

# SN-Progenitor Identification from Mass Loss

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# Outline

- H-rich Stars
- Super-Eddington versus “superwind”

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- H-poor (stripped) stars
- How to make “heavy” Black Holes / long GRBs?

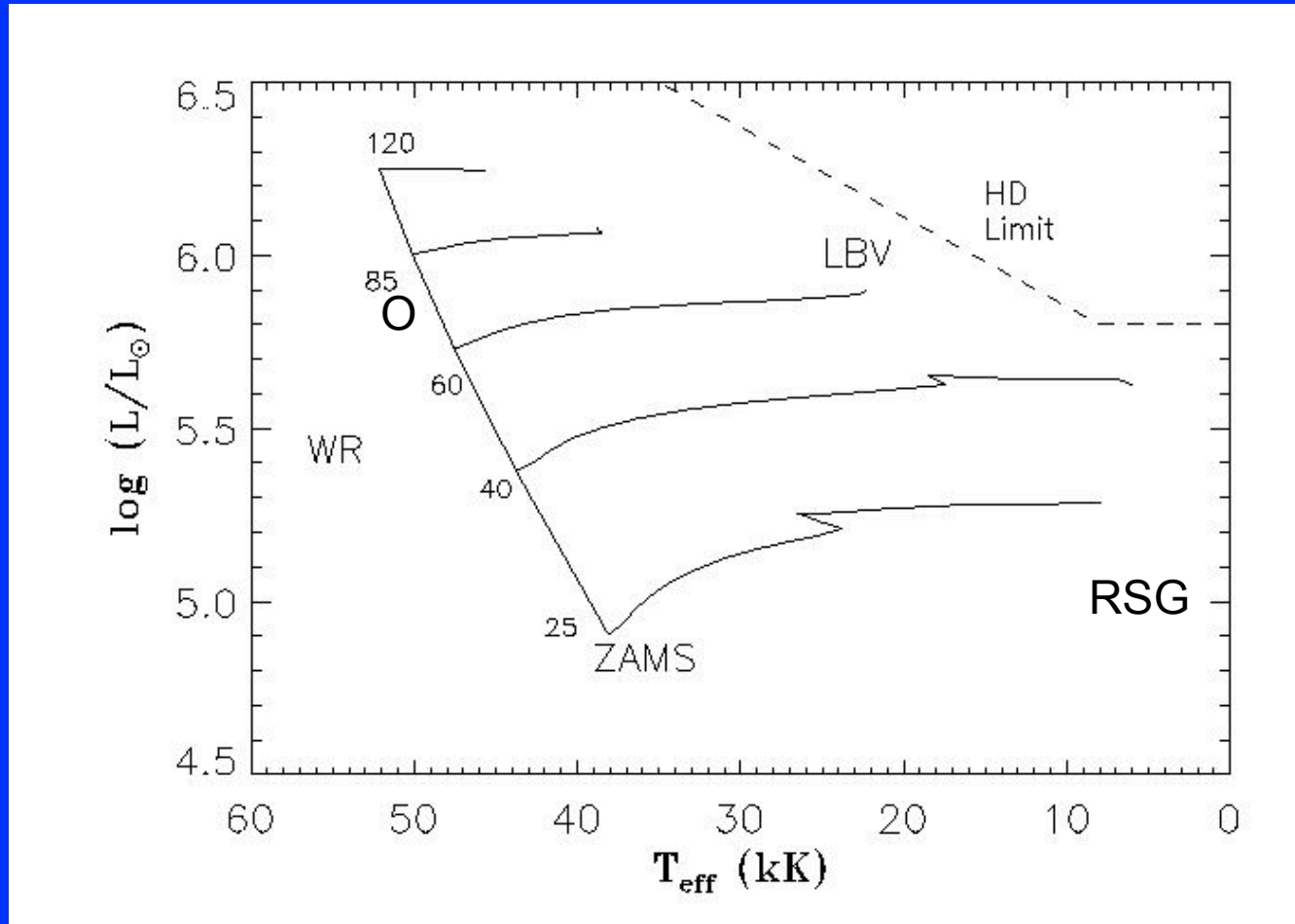
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- $dM/dt$  1D

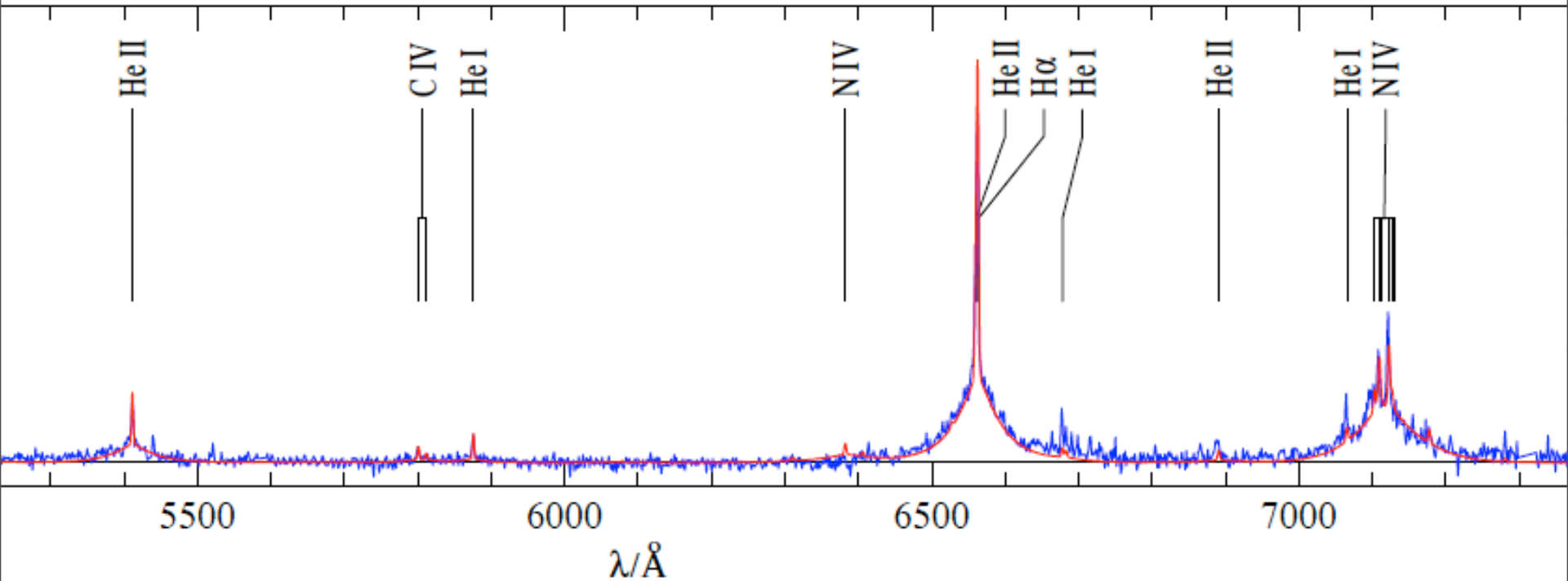
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- $dM/dt$  1D
- $dM/dt$  multi-D

