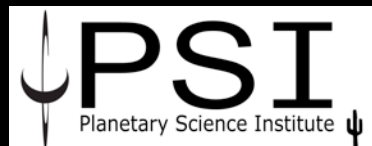


NASA's New Horizons Mission to the Planet Pluto



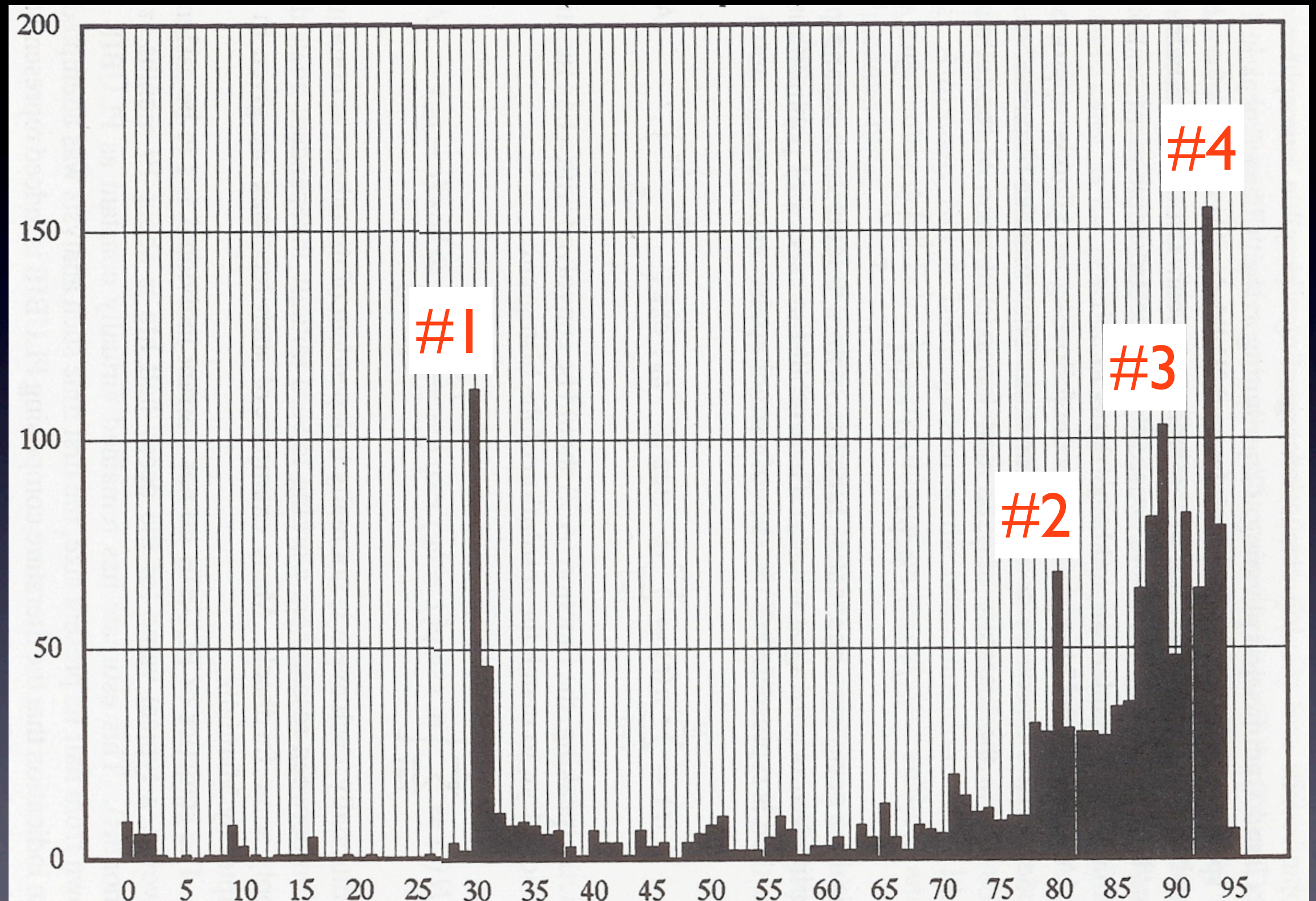
Dr. Henry Throop
Planetary Science Institute
and
NASA HQ



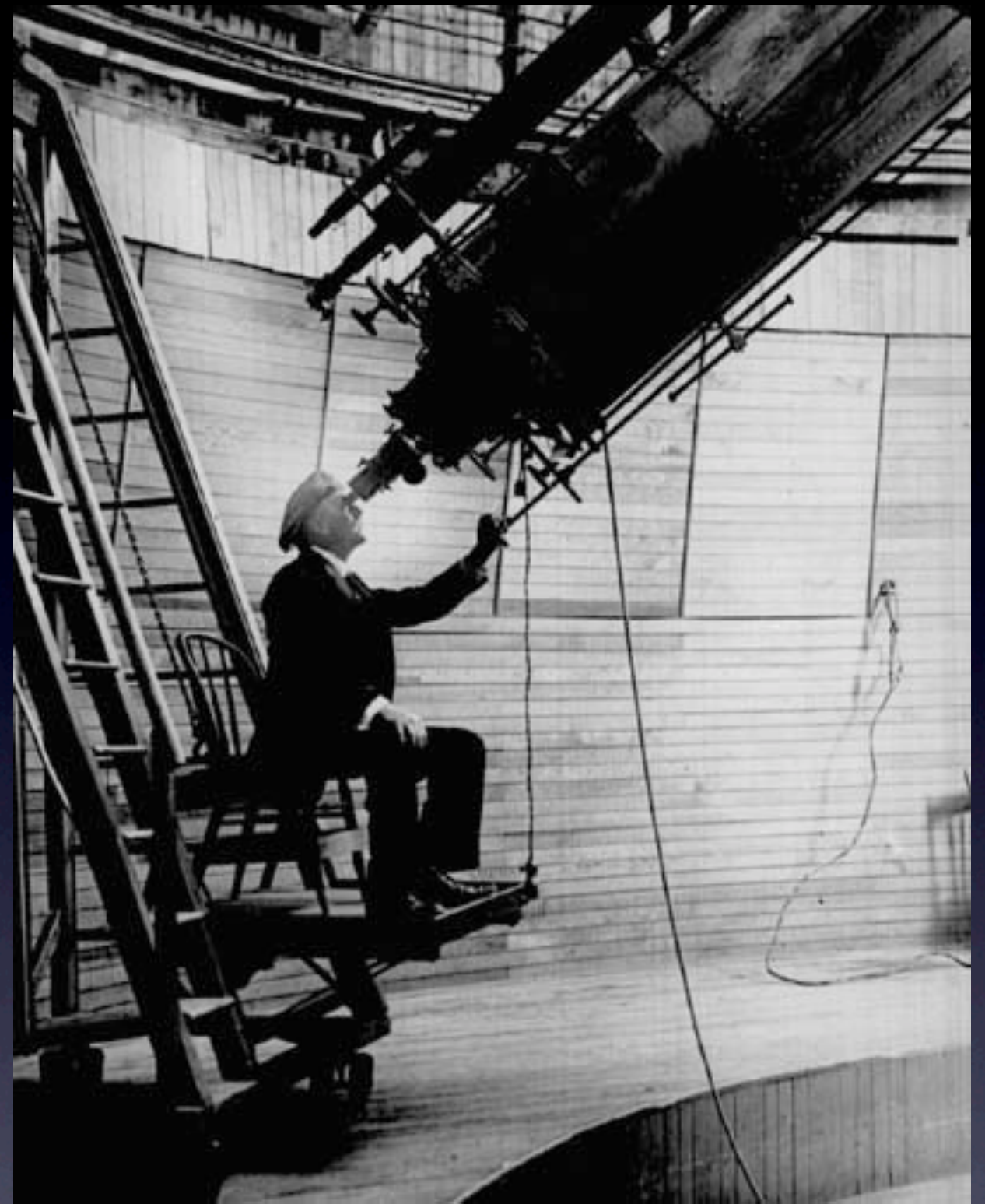
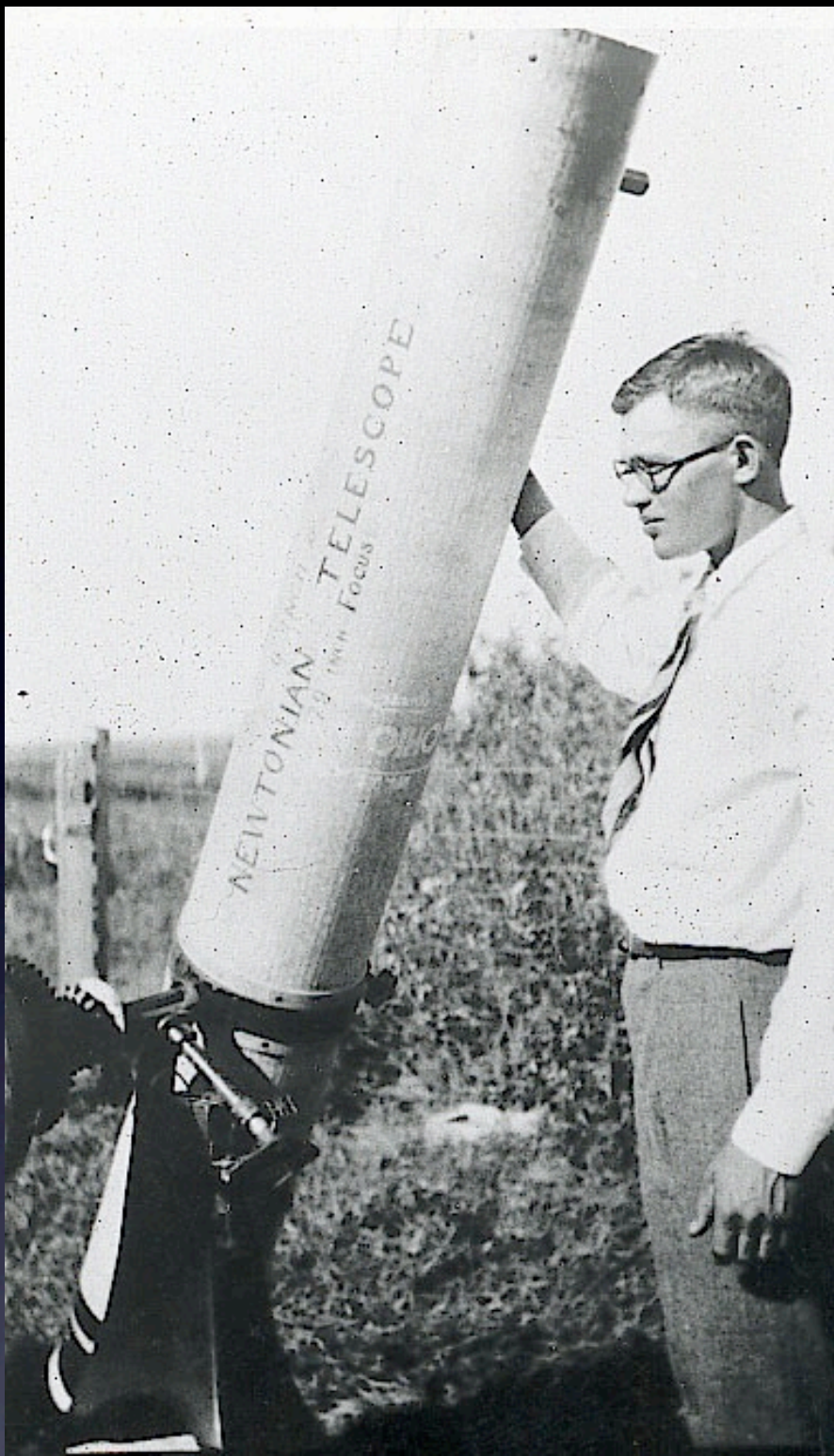
Geological Society of Washington February 1, 2012

Four Key Moments in Pluto's History

of Pluto papers per year

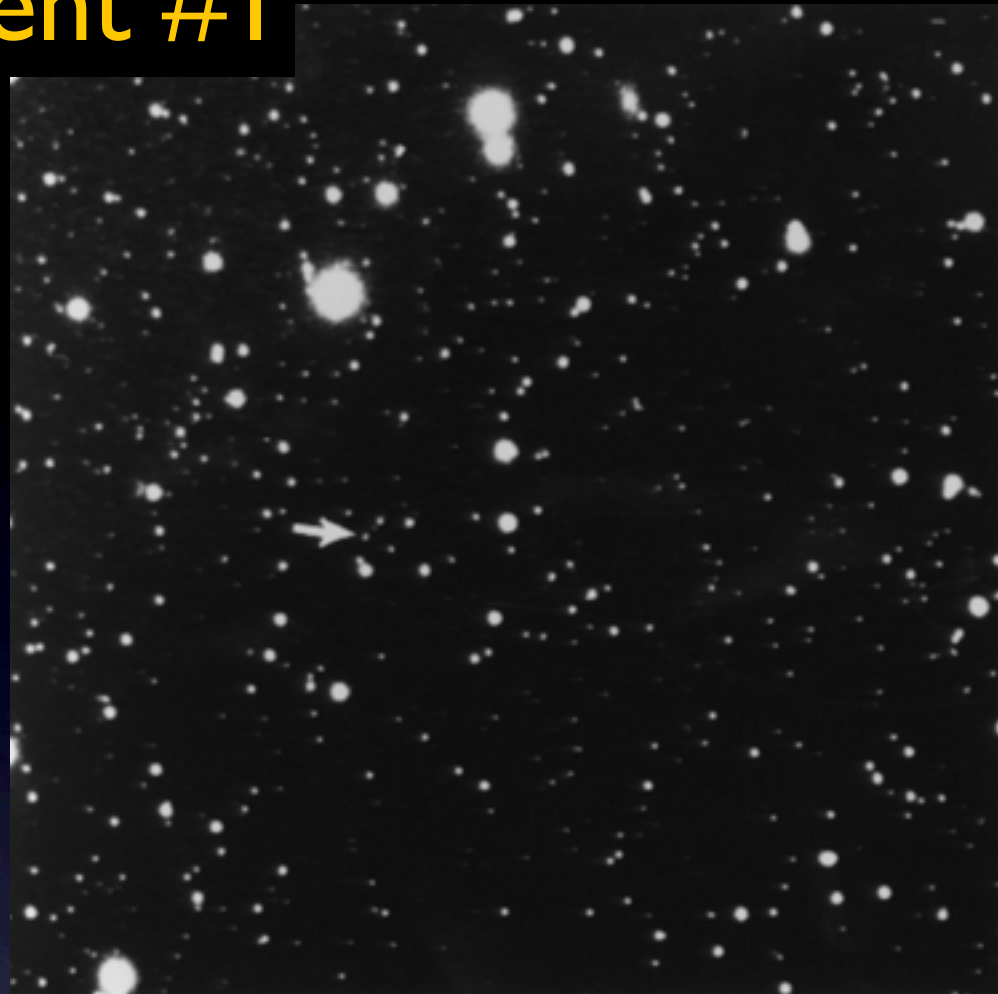


Year (from 1900)



1925: Clyde Tombaugh hired by Lowell Observatory to search for 'Planet X', which was inferred through anomalies in orbits of Uranus, Neptune.

