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# Distortion wave characteristics and starspot modelling in the RS CVn eclipsing binary SV Camelopardalis

C. V. S. R. Sarma, P. Vivekananda Rao and M. B. K. Sarma
*Centre of Advanced Study in Astronomy, Osmania University, Hyderabad 500 007*

**Abstract.** Four migrating groups of wave minima are identified in the light curves of SV Cam of which two show direct motion with period 3.02 and 1.6 yr while the other two display retrograde motion with periods 3.04 and 0.6 yr. Based on the methodology of Budding, we have modelled the four groups of spots to fit the distortion wave modulations. It is noticed that two of the spot groups, direct I and retrograde I, have preferred quadrature positions while the other two, direct II and retrograde II, are found to be at random positions. The sizes of starspots generally tended to diminish with time.

*Key words* : RS CVn binaries—SV Cam—starspots

## 1. Photometric distortion wave and its migration

Hall (1976) has classified SV Camelopardalis as a short period RS CVn binary system. For a detailed study of the photometric wave of the system, we have used the extensive photometric data published by Patkos (1982). Over 10,000 photoelectric observations (Patkos 1982) of SV Cam in *V, B and U* passbands spanning about seven years from 1973 to 1980 have been used for the investigation. The basic data have been corrected for the confirmed presence of third body in the system (Sarma *et al.* 1985).

Several periodic variations during noneclipse phases of an eclipsing binary are customarily analysed by Fourier analysis carried out to the 4th harmonic in sine and cosine terms. It is already well known that the photometric wave migrating over the light curve is caused by the combined effect of orbital and rotational motions of the spotted component of the binary. In the case of SV Cam, additional light complications like ellipticity and reflection effect arise due to the proximity of the two components of the eclipsing pair. Therefore the data sample is first Fourier analysed with the angle of external tangency $\theta = 36.°83$ obtained from our synthetic solution (Sarma 1988) by Wood's (1972) method. Based on the derived orbital elements and absolute dimensions of SV Cam (Sarma 1988) the theoretical coefficients of ellipticity (Russell & Merrill 1952) and that of reflection effect (Merrill 1970) are obtained from which the distortion wave coefficients are subsequently calculated. At the noneclipse light levels of 0.396, 0.536 and 0.716 mag for the *V*, *B* and *U* passbands of SV Cam respectively, an analysis of wave amplitudes leads us to conclude that the hotter component is responsible for the distortion wave and is therefore the spotted one. Regarding wave minima, we have analysed for $V$ passband alone and shown in figures 1a and 1b the shifts in various minima. In figure 2, these minima are plotted against phase cycles where squares denote direct I, plusses direct II, diamonds retrograde I and triangles retrograde II groups of wave minima. Suitable number of cycles are added to the phases of later minima (HJD 2442463...onwards) so that each group of minima represent a line with minimum residuals. The three distortion waves denoted by 'Hild 1970, 1976, 1978' are from the

