

Today

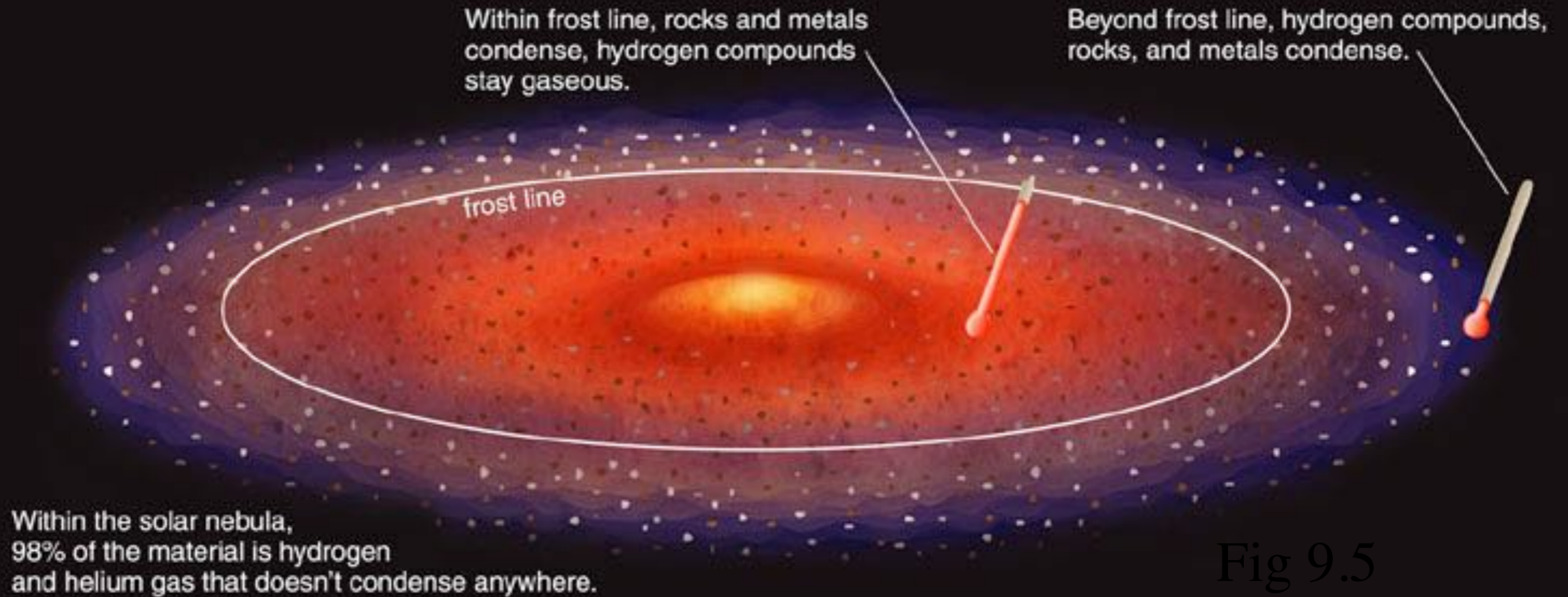
- The Little Things
 - Comets
 - Dwarf Planets

Last Exam in last class,
Thursday Dec. 7.
Homework also due then.

Comets



a Comet Hyakutake.



FROST LINE at about 3.5 AU

Inside the *frost line*: Too hot for hydrogen compounds to form ices
- only get rocky asteroids and planets

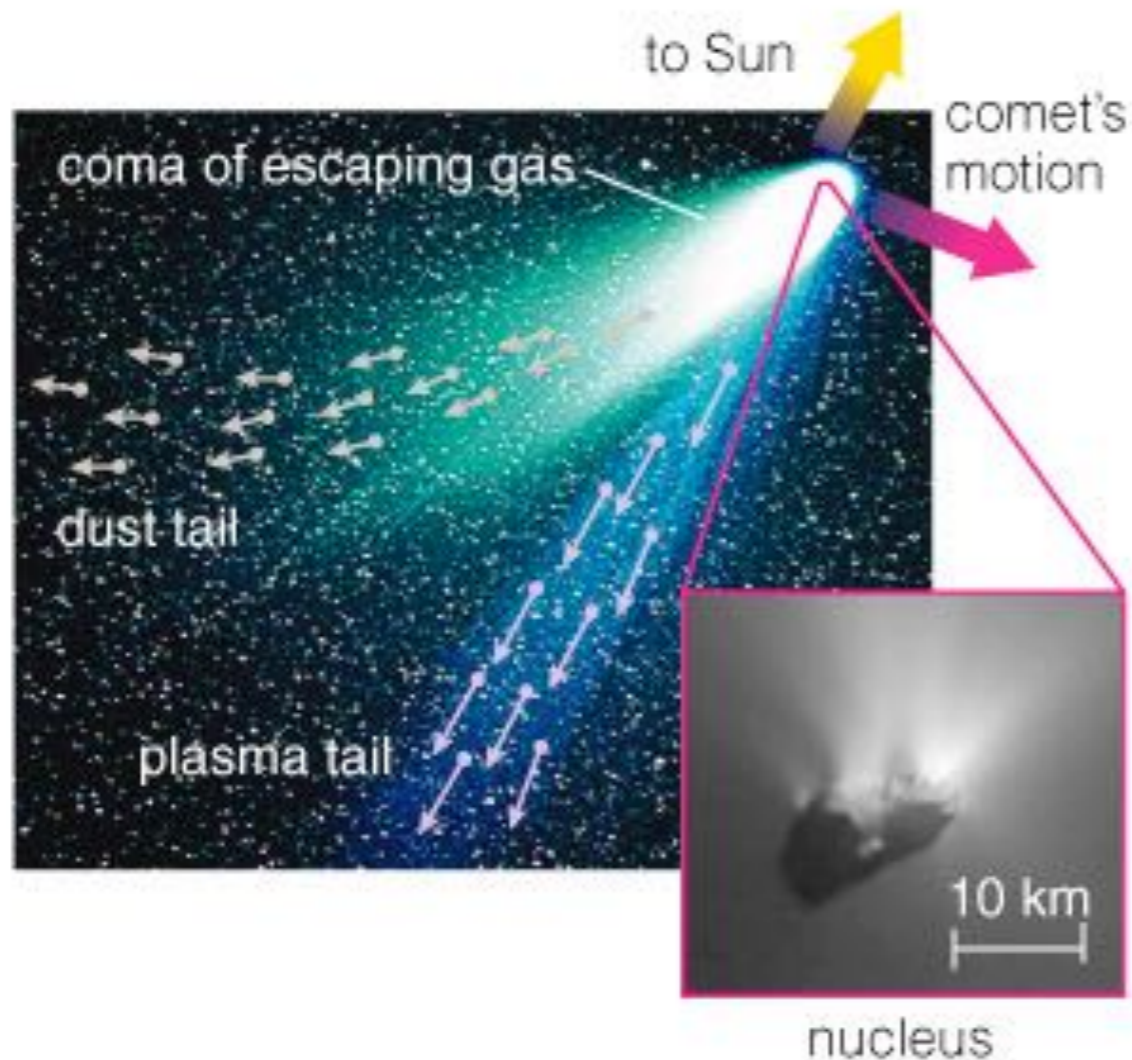
Outside the *frost line*: Cold enough for ices to form
- get icy moons and comets
- ice is a major component of their total mass

Comet Facts

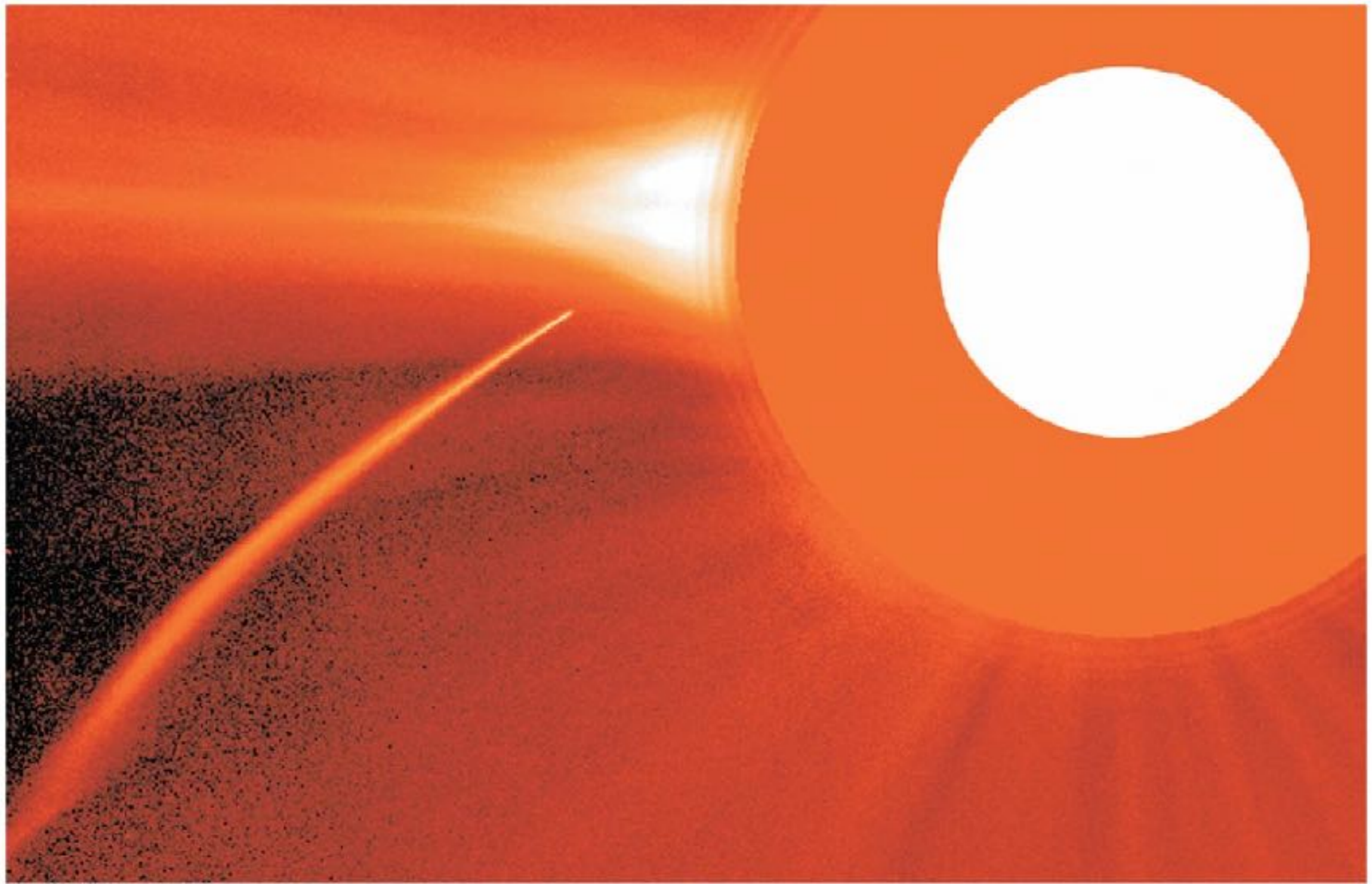
- Formed beyond the frost line, comets are icy counterparts to asteroids.
- Nucleus of comet is a "dirty snowball."
 - rubble pile of ice, rock, & tar with a hard coating
- Most comets remain perpetually frozen in the outer solar system and never develop tails.
- Only comets that enter the inner solar system grow tails.
 - i.e., the “apparition” of a comet is its brief-lived summer season while it is inside the ice line.
- Most comets on highly elliptical orbits
 - often highly inclined (out of ecliptic plane)

