The Essential Cosmic Perspective

Lecture 7
Overview and Formation of the Solar System

September 26, 2018

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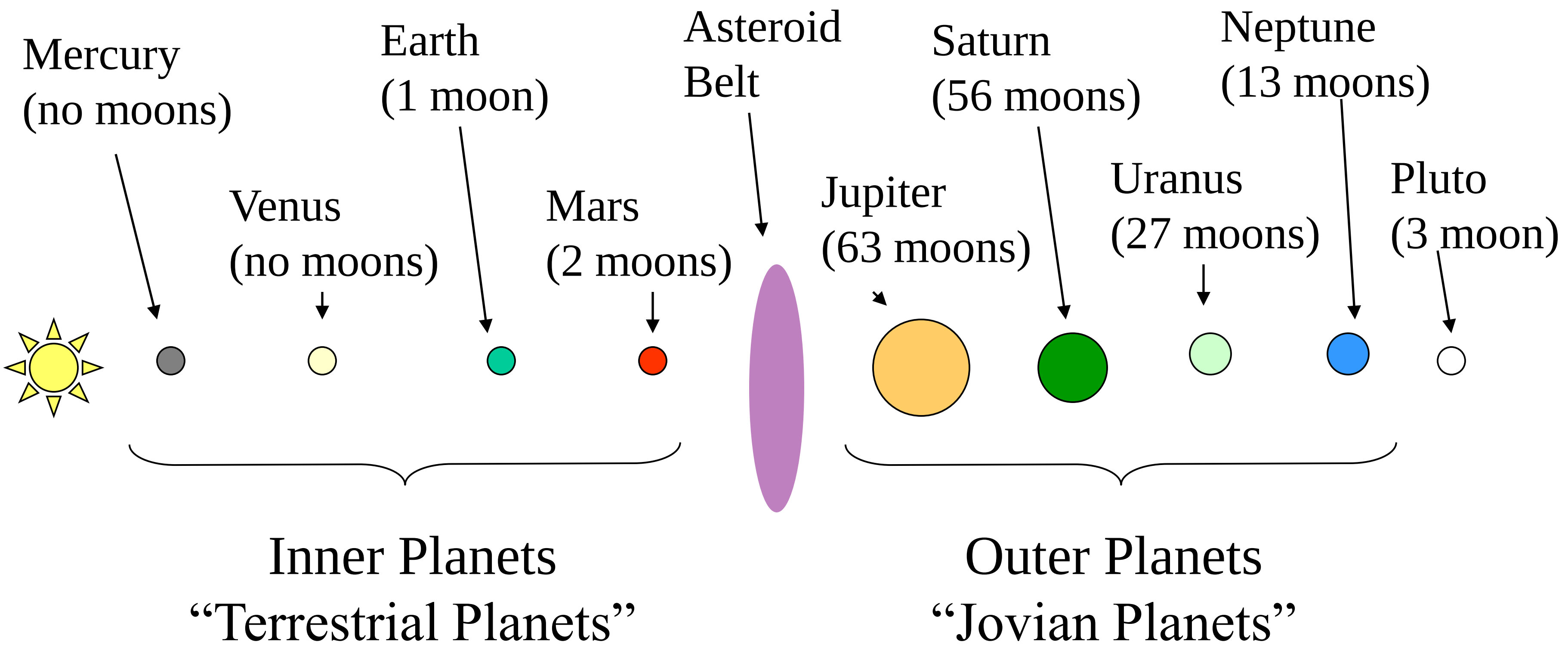
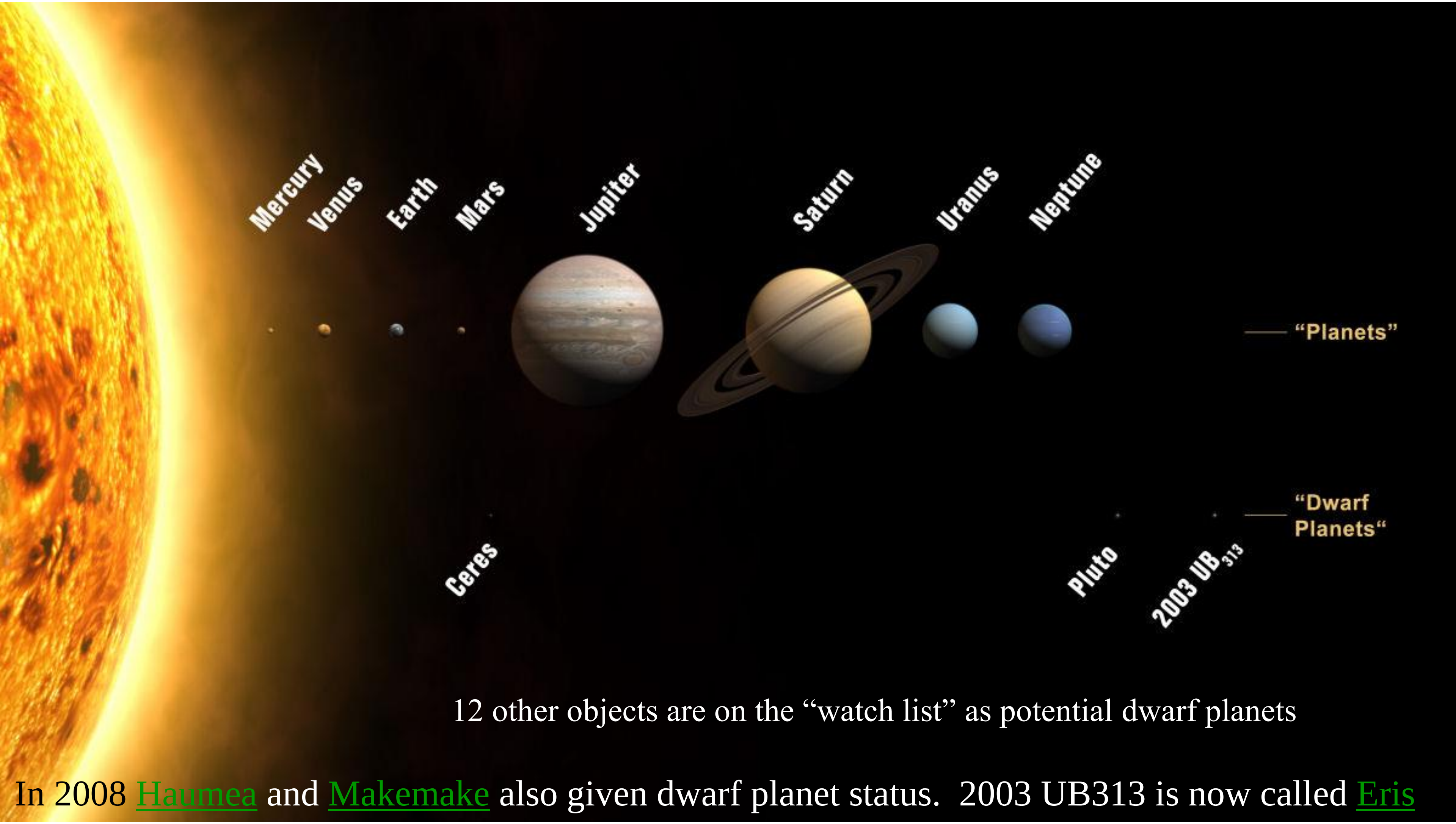
Overview of the Solar System



