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Spectroscopic orbit of R CMa

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Abstract. Spectroscopic observations of the Algol-type binary R CMa during 1980–81 are presented and definitive orbital elements obtained by combining all available measurements of radial velocity. Near circularity of the orbit and low mass function are confirmed.

Key words : Algol-type binaries—spectroscopic elements

1. Introduction

The single-lined spectroscopic binary R CMa has been observed spectroscopically by several authors: Jordan (1916), Sitterly (1940), Struve & Smith (1950) and Galeotti (1970). However, because of the peculiarities in the system such as low mass function, changes in light curve attributed to circumstellar gas, and changes in period, a thorough study including both spectroscopic and photometric observations was undertaken at the Japal-Rangapur observatory. In an earlier paper (Radhakrishnan *et al.* 1984a) we studied the period changes and came to the conclusion that R CMa is a triple system. In this paper we discuss our spectroscopic data and the orbit derived by combining them with all the previous data.

2. Observations

R CMa was observed spectroscopically with the Meinel spectrograph attached to the 48-inch telescope of the Japal-Rangapur observatory on 19 nights 1981 (February to May). We obtained 53 good spectra with a dispersion of 33 Å mm $^{-1}$ at Hγ. Exposures of 40 to 80 minutes on IIaO emulsion plates were required depending upon the eclipse phase and condition of the sky. The star was trailed during exposure to give spectra of 500 μ width. In addition, 13 spectra of the radial velocity standard α Lep (F0 Iab) were also recorded for testing the performance of the Meinel spectrograph. The 15 stellar lines measured by us for determining the radial velocities are listed in table 1. Heliocentric radial velocities of R CMa and α Lep are given in tables 2 and 3 respectively. The phases in table 2 are calculated from our (Radhakrishnan *et al.* 1984a) ephemeris :

$$\text{Hel. Min.} = \text{JD}2444648.3283 + 1^d.13593853\ E$$

which is appropriate for our epoch of observation.

From table 3 it is found that the measured radial velocities of α Lep are not correlated with hour angle. Therefore the differences in them cannot be attributed to spectro-graphic flexure effects. The mean of the 13 measurements comes out to be 24.2 ± 0.8 km s^{-1} which is in good agreement with the catalogue value of 24.7 ± 0.2 km s^{-1} (Astronomical Almanac 1982, page H42). Thus the radial velocities obtained with the Meinel spectrograph are compatible with the standard velocity system. It may be noted, however that the standard error for one plate is as high as 3 km s^{-1} for R CMa and 2.7 km s^{-1} for α Lep. Further in the case of α Lep there is a systematic reduction of velocity during the period of observations which amounts to about 4 to 5 km s^{-1} within 50 days. Such variations are not uncommon for supergiants like α Lep.

3. Determination of the spectroscopic orbit

Our radial velocity curve based on the data of table 2 is shown in figure 1. Spectroscopic elements obtained from it by using the methods of Russell & Wilsing (Russell 1902; Wolfe *et al.* 1967) and Stern (1941) are given in table 4. The corresponding theoretical curve is also shown in figure 1. These elements are not much different from those determined by earlier authors. Therefore it was decided to combine all the available data for obtaining a definitive solution. Since R CMa was found to be a triple system (Radhakrishnan *et al.* 1984a) the following procedure was adopted.

For each set of data the zero epoch (time of light minimum) was determined by applying the light time correction and the period was appropriately modified for calculating phases. The radial velocities were also corrected for the motion of the binary in the triple system. The orbital elements were than redetermined for each set of data separately by the above procedure. The main difference between them pertained to the value of the systemic velocity V_0. They are given in table 5 along

Table 1. List of lines measured in the spectrum of R CMa

Sl No.	Wavelangth Å	Identification
1.	3872.923	Fe I
2.	3878.574	Fe I
3.	*3933 684	Ca II
4.	*3956.639	Fe I, Ti I, Ca I
5.	*4030.615	Fe I, Mn I
6.	*4063.416	Fe I, Fe II
7.	*4071.687	Fe I, Fe II
8.	4077.714	Sr II
9.	4101.737	Hδ
10.	4226.728	Ca I
11.	*4250.510	Fe I, Fe II
12.	*4271.542	Fe I, Fe I
13.	*4340.477	Hγ
14.	4351.764	Fe II
15.	4481.327	Mg II

*Lines taken from Petrie's (1948) list.
Wavelengths of other lines are from Moore's (1945) tables.

