SPACE PHYSICS

Lecture 10

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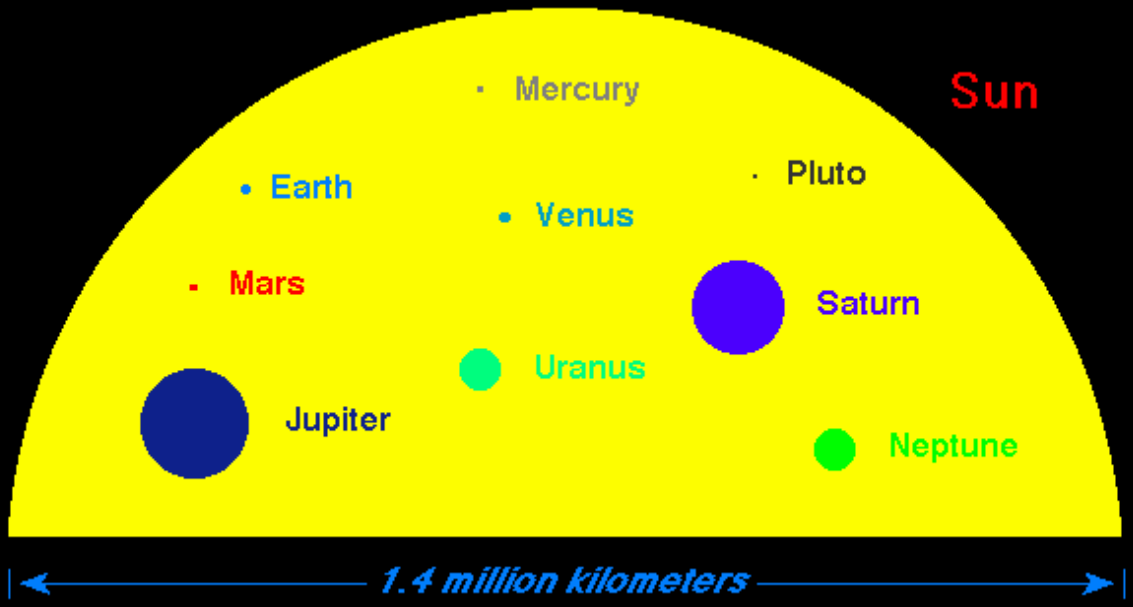
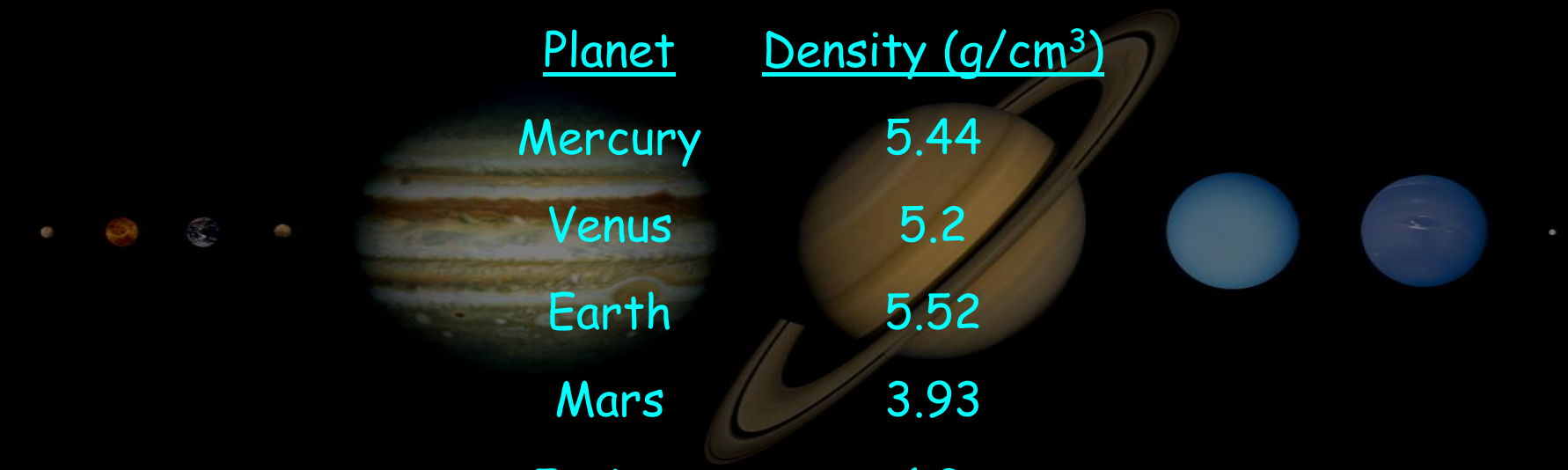
The Sun and its Planets to Scale



Let's look at the density of the Planets

Planet	Density (g/cm^3)
Mercury	5.44
Venus	5.2
Earth	5.52
Mars	3.93
Jupiter	1.3
Saturn	0.69
Uranus	1.28
Neptune	1.64
Pluto	2.06



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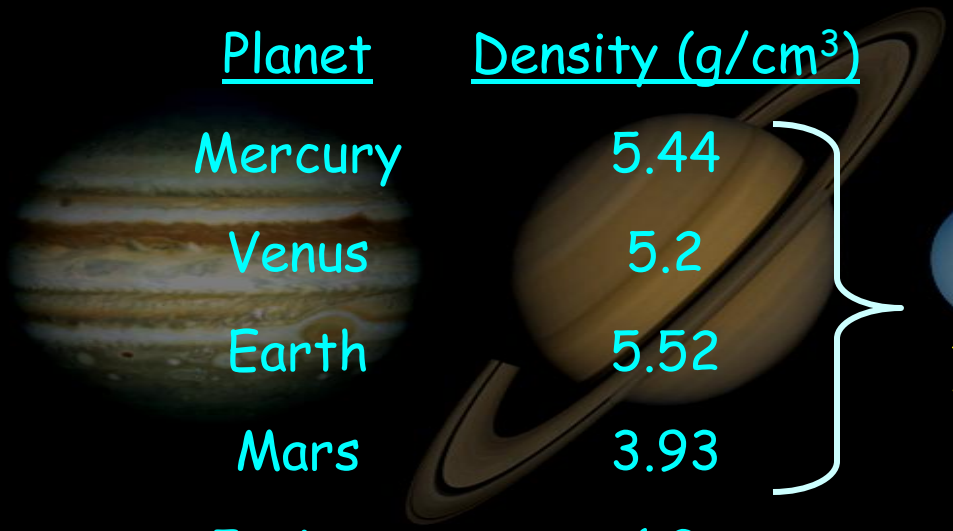

