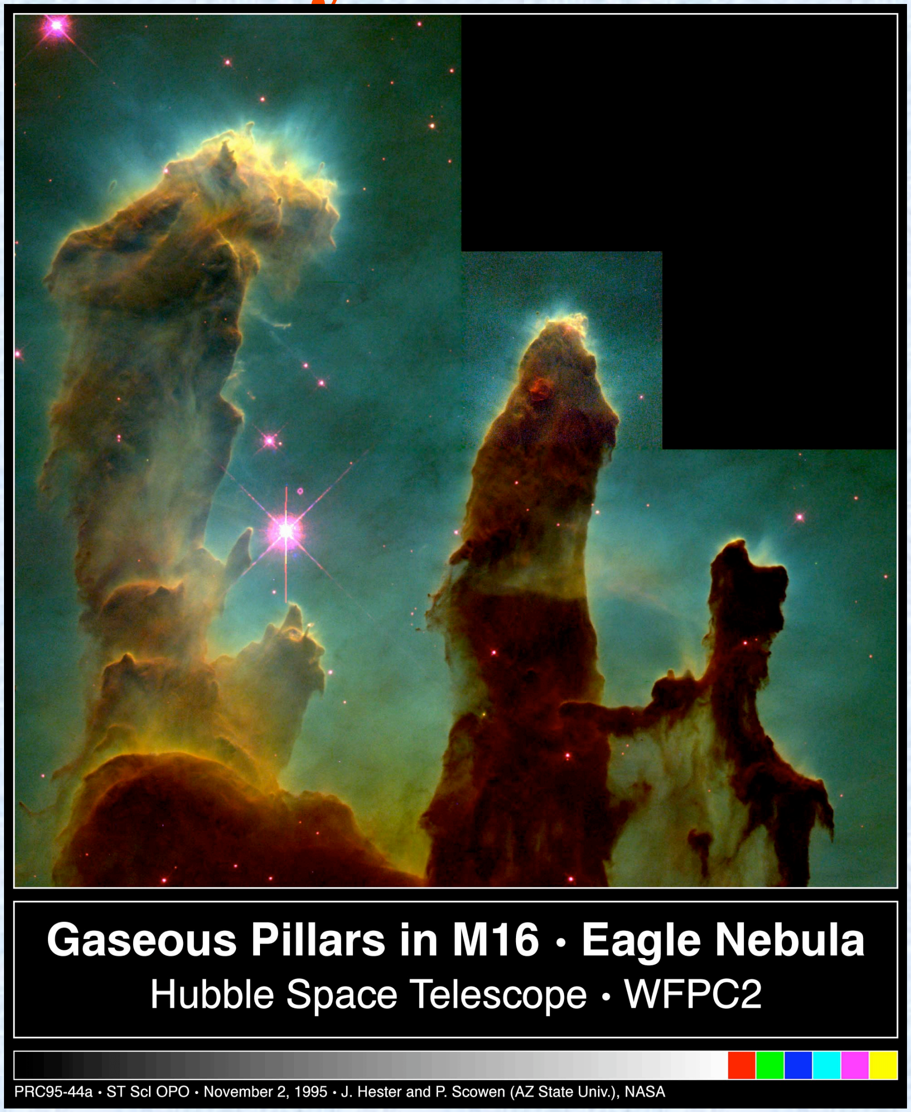
Astronomy 1 – Winter 2011



Lecture 21; February 28 2011

Previously on Astro-1

- Introduction to stars
- Measuring Distances
- Inverse square law: luminosity vs brightness
- Colors and spectral types
- Masses of stars

Stargazing Events

– Broida Hall
– March 7/8
– 2% credit, first come first served basis, register with TAs by sending them e-mail, starting now. The first 50 will be signed up for March 7. If there are more then 50 people they will be signed up for March 8.
– Registration will close this Friday
– Make sure to write ASTRO1 stargazing in the subject
– 2% Penalty if you register and don't show up!

Today on Astro-1

- The birth of stars
  - Mass determines the fate of stars
  - How do stars form?
  - Protostars
  - The life of stars on the main sequence
  - Life after the main sequence

The mass of stars determines their fate

All main-sequence stars are made of the same stuff…

So why are more massive stars more luminous?

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Answer: They're "turbocharged"

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Increased pressure in a turbocharged engine allows the engine to burn fuel faster and generate more power

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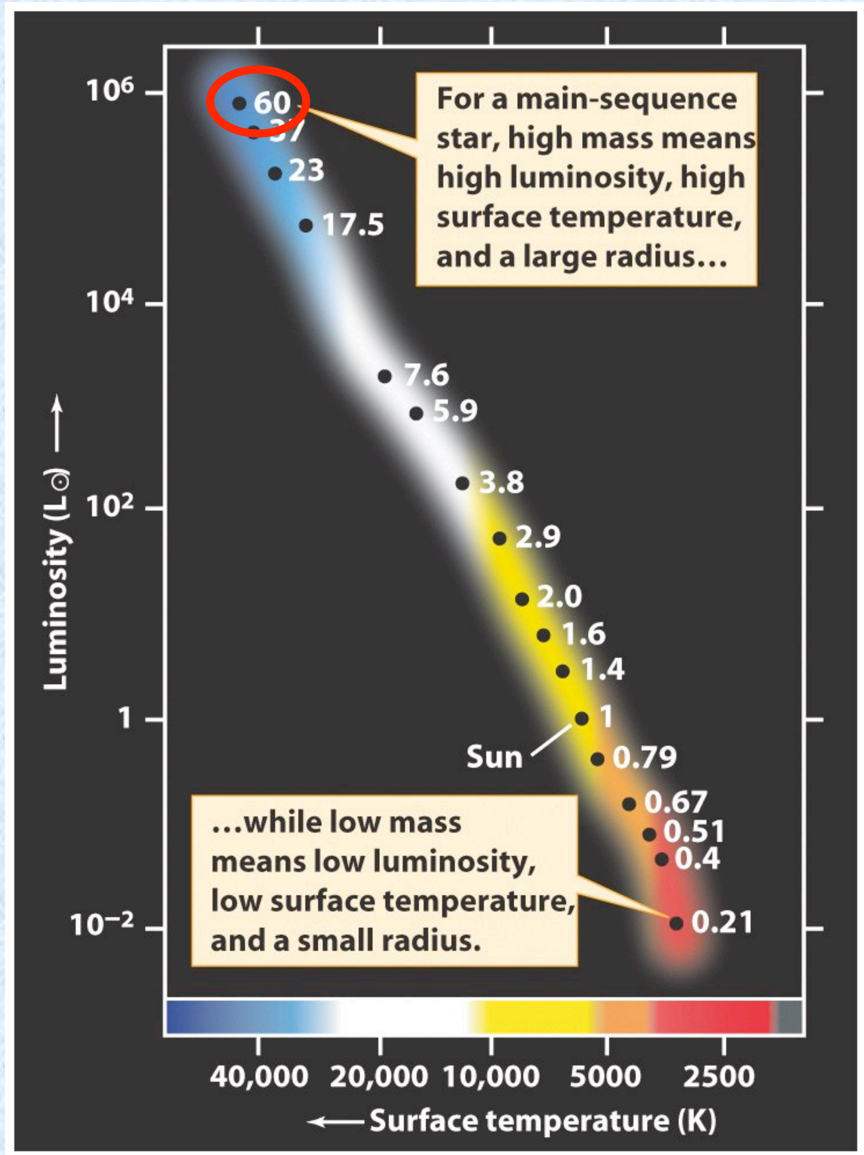
Increased pressure in a turbocharged engine allows the engine to burn fuel faster and generate more power

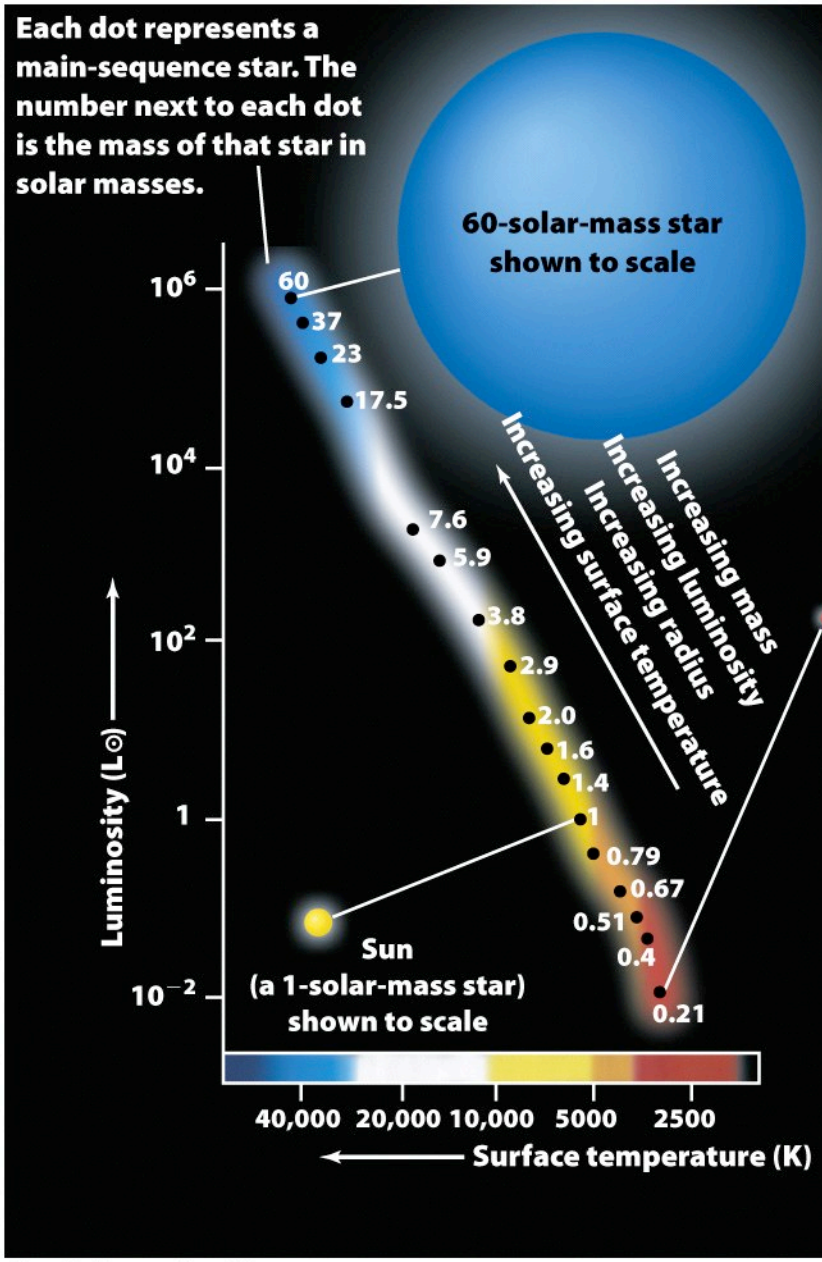
Stars work the same way.