New Solar System – August 2006

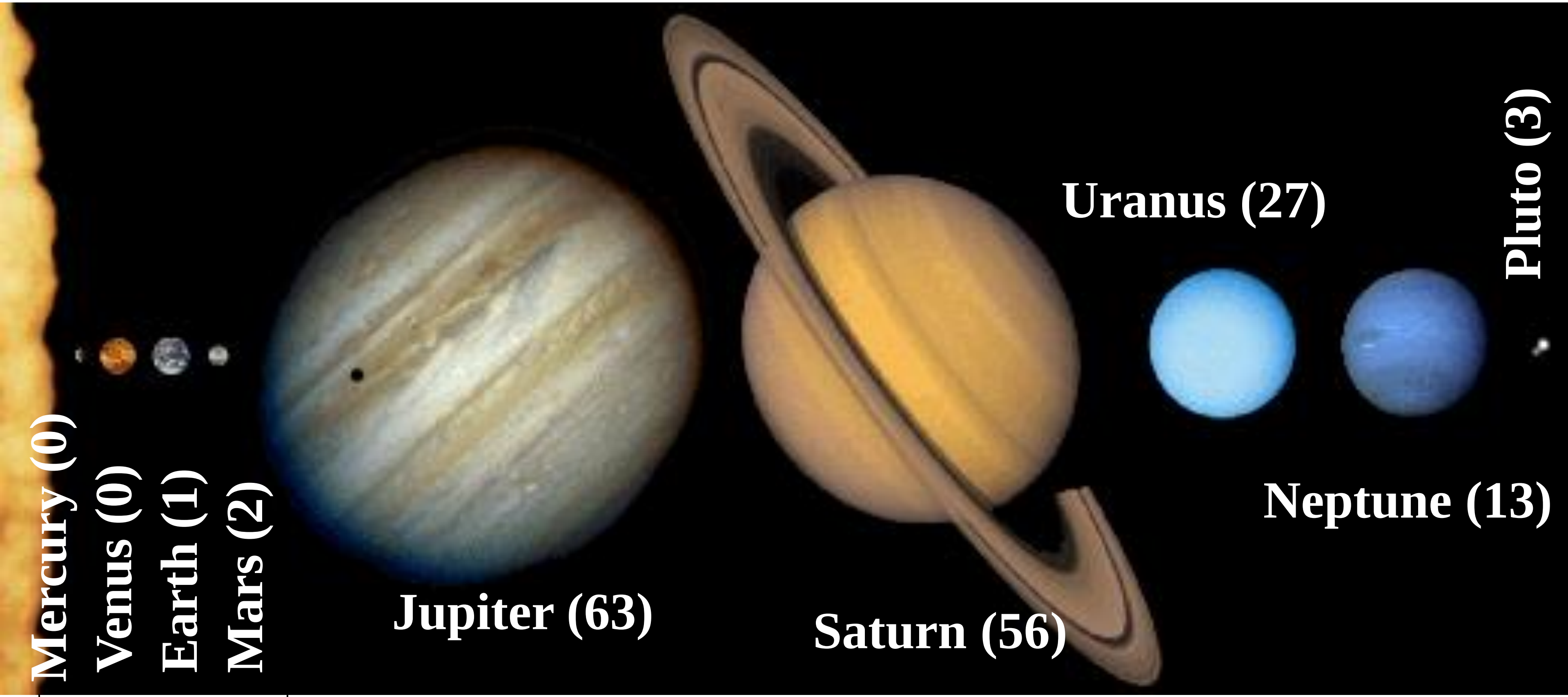


12 other objects are on the "watch list" as potential dwarf planets

In 2008 Haumea and Makemake also given dwarf planet status. 2003 UB313 is now called Eris

It is possible as many as 200 dwarf planets could be identified once the Kuiper Belt is explored.

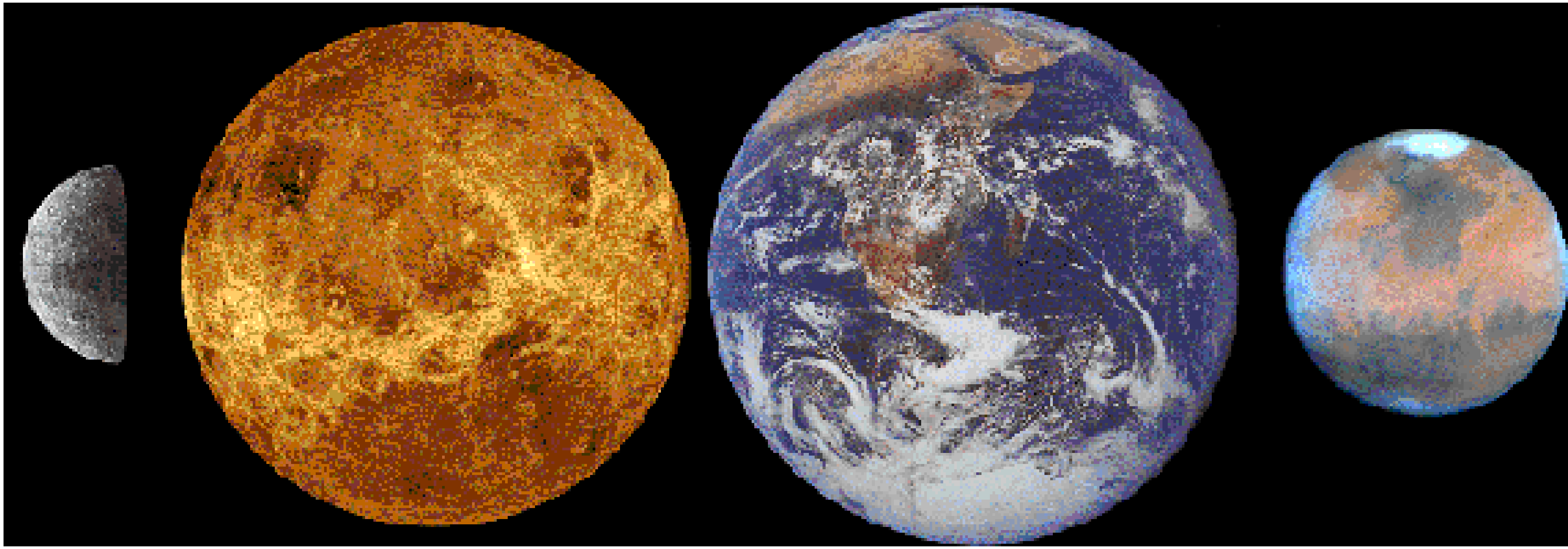
Solar System -- Size Scale



Inner Planets
or
Terrestrial
Planets

Outer Planets or
Jovian Planets
(do not include Pluto)

