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A photoelectric investigation of light variability in Ap stars (*)

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Summary. — The light variability of a number of peculiar A stars has been studied mainly in Strömgren colours u and v, and in peculiarity index Δa. Periods of light variability are proposed for HD 5601 ($1^{\mathrm{d}}.11$), HD 19712 ($2^{\mathrm{d}}.19$), HD 30849 ($15^{\mathrm{d}}.86$), HD 38823 ($8^{\mathrm{d}}.64$), HD 53116 ($11^{\mathrm{d}}.98$ or $18^{\mathrm{d}}.10$), HD 56022 ($0^{\mathrm{d}}.92$) and HD 81009 ($33^{\mathrm{d}}.97$). Evidence is presented for variability of HD 94660 on a much longer time scale (months, years). The light variations of HD 25267 do not support the rotation period proposed by Borra and Landstreet (1980). The character of the variability in Δa is discussed.

HD 30861, HD 52350 and HD 55892, all selected as comparison stars, are definitely variable. The variations associated with HD 55892 are periodic ($0^{\mathrm{d}}.94$). HD 31587 and HD 20319 are probably variable, but confirmation is needed.

Key words : Ap star — light variability — rotation period — peculiarity index.

1. **Introduction.** — Photometric variability is a well-known property of those types of chemically peculiar stars of the upper main sequence that include members with large magnetic fields. The common occurrence of small amplitudes and a large range in observed periods, from 0.5 day to several months and even more, prevents photometrists from providing data for large unbiased sets of stars. Selection effects with respect to the amplitude of the variations and to the frequency distribution of the periods occur in the presently available data.

There are however interesting aspects in the study of photometric variability of a representative set of these objects. First of all, the variations are believed to reflect the distribution of emitted light over the stellar surface. Convincing evidence that spectral and magnetic variations are also modulated by the rotation period has been accumulated in the past. Photometry thus provides the key for planning time-efficient spectroscopic studies of the stellar surface structure. The character of the variations as a function of wavelength should thereby help in the construction of realistic atmosphere models.

Furthermore, determination of rotation periods may give insight in the connection between rotation velocities, types of peculiarities and magnetic fields. Cramer and Maeder (1980) point out that the strength of the continuum depression near 520 nm is correlated with the mean surface magnetic field strength. The Δa peculiarity index which measures this depression (Maitzen, 1976) thus offers the possibility to collect information on the magnetic field structure in a relatively easy photometric way.

The survey of Vogt and Faúndez (1979) — further abbreviated to VF — for southern peculiar stars is of direct interest to photometrists in the southern hemisphere. They present Strömgren photometry of 341 peculiar stars, each measured on at least three different nights. Their list contains mean values of V, b-y, m_1 and c_1 and the standard deviations σ_V, $\sigma_{b\text{-}y}$, σ_{m_1} and σ_{c_1} for individual measurements (relative to the mean). Detailed information is given for 51 stars which show evidence for variability and which were observed more frequently. The distribution of these σ's over all stars is shown in figure 1. These distributions obviously depend on the intrinsic photometric variability of these objects, and on the accuracy of the measurements. The low scatter in the $\sigma_{b\text{-}y}$ diagram is a consequence of the similarity of the variations in b and y. The $\sigma_{b\text{-}y}$ distribution is probably dominated by measuring errors, in contrast to σ_V, σ_{m_1} and σ_{c_1}. The longer tail of the σ_{m_1} distribution is due to the diversity of the variability in the v filter, caused by a subgroup of stars showing important blocking effects, leading ultimately to variations in antiphase with b and u. The antiphase relation and the larger amplitudes in u lead to the observed σ_{c_1} distribution which is nearly totally determined by the intrinsic variability of the stars. Many of the stars discussed in section 5 were selected from these scatter data (mainly σ_{m_1} and σ_{c_1}) because of evidence of large amplitude variations.

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(*) Based on observations collected at the European Southern Observatory (ESO) on La Silla, Chile.

In view of the large diversity in periods, it is difficult to select time-efficient modes of observation without any *a priori* knowledge about the length of the involved period. Two or more observations per night are instructive if the observed star rotates relatively fast, but such a procedure is a waste of time if periods of the order of several weeks are involved. When measurements in various filters cannot be obtained simultaneously, it might therefore be useful to limit the number of filters to a minimum, until the length of the period is approximately known. Additional measurements for obtaining a complete set of light curves can be planned afterwards in a time-efficient way.

In this paper, the first results obtained at ESO in the context of a combined effort of astronomers of various European countries to study the aspects mentioned in this introduction, are presented. The results on the occurrence of Ap stars in clusters are published separately (Maitzen and Hensberge, 1981).

2. **Observations.** — The observational data presented here were obtained mainly by HMM and HH during observation time allotted by ESO to a project which resulted from the first meeting of the European Ap Workgroup. However, unpublished data obtained by HMM, MG and CD in other runs at ESO are also included in this paper. Information about the origin of the data presented here, and about the already published material on these objects that is discussed thereafter, is summarized in table I.

The large majority of observations were performed in the *uvbyg*$_1g_2$ system. The g_1 and g_2 filters used in this investigation are those described by Maitzen and Seggewiss (1980). They are centered at 501 nm and 521.5 nm respectively, and have a half width of 13 nm. The main part of the observations was obtained at the ESO 50 cm telescope with the standard ESO *uvby* filters.

For reasons explained in the introduction it has been preferred to collect data for a large number of stars in a time-efficient way, rather than to aim completeness of light curves in the whole set of filters. The main rule was to obtain high precision differential measurements in *all* Strömgren filters only for those stars which previously had proven to remain constant in brightness and colours over a time interval of at least one week. Stars known to vary substantially in shorter time intervals (VF) were studied mainly in Strömgren *u* and *v*. Observations of the latter type consisted of sequences C_1-Ap-C_2-Ap-C_1. Each symbol represents a measurement of « star + sky » resp. sky-background in the *u* and *v* filter for the considered peculiar star (Ap) and for both comparison stars C_1 and C_2. Individual sky integrations were performed over time intervals of 5 or 10 seconds, depending on the stellar brightness. The integrations for the stars were accumulated until the rms error on the mean value for a series of 1s integrations was less than 0.2 %, taking into account a minimum integration time of 20 s and a maximum of 90 s. This internal consistency condition was generally achieved within 20 s for stars brighter than 6th magnitude, and the full 90 s integration time was usually needed for the faintest stars of our programme i.e. $V \simeq 9^{\mathrm{m}}$. For these relatively faint objects, the rms error became sometimes as large as 0.25 % at the maximum integration time. Whenever these conditions were not fulfilled for the whole observation sequence in reasonable time intervals (taking into account the brightness of the star in the appropriate wavelength region), the measurement of the whole sequence was deleted. This rejection criterion proved to be helpful in judging the quality of the observations obtained in nights which were only partly of photometric quality.

For the Ap star a measurement in the y, g_1 and g_2 filter was added occasionally after the sequence of differential measurements in u and v, in order to determine the peculiarity index Δa introduced by Maitzen (1976). Δa is the excess a-value, $a = g_2 - \frac{1}{2}(y + g_1)$, relative to the a-value of a normal star with the same intrinsic $(b\text{-}y)_0$. The procedure to obtain the excess value is discussed in section 3.

The observations collected with the simultaneous four-channel spectrograph-photometer attached to the Danish 50 cm reflector were obtained following the same observations sequences. Usually, eight successive 8 second integration were combined to get reliable magnitudes. Each such group of « star + sky » measurements was followed by 3 integrations on sky-background.

The observations of stars tested for variability on longer time scales were performed in a similar way. However, the total integration times were somewhat longer, since the observation sequence was extended to C_1-Ap-C_2-Ap-C_2-Ap-C_1, or to C_1-Ap-C_2-Ap-C_3-Ap-C_2-Ap-C_1 in the case that three comparison stars were used. The main reason for spending more time on measurements of comparison stars, is that the discussion of the variability of these Ap stars requires to combine measurements obtained in different runs, usually with different equipment. Simultaneous observation of a sufficient number of comparison stars (preferentially with colours enclosing those of the Ap star), should permit the evaluation of effects caused by differences in the equipment. Potential observers are therefore urged to use the same set of comparison stars. Moreover, care was taken to restrict this type of observation to nights of excellent photometric quality to allow comparison with other absolute measurements. As a rule, the g_1 and g_2 filters were inserted in the filter sequence of these Ap stars, in order to determine their peculiarity index Δa.

3. **Reductions.** — 3.1 ACCURACY OF DIFFERENTIAL MEASUREMENTS. — Nearly all observations were carried out relatively close to the meridian (air mass $X < 1.3$). The errors which might be attributed to uncertainties in differential extinction corrections from the Ap star relative to the nearby comparison star are thus seldom larger than a few thousands of a magnitude, even in the *u* band. The accuracy of the differential measurements can be illustrated by the scatter of individual differential magnitudes between both comparison stars. Table II gives the relevant data for frequently observed stars. The scatter of differential magnitudes around their mean value is about $0^{\mathrm{m}}.005$ (standard deviation for a single measurement), both in *u* and *v*, and apparently independent of the stellar brightness.

