RS CVN STARS: CHROMOSPHERIC PHENOMENA

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ABSTRACT: The observational information regarding chromospheric emission features in surface-active RS CVn stars is reviewed. Three optical features are considered in detail: CaII H and K, Balmer H-alpha and HeI λ10830. While the qualitative behavior of these lines is in accord with solar-analogy/rotation-activity ideas, the quantitative variation and scaling is very poorly understood. In many cases, the spectroscopic observations with sufficient S/N and resolution to decide these questions have simply not yet been made. The FK Com stars, in particular, present us with extreme examples of rotation that may well press our understanding of surface activity to its limits.

INTRODUCTION

The intense chromospheric activity characteristic of the RS CVn stars is perhaps most clearly indicated by the presence of optical and ultraviolet emission lines. In a complete discussion, features such as CaII H and K; H-alpha; MgII h and k; Ly-alpha; HeI λ10830, λ5876; and UV resonance lines of OI, CI, CII, and SiII might be included. Constraints of time will force me to cover only a few of these in depth. In addition, I will discuss some chromospherically active objects that I believe to be of particular importance to our understanding of stellar activity. My biases will be plain: I will concentrate heavily on the optical chromospheric spectrum, since this is my area of expertise, and I anticipate that the UV will be emphasized by others with greater eloquence at this meeting.

CALCIUM II H AND K

Historically the CaII H and K lines were the first emission features to be recognized as indicating the presence of a stellar chromosphere. The lines are unquestionably our most valuable and intensively observed optical chromospheric signature. Our association

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of CaII emission and RS CVn stars is so intimate that it is almost a definition; certainly it is part of Hall's (1976) by now classic definition of the group: "...the orbital period is in the range one day to two weeks, the hotter component is of spectral type F or G and luminosity class V or IV, and strong H and K emission is seen outside of eclipse." Despite our wealth of new observational data in the last 6 or 7 years, this definition has held up exceedingly well. If we were to substitute the word "rotational" for "orbital" and perhaps increase the two week limit, I'd be very content with this. Bear in mind that I use the term "RS CVn" a bit loosely throughout this review.

A problem that immediately arises is how to discuss the "strength" of the CaII emission. Certainly the RS CVn's have reversals much stronger than those seen in ordinary (usually single) giants or subgiants, but it is important to quantify this statement. Wilson has published extensive lists of eye-estimated emission intensities, on a scale from 0 (no emission present) to 5 (strongest emission); the latest compilation is Wilson (1976). These estimates are from photographic spectra, with all of their limitations. In addition, any intensity estimate (or even a measurement from a tracing) is strongly dependent on resolution: if dispersions significantly lower than that used by Wilson are employed, the CaII emission will appear weaker with respect to the surrounding continuum. Lastly, this intensity scale is not terribly useful for the extremely active RS CVn's, as it "saturates" at the high end: nearly all the RS CVn's of type G-K have emission intensities of 5, but the lines are not equally strong nor are the stars equally active.

More quantitative (photoelectric) measures of H and K flux in giants have been recently published by Wilson (1982). He defines the flux at a wavelength λ by:

$$F_\lambda = E_\lambda / E_C$$

where E_λ is the energy in the 1 Å wide data channel and E_C is the energy in a nearby continuum bandpass. Wilson includes his earlier photographic intensity measurements in this paper, and we can thus obtain a rough calibration of estimated and measured flux for G-K III-IV stars (Table I). It is perhaps of interest that sigma, the scatter in the flux measurement, increases as the flux increases, but whether this indicates real chromospheric variability or merely difficulties with accurately estimating I(CaII) is not clear.

However, most of the RS CVn's have CaII emission much stronger than I=4. In the case of σGem, for example, the CaII reaches nearly to the surrounding continuum (Figure 1). This star has I=5 on Wilson's scale (as does V711 Tau), but this is hardly descriptive enough for emission so intense. The best and most astrophysically significant description of CaII emission is in terms of absolute surface flux. The most extensive compilation of such data is that of Linsky et al. (1979). The technique requires reasonably high resolution and S/N, but the

Table I
I(CaII) vs. F_K
F-G III-IV

I(CaII)	F_K	σ	N
1	0.143	0.018	57
2	0.152	0.027	38
3	0.188	0.033	25
4	0.236	0.045	19

