PROGENITORS OF CC SNe FROM SINGLE ROTATING MASSIVE STAR MODELS

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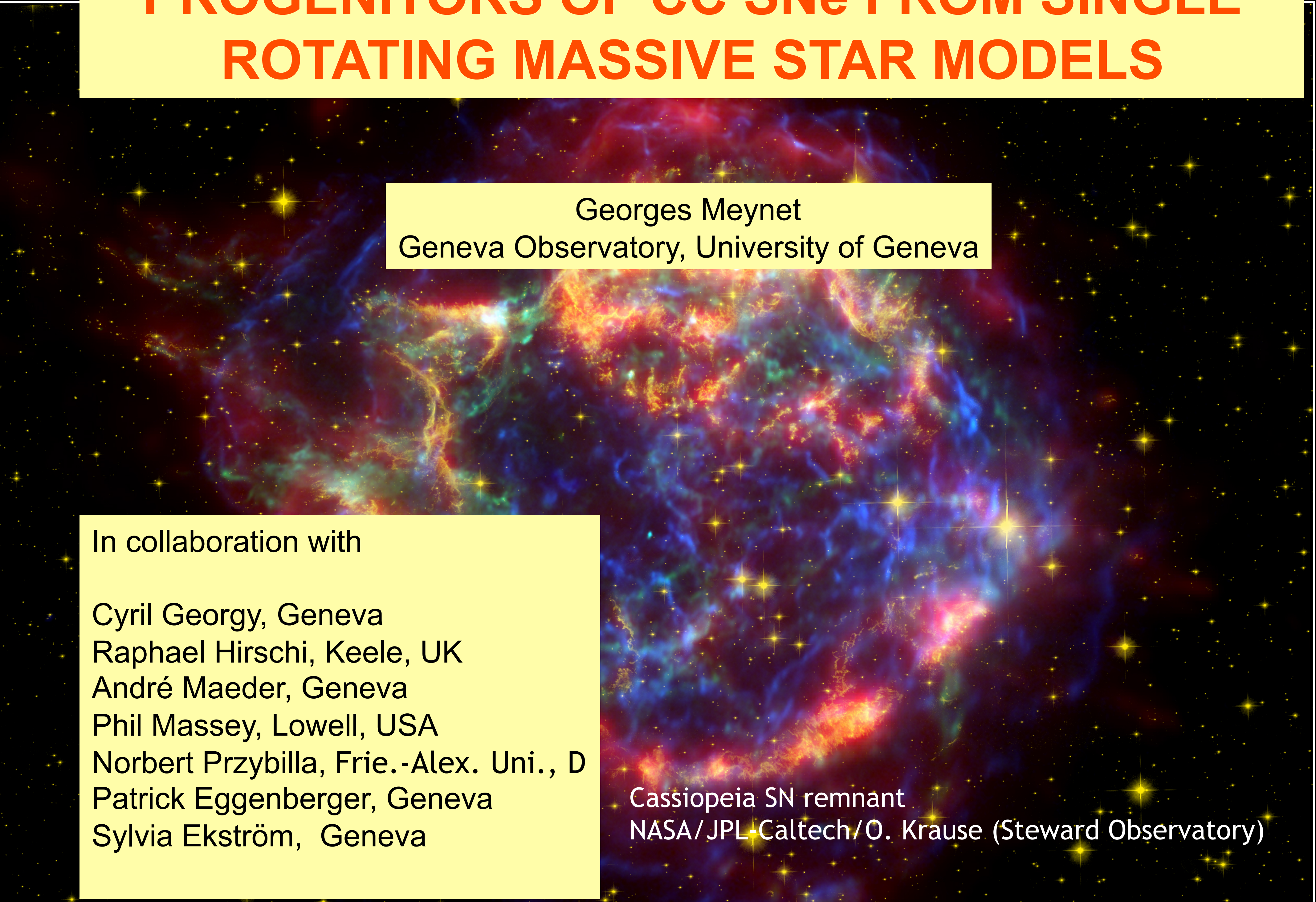
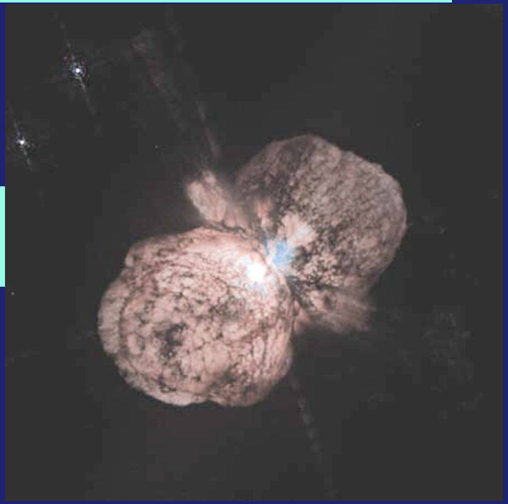


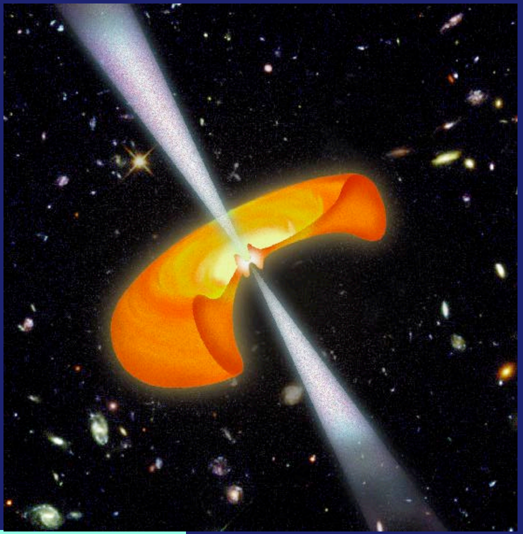
Cassiopeia SN remnant
NASA/JPL-Caltech/O. Krause (Steward Observatory)

SOME CURRENT CHALLENGES

How to explain lack of SN II-P from RSG progenitors between 18 and 25 Msol?



Can LBV explode as SNe?



PISN in local Universe?

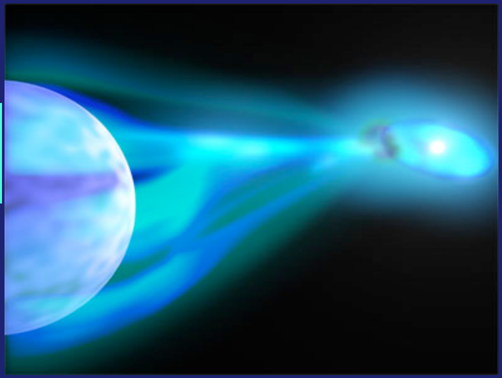
What are the progenitors of Gamma Ray Bursts?

Rotation rate of young pulsars?

SOME OLD STILL CURRENT CHALLENGES

LINK BETWEEN LIGHT CURVE SPECTRUM OF SN AND NATURE OF THE PROGENITOR?

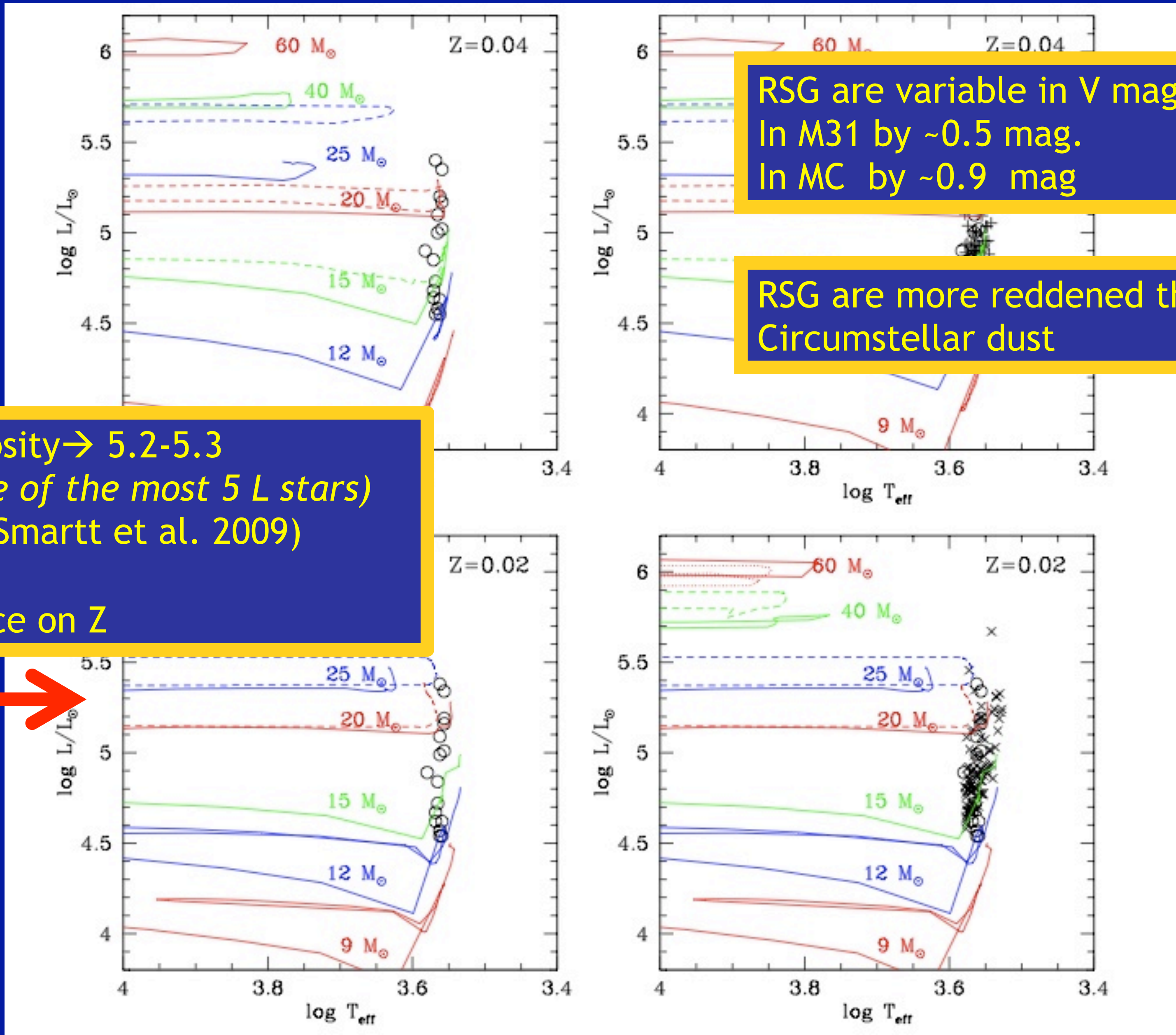
BINARY VERSUS SINGLE STAR?



MASS LIMITS BETWEEN NEUTRON STAR AND BLACK PROGENITORS (HOW DOES IT DEPEND ON Z)?

WHAT CAN WE SEE WHEN A BLACK HOLE IS FORMED?

RED SUPERGIANT POPULATIONS



RSG are variable in V mag. (not in K)
In M31 by ~0.5 mag.
In MC by ~0.9 mag

RSG are more reddened than OB stars
Circumstellar dust

Upper Luminosity→ 5.2-5.3
(median value of the most 5 L stars)
SNII-P→ 5.1 (Smartt et al. 2009)

No dependance on Z

Philip Massey, David R. Silva, Emily M. Levesque, Bertrand Plez, Knut A. G. Olsen, Geoffrey C. Clayton , Georges Meynet, and Andre Maeder (2009, ApJ 703,420)

