Stellar input to feedback

Radiation *

Winds *

Binarity *

Supernovae

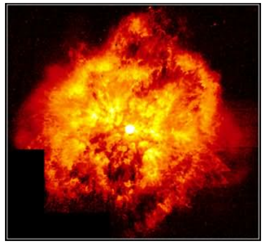
YSOs & protostellar jets

Accreting compact objects

Theoretical predictions depend on uncertain stellar physics (e.g.mixing, SN engines).

Also strongly on the initial conditions.

Radiative Feedback



$L > 10^5\ L_\odot$

Teff > 20000 K → **Strong UV flux**

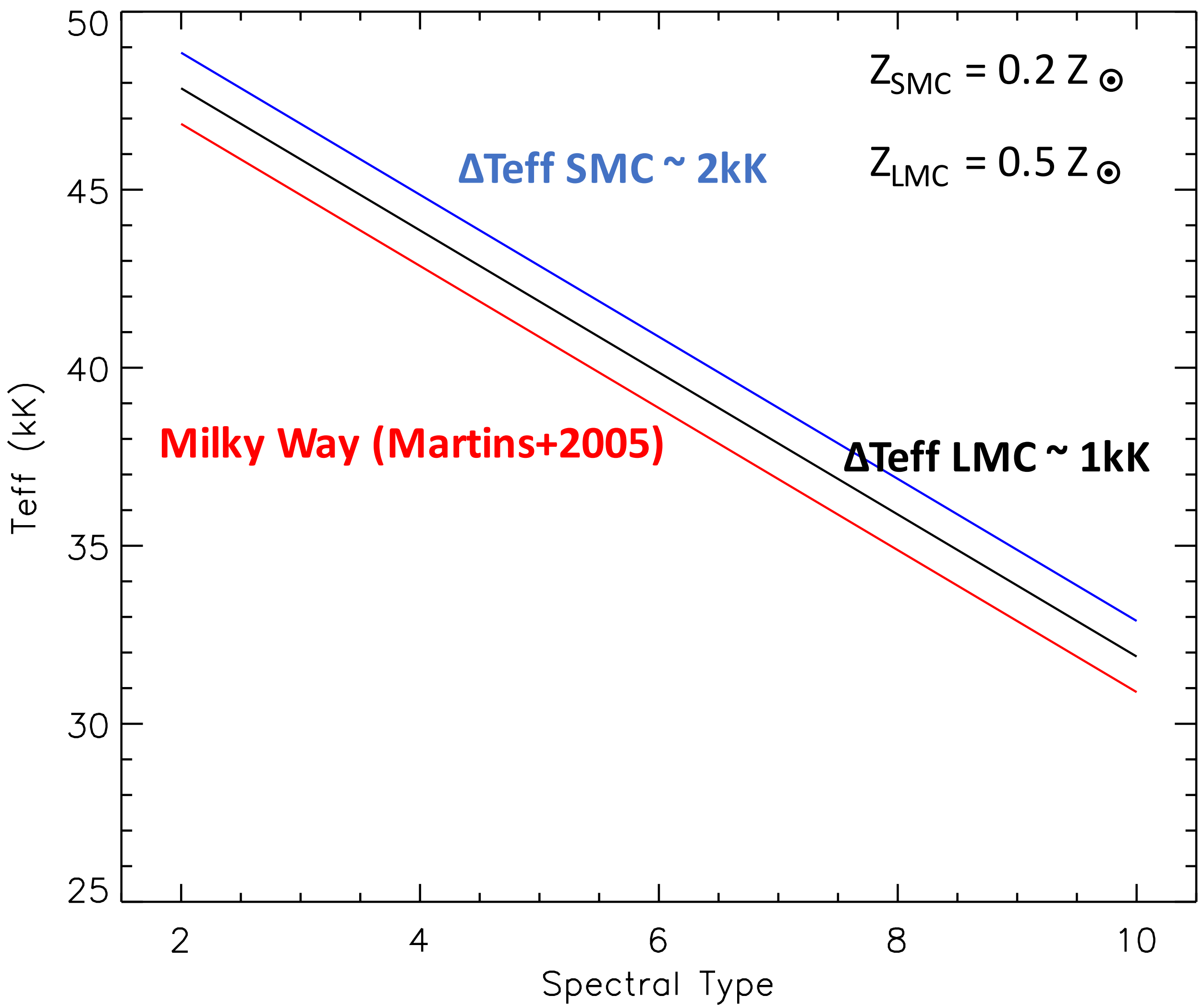
Lyman ionizing output dominated by earliest O stars (including H-burning WN stars)

Sp Type	M ($M_\odot$)	Teff (kK)	Q_0 (10^{49} s^{-1})
O3V	70	45	5
O5V	50	41	1.6
O7V	35	37	0.6
O9V	25	33	0.12
B0V	18	30	0.02
B1V	14	26	0.002

