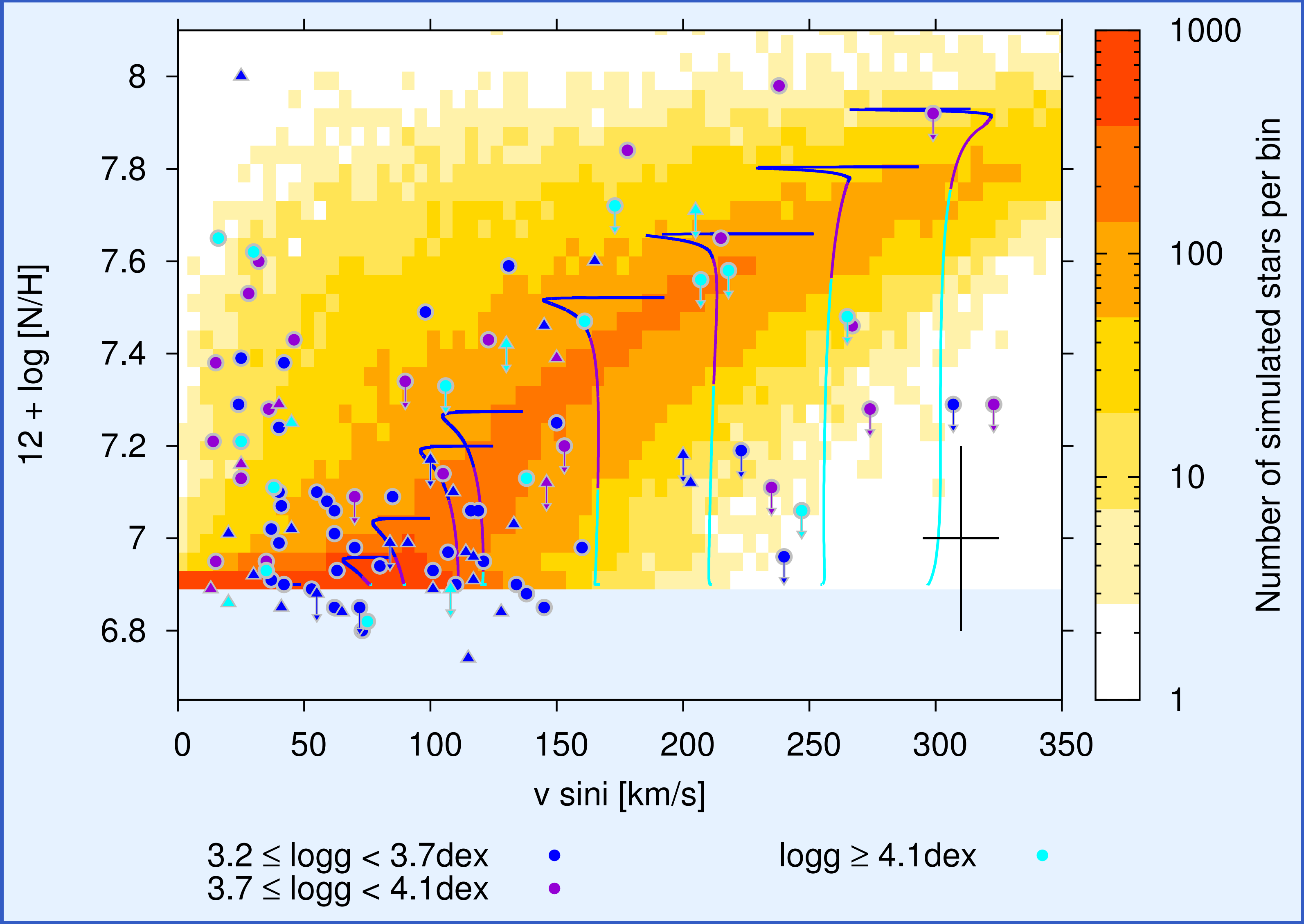
Very Massive Stars

Norbert Langer (Bonn University)

with

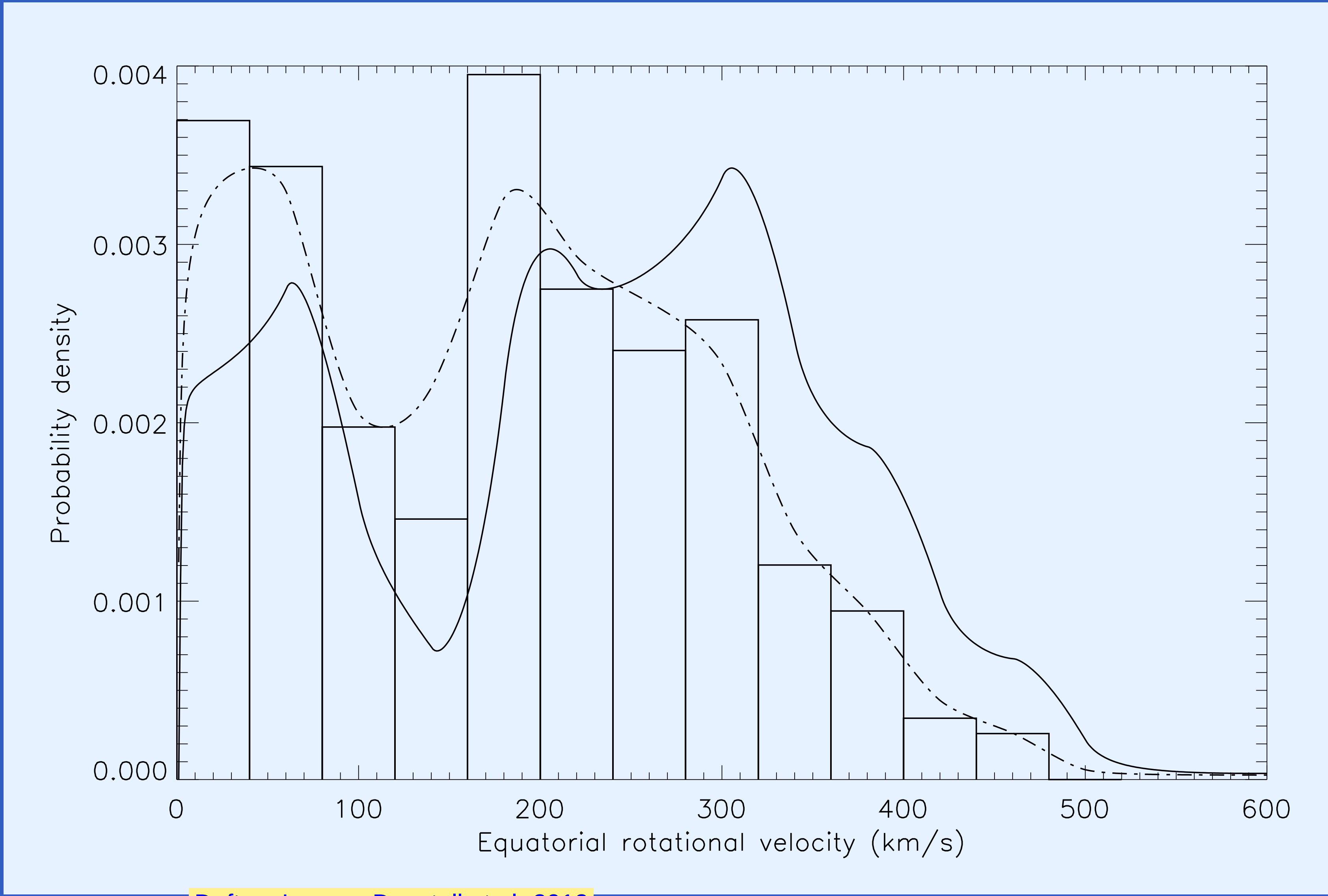
- Ines Brott (Vienna)
- Matteo Cantiello (UCSB)
- Selma de Mink (STScI)
- Karen Köhler (Bonn)
- Debashis Sanyal (Bonn)
- Alexandra Kozyreva (Bonn)
- Colin Norman (JHU)
- Alex Heger (Monash)
- Alex de Koter (Amsterdam)
- Onno Pols (Nijmegen)
- Jorick Vink (Armagh)
- Sung-Chul Yoon (Bonn)

