Massive Stars as Progenitors of SNe & GRBs

Norbert Langer (Bonn/Utrecht)

universitätbonn

Universiteit Utrecht

with

- Ines Brott (Utrecht)
- Matteo Cantiello (Bonn)
- Selma de Mink (Bonn)
- Karen Friedrich (Bonn)
- Bob van Veelen (Utrecht)
- Rob Izzard (Bonn)
- Colin Norman (Baltimore)
- Alex Heger (Minneapolis)
- Falk Herwig (Victoria)
- Rubina Kotak (Belfast)
- Philipp Podsiadlowski (Oxford)
- Sung-Chul Yoon (Bonn)

Outline

- Supernovae as function of initial mass
- Supernovae as function of metallicity
- Supernovae as function of rotation

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- Supernovae as function of initial mass
- Supernovae as function of metallicity
- Supernovae as function of rotation
- NOT: Supernovae as function of magnetic fields
- NOT: Supernovae from binaries

Supernovae as function of mass

$Z = Z_{\odot}$, no rotation

- e^--capture supernovae
- cc-supernovae: NS
- cc: BH; supernovae?
- NO $e^{\pm}$-supernovae (mass loss)

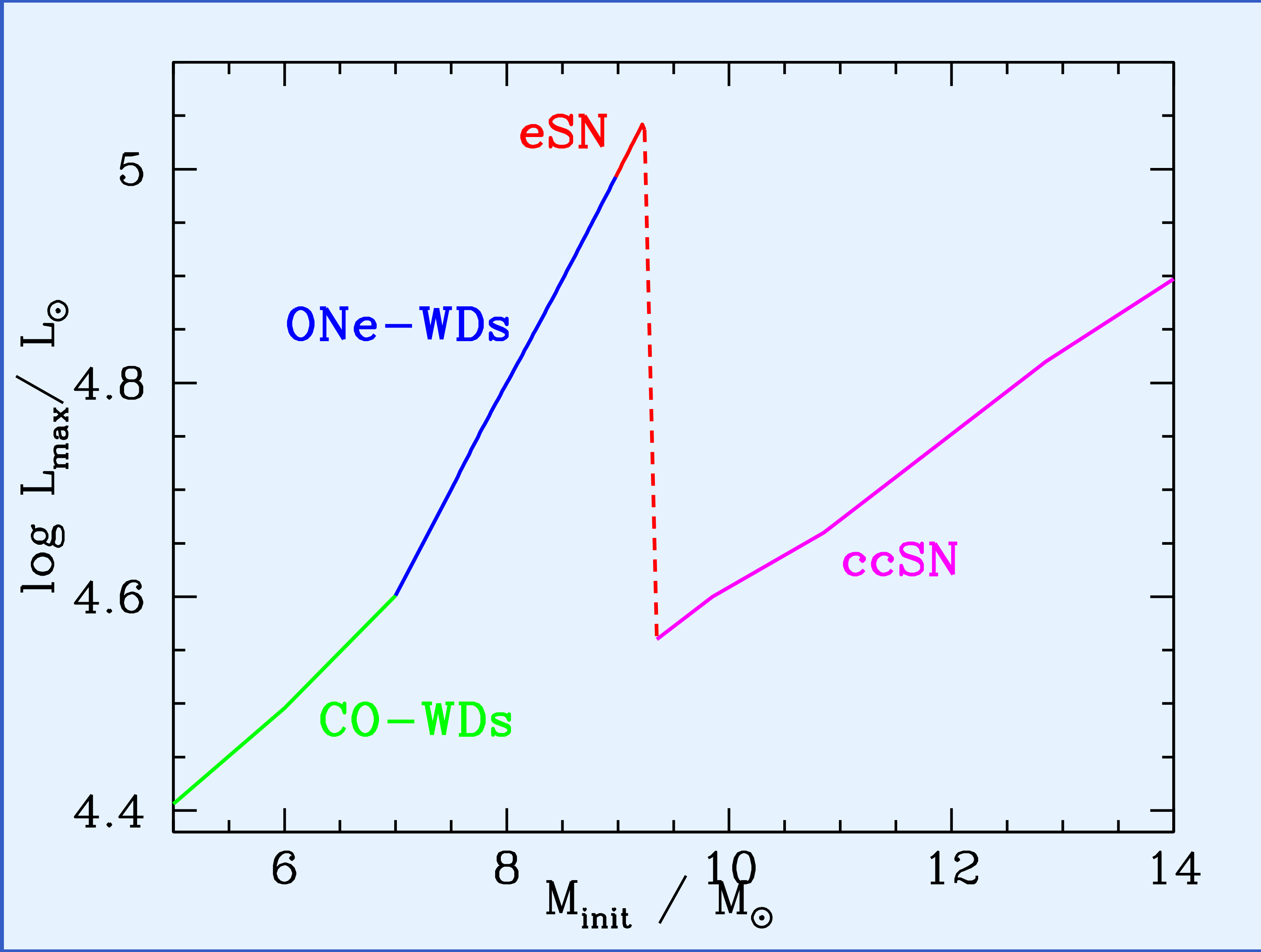
e^--capture supernovae

Nomoto 1984

($Z = Z_\odot$, no rotation)

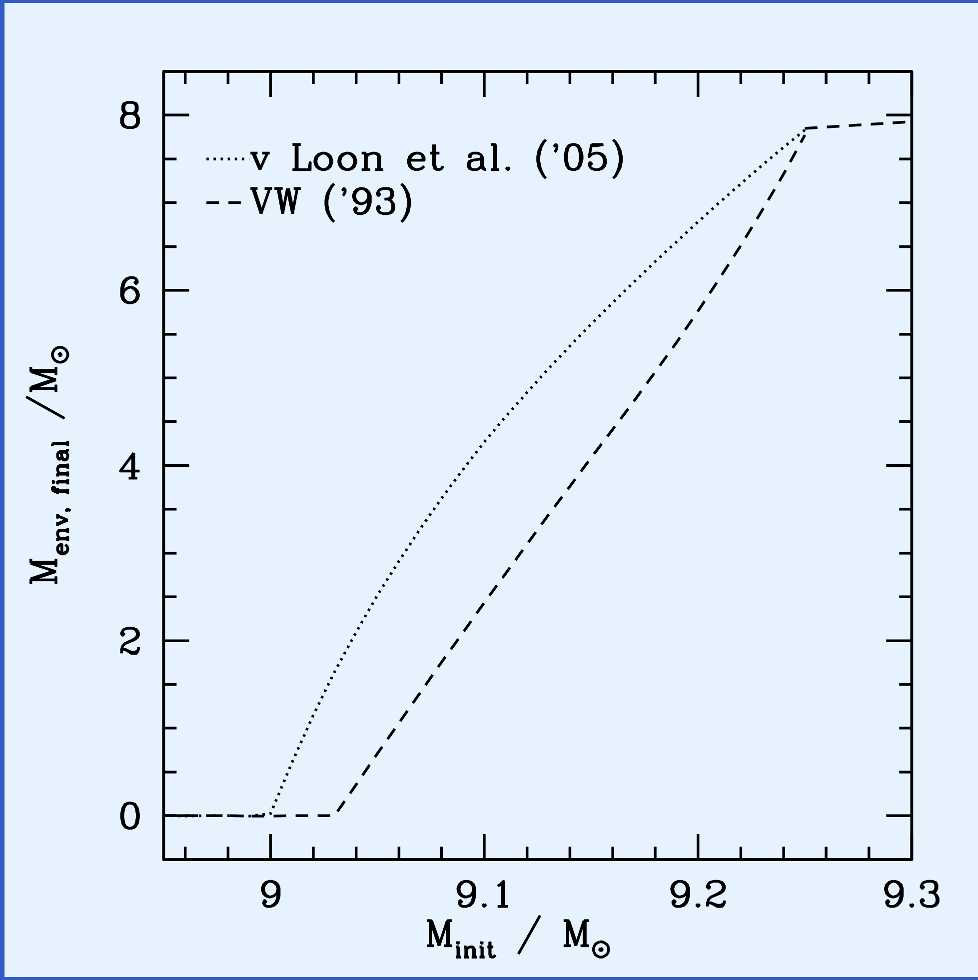
- small mass range (Poelarends)
  much larger in binaries; Podsiadlowski
- low SN energy? low nickel/metals (Janka)
- r-process? (Mathews)
- low kick (Podsiadlowski)
- potentially large range of envelope masses: $0.2 \ldots 8\,\mathrm{M}_\odot$
  $\rightarrow$ slow . . . fast ejecta

