THE ASTROPHYSICAL JOURNAL, 319:392–402, 1987 August 1

CCD ECHELLE OBSERVATIONS OF THE ACTIVE RS CVn SYSTEM II PEGASI

DAVID P. HUENEMOERDER AND LAWRENCE W. RAMSEY
Pennsylvania State University
Received 1986 October 13; accepted 1987 January 26

ABSTRACT

Optical spectra were obtained of II Peg on eight different nights in 1984 and 1985 to assess the strength and variability of surface activity indicators in this very active RS CVn system. These cross-dispersed echelle spectra covered the range from 390 nm to 900 nm at a resolution of 12,000. Emission was seen in the first four Balmer lines, in the Ca II infrared triplet, Ca II H lines, and in one observation, in He I D_3. The ratio of energy emitted in the Hα line to that in Hβ is similar to that in solar prominences, except during enhancements when the ratio decreases toward values more typical of solar flares. The Hα lines varied both in strength and in profile. There were slight variations in the Ca II infrared triplet lines. Exposure levels were too weak to assess the variations in Hγ, Hδ, or Ca II H. Relative to comparison star spectra, the TiO bands at 896 nm and 710 nm were slightly deeper in II Peg, which is indicative of cool spots.

Subject headings: stars: binaries — stars: individual (II Peg)

I. INTRODUCTION

II Peg (HD 224085) is a relatively bright ($V = 7.35$) and very active single-lined binary system and thus is relatively well studied. Vogt (1981) presented a fairly comprehensive investigation of photometry and limited spectroscopy to derive fundamental parameters for the system. He found from the photometry and low-resolution spectroscopy that the variations could be modeled by a single cool "star-spot." His observations showed that the Hα emission strength was directly correlated with spot visibility, but originated over a larger area of the stellar surface. Vogt also determined the rotational velocity, stellar radius, and orbital inclination, which placed the star well above the main sequence, in agreement with the general characteristics of RS CVn stars. The photometric study of Nations and Ramsey (1981) supported Vogt's conclusions and also showed how drastically the light curve can change in short time scales. They found that during the epoch of their observations the star had two spots or spot groups separated in longitude by $\sim 180°$.

The activity in II Peg is exhibited in all accessible regions of the electromagnetic spectrum. It has a rapidly migrating optical light curve of variable amplitude (Chugainov 1976; Rucinski 1977; Nations and Ramsey 1981). It is a radio source (Spangler, Owen, and Hulse 1977; Owen and Gibson 1978; Feldman 1983), a soft X-ray source (Walter *et al.* 1980), and has been identified with a hard X-ray transient (Schwartz *et al.* 1981). More recently, II Peg has been studied with the *International Ultraviolet Explorer* (*IUE*) satellite (Marstad *et al.* 1982; Linsky *et al.* 1984; Byrne *et al.* 1984). In the ultraviolet the chromospheric and transition region lines were strongly variable. Emission lines were strongest when the star was faintest.

We have obtained optical spectra of II Peg in order to examine the behavior and correlation of various activity indicators in the visible region. In particular, we have observed the hydrogen Balmer lines, the Ca II infrared triplet (IRT), the Ca II H line, He D_3, and TiO bands.

II. OBSERVATIONS AND REDUCTION

All observations were made with the 1.6 m telescope and fiber-coupled spectrograph system at the Black Moshannon Observatory of the Pennsylvania State University. An observation log is given in Table 1. The ephemeris used for the phase is that of Vogt (1981). The detector was an RCA SID501 charge-coupled device (CCD). Two grating and camera configurations were used. Six of the eight spectra were comprised of ~ 35 spectral orders covering the range from the Ca II H line at 396 nm to the TiO band at 886 nm with a resolution of $\lambda/\Delta\lambda$ of 12,000. There were 2.2 pixels per resolution element. The first two spectra, which were obtained before the final instrumental configuration was commissioned, imaged two orders (covering the Hα and Hβ lines) onto the CCD. These were of slightly lower resolution. (For a more complete description of the instrument, see Ramsey and Huenemoerder 1986.)

To quantitatively derive some indices related to the stellar surface activity in II Peg, we referenced the spectra to a "standard" stellar spectrum. The standard was chosen to be an inactive star of similar spectral type to II Peg. The standard was artificially rotationally broadened, aligned in wavelength with II Peg, and after normalization of continua to unity, subtracted from the II Peg spectrum. This then showed any excess or deficit emission in sensitive lines. Barden (1985) discussed the assumptions involved and gave examples of the procedure. The equivalent width (after adding one to the differenced spectrum) is a quantitative measure of the activity. This subtraction is important in the examination of crowded regions or where excess emission may not be obvious, since lines may be only slightly shallower than "normal" and may not display emission above the local continuum. The most important assumption implicit in this subtraction is that there are underlying and independent photospheric and inactive chromospheric contributions, which is true only in the case of very localized or transparent active regions. A more rigorous approach would be to reproduce the actual line profiles

TABLE 1

OBSERVATION LOG

UT Date	PHASE
1984 Dec 5	0.508
1984 Dec 9	0.105
1985 Aug 2	0.221
1985 Aug 3	0.370
1985 Sep 21	0.663
1985 Sep 29	0.841
1985 Oct 26	0.865
1985 Oct 28	0.272

through detailed modeling, which is beyond the scope of this work. The subtraction should be perfectly adequate in the relative sense on the same star, however, where we can detect relative changes in line strengths and profiles.

III. RESULTS

a) Choosing a Comparison Star

II Peg has been photometrically classified as a K2 dwarf to subgiant (Rucinski 1977; Vogt 1981; Nations and Ramsey 1981). Several stars near this spectral type and luminosity class were compared to II Peg in various spectral regions. All candidates were rotationally broadened to 20 km s^{-1} in accordance with Vogt (1981) and with our determinations. No star was completely satisfactory in all respects. The best match in the lines near 540 nm was given by HD 198149 (K0 IV), but then the wings and core of the Na D lines matched poorly. The sodium lines are both luminosity and temperature sensitive and should be an indicator of a good match. There was much better agreement there with HR 1084 (K2 V, ϵ Eri), but this star had deeper lines in the 540 nm region. Earlier and later dwarfs (HR 7642, K0 V; HR 8832, K3 V) gave poorer overall fits than the other two stars. Part of this discrepancy is no doubt due to failure to closely match the temperature and gravity of the comparison star to those of II Peg. Some could also be due to the activity of II Peg and the composite nature of its spectrum due to cool starspots.