Terrestrial Planets



Size = small

Composition = Rock/Metal

Spin = slow

Moons = few

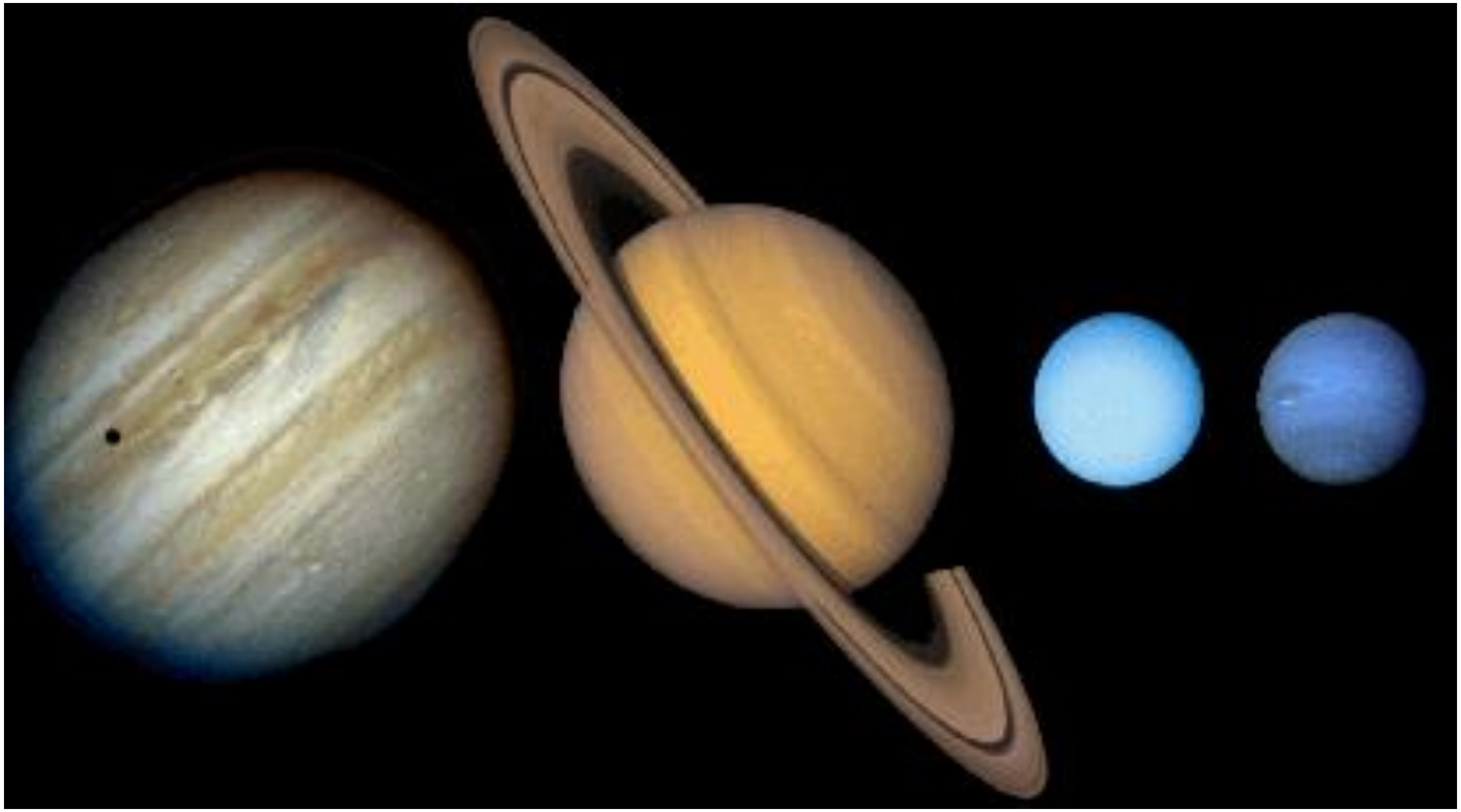
No rings

Do not generate much internal heat

Atmosphere = Oxygen Rich

Magnetic Field = None or weak

Jovian Planets



Size = large

Composition = Gas/liquid

Spin = fast

Moons = many

All have rings

Generate internal heat (not Uranus)

Atmosphere = Hydrogen Rich

Magnetic Field = Strong

Solar System Links

Simulation (click “Animate” to set into motion)

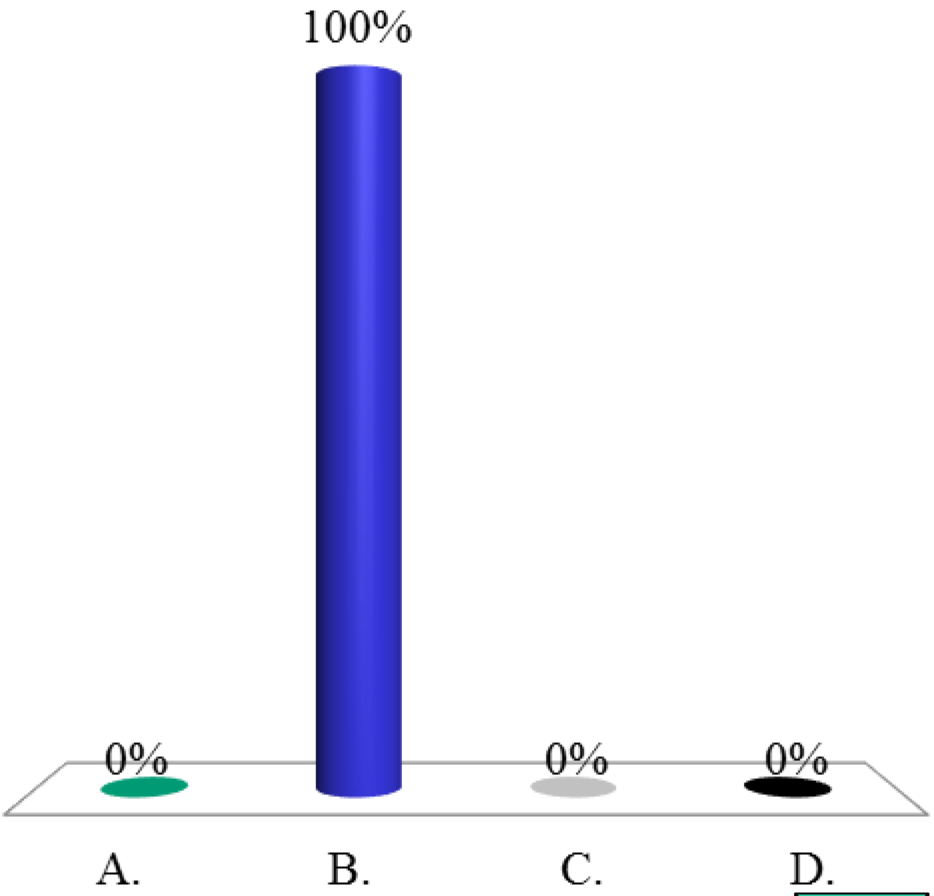
NASA Interactive simulator (creates static images)

NASA Solar System Exploration

Welcome to the Planets

Suppose a new solar system object is discovered that has a low density, a high magnetic field, and rotates rapidly. It is likely

A. a terrestrial planet.
B. a Jovian planet.
C. an asteroid.
D. a comet.



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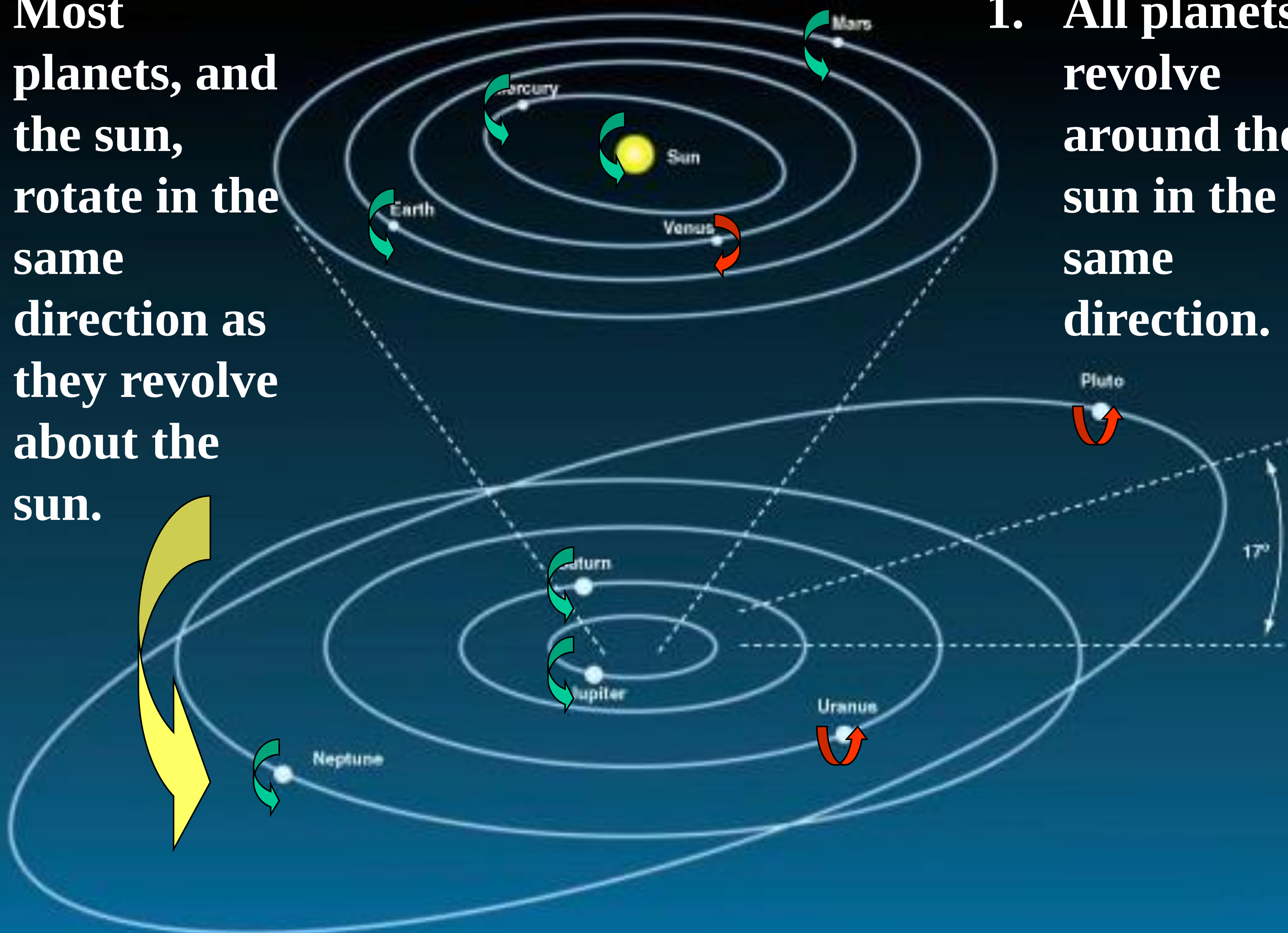
Clues for the Formation of the SS

