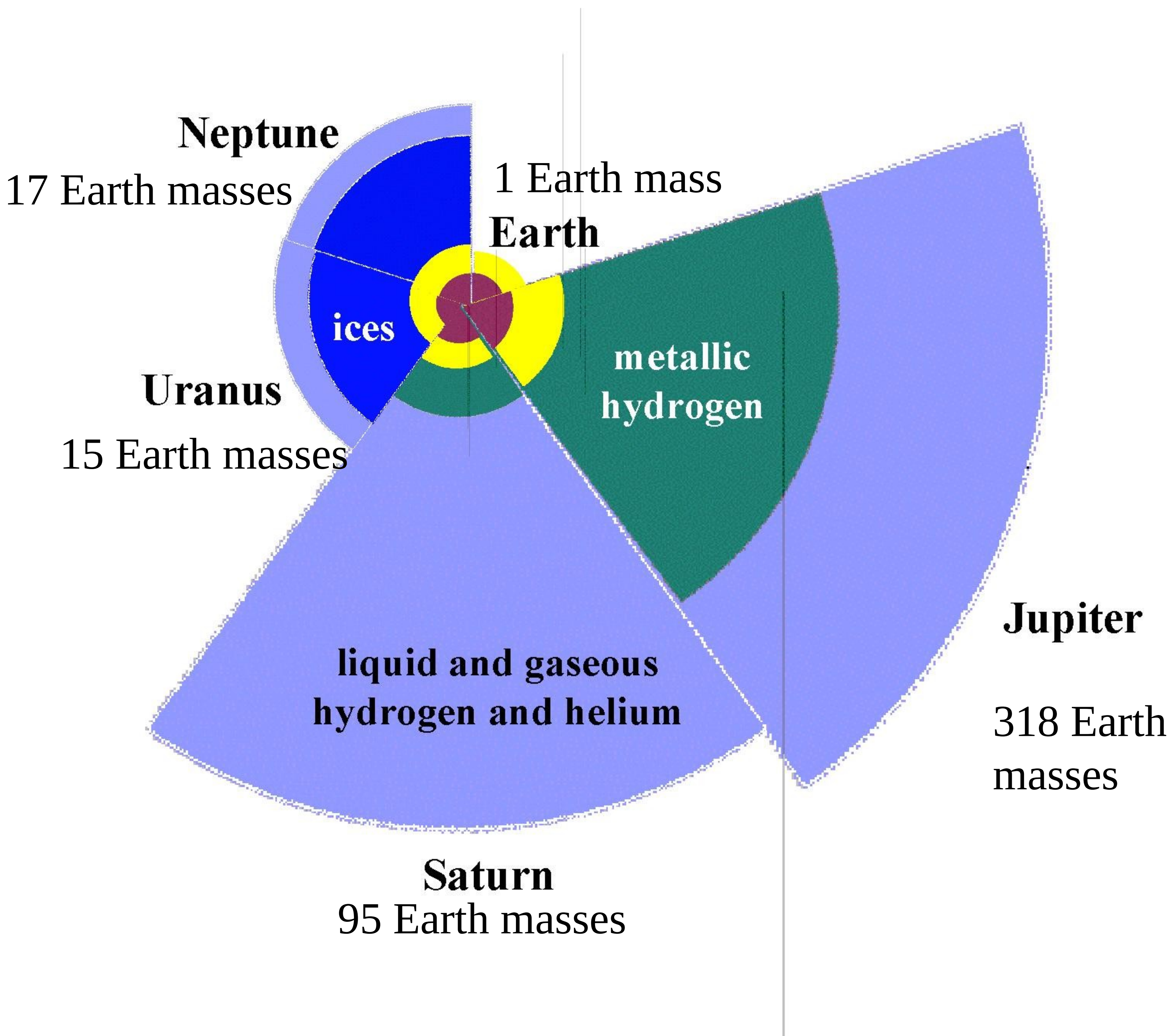
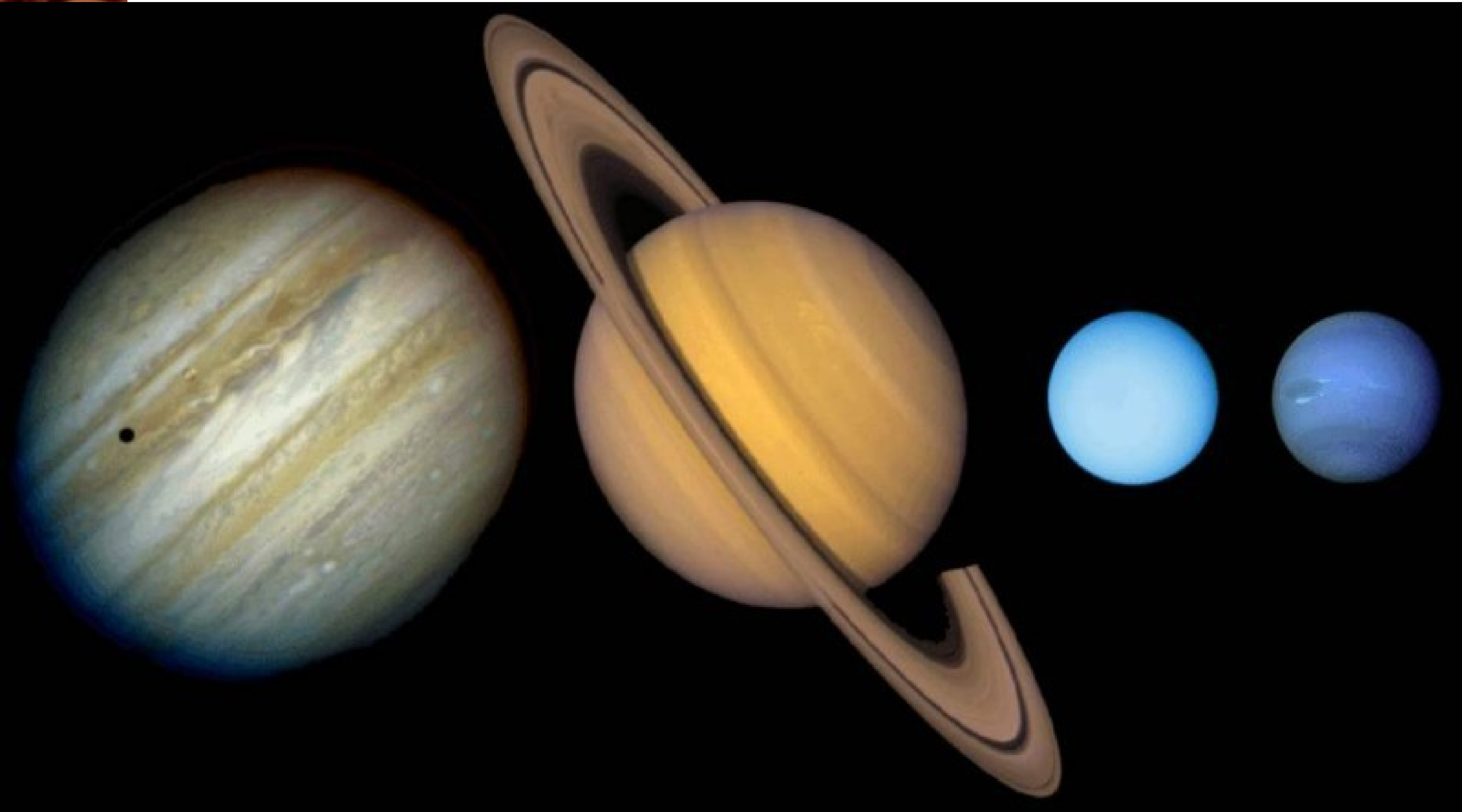
"When I die, I want to go peacefully like my Grandfather did, in his sleep--not screaming, like the passengers in his car."
coolfunnyquotes.com

Test 1 on Monday (Feb 26)
In class- bring a pencil- scantron

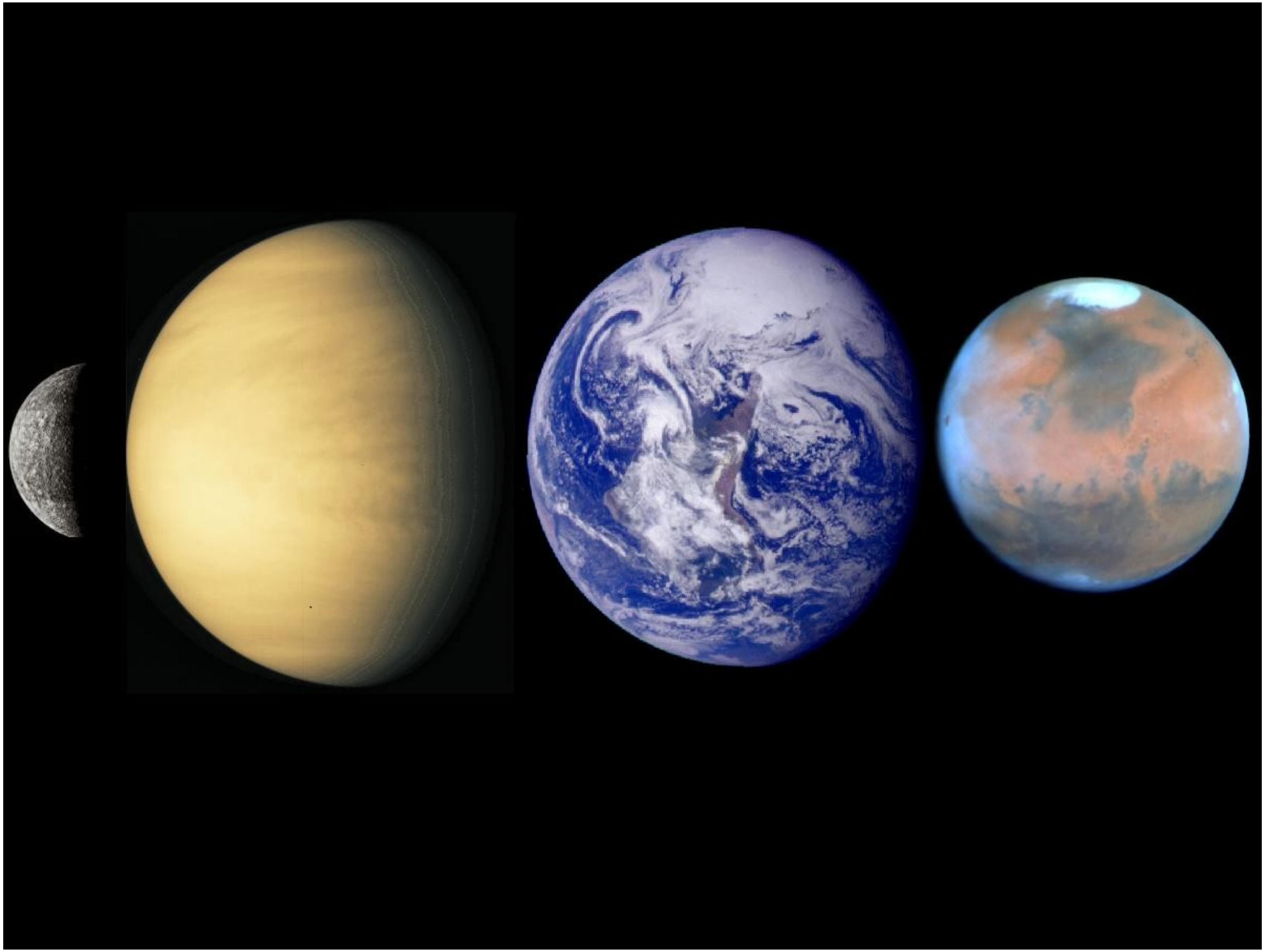

Neptune
17 Earth masses
1 Earth mass
Earth
ices
metallic hydrogen
Uranus
15 Earth masses
Jupiter
liquid and gaseous hydrogen and helium
318 Earth masses
Saturn
95 Earth masses

The Gas Giant Planets (Jovian and Neptunian).

