Properties of stripped-envelope supernovae

3.8m Seimei Telescope @ Okayama, since March 2019

Keiichi Maeda

Dept. Astron, Kyoto Univ.

keiichi.maeda@kusastro.Kyoto-u.ac.jp

Items

- **Introduction:**
  - Stripped Envelope Supernovae (SESNe).
  - SN ejecta as electromagnetic radiation emitter.
- **Early photospheric phase:**
  - High velocity materials in GRB (Gamma-Ray Burst)-SNe.
  - SESN high-mass end (?).
- **Late-time nebular phase:**
  - Progenitor mass sequence within the SESN class.
  - SESN general properties.
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  - A new candidate for a "Ultra-stripped" envelope SN.
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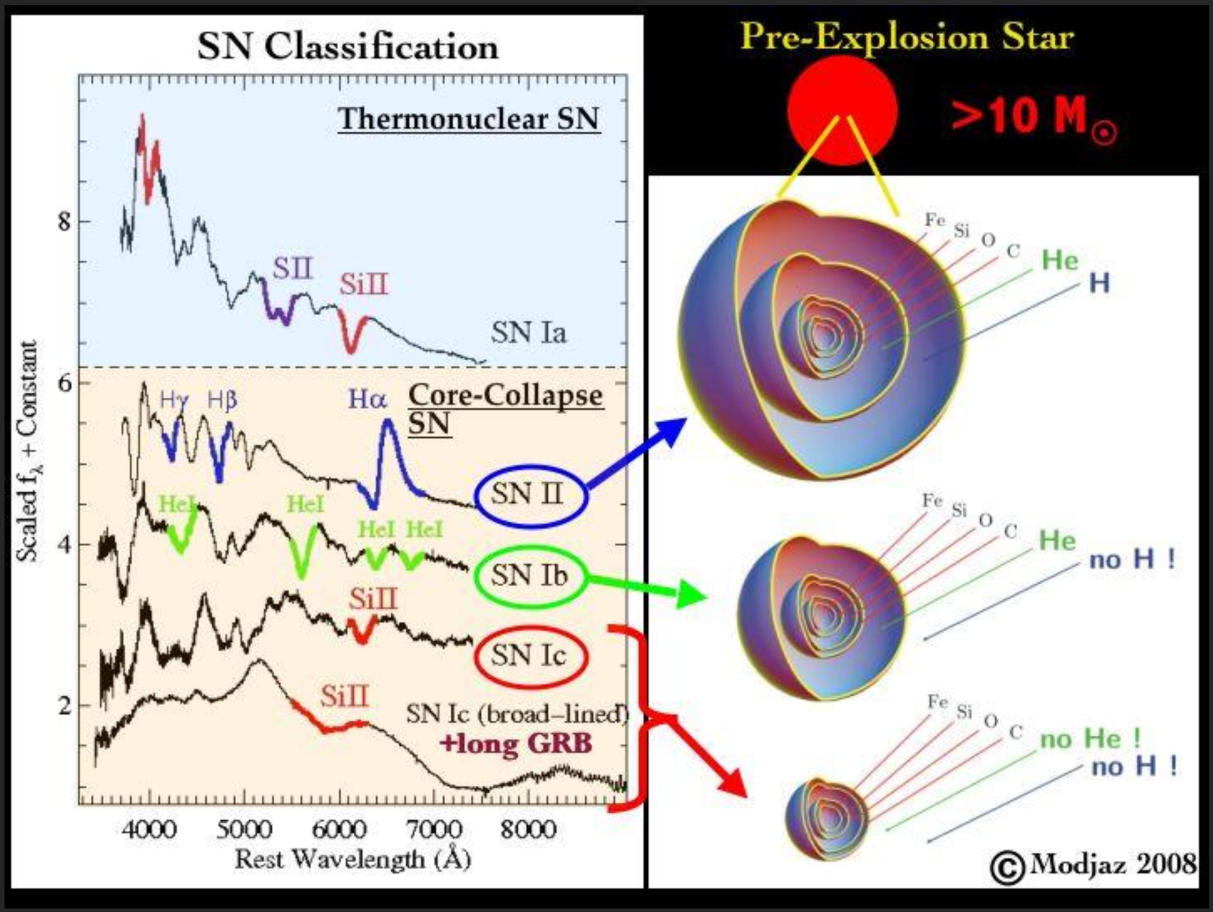
Stripped Envelope SNe (SESNe): Progenitors



SNe IIP/IIL:
H-rich Red-giant
~ 10M$_\odot$ (extended)

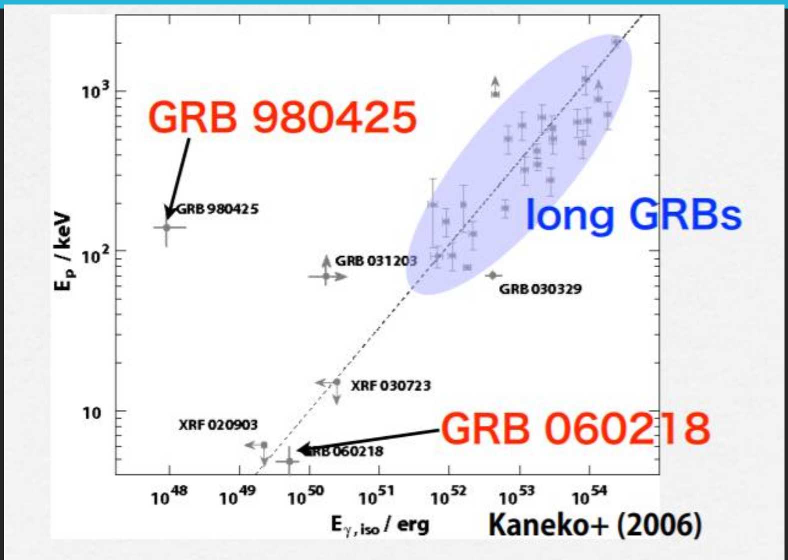
SNe IIb:
Little H left
> 0.1M$_\odot$ (extended)
> 0.01M$_\odot$ (compact)

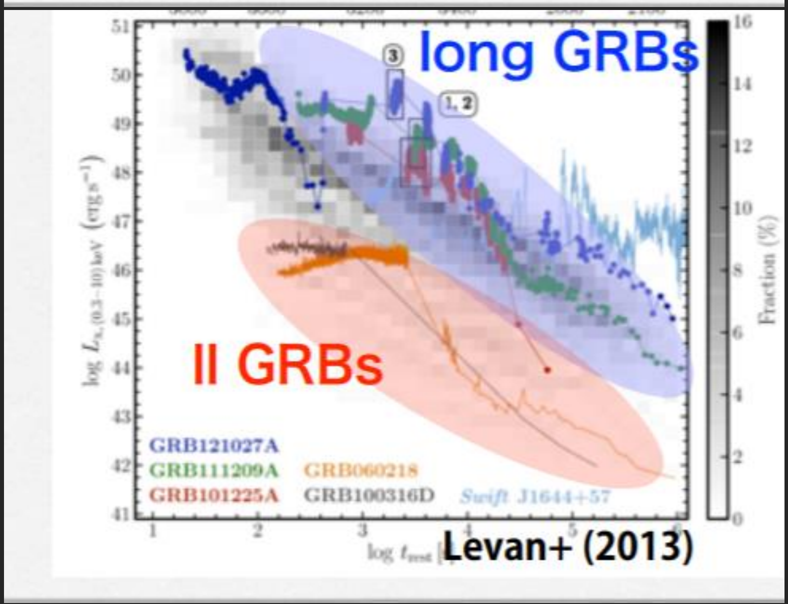
SNe Ib:
H envelope gone.

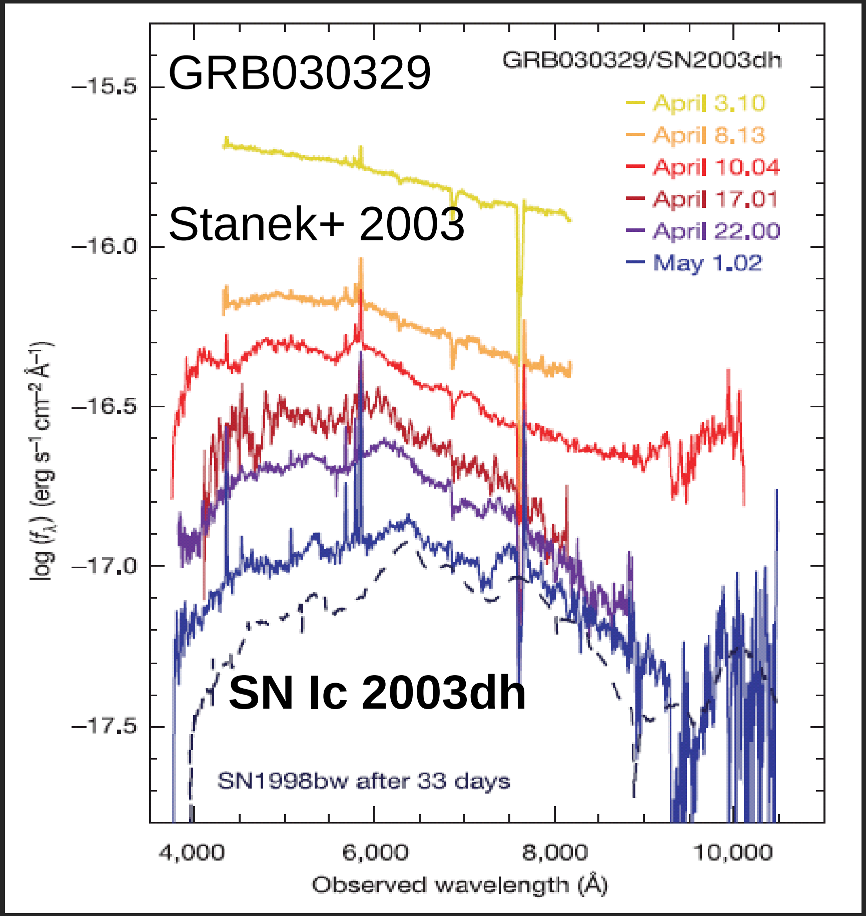
SNe Ic:
H + He gone.

