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THE SPECTROGRAPHIC ORBIT OF THE ECLIPSING BINARY HH CARINAE

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RESUMEN

Presentamos un estudio de las velocidades radiales del sistema binario eclipsante HH Carinae, y determinamos por vez primera sus elementos orbitales espectrográficos. Utilizando los resultados de un estudio fotométrico anterior de Söderhjelm, también determinamos los valores de las masas y dimensiones de las componentes.

ABSTRACT

We present a radial velocity study of the eclipsing binary system HH Carinae, and determine for the first time its spectrographic orbital elements. Using the results of a previous photometric study by Söderhjelm, we also determine the values of the masses and dimensions of the binary components.

Key words: **STARS-ECLIPSING BINARIES – STARS-INDIVIDUAL**

I. INTRODUCTION

HH Carinae (CPD–58° 2839 = HDE 303503 = LSS 2008) is a massive eclipsing binary, classified OB by Stephenson and Sanduleak (1971). It has at least three fainter visual companions (O'Connell 1968). HH Carinae was discovered as an eclipsing binary by O'Connell (1937), who also derived a photographic light curve (O'Connell 1968). Photoelectric light curves in the *UBV* system have been obtained by Söderhjelm (1975), who finds photometric distortions, attributable to continuum absorption by circumstellar material, and a period change indicating some mass transfer. For convenience, we repeat the results of Söderhjelm's analysis in Table 1 below. In this paper we present a radial velocity study of HH Car, giving for the first time the spectrographic orbital elements, and the masses and dimensions of both components.

TABLE 1

SODERHJELM'S PHOTOMETRIC ELEMENTS FOR HH CARINAE

Period P	=	3.23155 days
Time of Primary Minimum t_0	=	2441711.609 ± 0.001
Relative Radius of Small Star r_{pri}	=	0.210 ± 0.001
Relative Radius of Large Star r_{sec}	=	0.368 ± 0.003
Fractional Luminosity of Small Star L^B_{pri}	=	0.316 ± 0.005
Orbital Inclination i	=	81°.5 ± 0°.5
Mass Ratio m_{pri}/m_{sec}	=	1.1
Temperatures T_{pri}	=	45000 K
Temperatures T_{sec}	=	38000 K

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II. OBSERVATIONS AND RESULTS

We have obtained 56 spectrograms of HH Car between 1981 February and May, at the Cerro Tololo Inter-American Observatory (*CTIO*), with the image-tube spectrograph of the 1-m telescope. The spectrograms were recorded on IIIa-J emulsion, baked in "forming gas", at a dispersion of 4 A/mm, and extend from 3700 to 5000 A. The plates were calibrated by means of a spot sensitometer.

On our spectrograms we estimate that the hotter (but smaller and fainter) "primary" component has a spectral type about O8 V, because on several plates He II 4541 is visible (but fainter than He I 4471) at the appropriate velocity. The spectral type of the brighter "secondary" is B0 III, as estimated from the intensity of the Si IV line at 4088 A and the O II blend at 4346-51 A (see Morgan, Abt, and Tapscott 1978). In Figure 1 we show rectified intensity tracings of the spectrum of HH Car at phases 0.54 and 0.03. On the lower tracing, corresponding to the primary minimum, when the hot star is occulted by its cooler companion, the Si IV and O II lines are seen to be noticeably enhanced relative to the upper tracing, which corresponds to the secondary minimum.

We have not found clear evidences of spectral features associated with the circumstellar material; a higher spectral resolution and/or spectrograms covering Hα may be necessary for that purpose. On some plates we find weak emission at Hβ, most probably due to the nebular emission from the foreground Carina H II region.