What are their common features in contrast to the Terrestrial planets?

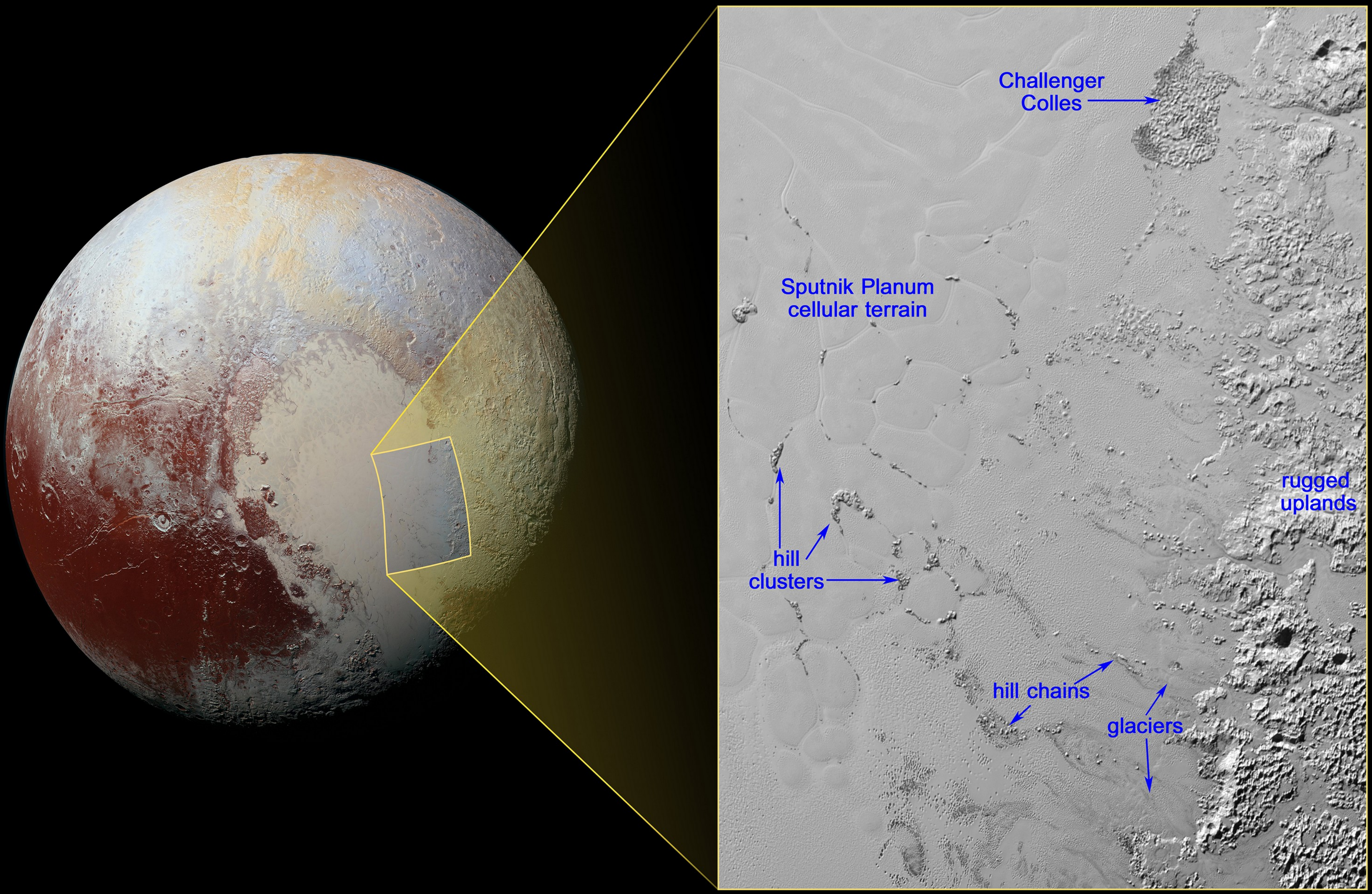


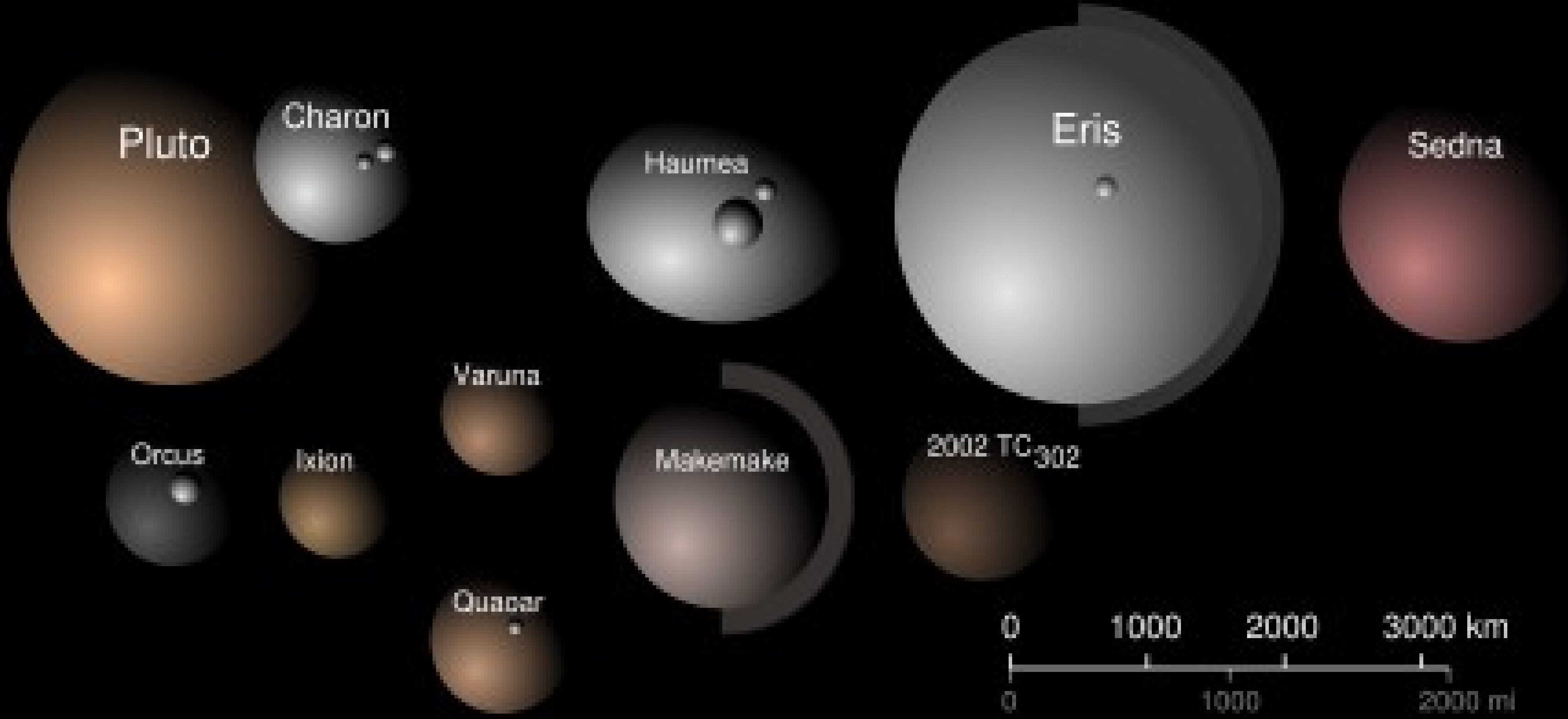
What are the common features of the Terrestrial planets in contrast to the Jovian ones?



Pluto and its moon Charon

Convective nitrogen ice.





Dwarf planets

Asteroids and comets

These are smaller objects in our solar system.

Important point: Asteroids indicate a transition from the inner solar system, which is rocky, to the outer solar system, which is colder, and therefore icy.

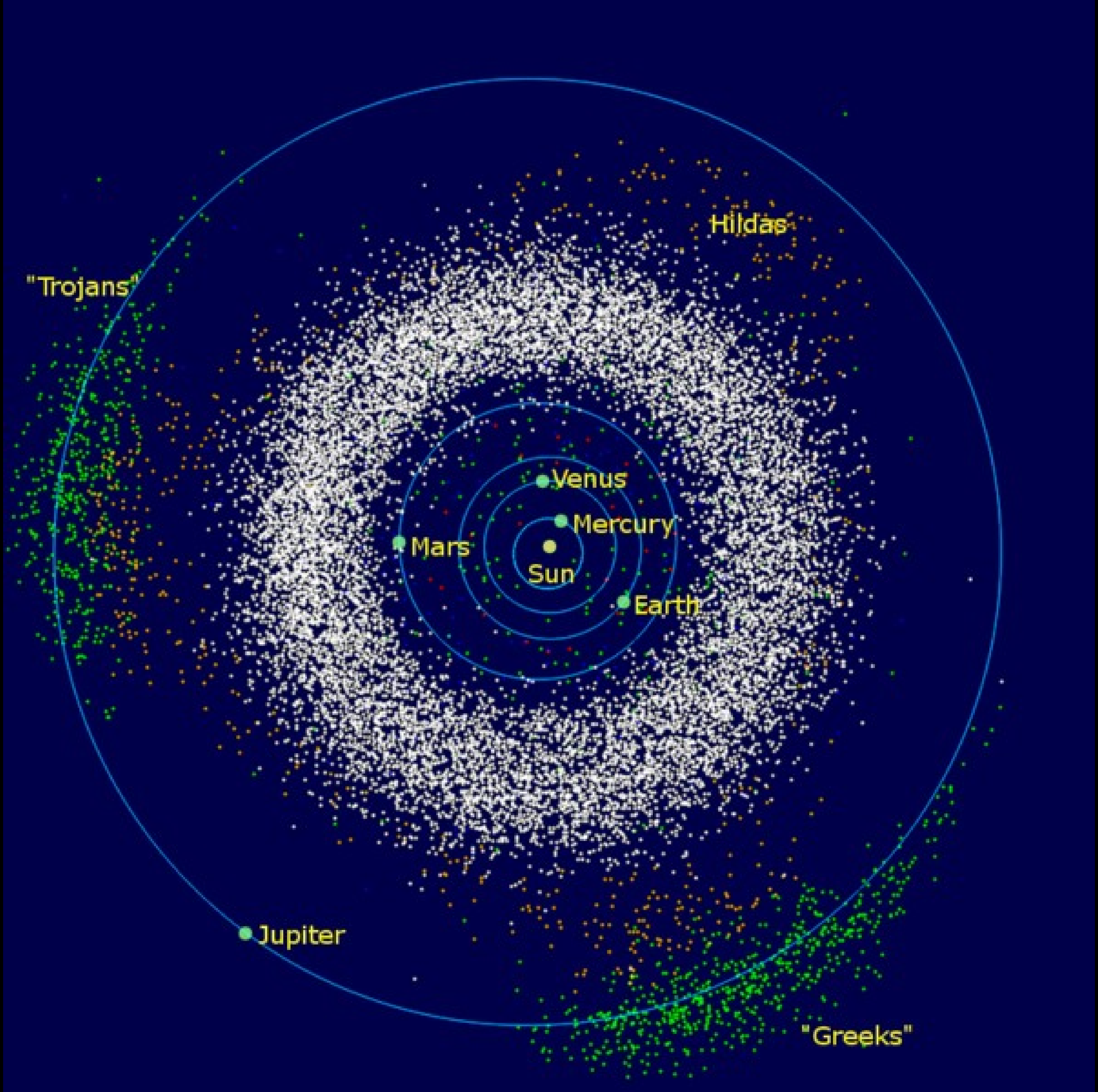
Asteroids and comets

Most asteroids are between Mars and Jupiter (2.1-3.4AU). There are
3 types:

