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uvby photometry of the chemically peculiar stars Alpha Andromedae, HD 184905, HR 8216, and HR 8434*,**

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Abstract. — Differential Strömgren *uvby* photometric observations from the Four College Automated Photoelectric Telescope of four chemical peculiar stars is presented and analyzed. The peculiar Hg-Mn star α And is found not to be a photometric variable within the errors of measurement contrary to some published studies. Observations of the magnetic CP star HD 184905 were used to refine the zero epoch and the period which was found to be 1.85435 days. Our photometry and that of Morrison & Wolff are generally quite similar. We find evidence for two sub-minima within the broad minimum in both u and y. The cool magnetic CP star HR 8216 is non-variable in agreement with previous studies that suggested it was constant or a very long period variable. The CP star HR 8434 has a period of 1.43242 days and shows a generally in phase variation of u, v, b, and y. The light curves have two nearly equally maximum and a sharp minimum. The largest amplitude is for u, 0.085 mag.

Key words: stars: individual α And, stars: individual HD 184905, stars: individual HR 8216, stars: individual HR 8434, stars: chemically peculiar A

1. Introduction

The paper presents differential photometry of four chemically peculiar (CP) stars in the Strömgren four color *uvby* system obtained between September 1990 and January 1994 with the 0.75-m Four College Automated Photoelectric Telescope (APT) on Mt. Hopkins, AZ. The dark count was first measured and then in each filter the sky-*ch-c-v-c-v-c-v-c-ch*-sky where sky is a reading of a sky patch, *ch* that of the check star, *c* that of the comparison star, and *v* that of the variable star. Corrections have not been made for neutral density filter differences among each group of variable, comparison, and check stars. Usually only one observation was made of a given star per night. Additional references to work on these stars can be found in Catalano et al. (1993) and earlier versions of this catalogue.

* Based on the SIMBAD data retrieval system, database of the Strasbourg, France, Astronomical Data Center

** Tables 1-4 are only available in electronic form; see the Editorial in A&AS 1994, Vol. 103, No. 1

2. Alpha Andromedae

Whether any HgMn star is a photometric and/or magnetic and/or spectrum variable is a question with a long history in the literature. Recently Adelman (1993) showed that the photometric variability claims for two HgMn stars, 53 Tau and HR 4072, could not be substantiated by a periodogram analysis and further that *uvby* photometry obtained at the Four College APT indicated that these stars were constant to within the errors of the data. Thus it is appropriate to consider photometry obtained for the HgMn star generally thought to most likely to be variable.

Alpha Andromedae (HR 15 = HD 358 = Alpheratz), the second brightest CP star and the brightest HgMn star, is both a visual binary (ADS 94) and a single lined spectroscopic binary with a period of 96.6960 days (Moore & Neubauer 1948; Aikman 1976; Pan et al. 1992). Pan et al. (1992) found interferometrically a light ratio of Δm = 1.99±0.04 mag at 550 nm. Thus most of the light comes from the primary star. Deutsch (1947) claimed that α And was a spectrum variable. Stift (1973) thought it was variable in light with a period of 0.9636 days and amplitudes of 0.03, 0.04, and 0.06 mag in V, B, and U, respectively. Winzer (1974) found to the contrary that it was constant in light. But Rakos et al. (1981) suggested that it is a photometric variable with an amplitude of 0.06 mag based on a 2 Å wide bandpass centered at λ3430.8 and a period similar to that of Stift.

A major problem for differential photometry is that α And is so much brighter ($V = 2.06$) than any nearby comparison stars. For our observations, the comparison star was HR 78 (= HD 1606), $V = 5.90$, spectral type B7 V, and the check star was HR 53 (= HD 1083), $V = 6.35$, spectral type A1 Vn (Hoffleit 1982). The variable was observed with a 5 magnitude neutral density filter, the comparison star with a 2.5 magnitude neutral density filter, and the check star with no neutral density filter. Other choices would have required substantially more observing time or the use of comparison stars further away from the variable. Eighty *uvby* observations (Table 1) were obtained with the typical standard deviation of the average for *ch-c* values being 0.006 mag for each color while those for *v-c* values were 0.007 or 0.008 mag. The *v-ck* standard deviations of the mean were 0.008 mag for u and b and 0.006 mag for v and y. These values argue strongly for constancy. Further a periodogram analysis showed that there were no significant frequencies with a power S/N of 1% or more except for u and b in which case the frequencies were 0.000 and 1.001 cycles day^{-1} which reflect constancy and the mean time between observations on successive clear nights, respectively, as reflected in the frequencies of the observing window. Photometry with smaller standard deviations could lower the upper limit on the variability, but clearly the claims of photometric variability in the literature of 0.02 mag and larger in the optical region are excluded.