There has been some discussion in the literature concerning the activity of HR 1084. Eaton and Poe (1985) concluded that the star is not variable, based on photometry from 1984. Others, as is briefly discussed by Saar *et al.* (1986), have seen moderate chromospheric activity, sometimes modulated by rotation. Our 1985 September observations showed no sign of activity. The Ca II H line had no detectable emission, but would have been easily noticed if it were as strong as that observed by Zarro and Rodgers (1983). Nor was there any appreciable difference in other sensitive lines indicative of activity between this star and others of similar spectral type. It thus seems that HR 1084 was suitable for use as an inactive dwarf standard at that epoch.

Among the comparison stars mentioned, there is little or no difference in the measured strengths of the sensitive lines ($<3\%$ in the equivalent width of Hα). The choice of HR 1084 was based primarily upon the good match of Na D to II Peg. Additional tests were done using II Peg as its own standard to investigate the possibility of small variations in temperature-sensitive lines without the uncertainty introduced by an imperfect match.

To ascertain that line mismatches were not due to any contribution from the as yet undetected spectroscopic companion, cross correlations against the unbroadened standard were made in several wavelength regions. In no case was there any evidence of line doubling. The cross-correlation peaks were all single and no broader than expected from rotation alone.

b) The Hydrogen Balmer Lines

All hydrogen Balmer lines within our spectral coverage (Hα, Hβ, Hγ, and Hδ) were in strong emission relative to the comparison star. In some cases, the lines stood out above their own local continuum: Hα was always present at a level of about twice the continuum intensity, and Hβ was usually filled in up to the local continuum, but was clearly above it during two observations (1984 December 5, 1985 August 2). The other two Balmer lines are in a region very crowded with strong absorption lines. It is necessary to use a comparison star to assess the relative emission by isolating the hydrogen line from its neighboring blends. Figure 1 shows the Hα region for II Peg, the difference between II Peg and the standard, and the difference between II Peg and its mean profile. Figure 2 shows the same for Hβ. In each figure, the lower resolution data, which have been interpolated to the same scale as the other spectra, are shown as dotted lines.

Both Vogt (1981) and Bopp and Noah (1980) observed strong variations in the strength of Hα in II Peg. The variations seemed to be comprised of two components, one which varied in phase with the orbit and one which was sudden and unpredictable. The former activity was correlated with spot visibility and attributed to an overlying active chromosphere. The impulsive enhancements were attributed to flarelike events. While our sampling of different phases is fairly good, our coverage within a single orbit is poor. No more than two observations were made within one orbit. As a result, we cannot easily isolate the time evolution of activity from that due to geometrical aspect. However, from the ratio of energy emitted in Hα to that in Hβ (E_α/E_β), we can see that some component of the variations are due to a change in character of the emission and not due to geometrical effects. Calculation of the relative energy emitted requires knowledge of the values of the $B-R$ color, which has been determined by Nations and Ramsey (1981).

Figure 3 shows the variation of Balmer line excess equivalent widths and E_α/E_β plotted against orbital phase. Figure 4 shows the E_α/E_β ratio plotted against the Hβ excess equivalent width. It is clear from Figure 4 that when Hβ is enhanced, the Hα is not proportionally increased in strength. The same behavior occurs in solar flares (Heasley and Mihalas 1976). As Huenemoerder and Ramsey (1987) discussed, the E_α/E_β ratio in RS CVn stars is typically in the range of four to eight, which is similar to prominences in the Sun, while flares have values ranging from less than one to two. Apparently, we have detected flarelike activity in the atmosphere of II Peg. The E_α/E_β ratio decreases due to an addition of lower decrement photons to a higher decrement background. We will refer to the two strongest Hβ (1984 December 5 to 1985 August 2) and lowest E_α/E_β events as flares. This conclusion is also consistent with the observations of Bopp and Noah (1980), who saw sudden enhancements in the strength of Hα followed by a long decay.

The Hγ and Hδ lines, while detected in emission, are not of high enough quality to detect any variations, since they are in a region of decreased stellar flux and of poorer instrumental response. The scatter and errors in the E_γ/E_β and E_δ/E_β spans the range seen in solar prominences to solar flares. In addition,

