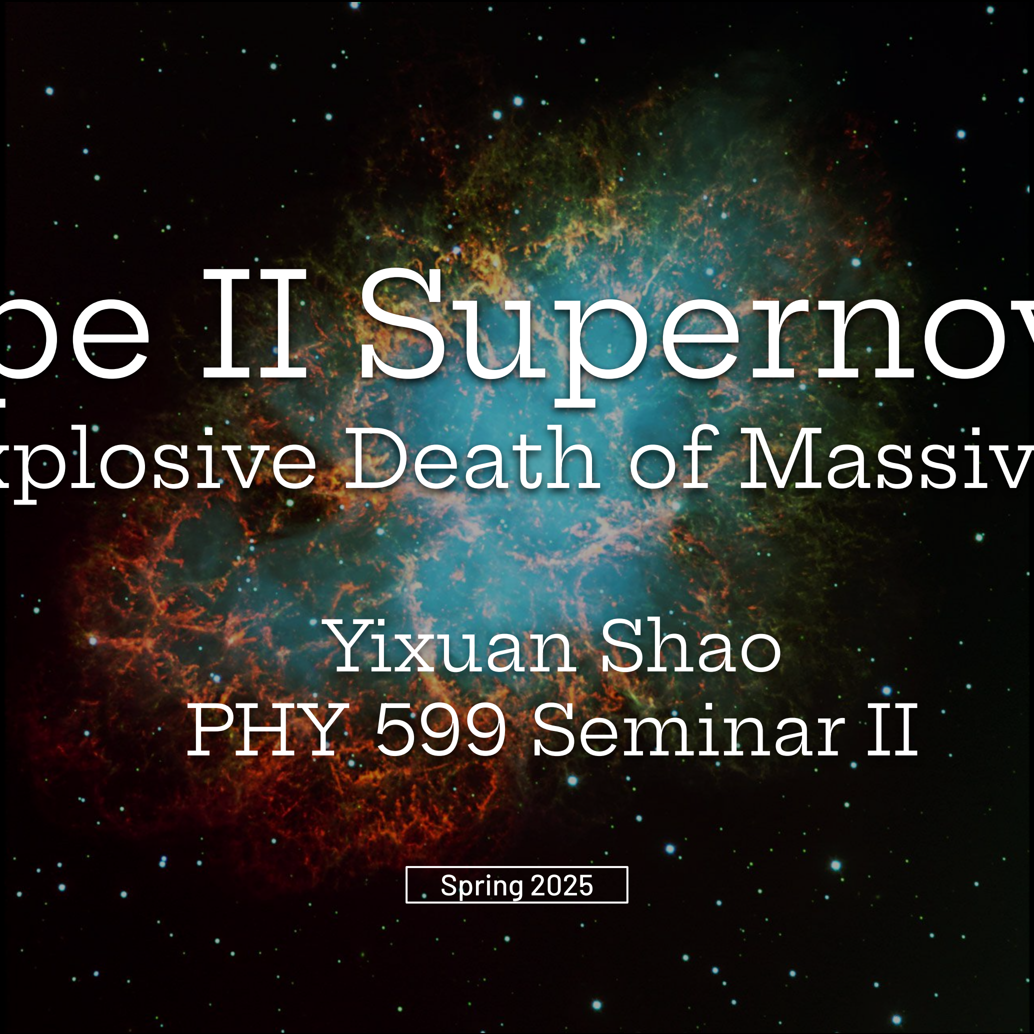

Type II Supernovae

The Explosive Death of Massive Stars

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PHY 599 Seminar II

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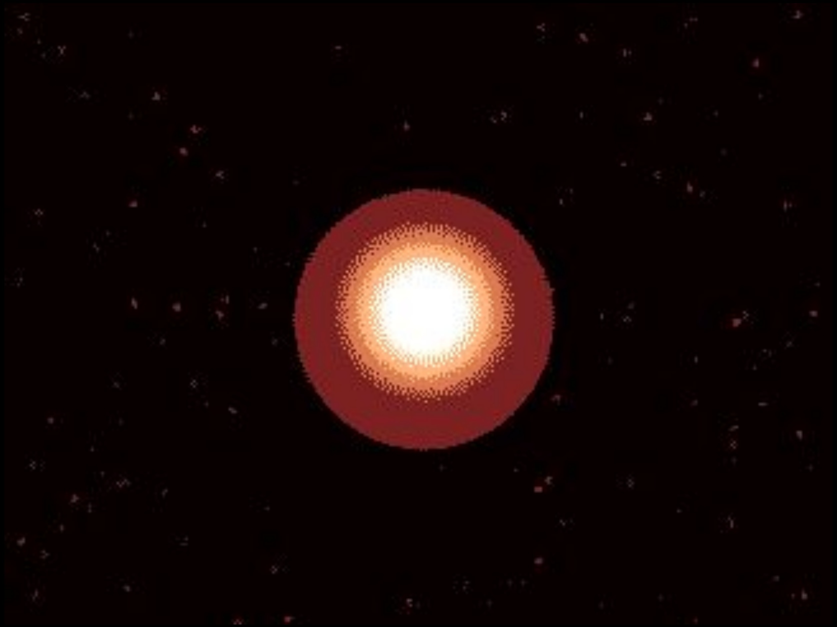
What is a Supernova?

