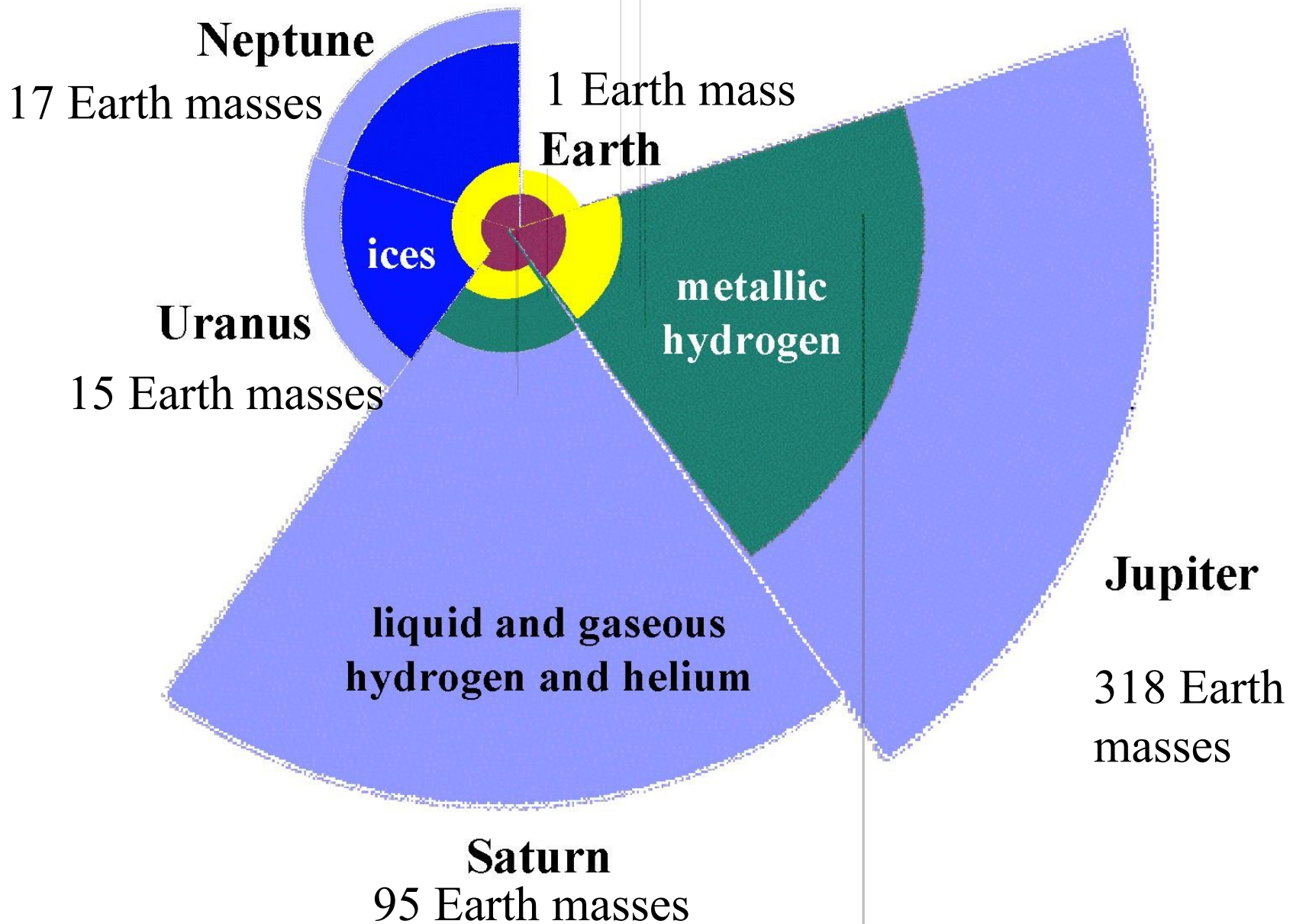


“When I die, I want to go peacefully like my Grandfather did, in his sleep-- not screaming, like the passengers in his car.”

coolfunnyquotes.com

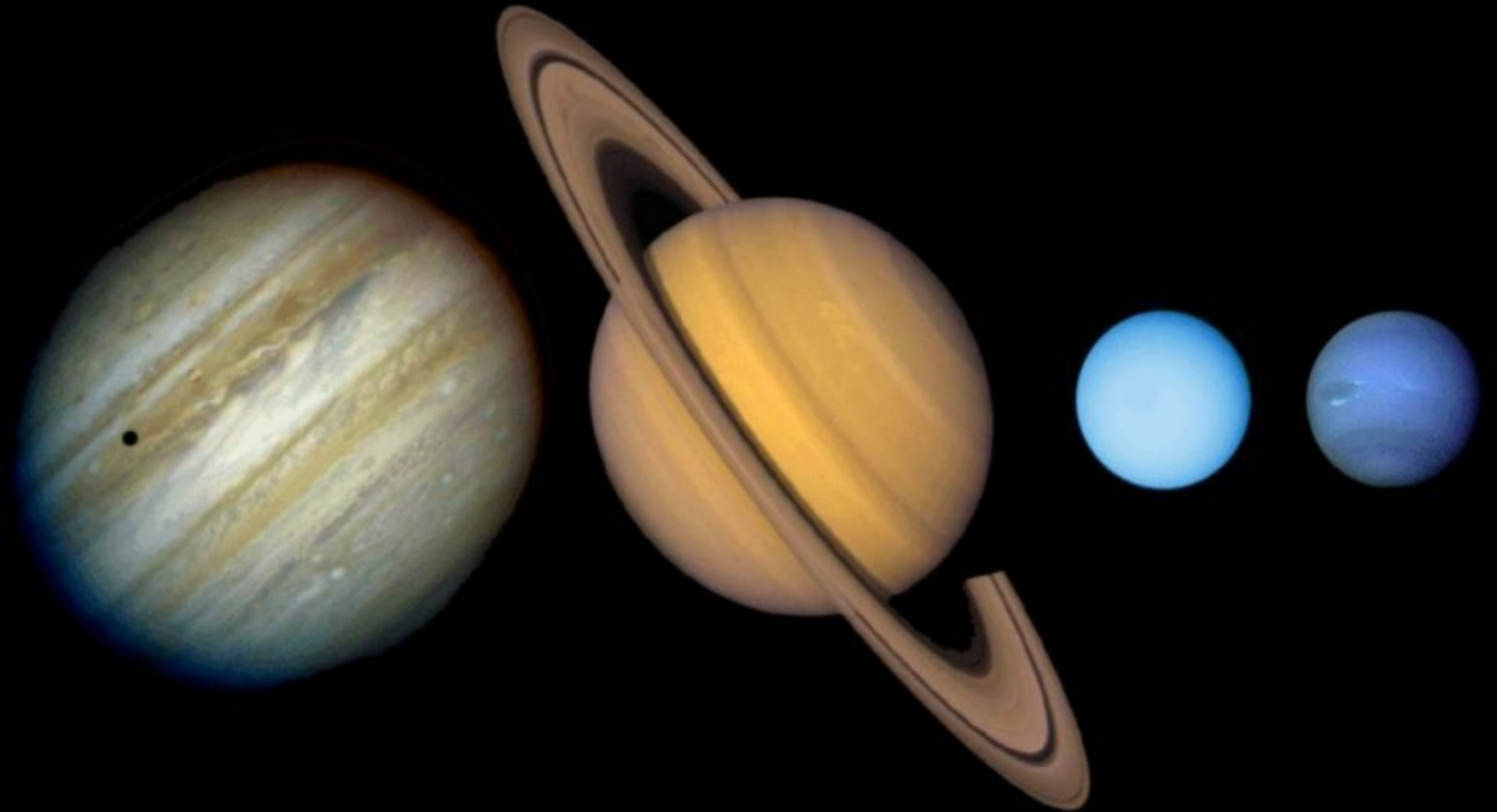
Test 1 on Monday (Sept. 30)

HW2 passed back on Friday and solutions posted, so no late work after that.