Moment #1



January 23, 1930

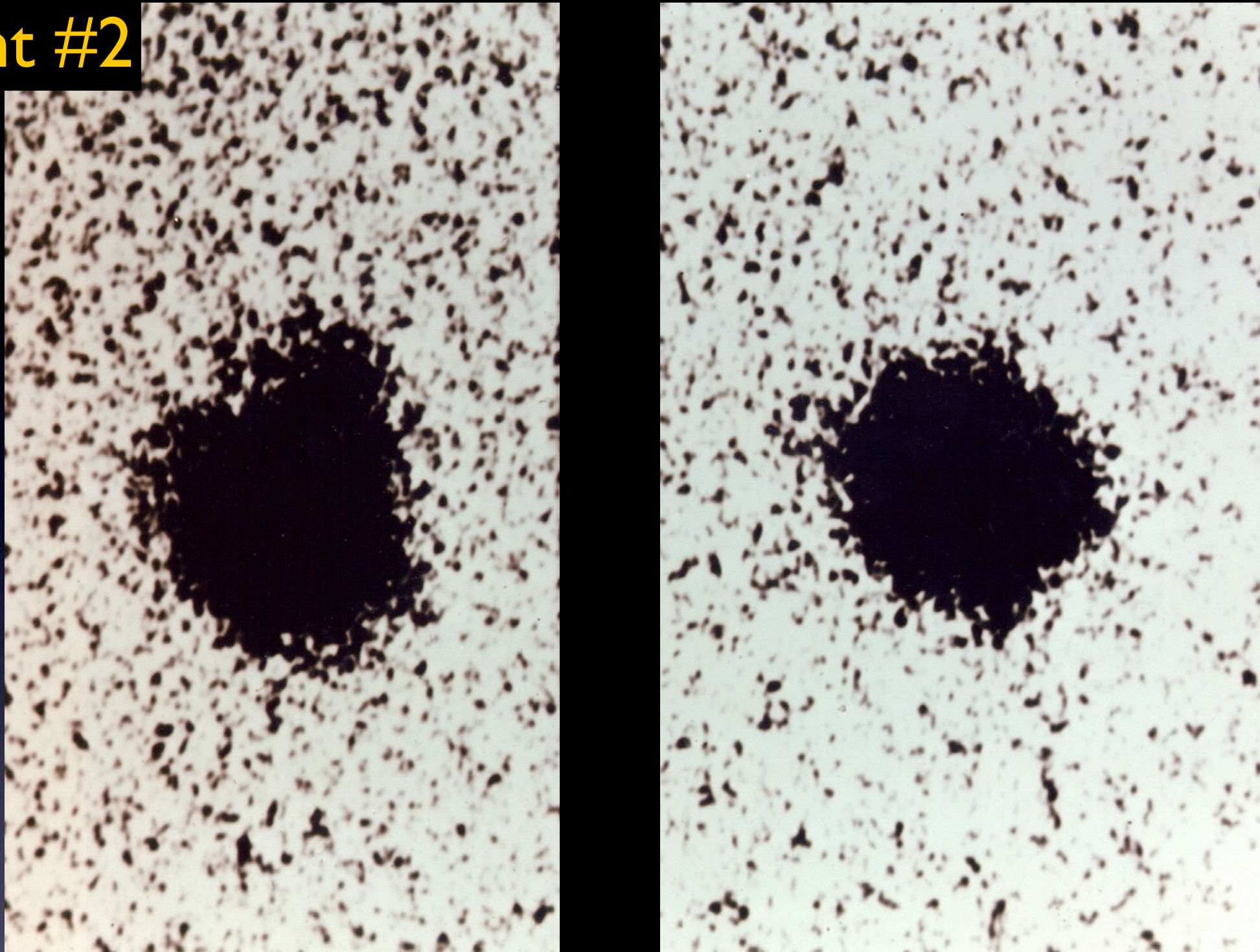


January 29, 1930

1930: Pluto discovered in photographic plates

Distance known, but mass, composition, size, etc. remain unknown for decades

Moment #2

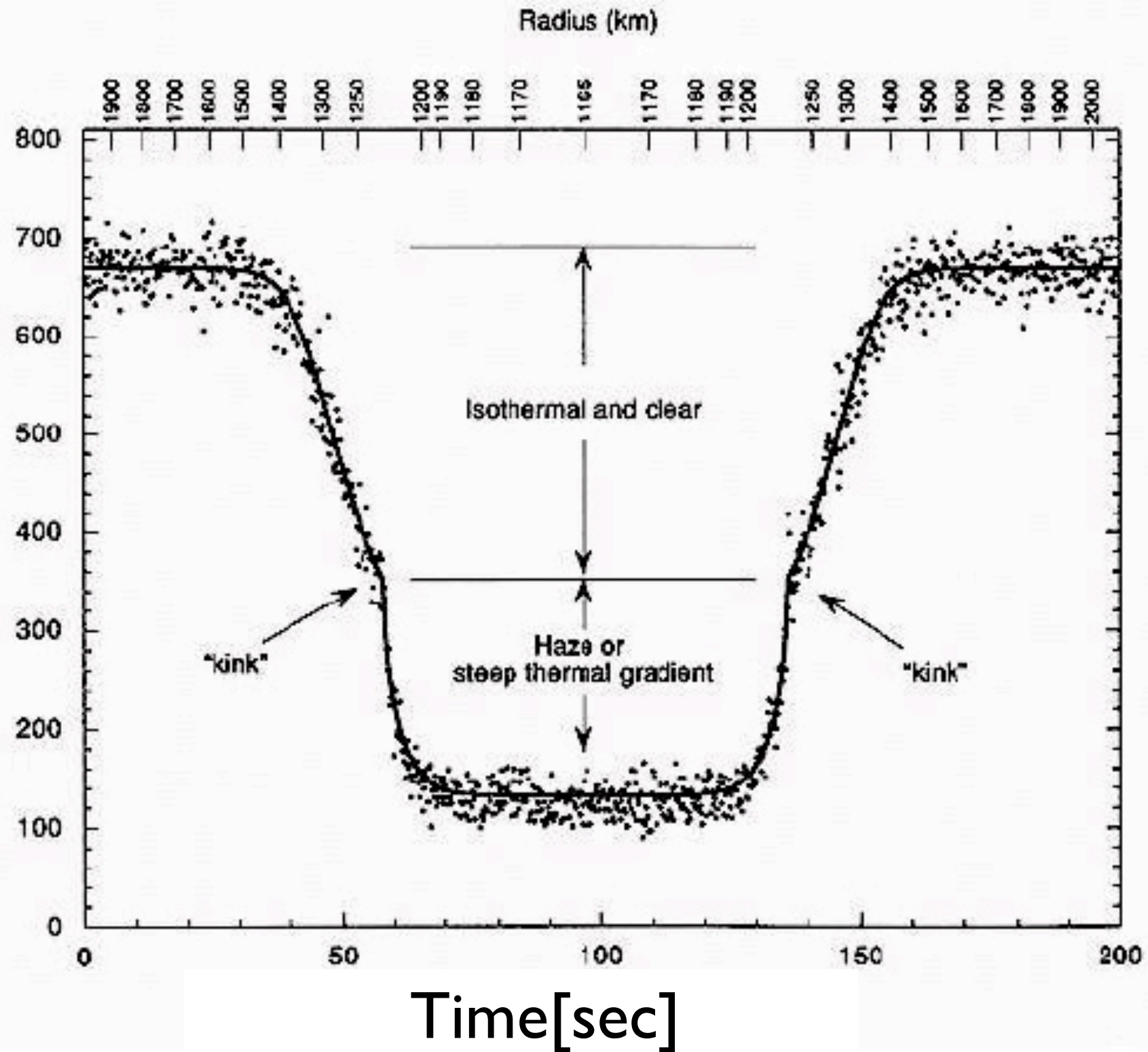


1978: Pluto's moon Charon discovered

Using Newton's laws, can measure system mass

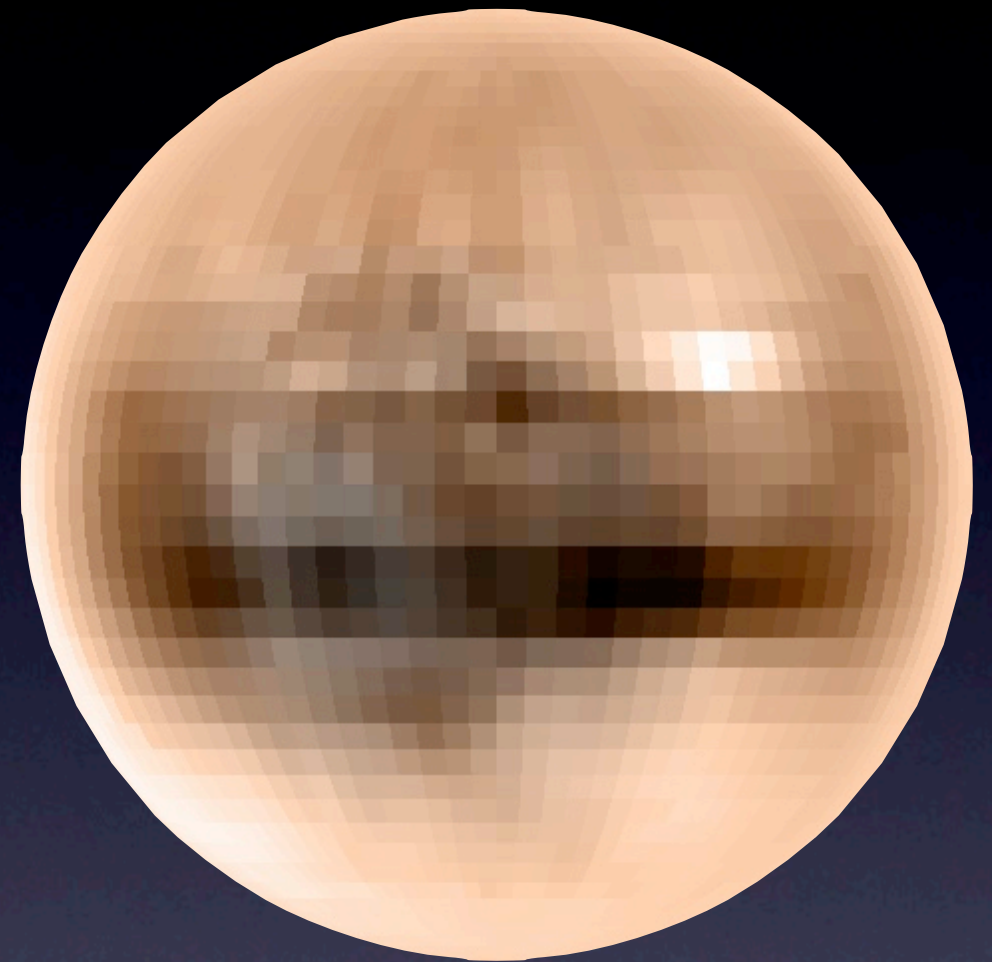
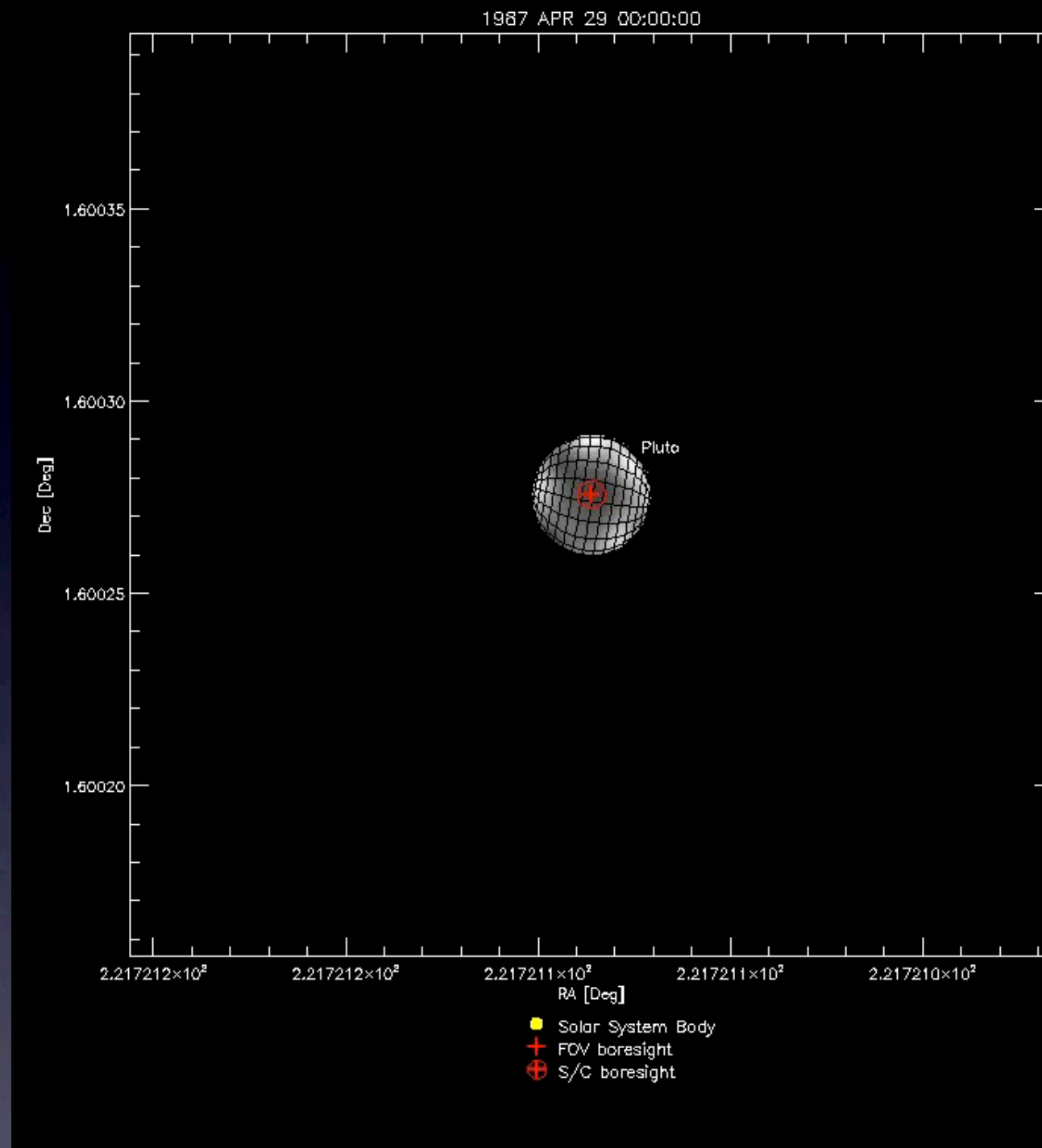
Moment #3

Flux from Star



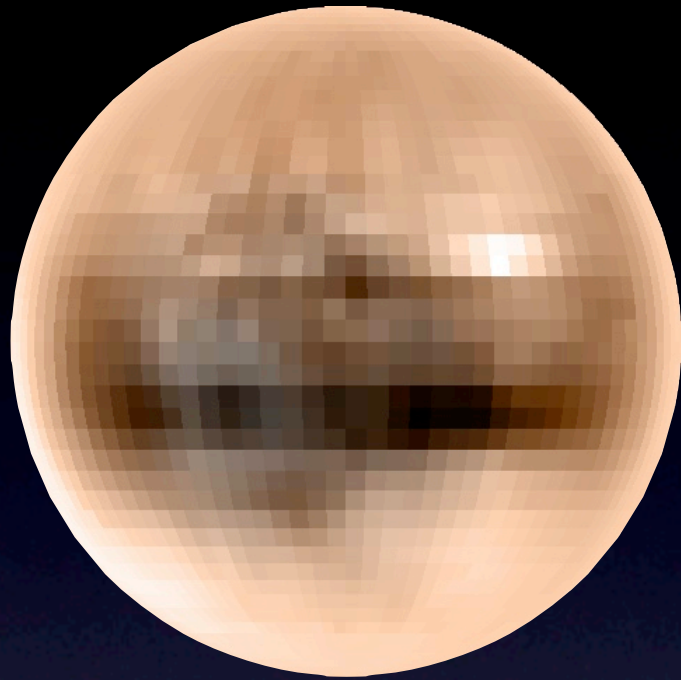
1988: Pluto is observed passing in front of a distant star. Its light slowly dims, revealing Pluto's *radius* and its *atmosphere*.

Moment #4

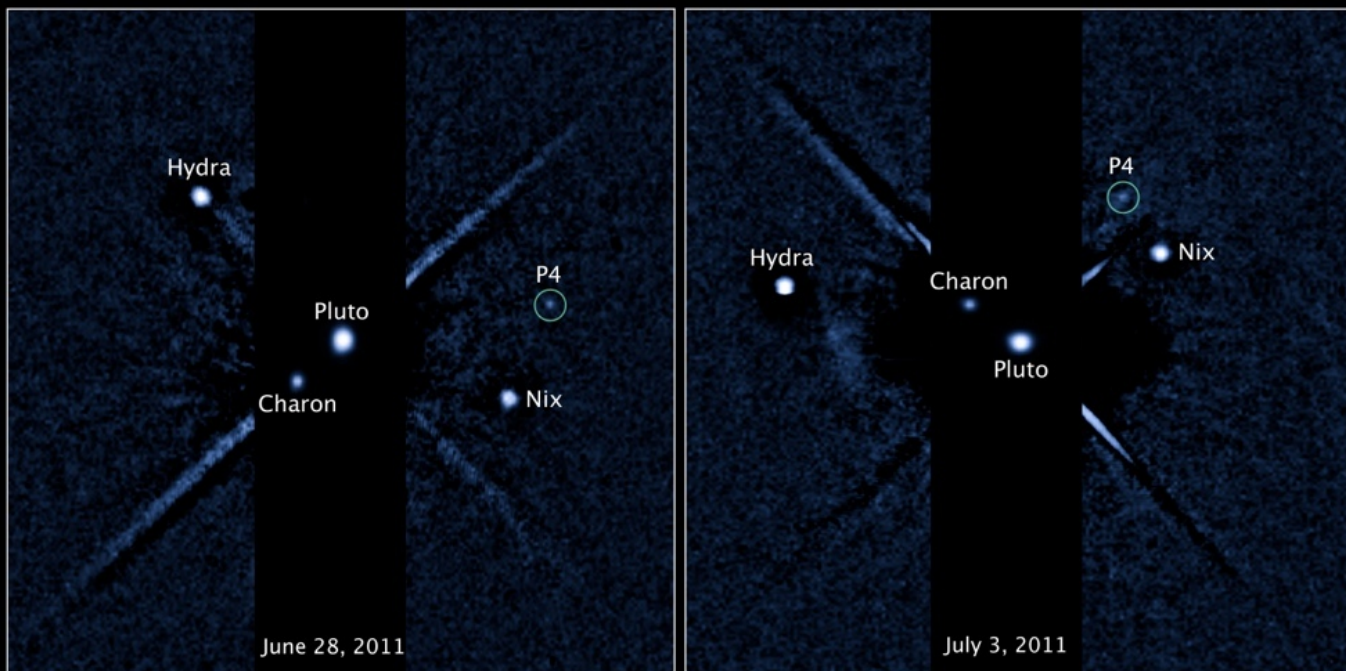


1982-1993: Charon/Pluto pass in front of each other, allowing rough surface maps to be made

Everything We Know About Pluto



- Radius ~ 1200 km
- Density ~ 2.0 g/cm³
- 248 year orbital period, 6 day rotational period
- Surface: Nitrogen ice, with methane, CO, water, and some red organic goo ('tholins'). 40 K.
- Atmosphere: nitrogen, methane, CO, ~ 10 μ bar
- Five bodies! Pluto, Charon, Nix, Hydra, P4
- No known terrain or geological features.
- Ancient surface with snow-filled craters?



