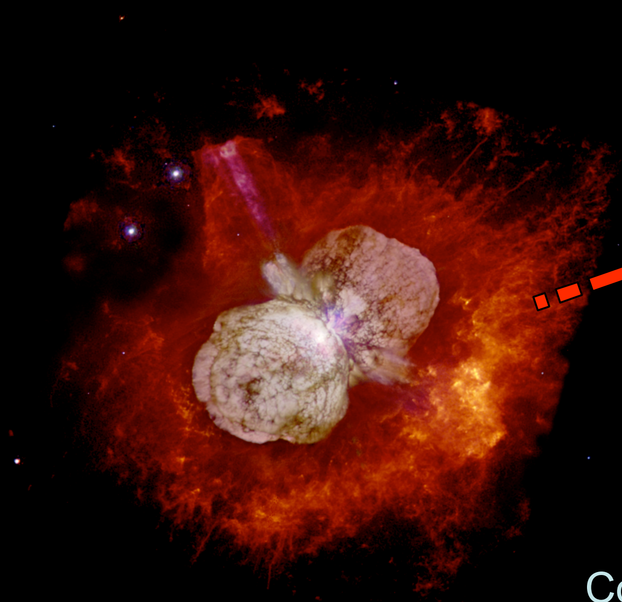
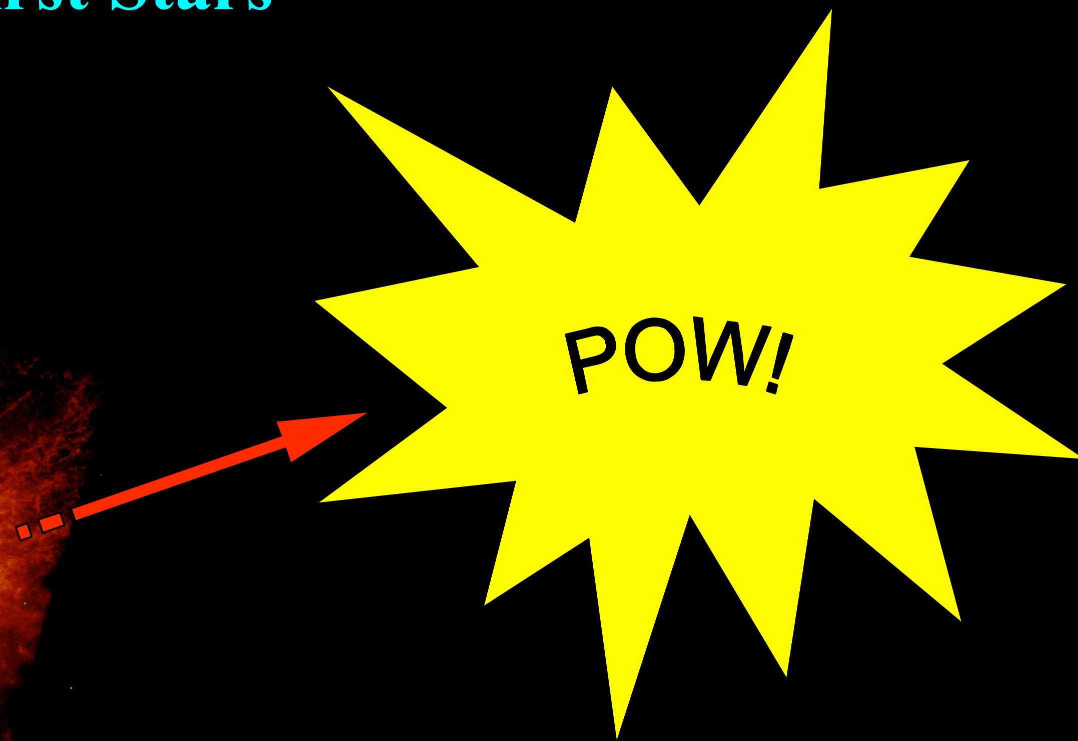
Possible Detection of a Pair-Instability Supernova in the Modern Universe, and Implications for the Evolution of the First Stars

