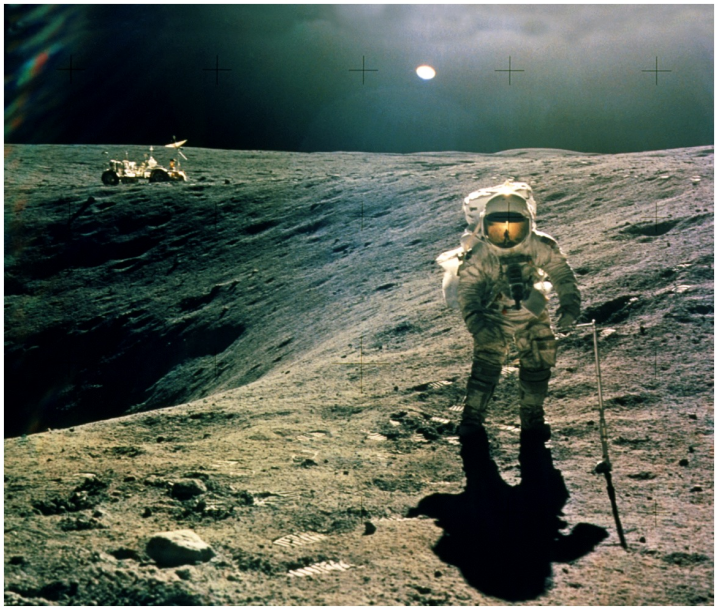
Astronomy 1 – Fall 2019



Chapter 10 Opener
Universe, Tenth Edition
John Young, *Apollo 16*, Science Source

iClicker problems? Try setting the frequency to AB like this:

1. Press and hold the power (labeled on/off) button until the Power light begins to flash.
2. Enter the frequency code using the buttons A, B, C, or D on the iclicker. The frequency code is 2 characters and should match the frequency of the instructors.
3. After entering the frequency code correctly, the power light will stop flashing

For more information, please see iclicker support

Lecture 8: October 23, 2019

Today on Astro 1

- How did the solar system form?
  - History inferred from craters
  - Composition from meteorites
- How did the moon form?
  - Not all satellites formed this way.
  - Satellites of other planets

Craters Reveal Geological History

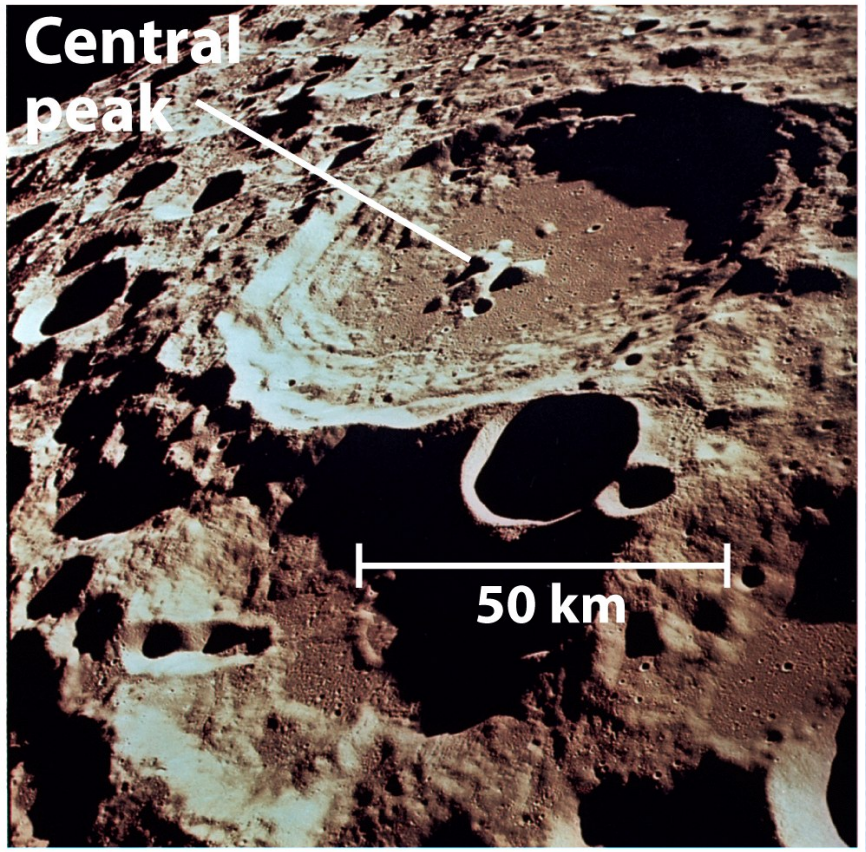


Figure 7-10a
Universe, Eighth Edition

- Asteroids/Comets on elongated orbits, can collide with planet/satellite

- Jovian planets: swallowed by atmosphere
- Terrestrial planets: impact crater (central peak!)

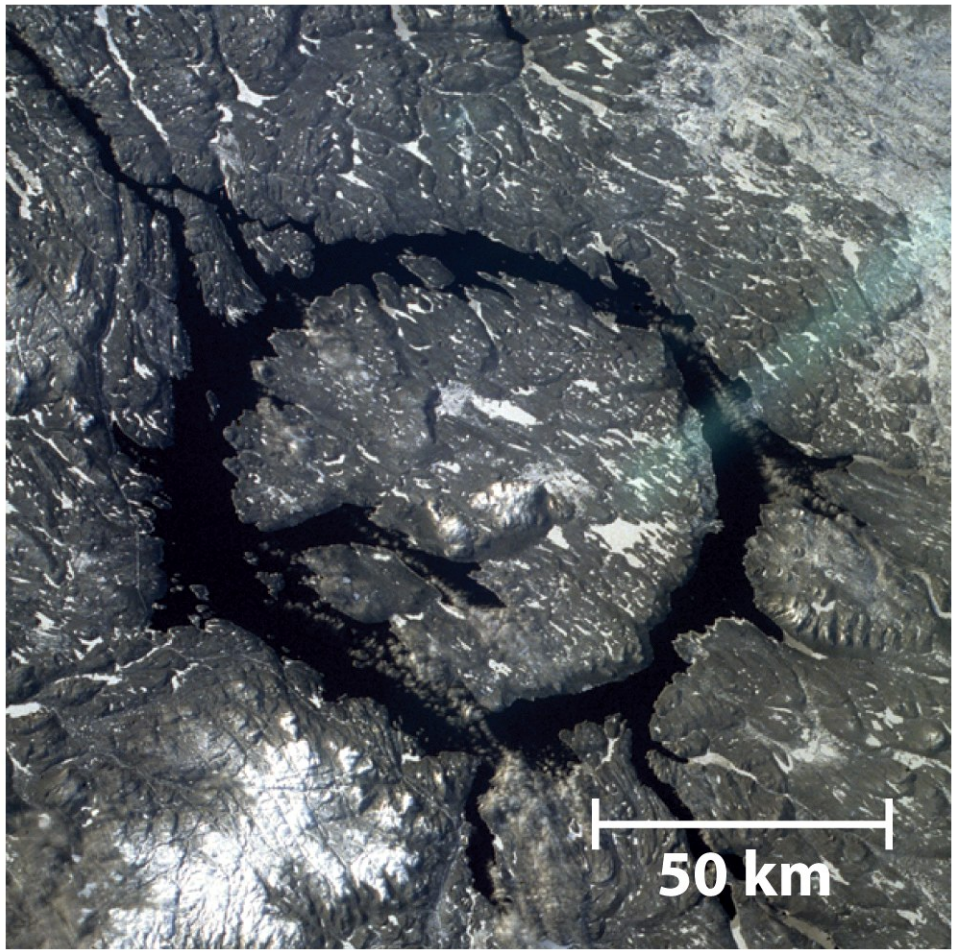


Figure 7-10b
Universe, Eighth Edition

Earth:

- Only < 200 craters
- Manicouagan Reservoir in Quebec
- Relic of a crater formed >200 million years ago; eroded by glaciers

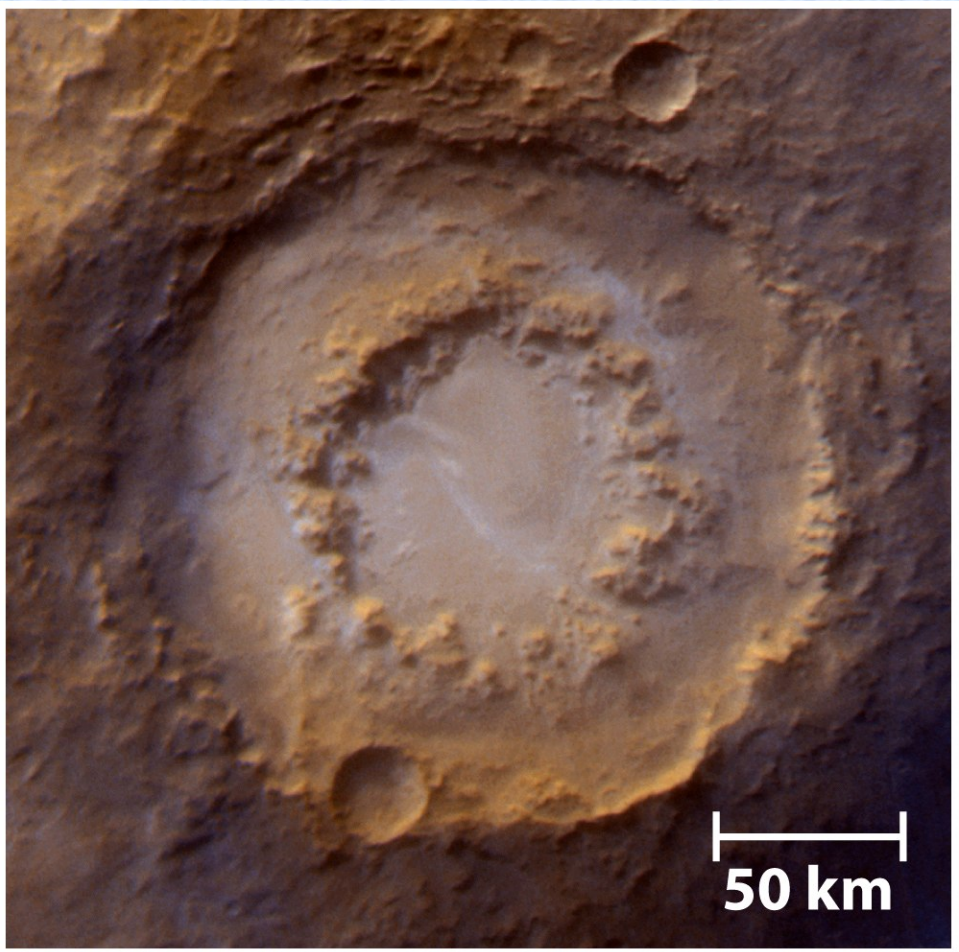


Figure 7-10c
Universe, Eighth Edition

Mars:

- Lowell Crater in the southern highlands, 201 km (125 miles) across
- Craters on top of craters
- Light-colored frost: condensation of carbon dioxide from atmosphere

Observations:

- LARGER worlds have more geological activity (volcanoes, faults, etc.)

- SMALLER worlds (the Moon, Mercury, Mars) have more craters than larger worlds (Earth, Venus)

- **What's the connection?**
  - **Geological activity erases craters**
  - **Larger planets must be more geologically active.**

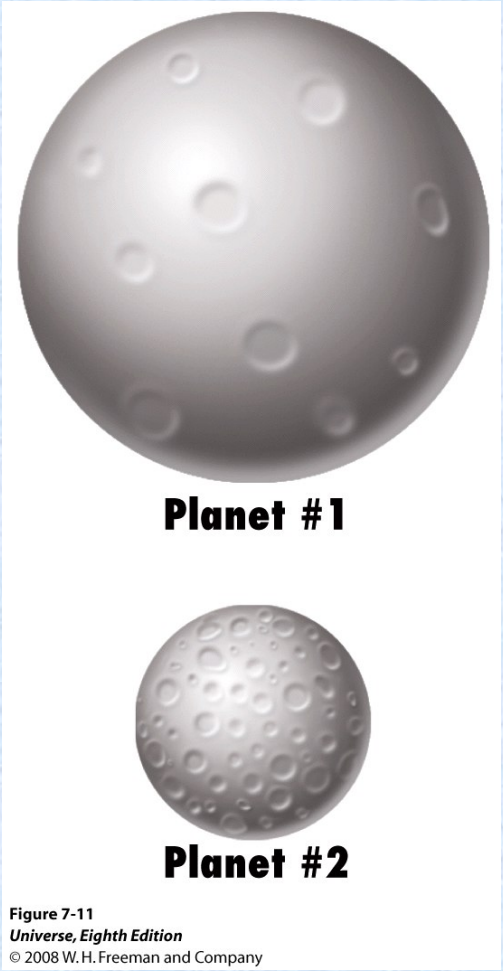


Figure 7-11
Universe, Eighth Edition

The Moon's Surface

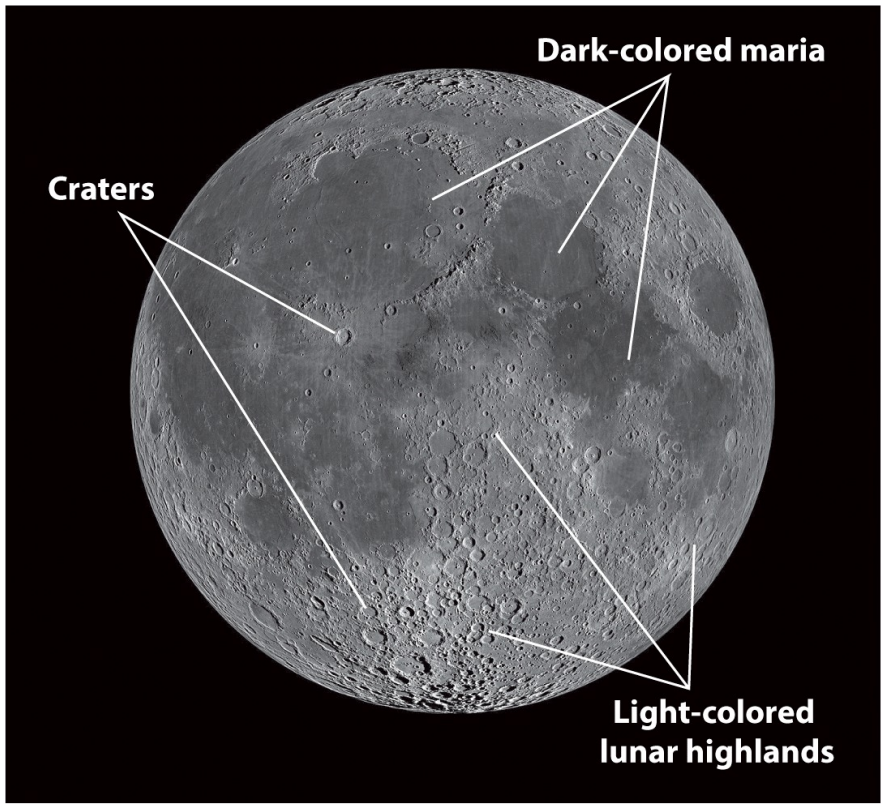
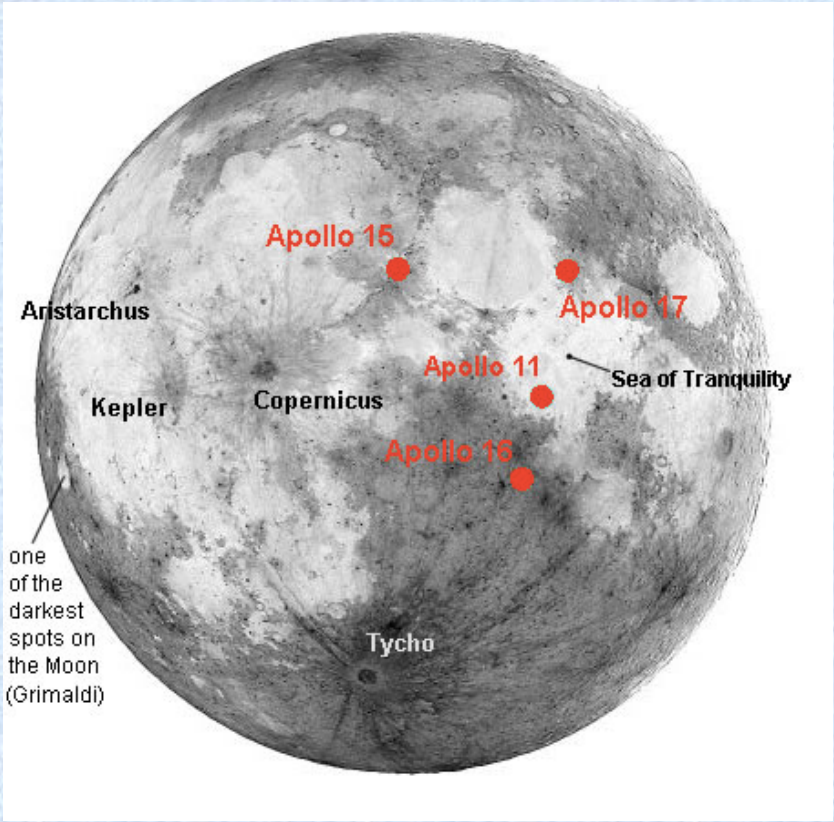
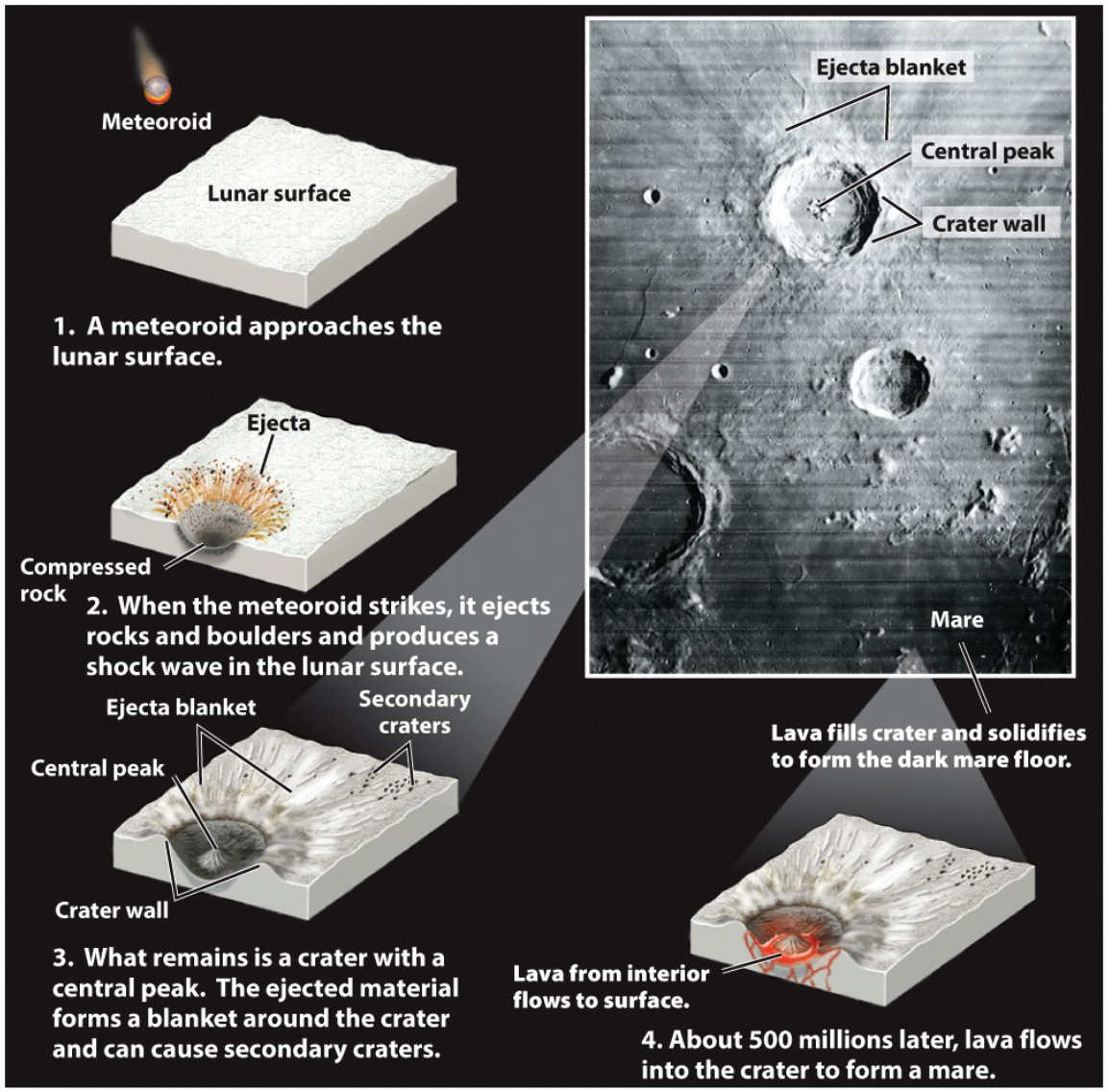


