11.17: Stars from Adolescence to Old Age (Exercise)

For Further Exploration

Articles

Balick, B. & Frank, A. "The Extraordinary Deaths of Ordinary Stars." *Scientific American* (July 2004): 50. About planetary nebulae, the last gasps of low-mass stars, and the future of our own Sun.

Djorgovsky, G. "The Dynamic Lives of Globular Clusters." *Sky & Telescope* (October 1998): 38. Cluster evolution and blue straggler stars.

Frank, A. "Angry Giants of the Universe." *Astronomy* (October 1997): 32. On luminous blue variables like Eta Carinae.

Garlick, M. "The Fate of the Earth." *Sky & Telescope* (October 2002): 30. What will happen when our Sun becomes a red giant.

Harris, W. & Webb, J. "Life Inside a Globular Cluster." *Astronomy* (July 2014): 18. What would night sky be like there?

Iben, I. & Tutokov, A. "The Lives of the Stars: From Birth to Death and Beyond." *Sky & Telescope* (December 1997): 36.

Kaler, J. "The Largest Stars in the Galaxy." *Astronomy* (October 1990): 30. On red supergiants.

Kalirai, J. "New Light on Our Sun's Fate." *Astronomy* (February 2014): 44. What will happen to stars like our Sun between the main sequence and the white dwarf stages.

Kwok, S. "What Is the Real Shape of the Ring Nebula?" *Sky & Telescope* (July 2000): 33. On seeing planetary nebulae from different angles.

Kwok, S. "Stellar Metamorphosis." *Sky & Telescope* (October 1998): 30. How planetary nebulae form.

Stahler, S. "The Inner Life of Star Clusters." *Scientific American* (March 2013): 44–49. How all stars are born in clusters, but different clusters evolve differently.

Subinsky, R. "All About 47 Tucanae." *Astronomy* (September 2014): 66. What we know about this globular cluster and how to see it.

Websites

BBC Page on Giant Stars: www.bbc.co.uk/science/space/u...ts/giant_stars. Includes basic information and links to brief video excerpts.

Encylopedia Brittanica Article on Star Clusters: http://www.britannica.com/topic/star-cluster. Written by astronomer Helen Sawyer Hogg-Priestley.

Hubble Image Gallery: Planetary Nebulae: http://hubblesite.org/gallery/album/nebula/planetary/. Click on each image to go to a page with more information available. (See also a similar gallery at the National Optical Astronomy Observatories: www.noao.edu/image_gallery/p...y_nebulae.html).

Hubble Image Gallery: Star Clusters: http://hubblesite.org/gallery/album/.../star_cluster/. Each image comes with an explanatory caption when you click on it. (See also a similar European Southern Observatory Gallery at: www.eso.org/public/images/ar.../starclusters/).

Measuring the Age of a Star Cluster: www.e-education.psu.edu/astr...ent/l7_p6.html. From Penn State.

Videos

Life Cycle of Stars: https://www.youtube.com/watch?v=PM9CQDlQI0A. Short summary of stellar evolution from the Institute of Physics in Great Britain, with astronomer Tim O'Brien (4:58).

Missions Take an Unparalleled Look into Superstar Eta Carinae: https://www.youtube.com/watch?v=0rJQi6oaZf0. NASA Goddard video about observations in 2014 and what we know about the pair of stars in this complicated system (4:00).

Star Clusters: Open and Globular Clusters: https://www.youtube.com/watch?v=rGPRLxrYbYA. Three Short Hubblecast Videos from 2007–2008 on discoveries involving star clusters (12:24).

Tour of Planetary Nebula NGC 5189: https://www.youtube.com/watch?v=1D2cwiZld0o. Brief Hubblecast episode with Joe Liske, explaining planetary nebulae in general and one example in particular (5:22).

