2024 Solar Eclipse

Image credit: Jayce Dowell

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Astr 2110

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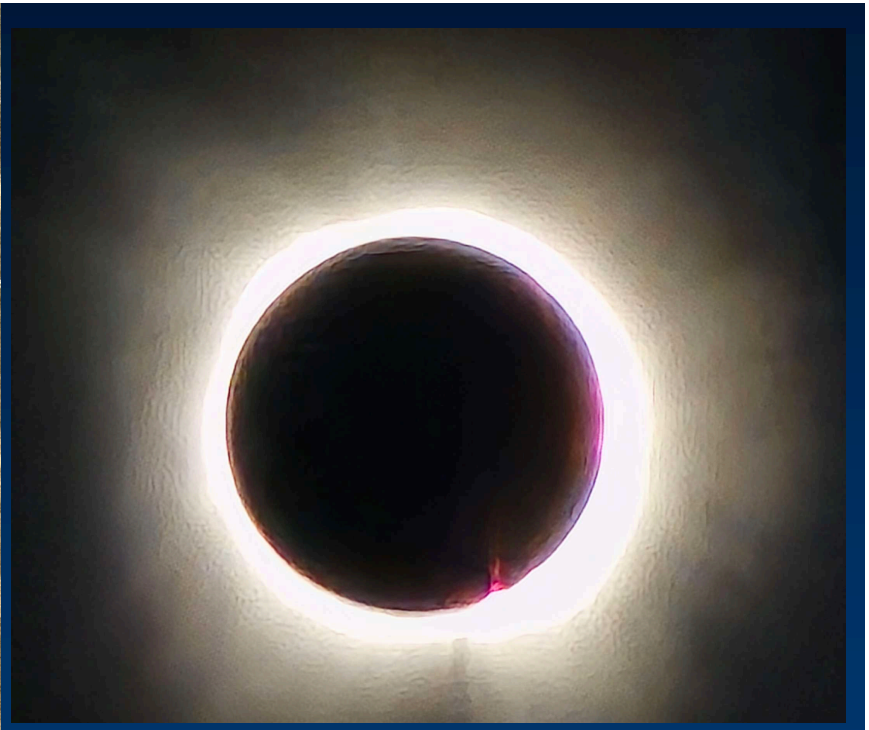


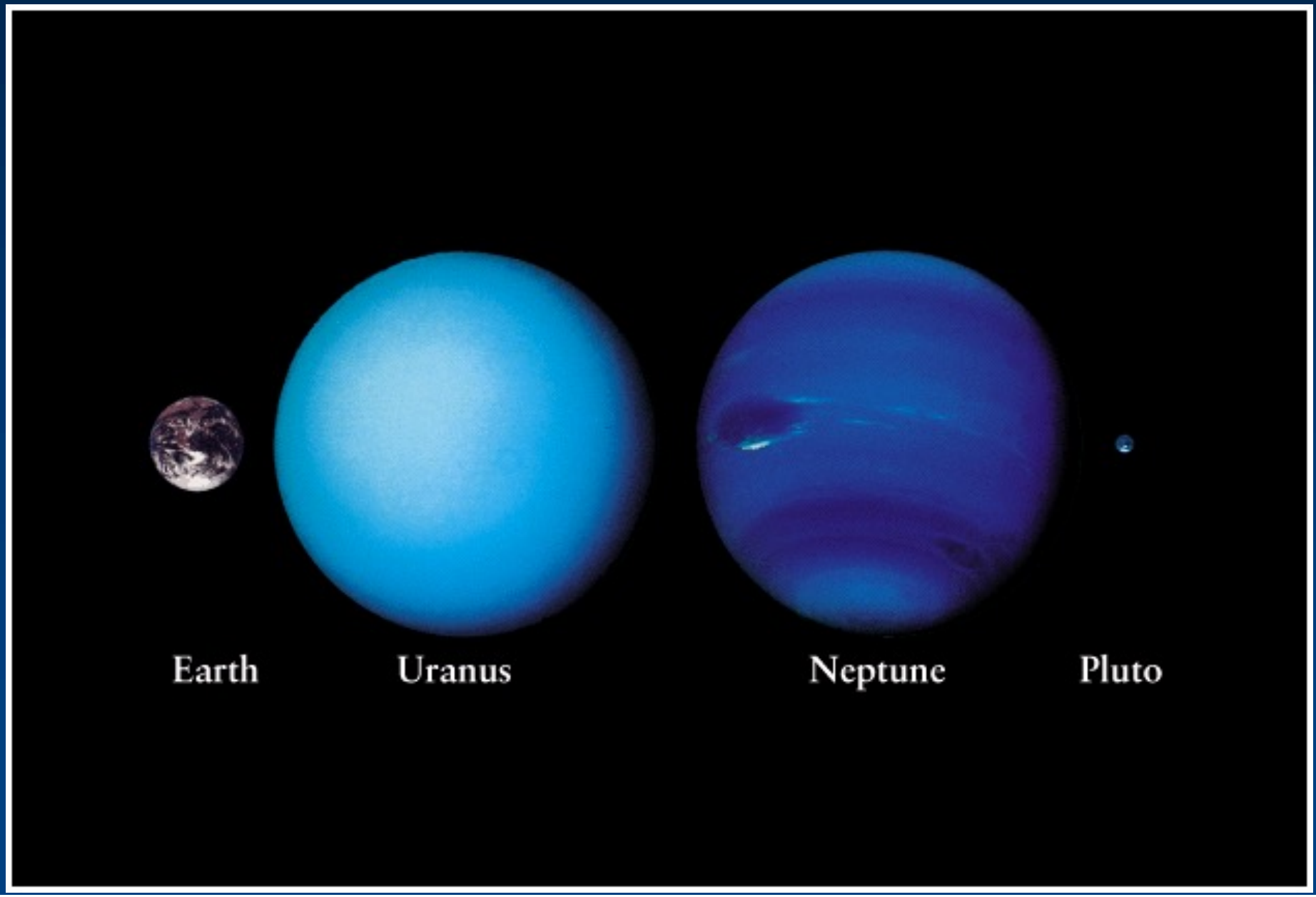
Astr 2110

Announcements

- Extra Credit: Send photo by end of day today
- Physics Day is this Saturday, April 13, student talks, free lunch. In PAIS 1100. Program is here:

https://physics.unm.edu/pandaweb/undergraduate/day2024/program.php

Uranus and Neptune



Uranus & Neptune basic data

	Uranus	Neptune
Semi-major axis	19 AU	30 AU
Orbital period	84 yrs	165 yrs
Rotation period	17 hrs	16 hrs
Inclination	98°	30°
Diameter	4.0 D_{Earth}	3.9 D_{Earth}
Mass	15 M_{earth}	17 M_{Earth}
Density	1318 kg/m^3	1638 kg/m^3
	1.3 g/cm^3	1.6 g/cm^3
Temp at cloud tops	55 K	55 K

Discovery of Uranus & Neptune

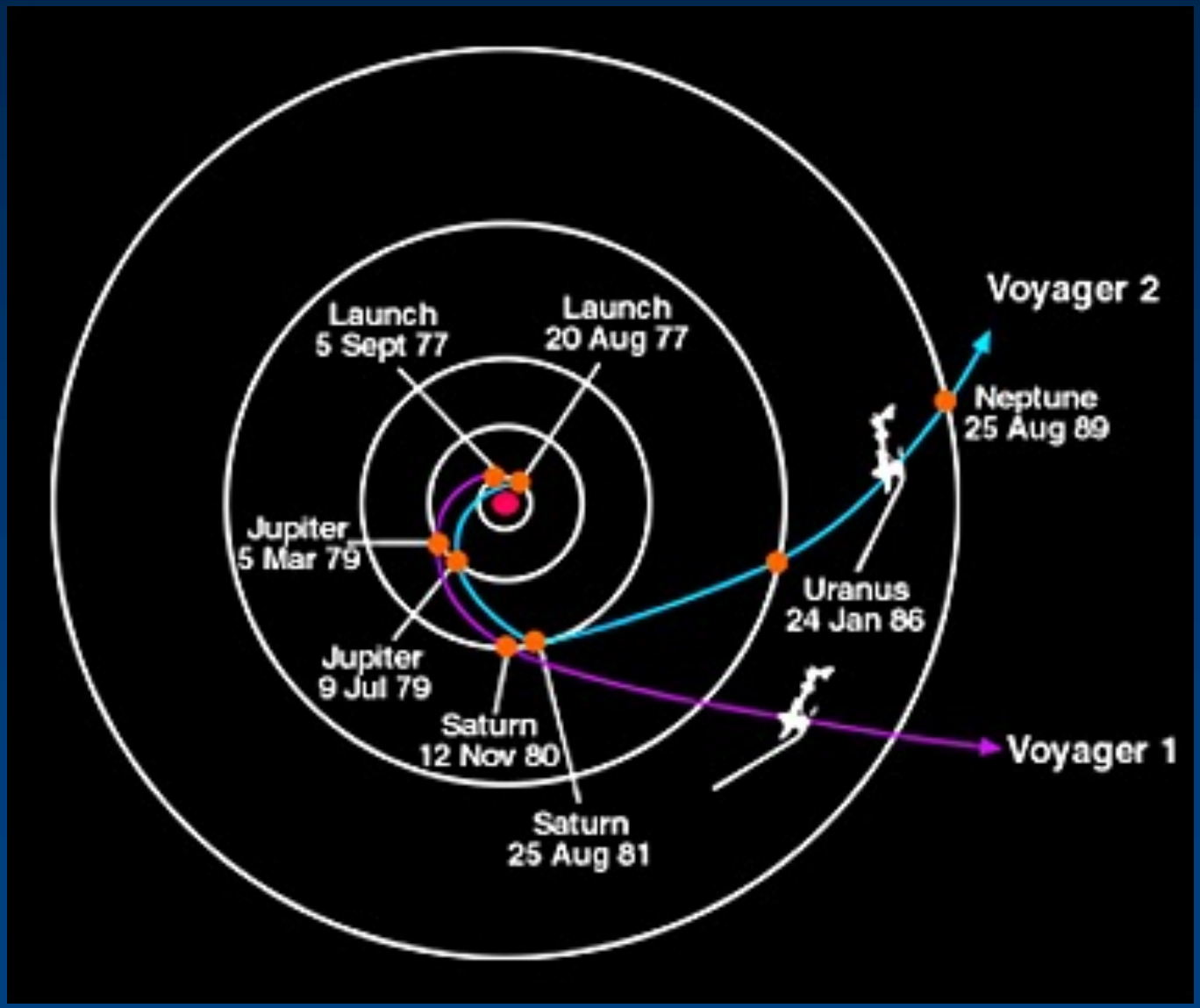
- Uranus: by chance – had been mapped many times as a star. William Herschel observed it through a telescope in 1781 – recognized it was a planet – fuzzy, and moved with respect to the background stars

- Neptune: scientific prediction - Uranus's orbit was not a perfect ellipse. Either Newton was wrong or something was pulling on it. Adams and LeVerrier in 1844/46 independently calculated where unseen planet might be. Galle (Berlin Obs) found it on 24 Sept 1846 in one night after receiving the predictions from LeVerrier.

