The nature of Type IIb supernova progenitors in binary systems

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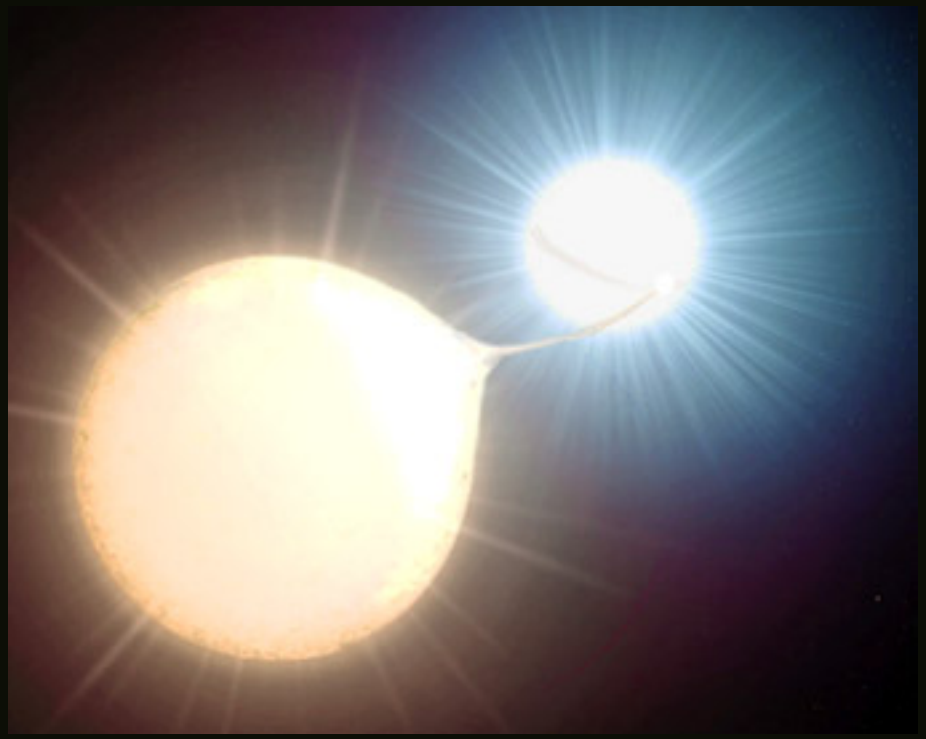


Supernovae through the Ages, Rapa Nui, Aug. 12, 2016

Type IIb Supernovae

- SN II initially → SN Ib later (days to weeks) : hydrogen-deficient ($M_H < 1$ Msun)

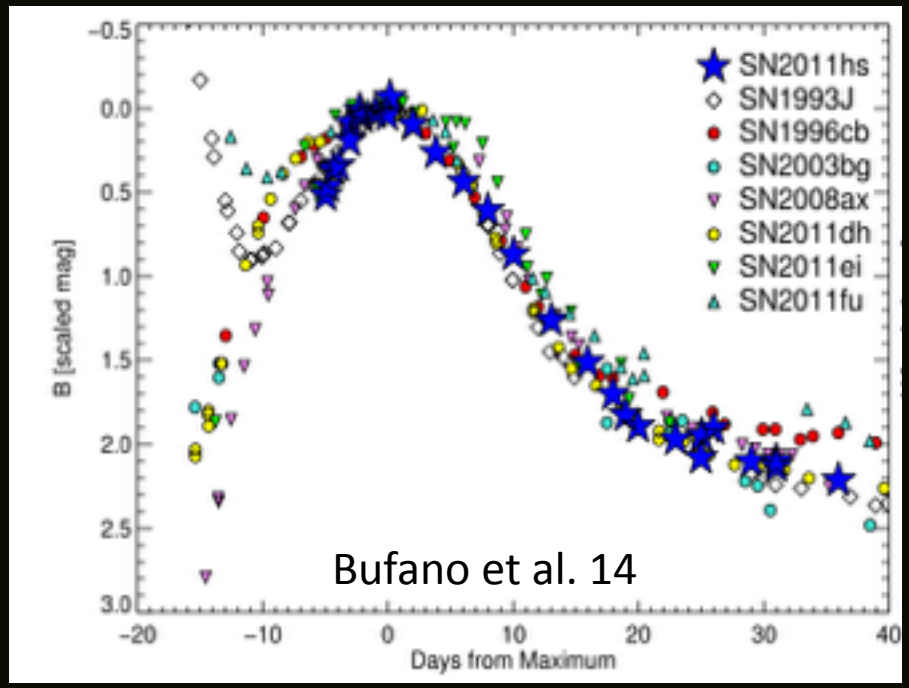
- Double peaks in the light curves, in some cases (e.g. 1993J, 2013df)

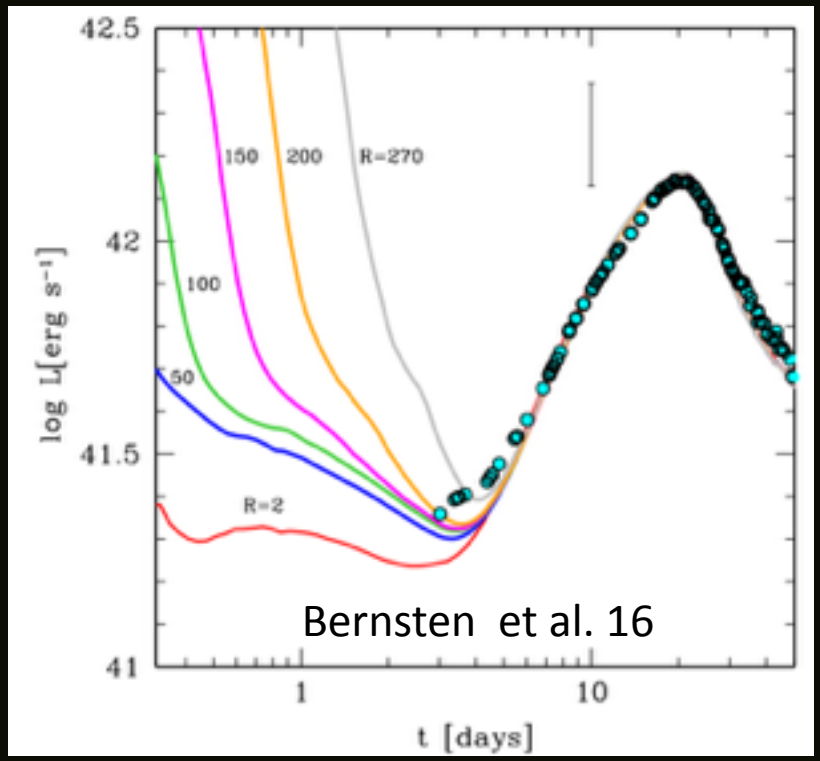
- Final mass of progenitors: 3 – 5 Msun for most cases (the corresponding initial mass = 11 ~ 18 Msun)

- Most of them must originate from binary systems

- How is the SN IIb diversity related to evolutionary paths of progenitors?

