On the nature of the WO3 star DR1 in IC 1613

F. Tramper, G. Gräfener, O.E. Hartoog, H. Sana, A. de Koter, J.S. Vink, L.E. Ellerbroek, N. Langer, M. García, L. Kaper and S.E. de Mink

1 Astronomical Institute 'Anton Pannekoek', University of Amsterdam, The Netherlands
2 Armagh Observatory, Northern Ireland
3 Space Telescope Science Institute, Baltimore, USA
4 Instituut voor Sterrenkunde, Universiteit Leuven, Belgium
5 Argelander Institut für Astronomie, University of Bonn, Germany
6 Centro de Astrobiología, CSIC-INTA, Madrid, Spain
7 Observatories of the Carnegie Institution for Science, Pasadena, USA
8 Cahill Center for Astrophysics, California Institute for Technology, Pasadena, USA

Abstract

We present the results of a quantitative spectroscopic analysis of the oxygen-sequence Wolf-Rayet star DR1 in the low-metallicity galaxy IC 1613. Our models suggest that the strong oxygen emission lines are the result of the high temperature of this WO3 star and do not necessarily reflect a more advanced evolutionary stage than WC stars.

1 Introduction

Oxygen-sequence Wolf-Rayet (WO) stars are extremely rare: only 8 are currently known. They are often thought to represent the evolutionary stage succeeding the carbon-sequence Wolf-Rayet (WC) phase (Smith & Maeder 1991). The strong oxygen emission then originates from the surfacing of this species at the end of core-helium burning. An alternative explanation is that the high excitation oxygen emission reflects a higher stellar temperature compared to WC stars (Crowther et al. 1998). Here, we attempt to discriminate between these scenarios by analyzing the optical to near-infrared spectrum of the WO3 star DR1 in IC 1613. Our full analysis is provided in Tramper et al. (2013).

2 Modeling DR1 in IC 1613

DR1 is a WO3 star located in the low-metallicity Local Group galaxy IC 1613. The metallicity of this system is $Z \sim 1/7Z_\odot$ (Bresolin et al. 2007), making DR1 the only WO star known...
in a sub-Small Magellanic Cloud metallicity environment (with $Z_{SMC} = 1/5 Z_{\odot}$). Using CMFGEN, we model the observed spectrum of DR1 to determine its stellar and outflow properties, in particular the oxygen and carbon abundance and the stellar temperature.

Our best model represents the spectrum of DR1 well safe for the O\textsc{vi} $\lambda\lambda$3811-34 emission, the strength of which is not fully reproduced (see Figure 1). DR1 has a luminosity that is $10^{5.74 \pm 0.10}$ times that of the sun and a temperature of about $150 \pm 25$ kK. Both these values are high compared to WC stars (see Figure 2). We suggest that the poorly fitted O\textsc{vi} $\lambda\lambda$3811-34 emission originates from a mechanism not accounted for in our model (possibly shock induced X-rays). Models that can reproduce this line need a high temperature and high oxygen abundance, but do not fit the rest of the spectrum.

We derive an oxygen abundance relative to helium of $O/He = 0.06 \pm 0.01$ by number and a carbon abundance $C/He = 0.45 \pm 0.05$. These values are comparable to those found for WC stars in various environments. The current surface abundances, including the mass fraction of helium, are plotted in Figure 3. Our abundances suggest that DR1 is more than half-way through its core-helium burning stage (see Tramper et al., 2013, for details).
3 Discussion and conclusions

The oxygen abundance is not enhanced compared to values found for WC stars in other studies. The temperature and luminosity, however, are higher. If DR1 is representative for the WO class, this would suggest that WO stars are not necessarily in a more advanced evolutionary stage than WC stars. Figure 2 shows that DR1 is located at a position in the HRD expected for the late stages of evolution of a 120 $M_\odot$ star at SMC metallicity, in which case its current mass would be about 18 $M_\odot$. Stars with a final mass larger than about 10 solar masses are likely to form black holes, producing a faint supernova or no supernova at all. If rapidly rotating, however, they may produce bright type Ib/c supernovae. Although DR1 still contains an appreciable amount of helium – 44% at the surface – this does not exclude that DR1 may end in a type Ic supernova. Supernova progenitors may have a surface helium mass fraction as large as 50 percent without this species being detected in the spectrum of the supernova (Dessart et al., 2011).

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Figure 3: Surface abundances predicted for helium-burning stars (Langer et al., 2007; Brott et al., 2011). The star symbols indicate the surface abundances of carbon (in red), oxygen (in green) and helium (in blue) found for DR1.

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