Nathan Smith
UC Berkeley





Collaborators on SN2006gy
UC Berkeley: A. Filippenko, W. Li, R. Foley, D. Pooley, R. Chornock, J. Silverman, J. Bloom, C. Hansen
U Texas: C. Wheeler, R. Quimby

BRIGHTEST. SUPERNOVA. EVER. (SN2006gy)

Death of an extremely massive star like Eta Carinae

Smith et al. 2007, ApJ, 666, in press (astro-ph/0612617)

SN2006gy:

Type IIn in NGC1260 (S0/Sa at 73 Mpc)

Total $E_{rad} > 10^{51}$ ergs … requires either:

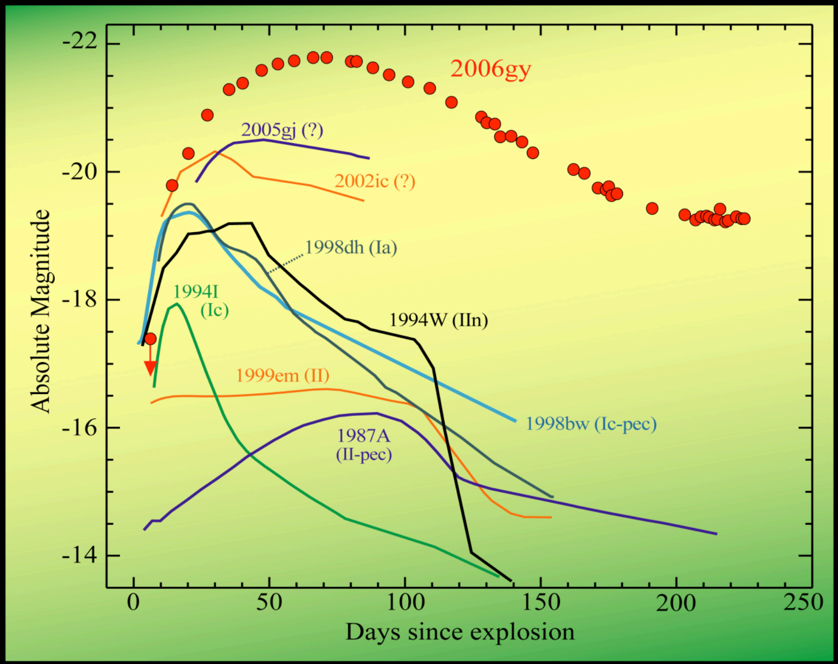
1. Star needs Mdot ≥ 0.5 $M_{\odot}$/yr if CSM int.
2. 10-20 $M_{\odot}$ of ^{56}Ni

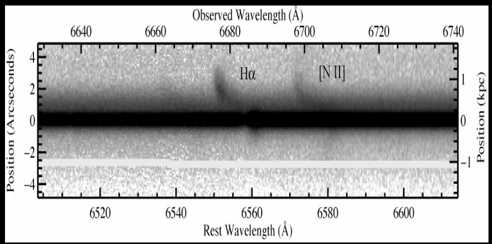
V_{exp}= 4,000 km/s (slow…massive H envelope)

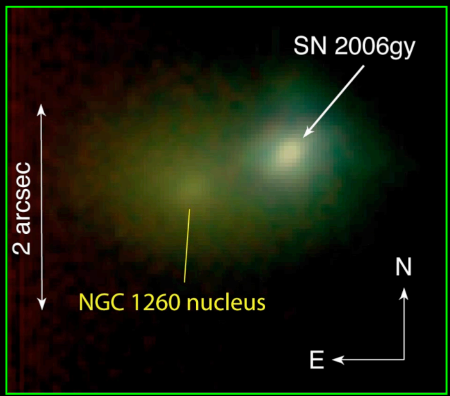
Massive circumstellar nebula (M = 10 $M_{\odot}$)
-- or wind with Mdot<1-2×10^{-2} $M_{\odot}$/yr
V_{exp}= 200 km/s
(not a RSG! More like an LBV)