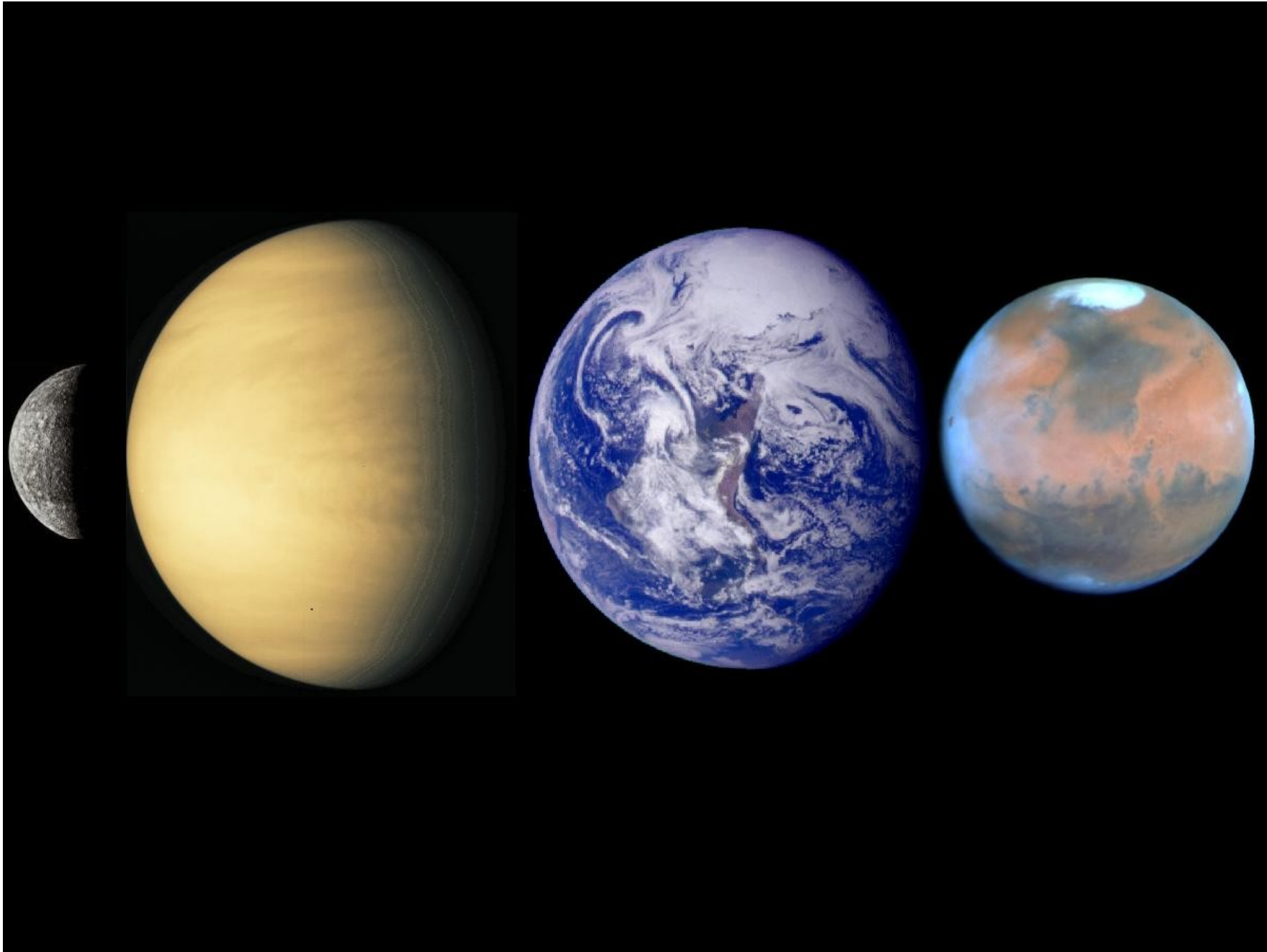


The Gas Giant Planets (Jovian and Neptunian).

Common features: more massive, no solid surfaces, rings, many moons, density \sim 1g/cc.

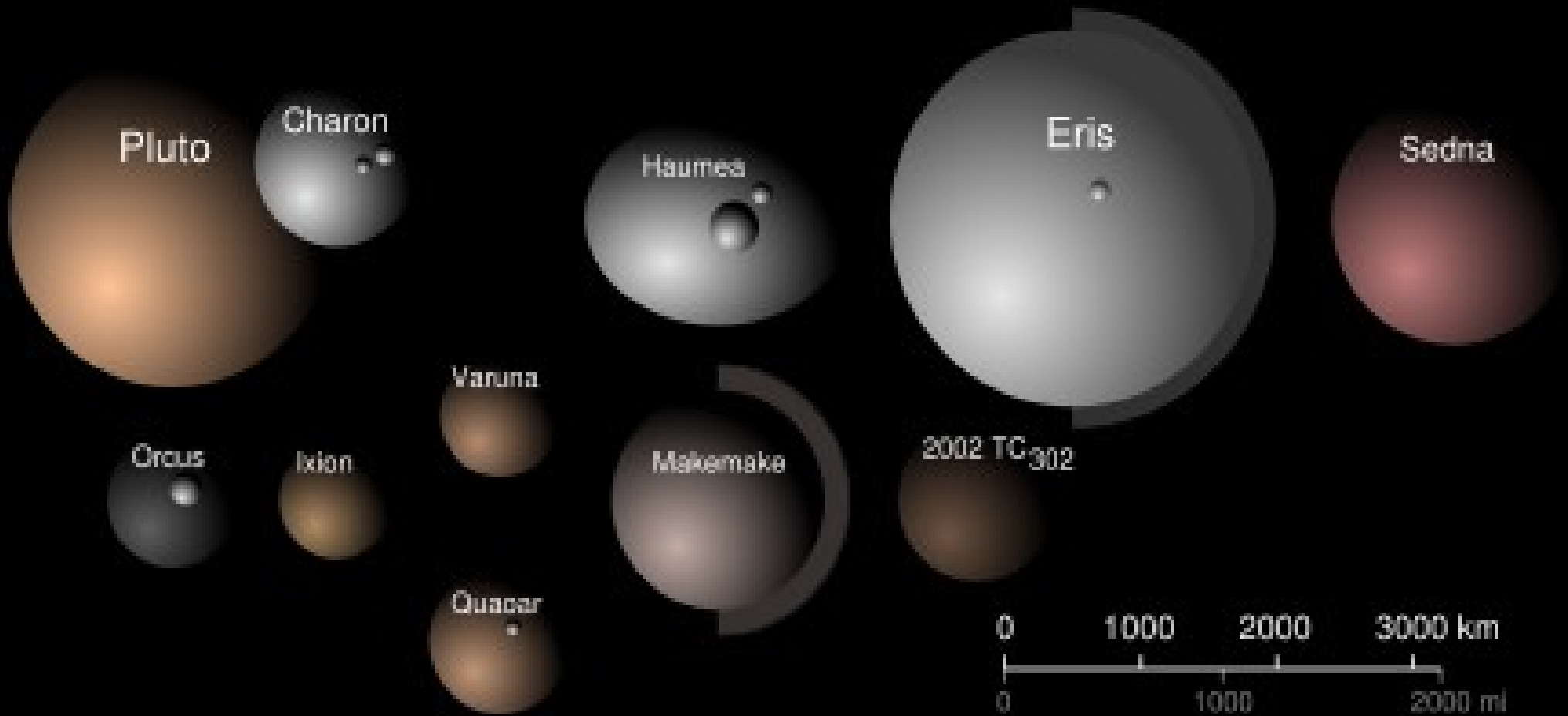


Terrestrial planets: **Common features:** rocky, few moon, no rings, closer to the Sun, density $\sim 5\text{g/cc}$



Pluto and its moon Charon





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**.

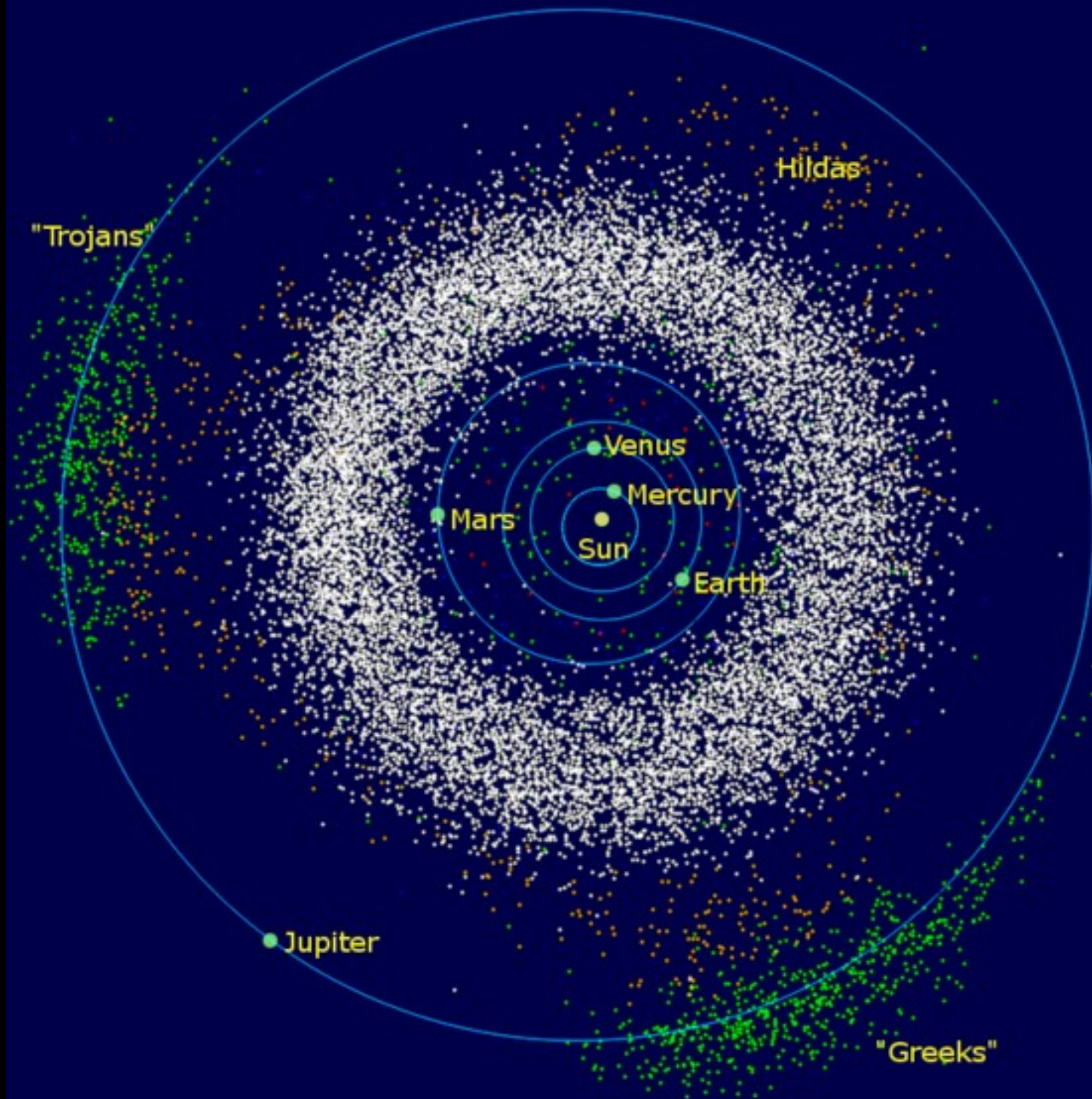
Asteroids and comets

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.



