Stellar Remnants

The evolution of a star depends almost entirely on its mass. For low-mass stars, nothing particularly dramatic happens over its lifetime. However, medium-mass stars and high-mass stars have dramatic events towards the ends of the long, stable parts of their lifetimes. These explosive events blast much of the stars' material out into the interstellar medium, and leave behind remnant objects that are among the most interesting in the universe.

In this unit, you'll study these exotic astronomical objects, and you'll study the processes which create them.

The following questions will guide your reading of this unit. The relevant parts of the textbook are Sections 14.6 and 14.7 and Chapter 15.

1 Planetary Nebulae and White Dwarfs

- What is a planetary nebula?
- How are planetary nebulae formed?
- How massive must a star be for a planetary nebula to be formed after its death?
- What accounts for the appearance of a planetary nebula?
- What happens to the central star during the process of the formation of a planetary nebula?
- Why do planetary nebula appear somewhat ring-shaped (at visible wavelengths) even though they may be closer to spherical shells or have other unusual shapes?
- Why are planetary nebula called "planetary" when they have nothing to do with planets?
- What are some properties of white dwarfs and how do they compare to main-sequence stars?
- What is the composition of a typical white dwarf?
- Ordinary stars use gas pressure, fuelled by fusion reactions, to balance gravity. White dwarfs do not sustain fusion reactions, so how do they maintain stability against gravitational collapse?
- How does the position of a medium-mass star on its H-R diagram change as the star evolves from a protostar through its main-sequence phase and the later stages of its life, culminating in a white dwarf? (See Figure 14-20 on Page 379 of the textbook.)

2 The Chandrasekhar Mass Limit

- What are some of the unusual properties of degenerate matter, such as is found in a white dwarf?
- How does the radius of a white dwarf depend on its mass?
- What is the concept of the Chandrasekhar mass limit? What is the approximate value of the Chandrasekhar mass limit? What is the significance of this value for observations of white dwarfs?
- How do planetary nebulae produce light?

3 Type Ia Supernovae

- What is a type Ia supernova? What are the typical ways in which type Ia supernovae occur?
- Which chemical elements are produced in type Ia supernovae explosions? How are they produced? How are they dispersed into the interstellar medium?
- What is the remnant left by a type Ia supernova explosion?
- What is a distinctive feature of the spectrum of a type Ia supernova?
- How are type Ia supernova used to help determine the distance of distant galaxies?

4 Type II Supernovae; Endgame for High-Mass Stars

- How does the evolution of a high-mass star differ from the evolution of lower-mass stars?
- What is nucleosynthesis? How, when, and why does it occur in a very massive star?
- What result does nucleosynthesis have on the composition of the interstellar medium?
- What is core collapse? When and why does it occur? What are the effects of core collapse? What is the resulting remnant?
- How does the position of a high-mass star on its H-R diagram change as the star evolves through its life? (See Figure 14-23 on Page 382 of the textbook.)

5 Supernova Remnants and Neutron Stars

- What is nuclear binding energy? What is its role in the late stages of stellar evolution for high-mass stars?
- What is the remnant left behind by a high-mass star? How does it form?
- Explain how a type-II supernova is created. How does the explosion take place, and what are the effects of the explosion?
- How does the spectrum of a type-II supernova differ from that of a type-Ia supernova?
- What are some of the properties of a neutron star? What is the mass limit for a neutron star? What happens if the mass limit is exceeded?
- What is some of the observational evidence for the existence of neutron stars? How were neutron stars first discovered?
- What is a pulsar?
- Why do neutron stars spin so much more rapidly than stars? Why does the rotation rate of a neutron star gradually decrease?
- What is the internal structure of a neutron star, as inferred from observations?

6 Black Holes

- What is a black hole? How do black holes form?
- What is the concept of *escape velocity*? How can you calculate the escape velocity from the surface of an astronomical object of mass M and radius R? How does the escape velocity change if an object of mass M contracts so that its radius decreases?

- Why is a black hole called *black*?
- What is a singularity?
- What is an event horizon? What is the Schwarzschild radius of a black hole?
- What is some of the observational evidence for black holes?

7 Gravitational Redshift and GPS

- What is the basic idea of Einstein's theory of general relativity? How is this perspective different from Newton's theory of gravity?
- What are some of the important predictions of Einstein's theory of general relativity?
- What is some observational evidence that supports Einstein's theory of general relativity?
- Why is taking relativity into account essential for the accuracy of the global positioning system (GPS)?