Progenitors of long gamma-ray bursts

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with thanks to:

- Rob Detmers (Utrecht)
- Alexander Heger (Los Alamos)
- Allard-Jan van Marle (Utrecht)
- Colin Norman (Baltimore)
- Jelena Petrovic (Nijmegen)
- Philipp Podsiadlowski (Oxford)
- Sung-Chul Yoon (Amsterdam)

Bottom line

long GRBs have a low-metallicity bias

- $\longrightarrow$ progenitors have lost their innocence (unlike for SNe Ia)
  we need to understand them to exploit GRBs for cosmology etc.
- the stronger the bias, the less are binaries in the picture
- strog bias $\longrightarrow$ progenitors not observed
- finally: a single star model might work

Collapsars

- massive core $\Rightarrow$ black hole
- rapid rotation $\Rightarrow$ centrifugal barrier
- compact size $\Rightarrow \frac{R_*}{c} \simeq \tau_{engine}$

Woosley 1993, ApJ, 405, 273

WR stars have strong mass loss $\rightarrow$ spin-down!

Langer 1998, A&A, 329, 551

therefore needed:

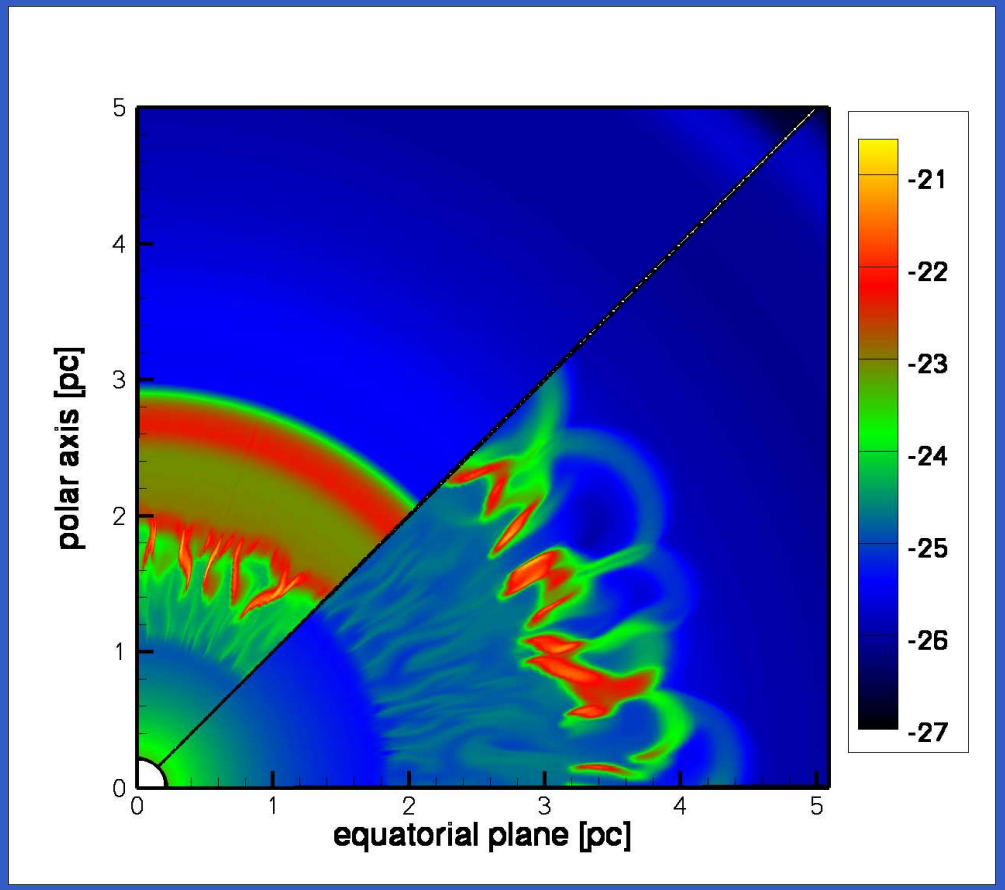
- small WR life time, or
- late spin-up, or
- small metallicity

WR bubbles ...

... in nature:

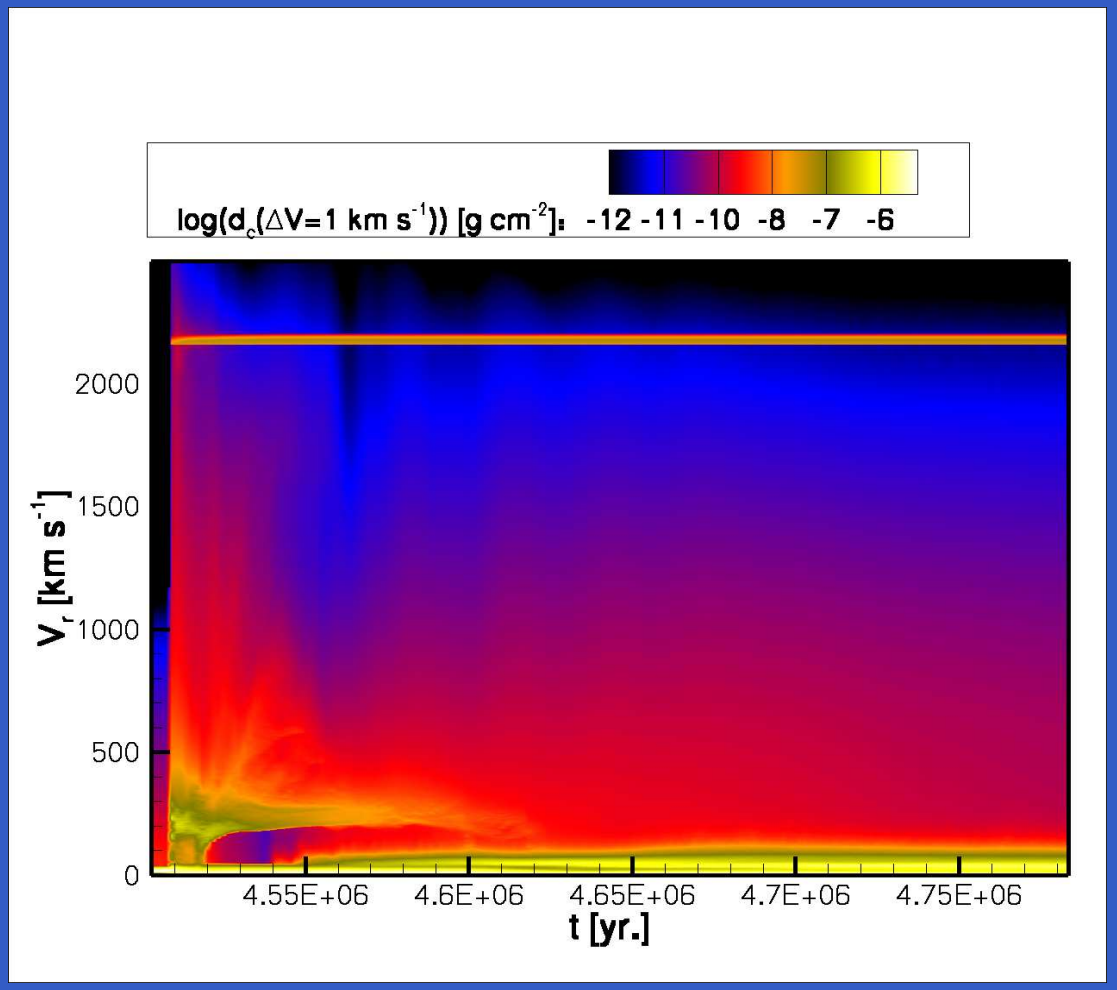
WR bubbles ...

