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BV photometry and Hα spectroscopy of the RS Canum Venaticorum binary II Pegasi

S. Mohin and A.V. Raveendran

Indian Institute of Astrophysics, Bangalore 560034, India

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Abstract. Differential *BV* photometry of II Peg obtained on a total of 57 nights during the years 1986–1991 and Hα spectroscopy obtained on 12 nights during the 1990–1991 observing season are presented. From an analysis of the available data on this object we find that significant changes in the mean light level of the system occur from season to season. The maximum light level had maintained a value less than or equal to 7.35 mag during 1976–1983, but after a drop in 1985 it has shown a slight increase from 1986 onwards. At larger amplitudes the brightness at minimum is found to decrease and the brightness at maximum to increase. During the period 1974–1991 we could identify a total of six spots or spot groups from the migration of the $\phi_{\rm min}$ and their life times range from two to seven years. The light curve obtained during 1989–1990 season was modelled assuming that the light variation is caused by a single circular spot. The resulting spot parameters reproduce the *V* and *B* light curves reasonably well; however, a substantial fraction of the spot lies in the invisible hemisphere indicating that the approximation of the spot or spot group by an equivalent circular spot is not valid. The Hα equivalent widths show a strengthening near the minimum of the light curve. The spectra obtained on one night (22 Nov 1990) show evidence of an optical flare.

Key words: stars: activity – binaries: spectroscopic stars: chromospheres – stars: individual: II Peg – stars: late-type – stars: variable

1. Introduction

The RS Canum Venaticorum binary II Peg (= HD 224085 = BD + 27° 4642) consists of a visible K2 IV primary and a spectroscopically invisible secondary. Several studies in different wavelength regions by many investigators (Spangler et al. 1977; Walter et al. 1980; Schwartz et al. 1980; Raveendran et al. 1981; Rodono et al. 1987; Andrews et al. 1988; Byrne et al. 1989; Huenemoerder et al. 1989; Rodono & Cutispoto 1992 and references therein). In addition to strong Ca II, H and K, and Hα emissions, the solar flare diagnostic line λ5876 of He I has also been detected in emission in the spectrum of II Peg (Buzasi et al. 1991). Simultaneous photometry and spectroscopy indicate a strong correlation between the light variation and the strengths of TiO bands (Bopp & Noah 1980; Huenemoerder et al. 1989; Buzasi et al. 1991). The most important evidence for the rotational modulation of plages in the case of RS CVn stars was provided by the IUE observations of II Peg which showed a clear enhancement of chromospheric and transition region lines centered about the light curve minimum (Rodono et al. 1987; Andrews et al. 1988; Byrne et al. 1989).

We observed II Peg as part of an on-going long-term photometric programme of RS CVn systems and related objects. In this paper we present *BV* photometry obtained during the years 1986–1991 and Hα spectroscopy obtained during the 1990–1991 observing season, and discuss the results.

Send offprint requests to: S. Mohin

2. Observations and data reduction

2.1. *BV* photometry

Photometric observations of II Peg were made on a total of 57 nights during the five observing seasons 1986–1987 (17 nights), 1987–1988 (10 nights), 1988–1989 (6 nights), 1989–1990 (16 nights), and 1990–1991 (8 nights) with the 34 cm reflector of Vainu Bappu Observatory, Kavalur (VBO) using standard *B* and *V* filters. HD 223094 (K2) and HD 224895 (K0) were observed along with the variable as comparison stars. The observations were made differentially with respect to HD 223094 and were transformed to the Johnson's *UBV* system. The average magnitude and $B-V$ of HD 223094 determined by us are 6.957 ± 0.013 and 1.621 ± 0.006, respectively. These values are used to convert the differential magnitudes and colours of II Peg to magnitudes and colours which are listed in Table 1. The typical uncertainty in the measurements of the differential magnitudes and colours is ~0.01 mag. Each value given in Table 1 is a mean of three to four independent measure-

Table 1. Magnitudes and colours of II Peg

J.D. (Hel) 2440000.+	V	$(B-V)$	J.D. (Hel) 2440000.+	V	$(B-V)$
1986–1987 Observing season					
6801.1340	7.515		6821.1020	7.601	
6802.1180	7.349	1.034	6823.1248	7.374	
6803.1145	7.326	1.032	6824.0946	7.427	
6804.0958	7.403	1.061	6825.0858	7.462	
6816.1134	7.342		6828.0824	7.510	
6817.1032	7.384		6830.0885	7.326	
6818.0958	7.423		6831.0852	7.394	
6819.0995	7.554	1.084	6832.0916	7.462	
6820.1115	7.722				
1987 – 1988 Observing season					
7175.0861	7.491		7184.1076	7.370	1.041
7176.0875	7.509		7185.0941	7.412	1.036
7178.1078	7.417	1.037	7201.0829	7.450	
7179.0985	7.480		7202.0829	7.496	
7183.0847	7.466		7203.0970	7.461	
1988–1989 Observing season					
7556.0771	7.581		7559.0814	7.419	
7557.0881	7.751	1.084	7560.0828	7.313	
7558.0847	7.731		7561.0833	7.346	
1989–1990 Observing season					
7852.2499	7.527	1.058	7895.1142	7.700	1.052
7853.1379	7.709	1.069	7896.0834	7.564	1.052
7854.0917	7.746	1.076	7912.1025	7.431	1.050
7855.1629	7.661	1.074	7913.0887	7.581	1.056
7856.0897	7.472	1.044	7916.0809	7.610	1.080
7867.0901	7.726	1.087	7917.0839	7.417	1.038
7877.1769	7.350	1.063	7918.0830	7.378	1.023
7878.1659	7.391	1.040	7919.0799	7.463	1.051
1990–1991 Observing season					
8280.0803	7.476	1.033	8299.0830	7.603	
8281.0769	7.445	1.059	8300.0846	7.545	1.042
8297.0848	7.484	1.091	8301.0936	7.459	1.098
8298.0834	7.526	1.058	8302.0874	7.523	1.079

