

Bell Ringer

1. What is the process called by which we could make Mars livable for humans?
2. How long would this process take?
3. How many moons does Mars have?



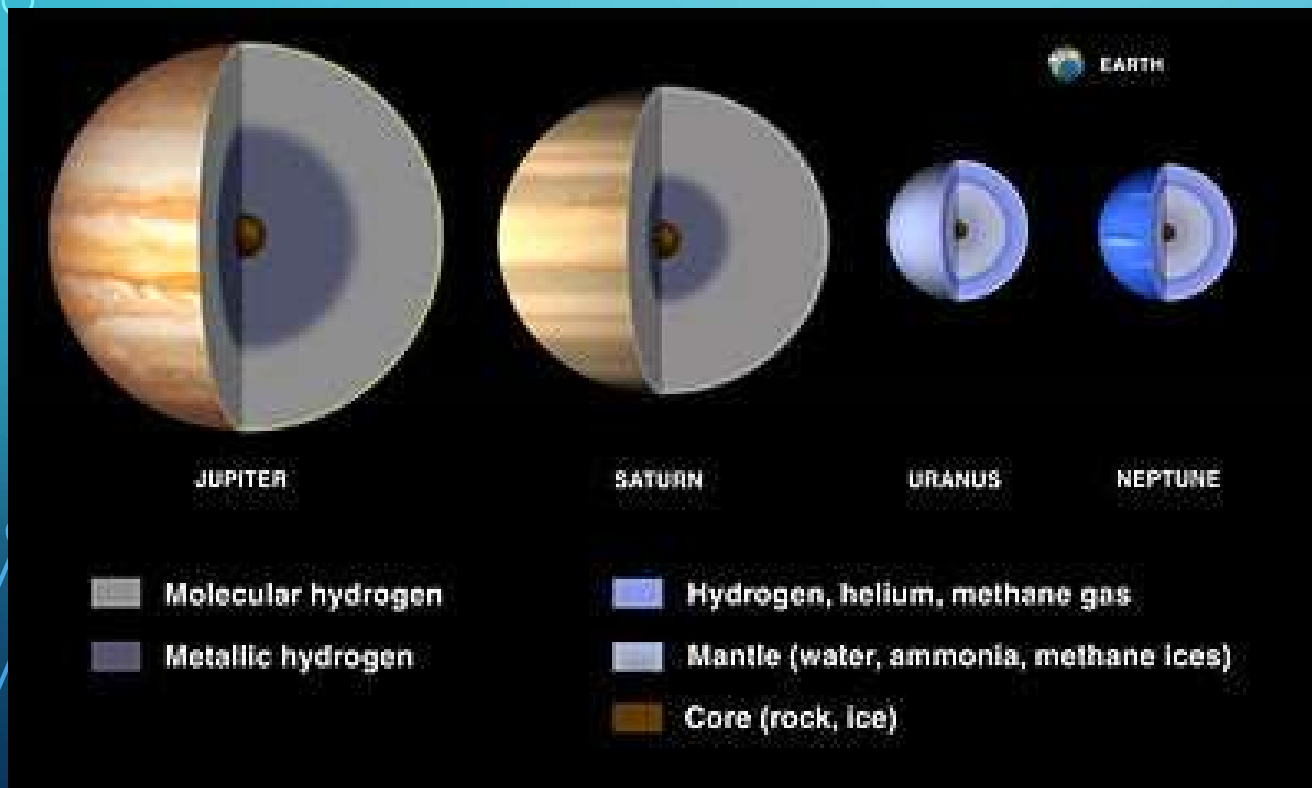
OUTER PLANETS



GOALS FOR TODAY

1. Understand the basic properties of the inner planets in general
2. Understand the basic properties of each of the inner planets
3. Understand the two groups that we can divide the inner planets into
4. Understand the properties of Pluto and other objects in the Kuiper Belt

OUTER PLANETS - CATEGORIES



1. Gas Giants

A. Jupiter

B. Saturn

2. Ice Giants

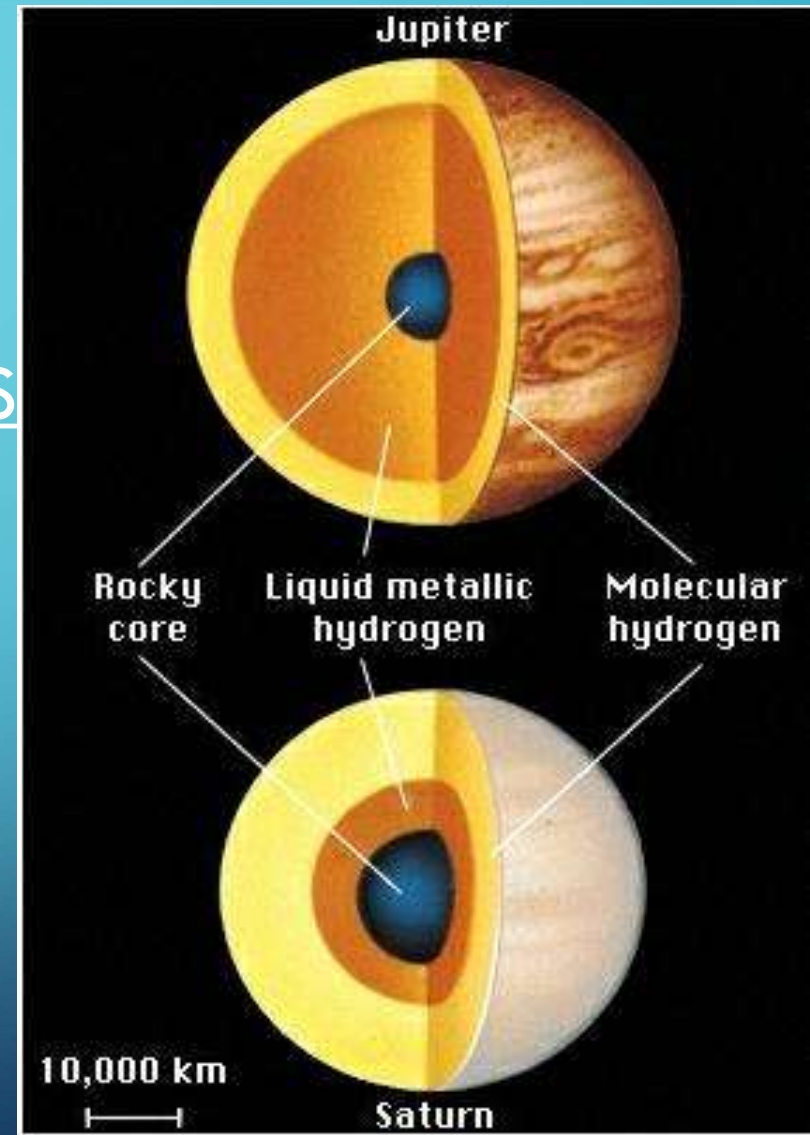
A. Uranus

B. Neptune

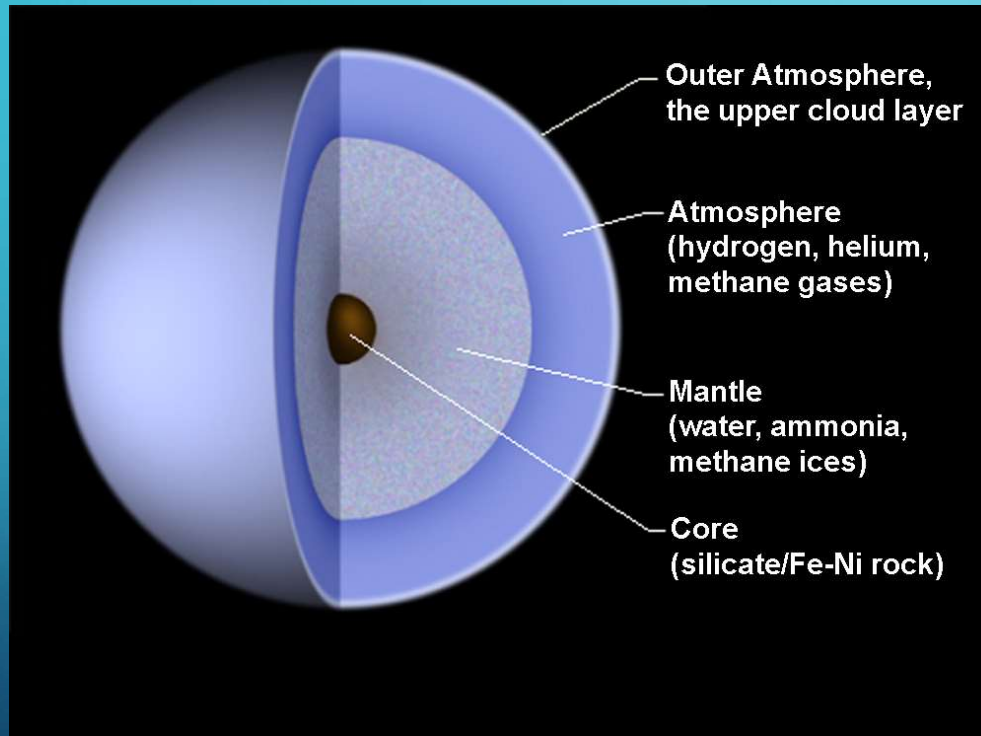
GAS GIANTS – BASIC PROPERTIES

1. Small rocky core
2. Mostly Hydrogen shells around it (some helium)
3. Between the outer layer of Hydrogen and the core, the middle tends to behave differently. Conducts electricity.

What other object in our solar system is mostly Hydrogen and Helium?

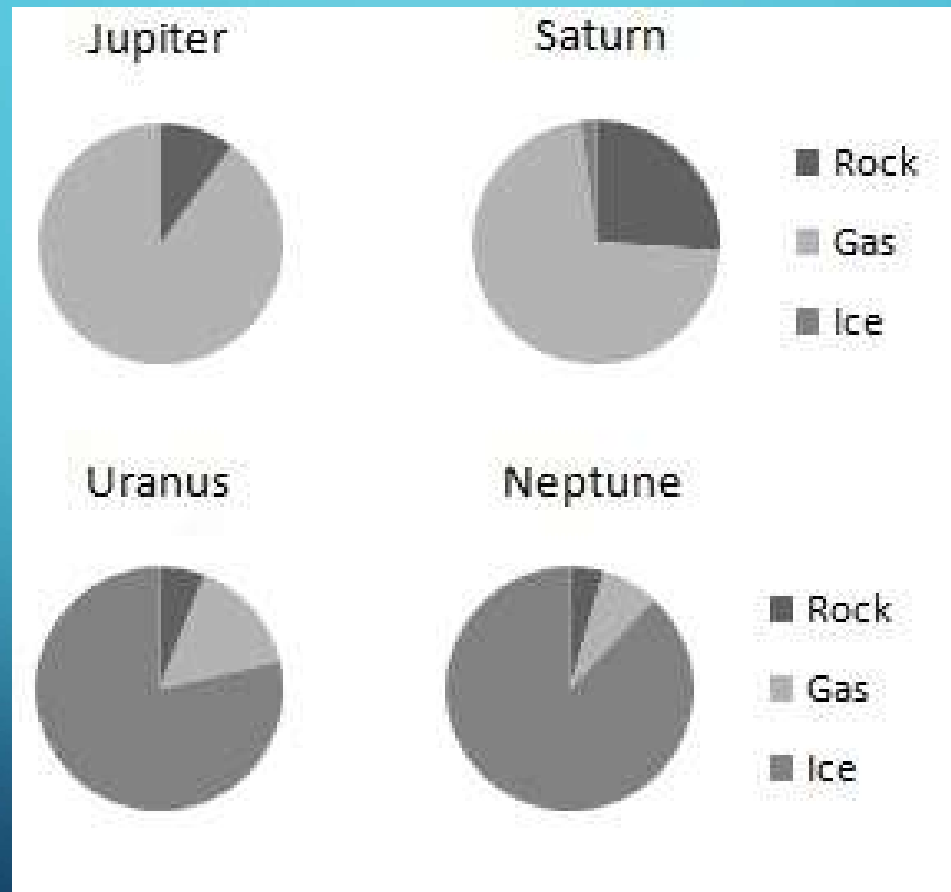


ICE GIANTS – BASIC PROPERTIES

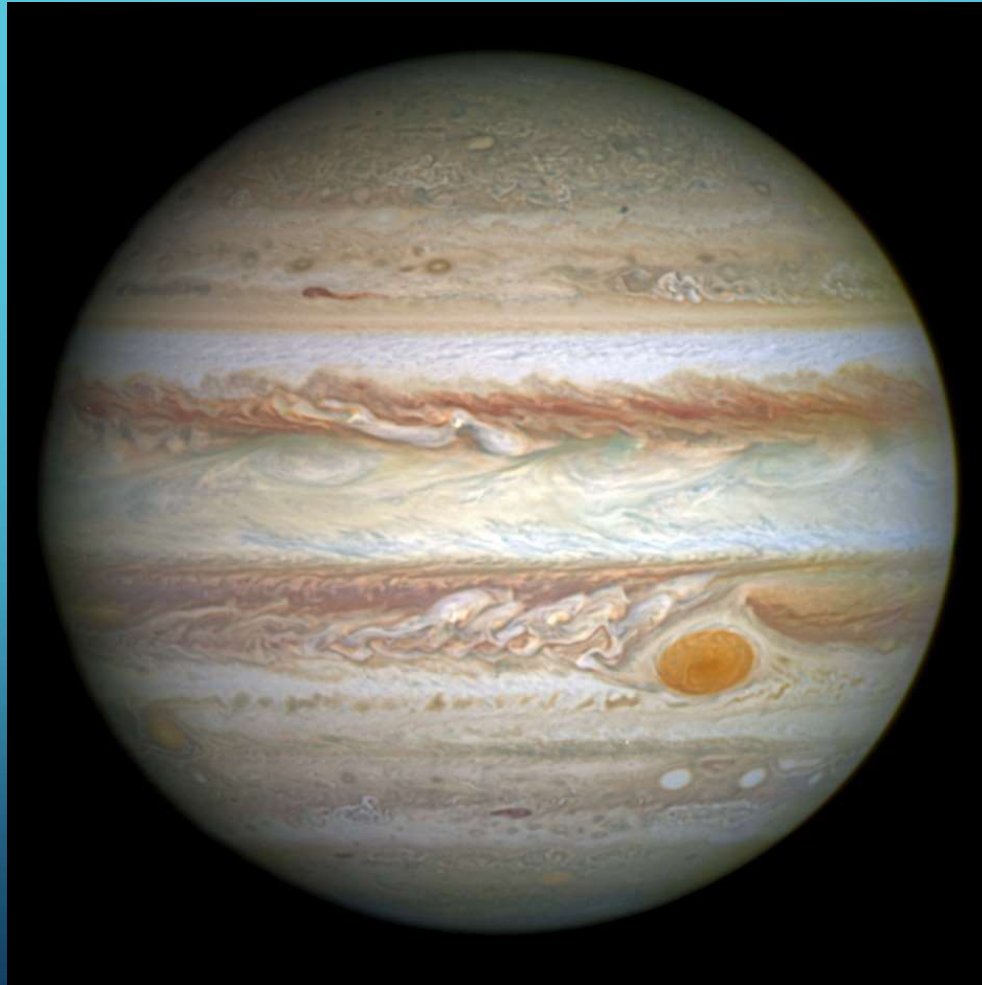


1. Rocky Core
2. Compressed water, methane, and ammonia (turns into hard icy shell)
3. Hydrogen/Helium gas shell around the ice

ICE GIANTS VS. GAS GIANTS



JUPITER





Zeus, Ceiling at Ny Carlsberg Glyptotek, Copenhagen. Photo © Malcar Förlag - GML

Jupiter

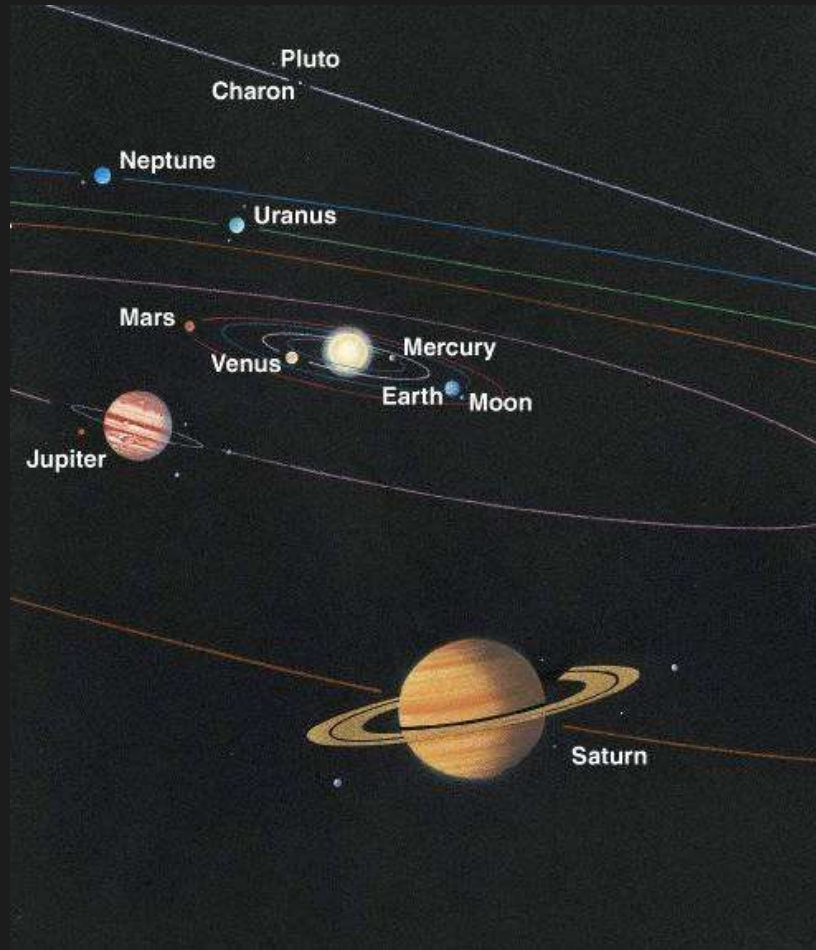
- Most important and powerful of the Roman Gods (Greeks called him Zeus)
- Ruler of the Heavens
- Son of Saturn and brother of Neptune and Pluto
- Usually shown with lightning bolts, Eagle was his symbol and messenger
- Why call it Jupiter?



Jupiter (Zeus) Source:



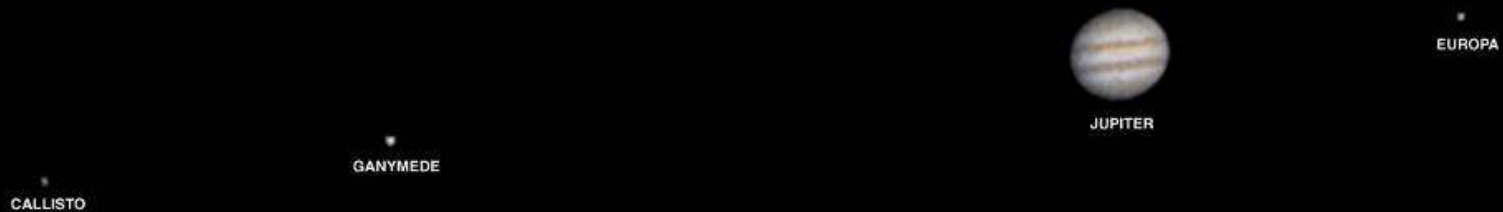
	Jupiter	Earth
Diameter (km)	143,800	12,800
Mass	320 M_E	1 M_E
Density (g/cm³)	1.3	5.5
Year	11.86 y_E	365 days
Day	9.8 hours _E	1 day
Distance (AU)	5.2	1
At cloud tops:		
Temperature (F)	-162°	61°
Moons	68+	1
Gravity	2.4	1



Jupiter

- Planet least like Earth
- Type example of outer planet — Jovian or Gas Giant
- Twice as massive as all other planets combined!
- Large system of orbiting satellites (moons)
- We have done flybys, orbiter, and probe
- No lander. Why?

Jupiter



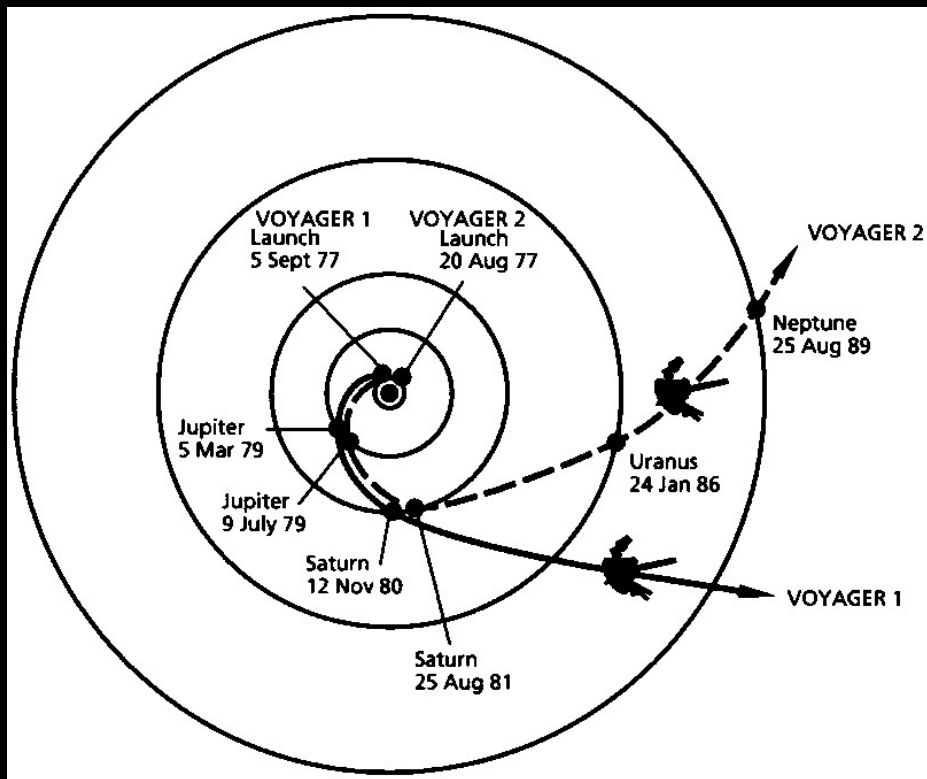
Zeus, Ceiling at Ny Carlsberg Glyptotek, Copenhagen. Photo © Maicar Förlag - GML.

- As seen from Earth with a telescope
- Rotates so rapidly (10 hours) that it is flattened at poles
- Clouds form "surface" visible in photos
- Large system of Moons

Spacecraft

- Pioneer 10 - 1973
- Pioneer 11 - 1974
- Voyager 1 and 2 - 1979
- Galileo 1996-2003
- Cassini - Dec. 2000
- New Horizons - Feb. 2007
- Juno - 2016 - now!