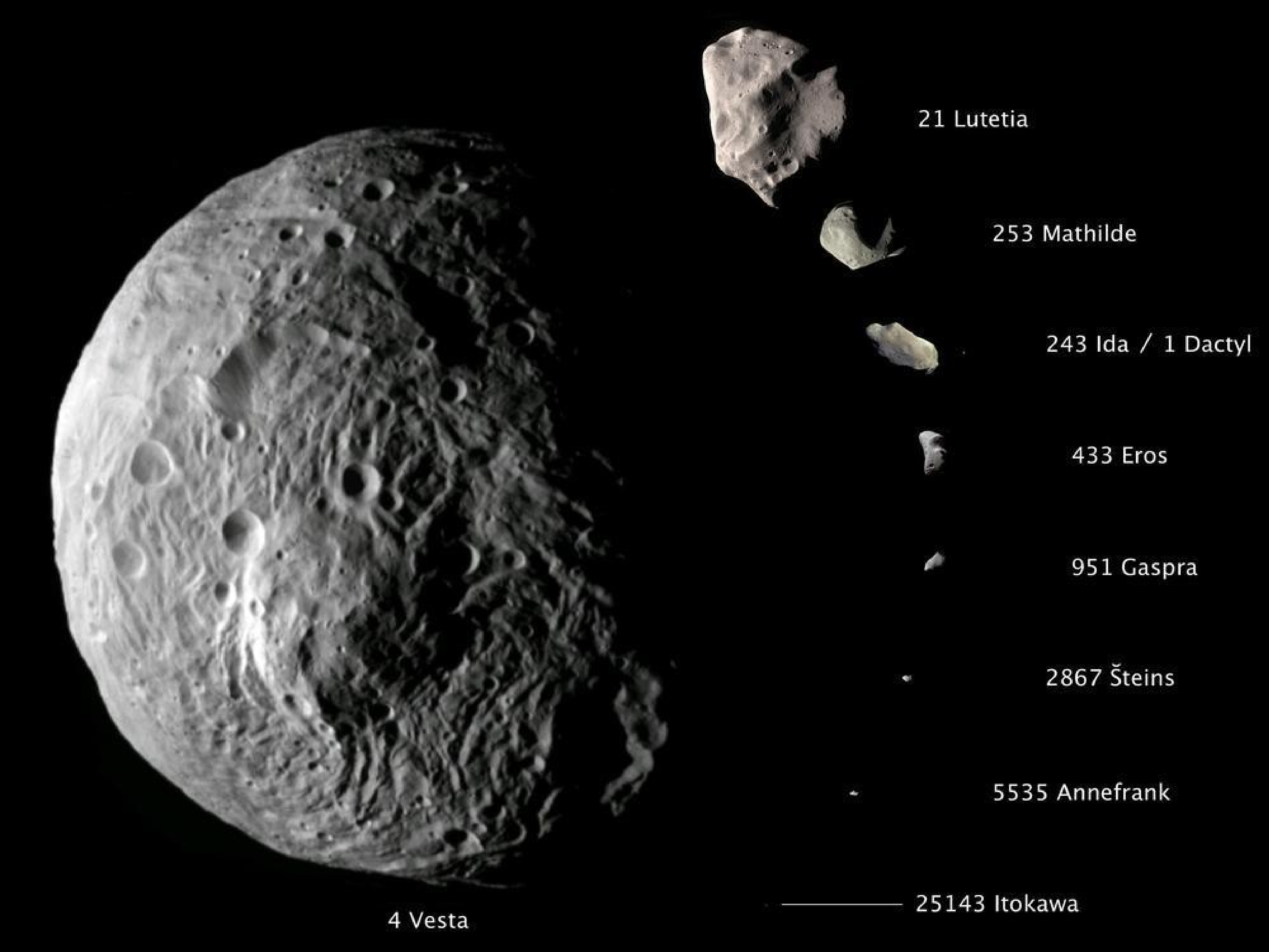
-At the inside of the asteroid belt (2.1AU-2.7AU) the asteroids are stony and metal-rich (like Earth rocks).

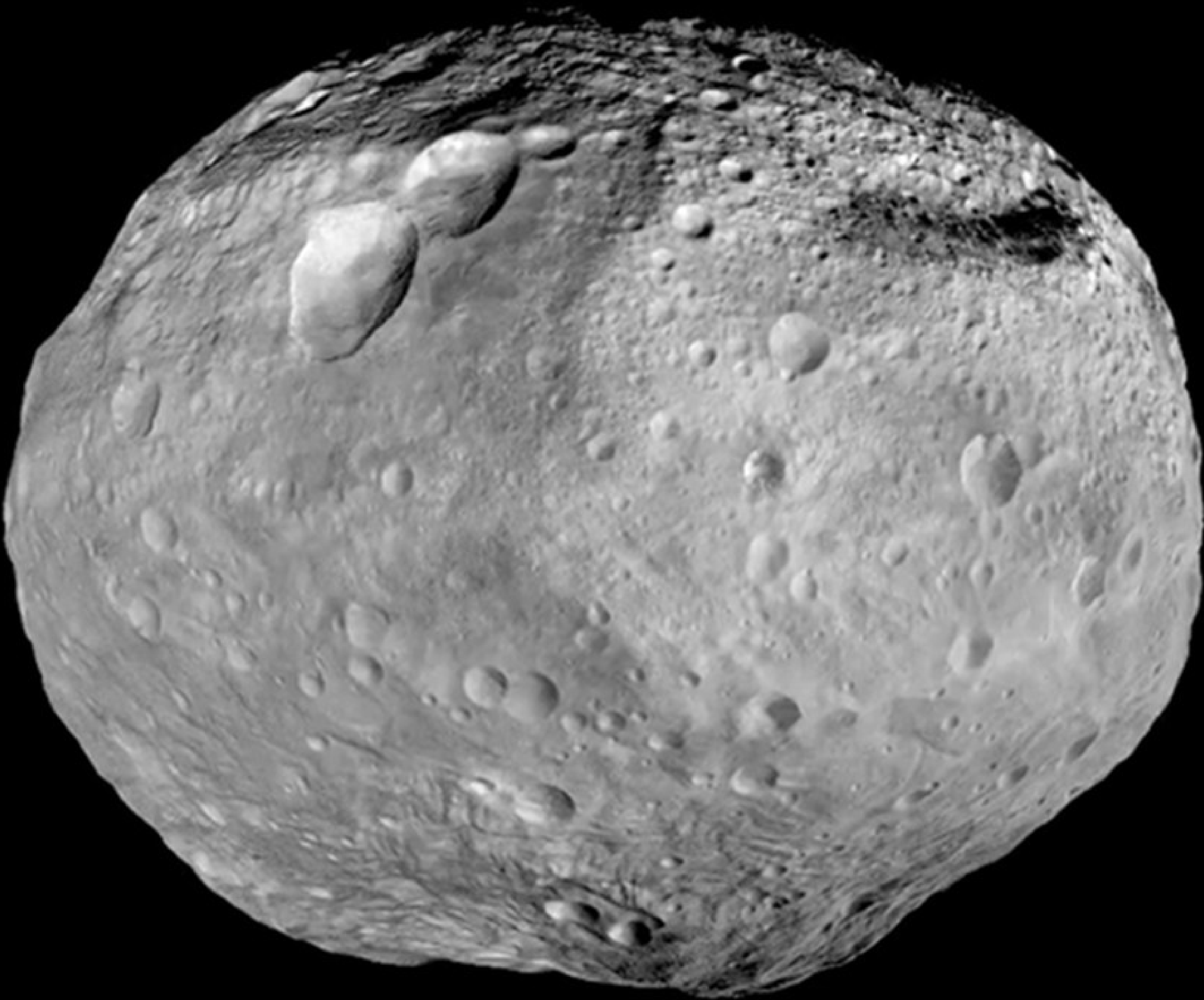
-Around 2.7AU, the asteroids become darker as they are carbon-rich.

-Past 3 AU, they become dirty snowballs. They are less dense than asteroids closer to the Sun.


Hildas
"Trojans"
Venus
Mercury
Mars
Sun
Earth
Jupiter
"Greeks"

Unlike as advertised in the movies, the asteroid belt is not a crowded place. We fly spacecraft right through it. However, over the course of billions of years, many collisions have occurred between asteroids.


