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LIGHT-VARIATIONS OF PECULIAR A STARS

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ABSTRACT

Light-curves have been established for three peculiar A stars: ϵ Ursae Majoris, χ Serpentis, and HD 224801. A new light-curve for α^2 Canum Venaticorum is presented. Results on thirteen other stars are given in tabular form. A period of the line-intensity variation of 21 Comae has been determined (Appendix 1). In Appendix 2, colors of twenty peculiar A stars are given.

I. INTRODUCTION

The peculiar A stars have recently come into prominence in astronomy as stars which frequently show large magnetic fields. The study of peculiar A stars began in 1906, when Sir Norman Lockyer and F. E. Baxandall[1] found that some absorption lines in the stars α Andromedae and ϵ Ursae Majoris undergo changes in intensity. In the same year Ludendorff[2] announced the variability of lines in α^2 Canum Venaticorum. In the years since 1906 the number of known peculiar A stars has grown steadily, and it is now clear that at least 10 per cent of all A stars are peculiar, in that lines of one or more groups of elements are strong in the spectrum. The peculiar A stars fall into two groups: (1) those with absorption lines some of which are abnormal but constant in intensity and (2) those with absorption lines some of which vary periodically (the spectrum variables). The study of brightness changes of peculiar A stars was initiated by Guthnick and Prager[3] in 1914, when α^2 Canum Venaticorum was observed. This star has been observed several times since 1914.[4] Two other stars have been observed previously for variation in total light, viz., ϵ Ursae Majoris[5] and HD 125248.[6]

The present investigation was undertaken with a view to extending our knowledge of the light-variations of peculiar A stars. The work was divided into two parts: (1) intensive observation of those stars, accessible at Yerkes Observatory, known to be spectrum variables and/or to have magnetic fields and (2) observation of a selected number of peculiar A stars that show no known line-intensity changes or magnetic fields.

II. EQUIPMENT AND PROCEDURE

The observations were made with two telescopes: the 12-inch refractor of the Yerkes Observatory and the 13-inch reflector of the McDonald Observatory. The measures were made at two effective wave lengths at Yerkes and at three effective wave lengths at McDonald. The yellow ($\lambda_{\text{eff}} \sim 5500$) and blue ($\lambda_{\text{eff}} \sim 4400$) were isolated by a Corning 3384 filter and by a cemented Corning 5030 plus Schott GG-13 filter, respectively. The ultraviolet ($\lambda_{\text{eff}} \sim 3550$) was isolated by a Corning 9863 filter for the third effective wave length at McDonald.

In this investigation two comparison stars were used when suitable near-by stars were available. The choice of comparison stars was made on the basis of color and no known

[1] *Proc. R. Soc., A*, London, **77**, 550, 1906.

[2] *A.N.*, **173**, 4, 1906.

[3] *Veröff. Sternw. Berlin-Babelsberg*, **1**, 44, 1914.

[4] M. Gussow, *A.N.*, **229**, 199, 1926–1927; P. Guthnick, *A.N.*, **205**, 100, 1917–1918; W. S. Tai, *M.N.*, **100**, 94, 1939; Nikonov and Brodskaya, *Bull. Abastumani Ap. Obs.*, **11**, 7, 1950.

[5] P. Guthnick, *Sitz. Preuss. Akad. Berlin*, No. 29, p. 657, 1931.

[6] Stibbs, *M.N.*, **110**, 395, 1950.

evidence of variability. In the reductions of the observations, mean extinction coefficients, for stars of about class A0, were used.[7]

III. THE OBSERVATIONS

Of the seventeen stars investigated, four show well-defined light-variation. These stars will be considered in detail, and the results on the thirteen other stars will be presented in tabular form. Light-curves of three peculiar A stars have been published previously by the writer.[8]

ϵ URSAE MAJORIS

ϵ Ursae Majoris is classified as A0p in the *Henry Draper Catalogue*. Several lines in the spectrum show abnormal intensities. Because of its brightness (1.69 mag.), it has been the subject of a number of investigations, notably by P. Guthnick,[9] Swensson,[10] and Struve and Hiltner.[11]

Guthnick found that the period of this spectrum variable is 5.0887 days. Observations by Struve and Hiltner and again by Swensson indicated that the minima of *Ca* II K were occurring later than the times predicted by Guthnick's period and epoch, by about 0.25 day. This would indicate a period slightly longer than 5.0887 days. Spectra taken on eleven nights during April–May, 1952, indicate that a minimum occurred about JD 2434130.9. The minimum predicted by Guthnick's elements occurs on JD 2434131.124, or about 0.2 day later than that found by the present series of plates. In view of the foregoing, it is concluded that Guthnick's elements predict the minima of *Ca* II K correctly.

Observations of the star's brightness were also carried out by Guthnick.[9] He found evidence of variation. In the present investigation, observations were made on seventeen nights in 1952. The star δ Ursae Majoris (A3; $3^{m}_{.}27$) was used for comparison. The observations are compiled in Table 1 and are plotted against phase in Figure 1. The observations show that ϵ Ursae Majoris varies in both yellow and blue light with amplitudes near 0.025 mag. There is little or no color change. Maximum light occurs near *Ca* II minimum intensity. The light-curve has two maxima separated by about $\frac{1}{2}$ period. It is noted that the two minima correspond to the phases when Struve and Hiltner[11] found that a number of lines in the spectrum of the star are double. If one compares the light-variation with Guthnick's velocity-curve (range 4 km/sec), it is found that maximum light occurs at the mean velocity when there is a change from approach to recession.

