Friday, March 10, 2017

Reading for Exam 3:

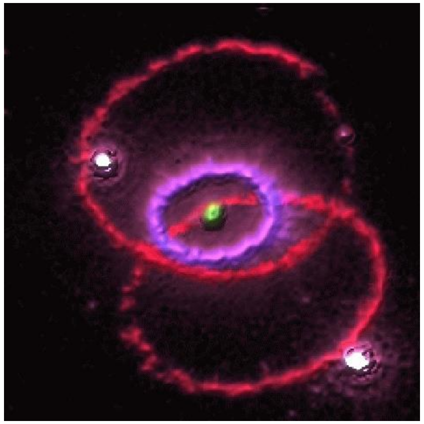
Chapter 6, end of Section 6 (binary evolution), Section 6.7 (radioactive decay), Chapter 7 (SN 1987A), Background: Sections 3.1, 3.2, 3.3, 3.4, 3.5, 3.8, 3.10, 4.1, 4.2, 4.3, 4.4, 5.2, 5.4 (binary stars and accretion disks). Plus superluminous supernovae, **not in the book**.

Astronomy in the news?

Potatoes can grow just about anywhere, including Mars, according to researchers who tested the idea put forth in the movie "The Martian." Scientists are growing potatoes in Mars-like soil from a Peruvian desert inside a CubeSat under extreme conditions, and the findings could not only benefit future Mars colonists but also help undernourished populations here on Earth.

Goal:

To understand the nature and importance of SN 1987A for our understanding of massive star evolution and iron core collapse. Chapter 7



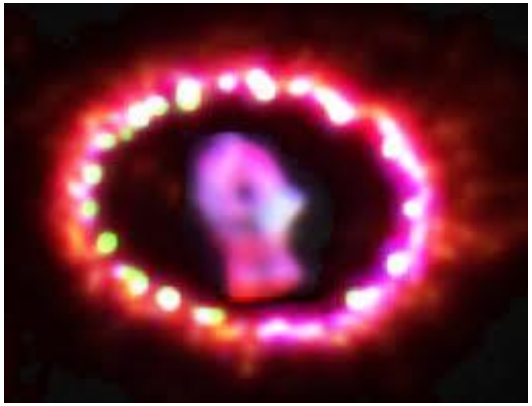
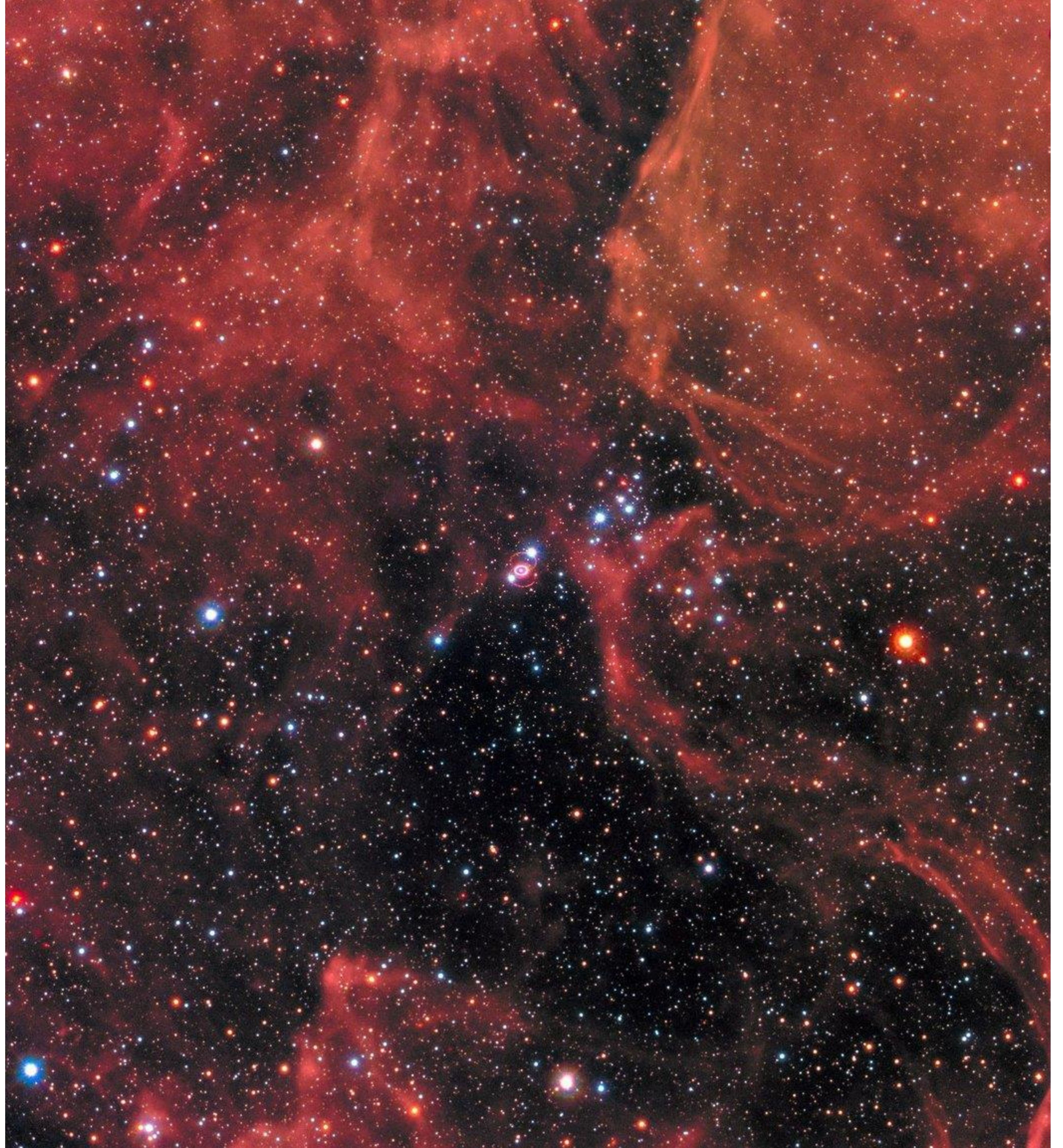


