

Discovering the Essential Universe



Neil F. Comins

CHAPTER 11

The Lives of Stars from Birth Through Middle Age



Chapter 12 Opener
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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.**



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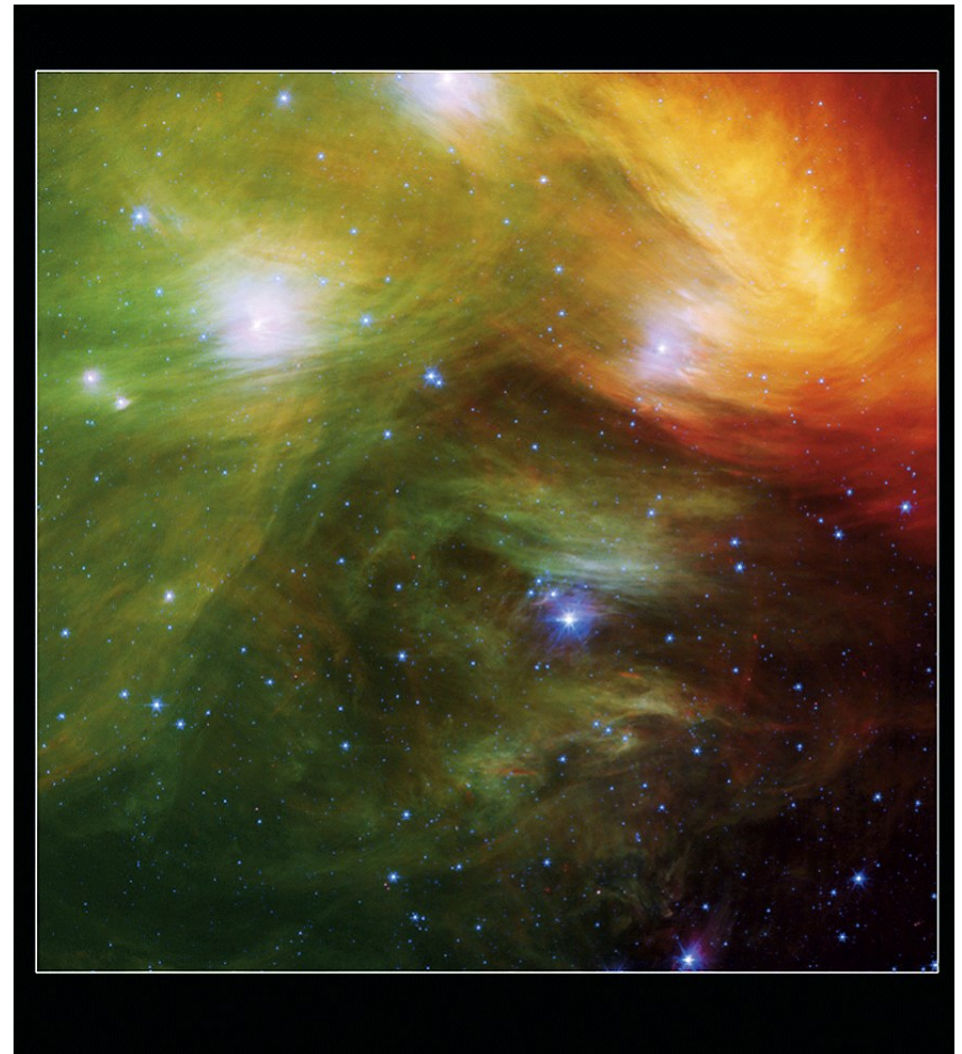


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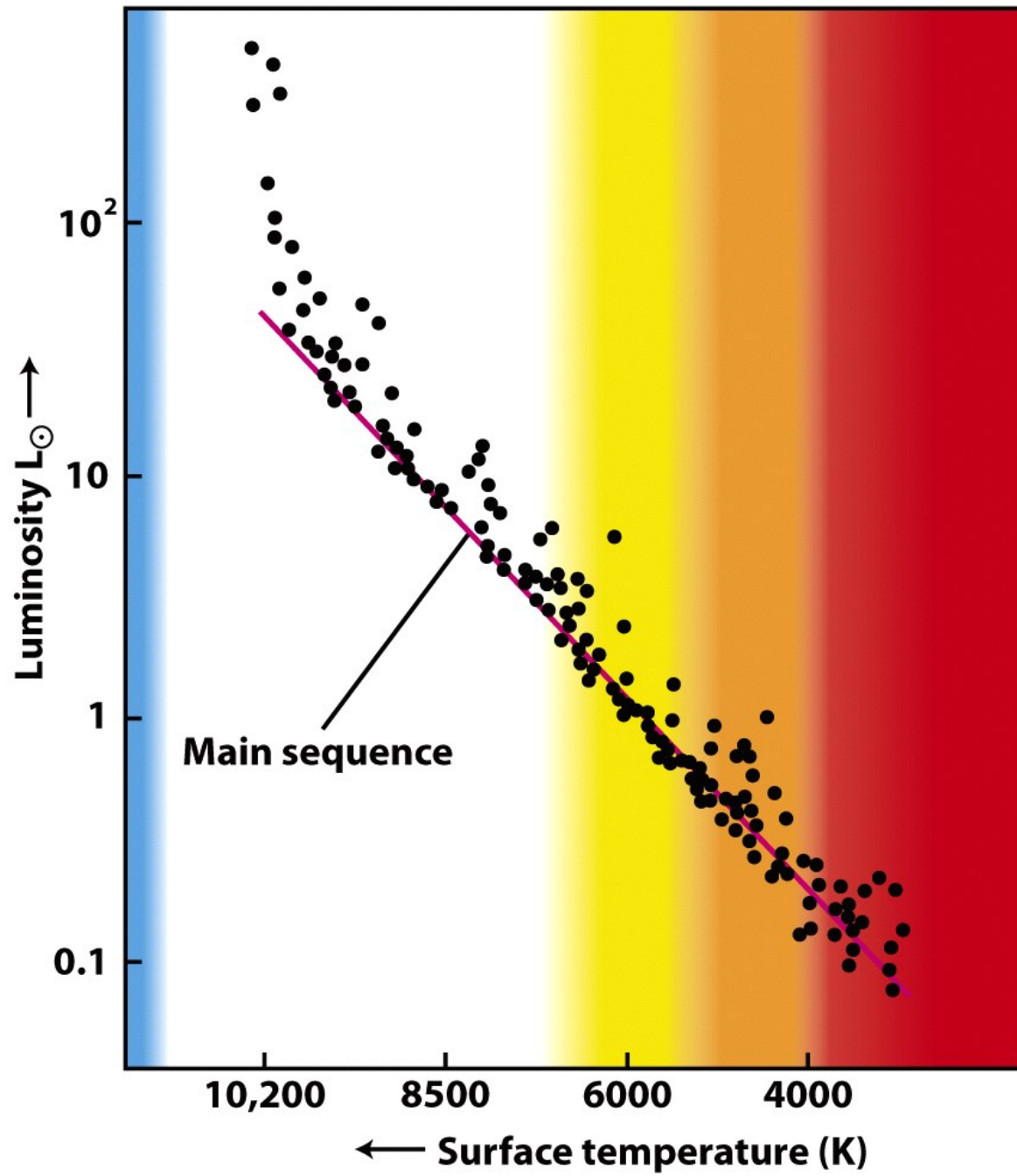
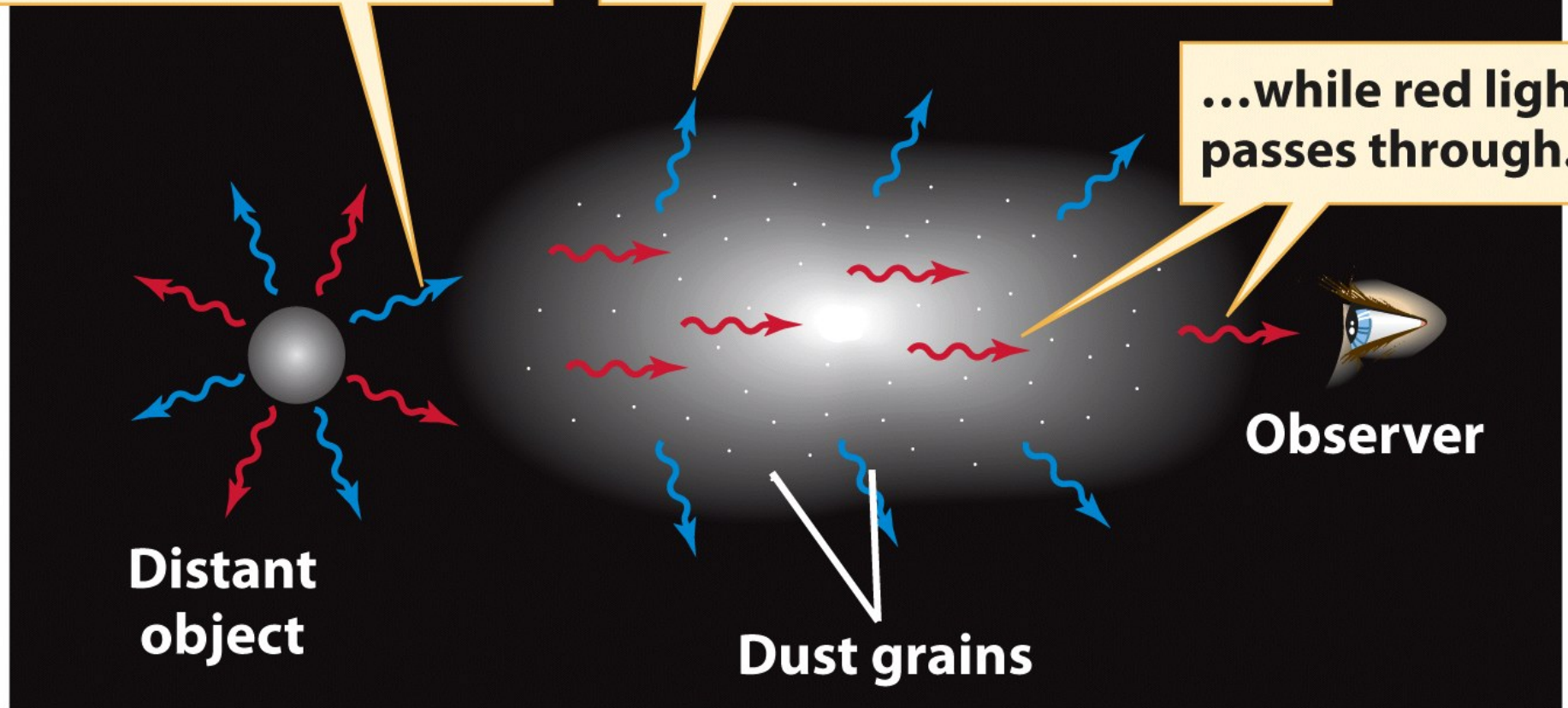


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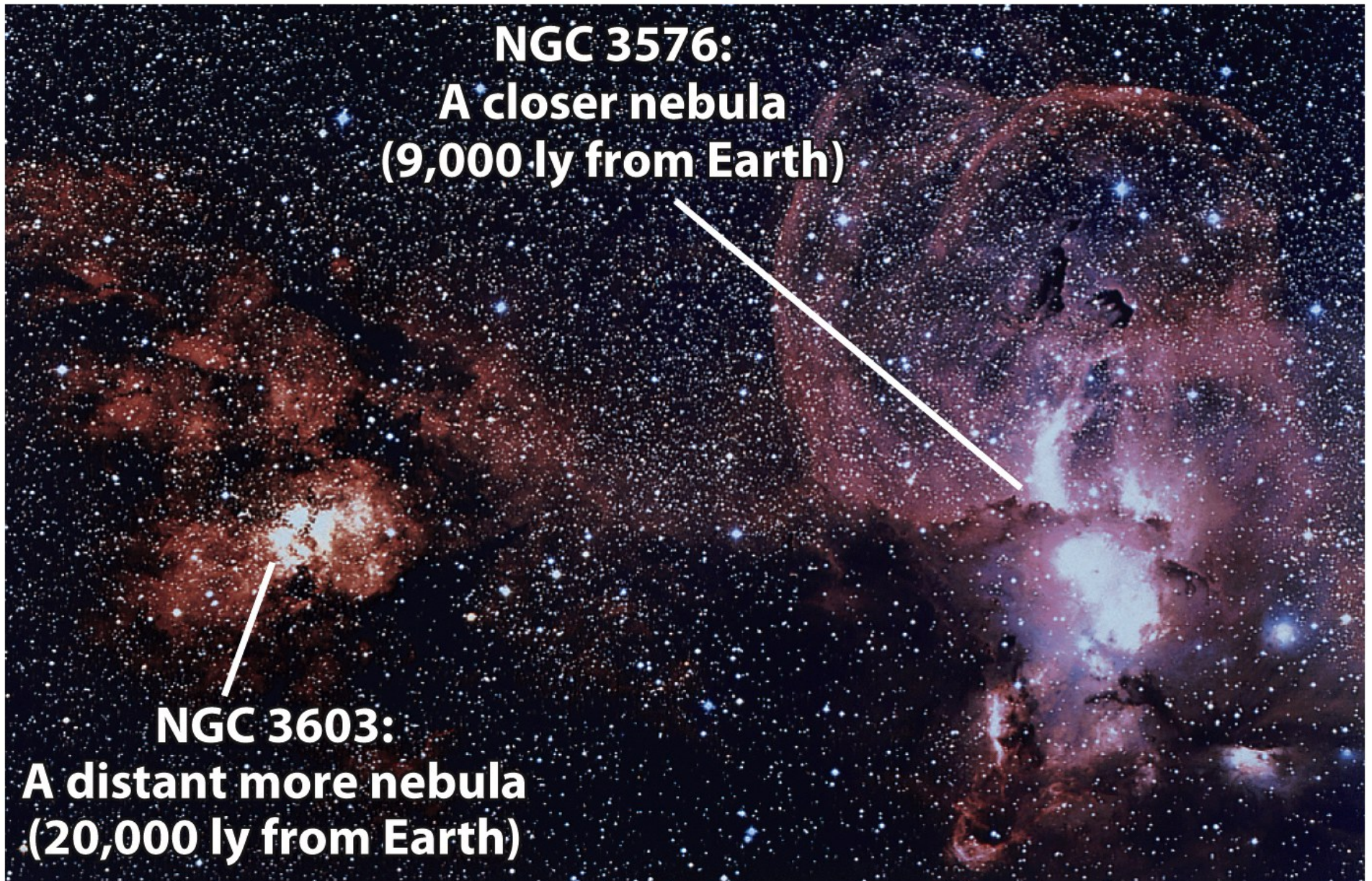
As light from a distant object travels through interstellar space...

