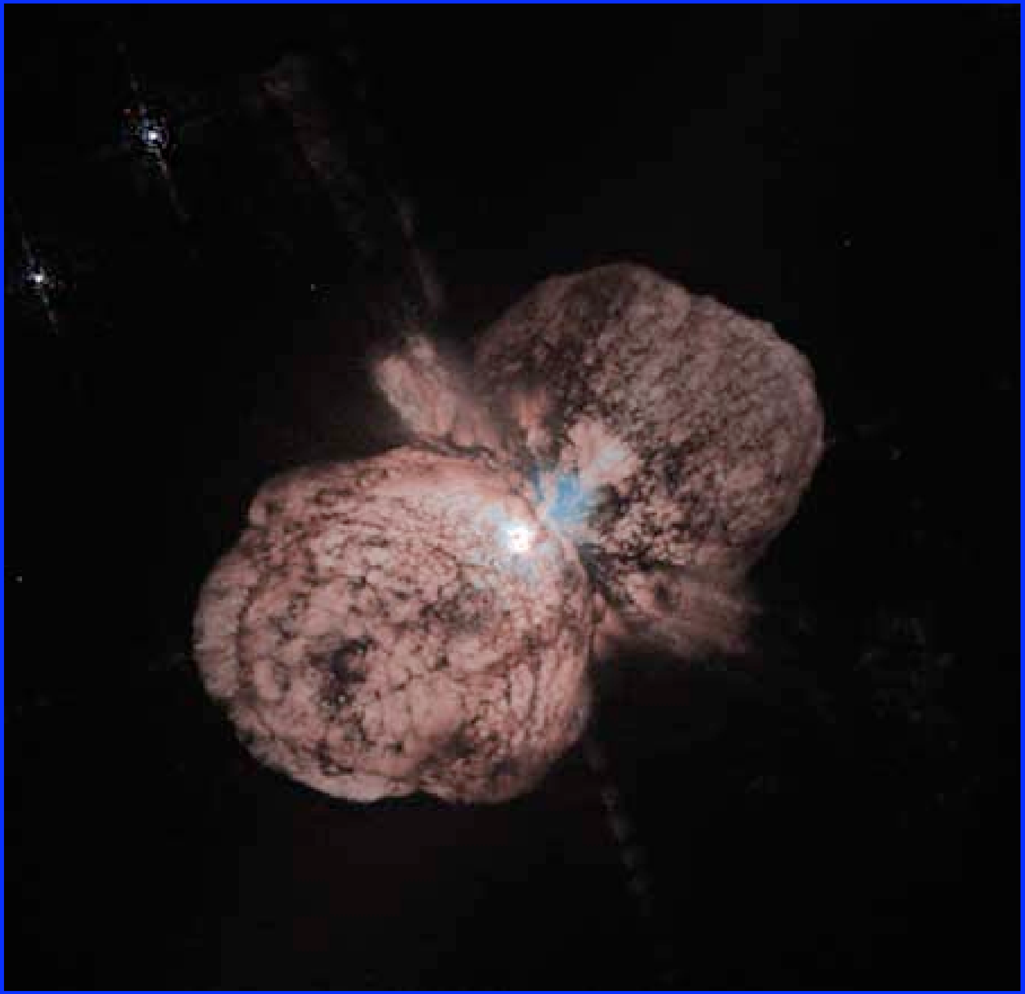
Yields as a function of Z

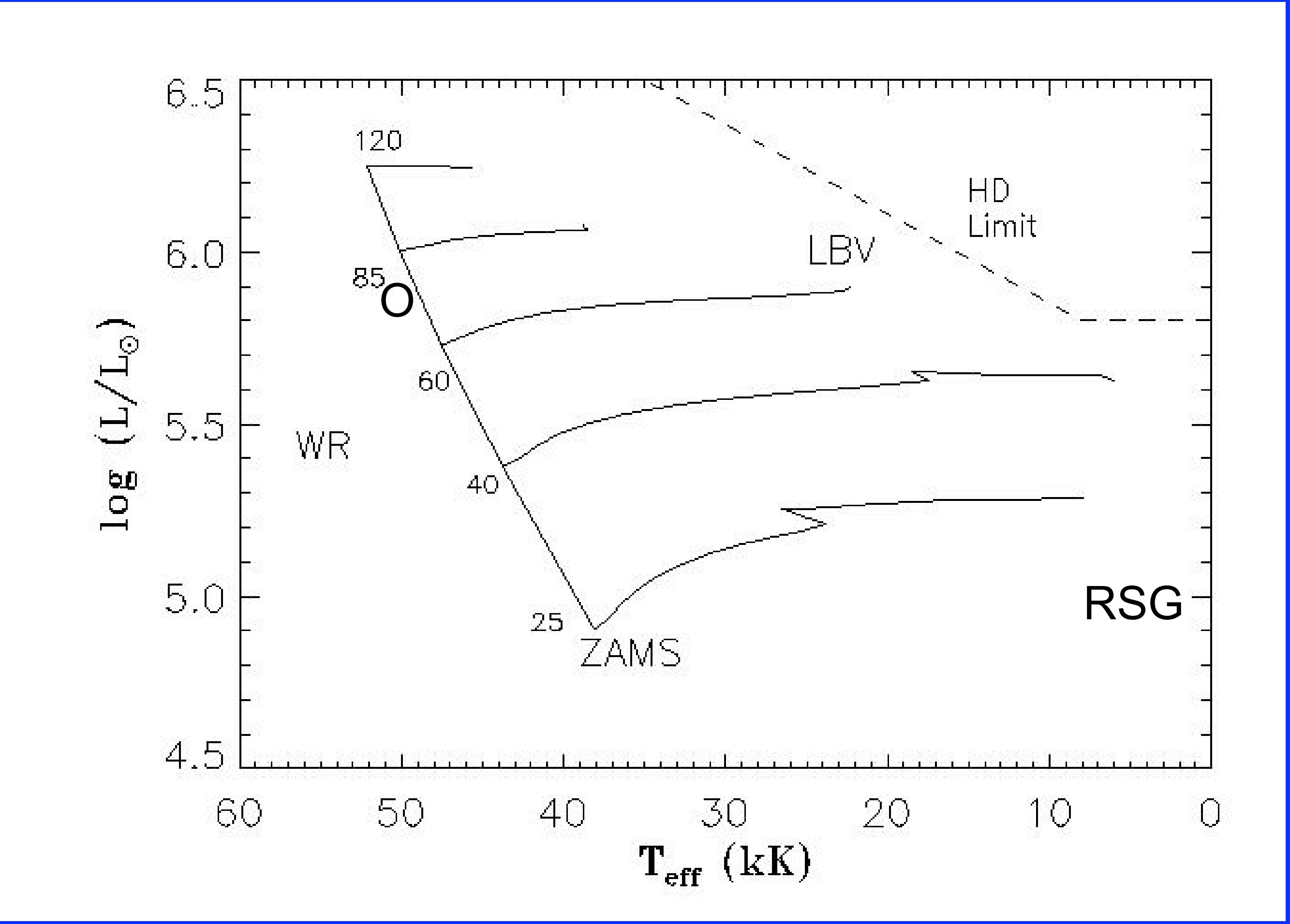


Jorick Vink (Armagh Observatory, UK)

Why massive stars?

- Rare but Bright
- Heavy metals
- Ionizing radiation
- kinetic energy input into ISM

Upper HRD- Massive Stars



Yields?

- Stellar wind mass loss
