

Chapter 12b: Beyond Neptune: The Kuiper Belt

Pluto and its many neighbors

KBO's: Kuiper Belt Objects

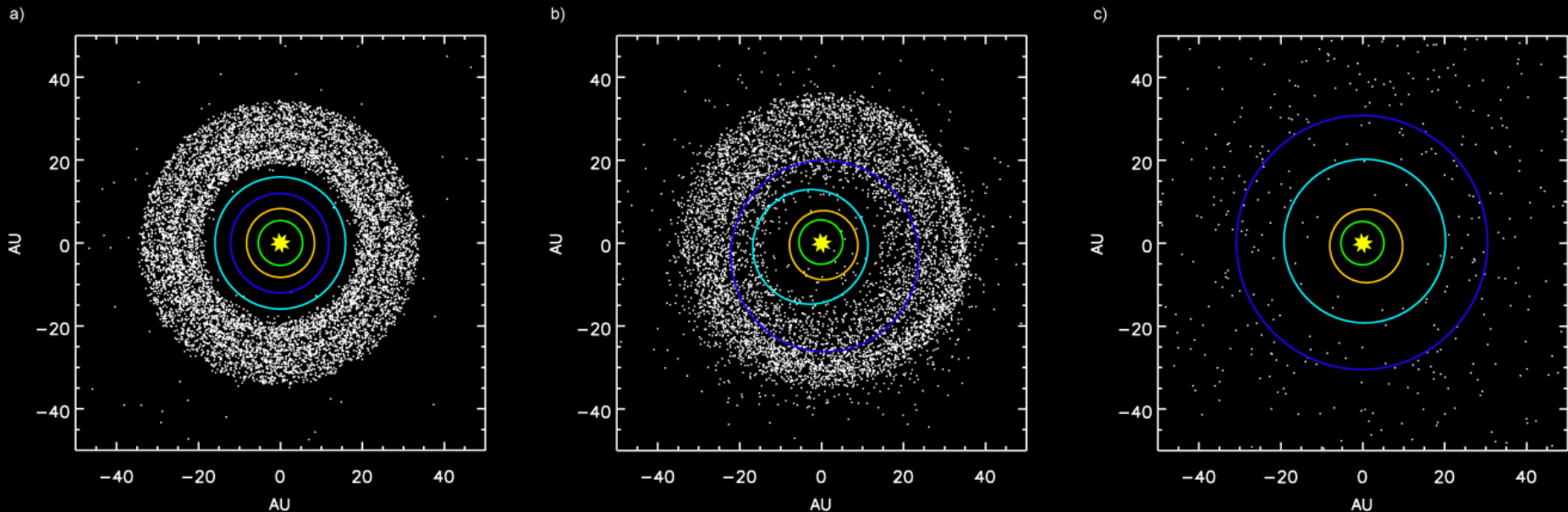
Are there More Planets Beyond Neptune?

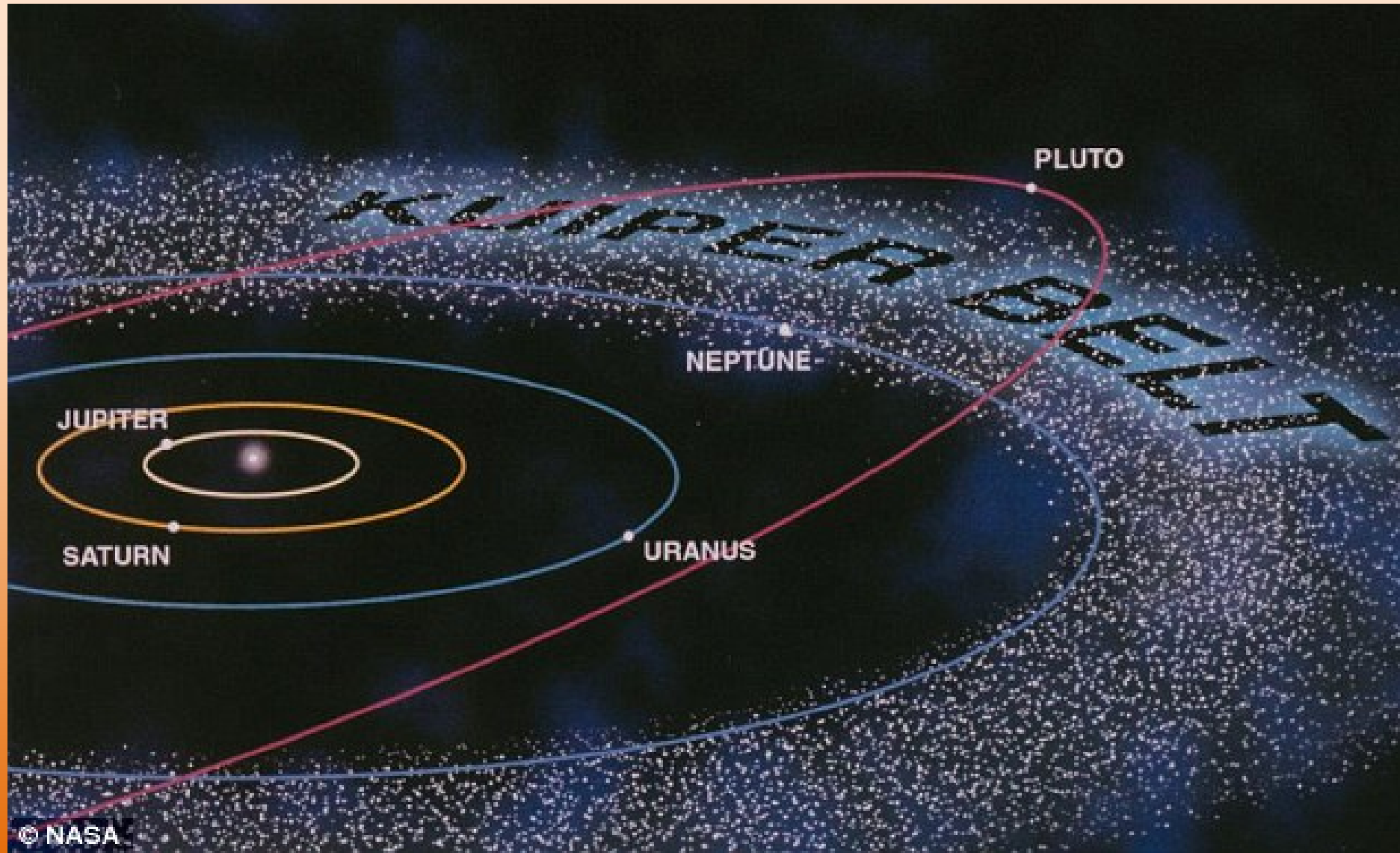
- A Recent [study](#) suggests at least two more “planets”, large enough to have enough gravity to orient orbits (by the “[Kozai Mechanism](#)”) away from the pure random orientations otherwise expected.
- Average inclination of orbits not 0, and perihelion point should, by selection effects, be near 180 degrees, and instead it’s 31 degrees.
- Support: Observed disks around a few other stars extend to a few hundred AU, so maybe planets could form that far out.
- Problems: very small sample of KBO’s. Sample size should get much better soon, so stay tuned.

