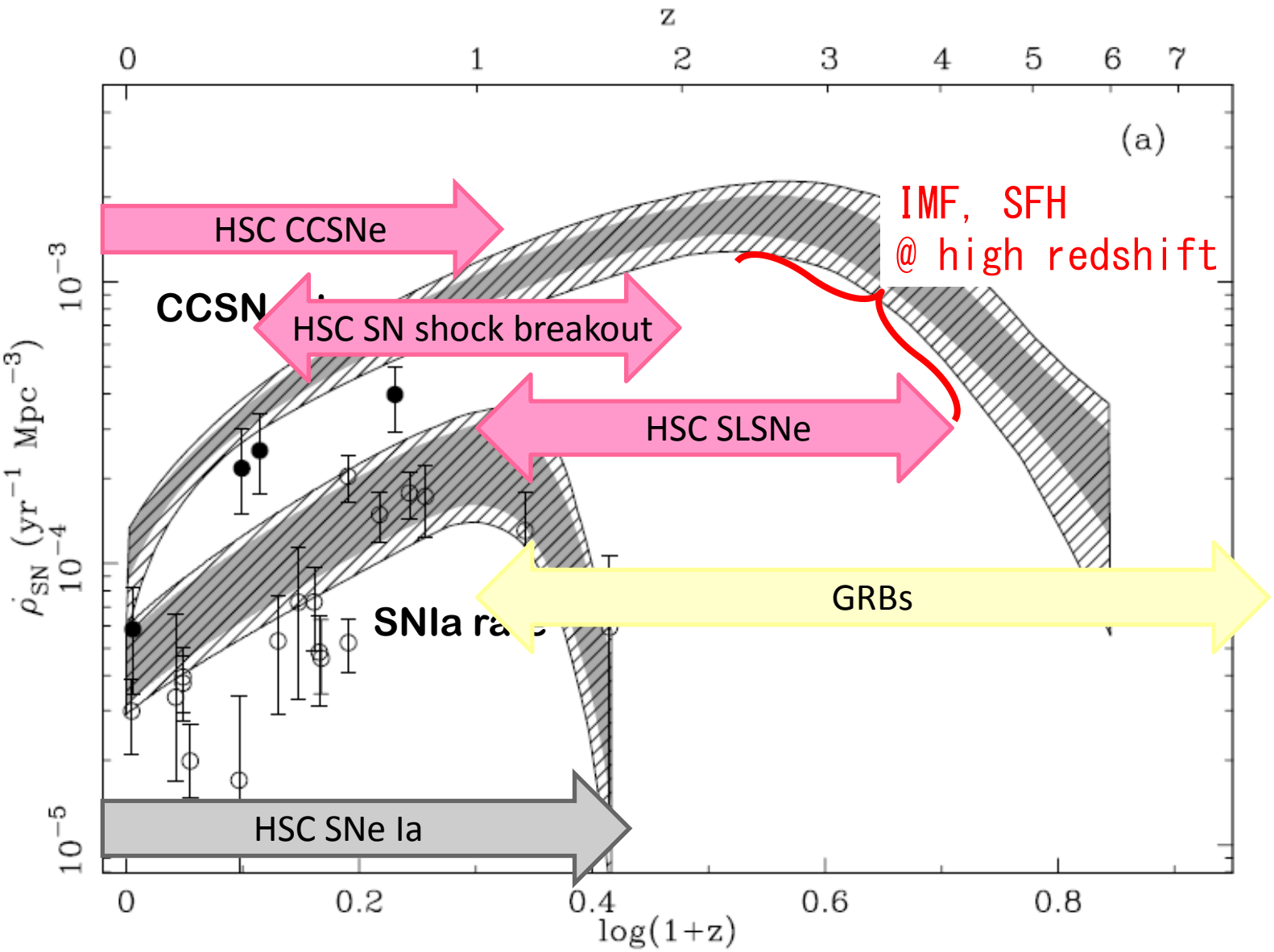
Supernovae near and far

Concluding Remarks: K. Nomoto

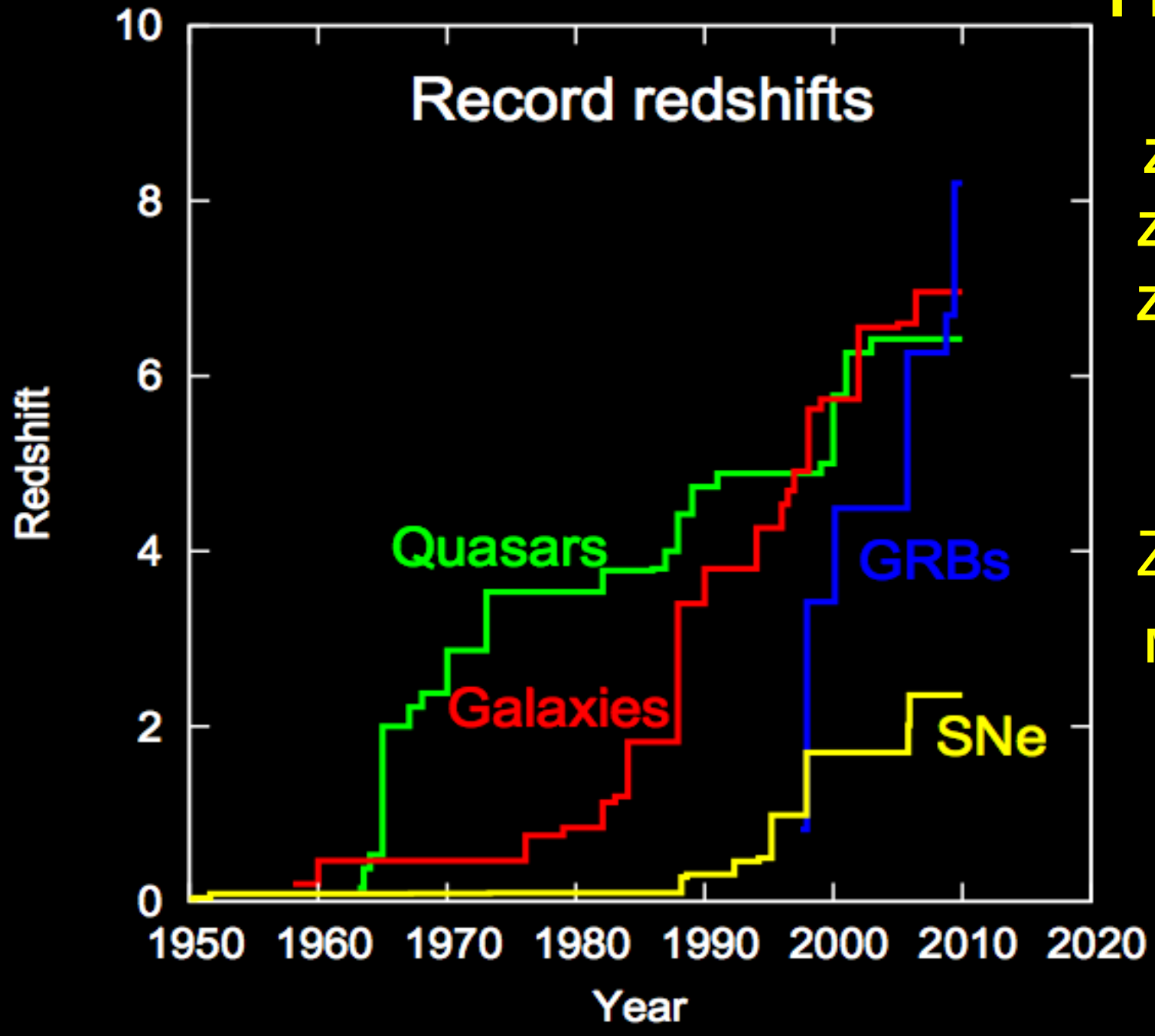
- Encourage and continue fruitful collaborations
- Identify common interests and join forces
- Link observations with theory

SN rate history



Hopkins & Beacom 06 and references therein

First Stars



Z=9.4: GRB

Z=8.6: galaxy

Z=7.1: Quasar

Z=3.9: SN

M(UV) = -21.7

(Cooke+2012)

Pop III Stars – Pop III GRBs – Pop III SNe ?