α^2 CANUM VENATICORUM

This star is designated as A0p in the *Henry Draper Catalogue*. Since it is also a bright star (2.90 mag.), it has been the subject of many investigations. In fact, α^2 Canum Venaticorum is the most extensively studied peculiar A star. Most of the investigations have been concerned with its spectrum; but the constancy of light was subject to investigation as early as 1914 by Guthnick and Prager.[3] They found that there was a range in brightness of 0.051 mag. M. Gussow[4] also observed the light of the star in 1925–1926 and found an amplitude of 0.034 mag. W. S. Tai[4] found an amplitude of 0.035 mag., and Nikonov and Brodskaya[4] found a change in color amounting to 0.06 mag.

In the present investigation the star was observed on nine nights. As comparison stars

[7] In the reductions of those observations made at McDonald Observatory it was necessary to take into account the dependence of the extinction coefficients on color if the stars were observed over large ranges of sec z.

[8] 73 Dra and ι Cas: *Ap. J.*, **117**, 21, 1953; and 56 Ari: *ibid.* (in press).

[9] *Sitz. Preuss. Akad. Berlin*, No. 27, 1931; No. 30, 1934.

[10] *Ap. J.*, **99**, 258, 1944.

[11] *Ap. J.*, **98**, 225, 1943.

14 C Vn (B9; $5^{m}.15$), HR 4875 (A2; $5^{m}.86$), and 15 C Vn (B9; $6^{m}.22$) have been used. The first, 14 C Vn, was suspected by Baker[12] of being a variable with rapid fluctuations and a range of 0.2 mag. Gussow[4] checked the constancy of the star during her investigation of α^2 C Vn and found no large fluctuations. In the present series of observations the com-

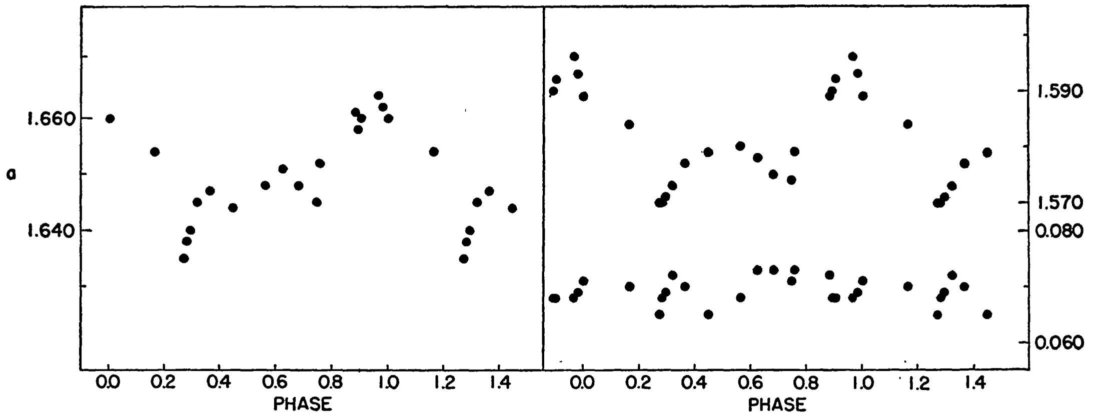

FIG. 1.—δ U Ma − ε U Ma: *a*, $\lambda_{eff} \sim 4400$; *b*, $\lambda_{eff} \sim 5500$; *c*, color

TABLE 1

PHOTOMETRIC OBSERVATIONS OF ε URSAE MAJORIS

DATE, 1952 U.T.	PHASE $P=5.0887$	δ UMa−ε UMa		
		Y	*B*	*C*
Jan. 24.360	0.279	1.570	1.635	0.065
27.448	.886	1.589	1.661	.072
29.467	.283	1.570	1.638	.068
Feb. 10.408	.629	1.578	1.651	.073
17.313	.986	1.593	1.662	.069
22.313	.969	1.596	1.664	.068
Mar. 17.313	.685	1.575	1.648	.073
Apr. 8.292	.004	1.589	1.660	.071
15.230	.368	1.577	1.647	.070
16.230	.564	1.580	1.648	.068
17.180	.751	1.574	1.645	.071
25.170	.321	1.573	1.645	.072
28.085	.894	1.590	1.658	.068
28.156	.908	1.592	1.660	.068
30.145	.299	1.571	1.640	.069
May 11.097	.451	1.579	1.644	.065
June 4.105	.169	1.584	1.654	.070
7.113	0.760	1.579	1.652	0.073

parisons of 15 C Vn with 14 C Vn (the mean of only two observations a night) show no deviations greater than 0.008 mag. from the mean. However, the star HR 4875 does show large residuals (0.02 mag.) when compared with both 14 and 15 C Vn. From these results it is concluded that 14 C Vn and 15 C Vn are constant in light and that HR 4875 is not. The observations are compiled in Table 2 and plotted against phase in Figure 2. Zero phase corresponds to *Eu* II maximum, according to the elements given by Miss G.

[12] *Pop. Astr.*, **34**, 148, 1926.

Farnsworth.[13] The observations have been corrected for the light of the companion, α^1 C Vn (F0; $5^m.39$).

