# Mass loss as a function of Z

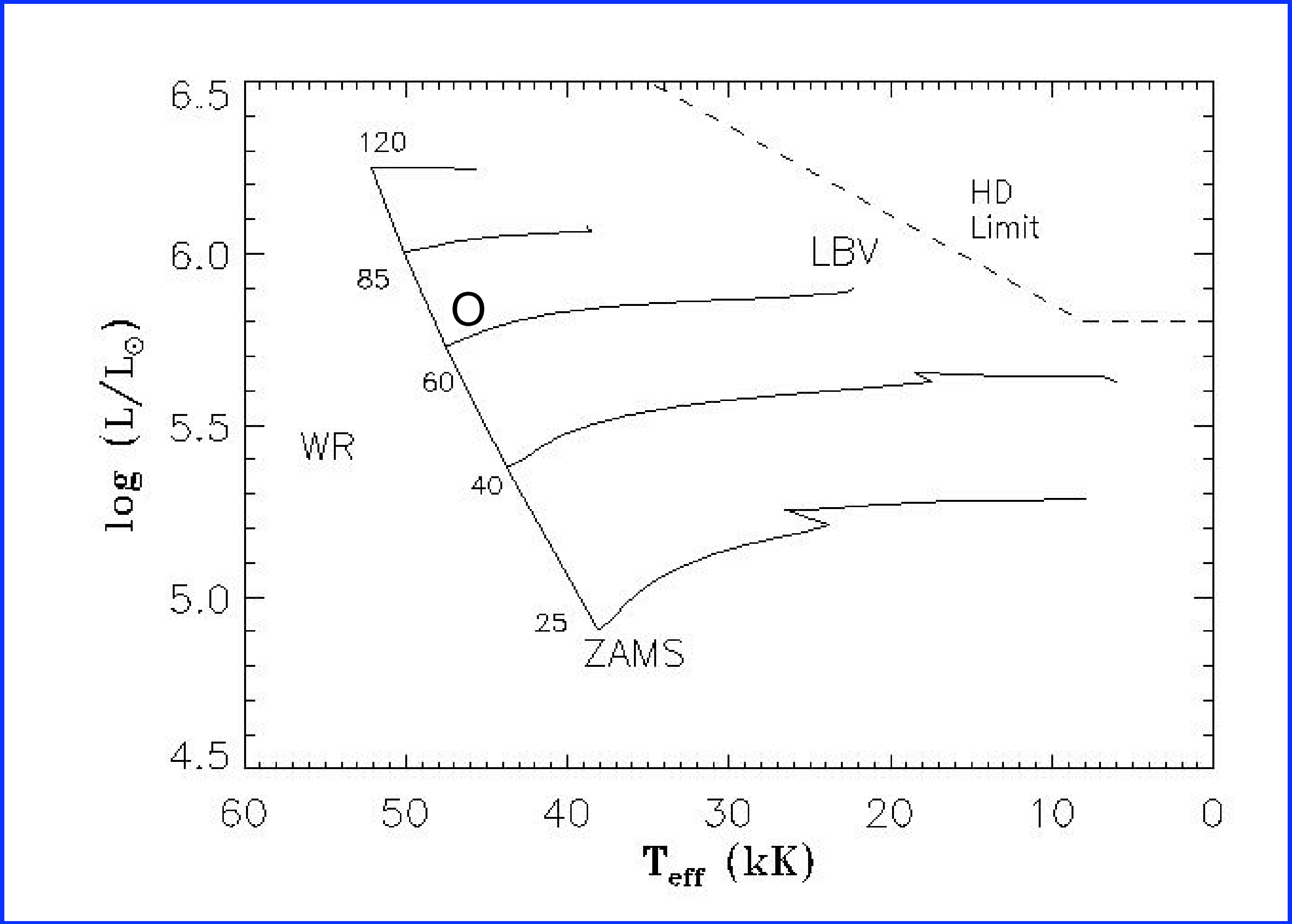
Jorick Vink (Armagh Observatory, UK/Ireland)

# Outline

- Intro
- CAK versus Monte Carlo
- O-type winds

- Bi-stability Jump
- Angular momentum loss

# Evolution of a Massive Star



# Mass Loss

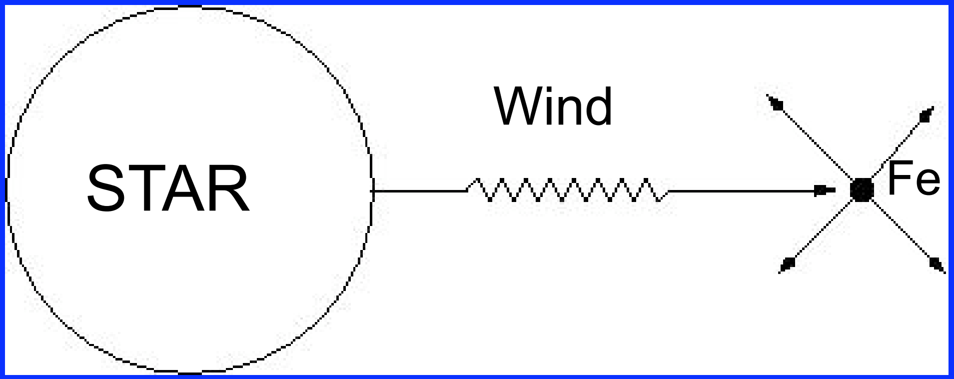
- Peeling off the star
  → O → LBV → WN → WC/WO → BH
  (e.g. Conti 1976)