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.





4 Vesta



21 Lutetia



253 Mathilde



243 Ida / 1 Dactyl



433 Eros



951 Gaspra



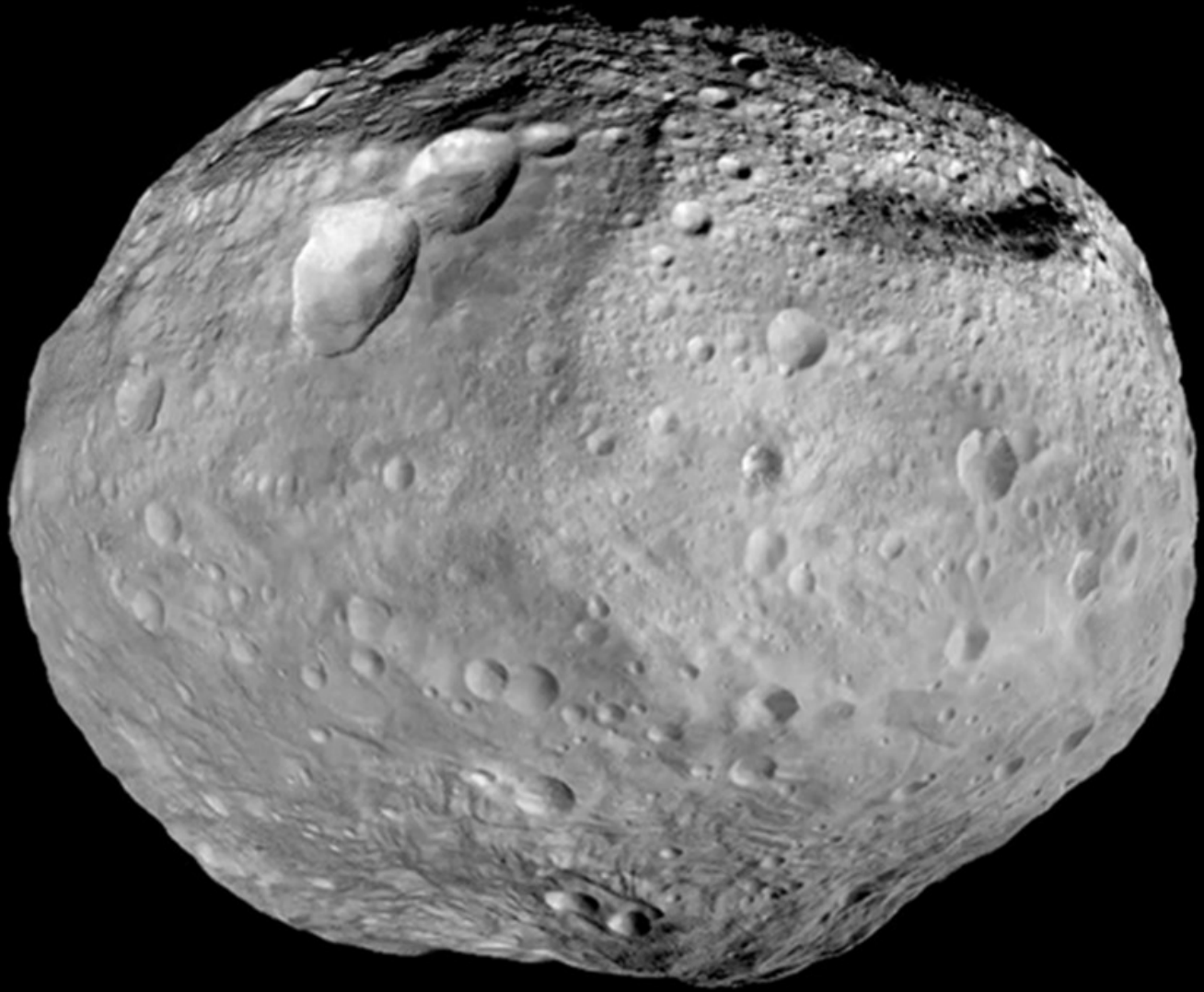
2867 Šteins



5535 Annefrank



25143 Itokawa



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.



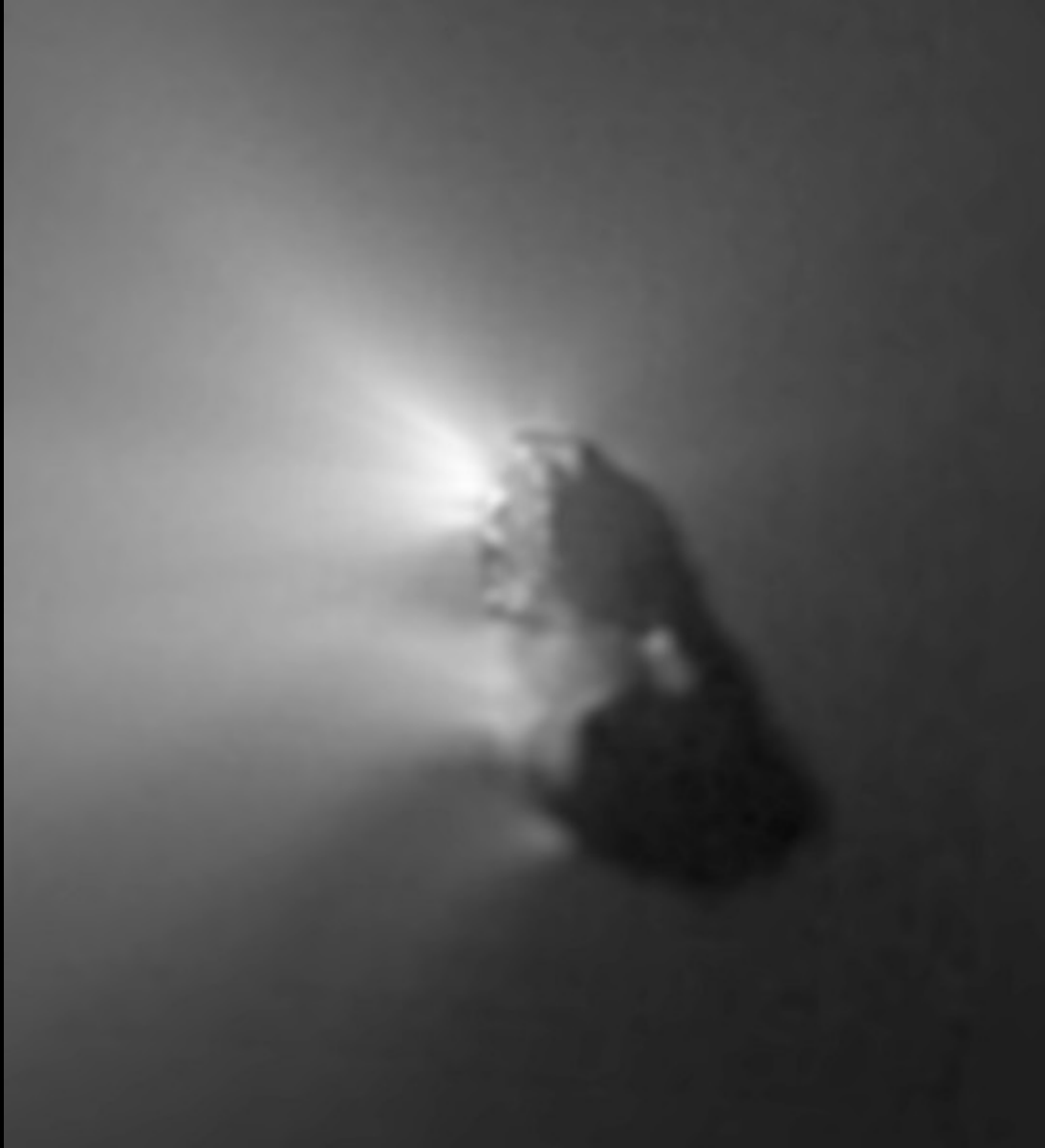
Important point:

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

The Kuiper belt and furthest is called the Oort Cloud



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- 50-200 year orbits. From Kuiper belt. Orbit near ecliptic plane.