$M > 10^5 M_\odot$:SMS (Super Massive Stars)

→ GR instability → Collapse

$M \sim 300 - 10^5 M_\odot$:

→ Collapse (& Explosion) → IMBH → SMBH ?

→ **Pop III GRBs ?**

$M \sim 140 - 300 M_\odot$:

→ **Pair Instability SNe** → Complete Disruption

$M(^{56}Ni) < 40\ M_\odot$

$M \sim 8 - 140 M_\odot$:

→ Core Collapse

→ **Pop III GRBs, Hypernovae**

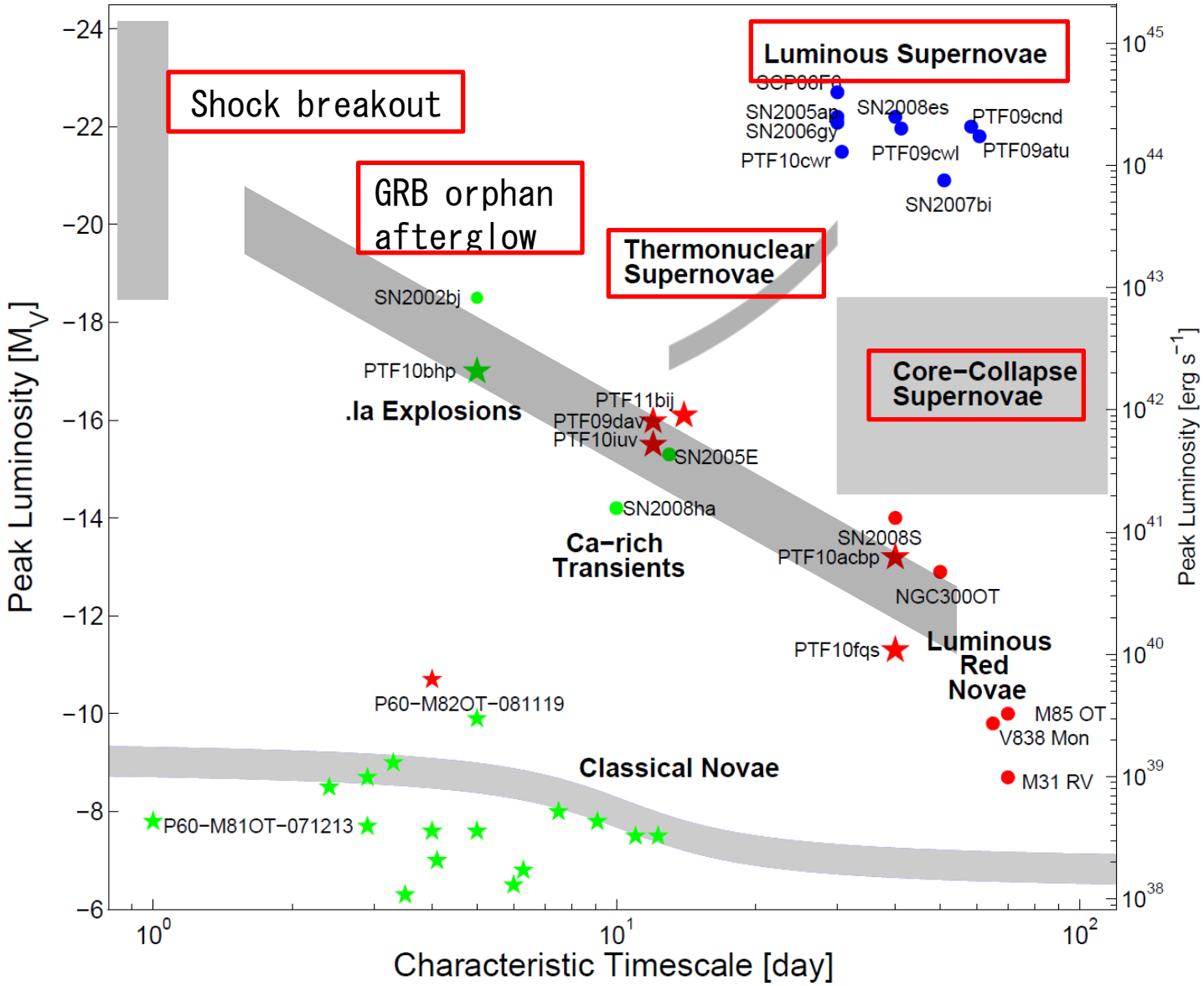
→ **SNe II** **$M(^{56}Ni) < 10\ M_\odot$**

