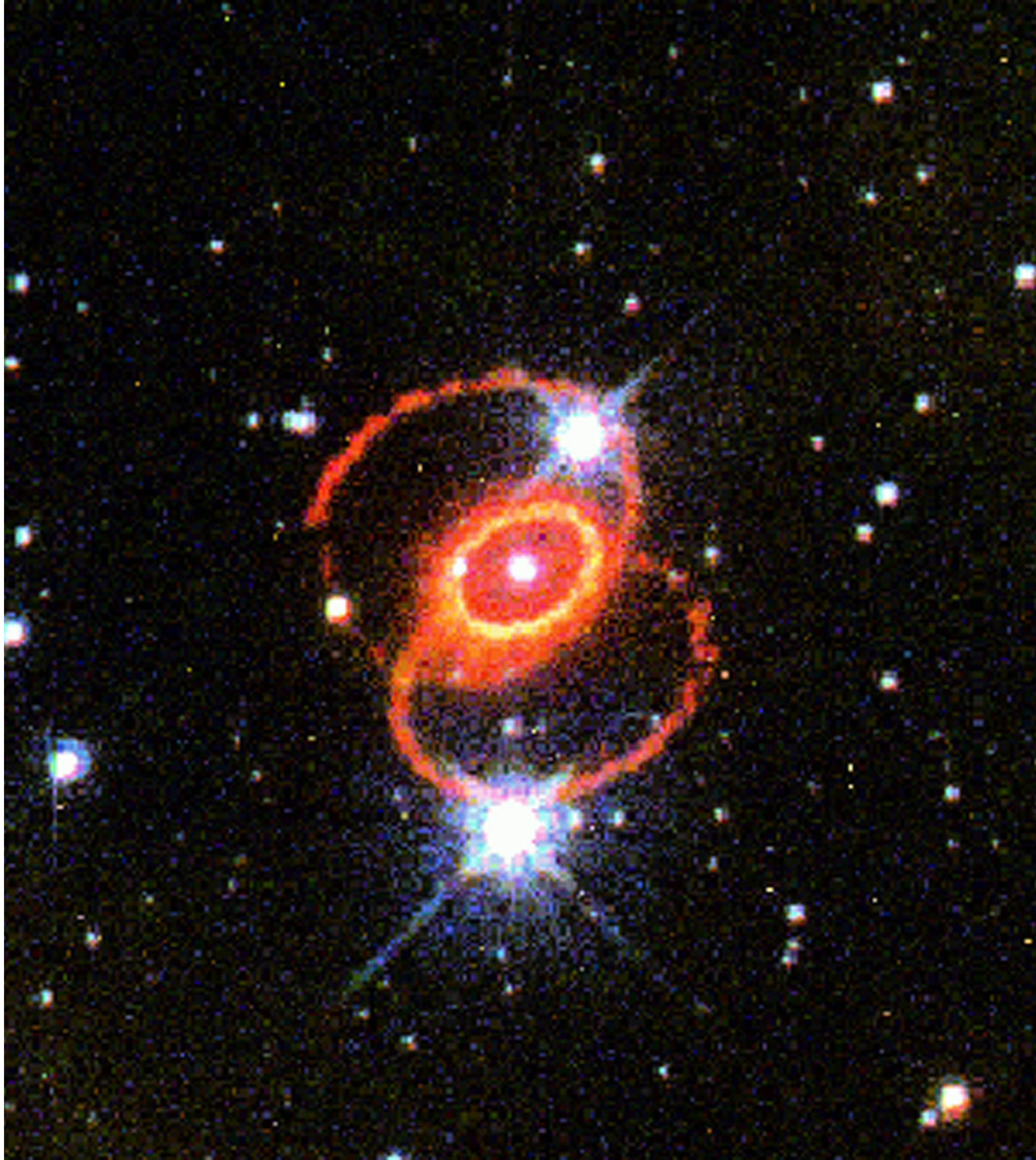
PHY 4905 | Modern Astrophysics

Lecture IV.