SN 1987a as seen by JWST's Near-Infrared Camera. Credit: NASA, ESA, CSA, M. Matsuura, R. Arendt, C. Fransson

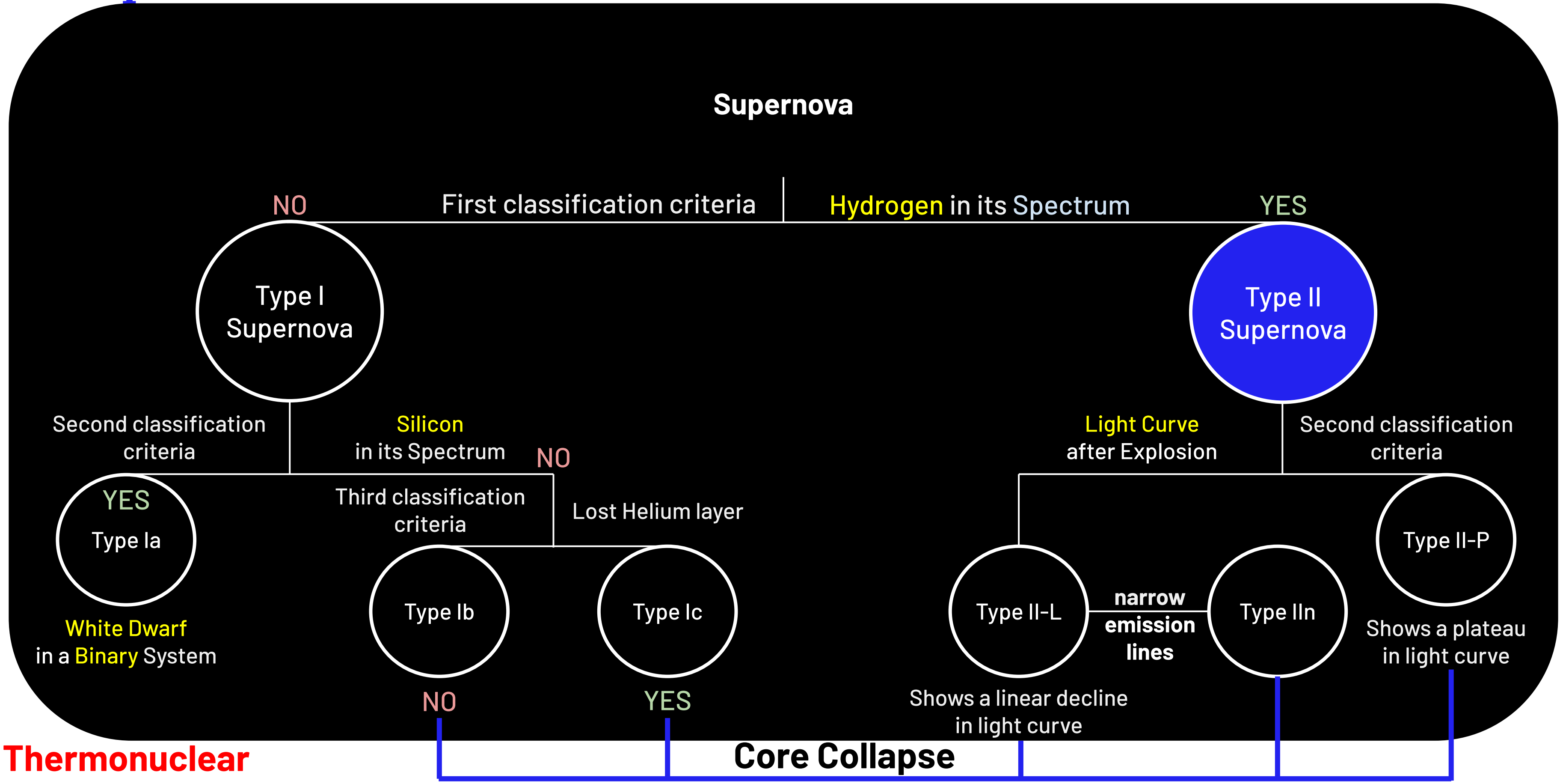
Supernova

A stellar explosion that occurs when a star reaches the end of its life, resulting in a rapid increase in brightness followed by the ejection of most of its mass into space.