- All planets orbit in roughly the same plane about the Sun.
- All planets orbit in the same direction about the Sun.
- Most planets rotate in the same direction.
- There are distinct differences between Inner and Outer planets

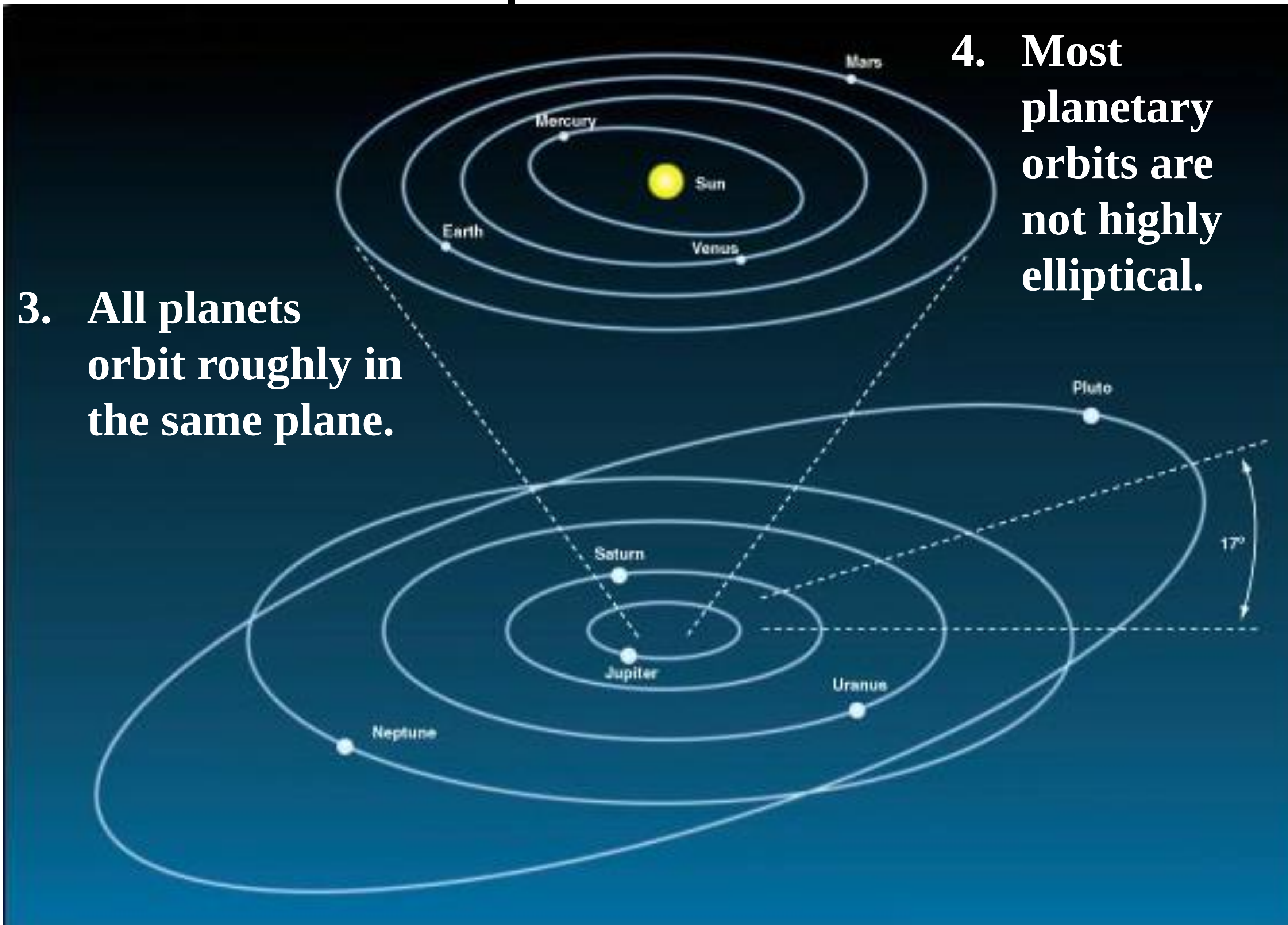
Orbital Properties of the Planets

2. **Most planets, and the sun, rotate in the same direction as they revolve about the sun.**

1. **All planets revolve around the sun in the same direction.**



Orbital Properties of the Planets



3. **All planets orbit roughly in the same plane.**
4. **Most planetary orbits are not highly elliptical.**

The Solar Constant (see also Ch.12 pp.306-307)

$$S_{\oplus} = \frac{\text{Solar energy received at Earth}}{\text{(per unit time)(per unit area)}} = 1400 \text{ Watts/m}^2$$

- For other planets:

  Solar constant at distance r (in AU) $= \dfrac{S_{\oplus}}{r^2}$

  – Mars: $r = 1.5$ AU $\quad S(\text{Mars}) = \dfrac{S_{\oplus}}{(1.5)^2} \approx 0.44\, S_{\oplus}$

  – Neptune: $r = 30$ AU $\quad S(\text{Neptune}) = \dfrac{S_{\oplus}}{(30)^2} \approx 0.001\, S_{\oplus}$

