# The mass-loss dominated lives of the most massive stars

HST

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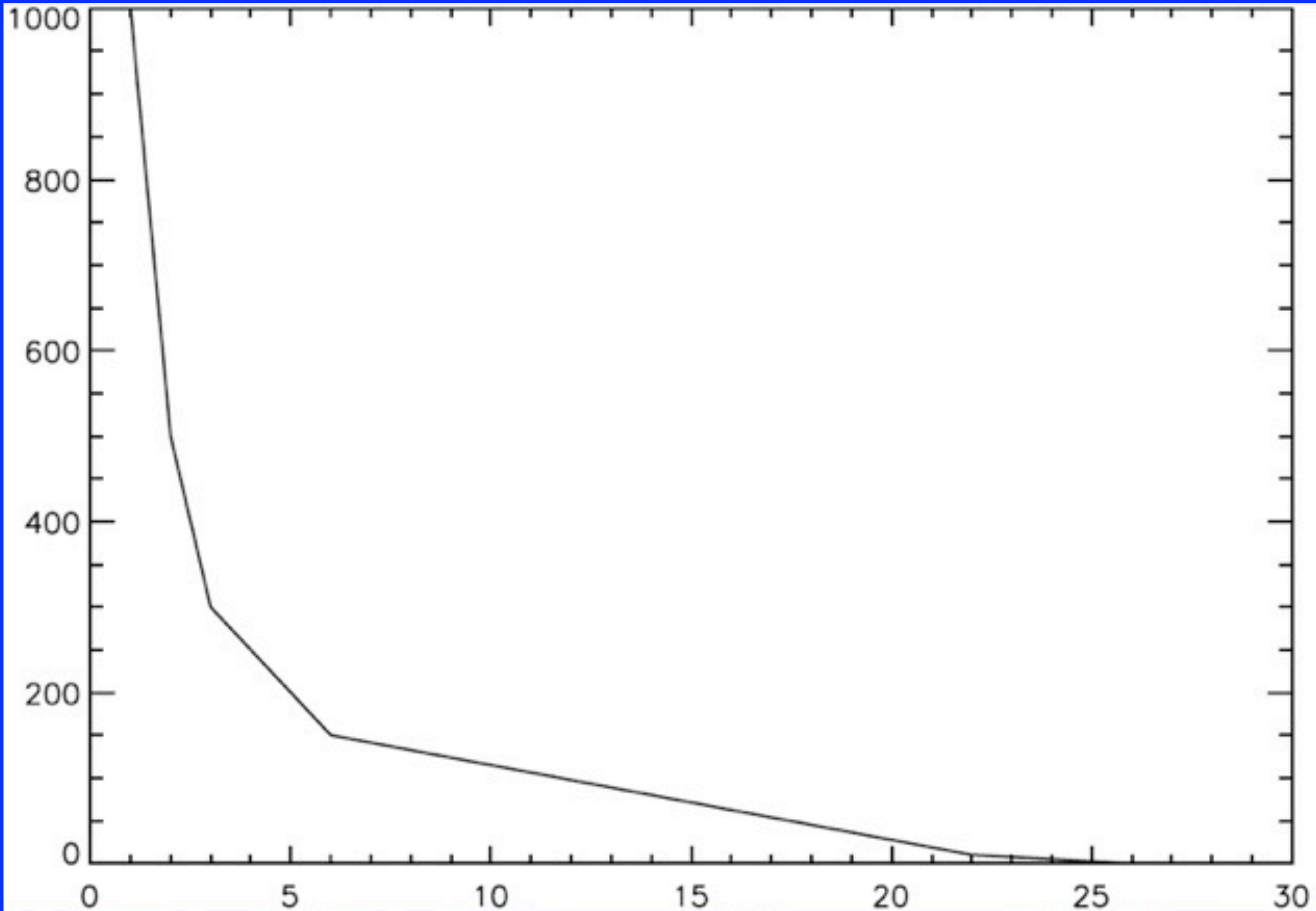