- **What drives the mass loss / envelope stripping?**
  - **Binary interaction? Then progenitors for binary NSs, BHs, …**

Link to (low-luminosity, long) GRBs







- **Central Engine?**
  - **Jet? Mixing?**

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Early-Phase spectral formation (opaque)

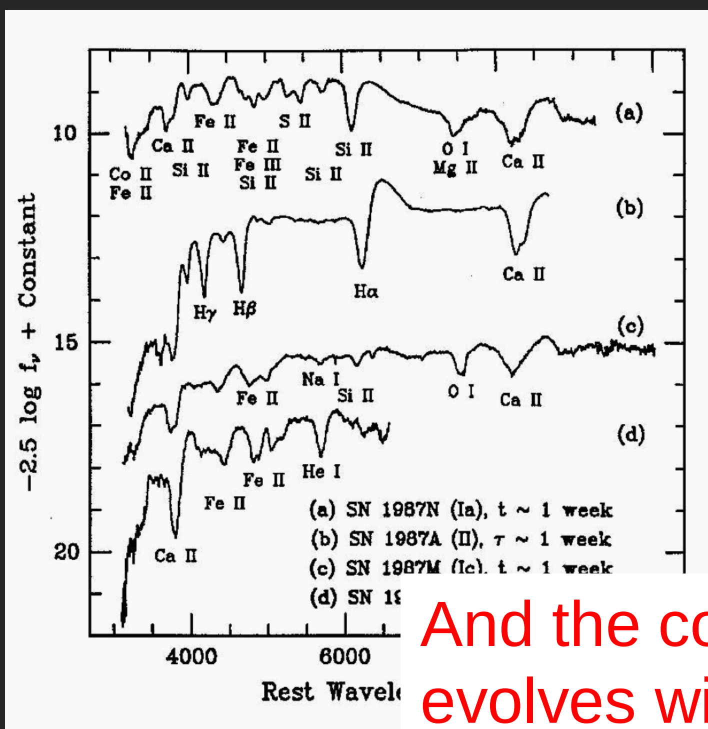
"Photosphere"

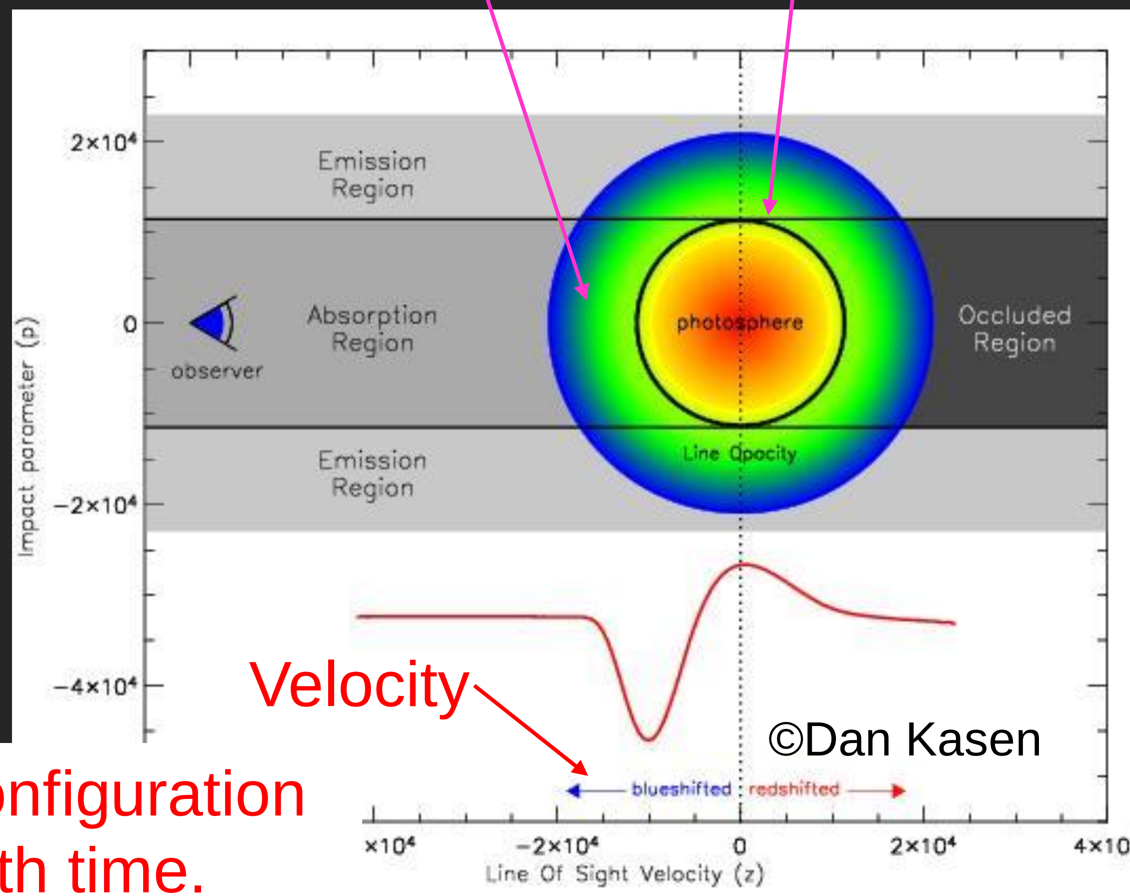
$$L = 4\pi R_{ph}^2 \sigma T_*^4$$

$$R_{ph} = v_{ph} t$$

Line forming region (Composition, Density)

Photosphere (T_{ph}, R_{ph}=Vt)





Velocity

©Dan Kasen

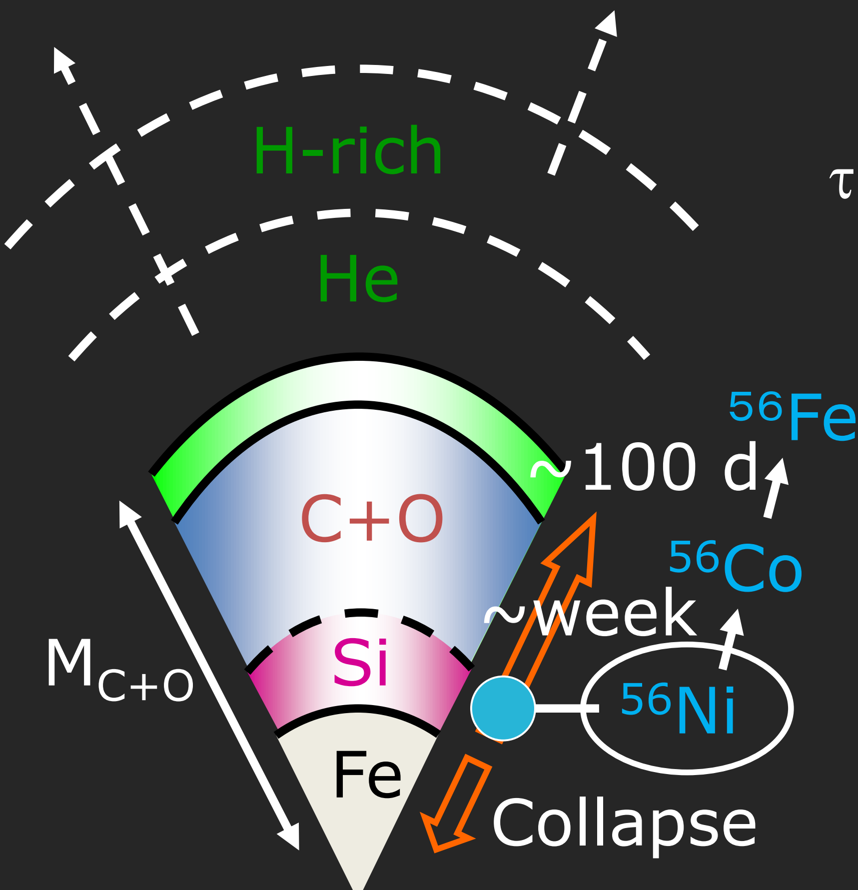
And the configuration evolves with time.

Radioactive Decay Model for SESNe

Parameters [M_{ej}, E, $M(^{56}Ni)$]

Light Curve

Spectra

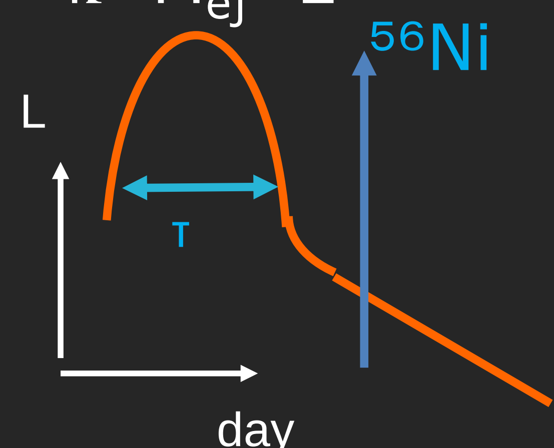


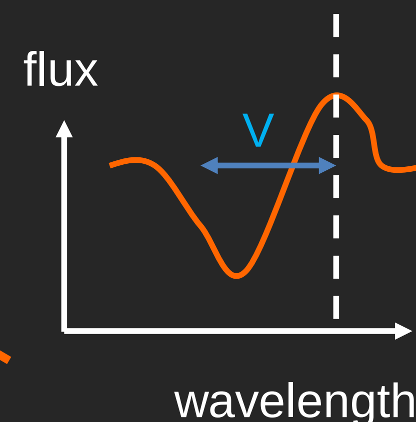
$$\tau \sim [\tau_{dyn} \bullet \tau_{diffusion}]^{1/2}$$

$$\sim \left(\frac{R}{V} \bullet \frac{\kappa M_{ej}}{R c} \right)^{1/2}$$

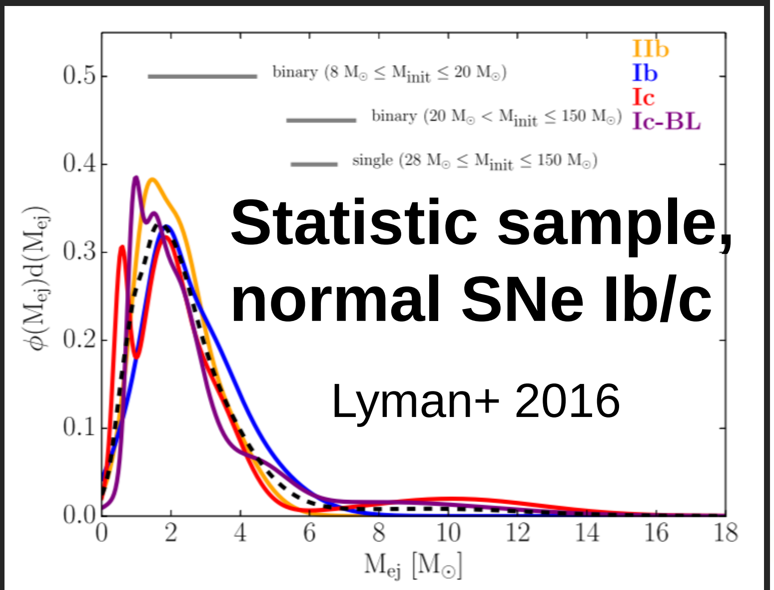
$$\propto \kappa^{1/2} M_{ej}^{3/4} E^{-1/4}$$