The first four planets have higher densities

Let's look at the density of the Planets

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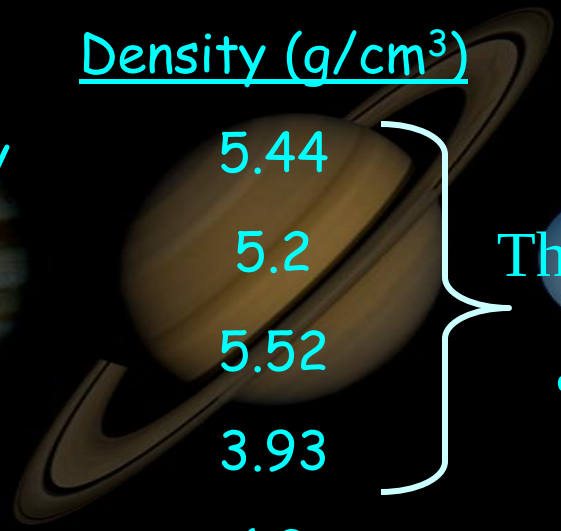


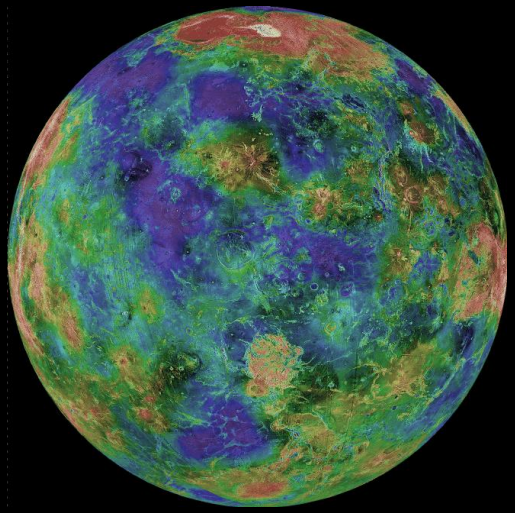
These planets are known as the Rocky Planets

Because their densities suggest that they are mostly made of rock and heavier materials

The Terrestrial (inner) Planets

- Small, dense and rocky
- Few moons, no rings

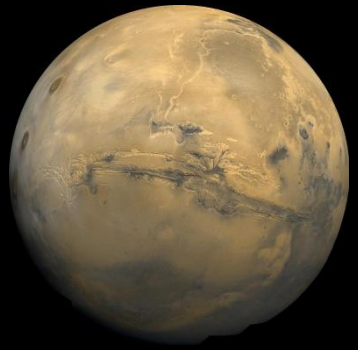
Mercury



Venus

Earth

Mars



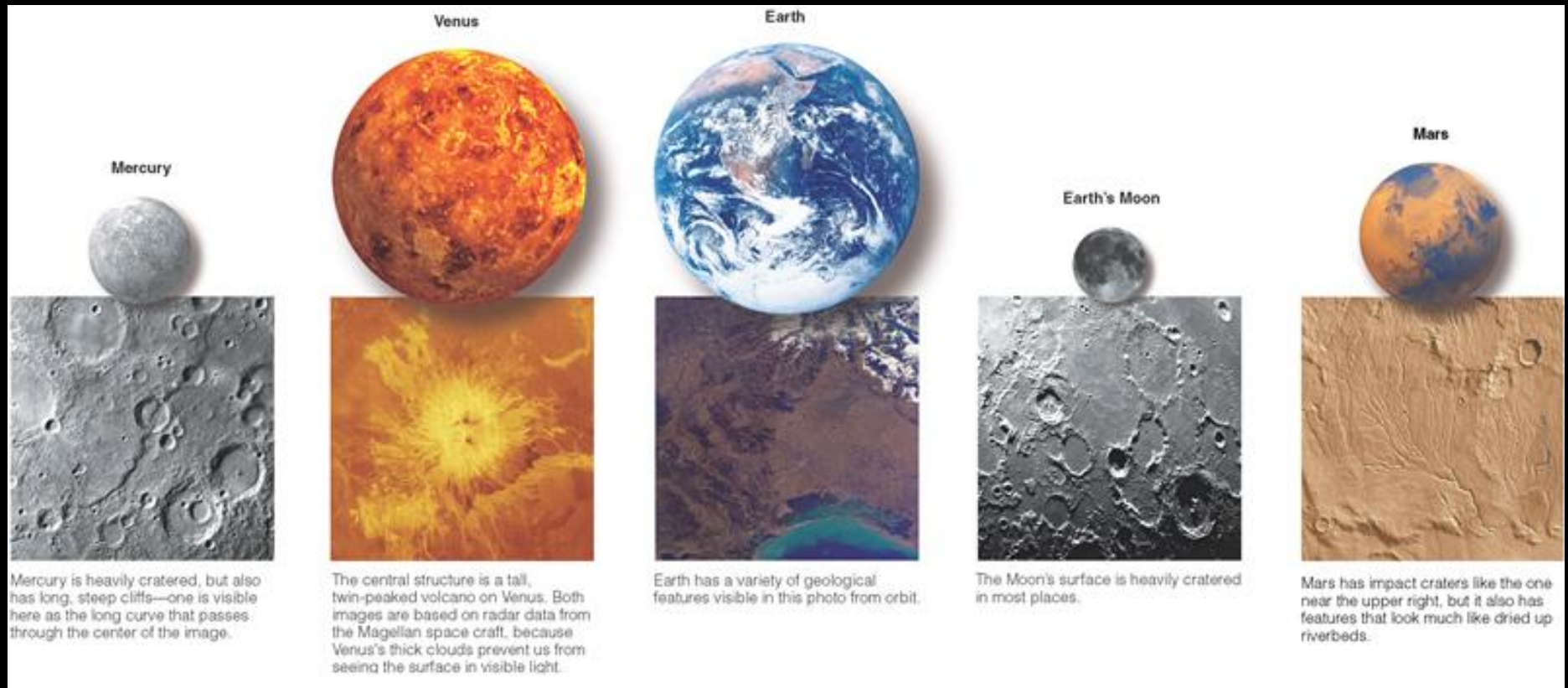
Similarities and Differences of the Terrestrial Worlds

From a distance, they appear very similar…

- rocky and small (we really can't see the surface of Venus directly) !

Examined close-up, They are very different…

- Mercury and Earth's Moon are ***airless*** and barren
- Mars has a very ***thin atmosphere***
- ***Earth has oxygen, water, and life!***
- Venus has a ***thick atmosphere*** and very hot!

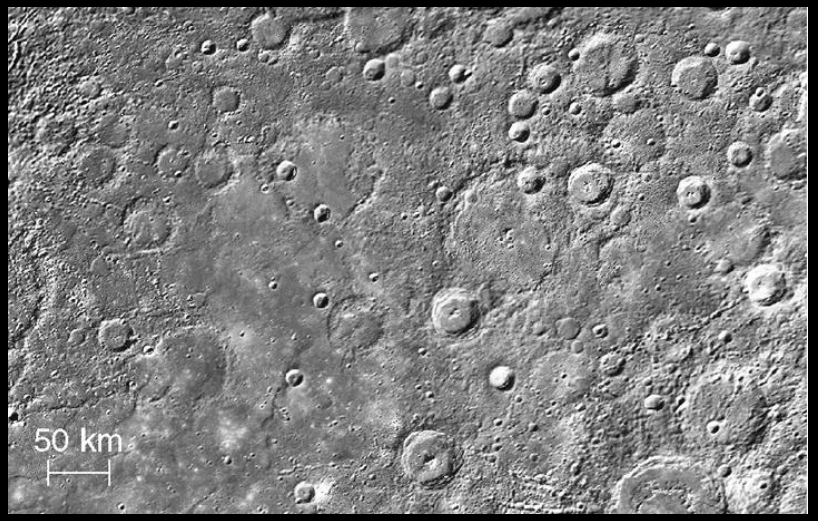


Mercury and Earth's Moon

Similarities between Mercury and the Moon:

The similarities between these two worlds can be explained by their small sizes:

- **Small size** ⇒ low surface gravity ⇒ low escape velocity ⇒ gas cannot be trapped by gravity on the surface.
- **No atmosphere** ⇒ large day/night temperature difference
- **Small size** ⇒ small initial heat content ⇒ they cool off fast ⇒ low level of geological activities



Surface of Mercury looks very similar to the Moon

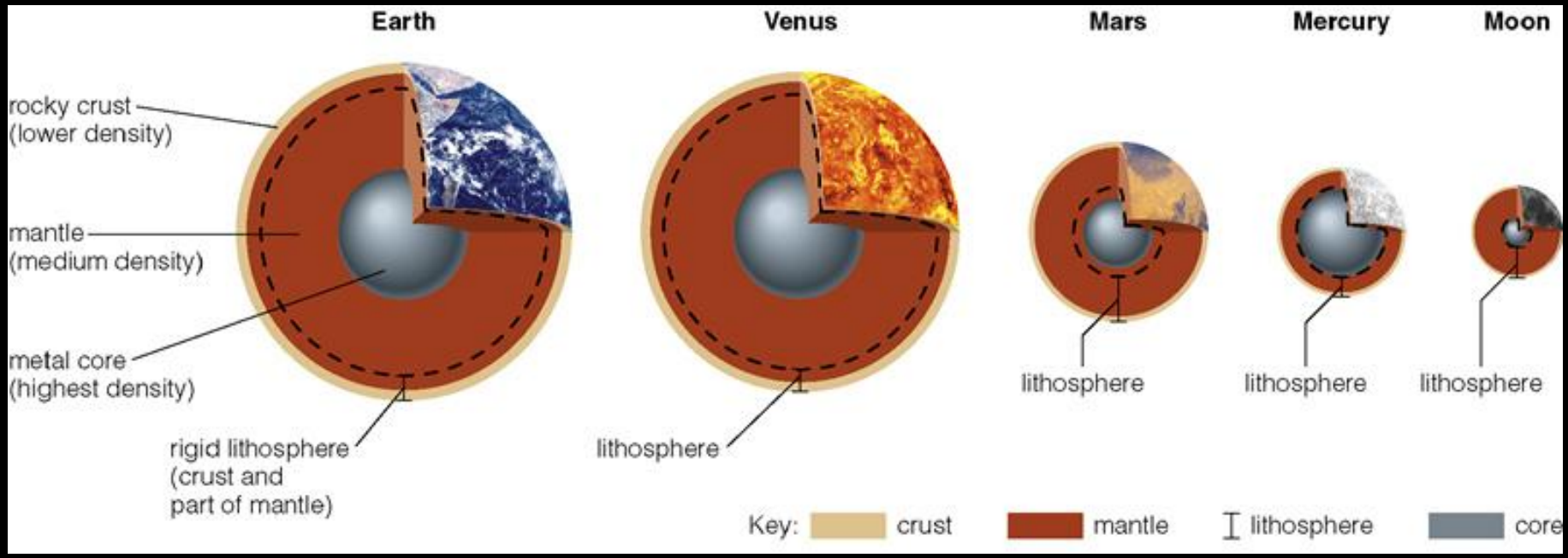
Internal Structure of the Terrestrial Planets

The internal structure of the terrestrial planets are similar. They all have

- Core – High density metal
- Mantle – Medium density rocky materials, such as silica (SiO_2), ***hot, semi-solid***
- Crust – lowest density rocks, such as granite and basalt (black lava rock…)

The layering of different density materials occurs due to *differentiation – heavy materials sink to the bottom while lighter material rise to the top…*

Lithosphere: The coolest and most rigid layer of rock near a planet's surface. Molten lava of Earth exists at a very narrow region beneath the lithosphere



Heating of the Terrestrial Planets

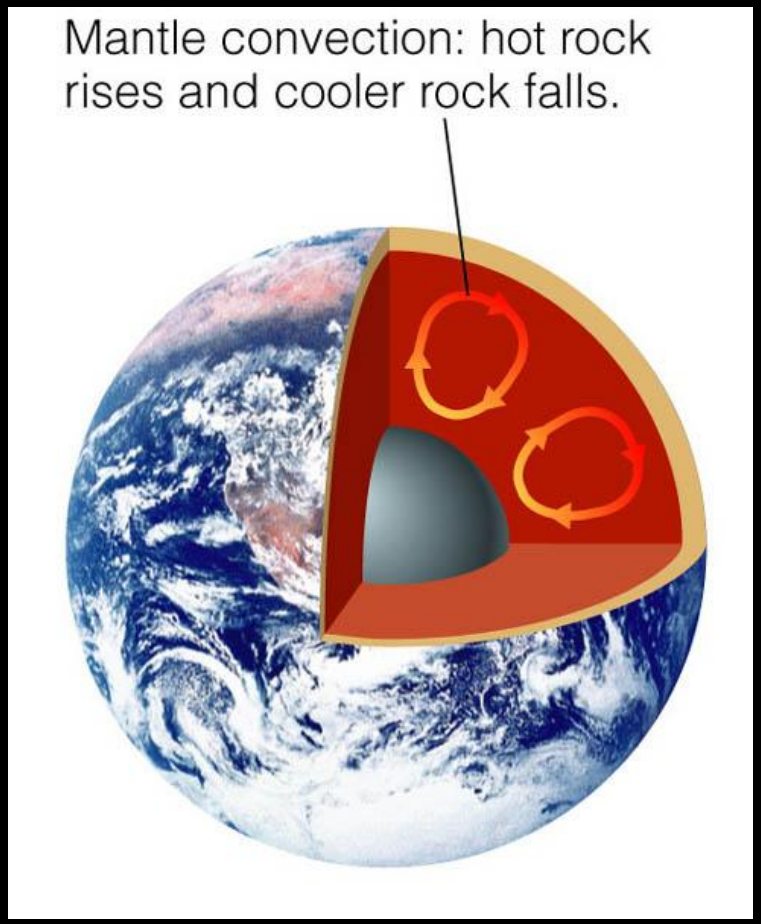
The interiors of the terrestrial planets are heated by:

- Gravitational potential energy of the accreting planetesimals are converted into thermal energy.