# Upper HRD- Massive Stars



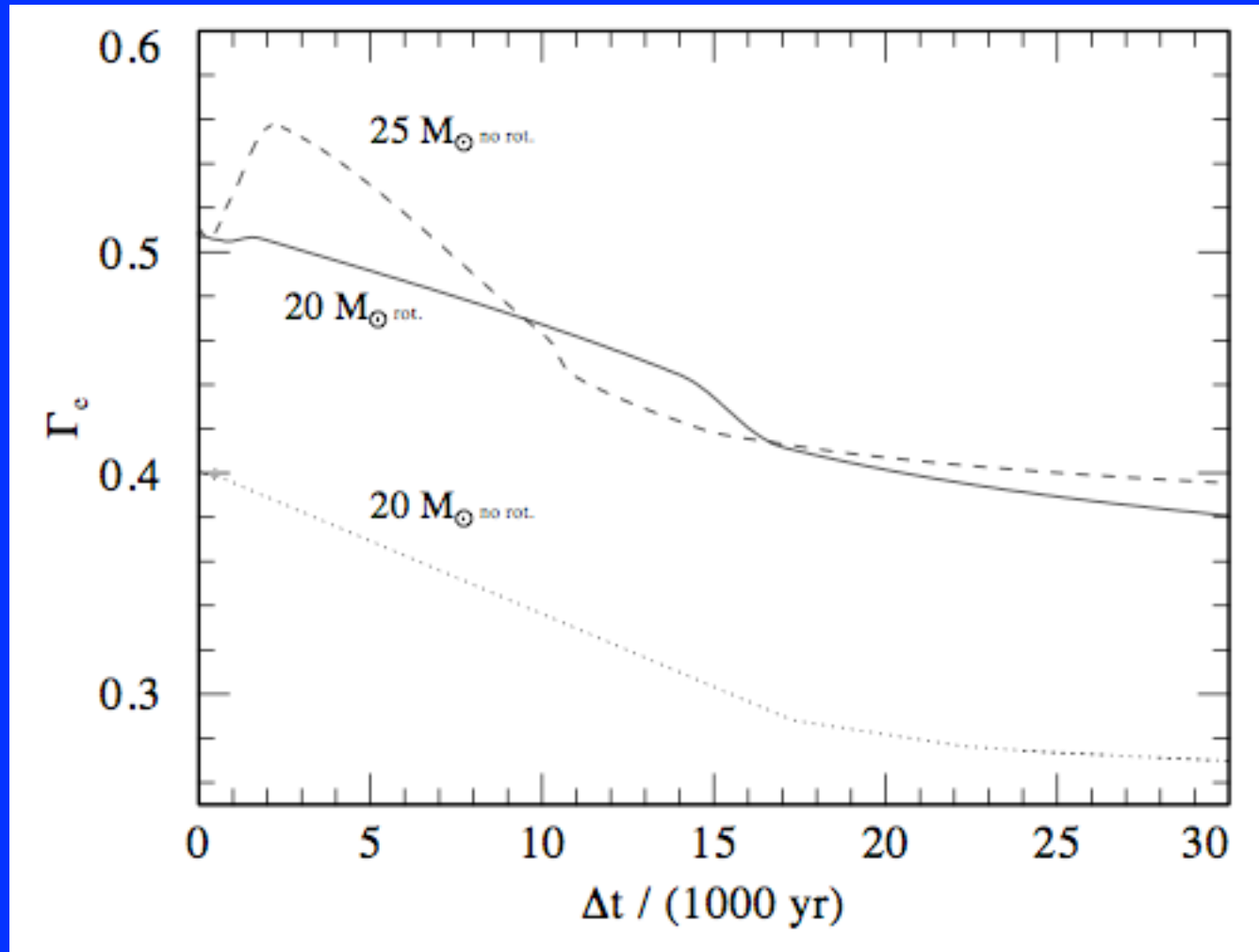
# The IIb SN 2013cu



Graefener & Vink (2016) Superwind!

(Gal-Yam+14: wind Groh+14: LBV)

# Eddington Factor at end of Life



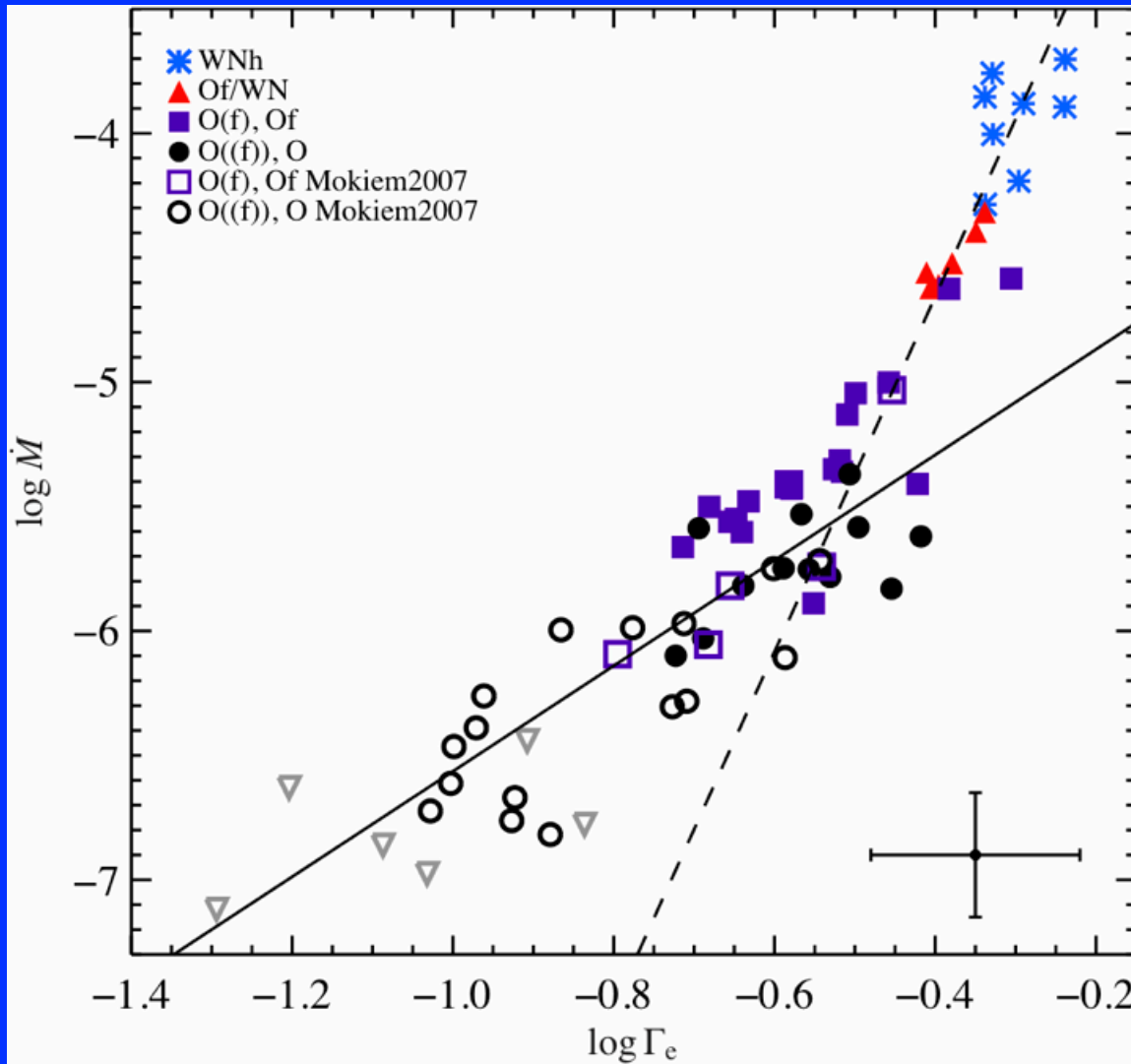
Grafener & Vink (2016)