H-R diagram with masses

•Greater mass… means greater central pressure & temperature…
•and so greater luminosity...
•and so shorter lifetime

•A star with 60 times the mass of the Sun...
•has 60 times as much nuclear fuel as the Sun…
but burns it 10^6 times as rapidly!





- A star with 60 solar masses has much higher pressure and temperature at its core than does the Sun.
- This causes thermonuclear reactions in the core to occur much more rapidly and release energy at a much faster rate — 790,000 times faster than in the Sun.
- Energy is emitted from the star's surface at the same rate that it is released in the core, so the star has 790,000 times the Sun's luminosity.
- The tremendous rate of energy release also heats the star's interior tremendously, increasing the star's internal pressure. This inflates the star to 15 times the Sun's radius.
- The star's surface must be at a high temperature (about 44,500 K) in order for it to emit energy into space at such a rapid rate.

- A star with 0.21 solar mass has much lower pressure and temperature at its core than does the Sun.
- This causes thermonuclear reactions in the core to occur much more slowly and release energy at a much slower rate — 0.011 times as fast as in the Sun.
- Energy is emitted from the star's surface at the same rate that it is released in the core, so the star has 0.011 of the Sun's luminosity.
- The low rate of energy release supplies relatively little heat to the star's interior, so the star's internal pressure is low. Hence the star's radius is only 0.33 times the Sun's radius.
- The star's surface need be at only a low temperature (about 3200 K) to emit energy into space at such a relatively slow rate.

Cosmic Connections 17
Universe, Eighth Edition

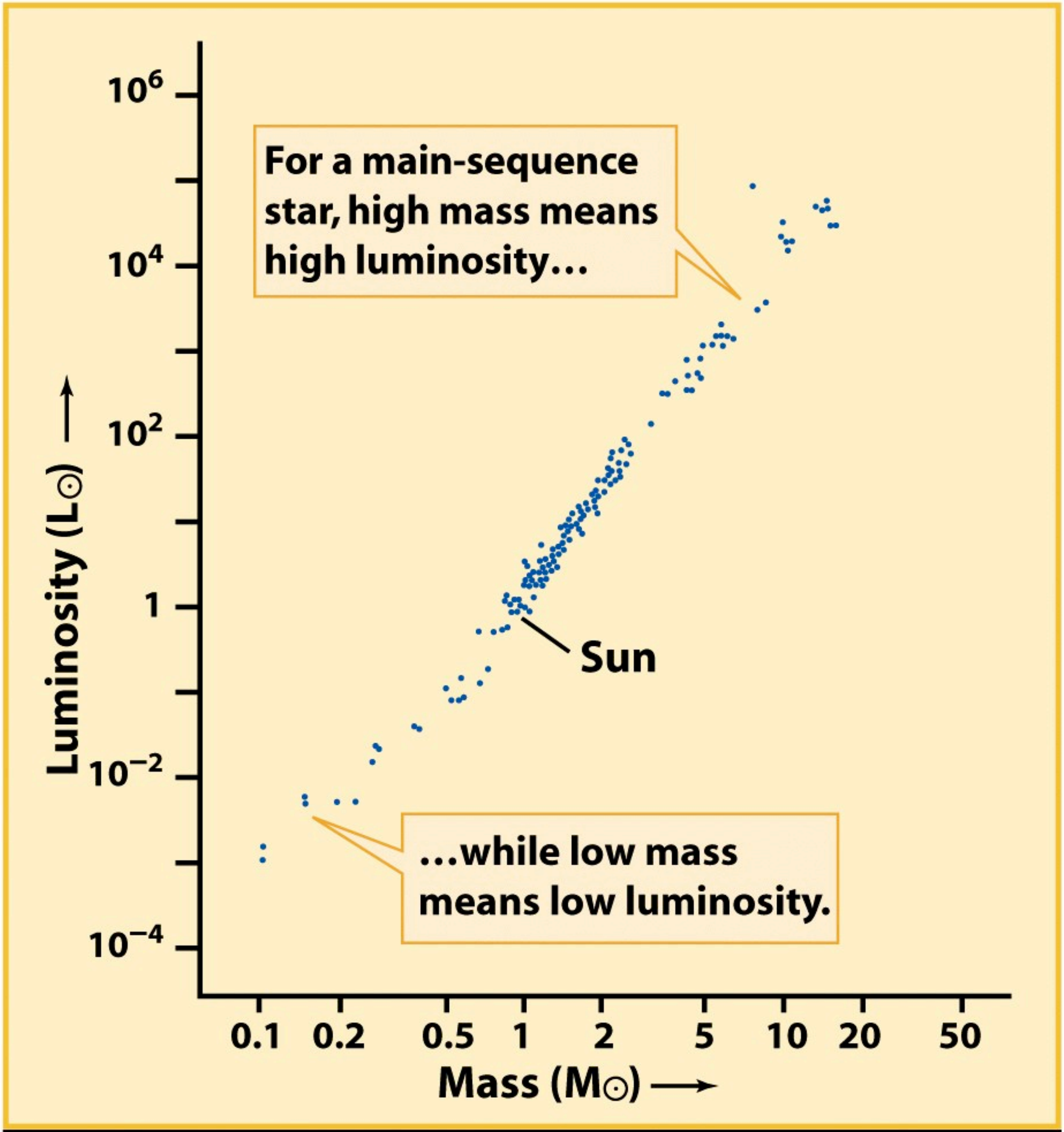


Figure 17-21
Universe, Eighth Edition

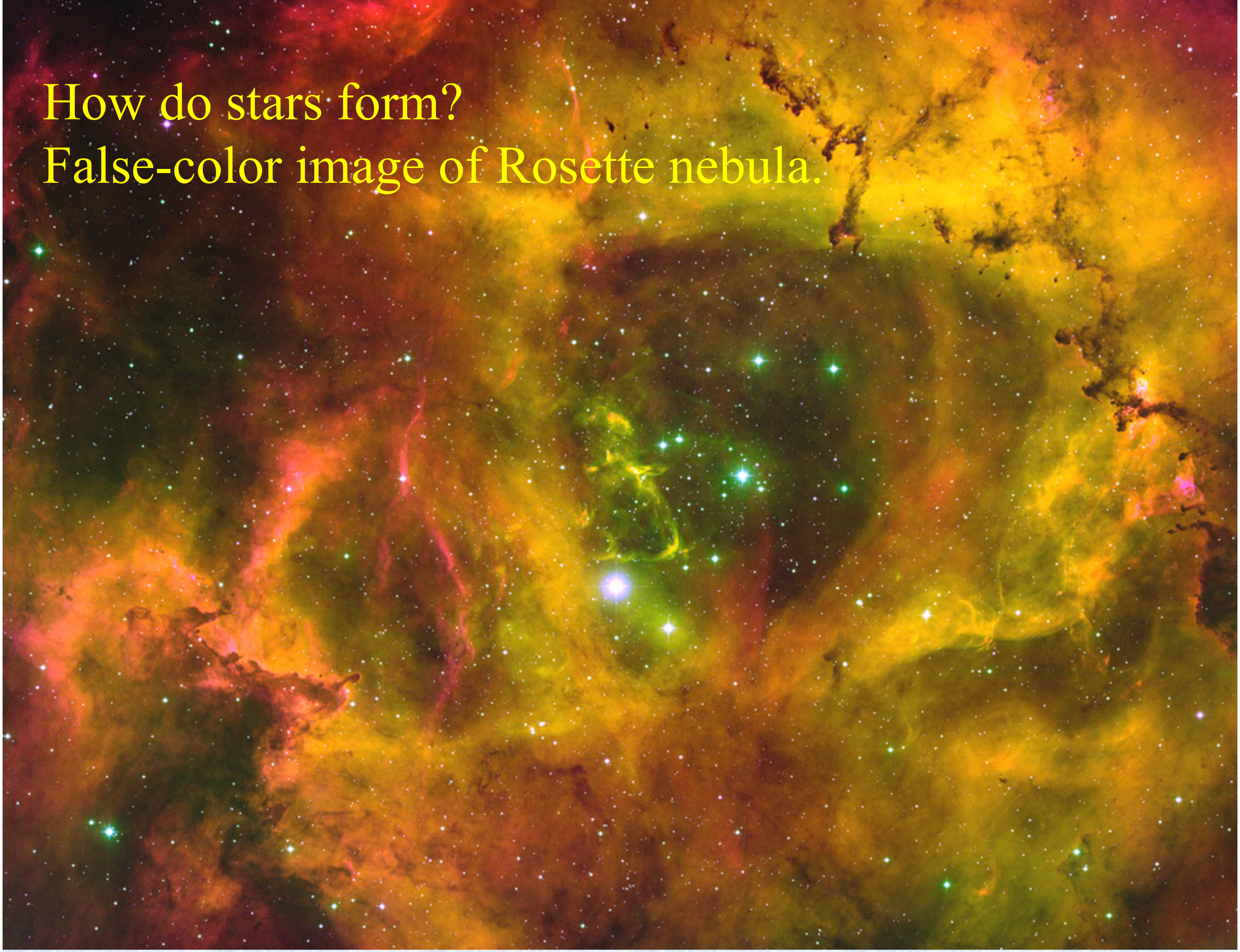
Question 21.1 (iclickers!)

- Why do more massive stars live a shorter life than stars like the sun?
  - A) Because they are easily bored
  - B) Because they collapse under their own weight
  - C) Because at higher pressure and temperature fusion happens much more fequently
  - D) Because they radiate energy out of the core more efficiently and therefore they loose energy more rapidly

But, how do stars form?

How do stars form?