ments. The Julian days of observation given in Table 1 are converted to orbital phases using the ephemeris (Raveendran et al. 1981):

$$\text{JD (hel.)} = 2443030.396 + 6\overset{\text{d}}{.}724464\ \text{E},$$

where the zero phase corresponds to the conjunction with the visible K2 IV primary in front and the period is the spectroscopic orbital period.

2.2. *Hα observations*

Hα region spectra of II Peg were obtained on a total of 12 nights during the 1990–1991 observing season, near simultaneously with the photometry obtained during that season. Observations were made with the Zeiss Cassegrain 102 cm telescope of the VBO using a Carl-Zeiss Universal Astronomical Grating Spectrograph (UAGS) with a Bausch and Lomb 1800 lines mm^{-1} grating blazed at 5000 Å in the first order. The detector used was a Thomson–CSF TH 7882 CCD chip coated for enhanced sensitivity to ultraviolet radiation and mounted in a liquid-nitrogen-cooled dewar. The data acquisition was done using a "Photometrics CCD system" supplied by Photometrics Ltd., USA. The UAGS setup with a 250 mm Schmidt camera gives a dispersion of ≈ 0.50 Å pxl^{-1} at Hα region. The slit width was set to give a projected width of around 2 pxl. Wavelength calibrations were carried out using a Fe–Ne hollow cathode tube.

The spectroscopic data were analysed on a VAX 11/780 computer using the interactive package RESPECT developed locally at VBO (Prabhu & Anupama 1991). The spectrum extraction procedures in RESPECT are based on optimal extraction algorithm discussed by Horne (1986).

Table 2. Hα data of II Peg

Date	JD (Hel.) 2440000.+	Phase	EW1 (Å)	FWHM (Å)	Height	EW2 (Å)
08 Oct 1990	8173.2549	0.799	0.80	2.68	0.33	−0.19
08 Oct 1990	8173.3365	0.811	0.61	2.27	0.28	−0.55
10 Oct 1990	8175.3431	0.109	1.40	3.02	0.54	+0.23
11 Oct 1990	8176.2889	0.250	0.77	2.09	0.36	−0.44
11 Oct 1990	8176.3323	0.256	0.66	1.83	0.35	−0.90
22 Nov 1990	8218.1413	0.474	1.93	3.62	0.53	+1.05
22 Nov 1990	8218.2198	0.485	1.62	3.31	0.50	+0.49
23 Nov 1990	8219.0945	0.615	0.93	2.99	0.32	−0.08
28 Nov 1990	8224.1602	0.369	1.25	2.75	0.46	+0.19
29 Nov 1990	8225.1694	0.519	0.88	2.11	0.40	−0.44
30 Nov 1990	8226.1934	0.671	0.61	1.83	0.32	−1.07
07 Jan 1991	8264.1375	0.314	0.70	2.13	0.33	−0.71
08 Jan 1991	8265.1278	0.461	0.57	2.04	0.27	−0.70
07 Feb 1991	8295.1049	0.919	0.45	1.60	0.29	−0.98
08 Feb 1991	8296.0785	0.064	0.49	1.77	0.27	−0.71

Only observations with a signal to noise ratio S/N ~ 100 were included in the analysis. The integration times ranged from 30 to 45 min for these spectra. In a few cases individual spectra with poor S/N ratio were co-added to improve the S/N ratio. In such cases each spectrum was individually extracted and then added after wavelength calibration. All the spectra were normalized to the continuum level defined in each spectrum by a straight line fit to the relatively line-free stable points.

The spectral resolution of the present observations is not good enough for a detailed profile analysis and hence we have concentrated our efforts only on equivalent width measurements. Two different estimates of Hα equivalent widths have been made from the programme star spectra; the first (denoted by EW1) was obtained by integrating the Hα emission profile above the continuum, and the second (denoted by EW2, cf. Fraquelli 1984) by subtracting the area below the continuum from the area above the continuum in the wavelength interval $\lambda\lambda 6550-6580$.