Figure 10-3
Universe, Tenth Edition
NASA/GSFC/Arizona State Univ./Lunar Reconnaissance Orbiter



Lunar Craters



Cosmic Connections 10
Universe, Tenth Edition

Crater Clavius

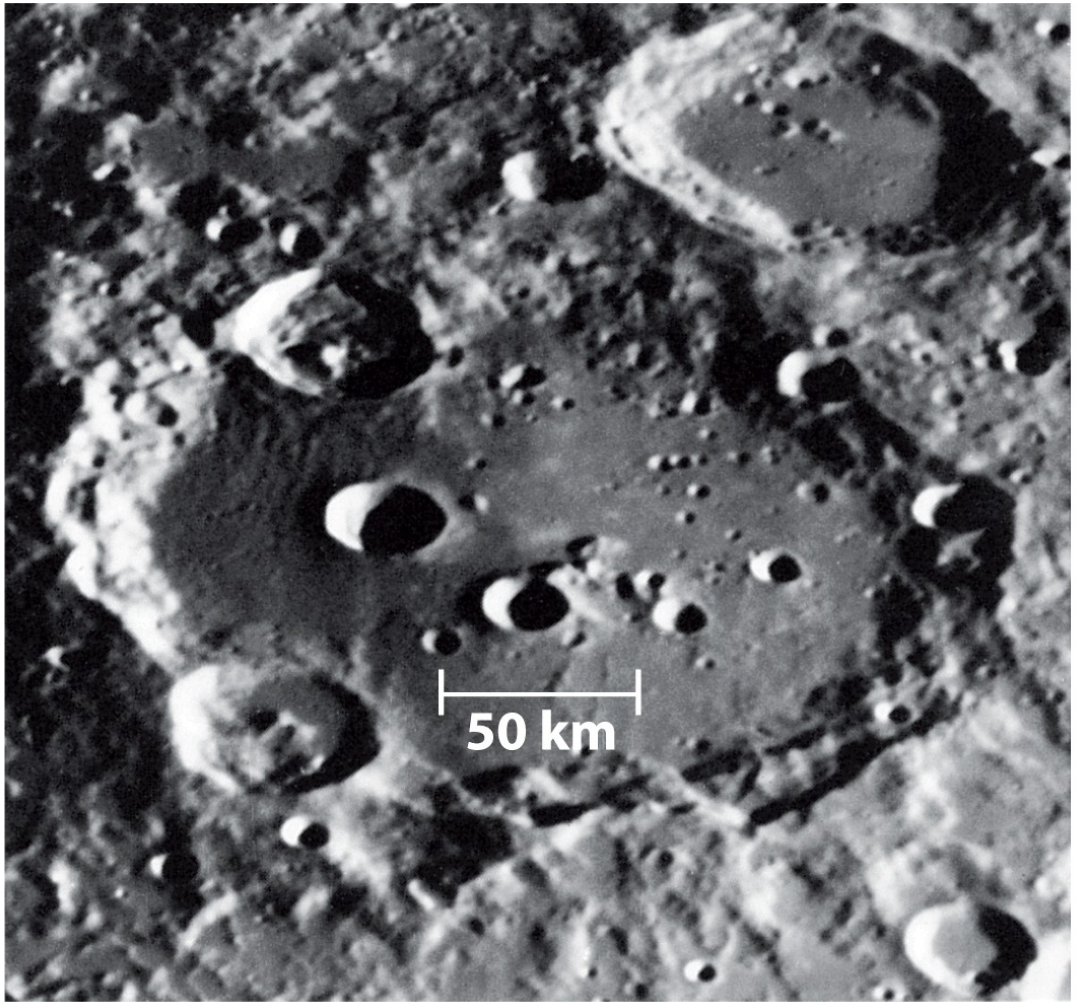


Figure 10-4
Universe, Tenth Edition
NASA

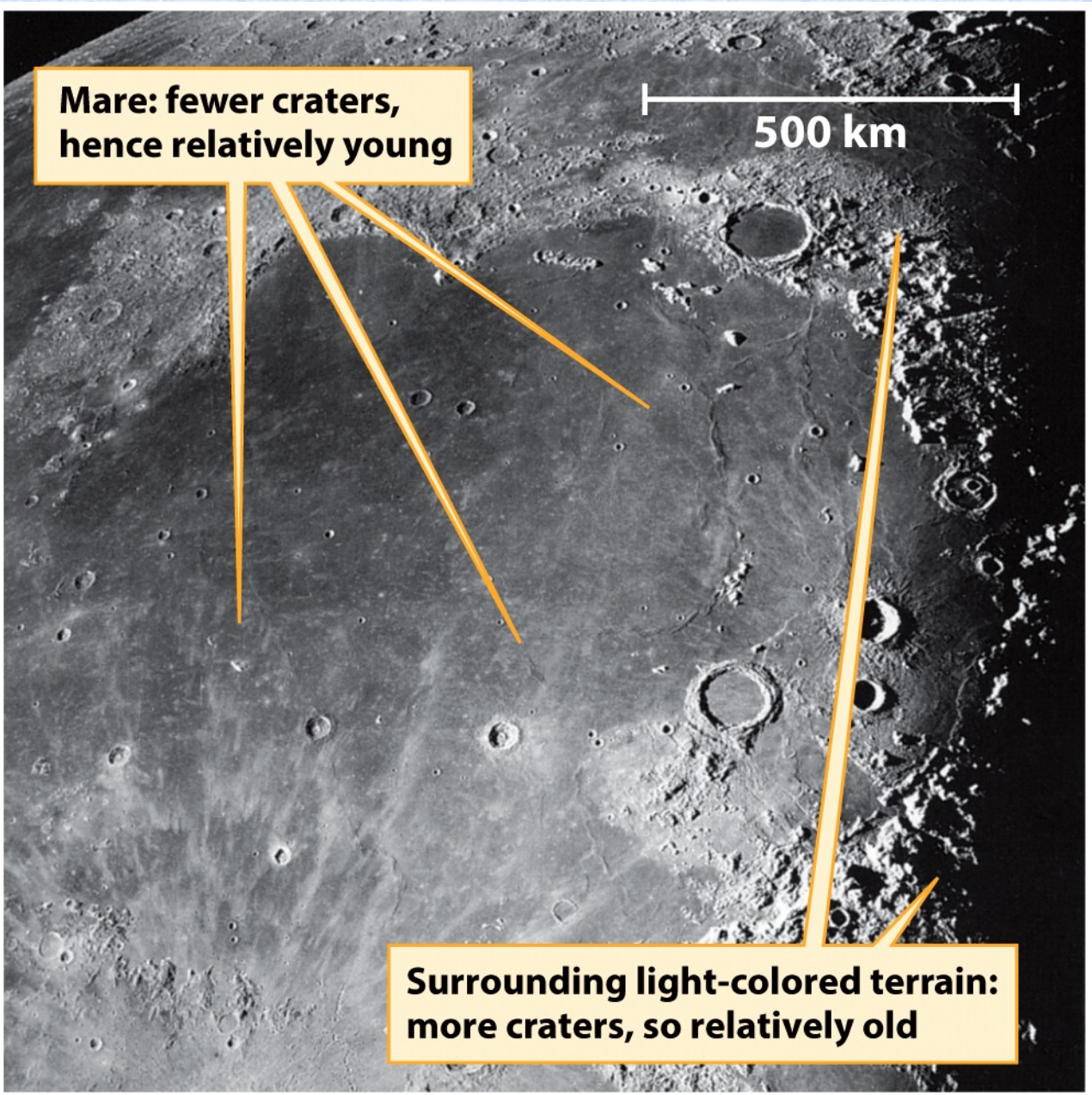


Figure 10-5
Universe, Tenth Edition
Carnegie Observatories

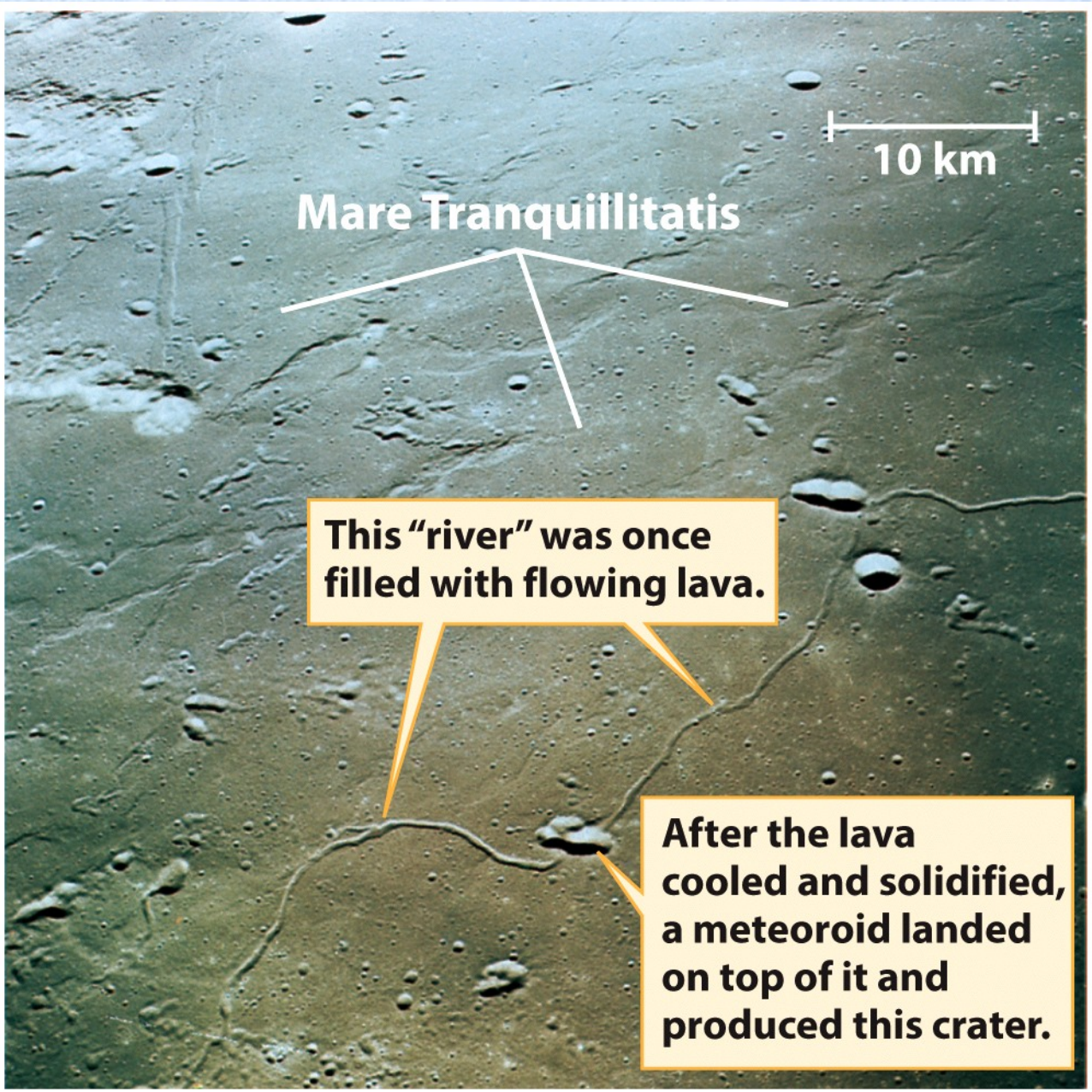


Figure 10-6
Universe, Tenth Edition
Apollo 10, NASA

Moon's Impact History

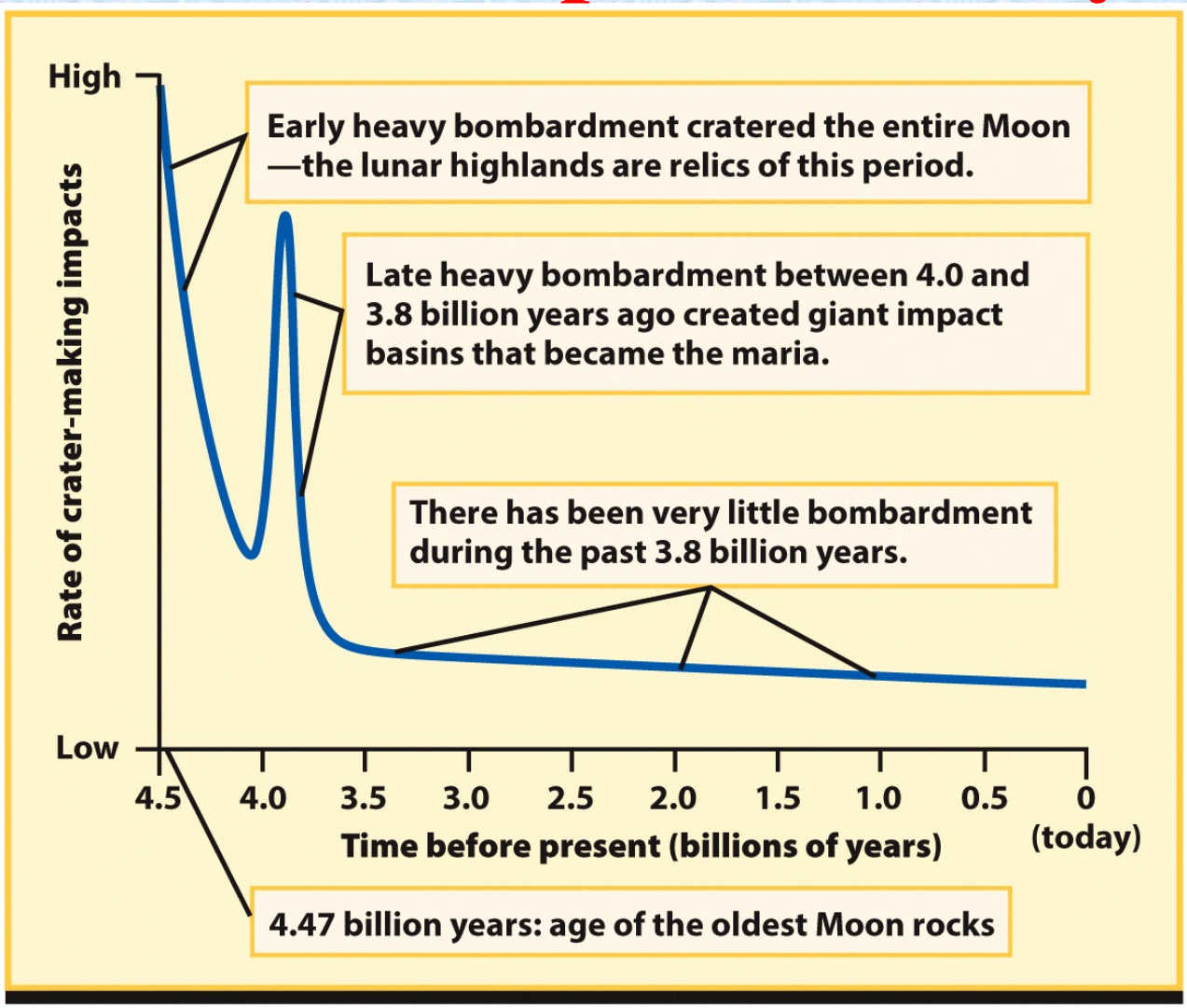


Figure 10-19
Universe, Tenth Edition
Adapted from T. Grotzinger, T. H. Jordan, F. Press, and R. Siever, *Understanding Earth*, 5th ed., W. H. Freeman, 2007

How Did the Moon Form?