Anatomy of a Comet

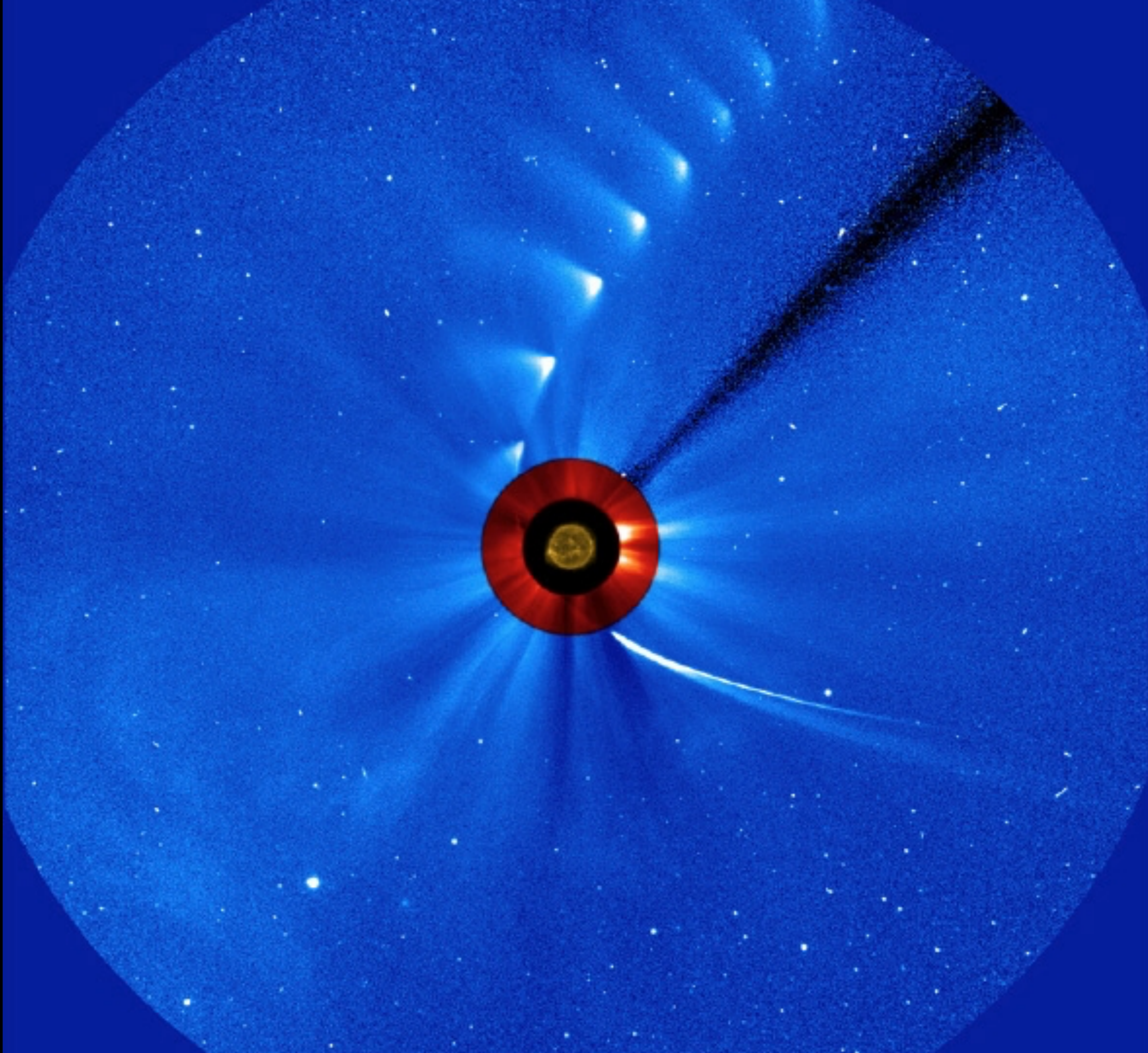
- Nucleus: actual object
- Coma is atmosphere that comes from heated nucleus.
- Plasma tail is gas escaping from coma, pushed by solar wind.
- Dust tail is pushed by photons.
- Larger debris follow comet's orbit; source of meteoroids.



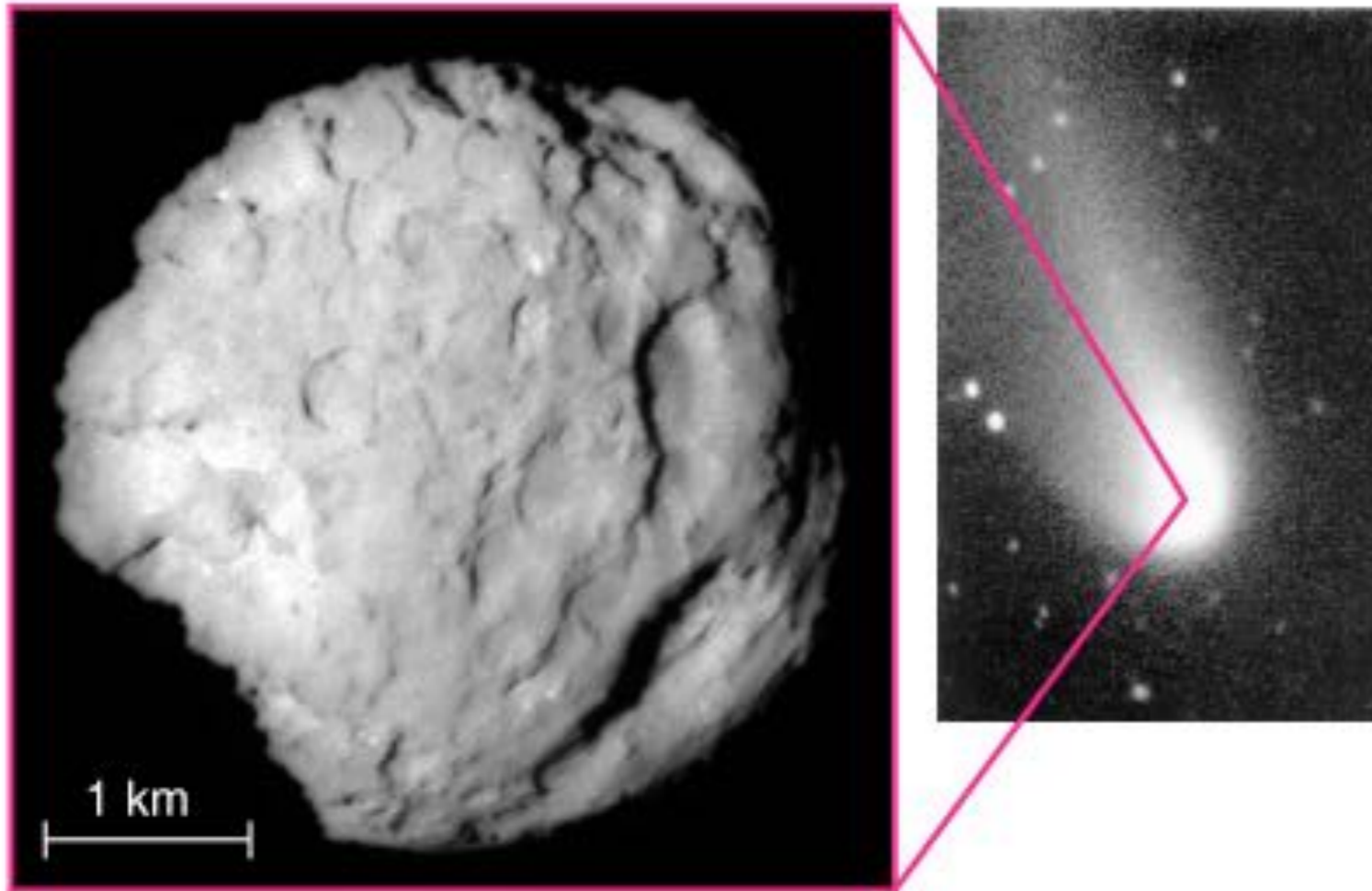
Sun-Grazing Comet



Time-lapse of a sun grazing comet evaporating



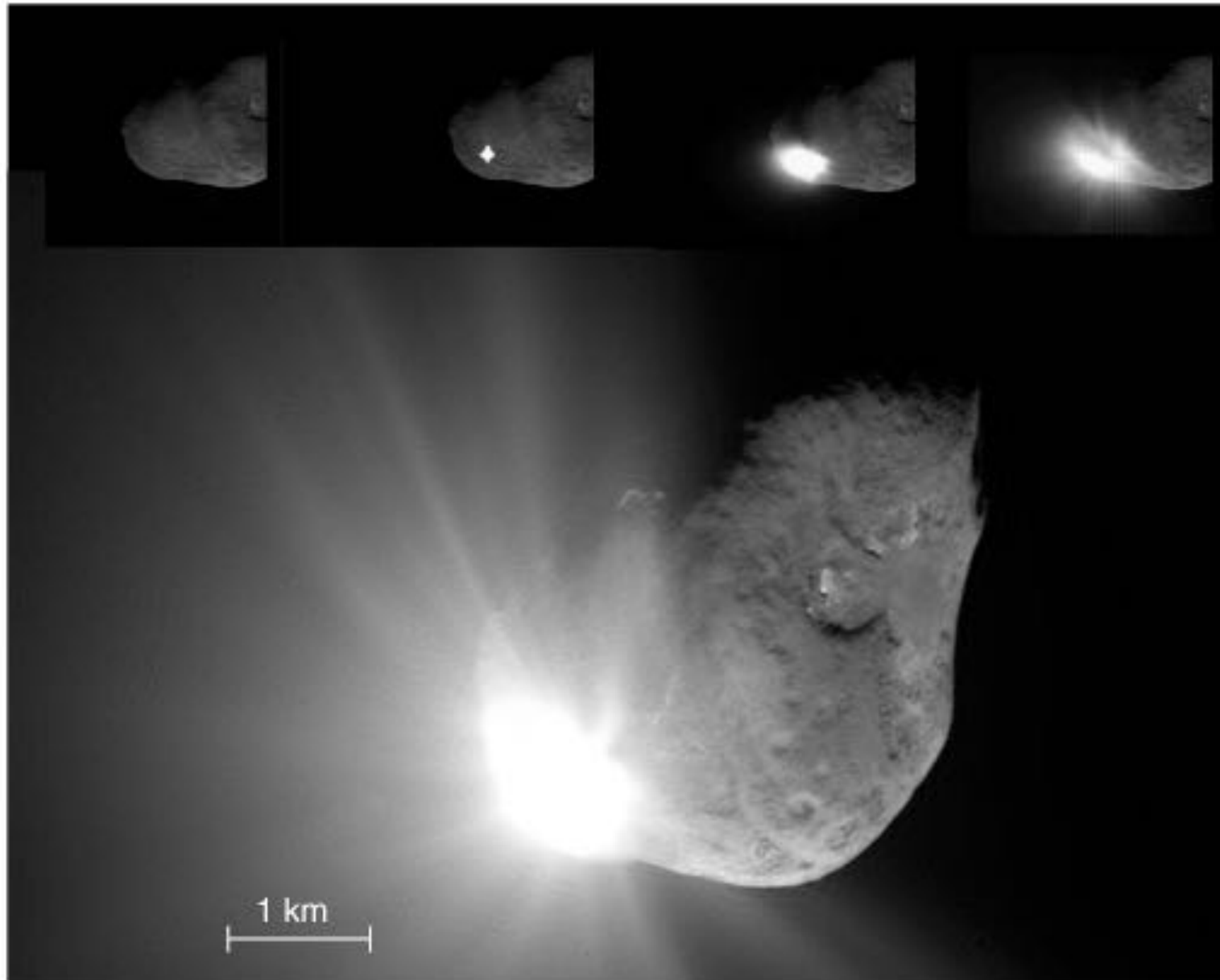
Nucleus of Comet



- A “dirty snowball” -
- a combination of rock, ice, and carbon-rich “tar”

- Source of material for comet’s tail -
- Tail only appears when comet nears the sun: ices are heated into vapor, forming coma and tail.

