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THE ELLIPTIC ORBIT OF THE WR BINARY SYSTEM CV SERPENTIS

Virpi S. Niemela[1], Nidia I. Morrell[2], Rodolfo H. Barbá[2,3], and Guillermo L. Bosch[3,4]
Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata, Argentina.

RESUMEN

Hemos realizado una nueva determinación de los parámetros orbitales del sistema binario (WC8+O8-9) CV Serpentis (HD 168206), mediante el análisis de observaciones espectroscópicas obtenidas en CTIO (Chile) y en CASLEO (Argentina), junto con datos previamente publicados. El período que mejor representa las variaciones de velocidad radial, tanto de las líneas de emisión de la componente Wolf-Rayet como de las absorciones de la componente O, es de 29.704 días. La curva de las variaciones de la velocidad radial de las líneas de absorción muestra una excentricidad de 0.19 ± 0.03, la cual no había sido advertida en previas investigaciones de este sistema. Además, espectrogramas échelle-CCD obtenidos recientemente en CASLEO, muestran perfiles complejos en las líneas de absorción, que sugieren la probable presencia de más de una estrella de tipo temprano en el sistema.

ABSTRACT

We have made a new determination of the orbital parameters of the WC8+O8-9 binary system CV Serpentis (HD 168206), through the analysis of spectroscopic observations obtained at CTIO (Chile) and CASLEO (Argentina), together with previously published data. The period that best fits the radial velocity variations of both the Wolf-Rayet emission lines and the O-type absorption lines, is 29.704 days. The curve of the radial velocity variations of the absorption lines shows an eccentricity of 0.19 ± 0.03, not noticed in previous studies of this binary system. In recent échelle CCD spectrograms obtained at CASLEO, the shape of the absorption line profiles appears complex, suggesting that probably more than one early type star might be present in the system.

Key words: **STARS: BINARIES: SPECTROSCOPIC — STARS: EARLY-TYPE — STARS: INDIVIDUAL (HD 168206) — STARS: WOLF-RAYET**

1. INTRODUCTION

CV Serpentis (HD 168206) was discovered as a spectroscopic binary with a period of 29.6 days, containing a Wolf-Rayet (WR) star of carbon type and an OB star by Hiltner (1945). He also derived the first orbital solution measuring the radial velocity variations of the strong WR emission line blend of C III-IV λ4652 Å and the H_γ absorption line of the OB component.

Since then, CV Serpentis has been the subject for numerous studies. Among them, Gaposhkin (1949) noted the presence of shallow eclipses in the photometry from Harvard patrol-plates; Hjellming & Hiltner (1963)

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[1]Member of the Carrera del Investigador Científico, CIC, Prov. de Buenos Aires, Argentina; Visiting Astronomer, CTIO, NOAO, operated by AURA Inc., for NSF.

[2]Member of the Carrera del Investigador Científico, CONICET, Argentina.

[3]Visiting Astronomer, CASLEO, Argentina

[4]Fellow of CONICET, Argentina.

observed a deep continuum eclipse reaching 0.55 mag, but similar eclipses could not be confirmed in further photometric investigations (e.g., Stepien 1970; Kuhi & Schweizer 1970; Schild & Liller 1975). Thus the system *had apparently stopped eclipsing.* Still partial eclipses were reported in the C III-IV blend λ4652 Å by Cherepashchuk (1972), and Morrison & Wolf (1972). More recently, Eaton, Cherepashchuk, & Khaliullin (1985), found marked atmospheric eclipses in some ultraviolet lines and also over large ranges of the ultraviolet continuum.

In order to understand the strange photometric behavior of CV Serpentis, Cowley, Hiltner, & Berry (1971) conducted a spectroscopic study leading to an improved orbital solution. They found that the deep eclipse observed by Hjellming & Hiltner (1963) had occurred in a conjunction with the OB-type star in front of the system.

The most complete spectroscopic investigation so far available was carried out by Massey & Niemela (1981). They proposed the presently accepted classification of WC8+O8-O9 III-V for the binary components and improved the period determination, finding a new orbital solution from the radial velocity variations of the O star absorptions and the C IV λ4441 Å emission line of the WR star. As in all previous studies, a circular orbit was assumed, resulting in mimimun mass values of 11 $M_\odot$ and 22 $M_\odot$ for the WR and O-type components, respectively.

Some systematic differences between the observed radial velocities of the absorption lines and the circular orbital solution are apparent in the work of Massey & Niemela (1981). Thus we felt that a new effort was worthwhile in the investigation of this system. Here we present the results of our new observations combined with previous data.

2. THE OBSERVATIONS

13 new blue photographic spectrograms of CV Serpentis were obtained with the Cassegrain spectrograph with IT attached to the 1-m telescope at CTIO, Chile. The spectra were secured on baked Kodak IIIa-J plates, and widened to 1 mm. The reciprocal dispersion is 45 Å mm^{-1} for these observations. The photographic spectra were digitized, and subsequently wavelength calibrated and measured using IRAF routines.

