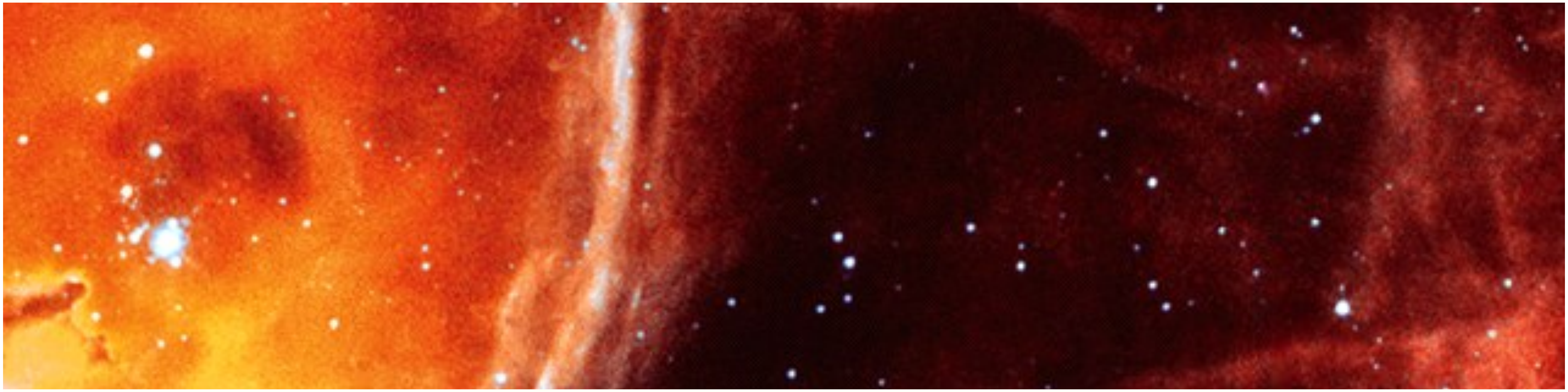
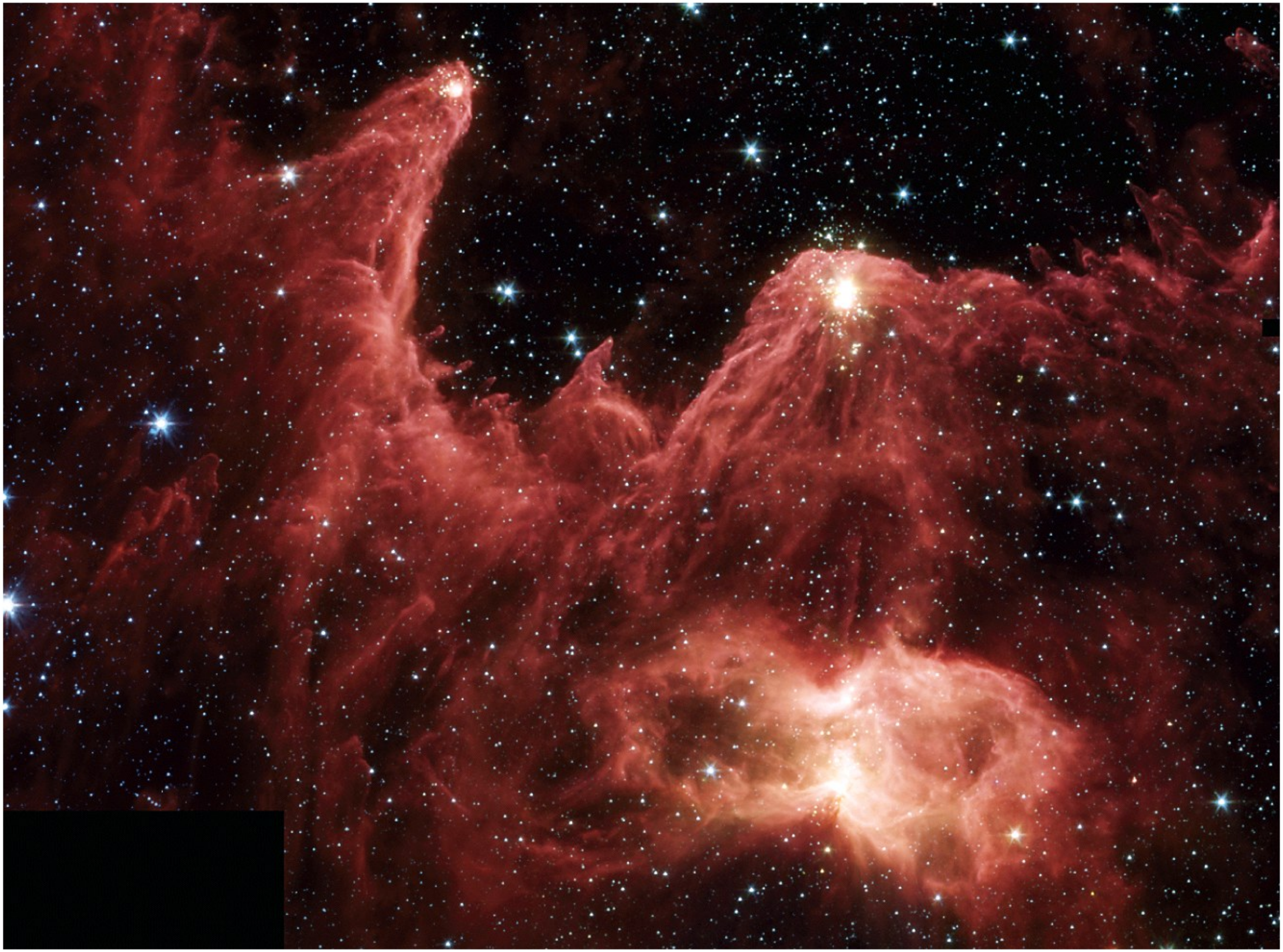
Discovering the Essential Universe



Neil F. Comins

CHAPTER 11

The Lives of Stars from Birth Through Middle Age



Chapter 12 Opener
Discovering the Universe, Eighth Edition

TABLE 12-1 Composition of the Interstellar Medium

	Particle number (%)	Mass (%)
Hydrogen (atoms and molecules)	90	74
Helium	9	25
Metals*	1	1

*Metals are all elements except hydrogen and helium.

