Tennessee State University

Digital Scholarship @ Tennessee State University

Information Systems and Engineering Management Research Publications

Center of Excellence in Information Systems and Engineering Management

1-1989

The Photometric Variability of the Chromospherically Active Binary Star HD 80715

Klaus G. Strassmeier
Tennessee State University

James T. Hooten
Dyer Observatory

Douglas S. Hall
Dyer Observatory

Francis C. Fekel
Dyer Observatory

Follow this and additional works at: https://digitalscholarship.tnstate.edu/coe-research

Part of the Stars, Interstellar Medium and the Galaxy Commons

Recommended Citation

Klaus G. Strassmeier et al 1989 PASP 101 107

This Article is brought to you for free and open access by the Center of Excellence in Information Systems and Engineering Management at Digital Scholarship @ Tennessee State University. It has been accepted for inclusion in Information Systems and Engineering Management Research Publications by an authorized administrator of Digital Scholarship @ Tennessee State University. For more information, please contact XGE@Tnstate.edu.

PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC
101: 107–113, January 1989

THE PHOTOMETRIC VARIABILITY OF THE CHROMOSPHERICALLY ACTIVE BINARY STAR HD 80715

KLAUS G. STRASSMEIER*

Dyer Observatory, Department of Physics and Astronomy, Vanderbilt University, Nashville, Tennessee 37235
and
Center of Excellence in Information Systems Engineering
Tennessee State University, Nashville, Tennessee 37209-1561

AND

JAMES T. HOOTEN, DOUGLAS S. HALL, AND FRANCIS C. FEKEL

Dyer Observatory, Department of Physics and Astronomy, Vanderbilt University, Nashville, Tennessee 37235

Received 1988 July 22, revised 1988 October 7

ABSTRACT

Differential *UBVRI* photometry of the double-lined BY Dra system HD 80715 (K3 V + K3 V) obtained in December 1987 is presented. We found the star to be a variable with a full amplitude of 0.06 mag in *V* and a period similar or equal to the orbital period of 3.804 days. We interpret the mechanism of the variability as rotational modulation due to dark starspots. In an attempt to detect chromospheric activity we obtained high-resolution CCD spectra at Ca II H and K and at Fe I 6430 Å and Ca I 6439 Å, the photospheric lines normally used for Doppler imaging. HD 80715 shows double H and K emission features at a flux level of log $\mathcal{F}$(H + K) ≈ 6.7 erg cm^{-2} s^{-1} for each component. Observations of 11 LMi as a standard star suggest that it was constant within the uncertainties of our photometry during December 1987.

Key words: BY Dra stars–HD 80715–stars: chromospheres–stars: rotation–11 LMi

1. Introduction

As part of our study of the spectroscopic and photometric behavior of chromospherically-active binary stars at Vanderbilt University, we are making differential *UBV* photometry of a sample of approximately 80 well-known and suspected variables (Strassmeier and Hall 1988*a*,*b*; Fekel and Hall 1985). Recently, Barden and Nations (1986, 1988) drew attention to the newly-discovered BY Draconis system HD 80715 (V = 7.7 mag; $\alpha = 9^h22^m27^s$, $\delta = +40°12'22''$; 2000.0) and, as a consequence of this, the system was included in the catalog of *Chromospherically Active Binary Stars* (= CABS; Strassmeier *et al.* 1988*a*). From four measurements which showed a standard deviation of 0.035 mag in *V*, Rufener and Bartholdi (1982) suspected the star to be a "microvariable", i.e., having an amplitude less than approximately 0.02 mag; hence, the star was put on the observing list of the 0.4-m Vanderbilt automatic photoelectric telescope (= APT; Boyd, Genet, and Baliunas 1986) on top of Mount Hopkins, Arizona.

Medium-resolution spectroscopy of this system was reported by Barden and Nations (1986) (= paper BN; updated by the same authors in 1988). Their observations showed HD 80715 to be a double-lined K3 V + K3 V system. Both components have variable Hα emission and strong Ca II infrared triplet emission reversals. However, no Ca II H and K observations had been obtained previously. The K3 V spectral-type classification is in accordance with earlier photometry by Cowley, Hiltner, and Witt (1967) from which they found $(B-V) = +0.98$ mag and $(U-B) = +0.78$ mag.

In this paper we report the results of our simultaneous photometric and spectroscopic observations obtained in December 1987. As a by-product we also list differential *UBVRI* photometry of 11 Leonis Minoris, a photometrically-variable, chromospherically-active single star with a rotation period of 18 days which also happens to be a *UBVRI* standard star.