Beyond Neptune, the Proto-Planetary Disk was Apparently Too Low Mass to Make More Large Planets

- Instead, the material here froze into thousands of objects a few hundred kilometers across or less. The rate of production of short-period comets suggests there are about 100,000 KBO's out there.
- A very few, have diameters over 1000 km, and most of these have now likely been discovered, at least in the inner Kuiper Belt where they are brightest

The “[Nice Simulation](#)” (After the French city Nice) where the simulations were done) of the Early Solar System evolution, suggests a 2:1 resonance between Jupiter and Saturn changed their early orbits, inducing Neptune to migrate beyond Uranus, and scattering the planetesimals of the Kuiper Belt







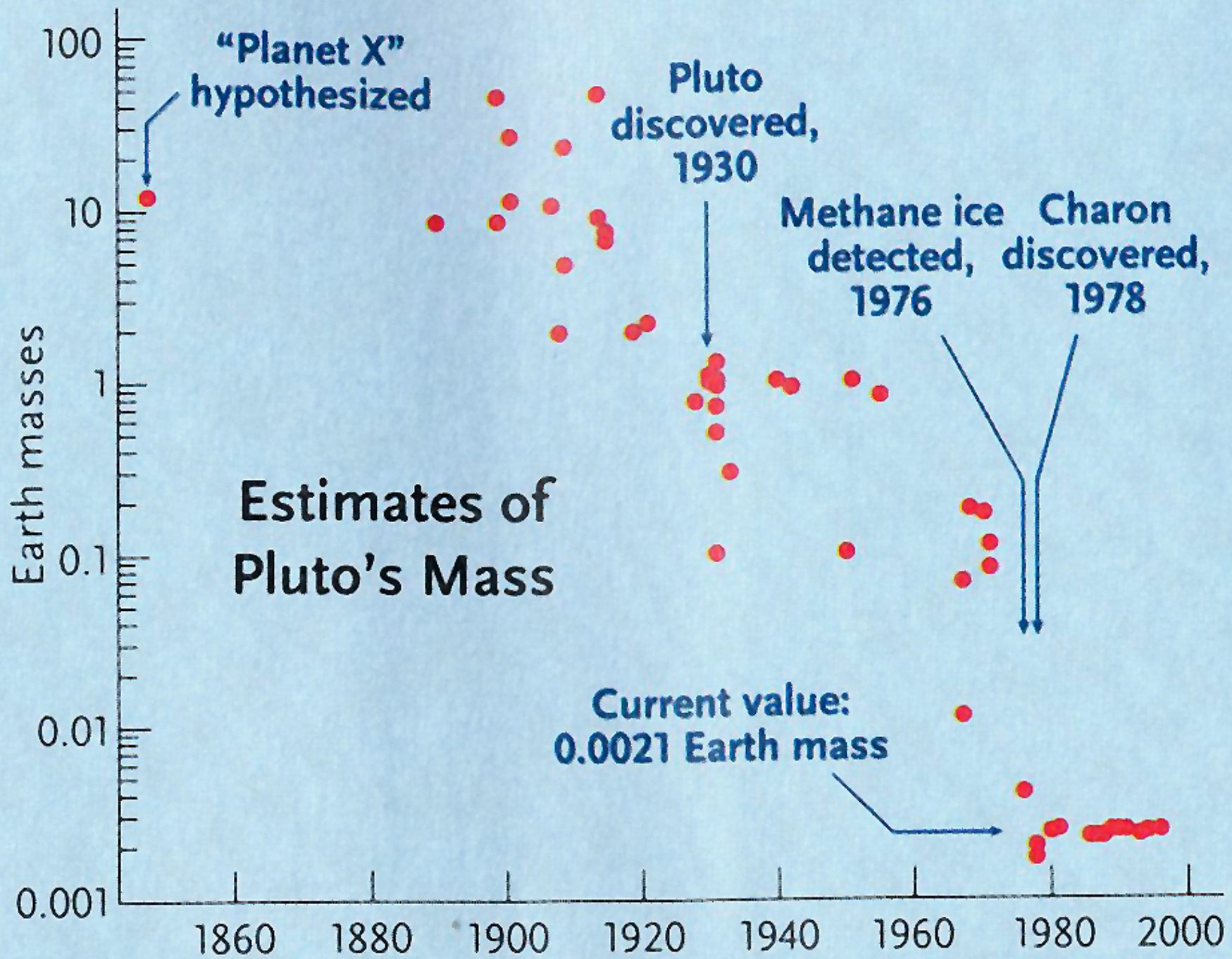
Oort Cloud cutaway drawing adapted from Donald K. Yeoman's illustration (NASA, JPL)

Collisions between Kuiper Belt Objects Thought to be the Main Source of Short-Period Comets

- Simulations show that at the relative velocities KBO's experience, that the pieces from collisions would result in many losing angular momentum and falling in on the highly elliptical orbits, like short-period comets have.
- Short period comets – a few miles across, not hundred(s) of miles across like KBO's.
- Highly elliptical orbits falling deep in towards the sun, where sunlight makes them easy to see (and fun to watch!)

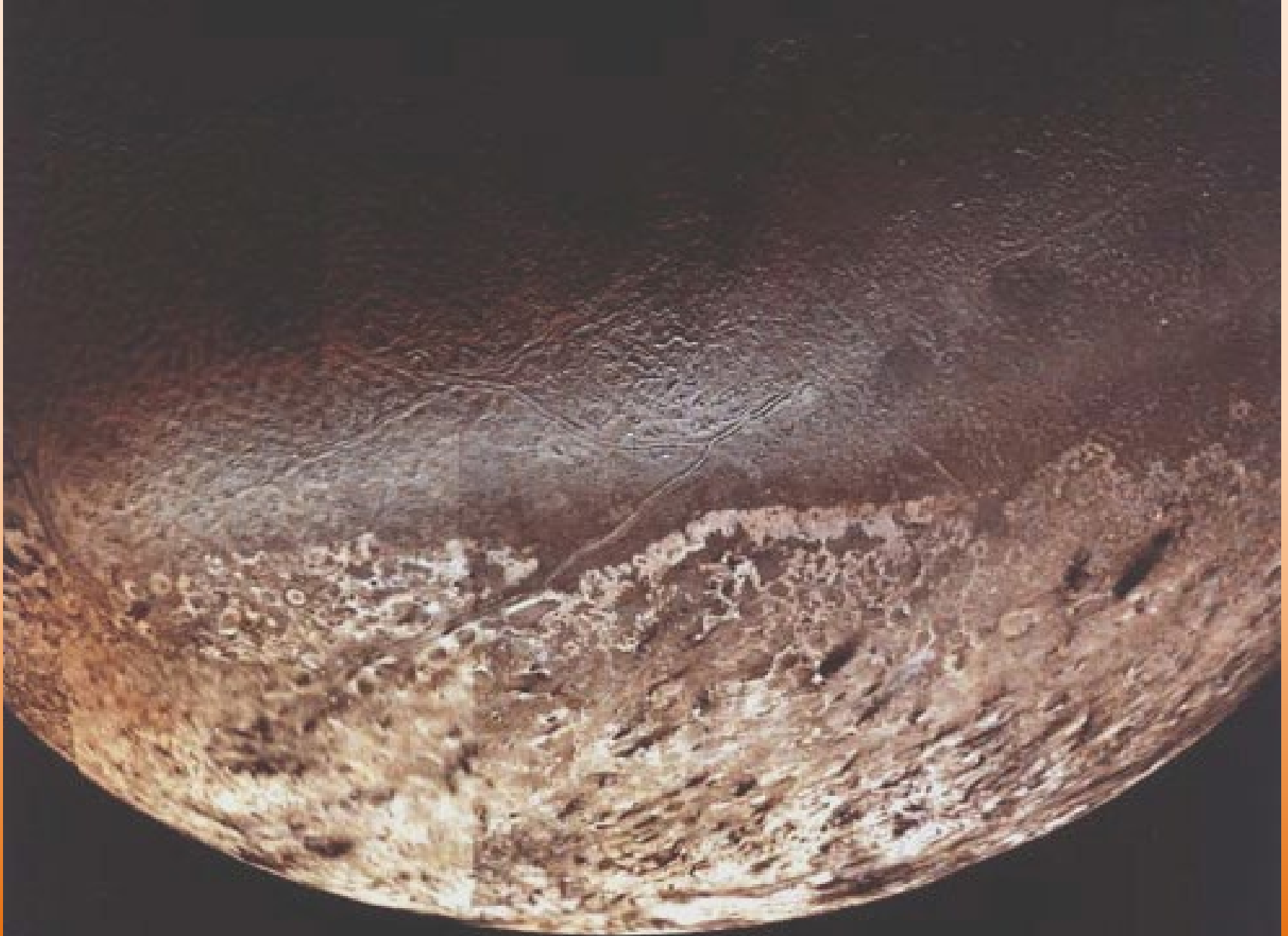
The Most Famous KBO: Why we kicked Pluto out of the planet club

- Several reasons:
- – It fails the first criterion for a planet – A planet will gravitationally clear its own orbital range
- – It has a highly inclined and elliptical orbit which crosses Neptune: an orbit like a comet, not a planet.
- – it's one of thousands of small objects out there; a new class of objects – the **Kuiper Belt Objects or KBO's**. We had indirect evidence they are probably out there as early as the 1950's, but didn't have the technology to discover directly until the the 1990's. Pluto was discovered in way ahead of its time, in 1930.
- – Its mass is tiny..... Check out this history...



