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II PEGASI: EVIDENCE OF EVOLVING STAR SPOT REGIONS

II Pegasi (HD 224085, K2 IV, <V>=+7.5 mag) is a single-line spectroscopic binary with an orbital period of 6.72 days and is a member of the RS CVn class of spotted variable stars. Multi-color photoelectric observations of II Peg were obtained on 14 nights from 6 UT October 1986 to 27 UT February 1987, using the 38 cm Cassegrain telescope at Villanova University Observatory. This reflector is equipped with a microprocessor controlled data aquisition system and pulse counting photometer utilizing an EMI 9658 photomultiplier tube. The observations were made with an H-alpha narrow and intermediate-band filter pair as well as with intermediate-band blue (λ4530), and yellow (λ5500) filters. HD 223332 (K5; V=+7.05 mag) was used as the comparison star and nightly mean differential magnitudes were determined from the observations. From these values, corresponding nightly mean differential color and H-alpha indices were also determined. The observing procedure, data reduction technique, filter characteristics, and an explanation of color indices have been given by Guinan and Wacker (1985).

The upper panel of Figure 1 is a plot of the nightly mean differential yellow (y) magnitudes versus phase. Orbital phases were computed according to the ephemeris of Rucinski (1977): JD = 2443033.10 + 6.724183 * E. The light curve displays a broad

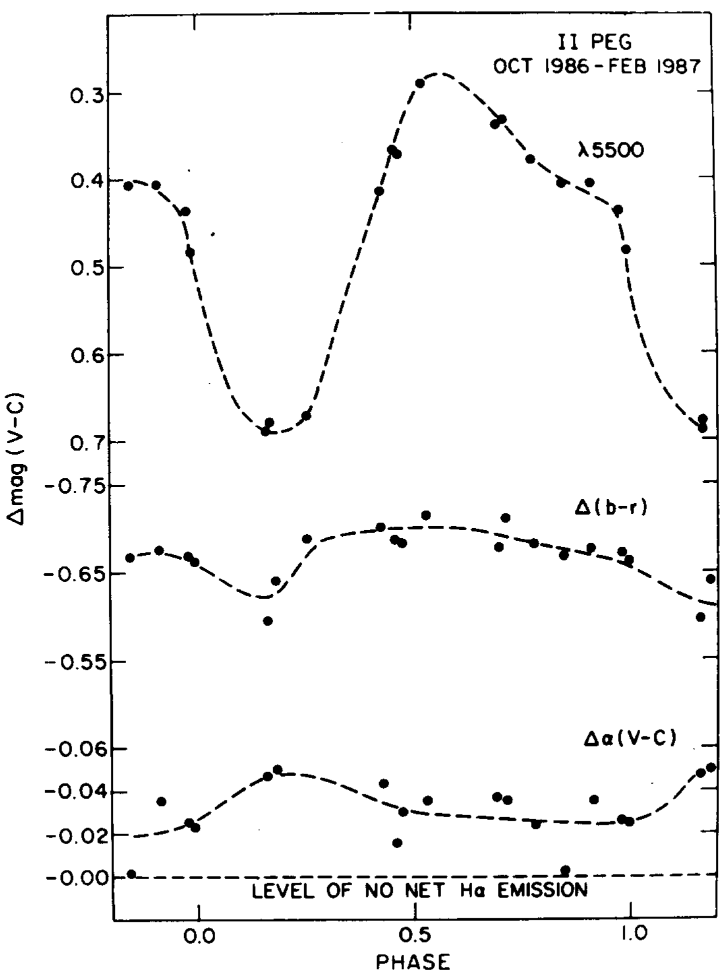

Figure 1

The 1986/87 photoelectric observations of II Peg are plotted against orbital phase. The upper part of the figure is a plot of the nightly mean differential magnitudes. A plot of the differential (b-r) magnitudes is shown in the middle of the figure. The lower portion of the figure shows a plot of the differential H-alpha index, where more negative values indicate greater net H-alpha emission.

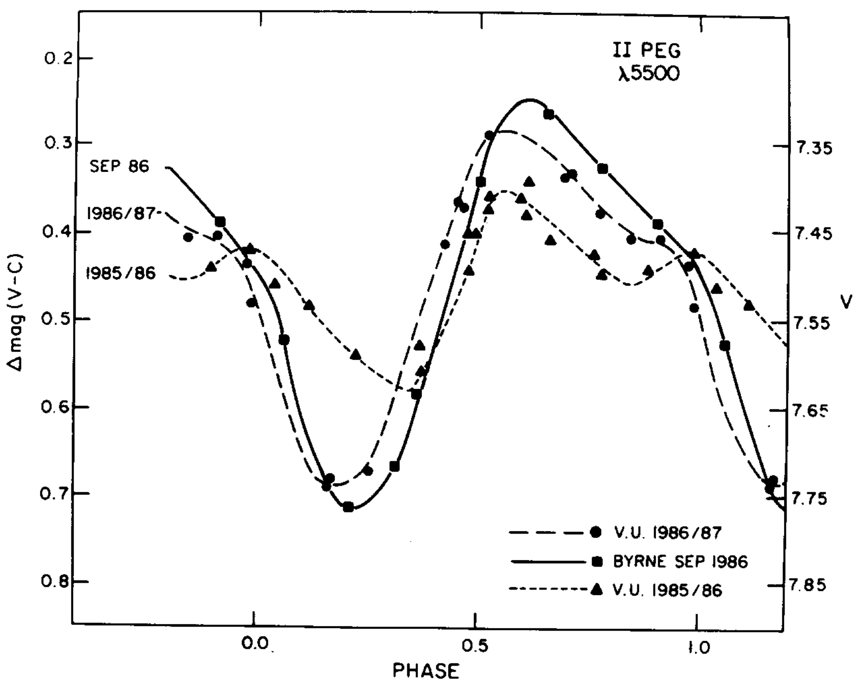

Figure 2

The 1985/86, September 1986, and the 1986/87 yellow light curves of II Peg are plotted against phase. The variations in the shape and amplitude of the light curves over this one year interval are evident.