... on the computer:



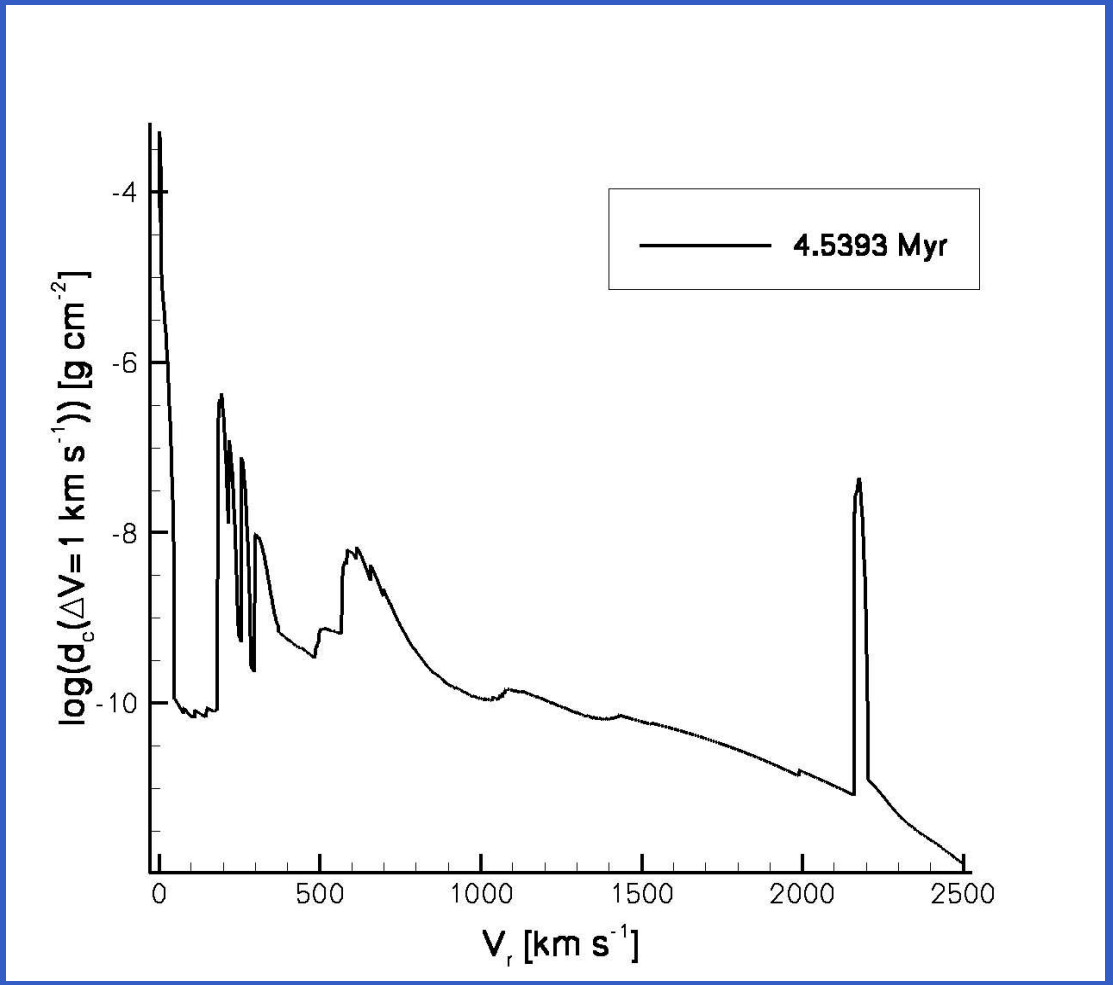
van Marle, Langer, Garcia-Segura 2005, A&A 444, 837

Column density: angle average



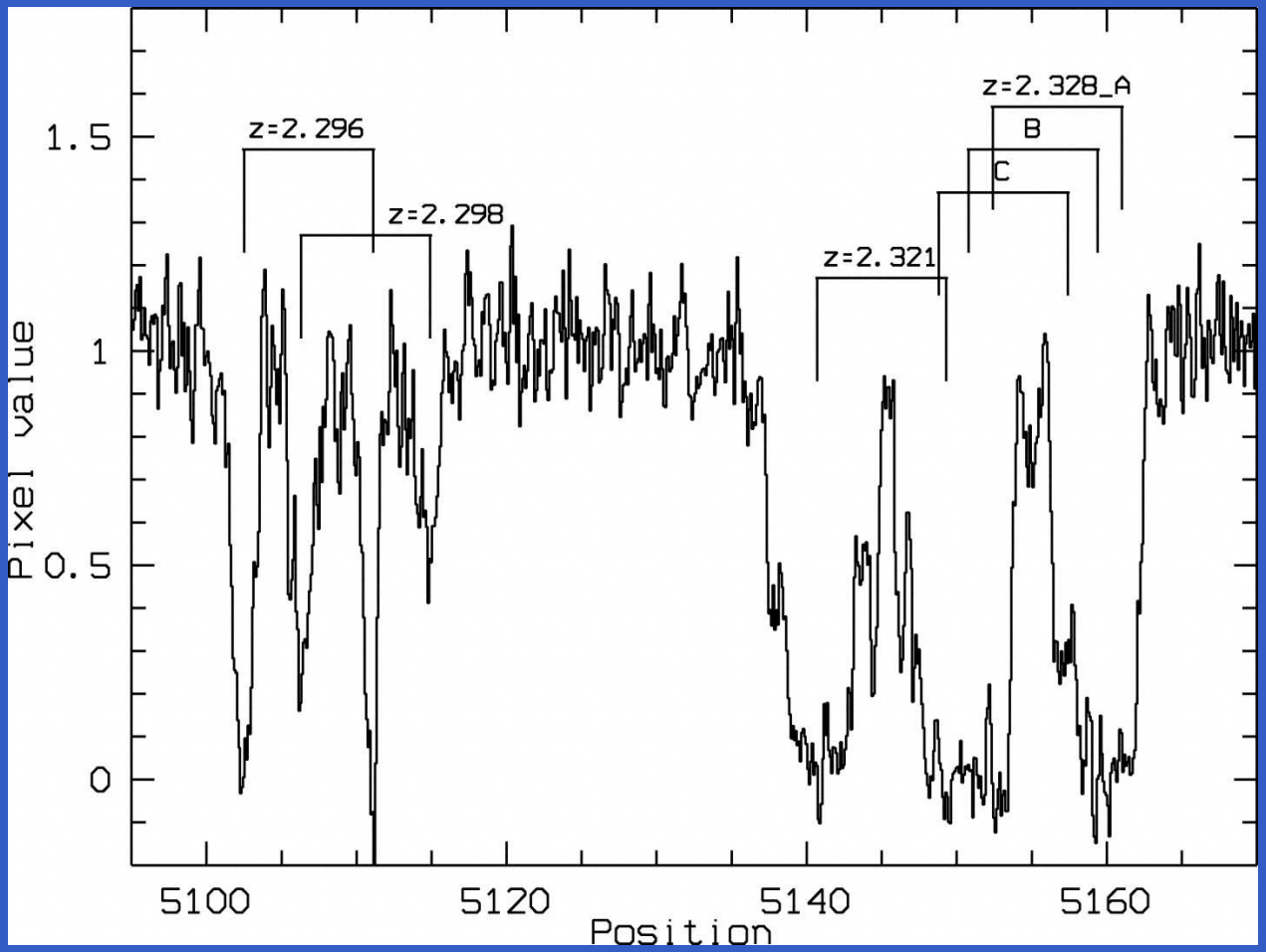
van Marle et al. 2005

Column density: single beam



van Marle et al. 2005

GRB021004 afterglow spectrum



Fiore et al. 2005, ApJ, 624, 853

also: Starling et al. 2005, MN, 360, 305

GRB021004: absorbing components

TABLE 5

GRB 021004 Logarithmic Ion Column Densities

System	Velocity Shift (km s^{-1})	Si IV (cm^{-2})	C IV (cm^{-2})	C II (cm^{-2})	C II* (cm^{-2})	Al II (cm^{-2})	Fe II (cm^{-2})	Mg II (cm^{-2})
2.328 A	0	15.30 ± 0.56	>15.2	13.40 ± 0.45	13.90 ± 0.58	13.55 ± 0.35[a]	13.34 ± 0.15	13.82 ± 0.24
2.328 B	−139	14.27 ± 0.16	>14.4	<13.2	<13.2	12.23 ± 0.35	12.53 ± 0.24	12.93 ± 0.60
2.328 C	−224	13.24 ± 0.17	14.40 ± 0.11	<13.2	<13.2	<12.0	<12.3	<12.8
2.321	−632	14.11 ± 0.08	15.04 ± 0.05	<13.2	<13.2	<12.0	<12.3	<12.8
2.298	−2729	13.43 ± 0.33	14.16 ± 0.20	14.28 ± 0.20[b]	<13.2	<12.0	12.68 ± 0.20	13.22 ± 0.10
2.296	−2913	13.79 ± 0.16	14.72 ± 0.25	13.43 ± 0.40	[b]	<12.0	<12.3	12.68 ± 0.21

Note.—Errors, upper and lower limits are 90% confidence intervals.

[a] For system $z = 2.328$ A we also measured a column density of Al III of 13.66 ± 0.30.

[b] The $z = 2.296$ C II* line is completely blended with the $z = 2.298$ C II line.