3.2 TRANSFORMATION OF THE ESO 50 CM OBSERVATIONS TO THE STANDARD SYSTEM. — The y magnitudes obtained with the ESO 50 cm telescope for the bright normal A stars, used to define the a-index normality line (Fig. 2), were matched to the V magnitudes published by Grønbech and Olsen (1976) — further abbreviated GO — through the equation :

$$V = y - 2.447\ (\pm\ 0.004 \text{ mean error for a single star})\ . \quad (1)$$

The fact that the thus calculated magnitudes for 6.5 to 10th magnitude stars in the field of NGC 2516 (Maitzen and Hensberge, 1981) agree excellently with those published by Snowden (1975) — $< V_{\text{obs}} - V_{\text{Snowden}} > = 0.000 \pm 0.009$ mean error 1 star — supports the validity of Equation (1) through the whole range of observed V magnitudes and b-y colours.

The colour transformations were based on the results of HD 6668, HD 55857, HD 56456 and HD 56876 only, since the other bright stars were not observed frequently in u, v and b.

Although this basis is small and does not include any of the 134 standard stars proposed by Grønbech *et al.* (1976), the good agreement between the published colours and those derived from the equations :

$$b\text{-}y = 1.098(b\text{-}y)_{\text{I}} + 0.902 \quad (2a)$$
$$v\text{-}b = 0.993(v\text{-}b)_{\text{I}} + 0.355 \quad (2b)$$
$$u\text{-}v = 0.988(u\text{-}v)_{\text{I}} + 0.604 \quad (2c)$$

gives reasonable confidence in the procedure (table III). The subscript I denotes colours obtained in the instrumental system of the ESO 50 cm telescope.

3.3 COMPARISON OF OBSERVATIONS OBTAINED AT THE DANISH AND ESO 50 CM TELESCOPE. — If validity of the transformation equations given by Grønbech *et al.* (1976) is assumed for measurements obtained with the simultaneous photometer of the Danish 50 cm telescope, the corresponding differential magnitudes Δu_{I}^* and Δv_{I}^* which would be measured with the ESO photometer might be calculated. Starting from the observations in table II, collected with the Danish telescope, we find :

for HD 19739-HD 20319 : $\Delta u_{\text{I}}^* = 1.791$ and $\Delta v_{\text{I}}^* = 1.452$
for HD 24975-HD 25385 : $\Delta u_{\text{I}}^* = -0.334$ and $\Delta v_{\text{I}}^* = -0.238$
for HD 53238-HD 53207 : $\Delta u_{\text{I}}^* = 0.292$ and $\Delta v_{\text{I}}^* = -0.305$

The agreement with the values actually measured at the 50 cm ESO telescope (table II) is good in v, but less convincing in u for the comparison stars of HD 19712 and HD 25267. It is not clear whether the assumed transformation formulae of GO are not the most appropriate ones, or whether small intrinsic stellar variability is involved (cf. the sections on the respective Ap stars).

3.4 THE PECULIARITY INDEX Δa. — A number of normal stars with b-y colour in the range -0.1 to 0.3 mag. were measured in y, g_1 and g_2 and their a-index was determined. These relatively bright stars were checked to be essentially unreddened, using the calibrations of Crawford (1978) and Crawford (1979). A small reddening correction of 0.015 mag. in b-y was applied to HD 6668, HD 6706 and HD 17081. These measurements were used to define the normality line $a = a((b\text{-}y)_0)$, given in figure 2.

The peculiarity index Δa is defined as the excess of the a-value of the Ap star relative to a normal star with the same intrinsic $(b\text{-}y)_0$ colour. All Δa values mentioned in this paper were calculated under the assumptions that the Ap star is unreddened and has constant b-y (b-y values were either measured or available in the literature). Some of the fainter Ap stars studied in this paper may be however considerably reddened. The influence of these assumptions on the published Δa values is discussed in section 7. We state here already that a reddening correction of 0.1 mag. would enhance the Δa value by 0.009 mag. (see slope of normality line in figure 2) and that a total range of variation of 0.05 mag. in b-y would cause a relative error in Δa of 0.0045 at phase of maximum b-y relative to phase of minimum b-y.

4. **Variability of comparison stars.** — The mean magnitude differences in table II are given for each run separately, to illustrate the level of consistency between data obtained in different runs and occasionally also with different equipment. (This problem is also considered in section 6, where observations obtained over several years are discussed.) The difference between the averaged differential magnitudes obtained by HMM, resp. HH, both using the same equipment, is larger than 3 σ ($\sigma^2 = \sigma_{\text{M}}^2/n_{\text{M}} + \sigma_{\text{H}}^2/n_{\text{H}}$, notation from table II) for Δv(HD 19739-HD 20319), Δv(HD 38856-HD 38866) and for HD 56456-HD 55892 in Δu, Δv and Δb. All other differential magnitudes obtained by these observers are consistent within 2σ.

The discrepancies found in the case of HD 56456-HD 55892, and the tendency towards larger internal scatter between the measurements obtained by HH, turn out to be due to variability of HD 55892 = HR 2740 (table IV). The fact that the variability is most pronounced in the v band, the amplitude of the variations, the spectral type FO IV (Malaroda, 1975) and the apparent rotational velocity $v \sin (i) = 40$ km/s (Slettebak *et al.*, 1975) are all compatible with the *hypothesis* that HD 55892 could be a mild Ap star. In that case the variations should be periodic. A period search for trial periods larger than 0.25 days suggests a period $P = 0.9363 \pm 0.005$ days (Fig. 3). However, it should be emphasized that confirmation of this suggestion, both through high resolution spectra and additional photometry, is recommended. HD 55892 does not show the typical depression around 520 nm. Four observations resulted in a value for $\Delta a = -0.003 \pm 0.001$. This is however no decisive argument against the Ap hypothesis, since some of the coolest well-known Ap-stars (e.g. HD 24712) do not show the depression either.

The Δv-inconsistency found for the comparison stars of HD 19712 and HD 38823 is less conclusive. These discrepancies however indicate that each of those pairs may contain a comparison star that varies over longer time intervals. This problem will be further discussed in the sections dedicated to HD 19712 and HD 38823.

The comparison stars for HD 30849 are not mentioned in this table, because all but one of them are variable. HD 30861 was omitted by HMM after two nights, whence it was found in both nights to show variations in time intervals of a few hours (eclipses ?) with an amplitude of the order of $0^{m}.1$ in u and v. HH added HD 31587 as comparison star, to check the constancy of HD 31640, but HD 31587 is very probably variable too. The individual measurements of HD 30861 and HD 31587, relative to the apparently constant (from absolute photometry considerations) star HD 31640, are given in table IV.

5. **Analysis of periodicity of light variations.** — Whenever enough observations are available, one or more of the techniques discussed by Renson (1978), Weiss and Kreidl (1980) or Hensberge *et al.* (1977), i.e. techniques based on the Lafler-Kinman method (Lafler and Kinman, 1965) the phase-dispersion-minimization method of Stellingwerf (1978) and the power spectrum method (Deeming, 1975), have been applied.

VF published a number of V, b-y, m_1 and c_1 measurements for most of the stars that we observed frequently. Generally such absolute measurements yield a lower precision than differential ones, for obvious reasons. Nevertheless, it is of interest to compare their data with ours, both for checking whether their data are compatible with the periodicity of the variations as derived from our observations, and — whenever possible — for improving the accuracy of the period. It will be shown that their photometry is indeed sufficiently accurate for such purpose. In order to be able to combine their data with our differential measurements, without introducing arbitrary shifts in magnitude, mean magnitudes for the comparison stars were calculated from the observations of HH. In this procedure, only data obtained in photometric nights with apparently constant or slowly time-varying extinction, have been considered. V magnitudes for the Ap stars were derived from our y measurements involved in the Δa sequence. Thus computed magnitudes yield of course not the same accuracy as our differential measurements ; however, when interpreted properly, they prove to be useful in linking together observations obtained in different runs and in different ways.

The results are discussed for each star separately. The quoted uncertainties of the period P refer to intervals around the most probable value, wherein 1° no differential measurement deviates more than 4 σ from a smoothed curve through the data, and 2° less than 25 % of the measurements deviate by 2 σ or more. Standard deviations for differential resp. absolute measurements were estimated to be 0.005 (from table II) and 0.008 (from VF) respectively. All trial periods are mentioned for which it was found that the data could be represented by fairly simple curves that fulfil the two conditions stated above. The classification given in parentheses after the star's name refers to Bidelman and Mc Connell (1973). Alternative classifications might be mentioned in the text.

HD 5601 = BD − 11°177 (Si) .

Nine observations by VF give only evidence for slight variability, mainly in c_1. The amplitude of the variations, studied differentially in u and v, is indeed rather small. It is clear, from the basic data in table V, that the variations in u and v are not simply in phase or antiphase. Eleven V measurements of HD 5601 yield $< V > = 7.651$, σ (1 meas.) = 0.007 (cf. VF : $< V > = 7.642$, σ (1 meas.) = 0.013). The depression near 520 nm is strong. From one complete set of *uvby* measurements, we derived from the comparison stars :

HD 6530 = HR 317 = 28 Cet :

V = 5.598	b-y = 0.005	m_1 = 0.146	c_1 = 1.100
(5.597)	(0.005)	(0.143)	(1.113)

HD 6706 = HR 329 = 30 Cet :

V = 5.713	b-y = 0.296	m_1 = 0.161	c_1 = 0.527
(5.720)	(0.289)	(0.160)	(0.517)

Between brackets, the corresponding results of GO are mentioned.

Analysis of the differential observations points to a period close to one day : $P = 1^{d}.110 \pm 0^{d}.002$.

No reasonable evidence for periodicity was found for other trial periods. Unfortunately, during the run of HH the star could only be observed in the beginning of the night. The number of observations is somewhat too small to yield a satisfactory phase coverage, especially in view of the rather complicated character and low amplitude of the variations (figure 4 shows a double wave in u and v, with primary extrema in v preceding the primary extrema in u by approximately 0.1 P).