The observations confirm the variation found by others. The amplitudes are 0.050 mag. in the yellow and 0.030 in the blue, with a color change of 0.02. The star is bluest at minimum light. The different ranges in the two colors will account for the diverse results obtained by the early observers. Miss Gussow's work was done with a potassium cell,

TABLE 2

PHOTOMETRIC OBSERVATIONS OF α^2 C Vn

DATE, 1952 U.T.	PHASE $P=5.46939$	14 C Vn$-\alpha^2$ C Vn			HR 4875 *minus* 14 C Vn	15 C Vn *minus* 14 C Vn	15 C Vn *minus* HR 4875
		Y	*B*	*C*	*Y*	*Y*	*Y*
Feb. 22.348....	0.376	2.379	2.393	+0.014	0.725	....	....
Mar. 17.308....	.757	2.401	2.398	− .003	.730	....	....
Apr. 8.320....	.781	2.402	2.403	+ .001	.716	....	....
15.344....	.065	2.426	2.418	− .008	.746	1.040	0.294
16.302....	.241	2.398	2.402	+ .004	.731	1.045	.314
17.240....	.412	2.383	2.383	+ .009	.720	1.035	.315
28.125....	.402	2.376	2.390	+ .014	.706	1.043	.337
30.210....	.784	2.404	2.400	− .004	0.721	1.036	0.315
May 12.210....	0.795	2.394	2.394	0.000	....	1.050	....

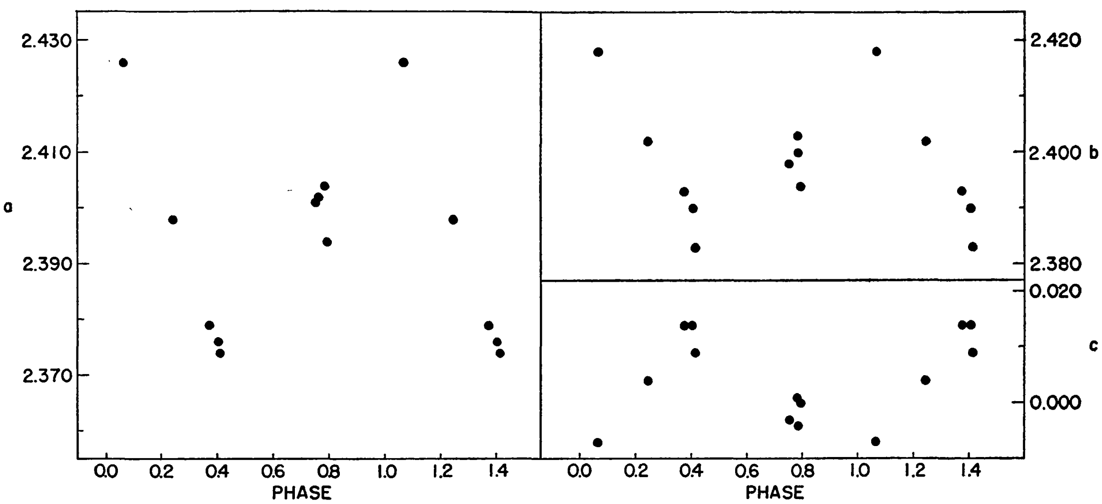

FIG. 2.—14 C Vn − α^2 C Vn: *a*, $\lambda_{\rm eff} \sim 5500$; *b*, $\lambda_{\rm eff} \sim 4400$; *c*, color

which has its maximum sensitivity near λ 4000, and the observations were made without a filter. Guthnick and Prager's observations were made with a sodium cell with maximum sensitivity at λ 5500, and they used no filter.

The star has been subject to study by Babcock and his associates.[14] There is a large magnetic field, and maximum negative field occurs at *Eu* II maximum intensity. This is the phase of maximum light, while minimum light occurs at the time of maximum positive magnetic field.

[13] *Ap. J.*, **75**, 364, 1932.

[14] H. W. Babcock and Sylvia Burd, *Ap. J.*, **116**, 7, 1952.

A comparison of the light-variation with the radial velocity, measured by the above observers and also by Struve and Swings,[15] shows that maximum light coincides with times of mean velocity, as *Eu* II changes from approach to recession and as *Cr* II changes from recession to approach. Minimum light occurs at times when the radial velocity of *Eu* II changes from recession to approach, while *Cr* II is at one of its two maxima of recession.

χ SERPENTIS

In the *Henry Draper Catalogue* χ Ser (HD 140160) is designated as A0p. Its magnitude is 5.26 The feature which marked this star as peculiar was the strength of the *Sr* II line at λ 4078. In a spectroscopic investigation of peculiar A stars, Deutsch[16] found that the lines of *Sr* II vary in intensity. He determined the period of variation to be 2.675 days. More recent observations by the same investigator[17] indicated that the period 2.675 days is not the actual period of variation but that the related period, 1.59584 days, is the true period. His elements are:

TABLE 3

PHOTOMETRIC OBSERVATIONS OF χ SER

DATE, 1952 U.T.	PHASE $P=1.59584$	HD 141400$-\chi$ SER			HD 141400 *minus* HR 5870
		Y	B	C	Y
Jan. 27.500	0.433	1.445	1.441	−0.003	....
Apr. 8.367	.467	1.443	1.428	− .015	....
15.363	.863	1.461	1.451	− .010	1.062
16.346	.467	1.450	1.428	− .022	1.064
May 11.230	.060	1.464	1.459	− .005	1.056
July 2.168	.606	1.463	1.450	− .013	1.054
4.130	.835	1.461	1.453	− .008	1.059
5.167	.485	1.441	1.436	− .005	1.056
6.130	.088	1.458	1.453	− .005	1.060
9.125	0.965	1.466	1.453	−0.013	1.065

$$Sr\ \text{II max.} = \text{JD } 2434134.06 + 1.59584\, E\,.$$

Photoelectric observations were made at Yerkes Observatory on ten nights. HD 141400 (A0; $6^{\mathrm{m}}.8$) was used as primary star for comparison with χ Ser; and HR 5870 (A0; $5^{\mathrm{m}}.72$) was observed as a check on HD 141400. The observations are given in Table 3 and are plotted in Figure 3 in accordance with the new elements given by Deutsch. The observations show that χ Ser varies in both the blue and the yellow with an amplitude of 0.02 mag. Maximum light corresponds to strontium maximum intensity.