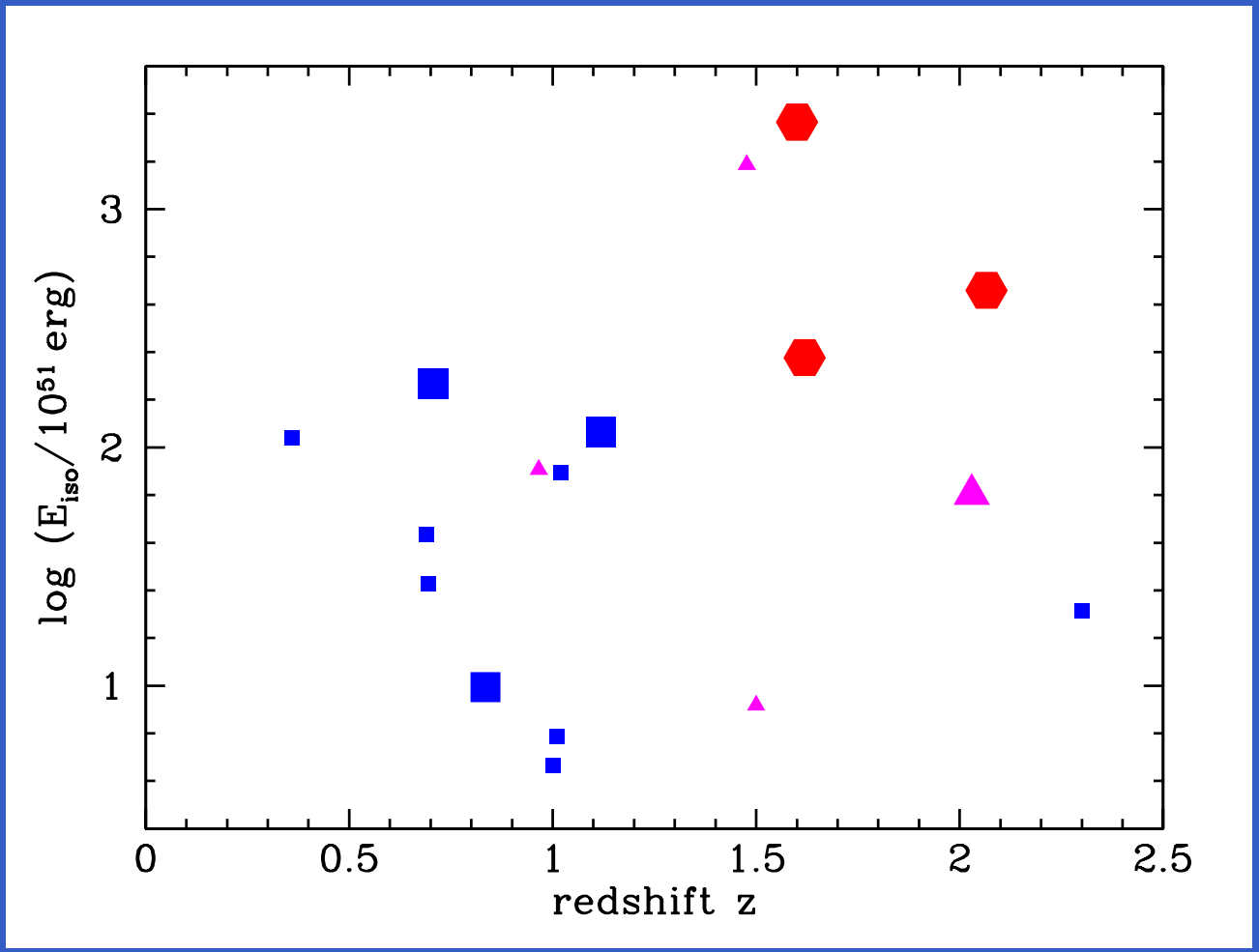
Fiore et al. 2005, ApJ, 624, 853

GRB021004 circumstellar medium

- independent proof of WR nature
- GRB021004: WR lifetime $< 50\,000$ yr !
- method applicable to stars, SNe, GRBs

GRB CSM density slope

van Marle, Langer, Achterberg & Garcia-Segura, in prep.



WR models at low metallicity

Need of magnetic core-envelope coulping

Spruit 2002, A&A 381, 923

- obtain low NS spins Heger et al. 2005, ApJ, 626, 350
- obtain low WD spins Suijs et al. 2006, in prep.
- low GRB/hypernova rate van Putten 2004, ApJ, 611, 81

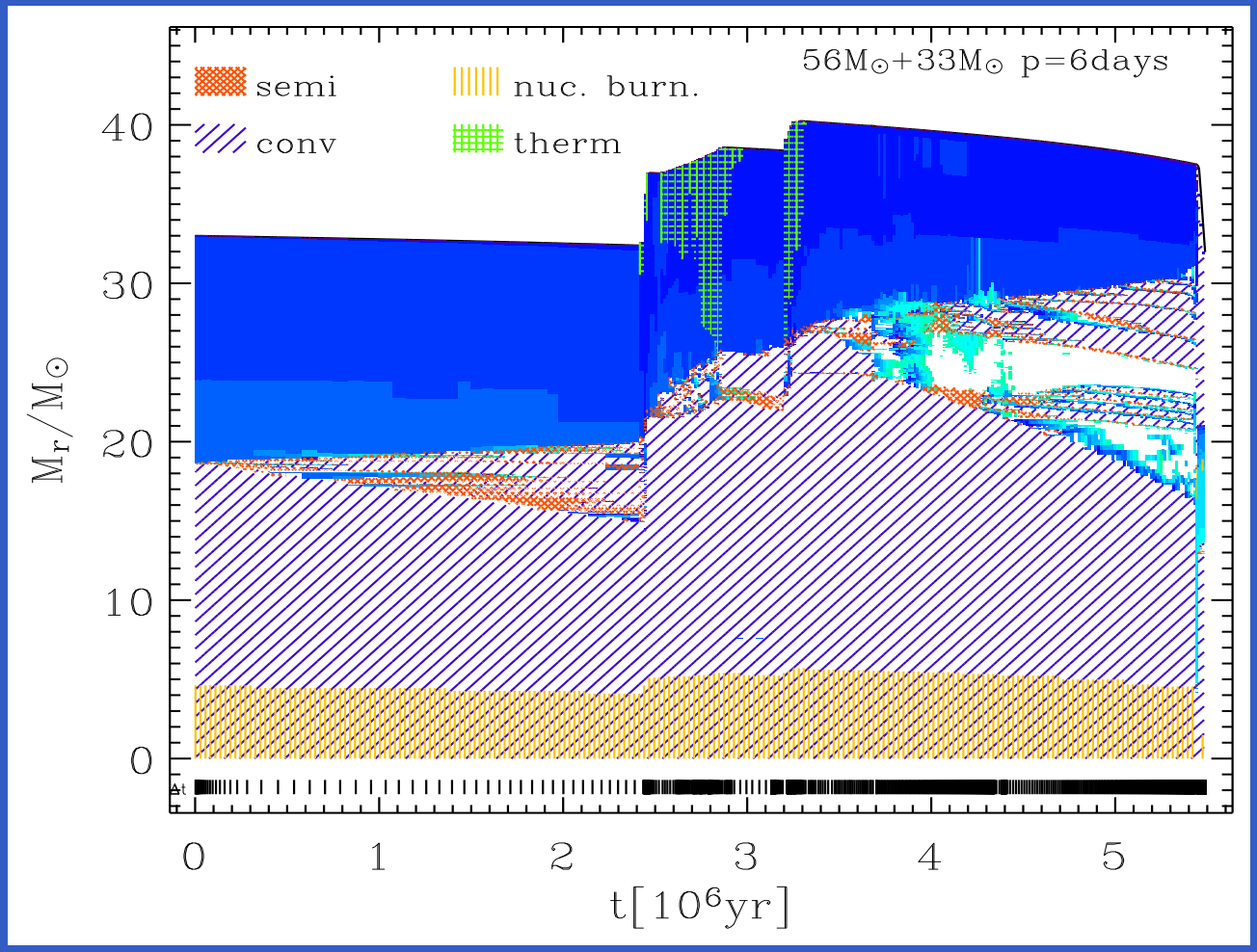
Hirschi et al. 2005, A&A, 443, 581

Problem: any GRB from single stars?

look at binary models...

