

The VLT-FLAMES Survey of Massive Stars

Chris Evans (UK ATC, Edinburgh)



Main collaborators:

Stephen Smartt, Rohied Mokiem, Alex de Koter, Ian Hunter
Danny Lennon, Philip Dufton, Jo Puls, Robert Ryans, Carrie Trundle



Science & Technology Facilities Council
UK Astronomy Technology Centre

NAM – April 2007



The VLT-FLAMES Survey of Massive Stars

- Motivations & background
- Observational details
- Results



Motivations & objectives

- **How does stellar evolution depend on metallicity (Z)?**



Motivations & objectives

- **How does stellar evolution depend on metallicity (Z)?**
- Are theoretical scalings of stellar mass-loss correct?



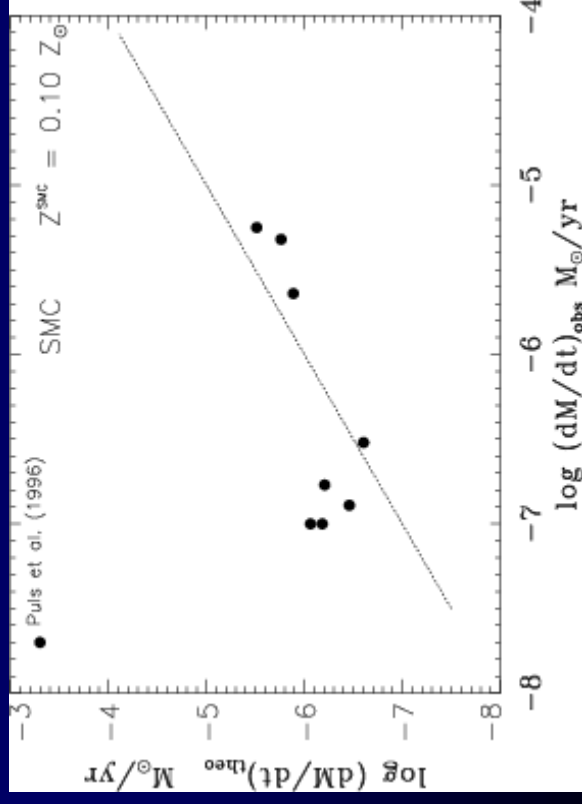
Z-dependence of stellar mass-loss rates

- Theory predicts that stellar mass-loss scales with metallicity:
 $\dot{M} \propto Z^{0.5-0.7}$ (Kudritzki et al. 1987, Vink et al. 2001)
- Crucial when looking at integrated populations, thinking about Pop III stars etc.

- Some tests are in the literature
but not well-sampled



NEED A LARGE, HOMOGENOUS
SAMPLE





Motivations & objectives

- **How does stellar evolution depend on metallicity (Z)?**

- Are theoretical scalings of mass-loss correct?

Are population synthesis codes up to the job ?

Are the chemical yields correct for galaxy evolution?

Do we understand the environmental constraints on SNe?