Radioactive Heating

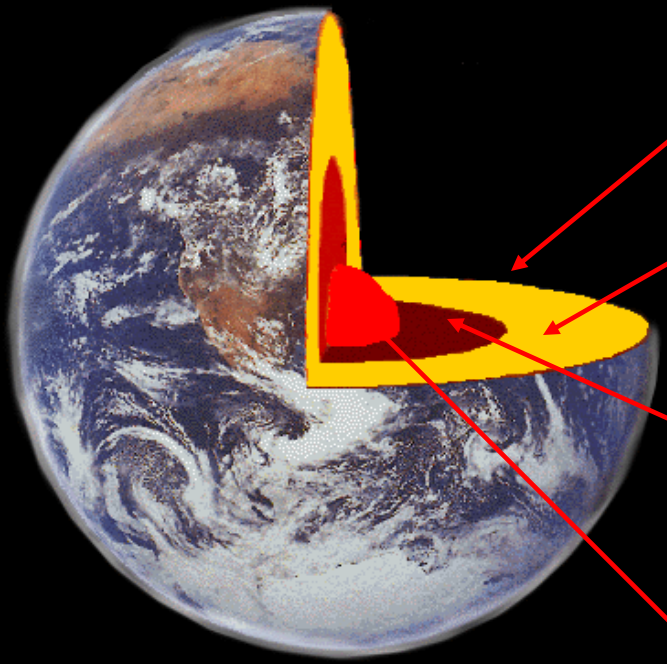
Radioactive materials (e.g., uranium, potassium, thorium) decay by emitting subatomic particles (***alpha particle***—nuclei of helium, ***beta particle***–electrons or positron, ***neutron***, ***proton***, etc.) and often gamma-ray, which collide with surrounding atoms, heating them up.

- Potassium-40 → Argon-40
- Uranium-234 → ……. → Lead-206



Internal heating causes ***Mantle Convection***---hot rock rises to the top and cools off, cool rock sinks to the bottom, resulting in the cooling of the planet…

How Do We Know This?



The Crust:

A Thin Rock Material

The Mantle:

A Dense and Mostly Solid Rock Material

The Outer Core:

Liquid Iron and Nickel

The Inner Core:

Solid Iron and Nickel

Density

The Density of Earth is 5.53

The Land is covered mostly by a type of rock called Granite

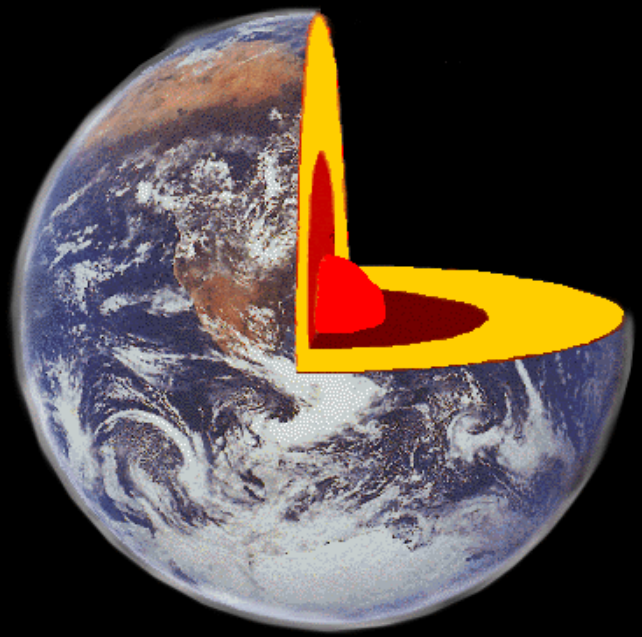
(density of Granite = 2.7 gm/cm^3)

The Ocean is mostly covered by a type of rock called Basalt

(density of Granite = 3.3 gm/cm^3)

Density of Rocks $\approx$ 3 gm/cm^3

The Density of Earth is 5.53 gm/cm^3



Density of Rocks $\approx$ 3 gm/cm^3

Density of Iron/Nickel $\approx$ 8 gm/cm^3

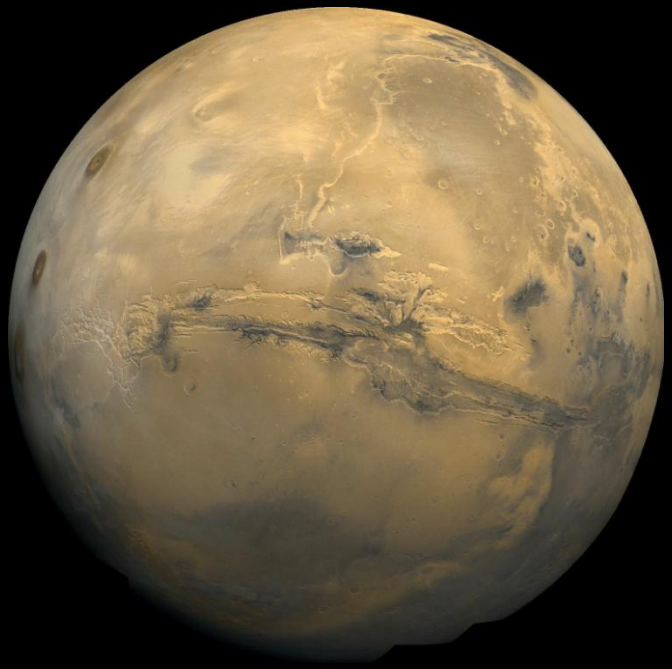
So we believe about $\frac{1}{2}$ the Earth is a Rock-like material and the other $\frac{1}{2}$ a heavy metal such as iron and nickel

The density of the Earth will be the average of the two:

$$\frac{8+3}{2} = 5.5$$

Density of Mars is 3.9 gm/cm^3

What does this tell us about the interior of Mars?



Mars has a much smaller Iron Core than Earth does

What does the density tell us about the interior of these bodies?

(do they have a very big core?)

Mercury density = 5.4 gm/cm^3

Venus density = 5.2 gm/cm^3

Moon density = 3.3 gm/cm^3

The Atmosphere of the Terrestrial Worlds

According to the Nebular Theory, the terrestrial planets were formed by metallic and rocky planetesimals. So,

Where did the gas come from?

- The gases came from comets and asteroids impact during the period of heavy bombardment.
- The gases are trapped in the interior of the planets, later released through volcanic ***out-gassing***.

But, why are their atmosphere so different?

Table 8.1 Atmospheres of the Terrestrial Worlds

World	Composition	Surface Pressure*	Winds, Weather Patterns	Clouds, Haze
Mercury	helium, sodium, oxygen	10^{-14} bar	None: too little atmosphere	None
Venus	96% CO_2 3.5% N_2	90 bars	Slow winds, no violent storms, acid rain	Sulfuric acid clouds
Earth	77% N_2 21% O_2 1% argon H_2O (variable)	1 bar	Winds, hurricanes	H_2O clouds, pollution
Moon	helium, sodium, argon	10^{-14} bar	None: too little atmosphere	None
Mars	95% CO_2 2.7% N_2 1.6% argon	0.007 bar	Winds, dust storms	H_2O and CO_2 clouds, dust

* 1 bar ≈ the pressure at sea level on Earth.

