A Massive Star Odyssey, from Main Sequence to Supernova
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Binaries among the WN population in the Magellanic Clouds

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Abstract. We have undertaken a large and extensive spectroscopic survey of WNE stars both in the SMC and LMC with various 2m and 4m telescopes, reaching a total of 78 nights, spread over three years, and obtaining over 1500 long-slit spectra of medium resolution. The first goal is a systematic search for binaries via periodic radial-velocity variations. We enlarged our dataset with photometric data from the OGLE and MACHO databases, and with archival X-ray data from the *ROSAT* and *Chandra* satellites.

1. Introduction

In low-metallicity environments, if we suppose no rotation, a large fraction of Wolf-Rayet stars are expected to belong to binary systems (Maeder & Meynet 1994), since the lack of metals in the atmosphere of the O-type star progenitor leads to a reduction of the mass-loss. Roche-lobe overflow (RLOF) is therefore expected to take place in binary systems, and leads primary stars to become WR, which would never do so if single (*e.g.*, Vanbeveren *et al.* 1998). A 100% binary frequency was theoretically expected for the WR population of the SMC (Bartzakos *et al.* 2001).

We have carried out a large spectroscopic campaign, using various 2m telescopes and the 4m CTIO telescope for the faintest stars, to detect binaries via radial velocity (RV) variations among the hottest WN stars (WNE = WN2-5) in the Magellanic Clouds. We enlarged our dataset with archival photometric data from OGLE and MACHO databases, to look at possible eclipses in binary systems. We also retrieved X-ray data from *ROSAT* and *Chandra* archives, in order to detect X-ray emission from colliding winds, to strengthen the binary status. Thus, considering RVs with time-coverage ranging up to 100 d, photometric variability, X-ray luminosities and spectra, line-profile variations, wind-wind collisions

effects and our own homogeneous spectral classification, we provide an accurate binary status for all WNE stars in the Magellanic Clouds.

2. Results

The main results for the SMC are: (*i*) the binary frequency is lower than expected. Among the eleven known WR stars in the SMC, five (possibly six) stars are single. These are SMC-WR 1, SMC-WR 2, SMC-WR 4, SMC-WR 10 and SMC-WR 11 (and probably also SMC-WR 9); (*ii*) we found blue-shifted hydrogen and helium absorption lines with constant RVs in the WR wind of most (single and binary) WN stars, making them fundamentally different from their Galactic counterparts; (*iii*) we detected clear X-ray emission from the three bright binaries: SMC-WR 5 (HD 5980, $P = 19.2$ d), SMC-WR 6 ($P = 6.5$ d) and SMC-WR 7 ($P = 19.5$ d). These X-rays are likely to be produced by wind-wind collision. No X-ray emission is found in the binary star SMC-WR 3 ($P = 10.0$ d), which could be explained by the probably very faint companion; and (*iv*) no periodic variations were found in the photometry except for the single star SMC-WR4, which shows a 6.55 d signal.

Combining all these results, the binary channel, although important, seems not to be dominant to form WR stars at low metallicity Z. Combining two different tests (namely the period changes and the post-RLOF mass ratio) we found no evidences for a past occurrence of RLOF in the binaries. It appears that only the SMC WC star SMC-WR 8 could have experienced such an event. As for single stars, we can not rule out the necessity of very high initial mass progenitors. However, rotation is found to probably play an important role.

In the LMC, combining the results already published of WC stars (Bartzakos *et al.* 2001) and our survey of 61 WNE stars, 2/3 of the WR population in this galaxy is now covered. The binary frequency is confirmed to be surprisingly lower (15 - 20 %, *i.e.*, between 8 and 12 binaries among the WNEs) than theoretically expected (52 %). We found photometric double-eclipses for two binaries (BAT99-19 and BAT99-129) which allow us to obtain reliable masses. A similar RV survey for the remaining WNL stars in the LMC has been started in 2001 (Schnurr *et al.*).

Complete discussion and detailed description of this study will be published elsewhere (Foellmi *et al.* 2003a,b).

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