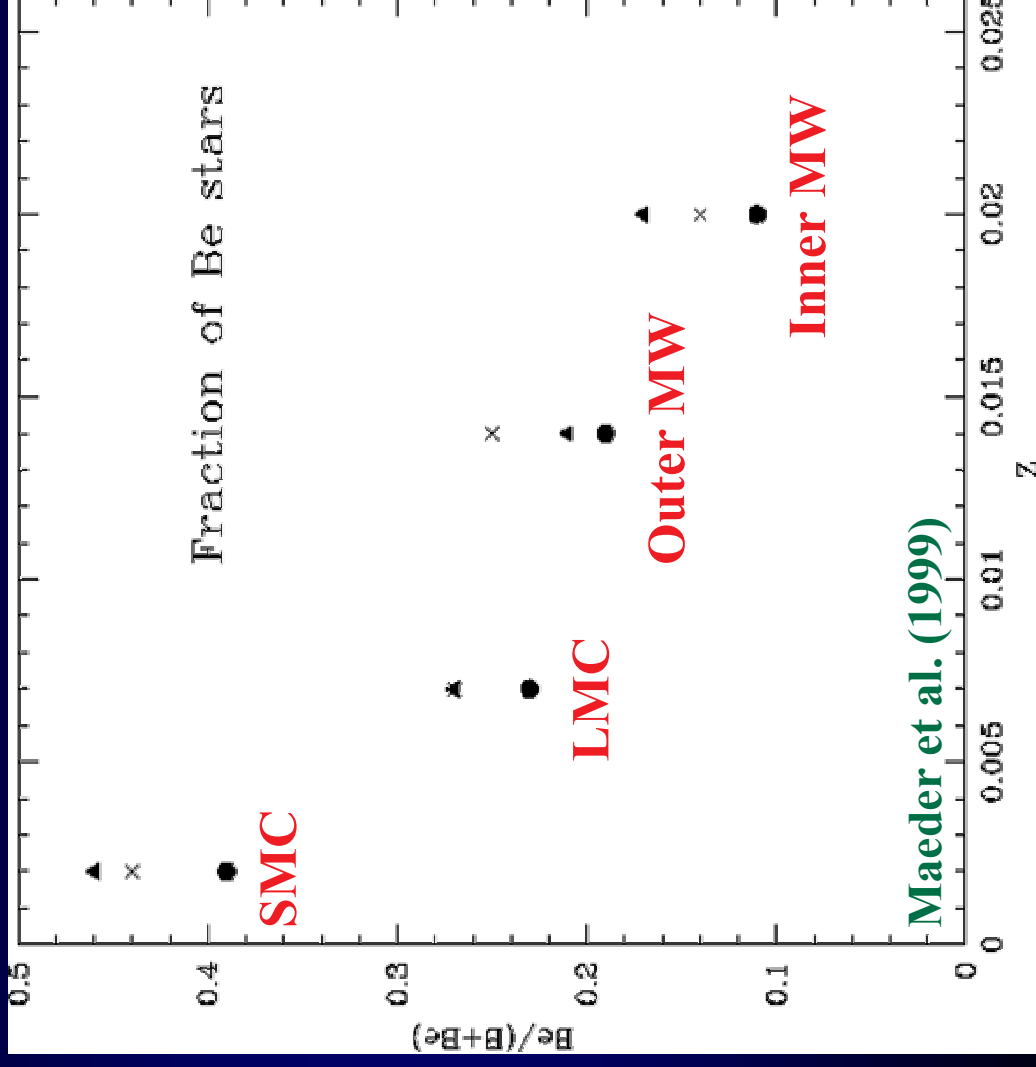


Motivations & objectives

- **How does stellar evolution depend on metallicity (Z)?**
- Are theoretical scalings of mass-loss correct?
- Do stellar rotational velocities vary with Z ?