...short-wavelength blue light is scattered or absorbed by dust grains...

...while red light passes through.



How dust causes interstellar reddening



NGC 3576:
A closer nebula
(9,000 ly from Earth)

NGC 3603:
A distant more nebula
(20,000 ly from Earth)

Reddening depends on distance

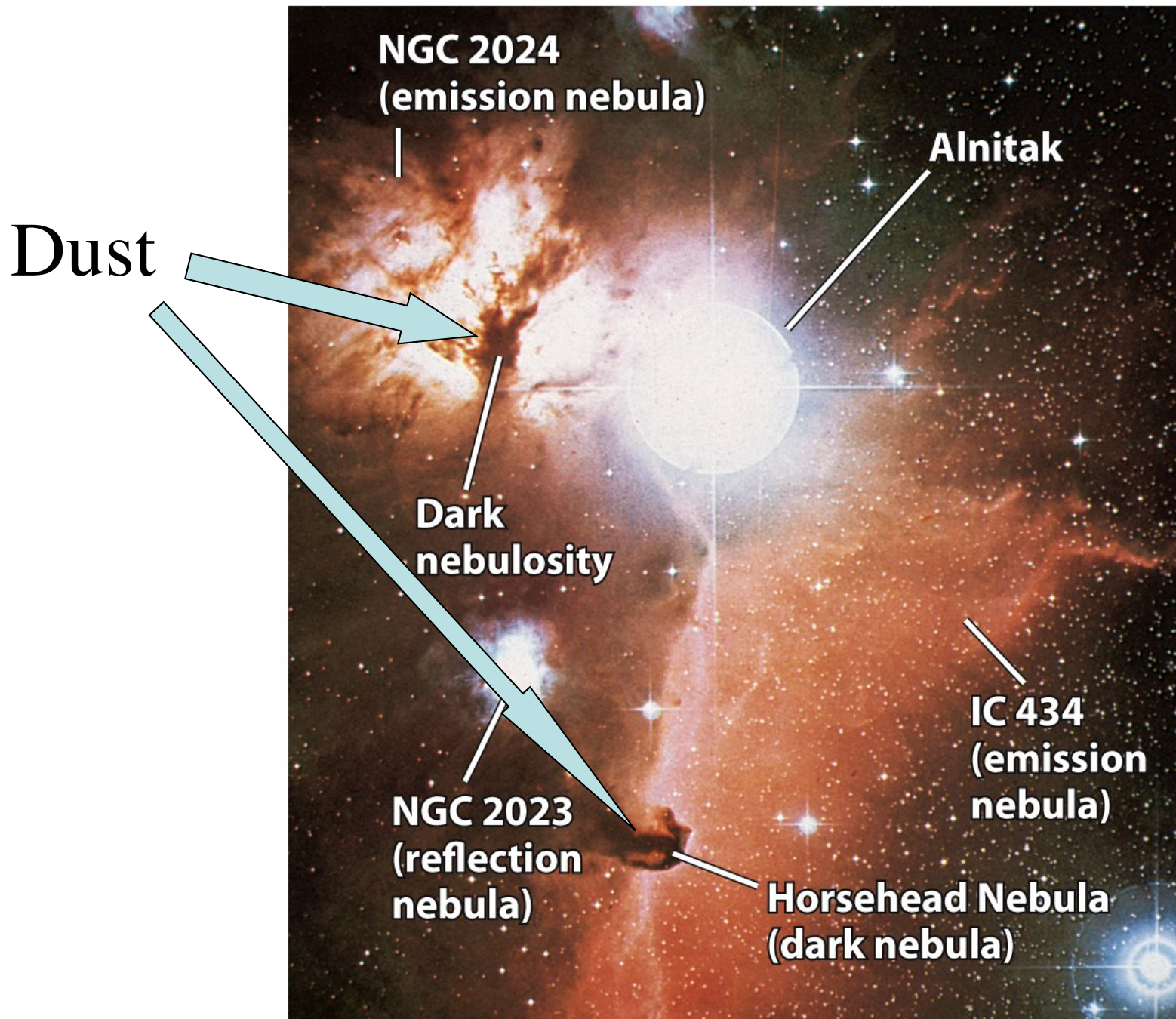
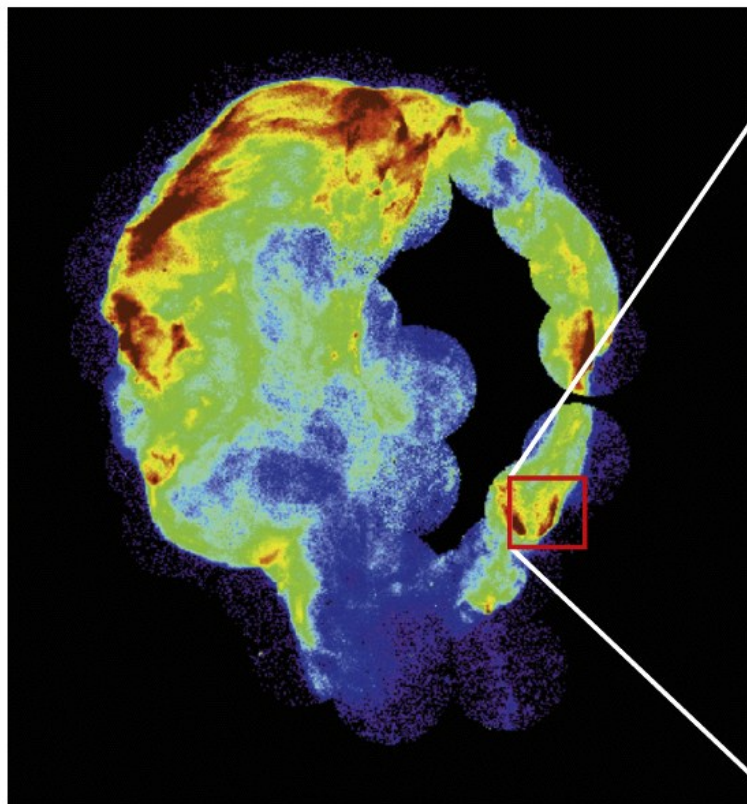
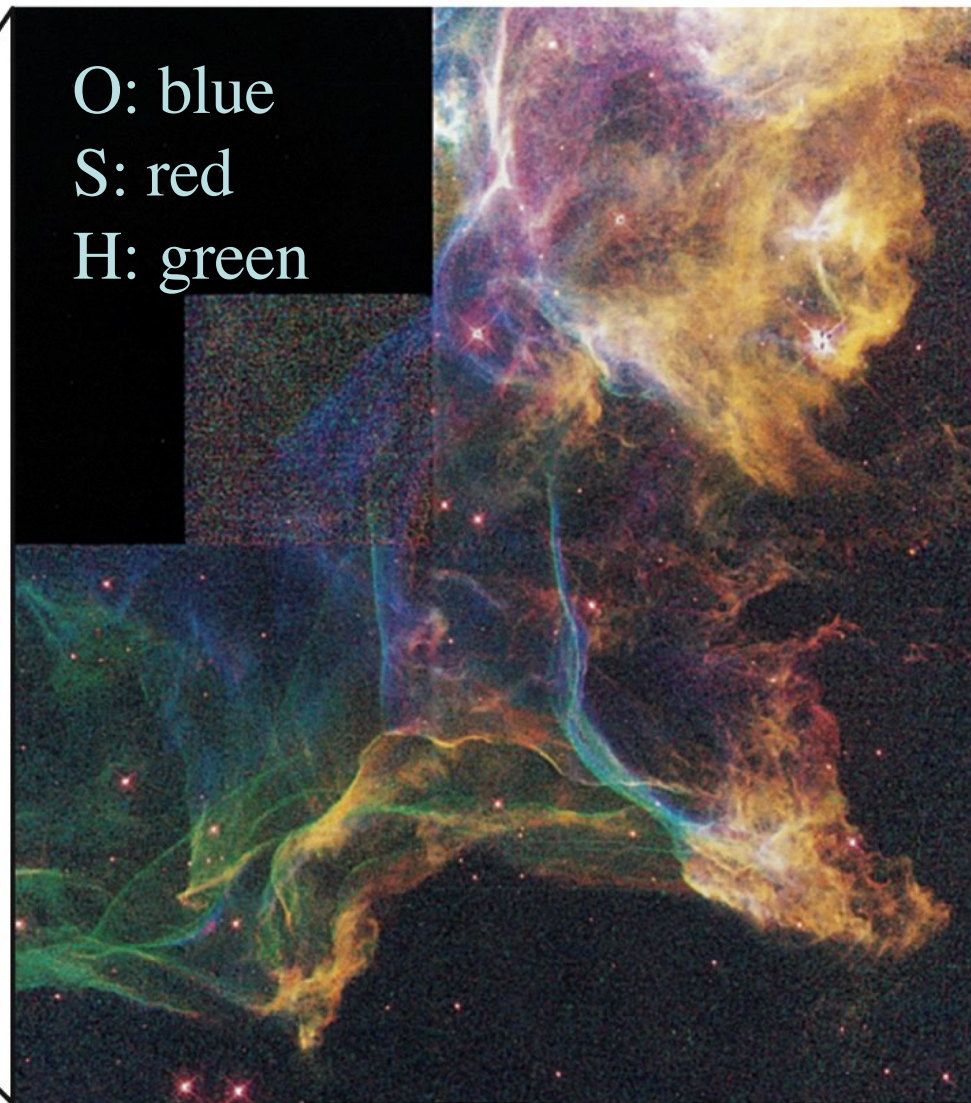


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Cygnus Loop - supernova remnant,
Exploded 20,000 years ago, distance 120 ly



a



b

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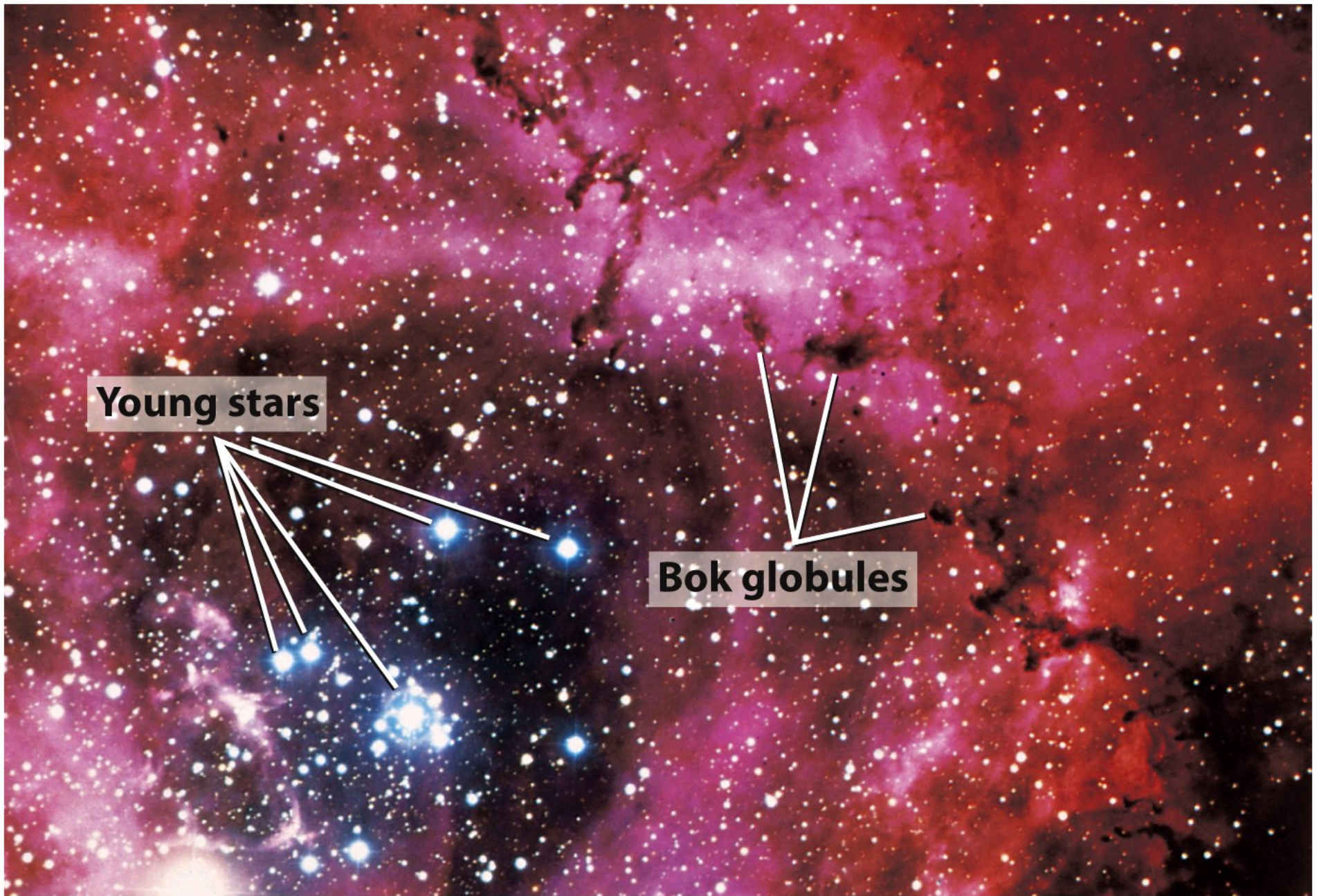
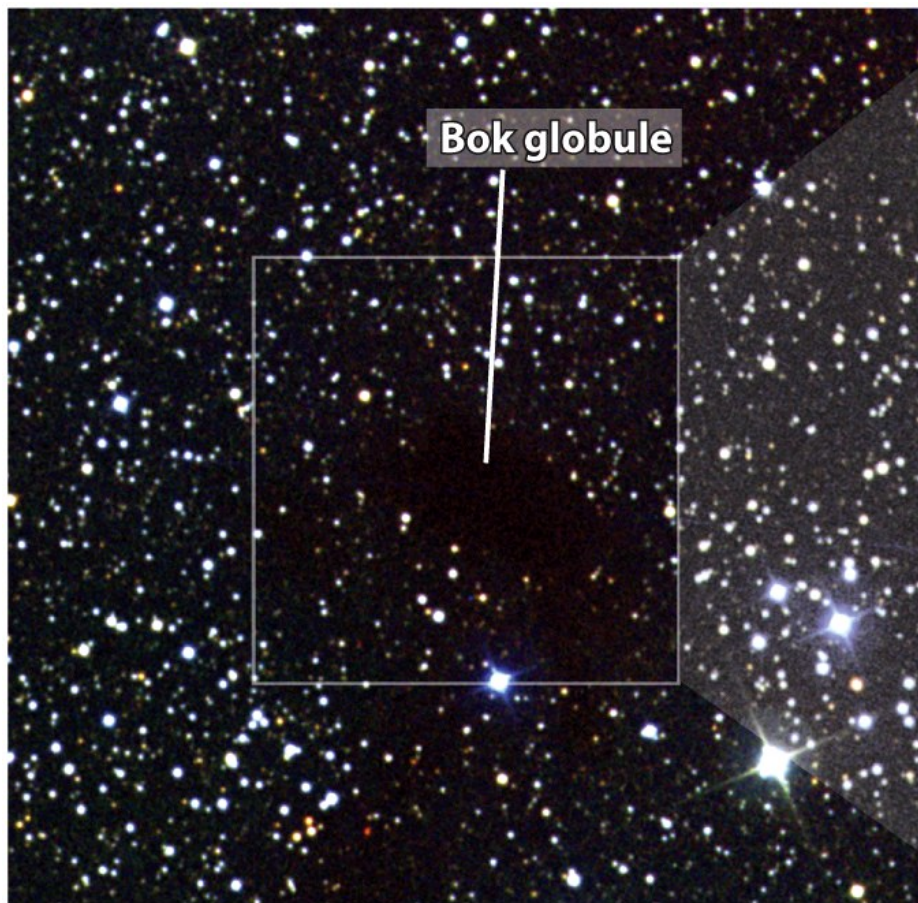
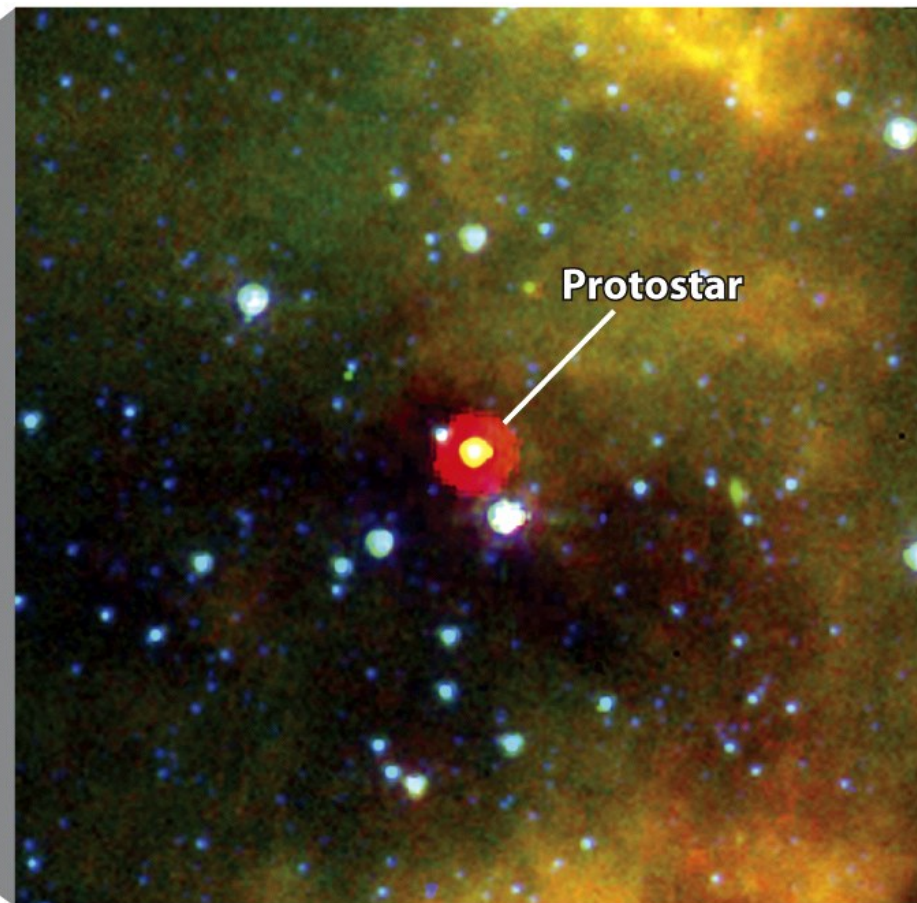