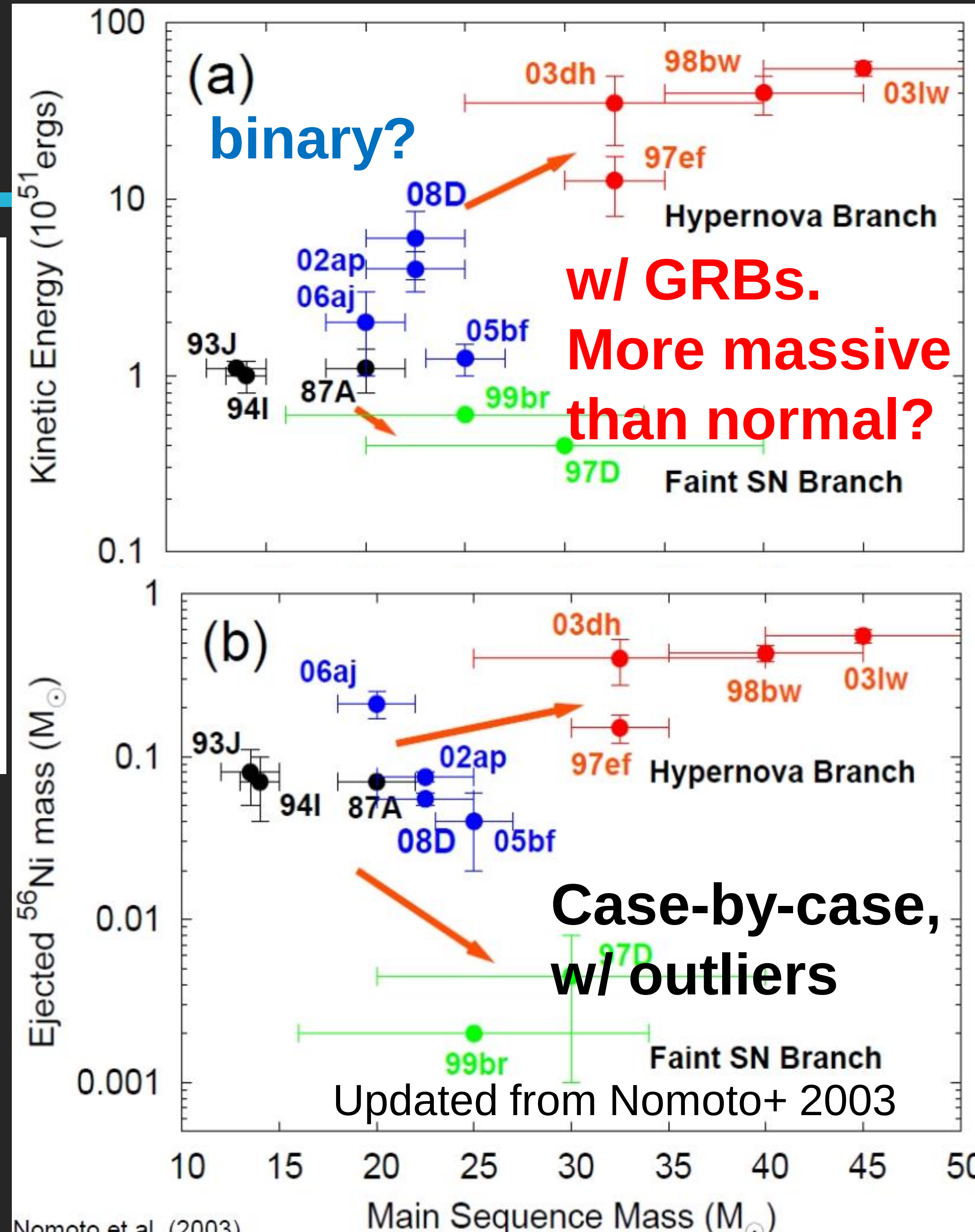
$$V \sim [E/Mej]^{1/2}$$





Photospheric Phase Modeling





Correlation:

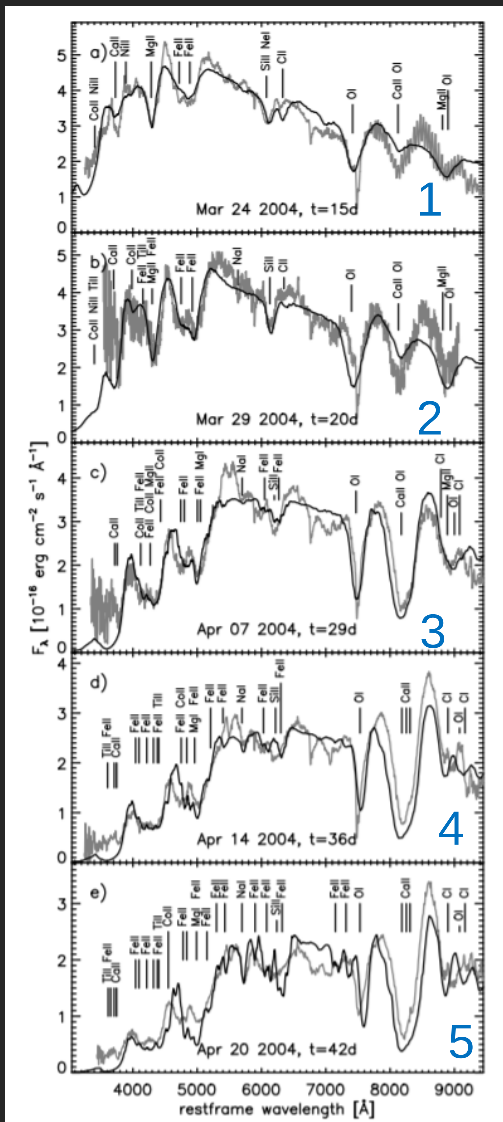
M_{ej} (M_{ms}) and E, ^{56}Ni.

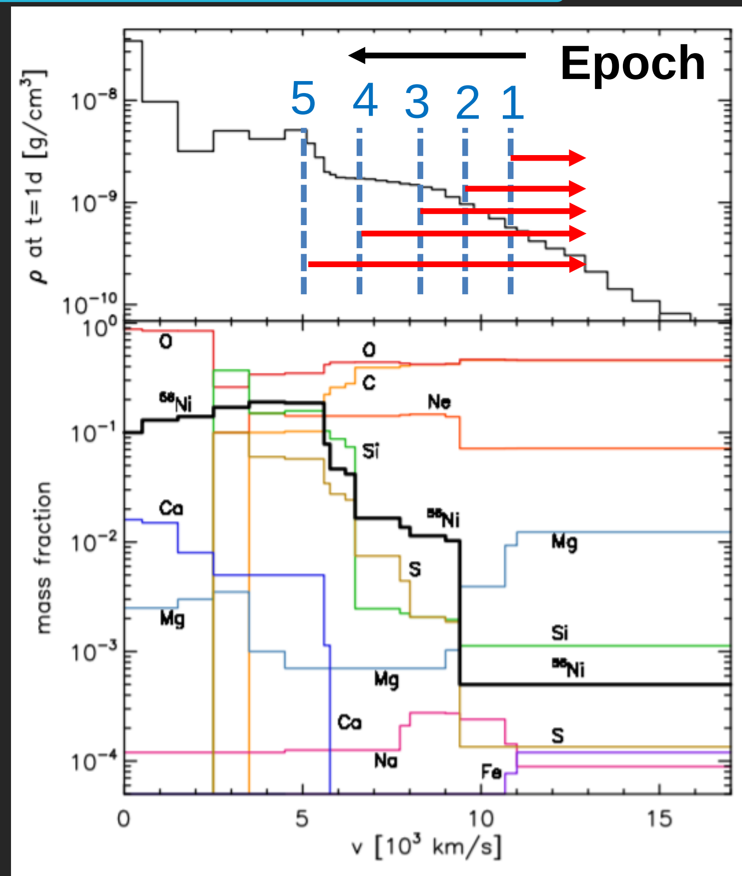
Mean properties:

M_{ej} <4$M_\odot$⇒ M_{ms}<20$M_\odot$.

IIb/Ib/c mostly binary?

