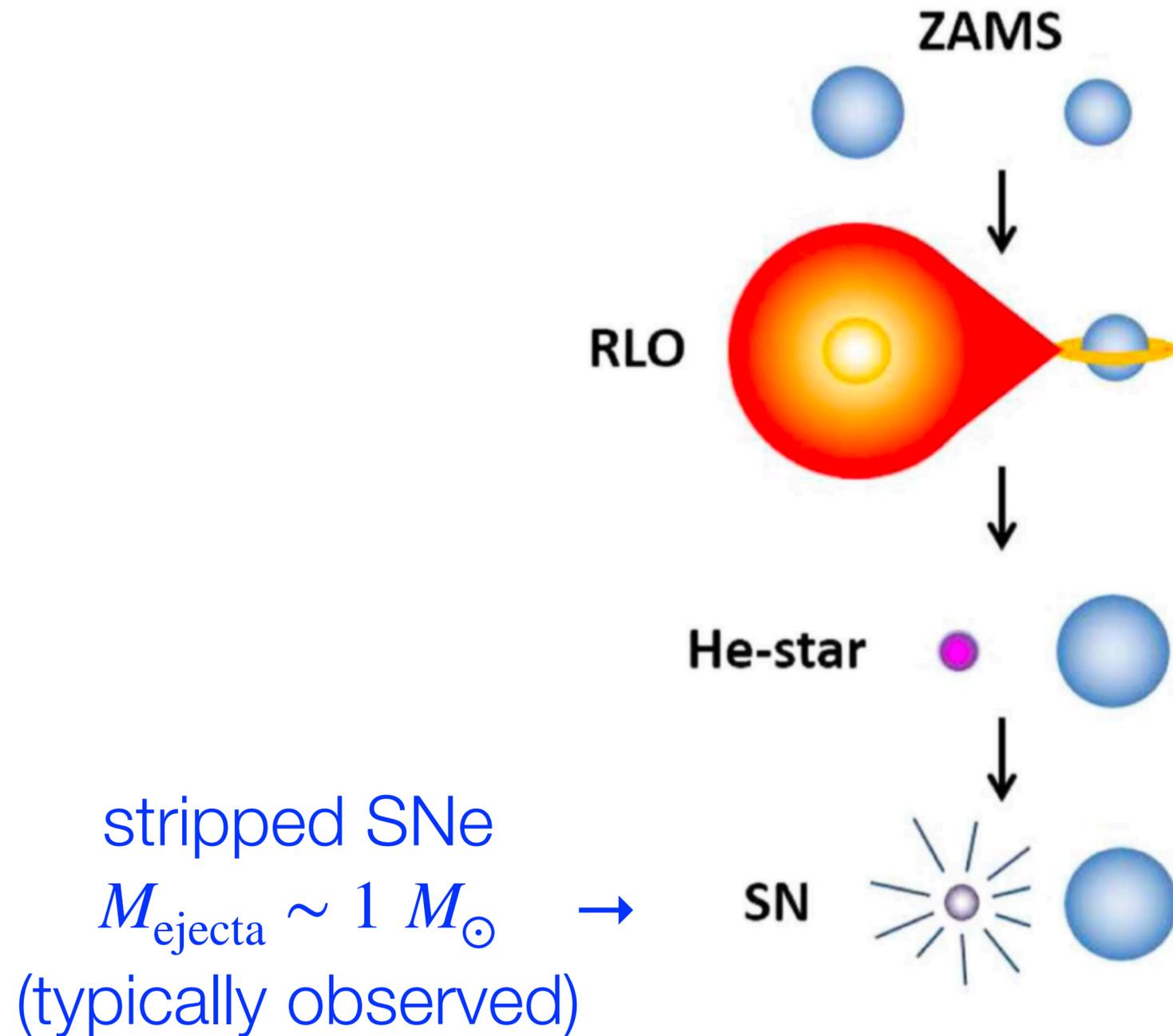# Type Ibn supernovae from ultra-stripped supernova progenitors

Takashi Moriya
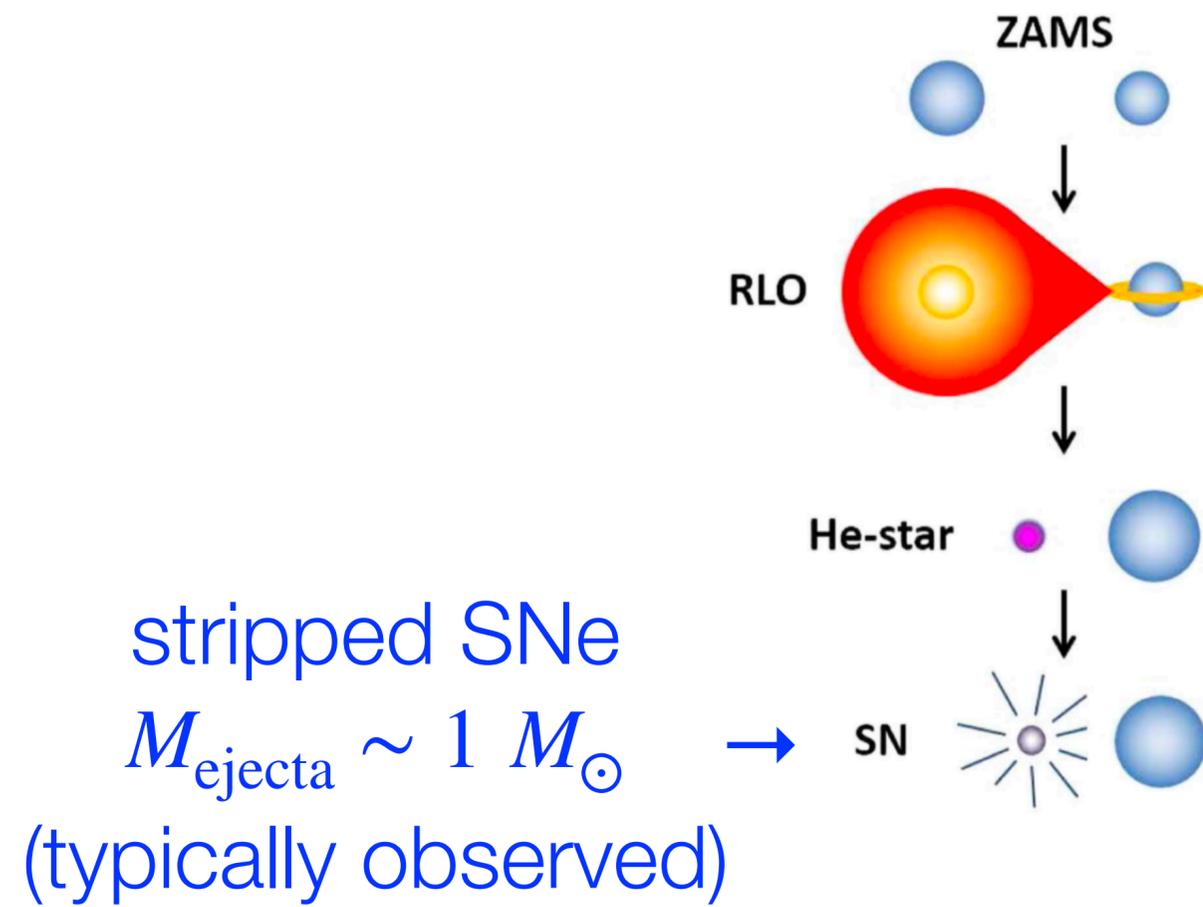National Astronomical Observatory of Japan
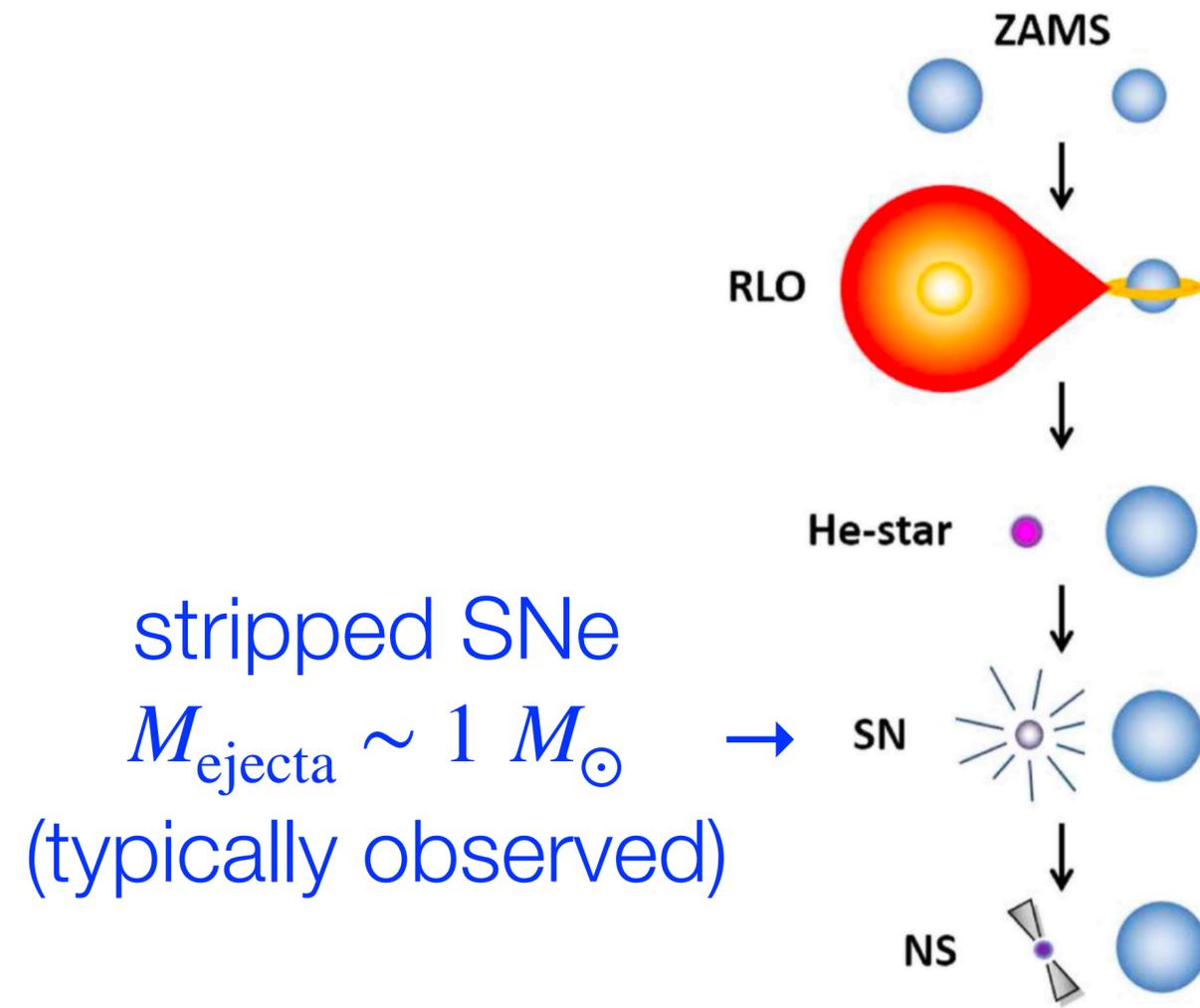
Ultra-stripped supernovae