2) Long period- >200 years, but more typically thousands of years! From Oort cloud- 10,000 to 100,000 AU! Orbits from any angle



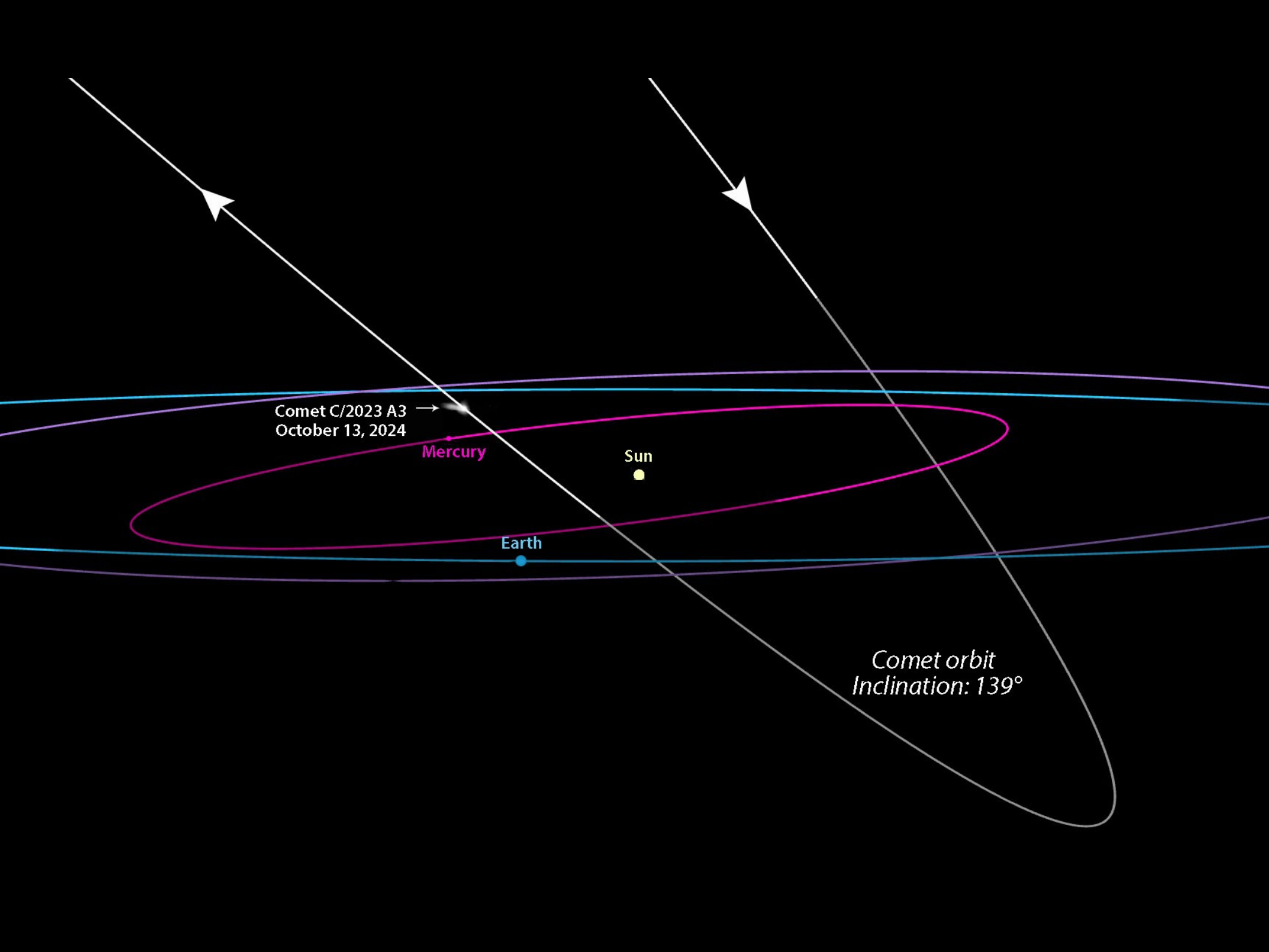
Comet C/2023 A3 (Tsuchinshan-ATLAS) is in the constellation of **Sextans**, at a distance of 150,038,727.3 kilometers from Earth. The current Right Ascension is 10h 41m 52s and the Declination is -06° 14' 45" (apparent coordinates). The latest observed magnitude of Comet C/2023 A3 (Tsuchinshan-ATLAS) is 3.1 (data provided by COBS).



theskylive.com

Map showing Comet C/2023 A3 (Tsuchinshan-ATLAS) in **Sextans** on September, 25 2024. Field of view: 50x30 degrees
[View interactive star map](#)

Comet C/2023 Tsuchinshan-ATLAS is visible now and getting better until mid-October.
Its orbital period is >80,000 years



Important point:

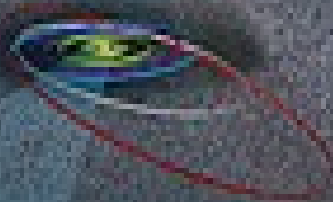
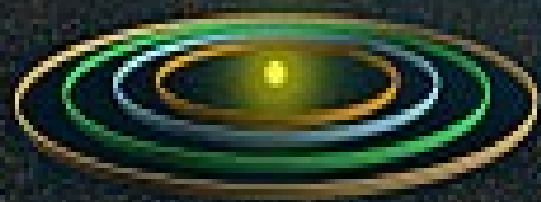
Comets provide the structure of the outer solar system beyond the planets.

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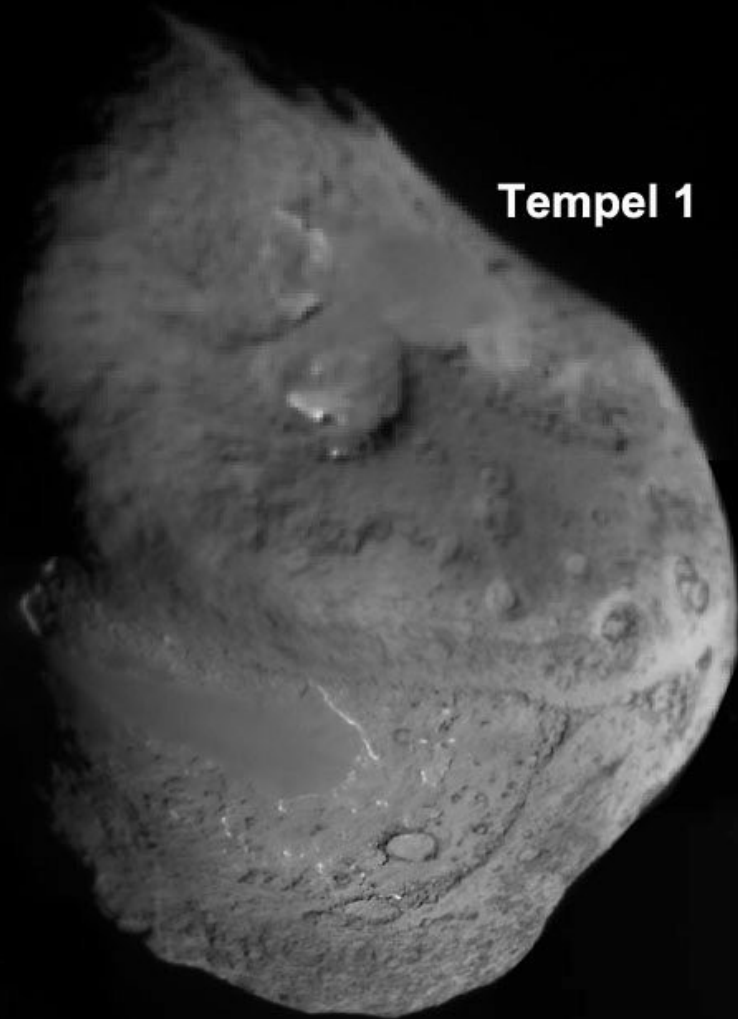


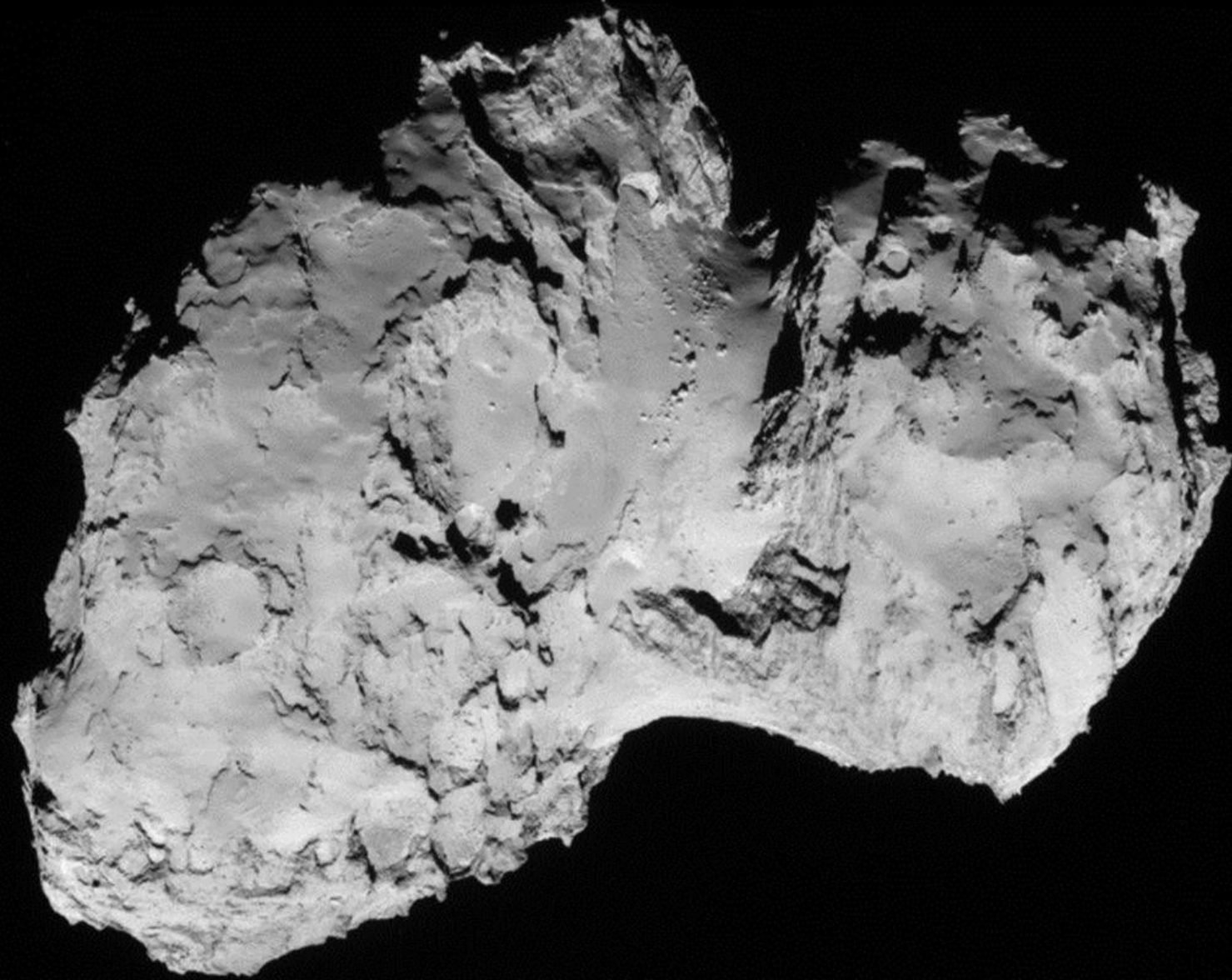
Oort Cloud

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 7: 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.

