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# A study of the long term photometric variation of the RS CVn star V711 Tau

Padmakar and S.K. Pandey

*School of Studies in Physics, Pt. Ravishankar Shukla University, Raipur 492 010, India*

**Abstract.** With a view to investigate the long term photometric behaviour of one of the most active double lined spectroscopic RS CVn type binary V711 Tau (K1 IV + G5 V) we examine its light curve for the last eighteen years (1977 – 1995). The light curve of this binary shows remarkable changes in terms of shape, amplitude as well as the phase of the minimum light. We parameterize these light curves in the framework of the starspot model to derive spot parameters (size, spot temperature, location etc.) to look for any systematic secular variation in them. The light curves could reliably be synthesized with a minimum of three spots with one always at the pole. The study however does not indicate any systematic secular variation in spot parameters.

*Key words* : RS CVn binaries – V711 Tau – light curves – stellar surface activity

## 1. Introduction

The RS CVn binary stars are a well established class of chromospherically active stars. Peculiar changes in amplitude, shape, mean light level and phase of minimum light of these stars have been long standing problems for astronomers. Though the problem of the unusual photometric behaviour of the RS CVn stars could be explained in terms of extinction of the light by circumstellar material or by pulsation of one of the components with the same period as that of the orbital motion, the explanation in terms of the surface activities viz. the presence of dark starspots on stellar surface is widely accepted. In terms of the starspot model the short term photometric variation (Period ~ $P_{orb}$) seen in these objects has been attributed to the rotational modulation of the starlight by the cool dark spots, analogous to sunspots, present on the active component of the system. The spots may cover 10% to 50% of the visual hemisphere of the active component. Starspot models can also account for the long term variations in light curves in terms of the effect of changes in size, location and distribution of the spots on the stellar surface. This explanation of the light variation is well supported by coordinated optical, spectroscopic observations, and Doppler imaging techniques. To extract spot parameters from observed light curves various starspot models have been developed (e.g.

Bopp & Evans 1973; Dorren 1987; Eker 1994). We have used the modeling technique developed by Dorren (1987) for its greater transparency.

V711 Tau is one of the brightest members (V ~ 5.7 mag) of RS CVn family and the most active double lined spectroscopic binary (K1 IV + G5 V) with an orbital period ~ 2.84 days. Extensive broad band and narrow band photometry of this star have been carried out by several investigators since its recognition as an RS CVn binary star in order to obtain a better understanding about the intriguing photometric behaviour. We have started an observing programme to study RS CVn stars using the 0.35m reflector telescope of our University Observatory, V711 Tau is one of the programme objects. Table 1 gives a summary of the available photometric data in the V band for the period 1977 – 1995 used for starspot modeling reported here. This includes our own observations taken during the period February 8 – 24, 1995 (Padmakar & Pandey 1996).

**Table 1.** Data source for V band photometry of V711 Tau.

| Year | Mean epoch (HJD) | No. of Obs. | $\Delta V_0$ (mag) | Reference |
|---|---|---|---|---|
| 1977.10 | 2443193.13 | 16 | 1.480 | Parthasarathy *et al.* 1981 |
| 1979.94 | 2444231.17 | 19 | 1.426 | Mekkaden *et al.* 1982 |
| 1980.10 | 2444288.50 | 19 | 1.435 | Mekkaden *et al.* 1982 |
| 1981.01 | 2444623.67 | 11 | 1.544 | Mekkaden *et al.* 1982 |
| 1981.11 | 2444657.50 | 13 | 1.524 | Mekkaden *et al.* 1982 |
| 1982.05 | 2445001.15 | 27 | 1.390 | Mohin & Raveendran 1993 |
| 1984.98 | 2446072.68 | 10 | 1.353 | Mohin & Raveendran 1993 |
| 1986.12 | 2446487.10 | 11 | 1.427 | Mohin & Raveendran 1993 |
| 1987.01 | 2446812.50 | 17 | 1.437 | Mohin & Raveendran 1993 |
| 1987.09 | 2446843.50 | 18 | 1.427 | Mohin & Raveendran 1993 |
| 1988.05 | 2447195.11 | 25 | 1.481 | Mohin & Raveendran 1993 |
| 1989.03 | 2447551.71 | 10 | 1.474 | Mohin & Raveendran 1993 |
| 1989.94 | 2447885.24 | 14 | 1.401 | Mohin & Raveendran 1993 |
| 1991.09 | 2448307.14 | 23 | 1.484 | Mohin & Raveendran 1993 |
| 1995.09 | 2449765.34 | 17 | 1.446 | Padmakar & Pandey S.K. 1996 |

