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THE O5–7 + WN BINARY SYSTEM HDE 320102

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RESUMEN

En base a observaciones espectrográficas obtenidas en CTIO, Chile, determinamos que HDE 320102 es un sistema binario O6+WN, con un período orbital de 12.595 días. Presentamos un análisis de los elementos orbitales del sistema basado en velocidades radiales de las líneas de absorción de la componente del tipo O6 y de las emisiones de He II λ4686 y N V $\lambda\lambda$4603–19 de la componente WN.

ABSTRACT

By means of spectrographic observations obtained at CTIO, Chile, we have determined that HDE 320102 is an O6+WN binary system, with an orbital period of 12.595 days. We present an analysis of the orbital elements of this system based on radial velocities of the absorption lines of the O6 component, and of the He II λ4686 and N V $\lambda\lambda$4603–19 emissions of the WN component.

Key words: **STARS – BINARIES — STARS – INDIVIDUAL (HDE 320102) — STARS – WOLF-RAYET**

1. INTRODUCTION

HDE 320102 (WR 97) is one of the only two stars classified as WN3+abs in the catalogue of galactic Wolf-Rayet stars (van der Hucht et al. 1981). The other WN3+abs is HD 9974 (WR 3). HDE 320102 was discovered to be a spectroscopic binary by Niemela (1982).

Only a few of the Wolf-Rayet stars known in our galaxy are WN3 type. They are quite more common in the Magellanic Clouds, comprising 30% of the total WR population of LMC and half of the WR stars in the SMC. It would be very important to compare the parameters of WR stars of similar spectral types in galaxies with different metallicities, as the MCs are known to be more deficient in metals than our galaxy. In particular, the location of HDE 320102 towards the centre of our galaxy implies that it may be evolving in a higher than solar metallicity environment due to the metallicity gradient of our galaxy. Therefore, HDE 320102 is a potentially interesting object as the galactic WN+O binary system with the earliest WN type component.

In this paper we present spectroscopic observations and an orbital solution yielding the mass ratio and estimates of minimum masses of the binary components of HDE 320102. Our results show that HDE 320102 is similar to other WNE+O type binaries known in our galaxy, but does not resemble the known WNE+O binaries in the MCs.

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2. OBSERVATIONS AND MEASUREMENTS

The observational material consists of 53 photographic spectrograms of HDE 320102, all obtained by VSN between 1980, May, and 1983, August, at the Cerro Tololo Inter-American Observatory (CTIO), Chile. These spectra were obtained with the image-tube spectrograph at the Cassegrain focus of the 1-m Yale reflector and their S/N is about 30. All the exposures were made on Kodak fine grain IIIa-J emulsion baked in "forming gas" ($N_2 + H_2$). The spectrograms have a reciprocal dispersion of 45 A mm^{-1}, and are 1-mm wide. They cover the spectral region from 3600 to 5000 A, and were developed in D-19 together with intensity calibrations obtained with a spot sensitometer.

The plates were measured for the determination of radial velocities with the Grant oscilloscope comparator-microphotometer at the Instituto de Astronomía y Física del Espacio (IAFE), Buenos Aires. All the absorption lines visible in the spectrograms were measured, usually including Hydrogen Balmer lines from H9 to Hβ (excluding Hϵ because of its blend with the interstellar Ca II H), He I lines at λ4026 and λ4471, He II lines at $\lambda\lambda$4200, 4541 and 4686. The broad WN N V emission lines at $\lambda\lambda$4603–4619, and He II at λ4686, were also measured on all the spectrograms. The journal of observations and the heliocentric radial velocities are listed in Table 1. The numbers in parentheses following the average velocities of the absorption lines in this table indicate how many lines were included in each mean value.

A few selected spectrograms and the corresponding calibrations were digitized with the Grant microphotometer. The resulting intensity tracings are shown in Figure 1.