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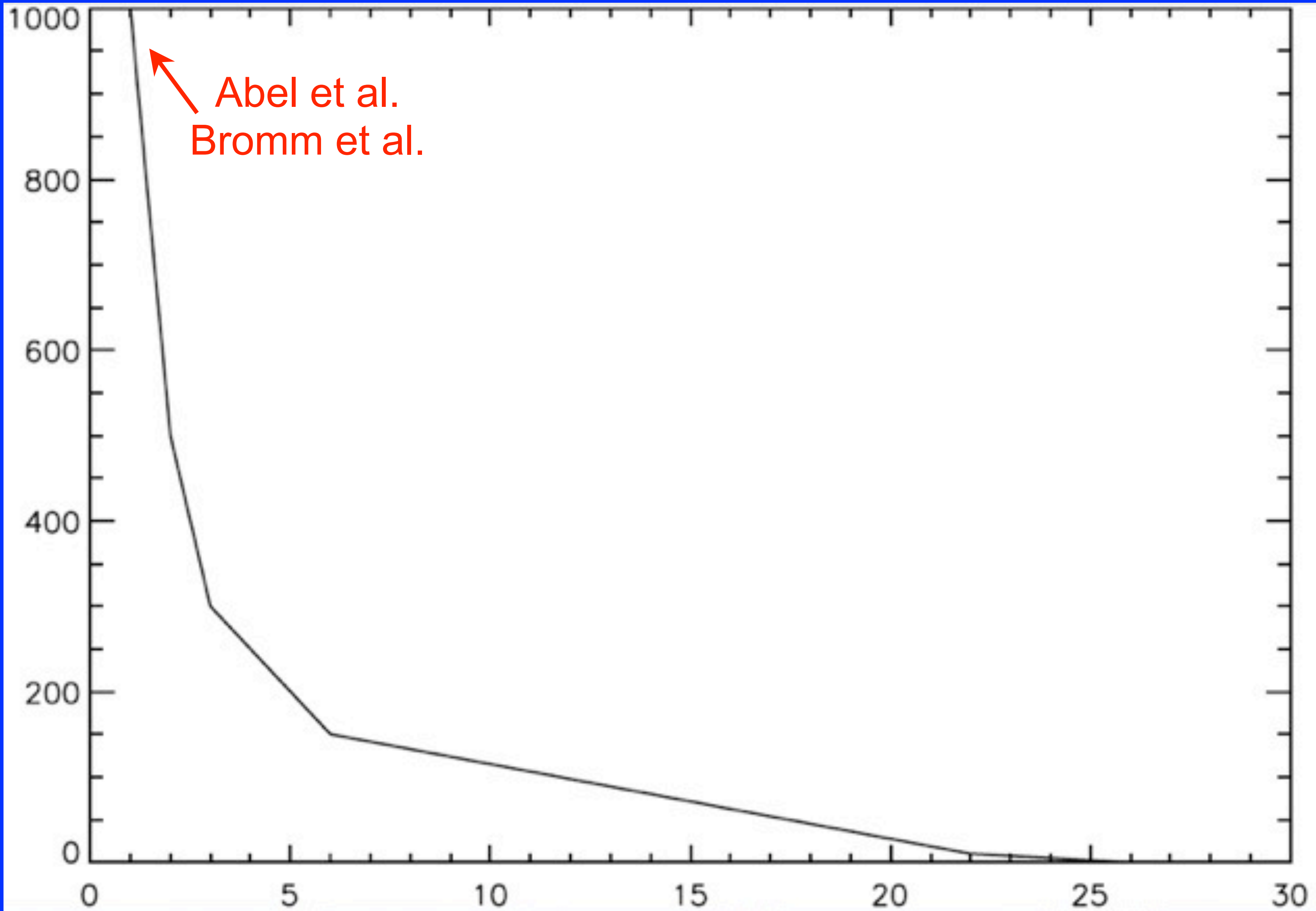
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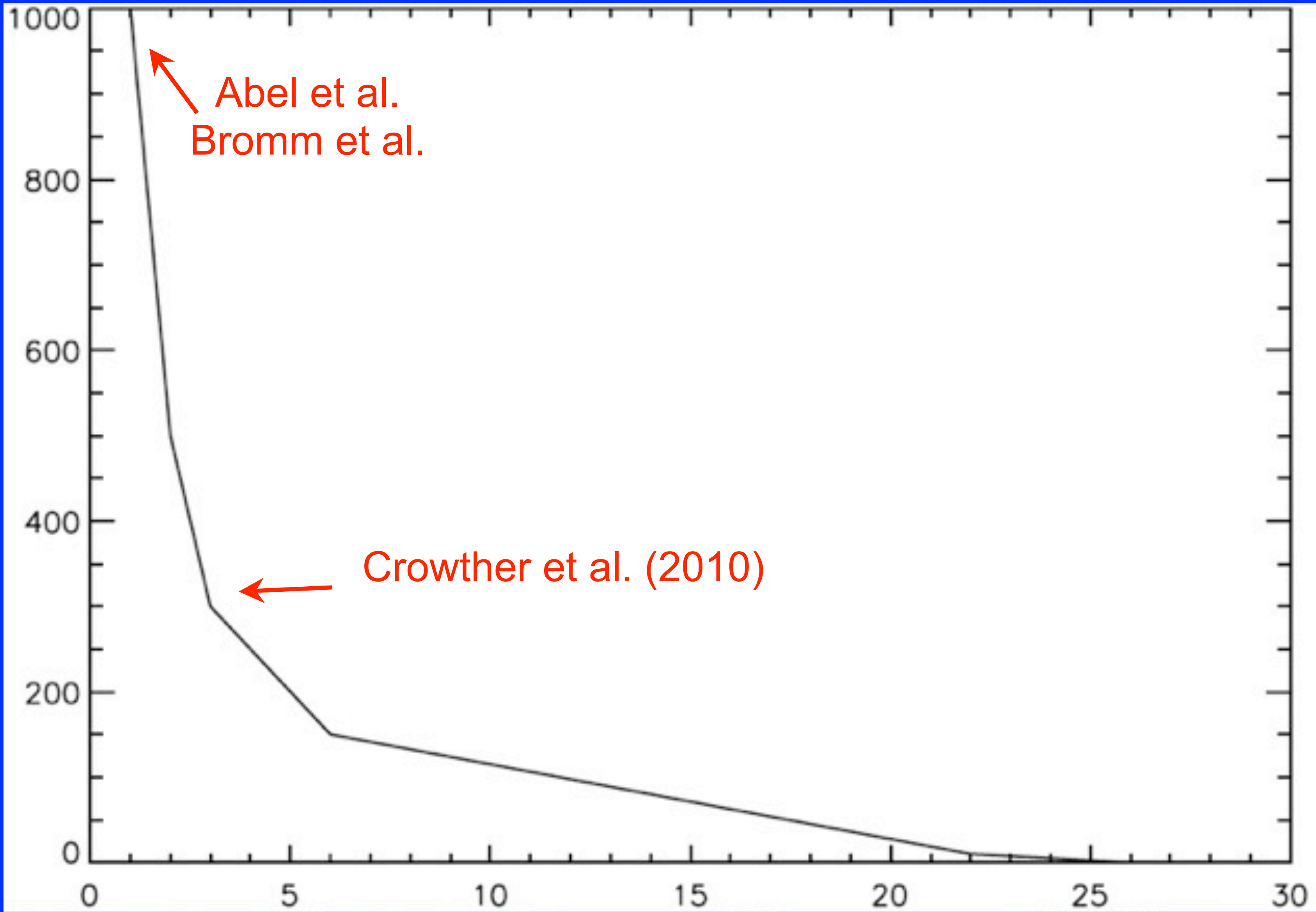
Abel et al.
Bromm et al.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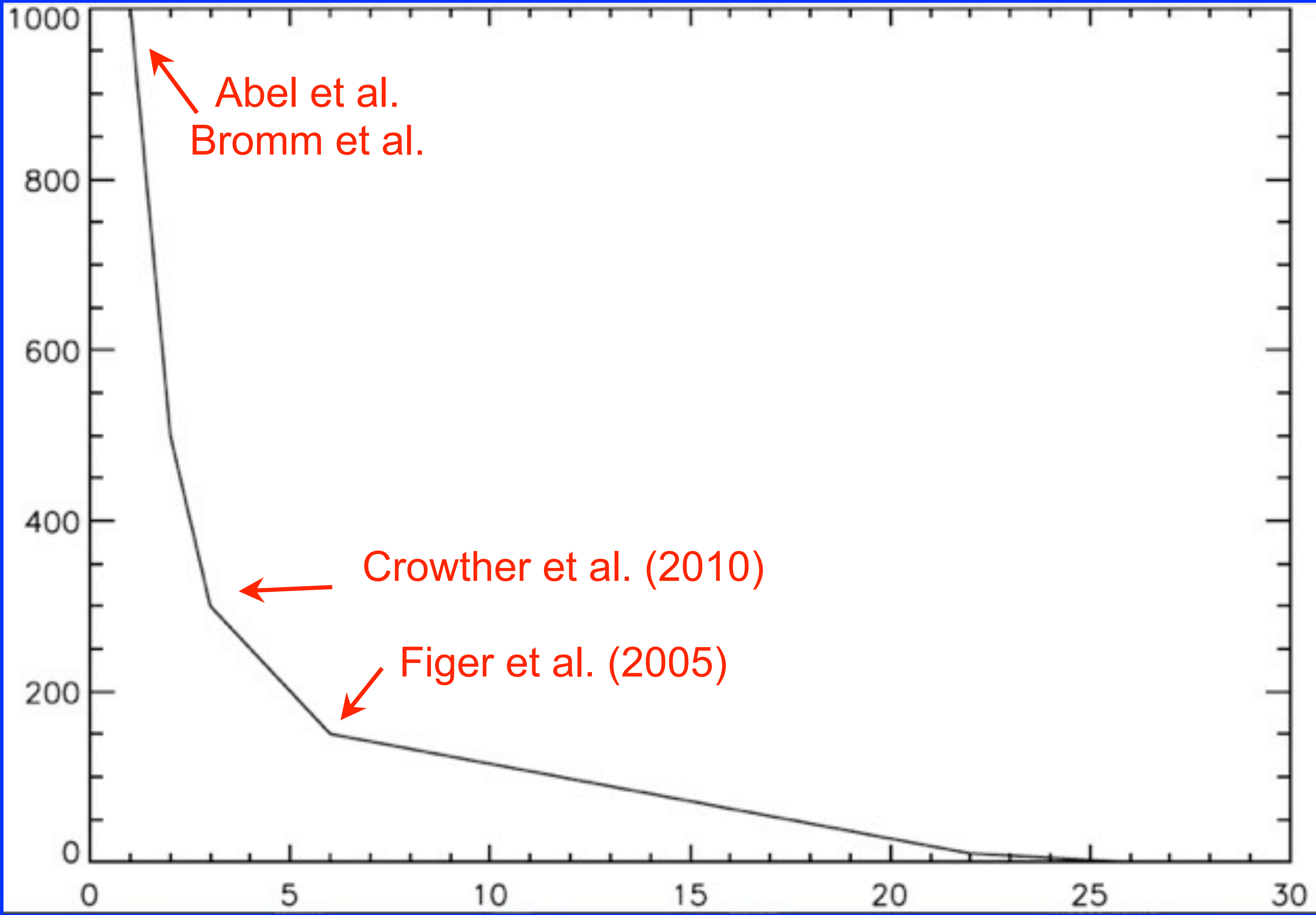
Crowther et al. (2010)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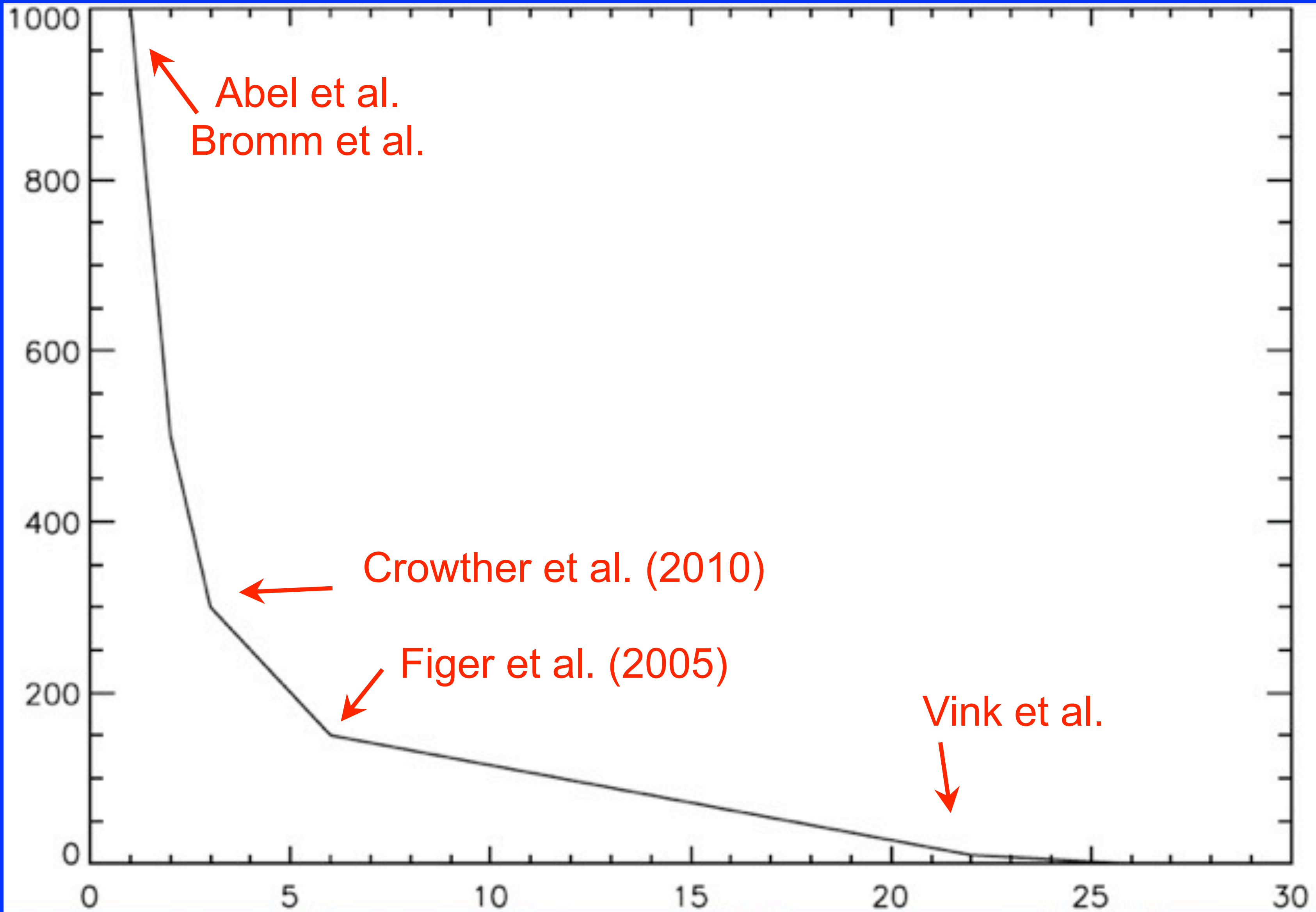

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Figer et al. (2005)
Vink et al.

# Outline

- Introduction on mass loss

- Gamma-dependence (WNh stars)
- Z-dependence (GRBs)
- Teff-dependence (LBVs and SNe II)

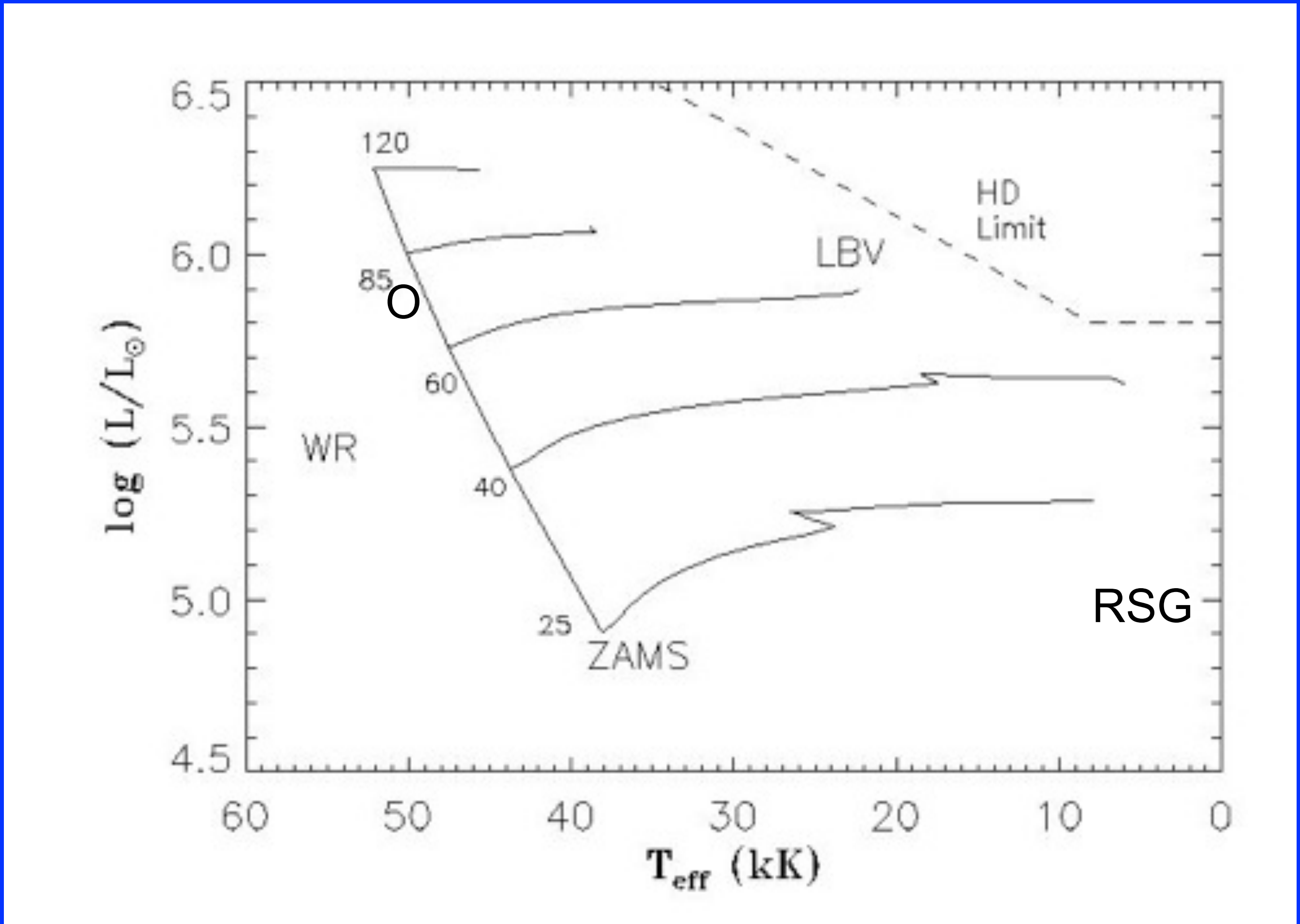
# Mass Loss

- Peeling off the star
  → O → LBV → Wolf-Rayet → SN Ibc
  (Conti 1976)