21 Lutetia
253 Mathilde
243 Ida / 1 Dactyl
433 Eros
951 Gaspra
2867 Šteins
5535 Annefrank
25143 Itokawa
4 Vesta



Important point:

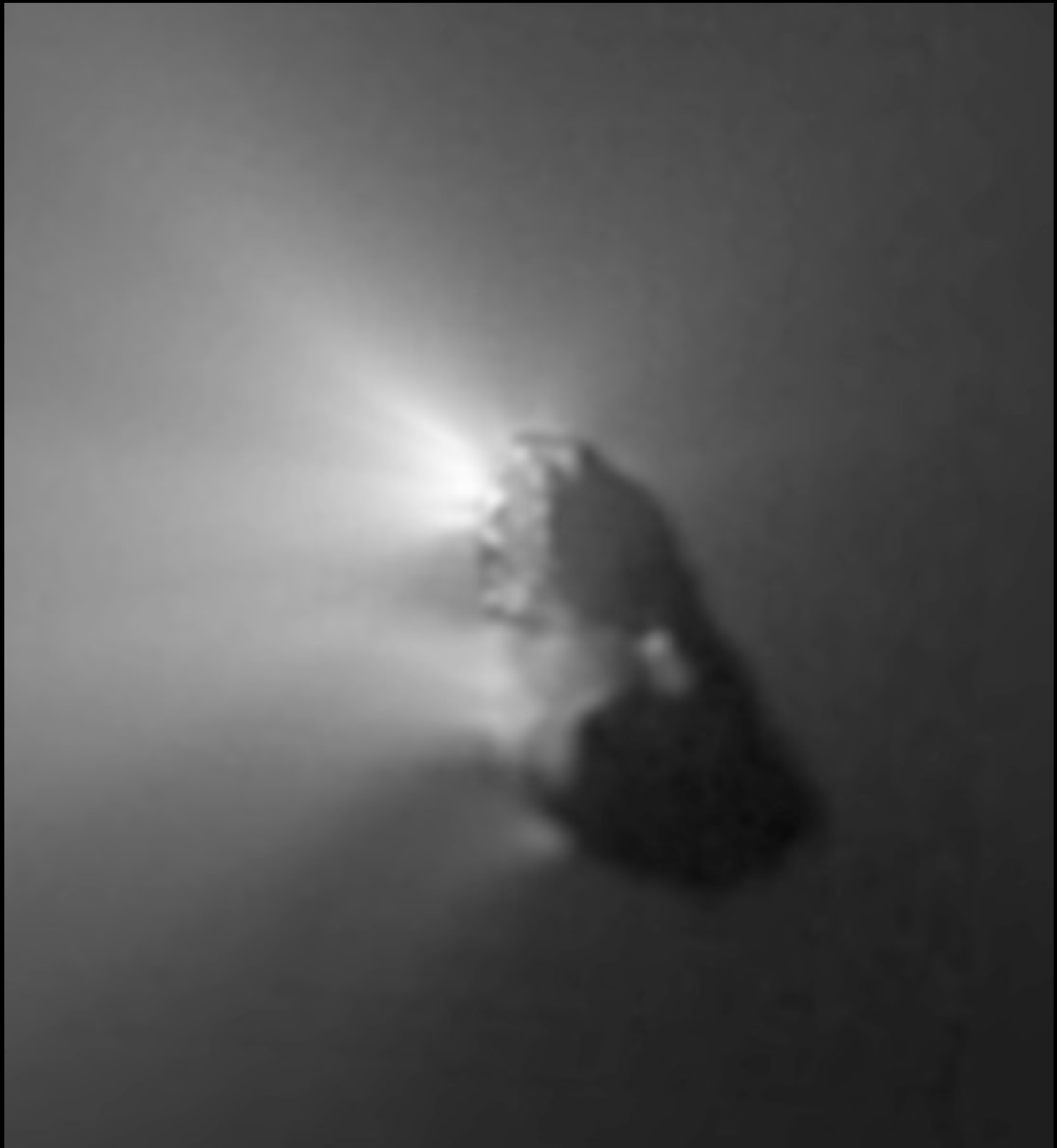
Comets provide the structure of the outer solar system beyond the planets.

The Kuiper belt and furthest is called the Oort Cloud

Comets

Comets are dirty snowballs in space. As they get close to the Sun (within about 3AU), the water/carbon dioxide/formaldehyde ice (known as volatiles) begins to evaporate.

A comet consists of 3 parts: nucleus, coma, and tail (2).



Nucleus is small 5-20 miles across usually. This is where all the material is.
As it heats up, "jets" of gas stream out.

Gas, dust and ice from the nucleus become the coma: perhaps 1 million km across.

Tails can extend for up to an AU!
2 kinds:
1) Ion tail of charged particles
2) Dust/gas tail.

2 varieties of comets:

1) Short period- 50-400 year orbits. From Kuiper belt. Orbit near ecliptic plane.

2) Long period- >500 years, but more typically thousands of years! From Oort cloud- 10,000 to 100,000 AU! Orbits from any angle

Important point:

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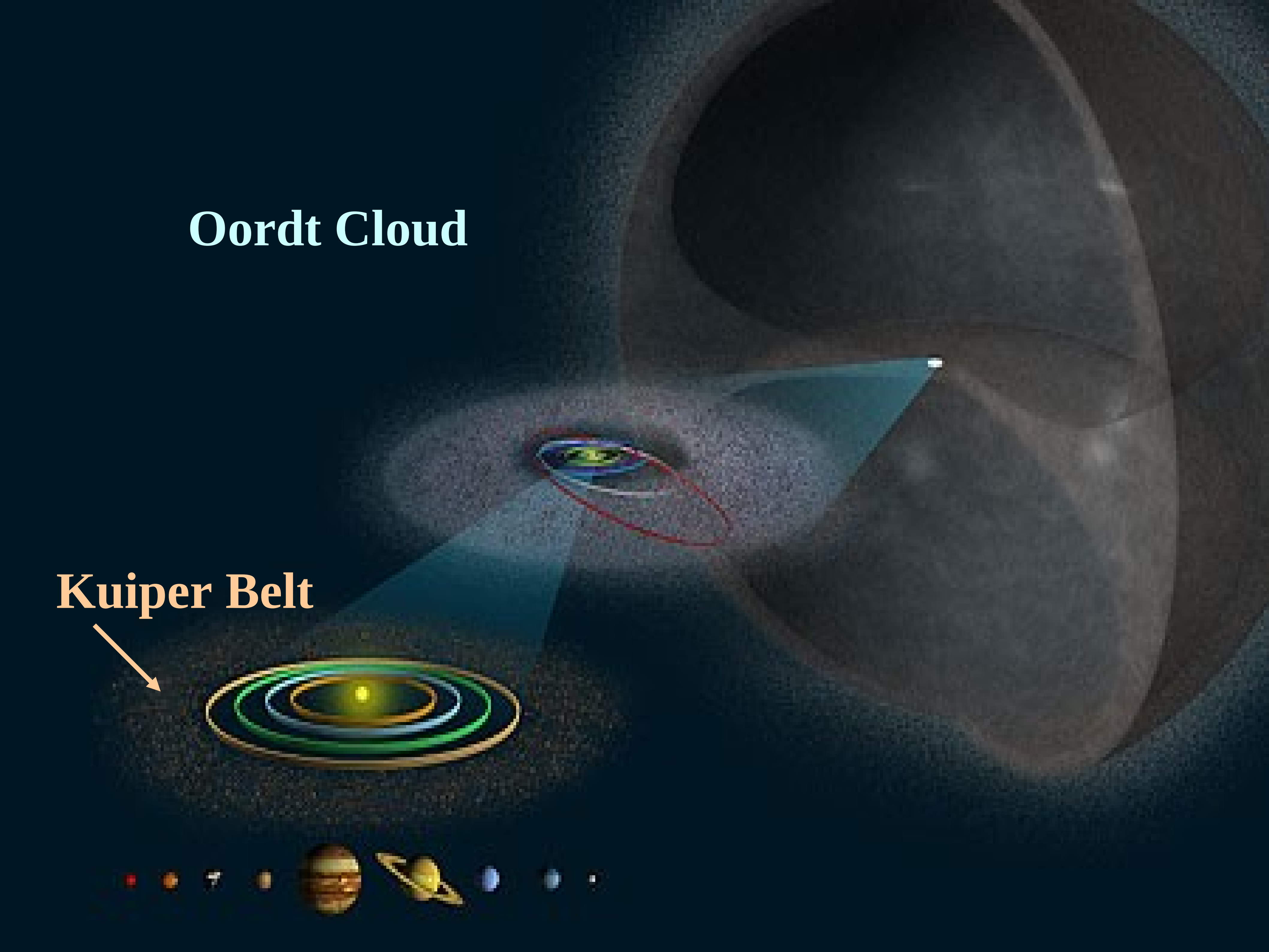
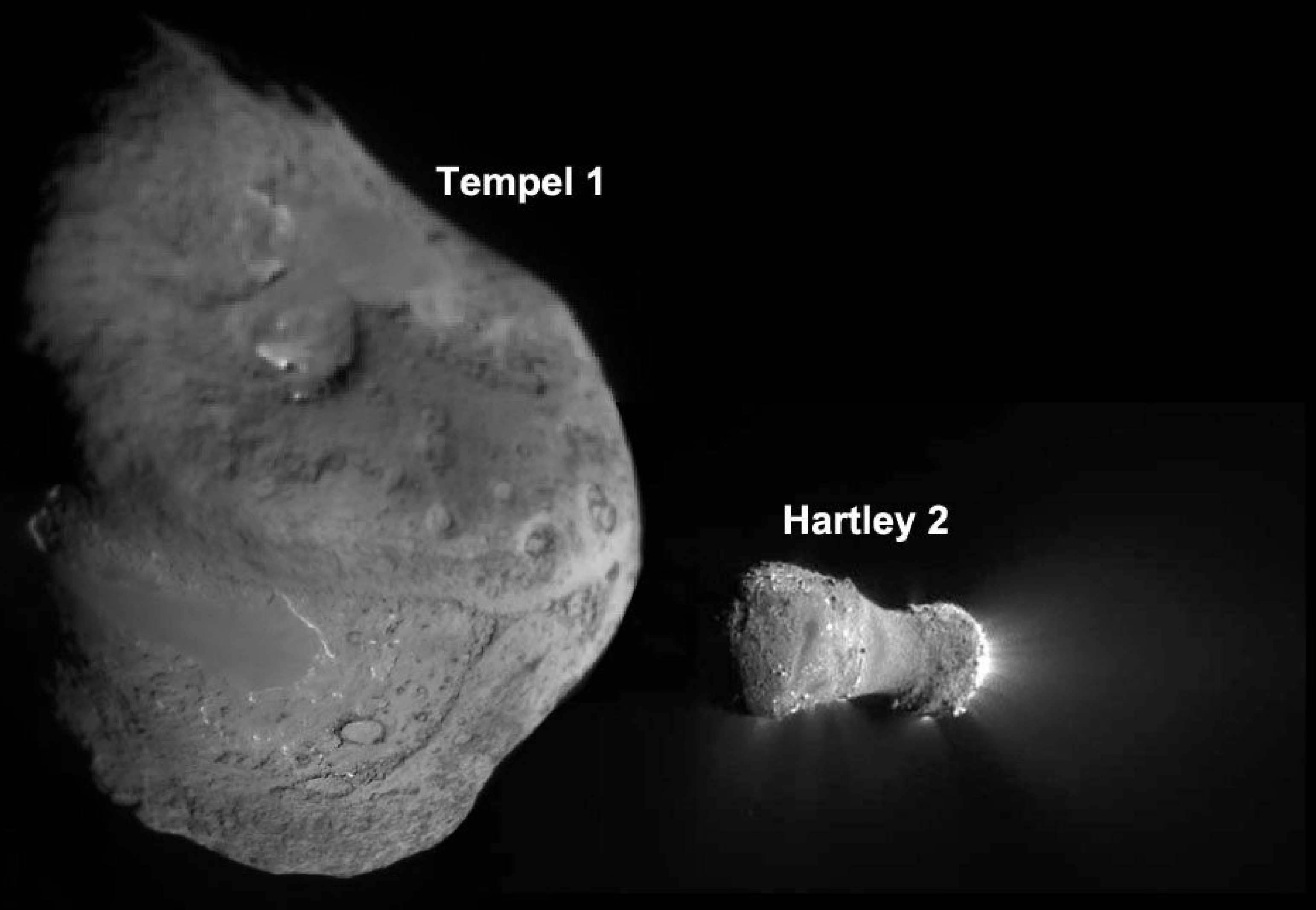

Oordt Cloud
Kuiper Belt

Tempel 1: 14x4x4km. Hartley 2: 2.2x0.6x0.4 km



Comet 67P/Churyumov-Gerasimenko

One last item to inventory: The Sun.