- It is MUCH colder in the outer regions than in the inner region

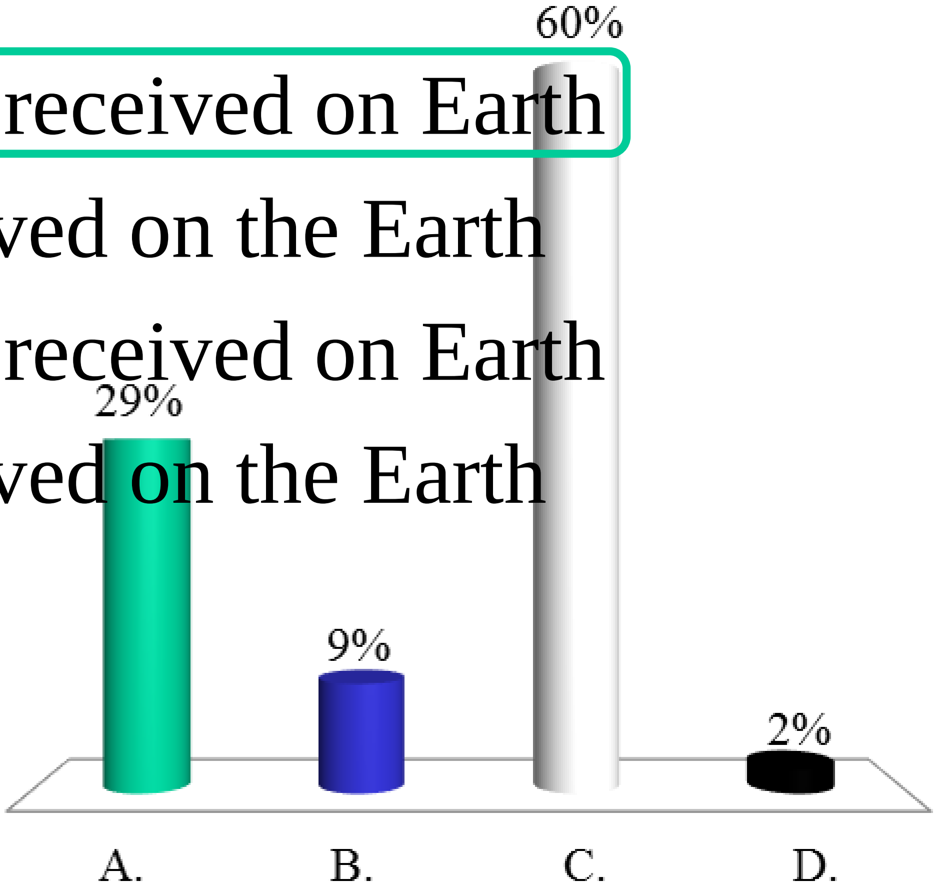
A spacecraft going to Mercury is at a distance of ½ AU from the Sun. How much light does its solar panels received compared to when it was on the Earth?

A. 4 times the amount it received on Earth

B. ¼ the amount it received on the Earth

C. 2 times the amount it received on Earth

D. ½ the amount it received on the Earth



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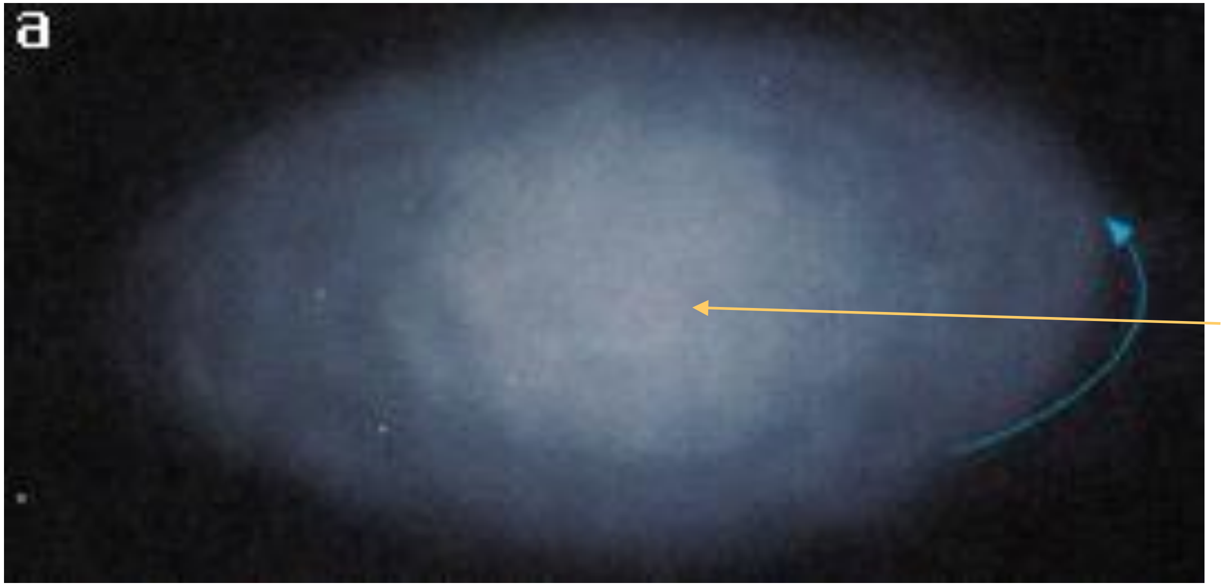
Condensation Temperature

- Condensation occurs when a gas cools and its molecules stick together to form a liquid or a solid
- Condensation occurs below a critical temperature that is different for different materials
- Metals and rocks: 1300 K to 1600 K
- Water, methane, ammonia “ices”: 100 K to 300 K

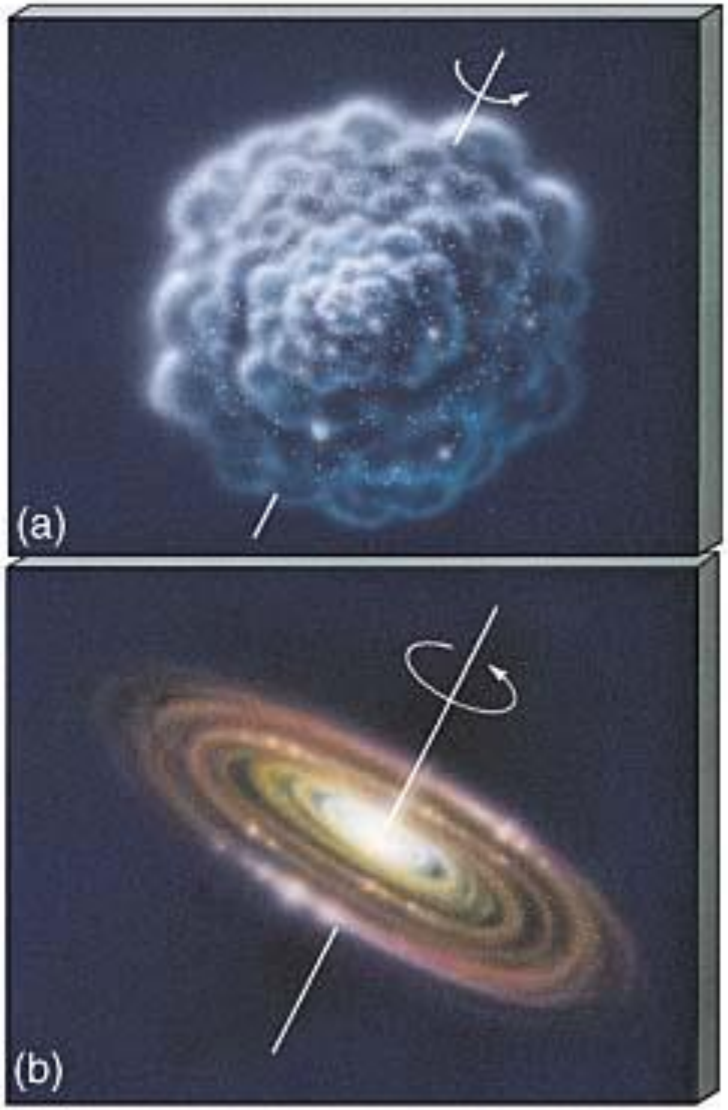
Formation of the SS – Nebular Theory

- Interstellar gas and dust contracts due to gravity
  - Size ~100 AU and ~2 M_{Sun}
  - Hydrogen and Helium and some trace elements
  - Started ~4.6 billion years ago.
  - Gas was very cold.