Table 12-1
Discovering the Universe, Eighth Edition

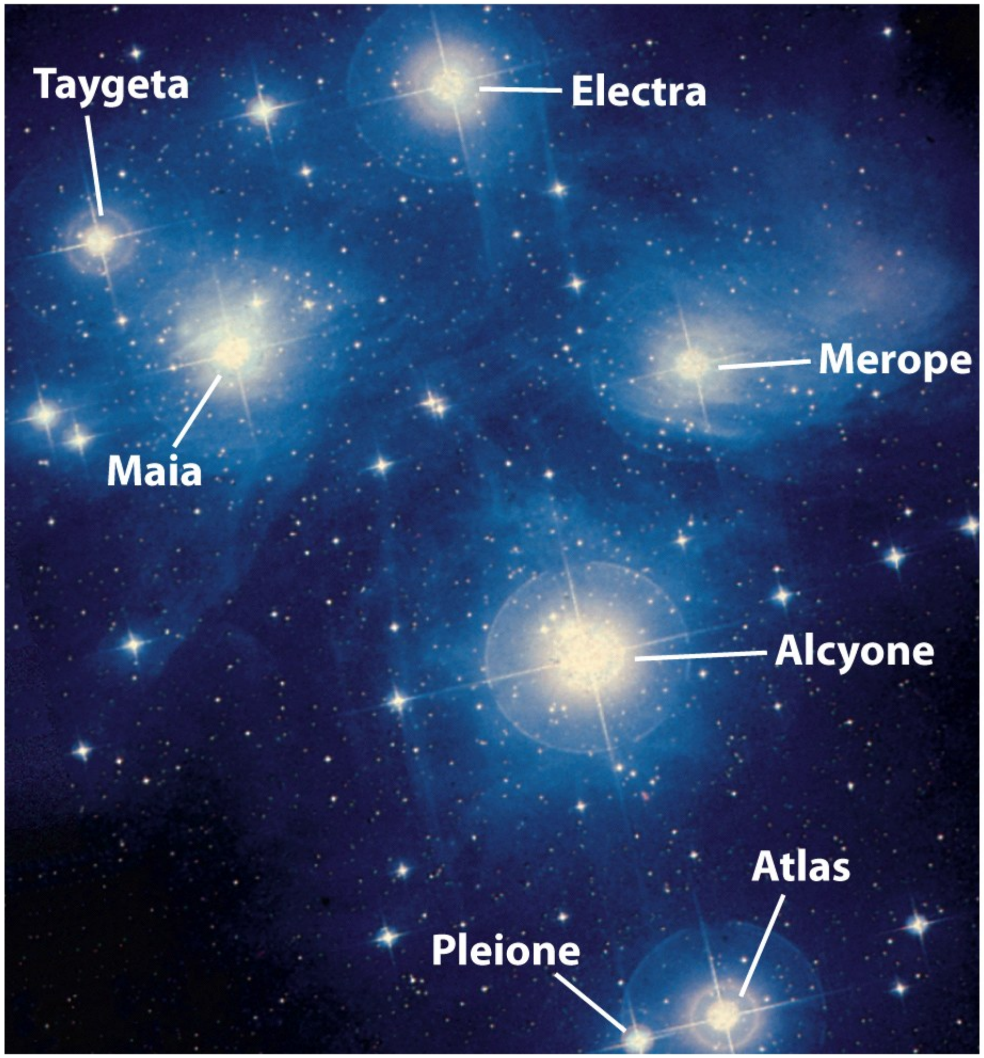


Figure 12-2a
Discovering the Universe, Eighth Edition

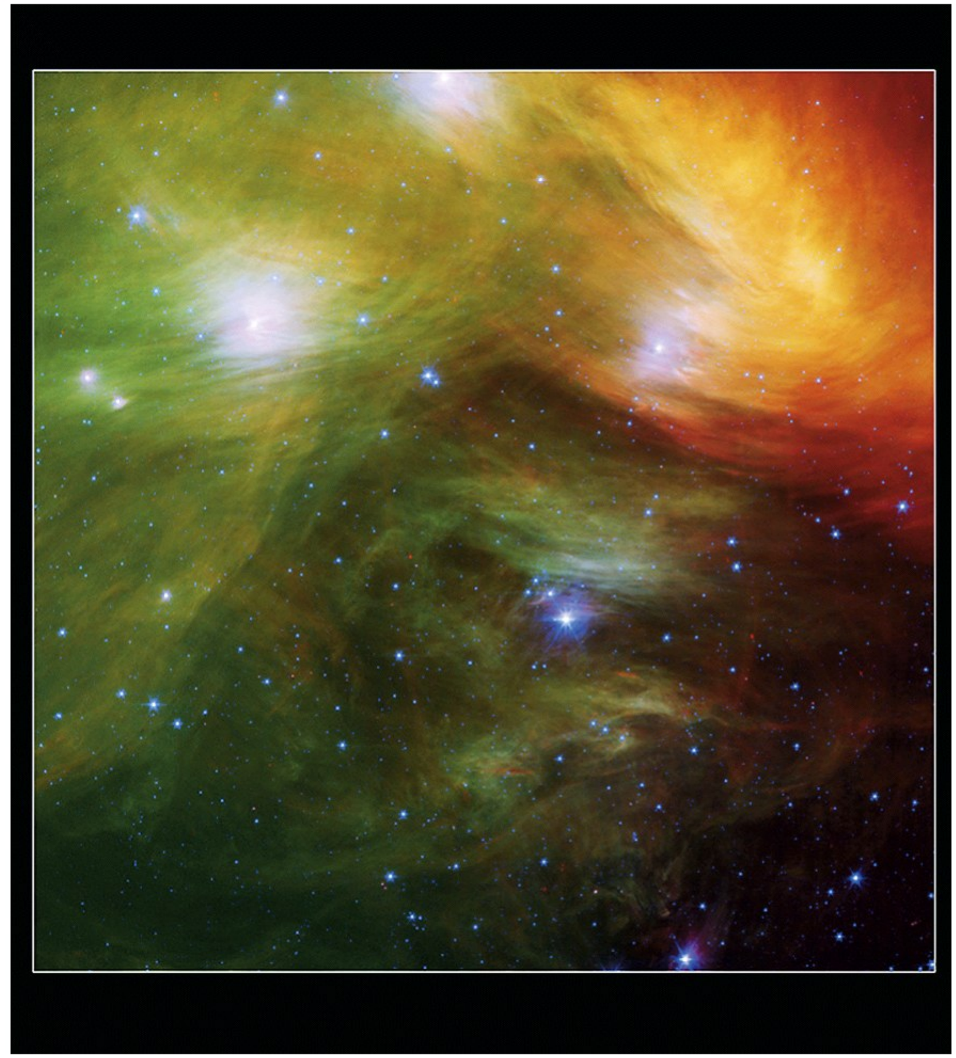


Figure 12-2b
Discovering the Universe, Eighth Edition

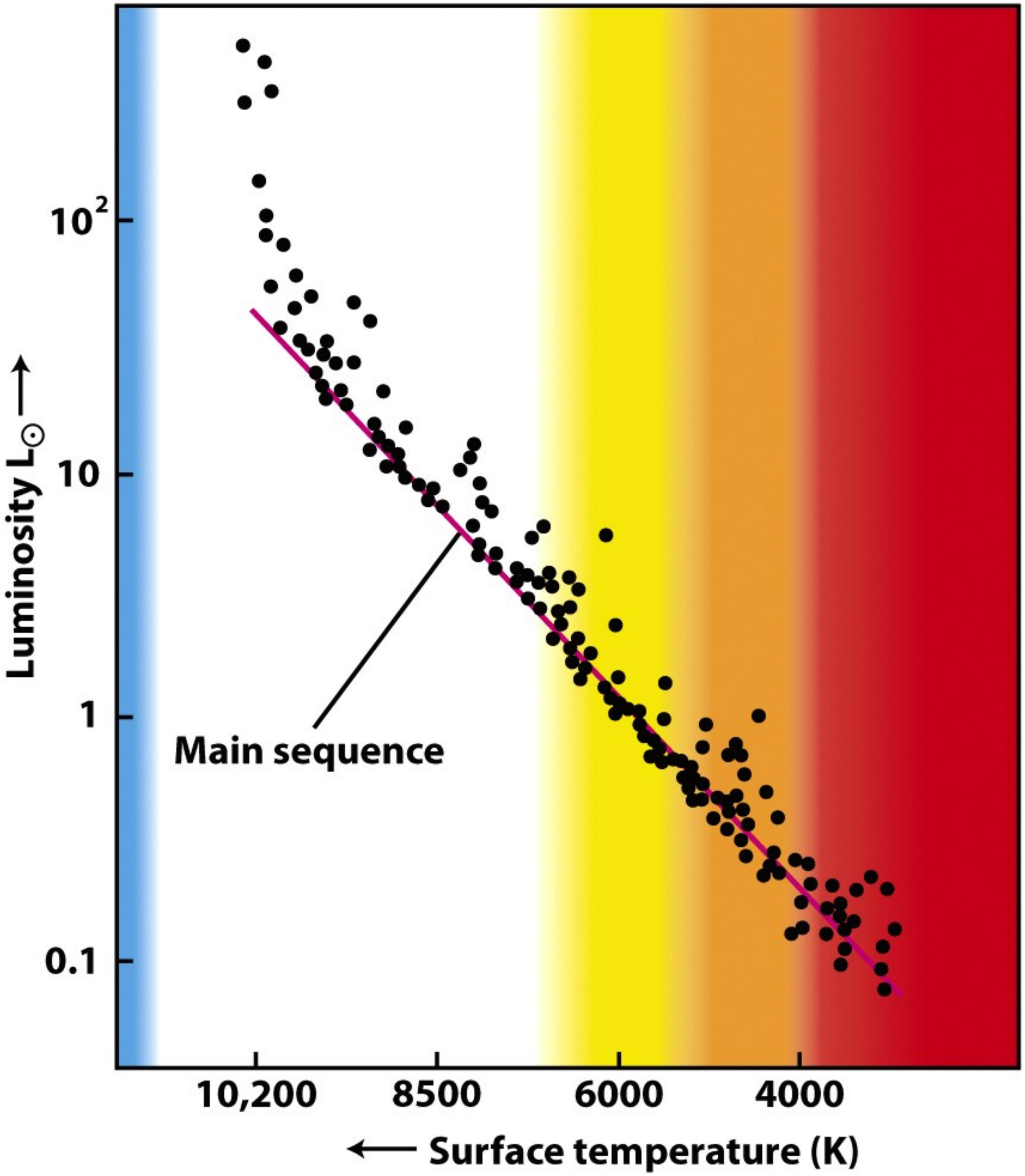
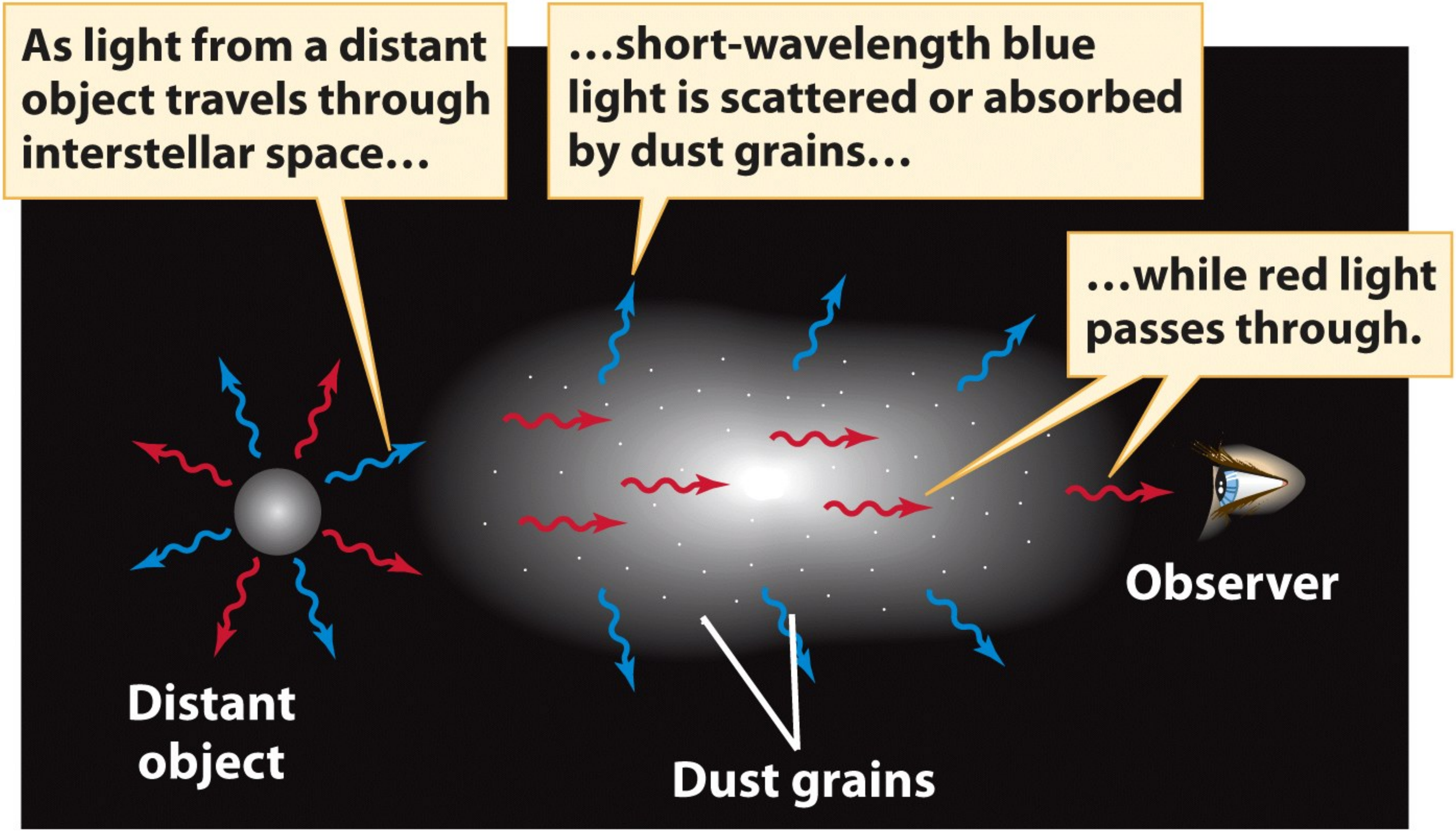
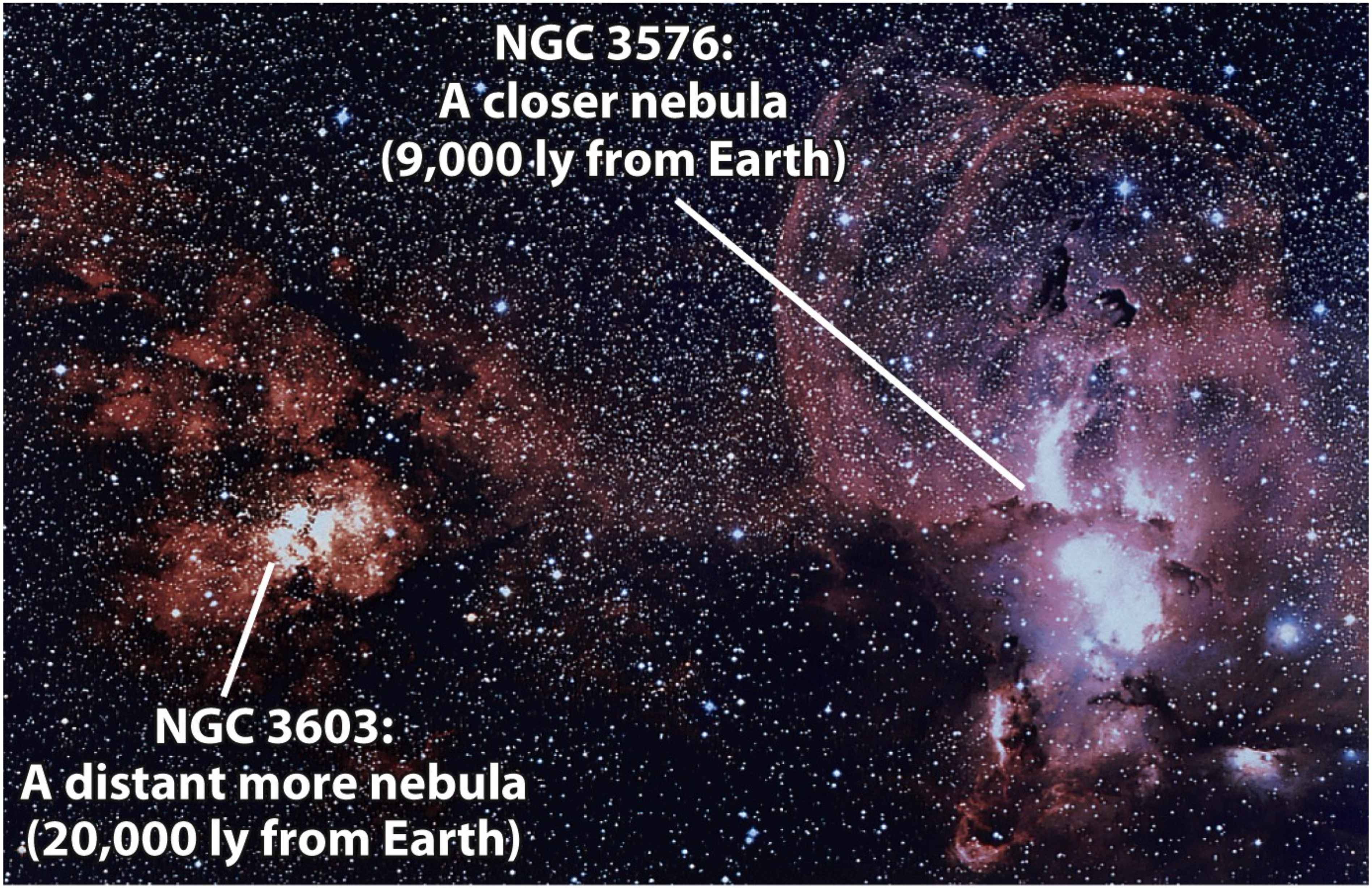