$dM/dt = f$  (Gamma)

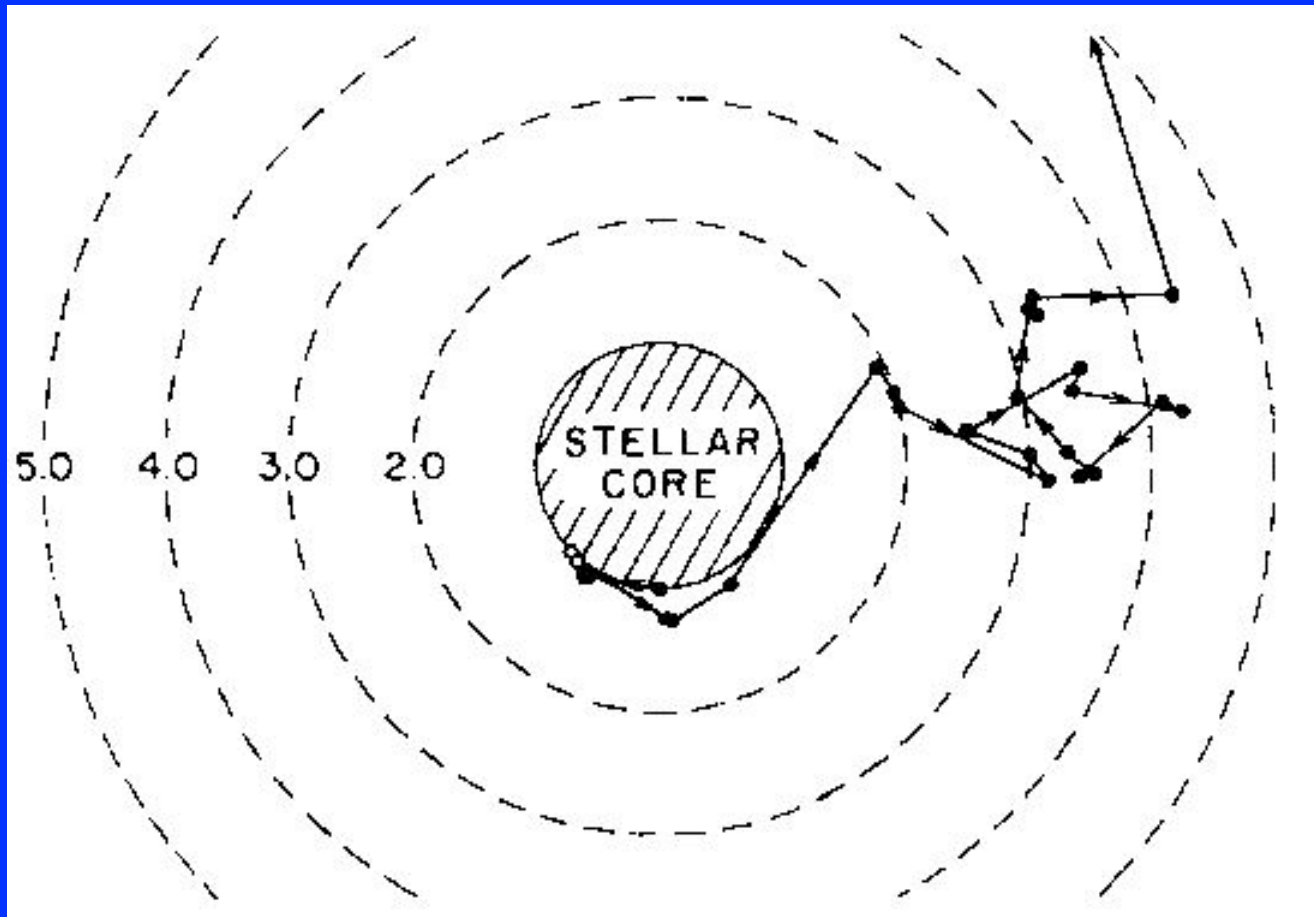
$$\Gamma = \frac{g_{\text{rad}}}{g_{\text{grav}}} = \frac{\kappa L}{4\pi cGM}$$

# VLT Flames Tarantula Survey



Bestenlehner et al. (2014)

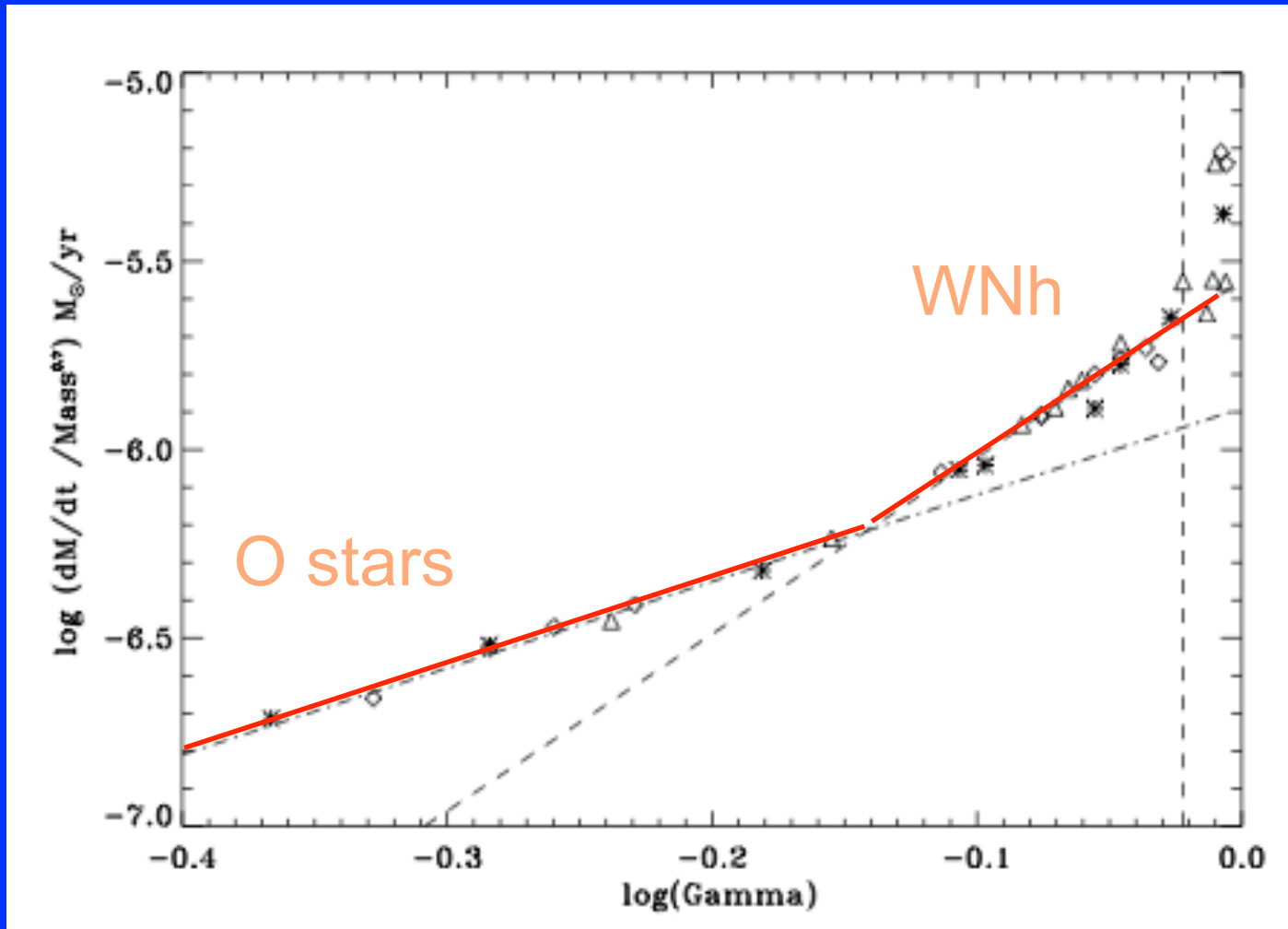
# Monte Carlo approach



(Abbott & Lucy 1985; Vink et al. 2000)