Pre-WD, Pre-SN luminosities



Poelarends et al. 2008

Final envelope masses



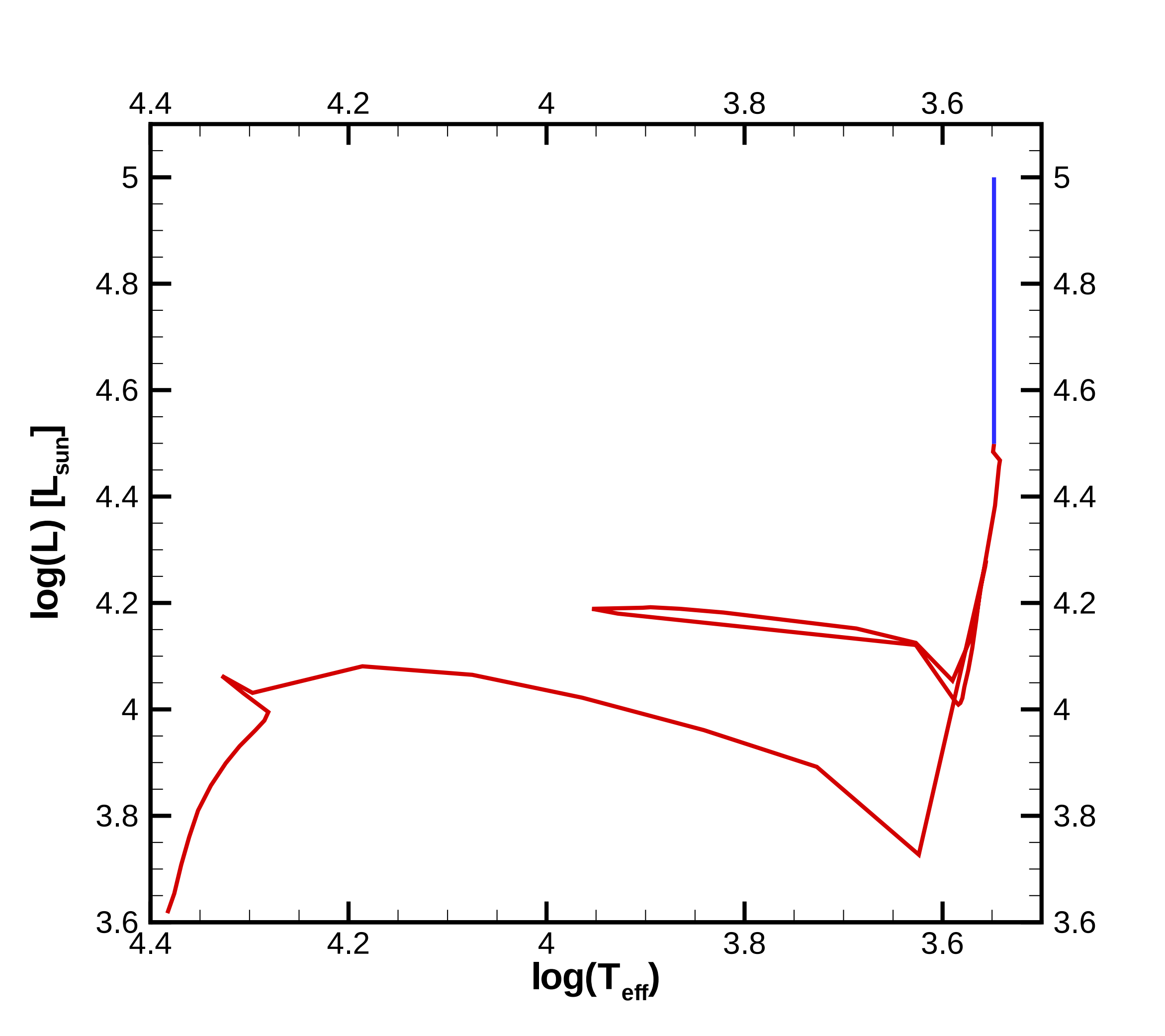
Poelarends et al. 2008

eSN range $Z = Z_\odot$

	$\lambda =$ parameterized			$\lambda = 0$		
	$M_{\rm low}/\,{\rm M}_\odot$	$M_{\rm high}/\,{\rm M}_\odot$	% EC	$M_{\rm low}/\,{\rm M}_\odot$	$M_{\rm high}/\,{\rm M}_\odot$	% EC
Reimers	8.67	9.25	8.4	7.86	9.25	19.7
VW93	9.03	9.25	3.2	8.82	9.25	6.2
van Loon	9.00	9.25	3.6	8.76	9.25	7.1

