Neutrinos & Supernova Nucleosynthesis

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Neutrino & Nuclear Astrophysics
2014 International Summer School on Astrocomputing
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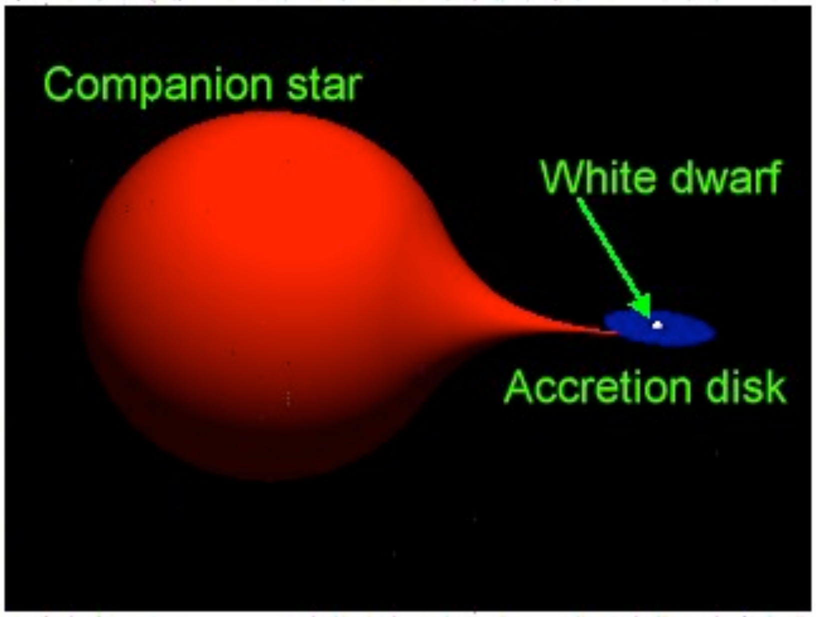
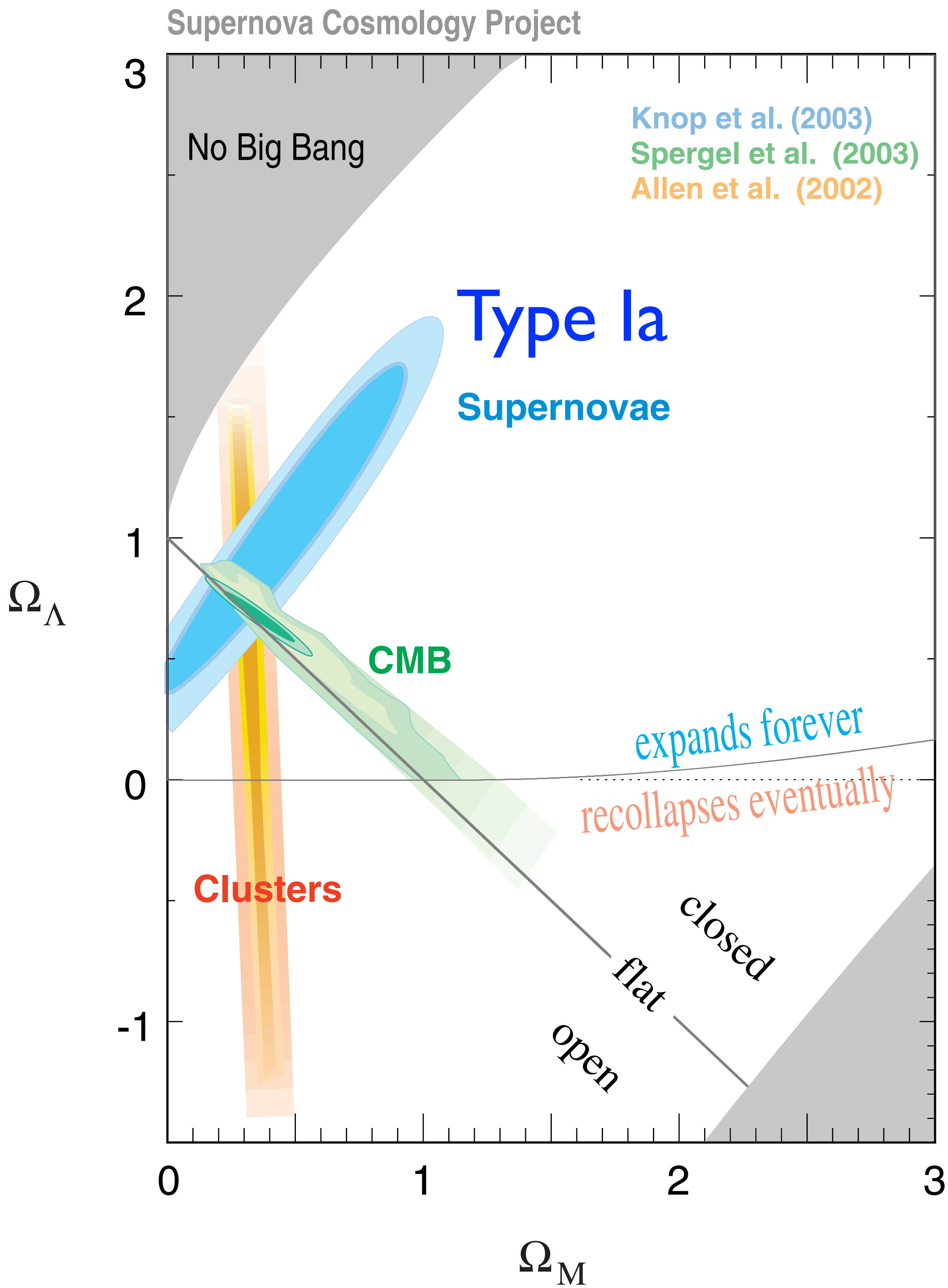
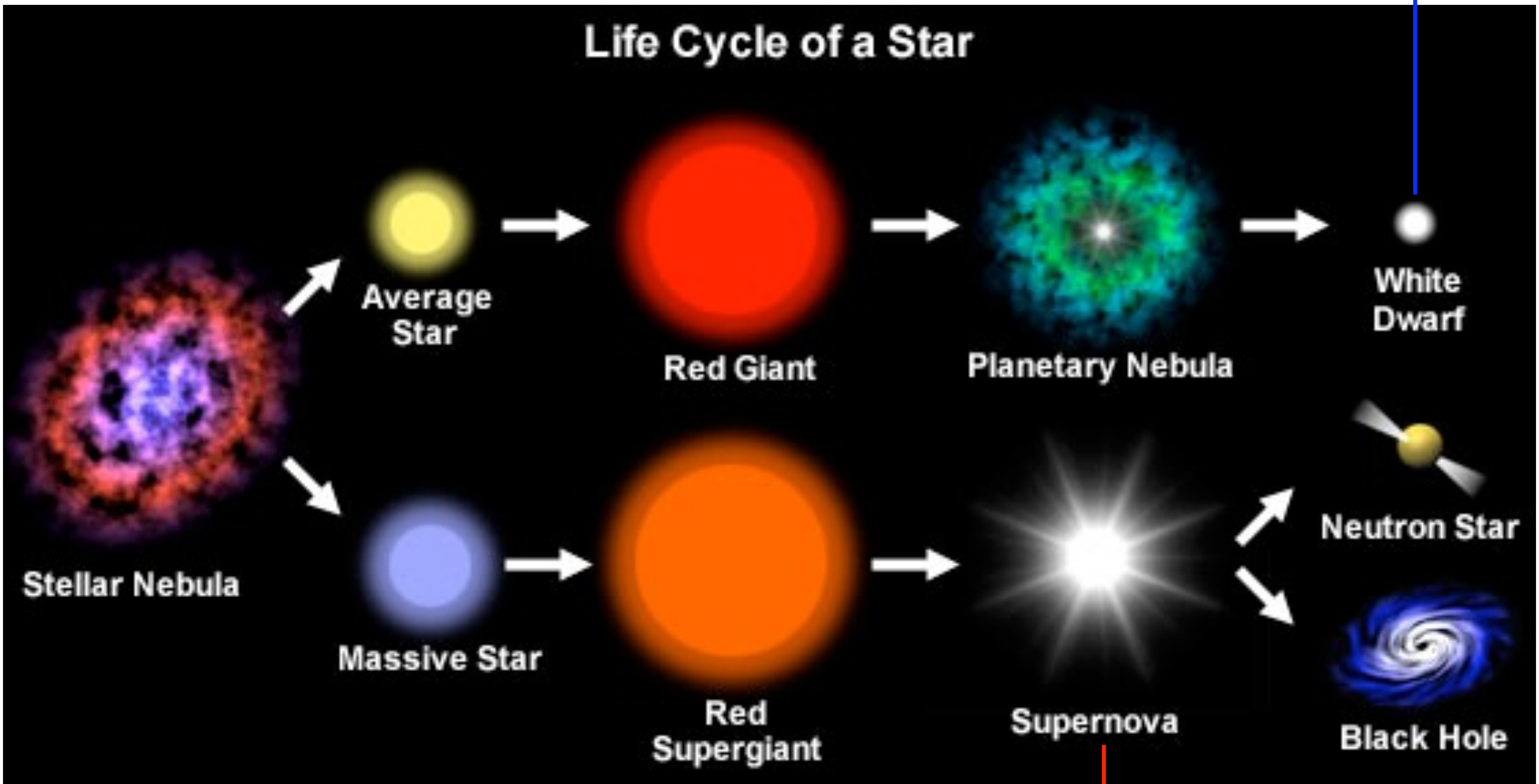