HD 19712 = BD − 2°563 (Cr-Eu) .

This Cr-Eu star was expected to have a rather short rotation period because the largest magnitude differences in the VF data occur in subsequent nights.

There is a small problem concerning the comparison stars. Although during the run of HMM as well as during the run of HH the differences in Δu and Δv magnitude between the comparison stars were found to be constant within the typical accuracy of the measurements, all individual Δv magnitudes measured by HH (in the sense HD 19739-HD 20319) are larger than any of the Δv's measured by HMM. This small, but systematic effect, might be due to variability of one of the comparison stars, in time intervals essentially larger than the length of our runs. It was noticed *a posteriori* that the scatter in the Δu and Δv light curves of HD 19712 is significantly reduced when the differential magnitudes relative to HD 19739 are considered, rather than to HD 20319. Therefore, small variations are tentatively attributed to HD 20319. It should be noticed that HD 20319 is already mentioned in the suspected variable catalogue (KZP 102410).

Unfortunately, Gerbaldi and Delmas usually measured relative to HD 20319 only. This fact, the large air mass at which they had to observe the star, and instrumental differences may have caused the extra scatter, and the shift in Δu which are apparent in figure 5.

To avoid any influence from these factors, the period was originally searched from the ESO 50 cm data only. Then, a more accurate period was determined by superposing minimum brightness observed in February 1979 and in November-December 1979.

All these data are given, relative to HD 19739 whenever possible, in table VI.

Finally, the six absolute measurements of VF were considered. Their significance is restricted because the total range of variation is only about four times larger than the statistical standard deviation of their individual measurements. Moreover, their u, v and b measurements may only be compared to our differential data, through use of absolute measurements of HD 19739 obtained by Drilling and Pesch (1973) : $V = 7.29$, $b\text{-}y = 0.15$, $m_1 = 0.19$, $c_1 = 0.85$. Such procedure, involving absolute measurements of different studies, introduces of course supplementary uncertainties. The scaling problem can be avoided in V. The accuracy given here relies therefore on the requirement that the VF observations were made close to maximum brightness in V :

$$P = 2\overset{\mathrm{d}}{.}1945 \pm 0\overset{\mathrm{d}}{.}005 \, .$$

The character of the light variations is quite complicated. A maximum near phase 0.8 is common to the four wavelength regions. The double wave character present in y and Δb disappears at shorter wavelengths. But, while the rise to maximum brightness in v is steep, it is the decline towards minimum brightness that is steep in u.

The strong 520 nm depression clearly varies with about a factor of 1.5. Δa and m_1 are larger when the star is brighter in y and b, and follow the double wave variation of y and Δb.

HD 25267 = HR 1240 = τ^9 Eri .

This well-known Si star is a single lined spectroscopic binary, with an orbital period of $5\overset{\mathrm{d}}{.}954$ (Sahade, 1950). Borra and Landstreet (1980) show that the variation of the effective magnetic field H_e (from − 15 G to − 345 G) follows the same period and conclude that orbital and rotation period are thus synchronized. Cramer and Maeder (1980) compute a mean surface field strength $H_s = 2$ kG. Our photometry does not support the conclusion of Borra and Landstreet (1980). A plot of our data in the orbital period (Fig. 6a) gives white noise. It is clear from the data in table VII, that during some nights noticeable variations occur, implying a larger gradient in magnitude than can be explained by the observed amplitude and a 6-day period.

Another argument against a $5\overset{\mathrm{d}}{.}95$ rotational period can be based on the rather large value of $v \sin i$ which is 34 km/s according to Uesugi and Fukuda (1970). A radius of about 4 $R_\odot$ and an inclination of the rotation axis to the line of sight close to 90° would be required to account for the observed rotational velocity. Although the radius would be larger than what one typically expects for a silicon star, one could accept this radius within the given uncertainties. But a rotational axis about orthogonal to the line of sight should have a reversal of polarity for the magnetic field as an observational consequence. This, however, is not the case. A smaller value of i, i.e. looking closer to the rotation pole, requires a shorter rotation period for a star with the same or smaller radius.

Although a fairly large number of observations is available, no period has been found that fits all measurements with the accuracy obtained for other stars in this paper. The u and v power spectra have no strong power peak in common. Releasing somewhat our demands on the unexplained scatter in the light curves, and taking into account that the true rotational period should produce a smooth single wave variation for H_e, we selected two periods of about 1.2 days which are of equal quality : $1\overset{\mathrm{d}}{.}2094$ and $1\overset{\mathrm{d}}{.}2135$. The remaining scatter in the u and v lightcurves however, is still 0.013 mag. as may be seen from figure 6b.

Systematic differences due to the use of different equipment cannot be considered responsible for this large scatter, since the measurements of HMM and HH — obtained with identical equipment — are already incompatible. Moreover no evidence for variability of the comparison stars has been found, neither during one of the three runs, nor by comparing results obtained in different runs. Apparently, the problem is connected with the binary nature of the star.

We suggest that an additional source of light variability, superposed on the variations reflecting the rotation of the silicon star, is present in the system. Possibly these additional variations are connected with the secondary star in the system.

More measurements will be obtained in the near future in a way which should permit disentangling both variations if they are both periodic with periods of the order 0.1 day to 20 days. Therefore, a further discussion is delayed to a later paper.

HD 30849 = CoD − 49°1449 (Sr-Eu) .

Eight observations from VF are known to show large scatter in c_1 due to strong variability in v. They give evidence for a period which is either longer than one week or close to or shorter than one day. From these VF data, Renson (1979) suggested $P = 1\overset{\mathrm{d}}{.}081$ as the most probable period.

Frequent observation of this star during the first nights of our run immediately showed that the correct period is much longer. Our differential u and v measurements (table VIII) point to double wave variation with a period in the vicinity of 16 days. Determination of magnitude and colours of the comparison star HD 31640 : $V = 8.053$; $b\text{-}y = 0.146$; $m_1 = 0.175$; $c_1 = 0.834$ allows the inclusion of the VF data in the period search. The solution is not unique, because too many cycles have elapsed since the VF observations. The lowest scatter is obtained for $P = 15\overset{\mathrm{d}}{.}865 \pm 0\overset{\mathrm{d}}{.}005$. However, slightly different periods, in particular $15\overset{\mathrm{d}}{.}731$, but also $15\overset{\mathrm{d}}{.}600$ and $15\overset{\mathrm{d}}{.}999$, represent the data nearly as well.

From figure 7, it might be seen that the variations in u and v are in phase, while the range in y is below the detection level of our absolute photometry. The VF data show that the variation in b mimics the variation in u, both in amplitude and shape. The continuum depression at 520 nm varies about 50 %, and is strongest when the star is fainter in uvb. Both maxima in Δa correspond to maxima in m_1 and $b\text{-}y$.

HD 38823 = BD − 0°1089 (Sr-Eu(F)) .

Four observations of VF reveal a large variability in v (> $0\overset{\mathrm{m}}{.}08$). Our study of this star shows that the total range in v is even significantly larger : nearly $0\overset{\mathrm{m}}{.}14$ (table IX). Nevertheless, the star is only very mildly peculiar judging from the hardly significant Δa-value measured over the whole rotation cycle.

In many respects this star is photometrically similar to HD 30849 : nearly constant in y, double wave variations in u and v in phase with each other, with a total range in v twice the range in u. However the variation in Δa does not follow the same relation with respect to the u and v light curve. Δa remains unchanged during the star's brightness change from primary maximum to primary minimum, and is hardly, but judging from the obtained accuracy (0.003 internal standard deviation on single Δa measurements), significantly larger in the other part of the cycle. The variations, the character of which is displayed in figure 8, have been found to obey the period $P = 8^{\rm d}.635 \pm 0^{\rm d}.002$. This result has been derived to this accuracy by including the VF data in the period search through the construction of « differential » u and v magnitudes from the VF data of HD 38823 and the results of Warren and Hesser (1977) for our comparison star HD 38856 : $V = 7.23$, b-$y = -0.060$, $m_1 = 0.117$, $c_1 = 0.428$. Thus constructed *differential* magnitudes are not expected to give results more accurate than 0.01. Neighbouring possible periods are situated near $8^{\rm d}.596$ and $8^{\rm d}.674$.

HD 53116 = BD − 0°1572 (Sr-Eu) .

Although the star has been observed only four times by VF, the extraordinarily large variability with evidence for an antiphase relation of variations in v resp. to u is obvious in their data.

In order to include the VF data in our period search, the colours of one of the comparison stars have to be known. However, absolute measurements in b and y are lacking. Only the u and v measurements of VF, which could be satisfactorily reconciled with our differential data on HD 53116-HD 53238, have been included in the analysis. No unique solution can be derived from these data (table X + VF data). The two competing possibilities are $P = 11^{\rm d}.978 \pm 0^{\rm d}.005$ and $P = 18^{\rm d}.105 \pm 0^{\rm d}.007$. Few additional observations at appropriate moments are planned, and will remove the ambiguity. Arguments against the shorter trial period are the rather large deviation from the mean curve of our y measurement at phase 0.998, and the considerable scatter of our differential measurements in u situated near $\phi = 0$. The $12^{\rm d}$ period was not rejected for this last argument, only because the most deviating observation was obtained during a rather poor night wherein measurements had to be deleted frequently because the conditions on the internal accuracy, outlined in section 3 were not fulfilled.

The largest objection against the $18^{\rm d}$ trial period is the small systematic deviation between the ESO and Danish 50 cm observations. If this period is the correct one, we should have missed nearly completely a secondary extremum which gets more pronounced at shorter wavelengths.