Pluto System
Hubble Space Telescope • WFC3/UVIS

More exploration
requires a close-up visit

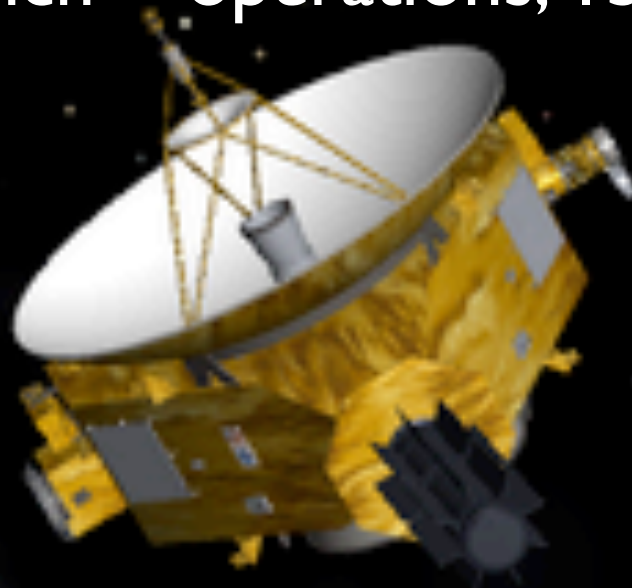
Why go to Pluto?

- It's ancient: Exploring Pluto tells us what the primordial solar system was like.
- It's unlike all the other planets.
- It's the gateway to the thousands of bodies in the outer Solar System, and distant Solar Systems.

A Spacecraft to Pluto

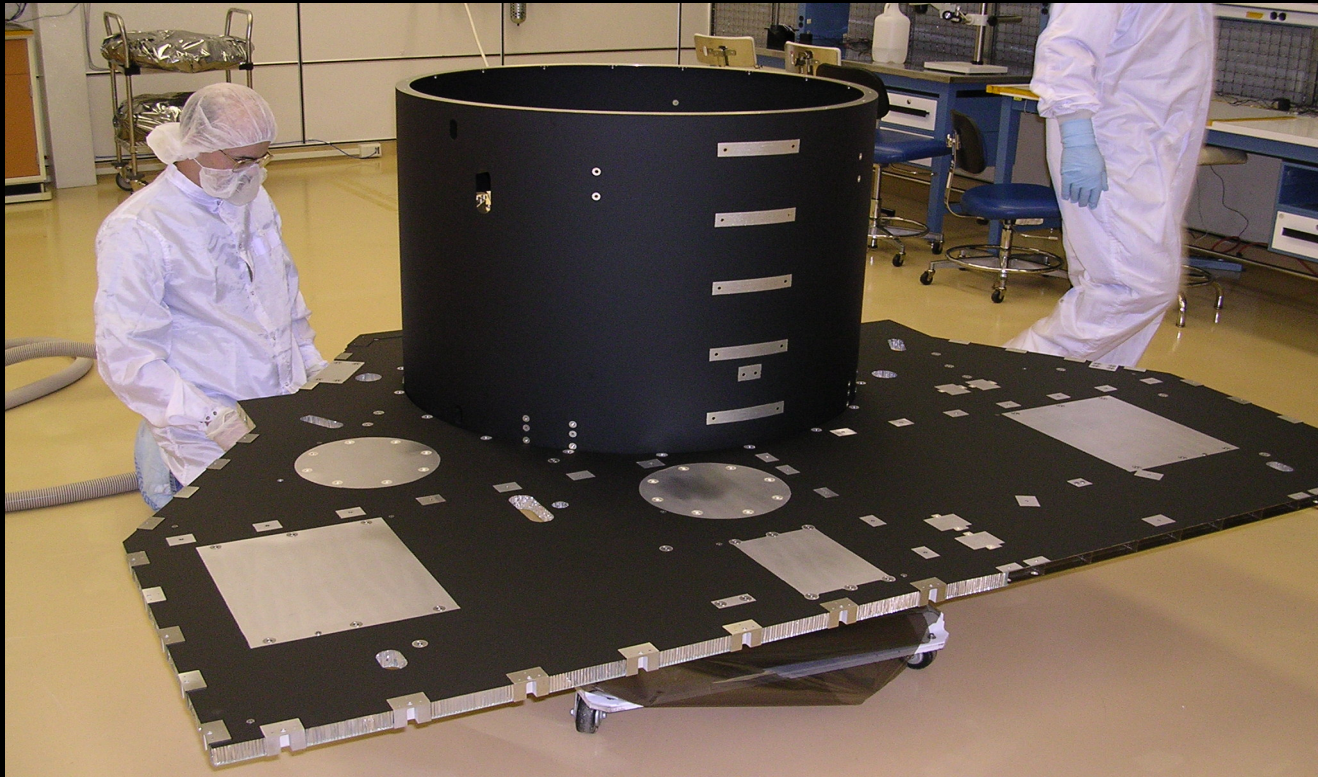
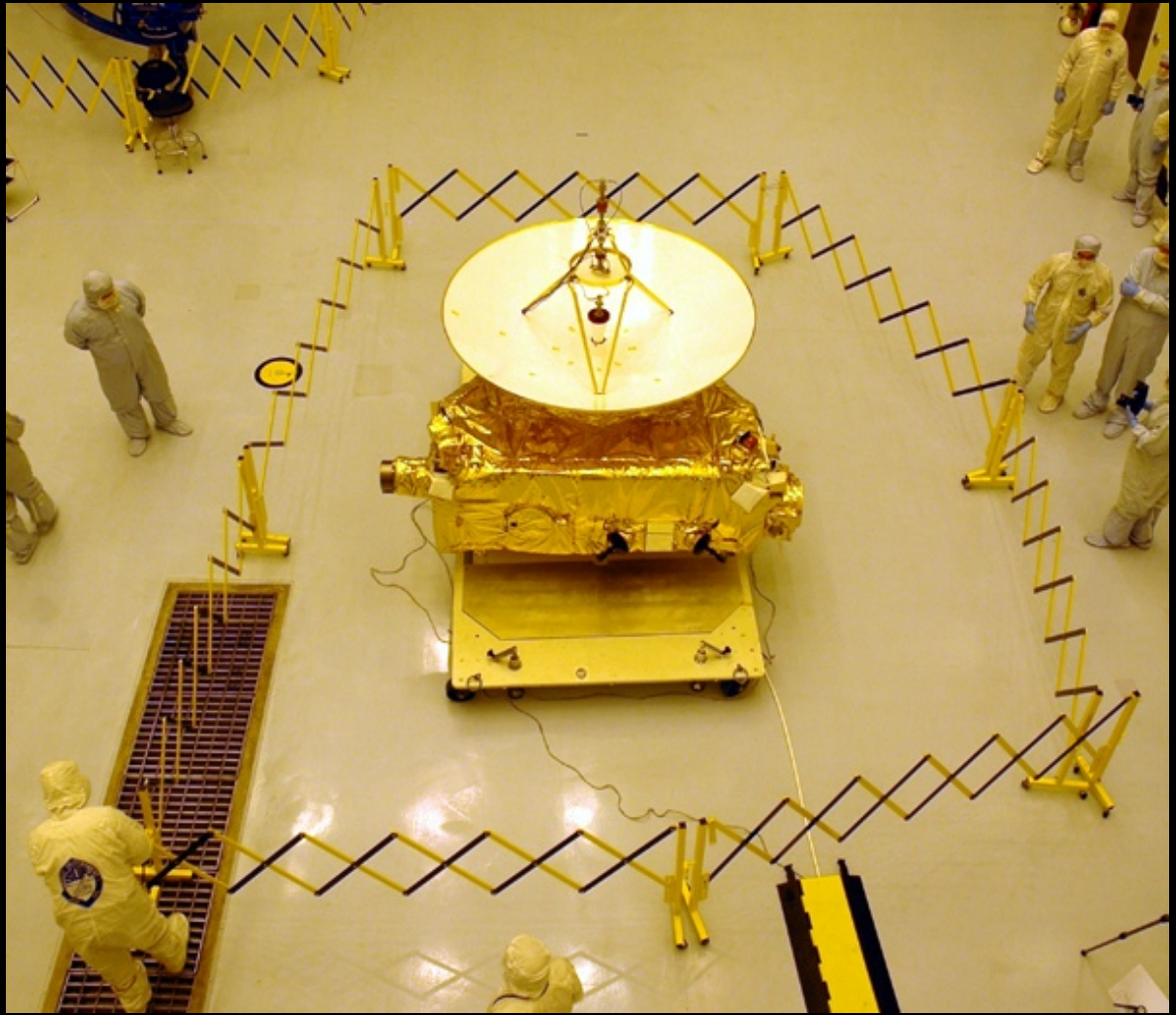
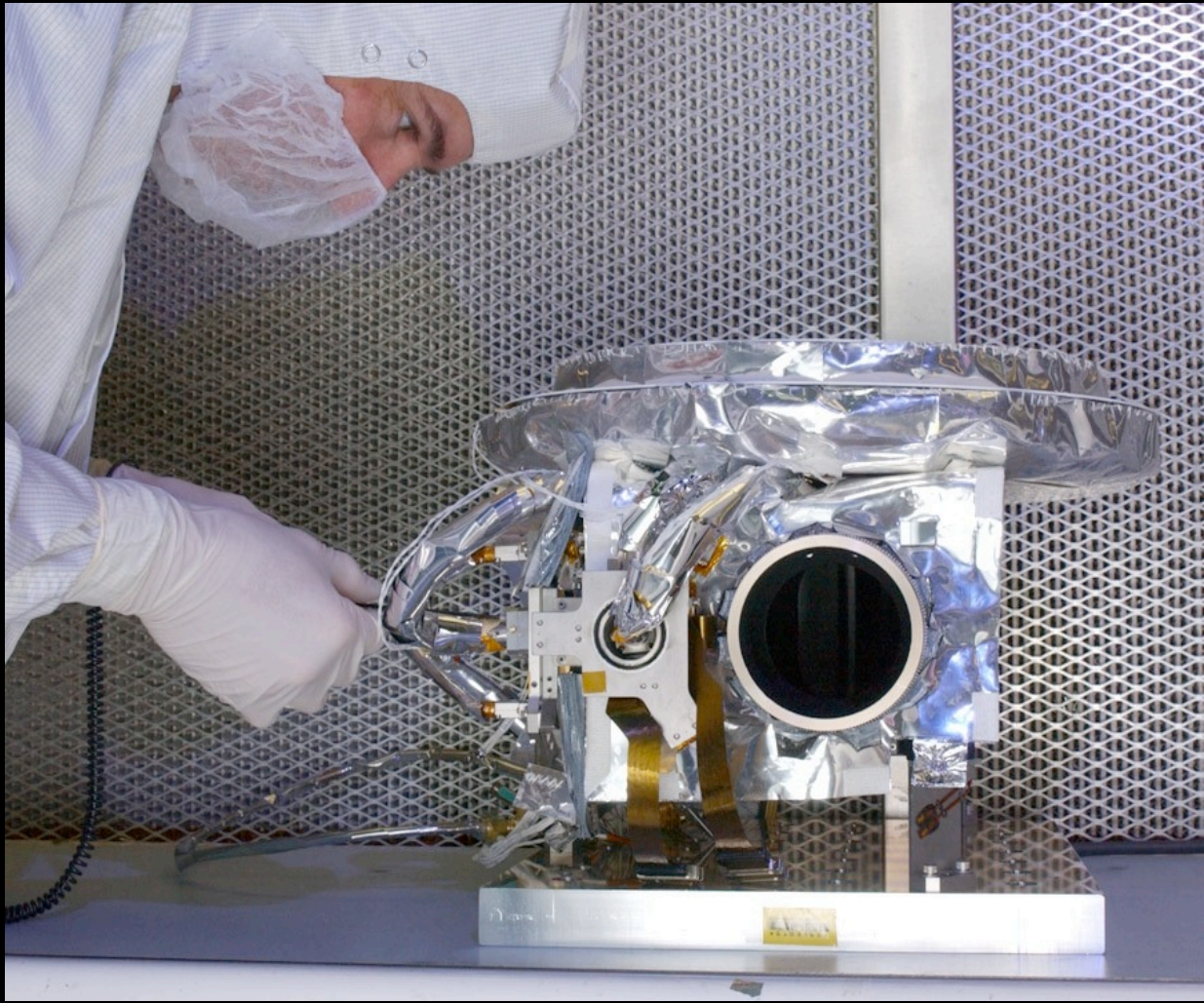
In 2001, NASA selected the New Horizons mission to fly to Pluto

- Joint proposal between Southwest Research Institute and JHU Applied Physics Lab
- 2006 launch, 2015 encounter
- The first spacecraft toward the last unexplored planet
- Five+ for the price of one!
- \$700 M for construction + launch + operations, 15 years
 - But...



How to Raise \$700 Million?





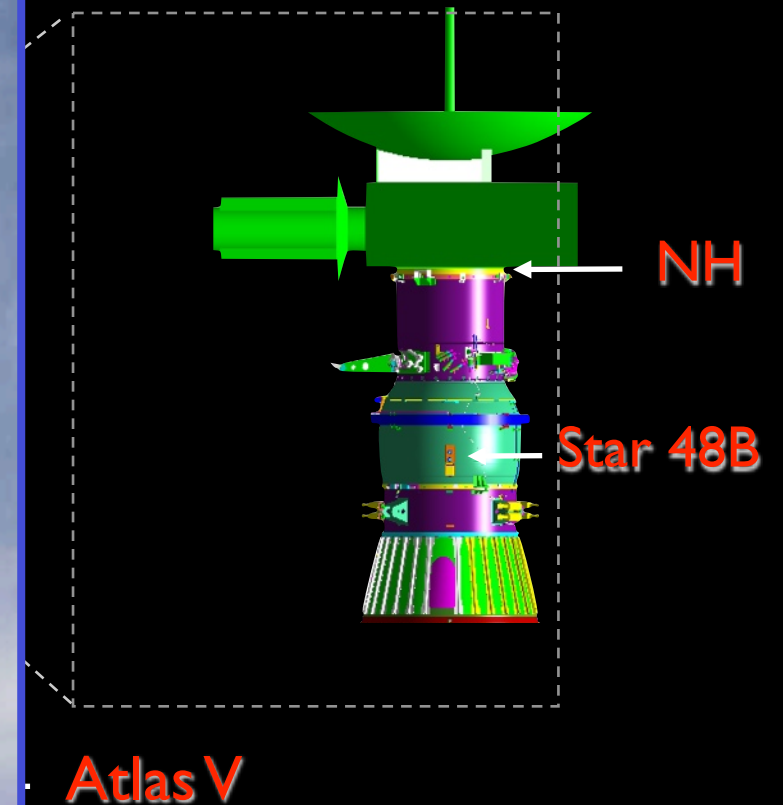
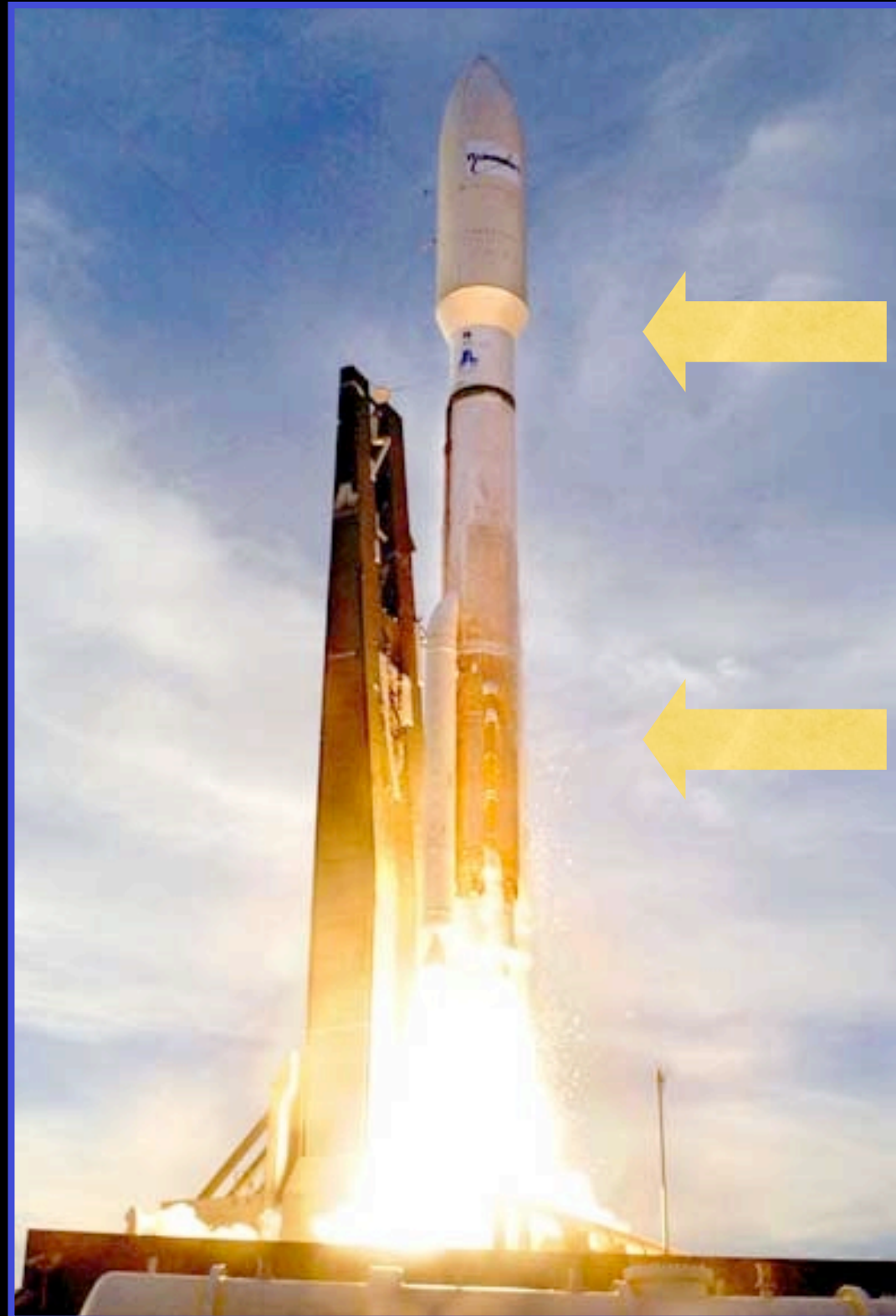