- SNe

Yields?

- Stellar wind mass loss
- SNe

- Amount of weight loss
- how do they die?

Metallicity (Z) effects

- 5 Msun → AGB → mass loss

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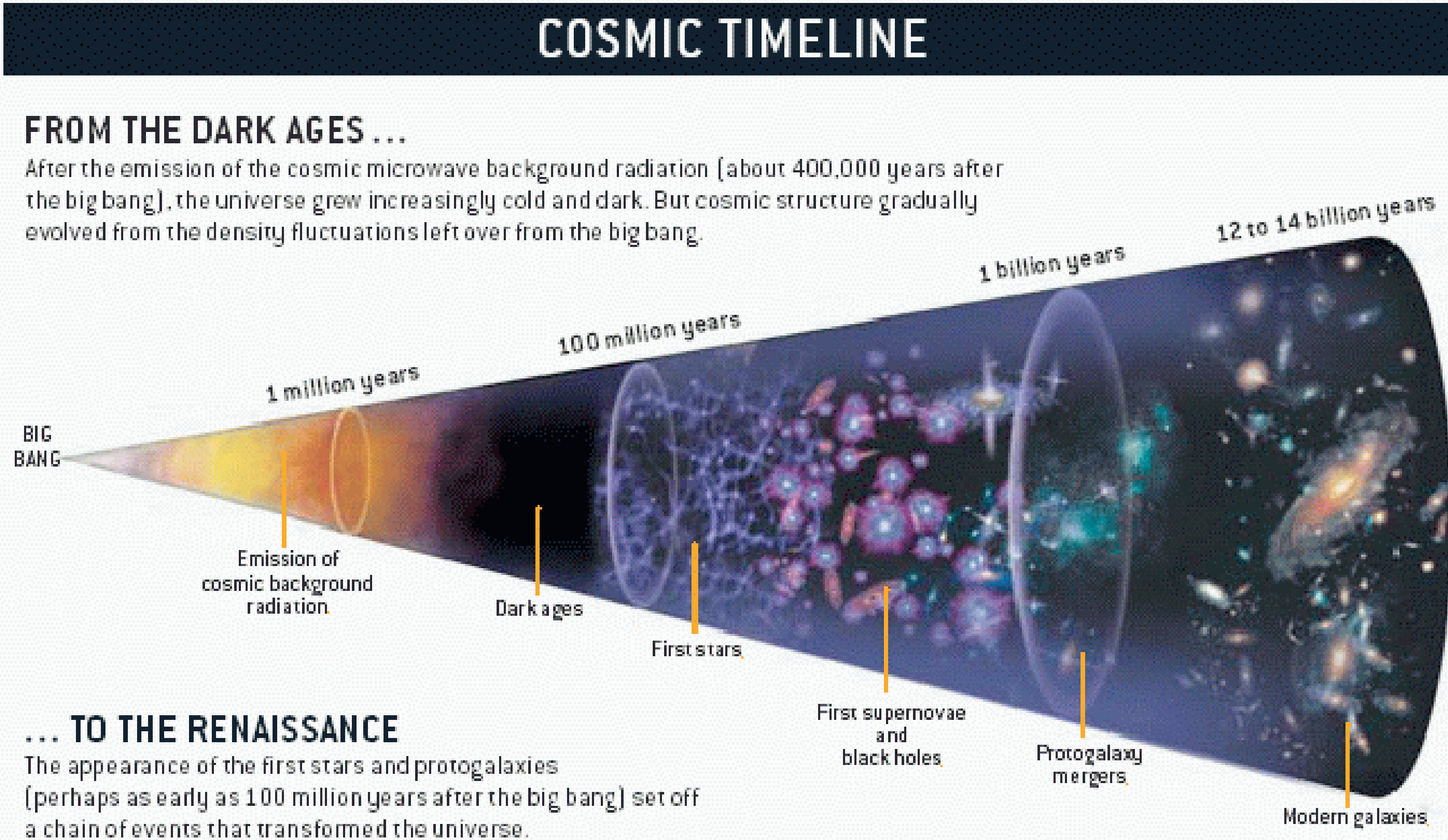
- 60 Msun → LBV → SNe?
- Kotak & Vink (2006) Pastorello et al. (2007)