Table 2. Measured radial velocitities of R CMa

H.J.D. 2444000+	Phase	Heliocentric Rad. Vel.	No. of lines measured
626.2391	.5542	−20.1	15
626.2815	.5916	−21.6	15
626.3218	.6270	−11.3	14
626.3683	.6680	− 0.4	14
627.1842	.3862	−54.9	14
627.2266	.4236	−48.8	14
627.2654	.4577	−42.4	15
627.3036	.4913	−29.5	13
628.1751	.2585	−70.1	13
628.2258	.3032	−59.2	13
628.2662	.3387	−64.7	13
628.3772	.4365	−37.9	12
629.2035	.1639	−58.0	14
629.2868	,2372	−61.4	14
629.3298	.2751	−57.4	15
630.1735	.0178	−51.9	15
630.3375	.1622	−55.4	13
631.1839	.9073	−20.1	14
631.3263	.0326	−39.2	15
637.2599	.2562	−68.7	15
637.3058	.2966	−59.8	13
637.3544	.3394	−62.2	14
653.1813	.2722	−71.3	14
653.2237	.3096	−65.2	15
653.3022	.3787	−53.0	15
654.1689	.1417	−56.3	13
654.2091	.1770	−69.3	13
654.2529	.2156	−66.1	15
654.3071	.2633	−61.6	13
655.2361	.0811	−55.7	15
655.2855	.1246	−53.6	15
656.1000	.8417	−18.2	14
656.1452	.8814	−19.8	14
656.1855	.9169	−18.7	14
657.0944	.7171	−13.2	15
657.1368	.7544	− 7.6	15
657.1750	.7880	− 9.6	14
657.2167	.8247	−11.3	15
658.2097	.6989	− 8.6	14
658.2556	.7393	− 0.9	14
659.0902	.4740	−40.9	15
659.1305	.5095	−36.0	13
659.1624	.5376	−34.0	15
659.2111	.5804	−27.1	14
673.1066	.8131	−12.3	14
673.1483	.8498	−21.0	14
673.1997	.8950	−20.7	15
706.0926	.8516	−20.1	14
706.1481	.9005	−28.5	13
707.0856	.7258	− 0.6	14
707.1238	.7594	−12.4	14
712.0970	.1375	−64.2	15
712.1477	.1821	−64.9	15

with the radial velocities of the binary in the triple system which are already taken into account. We find that the differences in V_0 are much larger than the third body motion. Hence they have to be attributed to the differences in the radial velocity systems which give rise to extra scatter in the combined radial velocity curve. We have, therefore, reduced all data to our system by adding the differences of V_0 values of various sets from ours as shown in table 5. The final definitive solution obtained by combining all data is also given in table 4. Figure 2 shows all available data reduced to our system as well as the theoretical curve corresponding to the final solution.

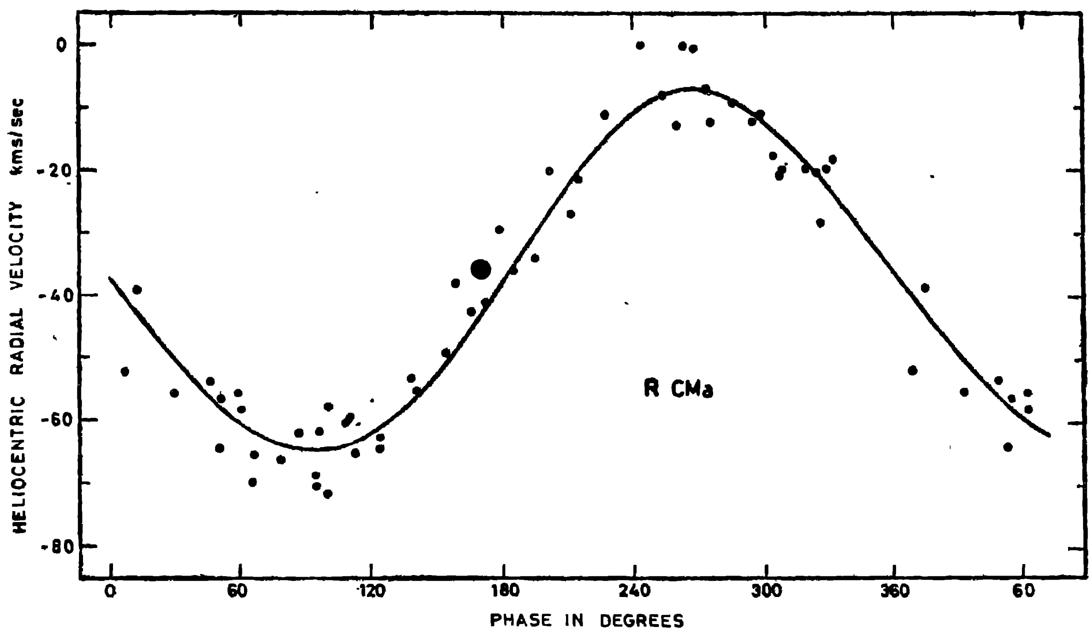

Figure 1. Radial velocity curve of R CMa based on data of Japal-Rangapur observatory.

