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uvby photometry of the magnetic chemically peculiar stars HD 11187, HD 15144, 20 Eridani and HR 8933 and the early F star HD 14940*

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Abstract. — Four College Automated Photoelectric Telescope differential Strömgren *uvby* photometric observations of four magnetic chemically peculiar stars are presented. One of our comparison stars was also found to be variable. Observations of the sharp-lined Si star HD 11187 are best described as representing a constant star. HD 15144 was also constant photometrically. However, its comparison star HD 14940 is definitely variable. But we were not able to find a period. It may be a δ Scu star. Our observations of 20 Eri and the *uvby* values of Renson & Manfroid show definite differences in the shapes of the light curve which suggest that this star may be undergoing a precession of its rotational axis. When we refined the period by using the minima we find a value of 1.92893 days. We refined Winzer's period of the relatively large amplitude variable HR 8933 to 2.86031 days. In v and b there are definite indications of a weak submaximum within the broad minimum.

Key words: stars: individual HD 11187 — stars: individual HD 14940 — stars: individual HD 15144 — stars: individual 20 Eri — stars: individual HR 8933 — stars: peculiar A — stars: variable

1. Introduction

During the first five years (September 1990 - July 1995) of the regular operation of the 0.75-m Four College Automated Photoelectric Telescope (FCAPT) on Mt. Hopkins, AZ, we obtained differential photometry of many magnetic Chemically Peculiar stars of the upper main sequence in the Stromgren *uvby* system. Our observing pattern was to measure the dark count and then in each filter the sky-ch-*c*-*v*-*c*-*v*-*c*-*v*-*c*-ch-sky where sky is a reading of the sky, ch that of the check star, *c* that of the comparison star, and *v* that of the variable star. This paper presents results for four CP stars HD 11187, HD 15144, 20 Eri, and HR 8933. The observations are given in Tables 1, 3, 4 and 5 along with their means and their standard deviations which are summarized in Table 2. No corrections have been made for neutral density filter differences among each group of variable, comparison, and check stars.

For each of our two variable stars with known periods, we plotted our data using the best published period to see if the data approximately confirmed this period. Then we applied the Scargle periodogram (Scargle 1982; Horne & Baliunas 1986) to our data. If the periodogram confirmed the published period, then we adjusted the period to make all data coincide as well as possible in phase. For stars without known periods we began our period finding investigations using the Scargle periodogram.

2. HD 11187

Babcock (1958) obtained three Palomar Observatory Pb spectrograms of HD 11187 and noted that the Ti II, Cr II, and Fe II lines indicated different magnetic field strengths. Preston (private communication) found it had relatively sharp spectral lines. Adelman's (1980) optical region spectrophotometry indicates that this star might be variable.

We obtained 100 observations (Table 1) of HD 11187 with the FCAPT primarily during the autumns of 1992, 1993, and 1994. HD 11335 (= HR 538, spectral type A3 V) and HD 12303 (= HR 590 = 4 Per, spectral type B8 III) (Hoffleit 1982) were the comparison and check stars, respectively.

The standard deviations of the mean comparison-check star values are about 0.006 mag (Tables 1 and 2) except for u which was 50% larger. But the standard deviations of the mean variable-comparison star values are about 0.004 mag. Thus HD 11187 is not particularly variable. Still we performed a periodogram analysis of all four magnitudes. No frequency had a power signal-to-noise value as large as

*Tables 1, 3, 4 and 5 are only available in electronic form: see the Editorial in A&A 1993, Vol. 280, page E1