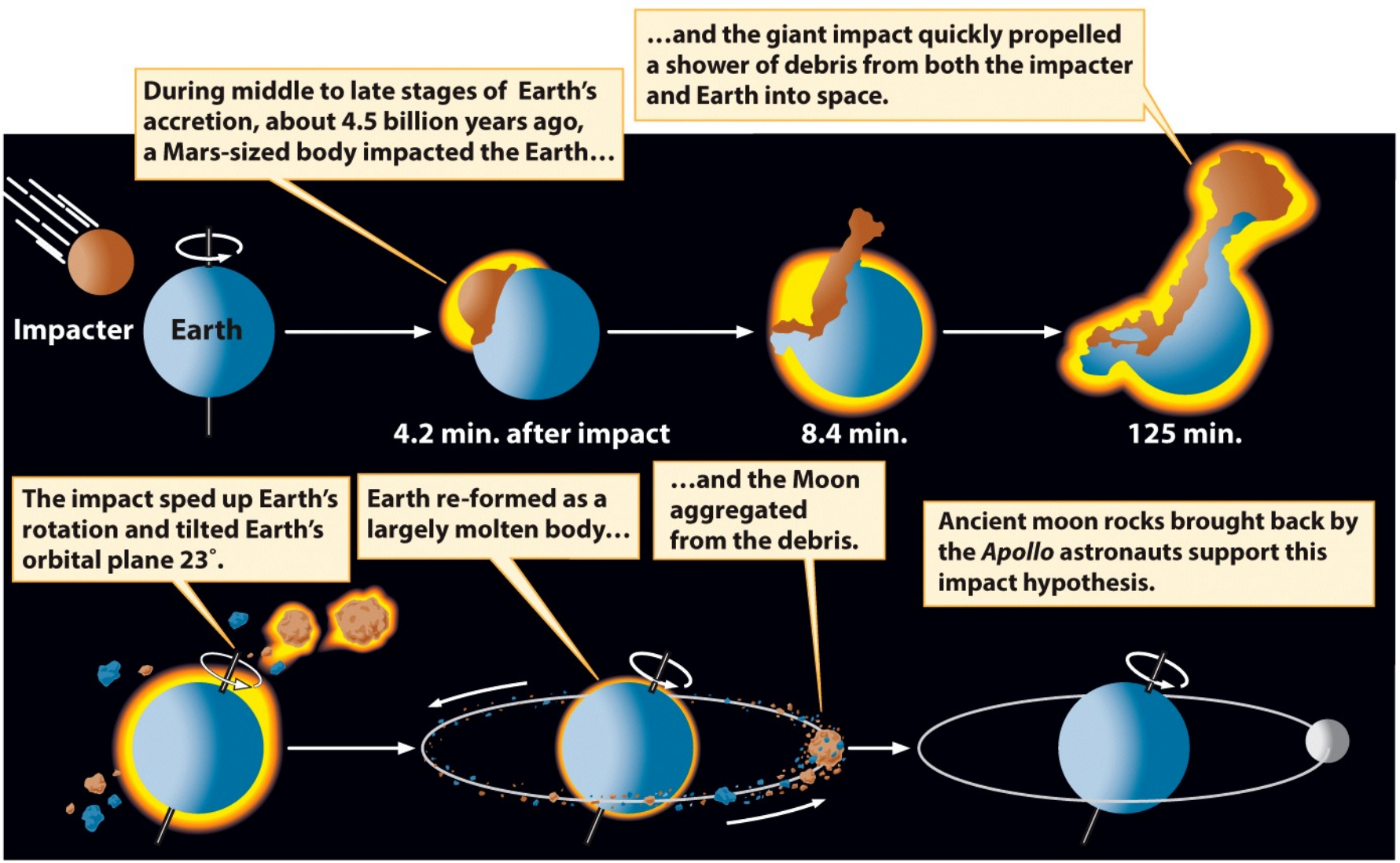


Figure 10-21
Universe, Tenth Edition
Adapted from T. Grotzinger, T. H. Jordan, F. Press, and R. Siever, *Understanding Earth*, 5th ed., W. H. Freeman, 2007

The Moon is Slowly Moving Away from the Earth

- Earth rotates every day, but the moon orbits the earth in a month.
- The tidal bulge of the Earth gets ahead of the Moon and pulls on the Moon, giving the Moon's orbit more energy.
- The Moon pulls back on the Earth (Newton's action/reaction), slowing down the rotation period of the Earth.
- Tidal friction converts rotational energy of the Earth into orbital energy of the Moon.

- *HW#4 – problems 10.22 and 10.23 ask you to calculate tidal forces (per last week's Discussion Sections; U11 box 10-1).*

How Well Do You Know the Moon?

Five Questions to test your comprehension of chapter 10.

You are living at a moon base and watch the motions of the Earth and Sun in the lunar sky. What would you see?

A. The Earth and the Sun would rise and set once a lunar month.
B. The Earth would rise and set once a lunar month, but the Sun would not appear to move significantly in the lunar sky.
C. The Earth would not appear to move significantly in the lunar sky, and the Sun would rise and set once a lunar month.
D. The Earth and Sun would not appear to move significantly in the lunar sky.
E. None of these answers are correct.

You are living at a moon base and watch the motions of the Earth and Sun in the lunar sky. What would you see?

A. The Earth and the Sun would rise and set once a lunar month.

B. The Earth would rise and set once a lunar month, but the Sun would not appear to move significantly in the lunar sky.

C. The Earth would not appear to move significantly in the lunar sky, and the Sun would rise and set once a lunar month.

D. The Earth and Sun would not appear to move significantly in the lunar sky.

E. None of these answers are correct.

The astronaut footprint on the Moon shown in this photograph will probably

A. exist for >10,000 years because there is very little weathering on the Moon.
B. exist for >10,000 years because the Moon's surface is hard and durable.
C. exist for <10,000 years due to erosion from wind in the tenuous lunar atmosphere.
D. exist for <10,000 years due to bombardment by large numbers of meteors.
E. Both C and D are correct.

Figure 10-15
Universe, Tenth Edition
Apollo 11, NASA

Q10.1

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E. Both C and D are correct.

Figure 10-15
Universe, Tenth Edition
Apollo 11, NASA

The large flat plains on the Moon are called maria. The maria were formed

A. in old sea beds.
B. when large meteors hit the Moon and flattened its surface.
C. when ancient lava flows solidified, sometimes in a very large crater.
D. when the surface of the Moon was eroded and flattened over millions of years by its tenuous atmosphere.
E. by tidal interactions between the Earth and Moon.

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E. by tidal interactions between the Earth and Moon.

Some areas of the Moon are relatively smooth, whereas other areas are heavily cratered. This is because

A. meteors did not strike the flat areas because they are in the Earth's shadow.
B. weathering has smoothed parts of the Moon.
C. plate tectonics has recycled parts of the lunar crust.
D. in some places lava flows have covered over older craters, leaving a smoother surface.
E. tidal forces between the Earth and Moon smoothed parts of the Moon.

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E. tidal forces between the Earth and Moon smoothed parts of the Moon.

The narrow snaking channels on the Moon are

A. due to water flowing on the Moon in the past.
B. due to lava flowing on the Moon in the past.
C. skid marks where meteors landed in the past.
D. due to tidal forces between the Earth and the Moon.
E. due to plate tectonic activity.

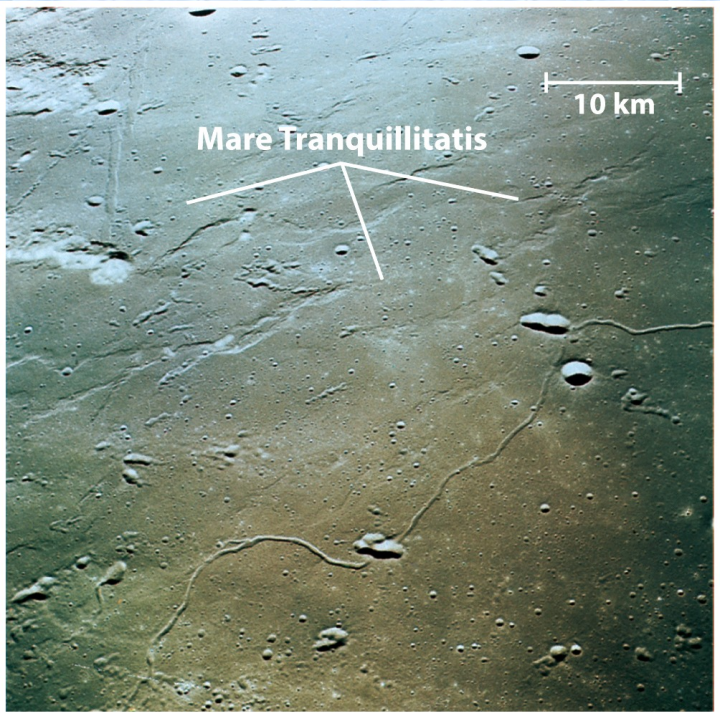


Figure 10-6
Universe, Tenth Edition
Apollo 10, NASA

Q10.5

The narrow snaking channels on the Moon are

A. due to water flowing on the Moon in the past.
B. due to lava flowing on the Moon in the past.
C. skid marks where meteors landed in the past.
D. due to tidal forces between the Earth and the Moon.
E. due to plate tectonic activity.

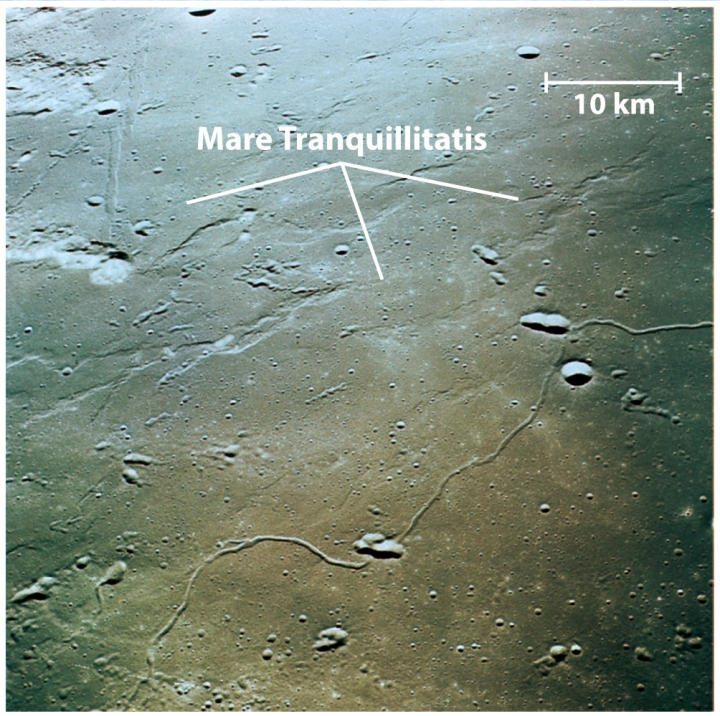


Figure 10-6
Universe, Tenth Edition
Apollo 10, NASA

The Composition of the Solar System

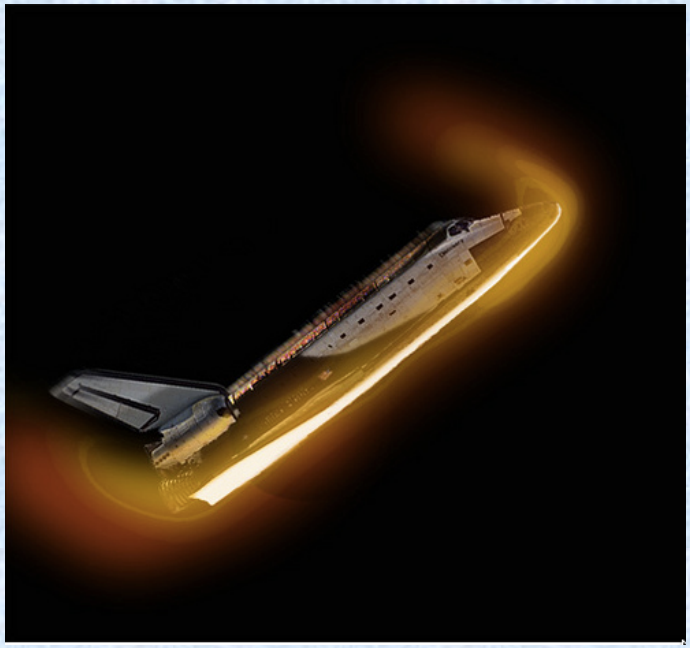
1. Most of the mass in the Sun, which is made mainly of hydrogen and helium.

2. We learned (on Monday) that these light elements escaped from the Earth. Why?

3. The composition of meteorites give us direct knowledge of the composition of the 'stuff' that formed Earth.

Meteorites: Rocks from Space

Figure 8-5
Universe, Eighth Edition



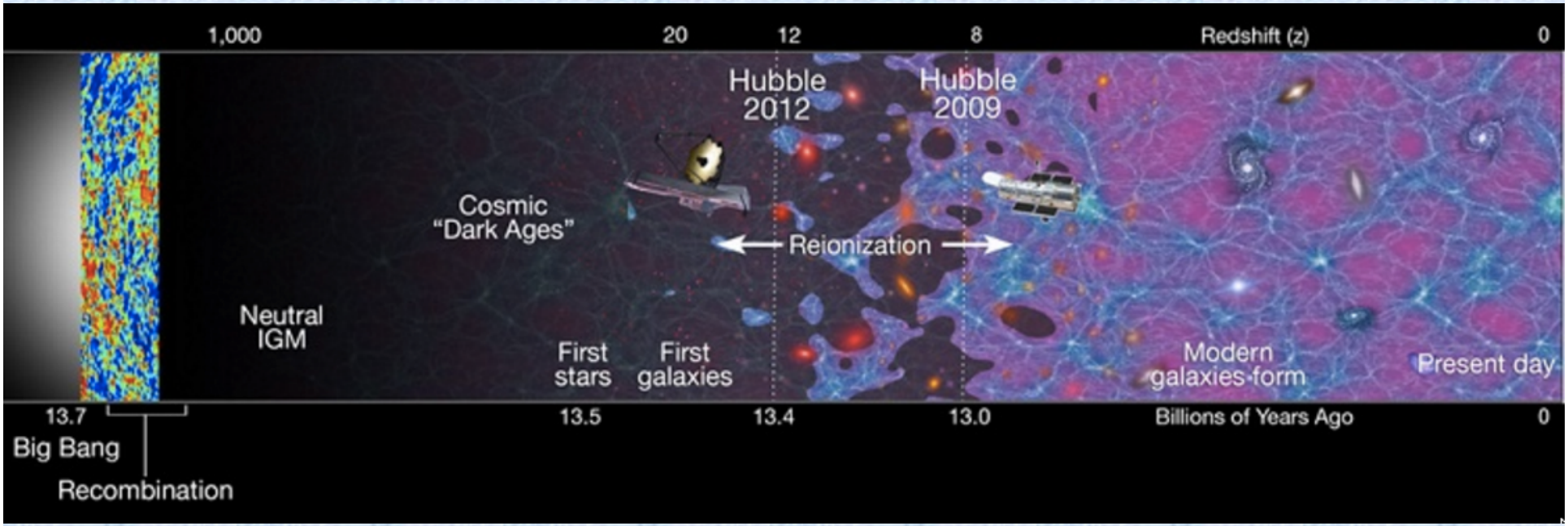
- ***How do we know it came from space?***

  Surface shows evidence of having been melted by air friction as it entered our atmosphere at 40,000 km/h (25,000 mi/h).