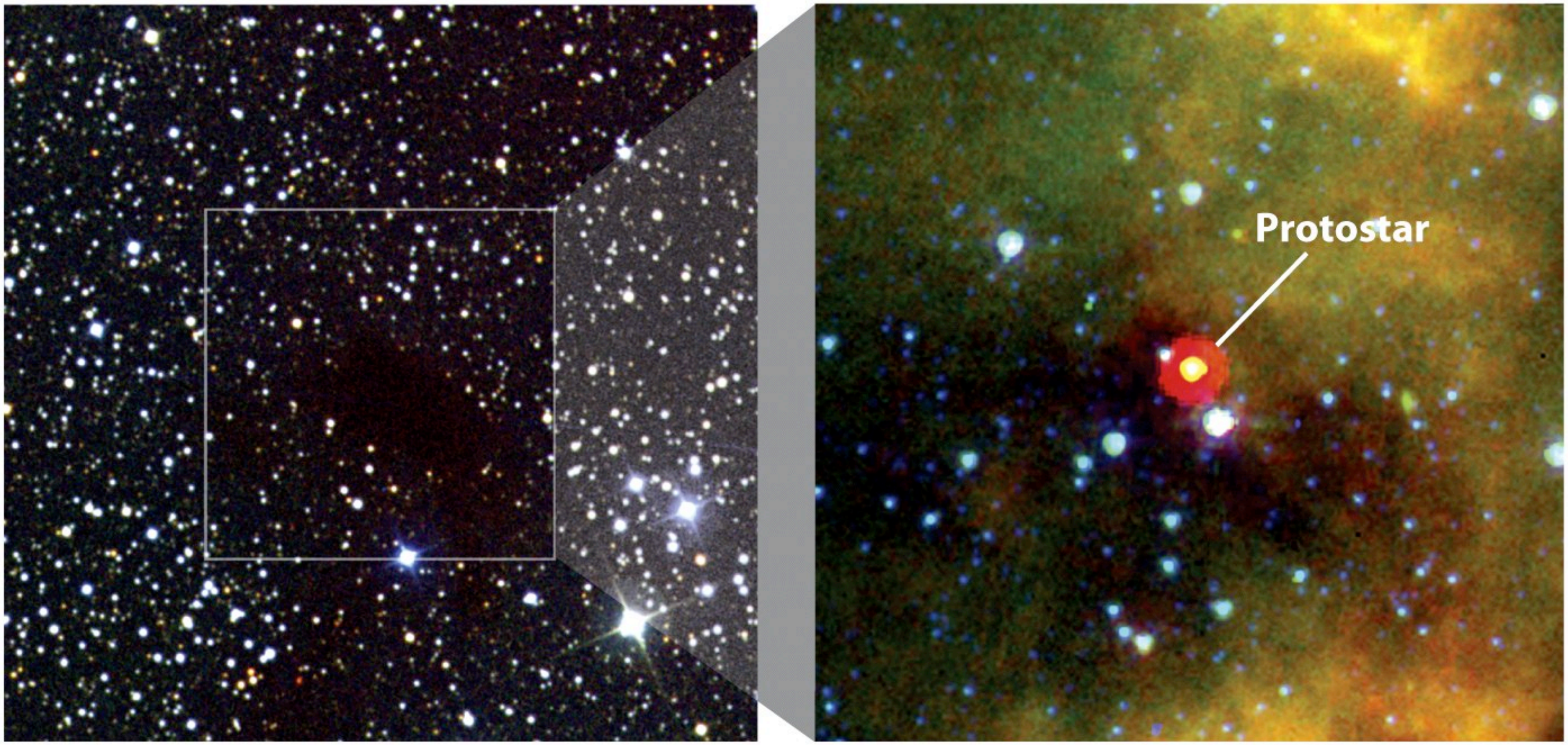
False-color image of Rosette nebula.



How do stars form?

(The Orion nebula as seen from CFHT).


Stars form within
"clumps" in the
interstellar medium.

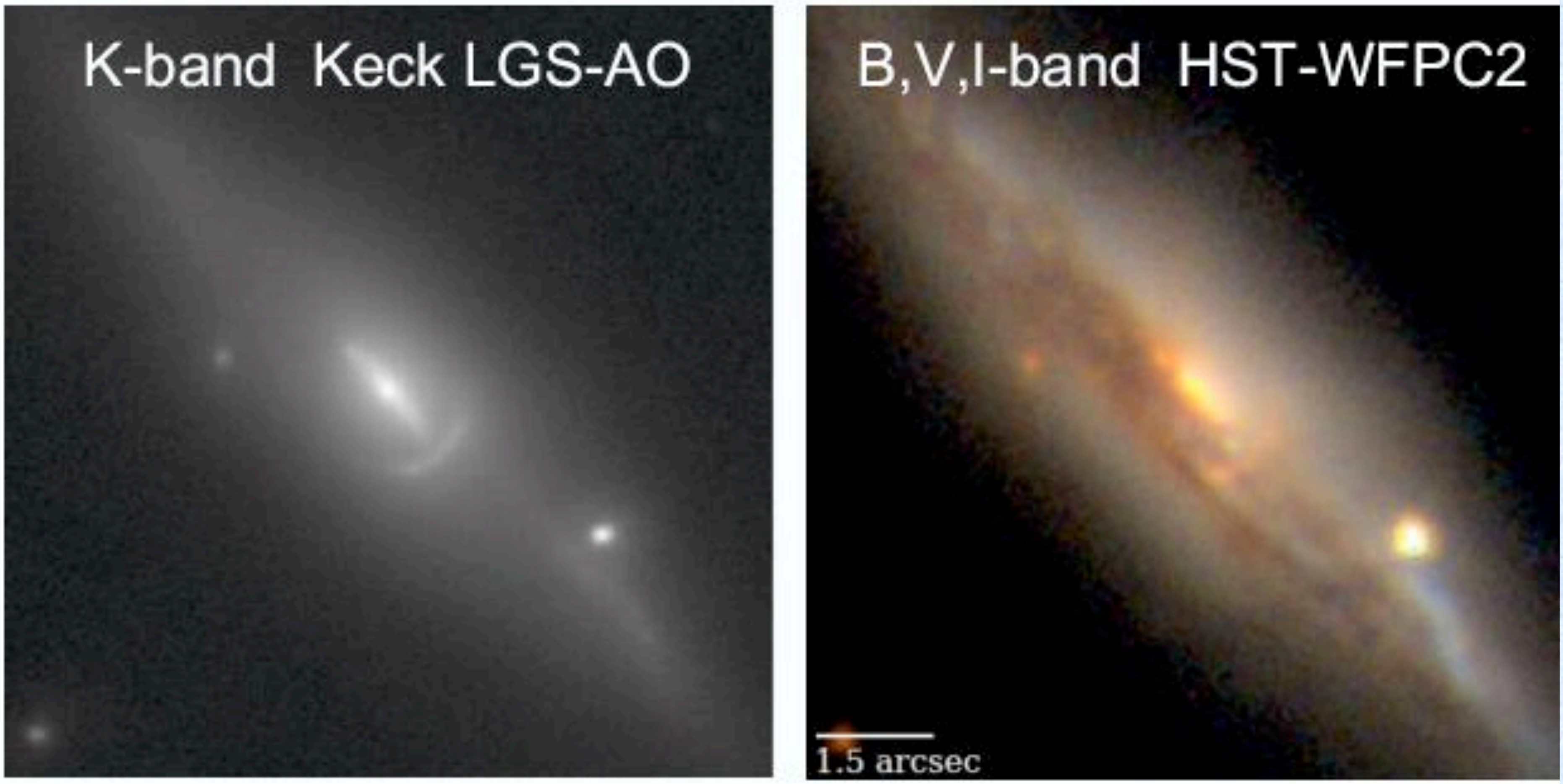


(a) A dark nebula

(b) A hidden protostar within the dark nebula

Figure 18-11
Universe, Eighth Edition

Spiral arms are good places to form stars (and dust!)