The Hunter diagram: early BV stars



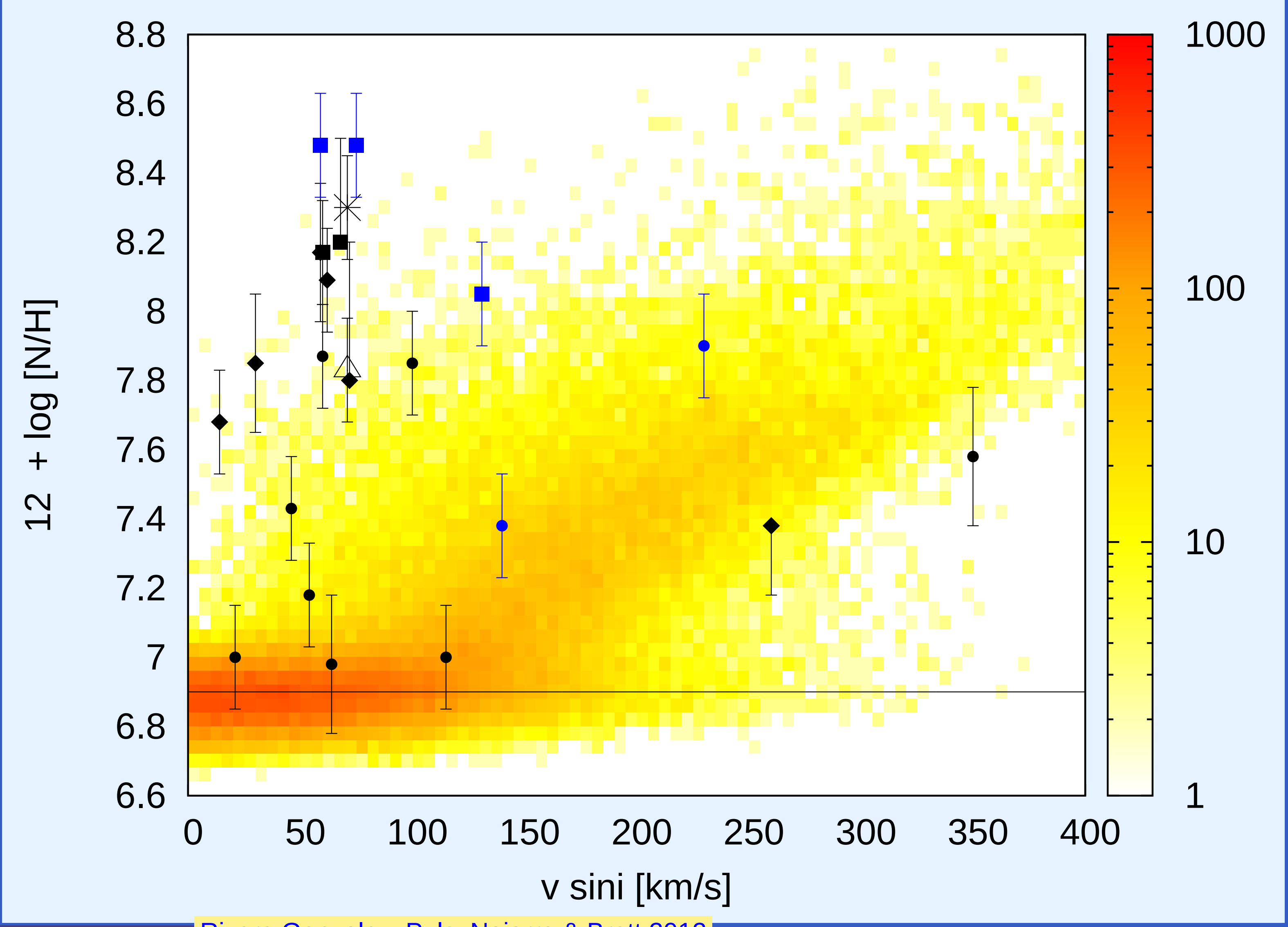
Brott, Evans, Hunter et al. 2011

The rotation rates: early BV stars



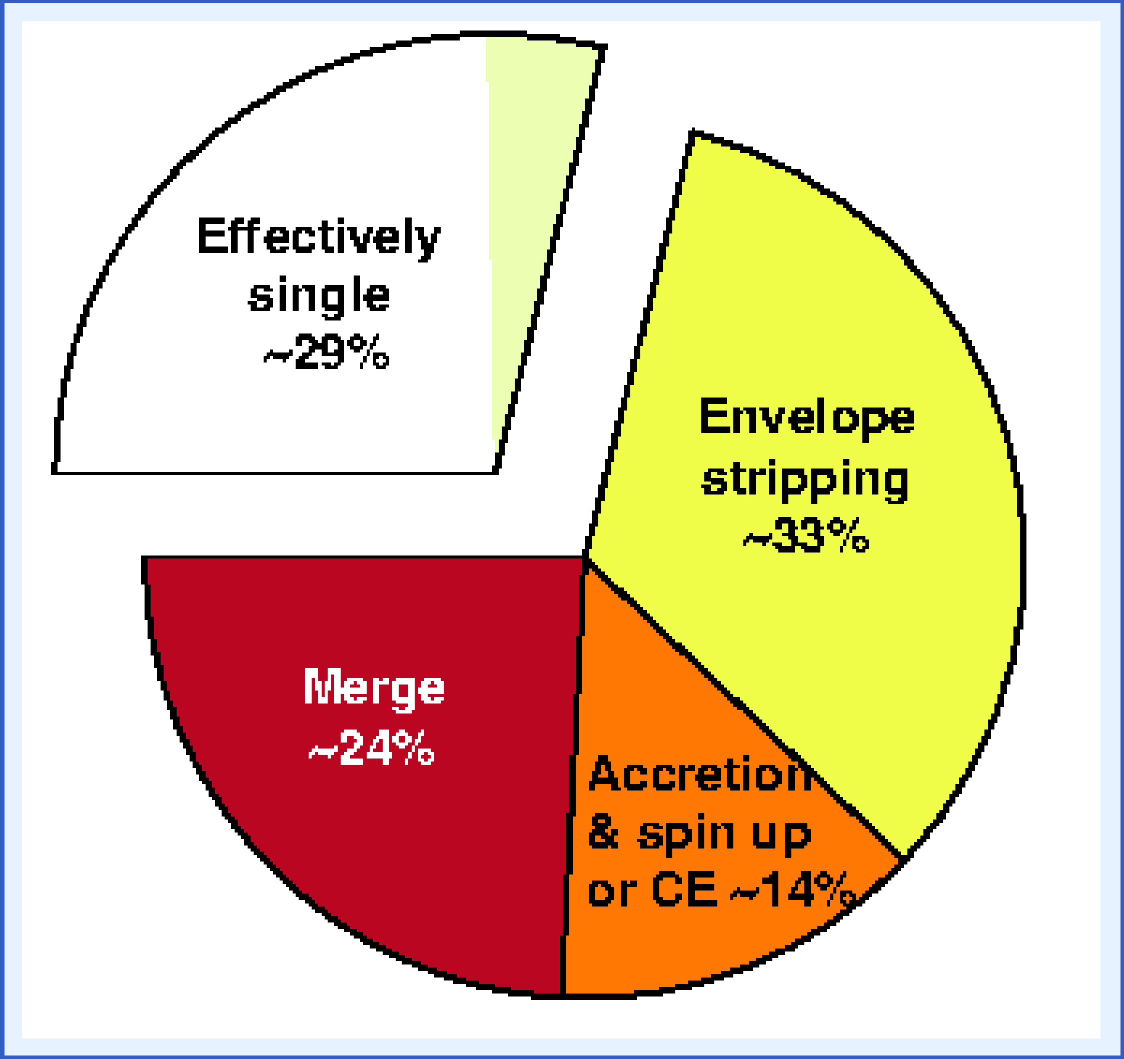
Dufton, Langer, Dunstall et al. 2012

The Hunter diagram: OV stars



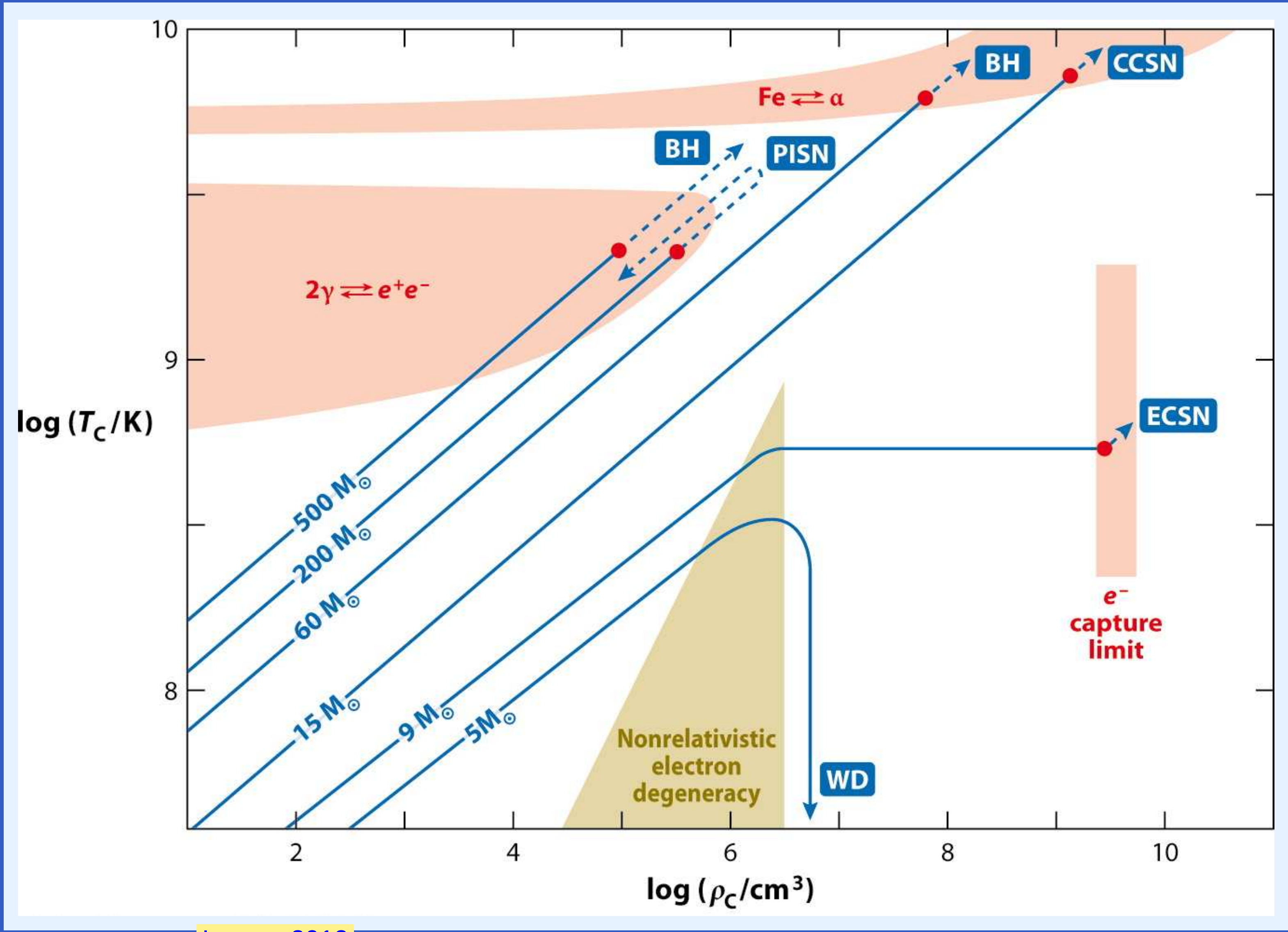
Rivero Gonzalez, Puls, Najarro & Brott 2012

Close binaries: O stars



Sana, de Mink, de Koter, et al. 2012

Why mass matters



Langer 2012

The Eddington limit

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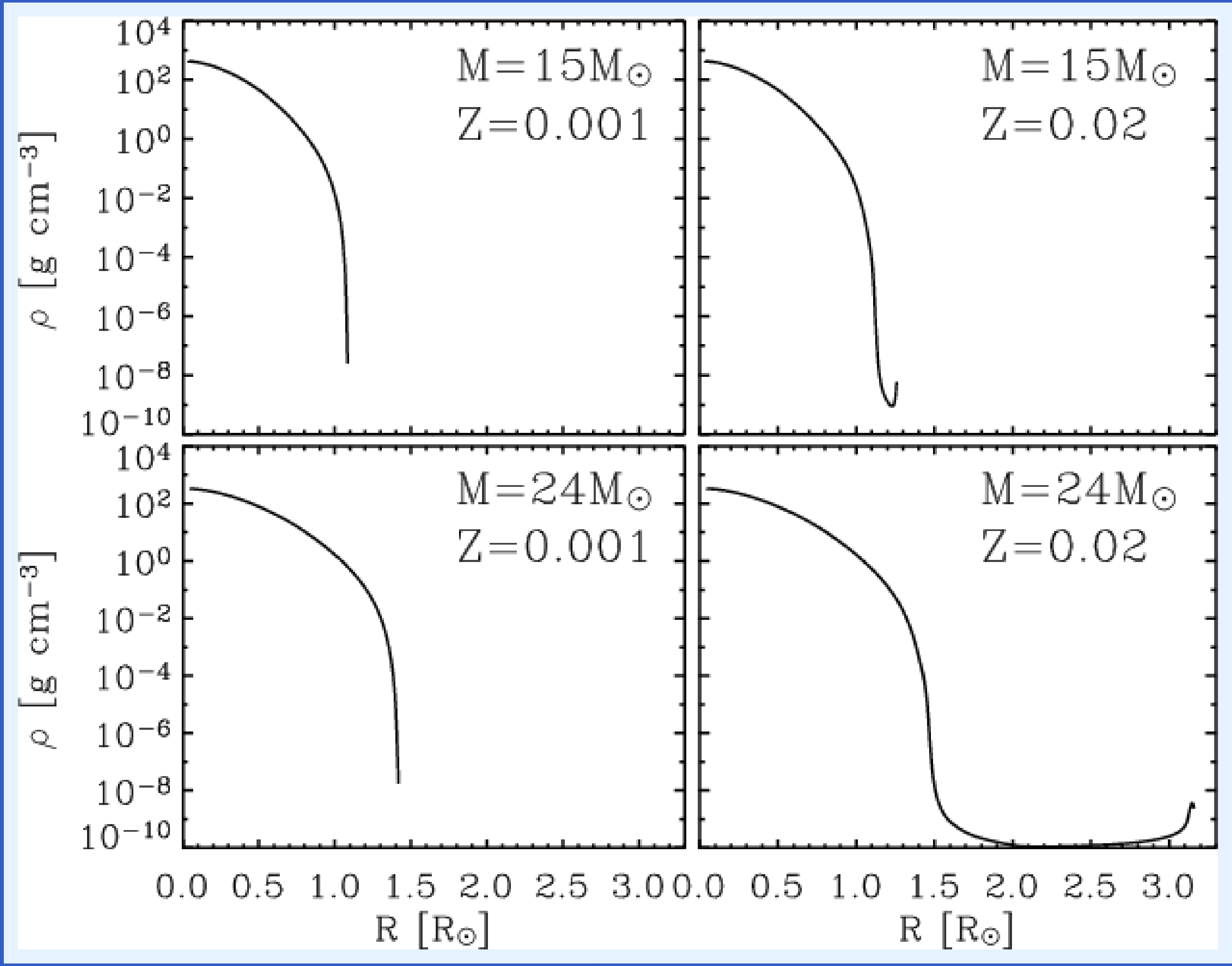
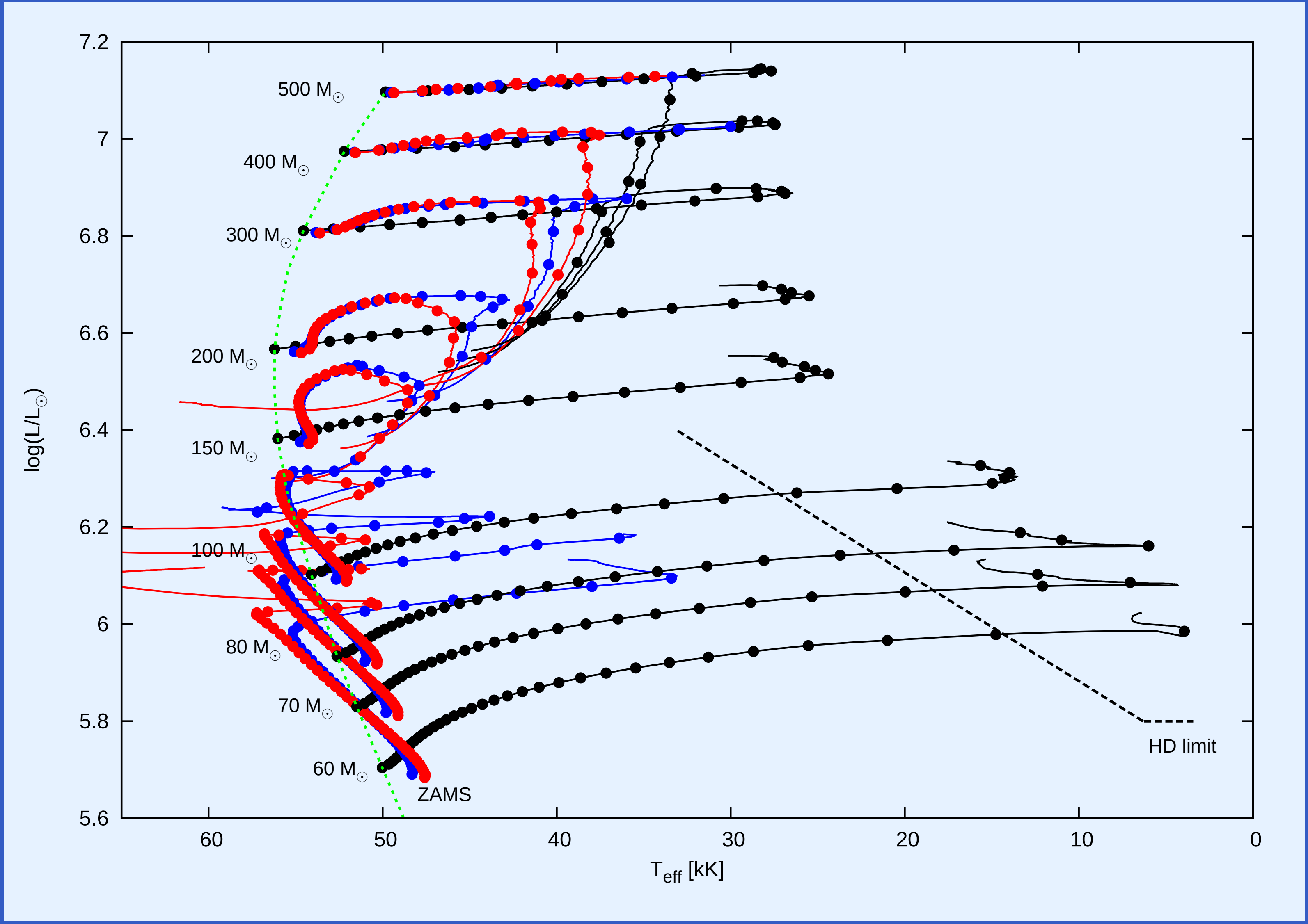
- inflation!