Supernovae

UF UNIVERSITY of FLORIDA

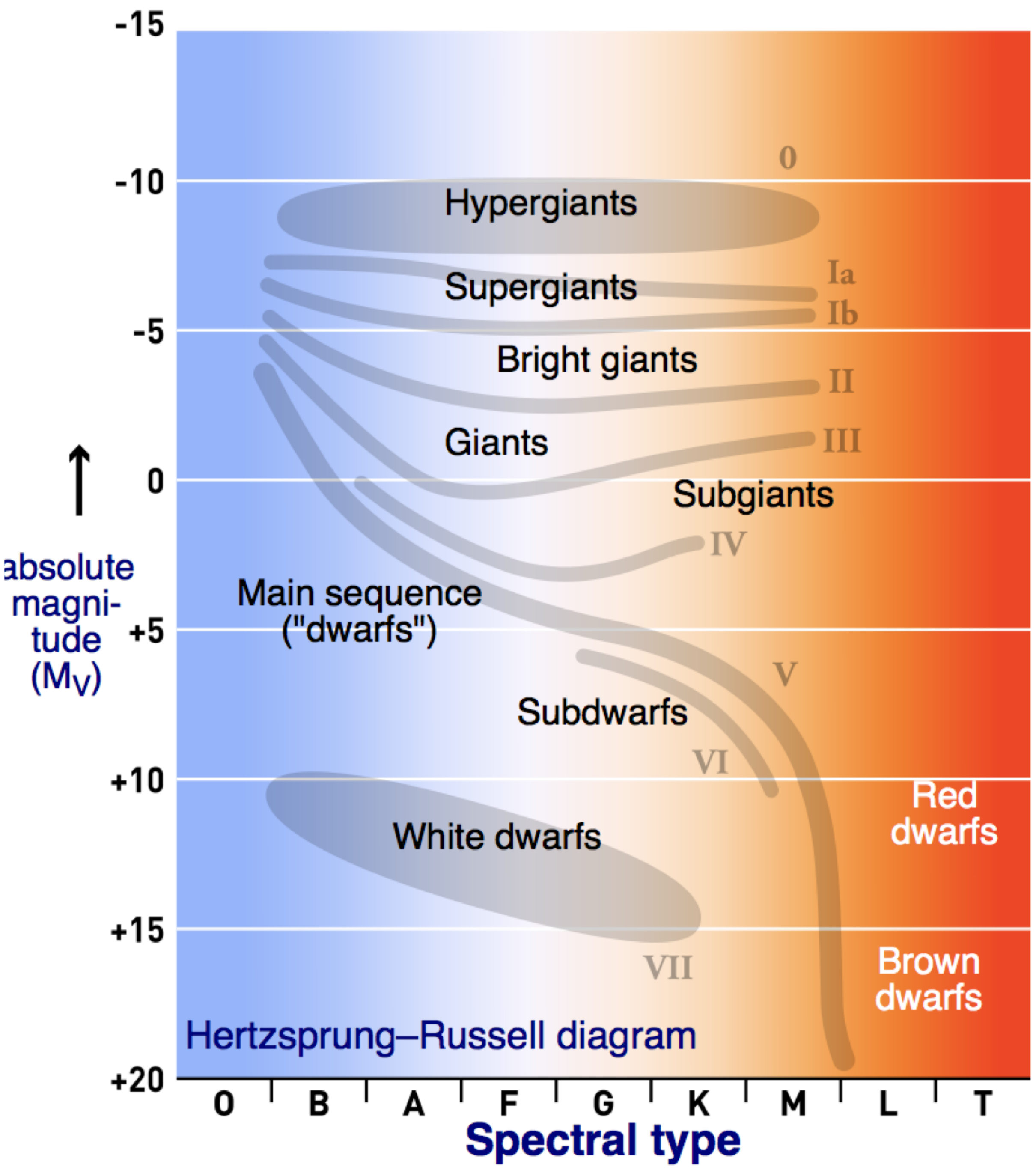
Imre Bartos | Fall 2018



Originally, stars were assigned a type A to Q based on the strength of the hydrogen lines present in their spectra. However, it was later realised that there was significant overlap between the types, and some of the letters were dropped. Continuity of other spectral features was also improved if B came before A and O came before B, with the end result, the spectral sequence: OBAFGKM. This sequence is ordered from the hottest to the coolest stars (http://astronomy.swin.edu.au/cosmos/H/Harvard+Spectral+Classification)

The spectral classes O through M […] are subdivided by Arabic numerals (0–9), where 0 denotes the hottest stars of a given class. (https://en.wikipedia.org/wiki/Stellar_classification)

Yerkes spectral classification
This two-dimensional (temperature and luminosity) classification scheme is based on spectral lines sensitive to stellar temperature and surface gravity, which is related to luminosity (whilst the Harvard classification is based on just surface temperature).



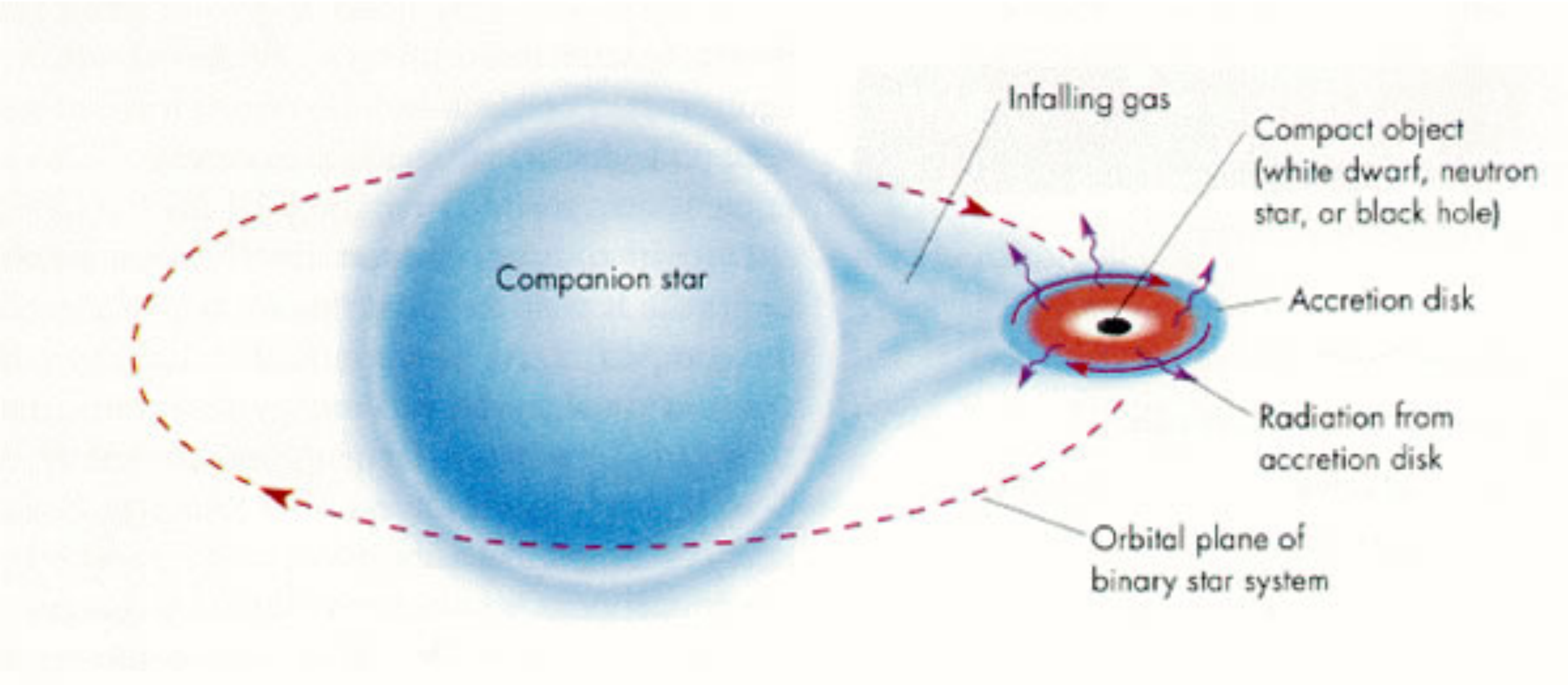
Classification

Absorption line and light curve

<table>
<tr><td rowspan="3">Type I
No hydrogen</td><td colspan="3">Type Ia
Presents a singly ionized silicon (Si II) line at 615.0 nm (nanometers), near peak light</td><td>Thermal runaway</td></tr>
<tr><td rowspan="2">Type Ib/c
Weak or no silicon absorption feature</td><td colspan="2">Type Ib
Shows a non-ionized helium (He I) line at 587.6 nm</td><td rowspan="6">Core collapse</td></tr>
<tr><td colspan="2">Type Ic
Weak or no helium</td></tr>
<tr><td rowspan="4">Type II
Shows hydrogen</td><td rowspan="3">Type II-P/L/N
Type II spectrum throughout</td><td rowspan="2">Type II-P/L
No narrow lines</td><td>Type II-P
Reaches a "plateau" in its light curve</td></tr>
<tr><td>Type II-L
Displays a "linear" decrease in its light curve (linear in magnitude versus time).[47]</td></tr>
<tr><td colspan="2">Type IIn
Some narrow lines</td></tr>
<tr><td colspan="3">Type IIb
Spectrum changes to become like Type Ib</td></tr>
</table>

https://en.wikipedia.org/wiki/Supernova

Novae



http://astro.hopkinsschools.org

Core collapse supernovae

Most relevant:
Iron-core collapse

When iron core reaches Chandrasekhar mass (1.4 Msun) when it overcomes electron degeneracy

Typical energy released: 10^53 erg

Can we estimate this?