- Removal of angular momentum

  (Langer 1998, Maeder & Meynet 2000)

# Upper HRD- Massive Stars



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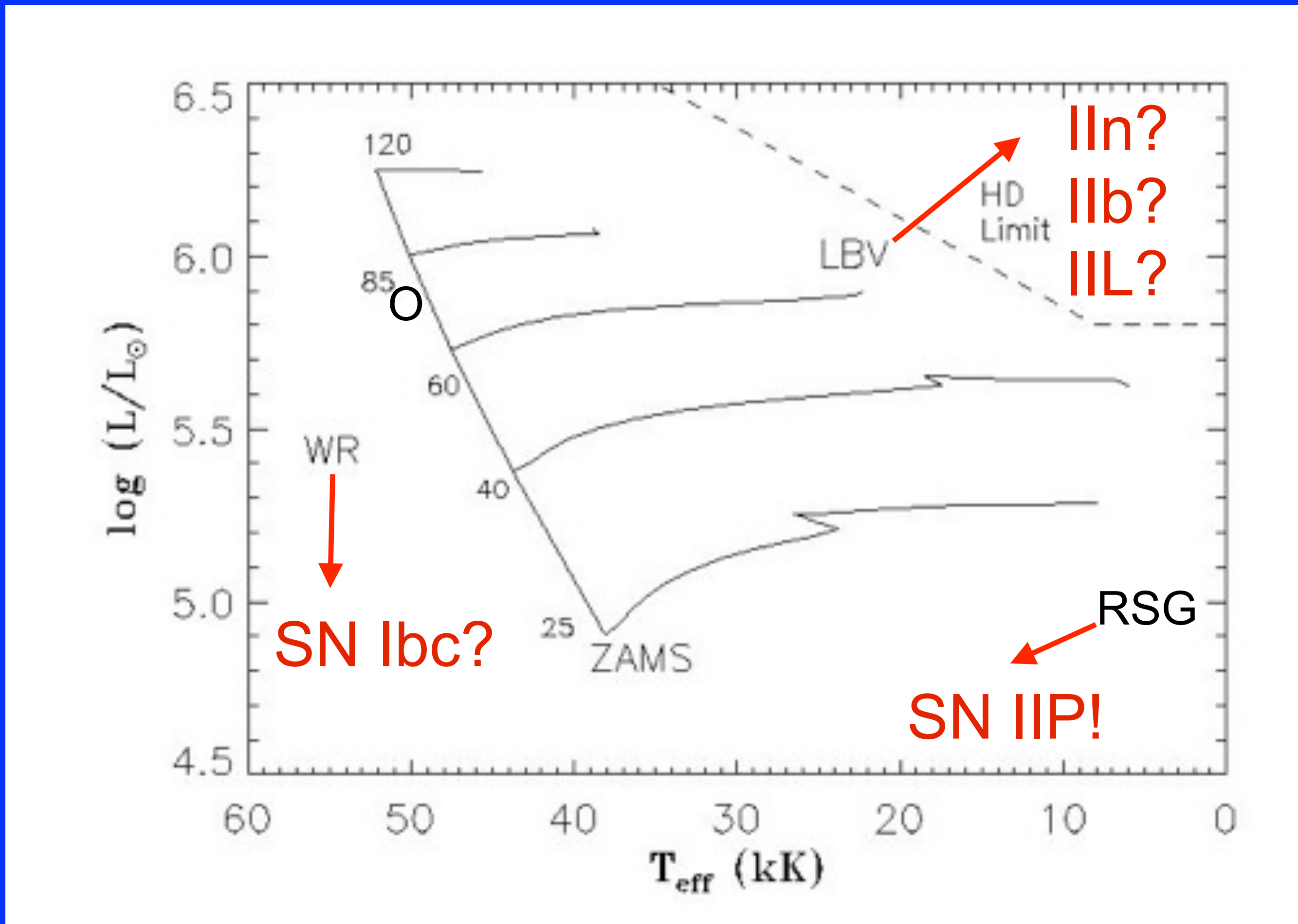

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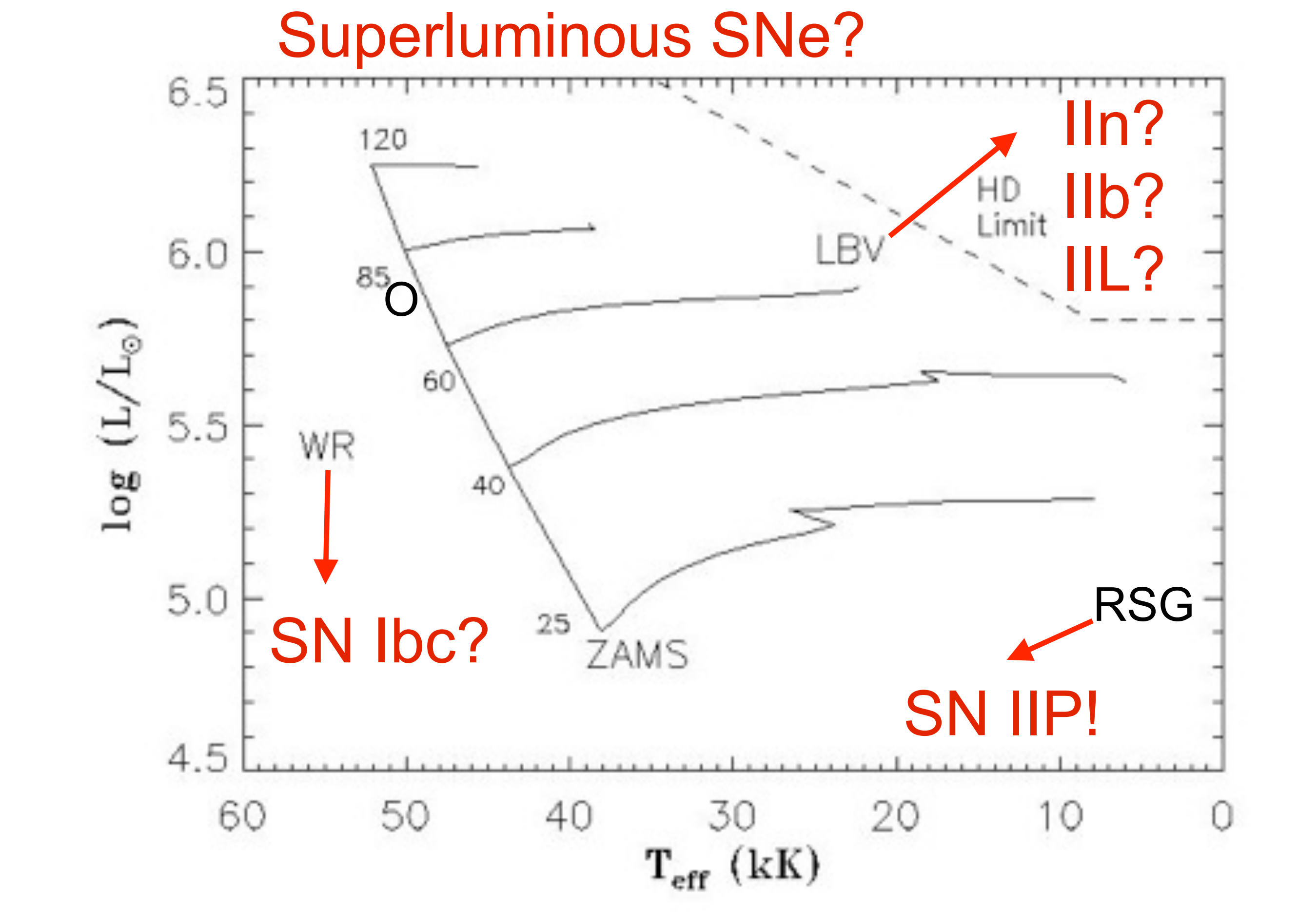
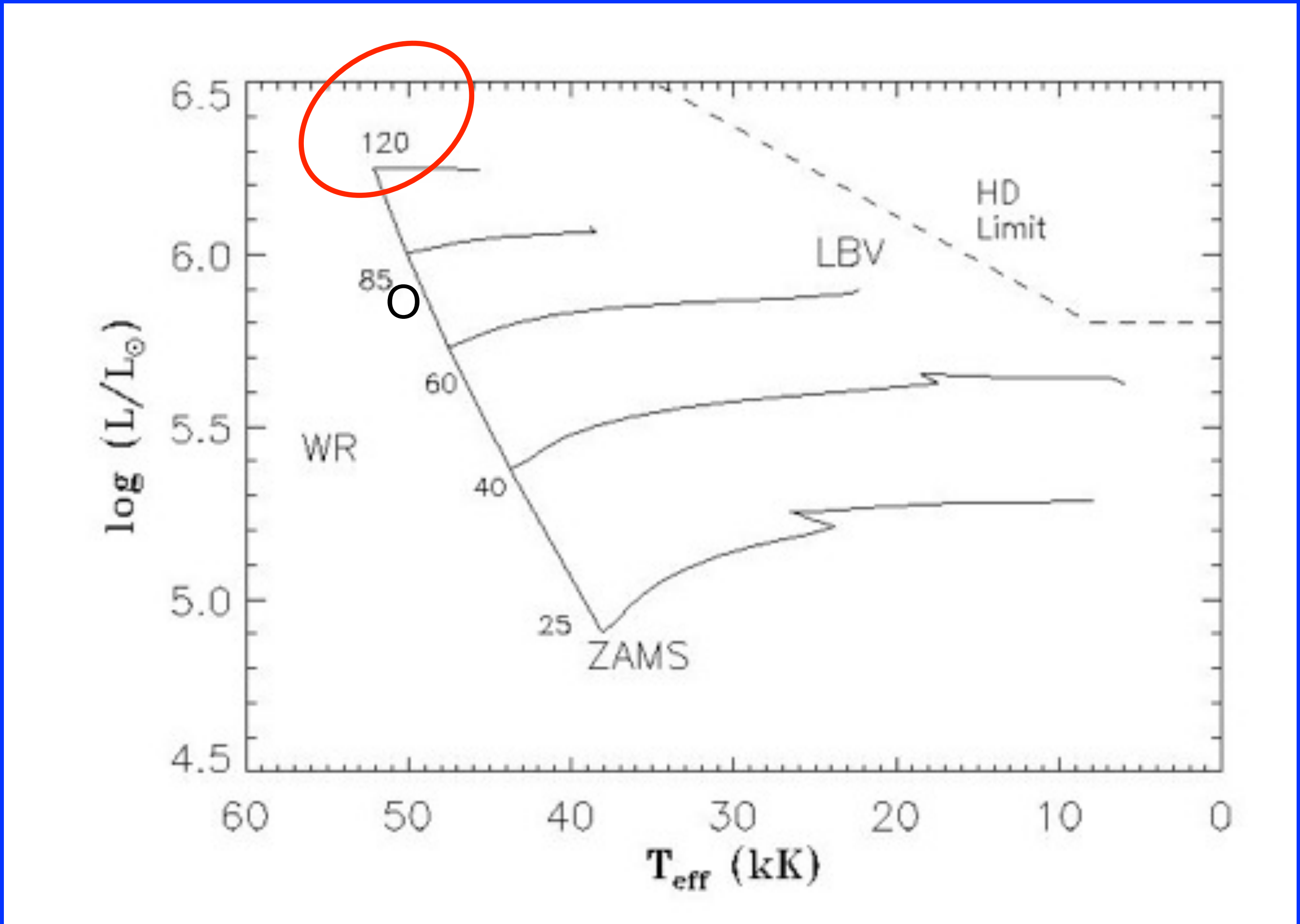


