

Binary progenitor models of type IIb Supernovae

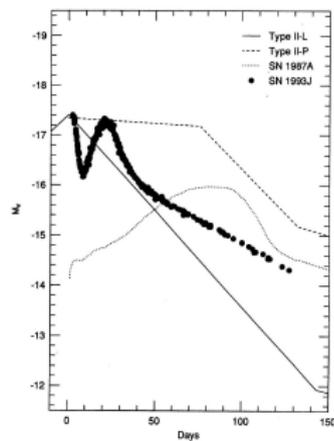
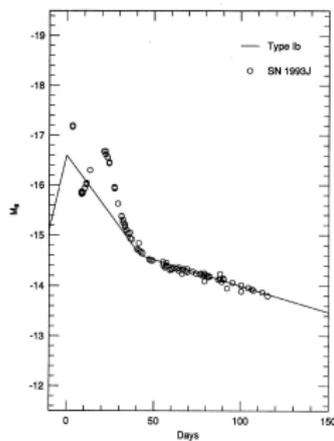
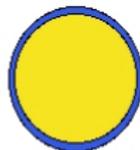
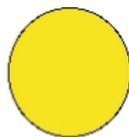
J.S.W. Claeys, S.E. de Mink, O.R. Pols, M.Baes

Which binaries?
Companion star?
Rate?

SN Ib

SN IIb

SN II



Benson et al., 1994

SN Ib**SN IIb****SN II**

Compact:

- Wolf-Rayet star
- Hydrogen envelope $< 0.1M_{\odot}$
- Similar to type Ib

Extended:

- Red supergiant
- Hydrogen envelope $> 0.1M_{\odot}$
 \Rightarrow This talk

(Chevalier & Soderberg 2010)

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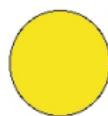
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(Chevalier & Soderberg 2010)

SN Ib

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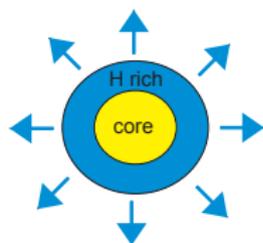
(Chevalier & Soderberg 2010)

Single vs. Binary channel

Progenitor: $M_{\text{H}}: 0.1 - 0.5 M_{\odot}$

Podsiadlowski et al. 1993; Woosley et al. 1994; Elmhadi et al. 2006

How can a star lose its hydrogen envelope?



- **Single star channel**

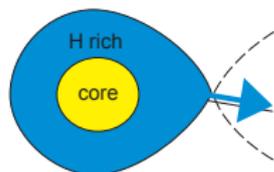
- Stellar wind
- Fine-tuning

- **Binary star channel**

- Interaction with its companion

Podsiadlowski et al. 1992; Maund et al. 2004; Stancliffe & Eldridge 2009

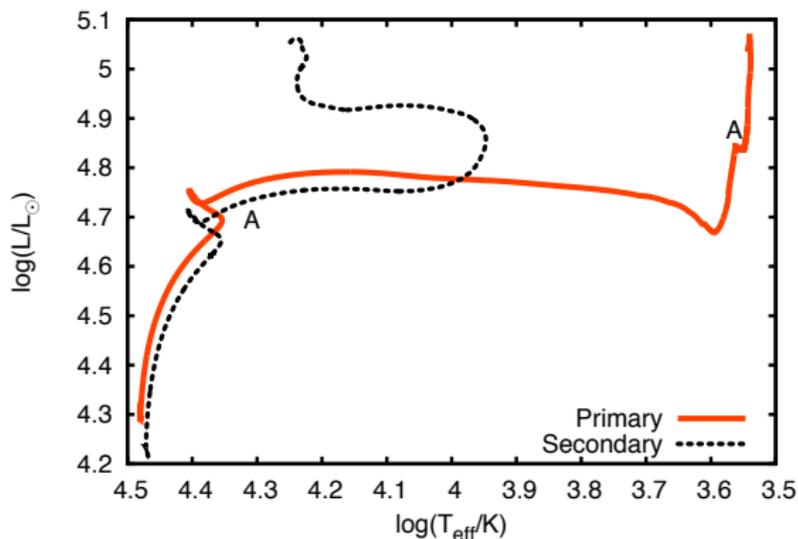
- Dominant channel



Which binaries produce type IIb SNe?

