The Astrophysical Journal, 297:691–701, 1985 October 15

HD 8358: A NEW ACTIVE CHROMOSPHERE BINARY

Bernard W. Bopp,[1,2,3] Thomas B. Ake,[4] Bret D. Goodrich,[5] John L. Africano,[5] P. V. Noah,[1]
R. J. Meredith,[1] Leigh Hunt Palmer,[6] and R. Quigley[7]
Received 1985 January 10; accepted 1985 April 15

ABSTRACT

The eighth-magnitude G star HD 8358 is shown to be an active chromosphere binary with orbital and photometric period 0.516 days. The star exhibits photometric variability of 0.1–0.2 mag in V, which is due to starspots. At times the light curve is stable for several months, indicating that the spots persist, essentially unchanged, for more than 200 rotations. On other occasions the spot configuration has changed in a month or less. The emission-line surface fluxes from Ca II, Mg II, and other chromospheric/transition-region lines in the spectrum of HD 8358 are nearly as high as the corresponding fluxes in V711 Tau (HR 1099) and UX Ari.

HD 8358 is an unusual member of the "short-period" group of active chromosphere binaries by virtue of its high space velocity, which makes the star a member of the old disk or halo population, and by virtue of its very broad and highly variable Hα emission. The behavior and profile of this emission are remarkably similar to those of HII 1883, a young, single, rapidly rotating K star.

Subject headings: stars: binaries — stars: chromospheres — stars: individual

I. INTRODUCTION

A paper by Bidelman (1981), reporting the discovery of peculiar and interesting stars on objective-prism plates, noted that the star HD 8358 (BD −00°210, SAO 109840) was of G spectral type with slightly fuzzy absorption lines. There could be two explanations for this: HD 8358 might be a double-lined spectroscopic binary (SB 2), unresolved at the dispersion of the objective-prism plate (108 Å mm^{-1} at Hγ), or else the star might be single, but rapidly rotating. Either way, the late spectral type and rapid rotation (either that of a single star or induced in a synchronously rotating binary) implied that HD 8358 should be chromospherically active. We subsequently added the star to our program of optical spectroscopic and photometric observations of active chromosphere stars at Kitt Peak National Observatory (KPNO), and obtained the first slit spectrograms of HD 8358 in 1981 September. These data showed the star to be an SB 2 with strong Hα and Ca II emission. Variations in radial velocity were obvious on exposures spaced an hour apart, indicating a very short orbital period.

In this paper we present the results of an extensive study of HD 8358 employing optical photometry and spectroscopy, as well as UV observations with the *IUE* satellite. HD 8358 exhibits a level of chromospheric activity as extreme as that seen in the RS Canum Venaticorum binaries V711 Tau (HR 1099) or UX Ari. Its relative brightness ($V \sim 8$) and short period suggest that it will be an attractive target for future optical, X-ray, and UV monitoring.

[1] Ritter Observatory and Department of Physics and Astronomy, University of Toledo.
[2] Visiting Astronomer, National Optical Observatory, Kitt Peak National Observatory, operated by Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.
[3] Guest Investigator with the *International Ultraviolet Explorer* satellite.
[4] Computer Sciences Corporation.
[5] Kitt Peak National Observatory.
[6] Department of Physics, Simon Fraser University.
[7] Department of Physics and Astronomy, Western Washington University.

II. PHOTOMETRY

We began photoelectric *UBV* observations of HD 8358 at KPNO in 1982 September and quickly determined that it varied by a few tenths of a magnitude in V, while showing only a very small variation in $(B-V)$ and $(U-B)$. The star is not an eclipsing binary, but instead shows an asymmetric light curve owing to the presence of very large starspots. Similar conclusions have recently been reported by Fekel, Hall, and Henry (1984), who found HD 8358 to vary by 0.14 mag in V with a tentative period of 0.520 days.

Our *UBV* observations were all obtained at the No. 2 0.9 m reflector at KPNO, using the differential photometry program and techniques that we have described previously (Bopp *et al.* 1984). The primary comparison star used for our observations was BD −00°212 (SAO 109848), with BD −00°221 (SAO 109876) observed as a check star. The data were transformed to the Johnson system using the matrix inversion method described by Harris, FitzGerald, and Reed (1981). A total of 273 *UBV* measures of HD 8358 were obtained between 1982 September and 1984 January. Average magnitudes and colors of HD 8358 and its comparison star are given in Table 1. A tabulation of the individual measures is available from the first author upon request.

The light curve of HD 8358 during the interval 1982 September–December is illustrated in Figure 1. The ephemeris used is

$$\phi = \text{JD } 2{,}445{,}330.6326 + 0^{d}.515503E ,$$

where the initial epoch is arbitrary. The stability of the light curve during 1982 permitted a very precise determination of the period. The estimated error in P is ± 0.000002 days. The variability is definitely the result of starspots (see, e.g., Eaton and Hall 1979; Bopp and Noah 1980; Vogt 1981). The light curve is quite asymmetric, and closely resembles the light curve of the active chromosphere binary II Pegasi (HD 224085) in 1976 (Ruciński 1977). The shape of the light curve indicates that the spot distribution is asymmetric in stellar longitude, with a smaller spot (or spot group) *trailing* a larger one in

TABLE 1

AVERAGE MAGNITUDES AND COLORS OF HD 8358

Interval	N	V	$(B-V)$	$(U-B)$
1982 Sep–Dec	136	8.155	0.697	0.141
1983 Aug–Oct	48	8.249	0.714	0.142
1983 Dec–1984 Jan	89	8.210	0.711	0.148
Comparison: BD −00°212		9.126	0.949	0.632

rotation (Bopp and Noah 1980). The small variations in $(B-V)$ and $(U-B)$ show the star to be redder at light minimum, consistent with cool starspot models. Note that we cannot determine which of the stars in the binary has the spot, or whether both are spotted. Certainly it is conceptually simpler to assume that only one of the binary components was spotted in 1982. In this case the corrected amplitude of the light variation is really ~0.35 mag in V, a very high value for an active chromosphere object.

While the 1982 photometric data show the spot to be stable over more than 200 stellar rotations, the observations obtained during 1983–1984 show that changes in the light curves are possible on time scales as short as a few weeks. When the data from this entire 1983–1984 observing season were subjected to period analysis, no coherent periodicity was found. In particular, the period of 0.515503 days would not fit the entire 1983–1984 data set. Since active chromosphere stars are known to exhibit erratic light-curve variations, due presumably to the development or decay of stellar active regions (Hall 1981), we split the 1983–1984 data set in half and analyzed the two halves separately.