# The most massive star?



# How massive is the most massive star?

$$g_{\rm rad} = \frac{\kappa F}{c} = \frac{\kappa L}{4\pi R^2 c}$$

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$$\Gamma = \frac{g_{\rm rad}}{g_{\rm grav}} = \frac{\kappa L}{4\pi c G M}$$

# Eddington Gamma Limit

- Upper Mass Limit
- Wind Mass Loss
- WR+LBV Radii & SNe/GRB progenitor modelling


# Confirmation “isolated” VFTS 682?

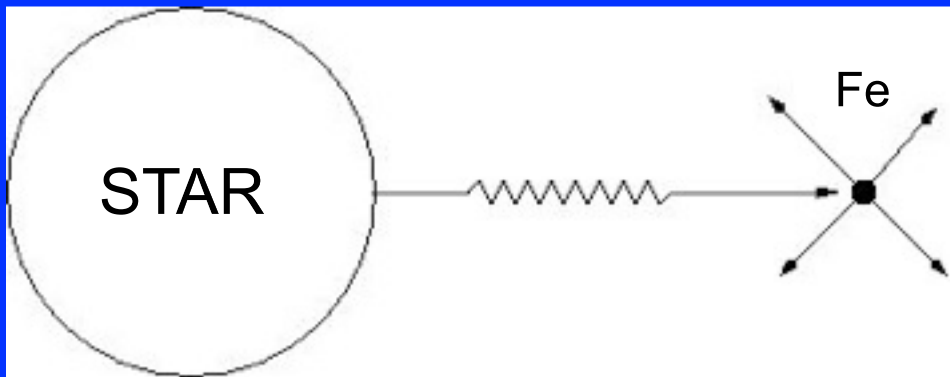
Bestenlehner et al. (2011)

VFTS: Vlt Flames Tarantula Survey
Evans et al. (2011)

# Fate of a 300 Msun star?

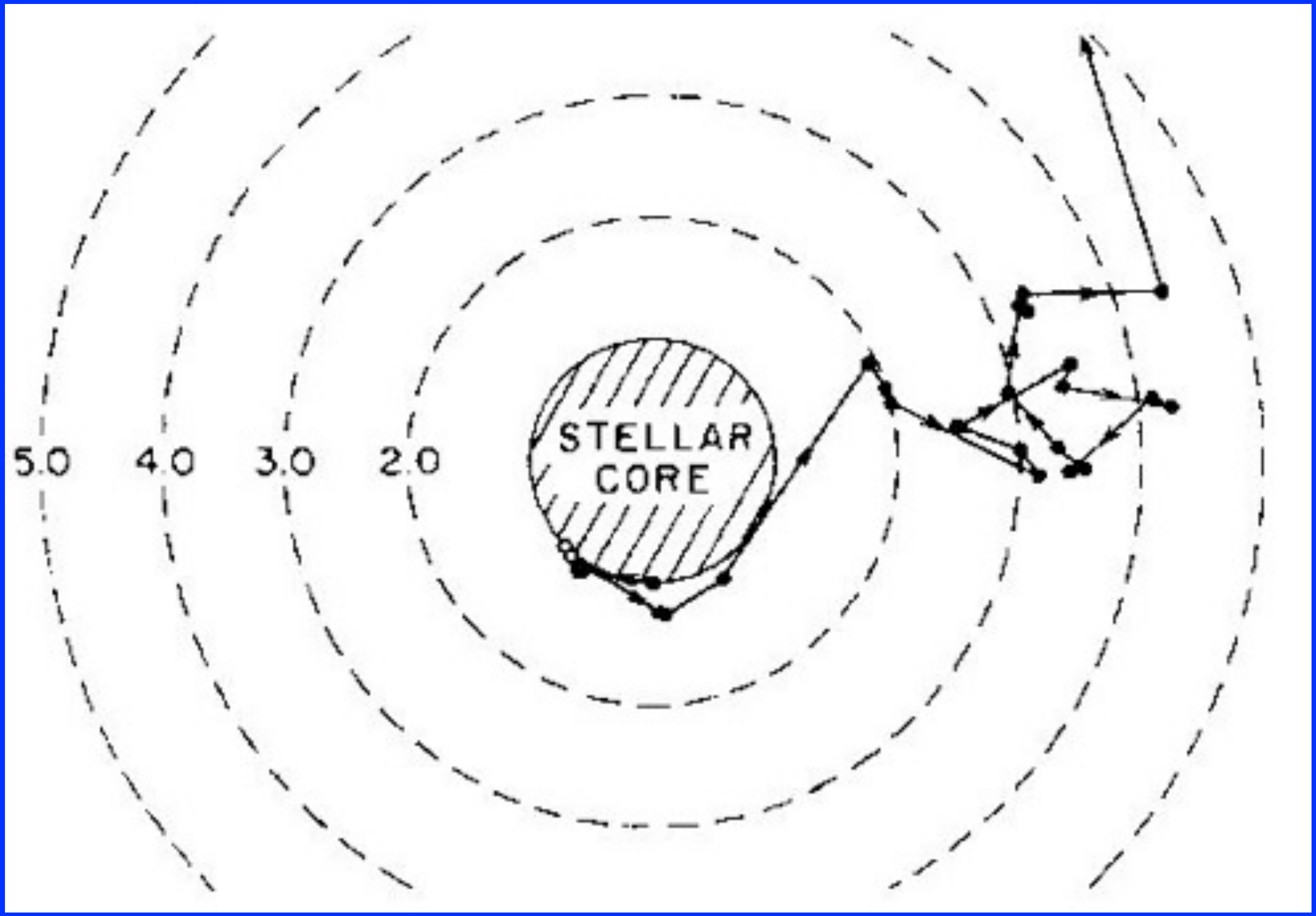
| | |
|---|---|
| • No Mass Loss? | Intermediate mass BH |
| • Modest loss? | PISN |
| • Strong Mass loss? | Stellar BH |
| • Extreme loss? | Neutron star |

# Line-driven winds




$dM/dt = f(L,M,Z,T_{eff})$

# Monte Carlo approach




Abbott & Lucy 1985

Vink et al. (2000)   dM/dt = f (L,M,Z,Teff)

# Fate of a 300 Msun star?

- Vink et al: log(dM/dt) = -4.2
  Mass = 150 Msun lower PISN range

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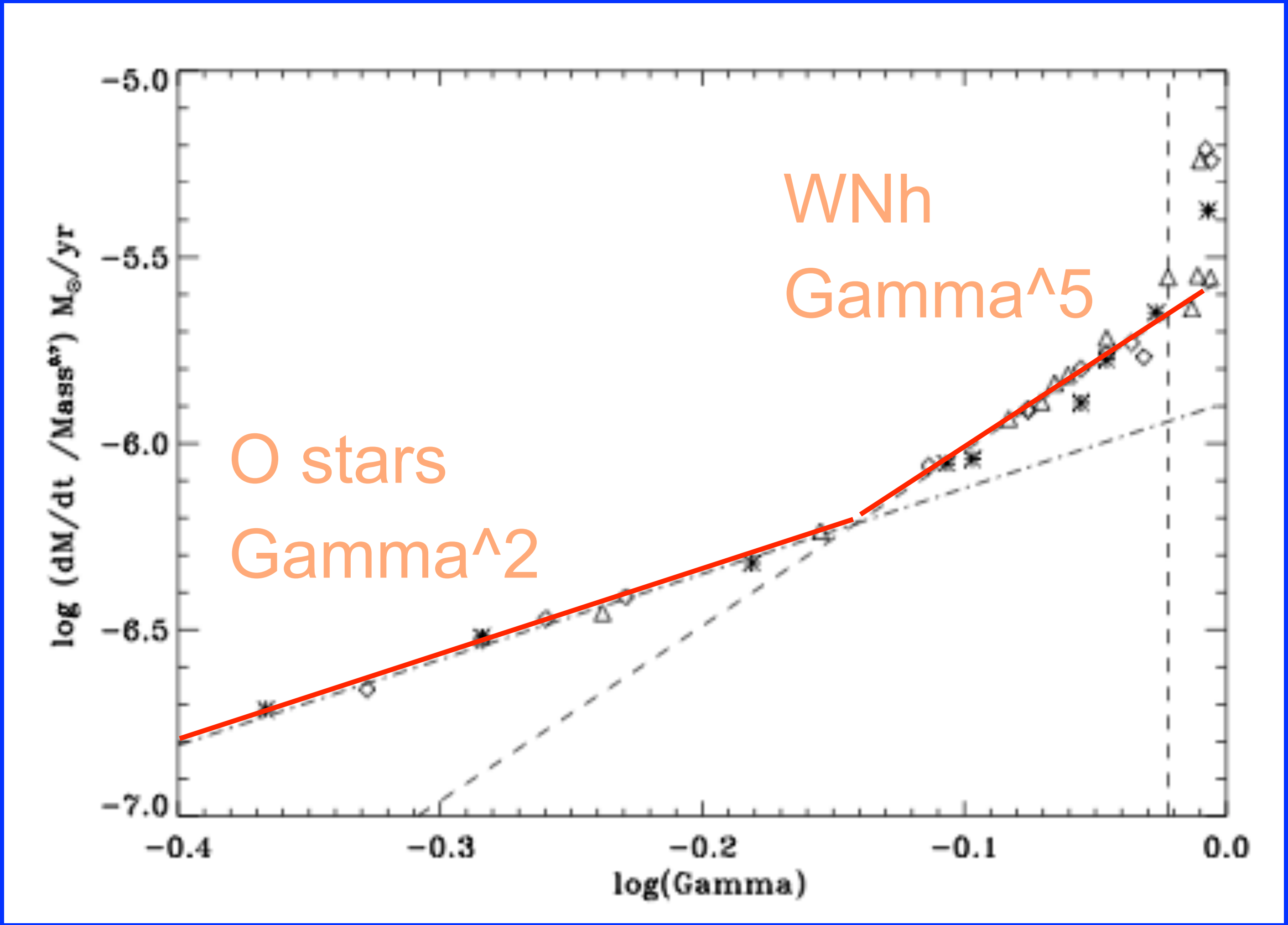
  Mass = 150 Msun lower PISN range

- Previously: log(dM/dt) = -3.9
  Evaporation!