Gravity Collapses Cloud

- Cloud collapses, rotates faster
  – Conservation of Angular Momentum -- ice skater pulls arms in, spins faster.
- Central core forms.
- Cloud flattens
  – No rotation to stop collapse



Disk Forms

- High pressure near center pushing inward (gravity)
- Temperature near center increases
- Proto-Sun begins to glow

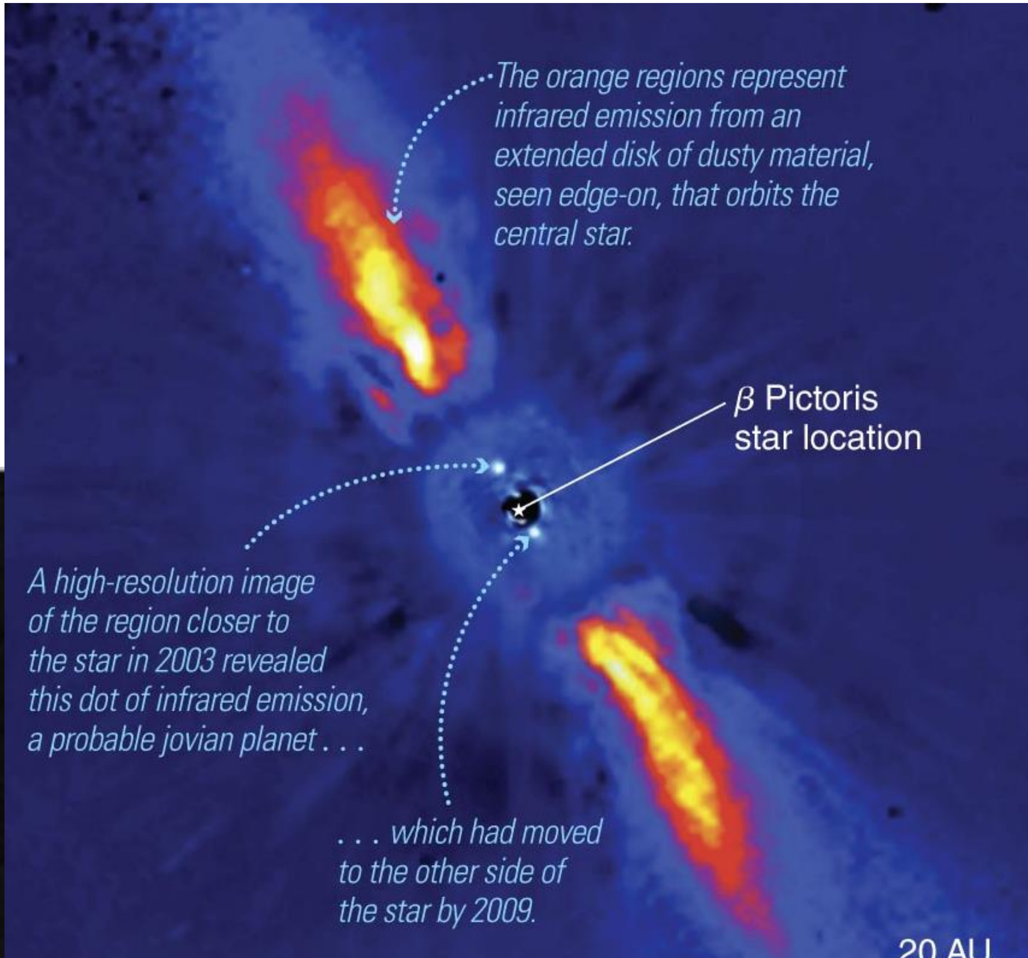


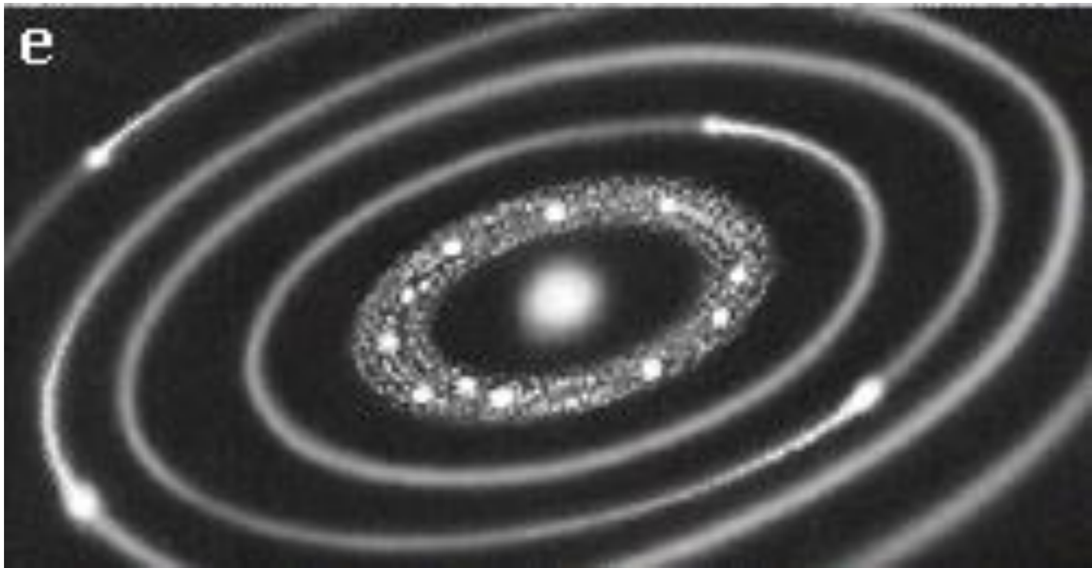
Fig. 6.16a (European Southern Observatory)

Planetesimals Form

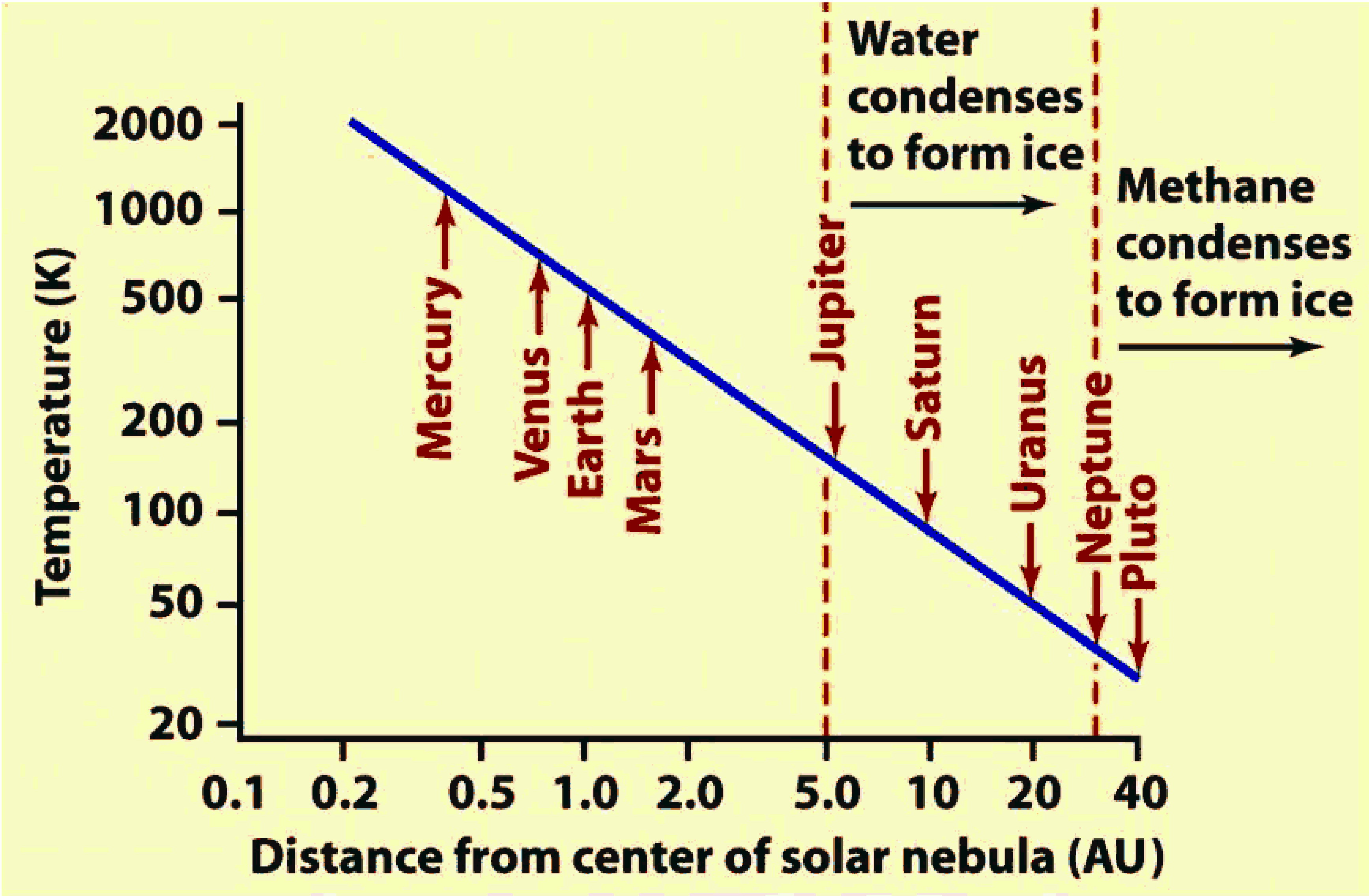
- Material in cloud clumps and collides
  - Form larger bodies through accretion
- Temperature high near proto-Sun.
  - Ices and gases in inner regions are vaporized
  - Planetesimals cannot hold on to light elements;
  - Lighter material moves outward
  - Only heavier elements remain near Sun.