Figure 12-8
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a A dark nebula



b A hidden protostar within the dark nebula

Figure 12-9
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>300 protostars

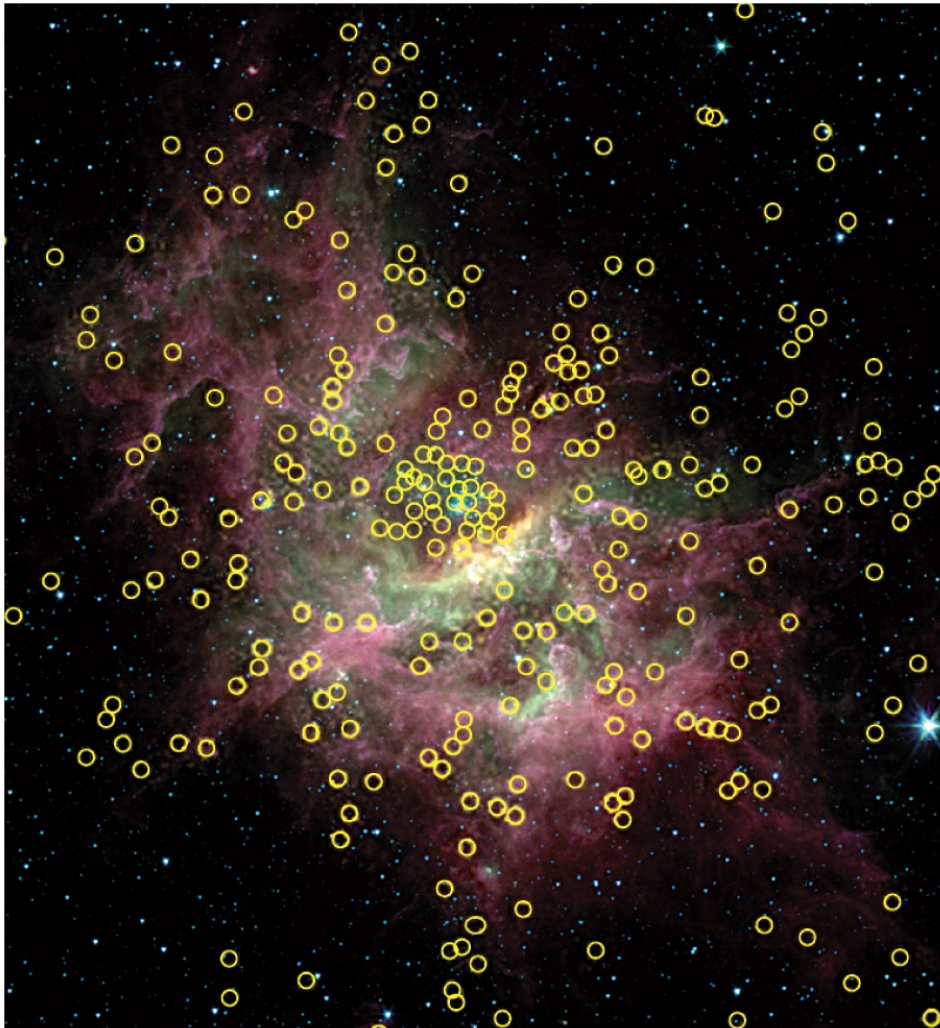


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2 pre-main-sequence stars

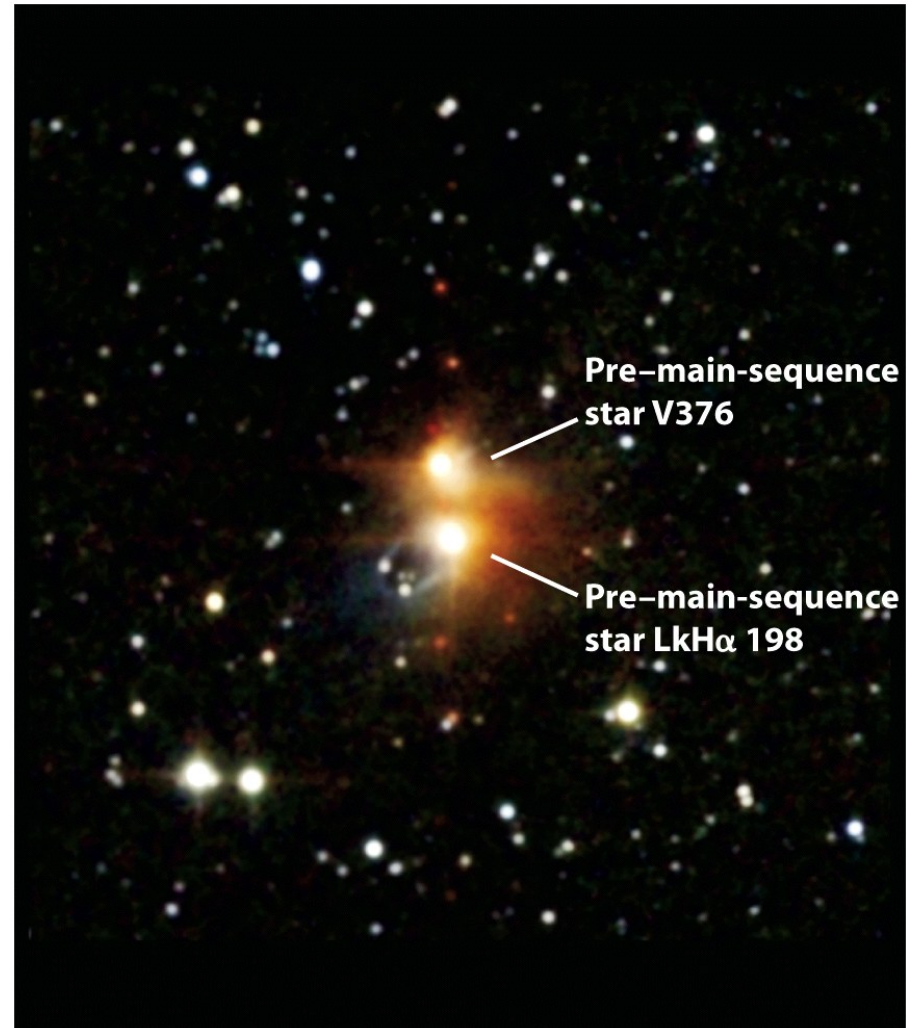
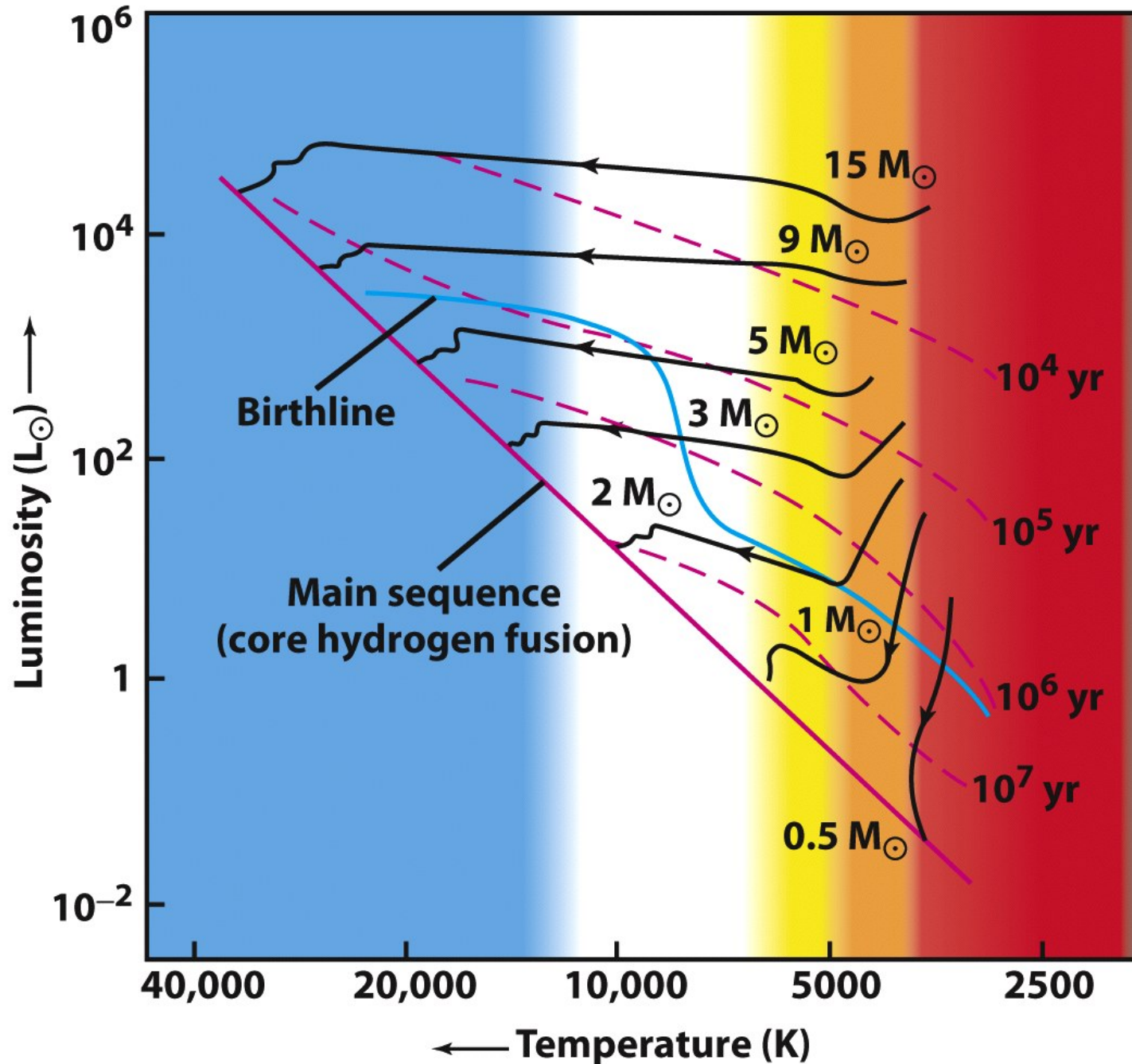


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Pre-main sequence evolutionary tracks