- Removal of angular momentum

  (e.g. Langer 1998, Maeder & Meynet 2000)

# Radiation-driven wind by Lines

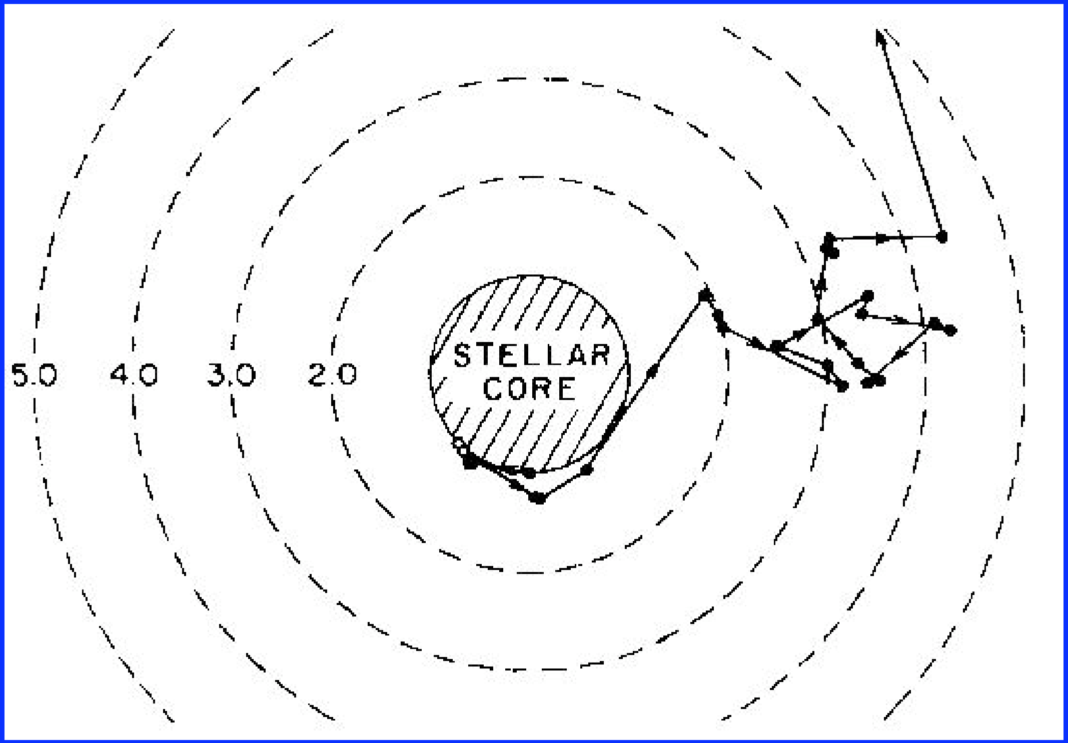
Lucy & Solomon (1970)
Castor, Abbott & Klein (1975) = CAK




dM/dt = f (Z, L, M, Teff)

# Monte Carlo Approach

Abbott & Lucy (1985)




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

dM/dt = f (Z, L, M, Teff)

