FYI Supernovae

Fully 95% of stars quietly expire, becoming white dwarfs, and then leak their energy away for billions of years, ultimately becoming black cinders in space. The remaining 5% of stars end their lives in truly spectacular fashion. When the core of these massive stars can no longer support the material above it, on the very day that iron is produced in the core, the entire star implodes. Several important events occur in a matter of seconds. One, the core is compressed by staggering force and is squeezed into a ball of neutrons and neutrinos—infinitesimally small elementary particles involved in many nuclear reactions. The neutrinos don't interact with matter under normal conditions. But when they are packed into a tiny ball, neutrinos can exert a tremendous amount of outward force. After the imploding star crushes the core to a neutron-star-sized sphere, it rebounds and sends shock waves through the star, and the star explodes into space. The explosion is called a **Type II supernova**. The explosion occurs in seconds and is so violent—with temperatures reaching 100 billion degrees K—that many elements can form in the first few minutes of the intense firestorm. The atoms previously produced by fusion in the core of the star (He, C, Mg, O, Si, S, and Fe) are mixed with smaller amounts of all the other elements as the star explodes, sending clouds and rings of material expanding into space. Supernovae are incredibly bright—about a billion times as bright as the sun—and remain that bright only for a few weeks. Over several months or years, supernovae fade away and leave only wispy clouds of hydrogen and oxygen to mark the spot of the event.

Figure 3-10 shows the Crab nebula, the cloud of material produced by a supernova in 1054 AD. These types of nebulae are

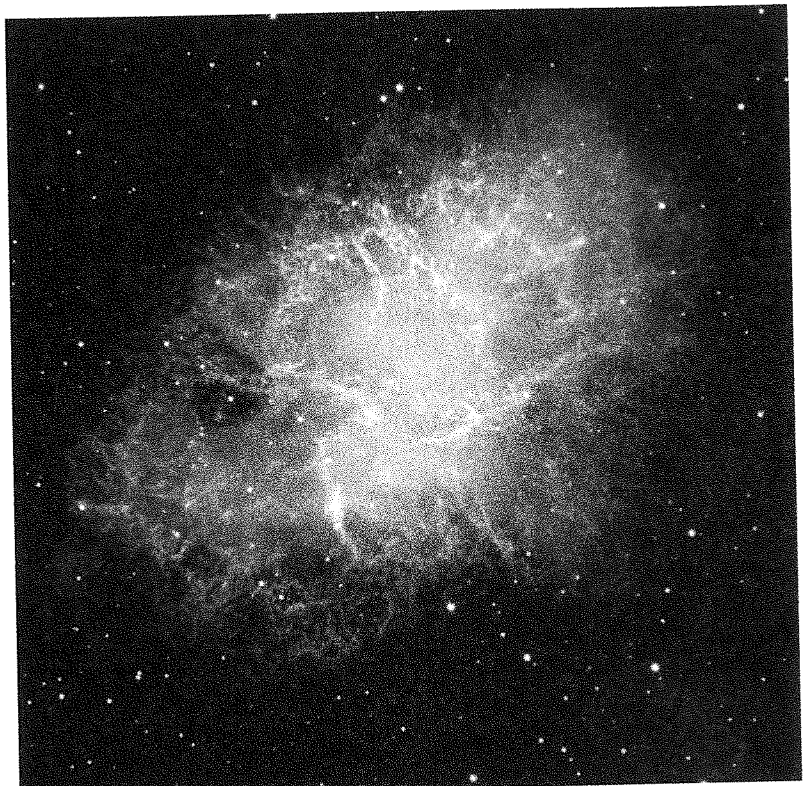

Figure 3-10: Image of the Crab nebula, which is in the constellation of Taurus

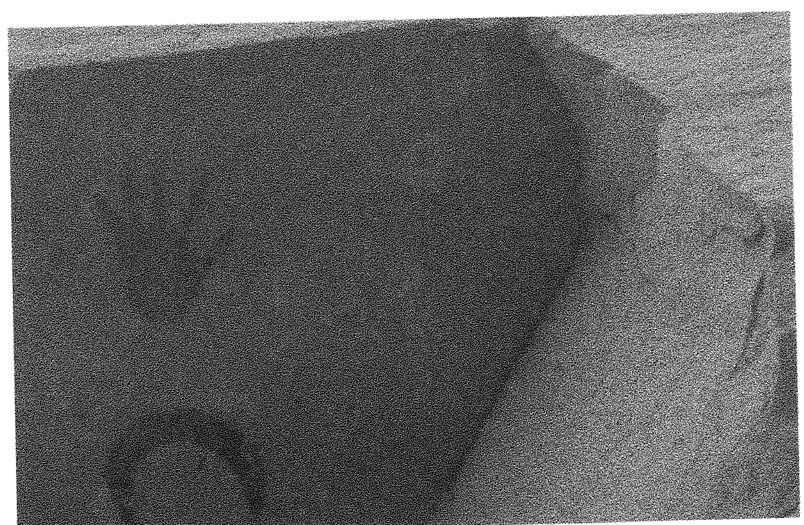

Figure 3-11: Photograph of a diagram, drawn by an Anasazi Indian artist in the southwestern United States, of the Crab supernova of 1054 AD appearing near a crescent moon. Indian artists often traced their own handprints, perhaps as a way of signing their work.