Lockheed-Martin Atlas V 55 I with Star 48B upper stage

Launch vehicle mass:
1 million kg

Spacecraft mass:
450 kg + 200 kg fuel

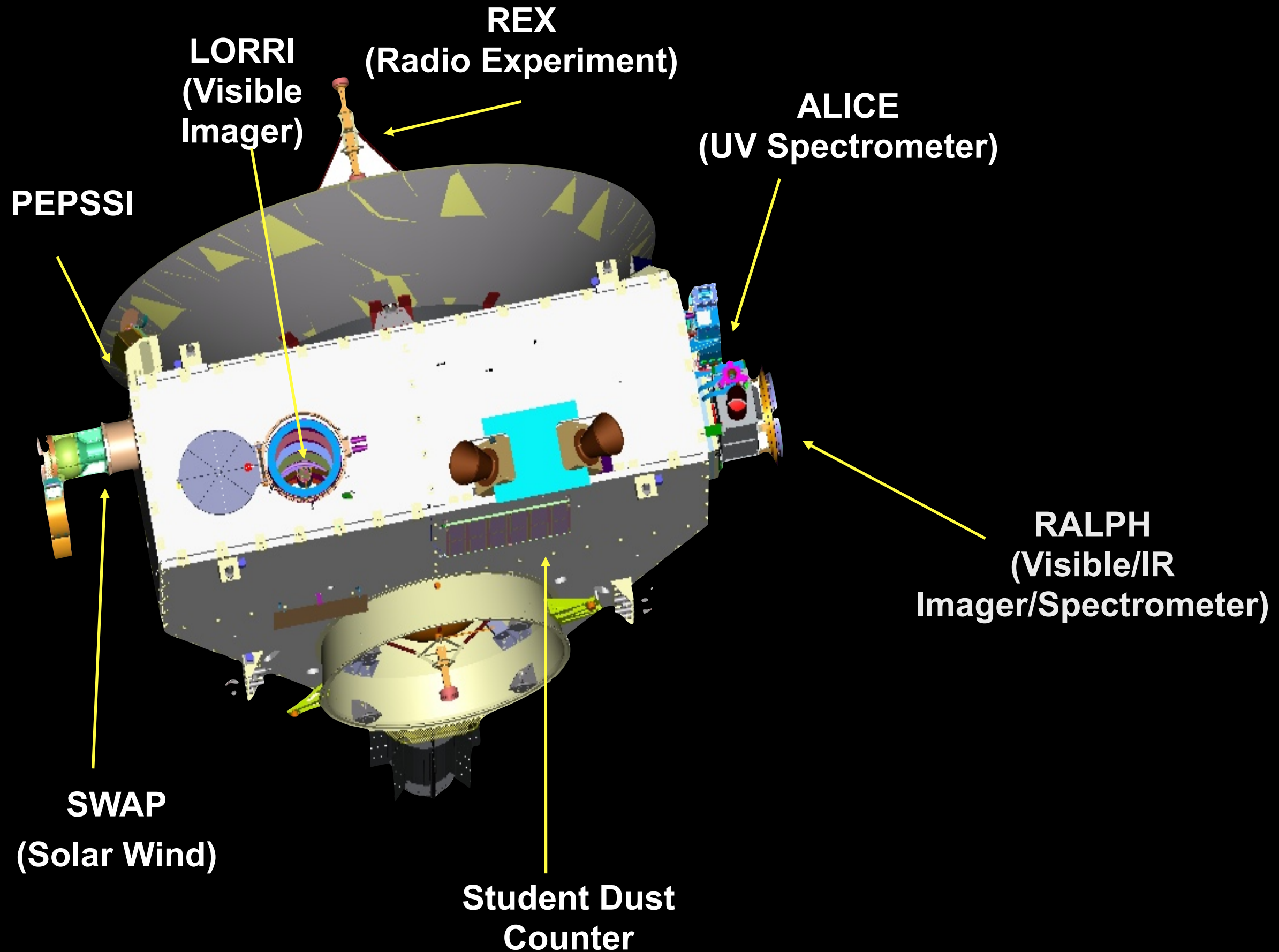
Instrument mass:
60 kg

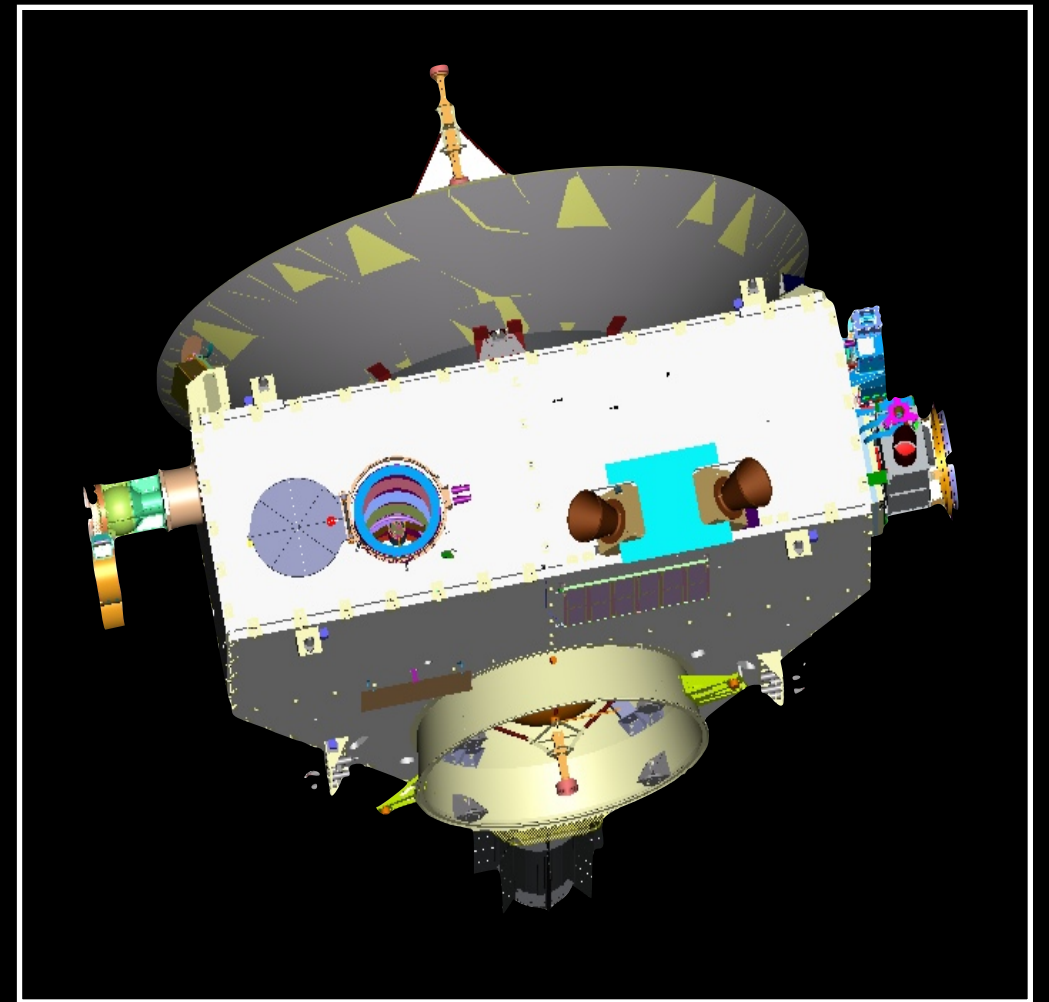






New Horizons Spacecraft





| | iPhone | New Horizons |
|-----------|----------------|-------------------------|
| Camera | 5 MP | 1 MP |
| Storage | 16 GB | 16 GB |
| Network | 3G | NASA Deep Space Network |
| Talk time | 4 hour, Li-ion | 88 years, Plutonium-238 |

New Horizons Mission Requirements

“Fly by Pluto-Charon. Accomplish all Group 1 science objectives and as many Group 2 and 3 as possible. If at all possible ... have a reasonable plan for visiting one or more KBO during an extended mission.”

Group 1 Objectives:

Characterize the global geology and morphology of Pluto and Charon

Map surface composition of Pluto and Charon

Characterize the neutral atmosphere of Pluto and its escape rate

Group 2 Objectives:

Characterize the time variability of Pluto's surface and atmosphere

Image Pluto and Charon in stereo

Map the terminators of Pluto and Charon with high resolution

Map the composition of selected areas of Pluto & Charon at high resolution

Characterize Pluto's ionosphere and solar wind interaction

Search for neutral species including H, H₂, HCN, and C_xH_y, and other hydrocarbons and nitriles in Pluto's upper atmosphere

Search for an atmosphere around Charon

Determine bolometric Bond albedos for Pluto and Charon

Map the surface temperatures of Pluto and Charon

Group 3 Objectives:

Characterize the energetic particle environment of Pluto and Charon

Refine bulk parameters (radii, masses, densities) and orbits of Pluto & Charon

Search for magnetic fields of Pluto and Charon

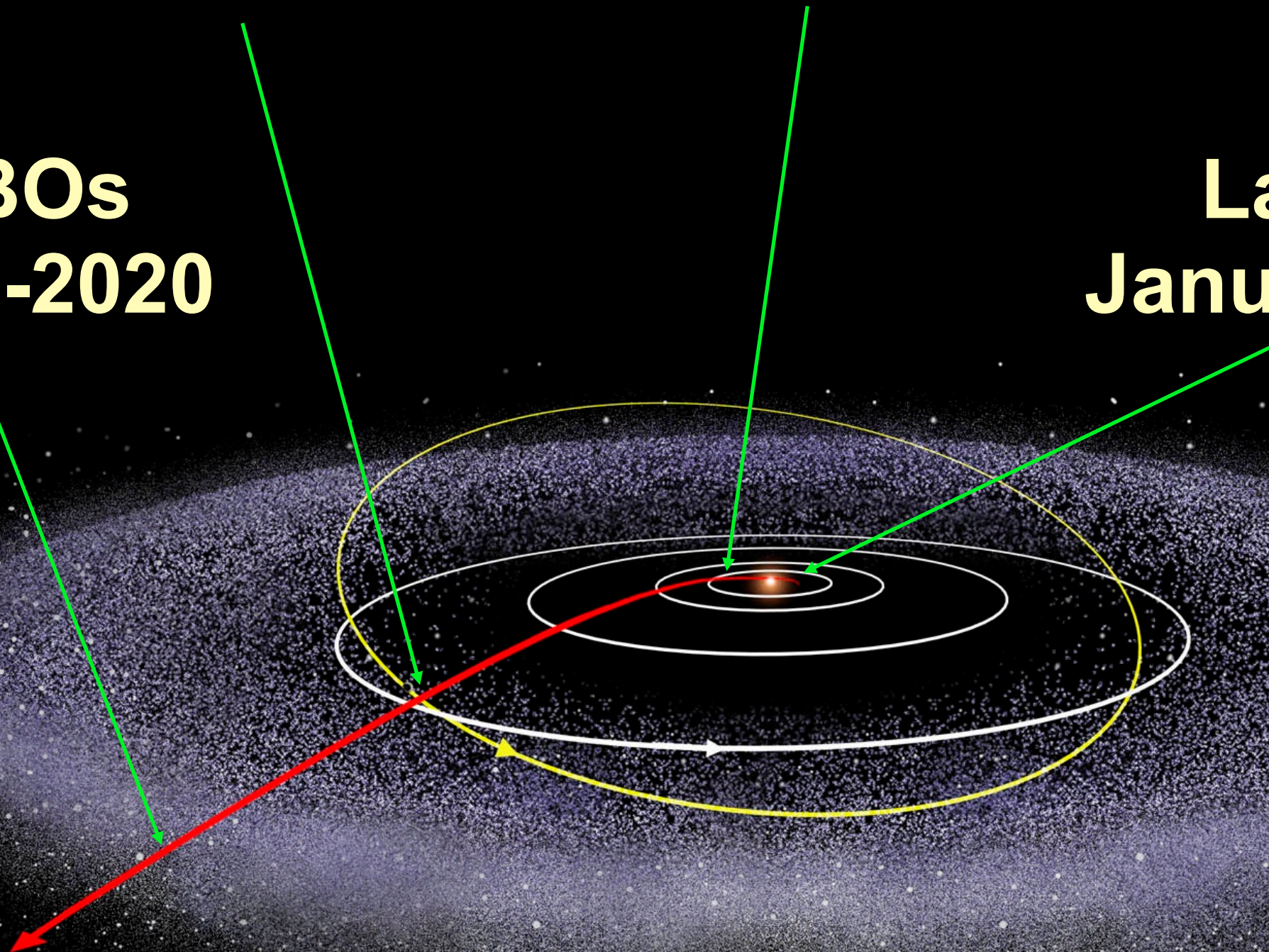
Search for additional satellites and rings