# Two O-star approaches

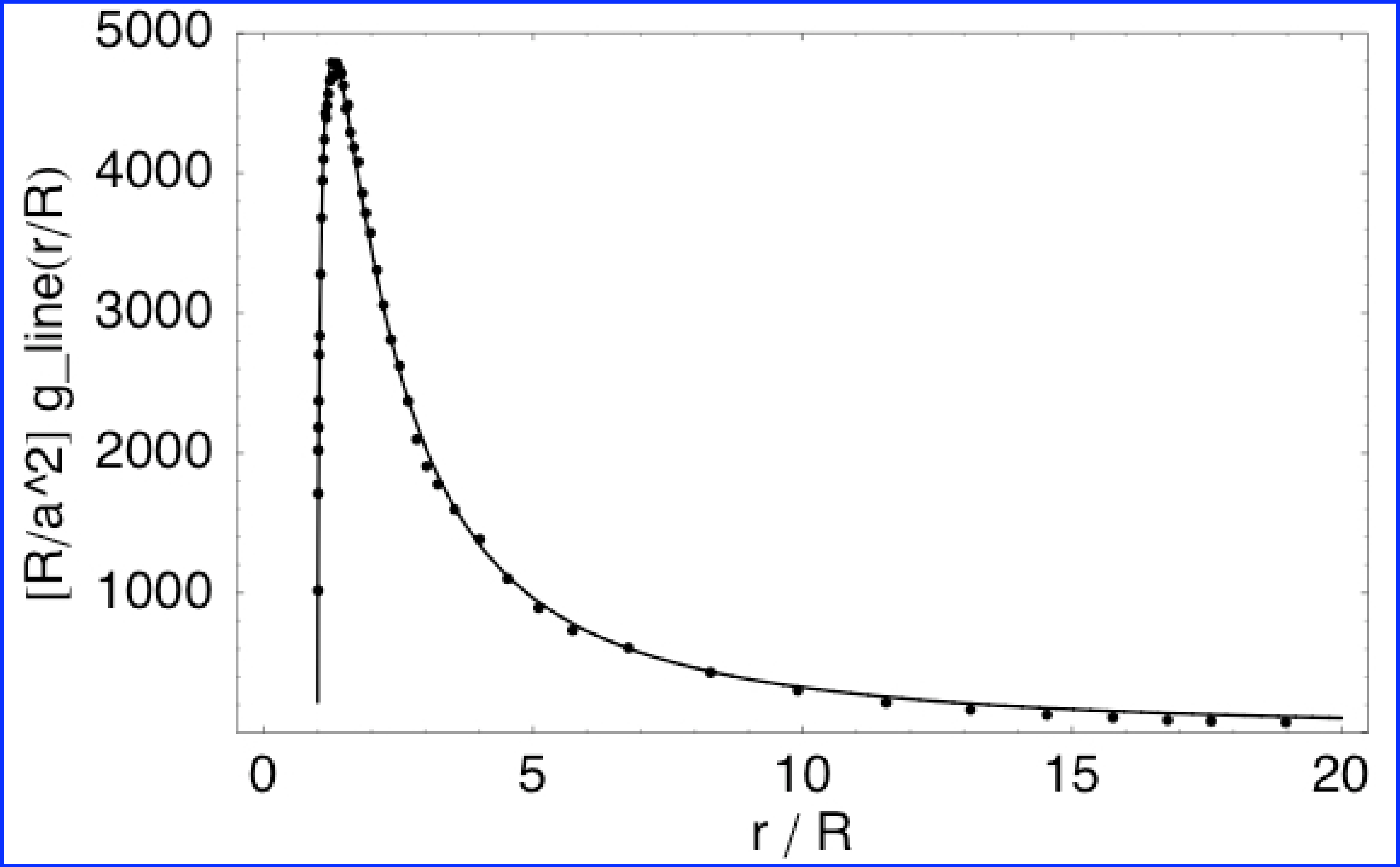
1. CAK-type
   → Line force approximated
   → v(r) predicted

Pauldrach et al. (1986); Kudritzki (2002)

2. Monte Carlo (Abbott & Lucy)
   → V(r) adopted
   → Line force computed – for all radii
   → multiple scatterings included

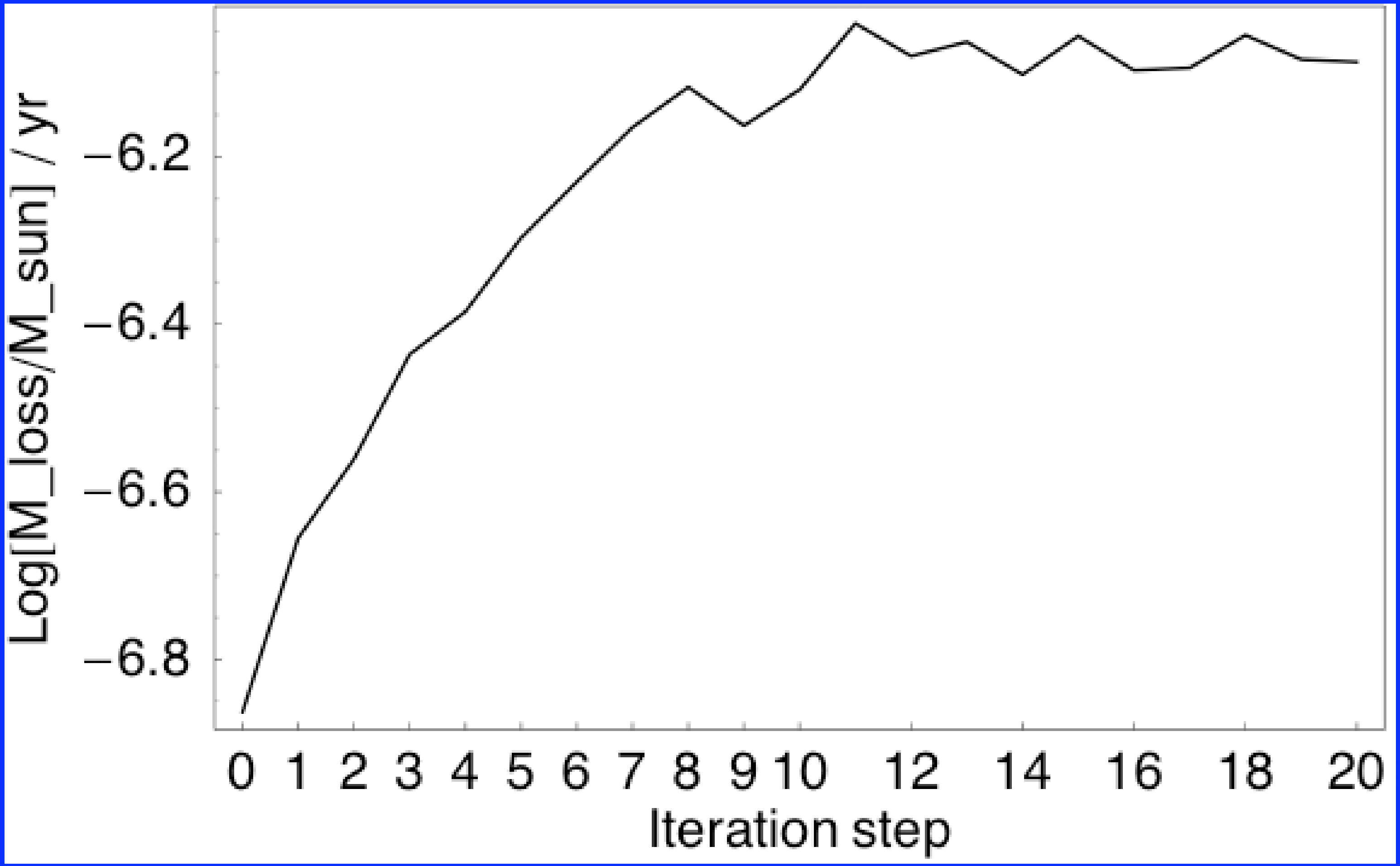
Vink, de Koter & Lamers (2000, 2001)

