RevMexAA (Serie de Conferencias), **33**, 91–93 (2008)

THE FIRST ORBITAL SOLUTION FOR THE MASSIVE COLLIDING-WIND BINARY HD 93162 (≡WR 25)

R. Gamen,[1] E. Gosset,[2] N. I. Morrell,[3] V. S. Niemela,[4] H. Sana,[2,5] Y. Nazé,[2] G. Rauw,[2] R. H. Barbá,[1] and G. R. Solivella[4]

RESUMEN

Luego de que, mediante observaciones del satélite *EINSTEIN*, se descubriera la existencia de intensa emisión de rayos X asociada a HD 93162 (WR 25), reiteradamente se ha supuesto que esta estrella debería formar parte de un sistema binario con colisión de vientos. Sin embargo, hasta ahora no se habían detectado variaciones de velocidad radial que permitieran demostrar esta hipótesis. Con el objeto de explorar la posible naturaleza binaria de HD 93162, la hemos observado espectroscópicamente desde el anõ 1994 hasta la fecha, encontrando variaciones periódicas de su velocidad radial que demuestran que WR 25 es un sistema binario de alta excentricidad, con un período orbital cercano a los 208 días.

ABSTRACT

Since the discovery, with *EINSTEIN*, of strong X-ray emission associated with HD 93162, this object was recurrently predicted by some authors to be a colliding-wind binary system. However, radial-velocity variations that would prove the suspected binary nature have never been found so far. We spectroscopically monitored this object in order to investigate its possible variability and to provide an answer to the above-mentioned discordance. We derived radial velocities from spectroscopic data acquired mainly between 1994 and 2006, and searched for periodicities. For the first time, periodic radial-velocity variations are detected. Our analysis definitively shows that the Wolf-Rayet star WR 25 is actually an eccentric binary system with a probable period of about 208 days.

Key Words: binaries: spectroscopic — stars: individual (HD 93162) — stars: Wolf-Rayet

1. INTRODUCTION

Massive stars of spectral types O and Wolf-Rayet (WR) are important objects that play a crucial role in the dynamic and chemical evolution of galaxies. They are the major source of ionizing and UV radiation and, through their huge mass-loss rates, they have a strong mechanical impact on their surroundings. Despite the importance of massive stars, our knowledge of these objects and of their evolution is still fragmentary.

The parameters that predominantly determine the evolution of a massive star are its mass and its mass-loss rate, although rotation could also have an important impact. In this context, massive O+O and WR+O binaries are key objects because their binary nature allows us to determine minimum masses from the radial velocity (RV) orbital solution and, if combined with techniques to extract the orbital inclination, absolute masses.

HD 93162 (WR 25 in van der Hucht 2001) is a bright ($V = 8.1$) galactic Wolf-Rayet star located in the Carina Nebula region. Its binary nature has been a matter of debate for many years. Previously reported RV studies have not revealed any orbital motion (Moffat 1978; Conti et al. 1979).

To investigate the binary status of WR 25, the massive star research groups of Liège and La Plata independently collected high-resolution spectra of this star over the past 10 years. Although the radial velocities measured in each data set showed variations larger than the expected errors, no single periodicity could be found until the data obtained by the two groups were combined.

2. RESULTS AND CONCLUSIONS

We observed WR 25 from 1994 to 2006 (except for two spectra acquired in 1973), at different observatories and with various instrumental configurations (see details in Gamen et al. 2006), obtaining 50 high-, 8 medium- and 12 low-resolution spectra.

[1]Departamento de Física, Universidad de La Serena, Benavente 980, La Serena, Chile (rgamen@dfuls.cl).

[2]Institut d'Astrophysique et de Géophysique, Université de Liège, Allée du 6 Août, 17, B-4000, Liège (Sart Tilman), Belgium.

[3]Las Campanas Observatory, The Carnegie Observatories, Casilla 601, La Serena, Chile.

[4]Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata, Argentina.

[5]European Southern Observatory, Chile.