In addition, 6 échelle spectrograms with a 1024 Tek CCD as detector were obtained at CASLEO, San Juan, Argentina. A 400 l mm^{-1} cross dispersor was used in the REOSC Cassegrain-échelle spectrograph attached to the 2.15-m telescope. This instrumental combination gives a resolution close to 15 000. The observations were processed and analyzed using IRAF routines.

3. RESULTS AND DISCUSSION

We have determined radial velocities for the absorption lines of the O-type star as well as for some emission lines arising in the WR star, namely C III-IV λ4652 Å, C IV λ4441 Å and He II λ4686 Å. With these values of radial velocities combined with data from the literature, we performed a new period search, which gave as the most probable value a period of 29.704 ± 0.002 days, in good agreement with the value of 29.707 days obtained by Massey & Niemela (1981).

With the new value of the period, we computed an orbital solution for the mean radial velocities of the absorption lines of the O-star. The absorption lines probably represent better the orbital motion than the broad and often variable WR emission lines largely arising in the stellar wind. The resulting orbital parameters from the absorption lines are listed in Table 1, and a plot of the radial velocity variations versus orbital phase is shown in Figure 1.

As seen in Figure 1 and Table 1, the most relevant difference between the present orbital solution of CV Ser and the orbital parameters determined for this system by Massey & Niemela (1981), is the value of the eccentricity that goes up to 0.19 ± 0.03 instead of the null value assumed in all previous studies. We note that in binary systems with periods as long as that of CV Ser, eccentric orbits are more common than circular ones. Orbital solutions fitted to the emission lines also give non negligible values of the eccentricity, with the only exception of the C III-IV blend λ4652 Å. This broad and complex emission feature is formed over different parts of the WR wind, and most probably suffers of saturation effects in the photographic data.

With the new ephemeris, we checked the list of times of minima published by Eaton et al. (1985) and found that the deep minimun observed by Hjellming & Hiltner (1963), did occur at phase 0.07, with the O star in front, as first noticed by Cowley et al. (1971). All the other observed minima in the list of Eaton et al. (1985) correspond to phases around 0.6, with the WR star in front.

TABLE 1

ORBITAL ELEMENTS OF CV SER DERIVED FROM THE ABSORPTION LINES

P	=	29.704 days (fixed)	;	$a\sin i$	=	49 ± 1 $R_{\odot}$
K	=	84 ± 3 km s^{-1}	;	e	=	0.19 ± 0.03
T_0	=	2444242.36 ± 0.81	;	ω	=	$225° \pm 10°$
γ	=	17 ± 2 km s^{-1}	;	f(M)	=	1.7 ± 0.2 $M_{\odot}$

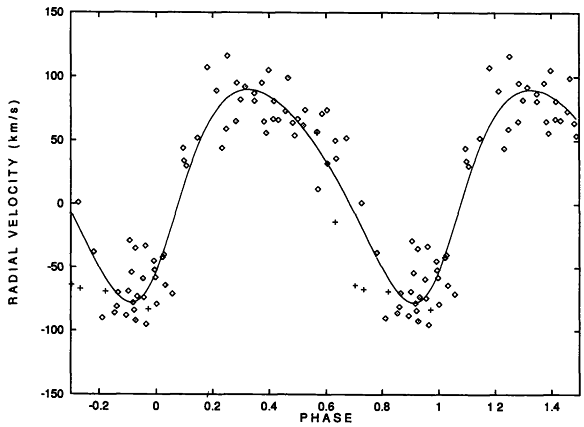

Fig. 1. Radial velocity curve of CV Ser. Diamonds represent photographic observations. Crosses represent échelle-CCD observations. The continuous line represents the orbital solution from Table 1.

The values of the semi-amplitudes (K) of the radial velocity variations of the emission lines are slightly different, namely 174 km s^{-1} for He II λ4686 Å, and 155 km s^{-1} for both C III-IV λ4652 Å and C IV λ4441 Å. Combining these values with the K value determined from the O star absorptions, results in minimum masses of 16 and 34 $M_{\odot}$ (using He II) or 14 and 26 $M_{\odot}$ (using C III-IV) for the WC8 and O8-9 components, respectively. These minimum masses are somewhat higher that the values derived by Massey & Niemela (1981).

The absorption lines in the échelle-CCD spectra show rather complex profiles. This is particularly evident in the case of He II λ5411 Åand He I λ5876 Å. These features could be interpreted as if there is more than one O type star responsible for these absorpion lines. The multiplicity hypothesis might also explain some of the strange photometric behavior of CV Ser as produced by orbital instabilities. This suspicion needs obviously further confirmation from more observations.

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