ZEEMAN EFFECT OBSERVATIONS IN THE RS CVn STAR HR 5110 AND IN LATE-TYPE STARS WITH STRONG Ca II EMISSION

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1. INTRODUCTION

Although magnetic fields are presumed to be of substantial importance in the physics of stellar chromospheres (e.g., Vaiana et al. 1981), firm detections of magnetic fields in stars later than type A are rare, if not entirely absent. For example, Boesgaard (1974) made careful photographic measurements of longitudinal fields in a number of dwarf stars, and obtained 5 σ or greater detection of fields at the level of 100 G in the G8 V stars in ξ Boo A and in the KO V star 70 Oph A. Robinson et al. (1980) studied ξ Boo A by means of an analysis of the widths of magnetically sensitive lines, and obtained a mean field magnitude of 2600 G. However, Marcy (1981) used the same technique and found no significant field in this star. Brown and Landstreet (1981) looked for longitudinal fields in a variety of late type stars with an adaptation of a Griffin-type radial velocity spectrometer, which yielded standard errors near 10 G. They found no fields in any of the stars which they surveyed, including ξ Boo A, 70 Oph A, and a number of RS CVn stars and other stars with strong Ca II K and He I 10830 A emission.

Because of the wide range of possible field strengths in late stars suggested by indicators of chromospheric activity, further measurements remain of interest. The RS CVn stars are of particular interest in this context, since the evidence for "star spots" (e.g., Eaton & Hall 1979) suggests that their magnetic fields may be more simply organized than in the sun, and such evidence as flaring, polarized radio emission (Owen & Gibson 1978; Brown & Crane 1978), and strong X-ray (Walter et al. 1978) and UV emission (e.g., Simon et al. 1980a) suggest the possibility of quite strong magnetic fields. We report, therefore, the results of photographic measurements of the longitudinal Zeeman effect in the spectra of a number of late-type selected from the list of Bopp and Talcott (1978), plus a series of spectrograms of the RS CVn binary system HR 5110. The observations of Bopp and Talcott's stars were made with the 2.2-m telescope of the University of Hawaii at Mauna Kea Observatory in 1979; the plates of

J. O. Stenflo (ed.), Solar and Magnetic Fields: Origins and Coronal Effects, 35–39.

HR 5110 were obtained by P. S. Conti with the Lick Observatory 3-m telescope in 1967-68. We thank Dr. Conti for permitting us to use his plates. These observations have, at best, uncertainties three times larger than those attained by Brown and Landstreet (1981), but since there are no stars in common to the two programs, the present results constitute a significant addition to the available data.

2. OBSERVATIONS AND RESULTS

Table 1 lists the stars observed and the numerical results. The first three columns are self-explanatory. The fourth gives the heliocentric Julian Date of midexposure; the observations at HJD < 2,440,000 are Conti's Lick spectrograms; the remainder are Mauna Kea plates. The next two columns give the results: the effective longitudinal field and the radial velocity, each with its standard error. The last digit of the error is of the same significance as the last digit of the value to which it refers. The final column gives the phase for HR 5110 computed from the ephemeris of Burke et al. (1980). HR 5110 is the only RS CVn system observed; the remaining stars, except for the standard dwarf beta Vir, were selected by Bopp and Talcott (1978) as having strong Ca II emission.

Table 1. Observations and Results

HD	Name/HR	Spect.	HJD 2400000+	H_{eff}(s) gauss	V_{rad}(s) km/s	phase
118216	5110	F2 IV	39630.714	+4(61)	+11.6(1)	0.98
118216	5110	F2 IV	39636.756	+50(64	-1.5(2)	0.29
118216	5110	F2 IV	39874.006	-228(89)	+5.4(4)	0.08
118216	5110	F2 IV	39955.866	-40(22)	+2.1(2)	0.40
118216	5110	F2 IV	44029.893	+103(106)	-0.3(2)	0.44
95212	4280	K5 III	44030.787	-126(60	+2.7(6)	
102870	β Vir	F8 V	44028.769	-270(105)	+6.0(3)	
161797	μ Her	G5 IV	44028.902	-64(70)	-14.8(3)	
163770	θ Her	K1 IIa	44029.974	-1(62)	-35.3(6)	
173764	β Sct	G4 IIa	44028.950	-74(92)	-8.3(4)	

The equipment used for the observations was described by Preston and Pyper (1965) for Lick Observatory, and by Wolff and Bonsack (1972) for Mauna Kea Observatory. The measurement and data reduction were carried out as described by Wolff and Bonsack. The results given are means over all of the lines measured on each spectrogram, and the standard errors of the mean are based upon the differences between the results of individual lines. The line list contained principally Fe and other metals; strong, saturated lines and apparently blended lines were avoided. The lists for the Lick spectrograms contained approximately 120 lines in the range $0.38 < \lambda < 0.46$ μm, while that for the Mauna Kea plates contained 70 lines in the range $0.45 < \lambda < 0.55$ μm. The errors given in Table 1 are similar to those obtained in extensive previous measurements of sharp-line Ap stars.

