RevMexAA (Serie de Conferencias), **8**, 9–12 (1999)

THE EFFECT OF METALLICITY ON THE WIND OF O STARS TODAY'S SPHEROIDALS?

Stéphanie Plante

Département de Physique and Observatoire du Mont Mégantic,
Université Laval, Québec, QC, G1K 7P4, Canada; splante@phy.ulaval.ca

RESUMEN

Con el objeto de cuantificar el efecto de la metalicidad en el viento de estrellas de gran masa, se determinaron tasas de pérdida de masa y velocidades terminales en una muestra de 29 estrellas O de ambas Nubes de Magallanes y se compararon estos valores con los resultados para estrellas galácticas. Estos parámetros fueron derivados a partir de espectros UV obtenidos con *HST*, espectros ópticos obtenidos en CASLEO y modelos de atmósferas. Se utilizó el código de Schmutz (1998), el cual reproduce las líneas de hidrógeno y helio presentes en la región óptica del espectro, para determinar la tasa de pérdida de masa, la luminosidad y la temperatura de cada esrella. Las velocidades terminales fueron calculadas con el código SEI (Groenewegen & Lamers 1989), el cual sintetiza los perfiles P Cyg en el UV que se forman en los vientos densos de las estrellas O. La teoría del viento impulsado por radiación predice una fuerte dependencia de la tasa de pérdida de masa con la metalicidad. Basándonos en nuestras observaciones se sugiere que esta dependecia no es tan fuerte, especialmente para estrellas gigantes y supergigantes de tipo O. Además, se encuentra que las velocidades terminales de estrellas O evolucionadas son casi insensibles a la metalicidad.

ABSTRACT

In order to quantify the effect of metallicity on the wind of massive stars, we determined mass-loss rates and terminal velocities for a sample of 29 LMC and SMC O stars and compared those values with results from galactic stars. We derived the desired quantities from *HST* UV spectra, optical spectra obtained at the CASLEO observatory and model atmospheres. We used the Schmutz (1998) code, which reproduces the hydrogen and helium lines present in the optical region, to determine the mass-loss rate, luminosity and temperature of each of the stars. Terminal velocities have been calculated with the SEI code (Groenewegen & Lamers 1989), which synthesized the UV P Cyg profiles formed in the dense winds of O stars. Radiation-driven wind theory predicts a strong dependence of the mass-loss rate with metallicity. Based on our observations, this dependence is not that strong, especially for giant and supergiant O stars. We also find that the terminal velocities of evolved O stars are almost insensitive to metallicity.

Key words: **STARS: ATMOSPHERE — STARS: EARLY-TYPE — STARS: MASS-LOSS**

1. INTRODUCTION

Massive stars are the major contributors to both the mechanical and luminous energy inputs in the ISM. Their strong winds are shaping the ISM, enriching it with metals and even helping to form new stars. Three important parameters can modify the wind mechanism and its output: temperature, luminosity and metallicity (Lucy & Solomon 1970; Castor, Abbott, & Klein 1975). For a long time now, different model atmospheres have been trying to determine the effect of each parameter on the evolution of the stars by reproducing optical and UV spectral signatures. Depending on the simplifications used, the results from the models have been quite convincing, especially for stars having a solar metallicity. In the case of lower metallicity stars, like those located in the LMC and SMC ($Z_{\rm LMC} = 0.25\ Z_\odot$ and $Z_{\rm SMC} = 0.1\ Z_\odot$; Lequeux et al. 1979), major difficulties arise and a complete treatment is needed (see Puls et al. 1996). Schmutz (1998) constructed a model including line-blanketing and a spherically expanding atmosphere, essential in the rigorous treatment of massive stars. We used this model on a sample of 29 O stars from the SMC and LMC and on the digital spectra of galactic O stars from Walborn & Fitzpatrick (1990) in order to study how metallicity affects the mass-loss rates of the stars. Theory predicts that $\dot{M} \propto L^{1.66}$ and $\dot{M} \propto Z^{0.8}$ (Puls et al. 1996).

We also used the SEI code (Groenewegen & Lamers 1989) to obtain the terminal velocities, from the UV