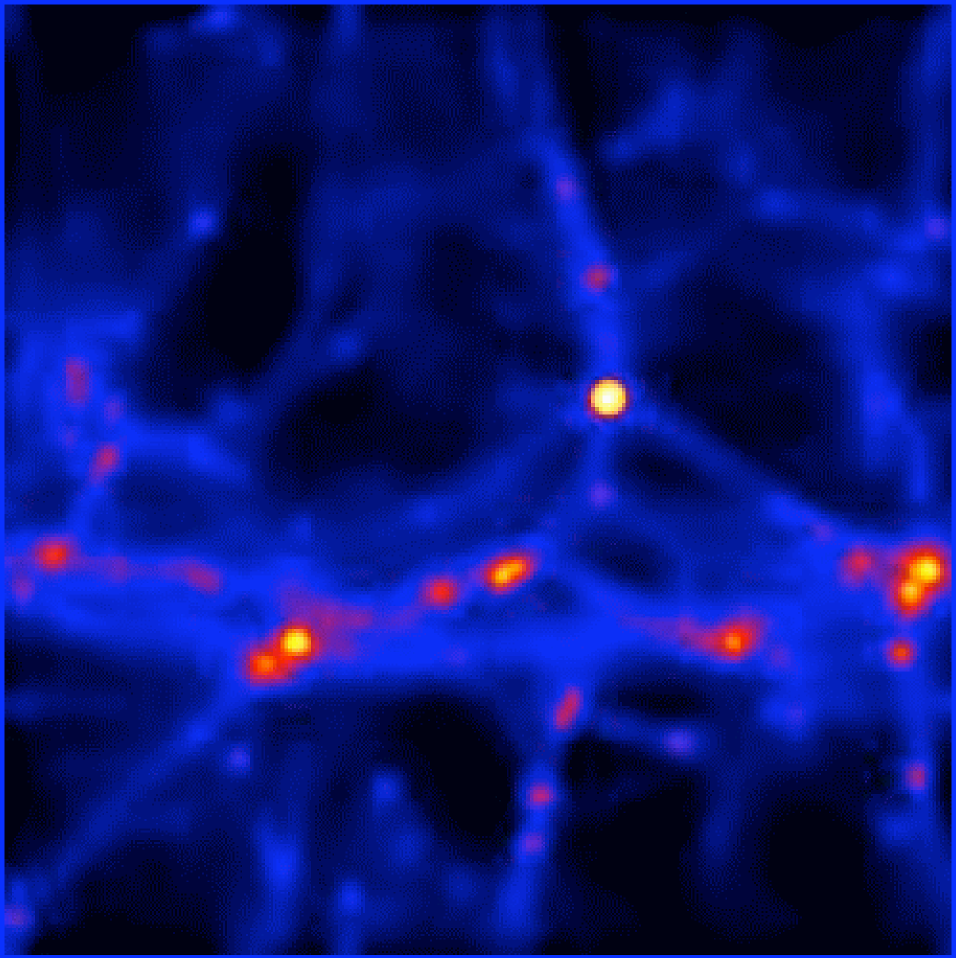
Metallicity (Z) effects

- 5 Msun → AGB → mass loss → Z?
- 10 Msun → RSG → SNe
- 60 Msun → LBV → WR → SNe?
- WILL be Z-dependent !