Source: kenobi-wan-obi.tumblr.com

Supernova Classification Tree



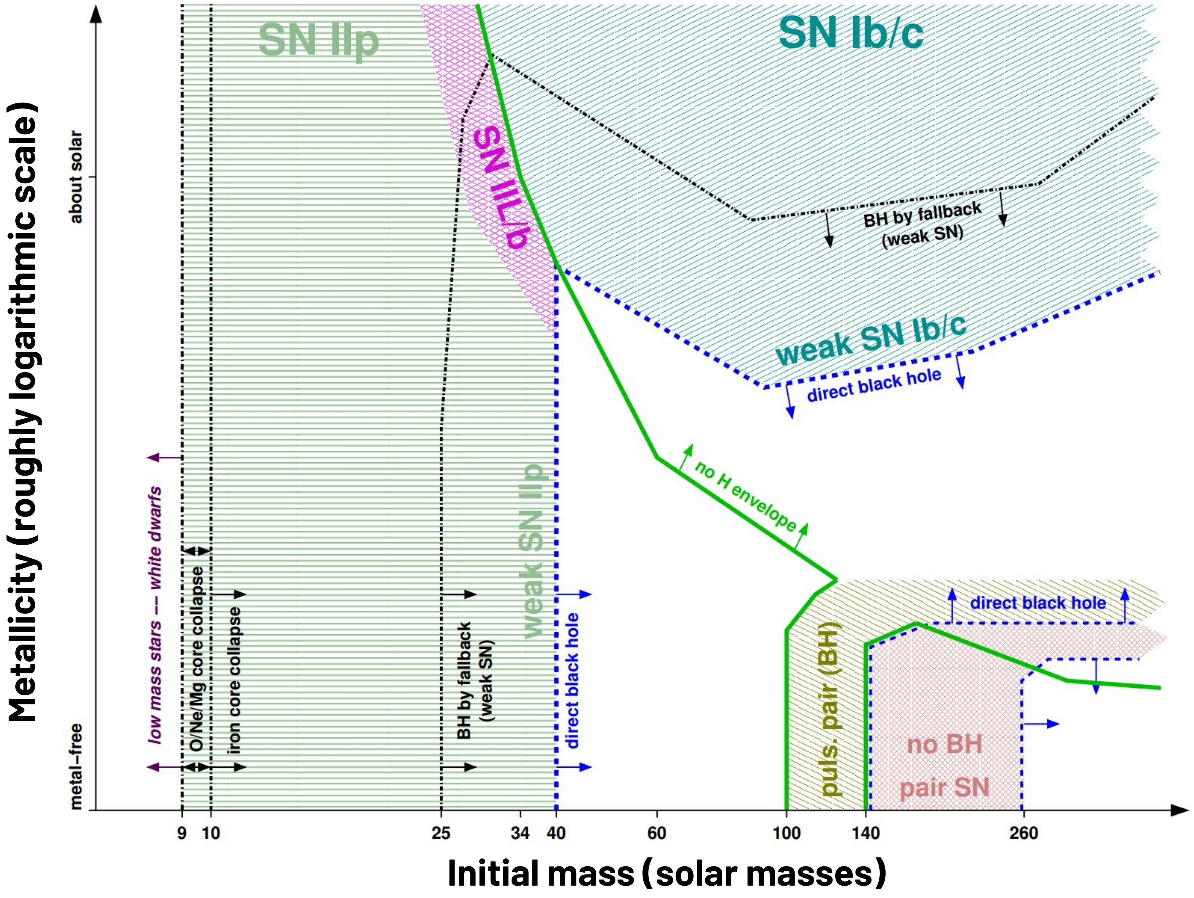
Definition

Basic properties of Type II Supernova

Progenitor Mass	• Typically originates from massive stars with an initial mass ≥8 to ~40 M☉ (M☉ ≈ 2×10^{33} kg).
Spectrum Features	• Hydrogen lines (Hα) are present in the optical spectrum, distinguishing Type II from Type I supernovae.
Light Curve	• Plateau (II-P), Linear decline (II-L), or Narrow emission (IIn) • Brightness decline slower than Type I Supernova
Energy Released	• ~10^{51} ergs (kinetic), ~10^{53} ergs (neutrinos)