3. HD 184905

Babcock (1958) discovered that HD 184905 (= V1264 Cyg = BD +43° 3290) was a magnetic variable. Burke & Thompson (1987) determined that the ephemeris for its photometric variability was

$$\mathrm{HJD}\,(V_{\max}) = 2440017.86{\pm}0.09{+}1.84532{\pm}0.00004\,E \text{ days.}$$

Their results were based on 32 V observations and 16 U and B observations, using HD 184787 as their comparison star, and some published data. The amplitudes of variability are 0.04 magnitudes in V and B, and 0.07 magnitudes in U. Previous photometry was by Burke et al. (1970), Morrison & Wolff (1971), Magalashvili & Kumsishvili (1976), Blanco et al. (1978), Brodskaja (1978), and Musielok et al. (1980). Most of these authors favored periods near 1.85 days although a few preferred the alias of 2.17 days.

Our *uvby* observations made over four seasons of observing used HD 184875 (= HR 7444), spectral type A2 V, as the comparison star and HD 186307 (= HR 7499), spectral type A6 V (Hoffleit 1982), as the check star. There were 106 u, v, b, and y measurements. For deriving the period in addition to our own data set, we used that of Morrison & Wolff (1971) as it was the only other *uvby* photometry and the *UBV* data of Blanco et al. (1978) as it contained the most data, 356 U, 350 B, and 336 V measurements.

None of the periodograms for the 33 *uvby* observations of Morrison & Wolff (1971) show any frequencies with a power S/N for 1% significance although 0.4604 cycles day^{-1} (period = 2.172 days) and 0.5415 cycles day^{-1} (period = 1.847 days) came close to this value for several colors. As the longer period peak had a slightly greater significance it is not surprising that Morrison & Wolff (1971) adopted the longer period.

The periodograms for the Four College APT data usually showed two significant frequencies: 0.4595 cycles day^{-1} (period = 2.176 days) and 0.5419 cycles day^{-1} (period = 1.845 days). For all four magnitudes, the higher frequency has the greater power. This suggests it is the true period.

The more extensive data set of Blanco et al. (1978) contains multiple observations for many nights covering typically 2 to 3 hours. This dataset's periodograms also show two significant frequencies: 0.4609 cycles day^{-1} (period = 2.170 days) and 0.5419 cycles day^{-1} (period = 1.845 days). For U and B, the higher frequency has a greater power than the shorter frequency, but for V it is reversed. With U having the largest amplitude, the shorter period is most likely correct as proposed by these investigators.

Also among the three data sets, the longer frequency is more consistent than the shorter frequency. Again this argues for the shorter period. Burke & Thompson (1987) who performed *UBV* photometry with multiple observations for several nights with a slightly larger range of phase than Blanco et al. (1978) also found the shorter period. They showed that their data showed more scatter for periods near 2.18 days.

To obtain a final period, we adopted the phase zero value of Burke & Thompson (1987). Then we added constant values to the y data of Morrison & Wolff (1971) and to the V data of Blanco et al. (1978) and Burke & Thompson (1987) so that the averages were those of our y photometry. When we overplotted the Morrison & Wolff (1971) and our own data, a small phase shift was evident. To bring these two data sets into agreement we increased the period to 1.84535 days. This period also satisfies the Blanco et al. (1978) and Burke & Thompson (1987) V data. We adjusted the zero epoch by 0.04 days to correct a small phase shift of the maximum. Our ephemeris is

$$\mathrm{HJD}\,(y_{\max}) = 2440017.82{\pm}0.05{+}1.84535{\pm}0.00002\,E \text{ days.}$$

The errors in the zero epoch and the phase are about one-half Burke & Thompson's (1987) values as a result of our longer base line. Figure 1 shows all four data sets plotted on top of one another. The Morrison & Wolff (1971) y values are inverted filled triangles, our y values are open circles, the Burke & Thompson (1987) V values are filled triangles, and the Blanco et al. V (1978) values are x's. The Blanco et al. (1978) values show the greatest scatter.