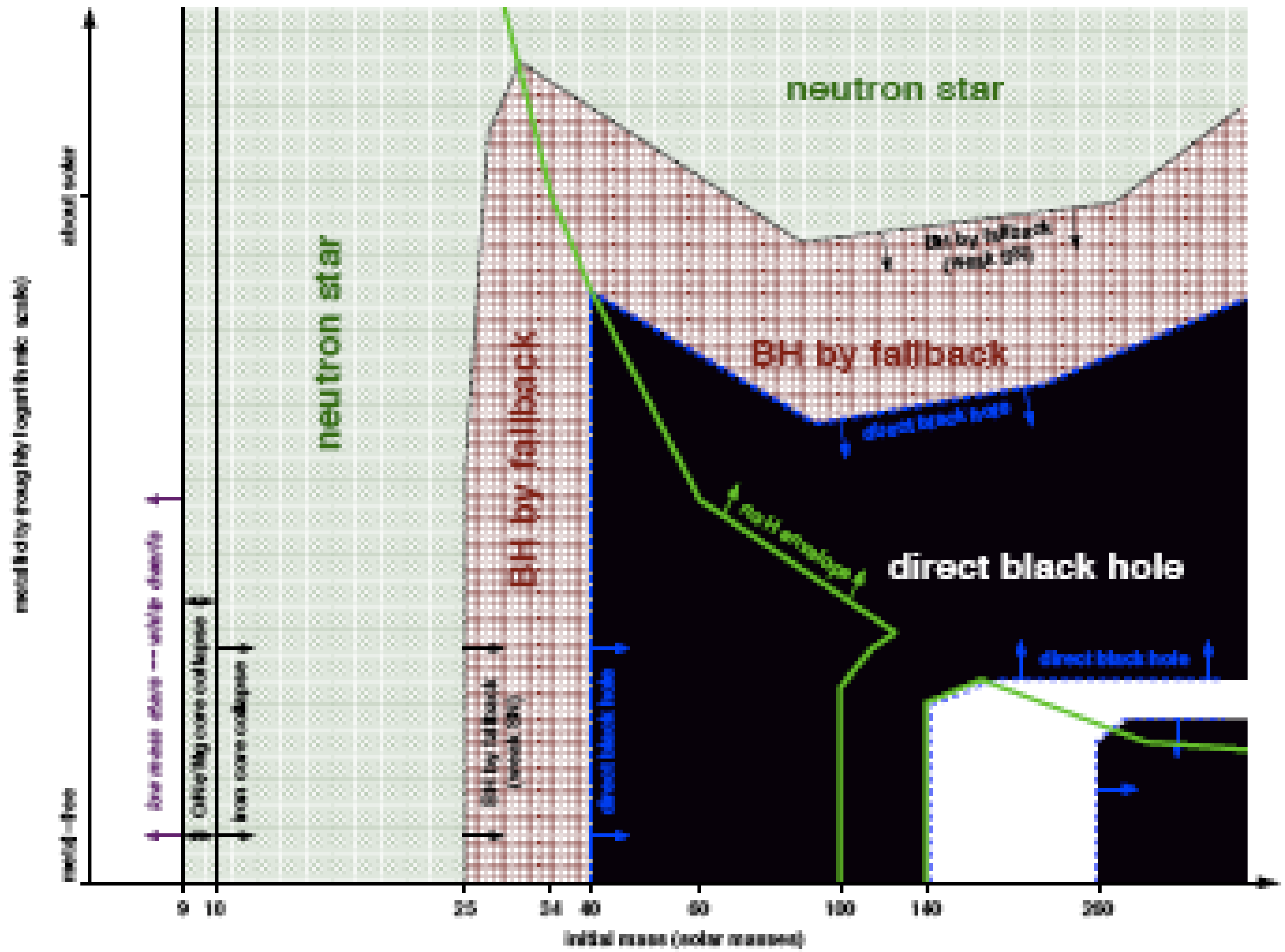
From Scientific American

The First Stars at Z = 0



Credit: Volker Bromm IMF Top Heavy?

How do massive stars die?



Heger et al. (2002)

140 - 260: PISNs!

Mass Loss and rotation

- Geneva models: rotational mixing: CNO enhanced → more mass loss

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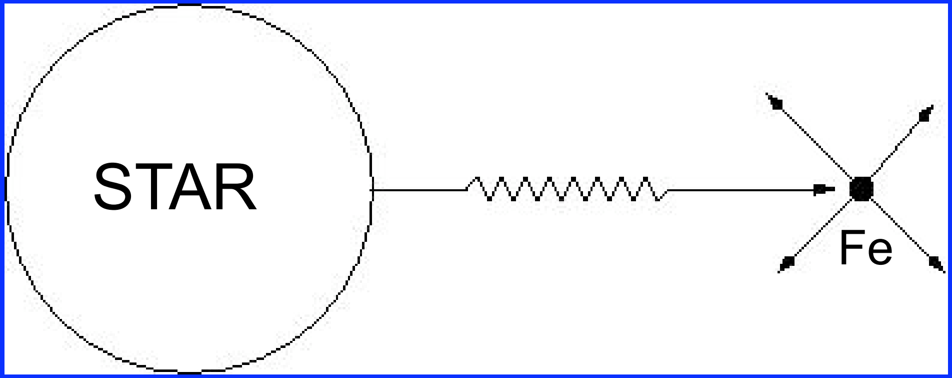
Mass Loss and rotation

- Geneva models: rotational mixing: CNO enhanced → more mass loss
- GRBs - rotation to get a jet (1)
- mass loss removes H (2)
- asymmetric mass loss!?
- low Z !?

Radiation-driven wind by Lines

Lucy & Solomon (1970)