In order to estimate the errors in the measurement of equivalent widths, a few standard stars of late spectral types were also observed on several nights. The equivalent widths EW2 obtained for these objects show that the method entails an uncertainty of ~0.2 Å. In both cases EW1 and EW2, the wavelengths for the integration were visually set on the computer monitor. To ascertain the consistency of the method independent measurements were made on the same spectra, and the measured EWs did not differ by more than 0.05 Å.

Table 2 gives the log of observations; it contains the Julian day of observation along with Hα emission equivalent width (EW1), full width at half maximum of Hα emission (FWHM), height of the Hα emission in terms of F_λ/F_c, the photometric phase reckoned from the ephemeris of Raveendran et al. (1981), and the equivalent width EW2.

3. Discussion

3.1. Light curves

The V observations and their mean epochs are presented in Table 1 and are are plotted in Fig. 1. The observations obtained during 1986–1987 season show that the shape of the light curve has undergone remarkable changes from that of the earlier season's light curve (Wacker & Guinan 1986; Byrne 1986; Boyd et al. 1987; Strassmeier et al. 1989). The amplitude is 0.4 mag, and the light minimum (V=7.722) and maximum (V=7.326) occur at 0^{p}50 and 0^{p}00, respectively. The amplitudes of the light curve just before and after 1986–1987 season were only around 0.20 mag (see Table 3).

Though the number of observations made during the 1988–1989 season is limited, the light curve is clearly defined close to both the minimum and maximum, which occur around 0^{p}25 and 0^{p}65 respectively. The amplitude is around 0.44 mag. The light curve obtained by Casas et al. (1989) immediately after our observations registered the highest so far observed amplitude of 0.50 mag. Doyle et al. (1988) also have reported a similar value for the amplitude around 1986.78, but the observational uncertainty in their case is of the order of 0.04 mag. Casas et al. (1989) have also reported that the system's maximum brightness during their observations was 7.250 mag, which is close to the value of 7.20 mag in 1974 (Chugainov 1976). The amplitude of light variation during 1989–1990 season is around 0.39 mag; the light maximum and minimum occur at 0^{p}80

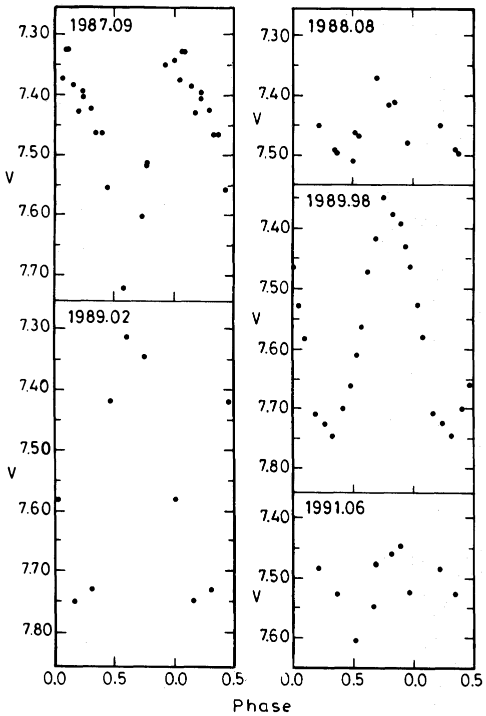

Fig. 1. The V light curves of II Peg obtained during the years 1986–1991. Phases are reckoned from JD (Hel.) 2443030.396 using the period 6^d.724464

and 0^p.35, respectively. Figure 2 is the plot of $B-V$ given in Table 1 against the corresponding observed visual magnitude. There is apparently no strong correlation between the $B-V$ colour and the visual brightness of II Peg; but there is a scatter of about 0.10 mag which is much larger than the expected observational uncertainty.

The photometric properties derived from the present observations together with those compiled from various sources are given in Table 3. Most of the quantities given in the table were evaluated from graphical plots of the observations. The ephemerides of Raveendran et al. (1981) were used throughout for our analysis.

3.2. *Brightness at light maximum and minimum*

Figure 3 is a plot of the brightness at light maximum V_{max} and minimum V_{min} from Table 3 against the corresponding amplitude. An inspection of Fig. 3 clearly reveals that at larger amplitudes the brightness at minimum decreases and the brightness at maximum increases. Chugainov's observations however do not conform to this trend. As argued by Vogt (1981), it may possibly be due to a zero-point magnitude difference between Chugainov's and the others' photometry. The behaviour of II Peg, as seen in Fig. 3, is similar to that seen in the case of UX Ari