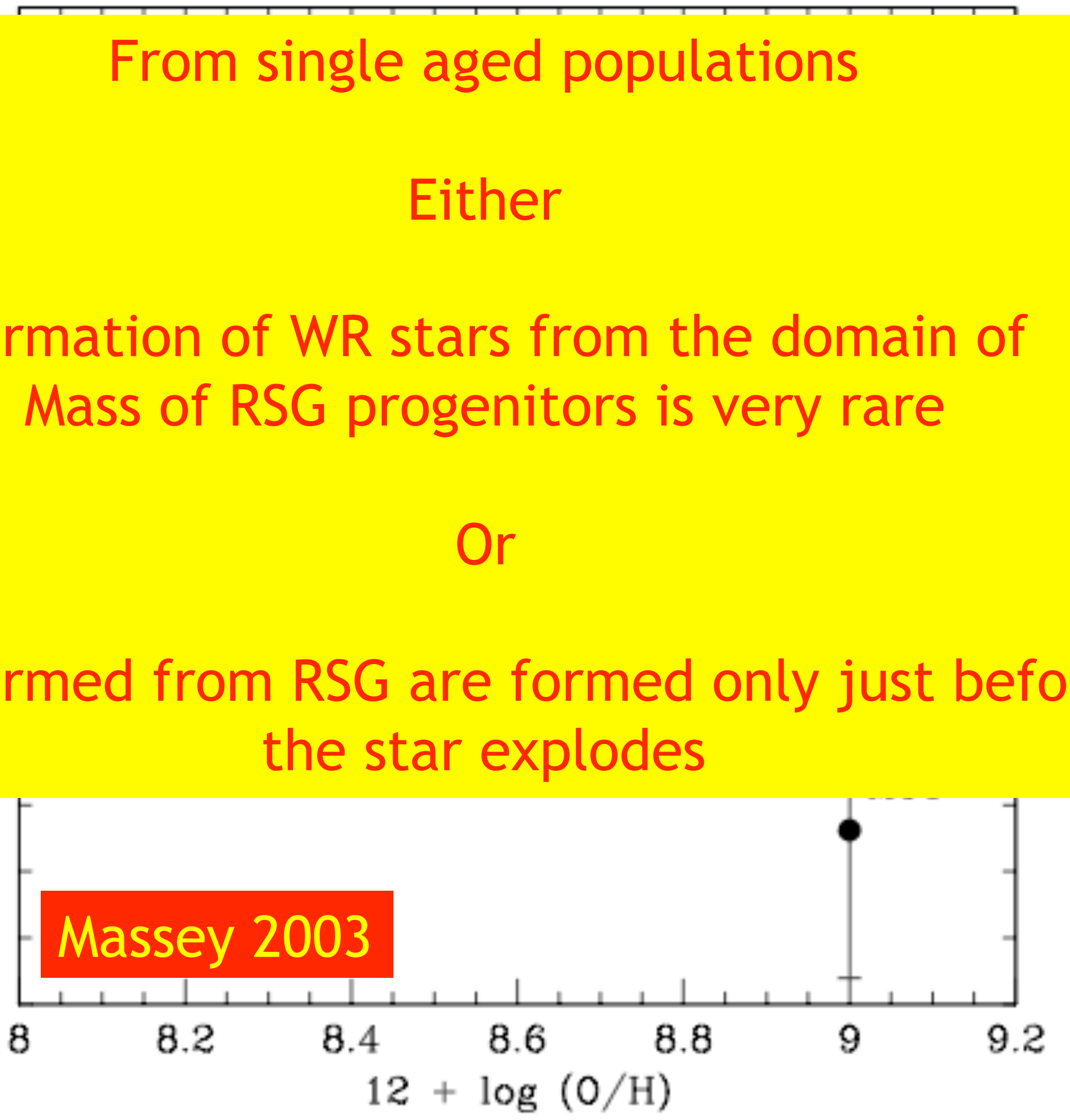
From single aged populations

Either

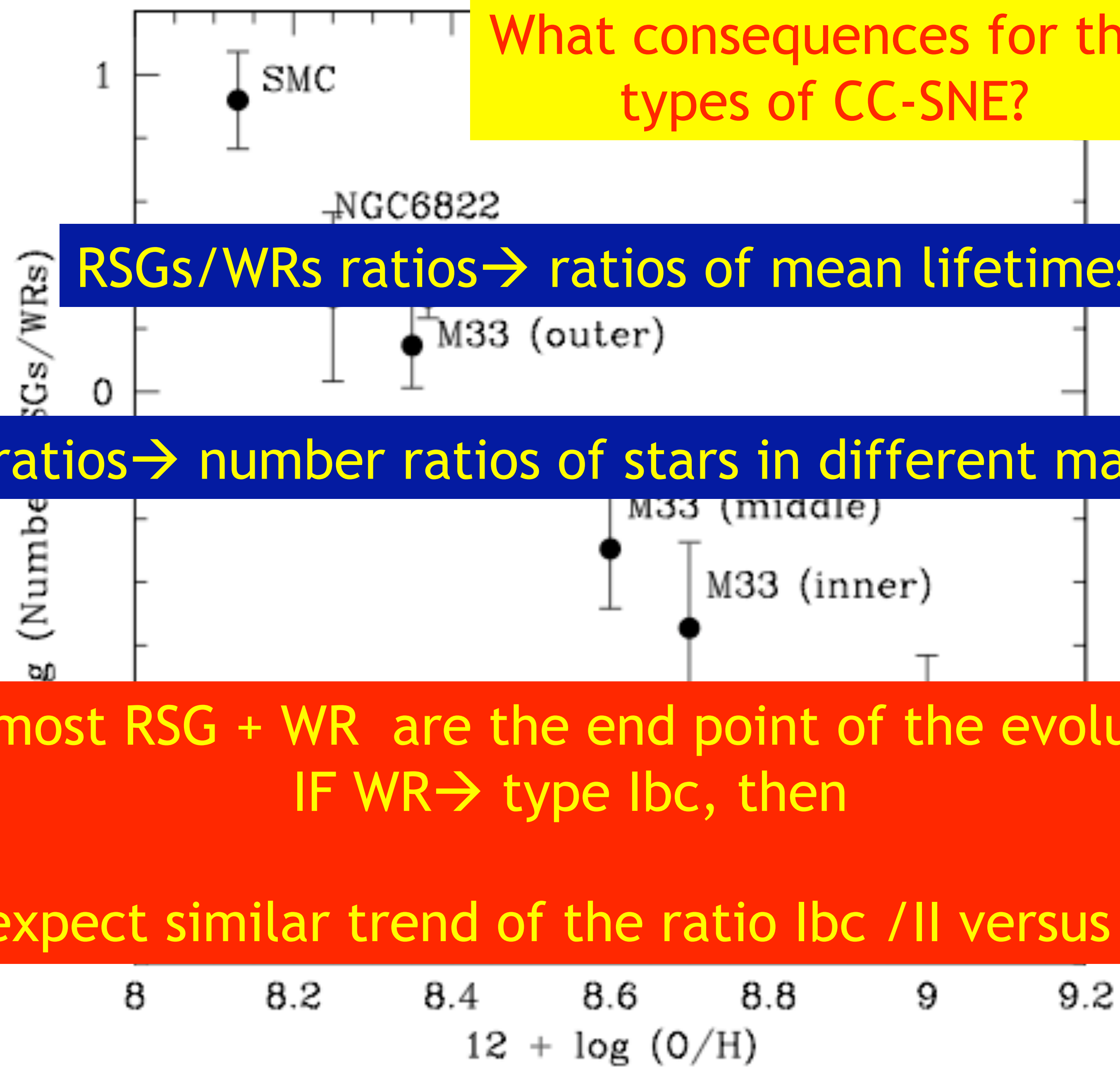
Formation of WR stars from the domain of
Mass of RSG progenitors is very rare

Or

WR formed from RSG are formed only just before
the star explodes



What consequences for the types of CC-SNE?

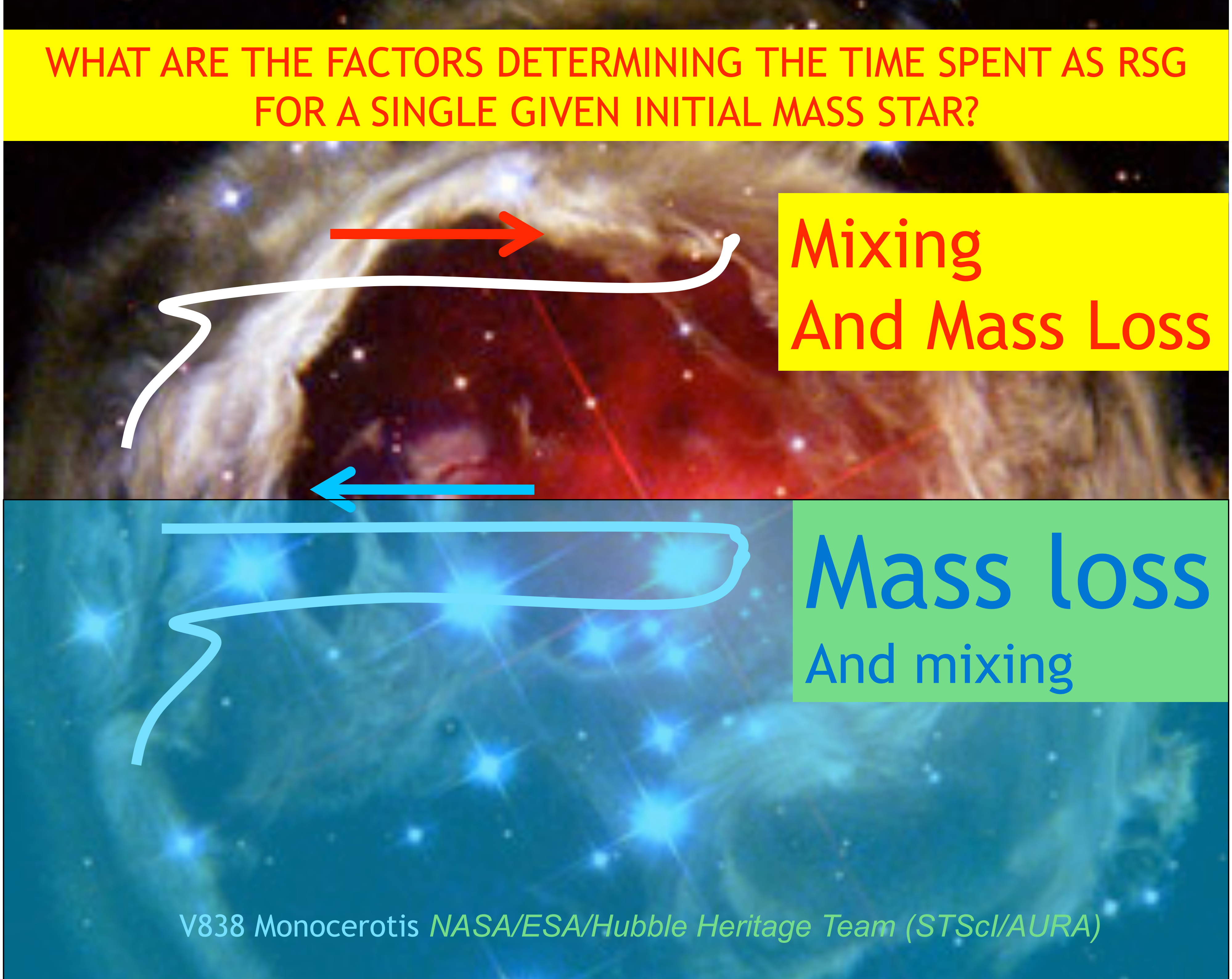


RSGs/WRs ratios→ ratios of mean lifetimes

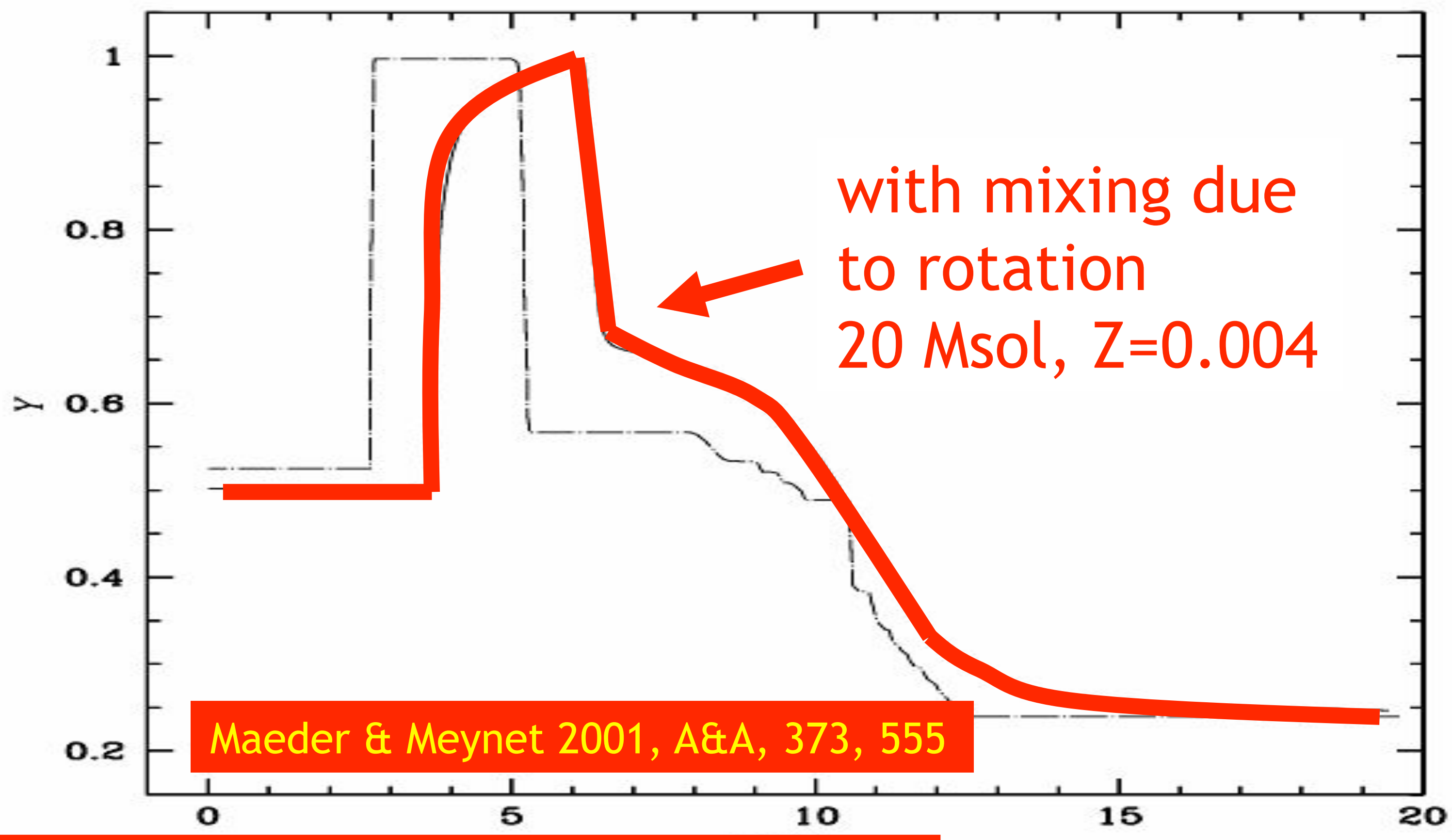
CC SN ratios→ number ratios of stars in different mass domains