- Extreme clumping log(dM/dt) = -4.9
  Mass = 270 Msun upper PISN range

# Gamma-dependence

# Mass loss - Gamma (L/M) Dependence




Vink et al. (2011)

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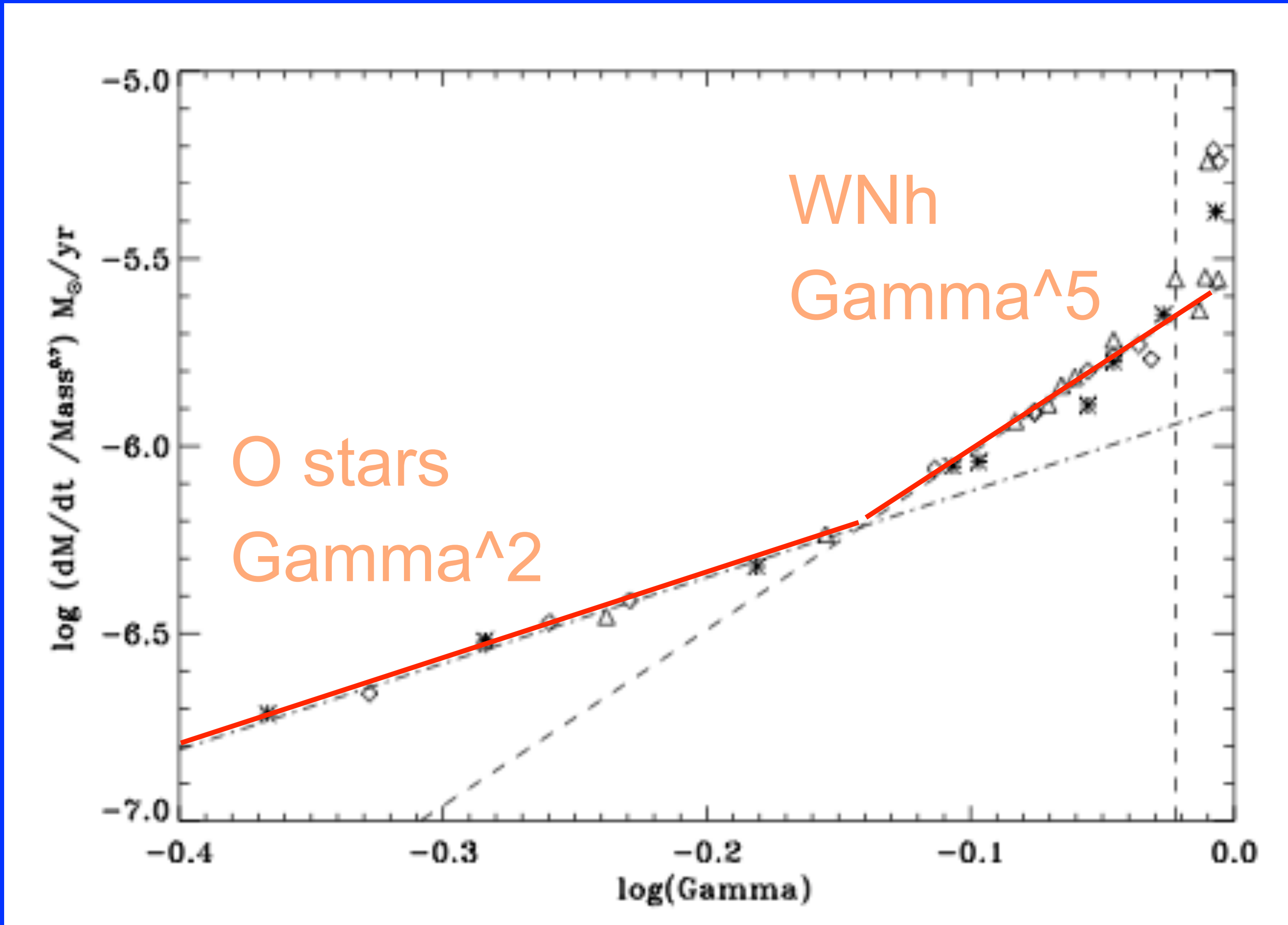



Vink et al. (2011)

Empirical Evidence: Graefener et al. (2011)

# Z dependence

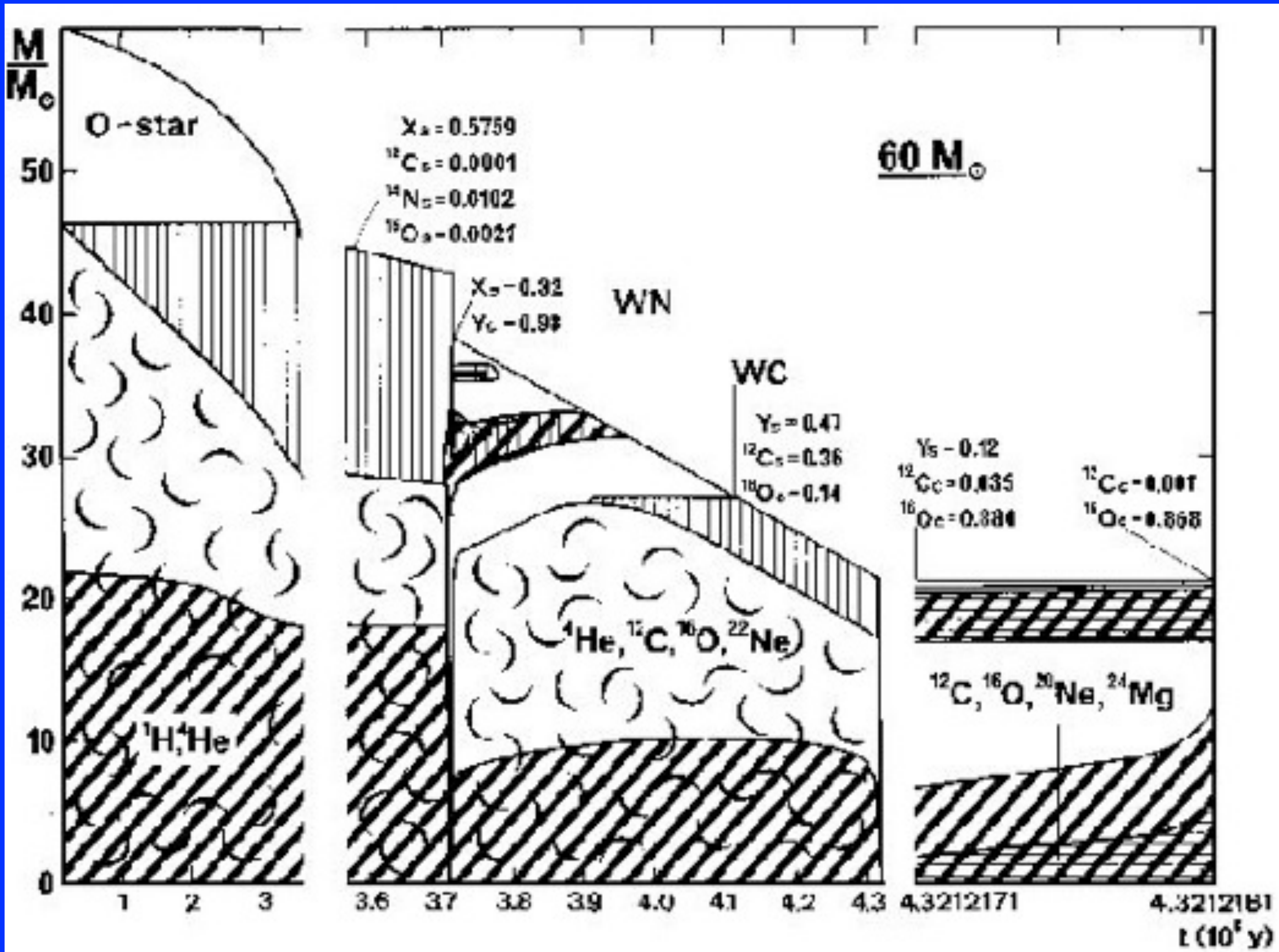
# Progenitor for Collapsar model

Woosley (1993)

- Rapidly Rotating
- No Hydrogen envelope: Wolf-Rayet

- But strong WR winds:
  Angular Momentum Loss

# WR stars produce Carbon !




Geneva models (Maeder & Meynet 1987)

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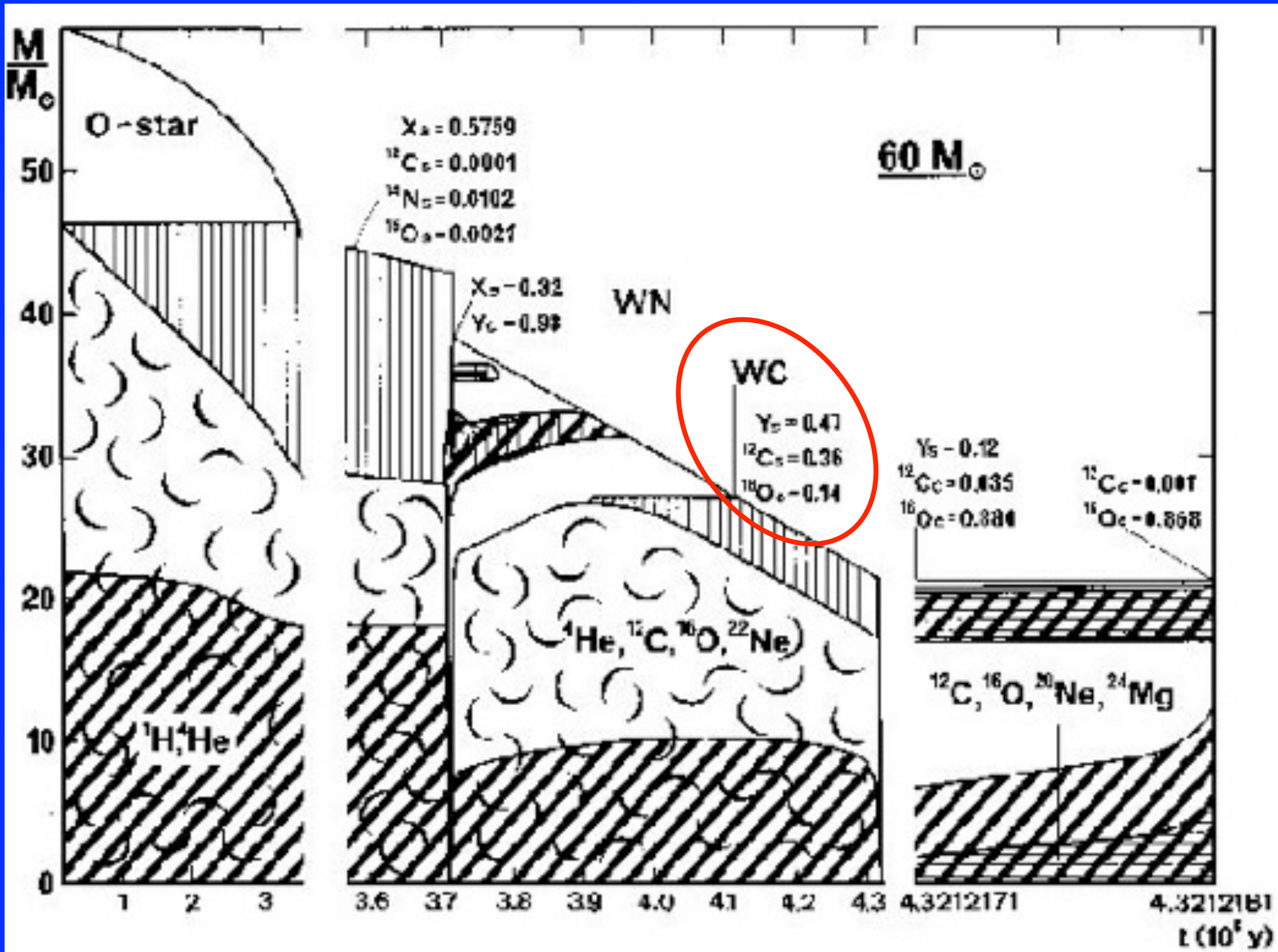