Superluminous Supernovae

- Power sources
  - CSM interaction (LBV-connection?)
  - Magnetar (= NS)
  - Radioactive decay
  - Fallback: Accretion onto BH or NS
- Progenitor: PISN, Core-collapse (BH vs. NS)

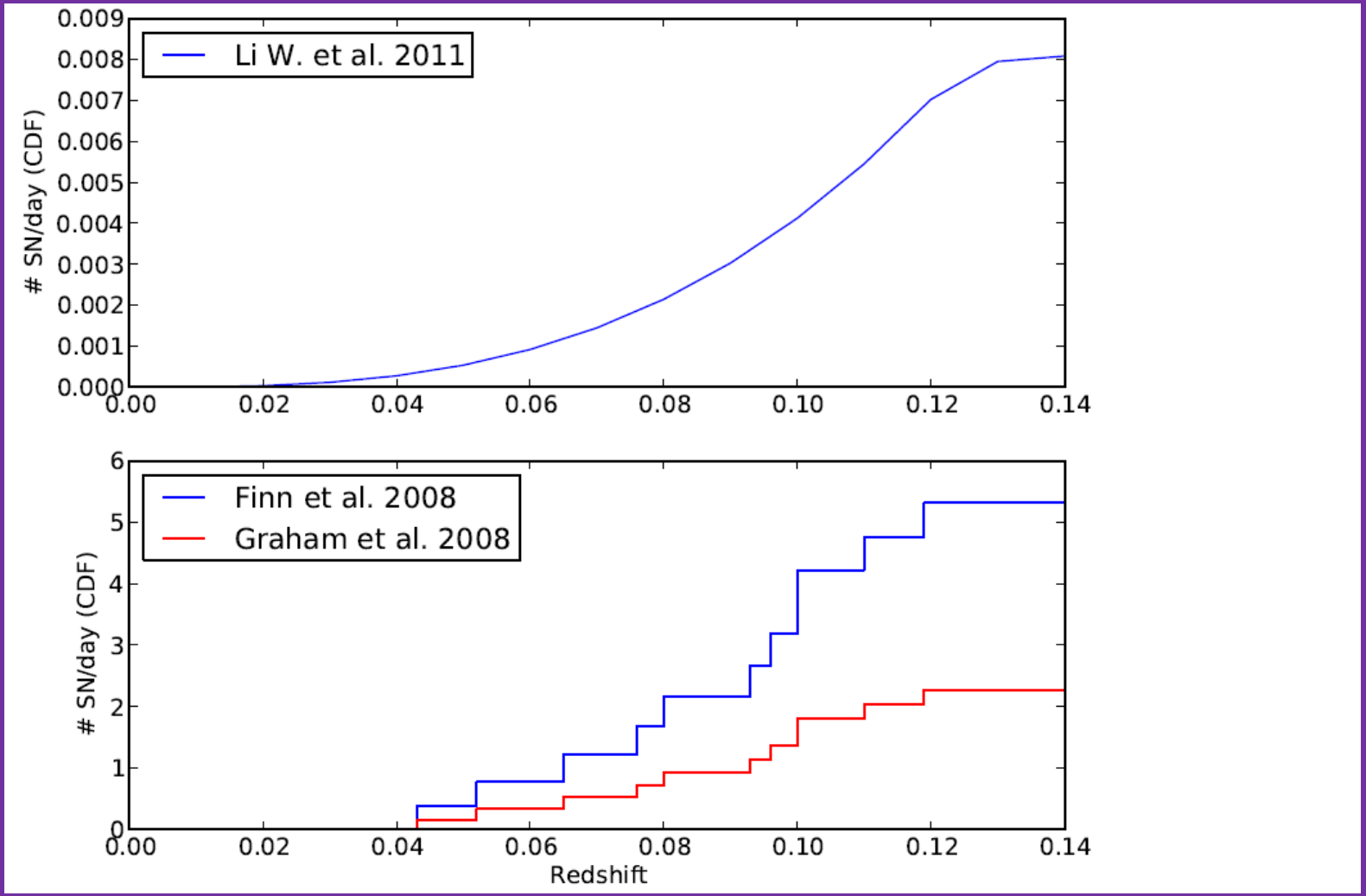
Time scales

day ⟷ year



Kasliwal 11

Detection of Schock Break Outs with DECam (de Jaeger et al)