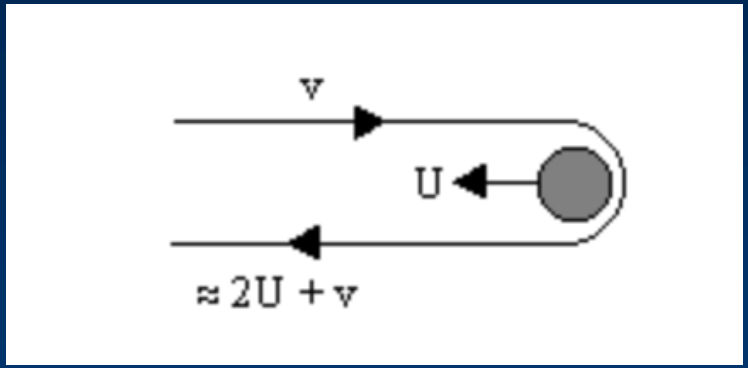
Spacecraft missions

- Voyager 2 has flown past Uranus & Neptune:
  - Uranus: January 1986
  - Neptune: August 1989
- Both have been extensively studied using the Hubble Space Telescope:
  - Long-term monitoring of atmospheric weather patterns
  - IR imaging of their atmospheres, rings, and moons
- Observed with JWST

Voyager 2 path



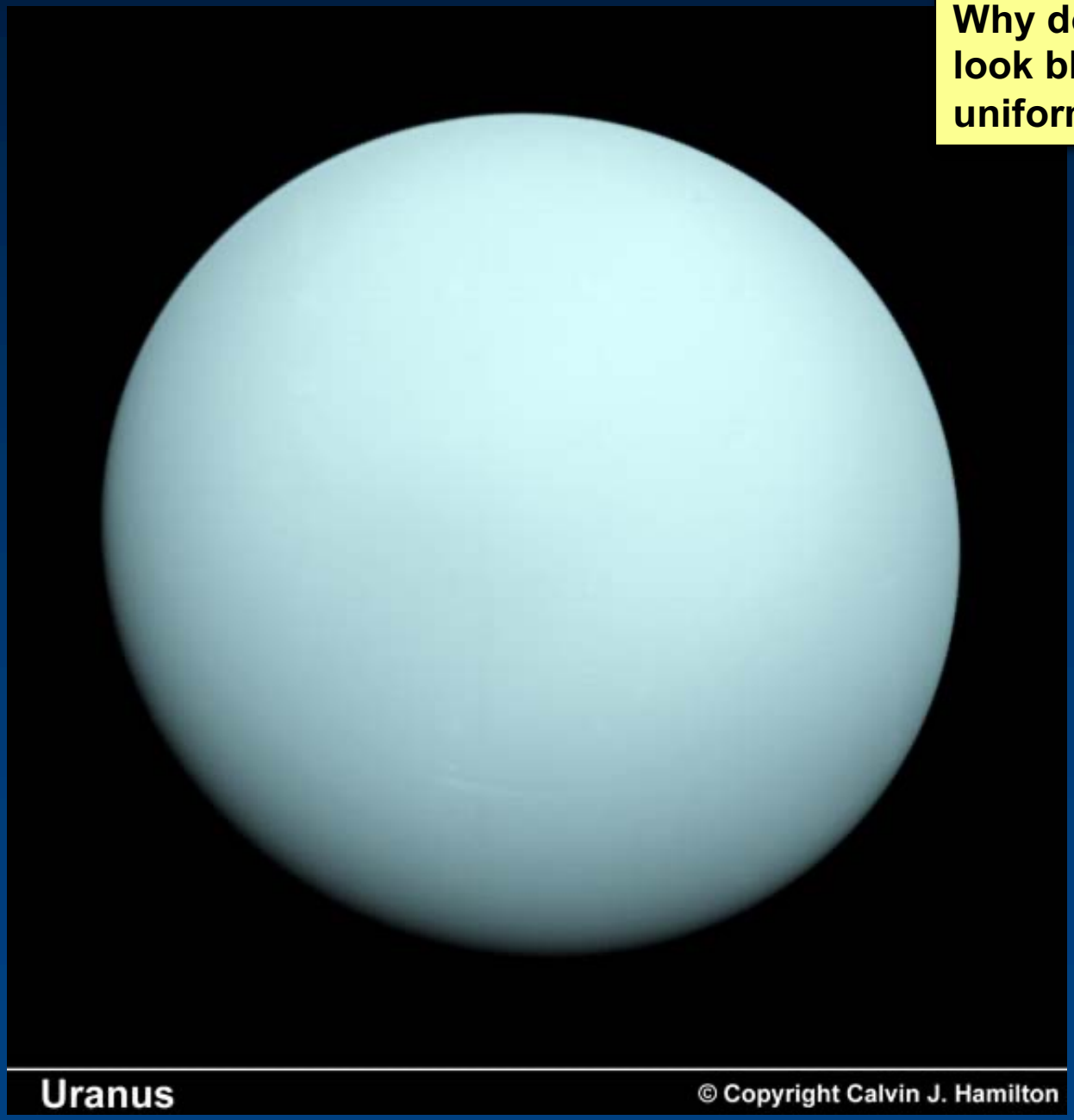
Gravitational Slingshot



$$mv_1^2 + MU_1^2 = mv_2^2 + MU_2^2$$ Energy conservation

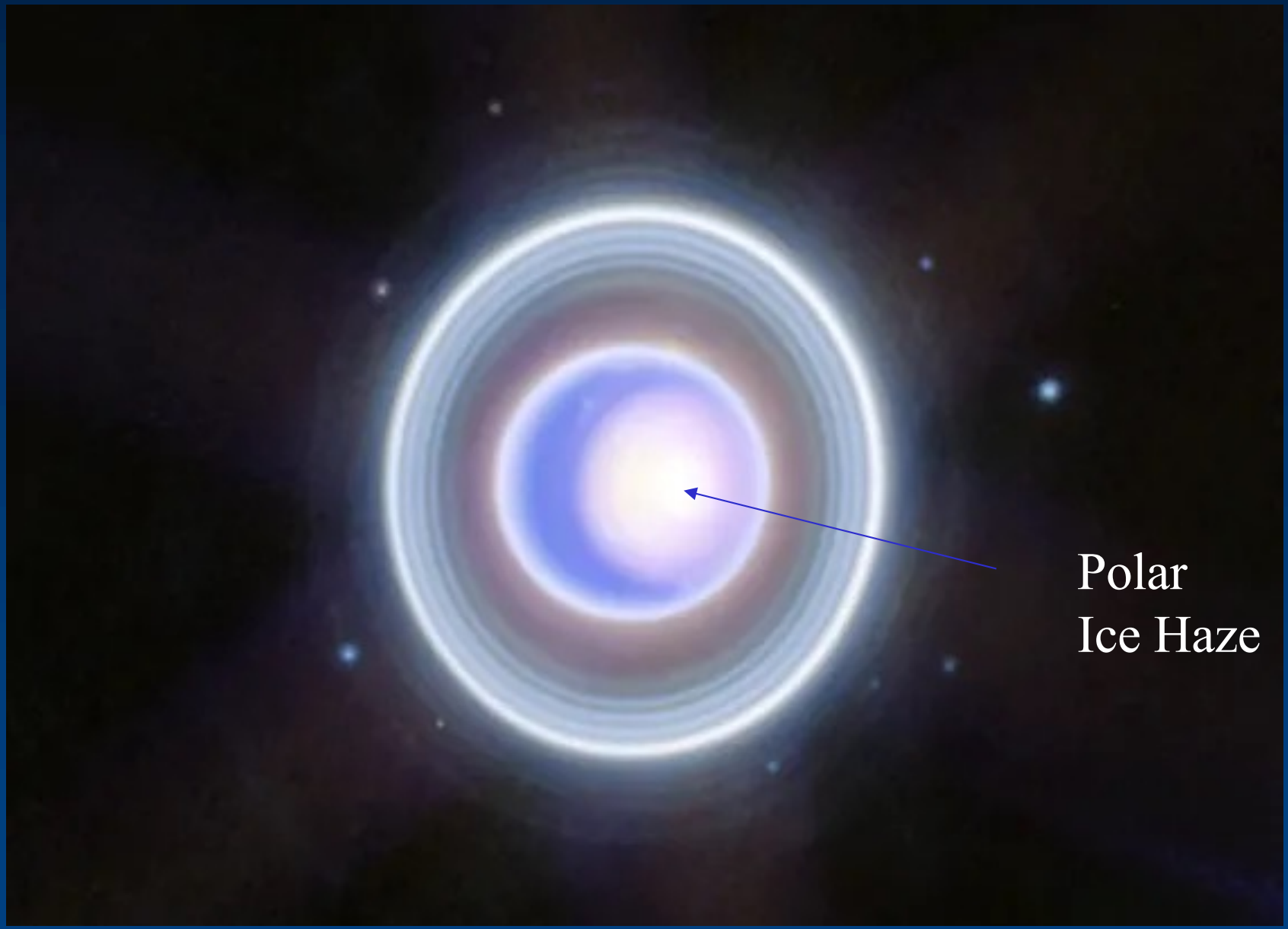
$$MU_1 - mv_1 = MU_2 - mv_2$$ Momentum cons.

$$v_2 = v_1 + 2U_1$$



Why does Uranus look blue, and so uniform?

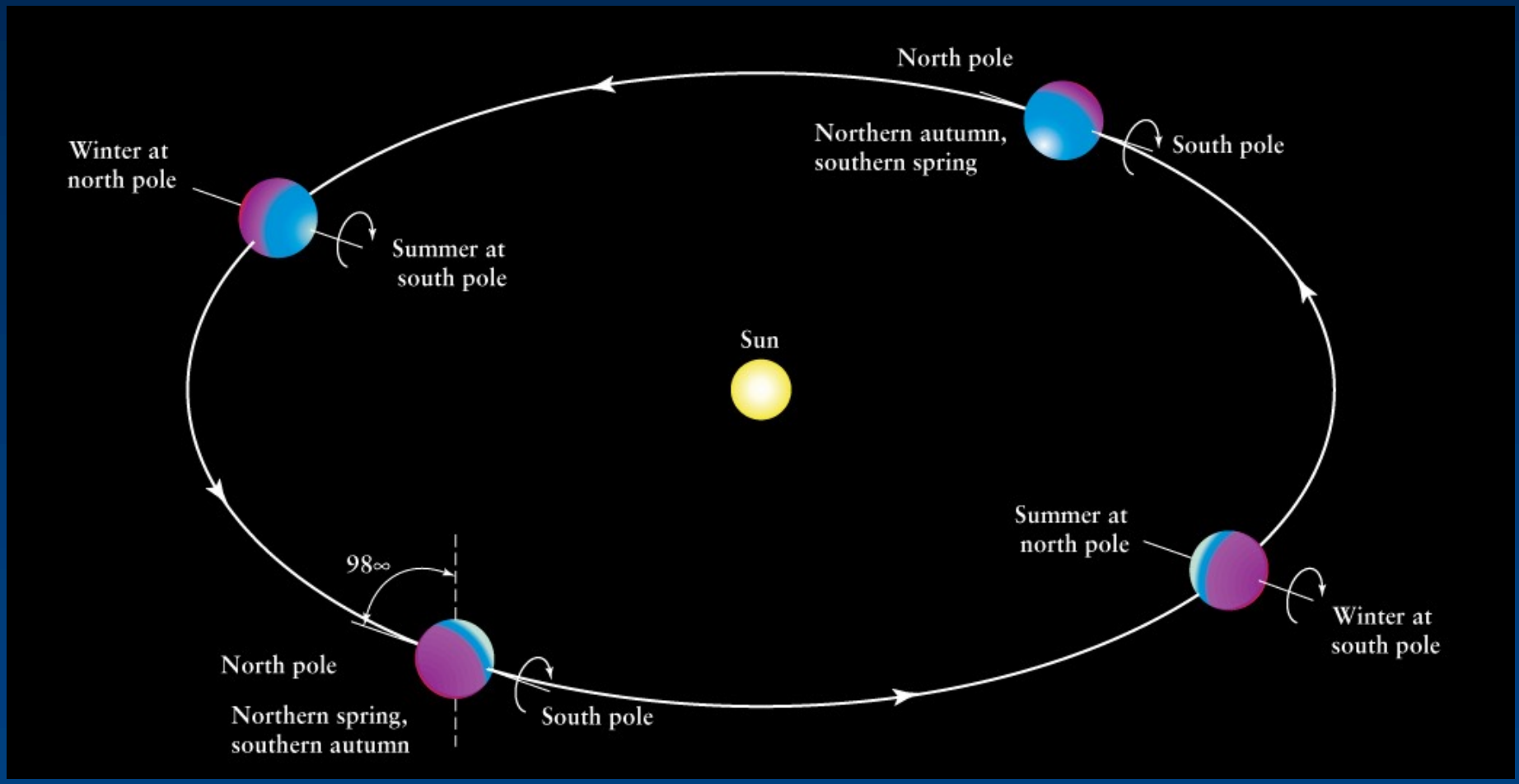
JWST Observations of Uranus, Rings and Moons