Voyager 1 and 2

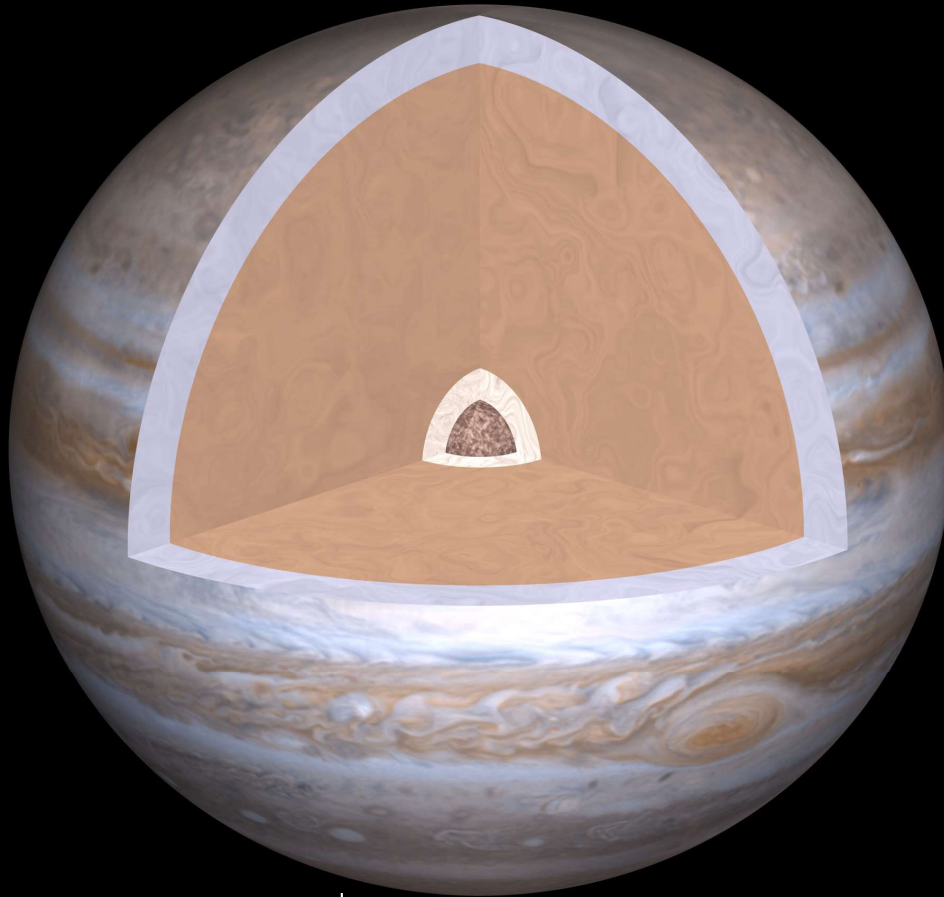
1977 launches

Study of gas giants

Voyager 1 is the farthest human-made object from Earth

Exiting the solar system, going into interstellar space

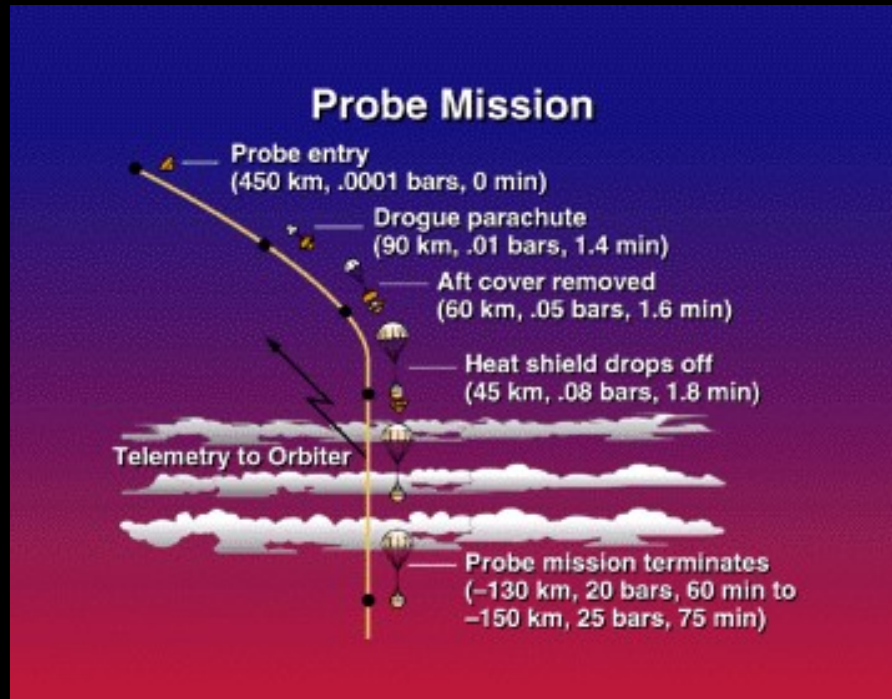
Jupiter's Interior



- Small core of rock and, iron several times Earth's mass
- Ice (H_2O)
- Liquid **Metallic** Hydrogen (H^+)
- Liquid Molecular Hydrogen (H_2)
- Gaseous Molecular Hydrogen (H_2)
- Atmosphere of H_2 with He, clouds of ammonia (NH_3) and water



Jupiter's Atmosphere



Gas

He

H₂

Jupiter

24%

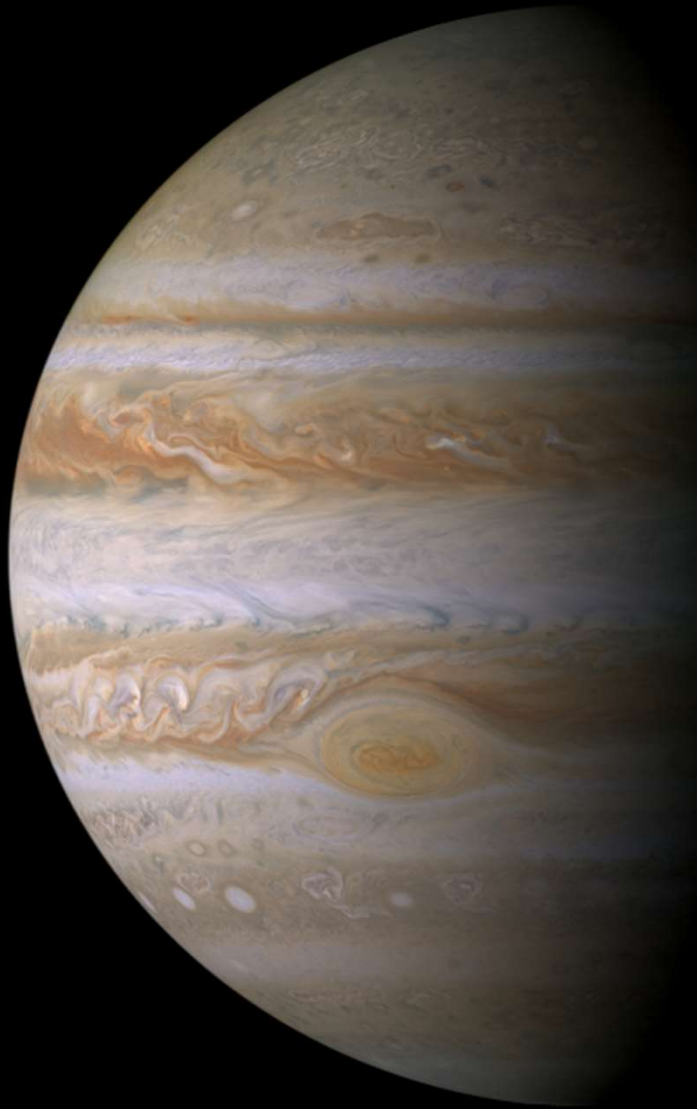
75%

Sun

25%

74%

Plus water, methane, ammonia in small quantities



Atmosphere convection

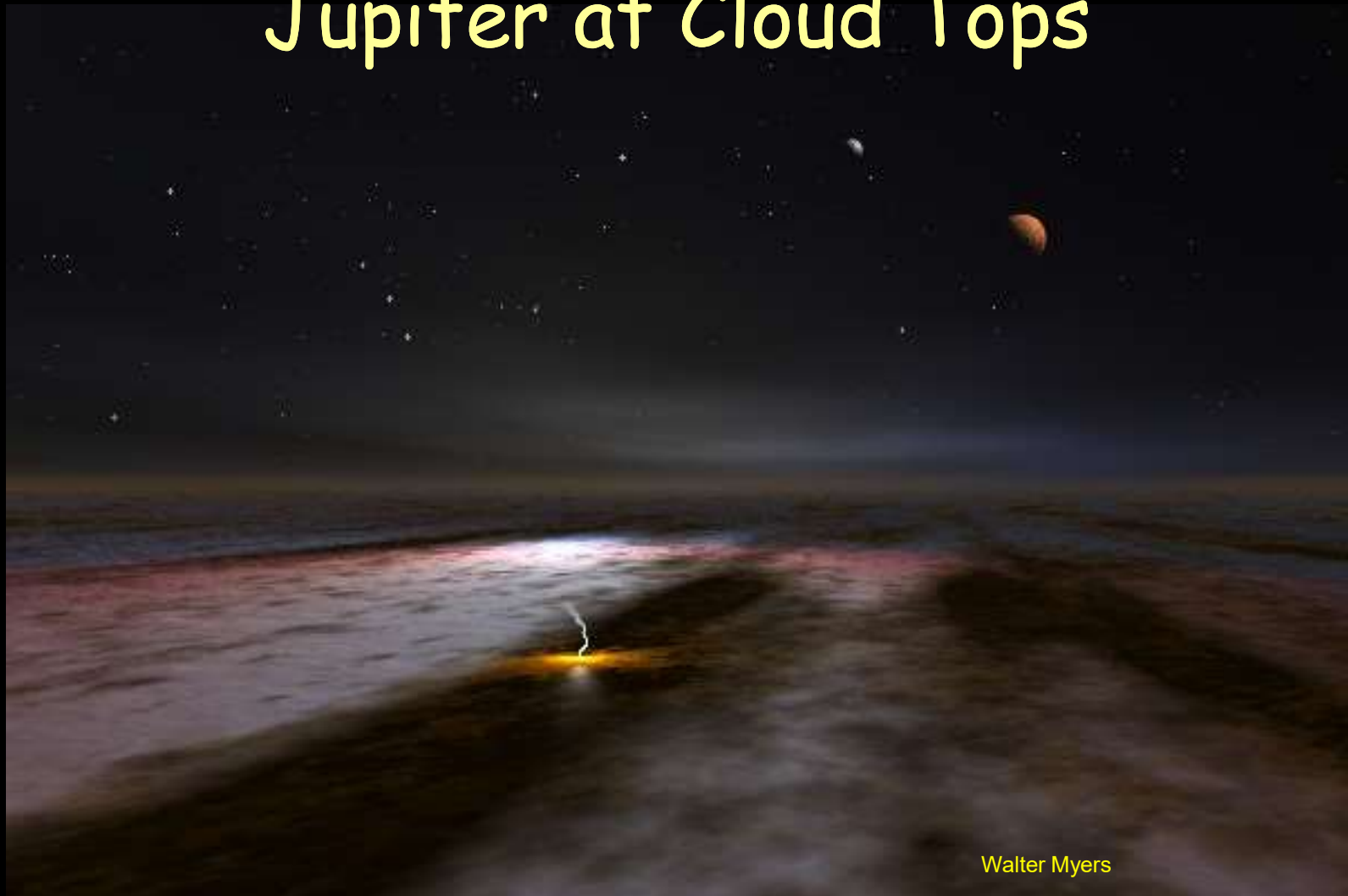
Bands (bright) and Zones (dark) are separately convecting layers of up- and down- welling gas

Affected by Jupiter's rapid spin

Turbulent cyclonic storms are shear between bands

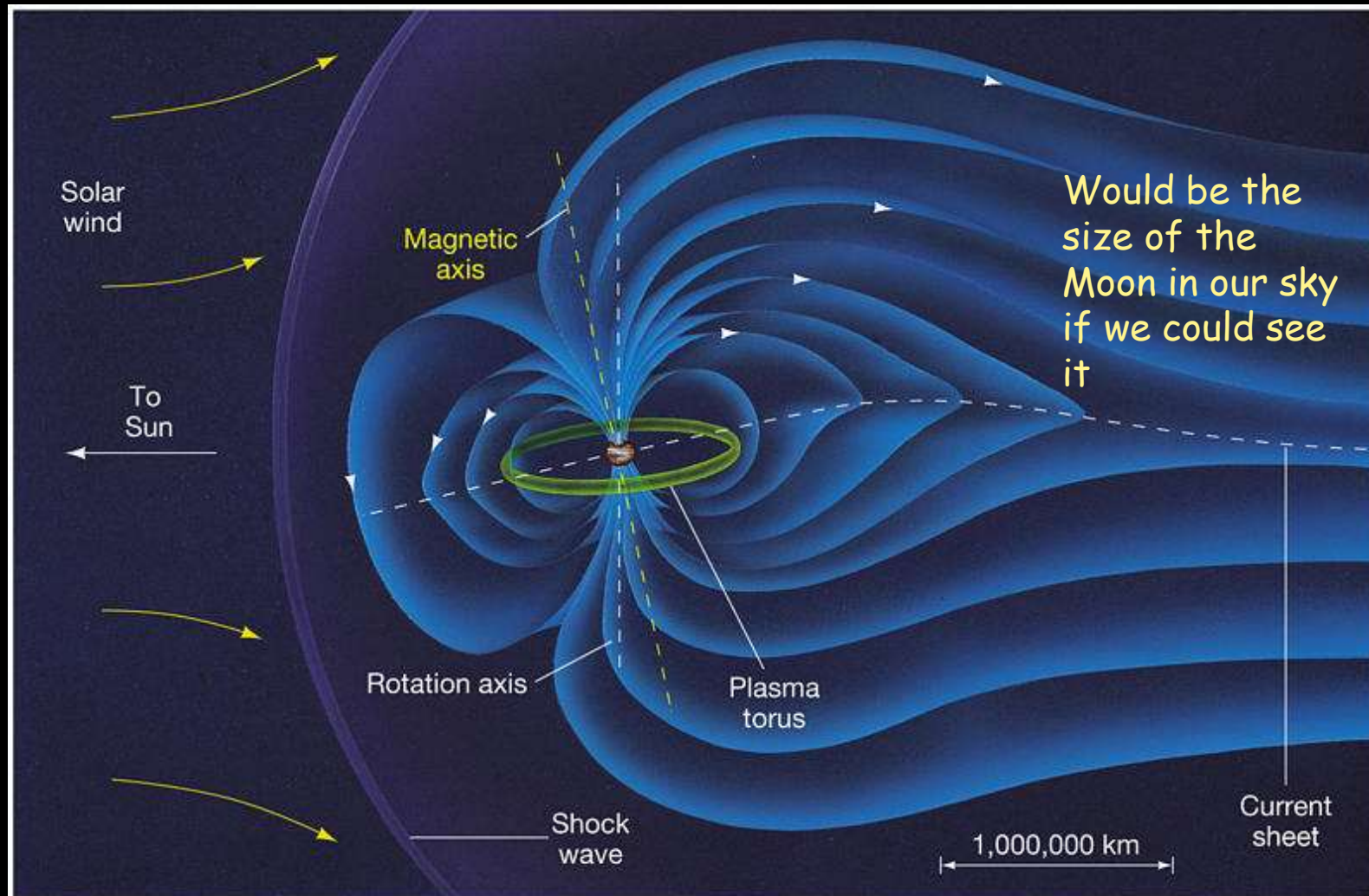
Solar and internal heating are sources of energy

Jupiter at Cloud Tops



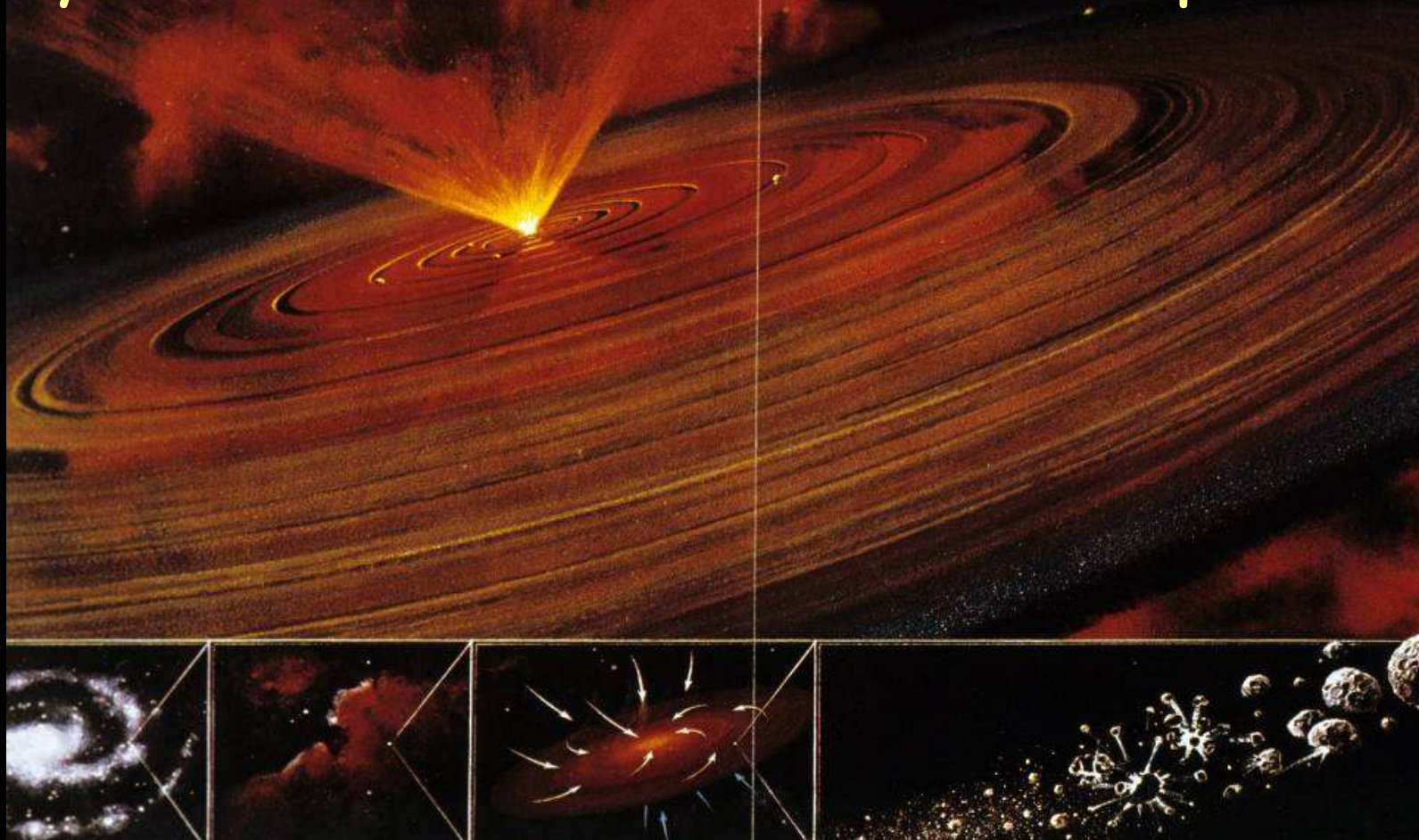
Walter Myers

Jupiter's magnetic field - gigantic!

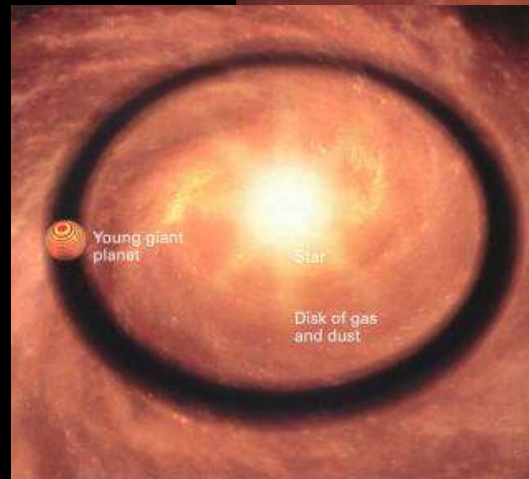


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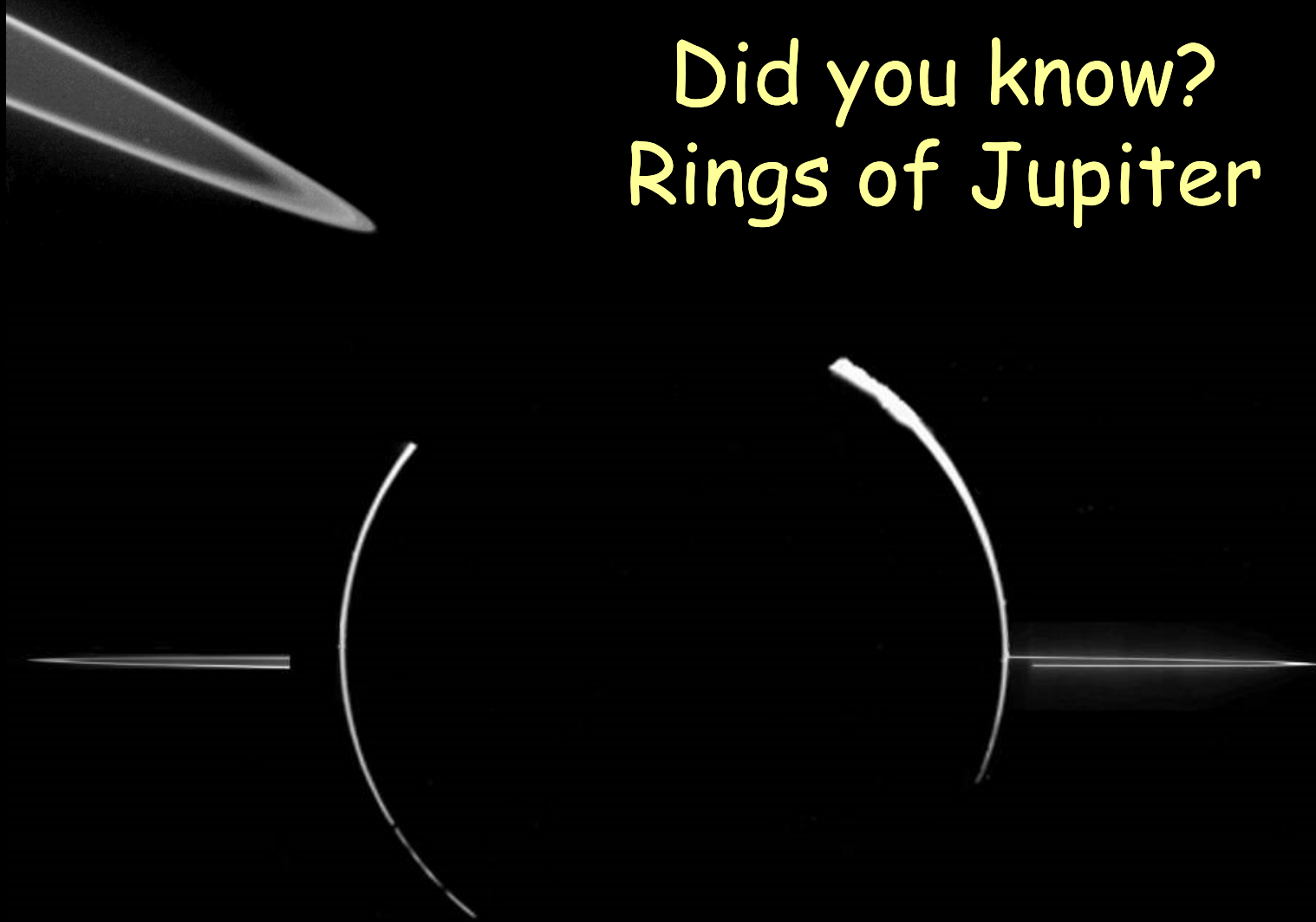
Why is Jupiter so big?
Why does it have such an odd composition?