# Line acceleration: g(r)



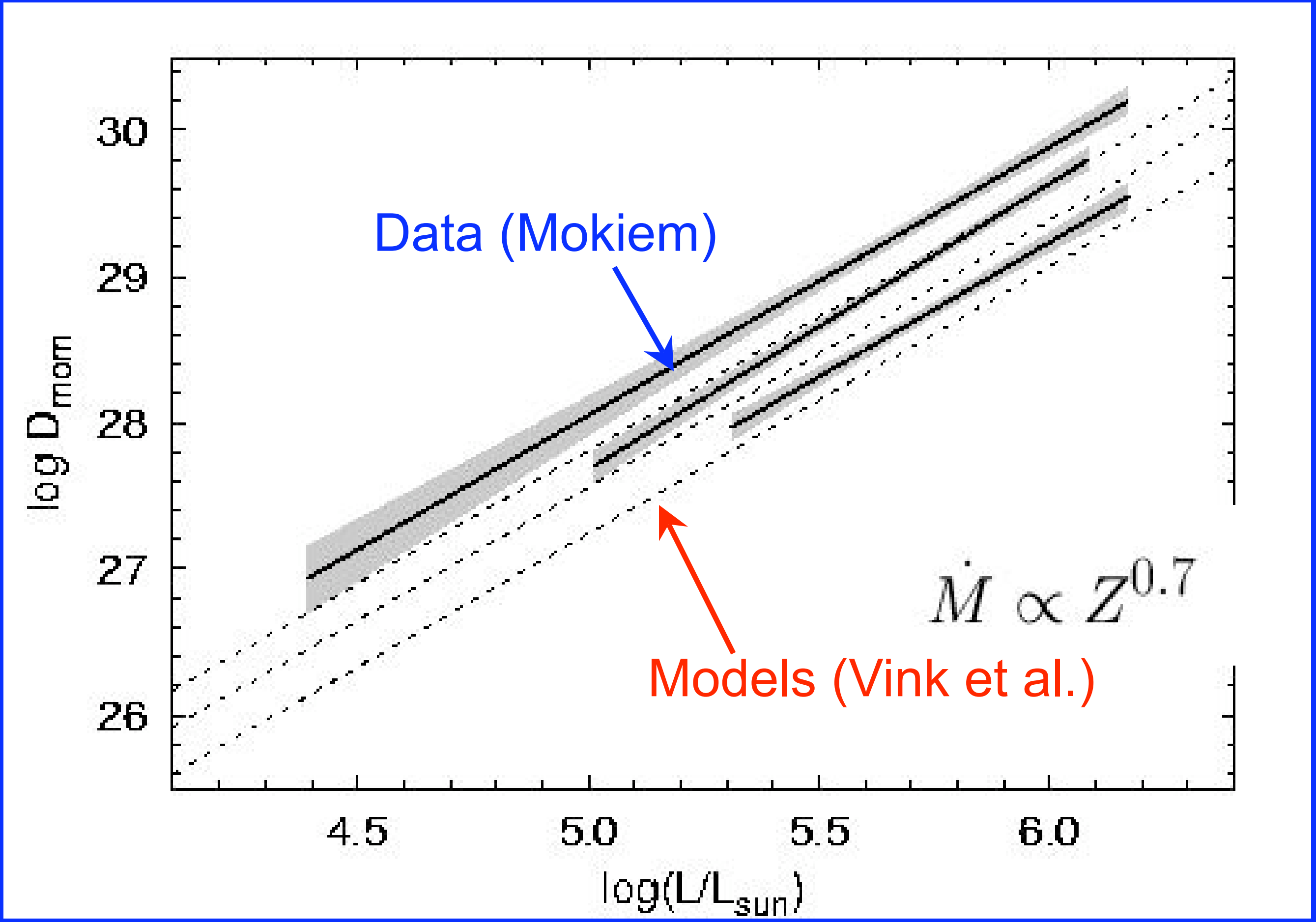

Mueller & Vink (2009)