Spectral synthesis: from outer to inner





Mazzali+ 17
(SN Ic 2004aw)

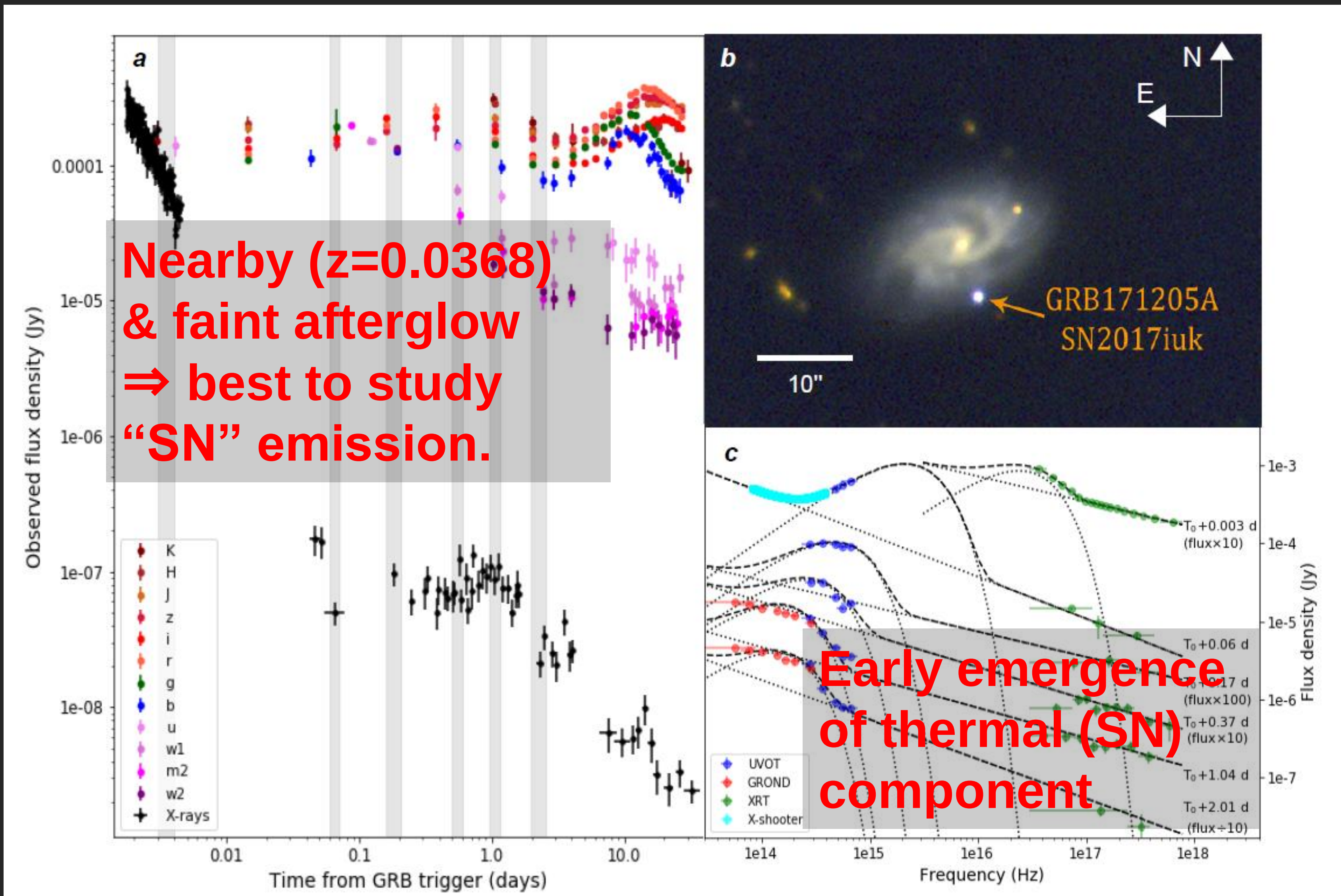
Caveat: Do not always trace most abundant ions.
Model does not cover all the possibilities.

This is "interpretation".

Izzo, de Ugarte Postigo, KM+, 2019, Nature

GRB171205A/SN 2017iuk

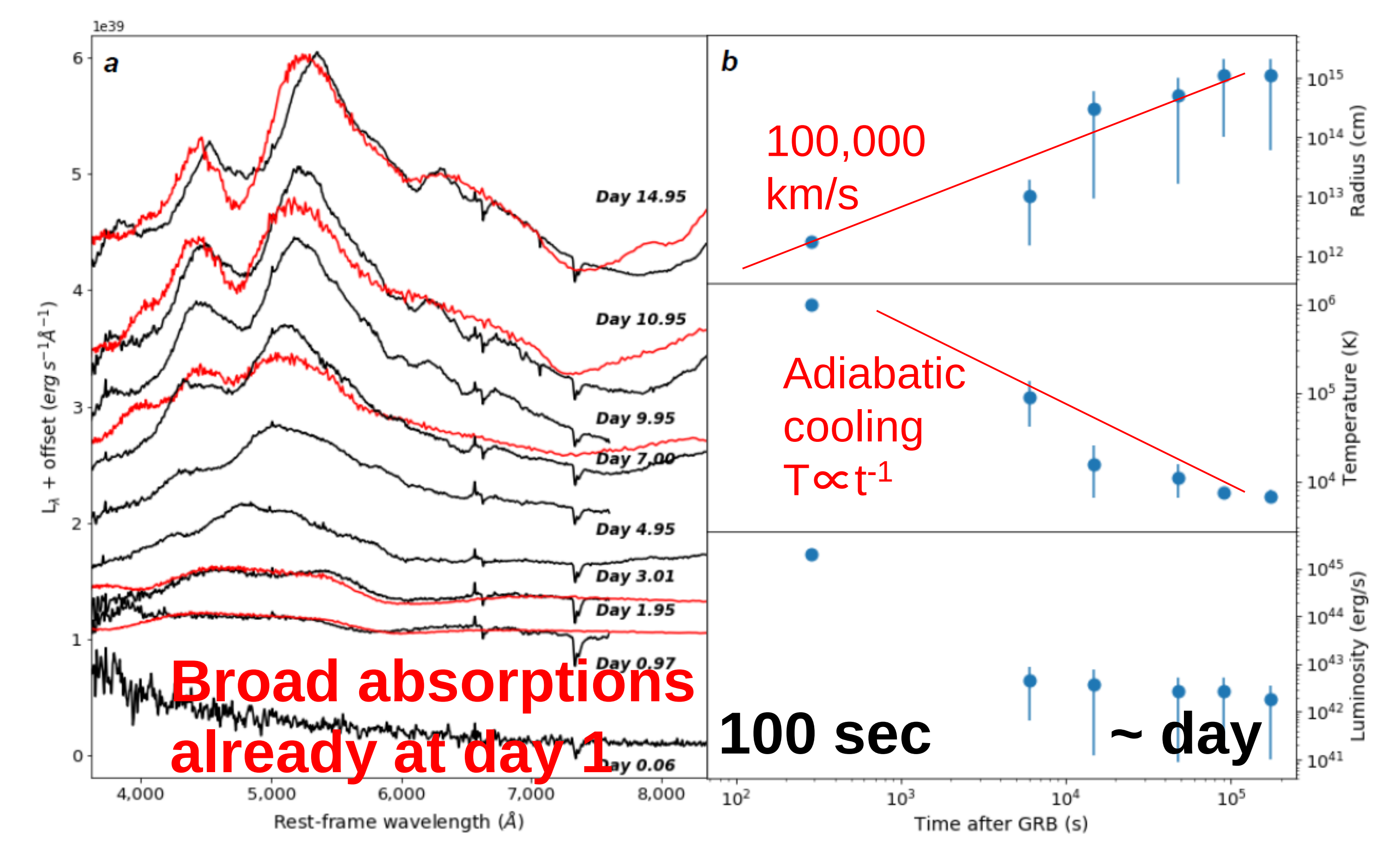
\# Non-thermal emission model: Suzuki, KM, Shigeyama, 2018



High velocity absorption detected from day 1

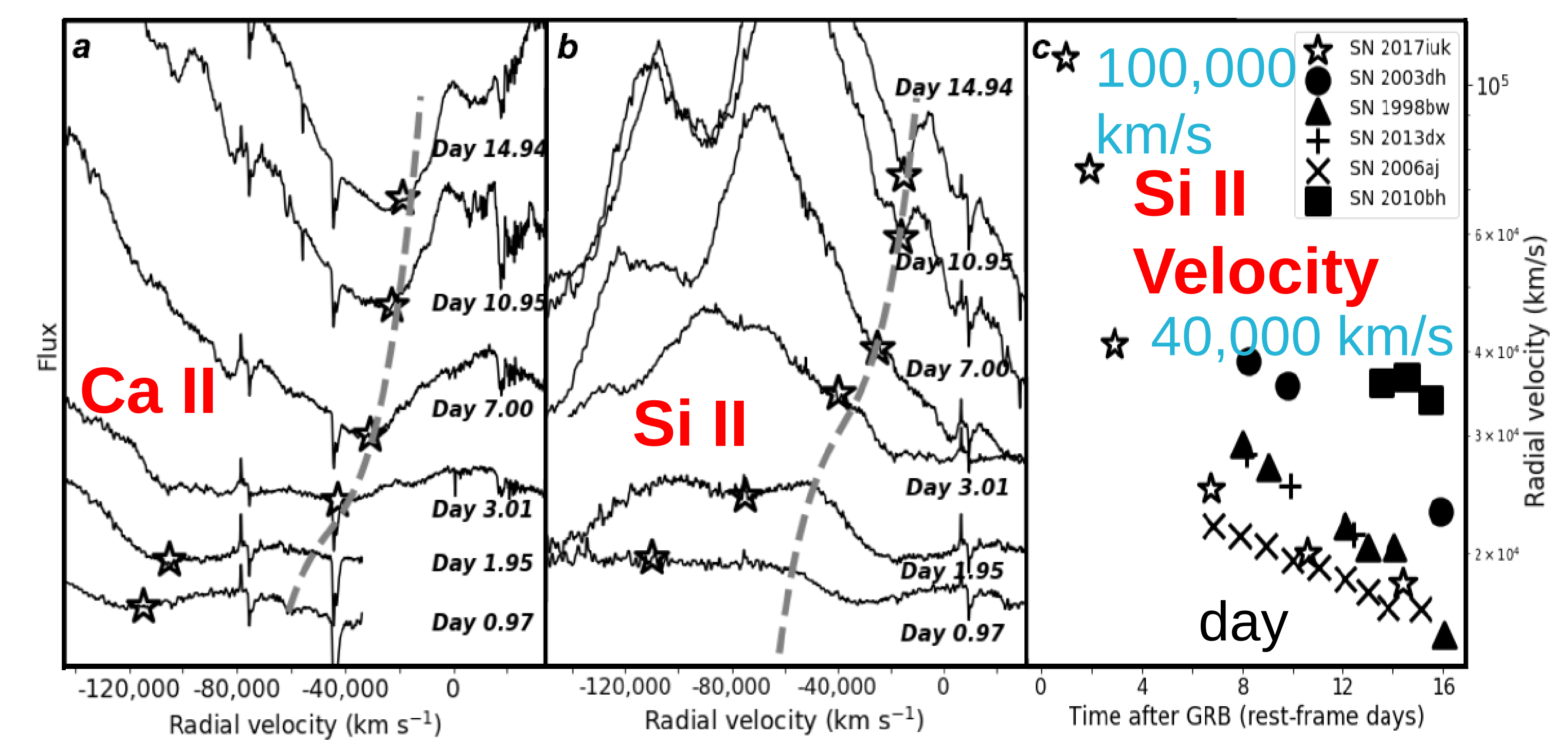
Spectral evolution
& 1D radiation model

BB fit



Model extending to 100,000 km/s to produce broad features

Highest velocity ever seen in SNe?