All the plates were measured for the determination of radial velocities with the Grant oscilloscope comparator-microphotometer available at the *IAFE*, Buenos Aires. All the lines visible in each spectrogram were measured. Table 2 gives the heliocentric radial velocities of both components, and of the interstellar Ca II K absorption, for all the plates used in the determination of the orbital

TABLE 2

HELIOCENTRIC RADIAL VELOCITIES (km s^{-1}) USED FOR THE DETERMINATION OF THE ORBITAL PARAMETERS OF HH CARINAE

Heliocentric JD (2440000 +)	Interstellar Ca II K	Primary (Fainter) Component[a]	Secondary Component[a]
4643.638	-34	-225(1)	174(4)
4644.720	-28	299(2)	-220(5)
4644.885	-13	216(2)	-287(4)
4646.673	-31	-107(2)	237(4)
4654.709	-47	154(2)	-279(4)
4656.569	-43	-204(3)	167(4)
4657.819	-37	202(3)	-258(4)
4659.626	-26	-162(3)	216(5)
4662.796	-49	-236(3)	243(4)
4683.568	...	183(2)	-240(5)
4683.599	-35	139(1)	-258(4)
4683.665	-23	114(3)	-257(4)
4683.836	-58	258(2)	-278(2)
4685.626	...	-189(3)	218(3)
4685.712	...	-131(3)	154(3)
4685.758	-18	-92(4)	175(4)
4686.722	-55	117(2)	-226(4)
4686.761	...	216(1)	-210(5)
4686.808	-54	177(2)	-258(5)
4686.828	-13	...	-209(4)
4686.861	3	245(3)	-260(5)
4688.599	...	-216(2)	248(2)
4688.642	-31	-228(3)	207(4)
4688.680	...	-90(3)	244(4)
4688.721	-10	-117(3)	254(5)
4688.781	-61	-213(3)	191(5)
4688.821	...	-186(2)	212(4)
4688.861	...	-139(1)	209(5)
4740.603	-18	-230(2)	231(4)
4741.605	-27	118(2)	-209(5)

a. The number between brackets indicates how many lines were included in each mean.

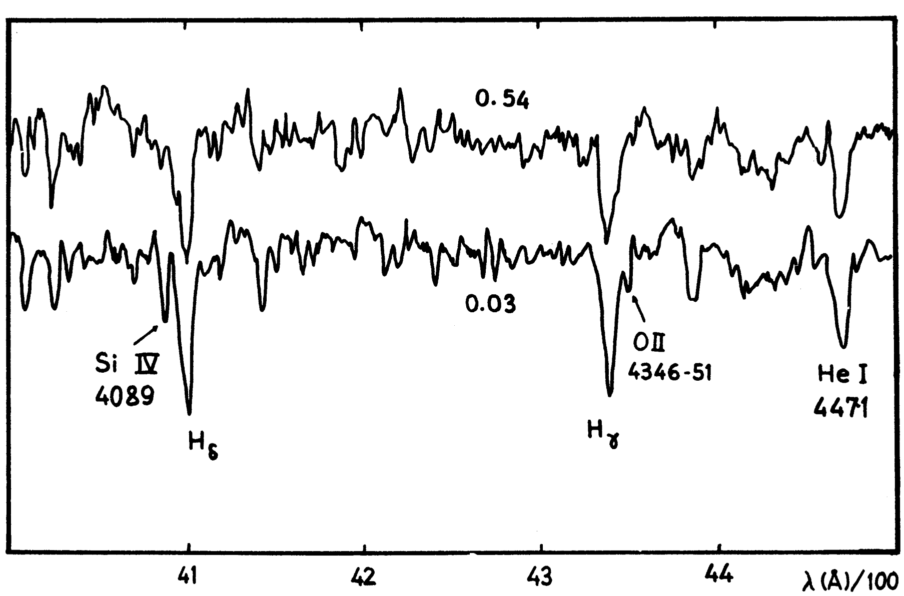

Fig. 1. Rectified intensity tracings of the spectrum of HH Carinae at orbital phases 0.54 and 0.03. The upper tracing corresponds to plate E4046, taken on JD 2444744.562 The lower tracing corresponds to plate E3877, taken on JD 2444655.649.