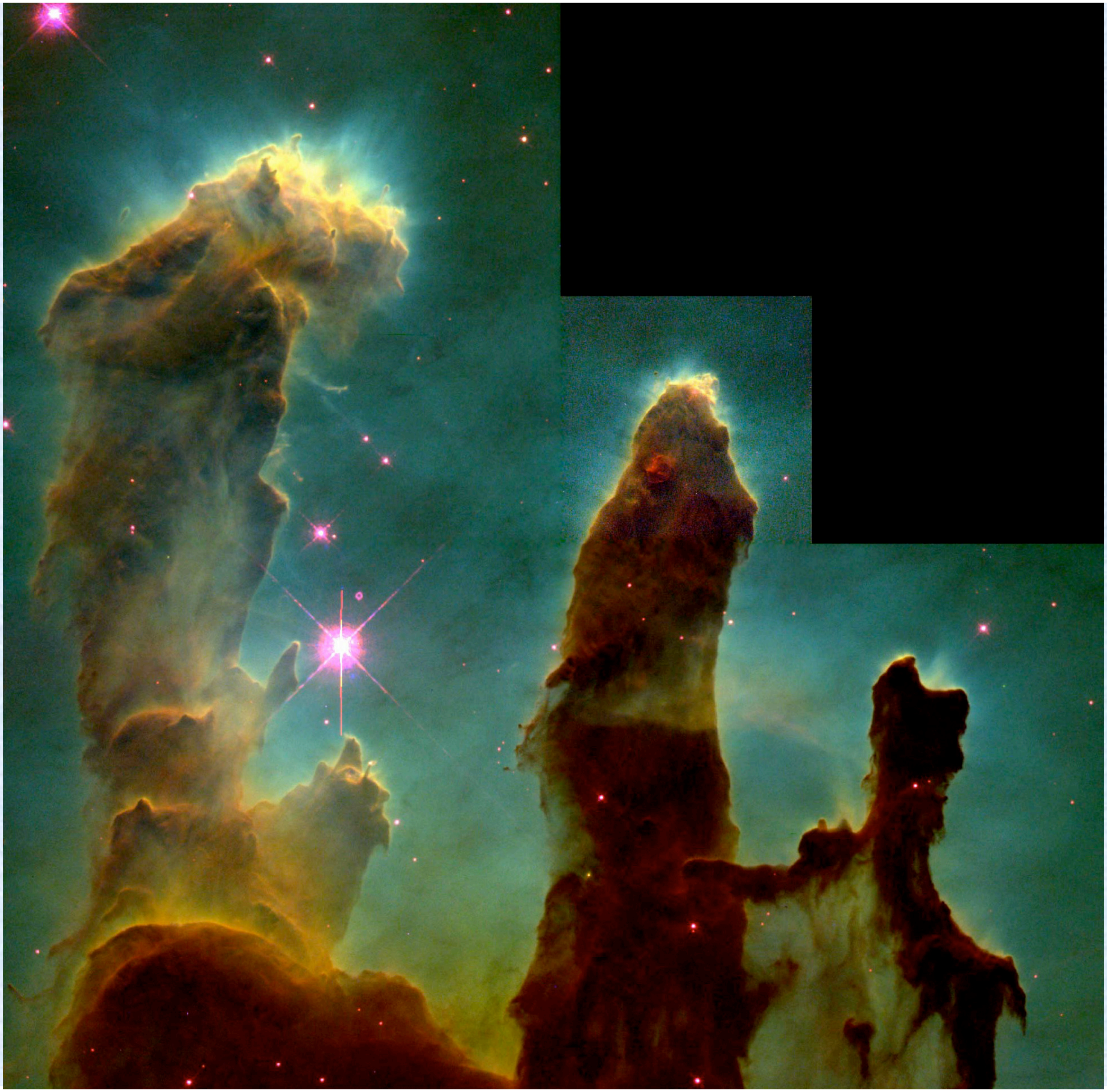


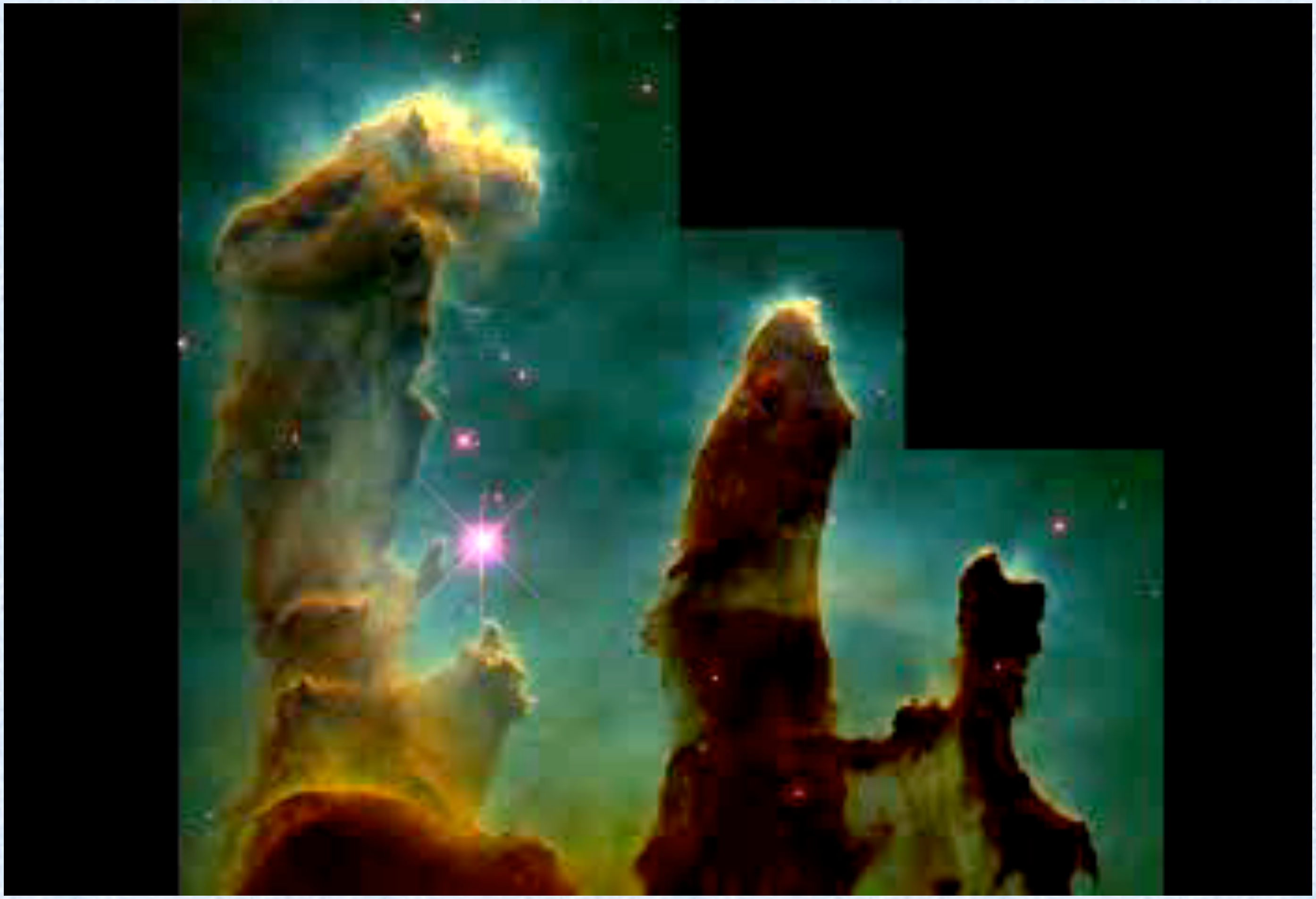
Protostars

collapsing gas cloud releases energy to make protostar shine

collapse stops when fusion begins
— establishes equilibrium.

The minimum mass to ignite fusion is 0.08 solar masses.





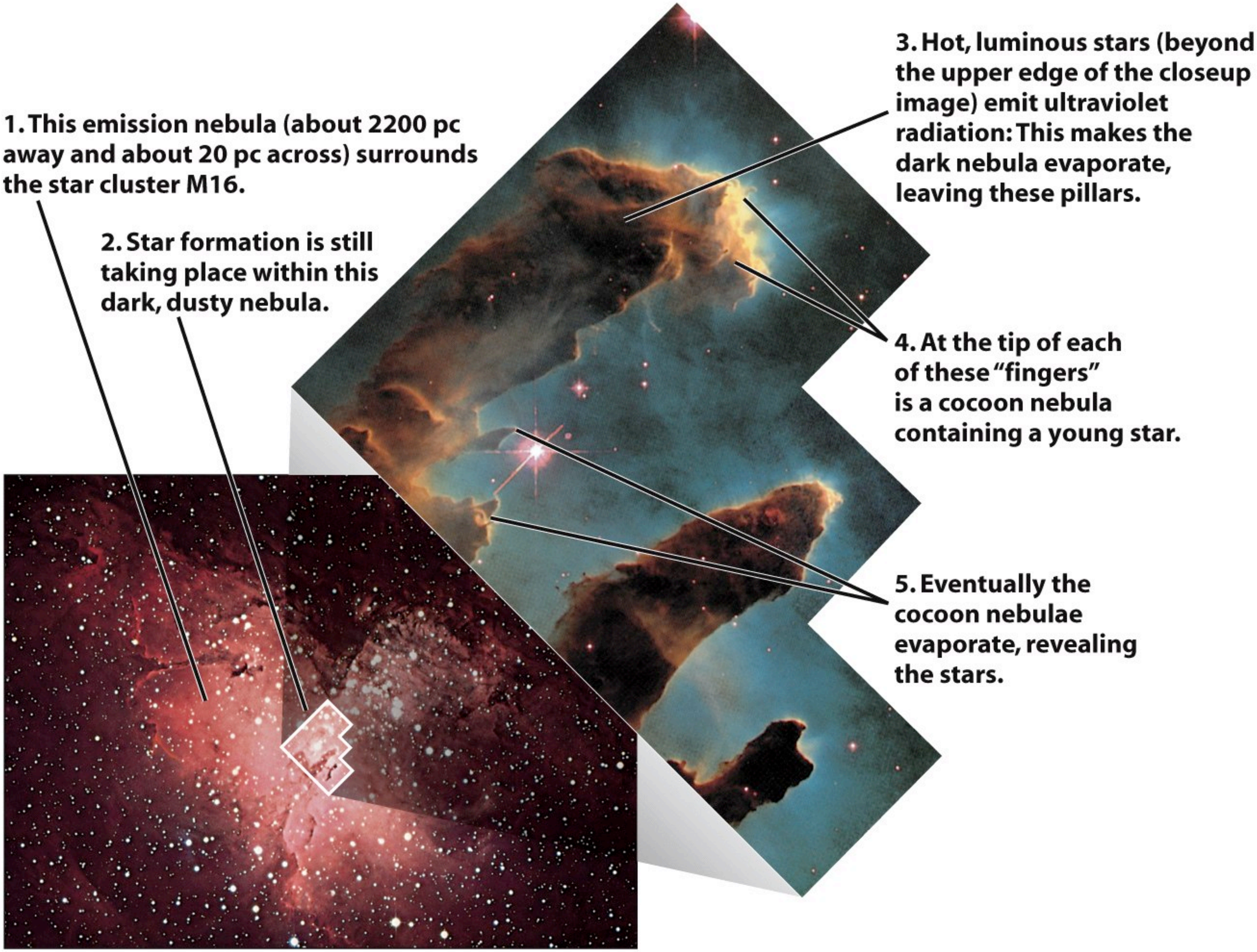


Figure 18-17
Universe, Eighth Edition

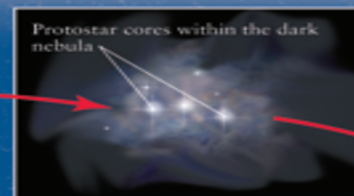
COSMIC CONNECTIONS

How Stars Are Born

If a clump of interstellar matter is cold and dense enough, it will begin to collapse thanks to the mutual gravitational attraction of its parts. If the clump is massive enough, it will evolve into a main-sequence star through the sequence of events shown here.

In this cold, dark nebula, gas atoms and dust particles move so slowly that gravity can draw them together.

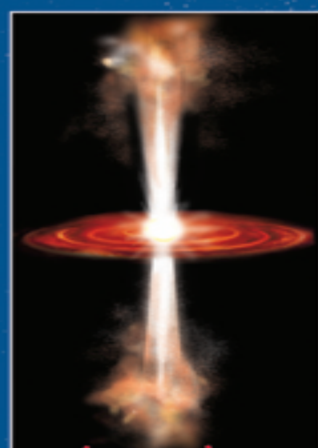
Gas and dust begin to condense into clumps, forming the cores of protostars.



As the cores condense, their density and temperature both increase.

As the protostars continue to heat up and accrete matter from the nebula, they begin to glow due to their increasing temperature.

Once the temperature at the center of a protostar becomes sufficiently high, thermonuclear fusion of hydrogen into helium begins. The mass that is continuing to fall onto the star forms an accretion disk.



In the T Tauri stage, the young star ejects mass into space in a bipolar outflow. A stellar wind blows away the remaining parts of the nebula that surround the star, exposing the star to space.

The ejected mass can induce a shock wave in the surrounding interstellar material, triggering the formation of additional stars.

Processes that cause the star to lose or gain mass come to an end, and the star stabilizes as a main-sequence star in hydrostatic equilibrium. The remnants of the accretion disk may remain as a protoplanetary disk, from which a system of planets may form around the star.

Question 21.2 (iclickers!)