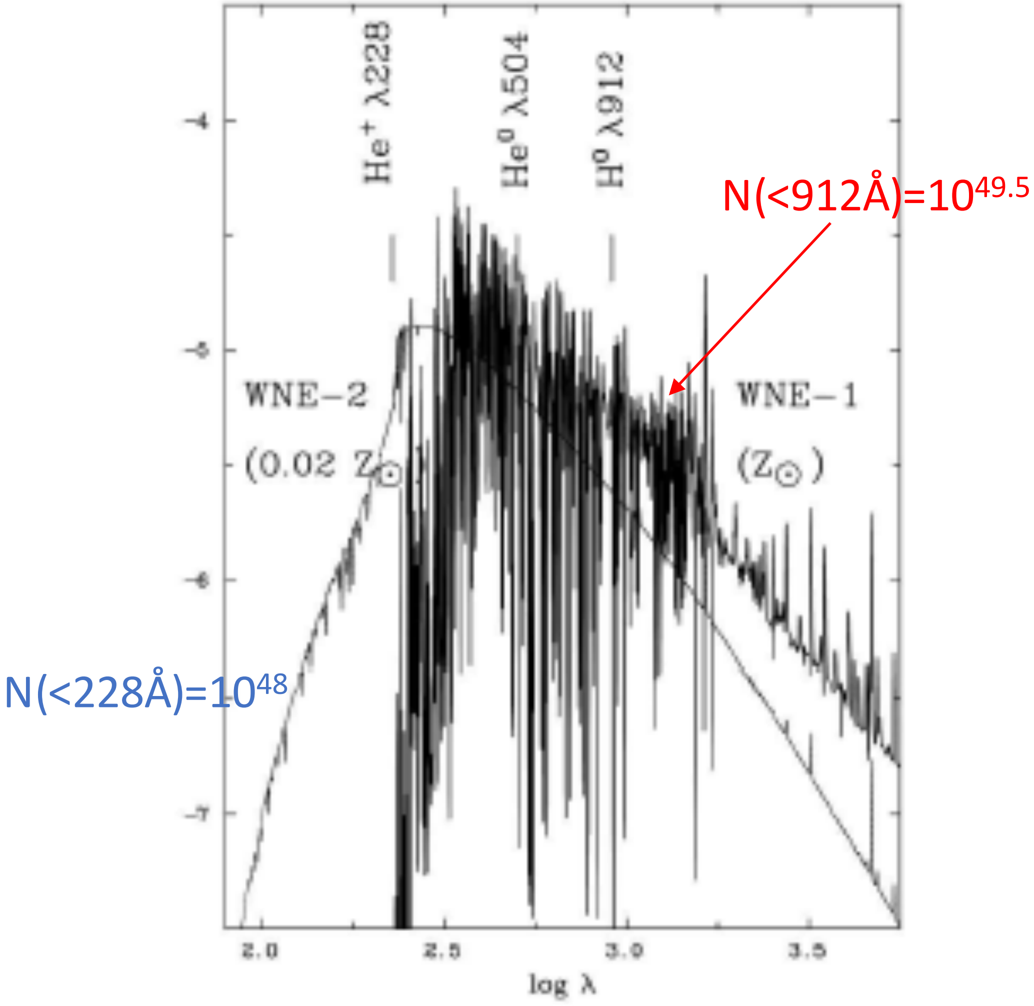
X 250

$$Q_i = q_i \times 4\pi R^2$$

$$q_i = \int_0^{\lambda_i} \frac{\pi \lambda F_\lambda}{hc} d\lambda$$



Metal poor O stars in the LMC & SMC have Teff which are (on average) 1 - 2 kK higher than counterparts in MW
➔ produce 10 – 20% higher ionizing output



Weaker winds from metal-poor WR stars leads to harder ionizing outputs (e.g. non-zero photons in He+ continuum > 54.4 eV)

Mechanical Feedback - Winds

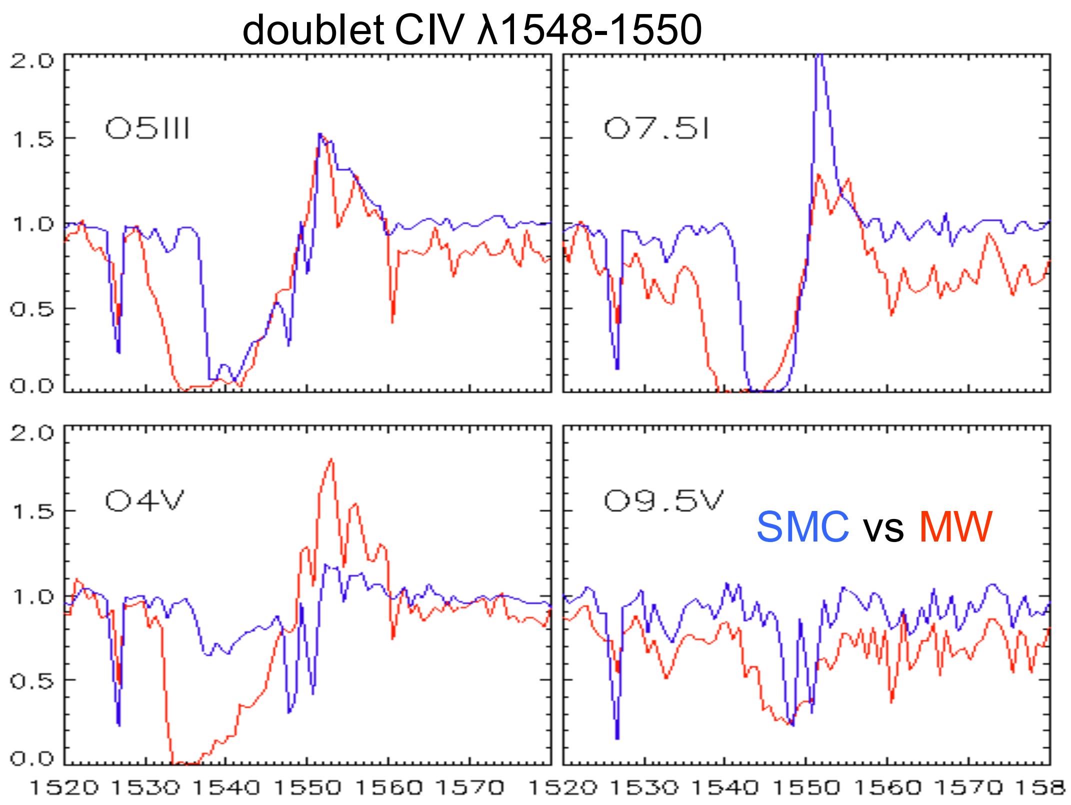
- Kinetic energy mix of luminous O, WR stars & LBVs owing to fast, relatively dense winds
- Cool supergiants minor contributors to wind momenta (slow wind but high mass-loss rates)

Spectral Type	V_∞ (km/s)	$\dot{M}$ (10^{-6} $M_\odot$/yr)	KE (O5V=1)	Momentum (O5V=1)
O5V	2900	1.3	1	1
O4Iaf	2300	6	3	4
B0Ia	1500	1	0.2	0.4
A0Ia	200	1	0.004	0.05
M0Ia	20	50	0.002	0.03
WR	2000	10	4	5