Soft X-rays indicate CS interaction

---- indicate progenitor Mdot=1-5×10^{-4} $M_{\odot}$/yr
---- far too weak to account for L_{rad}.
---- ***SOFT*** X-rays are ***not*** heavily absorbed







Z ≈ solar
SFR about 1.2 $M_{\odot}$/yr
(Kennicutt 1998)

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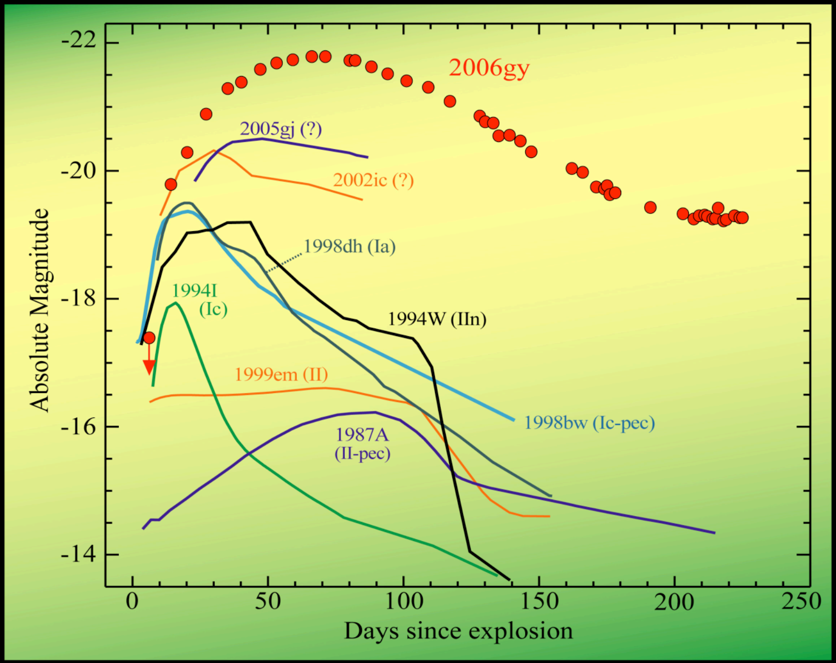

For CSM hypothesis:

L_{rad} requires
Mdot > 0.5 $M_\odot$/yr

Same as Eta Car's
average Mdot during
19th century LBV eruption.

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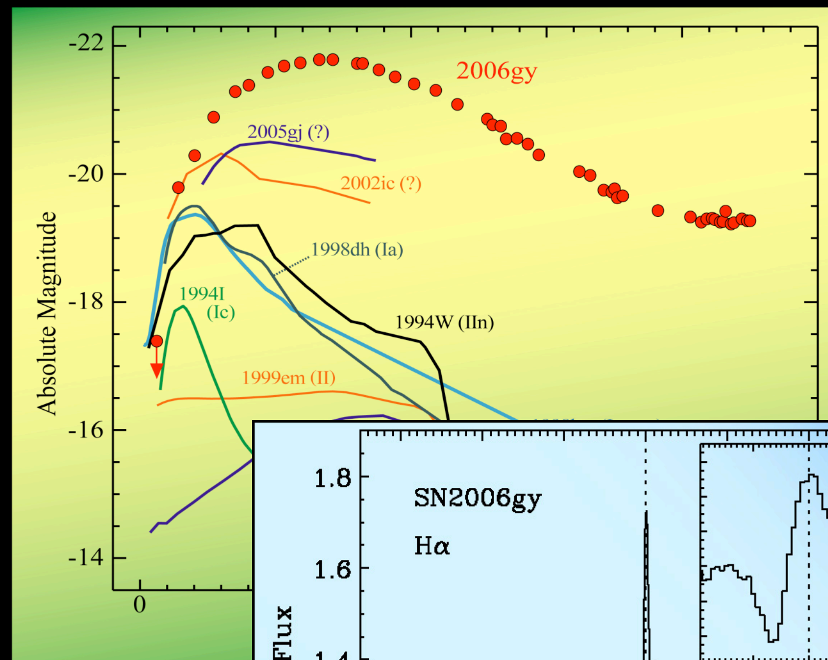

