Bull. Astr. Soc. India (1986) **14**, 48–55

Photometric study of the RS CVn binary II Pegasi

S. Mohin, A. V. Raveendran and M. V. Mekkaden
Indian Institute of Astrophysics, Bangalore 560 034

Received 1985 December 26; accepted 1986 January 27

Abstract. *B* and *V* photometry of II Peg obtained at Kavalur on 39 nights during 1980–81, 1981–82 and 1984–85 observing seasons is presented. From an analysis of the available data on this object we find that no two light curves agree in any of the following : shape, amplitude, phases of the light maxima and minima, mean light level, or brightness at the light maxima and minima. Phases of the light minima observed during the interval from 1979.83 to 1980.97 are found to lie on two distinct lines with different slopes; the respective photometric periods are $6^d.672 \pm 0^d.010$ and $6^d.694 \pm 0^d.002$. On the basis of the spot model it implies the simultaneous existence of two centres of activity located at different latitudes and longitudes on a differentially rotating star. It is also found that there is apparently no correlation between the colour $(B - V)$ and the visual magnitude, but there is a large scatter with a total range of ~ 0.1 mag, much larger than the expected observational error.

Key words : RS CVn binaries—II Peg

1. Introduction

II Peg (= HD 224085 = BD + 27° 4642) has been the object of several studies in wide wavelength regions by different investigators, since Chugainov (1976) obtained its first photometric light curve. As a result it is now recognized as one of the most active members of the RS CVn group of binaries (Hall 1976). II Peg is a single-lined spectroscopic binary with a period of 6.72 and displays strong and variable Ca II H and K emission (Halliday 1952; Bopp & Noah 1980). The visible component has a spectral type close to K2 IV (Vogt 1981). It is a strong source of radio emission and of both soft and hard x-ray flares (Spangler, Owen & Hulse 1977; Walter *et al.* 1980; Schwartz *et al.* 1980). II Peg is one of the four RS CVn binaries so far known that show Hα as pure emission feature above the continuum consistently at all times; the other three being V711 Tau, UX Ari, and DM UMa (Bopp 1982).

In this paper we present the results of *B* and *V* photometry obtained at Kavalur and also an analysis of the light curves based on the available photometric data II Peg.

2. Observations

Observations were made with the 34-cm Cassegrain reflector of the Kavalur in *B* and *V* on 18, 9, and 12 nights during the observing seasons 1980–81, 1981–82, and 1984–85 respectively. HD 223094 and HD224895 were observed along with the

Table 1. *V* and (*B* — *V*) values of II Peg

JD	*V*	*B* — *V*
2440000.+		
4571.204	7.580	1.028
4571.233	7.599	1.043
4574.185	7.536	1.053
4574.206	7.539	1.059
4583.103	7.593	1.080
4584.124	7.632	1.050
4588.080	7.584	1.092
4589.093	7.565	1.053
4590.084	7.616	1.085
4590.119	7.618	1.046
4590.162	7.615	1.068
4593.089	7.462	0.996
4593.128	7.436	1.042
4594.071	7.537	1.043
4594.098	7.547	1.046
4596.072	7.572	1.026
4603.098	7.575	1.070
4604.191	7.660	1.057
4606.156	7.462	1.018
4607.083	7.484	1.054
4608.086	7.568	1.067
4610.088	7.637	1.052
4612.070	7.536	1.048
4612.090	7.530	1.051
4618.100	7.640	1.065
4983.104	7.413	1.067
4984.135	7.511	1.097
4985.095	7.658	1.080
4986.096	7.617	1.070
4987.092	7.456	1.080
4988.095	7.413	1.080
4989.093	7.356	1.112
4991.094	7.502	1.063
4993.096	7.565	1.046
6051.222	7.496	1.083
6052.082	7.583	1.051
6052.129	7.586	1.024
6054.139	7.594	1.005
6055.084	7.558	1.037
6056.094	7.459	0.999
6056.125	7.427	1.019
6080.114	7.535	1.095
6084.084	7.387	—
6085.090	7.572	1.032
6087.103	7.537	1.041
6088.088	7.576	1.063
6089.075	7.486	—

variable as comparison stars. All observations were made differentially with respect to HD 223094. The magnitudes and colours of II Peg thus determined are listed in table 1. The magnitudes and colours of the comparison stars determined during these three seasons agree well with our earlier determination (Raveendran, Mohin & Mekkaden 1981).