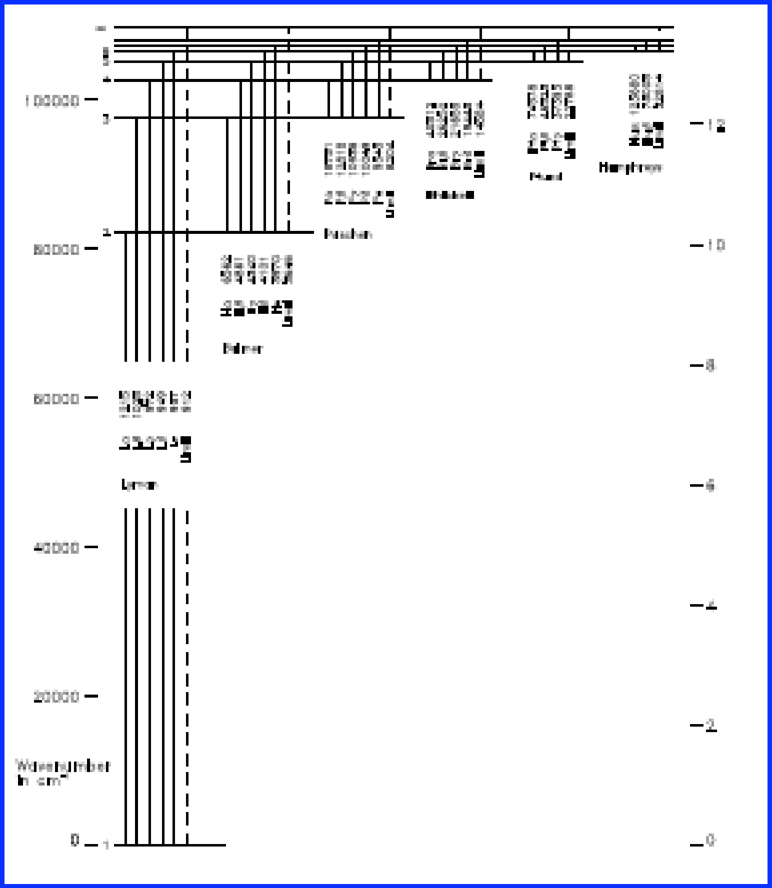
Outward Force → Mass Loss

with Z = (C,N,O, Si, etc., Fe)

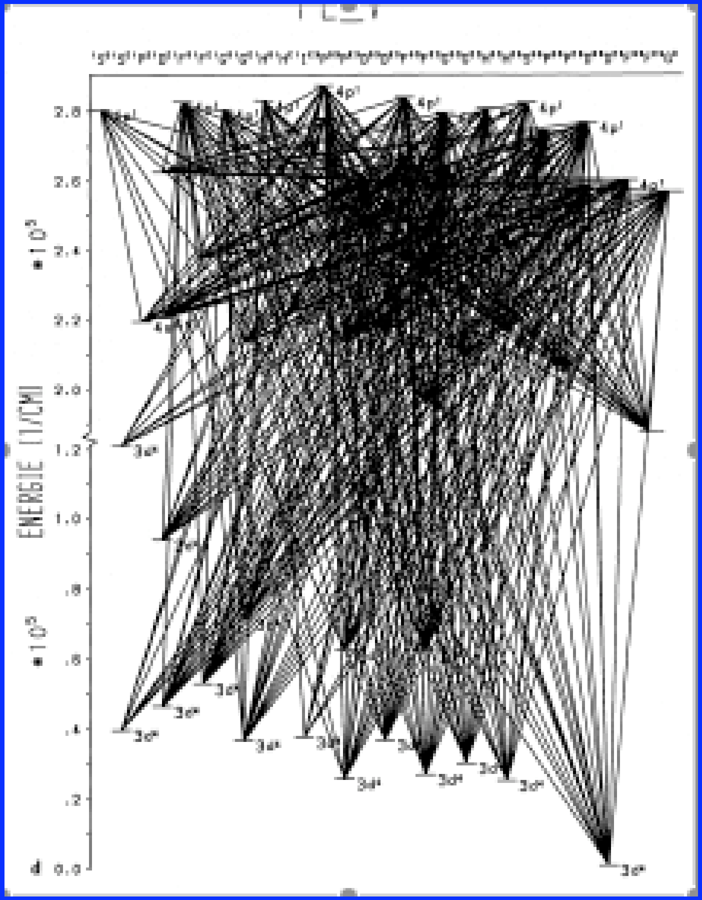
Which elements drive the wind?