1987ApJ...319..392H

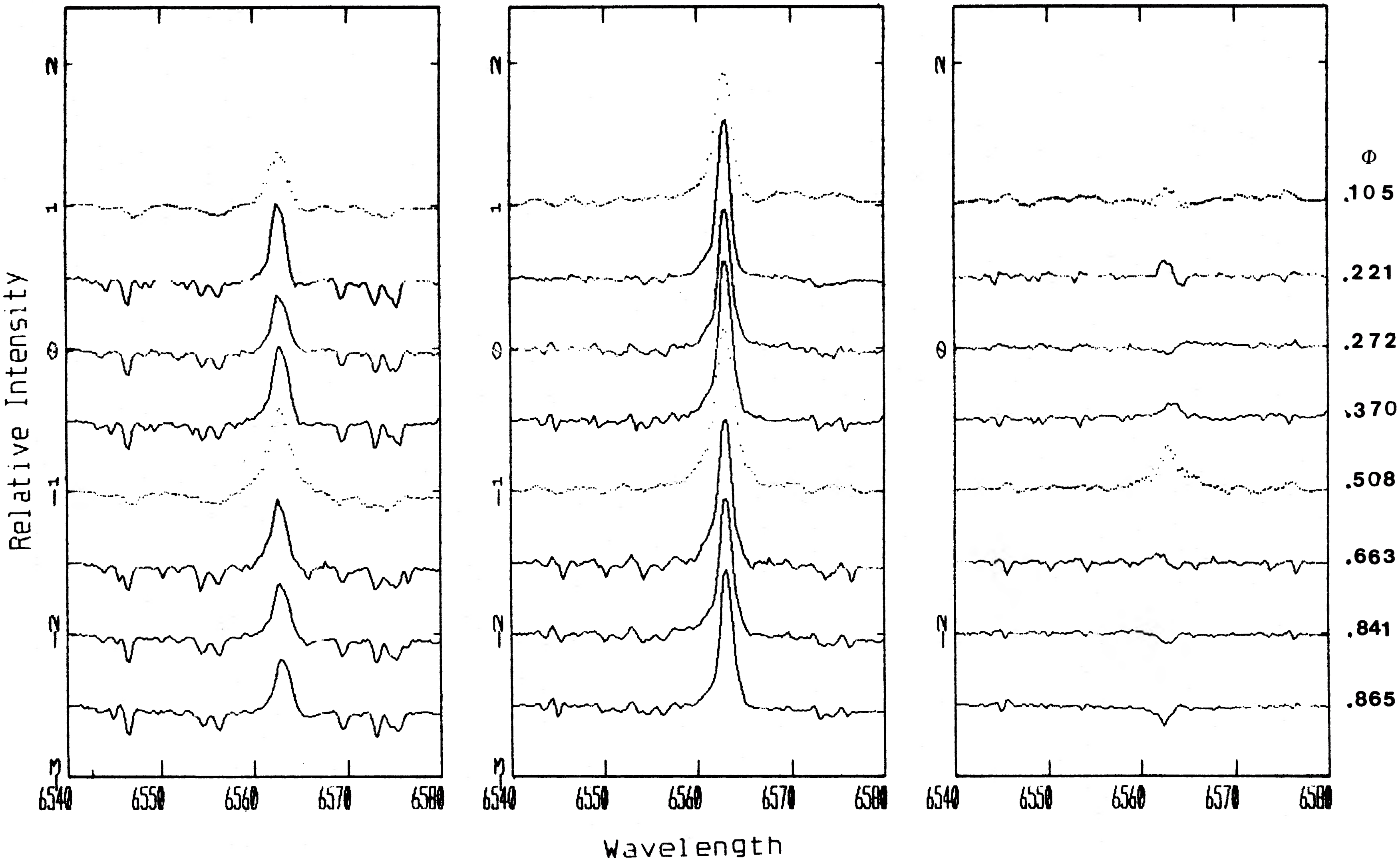

FIG. 1.—The Hα region of II Peg is shown in increasing phase order from top to bottom. The left-hand panel shows the observed profiles, all aligned to the same velocity scale. Continua were normalized to unity and then additively offset. The lighter-lined spectra are the lower resolution data which have been stretched to the same dispersion as the other spectra. The center panel shows the excess emission profiles derived by subtracting the aligned, normalized, rotationally broadened profile of HR 1084 (K2 V) from the higher resolution II Peg profiles, and the lower resolution profile of β Cet (K1 III) from the lower resolution spectra. The right-hand panel shows the differences of the individual II Peg spectra from the mean II Peg profile (formed excluding the low-resolution data).

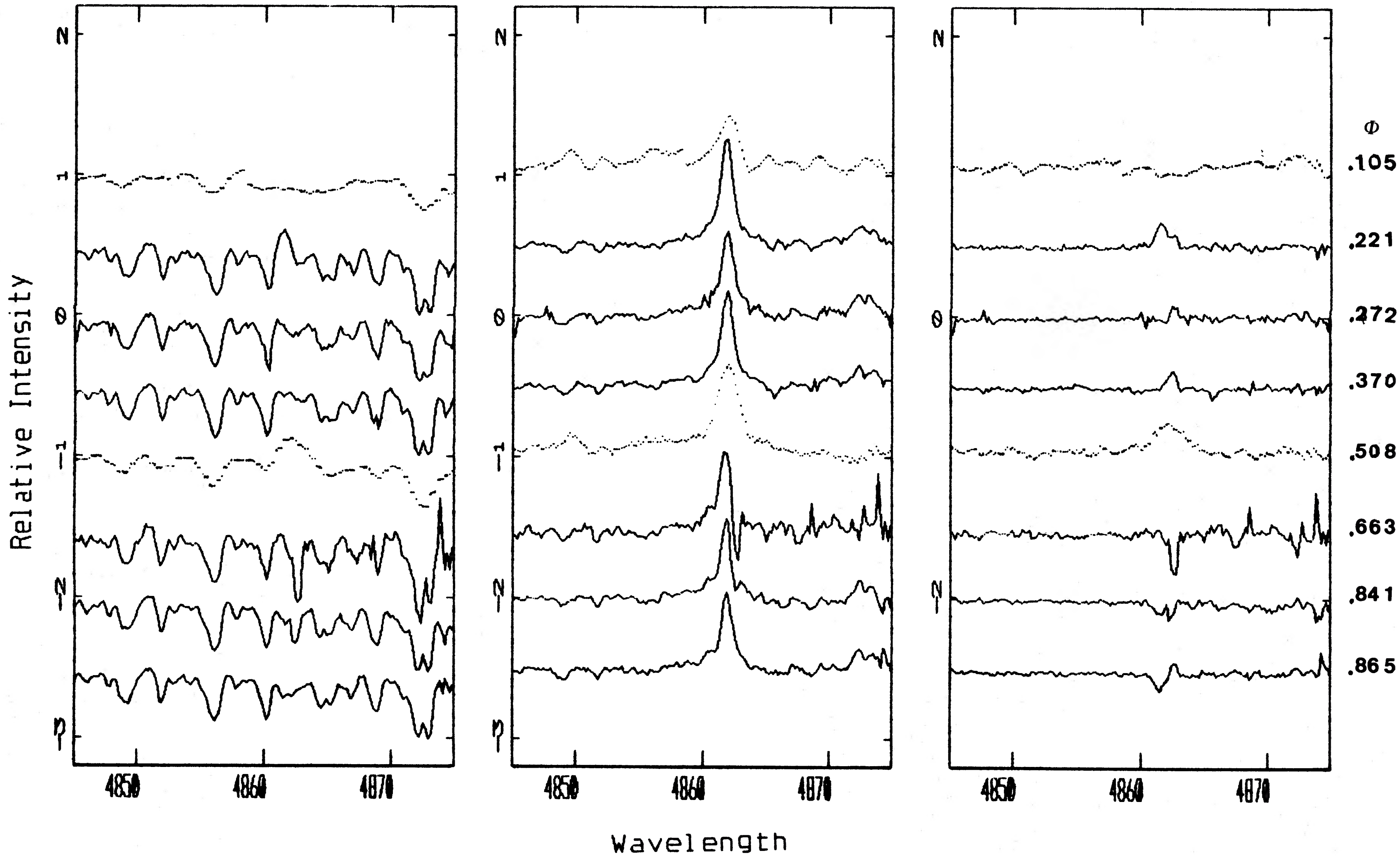

FIG. 2.—The Hβ region is shown similarly to Fig. 1. The sharp feature just redward of Hβ at phase 0.663 is due to a radiation event in the CCD substrate.