We determined the RV of WR 25 measuring the position of the N IV λ4058 emission line because this line is narrow and strong enough to minimize measurement errors. We first analyzed the data set consisting of the 50 high-resolution spectra, obtaining a most probable period $P = 208.3 \pm 0.5$ d. But, the phase plot with this period presented a clear gap around phase 1.0. The published data, although in good agreement with our orbital solution, did not help about this issue. The gap could be filled by low resolution data (errors larger than 10 km s^{-1}) obtained in May 1973 and April 2001, but despite the low weight given to these data in the solution, they had a large impact on the eccentricity and on the resulting orbital semiamplitude. Although the exact orbital solution remained uncertain, our data allowed us to conclude that WR 25 presents RV variations with a period of about 208 days indicative of an eccentric binary system (Gamen et al. 2006).

After this study, observing time at CASLEO, Las Campanas, and La Silla Observatories was allocated to monitor WR 25 during an expected minimum of RV on May, 2006. We could "fill" the gap with the spectra obtained, and noted that the N IV λ4058 emission line showed RVs down to -120 km s^{-1}, roughly confirming the published orbit. Also, we were pleasantly surprised when we noted that some He II absorption lines do deblend in two components with the redder one seeming to belong to an O-type companion star.

A preliminary orbital solution was derived using N IV λ4058 emission line and He II λ5411 absorption line, representing the WN and O stars respectively (Figure 1). The most important orbital parameters found are the period P=207.7±0.1 days and the eccentricity $e = 0.56 \pm 0.01$; the ratio of the semi-amplitudes ($K_O/K_{\rm WR}$) turns out to be at least larger than a factor 2. This means that the WR has at least a mass twice that of the O star. This points out to a great similarity between WR 25 and WR 22 (a 55 $M_\odot$ + 21 $M_\odot$ binary system in an 80-day period orbit, c.f. Rauw et al. 1996; Schweickhardt et al. 1999), particulary concerning the high mass of the WR component in WR 25. The preliminary solution gives high and shocking minimum masses of 75±7 and 27±3 $M_\odot$ for the WN and the O star respectively. They will probably be revised down when the full dataset will be analysed. The most massive stars known in binary systems in our Galaxy are two

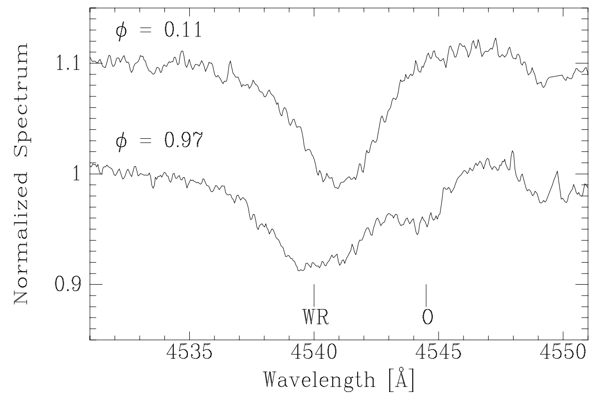

Fig. 1. The He II λ4541 absorption line observed on April, 2005 ($\phi \equiv 0.11$), and May, 2006 ($\phi \equiv 0.97$). The bottom spectrum shows how the lines from both components are deblended due to their extreme orbital radial velocities.

components of WR 20a. Their masses are 83 and 82 $M_\odot$ (Rauw et al. 2004; Bonanos et al. 2004). Could the WN component in WR 25 break those marks? To answer this, we need an orbital inclination and a refinement of the newly determined SB2 orbit as some corrections have to be made concerning the systemic velocity and the use of an emission line.

On the basis of the existing *XMM-Newton* data, Pollock & Corcoran (2006) found that the X-ray emission of WR 25 is variable. WR 25 was brighter in the X-ray domain on JD 2 452 843 which according to our ephemeris corresponds to a periastron passage. The star thus is brighter at periastron as predicted from colliding-wind theories (c.f. Rauw 2008).