Image of SN 1987A and environs in Large Magellanic Cloud, taken by Hubble Space Telescope, January 2017



One Minute Exam

What was the most important thing about SN 1987A in terms of the basic physics of core collapse?

➡ It exploded in a blue, not a red supergiant

⬅ It was surrounded by three rings

⬆ It produced radioactive nickel and cobalt

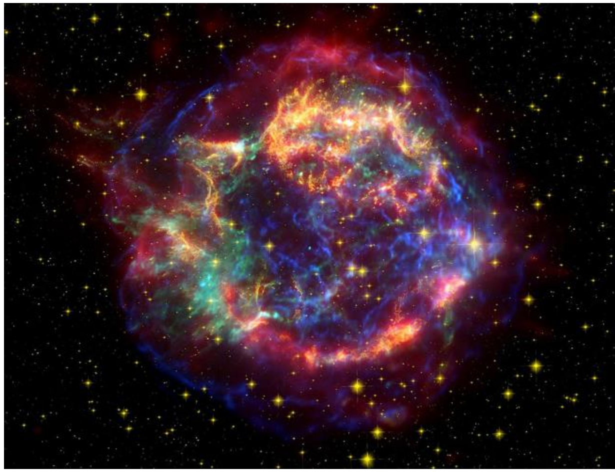
⬇ Neutrinos were detected from it

Saw neutrinos! Neutron star must have formed and survived for at least 10 seconds.

If a black hole had formed in the first instants, neither light nor neutrinos could have been emitted.

No sign of neutron star since, despite looking hard for 30 years.

Whatever is in the center of Cas A, most likely a neutron star, is too dim to be seen at the distance of the LMC, so SN 1987A might have made one of those (probably a neutron star, but not bright like the one in the Crab Nebula).



Also possible that after explosion and formation of neutron star, some matter fell back in and crushed the neutron star to become a black hole.

Dim neutron star or black hole? Still do not know.