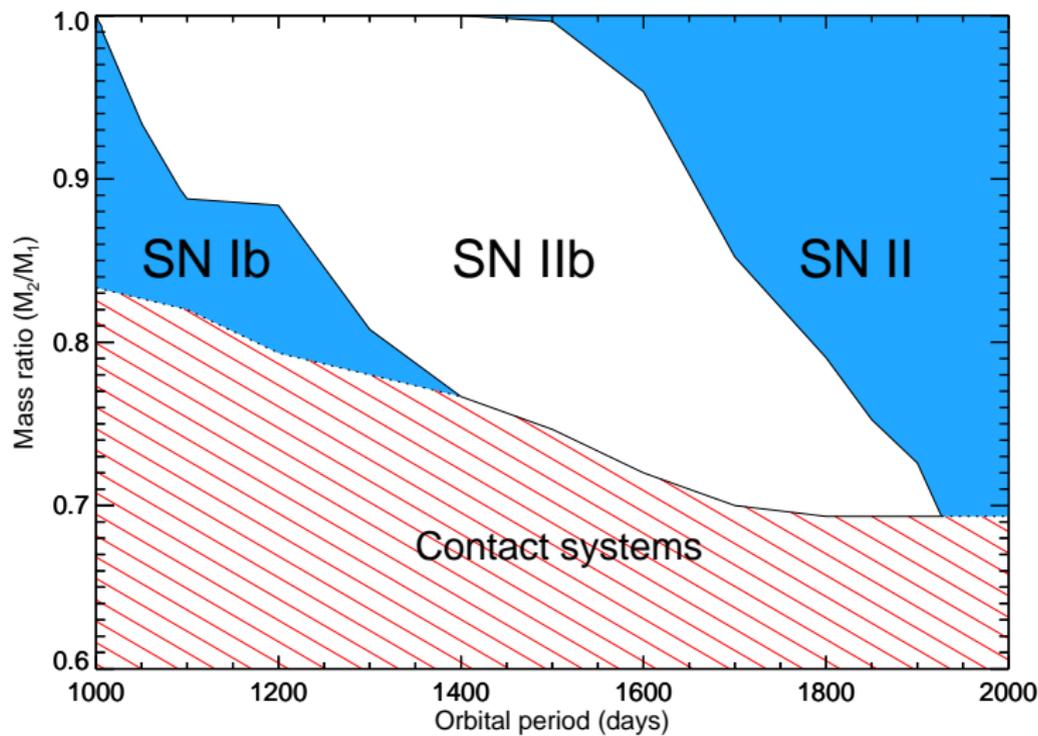
Example: progenitor system

Based on model: maund et al. (2004)



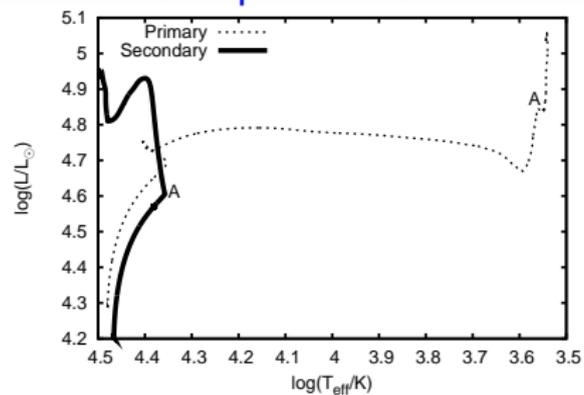
$15+14.35 M_{\odot}$, $P_{\text{orb}}=1500$ days

Calculations made with Eggleton's stellar evolution code



What about the companions?