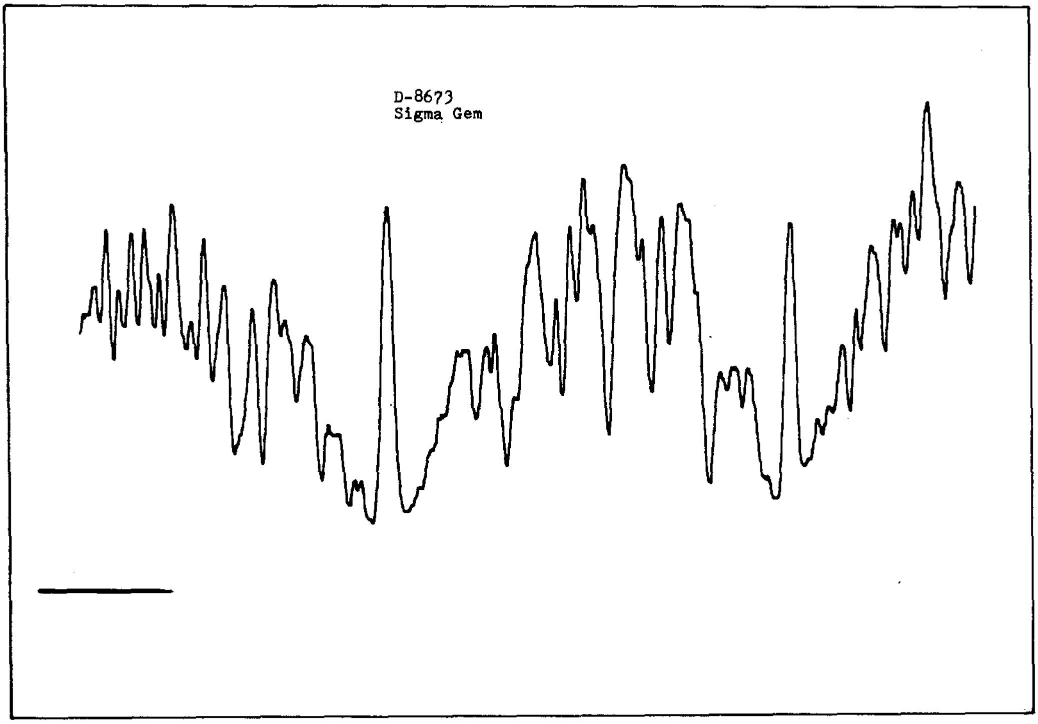

Figure 1: Density tracing of the CaII H and K region in the active-chromosphere giant σ Gem. Original dispersion 13 Å/mm. The clear plate level is indicated by the horizontal line.

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information that can be derived is invaluable in the construction of model stellar chromospheres. The surface flux at H and K also yields a measure of emission/chromospheric-activity that is not biased by the color of the star. For example, Linsky et al. note that the surface fluxes at K in αSco (M1Ib,I=4) are actually two orders of magnitude less than in αCom AB (F5V,I=1).

A few years ago we began a project at Toledo to obtain CaII flux measurements of RS CVn stars and look for correlations between chromospheric radiative losses and rotation rate. We obtained data at KPNO, and were able to borrow and analyze a number of spectrograms obtained at Lick and McDonald by Popper and Fekel. Some of the new results are presented in Table II. A comparison of our values for those stars also observed by Linsky et al. shows agreement in the fluxes to about 10%. I caution that due to possible errors in spectrophotometry, estimates in V-R, and the problems due to the continuum contribution from a secondary star, the flux measurements are good to perhaps 50%.

Table II
CaII Surface Fluxes of RS CVn Stars

Star	V-R*	$F(K_2)$ ergs/cm^2/s	$F(H_2)$ ergs/cm^2/s	N
RS CVn	(0.72)	1.2(+6)	9.7(+5)	1
TY Pyx	(0.55)	3.2(+6)	3.1(+6)	1
LX Per	(0.72)	1.3(+6)	8.6(+5)	1
SZ Psc	(0.70)	3.3(+6)	3.6(+6)	1
WW Dra	(0.72)	2.2(+6)	1.6(+6)	1
AR Lac	(0.77)	1.4(+6)	1.2(+6)	1
RT Lac	(0.77)	4.2(+6)	3.9(+6)	1
UX Ari	(0.72)	4.3(+6)	3.4(+6)	1
σ Gem	0.90	7.0(+5)	5.7(+5)	2
λ And	0.78	1.7(+6)	1.7(+6)	1
ζ And	0.84	8.7(+5)	1.1(+6)	1
V711 Tau	(0.77)	2.9(+6)	2.6(+6)	12
HR 4665	(0.77)	2.7(+6)	2.3(+6)	4
HR 6469	(0.47)	6.4(+6)	5.2(+6)	1
HR 7275	(0.77)	2.7(+6)	2.1(+6)	1
HR 8703	(0.90)	7.2(+6)	6.0(+6)	1
HD 81410	(0.80)	2.9(+6)	3.0(+6)	1
HD 82210	0.64	2.0(+6)	1.8(+6)	2
HD 86590	(0.54)	1.1(+7)	7.5(+6)	1
Sun	0.53	4.6(+5)	3.8(+5)	

*Estimates in parenthesis

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Two results from these data are worth noting:

1. There was no significant variation in the CaII flux of V711 Tau on 12 spectrograms.

2. No strong correlation was found between chromospheric loss rate at H and K (or H-alpha) and rotational velocity among the RS CVn stars.