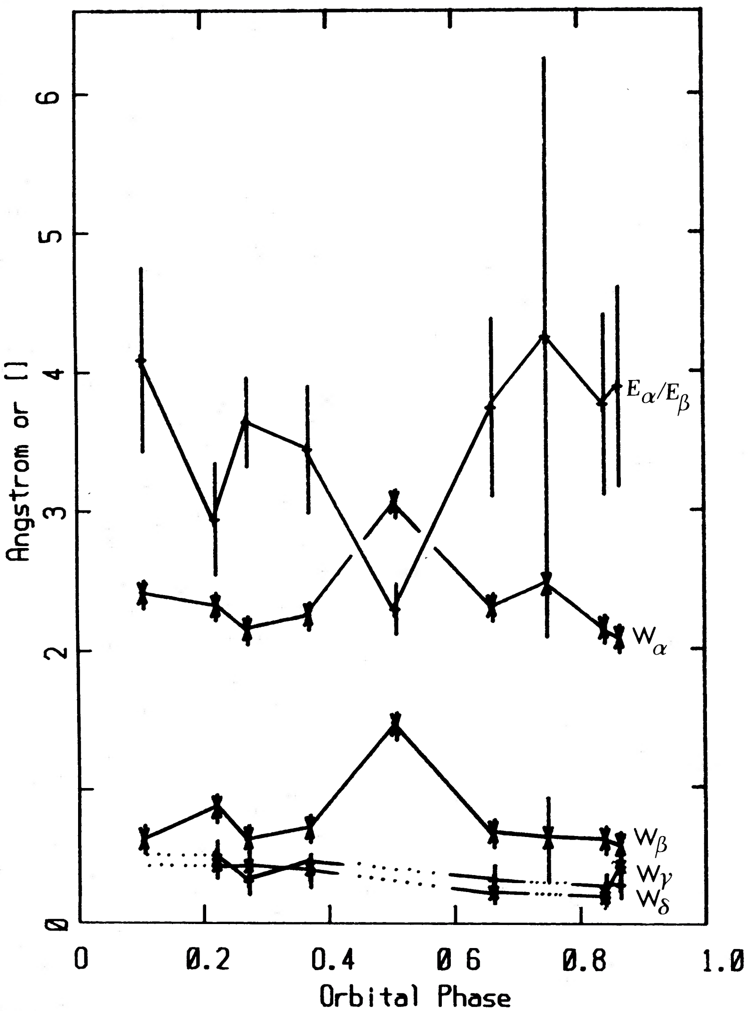

FIG. 3

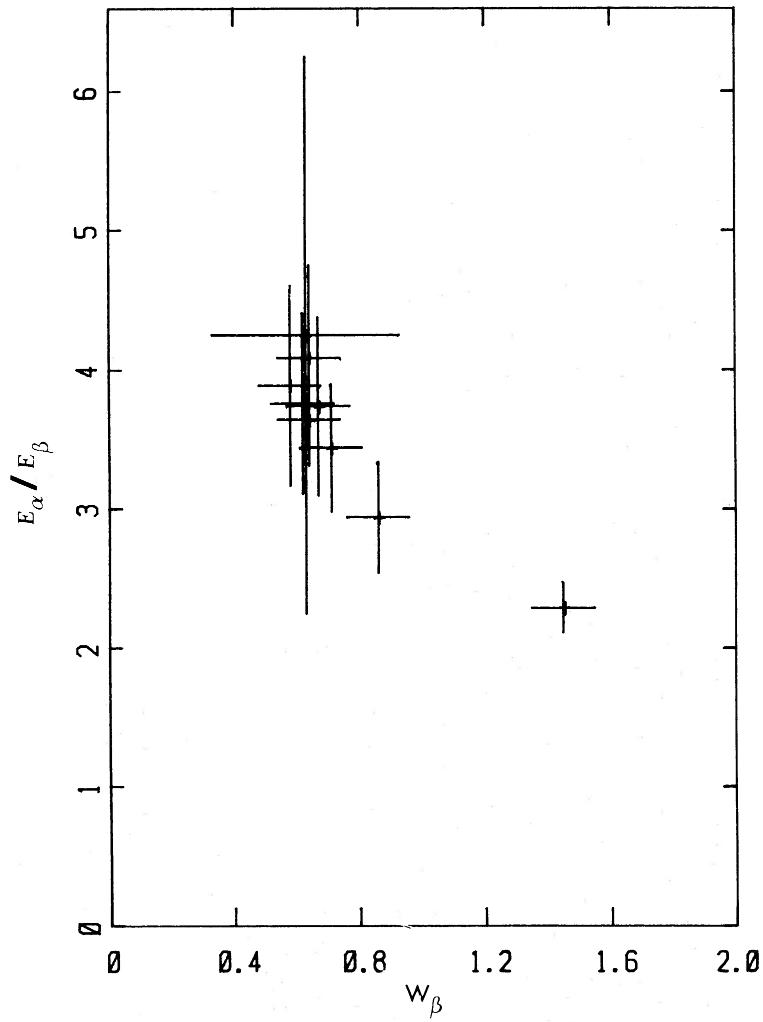

FIG. 4

FIG. 3.—The variations with phase (*from top to bottom*) of $E_\alpha/E_\beta W_\alpha$, W_β, W_γ, and W_δ are shown for II Peg. The point near phase 0.75 is taken from Huenemoerder and Ramsey (1987). These are excess equivalent widths, which are the difference between the II Peg equivalent width and that of an inactive star.

FIG. 4.—The E_α/E_β ratio vs. W_β is shown for II Peg at different times. The point with the largest error bars was taken from Huenemoerder and Ramsey (1987). Solar prominences have an ordinate which ranges from four to eight, while the solar chromosphere lies near two, and solar flares range from less than one to about two.