Goal – to understand the nature of a new class of superluminous supernovae

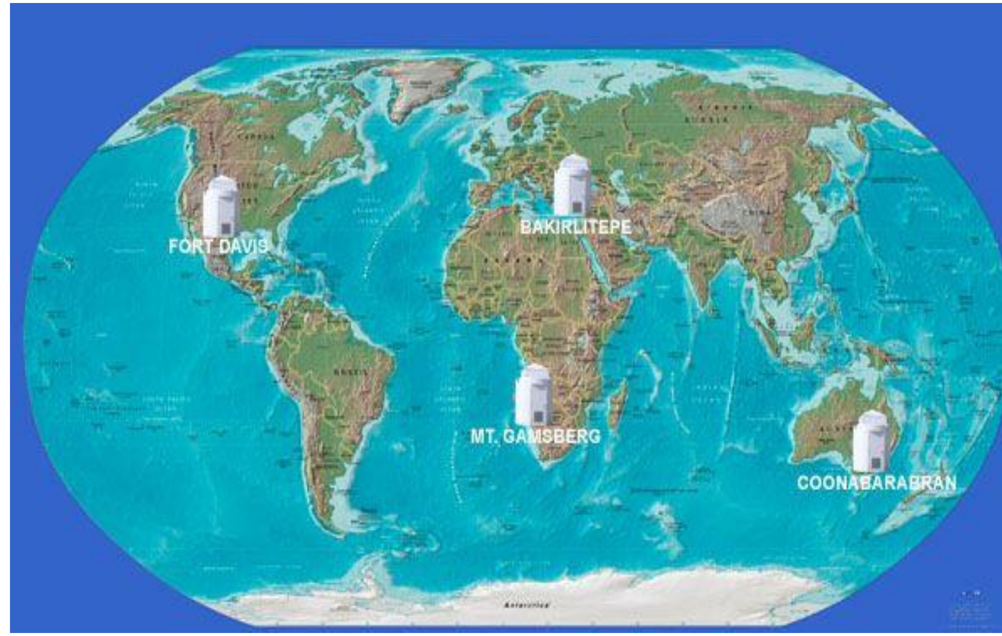
This material is NOT in the book!

Goal – to understand how we found the superluminous supernovae

We participated in the U. of Michigan ROtotic Transient Source Experiment (ROTSE) collaboration.

Four ROTSE telescopes around the world. Texas, Australia, Namibia And Turkey.

18 inch mirrors, 1.85 degree squared field of view. Moon is 0.5 degree



ROTSE can point and shoot within 6 secs of electronic satellite notification, take automatic snapshots every 1, 5, 20, 60 secs.

ROTSE3B and Hobby-Eberly Telescopes

The Texas Supernova Search

2004 - Texas graduate student Robert Quimby used ROTSE to conduct the ***Texas Supernova Search***, covering unprecedentedly large volumes of space.

Original (and on-going) goal: search nearby rich clusters of galaxies, Virgo, Leo, Coma, Perseus, Ursa Major, for supernova very early, days, after outburst.

Possible with large field of view, rapid cadence of ROTSE, impossible with small field of view searches that target individual galaxies.

Unbiased search - large galaxies, small galaxies, AGN nuclei, centers as well as outskirts.

Included vast volume of space, a billion cubic light years behind target clusters in ~5 years.

For Sky Watch

Find Virgo, Leo, Coma, Perseus, Ursa Major clusters of galaxies.

A New Type of Supernova

By far the most dramatic discovery by Robert Quimby and the Texas Supernova Search was a whole new class of "superluminous" supernovae, of order 10 to 100 times brighter than the classical types.

SN 2005ap – hydrogen poor

SN 2006gy- hydrogen rich

SN 2006tf – hydrogen rich

SN 2008es – hydrogen rich

SN 2008am – hydrogen rich

SN 2010kd – hydrogen poor

These supernovae tend to occur in small, irregular, galaxies with active star formation.

