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The Wolf-Rayet Population of Westerlund 1

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Abstract. New NTT/SOFI near-IR narrow-band imaging and spectroscopy reveals an additional four Wolf-Rayet (WR) stars in the massive cluster Westerlund 1, bringing the total WR population to 24. Sixteen of the WR stars in Wd1 have been classified WN5–11, while eight are WC8–9. An observed WR to RSG/YHG ratio of ∼3 suggests an age of 4.5–5.0 Myr, with WR stars descended from 40–55$M_{\odot}$ progenitors. On the basis of dust and hard X-ray emission, we estimate that 40–65% are probable members of massive star binary systems.

1. Introduction

Westerlund 1 (Wd1) is a highly reddened, open Galactic cluster located in the Scutum–Crux spiral arm of our galaxy. Previous studies of its stellar population reveal that Wd1 hosts a rich population of massive stars, with the current WR population estimated at 20 (Clark & Negueruela 2002, Negueruela & Clark 2005, Hopewell et al. 2005). Wd1 therefore provides an excellent opportunity for studying WR stars at solar or moderately super-solar metallicity.

Here we present the results of a near-infrared NTT/SOFI imaging and spectroscopic survey of the WR population of Wd1. We identify four additional WR stars within the cluster and derive important properties such as the extinction, distance and cluster age. In addition we address the WR binary fraction of Wd1.

2. WR Population

We have surveyed the WR population of Wd1 using a combination of NTT/SOFI narrow band images sensitive to characteristic WR emission features. The most successful filter combination for finding WR stars proved to be the 1.08 and 1.06μm(Figure 1) combination, where the former is tuned to 1.083μm He I emission that is present in most WR subtypes and the latter samples the continuum region. Indeed we find that all but two of the known WR stars in the cluster centre display a significant 1.08μm excess. In addition to recovering the known WR stars, this technique also identifies 4 candidate WR stars: WD1 U, WD1 V, WD1 W and WD1 X.

NTT/SOFI follow-up spectroscopy confirmed these candidates as bona fide WN stars, bringing the WR population to 24 - 16 WN and 8 WC. At present no near-IR classification scheme is available which is based on current optical

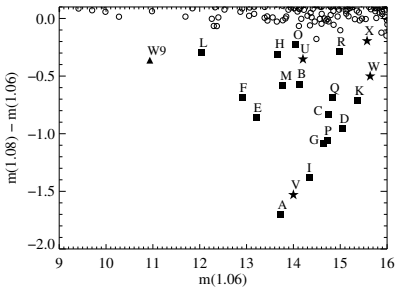

Figure 1. Comparison of SOFI interference photometry of Wd1 tuned to He II 1.08μm emission. Previously reported WR stars (squares) clearly exhibit a photometric excess, as does the B[e] star (triangle). Candidate WR stars (stars) which were spectroscopically confirmed as bona-fide WR stars are marked.

schemes. With this in mind, we have generated a scheme using the near-IR spectra of WR stars which have been classified via optical spectroscopy. For WN stars diagnostic lines are: He I (1.083 μm), He II (1.012, 2.189 μm) and Brγ. For WC stars classification is based on C II (0.990 μm), C III (0.971, 2.110 μm) and C IV (2.076 μm) near-IR line ratios. Late subtypes dominate both the WC and WN populations. All of the WC stars are classified as WC8 or WC9 and six display evidence of hot circumstellar dust. The WN stars range from WN5–11 and a qualitative assessment of the spectra suggests that ∼75% are H-poor.

3. Cluster Properties

We estimate an extinction of A_K=0.96 mag from synthetic JHK$_s$ colours of WR stars plus a distance modulus of 13.50 mag (5.0 kpc) to Wd 1 from absolute K$_s$ magnitudes of known cluster or association WR stars. An observed ratio of WR/(RSG + YHG)∼3 is best matched by an age of 4.5–5.0 Myr with a cluster turn off of 35 $M_\odot$ (∼O7V) such that the WR stars are descended from stars with initial masses 40–55 $M_\odot$.

Stars A, B, L and F have all been classified as high luminosity, hard X–ray emitters from *Chandra* observations. Binary WR stars are expected to be hard X-ray emitters, which suggests a binary fraction of ∼15–40%. Dust production is also a sign of binarity, with six WC stars showing evidence of hot dust, an additional ∼25% of the WR stars are likely binaries. Overall, 40–65% of the WR stars in Wd1 are estimated to belong to massive, binary systems.

References

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