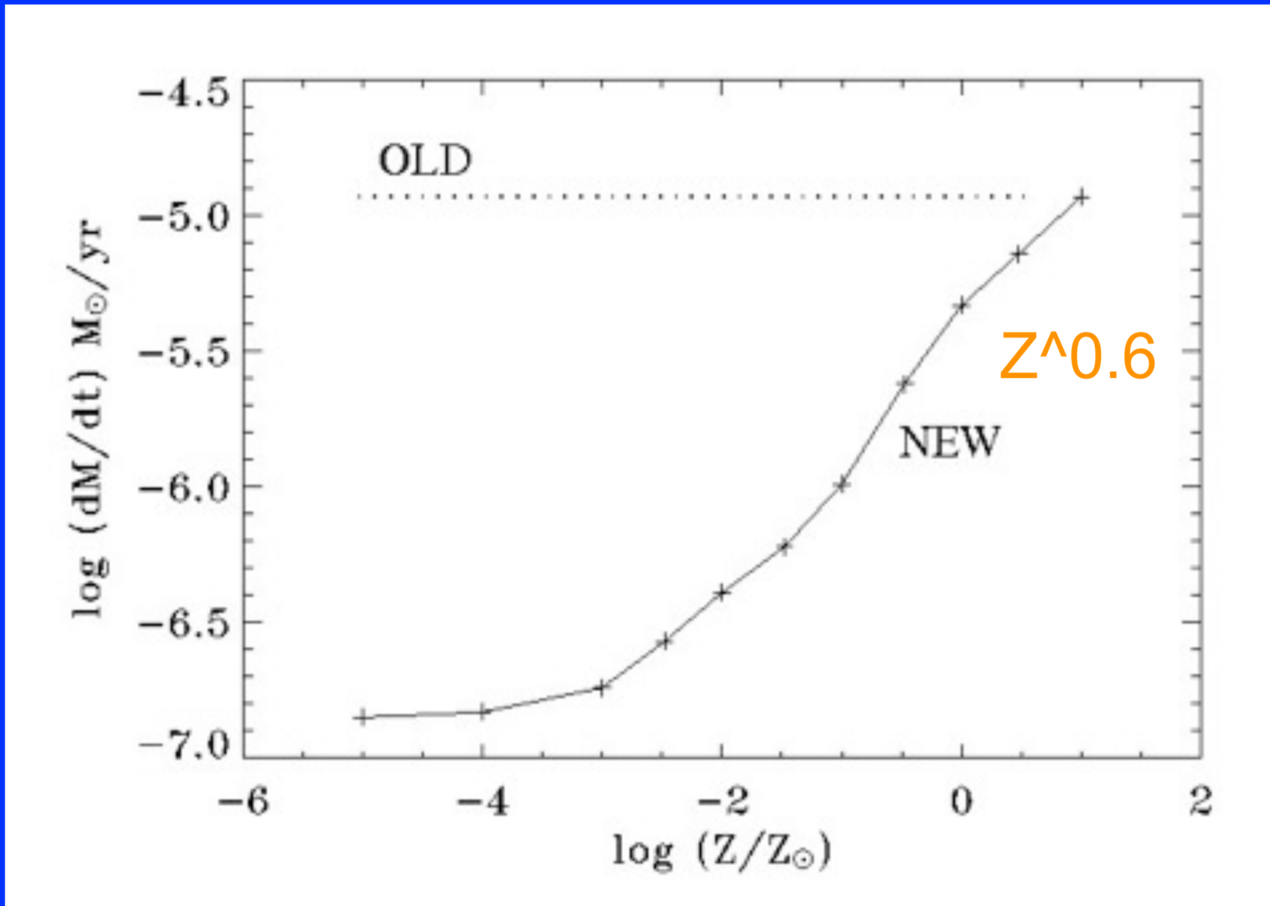

Geneva models (Maeder & Meynet 1987)

# Which element drives WR winds?

- If C → Mdot does NOT depend on host Z

- if Fe → Mass loss DOES scale with host Z

# Z-dependence of WR winds



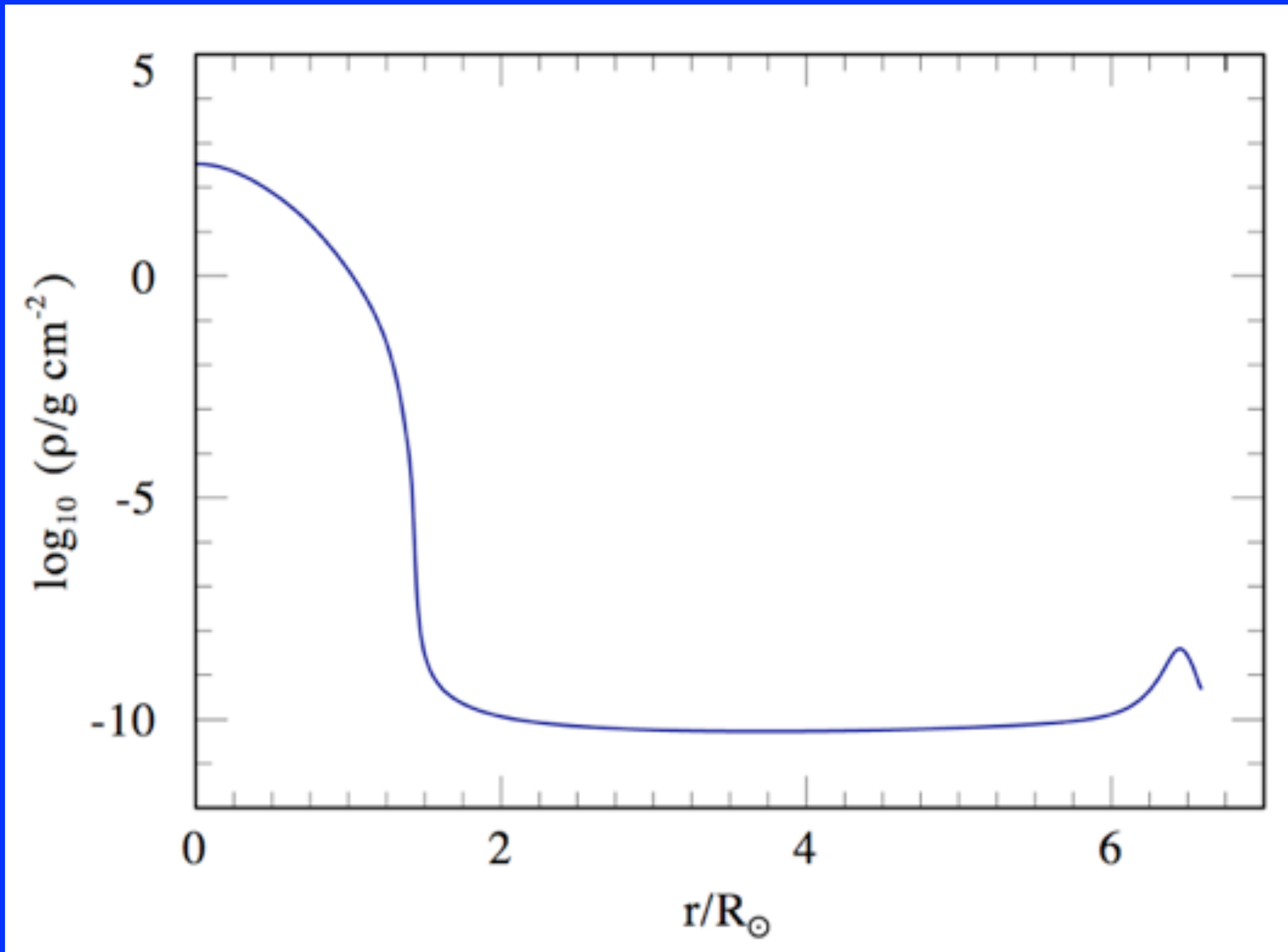

Vink & de Koter (2005)

# The WR radius problem

Observed WR stars are factor ~2 cooler than predicted

OPAL Fe-bump may inflate envelope

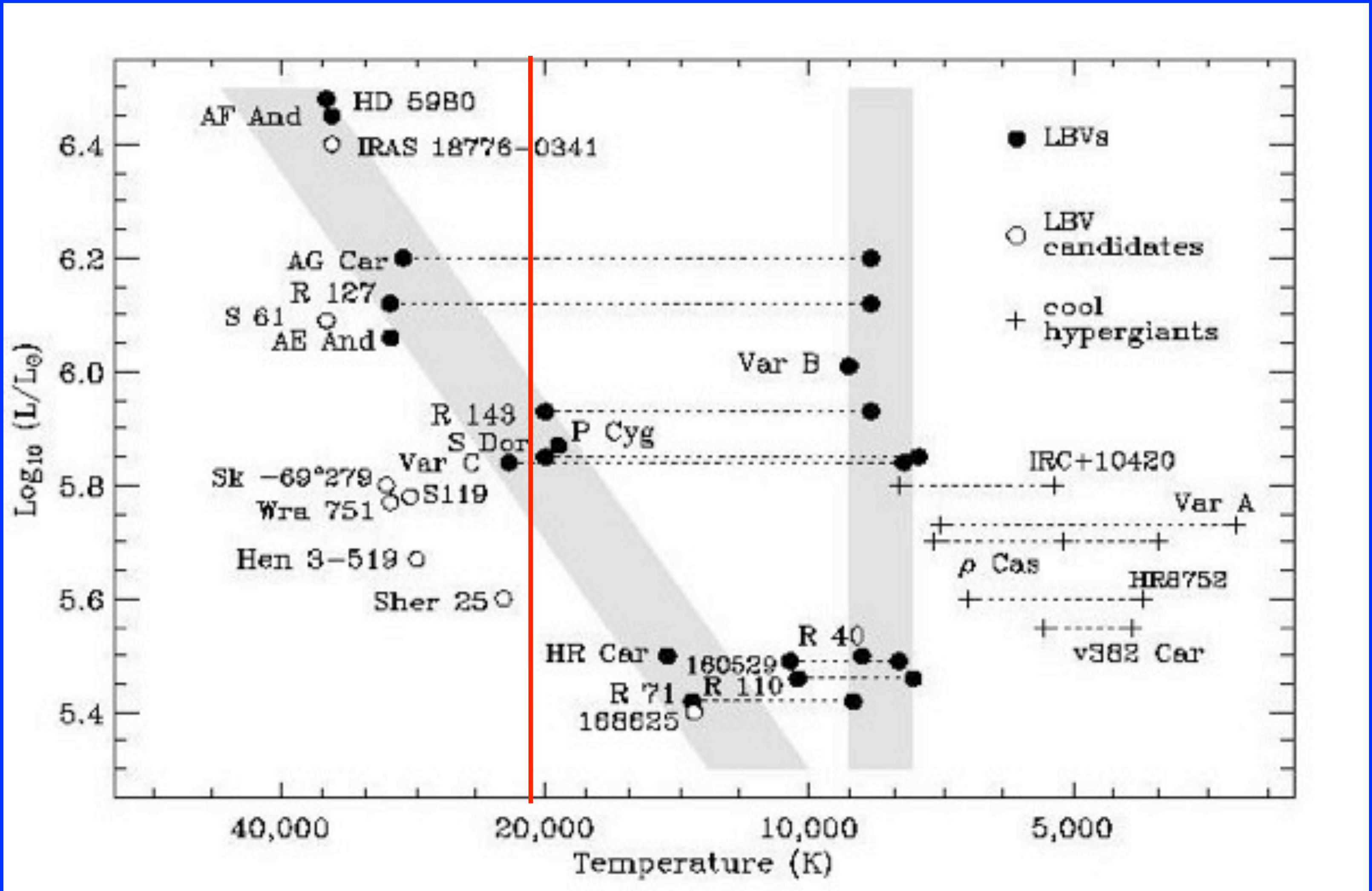
# WR+LBV Envelope Inflation




Graefener, Owocki & Vink (2012)