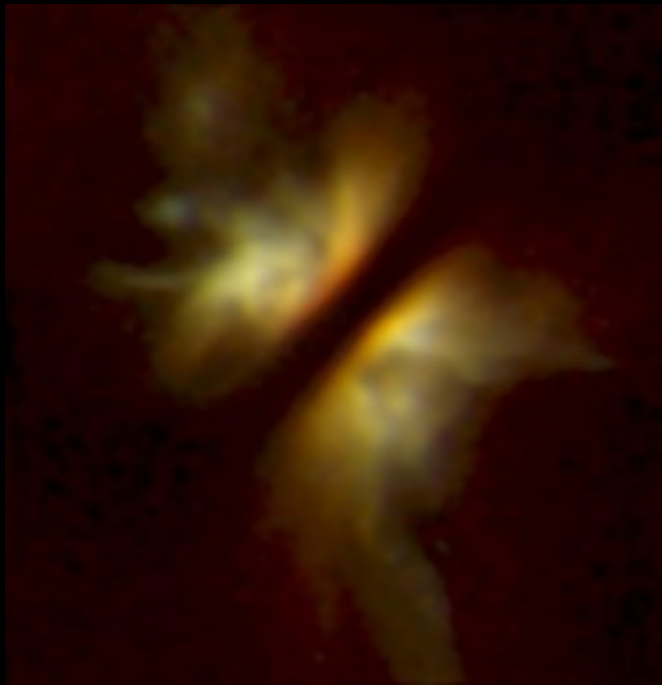
How to make a solar system! Summary slides later

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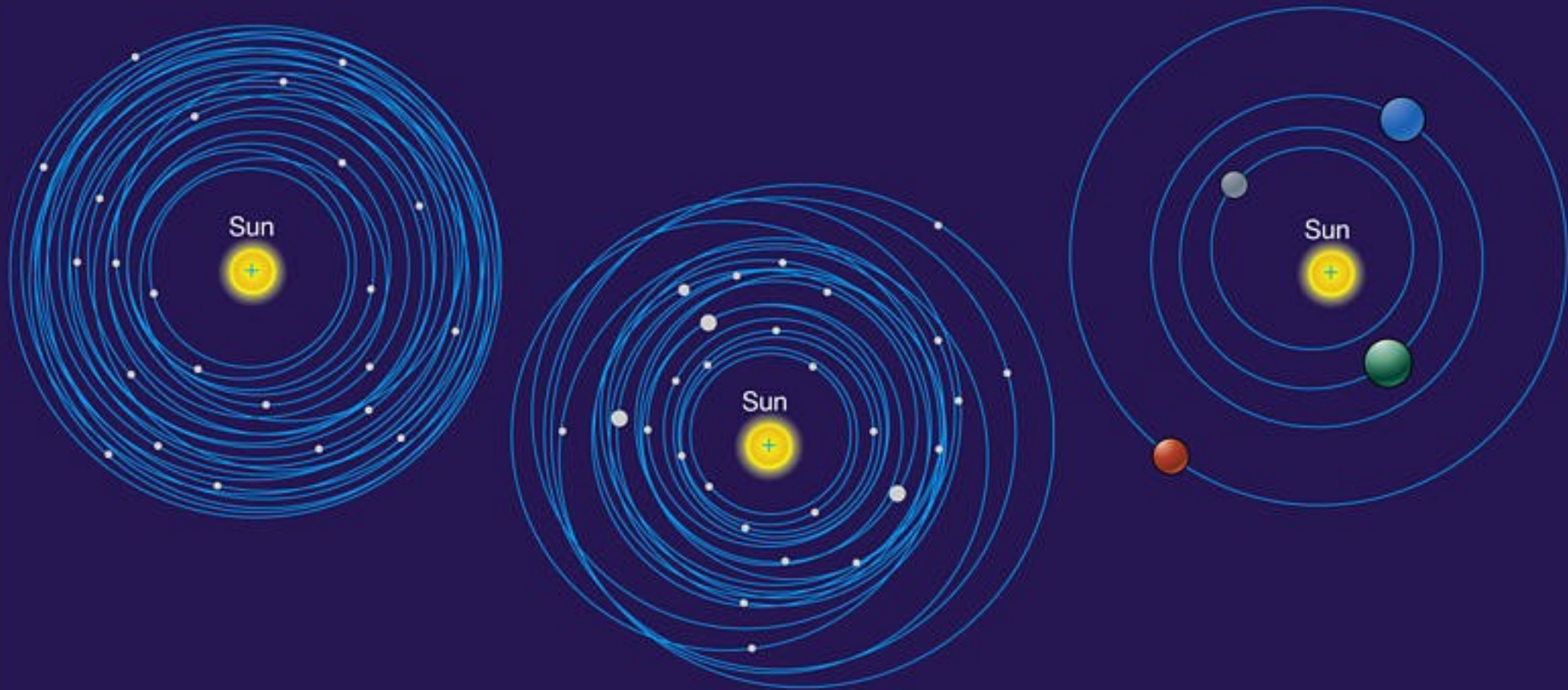
These dust particles begin to collide with each other, making rocks up to 1km in size.

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.



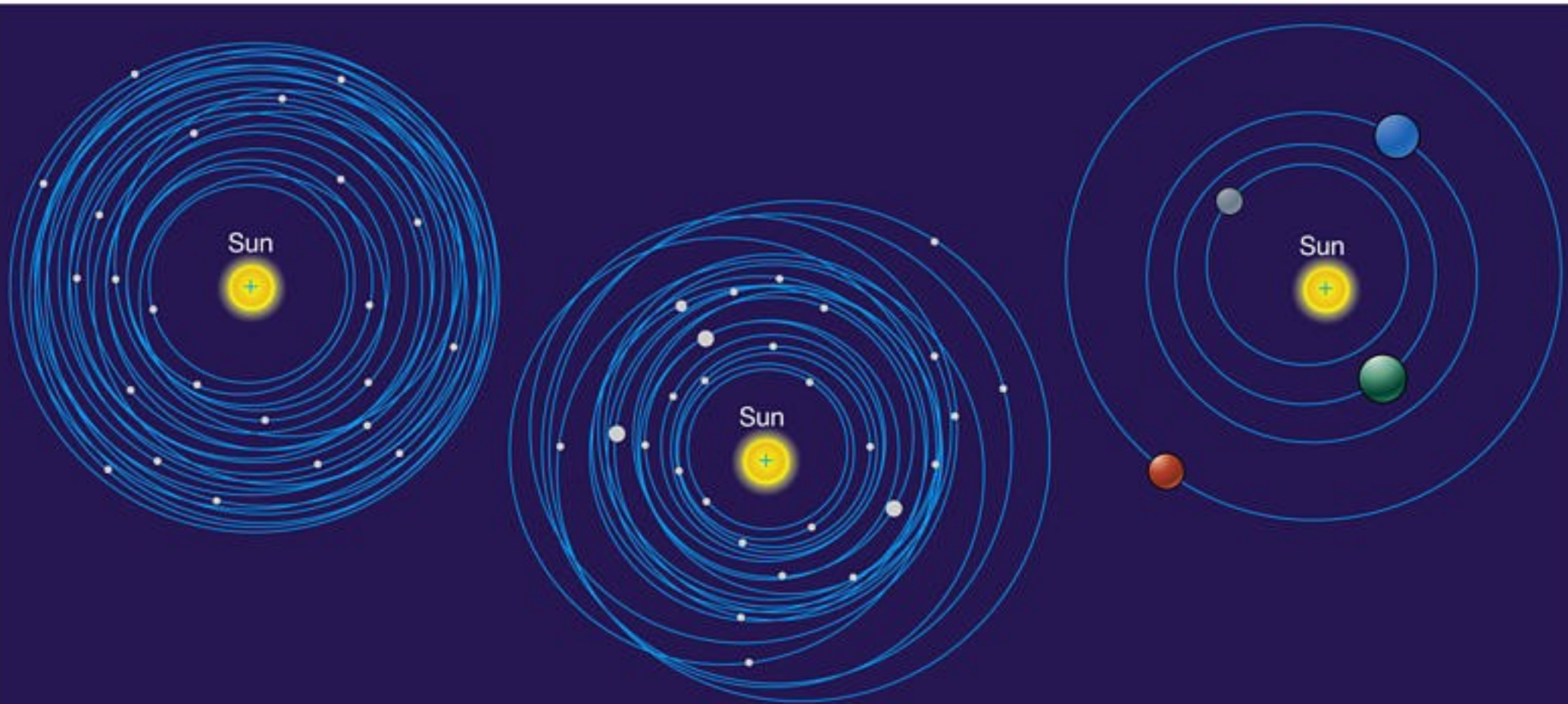
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Finally, comets, flung inward from the outer solar system, enriched the water supply (also from volcanoes). Earth and Mars are cool enough to keep this water.

