dwarf accumulates too much matter. As the white dwarf becomes more massive, the internal pressure required to support its weight increases. If the dwarf's mass exceeds the limit beyond which it can no longer maintain equilibrium, it will collapse inward and rapidly undergo carbon fusion before exploding.

The second type of supernova (Type II) occurs at the end of a single star's lifetime. As a massive star begins to expend the supply of hydrogen in its core to support nuclear fusion, the core becomes composed of heavier and heavier elements and rapidly increases in temperature. Eventually, the core becomes so heavy that it can no longer withstand its own gravitational force. The core collapses so rapidly that it actually "rebounds" outward, resulting in the giant explosion of a supernova.

Type I and Type II supernovae affect different types of stars. All high-mass stars eventually become Type II supernovae, but only a small fraction of low-mass stars become white dwarfs that eventually undergo a Type I supernova explosion. Because the mass of our Sun is too low, our Sun will never become a supernova.

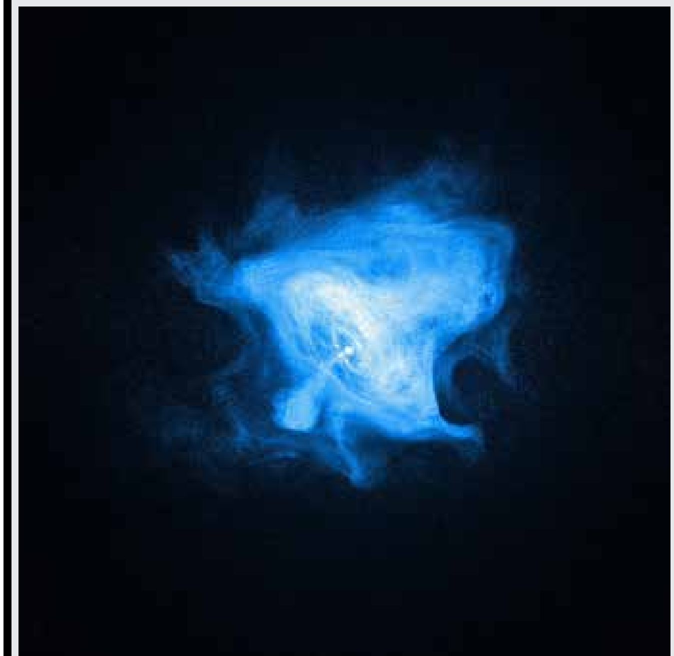
Neutron Stars and Pulsars

After a very massive star explodes, it can collapse inward into an extremely dense star composed almost entirely of neutrons, which are uncharged atomic particles. This is known as a **neutron star**. A neutron star with the Sun's mass could be packed into a sphere that is only about 16 km across. Neutron stars tend to have high rotational speeds, as a result of conservation of angular momentum, and also have very strong magnetic fields.

A **pulsar** is a rapidly rotating, highly magnetic neutron star. Pulsars were first observed in 1967 by Jocelyn Bell, a graduate student at Cambridge University—work for which her advisor Anthony Hewish won the 1974 Nobel Prize. Pulsars emit sharp, strong bursts of radio waves to Earth with clocklike regularity, at intervals between milliseconds and four seconds. The characteristic short, regular pulses come from radiation beams, emitted by very energetic accelerated charged particles, sweeping past Earth as the neutron star rotates. The rotation and pulse rates of pulsars gradually slow down as energy is radiated away.

Astronomers predicted that a neutron star should exist at the center of the Crab Nebula, and in 1968 a pulsar was detected there (Figure 2-20). The Crab Pulsar has since been observed across all electromagnetic wavelengths, from low-frequency radio waves to high-frequency gamma rays.

FIGURE 2-20[47]



An X-ray image of the Crab Nebula captured by the Chandra X-ray Observatory. The white dot near the center is a pulsar.

Black Holes

A very massive star may continue to collapse after the pulsar stage to become an even more tightly compressed object called a **black hole**. A star will form a black hole if it is sufficiently massive that the inward force of gravity overcomes the resistance of neutrons to become tightly packed together. According to stellar evolution theory, any star whose main-sequence mass is greater than about twenty-five times that of the Sun will eventually become a black hole.[48] Black holes are in fact not "holes" at all—they are massive objects with extremely small sizes and enormous densities. The gravitational attraction of a black hole is so great that, according to Einstein's theory of relativity, even light could not escape from within a given radius to the center of the black hole. The "surface" of a black hole, or in other words the boundary through which no light can escape, is called the **event horizon**.

The **Schwarzschild radius** (R_S) is the critical radius at which a spherically symmetric body becomes a black