**Pluto System
July 2015**

**Jupiter System
March 2007**

**KBOs
2016-2020**

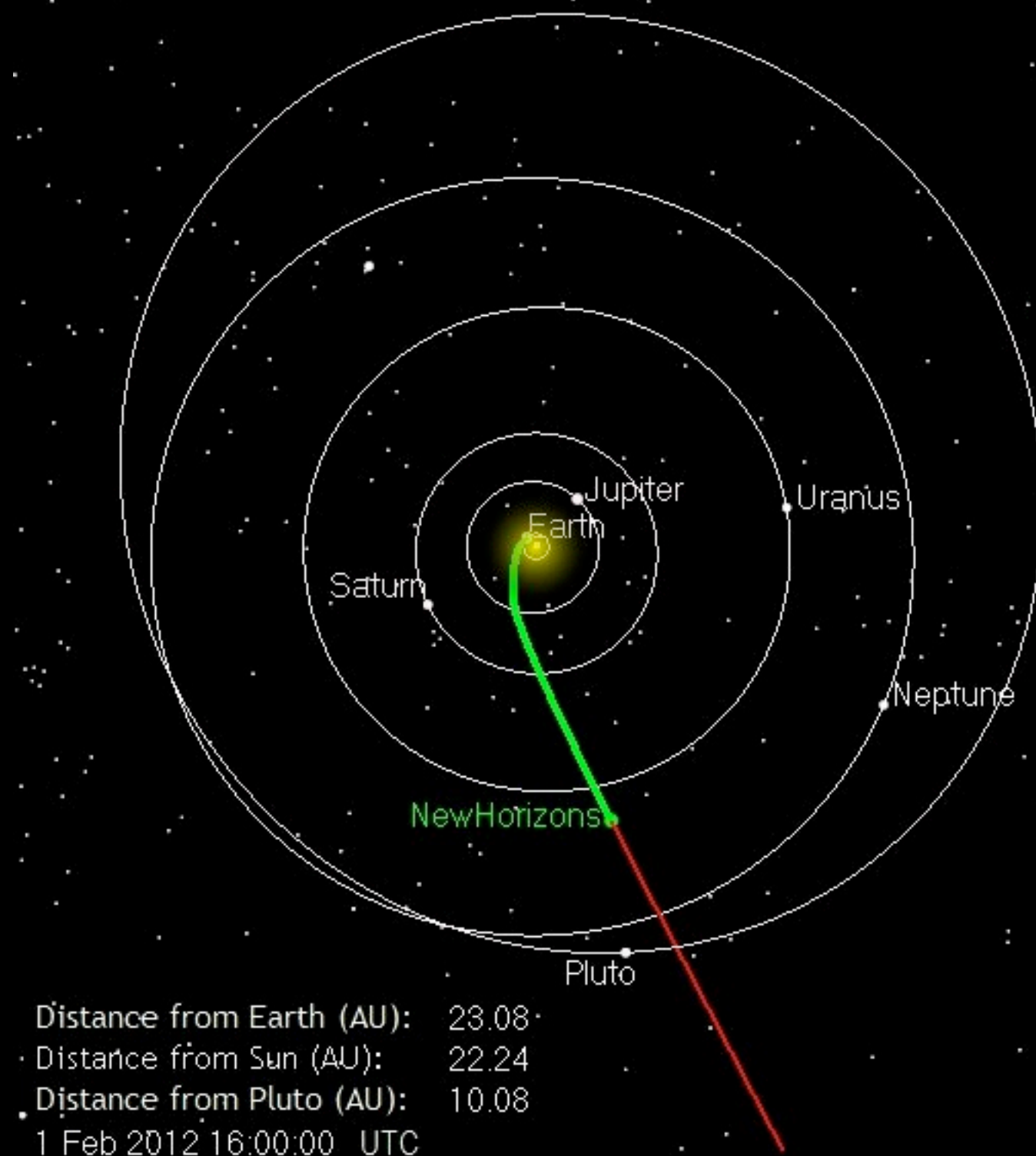
**Launch
January 2006**



New Horizons Mission Status

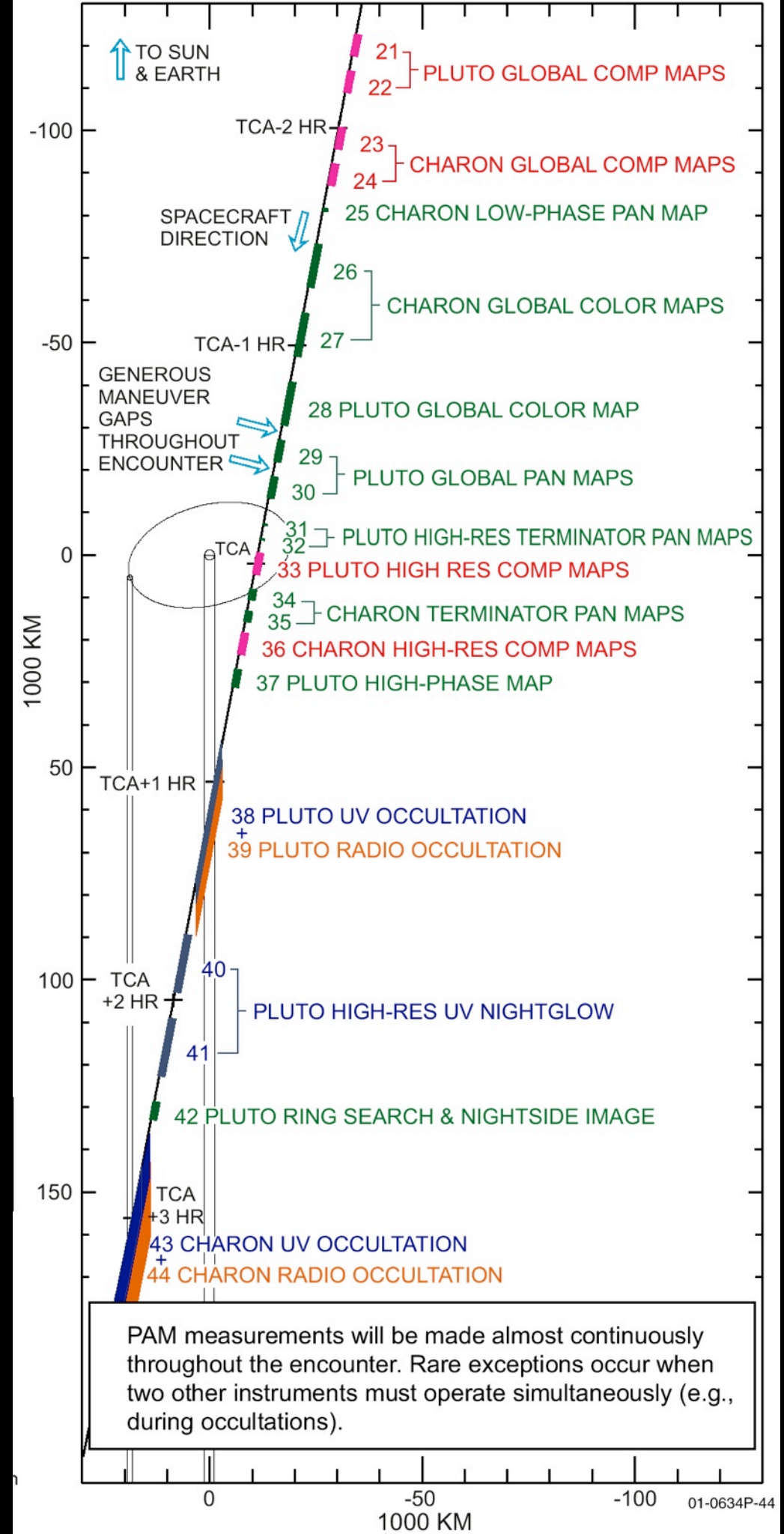
- Spacecraft healthy
- Team is planning encounter
- Spacecraft is in hibernation, with annual checkouts.
- More than halfway in time from launch
 - 80% of the way from inception!
- More than halfway in distance
- More than halfway in total distance travelled
- A lot more than halfway in \$\$ spent

New Horizons Full Trajectory - Overhead View



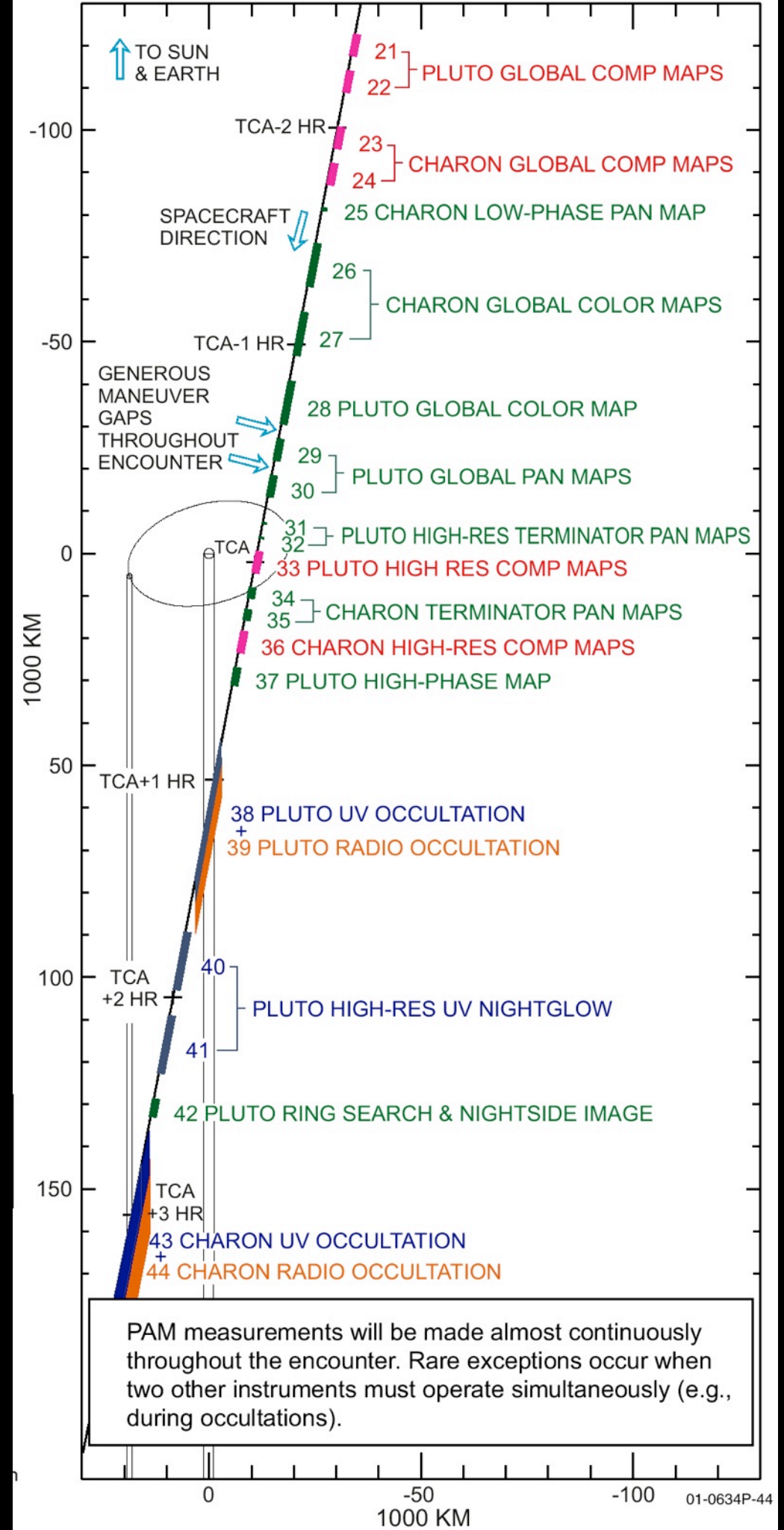
2015: Pluto System Encounter

- Spacecraft will fly between Pluto and Charon, 10,000 km from each.
- At encounter, spacecraft is traveling 1 million km/day.
- Pluto-Earth light-time is 4.5 hours.
- Entire encounter is pre-sequenced years in advance.
- We will record all data, and send it to Earth during 12 months post-flyby.



2015: Pluto System Encounter

- Six months of encounter science.
- Exceed Hubble resolution for 150 days.
- 5000x5000 pixel map of Pluto (500 m/pix)
- High-res 'postage stamps' of selected portions of surfaces (50 m/pix)
- Map Pluto night-side frost in Charon-light.
- Global composition maps.
- Radio & UV occultations of Pluto & Charon.
- Map surface temperatures.
- Directly measure Pluto's escape rate.
- Release all encounter data to public immediately.



New Horizons KBO Encounters

- We expect to fly by several Kuiper Belt Objects after Pluto.
 - Search for candidate KBOs is underway now.
 - Pluto is the most well-known of the KBOs - we will explore the diversity of the outer solar system!



New Horizon at Jupiter

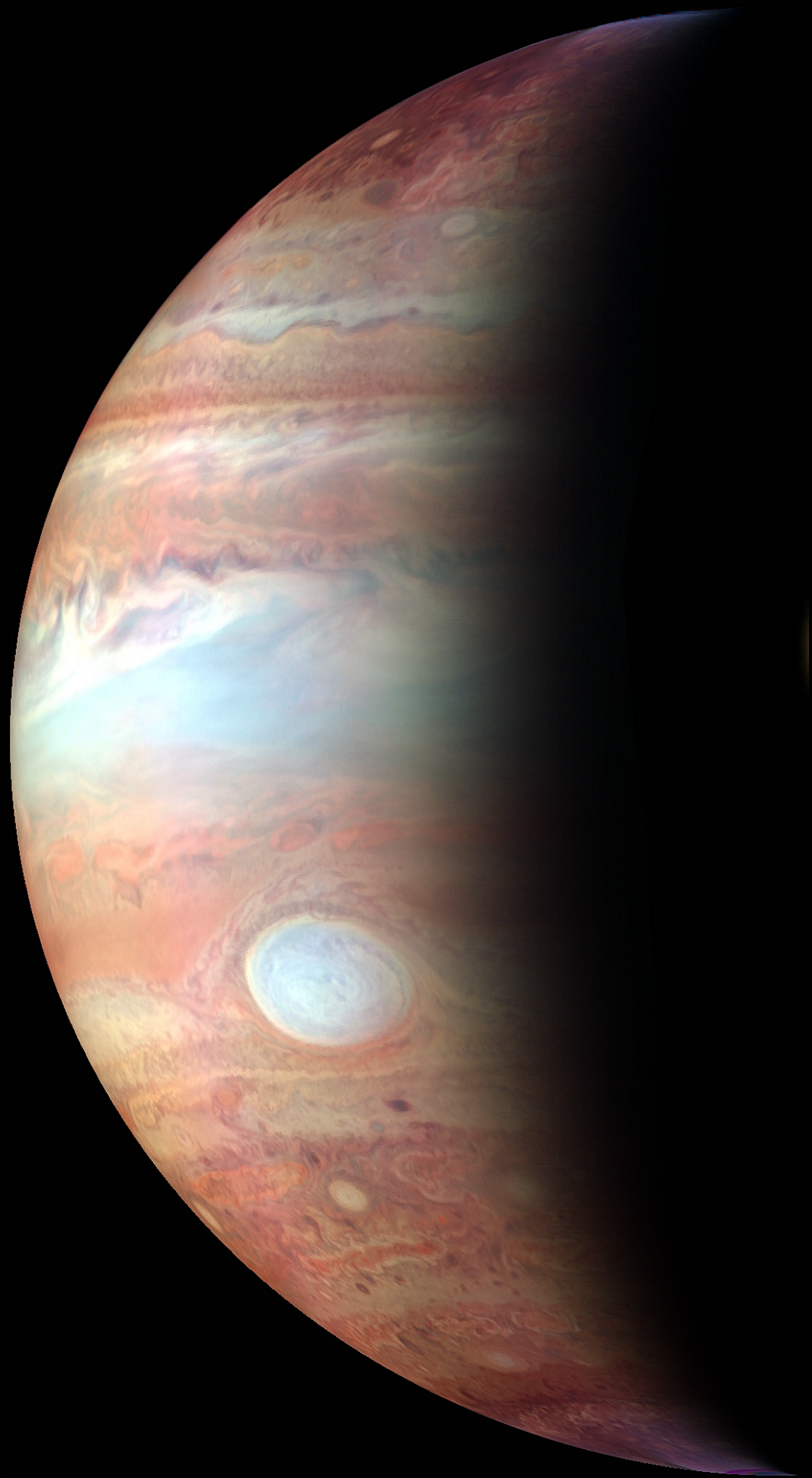
Highest resolution color
portrait of Jupiter ever

February 28, 2007
140 km/pixel

Red = 1.59 μm (Deep Clouds)

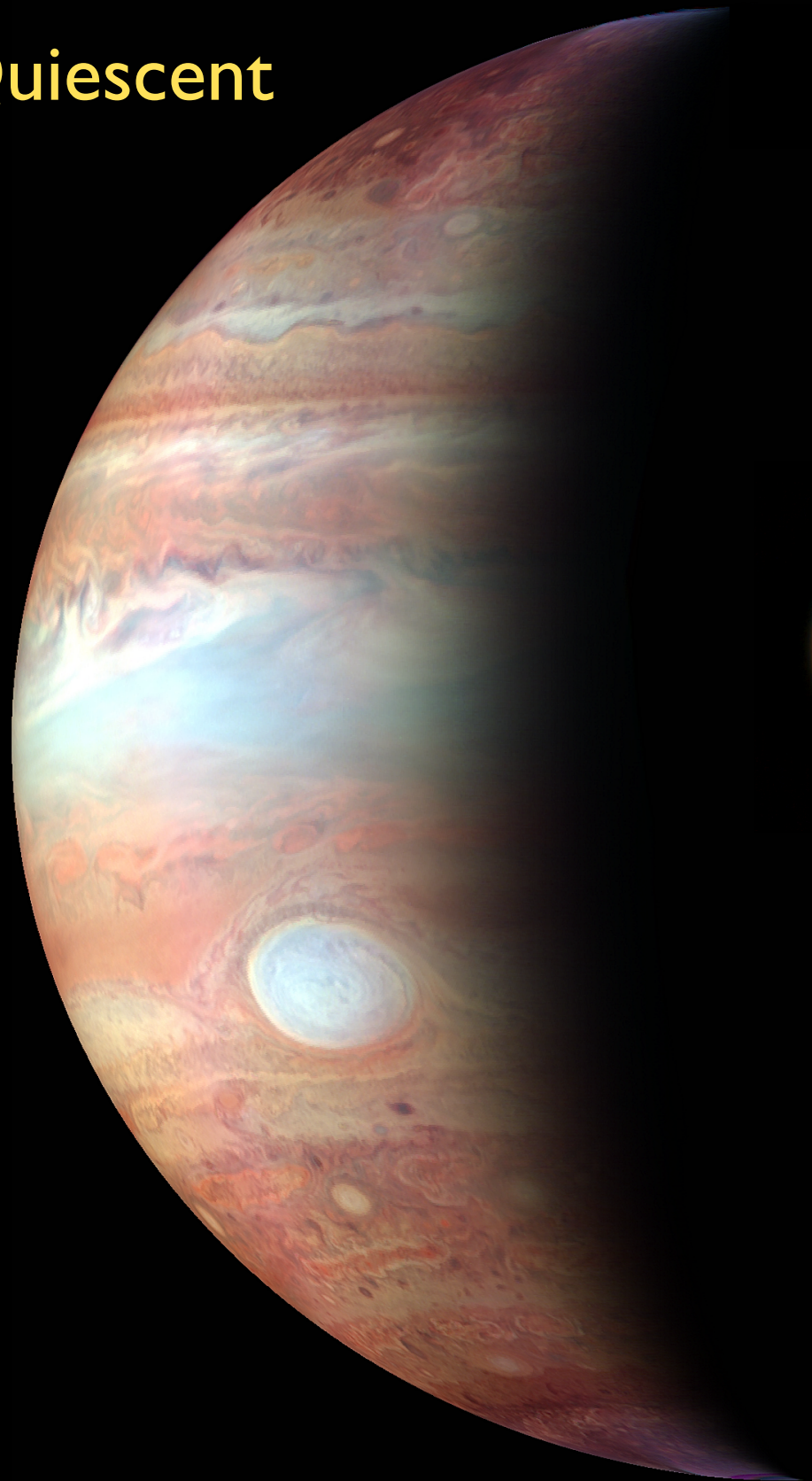
Green = 1.90 μm (Mid-level Clouds)