Anyway, the variation in v is in antiphase with the variations in u, b and y. The fairly strong 520 nm depression seems to get weaker when m_1 becomes smaller, as far as this might be estimated from the scarce Δa measurements (see Fig. 9).

HD 56022 = HR 2746 = OU Pup .

Renson *et al.* (1976) proposed a period $P = 0^{\rm d}.90 \pm 0^{\rm d}.02$ from 11 photometric observations over a 8 day interval in 1975 (Heck *et al.*, 1976). Our measurements for this bright Si star (table XI) confirm their result : $P = 0^{\rm d}.9183 \pm 0^{\rm d}.0013$. Between both runs too many cycles have elapsed to establish the period with higher accuracy. Therefore the period given here is entirely based on our data. An arbitrary phase shift was applied to fit the older data to ours. There is a shift in Δu and Δv magnitudes between our measurements of HD 56022-HD 56456 and the data published by Heck *et al.* (1976). The phase diagram displayed in figure 10 is constructed after correcting the Heck *et al.* (1976) m_1 data for the systematic effect mentioned in section 5, and after scaling our differential magnitudes to the standard system (adding 0.002 to $\Delta b_{\rm I}$ and $\Delta v_{\rm I}$, and subtracting 0.002 from $\Delta u_{\rm I}$, see eq. 2). These corrections reduce the shift, although it is not completely removed. This may be due to uncertainties in the scaling of the Heck and Manfroid photometry to GO. The variability in y, b and v is extremely small and apparently in phase with the variations in u. Minimum light in u extends over a large fraction of the cycle. The 520 nm depression is constant and has moderate strength.

HD 81009 = HR 3724 = KU Hya .

HD 81009 is a visual binary with a separation that varies between 0.1 and 0.2 second of arc. The orbital period is 58.93 years (van Dessel, 1972).

Van den Heuvel (1971) measured a positive effective field ($H_{\rm e} < 0.9$ kG) on four Zeeman plates and noticed that Eu and Sr lines are very strong ; Cr is moderately strong. Identification of spectral lines is in progress by Adelman and Shore (private communication).

Preston (1971) calculated a mean surface field $H_{\rm s} = 7.9$ kG from the resolved Zeeman pattern of Fe II 438.5 nm and from differential Zeeman broadening. The structure of this quite large magnetic field has never been studied however, presumably because the rotation period was not known at that time.

Wolff (1975) concluded, from photometric observations which span the interval 1973 January-May, that the period has to be either 69 or 34.5 days. From combination of Wolff's data with their own observations in January 1975, and two non-differential measurements by GO, Hensberge *et al.* (1976) favoured periods in the interval $34^{\rm d}.1 \pm 0^{\rm d}.2$.

The star was included in our photometry programme because a more accurate value of the period is needed to phase existing and planned spectral observations with the photometry. The period search was performed by considering the differential Δv magnitudes of Wolff (1975), those listed in table XII, and those obtained by subtracting the v magnitude of HD 80447 from the individual GO measurements for HD 81009 (Olsen, private communication). The resulting period is $P = 33^{\rm d}.97 \pm 0^{\rm d}.02$. The corresponding light curves are plotted in figure 11. The scatter is not diminished when periods of about twice that length are considered. Differential measurements of HMM obtained in February 1973 (JD 2 441 725 − 737) relative to a fainter comparison star, HD 80892, overlap with Wolff's run and add no new information. They confirm the flatness of the light curves between $\phi = 0.35$ and $\phi = 0.65$.

If the extrema of H_e should coincide with minimum and maximum light, then the observations of van den Heuvel suggest that H_e varies from roughly 0 at maximum light (minimum m_1) to roughly 1 kG at minimum light (maximum m_1). This type of variation and the much higher H_s value quoted by Preston (1971) are indicative of a geometry either with low obliquity (angle γ between rotation and magnetic axis $\lesssim 15°$) seen equator-on, or with high obliquity ($\gamma \gtrsim 75°$) seen nearly pole-on. It is impossible to discriminate between these possibilities, since the inclination of the rotation axis cannot be determined from the sharp spectral lines, which are not noticeably rotational broadened : $v \sin i < 10$ km/s (Preston, 1971). The true rotation velocity has to be much smaller than this upper limit. Assuming even a relatively large radius $R = 4\,R_\odot$, the derived period leads to $v = 6$ km/s.

6. **Evidence for Ap stars with longer periods.** — When periods much longer than the length of a common observing run are involved, a continued effort is needed to establish the variability and to demonstrate its periodicity. The results presented here are incomplete with respect to phase coverage. Nevertheless, publication is already justified because of usefulness for other potential observers. An important gain in significance can indeed be enjoyed when different groups of observations are obtained in similar ways.

As in section 5, the results are discussed for each star separately. In this discussion, absolute measurements from various sources are included. Therefore, the mutual consistency of the data has been investigated. The following conclusions should be taken into account when interpreting the Ap star data :

(a) The photometry of Cameron (1966) is consistent with GO, although considerable scatter is present. After elimination of six stars which show larger deviations in the colours, we calculated for the 33 remaining non-peculiar or Am stars common to both analyses : $\Delta V = V_{\text{Cameron}} - V_{\text{GO}} = 0.00$, $\Delta(b\text{-}y) = -0.002$, $\Delta m_1 = +0.004$ and $\Delta c_1 = 0.000$, with respective mean errors of 0.019, 0.008, 0.009 and 0.015. These errors are comparable with the accuracy quoted by the author.

(b) Systematic trends are obvious in the photometry of Heck (1977). The trends depend clearly on which of his two runs is considered (Fig. 12). His second run is of primary interest for comparison with our objects. For this run, deviations from the GO catalogue may be estimated from the relations

$$\begin{aligned} V_{\text{GO}} &= 1.040\ V_{\text{Heck}} - 0.183 \\ (b\text{-}y)_{\text{GO}} &= 0.995(b\text{-}y)_{\text{Heck}} + 0.001 \\ (m_1)_{\text{GO}} &= 1.200(m_1)_{\text{Heck}} - 0.023 \\ (c_1)_{\text{GO}} &= 0.973(c_1)_{\text{Heck}} + 0.010\ . \end{aligned}$$

The standard deviations for the corrected values of Heck relative to the GO values are 0.013 in V, 0.006 in $b\text{-}y$, 0.004 in m_1 and 0.006 in c_1.

(c) The photometry of Heck and Manfroid (1975) shows significant trends with respect to GO only for V and m_1. Their values will be corrected according to the relations

$$\begin{aligned} V_{\text{GO}} &= 1.002\ V_{\text{H,M}} - 0.038 \\ (m_1)_{\text{GO}} &= 0.894\ V_{\text{H,M}} + 0.021\ . \end{aligned}$$

The standard deviations for the (corrected) values of Heck and Manfroid relative to the GO-values are 0.009 in V, 0.004 in $b\text{-}y$, 0.006 in m_1 and 0.005 in c_1.

It should be noticed that these *linear* corrections were derived from comparison of bright stars only.

Table XIII summarizes the available data for the comparison stars. Taking into account the trends and accuracies mentioned above, no definite evidence for variability is present.

HD 50169 = BD − 1°1414 = MWC 823 .

This Cr-Eu-Sr star has strong flux depressions near 520 nm and in v. Heck *et al.* (1977) suggest a very long period (1200 days ?) from differential measurements in y, b and v relative to HD 50405. Within each of the five runs, the longest of which was 28 days, no significant drift in magnitude was found. But small differences exist between results obtained at different epochs. This star is certainly not a classical Ap star. The H_α line is variable both with respect to radial velocity and emission component, in time intervals as short as one day (Brewer, 1953). It is interesting to notice that the range of magnitudes observed in one run (up to a range of 0.055 in Δu in a 28 day run in December 1975) does not guarantee constancy in shorter time intervals, since the standard deviation for the primary comparison star relative to the second comparison star used in this run, HD 50040, is only about 0.01. Heck *et al.* (1977) attribute this scatter to erratic variations associated with circumstellar matter, apparently because they were unable to detect any periodicity.

Our purpose was, to assume as working hypothesis that the period is indeed long, and to add to the already existing data, two high precision measurements relative to three comparison stars. The two observations (see table XIV) span an interval of 38 days and yield essentially the same result. Changes in magnitude are extremely small, if significant at all (+ 0.003 in Δu, + 0.004 in Δv and Δb, + 0.002 in Δy when averaged over the *three* comparison stars). No change in magnitude is observed as compared to December 1975. The interpretation of small differences between the results obtained in 1971-1974 at the Bochum telescope in La Silla and the above mentioned results obtained in 1975-1979 at the ESO 50 cm telescope is not straightforward. Differences in sensitivity between both systems should not be underestimated.

The absolute photometry of Cameron (1966) for both HD 50169 and HD 50040 is of little value in this discussion, in view of the larger uncertainties. His result ($\Delta V = 0.70$, $\Delta(b\text{-}y) = -0.055$, $\Delta m_1 = 0.089$, $\Delta c_1 = -0.106$ in the sense HD 50169-HD 50040) is compatible with the later measurements. All evidence for long term variability remains in the scatter of the Bochum observations obtained between November 1971 and October 1974.

Summarizing, no evidence could be added to the long term variability of HD 50169. The possibility that a low amplitude periodic variability with a period of the order of a few days is lost in scatter due to measuring errors should not be disregarded at the present time. It will be prohibitively time consuming to exclude such possibility by using telescopes of the size used in this and previous investigations.

$$\text{HD } 52847 = \text{BD } - 22°3889 .$$

In 1973, the star was found to remain constant in *uvby* over a time interval of 8 days. Maitzen (1976) gives $\Delta a = 0.063 \pm 0.004$ from 16 measurements in the original Δa system.