Planets Form

- Outer planets form from all material
  - Cooler away from Sun
  - Planets can capture gases
  - Mainly gases (H and He), little rock and metal.
- Inner planets form from rock and metals.
  - Warmer near Sun
  - Only heavier elements remained near proto-Sun

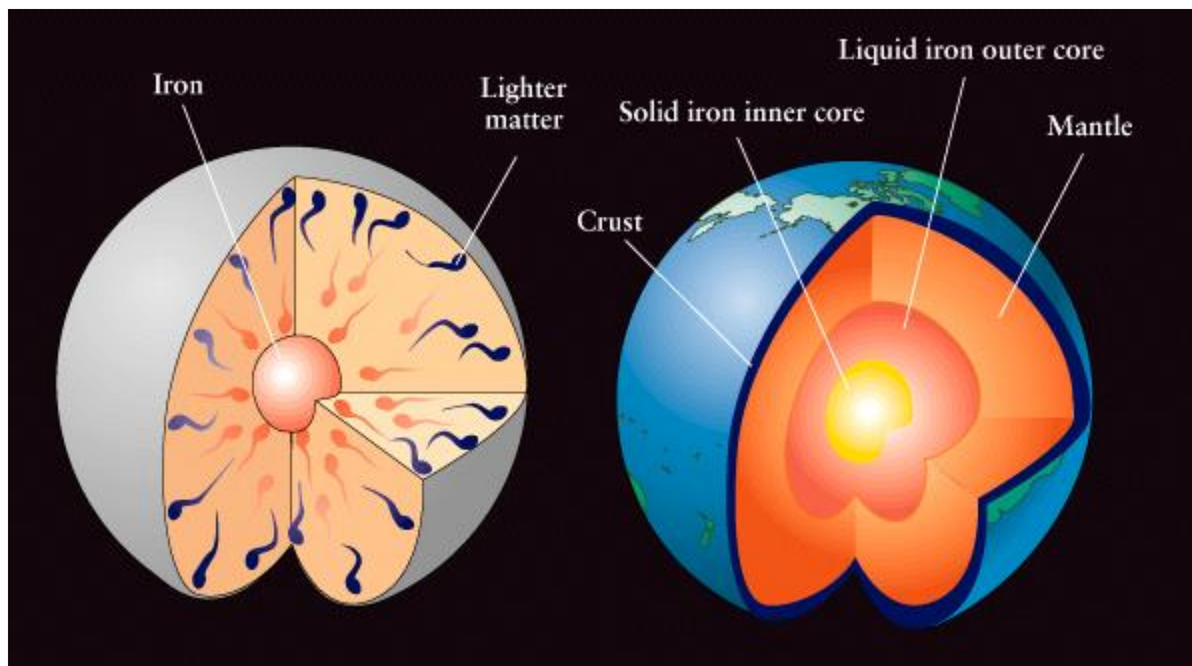


Temperature Distribution in the Solar Nebula



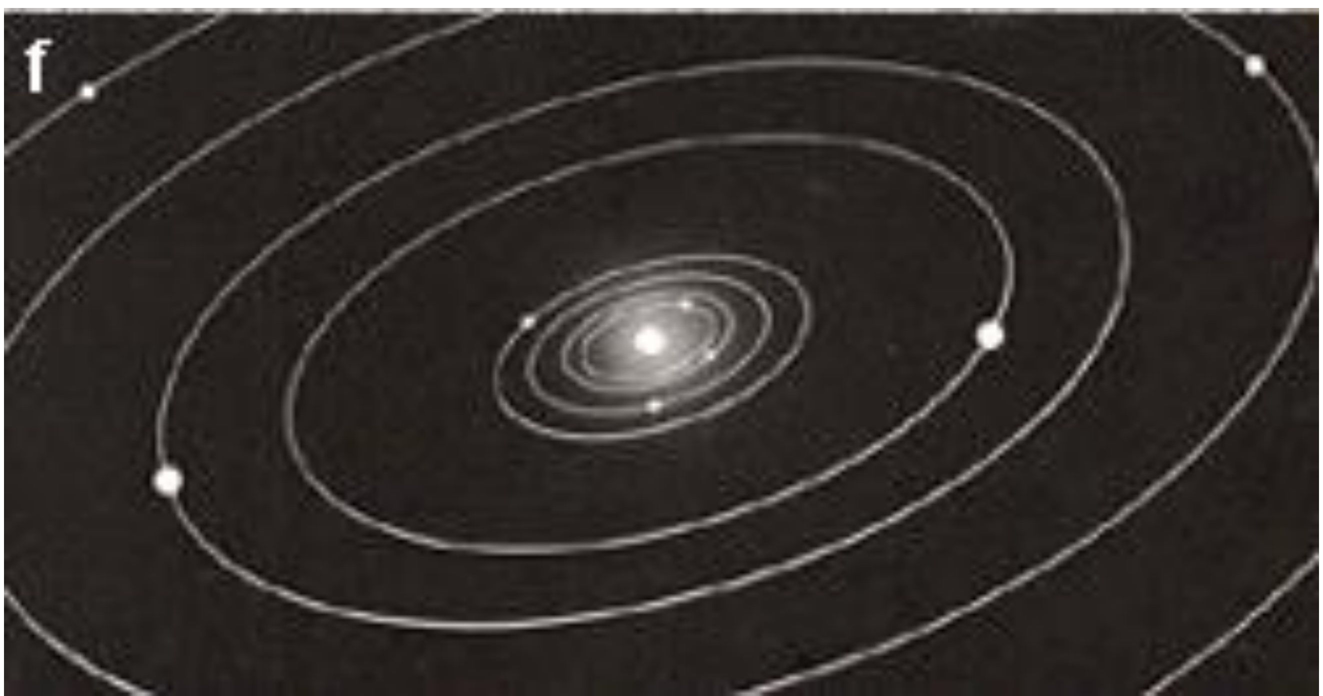
Planets are Differentiated

- Denser material moves inward in a liquid or gaseous planet
- Terrestrial planets were molten during early stages.
  - Metals found closest to center
  - Rocky material in outer parts of planet