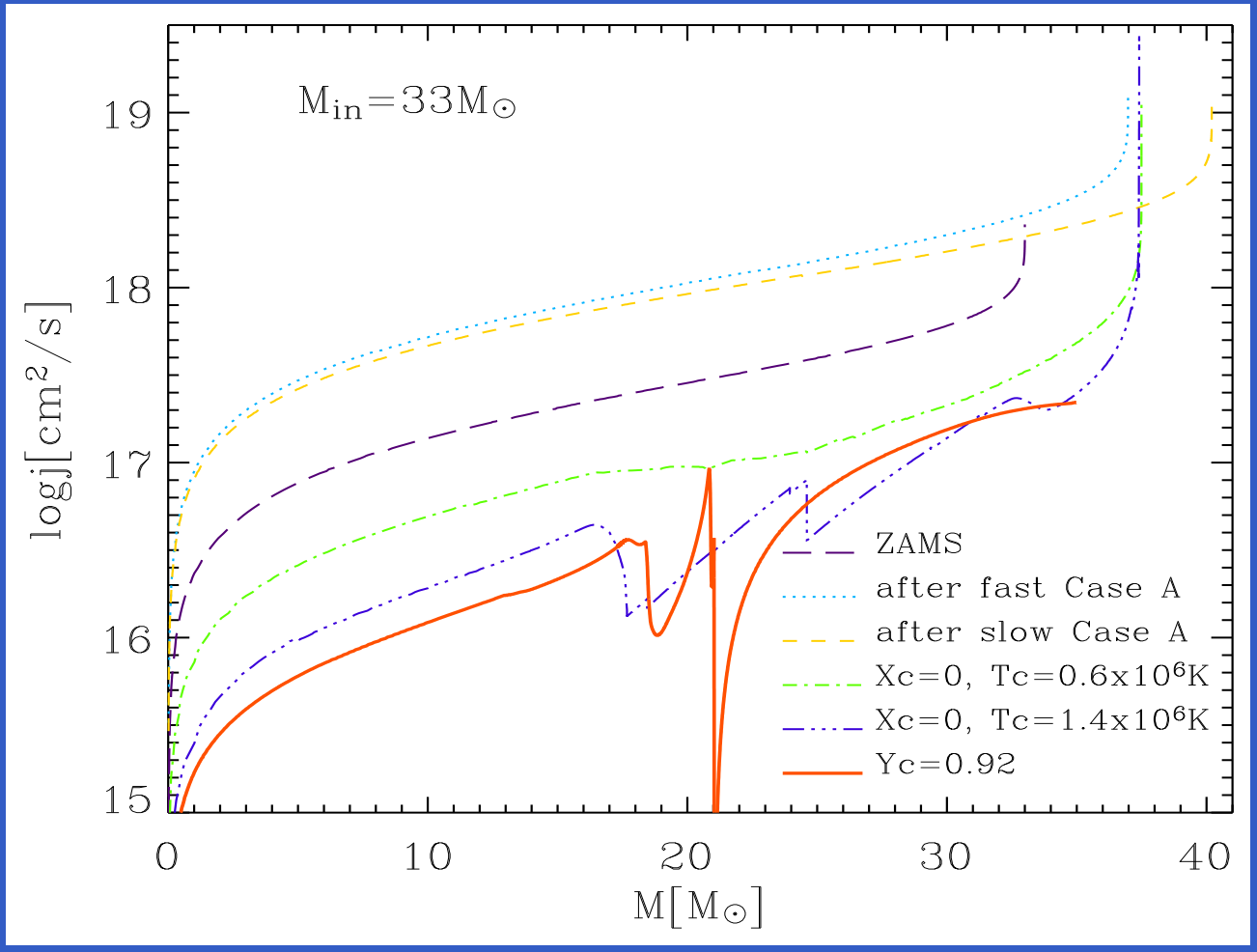
Accretion induced spin-up...

Petrovic, Langer, Yoon & Heger 2005, A&A 435, 247



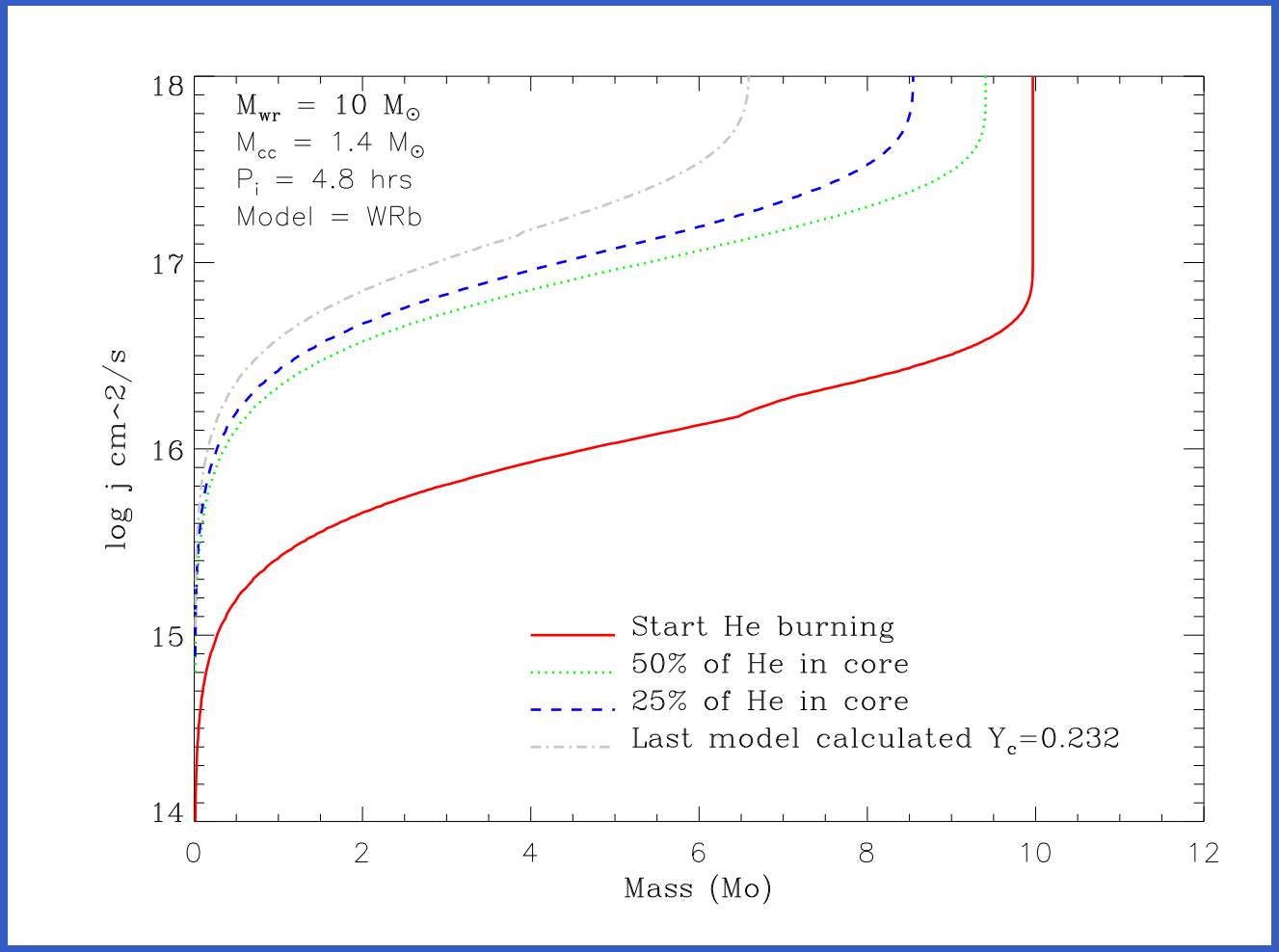
...does not work

Petrovic, Langer, Yoon & Heger 2005, A&A 435, 247



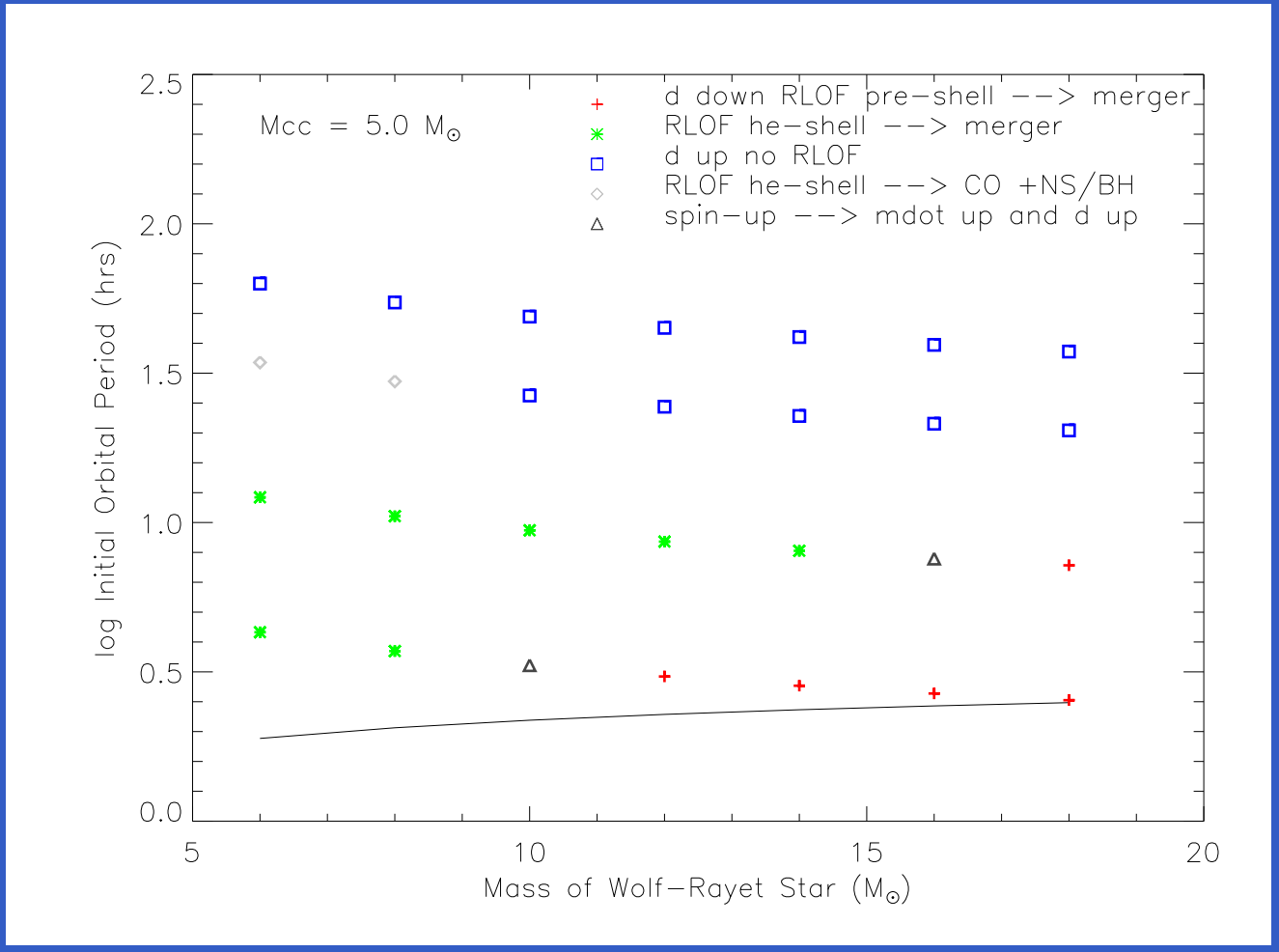
Tidally induced spin-up...