Let's look at the density of the Planets

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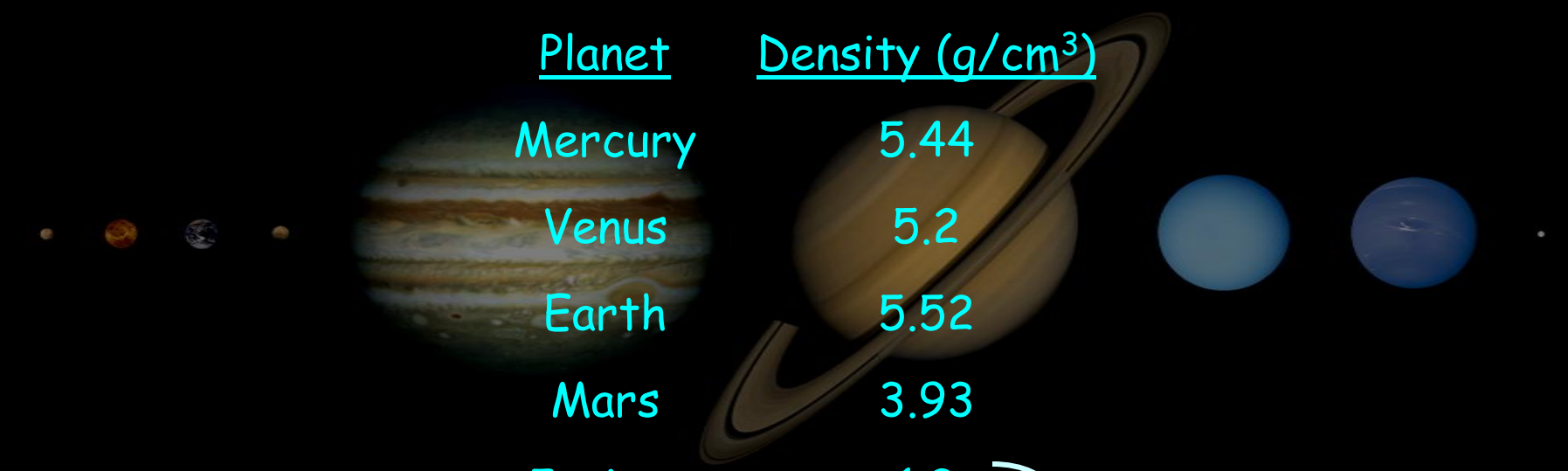
Saturn	0.69
Uranus	1.28
Neptune	1.64
Pluto	2.06

The next four planets have lower densities

Let's look at the density of the Planets



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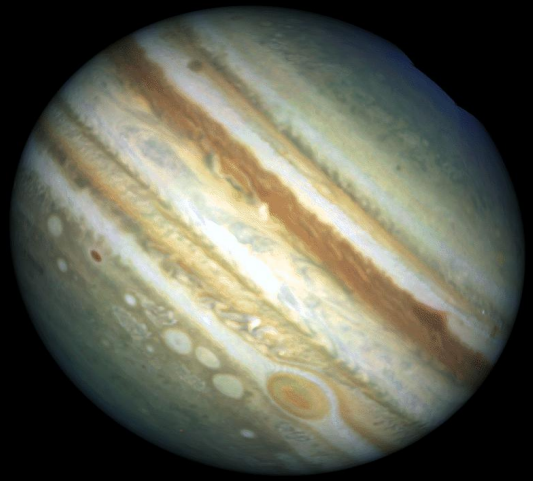
These Planets are known as the gaseous planets

Because their densities suggest that they are mostly made of gas

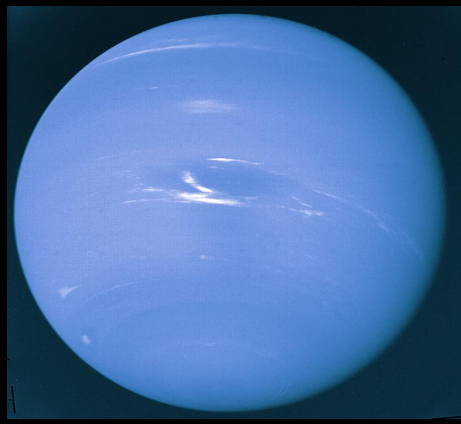
The Jovian (Outer) Planets



Jupiter

Saturn

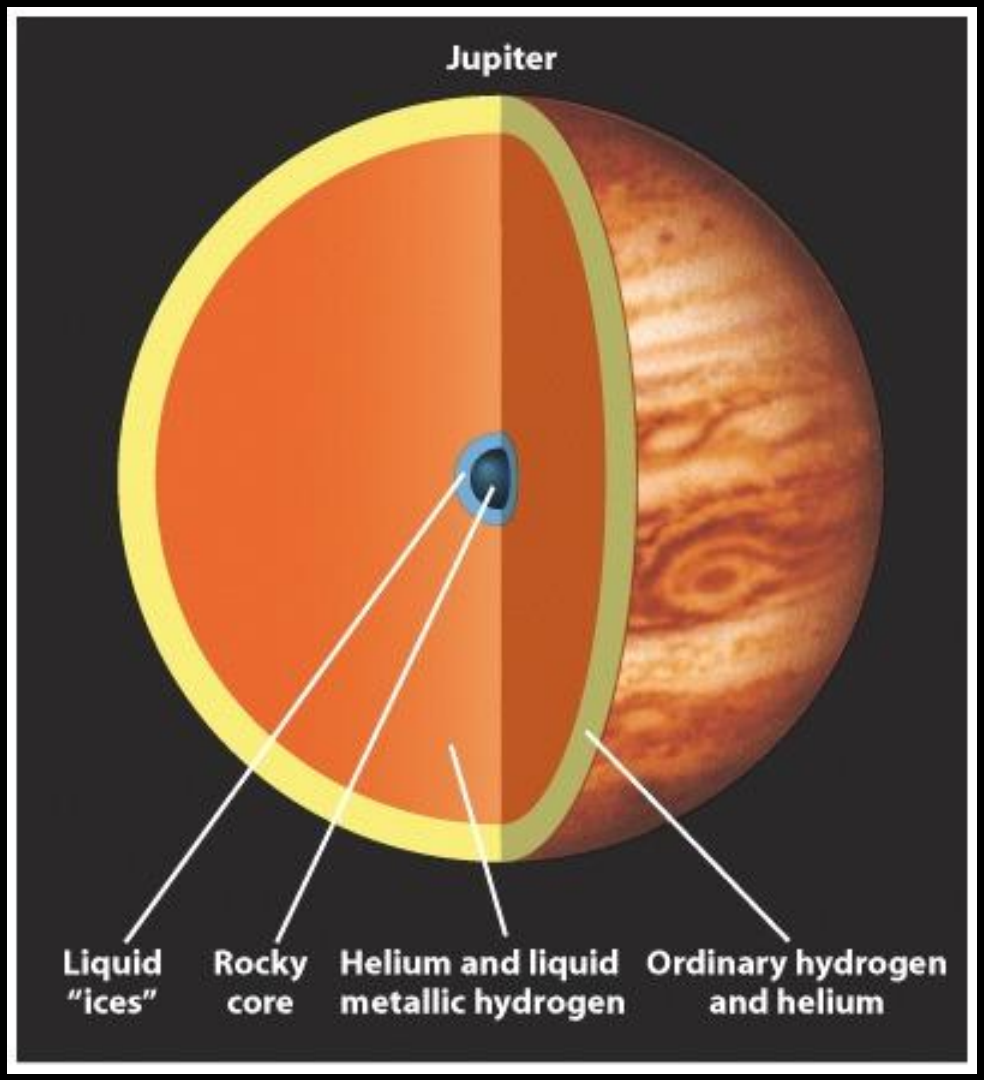
Uranus



Neptun

Large, gaseous, lots of moons, rings

Jupiter's Interior



The Density of Jupiter is 1.3 gm/cm^3

What does this tell us about the interior of Jupiter?