Inflation: He star models



Petrovic, Pols & Langer 2006

Inflation ≠ HD-limit



Köhler et al., in prep.

Inflation of main sequence stars

- inflation as f(Z):
  H-ZAMS: $Z_\odot \rightarrow M < 120 M_\odot$ Ishii et al. 1999
  $Z_{SMC} \rightarrow M < 200 M_\odot$
  $Z = 0 \rightarrow M < 1000 M_\odot$ Yoon et al. 2012
  He-ZAMS: $Z_\odot \rightarrow M < 15 M_\odot$ Petrovic et al. 2006
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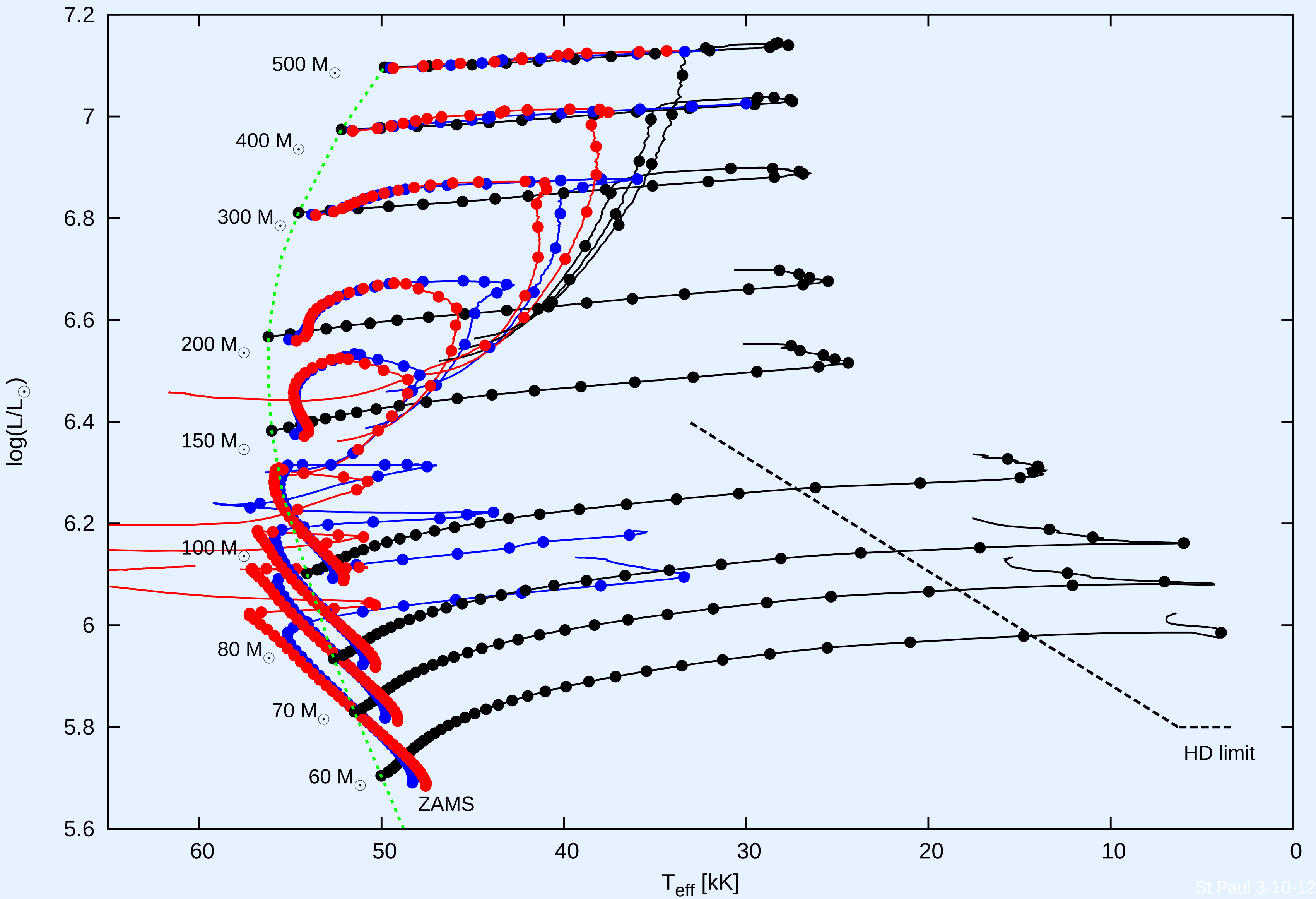
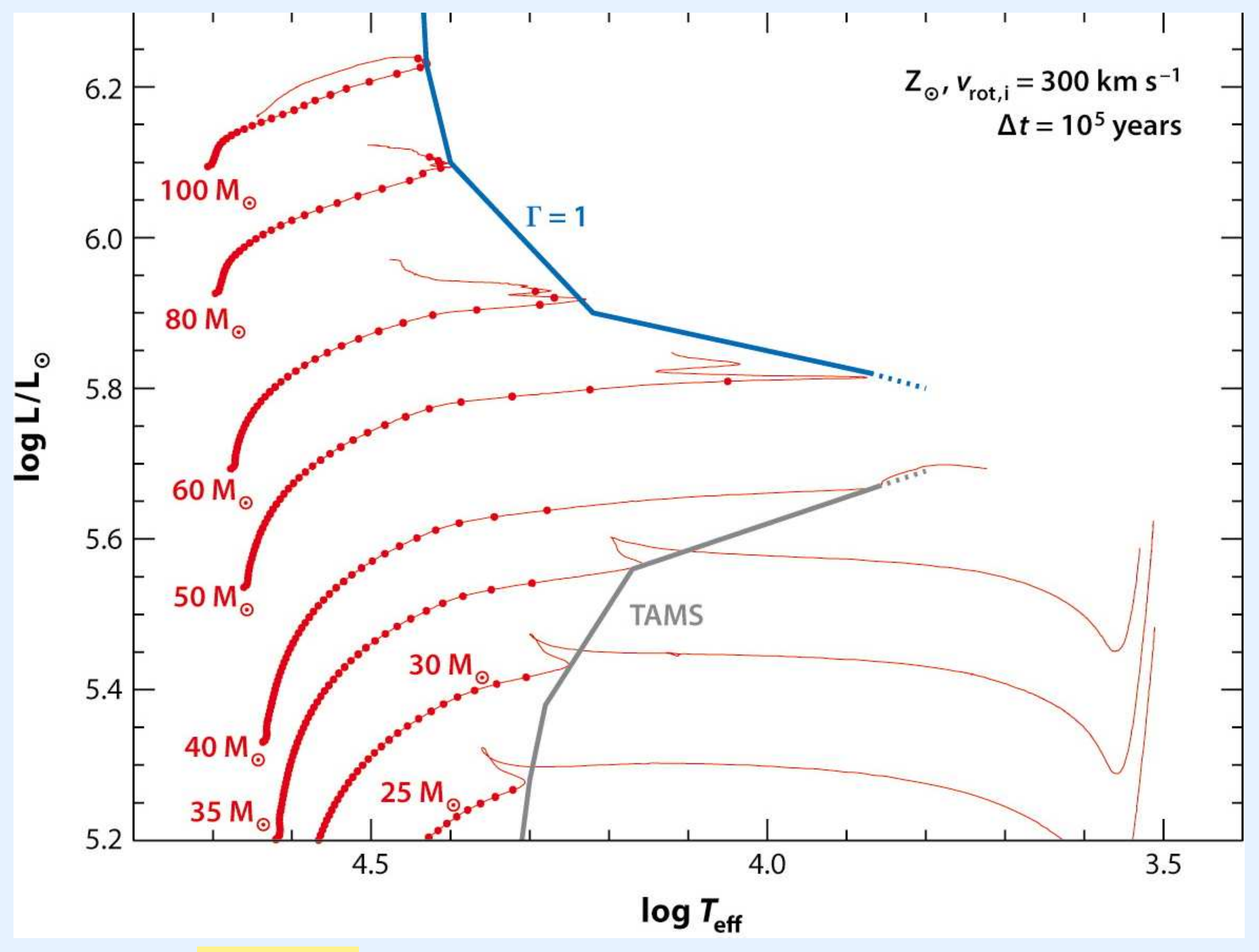
- $\frac{L}{L_{\rm Edd}} \sim \frac{\kappa L}{M}$:
  H $\to$ He $\Rightarrow \kappa \downarrow$ 2, $L(M) \uparrow 10$
  $\Rightarrow$ He-ZAMS crosses H-ZAMS!