Kinetic energy $1/2\ \dot{M}\ V_\infty$

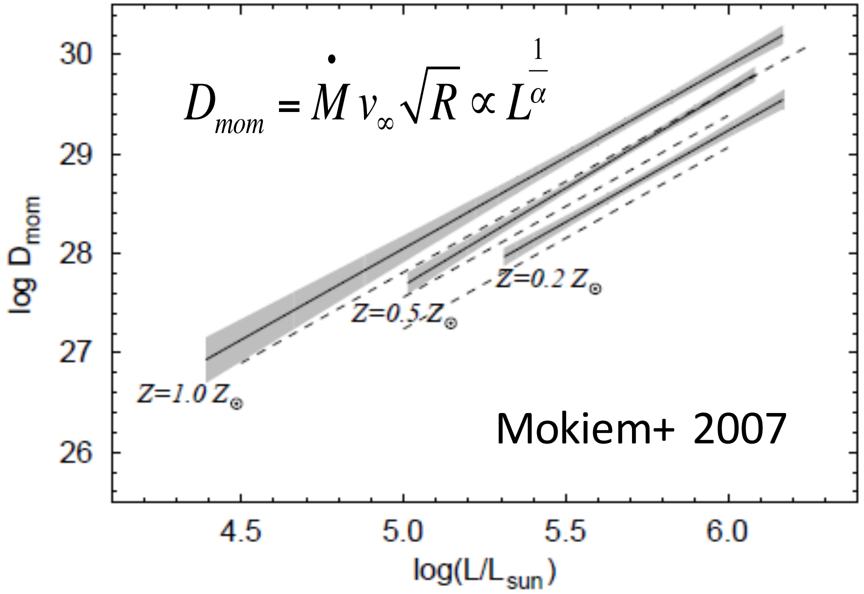
Momentum $\dot{M}\ V_\infty$

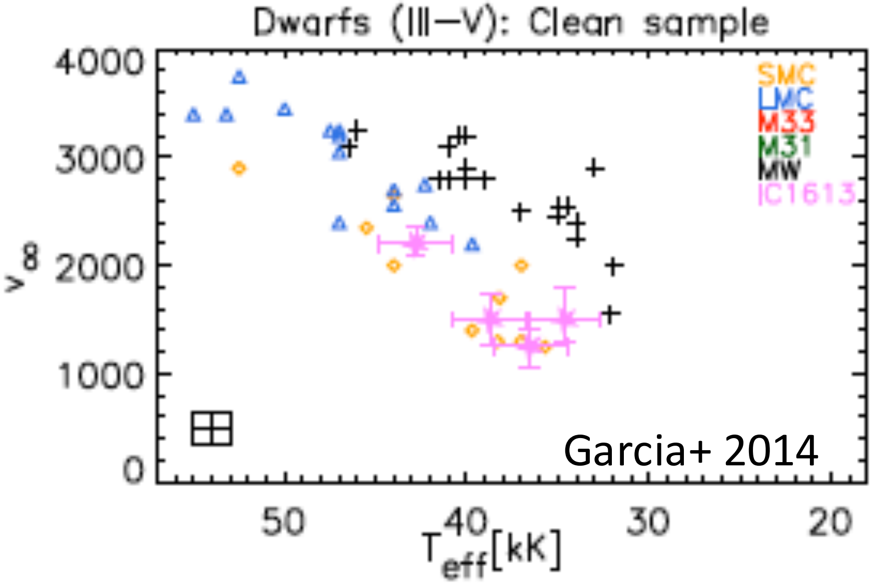
Mechanical Feedback - Winds



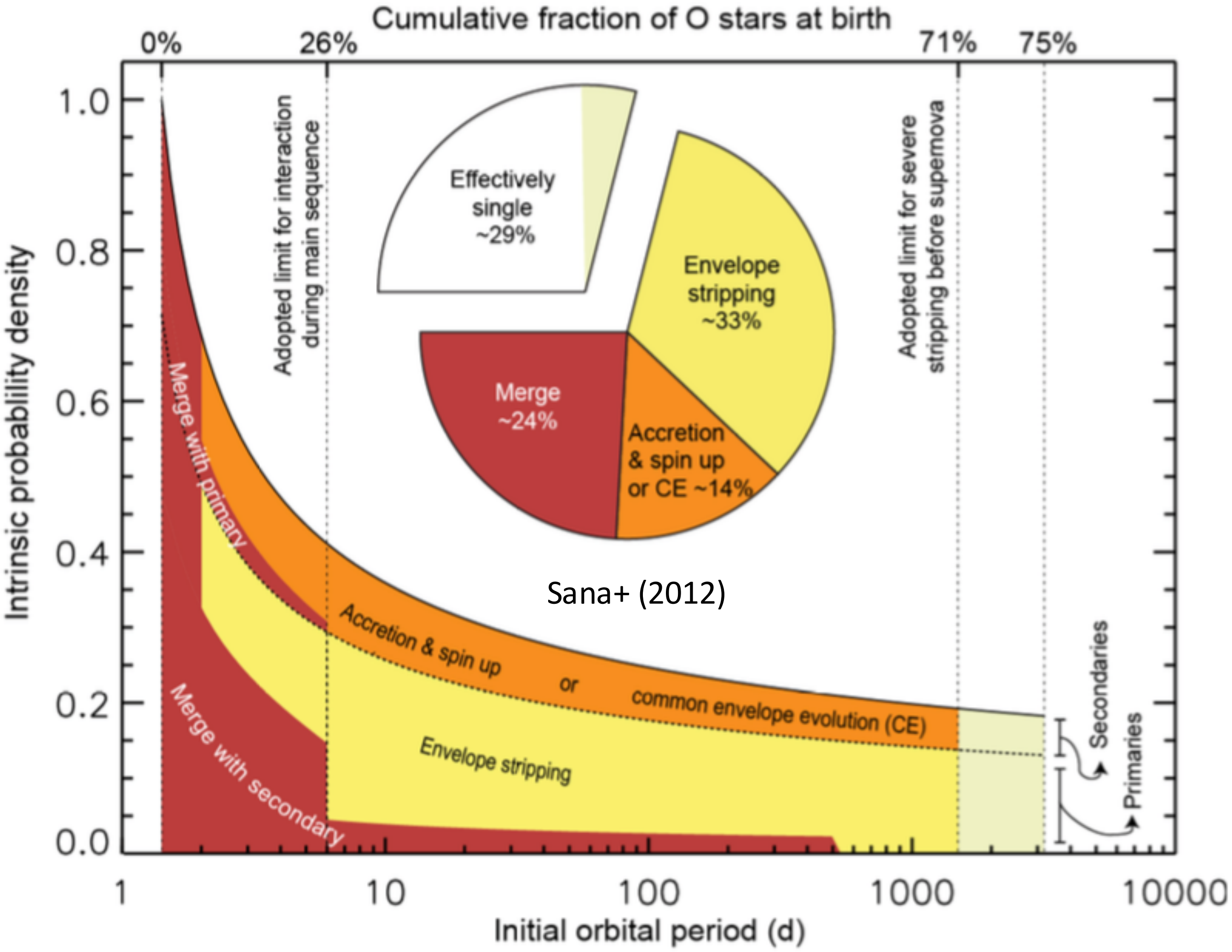
$\dot{M} \propto Z^{0.8}$ since Fe-peak elements dominate line driving