Table 3. Photometric characteristics of II Peg

Epoch	Amplitude	V_{max}	V_{min}	Phase min	References
1974.05	0.10	7.284	7.424	0.15	Chugainov (1976)
1974.65	0.32	7.200	7.500	0.15	Chugainov (1976)
1976.80	0.26	7.350	7.595	0.07	Rucinski (1977)
1977.65	0.42	7.350	7.773	0.90	Vogt (1979)
1979.82	0.17	7.430	7.598	0.65	Nations & Ramsey (1981)
				0.25	
1980.00	0.15	7.425	7.600	0.75	Raveendran et al. (1981)
				0.25	
1980.70	0.17	7.530	7.650	0.65	Bohusz & Udalski (1981)
				0.08	
1980.73	0.17			0.05	Hall & Henry (1983)
1980.97	0.22	7.440	7.660	0.00	Mohin et al. (1986)
				0.65	
1981.75	0.27			0.83	Rodono et al. (1983)
1981.76	0.22			0.77	Lines et al. (1983)
1981.83	0.20			0.69	Zeilik et al. (1982)
1982.05	0.29	7.360	7.656	0.70	Mohin et al. (1986)
1982.10	0.24			0.72	Henry (1983)
1983.10	0.11			0.77	Andrews et al. (1988)
1983.63	0.09			0.66	Evren (1988)
				0.10	
1983.76	0.05			0.74	Evren (1988)
				0.14	
1984.60	0.16			0.34	Evren (1988)

Table 3 (continued)

Epoch	Amplitude	V_{max}	V_{min}	Phase min	References
1984.63	0.12	7.483	7.623	0.35	Byrne et al. (1989)
				0.65	
1984.65	0.12	7.460	7.606		Kaluzny (1984)
1984.68	0.15			0.55	Arevalo et al. (1985)
1985.00	0.23			0.76	Strassmeier et al. (1989)
1985.01	0.20	7.390	7.590	0.70	Mohin et al. (1986)
				0.35	
1985.87	0.23			0.57	Boyd et al. (1987)
				0.24	
1985.88	0.21			0.24	Wacker & Guinan (1986)
				0.72	
1986.00	0.29			0.29	Strassmeier et al. (1989)
				0.71	
1986.77	0.47	7.322	7.791	0.65	Cutispoto et al. (1987)
1986.78	0.50	7.220	7.800	0.60	Doyle et al. (1988)
1986.80	0.45	7.325	7.775	0.58	Byrne (1986)
1986.90	0.40	7.290	7.690	0.63	Mekkaden (1987)
1986.96	0.40			0.57	Boyd et al. (1987)
				0.24	
1987.09	0.40	7.326	7.722	0.50	Present study
1987.92	0.15			0.23	Cano et al. (1987)
1987.79	0.27				Evren (1990)
1988.65	0.30			0.32	Evren (1990)
1988.78	0.41			0.65	Pajdosz et al. (1989)
1988.91	0.43			0.22	Cutispoto et al. (1989)
1989.02	0.44	7.310	7.750	0.25	Present study
1989.07	0.50	7.250	7.750	0.24	Casas et al. (1989)
1989.31	0.46			0.27	Evren (1990)
1989.50	0.43			0.38	Cutispoto et al. (1989)
1989.61	0.42			0.32	Evren (1990)
1989.98	0.39	7.350	7.740	0.35	Present study
1991.06			7.603	0.50	Present study

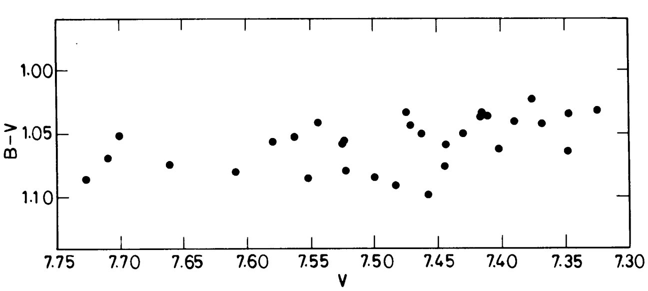

Fig. 2. Plot of $B-V$ against the corresponding V

and V711 Tau, two other active RS CVn stars (Mohin & Raveendran 1989, 1993 and references therein).

To find out the time variations in the brightness at light curve maximum and minimum the V_{max} and V_{min} given in Table 3 are plotted in Fig. 4 against the corresponding epoch of observations. As can be seen from Fig. 4 significant changes in the mean light level of the system occur from season to season. The maximum light level V_{max} has maintained a value less than or equal to 7.35 mag during 1976–1983. However, V_{max} and V_{min} show a tendency to increase and decrease, respectively (see Rodono & Cutispoto 1992) from 1985 onwards.

3.3. *Phase of light minimum and amplitude*

To find out the evolution of starspots or starspot regions we have plotted the phase of light minimum (ϕ_{min}) and V amplitude of light variation given in Table 3 against the corresponding mean epoch of observation in Figs. 5 and 6, respectively.