3. Light curves

The Julian days of observation are converted to orbital phases using the ephemeris:

$$\text{Phase} = JD\ 2443030.396 + 6^{d}.724464\ E,$$

where the initial epoch corresponds to the conjunction with the visible primary in front (Raveendran, Mohin & Mekkaden 1981). The V band observations are plotted in figures 1, 2 and 3. Each point is a mean of 3–4 independent observations. The probable errors of differential magnitude and colour are $\pm$ 0.014 mag and $\pm$ 0.014 mag respectively. The total uncertainty in V and $(B - V)$ are $\pm$ 0.019 mag and $\pm$ 0.015 mag. The mean epochs of observations are also given in each figure. It is clear that no two light curves agree with each other in any of the following

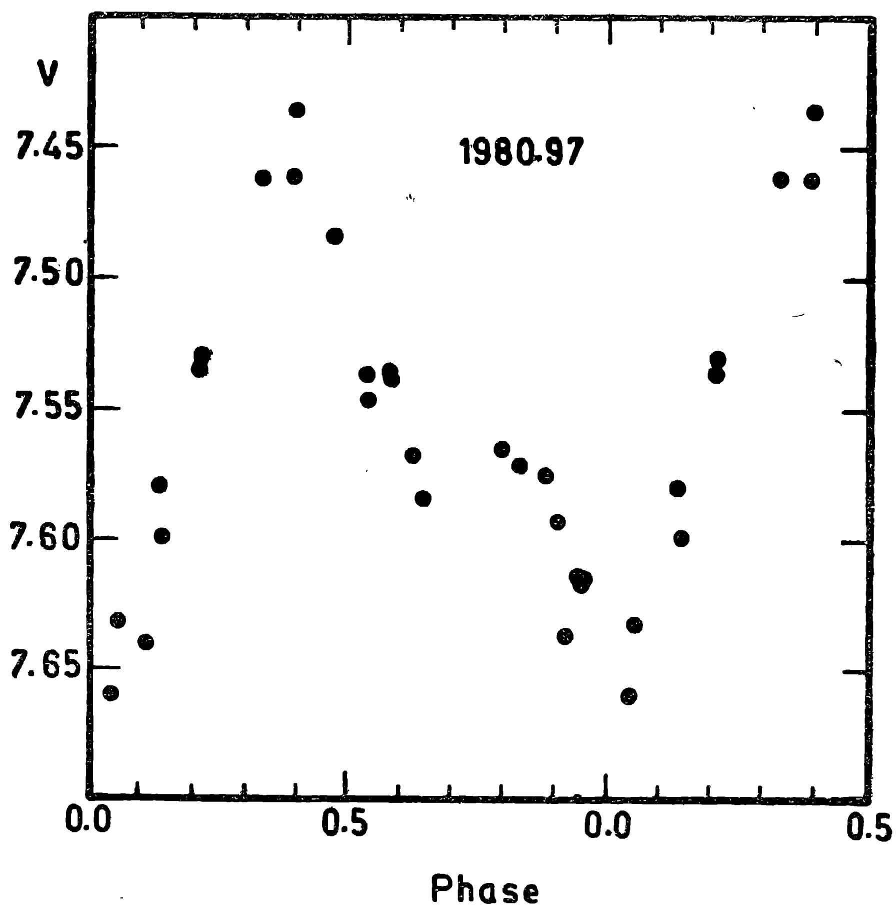

Figure 1. V light curve of II Peg obtained during 1980–81.