Figures 2 and 3 plot the light curve of HD 8358 over the intervals 1983 August–October and 1983 December–1984 January; the same photometric period and zero phase are

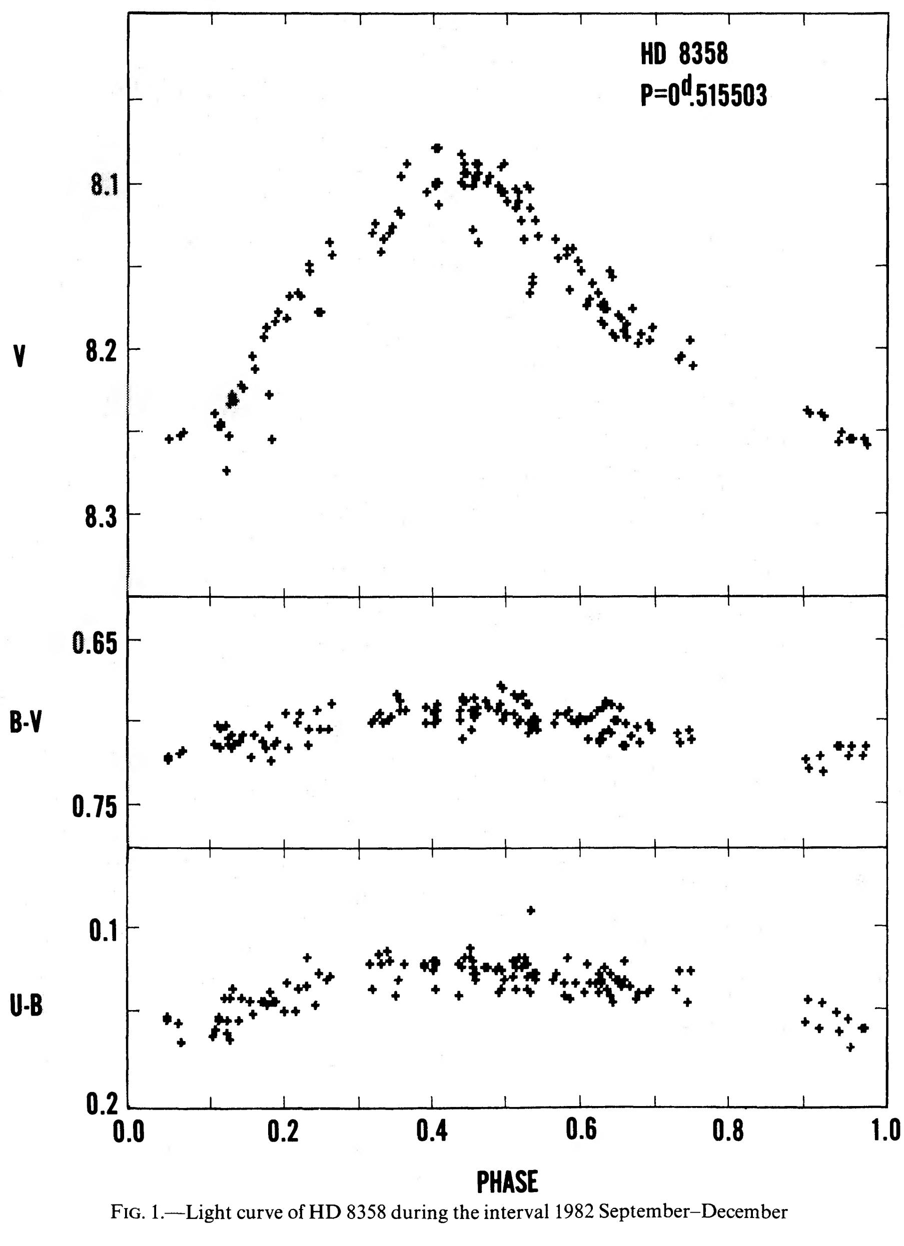

FIG. 1.—Light curve of HD 8358 during the interval 1982 September–December

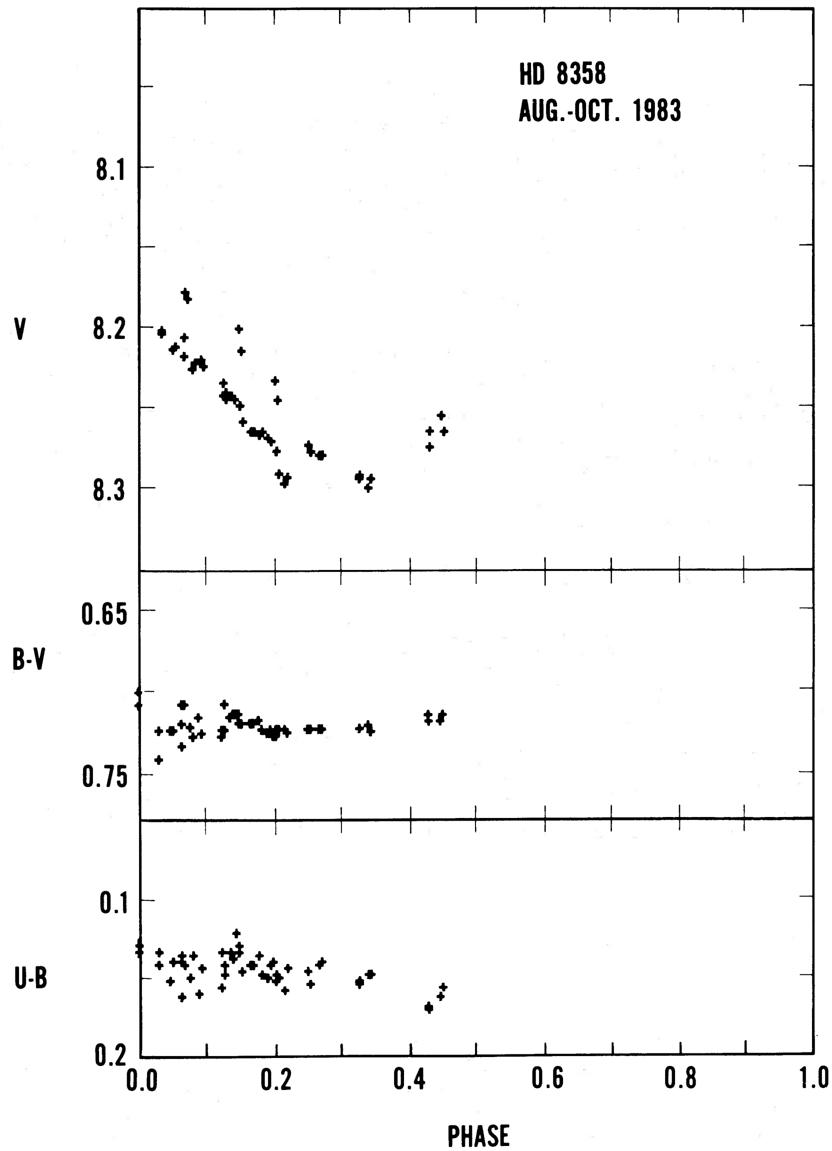

FIG. 2.—Same as Fig. 1, for the interval 1983 August–October

employed as in Figure 1, since we found it impossible to use the 1983–1984 data to extract a better period. Only half the phase is covered by the 1983 August–October observations, because of the nearly 12 hr period. However, it is clear that, in comparison with the 1982 data, there is a phase shift and a deeper minimum. The $(B-V)$ data show the star to be redder during 1983 August–October compared with 1982 (Table 1). Some of the obvious scatter in Figure 2 (and perhaps in Fig. 1 as well) is likely the result of intrinsic variations of the star(s) during the observing intervals.

By 1983 December the light curve of HD 8358 had undergone considerable change. There is no longer the broad minimum and apparently continuous variability of earlier months. There are instead "bumps" in V that extend over small ranges in phase, and the colors appear to show erratic variations.