An inspection of Fig. 5 clearly shows that on most occasions during the period 1974–1991 there were two

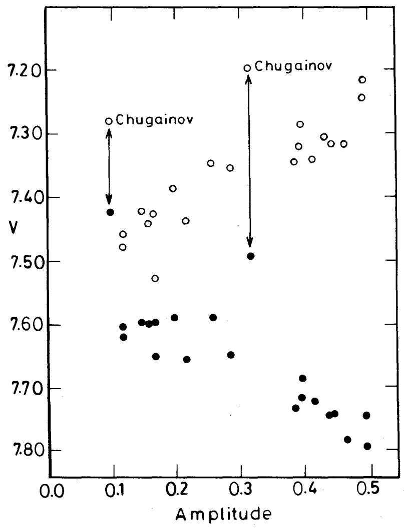

Fig. 3. Plot of the brightness at light maximum (open circles) and light minimum (filled circles) against the V amplitude during the period 1974–1991

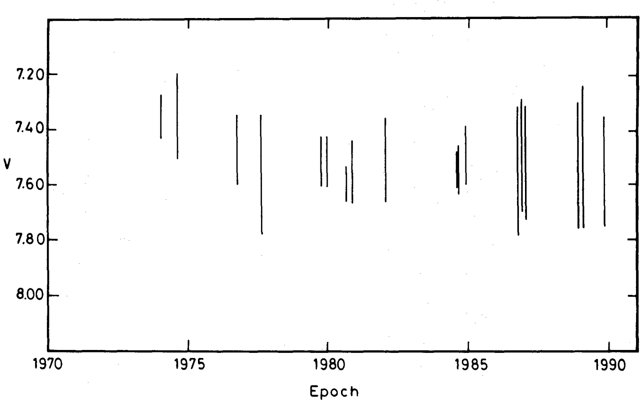

Fig. 4. Long-term V variability of II Peg. The vertical bars indicate the peak-to-peak amplitude of the light curves during the period 1974–1991

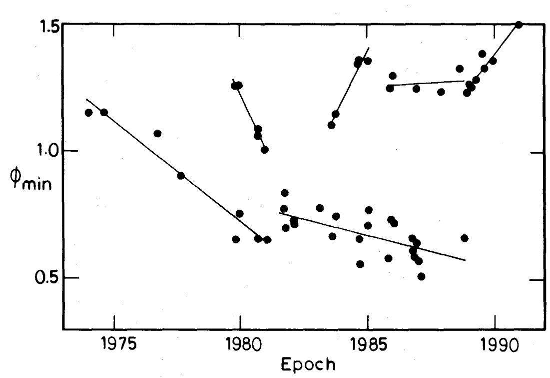

Fig. 5. Plot of the phase of light minimum versus mean epoch of observation

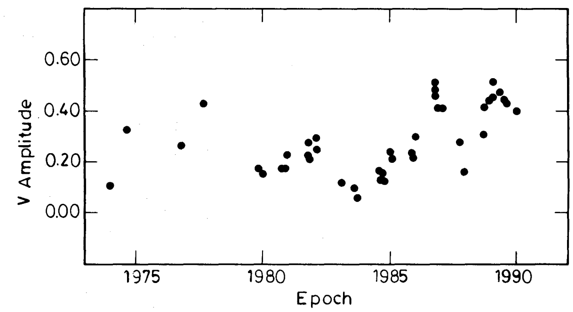

Fig. 6. Plot of V amplitude against the mean epoch of observation

prominent spots or spot groups present, as indicated by two light minima in the light curves. We could identify a total of six spots or spot groups from the migration of ϕ_{min}. Their life times (as indicated by the time interval during which a spot or spot group can be continuously traced from its slowly changing ϕ_{min}) range from two to seven years. The difference between their photometric periods and the orbital period indicates a range from -0.0037 to $+0.0042$ for $\Delta P/P$. Here Δ is in the sense photometric minus orbital period. A study of the available photometry from 1974–1981 by Rodono et al. (1983) have indicated that the two main features of the light curve, namely, the phase of light maximum and minimum migrate towards decreasing orbital phases at different rates (0.23 and 0.03 period per year respectively), with the minimum being almost synchronous with the orbital motion. They have argued that the difference in the migration rates produce the observed changes in the light curve, i.e. from almost sinusoidal, to asymmetric, to double-peaked to almost flat. But, if reference is made only to light minima and to a more extended period than that considered by Rodono et al. (1983), it is obvious (Fig. 5) that the phase migration of the light minima show both direct and retrograde motions.

Figure 6 shows that the amplitude of light curve is highly variable. In a recent analysis Evren (1990) has claimed that the amplitude variation is cyclic and the period is roughly four years. However, it is clear from the figure that II Peg had minimum amplitudes in 1980, 1984, 1988, whereas the maximum amplitudes occurred in 1978, 1982, 1987 and 1989 which are not separated by four years.

In a recent analysis of starspot lifetimes based on 40 spots or spot groups on 17 stars, Hall (1990) has argued that smaller spots (radius $<20°$) die before they can be disrupted by differential rotation, but larger spots are disrupted by differential rotation. He has proposed the following two scenarios: (i) a large spot, which originates in a rigidly rotating deep layer, is magnetically disconnected after a while and is disrupted by the characteristic of surface differential rotation, or (ii) a large spot is not disconnected magnetically but the deeper layers from which it originates has approximately the same differential rotation law as the surface layers. In the case of II Peg, the discontinuities in the migration which are interpreted as the disappearance (or weakening) of the existing spot or spot group and the appearance (or strengthening) of a new spot or spot group (Mekkaden et al. 1982; Hall 1990) indicate lifetimes in the range 2–7 yr. According to Hall's scenario this implies the formation of both large and small spots on the surface of II Peg.

