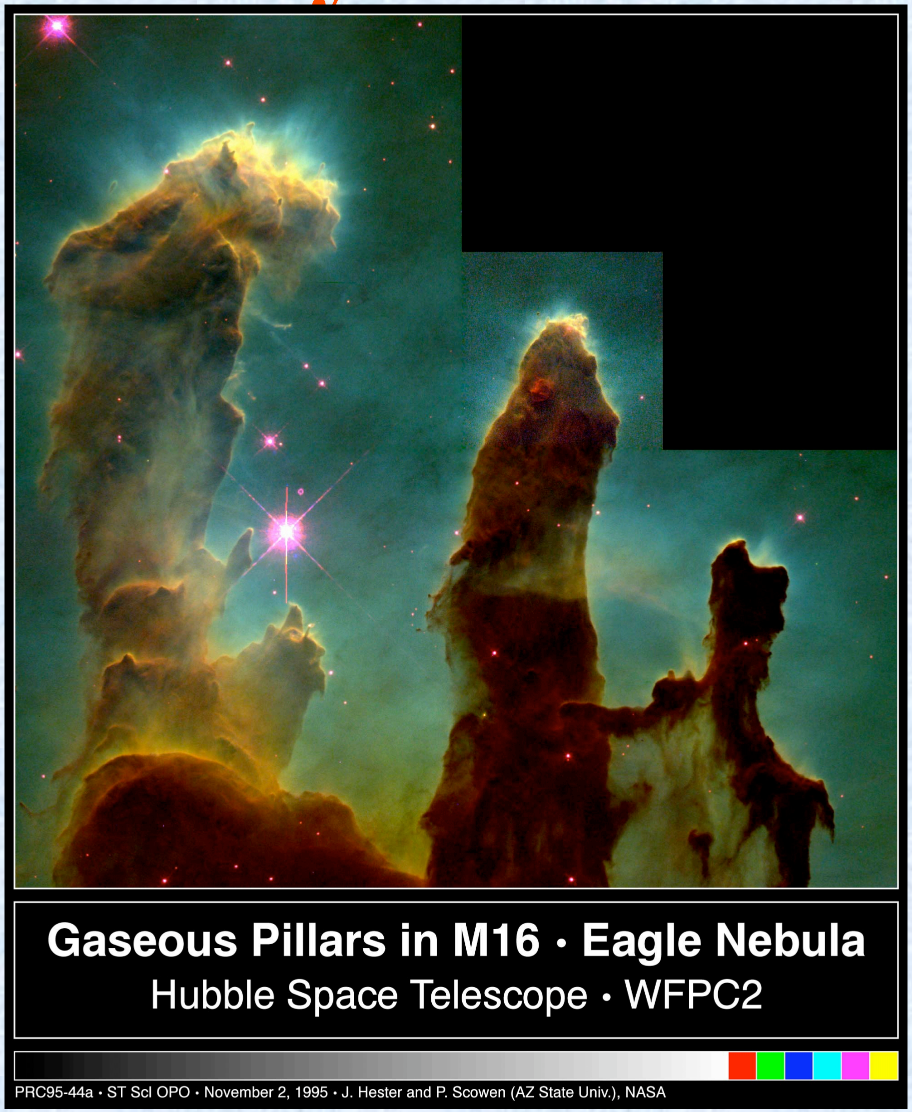
Astronomy 1 – Winter 2011



Lecture 11; January 31 2011

Previously on Astro-1

- **Properties of the Planets:**
  - Orbits in the same plane and direction
  - Inner planets are small and made of heavy elements
  - Outer planets are big and made of light elements
- **Other bodies in the Solar system**
  - There are seven large satellites (like the moon)
  - Outer solar system is populated by TNO, KBO and comets
- **How do we learn about solar system bodies?**
  - We send probes
  - Spectroscopy reveals the composition of atmospheres
  - Craters and magnetic fields reveal the presence of a liquid melted core

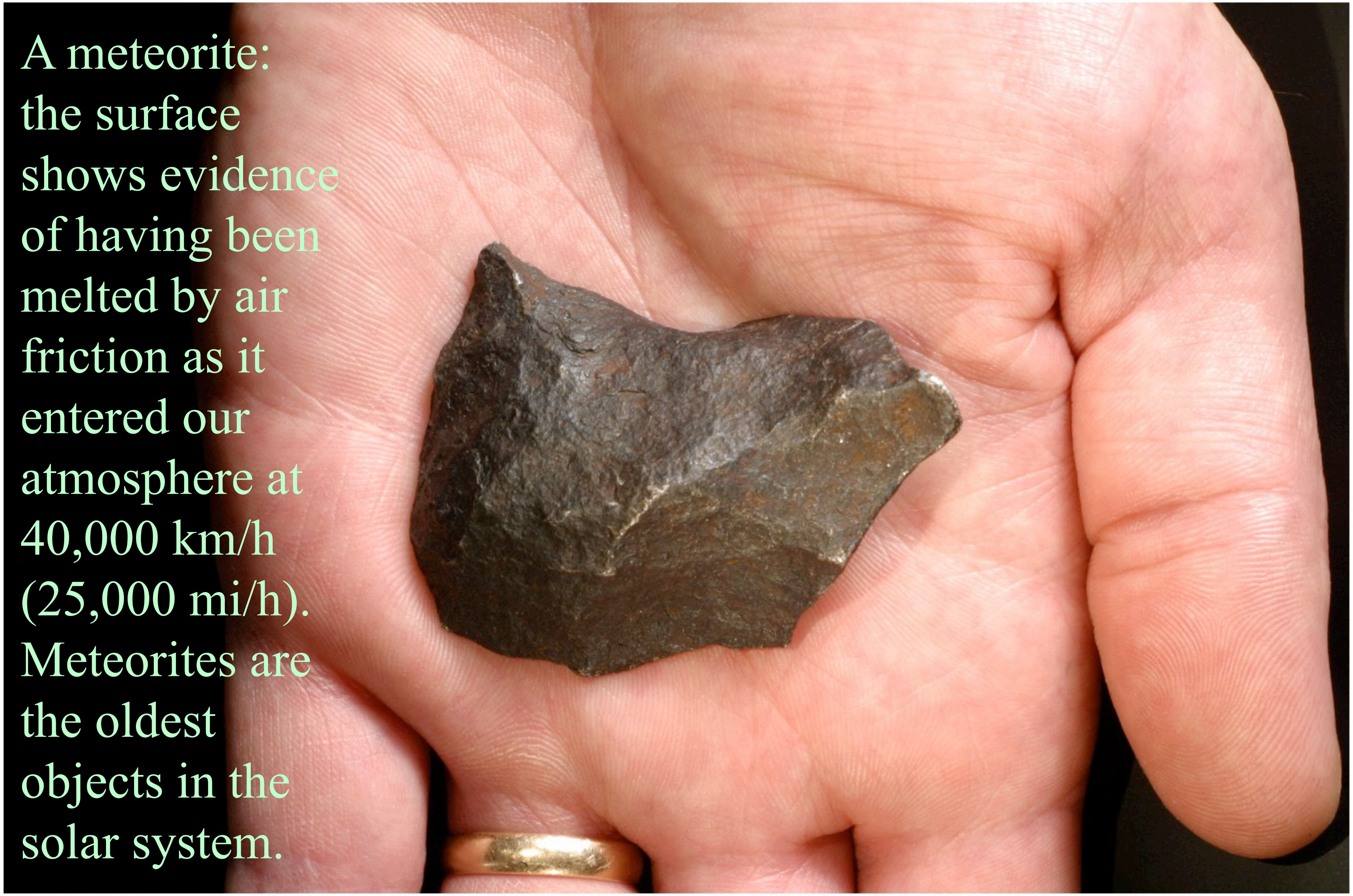
Today on Astro-1

- **The origin of the solar system**
- How old?
- How did it form?
  - Clues from our solar system
  - Clues from other worlds

A note on homework

- **For 7.28 you need to know the speed of hydrogen atoms on the sun's surface. It is 1.2 km/s and it is derived in 7.27. If you are interested do 7.27 as well.**

A meteorite: the surface shows evidence of having been melted by air friction as it entered our atmosphere at 40,000 km/h (25,000 mi/h). Meteorites are the oldest objects in the solar system.



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Original Radioactive Isotope	Final Stable Isotope	Half-Life (Years)	Range of Ages that Can Be Determined (Years)
Rubidium (^{87}Rb)	Strontium (^{87}Sr)	47.0 billion	10 million–4.56 billion
Uranium (^{238}U)	Lead (^{206}Pb)	4.5 billion	10 million–4.56 billion
Potassium (^{40}K)	Argon (^{40}Ar)	1.3 billion	50,000–4.56 billion
Carbon (^{14}C)	Nitrogen (^{14}N)	5730	100–70,000

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• Each type of radioactive nucleus decays at its own characteristic rate, called its half-life, which can be measured in the laboratory

• This is used in radioactive age-dating to determine the ages of rocks

• Age of oldest rocks in the solar system:

4.56×10^9 years

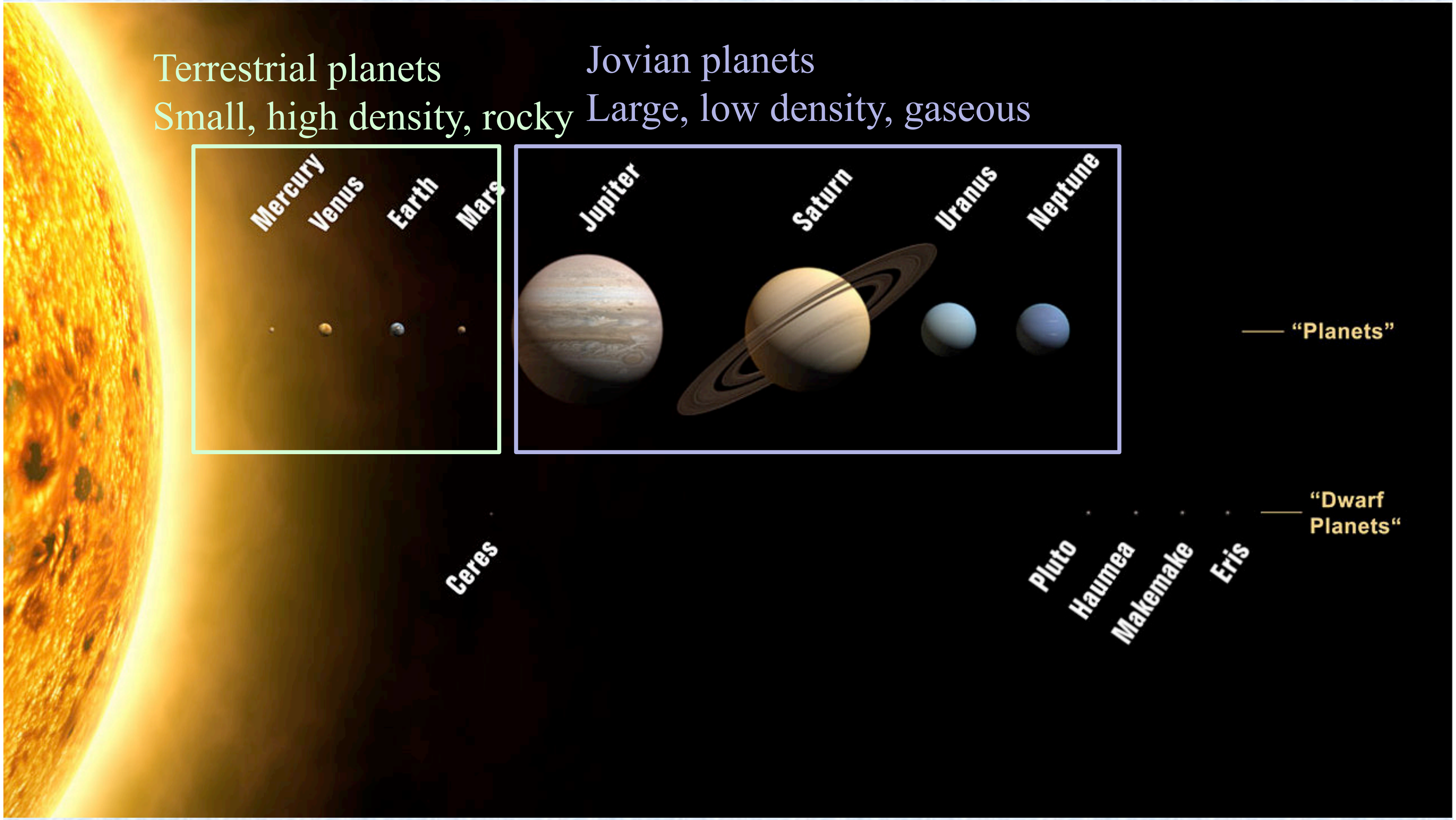
Terrestrial planets
Small, high density, rocky
Jovian planets
Large, low density, gaseous
Mercury
Venus
Earth
Mars
Jupiter
Saturn
Uranus
Neptune
"Planets"
Ceres
Pluto
Haumea
Makemake
Eris
"Dwarf Planets"

Table 8-1 Three Key Properties of Our Solar System

Any theory of the origin of the solar system must be able to account for these properties of the planets.