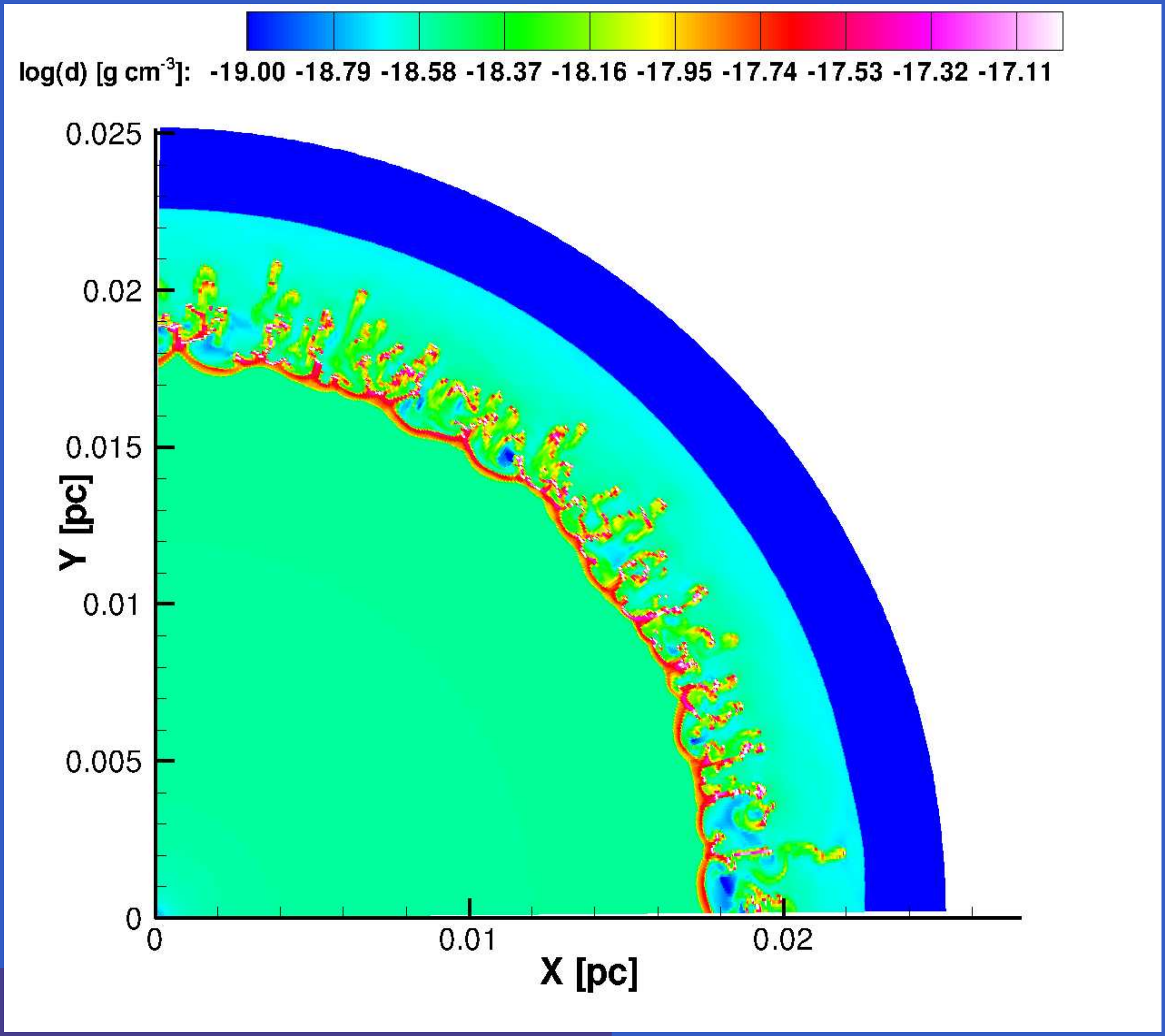
Poelarends et al. 2008

e^--capture supernovae: pre-SN HR-d

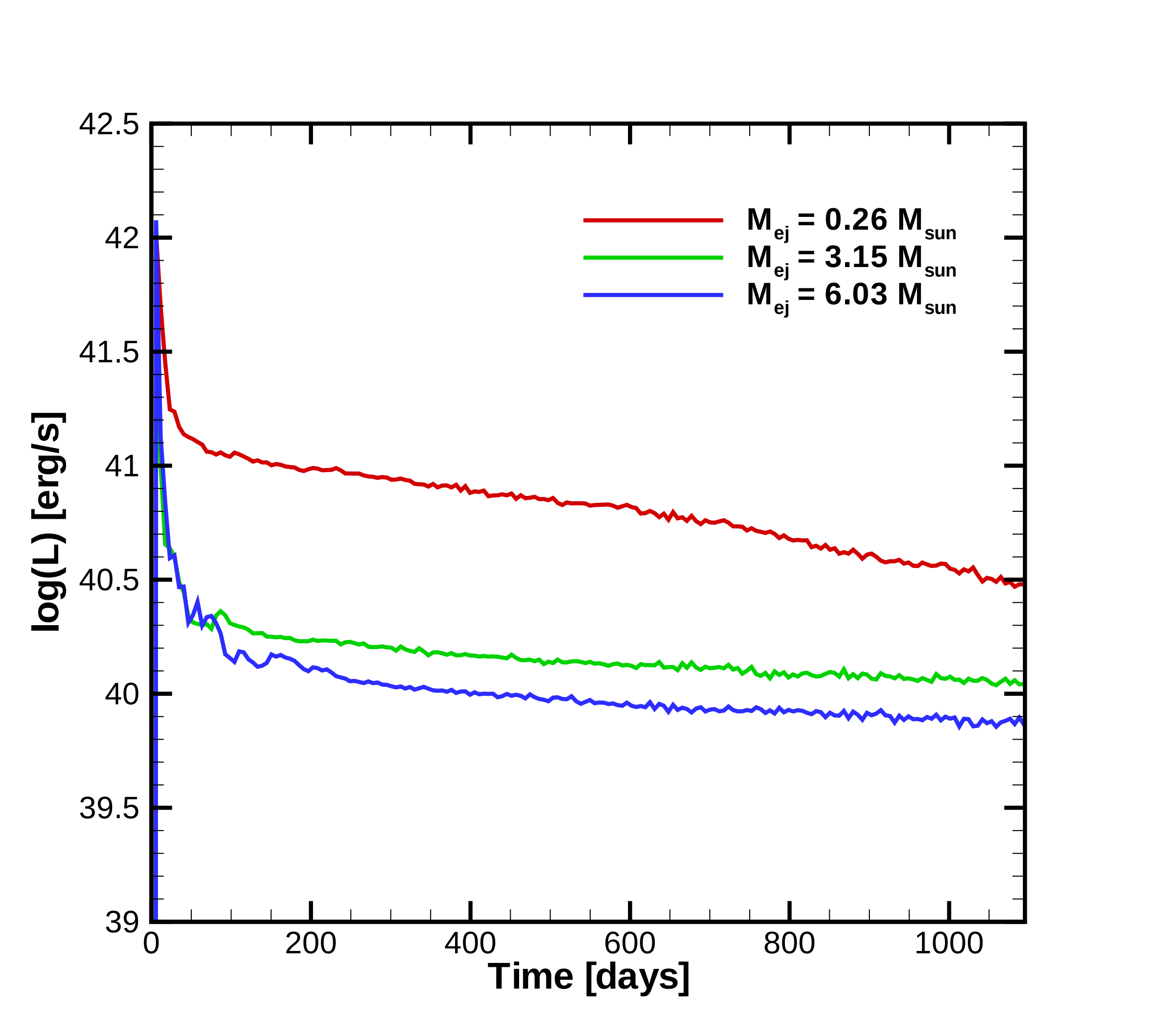


Poelarends et al. 2008

e^--capture supernovae: 2D model

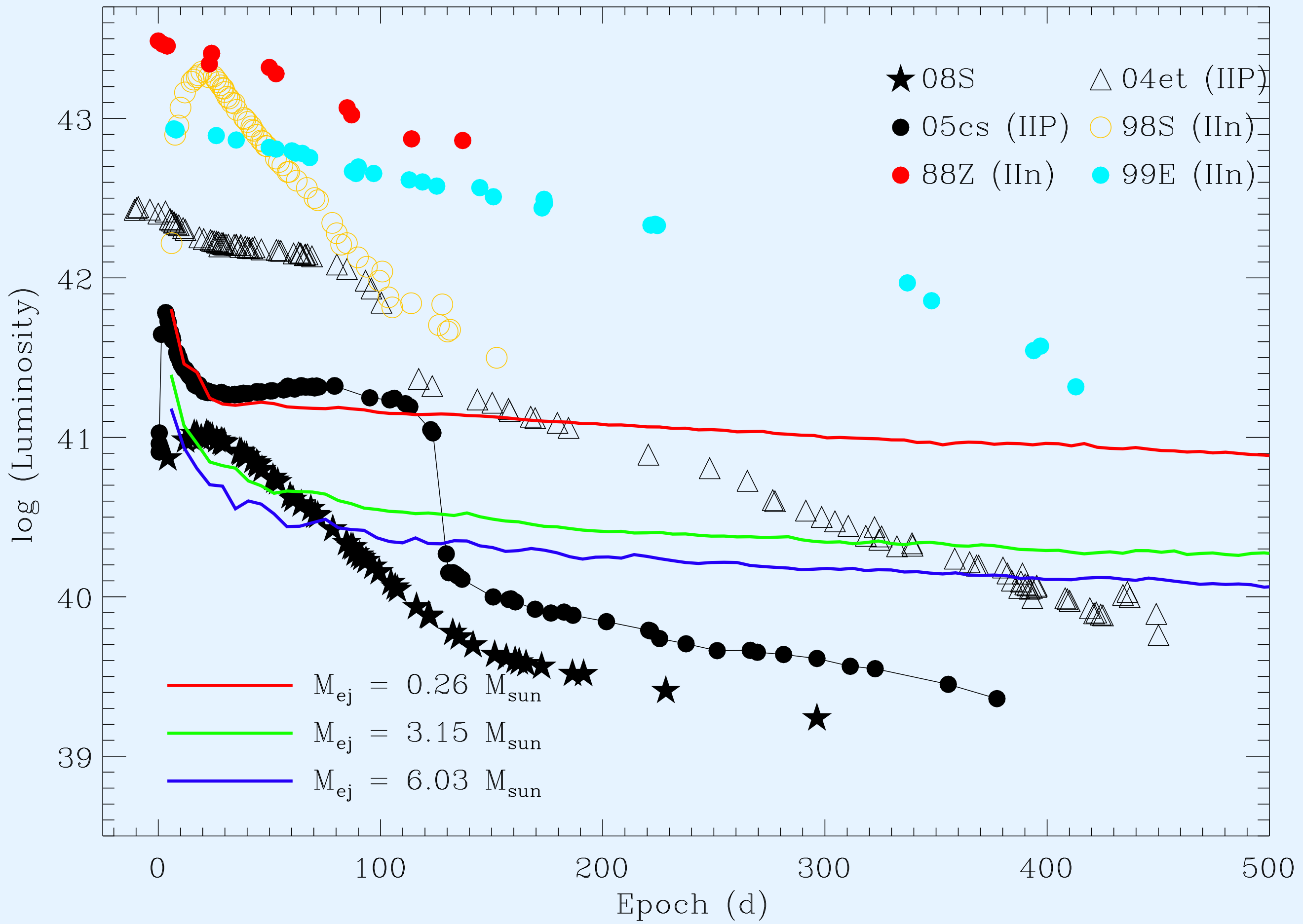


e^--capture supernovae: light curves