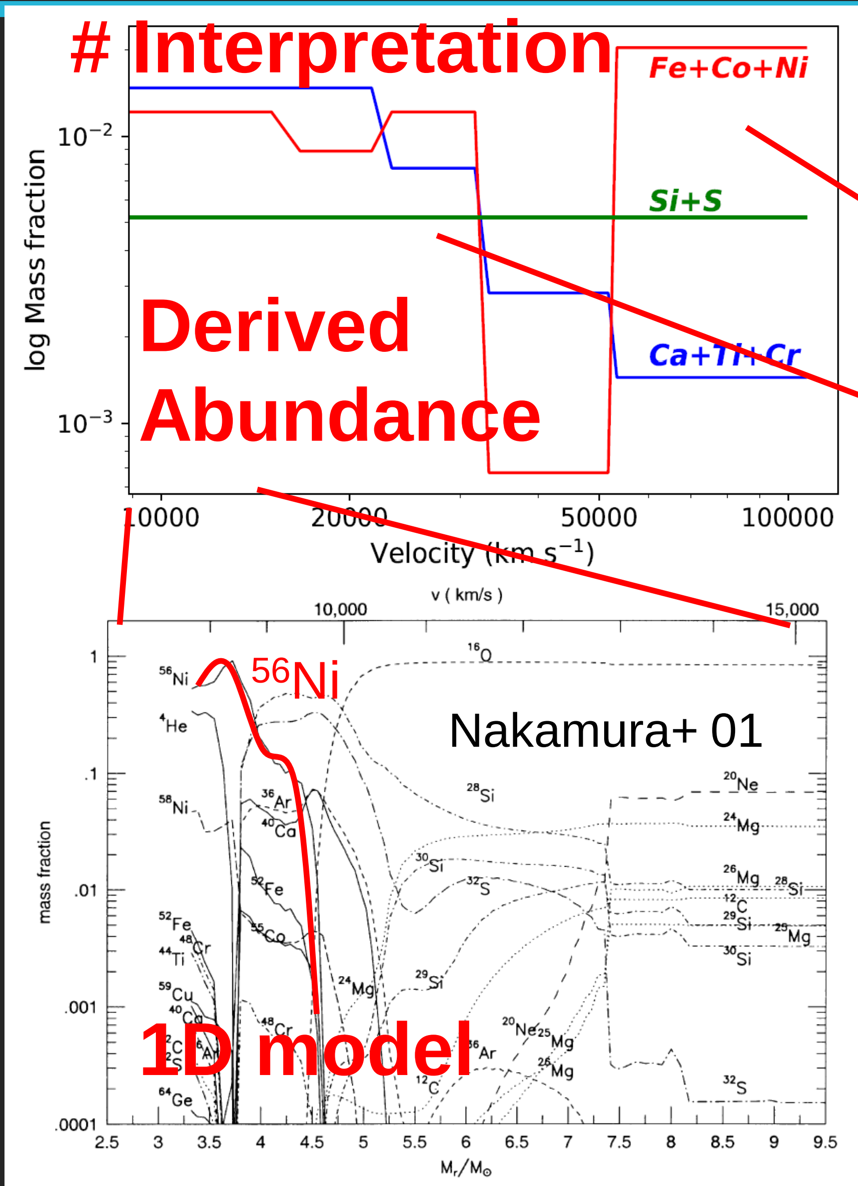


~ 100,000 km/s in the first few days.

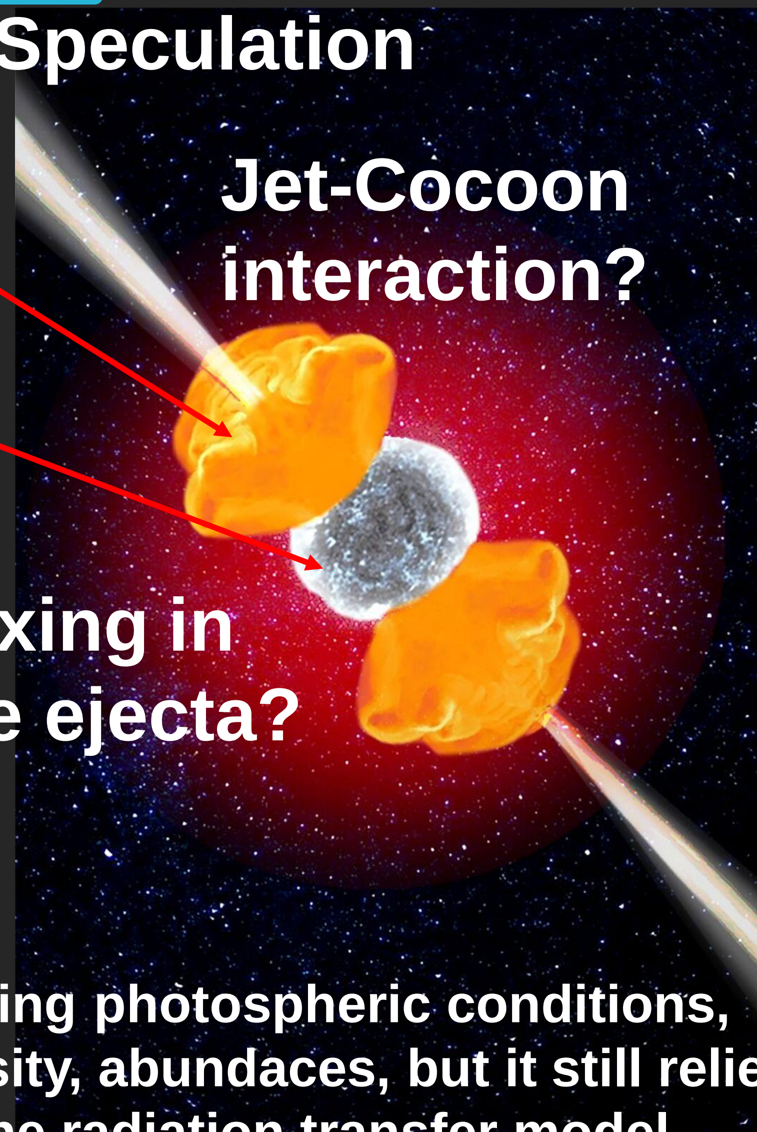
Outermost edge (w/ ~ $10^{-3} M_{\odot}$, no/little material above that).

Merged to previous examples (~ 30,000 km/s) at ~ 5 days.

Abundance inversion – jet/mixing (or both)?



Speculation



Varying photospheric conditions, density, abundaces, but it still relies on the radiation transfer model.

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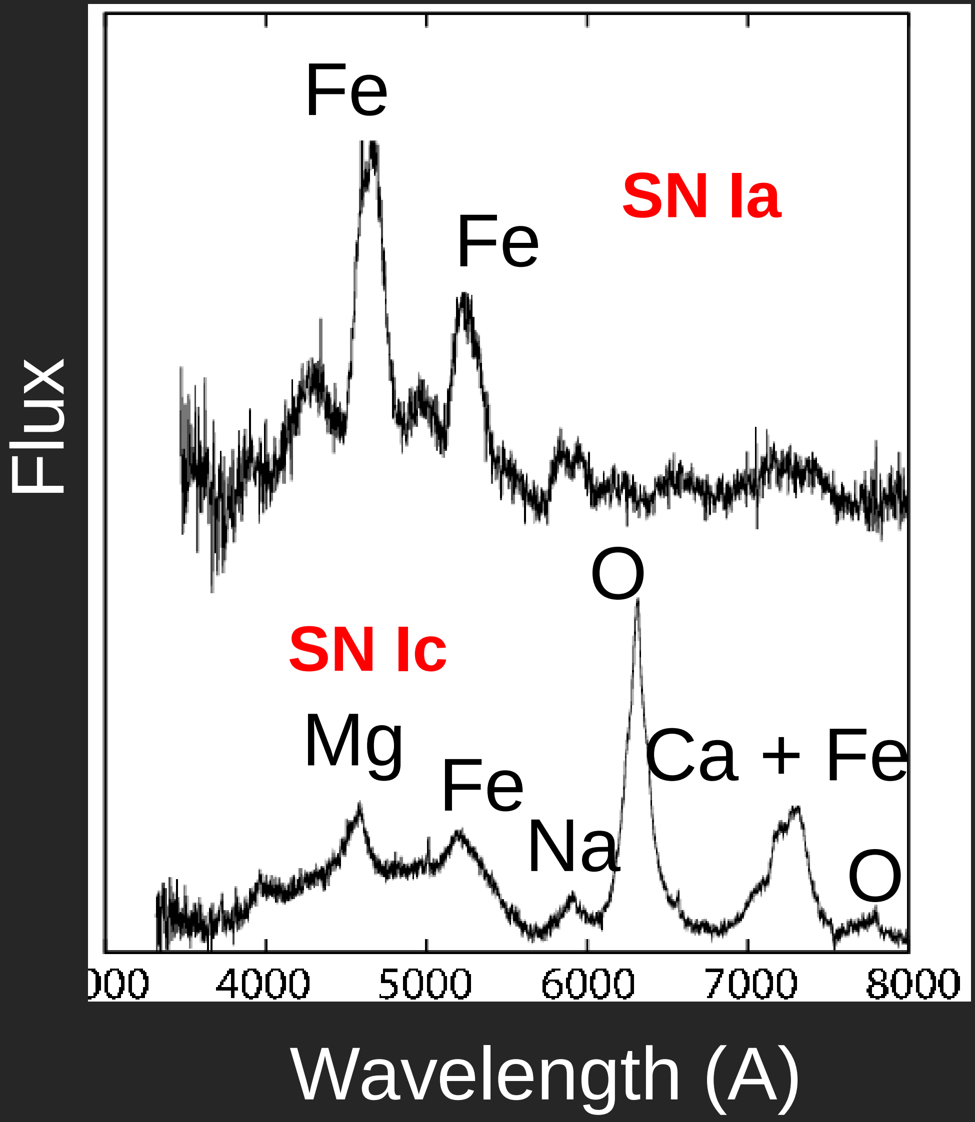
Late-Phase spectral formation (transparent)

