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ASTRONOMY

Chapter 22 STARS FROM ADOLESCENCE TO OLD AGE

PowerPoint Image Slideshow

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22.1 EVOLUTION FROM THE MAIN SEQUENCE TO RED GIANTS

- **Ant Nebula.** During the later phases of stellar evolution, stars expel some of their mass, which returns to the interstellar medium to form new stars. This Hubble Space Telescope image shows a star losing mass. Known as Menzel 3, or the Ant Nebula, this beautiful region of expelled gas is about 3000 light-years away from the Sun. We see a central star that has ejected mass preferentially in two opposite directions. The object is about 1.6 light-years long. The image is color coded—red corresponds to an emission line of sulfur, green to nitrogen, blue to hydrogen, and blue/violet to oxygen.

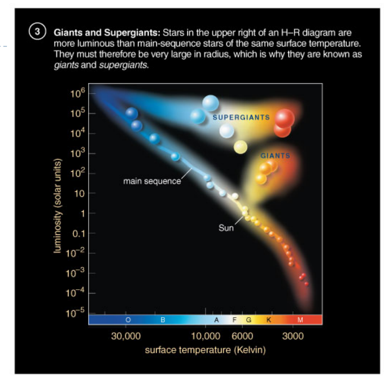
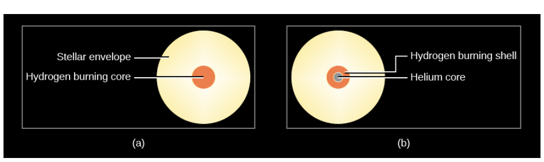
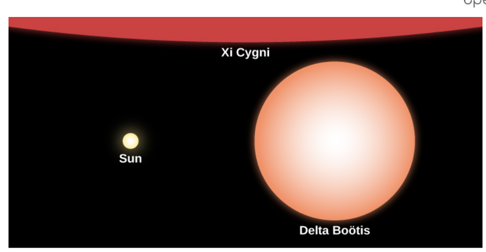


Figure 22.2



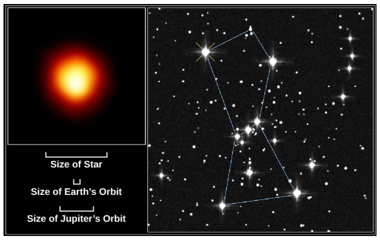
- **Star Layers during and after the Main Sequence.** (a) During the main sequence, a star has a core where fusion takes place and a much larger envelope that is too cold for fusion. (b) When the hydrogen in the core is exhausted (made of helium, not hydrogen), the core is compressed by gravity and heats up. The additional heat starts hydrogen fusion in a layer just outside the core. Note that these parts of the Sun are not drawn to scale.

Figure 22.3



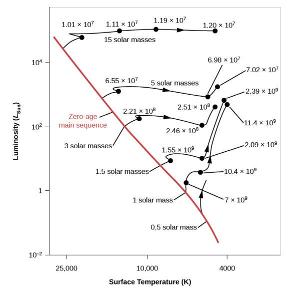
- **Relative Sizes of Stars.** This image compares the size of the Sun to that of Delta Boötis, a giant star, and Xi Cygni, a supergiant. Note that Xi Cygni is so large in comparison to the other two stars that only a small portion of it is visible at the top of the frame.

Figure 22.4



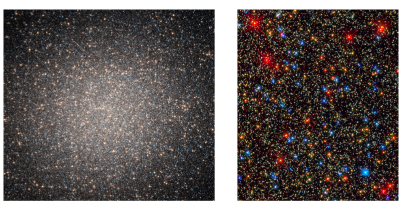
- **Betelgeuse.** Betelgeuse is in the constellation Orion, the hunter; in the right image, it is marked with a yellow "X" near the top left. In the left image, we see it in ultraviolet with the Hubble Space Telescope, in the first direct image ever made of the surface of another star. As shown by the scale at the bottom, Betelgeuse has an extended atmosphere so large that, if it were at the center of our solar system, it would stretch past the orbit of Jupiter. (credit: Modification of work by Andrea Dupree (Harvard-Smithsonian CfA), Ronald Gilliland (STScI), NASA and ESA)