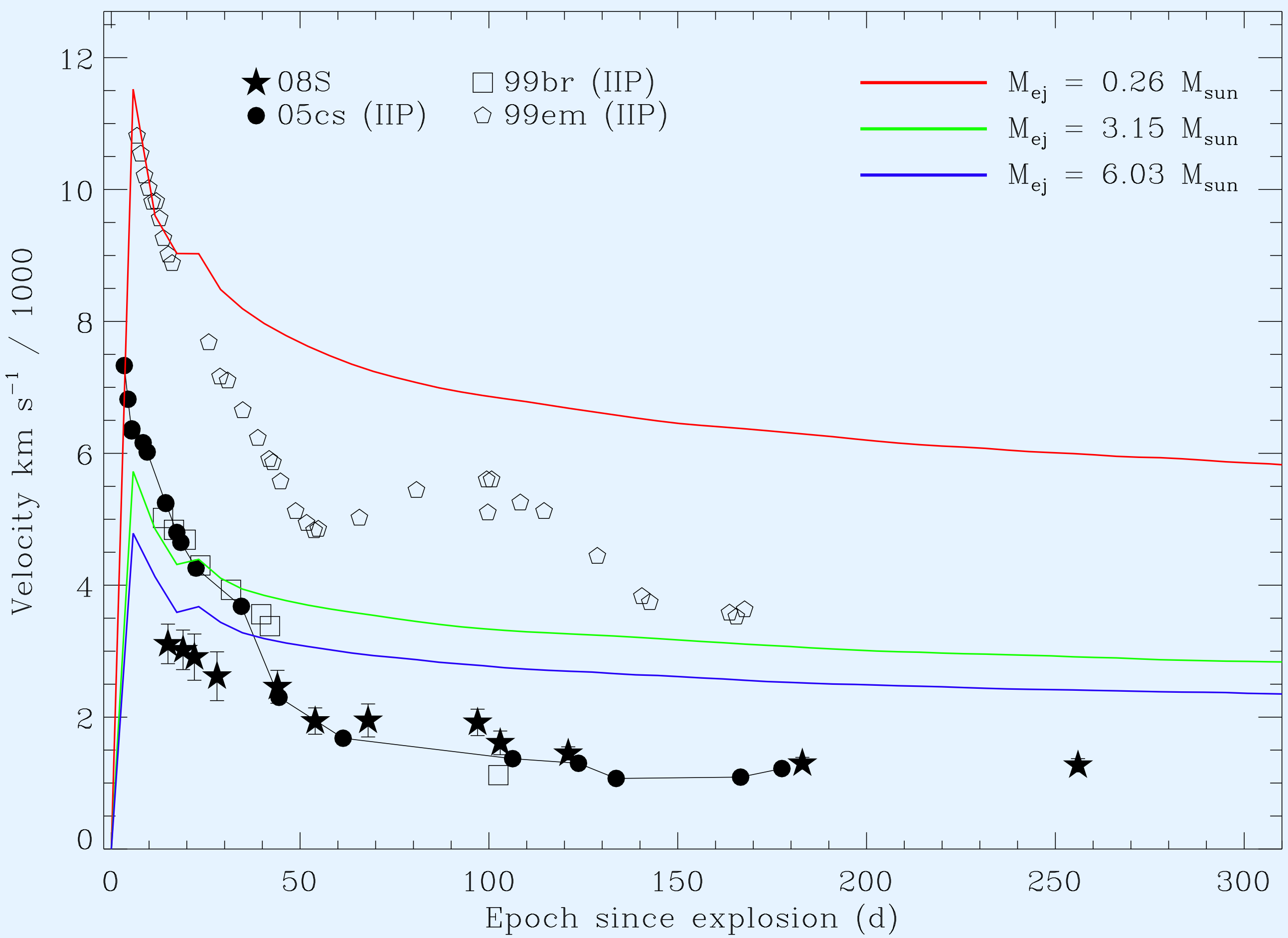
van Veelen et al., in prep.

e⁻-capture supernovae: light curves



van Veelen et al., in prep.

e^{-}-capture supernovae: velocities



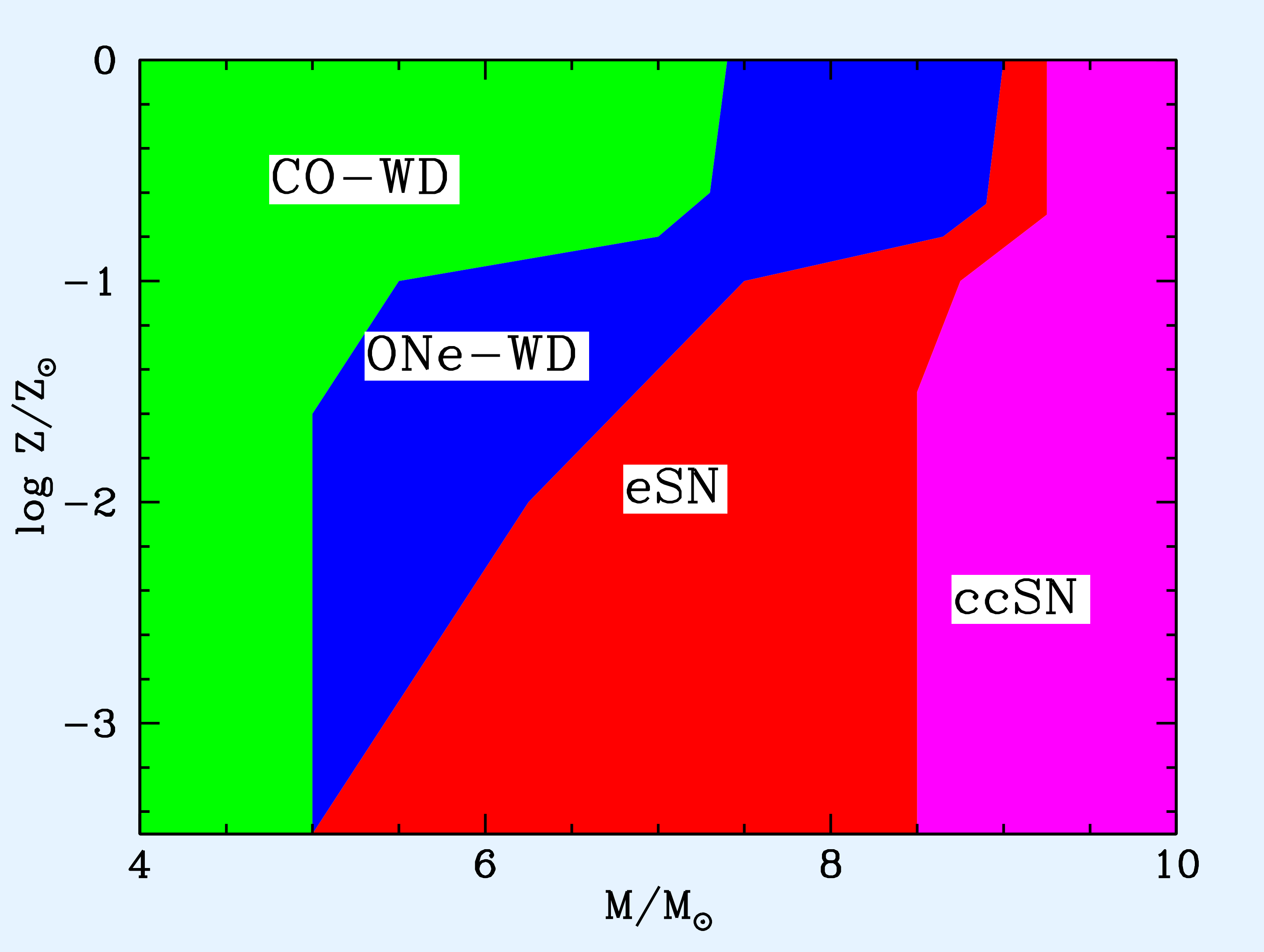
van Veelen et al., in prep.