The binary characteristics and light-curve information permit us to classify HD 8358 as an active chromosphere star which is a member of Hall's (1976, 1981) "short-period" group ($P < 1$ day). Many stars in this group are eclipsing variables as well (e.g., SV Cam, $P = 0.593$ days; UV Psc, $P = 0.861$ days; XY UMa, $P = 0.479$ days), but all show distortions of their light curves outside of eclipse that are the effects of cool starspots. HD 8358 shows no eclipses, but its photometric (rotational) period places it comfortably within this group. The relatively rapid changes in the light curve of HD 8358 are also commonly observed in the short-period group (Zeilik, Elston, and Henson 1983).

III. OPTICAL SPECTROSCOPY

Spectroscopic observations of HD 8358 were obtained at KPNO during observing runs at the coudé feed telescope in September of 1981, 1982, and 1983. The 1981 data were recorded photographically and cover either the Hα region or conventional blue (3800–4800 Å) wavelengths. The dispersions used were 15 Å mm^{-1} in the red and 18 Å mm^{-1} in the blue. The star shows double absorption lines of nearly equal intensity in both blue and red spectral regions. The lines of both binary

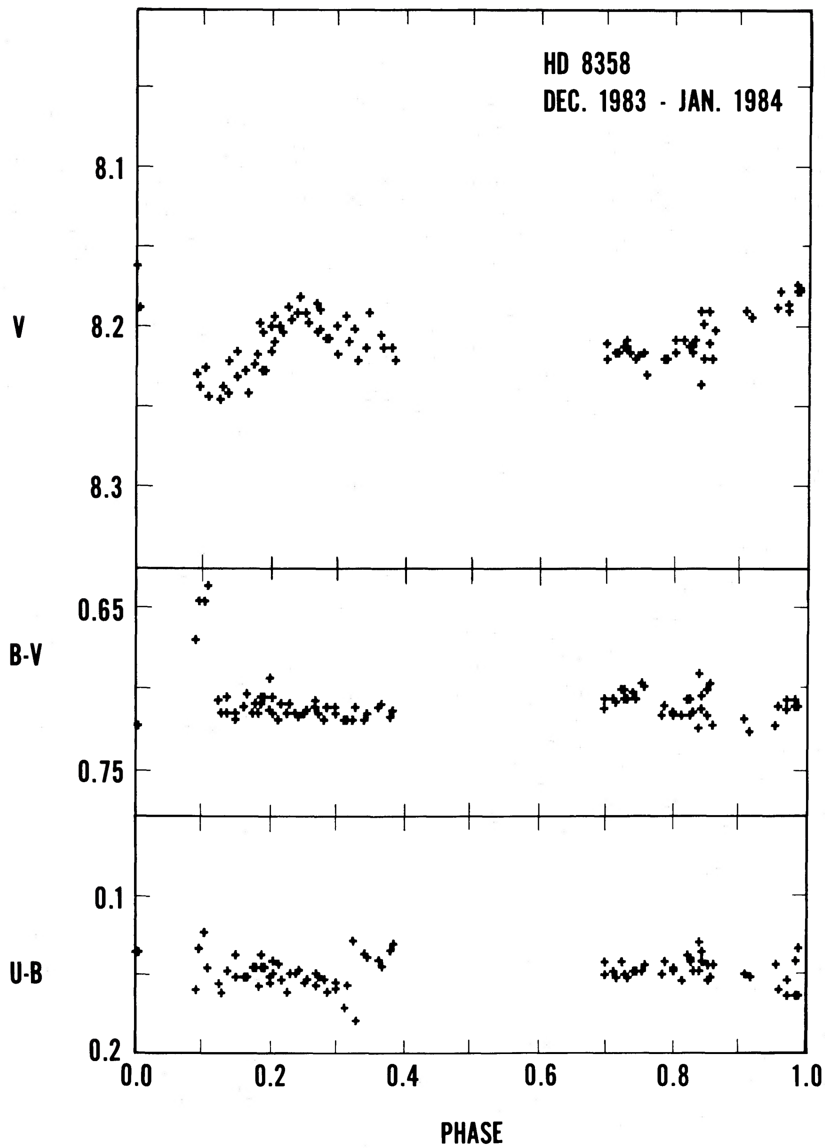

FIG. 3.—Same as Fig. 1, for the interval 1983 December–1984 January

components are quite rotationally broadened, and are consequently difficult to resolve except near maximum velocity separation. The spectral types of both stars are about G5 V. Strong Ca II emission, also rotationally broadened, is present in both binary components (Fig. 4). The emission features do not appear to be very intense compared with other active chromosphere stars, but the emission line surface flux actually exceeds that of V711 Tau. Our measure of the fluxes is performed in the fashion that is described by Bopp (1984); for $(V-R)$ we choose 0.56, a value appropriate for the G5 spectral type. The values of the emission surface fluxes in Table 2 represent integrated values for both components (the lines of the binary are unresolved on two of the plates). The precision of the flux measures is probably about 20%, so evidence for Ca II variability on short time scales is marginal at best.

The Hα line is an emission feature; the line is variable in intensity and profile on short time scales, and is much broader than the maximum velocity separation of the photospheric absorption lines. The behavior of the emission will be discussed in more detail below.

The spectra obtained in 1982 and 1983 were recorded with RCA or TI CCD detectors, covering about 200 Å centered at 6400 or 6500 Å. Coudé camera 5 and either grating B or grating D were used to provide resolutions of 0.9 or 0.4 Å. Standard KPNO routines were used to subtract bias and

TABLE 2

CA II EMISSION-LINE SURFACE FLUXES IN HD 8358

Date (1981 September UT)	Flux (ergs cm^{-2} s^{-1})	
	F(K)	F(H)
26.35	9.8(+6)	1.3(+7)
26.40	7.9(+6)	8.9(+6)
26.47	8.7(+6)	1.2(+7)

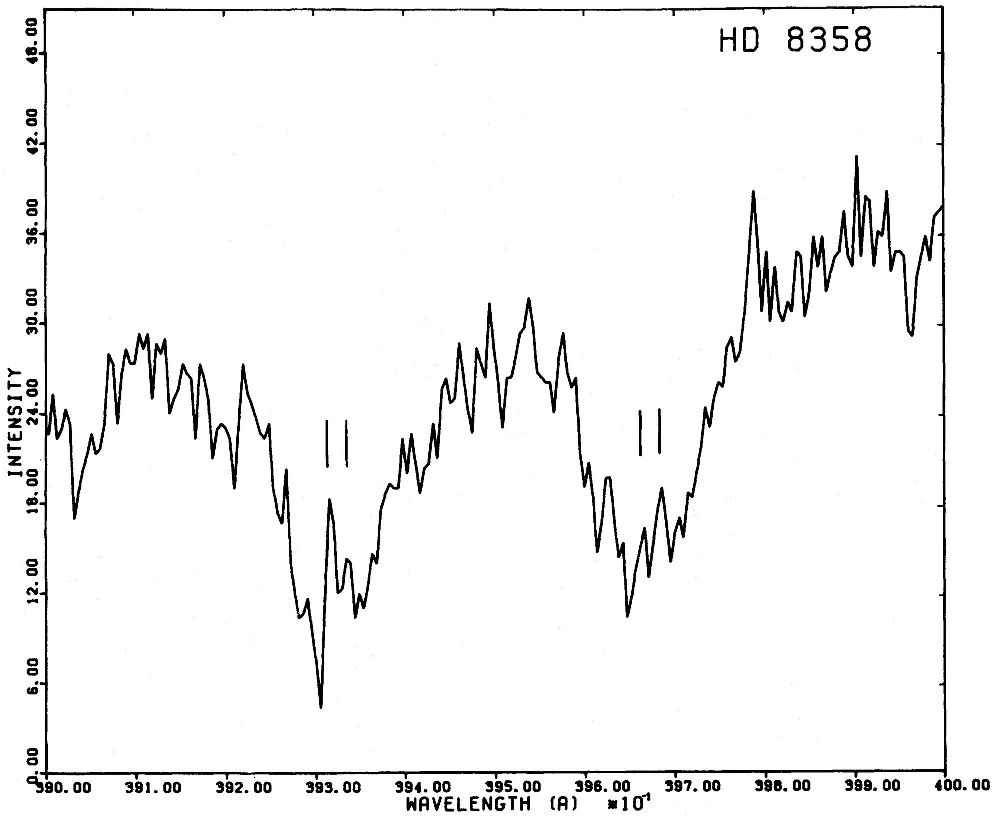

FIG. 4.—Region of Ca II lines in the spectrum of HD 8358. Emission reversals present in both components are indicated by vertical lines. The illustration is a tracing of a KPNO photographic spectrogram taken on JD 2,444,873.