Sun Forms

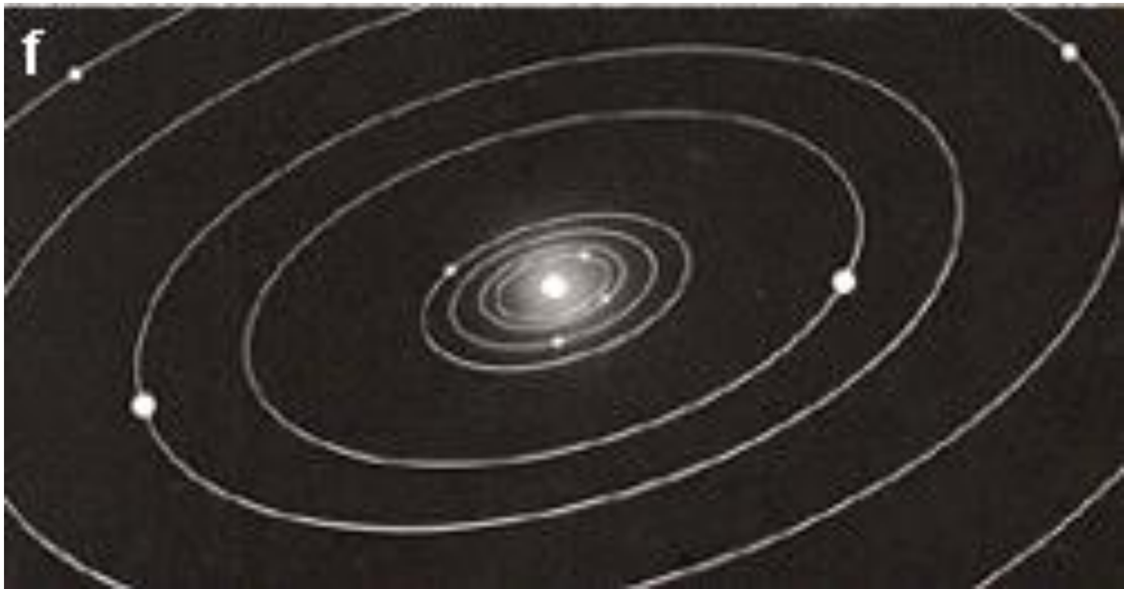
- Sun obtains sufficiently high pressure and temperature in core to start fusion
  (converts hydrogen to helium and produces energy)
- Gravitational contraction ends when energy balance achieved via core fusion (chapter 13)
- This is the time it officially becomes a star.



Solar System Today

- Process took ~100 million years.
- Planets still bombarded by left-over material (asteroids, meteoroids, and comets).
- 99.8% of the total mass is in the Sun; it’s nearly a thousand times more massive than everything else combined!

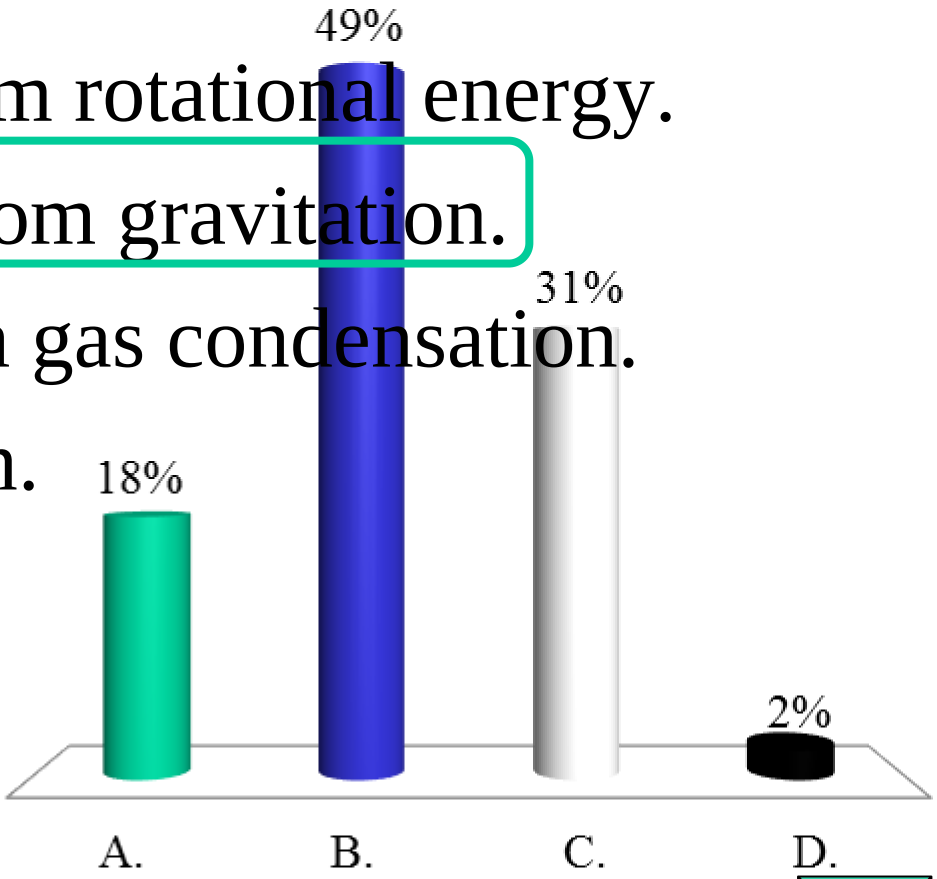
NASA movie



"Movie" of Solar System Formation

What process heated the early solar nebula as it slowly condensed toward a central protosun?

A. Frictional heating from rotational energy.
B. Collisional heating from gravitation.
C. Thermal heating from gas condensation.
D. Thermonuclear fusion.



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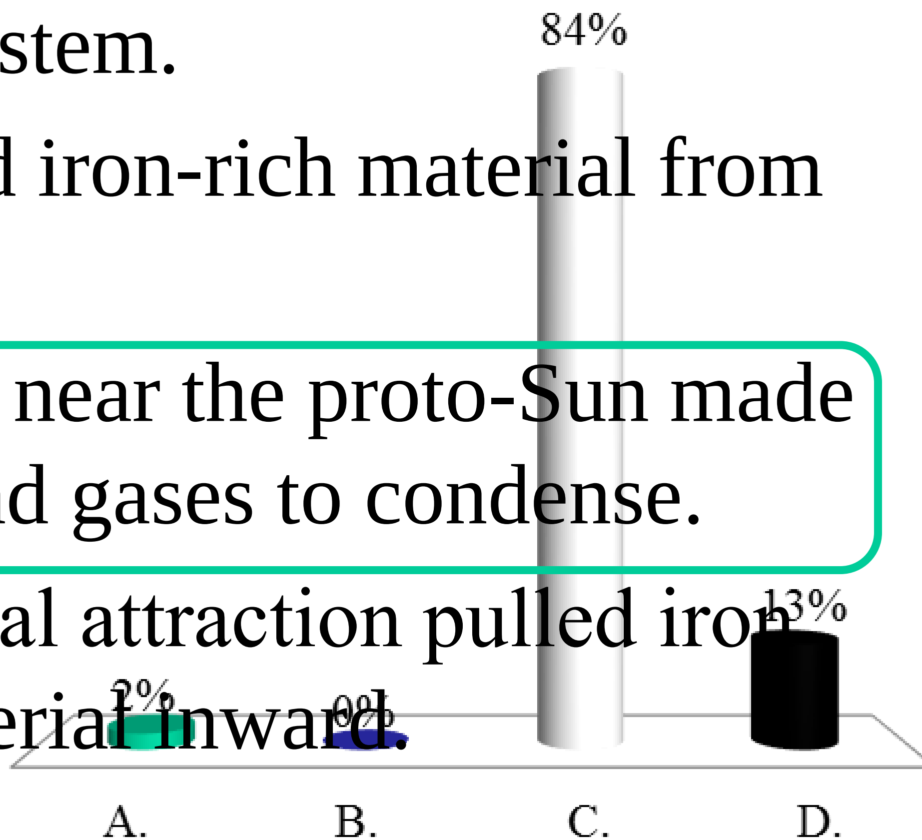
One explanation of why the planets near the Sun are composed mainly of rock and iron is that

A. the Sun’s magnetic field attracted all the iron in the young solar system.

B. the proto-Sun ejected iron-rich material from its surface.

C. the high temperature near the proto-Sun made it difficult for ices and gases to condense.

D. the Sun’s gravitational attraction pulled iron and other heavy material inward.



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Exam 1 Information

- Bring a #2 pencil!
- Bring a calculator. No cell phones or tablets allowed!
- Contents:
  - Star chart (20 points)
  - True/False (10 questions, 20 points)
  - Multiple Choice (30 questions, 60 points. Four of these require a calculation. One is about the contents of the Stephen Chew videos. See also the notes from lecture #1)