- How does the temperature of an interstellar cloud affect its ability to form stars?
    - A) Star formation is so complicated that it is not possible to say how one quantity, such as temperature, affects it
    - B) Higher temperatures inhibit star formation
    - C) Higher temperatures help star formation
    - D) Star formation is independent of the temperature of the cloud

Age-dating star clusters with the H-R diagram

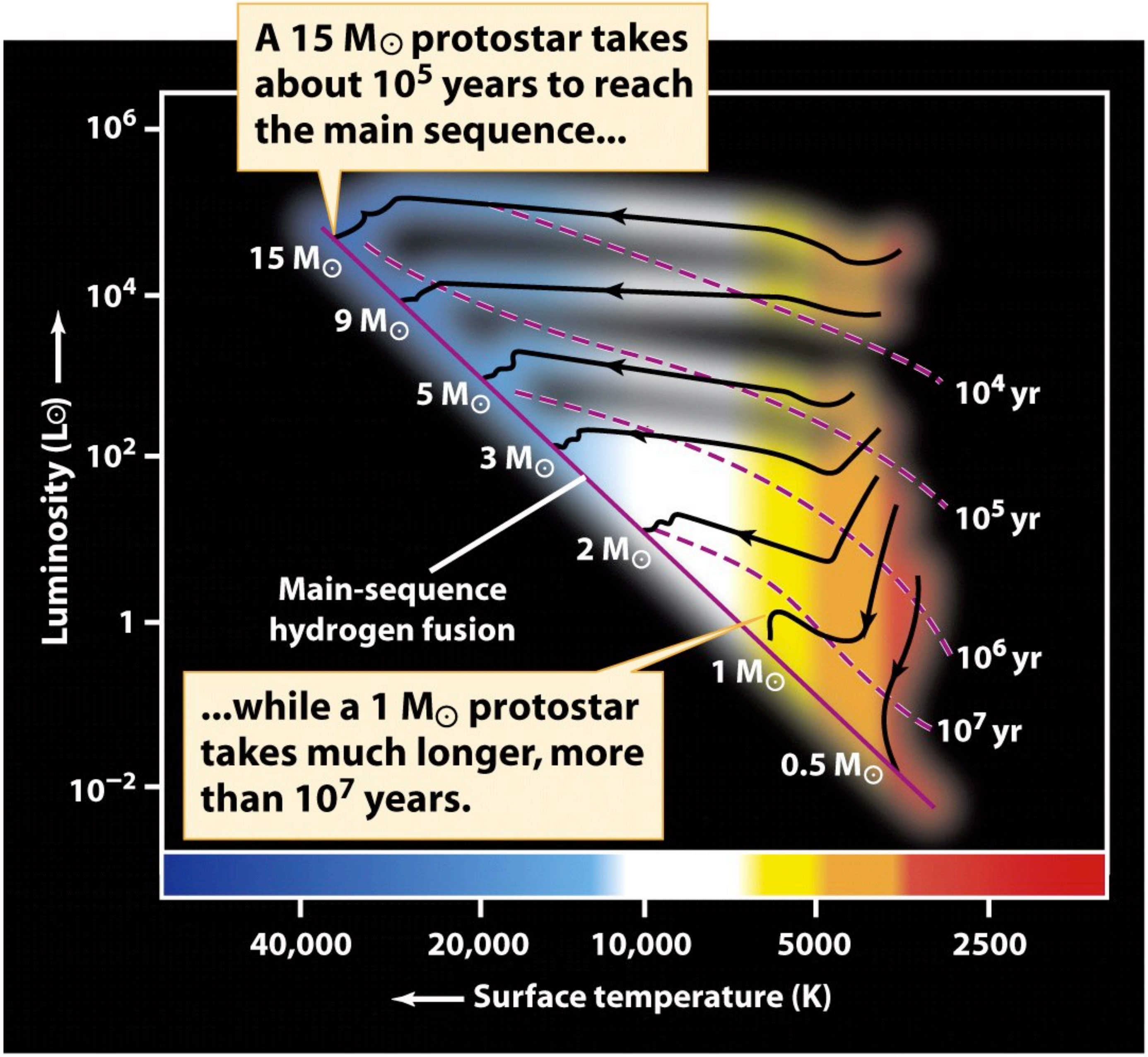
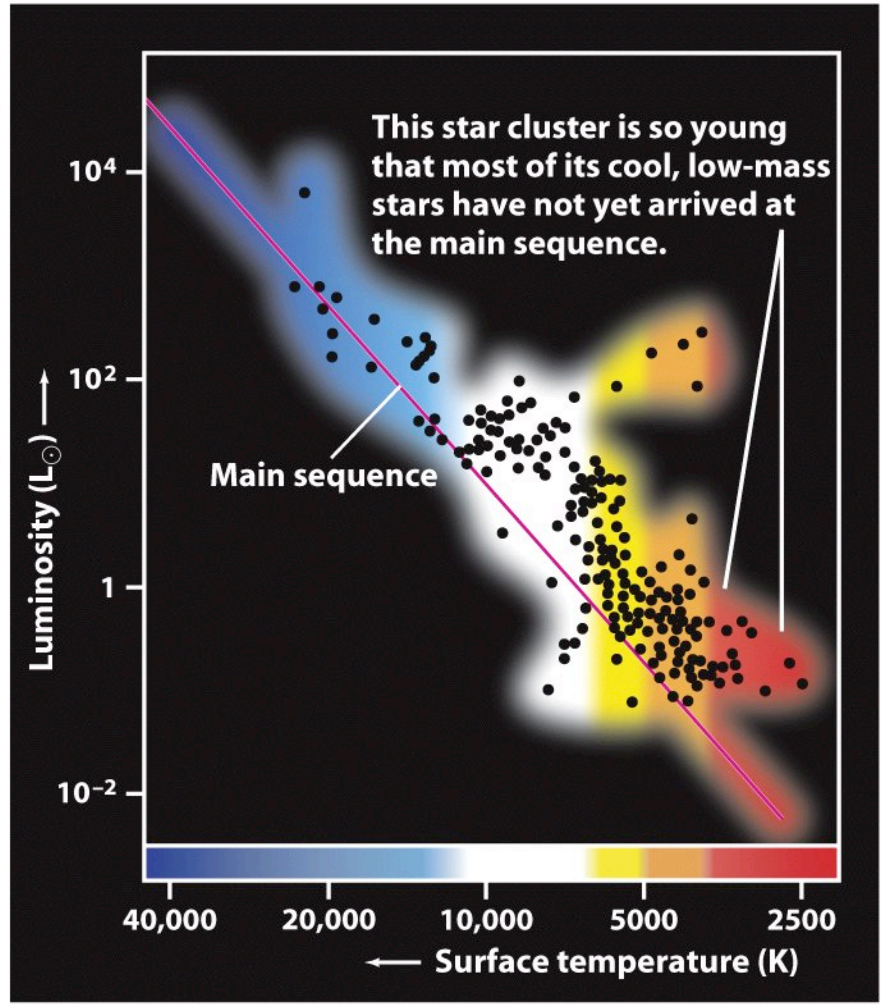