2. Observations and Reduction

2.1 *Photometry*

Our photometric observations were obtained on nine nights between 1987 December 21 and 30 at Mount Hopkins, Arizona, with the 0.4-m Vanderbilt APT under

---

*Visiting Astronomer, Kitt Peak National Observatory, National Optical Astronomy Observatories, operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

full microcomputer control. During that time only three program stars were on the master observing list of the APT: HD 26337, HD 80715, and 11 LMi. The telescope utilizes a thermoelectrically-cooled GaAs Hamamatsu R943-02 photomultiplier with filters which were selected to match *UBV* of the Johnson system and *RI* of the Kron-Cousins system.

The individual measurements were made differentially with respect to HD 80492 (V = 7.1 mag) as a comparison star, and the APT used HD 82741 (= HR 3809; V = 4.81 mag) as an additional check star. The resulting differential magnitudes, corrected for differential atmospheric extinction, are listed in Table 1. These values have been transformed to the Johnson *UBV* standard system but not to the Kron-Cousins *RI* system, because the transformation coefficients ϵ_r and ϵ_i were not known for this observing season. The resulting instrumental differential magnitudes (Δr and Δi), however, are very close to standard differential magnitudes (ΔR and ΔI) because the color difference between variable and comparison was so small, less than 0.1 mag in ($V-R$) and ($R-I$). Moreover, because HD 80715 is virtually constant in color as it varies, the light-curve amplitudes would be virtually unaffected by transformation. We estimate the external precision of our differential photometry to be ±0.012 mag in V, R, and I; ±0.015 mag in B; and ±0.020 mag in U.

TABLE 1

Photometry of HD 80715 minus HD 80492

Hel. J. D.	ΔV	Δ(U-B)	Δ(B-V)	Δ(V-R)	Δ(V-I)
2447151.8575	1.090	0.183	0.059	0.087	0.162
2447151.9629	1.114	0.206	—	0.085	0.159
2447151.9982	1.066	0.198	0.066	0.077	0.147
2447152.8725	1.141	—	—	—	—
2447152.9782	1.130	—	—	—	—
2447157.0324	1.141	0.192	0.070	0.084	0.166
2447157.0502	1.143	0.203	0.068	0.087	0.166
2447157.9187	1.114	0.211	0.064	0.081	0.159
2447157.9365	1.119	0.221	0.060	0.079	0.160
2447157.9543	1.120	0.201	0.065	0.082	0.162
2447157.9723	1.121	0.208	0.059	0.083	0.160
2447157.9903	1.113	0.222	0.058	0.084	0.161
2447158.0081	1.115	0.211	0.056	0.084	0.159
2447158.0259	1.115	0.221	0.058	0.085	0.158
2447158.0437	1.119	0.207	0.059	0.083	0.165
2447158.0617	1.125	—	—	0.082	0.157
2447158.8389	1.115	0.190	0.049	0.095	0.163
2447158.8569	1.085	0.222	0.035	0.082	0.156
2447158.8747	1.110	0.189	0.042	0.094	0.173
2447158.8927	1.103	0.192	0.052	0.084	0.156
2447158.9105	1.083	0.206	0.050	0.086	0.156
2447158.9462	1.088	—	0.058	0.077	0.140
2447158.9641	1.093	0.193	0.059	0.086	0.144
2447158.9820	1.093	0.214	0.053	0.083	0.162
2447158.9999	1.091	—	—	0.085	0.154
2447159.8364	1.143	—	0.061	0.098	0.167
2447159.8904	1.141	0.211	0.062	0.082	0.172
2447159.9082	1.142	0.234	0.037	0.089	0.180
2447159.9260	1.134	0.195	0.065	—	0.169
2447159.9440	1.147	0.174	0.079	0.094	0.178
2447159.9619	1.139	0.218	0.067	0.083	0.164
2447159.9800	1.153	0.218	0.059	0.100	0.166
2447159.9979	1.141	0.216	0.069	0.083	0.164
2447160.0161	1.141	0.210	0.060	0.084	0.171
2447160.0342	1.147	0.202	0.067	0.086	0.169
2447160.0522	1.135	0.206	0.071	0.085	0.160
Mean	1.119	0.206	0.059	0.085	0.162

2.2 *Spectroscopy*

Simultaneous with the photometry, two high-resolution CCD spectra were obtained at KPNO with the coudé feed telescope on the nights of December 27 and 29. The spectrograph was used with grating A and camera 5 in third order for the blue region (centered on 3950 Å) to give a dispersion of 4.7 Å mm^{-1}, and with camera 6 in second order for the red region (centered on 6435 Å) to give a dispersion of 2.0 Å mm^{-1}. The detector was the 512 × 512 Tektronix CCD which, combined with the slit width, allowed an effective wavelength resolution of 0.11 Å in the red and 0.24 Å in the blue. The Ca II H and K spectrum has been calibrated absolutely following the precepts of Linsky *et al.* (1979). All reductions were made in the common fashion with the coudé/CCD reduction software (Pilachowski and Barnes 1987) available within the IRAF[1] (Image Reduction and Analysis Facility) at KPNO.