REFERENCES

Bonanos, A. Z., et al. 2004, ApJ, 611, 33
Conti, P. S., Niemela, V. S., & Walborn, N. R. 1979, ApJ, 228, 206
Gamen, R., et al. 2006, A&A, 460, 777
van der Hucht, K. A. 2001, NewA Rev., 45, 135
Moffat, A. F. J. 1978, A&A, 68, 41
Pollock, A. M. T., & Corcoran, M. F. 2006, A&A, 445, 1093
Rauw, G., Vreux, J.-M., Gosset, E., Hutsemékers, D., Magain, P., & Rochowicz, K. 1996, A&A, 306, 771
Rauw, G., et al. 2004, A&A, 420, 9
Rauw, G. 2008, RevMexAA (SC), 33, 65
Schweickhardt, J., Schmutz, W., Stahl, O., Szeifert, T., & Wolf, B. 1999, A&A, 347, 127

DISCUSSION

A. Moffat - Congratulations on fine collaborative work with many observatories! I'd just like to mention that O. Schnurr has been sitting on high-quality FEROS spectra of WR 25 for some 5 years, unable to get a clear period. But now he (we!) will go back and we examine these (then do ?? nicely the rough periastron!) and verify your results. Of course it is always a good idea that different independent groups work on the same thing. I am also impressed how similar WR 25 in the galaxy is to R 145 in 30 Doradus (LMC) that I mentioned yesterday, although R 145 does appear to be even more extreme (higher luminosity, higher mass). Finally, NGC 3603 also contains 3 WNLh stars in its very dense core, compared to the 3 slightly fainter WNLh spread out in the Carina Nebula. We now have preliminary results for stars A1 (eclipsant, P=3.77 d, $L_x \sim L_x$ of WR 25!) and C (P=9 d, $L_x \geq 4$ times L_x of WR 25). For the former and for the primary of R 145, masses of over 100 $M_\odot$ are indicated.
N. Walborn - I would like to emphasize that this is not just another WR star, but a key object to understand massive stellar evolution. The Carina Nebula is the most powerful, nearby laboratory for that purpose, where the O3 stars where first recognized, including the now prototype O2If* star HD 93129A. In addition, there are 3 luminous WNL objects: HD 93162 (WR 25) with weak emission lines, and HD 92340 (WR 22), HD 93131 (WR 24) with strong lines. These 4 stars constitute a sequence of envelope development at similar mass and luminosity. WR 22 is also an (80 d) eccentric SB2 with an O main-sequence companion. These wide companions do not affect the WNh evolution which corresponds to very massive, single-star wind mass loss. WR 25 is also the second most X-ray luminous WR star, with a hard spectrum. However, there never had been any evidence for a companion from either radial velocities or direct images, until now. Van der Hucht has quoted a WN+O4f type on the basis of Moffat's spectra dissipation, but the latter correctly inferred a single spectrum, by analogy with WR 22, in which the emission and absorption lines move together. The motivation was a CWR interpretation of the X-rays. Have you measured the Balmer absorption lines in WR 25 to show directly that they move with the emission?It is important to do that to close the issue. It is also important to search for optical eclipses, very brief in WR 22.
R. Gamen - At this moment we only measured the N IV emission line. Of course, we will do an extensive study in the near future, including a photometric follow up.
G. Rauw - MISSING
N. Walborn - The narrow, symetrical, unshifted N IV λ4058 selective emission line is a better photospheric and velocity indicator than the Balmer absorption lines, which display a strong velocity gradient in such spectra and hence originate higher in the expanding atmosphere.
G. Rauw - You showed the very nice results for the detection of the secondary star in the He II lines. Can you already say anything about the He I lines?
R. Gamen - We see these lines, i.e. He I λ4471, become wider near periastron, but they do not deblend as well as He II lines do.
P. Massey - Did you set the γ velocity of the O star to that of the N IV value, or did you use the average absorption line value?
R. Gamen - We haven't done any consideration about the systemic velocity of the O star. We have to do that.