HD 224801 (=HR 9080).

The star HD 224801 is designated as A0p in the *Henry Draper Catalogue*. Its magnitude is 6.25. Lines at $\lambda\lambda$ 4128–4131 are strong, and the radial velocity is variable.[18] The star has a magnetic field (see Table 6, n. †). It was first observed photoelectrically in the late months of 1951. As comparison stars, HR 1 (A0; $6^{\mathrm{m}}.51$) and HR 9070 (B5; $6^{\mathrm{m}}.49$) were used. The observations gave strong indications of variability at that time.

[15] *Ap. J.*, **98**, 361, 1943.

[16] *Ap. J.*, **105**, 293, 1947.

[17] *Pub. A.S.P.*, **64**, 315, 1952.

[18] *Pub. David Dunlap Obs.*, **1**, 123, 1939.

It was again observed, beginning in July, 1952. Twenty-eight observational points on twenty-three nights were obtained at Yerkes Observatory, and an additional twenty-three observational points were obtained at McDonald Observatory on fifteen nights. The period of light-variation, which is 3.7422 days, has been found from the observations made at both observatories. The elements are:

$$\text{Light-max.} = \text{JD } 2434222.77 + 3.7422\,E\,.$$

In the series of observations made at Yerkes Observatory, HD 224801, HR 1, and HR 9070 received equal weight with respect to number of observations. It became evident from the comparisons of HR 1 with HR 9070 that one of the stars was not constant in light. On consulting the Yerkes plate files, it was found that a slit spectrogram had been obtained for the star HR 9070 in the course of the B-star program. The star had been classified as B3nne. To make certain which comparison star was variable, HR 9086 (B9; $6^{m}13$) was observed after September 16, 1952. HR 9070 was dropped after two nights. For the six observational points obtained while HR 9086 was observed, the comparisons of HR 1 with HR 9086 are in quite satisfactory agreement. During this interval, September 16, 1952—October 3, 1952, HD 224801 was observed at maximum light on two nights. The observations are compiled in Table 4, and the comparisons of HD 224801 with HR 1 are shown in Figure 4. The 1951 observations are indicated by open circles in this figure.

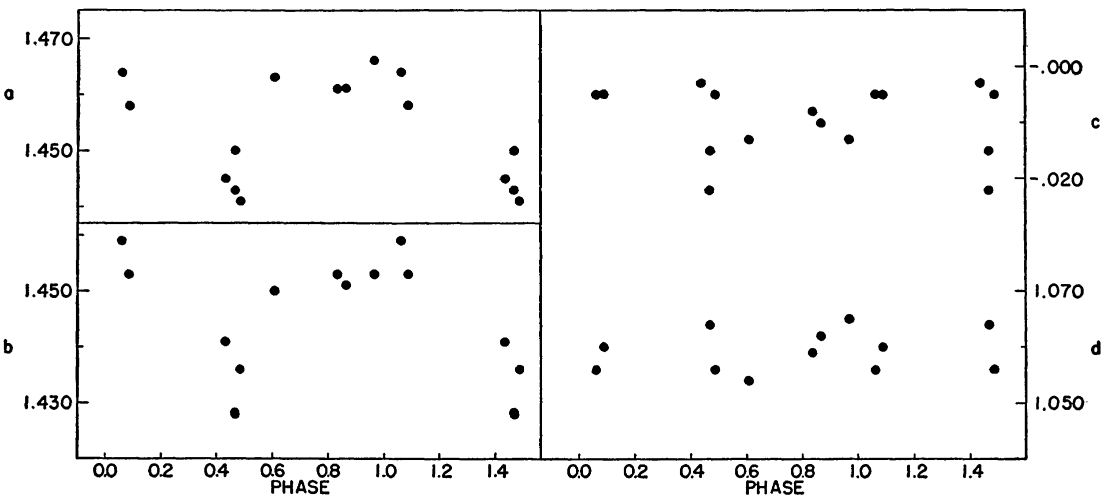

FIG. 3.—HD 141400 — χ Ser: *a*, $\lambda_{\text{eff}} \sim 5500$; *b*, $\lambda_{\text{eff}} \sim 4400$; *c*, color; *d*, comparison of HD 141400 with HR 5870 at $\lambda_{\text{eff}} \sim 5500$.

The yellow and blue light-curves from the McDonald observations are essentially the same as those shown by the Yerkes observations (Fig. 4). However, an ultraviolet light-curve was also obtained at McDonald. These observations are given in Table 5 and plotted in Figure 5. The comparisons of color, $U - B$, are also shown, as well as the comparisons of HR 1 with HR 9086 (all single comparisons).

The observations indicate that HD 224801 varies in the yellow with an amplitude of 0.04 mag. The amplitude in the blue is slightly smaller. There is a color change, $B - Y$, of 0.015, with the star bluest at minimum light. The ultraviolet amplitude is about 0.06 mag. The color change, $U - B$, is about 0.04 mag., with the star most ultraviolet at maximum light. Two maxima are shown by the blue observations, and there is evidence of two maxima in the yellow.