Property 1: *Sizes and compositions of terrestrial planets versus Jovian planets*	The terrestrial planets, which are composed primarily of rocky substances, are relatively small, while the Jovian planets, which are composed primarily of hydrogen and helium, are relatively large (see Sections 7-1 and 7-4).
Property 2: *Directions and orientations of planetary orbits*	All of the planets orbit the Sun in the same direction, and all of their orbits are in nearly the same plane (see Section 7-1).
Property 3: *Sizes of terrestrial planet orbits versus Jovian planet orbits*	The terrestrial planets orbit close to the Sun, while the Jovian planets orbit far from the Sun (see Section 7-1).

Table 8-1
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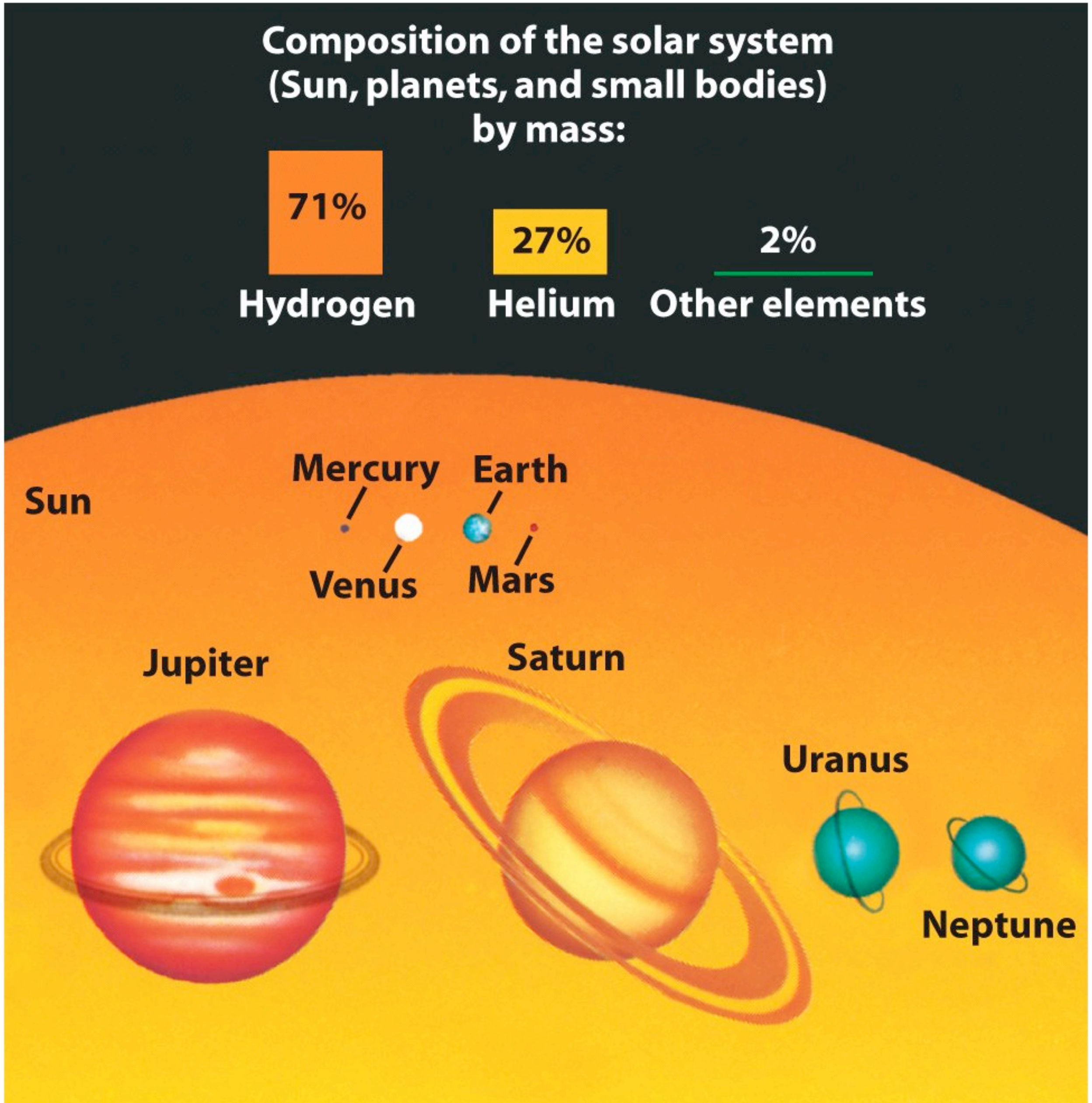

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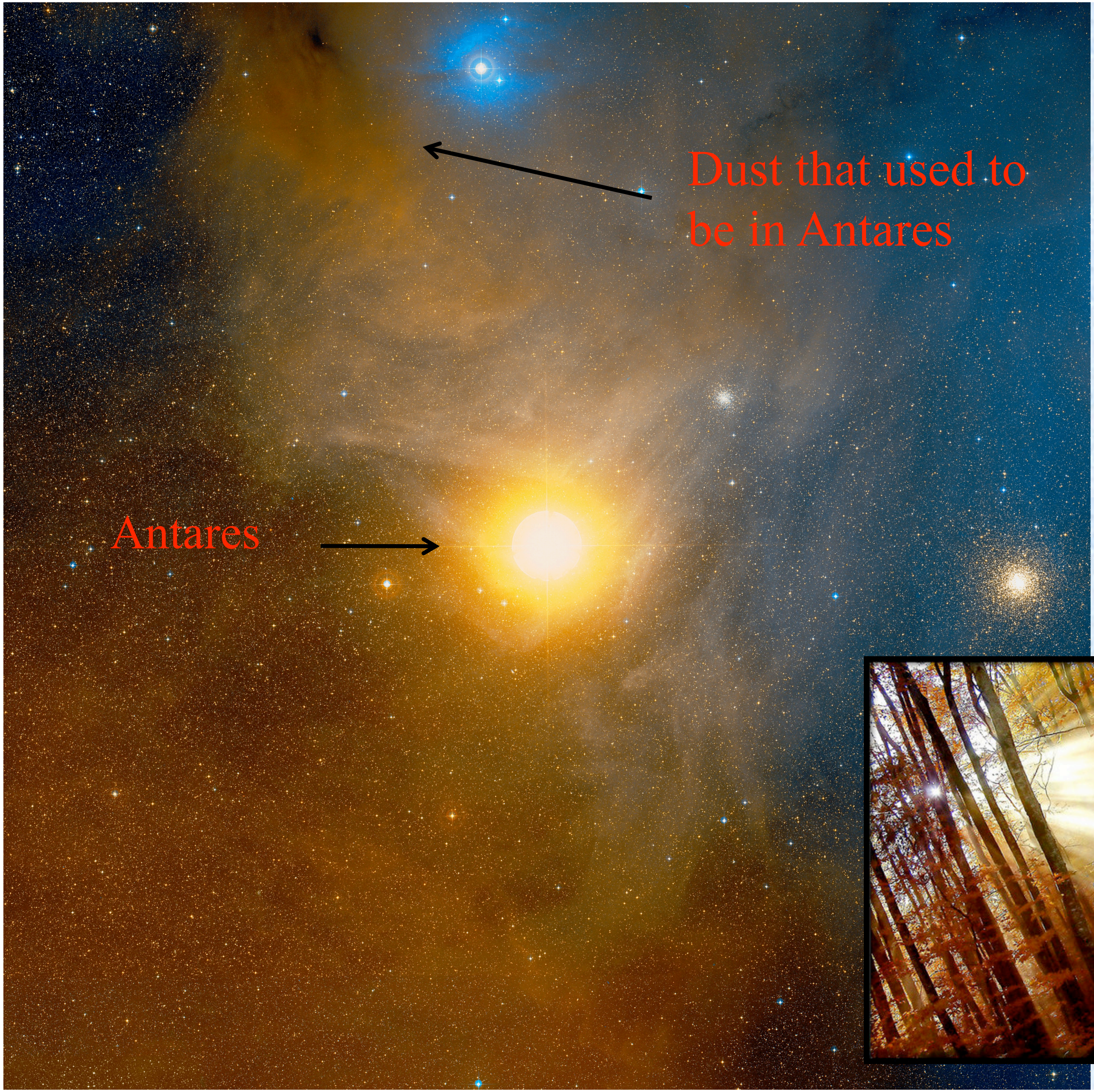
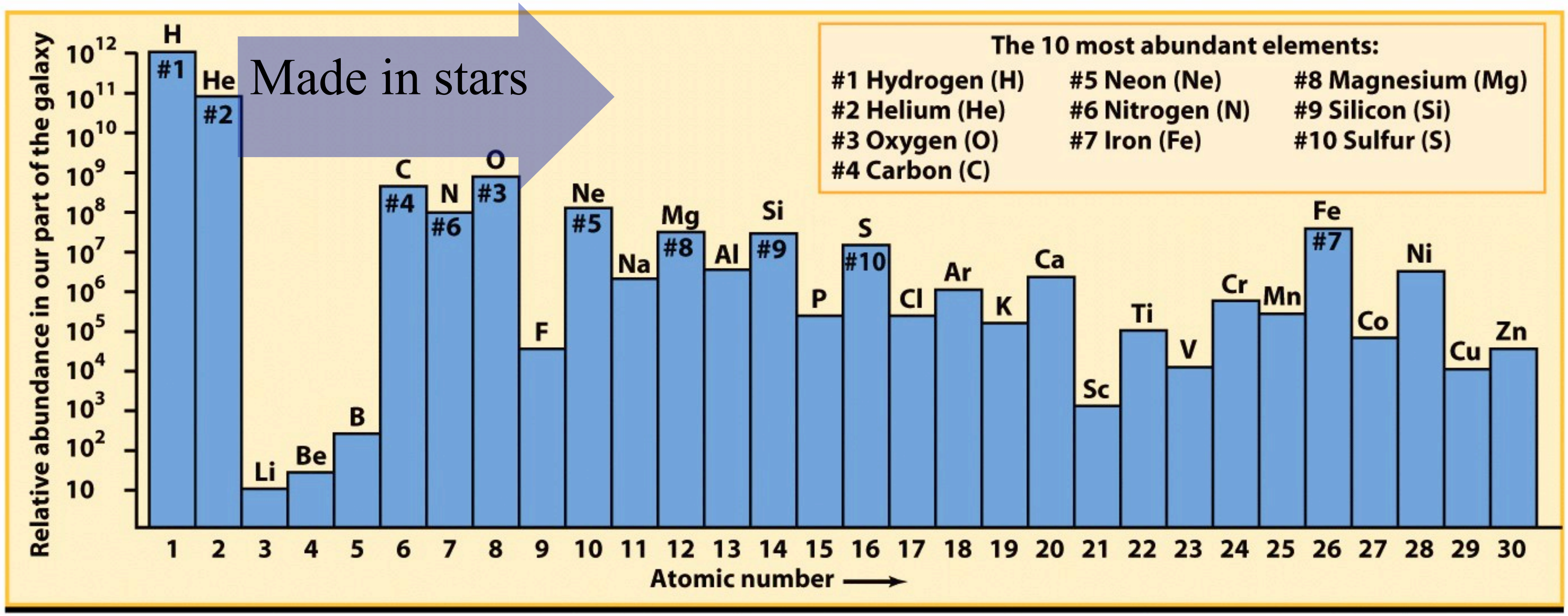


The dying star Antares is shedding material from its outer layers, forming a thin cloud around the star.