Table 2. Photometry summary

		u		v		b		y
HJD	v-c	ch-c	v-c	ch-c	v-c	ch-c	v-c	ch-c
HD 11187								
1992-93 (11 observations)								
average	0.343	-0.555	0.733	-0.982	0.805	-1.068	0.860	-1.104
std. dev.	0.006	0.011	0.006	0.008	0.004	0.006	0.004	0.007
1993-94 (50 observations)								
average	0.341	-0.563	0.739	-0.991	0.810	-1.068	0.866	-1.111
std. dev.	0.005	0.009	0.004	0.004	0.004	0.004	0.004	0.006
1994-95 (39 observations)								
average	0.339	-0.565	0.739	-0.994	0.809	-1.067	0.866	-1.108
std. dev.	0.004	0.006	0.004	0.005	0.004	0.005	0.004	0.006
all values								
average	0.341	-0.563	0.738	-0.991	0.809	-1.068	0.866	-1.109
std. dev.	0.005	0.009	0.004	0.006	0.004	0.005	0.004	0.006
20 Eri								
1990-91 (4 observations)								
average	0.074	0.665	0.779	0.162	0.930	0.014	1.023	-0.061
std. dev.	0.041	0.010	0.018	0.009	0.025	0.005	0.023	0.005
1991-92 (14 observations)								
average	0.082	0.655	0.770	0.157	0.918	0.018	1.012	-0.065
std. dev.	0.033	0.006	0.015	0.005	0.016	0.006	0.016	0.006
1992-93 (10 observations)								
average	0.115	0.650	0.794	0.152	0.936	0.015	1.031	-0.068
std. dev.	0.041	0.008	0.020	0.005	0.018	0.004	0.019	0.007
1993-94 (32 observations)								
average	0.091	0.651	0.784	0.159	0.920	0.030	1.025	-0.061
std. dev.	0.043	0.009	0.019	0.006	0.020	0.005	0.018	0.006
1994-95 (18 observations)								
average	0.088	0.655	0.784	0.159	0.916	0.034	1.019	-0.055
std. dev.	0.036	0.012	0.017	0.006	0.018	0.007	0.019	0.007
all values								
average	0.091	0.653	0.782	0.158	0.921	0.026	1.022	-0.061
std. dev.	0.040	0.010	0.019	0.006	0.020	0.009	0.019	0.007
HR 8933								
1993-94 (30 observations)								
average	0.781	-1.371	0.544	-1.225	0.458	-1.163	0.433	-1.133
std. dev.	0.024	0.005	0.008	0.005	0.012	0.004	0.010	0.004
1994-95 (39 observations)								
average	0.777	-1.369	0.541	-1.223	0.454	-1.164	0.431	-1.133
std. dev	0.028	0.004	0.009	0.004	0.014	0.003	0.012	0.004
all values								
average	0.778	-1.370	0.542	-1.224	0.456	-1.163	0.432	-1.133
std. dev.	0.026	0.005	0.009	0.004	0.013	0.003	0.011	0.004

Table 2. continued

HD 15144 and HD 14940

	u		v		b		y	
HJD	v-ch	v-c	v-ch	v-c	v-ch	v-c	v-ch	v-c
1990-91 (8 observations)								
average	1.184	1.593	1.193	1.360	1.017	1.433	0.950	1.556
std. dev	0.006	0.013	0.007	0.020	0.004	0.019	0.008	0.018
1993-94 (38 observations)								
average	1.188	1.640	1.190	1.390	1.026	1.438	0.958	-0.842
std. dev.	0.006	0.051	0.005	0.031	0.004	0.028	0.006	0.018
1994-95 (29 observations)								
average	1.191	1.643	1.192	1.392	1.032	1.439	0.964	-0.839
std. dev.	0.006	0.062	0.006	0.043	0.006	0.039	0.005	0.017
all values (There was a change in neutral density filters in the v-c observations between years 1990-91. The v-c average does not include the first 8 observations.)								
average	1.189	1.636	1.191	1.388	1.028	1.438	0.961	-0.841
std. dev.	0.006	0.055	0.006	0.036	0.007	0.032	0.006	0.018

that for 1% significance. The frequency with the highest such value was 0.1250 per day with a power S/N close to 1% for b and slightly less than this for v and y, but much less for u. We are suspicious of frequencies corresponding to an integral number of days. When we plotted the b data with this period we found it was a scatter diagram. As photometry of HD 11187 for the past two years (89% of the total) agrees very well, we conclude that this star has been constant during this period. It is probably worthwhile monitoring HD 11187 over a longer time period to see if it is variable.

