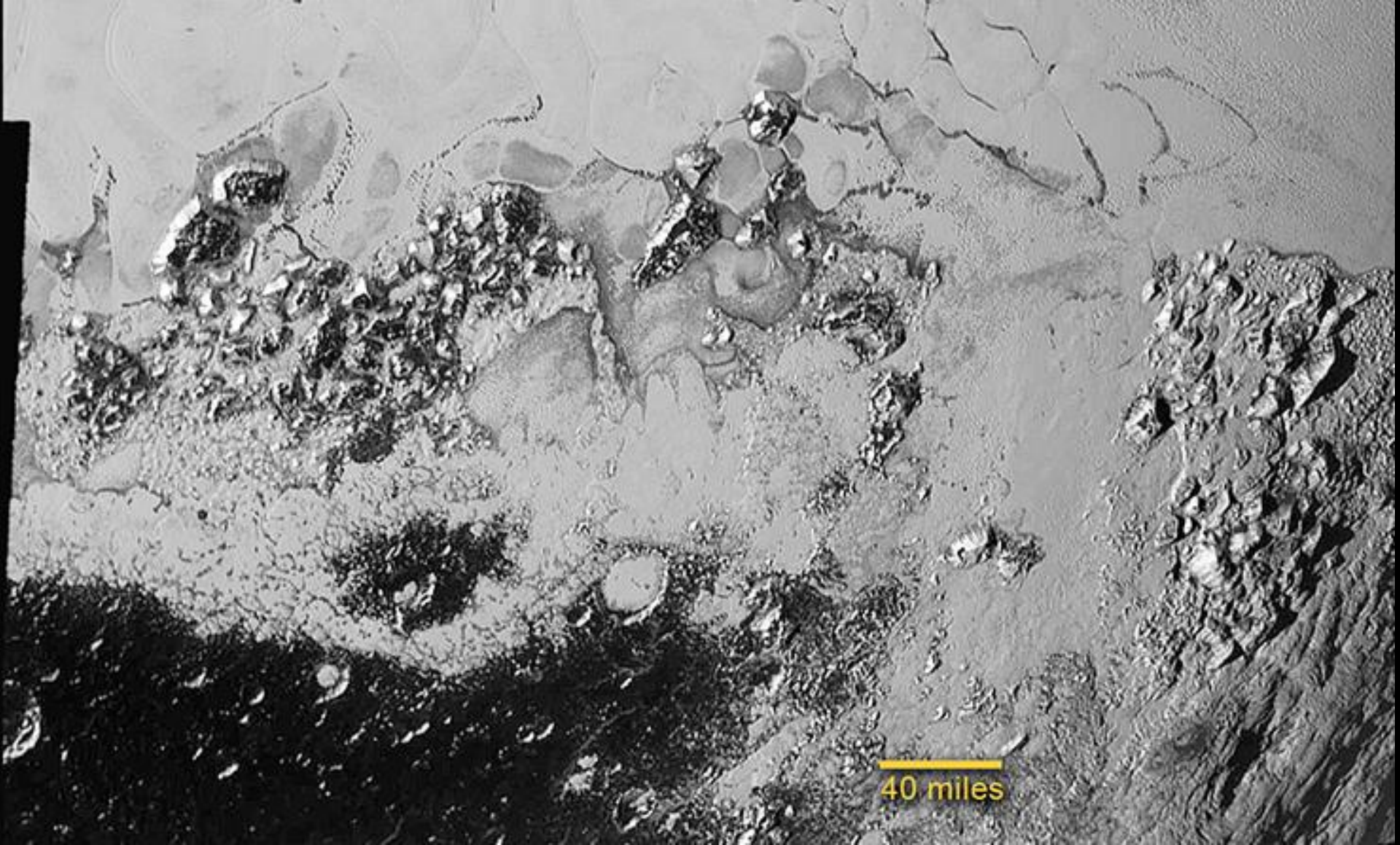
Polygonal cells

Sputnik Planum


20 miles







40 miles

Sputnik Planum

Polygons

Norgay Montes

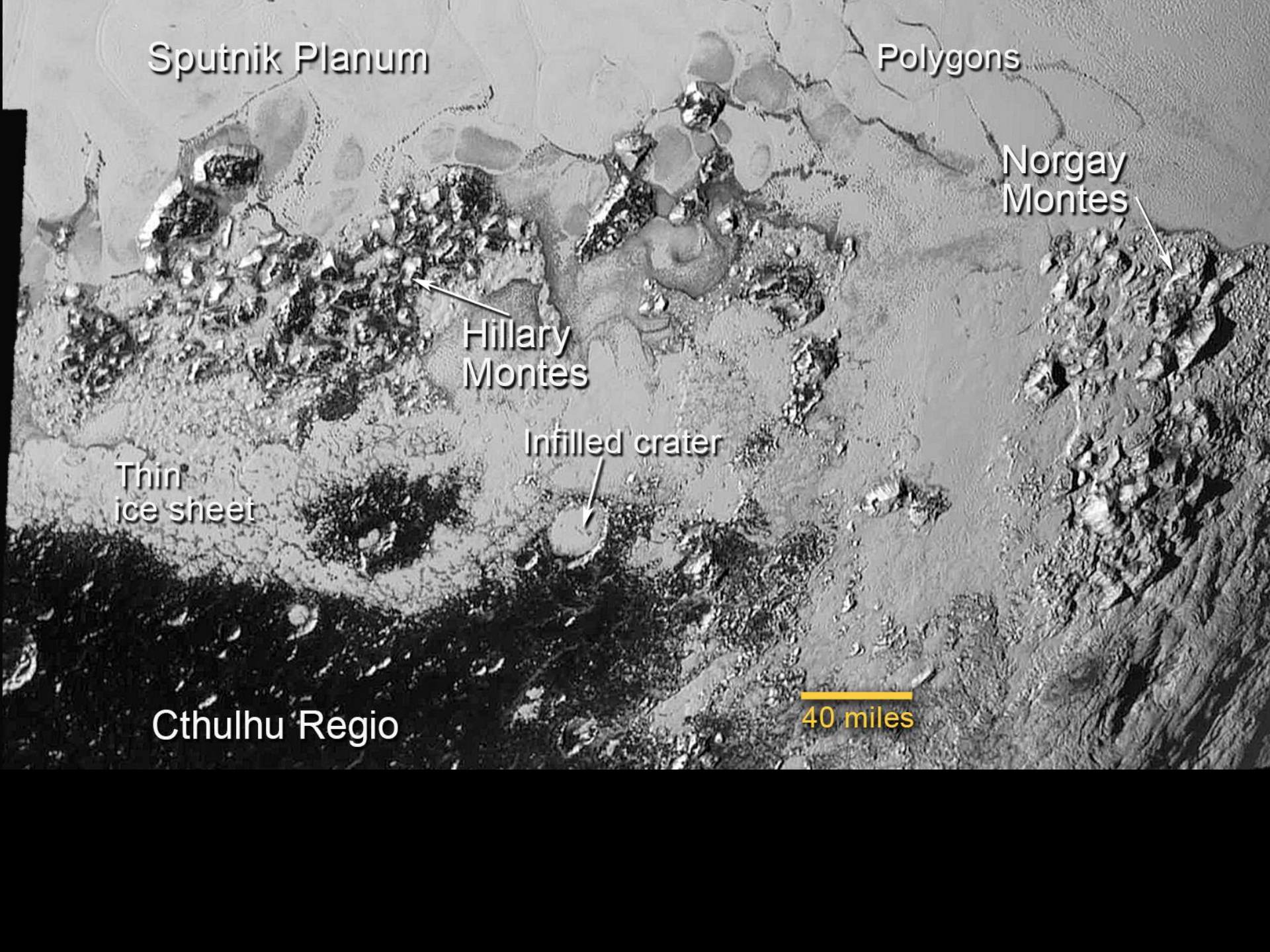
Hillary Montes