Supernovae as function of mass

(small Z, no rotation)

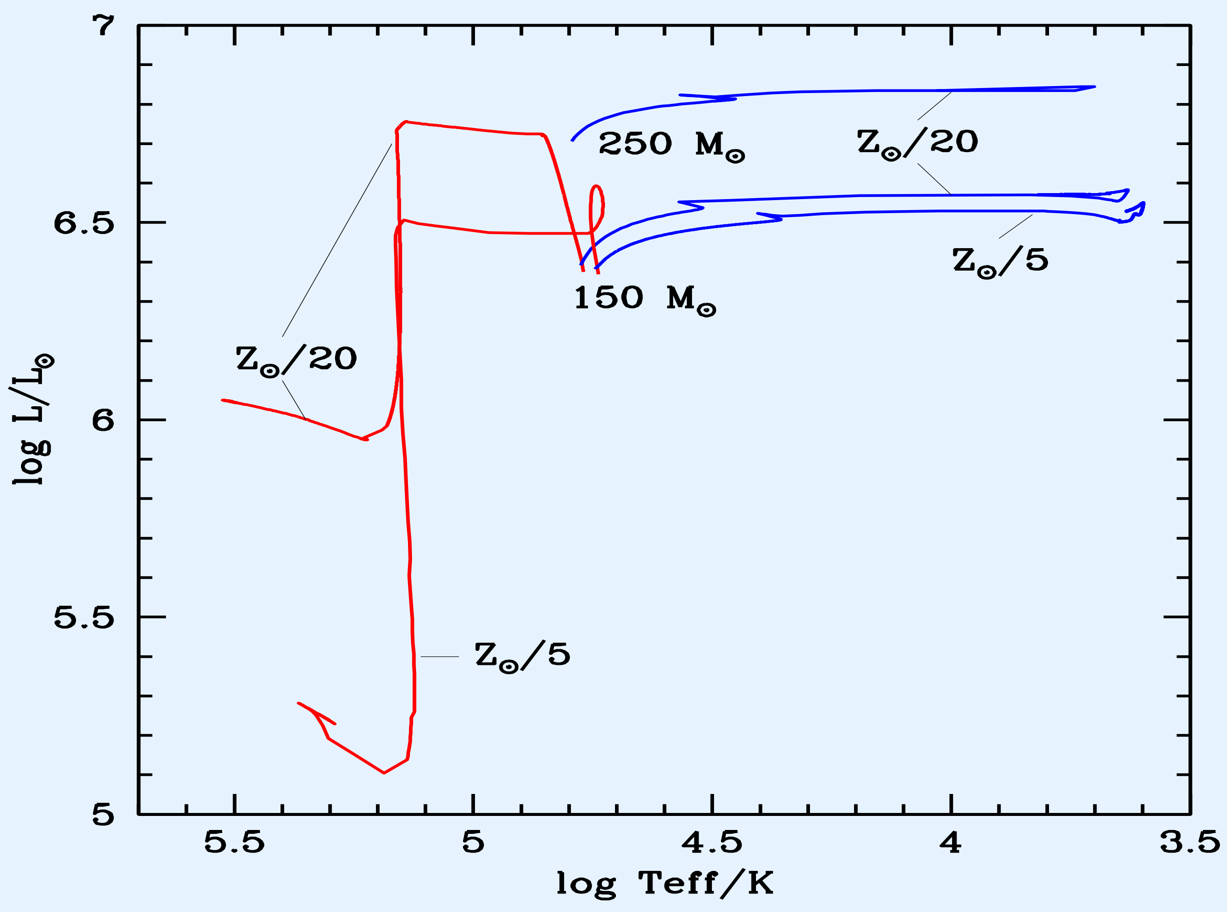
- e$^-$-capture supernovae
- cc-supernovae: fewer SNe Ib/c
- e$^\pm$-supernovae? YES