- ***How old are these rocks?***

  The ratios of various nuclei, a method called radioactive age dating, are used to determine the rocks formed **4.56×10^9 years ago.**

When did the solar system form?



- The age of the universe, **13.7 x 10^9 years,** has been measured from its expansion rate. The universe reached two-thirds of its present age before our solar system came into existence.
- The Sun and Earth are nearly as old as meteorites, the oldest objects in the solar system.

The Solar System is Mainly H and He

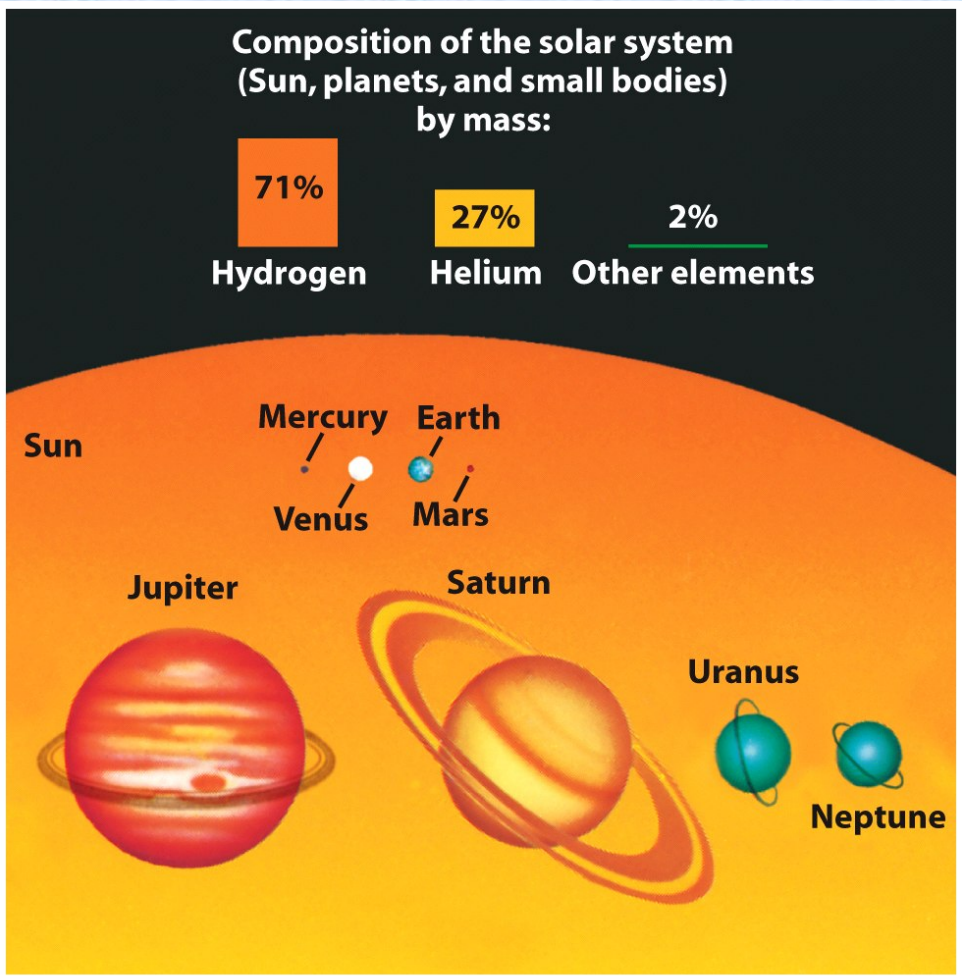
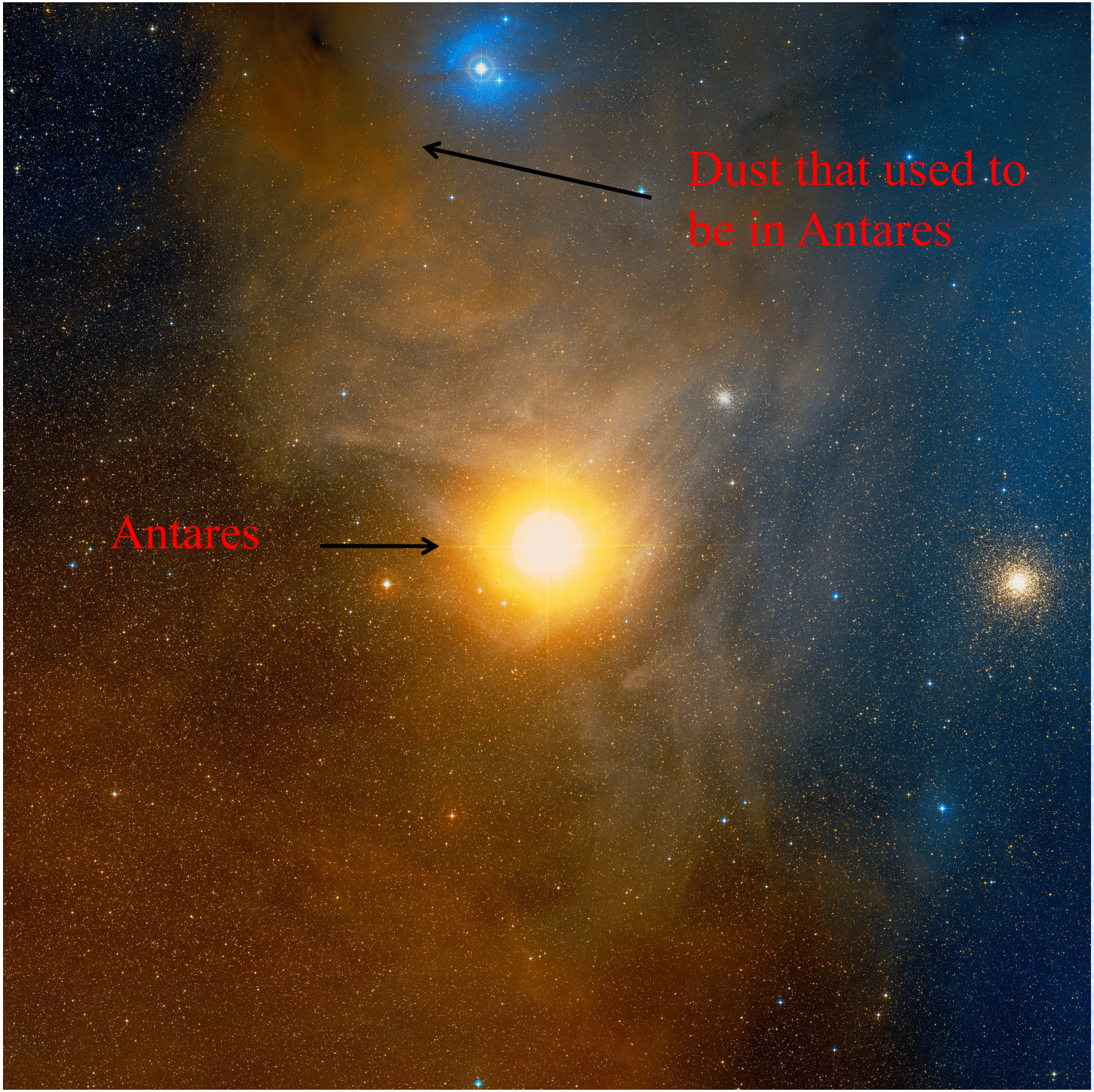


Figure 8-1
Universe, Eighth Edition

- All elements heavier than zinc (Zn) have abundances of fewer than 1000 atoms per 10^{12} atoms of hydrogen.
- All elements heavier than Boron (atomic number 5) were made inside stars.
- This composition is typical of the Universe as a whole.
- *Why is the composition of the Earth not very representative of the solar system?*



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

Stars Lose Mass ➔ Enrich Their Environment with Heavier Elements

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

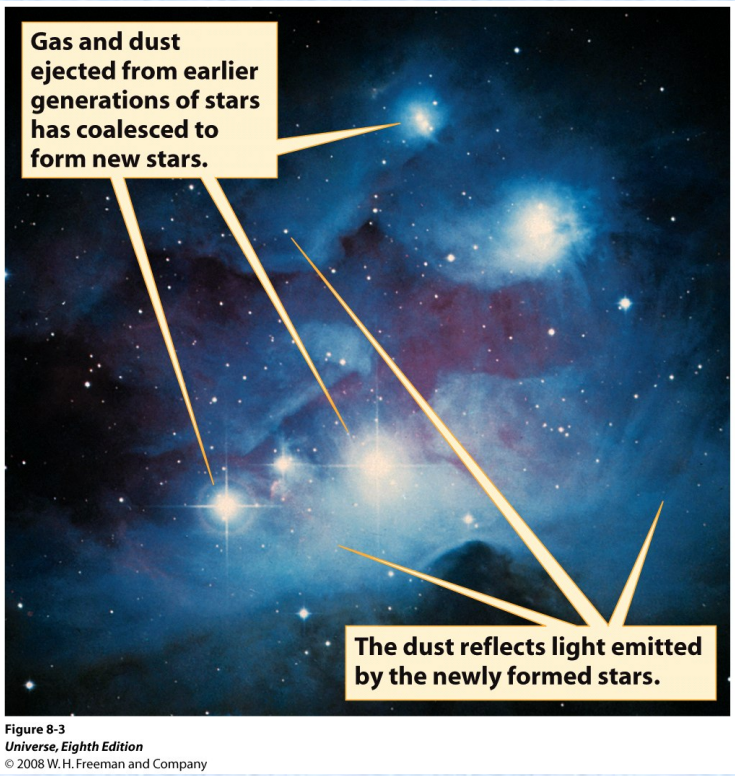


Figure 8-3
Universe, Eighth Edition

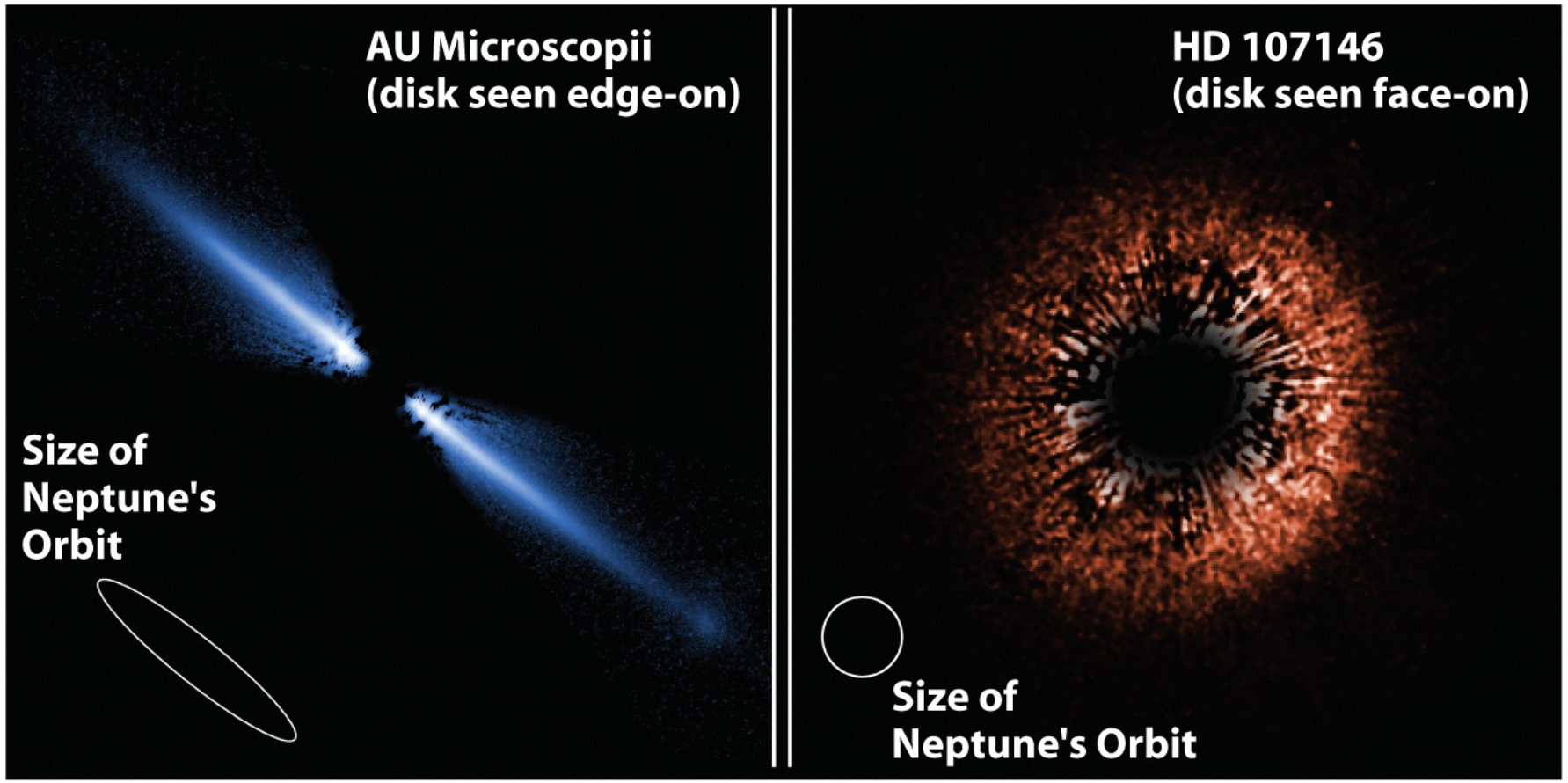
Why is this nebula blue?

To understand the formation of the planets, we need to look at the formation of the Sun.

Most of the mass of the solar system is in the Sun.

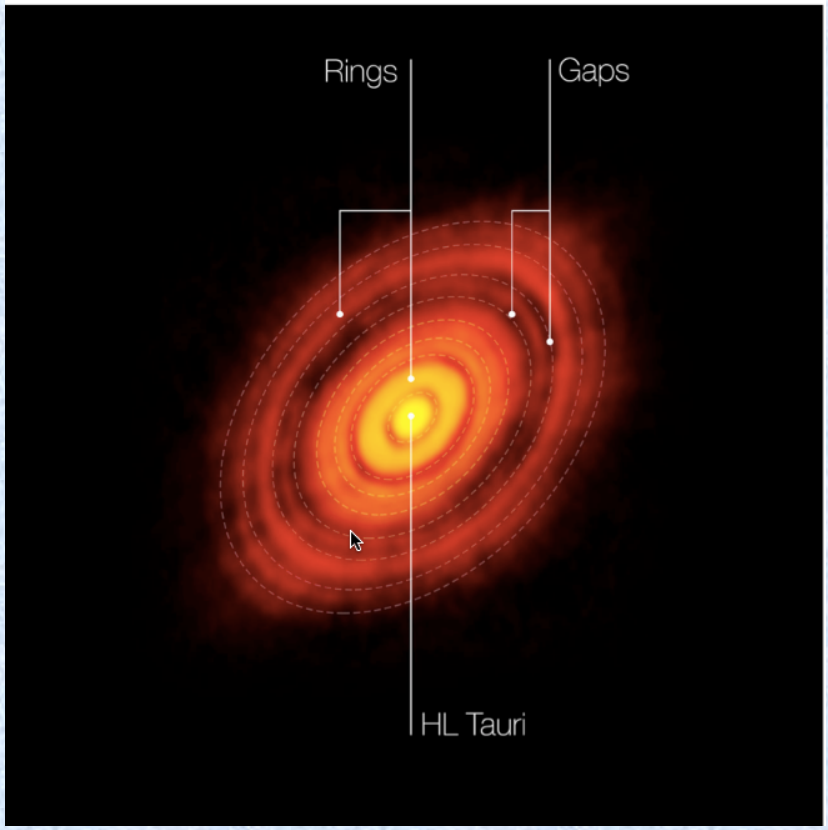
The Sun's composition is close to that of the protostellar nebula.