IF most RSG + WR are the end point of the evolution
IF WR→ type Ibc, then

expect similar trend of the ratio Ibc /II versus Z


WHAT ARE THE FACTORS DETERMINING THE TIME SPENT AS RSG FOR A SINGLE GIVEN INITIAL MASS STAR?
Mixing
And Mass Loss
Mass loss
And mixing
V838 Monocerotis NASA/ESA/Hubble Heritage Team (STScI/AURA)

Helium mass fraction



M_r/M_{sun}

<u>With mixing (due to rotation):</u>

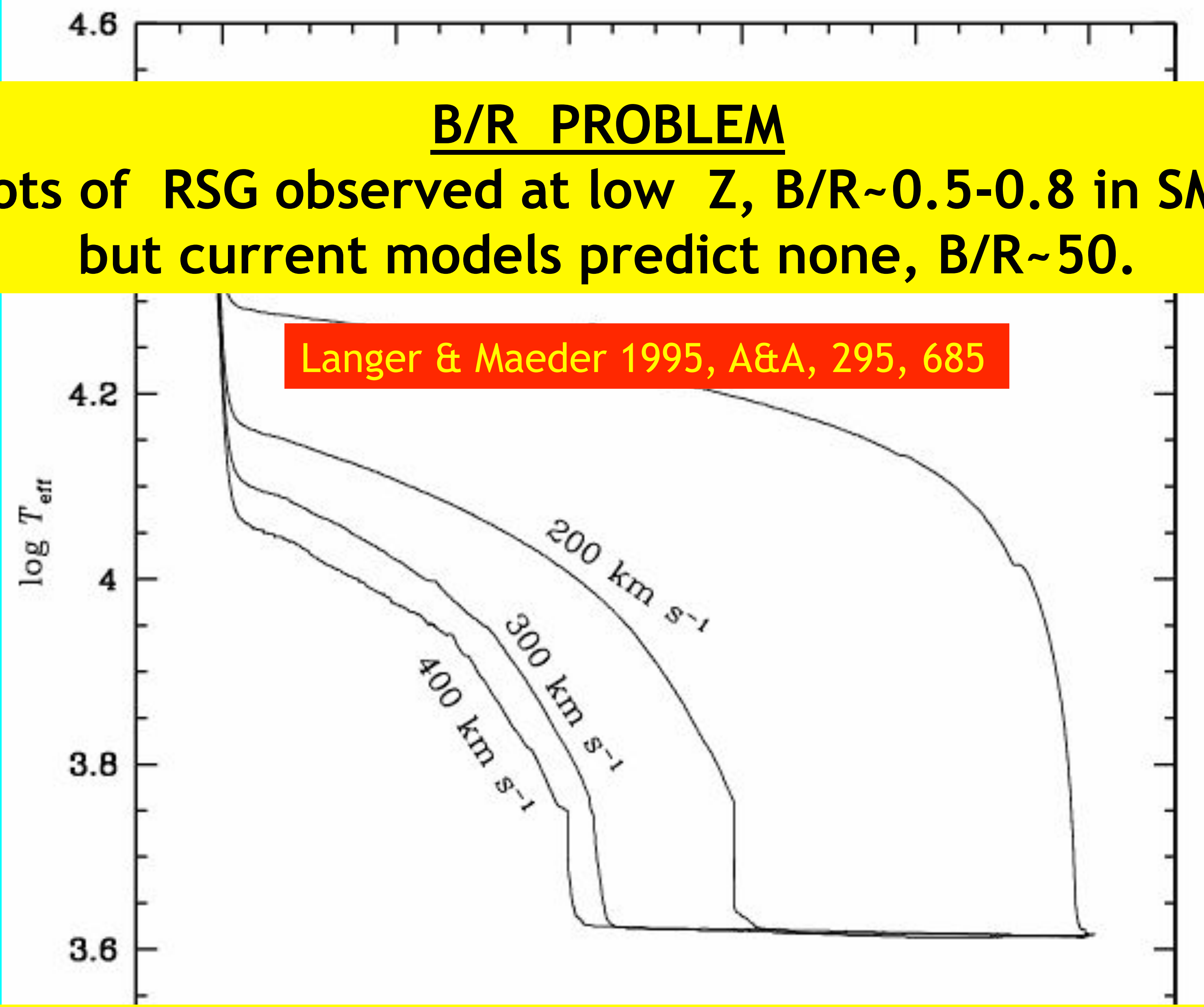
- Larger core
- More He in shell
- H shell less active
- no intermed. conv. zone

→ **RSG**

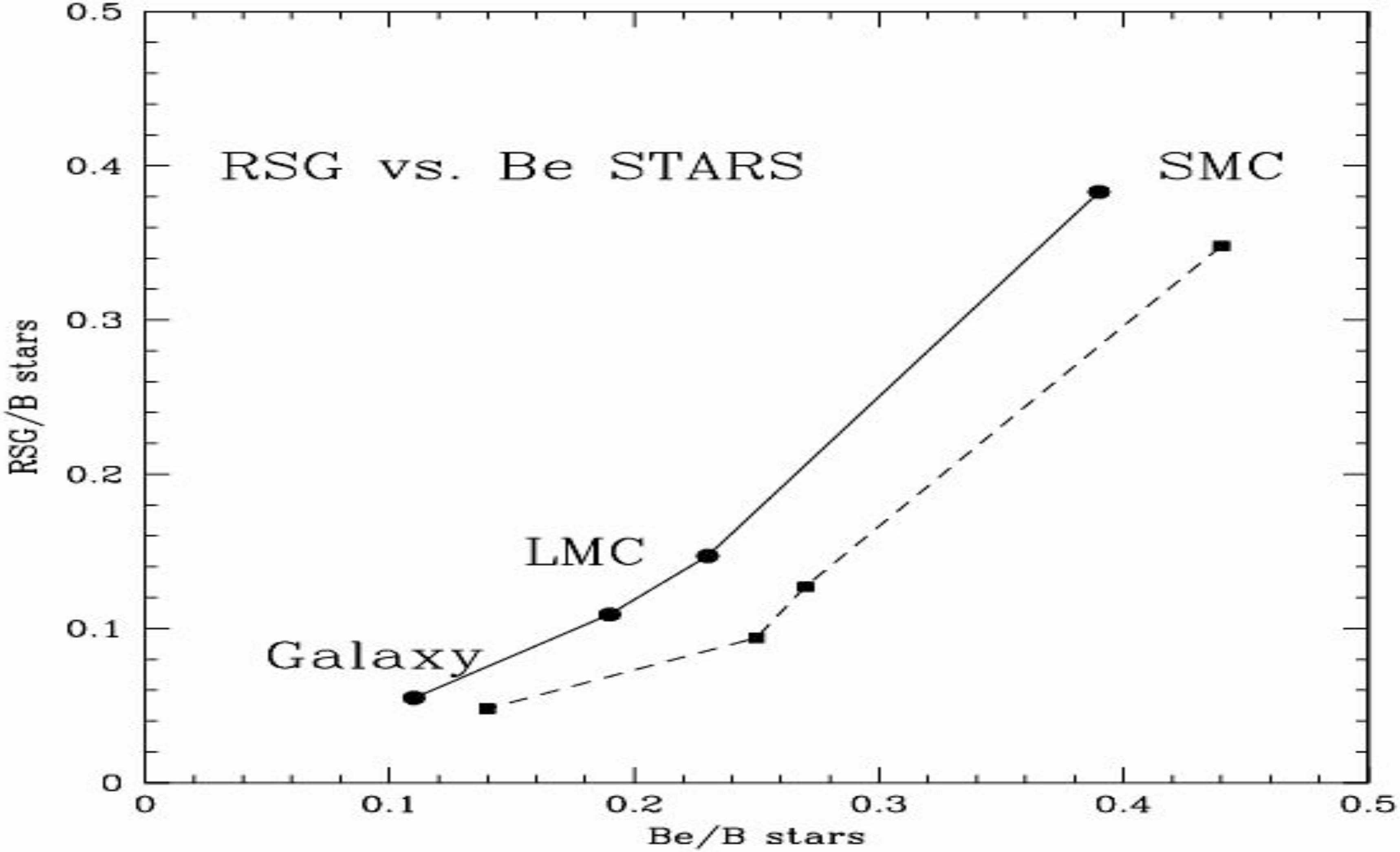
B/R PROBLEM

Lots of RSG observed at low Z, B/R~0.5-0.8 in SMC but current models predict none, B/R~50.