Models for Evolution to the Giant Stage



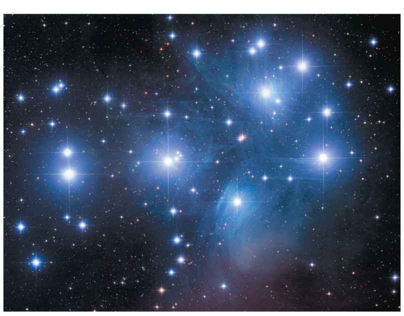
- **Evolutionary Tracks of Stars of Different Masses.** The solid black lines show the predicted evolution from the main sequence through the red giant or supergiant stage on the H–R diagram. Each track is labeled with the mass of the star it is describing. The numbers show how many years each star takes to become a giant after leaving the main sequence. The red line is the zero-age main sequence.

22.2 & 22.3 STAR CLUSTERS



- **Omega Centauri.**
  - (a) Located at about 16,000 light-years away, Omega Centauri is the most massive globular cluster in our Galaxy. It contains several million stars.
  - (b) This image, taken with the Hubble Space Telescope, zooms in near the center of Omega Centauri. The image is about 6.3 light-years wide. The most numerous stars in the image, which are yellow-white in color, are main-sequence stars similar to our Sun. The brightest stars are red giants that have begun to exhaust their hydrogen fuel and have expanded to about 100 times the diameter of our Sun. The blue stars have started helium fusion.

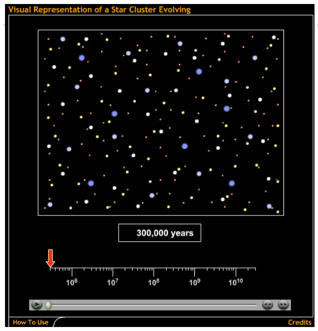
Globular cluster: Up to a million or more stars in a dense ball bound together by gravity



Open cluster: A few thousand loosely packed stars

Figure 22.7

- **Jewel Box (NGC 4755).** This open cluster of young, bright stars is about 6400 light-years away from the Sun. Note the contrast in color between the bright yellow supergiant and the hot blue main-sequence stars. The name comes from John Herschel's nineteenth-century description of it as "a casket of variously colored precious stones." (credit: ESO/Y. Beletsky)



Massive blue stars die first, followed by white, yellow, orange, and red stars.

PLAY Visual Representation of a Star Cluster Evolving

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Figure 22.8

- **Young Cluster H–R Diagram.** We see an H–R diagram for a hypothetical young cluster with an age of 3 million years. Note that the high-mass (high-luminosity) stars have already arrived at the main-sequence stage of their lives, while the lower-mass (lower-luminosity) stars are still contracting toward the zero-age main sequence (the red line) and are not yet hot enough to derive all of their energy from the fusion of hydrogen.

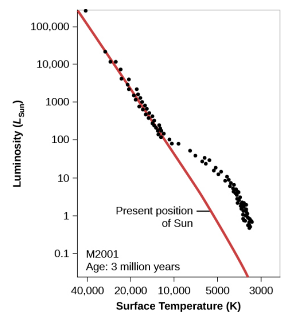

Figure 22.9

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- **Young Cluster NGC 2264.** Located about 2600 light-years from us, this region of newly formed stars, known as the Christmas Tree Cluster, is a complex mixture of hydrogen gas (which is ionized by hot embedded stars and shown in red), dark obscuring dust lanes, and brilliant young stars. The image shows a scene about 30 light-years across. (credit: ESO)

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Figure 22.10

- **NGC 2264 H–R Diagram.** Compare this H–R diagram to that in Figure 22.8; although the points scatter a bit more here, the theoretical and observational diagrams are remarkably, and satisfyingly, similar.

