Active OB stars: structure, evolution, mass loss, and critical limits
Proceedings IAU Symposium No. 272, 2010
C. Neiner, G. Wade, G. Meynet & G. Peters, eds.

doi:10.1017/S1743921311010672

IR mass loss rates of LMC and SMC O stars

Derck L. Massa[1], Alex W. Fullerton[1], Danny J. Lennon[1] and Raman K. Prinja[2]

[1]STScI, Baltimore, MD, USA

[2]Dept. of Astronomy, UCL, London, UK

Abstract. We use a combination of VJHK and *Spitzer* [3.6], [5.8] and [8.0] photometry, to determine IR excesses in a sample of LMC and SMC O stars. This sample is ideal for determining excesses because: 1) the distances to the stars, and hence their luminosities, are well-determined, and; 2) the very small line of sight reddenings minimize the uncertainties introduced by extinction corrections. We find IR excesses much larger than expected from Vink *et al.* (2001) mass loss rates. This is in contrast to previous wind line analyses for many of the LMC stars which suggest mass loss rates much less than the Vink *et al.* predictions. Together, these results indicate that the winds of the LMC and SMC O stars are strongly structured (clumped).

Keywords. stars: early-type, stars: mass loss, galaxies: Magellanic Clouds

1. Introduction

The effects of structure on wind diagnostics is now widely accepted. It causes Hα and radio and IR continuum measurements (n_e^2 diagnostics) to *over*-estimate mass loss rates, $\dot{M}$. Structure, and its accompanying porosity, can also cause wind line diagnostics to *under*-estimate $\dot{M}$ (Prinja & Massa 2010). We examine this effect in lightly reddened Magellanic Cloud O stars by deriving $\dot{M}$s from *Spitzer* IR excesses, and comparing the results to theoretical expectations from Vink *et al.* (2001). If clumping is significant, we expect the IR excesses to over-estimate the mass loss rates. Furthermore, comparing the LMC and SMC results allows us to examine metallicity effects on clumping.

2. Extinction Corrections

To determine IR excesses, the continua must be corrected for reddening, and this requires the assumption that a portion of the continuum is free of excess and has a known slope, typically $(B - V)$. Applying an extinction curve with an inappropriate $A(V)$ can introduce enormous errors in the inferred IR excess. In this regard, LMC and SMC O stars have a substantial advantage compared to Galactic O stars.

3. The Model

We use a generalization of the Lamers & Waters (1984) model which agrees with results from the Puls *et al.* (1996) Fastwind model when similar parameters are used. We ignore the effects of disks or non-standard, slowly accelerating velocity laws at this time. For the stellar parameters the following were adopted: For the LMC we used the Martins *et al.* (2002) calibrations for the stellar parameters, except for luminosities, where a distance modulus of 18.52 mag was used. We assumed $Z(\mathrm{LMC})/\mathrm{Z}_\odot = 0.6$. For the SMC we used the Massey *et al.* (2009) Spectral Type $\rightarrow T_{eff}$ calibration, a $DM = 18.91$ mag to determine $\log L(\mathrm{SMC})/\mathrm{L}_\odot$, and the Leitherer et al. (2010) $Z(\mathrm{SMC})/\mathrm{Z}_\odot = 0.2$ grid to determine masses. When measured terminal velocities, v_∞, were not available, we

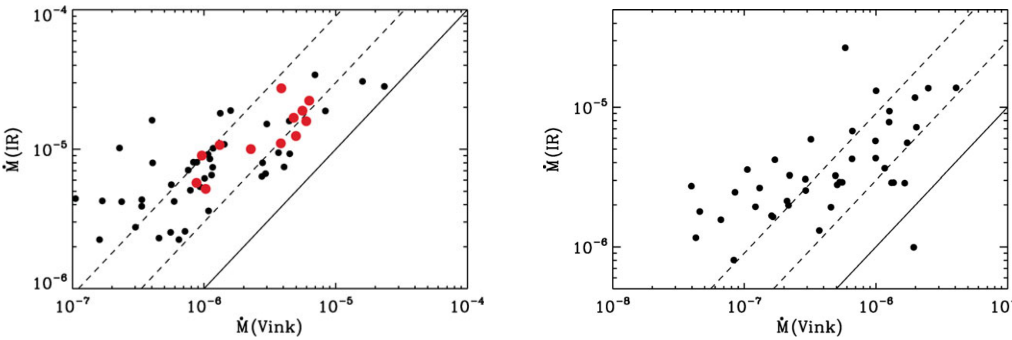

Figure 1. Mass loss rates from *Spitzer* excesses, $\dot{M}$(IR), as a function of theoretical expectations, $\dot{M}$(Vink), for the LMC (left) and SMC (right). For the LMC, P V results, infer $\dot{M}$s much smaller than $\dot{M}$(Vink). The red points depict stars which will be observed by *HST*. The solid line indicates $\dot{M}(\mathrm{IR}) = \dot{M}(\mathrm{Vink})$ and the dashed lines give $\dot{M}(\mathrm{IR}) = 3$ and $9\times\dot{M}(\mathrm{Vink})$.

used the Vink *et al.* (2001) formulae relating escape velocity and v_∞. TLUSTY (Lanz & Hubeny 2003) models of the appropriate temperatures, surface gravities and metallicities were used for the bare photospheres, and an $R(V) = 3.1$ extinction curve was assumed throughout (Fitzpatrick & Massa 2009).

4. Results

All of the IR mass loss rates (see, Fig. 1) are larger than expected and, as is well known, LMC mass loss rates are larger than SMC rates for similar stellar parameters. Furthermore, the relative disagreement between the IR, $\dot{M}$(IR), and Vink *et al.* (2001) mass loss rates, $\dot{M}$(Vink), is similar for the LMC and the SMC.

5. Conclusions

• IR excesses for LMC and SMC O stars are larger than those expected from theory by factors of 3 – 10.
• For LMC stars, the mass loss rates are vastly larger than those expected from UV wind lines (Massa *et al.* 2003, Fullerton *et al.* 2006).
• The relative disagreement between theory and observation is similar for both galaxies.
• If, as expected, clumping causes of the disagreement, then its effect appears to be weakly dependent on metallicity.

References

Fitzpatrick, E. L. & Massa, D. 2009, *ApJ*, 699, 1209
Fullerton, A. W., Massa, D. L., & Prinja, R. K. 2006, *ApJ*, 637, 1025
Lamers, H. J. G. L. M. & Waters, L. B. F. M. 1984, *A&A*, 136, 37
Lanz, T. & Hubeny, I. 2003, *ApJS*, 146, 417
Martins, F., Schaerer, D., & Hillier, D. J. 2002, *A&A*, 382, 999
Massa, D., Fullerton, A. W., Sonneborn, G. & Hutchings, J. B. 2003, *ApJ*, 586, 996
Massey, P., Zangari, A. M., Morrell, N. I., Puls, J. *et al.* 2009, *ApJ*, 692, 618
Prinja, R. K. & Massa, D. L. 2010, *A&A* 521, L55
Puls, J., Kudritzki, R.-P., Herrero, A., Pauldrach, A. W. A. *et al.* 1996, *A&A*, 305, 171
Vink, J. S., de Koter, A., & Lamers, H. J. G. L. M. 2001, *A&A*, 369, 574