Figure 12-2c
Discovering the Universe, Eighth Edition



How dust causes interstellar reddening

Figure 12-4a
Discovering the Universe, Eighth Edition



Reddening depends on distance

Figure 12-4b
Discovering the Universe, Eighth Edition

Dust

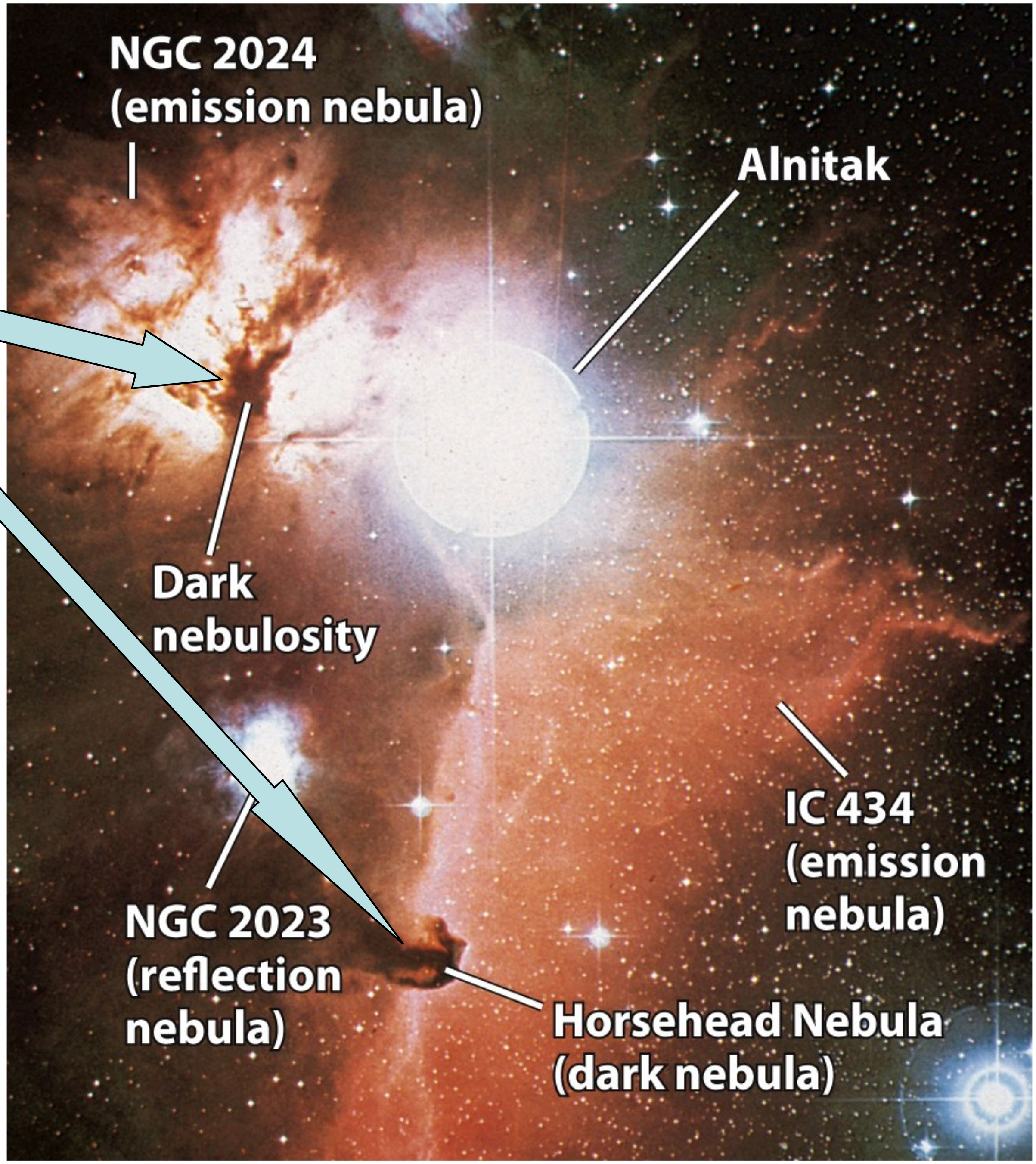
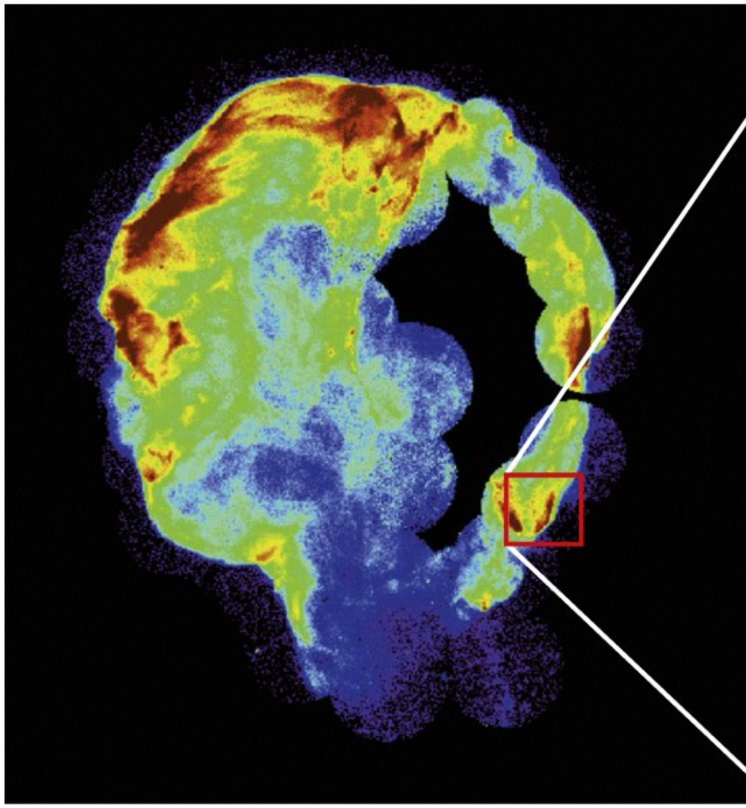
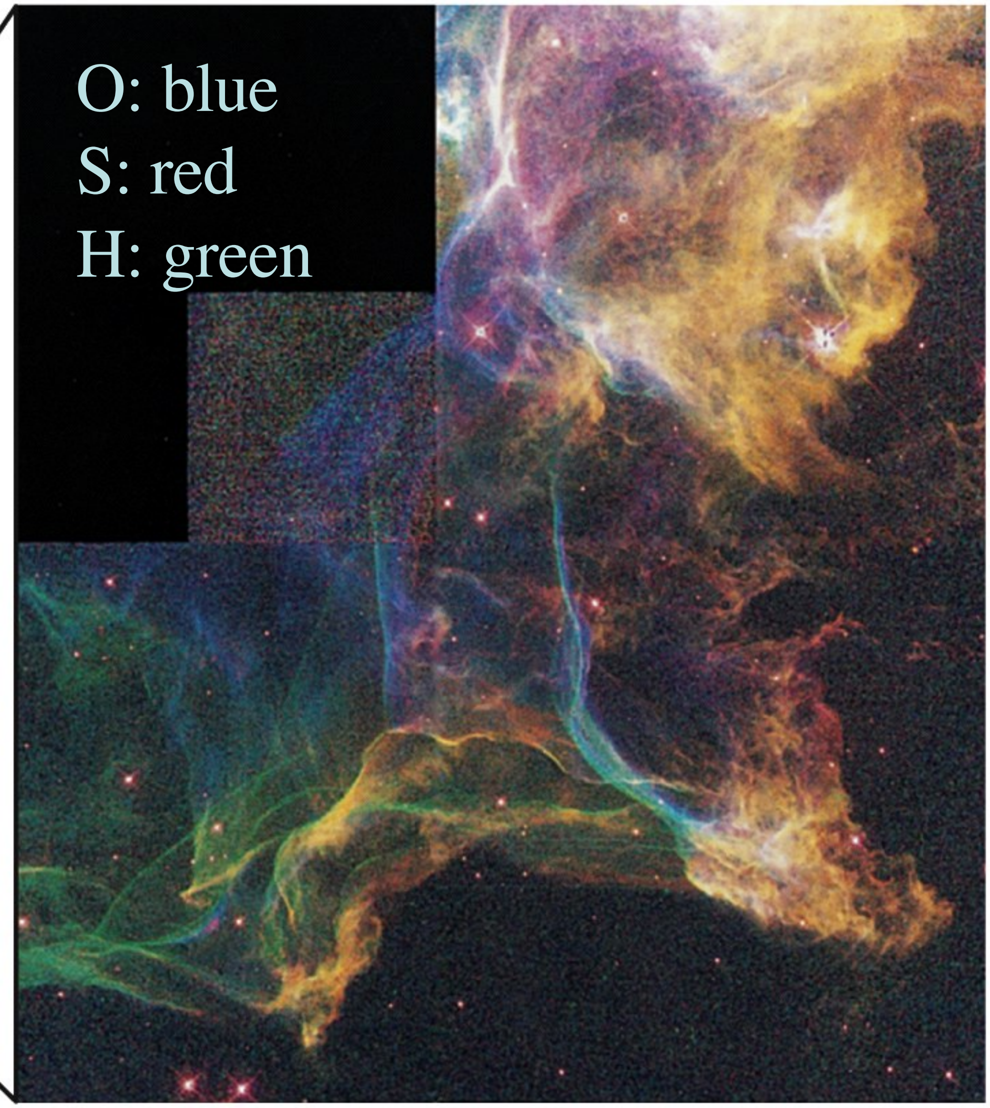


