Friday, March 2, 2012

Bonus topic, not in book

Reading: Chapter 8 - Sections 8.1, 8.2, 8.5, 8.6, 8.10

Astronomy in the news?

News:

Another type of supernova

Ask me about its properties, vote about type of explosion.
Analogous to astronomers querying nature with their telescopes

➡ Massive star, core collapse, neutron star

⬅ Exploding white dwarf

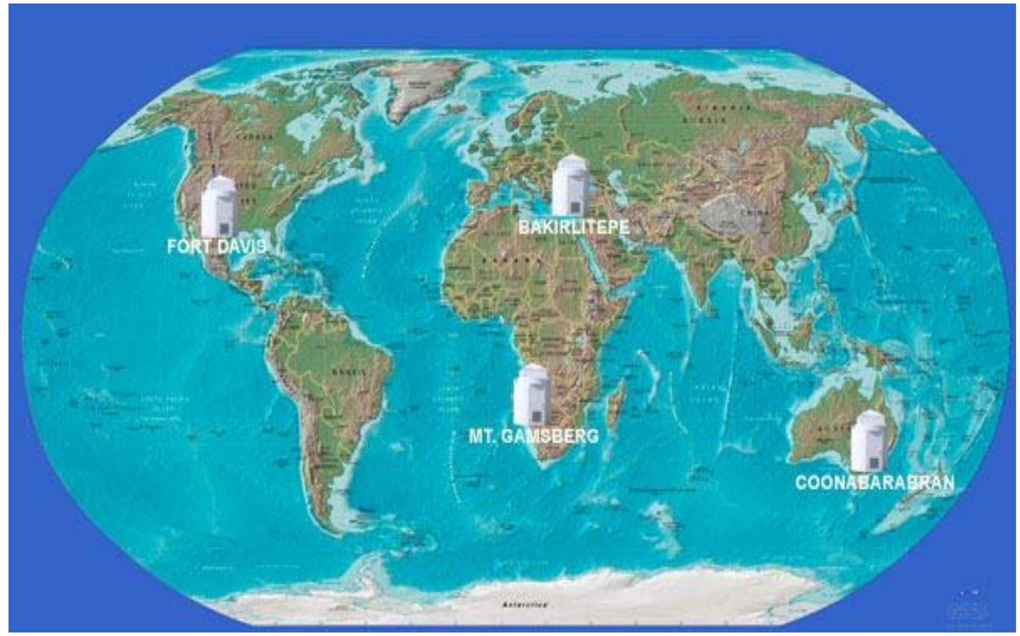
Goal – to understand the nature of a new class of super-luminous supernovae

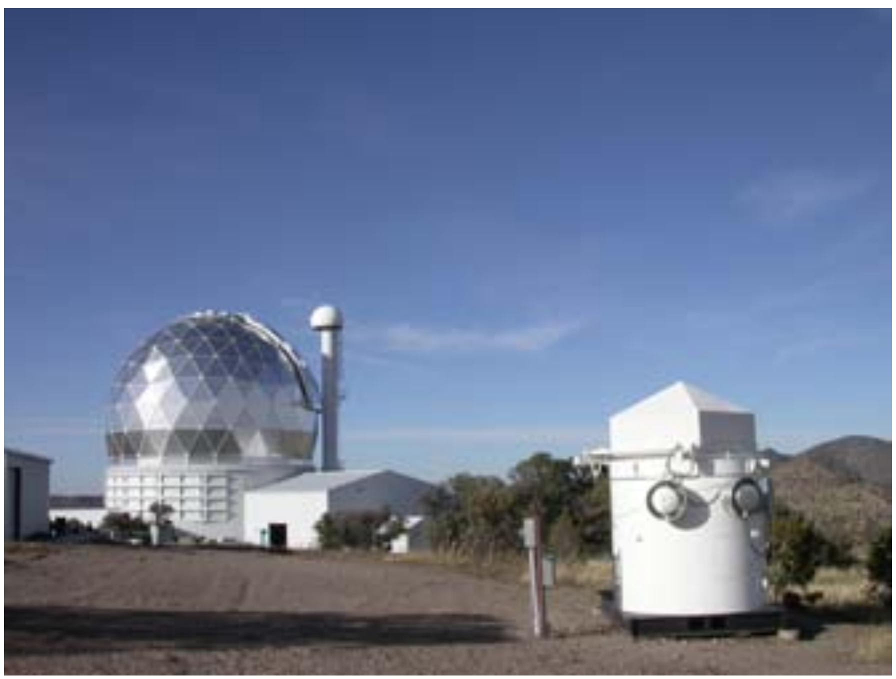
Goal – to understand how we found the super-luminous supernovae

We participate in the U. of Michigan RObotic Transient Source Experiment (ROTSE) collaboration.