Uranus' atmosphere

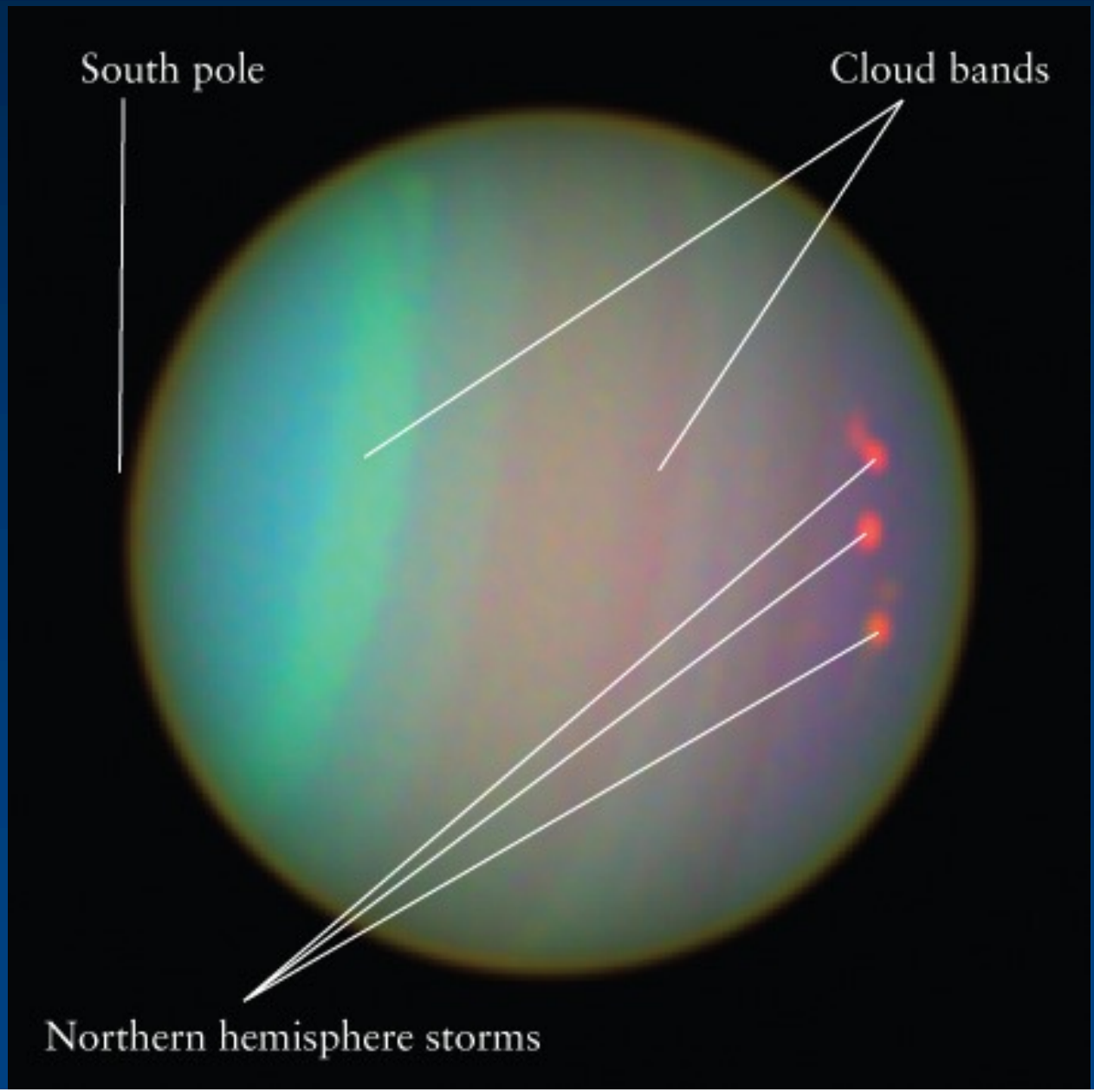
- Mostly H_2, He_2
- Colder than Jupiter or Saturn, ammonia and water have frozen and sunk deep down.
- But methane remains in gas form. There is 5-10 times as much methane in its atmosphere as in Jupiter or Saturn.
- Methane droplets only condense at high pressure, deeper down, so no clouds visible. Result is uniform appearance.
- Methane absorbs long wavelengths $\Rightarrow$ Uranus appears blue-green.

Uranus' radical tilt causes interesting illumination conditions. 84 year orbit. 42 years of light or dark at the poles!



For instance, storms appeared as northern hemisphere moved into springtime in 2004

HST UV, V, IR composite image, with extreme computer enhancement

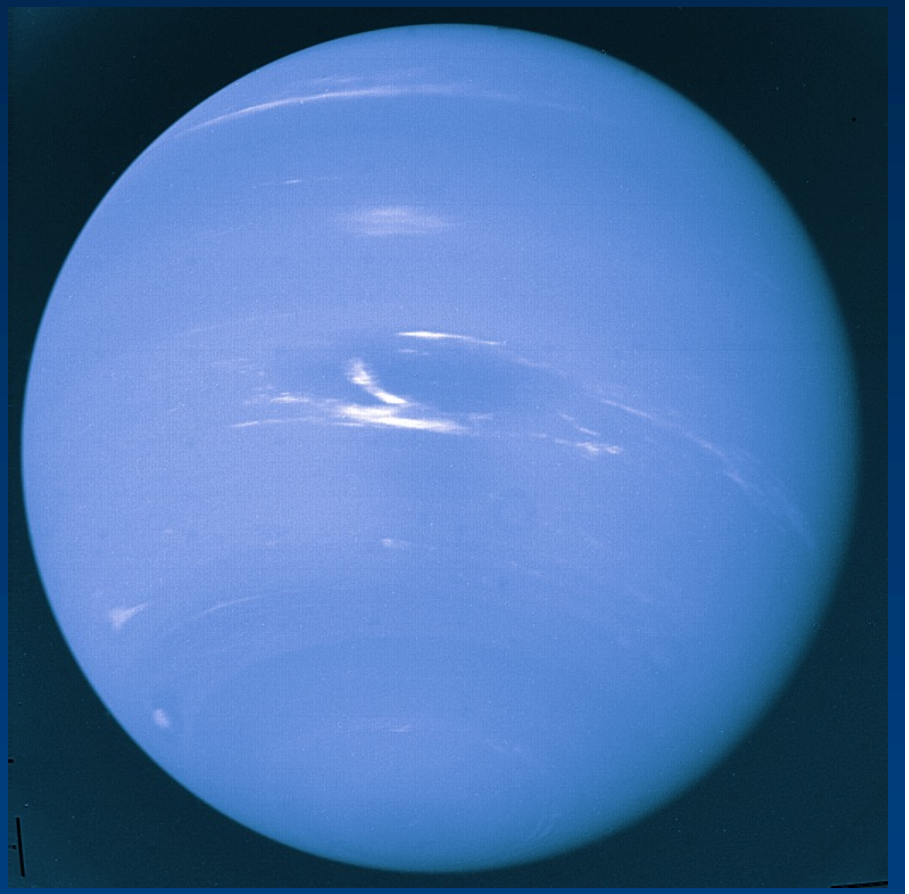


Extreme seasons

- Tilt is probably a result of an early collision with a planet-sized object when Uranus was forming
- Poles are in darkness for extremely long periods, but the temperatures over the whole of the planet are almost constant => Efficient heat transport away from Sun-facing pole.
- This heat transport may be the reason for lack of features in the atmosphere – perpendicular to wind flow, well-mixed atmosphere?
- Temperatures do not indicate internal heat source – only Sun's incident energy

Neptune

- Nearly a twin to Uranus, with blue due to methane. But cloud patterns visible. Probably liquid and frozen methane.

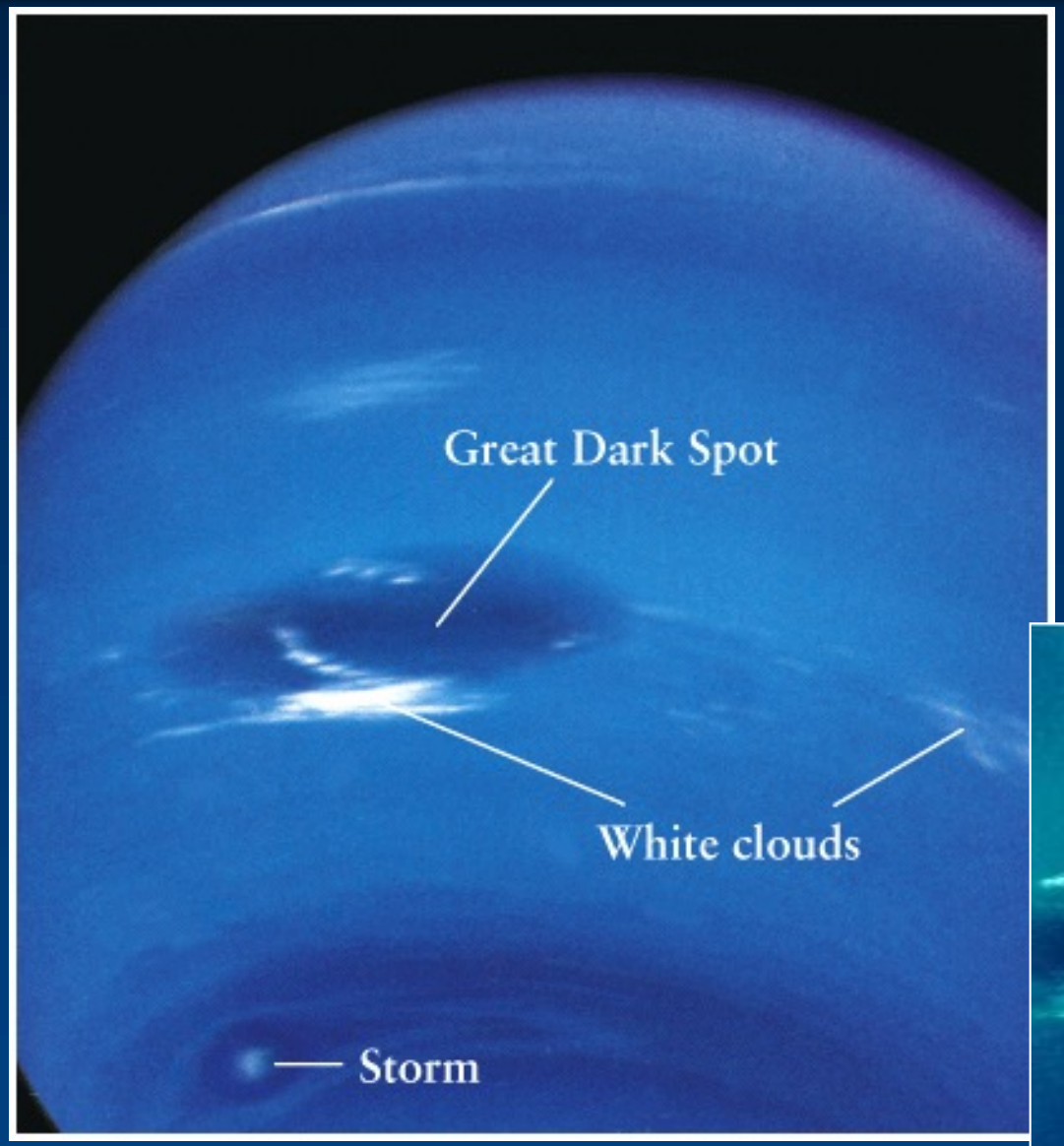


- Great Dark Spot found by Voyager 2 in 1989. Had disappeared by 1994 when HST observed it.