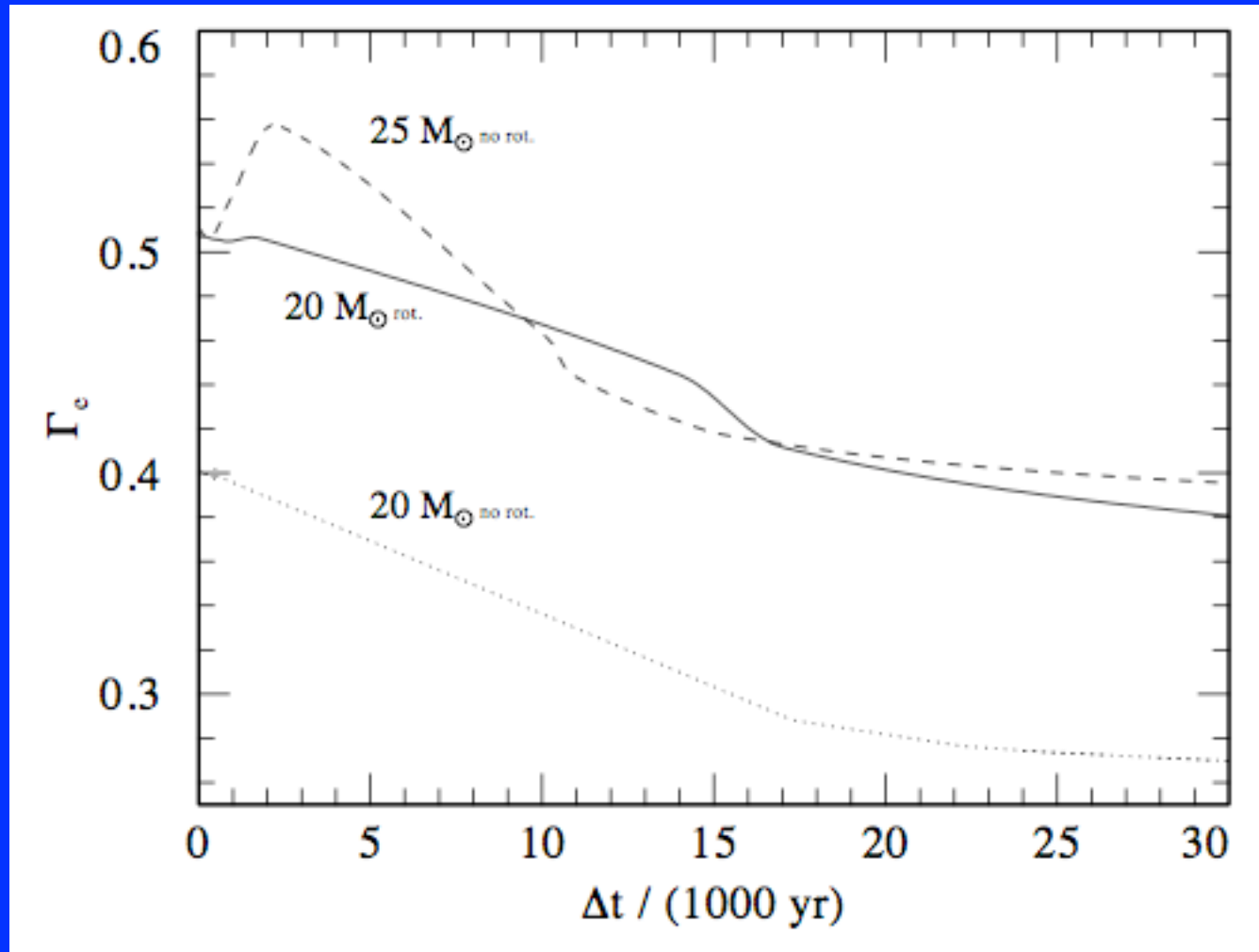
$$\dot{M} v_{\infty} > \frac{L_{*}}{c}$$

# KINK in $dM/dt$ - Gamma



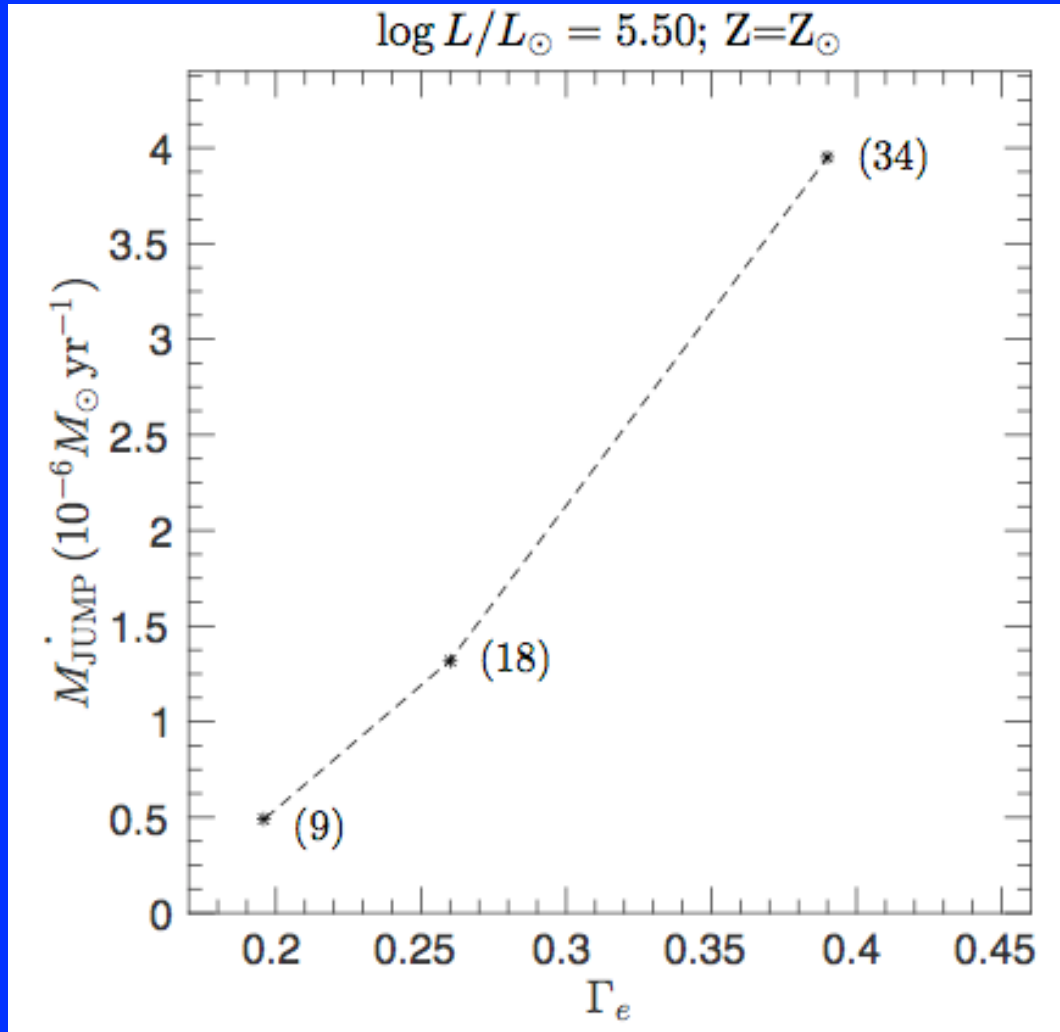
Vink et al. (2011)