Review Questions

1. Compare the following stages in the lives of a human being and a star: prenatal, birth, adolescence/adulthood, middle age, old age, and death. What does a star with the mass of our Sun do in each of these stages?
2. What is the first event that happens to a star with roughly the mass of our Sun that exhausts the hydrogen in its core and stops the generation of energy by the nuclear fusion of hydrogen to helium? Describe the sequence of events that the star undergoes.
3. Astronomers find that 90% of the stars observed in the sky are on the main sequence of an H–R diagram; why does this make sense? Why are there far fewer stars in the giant and supergiant region?
4. Describe the evolution of a star with a mass similar to that of the Sun, from the protostar stage to the time it first becomes a red giant. Give the description in words and then sketch the evolution on an H–R diagram.
5. Describe the evolution of a star with a mass similar to that of the Sun, from just after it first becomes a red giant to the time it exhausts the last type of fuel its core is capable of fusing.
6. A star is often described as "moving" on an H–R diagram; why is this description used and what is actually happening with the star?
7. On which edge of the main sequence band on an H–R diagram would the zero-age main sequence be?
8. How do stars typically "move" through the main sequence band on an H–R diagram? Why?
9. Certain stars, like Betelgeuse, have a lower surface temperature than the Sun and yet are more luminous. How do these stars produce so much more energy than the Sun?
10. Gravity always tries to collapse the mass of a star toward its center. What mechanism can oppose this gravitational collapse for a star? During what stages of a star's life would there be a "balance" between them?
11. Why are star clusters so useful for astronomers who want to study the evolution of stars?
12. Would the Sun more likely have been a member of a globular cluster or open cluster in the past?
13. Suppose you were handed two H–R diagrams for two different clusters: diagram A has a majority of its stars plotted on the upper left part of the main sequence with the rest of the stars off the main sequence; and diagram B has a majority of its stars plotted on the lower right part of the main sequence with the rest of the stars off the main sequence. Which diagram would be for the older cluster? Why?
14. Referring to the H–R diagrams in the previous exercise, which diagram would more likely be the H–R diagram for an association?
15. Pictures of various planetary nebulae show a variety of shapes, but astronomers believe a majority of planetary nebulae have the same basic shape. How can this paradox be explained?
16. Describe the two "recycling" mechanisms that are associated with stars (one during each star's life and the other connecting generations of stars).
17. In which of these star groups would you mostly likely find the least heavy-element abundance for the stars within them: open clusters, globular clusters, or associations?
18. Explain how an H–R diagram of the stars in a cluster can be used to determine the age of the cluster.
19. Where did the carbon atoms in the trunk of a tree on your college campus come from originally? Where did the neon in the fabled "neon lights of Broadway" come from originally?
20. What is a planetary nebula? Will we have one around the Sun?

Thought Questions

1. In the H–R diagrams for some young clusters, stars of both very low and very high luminosity are off to the right of the main sequence, whereas those of intermediate luminosity are on the main sequence. Can you offer an explanation for that? Sketch an H–R diagram for such a cluster.
2. If all the stars in a cluster have nearly the same age, why are clusters useful in studying evolutionary effects (different stages in the lives of stars)?
3. Suppose a star cluster were at such a large distance that it appeared as an unresolved spot of light through the telescope. What would you expect the overall color of the spot to be if it were the image of the cluster immediately after it was formed? How would the color differ after 10^{10} years? Why?
4. Suppose an astronomer known for joking around told you she had found a type-O main-sequence star in our Milky Way Galaxy that contained no elements heavier than helium. Would you believe her? Why?

5. Stars that have masses approximately 0.8 times the mass of the Sun take about 18 billion years to turn into red giants. How does this compare to the current age of the universe? Would you expect to find a globular cluster with a main-sequence turnoff for stars of 0.8 solar mass or less? Why or why not?
6. Automobiles are often used as an analogy to help people better understand how more massive stars have much shorter main-sequence lifetimes compared to less massive stars. Can you explain such an analogy using automobiles?