perform flat-field corrections. Wavelength calibration was provided by scans of iron-argon or thorium-argon hollow cathode lamps. Because of the short orbital period we limited our integration times to 1500 s, yielding 500–2000 counts per pixel in the continuum. The double-lined nature of the spectrum limited the signal-to-noise ratio for each binary component to an estimated 20–25 to 1.

a) *Radial Velocities and Orbit*

Velocity measurements of HD 8358 are complicated by the rotationally broadened double lines. We employed the interactive graphical techniques that we have previously used to measure velocities in the rapidly rotating K giant UZ Lib (Bopp *et al.* 1984). On the best CCD scans, 8–10 lines were measured, with resulting internal mean errors of about 5 km s^{-1}. However, on some scans, and on the few photographic plates, only a few lines (sometimes only two) could be measured with any certainty. The lines of one component were slightly weaker on the CCD scans; we identify this star as the slightly less massive secondary.

A total of 49 plates and CCD scans were obtained, of which 28 showed absorption features sufficiently unblended to permit velocity measures. We list these observations in Table 3. Standard period finding programs were used to analyze the radial velocities, and a period close to, but not identical with, the photometric period was indicated. With this preliminary period a least-squares computer program was used to derive orbital elements and their errors. The formal solution gave a very small and statistically insignificant value for the orbital eccentricity, which we have subsequently set equal to zero. The final orbital elements of HD 8358 are given in Table 4; the velocity curves are shown in Figure 5.

The values for $M_1 \sin^3 i$ and $M_2 \sin^3 i$ are small, indicating that the inclination angle is small. An appropriate value for the mass of a G5 V star is about 0.9 $M_\odot$, implying a value of the orbital inclination $i = 30°$. With assumed stellar radii of 0.9 $R_\odot = 6.3 \times 10^5$ km, the stars are separated by about twice this distance. With this geometry no eclipses are expected.

The broadening of the spectral absorption lines that we measure on the best single-line CCD scans corresponds to $v \sin i = 60 \pm 10$ km s^{-1}, or to an equatorial velocity ~ 120 km s^{-1}. For stars with radii 0.9 $R_\odot$ a rotation period of 0.516 days results in an equatorial velocity of ~ 90 km s^{-1}, in reasonable agreement with observations.

b) Hα *Emission Profile*

The Hα feature in HD 8358 is a broad emission line, exhibiting marked profile and equivalent width (EW) variability. The emission character of the line is by itself unusual: Hα emission is not uncommon among chromospherically active late dK and dM stars, but it is quite rare in earlier types. Even among the RS CVn binaries of conventional period (1 day–2 weeks), only a very few show Hα as an emission feature above continuum (Bopp and Talcott 1978).

The CCD scans centered near 6500 Å include the Hα line. Nineteen such scans were obtained on three successive nights in 1982 September (total phase coverage ~ 0.5) and eight of these, ordered in *photometric* phase, are shown in Figure 6. These data span six rotation cycles of HD 8358, and provide strong evidence for systematic profile variations in Hα.

TABLE 3

RADIAL VELOCITY OBSERVATIONS OF HD 8358

HJD 2,440,000+	PHASE	VELOCITY (km s^{-1}) 1	VELOCITY (km s^{-1}) 2	$O-C$ (km s^{-1}) 1	$O-C$ (km s^{-1}) 2
4873.852	0.386	−146.5	−0.2	−13.1	+27.4
5230.934	0.698	−11.5	−167.5	−1.7	−4.9
5232.948	0.603	−25.2	−146.3	+11.3	−12.9
5232.967	0.639	−9.1	−153.9	+14.7	−6.7
5232.984	0.672	−1.7	−163.6	+13.1	−6.5
5233.002	0.707	−3.6	−159.5	+4.9	+4.5
5233.827	0.307	−155.7	−24.9	−0.6	−21.1
5233.845	0.342	−150.1	−23.5	−2.6	−11.3
5234.823	0.238	−157.6	−8.7	+2.2	−10.0
5234.841	0.272	−159.0	−0.3	+0.3	−1.0
5234.859	0.308	−152.0	−19.8	+3.1	−15.9
5234.877	0.342	−159.0	−18.4	−11.6	−6.1
5599.788	0.833	−10.9	−158.2	+4.8[a]	−2.1
5599.938	0.123	−128.7	...	+8.2[a]	...
5599.957	0.160	−157.3	+14.1	−9.2[a]	+25.6
5600.969	0.123	−134.2	−10.1	+2.5	+13.9
5600.988	0.159	−143.9	−3.2	+3.8	+8.7
5601.007	0.196	−147.3	−0.2	+8.3	+3.1
5602.818	0.707	−16.3	−156.5	−7.9	+7.5
5602.838	0.746	−10.1	−158.5	−4.5	+8.6
5602.870	0.808	−12.9	−154.7	−2.3	+6.9
5602.888	0.843	−17.3	−155.0	+1.1	−1.8
5602.906	0.877	−29.4	−153.2	−0.5	−11.5
5602.924	0.912	−39.5	−156.3	+2.8	−29.3
5603.844	0.697	−13.2	−145.9	−3.3	+16.5
5603.861	0.729	−19.7	−171.0	−13.4	−4.6
5603.879	0.764	−10.8	−164.0	−4.9	+2.8
5603.896	0.797	−7.4	−163.6	+1.5	−0.1

[a] These primary-star velocities, and all the secondary-star velocities, have been given half-weight in the orbital solution.

TABLE 4

ORBITAL ELEMENTS OF HD 8358

Element	Value
P	0.515782 ± 0.000008 days
e	0.0
γ	−82.8 ± 1.8 km s^{-1}
K_1	77.2 ± 2.5 km s^{-1}
K_2	84.3 ± 5.2 km s^{-1}
T	JD 2445603.485 ± 0.173
$a_1 \sin i$	(0.548 ± 0.018) × 10^6 km
$a_2 \sin i$	(0.598 ± 0.037) × 10^6 km
$M_1 \sin^3 i$	0.118 ± 0.011 $M_\odot$
$M_2 \sin^3 i$	0.108 ± 0.009 $M_\odot$
M_1/M_2	1.09 ± 0.06

The Hα wavelength region is affected by many telluric water-vapor lines, some of which are marked by asterisks in Figure 6. Small changes in the emission profile are thus probably not real, and may well be due to nightly changes in humidity. However, there are certainly phase-related changes in the overall profile of Hα. For example, over the interval $\phi = 0.14$–0.28, Hα appears roughly rectangular in profile, having a total width of over 15 Å (~700 km s^{-1}), or about twice the velocity range in the absorption components (see the vertical tick marks above the absorption feature near 6594 Å). At $\phi = 0.36$–0.43, Hα is narrower (~550 km s^{-1}) and almost triangular in appearance. The phase interval 0.51–0.61 shows the line with a structure that hints at two components, with the red emission wing weakened compared with the blue. While it is tempting to identify this double-peaked profile as originating from two stars, velocity measures show the red component to have a radial velocity of about +100 km s^{-1}, unrelated to either star in the system (Fig. 5).