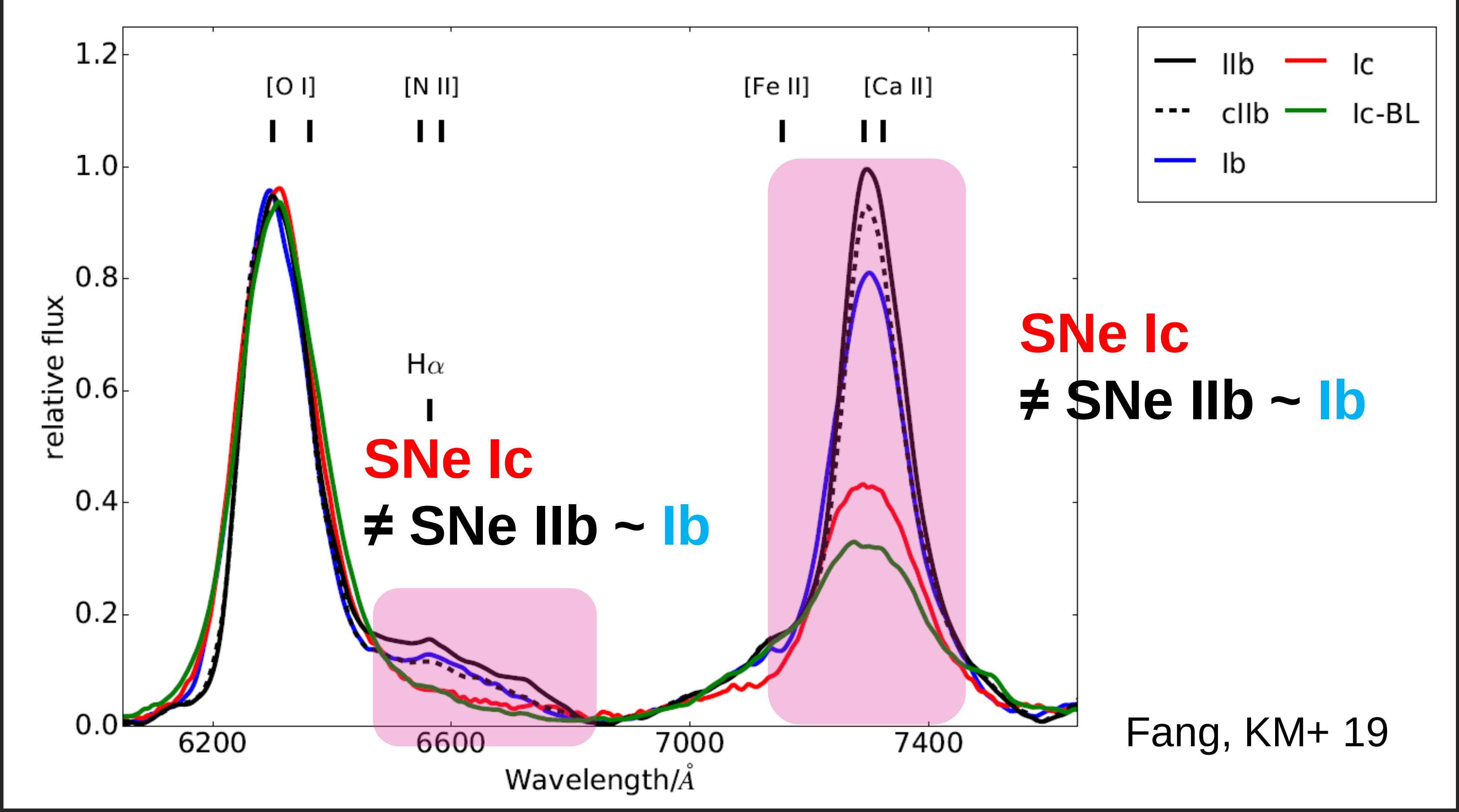


- Optically thin emission.
  - $\rho \propto t^{-3}$
- **Innermost region.**
- **Nothing hidden.**

Heating-Cooling balance in situ (transfer not that important).
NLTE rate equations.

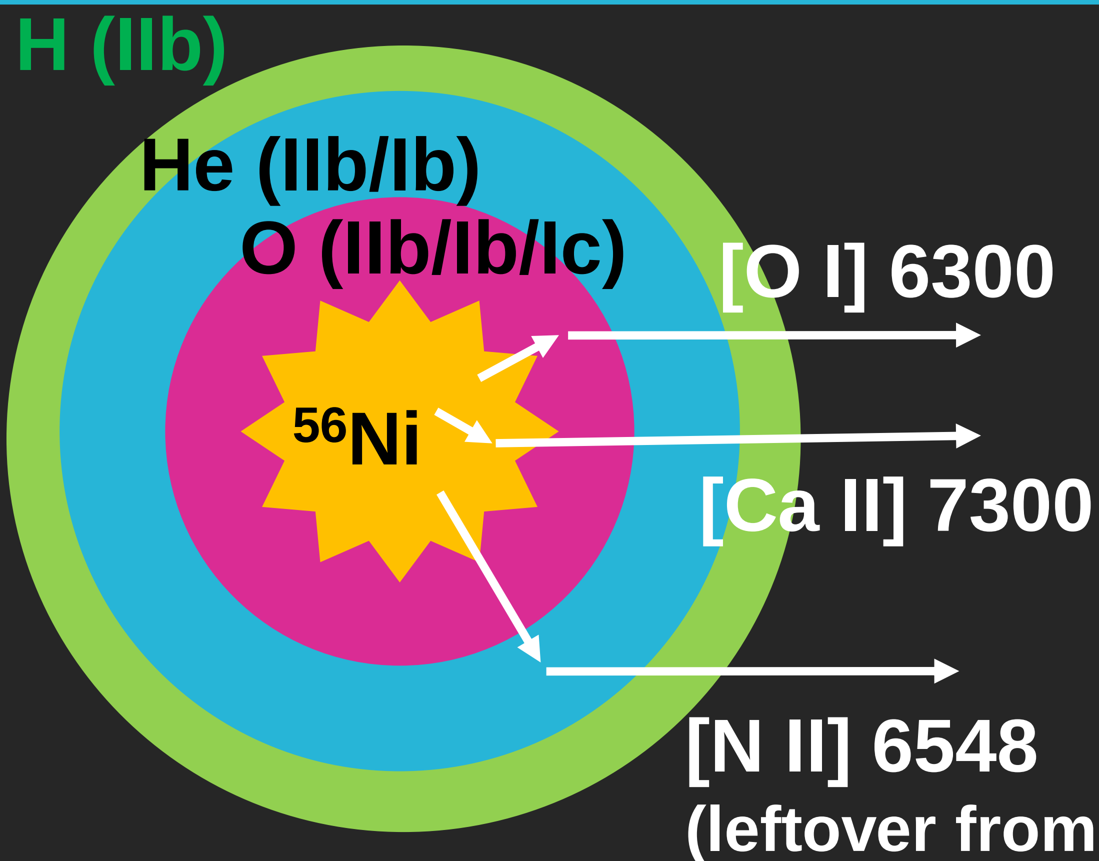
Pros: The "strongest" lines are relatively easy to handle.
 # Emission determined mainly by the energy balance, not by the rate equations.

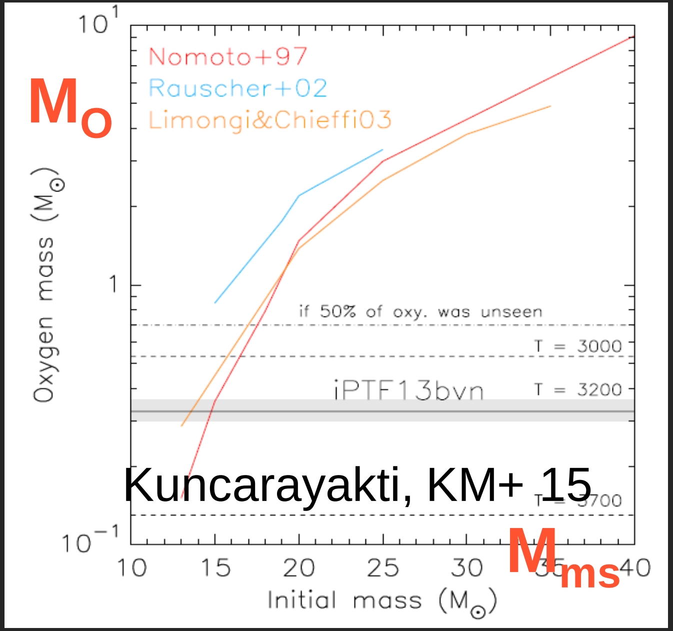
"Averaged" Nebular Spectra of SESNe



Nebular Spectra averaged for a sample of each class (12 SNe IIb, 12 SNe Ib, 22 SNe Ic).