With icy and rocky materials, Jupiter grew very large. Then it could hold onto H, He gases.



Did you know? Rings of Jupiter



Jupiter

Distance: 345,910 km
Radius: 71,492 km

2003 10 13 14:36:38 UTC
Real time



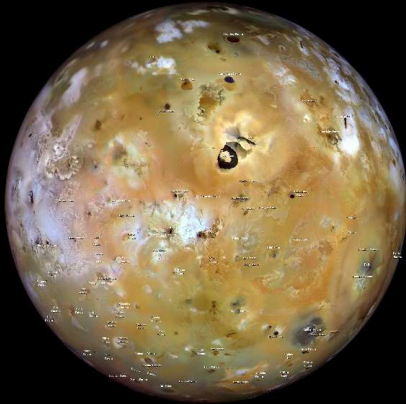
Jupiter's Rings

- Micron-sized particles of dark dust
- Very thin - 30 km wide
- Very different from Saturn's - stay tuned.

Speed: 0.000 m/s

Follow Jupiter
FOV: 35 13' 45.0" (1.00 x)

Jupiter's 4 (Galilean) Moons



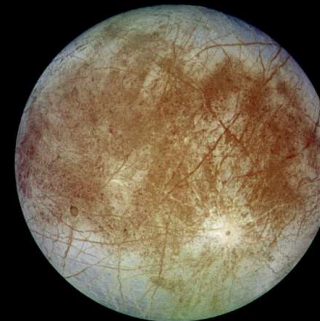
Io



Ganymede
(Largest in Solar System)



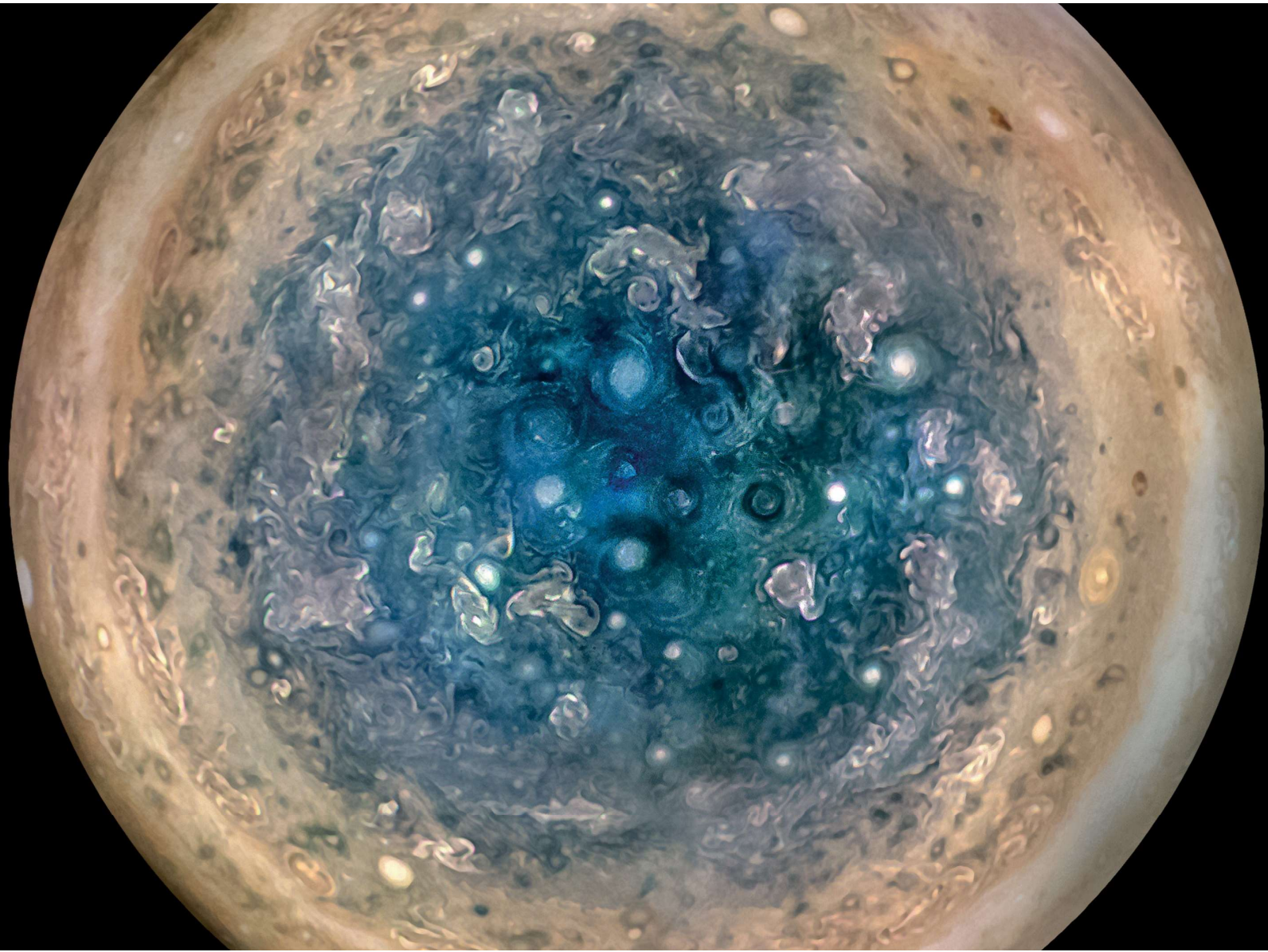
Callisto



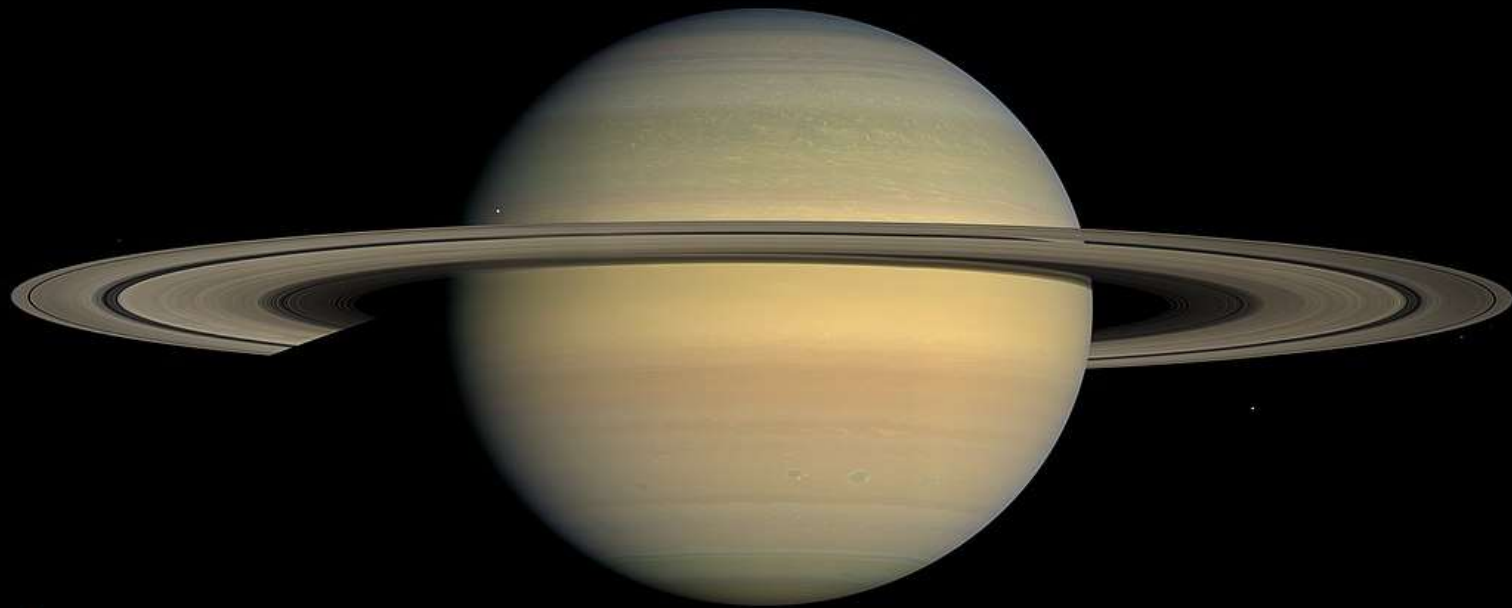
Europa

Extras





SATURN

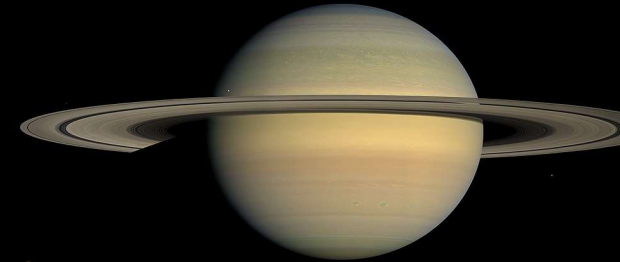


Mythical Saturn

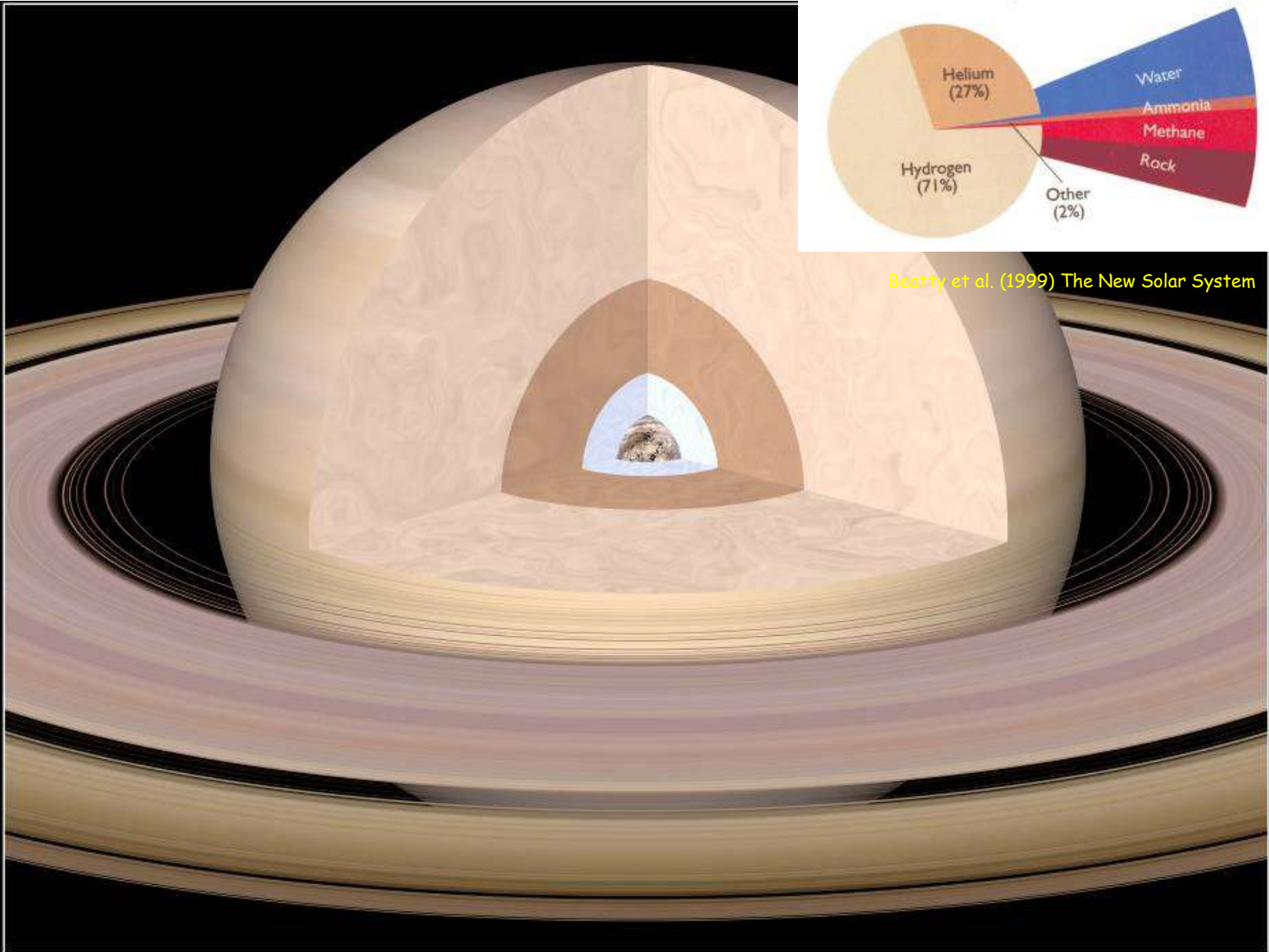
- God of time
- Cronus to the Greeks
- Son of Uranus and Gaia, one of the Titans
- Told that his son would dethrone him, he swallowed his children at birth
- His wife, Rhea (mother of Jupiter-Zeus) fled to Crete



Cronus



	Jupiter	Earth	Saturn
Diameter (km)	143,800	12,800	116,464
Mass	320 M_E	1 M_E	95 M_E
Density (g/cm³)	1.3	5.5	0.69
Year	11.86 y_E	365 days	29.46 y_E
Day	9.8 hours _E	1 day	10.2 hours _E
Distance (AU)	5.2	1	9.53
At cloud tops:			
Temperature (F)	-162°	61°	-217°
Moons	68+	1	62+
Gravity (surface)	2.4	1	0.916



The Interior of Saturn

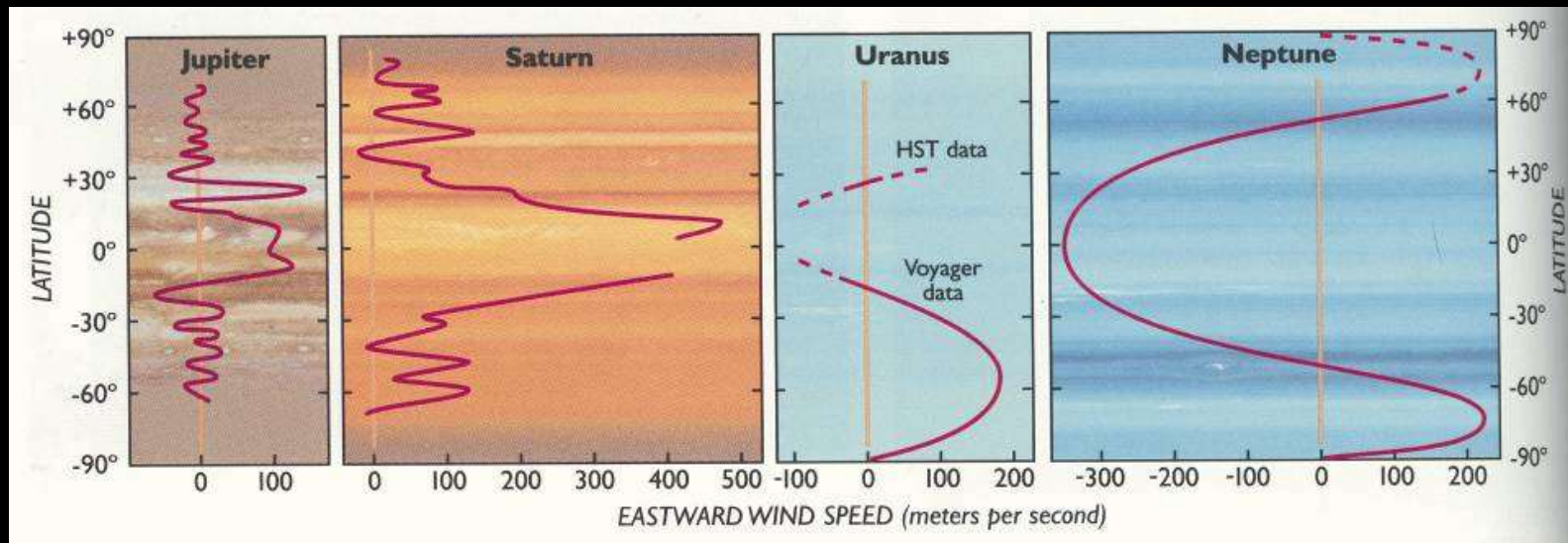
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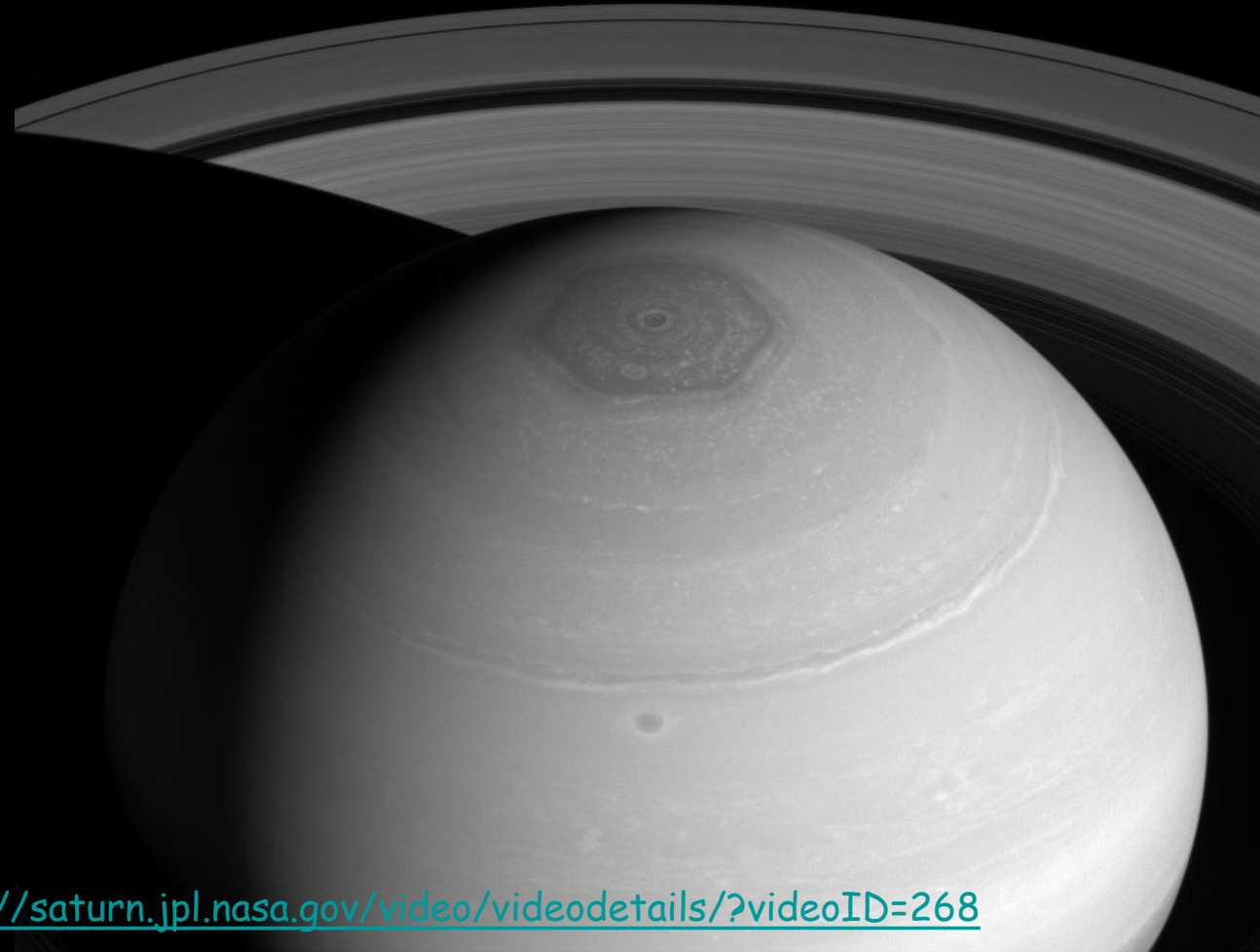
© 2006 Eþjörn Jónsson

Atmosphere

- Cloudy bands parallel to equator
- Cyclonic storms like Jupiter's
- Not as colorful
- High wind speeds!

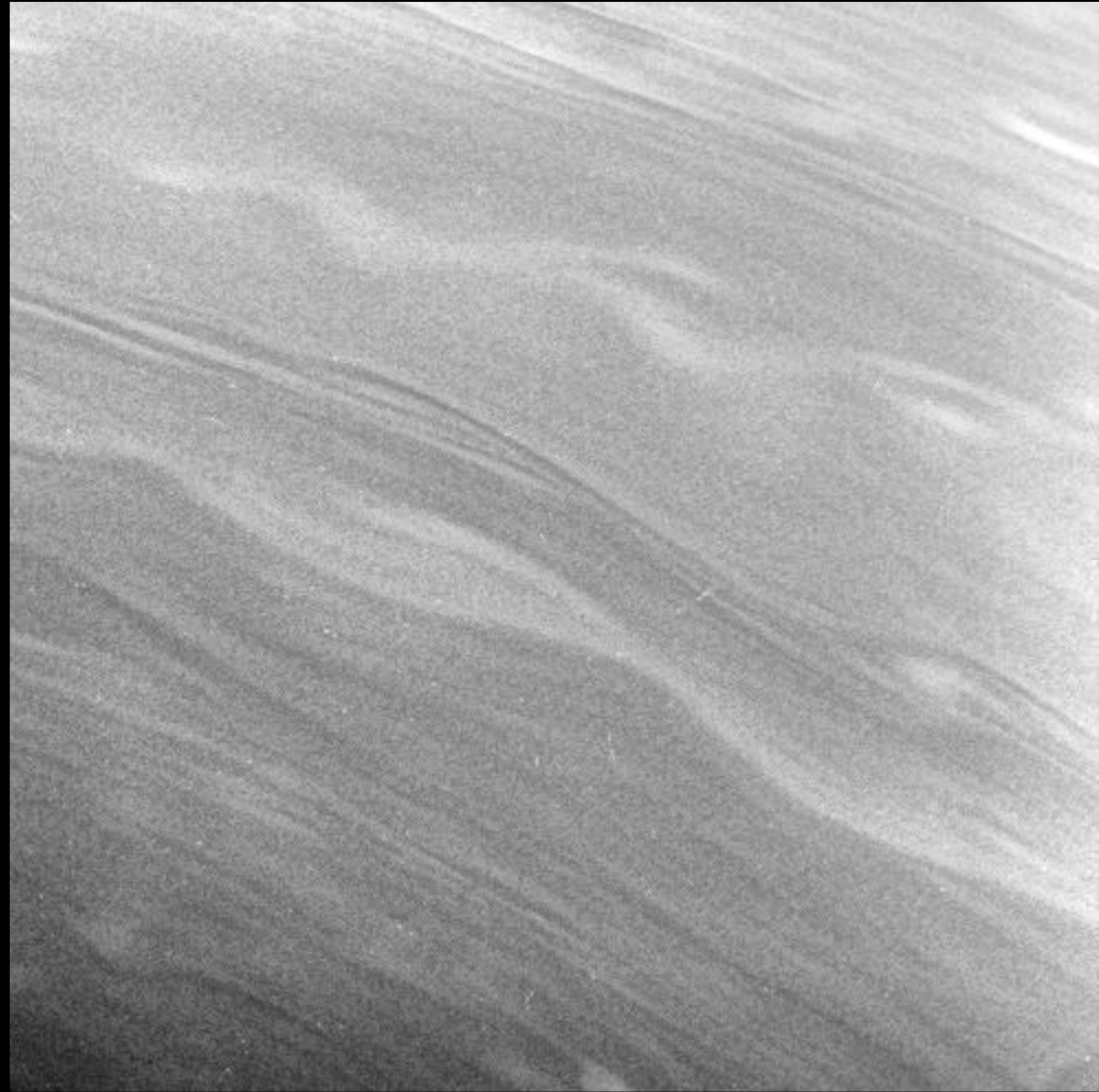


...?