ZAMS

RLO

He-star

stripped SNe
$M_{\mathrm{ejecta}} \sim 1\ M_\odot$ →
(typically observed)

SN

Tauris et al. (2017)

Ultra-stripped supernovae

stripped SNe
$M_{\mathrm{ejecta}} \sim 1\ M_\odot$ →
(typically observed)

Ultra-stripped supernovae

stripped SNe
$M_{\text{ejecta}} \sim 1\ M_{\odot}$ $\rightarrow$
(typically observed)

Ultra-stripped supernovae

separation becomes
very small ($\sim R_\odot$)

stripped SNe
$M_{\mathrm{ejecta}} \sim 1\ M_\odot$
(typically observed) →

Tauris et al. (2017)

Ultra-stripped supernovae

separation becomes
very small ($\sim R_{\odot}$)

stripped SNe
$M_{\mathrm{ejecta}} \sim 1\ M_{\odot}$ →
(typically observed)

ZAMS

RLO

He-star

SN

NS

HMXB

CE

NS +
He-star

Tauris et al. (2017)

Ultra-stripped supernovae

separation becomes
very small ($\sim R_\odot$)

expansion after the
central He burning
(more stripping)

stripped SNe
$M_{\mathrm{ejecta}} \sim 1 \, M_\odot$ →
(typically observed)

Tauris et al. (2017)

Ultra-stripped supernovae

separation becomes
very small ($\sim R_\odot$)

expansion after the
central He burning
(more stripping)

stripped SNe with
$M_{\mathrm{ejecta}} \sim 0.1\ M_\odot$
(2nd SN)

ultra-stripped SNe

stripped SNe
$M_{\mathrm{ejecta}} \sim 1\ M_\odot$
(typically observed)

Tauris et al. (2017)

Ultra-stripped supernovae

separation becomes
very small ($\sim R_\odot$)

expansion after the
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ultra-stripped SNe