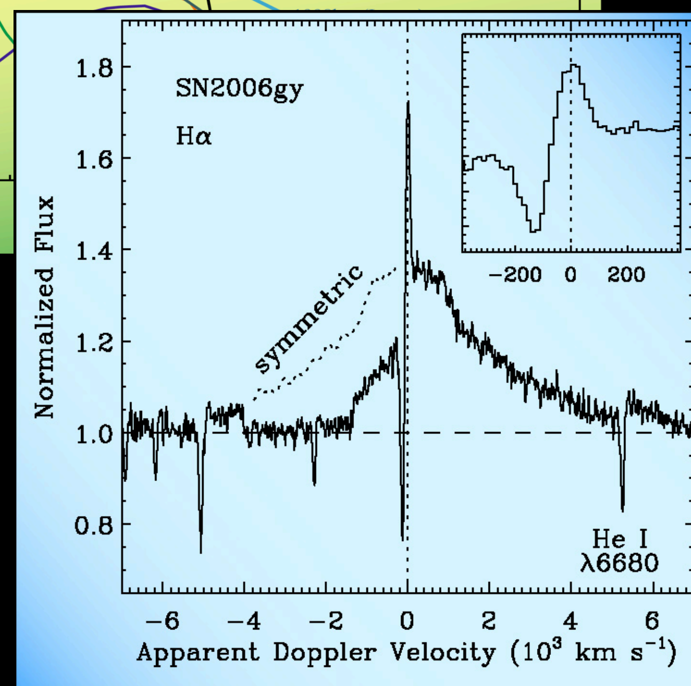

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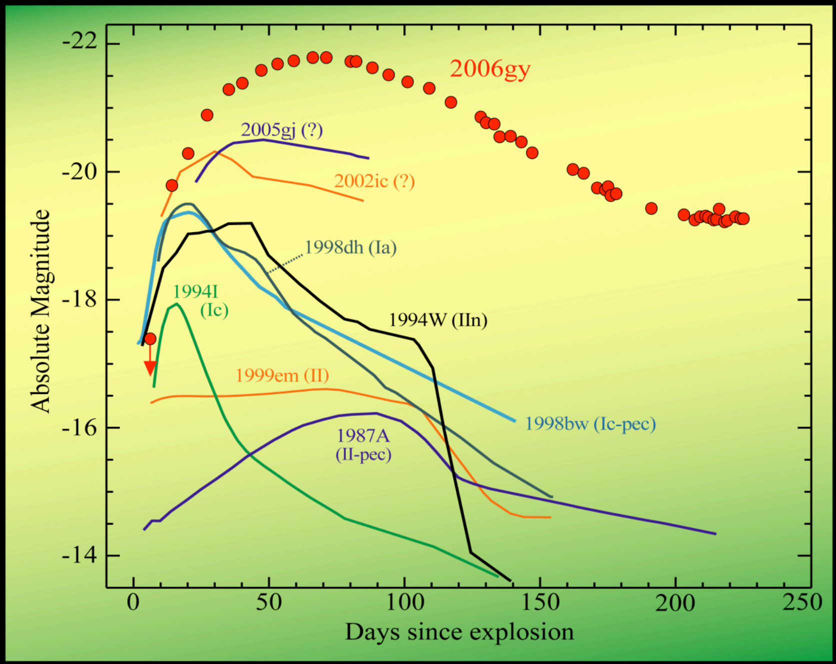