Supermassive star, originally $M \sim 100$ to $200 M_{\text{sol}}$

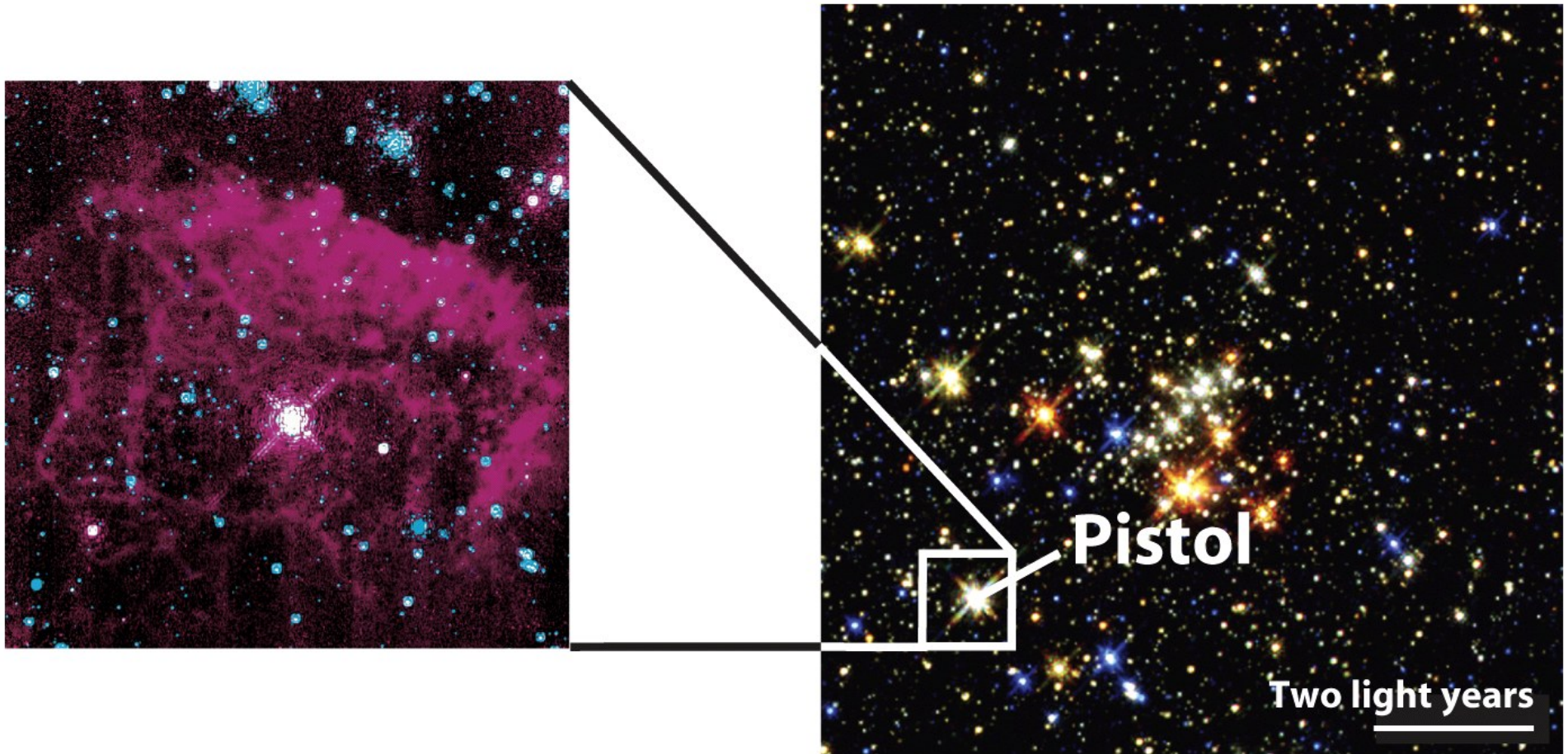


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1. This emission nebula (about 2200 pc away and about 20 pc across) surrounds the star cluster M16.

2. Star formation is still taking place within this dark, dusty nebula.

3. Hot, luminous stars (beyond the upper edge of this image) emit ultraviolet radiation: This makes the dark nebula evaporate, leaving these pillars.

4. At the tip of each of these pillars is a nebula containing a young star.

5. Eventually the nebulae evaporate, revealing the stars.

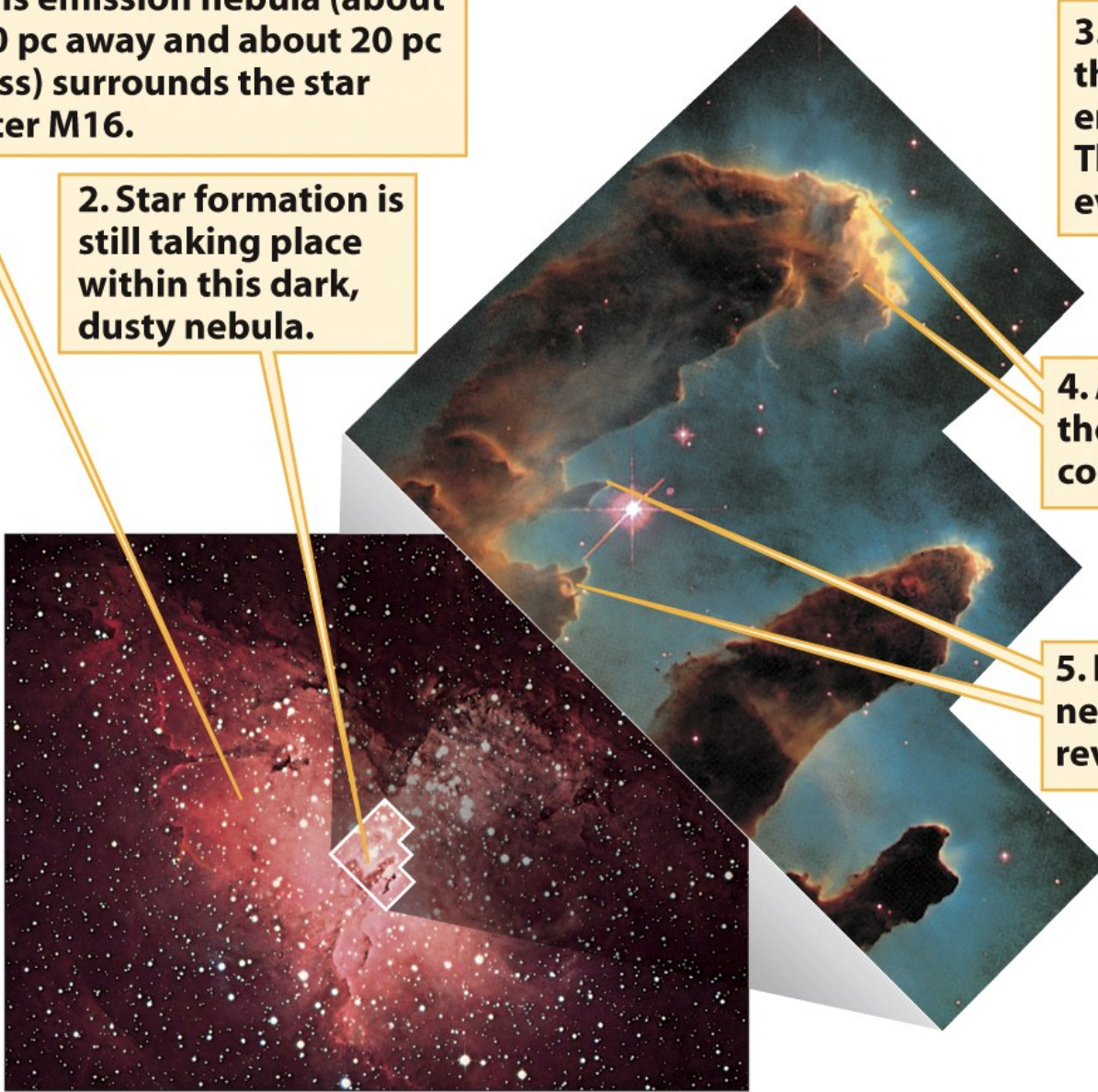


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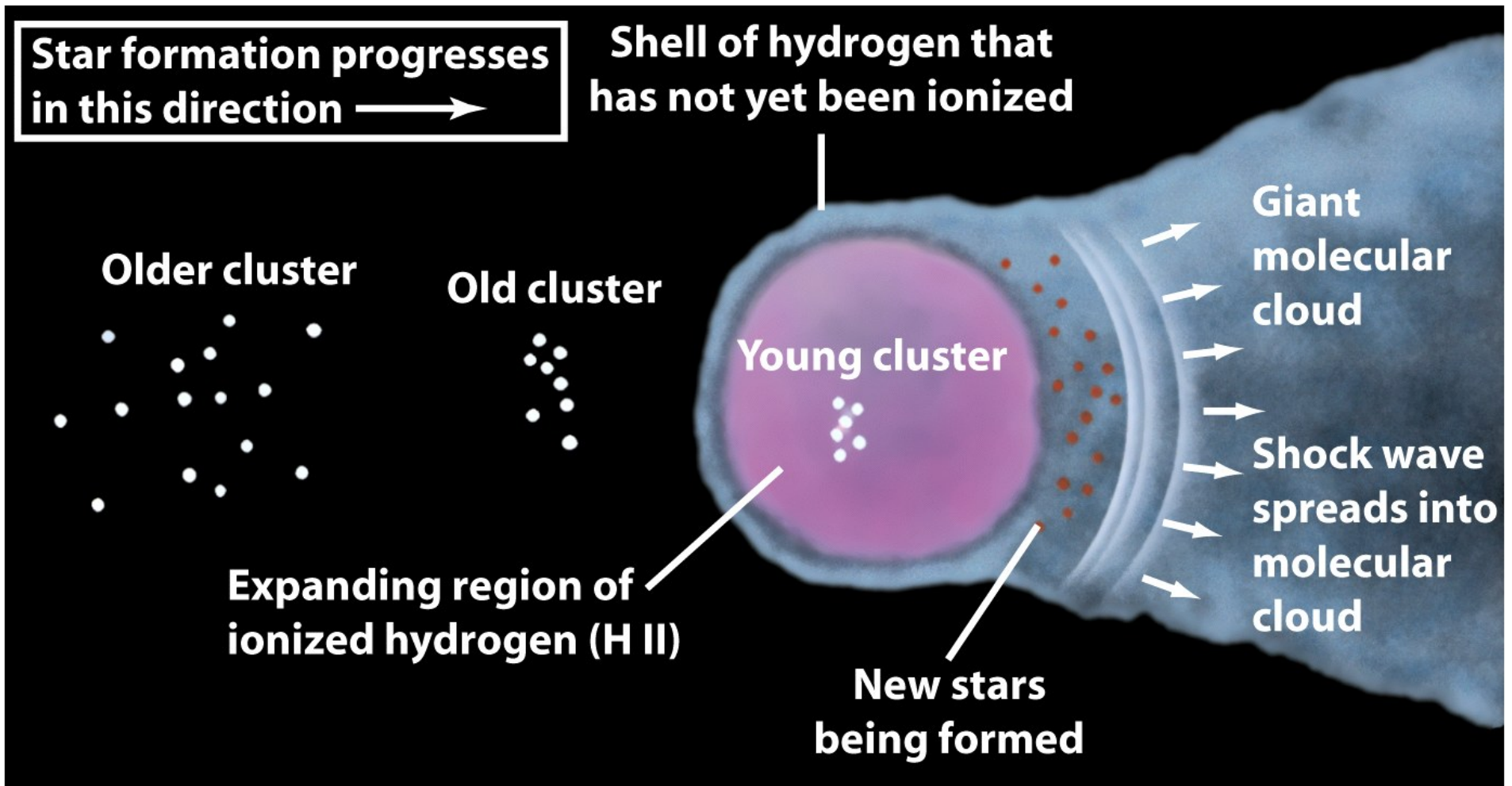
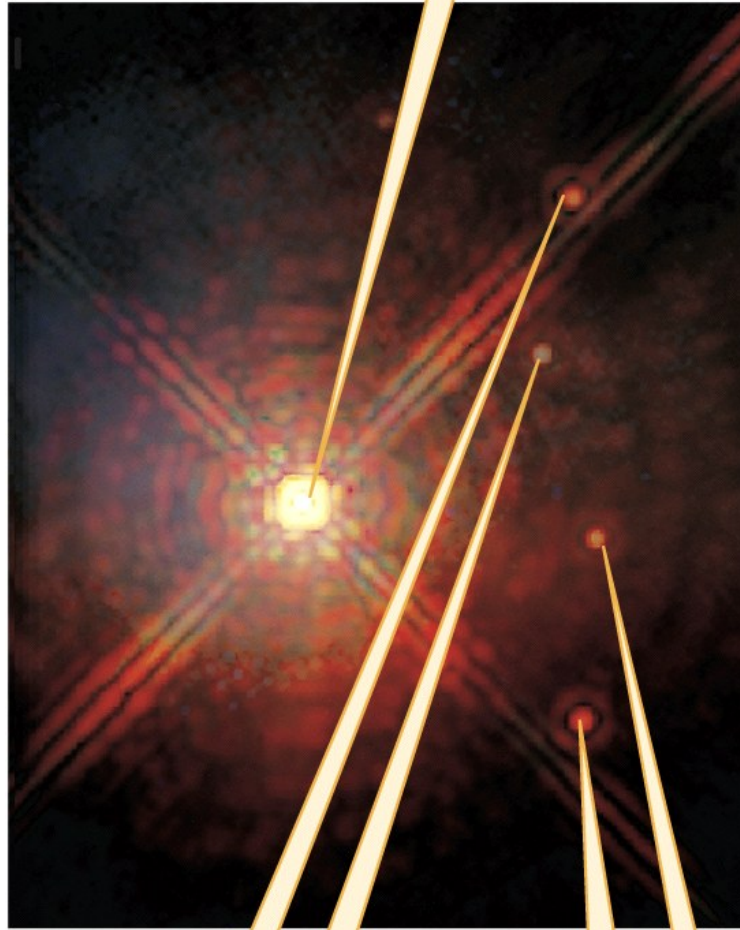


Figure 12-17a
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Radiation and stellar winds from this massive, luminous star...



...may have triggered the formation of these stars.