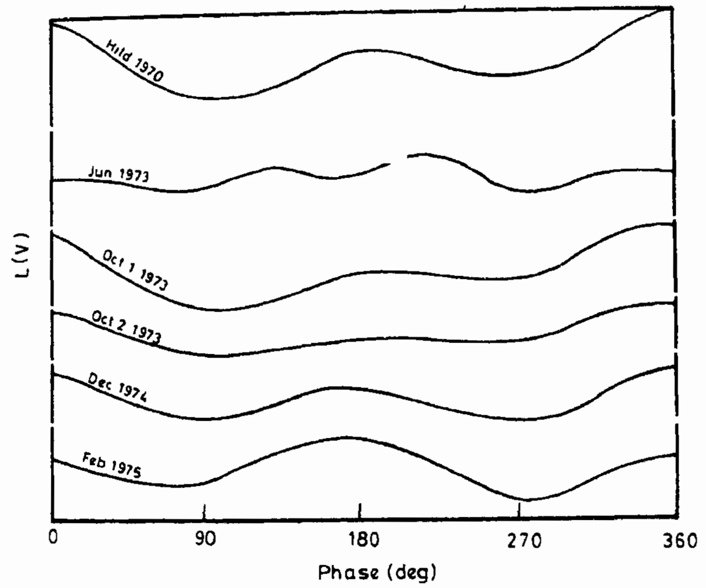


**Figure 1a.** SV Cam Distortion waves (i) YELLOW (Normal mag = 0.396)

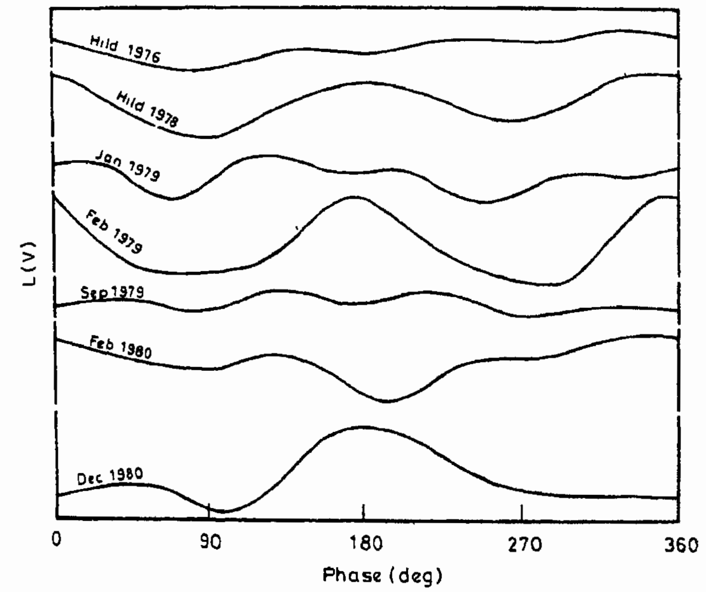


**Figure 1b.** SV Cam: Distortion waves (ii) YELLOW (Normal mag. = 0.396)

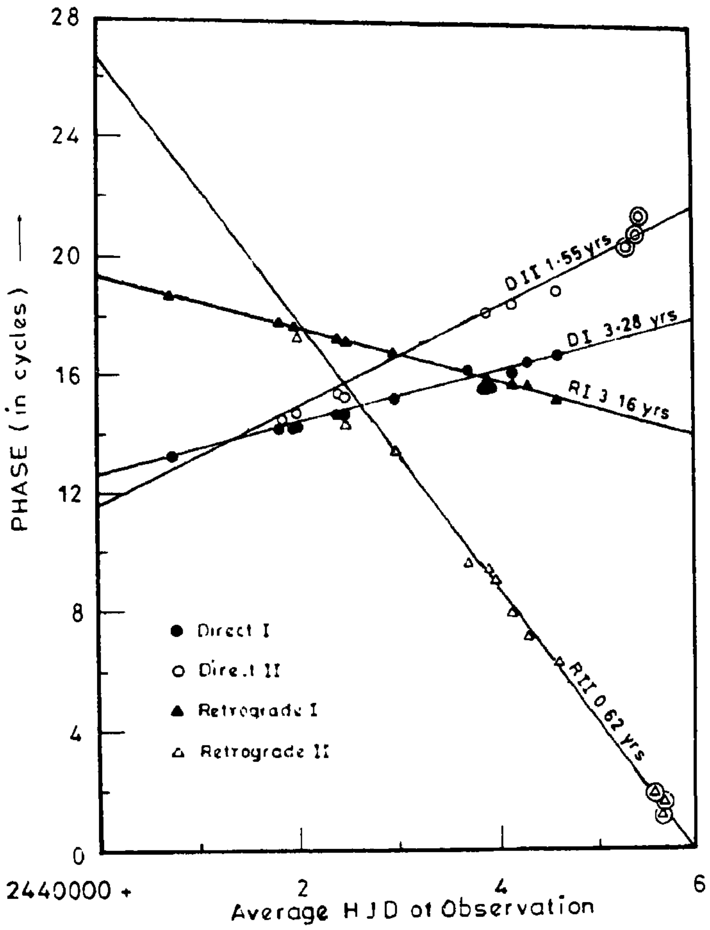


**Figure 2.** SV Cam Distortion wave migration.

observations of Hilditch *et al.* (1979) have also been useful in determining the slope of these 'migration lines'. Three more wave minima (shown by corresponding symbols encircled on direct II & retrograde II lines) from observations of Cellino *et al.* (1985) have also fitted the migration lines well. We could thus infer four periods of migration of the wave minima of 3.02 and 1.6 yr in the direct and 3.04 and 0.6 yr in the retrograde sense.