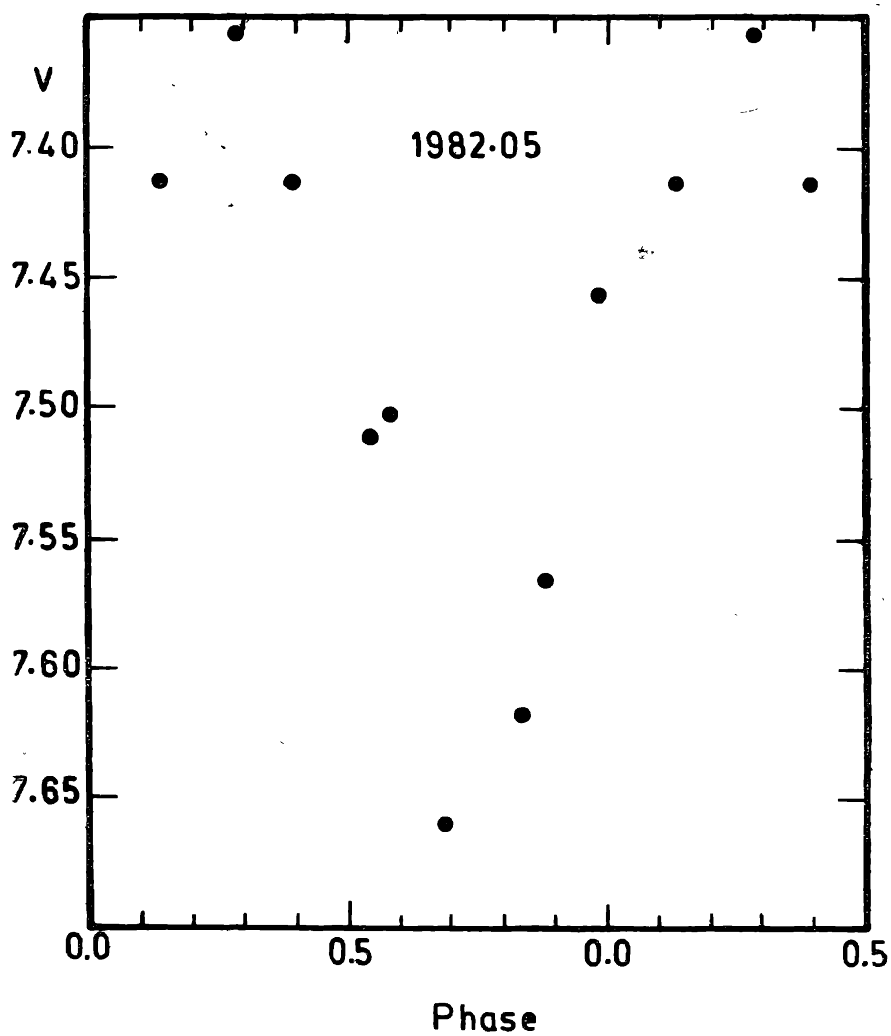

Figure 2. *V* light curve of II Peg obtained during 1981–82.

characteristics: shape, amplitude, mean light level, and brightness and phases of light maxima and minima.

Figure 4 is a plot of $(B - V)$ against the corresponding observed visual magnitude. There is apparently no correlation between the colour $(B - V)$ and the visual brightness of II Peg; but there is a scatter with a total range of $\sim$ 0.1 mag and this is much larger than the expected observational uncertainty.

4. Light minimum

In figure 5, we have plotted the phase of light minimum against the mean Julian day of observation. The values are visual estimates from the respective light curves. Photometric data on II Peg are taken from Chugainov (1976), Rucinski (1977), Vogt (1981), Nations & Ramsey (1981), Raveendran, Mohin & Mekkaden (1981), Bohusz & Udalski (1981), and Rodono, Pazzani & Cutispoto (1982).

It is interesting to see that during the interval from JD 2444175 to JD 2444595, the light curves had two minima indicating the simultaneous presence of two major