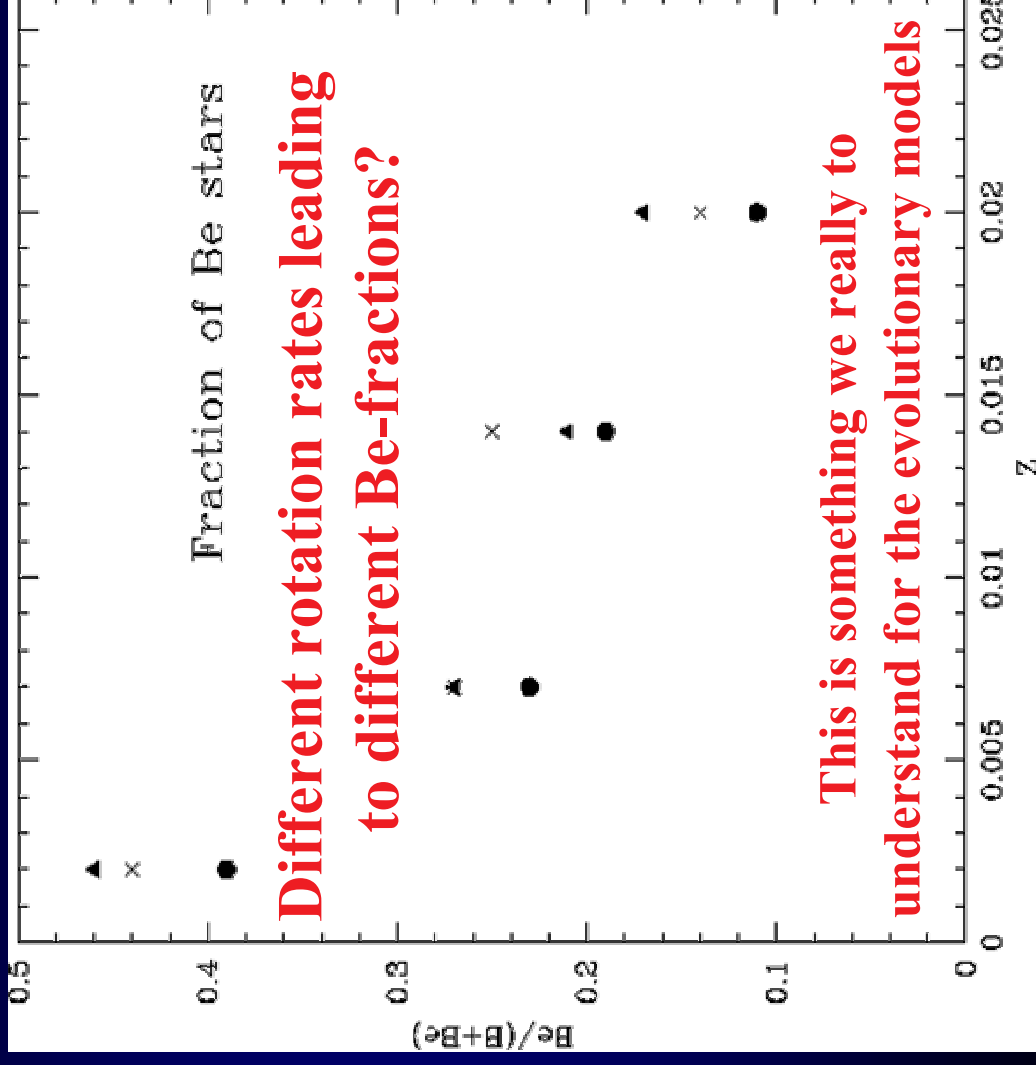


Be-fraction in clusters





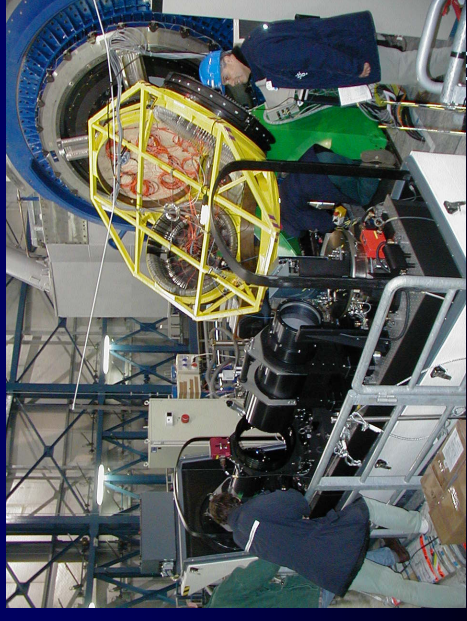
Be-fraction in clusters





FLAMES Large Programme

- Wanted a **LARGE** sample of OB stars at different metallicities
- ESO large programme (>100 hrs) observing clusters in:
 - Milky Way
 - LMC ($Z \sim 40\%$ solar)
 - SMC ($Z \sim 20\%$ solar)