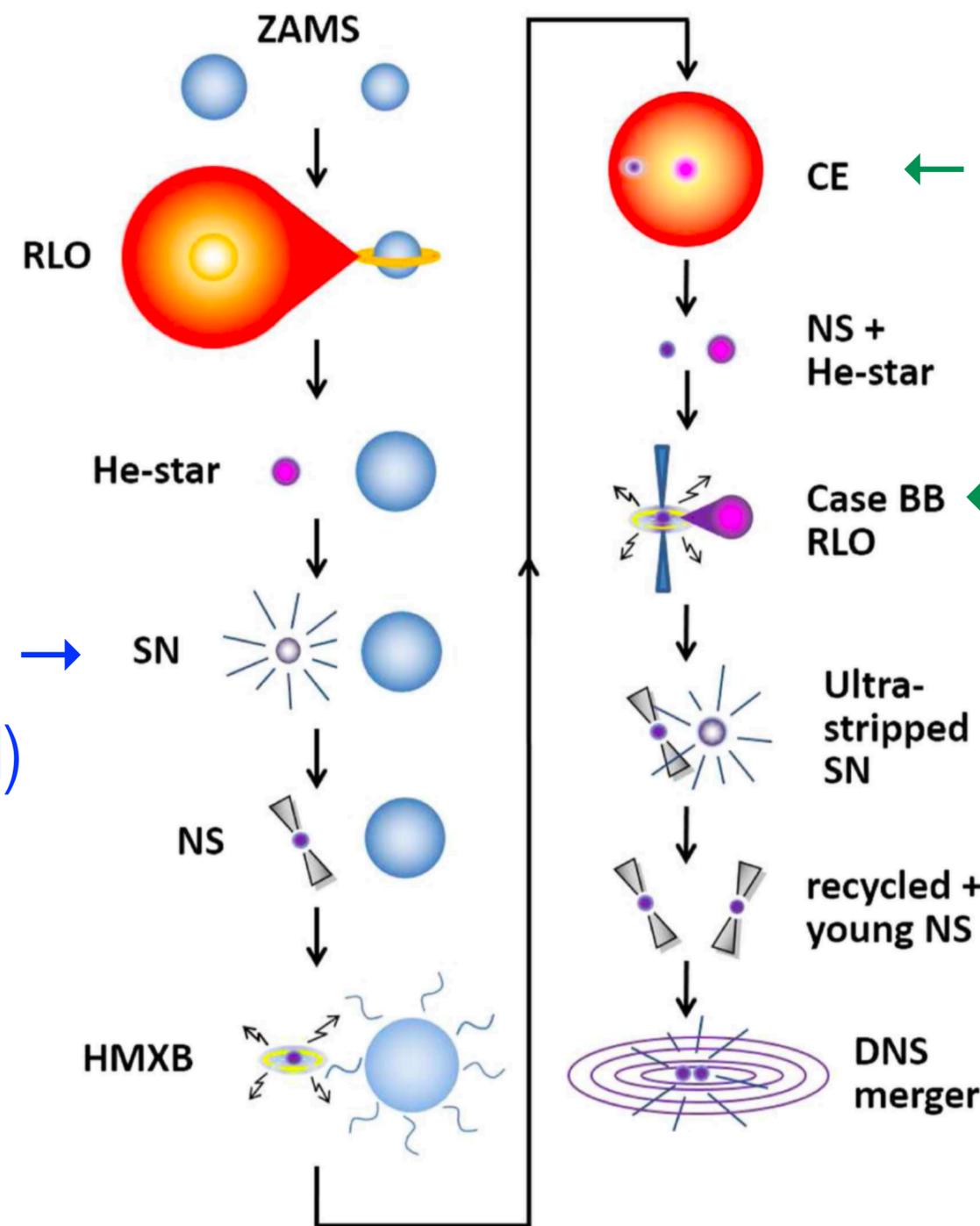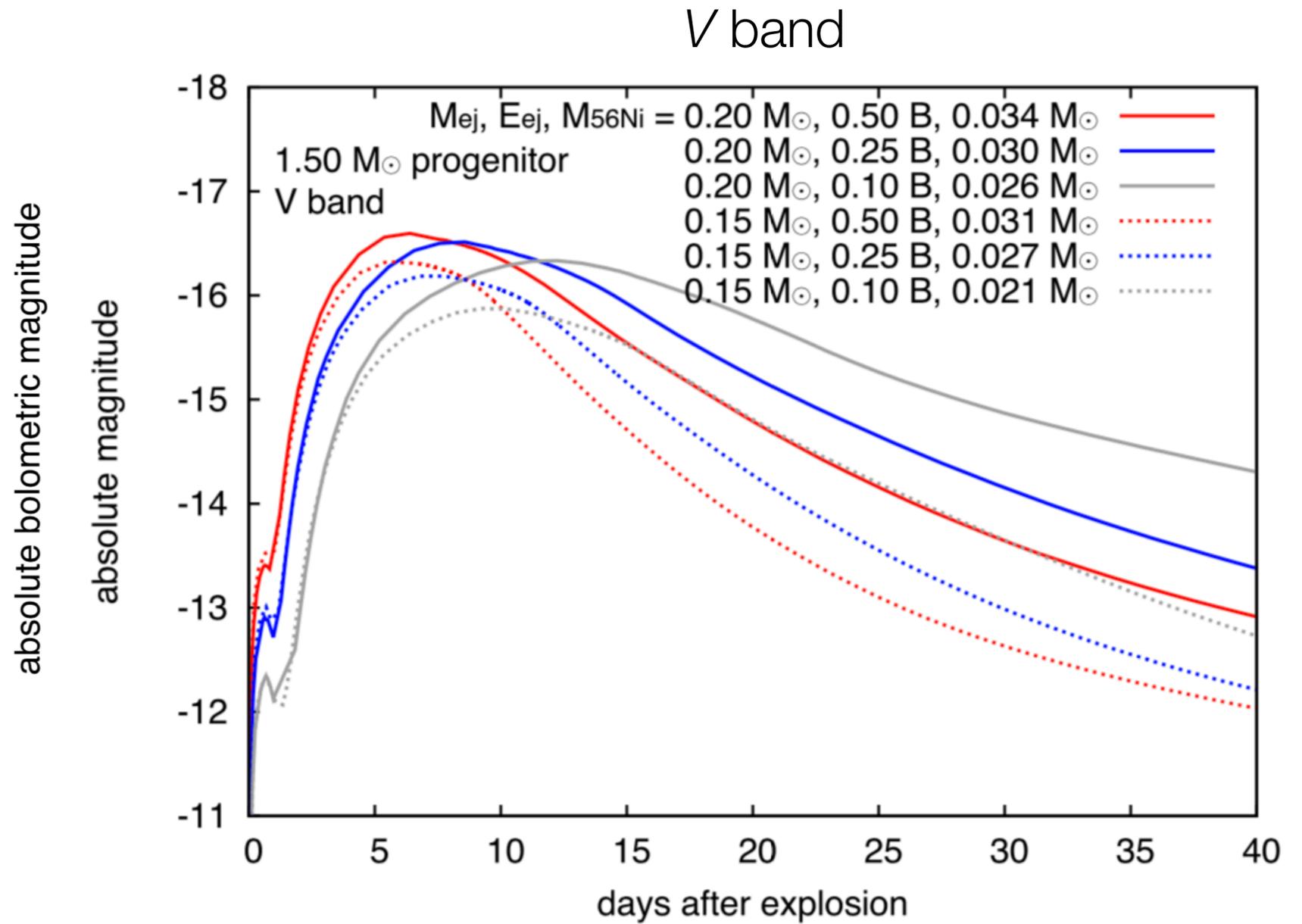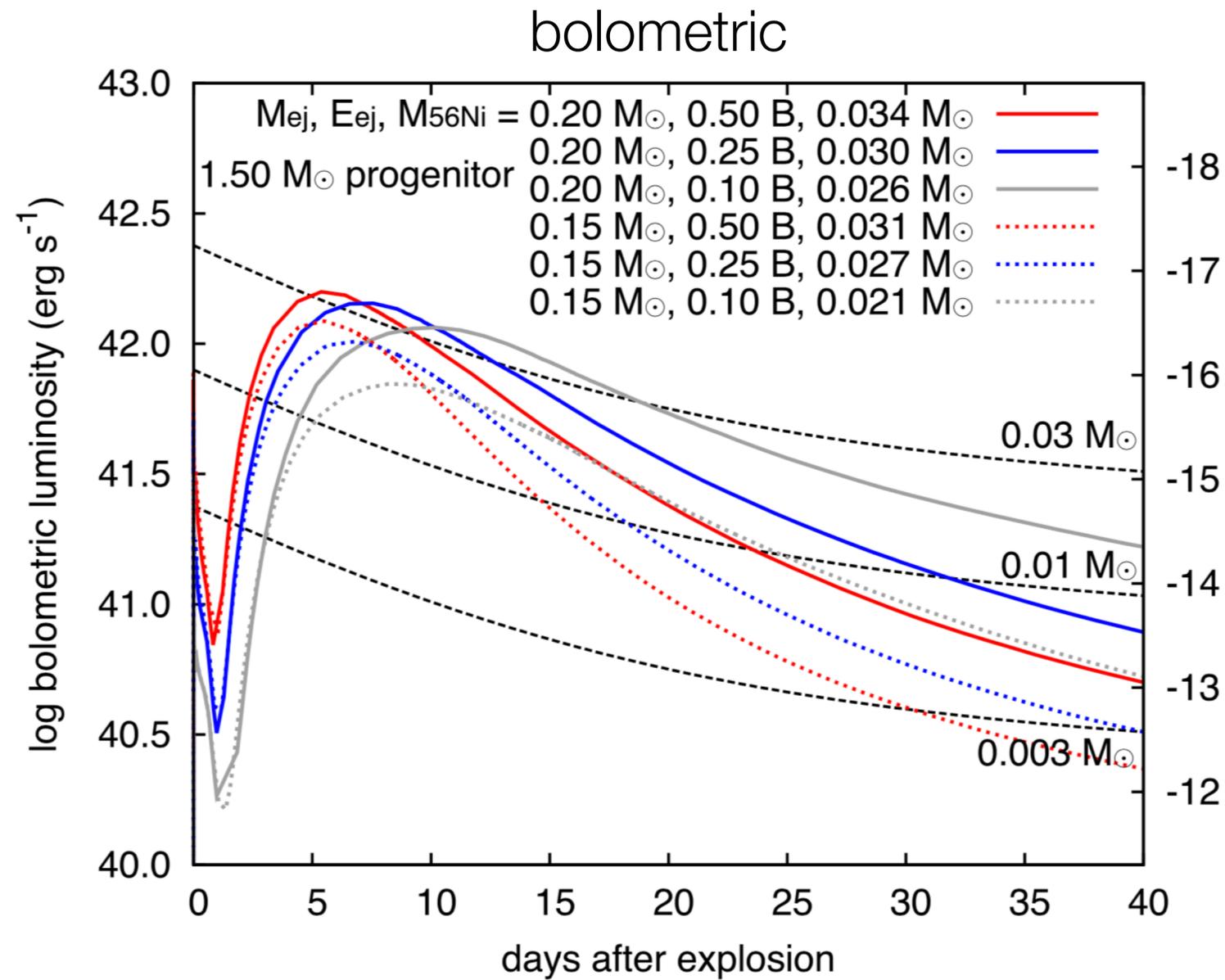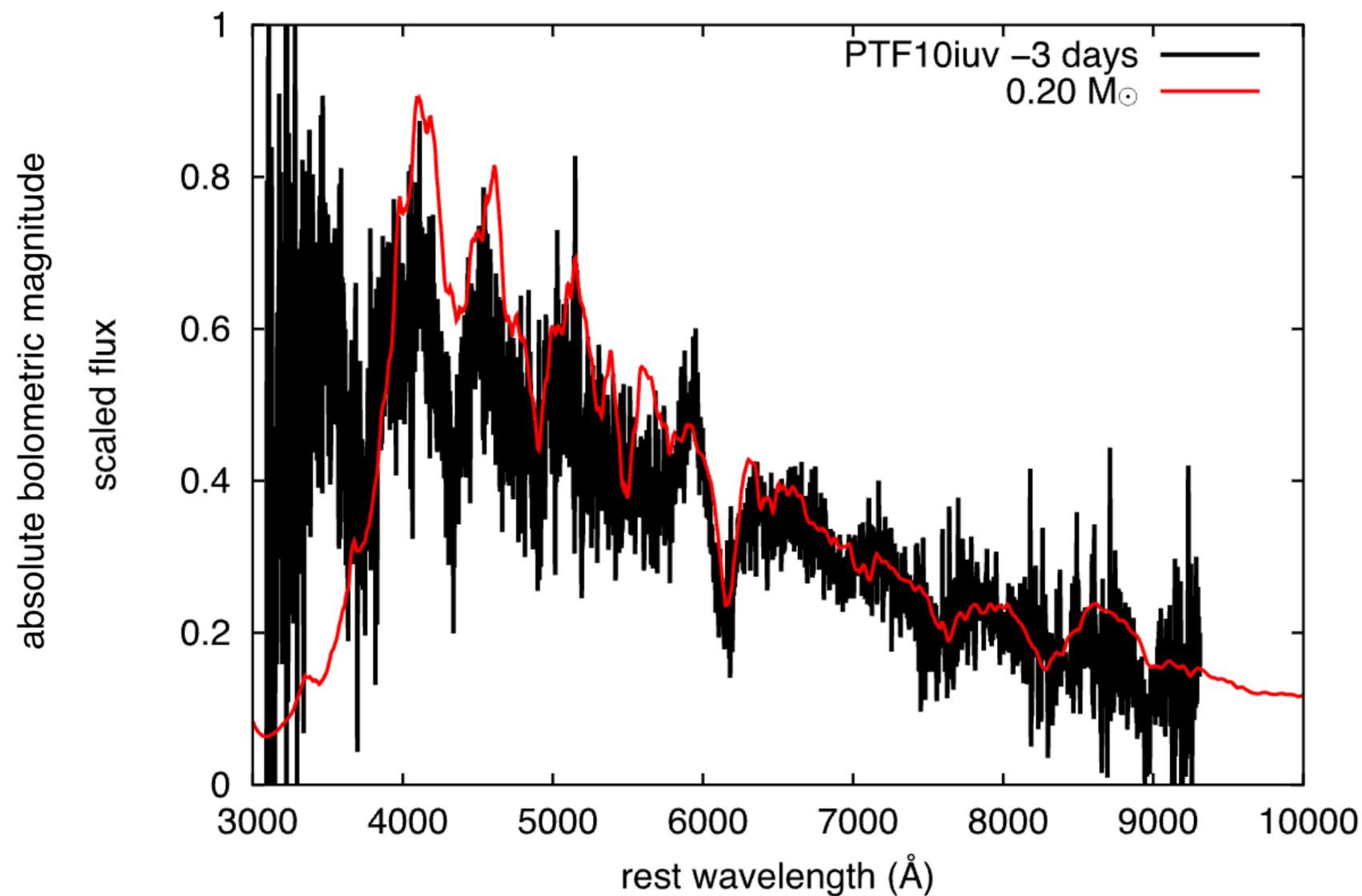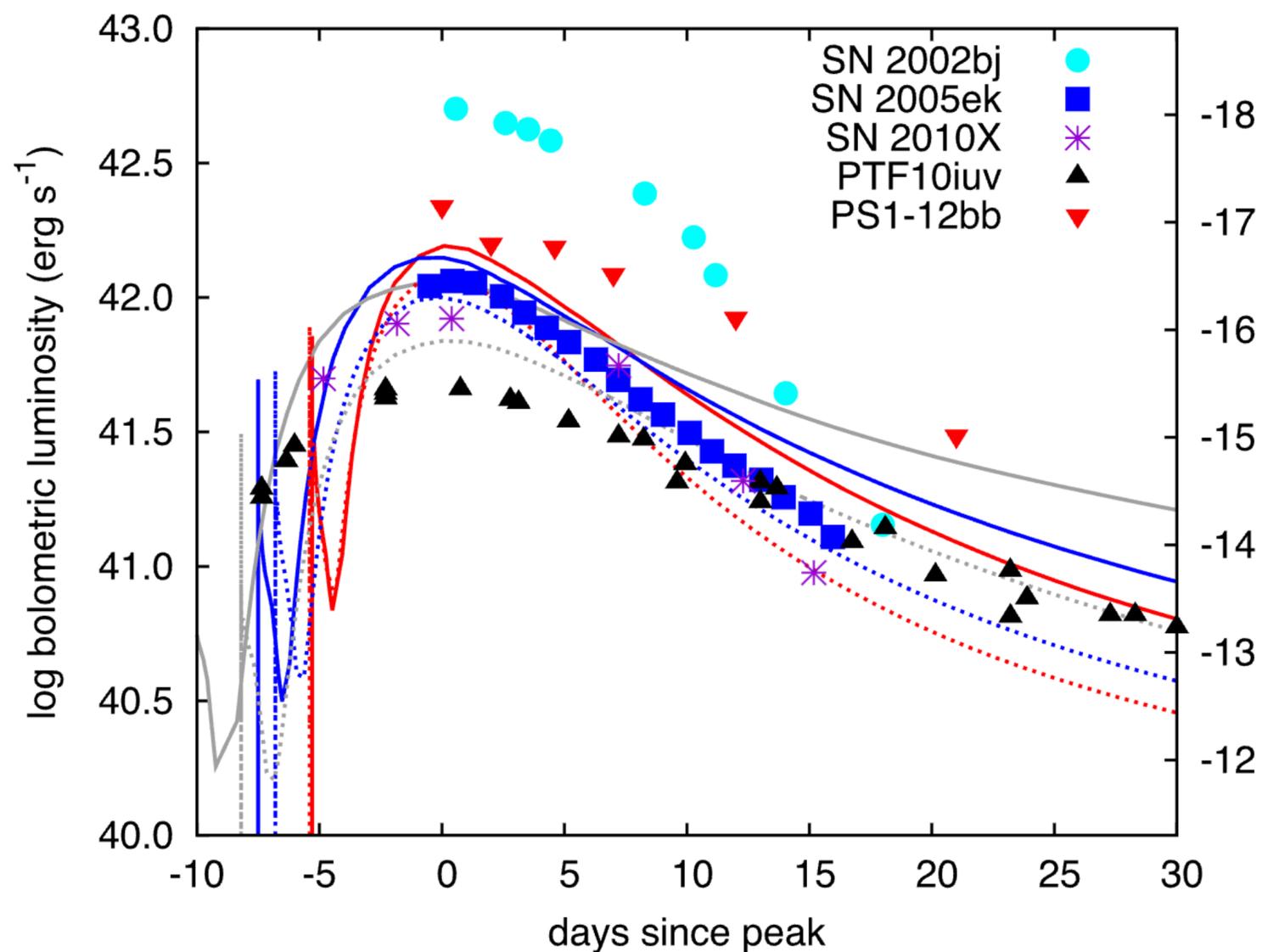stripped SNe
$M_{\mathrm{ejecta}} \sim 1 \ M_\odot$
(typically observed)