Langer & Maeder 1995, A&A, 295, 685

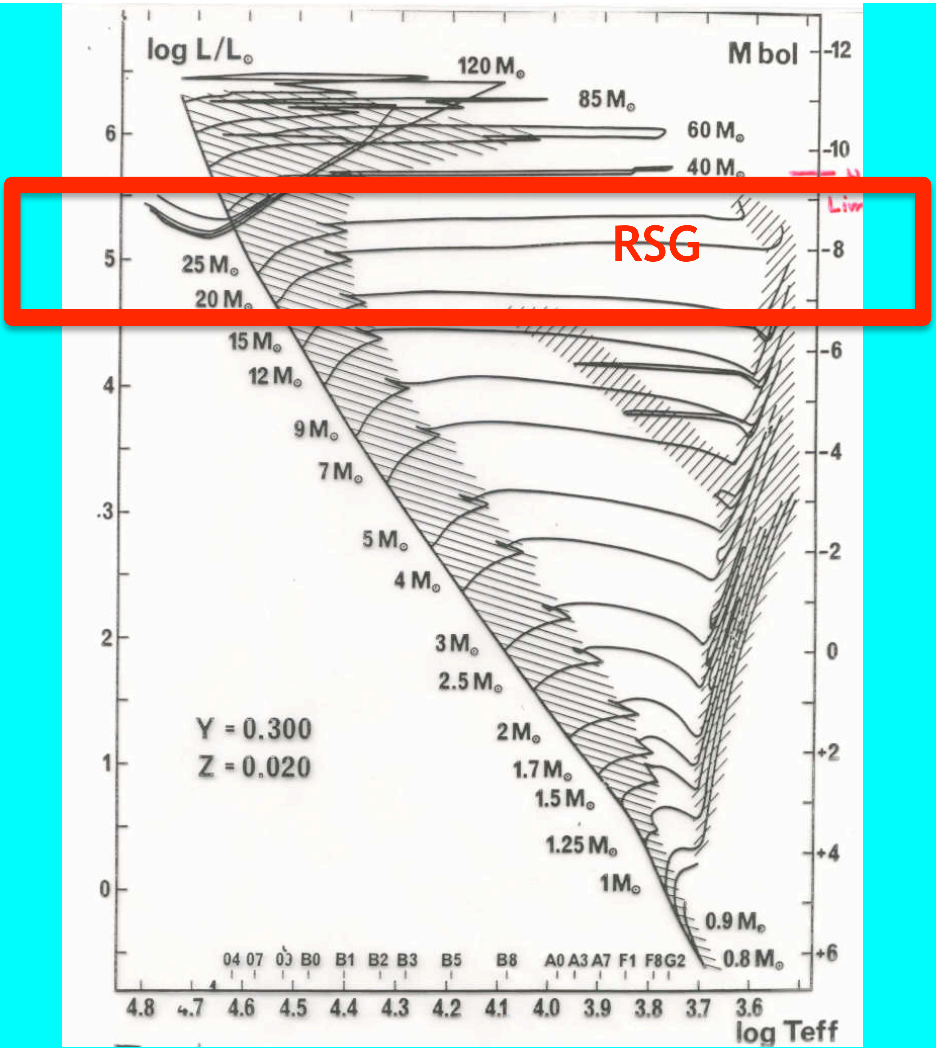


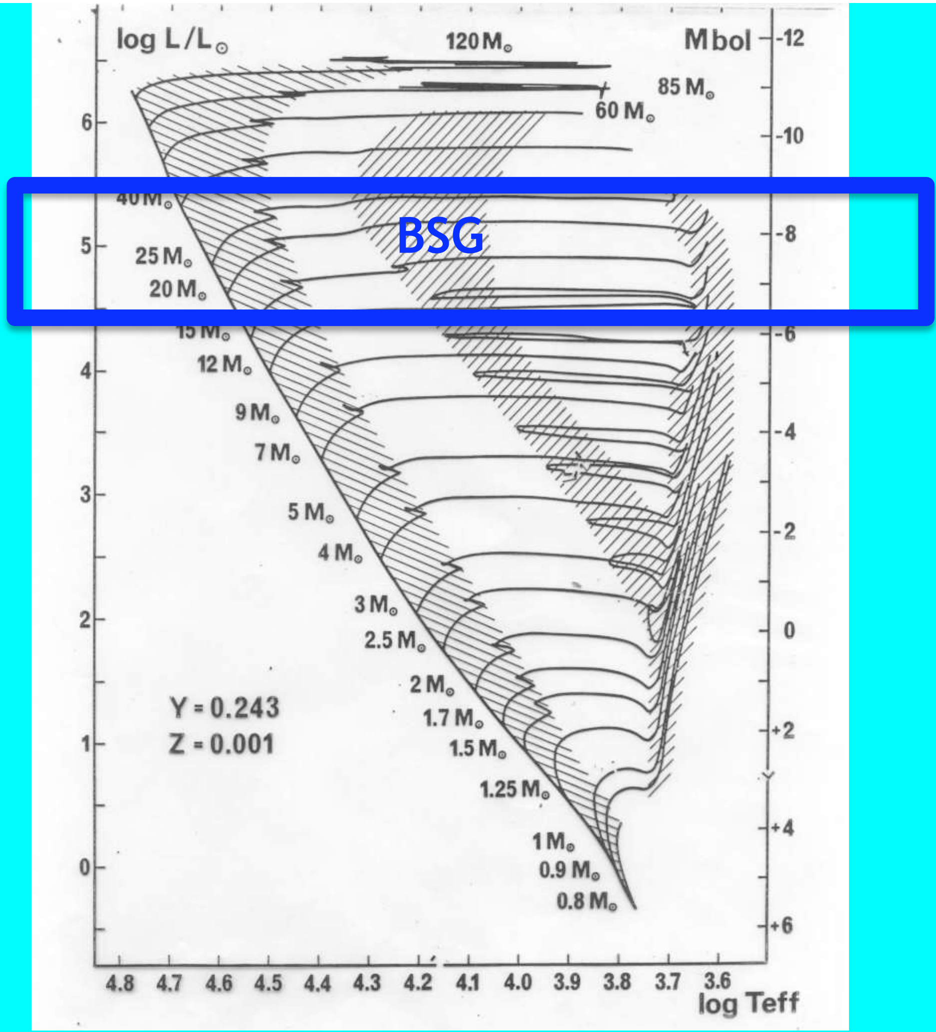
Models with mixing due to rotation are OK with B/R = 0.5-0.8 in SMC cf. Maeder & Meynet 2001



CONSISTENT WITH MODELS

More fast Rotators → More RSG



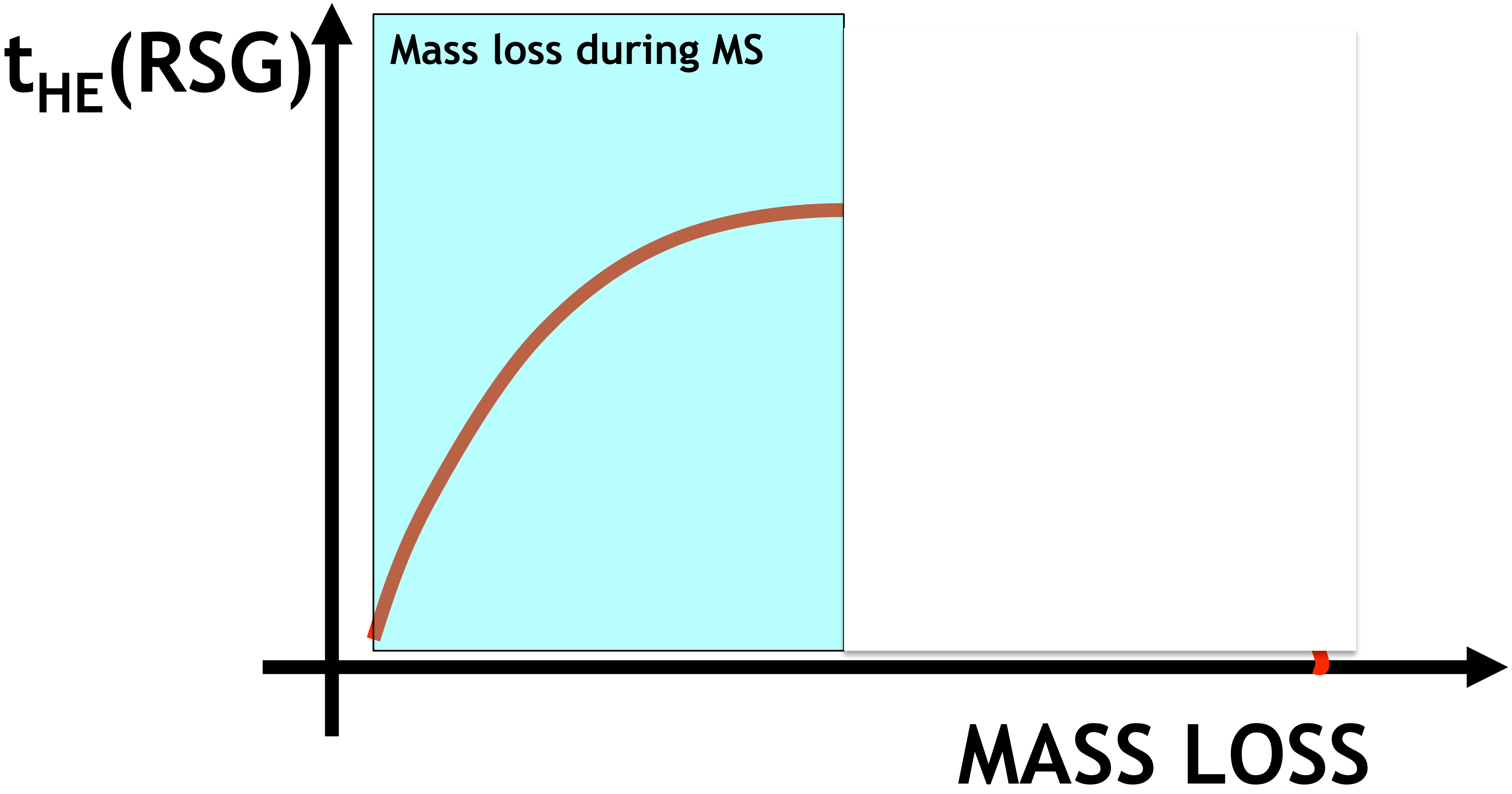


When the metallicity (mass loss) decreases, models predict that a still greater portion of the core He-burning phase occurs in the blue

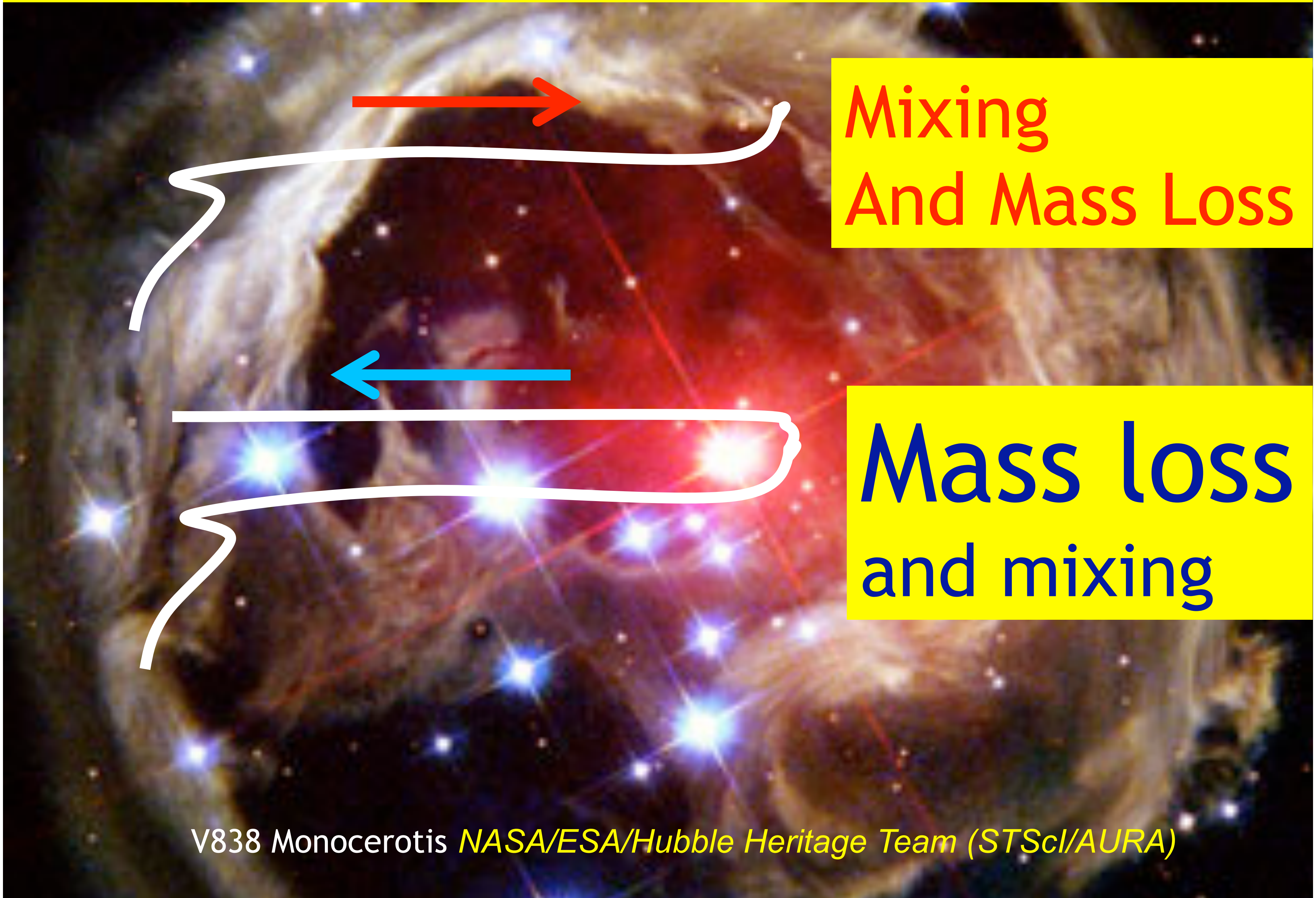
Mass Loss → Red

CHANGE OF MASS LOSS

For a given initial mass



WHAT ARE THE FACTORS DETERMINING THE TIME SPENT AS RSG FOR A SINGLE GIVEN INITIAL MASS STAR?