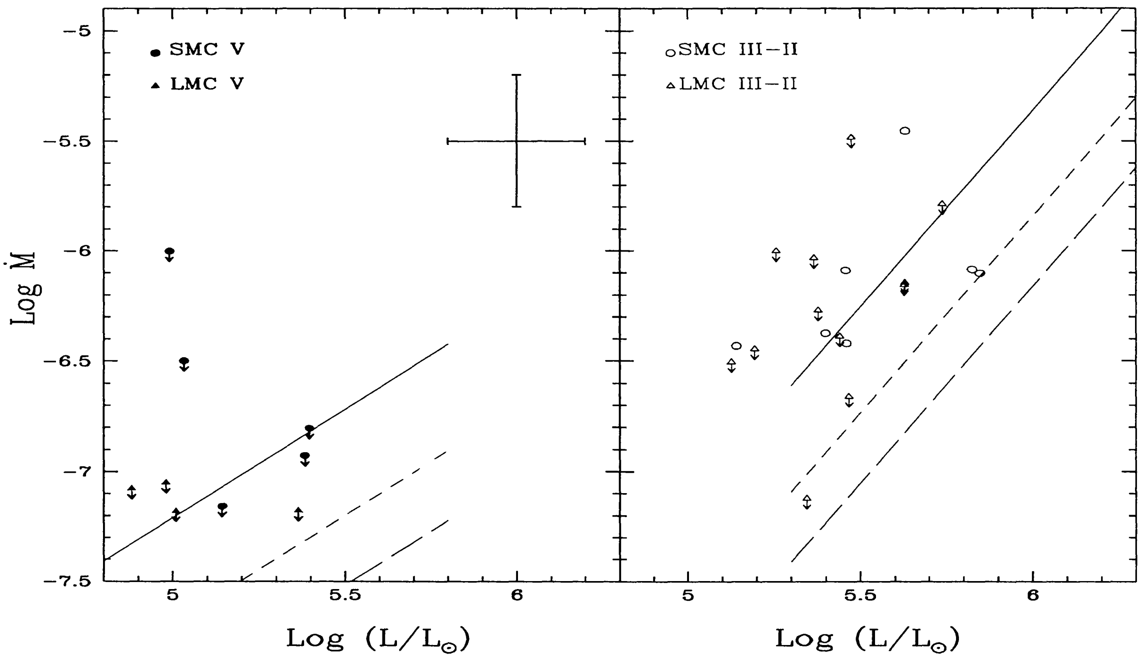

Fig. 1. Mass-loss rate as a function of luminosity and metallicity. The cross represents a typical error bar. The full line is a fit through the galactic values. The dashed lines have the same slope (1.66) as the galactic line, but are moved in ordinate following the theoretical prediction. This does not reproduce the values for the giants and supergiants. Observed mass-loss values for main sequence stars are upper limits, thus we cannot reach a conclusion.

spectra of the same sample of SMC and LMC stars. The mass-loss rates and terminal velocities are good indicators of the mechanical input of the wind in the ISM. By comparing the values from the galactic stars and from the Magellanic Clouds stars, we can obtain the effect of metallicity on the wind of O stars. Theory predicts that the terminal velocity is sensitive to the metallicity, but less than the mass-loss rate. It is feasible to ascertain if theoretical predictions are right with the sample we have.

2. OBSERVATION AND REDUCTION

The optical spectra of the Magellanic O stars have been obtained at CASLEO[1] (San Juan, Argentina) in December 1996. The REOSC spectrograph on the 2.1-m telescope has been used to cover the region from 3900 to 5400 Å with an effective resolution of 7 Å. The typical signal-to-noise ratio is of the order of 70. For comparison, we considered a sample of O stars located near the Sun. These have been presented by Walborn & Fitzpatrick (1990) in their digital atlas of O stars. The resolution of these spectra are of the order of 4 Å, and the signal-to-noise ratio of about 100.

The UV spectra have been observed by the refurbished *HST* and its Faint Object Spectrograph. They cover the near and far UV, from 1150 to 2300 Å, where most of the strong wind lines are seen. The typical signal-to-noise ratio is 20 per pixel, and the resolution is 2.7 Å, based on the *FWHM* of single interstellar lines. *IUE* spectra of galactic O stars, presented in Howarth & Prinja (1989), have been used as our sample at solar metallicity. We grouped these data by spectral type to increase the signal-to-noise (for more details, see Robert, Leitherer, & Heckman 1993). We also degraded their resolution to match *HST*'s ones.

[1] Operated under agreement between CONICET, SeCyT, and the Universities of La Plata, Córdoba, and San Juan, Argentina.