called **supernova remnants**. The Crab supernova must have been an awesome sight. Chinese astronomers noted it in their literature, and the Anasazi Indians drew petroglyphs of a large star on a sandstone cliff in New Mexico to mark the event. It is thought that our galaxy, the **Milky Way**, averages one supernova every 100 years, so our galaxy is long overdue for a supernova blast. A few stars near Earth, such as the large supergiant Betelgeuse, are poised to explode at any time. If Betelgeuse were to supernova, it would be over 600 times brighter than Venus, and you would be able to read a newspaper, or play softball at midnight, by its light. Even so, it would be about a million times dimmer than the sun. Fortunately, Betelgeuse is far enough from Earth that a supernova explosion and its accompanying release of huge amounts of deadly radiation would pose no danger to life on our planet.

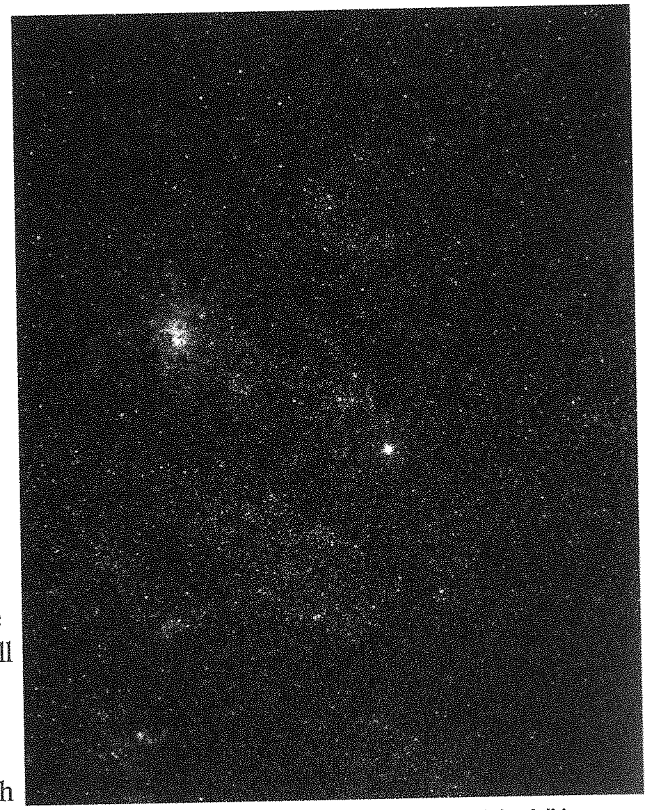

Figure 3-12: Photograph of Supernova 1987a, which is visible on the right, taken a few days after the supernova was discovered. Formerly a blue supergiant star called Sanduleak 69-202, the supernova occurred in the Large Magellanic Cloud, an irregular galaxy near the Milky Way. Supernovae can outshine entire galaxies for a period of time.

Supernova remnants differ in form and structure from other types of nebulae. They usually have a fragmented appearance with filaments of hydrogen gas strewn about. Most look like an explosion has taken place, a kind of cosmic fireworks display. Also, unlike planetary nebulae, which have shells of gas expanding away at speeds of tens of kilometers per second, the gases and atoms from a supernova explosion travel at thousands of kilometers per second.

There are two distinct ways that stars can end their lives as a supernova. The event is the endpoint of evolution for massive stars, but white dwarfs that exist in binary systems can also supernova. If a white dwarf is close enough to its companion star to draw mass and collect it on its surface, there will be a time when the mass buildup on its surface reaches a critical point. Because electron degeneracy fails to support the white dwarf if its mass is more than 1.4 solar masses, when that threshold is exceeded by the inflow of material from the companion, the white dwarf explodes. These are called **Type I supernovae** and are less bright and spectacular than Type II—those produced by the deaths of truly massive stars. Since Type I supernovae occur after building up similar amounts of mass on the surface of the white dwarf, they always produce the same amount of energy and so have the same luminosity. This fact makes them a valuable aid in determining the distances to faraway galaxies.

Checking In

1. What mechanism forms the elements in a supernova explosion?
2. How can you distinguish a supernova remnant from other types of nebulae?