Tauris et al. (2017)

Ultra-stripped supernovae

~ 70% of double NS systems
may come from this path
(e.g., Vigna-Gomez et al. 2018)

separation becomes
very small ($\sim R_\odot$)

expansion after the
central He burning
(more stripping)

stripped SNe
$M_{\mathrm{ejecta}} \sim 1\ M_\odot$
(typically observed)

stripped SNe with
$M_{\mathrm{ejecta}} \sim 0.1\ M_\odot$
(2nd SN)

ultra-stripped SNe
✓ **small ejecta mass to keep the
system bound**
✓ **small kick**

Tauris et al. (2017)

Predicted light curves

bolometric

V band

Moriya et al. (2017)

Comparison with observations

Some Ca-rich (Ca-strong) SNe may be ultra-stripped SNe

Moriya et al. (2017)

Ultra-stripped SN progenitor evolution and explosion simulations

- Müller et al. (2018)
  - developed 2.9 Msun He star in a compact binary
  - evolved the progenitor until core collapse with the Kepler code
  - performed multi-dimensional explosion simulations
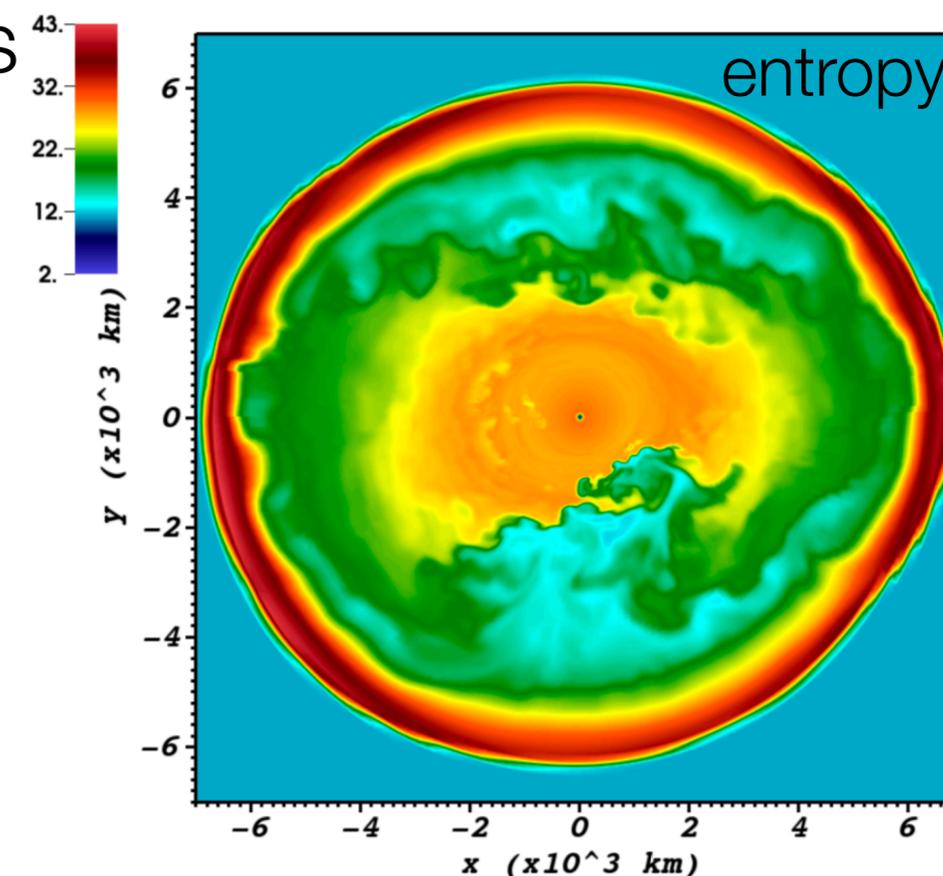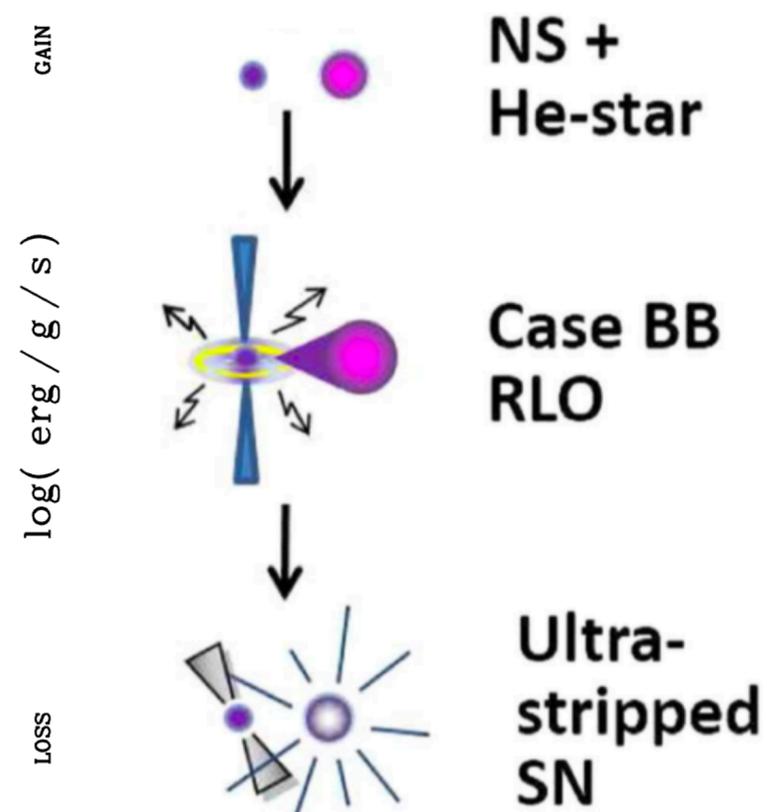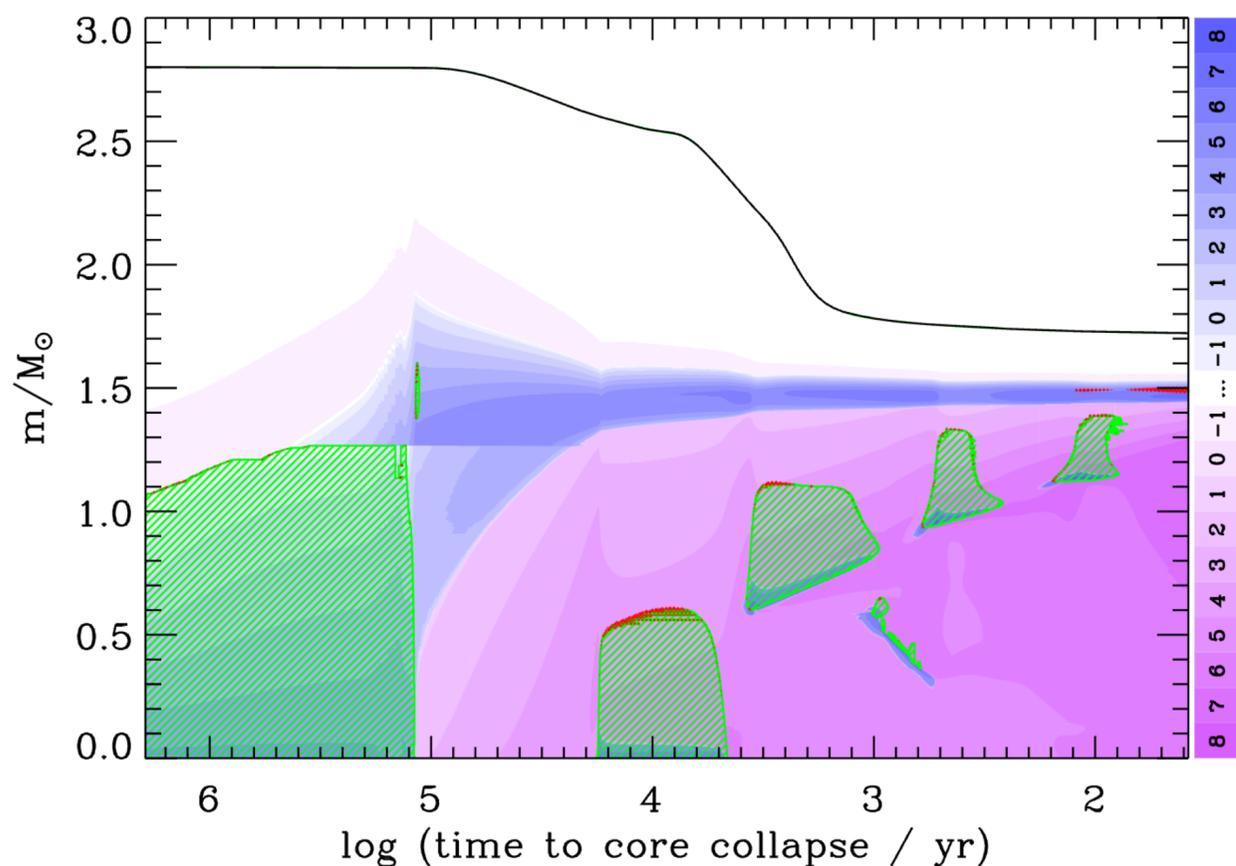
ejecta mass = 0.06 Msun
explosion energy = 9×10^{49} erg