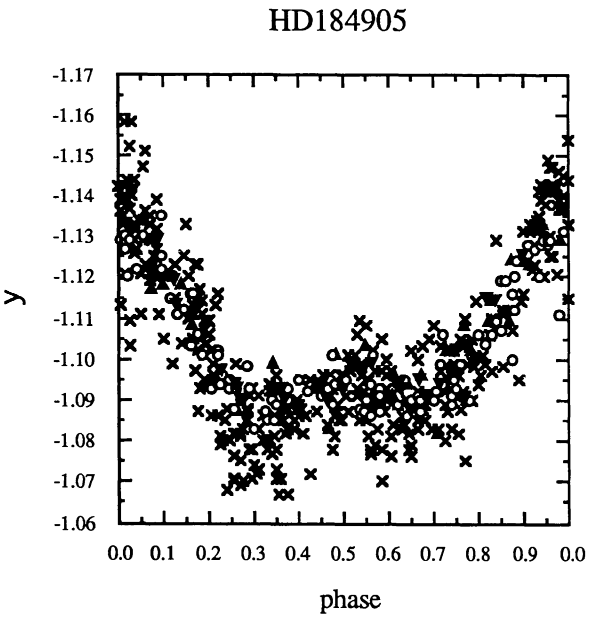

Fig. 1. The Morrison & Wolff (1971) y observations of HD 184905 are inverted filled triangles, the Four College APT y values open circles, the Burke & Thompson (1987) V values filled triangles, and the Blanco et al. (1978) V values x's. Data from published sources were converted to the Four College APT scale by the addition of appropriate constants. The data overlap well, but the scatter of the Blanco et al. data is greater than that of the other sets

Figure 2 compares the u, v, b, and y photometry obtained by Morrison & Wolff (1971) and the Four College APT. To the former values appropriate constants have been added to bring their averages into agreement. The amplitude in u is 0.105 mag, in v 0.025 mag, and in b and y 0.045 mag. For both u and y the broad minimum has two subminima, one of which is narrower and sharper than the other. Due to the sparser phase coverage of Morrison & Wolff and the generally good agreement of the light curves for each magnitude, we conclude that there are no evidence for a change in the shape of the light curves except perhaps in the broader secondary minimum in two decades. Some differences between y and V photometry in Fig. 1 are due to small shifts of order ± 0.01 mag due to changes in the telescope-instrument system of Blanco et al. (1978). Further HD 184905's 5200 Å broad, continuum feature affects y and V slightly differently so that the y

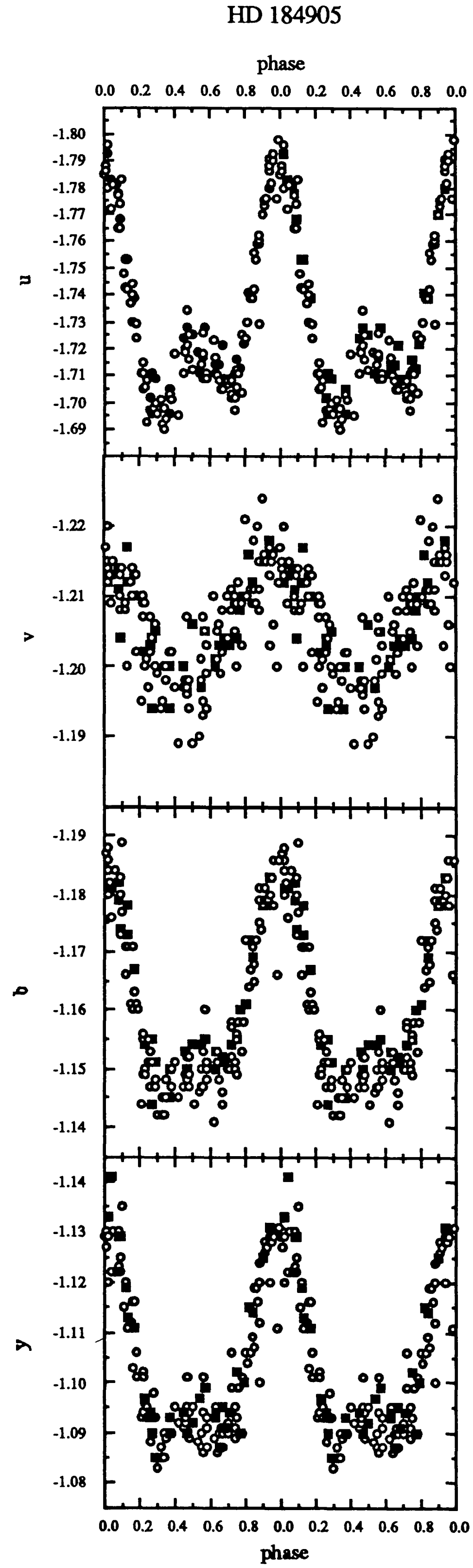

Fig. 2. Strömgren photometry of HD 184905. The Morrison & Wolff (1971) observations are filled rectangles while those from the Four College APT are open circles. The ephemeris is that given in the text. The agreement is excellent except near the broad subminimum in the minimum

and V magnitudes at a given phase do not necessarily have the same value (see Adelman 1982).