Protostellar Disks: Planets Are Likely Forming Here



Chapter 8 Opener
Universe, Tenth Edition
NASA, ESA, D. R. Ardila (JHU), D. A. Golimowski (JHU), J. E. Krist (STScI/JPL), M. Clampin (NASA/GSFC), J. P. Williams (UH/IfA), J. P. Blakeslee (JHU), H. C. Ford (JHU), G. F. Hartig (STScI), G. D. Illingworth (UCO-Lick) and the ACS Science Team

High Resolution Images of a Dusty Disk



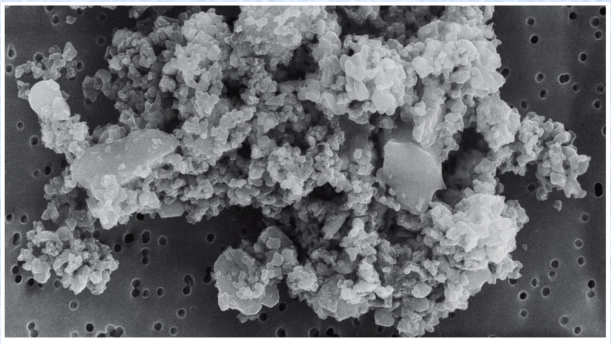
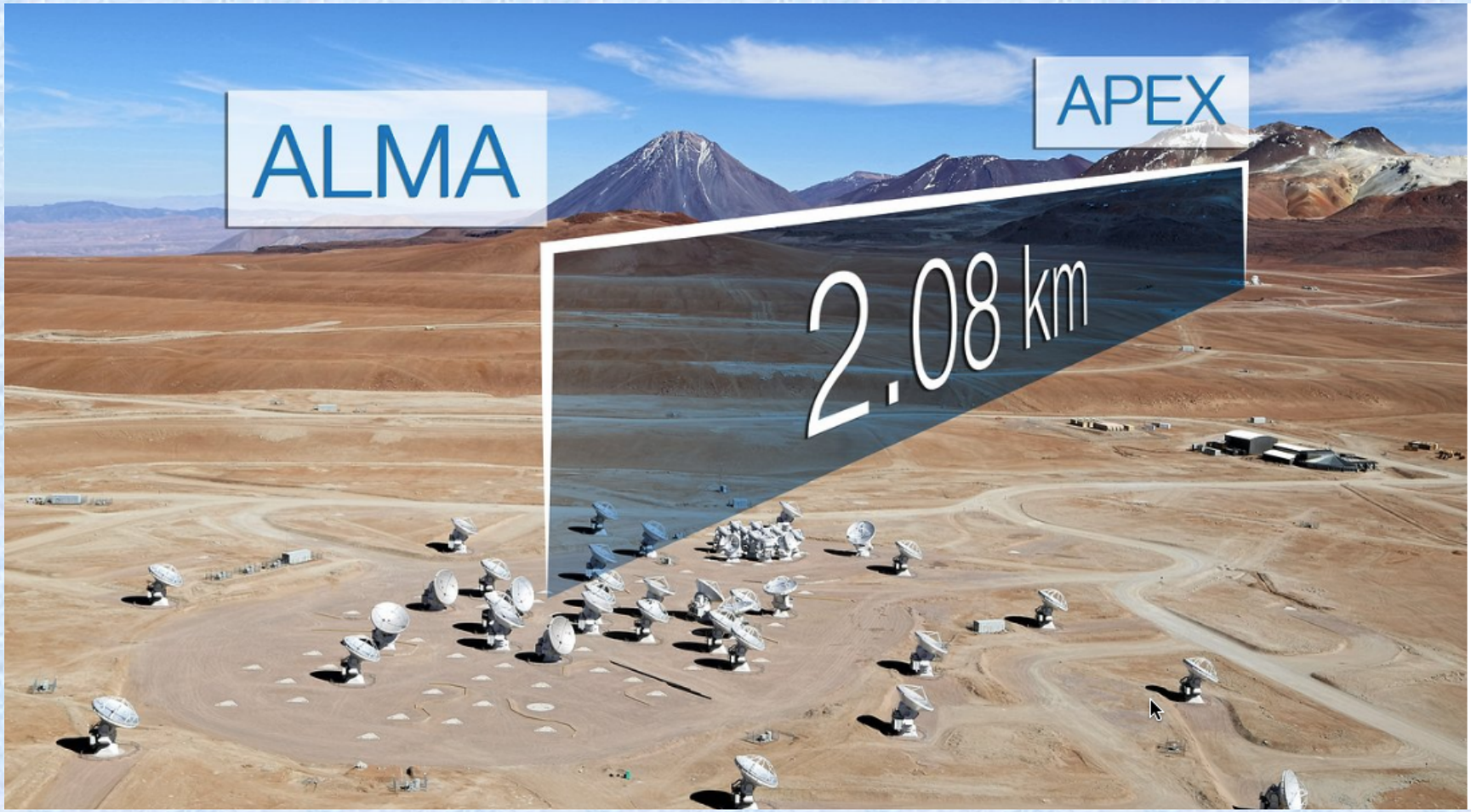


Figure 8-9
Universe, Eighth Edition

- The bands are almost certainly the result of planets forming in the disk.
- Grain collisions create pebbles that ultimately grow into larger bodies called planetesimals (and planets). Planets disrupt the disk creating the rings.
- Seen for first time! ALMA delivered 0.035" (5 AU) resolution.
- *How could such high resolution be achieved?*
- *What part of EM spectrum?*

Sub-mm Interferometry



Cool, but why are the young stars surrounded by disks?

Gravity Causes Interstellar Gas Clouds to Collapse

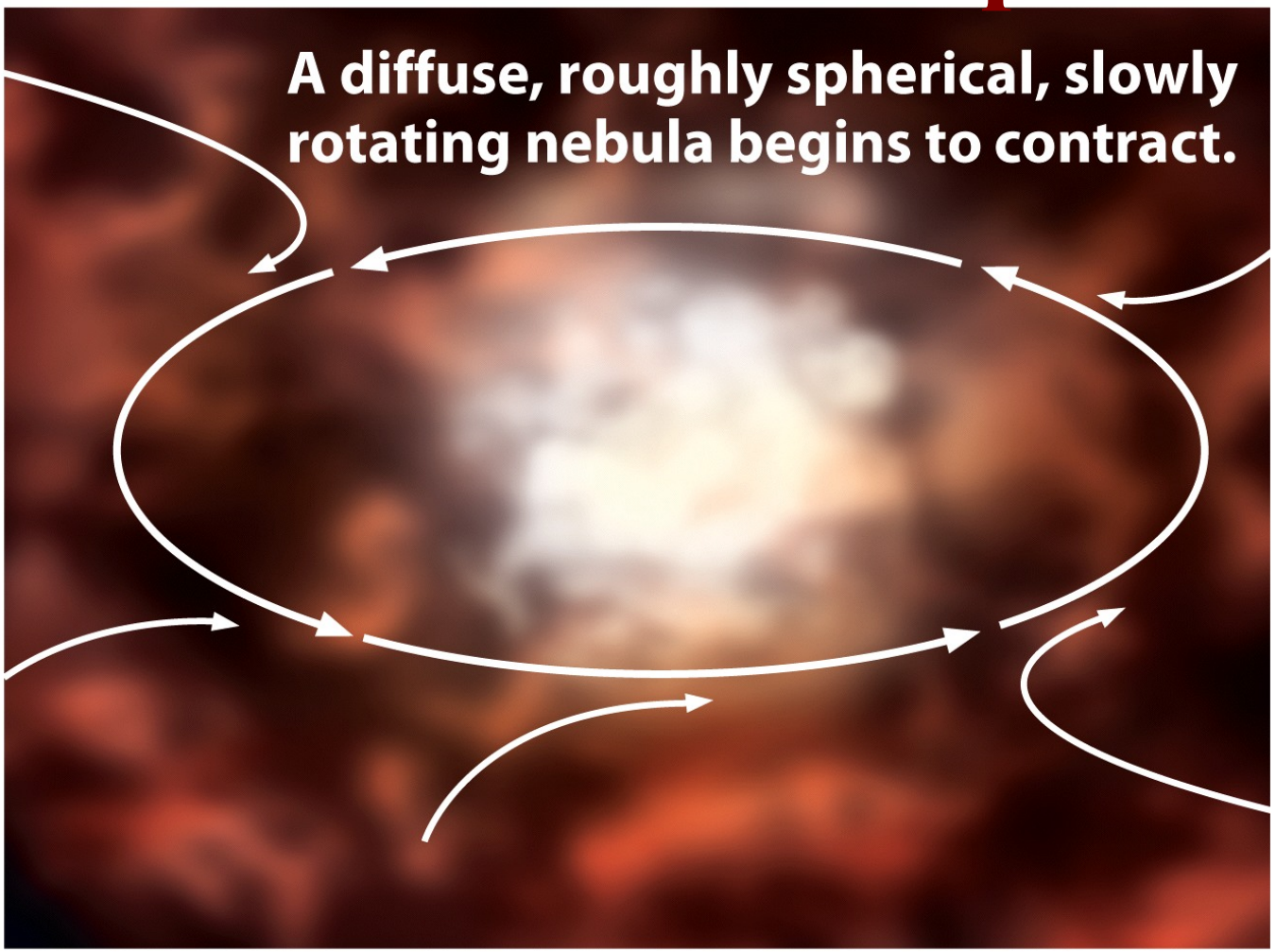


Figure 8-6a
Universe, Tenth Edition

Planets Form Out of Gas Disks

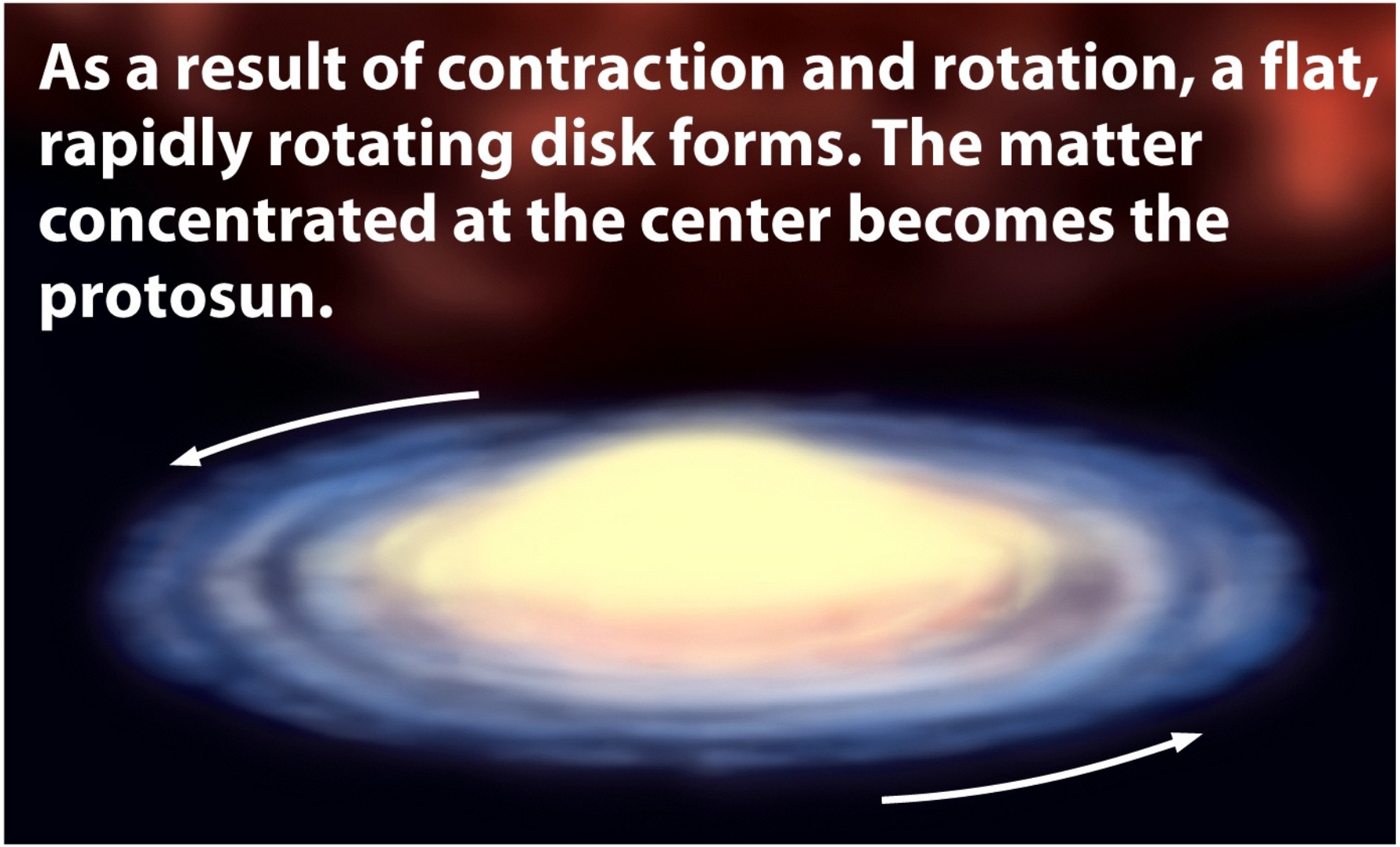


Figure 8-6b
Universe, Tenth Edition

Conservation of Angular Momentum

(a)

(b)

Figure 8-7
Universe, Eighth Edition

Taking a Closer Look at a Stellar Nursery

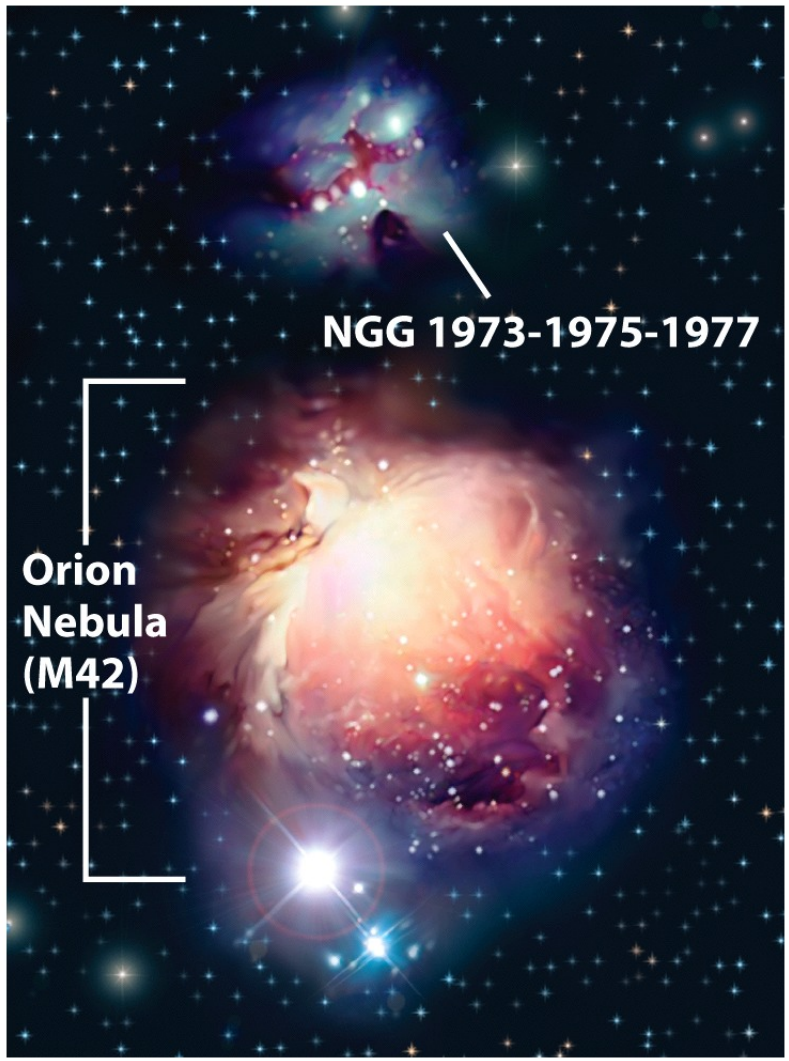


Figure 8-8a
Universe, Tenth Edition
Anglo-Australian Observatory image by David Malin