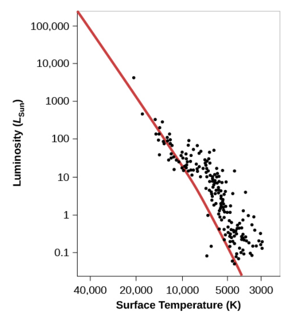

Figure 22.11

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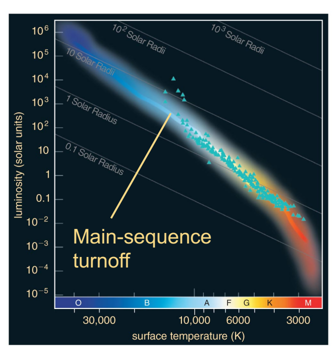
- **NGC 3293.** All the stars in an open star cluster like NGC 3293 form at about the same time. The most massive stars, however, exhaust their nuclear fuel more rapidly and hence evolve more quickly than stars of low mass. As stars evolve, they become redder. The bright orange star in NGC 3293 is the member of the cluster that has evolved most rapidly. (credit: ESO/G. Beccari)



This shows no stars with a life expectancy less than around 100 million years.

Figure 22.12

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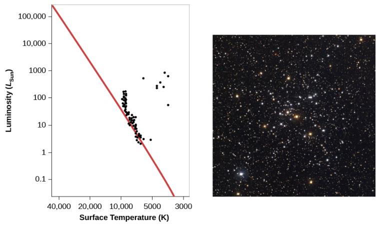

(a) (b)

- **Cluster M41.**

(a) Cluster M41 is older than NGC 2264 (see Figure 22.10) and contains several red giants. Some of its more massive stars are no longer close to the zero-age main sequence (red line).

(b) This ground-based photograph shows the open cluster M41. Note that it contains several orange-color stars. These are stars that have exhausted hydrogen in their centers, and have swelled up to become red giants. (credit b: modification of work by NOAO/AURA/NSF)

Figure 22.13

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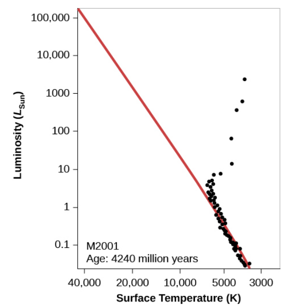

- **H–R Diagram for an Older Cluster.** We see the H–R diagram for a hypothetical older cluster at an age of 4.24 billion years. Note that most of the stars on the upper part of the main sequence have turned off toward the red-giant region. And the most massive stars in the cluster have already died and are no longer on the diagram.

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Figure 22.14

- **Cluster 47 Tucanae.** This H–R diagram is for the globular cluster 47. Note that the scale of luminosity differs from that of the other H–R diagrams in this chapter. We are only focusing on the lower portion of the main sequence, the only part where stars still remain in this old cluster.

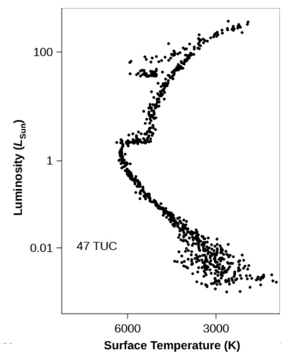

Figure 22.15

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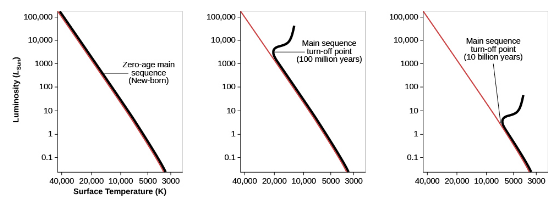
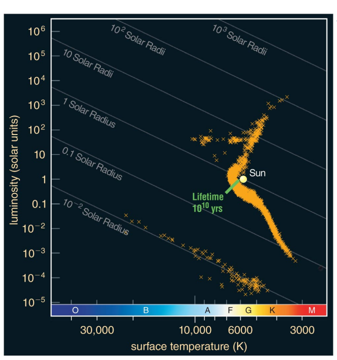


- **H–R Diagrams for Clusters of Different Ages.** This sketch shows how the turn-off point from the main sequence gets lower as we make H–R diagrams for clusters that are older and older.



Detailed modeling of the oldest globular clusters reveals that they are about 13 billion years old.