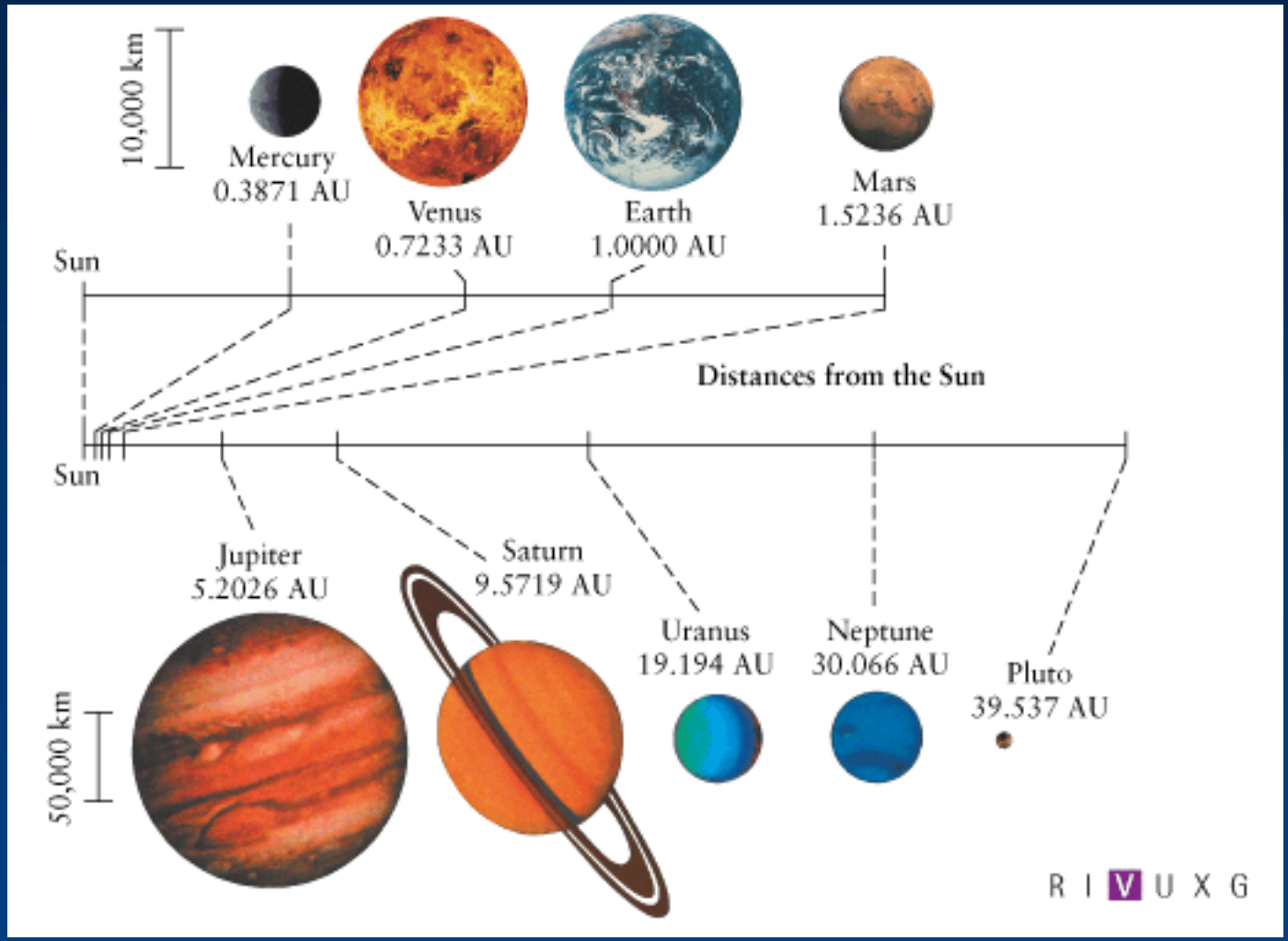
- T=55 K in upper atmosphere, like Uranus. But further from Sun. Emits more radiation than is received. Still contracting or tides? Extra internal heat may drive convection, causing clouds and storms

Neptune does show some weather patterns: must have some internal heat (still contracting? tides?)

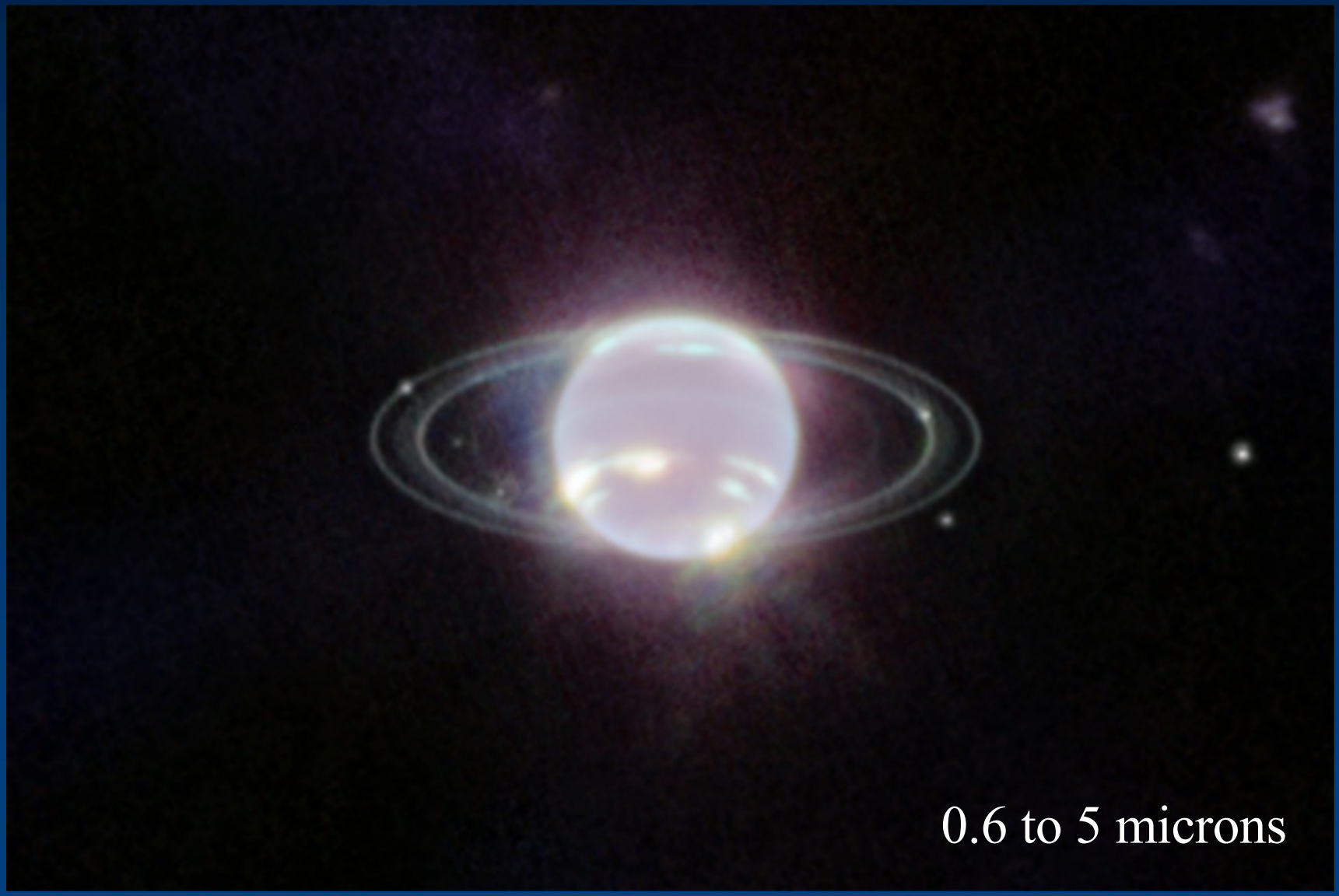
Wind speeds over 2000 kph fastest in the solar system



Uranus and Neptune have same temperature in their upper atmospheres (55K): Neptune must have more internal heat.



JWST Observations of Neptune and Rings



Both Uranus and Neptune have higher densities than Jupiter and Saturn. If they had same composition as Jupiter and Saturn, should they have the same density?

So they must have higher abundances of heavier elements. Why?

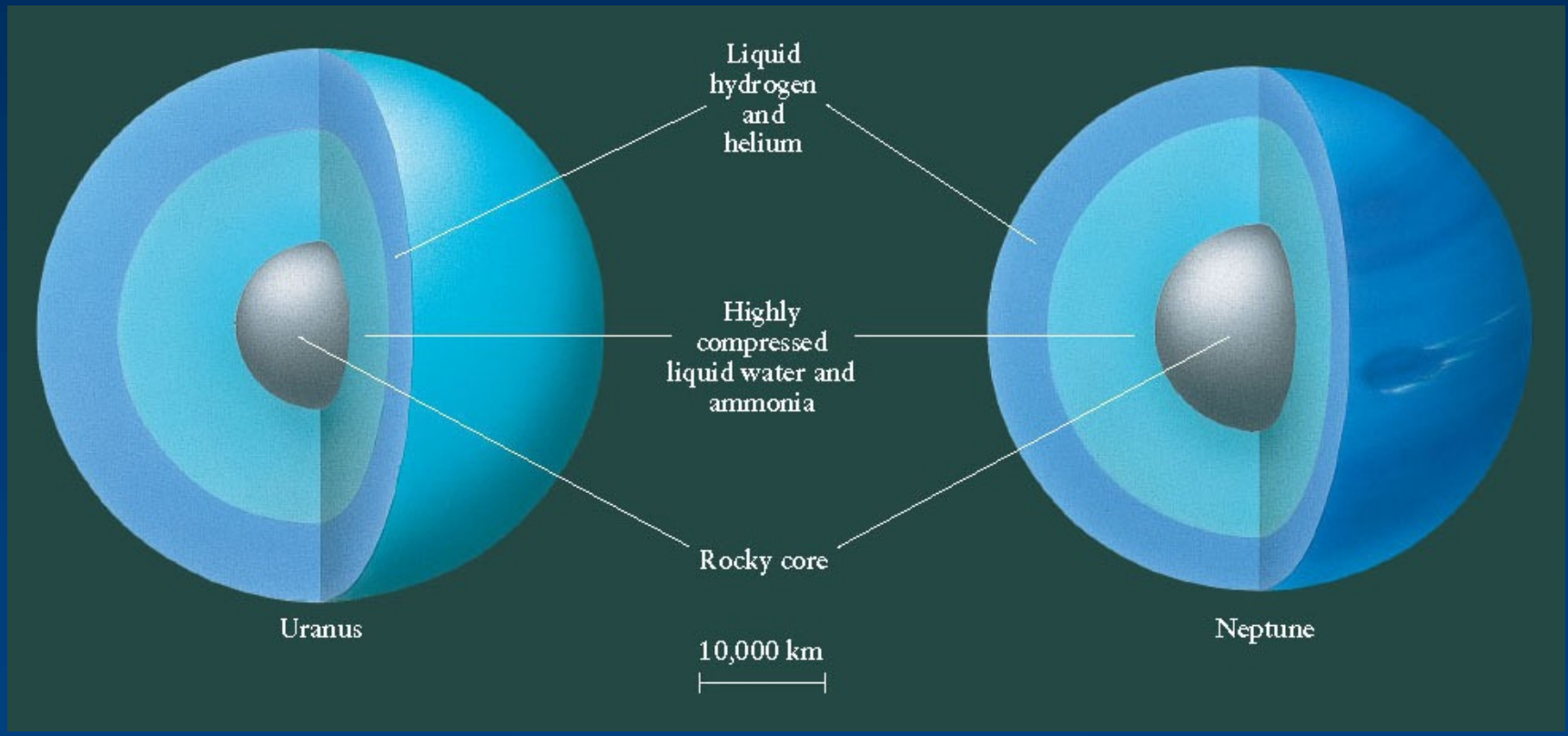
Possible explanation:

Formed closer to the Sun, then moved outwards due to gravitational interaction with Jupiter? In fact, at 30-40 AU, simulations indicate accretion process too inefficient. Planets orbit slowly, and not much material to accrete.