Progenitor diagnostics in the late phases





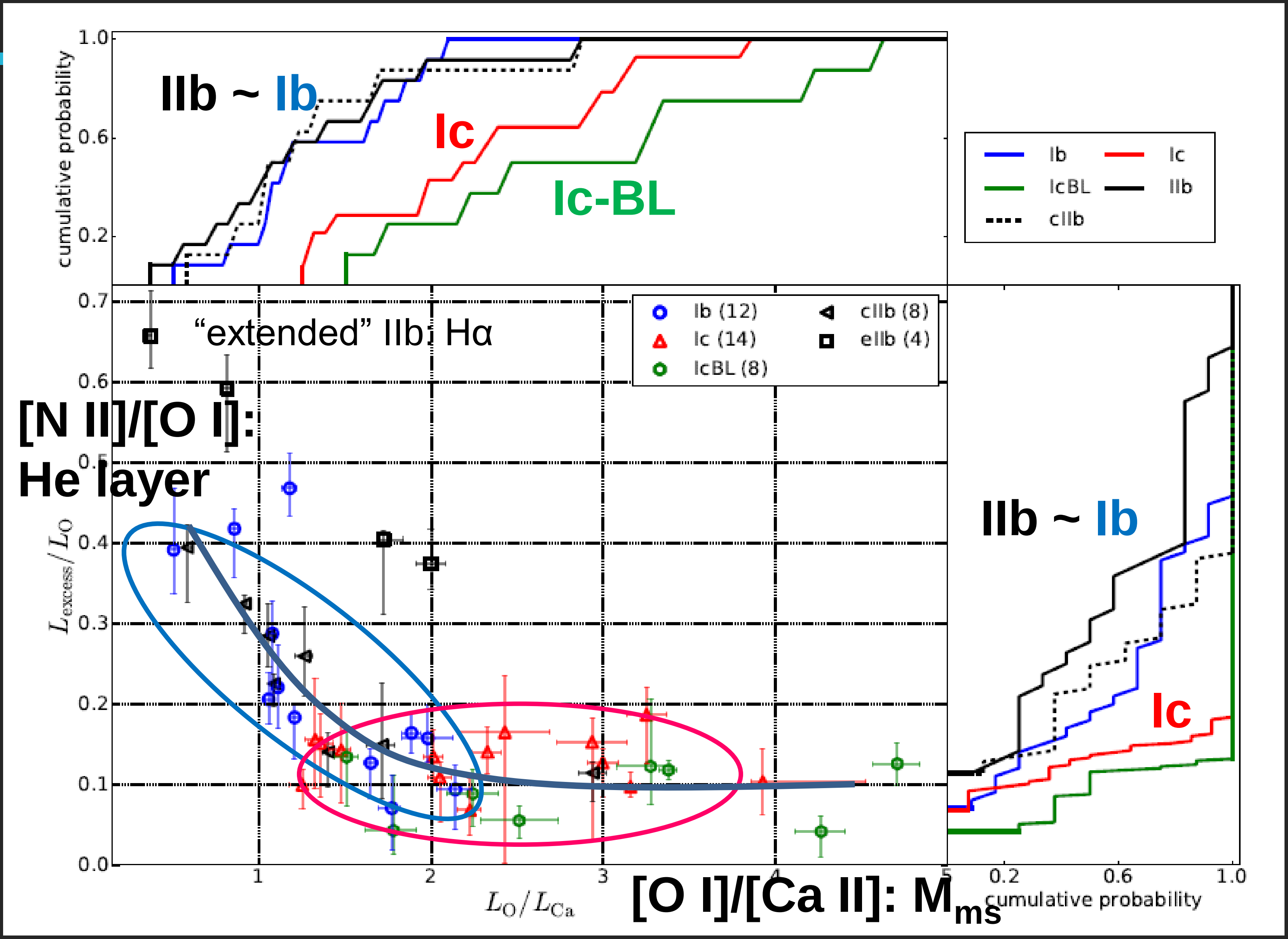
M_{ms}↑⇒[O I]/[Ca II] ↑

Fransson & Chevalier 1989
KM+ 07, Jerkstrand+ 15,
Kuncarayakti, KM+ 15

He layer ⇒[N II]/[O I]

Fang+KM 18

Fang, KM+, 2019, Nature Ast.



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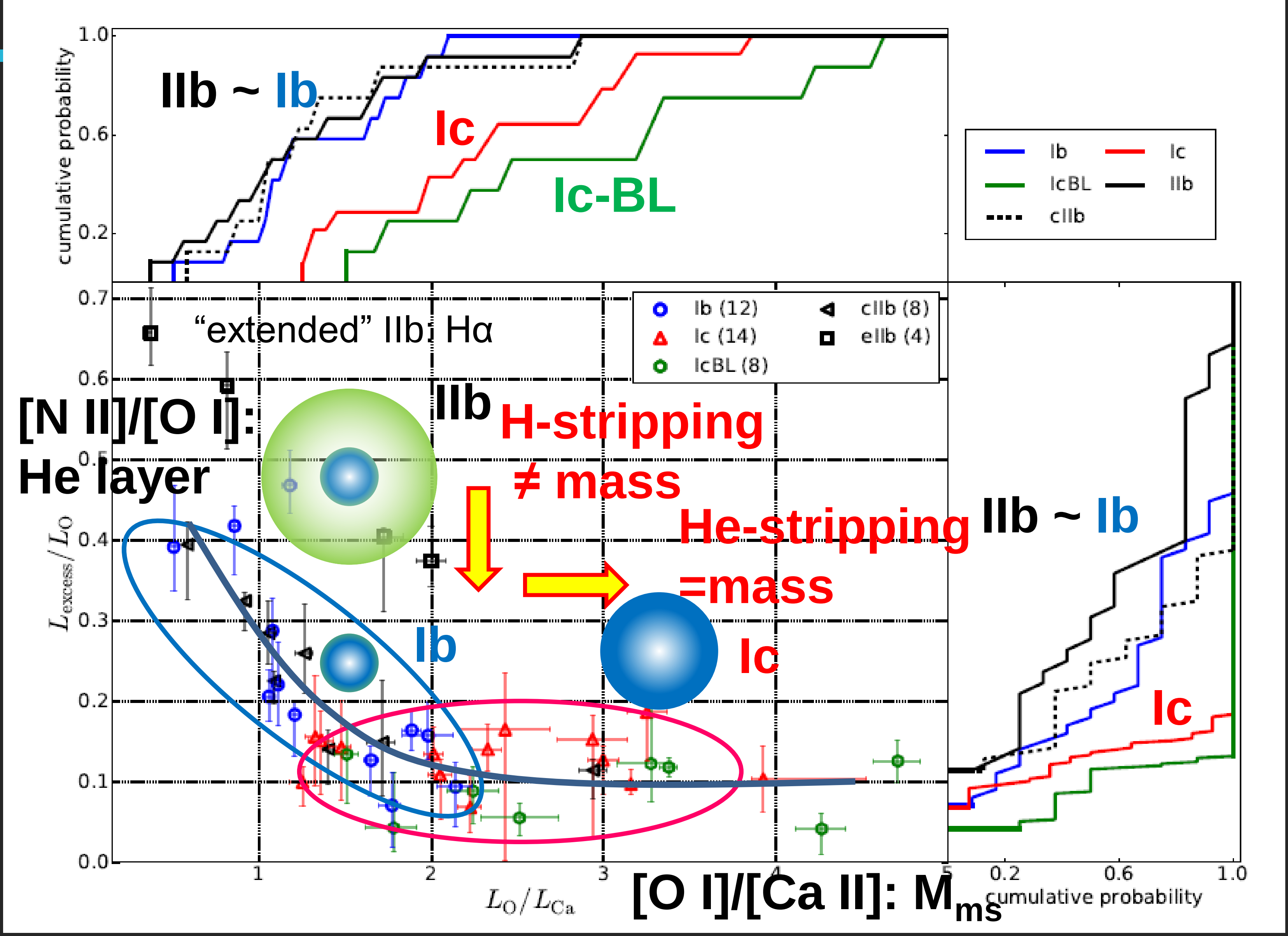
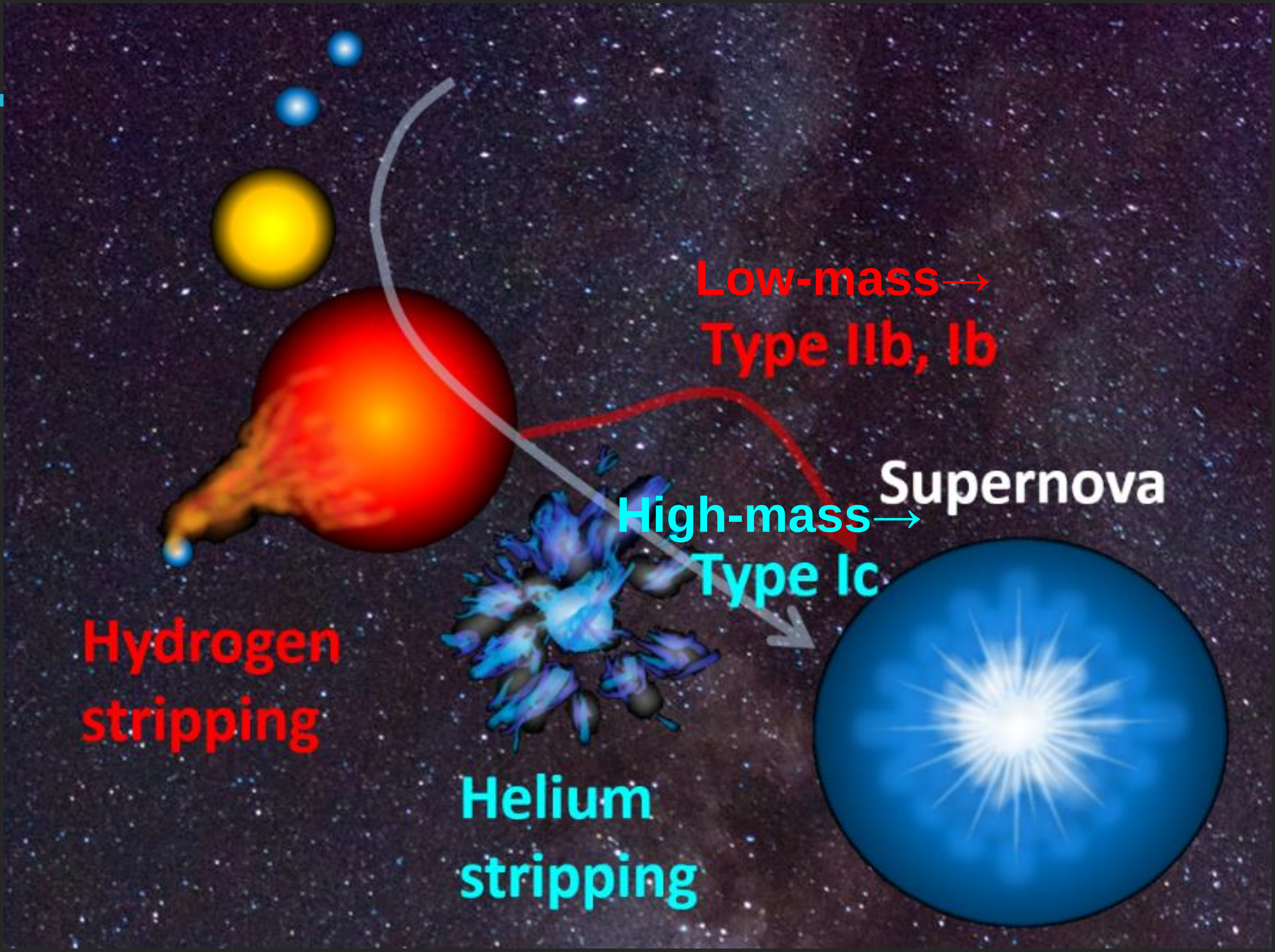
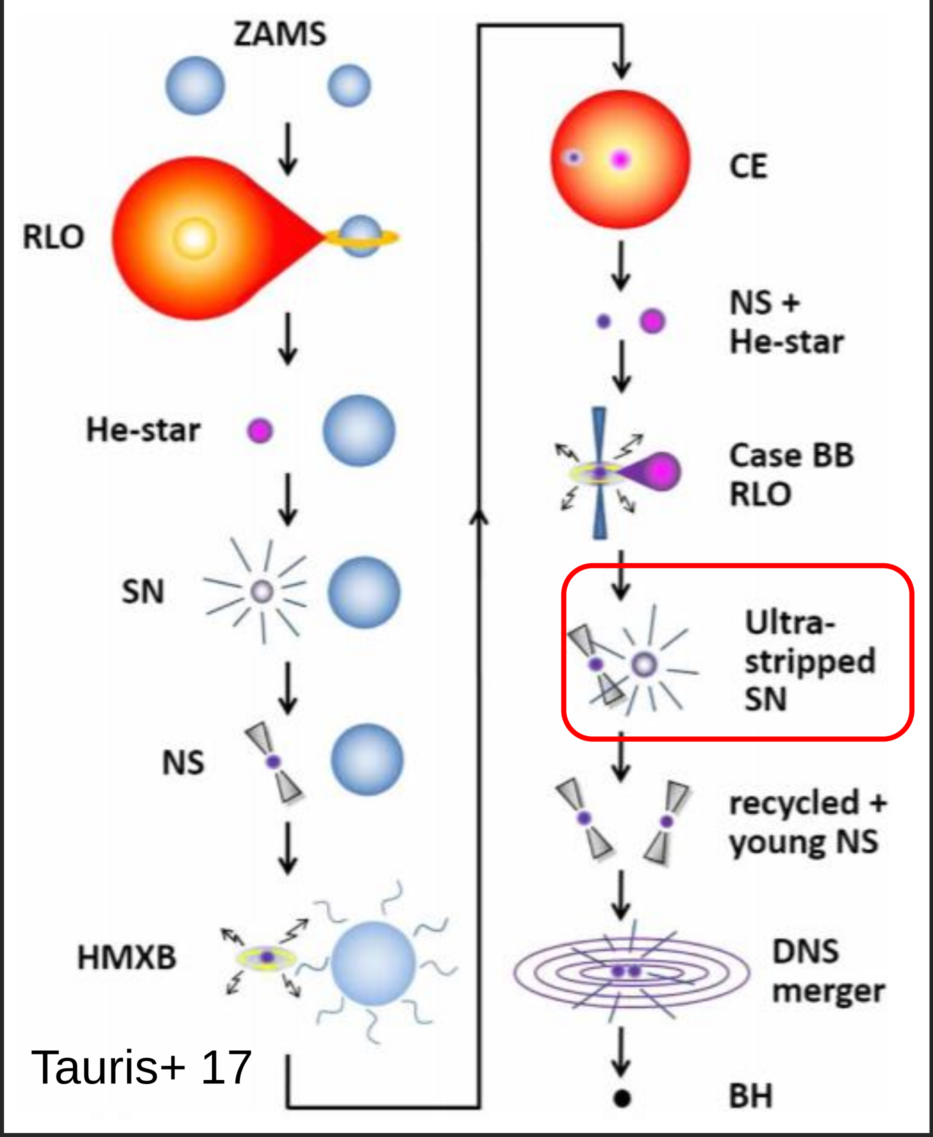