## 2. Spot modelling

The migration periods thus obtained have been used in starspot modelling of SV Cam by the analytical method of Budding (1977). We have developed computer code that is interactive. Spot parameters of various combinations can be adopted and a large number of trials are needed to arrive at a set of values to satisfactorily fit the observed distortion waves and colour variations. To reduce the number of free parameters so that the trial and error model computations take reasonable computer time, we had to approximate the model to circular spots of single temperature regime governed by the usual liner limbdarkening law. Since SV Cam is a totally eclipsing binary ($i = 90°$, Sarma 1988), it is assumed (Hall 1981; Rodono *et al.* 1986) that the rotational axis of the spotted star is also inclined 90° to the sky plane. Assuming synchronism between rotation and orbital periods and solar type differential rotation operating in the spotted star, one can easily compute the rotational period of the spot from the beat phenomenon of orbital period of the binary and the migration period of the wave minimum. This distribution of rotational periods can be tied to the scale of latitudes over a hemisphere of the spotted star. The spot is also assumed to be centred over the visible hemisphere when the corresponding wave minimum is observed. This means that the longitude of the spot is the same as the phase of the observed wave minimum.

Regarding the temperature and size of the spot, this pair of parameters cannot be easily decoupled unless well observed colour curves, especially infrared ones, are available. For want of data in R, I, ... filters we had to be content with a qualitative study of $U$, $B$ and $V$ distortion waves and the $(B - V)$ colour curve. We have distinguished two components of light variations for the purpose.

(i) the variation of general light level of each wave by huge polar spots or suitably distributed equatorial spots which are visible during all phases having a periodicity of 200 days, and

(ii) the phase modulated light caused by the large spots.

## 3. Characteristics of modelled starspots

We have obtained the rotational periods of the four spot groups as 0.5933656, 0.5936938d for direct I and direct II and 0.5927673, 0.5915226d for retrograde I and retrograde II respectively

The spot forming regions are generally at about a latitude of 40° (Eaton & Hall, 1979). As direct I and retrograde I groups of spots are on either side of co-latitude, we have assumed the difference of latitudes between them to be 10 so that when the derived rotational periods are tied to the scale of latitudes, we obtain a latitude of 40°.5 for the direct II as expected. The derived latitudes of the four groups of spots are 35° and 40°.5 for direct I and direct II, and 25° and 4°.3 for retrograde I and retrograde II respectively. The co-latitude is estimated to be 30°.1. The spot parameters modelled are given in table 1. One of the well fitted distortion waves (1975 February) is shown in figure 3. The waves with multiple minima did not fit the theoretical curves well.

## 4. Conclusions

In SV Cam, we have encountered four significant minima which have been interpreted in terms of four spot groups of which two (direct I and direct II) are above and two (retrograde I and retrograde II) below the co-latitude of the spotted star. While the temperatures of the spots are of the order of values with a typical uncertainity of 200° to 300°, the parameter $r$, the radius of the spot, is estimated with an accuracy of 0°.5. As the spots we have modelled are large, one can presume that the spots tend to diminish over time. Compared to starspot model based on numerical integration techniques, the semianalytical approach we have employed (Budding 1977) is advantageous in two

**Table 1.** SV Cam . Characteristics of spots

| S. No. | Date | Av HJD | Direct II Lng | Direct II Tmp | Direct II Size | Direct I Lng | Direct I Tmp. | Direct I Size | Retrorade I Lng | Retrorade I Tmp | Retrorade I Size | Retrograde II Lng | Retrograde II Tmp. | Retrograde II Size | Extra spot Lng. | Extra spot Tmp | Extra spot Size | Lat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Latitude of Spot Groups*: | | | 40°.5 | | | 35° | | | 25° | | | 4° 2 | | — | — | — | |
| 1. | Hld, 70 | 752 | 189° | 5400°K | 17° | 105° | 5000°K | 34° | 260° | 5000°K | 25° | 300° | 5000°K | 10° | 70° | 5000°*K* | 5° | 10° |
| 2 | Jun, 73 | 1860. | 168 | 5300 | 20.5 | 76 | 5000 | 20 | 276 | 4500 | 18 | 358 | 5000 | 11 | — | — | — | |
| 3 | Oct I, 73 | 1961. | 234 | 5400 | 26 | 103 | 5000 | 35 | 259 | 5000 | 19 | 334 | 5100 | 5 | 65 | 5000 | 7 | 0 |
| 4. | Oct II, 73 | 1981 | 258 | 5250 | 22.5 | 98 | 5000 | 30 | 216 | 4900 | 10 | 188 | 4900 | 10 | 75 | 4950 | 6 | 0 |
| 5. | Dec, 74 | 2418 | 190 | 5600 | 19 | 275 | 5000 | 26 | 93 | 5000 | 22 | 180 | 5150 | 5 | 80 | 5000 | 7 | 0 |
| 6. | Feb, 75 | 2463 | — | — | — | 278 | 5000 | 30 | 73 | 5000 | 23 | — | — | — | — | — | — | |
| 7. | Hld, 76 | 2957. | — | — | — | 87 | 5000 | 22 | 277 | 5000 | 13 | 184 | 4800 | 10 | 50 | 5000 | 11 | 0 |
| 8 | Hld, 78 | 3687. | 216 | 5500 | 15 | 85 | 4600 | 27 | 43 | 5200 | 5 | 265 | 4600 | 18 | — | — | — | |
| 9. | Jan, 79 | 3879 | 69 | 5000 | 26 | 250 | 5000 | 25 | 332 | 5000 | 13 | 169 | 5000 | 10 | — | — | — | |
| 10 | Feb, 79 | 3927 | 282 | 5000 | 30 | 230 | 5000 | 25 | 324 | 5000 | 5 | 69 | 4900 | 15 | 70 | 4900 | 25 | 0 |
| 11. | Spt, 79 | 4131 | 176 | 5500 | 19 5 | 81 | 5000 | 15 5 | 276 | 5000 | 15.5 | 350 | 5000 | 11 | — | — | — | |
| 12 | Feb, 80 | 4285. | — | — | — | 194 | 4900 | 29 | 275 | 5000 | 14 | 86 | 4800 | 17 | — | — | — | |
| 13. | Dec, 80 | 4582. | 360 | 5000 | 27 | 291 | 5100 | 30 | 99 | 4500 | 25 | — | — | — | 36 | 5000 | 10 | 0 |