Still a puzzle.

Interiors are similar

- Rocky core, similar to a terrestrial planet, surrounded by liquid water and ammonia (Windex???). Liquid molecular hydrogen and helium above, with gaseous atmosphere on top.



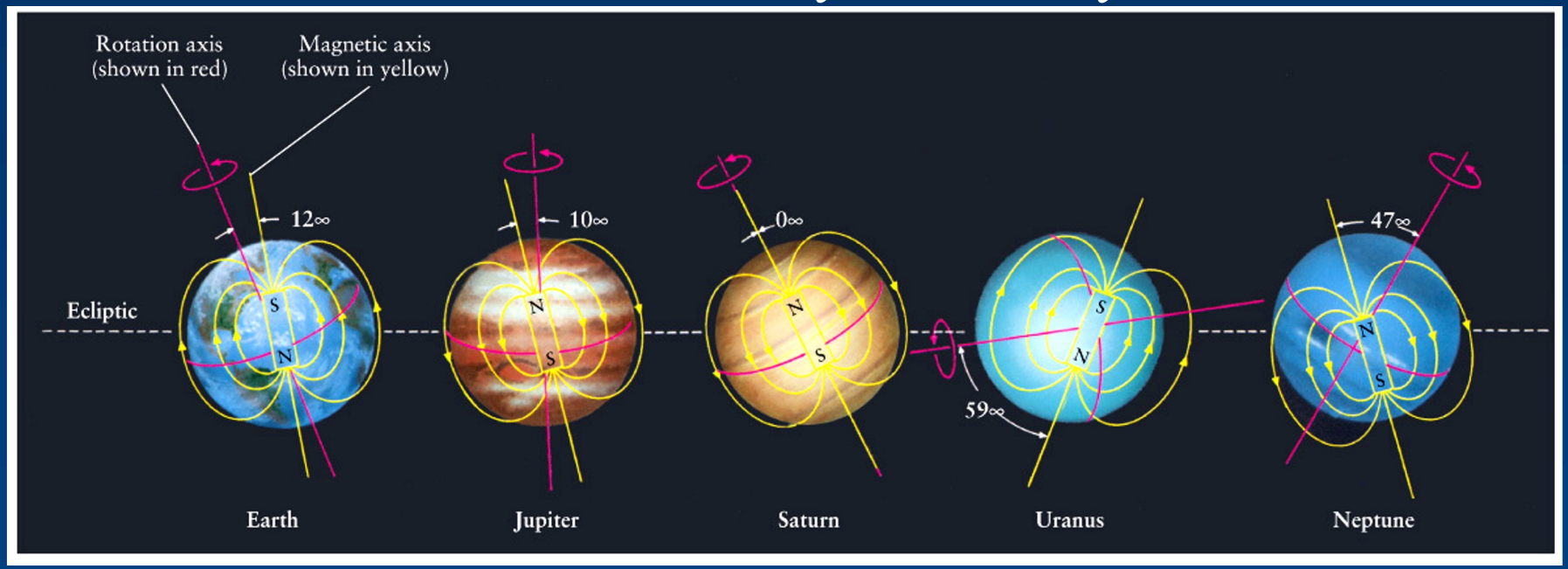
Interior pressure not sufficient to form liquid metallic hydrogen

Upper atmosphere: hydrogen, helium, ~2% methane (almost no ammonia or water)

Magnetic fields

- All Jovian planets have B-fields (Jupiter's field is the strongest; Saturn, Uranus & Neptune's fields are similar)

- Jupiter and Saturn: liquid metallic hydrogen. Uranus and Neptune: not dense enough for that, but expect ammonia liquid to be ionized, ammonia/water layer can carry current.



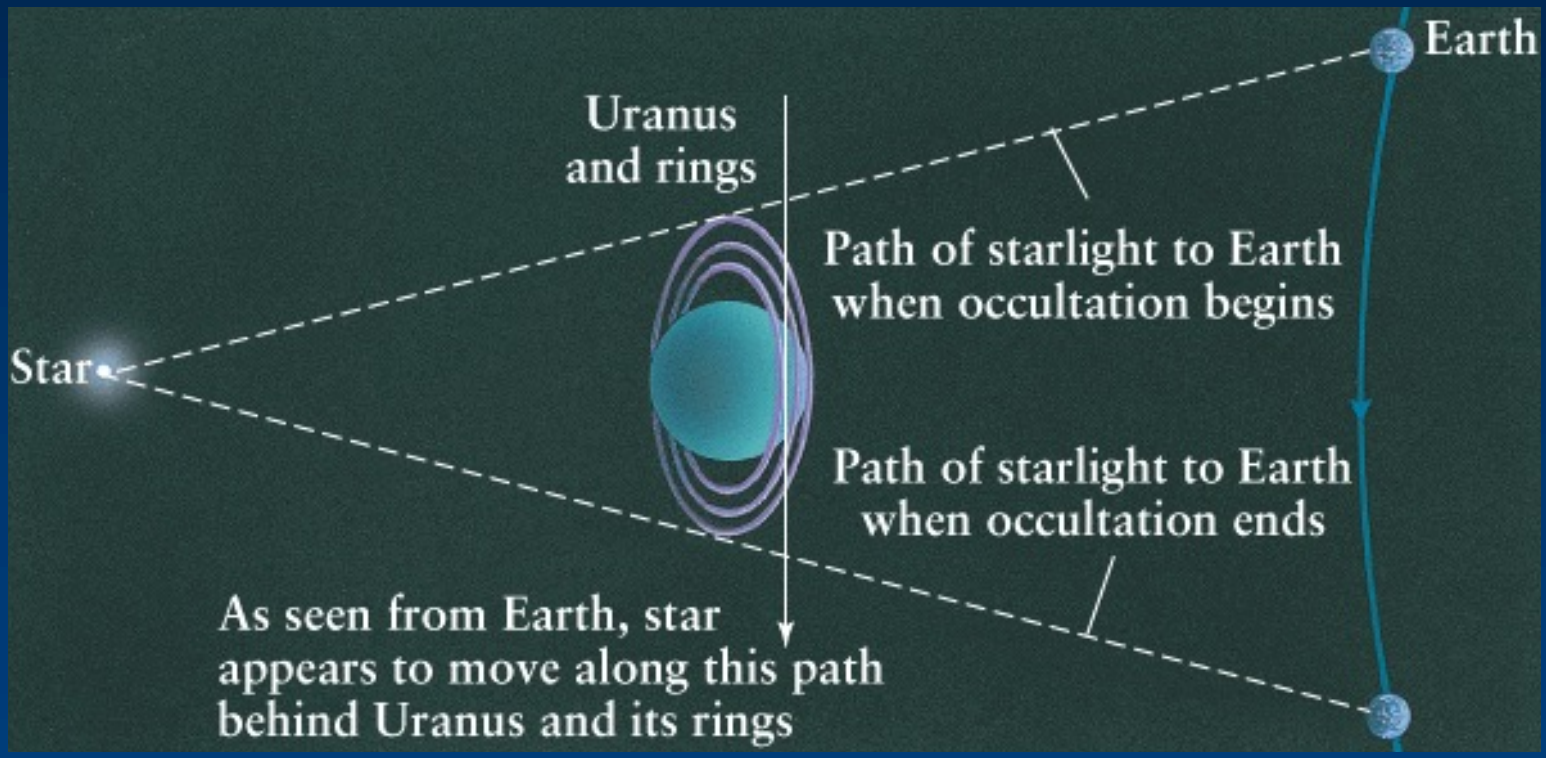
Reasons for misalignment and off-centering of Uranus and Neptune fields not clear

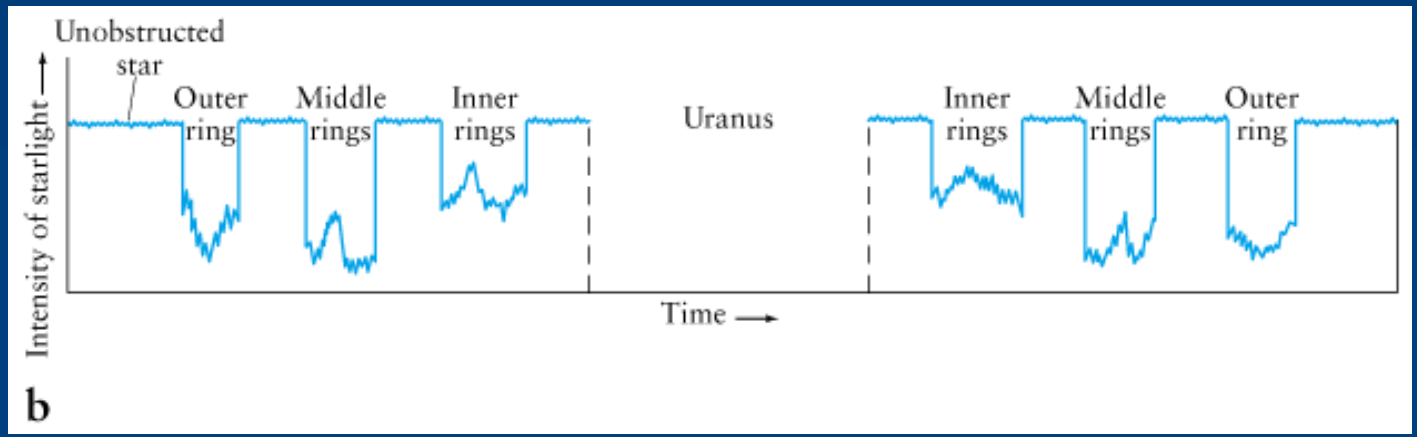
Rings

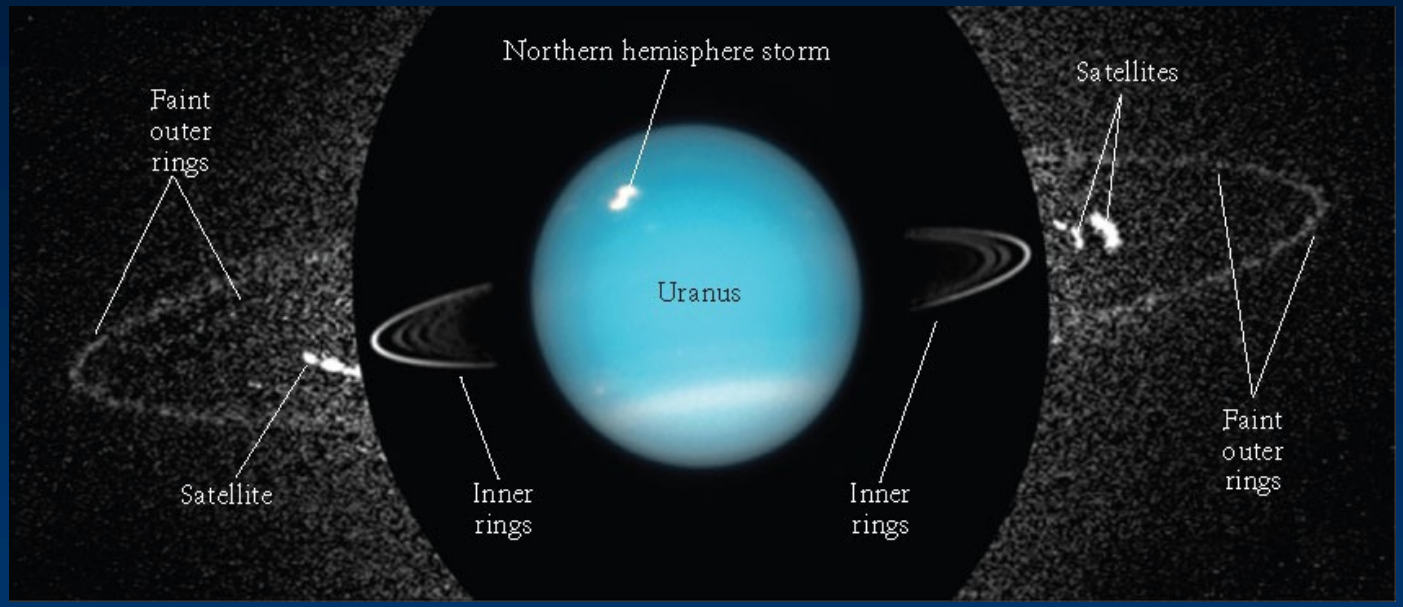
- Both have thin, dark ring systems, discovered from Earth during stellar occultations.
- Uranus's ring particle sizes are 10 cm to 10 meters. Not as reflective as Saturn's.
- Neptune's are narrower. Particles range from few μm to several meters.
- Both much darker than Saturn's.