SN 2006gy

The first to get major press was SN 2006gy

Rose to maximum in 70 days (1 to 2 weeks is typical) => large mass involved

~100 times brighter than normal

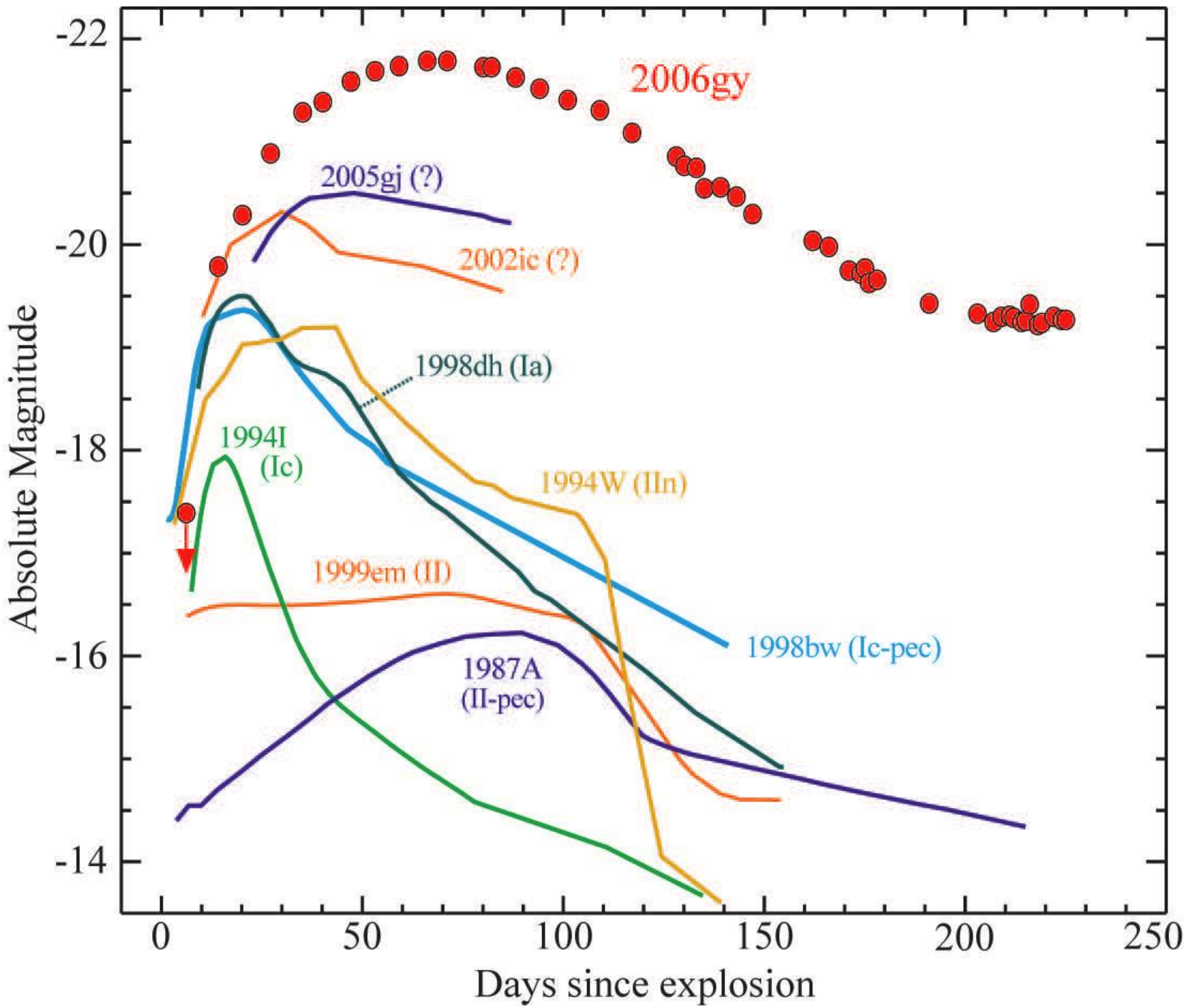
Slower decline

Rich spectrum, characterized by broad, intermediate, and narrow lines of Hydrogen, a Type II, but of a sort never seen before

Detailed analysis showed that SN 2006gy had to arise from a very massive star, ~100 solar masses

#3 on Time Magazine's list of top 10 science discoveries of 2007

(#1 was stem cells; #2 decoding of human genome; #4 700 new species including carnivorous sponges and giant sea spiders;)



SN 2006gy is much brighter than the normal Type II, SN 1999em

Goal – to understand why the superluminous supernovae are so bright

Shell-Shock Model

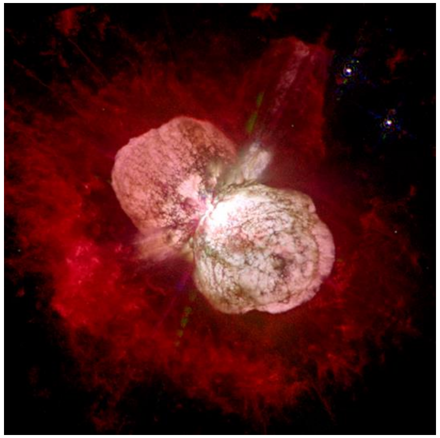
Need a massive shell of circumstellar matter expelled by the progenitor star prior to its explosion.

Shell sitting at a radius of about 100 times the size of the Earth's orbit, so does not need to expand at all to radiate.

Supernova then collides with that shell, efficiently radiates kinetic energy as radiant energy, no loss to expansion and cooling.

