

# Massive Stars Mass Loss



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*... for the stellar structure? ... for the environment?*

- Evolutionary timescale
  - Final fate (BH, NS or WD?)
  - Structure (CSM) and appearance (WR)
- chemical and dynamical evolution of Galaxies
  - trigger star formation
  - blow bubbles

## Mass Loss - Possible Driving Mechanisms

Metal Line Driving



Winds

Dynamical Instabilities

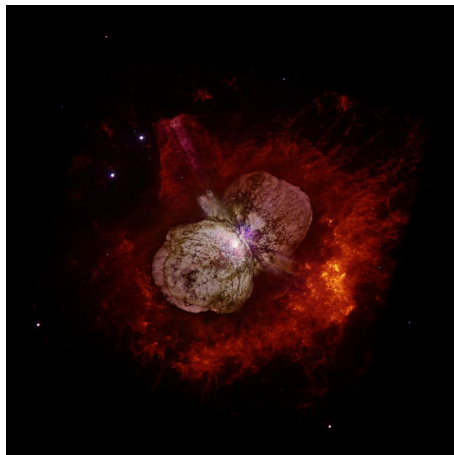


LBVs, Episodic Mass Loss,  
Super-Eddington winds

Binary interactions

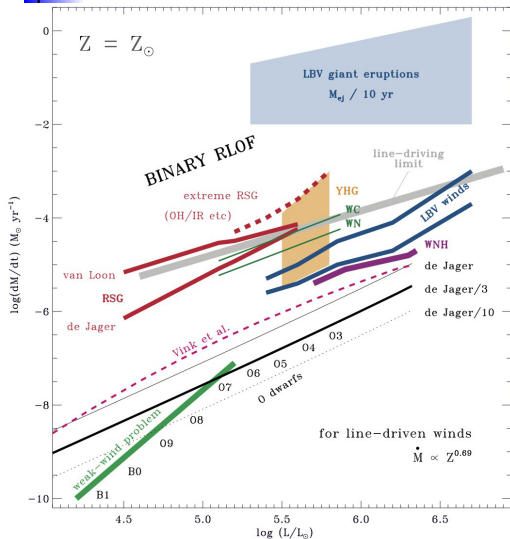


Roche Lobe Overflows



*Figure: 11* Car, false colors, from wikipedia.

# Mass Loss in Stellar Evolution Codes ( MESA )



Parametric models with large uncertainties (clumpiness, non-wind mass loss) encapsulated in efficiency factor:

$$\dot{M}(L, T_{\text{eff}}, Z, R, M, \dots)$$



$$\eta \dot{M}(L, T_{\text{eff}}, Z, R, M, \dots)$$

Figure: From Smith 2014, ARA&A, 52, 487S

Grid of  $Z_{\odot}$  stellar models:

- Initial mass:

$$M_{\text{ZAMS}} = \{15, 20, 25, 30, 35\} M_{\odot};$$

- Efficiency:

$$\eta = \left\{1, \frac{1}{3}, \frac{1}{10}\right\};$$

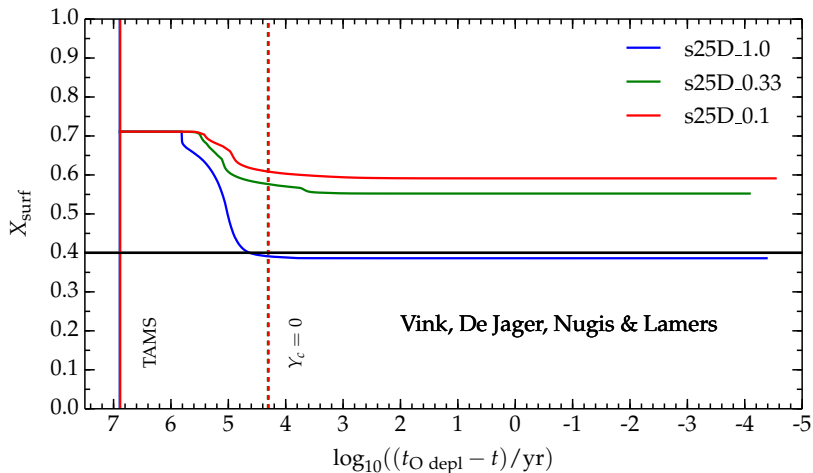
- Different combinations of wind mass loss rates for “hot”, “cool” and WR stars:

Kudritzki *et al.* '89; Vink *et al.* '01;

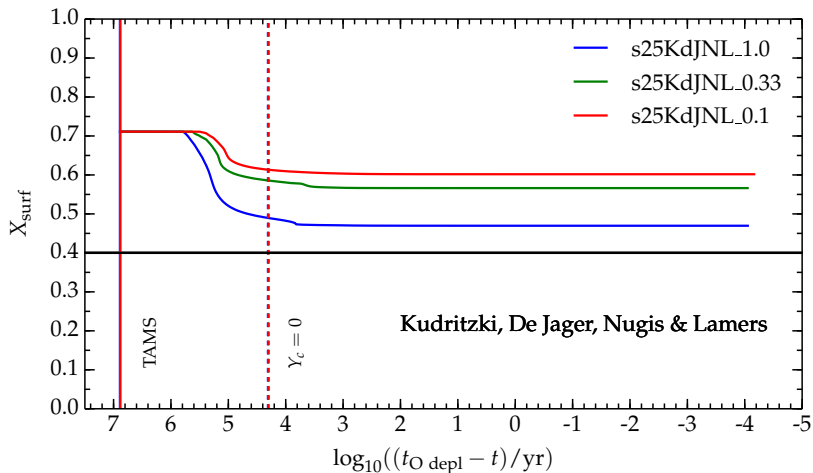
Nieuwenhuijzen *et al.* '90; De Jager *et al.* '88;

Nugis & Lamers '00; Hamann *et al.* '98.

Example:  $25 M_{\odot}$ ,  $Z_{\odot}$  from ZAMS to O depletion



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- Mass loss is important both for the stellar structures and their environment;
- Several mass loss mechanisms, hard to implement in stellar evolution codes;
- Large theoretical and observational uncertainties on the mass loss rate  $\dot{M}$ ;
- Effects of these uncertainties unexplored in a systematic way.

Thank you for your attention.