Note: most rings are within Roche limit for planet

Uranus' rings discovered accidentally during "occultation" experiment in 1977 to determine Uranus' size. Star flickered before and after.



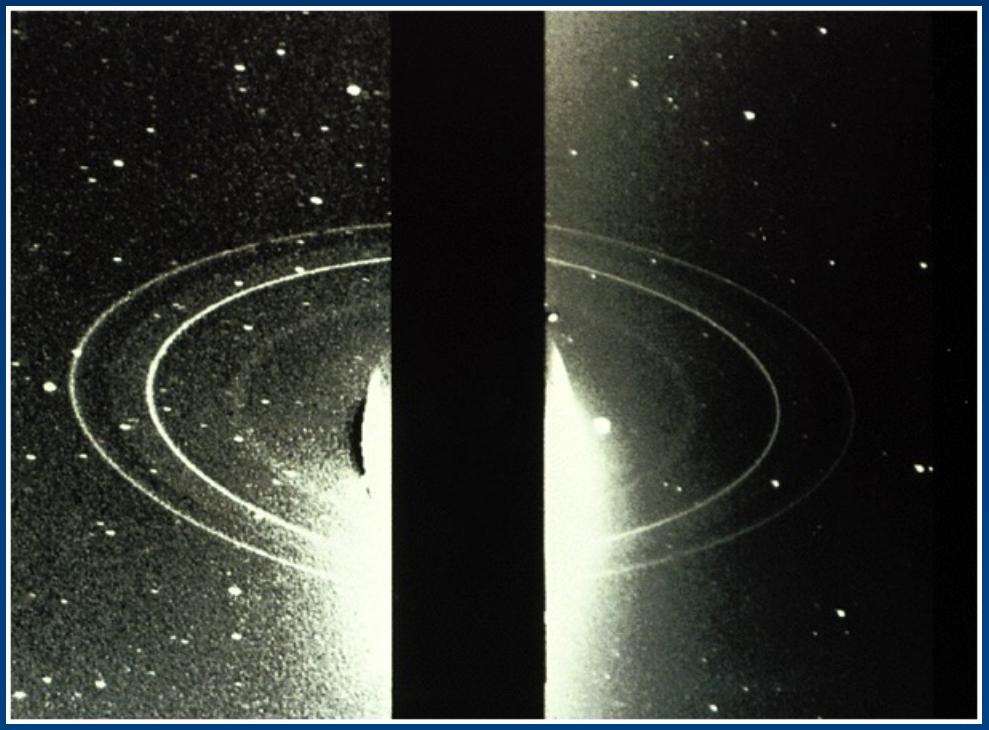


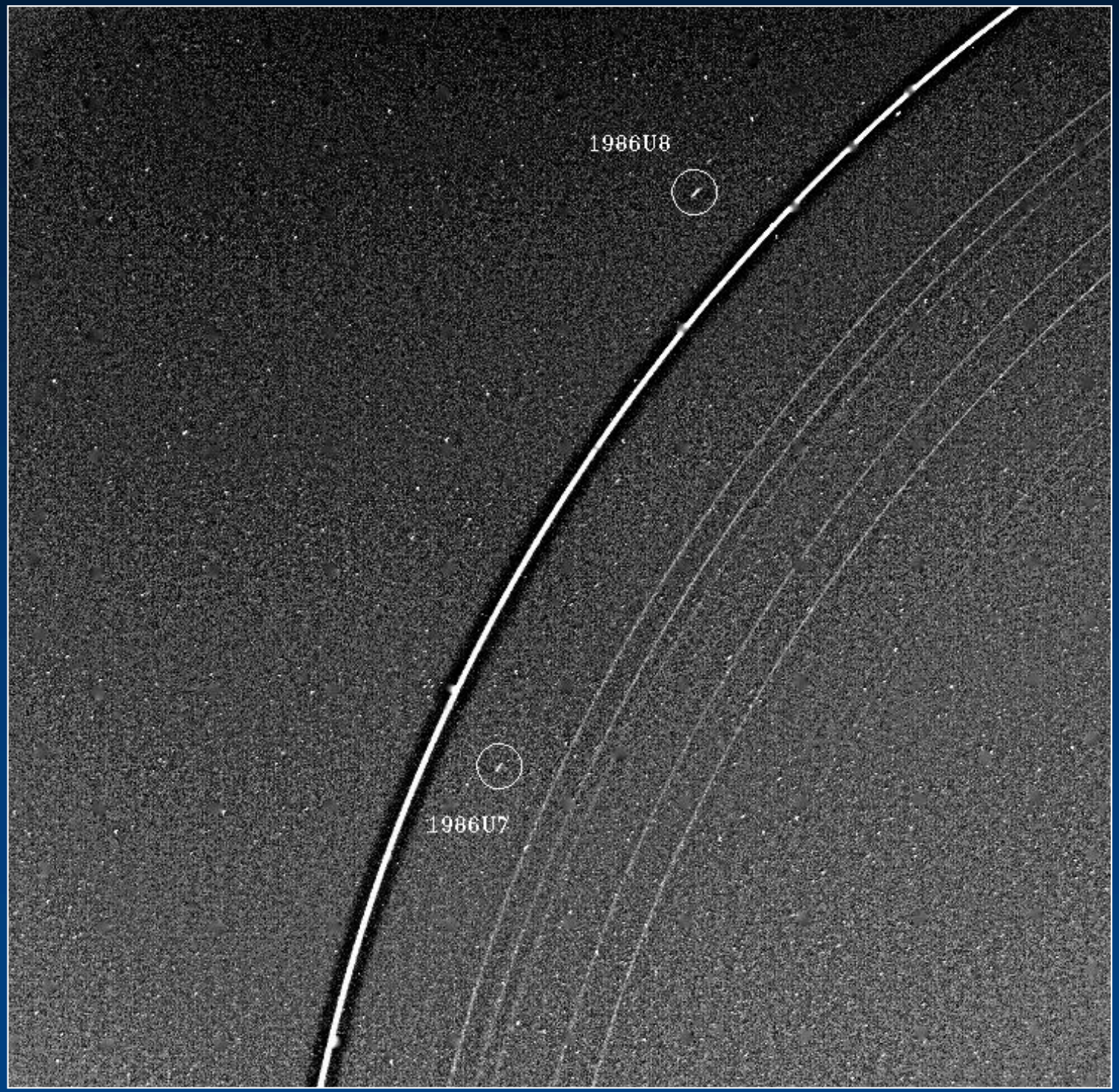


HST images, long exposure time to image outer rings

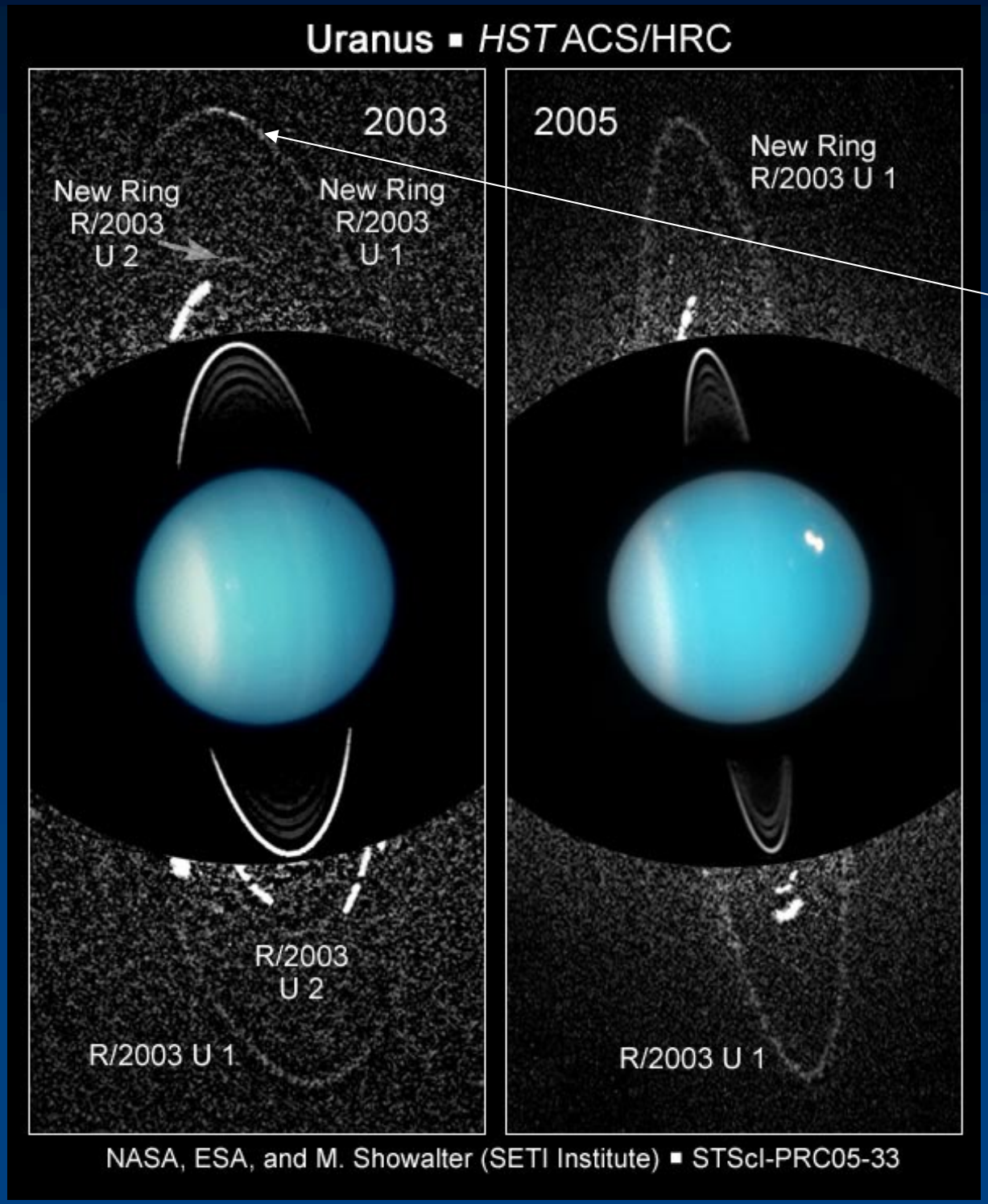
Why are these rings darker than Saturn's?
Rings cold enough to retain methane ice, not just water ice. When hit by electrons in the magnetosphere, methane converted into dark carbon compounds.