TABLE 4

PHOTOMETRIC OBSERVATIONS OF HD 224801*

DATE, 1951–1952 U.T.	PHASE $P=3.7422$	HR 1–HD 224801 Y	HR 1–HD 224801 B	HR 1–HD 224801 C	HR 1 *minus* HR 9070 Y	HR 1 *minus* HR 9086 Y
Sept. 14.304....	0.764	0.332	0.424	0.092	0.181	....
15.295....	.029	.378	.450	.072	.177	....
16.267....	.289	.329	.409	.080	.182	....
Oct. 10.338....	.721	.343	.418	.075	.169	....
25.205....	.694	.330	.426	.096	.179	....
Jan. 13.005....	.019	.371	.437	.066	....	....
July 24.333....	.680	.329	.420	.091	.182	....
29.333....	.016	.364	.440	.076	.193	....
31.366....	.559	.342	.430	.088	.177	....
Aug. 1.330....	.817	.353	.442	.089	.172	....
7.327....	.420	.336	.432	.096	.212	....
12.321....	.756	.324	.422	.098	.170	....
13.323....	.022	.368	.446	.078	.175	....
19.230....	.600	.331	.428	.097	.203	....
22.227....	.402	.329	.418	.089	.186	....
22.323....	.427	.335	.427	.092	.177	....
23.204....	.662	.331	.425	.094	.201	....
24.200....	.928	.363	.445	.082	.191	....
Sept. 5.150....	.122	.349	.427	.078	.202	....
5.190....	.134	.343	.426	.083	.195	....
5.250....	.148	.342	.425	.083	.188	....
16.142....	.059	.363	.440	.077	.174	0.448
17.155....	.330	.325	.414	.089	0.187	.442
23.198....	.944	.365	.442	.077	....	.437
28.121....	.260	.331	.414	.083	....	.444
28.312....	.311	.315	.406	.091	....	.438
28.364....	.317	.331	.422	.091	....	.446
Oct. 3.102....	0.591	0.334	0.426	0.092	....	0.451

* Yerkes observations.

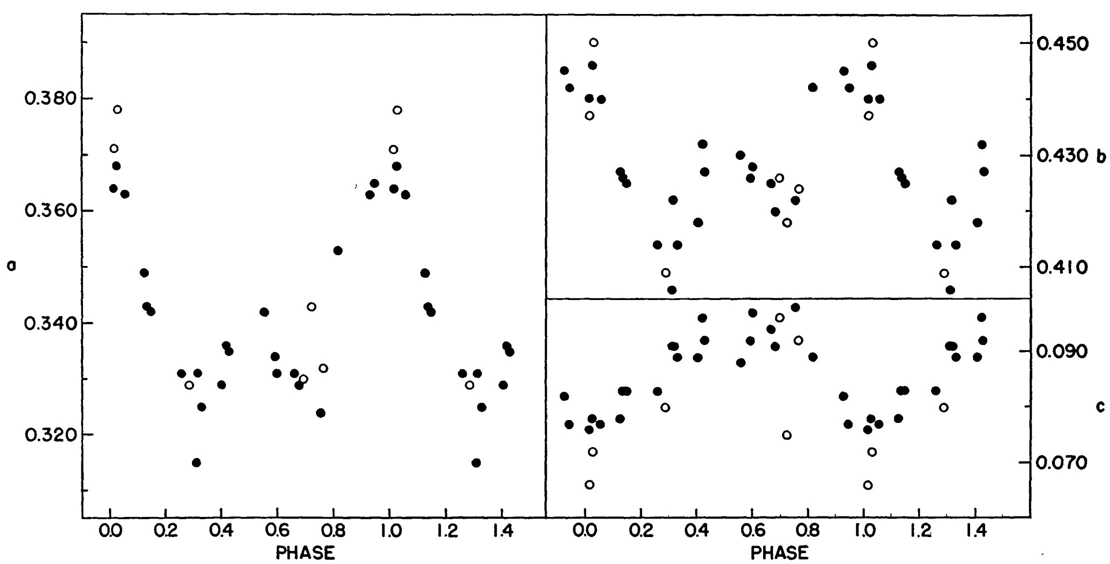

FIG. 4.—HR 1 — HD 224801: a, $\lambda_{\rm eff} \sim 5500$; b, $\lambda_{\rm eff} \sim 4400$; c, color

TABLE 5

PHOTOMETRIC OBSERVATIONS OF HD 224801*

DATE, 1952 U.T.	PHASE $P=3.7422$	HR 1−HD 224801 U	HR 1−HD 224801 $U-B$	HR 1 *minus* HR 9086 U
Nov. 6.173	0.696	0.884	0.439	0.972
11.046	.998	.926	.468	....
11.143	.024	.936	.483	....
12.181	.301	.888	.464	.972
14.162	.831	.916	.455	.965
15.137	.091	.915	.474	.953
19.119	.155	.890	.465	.958
20.147	.430	.883	.447	.976
Dec. 1.111	.360	.873	.446	.968
1.308	.413	.857	.429	....
2.090	.622	.865	.435	.965
2.314	.681	.860	.420	....
4.050	.145	.896	.460	.976
4.177	.179	.884	.450	.972
8.052	.214	.886	.460	.963
11.083	.025	.931	.475	.976
11.188	.053	.918	.471	.967
11.260	.072	.911	.453	.967
15.071	.090	.915	.469	....
15.160	.114	.899	.462	.964
15.266	.143	.874	.449	....
16.046	.351	.873	.443	.969
29.131	0.848	0.922	0.462	0.965

* McDonald observations.

