Massive Stars Near and Far
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Unraveling massive star and binary physics in the nearby low-Z galaxy SMC as a proxy for high-redshift galaxies

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Abstract. Low metallicity (Z) massive stars are among the main feedback agents in the early Universe and in present-day blue dwarf galaxies. The nearby star-forming SMC galaxy offers conditions which resemble those at redshift $z \sim 2$, i.e. where modern galaxies formed and star formation peaked. Here we present the recent results about the nature of the eclipsing O-type binary in the SMC, AzV 476, to gain insights on the properties of massive stars and binaries at earlier cosmic epochs. We find that the primary has surprisingly low mass while being much brighter and hotter than the secondary. To place the measured stellar properties in the evolutionary context we modeled the system and confirm that AzV 476 is a post-interaction binary with the primary already being core helium (He) burning, while still having a hydrogen-rich (H-rich) envelope. These results constrain massive binary evolutionary scenarios and guide the searches of stripped stars in low-Z environments.

Keywords. binaries: close, binaries: eclipsing, binaries: spectroscopic, stars: early-type, stars: fundamental parameters, stars: individual: AzV 476, Magellanic Clouds

1. Introduction

In the standard picture of binary interactions, it is believed that during stable mass transfer via Roche lobe overflow, more than 70% of the H-rich ($X_H > 0.6$) envelope of the donor star is removed. After the mass-transfer phase, the donor star is expected to evolve quickly into a helium- or WR-star as its remaining H-poor ($X_H \lesssim 0.4$) envelope is quickly removed by powerful stellar winds. In the Hertzsprung-Russell diagram (HRD) these stars can be found on the left side of the zero-age main-sequence (ZAMS). However, recent theoretical predictions of Klencki et al. (2021) suggest that the stripping process via Roche lobe overflow in low metallicity (Z) environments does only partially strip of the hydrogen-rich envelope. Hence, on the HRD, these core He-burning stars are located on the right side of ZAMS, in the same region as core H-burning OB stars.

In our study on the eclipsing binary system AzV 476 Pauli et al. (2022) we might have found one of these stars. Here we present the key results of this recent study, and briefly discuss their impact on our the understanding of massive star evolution at low Z.

2. Overview

AzV 476 harbors an O4 IV-III((f))p and an O9.5: Vn star. If treated as single stars, according to their spectra type, they should have $M_{\rm exp,1} = 49^{+7}_{-6}\,M_\odot$, and $M_{\rm exp,2} = 16^{+7}_{-3}\,M_\odot$ Weidner & Vink (2010). Yet, our orbital analysis revealed that the mass of the

Table 1. Fundamental stellar parameters.

	primary	secondary
$M_{\rm spec}$ $[M_\odot]$	29^{+17}_{-11}	22^{+13}_{-8}
$T_{\rm eff}$ [kK]	42^{+3}_{-3}	32^{+4}_{-4}
$\log\ L$ $[L_\odot]$	$5.65^{+0.2}_{-0.2}$	$4.75^{+0.2}_{-0.2}$
$\log\ \dot{M}$ $[M_\odot\ {\rm yr}^{-1}]$	$-6.1^{+0.2}_{-0.2}$	$-8.8^{+0.5}_{-0.5}$
$v \sin i$ $[{\rm km\,s}^{-1}]$	140^{+10}_{-10}	425^{+25}_{-25}
$X_{\rm H}$ (by mass)	0.73	0.73
$X_{\rm C}/10^{-5}$ (by mass)	2^{+2}_{-1}	21^{a}
$X_{\rm N}/10^{-5}$ (by mass)	45^{+5}_{-10}	3^{a}
$X_{\rm O}/10^{-5}$ (by mass)	80^{+10}_{-20}	110^{a}

Notes: [a] Fixed to standard CNO abundances, as no metal-lines of the secondary can be seen in the spectrum.

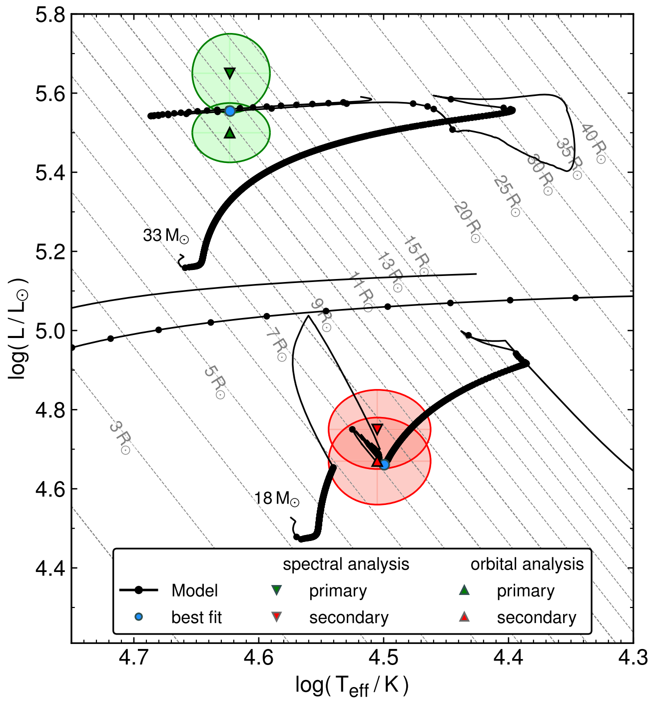

Figure 1. HRD showing the track of the binary evolutionary model (black line). The black dots on the tracks correspond to equidistant time-steps of 0.1 Myr to emphasize the most probable observable phases.

primary is only $M_{\rm orb,1} = 20.2^{+2.0}_{-2.0}\ M_\odot$, and thus a factor of 2.4 less massive than expected! The orbital mass of the secondary $M_{\rm orb,\,2} = 18.0^{+1.8}_{-1.8}\ M_\odot$ agrees with the expectations.

The fundamental stellar parameters of the individual binary components are given in Tab. 2. Note, that the mass-loss rate of the primary, due to the unusual high L/M ratio, is 10 times higher than expected from empirical relations of single stars (e.g. Ramachandran et al. 2019).

The low stellar mass, the unusually high mass-loss rate, and the altered CNO abundances of the primary as well as the fast rotation of the secondary strongly suggest that the binary has undergone a mass-transfer phase in the recent past. We calculated binary

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evolutionary models with the MESA code. Our best fitting model is shown in Fig. 1. It reproduces the observed stellar and orbital parameters and predicts that the primary of the system is already core He-burning while still being on the right side of the ZAMS in the HRD, hiding among the OB population. These findings, question the standard picture of post-interacting binary.

3. Implications

Uncovering core He-burning massive star in a early O-type binary in the SMC, greatly impact our understanding of stellar feedback in low Z environments, and thus of the early Universe. Binary stripped stars which do not lose their H-rich envelope, have weaker ionizing fluxes than those who do. In addition to that also their mechanical feedback is expected to be lower. The question remains if the system AzV 476 is unique or just the tip of the iceberg of an undiscovered population of partially stripped stars.

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