The ignored mass ejection in Müller et al. (2018)

- The progenitor has 1.7 Msun until 78 days before explosion
- Violent silicon burning is triggered at 78 days before explosion
  - due to strongly degenerate condition (Woosley & Heger 2015, Woosley 2019)
  - shock wave launched
  - 0.2 Msun (He envelope) is ejected
    - only 0.02 Msun He envelope remains

Table 8
Critical Masses in Close Binary Systems

| ZAMS Star [$M_\odot$]	Initial He Star [$M_\odot$]	Pre-SN Mass [$M_\odot$]	Characteristics
<13	<2.4	…	SAGB star, WD
13–13.5	2.4–2.5	2.0–2.1	SAGB star, rad-expansion ECSN, fast SN Ib, little ^{56}Ni
13.5–16	2.5–3.2	2.1–2.6	Si flash, rad-expansion, peculiar SN Ib
16–30	3.2–10	2.6–7	Ordinary SN Ib, Ic
30–120	10–60	7–30	Mostly BH, massive SN Ic
120–140	60–70	30–35	Weak PPISN, BH
140–250	70–125	35–62	Strong PPISN, BH
250–500	125–250	62–133	PISN, no remnant
>500	>250	>133	Black holes

Woosley (2019)

- Subsequent explosion of 1.5 Msun star leads to the mass ejection of 0.06 Msun with the explosion energy of 9×10^{49} erg

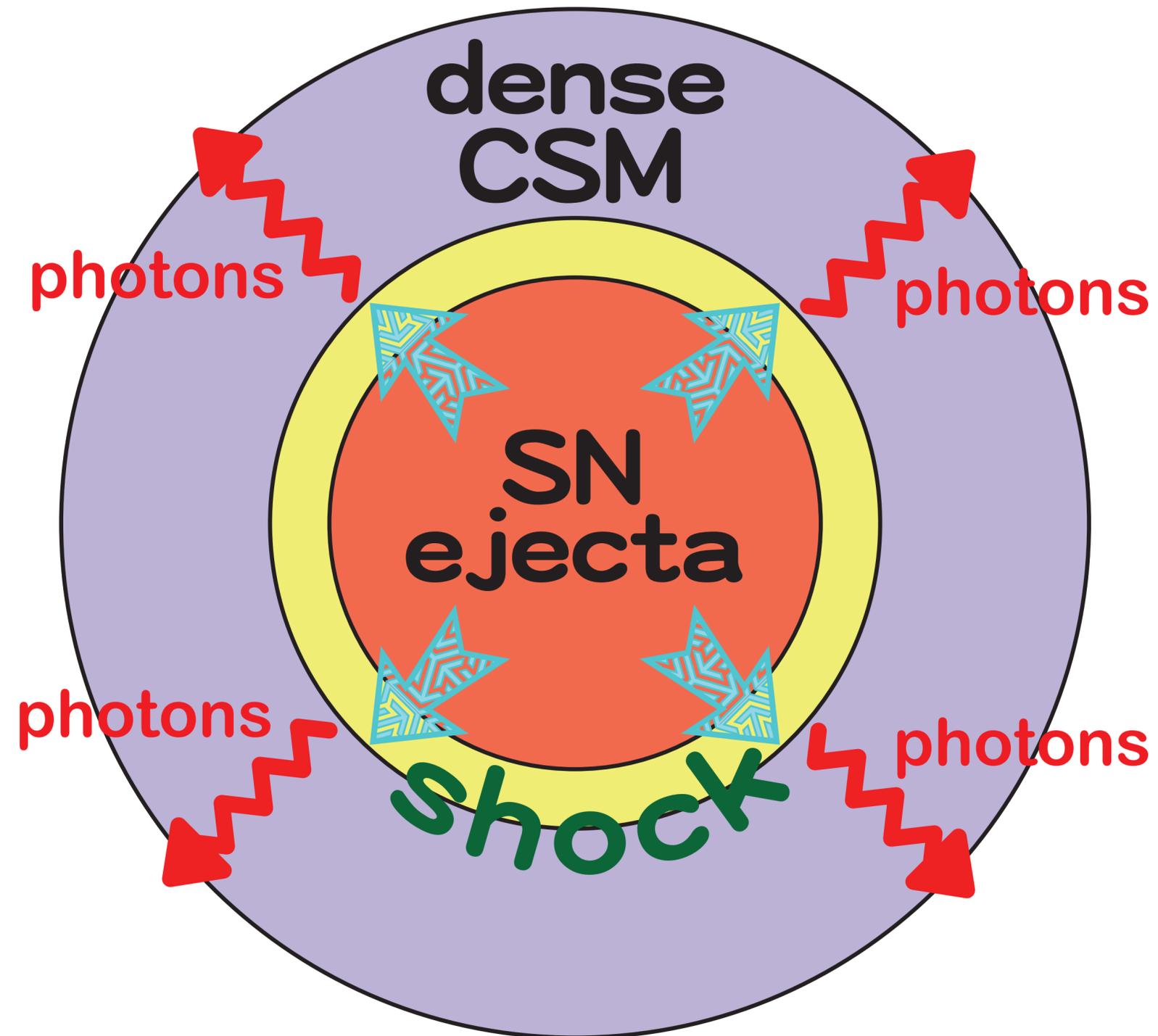# The ultra-stripped SN structure shortly before shock breakout