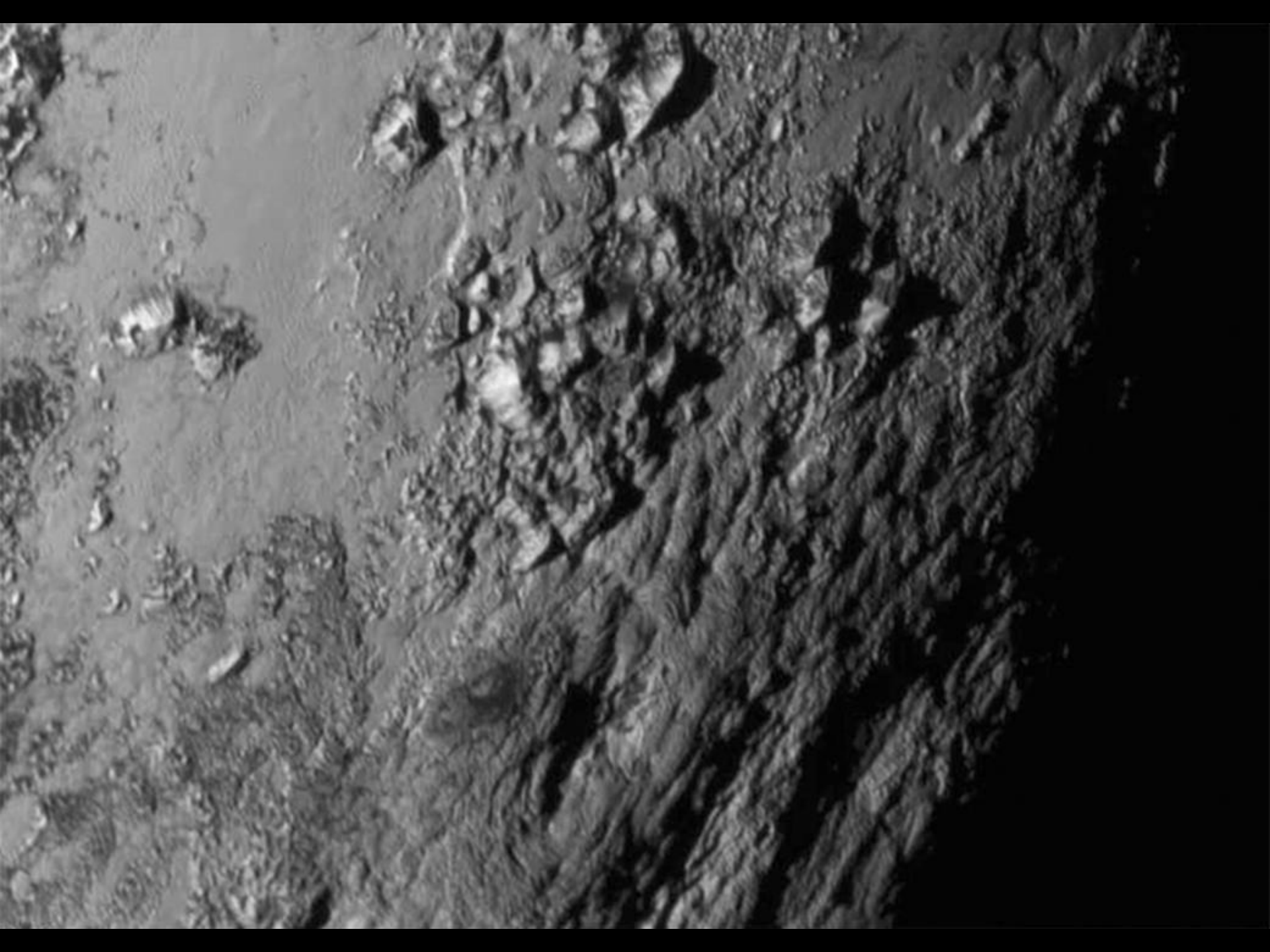
Infilled crater

Thin ice sheet

Cthulhu Regio

40 miles







Groenland Est



Lomonosov ice cap



East Greenland

Une atmosphère sur Pluton ?