The abundances of the 30 lightest elements



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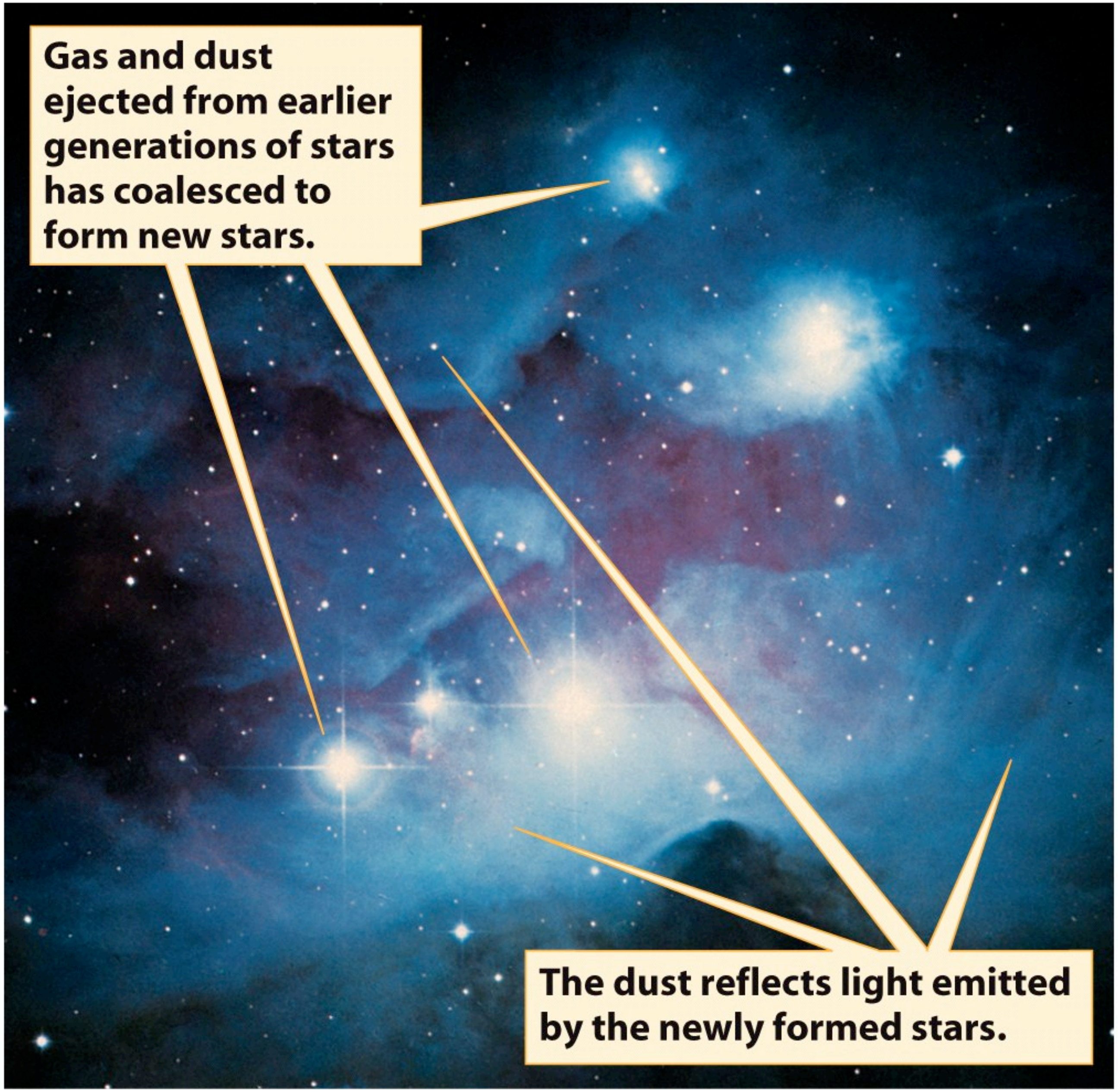
All elements heavier than zinc (Zn) have abundances of fewer than1000 atoms per 10^{12} atoms of hydrogen.



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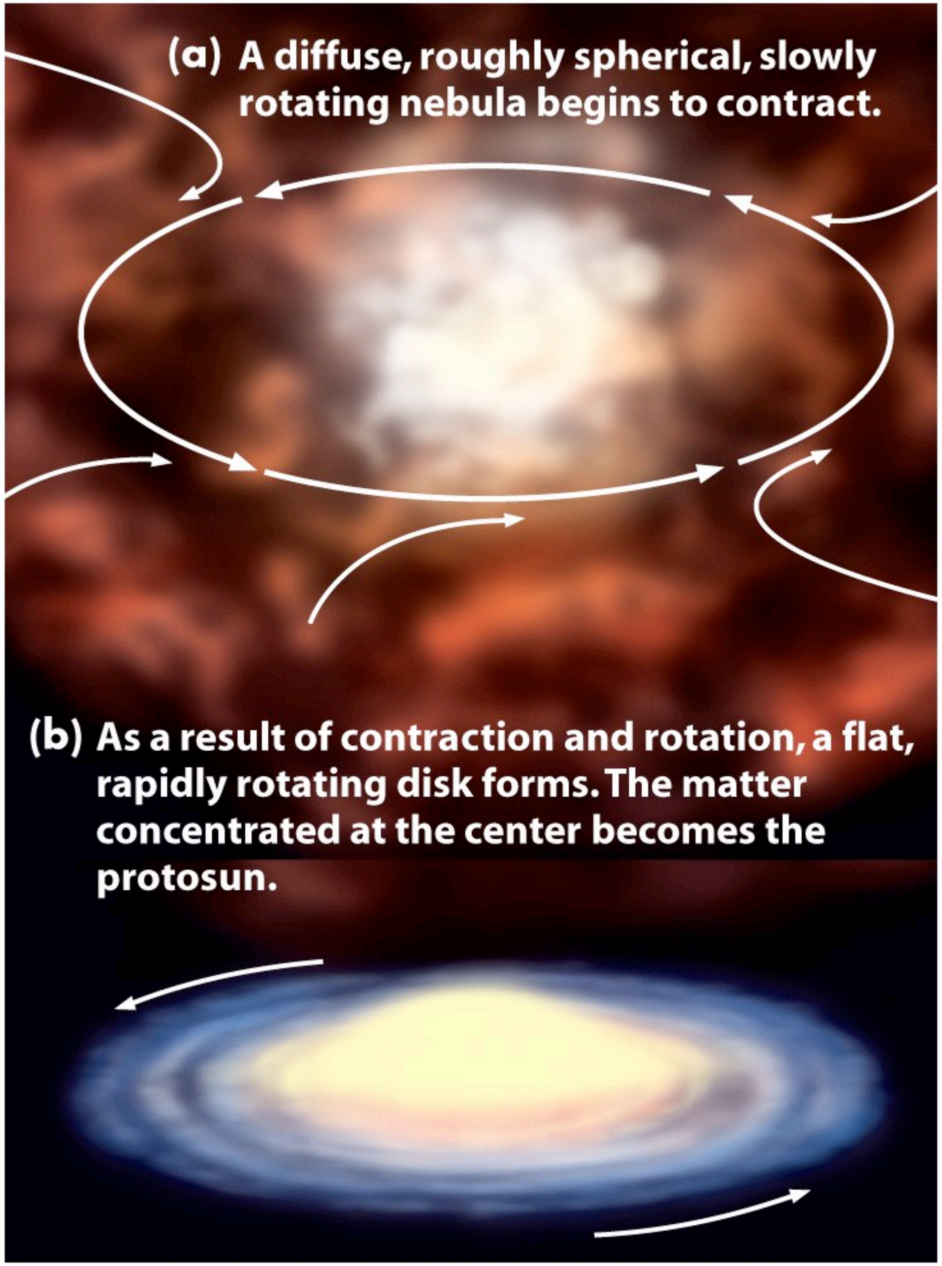
Question 11.1 (iclickers!)

- How has the present mix of chemical elements in the Universe been produced?
  - A) All the known elements have been formed by the radioactive breakup of the heavy elements formed in the initial Big Bang
  - B) All of the known elements were formed in the Big Bang
  - C)H and He were formed in the Big Bang, while the heavier elements have been slowly forming by collisions in cold interstellar gas clouds
  - D) H and some He were formed in the Big Bang, while the heavier elements have been slowly formed in the centers of stars over the life of the Universe.