Figure 12-17b
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Figure 12-18a
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Stars about to burn H

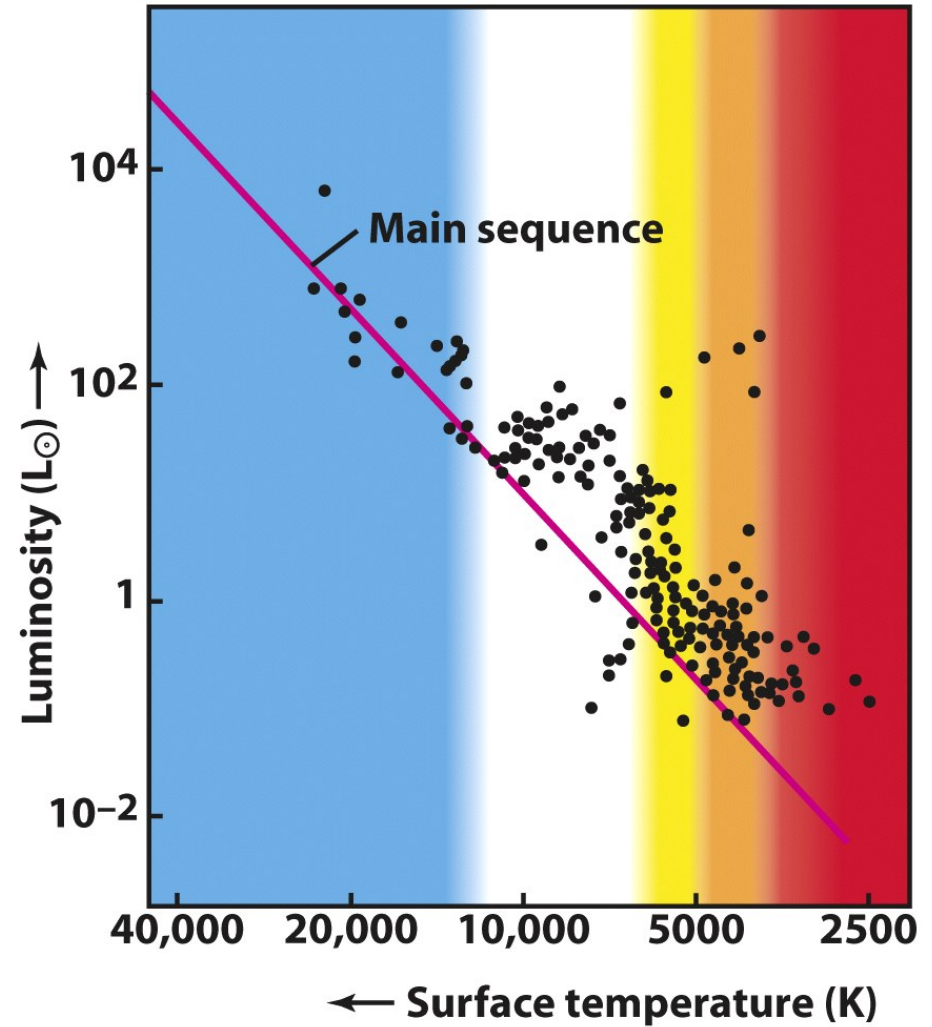


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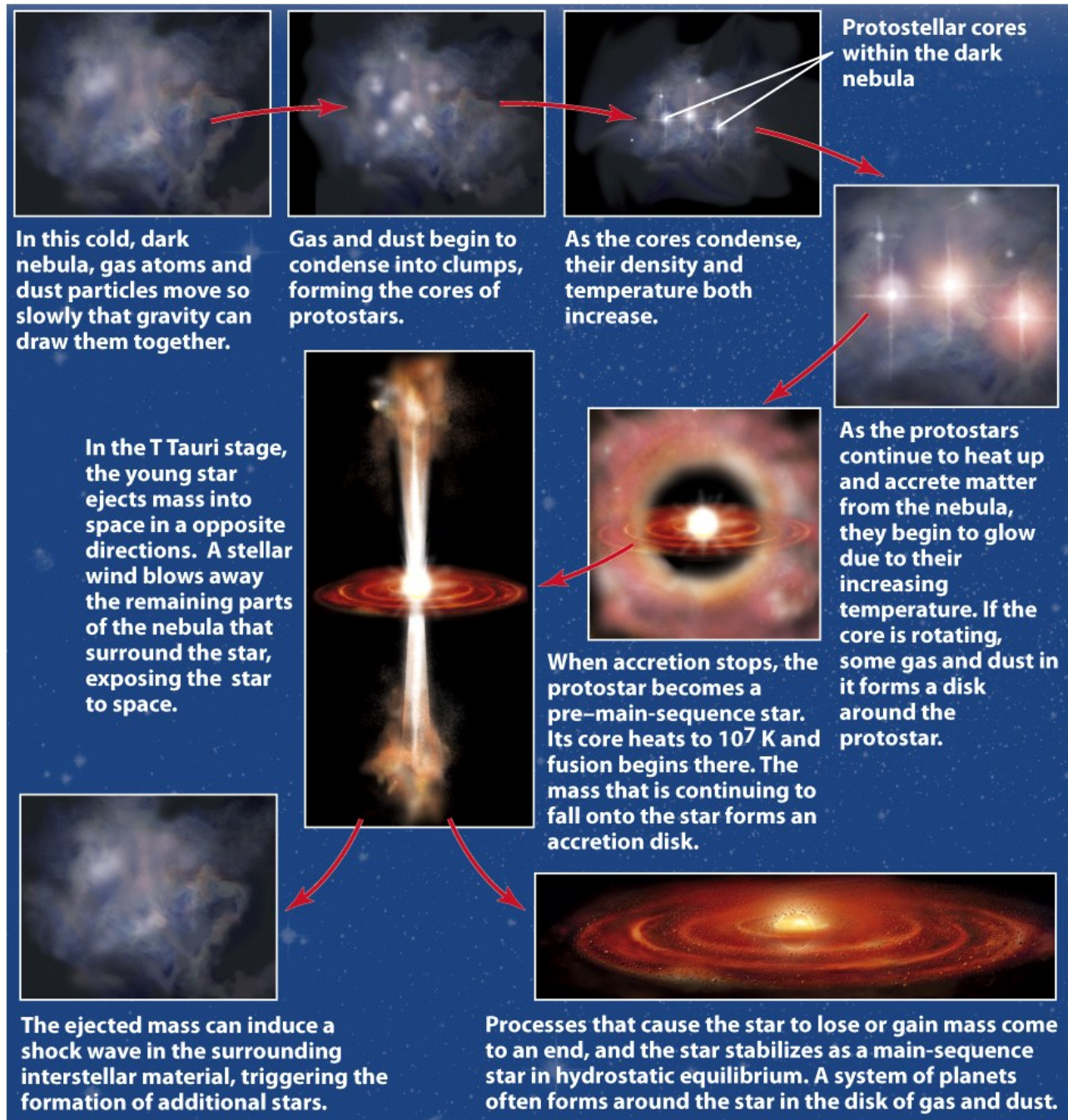


Figure 12-19

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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
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$$Lt = fMc^2$$

$$t \propto Mc^2/L$$

$$L \propto M^{3.5}$$



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

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

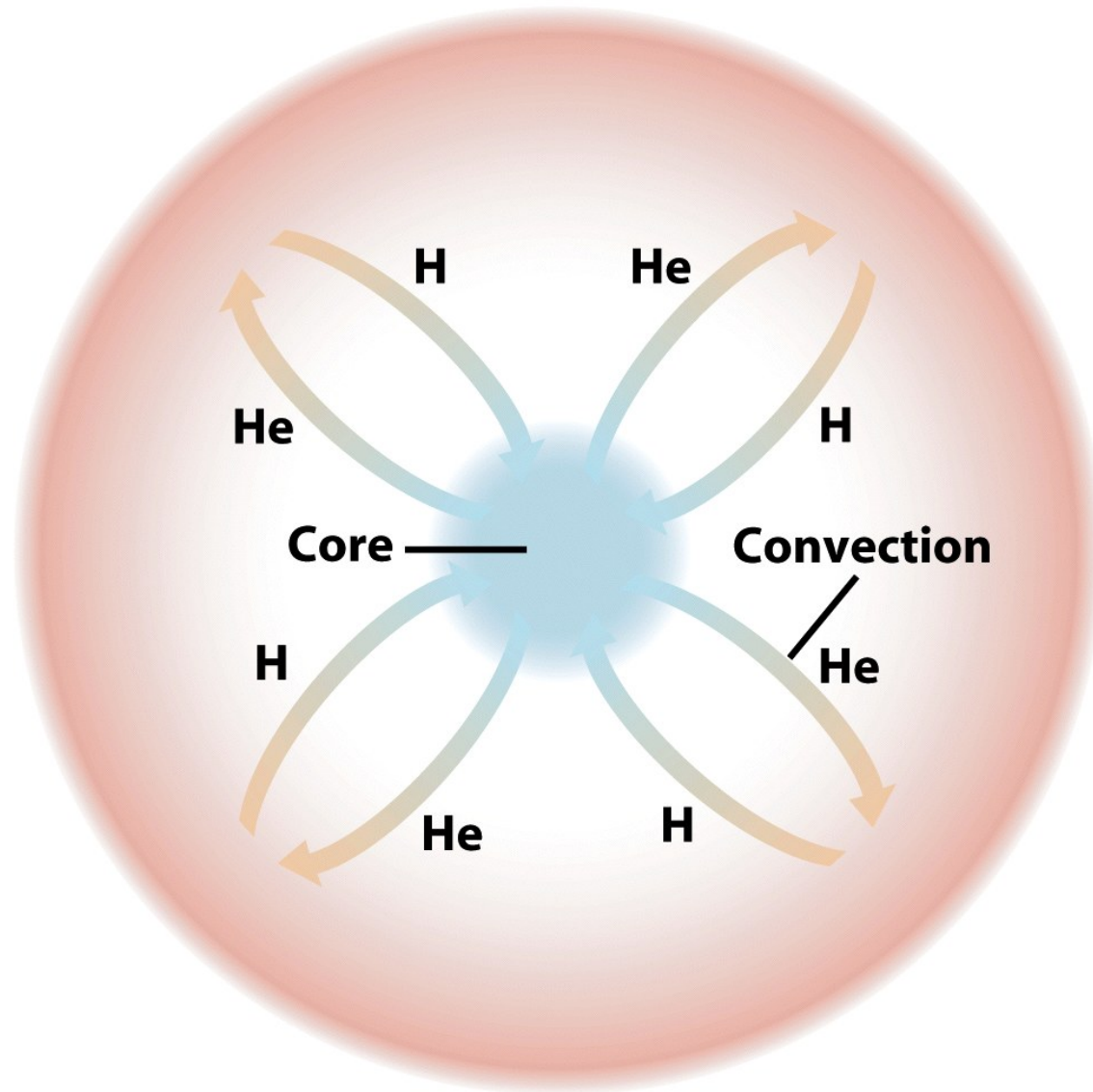


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Early and middle evolution of stars with more than $0.4 M_{\text{sol}}$

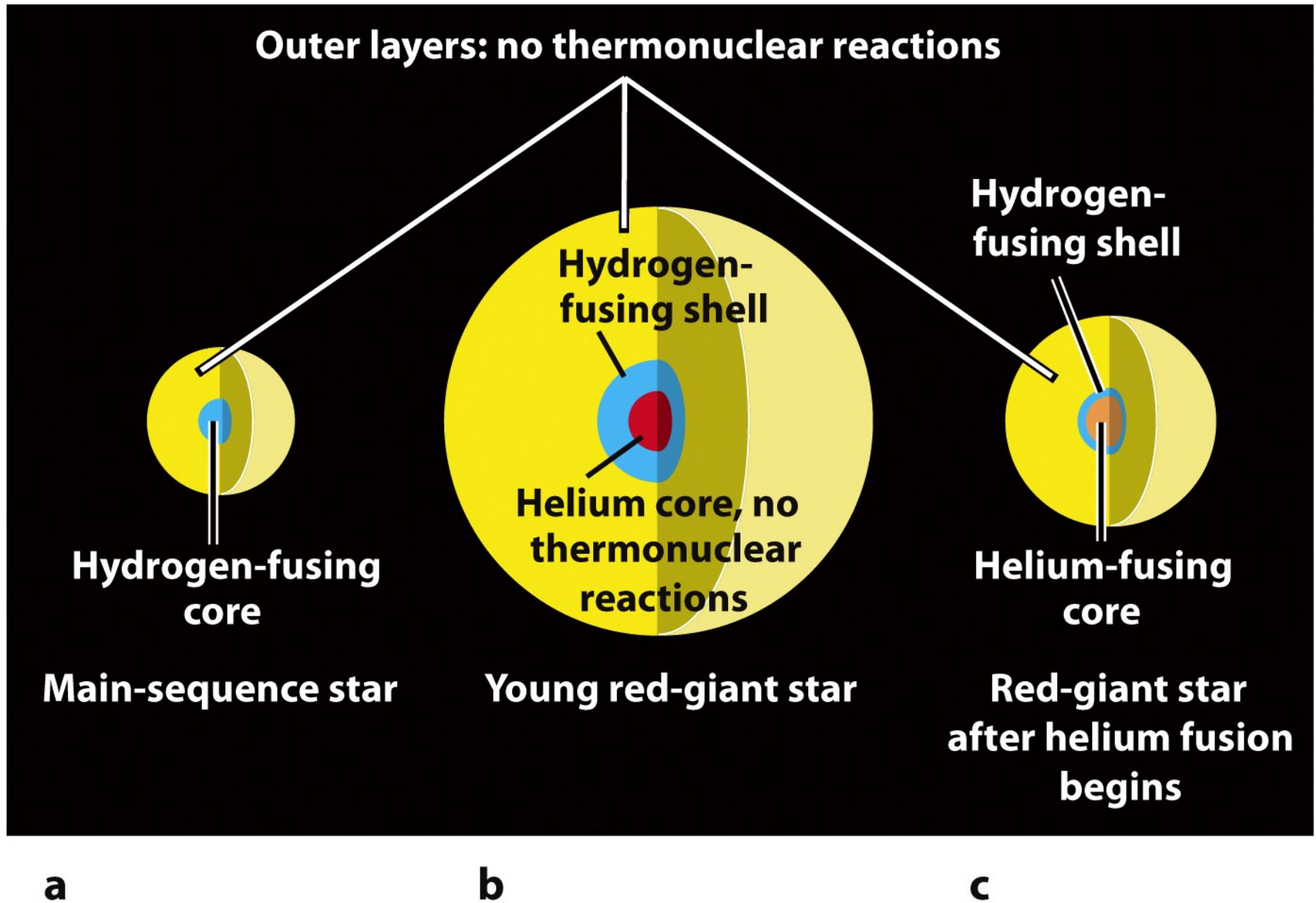
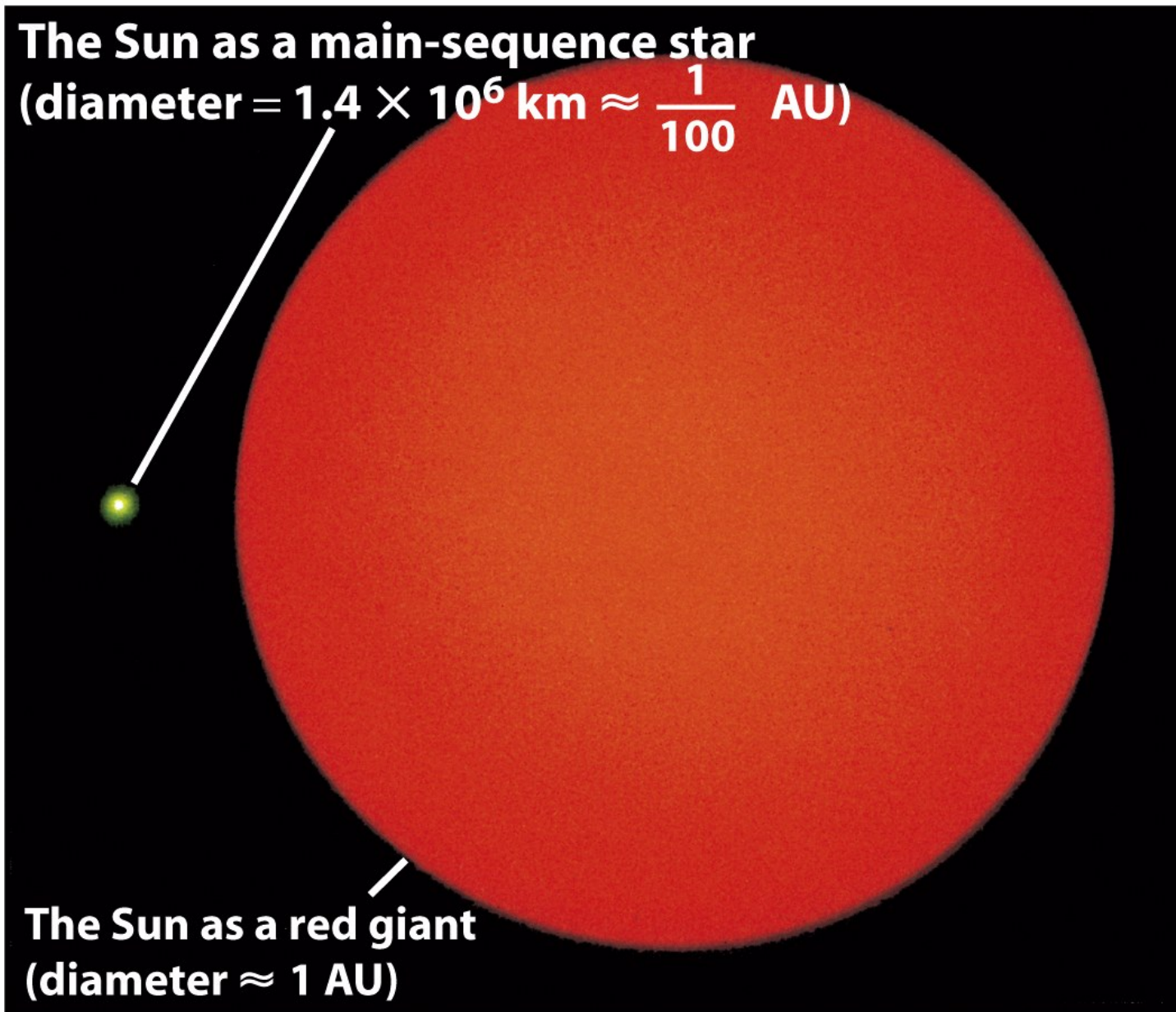