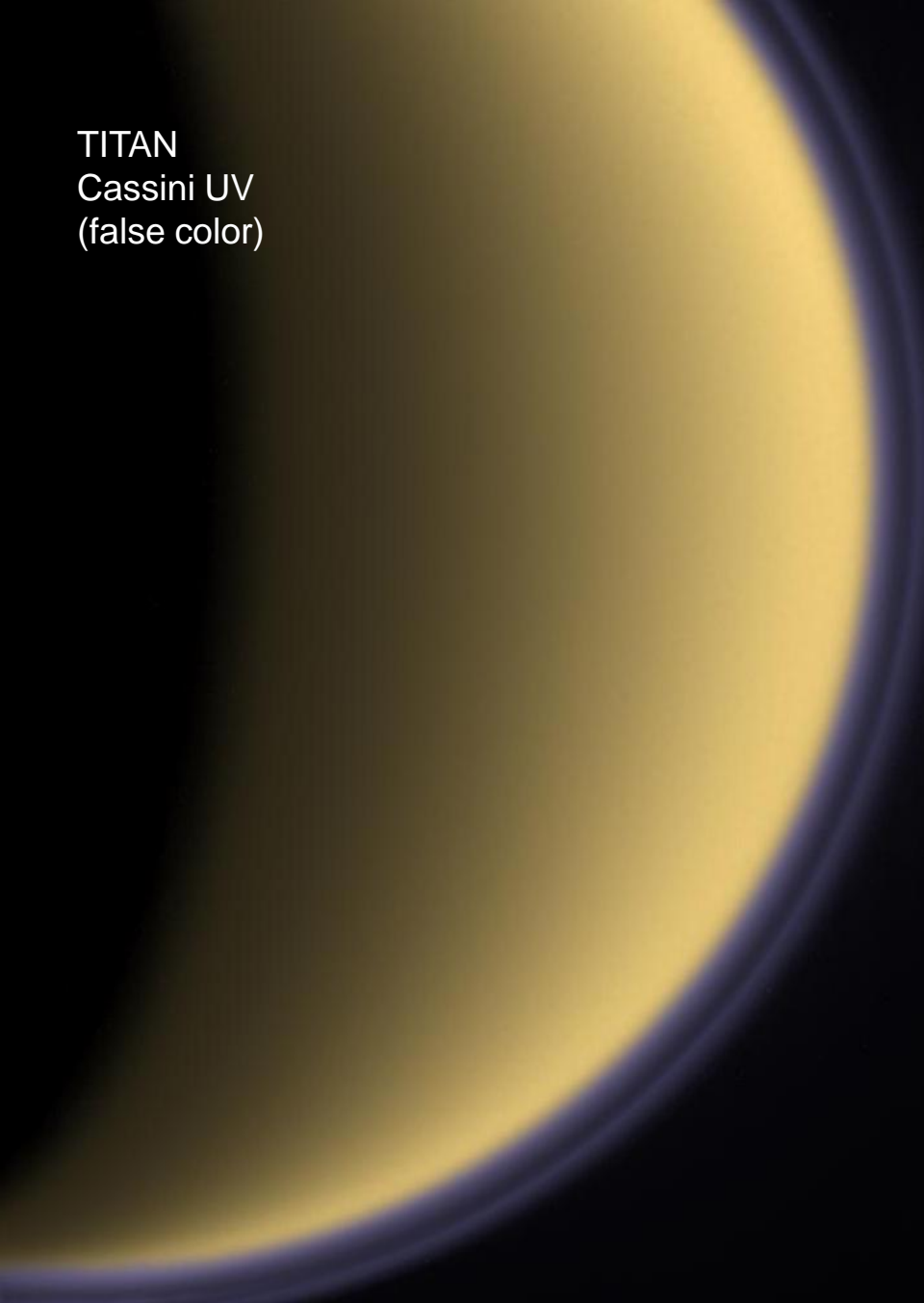


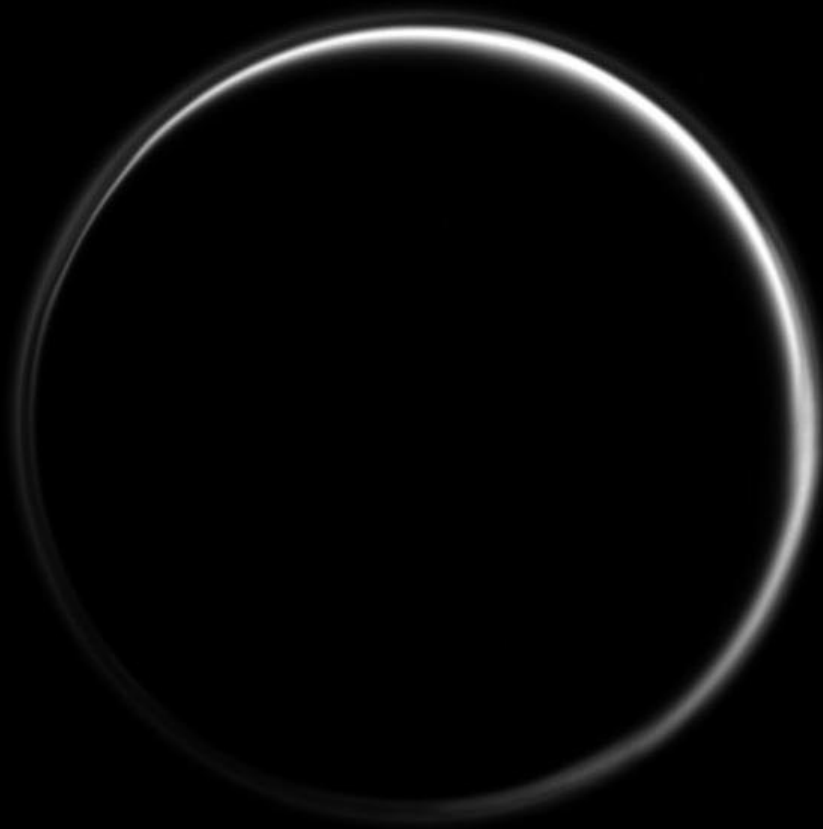


15 juillet, 2 millions de km après Pluton...

TITAN
Cassini UV
(false color)

Des Brumes organiques
comme sur Titan !



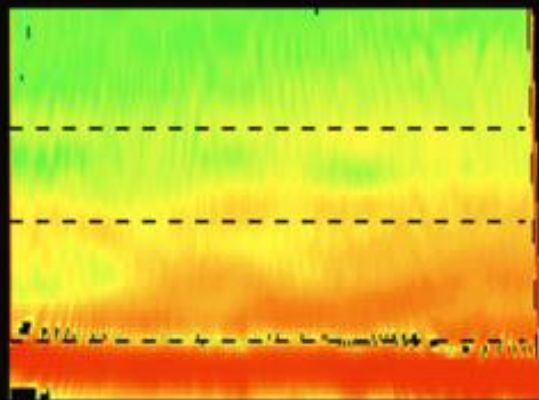


Titan
(Sonde Cassini, 2010)

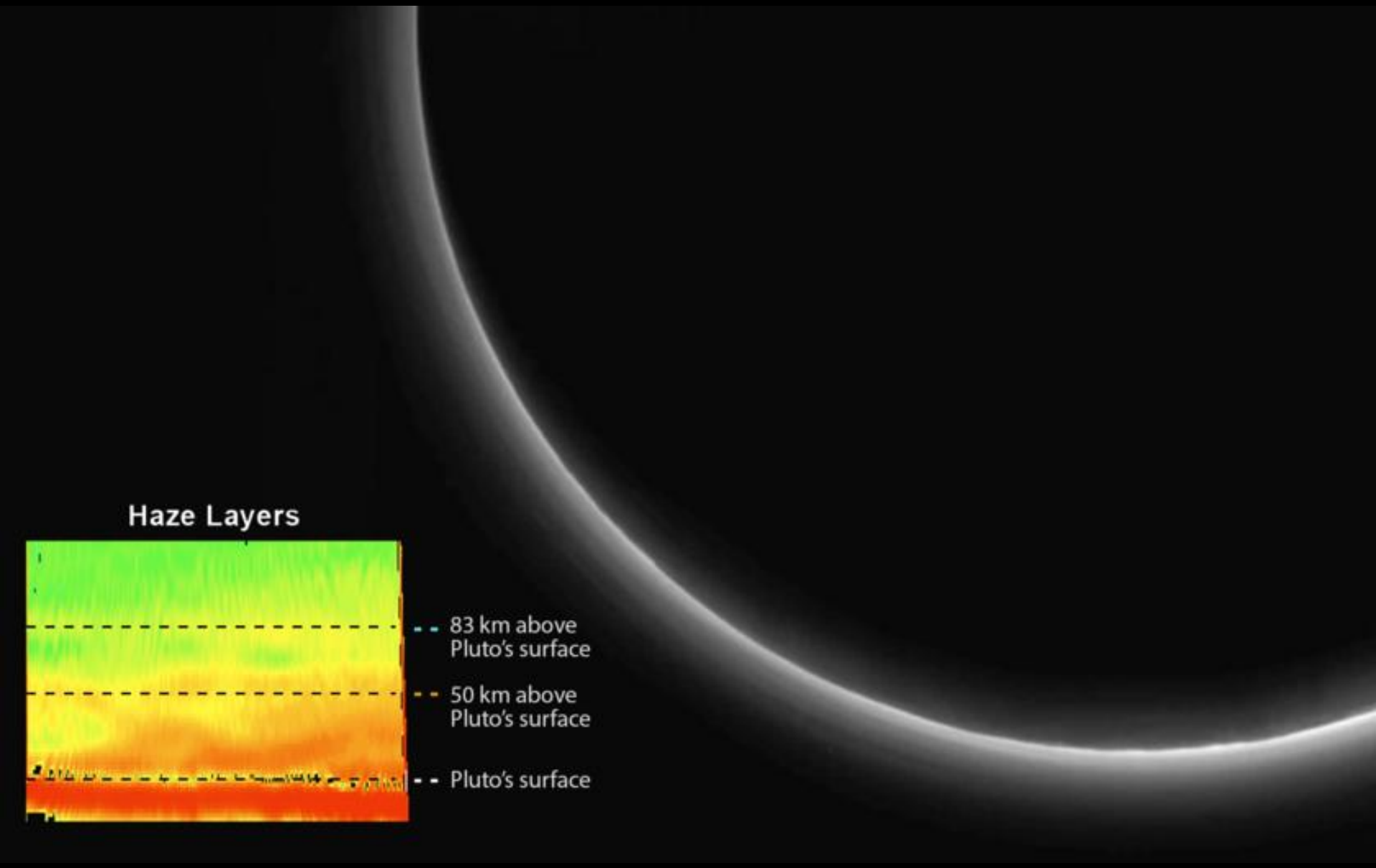


Pluton
(New Horizons, 2015)