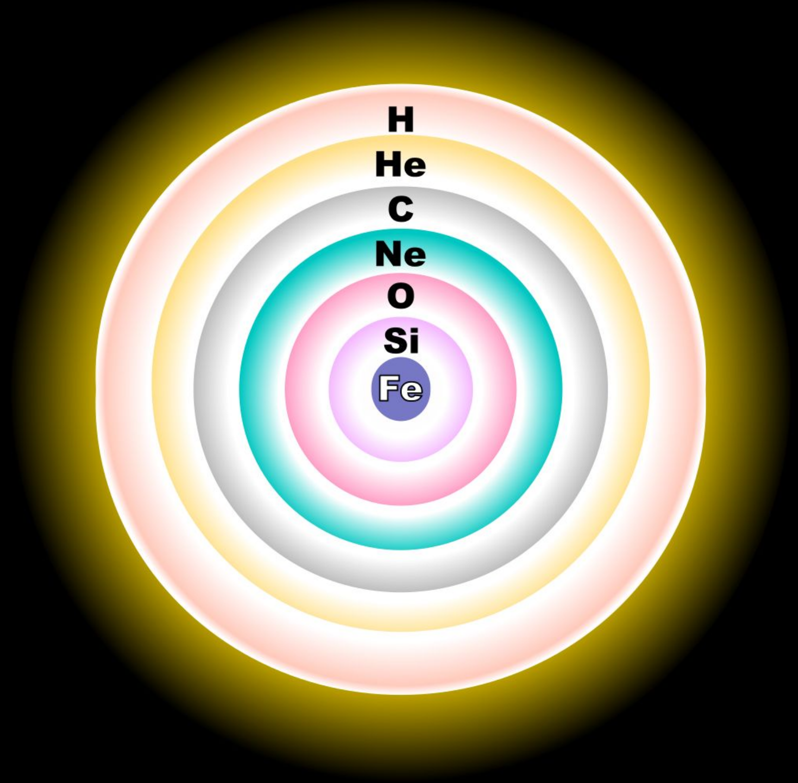
Progenitor Mass

Credit by Heger (2003) Fig. 2. Supernovae Types of non-rotating massive single stars as a function of initial metallicity and initial mass.



Formation

The onion-like layers of a massive, evolved star just before core collapse



Evolved star fusion shells Credit by R. J. Hall

This diagram shows a simplified (not to scale) cross-section of a massive, evolved star.

Where the pressure and temperature permit, concentric shells of Hydrogen (H), Helium (He), Carbon (C), Neon/Magnesium (Ne), Oxygen (O) and Silicon (Si) plasma are burning inside the star.

The resulting fusion by-products rain down upon the next lower layer, building up the shell below.

As a result of Silicon fusion, an inert core of Iron (Fe) plasma is steadily building up at the center.

Once this core reaches the Chandrasekhar mass, the iron can no longer sustain its own mass and it undergoes a collapse. This can result in a supernova explosion.

Core Collapse

(a) A massive, evolved star has onion-layered shells of elements undergoing fusion. An inert iron core is formed from the fusion of Silicon in the innermost shell.

