Cosmic Catastrophes Wheeler
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Review for Test #1
BACKGROUND AND INTRODUCTION TO SUPERNOVAE

The Universe is a strange place.

For stars, red is cool, white is hot, giant means bright and dwarf means dim.

Main Sequence — stars fuse hydrogen into helium and thus supply energy.

In evolution after the Main Sequence, "core" refers to the inner part of the star that is composed of elements heavier than hydrogen and "envelope" means the outer regions still composed of hydrogen.

Red Giant — when hydrogen burns out in the center, excess heat flowing from the contracting core causes the outer layers to *gain energy.* They then *expand and cool.* The envelope becomes larger, cooler, redder, and more luminous.

Planetary nebulae — Most stars less than 8 $M_\odot$ ($\odot$ is the symbol for the Sun, so 8 times the mass of the Sun) eject their outer envelopes of unburned hydrogen as planetary nebulae. Core of C and O cools to become white dwarf.

White Dwarfs — size of Earth, mass of Sun. Cooling time longer than the age of the Universe. Almost every white dwarf ever born in the Milky Way is still here.

Sirius is a main sequence star with a white dwarf companion orbiting around it.

Two most common explosion mechanisms — collapse of core of massive star to leave a compact remnant (neutron star or black hole) or exploding white dwarf.

Superluminous supernovae — rare, but 10 to 100 times brighter than "normal" supernovae. They may arise in very massive stars of about 100 $M_\odot$. Not yet determined whether they explode completely or leave a compact remnant.

Historical Supernovae in the Milky Way — several seen and recorded with naked eye in last 2000 years. SN 386 earliest on record, SN 1006 brightest, SN 1054, now the Crab Nebula, contains a rapidly rotating pulsar and suggestions of a jet. Tycho 1572, Kepler 1604. Cas A not clearly seen about 1680, shows evidence for jets, and a dim compact object in the center. The events that show compact objects also seem to show evidence of "elongated" explosions or "jets." SN 1006, and SN 1604 were probably Type Ia, exploding white dwarfs, SN1572 definitely was.

G1.9+0.3 — exploded 140 years ago, but buried in obscuring dust in the center of the Milky Way, probably a Type Ia.

SN 1987A — occurred in a very nearby galaxy, came from a massive star, about 20 $M_\odot$, shows elongated ejecta.

Extragalactic Supernovae — galaxies like our Milky Way produce about 1 supernova per 100 years. Supernovae occur about 1 per second in the Universe and are discovered about once per day in distant galaxies.

Supernovae are traditionally named alphabetically by discovery in a given calendar year.

Common intermediate mass elements are formed from "building blocks" of helium in stars: carbon, oxygen, neon, magnesium, silicon, calcium.

Intermediate mass elements are produced in massive stars before they explode, in white dwarfs during the explosion.

Stellar physics: there are more low mass stars than high mass stars. High mass stars live a shorter time than low mass stars. A short-lived star must be massive.

Galaxy physics: stars are born in the spiral arms of spiral galaxies. Elliptical galaxies have not formed stars in billions of years.

Type I supernovae — no evidence for hydrogen in spectrum.

Type II supernovae — definite evidence for hydrogen in spectrum.

Type Ia Supernovae — relatively brighter, no hydrogen or helium, avoid spiral arms, occur in elliptical galaxies, origin in lower mass stars. Observe silicon early on, iron later. Star is completely disrupted, no neutron star or black hole. Light curve shows peak lasting about a week, then more slowly decaying "tail."

Type II Supernovae — relatively dimmer that Type Ia, explode in spiral arms, never occur in elliptical galaxies, normal hydrogen observed at peak, massive stars, recently born, short lived. Observe H early on, O, Mg, Ca later. Probably result from core collapse of massive star. Light curve shows month's-long "plateau." Characteristic of explosion in a red giant.

Betelgeuse — red giant about 600 light years away, mass of 15 to 20 $M_\odot$, is expected to explode within 100,000 years, maybe tonight, as core collapse Type II supernova. Keep an eye on it.

Type Ib Supernovae — no hydrogen, but observe helium early on, O, Mg, Ca later. Occur in spiral arms, never in elliptical galaxies. Massive star core collapse.

Type Ic Supernovae — no hydrogen, little or no helium early on, O, Mg, Ca later. Occur in spiral arms, never in elliptical galaxies. Massive star core collapse.

Light curves of Type Ib and Ic are similar to Type Ia, but dimmer at maximum brightness.

Superluminous supernovae come in two categories, some are rich in hydrogen, some show no evidence for hydrogen. They explode in small galaxies with active star formation. Their light curves tend to rise and fall slowly, indicating a large mass of ejected material.