Haze Layers



- - 83 km above Pluto's surface
- - 50 km above Pluto's surface
- - Pluto's surface



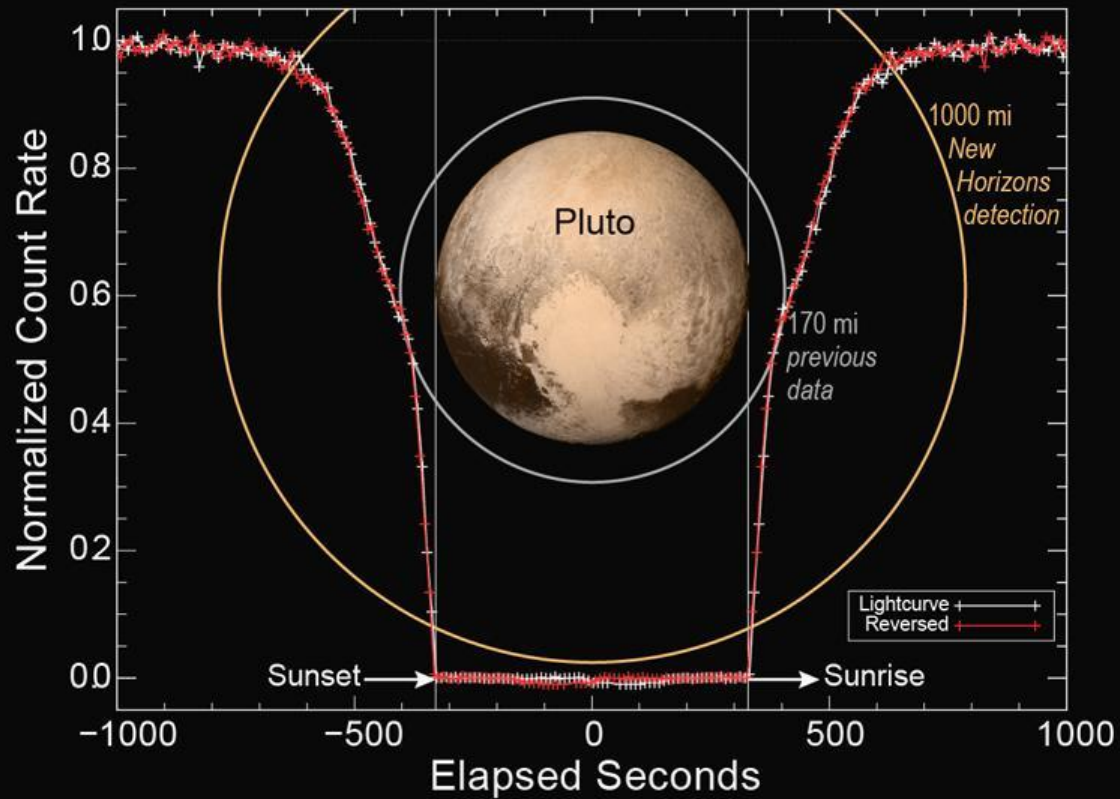
3D modeling of organic haze in Pluto's atmosphere

Tanguy Bertrand^a, François Forget^a,

ABSTRACT

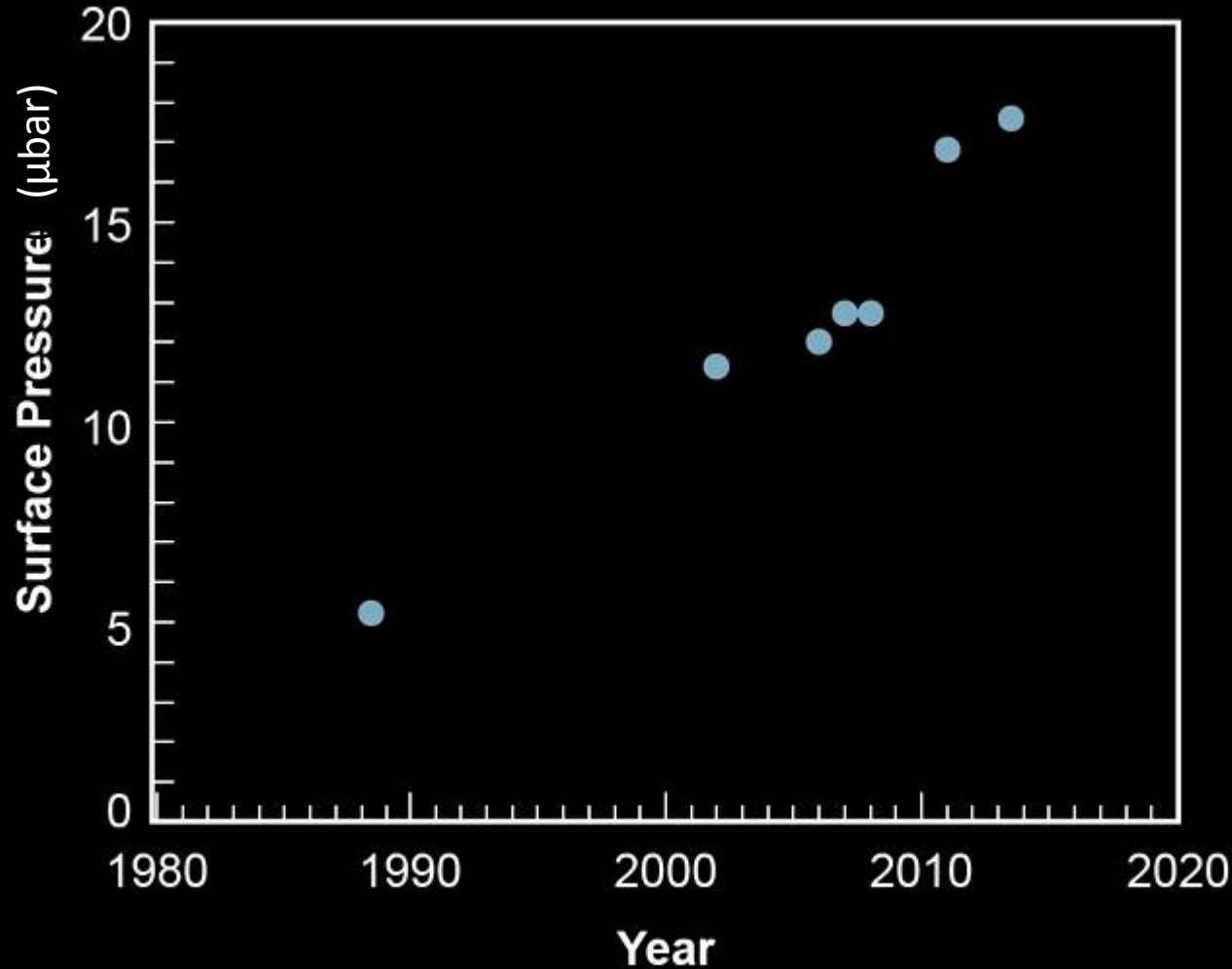
The presence of hazes in Pluto's atmosphere is strongly suggested. Haze aerosols are expected to form from photochemistry high in the CH₄/N₂ Pluto's atmosphere, as it is the case on Titan and Triton. Observations of Pluto's atmosphere have been made during the New Horizons flyby on July 14, 2015 and will provide better information about its structure, composition, as well as about a possible photochemistry. In order to prepare the analysis of this data and further investigate the formation of organic haze and its evolution at a global scale, we have implemented a simple parametrization of the formation and Circulation Model. The production of