At this moment, data are available at five epochs in *v, b* and *y* and at three epochs in *u* (table XV). They point to extremely small light variations, if any at all.

The second comparison star, HD 52350, which was added in the present observation run, shows larger variations (table XVI). The cause and character of its light variability are unknown. The absence of the 520 nm depression and the low m_1 value exclude the possibility that the star should belong to the Ap group.

$$\text{HD } 55540 = \text{BD } - 20°1779 .$$

In 1973, the star was found to remain constant in *uvby* over a time interval of 9 days. Maitzen (1976) gives $\Delta a = 0.070 \pm 0.005$ (original filter system), indicating pronounced peculiarity. Our measurements, separated by more than one month, are mutually consistent. Significant differences with earlier measurements occur in Δu (0.04) and, if the absolute photometry of October 1974 is considered, also in the *b* filter (table XVII). The difference in Δu seems to be real, in view of the accordance of results obtained in the same runs for HD 52847.

Additional evidence for light variability should be collected, before the star can be definitely considered as a long-period variable.

$$\text{HD } 94660 = \text{HR } 4263 .$$

The classification situation of this star is somewhat enigmatic. Jaschek and Jaschek (1959) give « Si » from 42 Å/mm plates. More recent classifications are « Ap (SiCr) » (Houk, 1978), and « AOp Eu Cr Si (Sr) v ? » (Brandi and Claria, 1973). Certainly, HD 94660 is not a very hot silicon star. Probably it is of a transitional type, somewhat like α^2CVn. Its Strömgren-Crawford indices indicate a B9 star with very strong metallicity. Borra and Landstreet (1975) measured in March 1974 from Hβ polarimetry a strong negative effective magnetic field : $H_e = -3300$ G $\pm$ 510 G. Cramer and Maeder (1980) added evidence for a large magnetic field. They calculated $H_s(Z, X) = 4.1$ kG, but this value is actually a lower limit because of the saturation effect mentioned in the introduction. The strong 520 nm depression is also corroborated by our $\Delta a = 0.077$, one of the largest values ever measured. As the dipole component of the magnetic field dominates in Ap stars, the real mean surface field H_s must be *at least* 7 kG. This means that HD 94660 should be one of these few outstanding peculiar stars for which H_s might be directly measured from Zeeman splitted lines, if the spectral lines are sufficiently sharp (long period or seen pole-on).

Heck *et al.* (1976) and Renson and Manfroid (1978) mention that HD 94660 was constant in light during 8 nights in February 1975, and 9 nights in January-February 1977. Their mean differential magnitudes, the available absolute measurements and our observations, which were made relative to the same comparison stars HD 93453 and HD 94724, are given in table XVIII.

Unfortunately, only one comparison star was used in the February 1975 run, where the largest deviation in Δu occurs. In view of the consistency obtained in the differential and absolute photometry of both comparison stars, the scatter in the HD 94660 observations collected between 1975 and 1980 has to be attributed to the intrinsic variability of the star.

The amplitude of the variations seem to decrease gradually from *u* to *y*. The *V* magnitude may well be constant. The presently available data indicate that there is no simple phase relation between the variations in *u, v* and *b*. The invariability of the star's brightness during two intervals somewhat longer than one week is firmly established. In both runs (with resp. 10 and 19 measurements) the standard deviation of a single measurement is less than 0.005 in all filters and no drift larger than 0.002 is detected. This points to a period of the order of several months or even longer which means that the star should show extremely sharp spectral lines.

HD 94660 will be further monitored, in order to establish the periodicity and the character of the variability. Magnetic field observations, and spectra at high dispersion in the 520 nm wavelength region would be valuable for interpreting the Δa photometry.

$$\text{HD } 101065 = \text{Przybylski's star} .$$

Many papers are devoted to the outstanding spectrum of this star. Efforts to study the photometric behaviour of the star have been published by Przybylski (1977, *V*), Heck *et al.* (1976, *uvby*) and Weiss and Kreidl (1980, Hβ). Przybylski (1977) finds HD 101065 constant over seven months in 1969 ($V = 8.000$), and a small decline in brightness from 1973 to 1977 ($V = 8.018$). Unfortunately, we have no comparison stars in common with his analysis, an error which will be restored in future runs. His primary comparison star, HD 100955, will be added to the observation sequence. Renson *et al.* (1976), and Weiss and Kreidl (1980) mention variations on a time scale of hours and minutes respectively.

In this run, HD 101065 was measured differentially to three comparison stars, including both HD 101128 and HD 101596, which were used by Heck *et al.* (1976). The comparison between their and our measurements (table XIX) is hampered by the presence of the systematic effects mentioned in the introduction to this section. The colours and magnitude of HD 101065 are indeed outside the range covered by the stars from which the correction for systematic effects has been derived. Moreover, the constancy of HD 101128-HD 101596 is doubtful.

Observations on various time scales should be continued before any conclusion can be drawn. It is hoped that publication of these observations will encourage potential observers to collect their observations in a way which is compatible with the existing ones.

$$\text{HD } 101189 = \text{HR } 4487 .$$

Our measurement agrees with the photometry of GO :

$$\begin{aligned} V &= 5.161 \text{ (GO : } 5.153 \pm 0.004 \text{ m.e.)} \\ b\text{-}y &= -0.013 \text{ (GO : } -0.014 \pm 0.002 \text{ m.e.)} \\ m_1 &= 0.125 \text{ (GO : } 0.126 \pm 0.001 \text{ m.e.)} \\ c_1 &= 0.885 \text{ (GO : } 0.884 \pm 0.001 \text{ m.e.)} \end{aligned}$$

We find no indication of the 520 nm depression : $\Delta a = -0.001$. The star might be slightly reddened (0.02 mag., see section 7), but the corresponding enhancement of 0.002 in Δa does not alter the conclusion.

Bidelman stated, in a letter to Renson dating from 1967-11-18 that he feels « fairly sure » about his Cr-Si classification, and Floquet (private communication, 1980) checked on a 12 Å/mm spectrum taken at ESO in July 1980, that silicon is prominent. Thus, it seems well-established that HD 101189 belongs to the CP2-group (terminology of Preston, 1974).

HD 101189 is the second CP2-star bluer than $b\text{-}y = 0$ that does not show the 520 nm depression (Maitzen, 1976, found $\Delta a = -0.001$ for HD 206742). It is not known whether an aspect effect is responsible (Δa could be significantly larger when the star is seen from another direction), or whether some intrinsic difference with other CP2 stars plays a role.

The fact that some hot CP2 stars may escape photometric detection using the peculiarity criterion $\Delta a \gg 0$, is annoying and the cause for this behaviour should be investigated. Fortunately, only few hot CP2 stars do not show up in Δa (certainly less than 5 %), so that frequency statistics based on Δa detection are only slightly influenced.

7. **Discussion.** — 7.1 De-reddening of Δa. — The determination of Δa involves the knowledge of the intrinsic $(b\text{-}y)_0$ colour of the Ap stars, so it is of interest to know whether the Ap stars studied in this paper are reddened or not. Although the applicability to peculiar stars of the calibrations of Crawford (1978), Crawford (1979), Strömgren (1966), and the Q-method (see e.g. Golay, 1974, p. 138) might be questioned, they should give at least some indication about the reddening. Since the dependence of Δa on $(b\text{-}y)_0$ is weak, about 1 : 11, the errors in the de-reddening correction will be small, probably a few thousandths of a magnitude.

We applied these methods to the Ap stars for which the necessary data are available (table XX). The Hβ index, which is needed to derive reddening corrections for the cooler stars of our sample, is however not known for some of the fainter stars. Consequently, no results are given for HD 30849, HD 38823, HD 52847, HD 53116 and HD 55540. *UBV* data were taken from Nicolet (1978), *uvby* data from GO, VF or this paper, Hβ from Hauck and Mermilliod (1980). Only two stars contained in table XX seem to be slightly reddened, i.e. HD 101189 and the variable comparison star HD 52350. Maitzen (1980) noticed already that, for hot Ap stars (notation of table XX)

$$E(b\text{-}y)_Q \geq E(b\text{-}y)_{[u\text{-}b]} \geq E(b\text{-}y)_{\min}$$

where $E(b\text{-}y) = (b\text{-}y) - (b\text{-}y)_0$. $E(b\text{-}y)_{\min}$ is the minimum reddening correction determined by shifting the Ap star in a $(b\text{-}y)$, $(B\text{-}V)$ diagram along the reddening vector towards the relation for normal unreddened stars. (Unreddened Ap stars have slightly lower *b-y*, see Maitzen (1980), Fig. 1.) Our results confirm his empirical relation. It is interesting that in the sample of 7 stars where the « Q » and « [*u-b*] » methods could both be applied, the difference between $E(b\text{-}y)_Q$ and $E(b\text{-}y)_{[u\text{-}b]}$ is larger than 0.02 mag. only when $\Delta a > 0.05$. This correlation is consistent with the fact that the *y* filter itself is partially influenced by the 520 nm depression. Further, one might notice that the two stars for which a positive reddening correction was obtained are also the only ones which do not show the depression.

7.2 Correction of Δa for variability in *b-y*. — The variability in *b-y* was measured only for some Ap stars ; it may be estimated however with sufficient accuracy from the VF paper for the other Ap stars.