abundance x number of lines

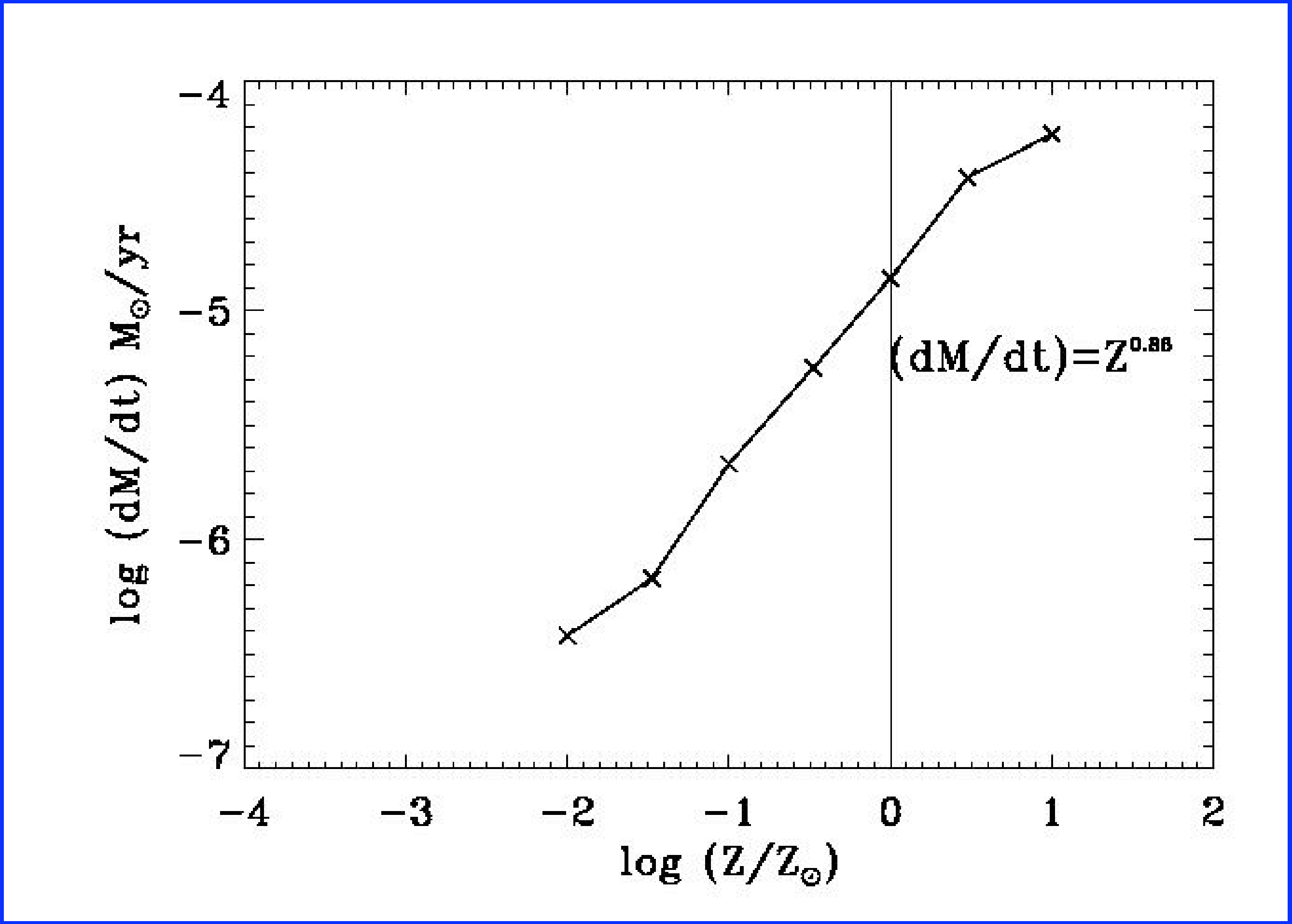
H atom



Fe V atom



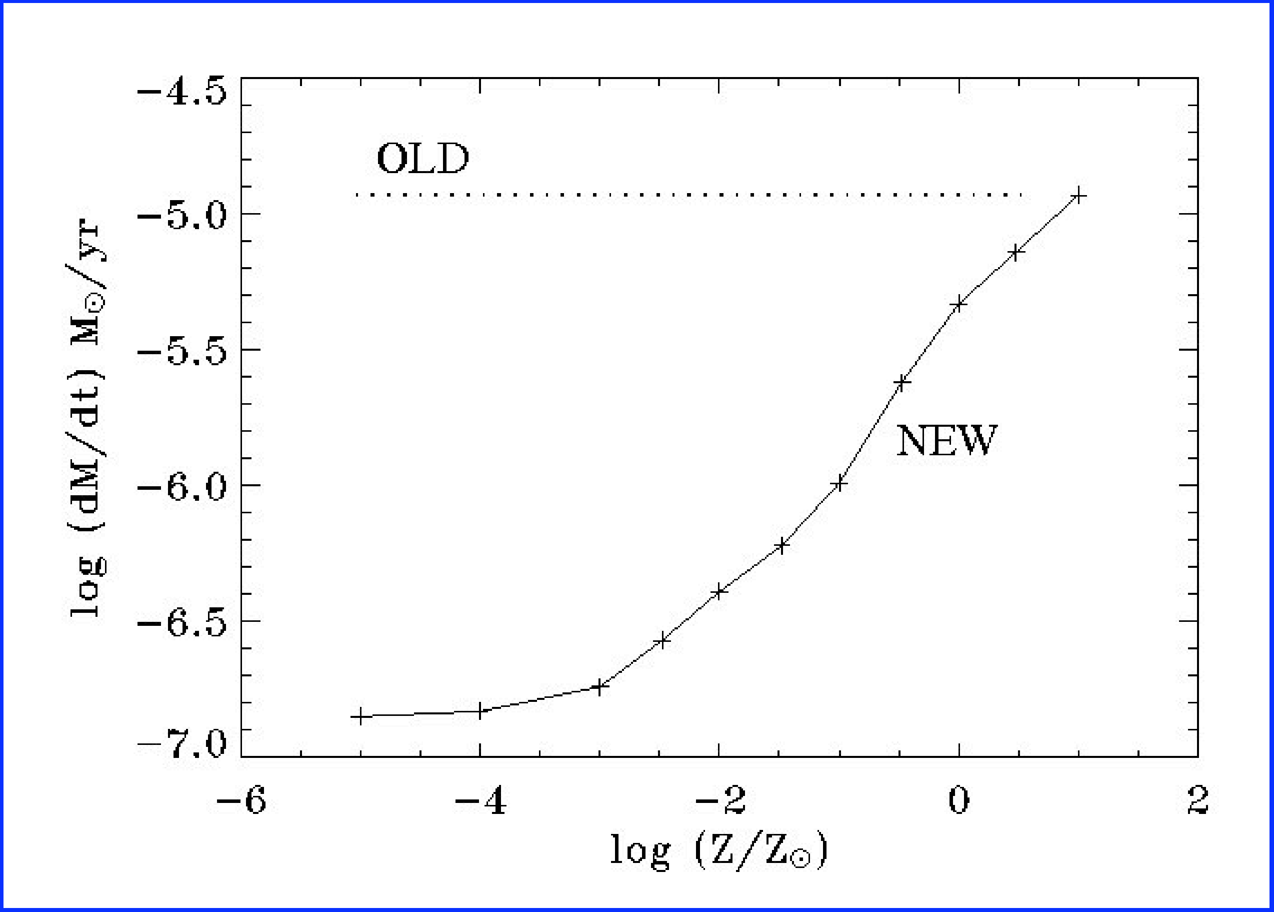
Mass-loss Z-dependence



Predictions: Vink et al. (2001)

Empirical: Mokiem et al. (2007)

Z-dependence of WR winds



Predictions: Vink & de Koter (2005)

Empirical: Crowther (2006)

Solution to GRB problem?