The formation of the sun and its planets



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(a) (b)

Figure 8-7
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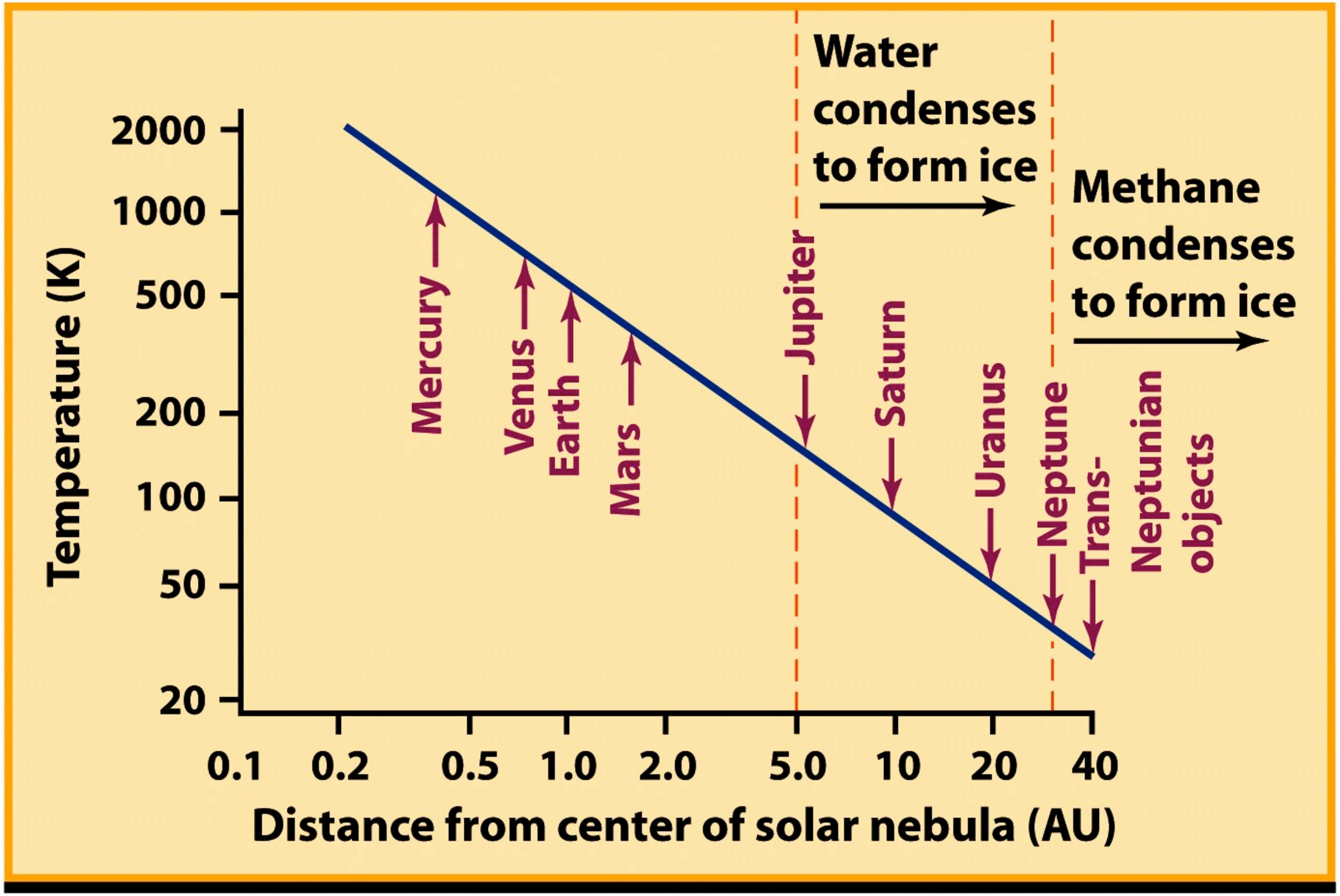

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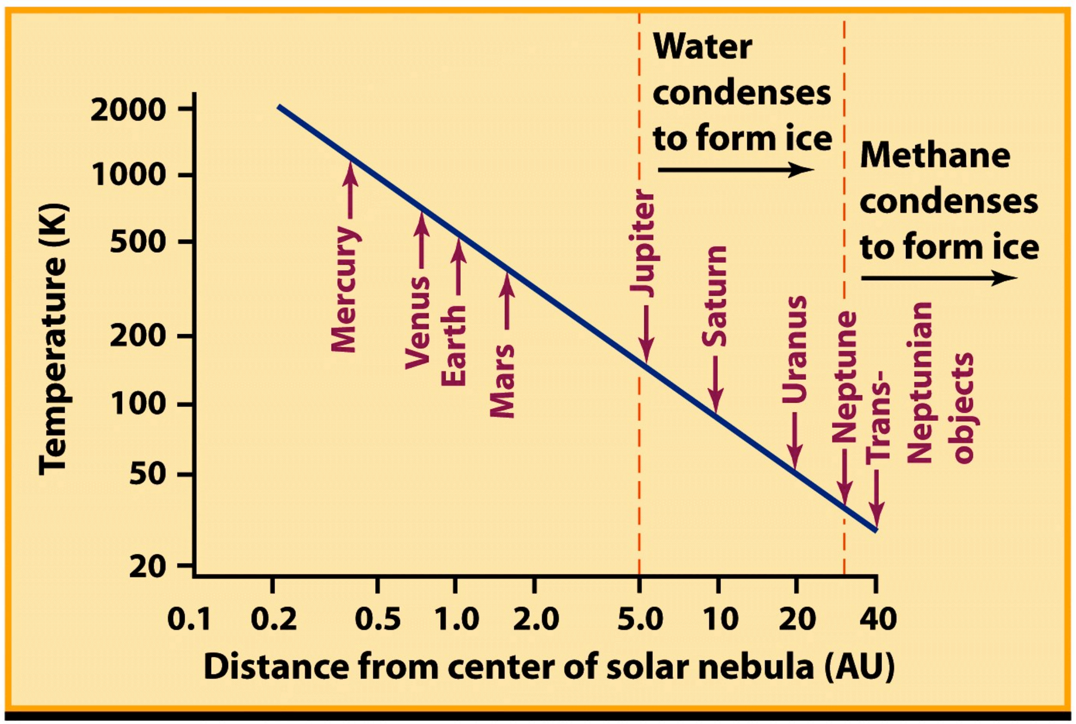
Probable temperatures variations across the solar nebula as the solar system was forming.



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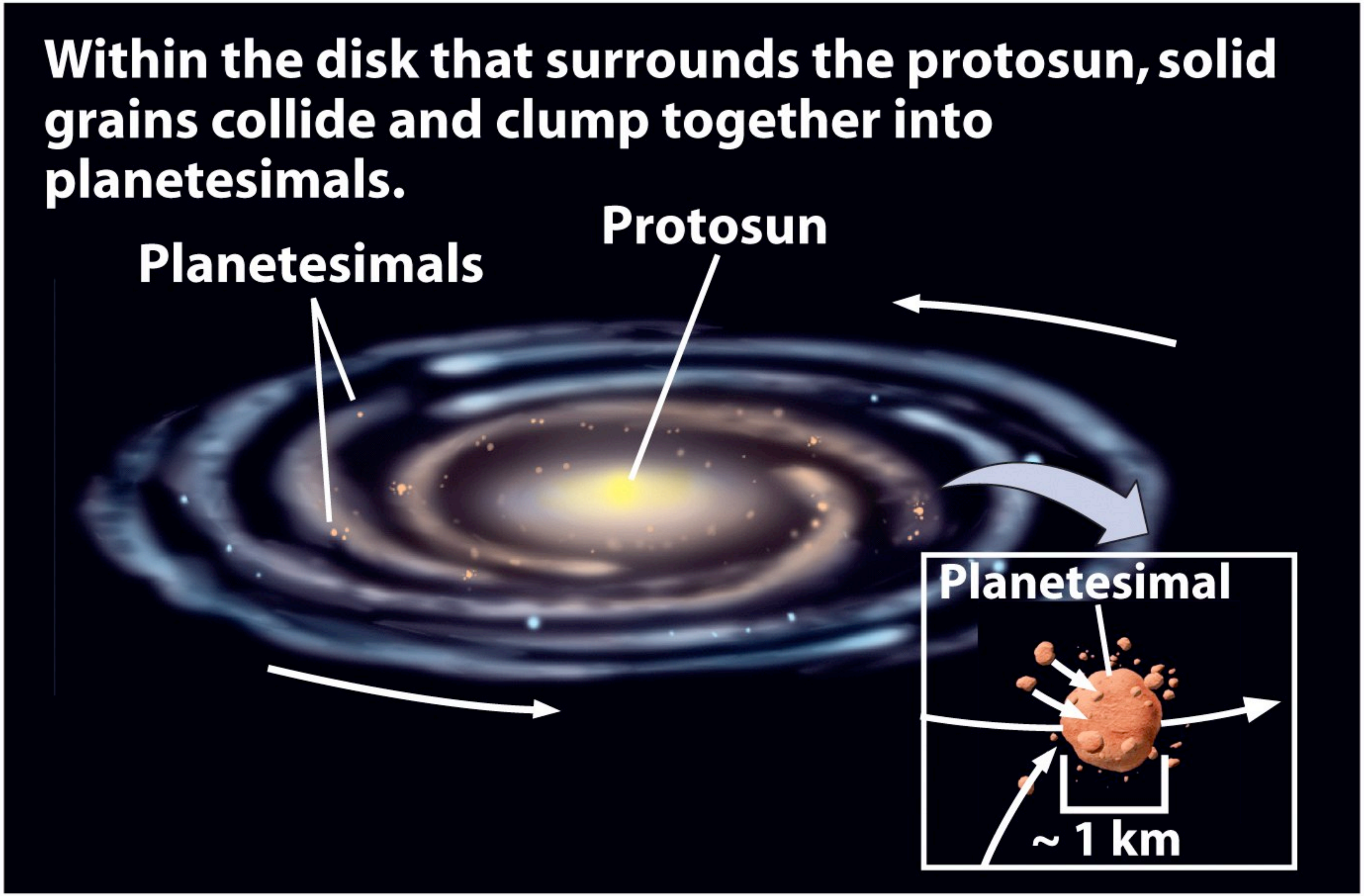
The young Sun was hotter than it is today. In the inner part of the solar system, only the heavier elements could remain solid – lighter stuff could not condense, and got blown farther out, until it found a spot cool enough to condense. Since there are fewer heavy elements, the terrestrial planets formed close-in are smaller than the gas giants.