3. HD 15144 and HD 14940

Roman (1949) noted the strength of the Sr II lines in HD 15144 (= HR 710 = ADS 1849). Although this star showed a variable magnetic field, Babcock (1958) could not determine a period. Further he found that this star was a spectroscopic binary with a period of 2.997814 days. Van Genderen (1971) obtained 8 photometric measurements using HD 15798 as the comparison star. It is unclear from his data whether this star is variable. Bonsack (1981) obtained spectrograms and confirmed the period of the binary's orbit. He also found a probable magnetic period of 15.9 days and estimated v sin i as 7.7 km s^{-1}.

Eight observations of HD 15144 were obtained during the 1990-91 observing season, 38 during 1993-94, and 29 during 1994-95 using HD 14940 (spectral type F0 IV/V) and HD 15130 (= HR 708 = 72 ρ Cet, spectral type, B9.5 Vn) (Hoffleit 1982) as the comparison and check stars, respectively. Examination of the 1σ values of the averages of the means for all four colors (Tables 2 and 3) suggested that the variable-check star data indicated that these two stars were constant. The variable-comparison and check-comparison star data showed that HD 14940 was a variable star. An examination of the references from SIMBAD showed that Weiss (1978a, b) had reported this F0 star to be a small amplitude variable with amplitudes of 0.02 to 0.04 mag. Our data indicates that HD 14940 is more variable in u than v than b than y and shows larger ranges of variability than Weiss (1978b). Our periodograms did not show any potentially significant frequencies for v, b, and y. For u frequencies close to 1 and 2 cycles day^{-1} were above the power S/N for 1% significance. But without many observations per night, it is best not to claim variability at such periods. As this star has the appropriate spectral type to be a δ Scu star, it should be observed continuously for several nights to check this possibility.

4. 20 Eri

Babcock (1958) noted that 20 Eri (= HD 22470 = HR 1100) had metal lines too broad to be measured for the Zeeman effect. Renson & Manfroid (1981) found that this B9pSi star was a relatively large amplitude variable with the amplitudes of v, b, and y about 0.06 mag and that for u being 0.11 mag Their ephemeris was

$$\text{HJD (light minimum)} = 2443485.50 + 1.93\ E.$$

The variations of u, v, b, and y are in phase. They used HR 1128 (= HR 23055, spectral type F0 IV) and τ^5 Eri(= HD 22203, spectral type B9.5 V + B9.5 V) (Hoffleit 1982) as comparison stars. Borra et al. (1983) made 12 measurements of 20 Eri using an Hβ Zeeman analyzer and