# Eddington Factor at end of Life



Grafener & Vink (2016)

# The Second Opacity Jump



Petrov, Vink & Grafener (2016)

# Large Wind Mass Loss

- “Normal” Winds up to  $0.00001 \text{ Msun/yr}$

# Large Wind Mass Loss

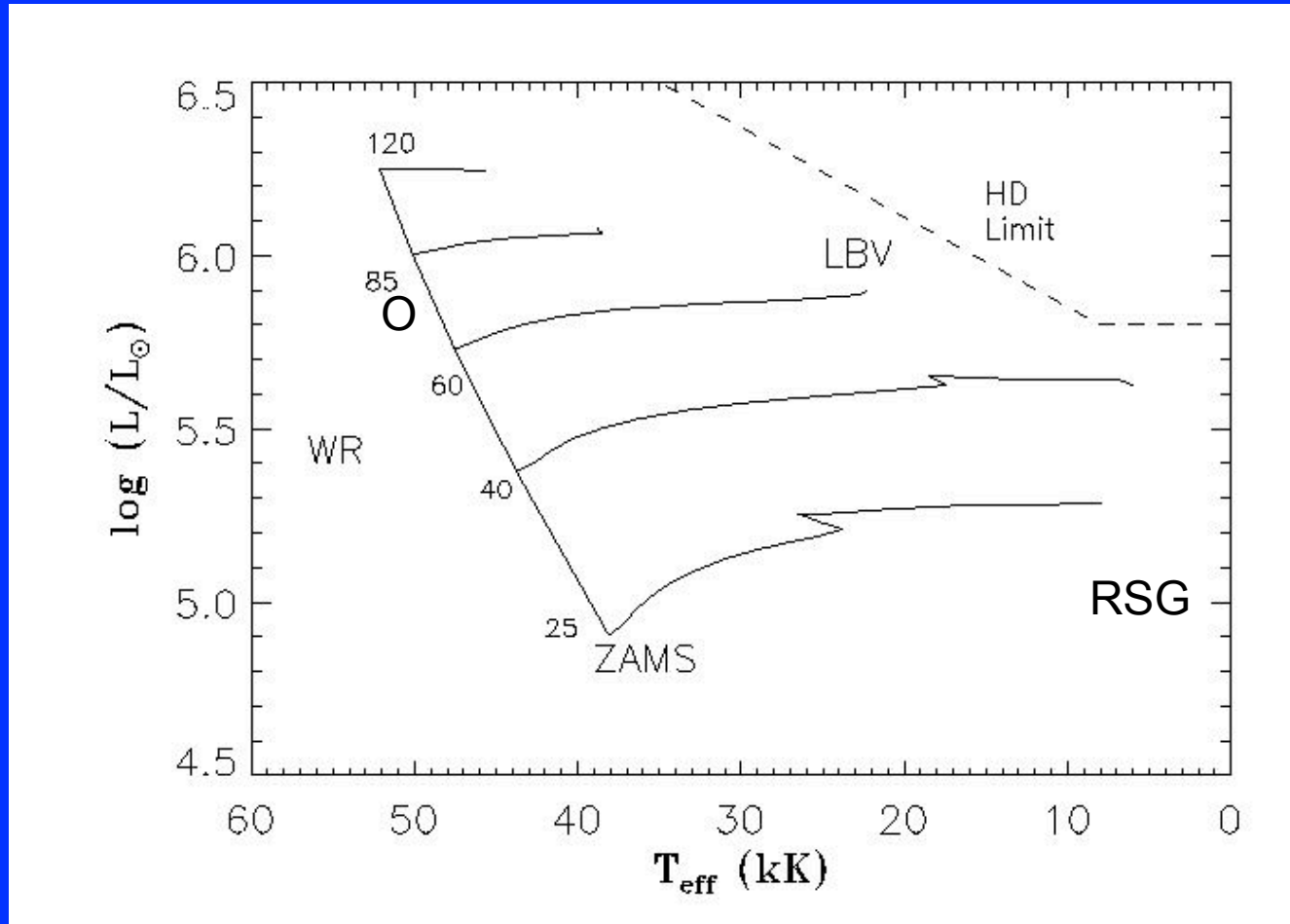
- “Normal” Winds up to  $0.00001 \text{ Msun/yr}$
- Superwinds up to  $0.001 \text{ Msun/yr}$   
“High Gamma”



