**Supernovae and Novae:**

**Type II Supernovae**

The core collapse and the formation of the neutron star releases enough energy to expand the overlying envelope and eject it into space.

The expanding shock wave heats and compresses the surrounding gas, causing it to fluoresce. These glowing shells of gas are called supernova remnants. One example is the Crab Nebula. The Crab Nebula is \( \sim 1800 \) parsecs from Earth and is \( \sim 2 \) parsecs in diameter. From the velocity of expansion, the explosion is projected to have occurred around 1000 A.D., consistent with Chinese observations of a "new star" in 1054 A.D.

Another example of a supernova remnant is the Veil Nebula in the constellation Cygnus.

(See star chart)

Neutron stars can only form in the mass range \( 1.4 M_\odot \leq M_{\text{neutron}} \leq 3 M_\odot \). Not all supernovae create a neutron star.
Veil Nebula (supernova remnant) in constellation Cygnus
Figure 21.9  This remnant of an ancient supernova is called the Crab Nebula (or M1 in the Messier catalog). It resides about 1800 pc from Earth and has an angular diameter about one-fifth that of the full Moon. Because its debris is scattered over a region of "only" 2 pc, the Crab is considered to be a young supernova remnant. In A.D. 1054 Chinese astronomers observed the supernova explosion itself. The center frame shows the Crab in visible light. The left and right frames, to the same scale, show the Crab Nebula in the radio and ultraviolet, respectively.
The luminosity of the supernova over time reaches a peak then fades with time. There are two main types of light curves:

The peak luminosity is \( \sim 10^{10} \) L\(_{\odot}\). This is roughly the luminosity of our entire Galaxy, but it comes from a single star.

There have only been 6 observed supernovae in our Galaxy in the last 1000 years. If it weren't for the obscuring dust and clouds in our Galaxy we would have expected to have seen more supernovae.

(See plot of supernovae locations)
Type II supernovae come from the core collapse of a highly evolved massive star.

Type I supernovae come from another process.

Nova + Type I supernovae

In a binary star system, two stars orbit around their common center of mass:

\[ \text{massive star} \rightarrow \text{less massive companion star} \]

The more massive star will evolve faster, blow up into a Red Giant and eventually become a white dwarf.

If the companion star evolves into a Red Giant, it can begin to transfer part of its atmosphere to the white dwarf.
In a recurrent nova, material falling onto the white dwarf accumulates until the temperature rises high enough to start it to the fusion and the material is partially ejected into space:

Now the cycle can repeat... The peak luminosity of a nova is ~ 10,000 Lsun, much less than that of a supernova.
If the nova explosion does not expel all of the infalling material, then the mass of the white dwarf will slowly grow. If the white dwarf mass exceeds the Chandrasekhar limit, then the white dwarf can no longer support itself and it will collapse.

The temperature will rapidly rise until helium and carbon fusion occurs. Helium fusion and carbon-carbon fusion begin, and the white dwarf is disrupted and destroyed.

This is the origin of a type I supernova, sometimes called a carbon-deflagration supernova.

Type I supernovae are all remarkably similar because their masses and composition are fixed. This makes them useful standard candles for determining distances to other galaxies.

e.g. \( L_{\text{Lum}} \sim 10^{40} \quad M_I \approx -2.5 \log(10) + 5 \approx -20 \)

Absolute magnitude

A measurement of the apparent magnitude, \( m \), allows distance to be determined.

\[ m - M_I = -5 + 5 \log(r) \]

\( m - M_I \) is (distance modulus) related (in parsecs, \( r \)).