SOURCE: ROBERT C. MARCIALIS / UNIV. OF ARIZONA

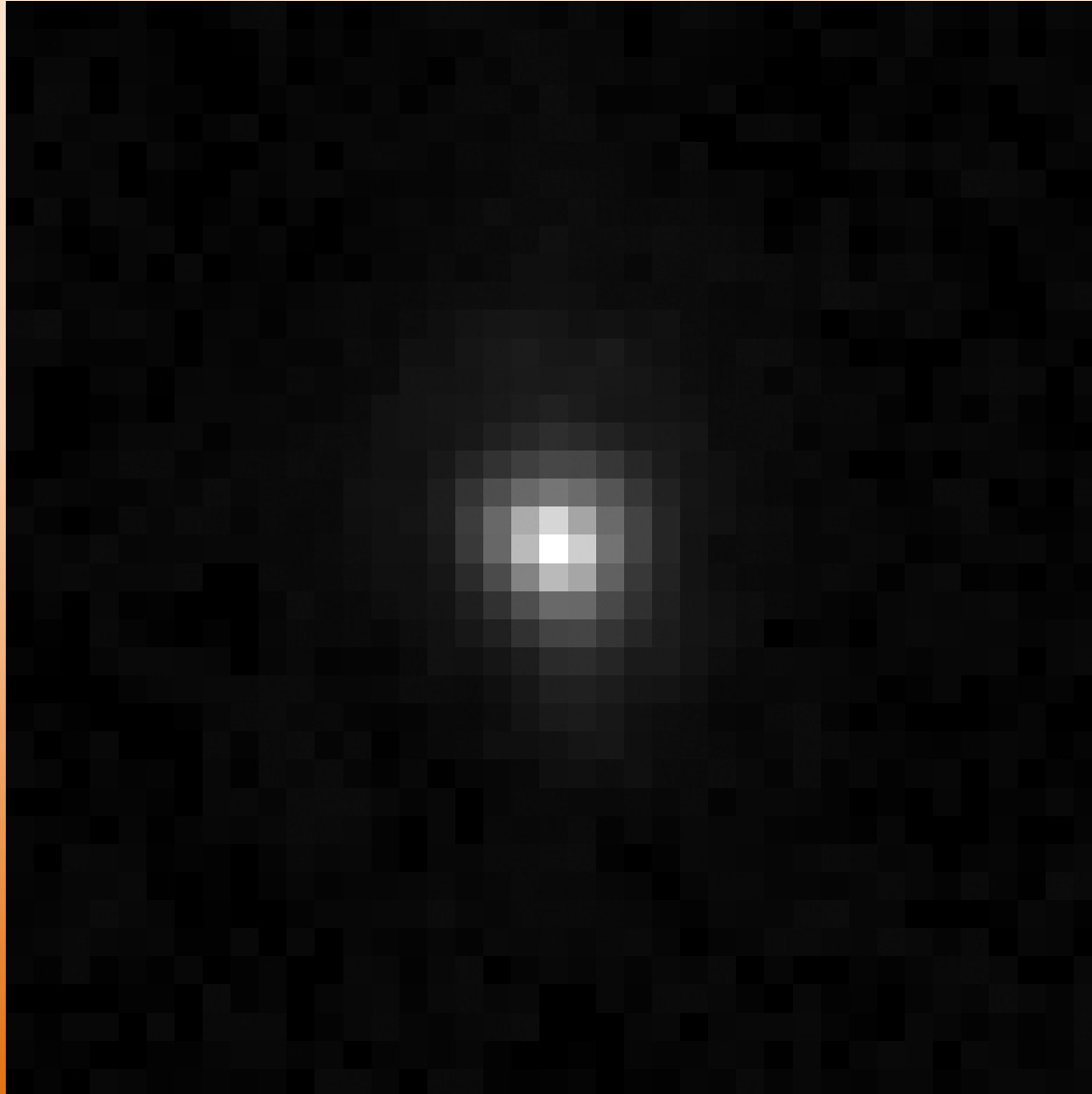
Triton – The first KBO photographed up close



Triton, the large moon of Neptune, must be a former KBO since it orbits Neptune backwards in a very elliptical orbit