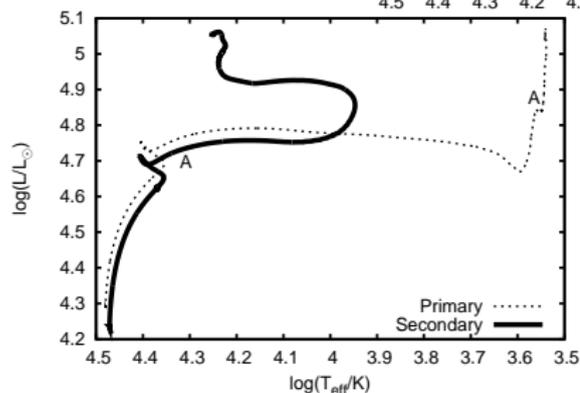
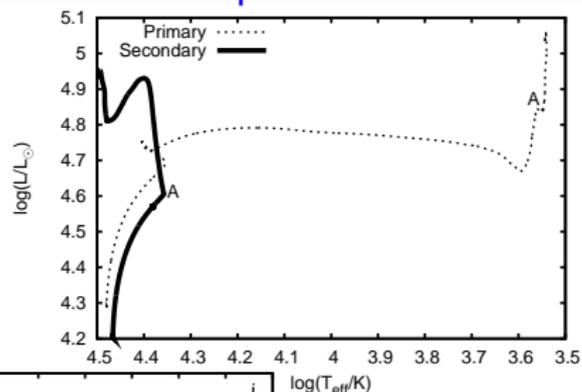
Companion: O-star



Companion: B-supergiant

Companion: K-supergiant

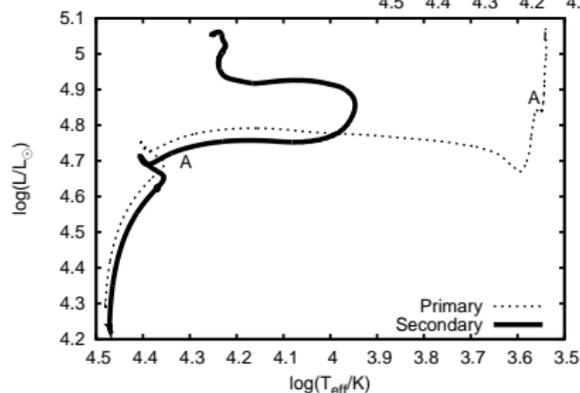
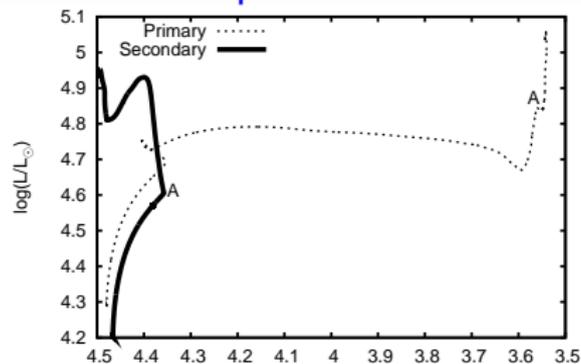
Companion: O-star