4. HR 8216

HR 8216 (= HD 204411) has been described as a cool magnetic CP star which is photometrically constant or has a very long photometric period. Preston (1970) suggested that it might be a long period variable from differences in various literature descriptions of its spectra and its published *UBV* colors. Abt & Snowden (1973) noted that their radial velocity measurements and those in the literature showed only marginal evidence for long period variability. Both Wolff & Morrison (1973) and Winzer (1974) indicated that HR 8216 is photometrically non-variable.

Caliskan (1994) compared Reticon spectra of HR 8216 taken at the Dominion Astrophysical Observatory at a reciprocal dispersion of 2.4 Å mm^{-1}, S/N = 200, 67 Å spectral range, and utilizing a set of central wavelengths which differ by 55 Å. In the regions of overlap for which one can normalize the spectra with confidence, any differences between the pairs of spectrograms are consistent with the quoted S/N ratio. As these spectra were taken between 1988 and 1993, this is strong evidence for spectroscopic consistency within this period.

Sixty-seven *uvby* observations of HR 8216 were obtained during four observing seasons with HD 205314 (= HR 8246), spectral type A0 V (Hoffleit 1982), as the comparison star and HD 203746, spectral type A1 V (Hoffleit et al. 1983), as the check star. The overall average of the observations shows that the standard deviation of the variable-check star is typically 0.004 mag for the four colors compared with 0.006 mag for the check-comparison star. There are 3, 24, 27, and 13 observations for the first, second, third, and fourth years of observation. The *v-c* averages for each color for each year are each typically within 0.002 mag of each other. The *ch-c* averages show a similar behavior. These values strongly suggest constancy. A periodogram analysis for each color shows that no frequency between 0.000 and 3.000 cycles day^{-1} had a sufficient power S/N for 1% significance. Thus we can conclude that HR 8216 is both a spectrum and a photometric constant for a period of order 4 years and perhaps longer.

5. HR 8434

Winzer (1974) discovered the photometric variability of HR 8434 (= HD 210071 = BD 55° 2679). He used HR 8389 as the comparison star and found a preliminary period of 0.6772 days from 13 *UBV* observations. The amplitudes of variability were 0.07 magnitudes in U and 0.05 magnitudes in B and in V. Seventy-seven *uvby* observations made over four observing seasons with the Four College APT used