ZAMS crossing

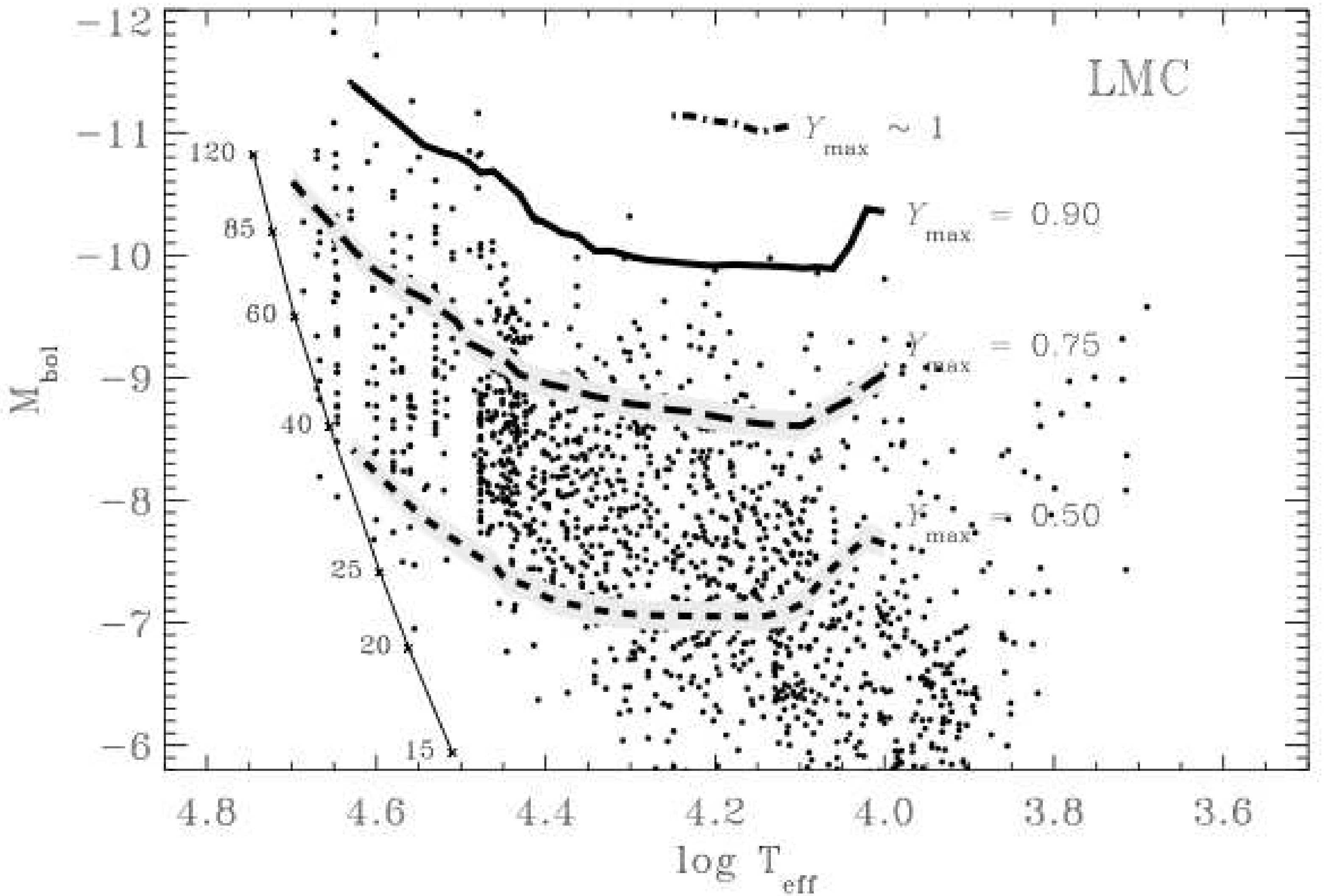


Eddington limit



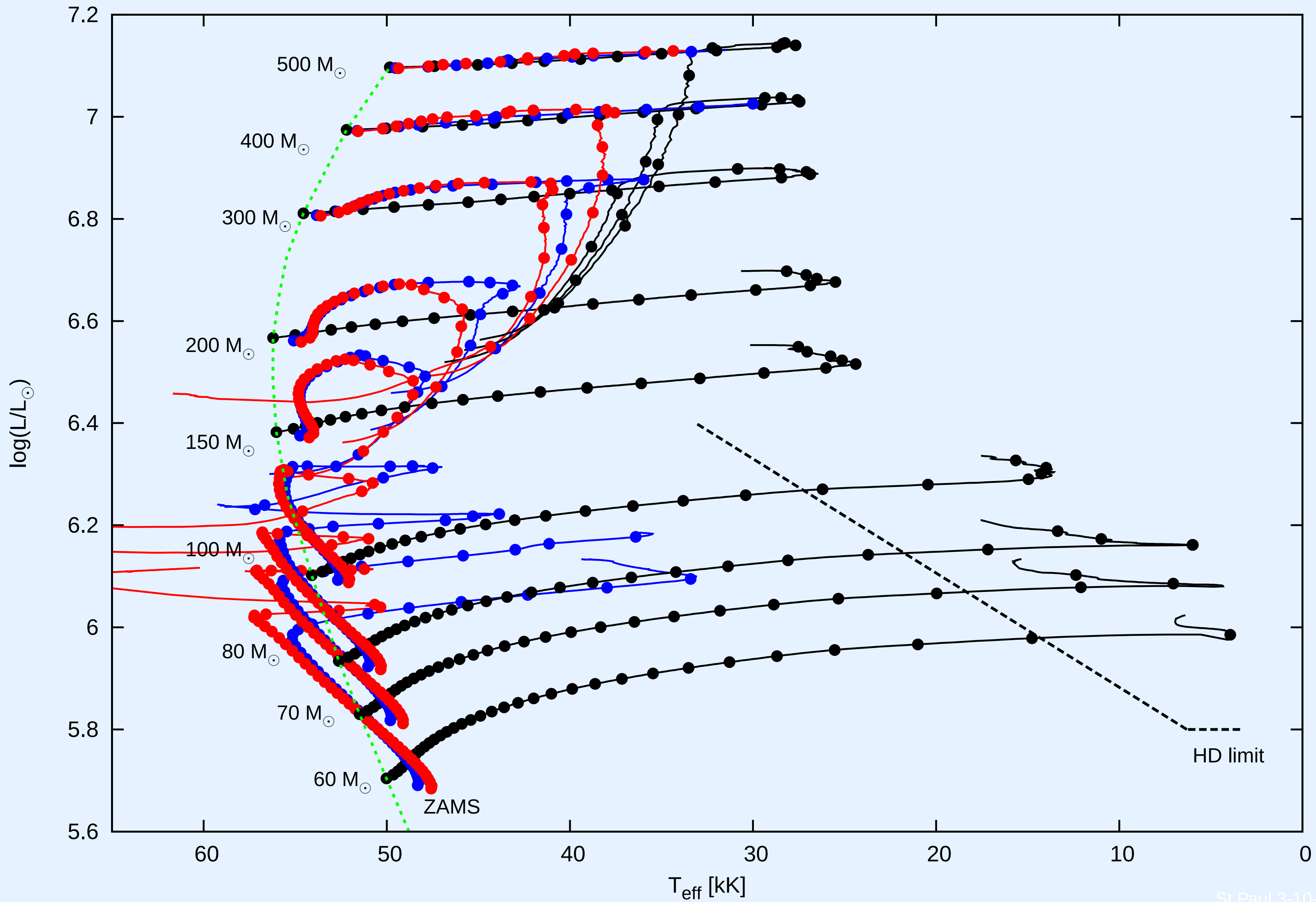
Langer 2012

Eddington limit

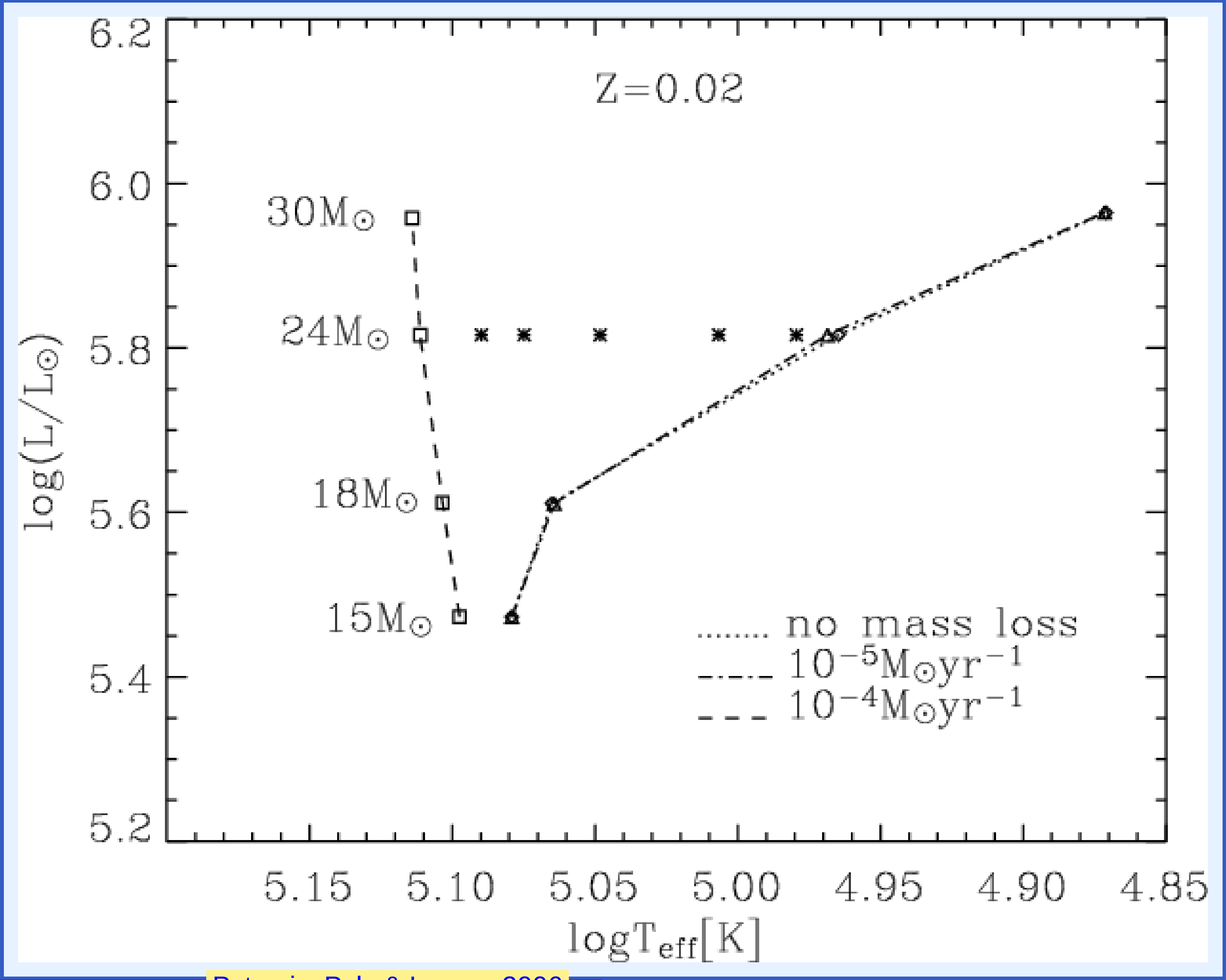


Ulmer & Fitzpatrick 1999

Eddington-limit



Inflation: $f(\dot{M})$



Petrovic, Pols & Langer 2006

Inflation: S Dor Variations?

Ingredients:

- $R(\text{inflated layer}) = f(\dot{M})$ Petrovic et al. 2006
- $\dot{M} = f(R)$ e.g. Vink: bistability

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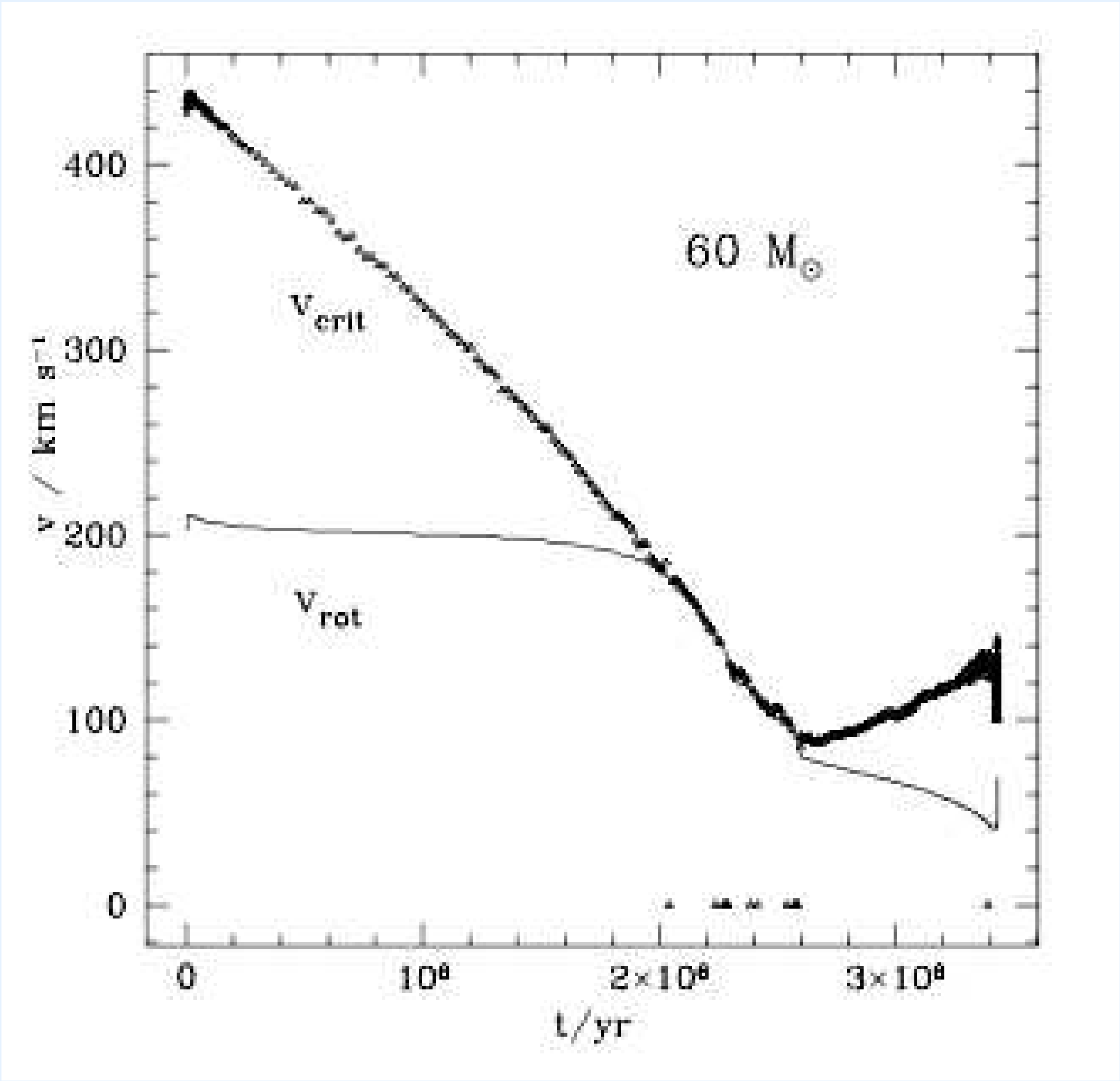
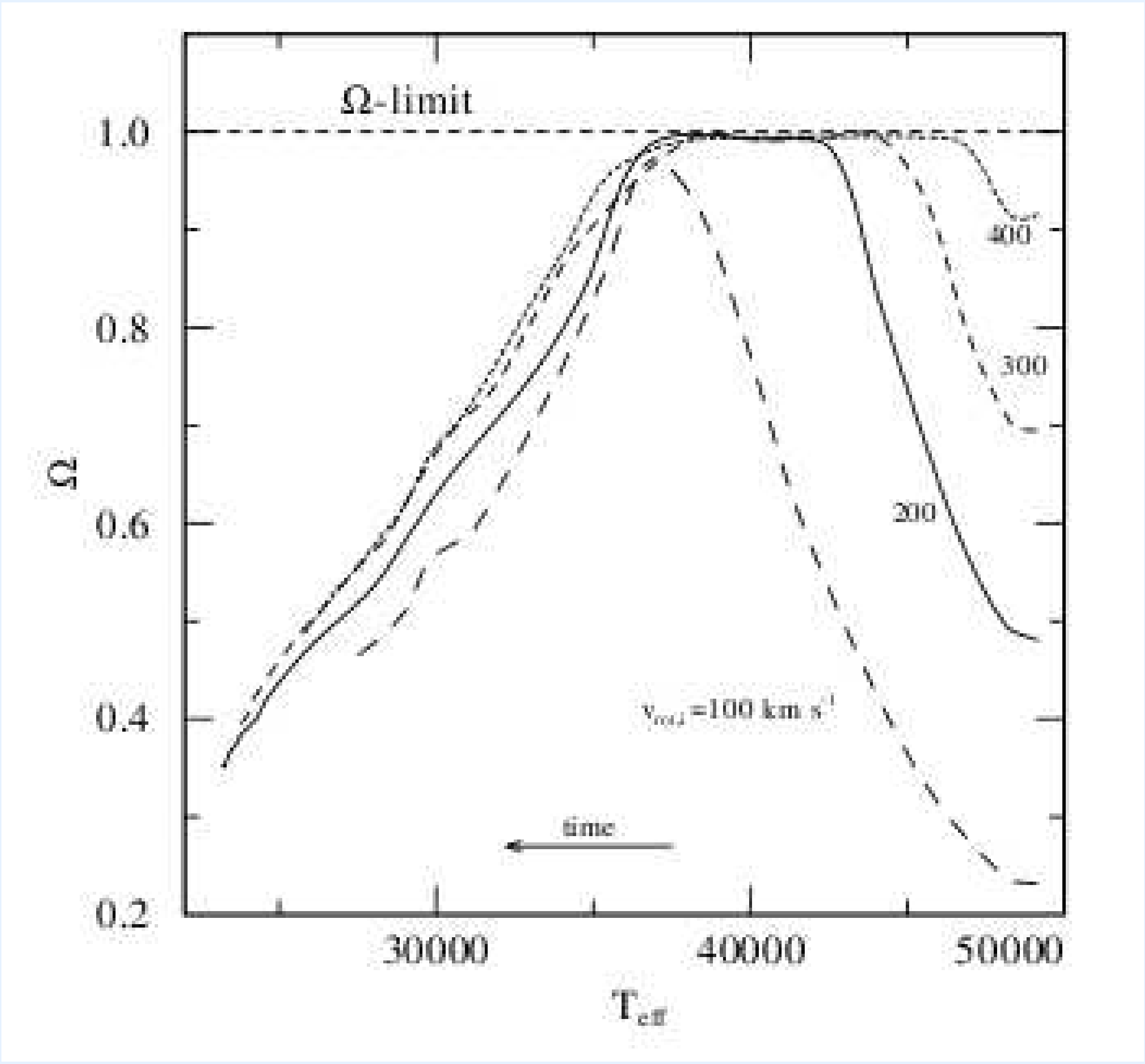
1) star compact: $\dot{M}$ small
$\rightarrow$ 2) inflation
$\rightarrow$ 3) $\dot{M}$ large
$\rightarrow$ 1) star compact