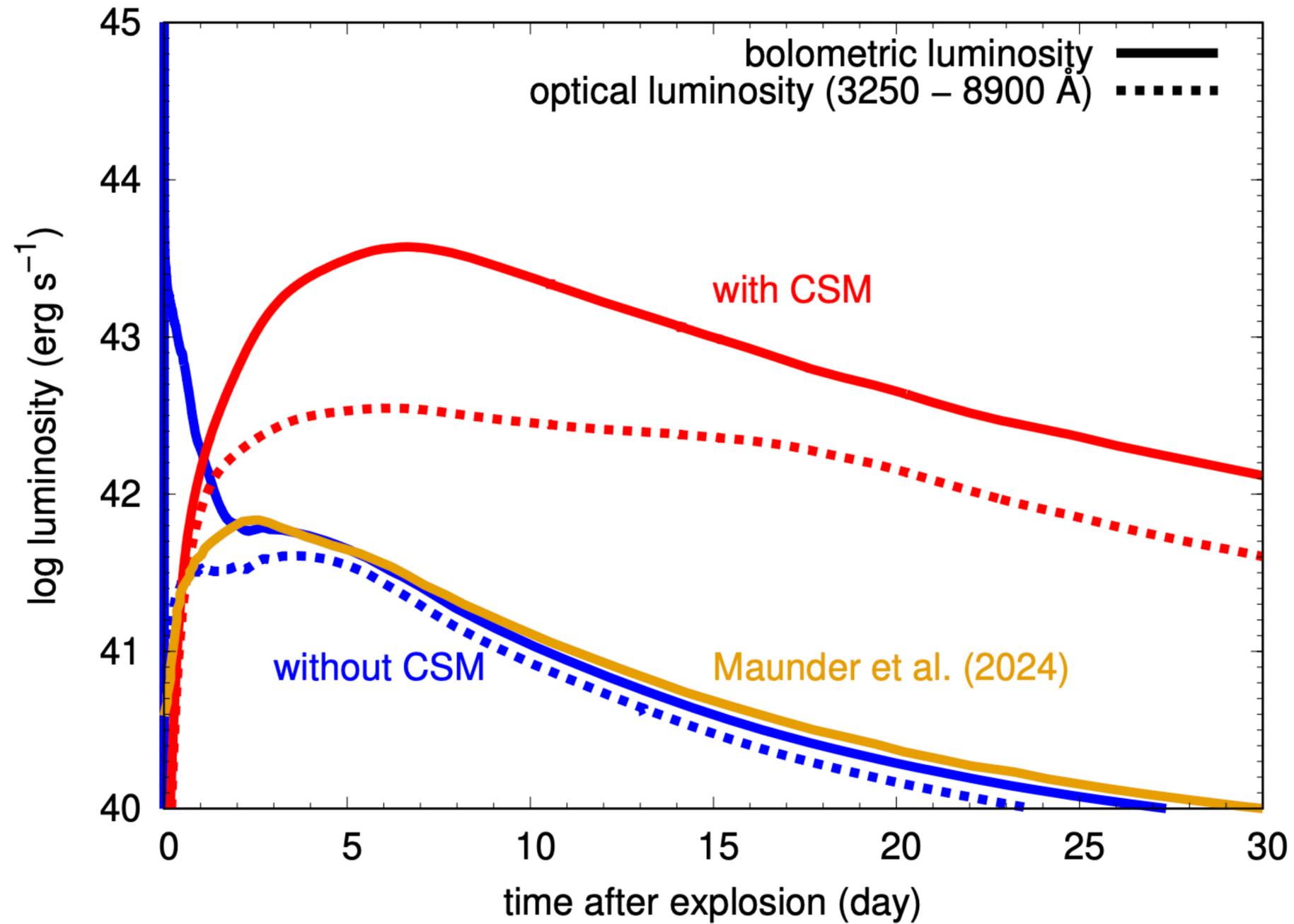The progenitor expands from ~ 0.1 Rsun to ~ 100 Rsun
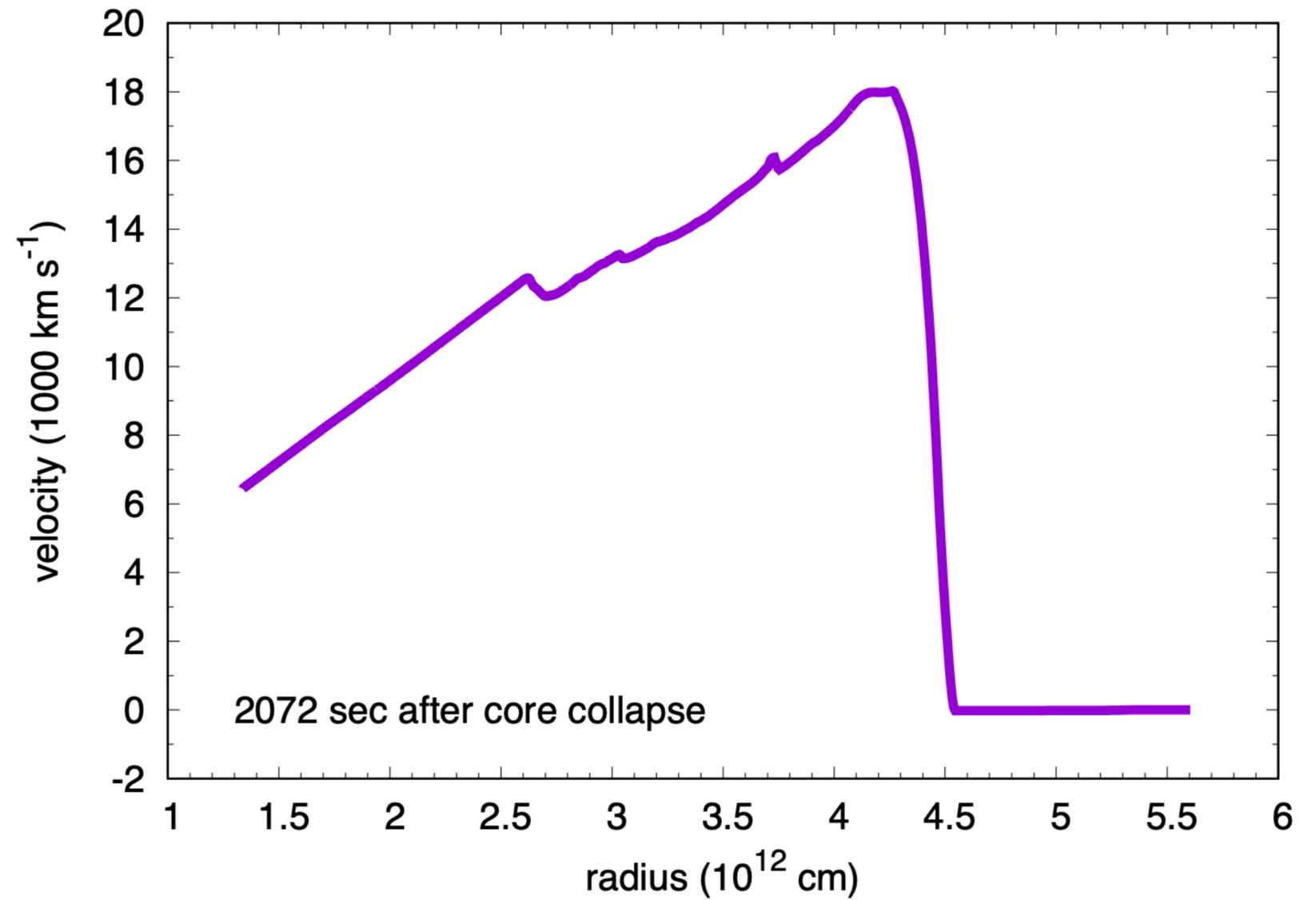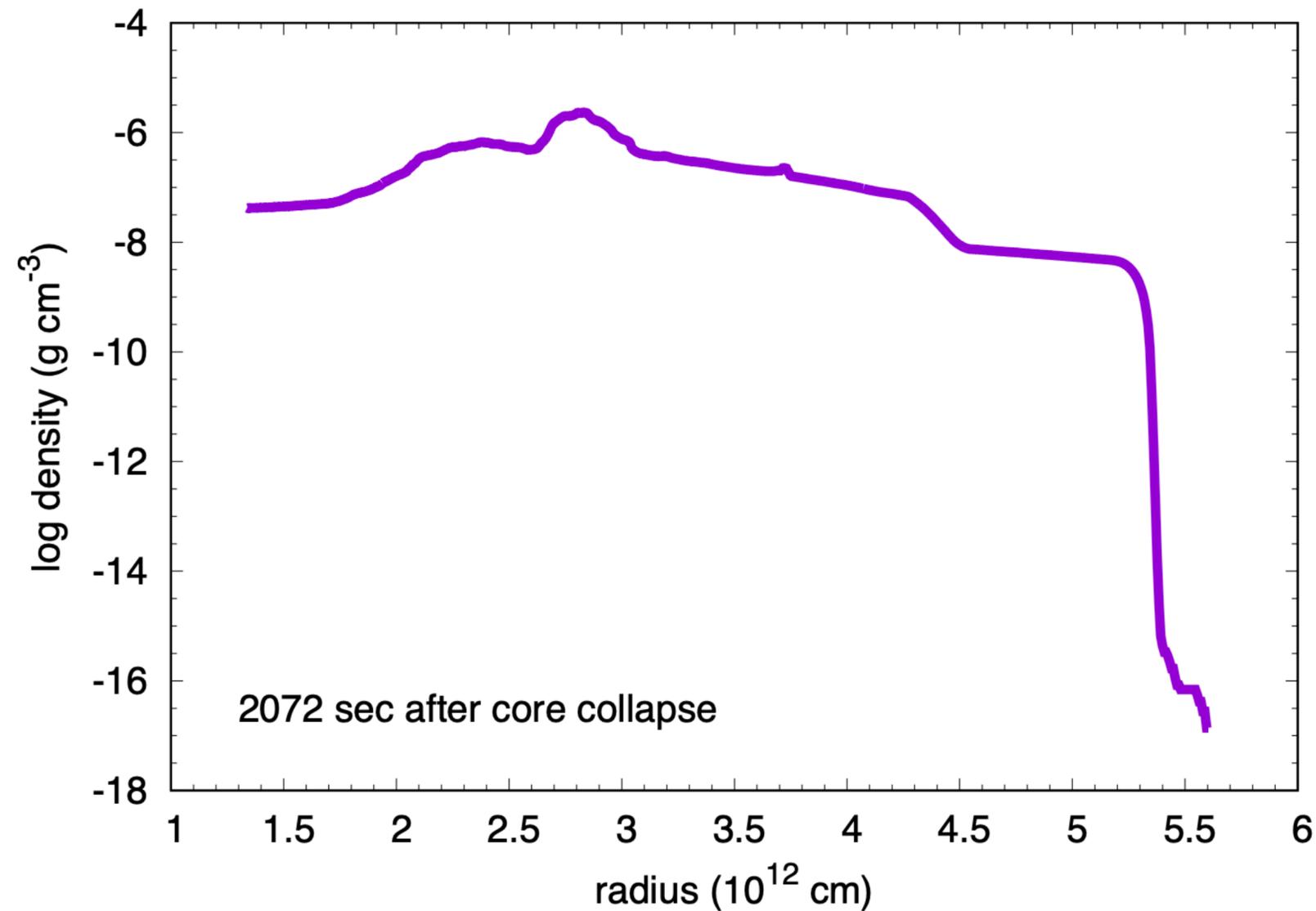