Summary: 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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Jovian Planets

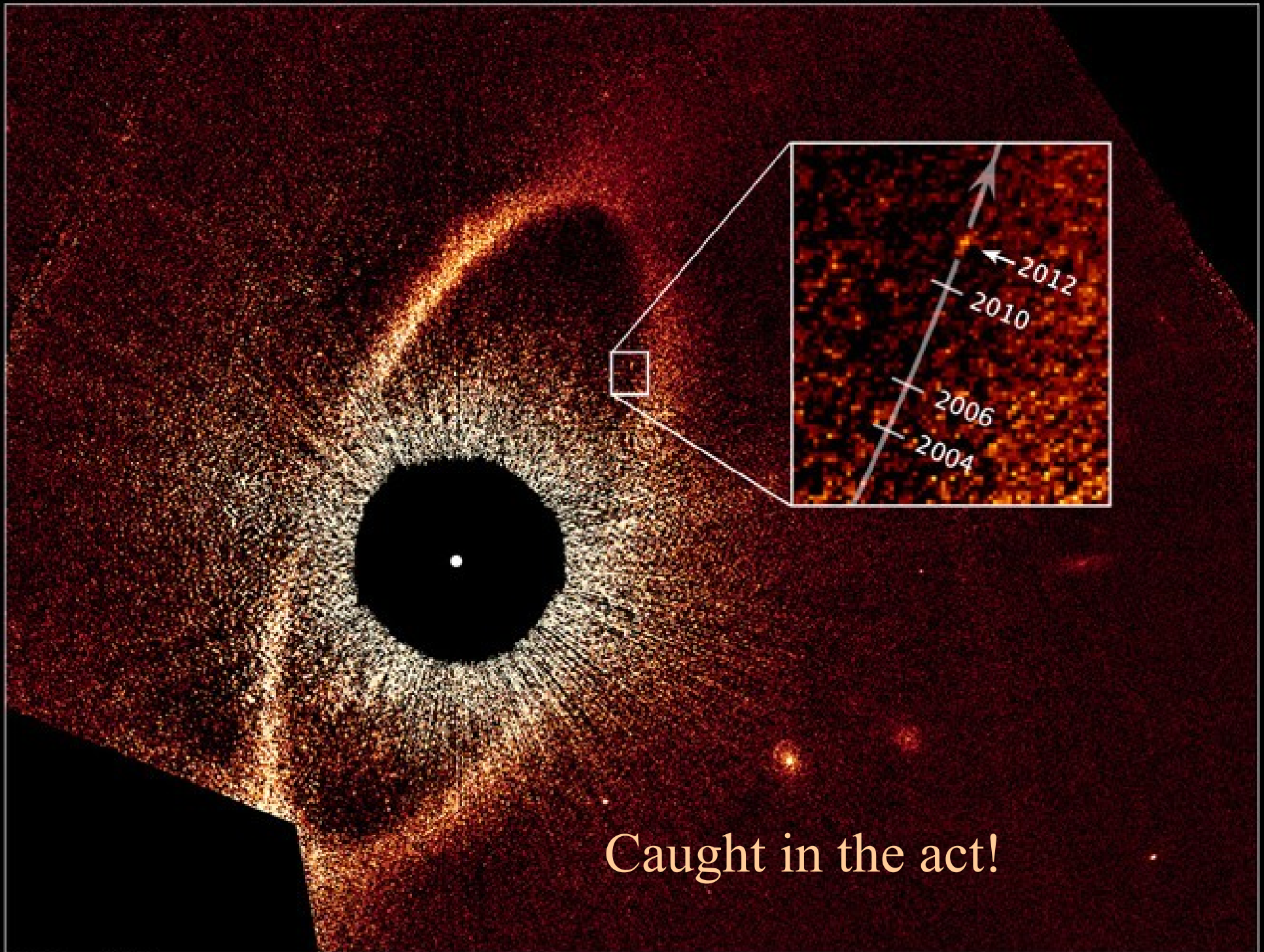
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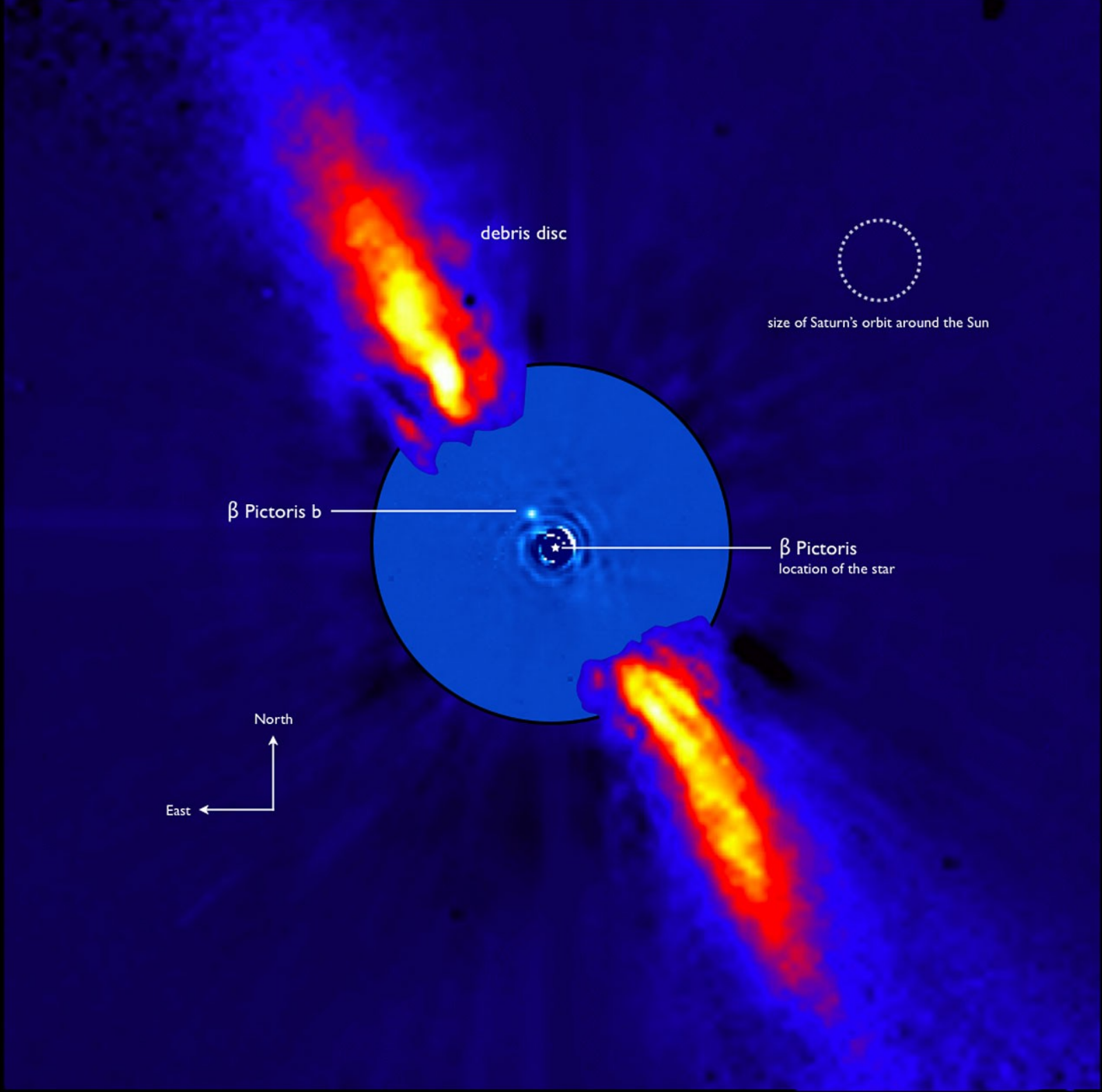
The largest objects now have enough gravity that gas in the nebula (disk) cannot escape and becomes bound to the planet. This creates huge, massive atmospheres.