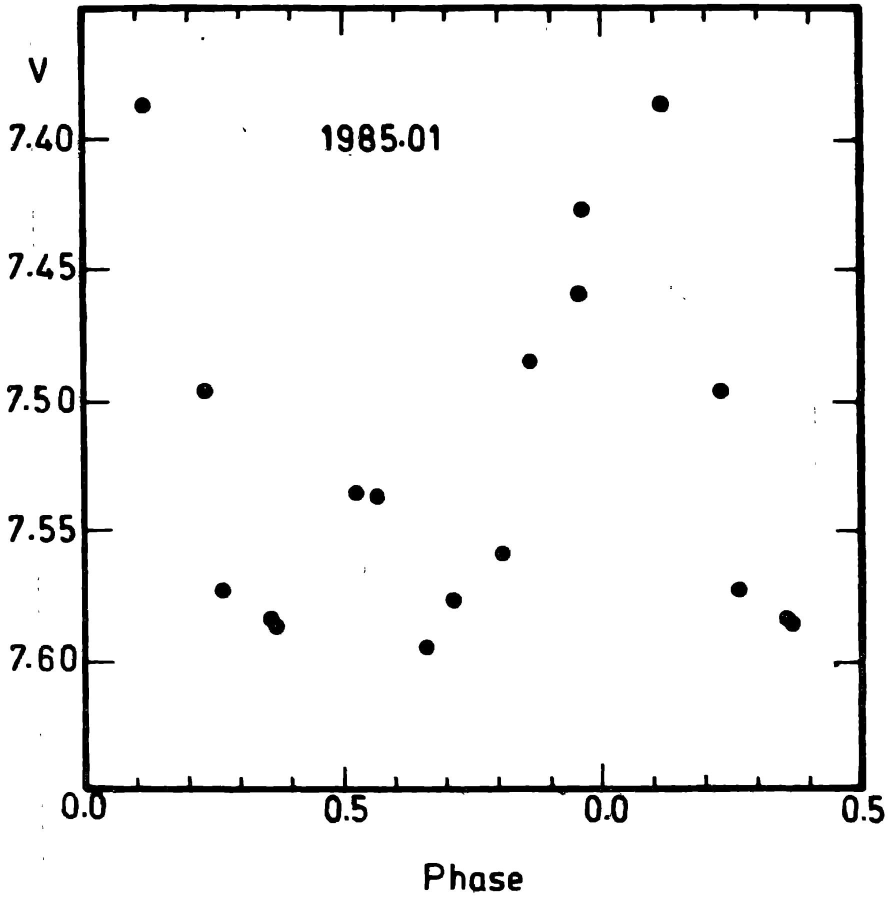

Figure 3. *V* light curve of II Peg obtained during 1984–85.

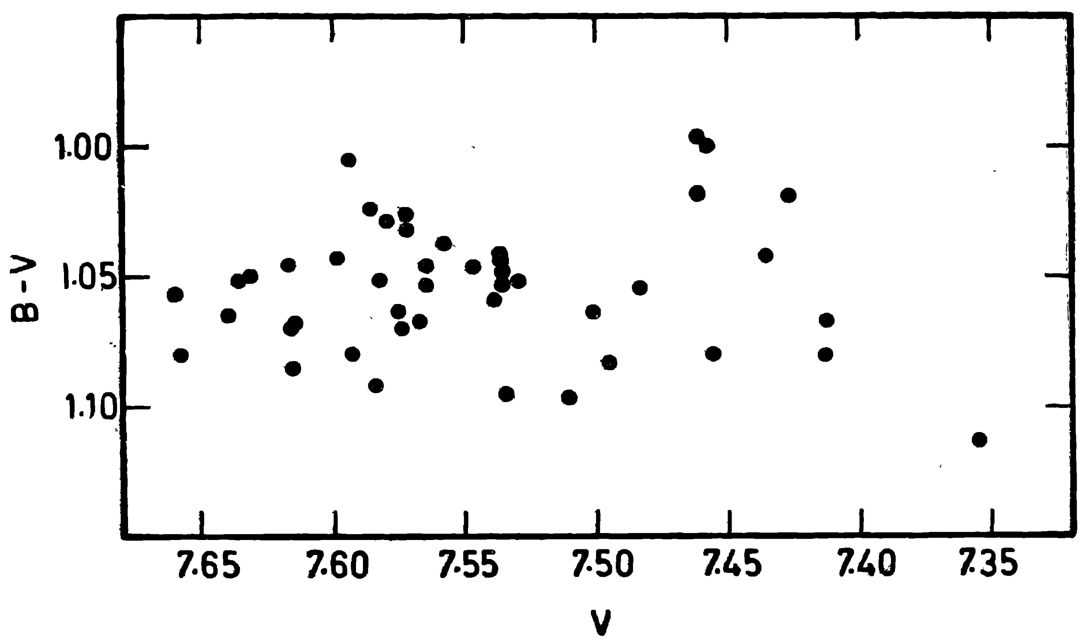

Figure 4. Plot of $(B - V)$ against the corresponding V magnitude obtained during 1980–81, 1981–82, and 1984–85.