It spins prograde, is made mostly of H and then He, and contains 99.87% of the mass of our entire solar system!

Quiz 4: which moon is your favorite?

A) Ours
B) Io
C) Europa
D) Titan
E) Enceladus
F) Triton
G) other

Making our solar system

How did our solar system come to be?

We have to use observations as constraints.

What are the features of our solar system that help to describe how it came about?

Solar system observations:

- We want to explain how our solar system came to be.
- To do this, we need observations to constrain our ideas.
    - List 3 observations that are properties of our solar system.

Solar system observations:

- All planets orbit in the same direction and nearly on the same (ecliptic) plane.
- Nearly all planets and major moons spin (and orbit) in the same direction.
- Terrestrial planets are close to the Sun, Jovian planets are farther from the Sun.
- The asteroid belt goes from rocky to icy
- Short period comets orbit near the ecliptic plane, longer period comets orbit in any direction.
- Most massive object (Sun) at the center.

First, you need the raw material.

Giant molecular cloud.

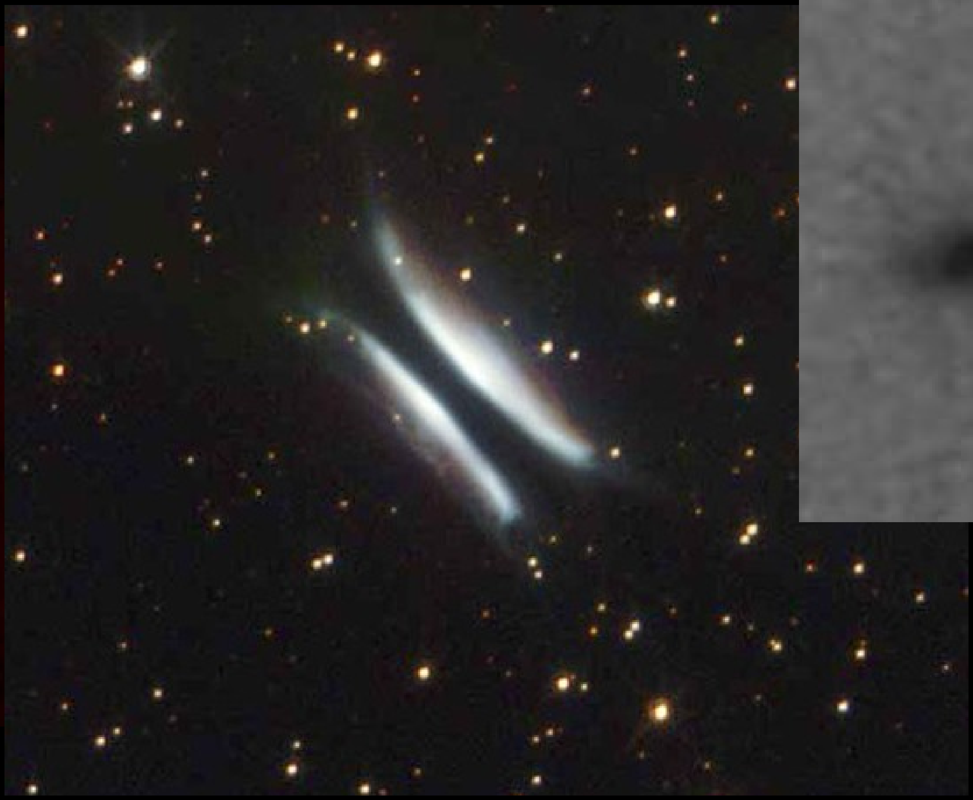
This is a region many million times the size of our solar system with many hundreds of times the mass of our solar system.


For various reasons, part of this cloud begins to collapse under its own weight.

How to make a solar system!

The spherical clouds that are collapsing to form our Sun flattens to a disk (the Universe loves pancakes!) within a few million years. The disk spins from angular moment given by the Galaxy.

The collapsing cloud heats up (from converting gravitational energy to heat!) more towards the center of the disk (which is more concentrated) than the outside (which can also cool easier). Spins too!



The collapsing cloud heats up (from converting gravitational energy to heat!) more towards the center of the disk (which is thinner) than the outside (which can also cool easier). Spins too!

As the nebula (disk) cools, elements like calcium, titanium and aluminum condense first, followed by iron, nickel, and silicates- the stuff we call rocks. But here they condense into tiny particles- like smoke or dust particles.

The collapsing cloud heats up (from converting gravitational energy to heat!) more towards the center of the disk (which is thinner) than the outside (which can also cool easier). Spins too!

As the nebula (disk) cools, elements like calcium, titanium and aluminum condense, followed by iron, nickel, and silicates- the stuff we call rocks.

These elements are cool enough to "stick" together when they meet. Forming dust up to 1cm in size.

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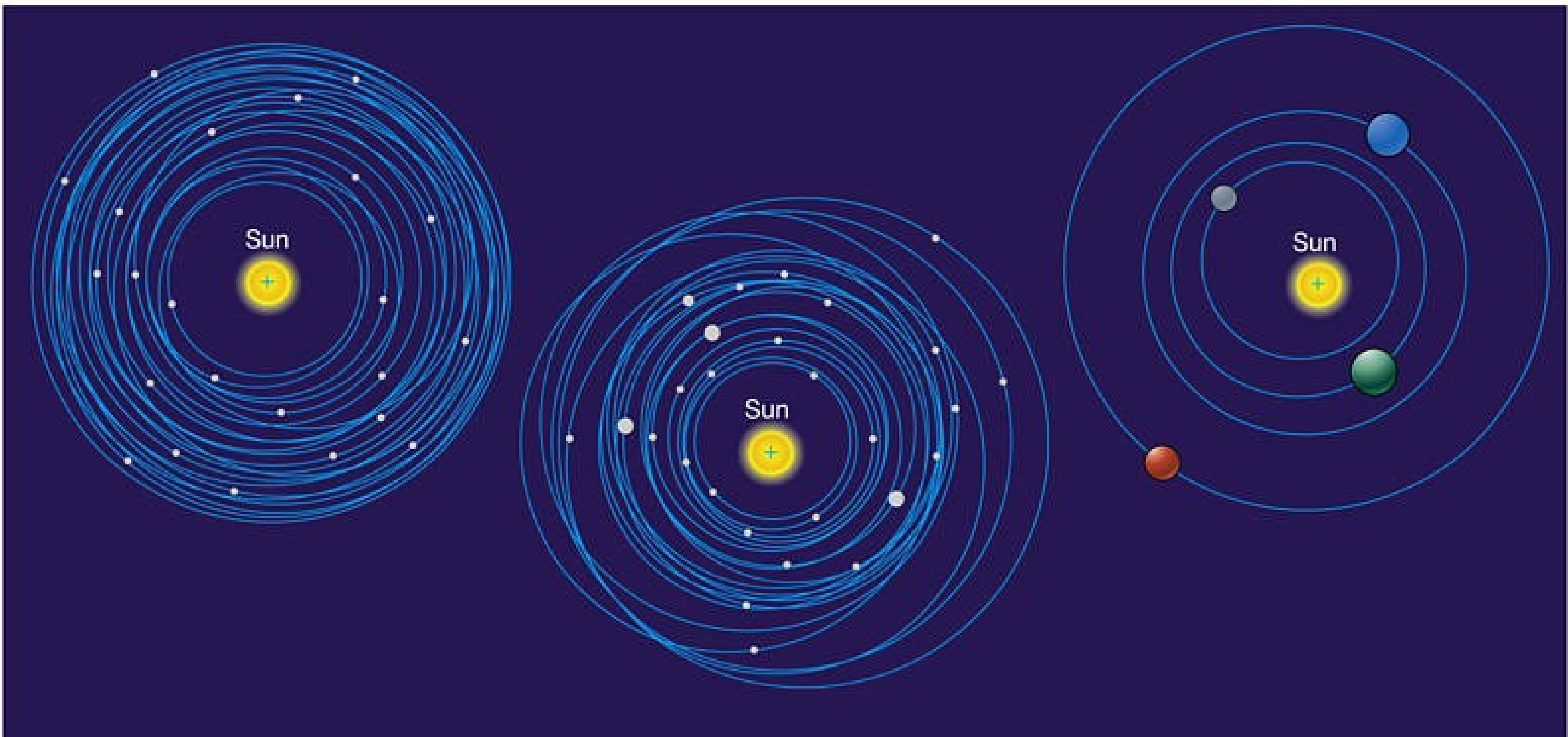
These dust particles begin to collide with each other, making rocks up to 1km in size.

Terrestrial Planets

At this point, we have to separate the Terrestrial planets from the Jovian planets.

The inner solar system remained too hot for ices to condense. The rocks were left to collide with each other. The biggest rocks began to methodically sweep up the smaller rocks in their orbital regions.

Eventually the largest rocks, now planets, solidified and the remaining small rocks (now asteroids) pelted the surfaces of the planets, further removing asteroids from the inner solar system.