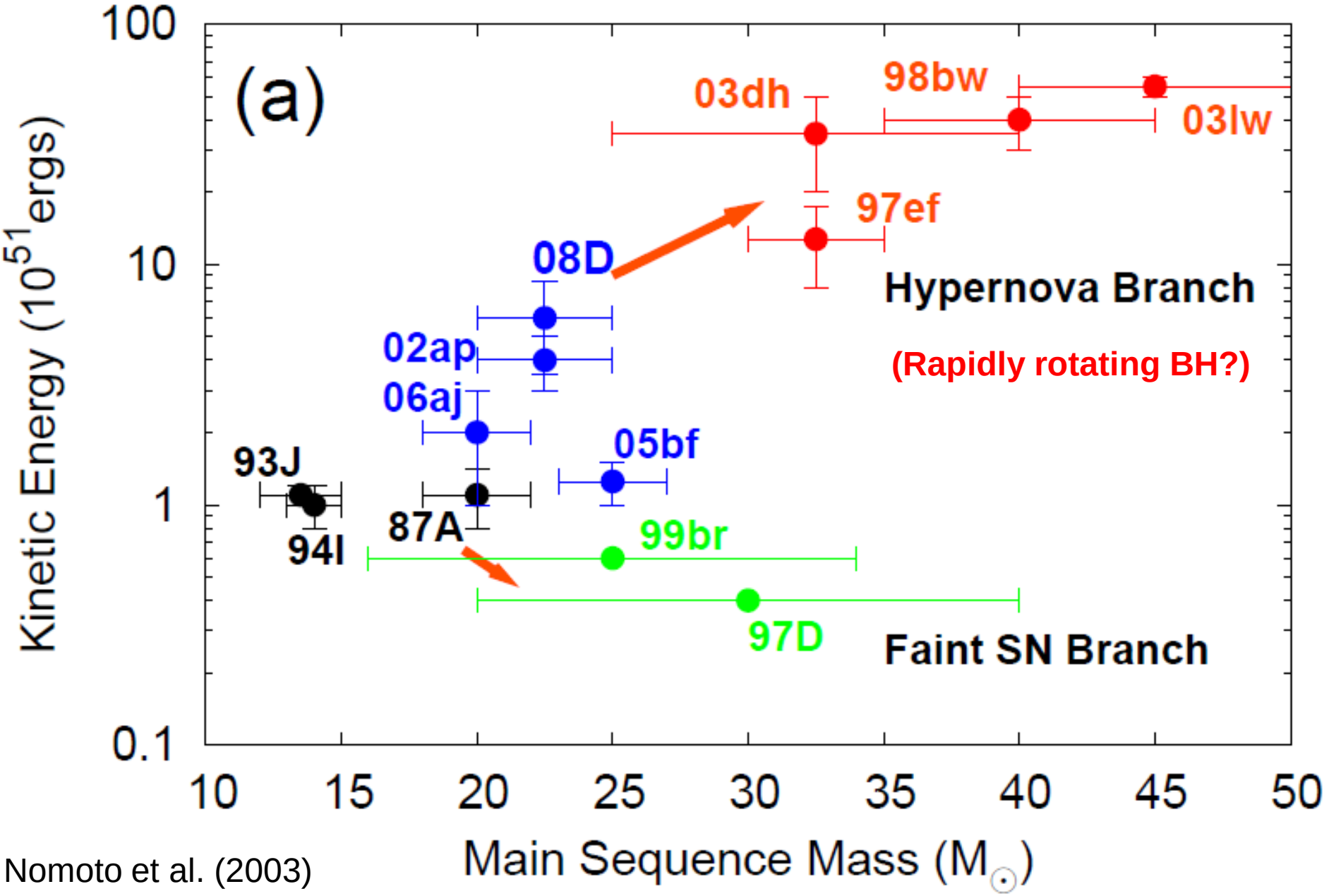


Diversity of Core-Collapse SNe

- Progenitor mass
- Mechanism
- Asphericity
- BH vs. NS

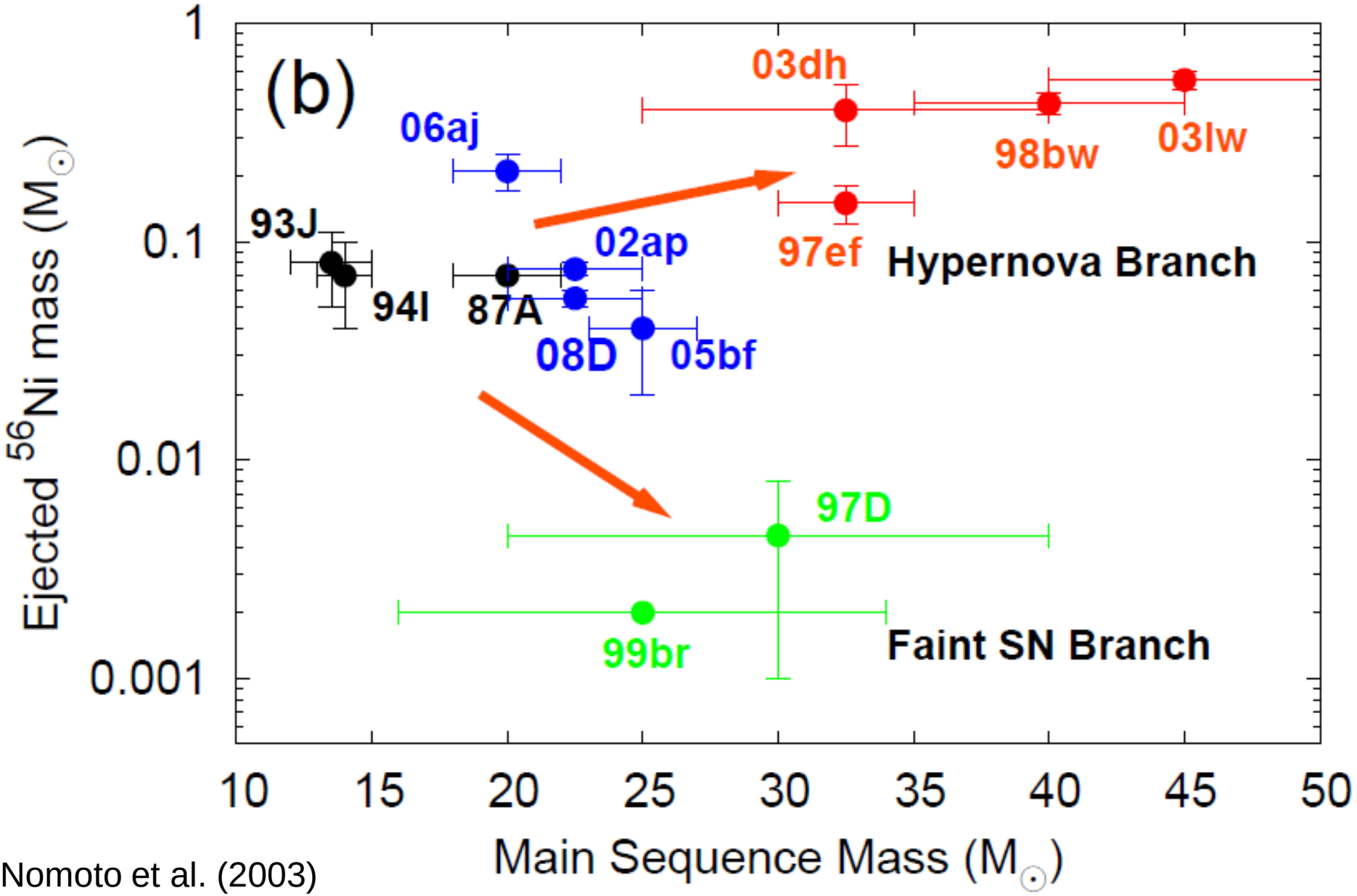