# T dependence

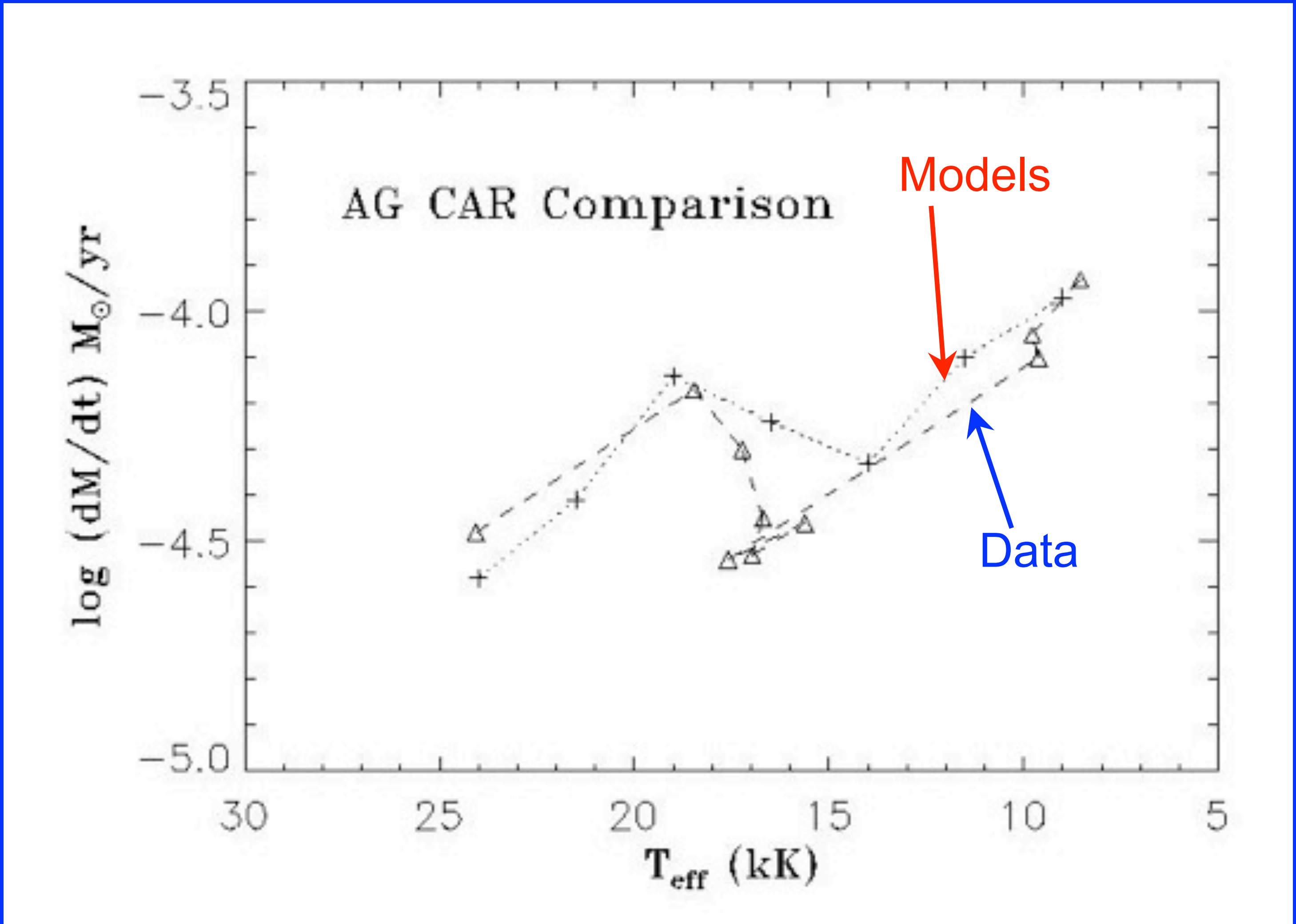
# LBVs in the HRD




Smith, Vink & de Koter (2004)

Monday, 12 March 2012

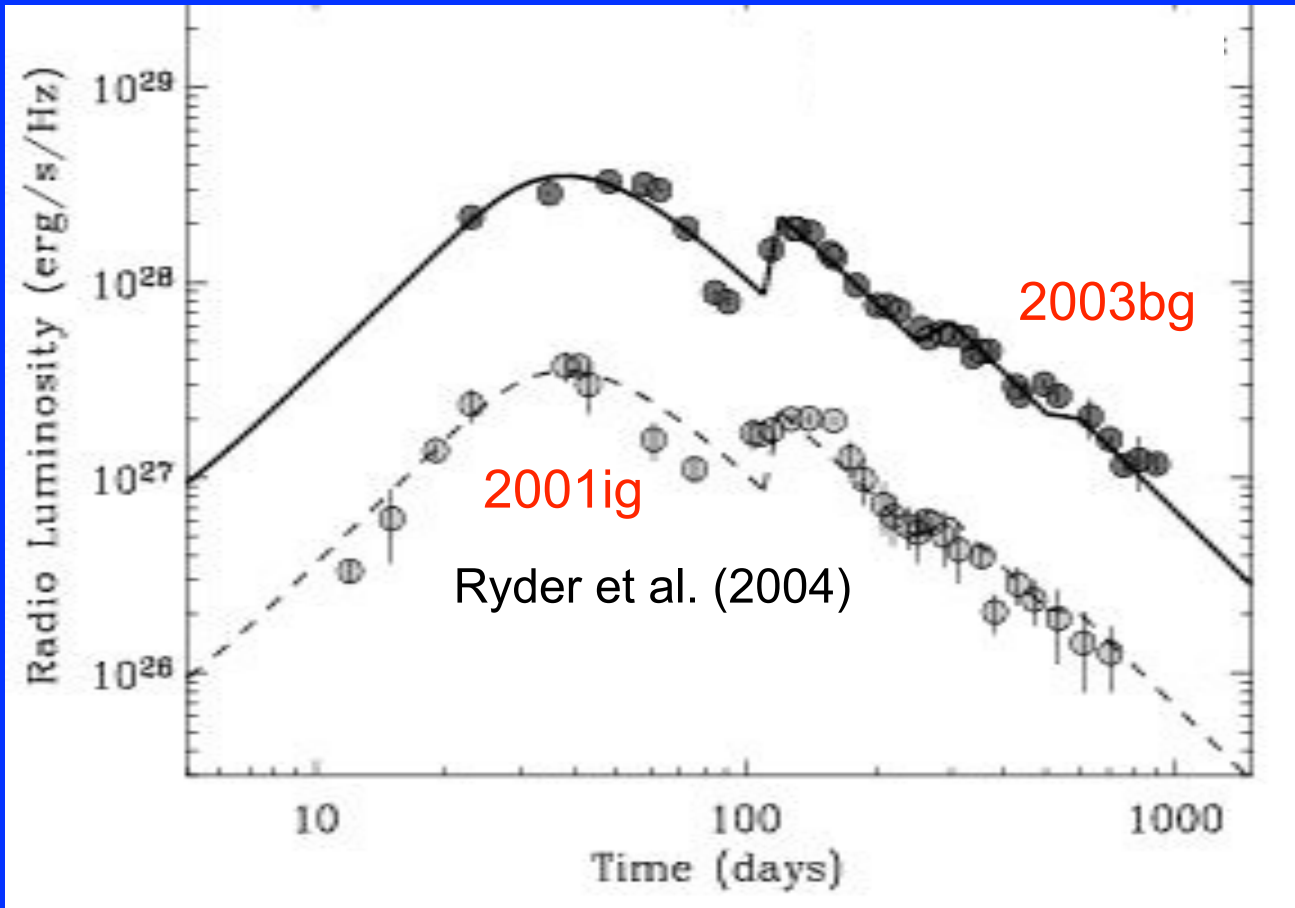
# The mass loss of LBVs




Data Stahl et al. (2001)

Vink & de Koter (2002)

# Radio supernova lightcurves




Soderberg et al. (2006)