Deep Impact



- Mission to study nucleus of Comet Tempel 1
- Projectile hit surface on July 4, 2005
- Lots of ices (as expected) but also a lot of tarry hydrocarbon materials

Wild 2



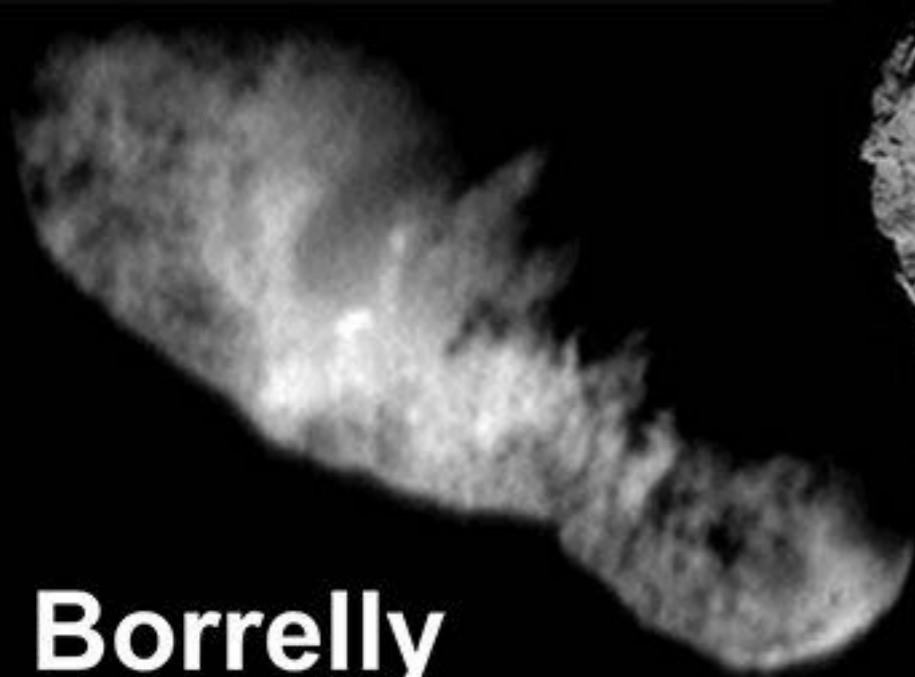
Halley



Hartley 2



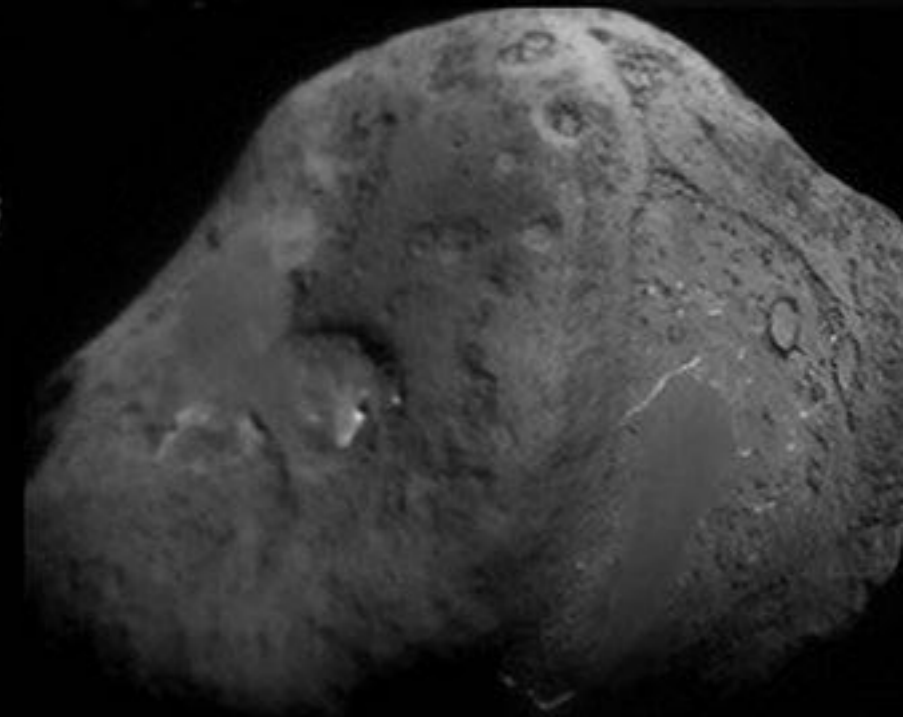
Borrelly



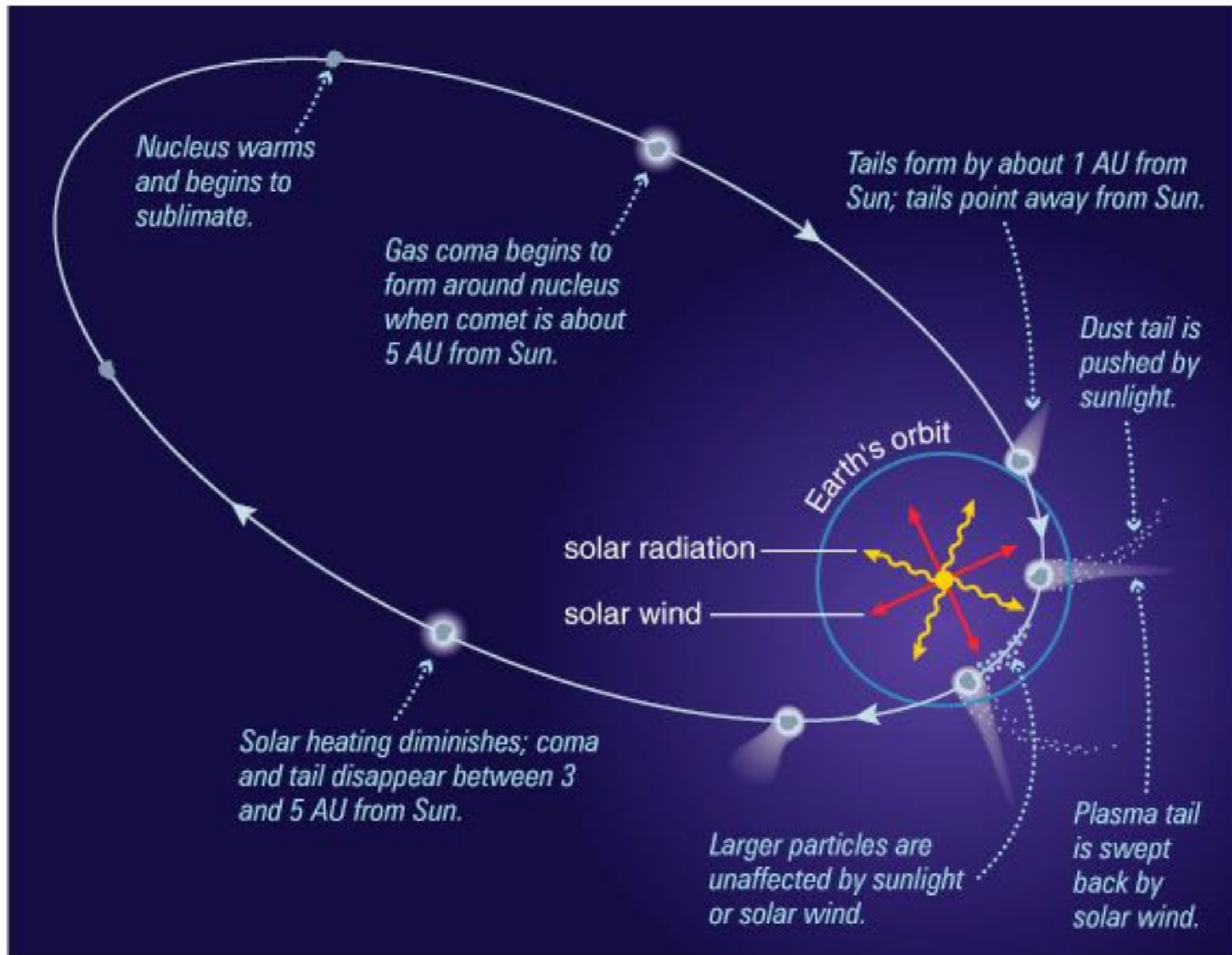
Churyumov–Gerasimenko



Tempel



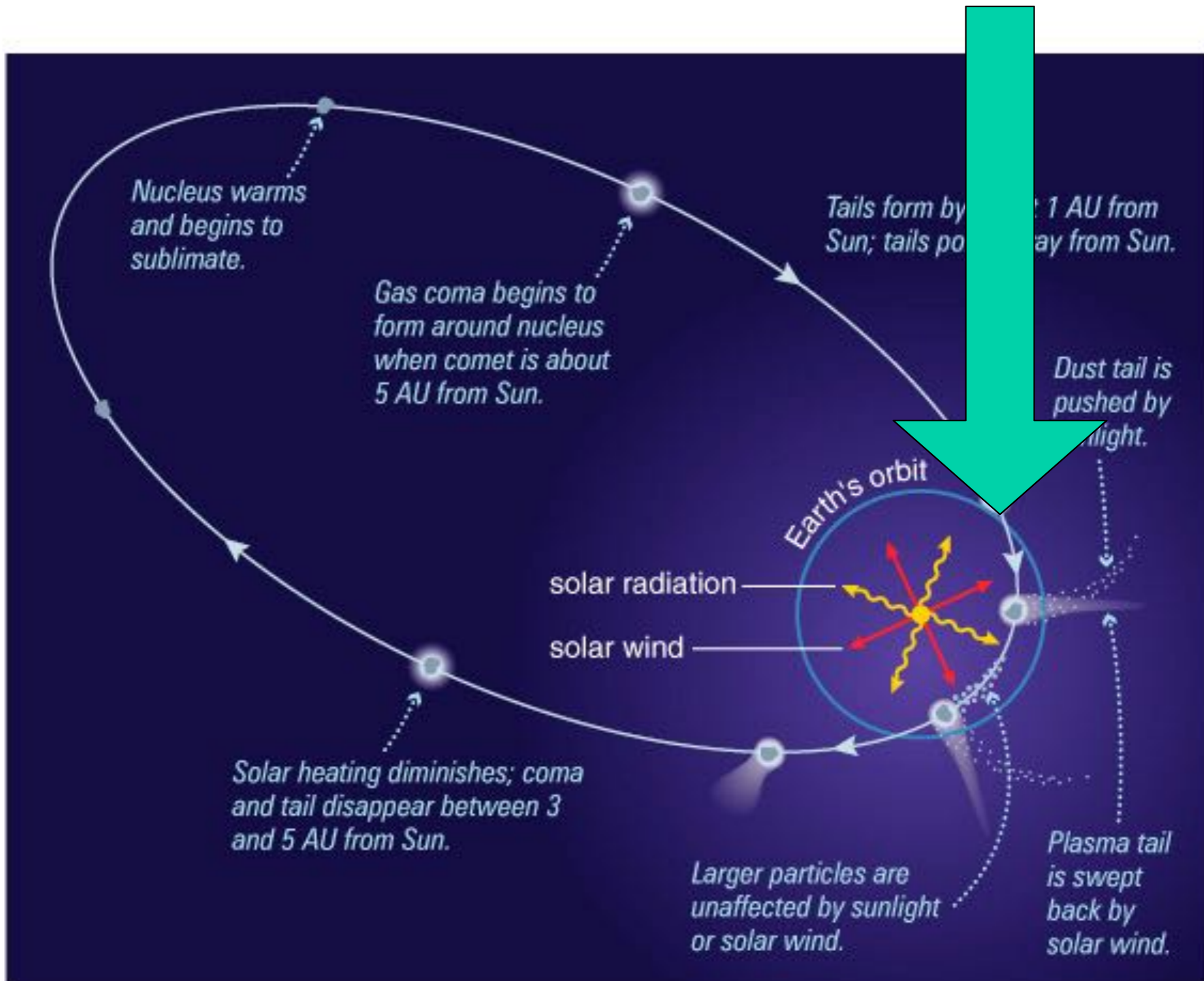
Growth of Tail

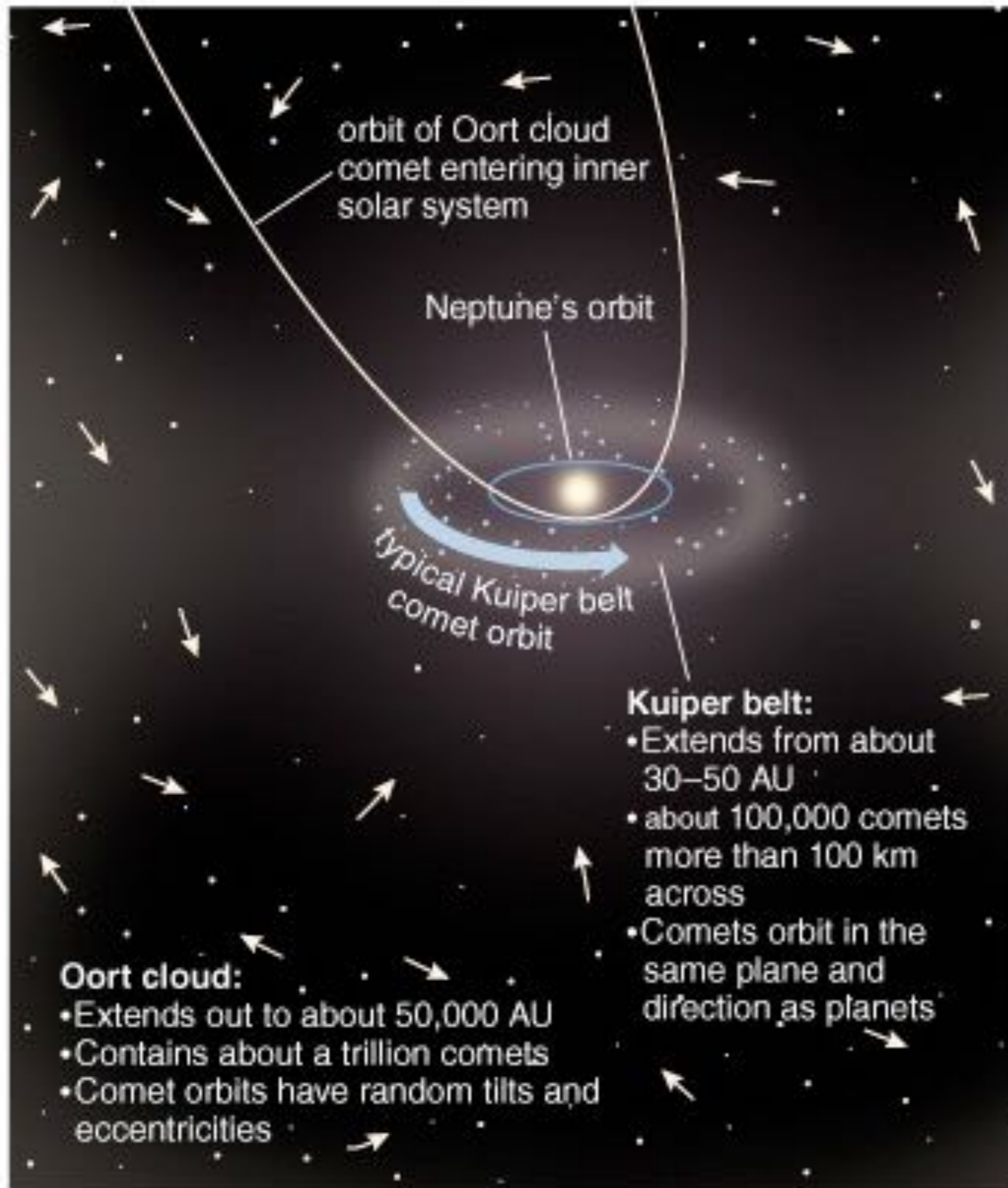




Comets eject small particles (**meteoroids**) that follow the comet around in its orbit and cause meteor showers when Earth crosses the comet's orbit.

annual meteor shower





Only a tiny number of comets enter the inner solar system; most stay far from the Sun.