- What can we learn from this on the nature of SN IIb progenitors?

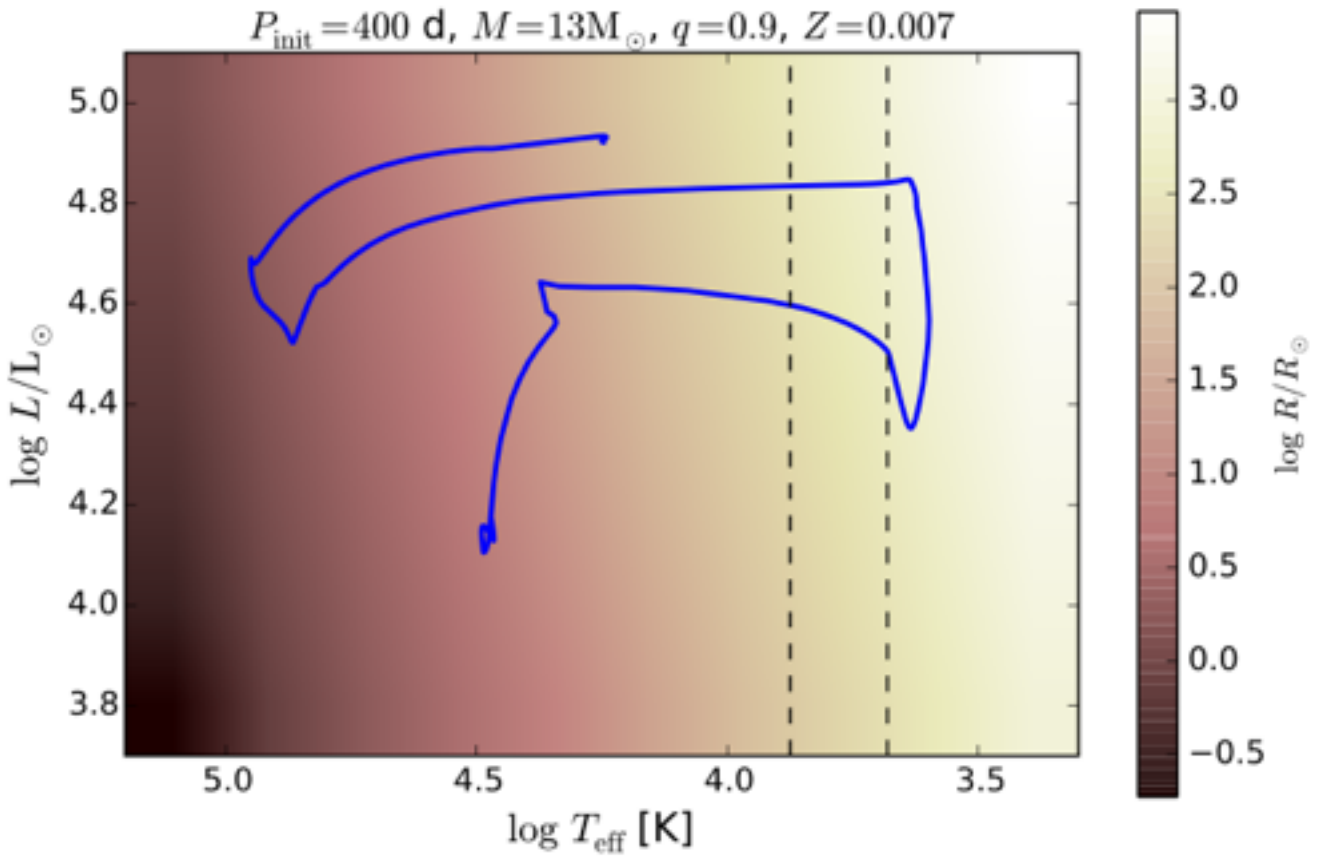




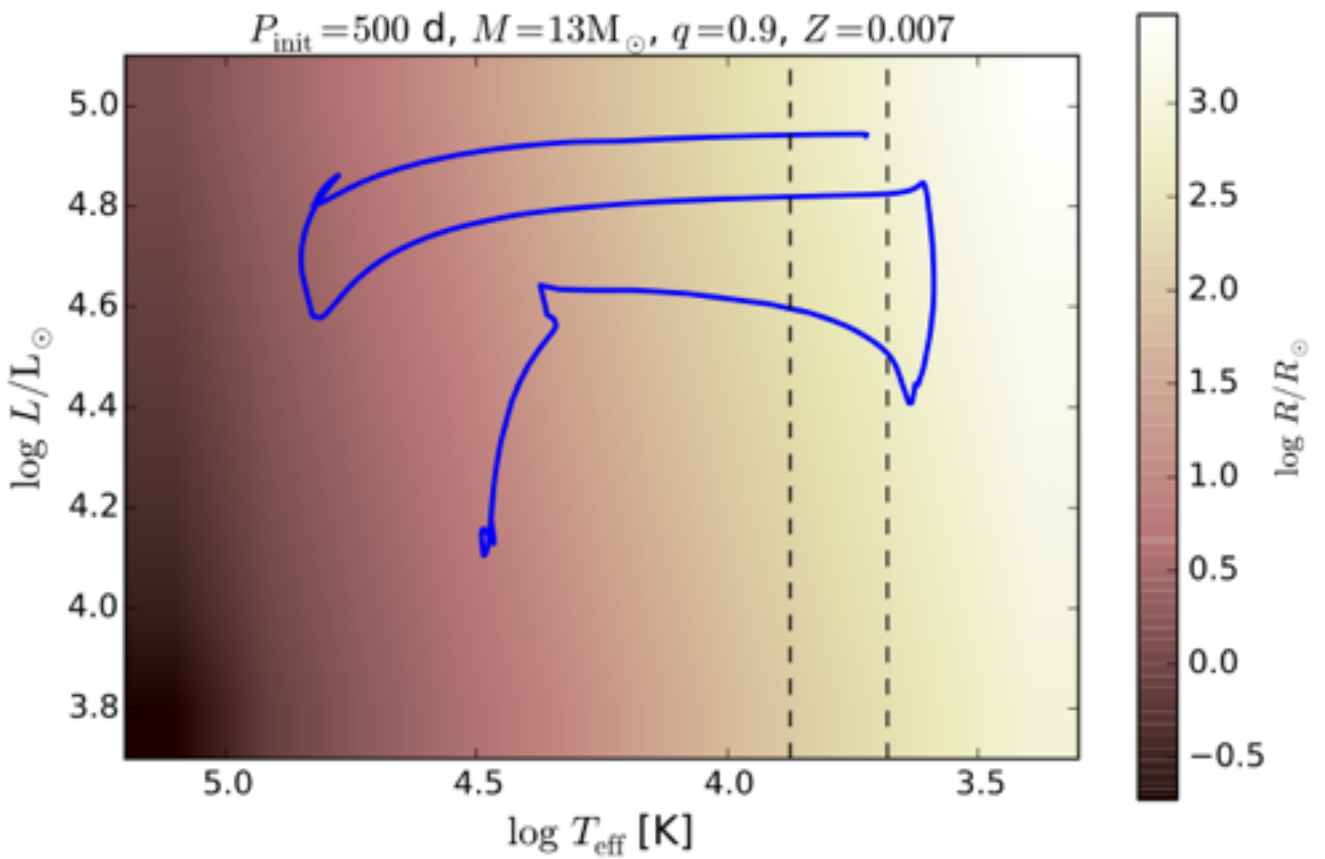
See also Woosley +94, Shigeyama + 94, Nakar & Piro14, etc.