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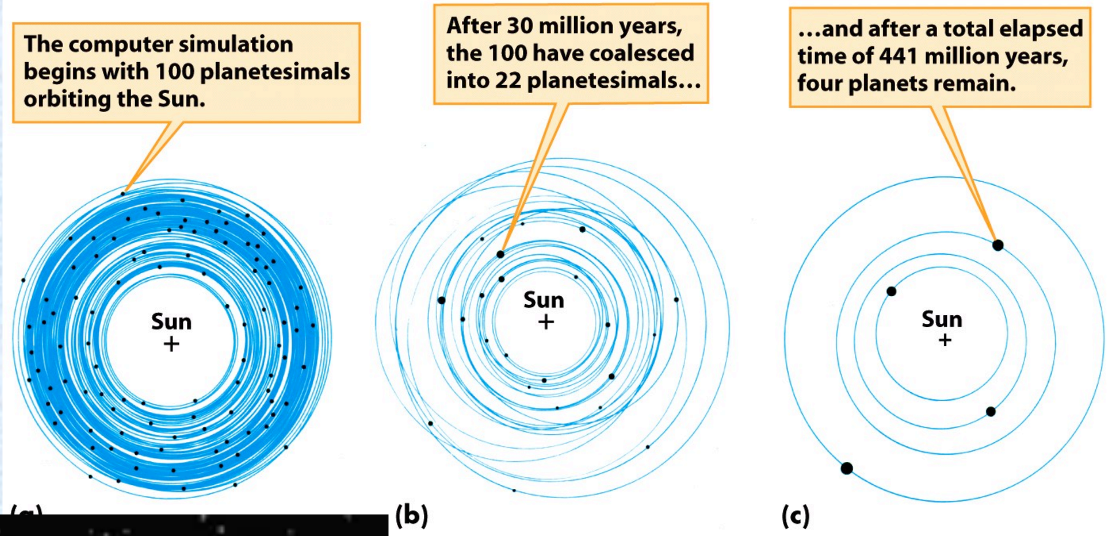
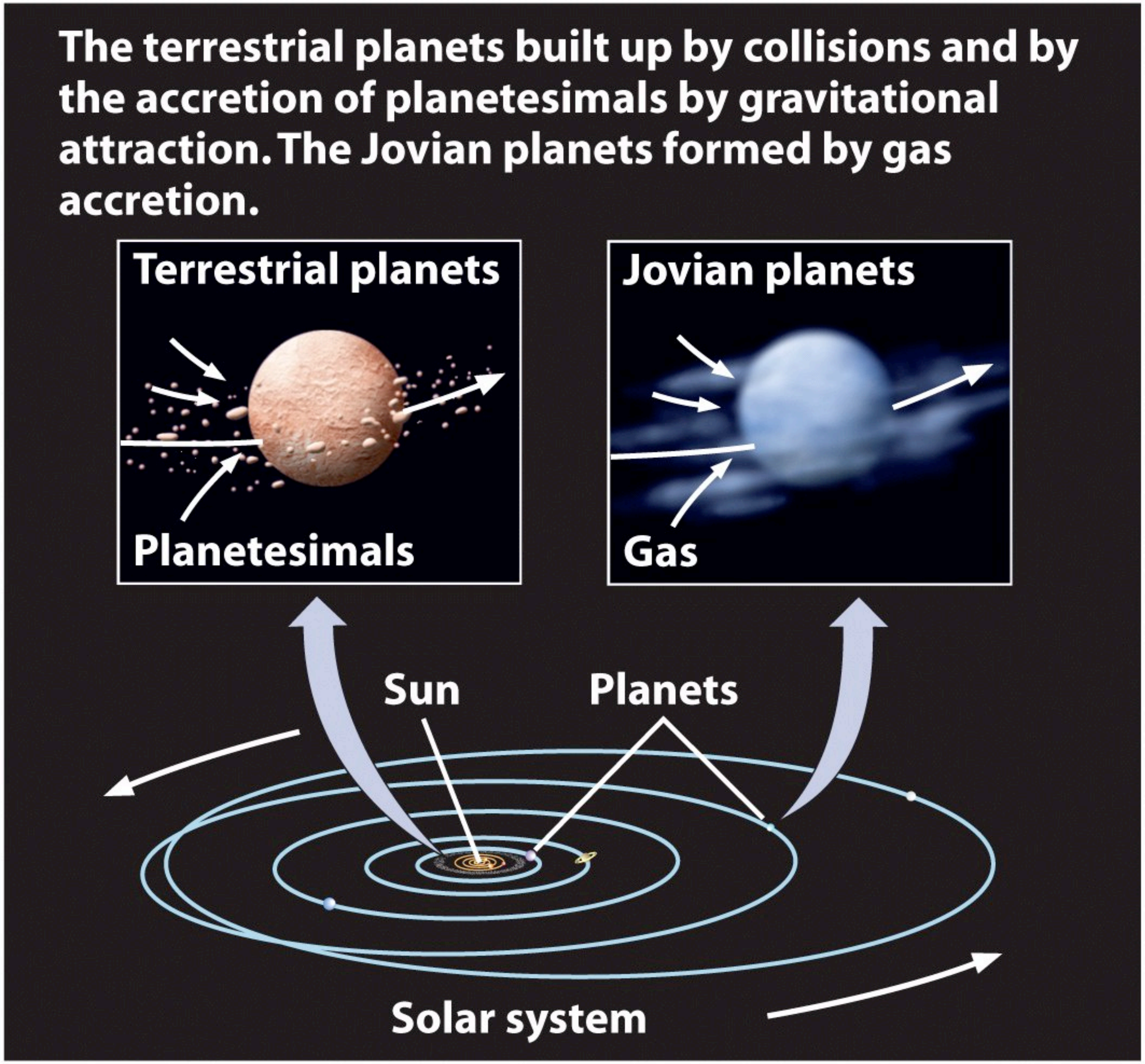

The computer simulation begins with 100 planetesimals orbiting the Sun.
After 30 million years, the 100 have coalesced into 22 planetesimals…
…and after a total elapsed time of 441 million years, four planets remain.
Sun
Sun
Sun
(b)
(c)



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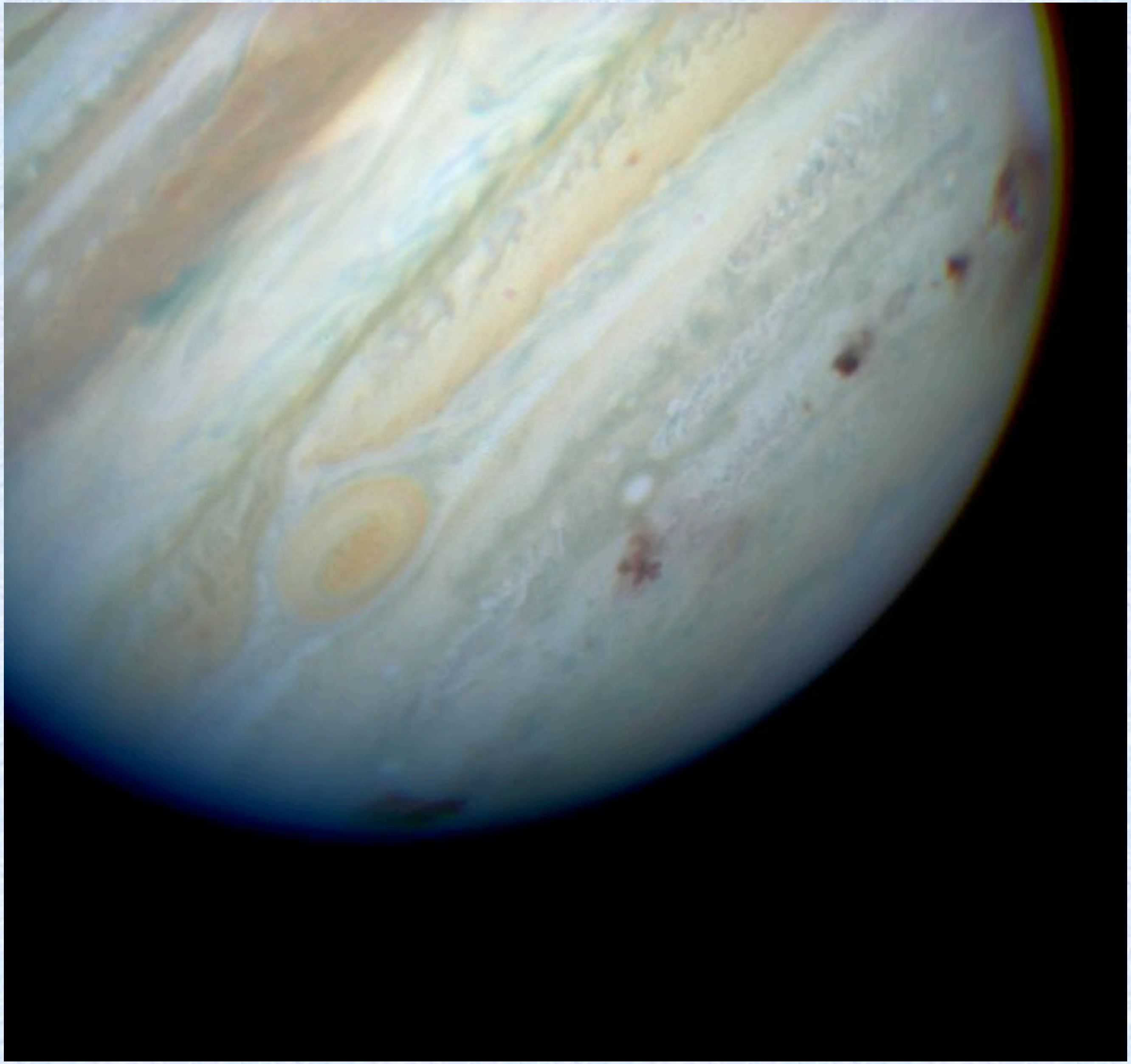
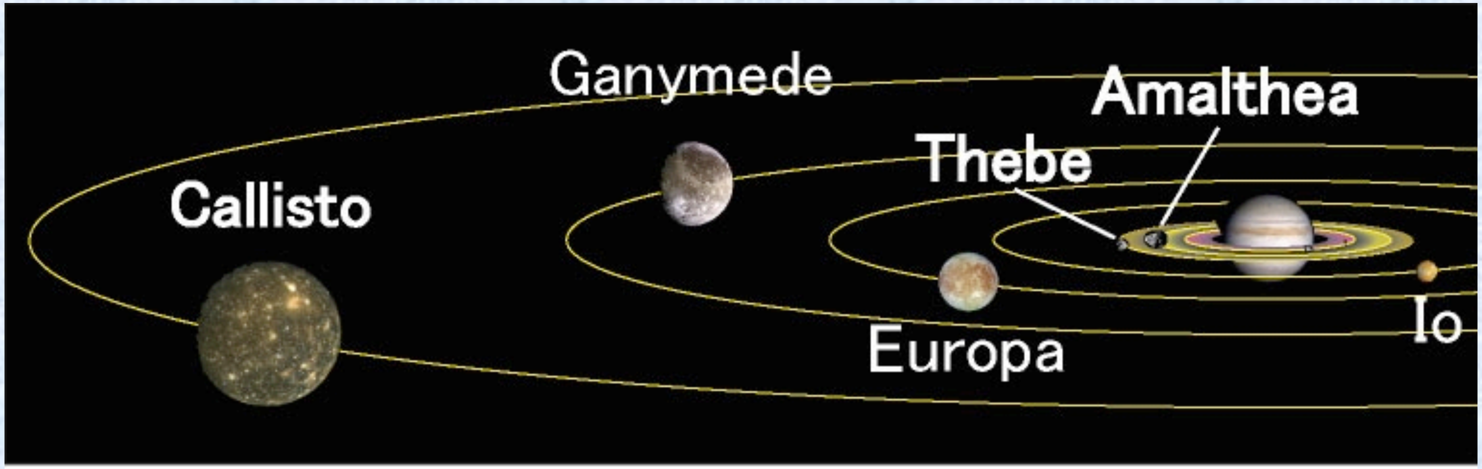
Core accretion Theory vs Disk instability theory for Jovian planets

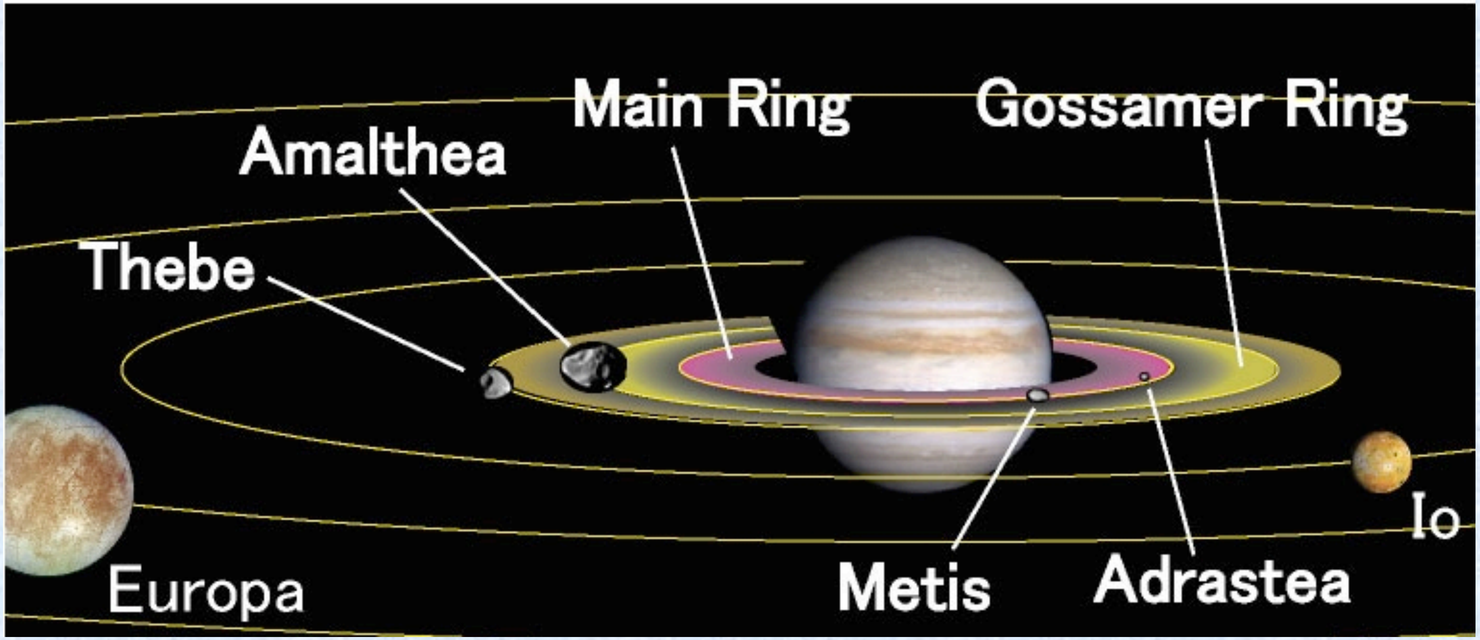


Planetesimal accretion is still happening! The rate has slowed. In 1994 comet Shoemaker-Levy 9 hit Jupiter.