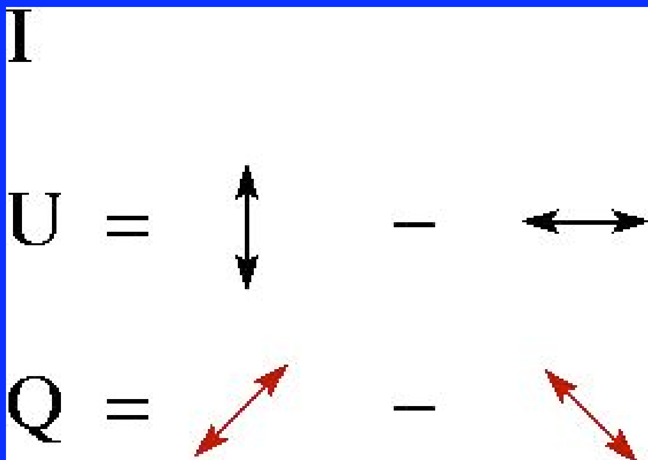
WR mass loss lower at low Z

→ less angular momentum loss

→ Long GRBs favoured at low Z

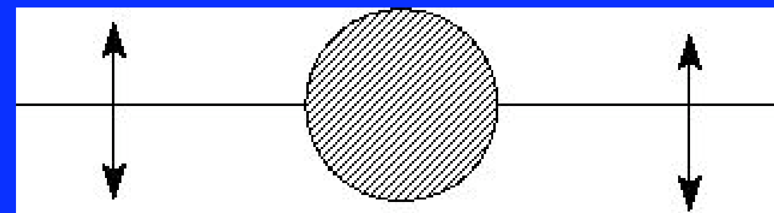
(Yoon & Langer 2005; Heger & Woosley 2006)