Progenitor Evolution: example

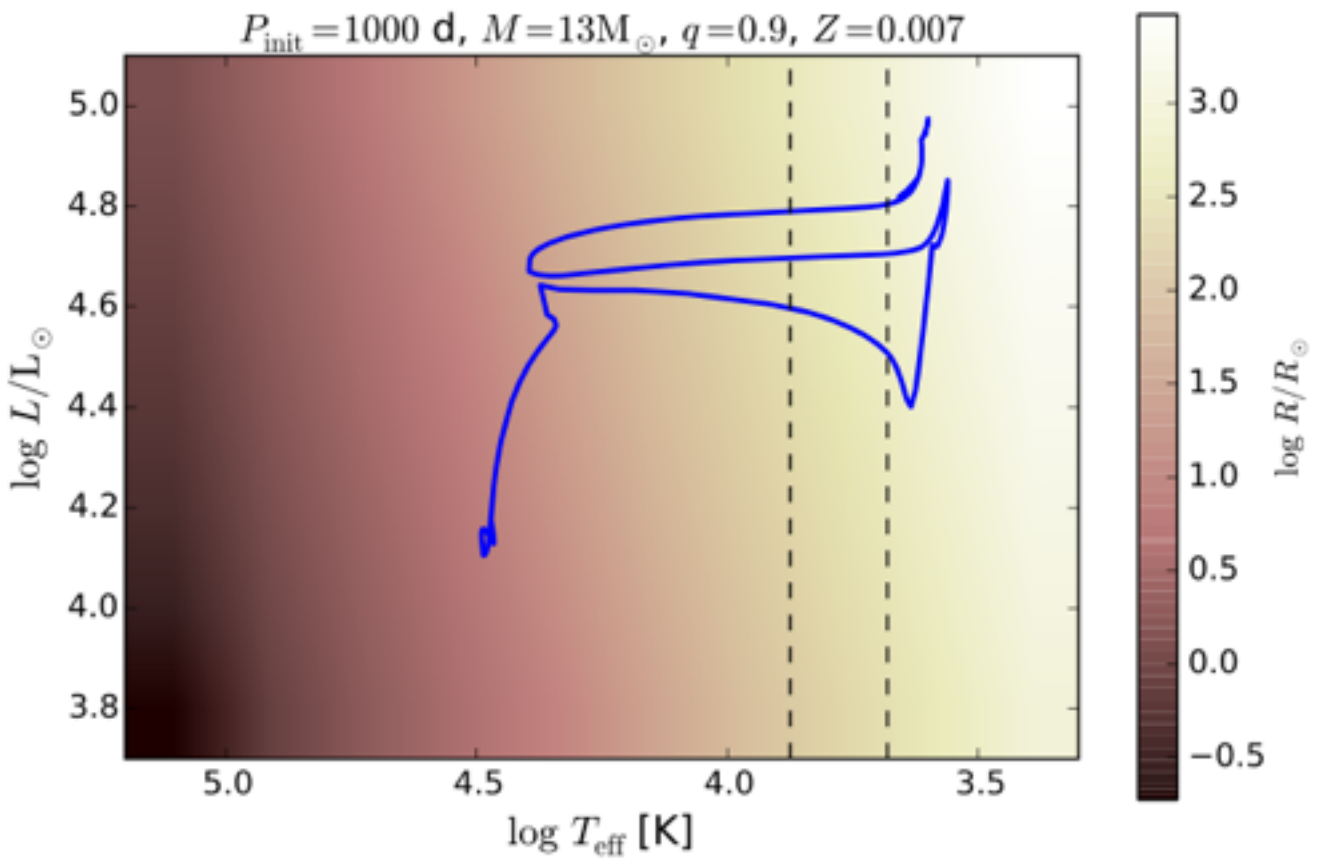
Cf. Podsiadlowski et al. 1993, Stancliff & Eldridge 2009, Claeys et al. 2011, Bersten et al. 2012