3. Discussion

3.1 *Period Analysis*

A period-finding program, based on least-squares fits to a *sine curve*, showed the best photometric period at 3.35 days (see Table 2) with relatively small uncertainties in all five colors of around ±0.10 day. The derived uncertainties given for each value of $P_{\rm phot}$ in Table 2 imply unrealistic small rms errors in the photometry for several of the bandpasses, thereby making the derived uncertainties unrealistically small. If we assume more realistic values

TABLE 2

HD 80715: Light curve parameters from the least-squares fit

Bandpass	n	P_{phot} [a] (days)	$\sum(O-C)^2$	Mean diff. brightness (mag)	Full amplitude (mag)
U	36	3.28 ±0.15	0.0621	1.371	0.095 ±0.023
B	34	3.33 ±0.09	0.0041	1.177	0.070 ±0.006
V	33	3.35 ±0.07	0.0023	1.119	0.059 ±0.005
R	37	3.36 ±0.13	0.0279	1.027	0.053 ±0.005
I	40	3.38 ±0.08	0.0033	0.954	0.043 ±0.006

[a] Note that the uncertainty here describes the precision of determining the period according to our technique and does not necessarily imply the accuracy of the period.

---

[1] IRAF is distributed by National Optical Astronomy Observatories, which is operated by the Association of Universities for Research in Astronomy, Inc., under contract to the National Science Foundation.

for the rms errors in the photometry, the uncertainty in the period becomes more like ±0.5 day, mostly due to the relatively small baseline in time (nine nights, less than three complete cycles). This value for the *photometric* period is, within its uncertainty, consistent with the 3.80-day *orbital* period. Therefore, we adopted the orbital period for our phase plot in Figure 1. Visual examination of the *V* light curves plotted once with the 3.80-day period