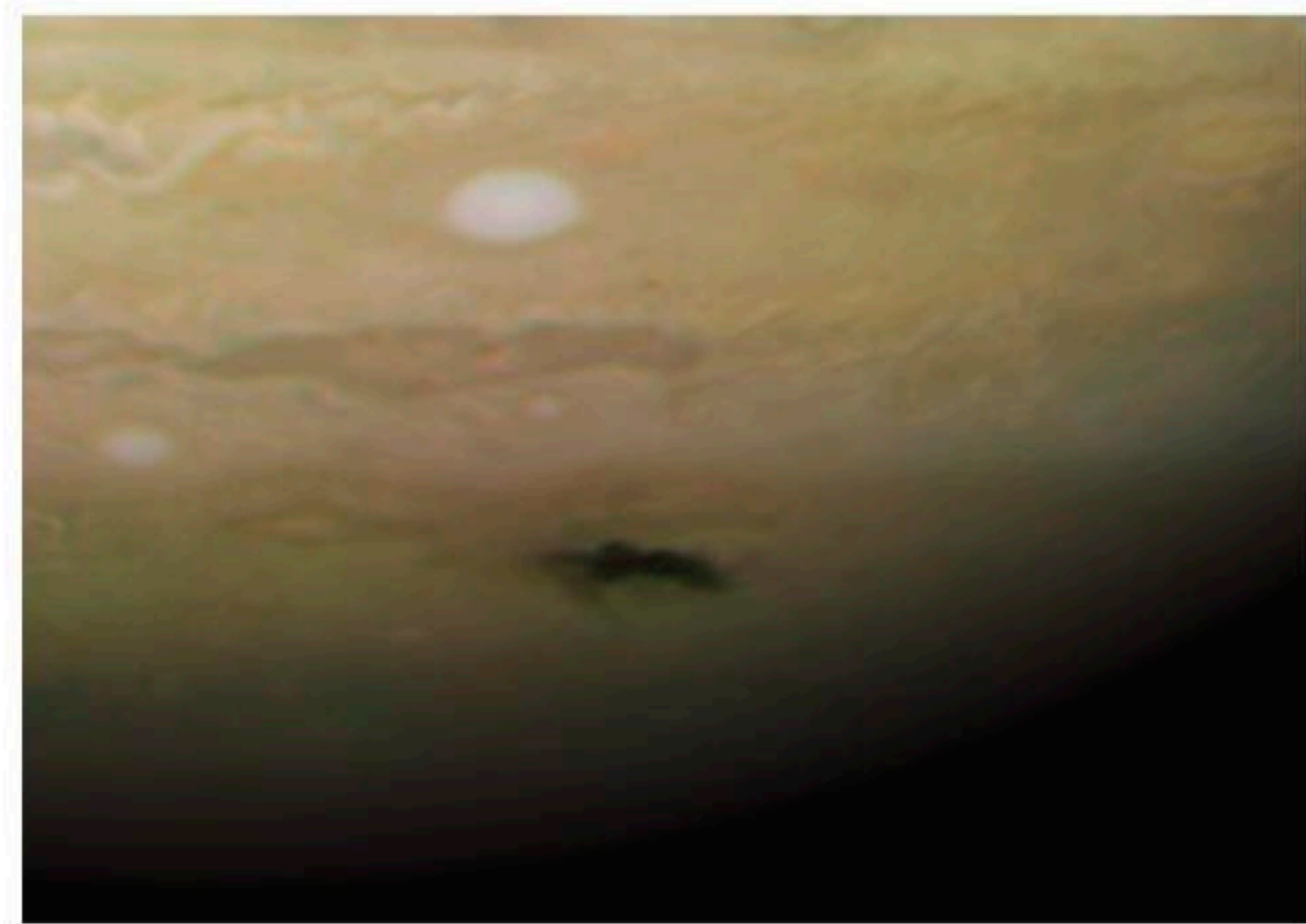
Oort cloud:

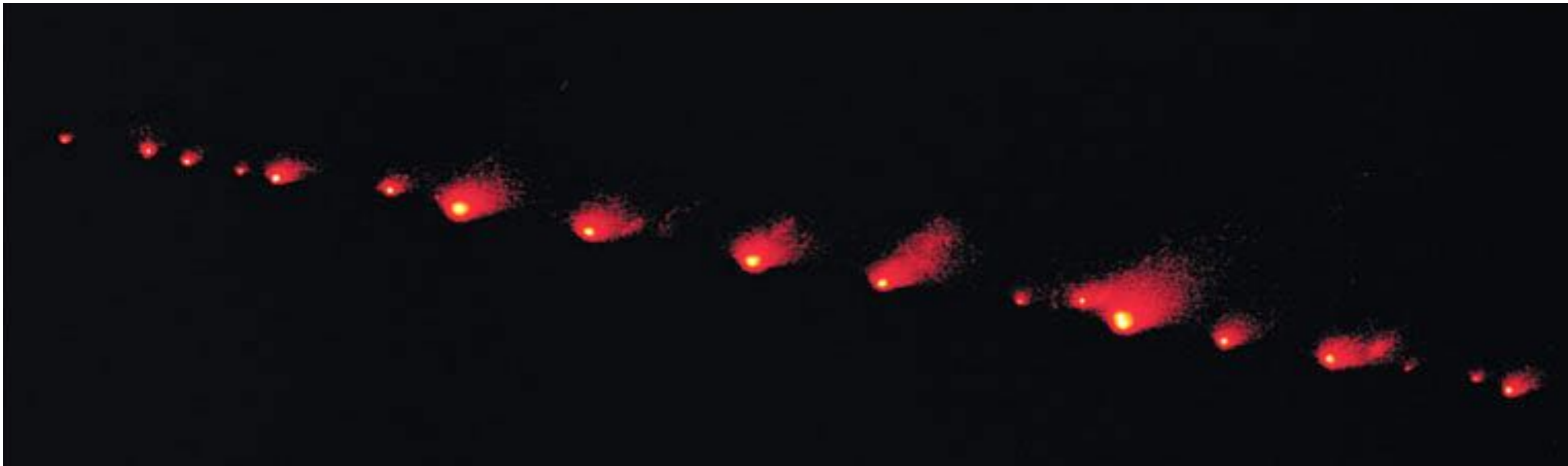
On random orbits extending to about 50,000 AU

Kuiper belt:

On orderly orbits from 30–50 AU in disk of solar system

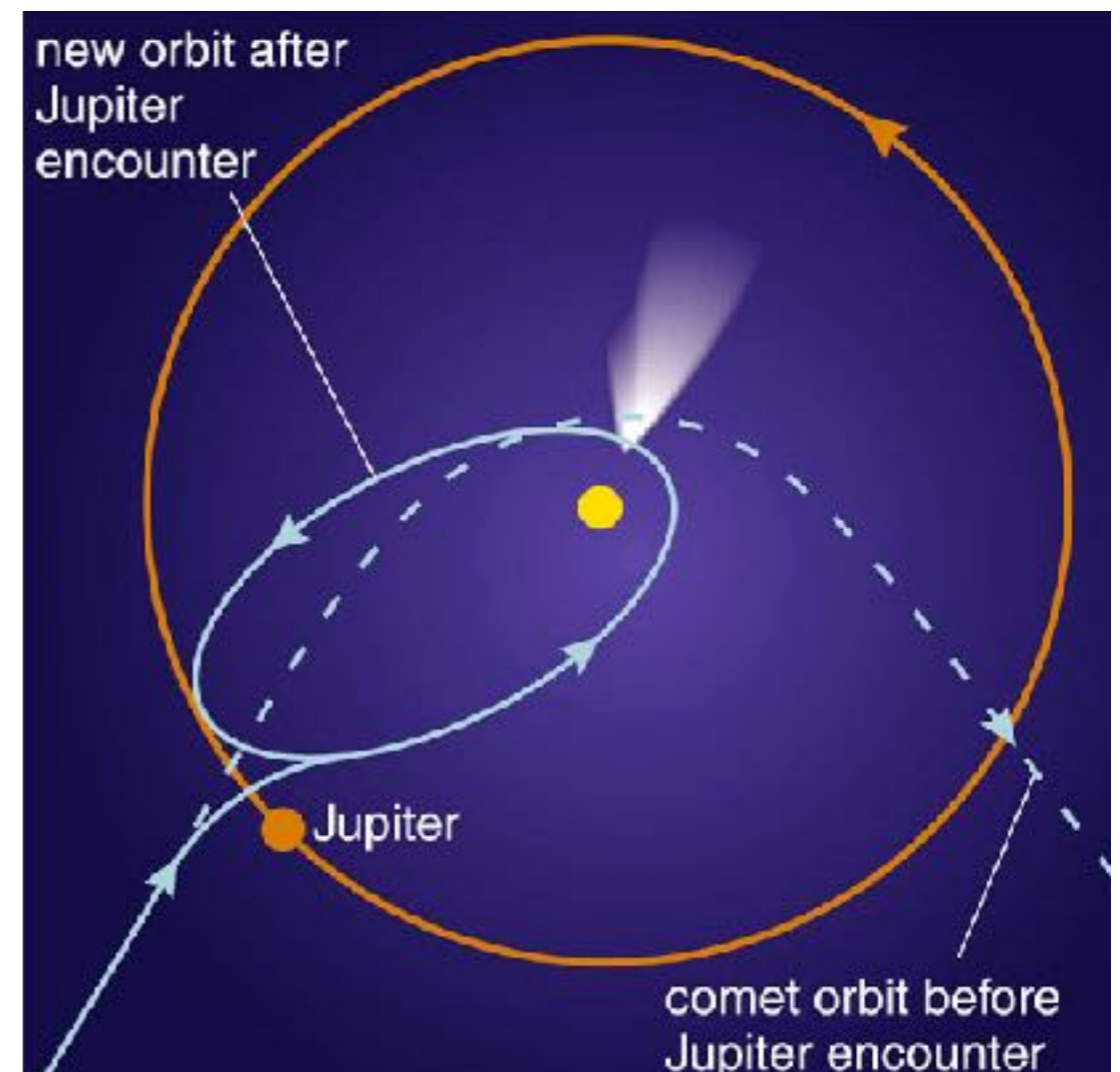
Have we ever witnessed a major impact?