- NS-powered LC ? Slow rise ?
  (little ^{56}Ni)

SNe [M_{ms}-E relation]



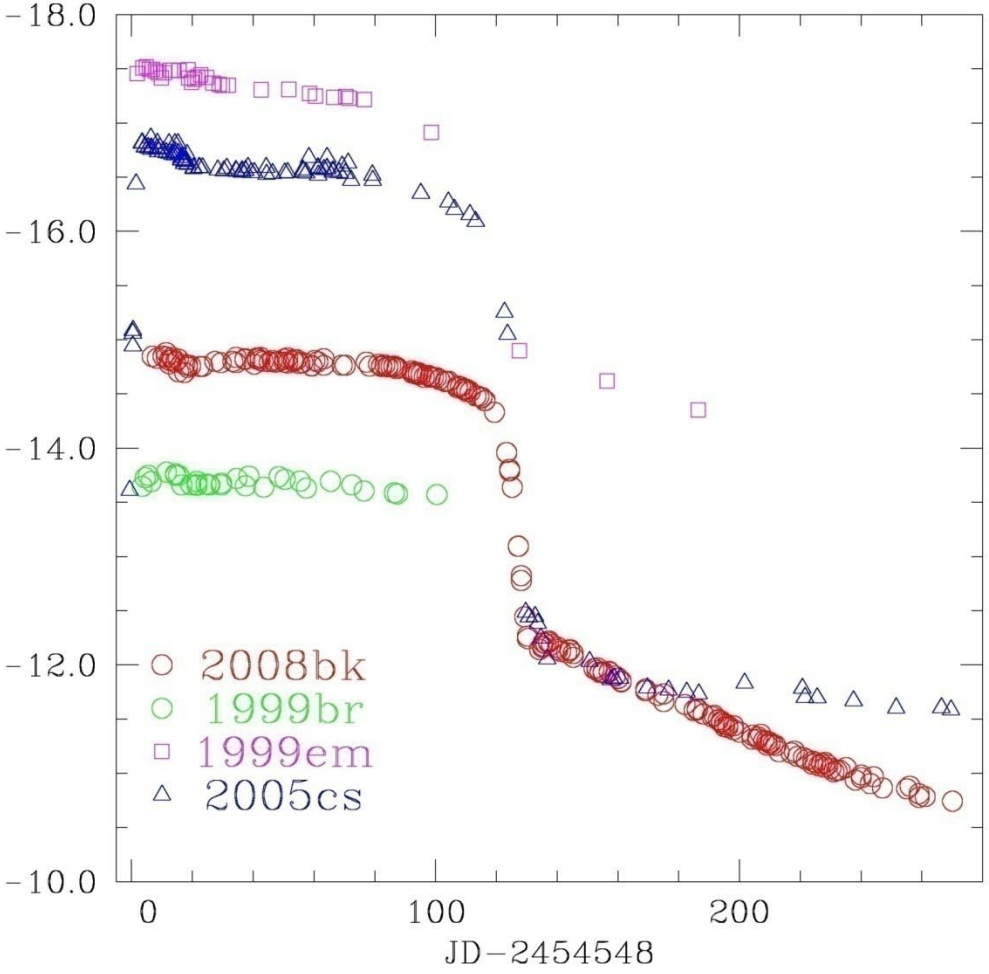
Nomoto et al. (2003)