The role of stellar evolution



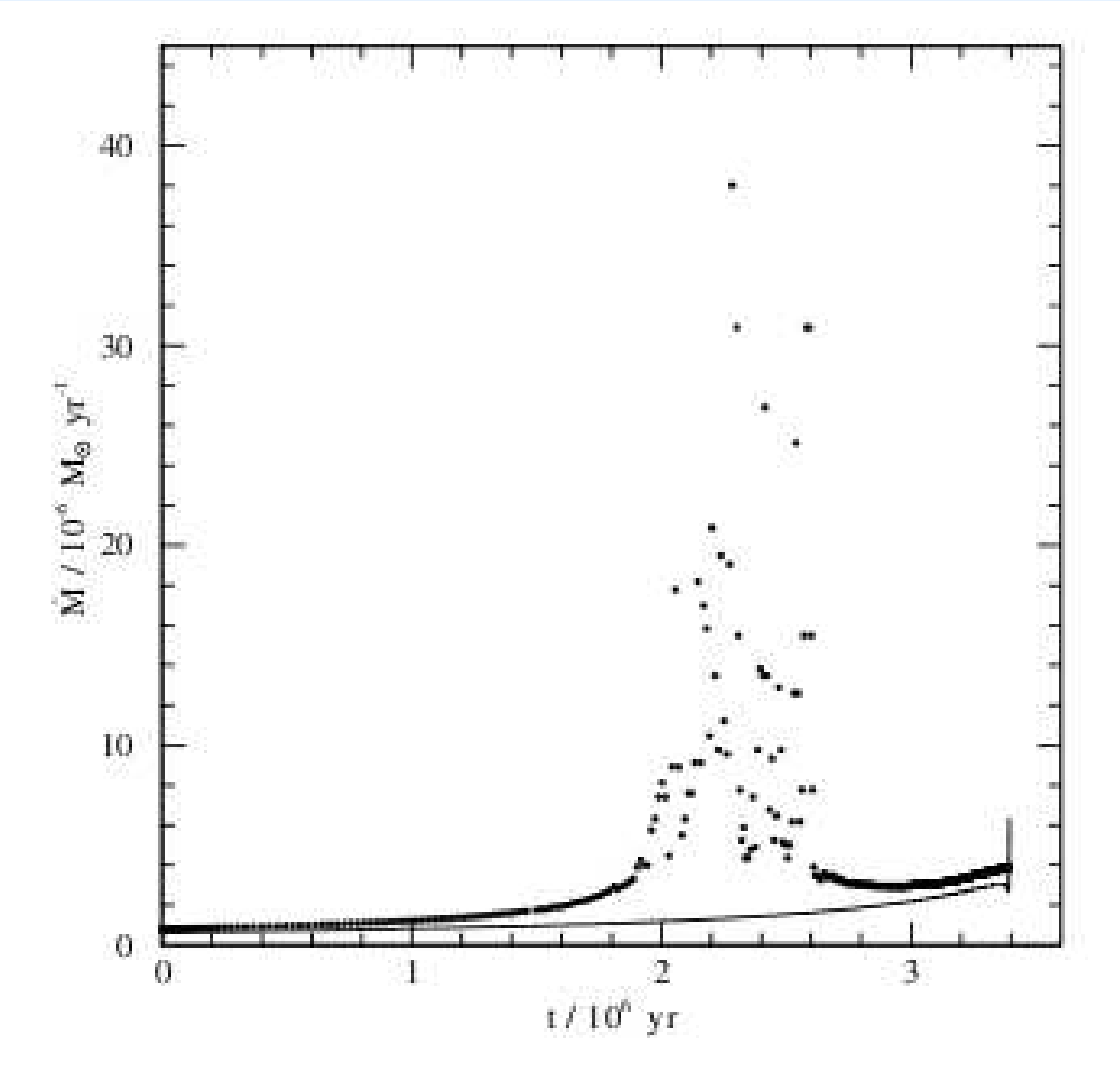
Langer 1998

MS evolution & the Ω-limit



Langer 1998

MS evolution: $\dot{M}$



Langer 1998

Mass loss rate at the Edd.-limit

nuclear timescale evolution: $\dot{M} \simeq \frac{M}{\tau_{\rm nuc}}$

$M = 100\,\mathrm{M}_\odot$: $\tau_{\rm nuc} = 3\,10^6$ yr $\rightarrow \dot{M} \simeq$ $3\,10^{-5}\ \mathrm{M}_\odot\ \mathrm{yr}^{-1}$

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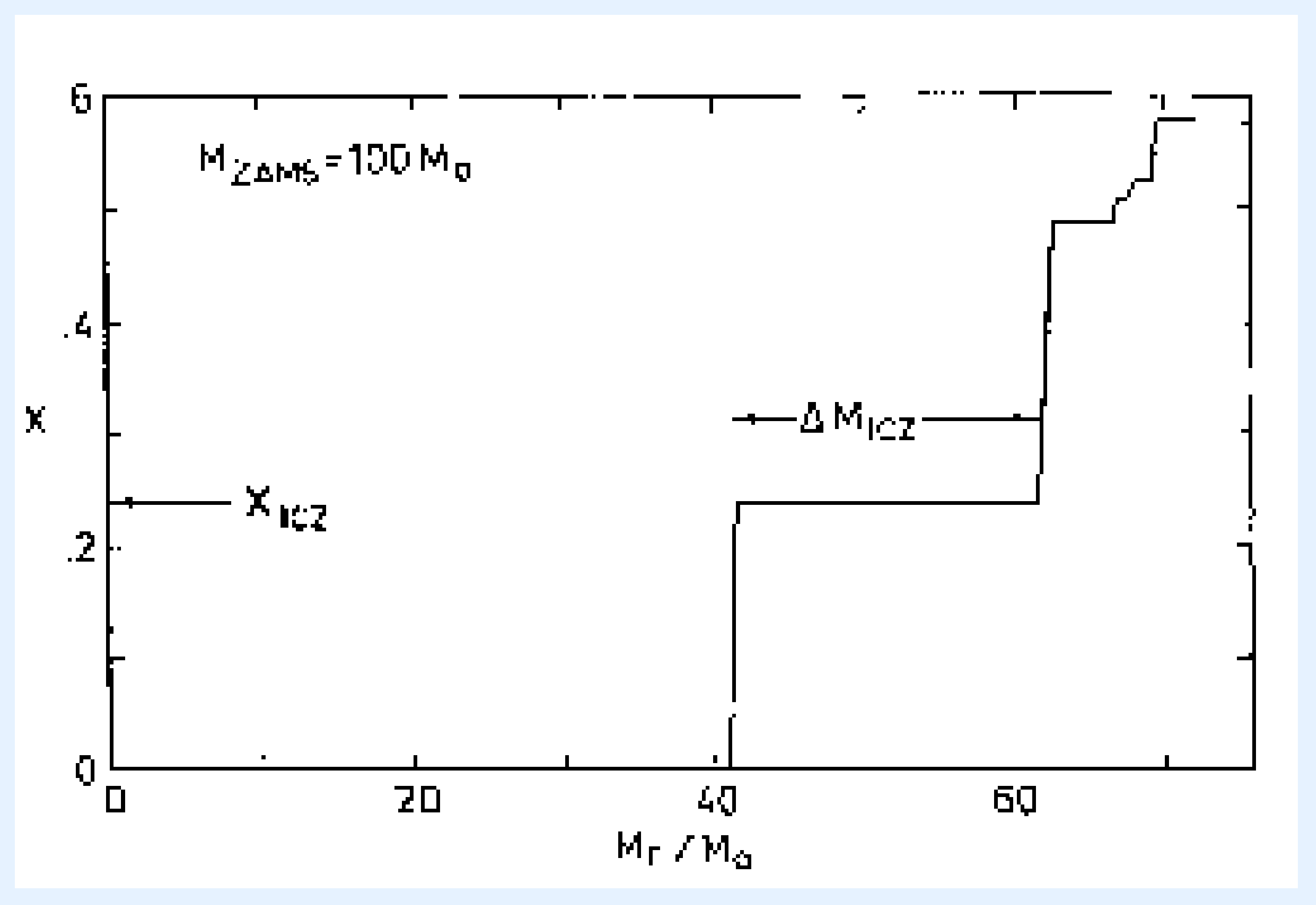
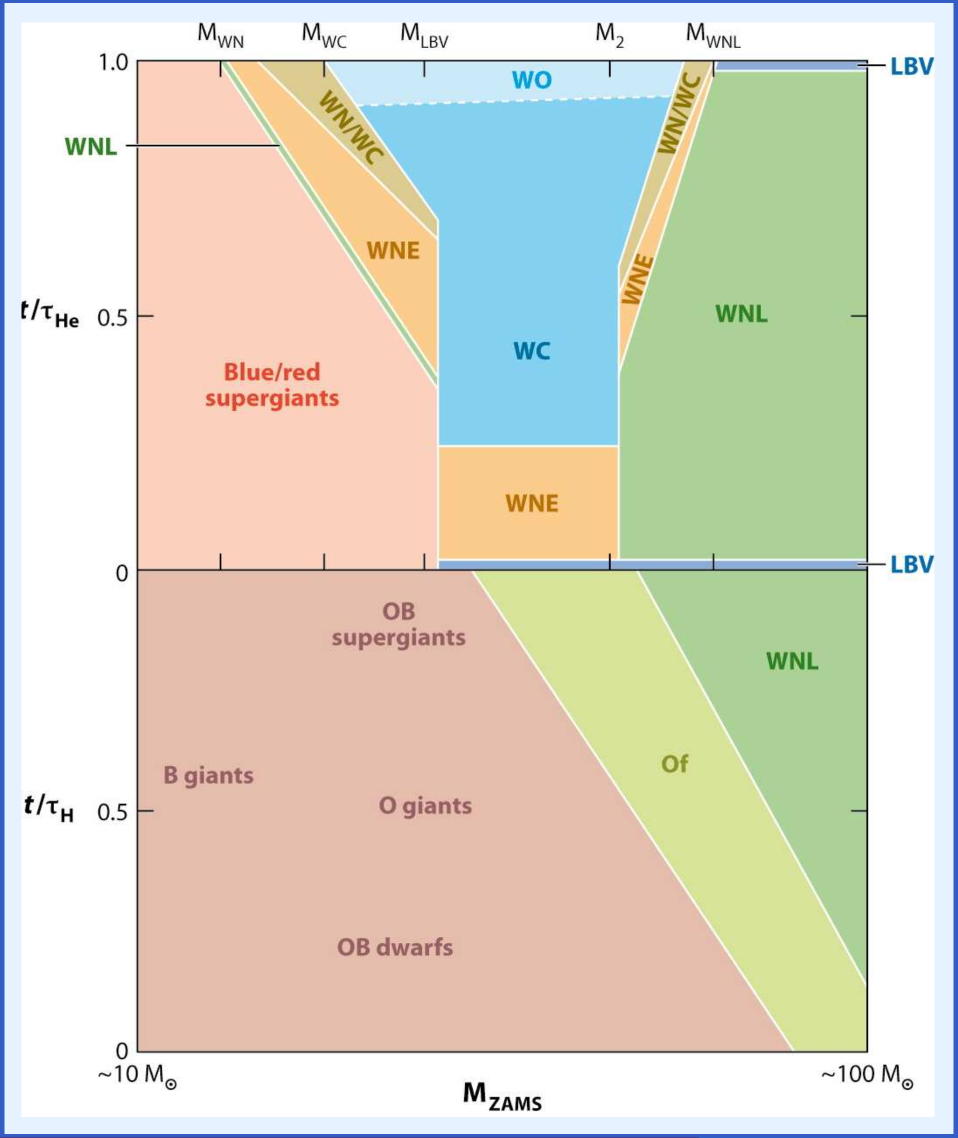
$\Rightarrow$ LBV eruptions need thermal timescale evolution