During the rotation cycle, *b-y* changes and so does the star's position relative to the normality line $a = a((b\text{-}y)_0)$. We checked for each star the influence of the variability in *b-y* on Δa. In general, this influence is negligible. The largest absolute correction has to be applied to HD 30869. The Δa amplitude of about 0.025 mag., as calculated with a mean *b-y* colour, should be lowered to 0.02 mag.

7.3 Discussion of the variability in Δa. — We obtained Δa values at different phases for eight stars in our sample, i.e. five hot (HD 5601, HD 19712, HD 25267, HD 53116, HD 56022) and three cool Ap stars (HD 30849, HD 38823, HD 81009). Our sample contains one hot (HD 53116) and one cool Ap star (HD 30849) wherein the 520 nm depression varies substantially. Maitzen and Seggewiss (1980) already pointed out that this depression is composed of two main components with different temperature behaviour : a narrow, rather deep feature centered on about 517.5 nm, showing its greatest strength at the hottest Ap stars, and a broad, rather shallow feature which peaks at somewhat longer wavelengths and at a lower temperature. Thus, evidence is presented that both, yet unknown, opacity sources vary through the rotation cycle.

Since a correlation between the strength of the depression and the surface magnetic field strength H_s is established by Cramer and Maeder (1980), one is tempted to consider variations in the mean surface field over the visible hemisphere as possible agent for the Δa variability, *via* varying Zeeman intensification of spectral lines. This explanation is consistent with the saturation effect discussed by Cramer and Maeder (1980). Their Z parameter saturates for fields $H_s \gtrsim 4$ à 5 kG. At such field strengths, groups of π and σ components of most spectral lines become locally totally separated, and the intensification saturates too. The weak dependence of H_s on aspect effects for dipole-like fields and this saturation effect should explain in a natural way why the depression remains fairly constant in most peculiar A stars.

If at least an important part of the variability is caused by the proposed effect, a phase correlation between H_s and Δa variability should exist. Moreover, the largest variability should occur rather in stars possessing *eccentric* magnetic dipole fields (causing larger H_s variability as in HD 65339 and HD 126515) not stronger than 5 kG, when seen under favourable inclination. The existing observational material does not yet permit to check these predictions.

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References

BIDELMAN, W. P., MCCONNELL, D. J. : 1973, *Astron. J.* **78**, 687.
BORRA, E. F., LANDSTREET, J. D. : 1975, *Publ. Astron. Soc. Pac.* **87**, 961.
BORRA, E. F., LANDSTREET, J. D. : 1980, *Astrophys. J. Suppl.* **42**, 421.
BRANDI, E., CLARIA, J. J. : 1973, *Astron. Astrophys. Suppl. Ser.* **12**, 79.
BREWER, K. R. W. : 1953, *Astrophys. J.* **118**, 265.
CAMERON, R. C. : 1966, *Georgetown Obs. Monograph* No. 21.
CRAMER, N., MAEDER, A. : 1980, *Astron. Astrophys. Suppl. Ser.* **41**, 111.
CRAWFORD, D. L. : 1978, *Astron. J.* **83**, 48.
CRAWFORD, D. L. : 1979, *Astron. J.* **84**, 1858.
DEEMING, T. J. : 1975, *Astrophys. Space Sci.* **36**, 137.
DESSEL, E. L. VAN : 1972, *Astron. Astrophys.* **21**, 155.
DRILLING, J. S., PESCH, P. : 1973, *Astron. J.* **78**, 47.
GOLAY, M. : 1974, in *Introduction to Astronomical Photometry* (publ. D. Reidel), Dordrecht, Netherlands.
GRØNBECH, B., OLSEN, E. H. : 1976, *Astron. Astrophys. Suppl. Ser.* **25**, 213.
GRØNBECH, B., OLSEN, E. H., STRÖMGREN, B. : 1976, *Astron. Astrophys. Suppl. Ser.* **26**, 155.
HAUCK, B., MERMILLIOD, M. : 1980, *Astron. Astrophys. Suppl. Ser.* **40**, 1.
HECK, A. : 1977, *Astron. Astrophys. Suppl. Ser.* **27**, 47.
HECK, A., MANFROID, J. : 1975, *Astron. Astrophys. Suppl. Ser.* **22**, 323.
HECK, A., MANFROID, J., RENSON, P. : 1976, *Astron. Astrophys. Suppl. Ser.* **25**, 143.
HECK, A., MAITZEN, H. M., RENSON, P. : 1977, *Astron. Astrophys.* **54**, 635.
HENSBERGE, H., DE LOORE, C., ZUIDERWIJK, E. J., HAMMERSCHLAG-HENSBERGE, G. : 1976, *Astron. Astrophys.* **48**, 383.
HENSBERGE, H., DE LOORE C., ZUIDERWIJK, E. J., HAMMERSCHLAG-HENSBERGE, G. : 1977, *Astron. Astrophys.* **54**, 443.
HEUVEL, E. P. J. VAN DEN : 1971, *Astron. Astrophys.* **11**, 461.
HOUK, N. : 1978, *Michigan Catalogue of Two-Dimensional Spectral Types for the HD Stars,* vol. **2**.
JASCHEK, M., JASCHEK, C. : 1959, *Publ. Astron. Soc. Pac.* **71**, 48.
LAFLER, J., KINMAN, T. D. : 1965, *Astrophys. J. Suppl.* **11**, 216.
MAITZEN, H. M. : 1976, *Astron. Astrophys.* **51**, 223.
MAITZEN, H. M., HENSBERGE, H. : 1981, *Astron. Astrophys.* **96**, 151.
MAITZEN, H. M., SEGGEWISS, W. : 1980, *Astron. Astrophys.* **83**, 328.
MAITZEN, H. M. : 1980, *Astron. Astrophys.* **89**, 230.
MALARODA, S. : 1975, *Astron. J.* **80**, 637.
NICOLET, B. : 1978, *Astron. Astrophys. Suppl. Ser.* **34**, 1.
PRESTON, G. W. : 1971, *Astrophys. J.* **164**, 309.
PRESTON, G. W. : 1974, *Annu. Rev. Astron. Astrophys.* **12**, 257.
PRZYBYLSKI, A. : 1977, *Proc. Astron. Soc. Australia* **3**, 143.
RENSON, P. : 1978, *Astron. Astrophys.* **63**, 125.
RENSON, P. : 1979, *Astron. Astrophys.* **77**, 366.
RENSON, P., MANFROID, J. : 1978, *Astron. Astrophys. Suppl. Ser.* **34**, 445.
RENSON, P., MANFROID, J., HECK, A. : 1976, *Astron. Astrophys. Suppl. Ser.* **23**, 413.
SAHADE, J. : 1950, *Astrophys. J.* **111**, 438.
SLETTEBAK, A., COLLINS, G. W., BOYCE, P. B., WHITE, N. M., PARKINSON, T. D. : 1975, *Astrophys. J. Suppl.* **29**, 137.
SNOWDEN, M. S. : 1975, *Publ. Astron. Soc. Pac.* **87**, 721.
STELLINGWERF, R. F. : 1978, *Astrophys. J.* **224**, 953.
STRÖMGREN, B. : 1966, *Annu. Rev. Astron. Astrophys.* **4**, 433.
UESUGI, A., FUKUDA, I. : 1970, *Contrib. Inst. Astrophys. Kyoto* No. 189.
VOGT, N., FAÚNDEZ, M. : 1979, *Astron. Astrophys. Suppl. Ser.* **36**, 477.
WARREN, W. H. JR, HESSER, J. E. : 1977, *Astrophys. J. Suppl.* **34**, 115.
WEISS, W. W., KREIDL, T. J. : 1980, *Astron. Astrophys.* **81**, 59.
WOLFF, S. C. : 1975, *Astrophys. J.* **202**, 127.

TABLE I. — *Summary of observational data discussed in this paper. For each run and each programme star, comparison stars, filters used (uv = only u and v ; Str = uvby ; a = yg_2g_1 ; Stra = $uvbyg_2g_1$) and number of observations are specified. References to published differential photometry are included.*

Star (HD)	Comp.stars (HD)	Run:79.11.19/79.12.06 Obs.: Maitzen Tel.: 50 cm ESO	Run:79.12.22/80.01.03 Obs.: Hensberge Tel.: 50 cm ESO	Run	Obs.	Tel.	Nr.obs.	Comp.stars (HD)	Published diff.phot.	Comp.stars (HD)
5601	6530,6706	uv(8), a(4)	uv(8), a(7)							
19712	19739,20319	uv(16), a(8)	uv(7), a(6)	Feb.79	Gerbaldi	Dan.50cm	Str(8)	20319		
25267	24975,25385	uv(18), a(9)	uv(18), a(10)	Feb.79	Gerbaldi	Dan.50cm	Str(8)	idem**		
30849	30861*,31640	uv(14), a(9)	uv(10), a(6)							
38823	38856,38866	uv(11), a(7)	uv(9), a(4)							
50169	50040,50109,50405	Stra(1)	Stra(1)						Heck et al.(1977)	50405,(50040,50109)
52847	52190,52350	Stra(1)	Stra(1)	Feb.73	Maitzen	ESO 1m	Stra(8)	52190		
				Mar.74	Maitzen	Boch.60cm	vba(2)	52190		
53116	53207,53238	-	uv(12), a(5)	Mar.80	Doom	Dan.50cm	Str(8)	idem**		
55540	55521,55816	Stra(1)	Stra(1)	Feb.73	Maitzen	ESO 1m	Stra(8)	55816		
				Mar.74	Maitzen	Boch.60cm	vba(2)	55816		
56022	55892,56456	Stra(8)	Str (15), a(3)						Heck et al.(1976)	56456
81009	80447,82428	va(4), ub(2)	uv(6), a(5)	Feb.73	Maitzen	ESO 1m	Stra(10)	80892	Wolff(1975)	80447,81728
				Jan.75	Hensberge	ESO 50cm	Str(4)	idem**		
94660	93453,94724	-	Stra(1)						Heck et al.(1976)	idem**
									Renson, Manfroid(1978),	idem**
101065	101128,101388,101596	-	Stra(1)						Heck et al.(1976)	101128,101596
101189	99104,101995,103884	-	Stra(1)							

(*) HD 30861 was found to be variable by Maitzen, and was replaced by HD 31587.
(**) See column 2.