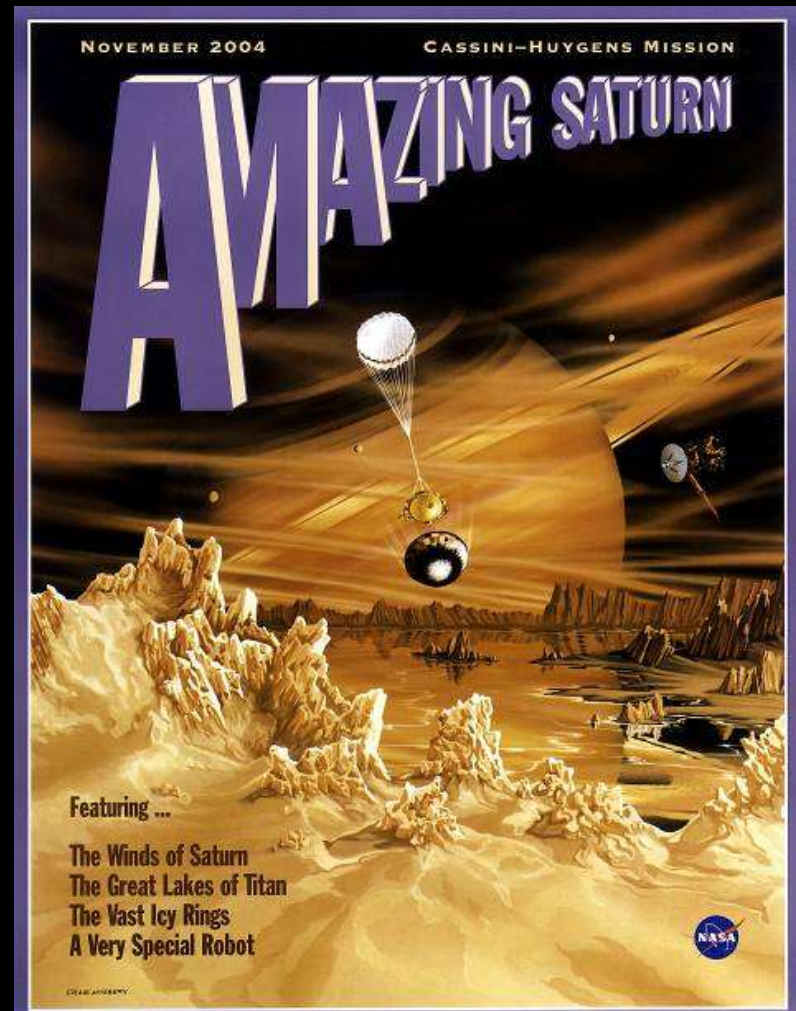
<http://saturn.jpl.nasa.gov/video/videodetails/?videoID=268>

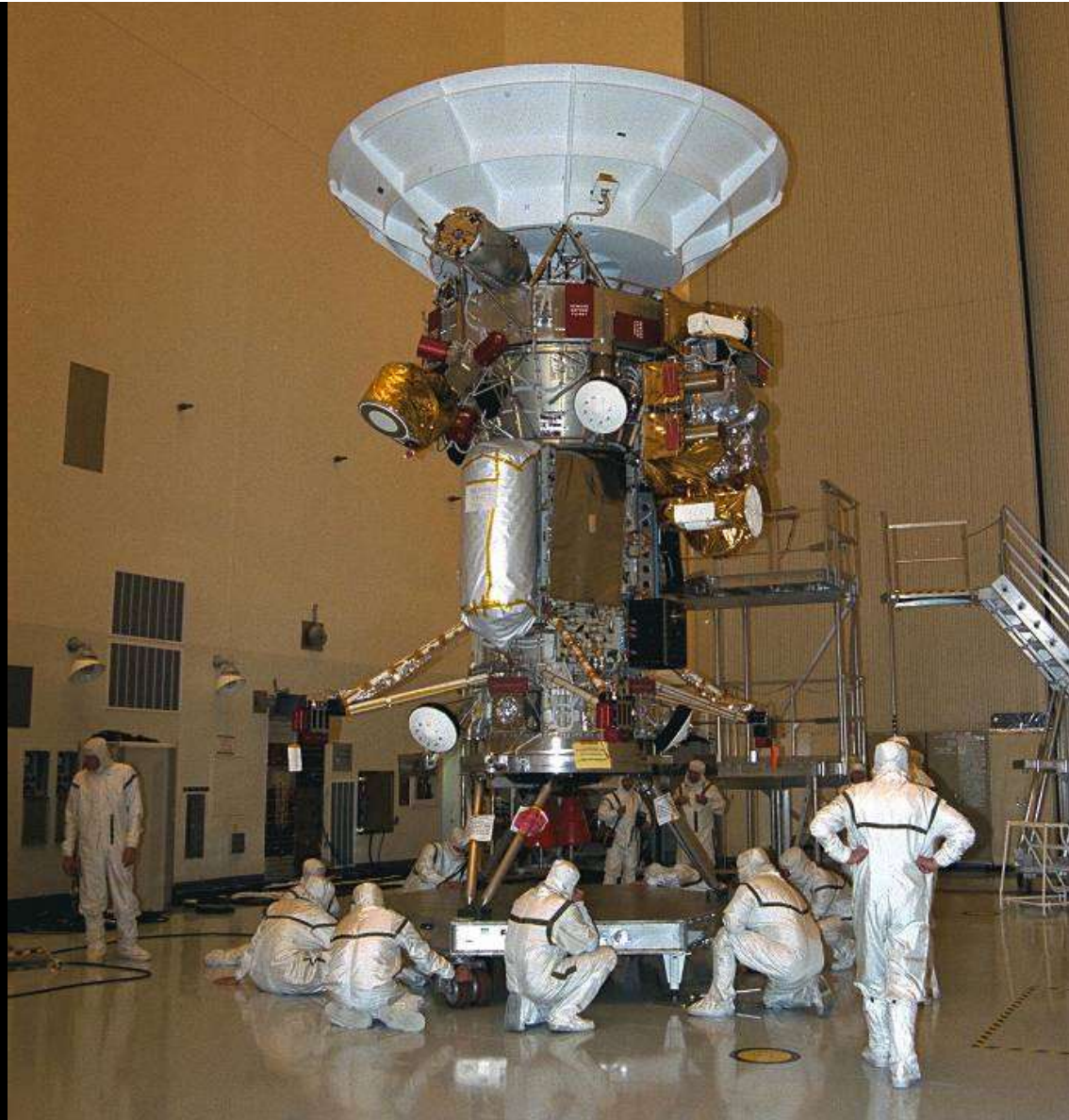
Upper
clouds made
of Ammonia
crystals



Cassini-Huygens

- Launched 1997
- At Saturn in 2004
- Large “flagship” mission in the style of Voyager 1 and 2
- Ended mission
September 2017



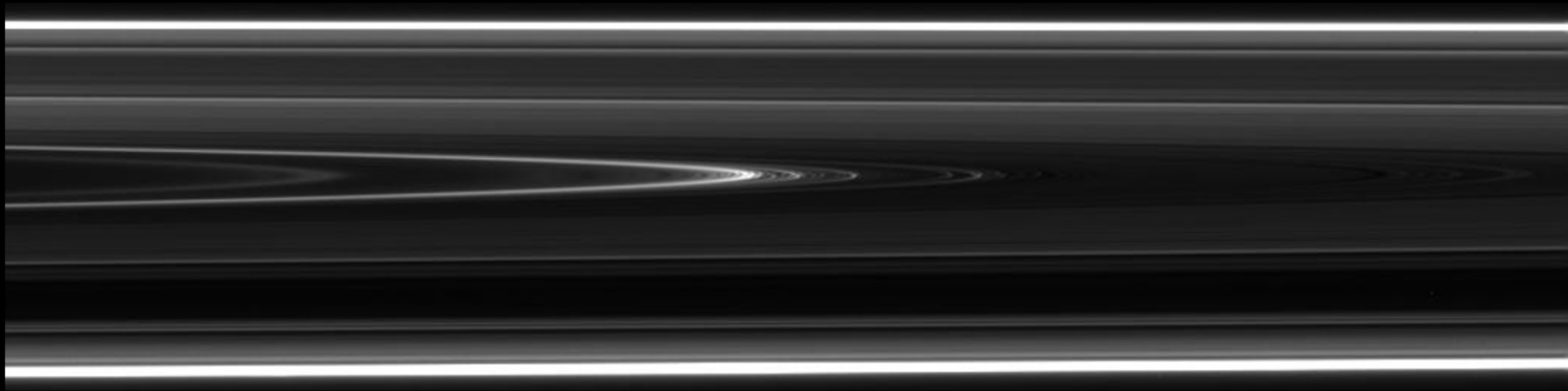


<https://www.youtube.com/watch?v=J7Z7yC3OkqE>

TITAN (Largest moon of Saturn)

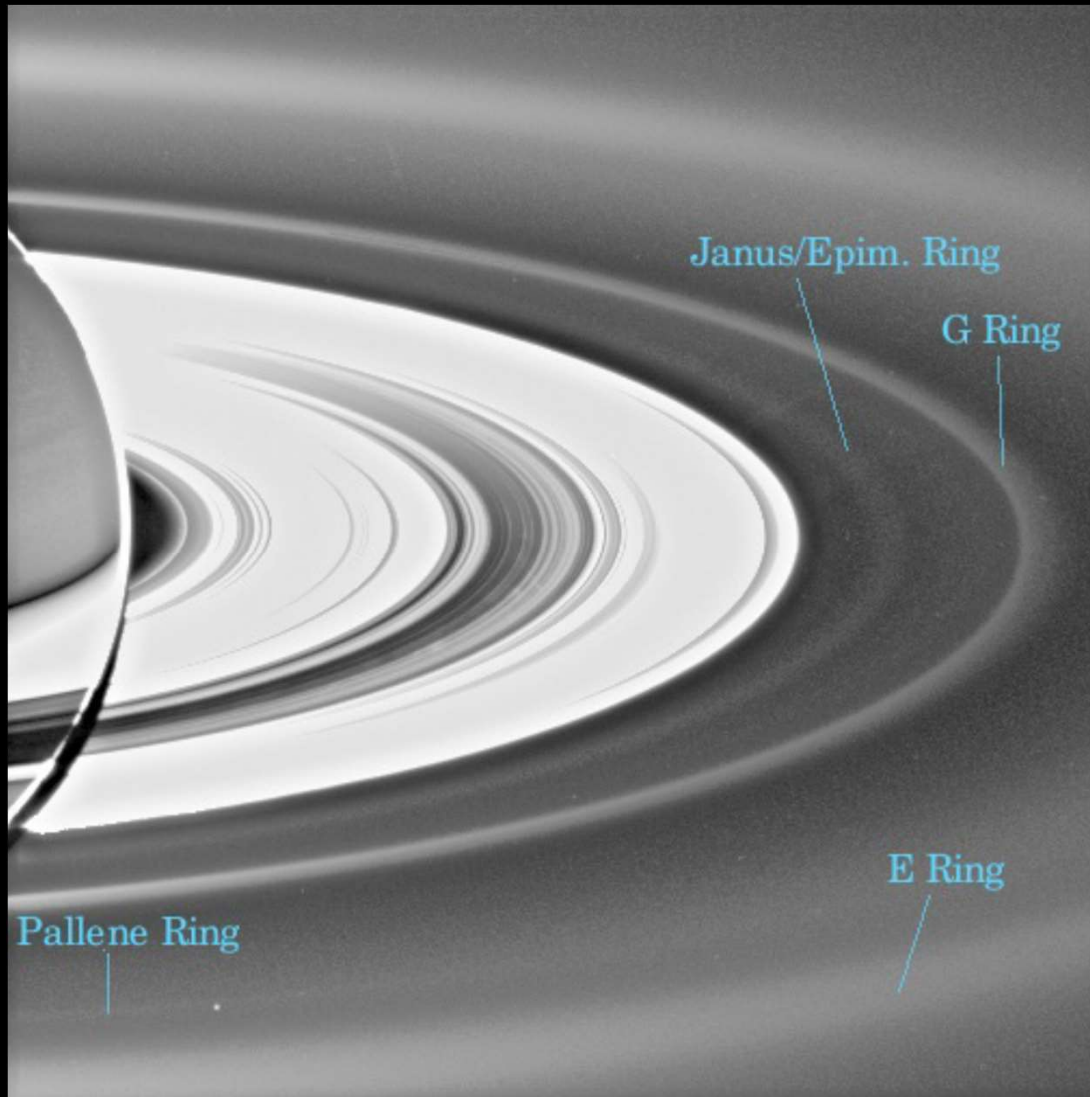


Rings of Saturn

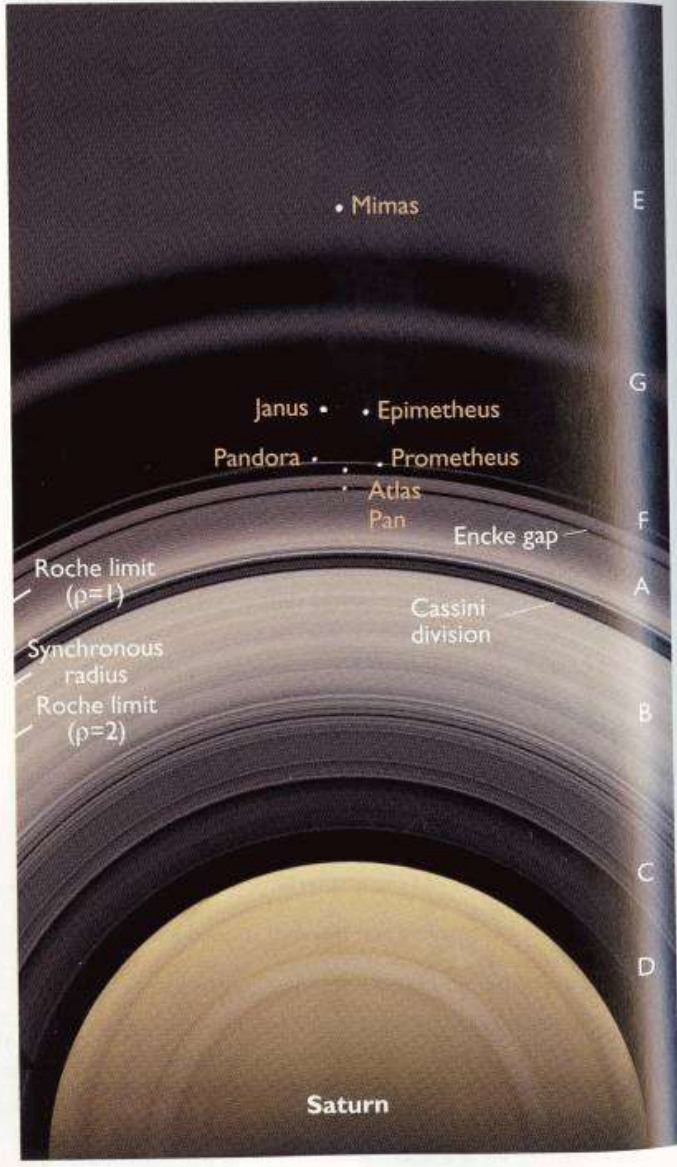
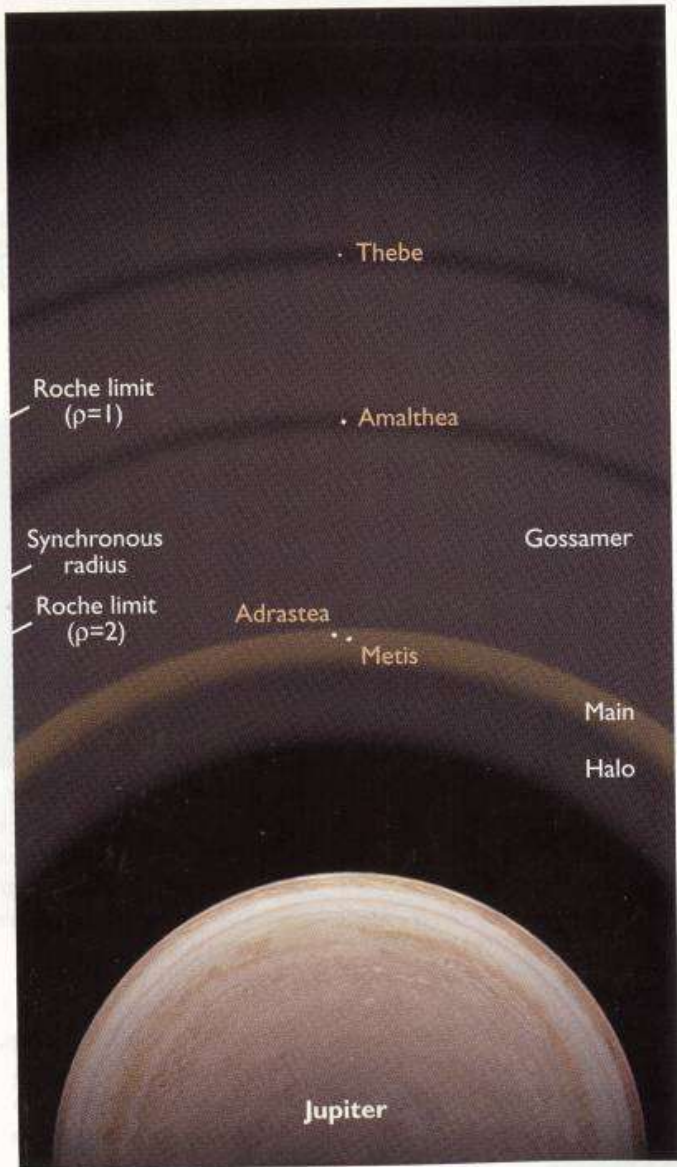


- 1 km thick, 70,000 km across
- Bright, made of water ice
- Would fill a satellite ~100 km diameter
- How did they form? Long ago, when Saturn formed?
Later, when a satellite ripped apart?

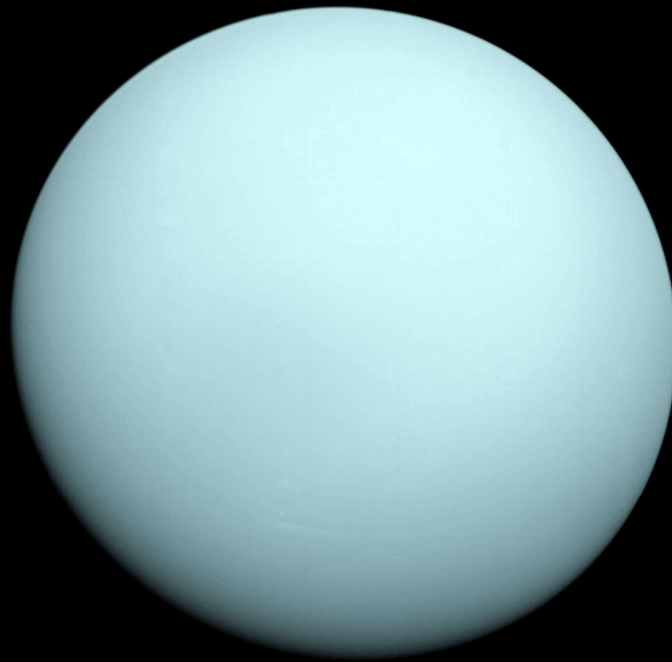
New rings from Saturn's small satellites - Shepherd Moons



Just like "where there's smoke there's fire", at Saturn, where there is a new ring, there's bound to be a moon! - J. Burns, Cornell



URANUS

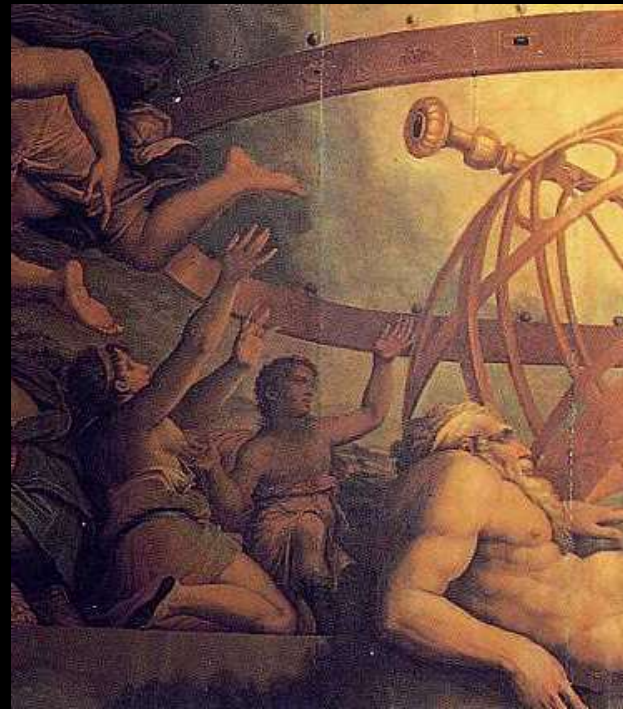


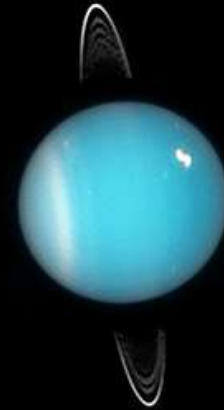
Uranus

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Mythical Uranus

- Embodiment of the sky
- Son and then Husband of Gaia
- Children the Titans (including Saturn)





Jupiter

Earth

Uranus

Diameter (km)

143,800

12,800

50,724

Mass

320 M_E

1 M_E

14.5 M_E

Density (g/cm³)

1.3

5.5

1.27

Year

11.86 y_E

365 days

84 y_E

Day

9.8 hours_E

1 day

17.25 hours_E (Retro)

Distance (AU)

5.2

1

19.21

At cloud tops:

Temperature (F)