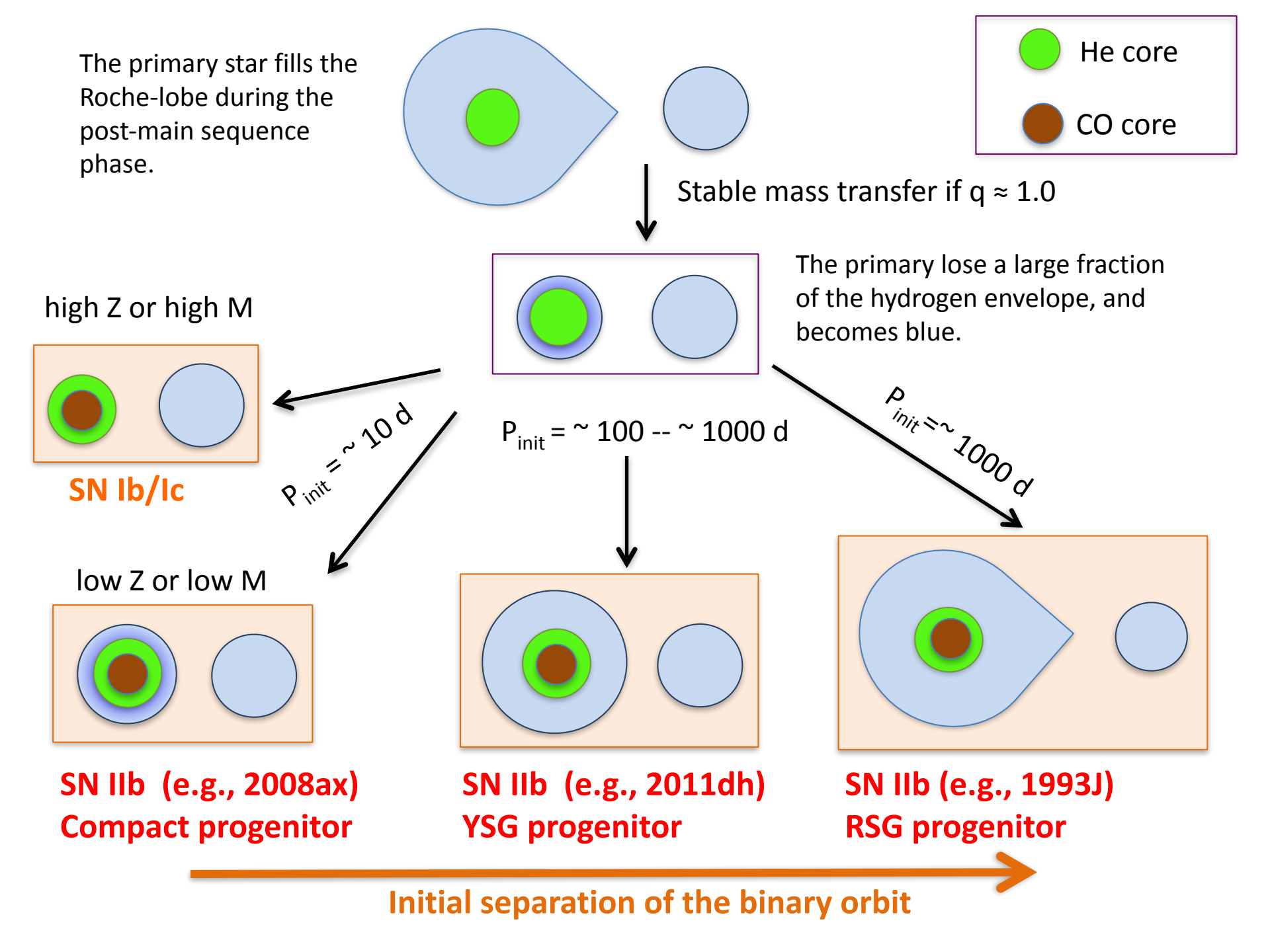


Progenitor Evolution: example

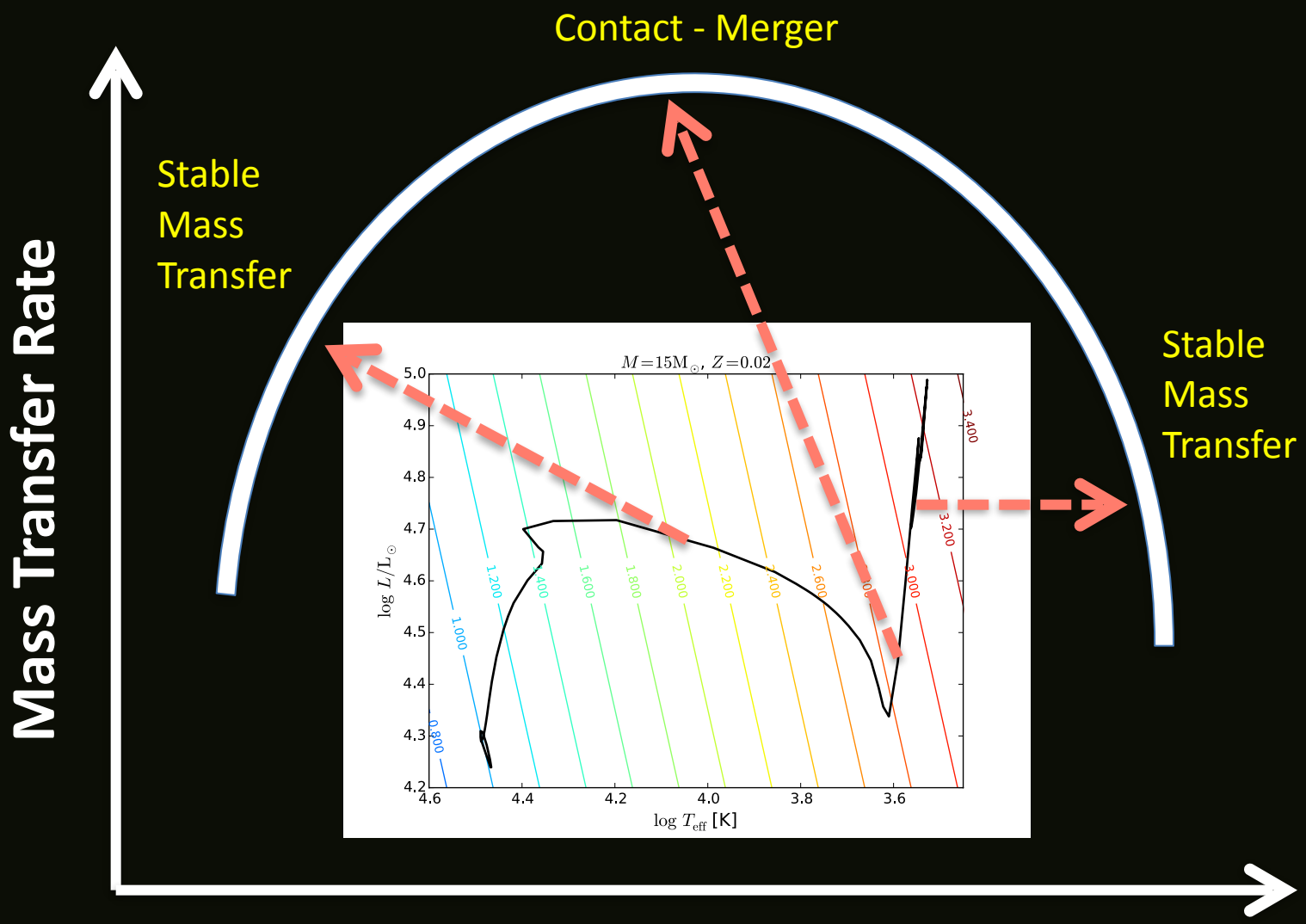


Progenitor Evolution: example

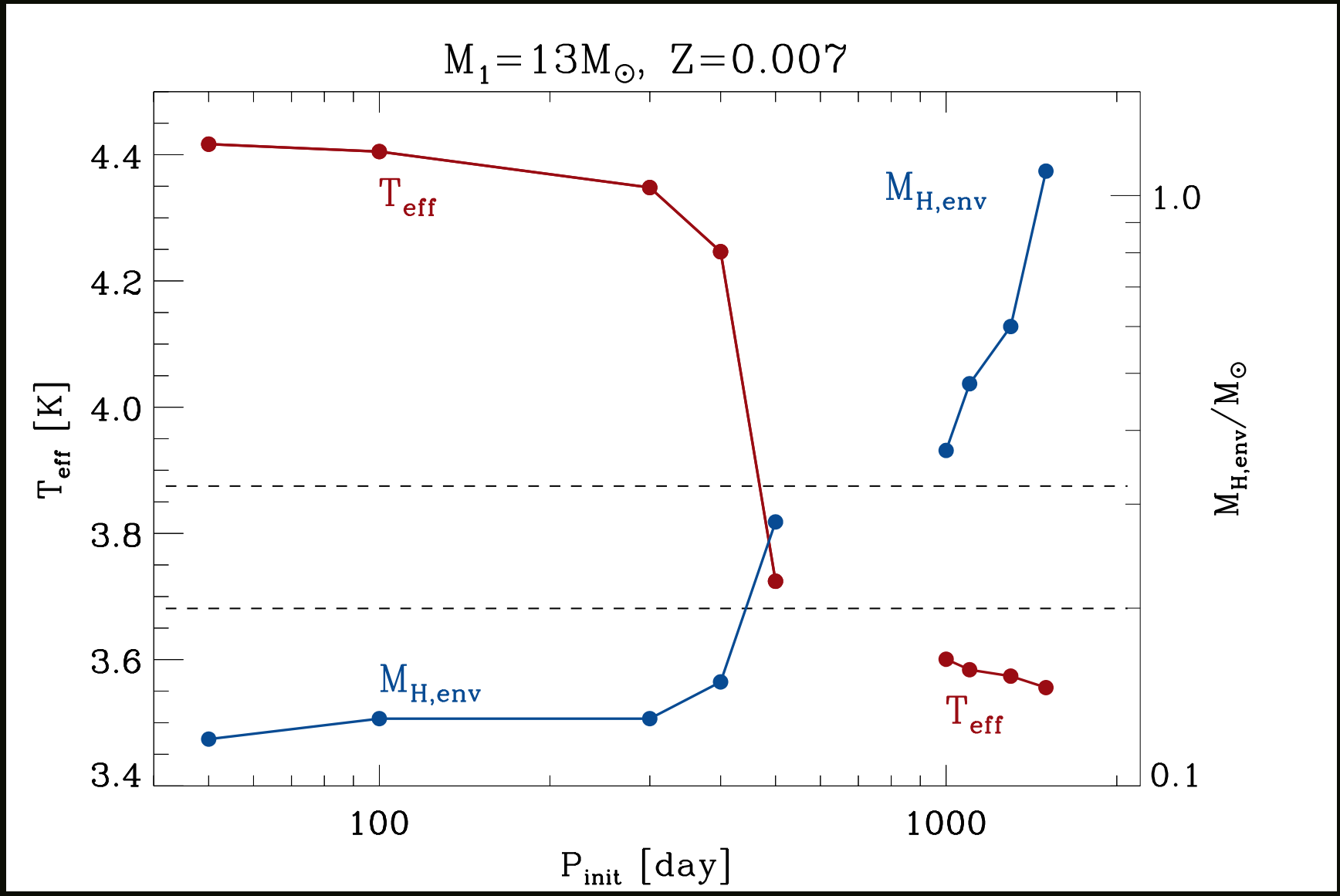



The primary star fills the Roche-lobe during the post-main sequence phase.
He core
CO core
Stable mass transfer if q ≈ 1.0
The primary lose a large fraction of the hydrogen envelope, and becomes blue.
high Z or high M
SN Ib/Ic
P init = ~ 10 d
P init = ~ 100 -- ~ 1000 d
P init =~ 1000 d
low Z or low M
SN IIb (e.g., 2008ax)
Compact progenitor
SN IIb (e.g., 2011dh)
YSG progenitor
SN IIb (e.g., 1993J)
RSG progenitor
Initial separation of the binary orbit