Detmers, Langer & Podsiadlowski, in prep.



...also does not work

Detmers, Langer & Podsiadlowski, in prep.



Other binary scenarios...?

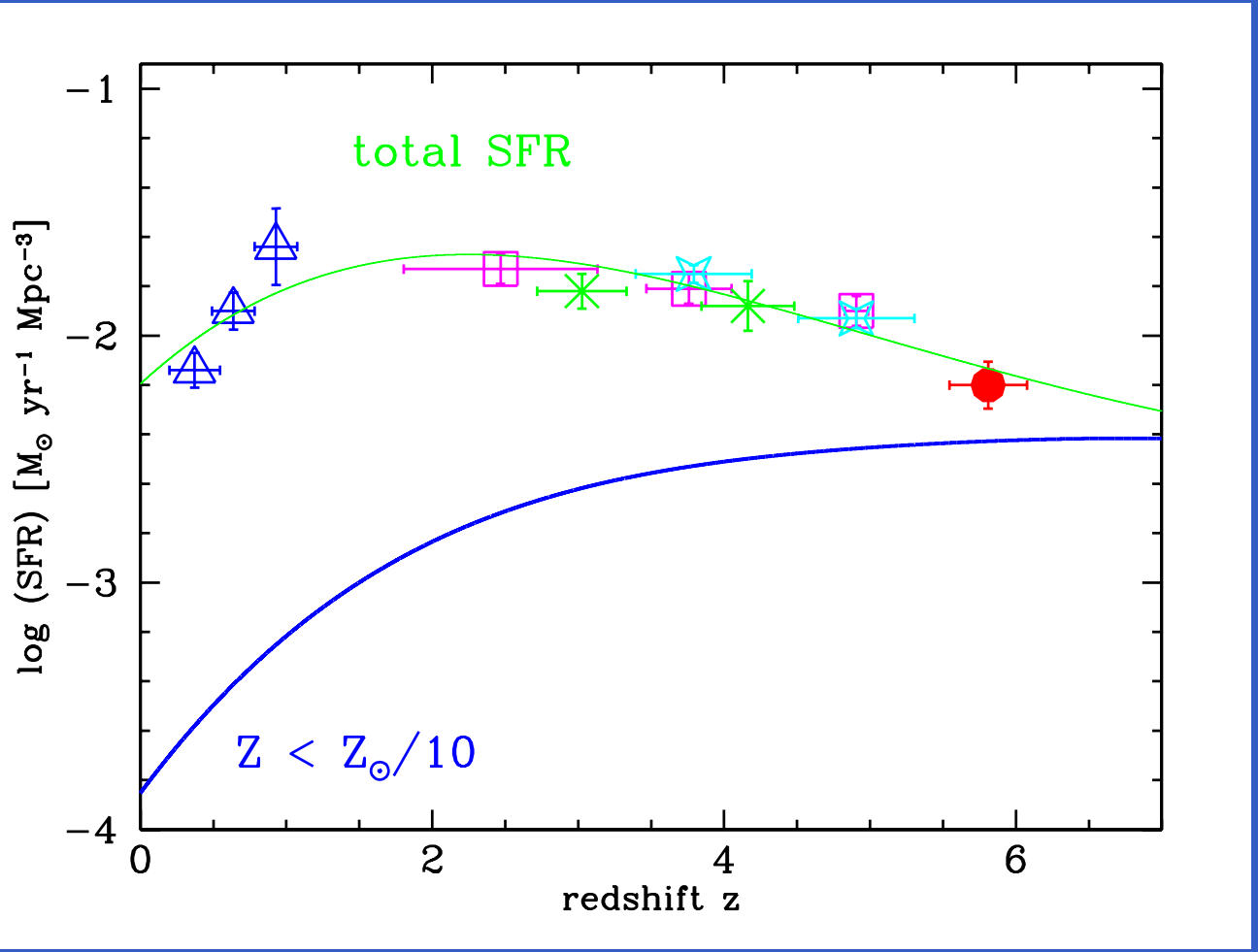
e.g. binary merger

Fryer & Heger 2005, ApJ 623, 302

... possible, but rare

Metallicity bias

Langer & Norman 2006, ApJL 638, L63



Metalicity bias $\longrightarrow$ single stars

locally: 1 GRB / 1000 SNe

assume GRBs come from $Z < Z_\odot/10$

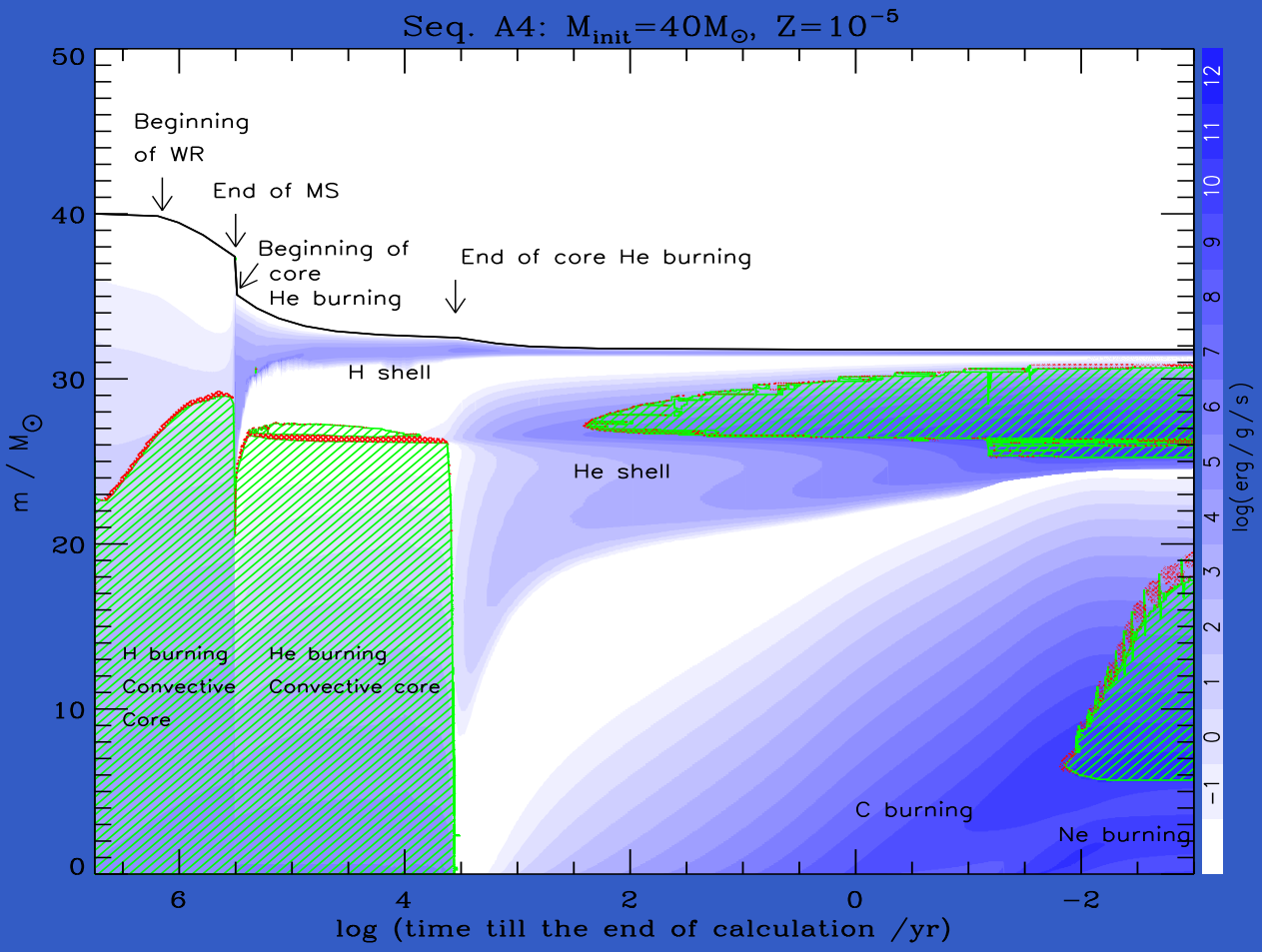
$\longrightarrow \frac{\#SNe(Z<Z_\odot/10)}{\#SNe} \simeq \frac{1}{100}$ (Langer & Norman 2006)

also: $\frac{\#SNe \rightarrow BH}{\#SNe} \simeq \frac{1}{20}$

$\Rightarrow$ EVERY BH makes a GRB!