-162°

61°

-319°

Moons

68+

1

27

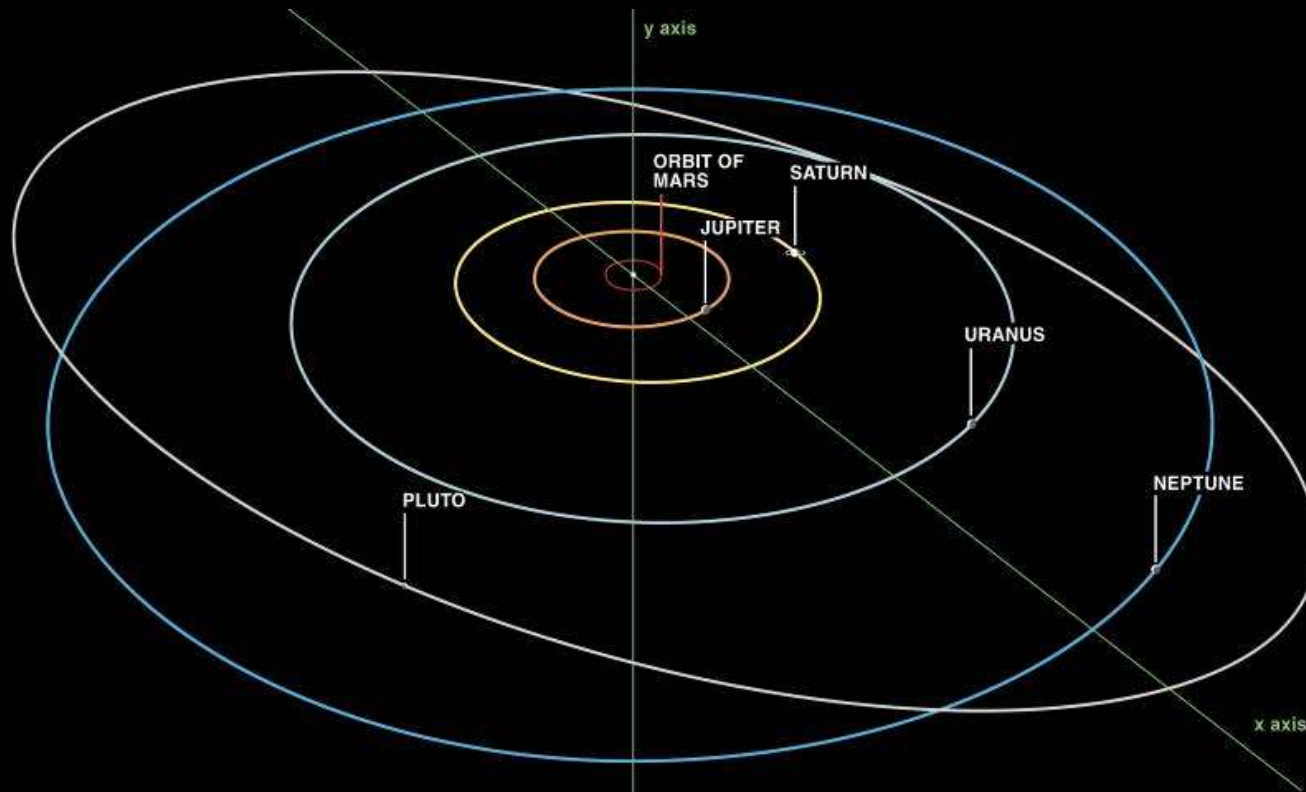
Gravity (surface)

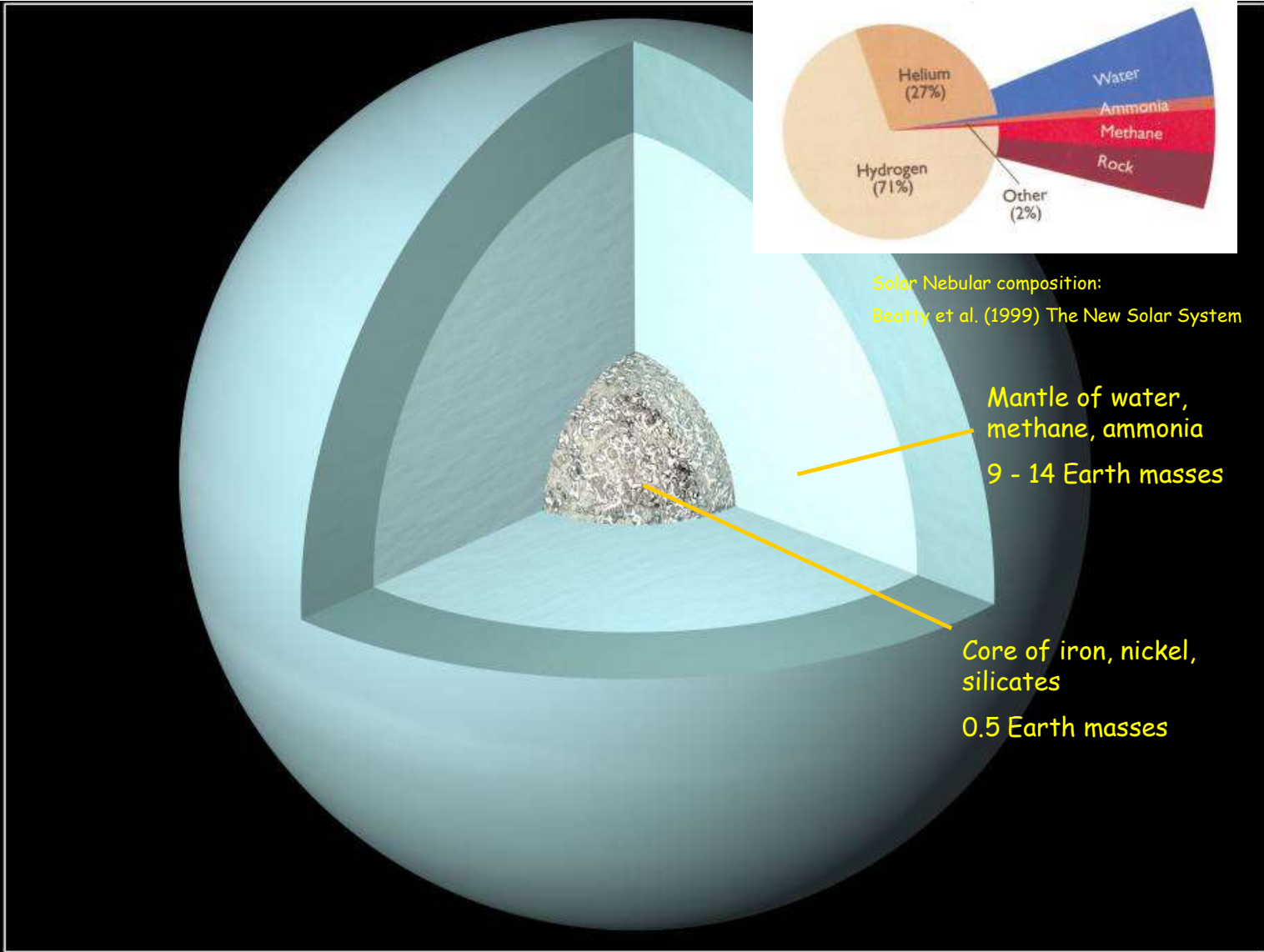
2.4

1

0.89

Orbit of Uranus



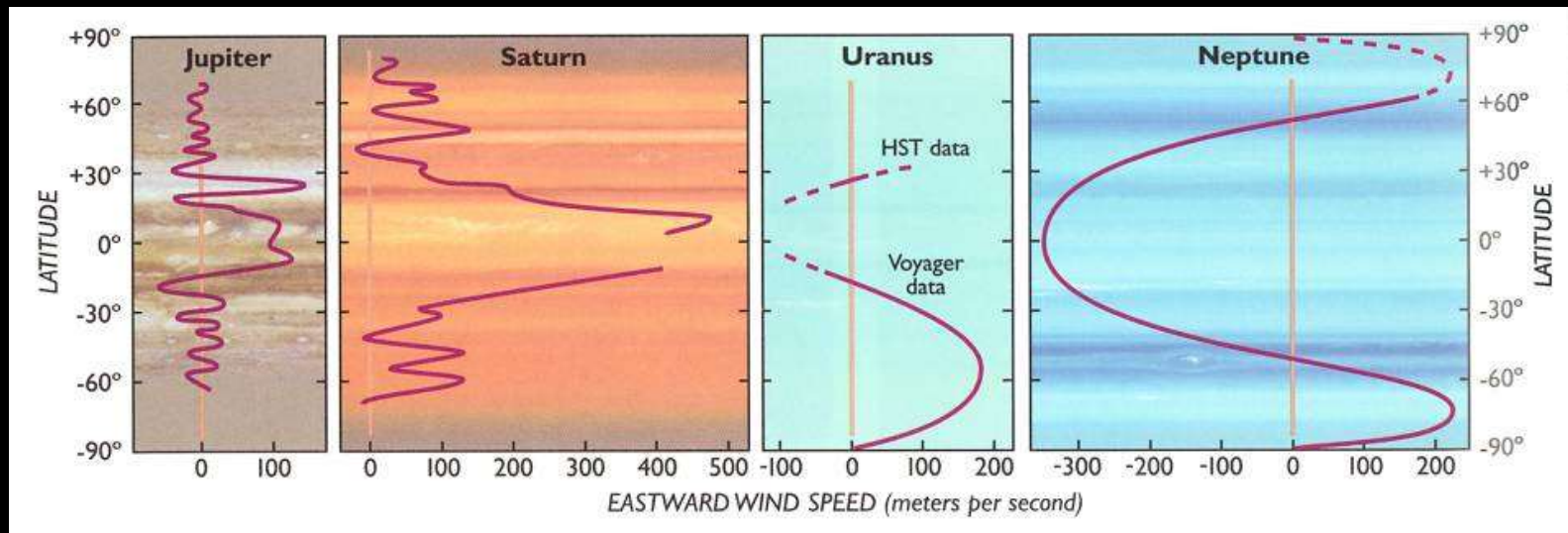


The Interior of Uranus

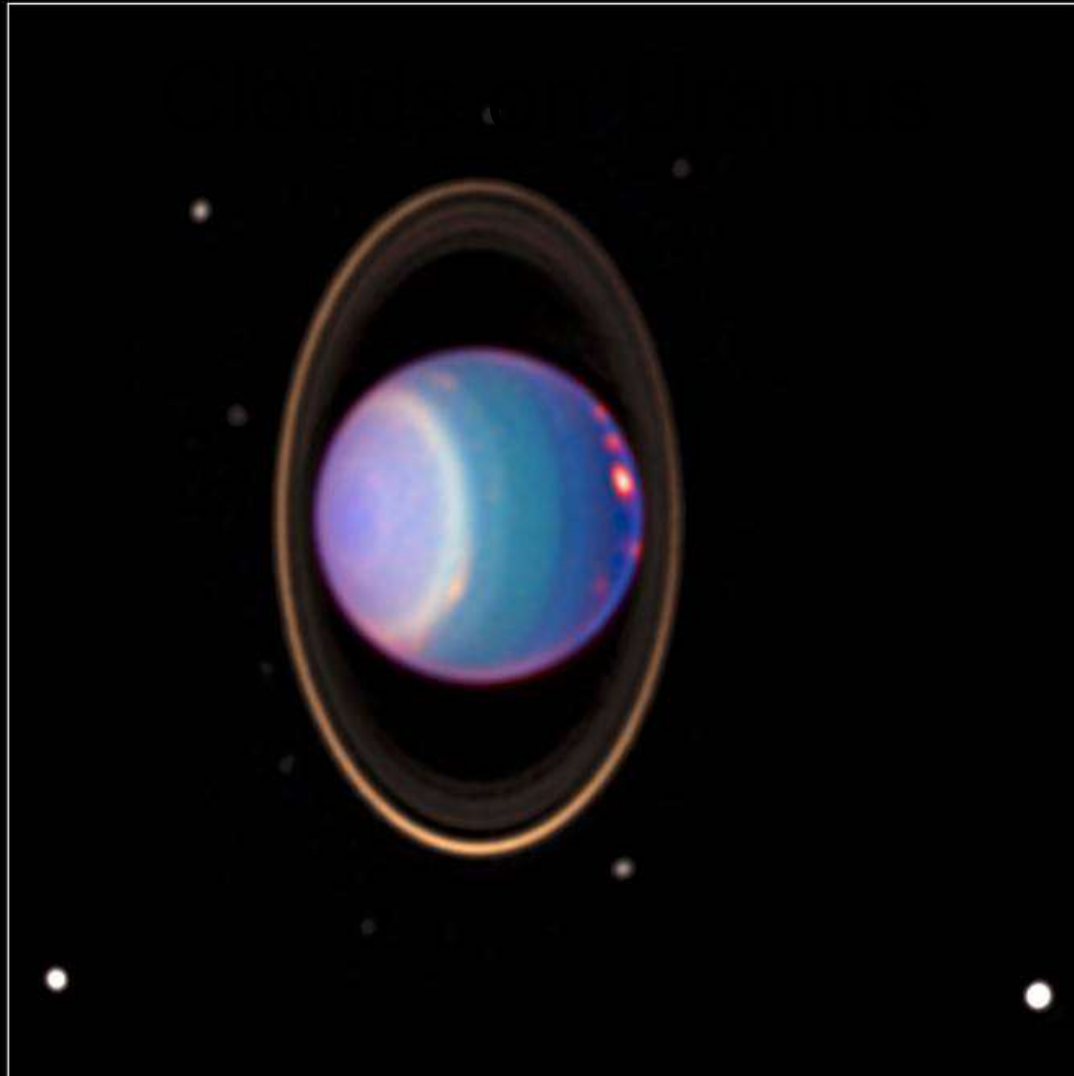
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Atmosphere & Wind Speeds

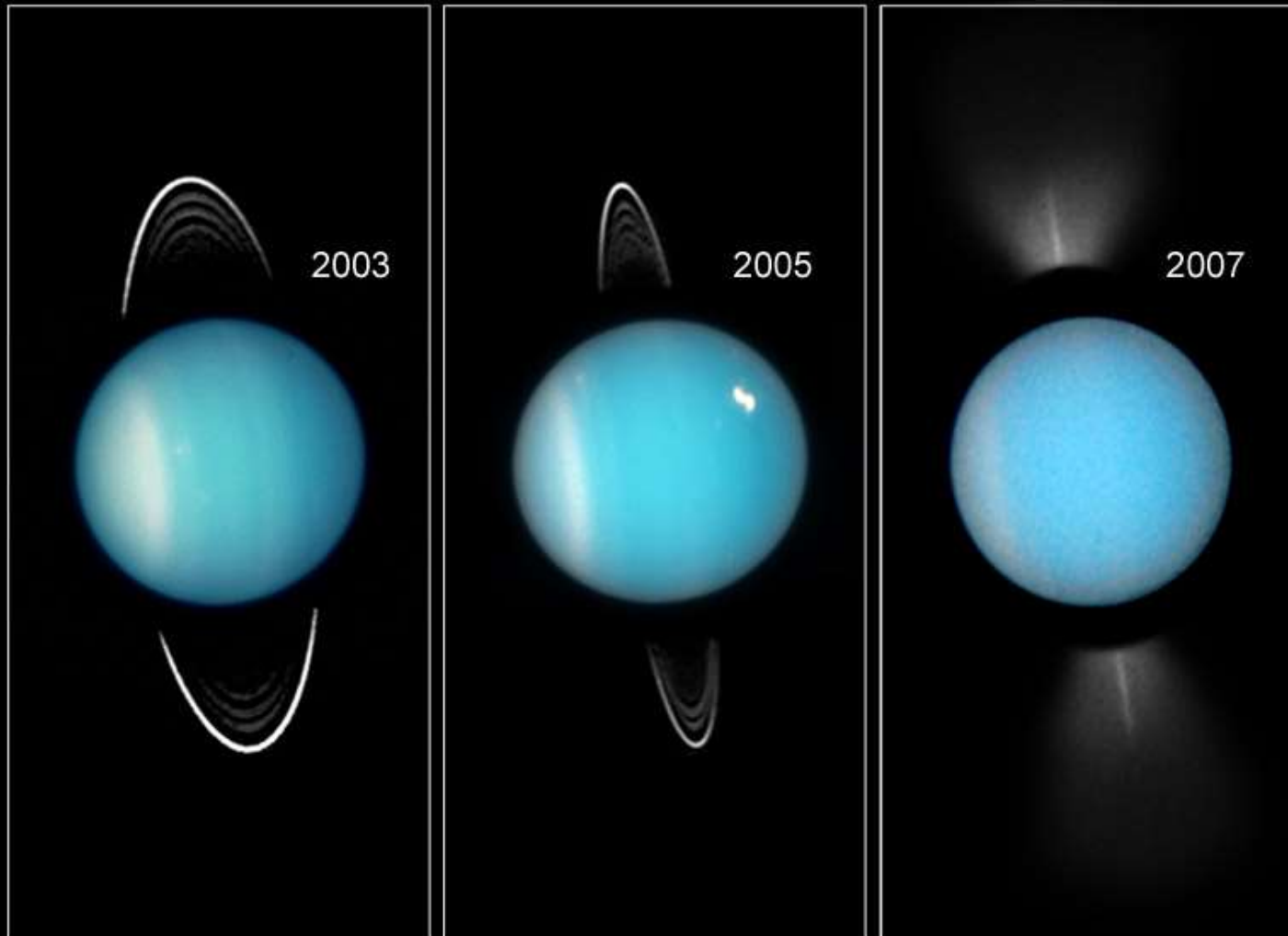
- Cloudy bands parallel to equator
- Cyclonic storms “missing”
- Not as much color variety as Jupiter or Saturn



Tilted on its side



Uranus ■ *Hubble Space Telescope ACS/HRC WFPC2*



NASA, ESA, and M. Showalter (SETI Institute) ■ STScI-PRC07-32

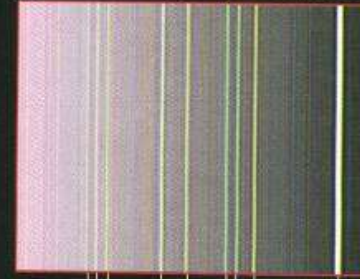


The moons Cordelia and Ophelia straddle the ϵ ring.

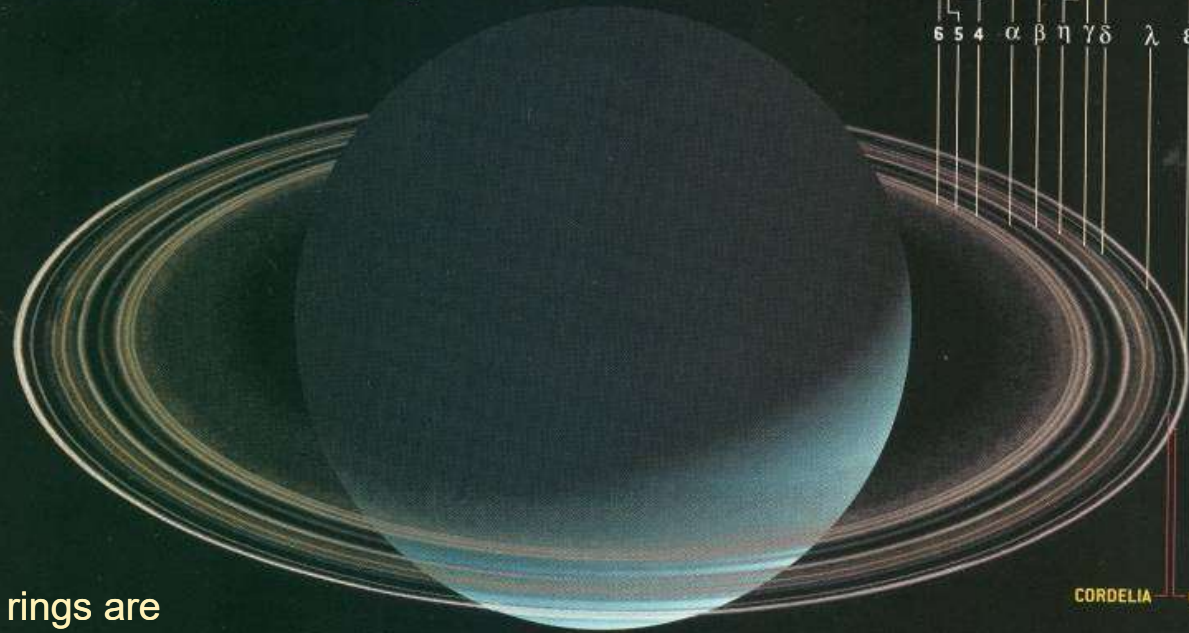


Using a different viewing angle and longer exposure, Voyager saw dust between the main rings.

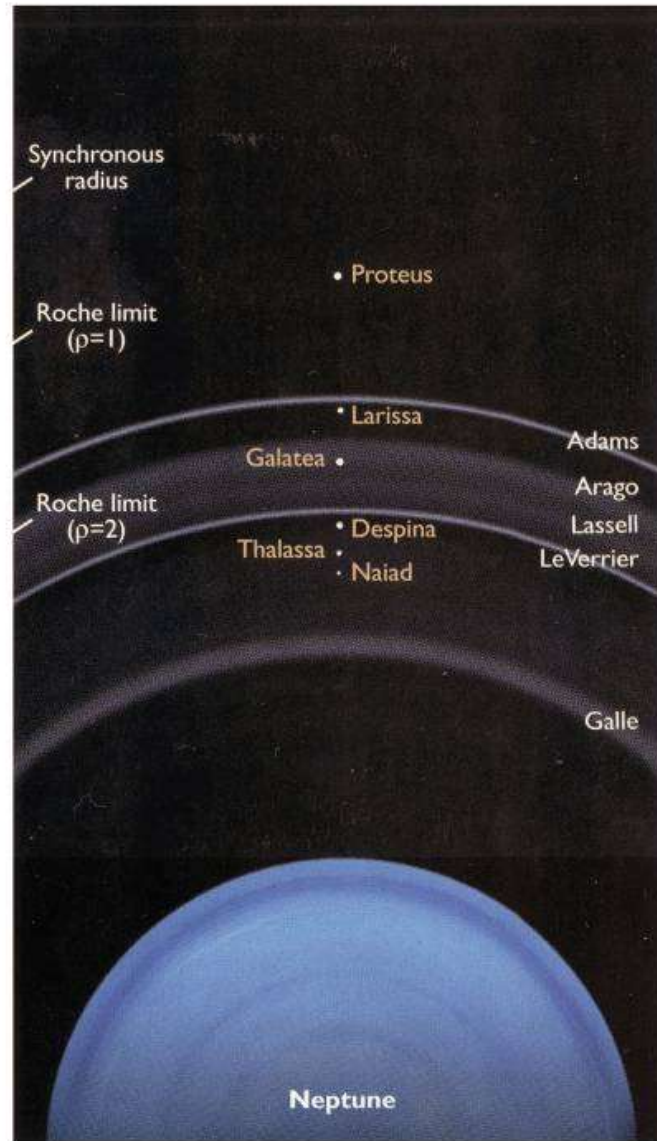
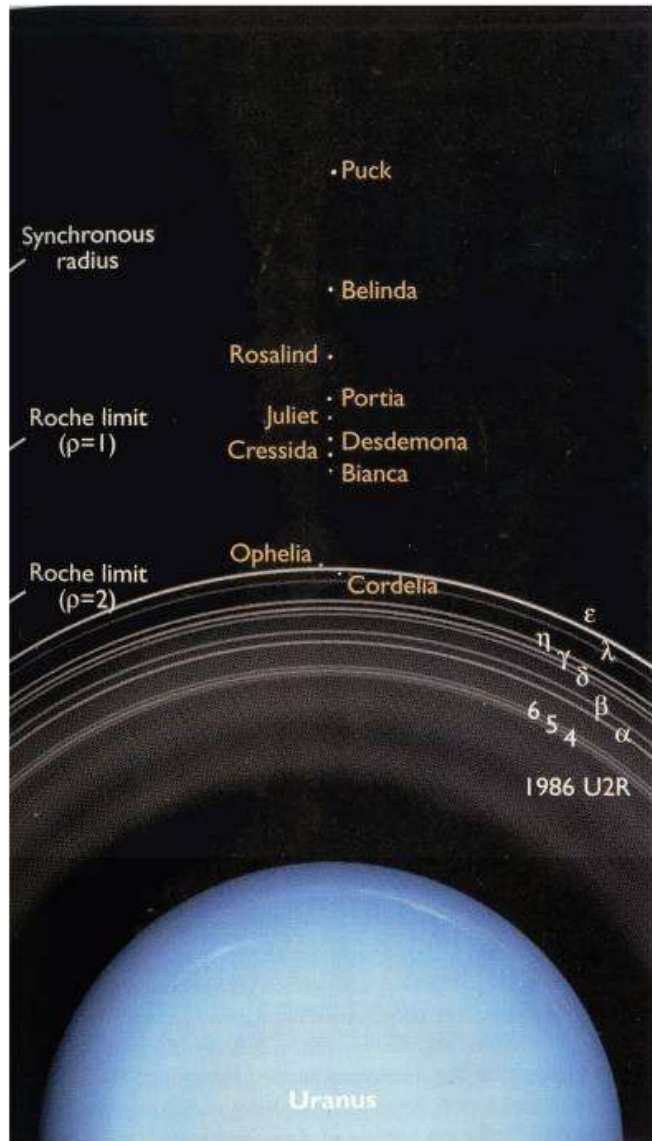
This false-color image hints at differing particle properties. The dusty λ ring is too faint to see here.