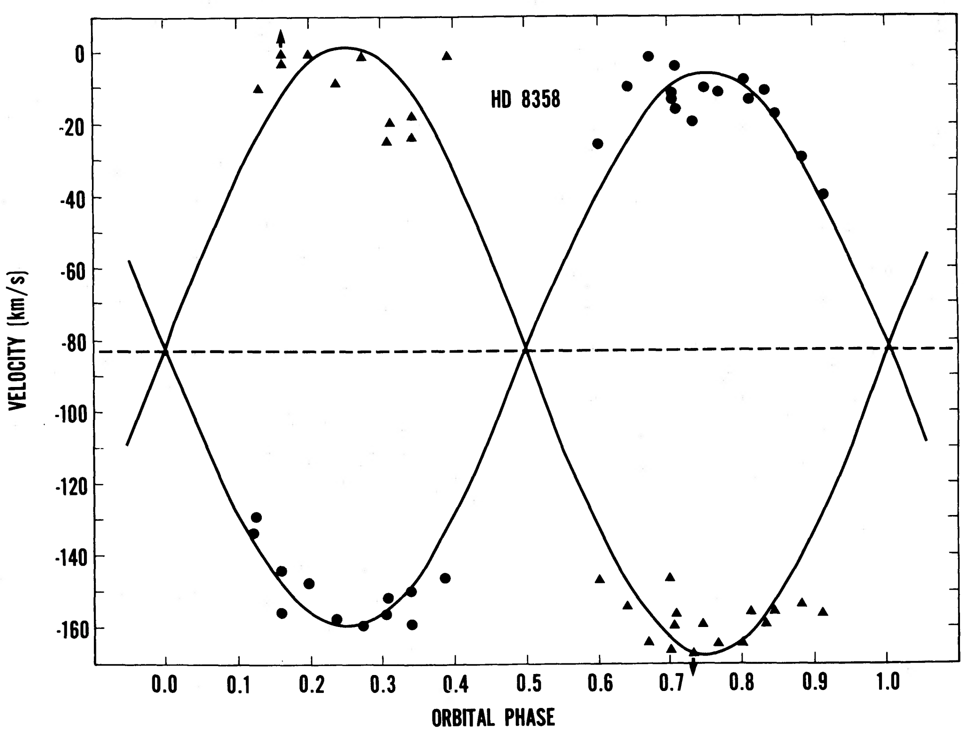

FIG. 5.—Radial velocity curves of HD 8358. Velocity measures of the primary star are indicated by the filled circles, those of the secondary by triangles. Arrows refer to measures of the secondary velocity of +14.1 and −171.0 km s^{-1} at phases 0.160 and 0.729, respectively.

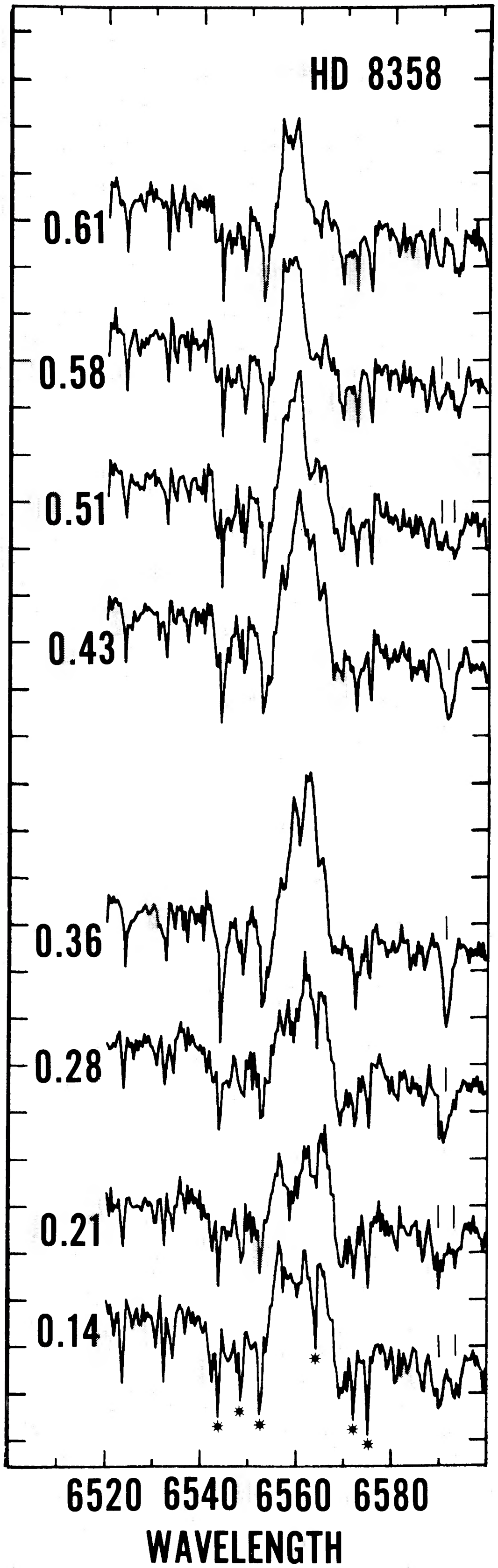

FIG. 6.—Variable Hα profile of HD 8358. Photometric phases are indicated at left. Tick marks on the ordinate represent 5% of continuum intensity. The positions of some strong telluric lines are indicated by asterisks; vertical tick marks near λ6590 identify absorption-line components of the two stars.

But while the *profile* of Hα may vary in a regular fashion, the emission EW does not show the same sort of behavior. In Figure 7 we plot the Hα EW measures obtained on the three nights of observation. On 1982 September 20 UT, the interval of observations extended from 0.36 to 0.61 in photometric phase. On that night Hα varied in EW by nearly a factor of 3, showing both the largest and the smallest EW of all three nights. Two rotation cycles later (September 21) the phases observed were between 0.21 and 0.40, but Hα showed constant EW. If we compare scans on these two nights at nearly identical phases, we find the Hα EW to be twice as large on September 20 as it is two rotations later. Similarly, the Hα EW is sensibly constant on September 22, but 50% differences in EW are seen in scans one night apart at identical photometric phases.

IV. *IUE* OBSERVATIONS

The high level of chromospheric activity that is indicated by the photometric variability, and by the Ca II and Hα emission, suggest that HD 8358 should show strong chromospheric and transition-region emission in the UV. We used the *IUE* satellite (Boggess *et al.* 1978) to observe HD 8358 over the wavelength region 1200–3000 Å. Discretionary time of one US 2 shift was granted on 1983 July 12, and two SWP low-dispersion, two LWR low-dispersion, and one LWR high-dispersion exposures were obtained, all using the large aperture. A log of the observations is given in Table 5.