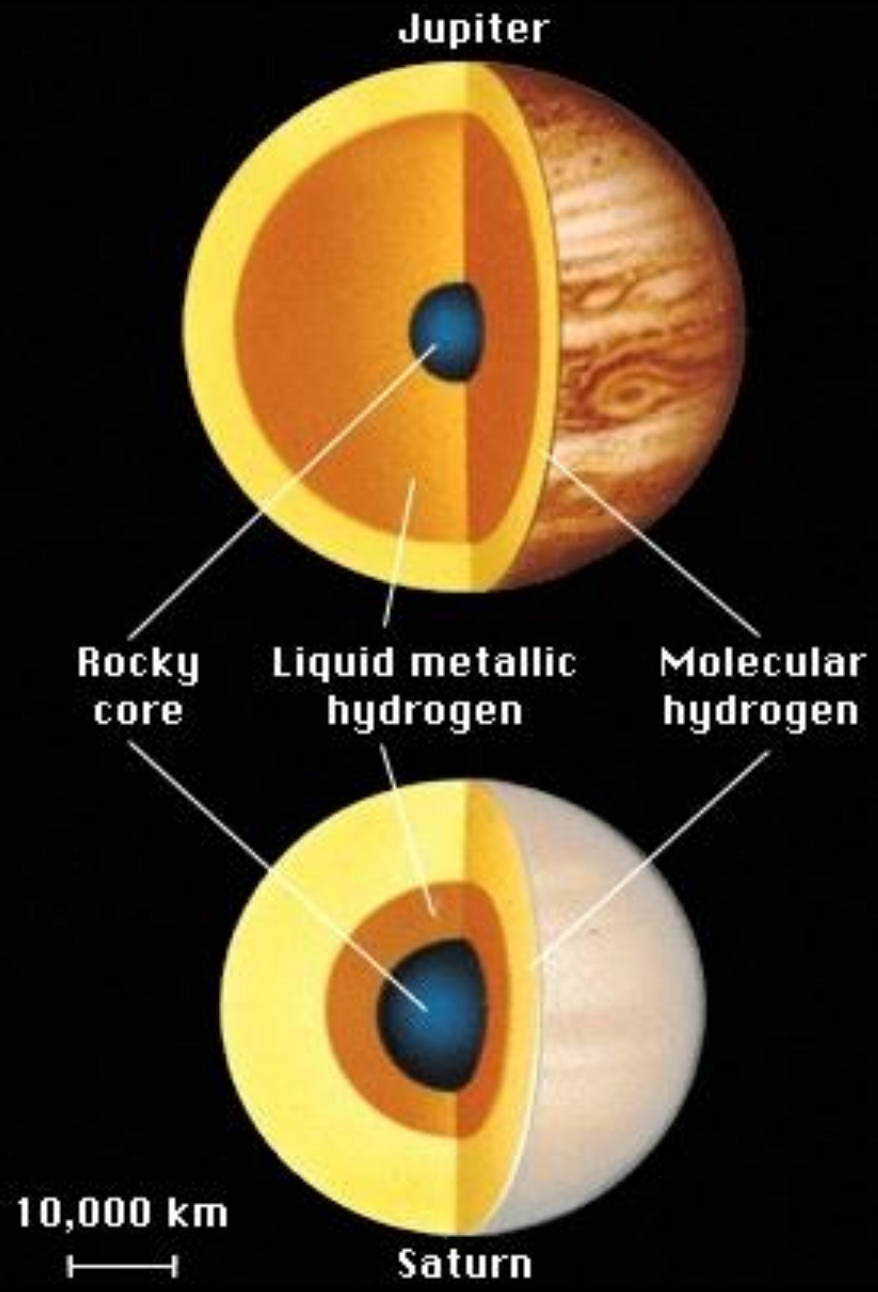
Since the density of Jupiter is so small the planet has to be made mostly of very light material