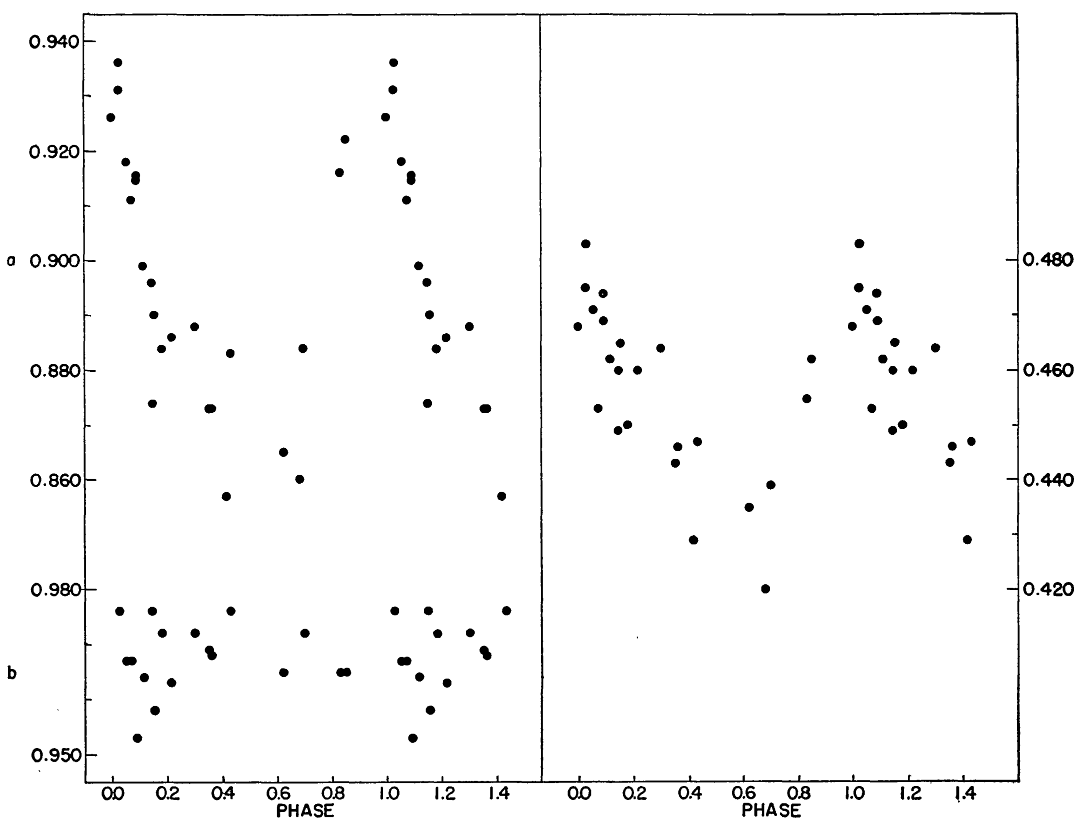

FIG. 5.—HR 1 − HD 224801: *a*, $\lambda_{eff} \sim 3550$; *b*, HR 1 − HR 9086 at $\lambda_{eff} \sim 3550$; *c*, $U-B$

73 DRACONIS

Observations of 73 Draconis, made in 1951, have been published previously.[8] Observations were made on fifteen nights in 1952. The new series confirms the variation in the yellow found in 1951, but with slightly smaller amplitude. The second maximum in the yellow is also confirmed. The minimum shown by the blue observations of 1951 is not present in the observations made in 1952. The results on the thirteen other stars are given in Table 6.

IV. DISCUSSION

Of the four stars discussed here and the three that were published previously,[8] six are known spectrum variables. On the other hand, two stars in Table 6, HR 1732 and 21 Comae, which do not show well-defined light-variation, are also spectrum variables. Another spectrum variable, 45 Leonis, gives no indication of variability in light. It appears that spectrum variables may or may not show decided light-variation.

The variable magnetic fields of two stars in Table 6, HD 133029 and HD 153882,

TABLE 6

HD Number	Other Desig.	α_{1900}	δ_{1900}	m	HD Type	Peculiarity	No. of Nights	Remarks
34452....	HR 1732	$5^h12^m.4$	33° 39′	5.39	A0p	λ 4128–4131	15	Light-variation indicated but evidence inconclusive (sp. var.)
38104....	27 *o* Aur*	5 38.2	49 47	5.52	A0	λ 4171	4	No indication of variability
42616....	....	6 6.6	41 44	6.95	A0p	λ 4128–4131	11	No indication in yellow and blue; some variation indicated in UV (mag. fld.)†
71866....	....	8 24.6	40 33	6.66	A0p	λ 4128–4131	6	Variation of small amplitude possible (mag. fld.)
4101.....	45 Leo‡	10 22.4	10 16	5.87	A0	λ 4078, λ 4171	7	No indication of variability (sp. var.) (mag. fld.)
108945...	21 Com	12 26.0	25 7	5.39	A3p	λ 4078	16	Light-variation indicated; but not well defined (sp. var.)
133029...	....	14 57.2	47 40	6.16	A0p	λ 4128–4131	10	No indication of variability (mag. fld.)
153882...	....	16 57.0	15 5	6.16	A0p	λ 4128–4131	18	Definite indication of variability in blue; curve not well defined (mag. fld.)
179761...	21 Aql§	19 8.7	2 7	5.10	B8	....	4	No indication of variability (mag. fld.)
204411...	HR 8216‖	21 23.3	48 24	5.31	A3	λ 4128–4131 λ 4171	8	Some indication of variability
205087...	HR 8240#	21 27.9	22 57	6.44	B9	λ 4078, λ 4171	4	No indication of variability
219749...	HR 8861	23 13.2	44 57	6.32	B9p	λ 4128–4131	5	Some indication of variability
220825...	*κ* Psc	23 21.8	0 42	4.94	A2p	λ 4078	6	Some indication of variability

* Nancy G. Roman, *Ap. J.* **110**, 232, 1949.

† Those stars which are known to have magnetic fields are listed by T. G. Cowling and H. W. Babcock (*M.N.*, in press).

‡ Nancy G. Roman, *ibid.*, **113**, 705, 1951.

§ W. W. Morgan, *Ap. J.*, **76**, 275, 1932.

‖ Unpublished.