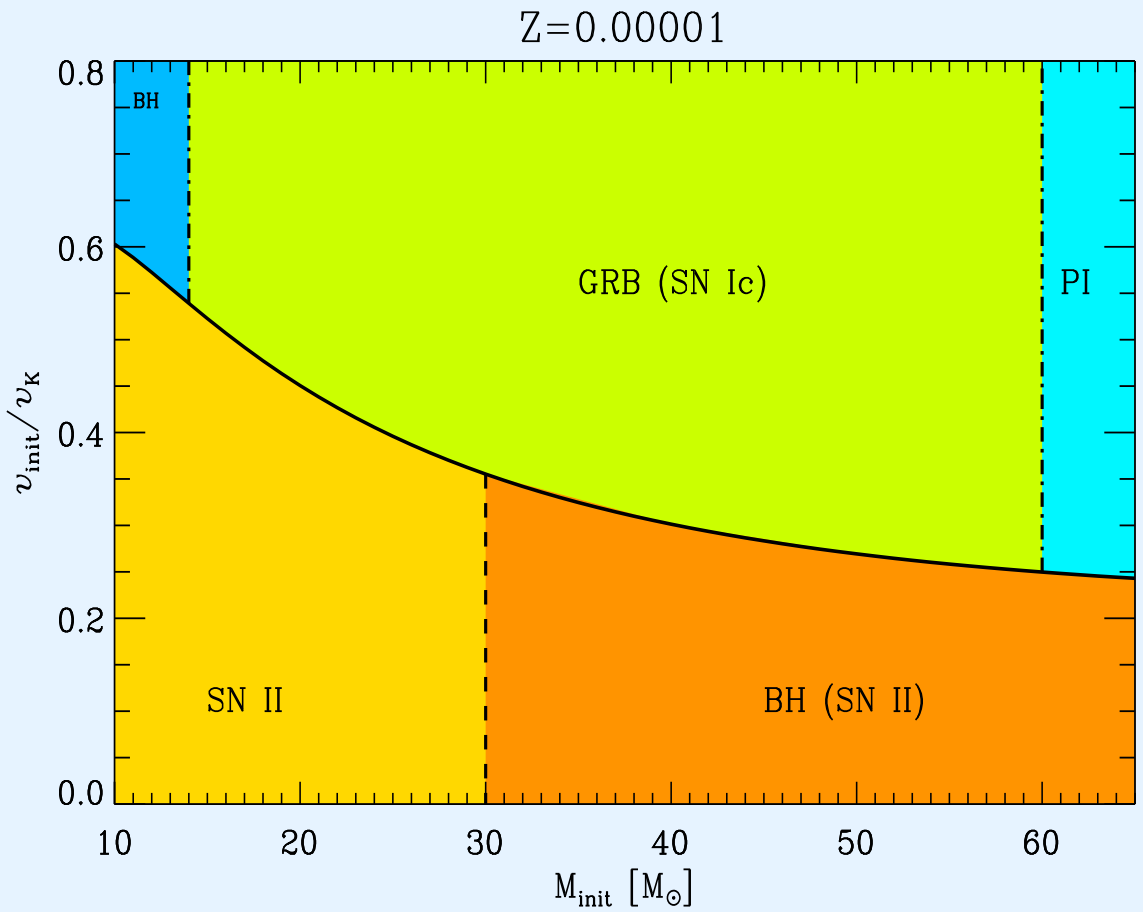
Chemically homogeneous evolution

Maeder 1987, A&A, 187, 159; Langer 1992, A&A, 265, L17



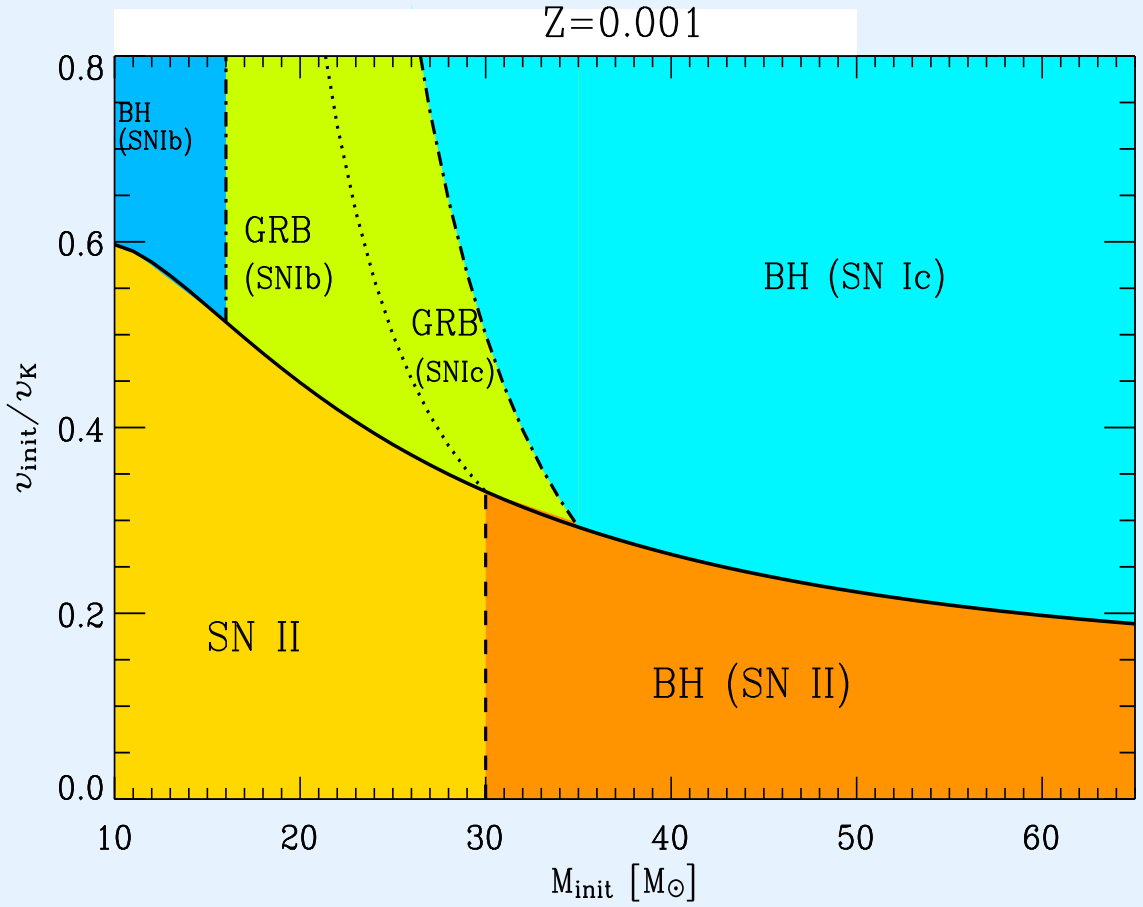
Yoon & Langer, 2005, A&A 443, 643 ; Woosley & Heger, 2006, ApJ 637, 914