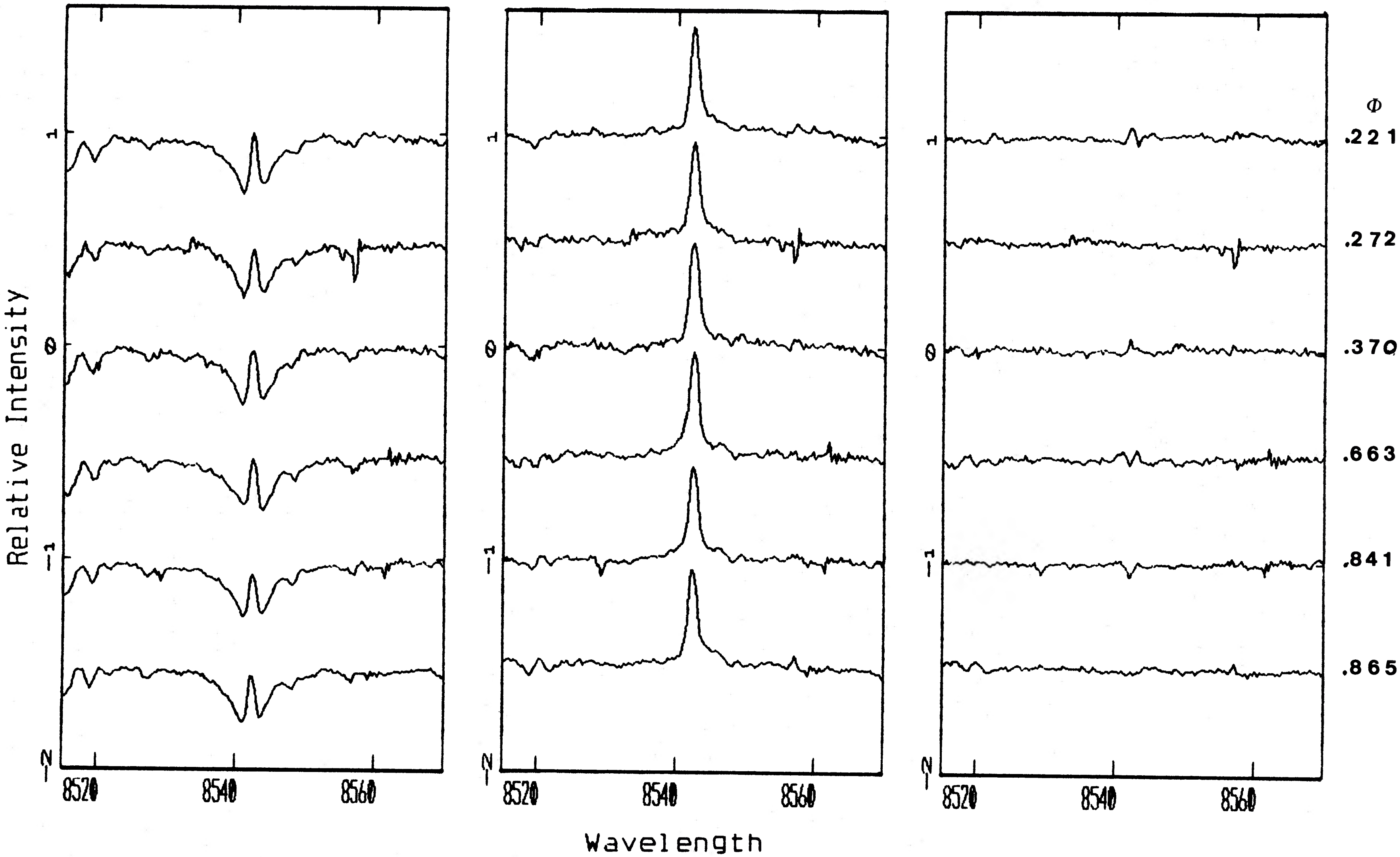

FIG. 5.—The Ca II 854.2 nm line is shown in the same fashion as Figs. 1 and 2

the observation with the strongest Hβ emission was with the early instrumental configuration which did not cover the higher Balmer lines.

The Hα profile was variable in shape as well as in strength (see Fig. 1). The line is peculiar, having a very sharp cutoff on the red wing. Vogt (1981) speculated that this asymmetry was caused by differential motions in the chromosphere. He, however, noticed no changes in the shape while the strength varied by a factor of 2.

Wavelength shifts were applied to the Hα regions to remove the effects of the orbital motion of the primary star as well as the Earth. We determined relative shifts between different nights' data from cross correlations of spectral regions with many strong lines (near 540, 517, and 484 nm). The difference between these spectra clearly show changes in the strength and shape of the Hα profile. The strongest Hα lines all had basically the same profile. Those with decreased emission were more symmetric, having more emission in the red wing. To ascertain whether the variations were due to a difference in radial velocity between the photospheric lines and Hα, cross correlations were made between one II Peg spectrum and the rest, after masking out either Hα or everything else with Gaussian noise. There were no systematic trends in the radial velocity differences and the profile variations, which may arise if an active region was being carried across the face of the star by rotation.

c) Ionized Calcium Emission

The Ca II H and K lines have long been the traditional diagnostics of chromospheric activity in cool stars. The Ca II H line is near the blue limit of our spectral coverage where the instrumental sensitivity is low. The stellar flux is also much lower in this region. We have detected the line in strong emission, but the data are too noisy to make any quantitative measurements of variability.

Of more recent interest in cool stars are the Ca II infrared triplet (IRT) lines (Linsky *et al.* 1979). These lines originate from the same upper atomic levels as the Ca II H and K lines and so should have similar physical significance. Our coverage includes the 849.8 nm and 854.2 nm lines. Here, our instrument, is much more sensitive, and the stellar flux is much greater. The 854.2 nm line is shown in Figure 5. A strong central reversal was always present in the II Peg spectra in both lines. They showed small but real variations, as determined by comparing II Peg spectra from different nights. The right-hand panel of Figure 5 shows the residuals between the individual spectra and the mean spectrum. The small residual features in this line are present in the 849.8 nm line as well. The changes marginally parallel the Hα and Hβ variations, but again, we are lacking the data in coincidence with the strongest Hβ flare event. The excess equivalent widths in the IRT lines are $\sim$0.08 nm and 0.11 nm for the 849.8 nm and 854.2 nm lines, respectively, with variations of $\sim$0.01–0.02 nm.

d) He I D_3

Perhaps the most significant observation in support of flare-like events is the detection of emission in the He I D_3 line at 587.6 nm. This line has a very high excitation level. It has been detected previously in active chromosphere stars in absorption and attributed to plages or coronal radiation (Wolff and Heasley 1984; Danks and Lambert 1955; Huenemoerder 1986). In the Sun, it is in emission in the strongest flares (Tandberg-Hanssen 1967, p. 250). None of our II Peg spectra show any absorption at the wavelength of the line. However, the 1985 August 2 observation (the second and smaller flare event) has a slight enhancement at the wavelength of He I D_3. We have looked for instrumental or reduction artifacts which could cause such a feature but have not found any justification to discount the identification. Known "hot" pixels were far away on the CCD, and radioactive decay spikes from the CCD substrate have a fundamentally different character. A comparison of the regions as was done for Hα clearly showed a difference far above the noise. An observation of α Cygni on the same night verifies the wavelength. We are quite confident that it is real emission, implying energetic processes. Figure 6 shows the He D_3 spectral region for II Peg, a comparison star, and α Cygni.

e) Titanium Oxide Absorption

Sunspots are cool enough so that TiO bands are present in absorption. Stars with cool spots should also show molecular bands if the spots or spot groups cover enough area. Vogt (1981) derived a spectrum of the spots on II Peg from low-resolution data from a ratio of spectra taken when the spot was in view to when hidden. The result clearly showed molecular bands of TiO and VO and indicated an equivalent spectral type for the spots of M6 or cooler. Analyses of photometry (Vogt 1978; Bopp and Noah 1980; Nations and Ramsey 1981) have determined a fractional spot coverage from 0.2 to 0.4 of the star's surface.

Our spectra include the TiO bands near 710 and 890 nm. Both were slightly deeper in II Peg as compared to a K2 V star, as is shown in Figure 7. In normal dwarf and subgiants near spectral types K0 to K2 the bands are not apparent. A comparison of II Peg to itself on different nights showed no significant variations in the bands. The band at 890 nm was the stronger of the two. This, however, depends upon the determination of the continuum, and unfortunately, the band head near the 710 nm falls outside our coverage, and this introduces a major uncertainty. The relative contribution at different wavelengths depends mainly upon the contrast between the photosphere and spotted region and the fractional area covered. We have synthesized the average II Peg spectrum in the two regions using a K2 V star (HR 1084) and M stars. The normalized spectra were aligned, weighted, added together, and then compared to the average normalized spectrum of II Peg. The weights were adjusted until visual inspection showed a good match. Assuming a contrast between the unspotted and spotted regions, the area covered can be calculated.