- VLT-FLAMES:
 - 137 fibres
 - 25 arcmin field-of-view
 - Spectral resolutions of 8,000 or 20,000





Target fields

Evans et al. (2005, 2006)

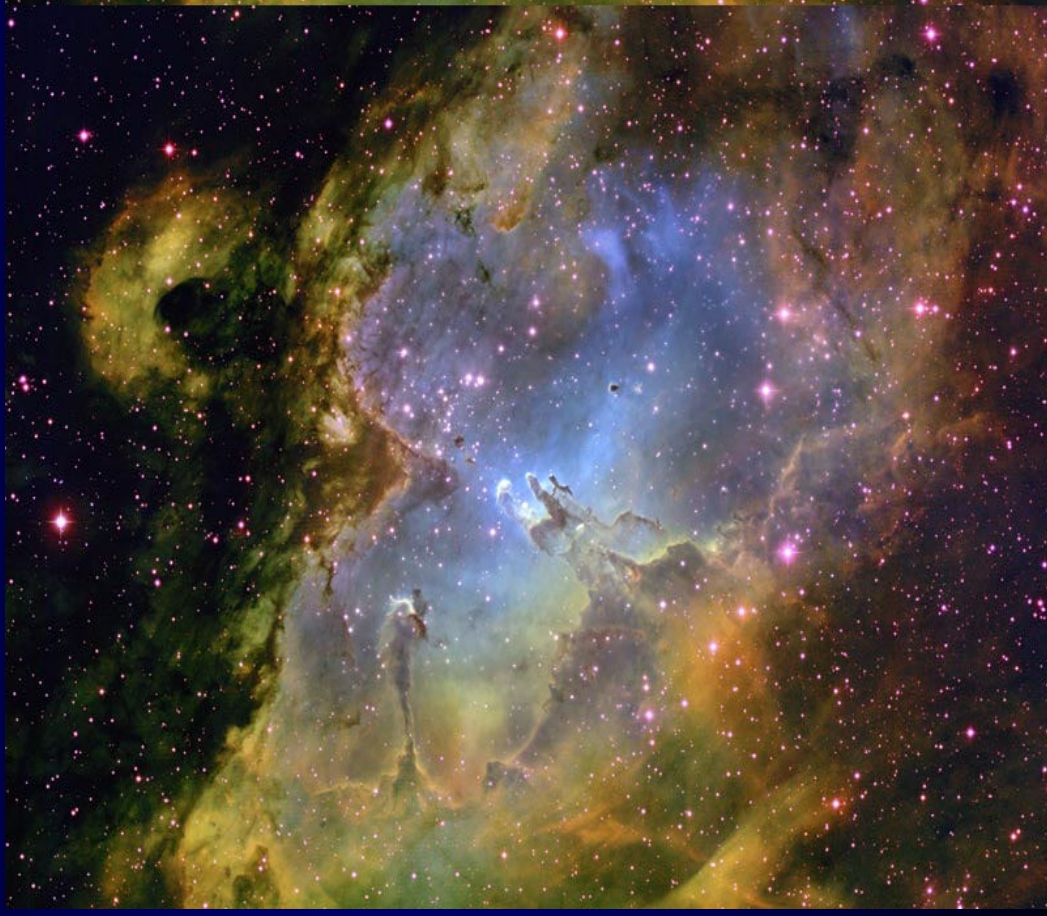
Fields chosen to sample a range of Z and ages:

‘Young’ clusters (<5 Myr)	‘Old’ clusters (10-20 Myr)
---------------------------------	-------------------------------