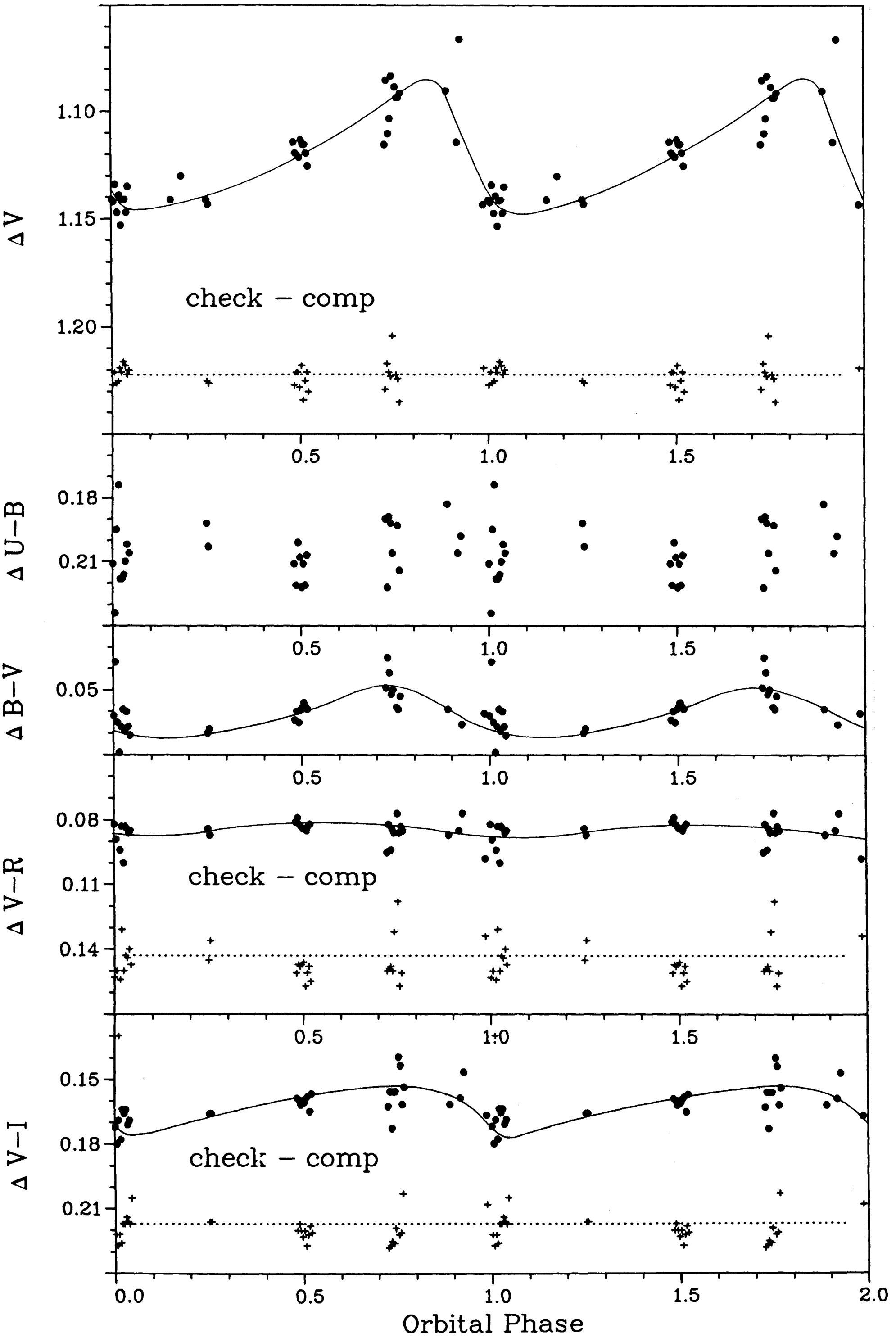

FIG. 1–Differential light and color curves for HD 80715 minus HD 80492. Phase has been computed from equation (1) with the *orbital* period of 3.804 days. All four colors show small variations in phase with the light-curve minimum, partially due to the temperature difference spot-photosphere. No fit has been drawn through the $(U-B)$ data because of their relatively large scatter compared to the amplitude.

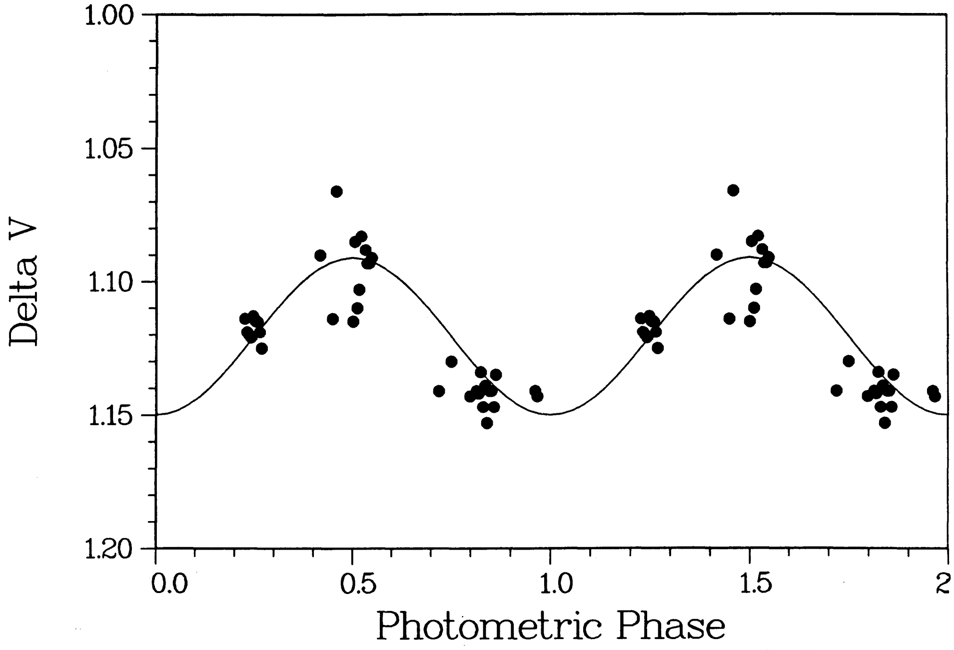

FIG. 2–Same V-light curve of HD 80715 as in Figure 1 but phase has been computed with the "best" *photometric* period of 3.35 days. A period-finding program, based on least-squares fit to a *sine curve,* showed the best period at 3.35 ± 0.5 days, the formal value being substantially different from the orbital period but with the large uncertainty still consistent with the 3.8-day period from the spectroscopy. For demonstration purposes we nevertheless plot the V data versus photometric phase.

(Fig. 1, upper panel) and again with the 3.35-day period (Fig. 2) showed some change in shape but no significant increase or decrease of the overall scatter. As discussed later, it would have been a major problem to explain a rotation period much shorter than the orbital period for an old disk star in a binary system with a very nearly circular orbit and $P_{\mathrm{orb}} \leq 100$ days.

Barden and Nations (1988) kindly provided us with an update of their preliminary orbit determination presented at the Cool Star Workshop in Santa Fe. Adding our one high-precision radial velocity obtained at a double-lined phase, which was made approximately three years later than the last measure of BN, we recomputed the orbital elements with a slightly modified version of the computer program of Wolfe, Horak, and Storer (1967). Final orbital elements for each component were computed with a differential correction program (Barker, Evans, and Laing 1967). BN list an orbital period of 3.8025 ± 0.0025 days which we revise to 3.80406 ± 0.000035 days. The formal solution of the eccentricity for both components is 0.011 ± 0.005 and 0.031 ± 0.005, respectively, but because ω does not differ by approximately 180°, we conclude that the orbit is circular or at best only very slightly eccentric (i.e., ≤ 0.01).