3.4. Spot modelling

There are many difficulties in modelling the observed light curves. One of the basic parameters involved in spot modelling is the brightness of the immaculate or the unspotted photosphere. It is very difficult to assign the unspotted magnitude since the brightness at light curve maximum has been found to vary in almost all well observed systems (Mohin & Raveendran 1992). A starspot model can account for the variation in brightness at light maximum by either of the two phenomena that are likely to occur on the surface of active stars: (i) changes in the longitudinal distribution of spots in the equatorial region, or (ii) changes in the area of spots in the polar region. Different values for the unspotted magnitude have been used in the modelling of the light curves of II Peg (Vogt 1981; Poe & Eaton 1985; Rodono et al. 1986). The highest value of $V_{max} = 7.20$ mag reported in the literature was obtained by Chugainov (1976) in 1974. While modelling the light curve obtained by him, Vogt (1981) found that satisfactory results could not be obtained with this value for the unspotted magnitude. So he argued that Chugainov's data suffer from a zero point error when compared to others' data also because the unspotted V magnitude was close to $V = 7.35$ mag and showed a flat maximum. Vogt's argument need not be a sufficient reason to question Chugainov's observation because Casas et al.'s (1989) value (7.25 mag) is close to Chugainov's value of 7.20. So in the present analysis Chugainov's values of $V = 7.20$ mag and $B = 8.22$ mag were assumed to represent the unspotted photosphere. Using the method described for the case of DM UMa (Mohin & Raveendran 1992), we have modelled the observations obtained during 1989–1990. These observations were chosen because during that season sufficient data were obtained in both B and V bands and we could include also the temperature as an unknown in the least square analysis.

II Peg is a single-lined spectroscopic binary and hence the orbital inclination i is unknown. Spot parameters were derived using $i = 45°$ and $75°$. The effective temperature of the undisturbed photosphere was assumed to be 4600 K. Calculations were carried out with the same quadratic limb-darkening law for both the spots and undisturbed photospheric region. We used the following coefficients: $A = 0.785$ and $B = 0$ for V band, and $A = 1.080$ and $B = -0.230$ for B band. The above values were derived by interpolations from the table given by Manduca et al.

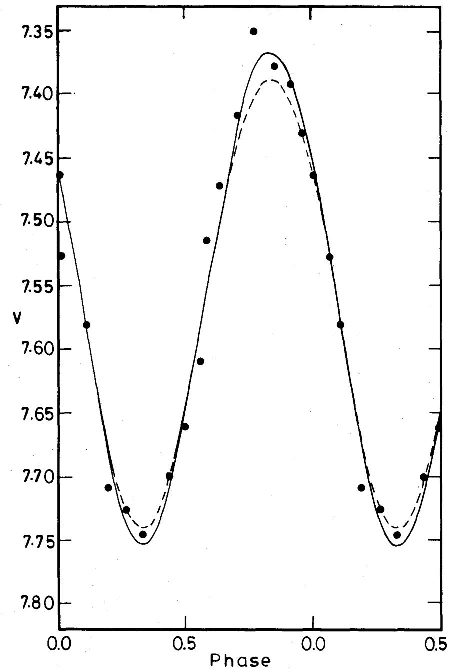

Fig. 7. The 1989.98 V light curve of II Peg along with the corresponding best fit computed curves for the assumed orbital inclinations $i = 45°$ (broken) and $i = 75°$ (continuous). Phases are reckoned as in Fig. 1

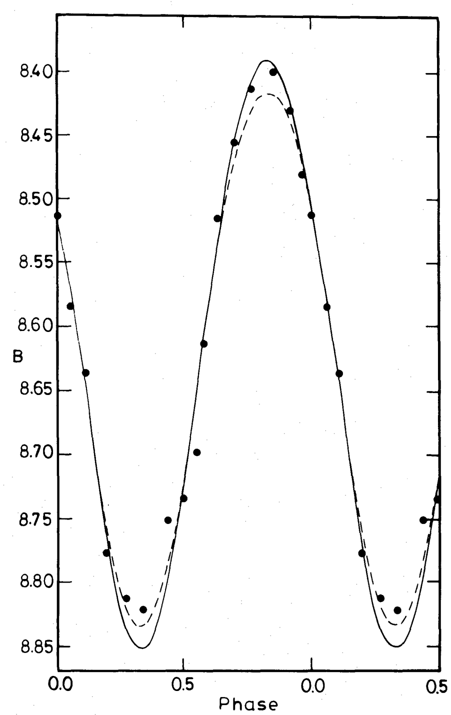

Fig. 8. The 1989.98 B light curve of II Peg along with the corresponding best fit computed curves for the assumed orbital inclinations $i = 45°$ (broken) and $i = 75°$ (continuous). Phases are reckoned as in Fig. 1