SNe [M_{ms}-M(^{56}Ni) relation]



Nomoto et al. (2003)

SN 2008bk: A low luminosity IIP

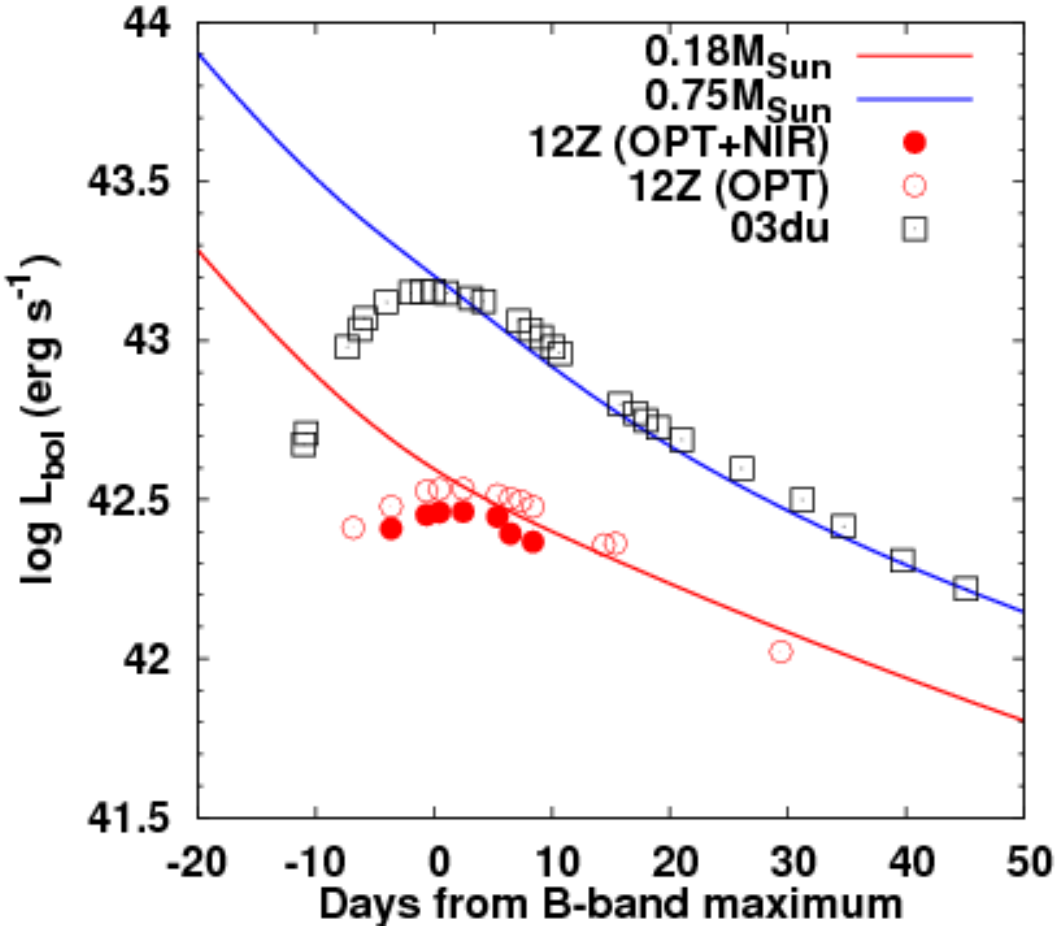


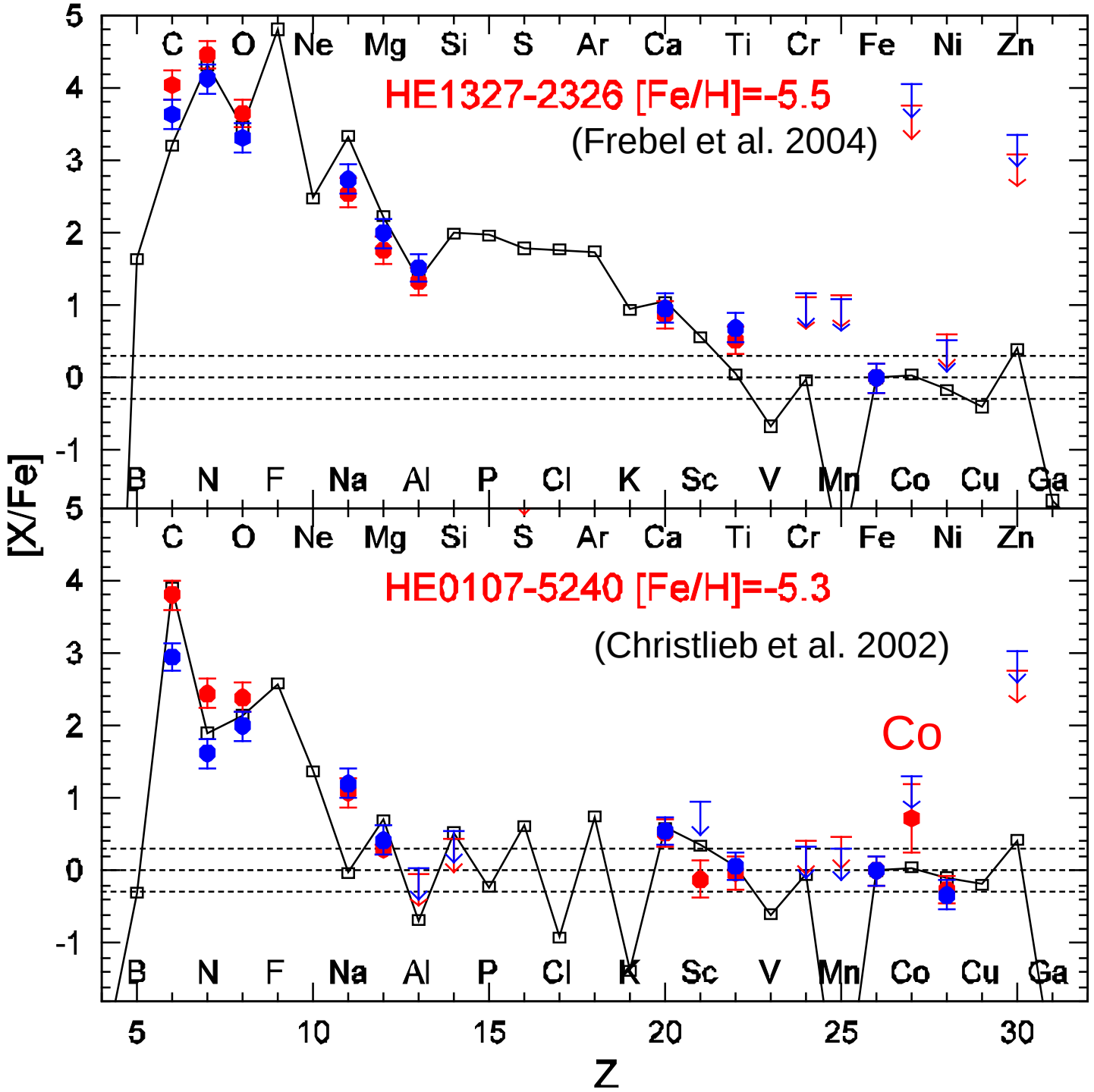
Distance modulus = 27.68
Derived from Cepheids . (Pietrzynski et al. 2010)

Very well definded absolute luminosity !!