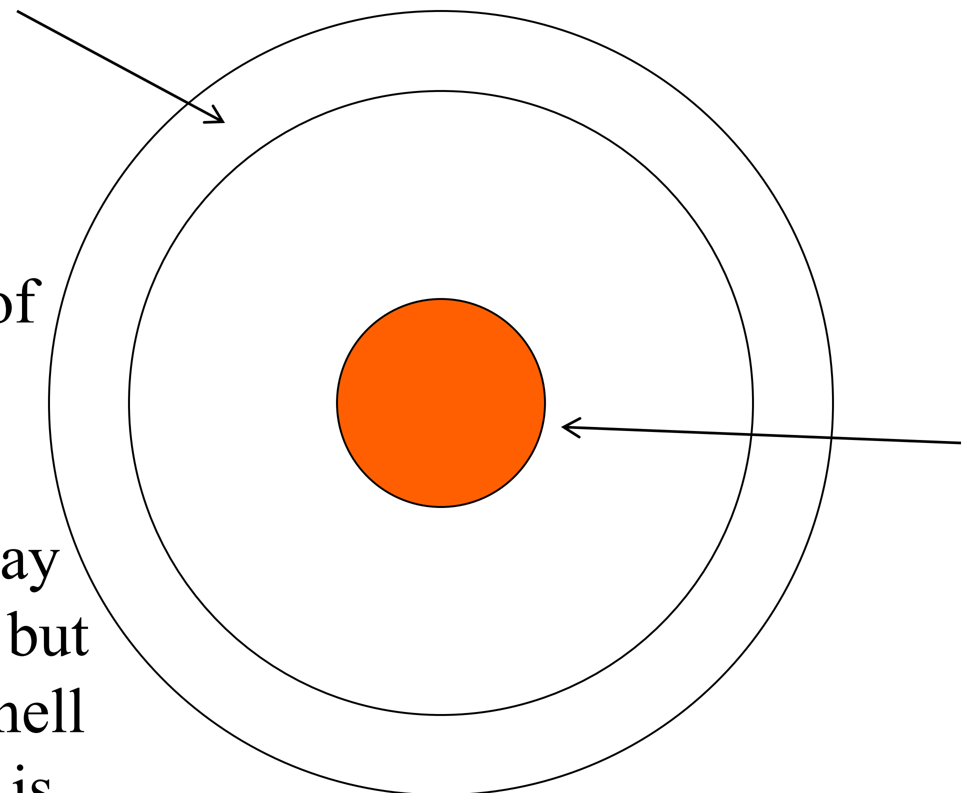
Candidate progenitor stars - Luminous Blue Variables such as Eta Carinae, known to eject shells of matter in a burst, mechanism unknown.

The shell-shock model works for SN 2006gy and related hydrogen-rich events, SN 2008es, SN 2008am



Simple Version of Shell-Shock Model

Shell of matter previously expelled by progenitor star with size about 100 times that of Earth's orbit



Supernova from massive star, but nature otherwise obscured by shell, so unknown

The supernova may expand and cool, but when it hits the shell its kinetic energy is converted to heat that is radiated efficiently

Another idea: Lots of radioactive ^{56}Ni

A very massive star, > 100 solar masses, gets so hot in the post-helium burning, oxygen-core phase, that its radiation, gamma-rays, convert some energy to matter and anti-matter, pairs of ***electrons*** and ***positrons***.

According to theory, this process reduces the energy available to exert pressure, the oxygen core contracts, heats, undergoes a thermonuclear explosion, totally disrupting the star: a ***pair-instability supernova.***

Computer models of the explosion produce a large amount, 10's of solar masses, of radioactive ^{56}Ni, the decay of which to ^{56}Co and then to ^{56}Fe is predicted to produce a very bright, slow light curve.

The Pair-Instability Supernova Model was wrong for the first extremely luminous supernovae that defined the class.

SN 2005ap - very bright requiring a large amount of nickel, but rather narrow light curve, meaning the ejected mass was modest.

Would require more ^{56}Ni to power the peak light than the total mass constrained by the width of the light curve. **Physically impossible, so power by radioactive decay ruled out.**

Need another mechanism for many of these very bright events.

What about SN 2005ap and similar hydrogen-poor events?

No Hydrogen, no sign of circumstellar interaction, must be massive, but cannot be radioactive decay.

Shell shock in shell of carbon and oxygen?

Some very massive stars might eject their hydrogen and helium in strong winds, then eject shells of carbon and oxygen.

Another actively discussed possibility is that the explosion is driven and illuminated by an especially rapidly rotating and highly magnetized neutron star (a magnetar, Chapter 8).

One Minute Exam

What can we say about all the superluminous supernova with some confidence?

➡ They have hydrogen

⬅ They do not have hydrogen

⬆ They are bright because of the shell-shock mechanism

⬇ They arise in very massive stars

One Minute Exam

What aspect is **not** a property of the Pair-Instability model?

➡ Creation of matter and anti-matter

⬅ Thermonuclear explosion of oxygen core

⬆ Production of many solar masses worth of radioactive nickel-56

⬇ Collapse of the core to form a neutron star