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The Sun today and as a red giant

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Post main-sequence evolution

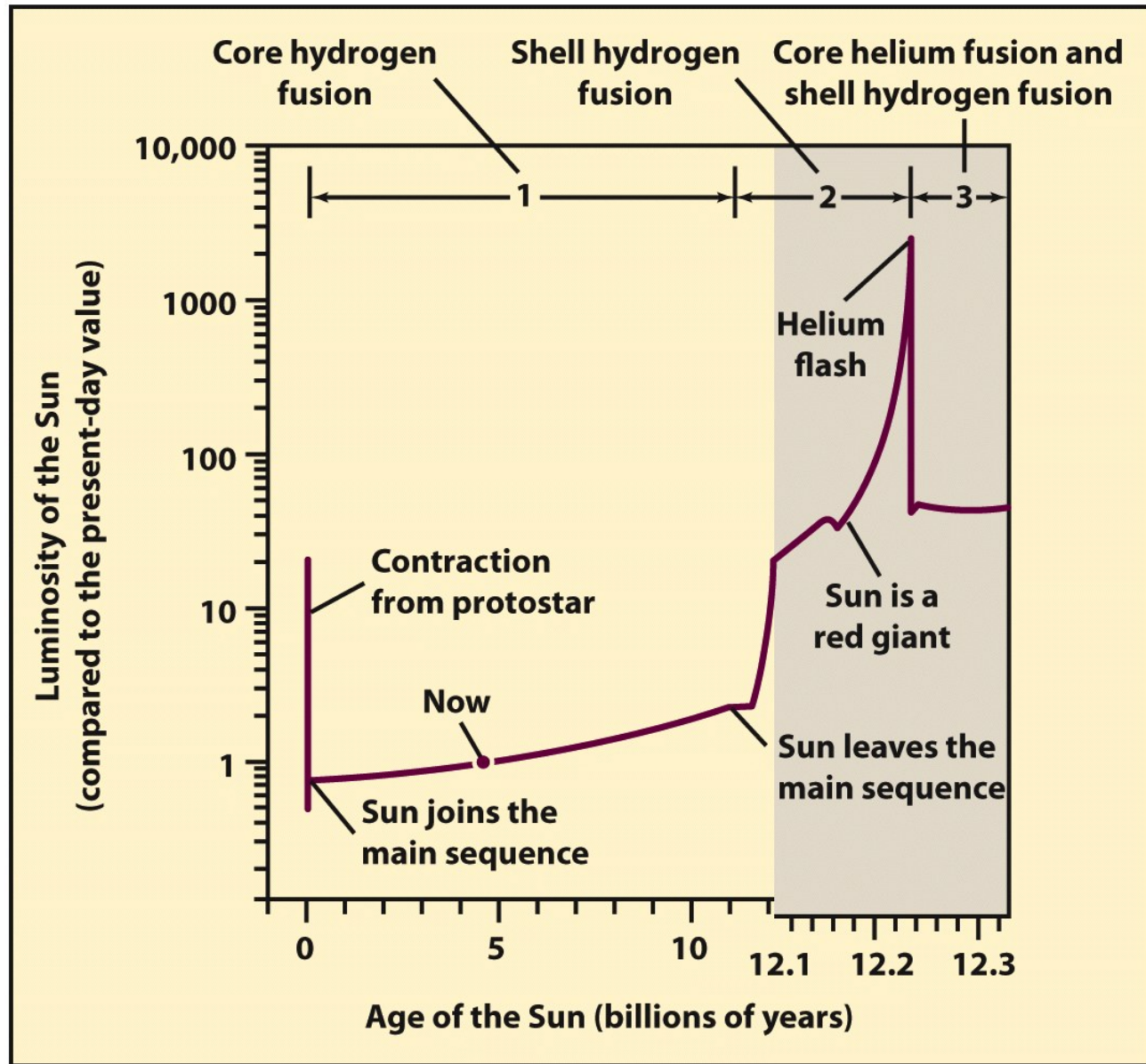


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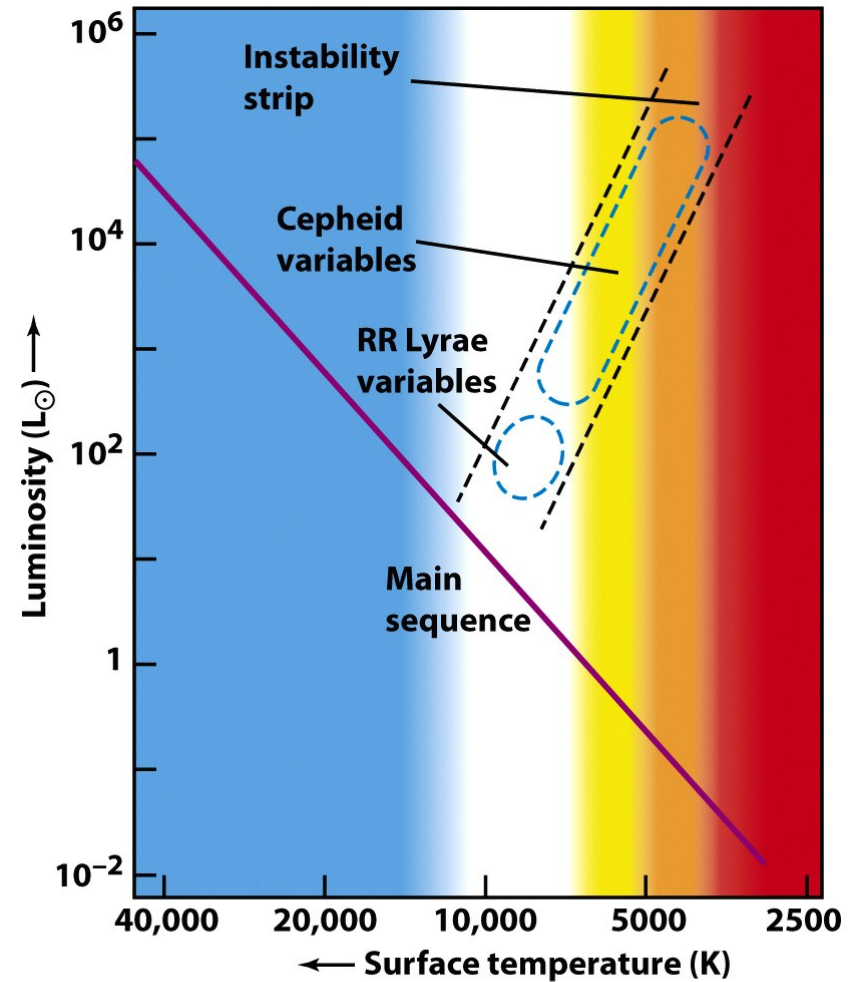
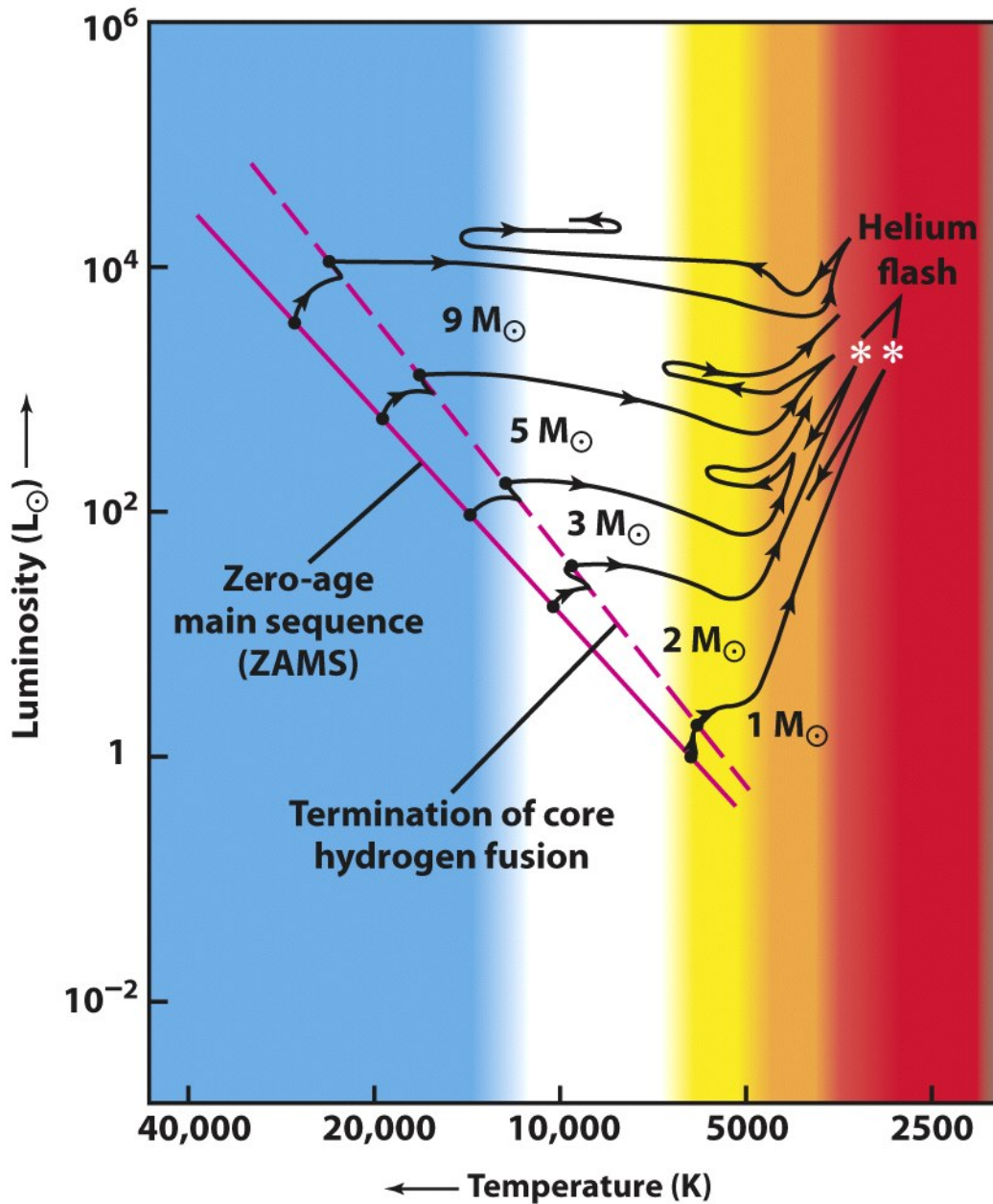


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Helium fusion:





a



b



c



d

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Cepheids:
 important for distance
 determinations