Alice Solar Occultation



Detection d'ethylene (C_2H_4) and Acetylene (C_2H_2)

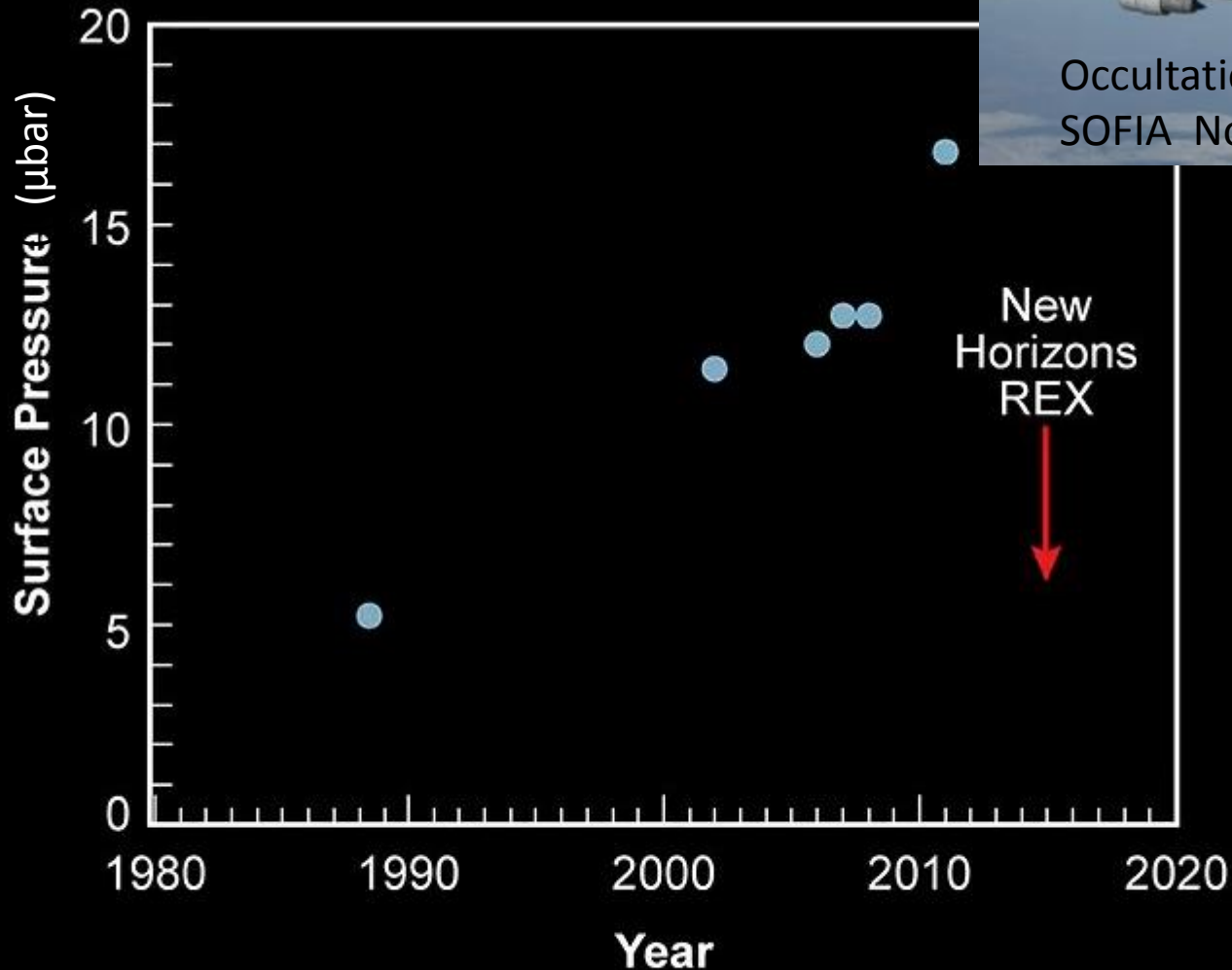
Estimation de la pression avant New Horizons (Occultations Stellaires)



Nouvelle mesure New H (Occultation radio REX)