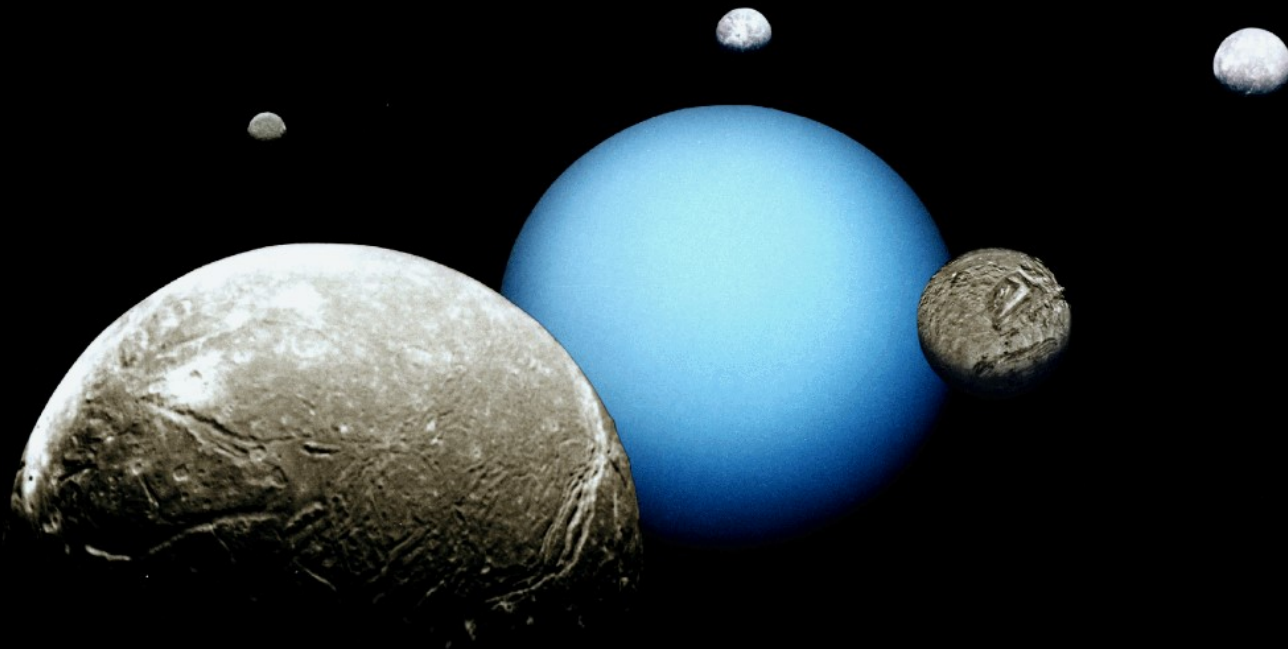
6 5 4 α β η γ δ λ ϵ



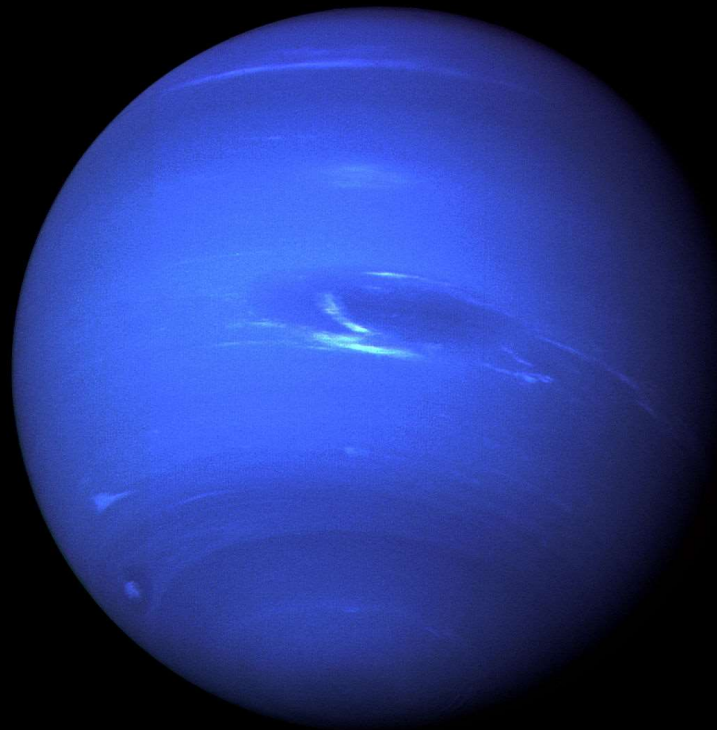
Uranus rings are among the darkest objects in the solar system



27 named
moons, 5
major ones



NEPTUNE

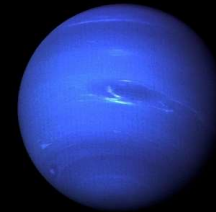


Mythical Neptune

- God of the Sea
- Poseidon to the Greeks
- Son of Saturn and Rhea (brother of Jupiter and Pluto)
- Symbols include dolphins, tridents, spears



Neptune calms the waves: Louvre
Lambert-Sigisbert Adam (1733- 1757)



Jupiter

Earth

Neptune

Diameter (km)

143,800

12,800

49,244

Mass

320 M_E

1 M_E

17.1 M_E

Density (g/cm³)

1.3

5.5

1.64

Year

11.86 y_E

365 days

164.8 y_E

Day

9.8 hours_E

1 day

16.1 hours_E

Distance (AU)

5.2

1

30.11

At cloud tops:

Temperature (F)

-162°

61°

-332°

Moons

68+

1

14

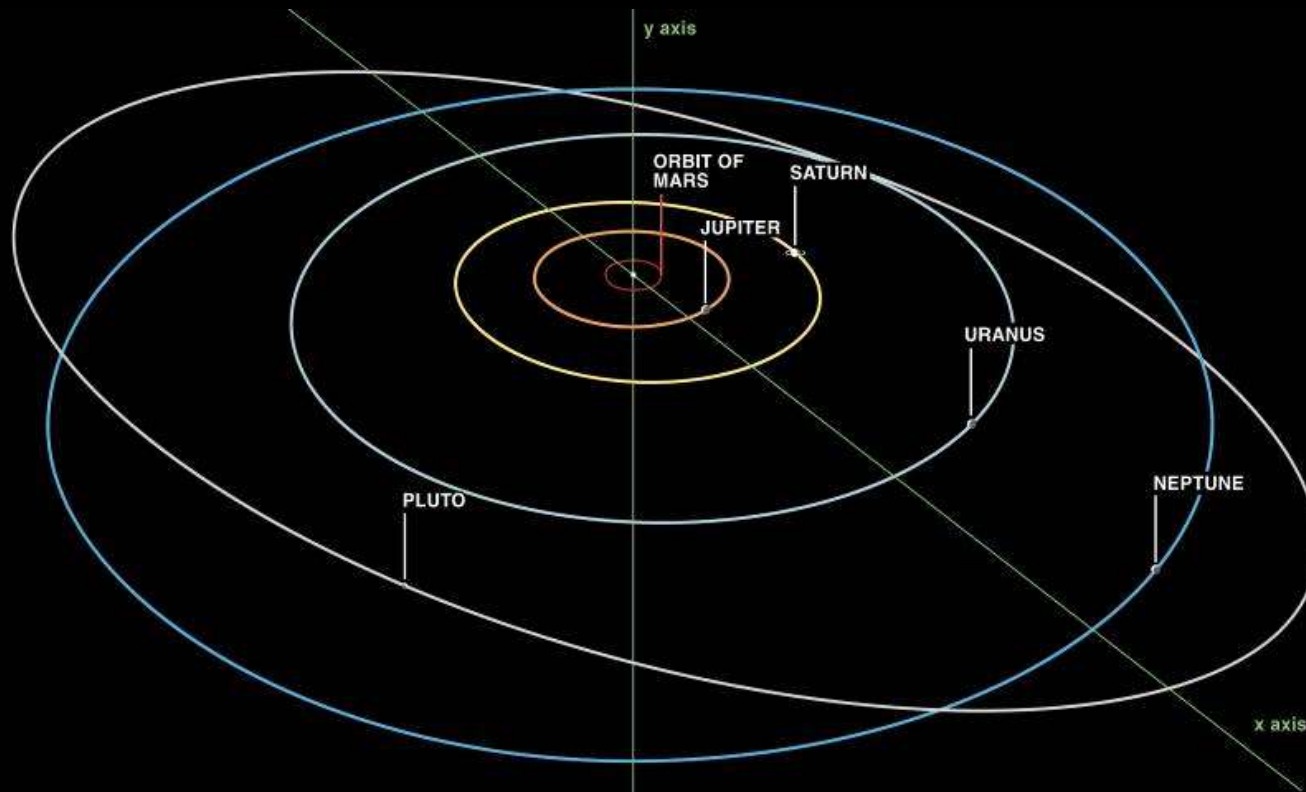
Gravity (surface)

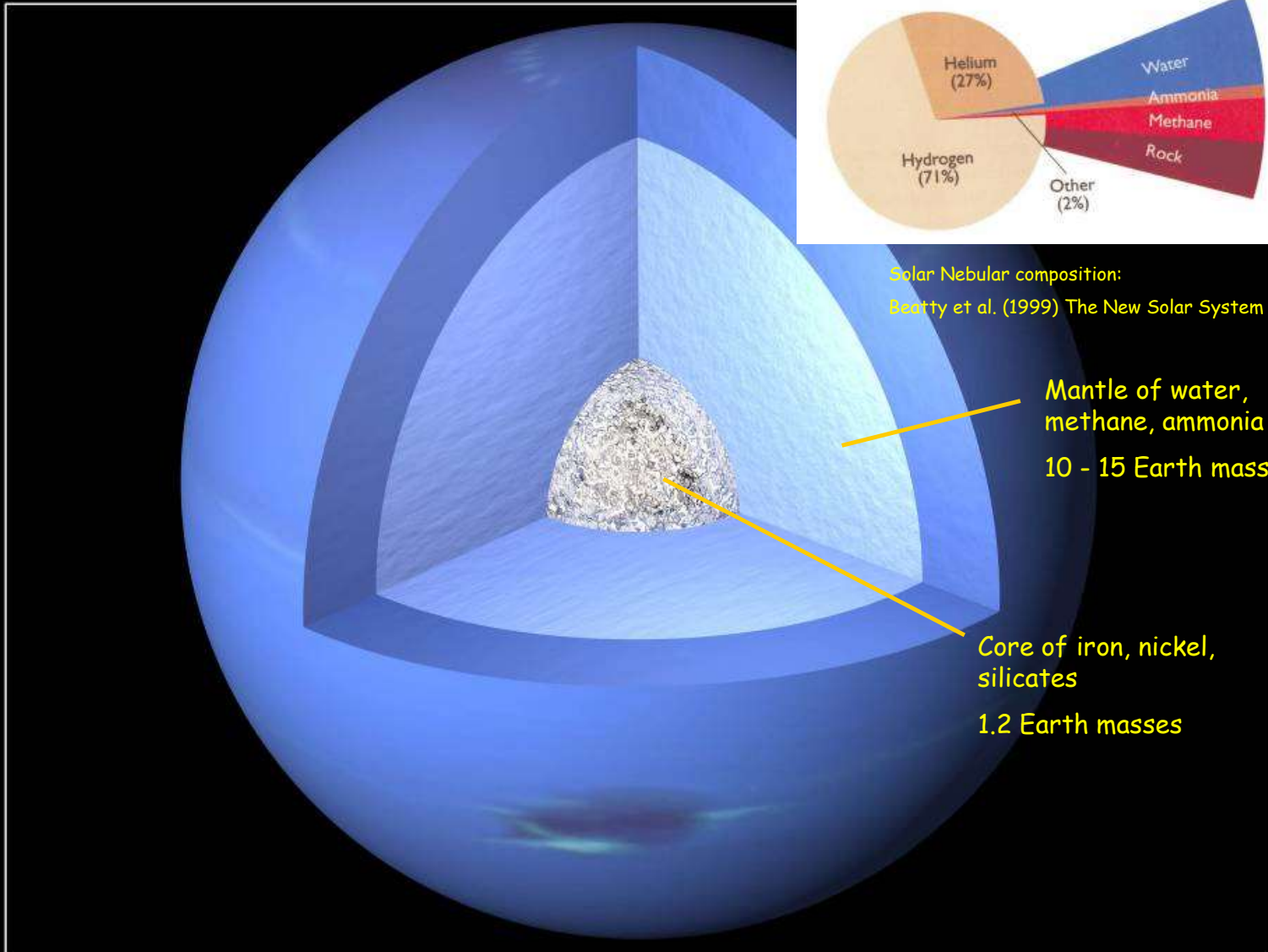
2.4

1

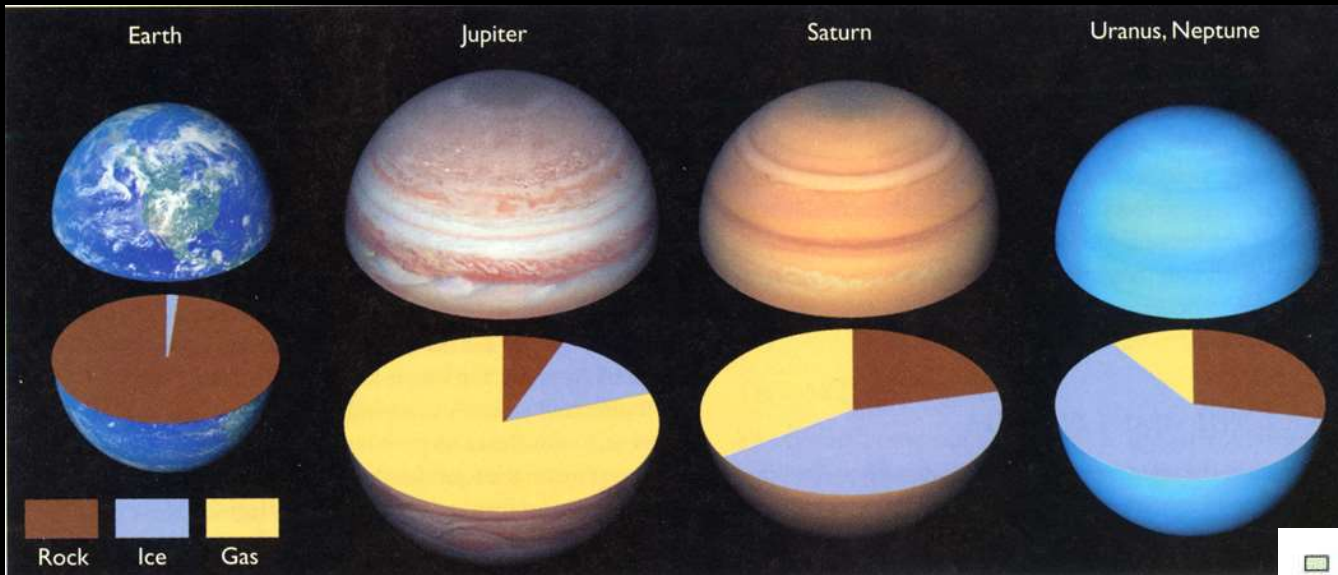
1.12

Orbit of Neptune

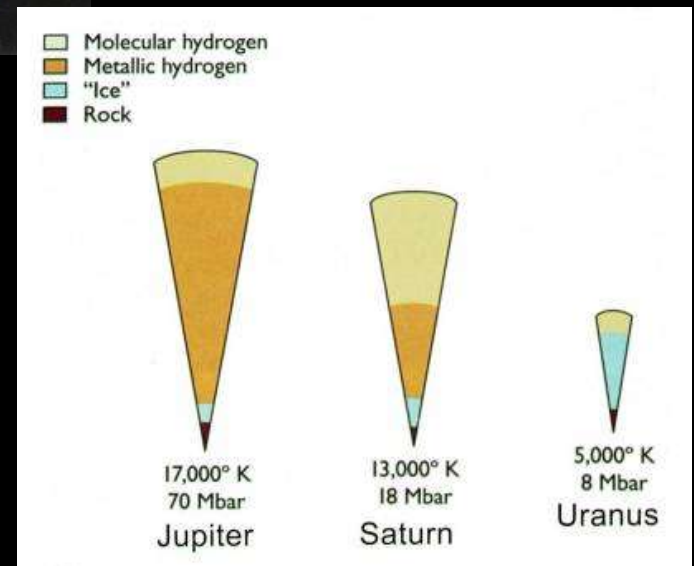


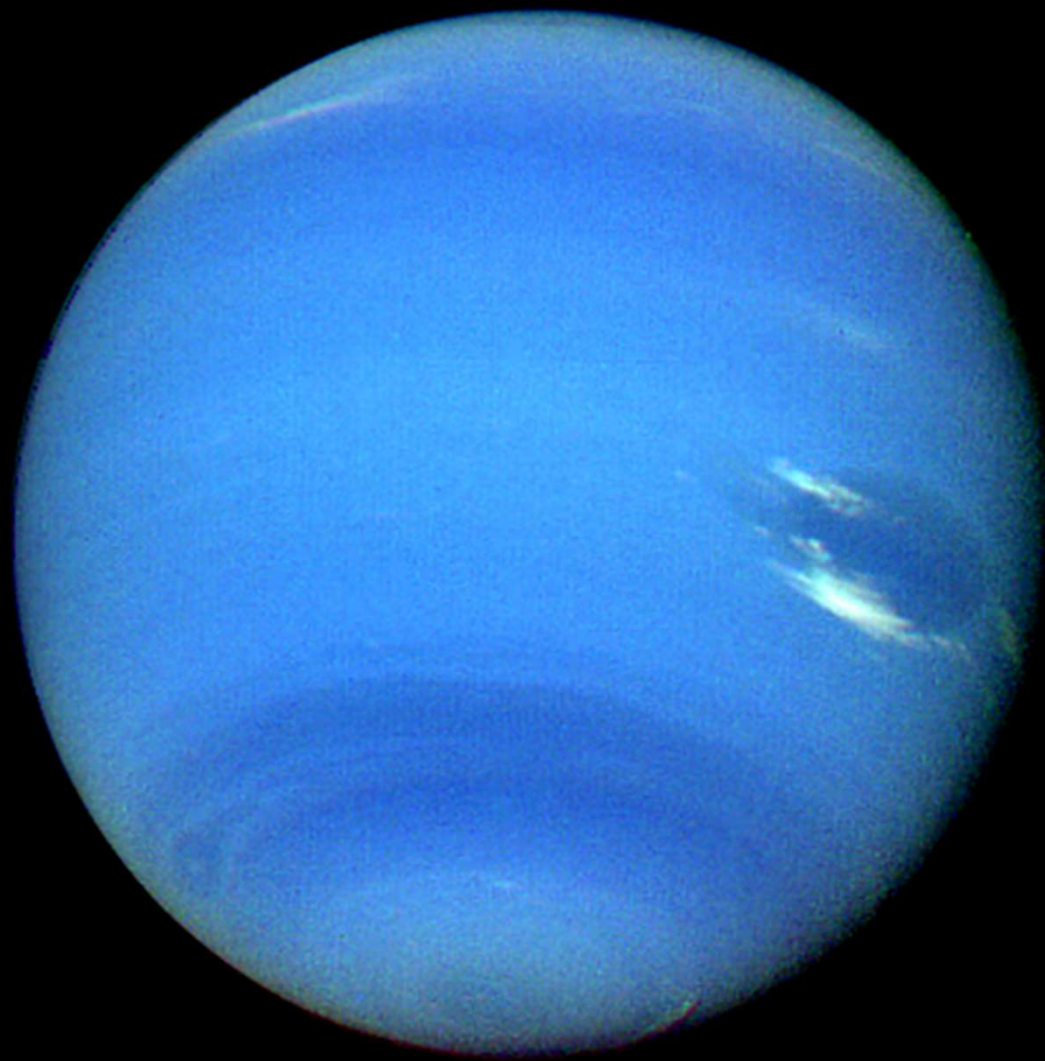


The Interior of Neptune

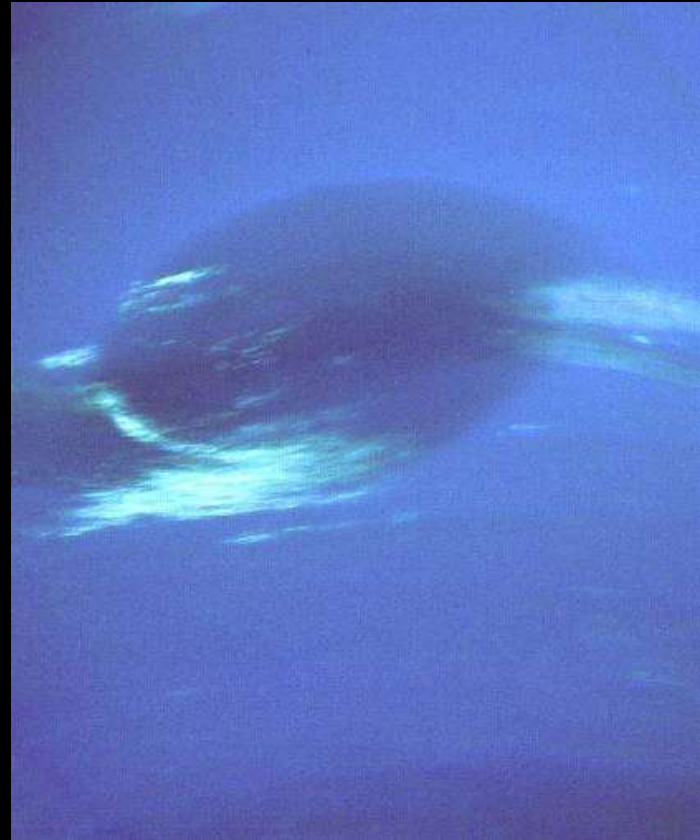
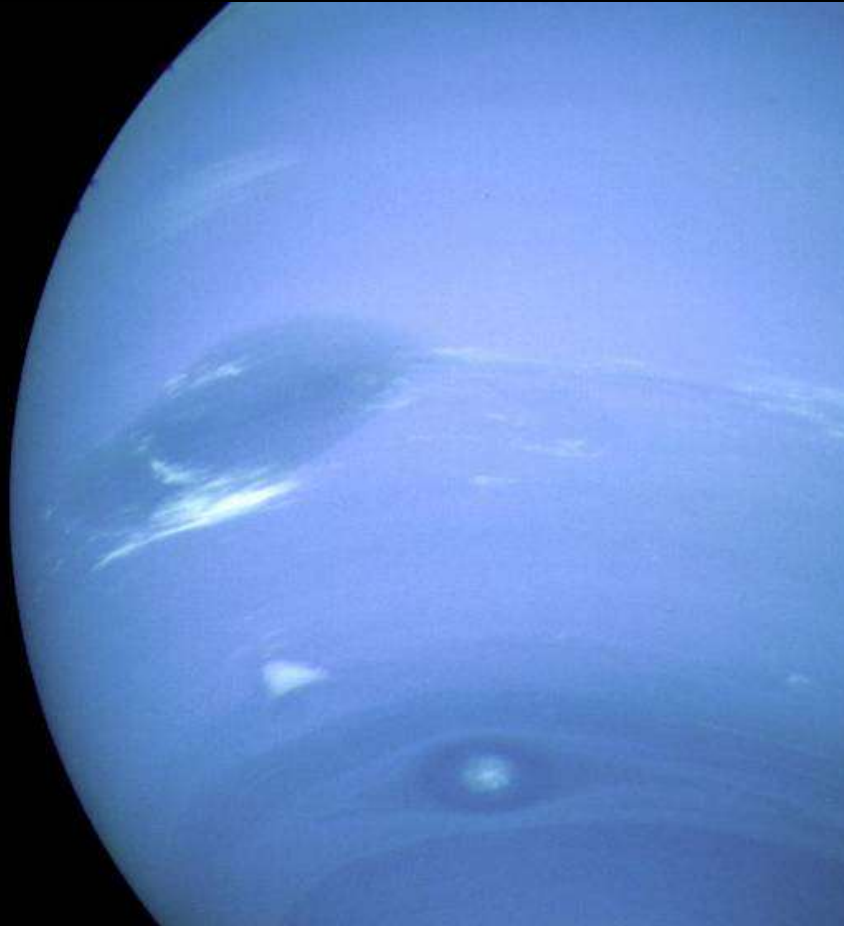