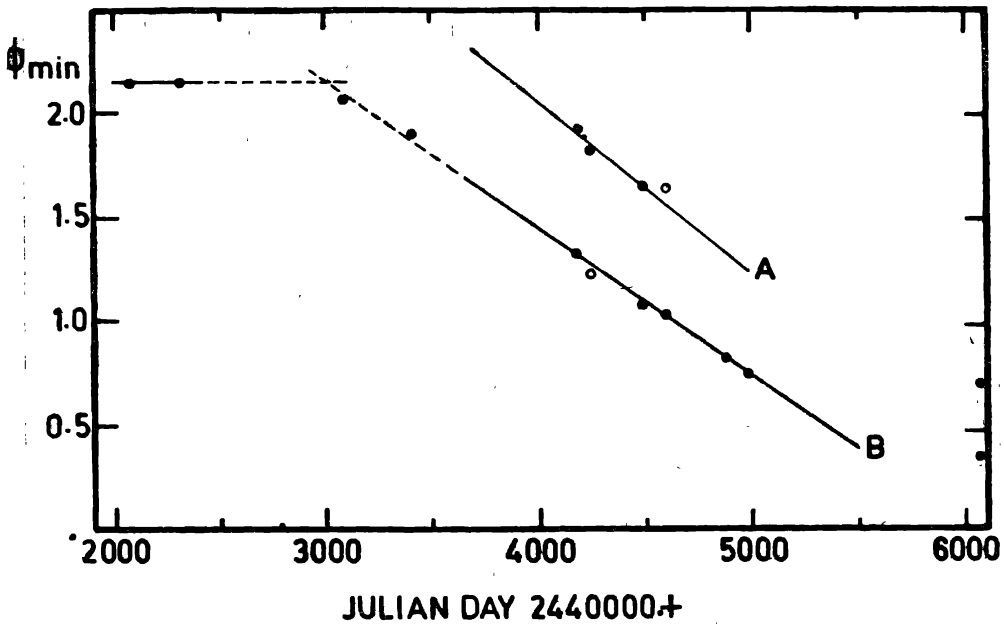

Figure 5. Phase of light minimum versus mean Julian date.

active regions, say A and B, separated in longitude. The solid lines represent the 'best-fit lines' passing through well defined minima. The slightly different slopes indicate different photometric periods of $6^d.672 \pm 0.010$ and $6^d.694 \pm 0.002$ days for these two regions A and B respectively. This implies that the respective regions were located at different latitudes also The minima observed at JD 2444878 and JD 2444988 were also included in group B for the solution of the photometric period since both lie close to the line passing through the minima of group B.

Further, we find that both the minima, observed by Rucinski in 1976 and Vogt in 1977, lie on the line corresponding to group B. Probably the active region had its origin sometime in 1976 and finally disintegrated sometime in 1981. This puts a limit of about 5–6 years for the life time of the active region. The minima belonging to group A which appeared in 1979 could not be traced after 1981 and hence probably had a shorter life time. Similar values for the life time for the centres of activity have been found in the case of DM UMa, another active member of the RS CVn system (Mohin *et al.* 1985).

The minima observed by Chugainov in 1974 follow a completely different path indicating that the corresponding activity had a different latitude and longitude. Again the recent photometry (figure 3) shows that the two minima observed do not fall on any of the two lines and hence probably are due to different active regions formed later.

5. Fractional light loss

Recently, Mohin *et al.* (1985) have suggested that in terms of the solar analogy, the fractional loss of light integrated over a photometric period would be a better