Occultation Stellaire 29 Juin
SOFIA Nouvelle Zelande

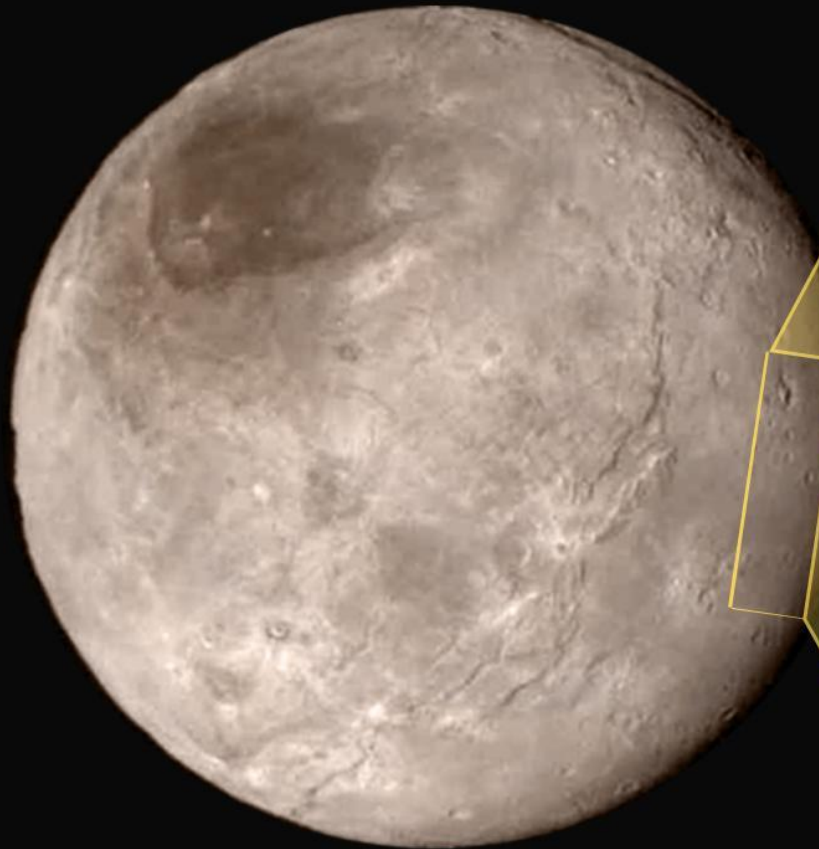


Charon et les satellites

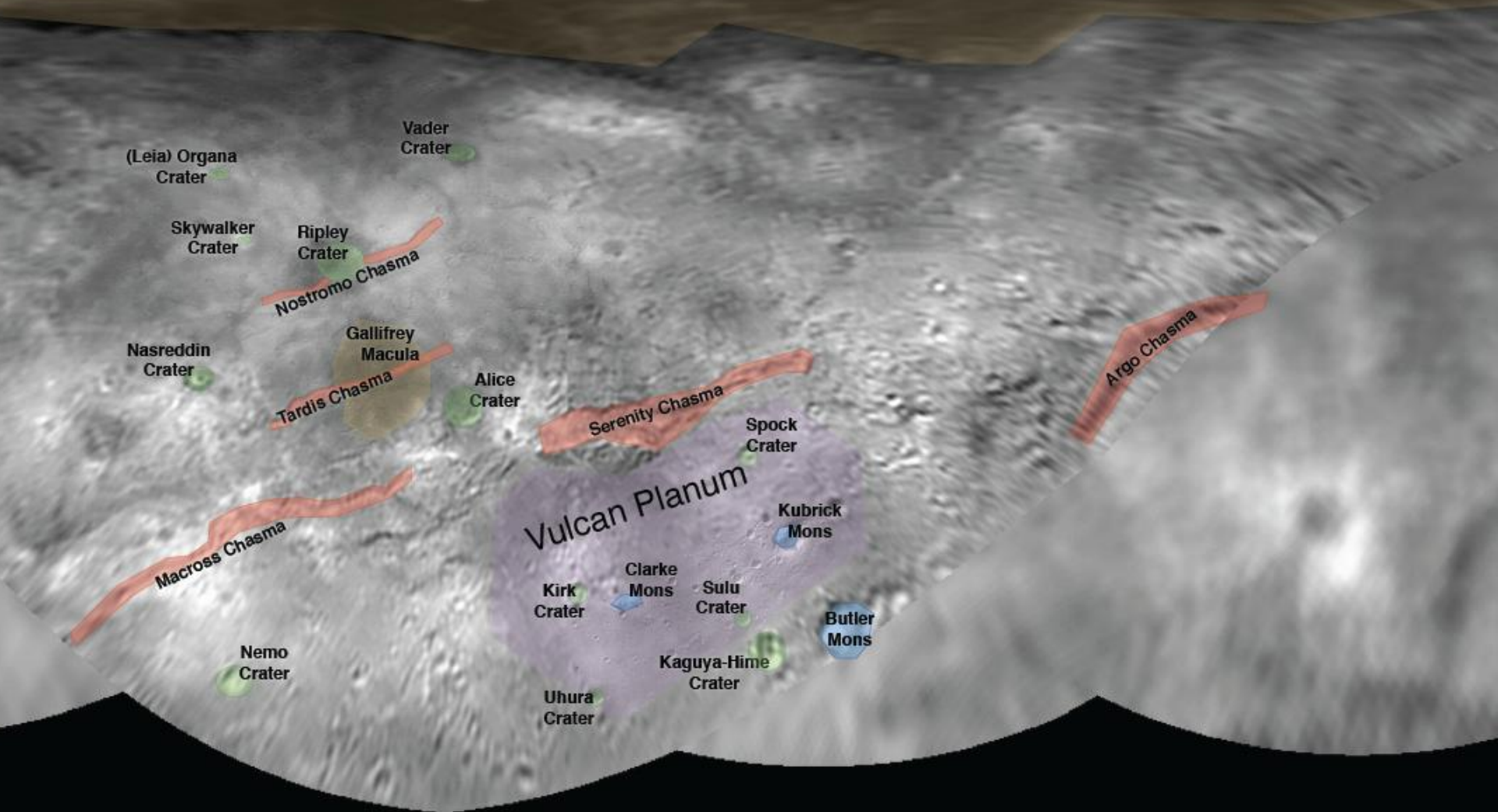


Charon à 466 000 km

Charon's Mountain in a Moat

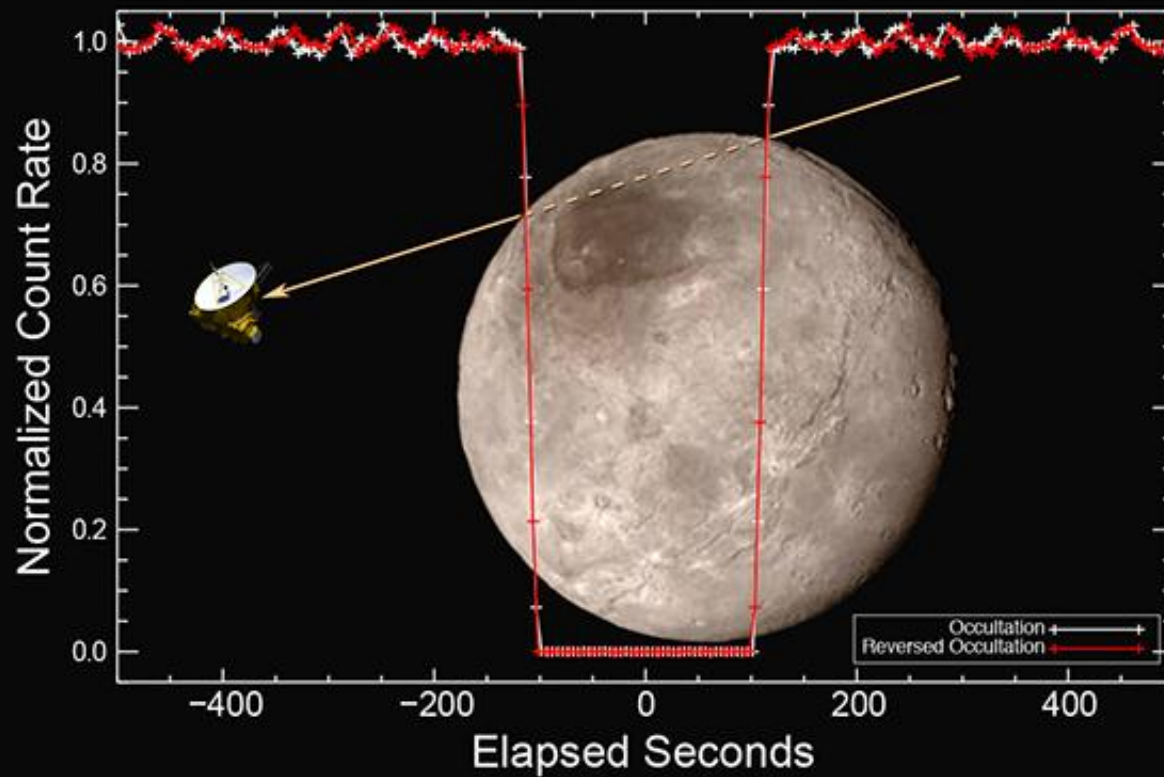


Mordor Macula



Informal Names for Features on Charon

Alice Solar Occultation of Charon



Nix

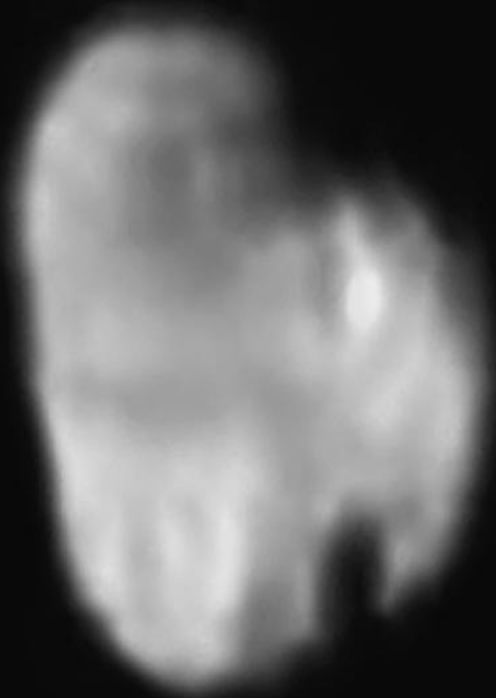
(42x36 km)



enhanced color

Hydra

(55 km)



black and white

La transmission des données prend du temps:

Total : 6 Go.