Milky Way	NGC 6611	NGC 3293, 4755
LMC	N11 (inc. LH 9/10)	NGC 2004
SMC	NGC 346	NGC 330

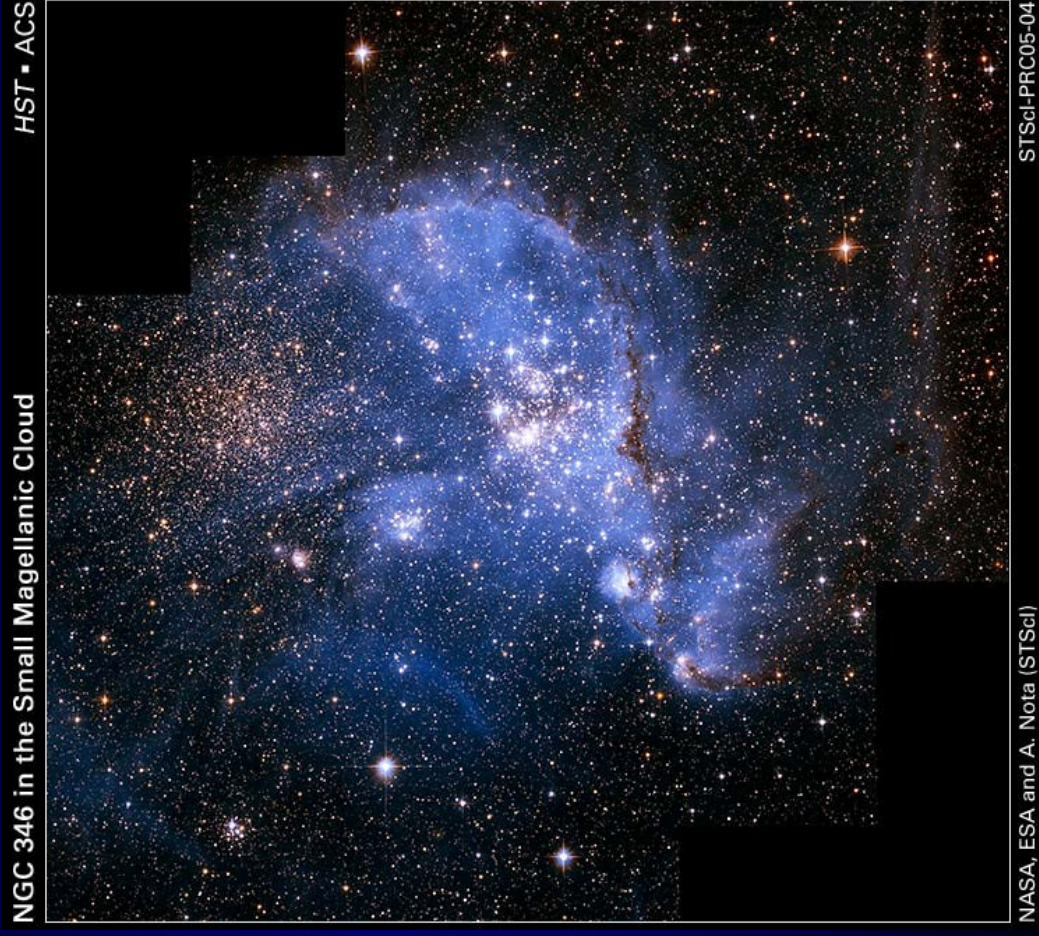


Target fields: NGC 6611 – Eagle Nebula



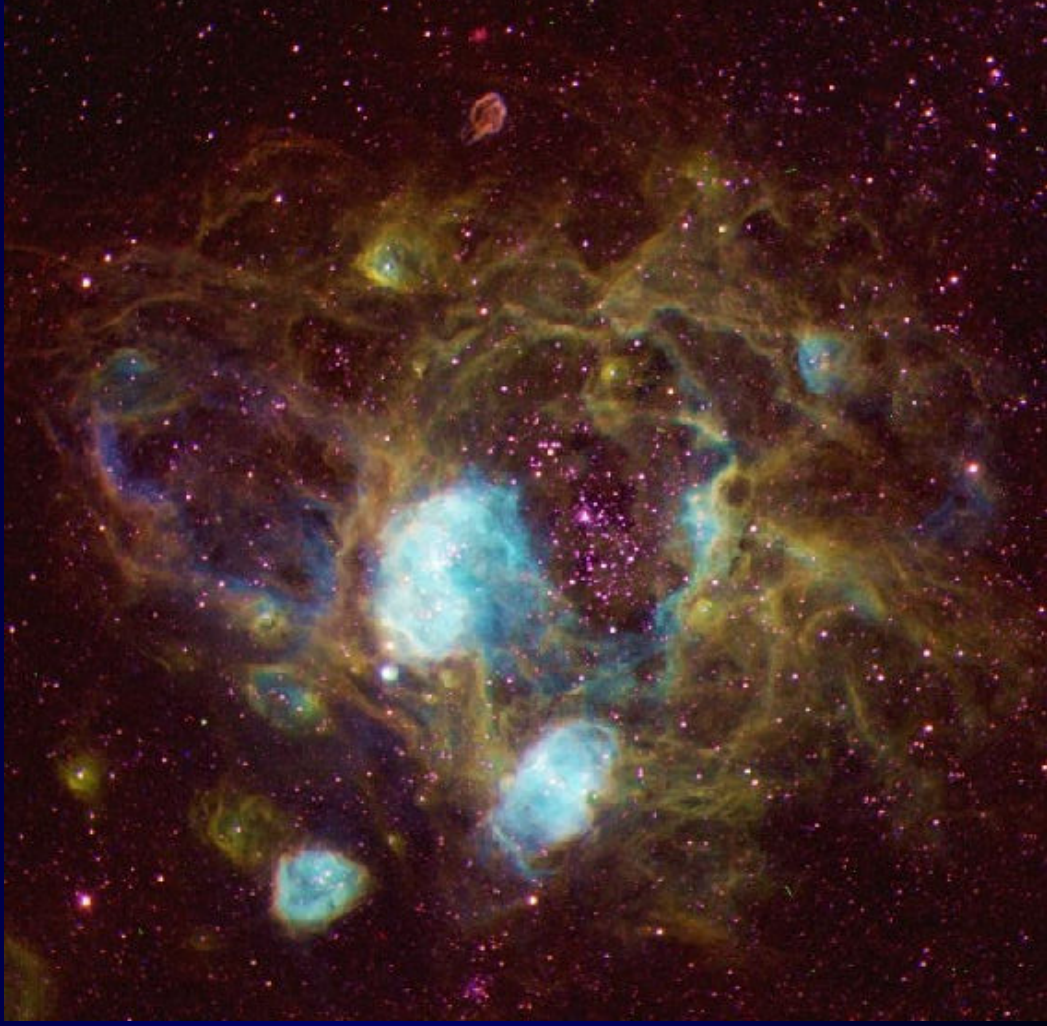


Target fields: NGC 346 in the SMC





Target fields: N11 in the LMC





Overall sample

Coverage from 3850-4750 & 6400-6650 Å, at $R \sim 20,000$

Field	O	Early B	Late B	AFG	Total
NGC3293	–	48	51	27	126
NGC4755	–	54	44	10	108
NGC6611	13	28	12	32	85
NGC330	6	98	11	10	125
NGC346	19	84	2	11	116
NGC2004	4 (+1 WR)	101	6	7	119
N11	44	76	–	4	124
Total	87	489	126	101	803



Science results

- O star analyses **Mokiem et al., 2006, 2007**
- Physical parameters of MW stars **Dufton et al., 2006**
- *vsini* analysis of the SMC/LMC stars **Hunter et al., in prep.**
- Abundance analysis of narrow lined stars **Hunter et al., 2007**
Trundle et al., submitted