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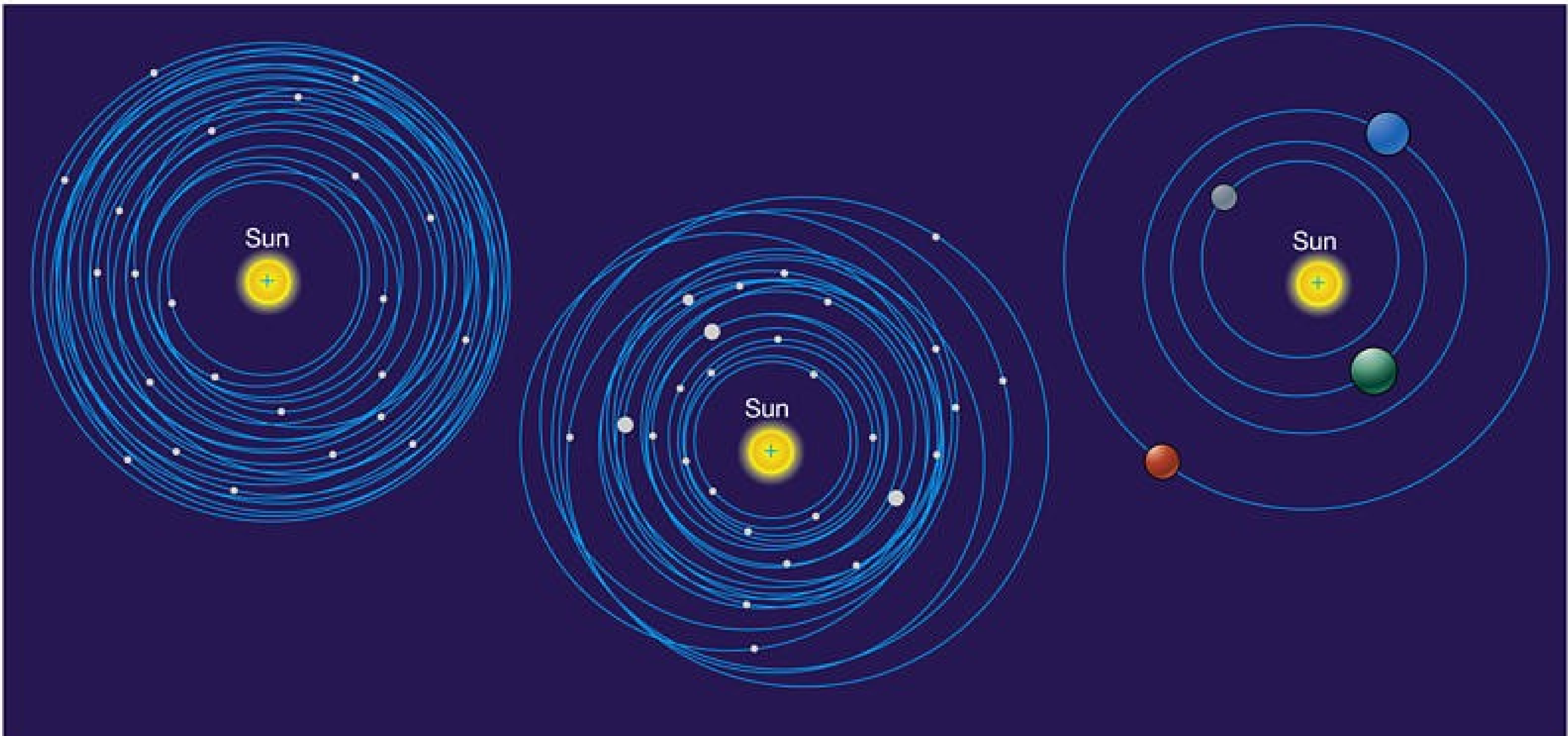
Finally, comets, flung inward from the outer solar system, enriched the water supply (also from volcanoes). Earth and Mars are cool enough to keep this water.

Terrestrial planets: pebbles → rocks → boulders → planetessimals → planets (NO ICE)



Jovian Planets

When we left off, km size rocks were floating amongst the gas and dust of the outer nebular (disk). It becomes cool enough for ice (water, ammonia) to form on the rocks and dust, condensing out of the nebula.

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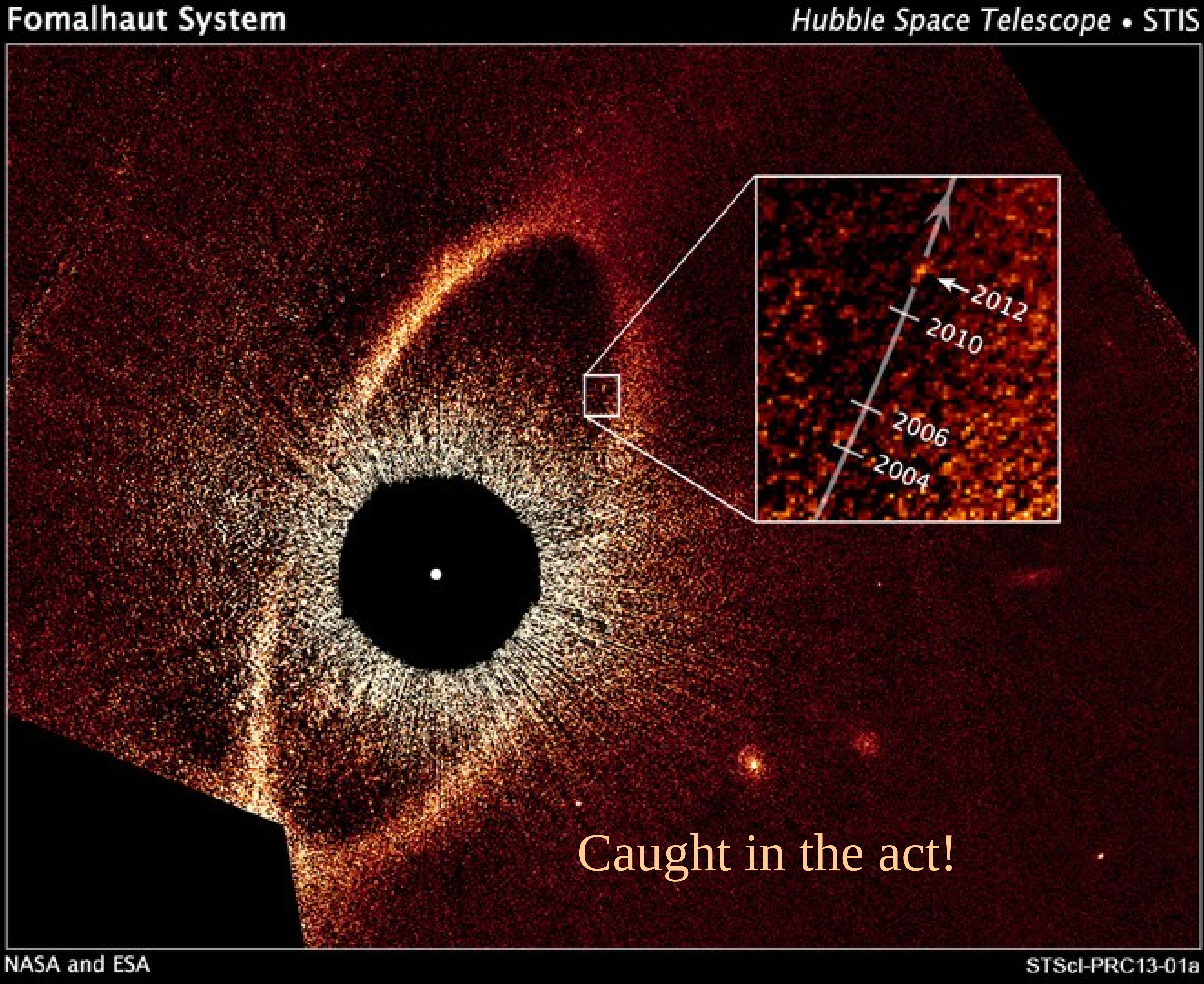
This drastically increases the size and amount of solid objects flying around. These solid bodies quickly collide, and sweep up other solid objects, becoming several times the mass of the Earth.

The largest objects now have enough gravity that gas in the nebula (disk) cannot escape and becomes bound to the planet. This creates huge, massive atmospheres.

