COMMISSION 27 OF THE I. A. U.
INFORMATION BULLETIN ON VARIABLE STARS

Number 3032

Konkoly Observatory
Budapest
8 June, 1987

HU ISSN 0374-0676

AUTUMN 1981 PHOTOMETRY OF THE RS CVn BINARY II PEGASI

II Pegasi (HD 224085; K2 IV) is an active, non-eclipsing RS CVn-type binary. The periodic light variability of this spotted star was discovered by Chugainov (1976), and subsequently confirmed by Rucinski (1977). A number of photometric investigations followed, demonstrating the extensive variety in the light curves of II Peg characterized by seasonal changes in maximum, mean, and minimum light, as well as in the phases of the light extrema. Using the Harvard archival plate collection, Hartmann, Londono, and Phillips (1979) showed that in the 40 years prior to 1945, II Peg was essentially constant in mean light, after which short and long term variability has been present. II Peg has been observed in V to be as bright as +7.19 mag (Chugainov 1976), and as faint as +7.78 mag (Vogt 1981a). The V-band light amplitude has ranged from 0.12 mag (Kaluzny 1984) to 0.45 mag (Byrne 1986). Analyzing the available light curves obtained between 1974 and 1981, Rodono, Pazzani, and Cutispoto (1983) determined that maximum and minimum light migrate towards decreasing orbital phases at different rates (0.23 and 0.03 period/year, respectively), with light minimum and the orbital motion essentially synchronized. Spectroscopically, Bopp and Noah (1980) observed the H-alpha emission of II Peg to be enhanced during maximum visibility of the spotted regions (i.e. photometric minimum). Spectra of the molecular absorption features of VO and the gamma system of TiO obtained by Vogt (1981a) for II Peg unambiguously revealed the spotted regions to be cooler than the surrounding photosphere. Subsequent light curve modeling by Vogt (1981b) determined the spots to be cooler by 1200 $\pm$ 100 K. Also, II Peg is a coronal soft X-ray source (Walter et al. 1980), a transient hard X-ray source (Schwartz et. al. 1981), and a radio emitter at centimeter wavelengths (Owen and Gibson 1978).

Intermediate and narrow band photoelectric observations of II Peg were obtained at Villanova University Observatory on 12 nights, from October 13 through December 01 UT, 1981.

A description of the instrumentation, observing procedure, data reduction technique, and a discussion of the differential color and H-alpha indices is given elsewhere (Dorren, Guinan, and McCook 1984). The comparison star was the same as used by Wacker and Guinan (1986). Nightly mean differential magnitudes were computed, in the sense variable minus comparison, for the intermediate band blue (λ 4530), red (λ 6585), far red (λ 7790), and narrow band H-alpha red (λ 6568) filters, from which nightly mean differential color and H-alpha indices were computed. The seasonal mean errors for the nightly $\lambda\lambda$ 4530, 6585, 7790, and H-alpha narrow band data sets are, respectively: 0.011, 0.008, 0.008, and 0.006 mag.

The top panel of Figure 1 presents the intermediate band red observations. The orbital phases were calculated according to the ephemeris of Vogt (1981a):

$$\text{HJD} = 2443033.47 + 6\overset{d}{.}72422\text{EE}$$

The phases of minimum and maximum light are, respectively, 0.35P and 0.80P. The amplitude of the photometric wave is about 0.21 mag. Maximum, mean, and minimum light, expressed differentially, have the following respective values: + 0.670, 0.770, 0.875 mag. The $\lambda\lambda$ 4530 and 7790 light curves are similar in shape and phases of the light extrema.

The middle panel of Figure 1 displays the differential color index. Δ(b-r)', computed from the intermediate band blue and red differential magnitudes. This index provides a measure of the color changes of the variable relative to the comparison star. No phase correlation appears to exist, and a considerable amount of observational scatter is present. The seasonal mean value of the Δ(b-r)' data set is -0.678 mag. The seasonal mean error for the Δ(b-r)' data set is $\pm$ 0.013 mag.

The bottom panel of Figure 1 displays the differential H-alpha index, $\Delta\alpha$(v-c). Based upon the spectral types of the variable and comparison stars, $\Delta\alpha$(v-c) = 0.00 $\pm$ 0.01 mag corresponds to the level of zero net H-alpha emission. The seasonal mean value of the $\Delta\alpha$(v-c) data set is -0.058 mag, indicating the presence of weak-to-moderate H-alpha emission. As with the color curve, no apparent phase correlation exists. Spectroscopic observations of II Peg by Vogt (1981a) determined the H-alpha emission to be global, though preferentially associated with the photometric visibility of the spotted regions. Strong variations in the H-alpha equivalent width correlated with phase were detected by Bopp and Noah (1980) who commented that the H-alpha emission profile of II Peg closely approximates that of the very active RS CVn-type star V711 Tauri (HR 1099). H-alpha spectroscopy of II Peg was obtained during June/July and September-November 1981 by Ramsey and Nations (1984).