Companion star
White dwarf
Accretion disk

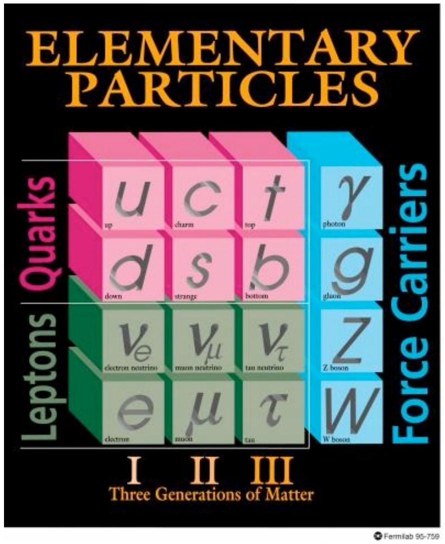

BERKELEY LAB


Supernova Cosmology Project
Knop et al. (2003)
Spergel et al. (2003)
Allen et al. (2002)
No Big Bang
Type Ia
Supernovae
CMB
Clusters
expands forever
recollapses eventually
closed
flat
open
Ω_Λ
Ω_M
3
2
1
0
-1
0
1
2
3

Type Ia SNe



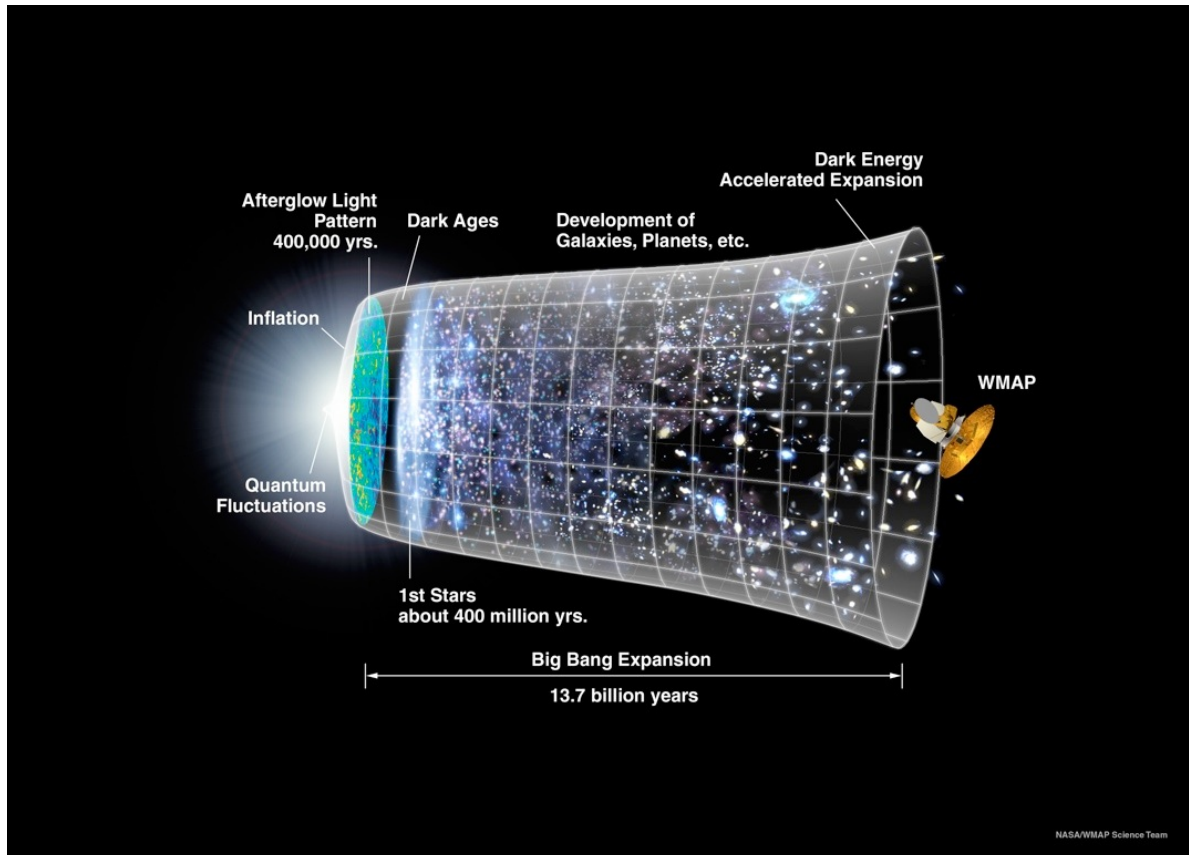
core-collapse SNe (mostly Type II)



Some of the Biggest Questions Connecting Quarks and the Cosmos

Board on Physics and Astronomy
US National Academy of Sciences

- What are the masses of the neutrinos, and how have they shaped the evolution of the universe?
- How were the elements from iron to uranium made?



