Outline: 3 Terms

- Eddington Gamma KINK
- Eddington Gamma INFLATION
- BI-STABILITY
(1) VMS in Context
(2) Evidence for VMS - Martins
(3) VMS Formation - Krumholz
(4) Winds from VMS - Vink
(5) Instabilities - Owocki
(6) VMS Evolution - Hirschi
(7) VMS Death - Theory
   Woosley & Heger
(8) VMS Death - Observations
   Nathan Smith
R136 a1
\[ \log(L/L_{\text{sun}}) = 6.94 \pm 0.09 \]
\[ M = 265 \, \text{M}_{\odot} \]

(Crowther et al. 2010)
R136 a1
log(L/Lsun) = 6.94 +/- 0.09
M             = 265 Msun

(Crowther et al. 2010)

Confirmation
“isolated”
VFTS 682?
R136 a1
\[ \log(L/L_{\text{sun}}) = 6.94 \pm 0.09 \]
M \quad = 265 M_{\text{sun}}

(Crowther et al. 2010)

Confirmation
“isolated”
VFTS 682?

VFTS 682
\[ \log(L/L_{\text{sun}}) = 6.5 \pm 0.2 \]
M \quad = 150 M_{\text{sun}}

M \quad = 200 M_{\text{sun}}

(Bestenlehner et al. 2011)
EVOLUTION = MASS LOSS

VMS evolve ‘Chemically Homogeneously‘

(Graefener et al. 2011)
Fate of a 300 Msun star

- No winds: 300 Msun BH
- Weak winds: PISN
- Strong Winds: Evaporation!
Line-driven winds

Castor, Abbott & Klein (1975)

Pauldrach, Puls & Kudritzki (1986)
Vink, de Koter & Lamers (2000, 2001)

\[ \frac{dM}{dt} = f (Z, L, M, Teff) \]
H atom  Fe V atom
Monte Carlo approach

(Abbott & Lucy 1985)
\[
dM/dt = f (\text{Gamma})
\]

\[
\Gamma = \frac{g_{rad}}{g_{grav}} = \frac{\kappa L}{4\pi cGM}
\]
KINK in $dM/dt = f(\Gamma)$

Vink et al. (2011)
Wind efficiency

\[ \eta = \frac{\dot{M}v_\infty}{L/c} \]

Vink et al. (2011)
VMS in VFTS

Bestenlehner et al. (2014)
KINK in VMS in VFTS

Bestenlehner et al. (2014)
Transition Point Of/WN

- $\eta = \tau = 1$

- $\frac{dM}{dt} = \frac{L}{vc}$

Vink & Graefener (2012)
\[ \Gamma = \frac{g_{\text{rad}}}{g_{\text{grav}}} = \frac{\kappa L}{4\pi cGM} \]
INFLATION
Radius Inflation

Ishii, Ueno & Kato (1999)
Grafener, Owocki & Vink (2012)
Solution around Fe-bump

Grafener, Owocki & Vink (2012)
LBV Radius Inflation

\[
\frac{R_{\text{out}}}{R_{\text{in}}} = \frac{1}{1 - W}, \quad W = \frac{\Delta P_{\text{rad}} R_{\text{in}}}{GM \rho_{\text{mean}}}
\]

Grafener, Owocki & Vink (2012)
LBVs in the HRD

Smith, Vink & de Koter (2004)
\frac{dM}{dt} = f (T)
BISTABILITY
Change in mass loss

→ dM/dt jumps up by factor 5  (Vink et al. 1999)

→ dM/dt jumps up by factor 30!  (Petrov et al. 2016)
Dense but Slow LBV winds
Do LBVs explode?

Trundle et al. (2008)
\( \frac{dM}{dt} = f \left( Z \right) \)
He II emission at high $z$ - Slow Winds from low $Z$ VMS?

Grafener & Vink (2015)
Summary

- VMS: 100 - 200 - 300 solar mass stars exist
- Upper-mass limit still unknown
- INFLATION makes Radii & Ages uncertain
Summary

- VMS: 100 - 200 - 300 solar mass stars exist
- Upper-mass limit still unknown
- INFLATION makes Radii & Ages uncertain

- \( \frac{dM}{dt} = f \left( \frac{L}{M} \right) = f \left( \Gamma \right) \) - KINK
- \( \frac{dM}{dt} = f \left( T \right) \) - LBV-SNe
- \( \frac{dM}{dt} = f \left( Z \right) \) - GRBs, BHs, PISNe

- Feedback as a function of metallicity