Post-LBV evolution



Langer 1987

Evolutionary scheme



Langer 2012

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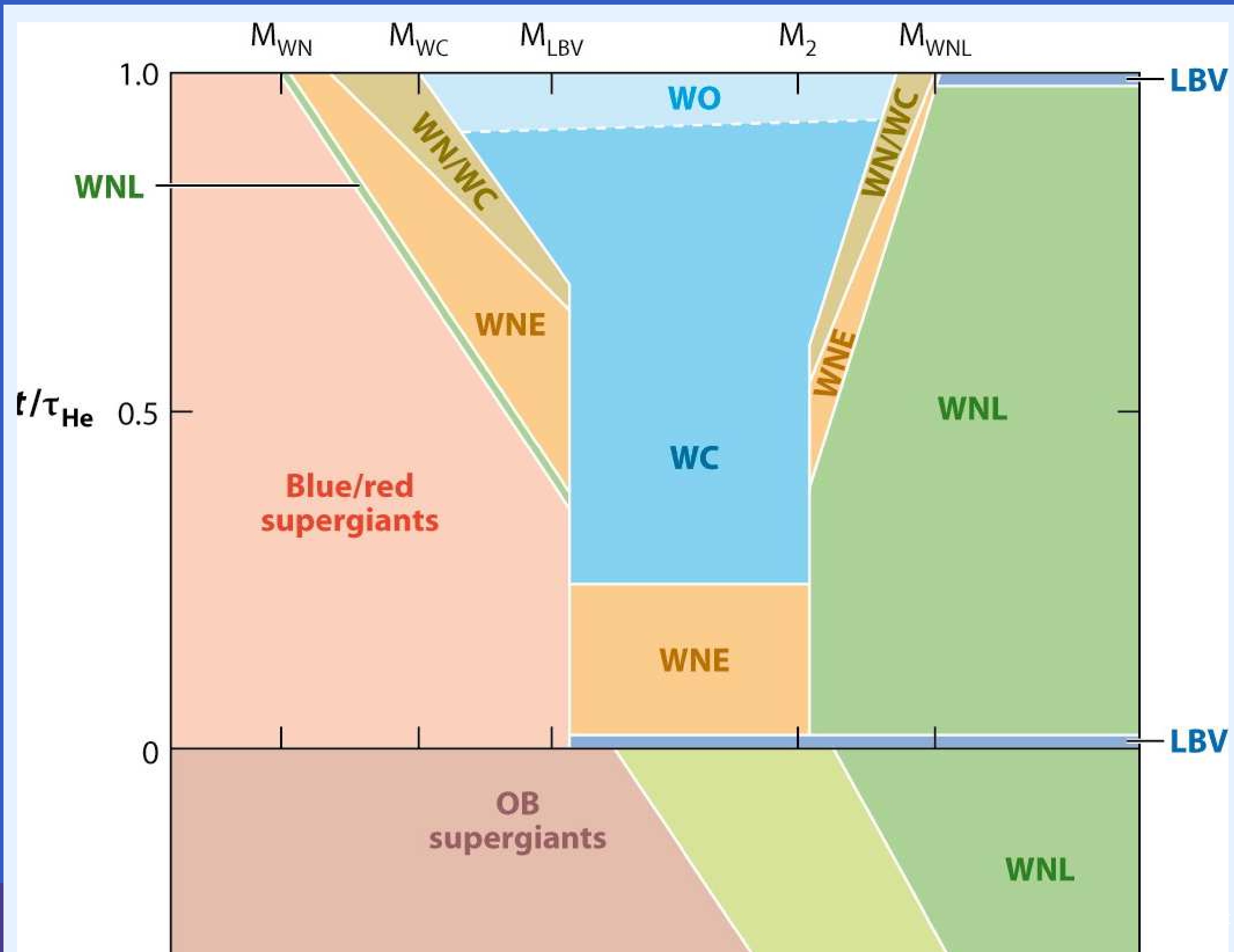
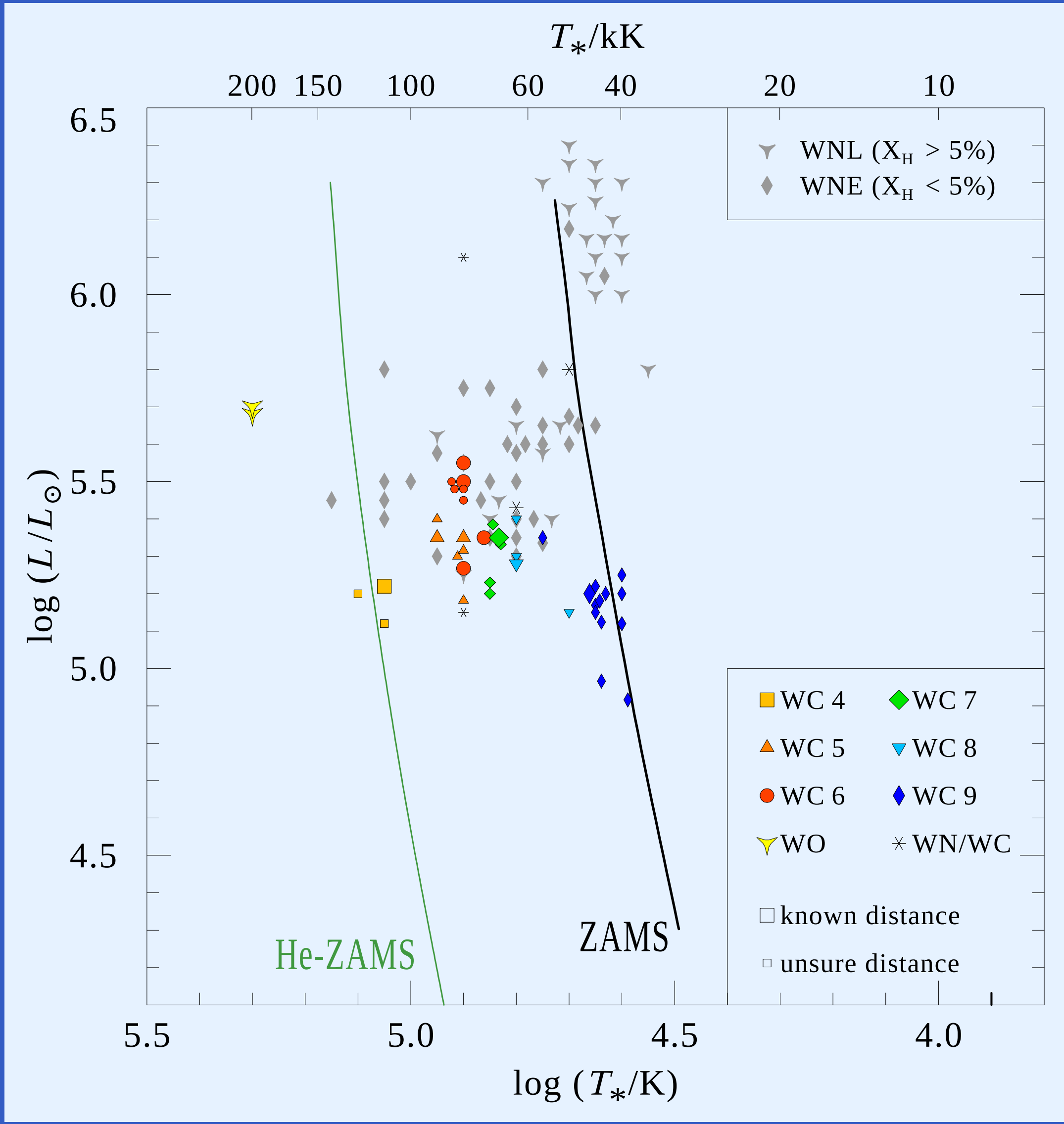


Galactic Wolf-Rayet stars



Sander, Hamann & Todt 2012

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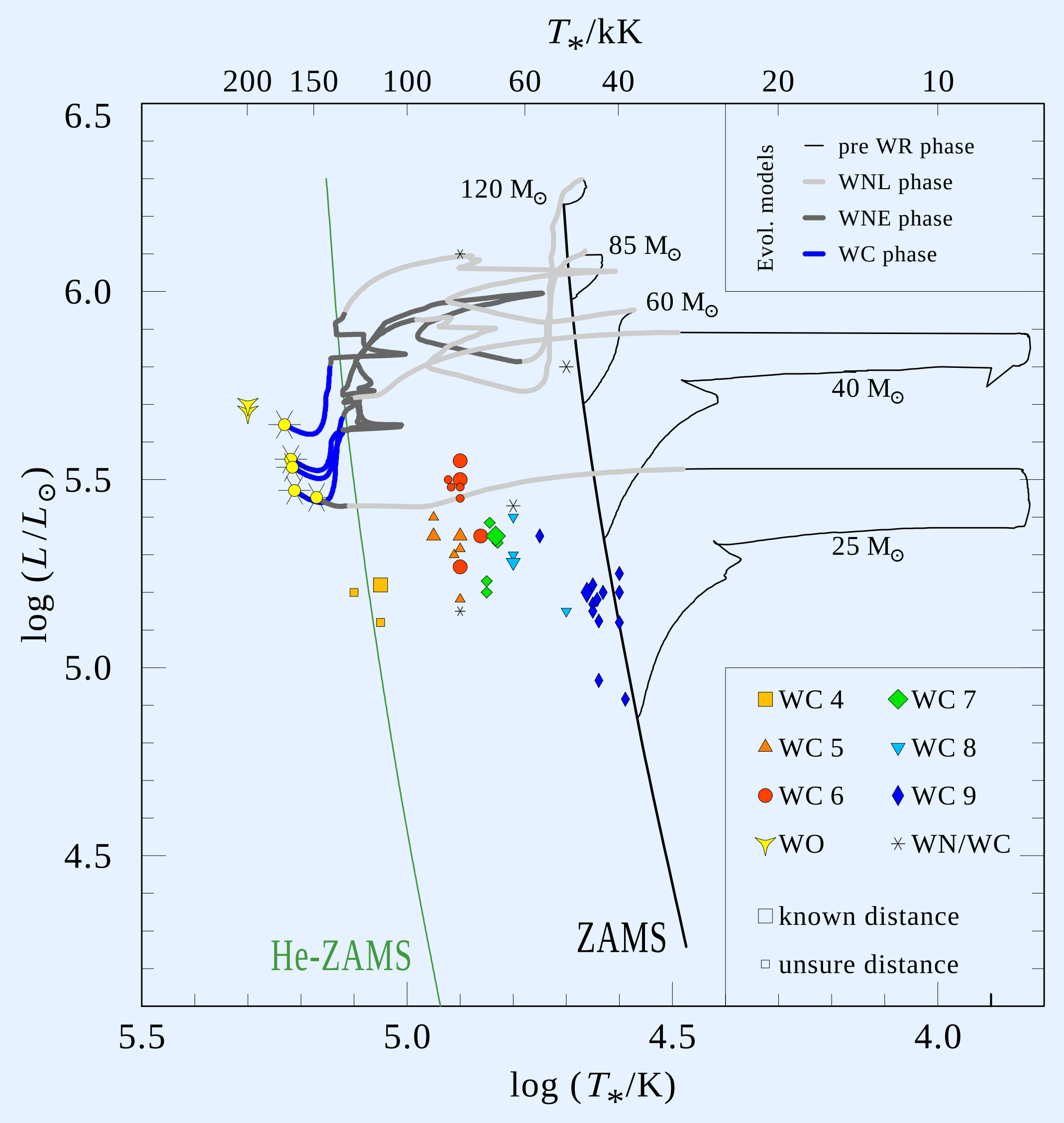
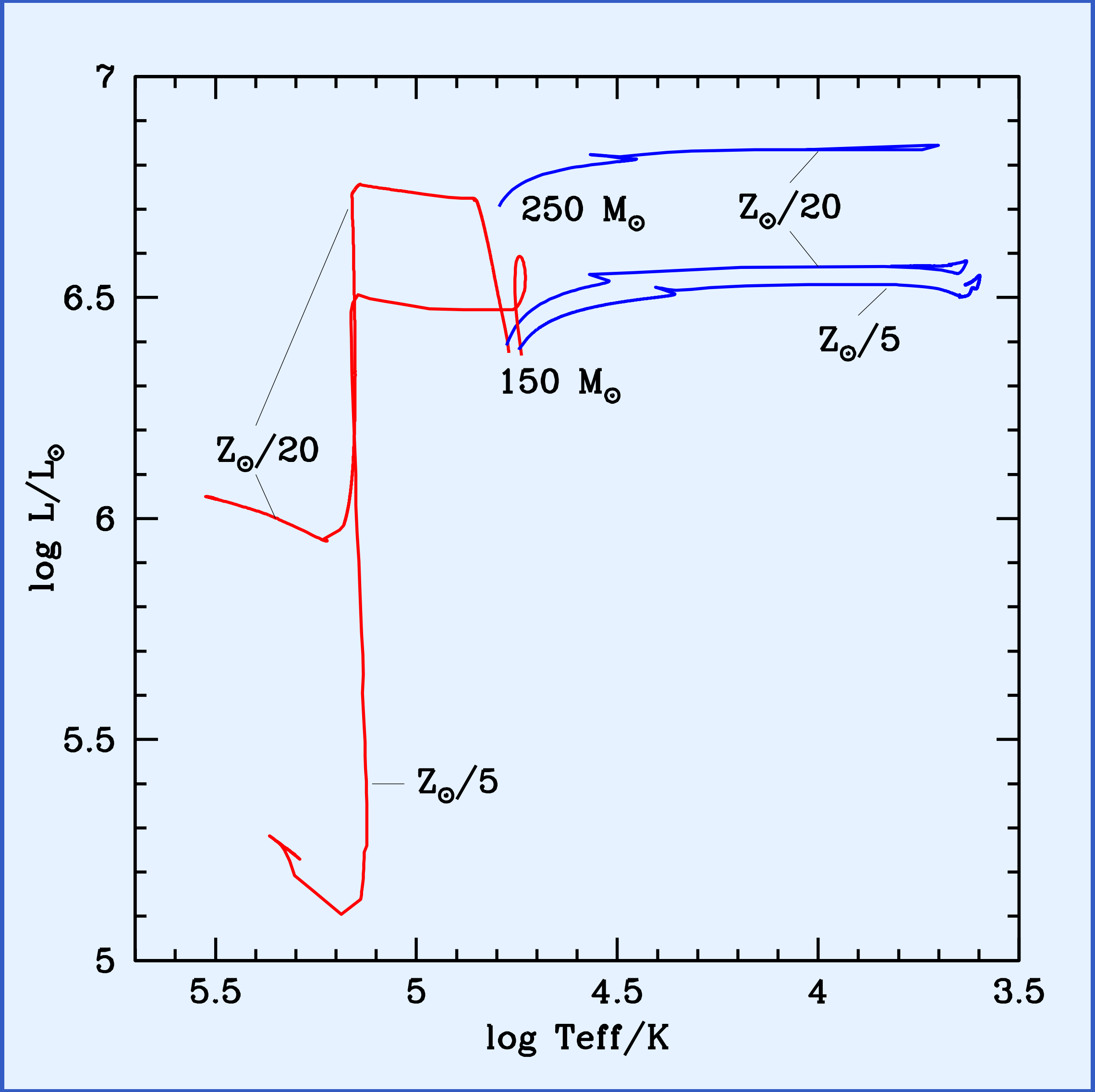