3. ANALYSIS OF THE OBSERVATIONS

From the radial velocities shown in Table 1 it is clear that, as already reported by Niemela (1982, 1994), the absorption lines have a radial velocity variation in antiphase with the emissions, thus implying that HDE 320102 is a binary system composed of a WN star and an O star. The absorption line component was classified as spectral type O5–7 (Niemela 1982). The present observations confirm this classification. Furthermore, superimposed to the He II λ4686 emission line, a faint absorption following the orbital motion of the O type component, points to a luminosity class V. The apparent profile variations of the He II λ4686 emission in Figure 1, are due to

TABLE 1

HELIOCENTRIC RADIAL VELOCITIES
OF HDE 320102 (WR 97)

	Radial velocity (km s^{-1})				Radial velocity (km s^{-1})		
HJD 2440000.+	Average Absorption	Aver. em. N V λ4603.19	He II em. λ4686	HJD 2440000.+	Average Absorption	Aver. em. N V λ4603.19	He II em. λ4686
4387.804	−79 (9)	24	72	5067.813	−96 (9)	58	41
4388.689	−94 (11)	83	73	5067.897	−78 (8)	...	34
4388.865	−88 (8)	120	121	5068.867	−78 (8)	131	171
4390.756	−96 (10)	116	132	5069.893	−110 (10)	178	109
4390.911	−91 (10)	...	85	5070.900	−82 (9)	156	63
4391.794	...	...	28	5071.904	−84 (10)	...	88
4654.869	−93 (9)	106	151	5123.825	−67 (9)	39	...
4655.871	−107 (7)	116	−17	5125.808	−17 (9)	12	−154
4657.862	−30 (9)	24	−73	5126.878	8 (6)	−38:	−103
4658.863	−24 (8)	−32	−132	5184.612	−114 (9)	156	42
4659.866	−8 (6)	−43	−176	5186.533	−64 (10)	20	−46
4739.854	−70 (9)	−40	...	5187.584	−27 (2)	−47	−126
4740.745	−63 (9)	−9	29	5188.631	0 (6)	−83	−110
4740.898	−77 (11)	52	...	5189.669	25 (7)	−148	−62
4741.779	−89 (7)	56	52	5190.672	13 (8)	−39	−58
4744.730	−93 (10)	47	−42	5191.688	1 (8)	−64	−24
4744.854	−83 (8)	...	−15	5192.660	−57 (9)	−34	...
4745.733	−81 (9)	11	−50	5196.667	−110 (6)	112	125
4745.877	−52 (7)	−47	−111	5197.645	−113 (9)	...	69
4892.497	−105 (7)	90	113	5198.667	−69 (8)	+45	−4
4893.514	−114 (5)	174	94	5199.606	−50 (8)	−38	19
4894.490	−88 (7)	84	99	5506.787	−17 (3)	−139	22
4895.509	−102 (4)	87	−21	5510.858	−100 (7)	...	81
4896.498	−48 (6)	45	−24	5512.751	−84 (9)	170	26
4897.506	1 (7)	−52	−64	5553.720	10 (5)	−72	−151
4898.543	7 (6)	−48	−119	5554.652	38 (8)	−99	−135

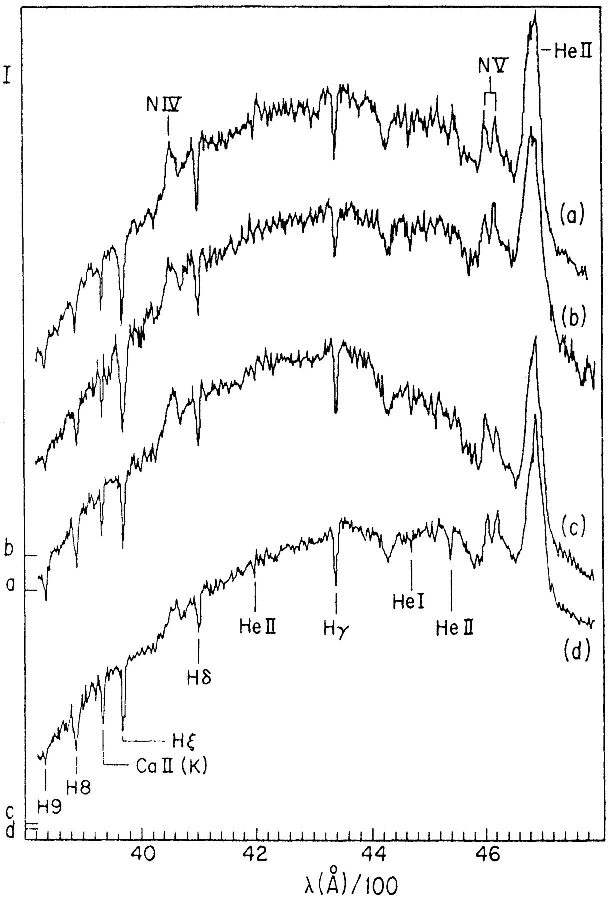

Fig. 1. Intensity tracings of the spectrum of HDE 320102 at the following phases: 0.00 (a), 0.25 (b), 0.50 (c) and 0.75 (d). The letters a, b, c, d on the left margin indicate the positions of the corresponding levels of zero intensity.

the opposite orbital motions of the absorption and emission components.