Four ROTSE telescopes around the world. Texas, Australia, Namibia andTurkey.

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

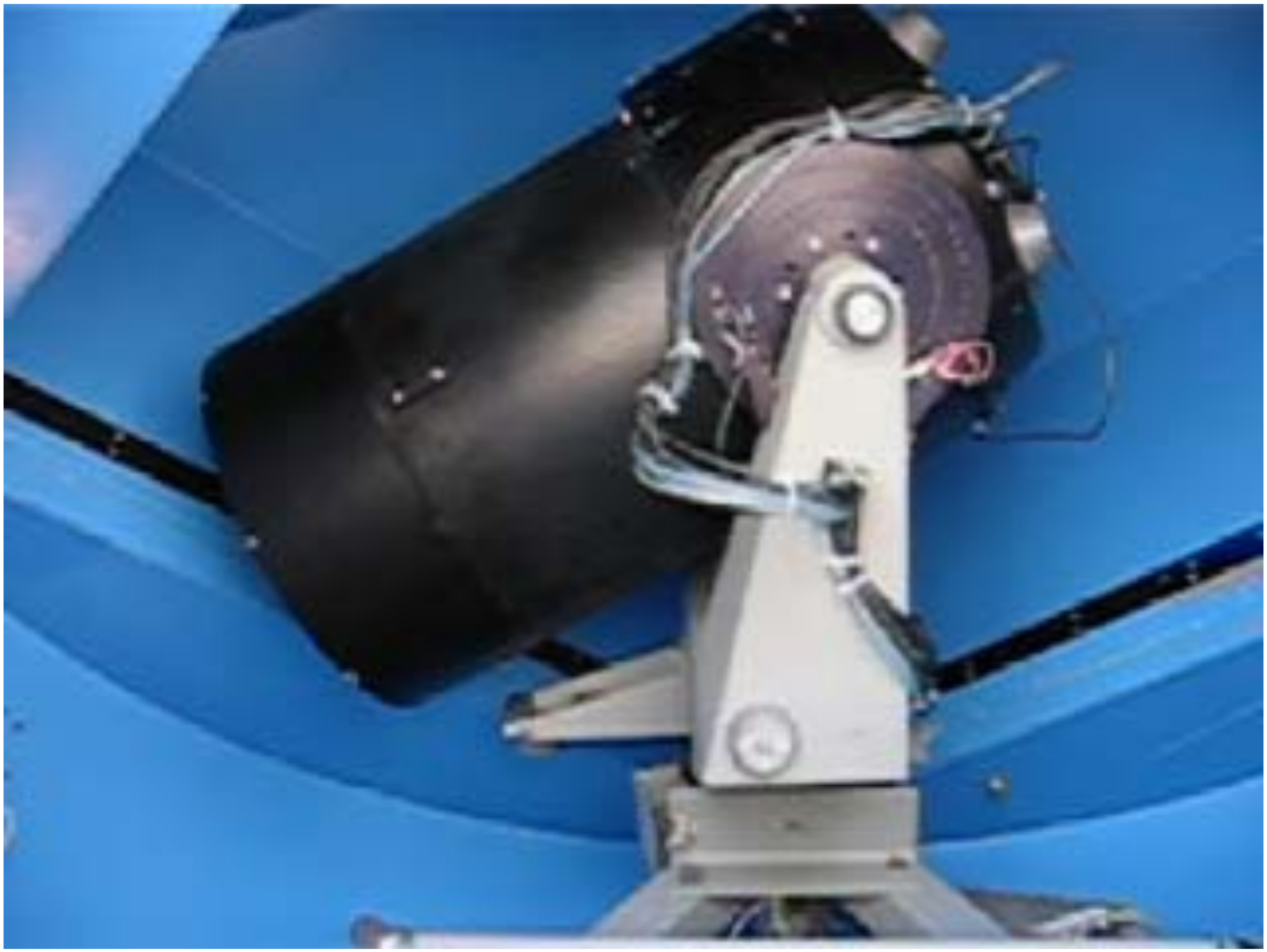




ROTSE can point and shoot within 6 secs of electronic satellite notification, take automatic snapshots every 1, 5, 20, 60 secs.