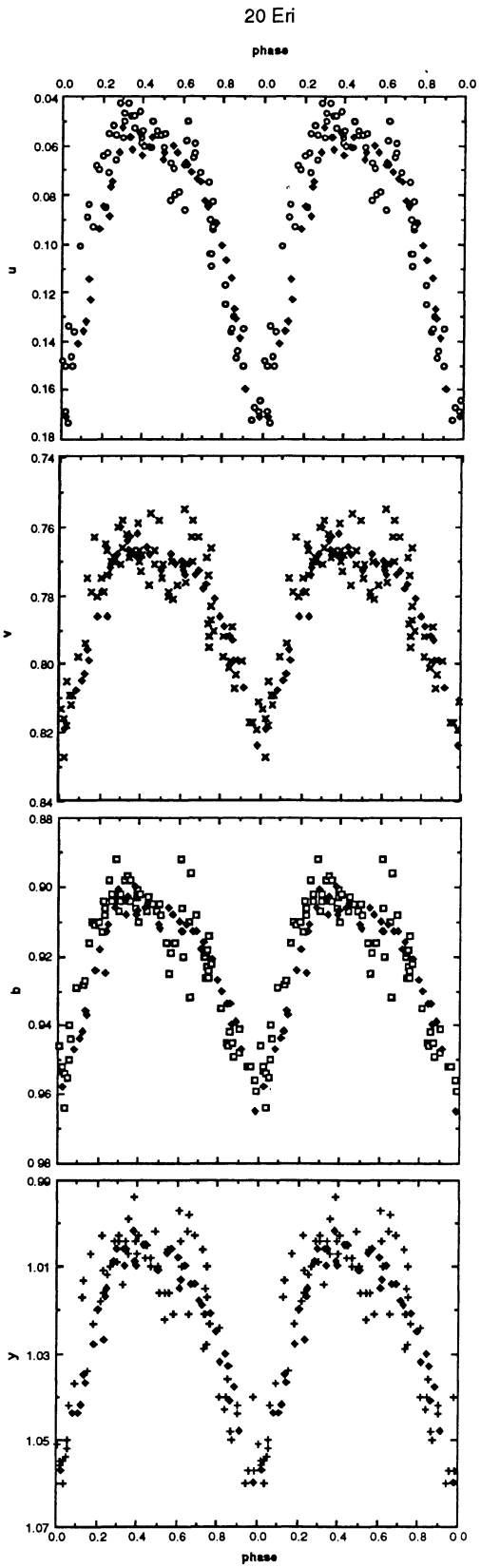

Fig. 1. *uvby* photometry of 20 Eri with the ephemeris HJD (light minimum)= 2443485.50 + 1.92893 E. The FCAPT u, v, b, and y values are represented by circles, crosses, open squares, and plus signs, respectively. Values from Renson & Manfroid (1981) are given by filled diamonds. The averages for each magnitude were adjusted to those for the FCAPT photometry

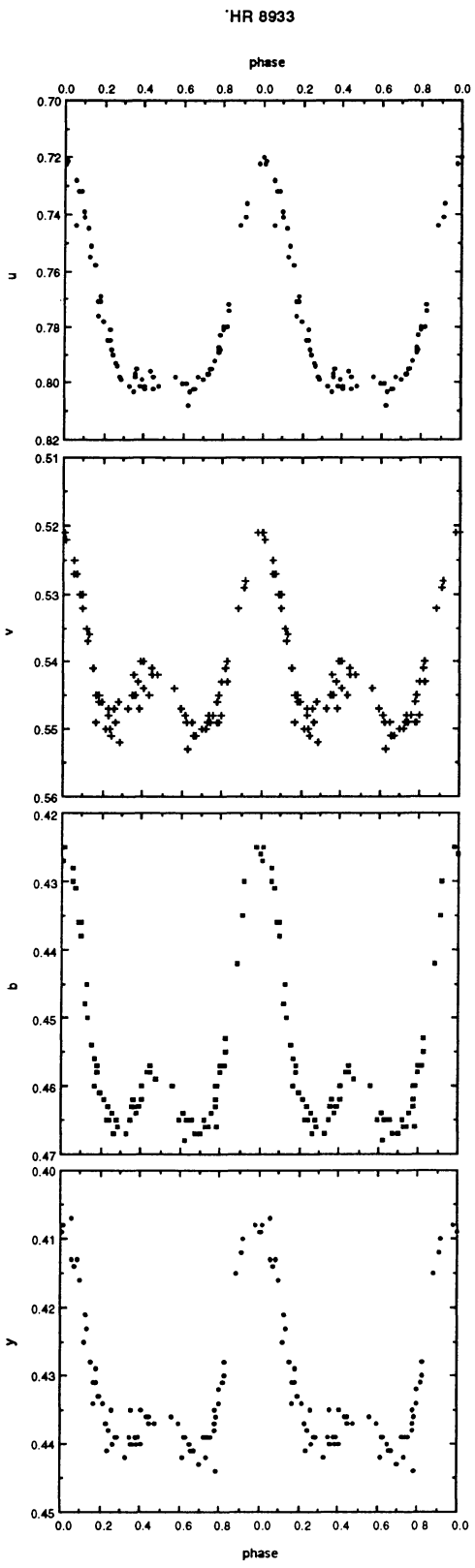

Fig. 2. *uvby* photometry of HR 8933 with the ephemeris HJD ($U_{\max}$)=2441240.80+2.86031 E