Ultra-stripped SN ejecta collide to CSM
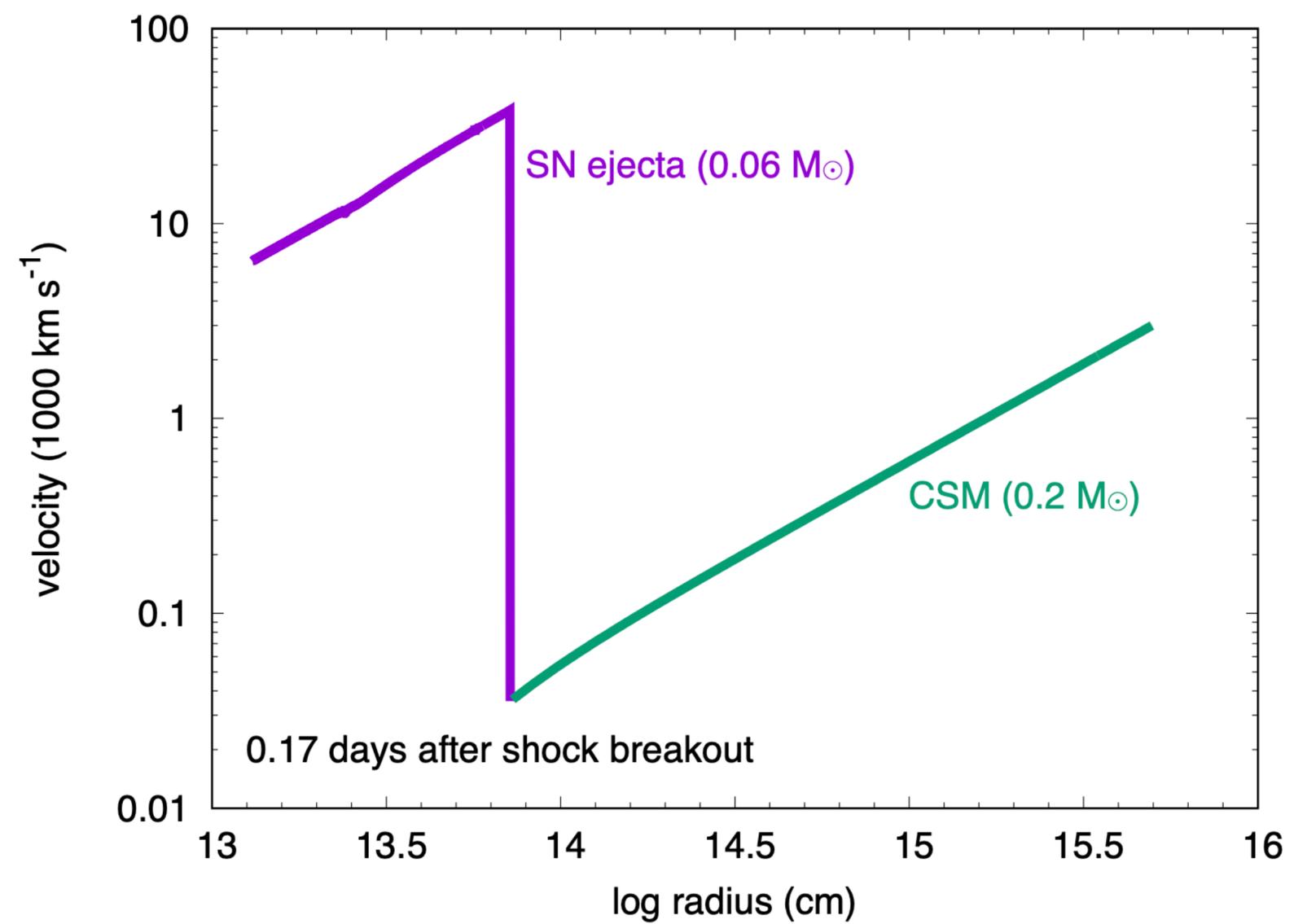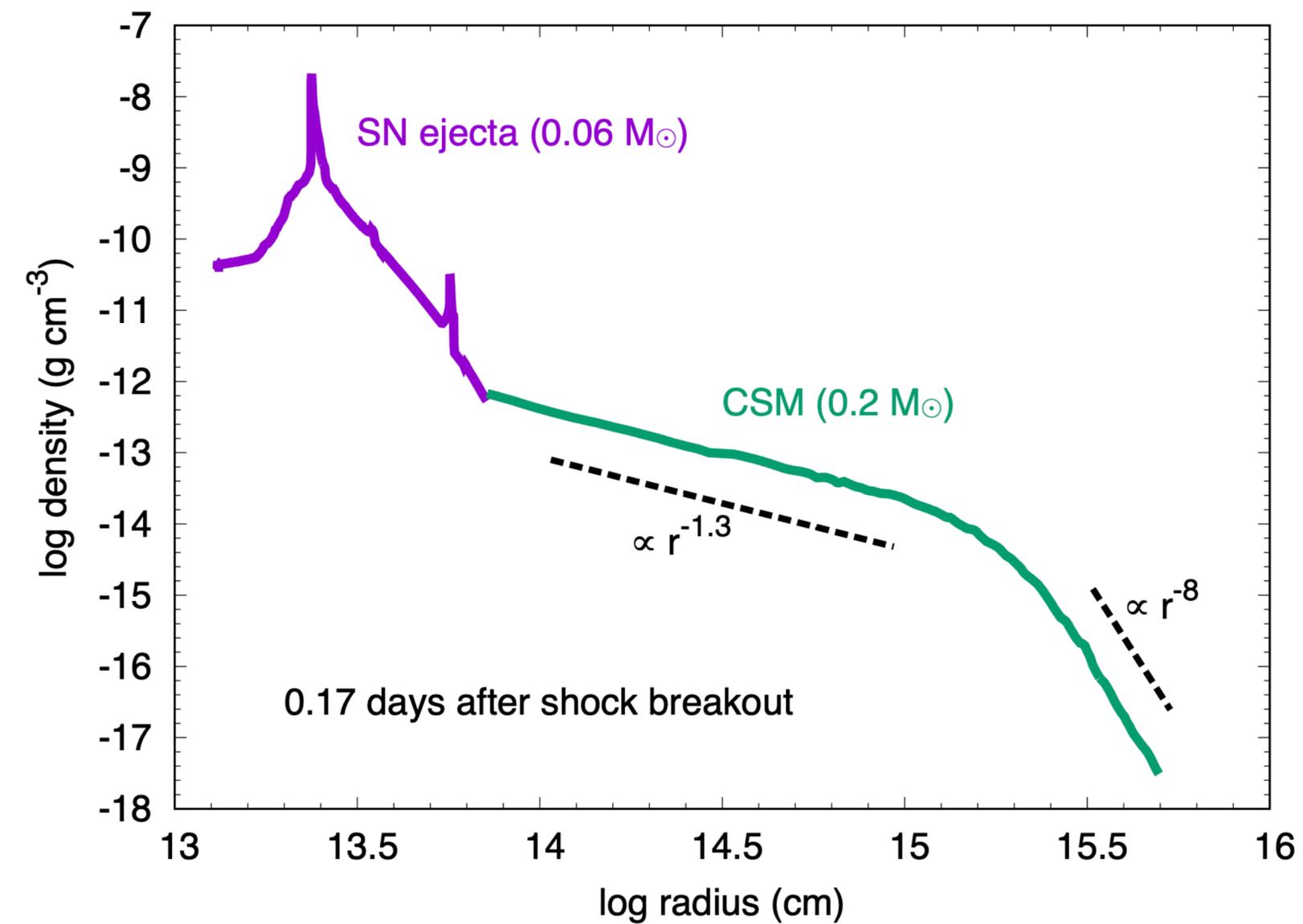
Supernovae in dense circumstellar matter (CSM)