Figure 12-5c
Discovering the Universe, Eighth Edition

Cygnus Loop - supernova remnant,
Exploded 20,000 years ago, distance 120 ly



a



b

Figure 12-7
Discovering the Universe, Eighth Edition

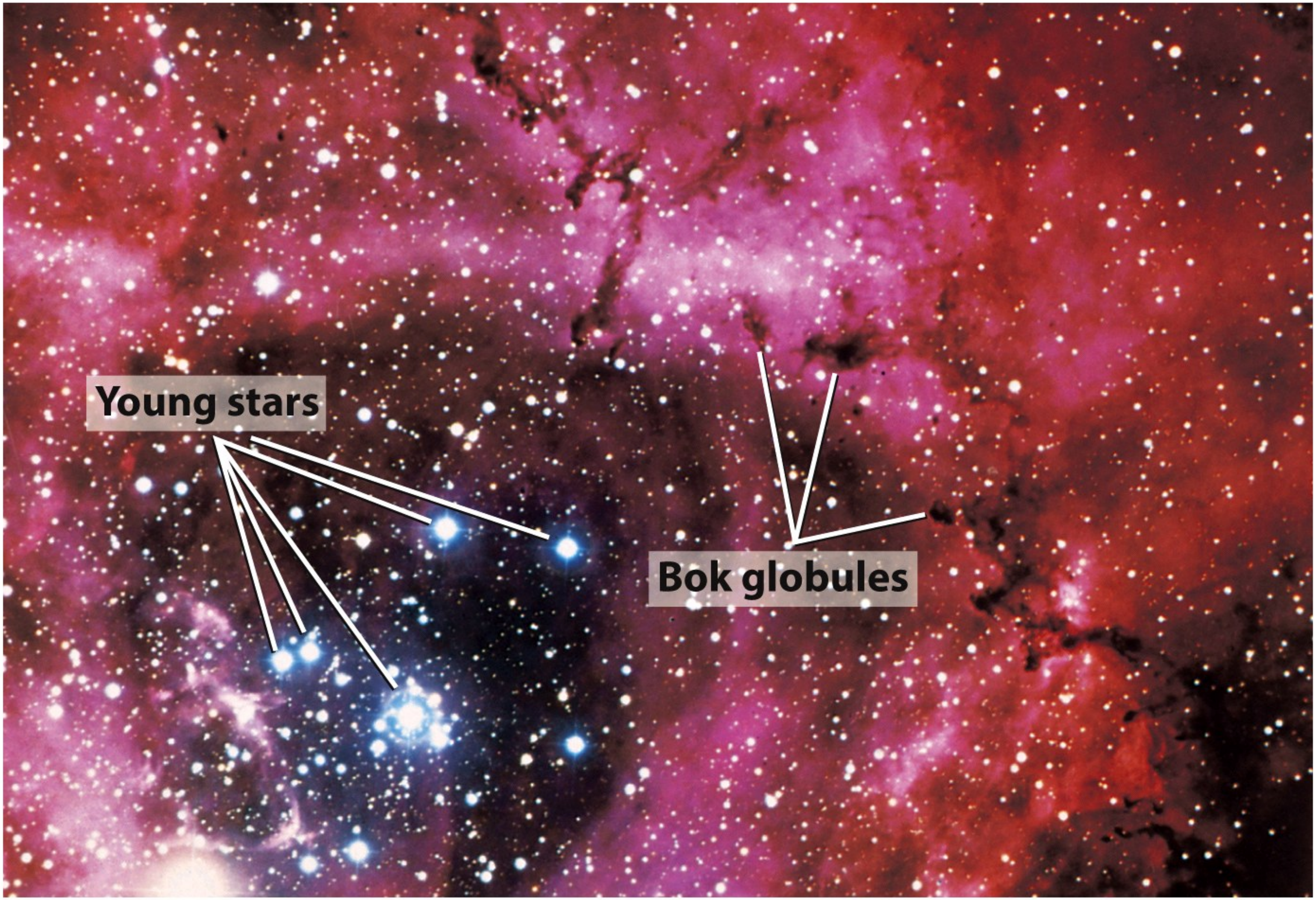
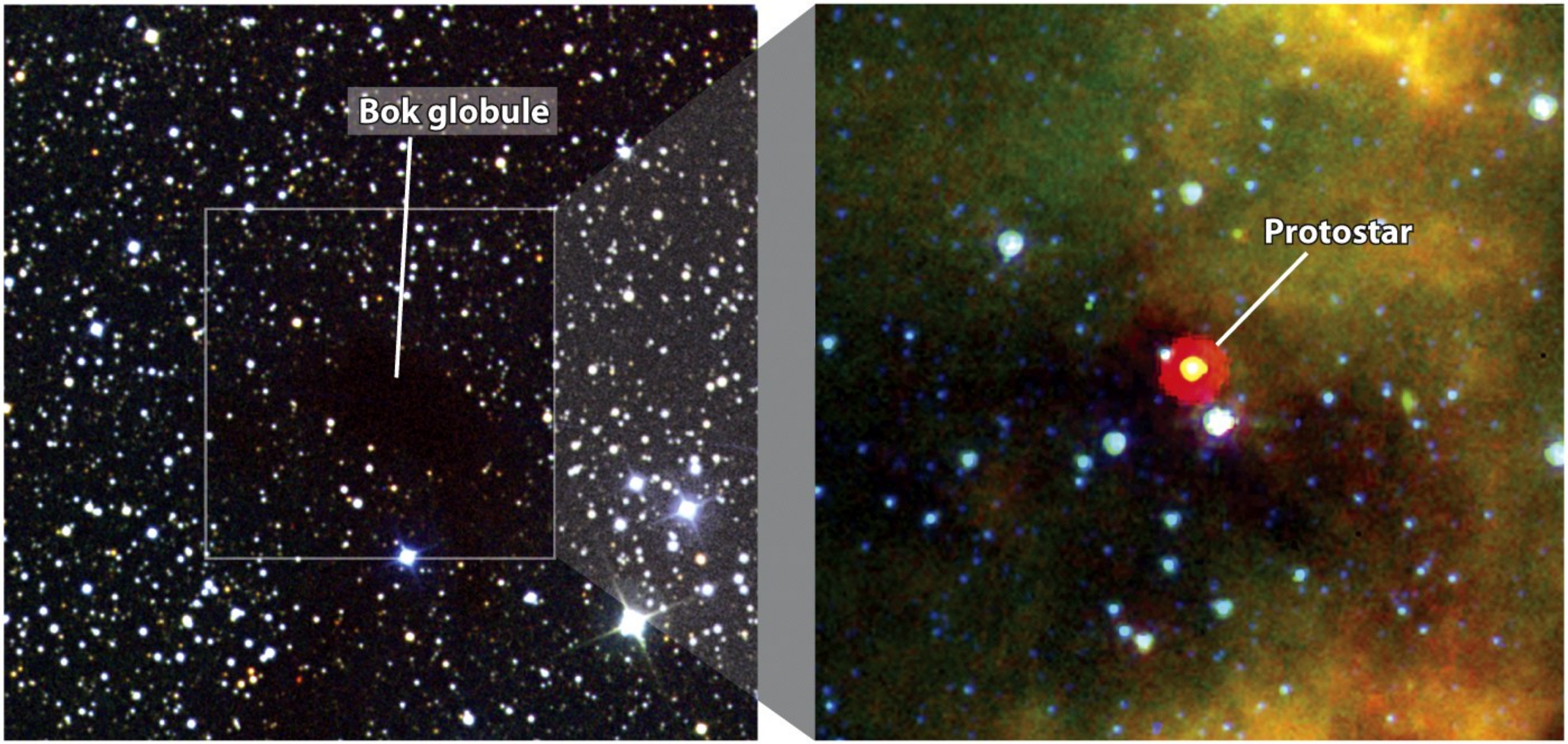


Figure 12-8
Discovering the Universe, Eighth Edition



a A dark nebula **b** A hidden protostar within the dark nebula

Figure 12-9
Discovering the Universe, Eighth Edition

>300 protostars

2 pre-main-sequence stars

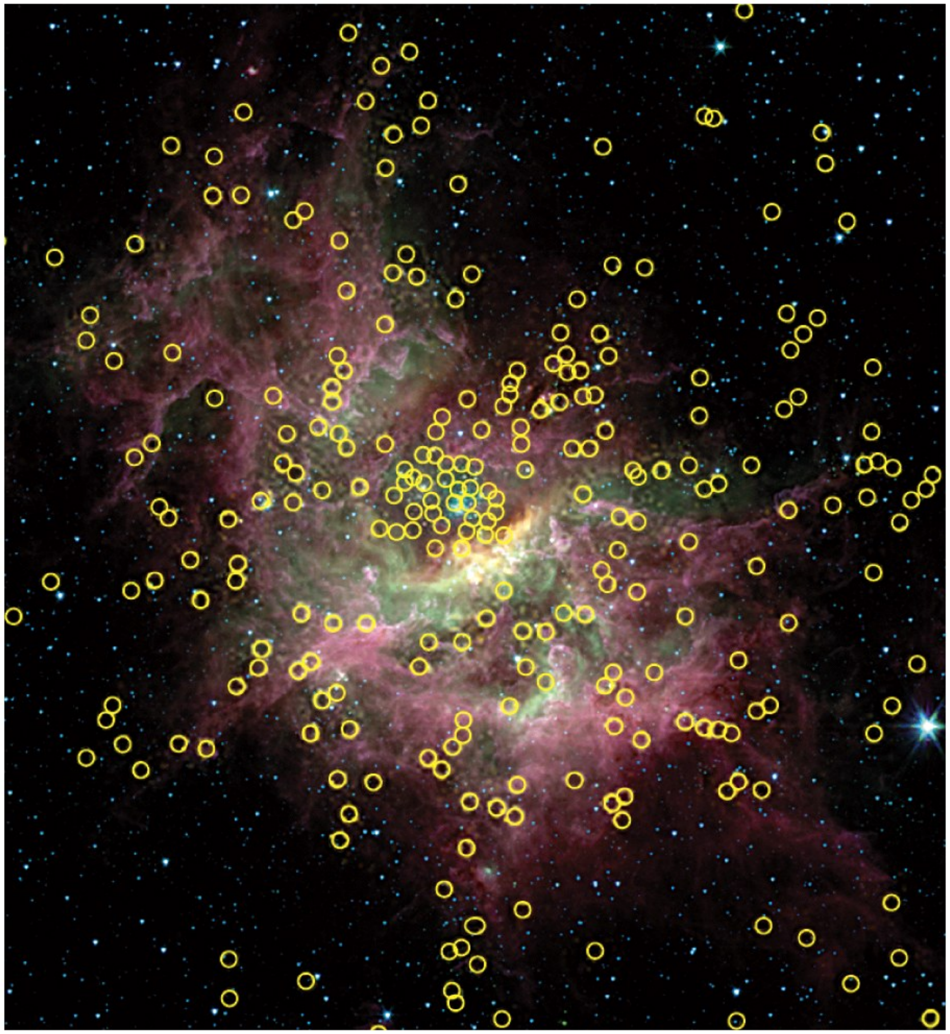


Figure 12-10
Discovering the Universe, Eighth Edition

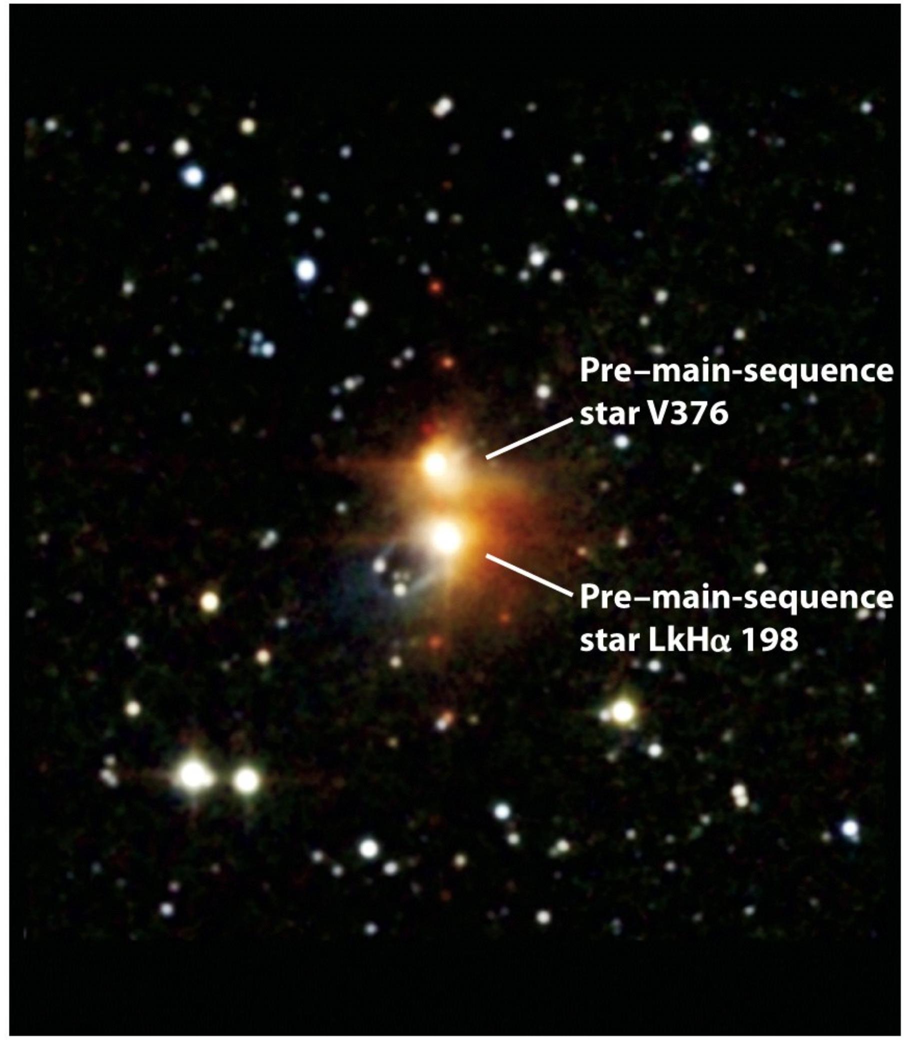
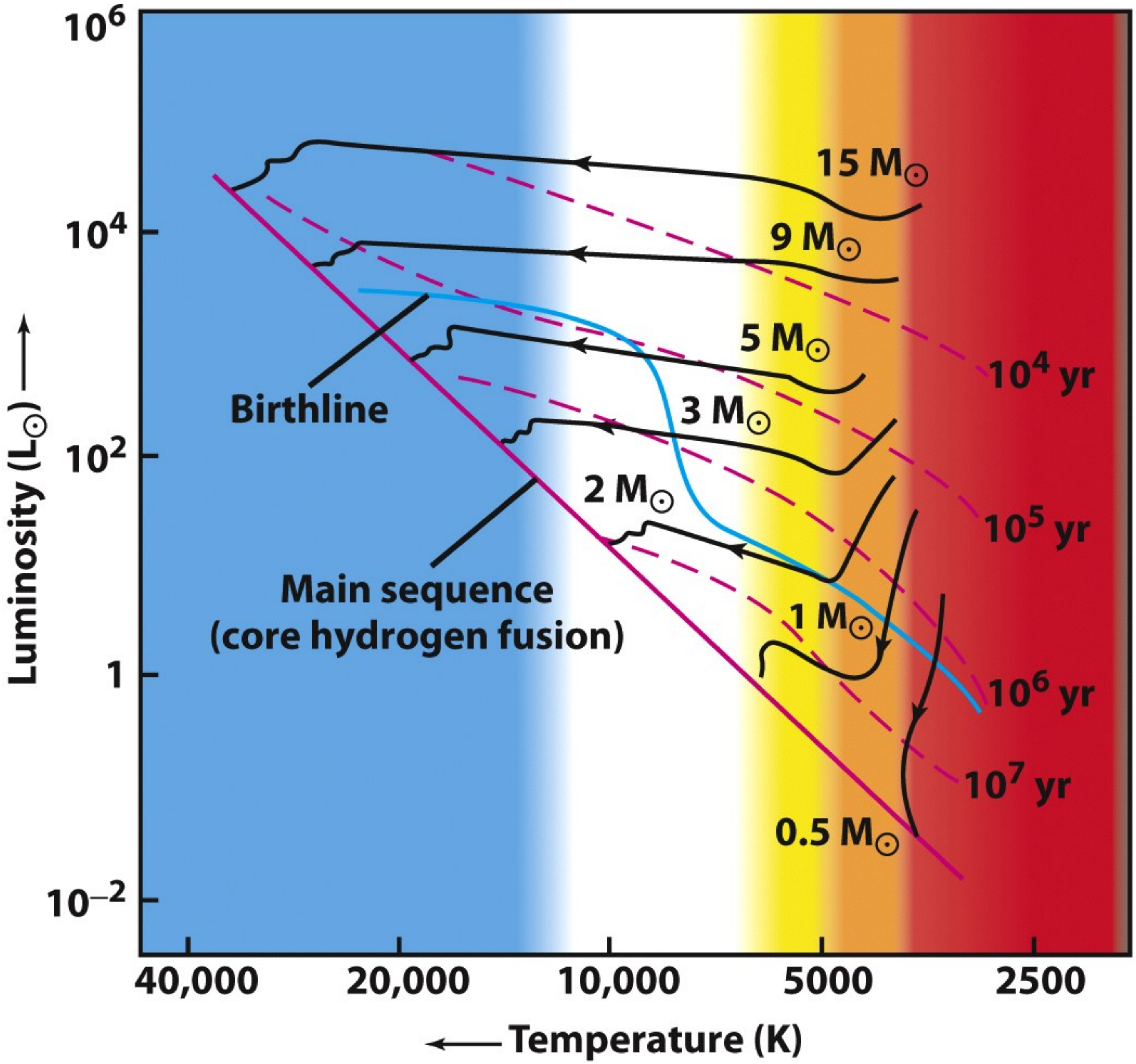