TABLE II. — *Instrumental differential magnitudes for frequently observed pairs of comparison stars. n is the number of differential measurements in the specified run (observer M : Maitzen, H : Hensberge, G : Gerbaldi, D : Doom ; telescope I : ESO 50 cm, D : Danish 50 cm) and σ is the standard deviation for a single differential measurement.*

C1 - C2	V(C1)	V(C2)	obs./tel.	n	Δu	σ	Δv	σ	Δb	σ	Δy	σ
HD 6530 - HD 6706	5.6	5.9	M/I	7	-0.421	0.010	-0.691	0.003				
			H/I	8	-0.419	0.004	-0.693	0.006				
HD 19739 - HD 20319	7.3	6.2	M/I	14	+1.803	0.006	+1.452	0.003				
			H/I	7	+1.806	0.006	+1.463	0.003				
			G/D	1	+1.790	-	+1.458	-	+1.249	-	+1.115	-
HD 24975 - HD 25385	7.3	7.4	M/I	15	-0.341	0.005	-0.239	0.005				
			H/I	18	-0.341	0.004	-0.239	0.006				
			G/D	8	-0.338	0.006	-0.242	0.003	-0.203	0.003	-0.159	0.003
HD 38856 - HD 38866	7.2	7.5	M/I	9	-1.161	0.004	-0.449	0.005				
			H/I	9	-1.157	0.005	-0.440	0.004				
HD 53238 - HD 53207	8.4	9.0	H/I	9	+0.293	0.004	-0.306	0.003				
			D/D	8	+0.285	0.007	-0.302	0.005	-0.495	0.007	-0.600	0.007
HD 56456 - HD 55892	4.8	4.5	M/I	5	-0.395	0.005	-0.251	0.003	+0.040	0.004	+0.277	0.005
			H/I	15	-0.404	0.006	-0.261	0.009	+0.033	0.005	+0.277	0.009
HD 80447 - HD 82428	6.6	6.1	M/I	4*	+0.460	0.006	+0.282	0.005				
			H/I	6	+0.462	0.006	+0.278	0.008				

(*) Only 2 measurements in Δu.

TABLE III. — *Comparison of the photometry of Grønbech and Olsen (1976) with the values calculated from eq. (2), for the stars used to establish the transformations.*

Star (HD)	b - y this paper	b - y G.O.	m_1 this paper	m_1 G.O.	c_1 this paper	c_1 G.O.
6668	0.132	0.132	0.201	0.201	0.817	0.814
55857	-0.108	-0.106	0.080	0.079	-0.064	-0.065
56456	-0.035	-0.036	0.110	0.110	0.780	0.785
56876	-0.073	-0.074	0.106	0.107	0.369	0.368

TABLE IV. — *Differential magnitudes for the apparently variable comparison stars HD 30861, HD 31587 and HD 55892. Subscript I refers to ESO 50 cm telescope.*

HD 30861 - HD 31640 HJD 2 440 000+	Δu_I	Δv_I	HD 31587 - HD 31640 HJD 2 440 000+	Δu_I	Δv_I
4197.618	-.677	-.801	4230.650	-1.493	-1.604
4197.738	-.654	-.779	4232.629	-1.420	-1.564
4197.835	-.573	-.686	4235.583	-1.424	-1.545
			4236.676	-1.419	-1.554
			4237.678	-1.434	-1.554
			4238.604	-1.416	-1.550
4198.606	-.655	-.766	4239.590	-1.427	-1.554
4198.717	-.560	-.681	4240.663	-1.416	-1.542
4198.837	-.602	-.723	4241.594	-1.432	-1.560
			4242.574	-1.414	-1.552

HJD 2 440 000+	HD 56456 - HD 55892 Δy	Δ(b-y)	Δm_1	Δc_1
4201.790	0.281	-0.259	-0.031	0.144
4202.857	0.281	-0.261	-0.031	0.154
4203.852	0.275	-0.260	-0.028	0.143
4205.818	0.268	-0.257	-0.030	0.143
4213.826	0.279	-0.260	-0.031	0.154
4231.645	0.291	-0.270	-0.027	0.161
4231.711	0.287	-0.267	-0.027	0.152
4232.752	0.289	-0.276	0.001	0.120
4234.815	0.277	-0.268	-0.021	0.148
4235.796	0.273	-0.264	-0.032	0.155
4236.824	0.272	-0.270	-0.021	0.153
4237.648	0.279	-0.265	-0.031	0.157
4237.815	0.264	-0.259	-0.044	0.168
4238.655	0.270	-0.265	-0.026	0.151
4239.658	0.271	-0.266	-0.028	0.156
4240.635	0.281	-0.277	-0.015	0.155
4240.819	0.267	-0.262	-0.036	0.164
4241.613	0.279	-0.268	-0.025	0.151
4241.817	0.272	-0.264	-0.025	0.144
4242.818	0.287	-0.276	-0.013	0.145

TABLE V. — *Instrumental differential magnitudes in the sense HD 5601-HD 6530, and absolute V and Δa photometry of HD 5601. Approximate standardized values may be calculated, although Δb_I and Δy_I were often not measured : $\Delta u \simeq \Delta u_I - 0.011$ and $\Delta v \simeq \Delta v_I - 0.007$.*

HJD= 2 440 000+	Δu_I	Δv_I	Δa	V
4201.531	1.705	2.033	-	-
4201.709	1.693	2.028	-	-
4202.534	1.679	2.014	0.059	7.638
4202.768	1.688	2.023	-	-
4203.549	1.688	2.009	0.061	7.654
4205.535	1.691	2.000	0.066	7.660
4208.666	1.733	2.019	-	-
4214.560	1.684	1.998	0.061	7.648
4235.560	1.686	1.994	0.061	7.650
4236.552	1.700	1.998	0.060	7.652
4237.573	1.717	2.023	0.056	7.646
4238.571	1.726	2.034	0.053	7.653
4239.538	1.699	2.020	0.053	7.643
4240.537	1.690	2.035	0.052	7.655
4241.556	1.697	2.037	0.053	7.660
4242.549	1.696	2.026	-	-

TABLE VI. — *Instrumental differential magnitudes (subscripts refer to telescope, as defined in table II), in the sense HD 19712-comparison star, and absolute V and Δa photometry of HD 19712. Approximate standardized values Δu and Δv relative to HD 19739 may be obtained from $\Delta u \simeq \Delta u_I - 0.016$, $\Delta v \simeq \Delta v_I - 0.018$.*

comparison star	HJD 2 440 000+	Δu_D	Δv_D	Δb_D	Δy_D
HD 19739	3921.543	-0.424	-0.280	-0.127	0.082
HD 20319	3921.543	1.366	1.178	1.122	1.207
	3922.545	1.322	1.164	1.118	1.190
	3923.559	1.349	1.184	1.134	1.203
	3924.552	1.341	1.196	1.141	1.201
	3925.562	1.322	1.163	1.122	1.188
	3927.551	1.349	1.172	1.124	1.196
	3928.548	1.360	1.198	1.123	1.189
HD 20319	3929.547	1.330	1.164	1.111	1.192
		Δu_I	Δv_I	Δa	V
HD 19739	4197.635	-0.458	-0.284	0.054	7.365
	4198.565	-0.461	-0.276	-	-
	4198.670	-0.464	-0.272	-	-
	4198.791	-0.464	-0.280	-	-
	4199.564	-0.466	-0.301		
	4199.667	-0.461	-0.296	0.057	7.355
	4200.550	-0.446	-0.278	0.062	7.341
	4200.666	-0.449	-0.265	-	-
	4200.771	-0.472	-0.273	-	-
	4201.591	-0.480	-0.308	0.060	7.340
	4202.675	-0.456	-0.280	0.055	7.336
	4203.573	-0.476	-0.300	0.052	7.351
	4203.755	-0.482	-0.307	-	-
	4205.686	-0.480	-0.293	0.050	7.349
	4208.682	-0.442	-0.286	-	-
	4214.610	-0.481	-0.302	0.053	7.345
	4232.573	-0.456	-0.292	0.055	7.372
	4233.578	-0.444	-0.270	0.052	7.369
	4235.545	-0.440	-0.280	-	-
	4238.558	-0.476	-0.280	0.048	7.353
	4239.575	-0.444	-0.286	0.046	7.362
	4240.573	-0.466	-0.274	0.045	7.359
HD 19739	4241.571	-0.458	-0.292	0.044	7.377

TABLE VII. — *Instrumental differential magnitudes (subscript D and I refer to the telescope, as in table II) in the sense HD 25267-HD 24975, and absolute V and Δa photometry of HD 25267. Standardized values Δu and Δv fulfil approximately the relations $\Delta u \simeq \Delta u_I - 0.021$, and $\Delta v \simeq \Delta v_I - 0.016$.*