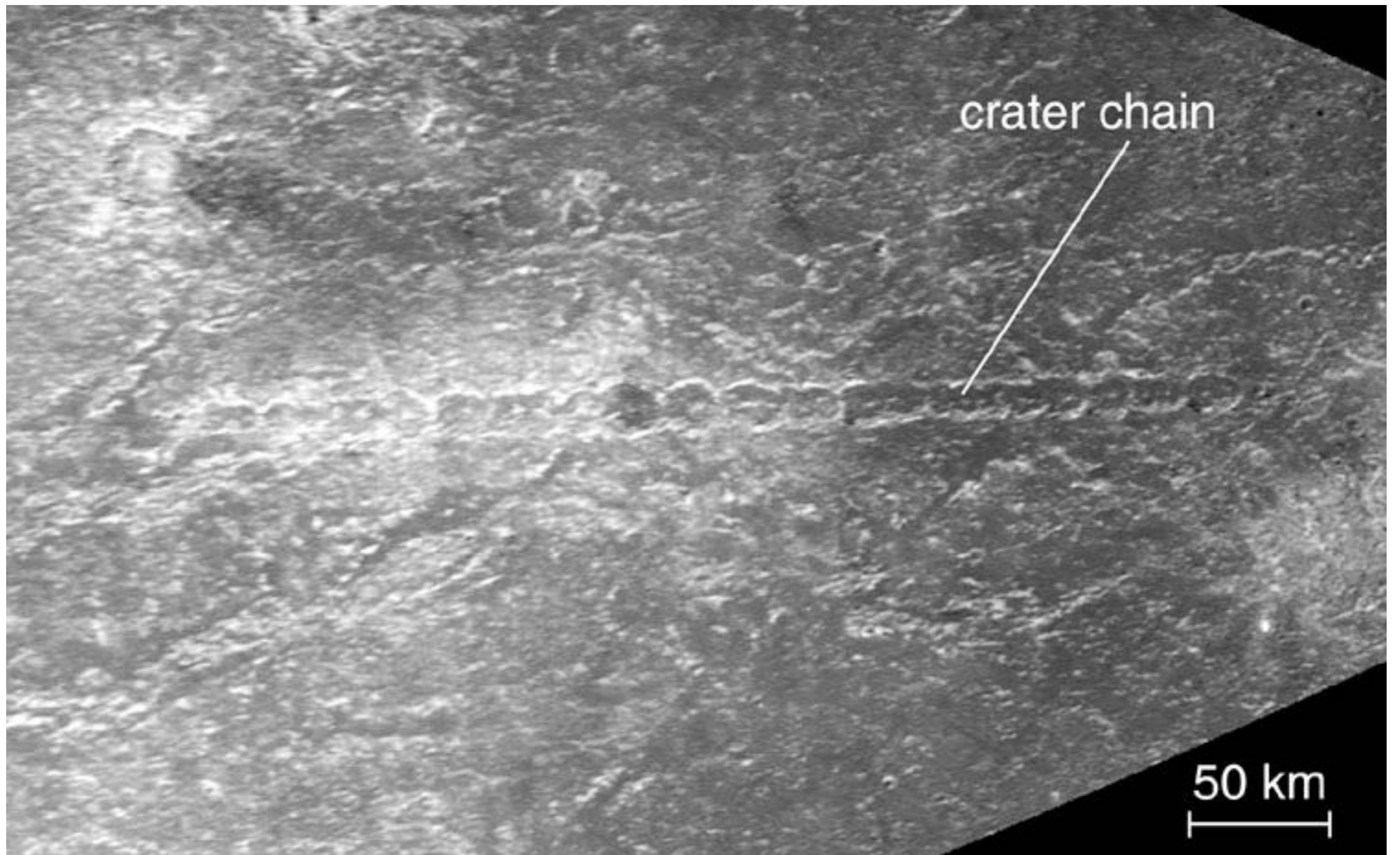




Comet SL9 caused a string of violent impacts on Jupiter in 1994, reminding us that catastrophic collisions still happen.

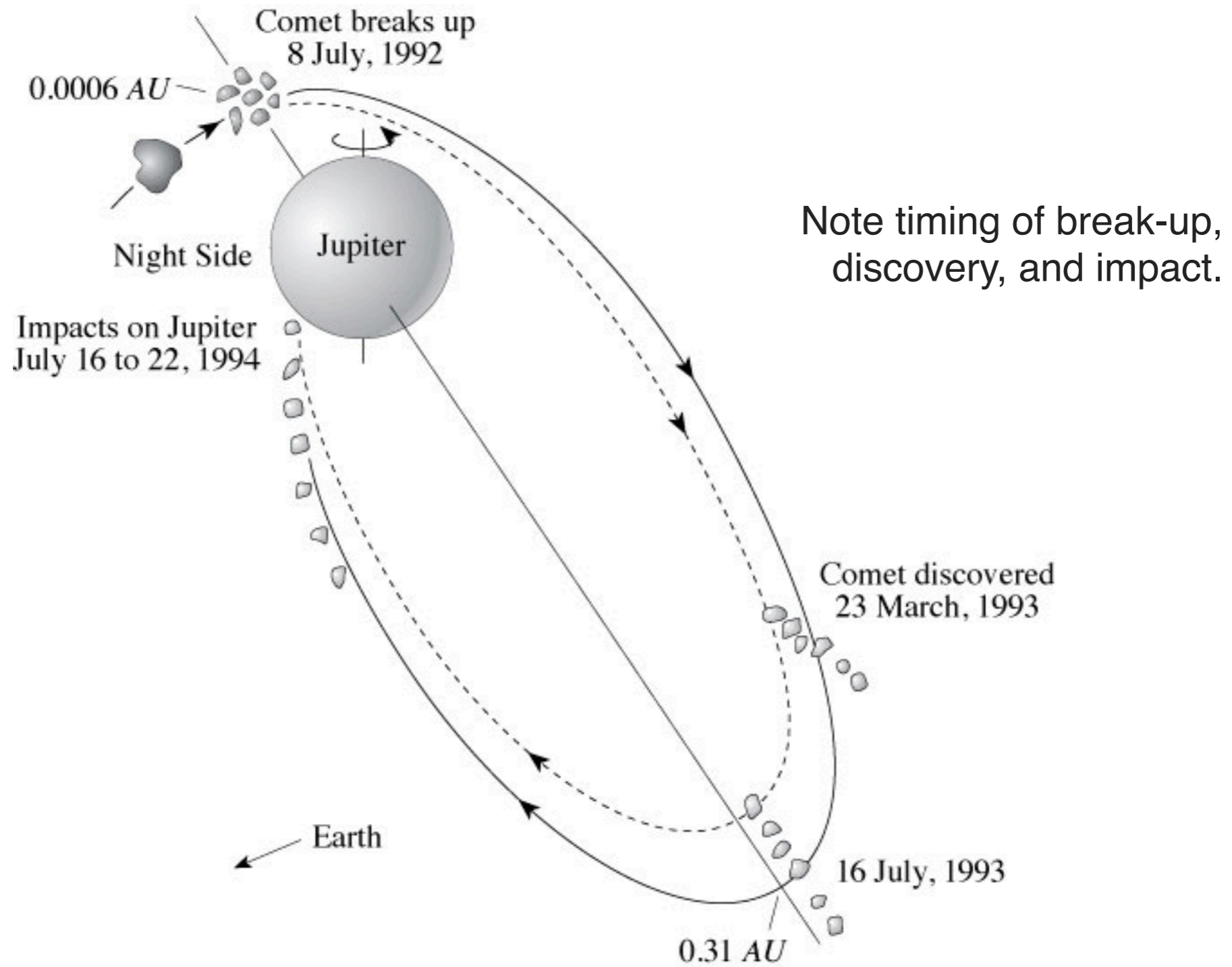
Tidal forces tore it apart during a previous encounter with Jupiter.





This crater chain on Callisto probably came from another comet that tidal forces tore to pieces.

Comet Shoemaker-Levy 9 (SL9)



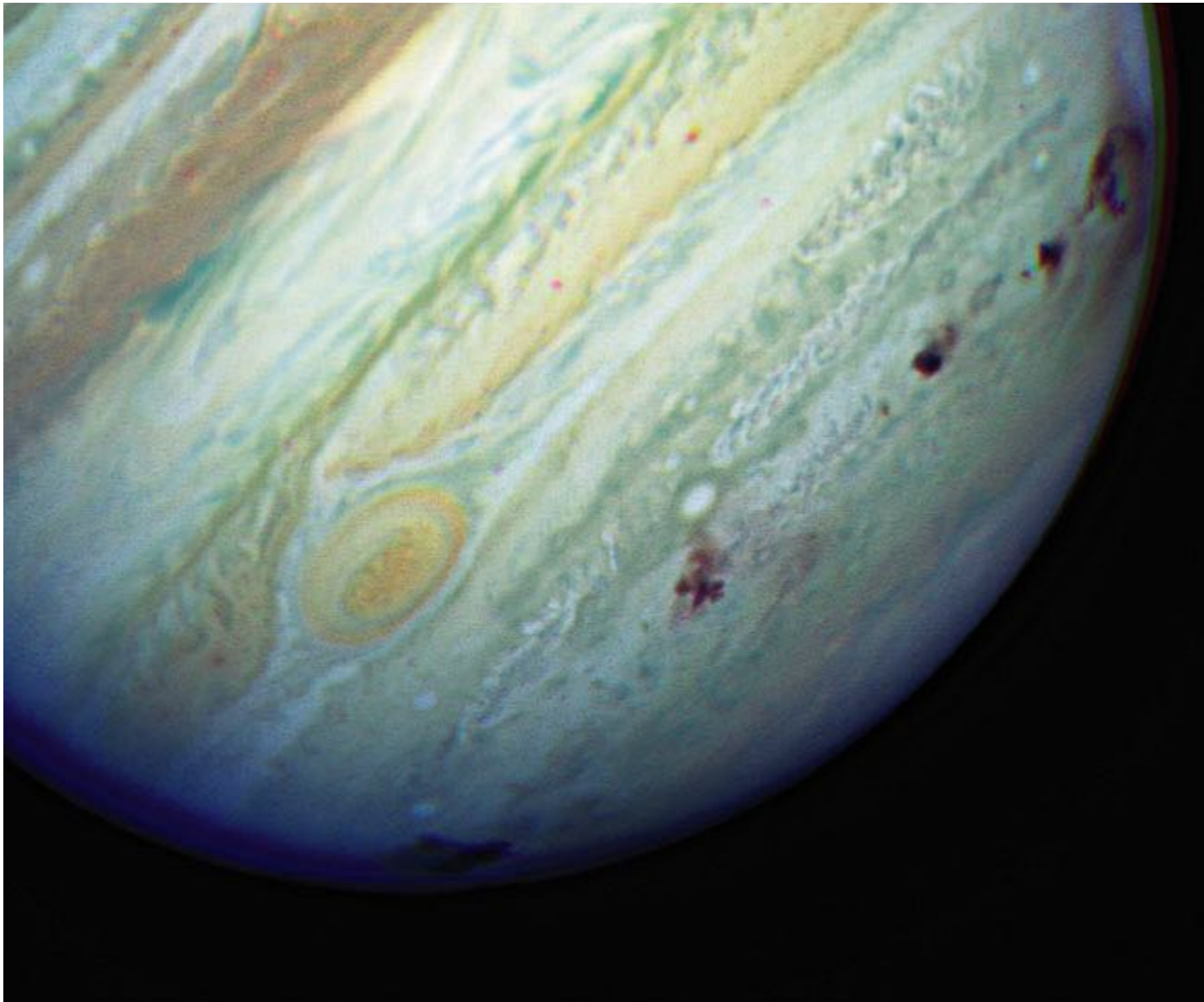
Comet SL9 passed within Jupiter's Roche limit and was disrupted into fragments. These fragments subsequently collided with Jupiter's at a speed of approximately 60 km/s (Jupiter's escape velocity).

SL9 movies

Jovian weather
forecast for 16-22
July 1994: a steady
rain of comet
fragments in the
southern hemisphere.