WD-SN transition regime as $f(Z)$



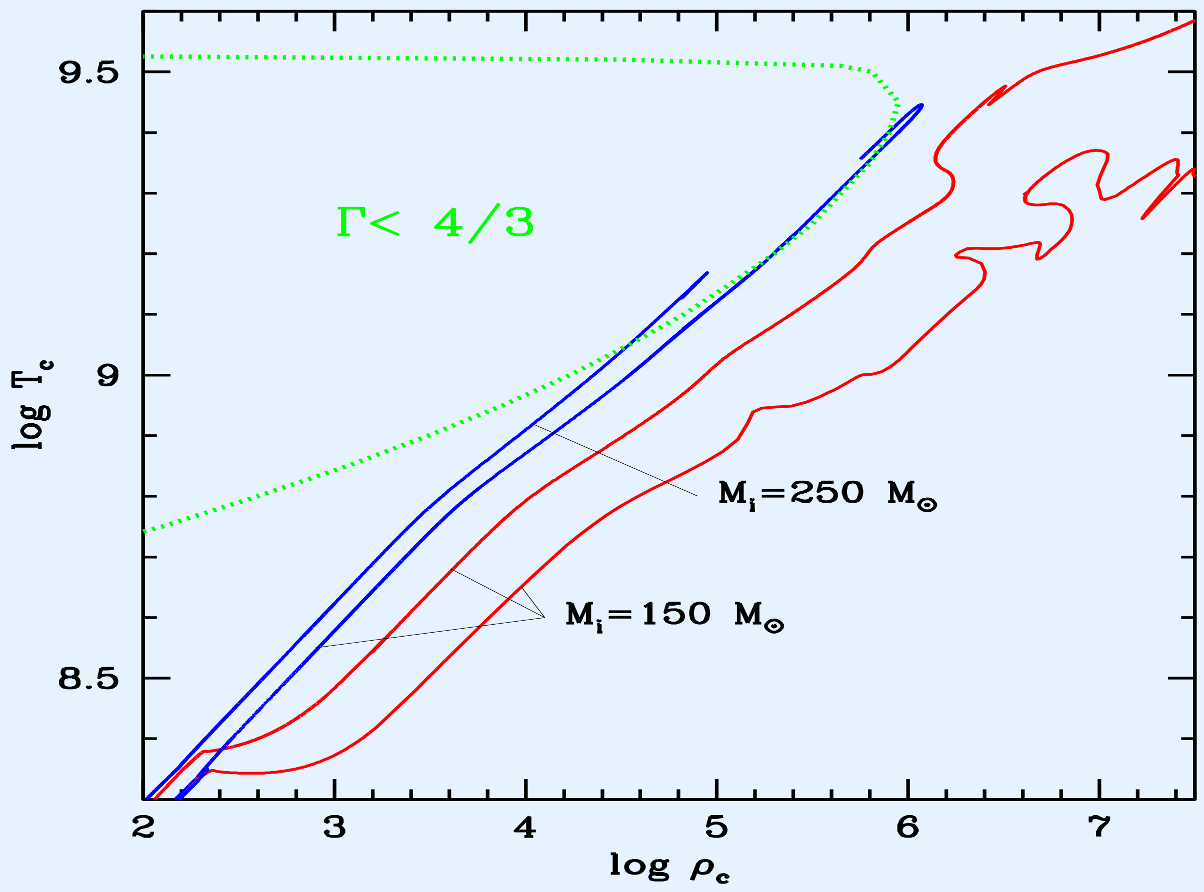
Poelarends 2008

$e^{\pm}$-pair creation



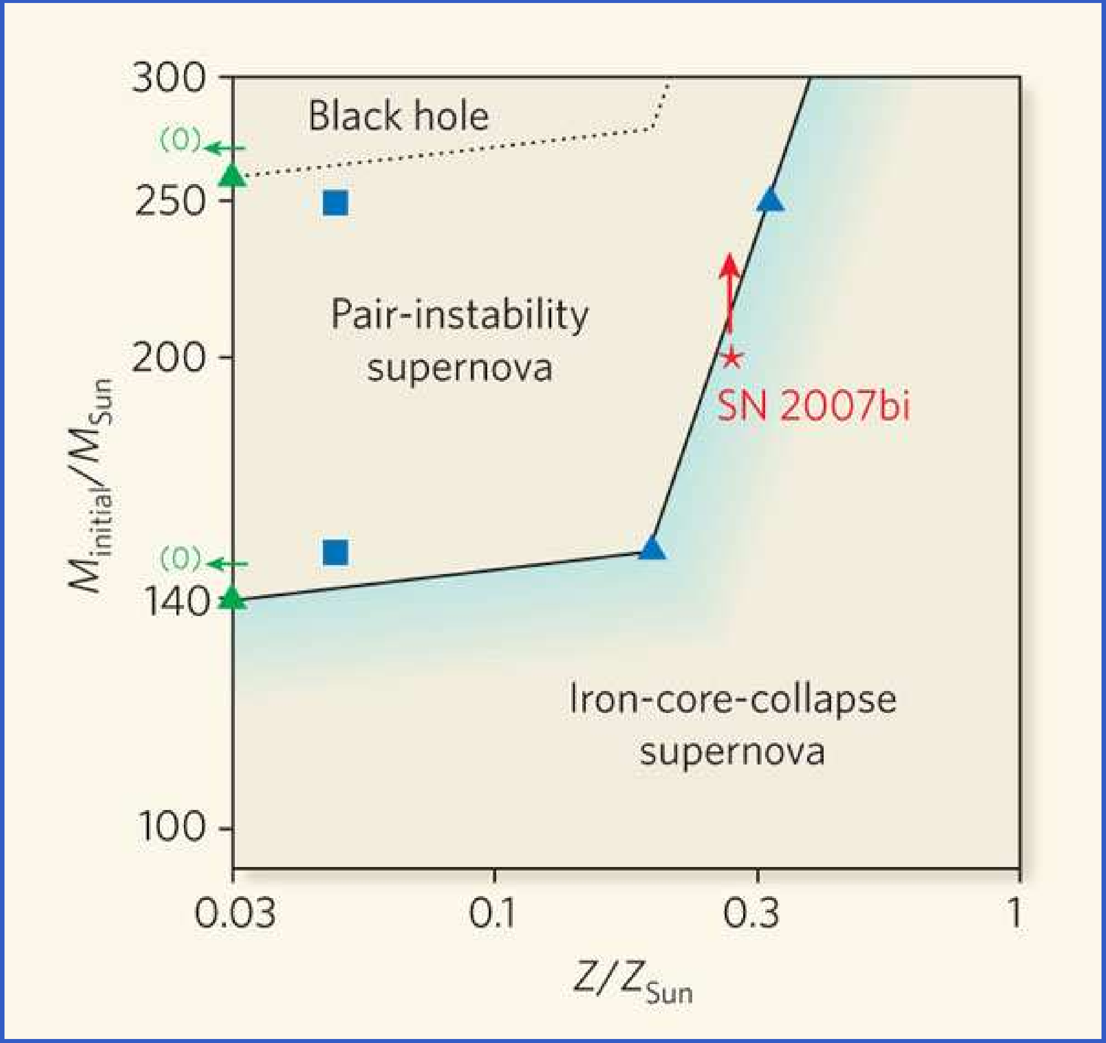
Langer et al. 2007

$T_c - \rho_c$-plane



Langer et al. 2007

$M - Z$-plane



Langer 2009

PCSN ejecta

	$O[M_\odot]$	$Ne[M_\odot]$	$Mg[M_\odot]$	$Si[M_\odot]$	$S[M_\odot]$	$Ar[M_\odot]$	$^{56}Ni[M_\odot]$
SN2007bi	$\sim 10^*$	4	$\sim 0.1^*$	22	10	1.3	$\sim 5^*$
100 $M_\odot$ He	44	4.1	4.4	23	10	1.5	5.8

- observations: Gal-Yam et al. 2009
- model (Z=0): Heger & Woosley 2002

Local $e^{\pm}$-SN rate

best mass loss rate (Vink & de Koter):
PCSNe from $Z < Z_\odot/3$

$$\longrightarrow \frac{\#SNe(Z{<}Z_\odot/3)}{\#SNe} \simeq \frac{1}{10}$$ (Langer & Norman 2006)

also: $\frac{\#stars{>}150\,\mathrm{M}_\odot}{\#stars10...150\,\mathrm{M}_\odot} \simeq \frac{1}{100}$??

$\Rightarrow$ 1 PCSN / 1000 SNe

Supernovae as function of rotation

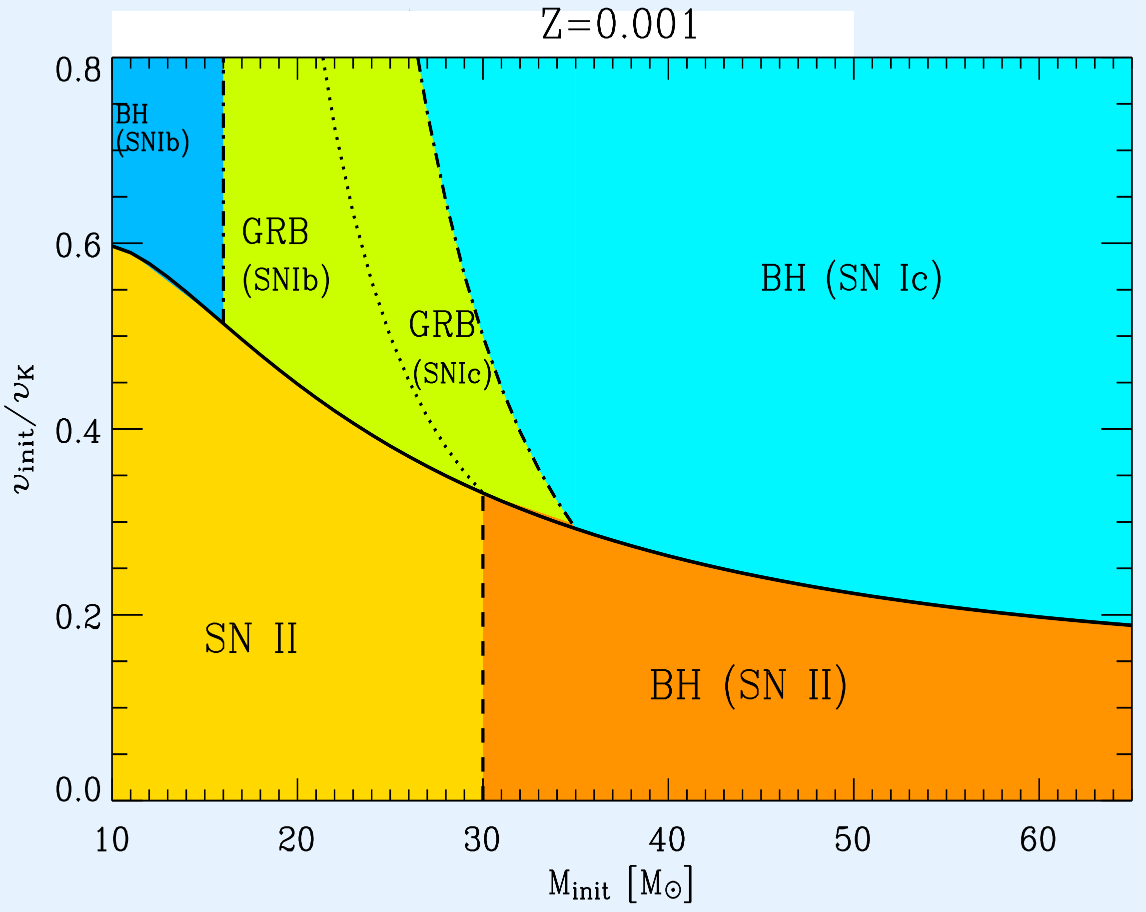
favoured at small Z: weaker winds

- chemically homogeneous evolution (Yoon)
  long GRBs

favoured in binaries:

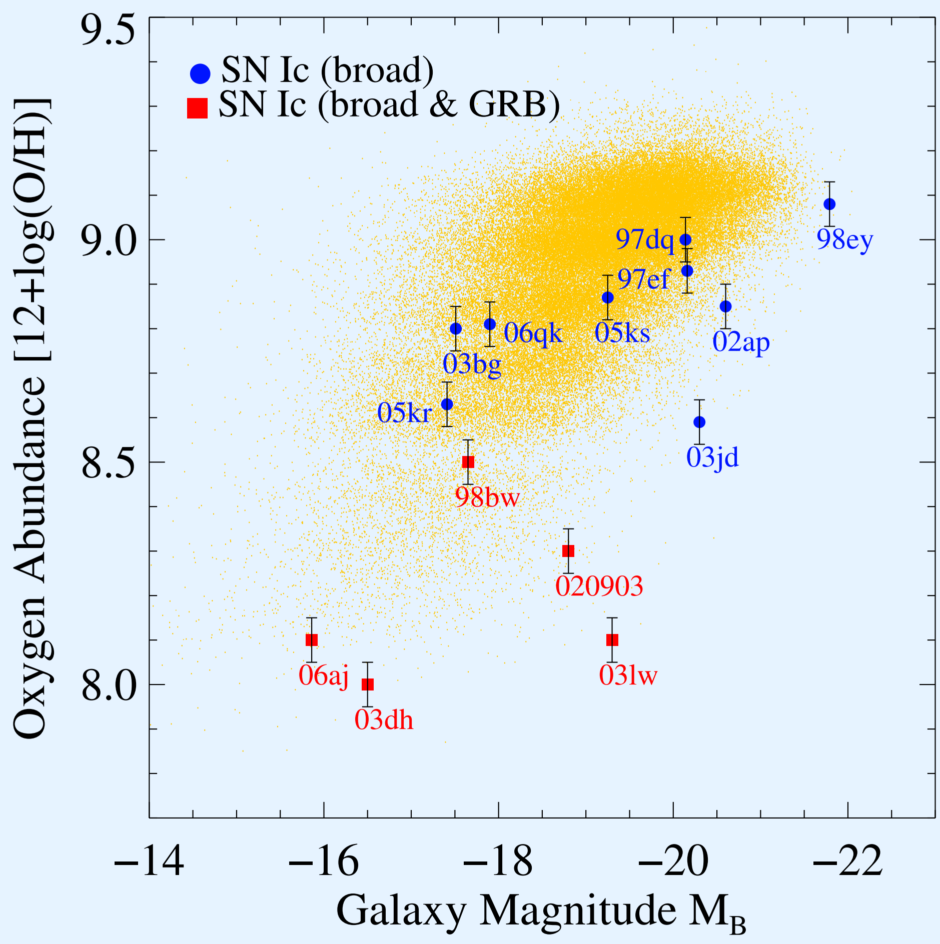
- Cantiello et al. 2007:
  mass transfer $\rightarrow$ spin-up $\rightarrow$ hom.
  evolution
- de Mink et al. (in prep.):
  fastest rotators: all in binaries?

GRB progenitors



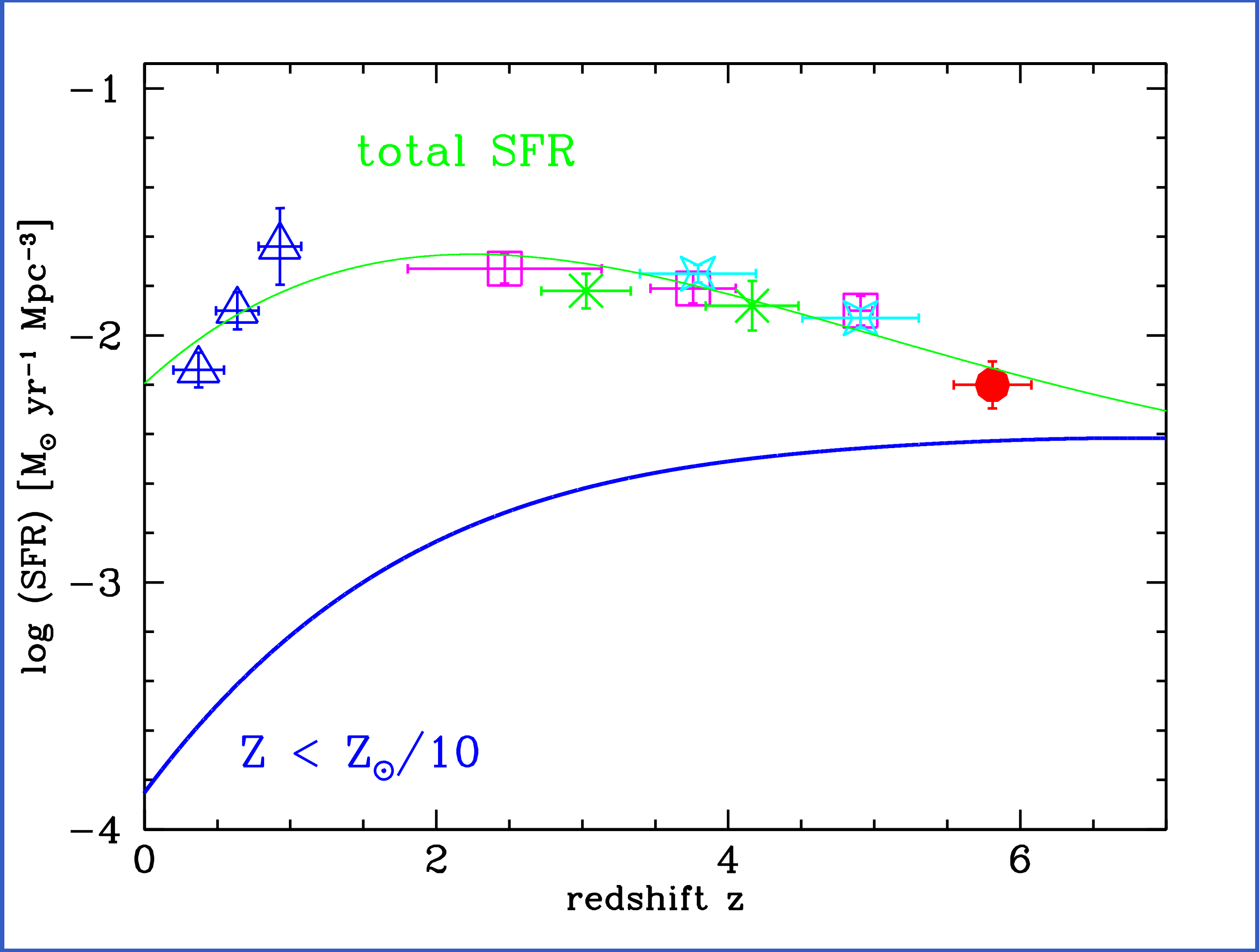
Yoon et al. 2006

GRB metallicity bias!