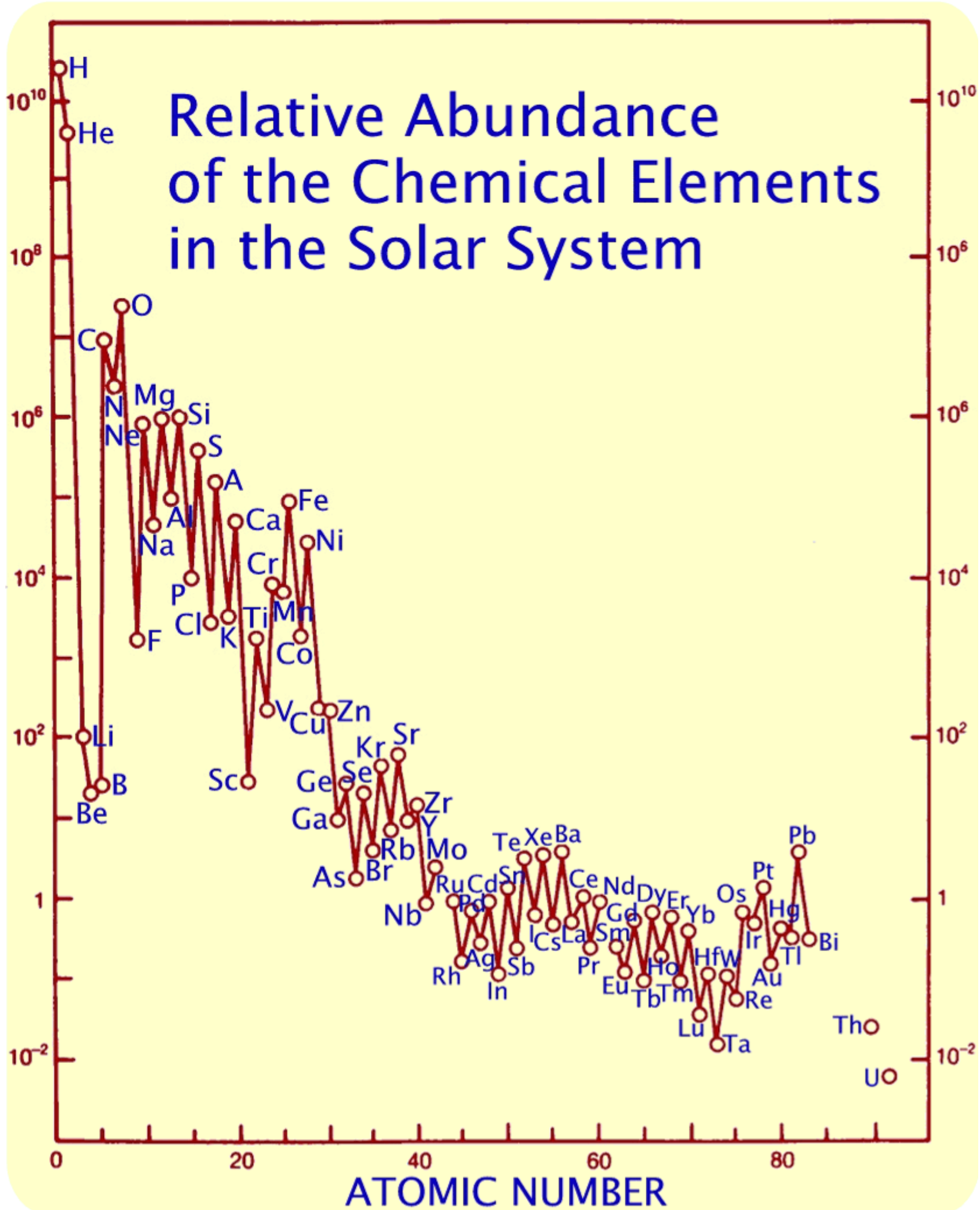
Big Bang:

75% H + 25% He
(by mass)

Sun:

70.7% H + 27.4% He
+1.9% “Metals”

$$\text{“}p\text{”} \rightarrow \text{“}n\text{”} + e^+ + \nu_e$$



How to Become a Star

Virial theorem for a contracting gas cloud

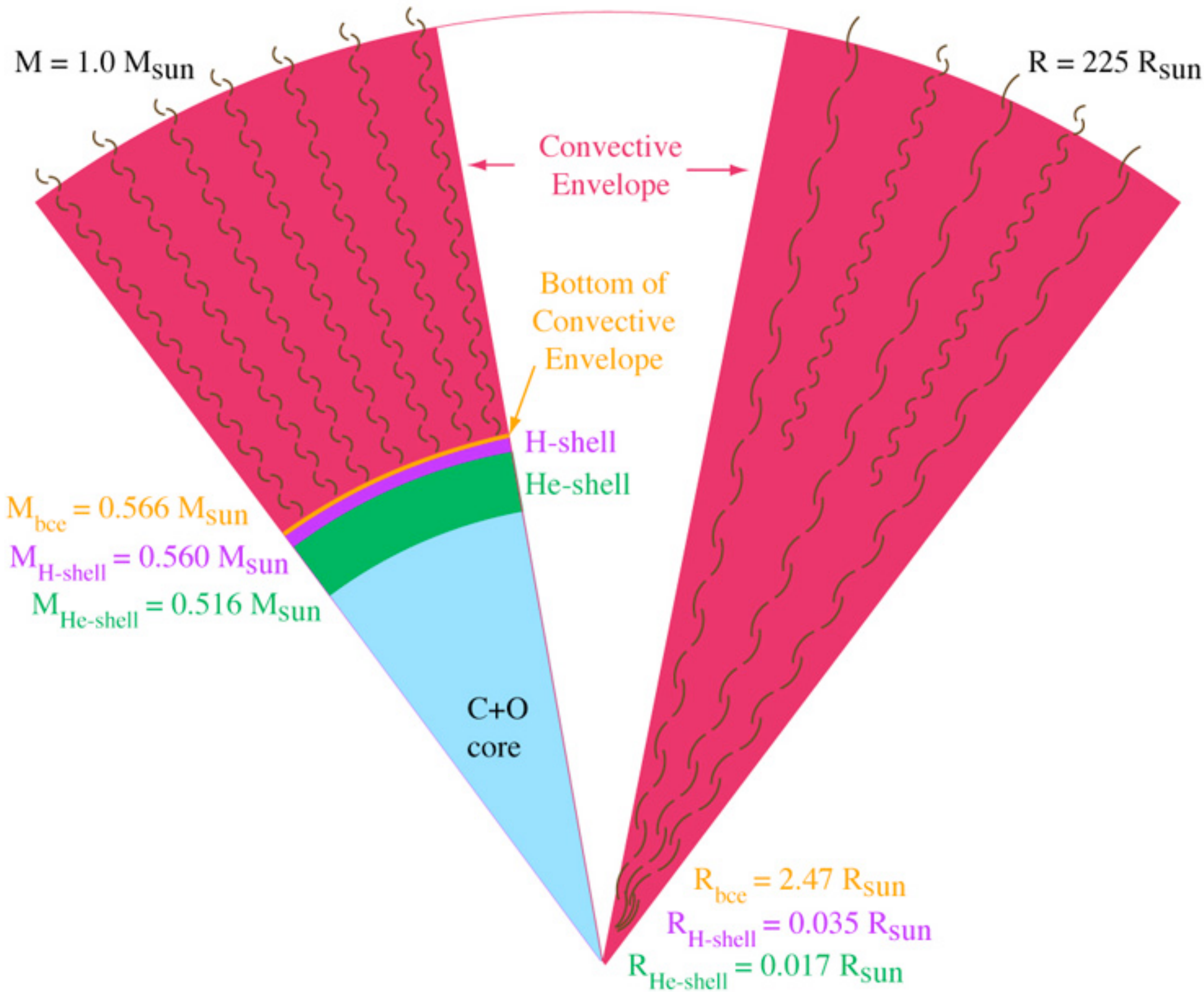
$$T_c + \frac{\hbar^2}{2m_e d^2} \sim \frac{GMm_p}{R}$$