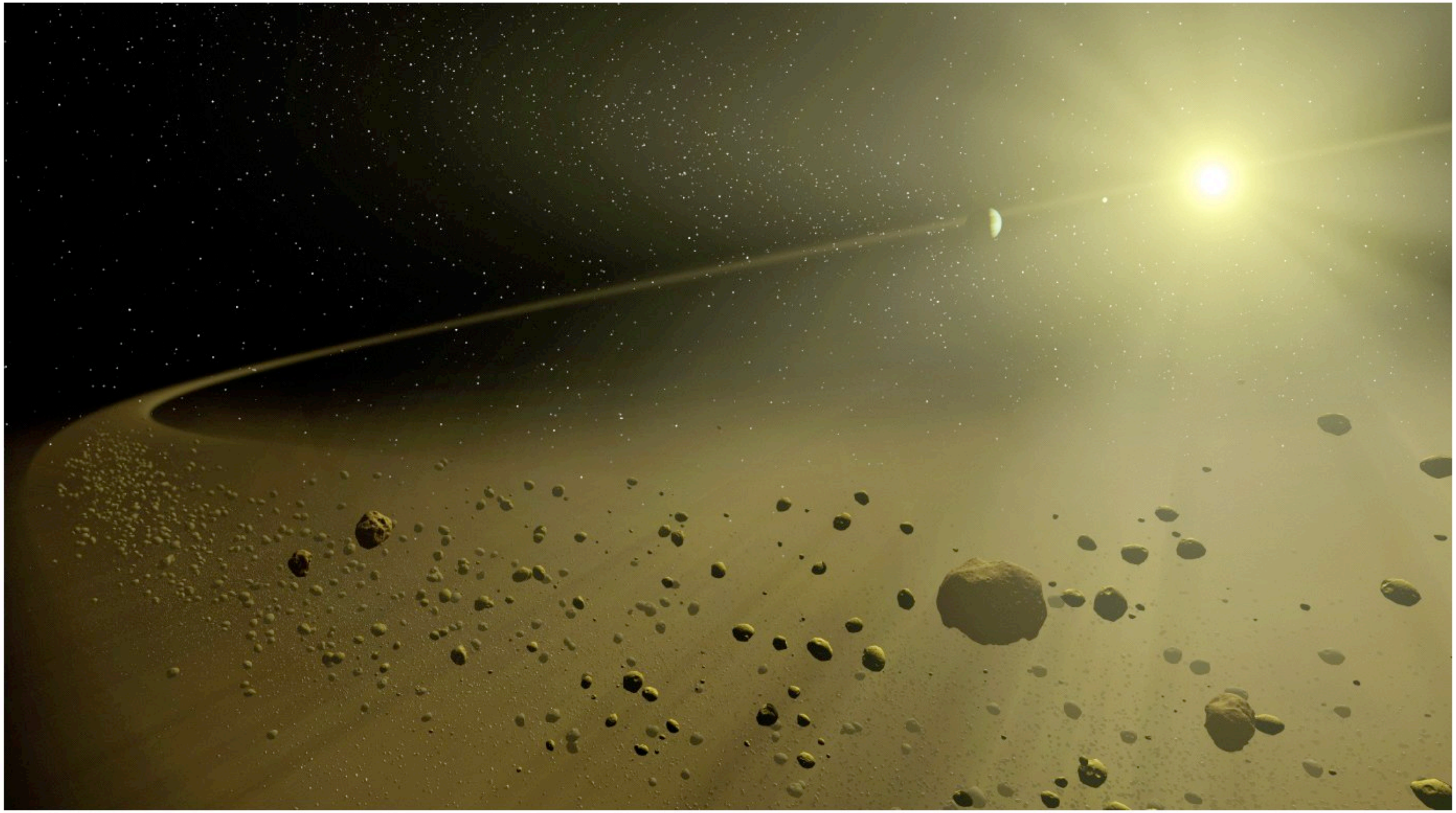
BBC Video

Jovian Planets and their satellites





The Kuiper Belt: The gravitational influence of the Jovian planets pushed small, icy objects to the outer reaches of the solar system past Neptune. The result shown in this artist's conception is the Kuiper belt, a ring populated by trans-Neptunian objects like Pluto, icy planetesimals, and dust.



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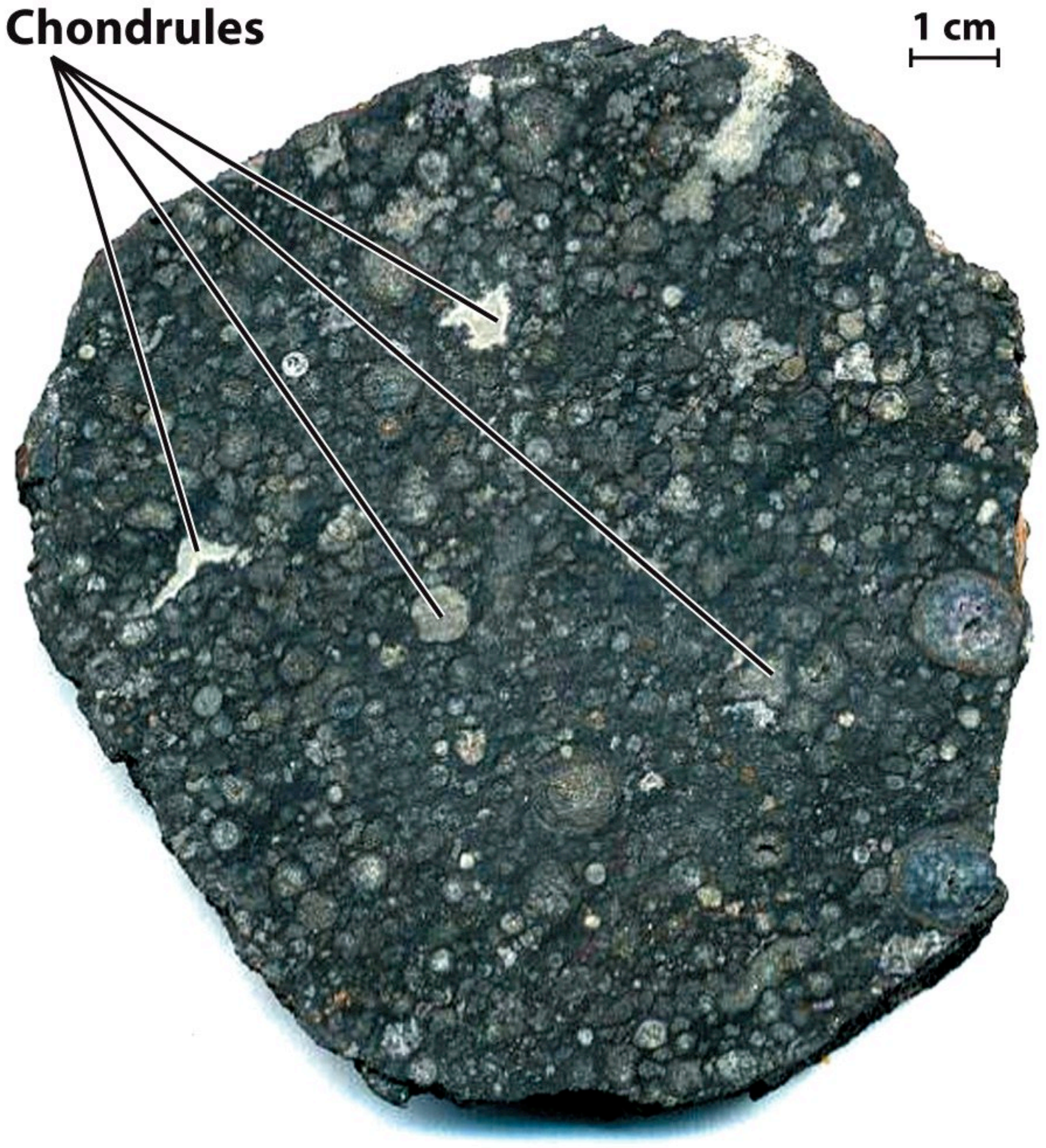

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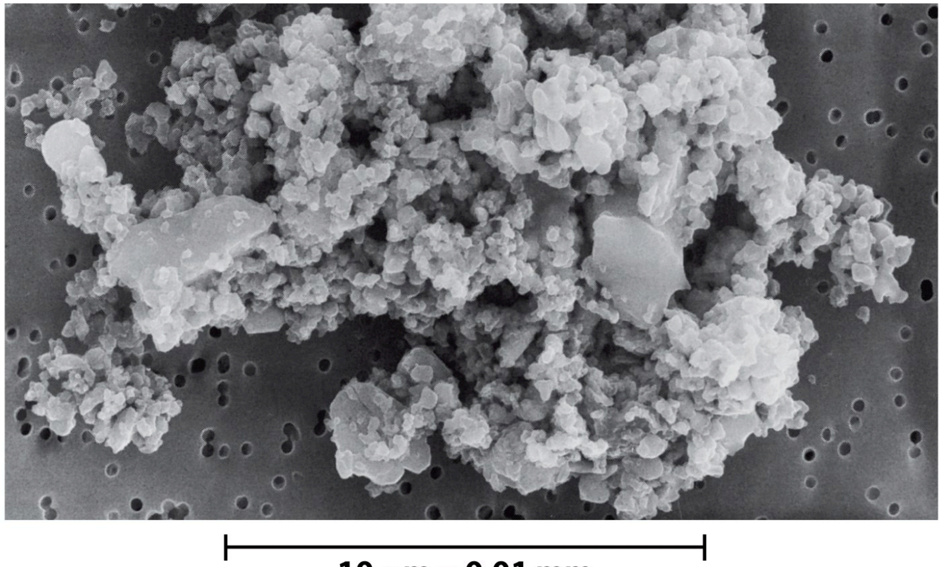
If you slice open a meteorite you see chondrules – regions that melted due to rapid heating and cooling in the early solar system.