Most recently, Fekel and Eitter (1989) used the CABS catalog and their latest observations to investigate the status of synchronization in chromospherically-active binary systems. They found that only 7% to 11% of the 94 systems with periods less than 30 days are asynchronously rotating, about 50% of the 13 systems between 30 and 70 days are asynchronously rotating, and the seven systems with periods greater than 70 days are nearly all or all asynchronously rotating. As was done by Hall (1988), cases of pseudosynchronous rotation were considered synchronous. These statistics support the purely hydrodynamic mechanism for synchronization and circularization proposed by Tassoul (1987). A 3.35-day rotation period for HD 80715 would, in the case of pseudosynchronization (Hut 1981; Hall 1986), require an orbital eccentricity of $e = 0.15$, clearly not consistent with the observed value.

With the revised orbital period of 3.80406 days and a mass ratio of $q = 1.036$ we may use equation (4) in Tassoul (1988) and find a *circularization* time for HD 80715 of $t_{\mathrm{circ}} \approx 2.7 \times 10^7$ years (we adopted the radius, luminosity, and mass of a K3 V star, a fractional gyration radius of 0.1, and $N = 10$).[2] Assuming that the *synchronization* time is ten times the spin-down time (conservative case) and using equation (10) in Tassoul (1987), one finds that $t_{\mathrm{syn}} \approx 2500$ years. The space motions of $(U,V,W) = (-22, -51, -28)$ km s^{-1} listed in Strassmeier *et al.* (1988*a*) are characteristic of the old disk population; thus, HD 80715 should have been in synchronous rotation and circular revolution for a long time.

3.2 *Light and Color Curves for HD 80715*

The individual differential *UBVRI* measures are pre-

---

[2] $N = 10$ represents the case of solar-type stars. The factor $10^{-N/4}$ in Tassoul's equations describes the effects of turbulence on the spin-down mechanism and is a free parameter.

sented in Table 1. The light and color curves are plotted in Figure 1 along with the check-minus-comparison star measures for ΔV, $\Delta(V-R)$, and $\Delta(V-I)$. Phase has been computed from

$$\mathrm{JD} = 2447159.89(\pm 0.09) + 3.80406 \times E\ , \qquad (1)$$

where the initial epoch is a time of minimum light.

A (sinusoidal) Fourier fit to all our V data shows a full amplitude of 0.059 ± 0.005 mag (Table 2). Three of the color curves, $(B-V)$, $(V-R)$, and $(V-I)$, show small amplitudes of 0.021 ± 0.005 mag, 0.005 ± 0.002 mag, and 0.015 ± 0.004 mag, respectively, which are in phase with the V light curve in the sense redder color at light minimum. This is a phenomenon seen in spotted stars; notice that the scatter in $(U-B)$ is almost twice the scatter in the other colors. Poe and Eaton (1985) demonstrated that a significant amount of the color amplitudes in spotted stars is due to the wavelength-dependent, limb-darkening coefficients. Only in I is the flux ratio, spot to photosphere, large enough and different enough from that in V to give a color variation which is dominated by the spot-minus-photosphere temperature difference. The situation for HD 80715 is further complicated by the fact that we have *two* rapidly rotating, chromospherically active components: We do not know a priori which one is the spotted one and, even worse, both stars could be spotted and the light and color curves a mixture of the variations from both stars. Thus, deriving a spot temperature might be misleading. Nevertheless, applying Vogt's (1981*a*) temperature method we may derive a temperature difference (star minus spot) of $\Delta T = 1500$ K ± 600 K. With T_{eff} (star) = 4730 K, which is appropriate for a K3 V star of $(V-R) = 0.82$, a spot temperature of approximately 3200 K ± 600 K results. The asymmetric shape of the light curve implies, if we assume that only *one* star is spotted, that there were at least two spots or spot groups close enough in longitude to produce only one light minimum. This is another characteristic very commonly observed among spotted stars; see, e.g., HK Lacertae (Oláh and Hall 1988), σ Geminorum (Strassmeier *et al.* 1988*b*), and II Pegasi (Poe and Eaton 1985). A similar (asymmetric) light-curve shape has been seen on II Peg in 1974 and 1976 (Vogt 1981*b*).

3.3 *Active Chromosphere Characteristics*

Figure 3 shows our Ca II H and K observation at an orbital phase of 0.253 (HJD2447158.9253). Both components have strong H and K emission well above the continuum and also Balmer Hε emission. Following the calibration procedure described in Linsky *et al.* (1979), we measured an absolute emission-line surface flux of $\log \mathcal{F}(\mathrm{H} + \mathrm{K}) \approx 6.7$ erg cm^{-2} s^{-1} for both components (Table 3; assuming $(V-R) = 0.82$).