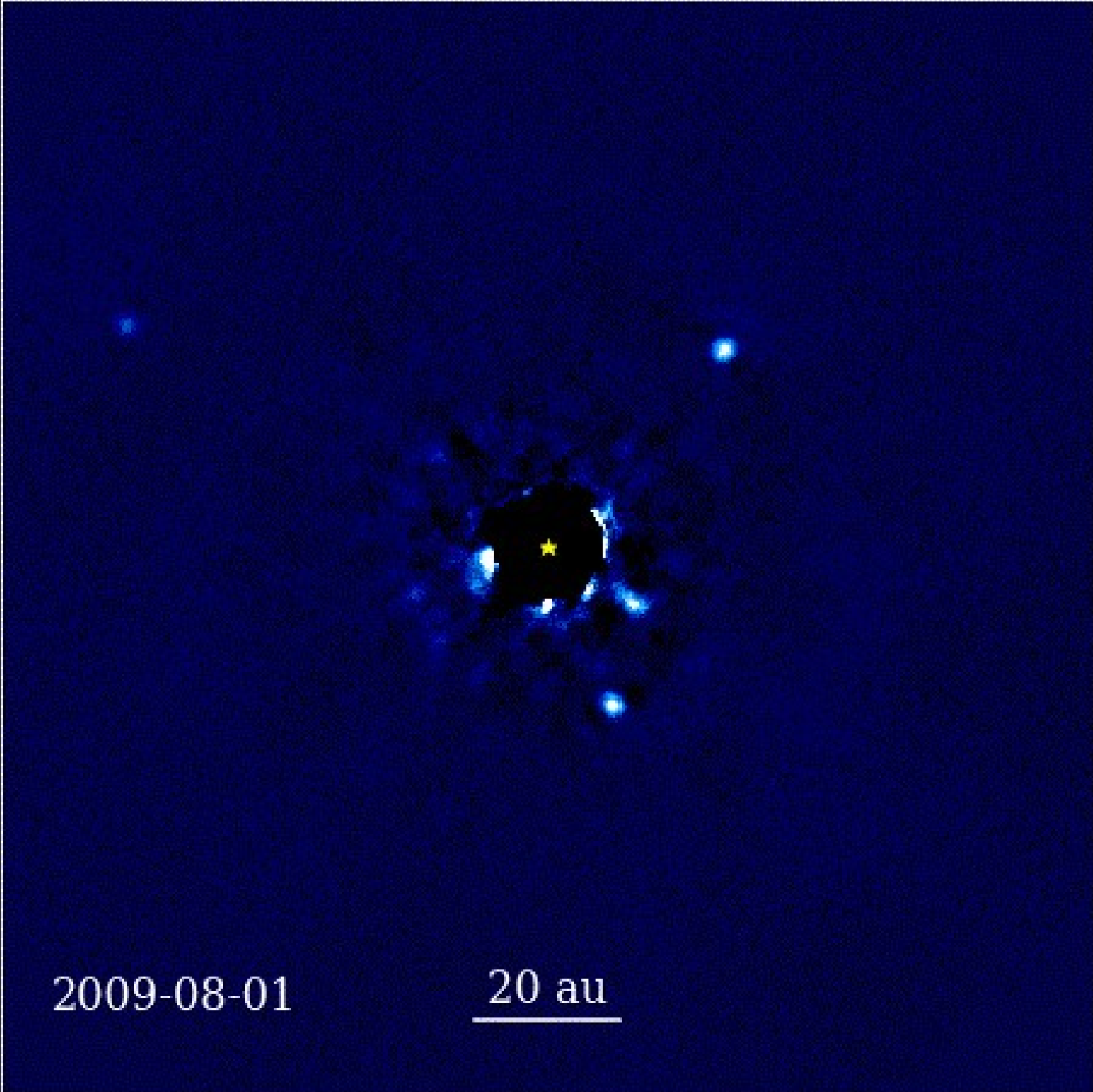
Summary: Gas giant Planets

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



Caught in the act!





2009-08-01

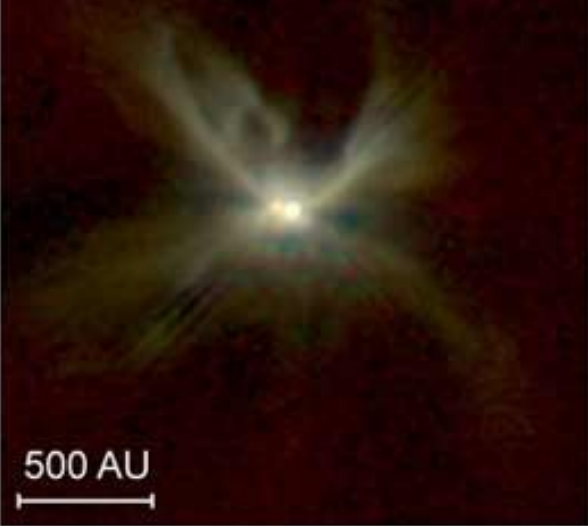
20 au

Meanwhile... in the Sun....

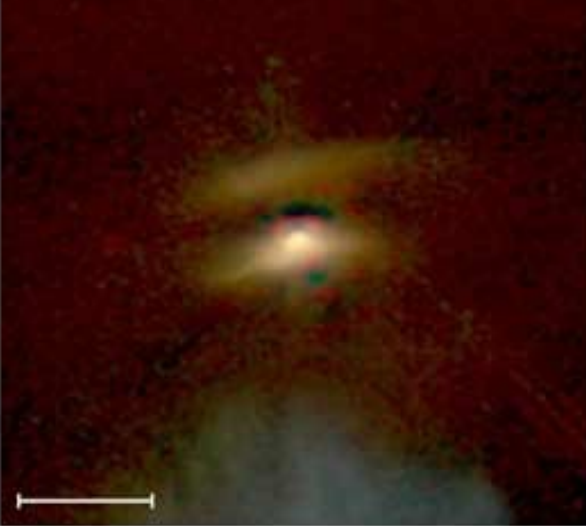
It has been slowly contracting and getting hotter.