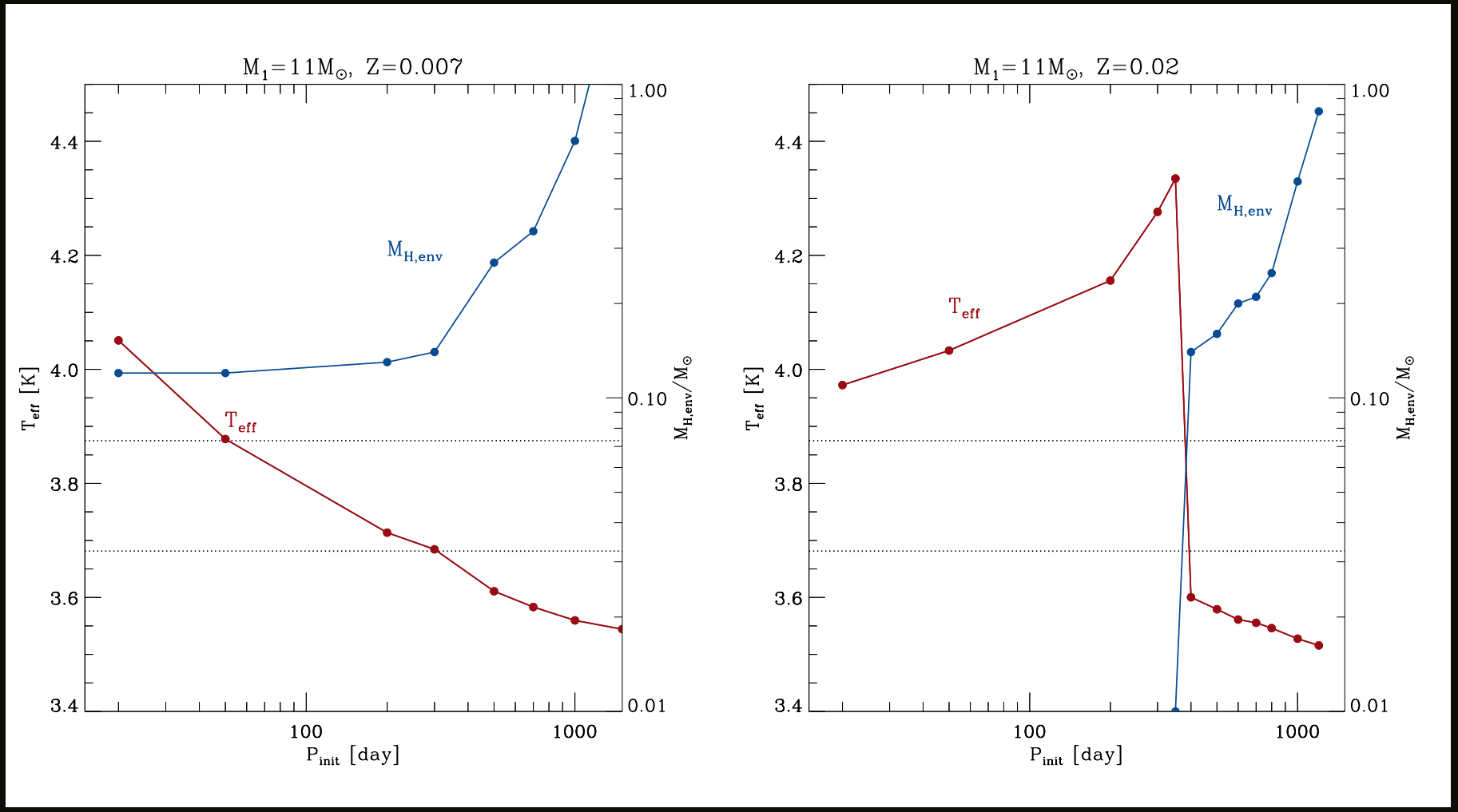
Massive Binary Evolution



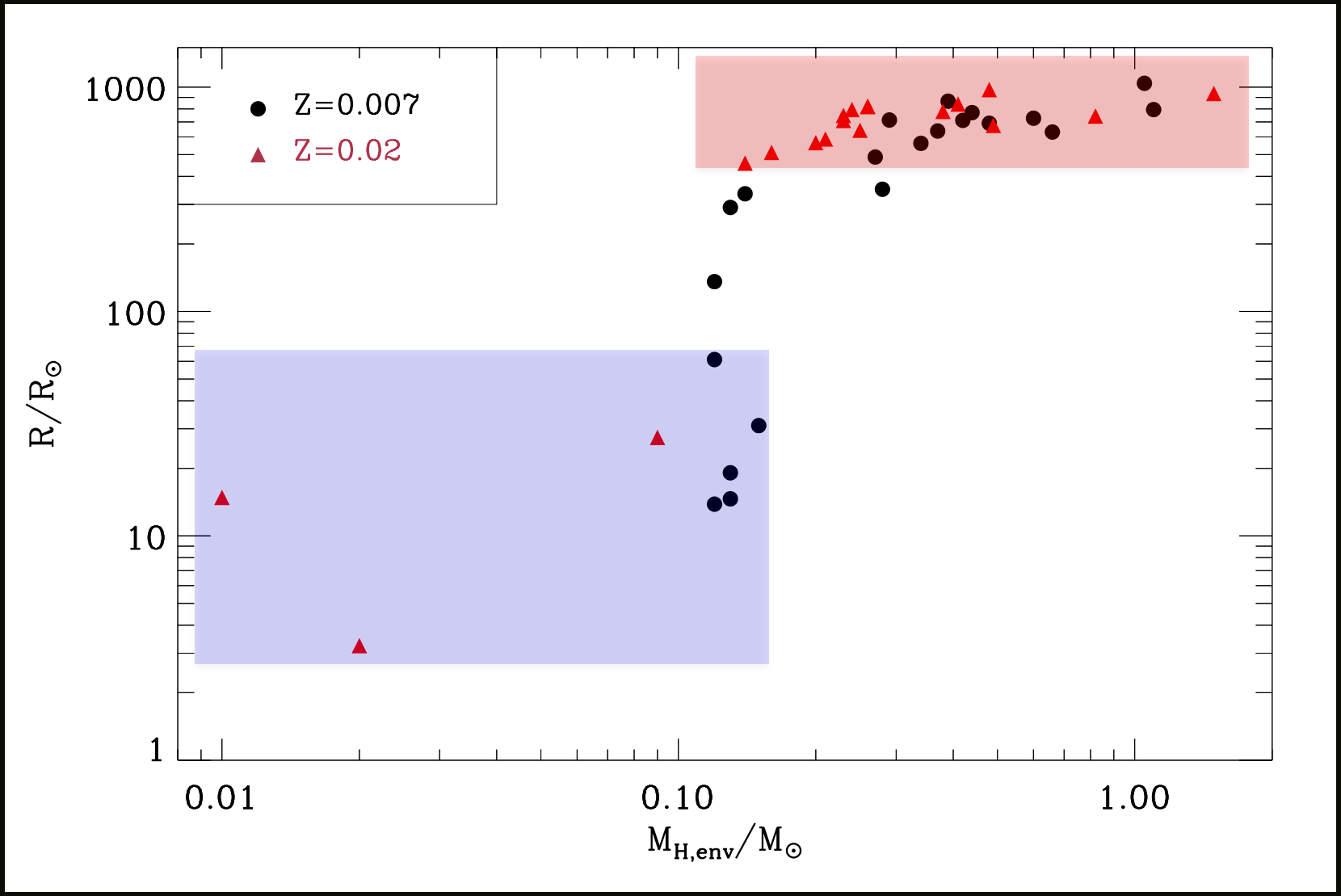
Dichotomy in radius: compact v.s. extended