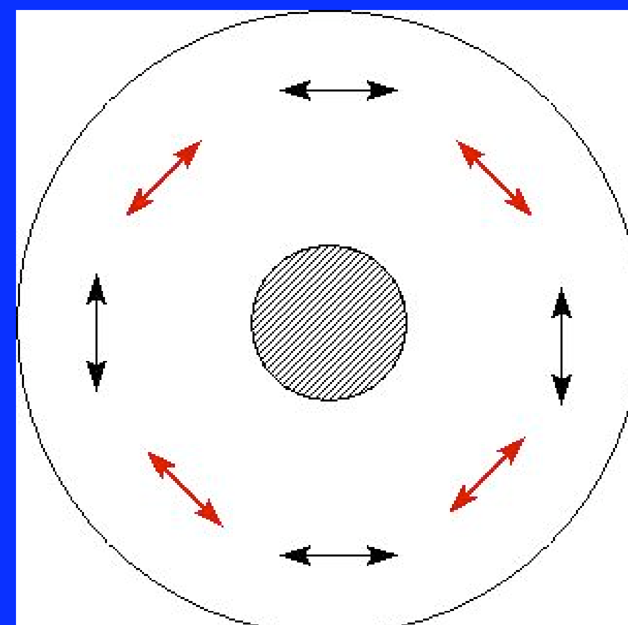
Polarimetry – asymmetry



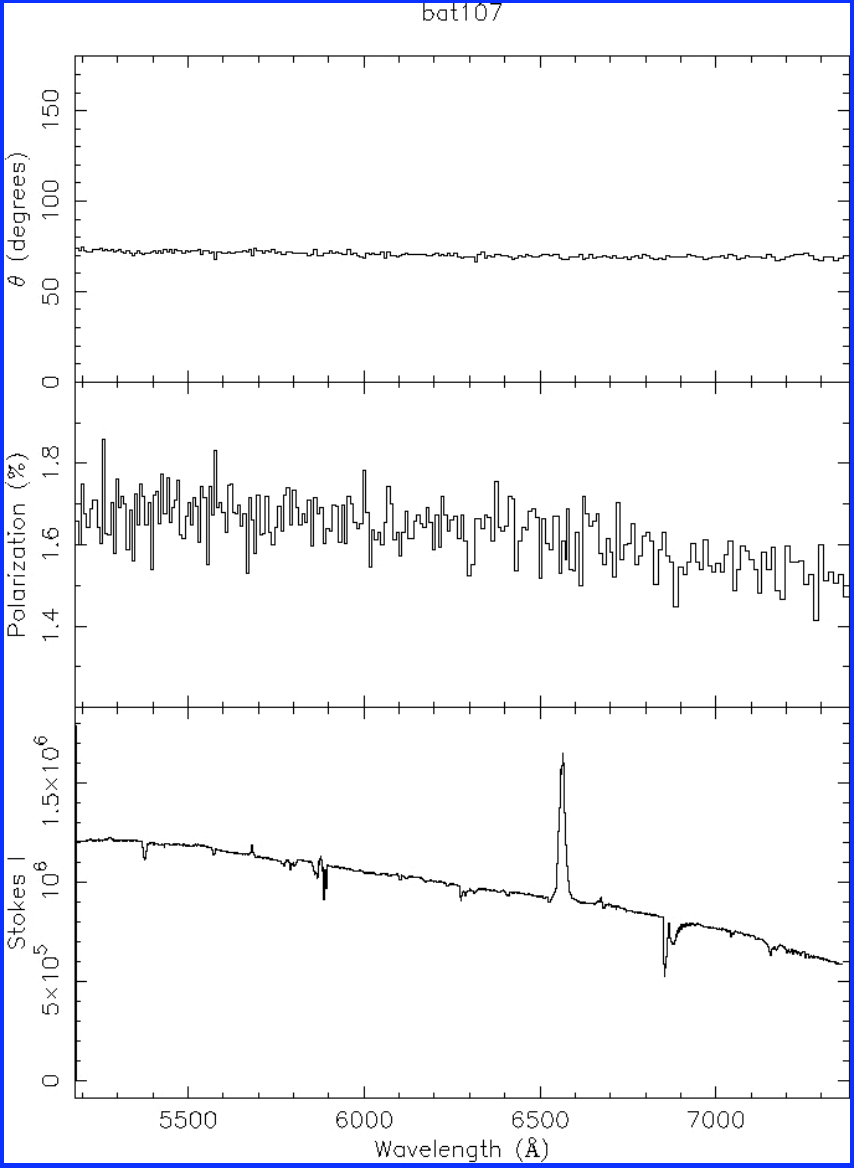
$$P = \sqrt{(U^2 + Q^2)}$$

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

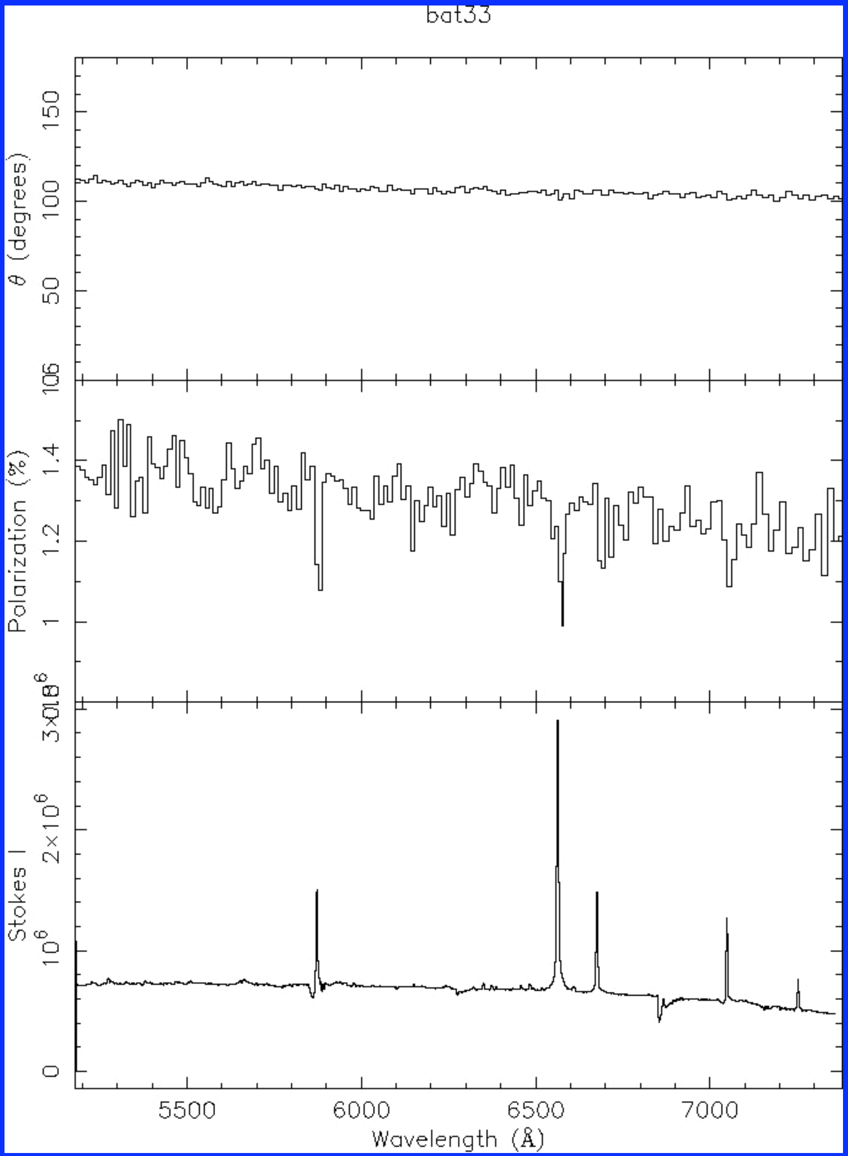




LMC WR spectropolarimetry



LMC WR spectropolarimetry



Statistics

- Be stars in galaxy: 60% line effects
- WR stars in galaxy 15-20%

  Harries et al. (1998)
- WR stars in LMC: 2/13   i.e.   15%

  Vink (2007)

Statistics

- Be stars in galaxy: 60% line effects
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- GRB upper threshold Z of 40-50% solar

E-ELT

- WR spectropolarimetry at low Z SMC metallicity
- Interplay between rotation and mass loss
- Which and how many massive stars make SNe, HNe, GRBs, PISNs, etc.