# Mass-loss iteration




Mueller & Vink (2009) - astro-ph 0810.1901

# Wind momenta at low Z




Mokiem et al. (2007b)

# The Bi-stability Jump

HOT O supergiants

dM/dt

fast wind

Fe IV

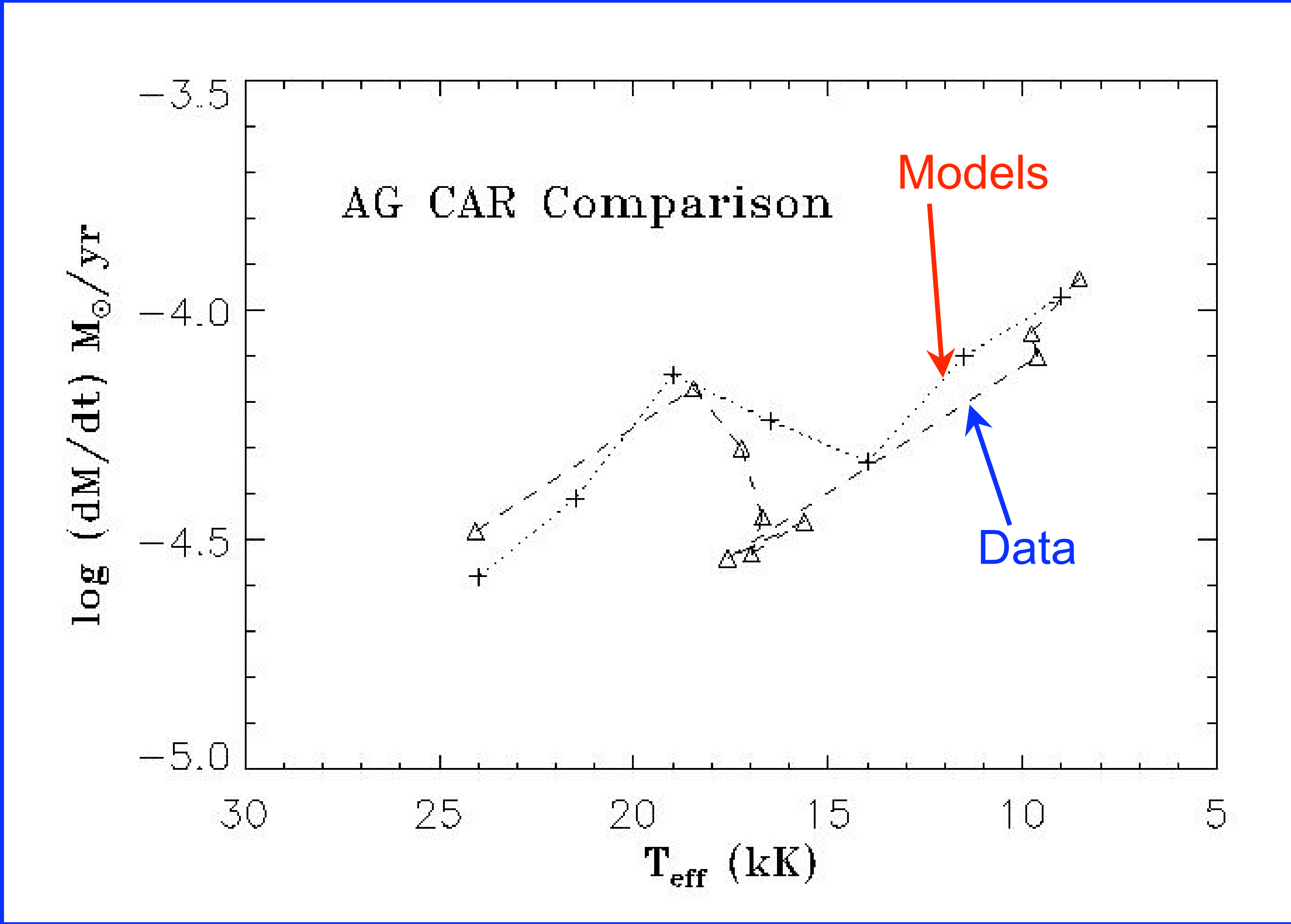
COOL B supergiants

dM/dt x 5

slow wind

Fe III

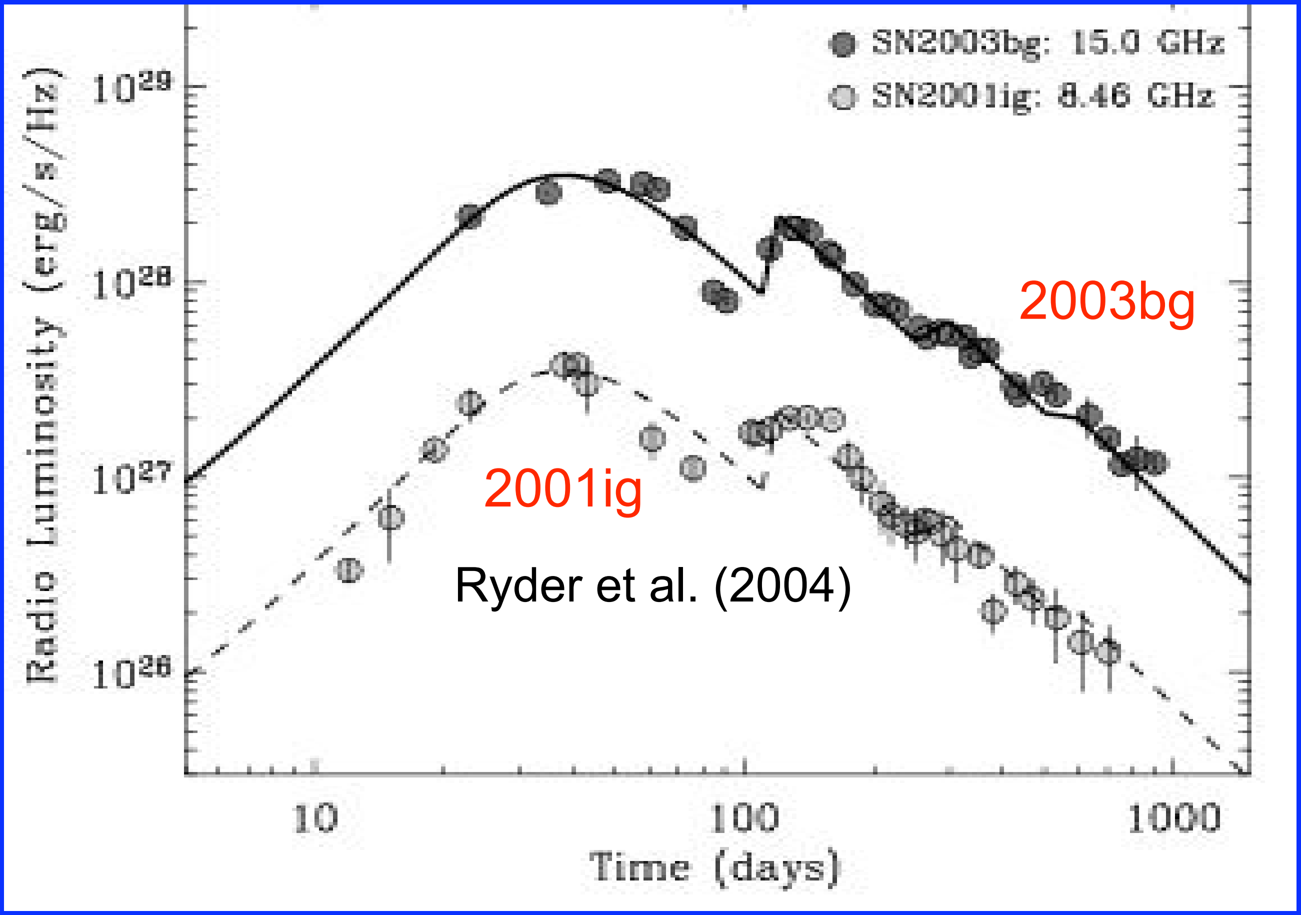
# Variable mass loss of LBVs




Stahl et al. (2001)

Vink & de Koter (2002)