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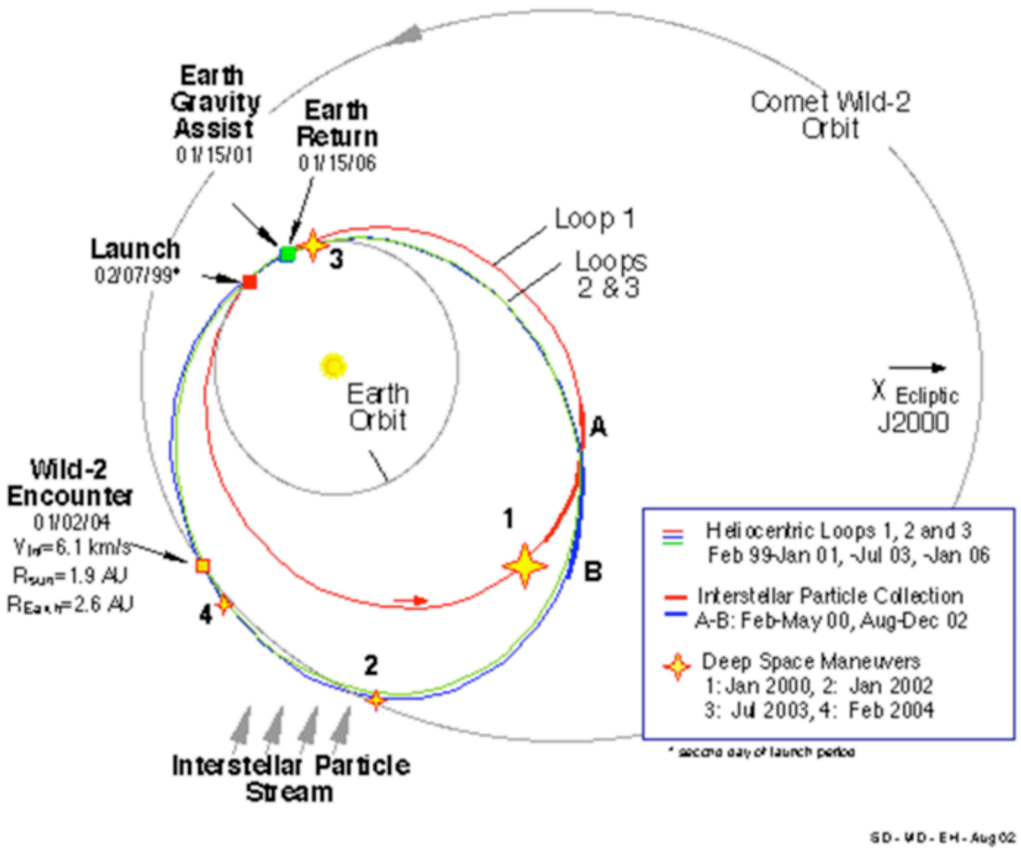
Stardust – mission to collect dust from interplanetary space and Comet Wild 2.

This highly magnified image shows a microscopic dust grain that came from interplanetary space. It entered Earth's upper atmosphere and was collected by a high-flying aircraft. Dust grains of this sort are abundant in star-forming regions like the Orion nebula. These tiny grains were also abundant in the solar nebula and served as the building blocks of the planets.



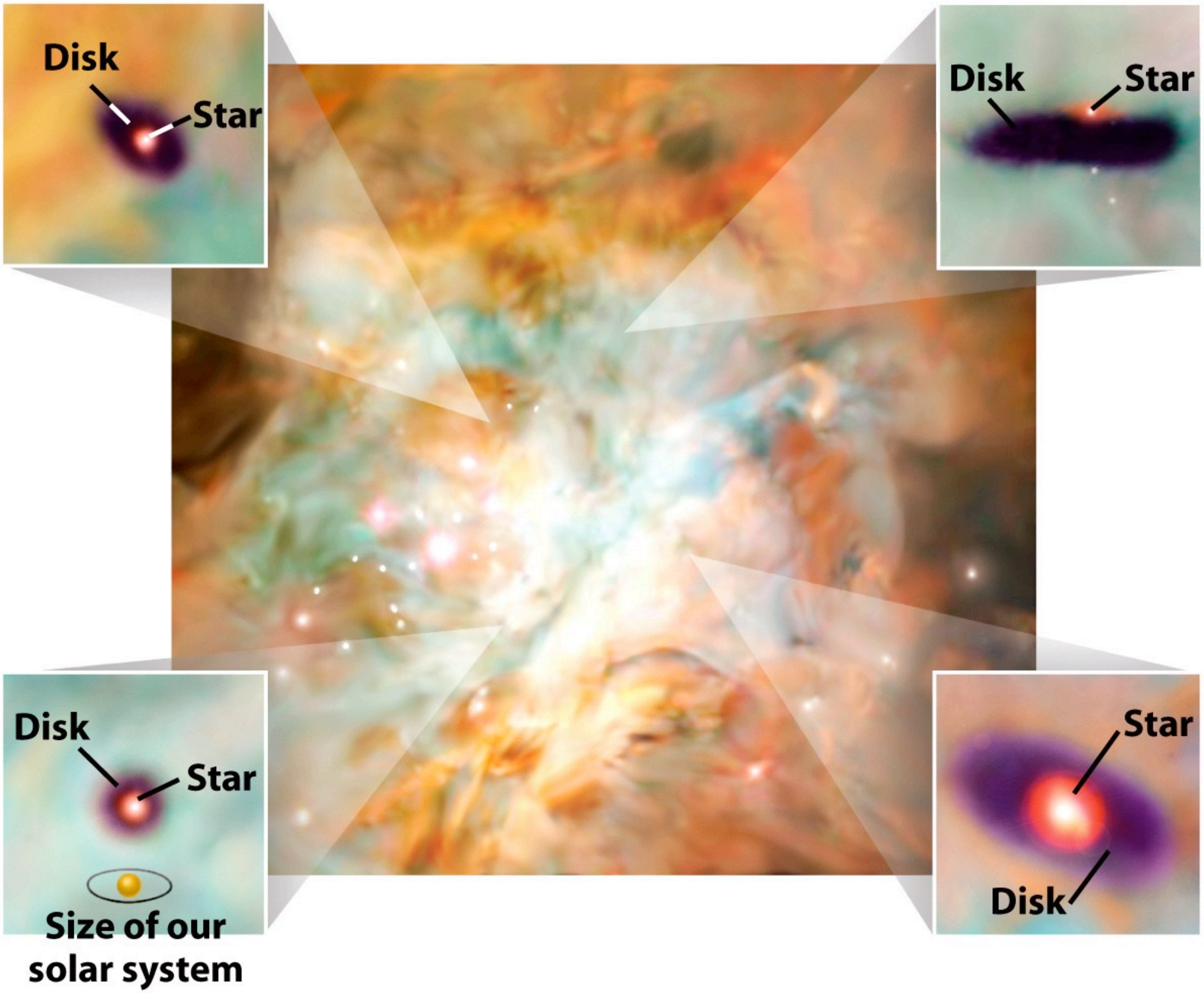
Question 11.2 (iclickers!)

- The formation of terrestrial planets around a star is thought to have occurred by what process?
  - A) Breakup of a large disk of matter which formed around the star
  - B) Condensation of gas from the original star nebula
  - C) Capture by the star of objects traversing the depths of space
  - D) Accretion or slow accumulation of smaller particles by mutual gravitational attraction

Question 11.3 (iclickers!)

- In order for the disk instability model to be able to account for the formation of the Jovian planets
  - A) The rocky material would have to be confined completely to the inner parts of the solar system
  - B) The gas in the nebular disk would have to be at the very high temperature
  - C) The gas in the nebular disk would have to be clumpy rather than smooth
  - D) The gas in the nebular disk would have to be mostly methane and ammonia rather than hydrogen and helium

Evidence from other worlds



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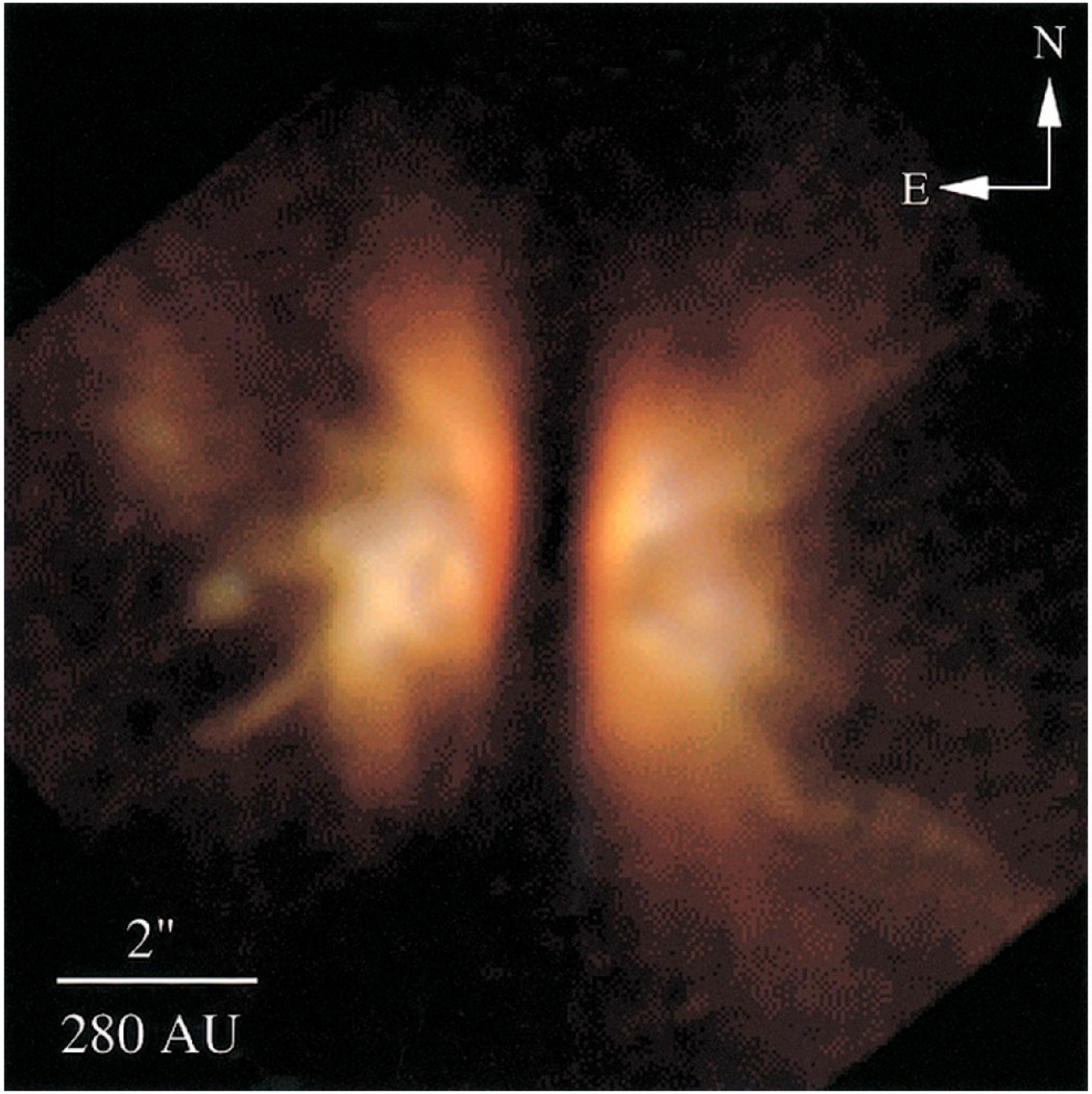