$$\left(\frac{M}{m_p}\right) d^3 \sim R^3 \Rightarrow$$

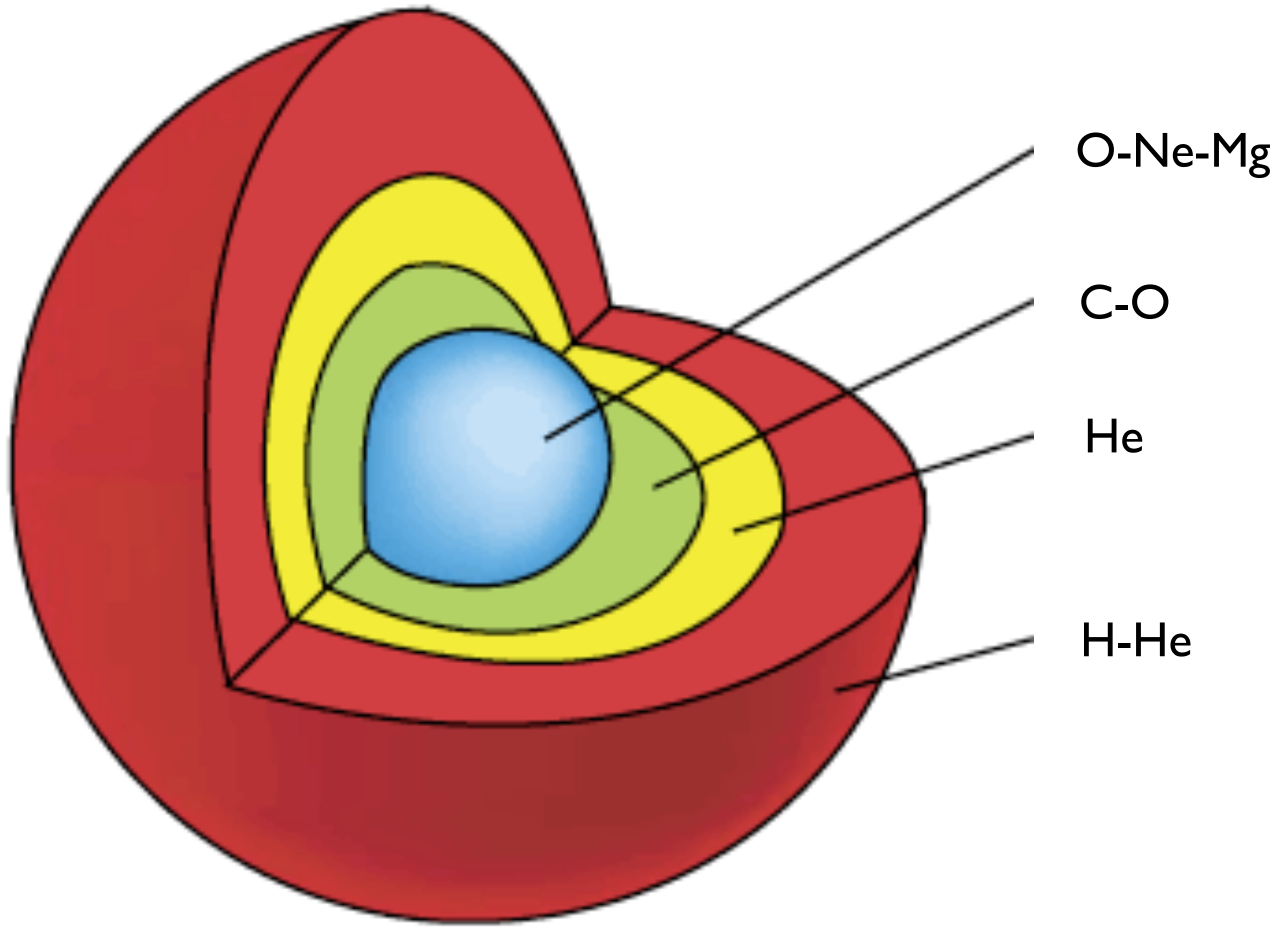
$$T_c \sim \frac{GMm_p}{R} - \frac{\hbar^2}{2m_e}\left(\frac{M}{m_p}\right)^{2/3} \frac{1}{R^2}$$

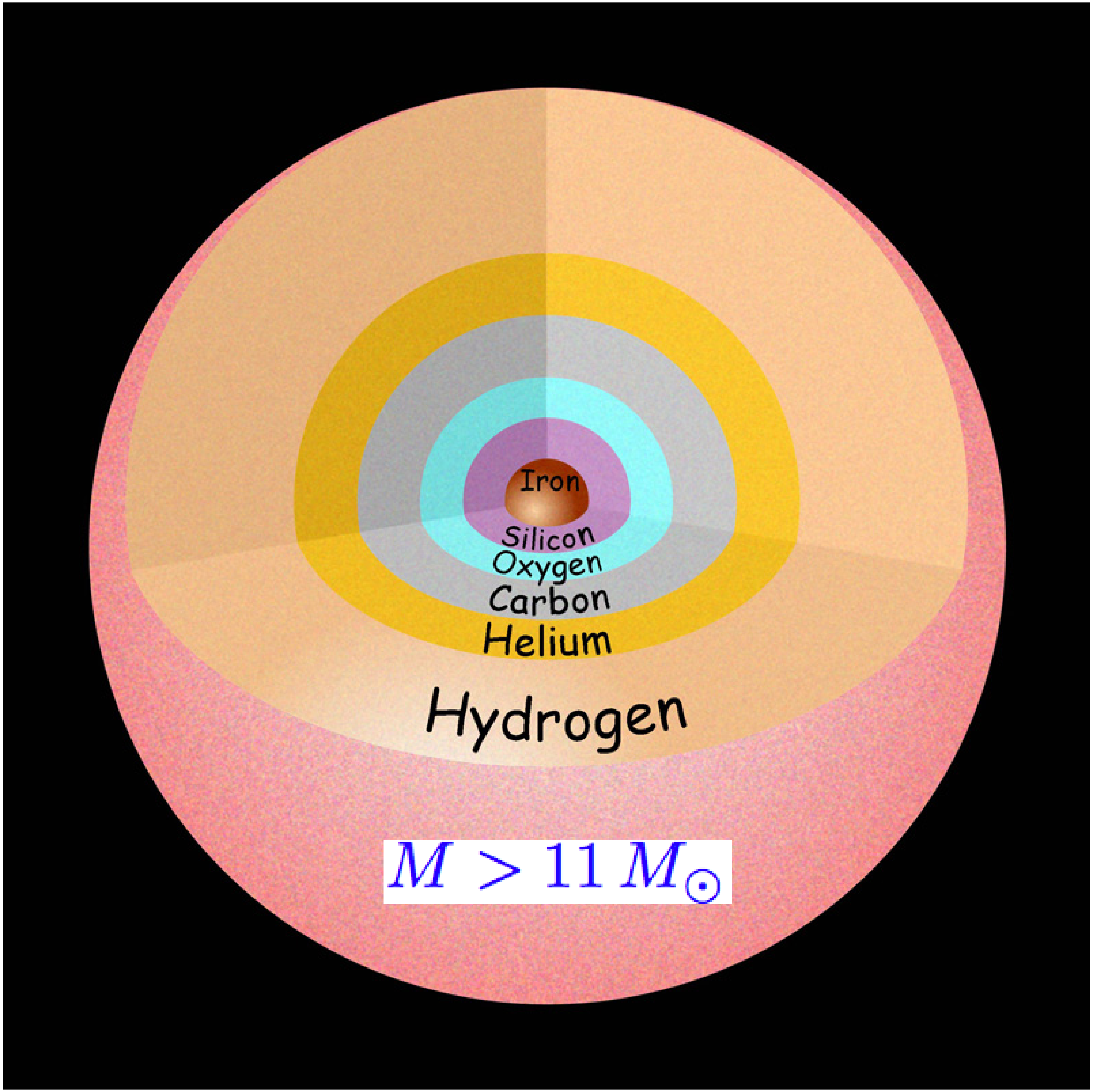
$$\Rightarrow T_{c,\mathrm{max}} \propto M^{4/3}$$