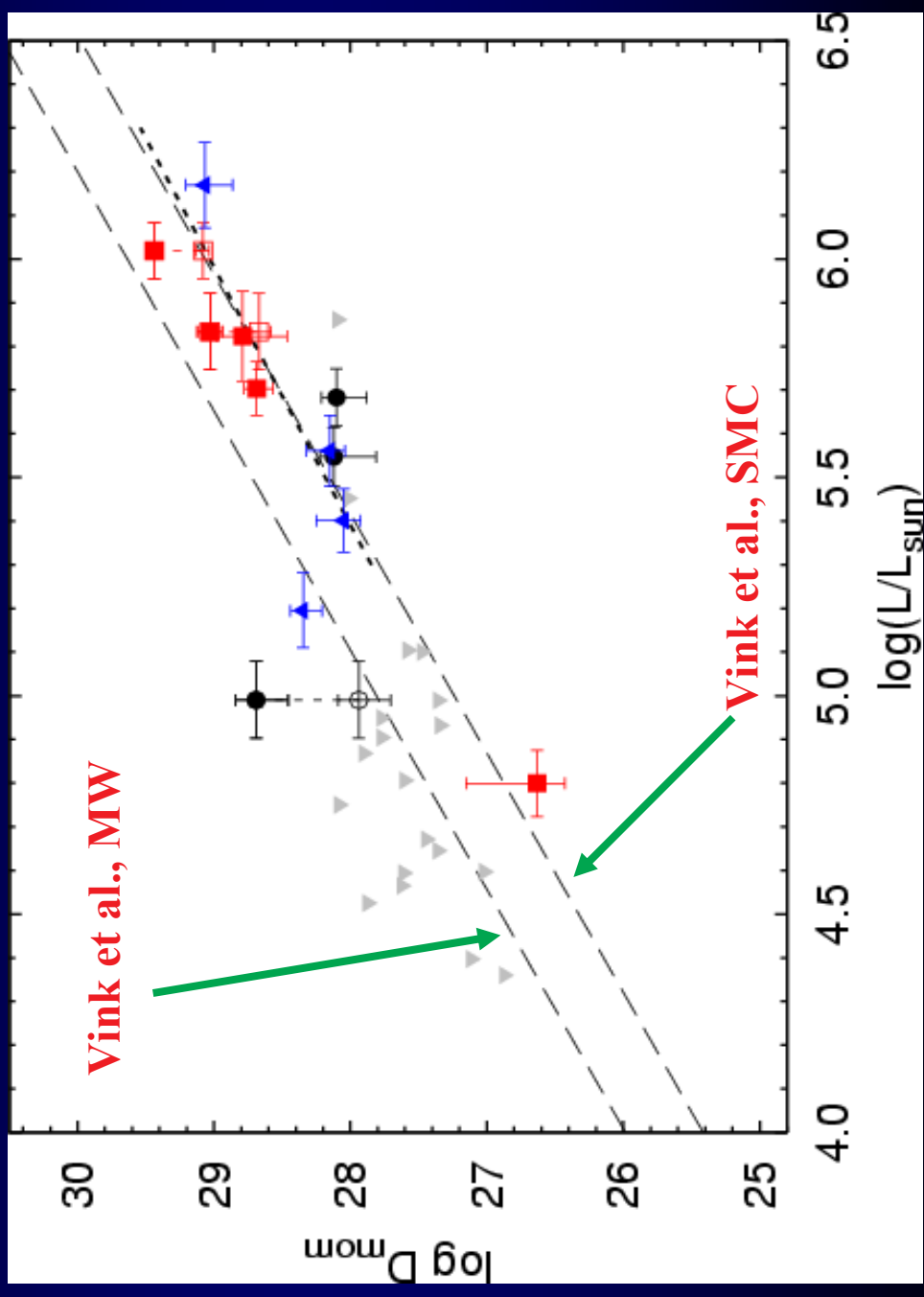
O star analysis

- 30 stars studied in each of the SMC & LMC
- Employs genetic-algorithm based optimisation of spectra from FASTWIND model atmospheres (Mokiem et al., 2005)
- 7 free parameters: T_{eff} , $\log g$, Y_{He} , v_{turb} , $v \sin i$, $\dot{M}$, β
- Initial model selected, then parameters mutated to give next generation – the best fitting of these is taken forward etc.



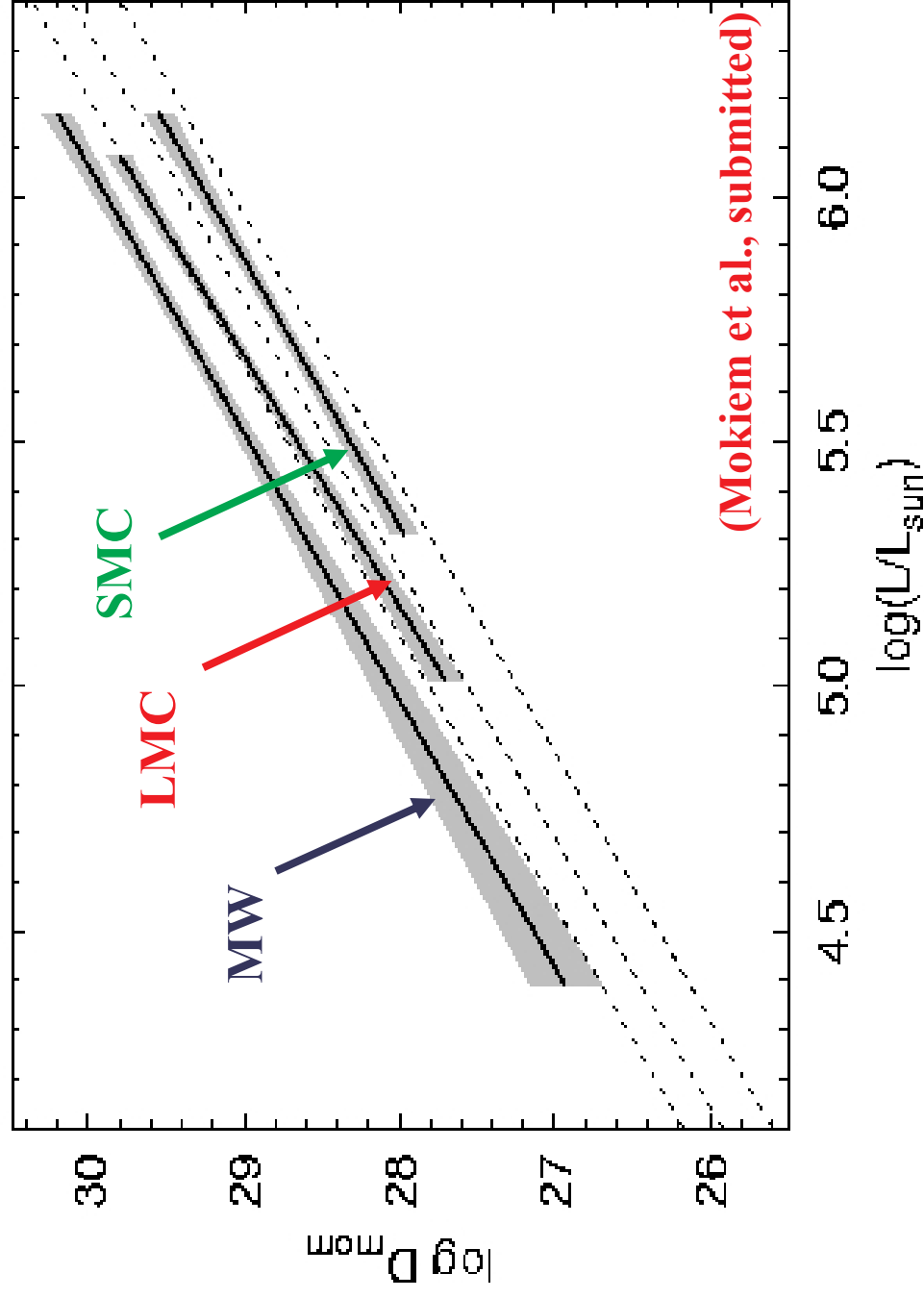
O star analysis: SMC results (Mokiem et al., 2006)