This is not the case of SN1999br and SN2005cs

Quasi-bolometric light curves of SN 2012Z





HMP Stars

([Fe/H] < -5)

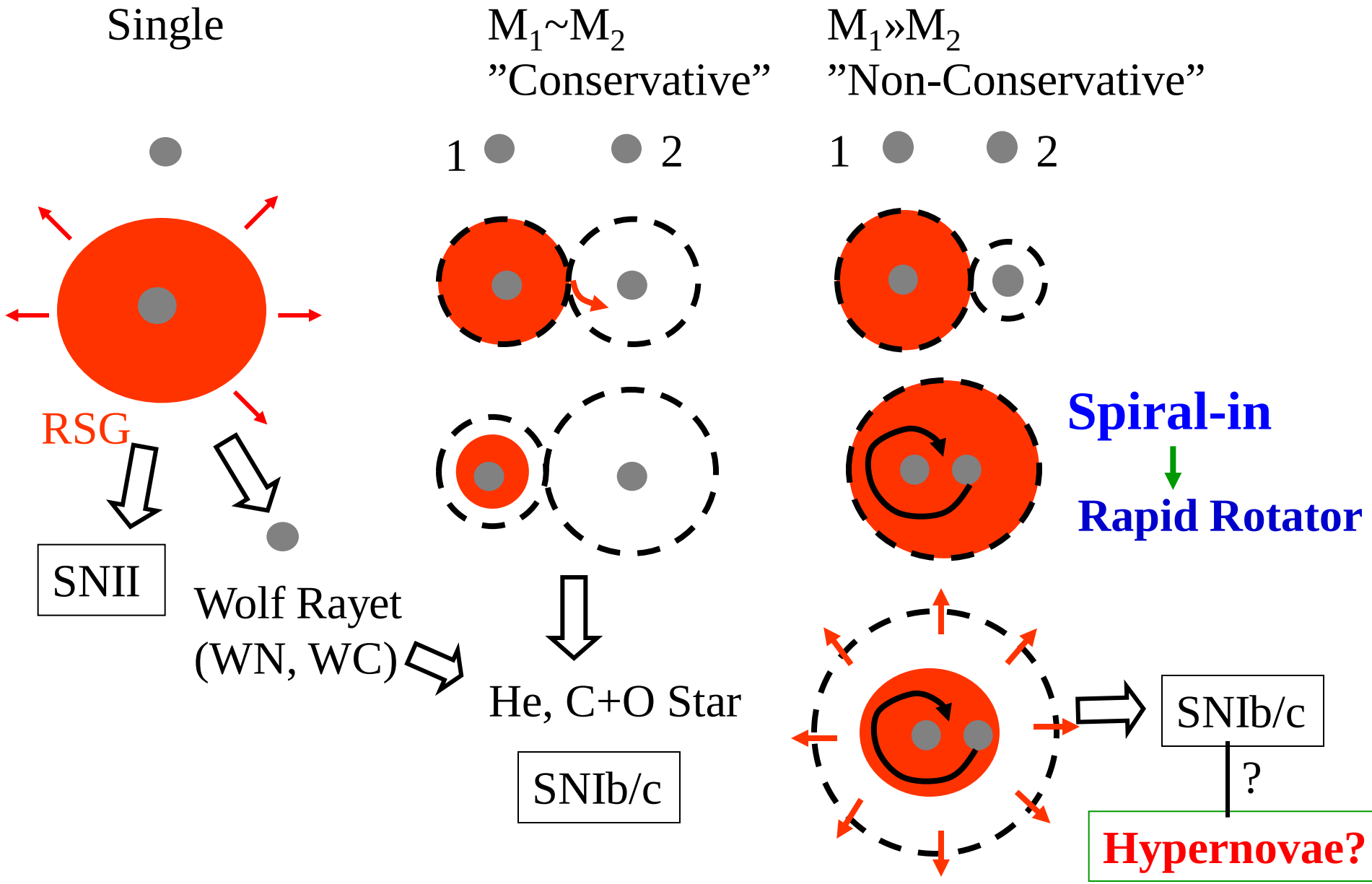
Jet-induced SN models

High E ➔
High Co/Fe
➔
Fallback ➔
Small Fe

Dark Hypernova

Tominaga et al. 2007

Hypernova Progenitor (no H, He)?