A new and extensive spectroscopic study of southern hemisphere RS CVn stars has recently been made by Collier (1982a) who finds a correlation (with much scatter) of CaII surface flux and rotation rate for eight objects.

It is of great importance to determine whether CaII intensity or flux in RS CVn's is modulated by stellar rotation period, implying concentration of emission in active regions. This has been assumed by many to be the case for the RS CVn's; I find the evidence for this behavior compelling, but I am not convinced it is always so. Certainly H and K flux measures have been used effectively to derive rotation periods in late-type MS stars (Vaughan et al. 1981), but Vaughan and colleagues found no clear evidence for periodic modulation of H and K flux in 6 giants.

One of the first investigations of CaII variability in RS CVn's was by Weiler (1978). His oft-quoted result was that there was a correlation between emission intensity and phase in UX Ari, RS CVn, and Z Her. However, Weiler also states that this correlation was only "moderately strong" for RS CVn itself, and marginal for UX Ari and Z Her. Three other binaries showed only random emission intensity variations.

Perhaps the best data, and the best evidence for periodic CaII variations are the results for λAnd given by Baliunas and Dupree (1982). Their observations showed that at light minimum the relative flux at K was larger by 25-100% than at light maximum. In addition, flux changes were accompanied by complex profile changes, with $V/R < 1$ occuring only near light maximum. The behavior of the MgII h and k asymmetries as a function of photometric phase was consistent with that of CaII.

Possibly complicating this analysis are the observations of rapid variability of CaII by Baliunas et al. (1981). Their interesting results showed fluctuations of up to 7% in the H and K emission of ε Eri, a young active K2V star. K-line variations of as much as 10%, on a time scale of 10 minutes, were seen in λ And. The authors conclude that much of the rapid variability is related to flaring activity; the brightenings observed at H and K in these stars is, however, several orders of magnitude larger than the total radiative output of typical solar flares. Apparently large portions of the chromospheric emission come from coherent active regions, of size ~1% of a stellar radius.

H-ALPHA

The Balmer H-alpha line is perhaps the most accessible chromospheric diagnostic in late-type stars. With the use of red-sensitive detectors (the peak QE of S-20 image tubes, Reticons, and CCD's is very near H-alpha) it is particularly easy to observe, and a reference continuum level may be readily established (unlike the situation near the CaII H and K lines). We associate the presence of H-alpha emission in late type dwarfs, giants, and subgiants with strong chromospheric activity. For example, all the dMe stars (where the "e" denotes the presence of Balmer emission) show stellar flare activity, and the quiescent H-alpha emission strength is well correlated with the frequency of photometric flaring (Gershberg and Shakovskaya 1971).

The situation, however, is not as clear in the case of the RS CVn binaries. I know of only four RS CVn's that show H-alpha as a pure emission feature above continuum at all times: V711 Tau (HR 1099), UX Ari, II Peg, and DM UMa (BD + 61° 1211). Although these are clearly among the most active RS CVn's, there are other systems, with comparable CaII H and K flux and orbital period (e.g., AR Lac) which show the H-alpha feature in absorption. In fact, emission at H-alpha is rare in RS CVn's: the two dozen systems that we surveyed at 1.5 A resolution (Bopp and Talcott 1978) showed only five emitters, and in three of these (HK Lac, SZ Psc, HD 86590) the emission was present only 10-20% of the time.

Certainly the H-alpha feature is enhanced during radio-flaring intervals. During what we now recognize as a rather small (~150 mJy) radio flare on V711 Tau in September 1976, Weiler et al. (1978) reported an increase in H-alpha EW of about a factor of three. During a very strong radio flare (peaking near 1000 mJy) in February 1978, both Popper (1978) and Fraquelli (1978) reported H-alpha EW enhancements of 3-5X. The H-alpha emission profile during the 1978 flare of V711 Tau was very broad (~400 km/s total width) and showed a pronounced redward asymmetry (Furenlid and Young 1978, Hearnshaw 1978). Fraquelli (1982), using H-alpha data obtained with concurrent radio monitoring over an interval of several years, demonstrates that there is a good correlation between the H-alpha flux and the log of the radio flux from V711 Tau.

It is significant that during radio outbursts the H-alpha emission behavior tracks with the radio flux, and is not modulated by orbital or rotational period. During the 1976 event, the H-alpha line rose to maximum EW in unison with the radio (and Ly-alpha) flux, then slowly faded on a time scale comparable to that of the radio decay time (several days). The H-alpha emission showed no modulation with the 2.8 day rotational/orbital period, as if it was produced over a very large area of the star, and was not concentrated near the active region that was presumably the site of the outburst.