Wind velocities of radiatively driven winds predicted to be Z dependent (V_∞ ~ $Z^{0.1}$)

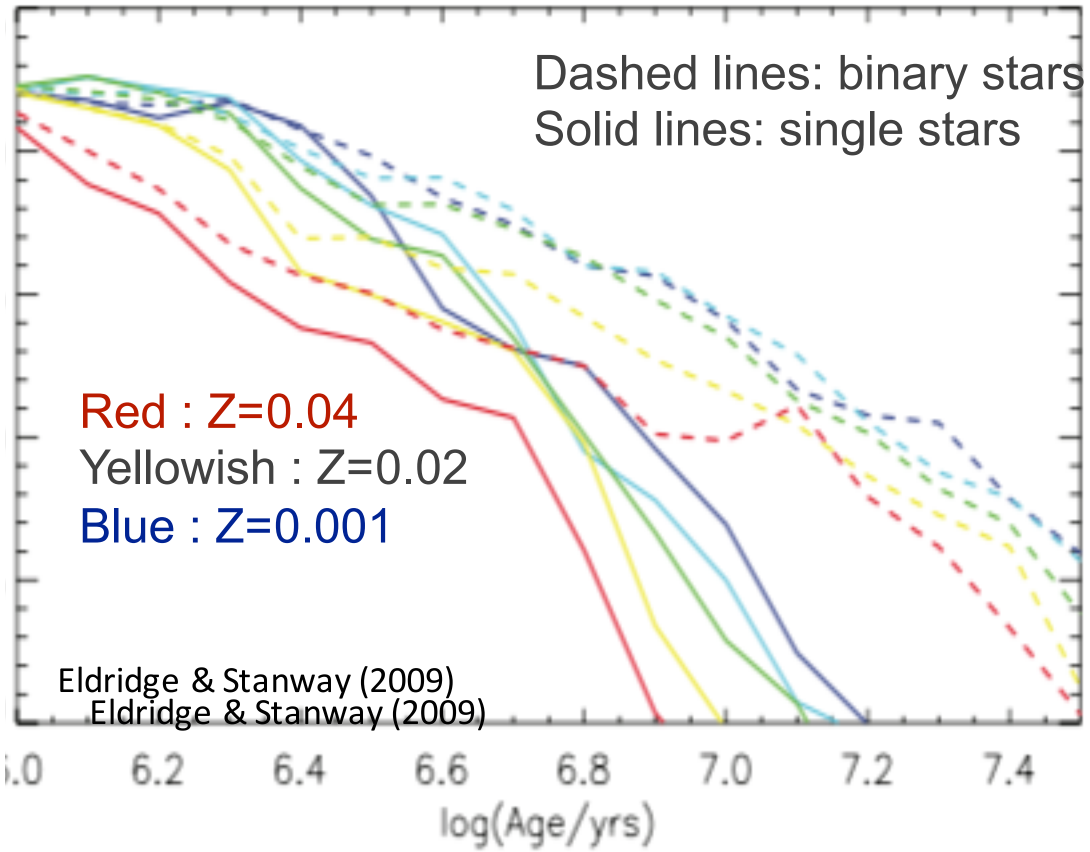




Binarity



H-Beta emission from simulated massive-star ionized nebula.