ROTSE has:
Discovered the optical transient ***during*** the 30 second gamma-ray burst;
Followed the light in unprecedented detail;
Relayed the discovery and coordinates to the HET for spectroscopic follow up.

ROTSE IIIb in action



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 “super-luminous” supernovae, of order 10 to 100 times brighter than the classical types.

SN 2005ap

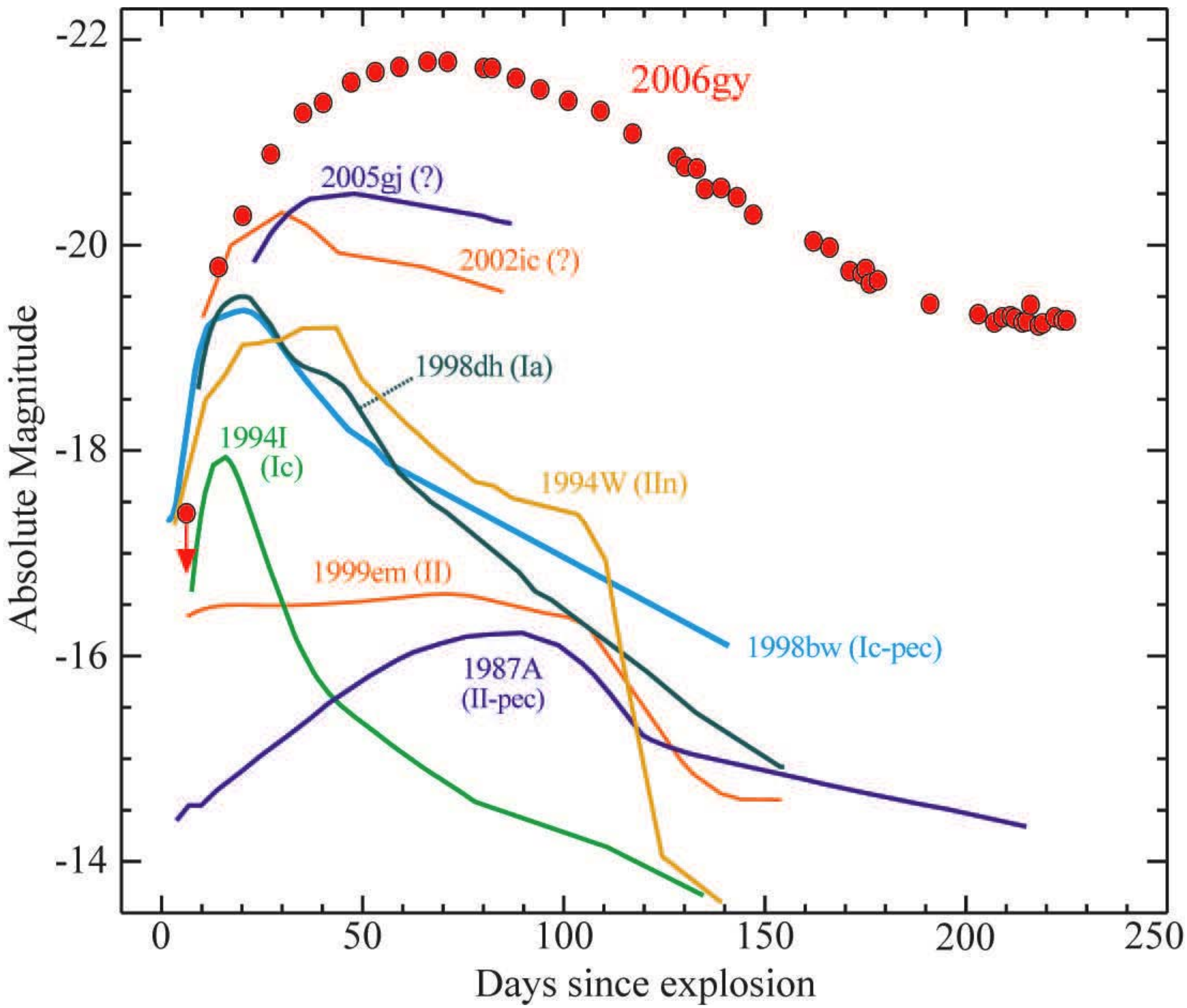
SN 2006gy

SN 2006tf

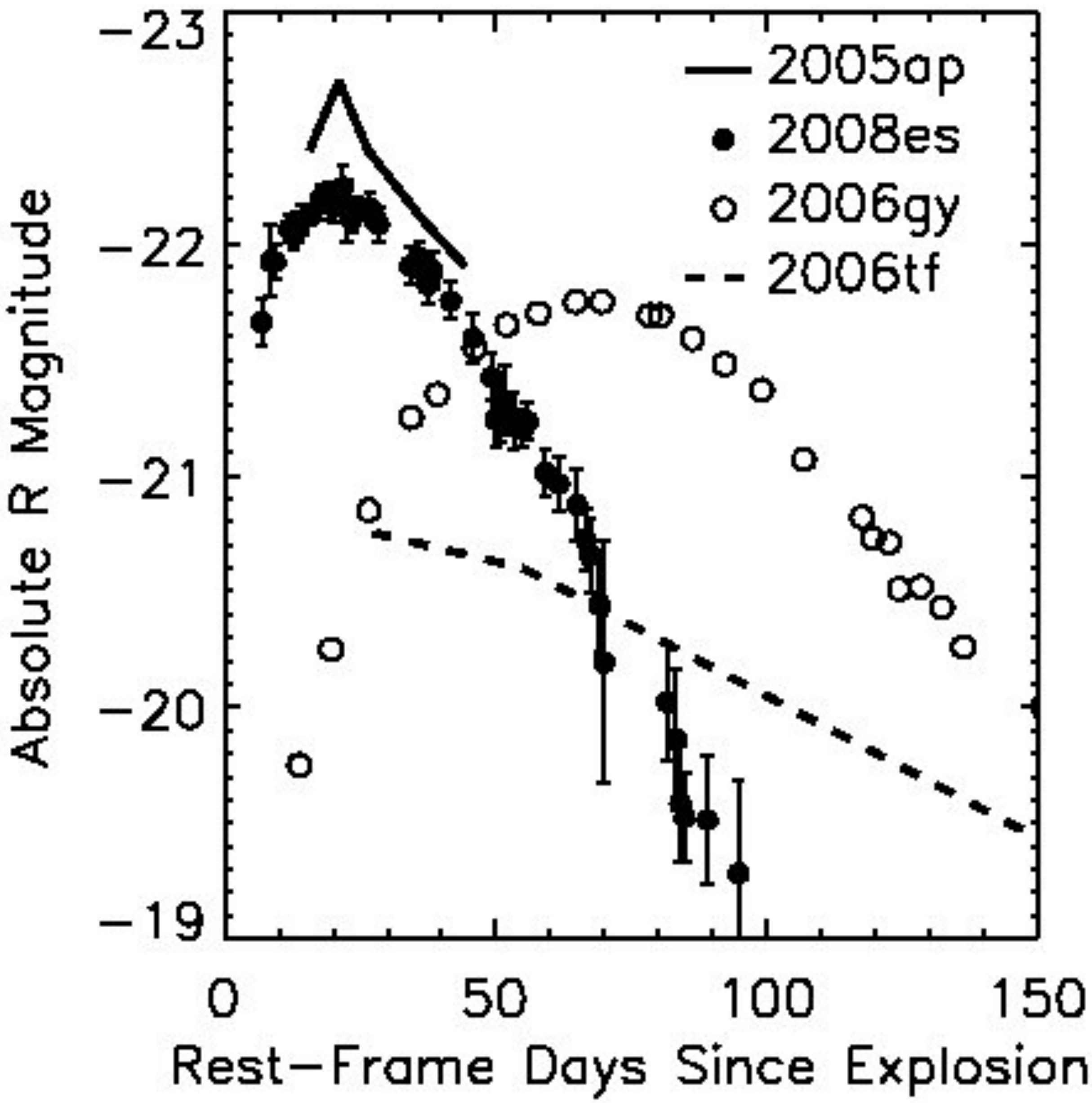
SN 2008es

SN 2008am (Manos working on this now)

SN 2010kd



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



SN 2005ap and SN 2008es are even brighter yet.