Comparison of Compositions

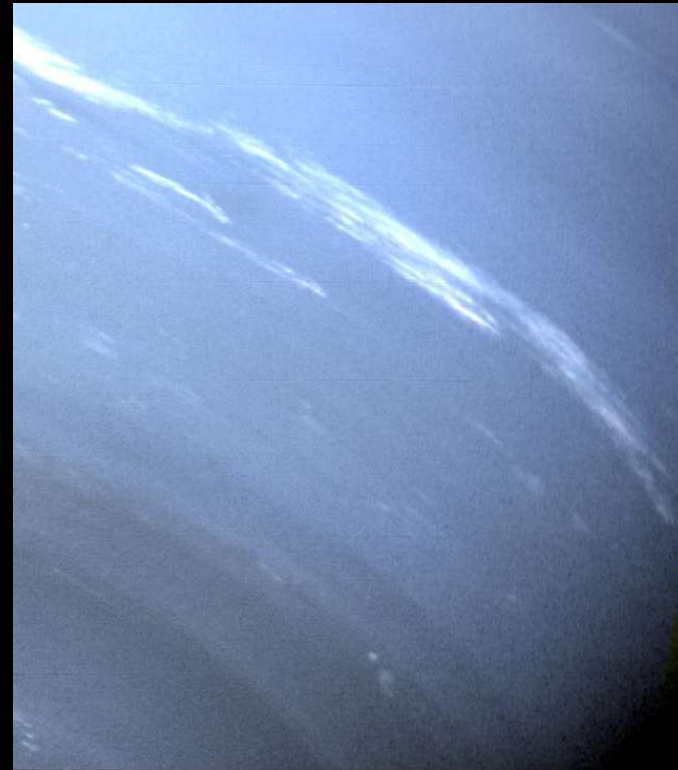




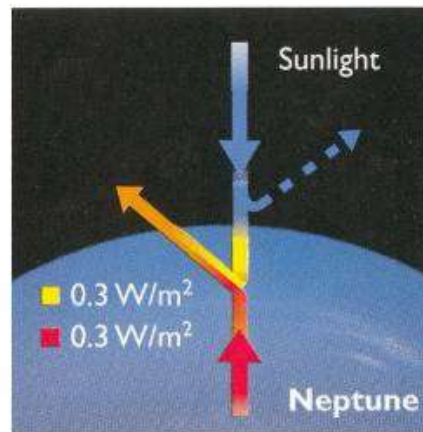
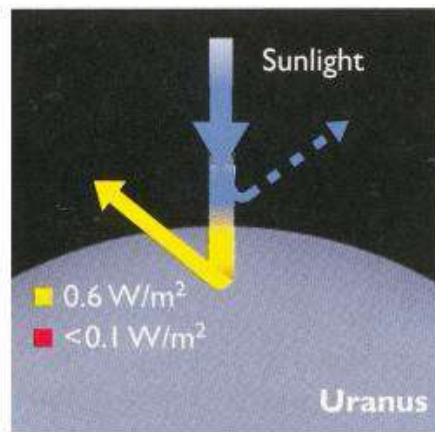
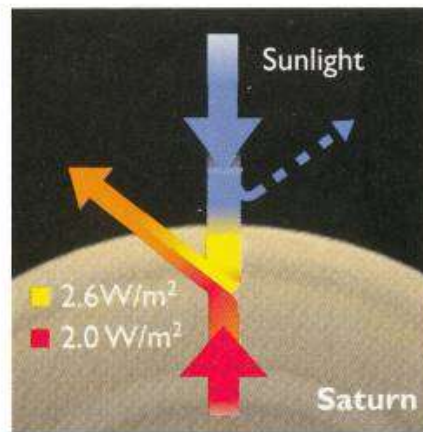
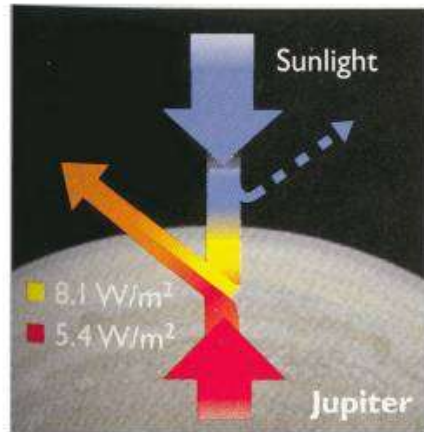
Cyclonic Storms



Methane Ice Clouds



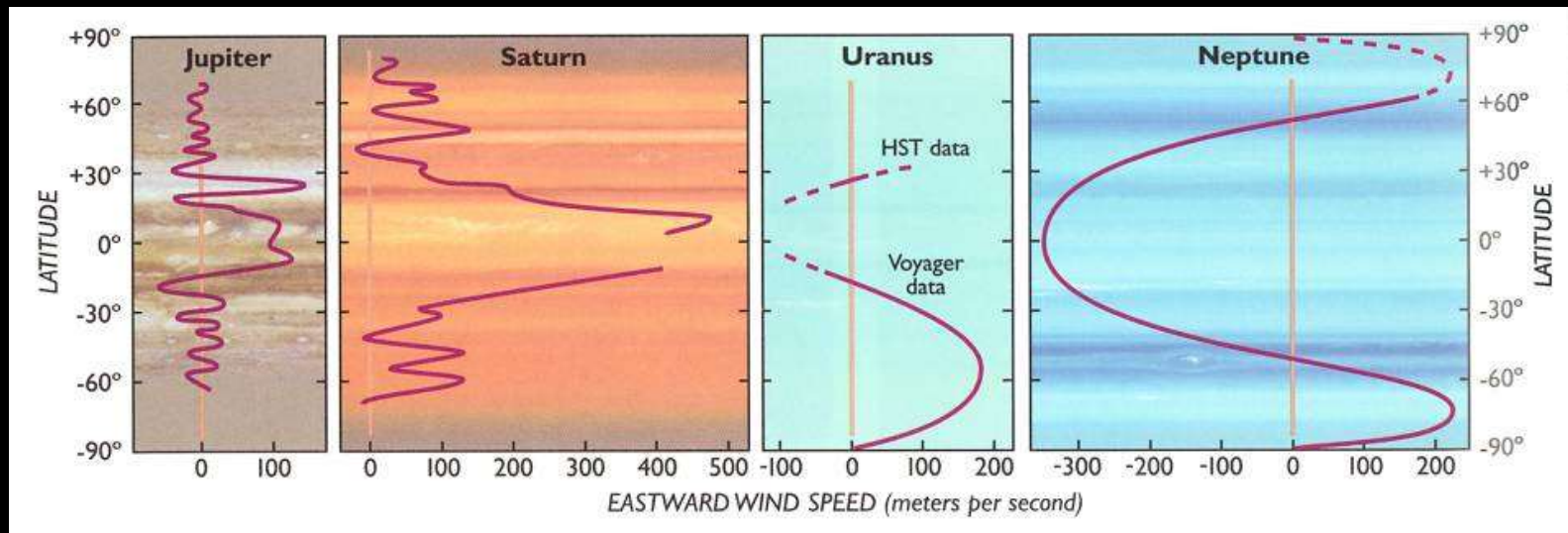
Heat: Solar and Internal



- Some internal heat inside Neptune

Atmosphere & Wind Speeds

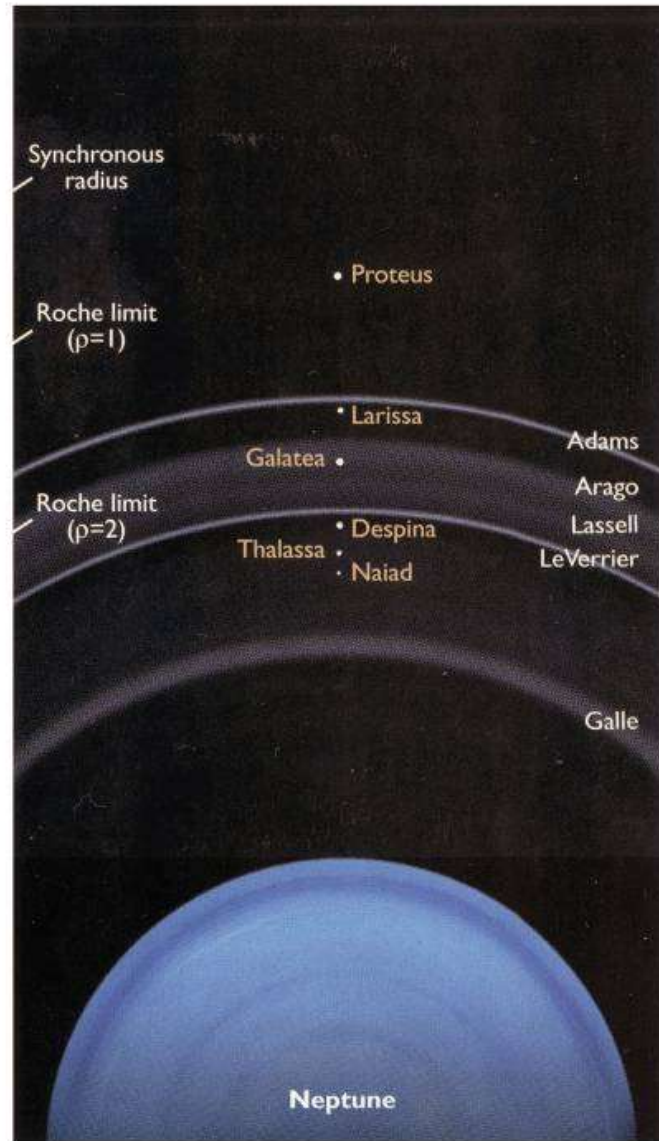
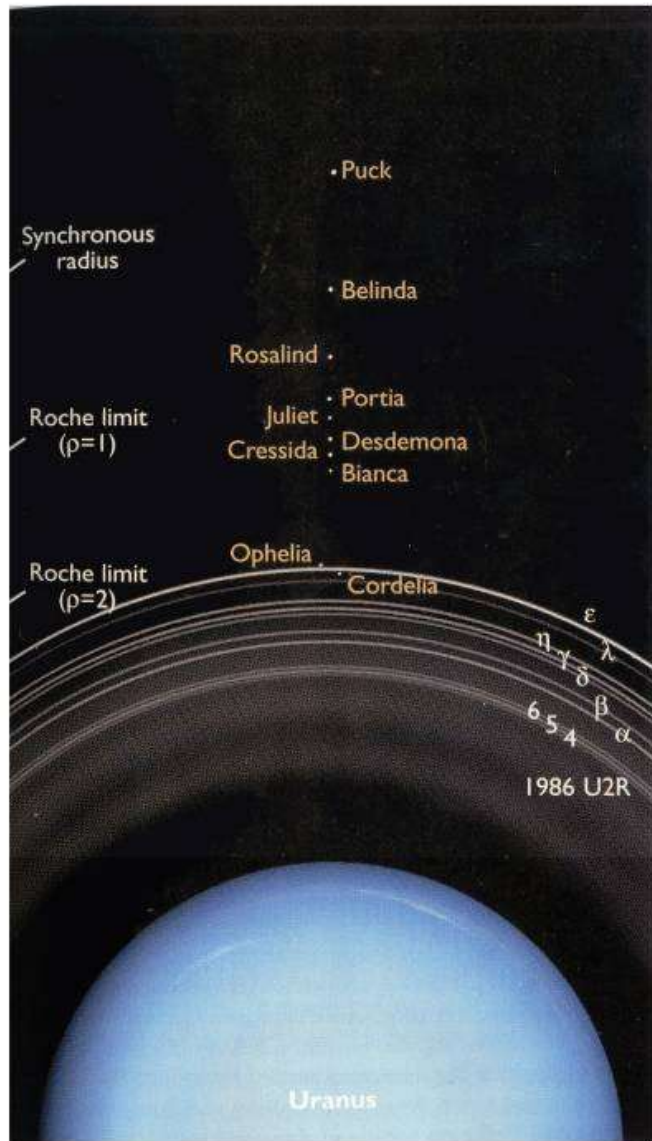
- Cloudy bands parallel to equator
- Deep blue color compared with Jupiter or Saturn
- High winds



Neptune's rings

Ring Arcs:
Liberte, Egalite, Fraternite





PLUTO / KUIPER BELT



Dwarf Planet?





Pluto and
its
satellites



Mythical Pluto

- God of dead and underworld
- Hades to the Greeks
- Brother of Jupiter and Neptune
- Pluto abducted Proserpina, making her queen of his kingdom of the spirits, a loss which her mother Ceres (Demeter), the goddess of crops, mourns so grievously that all plant growth on Earth is lost. Spring marks her annual release and fall marks her return to the underworld.



Pluto kidnaps Proserpina and takes her to the underworld. Bernini (1621)



Jupiter

Earth

Pluto

Diameter (km)

143,800

12,800

2,374

Mass

320 M_E

1 M_E

.0025 M_E

Density (g/cm³)

1.3

5.5

2.02

Year

11.86 y_E

365 days

248 y_E

Day

9.8 hours_E

1 day

6.39 days (retro)

Distance (AU)

5.2

1

39.48

At cloud tops:

Temperature (F)

-162°

61°

-388°

Moons

68+

1

1 (sort of)

Gravity (surface)

2.4

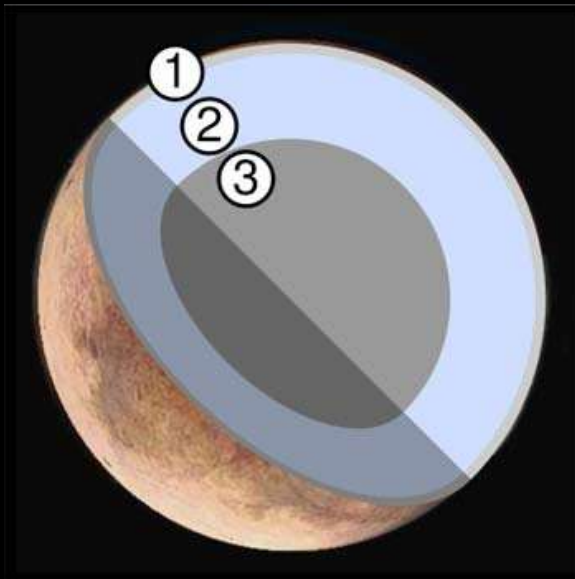
1

.071

NOT a gas or ice giant...or a planet even

Pluto's Overall Composition

- Density 2.07 g/cm^3
- 5% Methane
- 20% Water ice
- 75% silicate rock and iron
- What body is this like?

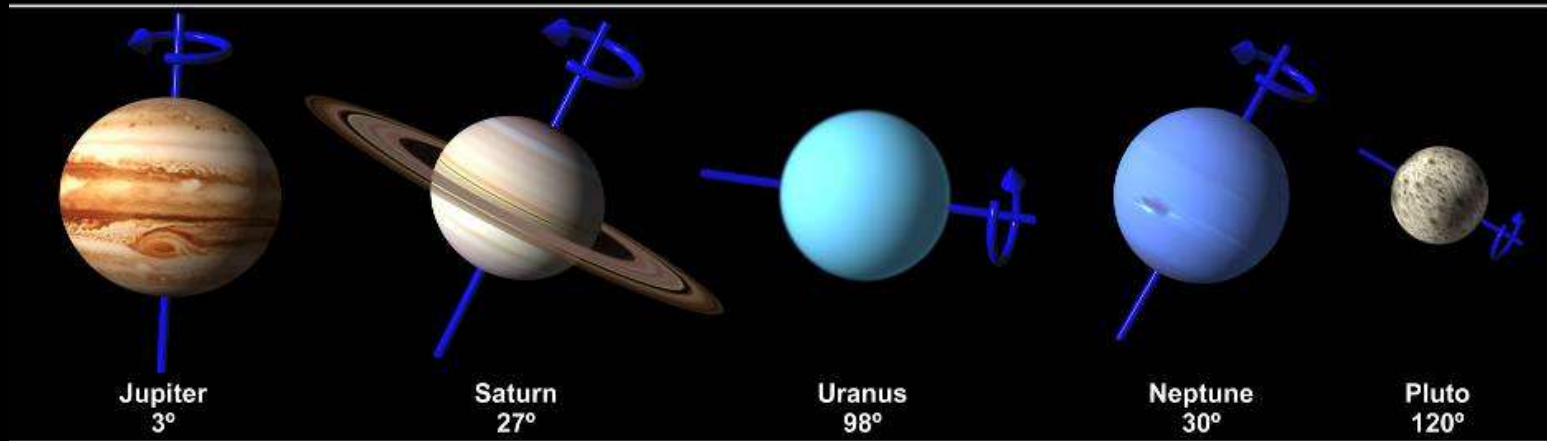


Pluton and Charon



- 250 y to orbit Sun
- Highly elliptical orbit
 - Sometimes closer than Neptune
- 19° inclined orbit
- Spin axis tilted 122°
- 5 known moons (sort of)
 - 2 in 2005, 2 in 2012
- Temperature 35° K
- Charon is half the diameter of Pluto (1200 versus 2300 km)

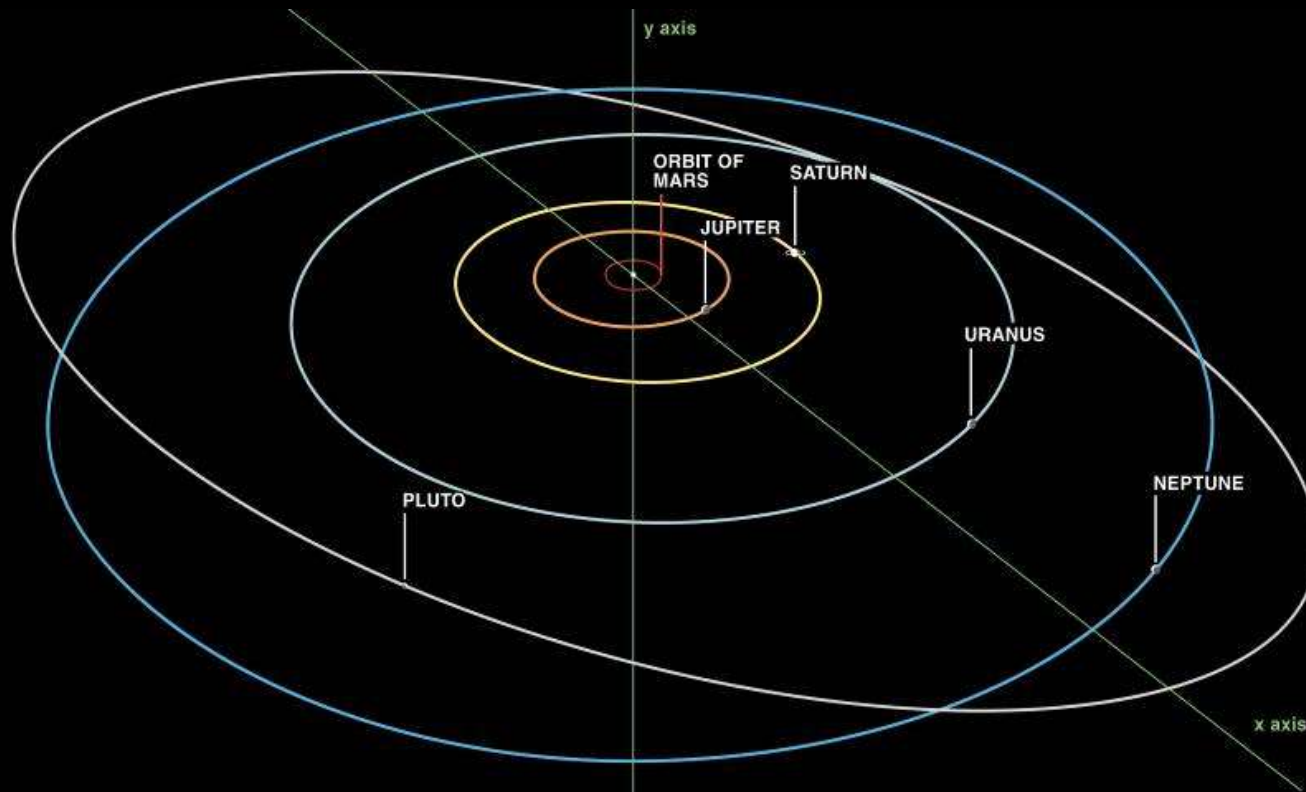
Tilt of Spin Axes: Outer Planets



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Like Uranus, Pluto “rolls” on its orbit around the Sun.