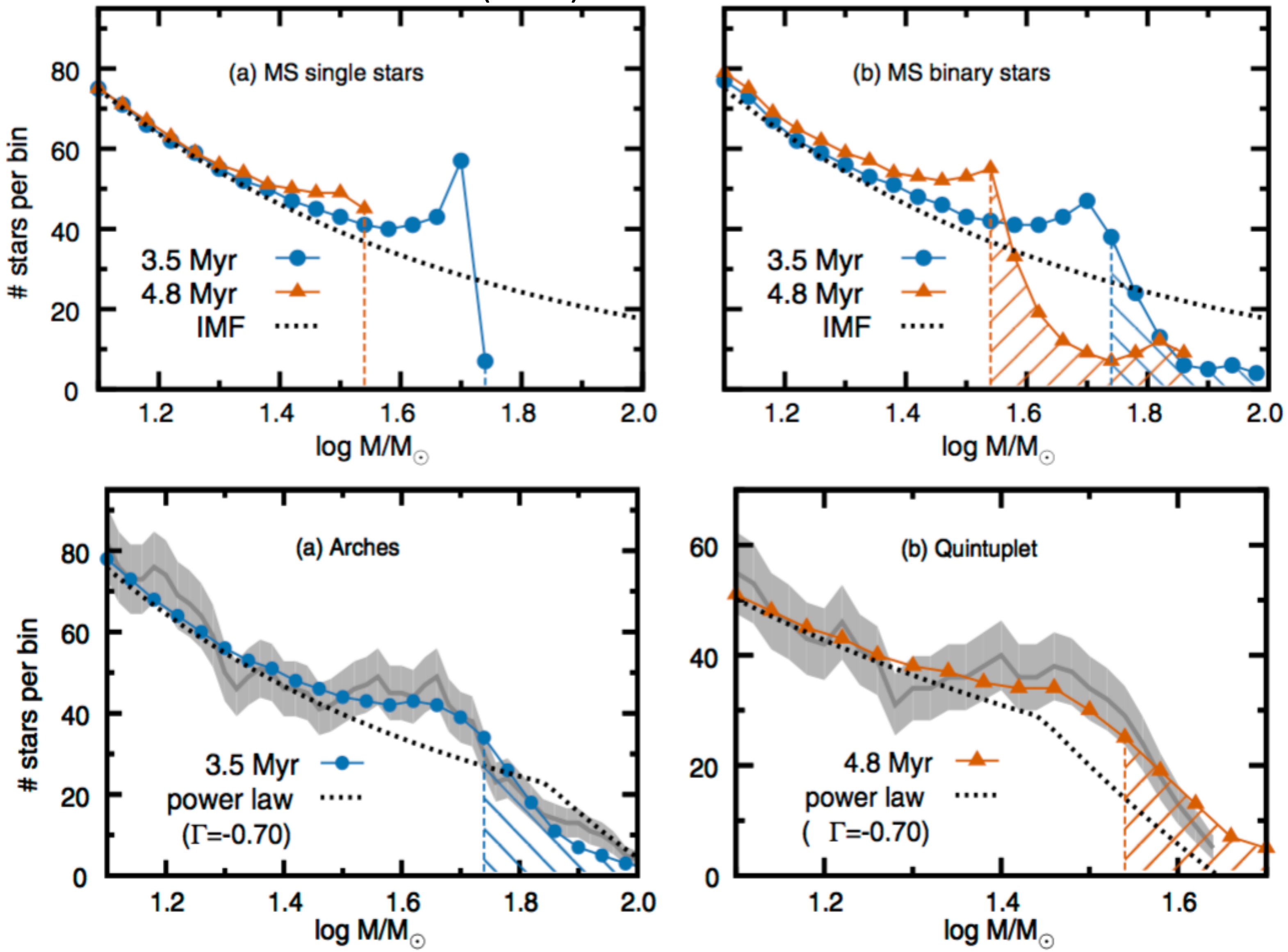


Sana, de Mink et al. (2012) inferred that over 70% of O stars are in interacting binaries.

Binarity effect > Metallicity effect

Binarity

Schneider+ (2014)