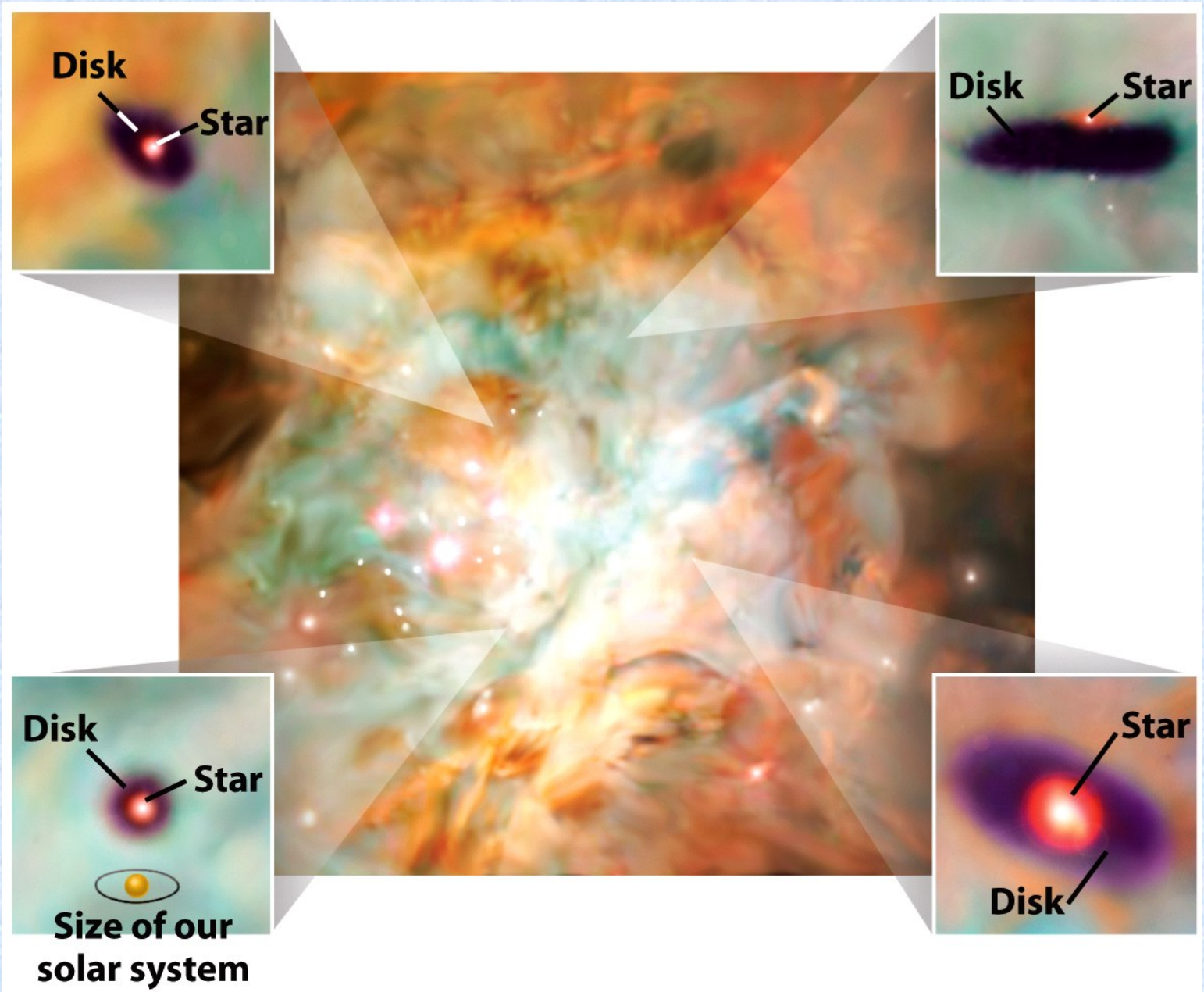


Figure 8-8b
Universe, Eighth Edition

Heat from the Hot Proto-sun Separated the Solar Nebular into Two Regions

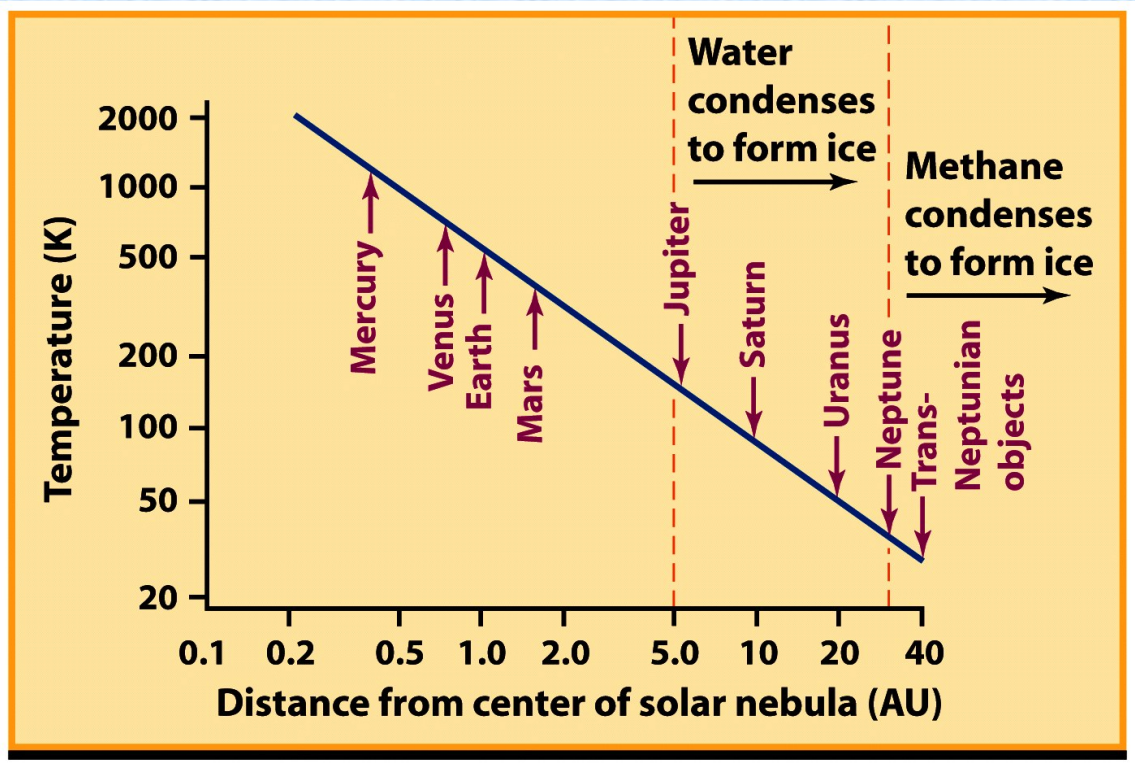


Figure 8-10
Universe, Eighth Edition

Inner Region: Only rocky and metallic materials remained solid
Outer Region: Icy frost condensed beyond the snowline providing more mass for planet building.