To model the dependence of the determined weights, we have adapted the analysis of Vogt (1981) to spectroscopic data. The flux from a region of a stellar surface can be expressed as

$$f_A = \left(\frac{R}{D}\right)^2 S_A(\lambda) G_A(\beta, i) .$$

In this equation, R is the stellar radius, D the distance from the observer, S is the specific intensity, and G is a geometrical quantity which depends upon the linear limb-darkening coefficient, β, and the inclination of the polar axis to the line of sight, i. The subscript, A, refers to the area of interest upon the stellar surface. The geometrical quantity is

$$G(\beta, i) = \iint (1 - \beta + \beta \cos \gamma) \cos \gamma \sin \theta d\theta d\phi ,$$

where gamma is the angle between the surface normal and the

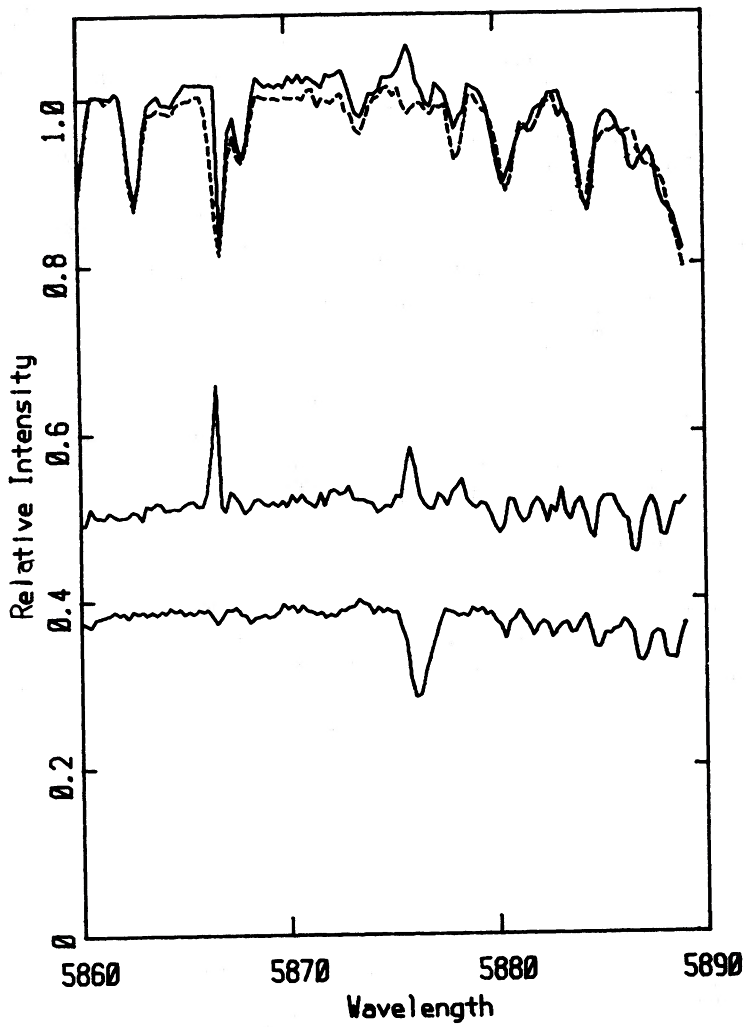

FIG. 6.—The He D_3 587.6 nm region is shown for II Peg on 1985 August 2 (*top solid line*) and for 1985 October 25 (*dotted line*). Their difference is shown offset below them. The spike near 586.5 nm is due to a known CCD defect. The bottom line is the offset spectrum of α Cygni on 1985 August 2. The two II Peg spectra and that of α Cyg were aligned on their Na D lines.

line of sight, θ is the stellar colatitude, ϕ is the stellar longitude, and the integration is carried out over the region of interest. Also,

$$\cos \gamma = \cos \theta \cos i + \sin \theta \sin i \cos \phi$$

expresses the relationship between γ and the stellar colatitude, longitude, and inclination. For an unspotted hemisphere,

$$G_*(\beta, i) = \pi(1 - \beta/3) .$$

Using the subscript $*$ to refer to an immaculate stellar surface and subscript s to refer to a spotted region, the relative flux (that is, with normalized or arbitrary continuum) from a spotted stellar surface is

$$f_\lambda = S_*(\lambda)(G_* - G_s) + S_s(\lambda)G_s .$$

This may be related to the synthesis weights, after a little algebra and the definition of normalization of spectra, as

$$\frac{w_*}{w_s} = \frac{S_{c*}}{S_{cs}}\left(\frac{G_*}{G_s} - 1\right) ,$$

where w_* and w_s are the weights applied to the spectra used for the unspotted and spotted regions, respectively, and the c subscript refers to the local continuum.

The ratio, S_{c*}/S_{cs}, or contrast, may be estimated from the Barnes-Evans relationship between the $(V-R)$ color and visual surface flux (Barnes, Evans, and Moffett 1978). For stars with $(V-R) > 0.7$, the relationship is linear and is

$$F_v = 3.841 - 0.321(V-R)_0 ,$$

where F_v is the visual surface brightness parameter (with units of magnitudes) and $(V-R)_0$ is the unreddened stellar color. This may be generalized to an arbitrary bandpass, X, as

$$F_x = F_v + 0.1(V-X) = 3.841 - 0.321(V-R) + 0.1(V-X) .$$

The contrast is thus:

$$C_x = \frac{S_{c*}}{S_{s*}} = \text{dex}\,\{1.28[(V-R)_s - (V-R)_c] - 0.4[(V-X)_s - (V-X)_c]\} .$$

We now have all that we need to derive the spot geometry from the synthetic weights and the assumed equivalent spectral