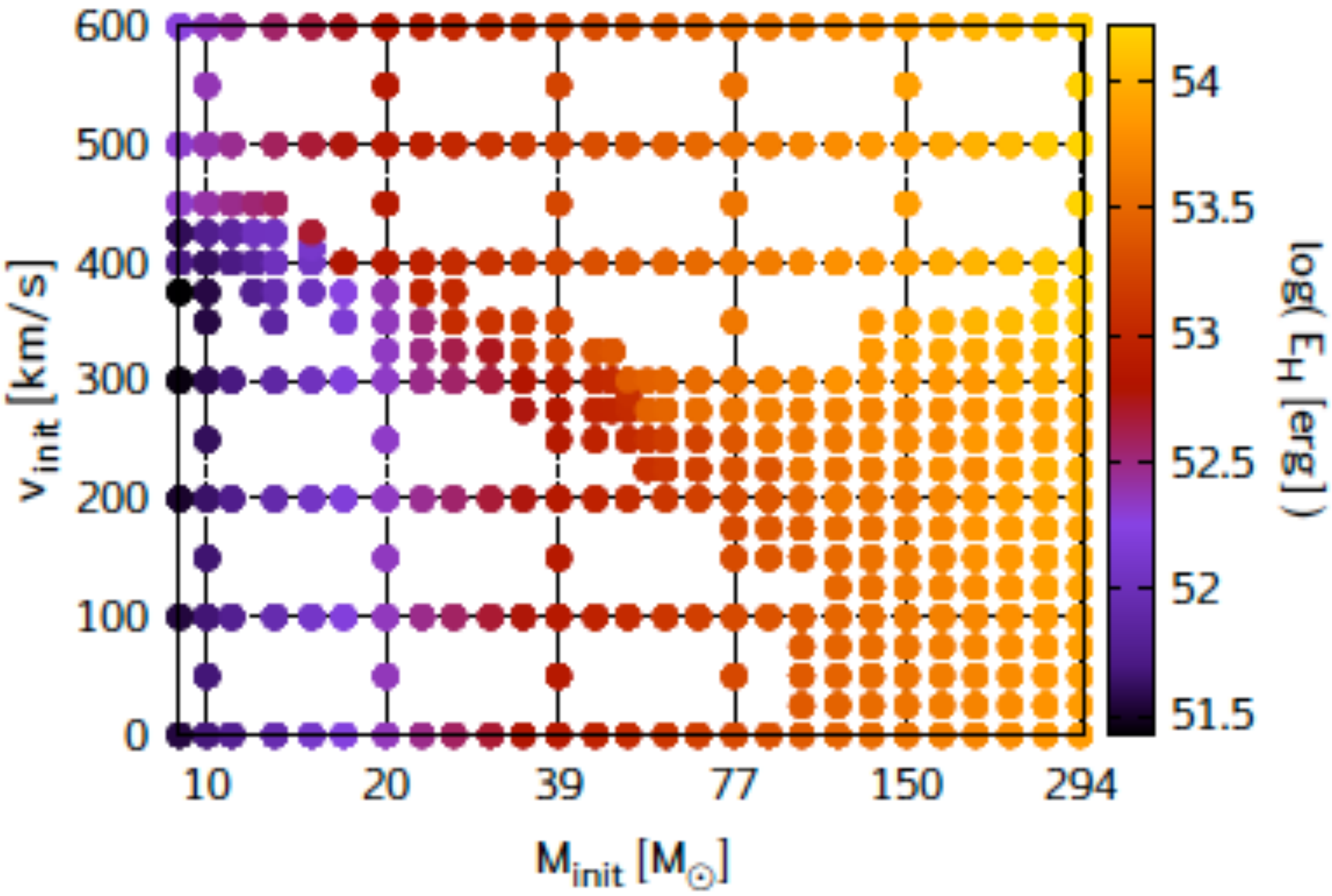


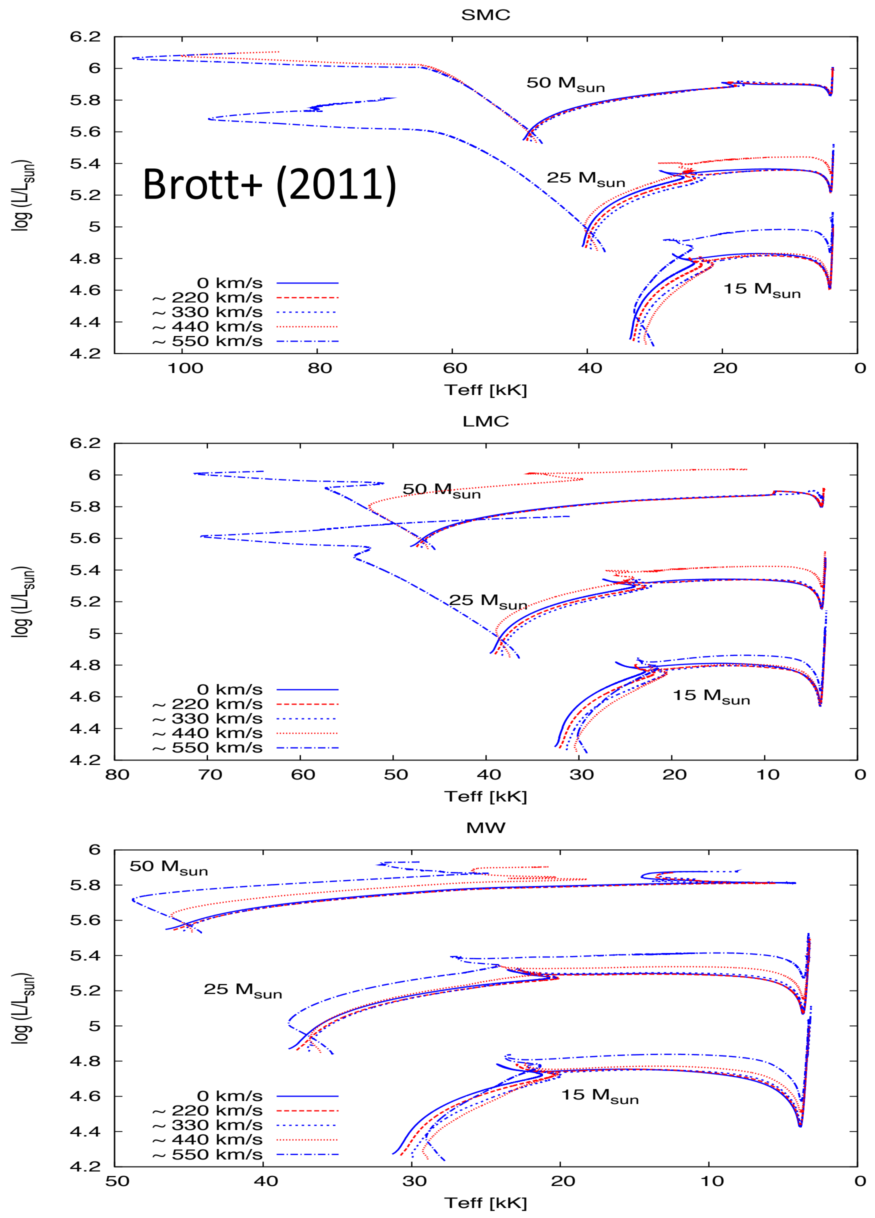
There is large theoretical uncertainty in photoionisation feedback timing and magnitude.

Binarity makes a huge difference

Rotation

Szécsi+ (2015)