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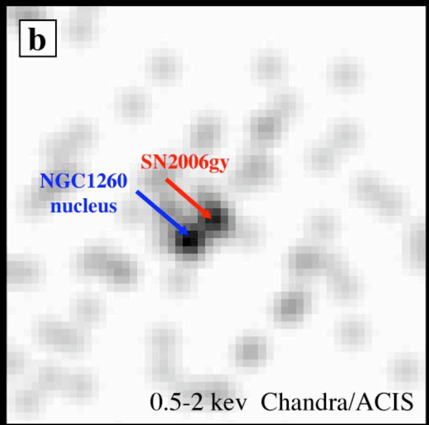
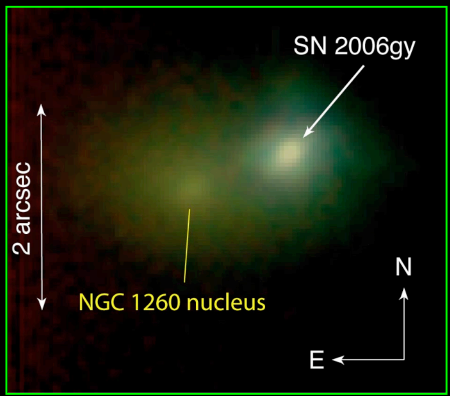




GEE, WHY WAS GY SO BRIGHT?

Two plausible options for the power source…

…both require a very massive star with H envelope intact.

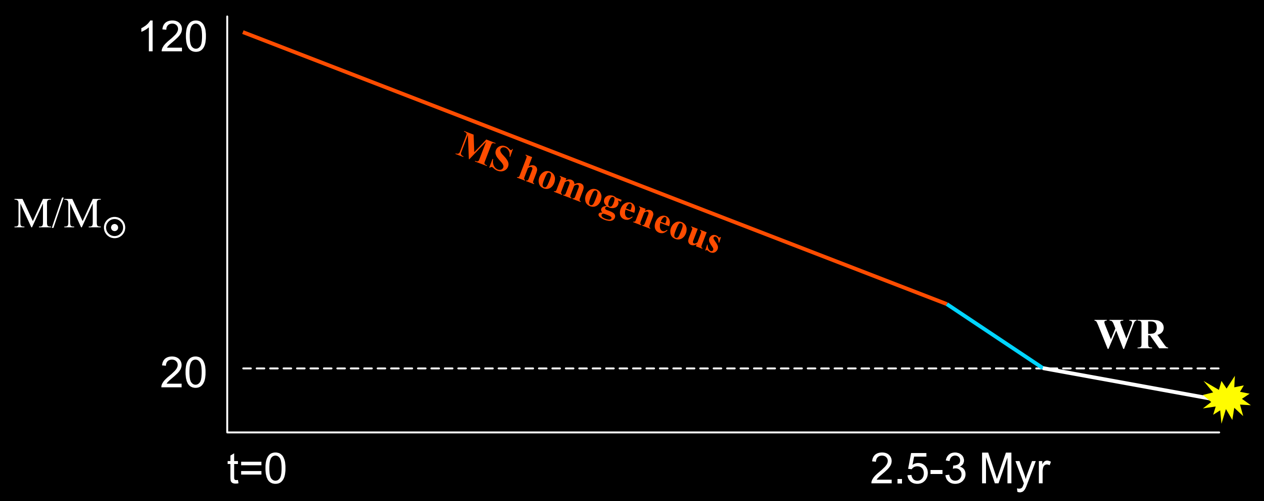
ENGINE:	***PROs:***	***CONs:***
CSM Interaction Shock runs into 10s of $M_\odot$ KE → Light (LBV eruption, PPI, ~~Type IIa~~)	We see CSM Interaction in IIn spectrum and X-rays Could work if star had Eta Car-like outburst 10-20 yr before final SN	X-rays: 1000x too weak narrow Hα: 50x too weak little/no deceleration light curve and spectrum unlike almost any other IIn
PISN need 10-20 $M_\odot$ of ^{56}Ni	Slow rise, low V_{Exp} very massive envelope Slow decay, long duration CSM interaction Mdot from X-rays and Hα are plausible (normal LBV wind)	Surprising ?

MASS LOSS AND MASSIVE STAR EVOLUTION

How can you get a PISN and Type IIn in the modern Universe?

Star needs to retain massive H envelope at death.