Table 3. Measured radial velocities of α Lep

H.J.D. 2444000+	Hour angle	Heliocentric radial velocity km s^{-1}
626.2093	$+0^h.9329$	29.4
627.1531	− .3511	27.1
628.1473	− .4232	24.5
629.1749	+ .3090	28.0
630.1374	− .5280	23.1
631.1520	− .1089	26.8
653.1562	+1.4653	22.5
654.1425	+1.2016	22.2
655.1669	+1.8565	24.2
656.0694	− .4244	22.7
657.0632	− .5065	19.9
659.0632	− .3737	21.8
673.0768	+ .8792	22.5

Table 4. Spectroscopic elements of R Canis Majoris

Element	Japal-Rangapur data		All data
	Russell-Wilsing	Sterne	
e	0.039 ± .034	0.039 ± .023	0.049 ± .019
V_0 (km s^{-1})	−36.72 ± 0.71	−36.72 ± 0.48	−37.10 ± 0.78
K (km s^{-1})	28.97 ± 0.89	28.68 ± 0.60	27.78 ± 0.48
ω	311.2 ±50.5	299.8 ±39.1	173.9 ±21.2
T_p	663.7737± .1590	663.9286± .0455	
$a \sin i$ (10^5 km)	4.52 ± 0.14	4.47 ± 0.22	4.33 ± 0.18
$f(m)/M_\odot$	0.0029	0.0028	0.00251± .00014

Table 5. Systemic velocities for various sets of data

Data set (yr)	No. of spectra	Velocity in triple system	V_0	ΔV_0
Jordan (1908–12)	49	+1.13	-40.7 ± 1.7	+4.2
Sitterly (1929–31)	22	−1.15	-34.8 ± 1.8	−1.7
Struve & Smith (1948–49)	42	−1.04	-43.5 ± 1.6	+7.0
Galeotti (1966)	17	0	−45.5	+9.0
Present work (1981)	53	+0.86	-36.5 ± 0.8	0

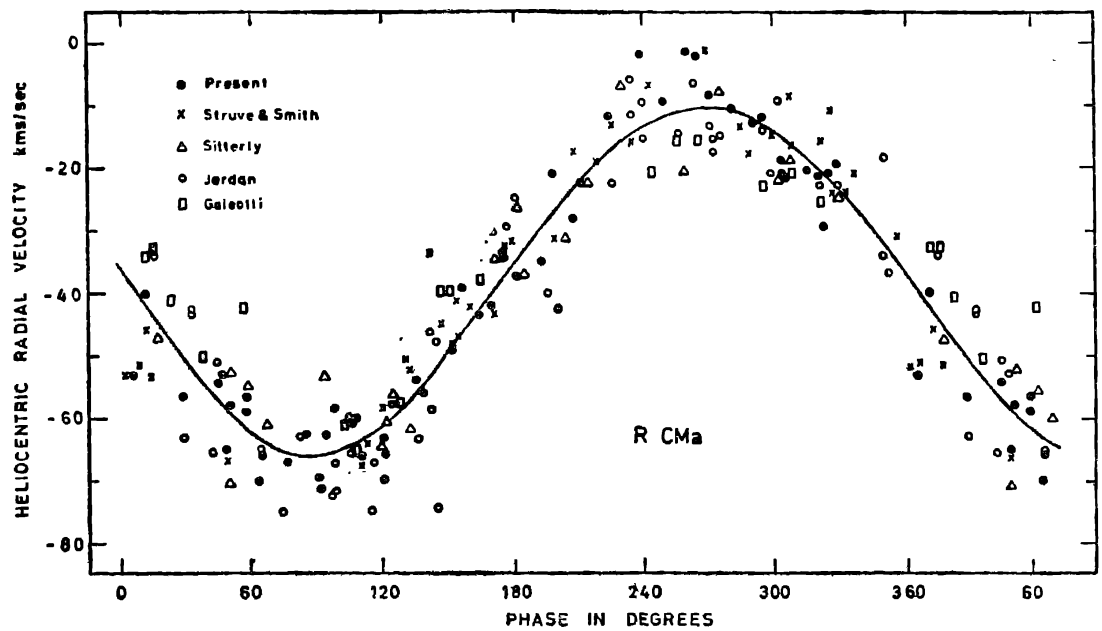

Figure 2. Combined radial velocity curve of R CMa based on all available data.

4. Conclusion

We confirm the near circularity of the orbit of R CMa (e = 0.049 ± .019) and the low value of mass function: $f(m)$ = 0.00251 ± .00014 $M_\odot$. Assuming a mass of 1.52 $M_\odot$ for the primary of spectral type F2V we get a mass of 0.199 ± .004 $M_\odot$ for the secondary which is confirmed by our photometric data (Radhakrishnan *et al.* 1984b).

Figure 2 shows a scatter of about 5 km s^{-1} in the observed radial velocities. It is partly due to inherent errors of measurement and partly due to rotationally broadened and weak lines in the spectrum of the star which further limit the accuracy of measurement.

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