V838 Monocerotis *NASA/ESA/Hubble Heritage Team (STScI/AURA)*

CHANGE OF MASS LOSS

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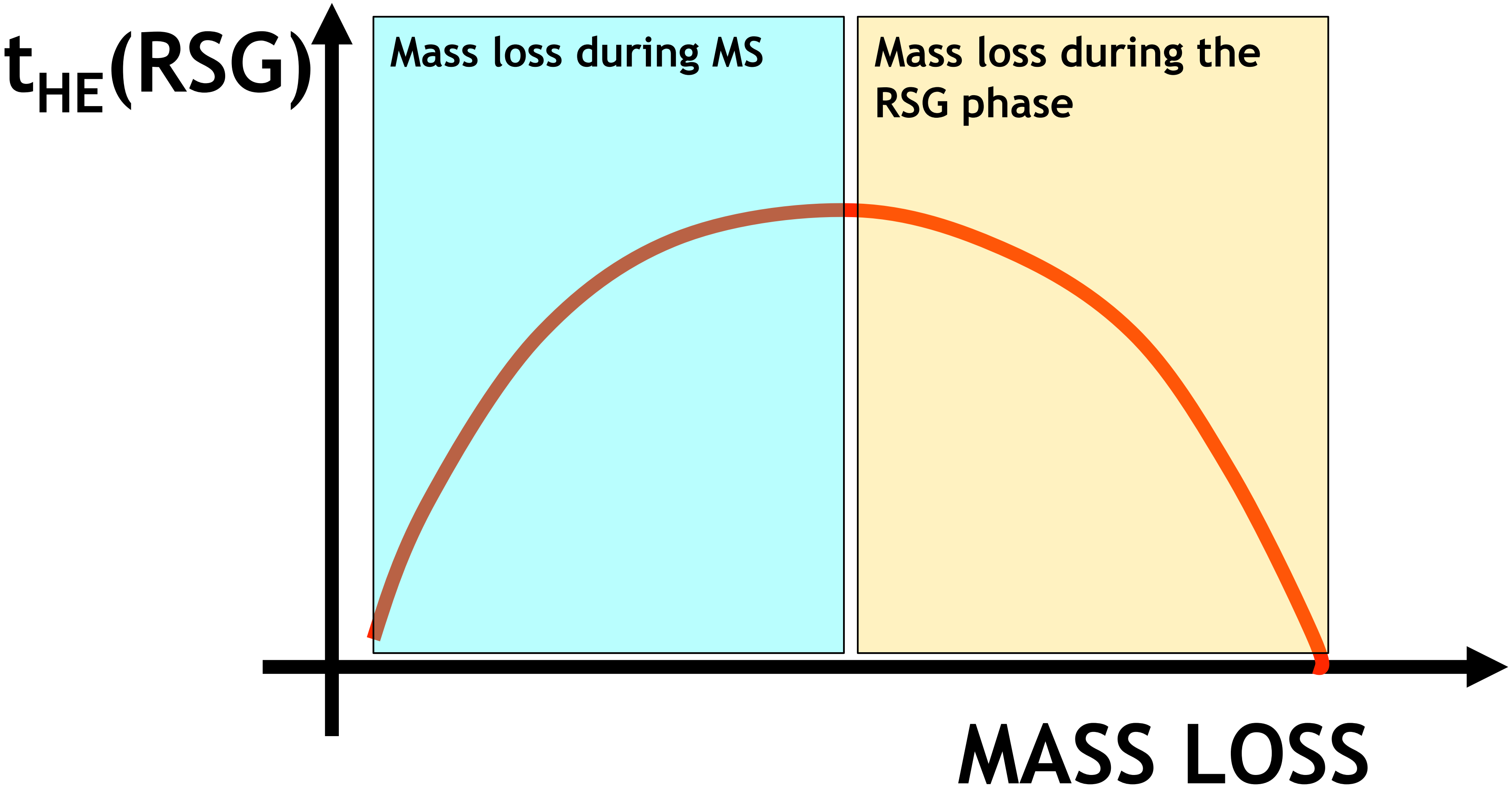
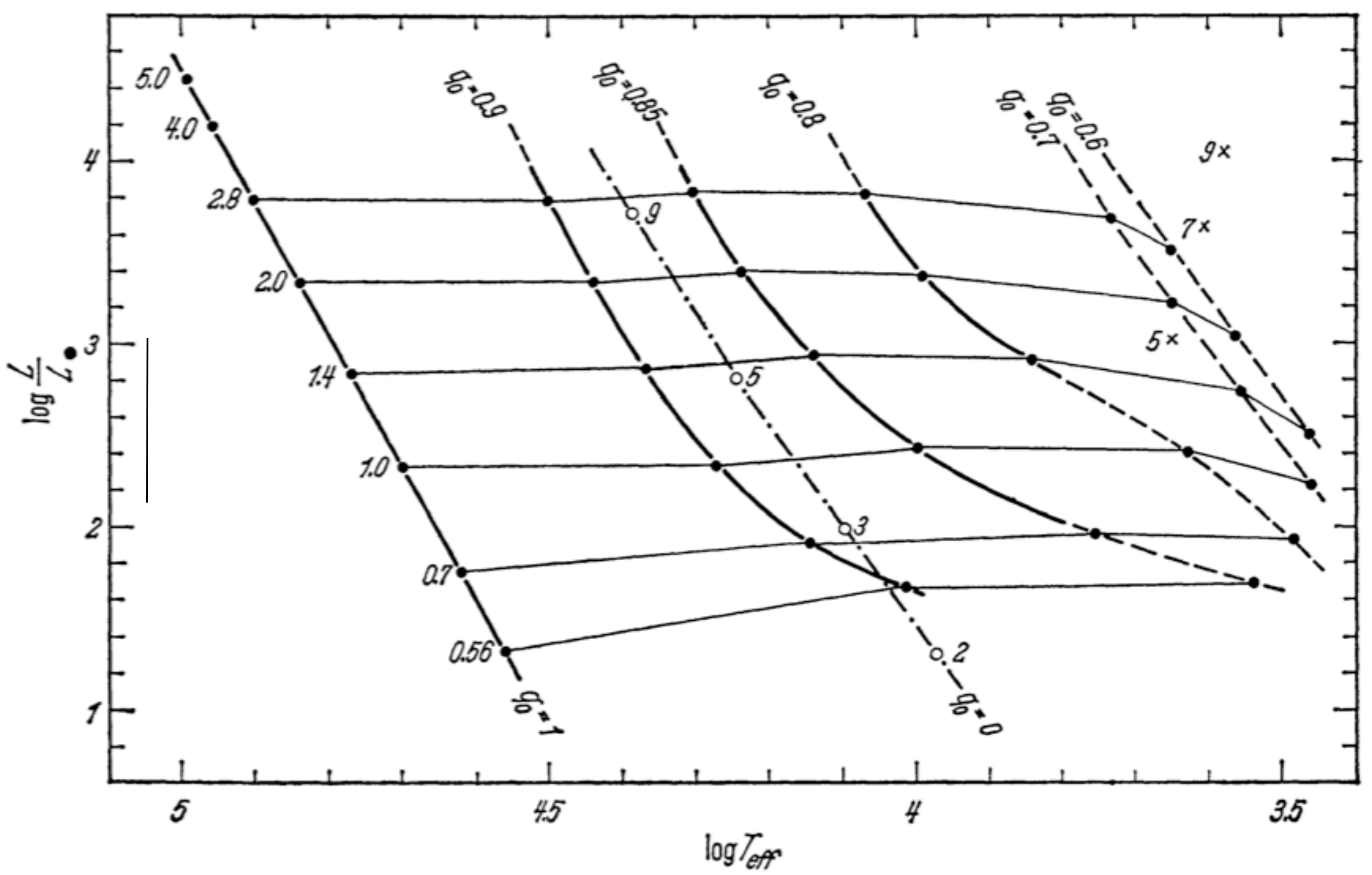




Giannone 1967

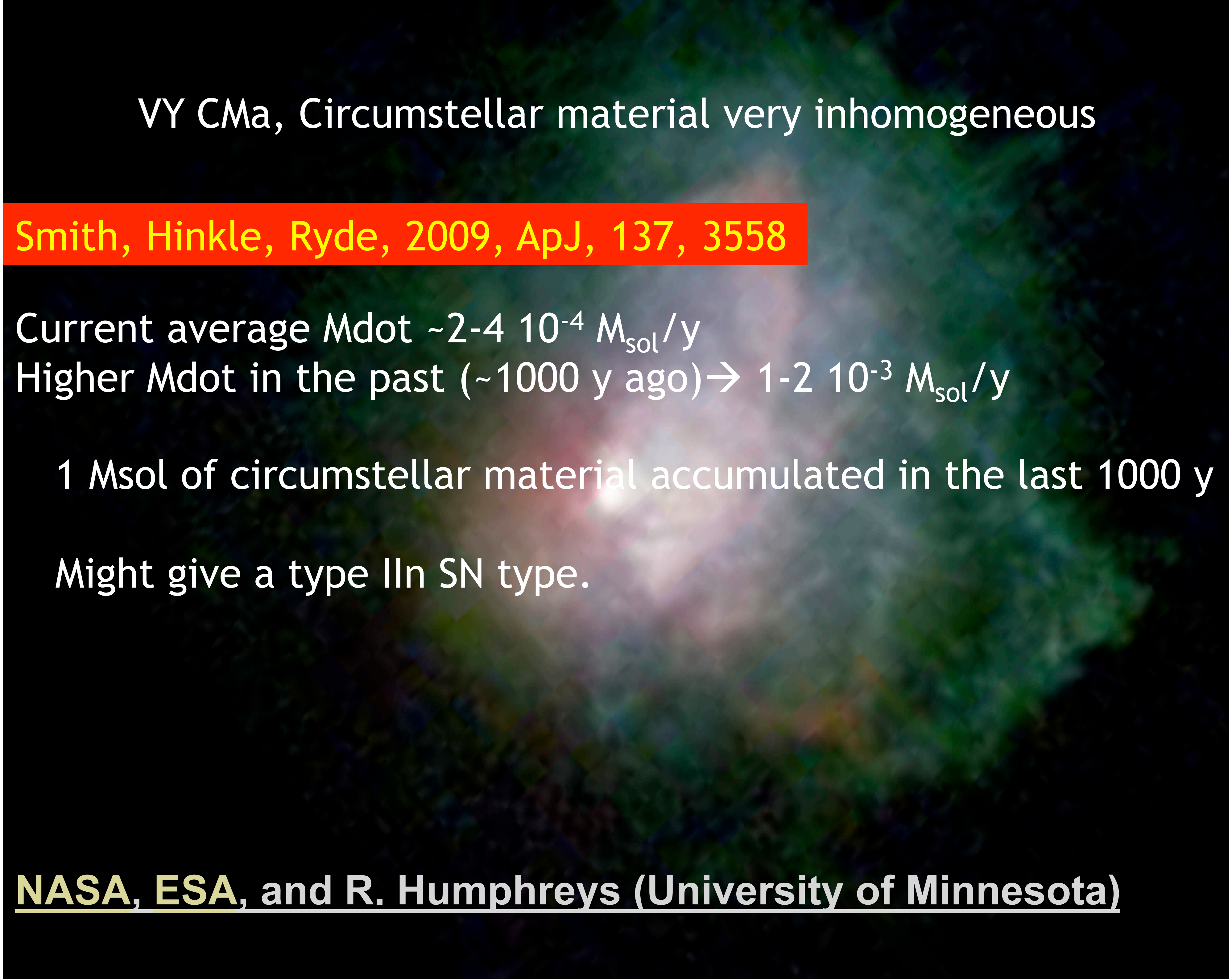
VY CMa, Circumstellar material very inhomogeneous

Smith, Hinkle, Ryde, 2009, ApJ, 137, 3558

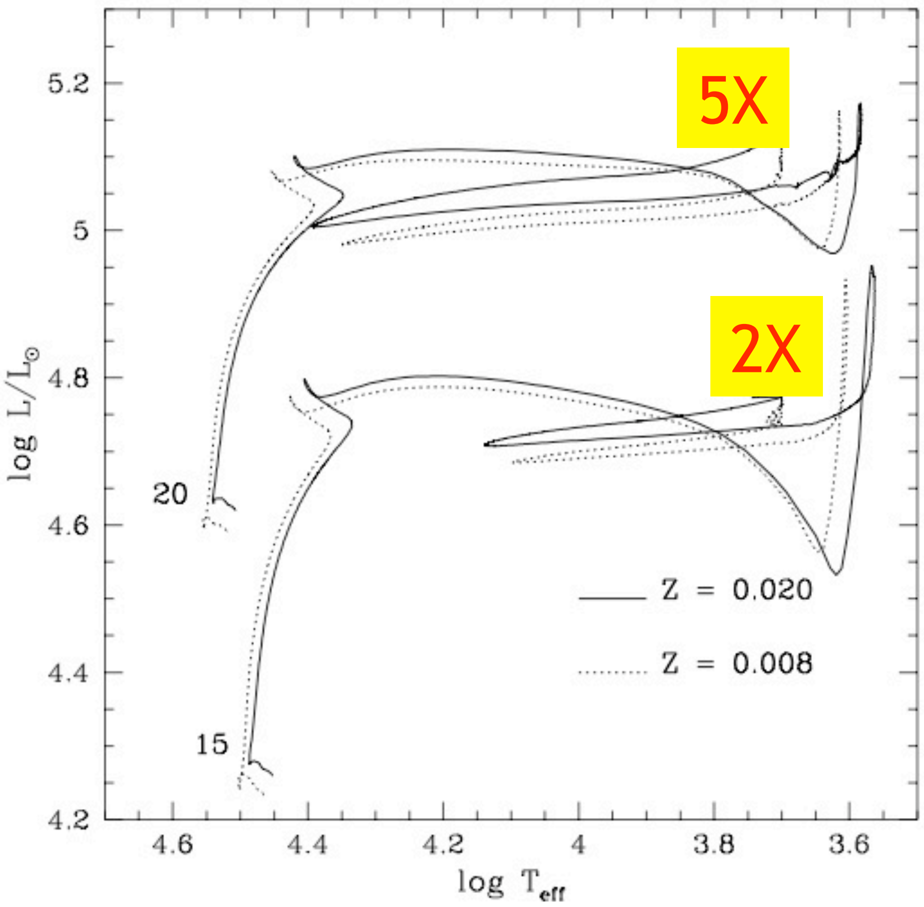
Current average Mdot ~2-4 10^{-4} M_{sol}/y
Higher Mdot in the past (~1000 y ago)→ 1-2 10^{-3} M_{sol}/y