Table 4. The spot parameters derived for the light curves of II Peg for 1989–90 season

	Inc. (i) = 45°	Inc. (i) = 75°
Polar distance (degrees)	161.4 ± 0.7	164.0 ± 0.7
Longitude (degrees)	118 ± 1	119 ± 1
Radius (degrees)	118.0 ± 1.0	95.0 ± 1.4
Temperature (K)	3780 ± 55	3750 ± 80
Fractional area	0.735 ± 0.008	0.541 ± 0.012
s. d. of fit (mag)	0.019	0.022

(1977) for the solar composition. The computed best fit V and B light curves are shown in Figs. 7 and 8 along with the observed values. The results of the least square analysis are given in Table 4. The standard deviations of the fit in the two cases are nearly identical and there is a close agreement in the derived polar distances, longitudes and temperatures. However, there is a large difference in the value of the derived spot radii. In both cases a substantial fraction of the spots lies in the invisible portion of the stellar surface, the fraction being largest for $i = 45°$. Doyle et al. (1988) have suggested a more complex triangular distribution of spots to account for the large amplitude light variation observed during Sep – Nov 1986.

3.5. *Hα observations*

The Hα observations show that the emission is variable and it is strongly anticorrelated with the photometric phase. The average values of EW1 and FWHM are ~0.91 Å and ~2.40 Å respectively. The nightly EW1 values range from 0.61 to 1.93 Å. Bopp & Noah's (1980) observations obtained during 1978 show a large scatter in equivalent width (EW) ranging from ≈0.2 to ≈2.0 Å, with a tendency to cluster in phase. Ramsey & Nations (1984) have reported Hα EW values ranging from −0.07 to 1.94 Å obtained during 1981 at two different spectral resolutions (≈1 and 0.5 Å). Observations during July 1984 indicate EW values from 0.69 to 1.39 Å (Byrne et al. 1989). While spectra obtained on five consecutive nights (Nov–Dec 1984) showed a monotonically decreasing EW values from 1.22 to 0.64 Å, a single spectra obtained after three weeks showed the EW to be 0.86 Å (Liu & Tan 1987). The observations given in Table 2 and plotted in Fig. 9 clearly show that the star was monitored at almost all the orbital phases.

An inspection of Fig. 9 indicates that II Peg shows a very strong and asymmetrical Hα emission line. Moreover, all earlier investigators of II Peg have remarked on

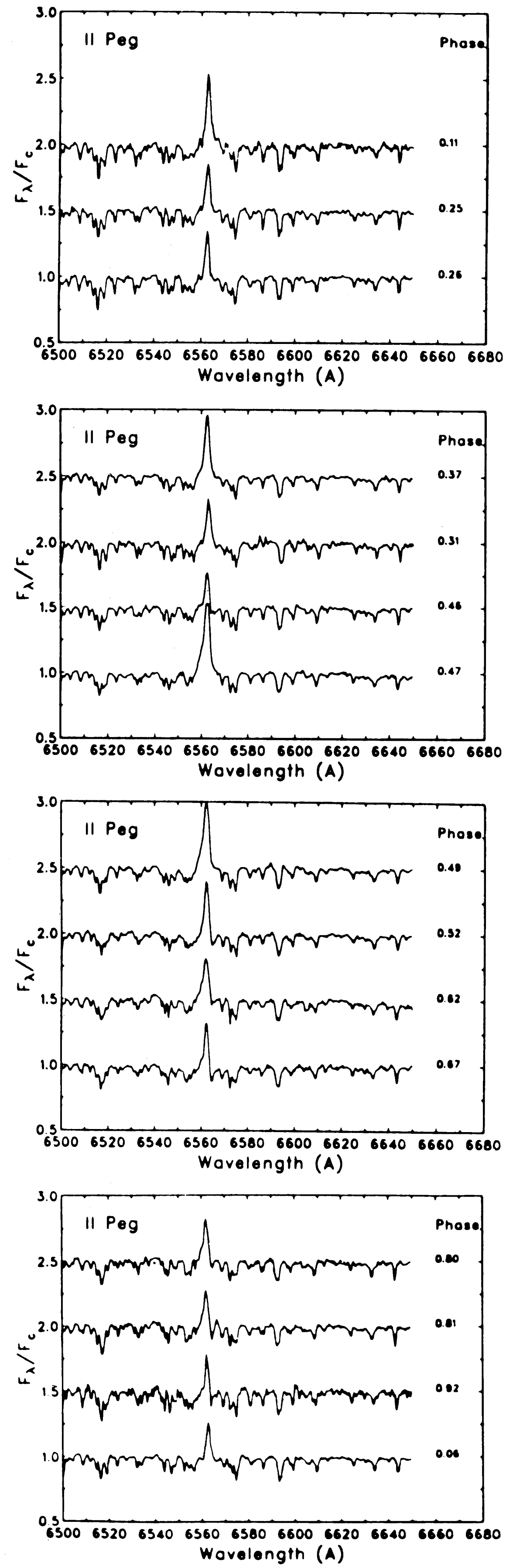

Fig. 9. Hα spectra of II Peg. The spectra are adjusted in wavelength to line up the absorption lines. Each spectrum is normalized to continuum and shifted by 0.5. Phases are reckoned as in Fig. 1

the variability of the Hα profile. Our data confirm the observations of Vogt (1981) who reported that *the notch* in the profile occurs precisely at the nominal Hα rest wavelength with respect to the absorption lines and the centroid of the emission lies blueward. The emission is always fixed in wavelength with respect to the absorption lines and occurs at the expected position of Hα. This clearly demonstrates that the emission is associated with the visible K2 IV primary without any contamination.