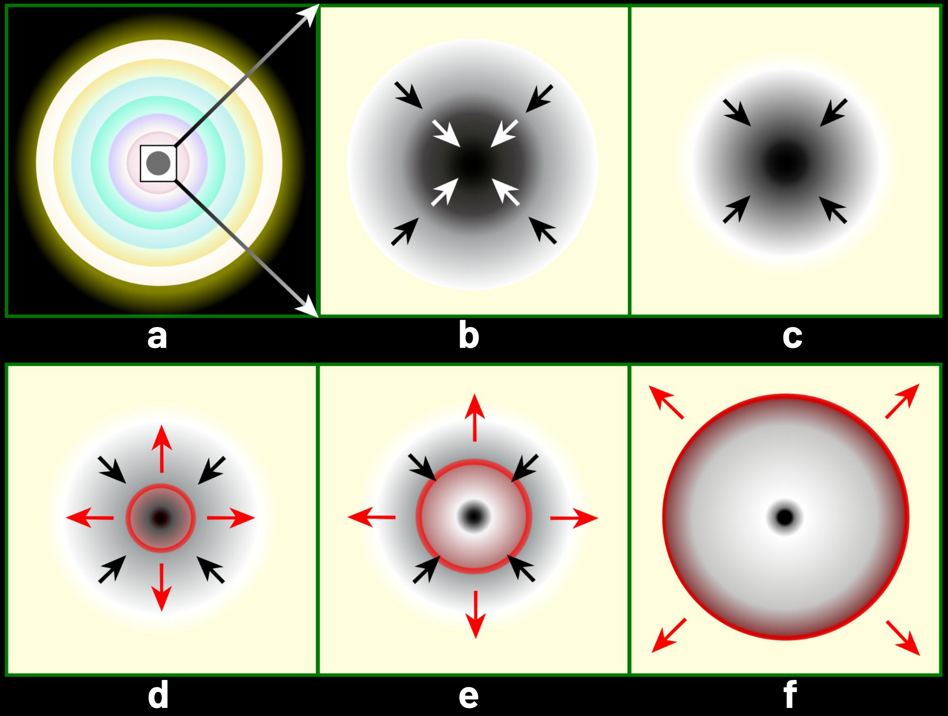
(b) This iron core reaches Chandrasekhar-mass and starts to collapse.

(c) The inner core compresses into neutrons and the gravitational energy is converted into neutrinos.

(d) The infalling material bounces off the nucleus and forms an outward-propagating shock wave (red).

(e) The shock begins to stop as nuclear processes run energy away, but it is re-invigorated by interaction with neutrinos.

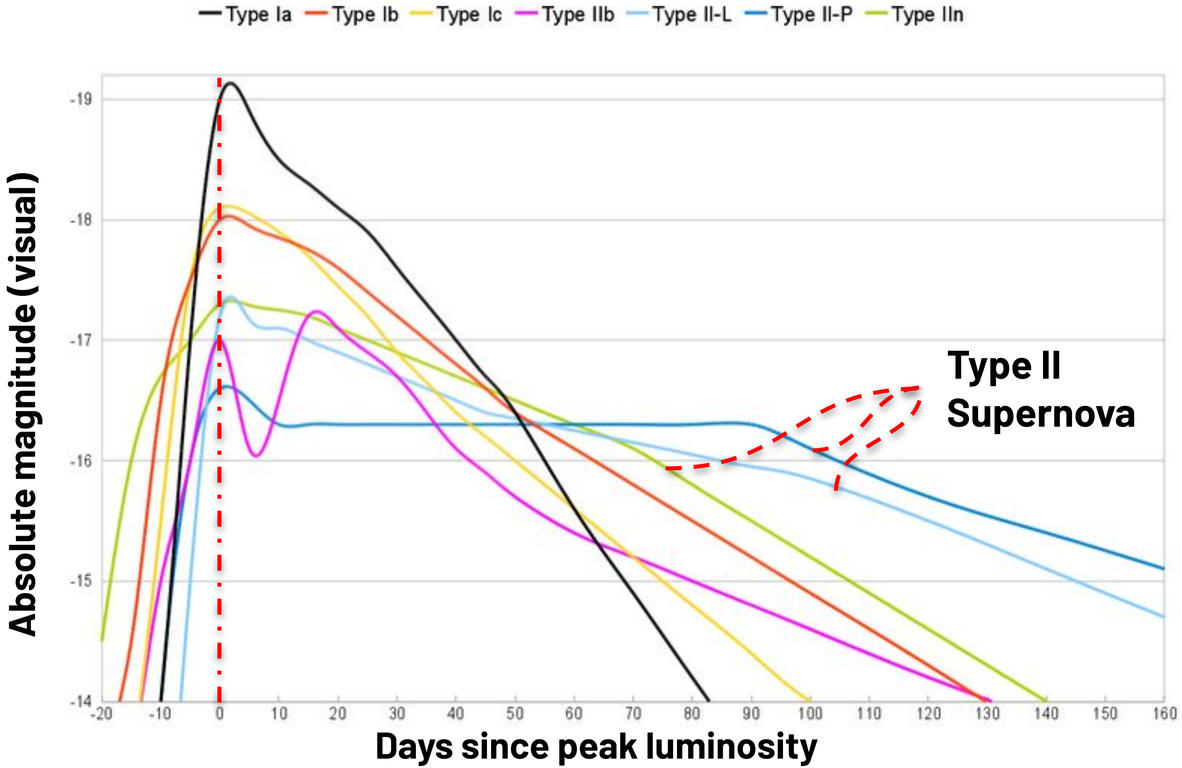
(f) The material outside the inner core is ejected, leaving behind only a degenerate remnant.