The Beginning of the End

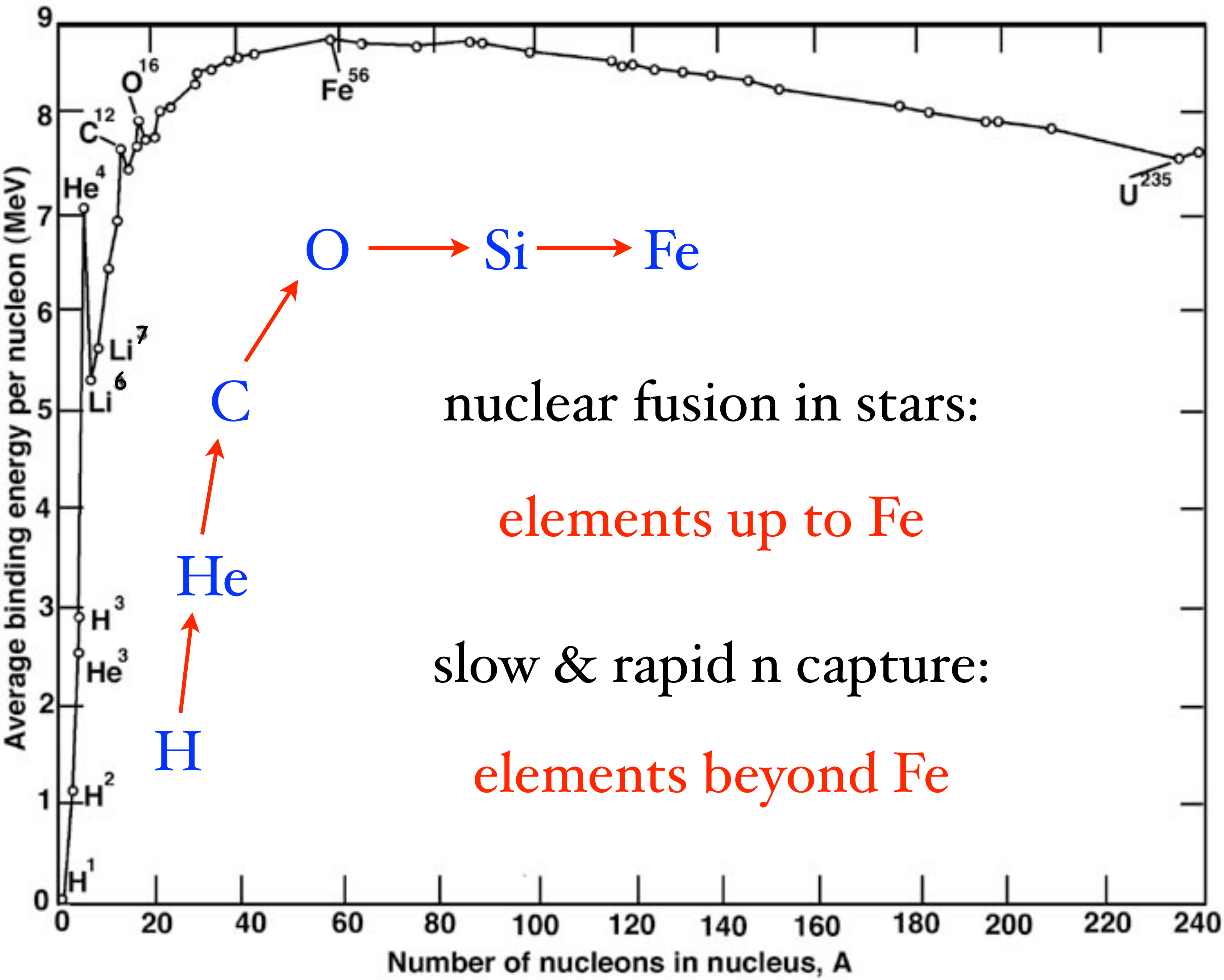


$M \sim 8\text{–}11\, M_\odot$




Iron
Silicon
Oxygen
Carbon
Helium
Hydrogen
$M > 11\,M_\odot$

Stars as Nuclear Reactors



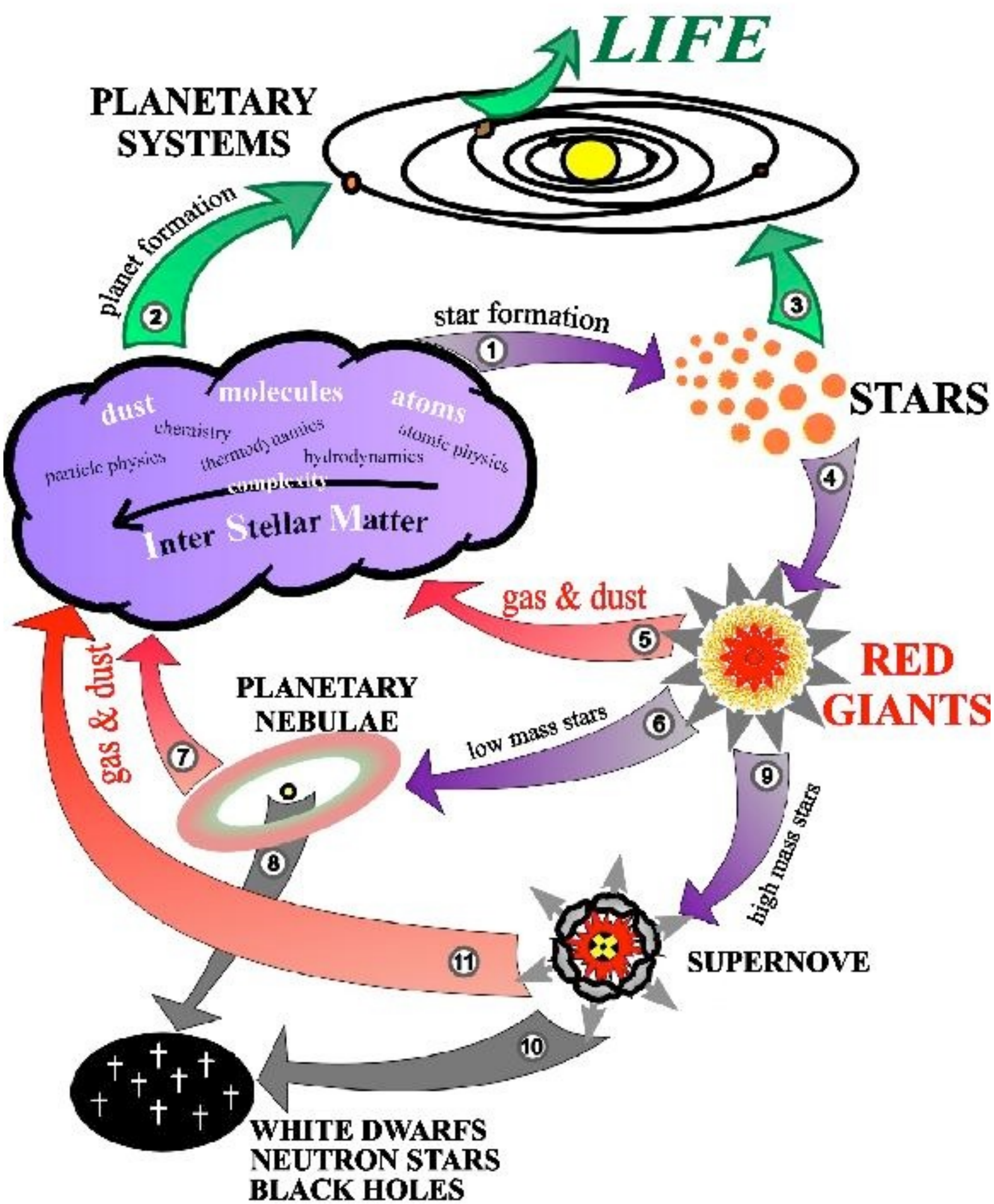
nuclear fusion in stars:

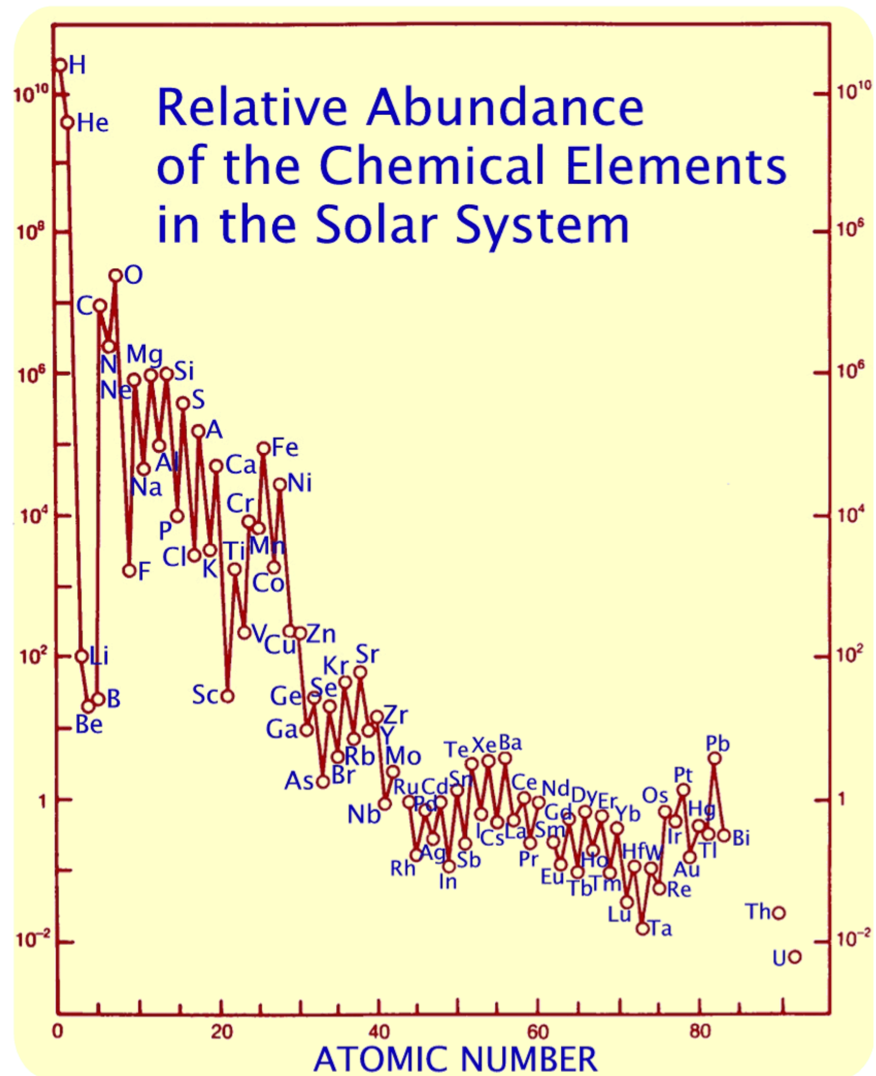
elements up to Fe

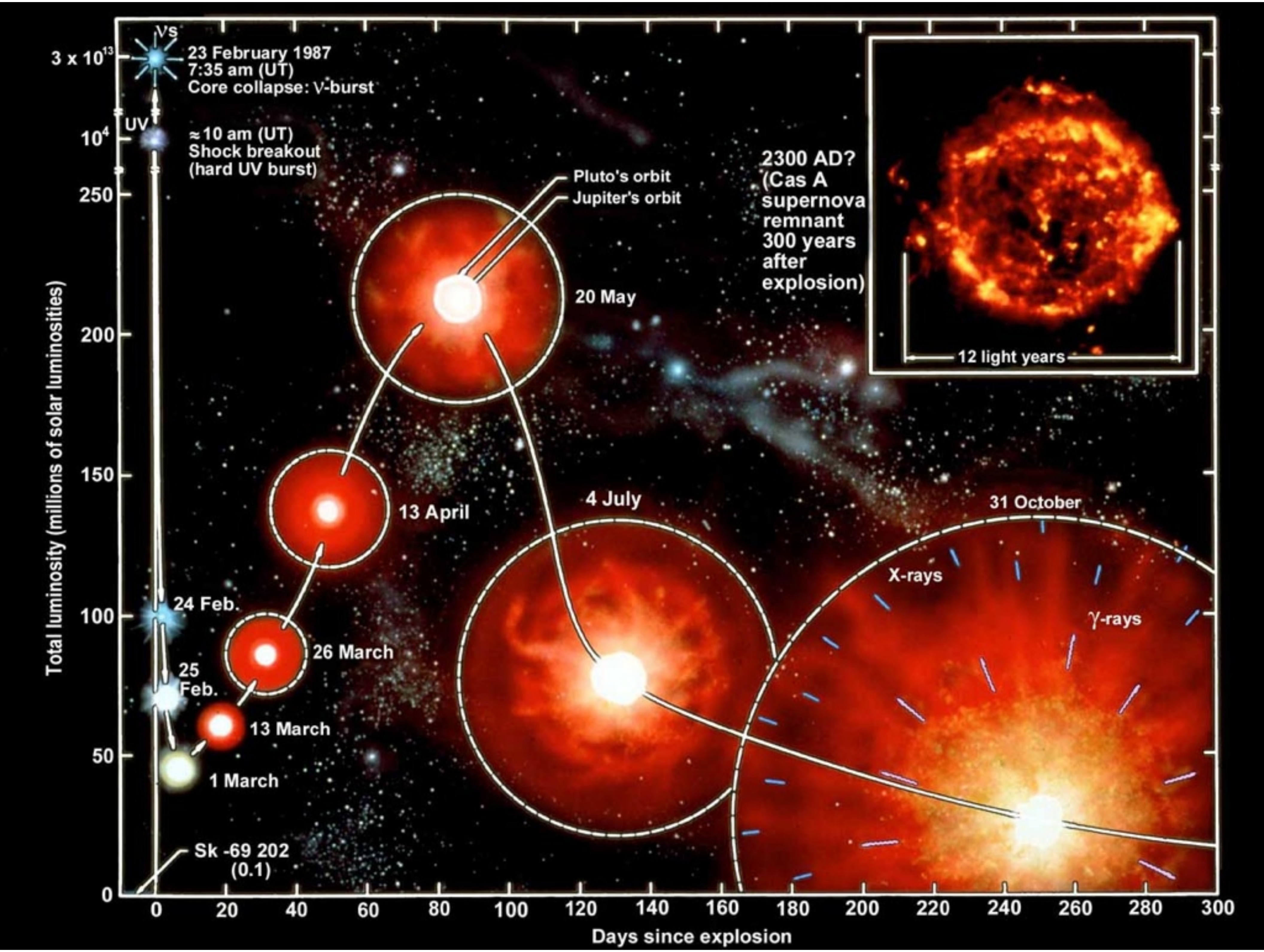
slow & rapid n capture:

elements beyond Fe

Arise from the Ashes

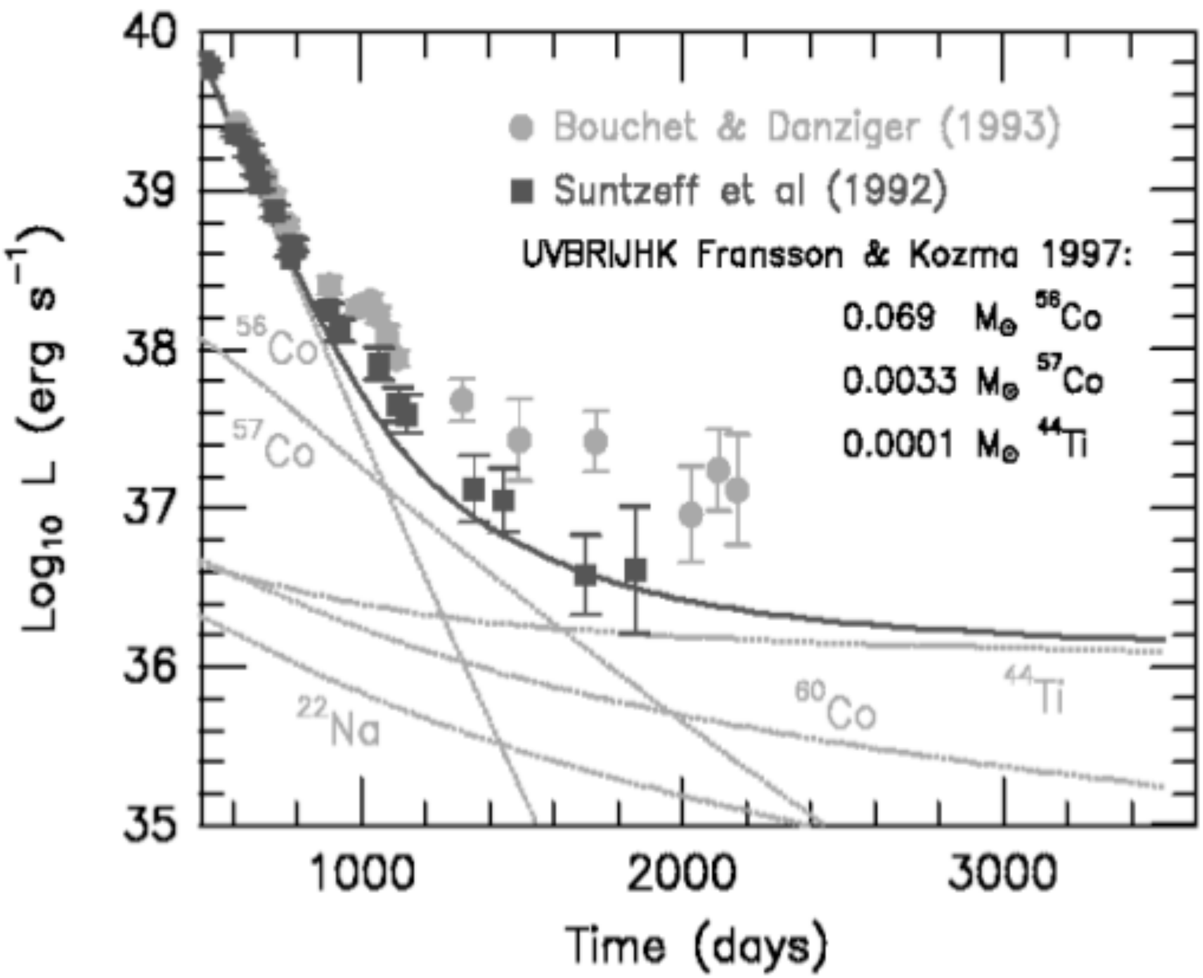


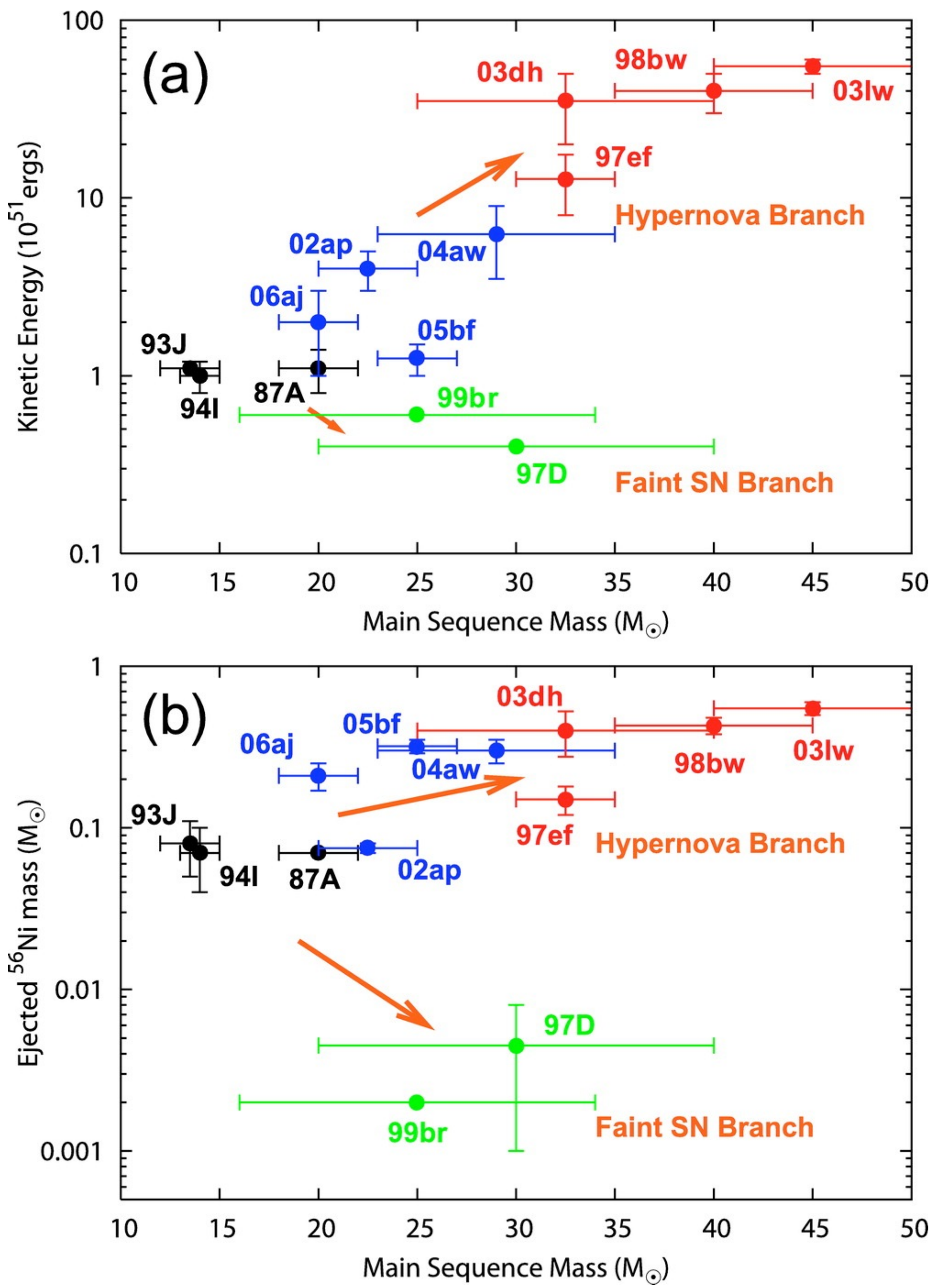



νs
3 x 10^13
23 February 1987
7:35 am (UT)
Core collapse: ν-burst
UV
10^4
≈10 am (UT)
Shock breakout
(hard UV burst)
250
200
150
100
50
0
Pluto's orbit
Jupiter's orbit
20 May
2300 AD?
(Cas A
supernova
remnant
300 years
after
explosion)
12 light years
13 April
4 July
31 October
X-rays
γ-rays
24 Feb.
26 March
25
Feb.
13 March
1 March
Sk -69 202
(0.1)
Total luminosity (millions of solar luminosities)
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
Days since explosion

The Energy from Radioactivity in SN1987A

- Early Light Curve Dominated by ^{56}Ni and ^{57}Co Radioactivity (Gamma-Ray Lines Detected by SMM and OSSE, respectively)
- Late Light Curve Power Source Unknown: ~10^{-4} $M_{\odot}$ of ^{44}Ti? Pulsar?
- Detection by INTEGRAL Possible, if ^{44}Ti Source