Figure 12-11
Discovering the Universe, Eighth Edition

Pre-main sequence evolutionary tracks



Supermassive star, originally M~100 to 200 M_{sol}

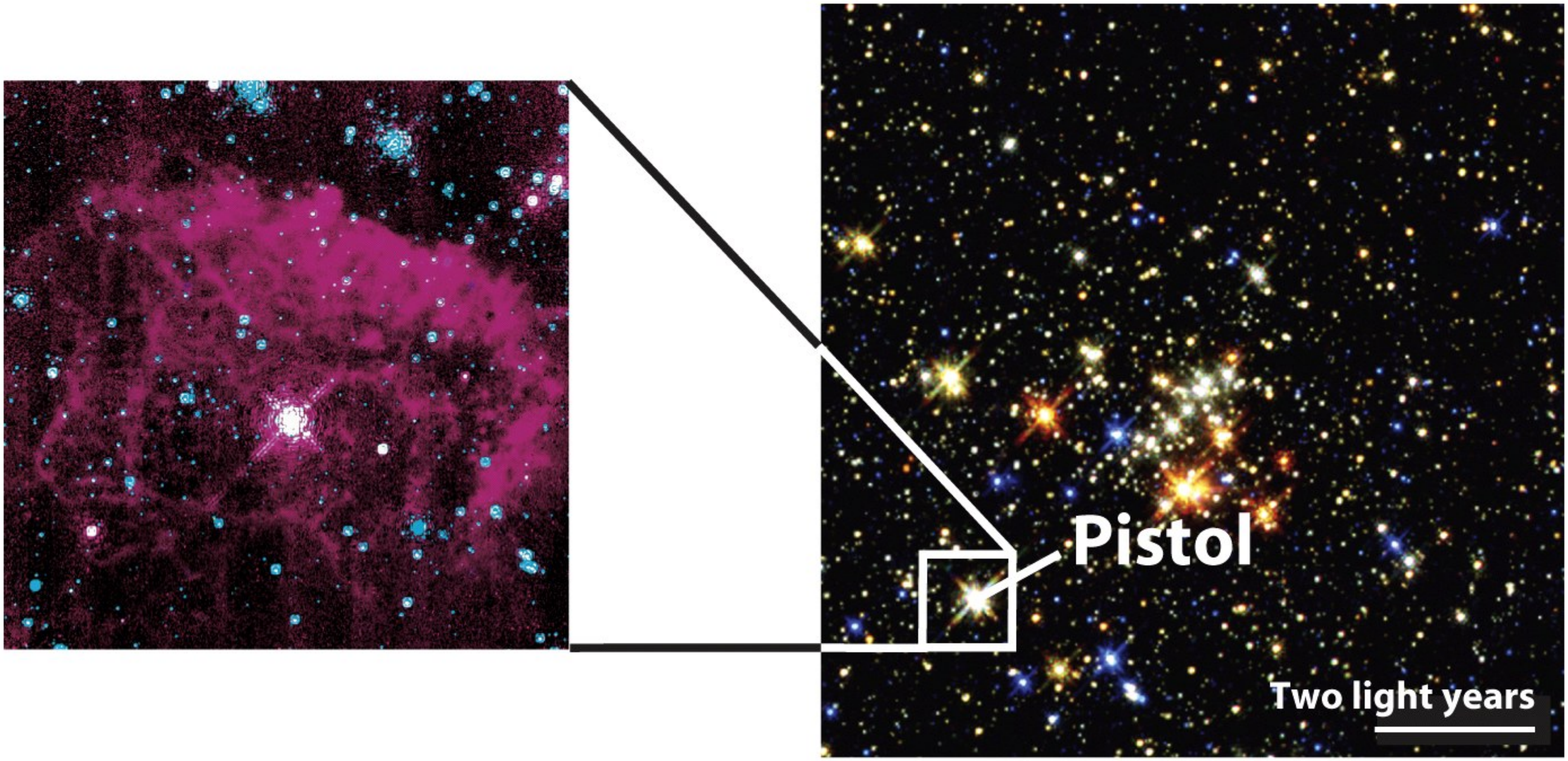


Figure 12-14a
Discovering the Universe, Eighth Edition

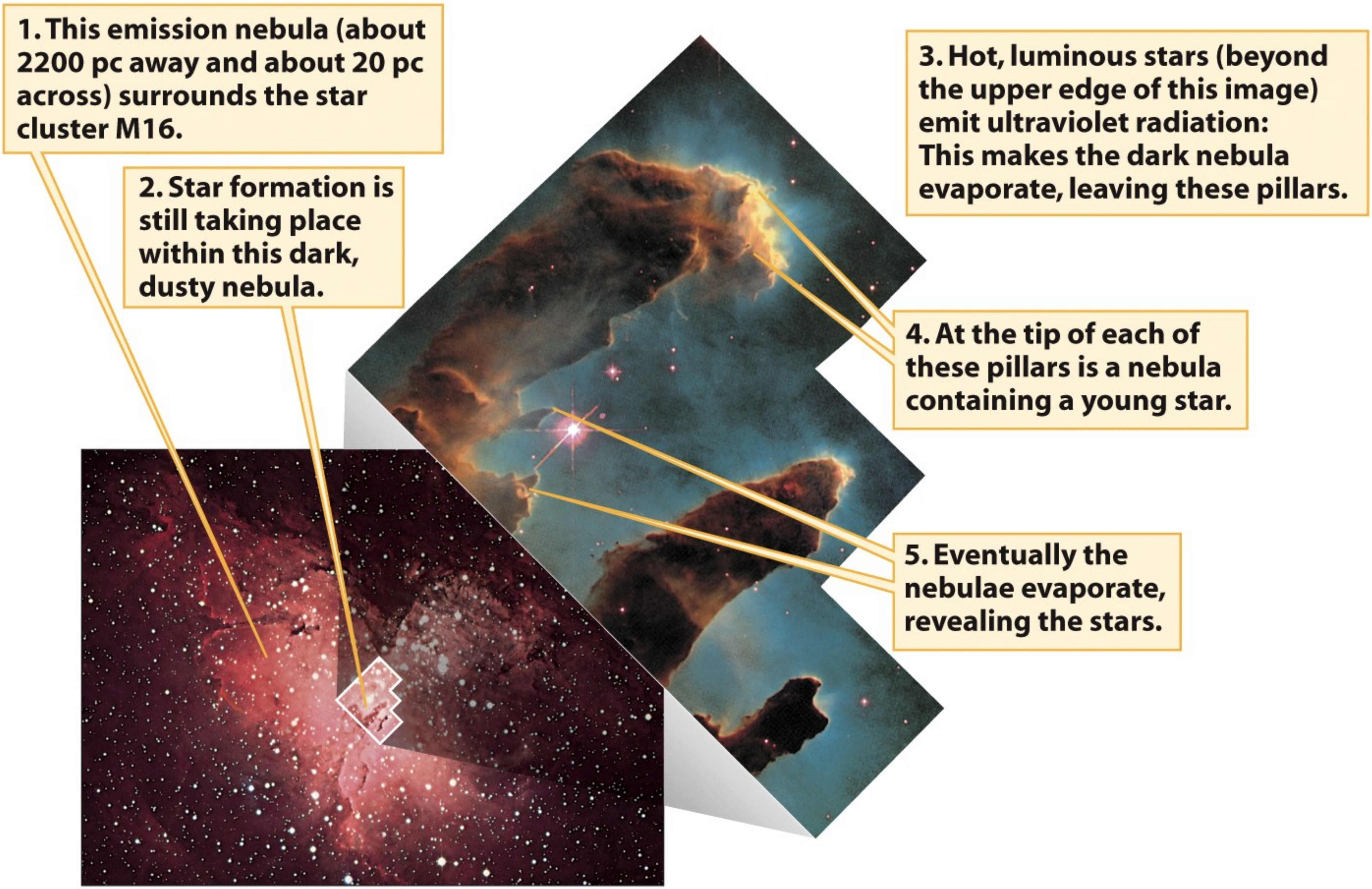


Figure 12-15
Discovering the Universe, Eighth Edition

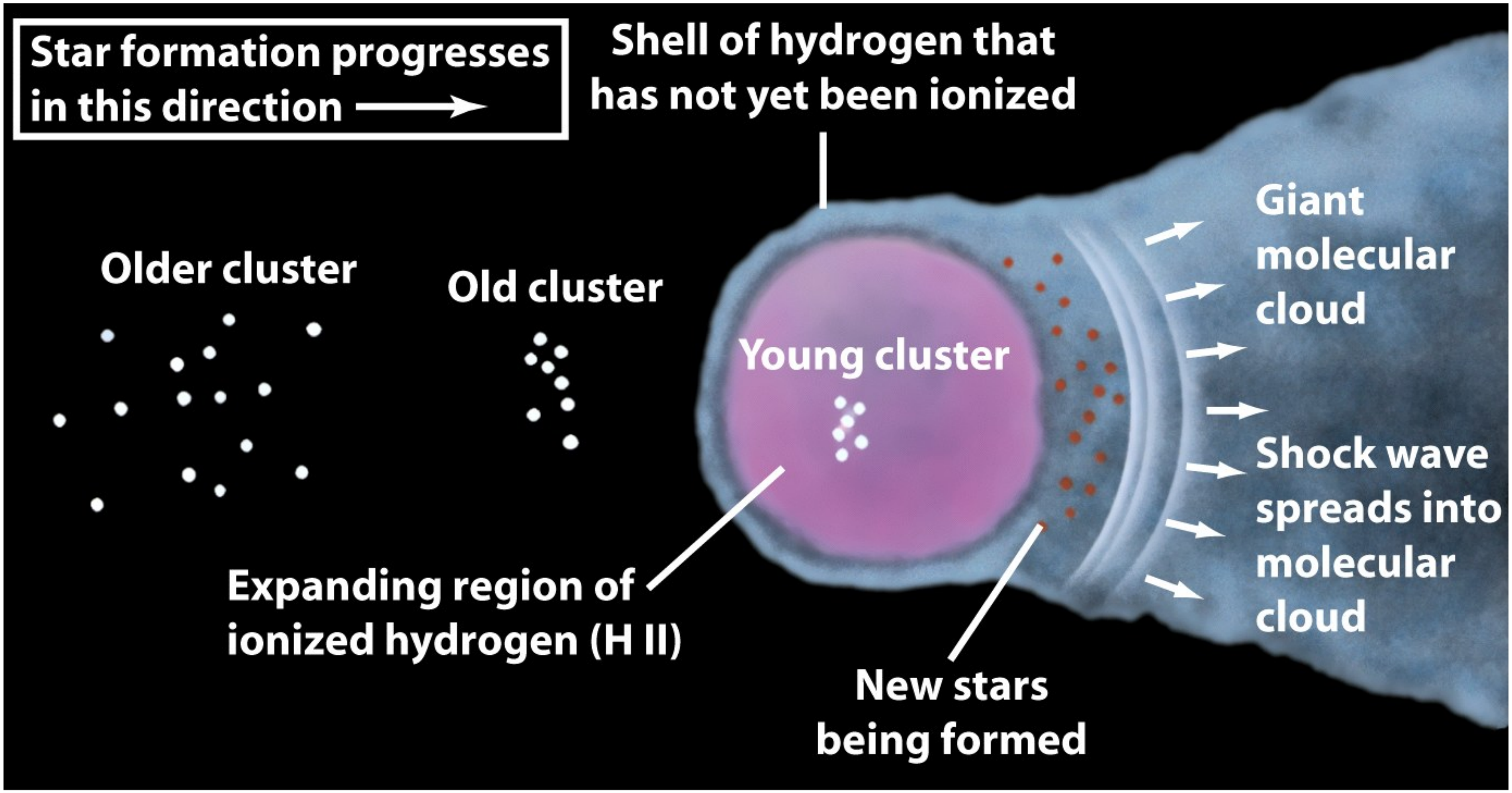


Figure 12-17a
Discovering the Universe, Eighth Edition

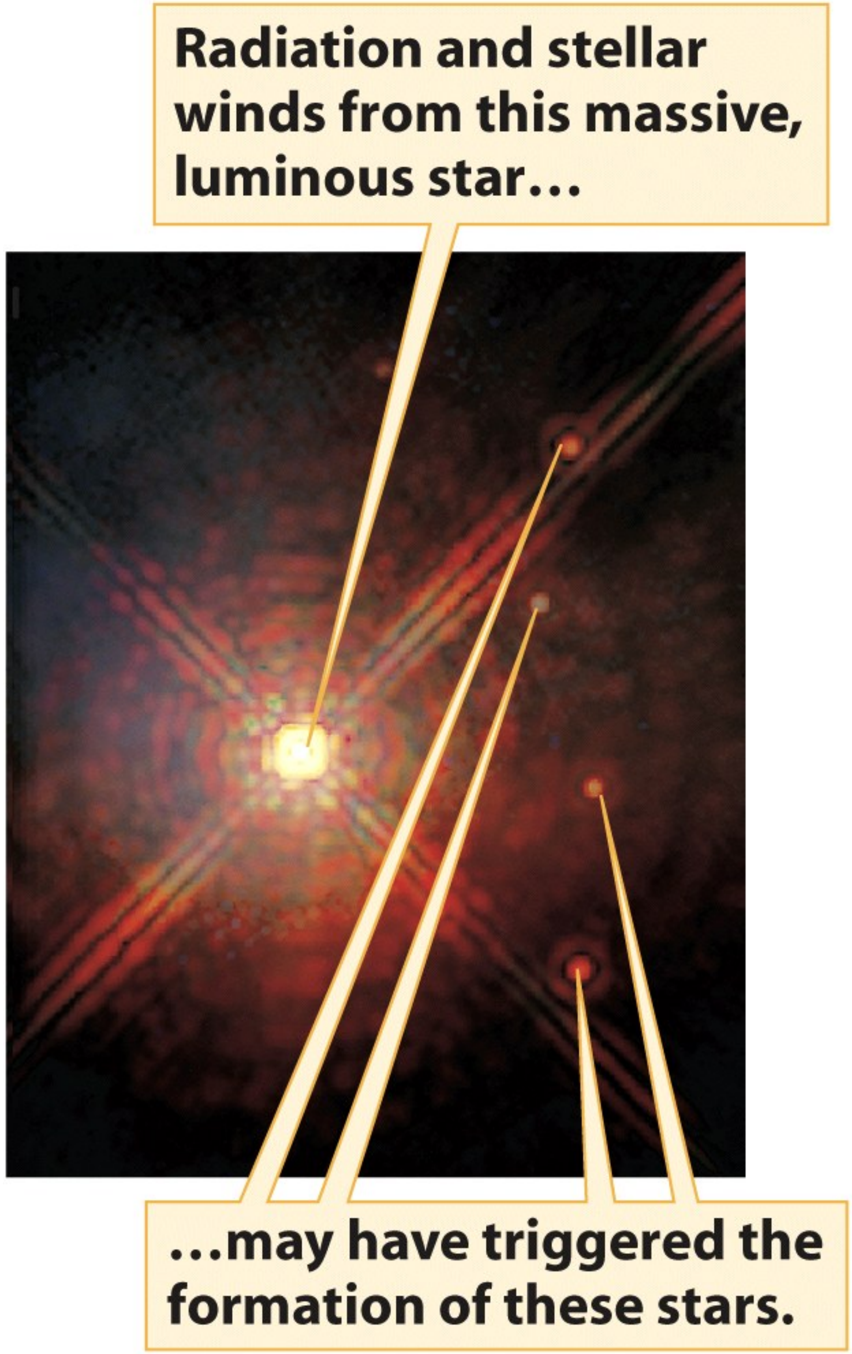


Figure 12-17b
Discovering the Universe, Eighth Edition

Figure 12-18a
Discovering the Universe, Eighth Edition

Stars about to burn H

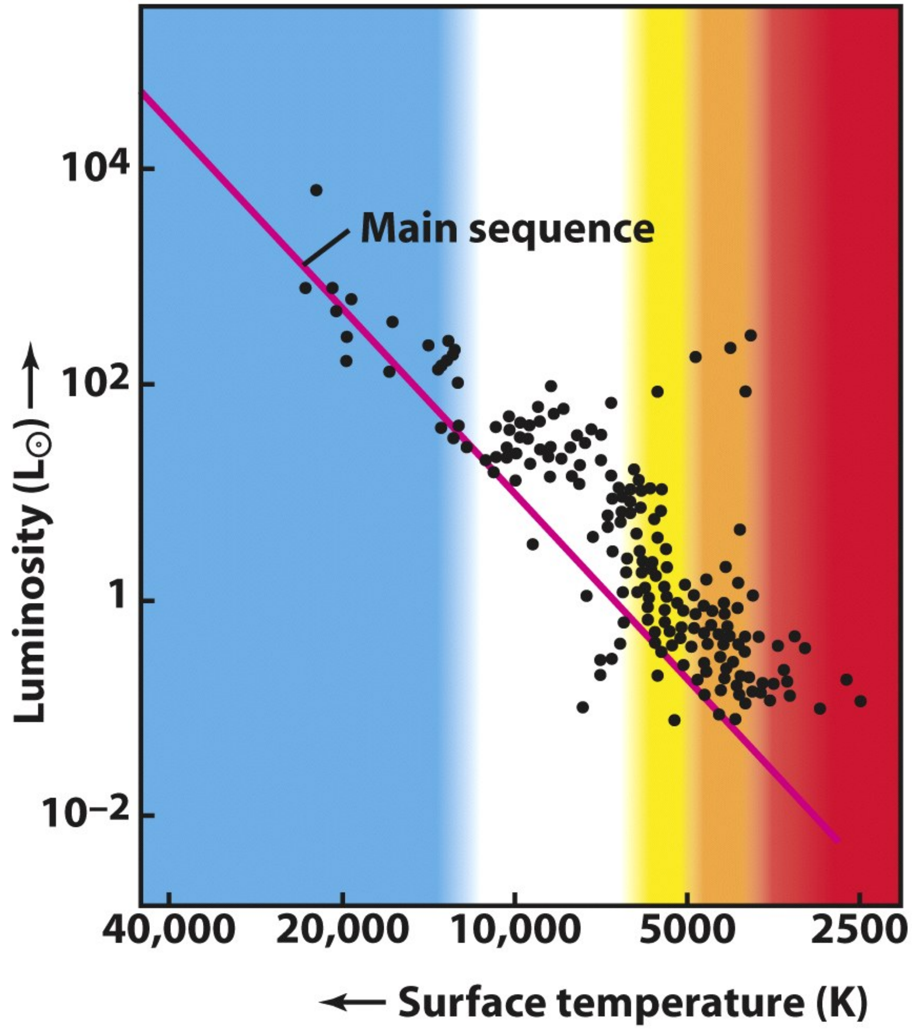


Figure 12-18b
Discovering the Universe, Eighth Edition

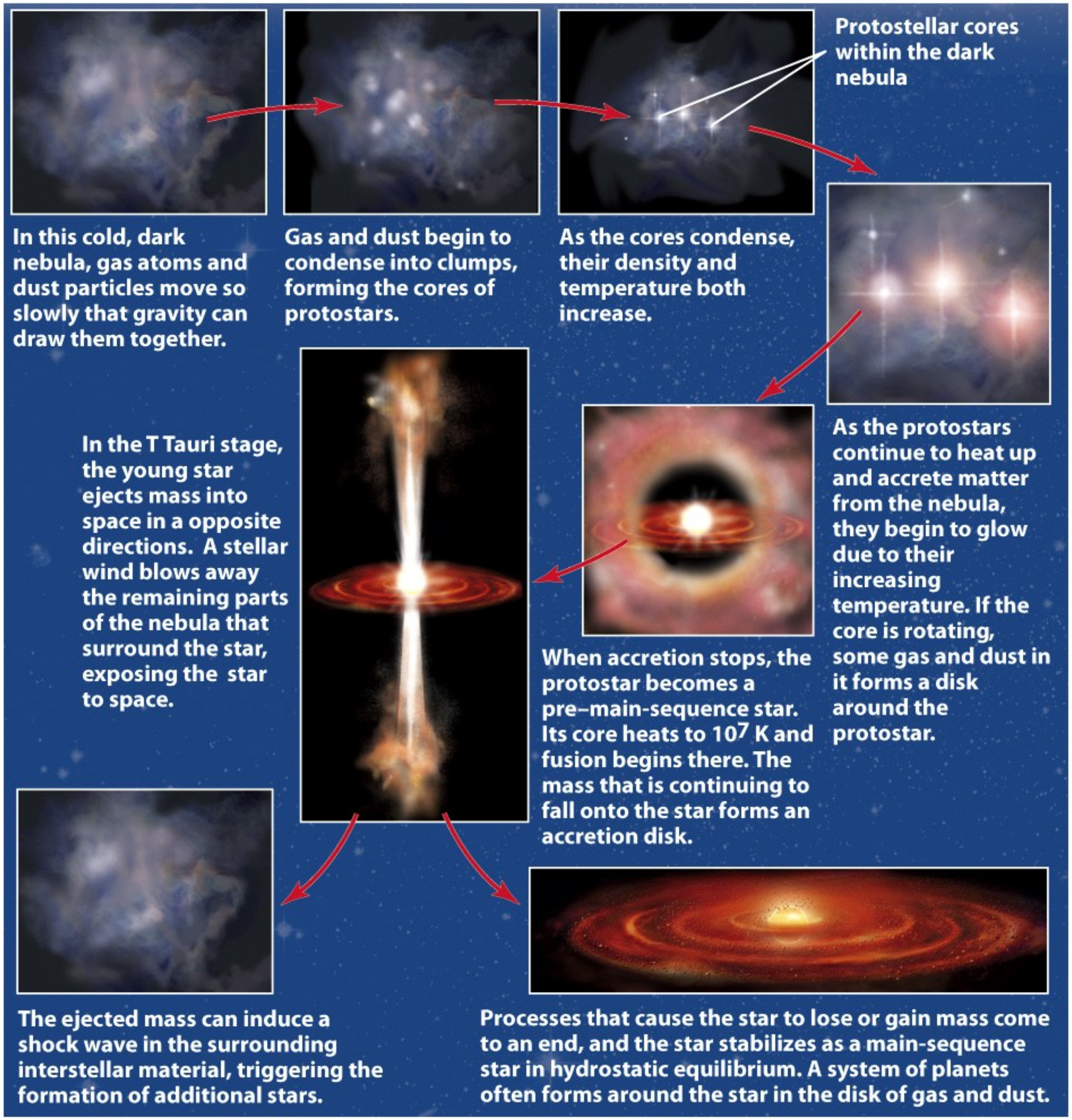


Figure 12-19

Discovering the Universe, Eighth Edition

TABLE 12-2 Main-Sequence Lifetimes

Mass ($M_\odot$)	Surface temperature (K)	Luminosity ($L_\odot$)	Time on main sequence (10^6 years)	Spectral class
25	35,000	80,000	3	O
15	30,000	10,000	15	B
3	11,000	60	500	A
1.5	7000	5	3000	F
1.0 (Sun)	6000	1	10,000	G
0.75	5000	0.5	15,000	K
0.50	4000	0.03	200,000	M