## 2. Starspot modeling

A detailed study of the photometric variation attributed to starspots can provide useful information on the physical characteristics (size, location, effective spot temperature etc.) of the spots, and numerous attempts have been made to this end through the modeling of observed light curves. The photometric variation of the spotted stars can be written as

$$\Delta m_c = f(\phi, \lambda, \beta, \gamma, \Delta T, i, u_{st}, u_{sp})$$

where

| | | | | | |
|---|---|---|---|---|---|
| $\phi$ | = Phase | | $\lambda$ | = | Longitude of the starspot |
| i | = Stellar inclination | | $\beta$ | = | Latitude of the starspot |
| $u_{sp}$ | = Limb darkening coeff. of the spot | | $\gamma$ | = | Size of the starspot |
| $u_{st}$ | = limb darkening coeff. of the star | | | | |
| $\Delta T$ | = Temperature difference between the photosphere and the spot | | | | |

This parametric equation contains two dimentional integration of a rather complicated function. With the assumption that spots or spot groups are circular in shape, Dorren (1987) obtained analytical solution by direct integration over the spot surfaces to derive synthetic light curve. While adopting Dorren's technique we have introduced polar spots to adjust the maximum brightness level $\Delta V_0$ of each individual light curve, and the spots elsewhere on the stellar surface were used to modulate the amplitude and shape of the light curve. At the time when the stellar surface is unspotted, brightness should have reached its maximum value and to satisfy this requirement we have taken $\Delta V_0$ for the epoch 1984 as the reference point for unsp otted brightness level. The individual light curves were then fitted with three spots (with one always at the pole) using the method of least squares. The optimum values of the spot parameters were obtained by minimizing $\chi^2$ with respect to each one of the parameters. $\chi^2$ gives an appropriately weighted sum of squares of residuals between observational data $\Delta m_o$ and the theoretical fitting function $\Delta m_c$ i.e.

$$\chi^2 (\lambda, \beta, \gamma, \Delta T, \mathrm{i}, \mathrm{u}) = \sum_{j=1}^{n} \frac{[\Delta m_o - \Delta m_c (\phi j, \lambda, \beta, \gamma, \Delta T, \mathrm{i}, u_{st}, u_{sp})]}{2} \quad \sigma_j^2$$

The grid search method was used to minimize $\chi^2$ with respect to the parameters $\lambda$, $\beta$, $\gamma$, $\Delta T$, i, $u_{st}$ and $u_{sp}$ (Bevington 1969). The best fit parameters then give the characteristics of dark spots present on the stellar surface.

The spot parameters evaluated from the observed light curves of the V711 Tau using the starspot modeling procedure described above are given in Table 2. The observed data points along with the synthetic light profiles are displayed in Figure 1. The light curves could reliably be synthesized with a minimum of three spots with one always at the pole.