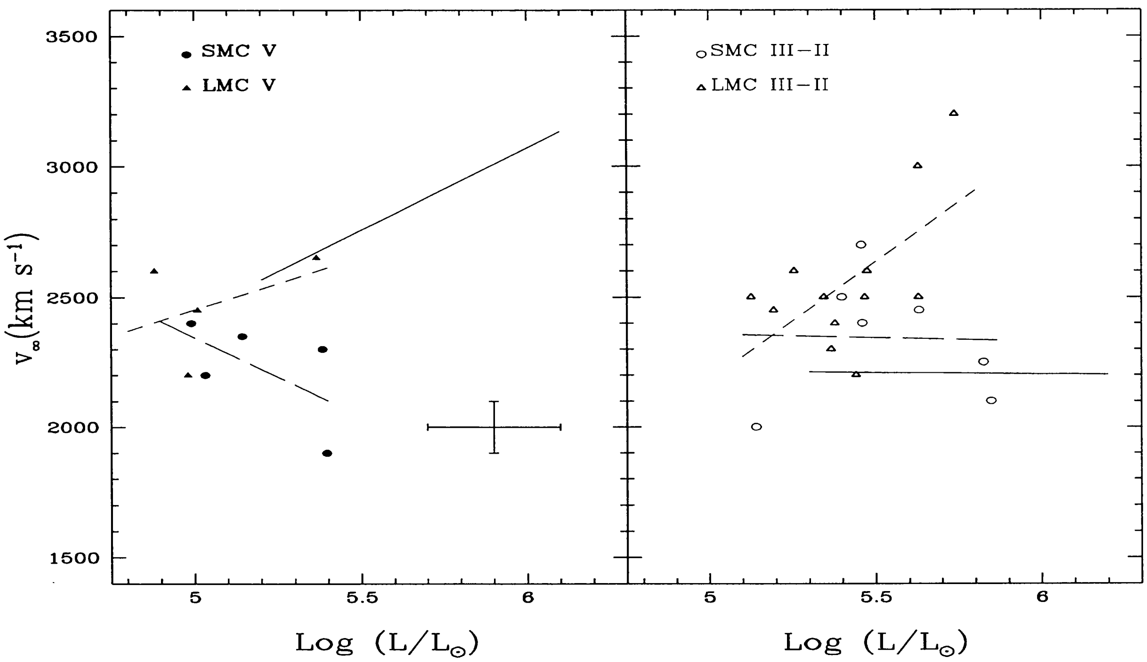

Fig. 2. Terminal velocity as a function of spectral type and luminosity. The cross represents a typical error bar. The full line represents a fit through the galactic values, as the small dashed line is a fit through LMC values and the long dashed line is a fit through the SMC values. The terminal velocity is proportional to metallicity for main sequence stars, but we observe the opposite for giants and supergiants.

3. THE EFFECT OF METALLICITY ON MASS-LOSS RATES AND TERMINAL VELOCITIES

We used the SEI code (Groenewegen & Lamers 1989) on the UV spectra of the Magellanic stars to obtain the terminal velocities. The line-driven wind theory predicts that v_∞ also depends on metallicity (Castor, Abbott, & Klein 1975). Figure 2 shows the value we obtain as a function of metallicity and luminosity. The predicted tendency is observed for the main sequence stars. No correlation is obtained for the supergiants. This implies that the profiles are saturated in the regime of luminosity of the supergiants, even at a metallicity as low as 0.1 solar.

We have reproduced the hydrogen and helium lines of the optical spectra with the code of Schmutz (1998). The best fit possible gives us the luminosity, the effective temperature, helium content, gravity, and mass-loss rate. This last value depends on the terminal velocity determined earlier with the SEI code of (Groenewegen & Lamers 1989). Figure 1 presents the dependence of mass-loss with metallicity and luminosity. Theory predicts that $\dot{M} \propto L^{1.66}$ and $\dot{M} \propto Z^{0.8}$ (Puls et al. 1996). This is not what is observed for the giant and the supergiant stars, where the mass-loss rates are less sensitive to metallicity than predicted. Sadly, we only have upper-limits for the main-sequence stars, the resolution of the spectra being too poor. There is even a tendency for the terminal velocities to be higher at lower metallicities in the giant and supergiant regime. This is probably not realistic if we take into account the high dispersion of the galactic values.

4. CONCLUSION

As demanded by many observations of Starburst galaxies in low metallicity environments (see Legrand et al. 1997, for example), we observe that mass-loss rates are higher than theory predicts for low metallicity stars. This has a profound impact on the evolution of these stars, as well as on the population one can observe in a given environment. Moreover, the terminal velocities in the giant and supergiant stages are at least independent on metallicity, implying that the mechanical input in the ISM by evolved massive stars is independent of metallicity.

REFERENCES

Castor, J. I., Abbott, D. C., & Klein, R. I. 1975, ApJ, 195, 157
Groenewegen, M. A. T., & Lamers, H. J. G. L. M. 1989, A&AS, 79, 359
Howarth, I. D., & Prinja, R. K. 1989, ApJS, 69, 527
Legrand, F., Kunth, D., Roy, J.-R., Mas-Hesse, J. M., & Walsh, J. R. 1997, A&A, 326, L17
Lequeux, J., Peimbert, M., Rayo, J. F., Serrano, A., & Torres-Peimbert, S. 1979, A&A, 80, 155
Lucy, L. B., & Solomon, P. M. 1970, ApJ, 159, 879
Puls, J., et al. 1996, A&A, 305, 171
Robert, C., Leitherer, C., & Heckman, T. M. 1993, ApJ, 418, 749
Schmutz, W., 1998, in ASP Conf. Ser. Vol. 131, Boulder-Munich II: Properties of Hot, Luminous Stars, ed. I. Howarth (San Francisco: ASP), 119
Walborn, N. R., & Fitzpatrick, E. L. 1990, PASP, 102, 379

Jorge Melnick, Werner Schmutz y Joel Parker.