The spectral classification of the WN component is WN3 according to the catalogue of galactic WR stars (van der Hucht et al. 1981). However, as shown in Figure 1, in the spectrum of HDE 320102 the N IV λ4058 emission line appears similar to the N V $\lambda\lambda$4603–19 emission in our spectrograms. Therefore, a spectral classification of the WN component as WN4 seems more appropriate.

The period of this spectroscopic binary was redetermined applying a period search routine to the enlarged set of data of the present paper. Periods between 0.1 and 30 days were searched. The period search routine was applied separately to the average velocities of the absorption lines, to the average velocities of N V $\lambda\lambda$4603–4619 emissions, and to the velocities of the He II λ4686 emission. The best periods found in each case are, respectively, 12.600, 12.593

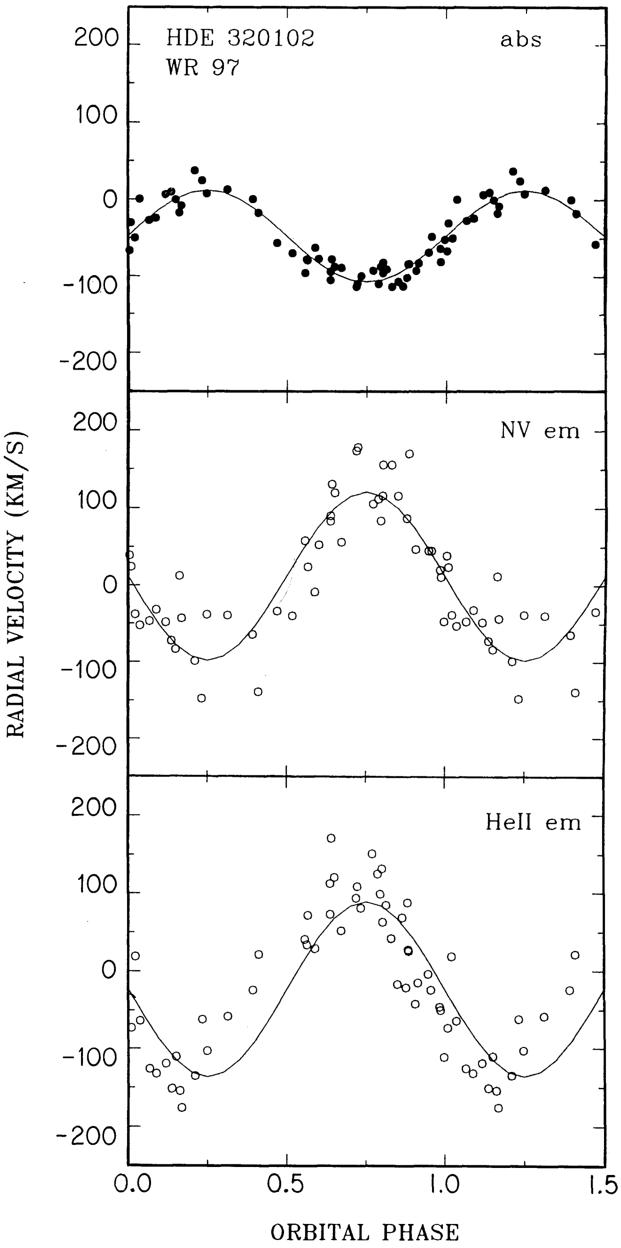

Fig. 2. Radial velocities (km s^{-1}) plotted as function of the orbital phase for: the average of the absorptions, the average of the N V emissions, and the He II emission line at λ4686. The full lines are the theoretical radial velocity curves defined by the orbital elements in Table 2 except that the velocity curve for the He II emission has been shifted to the same T_0 as the velocity curves of the absorptions and N V emissions. Note the phase shift between the observed radial velocities of the He II λ4686 emission and the velocity curve.