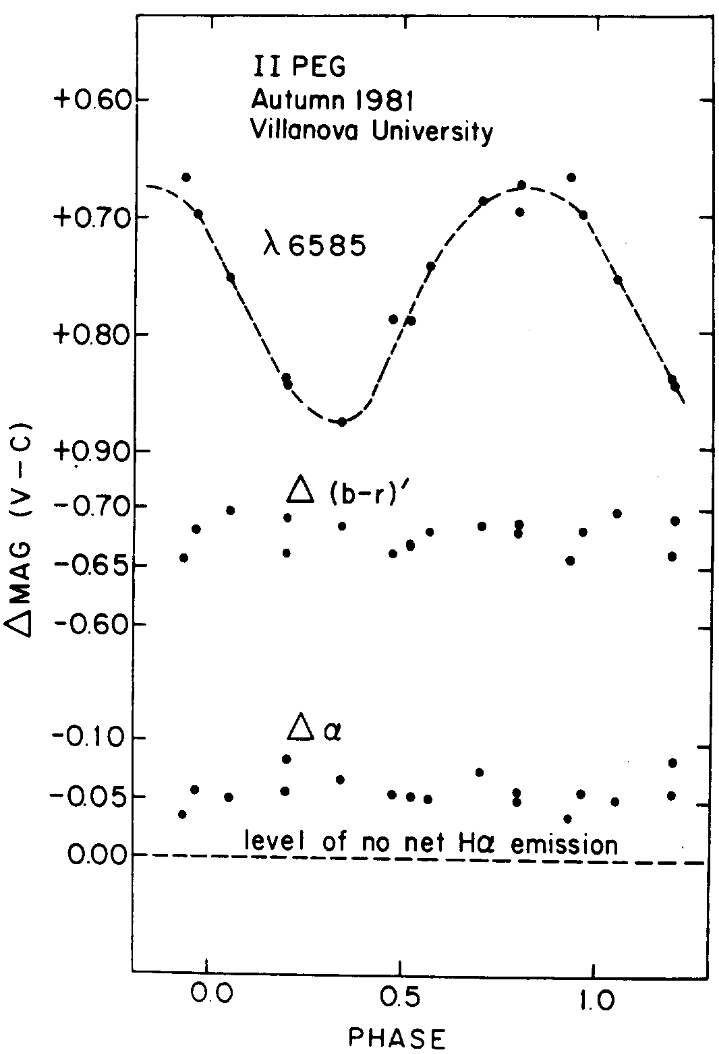

Figure 1: The Autumn 1981 photoelectric observations of II Peg, made differentially with respect to HD 223332, are presented. The top panel is a plot of the nightly mean differential red magnitudes. The middle panel is a plot of the color index. The bottom panel is a plot of the differential H-alpha index, where more negative values represent greater net H-alpha emission.

As stated in their paper, no clear evidence was found for a phase dependence of the H-alpha emission. The ephemeris of Vogt (1981a), which we use to phase our observations, was used to recompute the phases of the Autumn 1981 H-alpha spectra of Ramsey and Nations. The phase of weakest H-alpha emission coincides with the maximum of our light curve. An identical relationship was found by Ramsey and Nations (1984) between the equivalent widths of their H-alpha spectra and the V light curve obtained by Lines et al. (1983).

Light curves of II Peg obtained concurrently with those we present have been published by Zeilik et al. (1982), Lines et al. (1983) and by Byrne (as given in Rodono et al. 1986a). As with the H-alpha data of Ramsey and Nations, the ephemeris which we use to phase our observations was used to recompute the phases of the light curves of Lines et al. and Byrne. Even though different comparison stars were used, all three light curves agree in the phases of the light extrema, as well as amplitude and overall shape. The Lines et al. and Zeilik et al. observations have the best coverage, revealing the maximum to be significantly broader than the minimum. Furthermore, the amplitude of our intermediate band red light curve agrees with that of the broad band red light curve of Zeilik et al.Of perhaps the greatest significance in the results of monitoring the activity of II Peg concerns IUE observations obtained in early October 1981. The emission line fluxes of the chromosphere and transition regions achieved their maximum strength during photometric minimum, providing strong evidence that stellar plages overlie starspot regions (Marstad et al. 1982; Rodono et al. (1986b).

Multi-color photometry of II Peg has been conducted by Vogt (1981a). Nations and Ramsey (1981), Rodono et al. (1986a), Byrne (1986), and Wacker and Guinan (1986). All of these studies have shown the color curve to be reddest when the light curve is faintest, consistent with cool starspot models. The $\Delta(b-r)'$ curve formed from the 1985/86 photometry of Wacker and Guinan (1986), which used the same instrumentation and comparison star as this study, had a seasonal mean value of -0.669 mag. Comparing this value with that presented here for our Autumn 1981 observations indicates II Peg was on the average slightly bluer (by about 0.01 mag) during Autumn 1981 than in 1985/86. However, at both blue and red wavelengths, mean light for 1985/86 is brighter (by at least 0.04 mag) than during Autumn 1981. In the context of the cool starspot model, a spotted single star is expected to become bluer in color as its mean light brightens. Assuming the photospheric temperature of II Peg remains constant, the discrepancy in the seasonal changes between color and mean light of II Peg measured by our Autumn 1981 and 1985/86 observations may reveal a change in starspot temperature (Wacker and Guinan 1986). Light curve modeling by Poe and Eaton (1985) of multi-color photometry of II Peg obtained in 1977, 1979, and 1980 found evidence for seasonal changes in starspot temperature by as much as ∿ 300 K. They suggested the possibility that spots cool down when spot area remains constant and warm up when new spots are being created (Poe and Eaton 1985).

Recently, Byrne (1986) reported on his September 1986 photometry of II Peg, showing it to have the largest observed V light amplitude (0.45 mag) to date, and a well defined $(V-I)_C$ color variation, having an amplitude of 0.10 mag. Additionally, the mean value of the $(V-I)_C$ color index (+1.27 mag) is redder than previously observed.

Multi-color intermediate and narrow band photometry of II Peg for the 1986/87 observing season has been completed at Villanova (Boyd et. al. 1987), confirming the large amplitude and the wavelength dependency of the light variation. It would be of utmost interest to commence in the summer of 1987 both spectroscopic and photometric observations of II Peg in order to ascertain the extent to which the area, temperature, and configuration of the spots have evolved from their 1986/87 values.

We wish to thank Michael Davis and Craig Harris for contributing to the observations while students at Villanova University.

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