\# Unpublished.

have been discussed;[19] they do not show noticeable spectral variations. There is no indication of light-variation for the first star from the ten nights it was measured, while light-variation is indicated for HD 153882, but a curve is not well defined. On the other hand, α^2 Canum Venaticorum has a magnetic field with about the same range as that of HD 153882, and in this case light-variation as well as spectrum variation is large and well defined. From this investigation there is no apparent relation between light-variation and magnetic variation.

Four of the seven stars with well-defined light-variation show two maxima (or

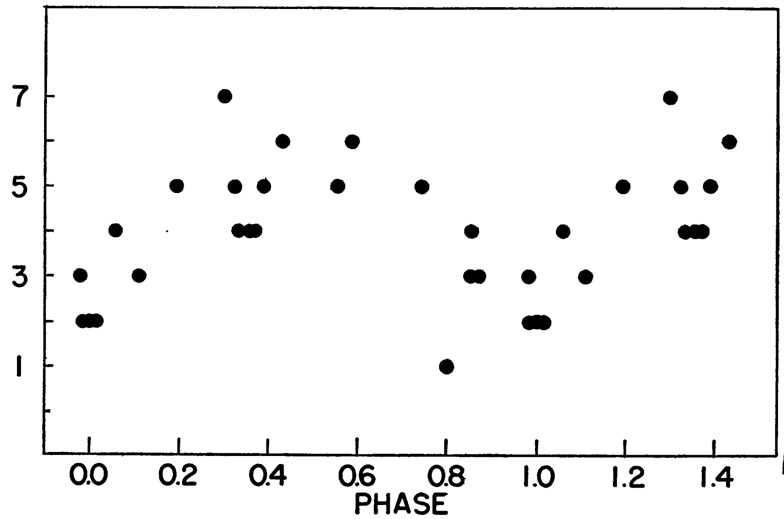

FIG. 6.—Intensity variation of λ 4215 in the spectrum of 21 Comae

minima). They are: 73 Draconis, ε Ursae Majoris, 56 Arietis, and HD 224801. An exception, α^2 Canum Venaticorum, did show definite evidence of a hump on the rising portion of some of the light-curves determined by Guthnick[4] and Miss Gussow.[20] It seems that the occurrence of double waves in the light-curves of peculiar A stars is not uncommon.

APPENDIX 1

In the course of the program, spectra were obtained of 21 Comae on twenty-one nights, in an effort to determine the period of spectrum variation in the same interval that observations were made photoelectrically. The variable line, *Sr* II λ 4215, was compared with a feature at λ 4170. Independent eye-estimates of the ratio on a scale 1–7 were made on three occasions separated by two-month intervals. The means of the estimates, rounded off to the nearest integer, are given in Table 7.

The present series of plates at once suggests a long period, as do plates taken twenty years ago; however, in the present series, spectra obtained on five nights during one observing week indicate rapid changes. It has been found that the period 7.75 days[21] agrees best with the current series. The intensity estimates are plotted in Figure 6, where zero phase is taken as

$$Sr\,\text{II min.} = \text{JD}2434101.73\,.$$

[19] H. W. Babcock and Sylvia Burd, *Pub. A.S.P.*, **63,** 81, 1951; Guro Gjellestad and H. W. Babcock, *Ap. J.*, **117,** 12, 1953.

[20] *A.N.*, **237,** 334, 1929–1930.

[21] These observations do not eliminate the related periods near 1 day.

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TABLE 7

INTENSITY ESTIMATES OF λ 4215

Plate X	Date, 1952 U.T.	λ 4215	Phase*
1976.........	Feb. 9.275	5	0.554
1984.........	23.278	4	.360
1986.........	Mar. 2.265	5	.391
1990.........	16.239	5	.195
1992.........	17.260	5	.326
1995.........	29.248	3	.873
1997.........	30.228	2	.999
2002.........	Apr. 15.178	4	.058
2006.........	17.072	7	.302
2009.........	18.084	6	.433
2010.........	19.072	6	.584
2013.........	28.250	5	.744
2015.........	29.107	4	.855
2018.........	30.107	2	.984
2021.........	May 1.107	3	.112
2025.........	3.094	4	.369
2027.........	14.203	1	.803
2031.........	26.094	4	.337
2037.........	30.094	3	.853
2038.........	31.094	3	.982
2040.........	June 8.108	2	0.016

* Phase = 0 at JD 2434101.73 + 7.75E.

TABLE 8

COLORS OF STANDARD STARS

Star	$B-V$	$U-B$	Star	$B-V$	$U-B$
α Ari.............	1.149 (1.153)	1.10 (1.12)	β Cnc.............	1.483 (1.478)	1.77 (1.77)
HR 875...........	0.068 (0.085)	0.08 (0.05)	η Hya.............	−0.178 (−0.196)	−0.75 (−0.74)

TABLE 9

COLORS OF PECULIAR A STARS

Star	$B-V$	$U-B$	Star	$B-V$	$U-B$
ι Cas..............	+0.13	+0.04	α C Vn (A+B)......	−0.09	−0.33
56 Ari..............	− .11	− .45	78 Vir.............	+ .02	.00
HR 1732...........	− .21	− .63	β C Br............	+ .27	+ .14
27 Aur.............	+ .02	+ .05	73 Dra............	+ .07	+ .13
HD 42616..........	+ .08	+ .03	γ Equ..............	+ .25	+ .13
53 Cam............	+ .16	.00	HR 8216...........	+ .06	+ .17
HD 71866..........	+ .07	.00	HR 8240...........	− .09	− .27
45 Leo.............	− .06	− .09	HR 8861...........	− .06	− .25
21 Com............	+ .04	+ .12	κ Psc..............	+ .01	− .03
ε U Ma............	−0.03	+0.02	HD 224801.........	−0.09	−0.36