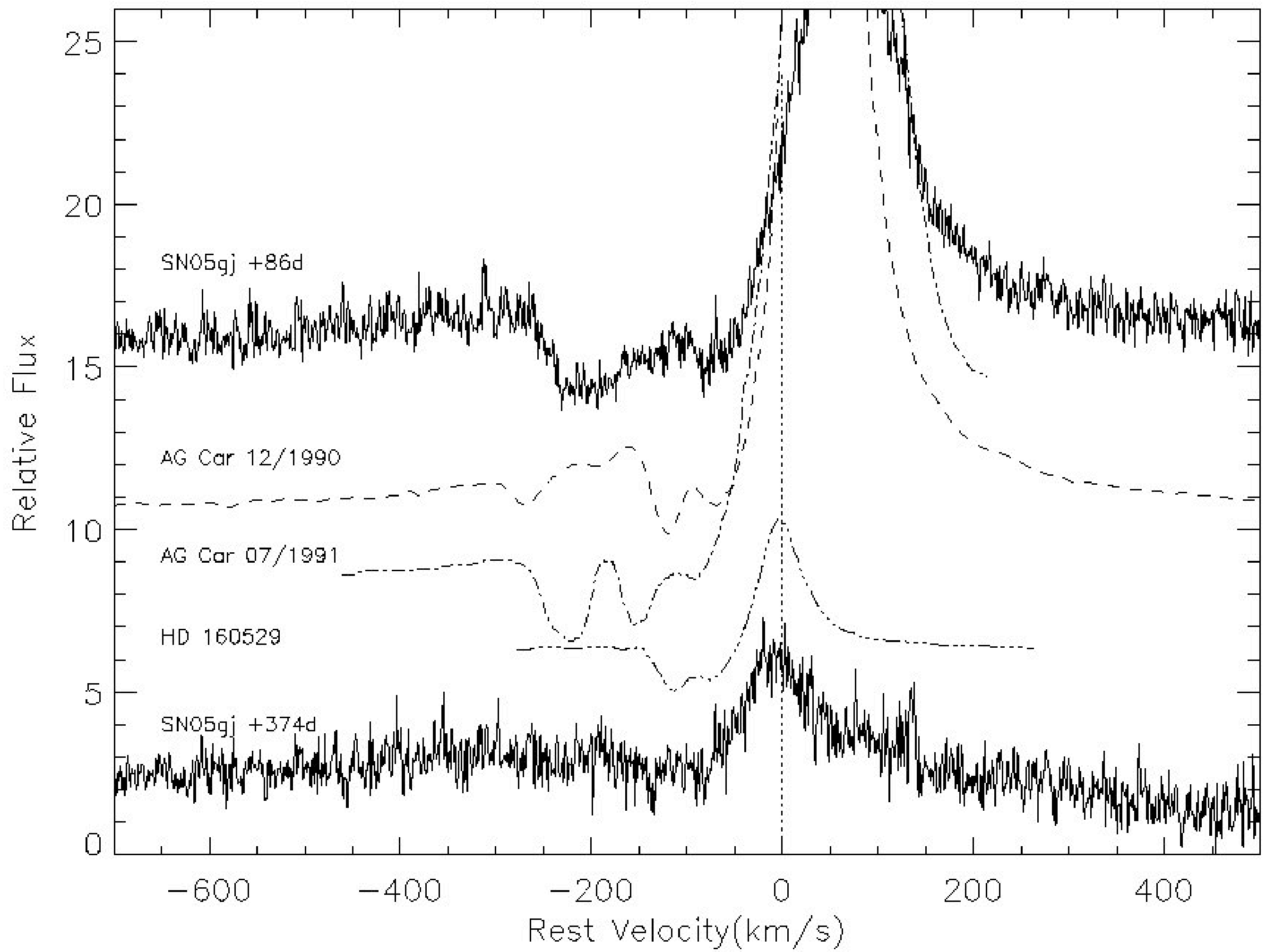
# Radio supernova lightcurves




Soderberg et al. (2006)

Kotak & Vink (2006): LBV

# Do LBVs explode?

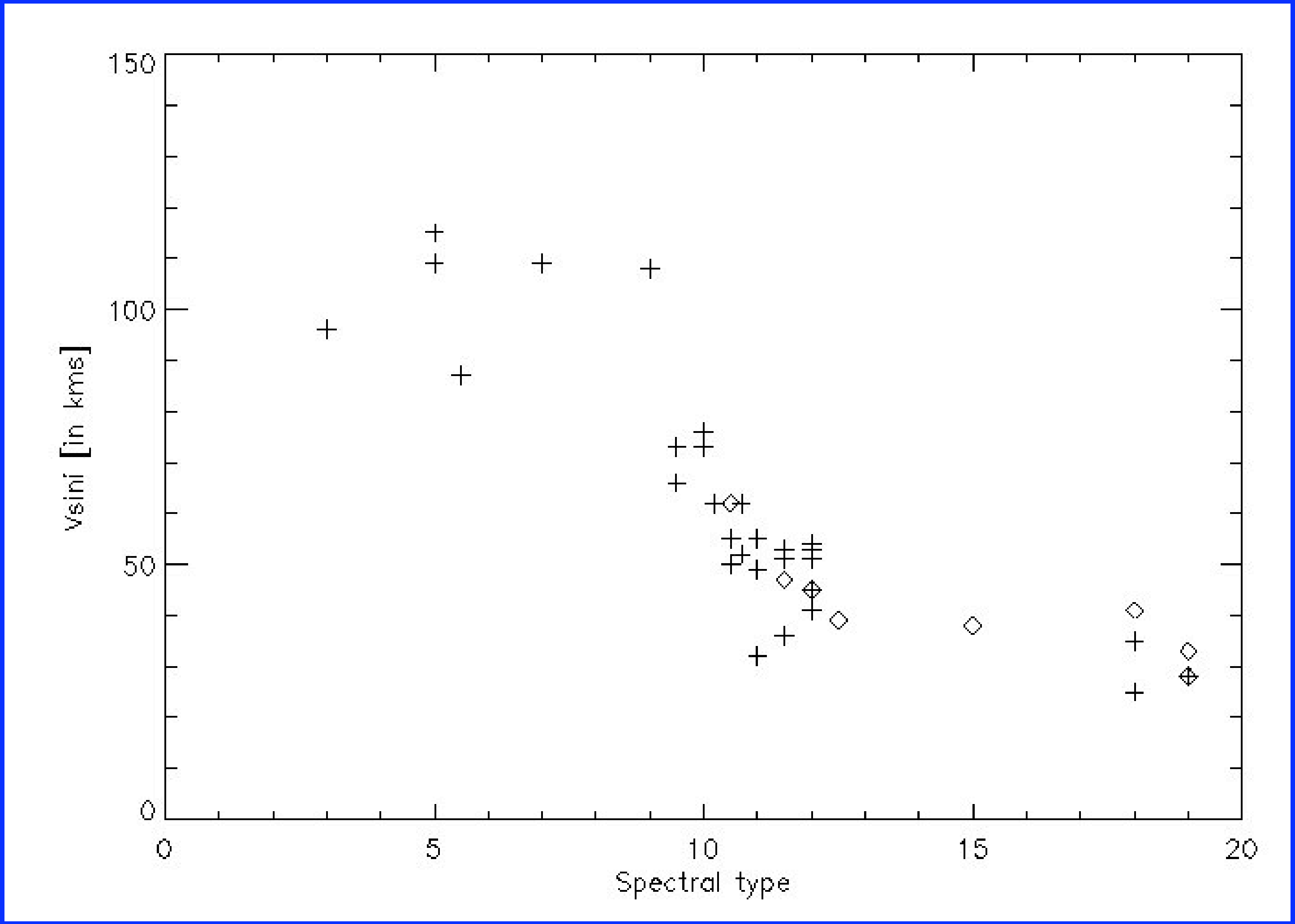



Trundle, Kotak et al. (2008)