Models at Z=10^{-5}



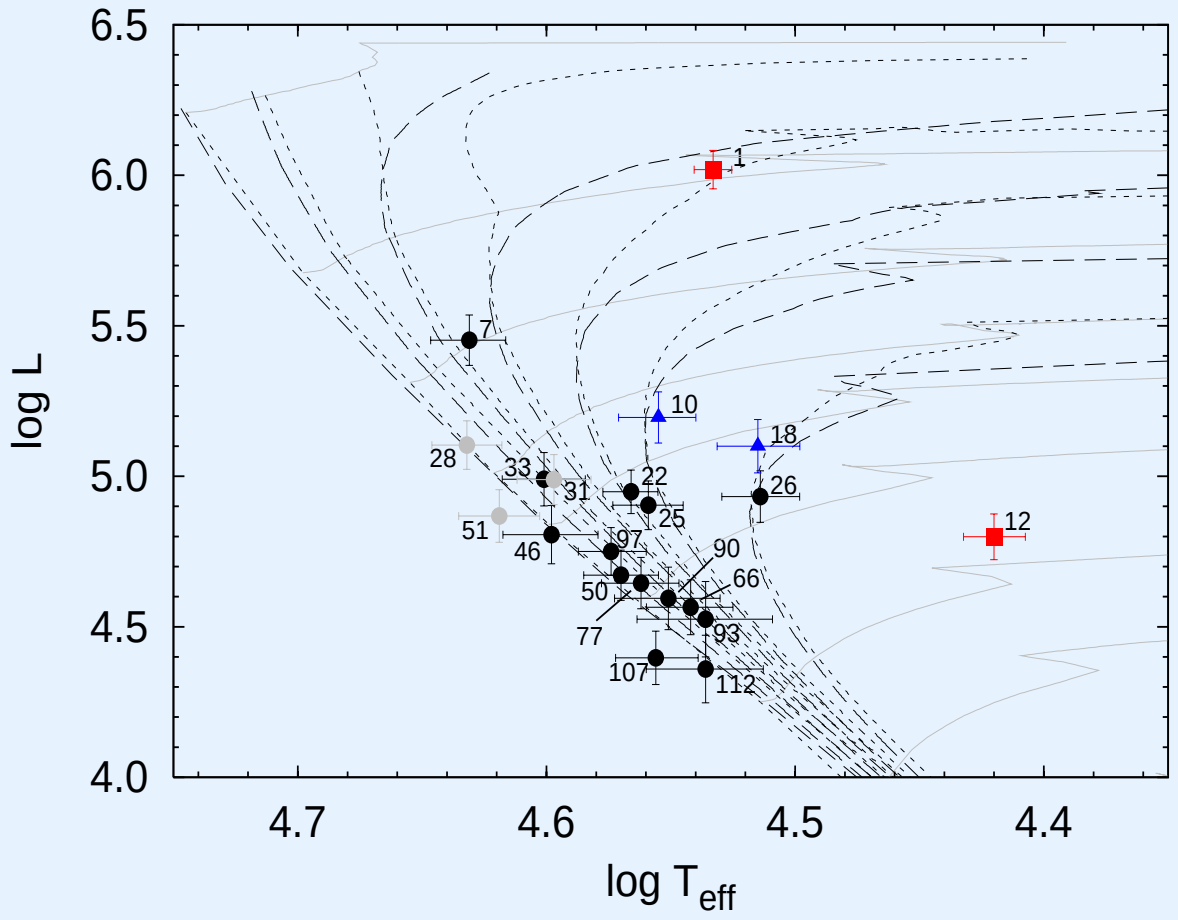
Yoon, Langer & Norman, in prep.

Models at Z=10^{-3}



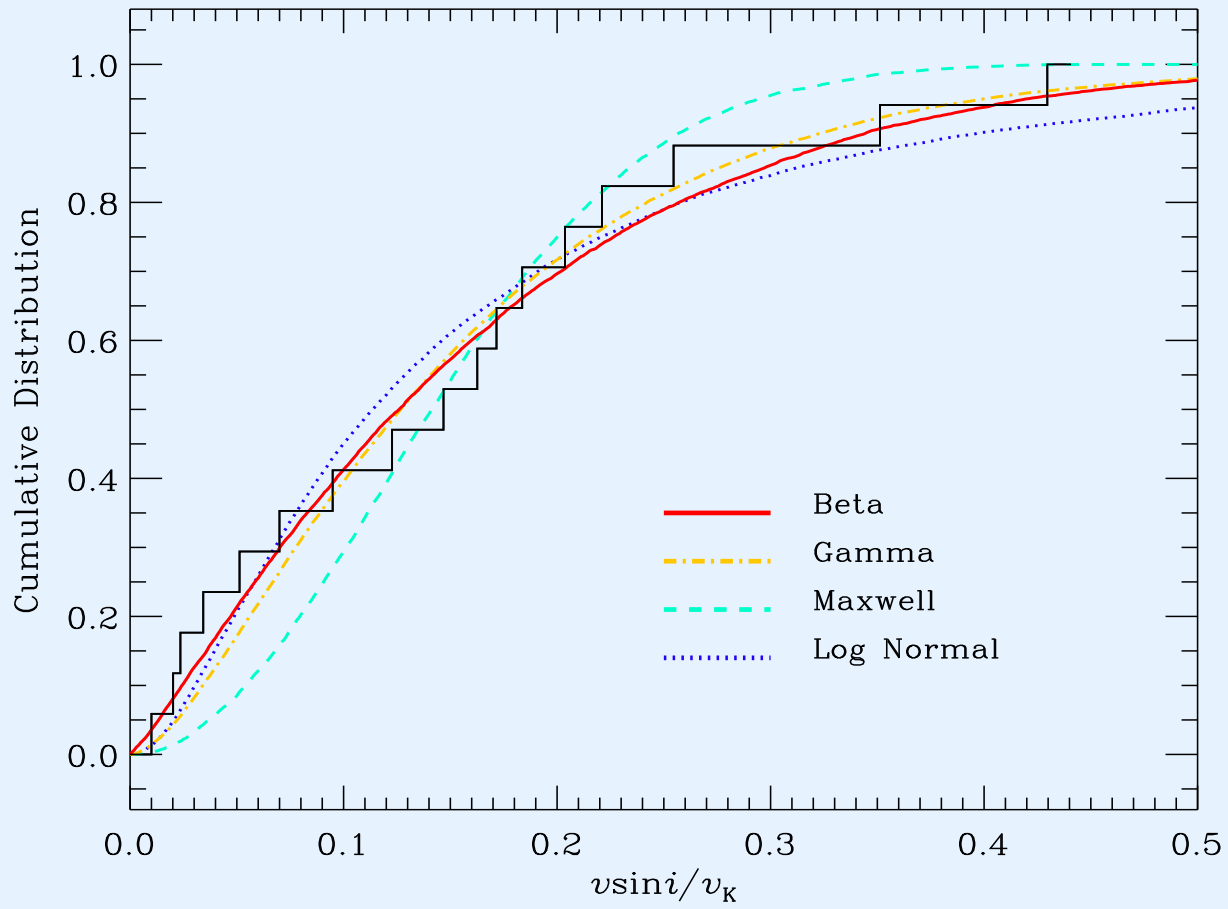
Yoon, Langer & Norman, in prep.

Observations: NGC 346!!



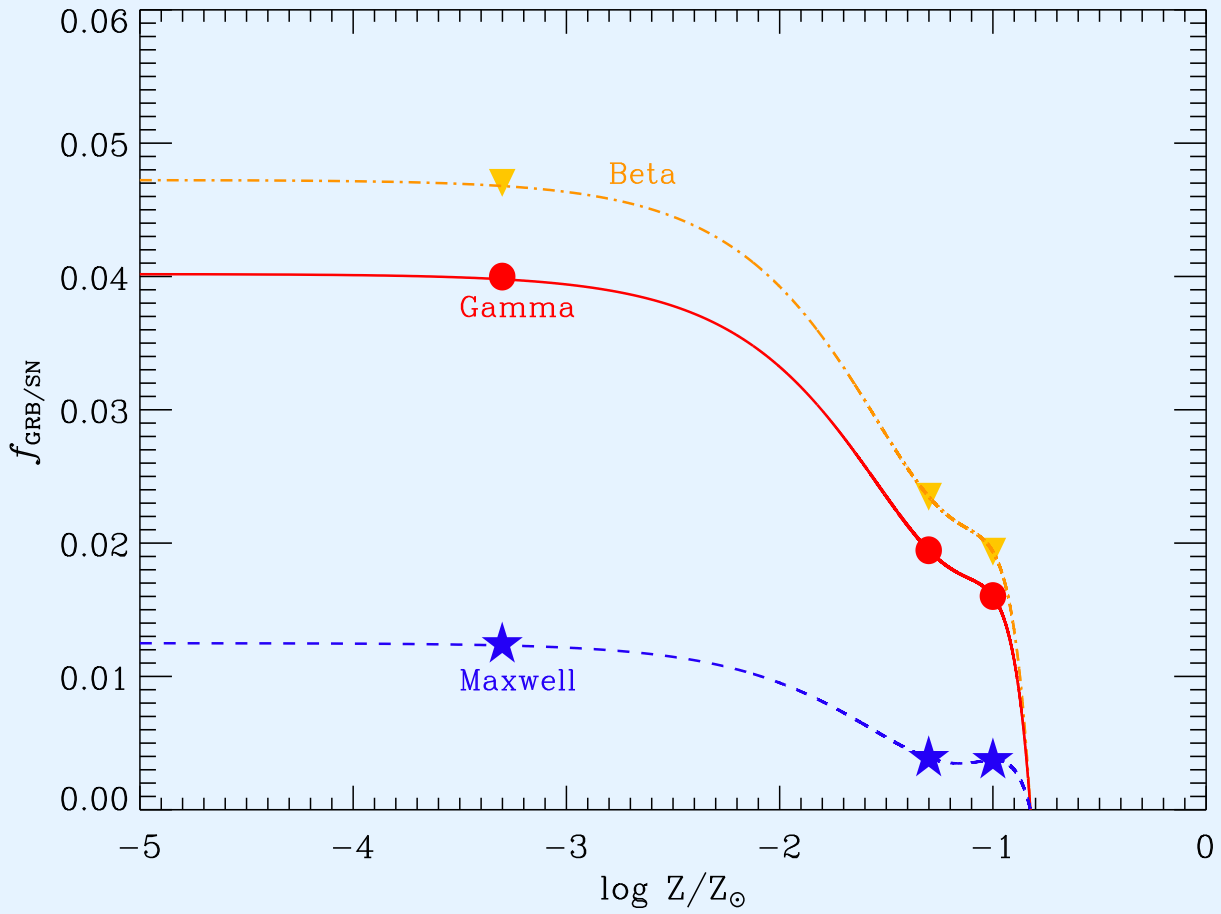
Mokiem et al. 2006, A&A, in press

Rotational velocities? NGC 346!!