TABLE 2

CIRCULAR ORBITAL ELEMENTS OF HDE 320102 (WR 97)[a]

Parameter	Average absorption	Average N V emission	He II emission
V_0 (km s^{-1})	−48± 2	11 ± 4	−10± 4
K (km s^{-1})	60± 2	110± 6	117± 5
T_0 (2440000.+)	4897.057± 0.02	4897.057± 0.02	4896.189± 0.02
σ (km s^{-1})	9	27	25
a sin$^3 i$ (R$_\odot$)	14.8± 0.5	27.1± 1.5	28.9± 1.2
M (WR) sin$^3 i$ (M$_\odot$)	...	2.3± 0.3	2.5± 0.3
M (O) sin$^3 i$ (M$_\odot$)	...	4.1± 0.6	4.8± 0.6

[a] P = 12.595 days, fixed; T_o is the moment when the O star is closest to the observer; σ is the rms scatter about the computed curves.

and 12.595 days, all three with an estimated uncertainty of 0.005 days. The three periods agree within the estimated uncertainties. All other periods have considerably lower probabilities, and all the possible periods longer than 20 days show multiple waves.

Since the emission lines are (very) broad and asymmetric, their radial velocities have larger errors of measurements than those derived from the mean of the absorption lines. Consequently, we have adopted the value which gave the best orbital fit for the absorption line mean velocities as the true orbital period. This turned out to be 12.595 days. Figure 2 shows the observed radial velocities plotted in this period. Within the observational errors, the orbit appears to be circular, but due to the uneven distribution of our observations, small eccentricities cannot be ruled out. T_0 = HJD 2444896.664 corresponds to the time when the O star was closest to the observer and we estimate its observational uncertainty to be of the order of the exposure times of the spectra (about 1 hr).

The orbital parameters of HDE 320102 listed in Table 2 are derived from the best-fit circular orbits for the absorption and emission line velocities, which are also plotted in Figure 2. We note that, within the estimated uncertainty, the emission lines of N V and He II show the same amplitude of their radial velocity variations. No phase shifts are noticeable between the absorption line and the N V emission radial velocity orbits, but He II emission appears to be slightly shifted in phase. This is illustrated in Figure 2 by plotting the observed radial velocities of He II λ4686 emission with a circular orbit shifted to the T_0 corresponding to the orbital fits for absorptions and N V emission lines. As usual in binary components with WR type spectra, the systemic velocity of the WR emissions is more positive than that of the O type absorptions. This is probably due to the presence of faint blue-shifted absorption components of the emission lines, not readily seen on our spectrograms.

4. DISCUSSION

The values for the minimum masses of both binary components in HDE 320102, namely $M(WR)\,sin^3 i \cong 2\ M_\odot$ and $M(O)\,sin^3 i \cong 4\ M_\odot$ are rather low; the actual masses could well be 10 times larger. Therefore, we expect a small orbital inclination. A polarimetric study is in progress to estimate the orbital inclination of HDE 320102.

The mass ratio of the binary $M(WR)/M(O) \cong 0.54 \pm 0.02$, turns out to be similar to the mass ratios of almost all other galactic binary systems that include WN4 or WN5 stars (cf. Smith & Maeder 1989). This result can be compared with the low value of the mass ratio $M(WR)/M(O) = 0.18$ obtained by Moffat (1982) and Hutchings et al. (1984) for the WN3+O spectroscopic binary R 31 (Sk 108) in the SMC.

On the other hand, the WN3+O binary Sk 34–71° in the LMC seems to have a mass ratio of about 0.6 (Niemela 1991), and rather large minimum masses. From the available data, the WNE+O binaries in our galaxy and the Magellanic Clouds appear rather different. However, more detailed orbital studies of a significant sample of binary systems are required for a definitive statement of such differences.

As can be seen in Figure 1, the spectrum of HDE 320102 is dominated by the absorption lines of the O type star. Assuming a spectral type O6V for the absorption line component, the absolute magnitude and intrinsic colors corresponding to this spectral type would imply a minimum distance of 5.0 kpc for HDE 320102 (assuming negligible contribution of the WN component to the M_V). The center of mass radial velocity of the absorption lines also indicates a kinematic distance of about 5 kpc, although this value has a considerable uncertainty at the galactic longitude of HDE 320102, $l = 354°$.

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