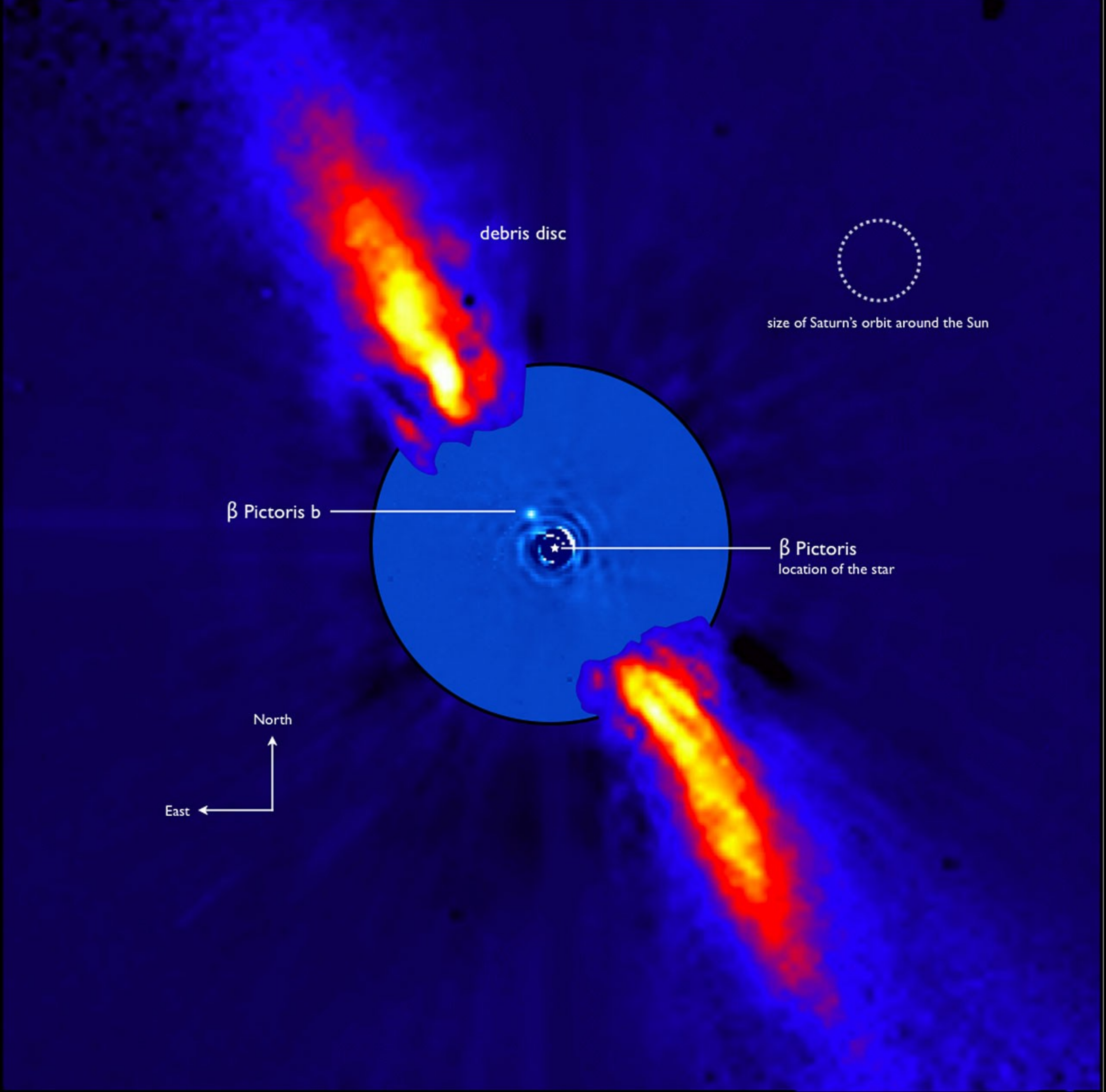
Gas giant Planets

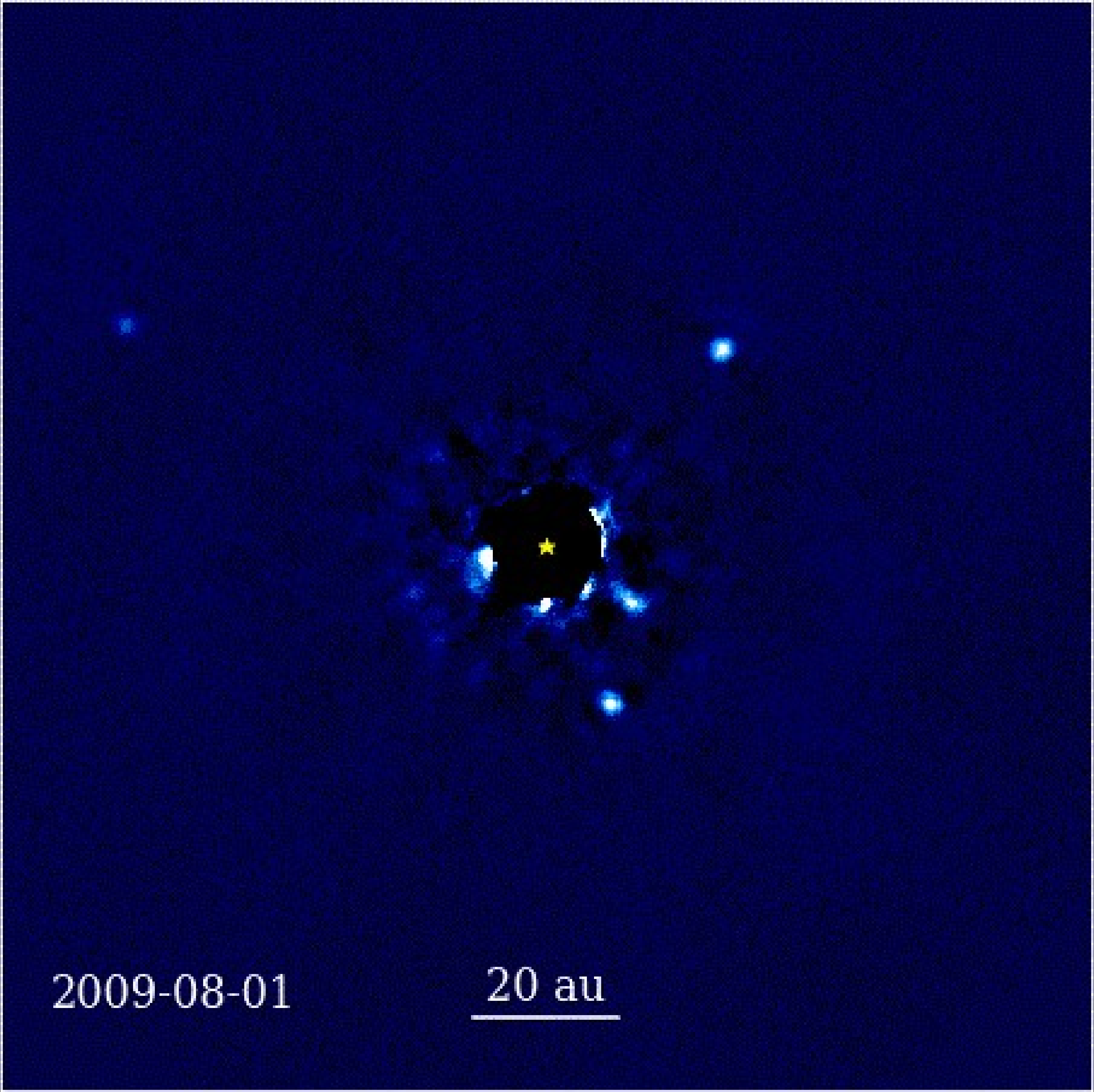
Pebbles → boulders → +ice → massive cores → +H → massive planets.

Option 2: A ‘swirl’ in the disk collapse altogether to form a gas giant planet in 1 step.



Caught in the act!

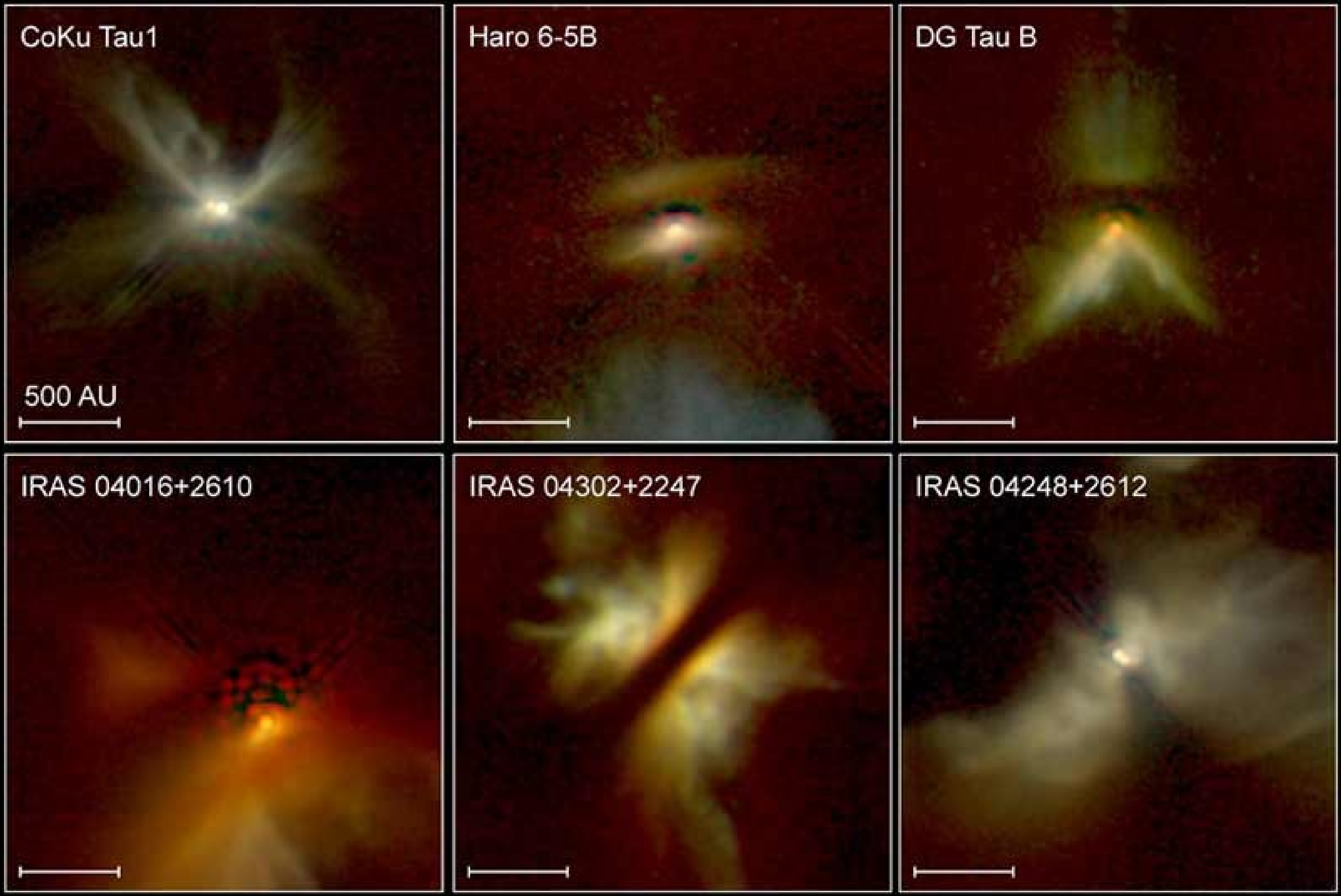

debris disc
size of Saturn's orbit around the Sun
β Pictoris b
β Pictoris
location of the star
North
East


2009-08-01
20 au

Meanwhile… in the Sun….

It has been slowly contracting and getting hotter.

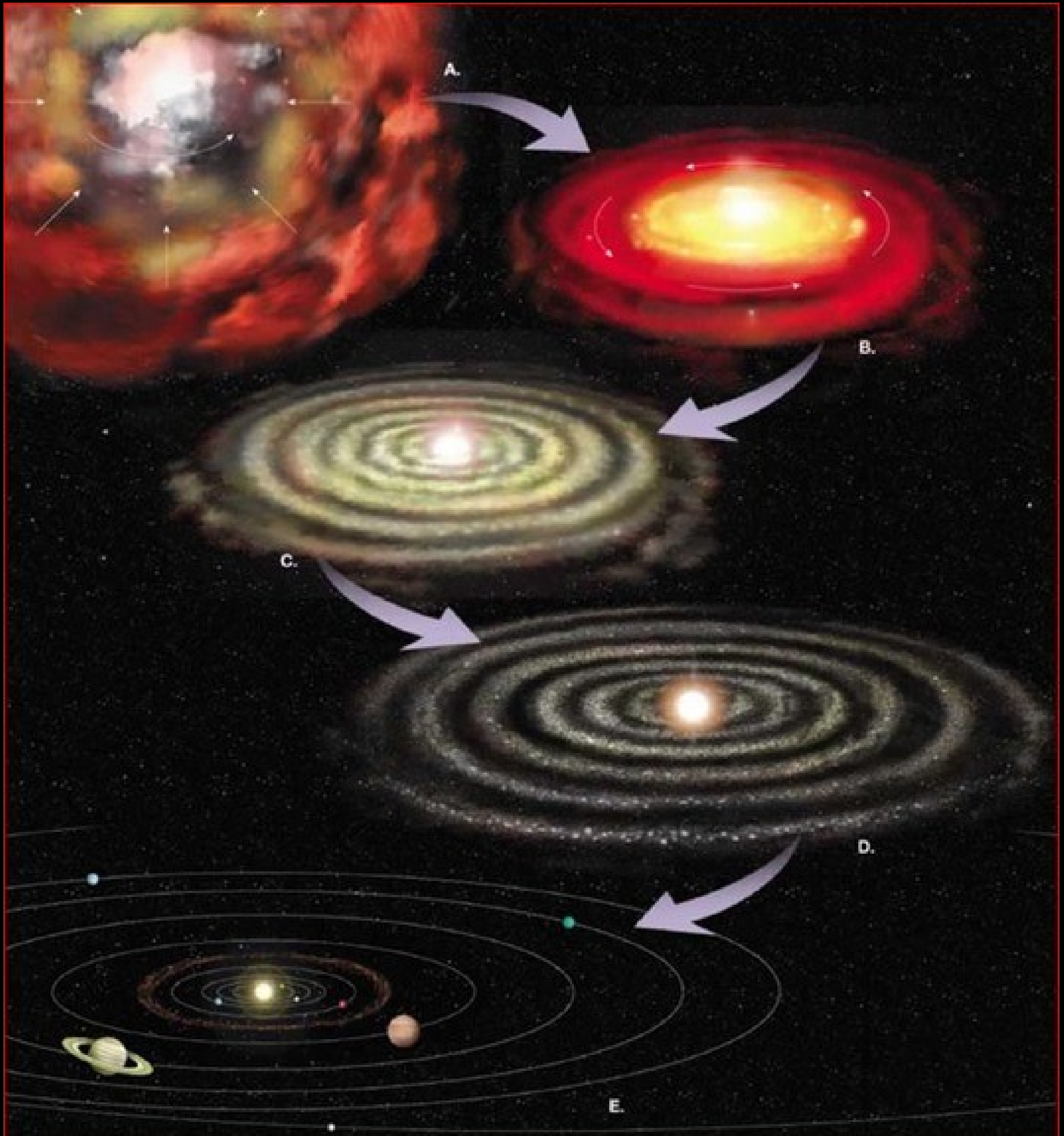
When the center reaches about 1 million Kelvin, nuclear fusion begins.