...But in the modern Universe, massive stars are supposed to lose mass through winds and become WR stars before they die.



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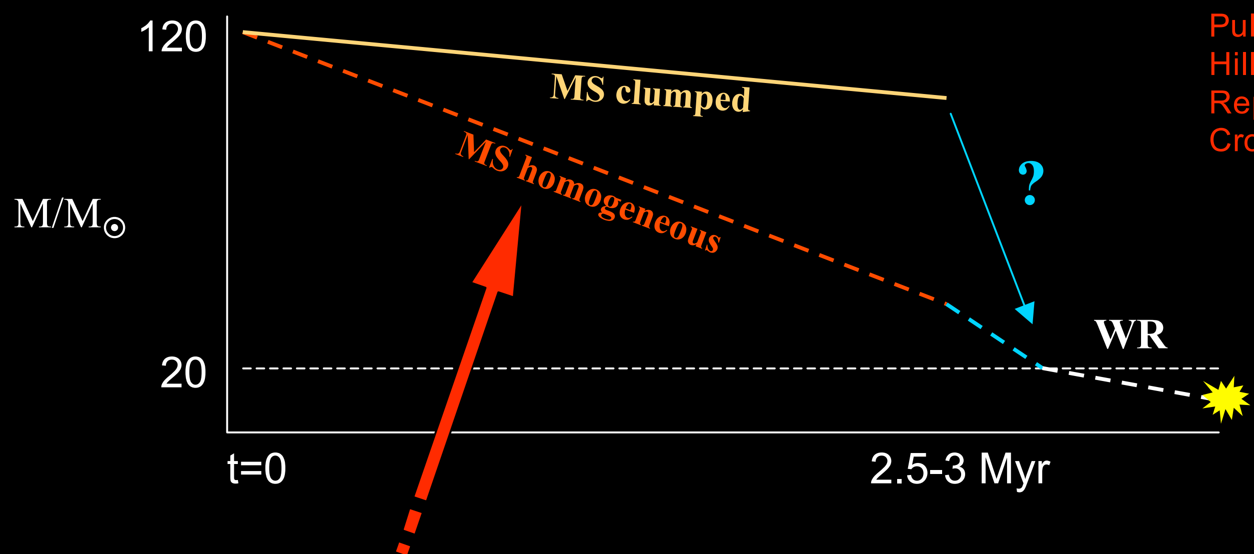
Instead, recent observations indicate that because of clumping in hot-star winds, O-star mass-loss rates ***are factors of 3-10 lower***.

Fullerton et al. 2006
Bouret et al. 2005
Puls et al. 2006
Hiller et al. 2003
Repolust et al. 2004
Crowther et al., etc.



Note: The so-called "standard" mass loss rates are those given by Nieuwenhuijzen & de Jager (1990), derived from Hα and radio continuum assuming ***homogeneous*** winds.

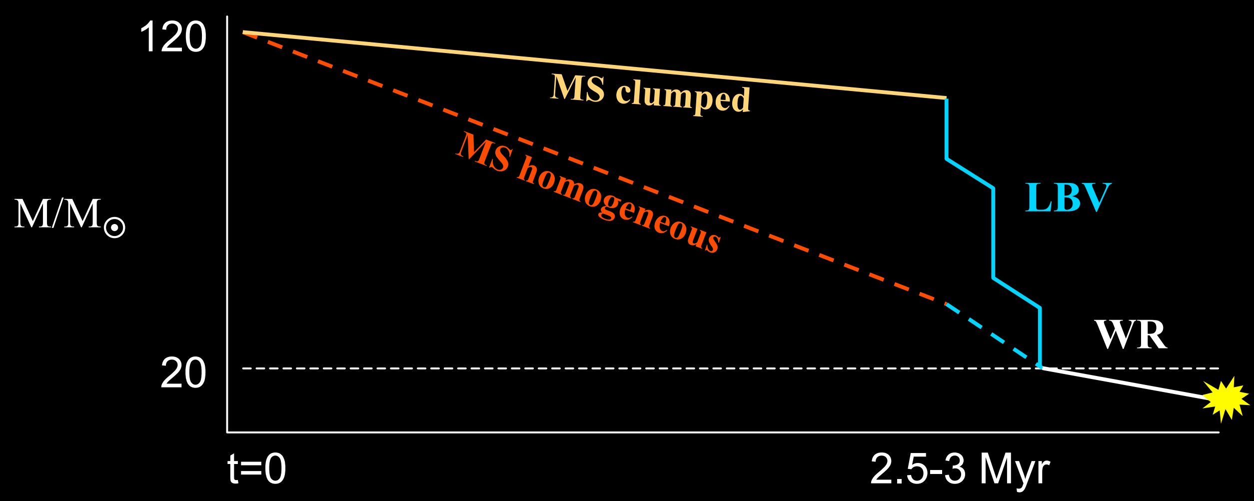
But..."standard" mass-loss rates have been *misoverestimated.*