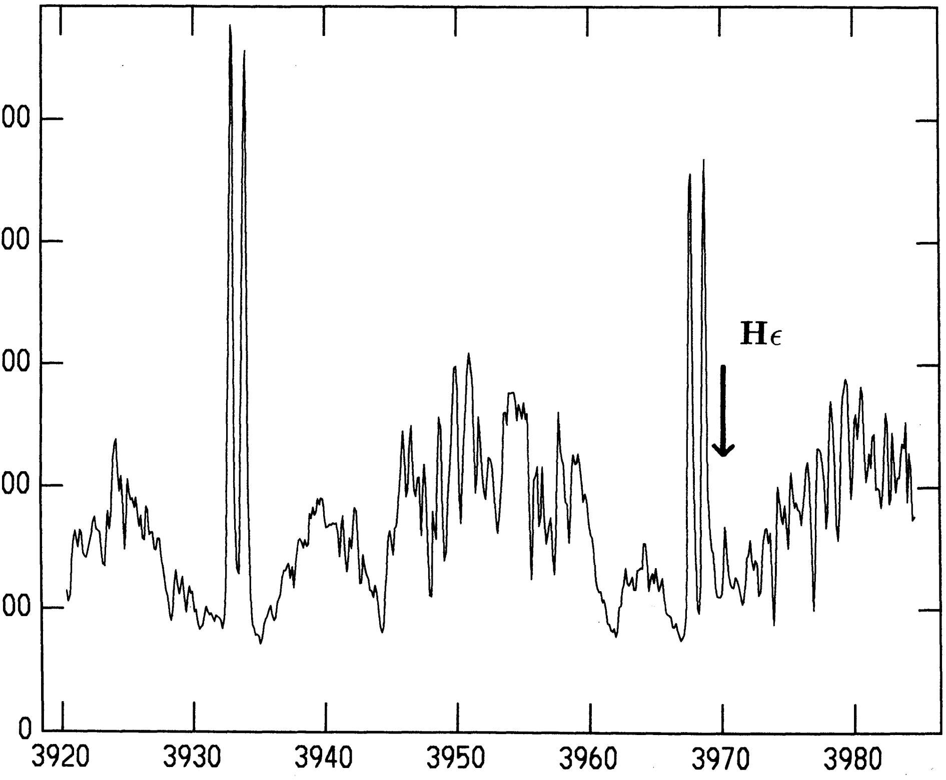

FIG. 3–Ca II H and K CCD spectrum of HD 80715. Both components have strong emission lines well above the continuum. The stronger (= blueshifted) K emission line corresponds to component *a*. The arrow indicates the Hε emission line from component *b*. Note that the Hε emission line from component *a* is blended with the Ca II H emission line from component *b*.