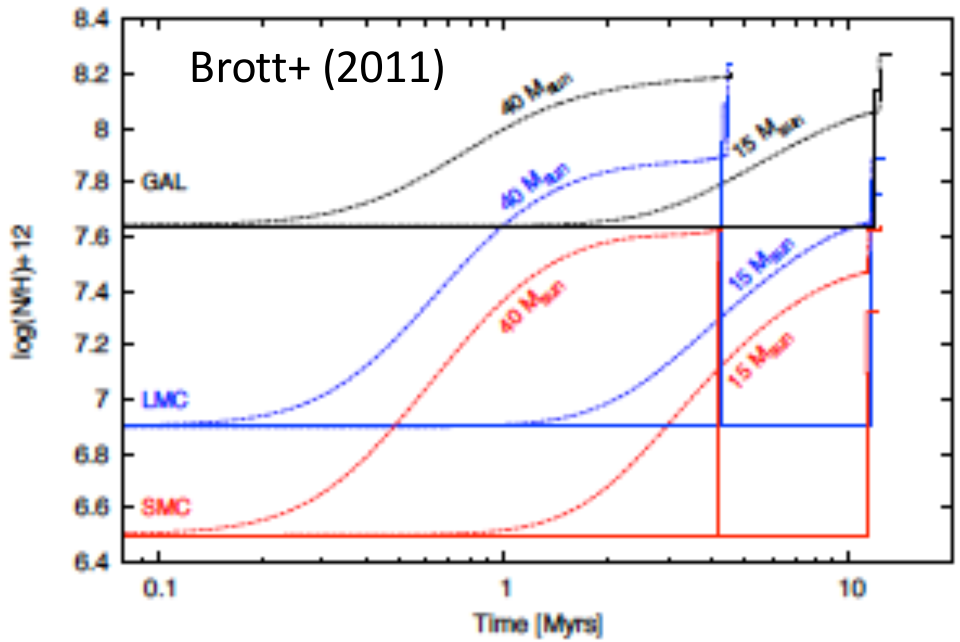


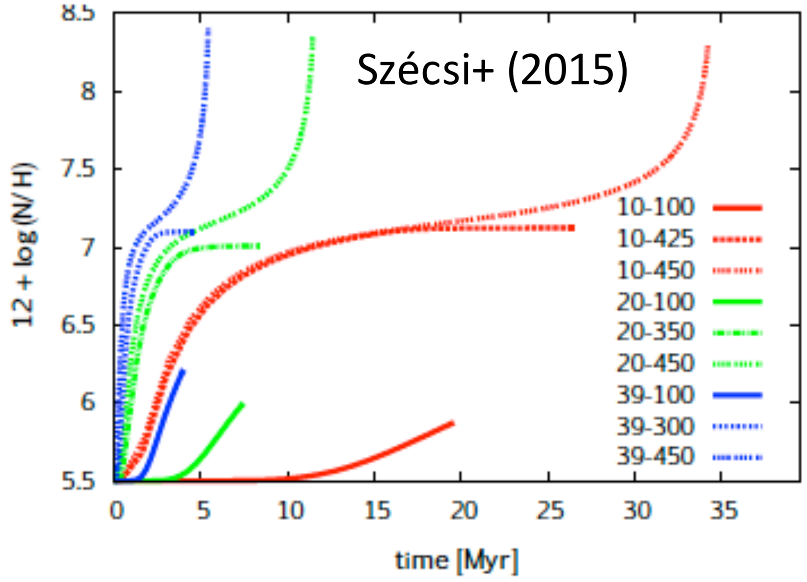


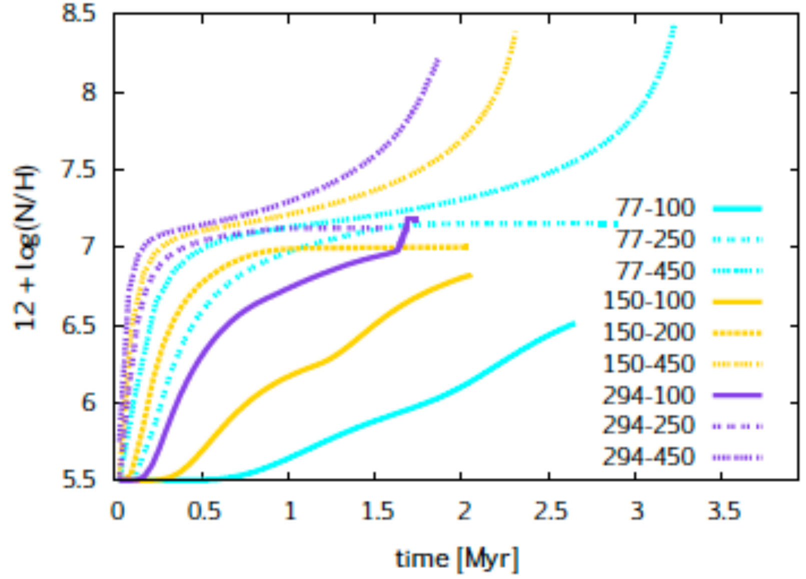
Rotation rates are also predicted to affect details of integrated ionizing fluxes.

Chemical Feedback

- **Transport of angular momentum and mixing: rotation changes surface abundances**



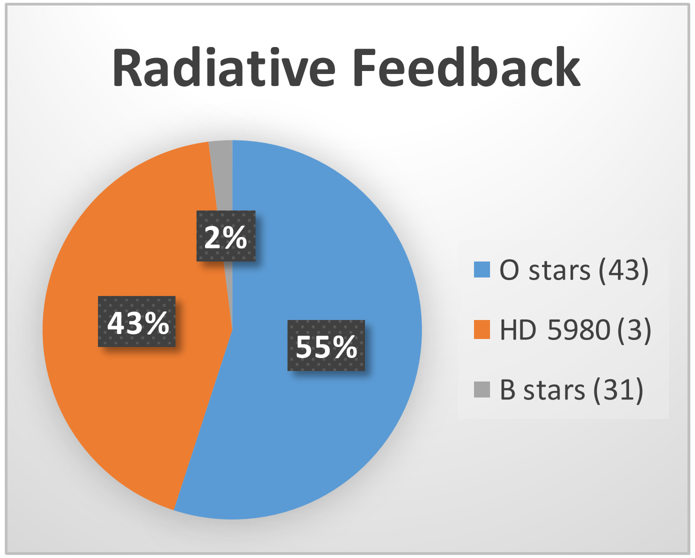


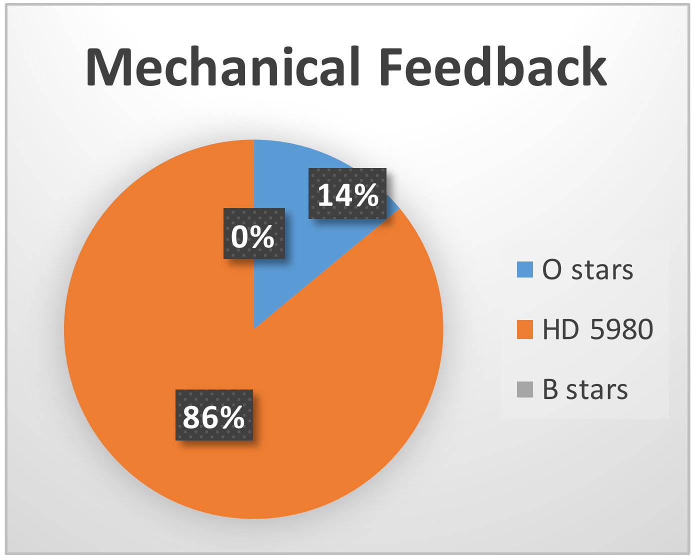


- **BUT minor players with respect to SNe, although WC-type stars contribute (a little) to carbon production**