Regarding quiescent intervals, if solar analogies are invoked, we might expect H-alpha emission in RS CVn stars to vary in antiphase with the V-band measures (or at least to show some modulation with orbital period). The observational evidence for this effect is limited. Fraquelli (1982) finds no correlation between H-alpha flux in V711 Tau and distortion wave minimum, and similar results (with more limited data and lower resolution) are reported by Bopp and Talcott (1978). In that same paper, we also showed a phase-dependent variation of H-alpha emission in UX Ari where V minimum was seen near emission maximum. This result is often referred to as support for "classical" ideas about the distribution of H-alpha emission in active regions. I certainly stand by our data, but I would like very much to re-do the UX Ari observations with higher spectral resolution and S/N--the contribution of the H-alpha absorption profile in the hotter primary of the system needs to be taken into account properly.

Certainly there are (quiescent?) intervals when the H-alpha emission in RS CVn's is "well behaved": in 1979 the EW of the line in V711 Tau did vary in antiphase with the distortion wave (Nations and Ramsey 1980) and phase dependent variability of H-alpha has been seen in II Peg (Bopp and Noah 1980). However, these are more the exception than the rule. In general the emission behavior is stochastic rather than regular, with variability present on time scales of at least a few minutes. The narrow-band H-alpha photometry of V711 Tau by Dorren et al. (1981) presents perhaps the best overview: their observations over several observing seasons showed no phase dependence of the emission in 1977-78 but some evidence of coherent variations in 1979. Overall, however, their H-alpha index was characterized by large scatter, not observational in origin. Flares which increased the index by 0.03-0.04 mag. were seen, and significant variability on a time scale of minutes was frequently present. This last point concerning rapid variability has been very neglected by spectroscopists. About the extent of the spectral data in this regard is my suspicion (Bopp 1979) that V711 Tau showed rapid (~20 minute) changes in H-alpha EW of ±20%, but this is in need of confirmation. I did not have sufficient resolution to look for rapid profile changes; do they exist?

In those RS CVn's that show sporadic H-alpha emission (that is, where emission above continuum is seen perhaps 10-20% of the time) the behavior of the feature is every bit as puzzling. The two systems I single out for discussion are SZ Psc (P = 3.97 days, sp. K1IV+F8V) and HK Lac (P = 24.4 days, sp. K0III+F?). In the case of SZ Psc, the H-alpha line in the active K-star is usually a weak absorption feature, presumably partly filled by chromospheric emission. During a single month in 1978, however, the line profile changed to a broad (~300 k/s) double peaked emission (Bopp 1981). I was unable to explain this in the context of surface activity; in particular, I felt the time scale of the behavior (weeks) ruled out a flaring origin. Instead, I proposed that the emission was circumstellar in origin, produced from a ring or shell of gas around the K-star, ultimately originating in a transient mass-transfer event. Ramsey and Nations (1981), however, observed another H-alpha outburst in this system, similar in duration, and were able to fit their data into the general context of a surface outburst. Still, it was necessary to postulate transient ring or disk structure in the system.

HK Lac, a system with a markedly different orbital configuration, may be capable of producing such structures also: one spectrogram obtained in 1977 (Bopp and Talcott 1980) showed a double peaked H-alpha emission line, identical in appearance to the SZ Psc feature. In the 1980 paper, we attempted, perhaps not entirely convincingly, to ascribe this profile in HK Lac to a sporadic prominence-like ejection of material. But the resemblance of the profiles is so striking that I wonder if shell/ring structures are not a possibility in HK Lac also.

Finally, I should not fail to mention the H-alpha absorption line behavior; this after all is the type of profile seen most commonly in RS CVn's. The low resolution surveys suggested that for those stars for which H-alpha is seen in absorption, it is indeed a normal feature, not filled in by emission, and not showing any EW variability (to a ±20% level) with phase (Bopp and Talcott 1978). However, a survey that we did a few years ago with 0.3 Å resolution showed some interesting results (Smith and Bopp 1982). We found all the RS CVn stars to have abnormal H-alpha profiles when compared with appropriate MK standards. In each case, the H-alpha core intensity was elevated relative to that of the standard (Figure 2). The H-alpha absorption lines of all the

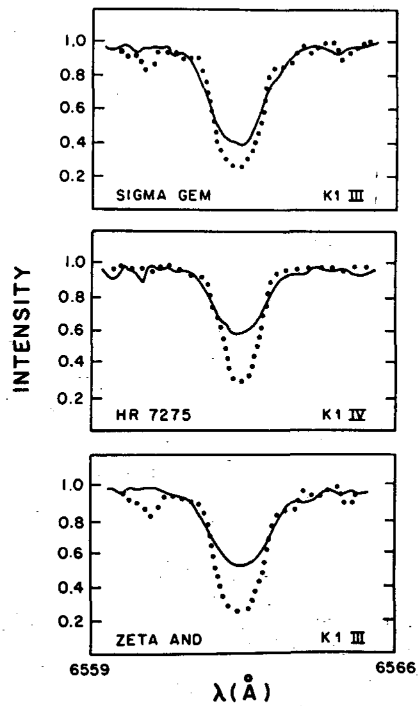

Figure 2: H-alpha profiles of RS CVn-like stars (solid lines) superimposed on those of MK standards (dotted lines).