99% is released as neutrinos

What is the neutrino flux at Earth?

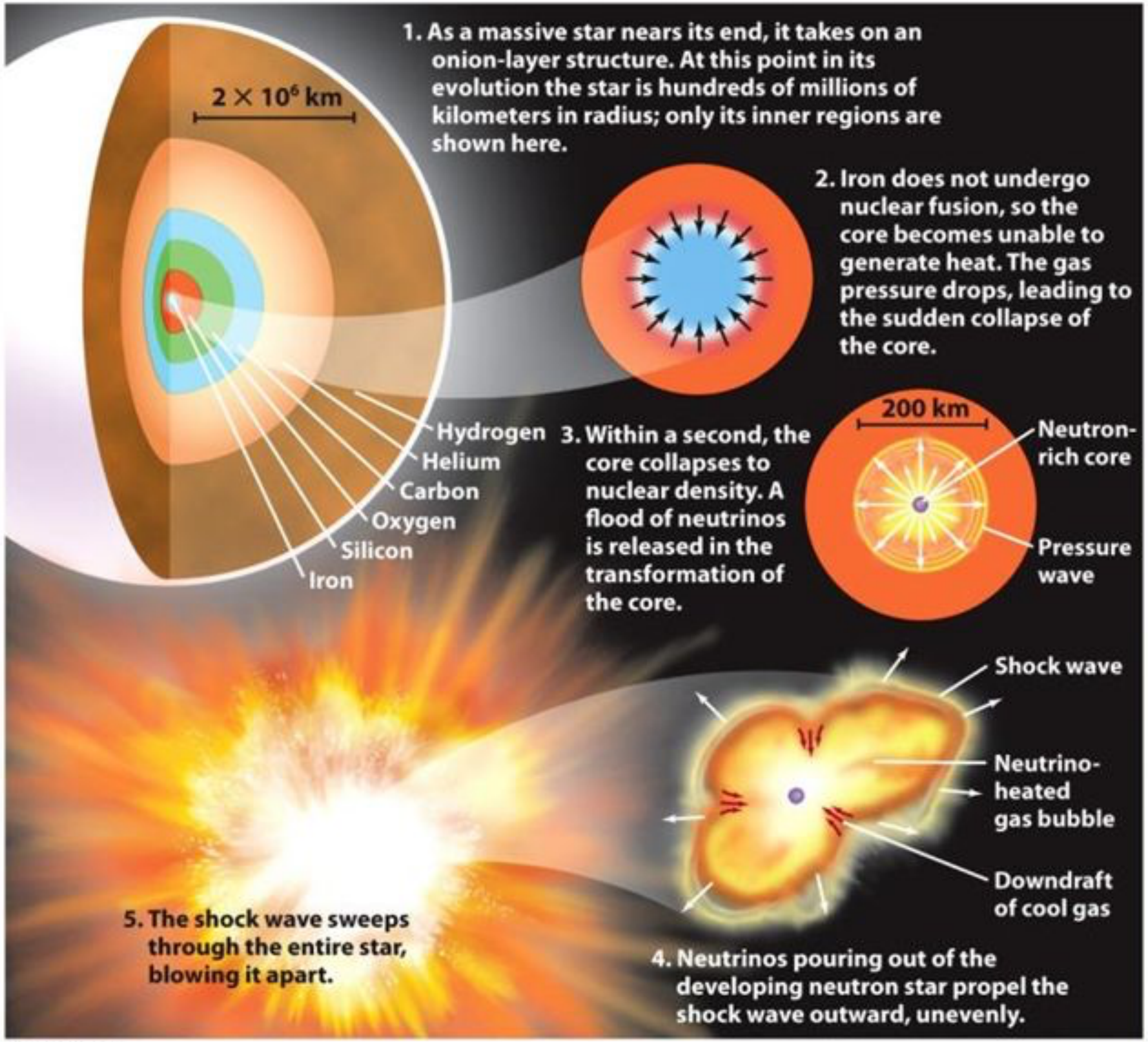
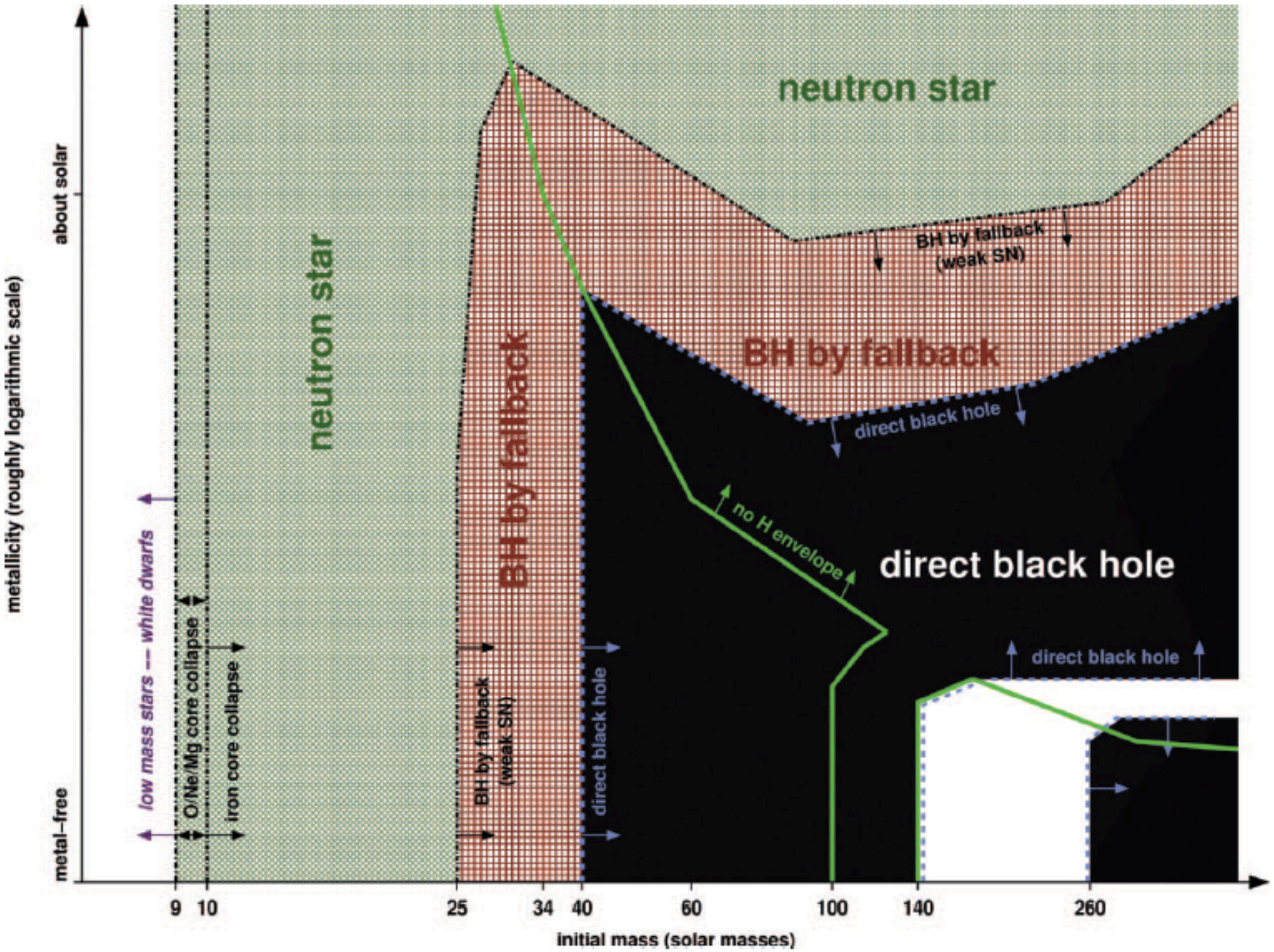