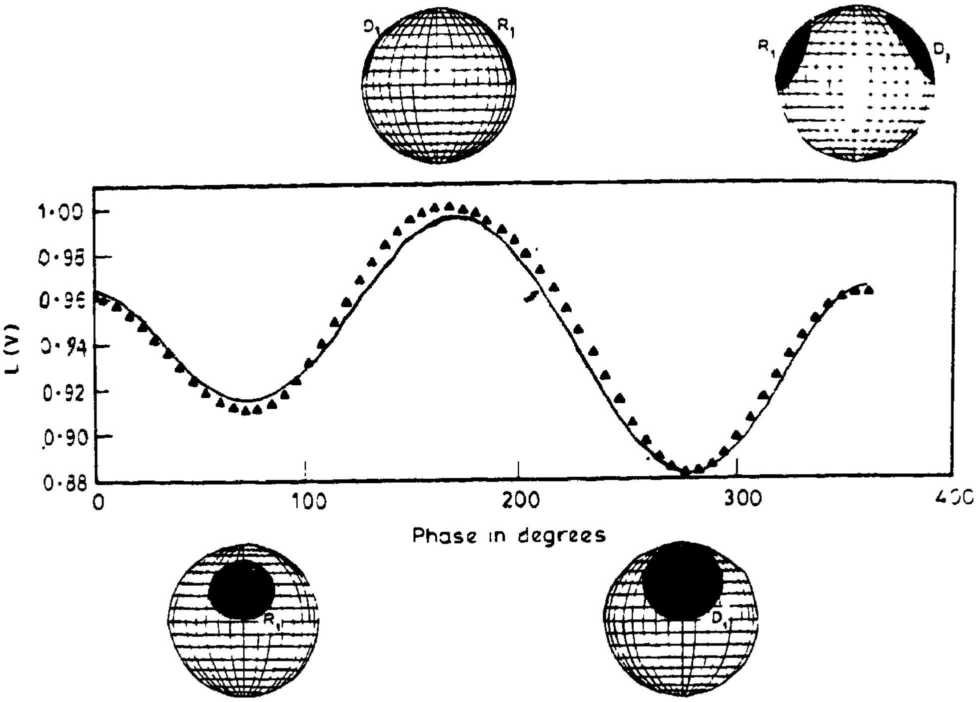


**Figure 3.** SV Cam. Model fit of 1975 February distortion wave.

respects. One is that the computing time required is reasonably limited though the volume of parameter space has to be constrained with necessary model inputs. Secondly the development of the starspot model (for example, distorted stars with non-linear limb darkening laws) is simply by incorporation of a few more parameters in the equation of condition. The derivation of spot latitudes from the migration rates of wave minima is one clear advantage gained independent of spot modelling. However, the results can only be ratified by high resolution spectroscopic observations which give a second dimension to the disc integrated light of the spotted star. Regarding the preferred longitudes of the spots, one can notice that the deeper minima oscillate about 100 and 270°, which are quadrature positions of the light curve. Recently M. Zeilik & E. Budding (1987 personal comminication) have also investigated the spots of SV Cam and showed that at 110 and 270°, the spots tend to be centred.

Long-time base-line infrared photometry supplemented by high resolution spectroscopy of the system is needed for a more detailed modelling of the spots.


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