Wind momentum
 $= f(\dot{M}, v_{\text{inf}}, R)$



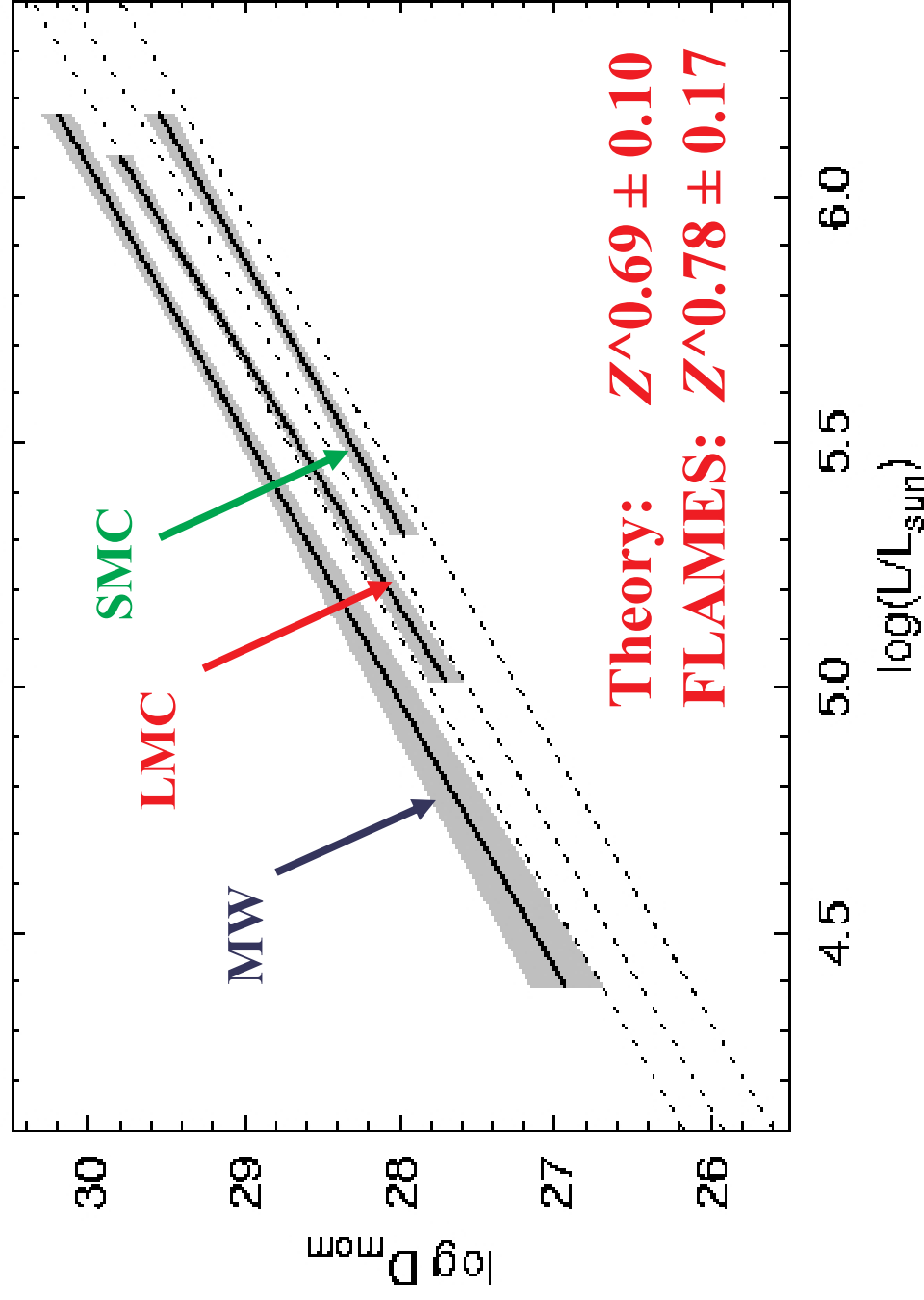


Z-dependence of stellar mass-loss rates





Z-dependence of stellar mass-loss rates





B star analysis

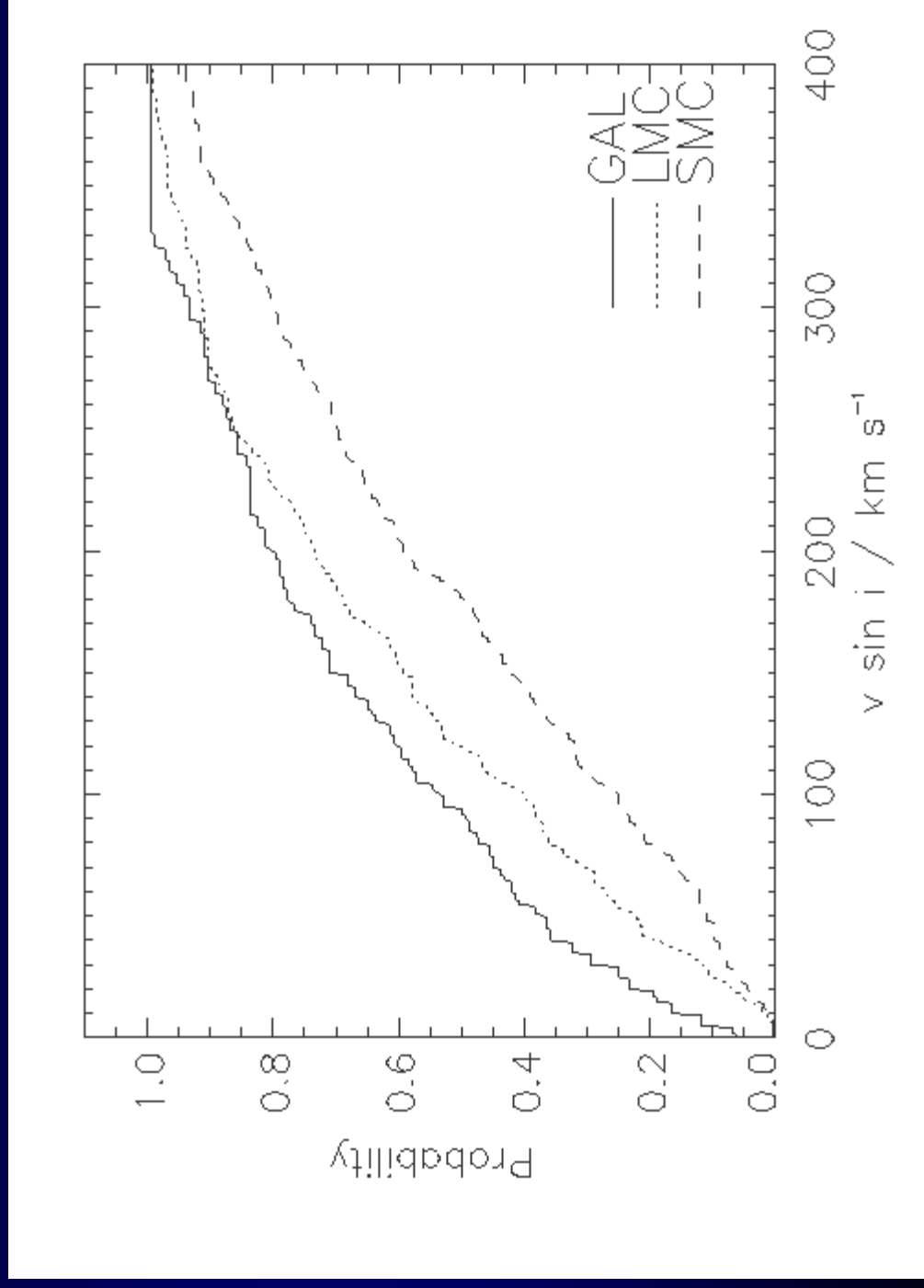
Hunter et al. (2007);
Trundle et al., (sub.)

- B stars analysed using TLUSTY hydrostatic models:
 - T_{eff} , $\log g$, μ -turb, $v \sin i$
 - light element abundances: C, N, O, Si & Mg
- Combine $v \sin i$ and N abundances to test evolutionary models



Z-dependence of $v \sin i$

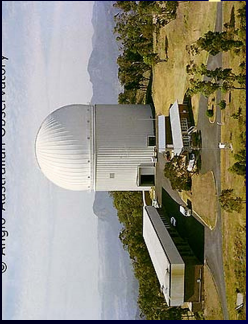
Hunter et al. (in prep.)





Summary

- FLAMES provides a large, homogenous sample of OB spectra
- First empirical test of Z-dependence of mass-loss
- Evidence of Z-dependence of $v \sin i$
- Crucial info for evolutionary codes, populations synthesis codes, SNe models, models of long-duration GRBs etc.



The bigger picture with AAOmega

- New project with AAOmega at the AAT to map the kinematics of 100,000 stars in the SMC+LMC system
- Star-formation histories, IMFs, abundances etc.
- Pilot data obtained in Feb & Dec 2006
- Long-term status requested in 07B proposal for 100 nights
- P.I. Jacco van Loon (Keele) + 24 co-Is
- *<http://www.astro.keele.ac.uk/AAOmega>*

End.