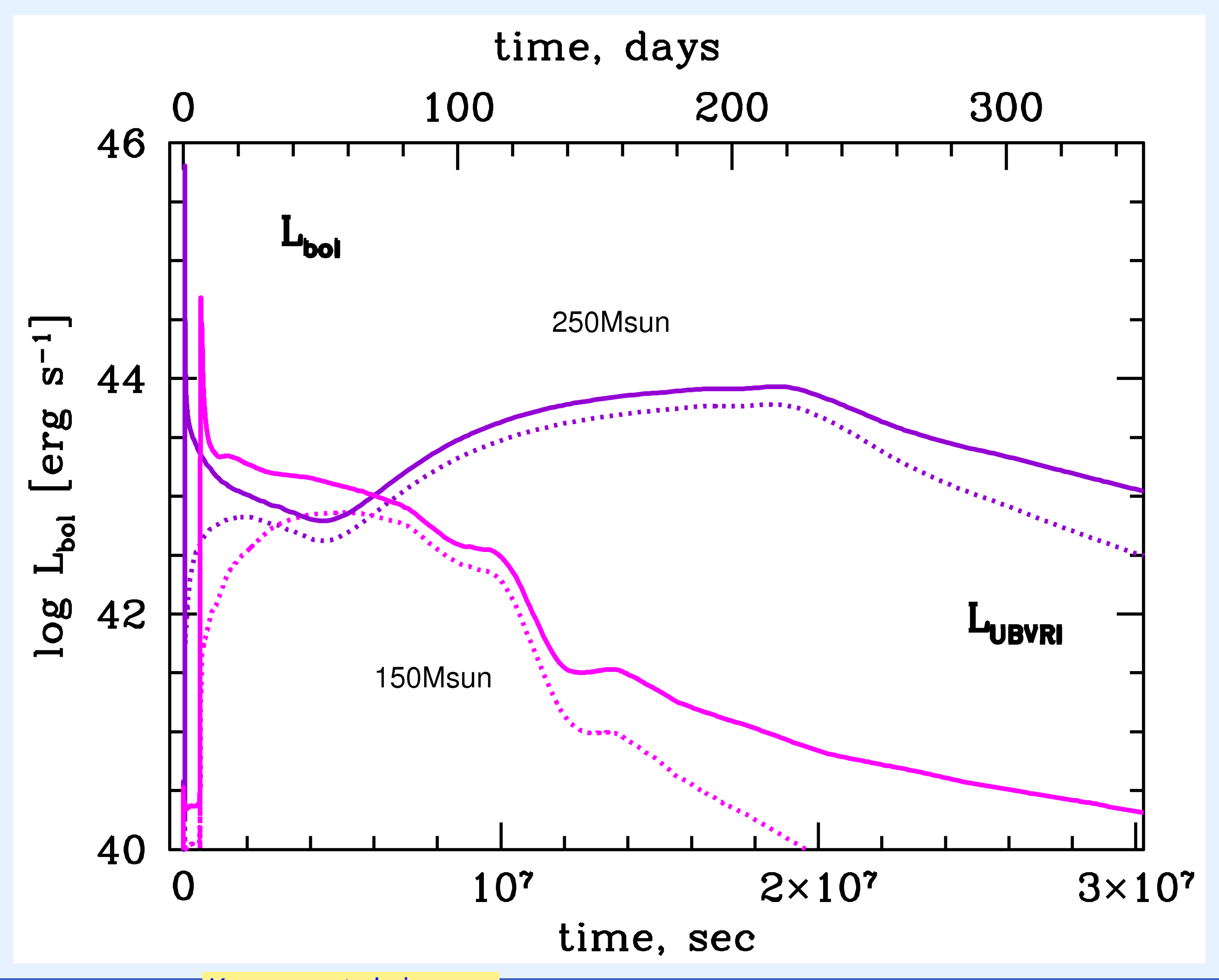
Sander, Hamann & Todt 2012

Local low-Z VMS



Langer, Norman, de Koter et al. 2007

Local Pair-Instability SNe



Kozyreva et al., in prep.

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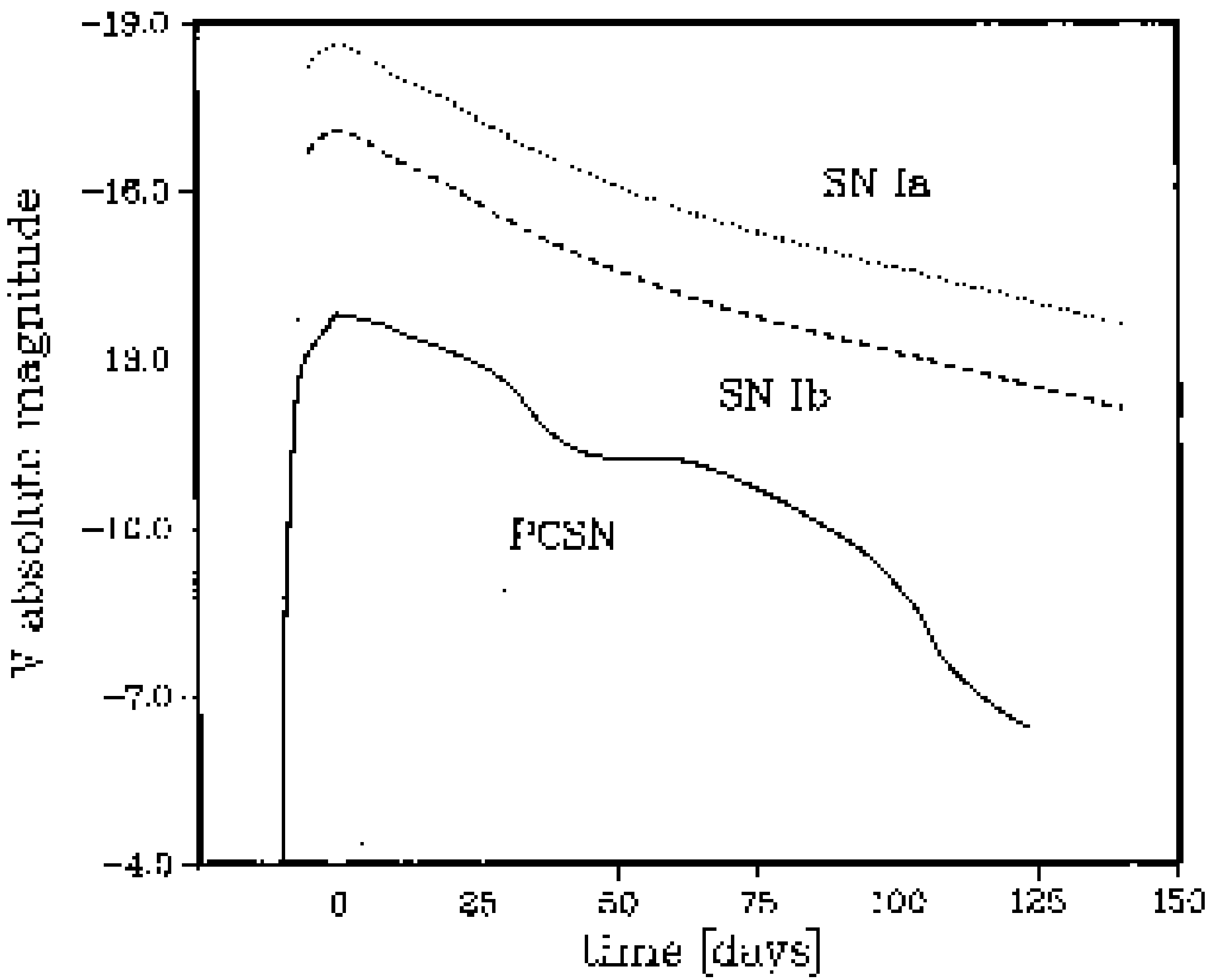
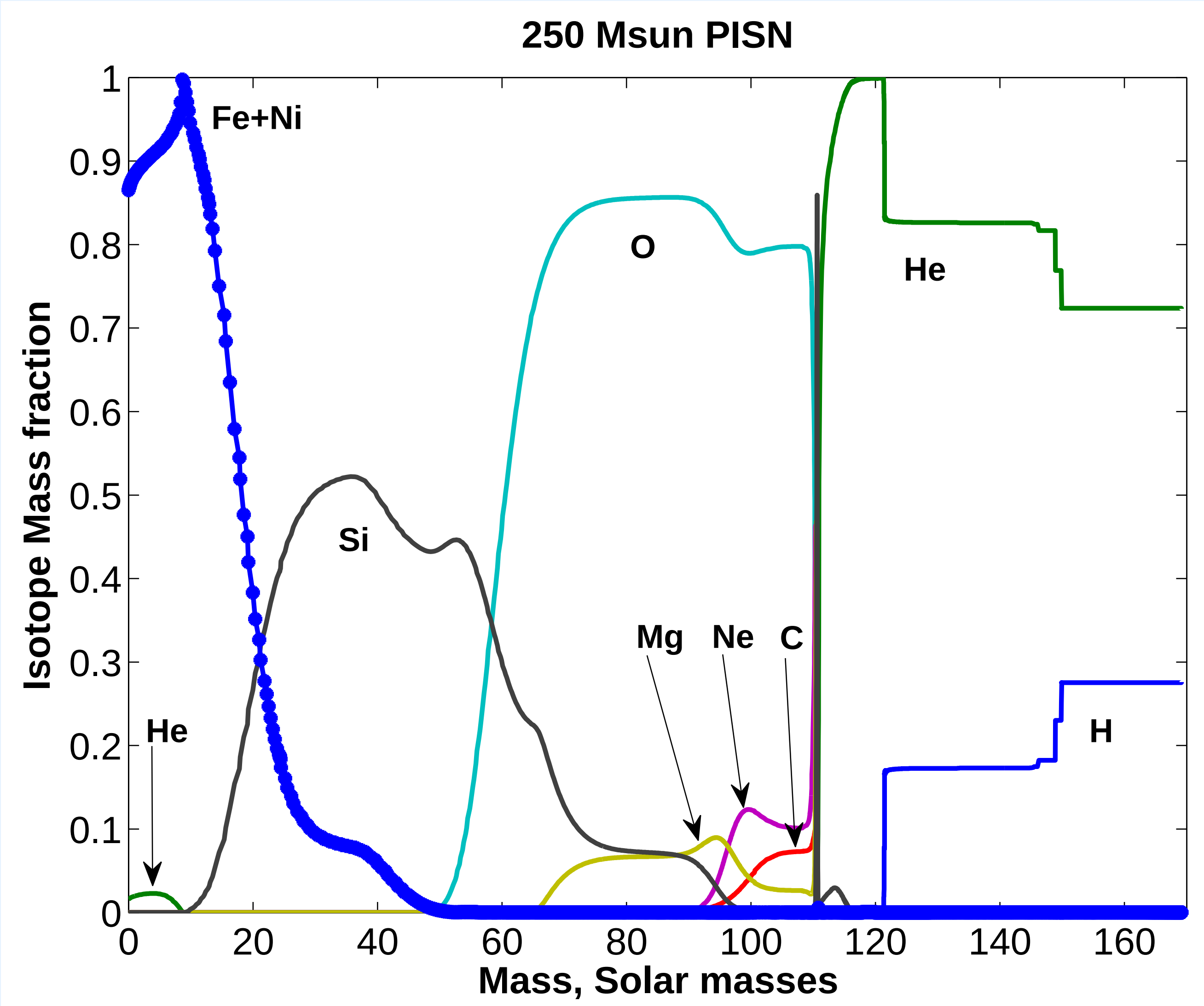