## 3. Discussion

A survey of the literature on this system shows that the shape of light curve has undergone significant seasonal changes from almost symmetrical and sinusoidal to asymmetric and double peaked, and sometimes becoming almost flat. The amplitude of variation in V photometric band has been reported to lie in the range 0.05 to 0.24 mag (Mohin & Raveendran 1993). The phase of minimum light and mean light level rapidly changes with time (Mekkaden *et al.* 1982; Bartolini *et al.* 1983; Rodono *et al.* 1986; Strassmeier *et al.* 1989; Mohin & Raveendran

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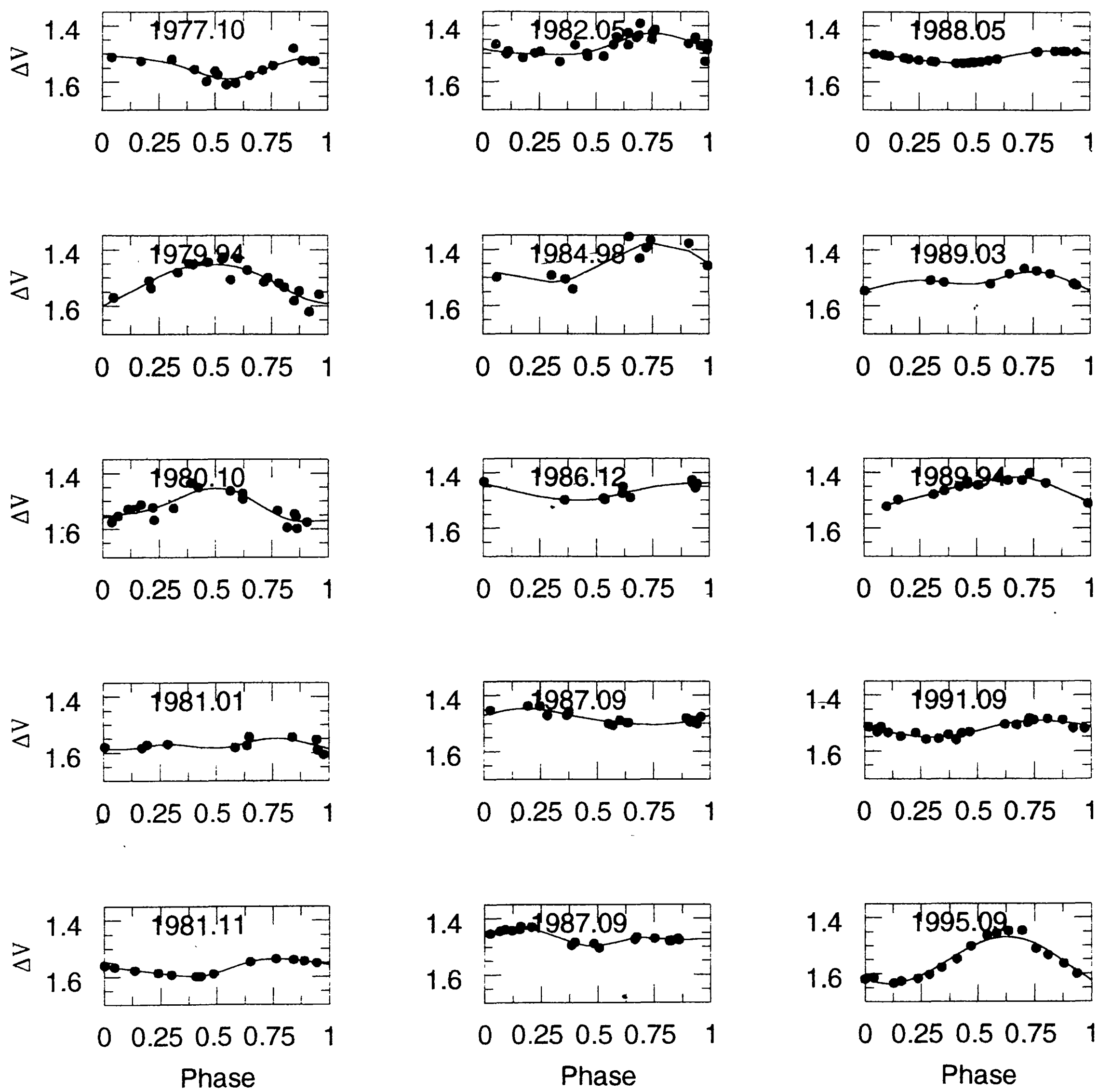