Blue = 1.85 μm (Upper-Level Hazes)



New Horizons
February 2007

Quiescent



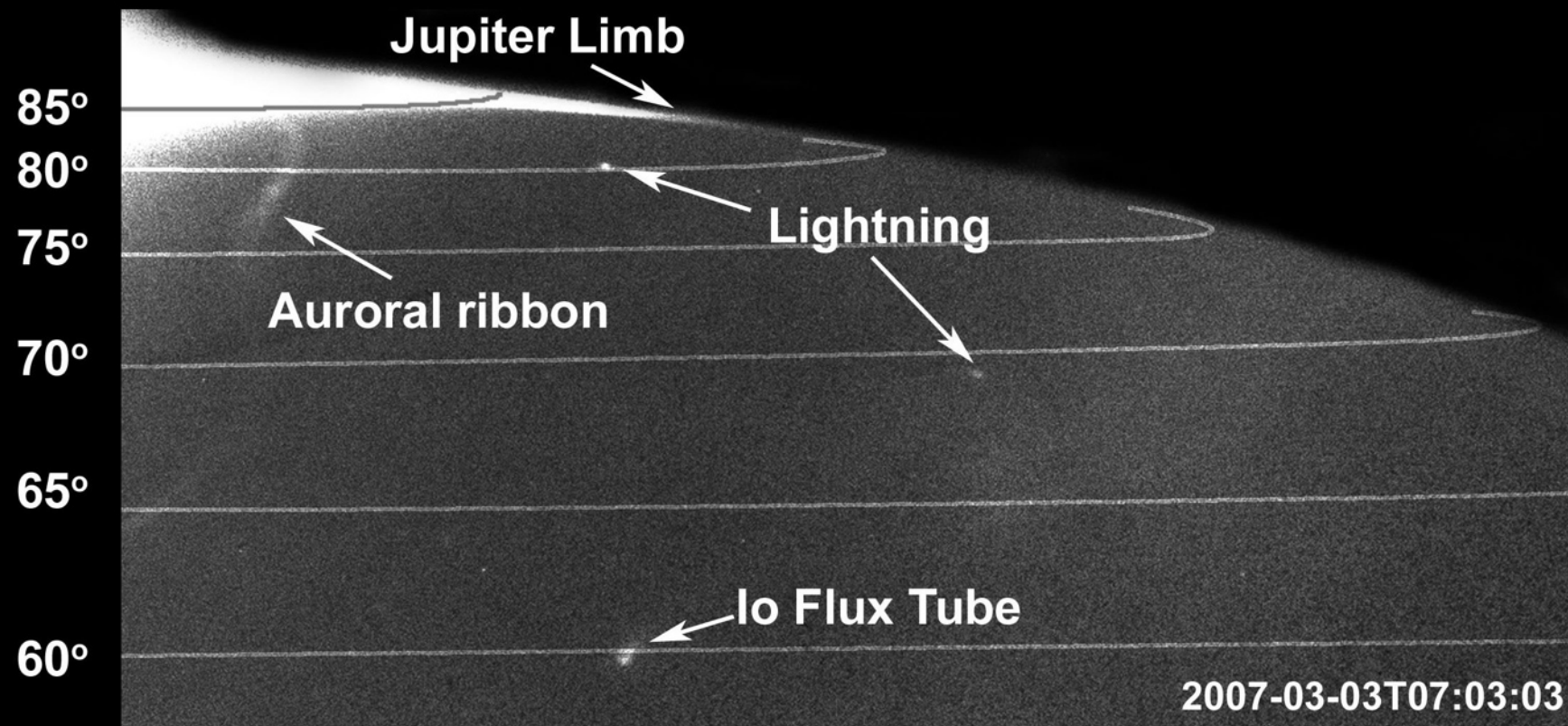
Cassini
December 2000

Active



New Horizons:

First images ever of Jovian polar lightning



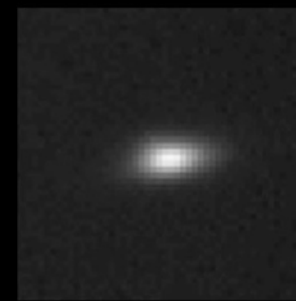
80.4°, 123.5°



79.6°, 208.5°



69.7°, 121.4°



-66.0°, 190.0°



-68.9°, 222.6°

Examples of Polar Lightning Strikes

Observations of volcanoes on Io, 2007

Visible

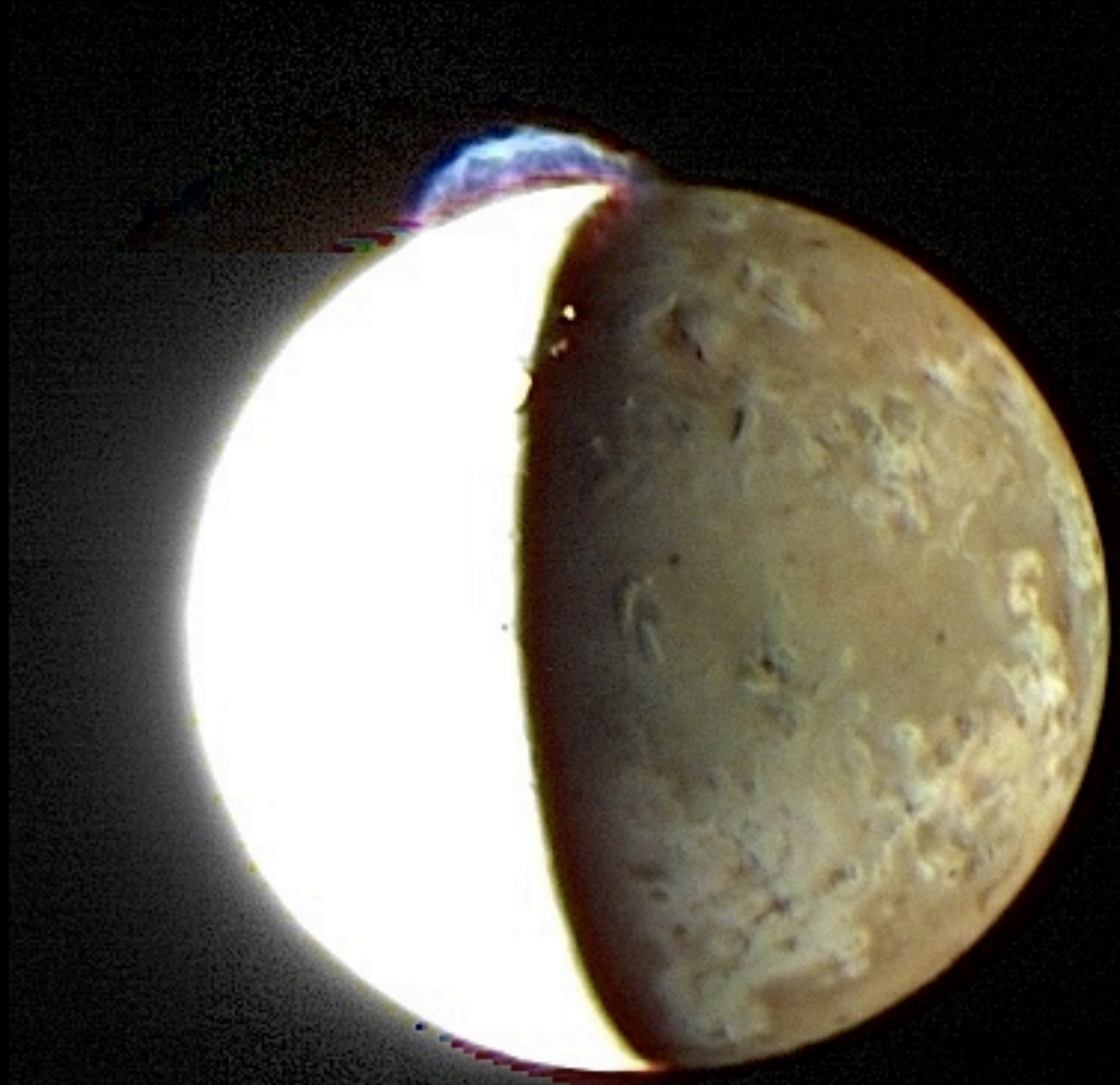
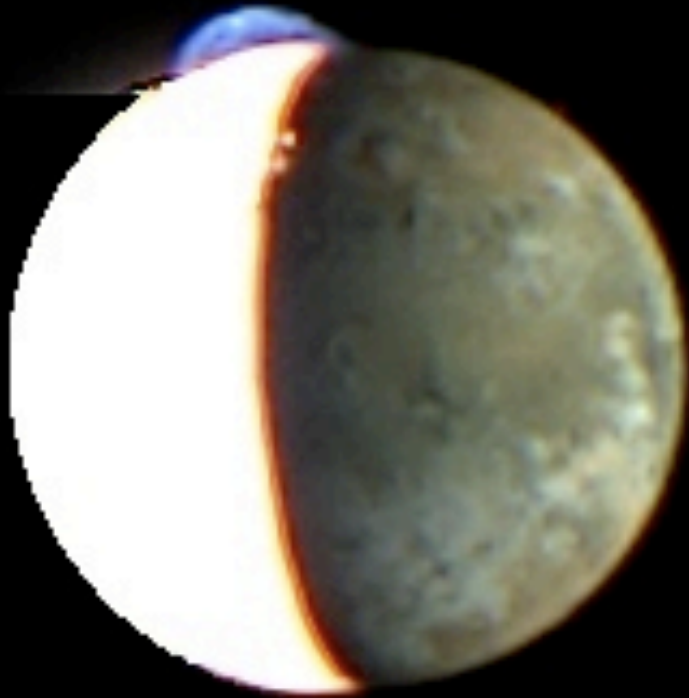


Color



IR

Nightside Color Imaging of Io



The Jovian Ring from New Horizons

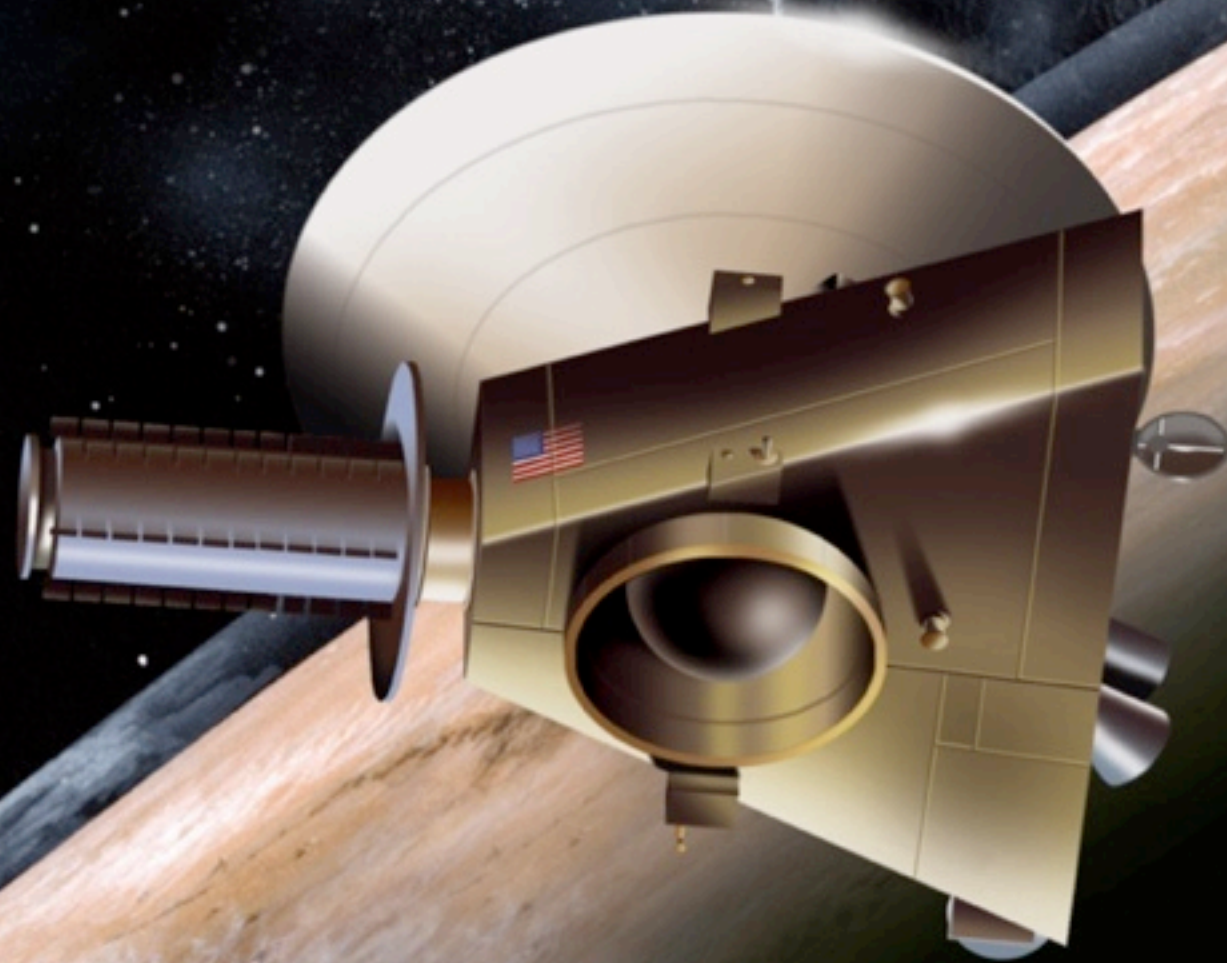


Tvashtar Plume on Io

- 5 frames
- 8 minutes



Onward...



July 14, 2015

<http://pluto.jhuapl.edu/>

The End

Backup Slides

IAU Definition of Planet (2006)

“The IAU therefore resolves that "planets" and other bodies in our Solar System, except satellites, be defined into three distinct categories in the following way:

(1) A "planet" is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and (c) has cleared the neighborhood around its orbit.

(2) A "dwarf planet" is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, (c) has not cleared the neighbourhood around its orbit, and (d) is not a satellite.

(3) All other objects except satellites orbiting the Sun shall be referred to collectively as "Small Solar-System Bodies".

Problem I: The 400+ extrasolar planets aren't 'planets'?

Problem II: Jupiter isn't 'rigid', so it isn't a planet?

Problem III: Saturn isn't round, so it isn't a planet?

Problem IV: The Earth has not 'cleared its neighborhood', so it isn't a planet?