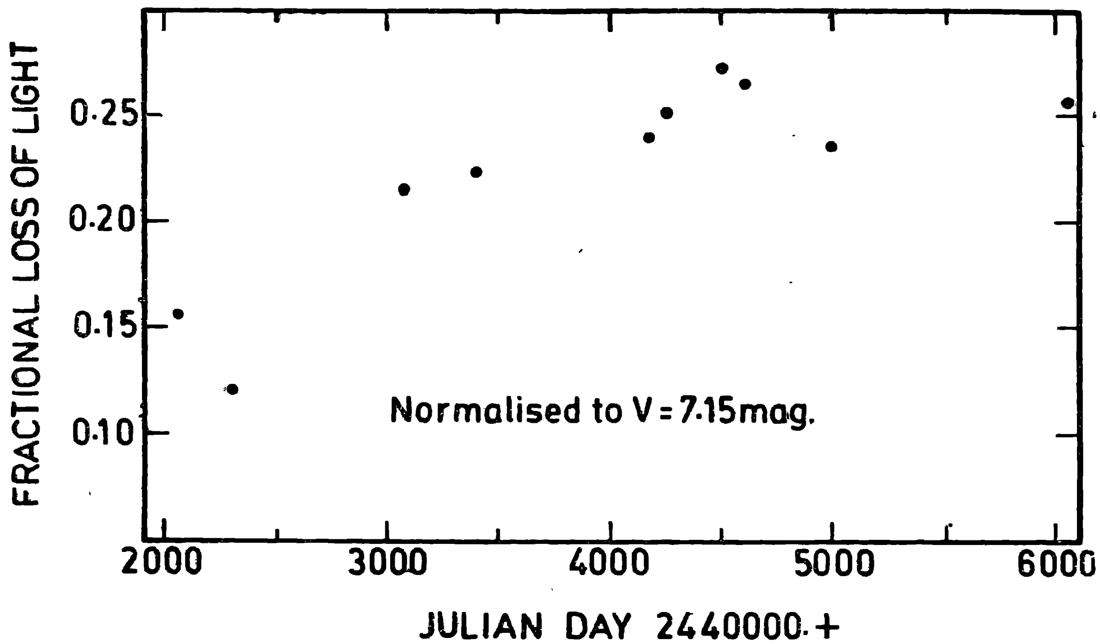

Figure 6. Relative fractional light loss in *V* versus mean Julian date.

index for the activity level than the amplitude of the photometric wave usually referred to. In figure 6 we have plotted the fractional loss of light taking $V = 7.15$ mag as the reference level which is the highest maximum so far observed. Choice of any other reference magnitude to represent the unspotted photosphere would not cause any change in the nature of the curve except a vertical shift. It is evident that from JD 2442000 to JD 2444000 fractional loss of light showed an increasing trend and then remained nearly constant till JD 2446070 corresponding to the epoch of recent observation.

For a better understanding of the evolution of the 'active regions' and their life times, we need more frequent observations of this system in wide wavelength regions, which are planned.

Acknowledgements

We are grateful to the late Dr. M. K. V. Bappu and Dr. J. C. Bhattacharyya for their kind encouragement during the course of this work.

References

Bohusz, E. & Udalski, A. (1981) *Acta Astr.* **31**, 185.
Bopp, B. W. & Noah, P. V. (1980) *Publ. Astr. Soc. Pacific* **92**, 333.
Bopp, B. W. (1982) *IAU Coll. No.* 71 : *Activity in Red-Dwarf Stars*, Reidel, p. 363.
Chugainov, P. F. (1976) *Bull. Crim. Ap. Obs.* **54**, 89.
Hall, D. S. (1976). *IAU Coll. No.* 29: *Multiple Periodic Variable Stars*, Reidel, p. 287.
Halliday, I. (1952) *J. R. Astr. Soc. Canada* **46**, 103.

Mohin, S. *et al.* (1985). *Ap. Sp. Sci.* **115**, 353.
Nations, H. L. & Ramsey, L. W. (1981). *Astr. J.* **86**, 433.
Raveendran, A. V., Mohin, S. & Mekkaden, M. V. (1981). *M.N.R.A.S.* **196**, 289.
Rodono, M., Pazzani, V. & Cutispoto, G. (1982). *IAU Coll. No.* 71: *Activity in Red-Dwarf Stars*, Reidel, p. 179.
Rucinski, S. M. (1977). *Publ. Astr. Soc. Pacific* **89**, 280.
Schwartz, D. A. *et al.* (1980). *Bull. Am. Astr. Soc.* **12**, 513.
Spangler, S. R., Owen, F. N. & Hulse, R. A. (1977). *Astr. J.* **82**, 169.
Vogt, S. S. (1981) *Ap. J.* **247**, 975.
Walter. F. M., Cash, W., Charles, P. A. & Bowyer, C. S. (1980) *Ap. J.* **236**, 212.