# Are the LBV winds changing the evolutionary paradigm?

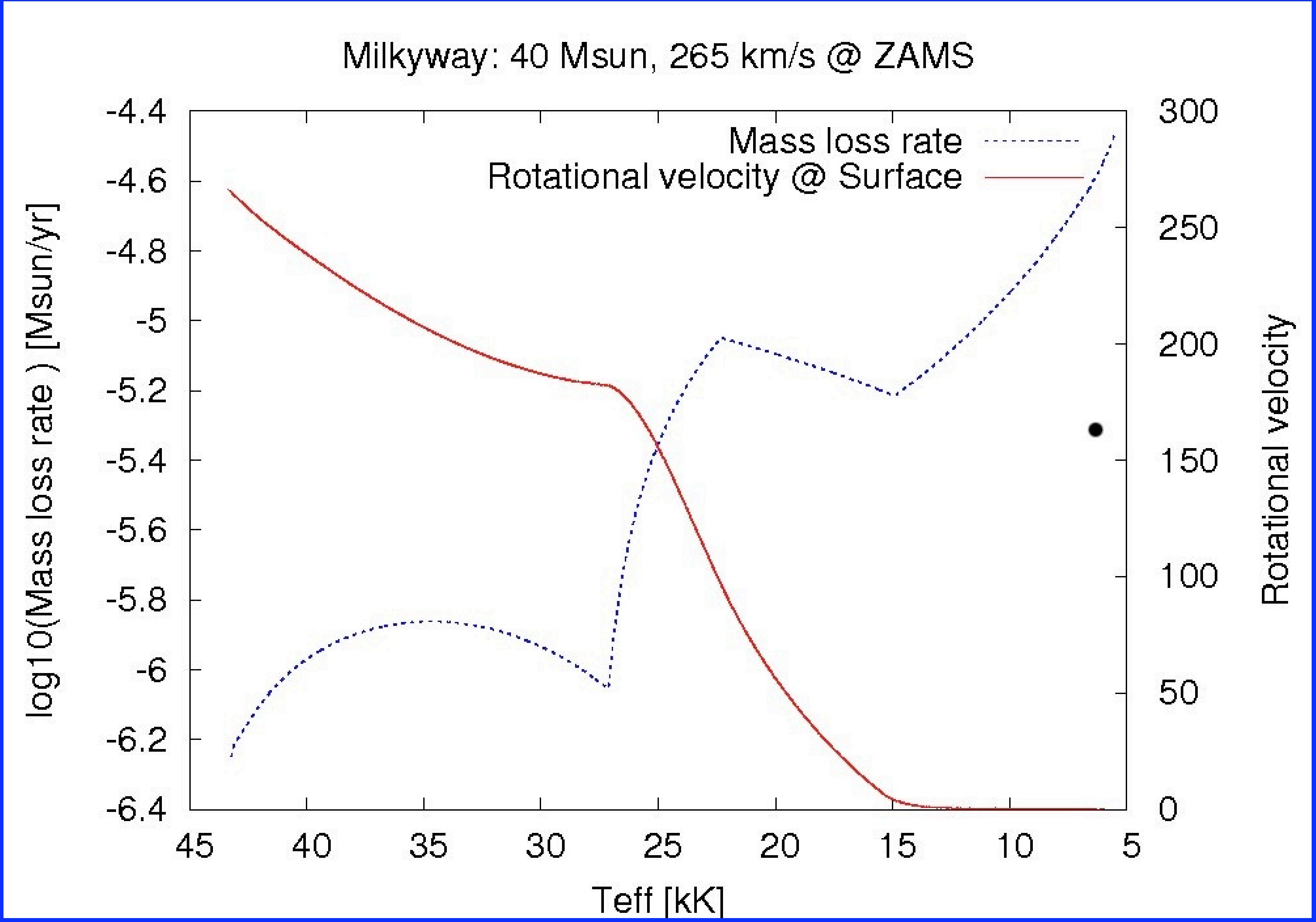
- canonical: O → LBV → WR → SN
- suggested: O → LBV → SN

# OB rotation rates




Markova & Puls (2008)

# Bi-stability braking?




Brott, Langer

Vink (2008) - astro-ph 0809.4789

# Summary

- Mdot scalings with L & Z
- Monte Carlo + dynamics:   v(r) + Mdot

Bi-Stability Jump:

- LBV variations (SN progenitors?)
- Rotation rates between O and B