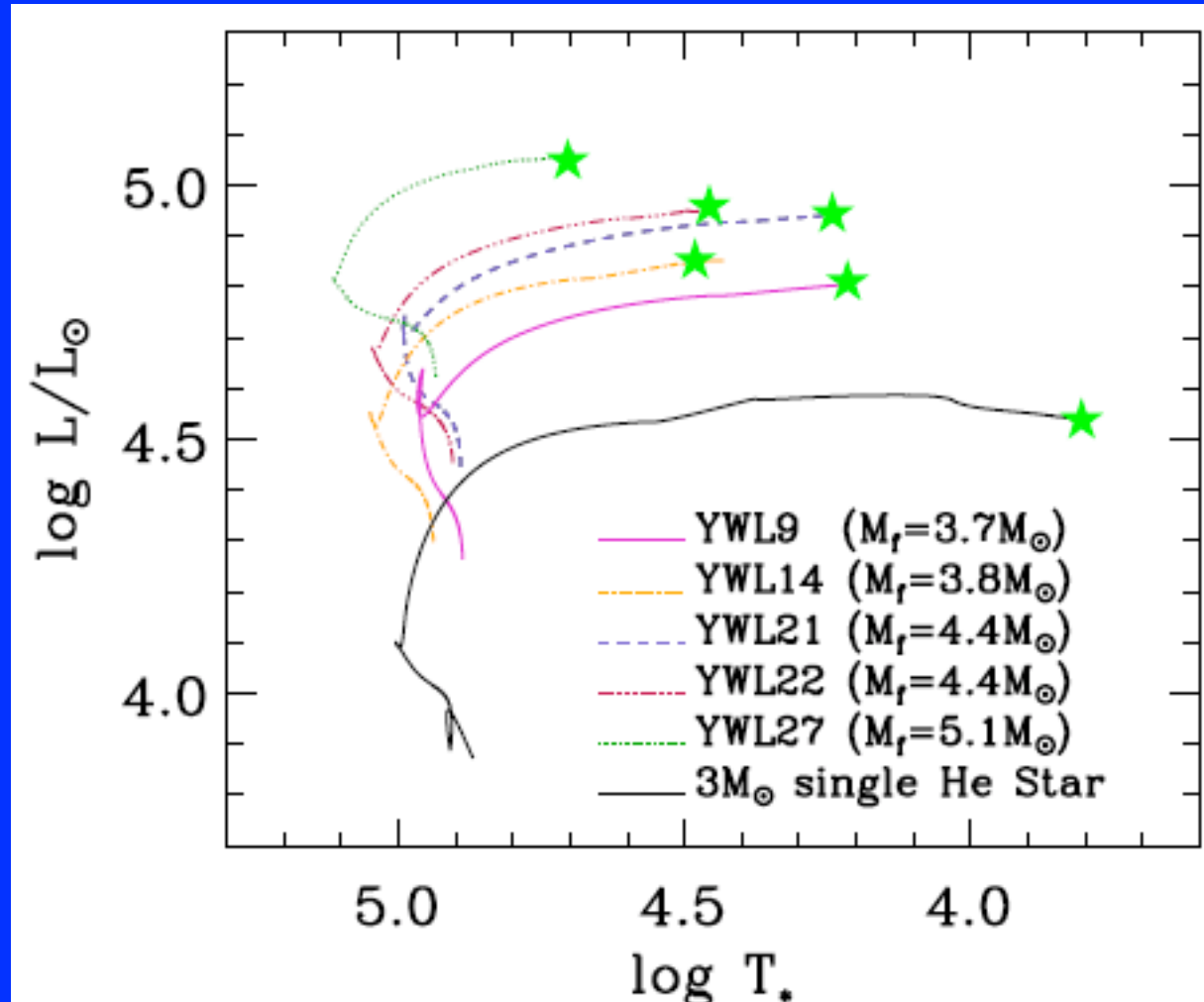
# Large Wind Mass Loss

- “Normal” Winds up to  $0.00001 \text{ Msun/yr}$
- Superwinds up to  $0.001 \text{ Msun/yr}$   
“High Gamma”
- Super-Eddington winds up to  $0.1 \text{ Msun/yr}$

# Upper HRD- Massive Stars

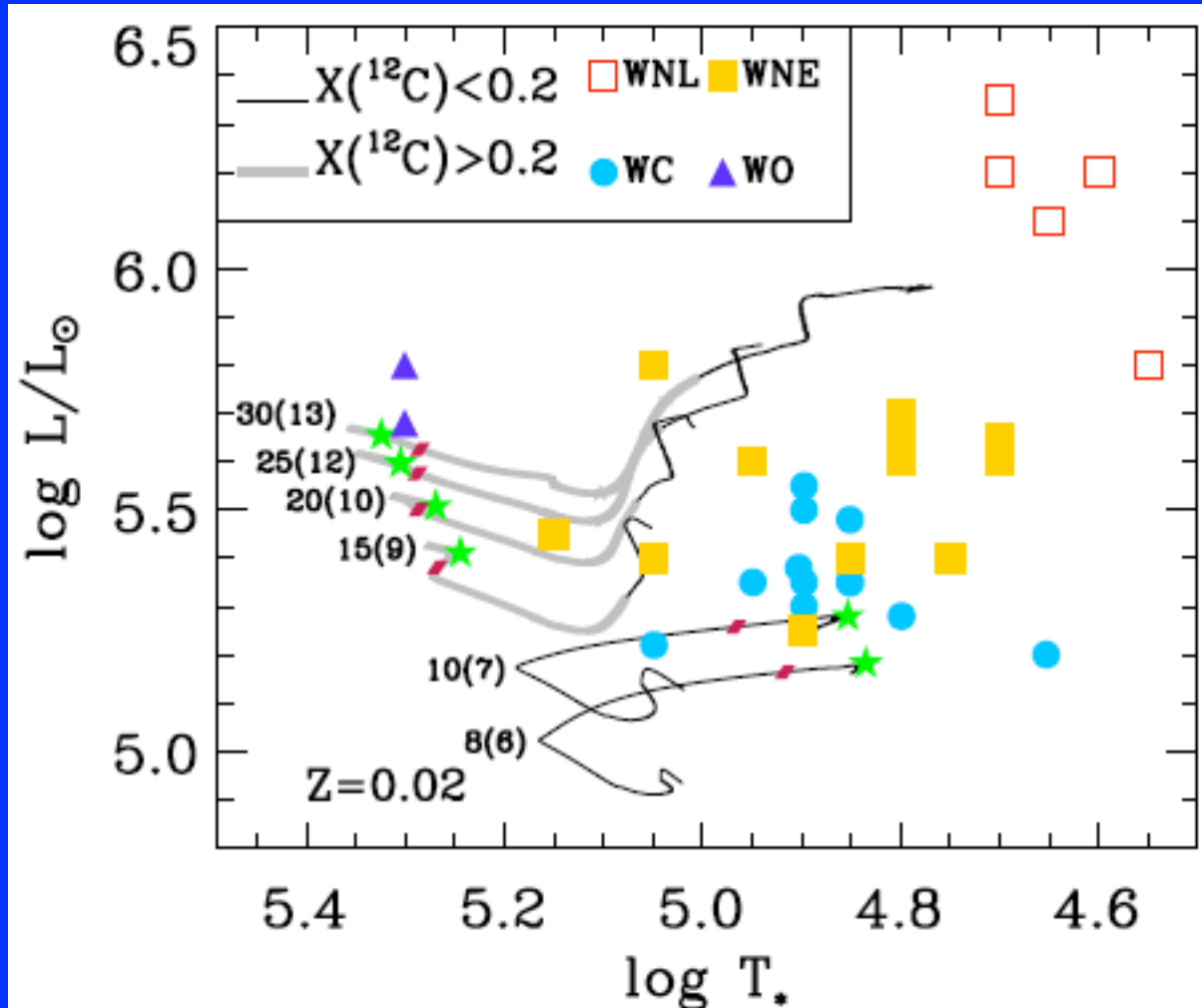


# Binary stripped stars as Type Ic Progenitors



Yoon et al. (2012) A&A Letter

# WC/WO as Type Ic Progenitors



Yoon et al. (2012) A&A Letter

# Progenitor for Collapsar model

Woosley (1993)

- Rapidly Rotating
- No Hydrogen envelope: Wolf-Rayet

# Progenitor for Collapsar model

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- But.....winds: Angular Momentum Loss

# Solution to GRB problem?

WR Mass Loss decreases at low  $Z$

Vink & de Koter (2005)

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# Solution to GRB problem?

WR Mass Loss decreases at low  $Z$

Vink & de Koter (2005)

- less Angular Momentum Loss
- Long GRBs favoured at low  $Z$

# Are low-Z WRs fast rotators?

- No  $v \sin i$

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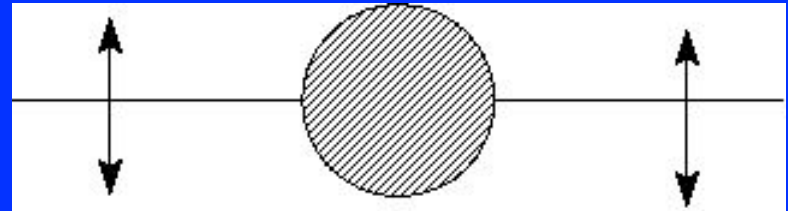
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# Are low-Z WRs fast rotators?