Stellar Feedback in the SMC

N(LyC)$_{SMC}$ = 7.10^{50} ph/s

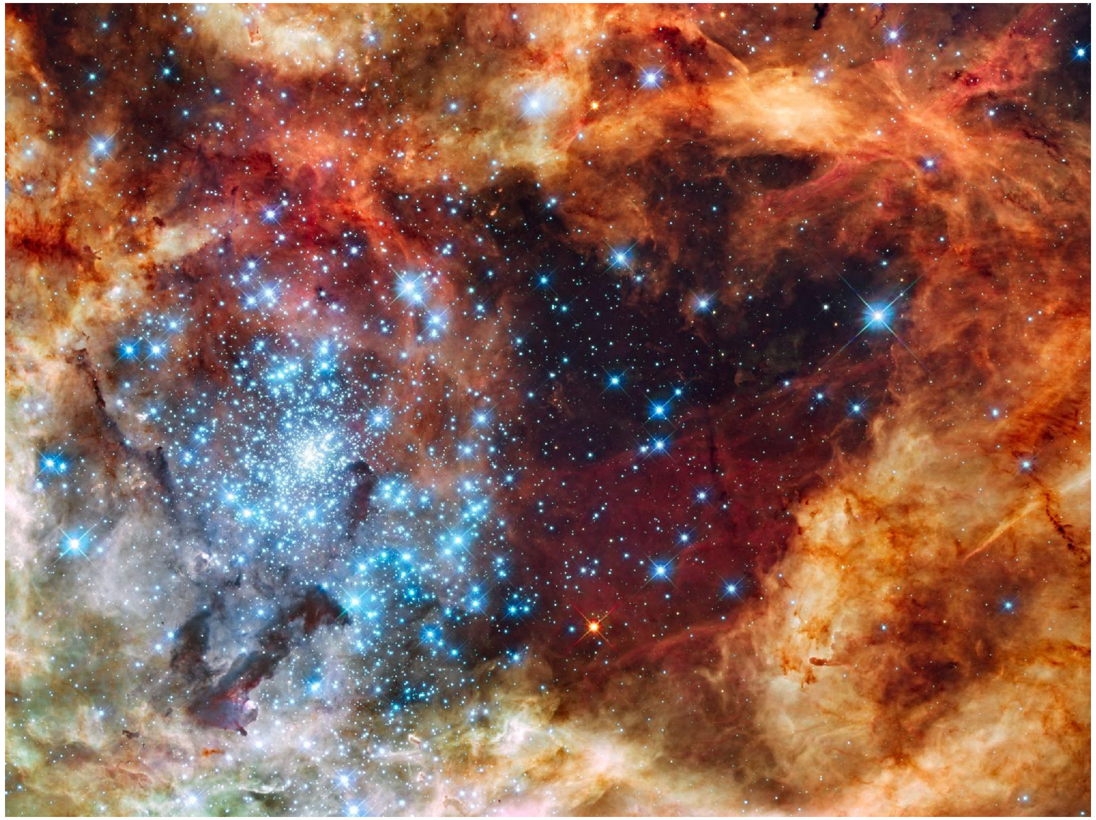




Several hundred O stars
Dozen WR stars, Brightest HII region NGC 346
Mup ~ 90 Msun

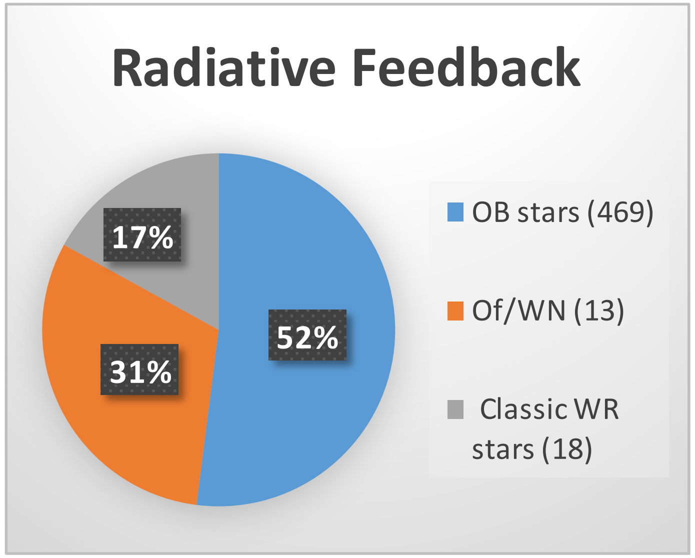
Stellar Feedback in the LMC

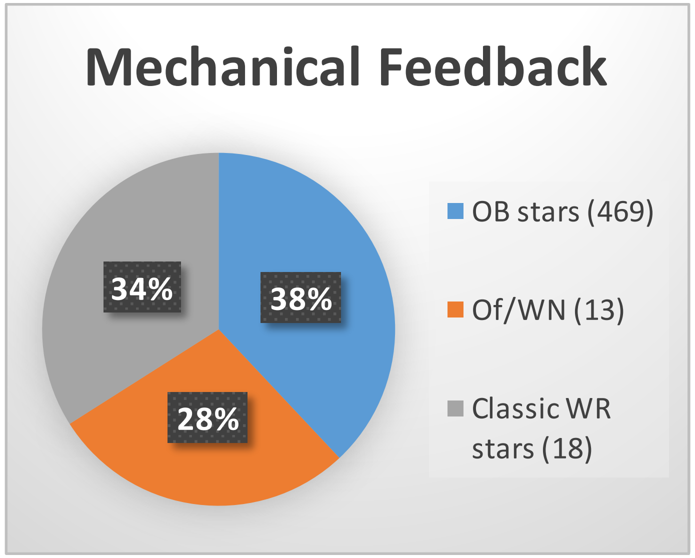
$N(LyC)_{LMC}$ = 4.10^{52} ph/s



Several thousands O stars
140 WR stars, Brightest HII region 30 Dor

Mup ~ 300 Msun





Summary: What can stellar theory say?

- **Radiative: Lyman ionizing output dominated by earliest O stars + H-burning WN – Harder radiation from classical WR stars**
- **Mechanical: Kinectic energy mix of luminous O,WR & LBs owing to fast, relatively dense winds – Cool supergiants minor contributors to wind momenta (slow winds but high mass-loss rates)**
- **Chemical: minor players with respect to SNe, although WC-type stars contribute to carbon production**
- **Understanding binary interactions is required to predict the timing, location & magnitude of their output.**
- **(The metallicity dependence of [especially] energetic SNe…may be vital for feedback in the early universe, dwarf galaxies & GCs.)**