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

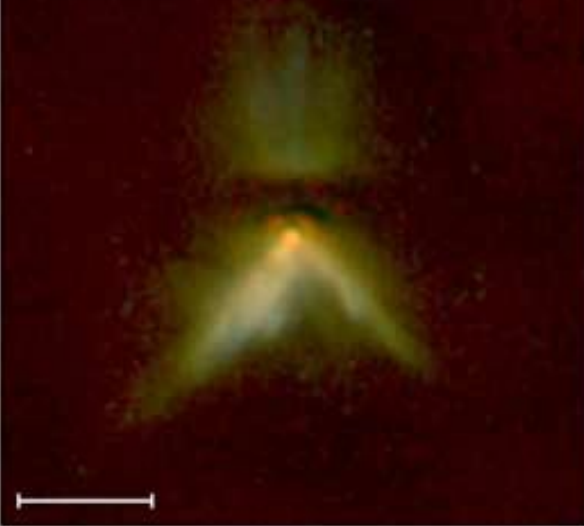
CoKu Tau1



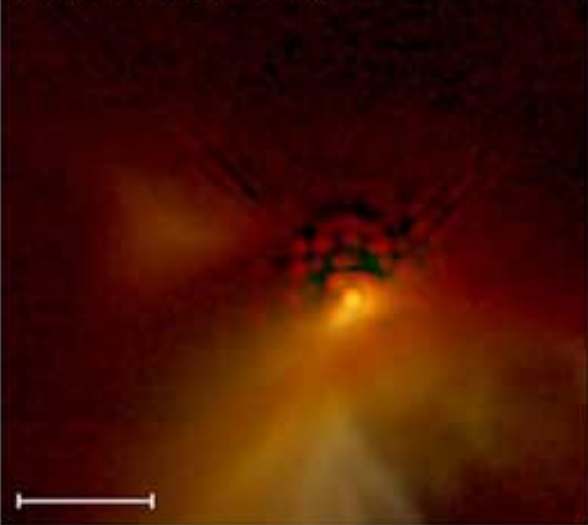
Haro 6-5B



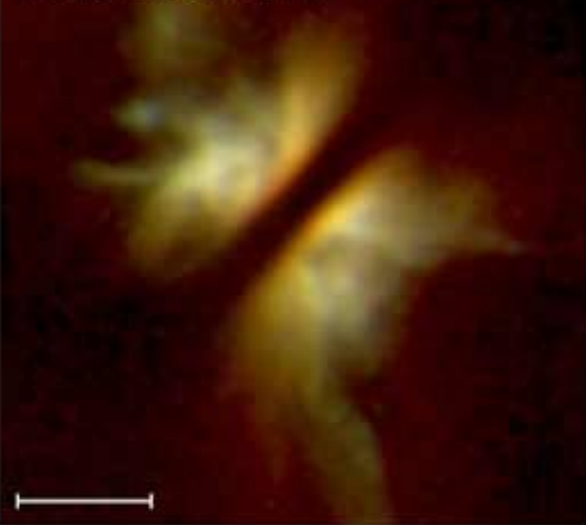
DG Tau B



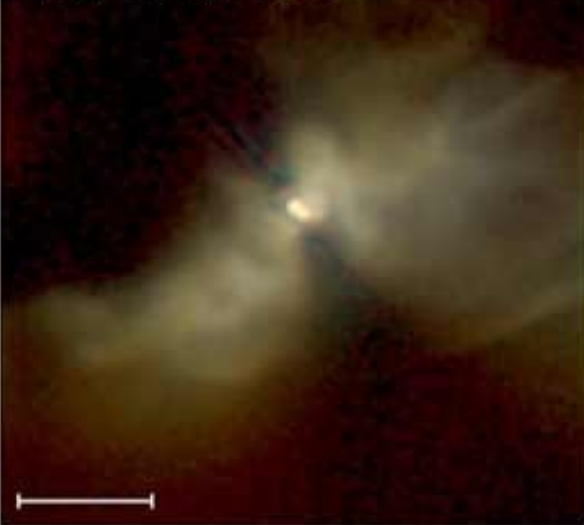
IRAS 04016+2610



IRAS 04302+2247



IRAS 04248+2612

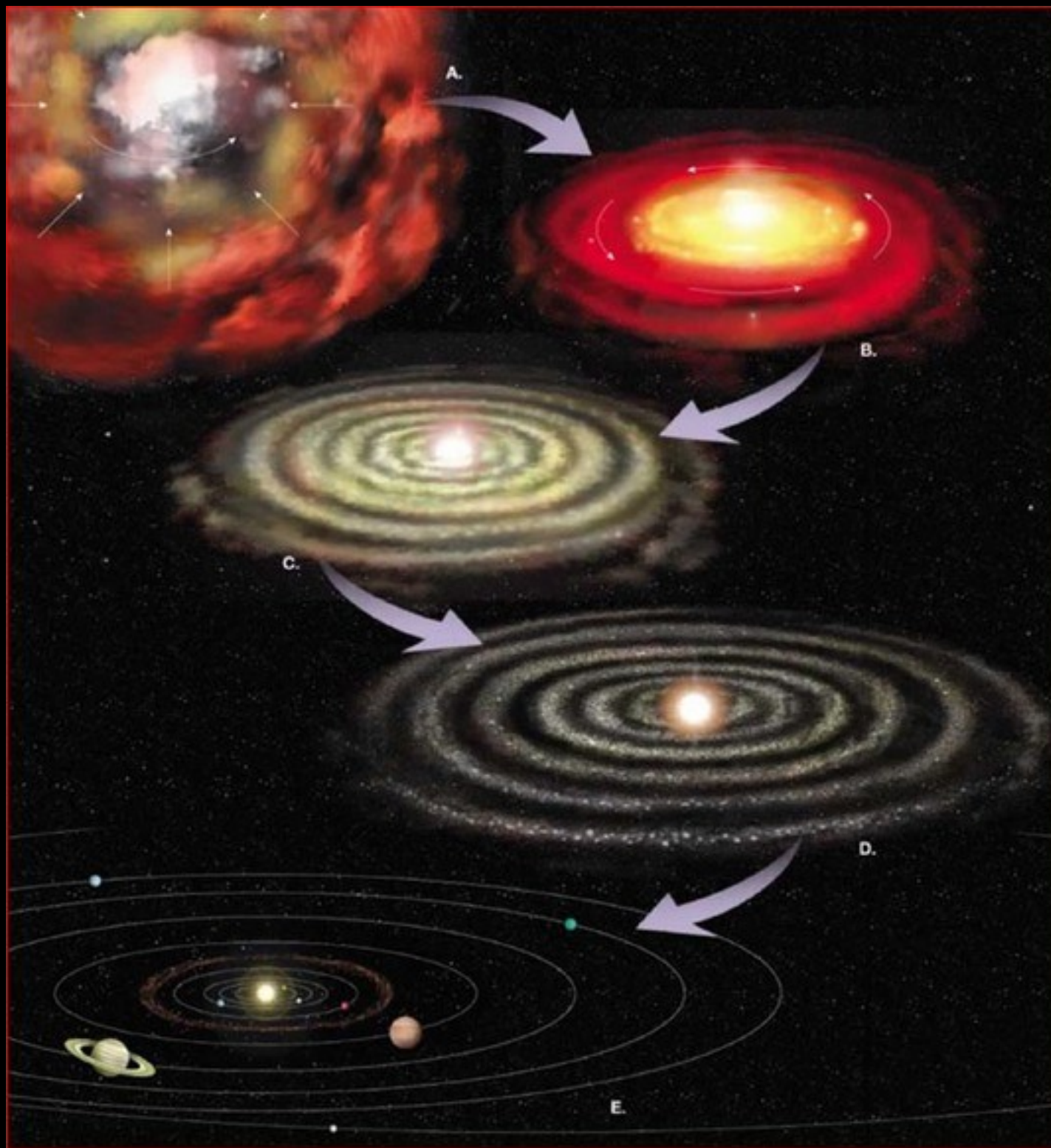


Clean up.

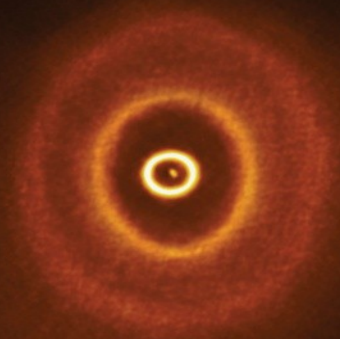
Once fusion in the Sun begins, any remaining gas gets blown away, back into the galaxy.

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



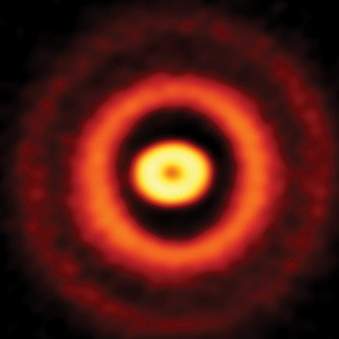


GW Ori

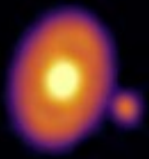


2018

2017

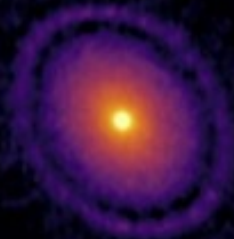


HT Lup

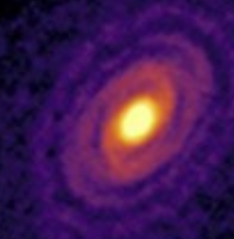


10 au

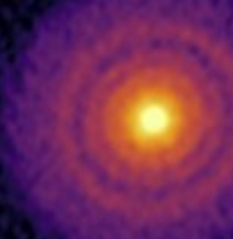
GW Lup



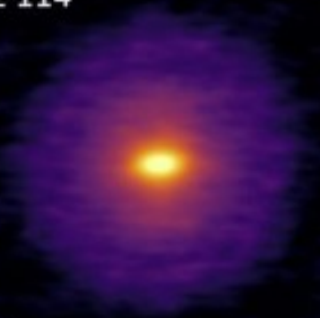
IM Lup



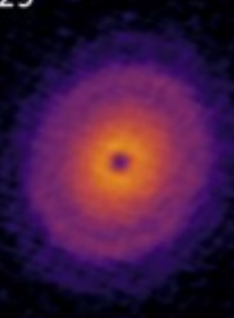
RU Lup



Sz 114



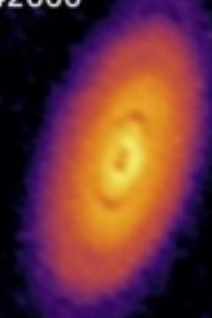
Sz 129



MY Lup



HD 142666

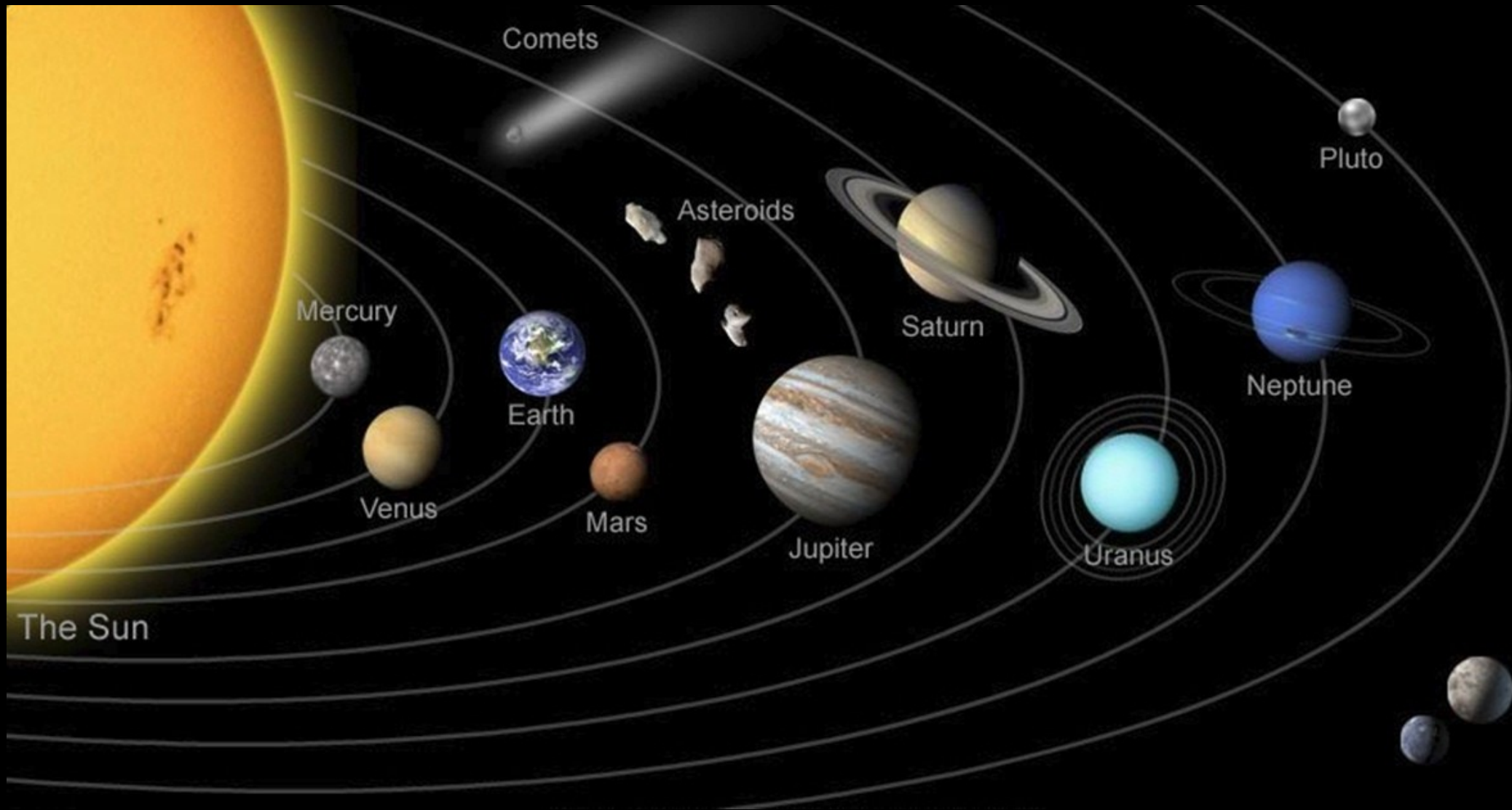


**The entire solar system
was forming together, at
the same time.**

**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.

We now have 1 example of
solar system formation!

We need to apply the scientific
method and observe other solar
systems before we can
determine if the theory is
correct.

Planets around other stars- exoplanets

A dense field of colorful stars in space, with the text "90% of all stars have planets!" overlaid in white. The stars are in various colors including red, blue, yellow, and white, and are scattered across the dark background of space. The text is centered and written in a large, white, sans-serif font.

90% of all
stars have
planets!