Figure 18-10
Universe, Eighth Edition

(a) The star cluster NGC 2264

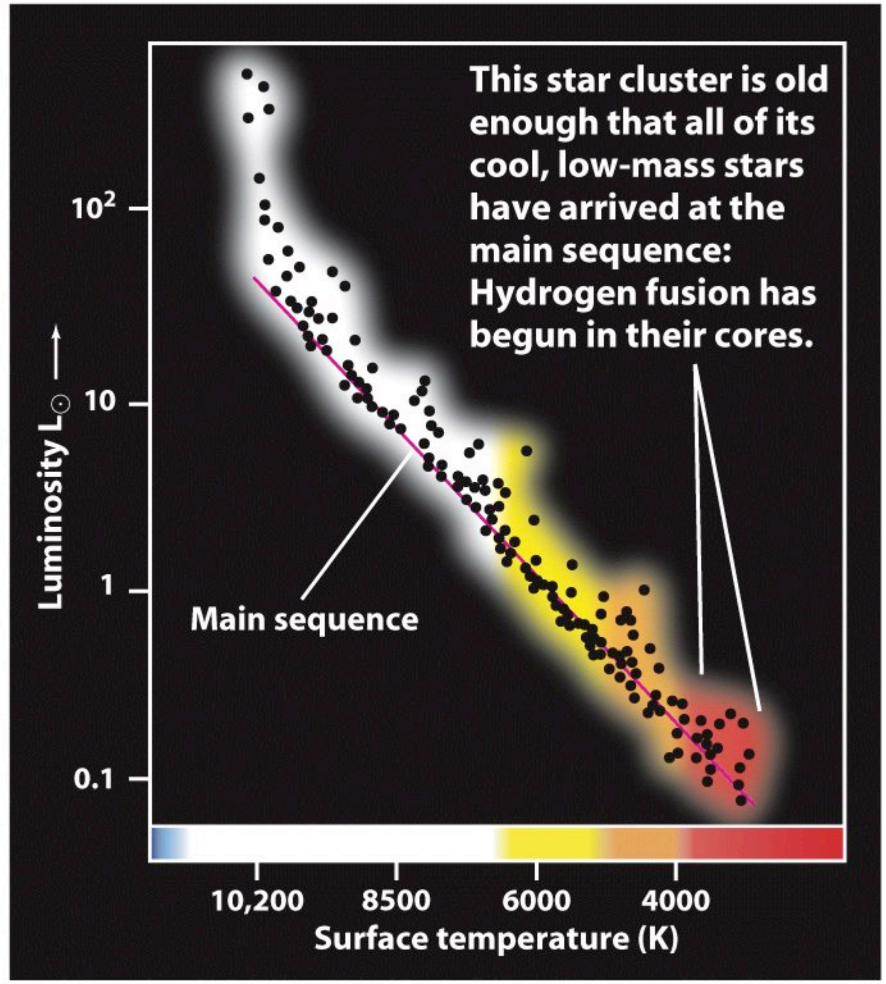


(b) An H-R diagram of the stars in NGC 2264

Figure 18-18

Universe, Eighth Edition

(a) The Pleiades star cluster

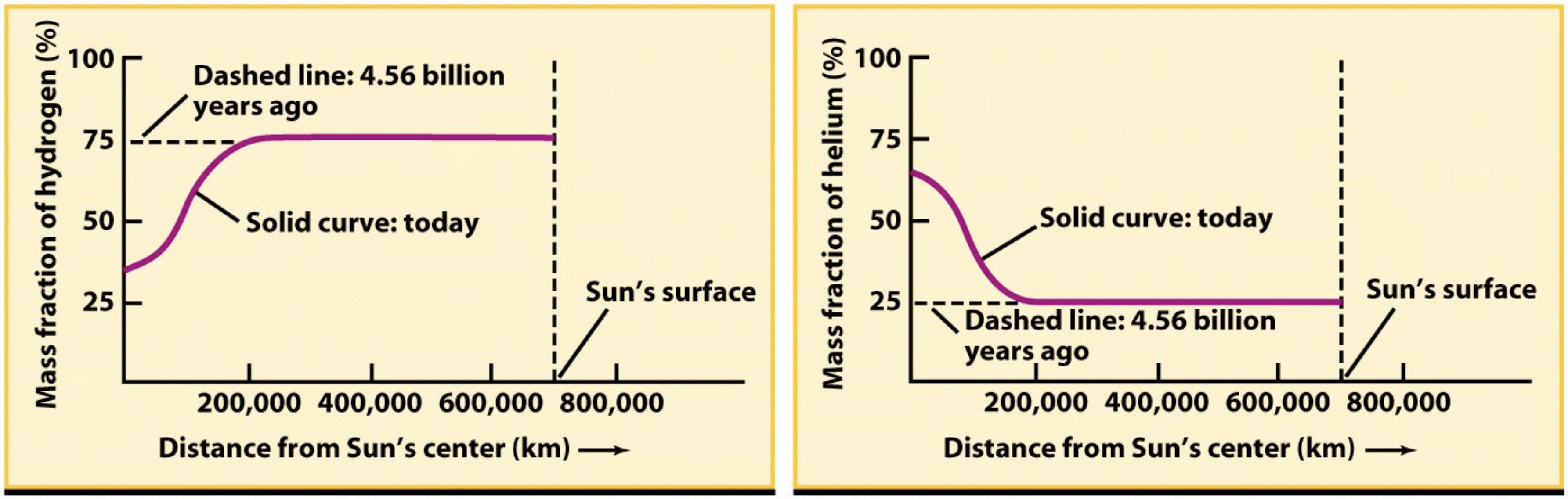


(b) An H-R diagram of the stars in the Pleiades

Figure 18-19
Universe, Eighth Edition

Evolution of stars on the main sequence

Evolution of the Sun's interior



(a) Hydrogen in the Sun's interior

(b) Helium in the Sun's interior

Figure 19-1
Universe, Eighth Edition

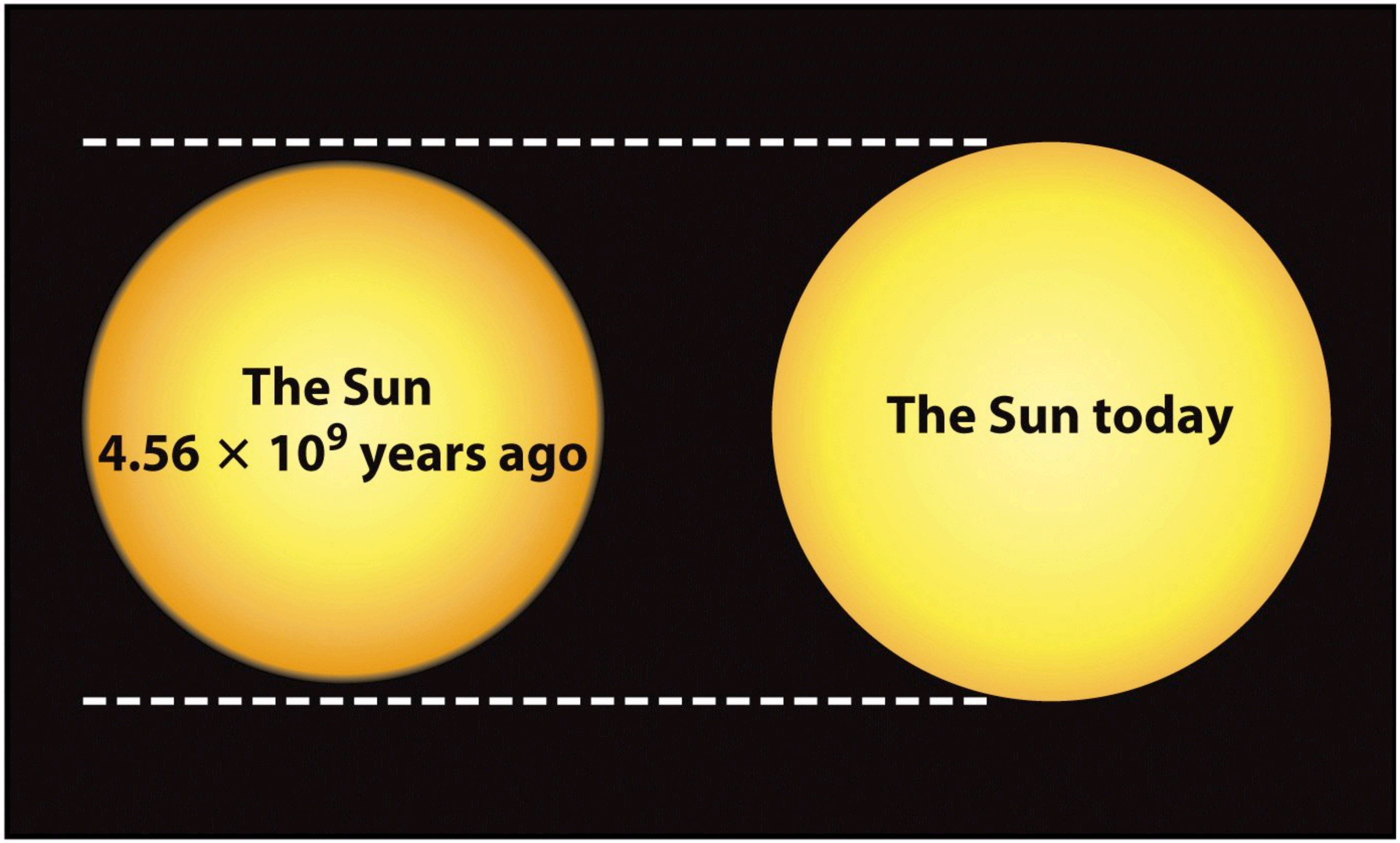


Figure 19-2
Universe, Eighth Edition

Over the past 4.56 $\times 10^9$ years, much of the hydrogen in the Sun's core has been converted into helium, the core has contracted a bit, and the Sun's luminosity has gone up by about 40%. These changes in the core have made the Sun's outer layers expand in radius by 6% and increased the surface temperature from 5500 K to 5800 K.

Table 19-1 Approximate Main-Sequence Lifetimes

Mass ($M_\odot$)	Surface temperature (K)	Spectral class	Luminosity ($L_\odot$)	Main-sequence lifetime (10^6 years)
25	35,000	O	80,000	4
15	30,000	B	10,000	15
3	11,000	A	60	800
1.5	7000	F	5	4500
1.0	6000	G	1	12,000
0.75	5000	K	0.5	25,000
0.50	4000	M	0.03	700,000

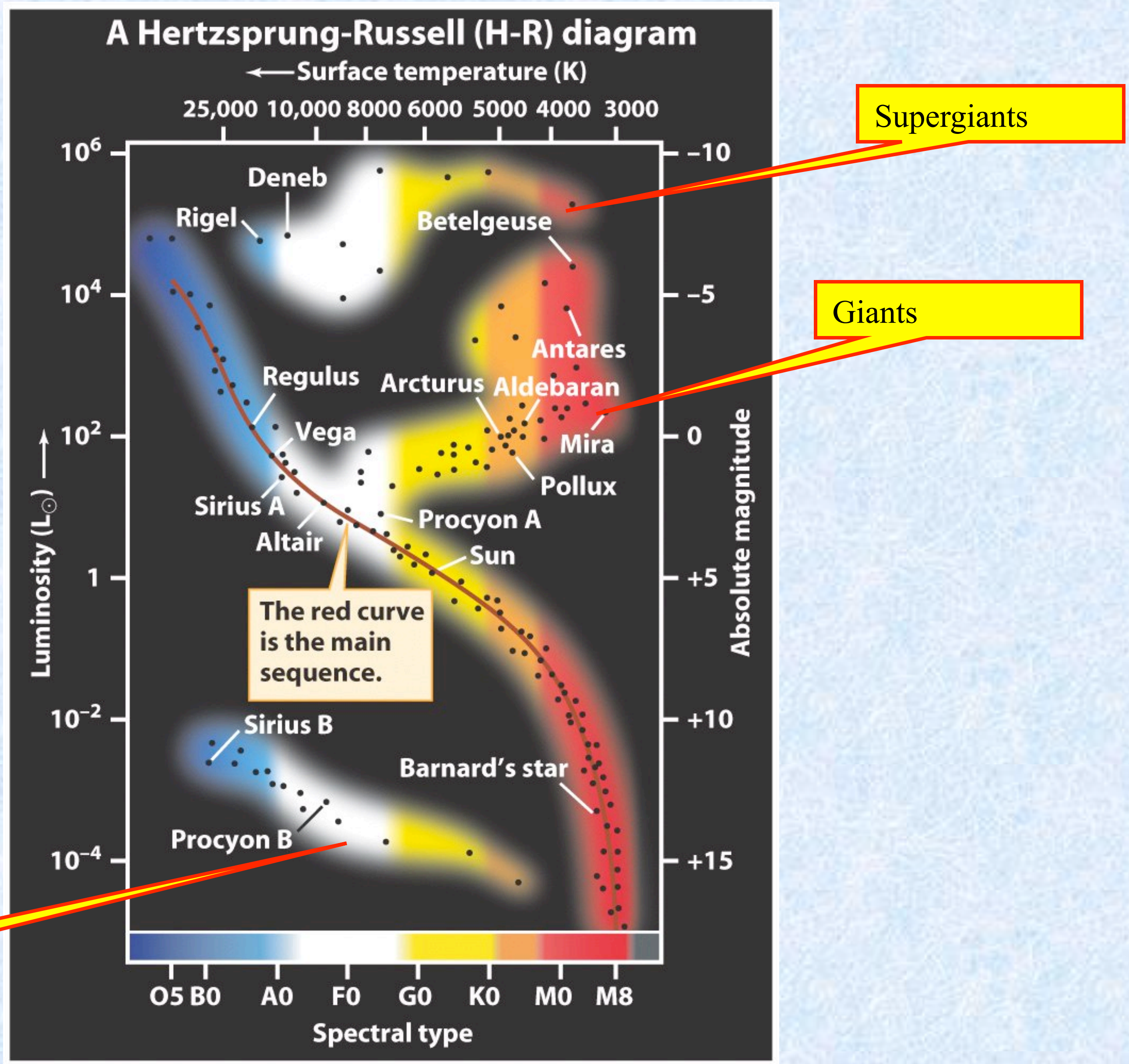
The main-sequence lifetimes were estimated using the relationship $t \propto 1/M^{2.5}$ (see Box 19-2).