Neptune's rings and faint disk ending between brightest rings - Voyager 2 images



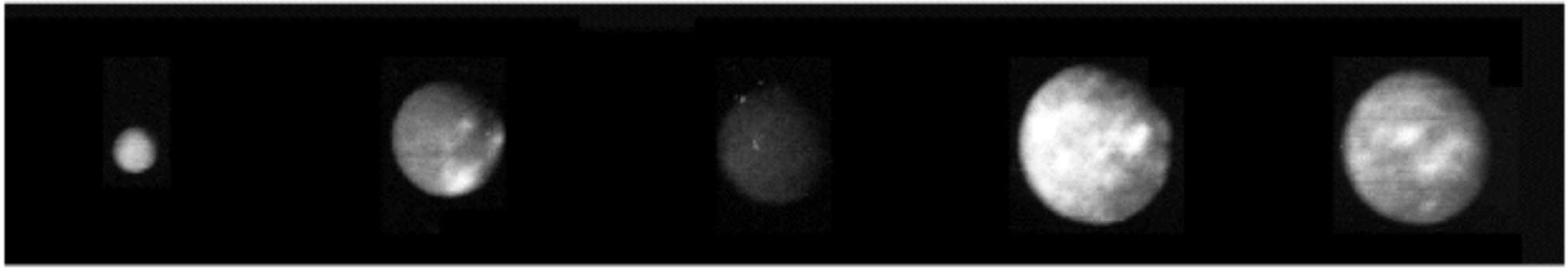


Voyager 2: Uranus's bright Epsilon ring is shepherded by two satellites, Cordelia and Ophelia



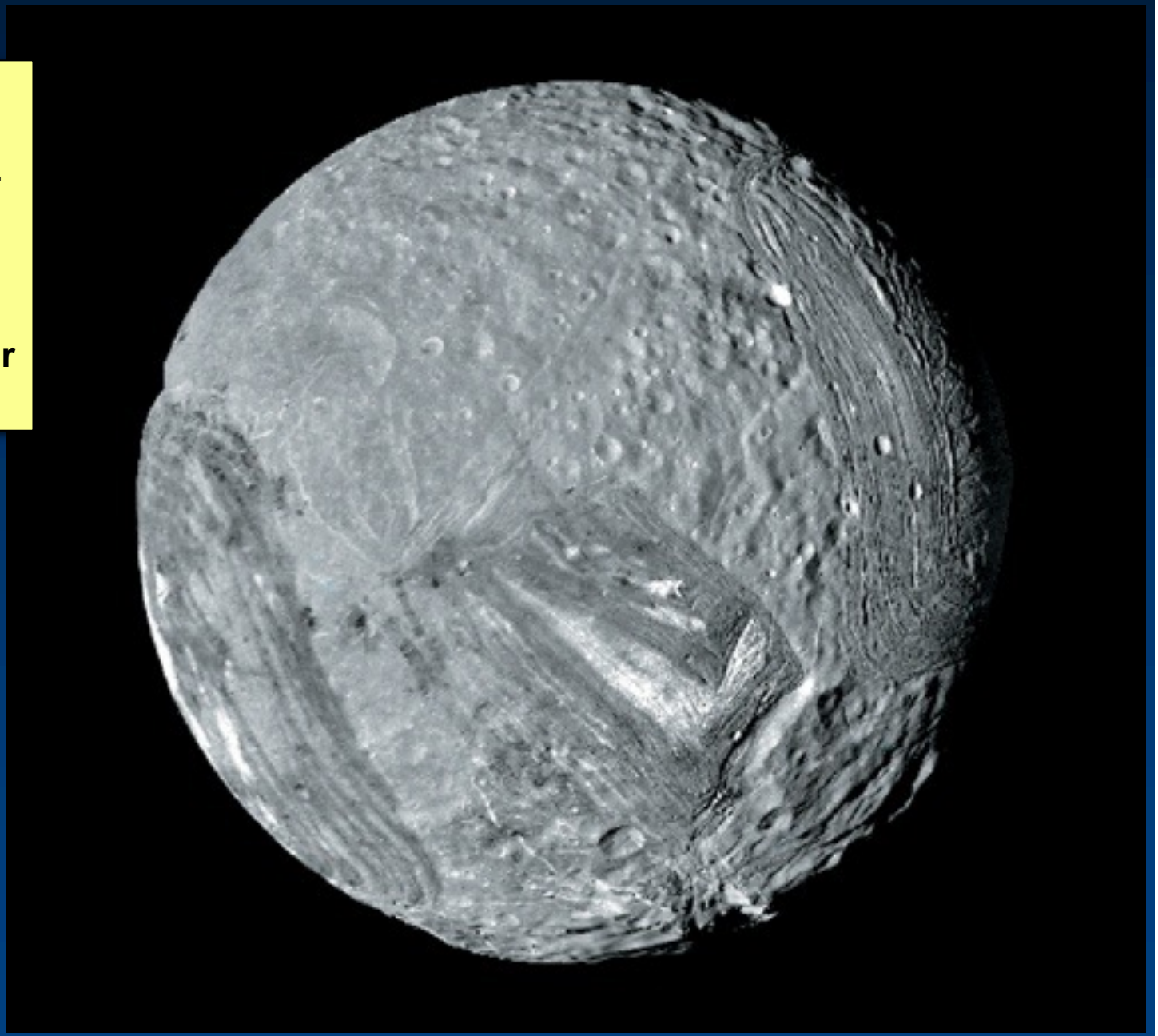
Two outer rings, outermost fed by dust kicked out from impacts on a newly discovered satellite Mab.

Uranus' satellites (27)



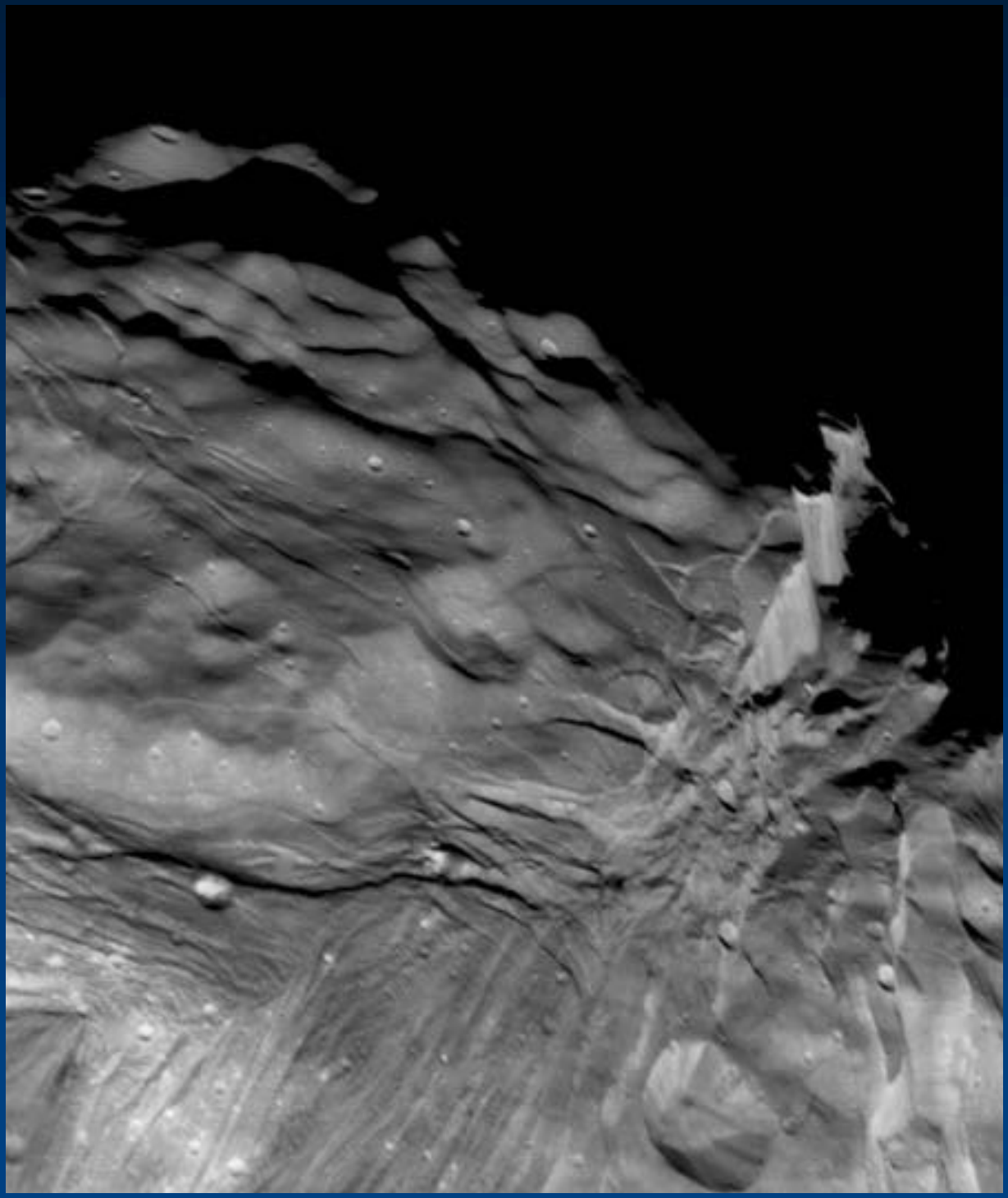
- 5 large, icy moons
- ~13 smaller ones cluttered in the rings
- Plus a number of smaller, outer moons with retrograde rotation (captured asteroids)

Miranda – two very different types of terrain. One cratered, dating to > 4 billion years ago. Other suggests some upheaval. Reasons not clear. Disruptive event or tidal heating in the past?