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  - > Linear Polarimetry

# Polarimetry – 2D axi-symmetry

$$\begin{array}{l} \mathbf{I} \\ U = \begin{array}{c} \updownarrow \\ - \\ \rightleftarrows \end{array} \\ Q = \begin{array}{c} \nearrow \\ - \\ \searrow \end{array} \end{array}$$

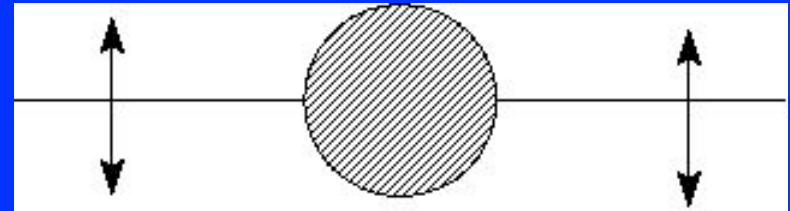


$$P = \sqrt{U^2 + Q^2}$$

$$\theta = \frac{1}{2} \arctan\left(\frac{U}{Q}\right)$$

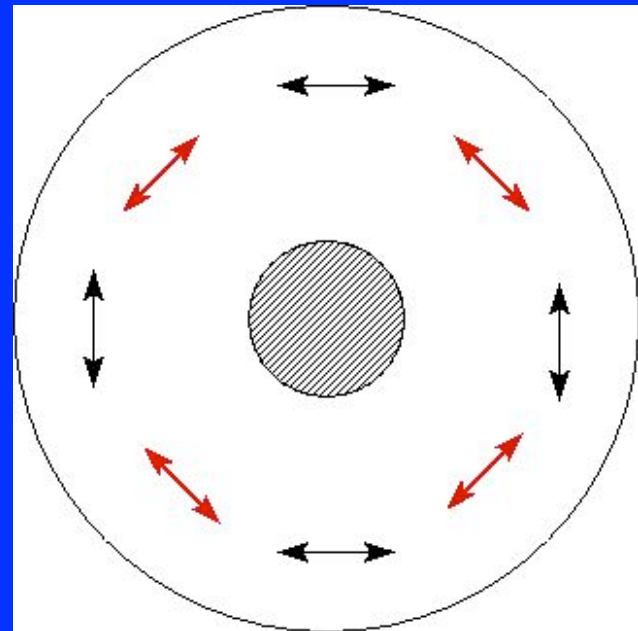
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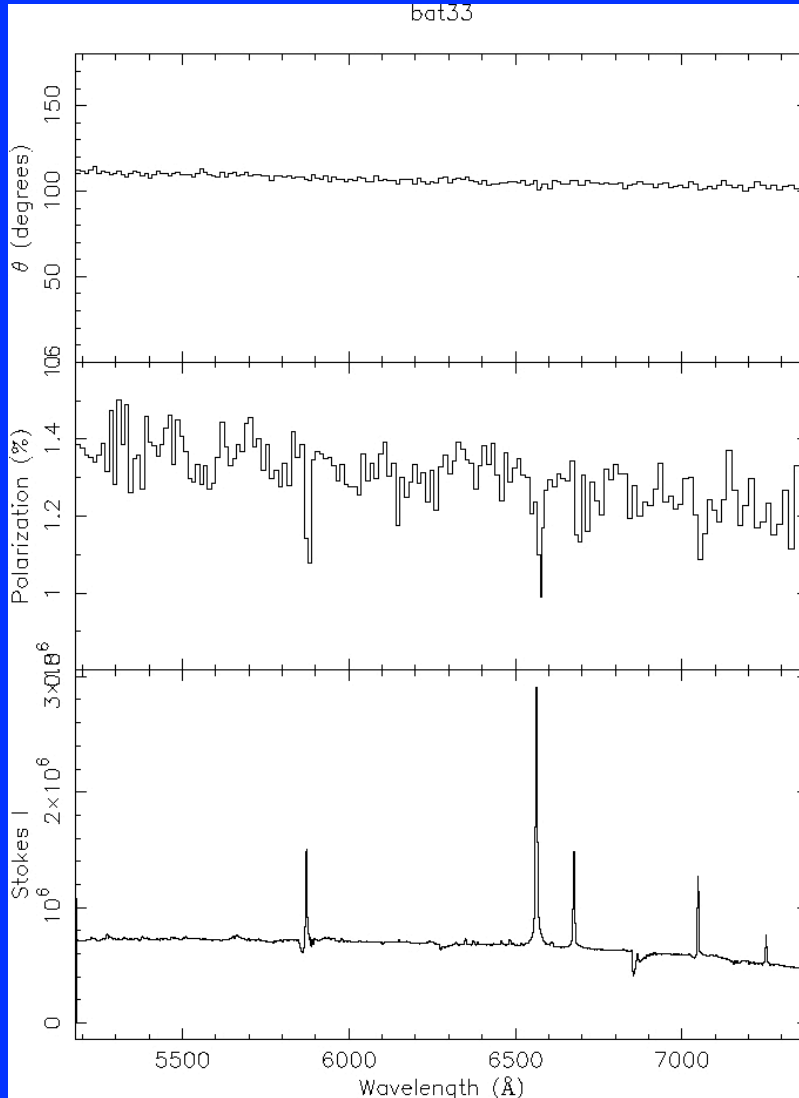


