Lecture 26 — Why we really do understand Core-Collapse? Begin Relativity
Core Collapse

The Exploding Core of a Supernova

Only 0.4 s after supernova eruption begins, the exploding core remains spherical.

Within 0.025 s, convection begins as hot gas (blue) rushes outward in great plumes.

The asymmetric convection blasts outward through the star, blowing it apart in hours.

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Clicker Question

You observe a supernova spectrum with strong Balmer Lines. It means you are seeing

(a) SN Ia
(b) Nova
(c) Core Collapse
(d) Can not tell
You observe a supernova spectrum with no Balmer lines, but a strong Silicon line with absorption at 6150 Å. It means you are seeing

(a) SN Ia
(b) Nova
(c) Core Collapse
(d) Can not tell
The Crab: SN 1054

The Crab Nebula

Filaments of gas rush away from the site of the supernova of 1054 AD

Visual-wavelength image

Glow produced by synchrotron radiation.

Photons

Magnetic line of force

Path of electron
SN 1987A

Supernova 1987A

The star that exploded

The supernova in 1987

2004 image

Remains of the star

Shockwave expanding into ring of gas

Visual-wavelength image

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SN 1987A Evolution
Core Collapse Mechanism

\[
\begin{align*}
\nu_e + n &\rightarrow p + e^- \\
\bar{\nu}_e + p &\rightarrow n + e^+
\end{align*}
\]
Core Collapse Mechanism 3D Instability
From Li et al. (2007)

<table>
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SN 1993W
ReCap I

- **Type Ia Thermonuclear Explosion of White Dwarf**
  - Explosion powered by fusion of C + O \(\rightarrow\) \(^{56}\text{Ni}\)
  - Light Curve powered by radioactive decay

\[
^{56}\text{Ni} \rightarrow^{56} \text{Co} \text{ 6 day half life}
\]

\[
^{56}\text{Co} \rightarrow^{56} \text{Fe} \text{ 77 day half life}
\]

- **Core Collapse Supernovae**
  - Death of Massive Star
ReCap II

- Powered by Gravity
- Most Energy comes out in neutrinos
- Shock powers both the explosion and the light curve
Supernova Remnants

The supernova remnant called the Cygnus Loop is 5000 to 10,000 years old and 30 ly in diameter.

Visible light produced by gas expanding into surrounding interstellar medium.

Supernova remnant N132D is 3000 years old and 80 ly in diameter. It is 180,000 ly from Earth.

Shock waves in expanding gas heat it to millions of degrees, and it emits X-rays.

Geminga (Cas A) is a supernova remnant about 300 years old and 10 ly in diameter.

Infrared radiation from dust condensing out of the gas.

Cas A is also bright at radio wavelengths.
Okay we’ve seen that even though core collapse supernovae don’t explode in our calculations, we have empirical evidence to support our basic picture. Does that mean we basically understand how massive stars die? Why or why not?

How would you generalize this to another topic, for example, Global Climate Change?
Read Chapter 13 on Relativity
Relativity or Why Einstein is famous

- Special Theory of Relativity
- General Theory of Relativity
Special Relativity
Speed of Light in Vacuum Must be Maximum and same for everyone

Example 2: Consider two cars, A and B, headed toward an intersection. Both cars are equally far from the intersection and are headed toward it at 100 km/hr. They will collide when they reach the intersection. However, if you are standing straight down the street in the direction that car A is heading you will see the light from car A moving faster than the light from car B. Thus, you would see car A get to the intersection before car B and thus there should be no collision.

What!? That’s not possible. The collision happens, it should not depend on where we are located as to whether or not we see the collision to occur.

If \( c \) were not absolute, you would see car A reach the collision point before car B.