Spectroscopic studies by Bopp & Noah (1980) have shown that the Hα emission strength is well correlated with the photometric phase in the sense that the emission is more intense near the light curve minimum. They have also noted several sudden *flare-like* enhancements of Hα with decay times up to several days. We attempted to have near-simultaneous photometry and spectroscopy. Due to the unfavourable sky conditions we could begin the photometry of the star only three months after the beginning of the spectroscopic observations. Though the phase coverage is incomplete, the light curve is well-defined near the light minimum. The Hα EW1 in Table 2 is plotted in Fig. 10 along with the V light curve. It is evident from this figure that the emission is variable and there is a strong anticorrelation. It is interesting to see that all values of EW1 except four are below 0.90 Å. Out of these four, two values fall at the same ordinate with a difference of 0.3 Å. These two values were obtained on the same night, namely, on 22 Nov 1990. Recently, Buzasi et al. (1991) have concluded that II Peg appears to flare approximately once in every five hours. Their conclusion is based on rapidly changing He D_3, Hα and Hβ emissions obtained on a single night. Moreover, Fig. 10 indicates that II Peg shows a tendency for flaring up close to the photometric minimum, i.e. when the spotted region is in the visible hemisphere.

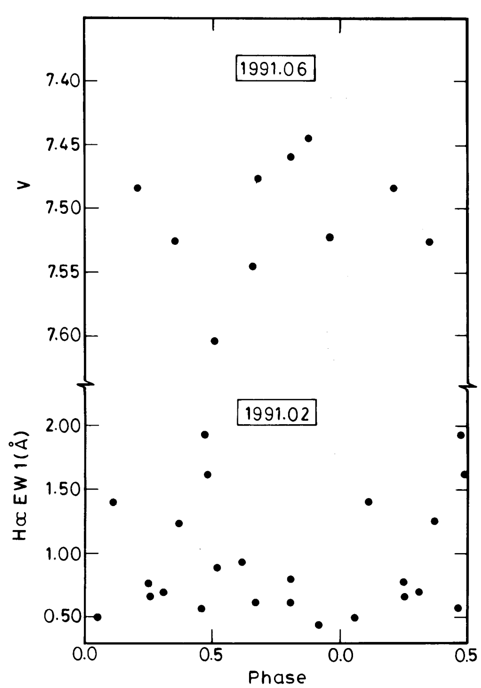

Fig. 10. Top panel shows the V light curve and the bottom panel the variation of EW1. Phases are reckoned as in Fig. 1. The mean epochs of observation are indicated in the figure

4. Conclusions

The differential BV photometry of II Peg obtained on a total of 57 nights during the years 1986 – 1991 and Hα spectroscopy obtained on 12 nights during the 1990 – 1991 observing season are presented. The light curves of II Peg are mostly asymmetrical in shape and rapid changes occur in the mean light level of the system from season to season. Its maximum light level was close to 7.35 mag during 1976–1983, but after a drop in 1985 it has shown a slight increase from 1986 onwards.

The behaviour of ΔV_{max} and ΔV_{min} in relation to the amplitude of light variation has been analysed. At larger amplitudes the brightness at minimum decreases and the brightness at maximum increases, both converging to a particular value of ΔV at very low amplitudes. In terms of the starspot model this implies, qualitatively, either of the following scenarios as suggested by Bartolini et al. (1983): (i) At lower amplitudes, spots are evenly distributed in longitudes and are predominantly present at higher latitudes and hence are seen through out the entire rotational period. (ii) At higher amplitudes, spots are more concentrated about some longitude and are predominantly located at lower latitudes and hence disappear from view during a fraction of the rotational period.

We have investigated the behaviour of the phase of light minimum over the years. II Peg shows both direct and retrograde migrations of the phase of light minimum. We could identify a total of six spot groups during the period 1974–1991. On most occasions there were two prominent spot groups present. Observations of II Peg indicate a lifetime of two to seven years for a spot forming region.

The Hα emission equivalent widths in II Peg indicate a modulation with the photometric phase in the sense that the emission equivalent width is more intense near the light curve minimum. The spectra of II Peg obtained on 22 Nov 1990 show strong evidence of a flare. The present observations do indicate a strong relationship between spot activity as implied by the optical light curve, and chromospheric activity as implied by the Hα emission equivalent width variation.

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