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surface-active stars are thus partially filled by chromospheric emission, though this subtlety was not noticeable at lower (~1 Å) resolution. Once again, we have no information on whether the partial filling of the H-alpha profile is variable with rotational phase, or if profile changes are evident (our high resolution observations were part of a survey program only). However, extensive, high quality H-alpha observations have been obtained by Fekel (1982) in the northern hemisphere and by Collier (1982) in the southern. I look forward to the publication of their results.

HELIUM I λ10830

The λ10830 line is potentially one of the most important chromospheric (and perhaps even coronal) diagnostics. It is also the least-studied feature that I will discuss. The line is present as an absorption feature in the spectrum of many G and K stars. Of course in an ordinary late-type stellar atmosphere the line should not be present at all, since the metastable lower state of the transition that produces the feature lies 20 eV above the ground state. Clearly the HeI feature is produced in an overlying high temperature region, but the mode of excitation is not clear. There have been a variety of mechanisms proposed to explain the existence of λ10830 in cool stars: Athay (1965) invoked direct excitation by electron collisions in a hot chromosphere; Shine, Gerola and Linsky (1975) proposed diffusion of the helium into a high temperature region where it could be collisionally excited; Zirin (1975, 1976) argued that 10830 is excited by coronal soft X-ray emission, implying that the emission measure of stellar coronae may be determined by measurement of the line.

The only detectors that are presently capable of recording the λ10830 line with adequate resolution are S-1 image tubes and bare (unintensified) Reticons. The published Reticon data have excellent S/N; O'Brien and Lambert (1979) illustrate impressive spectra showing variable HeI emission in Arcturus, where the emission intensity is only a few percent above continuum. Definite variations in the HeI emission were seen on a time scale of about a week, and more rapid variability was suspected. In addition, O'Brien and Lambert observed variable P-Cygni structure in the line, implying variable mass outflow. They mention, but do not discuss, additional detections of HeI emission in γ Aql (K3II) and γ Dra (K5III); strong λ10830 absorption was observed in β Dra (G2II) and β Cet (K1III).

The vast majority of the observations of the λ10830 line have been made by Zirin using S-1 image tubes with photographic plates. The resolution and S/N with the S-1 are considerably lower than comparable Reticon figures, but the image tube is much faster, and is well suited for survey work. The initial photographic results were presented by Vaughan and Zirin (1968) and Zirin (1976). The latest compilation (Zirin 1982) presents data on 455 stars, including many with CaII K-line intensity estimates and known X-ray sources.

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With this large a sample, a number of statistical tests are possible. Zirin finds, for example, that binary stars have much higher λ10830 absorption EW's than single stars, but the EW is not correlated with period, except that binaries with periods >200 days show no enhancement. In addition, λ10830 EW is strongly correlated with the X-ray flux of the star relative to its visual luminosity. This suggests that λ10830 measurements may be a convenient way of surveying coronal emission measures: a kind of "poor man's EINSTEIN". Zirin has also compared λ10830 EW and Wilson's (1976) K-line intensity estimates, and the correlations are reasonably good for G and K stars.

Despite these encouraging correlations, the behavior of HeI λ10830 in individual stars, and particularly RS CVn's, is bewildering. The line in the RS CVn's is nearly always seen as an absorption feature according to Zirin (1982), though weak emission of the sort seen by O'Brien and Lambert would not have been detectable photographically. The line is quite variable; changes of factors of 2-3 in EW are not uncommon. Though other stars with extended atmospheres/shells show λ10830 emission, the only RS CVn to ever show strong emission was HR 5110. The observed emission EW was 200 mA on two occasions, two years apart. A third observation a year later showed no HeI feature of any kind! Additionally, the correlation between HeI EW and CaII intensity appears to break down badly for the most extreme CaII emitters: both V711 Tau and HD 115043 have I(CaII)=5, yet the HeI absorption EW's are only 200 mA for V711 Tau (the Sun has an EW of 75-100 mA) and 0 mA for HD 115043.

Finally, it may well be that binarity may influence the behavior of this feature more than we suspect. Zirin (1981) has obtained spectrograms of several eclipses of Algol in the wavelength region of λ10830, where the spectrum is dominated by the X-ray source Algol B. He finds the EW of the HeI absorption feature to be an incredible 6000 mA, the strongest yet measured in a G-K star.