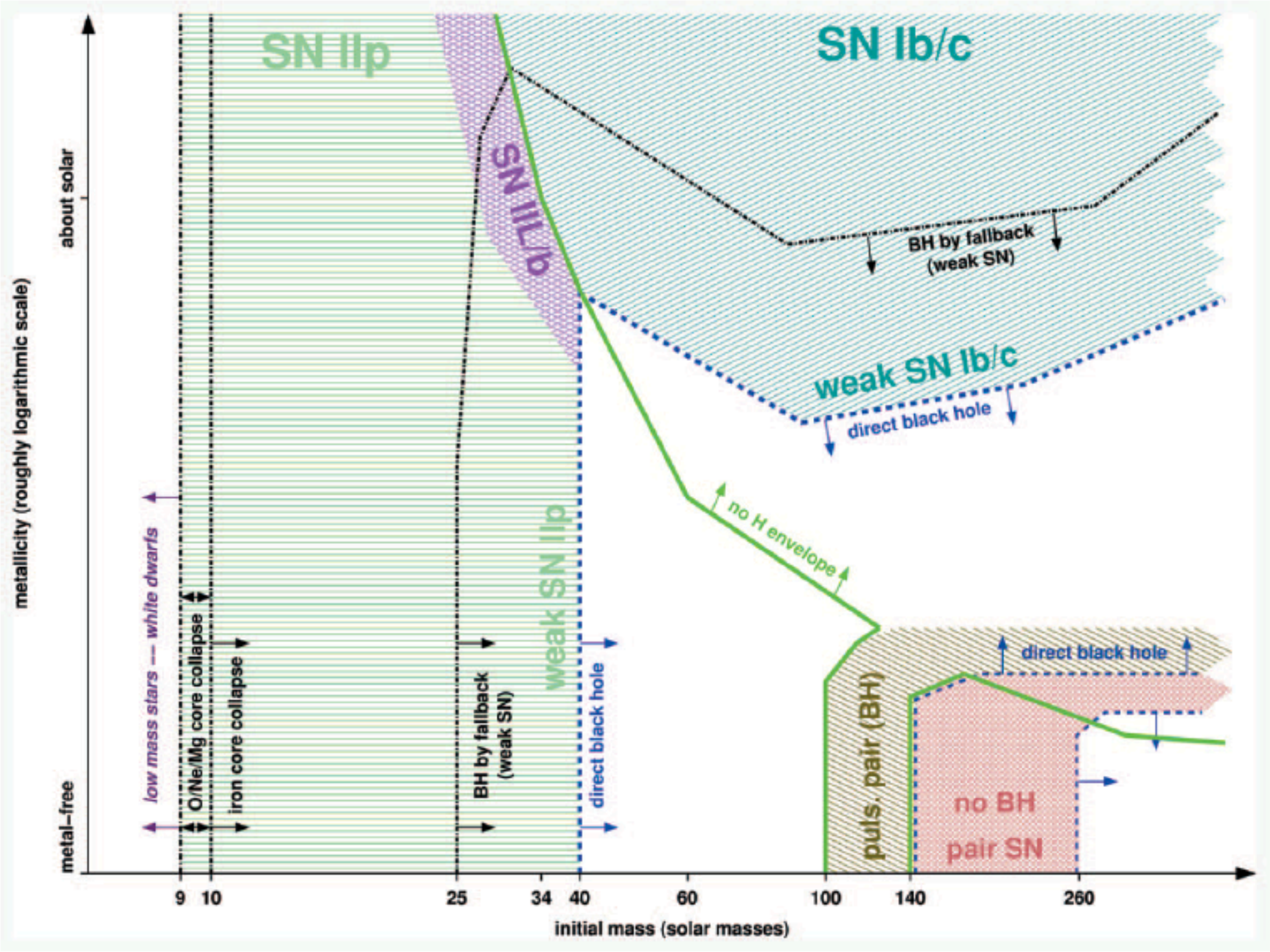
Figure 20-14
Universe, Tenth Edition
Illustration by Don Dixon, adapted from Wolfgang Hillebrandt, Hans-Thomas Janka, and Ewald Müller, "How to Blow Up a Star," *Scientific American*, October 2006