Low-mass→
Type IIb, Ib
Supernova
High-mass→
Type Ic
Hydrogen
stripping
Helium
stripping

Ultra-stripped envelope SNe



Tauris+ 17

2nd SN toward the formation of compact binary NSs.

Close orbit: C+O or H star

No binary disruption:

low mass ejecta (< $0.5M_{\odot}$)

⇒ <~ 2 $M_{\odot}$ He or C+O star

⇒ corresponding to

M_{ZAMS} < 11 or 12 $M_{\odot}$

⇒ Low-E + low M(^{56}Ni)

(e.g., Suwa+ 2015)

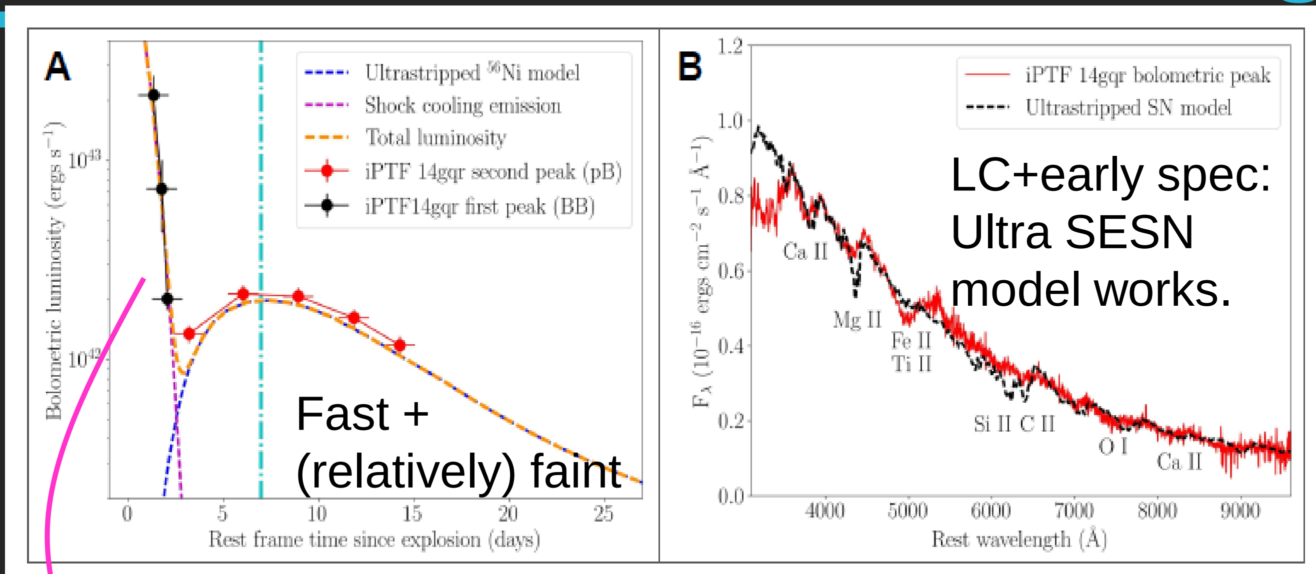
Prediction:

"Faint" and "Fast" transient

(e.g., Tauris+ 13, 15; also Kawabata+ 10)

De+ 18, Science

Ultra-SESN candidate iPTF14gqr



$M_{ej} \sim 0.2 M_\odot$

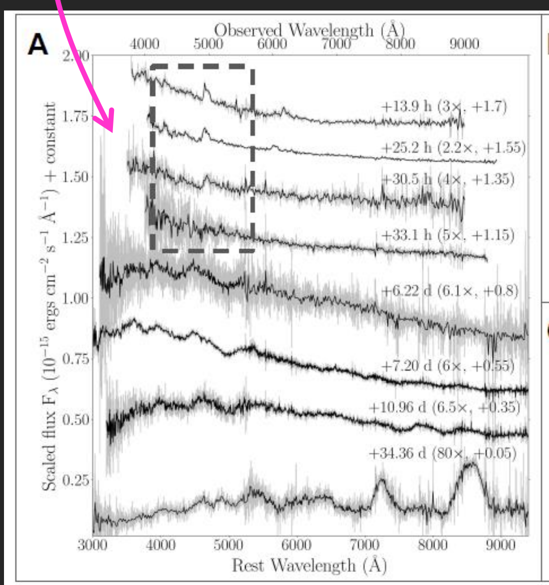
$E \sim 0.2 \times 10^{51}$ erg

$M(^{56}Ni) \sim 0.05 M_\odot$

Confined CSM:

$\sim 0.01 M_\odot$

at < 10^{14}cm



Dense CSM

(frequently observed

for core-collapse SNe.

⇒massive star origin.

Another candidate:

iPTF16hgs (De+ 18b)

Our SN and Transient follow-up program

3.8m Seimei Telescope
Okayama observatory
Kyoto University
2019B (Aug – Dec 2019)
36 nights (more than half fro quick ToOs)

1.5m Kanata Telescope
Higashi-Hiroshima obs.
Hiroshima University

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