MASS LOSS AND MASSIVE STAR EVOLUTION

This leaves us with two plausible alternatives...

OPTION 1: Giant eruptions of LBVs like Eta Carinae make up the difference.

(see Smith & Owocki 2006)



MASS LOSS AND MASSIVE STAR EVOLUTION

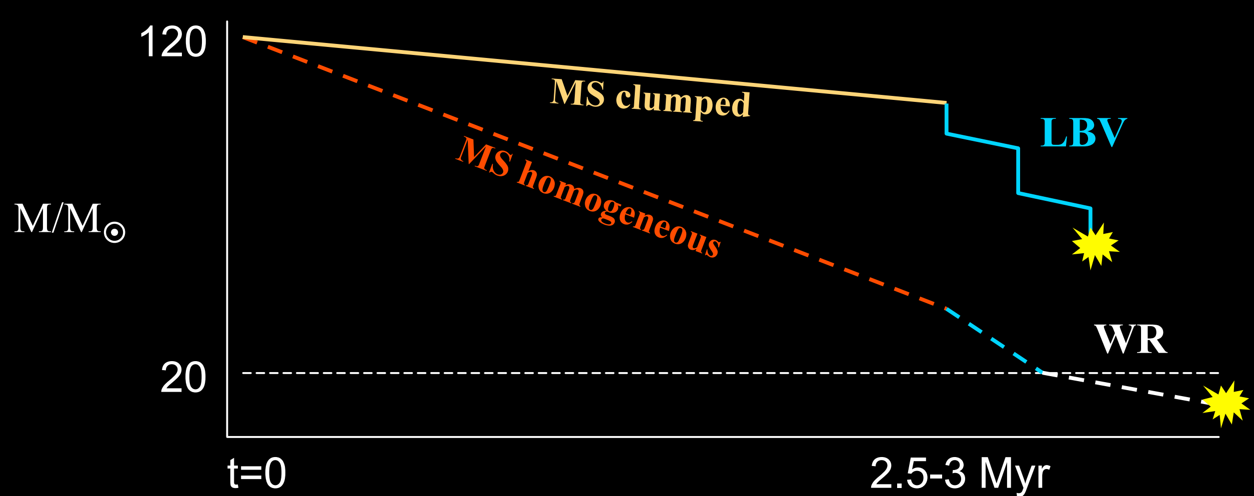
This leaves us with two plausible alternatives...

OPTION 1: Giant eruptions of LBVs like Eta Carinae make up the difference.

(see Smith & Owocki 2006)

or...

OPTION 2: Even LBV mass-loss is insufficient, and the star explodes "prematurely" without shedding its H envelope.



Type IIn SNe and SN2006gy ?

Caveat: For initial mass below 40 $M_{\odot}$ its no problem because they become RSGs.

BOTH are probably right, depending on initial mass...

MASS LOSS AND MASSIVE STAR EVOLUTION

At solar metallicity, MS mass loss is not so different from Pop III stars!

Very little mass loss on MS…

...star dies with more massive He core. Similar fate as PISN?

Angular Momentum evolution?

Will they have LBV-like eruptions?