Jupiter is made mostly of Hydrogen and Helium gas

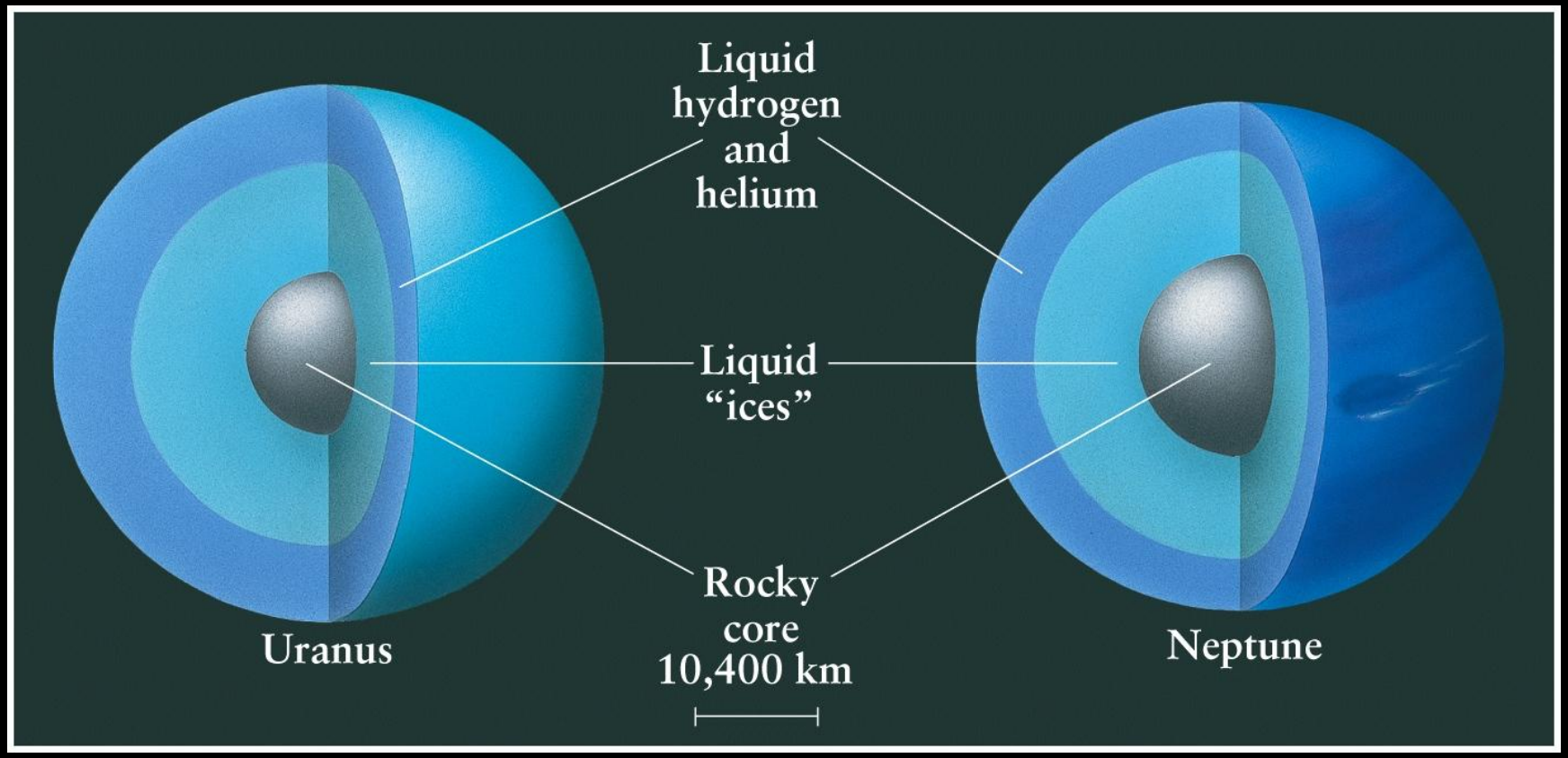
The Density of Saturn is 0.69 gm/cm^3

Saturn is also made up mostly of Hydrogen and Helium

The density of Saturn is less than 1 gm/cm^3
so this planet can float in water

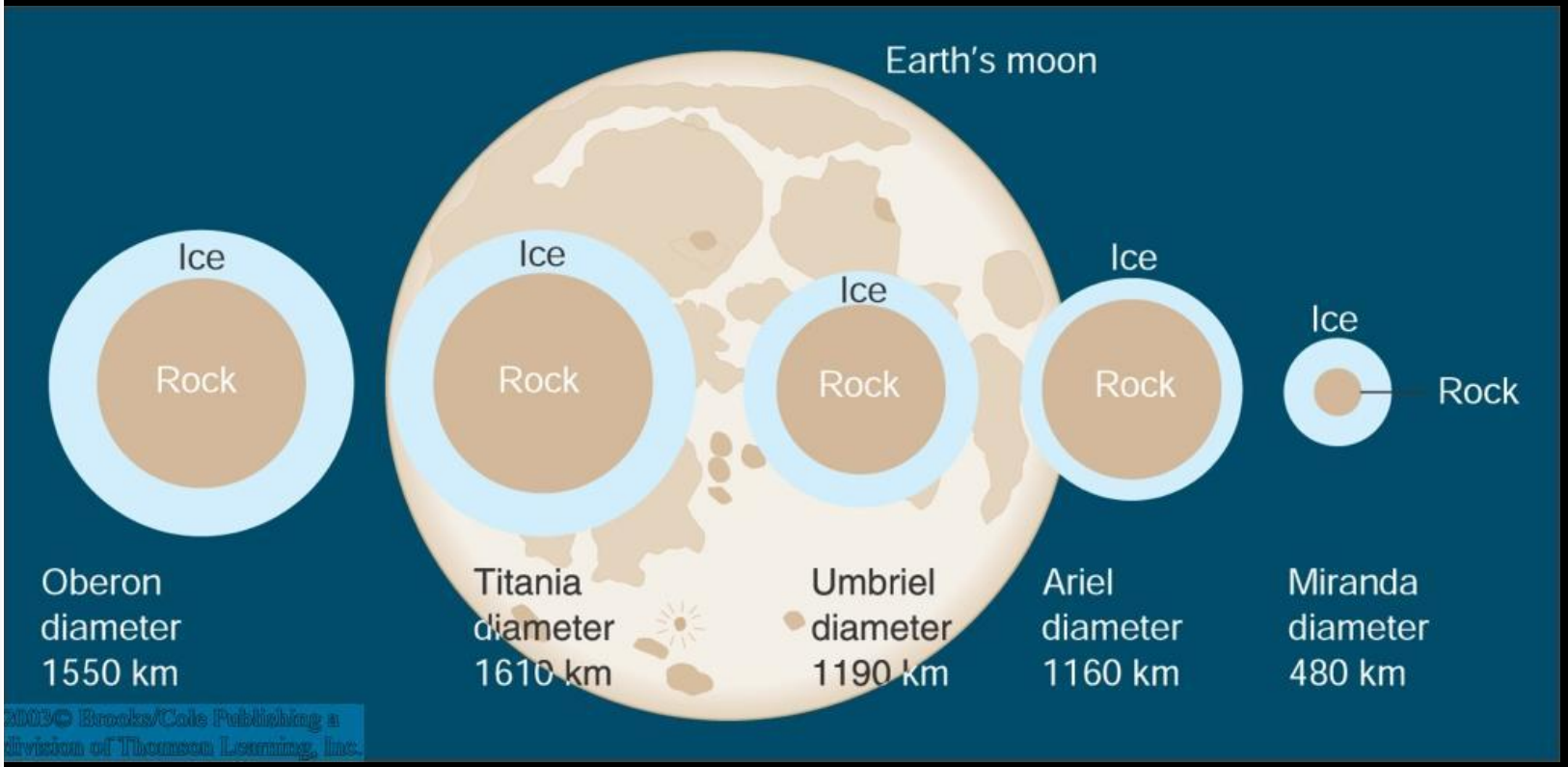

Jupiter
Rocky core
Liquid metallic hydrogen
Molecular hydrogen
10,000 km
Saturn

Structures of Uranus and Neptune



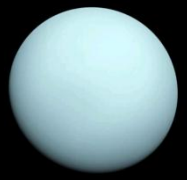
Relatively thin atmospheres compared to Jupiter and Saturn, but still quite extensive compared to terrestrial planets

Interiors of Uranus's Moons

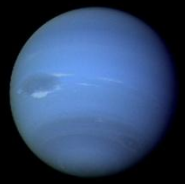


Large rock cores surrounded by icy mantles.

What does the density tell us about the interior of Uranus and Neptune?



Uranus density = 1.28 gm/cm^3



Neptune density = 1.64 gm/cm^3

Like Jupiter and Saturn these planets have low densities which suggest they are primarily made of gas.

(in this case methane)