**Figure 1.** Starspot modeling of the V711 Tau light curves.

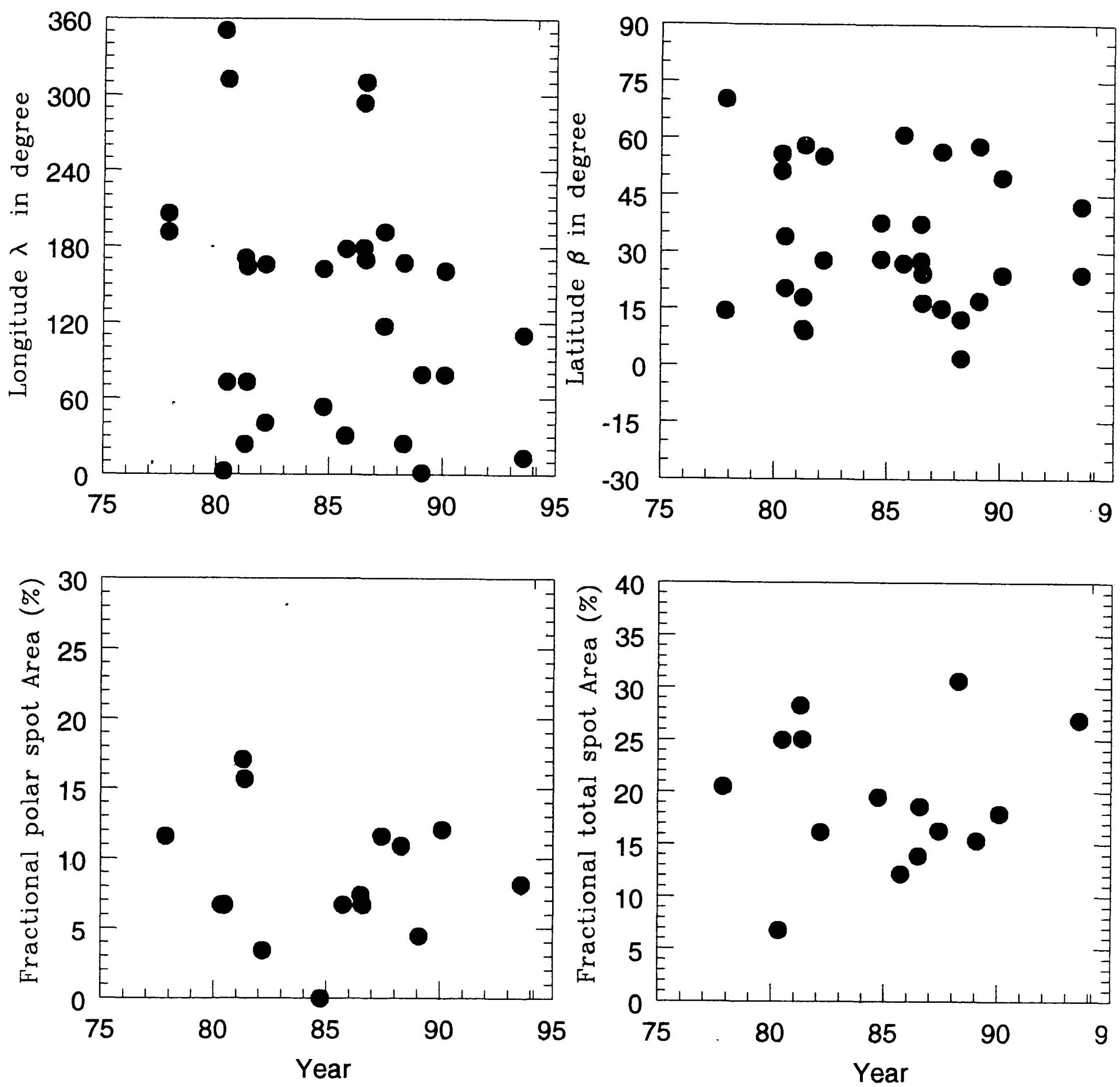


**Figure 2.** Variation of the parameters with time.

**Table 2.** The spot parameters derived for the light curves of V711 Tau.

| Year | Spot 1 | | | Spot 2 | | | Polar spot | Total | No. of | $\chi 2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | $\lambda_1$ | $\beta_1$ | $r_1$ | $\lambda_2$ | $\beta_2$ | $r_2$ | r | area | Obs. | |
| 1977.10 | 191.28 | 70.27 | 17.77 | 206.06 | 14.34 | 16.67 | 27.90 | 20.56 | 16 | $4.37 \times 10^{-4}$ |
| 1979.94 | 351.4 | 55.80 | 23.22 | 2.39 | 51.26 | 11.48 | 21.06 | 16.78 | 19 | $7.12 \times 10^{-4}$ |
| 1980.10 | 312.20 | 33.95 | 26.13 | 72.34 | 20.34 | 22.76 | 21.53 | 24.98 | 19 | $6.51 \times 10^{-4}$ |
| 1981.01 | 23.94 | 17.89 | 17.93 | 171.05 | 9.62 | 20.47 | 34.00 | 28.26 | 11 | $3.84 \times 10^{-4}$ |
| 1981.11 | 72.63 | 57.99 | 15.10 | 164.17 | 8.89 | 19.83 | 32.5 | 25.04 | 13 | $5.69 \times 10^{-4}$ |
| 1982.05 | 40.61 | 55.13 | 20.87 | 165.89 | 27.65 | 20.27 | 15.01 | 16.16 | 27 | $5.31 \times 10^{-4}$ |
| 1984.98 | 53.17 | 37.65 | 26.64 | 162.44 | 28.08 | 24.36 | 00.00 | 19.52 | 10 | $2.01 \times 10^{-3}$ |
| 1986.12 | 178.23 | 60.98 | 14.24 | 130.50 | 26.98 | 12.71 | 21.06 | 12.20 | 11 | $3.04 \times 10^{-4}$ |
| 1987.01 | 293.63 | 37.44 | 17.32 | 179.12 | 27.61 | 14.88 | 22.15 | 13.91 | 17 | $1.58 \times 10^{-4}$ |
| 1987.09 | 310.23 | 24.32 | 16.90 | 169.63 | 16.58 | 22.51 | 21.06 | 18.62 | 18 | $4.22 \times 10^{-5}$ |