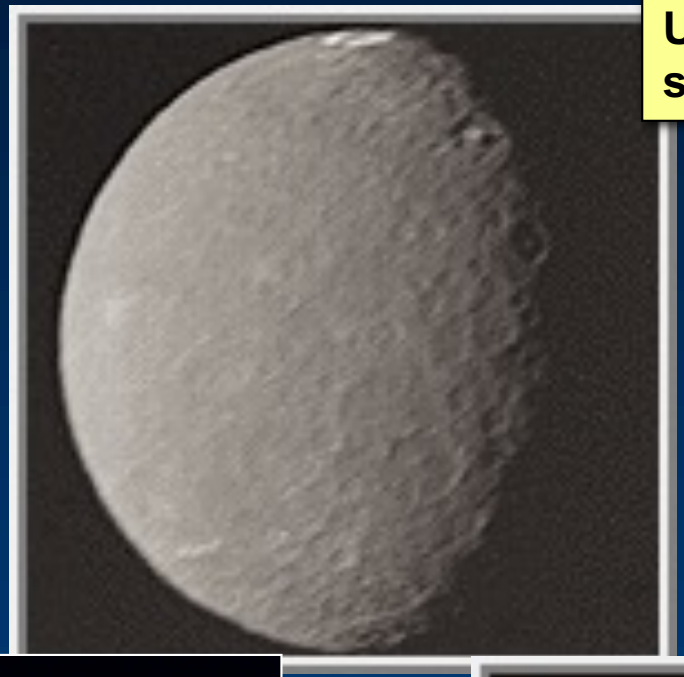


Worksheet 13

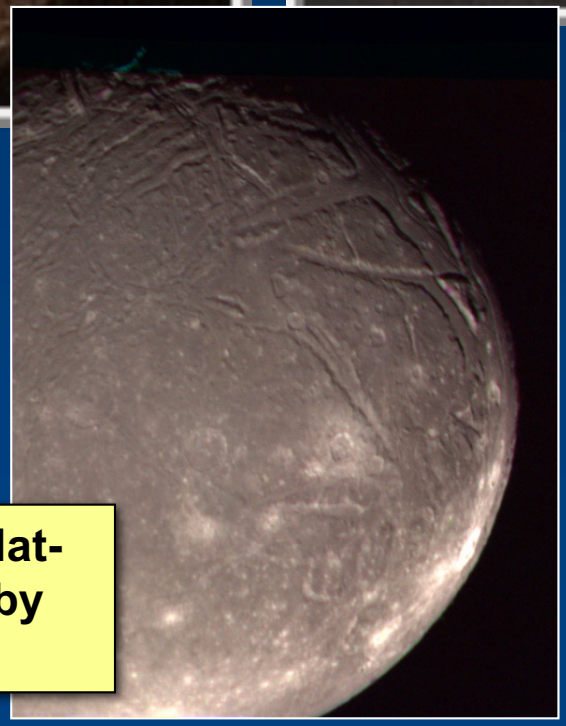
10 km high cliff



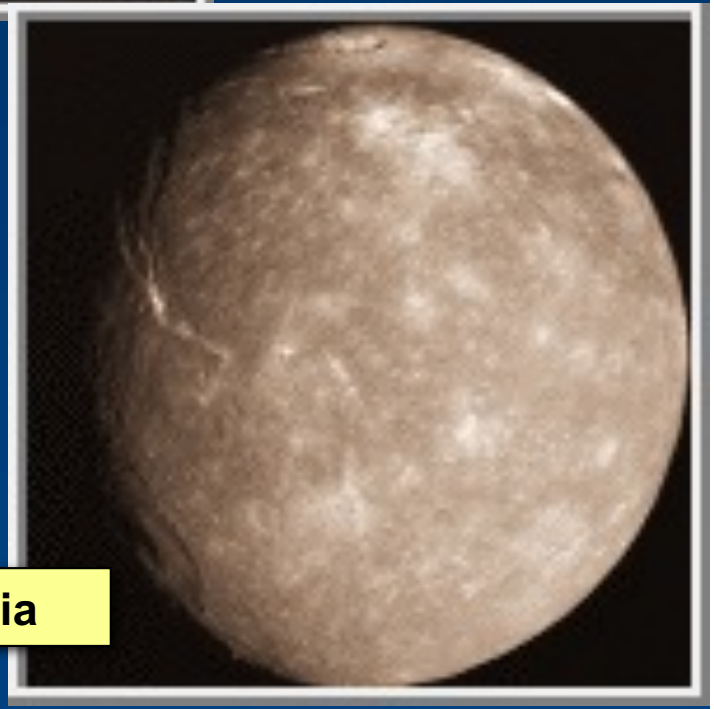
Oberon: old surface



Umbriel: old surface

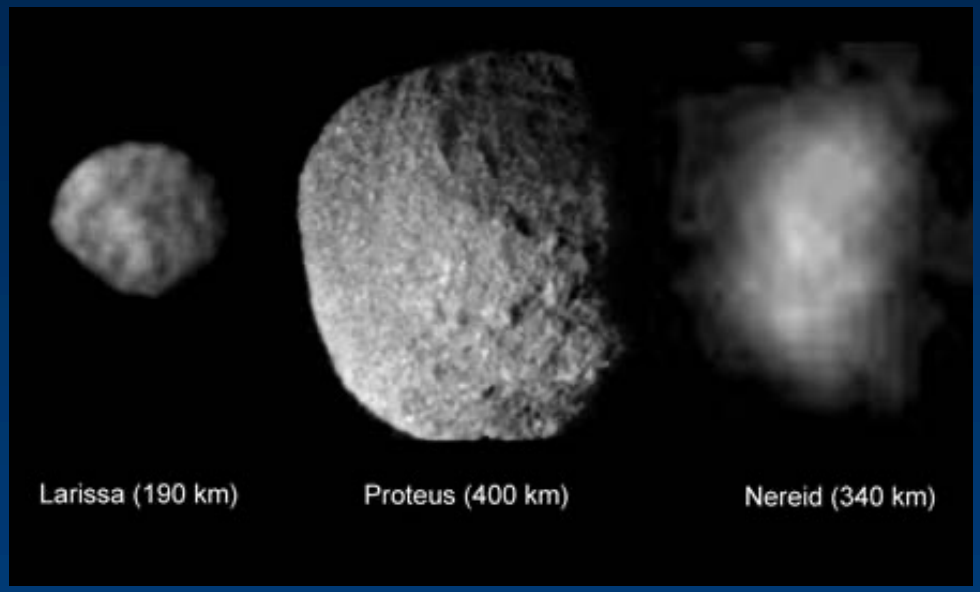


Ariel: younger surface, flat-floored valleys, flooded by ice lava



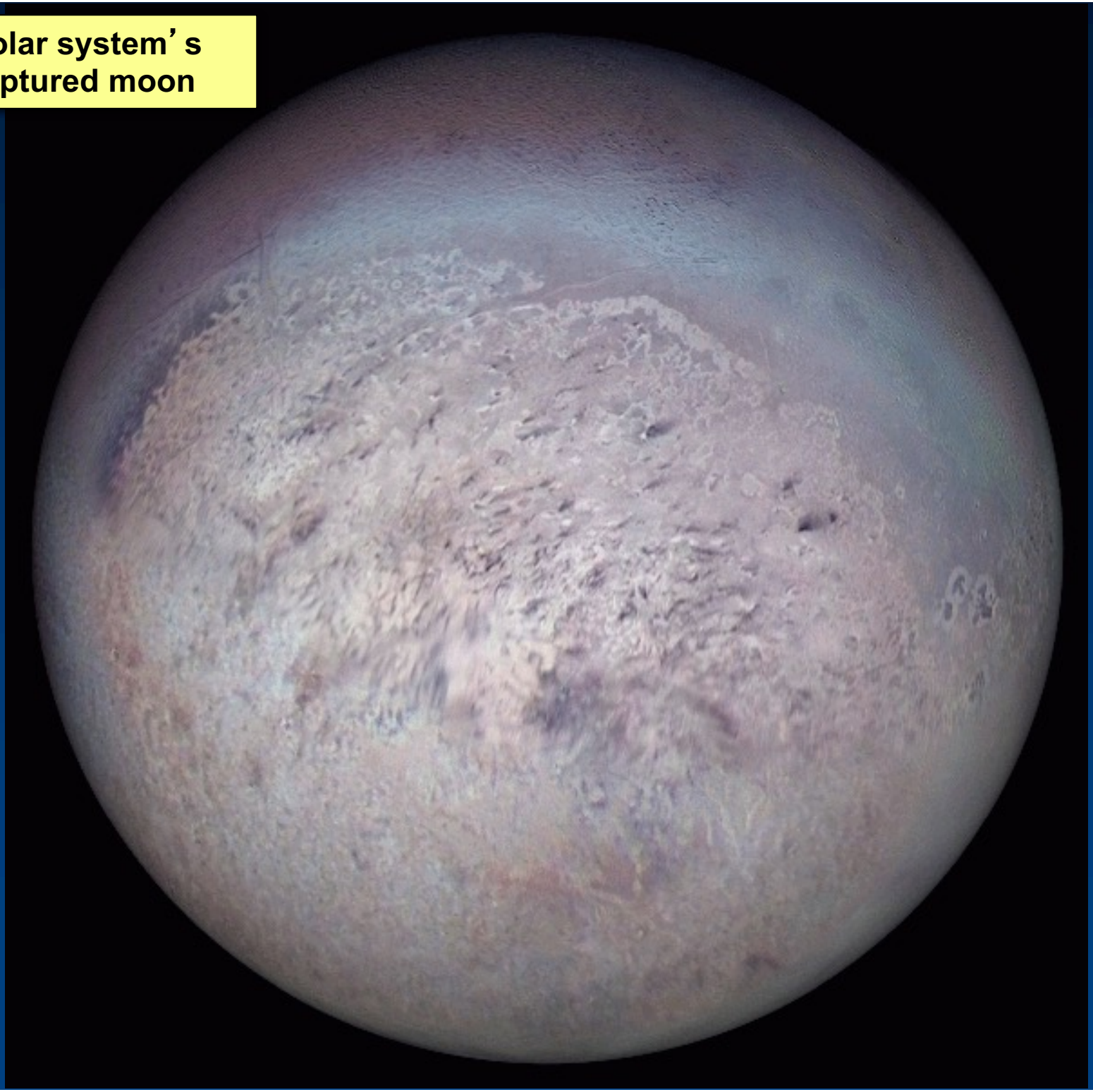
Titania

Neptune's satellites (13)



- Triton (2707 km) much larger than the rest
- Highly inclined, retrograde orbit
  => captured, formed elsewhere

Triton: Solar system's largest captured moon

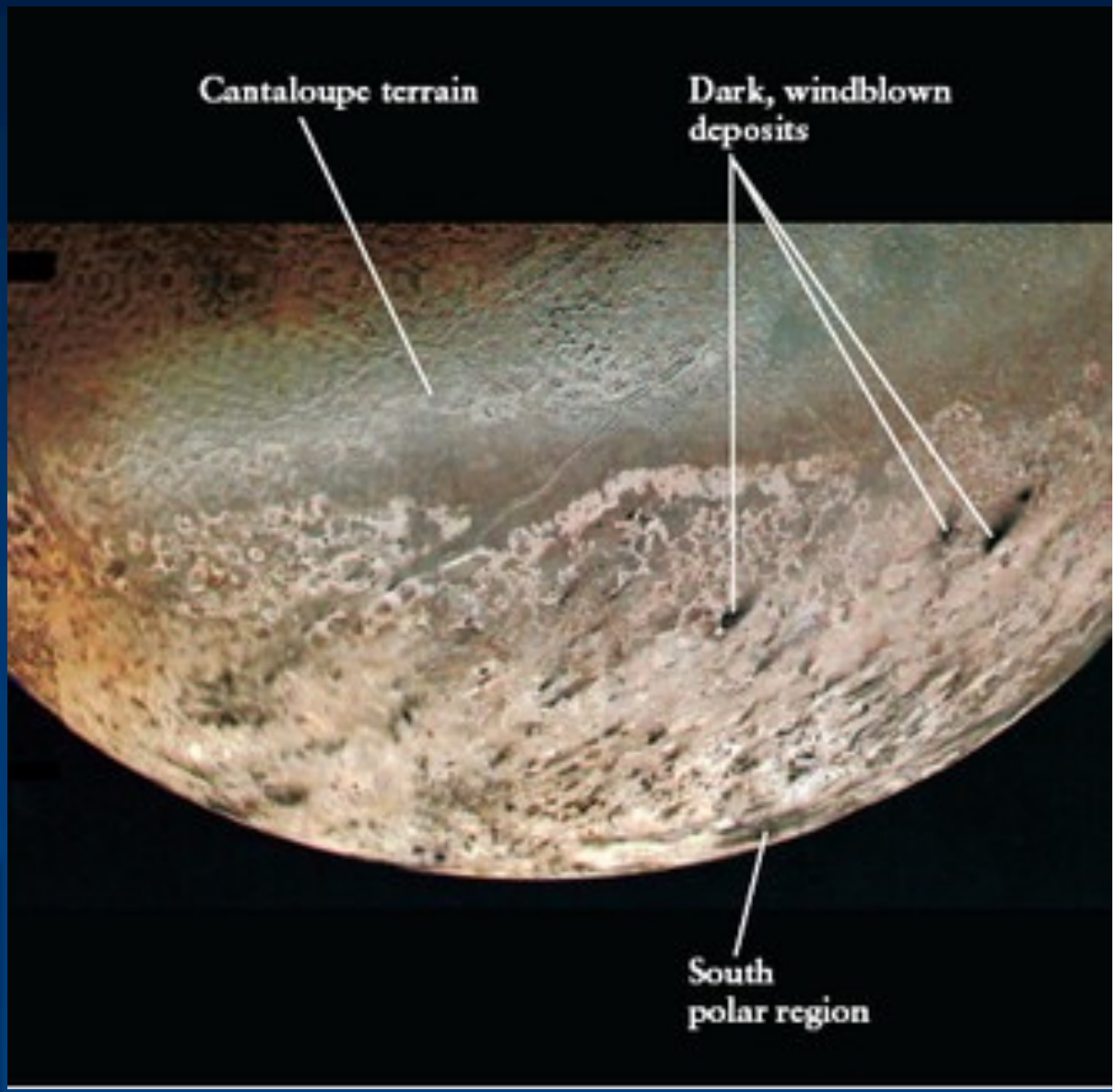


Tenuous nitrogen and methane atmosphere. Despite cold, sunlight can still evaporate some ices from surface.

Cantaloupe terrain thought to be due to volcanism and rifting of the surface. Age < 0.3 billion years from crater counts. Southern part is large polar nitrogen ice cap.

Nitrogen plumes in south => Sub-surface greenhouse effect causing geysers?

Lack of craters suggest recent internal heat source though, causing geysers



- Tectonic activity is likely related to its capture.

- Initial, highly elliptical orbit would become circularized by tidal forces. Varying tidal stresses may have led to internal heat.

- Tidal force, along with retrograde orbit, causing Triton to spiral in toward Neptune.

- It should fall inside of Roche limit in 10^8 years
  $\Rightarrow$ spectacular rings?