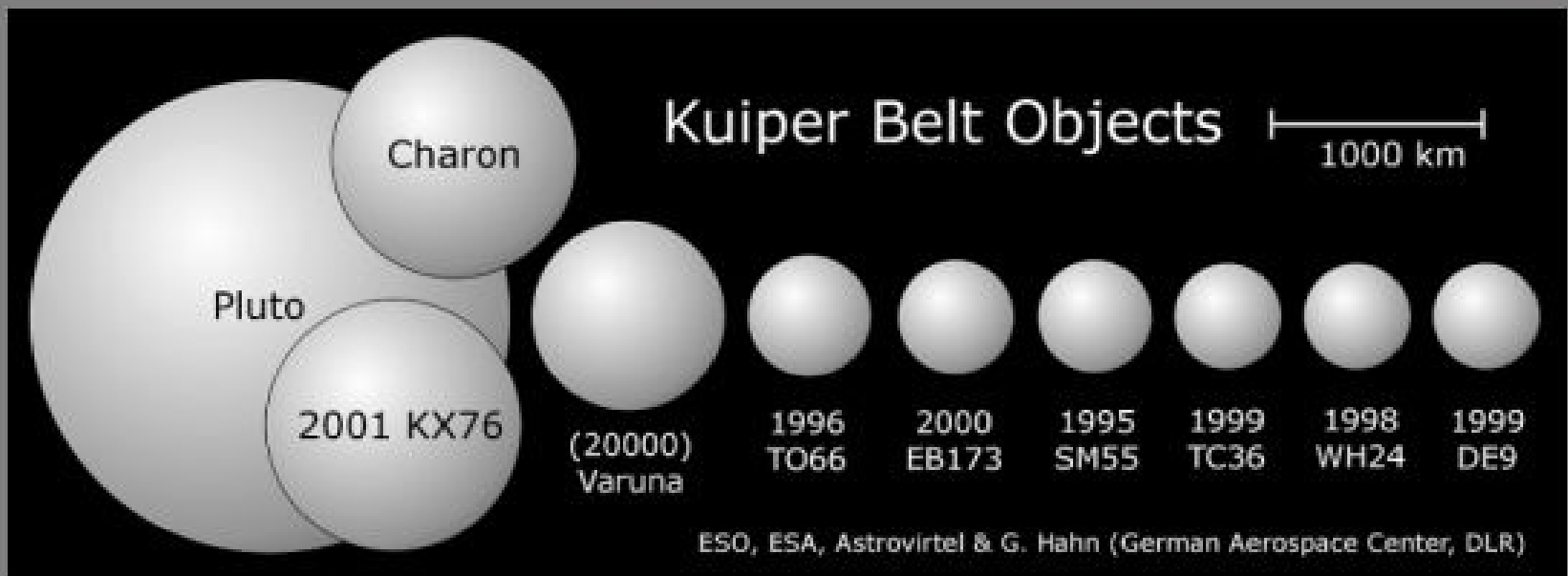
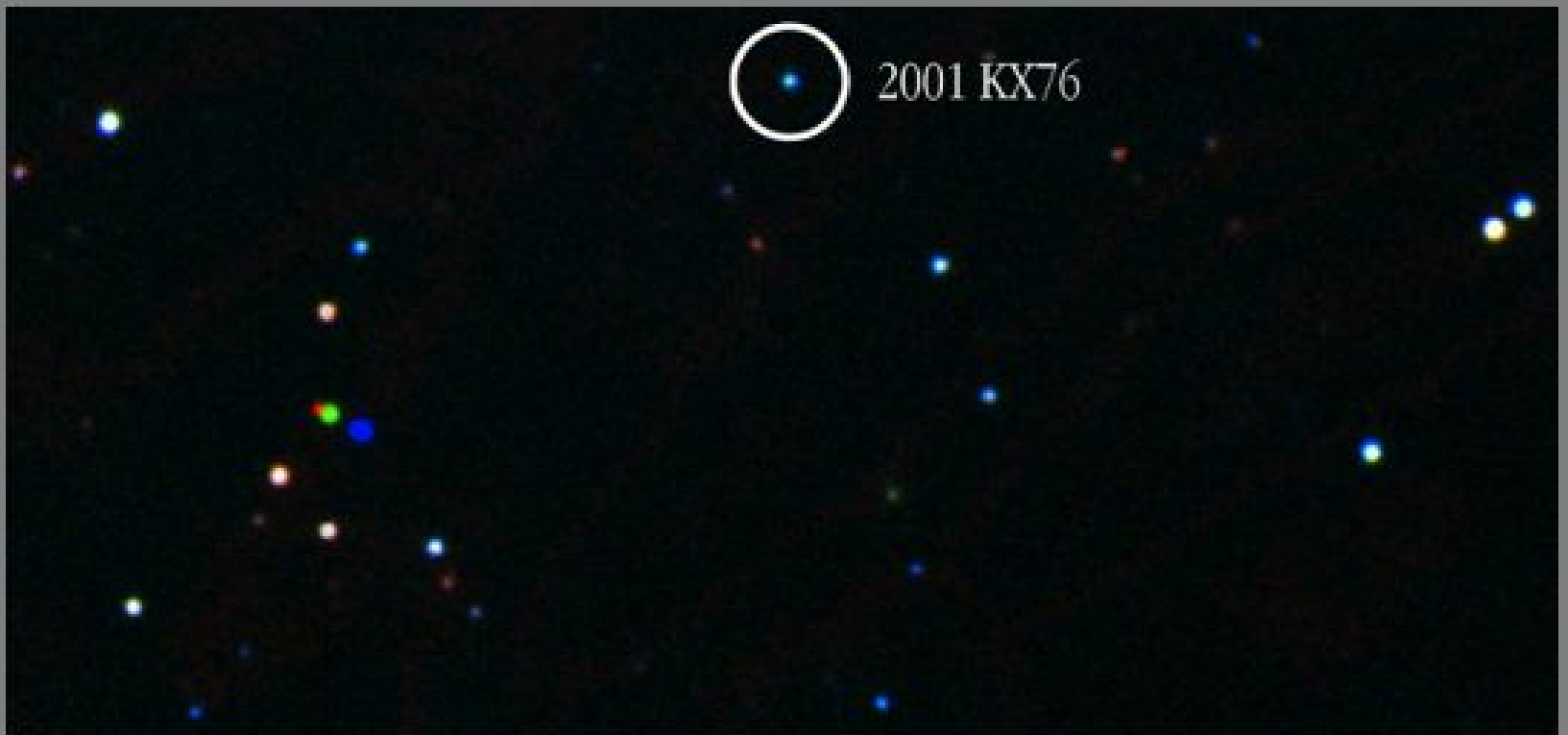
- Frozen N₂ on the bottom (polar) region, and cantalope surface of other ices near equator.
- Black carbon-spewing geysers in the thin Nitrogen frost polar region, where perhaps absorbing solar radiation by the dark stuff causes vaporization of the Nitrogen and fracture/geysering.

Eris (aka 2003 UB313) – Just slightly smaller than Pluto



Largest KBO's: Comparison with Earth/Moon

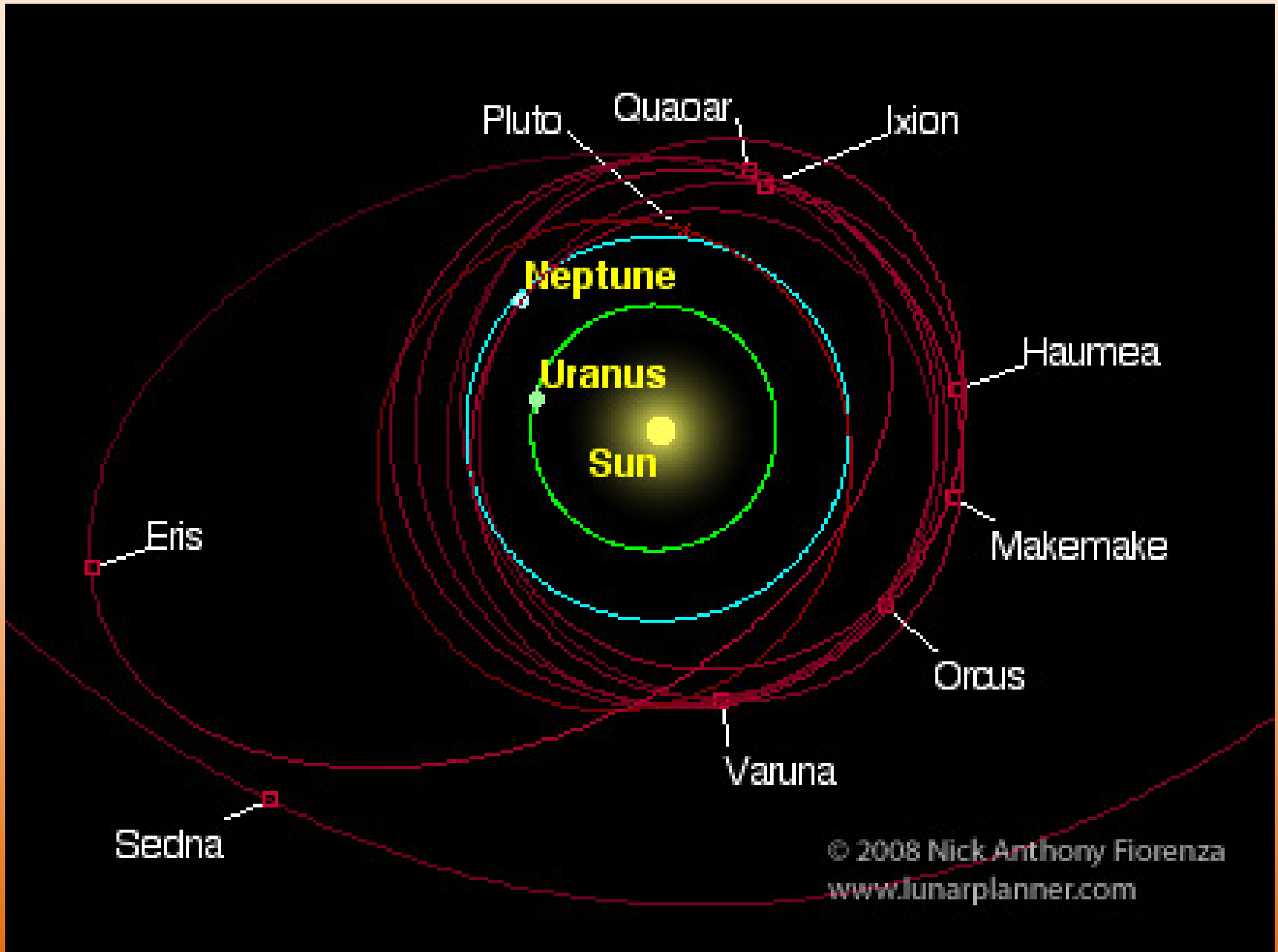




Largest known trans-Neptunian objects (TNOs)



Orbits of the Larger Discovered KBO's



The New Horizons Mission to Pluto

- Launched in 2003, arrived at Pluto on Bastille Day 2015 (July 14)
- We had a [“Pluto-Palooza!” event at Cabrillo Observatory](#) to show the local school kids the very first images coming in.
- Amazing images of a surprisingly active surface for such a cold tiny place...