The SWP data show HD 8358 to have the intense UV emission that is ordinarily seen in active chromosphere stars (Fig. 8). Table 6 gives emission-line identifications and observed fluxes extracted from SWP 20450. These line fluxes were integrated with respect to the local "continuum," which was dominated by noise shortward of 1800 Å. The conversion of these fluxes to the more astrophysically useful surface fluxes requires knowledge of the stellar angular diameter. We use the technique outlined by Linsky *et al.* (1979), which relates V-band surface flux and $(V-R)$; again we choose $(V-R) = 0.56$ and assume no interstellar reddening or extinction. The surface fluxes and a comparison of these values with respect to the quiet Sun appear as columns (4) and (5) of Table 6. Note that the values in column (4) assume that both components of HD 8358 show a comparable level of activity; if one star dominates, the surface fluxes should be increased by a factor of 2. A comparison of the values in column (5) of Table 6 with the results of Simon and Linsky (1980); Linsky *et al.* (1982); and Hartmann, Dupree, and Raymond (1982) shows HD 8358 to have line flux ratios that are characteristic of highly active RS CVn stars (V711 Tau, UX Ari) or W Ursae Majoris binaries (VW Cep). Unfortunately we can make no comment on the possible variation of UV emission over the rotational phase (Linsky 1983); the short exposure time of SWP 20451 (necessitated by high background radiation) does

TABLE 5

IUE OBSERVATIONS OF HD 8358, 1983 JULY 12

IUE Image	Start Time (UT)	Duration (min)
LWR 16335	12:46	2
SWP 20450	12:52	150
LWR 16336	15:27	3
SWP 20451	16:02	60
LWR 16337	17:07	140

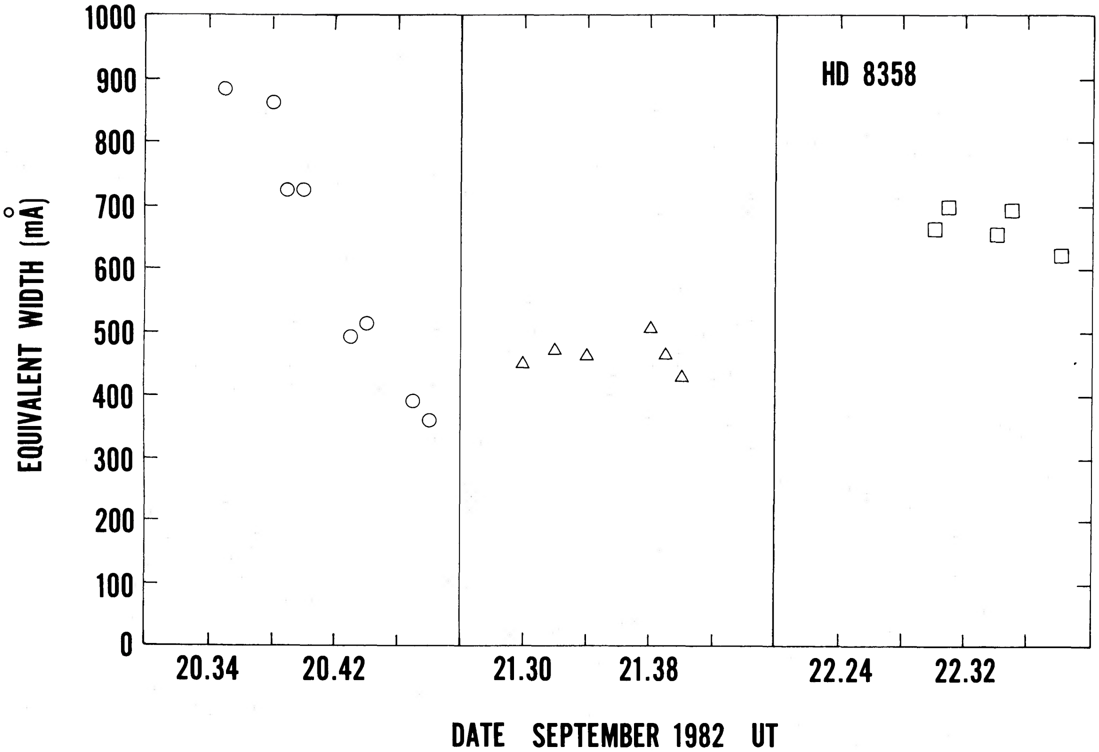

FIG. 7.—Hα equivalent width variability in HD 8358

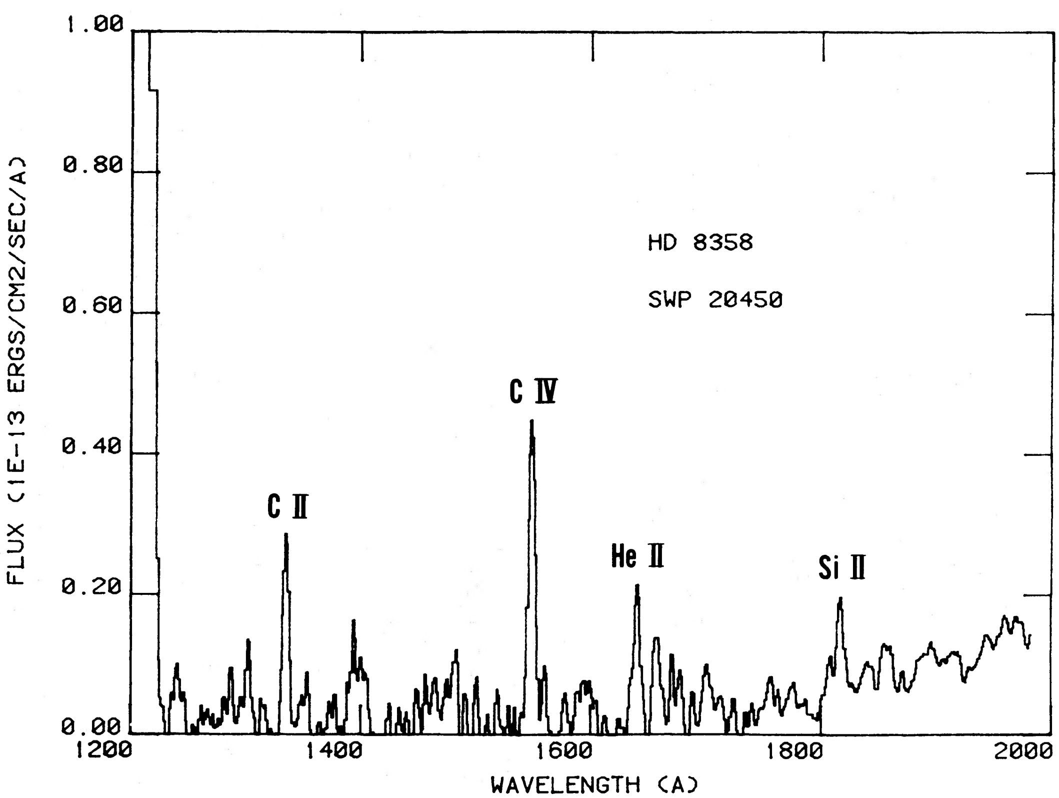

FIG. 8.—*IUE* low-resolution SWP observation of HD 8358

TABLE 6

UV EMISSION-LINE FLUXES IN HD 8358 (ergs cm^{-2} s^{-1})

Line (1)	λ (Å) (2)	Observed Flux (3)	Surface Flux (4)	Surface Flux / Quiet Sun (5)	$[f(\text{line})/l_{\text{bol}}] \times 10^{-7}$ (6)
N V	1241	3.9:(−14)	1.5:(5)	234:	28
O I	1302	5.4(−14)	2.0(5)	36	39
C II	1335	14.7(−14)	5.5(5)	82	105
Si IV	1399	14.8(−14)	5.6(5)	156	106
S I, C I	1482	4.9(−14)	1.8(5)	...	35
C IV	1549	30.0(−14)	1.1(6)	167	214
He II	1640	11.0(−14)	4.1(5)	342	79
C I	1657	8.0(−14)	3.0(5)	36	57
Si II	1808, 1817	10.3(−14)	3.9(5)	16	74
Mg II	2795, 2803	3.54(−12)	1.3(7)	10	2530

not permit us to compare line fluxes accurately on the two scans.