elements (see Section 3). We did not use the velocities derived from the Balmer absorption lines, because they are noticeably distorted by blending effects, even at quadratures. This "pair-blending effect" (Petrie, Andrews, and Scarfe 1967) is less significant for the He I lines; therefore, in order to study the orbital motions we have averaged the radial velocities of the He I lines at 3819, 4026, 4143, 4387 and 4471 A. These average radial velocities are listed in Table 2. We estimate that the uncertainty in radial velocity for an individual plate is 15 Km s^{-1} for the brighter secondary component, and 40 Km s^{-1} for the primary, whose lines are weaker and more difficult to measure.

We have obtained also a spectrogram of the brightest visual companion to HH Car, namely CPD–58°2840, with the same spectrograph and instrumental parameters. The spectral type of CPD–58°2840 estimated from this spectrogram is F0-2 II, and its heliocentric radial velocity, determined from the average of 14 absorption lines, is 24 ± 5 Km s^{-1}, in fair agreement with the baricentric velocity of HH Car (see Table 3). However, we would hesitate to conclude that this star is physically associated with HH Car, since, being bolometrically fainter and therefore presumably less massive, we would not expect it to be more evolved than the components of HH Car. If stellar evolution proceeds approximately with constant bolometric magnitude, as indicated by most recent theoretical evolutionary models (see e.g., Maeder 1981), a star with a spectral type F0-2 II would correspond to an initial mass less than 9 $M_\odot$ (see Fig. 2 in Maeder 1981), whereas stars with spectral types between B0 and O8 should have initial masses higher than 15 $M_\odot$

TABLE 3

SPECTROGRAPHIC ORBITAL ELEMENTS OF HH CARINAE[a]

Parameter	Primary	Secondary
V_0 km s^{-1}	+ 25 ± 20	− 9 ± 10
K km s^{-1}	202 ± 15	247 ± 8
a sin i ($R_\odot$)	13 ± 1	15.8 ± 0.5
m $\sin^3$ i ($m_\odot$)	17 ± 2	14 ± 2

a. From a period = 3.23155 days and an assumed eccentricity e = 0.

III. THE RADIAL VELOCITY ORBIT

We have adopted the ephemeris given by Söderhjelm (1975):

$$\text{primary minimum} = \text{JD } 2441711.609 + 3.23155 \text{ E} .$$

From our observations it is not possible to add information about the period variation reported by Söderhjelm.

For the determination of the orbital elements we have used only the radial velocities obtained from 31 spectrograms taken near quadratures, namely.

$$0.15 < \phi < 0.35 \quad \text{and} \quad 0.65 < \phi < 0.85 .$$

Since Söderhjelm (1975) found no evidence of an eccentric orbit, the spectrographic orbital parameters