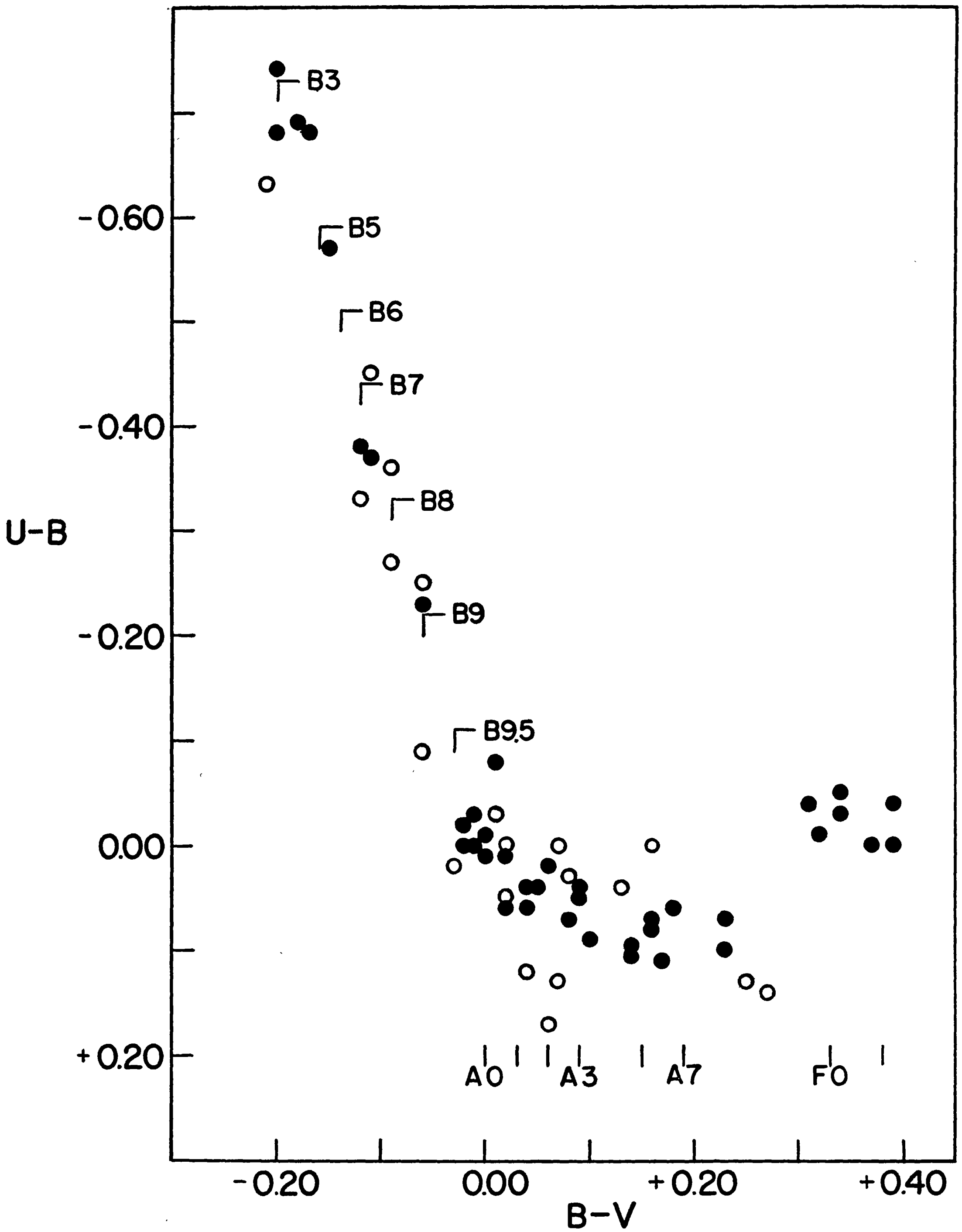

FIG. 7.—$U - B$ versus $B - V$ for the peculiar A stars and normal dwarf stars. The peculiar stars are indicated by the open circles.

APPENDIX 2

Observations for color have been made of eighteen peculiar A stars at McDonald Observatory. These colors have been referred to Johnson and Morgan's $B - V$ and $U - B$ system.[22] The extinction observations were reduced in a manner similar to that described by Johnson and Morgan[23] and by Sharpless.[24] The transformation to the above system depends on observations of four standard stars. These standards and the values of the indices, $B - V$ and $U - B$, from the present set of observations are listed in Table 8. Johnson and Morgan's[23] values are given in parentheses.

The peculiar stars with the observed values of $B - V$ and $U - B$ are given in Table 9. The author is indebted to Dr. D. L. Harris for the values for 78 Virginis and β C Br.[25]

It is of interest to compare $B-V$ and $U-B$ for the peculiar stars with the intrinsic colors of normal stars. This is done in Figure 7, where the peculiar stars are shown by open circles and the normal main-sequence stars by the filled circles. The intrinsic colors of the normal stars have been provided by Drs. W. W. Morgan, D. L. Harris, and H. L. Johnson (in press). It is concluded from this diagram that the peculiar A stars follow the same run of $B - V$ versus $U - B$ as do the normal dwarfs.

In conclusion I wish to thank Dr. W. A. Hiltner for supervising this work.

[22] *Ap. J.* (in press).

[23] *Ap. J.*, **114**, 522, 1951.

[24] *Ap. J.*, **116**, 251, 1953.

[25] The agreement between the author's values of $B - V$ and $U - B$ for ϵ Ursae Majoris and α Canum Venaticorum (A + B) and those of Harris for the same stars (unpublished) is quite satisfactory.