Binary's Final Fates

Massive Companion ➔ SN IIb ➔
NS + Companion Star (> 10 $M_\odot$)

Spiral-In of a Small Mass Companion ➔
Large Angular Momentum &
Enhanced Mass Loss ➔ Small M(H) ➔
SN IIb ➔ NS + No Companion : **Cas A ?**

M_1 > 25 $M_\odot$ ➔ Spiral-In ➔ BH (rotating) ➔
SN IIb : Hypernova ? (SN 2003bg?)

SN Ia Diversity

Observations

- Normal, 91T, 91bg, 02cx (Iax?),
- 02ic (Ia/IIn, IIa?)
- Companion ? CSM?

Theoretical Models

- SD (sub-Ch, super-Ch)
- DD (sub-Ch, super-Ch

Observational differences among SN Ia progenitors

	Companion Left?	Central density @ ignition	Circumstellar material (CSM)
Single degenerate, Chandrasekhar mass (SD – M_{Ch})	YES	$\sim 10^9$ [g cm^{-3}] (stable IGE + ^{56}Ni)	YES
Single degenerate, sub-Chandrasekhar mass (SD – sub M_{Ch})	YES	$\sim 10^7$ [g cm^{-3}] (^{56}Ni)	YES
Double degenerate merger (violent or slow DD mergers)	NO	$\sim 10^7$ [g cm^{-3}] (^{56}Ni)	NO

SN Ia: DD, SD ➔ Sub-Ch, Chandra

	surface burning	➔	sub-Ch	Chandra
ρ_c (g cm^{-3})	~10^6		$10^{7\text{-}8}$	$10^{9\text{-}10}$

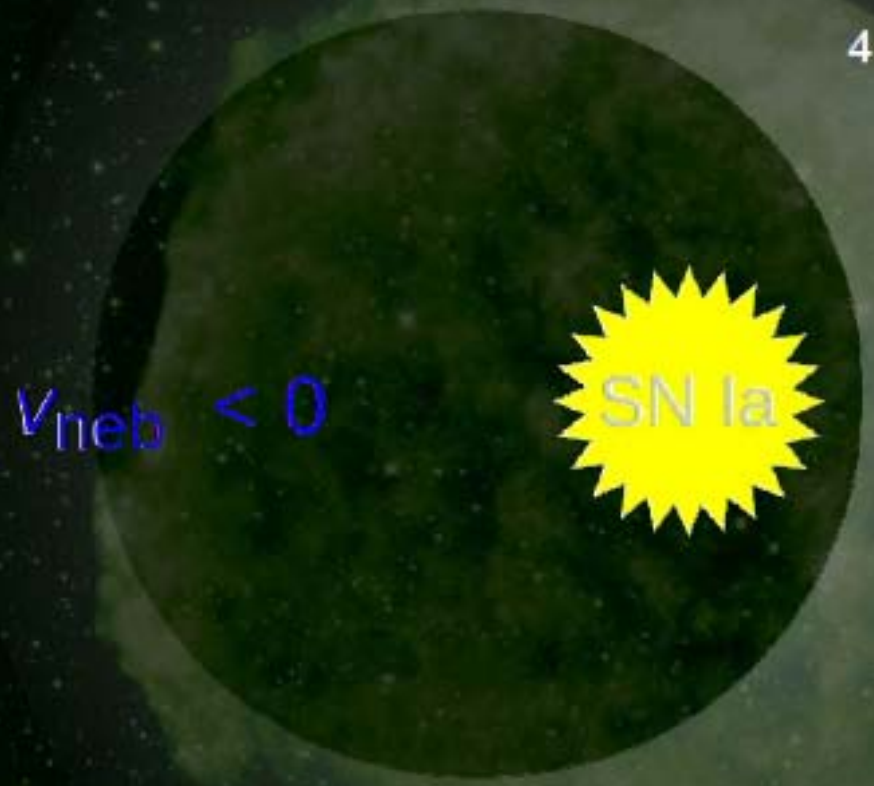
DD	C-detonation ?	➔	C-det	
	steady C-burning?	➔		ONeMg WD
	no ignition ?	➔		C-deflag
SD	He flashes ?	➔		C-deflag
	He detonation ?	➔	C-det	

Non-cylindrically symmetric CSM?

$$4\pi r^2 \frac{L}{4\pi D^2} = 4\pi r^2 \sigma T^4$$

$$\Rightarrow$$

$$D_{evap} \propto L^{1/2}$$



eccentric cavity
CSM ?

We propose that an asymmetric explosion carves an asymmetric cavity in the CSM via dust evaporation and ionization of Na I and Ca II.

Supernovae near and far

- Encourage and continue fruitful collaborations
- Identify common interests and join forces
- Link observations with theory

- Observations: Joint proposals ?

➔Next week ….