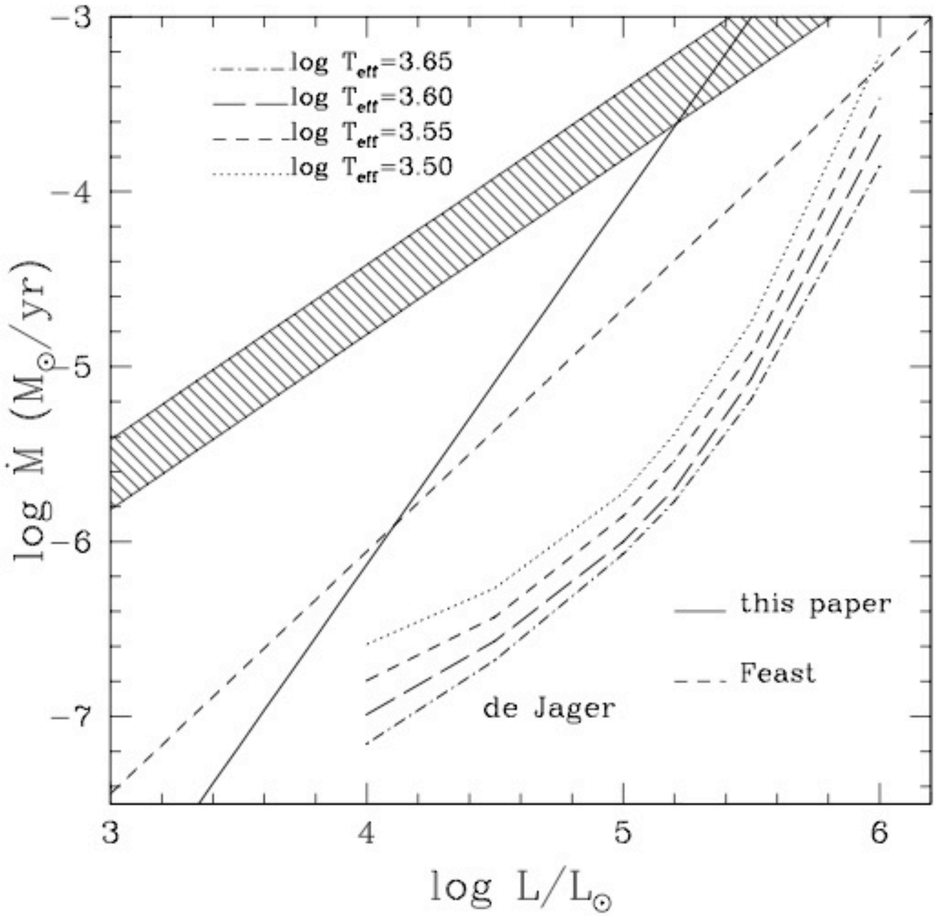
1 Msol of circumstellar material accumulated in the last 1000 y

Might give a type IIn SN type.



NASA, ESA, and R. Humphreys (University of Minnesota)





Salasnich, Bressan, Chiosi, 1999, A&A, 342, 131

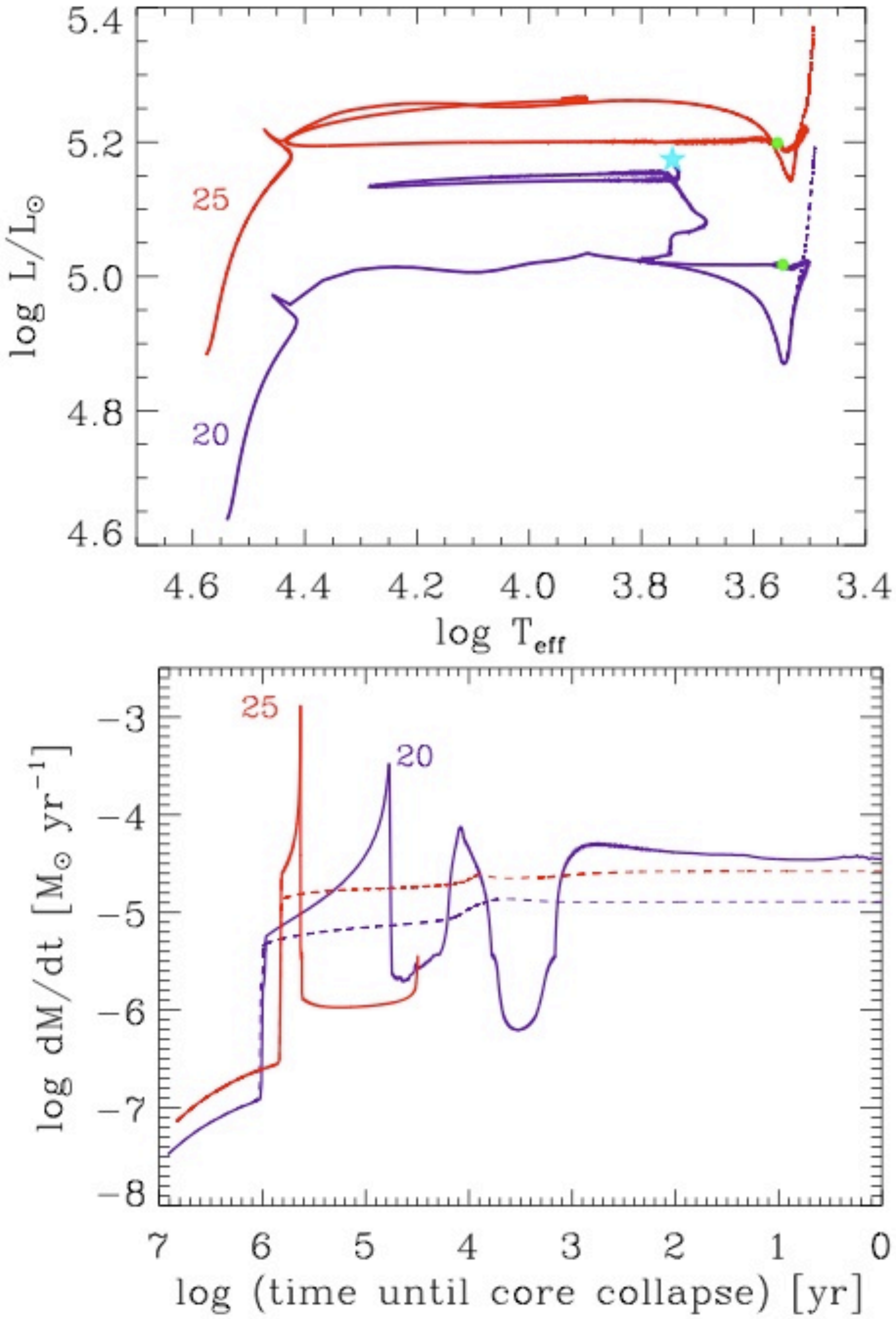
See also Yoon & Cantiello , 2010, eprint arXiv:1005.4925

20 M_{sol} % He-burning lifetime with log T_{eff} > 4.2
End He-burning surface hydrogen ~0.5.

Reduction inferior mass limit for removal of outer envelope from 25 M_{sol} to ~19 M_{sol}

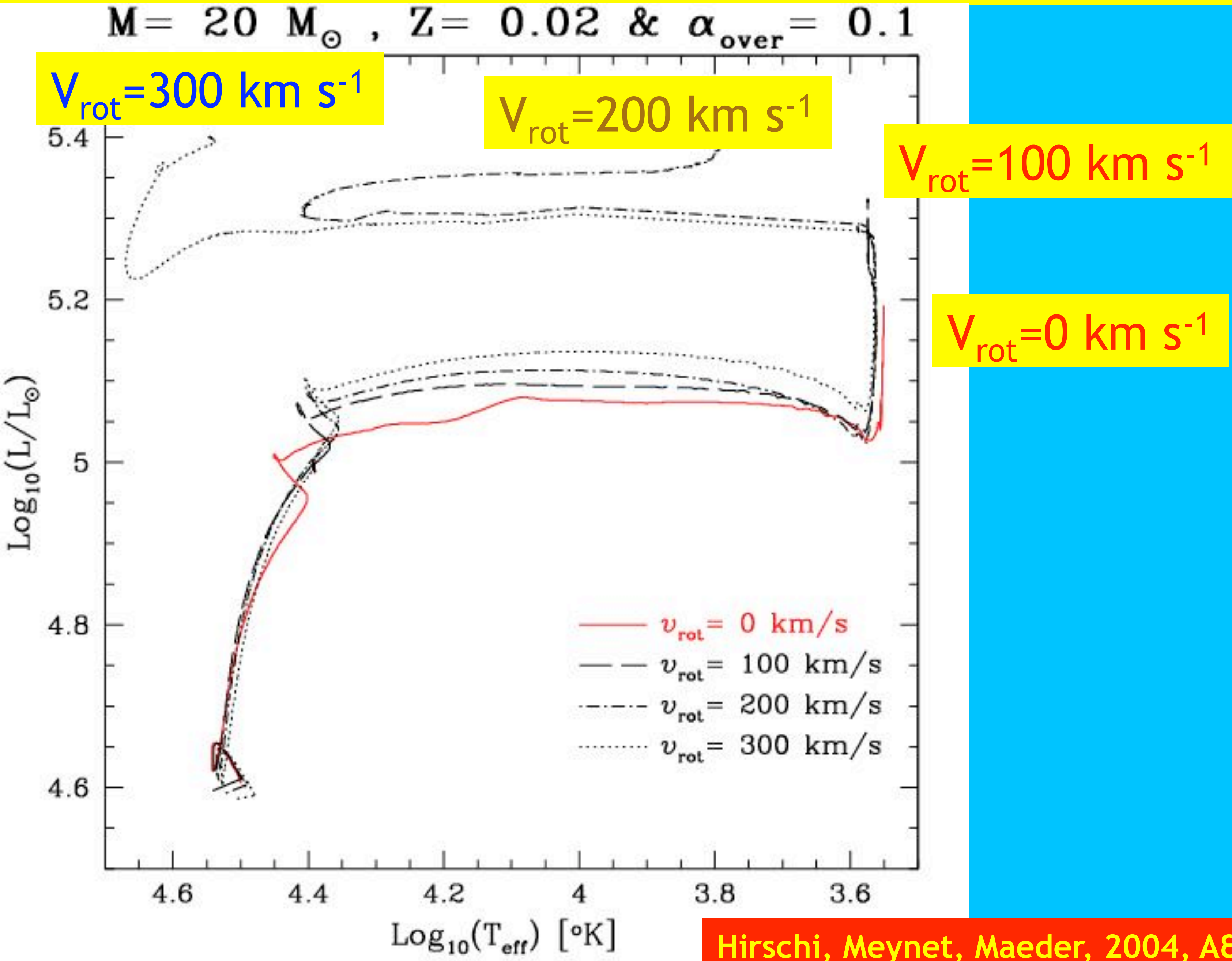
May explain lack of SNII-P progenitors with M > 17 M_{sol}