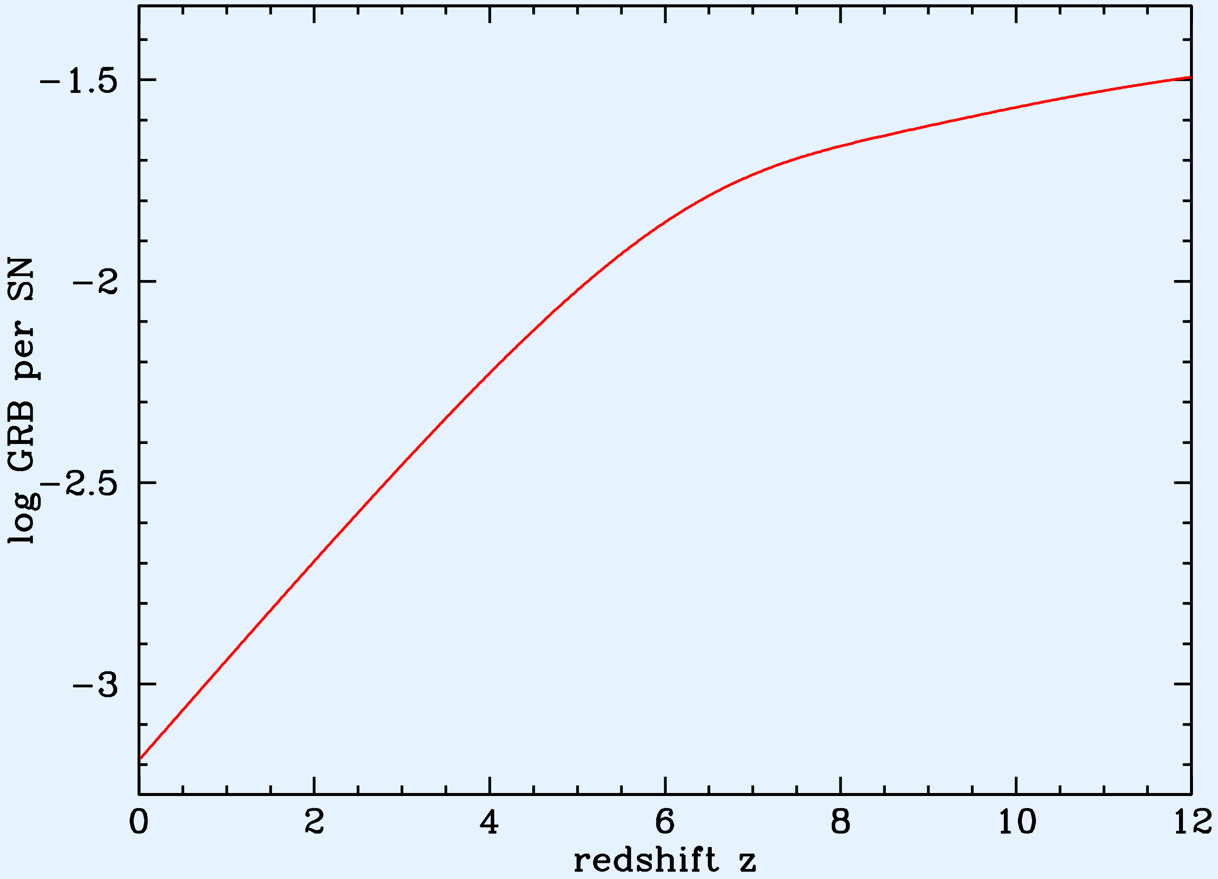
Modjaz et al. 2007

Metallicity bias



Langer & Norman 2006

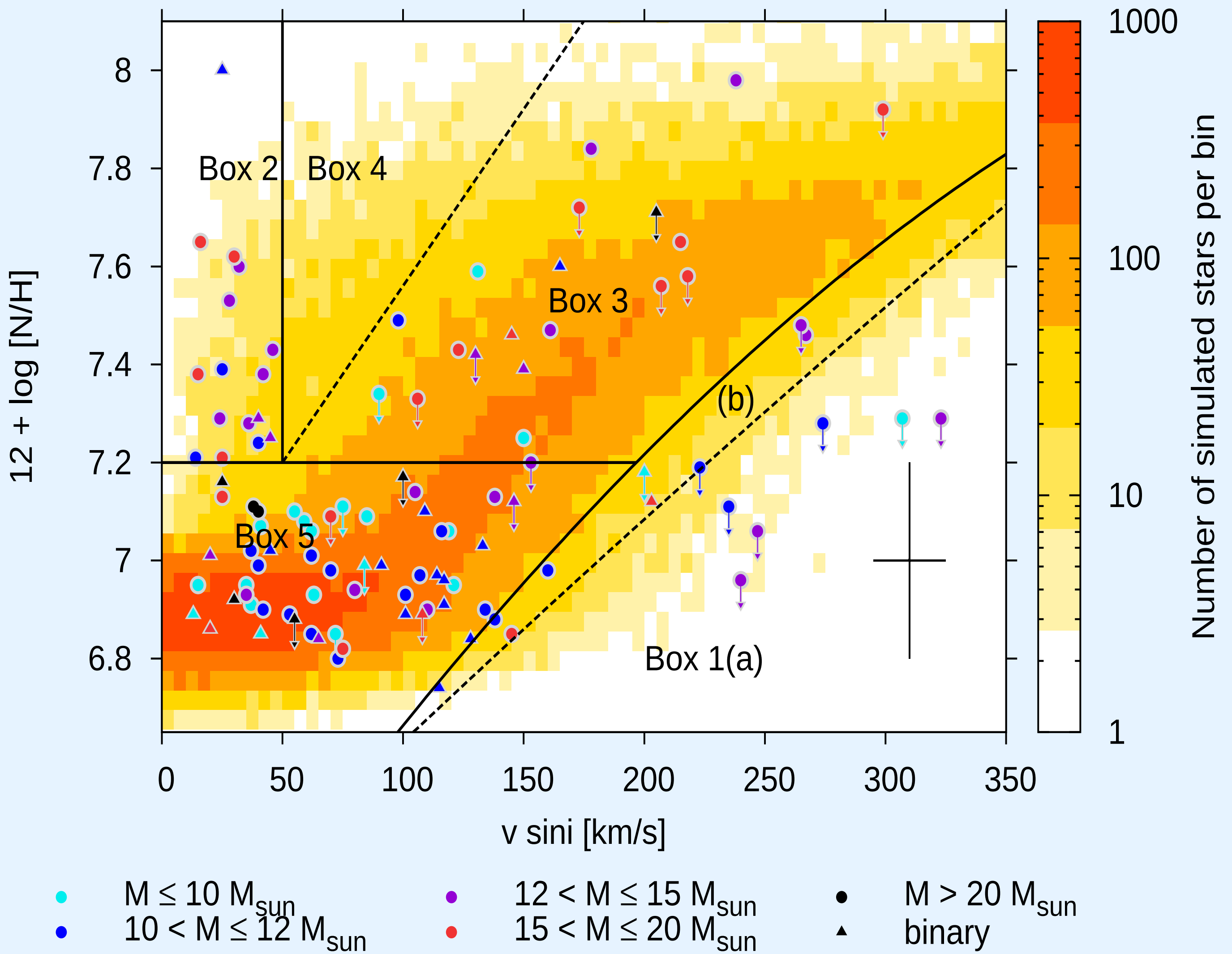
GRB/SN ratio as f(z)



Yoon et al. 2006

VLT-FLAMES Survey of Massive Stars

PI: Smartt



Brott et al., in prep.

Conclusions

- e^{-}-capture supernovae
  local, $Z_\odot$; more at low Z;
  r-process? (Wanajo+, He-shell?)

- e$^{\pm}$-supernovae
  predicted, observed (SN2007bi)
  low Z, but local (SMC)
  huge yields...!

- rotation effects: strongest at low Z
  lGRBs

- strong metallicity trends!