Remnant



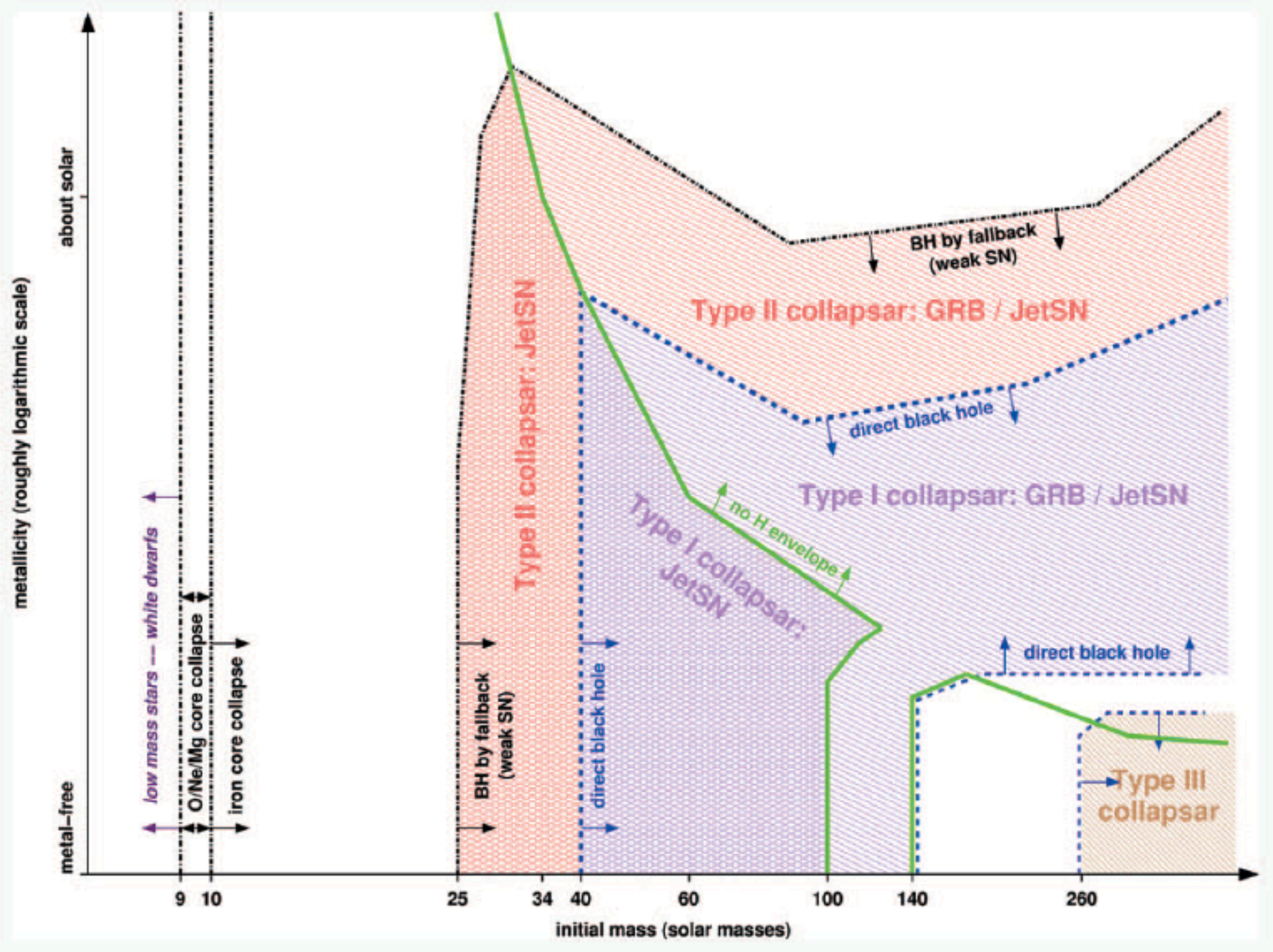
Heger+ ApJ 2003

Supernova explosion



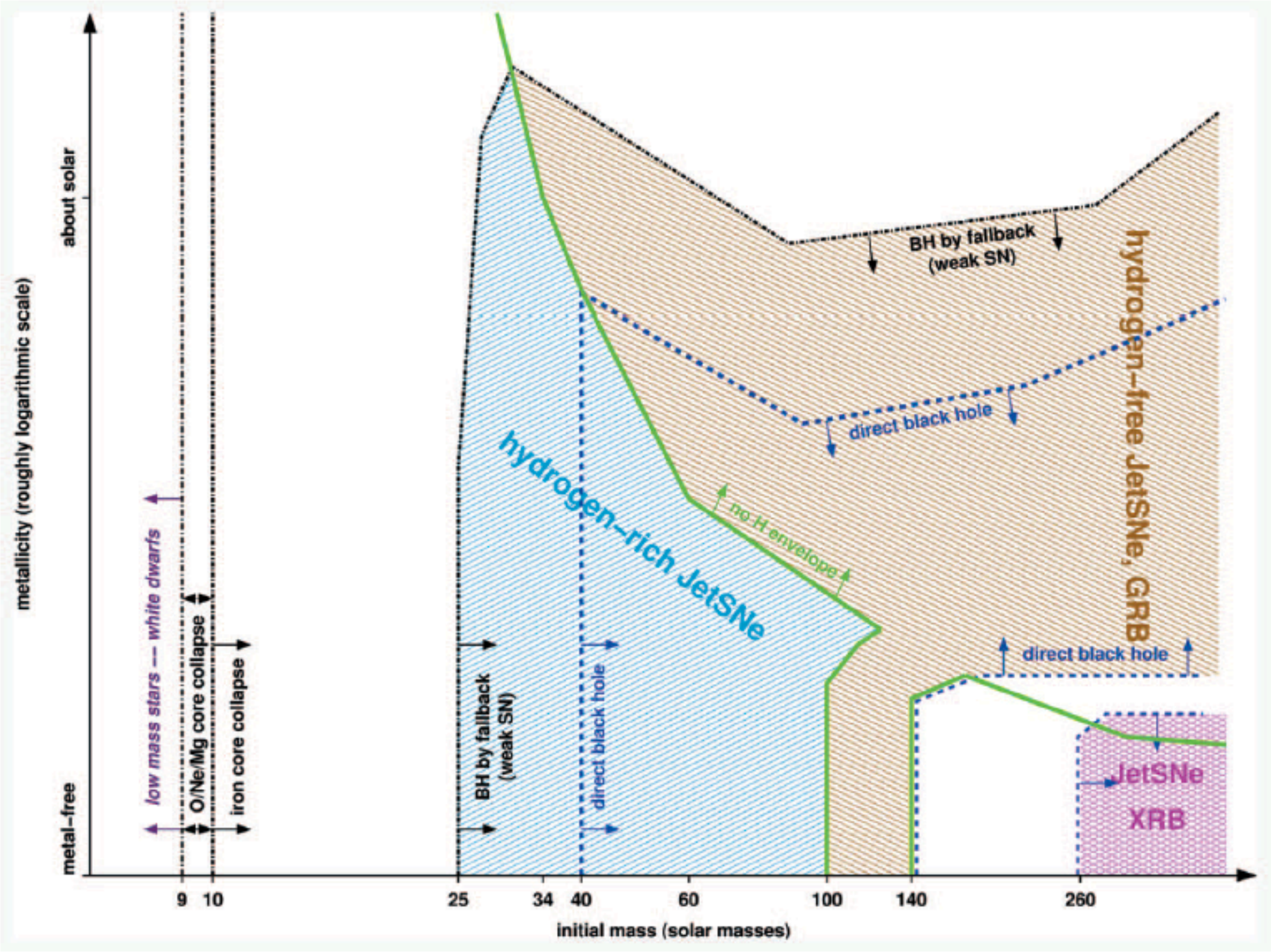