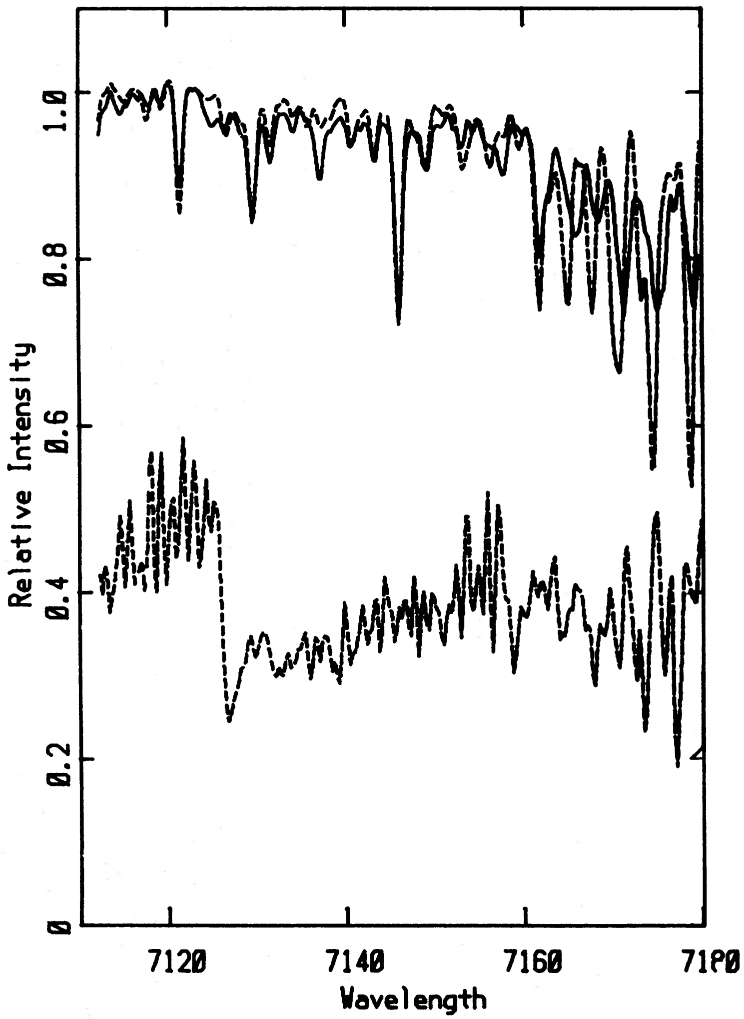

FIG. 7a

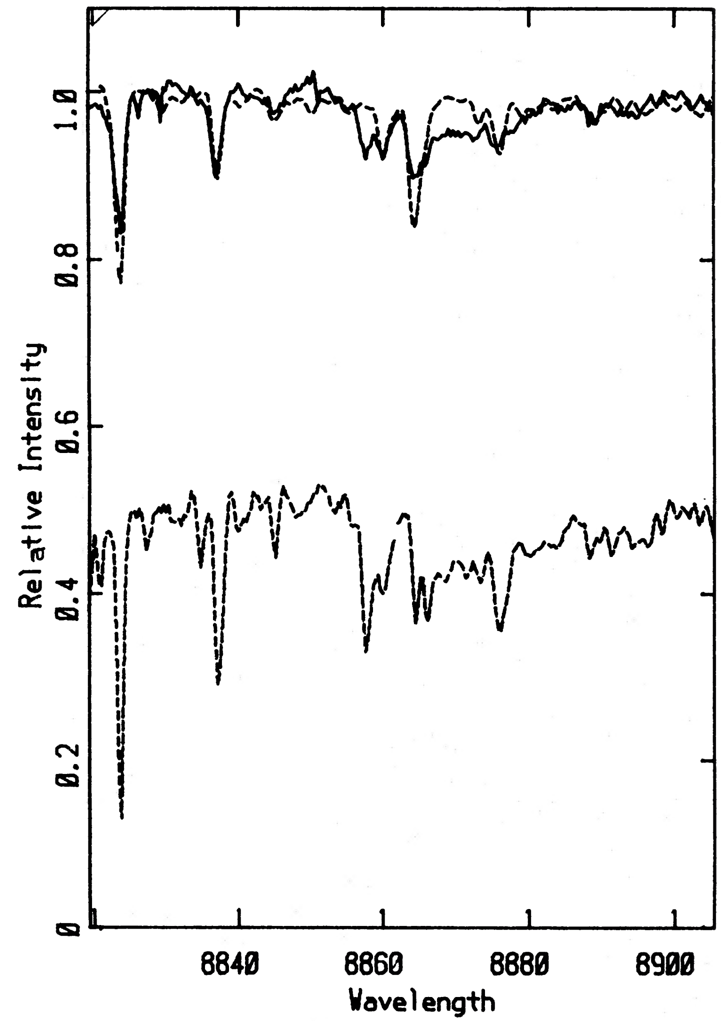

FIG. 7b

FIG. 7.—The TiO regions for II Peg (*upper solid line*) are compared to a standard star (HR 1084, K2 V) (*upper dotted line*). Below them is an offset spectrum of an M4 star (HR 5603) to mark the position of the molecular bands. Note that II Peg's spectrum is appreciably deeper compared to the standard at 886 nm, while at 772 nm, it is only slightly deeper.

types of the photosphere and spots. The weights and the contrast specify G_s. The spot and stellar geometry can then be adjusted to achieve consistency. The solution is, however, nonunique, since there are, in principle, an infinite number of choices of spot size, shape, and location which will produce a given value of G_s. The phase behavior can remove some of this nonuniqueness. Since we did not detect any phase variations in the TiO data, we have assumed that the spot is a circular polar spot. While this assumption is not strictly necessary, it is the simplest case and is instructive. Photometric data from this epoch, which could provide valuable geometric constraints, is not yet publicly available. The weights required in a synthesis with a K2 V (HR 1084) and an M5 III (HD 175865) were $0.05 < w_s < 0.01$ at R and $0.15 < w_s < 0.2$ at I. Using contrasts of 8.6 and 2.9 for these bands, respectively (from canonical K2 V and M5 III colors of Johnson 1966), G_s/G_* is $\sim$0.3–0.50 from the 710 nm data, and 0.35 to 0.40 from the 860 nm data. Using the smaller range, the spot radius is $\sim 60°$ for an inclination of 60° and increases to 80° for an inclination of 90°. The coefficient of limb darkening used was $\beta = 0.6$, but the result is not very sensitive to this. Nor does the result depend strongly upon the luminosity class of the M star chosen for the equivalent spot spectrum, since the TiO bands are nearly independent of surface gravity (Wing and Yorka 1979). The spot size is in good agreement with the results of Vogt (1981).

f) Other Metal Lines

We have examined several spectral regions in II Peg in search of variability in temperature-sensitive metal lines. We did not choose lines and examine them but rather chose spectral orders with many lines and compared the observations of II Peg made on different nights. Specifically, we looked at the regions centered on 556 nm, 543 nm, 530 nm, 517 nm, and 494 nm. Each order was $\sim$10 nm wide. Partial line identifications were made using a spectrum of a sharp lined star (HR 1084, K2 V), the α Boo atlas (Griffin 1968), and a table of solar lines (Moore, Minnaert, and Houtgast 1966). The regions contain many lines which are very strong or moderately strong in sunspots. Instrumental effects become very important at this level of weak variations ($<1\%$) or so of the continuum). Small differences in the dispersion on different nights, due to slight variations in spectrograph focus, result in imperfect alignment along an order. The instrumental sensitivity along the order often limited the comparison of spectra to the central region where the data were less noisy. The Mg *b* lines at 517.27 nm and 518.362 nm and Fe I 516.63 nm showed slight residuals on different nights, as did the blend, Fe I 495.75 nm, 495.76 nm. These are all deep lines which have a strong temperature dependence, but we cannot yet exclude the possibility of nonlinearities introduced from the scattered light background correction in deep lines (to $\sim$30% of the continuum). We did not detect any variations which we can confidently assign to actual variations in the star.