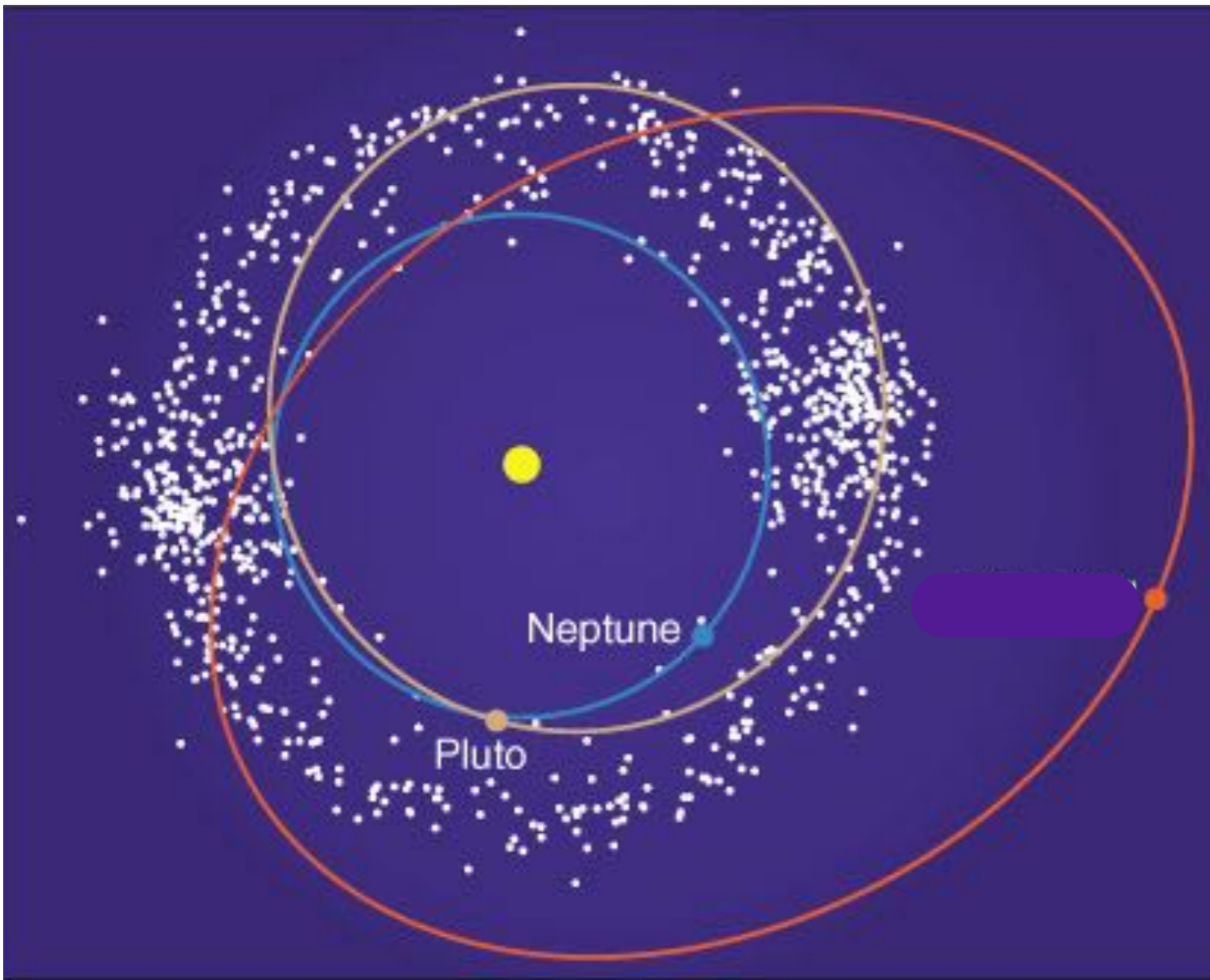


Impact sites from fragments of comet SL9 in infrared light



Impact sites - dusty in optical light. All at same latitude.

Kuiper Belt



- disk of objects beyond the orbit of Neptune
- Like more distant, icy version of asteroid belt
- Many small objects; some large ones (like Pluto)

Pluto is the first known example of large Kuiper Belt objects

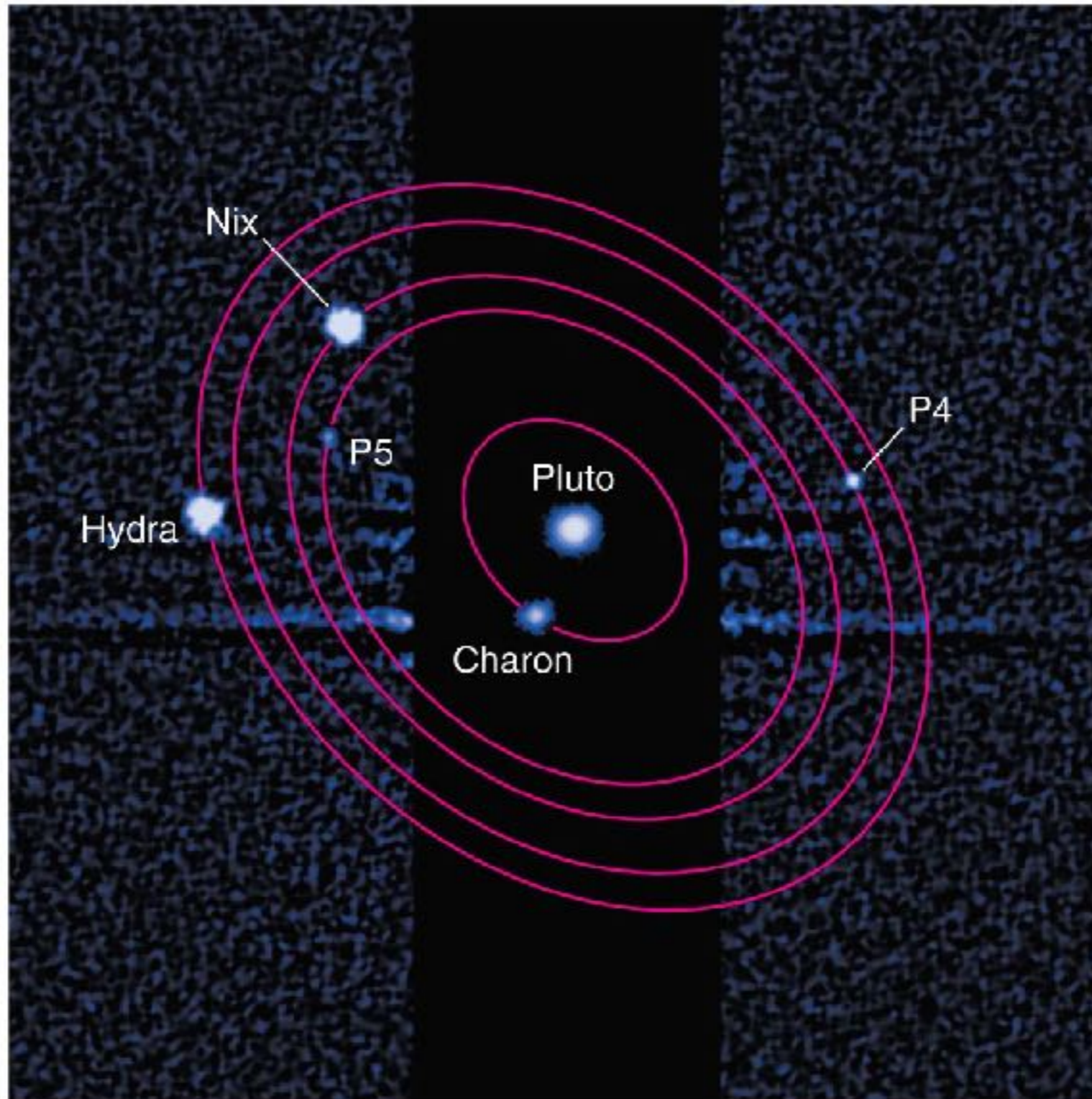


**Hubble picture
of Pluto**

What is Pluto like?

- Its largest moon Charon is nearly as large as Pluto itself.
 - Tidally locked: perpetually face each other.
 - also has 4 tiny moons
- Pluto is very cold (40 K).
- Pluto has a thin nitrogen atmosphere that refreezes onto the surface as Pluto's orbit takes it farther from the Sun.

Hubble's View of Pluto and Its Moons



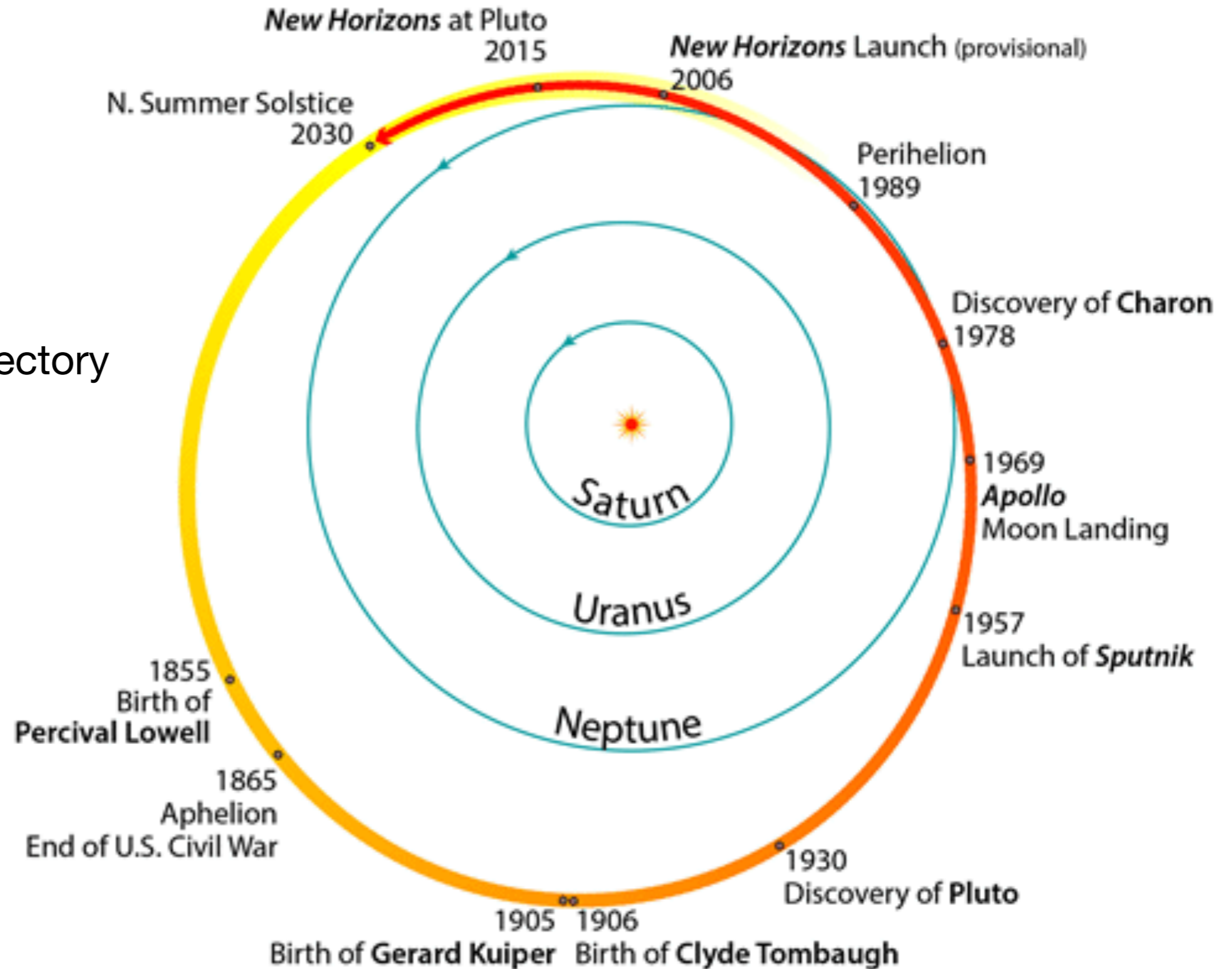
a This Hubble Space Telescope photo shows Pluto and its five known moons, along with orbital paths for the moons. Horizontal stripes are scattered light from Charon and Pluto in the long exposure.