THE FK COMAE STARS

The FK Comae stars are rapidly rotating G-K giants, all having v sin i ~75-120 km/s. The stars show no evidence of duplicity; I have set limits of <±3 km/s for the velocity variations of HD 199178 over a four year interval, and the recent velocity data on FK Com, obtained by McCarthy and Ramsey (1982), set a limit of <±5 km/s for this object. The observational data are summarized in Table III; a more detailed description of their properties may be found in Bopp(1982).

The late spectral type and rapid rotation certainly suggest that these stars should have very strong chromospheric emission features, and this is indeed the case. Bopp and Stencel (1981) report IUE observations that show FK Com and HD 199178 to exceed the "classical" RS CVn's by up to an order of magnitude in the flux from emission lines such as OI λ1300, SiII λ1530, and CII λ1335. The CaII H and K lines

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are similarly strong. Though the reversals do not appear particularly strong to the eye, again the appropriate quantity to examine is the absolute surface flux. I obtain, from two KPNO spectrograms taken in March 1979, concurrent with Rucinski's (1981) photometry:

$$F(K_2) = 7.1 \times 10^6 \quad F(H_2) = 4.9 \times 10^6 \quad \text{ergs/cm}^2\text{/s}$$

These values are higher than any given by Linsky et al. (1979) and are 2-3x greater than our measured surface fluxes for the cool component of V711 Tau. I did not see any significant variability in the flux between my two spectrograms, obtained two nights apart, at photometric phases 0.15 and 0.95 when the star was at about the same visual brightness. Bolton (1977), however, finds the emission lines of H and K to be highly variable in intensity on a number of his spectrograms. The existence of phase-dependent variability of H and K in the FK Com stars is as yet uninvestigated, however.

Table III
Properties of FK Com Stars

Name	V	Sp.	v sin i (km/s)	Photometric Period(days)	Velocity Var. (km/s)
FK Com	8.2	G2III	120	2.400	< ± 5
HD 199178	7.3	G5III/IV	~80	3.337	< ± 3
UZ Lib	9.2	K0III	~80	4.75	< ± 25:
[1]HD 32918	8.6	K2III	50	9.55	< ± 3
[1]HD 36705	6.9	G8III	70	0.51	< ± 5

[1]Data from Collier (1982b).

The CaII H and K emission profiles appear to be dominated by rapid rotation in all the objects. In particular, measures of H and K on my coudé spectrograms of FK Com yield values of 120 km/s for the broadening, identical to that seen in the metallic absorption features and in the MgII emission (Bopp and Stencel 1981).

I must note that the evolutionary status of the FK Com objects is puzzling. We have suggested (Bopp and Rucinski 1981) that the FK Com stars represent the further evolution of contact binary systems, evolved to coalescence (e.g., Webbink 1976). Though alternate binary models for FK Com itself have been proposed (Walter and Basri 1982), I believe the new velocity data effectively rule these out.

A disturbing aspect of the chromospheric behavior of the FK Com

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stars is the velocity behavior of the CaII emission. It is almost an article of faith among spectroscopists that the velocities one obtains for the chromospheric CaII emission and the photospheric absorption lines do not differ (at least at a 2-3 km/s confidence level). However, the velocities I obtain from CaII in all the FK Com stars show the lines to be shifted by ~15km/s to the red of the absorptions. I have no ready explanation for this, but it is not due to any profile asymmetry in CaII.

But far and away the biggest challenge to spectroscopists is to explain the H-alpha profile of FK Com. The line is a nightmare. Figure 3 shows a KPNO CCD observation (resolution ~0.5A) of the red region that we obtained in April 1982. The emission profile shows a