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It will be seen at once that none of the derived values of H_{eff} are as large as three times their standard error. We conclude, therefore, that we have made no reliable detections of magnetic fields, but we offer the data as representing upper limits to the possible net longitudinal fields in these stars at the epochs of the observations.

3. DISCUSSION

HR 5110. The spectroscopic orbit of this binary system was discussed most recently by Conti (1967), who found the system to consist of an F2 IV primary and a G-K secondary with a mass ratio near 0.3. Hall (1976) includes HR 5110 in his list of RS CVn variables, although HR 5110 in many ways resembles an Algol system, e.g., in its mass ratio and X-ray properties (Simon et al. 1980b). HR 5110 underwent a radio outburst in late 1979 May (Feldman 1979), but Simon et al. (1980b) observed that C IV and other high-temperature transition region lines were not enhanced, and these authors suggested that the radio outburst may have been the result of a binary mass-transfer event, rather than a magnetically-driven flare.

The Zeeman-effect observations presented in Table 1 cover reasonably well one-half of the orbit. Thus, all of the surface was sampled by these observations, except for an antipodal region which is permanently hidden as a result of the low inclination (Conti 1967). No significant magnetic field was detected; an upper limit of 100 G is suggested. The radial velocities from the 1967-68 Lick spectrograms agree well with the mean curve given by Conti based upon observations made in 1965-66. The Mauna Kea spectrogram, obtained in 1979, gives a somewhat deviant velocity, which would agree with the curve if the phase were reduced by 0.09. No large systematic difference has previously been noted between Mauna Kea and Lick coude velocities. The Mauna Kea spectrogram was obtained about one week after the onset of the radio flare; no magnetic effects were detected, which is in accord with the Simon et al. (1980b) suggestion regarding the origin of the flare. However, all such effects may have subsided in the week since the flare began.

Other Stars. Three of the stars observed are included in Wilson's (1976) catalog of Ca II emission line widths and strengths, in which he estimates strengths on a scale 0-5. μ Her rates 0 on this scale, β Sct, 2, and θ Her, 3. HR 4280 is included in Joy and Wilson's (1949) list of stars with Ca II emission, where its emision strength is given as 1 on a scale which apparently extends to 50. μ Her gives no other indications of an active chromosphere: Hartmann et al. (1982) find no detectable UV C IV emission, and Vianna et al. (1981) find a relatively weak X-ray luminosity compared to other G stars. θ Her has strong and variable emission at He I 10830 A as well as the K line (Zirin 1976) and Reimers (1982) find it to be a "hybrid" star, with significant chromospheric C IV emission, and a cool wind. However, recent IUE data shows no detectable C IV (Simon unpublished).

β Sct has apparently not been observed in the UV or X-ray regions. The remaining stars β Vir, is an F8 V standard which was observed to calibrate exposure times. It has not been noted to have Ca II emission, and a low Li abundance (Duncan 1981), low rotation (Smith 1978), and low X-ray luminosity (Pallavicini et al. 1981) are in accord in indicating advanced age.

The above stars cover a range of luminosities and a range of chromospheric activity. One active RS CVn system has been well sampled. None show significant net longitudinal magnetic fields greater than 100 G. It is clear that it is not possible to distinguish among the categories of late-type stars by means of observations of the longitudinal Zeeman effect using the photographic technique, and the results of Brown and Landstreet (1981) indicate that modern techniques of higher precision lead to the same conclusion.

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DISCUSSION

BASRI: I would like you to clarify what you mean by "organized magnetic fields". Do you mean that there should be more of one polarity on an entire hemisphere of the star?

BONSACK: By "organized magnetic fields" I mean a field appproaching the simple dipolar structure apparently present in early-type stars, rather than a solar-type configuration. In such a dipolar field, the observed hemisphere is usually dominated by a single polarity.

UCHIDA: Your sample did not include such active objects as UX Ari or V 711 Tau, which show coronae and flaring activities indicating the presence of strong magnetic fields. Is there any observational reason for this?

BONSACK: These stars were not available at the time of this single observing session. It clearly would be of interest to extend the observations. Note that Brown and Landstreet observed several additional RS CVn systems (including UX Ari and V 711 Tau) with a claimed sensitivity of about 10 G and found nothing.

WALTER: HR 5110 is not a particularly good choice to use to claim that all RS CVn systems fail to show "organized" magnetic structure. Most of the light in this system is from the F2 IV; the active star is considerably less luminous, and is the star likely to have the strong magnetic fields. Better choices to test the hypothesis may be II Peg, as used by S. Vogt, or HR 7275.

BONSACK: We make no claim about systems which have not been observed. The primary of HR 5110 is not the most active star, but strong magnetic fields may link both stars, as suggested by Uchida et al. (*PosterPaper*). Other stars have been observed by others with null results, including II Peg by Vogt, and several by Brown and Landstreet (see answer to Uchida's question).