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

SN 2006gy

NASA publicity machine engaged (Chandra X-ray observations)

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

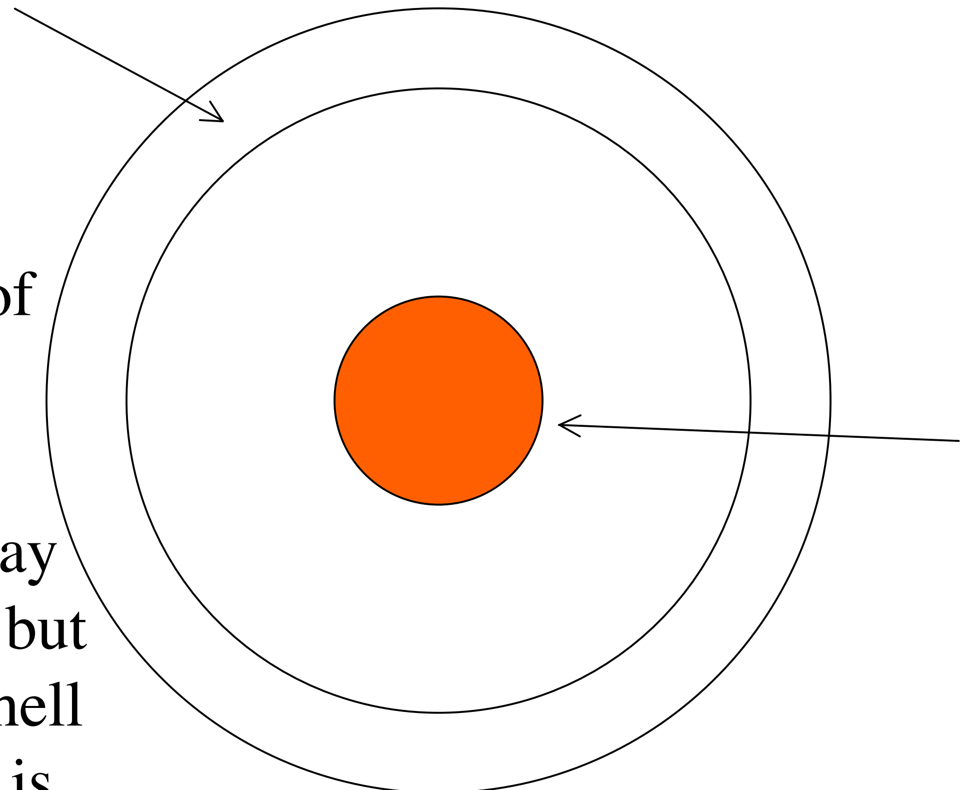
(after decoding of human genome and before 700 new species including carnivorous sponges and giant sea spiders; #1 was stem cells)

Robert Quimby won the 2010 Robert J. Trumpler Award of the Astronomical Society of the Pacific for Best PhD Dissertation in Astronomy

Goal – to understand why the super-luminous supernovae are so bright

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

Shell-Shock Model

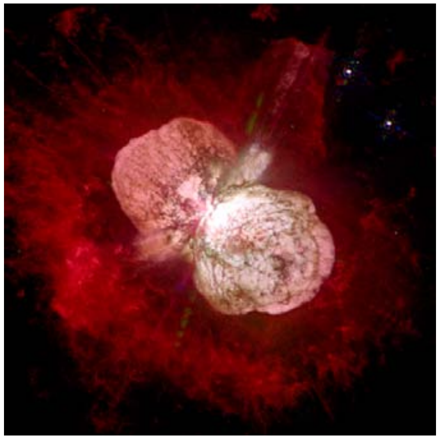
Need a massive shell of circumstellar matter expelled by the progenitor star prior to its explosion.

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



JCW proposed a different kind of explosion for SN 2006gy, first worked out theoretically 40 years ago, more recently hypothesized to occur among the first stars ever formed in the Universe, but never seen.

A Pair-Formation Supernova (focus of Manos' current research)

The energy of high-energy photons can be converted to mass ($E = mc^2$) in the form of particles and their anti-particles, same mass, opposite electrical charge, matter and anti-matter. When matter and anti-matter combine they produce pure energy.

From Wikipedia: **Warp core** A primary component of the warp drive method of propulsion in the Star Trek universe is the "gravimetric field displacement manifold," more commonly referred to as a *warp core*. It is a fictional reactor which taps the energy released in a matter-antimatter annihilation to provide the energy necessary to power a starship's warp drive, allowing faster-than-light travel. In the *Star Trek* universe, fictional "dilithium crystals" are used to regulate this reaction. Usually, the reactants are deuterium, an isotope of hydrogen, and antideuterium (its antimatter counterpart).

Also Angels and Demons – vial of anti-matter threatens to explode the Vatican.

Other examples of anti-matter in books, film?

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-formation 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 Formation 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.

Shell shock works for some: SN 2006gy, SN 2008am.

An example of pair formation?

SN 2007bi has no Hydrogen, no sign of circumstellar interaction, must be massive and is bright, radioactive decay is consistent, could be a pair-formation supernova.

What about SN 2005ap and similar 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.

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