22 Mo / jour MAX \Rightarrow 500 days

- **15-20 juillet** : ~5% des données transmises
- **20 juillet – 14 septembre**: telemetrie et données locales
- **A partir du 14 septembre**: Pendant ~un an : récupération des données (non compressées !).

Après 2015

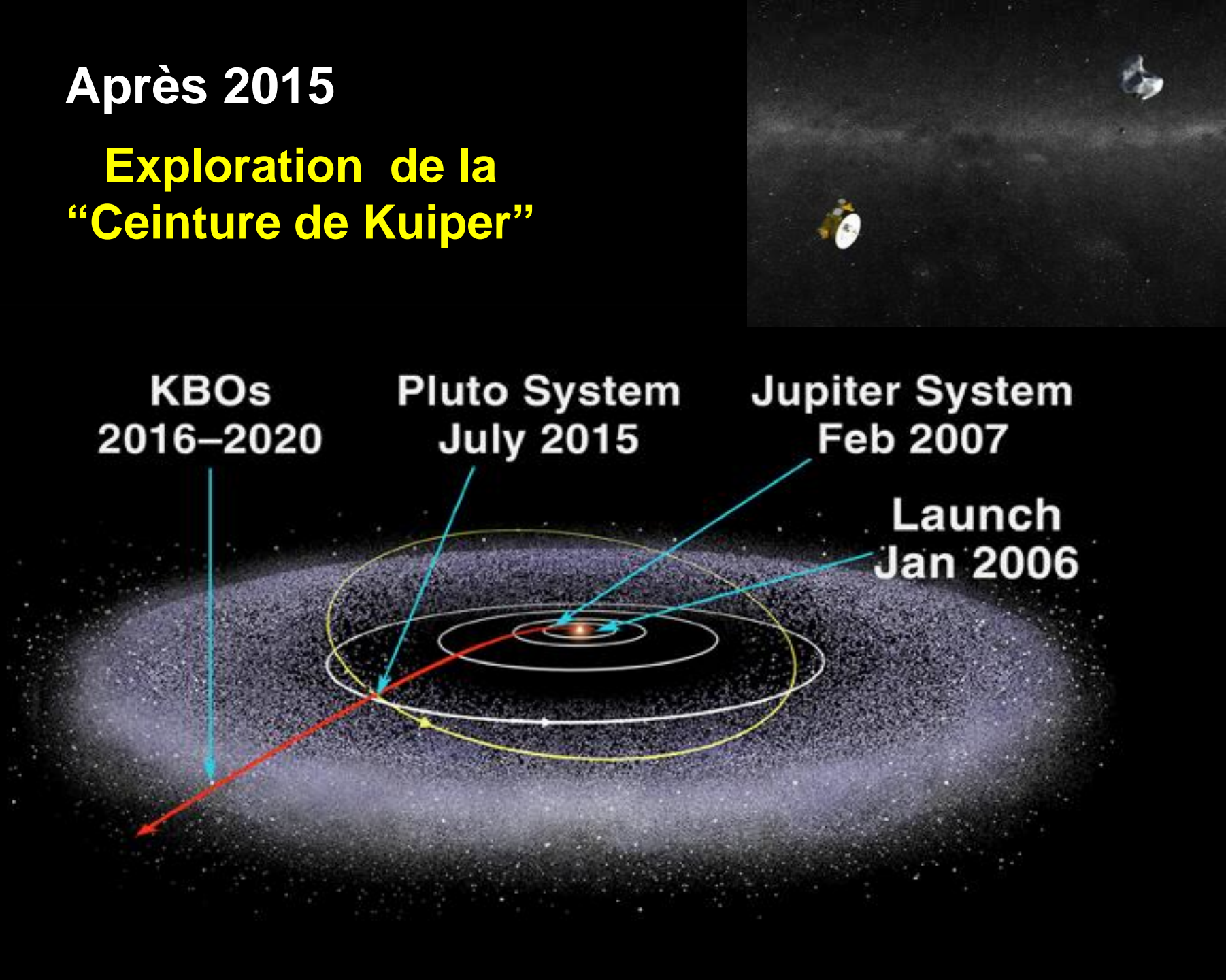
**Exploration de la
"Ceinture de Kuiper"**