Core collapse scenario Credit by R. J. Hall

Light Curve of Supernova

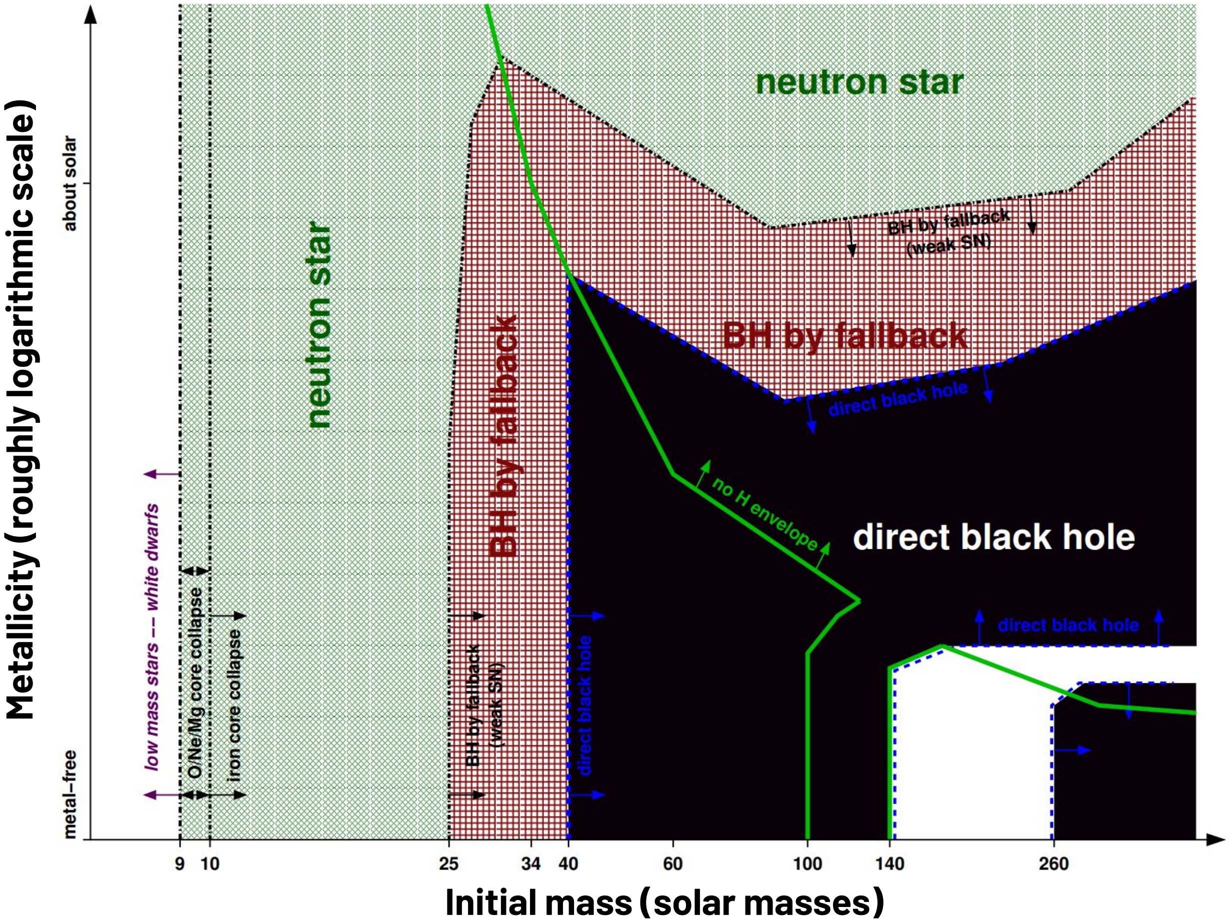
Type II Supernovae are primarily distinguished by a much slower decline in luminosity when compared to the days after the event, highlighted by a prolonged plateau.