Table 19-1
Universe, Eighth Edition

Life after the main sequence

When a star first forms, it is a main–sequence star that consumes hydrogen in its core

Stars that are *not* on the main sequence are later stages in stellar evolution



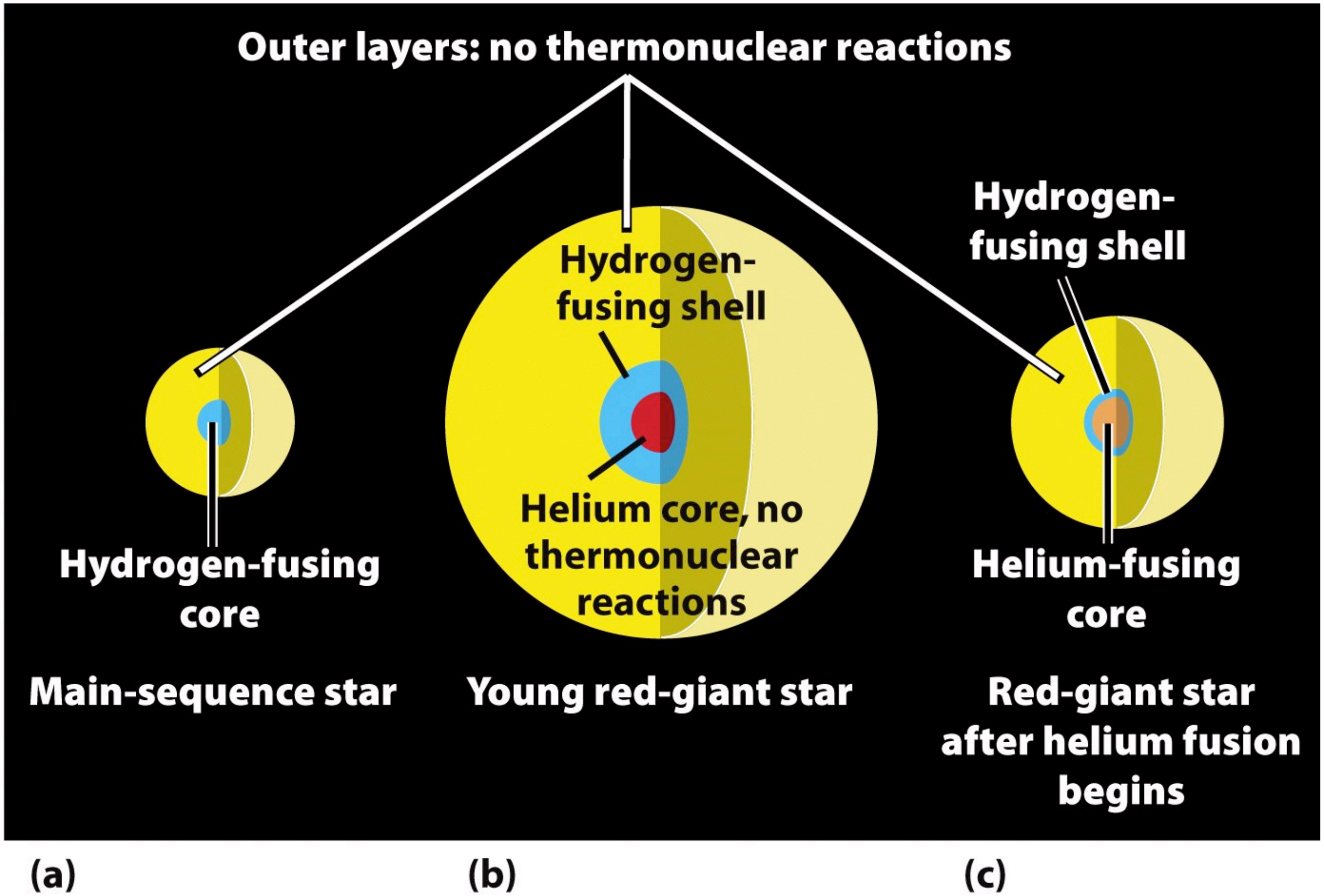
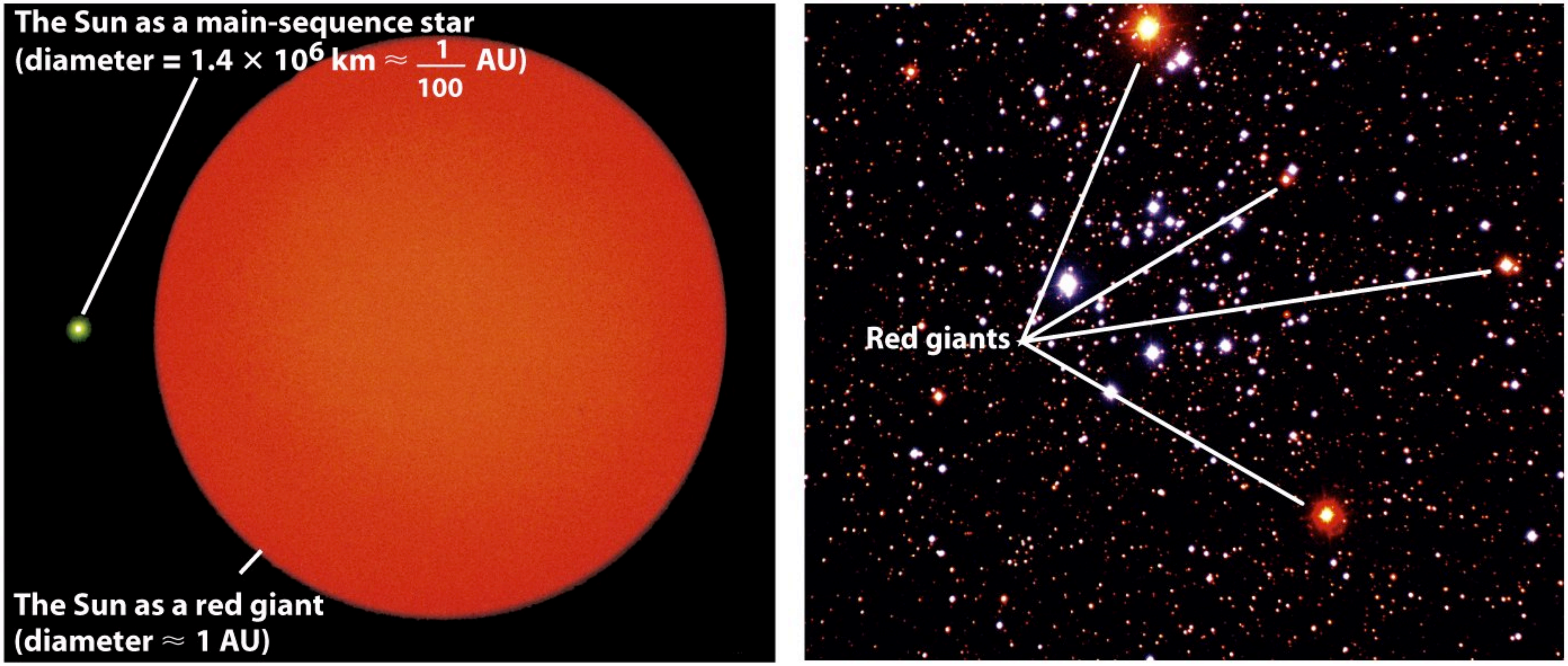


Figure 19-6
Universe, Eighth Edition

These three pictures are *not* drawn to scale. The star is about 100 times larger in its red-giant phase than in its main-sequence phase, then shrinks somewhat when core helium fusion begins.

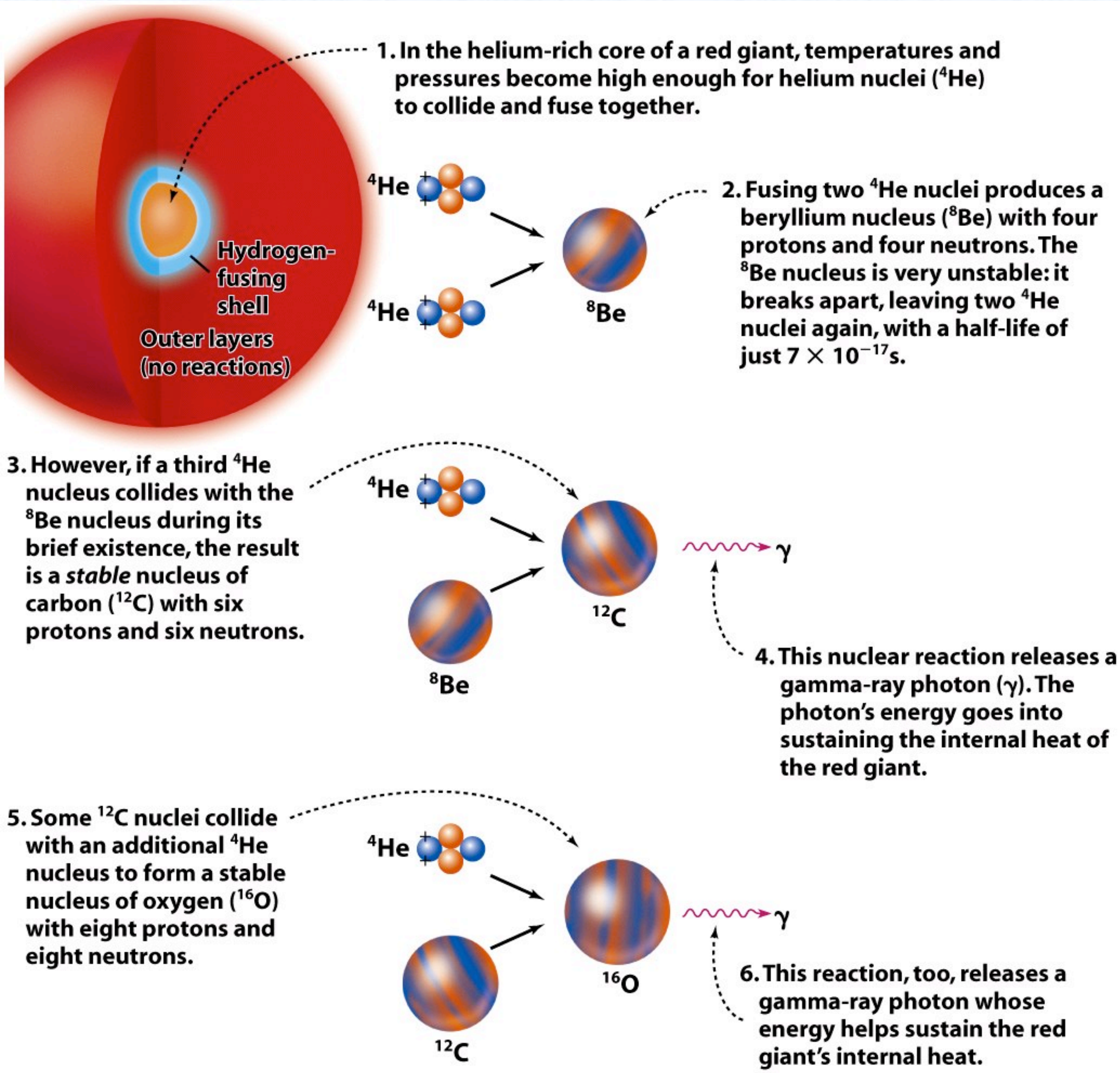
Stages in the Evolution of a Star with More than 0.4 Solar Masses