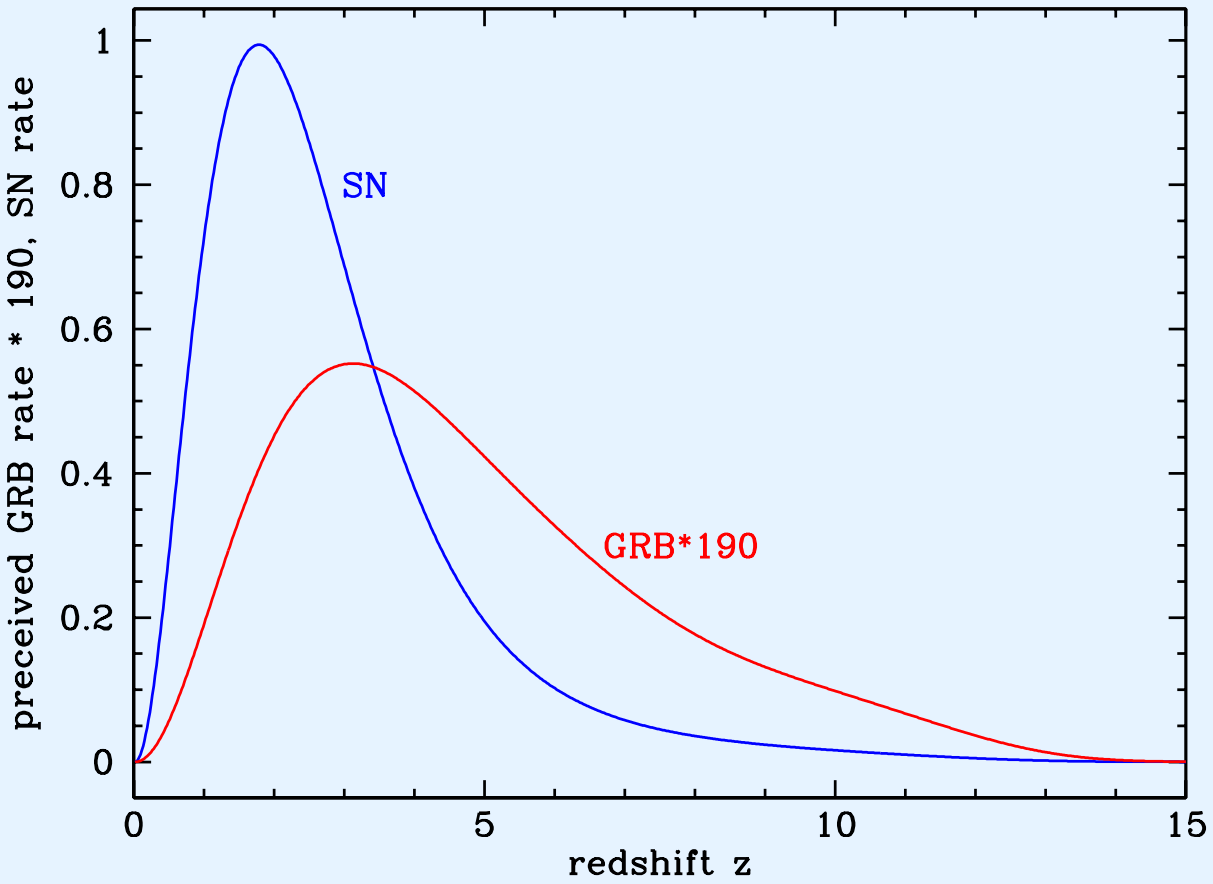
Mokiem et al. 2006

Predited GRB/SN ratio as f(Z)



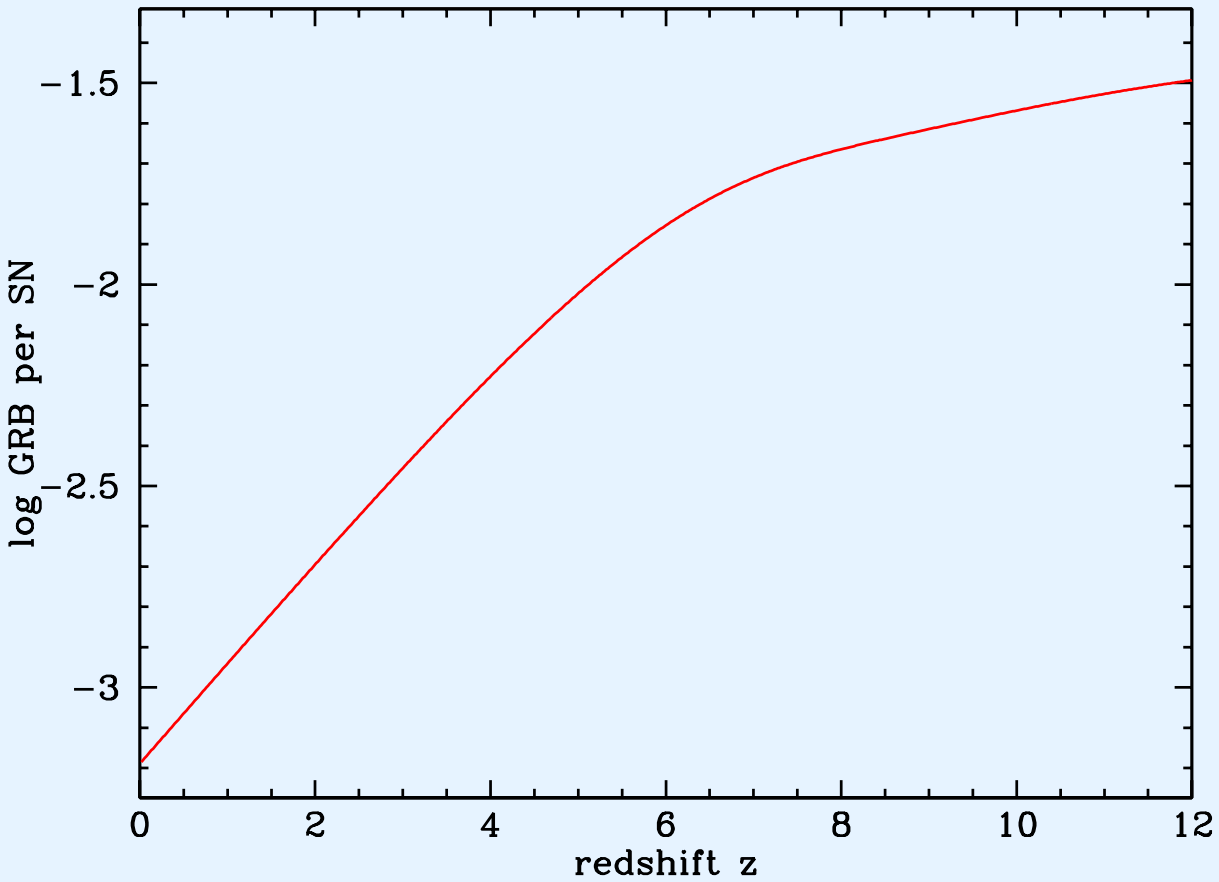
Yoon, Langer & Norman, in prep.

Preceived SN, GRB rates as f(z)



Yoon, Langer & Norman, in prep.

GRB/SN ratio as f(z)



Yoon, Langer & Norman, in prep.

Summary: GRB progenitors

- absorption line systems!?
- typical GRB $\Rightarrow$ low Z !?
- accretion induced, tidal spin-up models unsuccessful
- working single star models at low Z
- low-Z bias: $\Rightarrow$ single stars dominate GRBs
- large number of high z GRBs (50%: $z > 5$)