The Mg II profiles from the LWR high-resolution image are illustrated in Figure 9. The lines are rather rectangular with a FWHM of 2 Å ($\sim$200 km s^{-1}), and probably represent two blended stellar components. Flux-weighted central wavelength measures for the Mg *h* and *k* lines yield a velocity of -90 ± 12 km s^{-1}, in good agreement with the center-of-mass velocity of the binary. This argues that the Mg II emission, like the Ca II H and K reversals, is present in both components of the binary and with approximately equal intensity. The velocity separation between the two stars at this orbital phase is about 130 km s^{-1}, so if only one star were the source of the emission, a noticeable shift from the center-of-mass velocity would be observed.

Finally, we may calculate the relative fluxes $[f(\text{line})/l_{\text{bol}}]$ which are distance independent and give us a measure of how much of the stellar luminosity is channeled into each form of activity. These values are presented in column (6) of Table 6. The values show the same correlation as that reported by Ayres, Marstad, and Linsky (1981) for F–K dwarfs and giants. The general level of activity of HD 8358 is close to, but slightly less than, the values for V711 Tau and UX Ari.

The various signatures of stellar activity, especially the strong He II λ1640 emission, suggest that HD 8358 will be an intrinsically strong X-ray source, although it does not appear to have been detected serendipitously by *Einstein* (R. Stern 1984, private communication).

V. KINEMATICS

The orbital parameters of HD 8358 are unusual in that the center-of-mass velocity is quite negative. It is instructive to

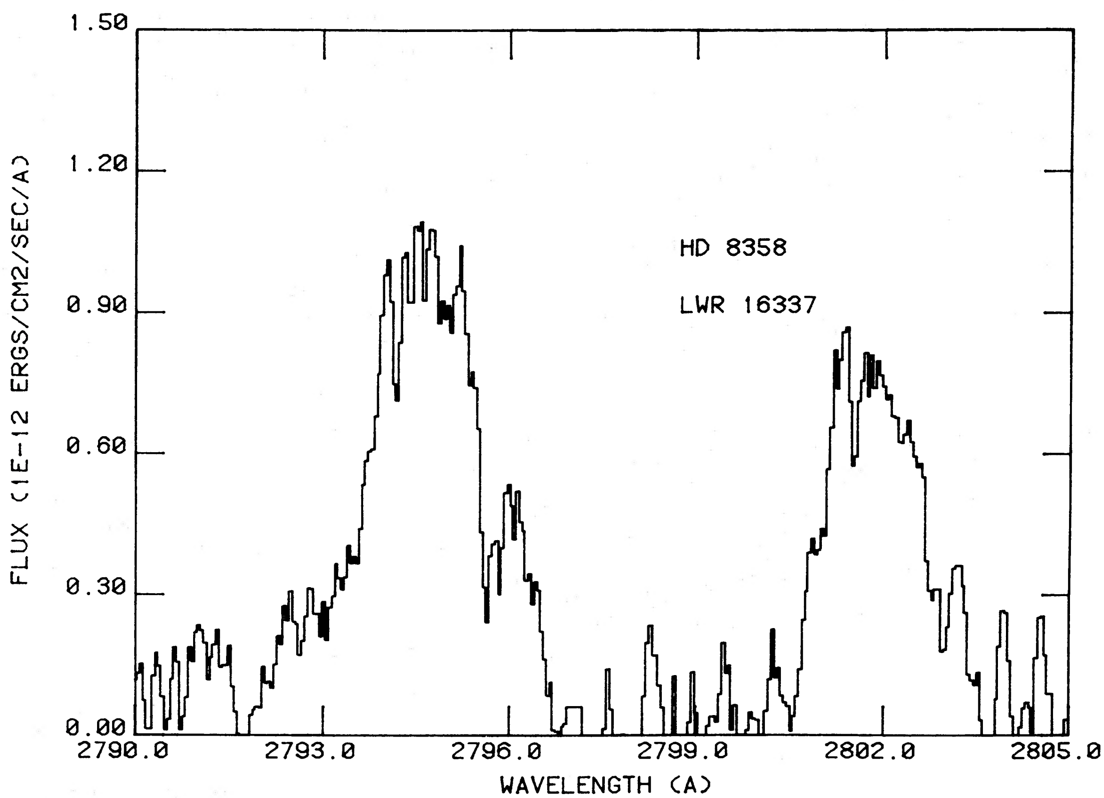

FIG. 9.—*IUE* high-resolution observation of the Mg II emission lines in HD 8358 obtained near orbital phase 0.16

compute the galactic velocity components for HD 8358. The SAO proper motions are

$$\mu_\alpha \cos \delta = -0.111 \text{ arcsec yr}^{-1}$$
$$\mu_\delta = -0.258 \text{ arcsec yr}^{-1} .$$

Choosing $M_v = 5$ for each component leads to a distance of 60 ± 10 pc, yielding (in km s^{-1})

$$U = +91 \pm 10 ,$$
$$V = -61 \pm 5 ,$$
$$W = +34 \pm 6 .$$

When plotted on the (U, V)-plane (Eggen 1969), the kinematic properties of HD 8358 are those of the old disk/halo population. Although it is conventional to associate stellar chromospheric activity with youth (e.g., the Pleiades; Stauffer 1984), there are certainly BY Draconis and RS CVn variables that are kinematically old. BD $-00°4234$ (Peterson *et al.* 1980) is a metal-poor SB 2 that is also a BY Dra star, and the RS CVn binary AS Dra ($P = 5.4$ days) has a center-of-mass velocity of -97 km s^{-1} and is metal deficient (Greenstein, Hack, and Struve 1957) as well. Nevertheless, there are, to our knowledge, no other members of Hall's *short-period* group with space motions as extreme as those of HD 8358.

VI. SUMMARY AND CONCLUSIONS

We have described some observational aspects of HD 8358 that are typical of active chromosphere stars. The binary has orbital and photometric characteristics that place it within Hall's "short-period" group of active chromosphere objects. Similarly, the Ca II and ultraviolet emission fluxes, though high, are comparable to what is seen in some RS CVn systems of longer period (e.g., V711 Tau, UX Ari).