(a) The Sun today and as a red giant

(b) Red giant stars in the star cluster M50

Figure 19-4
Universe, Eighth Edition



Cosmic Connections 19
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A star becomes a red giant after the fusion of hydrogen into helium in its core has come to an end. As the red giant's core shrinks and heats up, a new cycle of reactions can occur that create the even heavier elements carbon and oxygen.

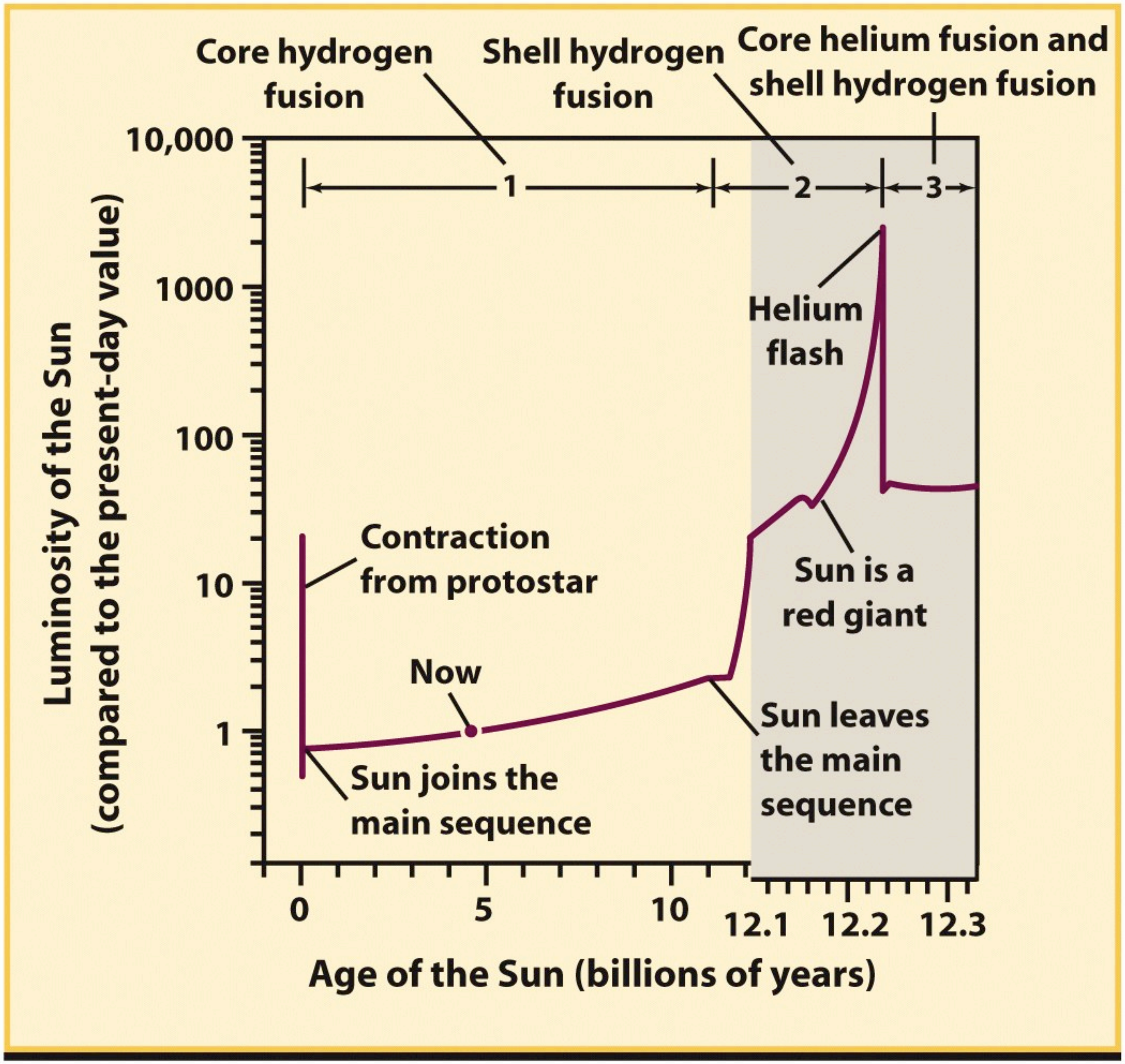

Figure 19-8
Universe, Eighth Edition

The post–main-sequence evolution is much more rapid, so a different time scale is used in the right-hand portion of the graph.

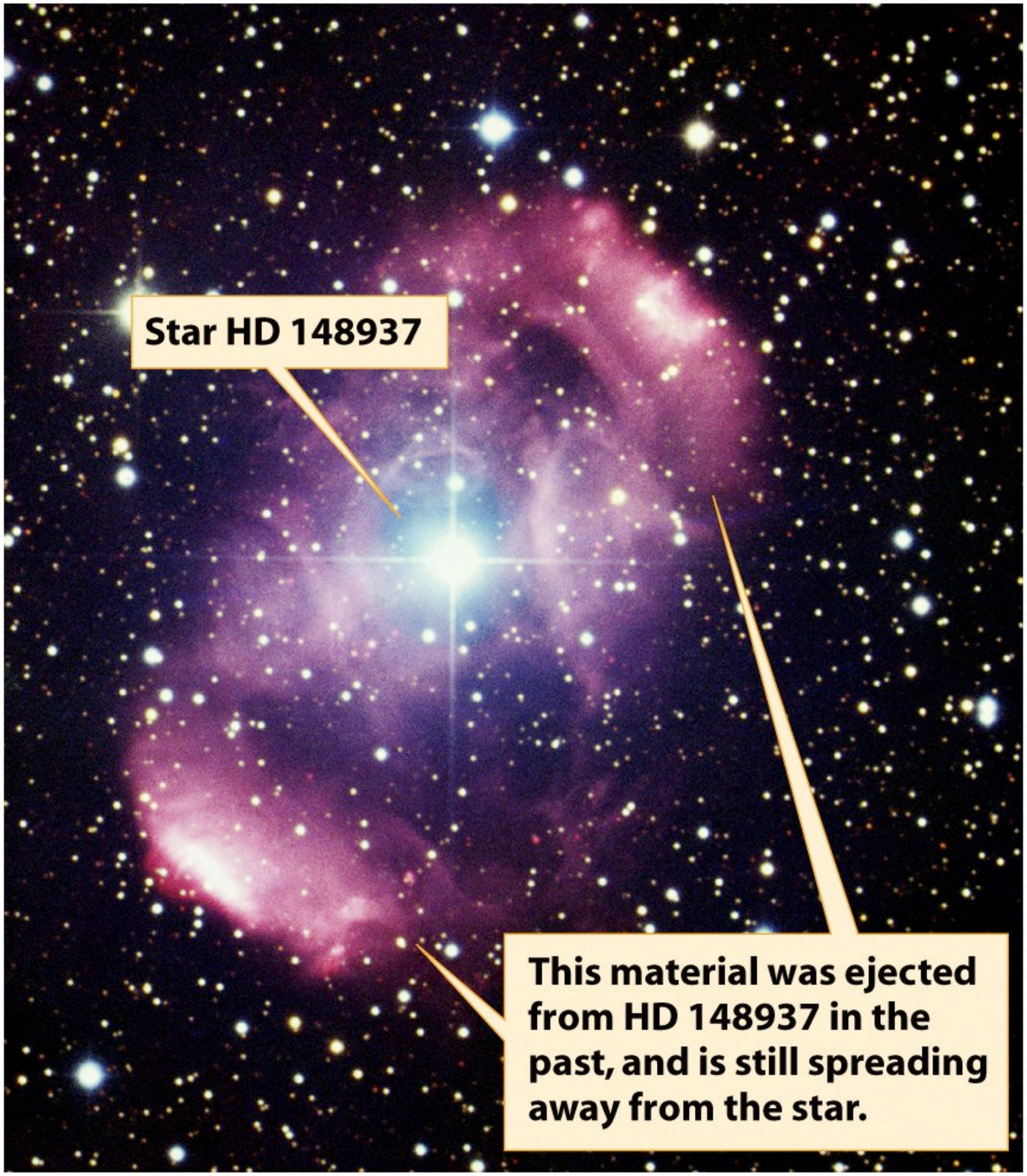

Figure 19-5
Universe, Eighth Edition

As stars age and become giant stars, they expand tremendously and shed matter into space. This star, HD 148937, is losing matter at a high rate. Other strong outbursts in the past ejected the clouds that surround HD 148937. These clouds absorb ultraviolet radiation from the star, which excites the atoms in the clouds and causes them to glow. The characteristic red color of the clouds reveals the presence of hydrogen that was ejected from the star’s outer layers.

Question 21.3 (iclickers!)

- The major source of energy in the pre-main sequence life of the Sun was
  - A) gravitational
  - B) nuclear fusion
  - C) chemical burning of carbon atoms
  - D) nuclear fission

Summary

- The Main-Sequence is a mass sequence
- High mass stars live fast and die young
- Stars form in clouds of cold gas, collapsing under gravitational instability
- Protostars are heated by gravitational collapse and often form disks and jets around them
- H-R diagrams can be used to age-date star clusters.
- Stars on the main sequence burn hydrogen in the core

The End

See you on friday!