found definite evidence of a reversing magnetic field with extreme values greater than 1 kG. Their data could be fit by 0.6785 and 1.935 day periods. Manfroid & Mathys (1985), using additional photometry, revised the period to 1.9387 days which compares with 1.9285 days found by Zelwanowa & Schöneich (1985).

The FCAPT observations of 20 Eri used τ^5 Eri and HR 1128 as the comparison and check stars, respectively. Seventy-eight observations were obtained, 4 during the 1990-91 observing season, 14 during 1991-92, 10 during 1992-93, 32 during 1993-94, and 18 during 1994-95 (Table 4). Our periodogram for v indicated a significant frequency of 0.51845 cycle day^{-1} which is equivalent to a period of 1.92883 days. With this period our light curves looked somewhat similar to those of Renson & Manfroid (1981), but our minimum was not at phase zero. To do this we adjusted the period to 1.92893 days. In comparing minima we just examined the few points in their vicinity.

As we had Renson & Manfroid's data we added a constant to each magnitude so that the averages were the same and then overplotted both sets of data (Fig. 1). Immediately it was obvious that the shapes of the light curves were somewhat different. Our data suggested slightly larger amplitudes of variation, differences in the rise and fall times, and indications that the maxima had structure, two submaxima. Our observations were taken over a much longer time span than their's. But, during each observing season we did not necessarily sample the entire light curve. So for example, most of the evidence for the structure in the maximum is due to observations taken during the first two seasons. Slight adjustments to the period would move our values relative to those of Renson & Manfroid, but not significantly change the comparison.

From these observations we conclude that it is probable that 20 Eri changes the shape of its light curve in of order 15 years. It is desirable to obtain additional photometry of this star especially sufficient observations to determine the shapes of the light curves in several seasons. The changes in the light curves are similar to those seen for 56 Ari (Adelman & Fried 1993), CU Vir (Pyper et al. 1993), and 108 Aqr (Adelman & Knox 1994) and may be evidence for precession of the rotational axis.

5. HR 8933

Kizilirmak & Wood (1967), who obtained wide and narrow band photometry with half transmission widths of 150 and 35 Å, respectively, of the Hβ and Hγ lines, found that HR 8933 (=HD 221394) was variable in both lines, but had too few observations to derive a period. Winzer (1974) obtained at least 15 differential measurements in U, B, and V, using HD 221605 as the comparison star, and found that this star is a large amplitude variable. The amplitude in U is almost 0.08 mag His ephemeris was

$$\text{HJD } (U_{\max}) = 2441240.80 + 2.8419\ E.$$

The variations in U, B, and V are in phase. Winzer says that the light maxima are very sharp while the minima are quite broad and flat. This can be interpreted as due to the presence of a bright spot.

During the fall of 1994 and 1995, 30 and 39 differential observations, respectively, of HR 8933 were obtained with the FCAPT. HD 220933 (= HR 8915 = 69 Peg,), a HgMn star, was the comparison star and HD 221673 (A0) the check star. The periodograms suggest a frequency of 0.3496 cycles day^{-1} which corresponds to 2.8604 days. Our data with such a period has the same form of the light curve as those of Winzer, but is phase shifted by about 0.10. To bring the maxima into coincidence required adjusting the period to 2.86031 days. Figure 2 shows the u, v, b, and y photometry with Winzer's epoch of maximum light and our period. The amplitudes are 0.08 mag, 0.04 mag, 0.04 mag, and 0.035 mag, in u, v, b, and y, respectively. There are clear submaxima in the light minima for v and b. All four magnitudes appear to have in phase primary maxima.

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