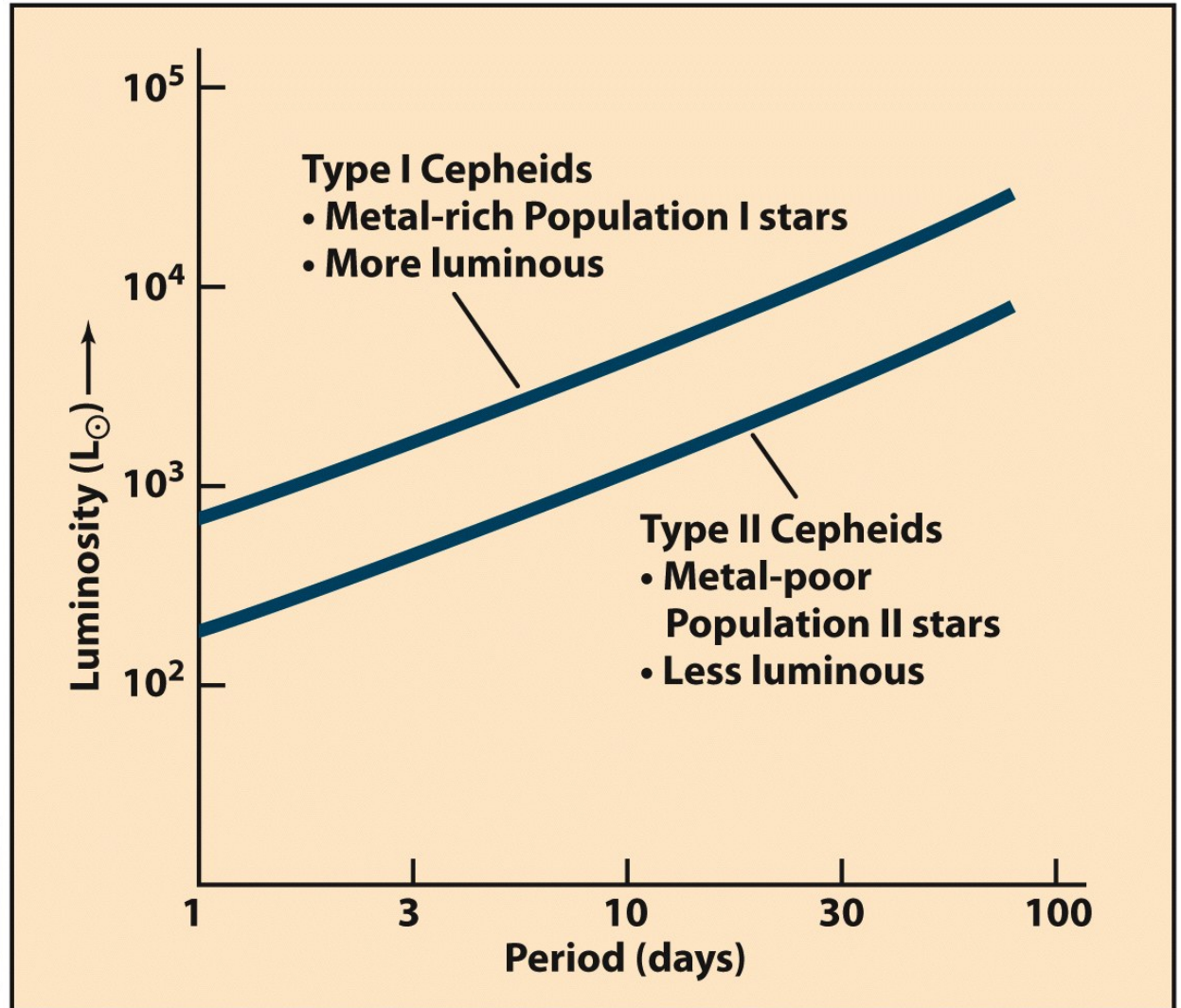


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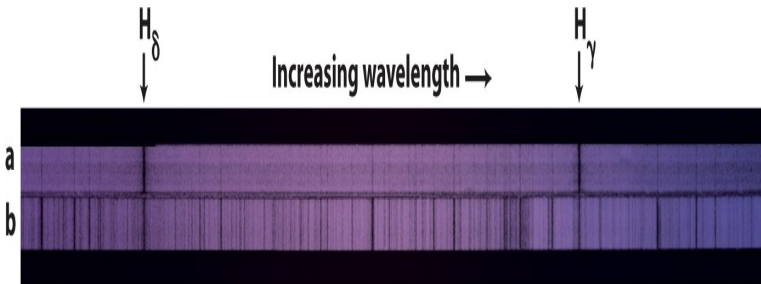


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H-R diagram of a globular cluster (M55)

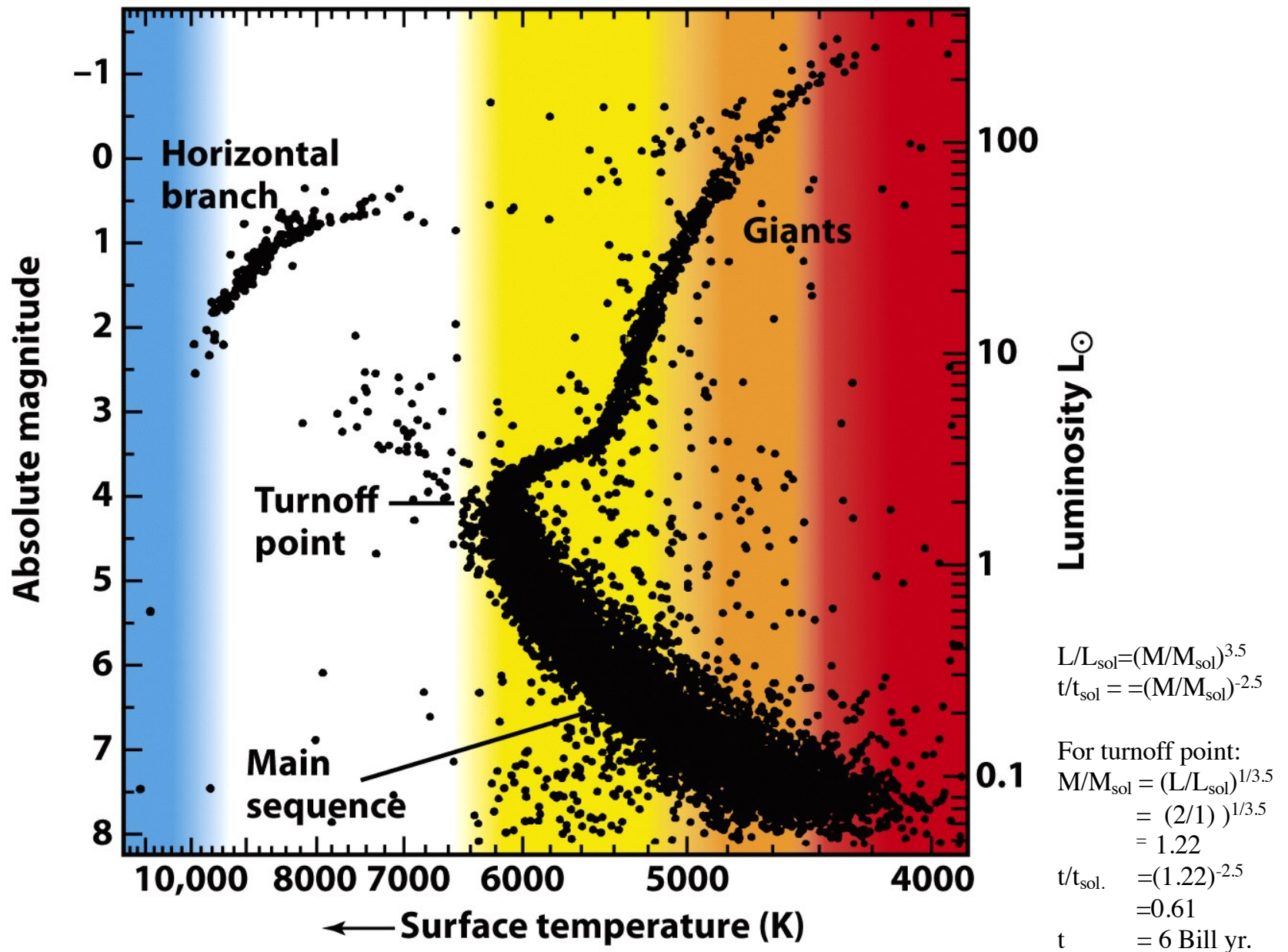


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H-R diagram of a globular cluster (M55)

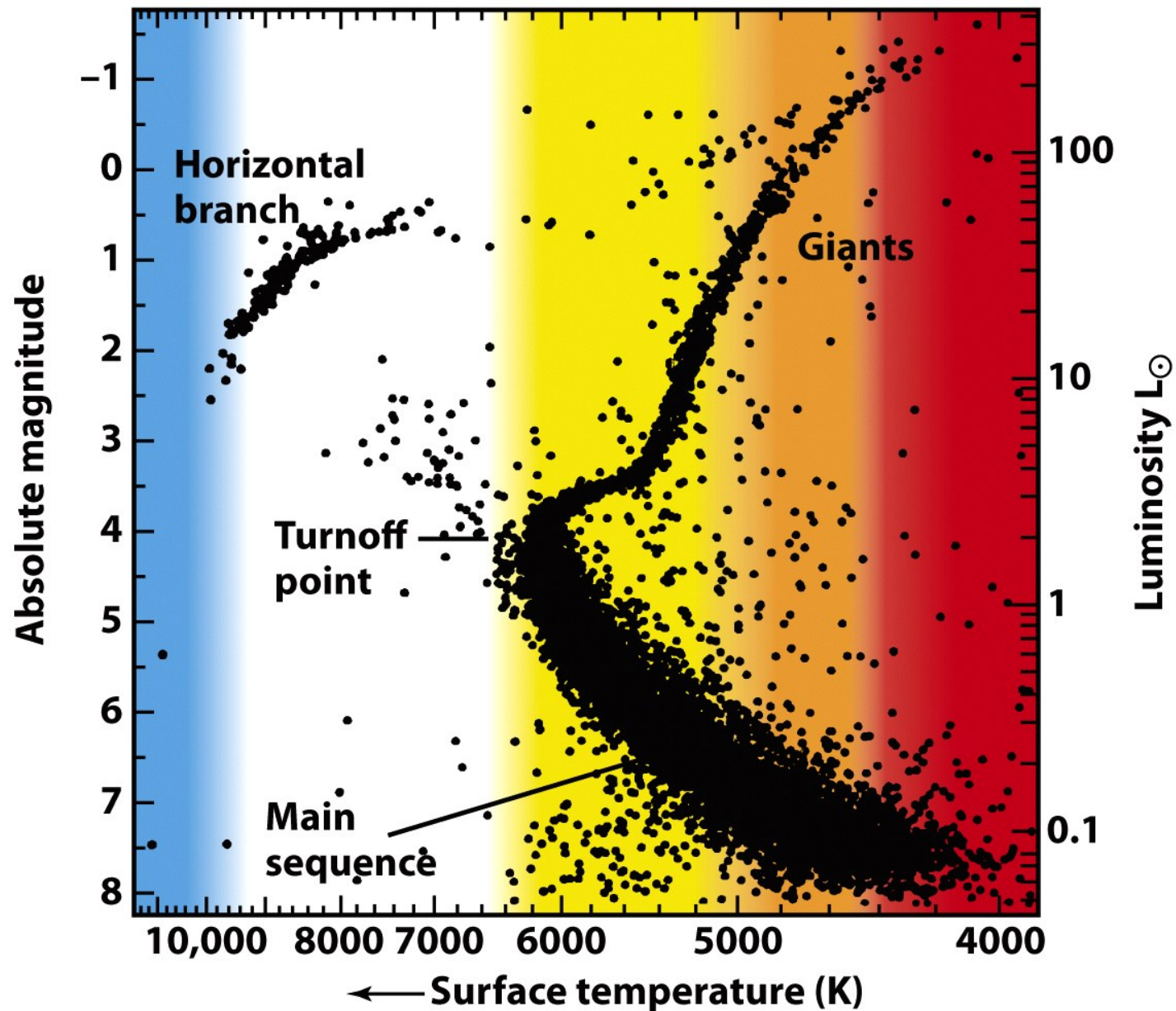


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Simulation of the evolution of a cluster from 0 to 4.5 billion years