plutosmoonsorbits.mp4

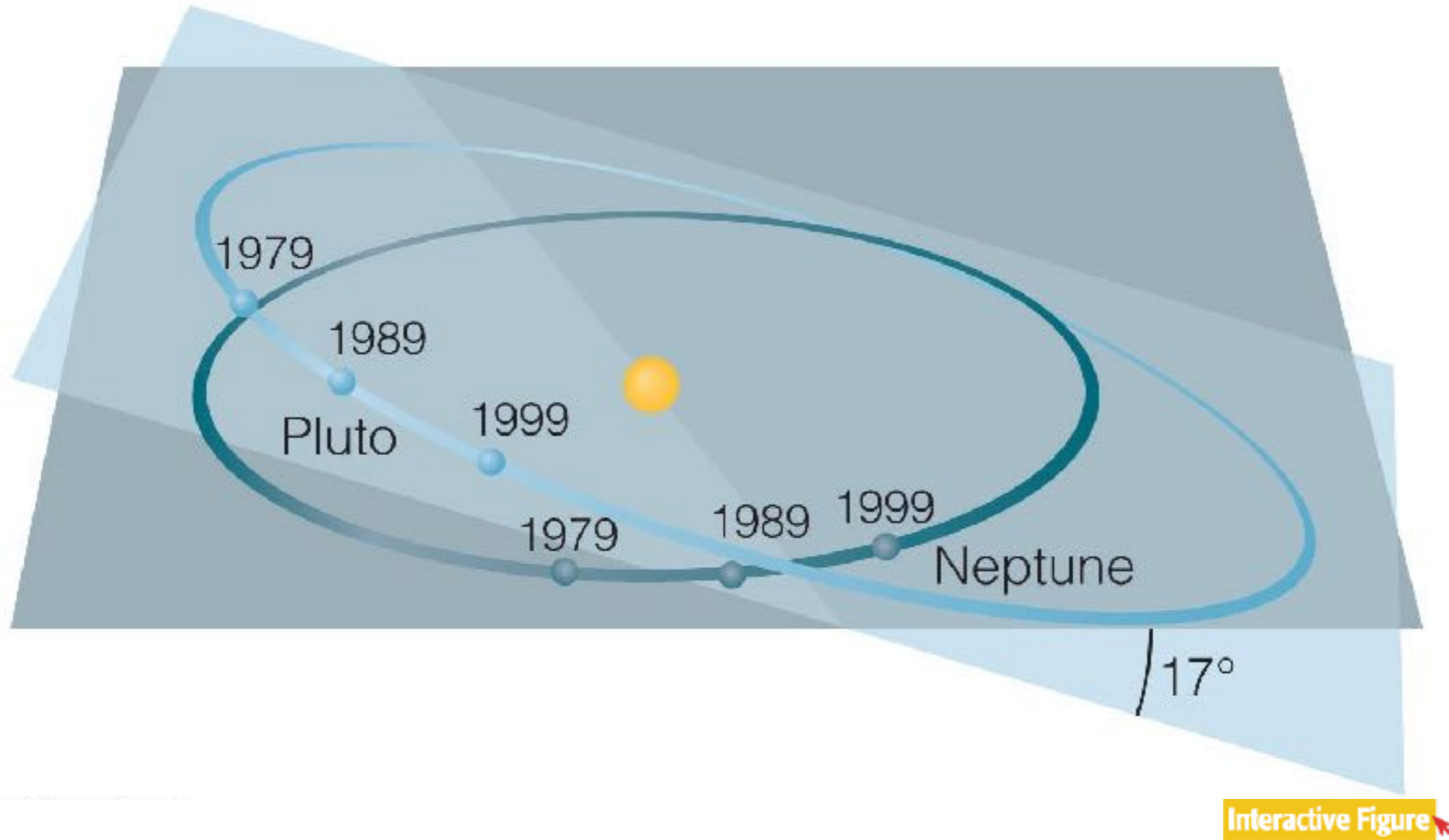
What is Pluto like?

- Summer ending (perihelion in 1989)

Pluto Orbit &
New Horizons trajectory

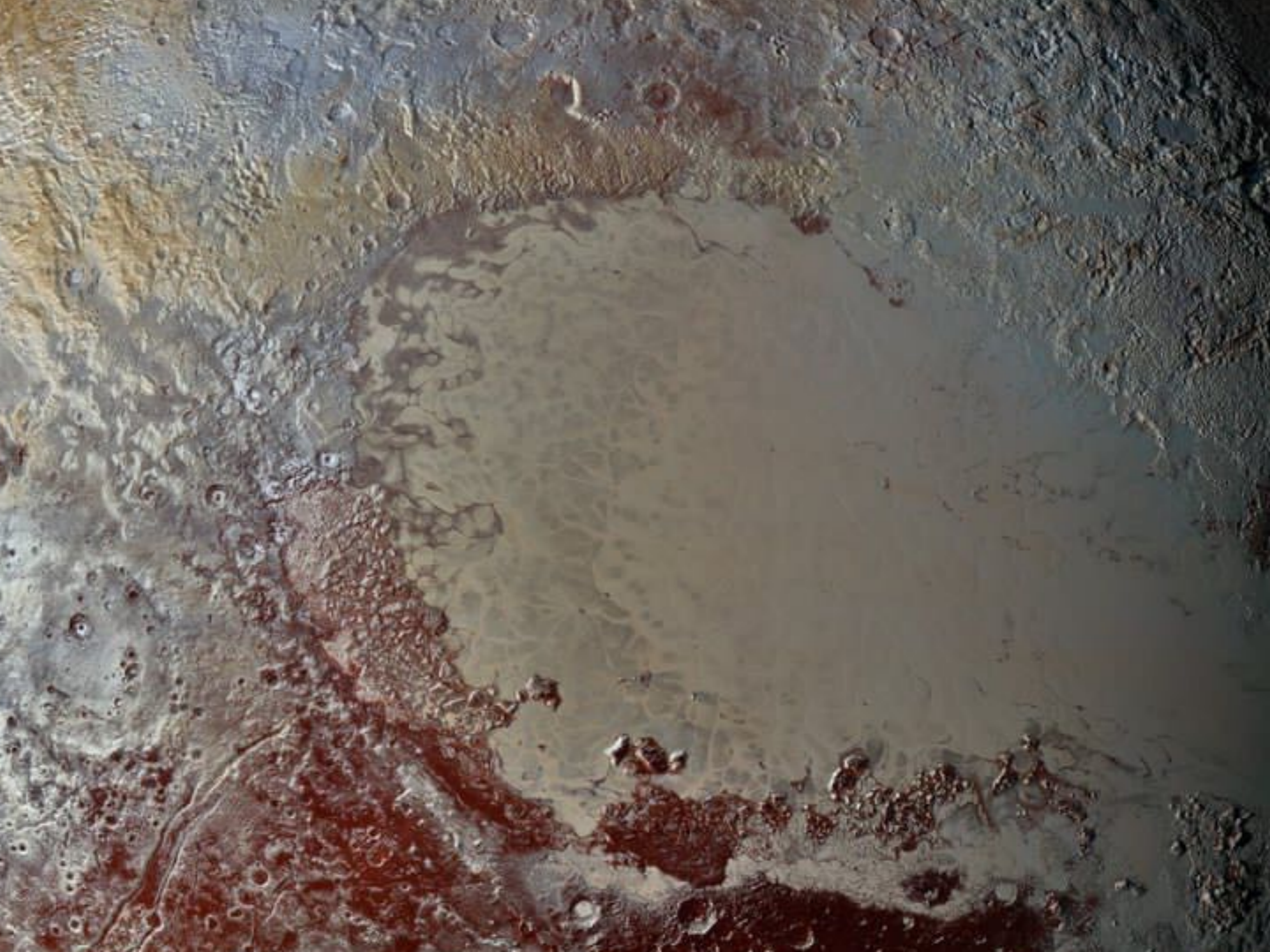


Pluto's Orbit



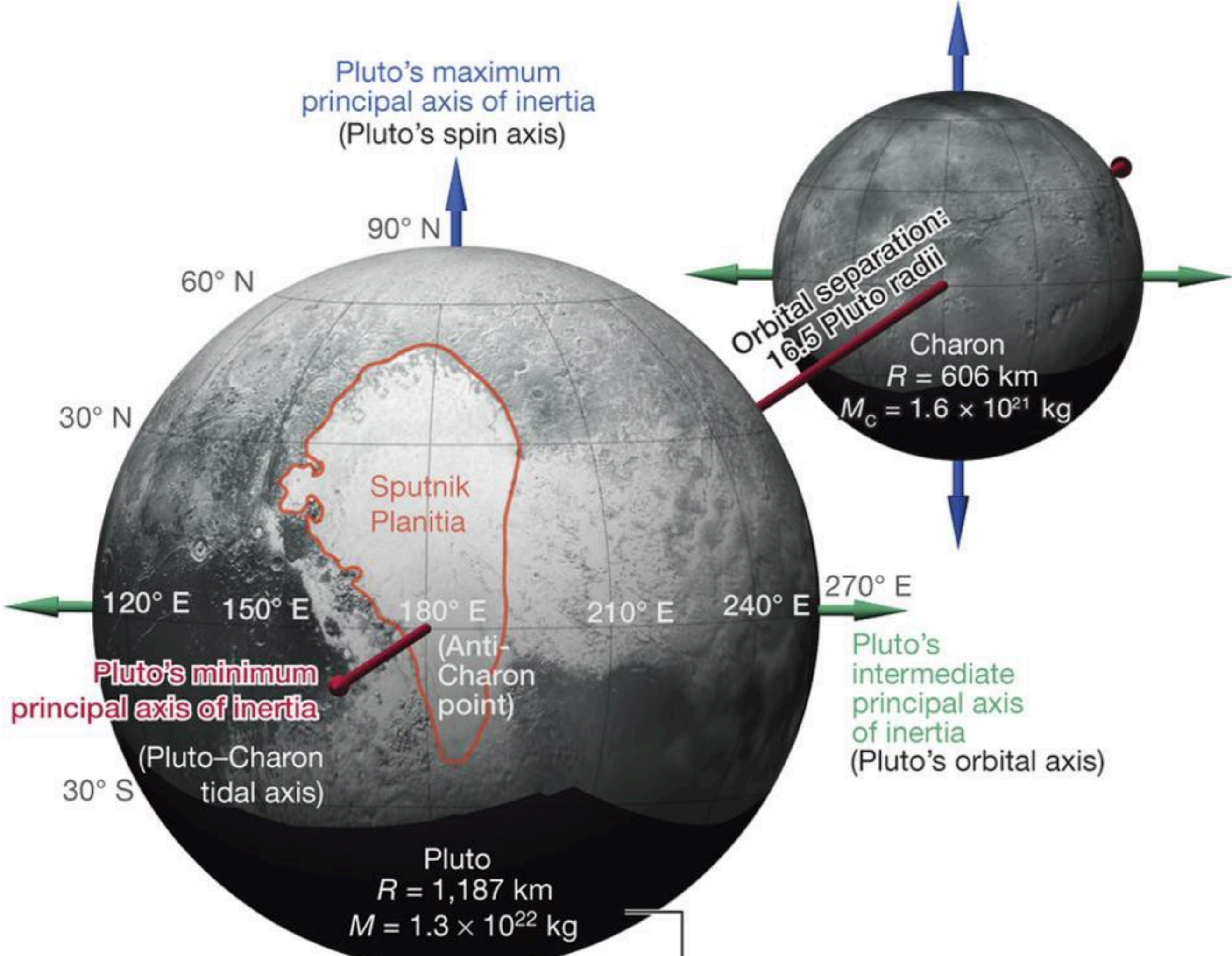
- Pluto will never hit Neptune, even though their orbits cross, because of their 3:2 orbital resonance.
- Neptune orbits three times during the time Pluto orbits twice.





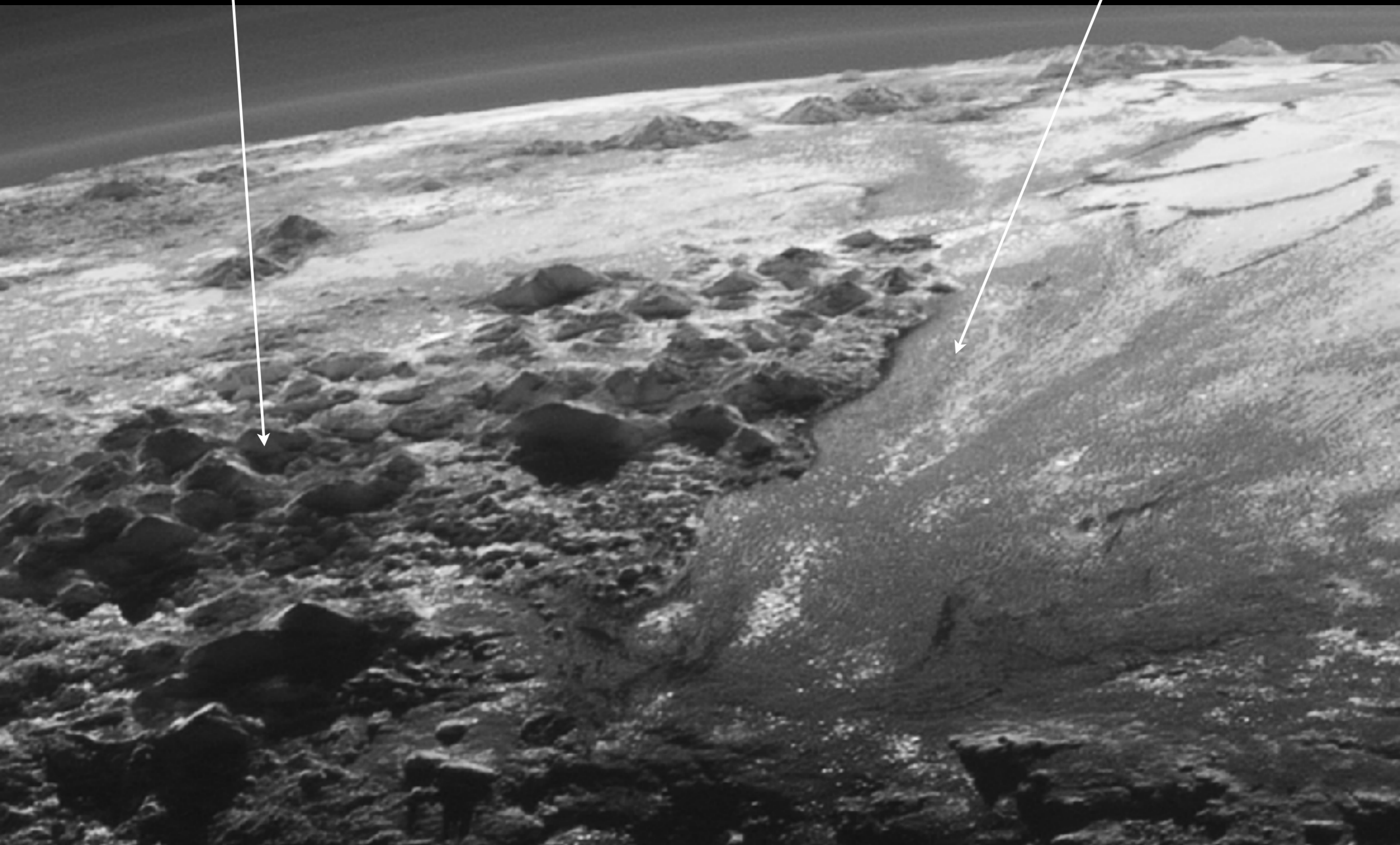
What is Pluto like?