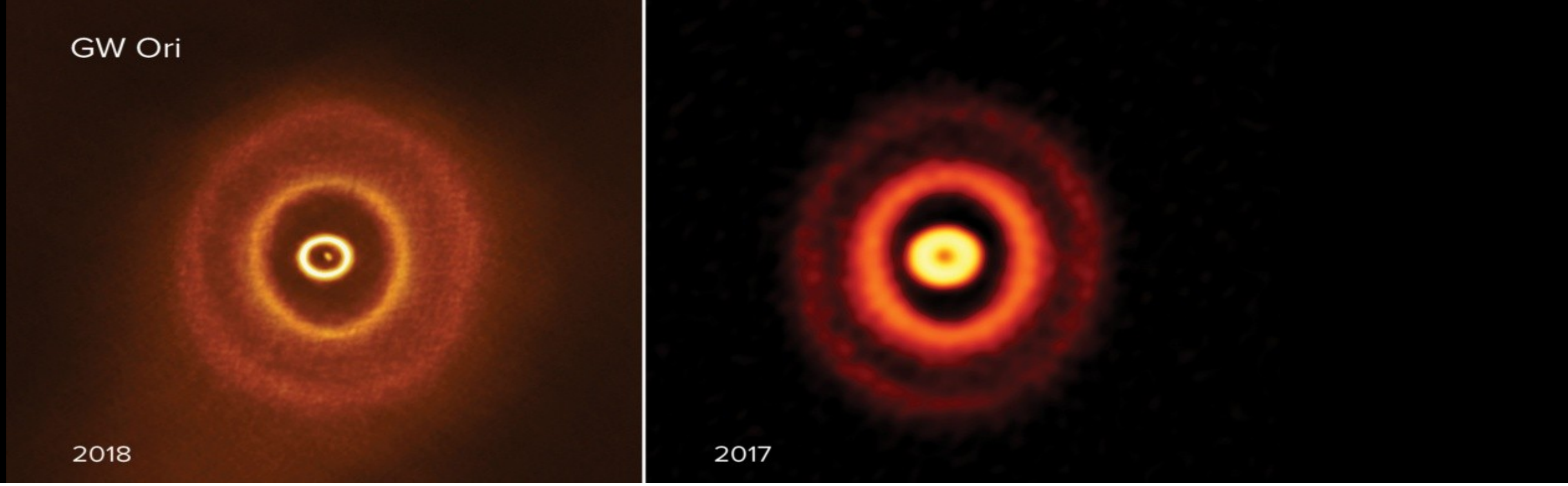

CoKu Tau1
500 AU
Haro 6-5B
DG Tau B
IRAS 04016+2610
IRAS 04302+2247
IRAS 04248+2612

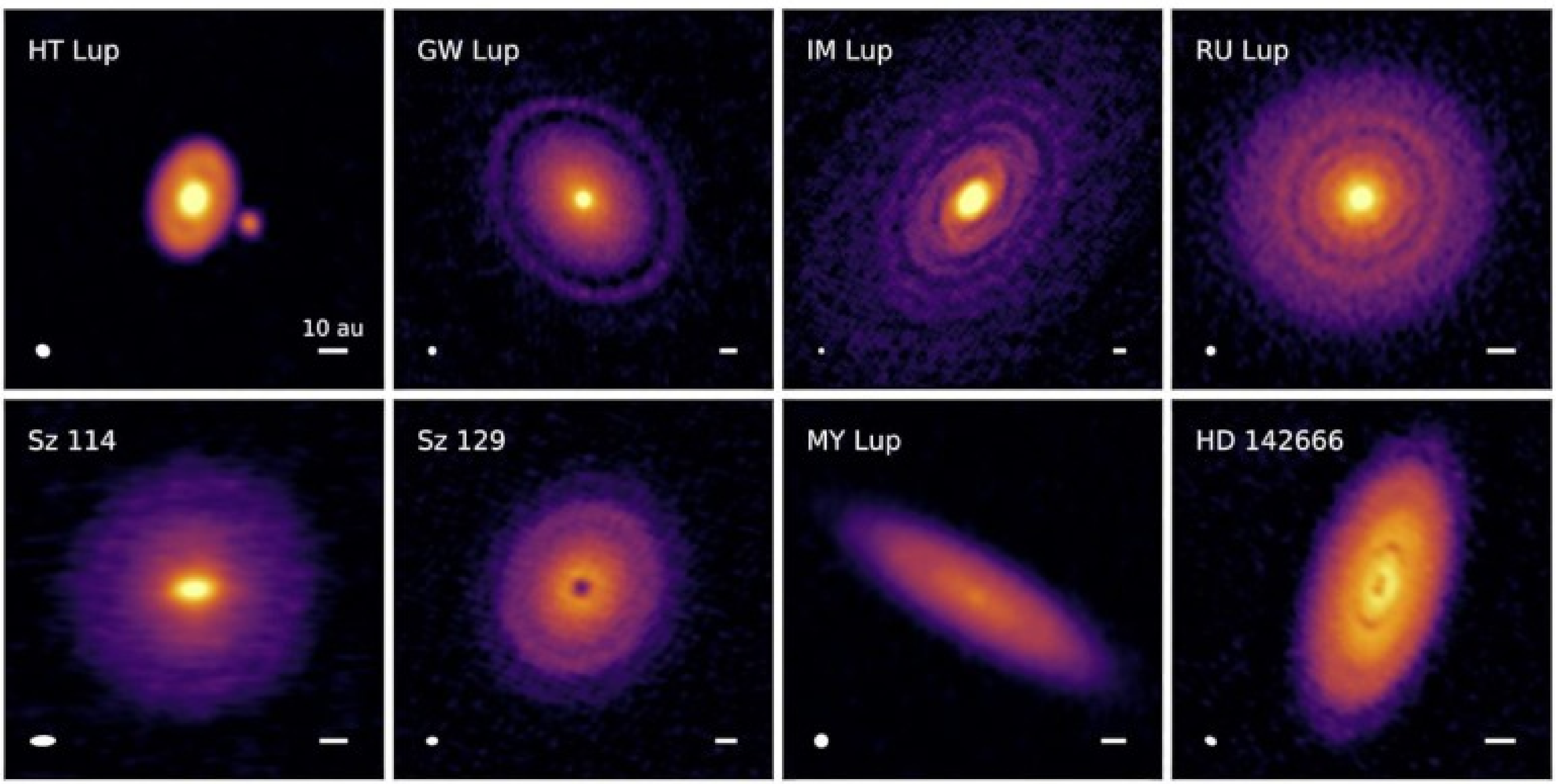
Clean up.

Once fusion in the Sun begins, any remaining gas gets blown away, back into the galaxy.

Over time, remaining asteroids, comets, and other bits gravitationally interact with larger bits- either being ejected or swallowed.


A.
B.
C.
D.
E.


GW Ori
2018
2017

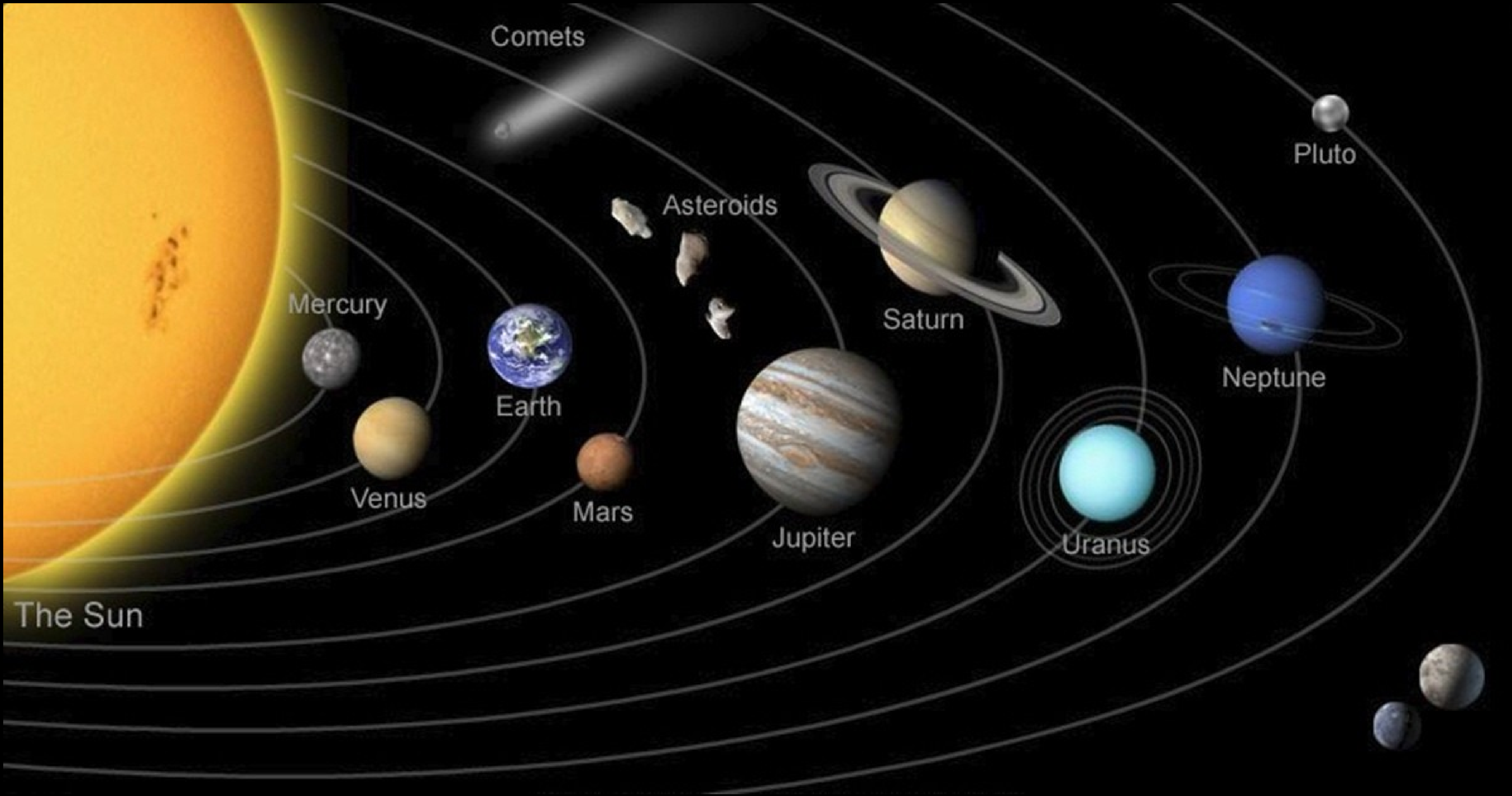

HT Lup
10 au
GW Lup
IM Lup
RU Lup
Sz 114
Sz 129
MY Lup
HD 142666

The entire solar system was forming together, at the same time.

It took roughly 50-100 million years in total.

The solar system is now 4,600 million years old.

Our very ordered solar system.



Terrestrial planets form close to stars, where it is warm.
Gas giants must form past the ice line, to gain sufficient mass to hold H.