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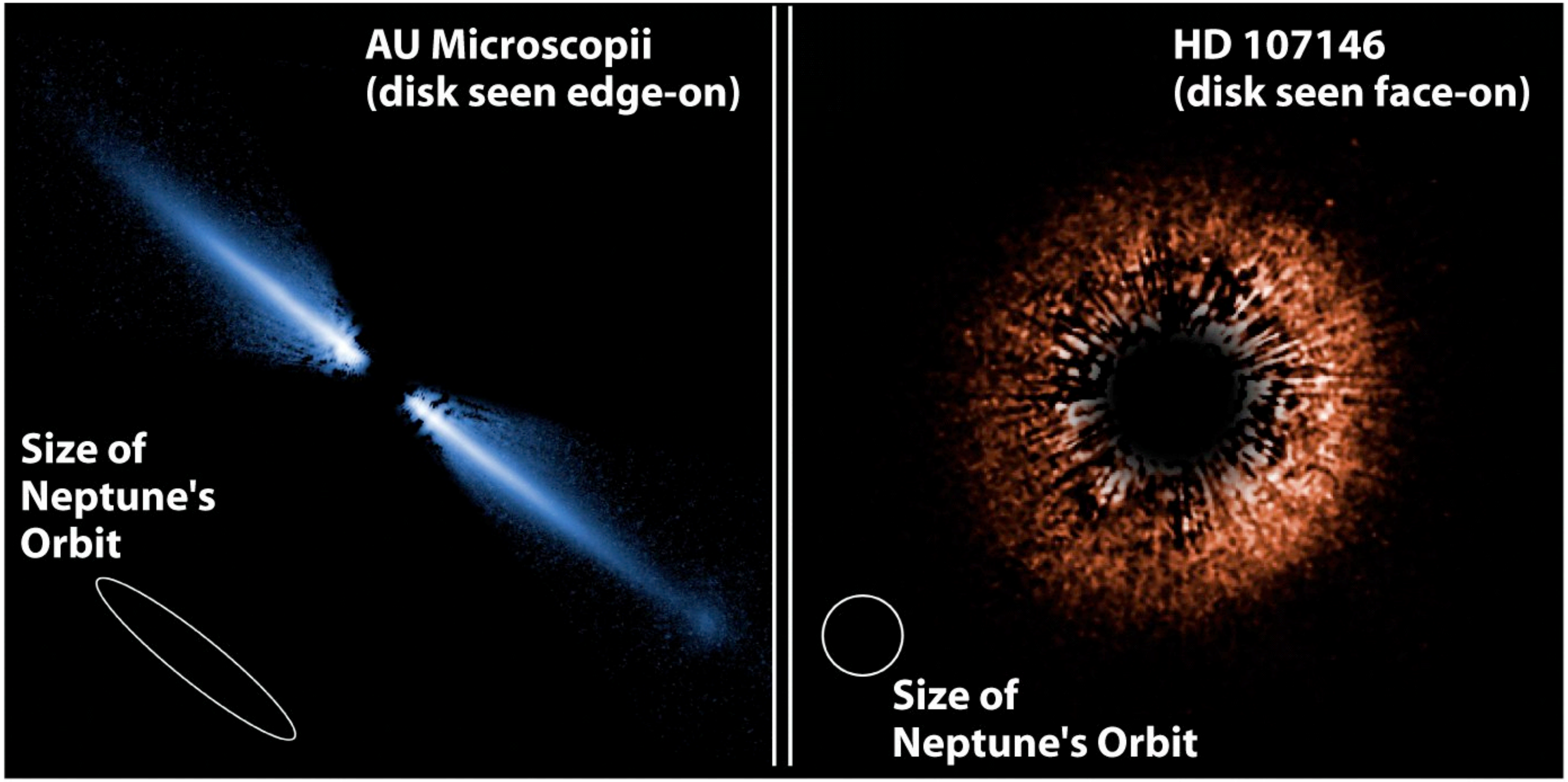
Infrared image showing IRAS 043022247, a young star that is still surrounded by a disk of gas and dust – it is much larger than our solar system and will shrink.



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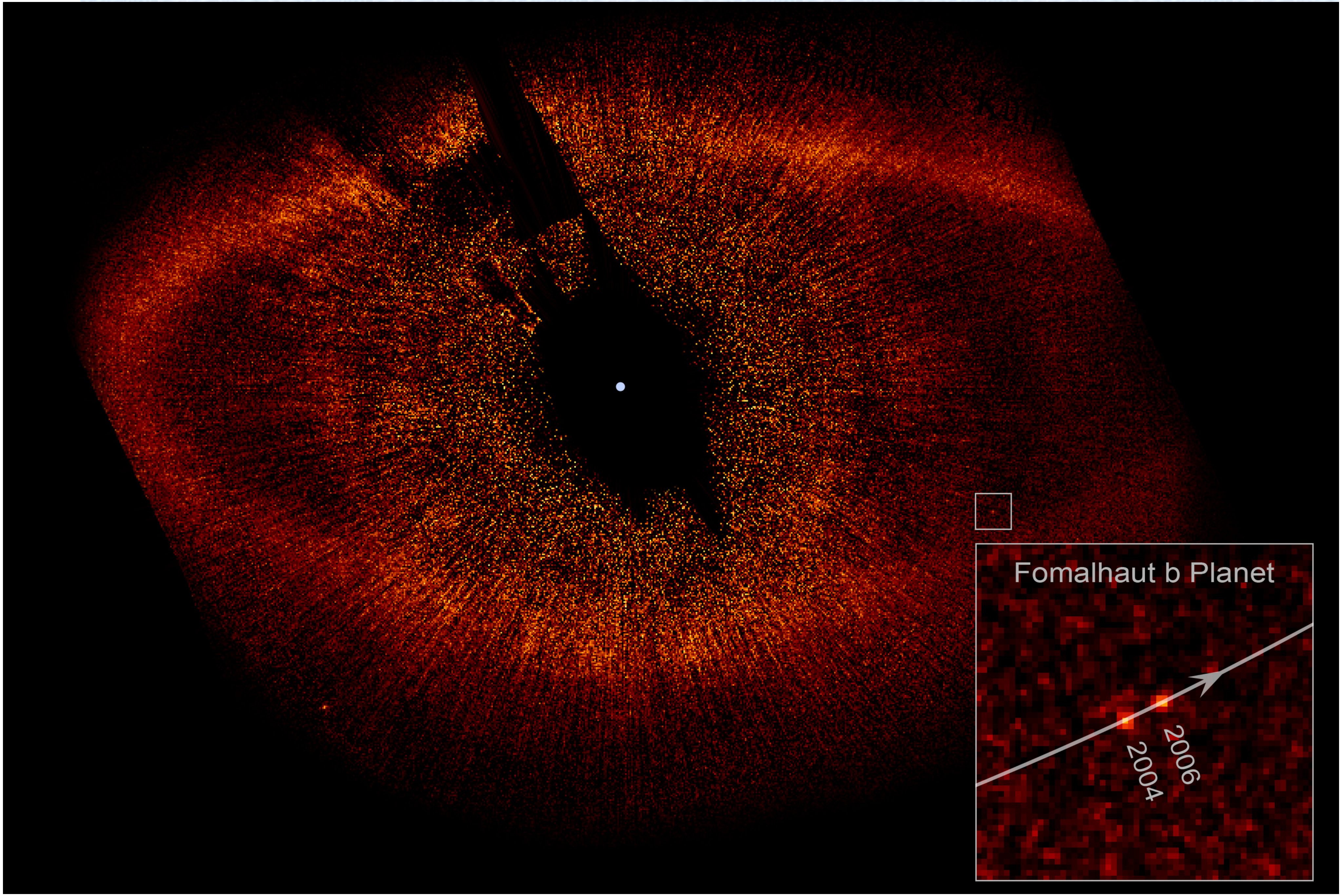
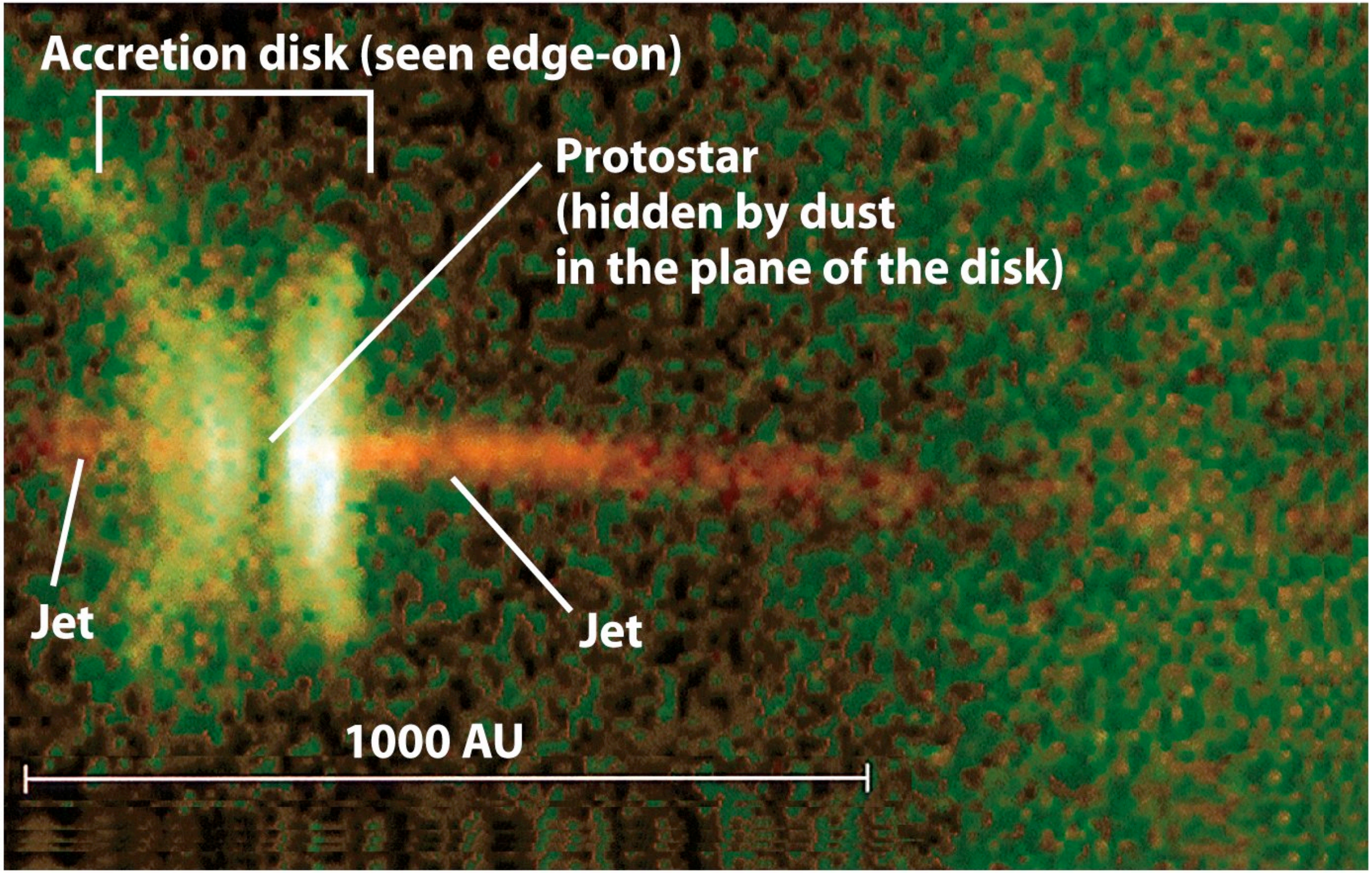

Fomalhaut b Planet
2006
2004



Jets from a young star

Figure 8-15a
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Summary

- Solar System Formation: the nebular hypothesis.
- The Sun:
  - formed by gravitational contraction of the center of the nebula.
- Terrestrial planets:
  - formed through accretion of dust particles into planetesimals, then into larger protoplanets.
- Jovian planets:
  - Began as rocky protoplanetary cores, similar in character to the terrestrial planets. Gas then accreted onto these cores.
  - Alternatively, they formed directly from the gases of the solar nebula. In this model the cores formed from planetesimals falling into the planets.

The End

See you on wednesday