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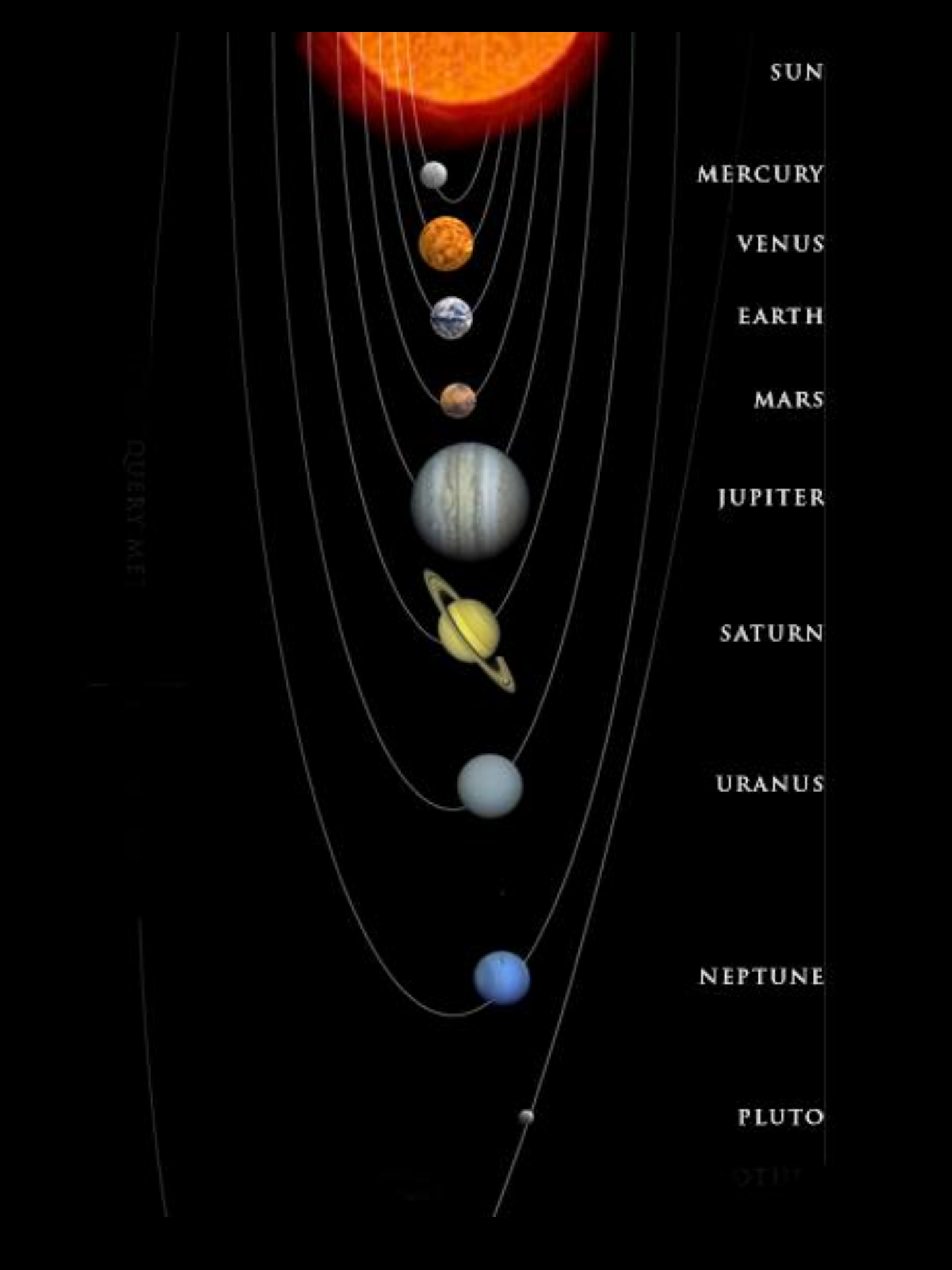
Pluto	2.06

And Pluto is Somewhere in between

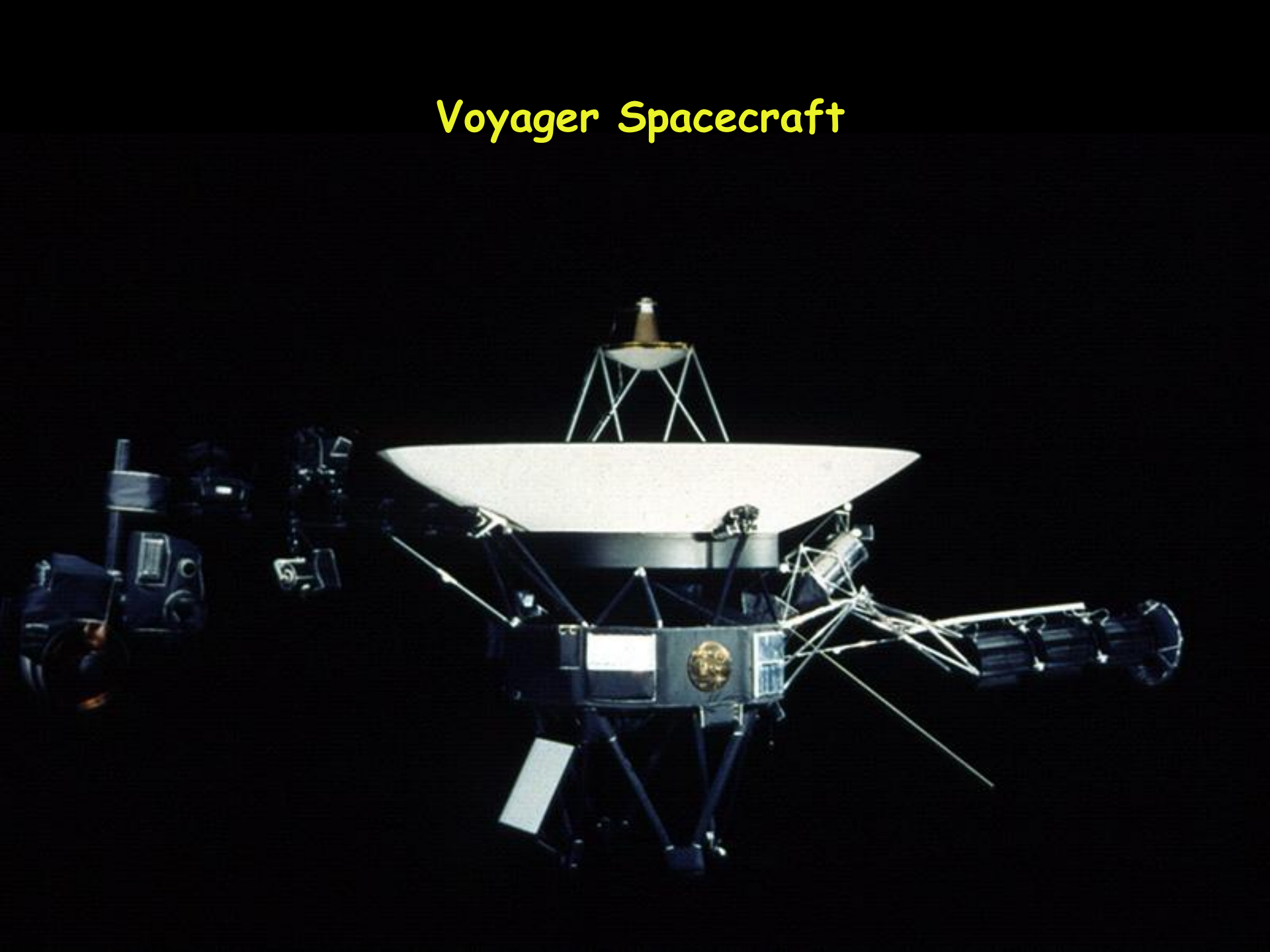
Pluto

density = 2.06 gm/cm^3

Since Pluto is so far away it is hard to see the planet. Since it is good at reflecting light scientists suspect there is ice at the surface, possibly frozen Nitrogen


SUN
MERCURY
VENUS
EARTH
MARS
JUPITER
SATURN
URANUS
NEPTUNE
PLUTO

Voyager Spacecraft



The Voyager Spacecraft on its way, looking back at Earth and our Moon