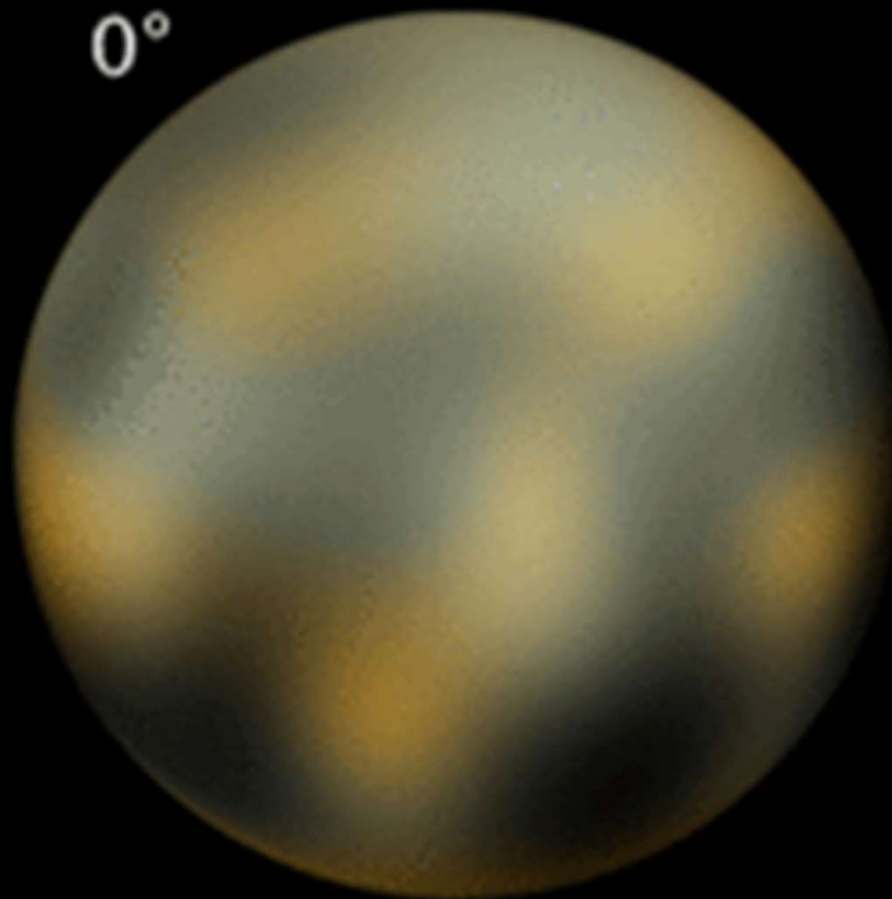
Orbit of Pluto



- Highly inclined and elliptical orbit

Pluto from HST

0°



Pluto! From New Horizons



HST 2006

Tombaugh Regio

- Nitrogen,
some methane
- Water ice
mountains

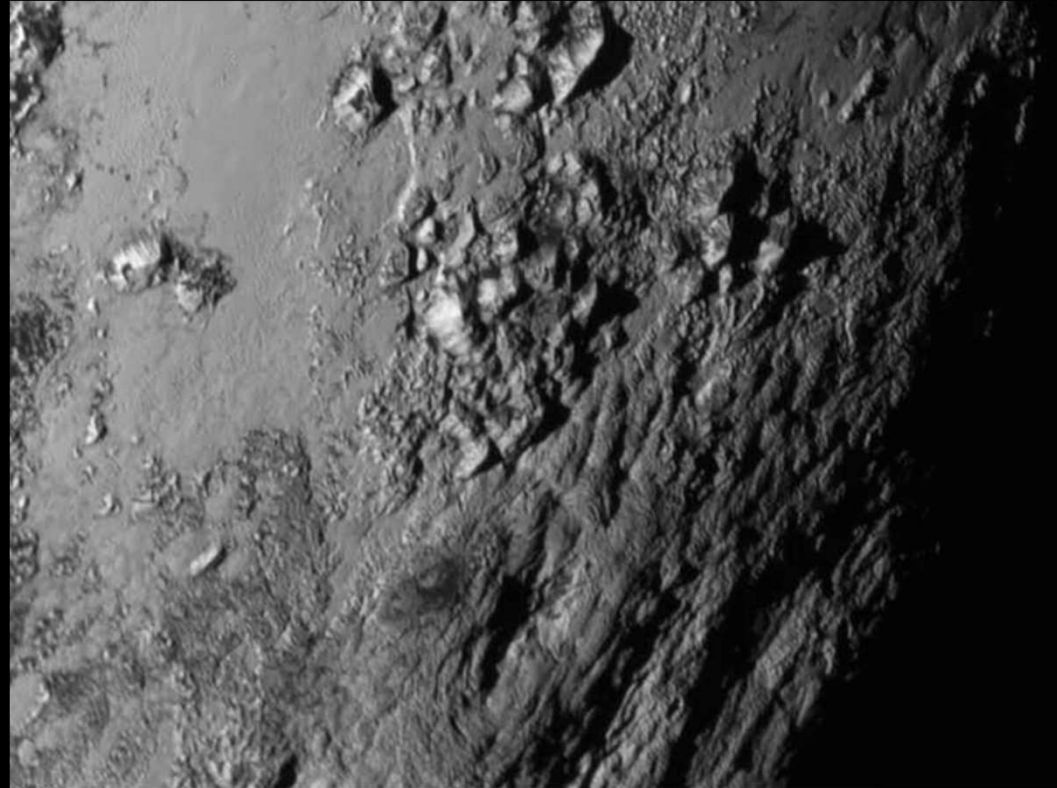
New Horizons



Pluto landforms

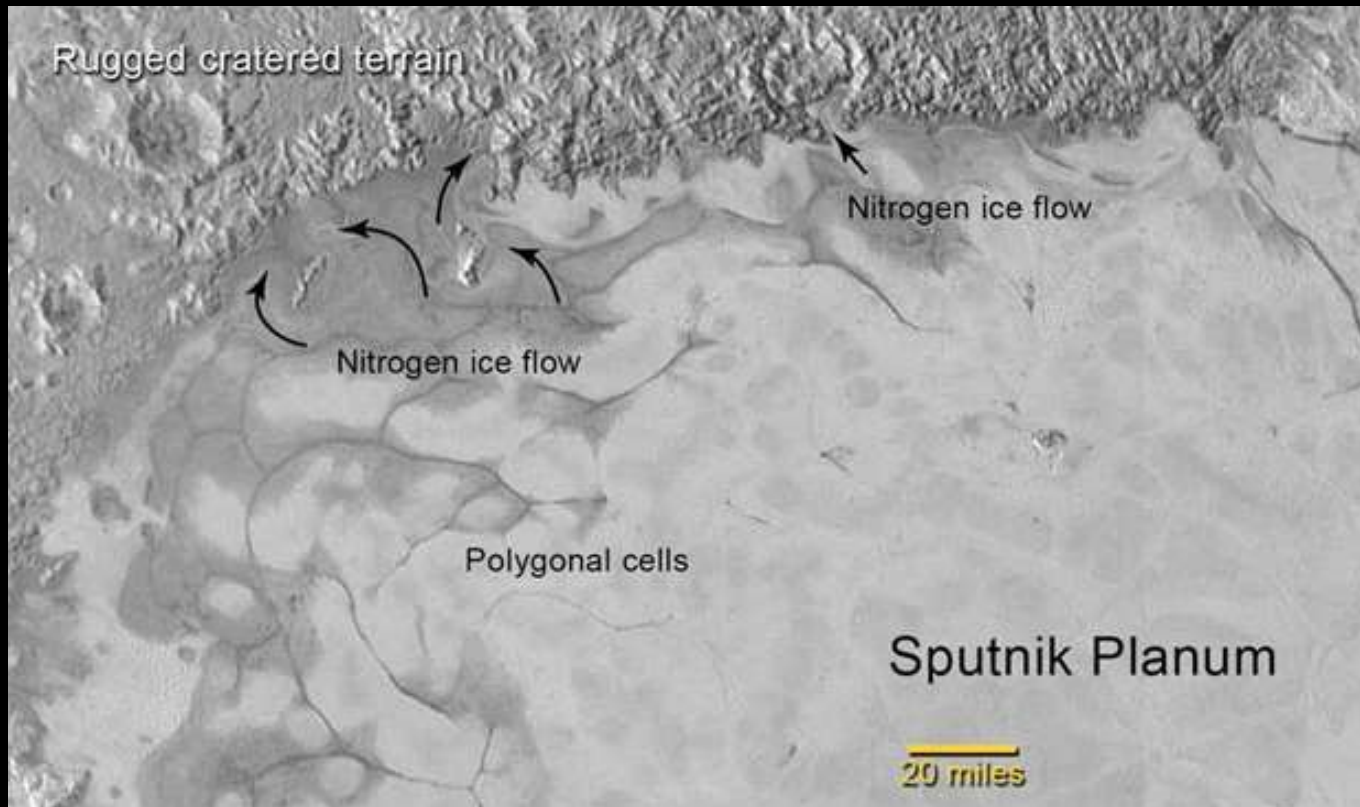
- Edge of Tombaugh Regio
- Water ice mountains

<https://www.youtube.com/watch?v=g1fPhhTT2Oo>



New Horizons

Nitrogen Glaciers



New Horizons

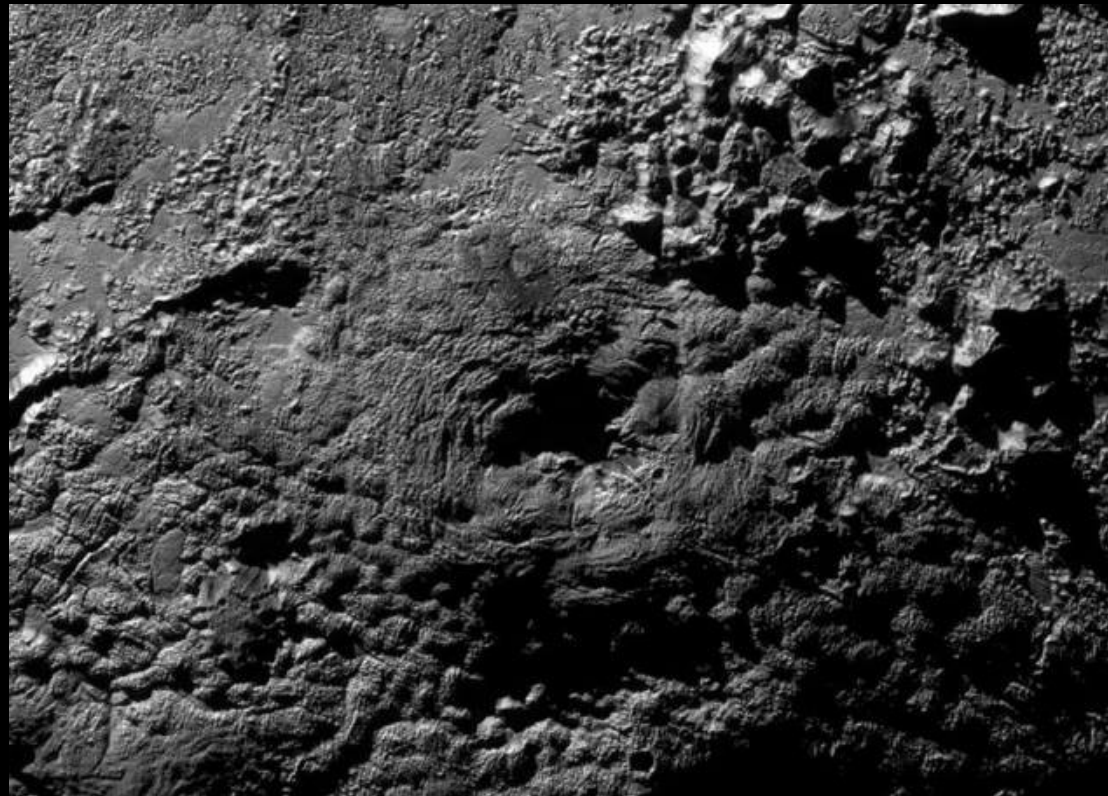
Pluto landforms

- Sputnik Planum
- Dunes?



New Horizons

Pluto landforms



New Horizons

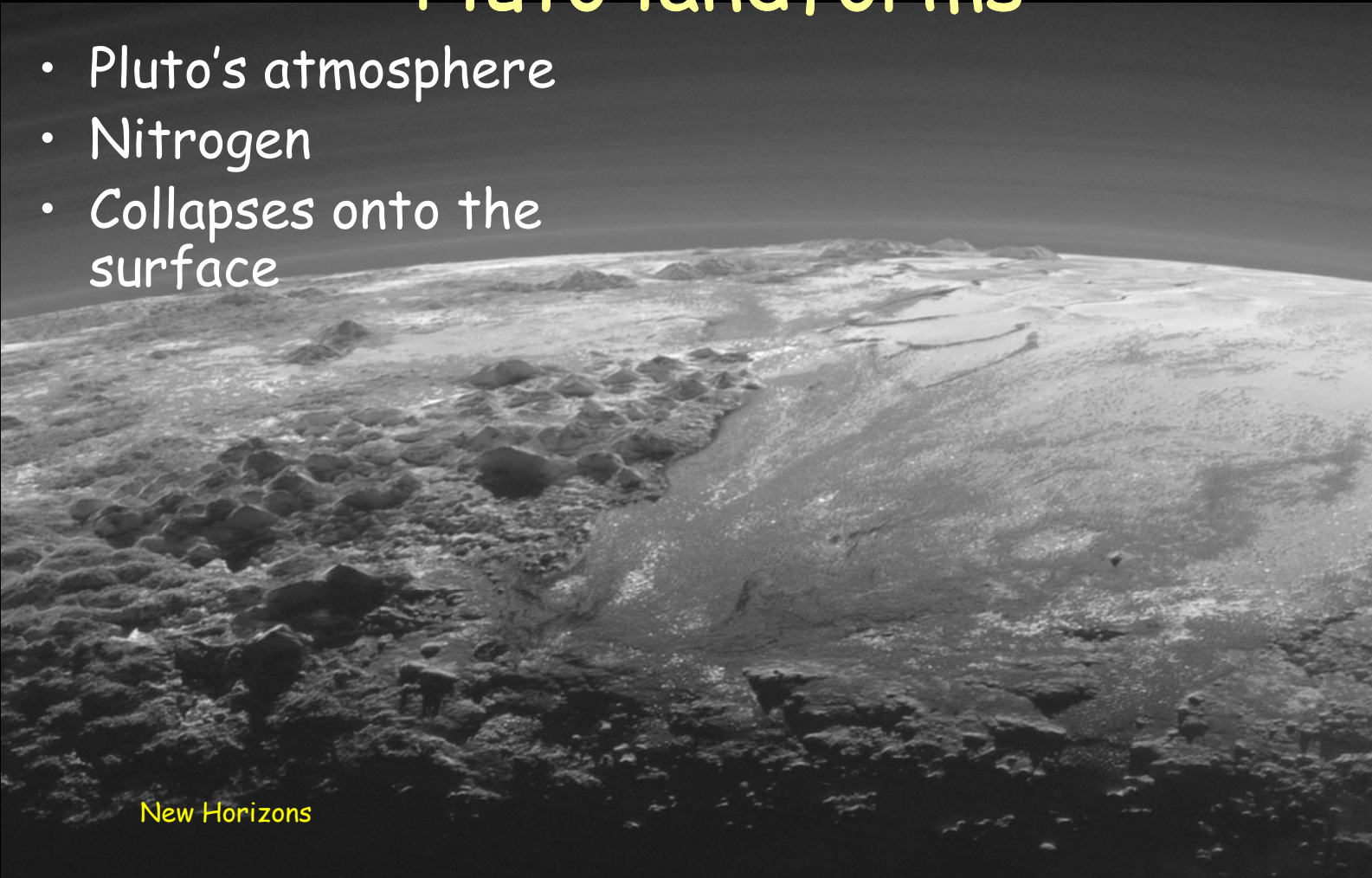
Pluto landforms



New Horizons

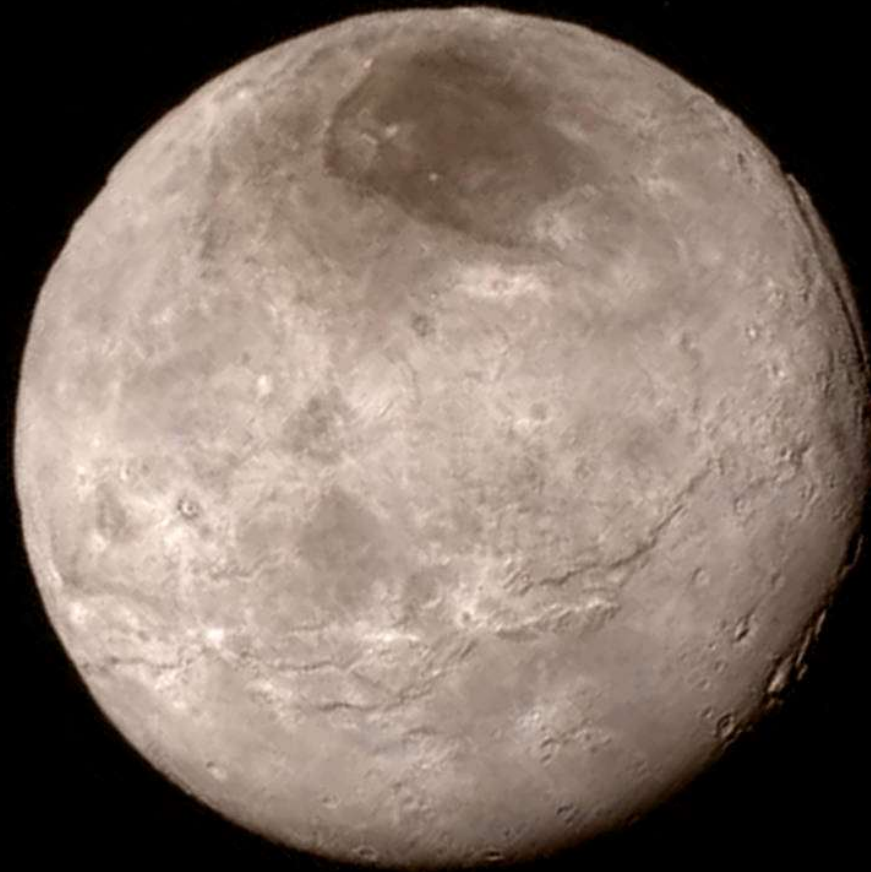
Pluto landforms

- Pluto's atmosphere
- Nitrogen
- Collapses onto the surface



New Horizons

Charon pretty cool too



HST 2006

Mordor - Because NASA = nerds



Charon and the Small Moons of Pluto



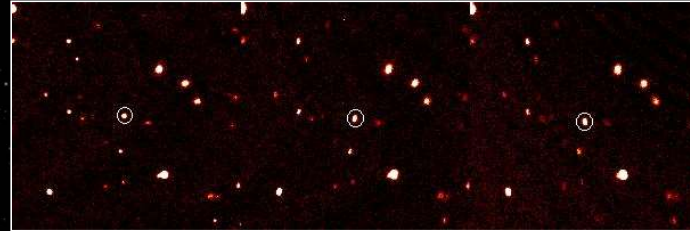
New Horizons on its way out!

- Will pass by another KBO in 2019



New Horizons

Eris: 10th from Sun

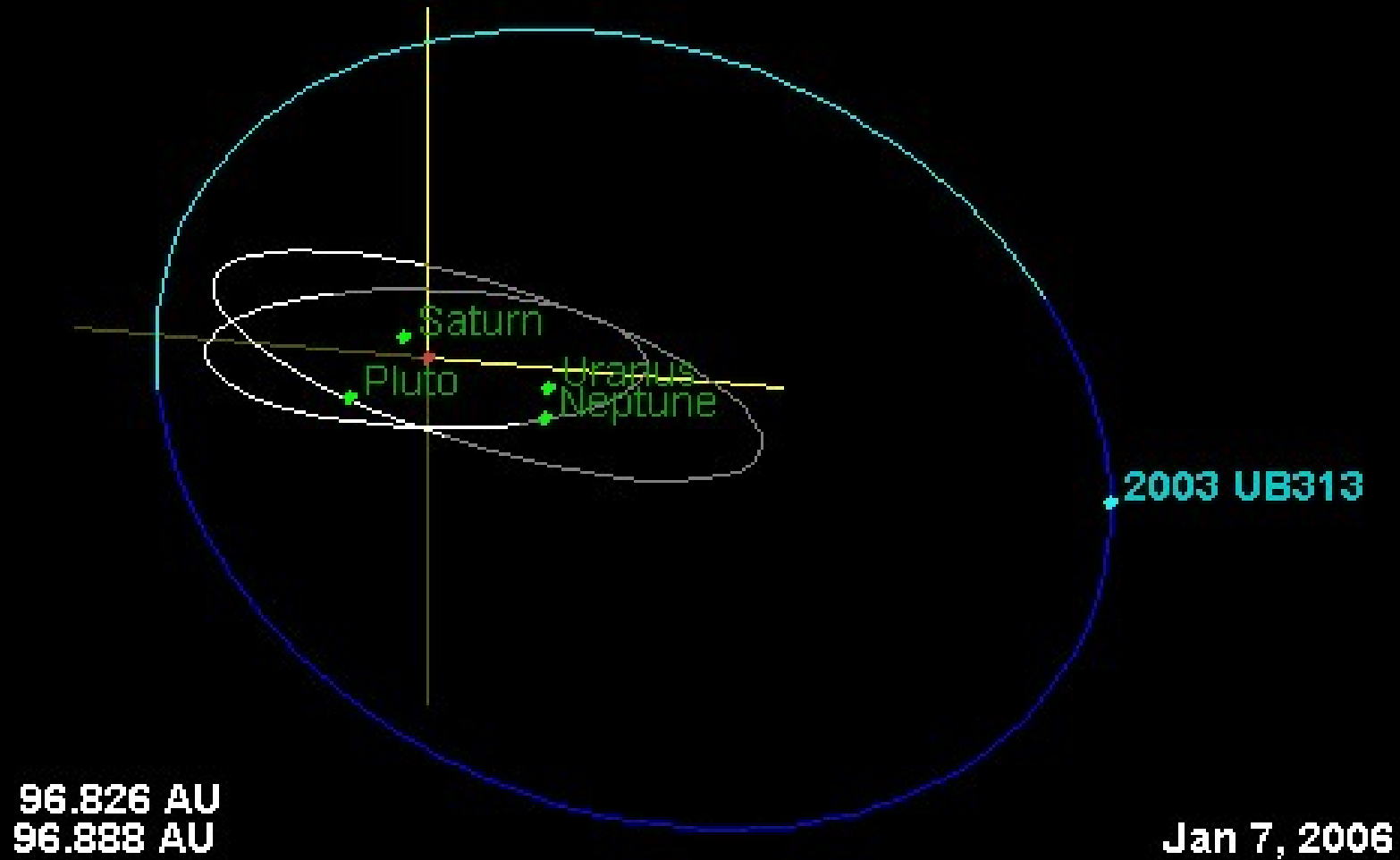


Discovery images
M. Brown: www.gps.caltech.edu/~mbrown/planetlila/

You are here.

Artists Conception: NASA/JPL-Caltech/R. Hurt

Orbit of Eris



Kuiper Belt Disk-like Kuiper Belt

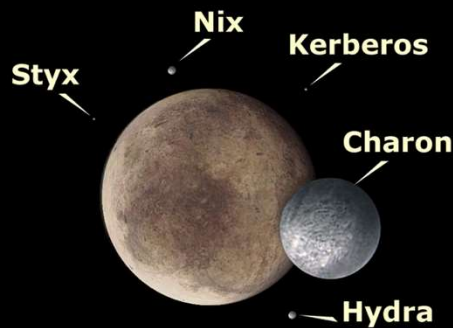


- The **Kuiper belt** extends outward from the orbit of Neptune to about 50 AU (Earth-Sun distance). Some are shown above, but the biggest known are too new to be included.
- The “pancake-shaped” belt contains a population of many hundred thousand members, 70,000 of which are >100 km diameter.

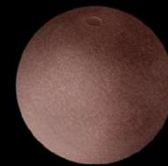
Largest known trans-Neptunian objects (TNOs)



Eris



Pluto



Makemake



Haumea



Sedna



2007 OR₁₀



Quaoar



Orcus





2003 UB₃₁₃
-2,600 km

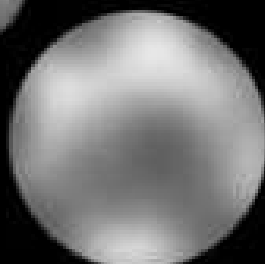


Sedna
-1,600 km

Charon
1,250 km



Quaoar
-1,250 km



Pluto
2,250 km



Moon
3,476 km

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