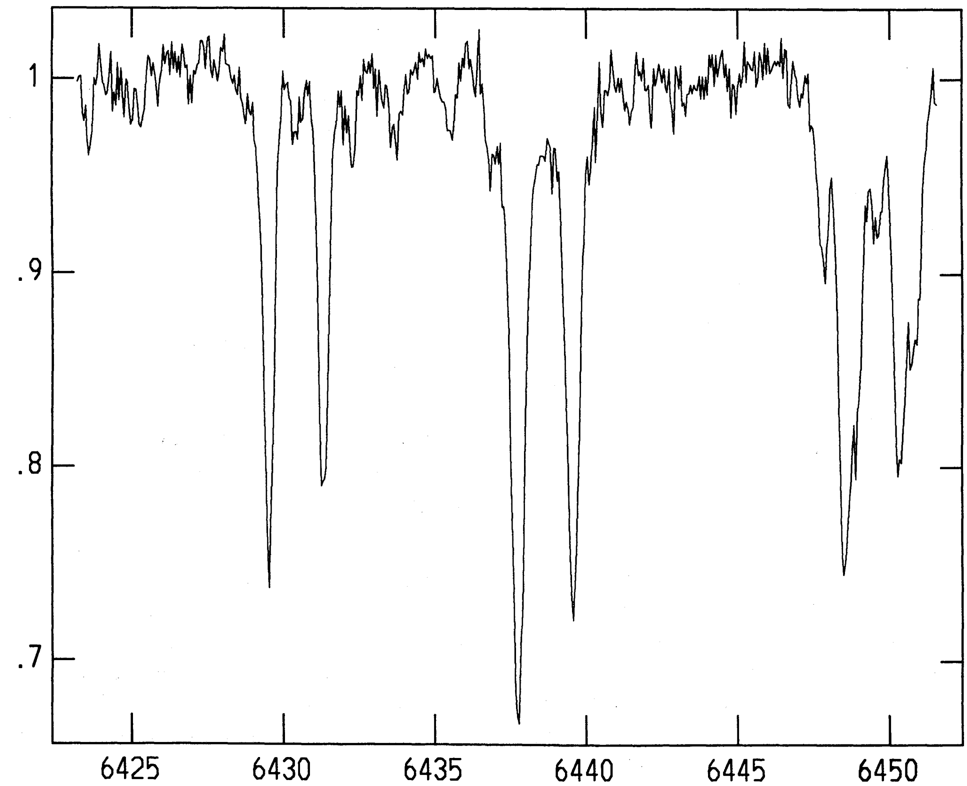

FIG. 4–High-resolution CCD scan of the Fe I 6430 Å and Ca I 6439 Å lines at a double-lined phase. Both lines are rotationally broadened by ≈ 10 km s^{-1}. Note that the weaker (= redshifted) line corresponds to component *a*.

TABLE 3

HD 80715: Spectroscopic results

	component *a*	component *b*
$\log\mathcal{F}(K_1)$[a]	6.45	6.45
$\log\mathcal{F}(H_1)$	6.28	6.32
$\log R_{HK}$[b]	-3.80	-3.77
$\log\mathcal{F}(H\epsilon)$	blend	5.79
$v\sin i$ (km s^{-1})	10.4±1.5	10.4±1.5
radial velocity (km s^{-1}) (HJD 244 7157.0531)	+36.4	-47.0

[a] Fluxes in erg cm^{-2} s^{-1}.

[b] The fraction of the stellar luminosity σT^4_{eff} which appears as emission in the H and K lines.

Figure 4 is a plot of the spectral region around 6435 Å showing the Fe I 6430 Å and Ca I 6439 Å lines. The FWHM for the two components, corrected for instrumental profile, is 0.382 Å. Both lines are rotationally broadened by 10.4 ± 1.5 km s^{-1} assuming a macroturbulence profile of 3 km s^{-1}. With this value for $v \sin i$ and the assumption that the rotation period is equal to the orbital period, we derive minimum radii of 0.78 ± 0.11 $R_\odot$, consistent with the dwarf luminosity classification. Using the IAU radial-velocity standard β Virginis (3.8 km s^{-1}) and a cross-correlation program available at KPNO (Willmarth and Abt 1985), we find the velocities for components *a* and *b* to be +36.4 and −47.0 km s^{-1}, respectively. The $O-C$ residuals computed using our new radial-velocity solution are −0.07 and −0.19 km s^{-1}, respectively.

3.4 *11 LMi as a Standard Star*

Skiff and Lockwood (1986) found 11 LMi to be variable with an amplitude of 0.033 mag in Strömgren *y* and a rotation period of 18.0 days. Earlier, Noyes *et al.* (1984) derived an 18.1-day rotation period from Ca II K line flux monitoring at Mount Wilson. During our nine-night run with the APT we also made a total of 30 differential *UBVRI* measures of 11 LMi using the same comparison and check star as for HD 80715. In Table 4 we list the rms deviations from the means in *V* and in the color indices. The rms deviation in *V* is so small, only ±0.012 mag, that we may conclude that 11 LMi was essentially constant during the time of our observations in December 1987. Despite the very short baseline, only one-half of a rotation cycle, we present these data for future use by other investigators.

We would like to thank Louis Boyd and Russ Genet for their enthusiastic help with the APT observations. K.G.S. acknowledges receipt of the Henri Chretien Award 1987 of the American Astronomical Society.