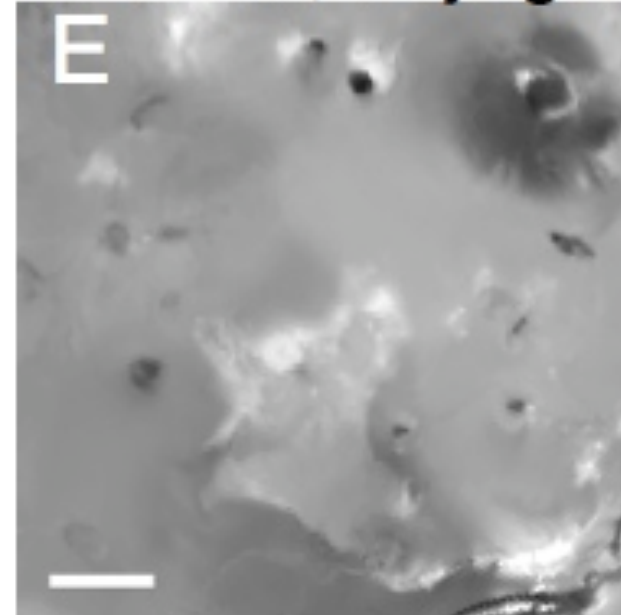
Changes at Lerna and Masubi



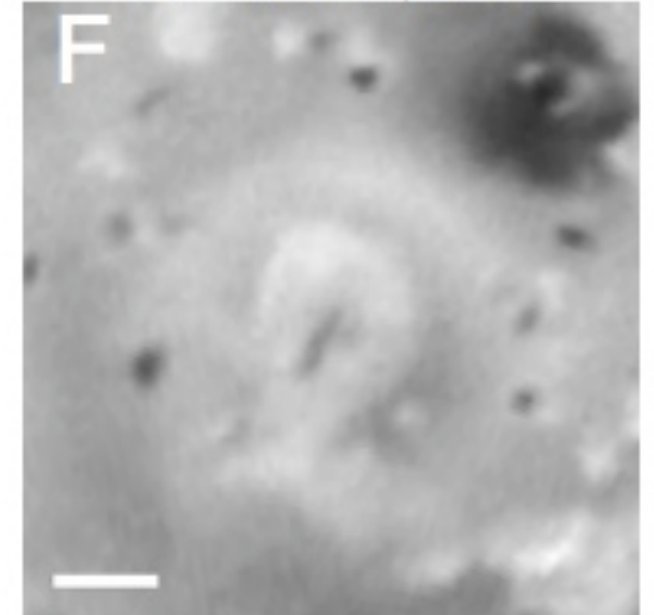
Lerna: New lava flow and deposits from an active plume

Masubi: new lava flow and deposits from two active plumes

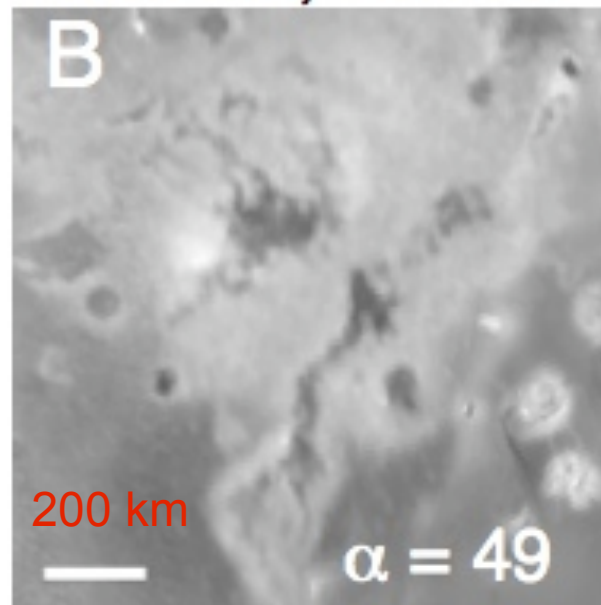
N. Lerna, Voyager



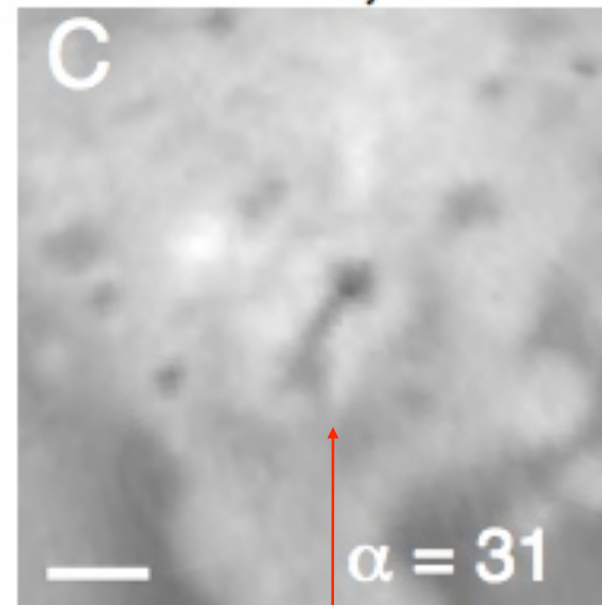
N. Lerna, NH



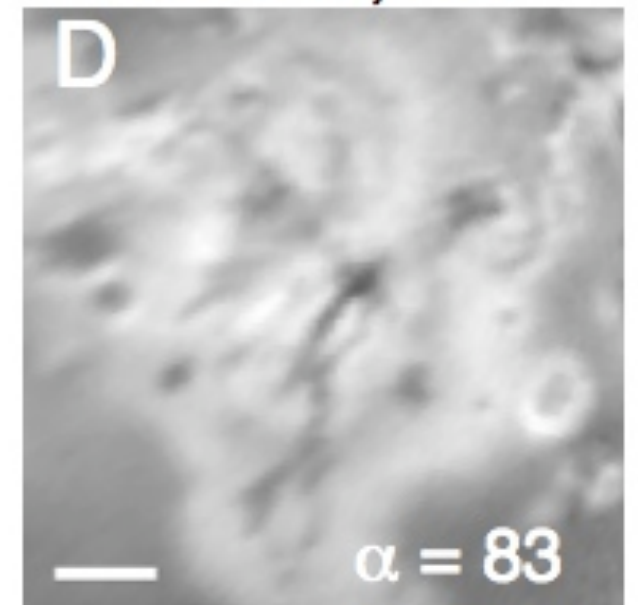
Masubi, Galileo



Masubi, NH

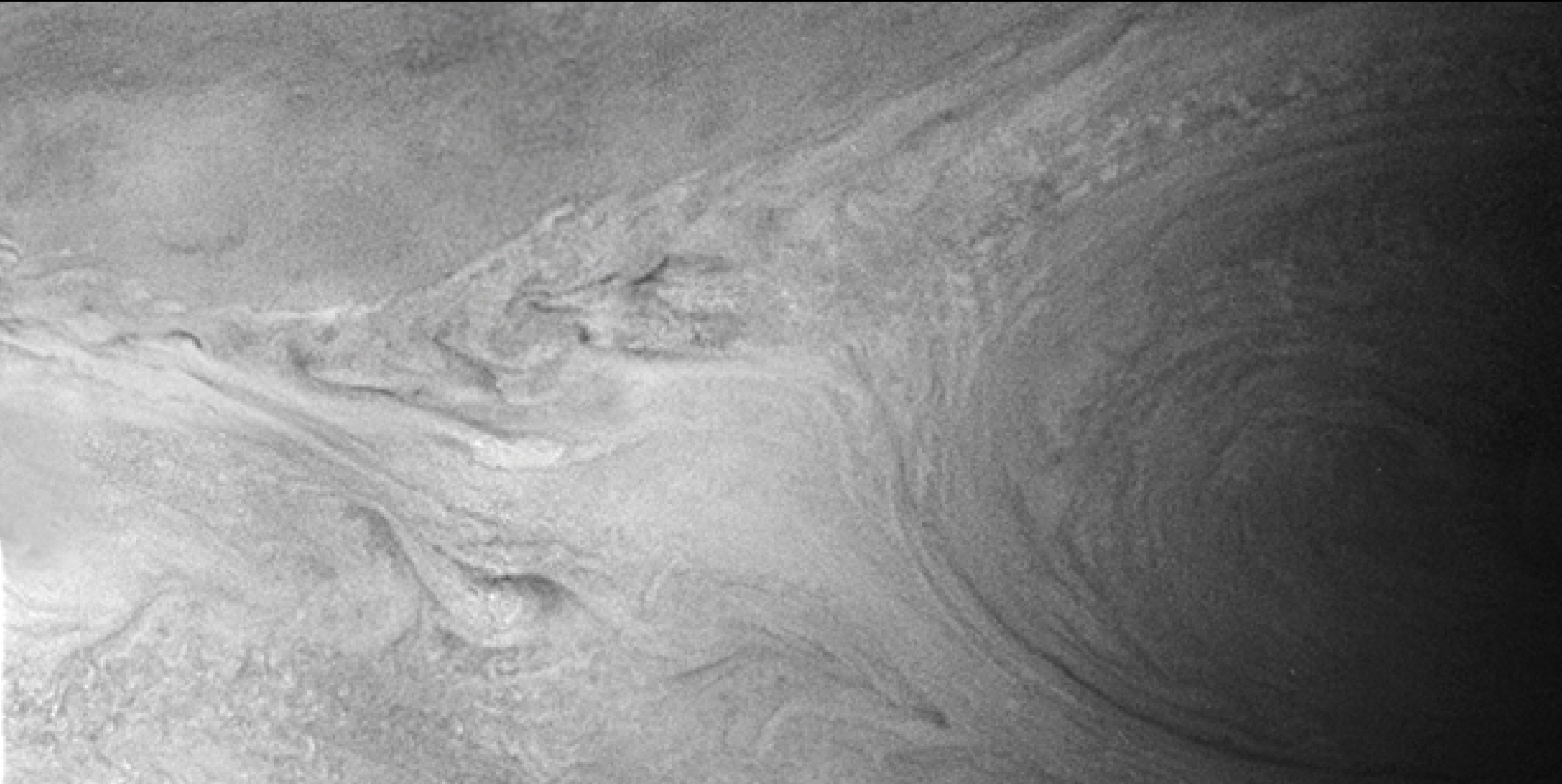


Masubi, NH



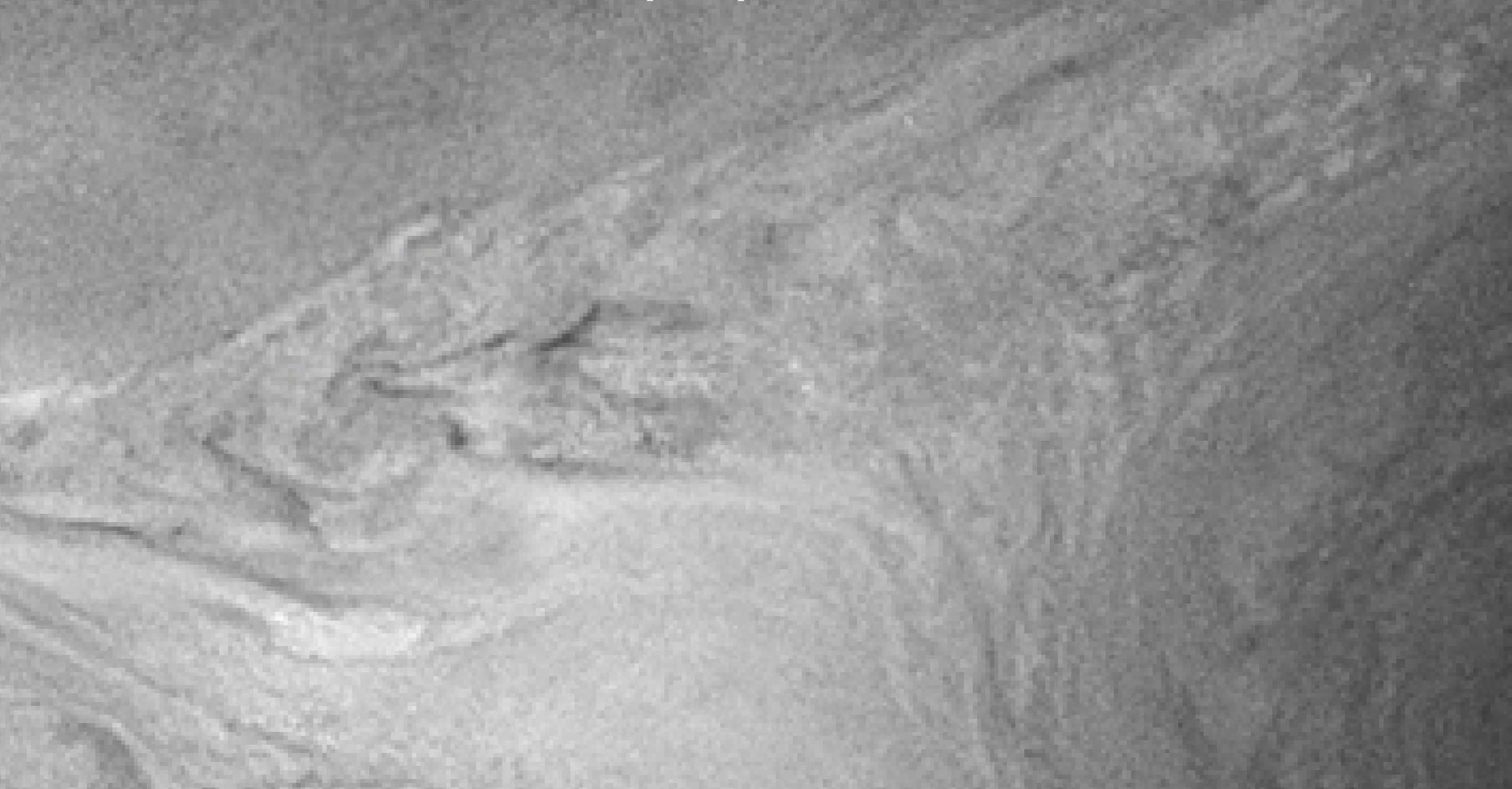
240 km
lava flow

GRS Environs And “Not-so-Turbulent” Wake...



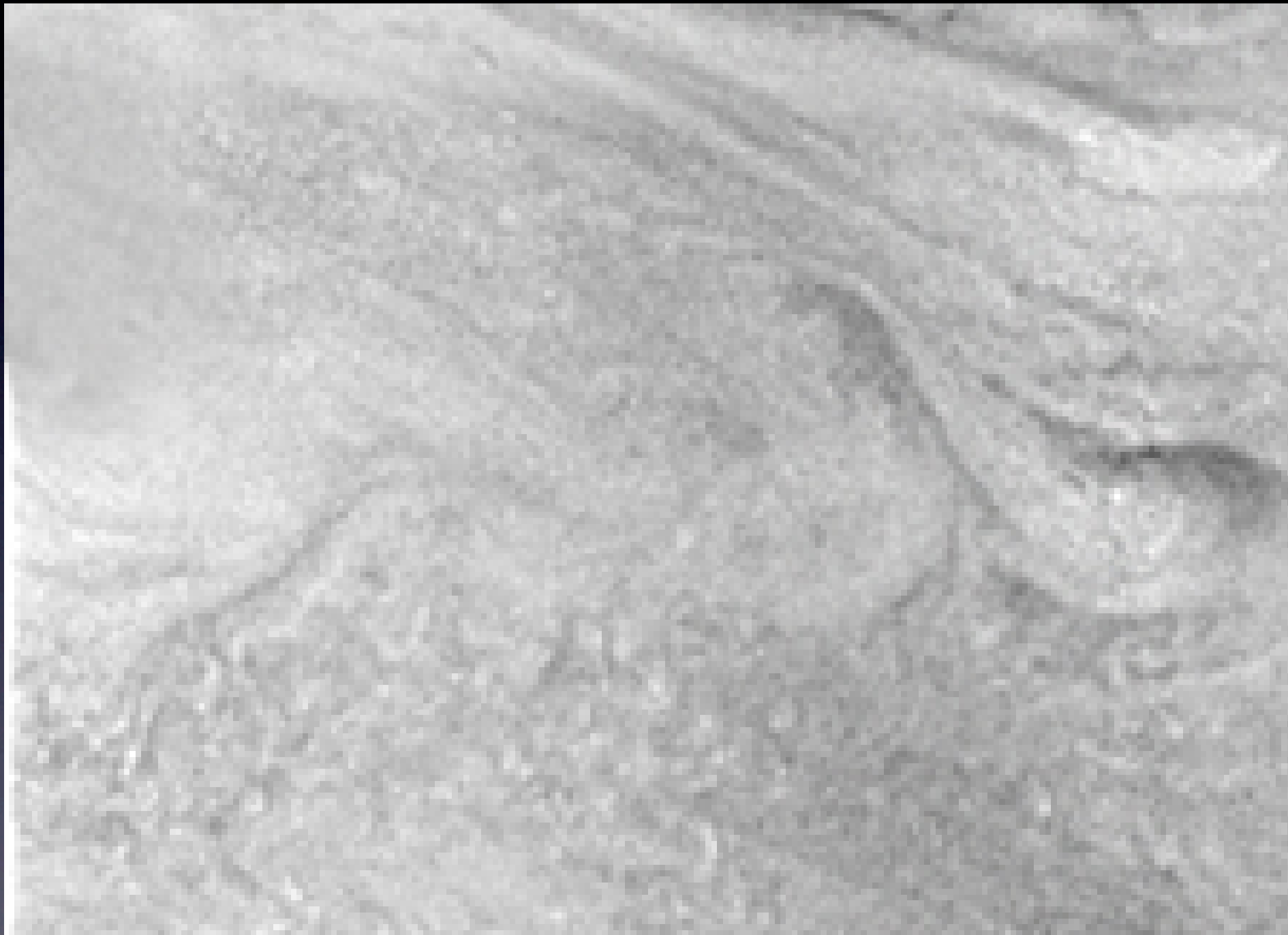
LORRI Image: 10 km/pixel

GRS Environs
And “Not-so-Turbulent” Wake...
But Still Very Dynamic at Small Scales