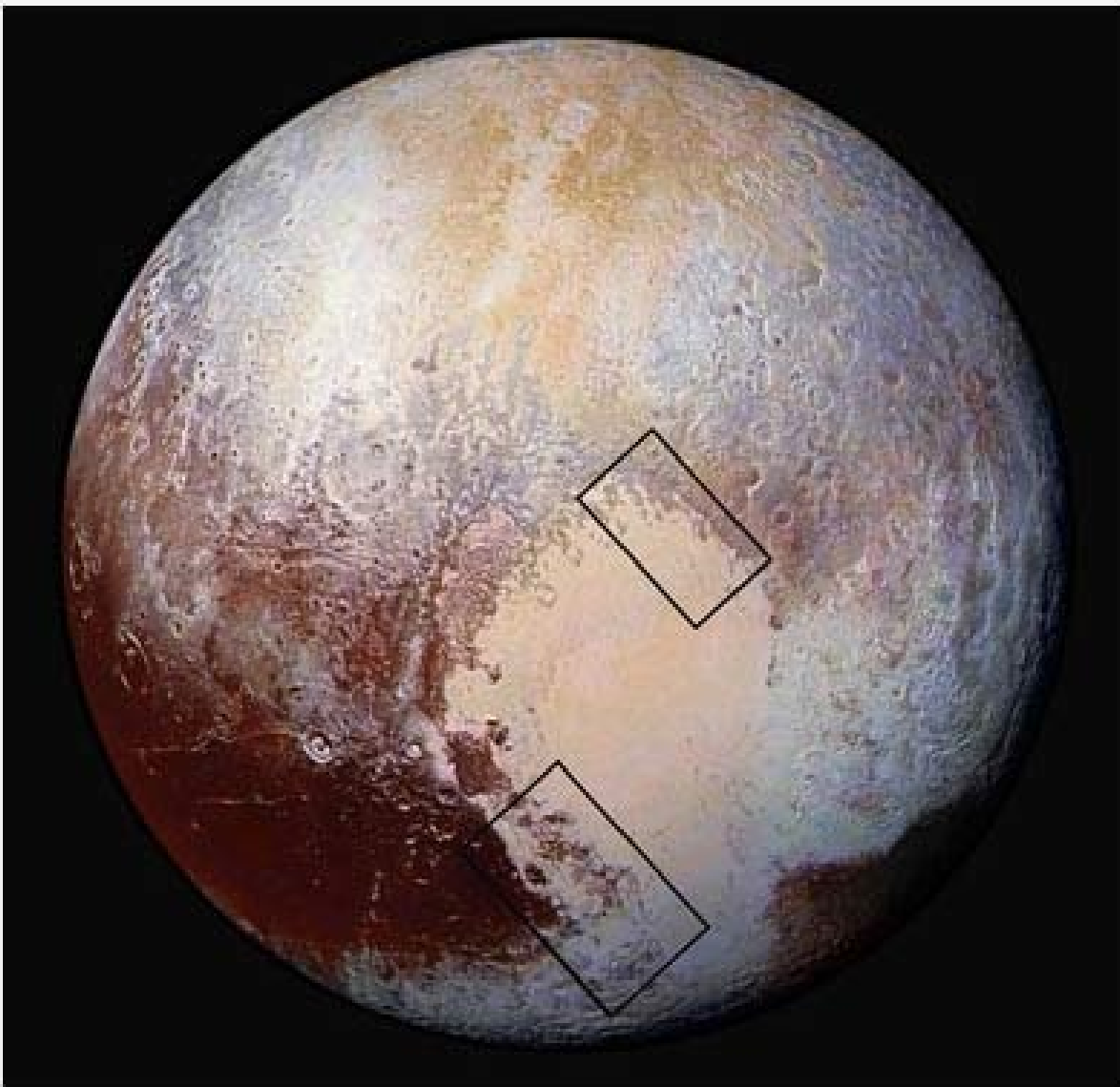
Pluto and its Very Large Moon Charon



Pluto, Up Close Thanks to New Horizon Mission Flyby



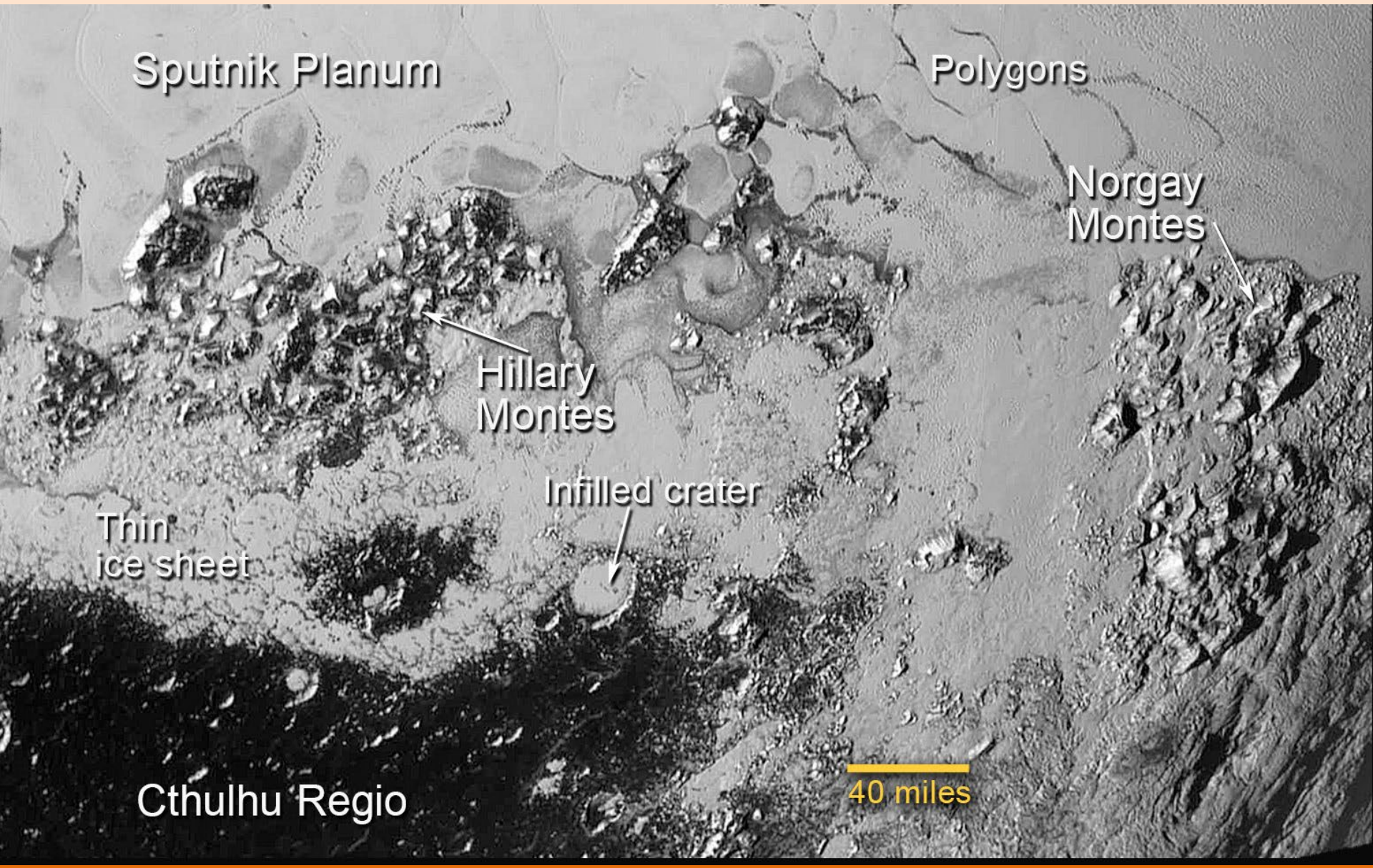
False Color



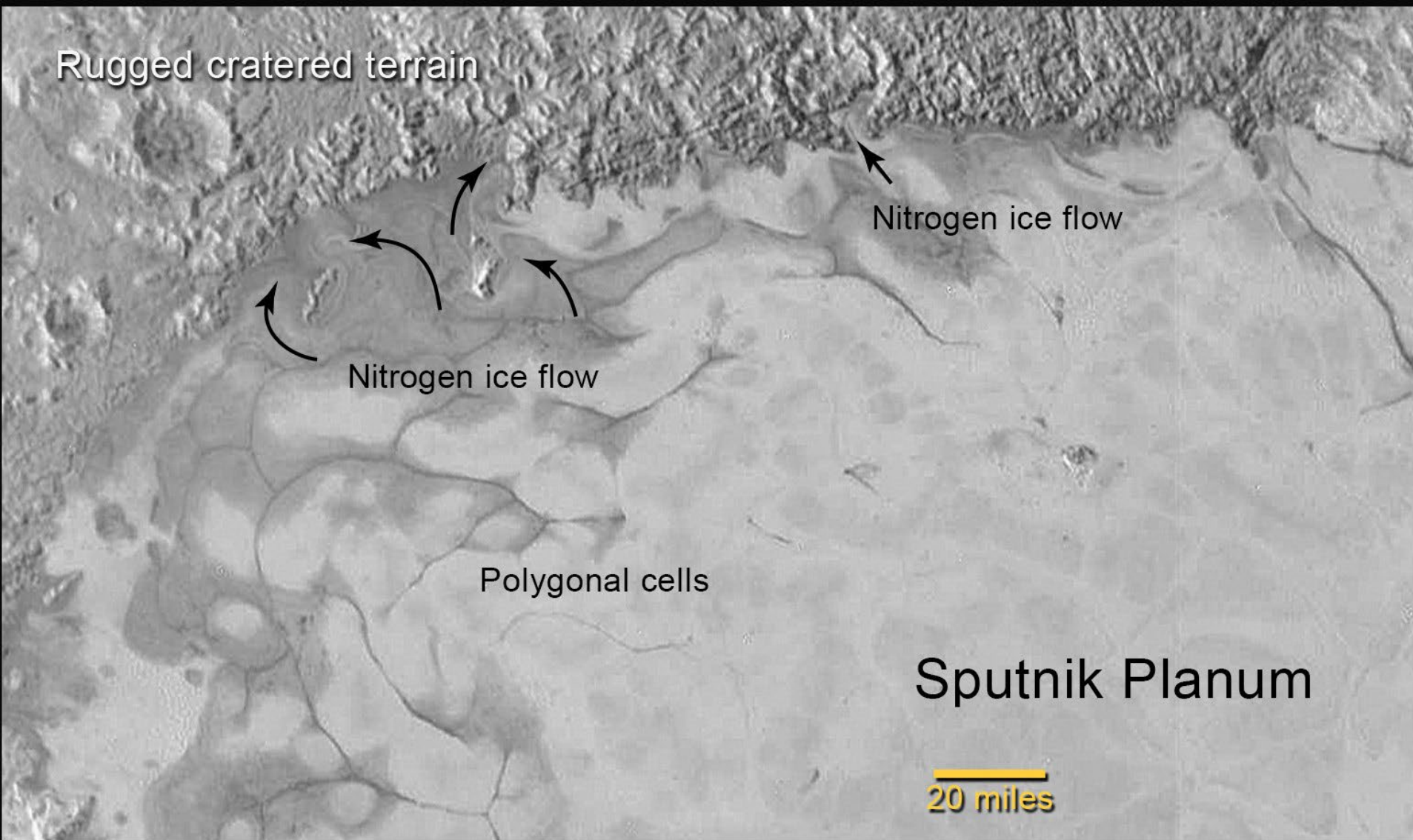
The big heart-shaped plain now called **“Sputnik Planum”**. Boxes show two regions we’ll see in greater detail. Lower left is the next slide...

Four images from New Horizons’ Long Range Reconnaissance Imager (LORRI) were combined with color data from the Ralph instrument to create this enhanced color global view of Pluto. Rectangles indicate the areas seen in greater details below.
NASA / JHU-APL / SWRI