**KBOs
2016–2020**

**Pluto System
July 2015**

**Jupiter System
Feb 2007**

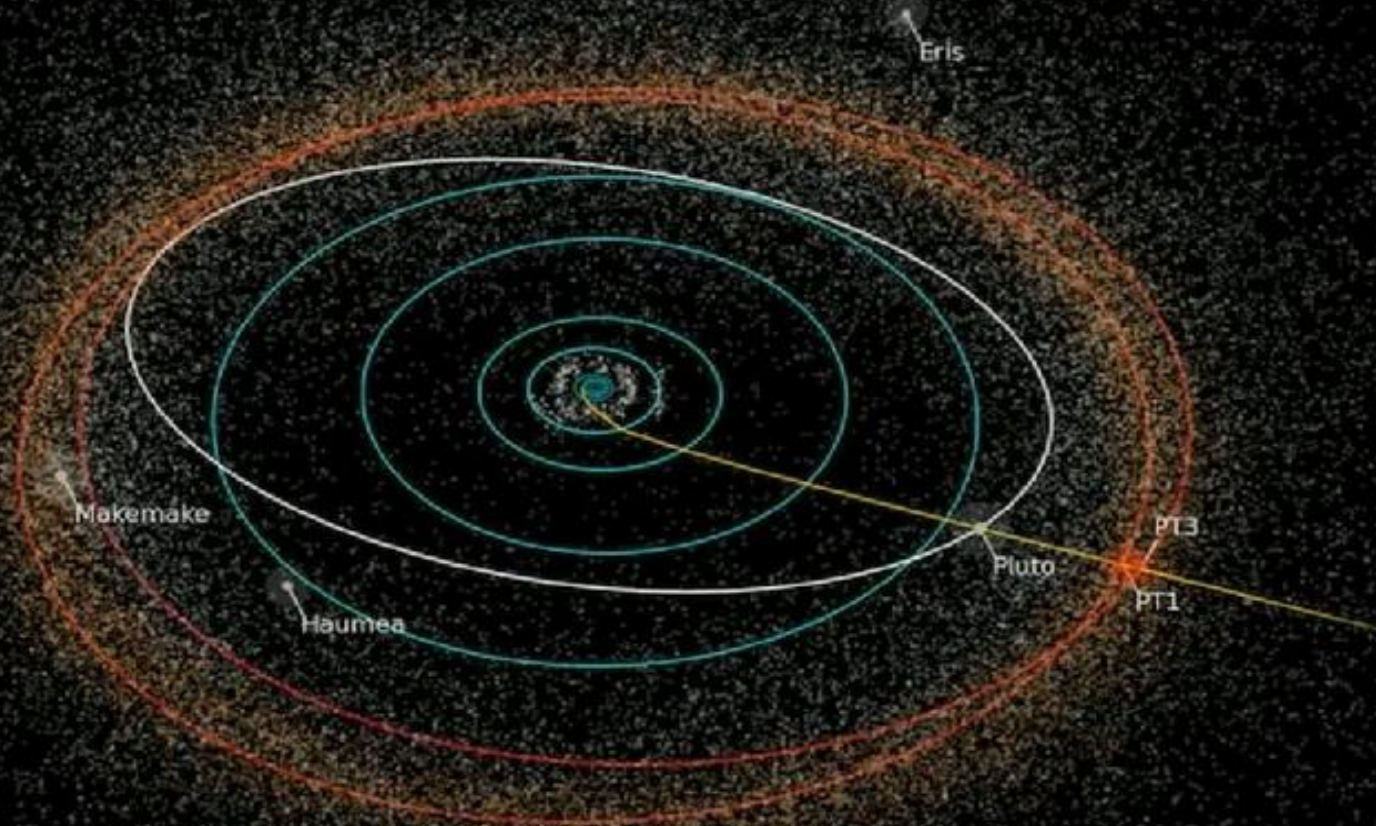
**Launch
Jan 2006**



Survole d'un objet en 2019 (taille : 50 à 100 km). Au choix:

- « PT1 » ($\Delta V = 56 \text{ m/s}$) \Rightarrow 31/12/2018
- « PT3 » ($\Delta V = 119 \text{ m/s}$) \Rightarrow 15/03/2019

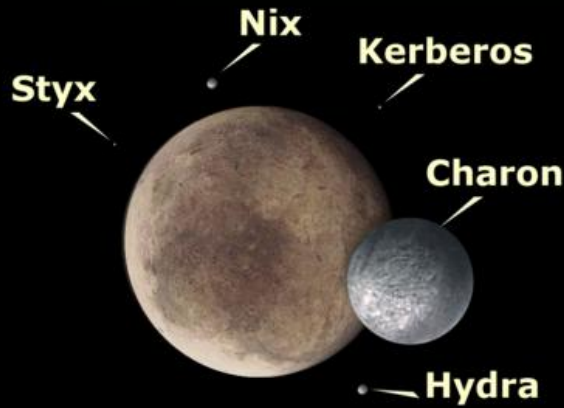
Manœuvres du 22 octobre 2015 au 15 novembre 2015



Largest known trans-Neptunian objects (TNOs)



Eris



Pluto



Makemake



Haumea



Sedna



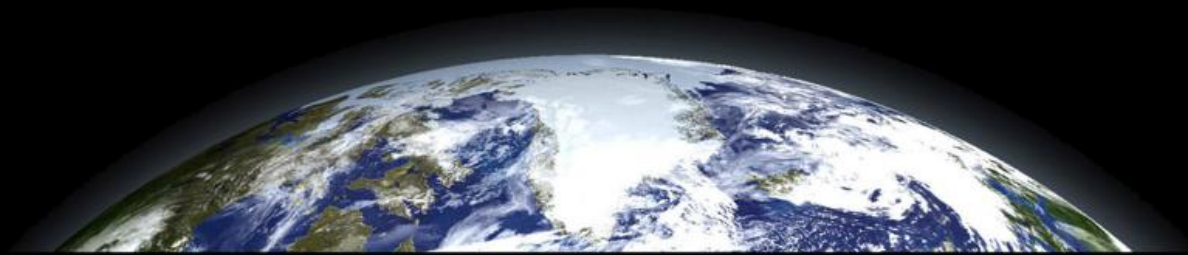
2007 OR₁₀



Quaoar



Orcus



2006: Pluton Planète Naine

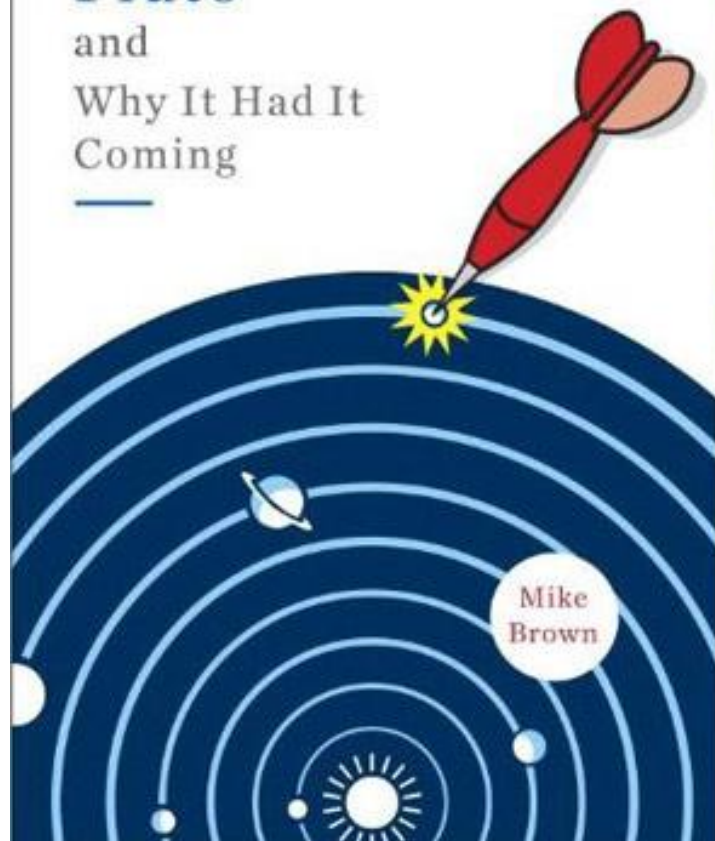
Union Astronomique Internationale:

*« Une « planète » est un corps céleste qui : (a) est en orbite autour du Soleil, (b) a une masse suffisante pour que sa gravité dépasse les forces du corps solide et qu'il se maintienne par équilibre hydrostatique sous une forme quasi-sphérique, et (c) **a nettoyé tout voisinage autour de son orbite.** »*



IAU's General Assembly in Prague, 2006

How I Killed
Pluto
and
Why It Had It
Coming



2010

POOR
PLUTO



Conclusions:

- Pluton: un monde actif et complexe
- Pluton, Charon, etc: un système planétaire riche
- Pluton, Charon, etc: une fenêtre vers l'immense population des objets « trans-neptuniens »

A suivre : l'essentiel des données et à venir!



Equipe New Horizons, janvier 2015

Conclusions:

- Pluton: un monde actif et complexe
- Pluton, Charon, etc: un système planétaire
- Pluton, Charon, etc: une fenêtre vers l'im des objets « trans-neptuniens »

A suivre : l'essentiel des donné



Equipe New Horizons, janvier 2015



Merci pour votre
attention...