Progenitors of type IIn with circumstellar envelope of only a few M_{sol}

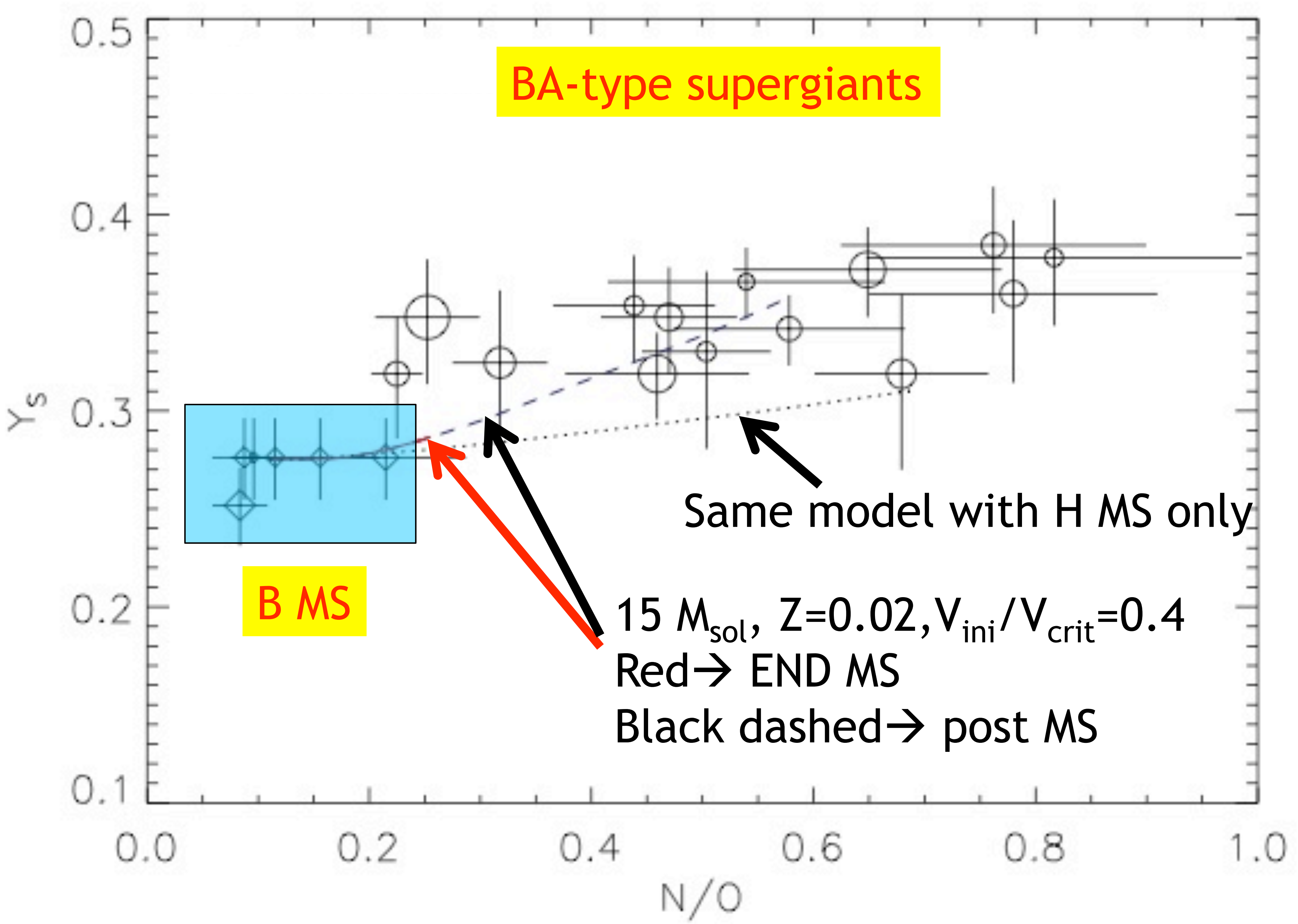


Yoon & Cantiello , 2010, eprint arXiv:1005.4925

Effect of rotation



Hirschi, Meynet, Maeder, 2004, A&A, 425, 649



Przybilla,Firnstein,Nieva, Meynet, Maeder, 2010, A&A, accepted

Yellow supergiants

Upper Luminosity: OK

Theory predict too many
Stars here not OK

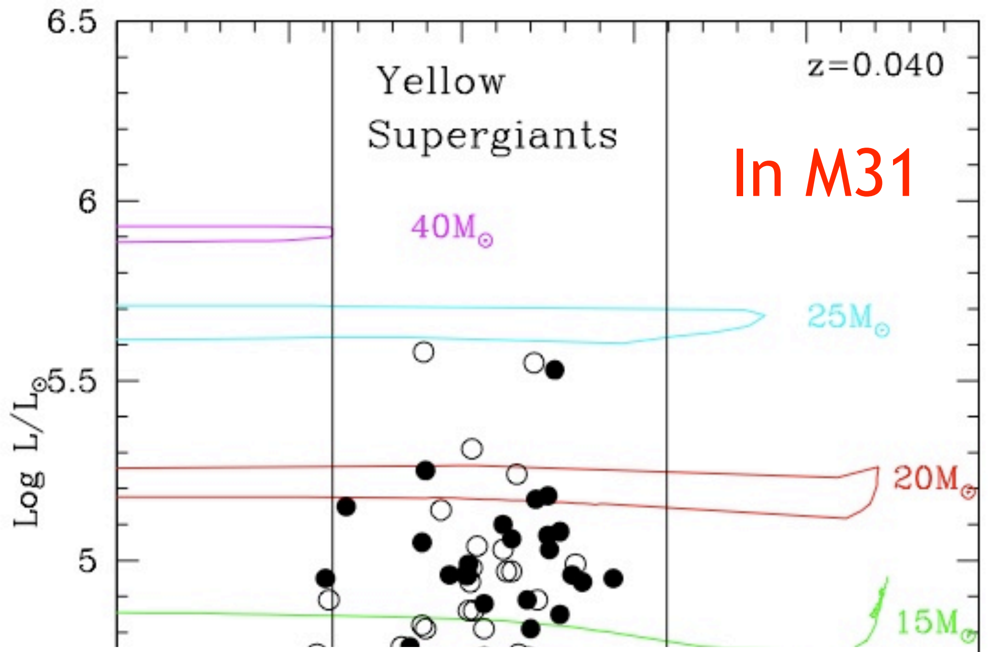


Table 6. Number of Yellow Supergiants Compared to Models

Models from Meynet & Maeder 2005

Mass Range	# All	# Certain	Ratio relative to 12-15$M_\odot$ All	Certain	Models
12-15$M_\odot$	41	20	1.0	1.0	1.0
15-20$M_\odot$	28	16	0.7	0.8	0.6
20-25$M_\odot$	8	4	0.2	0.2	0.2
25-40$M_\odot$	0	0	0.0	0.0	0.5
15-25$M_\odot$	36	20	0.9	1.0	0.8

.5

03, 441

Z=0.014 with rotation, in prep

CONCLUSIONS

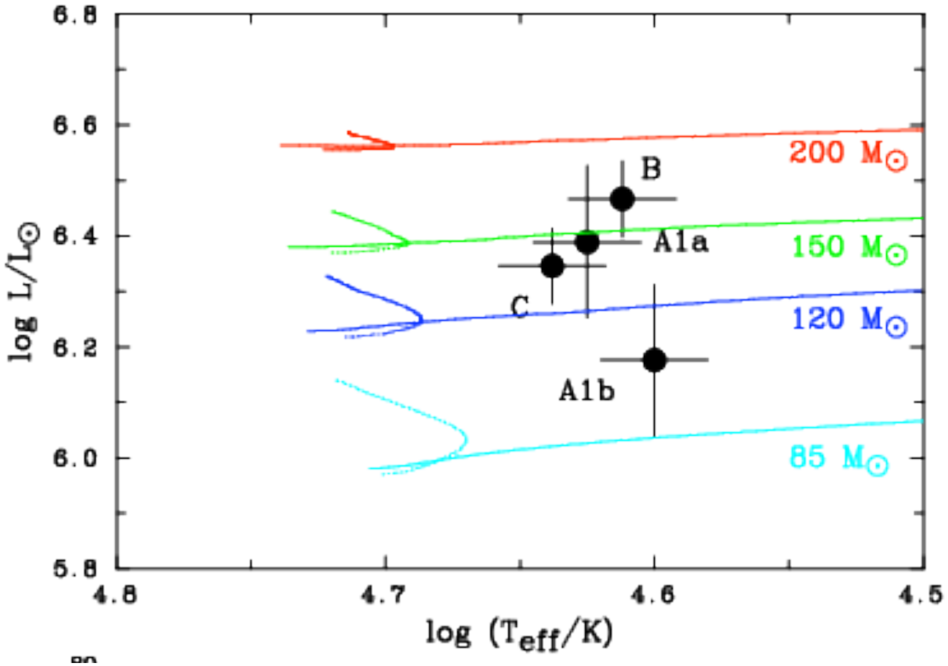
→Mass loss and mixing are key factors
→M, Z, rotation, magnetic field, binariry
→Diversity of SN outcomes

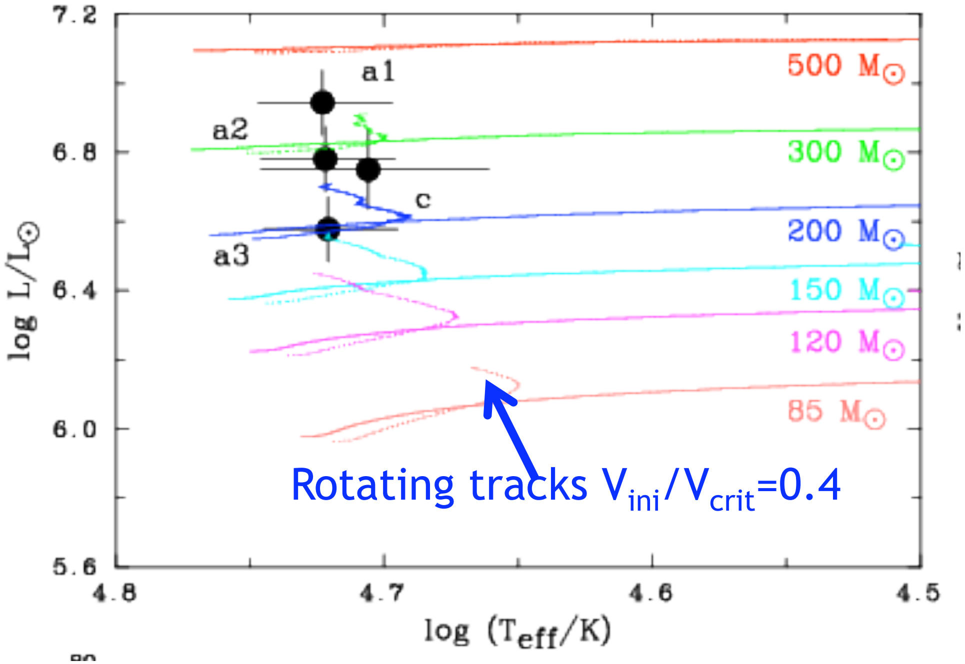
Difficulty is to disentangle these various effects in order to estimate their respective importance

→ Mass loss rates for RSG are likely underestimated

Milky way, NGC 3603 :
10^4 M_{sol}, , age ~1.5 Myr
Masses→ 83 – 180 M_{sol}

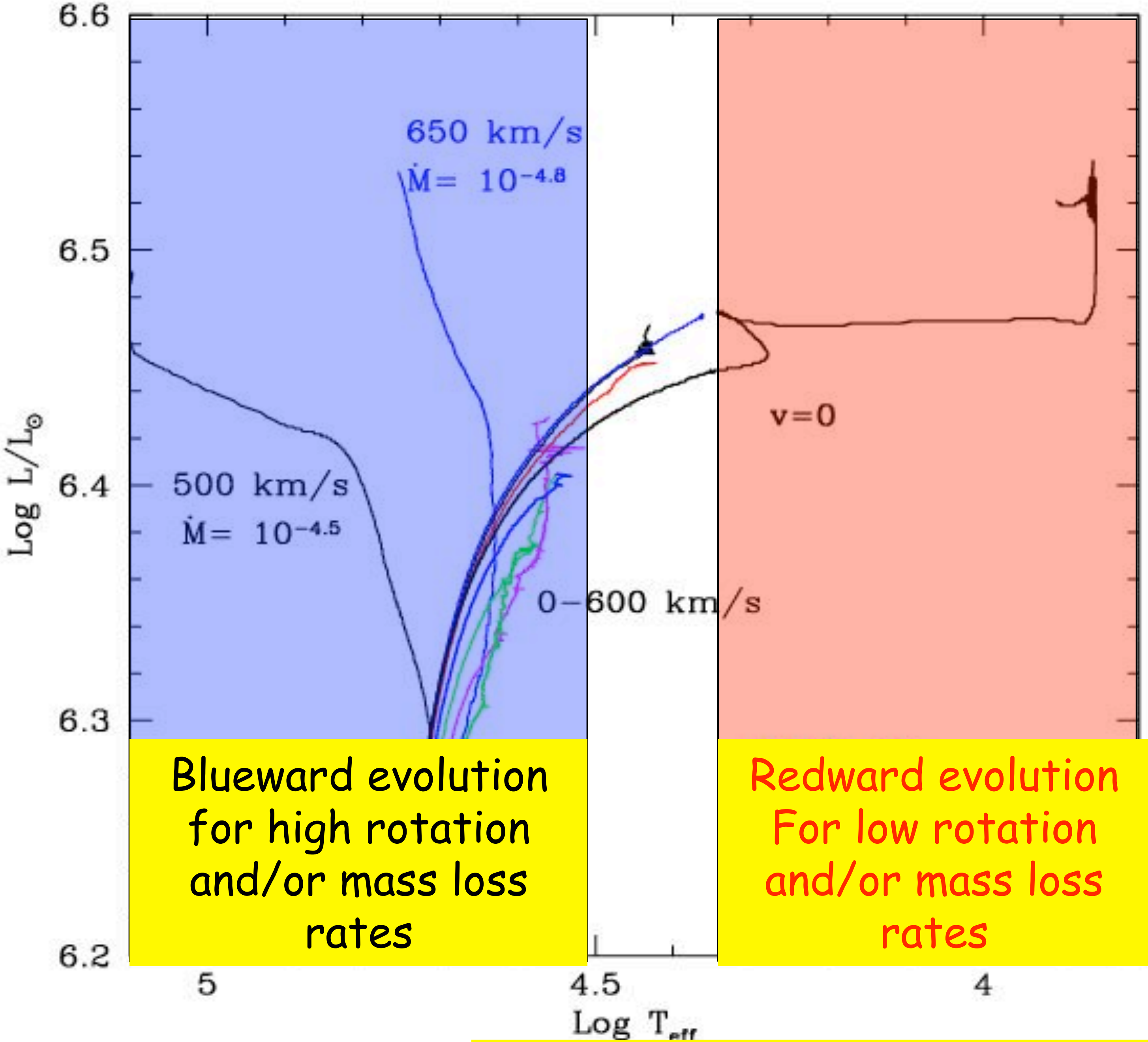
LMC, R136 :
5 10^4 M_{sol}, , age ~1.7 Myr
Masses→ 135- 320 M_{sol}