Lower Left Box in Detail: The southern region of Pluto's Sputnik Planum contains newly discovered ranges of mountains that have been informally named Hillary Montes and Norgay Montes, in honor of Sir Edmund Hillary and Tenzing Norgay, the first two humans to reach the summit of Mount Everest in 1953.



Upper Right Box: No craters on Sputnik Planum - says it can be at most a few million years old. Some process must regularly re-surface these areas

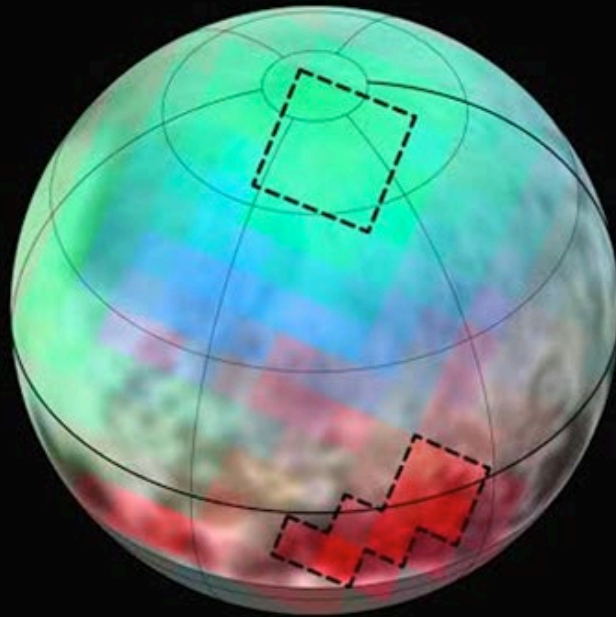


**Plutonian mountains above a flat plane of frozen nitrogen.
Pluto's mountains are ~10,000 ft high - as high as the Sierras.
Surprising given how cold it is there**