Table 12-2
Discovering the Universe, Eighth Edition

$$Lt = fMc^2$$

$$t \alpha Mc^2/L \qquad L \alpha M^{3.5}$$

$$t \alpha M^{-2.5}$$

Evolution of low-mass stars

Red dwarfs

85% of all stars

0.08 M_{sol}
to
0.4 M_{sol}

Burn all H to He, then cool and move down the main sequence

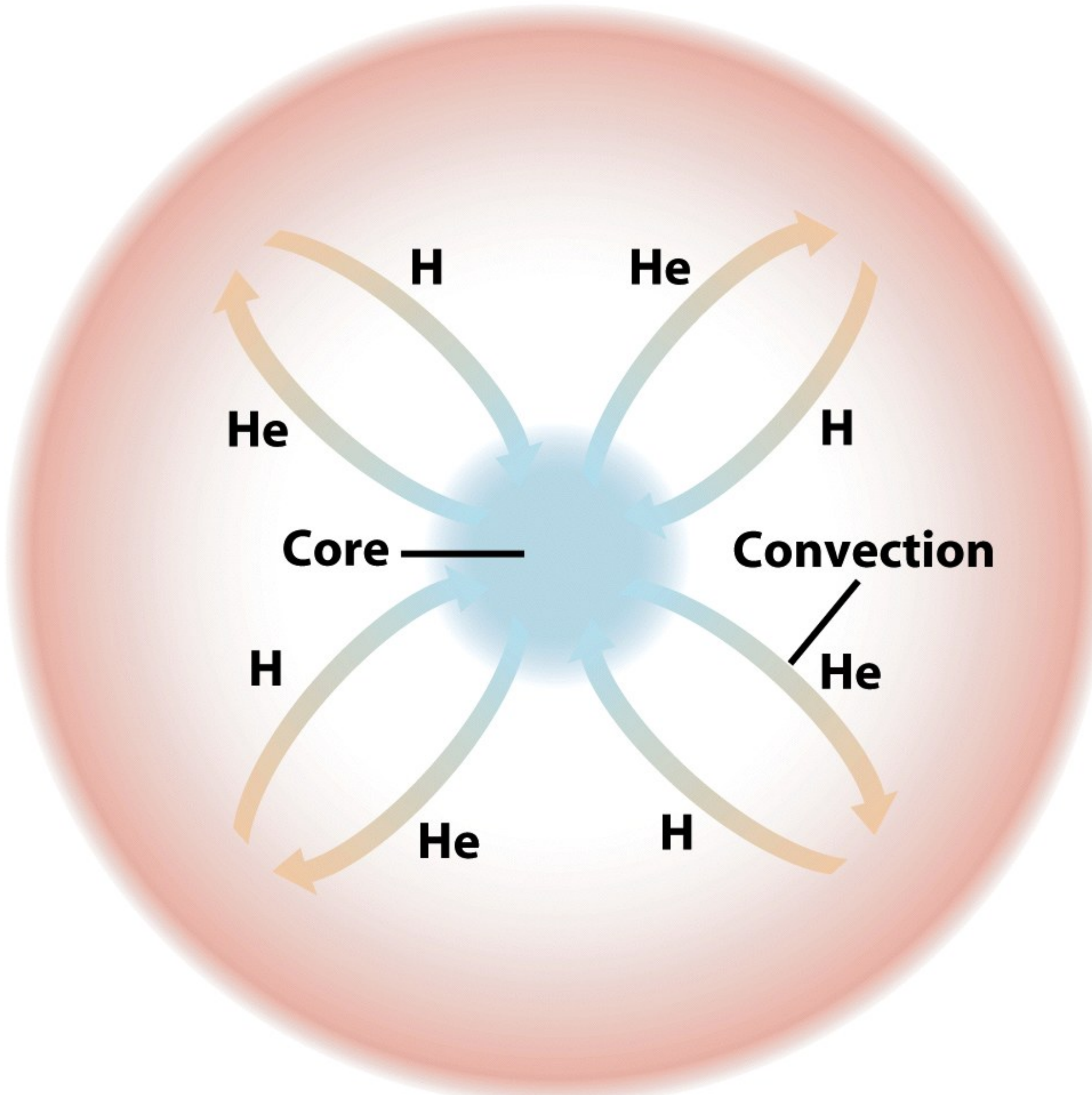


Figure 12-20
Discovering the Universe, Eighth Edition

Early and middle evolution of stars with more than 0.4 M_{sol}

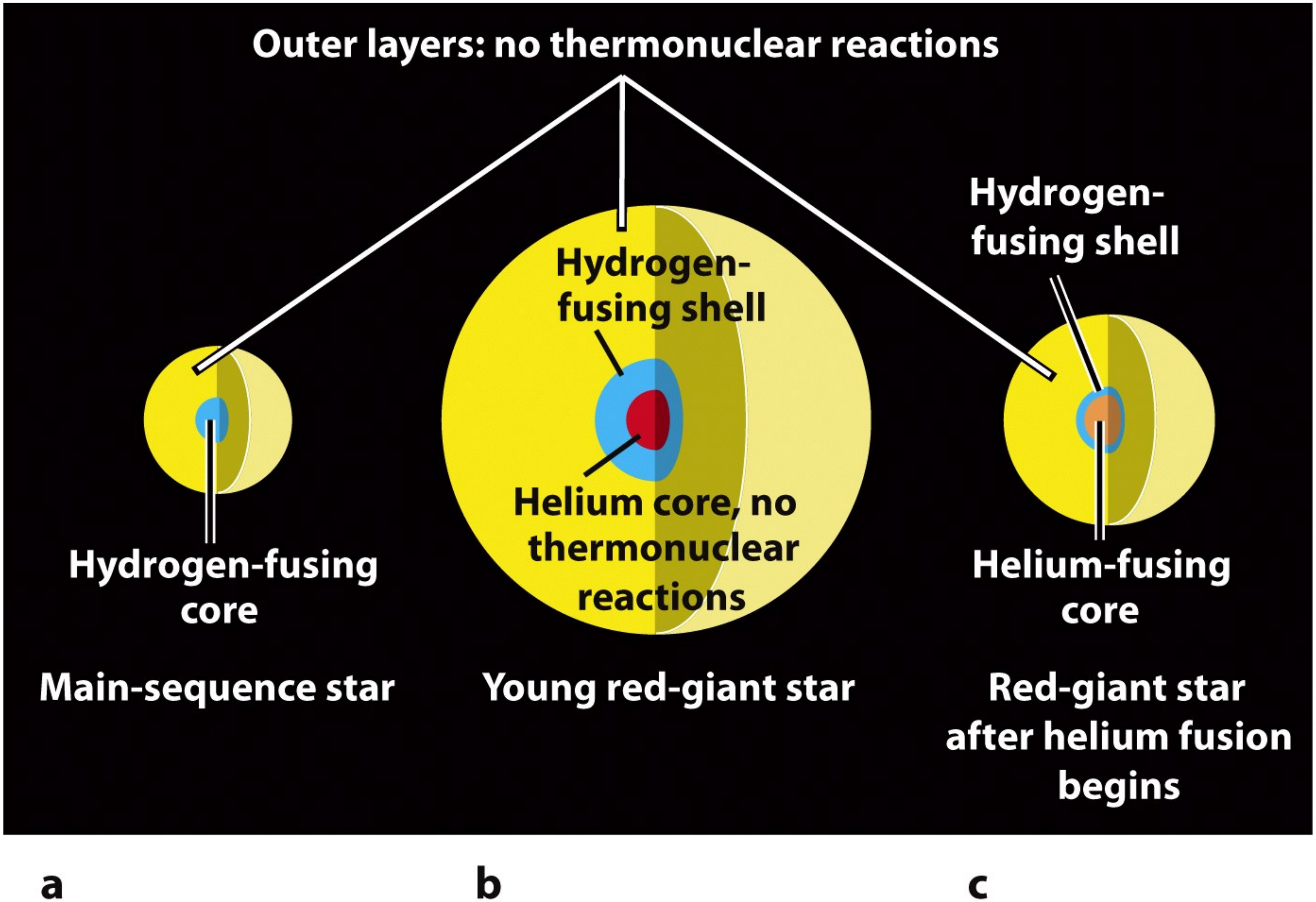
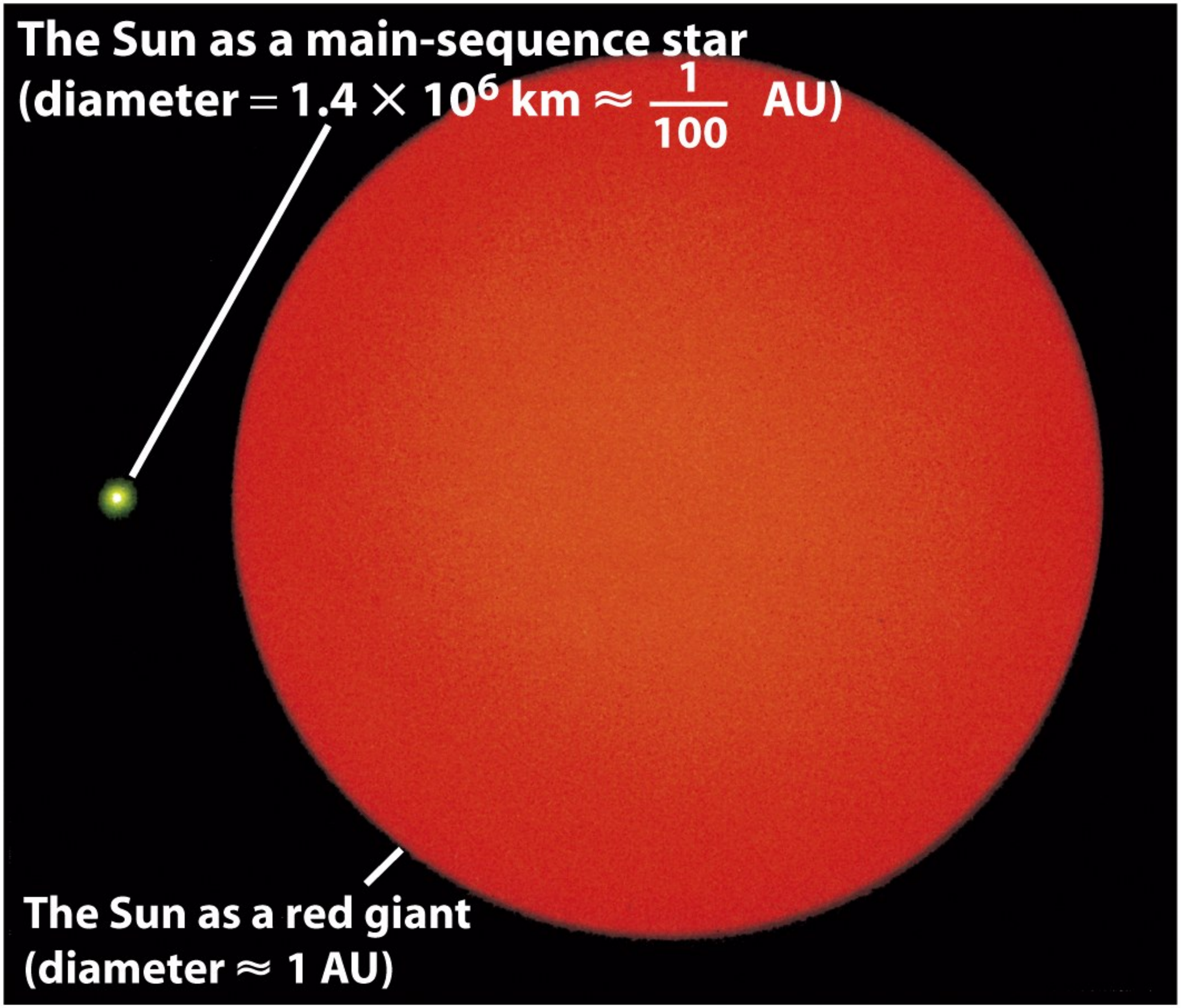


Figure 12-21
Discovering the Universe, Eighth Edition



The Sun today and as a red giant

Figure 12-23a
Discovering the Universe, Eighth Edition

Post main-sequence evolution

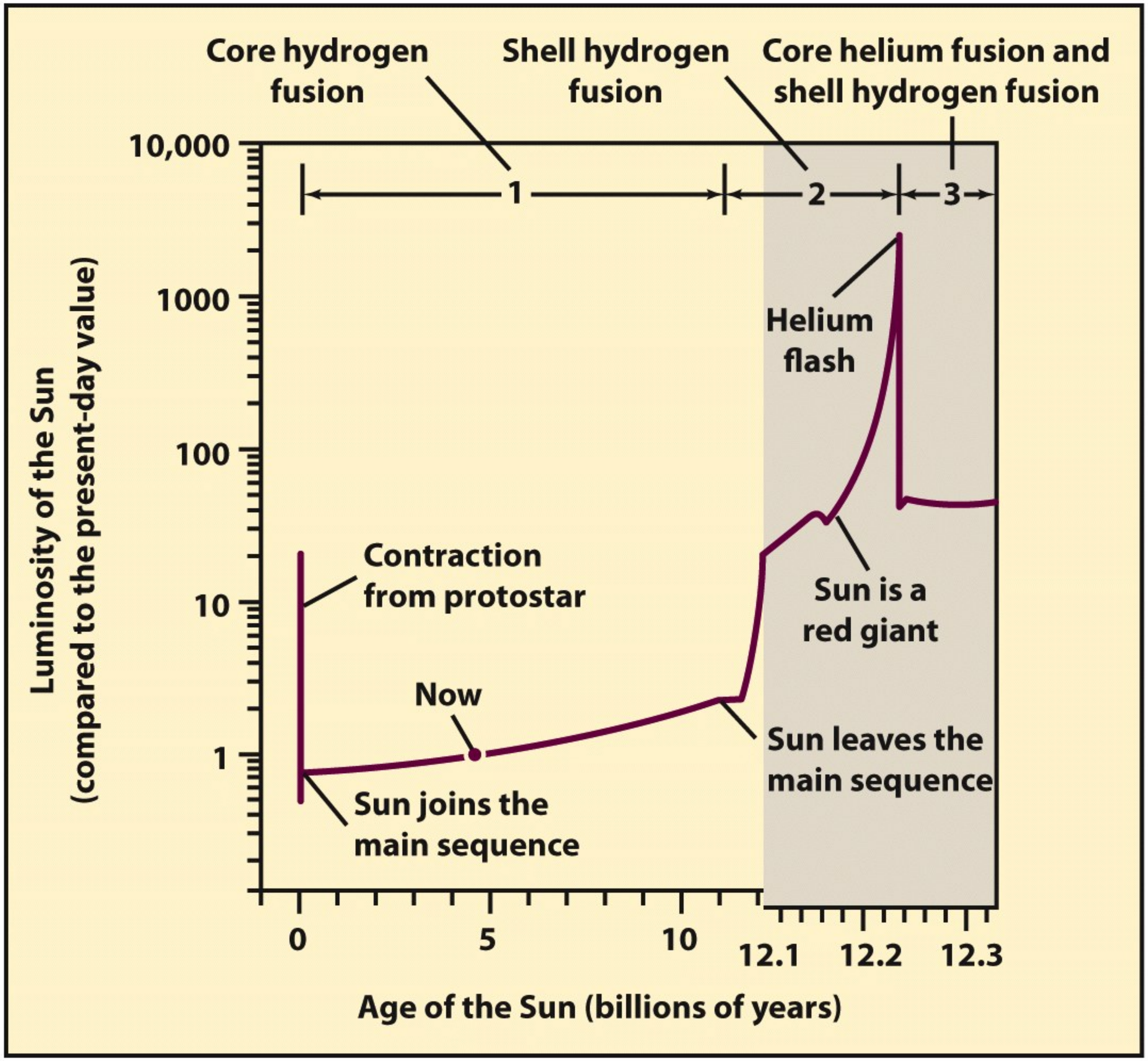
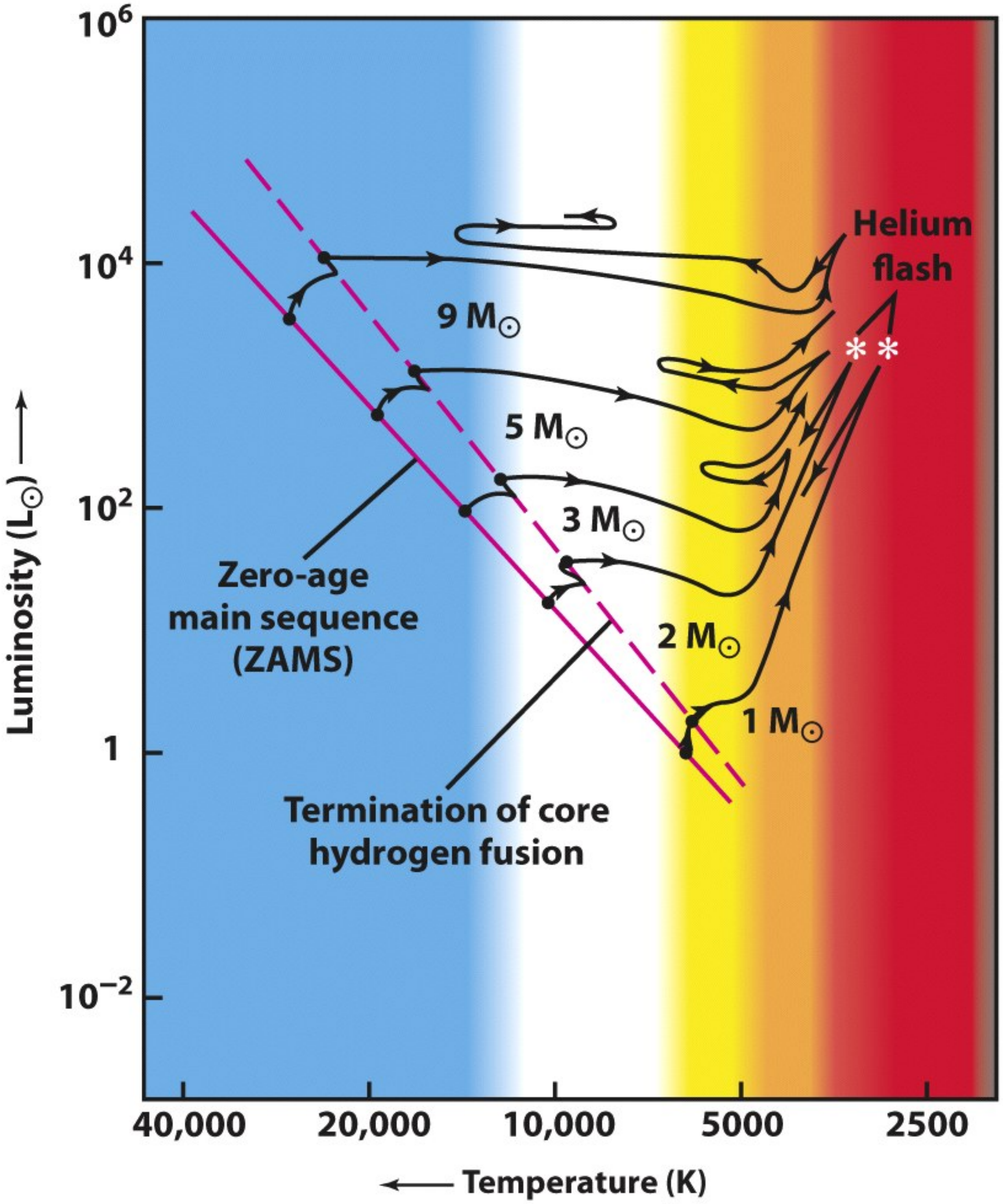


