Wolf-Rayet Phenomena in Massive Stars and Starburst Galaxies
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New observational results on the colliding wind WR+O binary WR 30a

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1. Introduction

WR 30a (MS 4) was first suspected as a possible Wolf-Rayet star by McConnell & Sanduleak (1970) during a deep objective-prism survey performed around the Carina Nebula region. From subsequent studies, the spectrum turned out to be composite, with a WR component classified WO4 (or alternatively WC4, WO5 and WC3) and an O component classified O4. Niemela (1995) reported the first, and up-to-now unique, radial velocity study for that star. She noticed large variations of C IV λ4658 from night to night, suggesting that WR 30a might be a short period binary. A plot of the C IV emission-line velocities versus the He II absorption ones clearly indicates that they are exhibiting opposite binary motions. The apparent velocity amplitudes imply a rather low mass ratio $M_{\rm WO4}/M_{\rm O4} = 0.15$, although the radial velocities of the C IV line could be distorted due to line-profile variations.

In the present paper, we confirm the binary nature of WR 30a and propose, for the first time, a value for the orbital period of the system: $P = 4.62$ days. Other orbital parameters are also derived and discussed. We also provide evidence that the system is the site of a colliding wind phenomenon.

2. Observations

In March-April 1997, we performed differential photometry of WR 30a through a Johnson V filter with the Bochum 0.6m telescope at La Silla. The telescope was equipped with a direct camera and a Thomson 384×576 CCD. Comparison stars have been chosen in the field on the same frames than WR 30a. The typical exposure time was 5 minutes. About 100 frames were acquired distributed over the 30 days of the run.

Medium resolution spectra of WR 30a in the blue-violet range were obtained during several observing runs in 1996 and 1997 with the *ESO* 1.5m telescope equipped with a Boller & Chivens Cassegrain spectrograph. The grating provided a reciprocal dispersion of 32.6 Å mm^{-1}. The detector was a thinned, UV flooded CCD. The spectral resolution as measured on the helium-argon comparison spectra is 1.2 Å. The WR line selected for the bulk of the observations is C IV λ4658, although the O IV $\lambda\lambda$3811–34 lines are covered by a few spectra.

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3. Analysis and results

When plotted as a function of time, the differential V magnitudes clearly exhibit weak almost sinusoidal variations. Some 6.5 cycles are observed over the 30 days. Different period-searching techniques suggest $\nu = 0.215\,\mathrm{d}^{-1}$ ($P = 4.65\,\mathrm{d}$) as the value for the period, with a natural width of the Fourier peaks of $0.03\ \mathrm{d}^{-1}$. The corresponding peak-to-peak amplitude is about 0.024 magnitudes.

The C IV λ4658 line in WR 30a exhibits strong line-profile variations which, at first sight, display no clear trend. However, the 1997 sequence of daily observations is extremely similar to the 1996 one. From an examination of both sequences, we conclude that the line-profile variability is fully deterministic. We have computed, for each spectrum, the first order moment of the C IV λ4658 line in order to characterize the line variations. A period search among the first order moments suggests a series of strongly aliased frequencies among which we point out $\nu = 0.2075$, 0.2105, 0.2135, 0.2165, 0.2195 and $0.2225\,\mathrm{d}^{-1}$. This independent result is in good agreement with the period derived from the photometry. The most plausible common alias is $\nu = 0.2165\,\mathrm{d}^{-1}$ corresponding to a period of 4.62 d. The deterministic line-profile variations of the emission lines are perfectly phase-locked with the orbital period. However, the radial velocities of the C IV λ4658 line are not expected to represent the true motion of the WR component.

The spectrum of WR 30a also displays prominent absorption lines of hydrogen and helium belonging to the hot O star companion. The intensity of most of these features changes as a function of time. The radial velocities of He II λ4200, He II λ4542 and Hγ were combined to derive a mean radial velocity. Assuming a circular orbit, we have computed a least-square fit to these mean radial velocities. The related solution yields an amplitude $K_{\mathrm{O}} = 31.7 \pm 2.6(1\sigma)\,\mathrm{km\,s^{-1}}$ and a corresponding mass function $f(m) = 0.015\,\mathrm{M_{\odot}}$. Our radial velocity curve further indicates that the O star is in front of its WR companion at the time of minimum light.

4. Conclusion

WR 30a exhibits photometric and spectroscopic variations that can be attributed to the binarity of the system. The WO4 component is certainly the fainter of the two stars. The system is unique in the sense that minimum light occurs when the O star is in front. The phase-locked variations of the C IV λ4658 emission-line profiles are rather indicative of a wind interaction between the components. We expect the wind of the WR to overwhelm the O star one and the shock is most probably wrapped around this latter star.

References

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