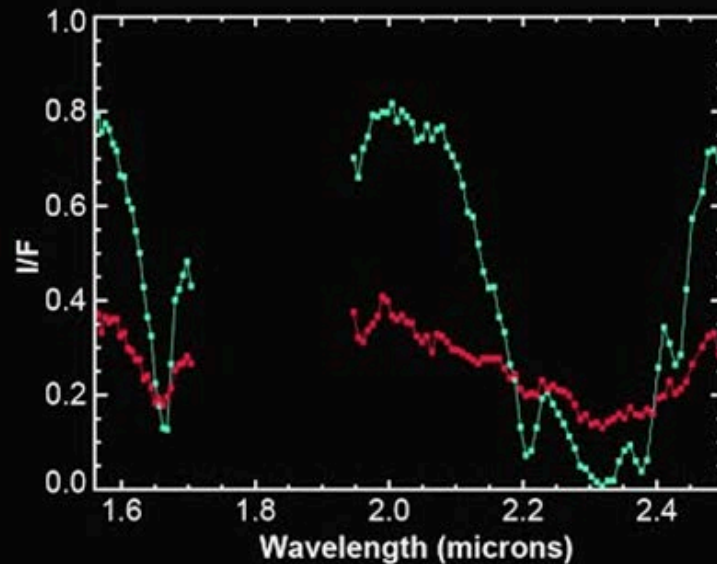


Reflection spectra show molecular bands, telling us the surface chemistry

Methane on Pluto



Infrared Spectral Image



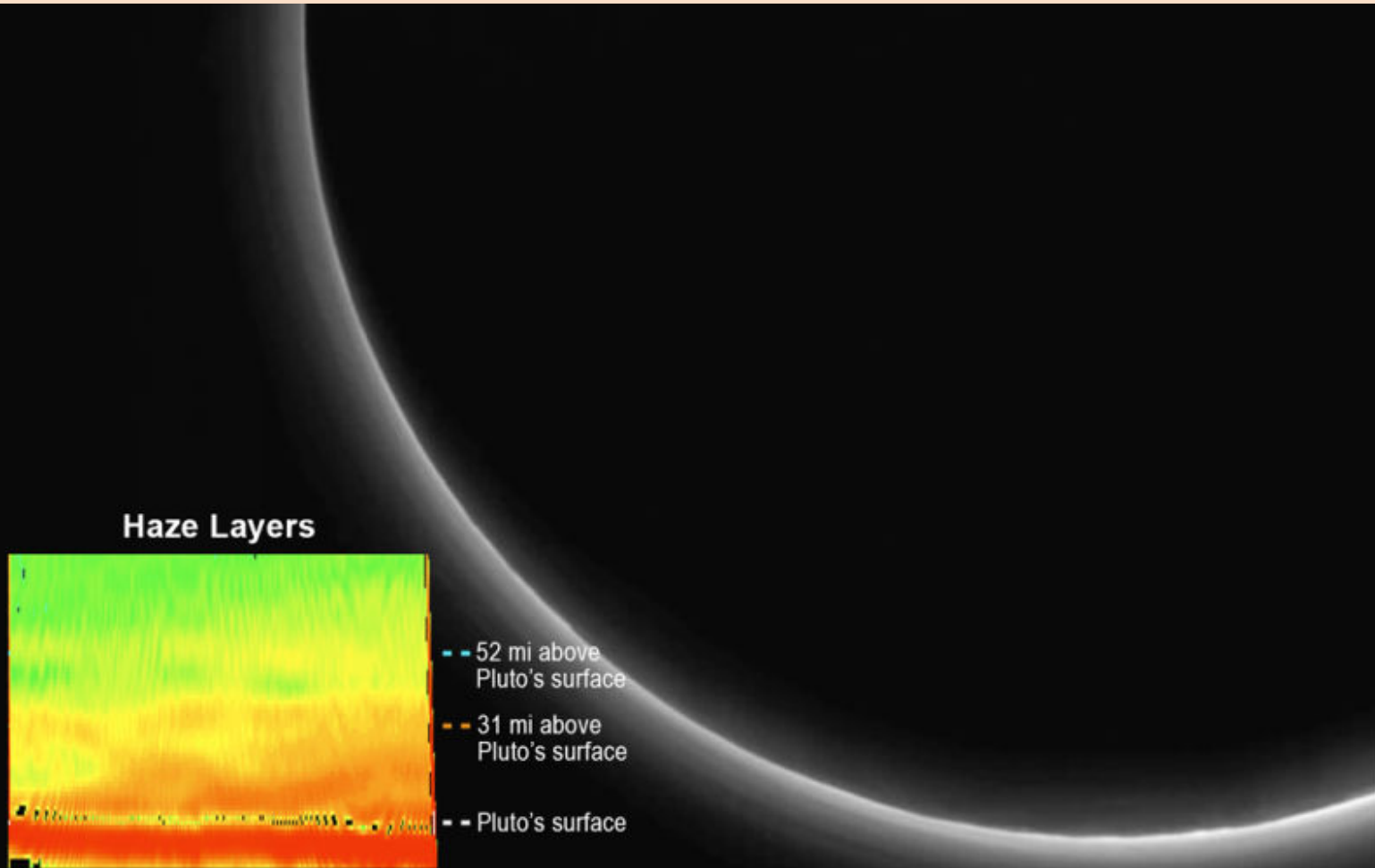
Glacial Nitrogen on Pluto

- Nitrogen freezes at a temperature of -210°C or 346°F below zero; this is warmer than the temperature of Pluto's daytime equator, which is -390°F now (-375°F at perihelion, in 1989).
- Pluto is entering a century long winter now, its thin nitrogen atmosphere freezing out onto the ground now as the Mission arrived.
- Nitrogen and CO are lightly frozen and flow like glaciers at Pluto's current temperature of -390°F

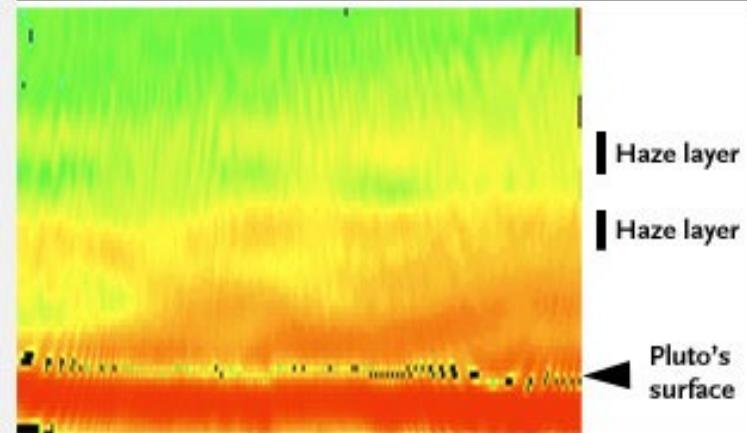
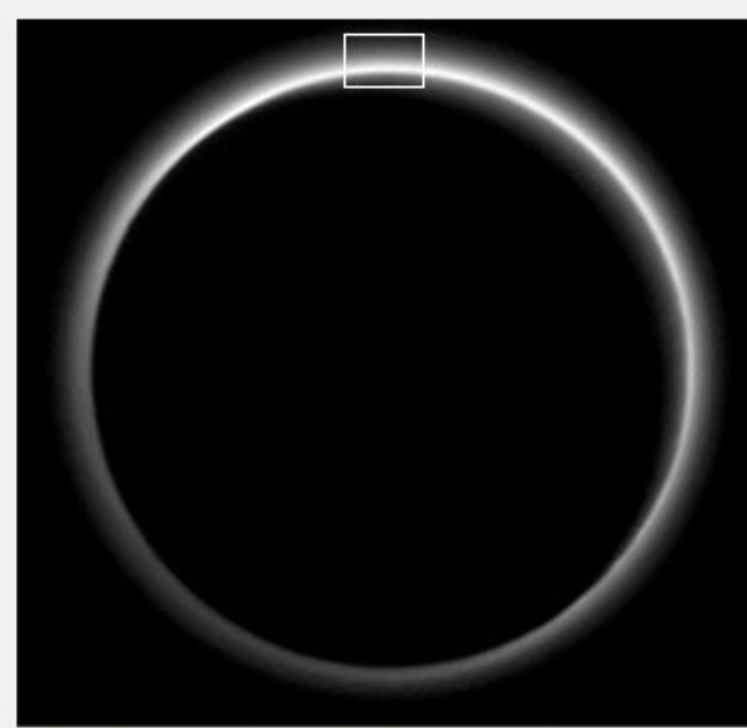
Pluto, backlit by the sun, showing the thin atmosphere of 90% N₂ and 10% organics. If all of it were frozen onto the ground, it would coat Pluto with a layer of frost only 1 mm thick



**False-color shows density of haze layers.
Organics most likely. Surface pressure is
1/100,000 that of Earth**



The atmosphere appears to have some structure; layers, and also higher and lower pressure regions. Pluto spins once in 6.5 days, so there is a Coriolis force and a weak solar temperature gradient which might produce a bit of “weather”?