- Ice mountains.
- Nitrogen glaciers & ice cap.
- Ice volcanoes.
 - Surprisingly young surface
 - Nitrogen atmosphere both refreezing onto surface
 - and evaporating into space



ice mountains

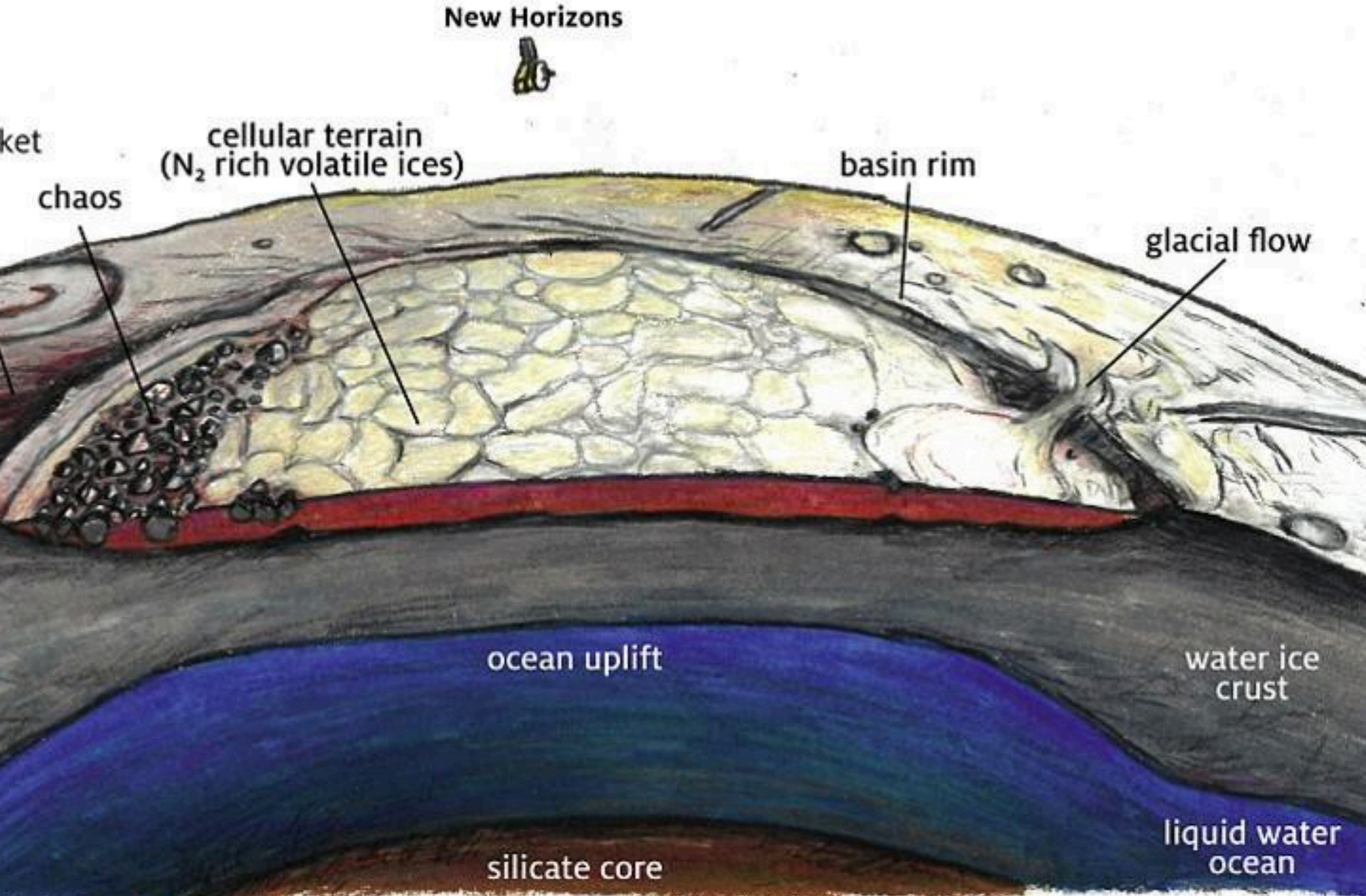
nitrogen glaciers



Nitrogen ice on Pluto flowing like water ice on earth

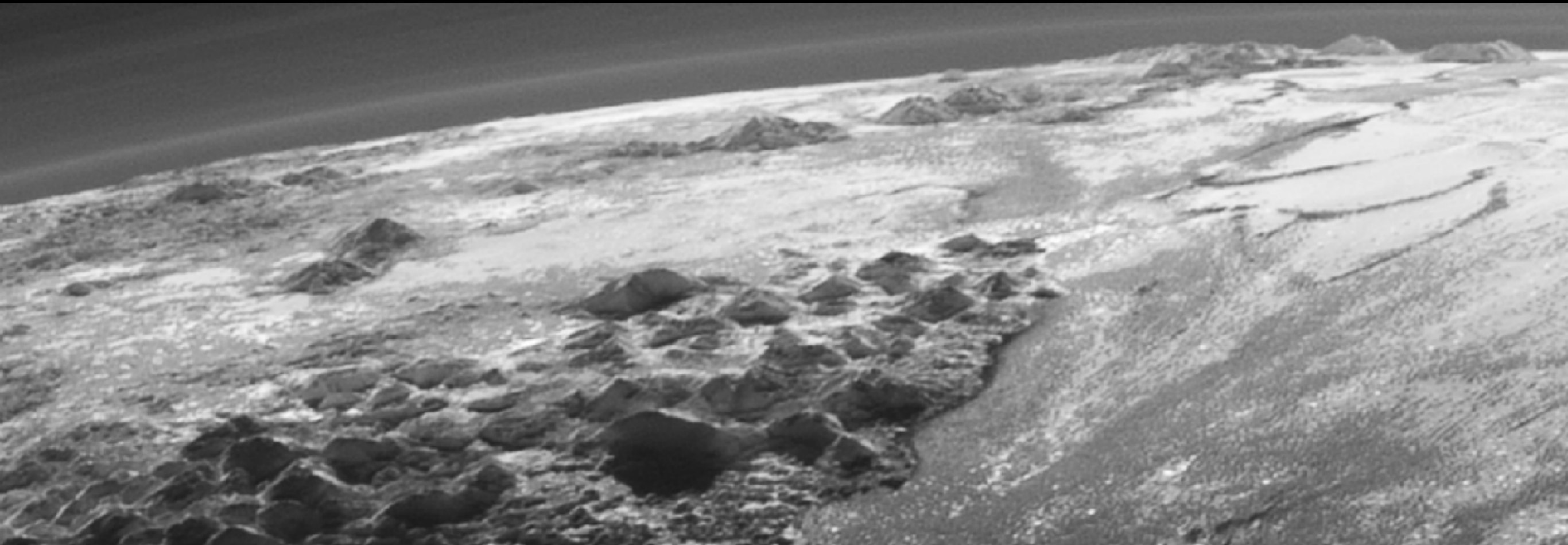


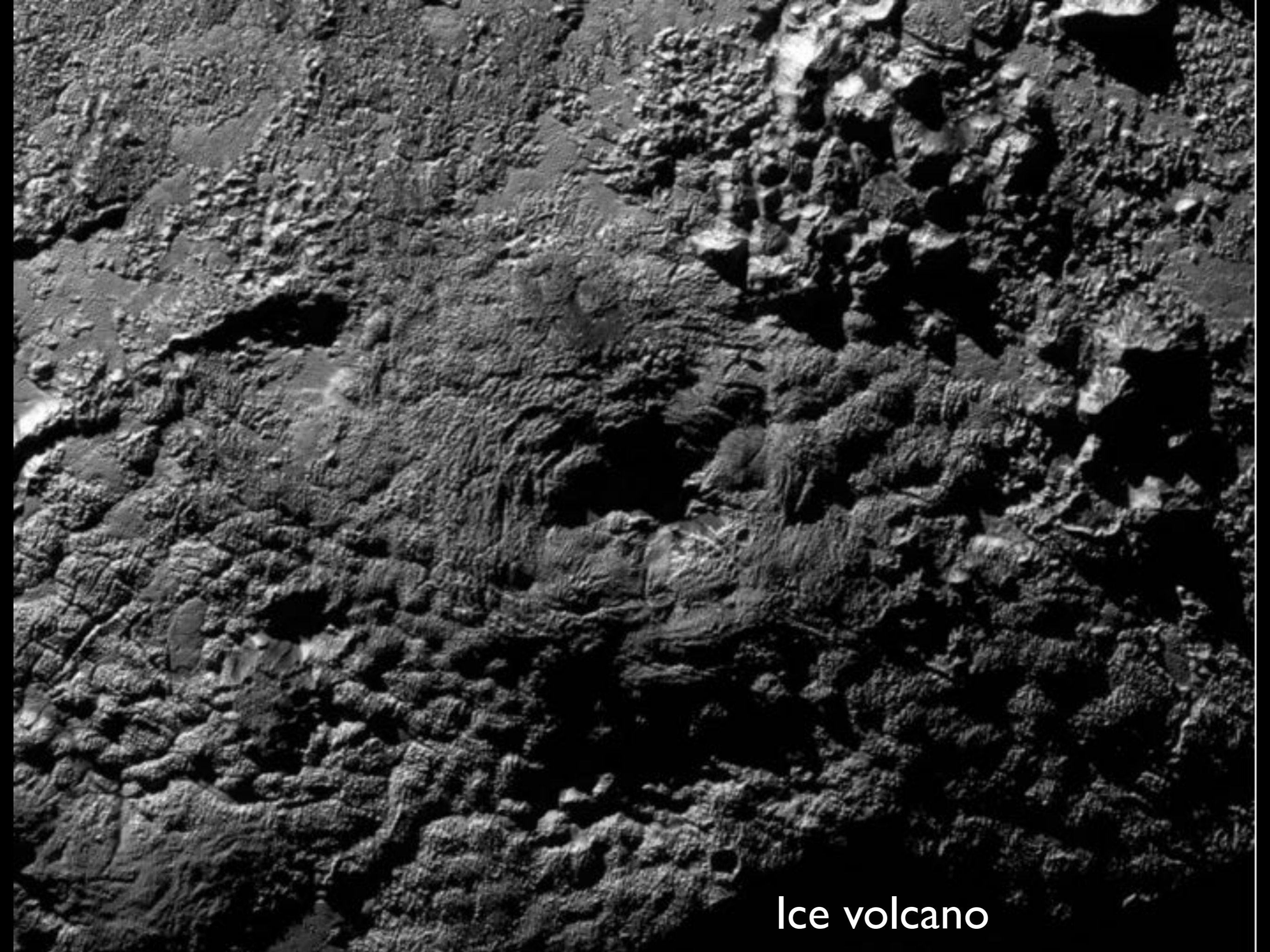
Sputnik Planitia, Pluto



Competing hypotheses for Sputnik Planitia

- Impact basin filling in with nitrogen ice in thin spot of crust over upwelling subsurface ocean
- Ice cap at coldest latitude (30° on Pluto!) whose weight presses down on water ice to compress & sink basin





Ice volcano

Pluto's atmosphere looking back towards the sun

Thin nitrogen atmosphere
some being lost to space;

some re-freezing onto single ice cap (Sputnik Planitia)



Charon

Charon is very different

no atmosphere
darker surface
more craters
long chasms