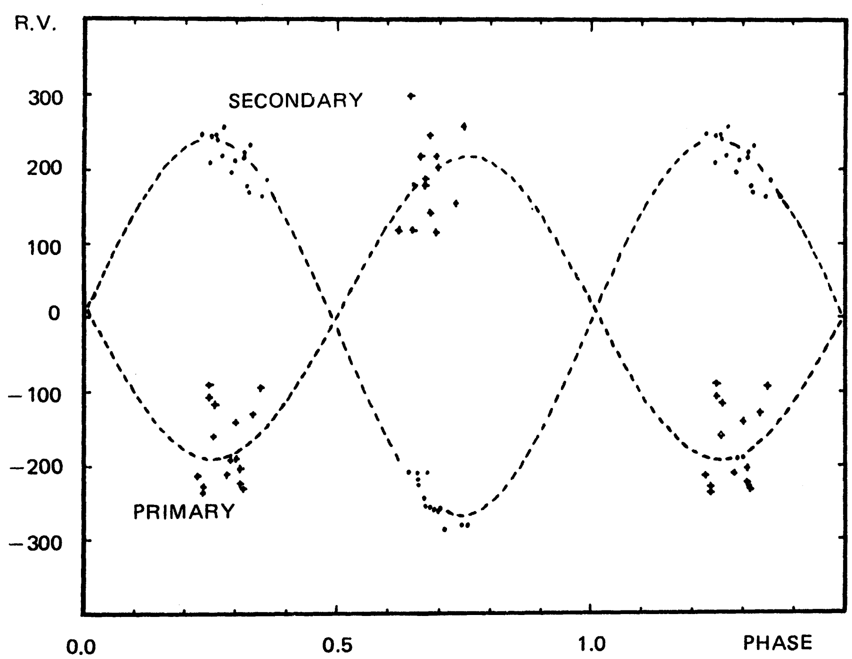

Fig. 2. The observed radial velocities of HH Carinae and best-fit sinusoids for both components.

listed in Table 3 have been derived from best-fit sinusoids. In Figure 2 we plot the heliocentric radial velocities, and the velocities computed from the circular orbits as defined by Table 3.

IV. DISCUSSION

We have combined our spectrographic orbital parameters (Table 3) with Söderhjelm's results (Table 1) in order to obtain the masses and dimensions of the binary system. These are listed in Table 4.

TABLE 4

MASSES AND DIMENSIONS IN HH CARINAE

Parameter	Primary	Secondary
mass ($m_\odot$)	17	14
a ($R_\odot$)	13.1	16.0
R ($R_\odot$)	6.1	10.7
log g	4.1	3.5

In view of the spectral types we have determined and their corresponding temperatures (Schmidt-Kaler 1982), we note that Söderhjelm's estimate of the surface temperatures turns out to be too high (by about 10000 K). With this exception, our results confirm his description of the general features of this semidetached binary system.

The mass of the primary component falls slightly below the theoretical ZAMS curve in the mass-spectral type relation plotted by Hutchings (1975). Perhaps a small correction to our masses is needed in order to compensate for blending effects that may still affect the He I lines we have used. A study on higher-dispersion spectrograms would clarify this point.

On the radius-mass relation plotted by Hutchings (1975), the primary component of HH Car falls near the main sequence, while the lobe-filling secondary lies at a lower gravity, in agreement with the luminosity classes we have determined on our spectrograms.

In summary, we have arrived to a consistent picture of HH Car, which is confirmed as a good example of non-conservative mass transfer, the presently more massive star being too faint to be explained by mass transfer without mass loss from the binary system (Söderhjelm 1975).

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REFERENCES

Hutchings, J.B. 1975, *Pub. A.S.P.*, 87, 529.
Maeder, A. 1981, *Astr. and Ap.*, **102**, 401.
Morgan, W.W., Abt, H.A., and Tapscott, J.W. 1978, *Revised MK Spectral Atlas for Stars Earlier than the Sun* (Yerkes Observatory, University of Chicago and Kitt Peak Ntl. Observatory).
O'Connell, D.J.K. 1937, *Astr. Nachr.* **264**, 141.
O'Connell, D.J.K. 1968, *Ric. Astr. Spec. Vaticana,* 7, 399.
Petrie, R.M., Andrews, D.H., and Scarfe, C.D. 1967, in *IAU Symposium No. 30, Determination of Radial Velocities and their Applications*, eds. A.H. Batten and J.F. Heard (Academic Press), p. 221.
Schmidt-Kaler, Th. 1982, in *Landolt-Bornstein Numerical Data and Functional Relationships in Science and Technology,* eds. K. Schaifers and H. Voigt (Springer-Verlag), Vol. **2**.
Söderhjelm, S. 1975, *Astr. and Ap. Suppl.*, **22**, 263.
Stephenson, C.B. and Sanduleak, N. 1971, *Luminous Stars in the Southern Milky Way* (Warner and Swasey Observatory Pub.), **1**, *1*.

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