Tominaga et al. (2007)

normal SNe

$M \sim 12\text{–}25\, M_\odot$

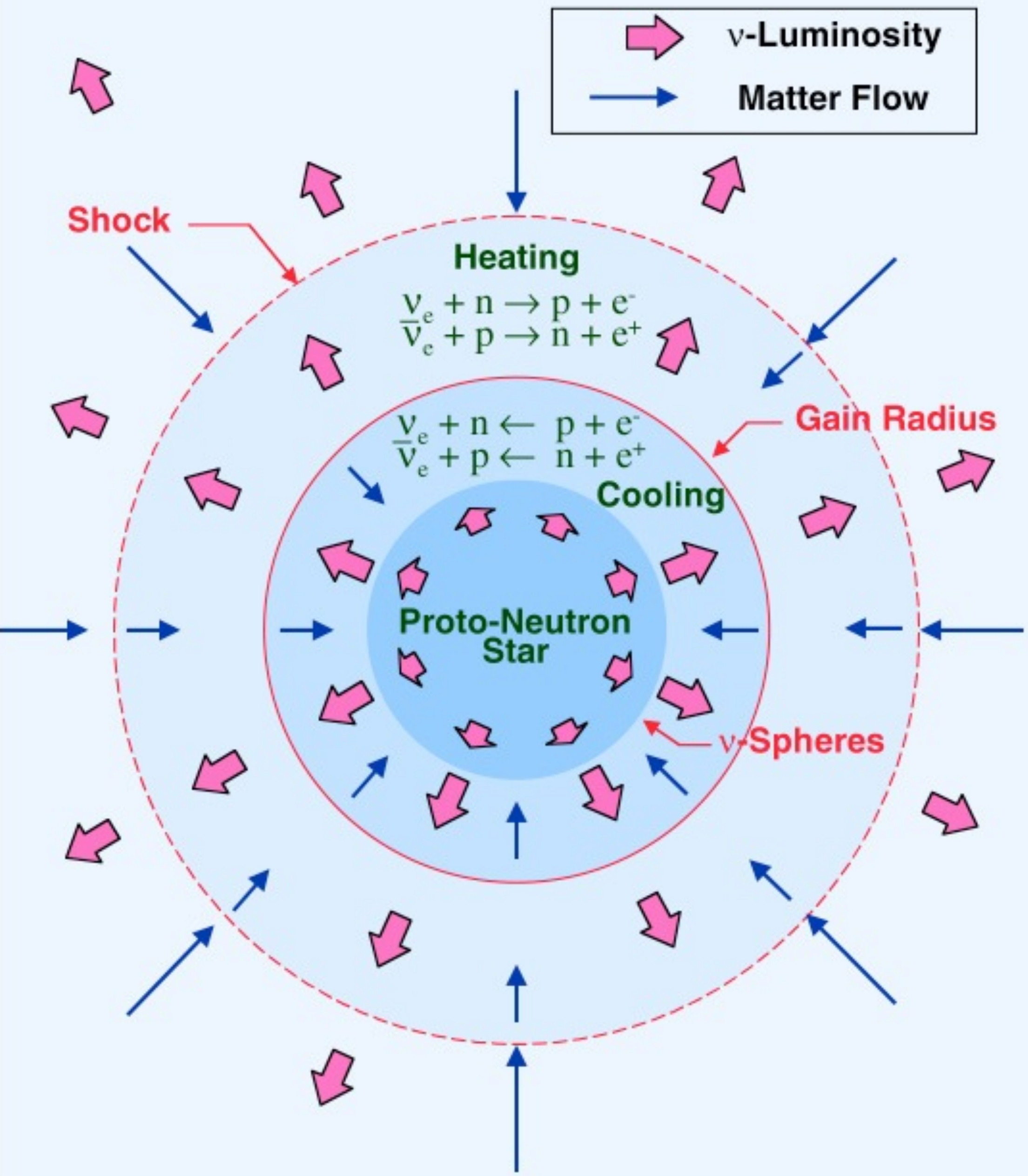
HNe

$M \sim 25\text{–}50\, M_\odot$

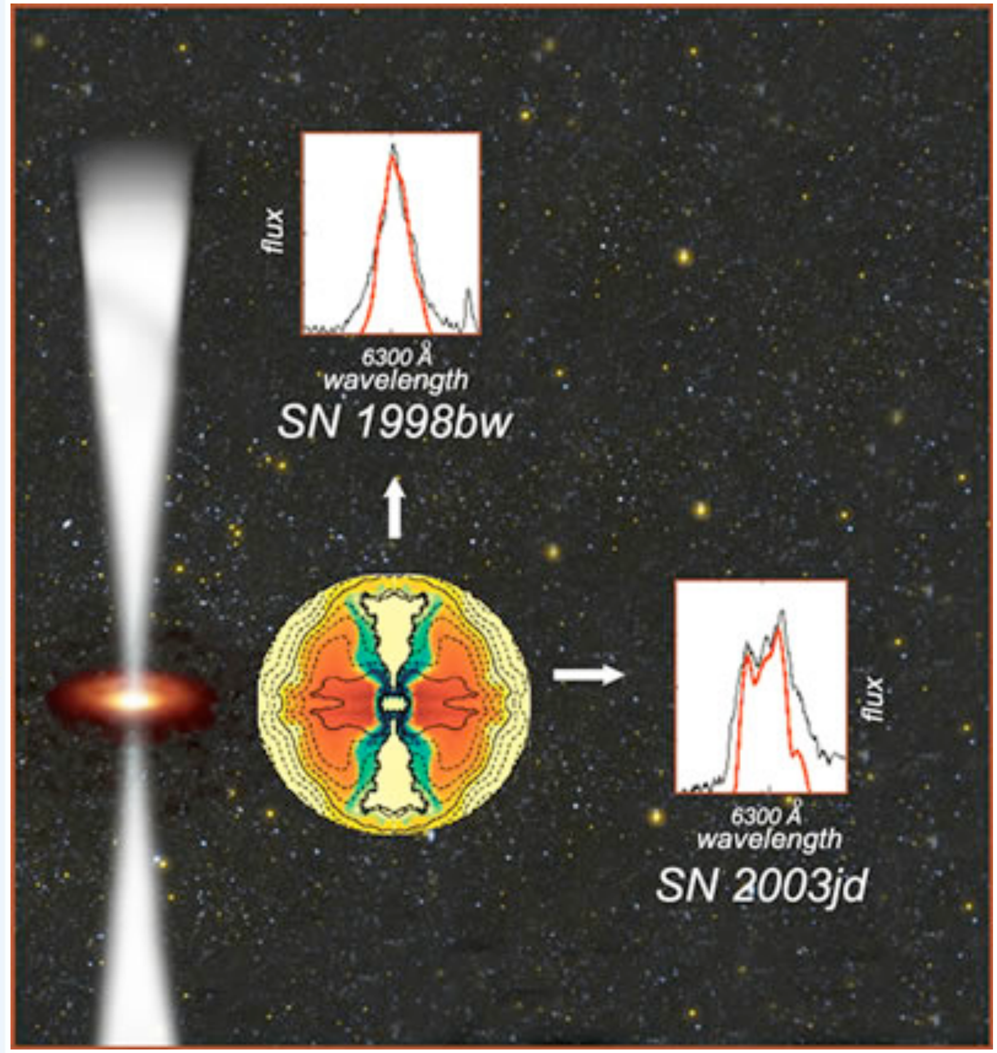
faint SNe

$M \sim 25\text{–}50\, M_\odot$

low-mass & normal SNe: neutrino-driven



HNe: strong jets



faint SNe: weak jets