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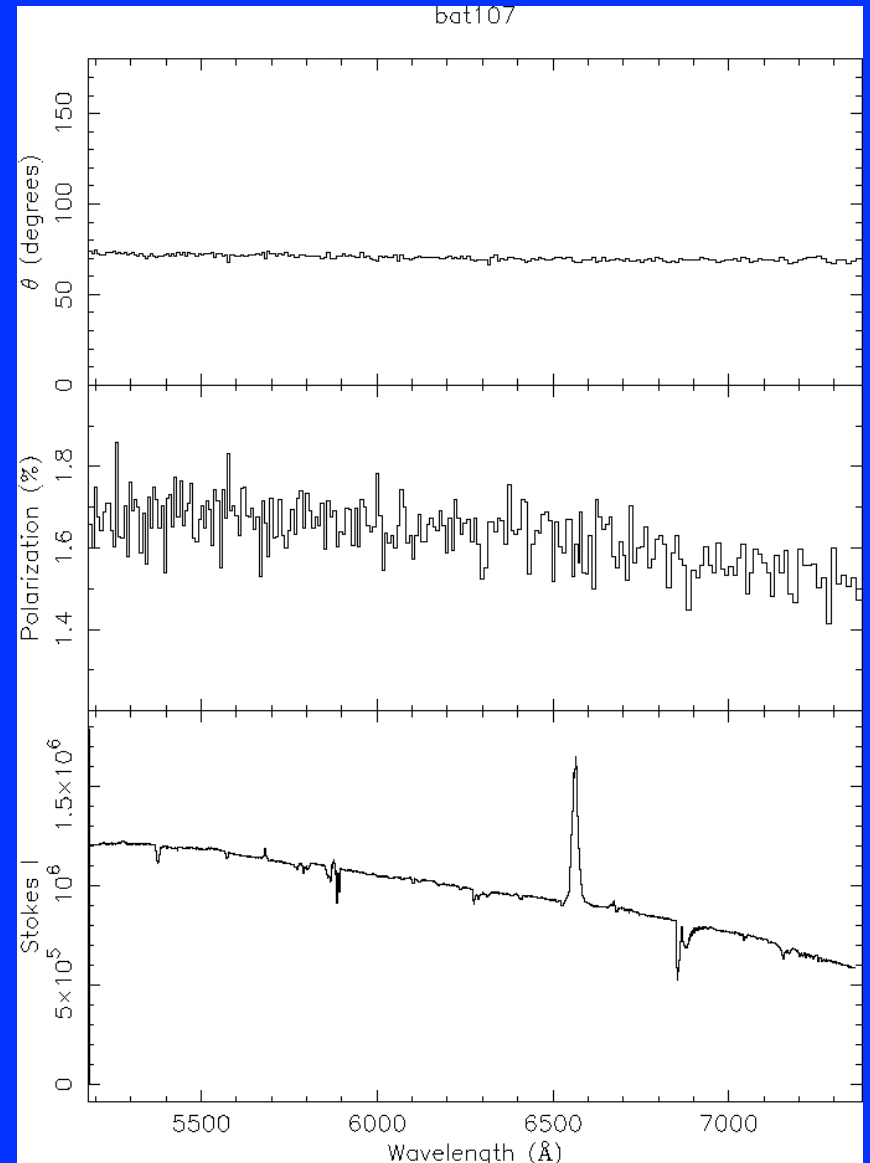
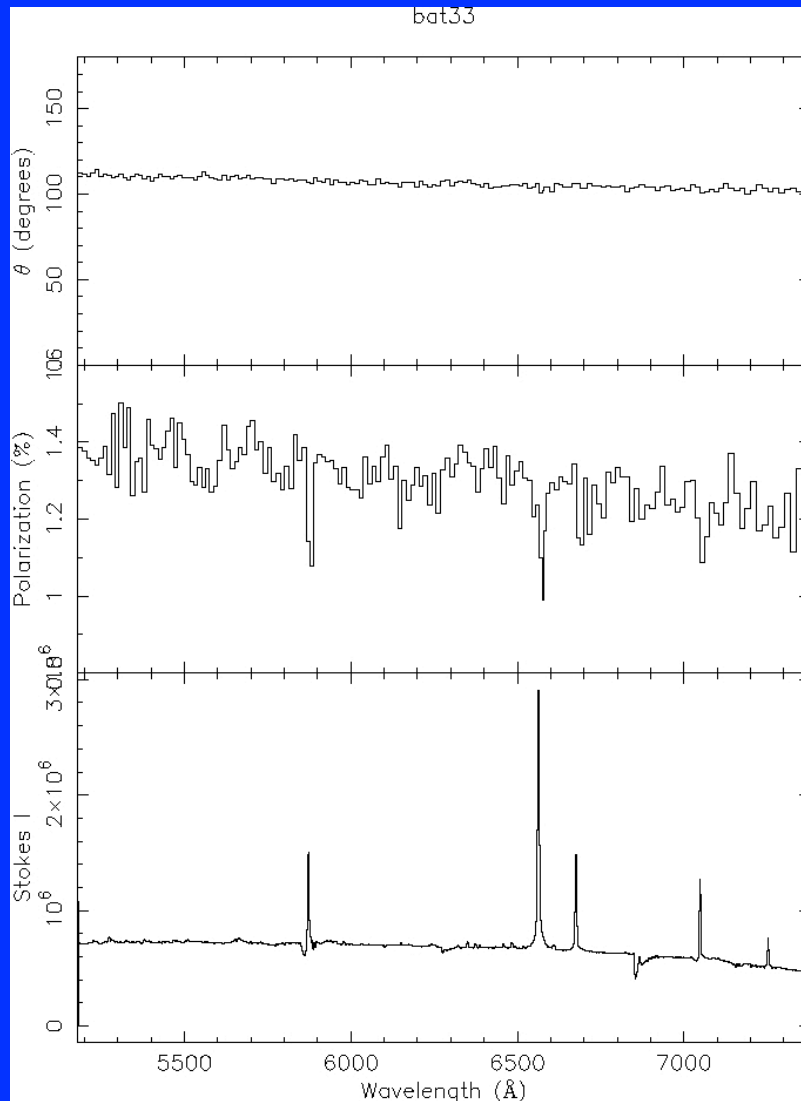


# LMC-WR polarimetry with VLT



Vink (2007, A&A, 469, 707)

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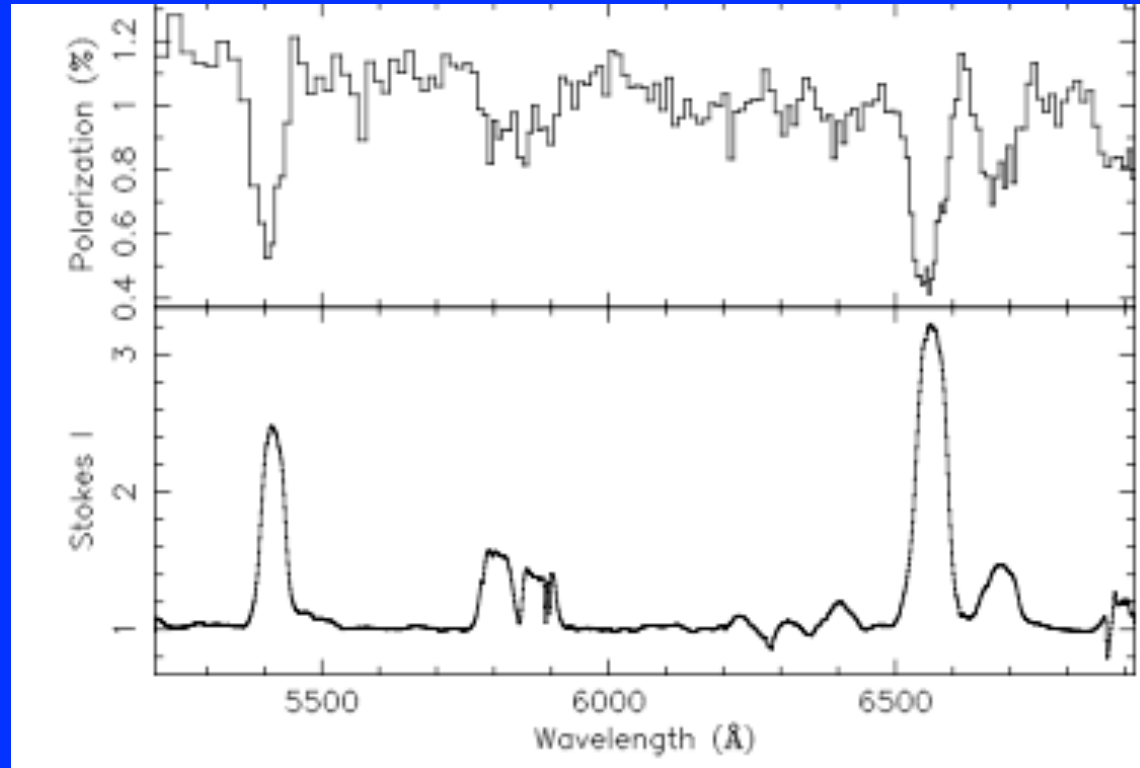
Vink (2007, A&A, 469, 707)



# Population of Rotating WRs!

POL %

Stokes I



Vink, Graefener & Harries, A&A Letter (2011)

# Low Z WR conclusions

Vink & Harries 2017 A&A

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# Low Z WR conclusions

Vink & Harries 2017 A&A

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- 10% sub-group of rotating WRs from LBV-like progenitor

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- 2D effects relevant: Linear Polarimetry!