Figure 12-24a
Discovering the Universe, Eighth Edition



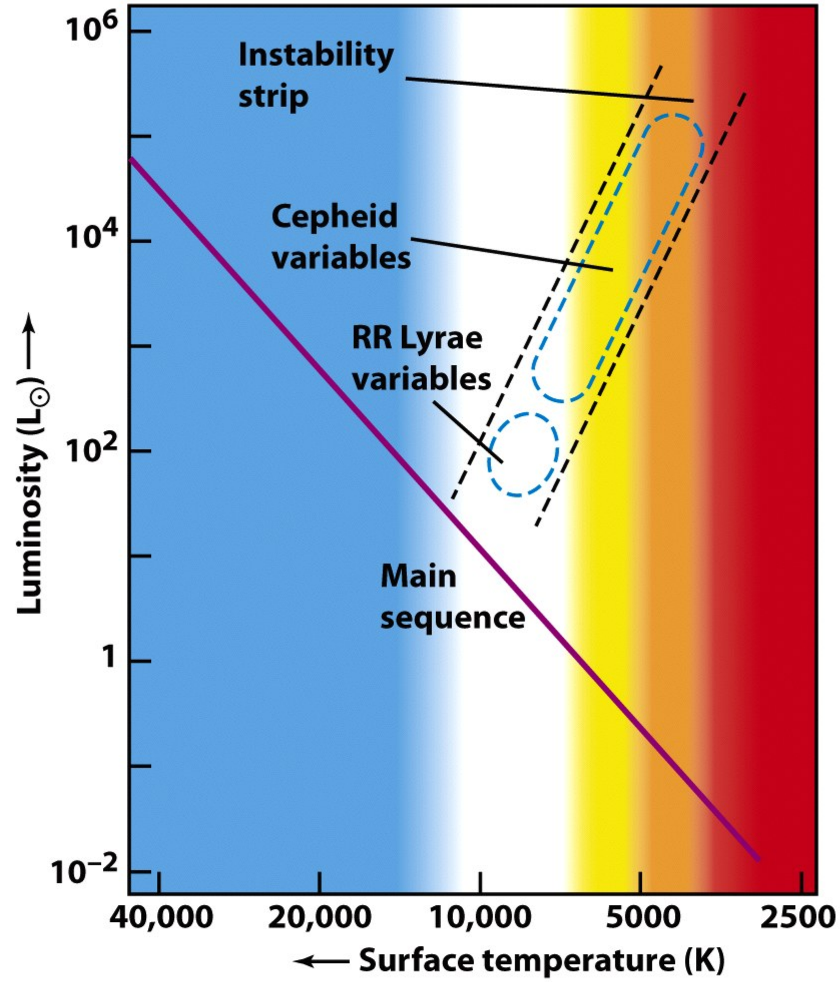


Figure 12-25
Discovering the Universe, Eighth Edition

Helium fusion:

$$^{4}He + ^{4}He + ^{4}He \rightarrow ^{12}C + \gamma$$

$$^{12}C + ^{4}He \rightarrow ^{16}O + \gamma$$

Cepheids: important for distance determinations

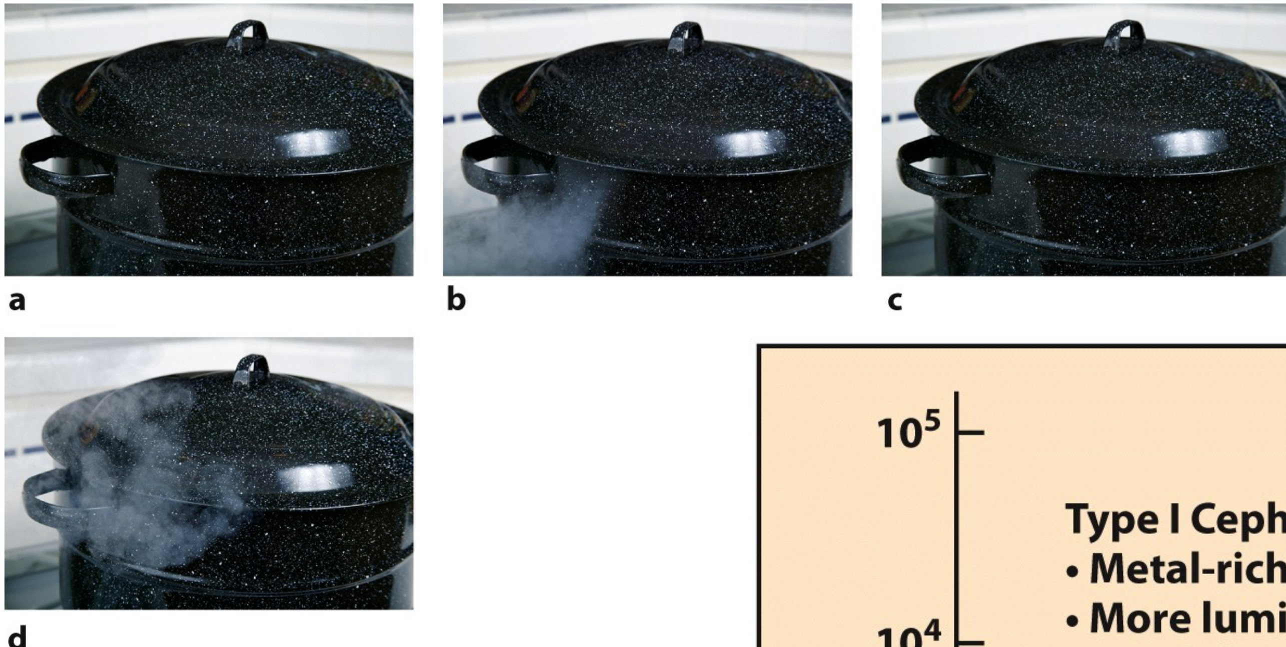


Figure 12-26
Discovering the Universe, Eighth Edition

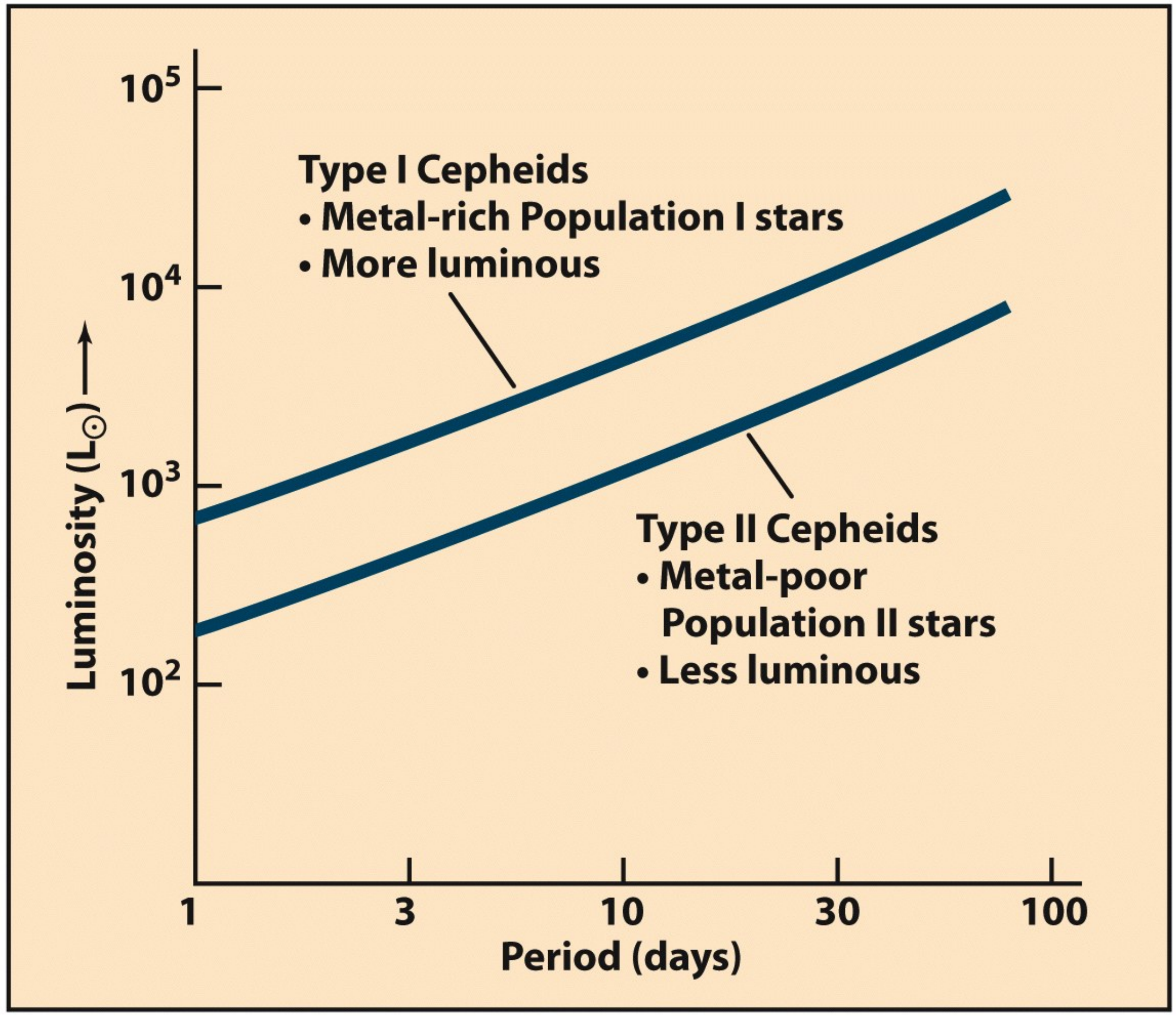


Figure 12-27
Discovering the Universe, Eighth Edition

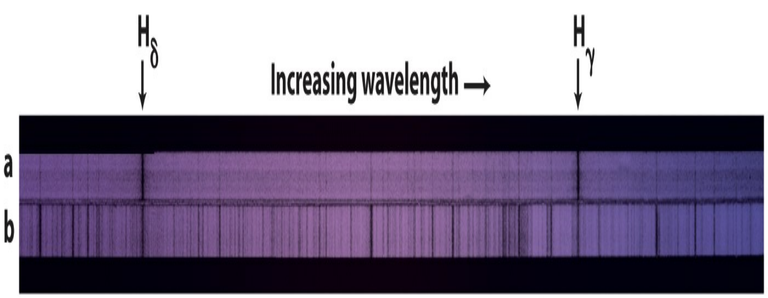


Figure 12-31
Discovering the Universe, Eighth Edition

H-R diagram of a globular cluster (M55)

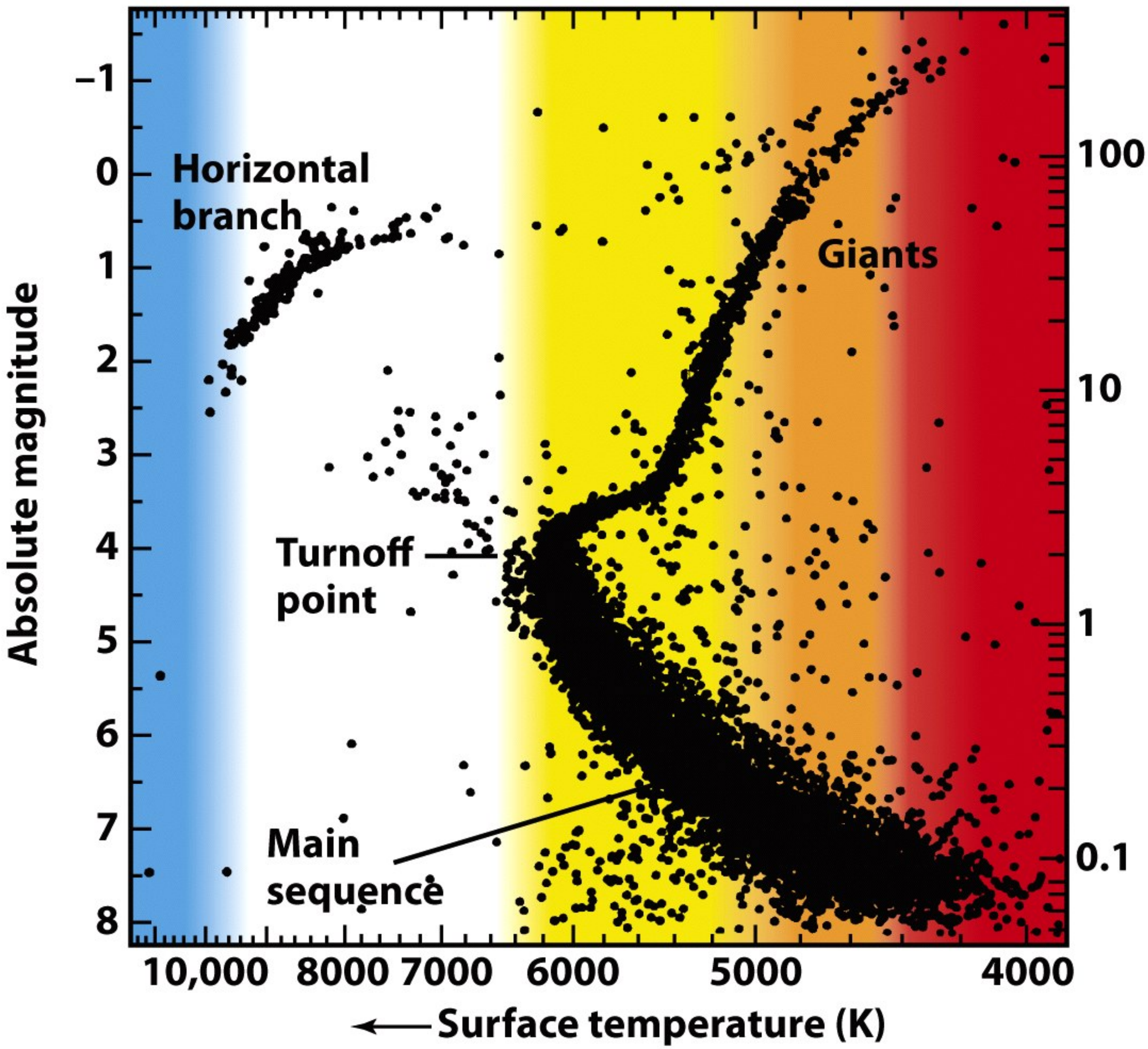


Figure 12-29
Discovering the Universe, Eighth Edition

$L/L_{sol}=(M/M_{sol})^{3.5}$
$t/t_{sol} = =(M/M_{sol})^{-2.5}$

For turnoff point:
$M/M_{sol} = (L/L_{sol})^{1/3.5}$
$= (2/1)\ )^{1/3.5}$
$= 1.22$
$t/t_{sol.} =(1.22)^{-2.5}$
$=0.61$
$t = 6$ Bill yr.

H-R diagram of a globular cluster (M55)