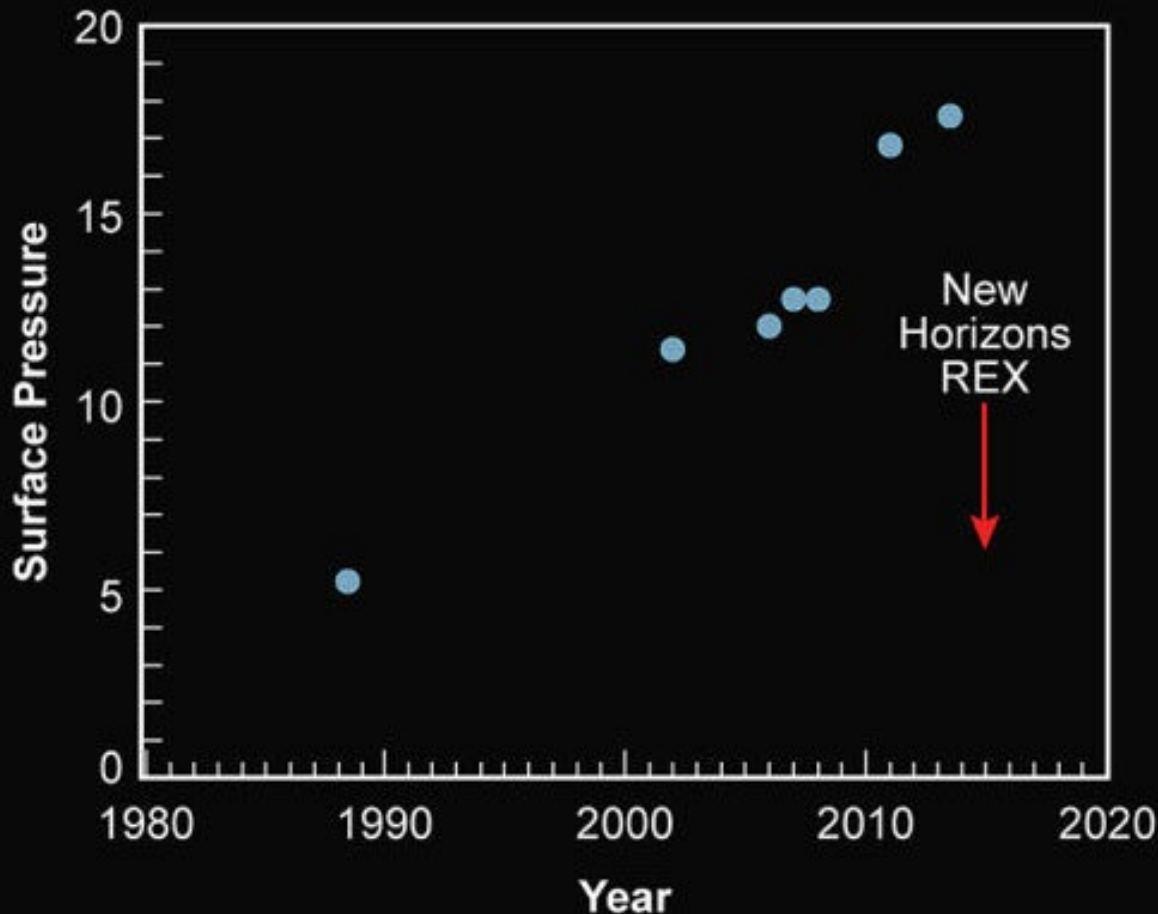


About 7 hours after coming closest to Pluto on July 14, 2015, New Horizons slipped into Pluto's shadow and captured this view of its tenuous yet hazy atmosphere backlit by the Sun. The haze extends much farther than expected, and it contains at least two distinct layers.

NASA / JHU-APL / SWRI

Pluto was closest to the sun in 1989 in its 248 year orbit. Thermal inertia makes our hottest summer days in August and not June. Likewise, Pluto's atmosphere was actually thickest right before New Horizon Arrived, and its now re-freezing (red arrow).

Changes in Pluto's Surface Pressure



Pluto's moons

Hydra
36 x 21 miles



Kerberos
Diameter = 19 miles



Nix
35 X 16 miles



Charon
Diameter = 750 miles



Styx
Diameter = ? miles



Nix

Hydra

enhanced color

black and white

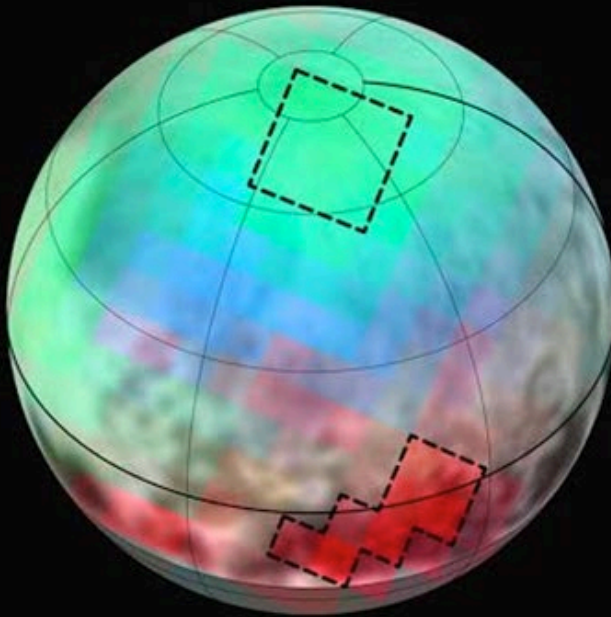
New Horizons recorded these images of two of Pluto's four small moons. Nix has an irregular shape (seen here roughly end-on in false color); it's about 42 km (26 miles) long and 36 km (22 miles) wide. Hydra appears roughly spherical and is 55 km (34 miles) across.

NASA / JHU-APL / SWRI

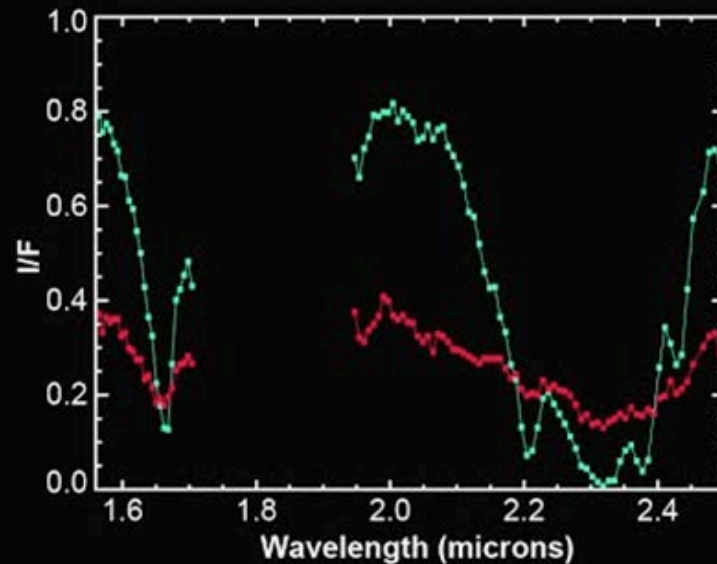
Two of
Pluto's 5
moons.
Cool
[animation](#)
of the
rotation of
all moons

Methane ice (too cold to be a gas) on Pluto. Distribution and texture varies

Methane on Pluto



Infrared Spectral Image





**A Large KBO in
its own right –
Pluto's moon
Charon
(pronounced
"Sharon")
Clearly a
complex
history needed
to explain
Charon's varied
surface.**

Young and Geologically Active Charon

- Surprising, given how small and cold it is. But the steep long cliffs show powerful tectonic fracturing
- The lack of craters over large areas shows it has major areas that are young.
- The large dark area looks to be an ancient impact crater

And Last – There's the Object MU69

- This is a KBO which will be visited by the New Horizons spacecraft in 2018. Important to get precise shape and orbit for this in order to plan that encounter properly.
- MU69 had 3 predicted occultations of stars in 2017. Much effort and NASA money went into trying to get these events.
- Here's a [9 min high quality video](#) of what it's like to be part of a big occultation effort.

Key Points – Chap 12 Kuiper Belt

- Pluto is not a planet, but instead the largest KBO
- KBO orbits are more elliptical, less confined to ecliptic plane
- KBO's are mostly ice, surfaces of Pluto and Triton have frozen nitrogen
- Pluto system shows tectonic activity, icy volcanism from water/ammonia or other cryovolcanic mixtures?
- Pluto's mountains are as high as the Sierra – surprising given there are no tectonics and only cryovolcanism
- Collisions between KBO's almost certainly are the source of short-period comets.
- Despite small size and weak gravity, many KBO's have moons, even tiny Pluto has at least 5.