The Birth of Stars
Chapter Twenty

Guiding Questions

1. Why do astronomers think that stars evolve?
2. What kind of matter exists in the spaces between the stars?
3. In what kind of nebulae do new stars form?
4. What steps are involved in forming a star like the Sun?
5. When a star forms, why does it end up with only a fraction of the available matter?
6. What do star clusters tell us about the formation of stars?
7. Where in the Galaxy does star formation take place?
8. How can the death of one star trigger the birth of many other stars?

Understanding how stars evolve requires both observation and ideas from physics

• Because stars shine by thermonuclear reactions, they have a finite life span
• The theory of stellar evolution describes how stars form and change during that life span
Interstellar gas and dust pervade the Galaxy

- Interstellar gas and dust, which make up the interstellar medium, are concentrated in the disk of the Galaxy.
- Clouds within the interstellar medium are called nebulae.
- Dark nebulae are so dense that they are opaque.
- They appear as dark blots against a background of distant stars.
- Emission nebulae, or H II regions, are glowing, ionized clouds of gas.
- Emission nebulae are powered by ultraviolet light that they absorb from nearby hot stars.
- Reflection nebulae are produced when starlight is reflected from dust grains in the interstellar medium, producing a characteristic bluish glow.
Reflection nebulae

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.

Distant object

Dust grains

Observer

How dust causes interstellar reddening

NGC 3576: A closer nebula

NGC 3603: A distant nebula

Reddening depends on distance
Vega

Lanes of interstellar dust

Deneb

Altair

H II region

We see spiral galaxy M83 nearly face-on

Spiral arms

H II regions lie along the spiral arms
Protostars form in cold, dark nebulae

- Star formation begins in dense, cold nebulae, where gravitational attraction causes a clump of material to condense into a protostar.
- As a protostar grows by the gravitational accretion of gases, Kelvin-Helmholtz contraction causes it to heat and begin glowing.
Protostars evolve into main-sequence stars

- A protostar’s relatively low temperature and high luminosity place it in the upper right region on an H-R diagram
- Further evolution of a protostar causes it to move toward the main sequence on the H-R diagram
- When its core temperatures become high enough to ignite steady hydrogen burning, it becomes a main sequence star

The more massive the protostar, the more rapidly it evolves

During the birth process, stars both gain and lose mass

- In the final stages of pre–main-sequence contraction, when thermonuclear reactions are about to begin in its core, a protostar may eject large amounts of gas into space
- Low-mass stars that vigorously eject gas are called T Tauri stars
A circumstellar accretion disk provides material that a young star ejects as jets.

Clumps of glowing gas called Herbig-Haro objects are sometimes found along these jets and at their ends.
Young star clusters give insight into star formation and evolution

- Newborn stars may form an open or galactic cluster
- Stars are held together in such a cluster by gravity
- Occasionally a star moving more rapidly than average will escape, or “evaporate,” from such a cluster
- A stellar association is a group of newborn stars that are moving apart so rapidly that their gravitational attraction for one another cannot pull them into orbit about one another
1. This emission nebula (about 2000 pc away and about 20 pc across) surrounds the star clusterMessier 16.

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

3. Hot, luminous stars (beyond the upper edge of the image) heat each ultraviolet radiation. This ionizes the surrounding gas, clearing away the surrounding dust and revealing these pillars.

4. At the tip of each of these "magnets" is a very hot nebula containing a young star.

5. Eventually the center nebula evaporates, revealing the stars.

(a) The star cluster NGC 2264

(b) An H-R diagram of the stars in NGC 2264

This star cluster is so young that most of its stars have not yet neared the main sequence. Some stars have not even left the pre-main sequence.

(a) The Pleiades star cluster

(b) An H-R diagram of the stars in the Pleiades

This star cluster is old enough that all of its stars have reached the main sequence. Only high-mass stars have begun to evolve off the main sequence.
Star birth can begin in giant molecular clouds. The spiral arms of our Galaxy are laced with giant molecular clouds, immense nebulae so cold that their constituent atoms can form into molecules, creating star-forming regions. These regions appear when a giant molecular cloud is compressed, which can be caused by the cloud’s passage through one of the spiral arms of our Galaxy, by a supernova explosion, or by other mechanisms.

O and B Stars and Their Relation to H II Regions

- The most massive protostars to form out of a dark nebula rapidly become main sequence O and B stars.
- They emit strong ultraviolet radiation that ionizes hydrogen in the surrounding cloud, thus creating the reddish emission nebulae called H II regions.
- Ultraviolet radiation and stellar winds from the O and B stars at the core of an H II region create shock waves that move outward through the gas cloud, compressing the gas and triggering the formation of more protostars.
Supernovae compress the interstellar medium and can trigger star birth.
Key Words

- accretion
- Barnard object
- bipolar outflow
- Bok globule
- circumstellar accretion disk
- cluster (of stars)
- cocoon nebula
- dark nebula
- dust grains
- emission nebula
- evolutionary track
- fluorescence
- giant molecular cloud
- H II region
- Herbig-Haro object
- interstellar extinction

- interstellar medium
- interstellar reddening
- nebula (plural nebulae)
- nebulosity
- OB association
- open cluster
- protoplanetary disk (proplyd)
- protostar
- recombination
- reflection nebula
- stationary absorption lines
- stellar association
- stellar evolution
- supernova remnant
- supersonic
- T Tauri star