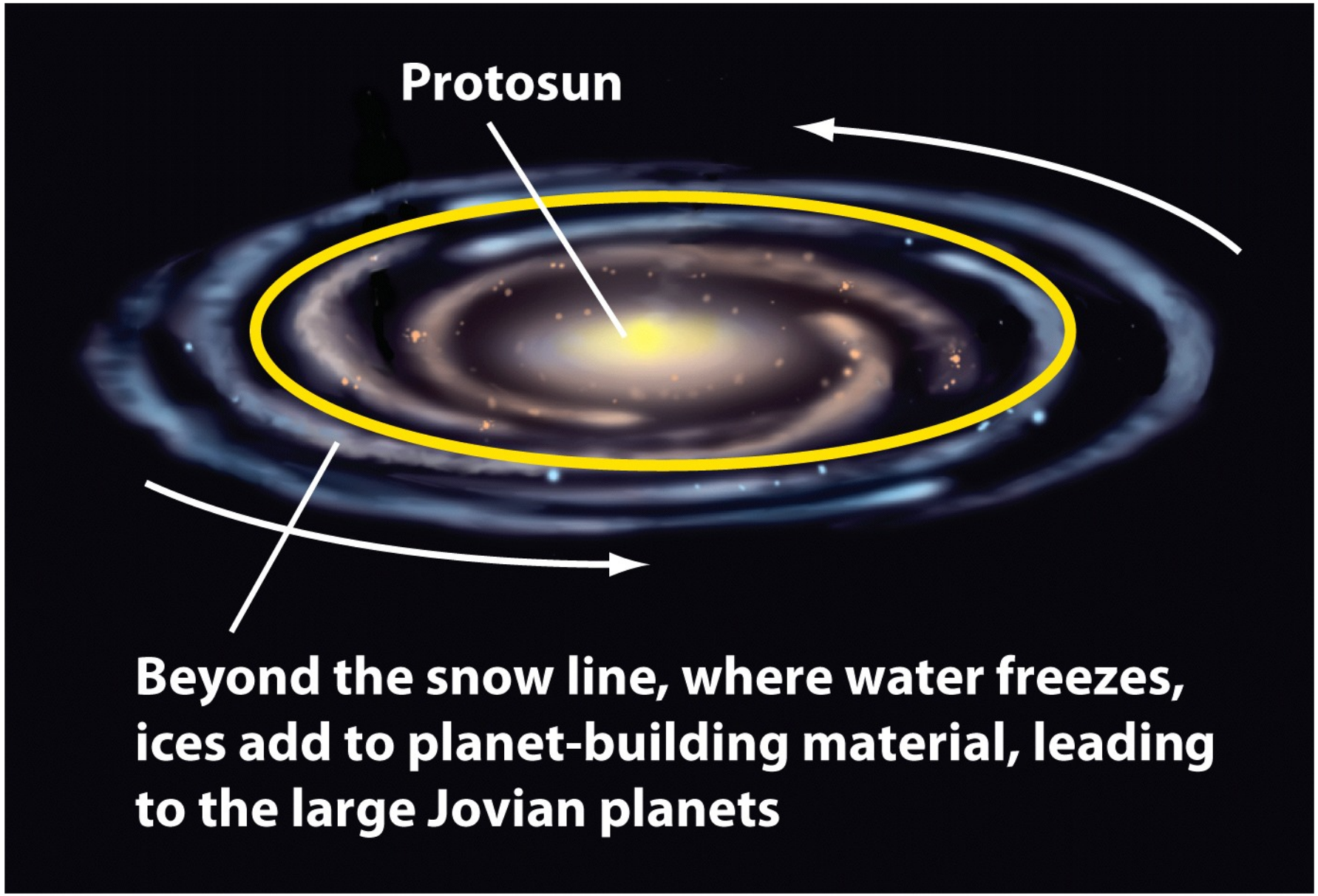


Figure 8-10b
Universe, Tenth Edition

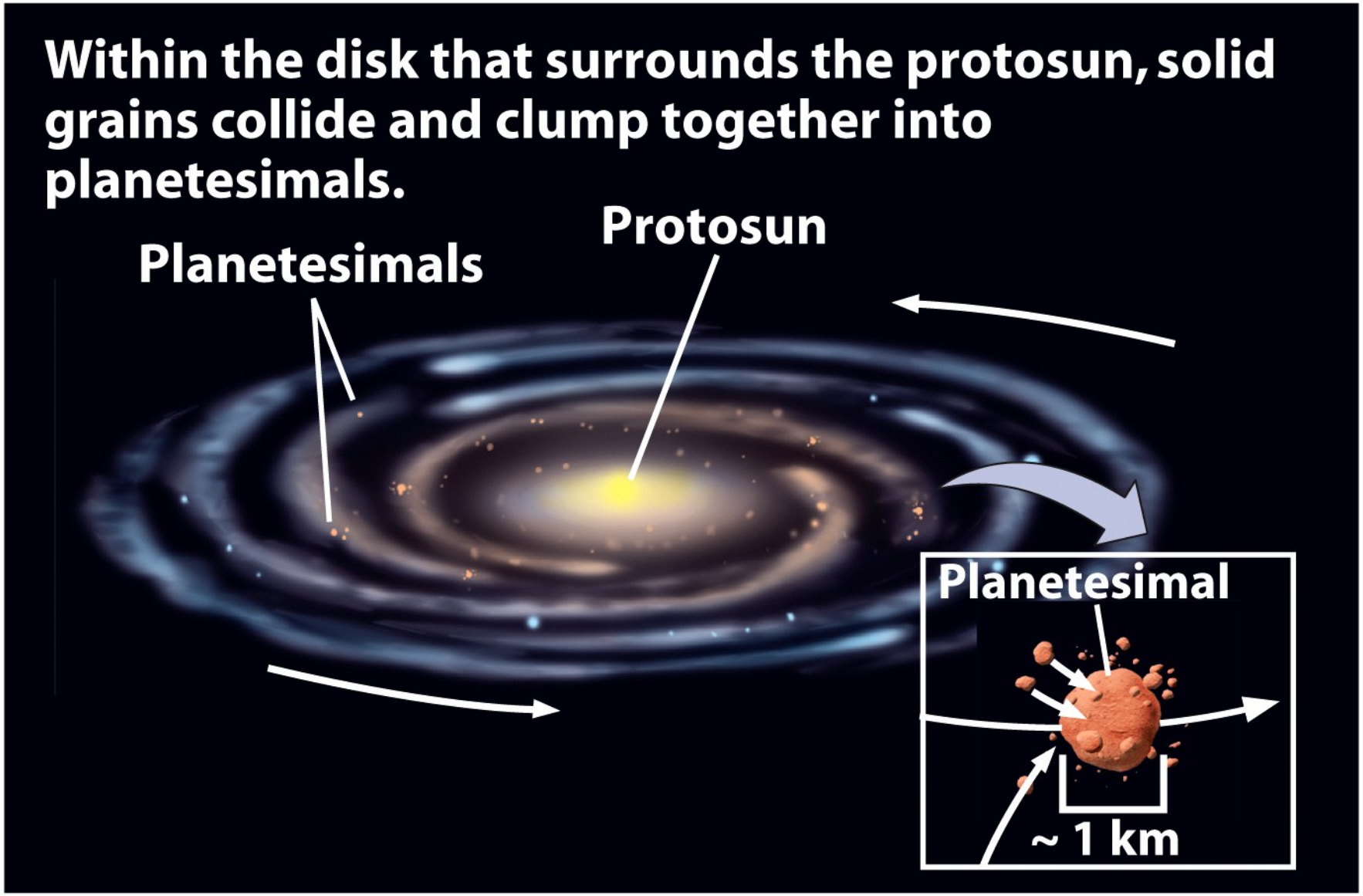


Figure 8-13a
Universe, Eighth Edition

Accretion of the Terrestrial Planets

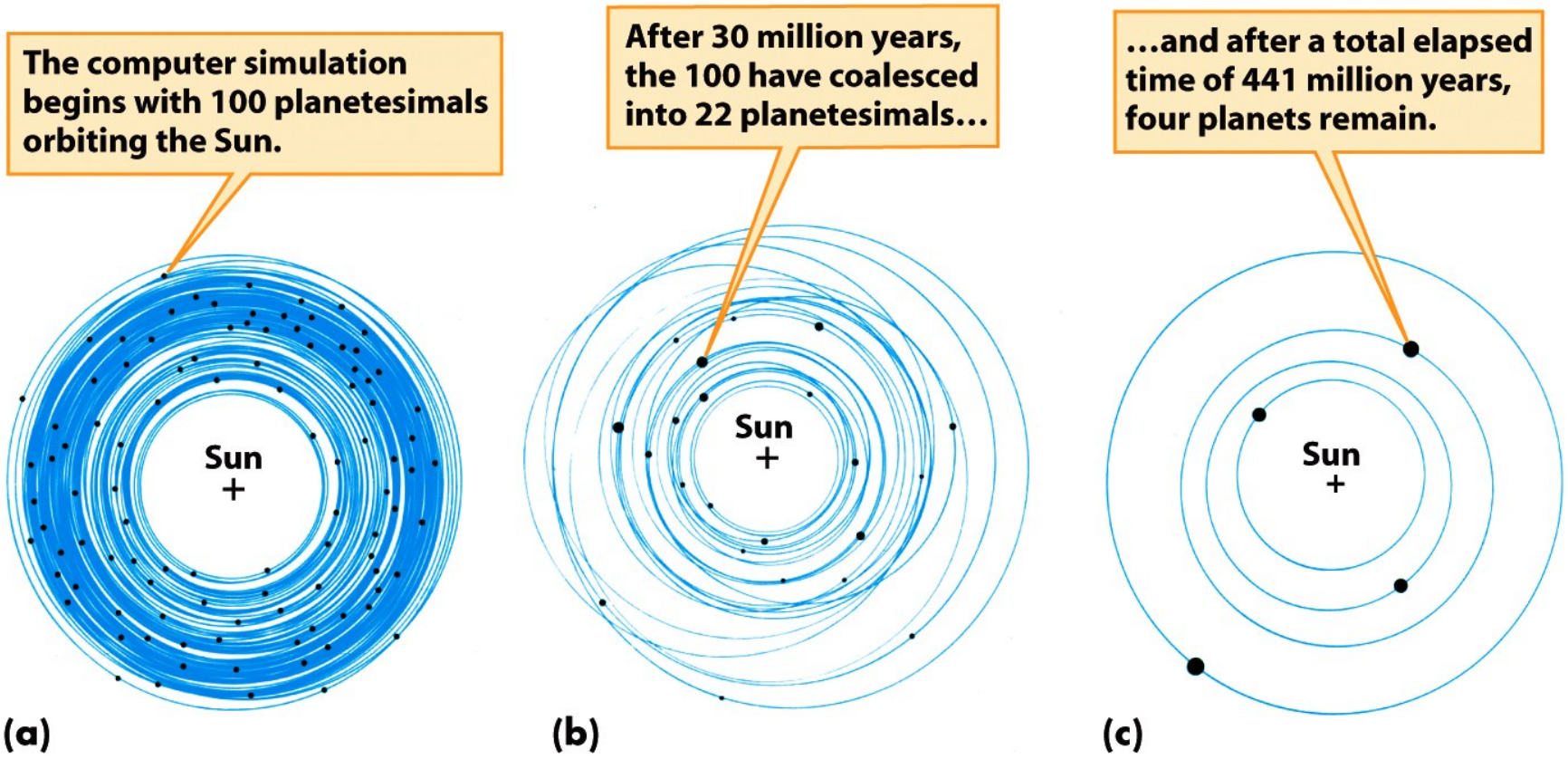


Figure 8-12
Universe, Eighth Edition

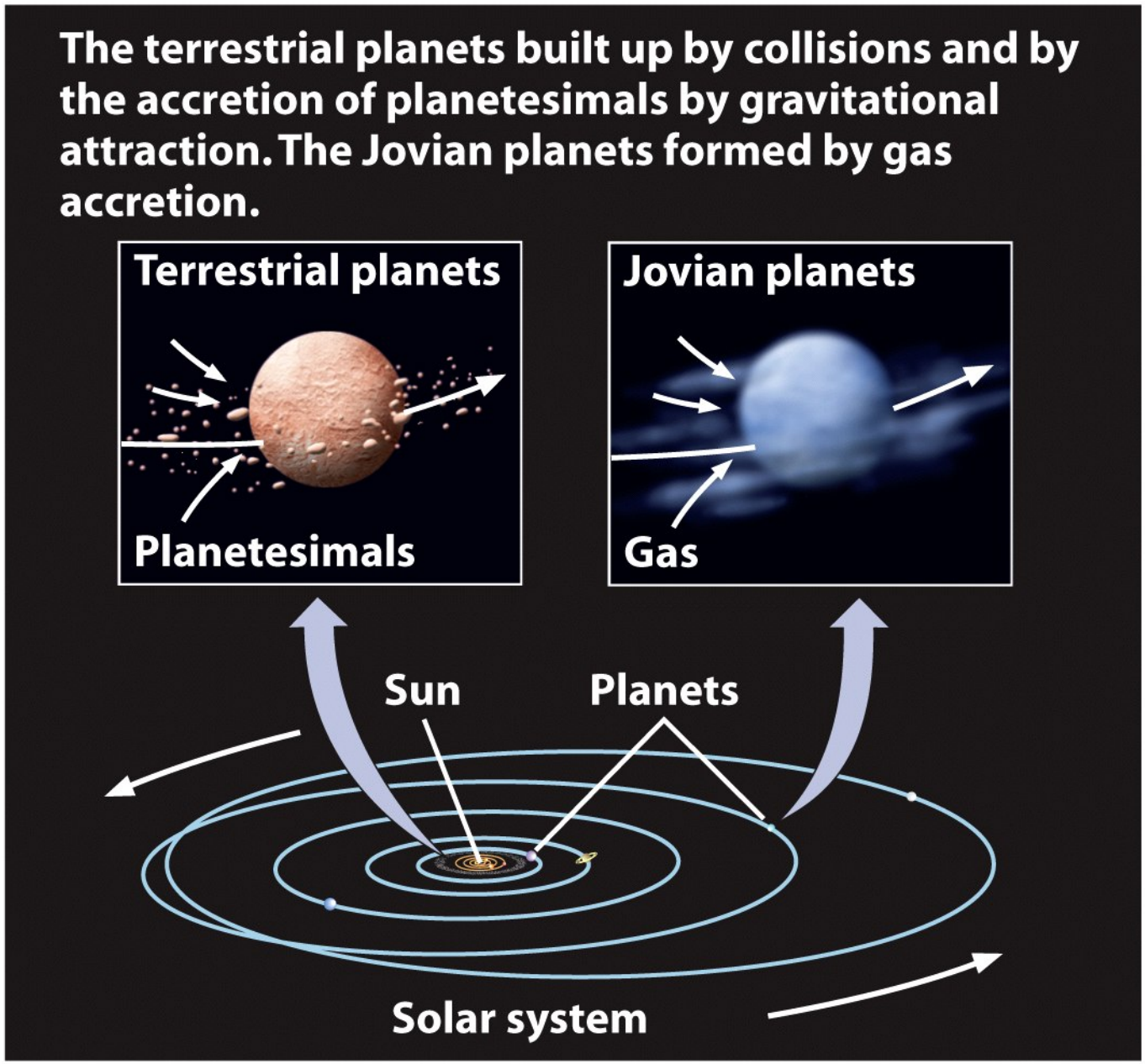


Figure 8-13b
Universe, Eighth Edition

Planetary Migration

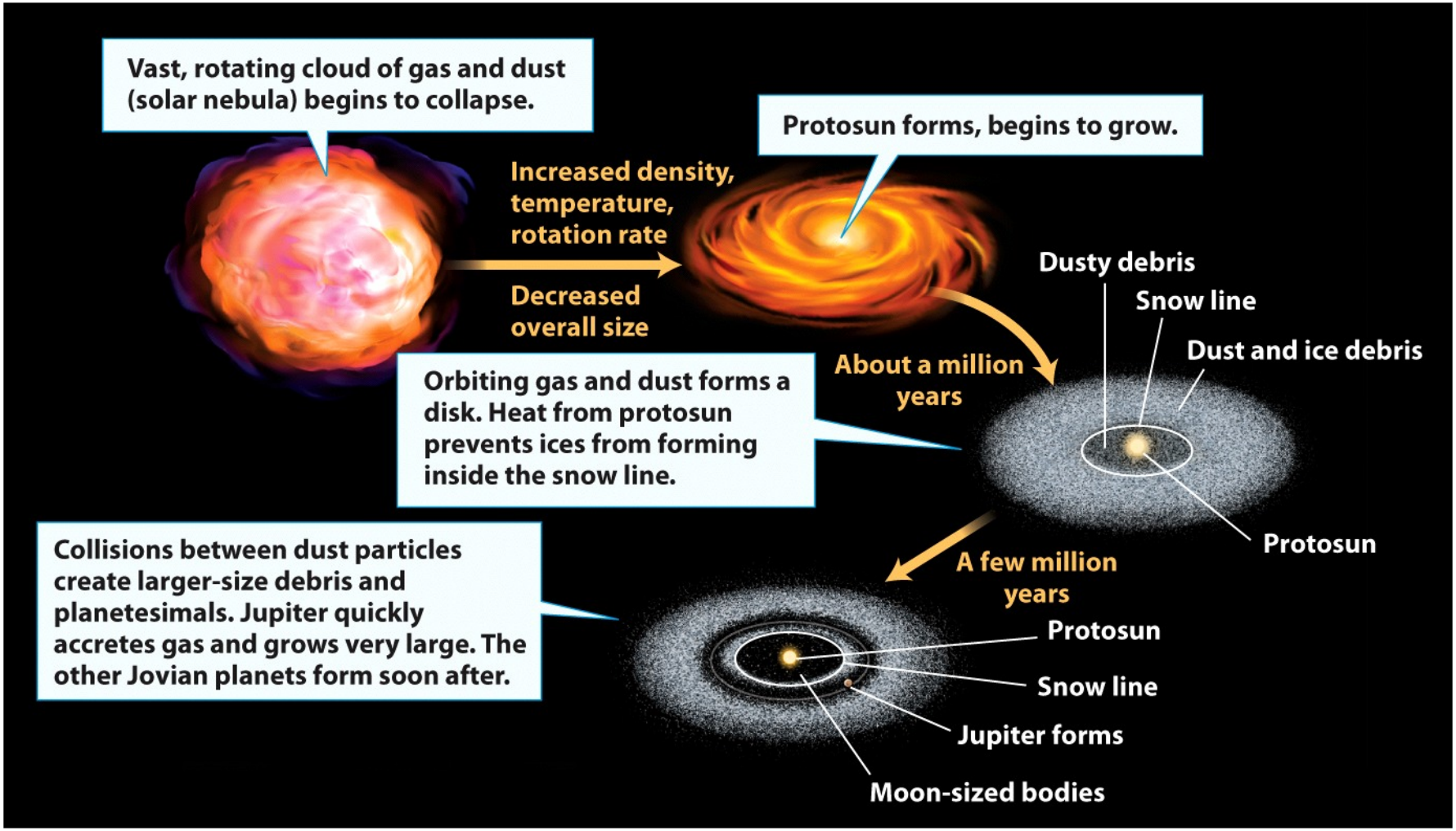


Figure 8-13 part 1
Universe, Tenth Edition

Planetary Migration

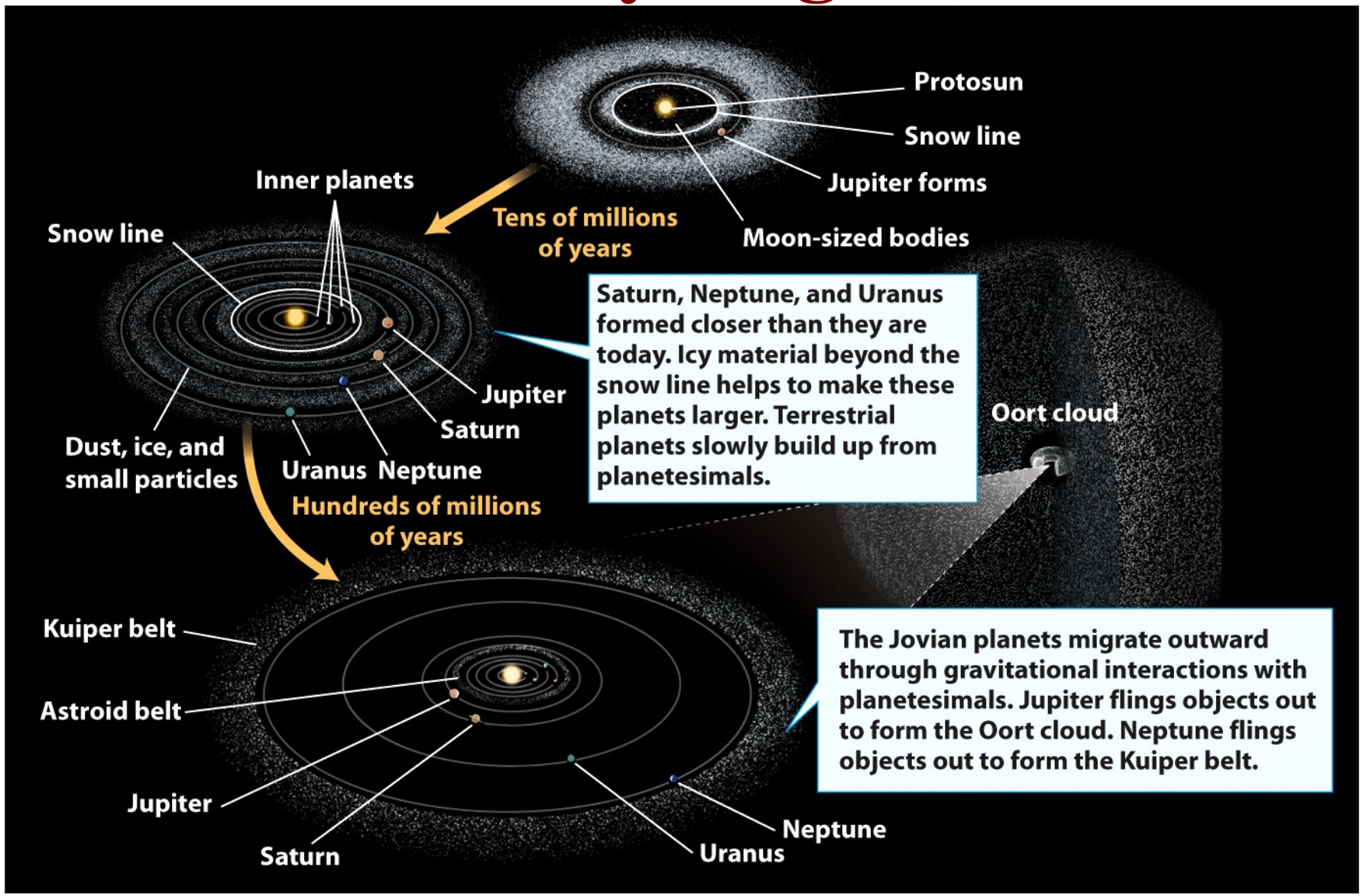


Figure 8-13 part 2
Universe, Tenth Edition

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.

