

## Stellar Evolution

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**TEXTBOOK ERROR:** Note that Figure 14.3 on Page 365 of the textbook is just a repeat of Figure 14.2 on Page 364.

We humans, ever anthropomorphizing, look at stars and imagine them as living things, having a birth, a life, and a death. This unit of the course studies the life cycles of stars. The following unit, on stellar remnants, studies the objects that remain after stars have gone through their life cycles.

The lifetimes of stars are typically in the billions of years, although the more massive the star, the shorter the lifetime. The “birth” and “death” of a star take a relatively short time compared to the long middle part of the “life” of a star. In the long middle part, in which the star is relatively stable, hydrostatic equilibrium is the key concept. There are two opposing forces, gravity (which tends to compress the star into a smaller volume), and gas pressure (which tends to expand the star into a larger volume. For the long middle period of a star’s life, these two opposing forces balance, and so the star is in a fairly constant state. The birth and death phases of a star’s life are typically much more dramatic, especially for high-mass stars.

The following questions will guide your reading of this unit. The relevant part of the textbook is Chapter 14.

### 1 Star Formation

- Where do stars form?
- How do stars form?
- Describe some of the main properties of interstellar clouds of gas and dust. What is their role in star formation?
- What are protostars? How do they form? What is the role of a protostar in stellar formation? How do the properties of protostars differ from those of interstellar clouds of gas and dust? How do the properties of protostars differ from those of stars?
- How do protostars evolve?
- What are bipolar gas flows?
- Why are stars that have extremely high masses rare?

### 2 Nebulae

- What is a nebula?
- What are the three main types of nebulae?
- Why do reflection nebulae appear blue?
- Why are dark nebulae called “dark?” How can we observe them?
- What is the appearance of an emission nebula? What is their appearance, and what explains their appearance?

### 3 Giant Molecular Clouds and Star Formation

- What are the basic properties of giant molecular clouds?
- How do clumps form in giant molecular clouds?
- How do clumps in giant molecular clouds evolve? What are the conditions for which this kind of evolution takes place?
- Where are protostars found on an H-R diagram? How do their locations on an H-R diagram change as they evolve?
- How long does it take for a protostar to become a main-sequence star?
- What is the “birth line?” What is its significance?

### 4 Stellar Mass is Stellar Destiny

- How massive are low-mass stars, medium-mass stars, and high-mass stars? In which category is the Sun?
- Which property mainly determines the evolution of a main-sequence star?
- What are brown dwarfs? What are some of their properties?
- What is the proton-proton chain? Describe some of its properties. What is its effect in stars?
- What are red dwarfs? What are some of their properties?
- What is the CNO cycle? Describe some of its properties. What is its effect in stars? In which kind of stars is it important?

### 5 Life on the Main Sequence

- What is hydrostatic equilibrium? Which kinds of stars are in hydrostatic equilibrium?
- Explain how the luminosity of a main-sequence star changes over time. What is the reason for the change?

### 6 Variable Stars

- What is a variable star?
- What are the different types of variable stars? What are some of the properties of each type?
- What causes each type of variable star to vary? At which stage in their evolution is each type of variable star?

### 7 Death for the Sun

- Explain the life history of a medium-mass star. Explain each stage in detail, and explain the reasons for each important event in the later stages of evolution of a medium-mass star. What is the outer appearance of the star at each stage in its later evolution?
- What is the triple-alpha process? What is its effect in a star?

- What is the helium flash? When does it occur, and what is the star like when it occurs?
- Explain the yellow-giant phase of the evolution of a medium-mass star.
- Explain the second red-giant phase of the evolution of a medium-mass star.