Heger+ ApJ 2003

Collapsars



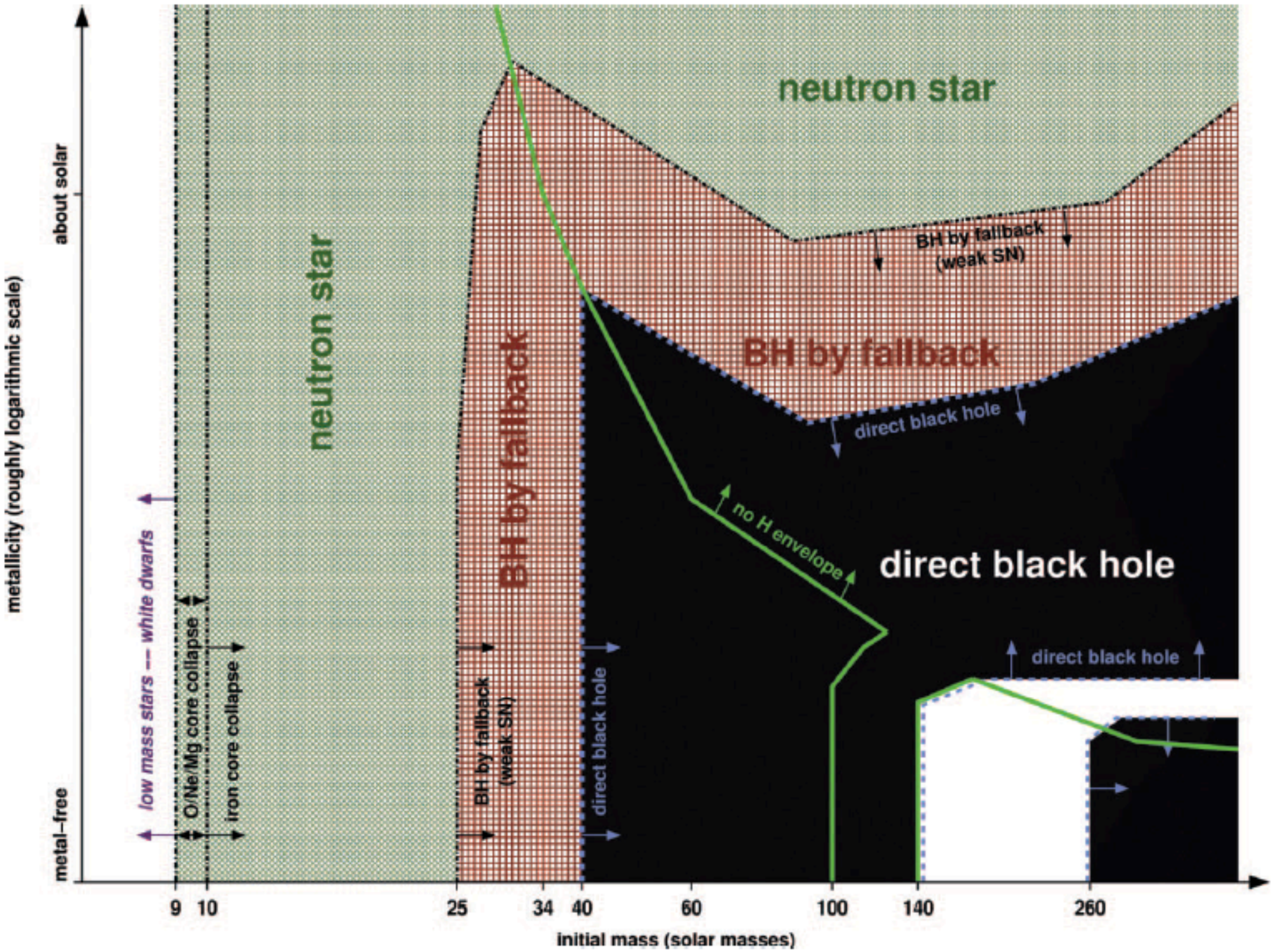
Heger+ ApJ 2003

Beamed outflow (jet)