Light curves

Comparison with Type Ibn supernovae

Supernovae showing interaction signatures with He-rich CSM

Type Ibn SN template

without CSM	**·····**
with CSM ($B_q = 1$)	▬
($B_q = 0.5$)	▬
($B_q = 2$)	▬

SN 2020bqj

SN 2010al

SN 2005la

SN 2023xgo

SN 2023utc
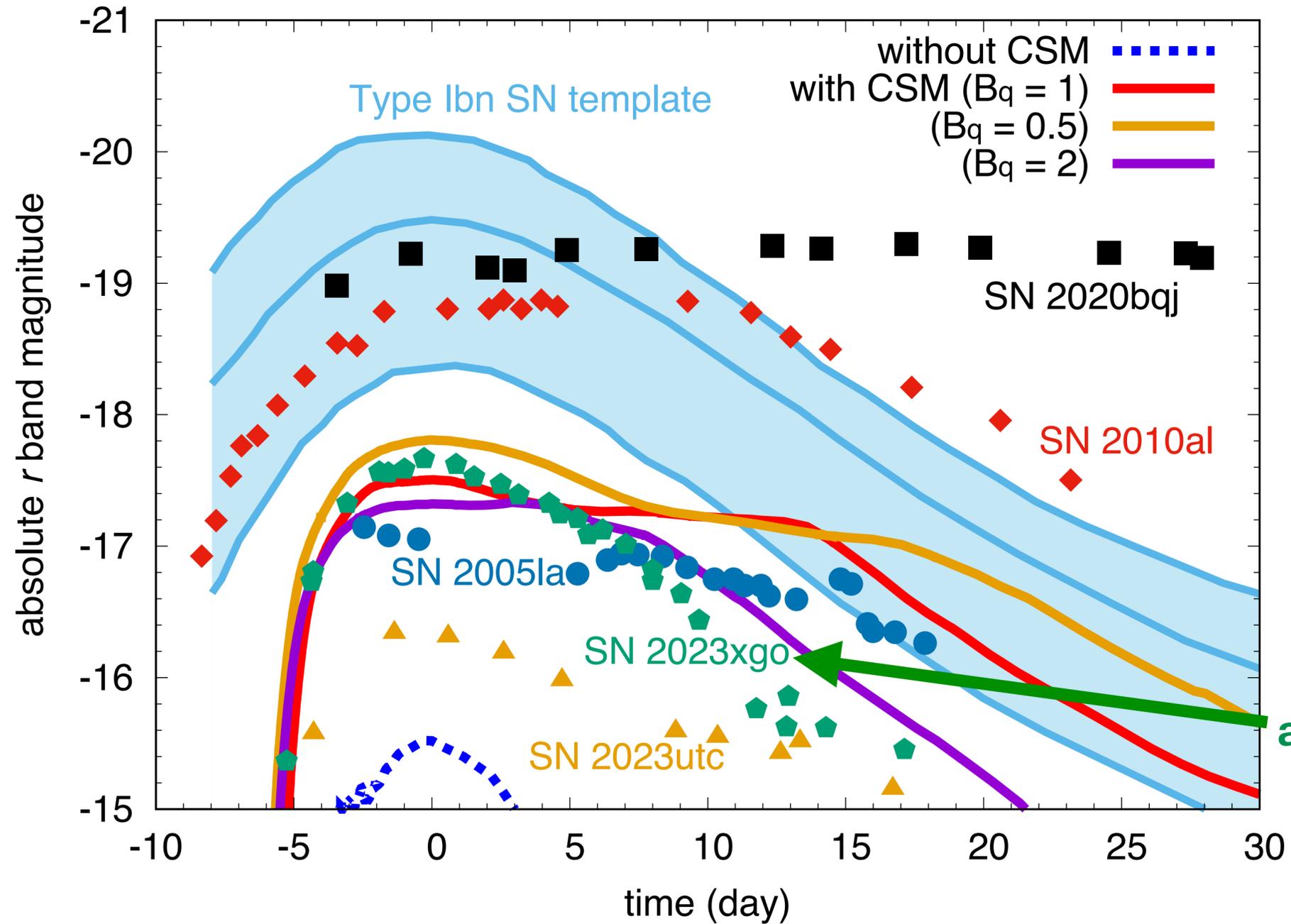
**Type Ibn SN from
an ultra-stripped progenitor?
(Gangopadhyay et al. 2025)**

absolute r band magnitude

time (day)

The first ultra-stripped SN iPTF14gqr

$$M_{\mathrm{CSM}} \sim 0.01\ M_{\odot}$$

De et al. (2018)
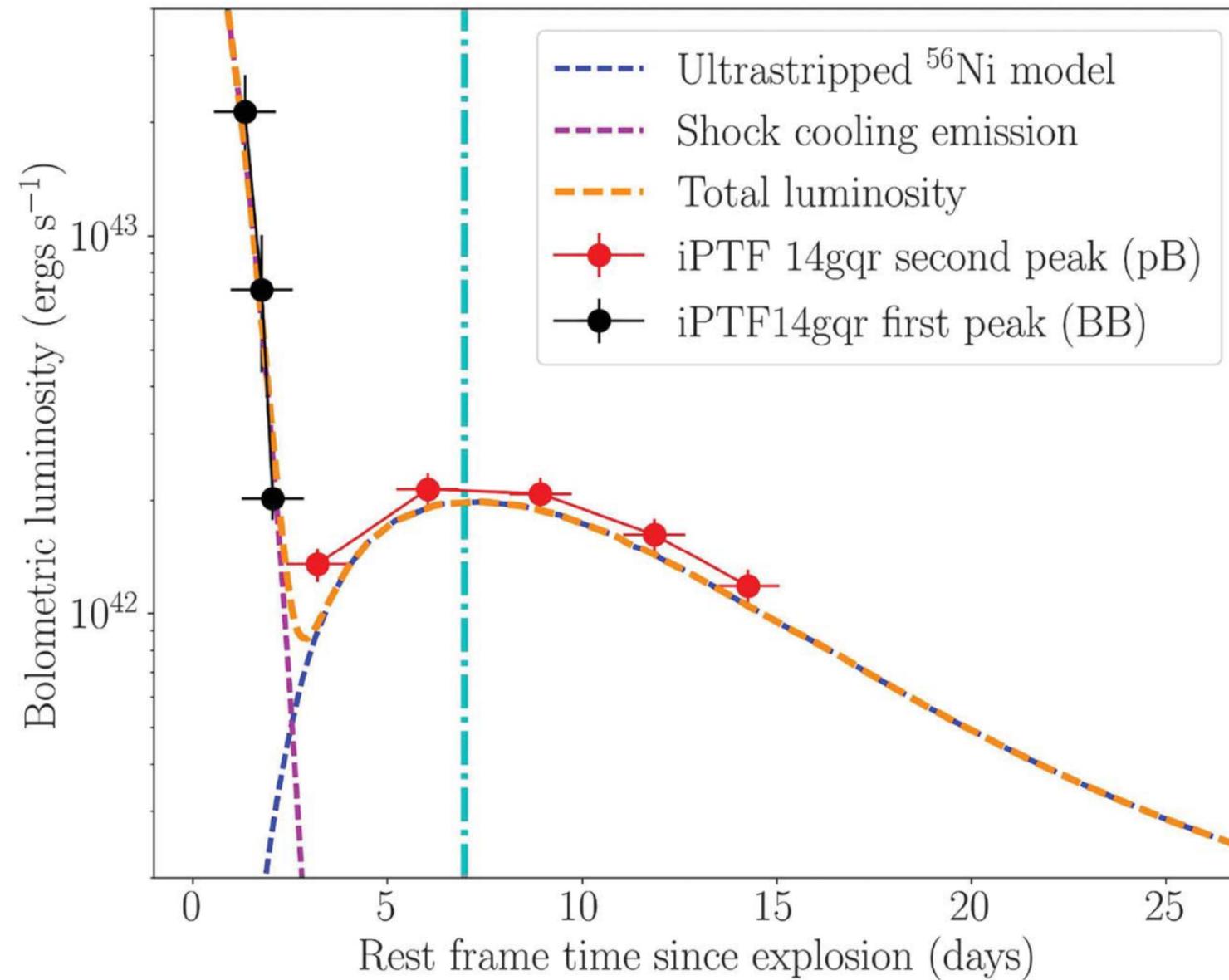
The unexpected mass loss

Zero Age Main Sequence (MS) binary

Roche Lobe overflow (RLO)

MS star - He star binary

First Type Ib/c SN

He star - NS binary

Common envelope spiral in

High mass X-ray binary phase

MS star - neutron star (NS)

He star (stable/unstable) RLO. Most He is ejected from the system

Stripped He star + NS **Intense mass loss leads to expanding envelope.**

iPTF 14gqr: Ultra-stripped SN inside He-rich envelope.

Double NS system

De et al. (2018)

Rates

- Ultra-stripped SNe are predicted to be 0.1-1% of core-collapse SNe
- Type Ibn SNe are around 1% of core-collapse SNe
- A large fraction of ultra-stripped SNe can end up with Type Ibn SNe

Summary

Knowing what kind of SNe result from ultra-stripped progenitors is important

Ultra-stripped SN progenitors can experience strong mass loss triggered by violent Si burning shortly before explosion

caused by strongly degenerate conditions

Ultra-stripped SN properties can be affected by mass ejection

Ultra-stripped SNe can be observed as Type Ibn SNe