Herzig, El Eid, Fricke & Langer 1990

Local Pair-Instability SNe: Yields



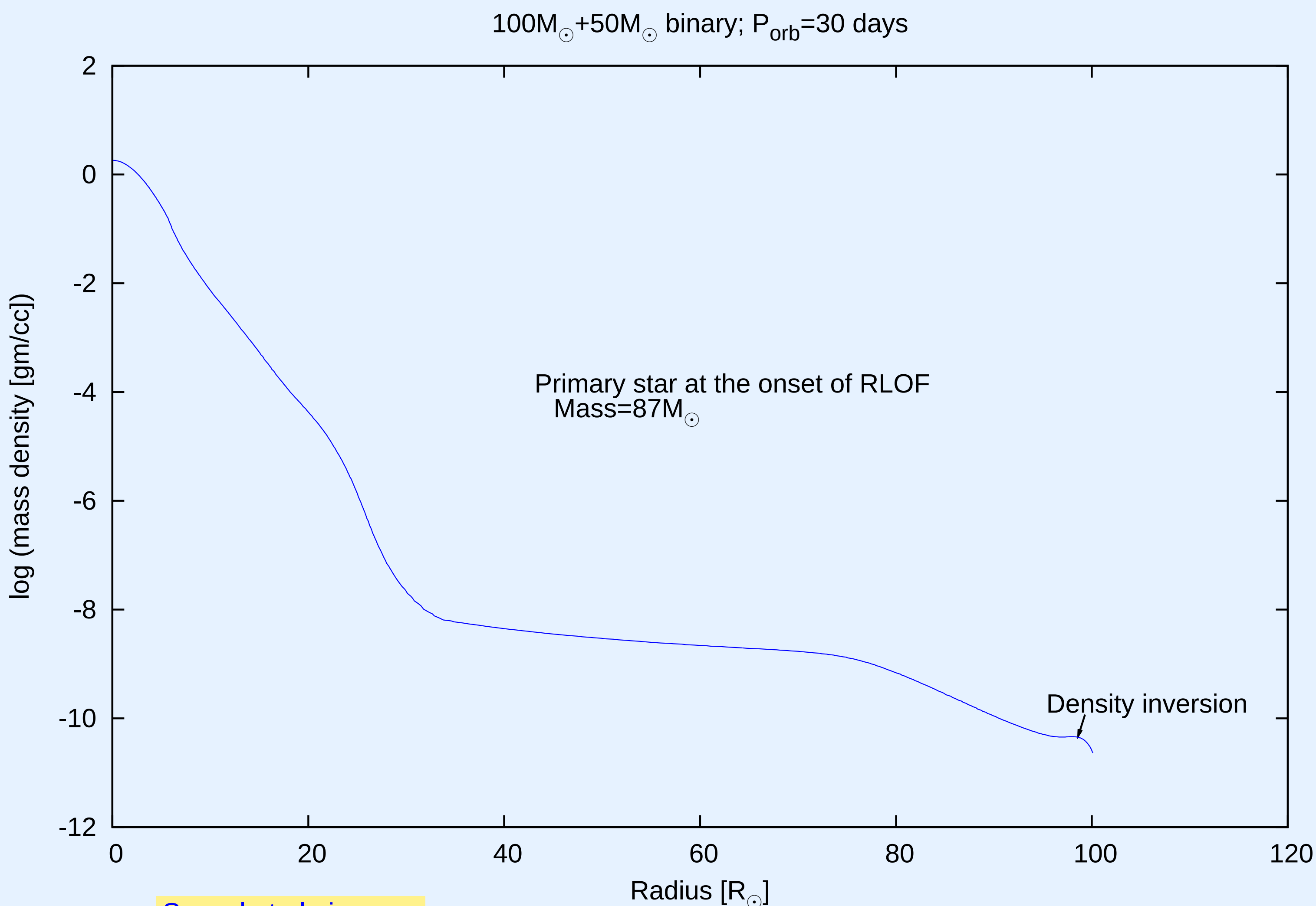
Kozyreva al., in prep.

Summary

- Complex physics at the Ω-limit
- Inflation: ZAMS crowing, S Dor variability?
- Eruptions $\leftarrow \tau_{\rm th}$-evolution
  $\Rightarrow$ erupting LBVs: after core-H, core-He burning
- PISNe in the local universe

VMS binary evolution

Y$_c$=0.8254



Sanyal et al., in prep.

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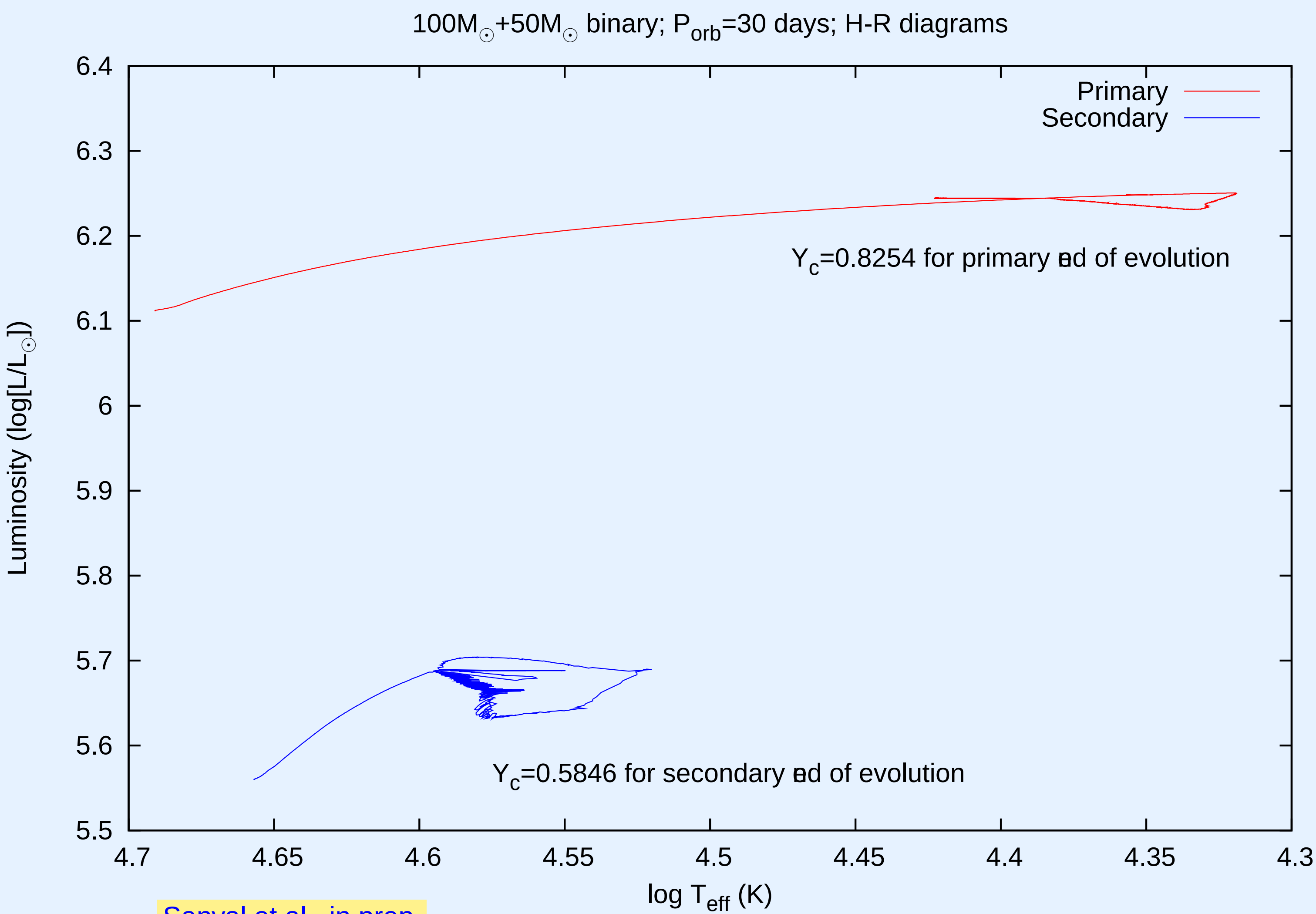

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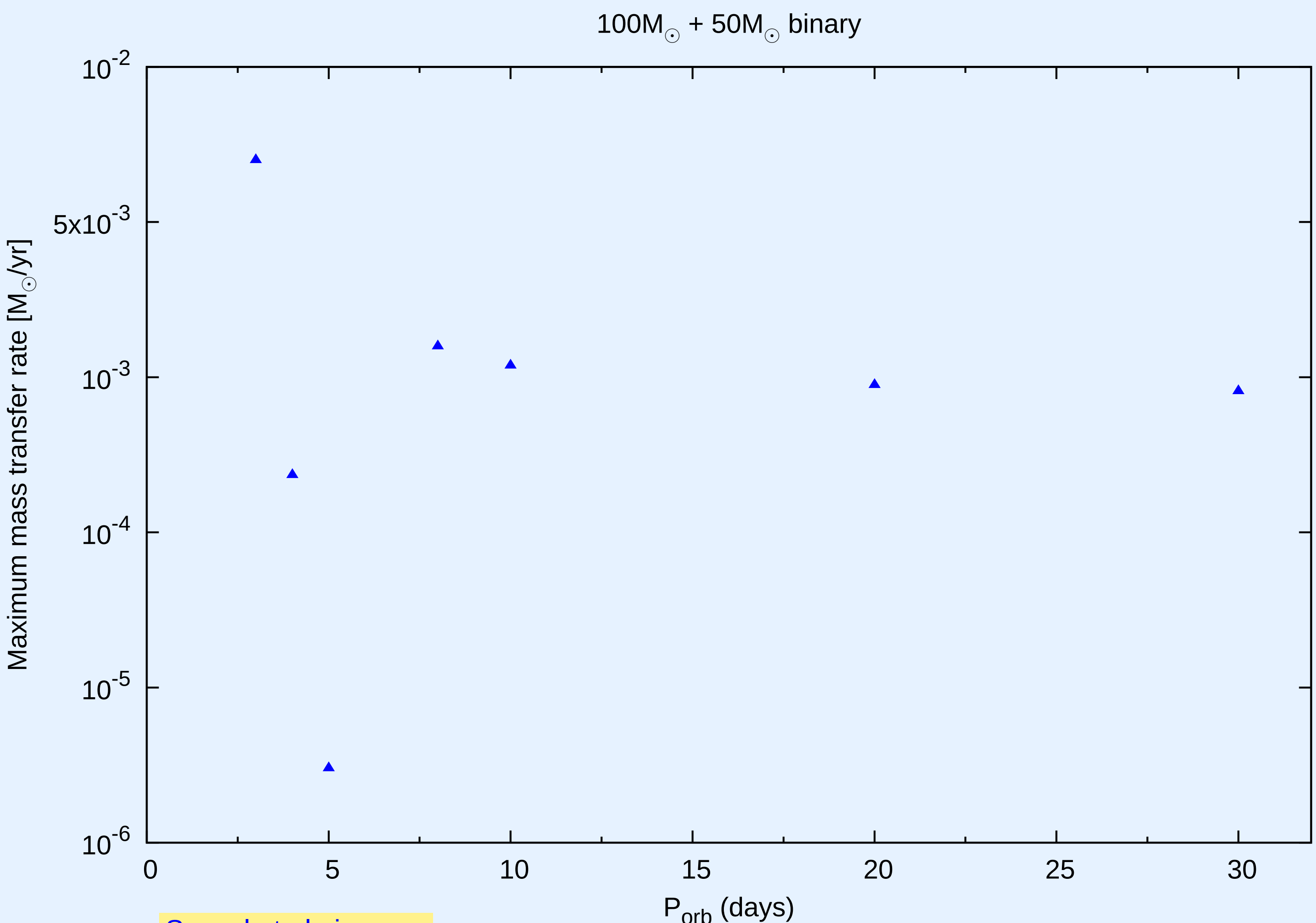

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