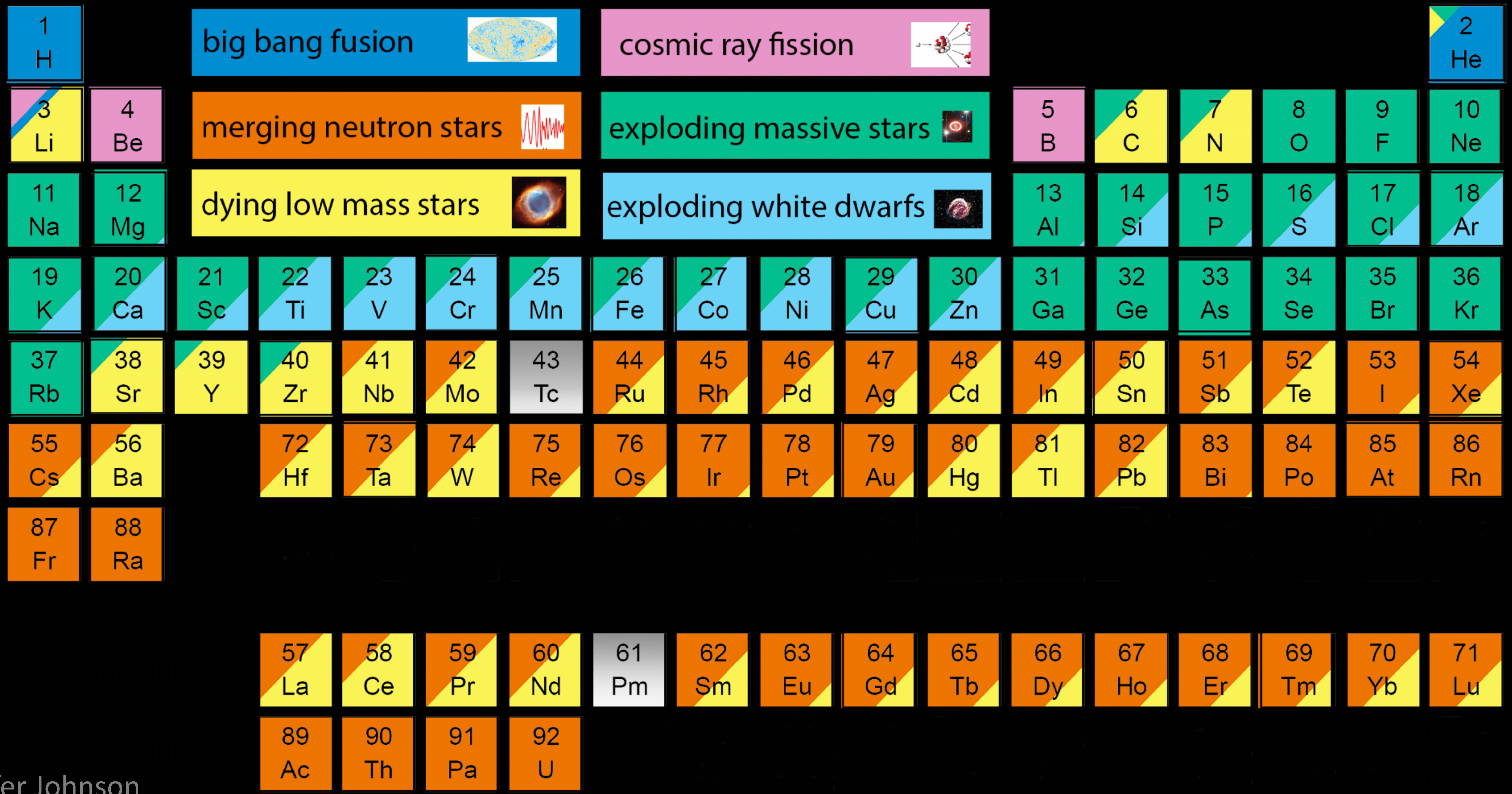
Heger+ ApJ 2003

Remnant



Heger+ ApJ 2003

The Origin of the Solar System Elements



Jennifer Johnson

SN 1987A

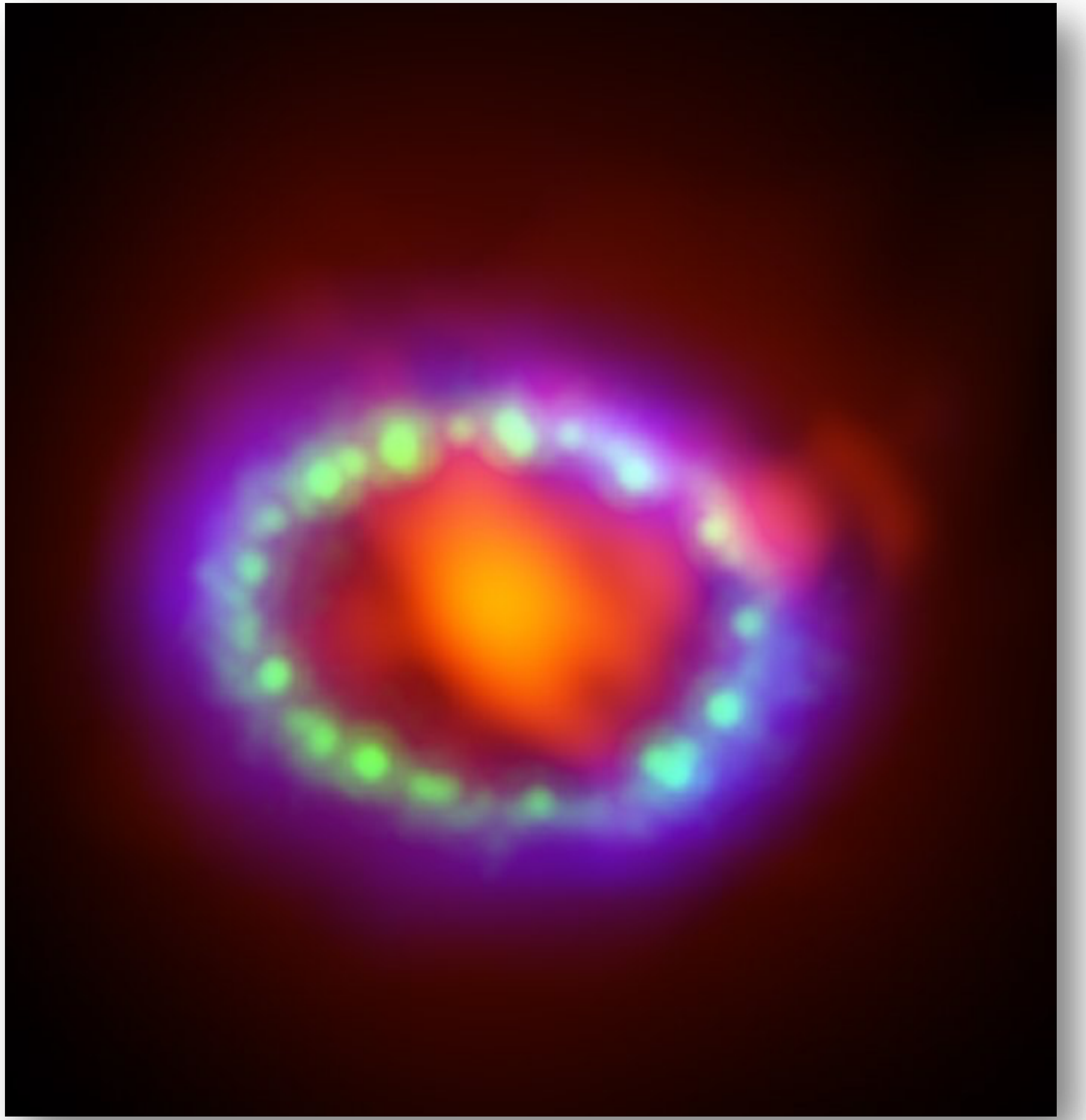
In Large Magellanic Cloud at ~50 kpc

Progenitor star: blue supergiant

Visible to the naked eye from the Southern hemisphere

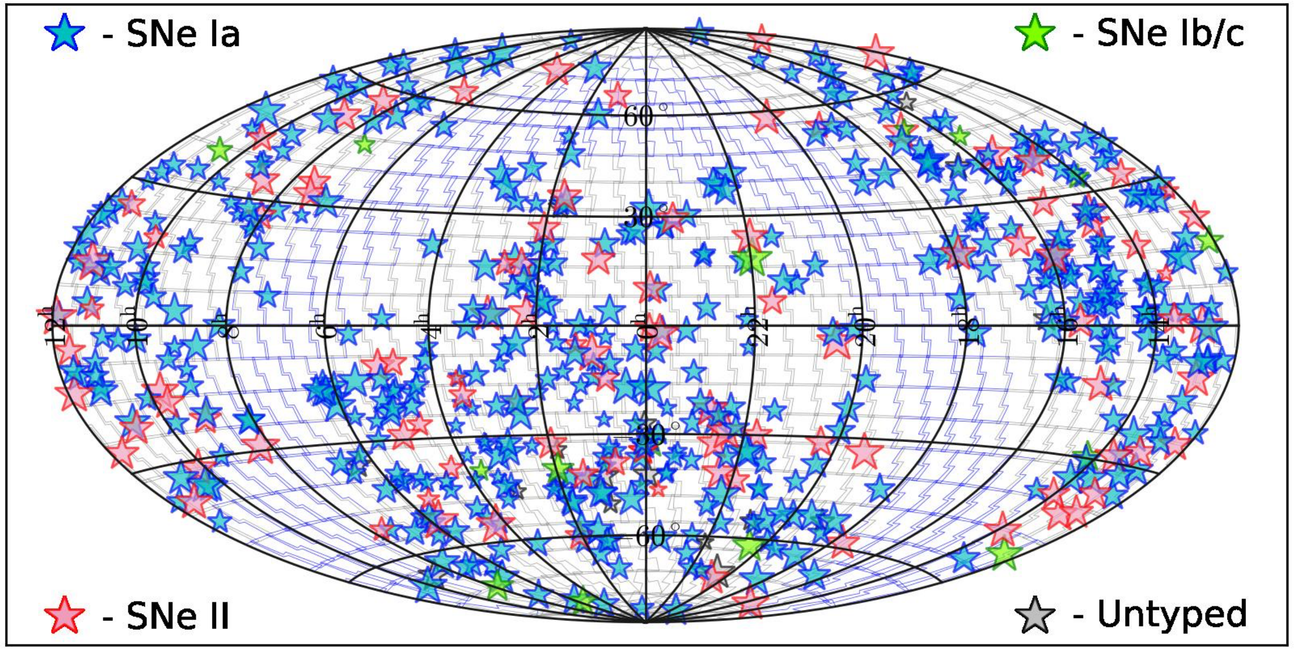
Detection of 25 neutrinos
2-3 hours before the first light was detected

