THE SPECTROGRAPHIC ORBIT OF DW CARINAE

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RESUMEN. Presentamos velocidades radiales del sistema binario eclipsante DW Carinae, y determinamos por vez primera sus elementos orbitales espectrográficos. Este sistema binario parece ser muy apropiado para determinaciones precisas de masas y radios de estrellas B tempranas.

ABSTRACT. We present radial velocities of the eclipsing binary system DW Car, and determine for the first time its spectrographic orbital elements. This binary system appears to be very suitable for accurate determinations of masses and radii of early B type stars.

I. INTRODUCTION

DW Carinae (=HDE 305543) is an eclipsing binary showing a double-lined early B type spectrum (Levato and Malaroda 1981). It is also a member of the open cluster Collinder 228 (Feinstein *et al.* 1976, Turner and Moffat 1980). The eclipsing nature of DW Carinae was discovered by Hertzsprung (1924), who derived a period of 0.66382 days from 251 photographic magnitudes (as it turned out, the true period is twice Hertzsprung's value). He also published a photographic light curve of DW Car. Other photographic light curves have been published by van den Hoven van Genderen (1939) and Gaposchkin (1953). The light curve displays two very similar minima, and the brightness of the system remains constant between eclipses, indicating that probably there are no significant effects of tidal distortion or reflection. We note, however, that the photographic magnitudes may be of insufficient quality to show those effects.

To our knowledge, no photoelectric light curve of DW Car has been published, nor is there any spectral study of this binary system available. In this paper we present a radial velocity study of DW Car, giving for the first time the spectrophotographic orbital elements and the masses of both components.

II. OBSERVATIONS AND RESULTS

We have obtained 62 *blue* and 5 *red* spectrograms of DW Car between 1981 January and 1983 April at the Cerro Tololo Inter-American Observatory (CTIO) with the Cassegrain spectrographs of the 1.5 m, 1-m and 0.91 m telescopes (plates labeled C-, E- and A-, respectively). The

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E plates were taken using a Carnegie image-tube. The spectrograms were recorded on either Kodak IIa-O (plates C- and A-) or IIIa-J (plates E-) emulsions, baked in *forming gas*. More information on the spectrograms is given in Table 1.

TABLE 1

SPECTROGRAMS OF DW CARINAE

JULIAN DATE (2440000 +)	TELESCOPE	DISP (Å/mm)	NUMBER OF SPECTROGRAMS	OBSERVER
4642-4645	1.0 m	43	5	RHM
4649-4653	1.5 m	39	4	HL
4654-4658	0.9 m	40	4	HL
4653-4662	1.0 m	43	12	VSN
4682-4688	1.0 m	43	33	OEF
4682-4688	1.0 m	86	5	OEF
5444-5452	1.0 m	43	4	NM

All the plates were measured for the determination of radial velocities with the Grant oscilloscope comparators available at the La Plata Observatory and at the IAFE, Buenos Aires. Table 2 gives the mean heliocentric radial velocities of the interstellar Ca II K absorption for the different observing runs and spectrographs used. The values corresponding to observations made with the 1-m image-tube spectrograph agree well with each other within the observational errors. In view of the results in Table 2, we have added corrections of -21 km/s and -28 km/s to the few stellar radial velocities derived from the C- and A plates, respectively.

TABLE 2

AVERAGE RADIAL VELOCITIES OF INTERSTELLAR Ca II K

TELESCOPE	OBSERVER	NUMBER OF SPECTROGRAMS	HELIOCENTRIC RADIAL VELOCITY (KM/S)	MEAN ERROR (KM/S)
1.0 m	RHM	5	-30	4
1.0 m	VSN	12	-23	3
1.0 m	OEF	32	-26	3
1.0 m	NM	3	-26	
0.9 m	HL	2	+2	
1.5 m	HL	4	-5	3

All the lines visible in each spectrogram were measured for the determination of radial velocities. However, we have not used the velocities derived from the Balmer absorption lines, which are noticeably distorted by blending effects, even at quadratures. This *pair-blending effect* (Petrie *et al.* 1967) does not appear to affect the He I lines significantly (see, however, Section 4); therefore, in order to study the orbital motions we have averaged the radial velocities of the He I Lines at 4026, 4387 and 4471 Å. These average radial velocities are listed in Table 3.

III. THE RADIAL VELOCITY ORBIT

We have adopted the ephemeris given in the General Catalogue of Variable Stars (Kukarkin *et al.* 1969):

light minimum = JD 2424550.362 + 1.3277504 E

Since the light minima are almost equal, we have arbitrarily defined one of the stars as component A. The ephemeris we have adopted gives the times when star B eclipses star A. We should

note that other published ephemerides give times of minimum corresponding to the eclipse of star B by star A (Gaposchkin 1953, Wood *et al.* 1980). We note also that the period given by van den Hoven van Genderen (1939) is slightly different. From our observations it is not possible to improve the period.