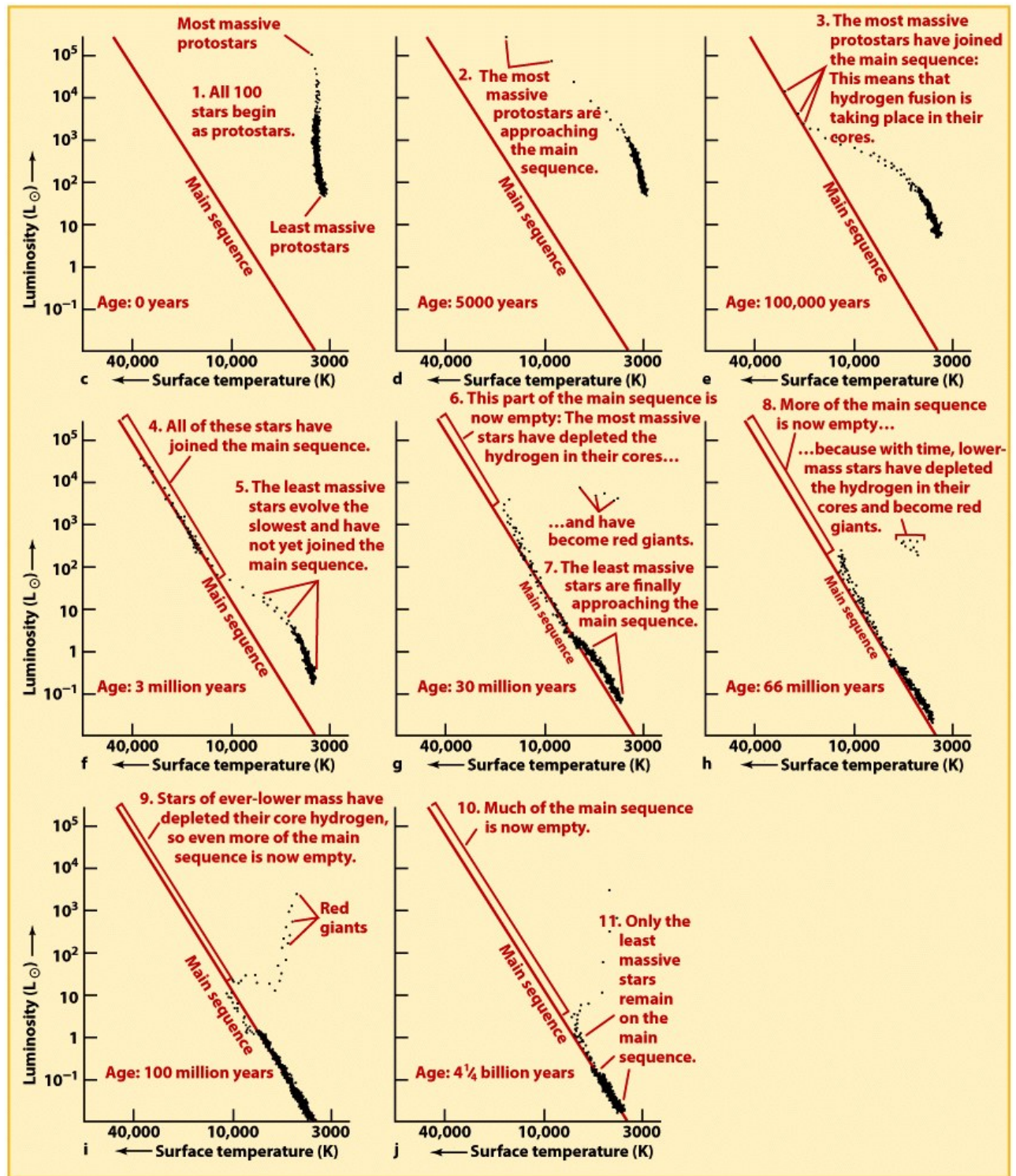
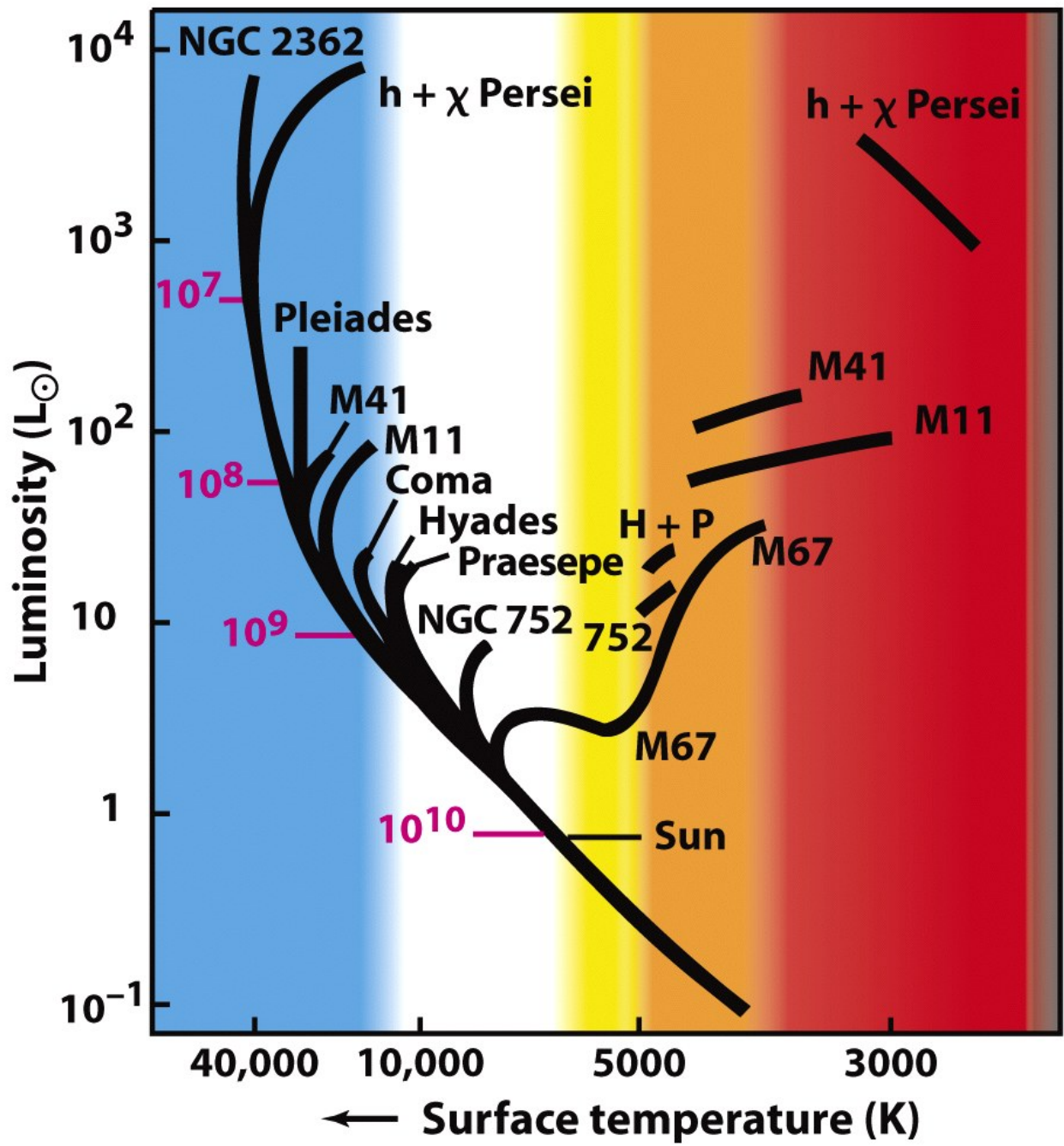


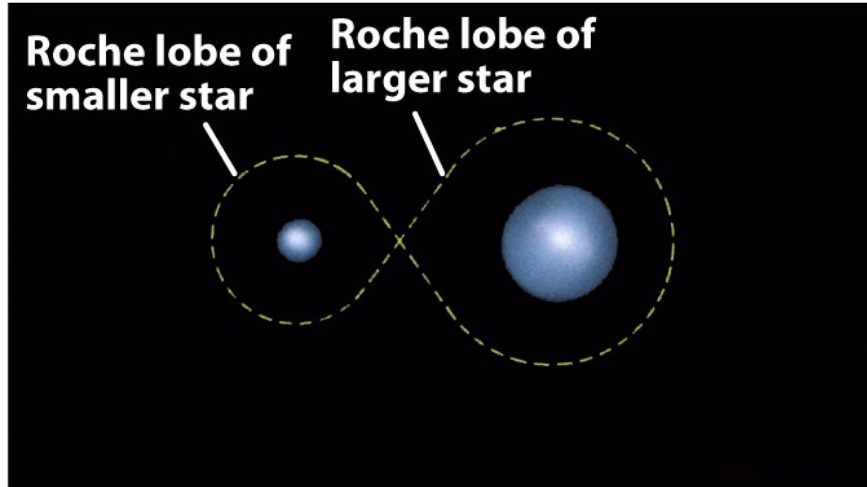
Figure 12-30c-j



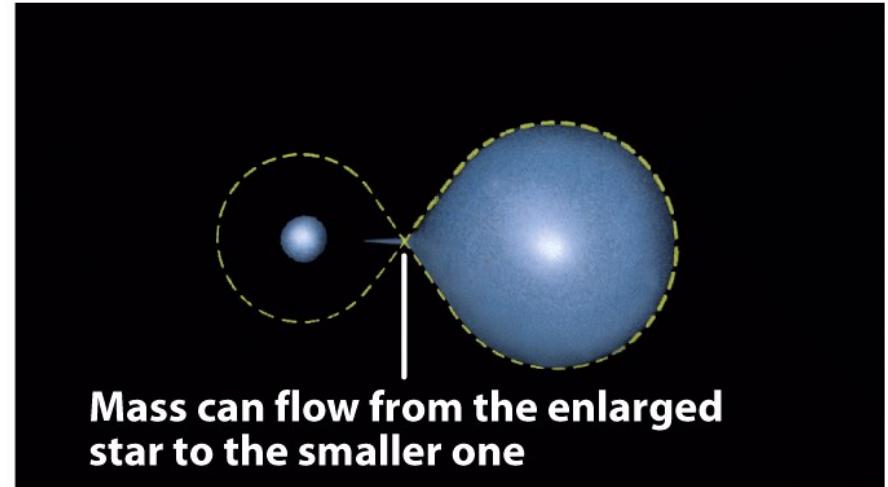
The turnover point gives the age (yr) of the cluster (in red).

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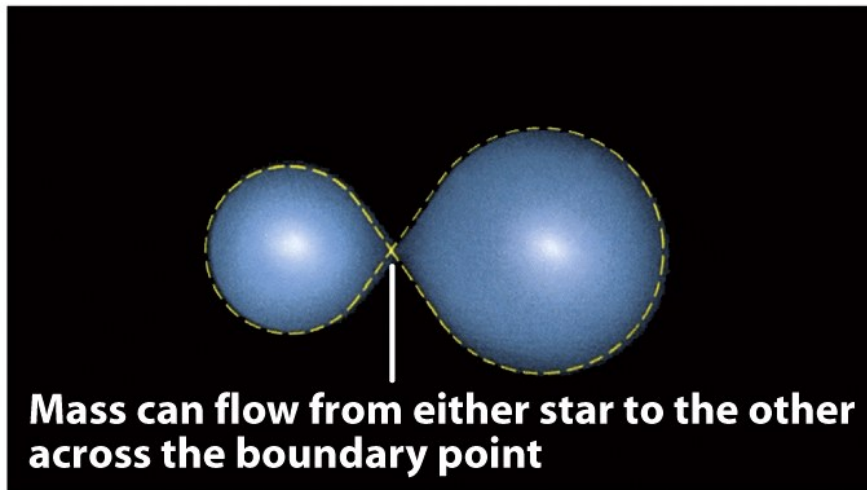
Binaries



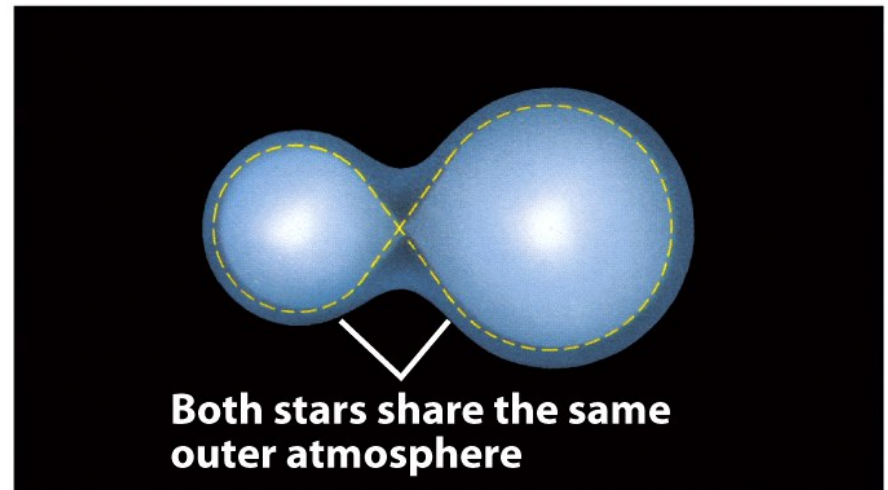
a Detached binary: Neither star fills its Roche lobe.



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.

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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

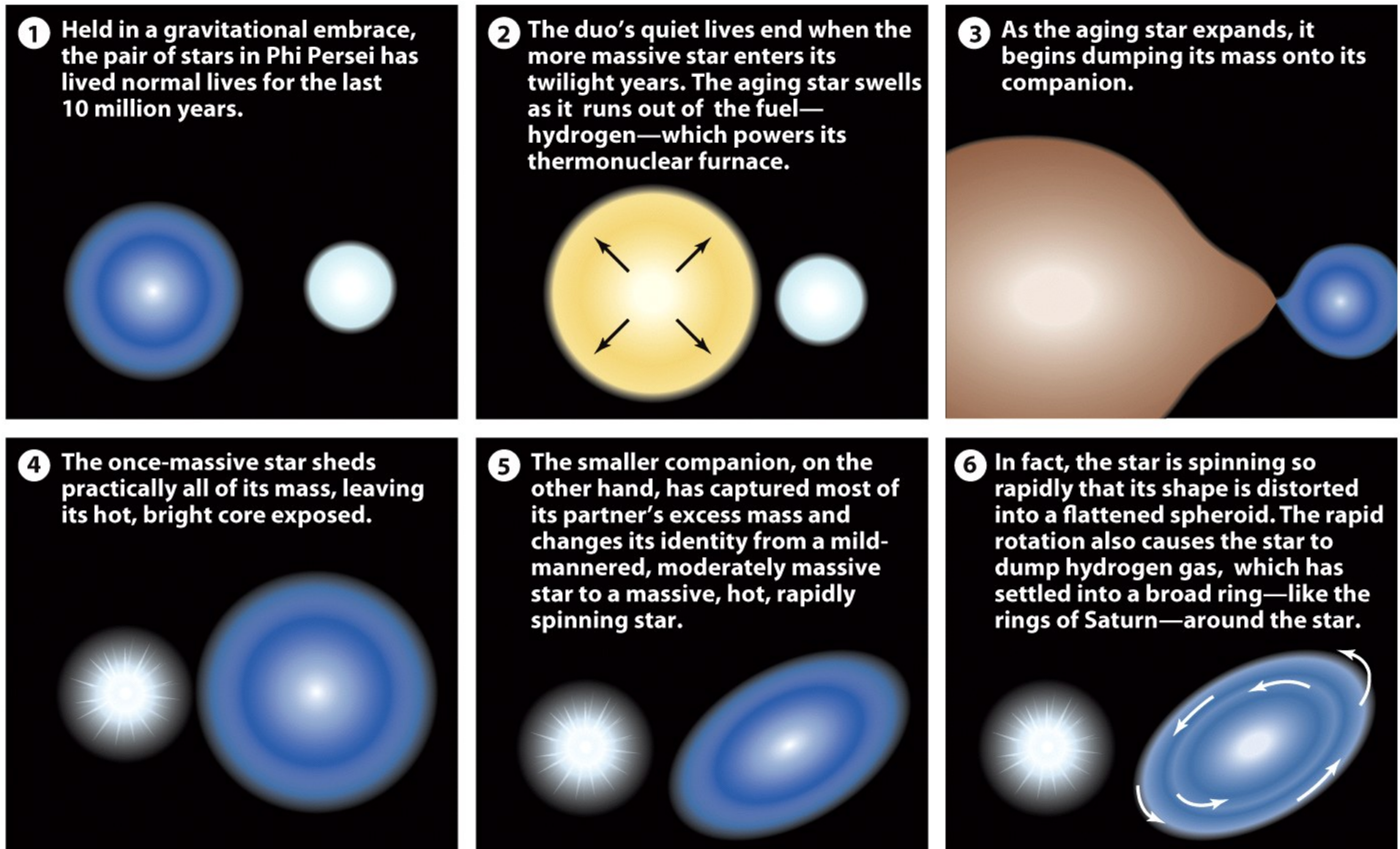


Figure 12-34

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