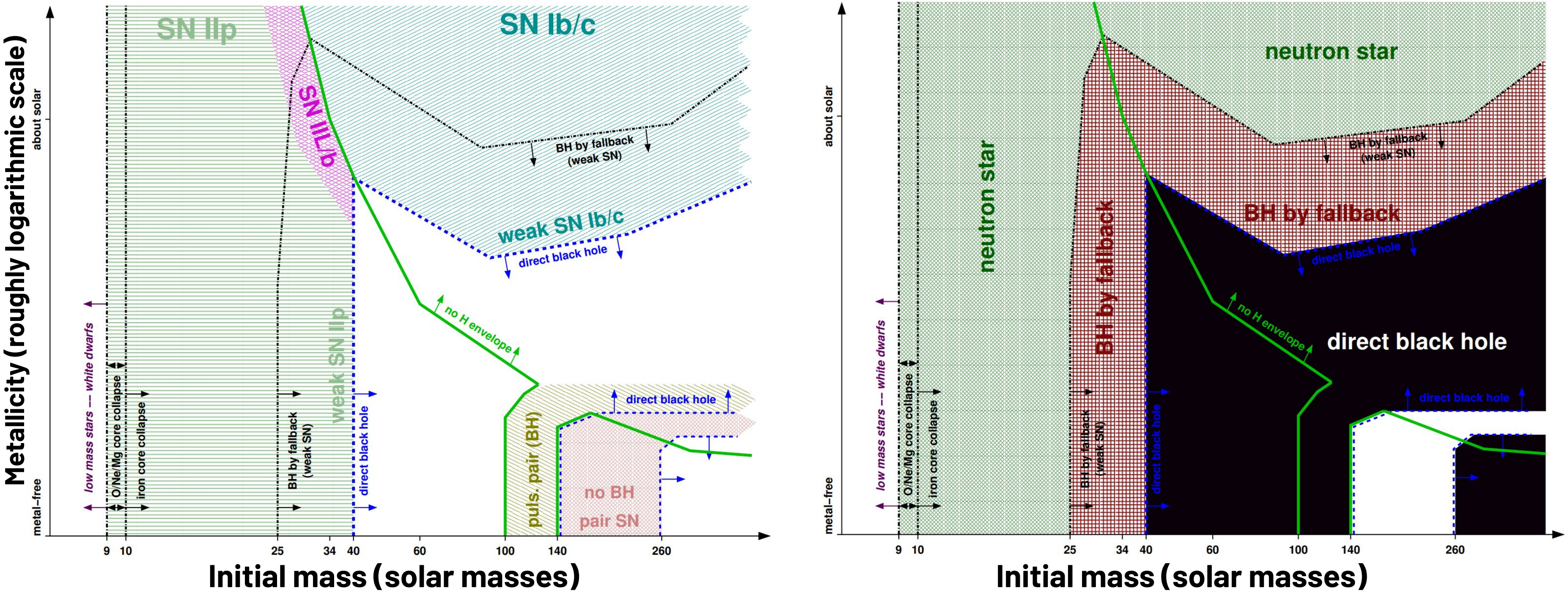
Credit belongs to Lithopsian

Remnants of Supernova

Credit by Heger (2003) Fig. 1. Remnants of massive single stars as a function of initial metallicity and initial mass.