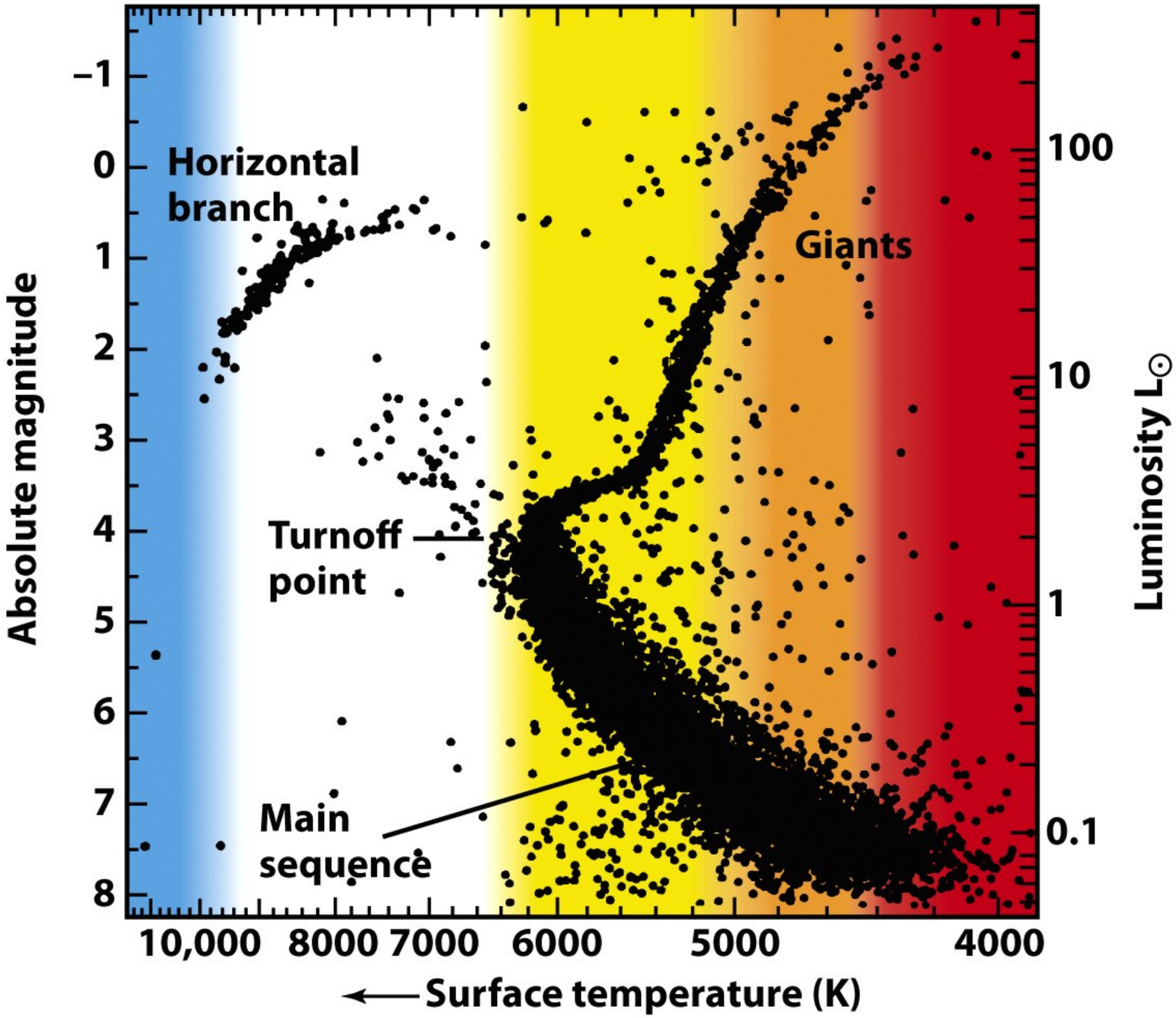


Figure 12-29
Discovering the Universe, Eighth Edition

Simulation of the evolution of a cluster
from 0 to 4.5 billion years

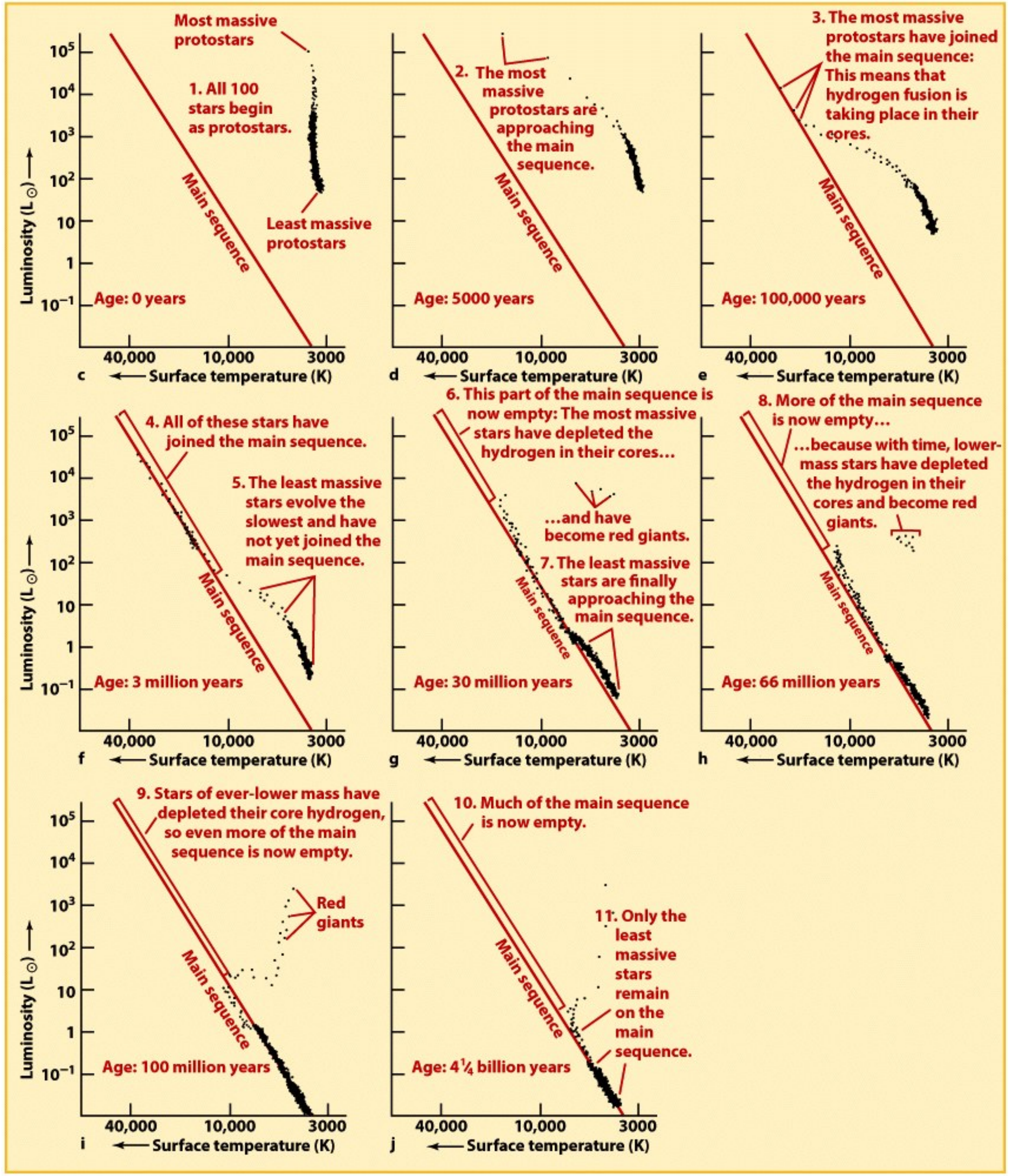


Figure 12-30c-j

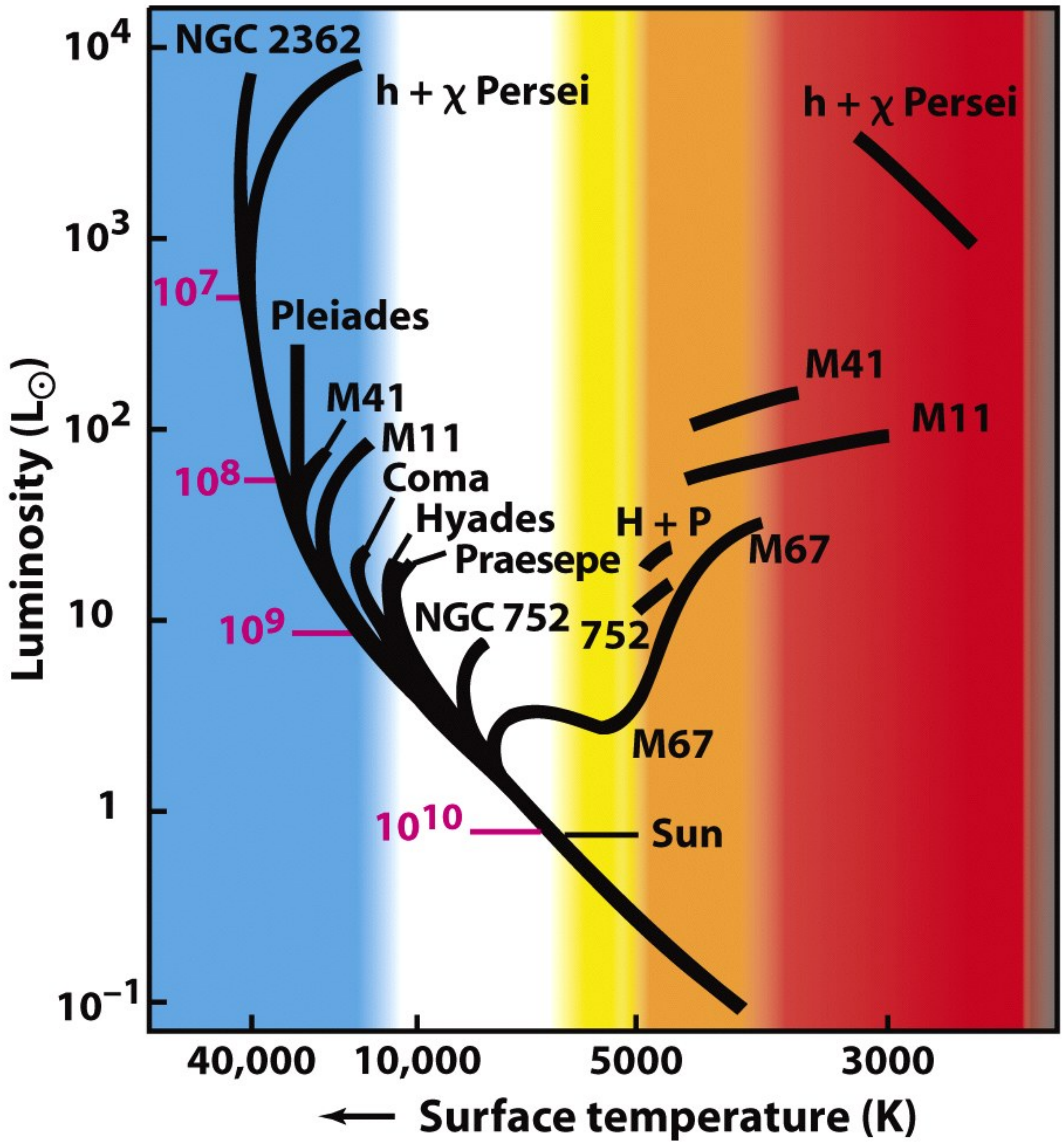
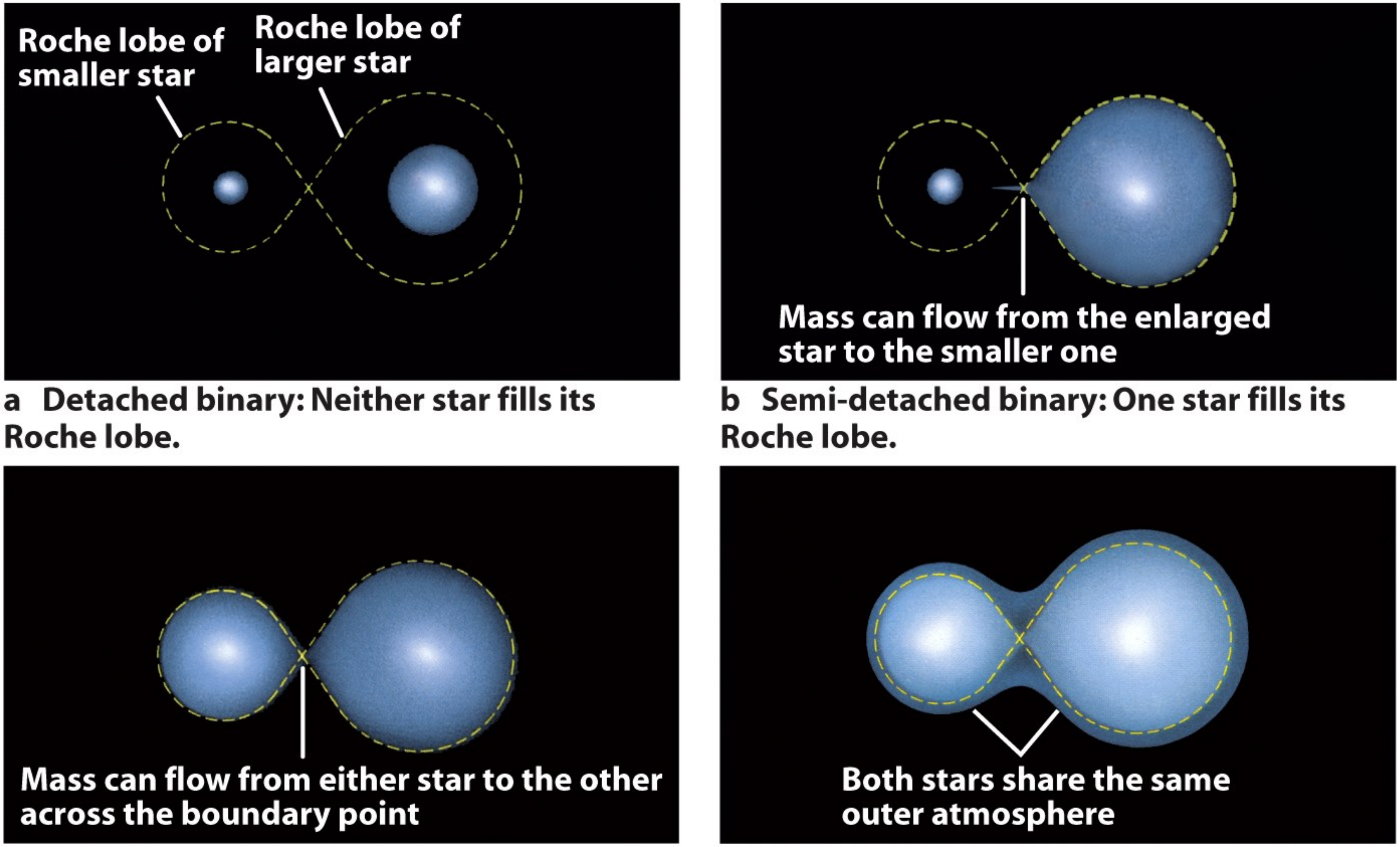


Figure 12-30b
Discovering the Universe, Eighth Edition

The turnover point gives the age (yr) of the cluster (in red).

Binaries



a Detached binary: Neither star fills its Roche lobe.

b Semi-detached binary: One star fills its Roche lobe.

c Contact binary: Both stars fill their Roche lobes.

d Overcontact binary: Both stars overfill their Roche lobes.

Figure 12-32
Discovering the Universe, Eighth Edition

Each star in a binary system has a Roche lobe.
Within a Roche lobe, orbital material is bound to the star.

A companion star can influence the evolution

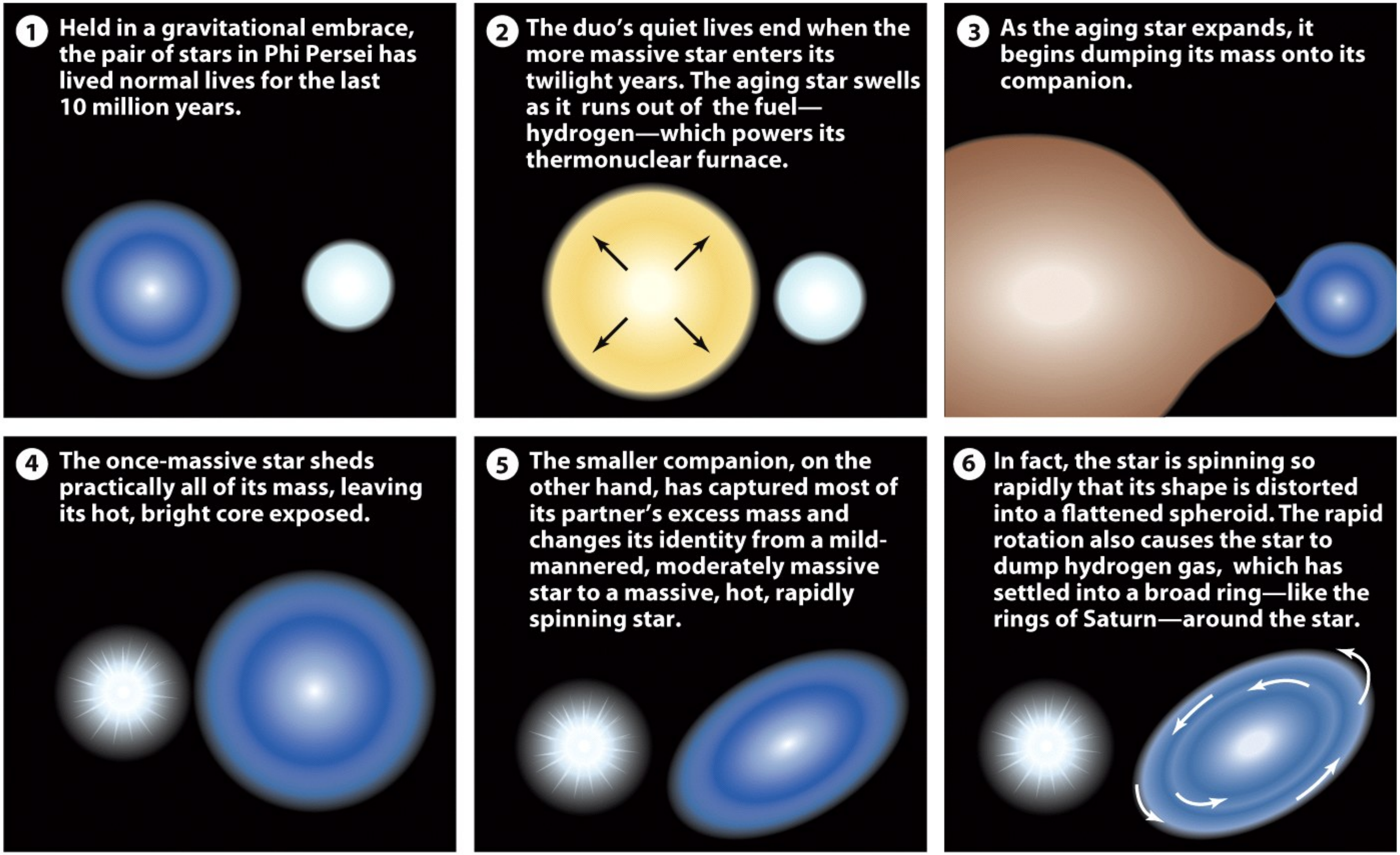


Figure 12-34
Discovering the Universe, Eighth Edition