TABLE 3

HELIOCENTRIC RADIAL VELOCITIES (KM/S) USED FOR THE DETERMINATION OF THE ORBITAL PARAMETERS OF DW CARINAE

HELIOCENTRIC JULIAN DATE (2440000 +)	STAR A	STAR B
4642.831	+279	-303
4642.878	+244	-325
4643.684	-206	+224
4644.735	-248	+223
4645.635	+232	-230
4650.859	+221	-355
4654.828	-	-264
4654.854	+234	-282
4655.655	-174	+161
4656.619	-174	+153
4656.813	-302	+261
4656.828	-	+256
4657.593	+192	-253
4658.766	-	-259
4659.613	-171	+137
4660.655	-223	+212
4661.652	+137	-160
4662.718	+243	-312
4682.680	+247	-343
4682.687	+207	-303
4682.742	+223	-309
4684.664	-291	+252
4684.734	-273	+235
4684.781	-181	+279
4684.828	-199	+206
4686.563	-	-232
4686.617	+264	-243
4686.656	+237	-264
4686.695	+264	-266
4686.734	+250	-262
4686.773	+250	-
4688.633	-261	+263
4688.672	-270	+235
4688.711	-256	+263
4688.766	-250	+245
4688.773	-264	+189
4688.812	-170	+247
5451.663	+96	-178
5452.667	+208	-273

For the determination of the orbital elements we have used only the radial velocities corresponding to observations near quadratures, namely

$0.15 < \theta < 0.35$ and $0.65 < \theta < 0.85$

The orbital parameters listed in Table 4 have been derived from the best-fit sinusoids plotted in Fig. 1.

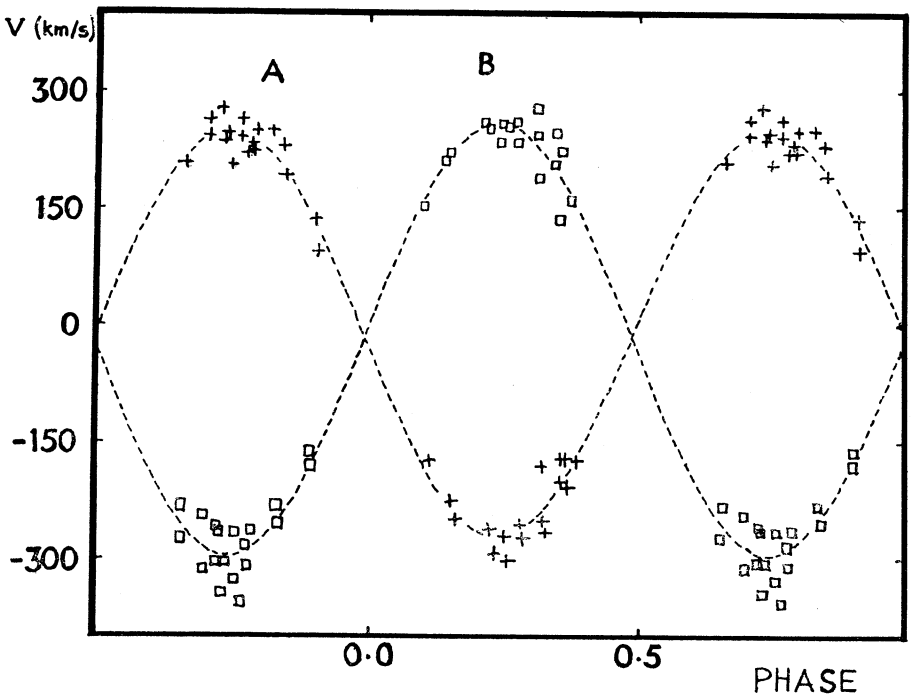

Fig. 1. The observed radial velocities of DW Carinae and best-fit sinusoids for both components.

TABLE 4

CIRCULAR ORBITAL ELEMENTS OF DW CARINAE

PERIOD	=	1.3277504 days
V_o(A)	=	-10 ± 5 km/s
V_o(B)	=	-16 ± 5 km/s
K_A	=	261 ± 10 km/s
K_B	=	278 ± 10 km/s
$a_A \sin i$	=	4.8×10^6 km = 6.9 $R_\odot$
$a_B \sin i$	=	5.1×10^6 km = 7.3 $R_\odot$
$M_A \sin^3 i$	=	11.1 solar masses
$M_B \sin^3 i$	=	10.4 solar masses

IV. DISCUSSION

In our spectrograms we find for component A (the one whose absorption lines are blueshifted at phase 0.25) a spectral type B1 V, and a slightly later spectral type for component B. The values of M $\sin^3$ i are 11.1 and 10.4 solar masses for components A and B, respectively. These values fit well into the mass-spectral type relation plotted by Hutchings (1975). Of course, a small correction may be necessary, in order to compensate for blending effects that may still affect the He I lines we have used. Andersen (1975) has shown that systematic effects may be present even in cases when these lines are separated by several times their widths. In the spectrum of DW Car, at quadratures, the separation of the two components of He I 4026 is approximately three times the line width. Clearly, a study on higher-resolution spectrograms is highly desirable.

The importance of DW Car lies in the scarcity of early-type close binaries available for really accurate spectroscopic and photometric analyses (see Popper 1980). We have already mentioned the possible absence of significant proximity effects in the light curve of DW Car. Concerning the radial velocities, although line blending effects in the hydrogen lines are severe, careful modeling of the stronger He I lines, or a careful selection of suitable lines on high-resolution spectrograms, would probably yield radial velocities completely free from systematic effects.

In summary, a good photoelectric light curve and a series of high dispersion spectrograms, both relatively easy to obtain, would provide accurate masses and radii, adding the two components of DW Car to the very small amount of observationally well-known early B stars.

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