maximum at about 0.55 phase and a minimum occurs near 0.18 phase. The corresponding light amplitude is approximately 0.40 mag in yellow light. In addition to this large light amplitude, the light curve shows a noticeable inflection at approximately 0.85 phase. The corresponding blue and red light curves (not pictured) have the same shape as the yellow light curve and have light amplitudes of +0.43 mag and +0.31 mag respectively, indicative of a strong wavelength dependence of the light variation.

The middle panel of Figure 1 presents a plot of the nightly mean differential (b-r) color index. The mean value is $\Delta\overline{(b-r)}$ = -0.674 mag. Despite some observational scatter, Δ(b-r) exhibits an obvious phase dependence, in which the color index is most positive (i.e. reddest) when the star is faintest and vice versa. This behavior is consistent with cool starspot models in which the spotted star dominates the light of its companion.

The bottom panel of Figure 1 displays the differential H-alpha index α(v-c), which gives a measure of the net H-alpha emission and is an indicator of chromospheric activity. The seasonal mean value of the $\Delta\alpha$(v-c) data set is -0.031 mag. Based upon the spectral types of the variable and comparison stars, the level of zero net H-alpha emission corresponds to the value $\Delta\alpha$(v-c) $\simeq$ 0.00 $\pm$ 0.01. As shown by this plot, Hα emission is greatest when the star is faintest- an occurrence which supports the theory of large-area starspots and related plages.

Preliminary spot modelling of the light curves was carried out using the computer code developed at Villanova (Dorren et al., 1981). A photospheric temperature of 4700K was adopted for the visible star of the binary from its K2 IV spectral type (Novotny 1973). The light contribution of the unseen star of the binary system was assumed to be negligible since its spectrum is not seen at visible wavelengths. Also, the inclination of the active star's rotation axis to the line of sight was assumed to be $i \sim 65^{\circ}$ (Vogt 1981). The limb darkening coefficients used in computing the theoretical light curves were obtained from the compilations of Al- Naimiy (1978). The amplitudes and shapes of the light curves were fit by assuming two major spot groups of different sizes and located at different stellar latitudes. The spots are separated by $\sim 120^{\circ}$ in stellar longitude and cover about 12 percent of the total surface area of the star. (A minimum of $\sim$24 percent of the star's surface area is spot covered if the spots are symmetrically placed about the star's rotational equator). The assymetric shape and the observed inflection in the light curves could only be reproduced with two spot regions. A spot temperature of T(spot) = 3450K $\pm$ 150K was found from the wavelength dependence of the light curves. This value is in good agreement with spot temperatures determined previously for II Peg by other investigators using different methods (eg. Vogt (1981a;b); Nations and Ramsey 1981; Poe and Eaton 1985; Rodono et al. 1986).

Two recent light curves of II Pegasi, that of Wacker and Guinan (1986) obtained during 1985/86, and that of Byrne (1986) obtained in September 1986, provide interesting comparisons to our 1986/87 light curve, (Figure 2). As can be seen from the figure, the 1985/86 observations indicate a light amplitude of 0.23 mag in yellow which is much smaller than that found less than one year later. However, the level of mean brightness of the star did not significantly change during this interval. Also of interest is the shape of the 1985/86 light curve which shows a shallow secondary minimum and second maximum where the inflection in the light curves occurs during 1986/87. Although not well determined, Byrne's light curve displays the largest amplitude of the three, with a value of $\sim$ 0.45 mag in the V-bandpass. Byrne's observations do not indicate an inflection in the light curve, possibly because there are only a few observations defining this section of the light curve. There appears to be a change in slope occurring between approximately 0.7 phase and 0.9 phase in Byrne's light curve, perhaps due to the inflection.

Since the mean brightness and color of the star did not change significantly between these two years, the total spot area has remained relatively constant. From a comparison of the three available light curves, it appears that the two spot regions of II Peg migrated closer together from 1985/86 to 1986/87. The longitudinal separation of the spots was approximately 160° during 1985/86 and, as discussed previously, about 120° apart during 1986/87. Also, the phase of minimum light has shifted from about 0.30P during 1985/86 to 0.18P in 1986/87 which indicates a drift in the mean longitude of the spot forming region. This phenomena could arise from differential rotation of the star since two spot groups appear to be located at different stellar latitudes. Other RS CVn-type stars appear to show this effect. For example, Lambda Andromedae shows a differential rotation rate between its two large spot groups of $\sim$ 15 degrees per rotation (Dorren and Guinan 1984).

These recent observations of II Pegasi suggest that the system is undergoing a relatively rapid change in the distribution of the starspots. To determine whether this will continue for some time, or will be relatively shortlived, more observations of this star are necessary in the next observing season.

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