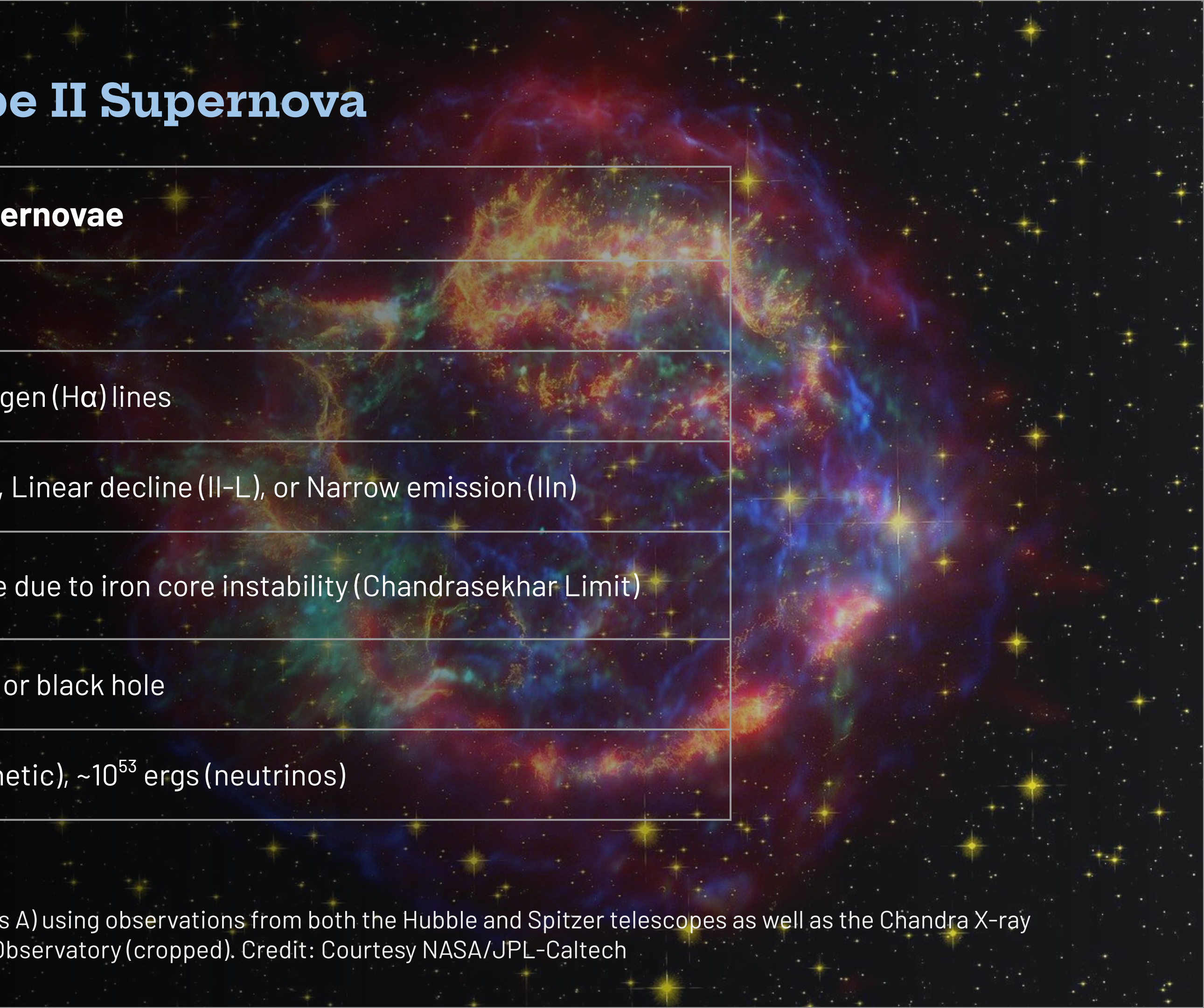
Compare Progenitor Mass and Remnants of SN



Credit by Heger (2003) Fig. 1&2.

Final Profile of Type II Supernova

Property	Type II Supernovae
Progenitor Mass	~8 – 40 $M_\odot$
Spectrum	Strong hydrogen (Hα) lines
Light Curve	Plateau (II-P), Linear decline (II-L), or Narrow emission (IIn)
Explosion Mechanism	Core collapse due to iron core instability (Chandrasekhar Limit)
Remnant	Neutron star or black hole
Energy Released	~10^{51} ergs (kinetic), ~10^{53} ergs (neutrinos)



A false color image of Cassiopeia A (Cas A) using observations from both the Hubble and Spitzer telescopes as well as the Chandra X-ray Observatory (cropped). Credit: Courtesy NASA/JPL-Caltech

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THANK YOU

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DLC (Additional Content)

Type II-b Supernova

A Type IIb supernova has a weak hydrogen line in its initial spectrum, which is why it is classified as a Type II. However, later on the H emission becomes undetectable, and there is also a second peak in the light curve that has a spectrum which more closely resembles a Type Ib supernova.

SN 1993J Credit by NASA, ESA, and G. Bacon (STScl)

NGC 3184 Credit by Bernese Highlands, et al.

Type V Supernova (Supernova imposters)

Supernova impostors are stellar explosions that appear at first to be a supernova but **do not destroy their progenitor stars**. As such, they are a class of extra-powerful novae.

Origin of the Plateau Phase

- After the core collapses and the star explodes, a **shock wave** propagates through the outer layers, causing the ejected material to heat up and emit radiation.
- Initially, the supernova is powered by the **shock-deposited energy** from the explosion and **radioactive decay** (mainly **56Ni→56Co→56Fe**), making it very bright.
- In Type II-P supernovae, the progenitor retains a **thick hydrogen envelope** before explosion.
- As the ejecta expand, the hydrogen remains **fully ionized (hot plasma)** for an extended period.
- Eventually, as the ejecta cool, **hydrogen begins to recombine** (protons and electrons combine to form neutral hydrogen atoms).
- This **recombination releases energy**, maintaining a relatively stable luminosity for **~100 days** → forming the **plateau**.