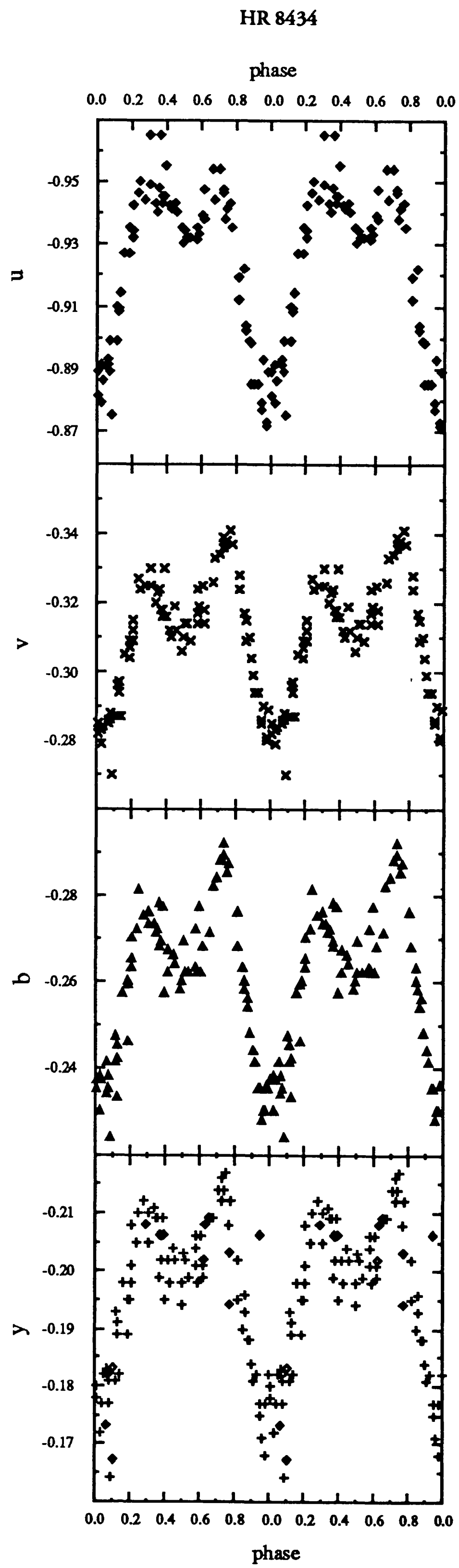

Fig. 3. Four College APT *uvby* photometry of HR 8434 (filled diamonds for u, crosses for v, filled triangles for b, and pulses for y) as a function of its 1.43242 day period and a zero phase of HJD = 2441613.79. In the y panel, Winzer's (1974) V values are shown as open diamonds. A constant value was added to his data to put them on the y magnitude scale

HD 209124 (= HR 8389), spectral type A0 III-IV, as the comparison star and HD 211336 (= HR 8494), spectral type F0 IV (Hoffleit 1982), as the check star (Table 4). Separate periodogram analyses of u, v, b, and y data showed that the most likely frequency was 0.6981 cycles day^{-1} corresponding to a period of 1.4325 days. When Winzer's (1974) V data were used with our y data (a constant was added to the V data so that its average agreed with that of our y data), the frequency was 0.69800 cycles day^{-1}. However, to bring the V and y data into best coincidence as well as to have the smoothest y light curve a period of 1.43242 days (a frequency of 0.69813 cycles day^{-1}) was found. This corresponds to a secondary maximum near the primary maximum in the combined V and y data periodogram. To define the phase zero point, we used Winzer's time of $U_{\rm max}$, HJD 2441613.79, which we find corresponds to the flux minimum.

Figure 3 shows the light curves. Rather than Winzer's (1974) simple sinusoidal variation, we find two nearly equal maxima and a sharp minimum. The u, v, b, and y light curves vary in phase with similar but not quite identical shapes. The amplitudes of these light curves are 0.085 mag for u, 0.06 mag for v and b, and 0.05 mag for y. Except for u, which is larger, they agree well with Winzer's (1974) amplitudes for U, B, and V. In the u light curve the two maxima have about the same extreme values while in those for the other three colors the primary maximum is of order 0.01 mag greater. Examination of the data taken in different years suggests that part of the scatter may be due to secular changes in the light curves similar to those found for 56 Ari by Adelman & Fried (1993). However, to demonstrate this behavior requires considerably more data than we have obtained. The double maximum suggests the presence of two large spots.

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References

Abt H.A., Snowden M.S. 1973, ApJS 25, 137
Adelman S.J. 1982, A&AS 49, 663
Adelman S.J. 1983, A&A 259, 411
Adelman S.J., Fried R. 1993, AJ 105, 1103
Aikman G.C.L. 1976, Publ. Dom. Astrophys. Obs. Victoria 16, 379
Babcock H.W. 1958, ApJS 11, 216
Blanco C., Catalano F.A., Strazzulla G. 1978, A&AS 31, 205
Brodskaja E.S. 1978, Variable Stars 20, 517
Burke E.W. Jr., Rolland W.W., Boy W.R. 1970, J.R. Astron. Soc. Can. 64, 353
Burke E.W. Jr., Thompson S.K. 1987, PASP 99, 852
Caliskan H. 1994, Ph. D. Thesis, University of Istanbul, in preparation
Catalano F.A., Renson P., Leone L. 1991, A&AS 98, 269
Deutsch A.J. 1947, ApJ 105, 283
Hoffleit D. 1982, The Bright Star Catalogue, 4th edition, Yale University Observatory (New Haven, CT, U.S.A.)
Hoffleit D., Saladyga M., Wlasuk P. 1983, A Supplement to the Bright Star Catalogue, Yale University Observatory (New Haven, CT, U.S.A.)
Magalashvili N.L., Kumsishvili J.I. 1976, Inf. Bull. Var. Stars, No. 1167
Moore J.M., Neubauer F.J. 1948, Lick Obs. Bull. 20, 1
Morrison N.D., Wolff S.C. 1971, PASP 83, 474
Musielok B., Lange D., Schoeneich W. et al. 1980, Astron. Nachr. 301, 71
Pan X., Shao M., Colavita M.M. et al. 1992, ApJ 384, 624
Preston G.W. 1970, PASP 82, 878
Rakos K.D., Jenker H., Wood H.J. 1981, A&A 55, 53
Stift M.J. 1973, A&A 22, 209
Winzer J.E. 1974, Ph. D. Thesis, University of Toronto
Wolff S.C., Morrison N.D. 1973, PASP 85, 141