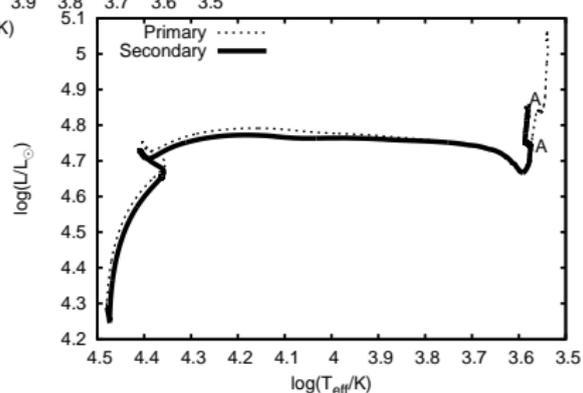
Companion: B-supergiant

Companion: K-supergiant

Companion: O-star

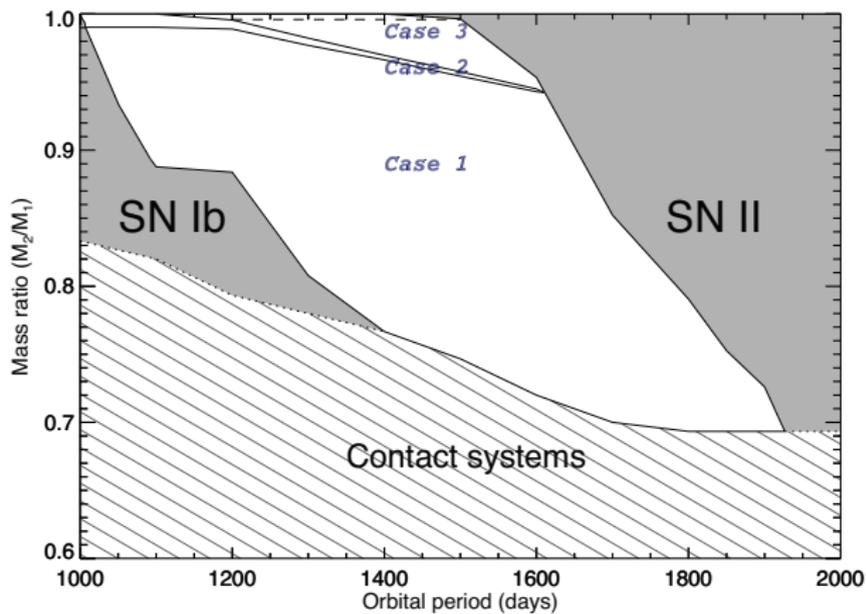


Companion: B-supergiant

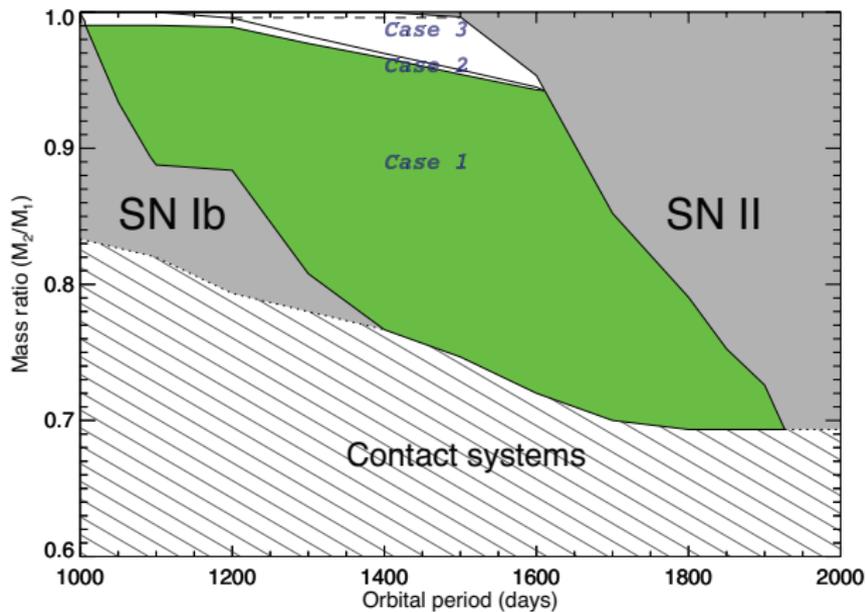


Companion: K-supergiant

Evolution of the companion?