IV. DISCUSSION AND CONCLUSIONS

The Sun is the primary paradigm for the interpretation of the phenomena seen in the spectra and photometry of active cool stars. The Sun has a wide range of activity manifested in spots, plages, prominences, and flares, all apparently driven by a magnetic dynamo whose magnitude depends upon the rotation and differential rotation rates in addition to the internal structure. It is an uncertain but logical generalization to extrapolate these phenomena by many orders of magnitude to interpret the characteristics of the active cool stars. Yet we should maintain some caution in directly mapping scaled-up versions of solar features onto other stars, particularly when the stars in question are evolved giants, as are many RS CVn systems. Since we cannot directly image the stellar surfaces, we must rely on indirect methods and theoretical models to extricate the individual phenomena and their geometrical structure from the total flux alone. To do this, we rely upon the stellar rotation which sweeps the surface across our line of sight and upon observations in different energy ranges which sample various heights or physical processes in the stellar atmosphere.

In II Peg, the most predominant activity had a rather global longitudinal coverage over the stellar surface, since there was little variation with phase in any of the spectral regions examined. Whether this is true in general or is only a consequence of the distribution of surface features at the epoch of our observations requires further synoptic data. Indeed, past studies have indicated more variability than we have seen here. The Ca II emission is generally attributed to a chromosphere, as is Hα emission. However, the ratio of energy in the first two Balmer lines is usually more similar to that seen in solar prominences than that observed in the solar chromosphere. The volume required to produce the Balmer emission seen in a star like II Peg, however, would have to be very large (see Huenemoerder and Ramsey 1986).

The largest variations in the Balmer lines were due to flare-like events in which the ratio of energy in Hα to that emitted in Hβ drops, indicating the addition of a component with a ratio more typical of solar flares ($E_\alpha/E_\beta \approx 1$) to the more normal component with $E_\alpha/E_\beta \approx 4$. The presence of He D_3 emission during a Balmer line enhancement also indicated very high density and high-temperature material. The changes thus were not due to the varying geometrical aspect of active regions.

While the photospheric spectrum in general was reasonably matched by a K0 to K2 dwarf or subgiant, the TiO bands were stronger in II Peg. This indicated of the presence of cool regions or starspots in the photosphere. An equivalent spectral type near M5 implied a radius of $\sim 60°$ in latitude.

We acknowledge the support of the National Science Foundation through grant AST83-17867. We also thank an anonymous referee for comments which improved the presentation of this paper.

REFERENCES

Barnes, T. G., Evans, D. S., and Moffett, T. J. 1978, *M.N.R.A.S.*, **183**, 285.
Barden, S. C. 1985, *Ap. J.*, **295**, 162.
Bopp, B. W., and Noah, P. V. 1980, *Pub. A.S.P.*, **93**, 333.
Byrne, P. B., *et al.* 1984, in *Proc. 4th European IUE Conf.*, 1984 May 15–18 (Rome), ed. E. Rolfe and B. Battrick (ESA SP-218), p. 343.
Chugainov, P. F. 1976, *Izv. Krymsk. Astrofiz. Obs.*, **54**, 89.
Danks, A. C., and Lambert, D. L. 1985, *Astr. Ap.*, **148**, 293.
Eaton, J. A., and Poe, C. H. 1985, *Inf. Bull. Var. Stars*, No. 2712, p. 1.
Feldman, P. A. 1983, in *IAU Colloquium 71, Activity in Red-Dwarf Stars*, ed. P. B. Byrne and M. Rodono (Dordrecht: Reidel), p. 429.
Griffin, R. F. 1968, *A Photometric Atlas of the Spectrum of Arcturus* (Cambridge: Cambridge University Press).
Heasley, J. N., and Mihalas, D. 1976, *Ap. J.*, **205**, 273.
Huenemoerder, D. P. 1986, *A.J.*, **92**, 673.
Huenemoerder, D. P., and Ramsey, L. W. 1987, *Ap. J.*, submitted.
Johnson, H. L. 1966, *Ann Rev. Astr. Ap.*, **4**, 193.

Linsky, J. L., *et al.* 1979, *Ap. J. Suppl.*, **41**, 481.
———. 1984, in *Proc. 4th European IUE Conf.*, 1984 May 15–18 (Rome), ed. E. Rolfe and B. Battrick (ESA SP-218), p. 351.
Marstad, N., *et al.* 1982, in *Four Years of IUE*, ed. Y. Kondo, J. Meade, and R. D. Chapman (Greenbelt, MD: NASA), p. 554.
Moore, C. E., Minnaert, M. G. J., and Houtgast, J. 1966, *The Solar Spectrum 2395 Å to 8770 Å*, (Washington, DC: GPO).
Nations, H. L., and Ramsey, L. W. 1981, *A.J.*, **86**, 433.
Owen, F. N., and Gibson, D. M. 1978, *A.J.*, **83**, 1488.
Ramsey, L. W., and Huenemoerder, D. P. 1986, in *Proc. Soc. Photo-Opt. Instrum. Eng.*, **627**, 282.
Rucinski, S. M. 1977, *Pub. A.S.P.*, **89**, 280.
Saar, S. H., Linsky, J. L., and Duncan, D. K. 1986, in Proc. 4th Cambridge Workshop, *Cool Stars, Stellar Systems, and the Sun*, ed. M. Zeilik and D. M. Gibson (Berlin: Springer-Verlag), p. 275.
Schwartz, *et al.* 1981, *M.N.R.A.S.*, **196**, 95.
Spangler, S. R., Owen, F. N., and Hulse, R. A. 1977, *A.J.*, **82**, 989.
Tandberg-Hanssen, E. 1967, *Solar Activity* (Waltham, MA: Blaisdell).
Vogt, S. S. 1981, *Ap. J.*, **247**, 975.
Walter, F. M., Cash, W., Charles, P. A., and Bowyer, C. S. 1980, *Ap. J.*, **236**, 212.
Wing, R. F., and Yorka, S. B. 1979, in *IAU Colloquium 47, Spectral Classification of the Future*, ed. M. F. McCarthy, A. G. D. Philip, and G. V. Coyne (Vatican Obs.), p. 519.
Wolff, S. C., and Heasley, J. N. 1984, *Pub. A.S.P.*, **96**, 231.
Zarro, D. M., and Rodgers, A. W. 1983, *Ap. J. Suppl.*, **53**, 815.

David P. Huenemoerder and Lawrence W. Ramsey: Department of Astronomy, 525 Davey Laboratory, University Park, PA 16802