The Hα emission line, however, is one quite puzzling, and perhaps even extraordinary, feature of HD 8358. As stated previously, the mere *presence* of Hα as an emission feature above continuum at all times is worthy of comment. Among the bonafide RS CVn systems, we are aware of only four objects (out of several dozen) that exhibit this behavior: V711 Tau, UX Ari, DM UMa (BD $+61°1211$), and the newly recognized system EZ Peg (Howell and Bopp 1985). The short-period group of active chromosphere binaries has been less thoroughly studied, but recent observations by A. Young and by S. Barden (1984 private communication) show several of these objects to have Hα profiles that are partially filled *absorption* features, with the line rarely being seen as emission above continuum.

The profile of Hα in HD 8358 is remarkable as well. The extreme width of the feature is without precedent in RS CVn stars. In UX Ari, DM UMa, and EZ Peg the Hα emission feature is always less than 2 Å full width, and may be only instrumentally wide (Crampton, Dobias, and Margon 1979). The Hα profiles that Fraquelli (1981) shows for V711 Tau typically have full width at continuum of 5–7 Å, although apparently this profile is a superposition of emission components from both stars in the system. Recall that the Hα feature in HD 8358 is 15 Å full width at continuum, and this value varies only slightly with orbital phase.

One star that exhibits an Hα profile similar to that of HD 8358 is the chromospherically active Pleiades K dwarf HII 1883. This star has been investigated photometrically by van Leeuwen and Alphenaar (1983) and by Stauffer (1984). Stauffer shows HII 1883 to vary by 0.15 mag in V with period 0.236 days. Stauffer *et al.* (1984) confirm that the variability is due to starspots, since the observed $v \sin i$ of 140 km s^{-1} corresponds to what is expected for a K dwarf with that rotational period.

A study of the Hα emission profile in HII 1883 has recently been completed by Marcy, Duncan, and Cohen (1985), with the following results:

1. The line has a full width of $\sim$700 km s^{-1} at the continuum—about 5 times the value of $v \sin i$.
2. The line profile varies systematically with photometric phase.
3. There are night-to-night variations in Hα EW which are not phase-related.

All this behavior, as well as the appearance of the Hα line in the two stars, is strikingly similar. This is all the more remarkable since HII 1883 is single and HD 8358 a binary; HII 1883 is young and HD 8358 is, kinematically at least; a hundred times older. It is certainly possible that these similarities in Hα profile and behavior are a coincidence, produced by very different sources. But perhaps the origins are indeed similar. Marcy, Duncan, and Cohen (1985) suggest that the emission in HII 1883 originates in a corotating shell with thickness about $1\frac{1}{2}$ stellar radii. Such a configuration applied to the HD 8358 binary system would not be dynamically stable, but perhaps a corotating ring of gas might be replenished by material lost via a wind. Regardless, a more thorough study of the Hα profile in HD 8358 is clearly called for.

We are grateful to Dr. Yoji Kondo for his award of discretionary observing time with the *IUE* satellite. Joel Eaton's comments were helpful in improving this paper. We thank Chris Anderson and the MADRAF staff for assisting with reduction of the photographic data. Research on stellar chromospheric activity at the University of Toledo is supported by grants from NSF (AST 81-15098) and NASA (NAGW-229).

REFERENCES

Ayres, T. R., Marstad, N. C., and Linsky, J. L. 1981, *Ap. J.*, **247**, 545.
Bidelman, W. P. 1981, *A.J.*, **86**, 553.
Boggess, A., *et al.* 1978, *Nature*, **275**, 372.
Bopp, B. W. 1984, *Ap. J. Suppl.*, **54**, 387.
Bopp, B. W., Goodrich, B. D., Africano, J. L., Noah, P. V., Meredith, R. J., Palmer, L. H., and Quigley, R. 1984, *Ap. J.*, **285**, 202.
Bopp, B. W., and Noah, P. V. 1980, *Pub. A.S.P.*, **92**, 717.
Bopp, B. W., and Talcott, J. C. 1978, *A.J.*, **83**, 1517.
Crampton, D., Dobias, J., and Margon, B. 1979, *Ap. J.*, **234**, 993.
Eaton, J., and Hall, D. S. 1979, *Ap. J.*, **227**, 907.
Eggen, O. J. 1969, *Pub. A.S.P.*, **81**, 553.
Fekel, F., Hall, D. S., and Henry, G. W. 1984, *Inf. Bull. Var. Stars*, No. 2543.
Fraquelli, D. 1981, Ph.D. thesis, University of Toronto.
Greenstein, J. L., Hack, M., and Struve, O. 1957, *Ap. J.*, **126**, 281.
Hall, D. S. 1976, in *IAU Colloquium 29, Multiple Periodic Variable Stars*, ed. W. S. Fitch (Dordrecht: Reidel), p. 287.
———. 1981, in *Solar Phenomena in Stars and Stellar Systems*, ed. R. Bonnet and A. Dupree (Dordrecht: Reidel), p. 431.
Harris, W. E., FitzGerald, M. P., and Reed, B. C. 1981, *Pub. A.S.P.*, **91**, 507.
Hartmann, L., Dupree, A. K., and Raymond, J. C. 1982, *Ap. J.*, **252**, 214.
Howell, S. B., and Bopp, B. W. 1985, *Pub. A.S.P.*, **97**, 72.
Linsky, J. L., 1983, in *IAU Colloquium 71, Activity in Red-Dwarf Stars*, ed. P. B. Byrne and M. Rodonò (Dordrecht: Reidel), p. 39.
Linsky, J. L., Bornmann, P. L., Carpenter, K. G., Wing, R. F., Giampapa, M. S., Worden, S. P., and Hege, E. K. 1982, *Ap. J.*, **260**, 670.
Linsky, J. L., Worden, S. P., McClintock, W., and Robertson, R. M. 1979, *Ap. J. Suppl.*, **41**, 47.
Marcy, G. W., Duncan, D. K., and Cohen, R. D. 1985, preprint.

Peterson, R. C., Willmarth, D. W., Carney, B. W., and Chaffee, F. H. 1980, *Ap. J.*, **239**, 928.
Ruciński, S. 1977, *Pub. A.S.P.*, **89**, 280.
Simon, T., and Linsky, J. L. 1980, *Ap. J.*, **241**, 759.
Stauffer, J. 1984, *Ap. J.*, **280**, 189.
Stauffer, J. R., Hartmann, L., Soderblom, D. R., and Burnham, N. 1984, *Ap. J.*, **280**, 202.
van Leeuwen, F., and Alphenaar, P. 1983, in *IAU Colloquium 71, Activity in Red-Dwarf Stars*, ed. P. B. Byrne and M. Rodonò (Dordrecht: Reidel), p. 189.
Vogt, S. S. 1981, *Ap. J.*, **250**, 327.
Zeilik, M., Elston, R., and Henson, G. 1983, *A. J.*, **88**, 532.

JOHN L. AFRICANO and BRET D. GOODRICH: Kitt Peak National Observatory, P.O. Box 26732, Tucson, AZ 85726

THOMAS B. AKE: Computer Sciences Corporation, NASA/Goddard Space Flight Center, Code 685, Greenbelt, MD 20771

BERNARD W. BOPP, R. J. MEREDITH, and P. V. NOAH: Department of Physics and Astronomy, University of Toledo, Toledo, OH 43606

LEIGH HUNT PALMER: Department of Physics, Simon Fraser University, Burnaby, BC V5A 1S6, Canada

R. QUIGLEY: Department of Physics and Astronomy, Western Washington University, Bellingham, WA 98225