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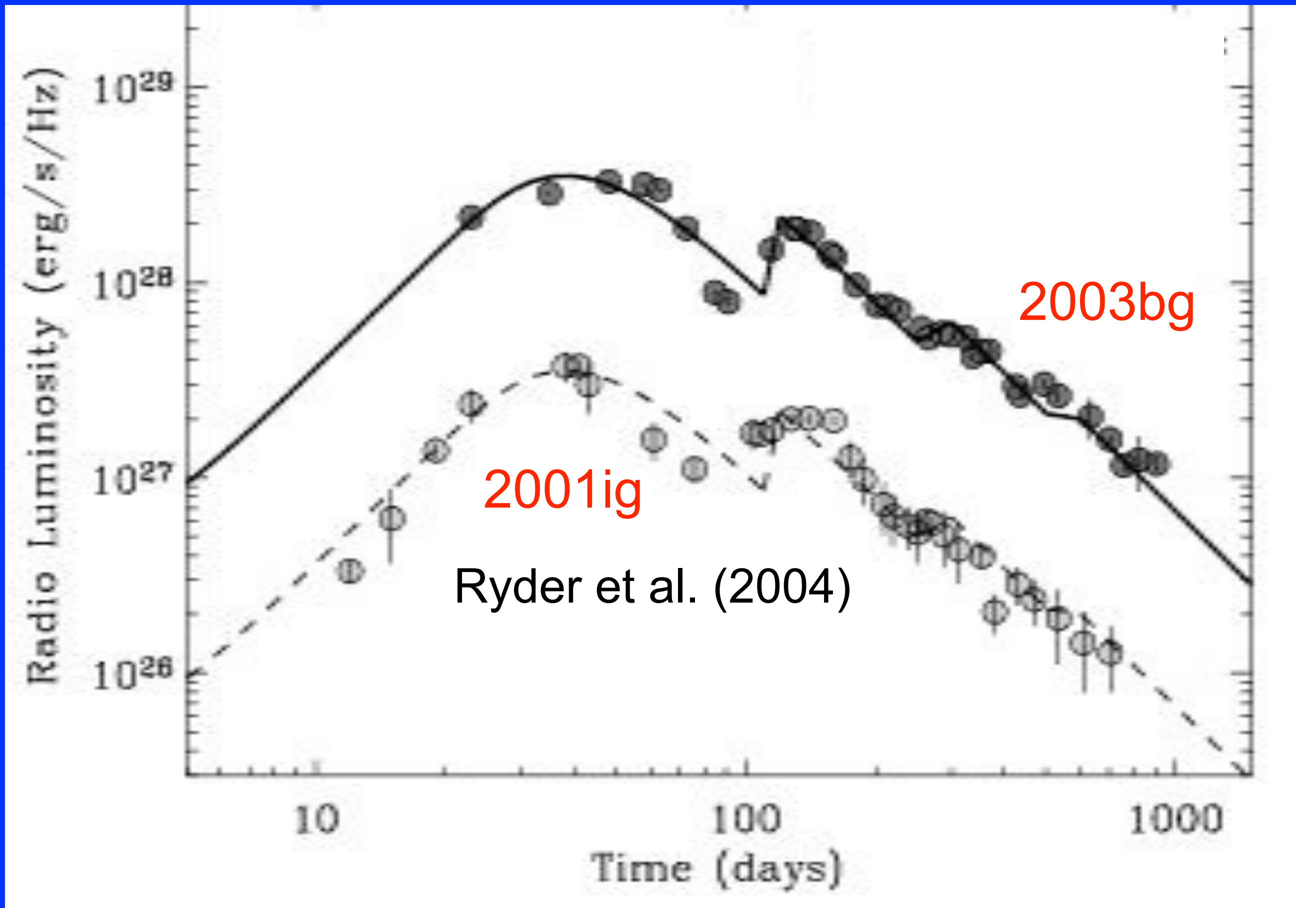
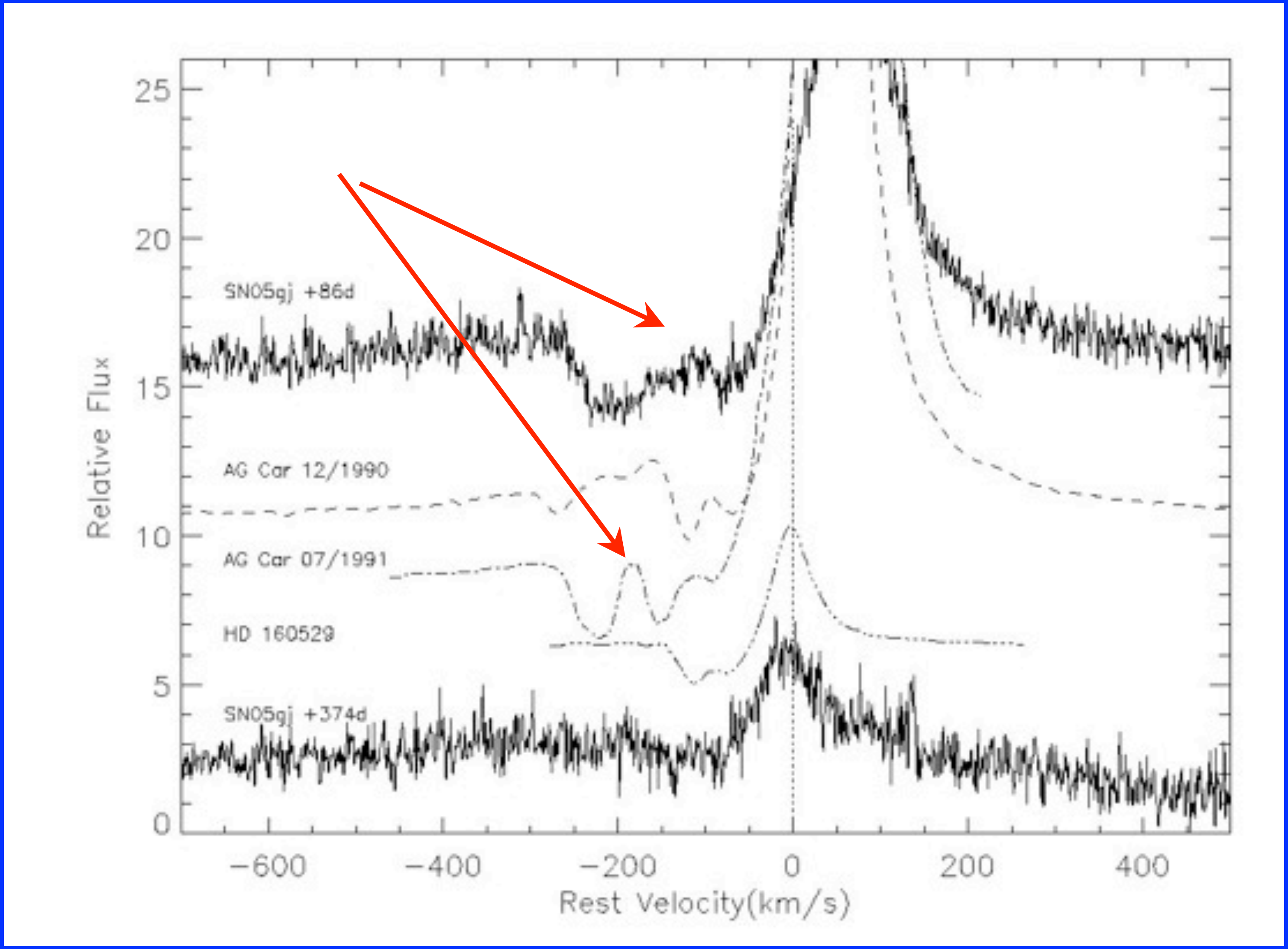



Soderberg et al. (2006)

LBV

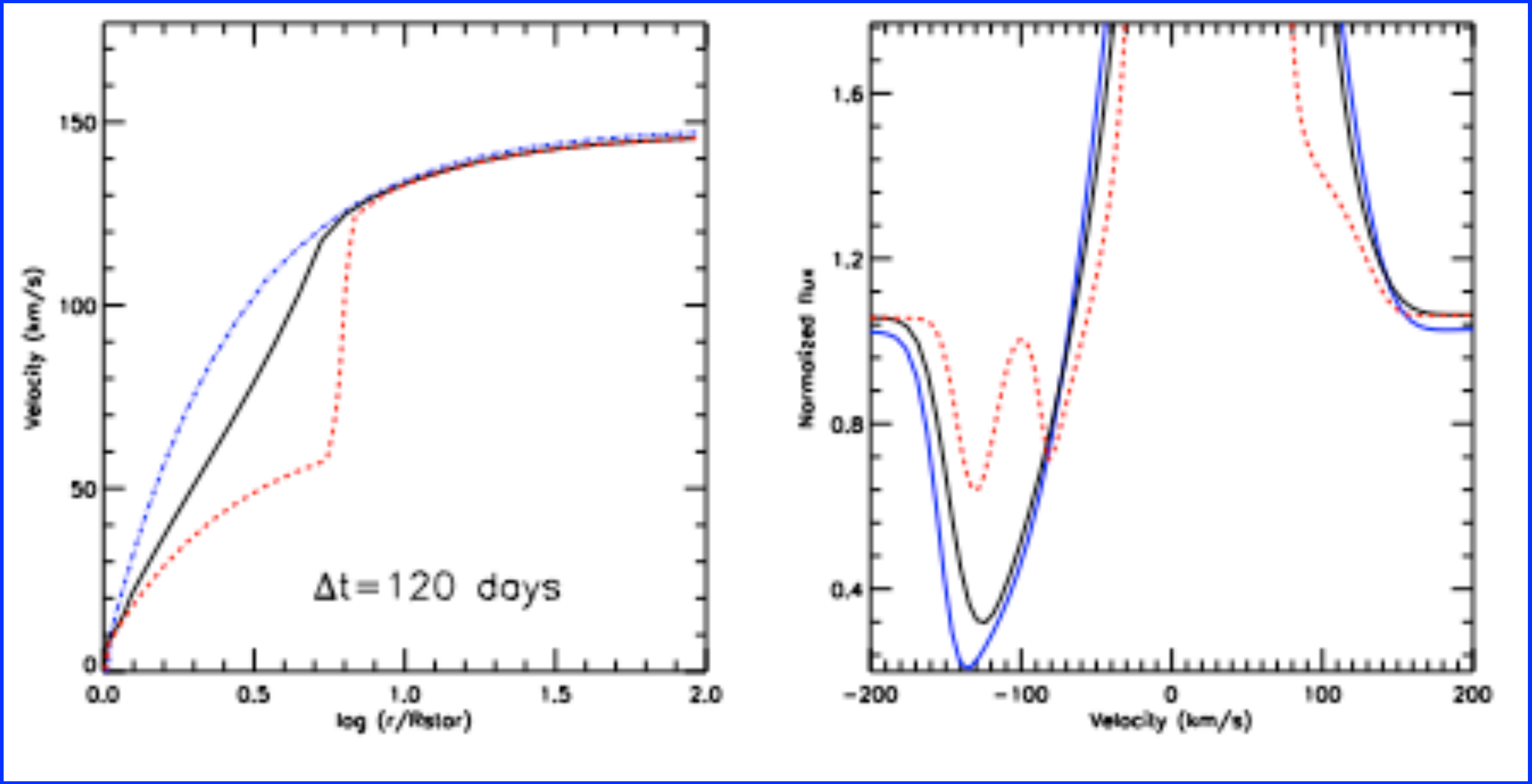
Kotak & Vink (2006)

# Do LBVs explode?



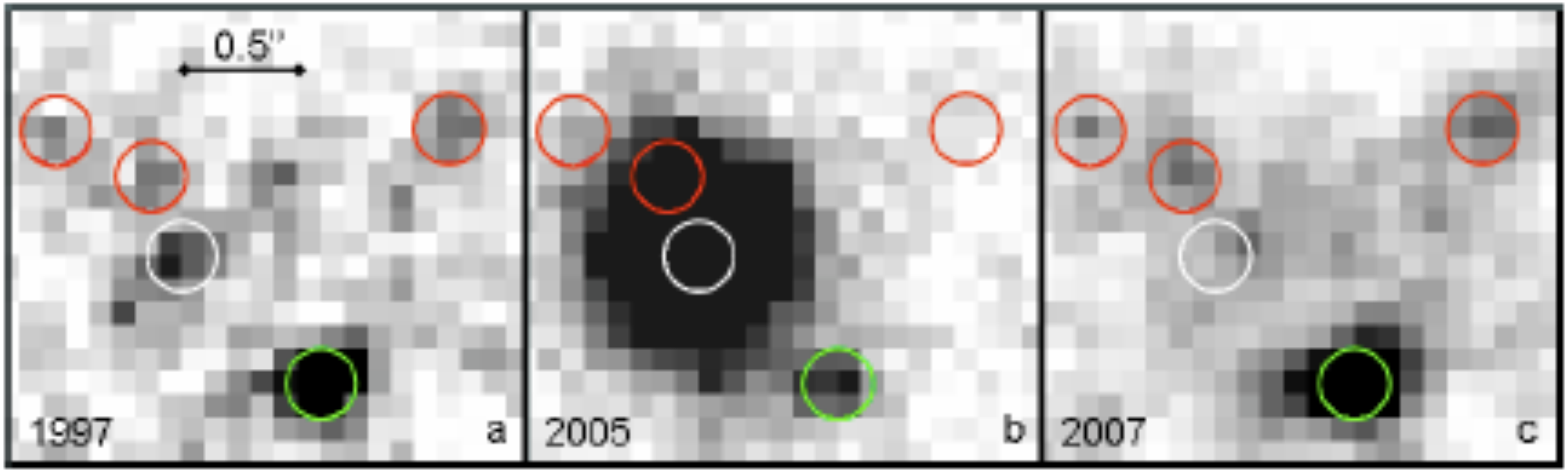

Trundle et al. (2008)

# Changing mass loss!




Groh & Vink (2011)

# Progenitor image of 2005gl




Gal-Yam & Leonard (2009)

# Summary

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- Links between WRs+LBVs & SN-types