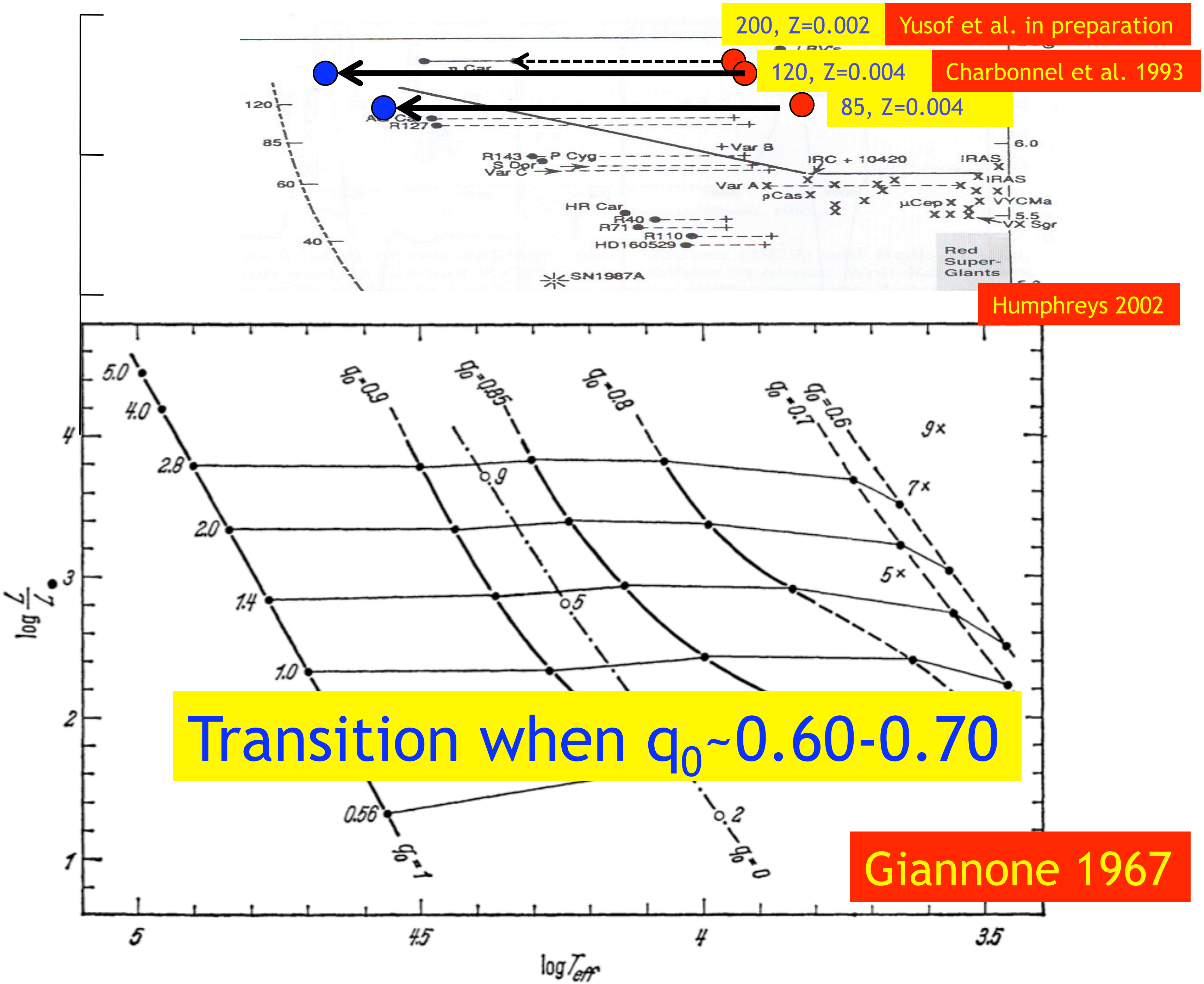


Crowther, Schnurr, Hirschi, Yusof, Parker, Goodwin, Abu Kassim, 2010, MNRAS, in press

STARS WITH MASSES ABOVE 150 M_{sol}



Maeder, Meynet, Hirschi, 2005, ASP Conf Ser. 332


200, Z=0.002
Yusof et al. in preparation
120, Z=0.004
Charbonnel et al. 1993
85, Z=0.004
Humphreys 2002
Red Super-Giants
SN1987A
Transition when q$_0$~0.60-0.70
Giannone 1967
log T_{eff}
log $L/L_\odot$

150 M_{sol}, Z=0.002

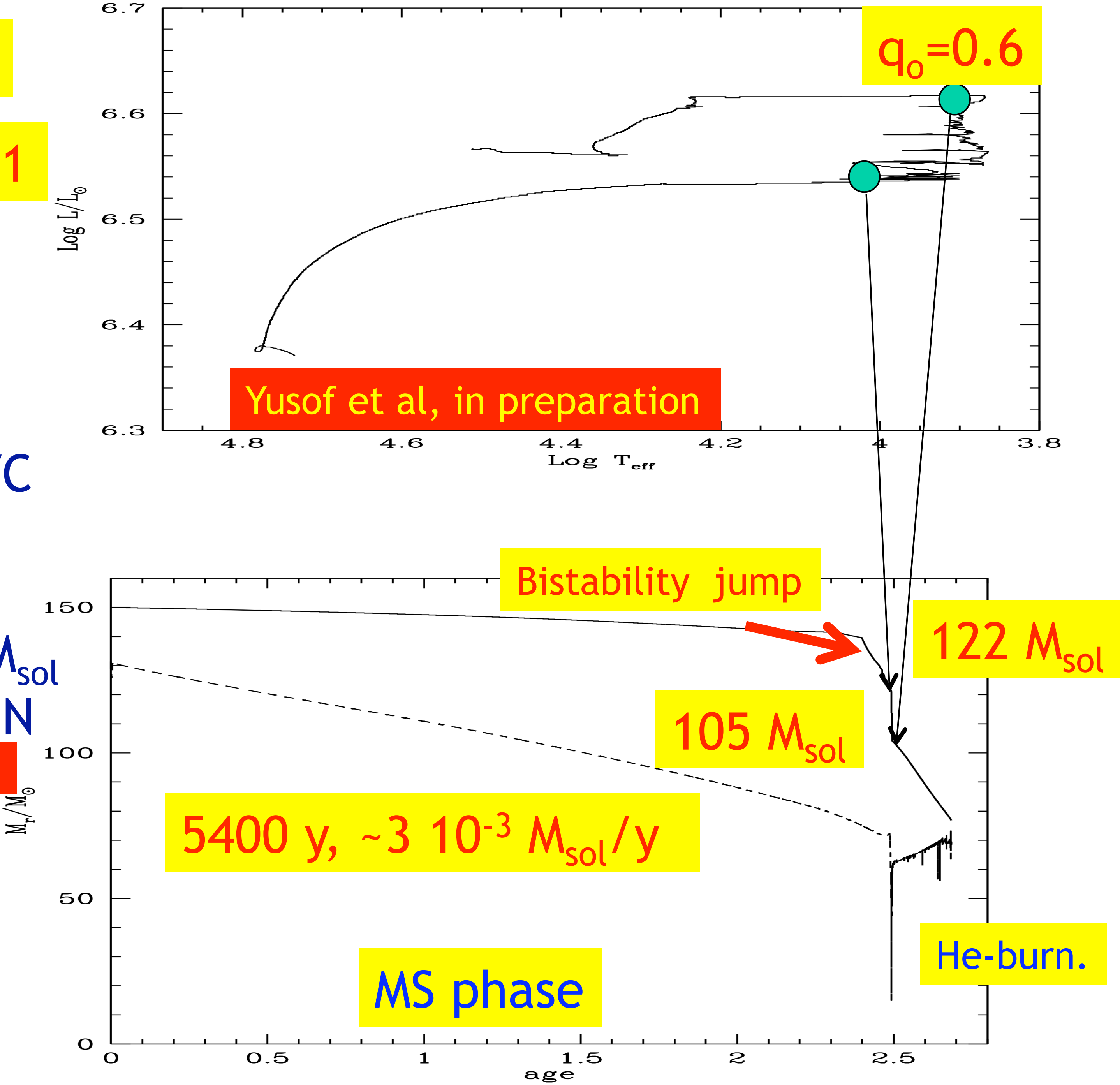
M_{dot}: Vink et al 2001

NO LBV explosion

SN progenitor→ WC

He core mass ~70 M_{sol}
→ Pair Instability SN

Woosley, Blinnikov, Heger , 2007

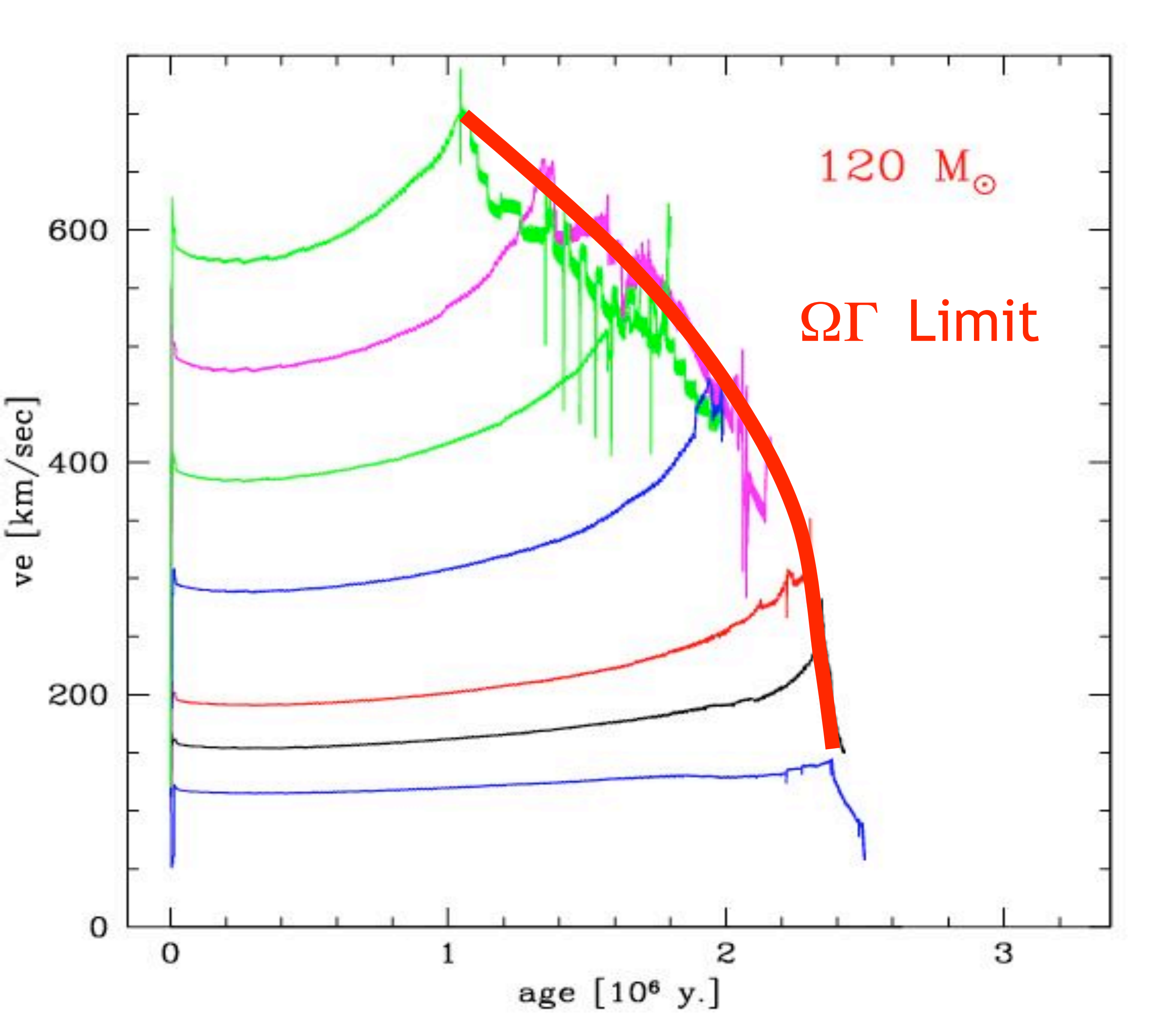


Possible reason for high mass loss rates

L increases
M decreases

Γ increases
Ve increases
Vcrit decreases

→ Strong mass loss



CONCLUSIONS

→ The case of SN originating from LBV must be very rare

→ Very massive stars (if Mdot not too high, Z low) → PISNe

CONSTRAINTS ON CC SNe
CAN ALSO PROBABLY COME FROM
POWERFUL STARBURSTS→ SUPERNOVAE PEAK