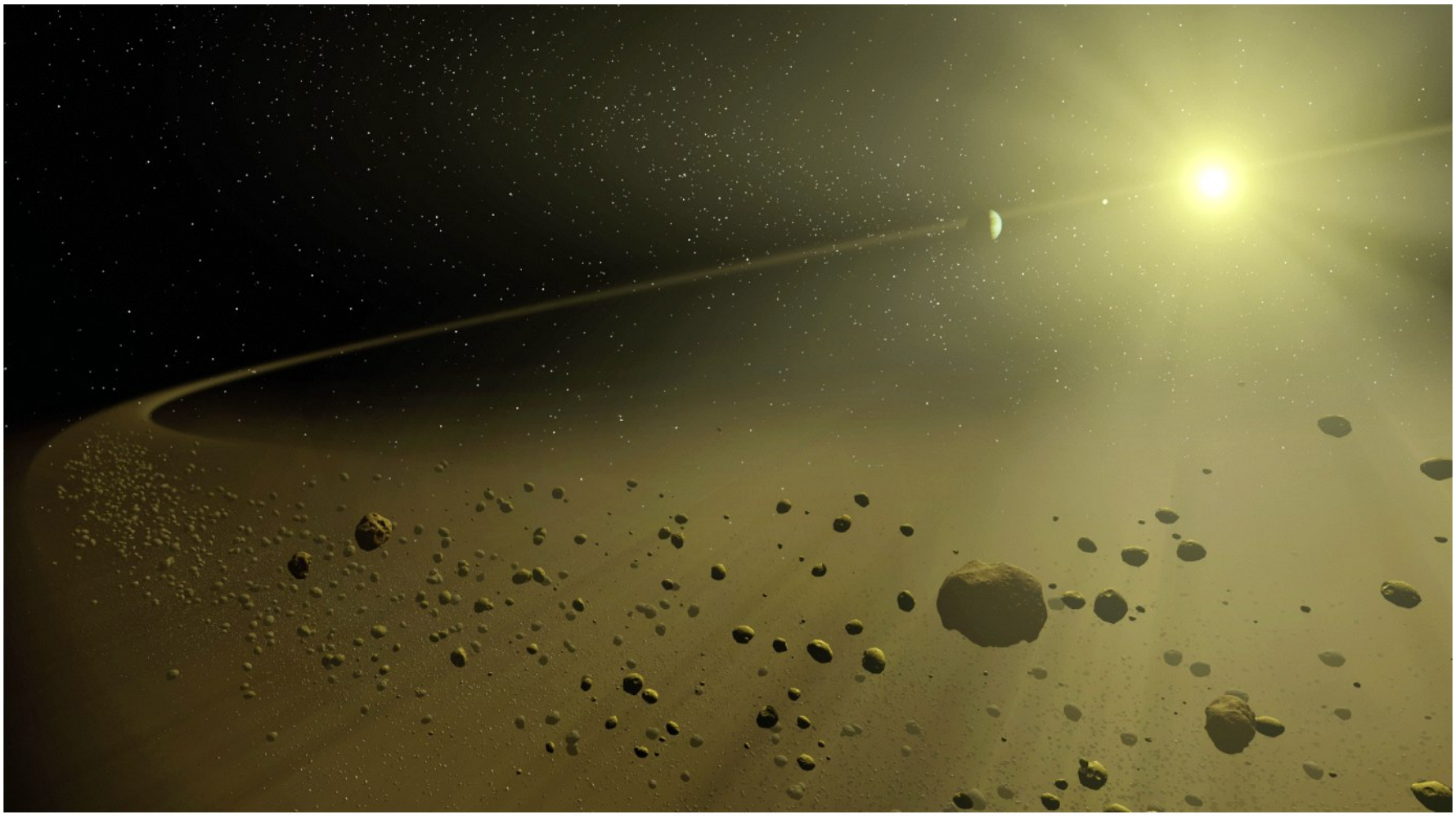


Figure 8-14
Universe, Eighth Edition

Kuiper Belt vs. Oort Cloud

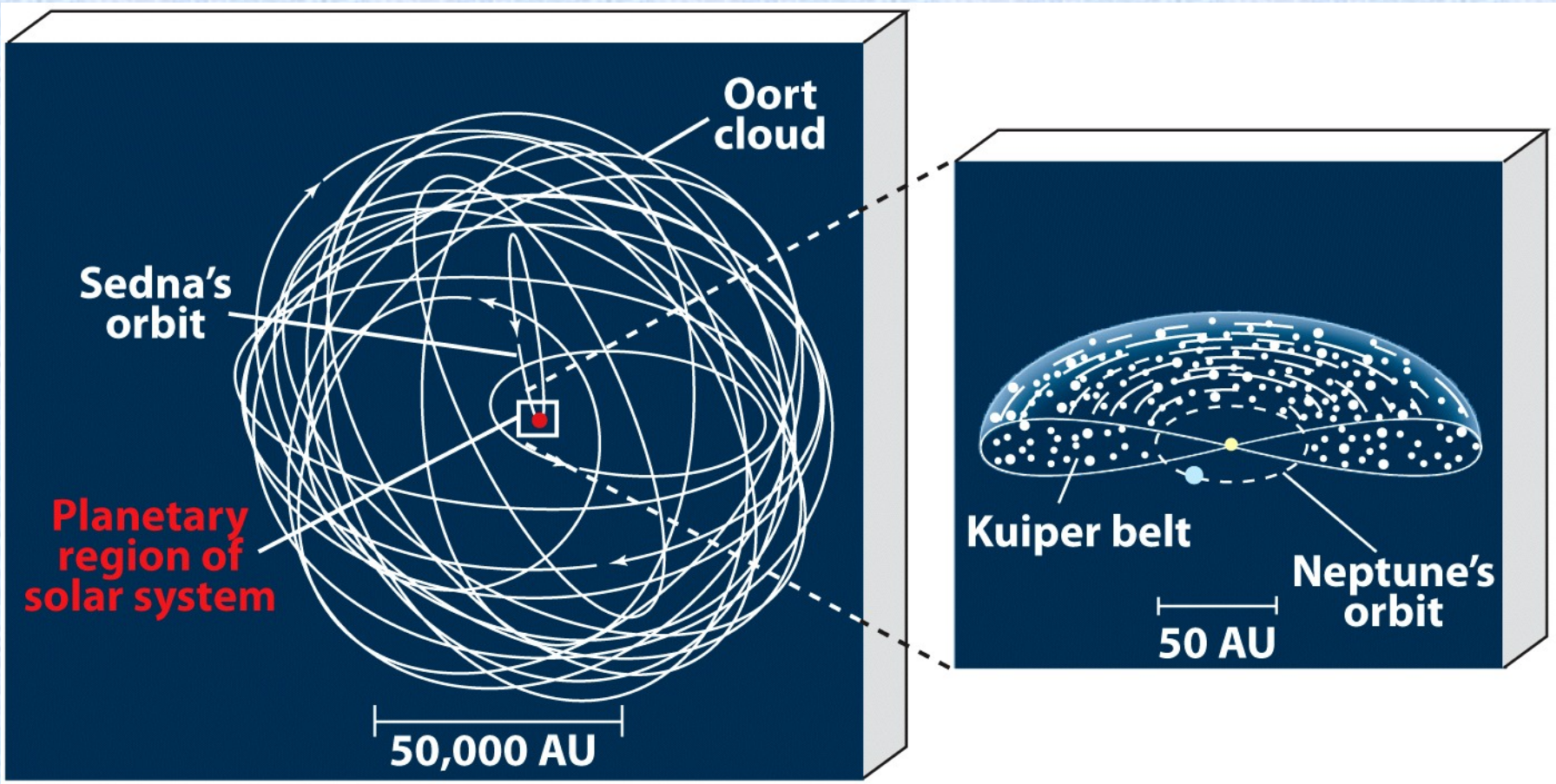


Figure 8-14a part 2
Universe, Tenth Edition

What about the other satellites?

Giant Satellites in the Solar System

Table 7-2 The Seven Giant Satellites

	Moon	Io	Europa	Ganymede	Callisto	Titan	Triton
Parent planet	Earth	Jupiter	Jupiter	Jupiter	Jupiter	Saturn	Neptune
Diameter (km)	3476	3642	3130	5268	4806	5150	2706
Mass (kg)	7.35×10^{22}	8.93×10^{22}	4.80×10^{22}	1.48×10^{23}	1.08×10^{23}	1.34×10^{23}	2.15×10^{22}
Average density (kg/m^3)	3340	3530	2970	1940	1850	1880	2050
Substantial atmosphere?	No	No	No	No	No	Yes	No

R I V U X G

(NASA/JPL/Space Science Institute)

Table 7-2
Universe, Eighth Edition

- Seven large satellites almost as big as terrestrial planets
  - Comparable in size to Mercury
  - Only Titan has an atmosphere
- Remaining satellites (>140 known today!) much smaller

Spectroscopy of Titan (iclickers Question)

A ground based telescope is pointed at the atmosphere of Titan and a spectrum is obtained. The spectral lines observed in this spectrum:

A) Can only be features of Titan

B) can be characteristic of the Earth's atmosphere as well as Titan's atmosphere

C) Can be characteristic of the cooler outer layers of the Sun's atmosphere as well as of Titan's atmosphere

D) can be characteristic of the atmosphere of Titan and the Earth and also of the cooler outer layers of the Sun's atmosphere.

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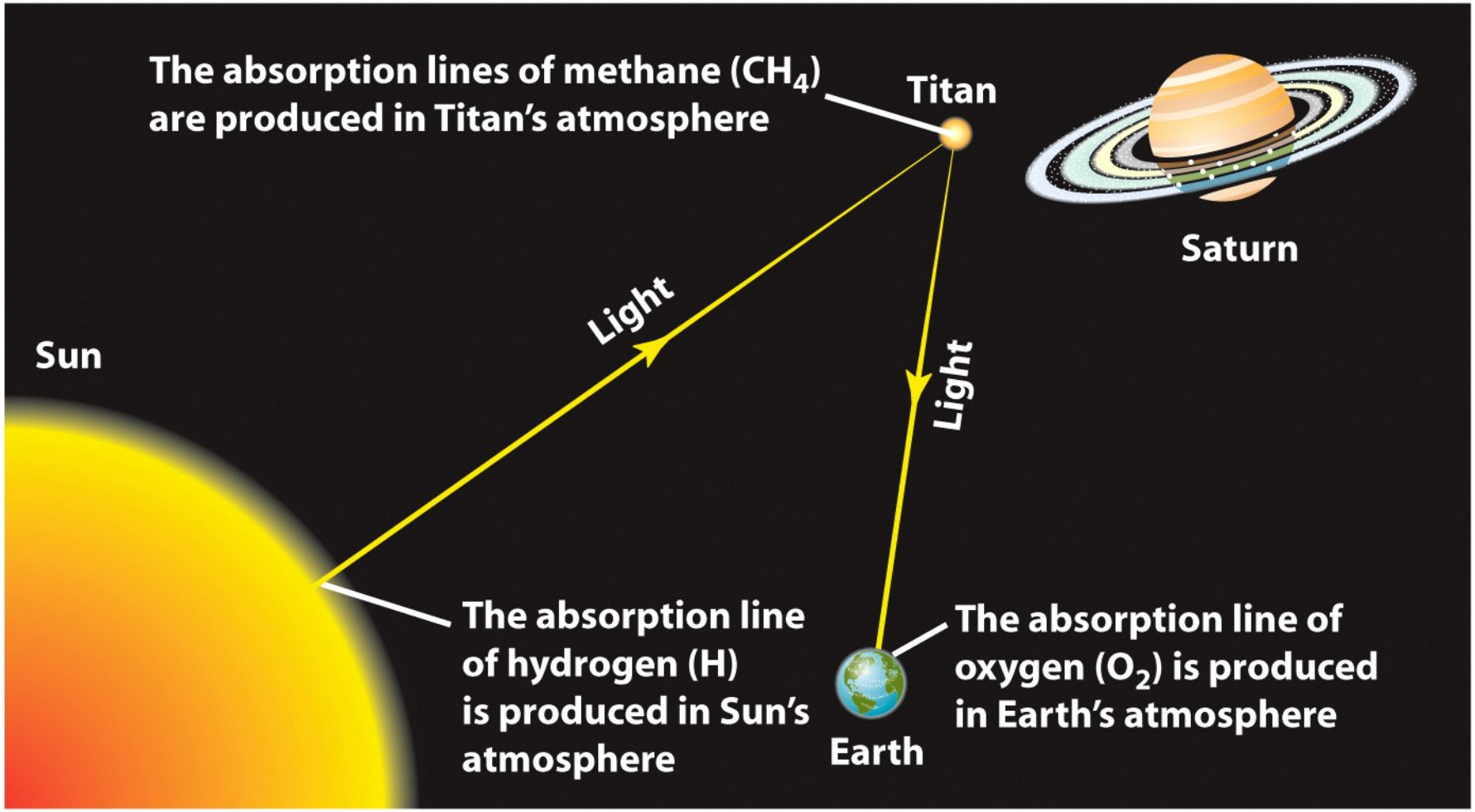
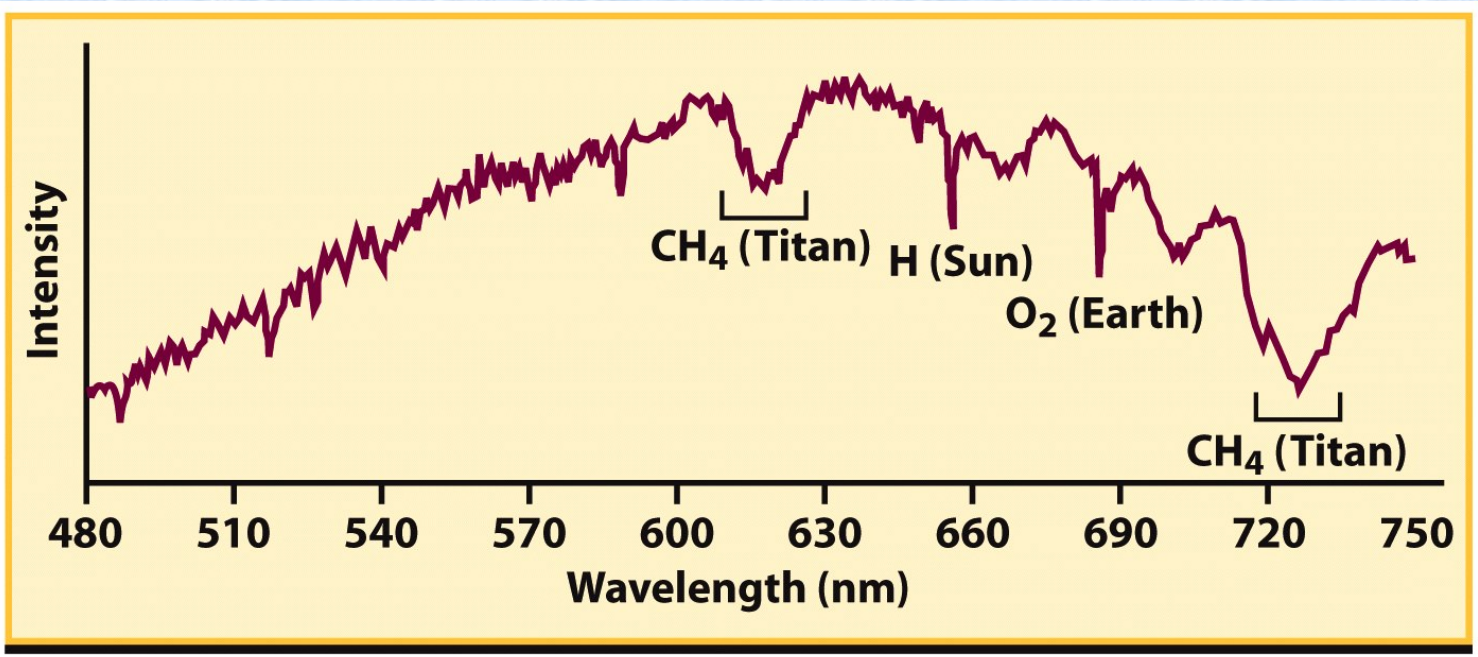
D) **Can be characteristic of the atmosphere of Titan and the Earth and also of the cooler outer layers of the Sun's atmosphere**.



Interpreting Titan's spectrum

Figure 7-3c
Universe, Eighth Edition

Spectroscopy:
Chemical Composition of Atmosphere



The spectrum of sunlight reflected from Titan

Figure 7-3b
Universe, Eighth Edition

- Dips: due to absorption by hydrogen atoms (H), oxygen molecules (O_2), and methane molecules (CH_4)
- Only methane actually present in Titan's atmosphere

Jupiter's moon Europa

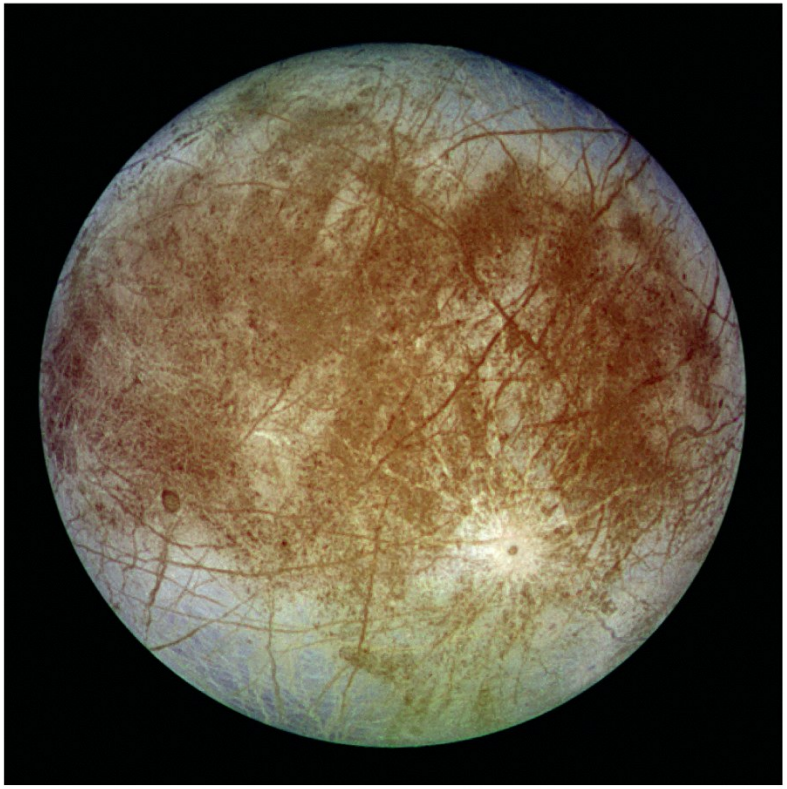
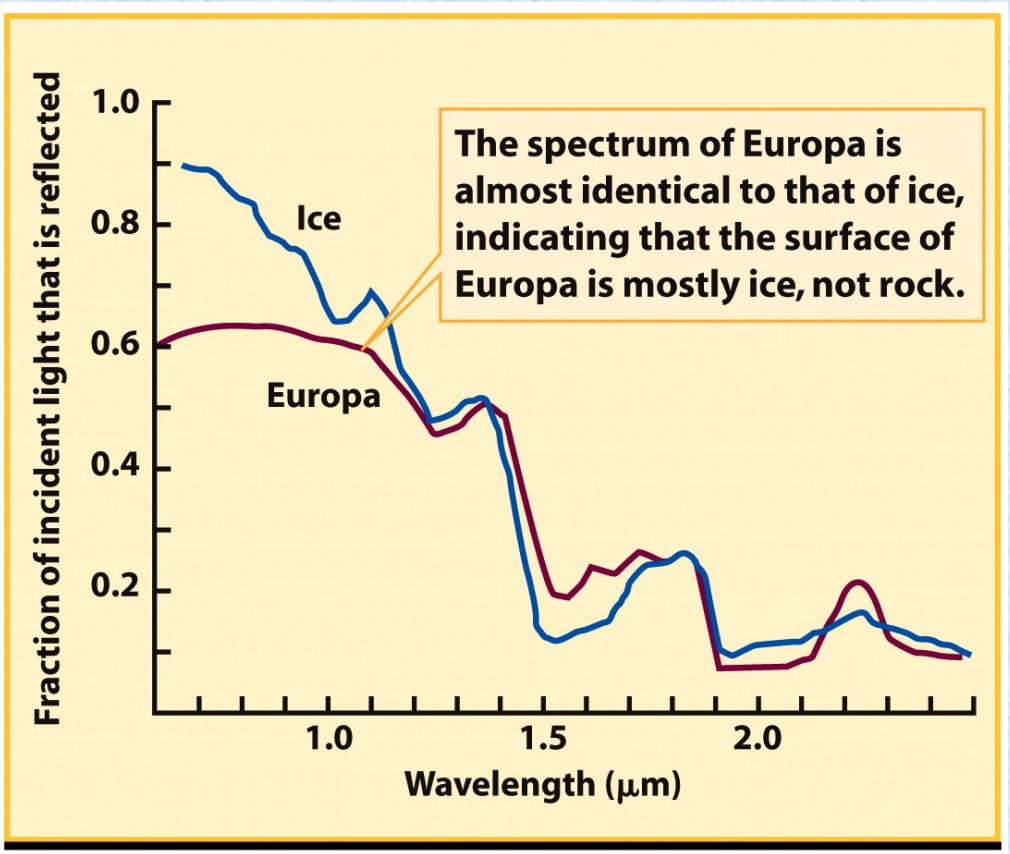


Figure 7-4a
Universe, Eighth Edition



The spectum of light reflected from Europa

Figure 7-4b
Universe, Eighth Edition

Europa:

- No atmosphere
- Sun light reflected from surface

Summary of Solar System Formation

- Collisional ejection theory for the Moon's origin
  - Molten, early moon formed from debris of proto-planet & Earth collision
  - The lunar highlands have some very old rocks (Earth's age roughly); the maria are younger (3.8 − 4.1 billion. years).
- 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.