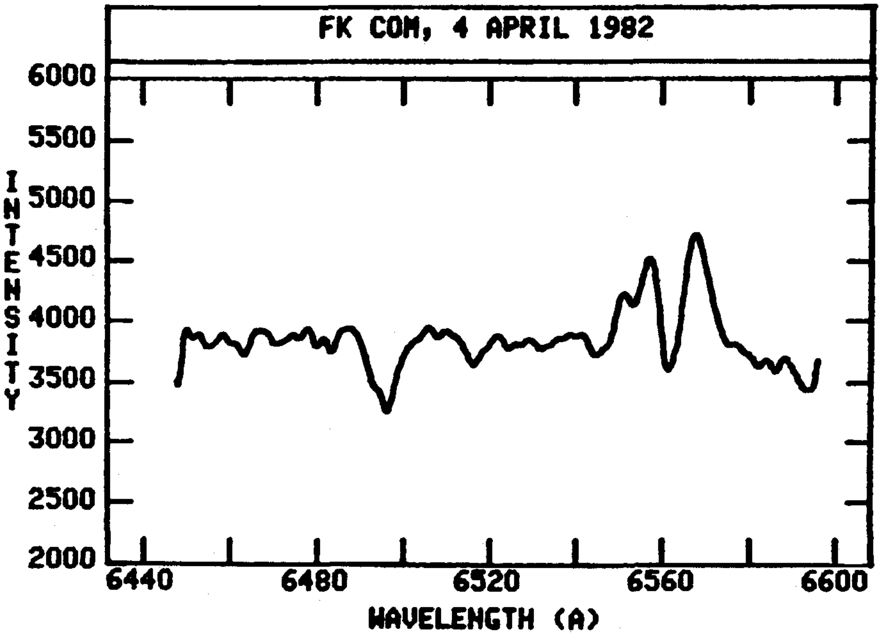

Figure 3: The red region of FK Com, from a KPNO CCD scan. Note the 20Å wide H-alpha emission feature.

full width of ~1000 km/s, a factor of two larger than the (flare enhanced) H-alpha width of V711 Tau. The line is variable in profile and intensity on a night to night time scale. In addition, H-alpha flares, where the emission EW has increased three-fold in the course of about two hours, have been reported by Walter and Basri (1982) and Ramsey and Nations (1981). At least at certain epochs, the H-alpha profile is seen to vary regularly, in the sense that the V/R emission ratio and H-alpha EW are correlated with photometric phase (Ramsey et al. 1981, Walter and Basri 1982).

With its extreme rotation, FK Com provides us with an extreme test of our rotation-activity ideas. It may well be, however, that the H-alpha profile of FK Com is telling us little about the chromosphere of this object and much about an extended atmosphere or mass-loss mechanism. Even if it is so that "one man's chromosphere is another man's extended atmosphere", an understanding of the H-alpha profile of FK Com is a spectroscopic task of the highest priority.

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REFERENCES

Athay, R. G.: 1965, Astrophys. J. 145, 784.
Baliunas, S. L. and Dupree, A. K.: 1982, Astrophs. J. 252, 668.
Baliunas, S. L., Hartmann, L., Vaughan, A. H., and Dupree, A. K.: 1981, Astrophys. J. 246, 473.
Bolton, C. T.: 1977, private communication.
Bopp, B. W.: 1979, Inf. Bulletin Var. Stars, No. 1669.
Bopp, B. W.: 1981, Astron. J. 86, 771.
Bopp, B. W.: 1982, in Second Cambridge Workshop on Cool Stars, Stellar Systems and the Sun, Vol. I, p. 207.
Bopp, B. W., and Noah, P. V.: 1980, Publ. Astron. Soc. Pacific, 92, 333.
Bopp, B. W., and Rucinski, S. M.: 1981, in IAU Symposium 93, Fundamental Problems in the Theory of Stellar Evolution, ed. D. Sugimoto, D. N. Schramm, and D. Q. Lamb (Dordrecht: Reidel), p. 177.
Bopp, B. W., and Stencel, R. E.: 1981, Astrophys. J. (Letters), 247, L131.
Bopp, B. W., and Talcott, J. C.: 1978, Astron. J., 83, 1517.
Bopp, B. W., and Talcott, J. C.: 1980, Astron. J., 85, 55.
Collier, A. C.: 1982a, Ph.D.Thesis, University of Canterbury.
Collier, A. C.: 1982b, Mon. Not. Roy. Astron. Soc., in press.
Dorren, J. D., Siah, M. J., Guinan, E. F., and McCook, G. P.: 1981, Astron. J. 86, 572.
Fekel, F.: 1982, private communication.
Fraquelli, D. A.: 1978, Astron. J., 83, 1535.
Fraquelli, D. A.: 1982, Astrophys. J. (Letters), 254, L41.
Furenlid, I., and Young, A.: 1978, Astron. J., 83, 1527.
Gershberg, R. E., and Shakovskaya, N. I.: 1971, in IAU Colloq. No. 15, Veroff. Der Remeis-Sternwarte Bamberg, BD. IX, NR. 100, p. 126.
Hall, D. S.: 1976, in IAU Colloq. No. 29, Multiple Periodic Variable Stars, edited by W. S. Fitch, (Dordrecht: Reidel), p. 287.
Hearnshaw, J. B.: 1978, Astron. J., 83, 1531.
Linsky, J. Worden, S., McClintock, W., and Robertson, R.: 1979, Astrophys. J. Suppl. 41, 47.