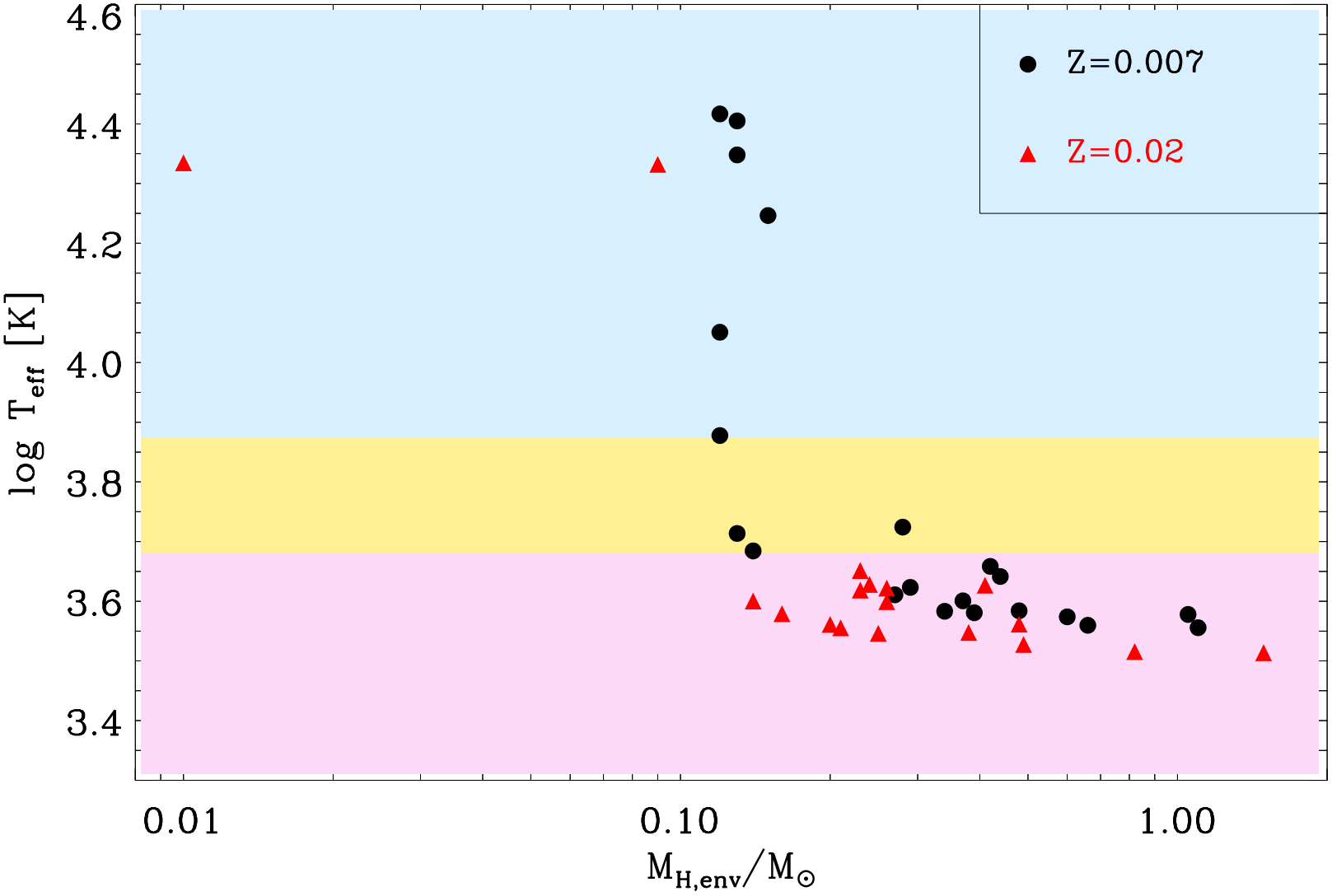
Metallicity Effect



H envelope mass v.s. Radius

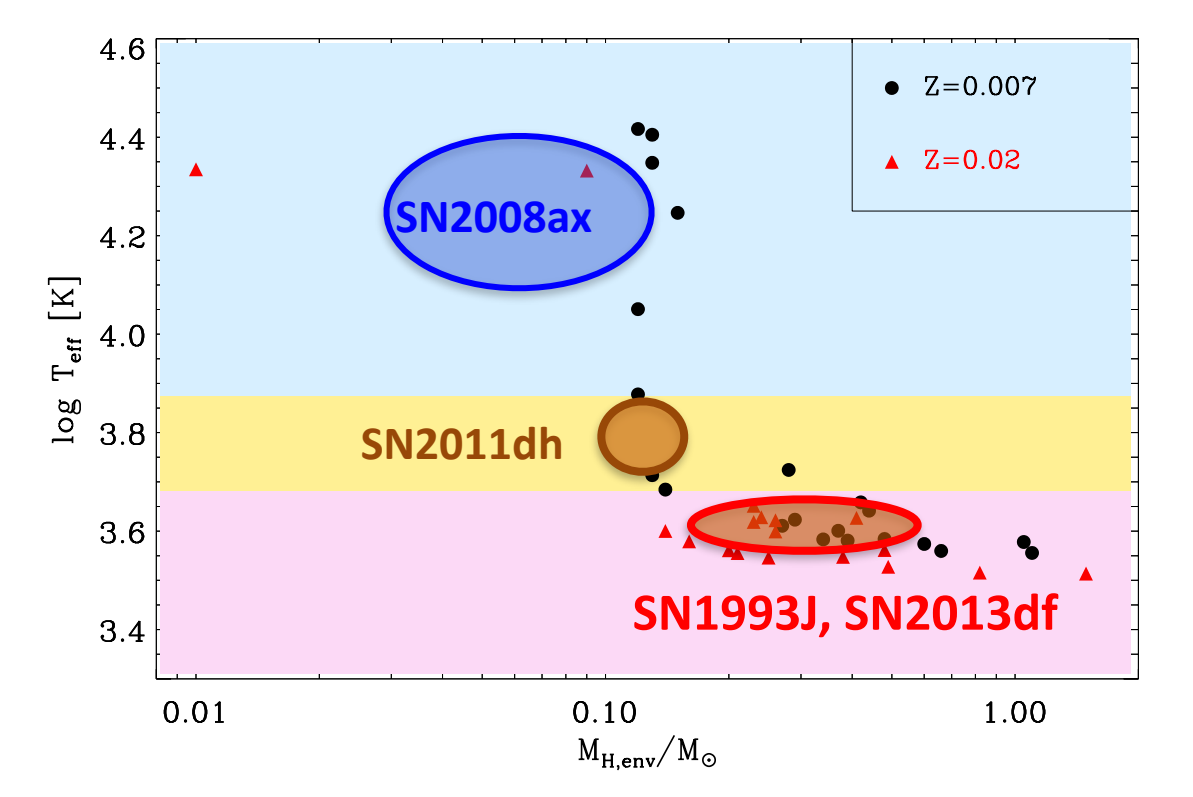


H envelope mass v.s. Temperature



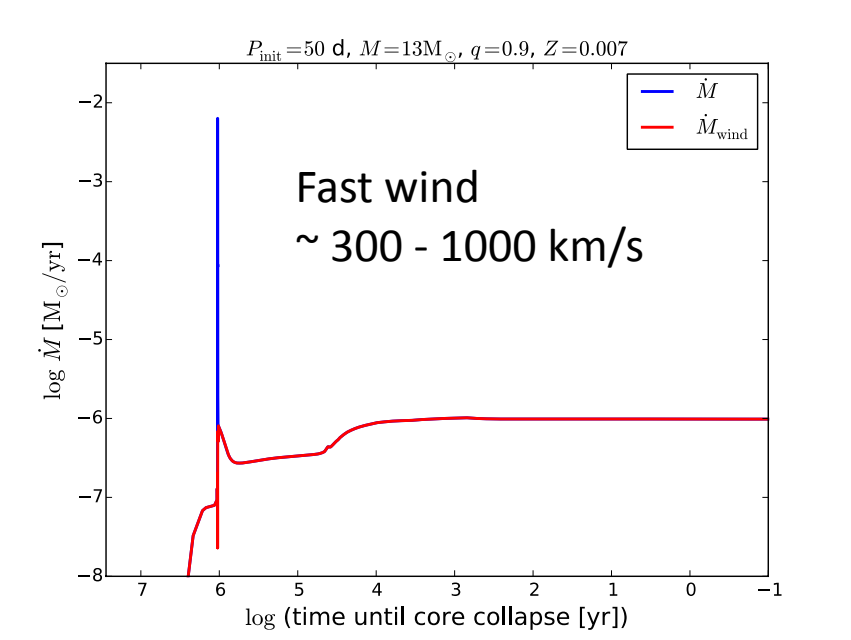
Comparison with Observations

	M_H-Envelope	Teff	Radius	Ref.
SN 1993J	~ 0.2 - 0.4 Msun	4265 K	650 Rsun	
SN 2011dh	~ 0.1 Msun	6000 K	267 Rsun	Bernsten +12
SN 2013df	~ 0.2 – 0.4 Msun	4250 K	545 Rsun	Van Dyk+14
SN 2008ax	~ 0.06 Msun	15000 K	20 – 50 Rsun	Folatelli+15

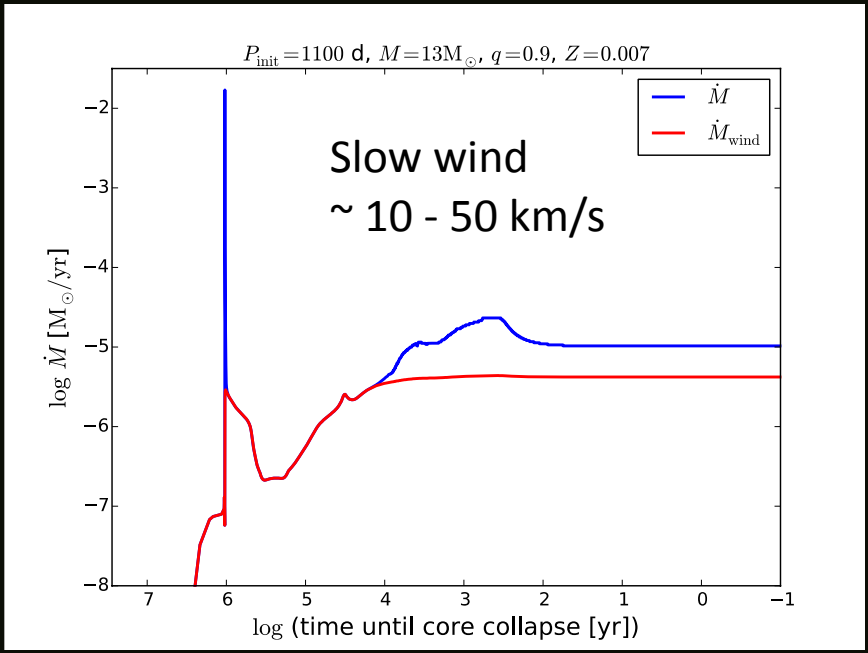


Mass Loss / Polarization

Compact Progenitor
Detached at the pre-SN stage



Extended Progenitor
Semi detached at the pre-SN stage



Some progenitors may fill (or close to fill) the Roche lobe radius shortly before SN explosion.

→ Higher mass loss rate during the final stage (e.g., Maeda et al. 2015)

→ Polarization! (e.g., SN 1993J, Hoeflich 1995; 2011dh, Mauerhan et al. 2015)

Conclusions

- Post main sequence evolution of massive stars is a “magnifying glass” of stellar evolution (Kippenhahn)

- SN IIb progenitors are an excellent test bed for stellar evolution theory.

- Dichotomy in terms of radius (compact v.s. extended)
  - Compact progenitors would become more common for lower Z

- Yellow SG solutions (T ~ 6000 K) are relatively difficult to obtain, but somewhat easier for lower Z

- Strong correlation between the size/temperature and hydrogen envelope mass : larger/colder for higher M_H.

- Higher mass loss rates for more extended progenitors.

- Mass transfer during the pre-SN stage for extended progenitors → polarization?