TABLE 4

Photometry of 11 LMi minus HD 80492

Hel. J. D.	ΔV	Δ(U-B)	Δ(B-V)	Δ(V-R)	Δ(V-I)
2447152.0068	-1.339	-0.120	-0.128	-0.053	-0.210
2447157.0412	-1.323	-0.122	-0.126	-0.055	-0.198
2447157.9274	-1.328	-0.117	-0.116	-0.058	-0.207
2447157.9453	-1.325	-0.120	-0.117	-0.059	-0.203
2447157.9631	-1.328	-0.118	-0.118	-0.058	-0.205
2447157.9813	-1.327	-0.119	-0.118	-0.061	-0.207
2447157.9991	-1.322	-0.115	-0.124	-0.055	-0.202
2447158.0169	-1.321	-0.118	-0.125	-0.054	-0.200
2447158.0347	-1.326	-0.118	-0.118	-0.057	-0.201
2447158.0526	-1.320	-0.116	-0.126	-0.057	-0.200
2447158.8479	-1.311	——	——	-0.028	-0.167
2447158.8657	-1.334	-0.110	-0.119	-0.060	-0.202
2447158.8836	-1.324	-0.119	-0.128	-0.049	-0.195
2447158.9017	-1.330	-0.119	-0.126	-0.043	-0.202
2447158.9551	-1.336	-0.100	-0.135	-0.047	-0.219
2447158.9909	-1.328	-0.125	-0.122	-0.060	-0.209
2447159.0088	-1.349	——	——	-0.084	-0.221
2447159.0268	-1.310	-0.113	-0.148	-0.019	-0.177
2447159.0449	-1.316	-0.131	-0.126	-0.044	-0.194
2447159.0629	-1.327	——	-0.121	-0.069	-0.214
2447159.8810	-1.322	-0.128	-0.119	-0.047	——
2447159.9169	-1.322	-0.123	-0.125	-0.066	-0.196
2447159.9349	-1.329	-0.131	-0.116	-0.066	-0.210
2447159.9528	-1.322	-0.118	-0.130	-0.055	-0.205
2447159.9709	-1.330	-0.126	-0.117	-0.053	-0.199
2447159.9888	-1.317	-0.128	-0.127	-0.054	-0.200
2447160.0068	-1.327	-0.135	-0.114	-0.057	-0.207
2447160.0251	-1.321	-0.125	-0.124	-0.046	-0.202
2447160.0432	-1.315	-0.133	-0.129	-0.054	-0.194
2447160.0611	-1.322	-0.134	-0.124	-0.058	-0.204
Mean :	-1.325	-0.122	-0.124	-0.054	-0.202
σ ±	0.012	0.011	0.008	0.011	0.009

This research was partially supported by NASA grant NAG8-111.

REFERENCES

Barden, S. C., and Nations, H. L. 1986, in *Cool Stars, Stellar Systems, and the Sun*, ed. M. Zeilik and D. M. Gibson (Heidelberg: Springer), p. 262 (BN).

______. 1988, private communication.

Barker, E. S., Evans, D. S., and Laing, J. D. 1967, *Roy. Obs. Bull.*, No. 130.

Boyd, L. J., Genet, R. M., and Baliunas, S. L. 1986, *I.A.P.P.P. Commun.*, **25**, 15.

Cowley, A. P., Hiltner, W. A., and Witt, A. N. 1967, *A.J.*, **72**, 1334.

Fekel, F. C., and Eitter, J. J. 1989, *A.J.*, submitted.

Fekel, F. C., and Hall, D. S. 1985, *I.A.P.P.P. Commun.*, **20**, 37.

Hall, D. S. 1986, *Ap. J. (Letters)*, **309**, L83.

______. 1988, in *Proceedings of the Tenth Regional European I.A.U. Meeting*, ed. P. Harmanec (Prague: Czechoslovakian Academy of Science), p. 123.

Hut, P. 1981, *Astr. Ap.*, **99**, 126.

Linsky, J. L., Worden, S. P., McClintock, W., and Robertson, R. M. 1979, *Ap. J. Suppl.*, **41**, 47.

Noyes, R. W., Hartmann, L. W., Baliunas, S. L., Duncan, D. K., and Vaughan, A. H. 1984, *Ap. J.*, **279**, 763.

Oláh, K., and Hall, D. S. 1988, *Commun. Konkoly Obs.*, No. 91, 123.

Pilachowski, C., and Barnes, J. 1987, *IRAF Reduction of Coudé/CCD Spectra* (Tucson: NOAO/KPNO).

Poe, C. H., and Eaton, J. A. 1985, *Ap. J.*, **289**, 644.

Rufener, F., and Bartholdi, P. 1982, *Astr. Ap. Suppl.*, **48**, 503.

Skiff, B. A., and Lockwood, G. W. 1986, *Pub. A.S.P.*, **98**, 338.

Strassmeier, K. G., and Hall, D. S. 1988*a*, *Ap. J. Suppl.*, **67**, 439.

______. 1988*b*, *Ap. J. Suppl.*, **67**, 453.

Strassmeier, K. G. *et al.* 1988*b*, *Astr. Ap.*, **192**, 135.

Strassmeier, K. G., Hall, D. S., Zeilik, M., Nelson, E., Eker, Z., and Fekel, F. C. 1988*a*, *Astr. Ap. Suppl.*, **72**, 291 (= CABS catalog).

Tassoul, J.-L. 1987, *Ap. J.*, **322**, 856.

______. 1988, *Ap. J. (Letters)*, **324**, L71.

Vogt, S. S. 1981*a*, *Ap. J.*, **250**, 327.

______. 1981*b*, *Ap. J.*, **247**, 975.

Willmarth, D. W., and Abt, H. A. 1985, in *IAU Colloquium 88, Stellar Radial Velocities*, ed. A. G. D. Philip and D. W. Latham (Schenectady: Davis Press), p. 99.

Wolfe, R. H., Horak, H. G., and Storer, N. W. 1967, in *Modern Astrophysics*, ed. M. Hack (Paris: Gauthiers-Villars), p. 251.