| 1988.05 | 117.06 | 56.56 | 13.09 | 191.53 | 15.08 | 11.86 | 27.86 | 16.32 | 25 | $4.50 \times 10^{-5}$ |
| 1989.03 | 24.39 | 12.28 | 25.55 | 167.49 | 1.87 | 25.78 | 27.02 | 30.64 | 10 | $8.24 \times 10^{-5}$ |
| 1989.94 | 78.81 | 58.01 | 17.97 | 1.40 | 17.20 | 20.23 | 17.16 | 15.40 | 14 | $1.34 \times 10^{-4}$ |
| 1991.09 | 78.58 | 49.72 | 15.35 | 161.05 | 23.96 | 12.36 | 28.42 | 17.94 | 23 | $9.89 \times 10^{-5}$ |
| 1995.09 | 13.55 | 42.21 | 27.85 | 110.45 | 24.09 | 21.81 | 23.30 | 26.90 | 17 | $2.87 \times 10^{-4}$ |

1993 and references therein). Figure 2 shows variation of the starspot parameters : longitude ($\lambda$), latitude ($\beta$), percentage fractional polar spot area and the total spot area, with time. One can see from Figure 2 that there is no indication of any preferred longitudinal active belt. This is in disagreement with the deductions of Zelik *et al.* (1990) for the short period RS CVn variables. Starspots are found to lie in the latitude range 0° – 75° and this therefore rules out the possibility of any latitudinal confinement of the starspots. Fractional polar and total areas of the dark spot do not indicate any periodicity. Therefore, our analysis based on the light curves of V 711 Tau for the last eighteen years does not reveal any systematic variation in the spot parametrs (e.g. the famous 11 year sunspot cycle).

## 4. Acknowledgements

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