McCarthy, J. K., and Ramsey, L. W.: 1982, in preparation.
Nations, H. L., and Ramsey, L. W.: 1980, Astron. J., 85, 1086.
O'Brien, G., and Lambert, D. L.: 1979, Astrophys. J. (Letters), 229, L33.
Popper, D. M.: 1978, Astron. J., 83, 1522.
Ramsey, L. W., and Nations, H.: 1981, Publ. Astron. Soc. Pacific, 93, 732.
Ramsey, L. W., and Nations, H. L.: 1982, Second Cambridge Workshop on Cool Stars, Stellar Systems and the Sun, Vol. I, p. 225.
Ramsey, L. W., Nations, H. L., and Barden, S.: 1981, Astrophys. J. (Letters), 251, L101.
Rucinski, S.: 1981, Astron. Astrophys. 104, 260.
Shine, R., Gerola, H., and Linsky, J.: 1975, Astrophys. J., 202, L101.
Smith, S. E., and Bopp, B. W.: 1982, Astrophys. Lett., in press.
Vaughan, A. H. and Zirin, H.: 1968, Astrophys. J., 152, 123.
Vaughan, A. H. et al.: 1981, Astrophys. J., 250, 276.
Walter, F., and Basri, G.: 1982, Astrophys. J., in press.
Webbink, R. F.: 1976, Astrophys. J., 209, 829.
Weiler, E. J.: 1978, Mon. Not. Roy. Astron. Soc., 182, 77.
Weiler, E. J., et al.: 1978, Astrophys. J., 229, 919.
Wilson, O. C.: 1976, Astrophys. J., 205, 823.
Wilson, O. C.: 1982, Astrophys. J. 257, 179.
Zirin, H.: 1975, Astrophys. J. (Letters), 199, L63.
_____. 1976, Astrophys. J. 208, 414.
_____. 1981, preprint.
_____. 1982, preprint.

DISCUSSION

Dupree: I would like to ask that caution be exercised in the use of the 10830 Å line as a coronal diagnostic. First of all, the line is very difficult to measure since it is measured using photographic plates and it is confused by blends. Secondly, the case for X-ray excitation of the line was developed only for the Sun which is a dwarf star without an extended atmosphere. It is not at all certain that it would apply to giants or subgiants. Now I have a question. A potentially interesting application of the 10830 Å measurement is in the width of the line. O'Brien's measurements suggest that the terminal velocities of these lines for supergiants and, possibly, supergiant stars agree with the terminal velocities measured from circumstellar absorption lines. My question is whether the spread in the width of the lines in the compilation of Zirin's give any indication of outflows i.e. are they broad, do they show any phase dependence, can we get any information on the wind from looking at the profiles?

Bopp: I certainly agree with your comments that this line is not yet a reliable coronal diagnostic. But I was impressed by Zirin's latest compilation and would encourage additional observations. He did not however attempt to measure velocities or widths. The 10830 feature as recorded in RS CVn and similar systems has a width which appears to be instrumental with the exception of Algol B.

Linsky: After listening to this talk I would urge observers to measure quantities that contain useful information. For instance in the Sun the Hα line is very complicated both observationally and theoretically. In a solar plage for instance the line centre is brighter than in the surroundings but about 0.5 Å off centre it is darker. So if one has a composite Hα spectrum you don't know what you are looking at. In the dMe star we know, both theoretically and observationally, that as you go from the least to the most active stars first Hα goes dark and then it gets bright. So Hα is very confusing and if we spend our valuable observing time watching this thing it may contain no information. Secondly, the Ca II line is a better line to use but may have very little contrast. In particular in the Sun we know that the rotational modulation of the Sun is small whereas in the UV and X-ray lines it is very large. I would like to show a viewgraph to stress this point (Fig.3, Andrews et al., this volume). In the case of II Peg, which has a large photometric variability, if one looks at a chromospheric line such as Mg II it will show only a very small variation of the order of 40-50%. Higher temperature lines however show variation by a factor of 5. So I think it is important to look at lines which show large variation if one wishes to study a plage.

Goldberg: With regard to He I 10830 there is a line which can tell us whether 10830 is being radiatively or collisionally excited i.e. the singlet counterpart at 20582 Å, I believe it is. It may be necessary to have a star with the right radial velocity to get the line away from CO_2 absorption. I wonder if anyone has tried to observe that line?

Bopp: No I am sure not. I think there would be problems with appropriate detectors. The 10830 line requires at least 0.5 Å resolution to pick it up.

Goldberg: I think the instrumentation is good enough to do it with Fourier Transform Spectrometers.

Basri: I would just like to say that I presented results at the Zurich meeting (IAU Symp. No. 102) which show no correlation between MgII and activity. I would like to caution however that using the Linsky technique i.e. using (V-R) to get CaII fluxes in RS CVn stars seems very dangerous because of contamination from the other star. I urge people to try to observe the flux directly to try to answer this question directly.

Bopp: I certainly agree. In the text of my talk I caution that the tabulated values are probably only good to 50% or so.

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