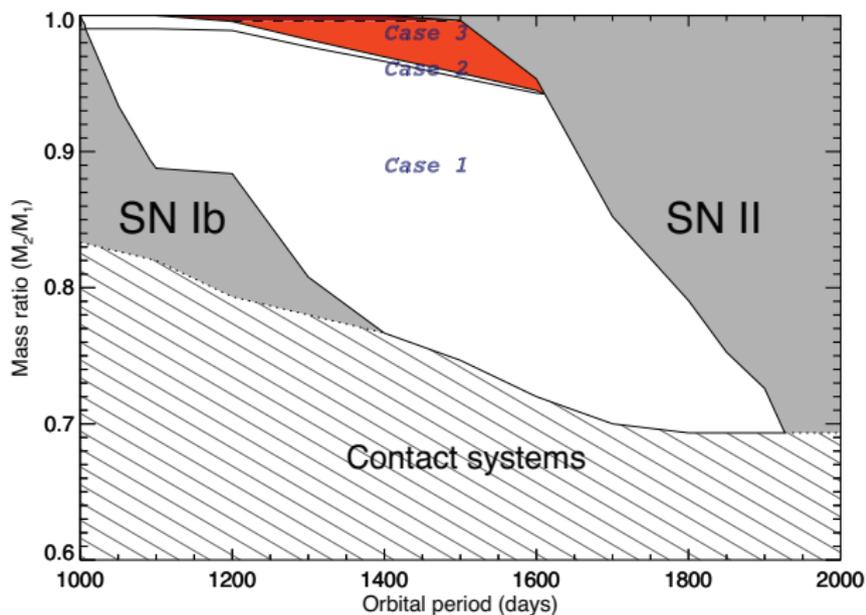


Evolution of the companion?



Case 1: O-star
⇒ 90%

Evolution of the companion?



Case 3: K (red)
supergiant
 $\Rightarrow 7\%$

Can we explain the rate of
IIb's?

The observed and predicted rate

- Observed rate: Extended IIb

$$\frac{\text{SNe IIb}}{\text{Core Collapse}} \approx 3\%$$

Smartt et al. (2009), Van den Bergh et al. (2005),
Li et al. (2007), Arcavi et al (2010)

- Predicted rate (standard assumptions)

$$\frac{\text{SNe IIb}}{\text{Core Collapse}} \approx 0.6\%$$

Close Binary fraction: 50%, flat initial mass ratio distribution,
flat in log period

Increase binary fraction:
 $\approx 1\%$

favour "Twin binaries":
 $\approx 1.35\%$

Non-conservative:
 $\approx \times 1.6$

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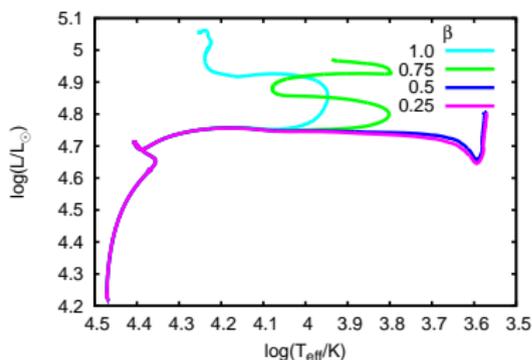
- **In comparison: Single Stars**

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What can Ilb's teach us?

Accretion Efficiency

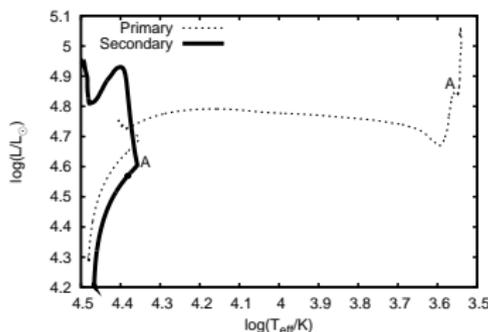
- Due to spin-up of accreting star \rightarrow Binary system loses mass (Packet 1981)



- Decrease of binary systems evolving to SNe type IIb with companion a B-supergiant

Internal mixing

- Companion of SN 1993J (and SN 2001ig) BSG:
→ Most rare scenario
 - [Schwarzschild Criterion](#): accreting during Main Sequence:
Companion: O-star



- [Ledoux criterion](#): More companions evolve to B-supergiant (Braun & Langer (1995))

Conclusion

1. Binary interaction can explain the characteristics of the observed SNe type IIb

But:

- Enough to explain the rate?
- Room for other channel (e.g. talk: Cantiello)?

2. More accurate rate by upcoming automated surveys (e.g. PTF, Pan-STARRS,...)
3. Observations IIb SNe and their companions: learn about stellar and binary physics

Thanks!