No NS remnant has been observed



Observations

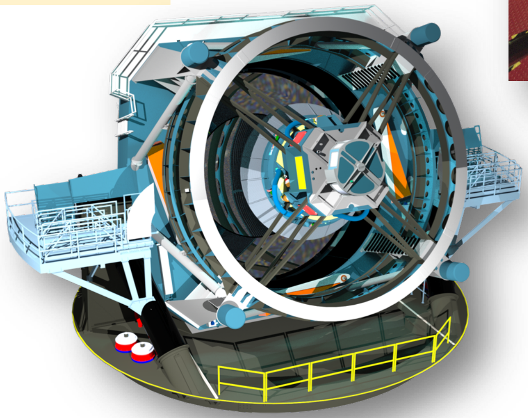
ASAS-SN

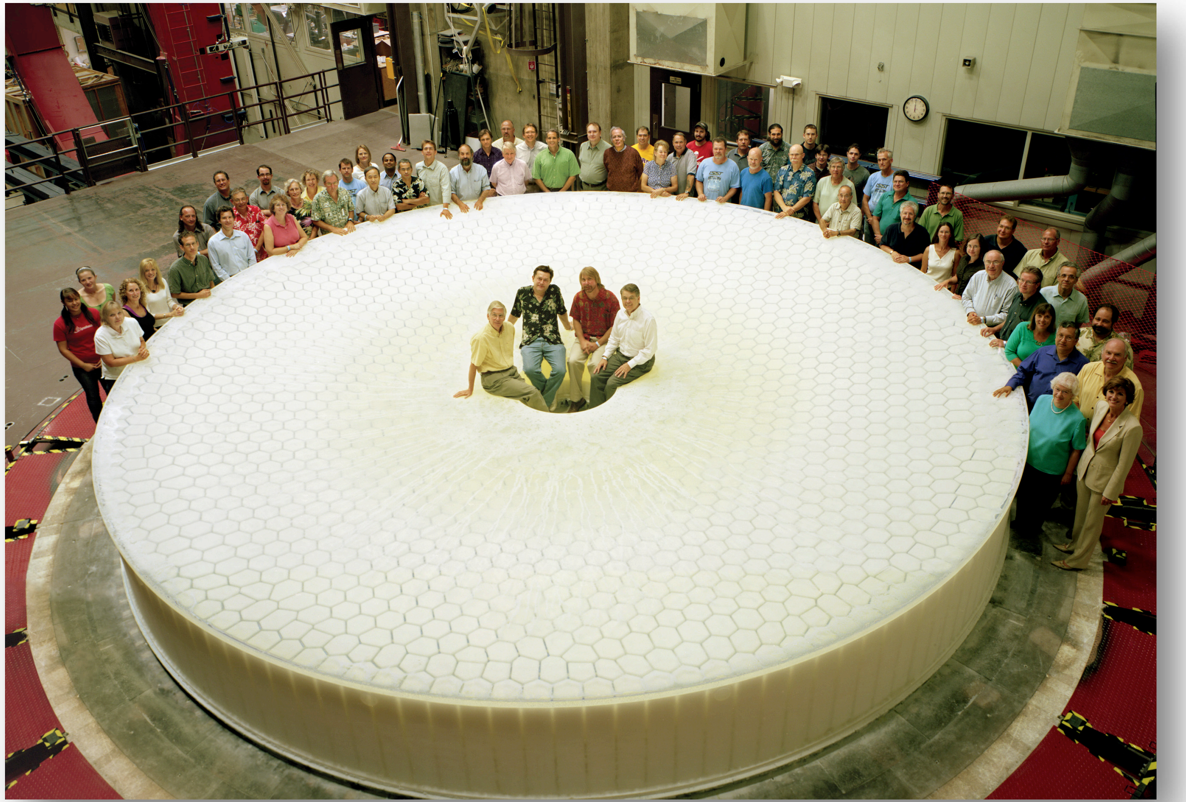


Multiple, very small telescopes that scan the whole sky every night.

Observations

Zwicky Transient Facility (ZTF)
Regular scans of the sky, rapid ToO response





Large Synoptic Survey Telescope (LSST, 2022)
Regular scans of the sky, very high sensitivity (9m)

Detections

Type Ia --- standard candle for cosmic distance ladder

Gravitational waves --- maybe only from galactic CCSNe?

Neutrino observations

Process	Typical $\lvert h \rvert$ (at 10 kpc)	Typical f (Hz)	Duration Δt (ms)	E_{GW} $(10^{-10}\,M_\odot c^2)$	Limiting factors or processes
Prompt convection	10^{-23}–10^{-21}	50–1000	0 to $\sim$30	$\lesssim 0.01$–10	Seed perturbations, entropy/lepton gradient, rotation
	(Emission characteristics depend on seed perturbations.)				
PNS convection	2–5×10^{-23}	300–1500	500 to several 1000	$\lesssim 1.3\left(\frac{\Delta t}{1s}\right)$	Rotation, BH formation, strong PNS g-modes
Neutrino-driven convection and SASI	10^{-23}–10^{-22} (peaks up to 10^{-21})	100–800	100 to $\gtrsim$1000	$\gtrsim 0.01\left(\frac{\Delta t}{100\text{ ms}}\right)$ $\lesssim 15\left(\frac{\Delta t}{100\text{ ms}}\right)$	Rotation, explosion, BH formation

Ott CQG 2008