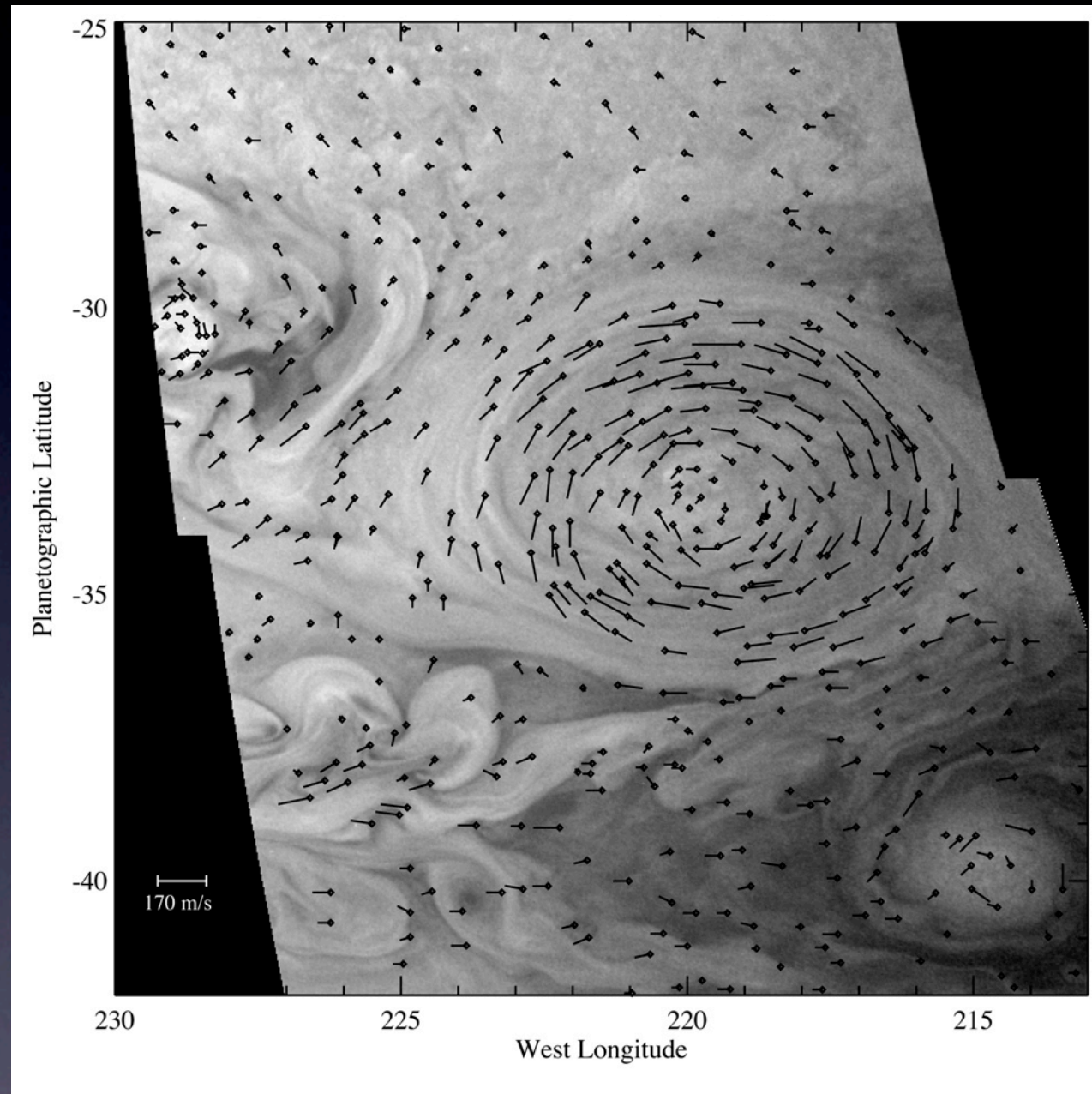
LORRI Image: 10 km./pixel

GRS Environs
And “Not-so-Turbulent” Wake...
But Still Very Dynamic at Small Scales

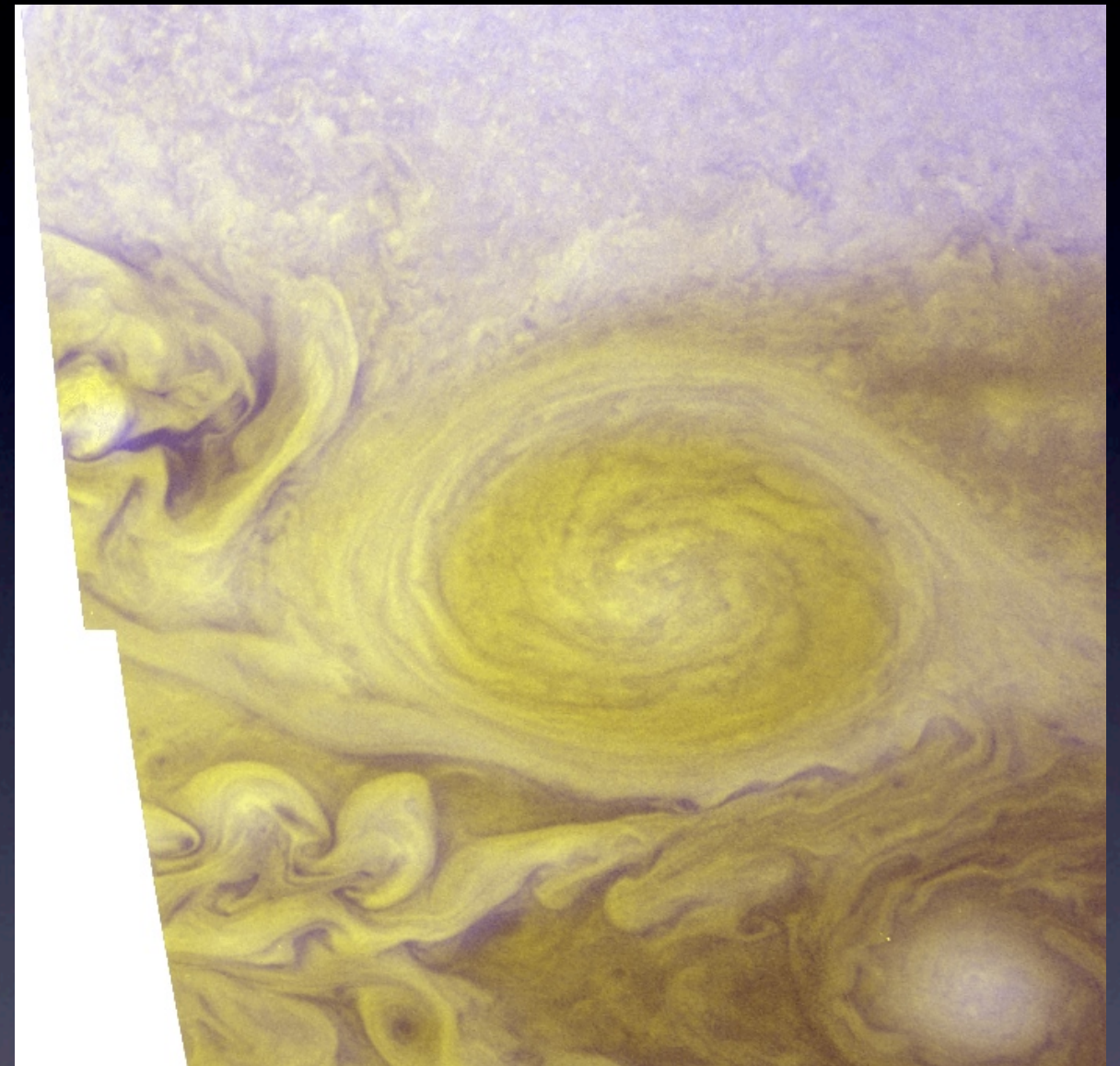


LORRI Image: 10 km./pixel

Little Red Spot



LORRI: 30-minute separation, dot
Is the starting point of vector



LORRI + HST colorized image

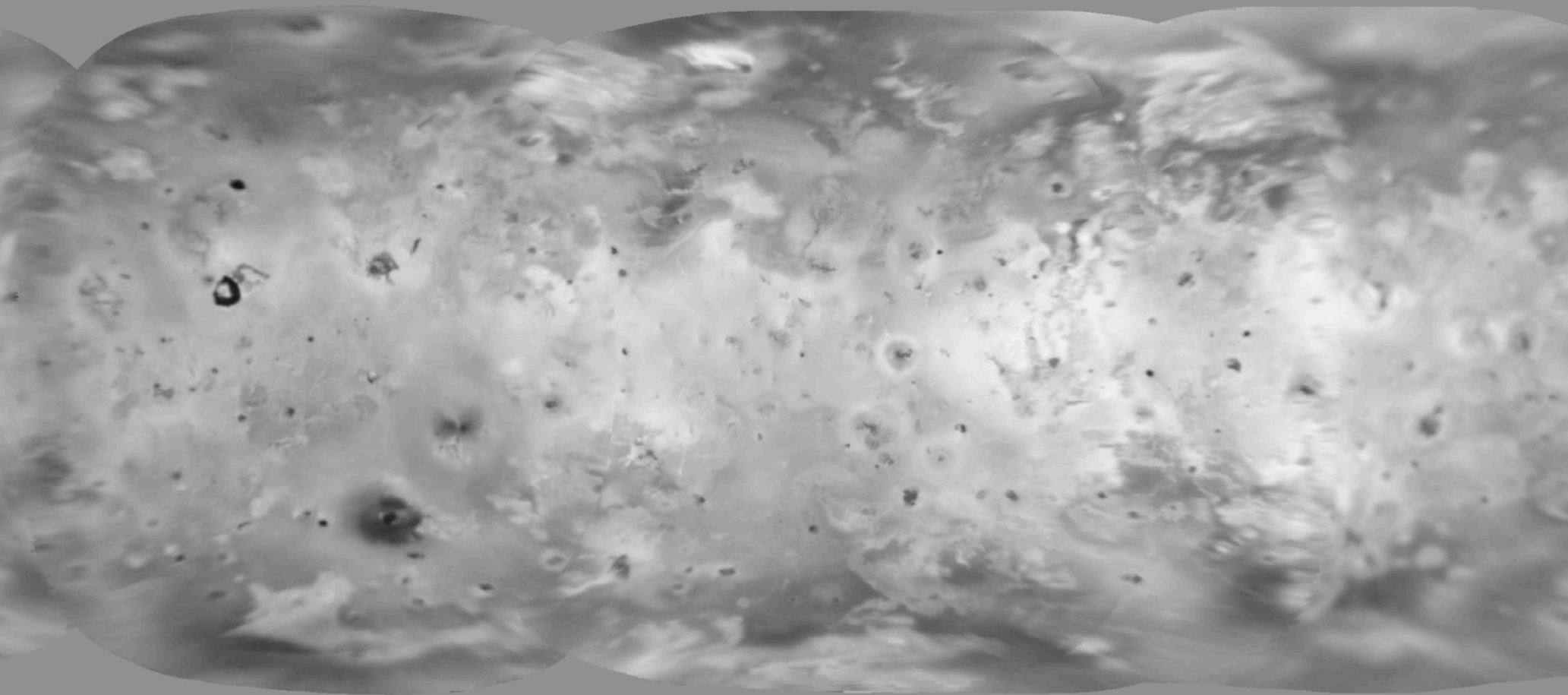
New Horizons: Results on Jupiter's Atmosphere

- New Horizons saw Jupiter in a relatively quiescent state in February 2007
 - Allowed detailed views of relatively deep clouds
- Polar lightning discovered.
 - Radiative flux due to lightning is stronger throughout high lat regions
 - Consistent with Zonal winds show little change, as expected
- Little Red Spot
 - Higher wind speed than for predecessor ovals in Voyager or Galileo images
 - Unclear when change occurred.

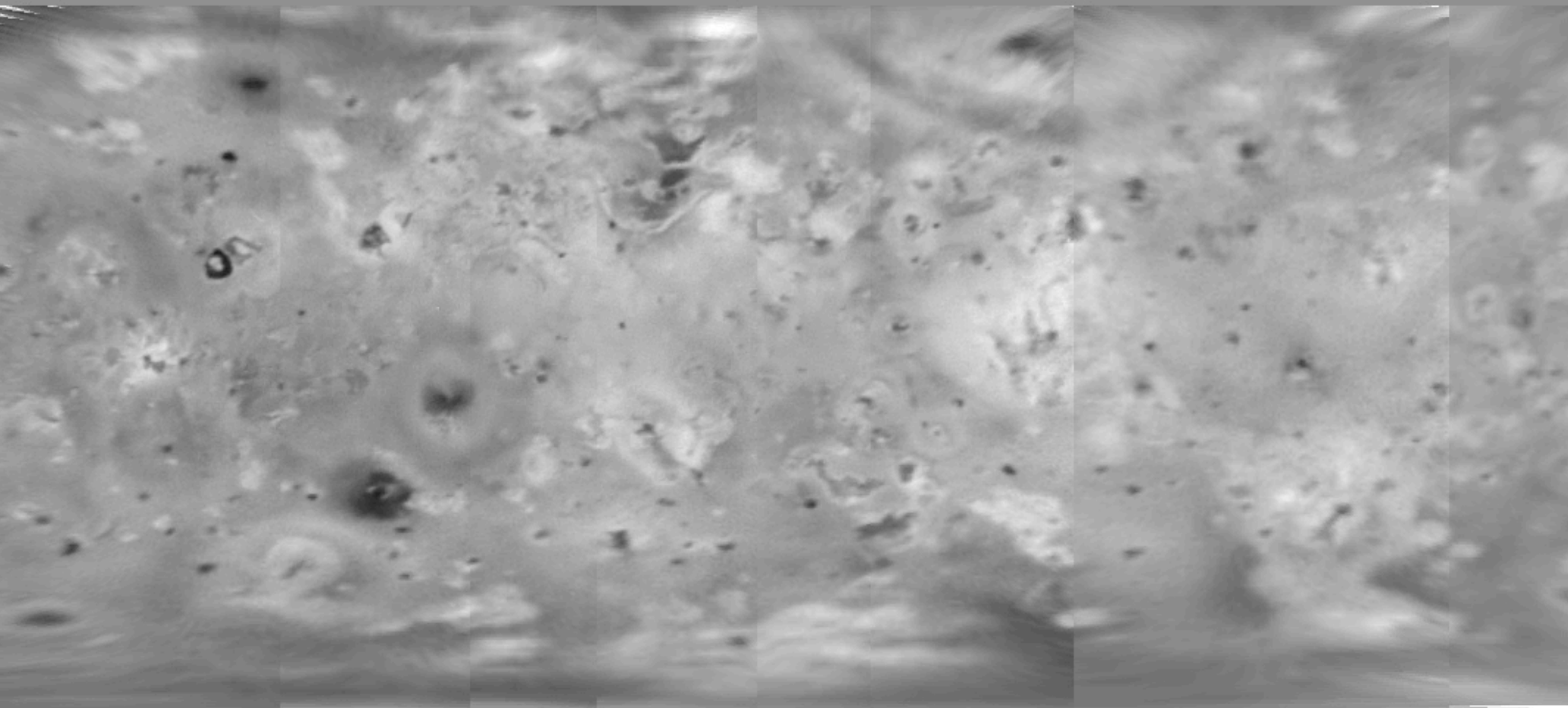


10 years of surface changes

Galileo
~1997



New
Horizons
2007



πλανετ

Greek definition of Planet: 'Wandering star'

planet ('plænɪt), *n.*¹ Forms: 3-6 **planete**, (4-6 **-ette**, 5 **-ett**, *Sc.* **-ait**, 6 *Sc.* **-eit**, 7 **plannet(t)**, 5- **planet**.

[ME. *a.* OF. *planete* (F. *planète*), ad. late L. *planōta* or *planōtōs* (cited only in pl. *planōtæ* = cl. L. *stellæ errantes*), *a.* Gr. *πλανήτης* wanderer, hence, in *pl.* (*ἀστέρες*) *πλανῆται* wandering stars, planets, f. *πλανᾶν* to lead astray, in *pass.* to wander. (Another Gr. form was *πλάνης*, *-ητος*, in pl. *πλάνητες* *ἀστέρες*, L. *planōtes*.)]

† **1. a.** *Old Astron.* A heavenly body distinguished from the fixed stars by having an apparent motion of its own among them; each planet, according to the Ptolemaic system, being carried round the earth by the rotation of the particular sphere or orb in which it was placed. *Obs.*

The seven planets, in the order of their accepted distance from the Earth, were the Moon, Mercury, Venus, the Sun, Mars, Jupiter, and Saturn.

[c1050 *Byrhtferth's Handboc in Anglia* (1885) VIII. 320 þa steorran þe man hæet planete on lyden.]

a1300 *Cursor M.* 1550 (Cott.) þe planetes all ar went again O þair first making in to þe state.

c1400 *Destr. Troy* 4366 Venus the worthy..of planettes of prise has hor pure nome.

c1420 *LYDG. Assembly of Gods* 1695 The seuyn planetty's Hauē her propre names by astronomers.

c1470 *HENRY Wallace* xi. 500 Quhill day began to peyr; A thyk myst fell, the planet was not cleyr.

1481 *CAXTON Myrr.* i. xx. 60. A way that is comune to the vii planetes.

1600 *NASHE Summer's Last Will* D i. Resplendent Sol, chiefe planet of the heauens.

1621 *BURTON Anat. Mel.* i. ii. i. ii. (1651) 45 Gregorius Tholosanus makes seven kindes of ætherial spirits or angels, according to the number of the seven Planets, Saturnine, Jovial, Martial.

1687 tr. *Marana's Turkish Spy* i. xii. 35 It is a great while since we have had any Commerce here with the Sun; there being forty nine Days since this beauteous Planet appeared to us.

1727 *BAILEY* vol. II. s.v., There is none of the Planets, except the Sun that shines with his own Light.

1766 *PORNY Heraldry* (1787) 19 Arms..are blazoned..by Planets, when they belong to Sovereign Princes, Kings, and Emperors.