HJD= 2 440 000+	Δu_D	Δv_D	Δb_D	Δy_D
3919.580	-3.507	-3.039	-2.792	-2.605
3920.565	-3.457	-3.018	-2.774	-2.590
3921.577	-3.500	-3.028	-2.783	-2.601
3922.579	-3.532	-3.048	-2.803	-2.613
3924.599	-3.515	-3.043	-2.794	-2.611
3926.598	-3.512	-3.033	-2.789	-2.600
3928.589	-3.511	-3.035	-2.786	-2.600
3929.581	-3.526	-3.045	-2.801	-2.614
HJD= 2 440 000+	Δu_I	Δv_I	Δa	V
4197.592	-3.495	-2.987	-	-
4197.697	-3.503	-3.007	0.030	4.658
4197.826	-3.512	-2.999	-	-
4198.571	-3.487	-2.992	-	-
4198.695	-3.498	-2.994	0.033	4.656
4198.828	-3.501	-3.002	-	-
4199.572	-3.501	-3.000	-	-
4199.799	-3.473	-2.988	-	-
4200.589	-3.497	-3.020	-	-
4200.823	-3.481	-2.997	-	-
4201.635	-3.527	-3.015	0.032	4.637
4202.778	-3.539	-3.024	0.034	4.619
4203.583	-3.476	-2.976	0.030	4.670
4203.804	-3.502	-3.003	-	-
4205.696	-3.492	-2.997	0.032	4.660
4212.660	-3.507	-3.007	0.031	4.643
4213.770	-3.535	-3.025	0.035	4.637
4214.617	-3.511	-3.010	0.036	4.647
4230.633	-3.534	-3.033	-	-
4232.595	-3.524	-3.025	0.044	4.652
4233.551	-3.526	-3.027	0.042	4.666
4233.692	-3.502	-3.022	-	-
4235.680	-3.525	-3.031	-	-
4236.574	-3.543	-3.036	-	-
4237.559	-3.515	-3.022	-	-
4237.696	-3.523	-3.023	0.050	4.642
4238.544	-3.484	-3.012	0.036	4.674
4238.669	-3.486	-3.020	-	-
4239.558	-3.504	-3.021	0.039	4.651
4239.688	-3.488	-3.016	0.039	4.659
4240.562	-3.533	-3.027	0.043	4.639
4240.691	-3.527	-3.031	-	-
4241.541	-3.549	-3.028	0.039	4.653
4241.671	-3.522	-3.034	0.036	4.642
4242.538	-3.516	-3.033	0.039	4.661
4242.701	-3.523	-3.027	-	-

TABLE VIII. — *Instrumental differential magnitudes in the sense HD 30849-HD 31640, and absolute V and Δa photometry of HD 30849. In this particular case, $\Delta u \simeq \Delta u_I$ and $\Delta v \simeq \Delta v_I$.*

HJD= 2 440 000+	Δu_I	Δv_I	Δa	V
4197.621	0.992	0.978	-	-
4197.739	0.996	0.973	0.032	8.855
4197.837	0.993	0.971	-	-
4198.607	0.967	0.941	-	-
4198.719	0.969	0.938	0.023	8.855
4198.838	0.972	0.932	-	-
4199.693	0.970	0.919	-	-
4200.720	0.966	0.915	0.030	8.846
4201.668	0.975	0.939	0.026	8.864
4202.792	0.998	0.973	0.035	8.854
4203.624	0.988	0.968	0.037	8.871
4205.790	0.969	0.924	0.031	8.855
4213.790	0.979	0.960	0.016	8.860
4214.633	0.968	0.938	0.020	8.866
4230.650	0.966	0.927	-	-
4232.629	0.970	0.916	-	-
4235.583	0.998	0.972	0.030	8.855
4236.676	0.993	0.955	-	-
4237.678	0.978	0.925	-	-
4238.604	0.951	0.897	0.024	8.859
4239.590	0.964	0.911	0.012	8.851
4240.663	0.970	0.953	0.028	8.859
4241.594	0.998	0.983	0.022	8.867
4242.574	1.002	1.003	0.034	8.859

TABLE IX. — *Instrumental differential magnitudes in the sense HD 38823-HD 38856, and absolute V and Δa photometry of HD 38823. Approximate standardized values may be obtained from $\Delta u \simeq \Delta u_I + 0.013$, $\Delta v \simeq \Delta v_I + 0.020$.*

HJD= 2 440 000+	Δu_I	Δv_I	Δa	V
4198.705	1.408	0.784	-	-
4199.684	1.384	0.750	0.009	7.329
4199.824	1.379	0.744	-	-
4200.832	1.402	0.797	0.011	7.326
4201.720	1.444	0.874	0.010	7.348
4202.804	1.444	0.878	-	-
4203.678	1.399	0.820	0.016	7.330
4203.827	1.405	0.817	-	-
4205.803	1.419	0.814	0.013	7.324
4213.811	1.411	0.816	0.014	7.336
4214.777	1.417	0.821	0.015	7.337
4230.677	1.385	0.807	-	-
4232.664	1.424	0.821	-	-
4234.681	1.391	0.749	0.006	7.332
4235.698	1.414	0.805	-	-
4236.709	1.449	0.880	-	-
4237.664	1.433	0.859	0.014	7.338
4238.617	1.397	0.808	0.012	7.320
4241.651	1.401	0.794	0.007	7.335
4242.716	1.385	0.751	-	-

TABLE X. — *Instrumental differential magnitudes (subscript D and I refer to telescope, see table II) in the sense HD 53116-HD 53238. Approximate standardized values may be obtained from $\Delta u \simeq \Delta u_I - 0.007$ and $\Delta v \simeq \Delta v_I - 0.011$.*

HJD= 2 440 000+	Δu_I	Δv_I	Δa	V
4230.732	0.020	0.298	-	-
4231.817	0.008	0.334	-	-
4232.678	0.010	0.362	-	-
4233.719	0.011	0.354	-	-
4234.701	0.017	0.354	-	-
4235.826	0.053	0.331	0.060	8.879
4236.732	0.077	0.310	0.059	8.892
4237.629	0.100	0.300	0.052	8.924
4237.801	0.103	0.304	-	-
4238.819	0.111	0.305	-	-
4239.641	0.111	0.292	0.038	8.923
4242.681	0.039	0.308	0.063	8.908
HJD= 2 440 000+	Δu_D	Δv_D	Δb_D	Δy_D
4301.602	0.079	0.289	0.378	0.511
4302.601	0.050	0.300	0.355	0.486
4304.606	0.006	0.351	0.336	0.435
4305.606	0.013	0.358	0.331	0.425
4306.632	0.024	0.349	0.349	0.454
4307.607	0.051	0.328	0.361	0.477
4308.606	0.087	0.313	0.381	0.510
4309.590	0.113	0.302	0.389	0.528

TABLE XI. — *Differential photometry for HD 56022-HD 56456. Results given in this table are reduced to the standard system established by GO, using eq. (2).*

HJD= 2 440 000+	Δy	Δ(b-y)	Δm_1	Δc_1	Δa
4199.807	0.132	0.020	0.053	0.205	0.019
4200.780	0.136	0.019	0.044	0.217	0.018
4201.790	0.127	0.025	0.040	0.216	0.022
4202.857	0.132	0.019	0.050	0.209	0.021
4203.852	0.133	0.019	0.042	0.219	0.023
4205.818	0.128	0.014	0.054	0.185	0.022
4213.826	0.130	0.019	0.050	0.213	0.026
4214.781	0.133	0.016	0.053	0.209	0.019
4231.645	0.117	0.020	0.054	0.174	0.022
4231.711	0.127	0.018	0.053	0.190	0.021
4232.752	0.132	0.021	0.039	0.226	0.022
4234.815	0.131	0.020	0.052	0.212	-
4235.796	0.134	0.018	0.053	0.209	-
4236.824	0.133	0.023	0.042	0.215	-
4237.648	0.131	0.014	0.059	0.207	-
4237.815	0.131	0.016	0.059	0.198	-
4238.655	0.132	0.018	0.056	0.205	-
4239.658	0.132	0.016	0.054	0.206	-
4240.635	0.121	0.032	0.035	0.197	-
4240.819	0.125	0.014	0.059	0.174	-
4241.613	0.126	0.019	0.055	0.177	-
4241.817	0.127	0.025	0.059	0.187	-
4242.818	0.120	0.031	0.037	0.211	-

TABLE XII. — *Instrumental differential magnitudes, in the sense HD 81009-HD 80447 and Δa measurements for the Ap star HD 81009.*

HJD +2 440 000	Δa	Δu_I	Δv_I	Δb_I	Δy_I
2427.711	-	-0.099	0.118	-0.054	-0.110
2428.692	-	-0.092	0.108	-0.057	-0.108
2430.678	-	-0.102	0.108	-0.061	-0.111
2432.692	-	-0.098	0.102	-0.066	-0.110
4198.852	0.037	-	0.099	-	-0.112
4201.847	0.033	-	0.085	-	-0.105
4205.848	0.029	-0.109	0.077	-0.068	-0.109
4213.842	0.031	-0.102	0.070	-0.072	-0.112
4231.832	-	-0.100	0.108	-	-
4233.815	0.031	-0.098	0.103	-	-
4234.847	0.029	-0.105	0.088	-	-
4237.847	0.029	-0.101	0.079	-	-
4238.854	0.030	-0.108	0.071	-	-
4241.834	0.029	-0.111	0.062	-	-

TABLE XIII. — *Magnitude and colours of comparison stars. Comparison with results from other sources (GO : Grønbech and Olsen, 1976 ; C : Cameron, 1966 ; H : Heck, 1977 ; H, M : Heck and Manfroid, 1975). See text for discussion of systematic effects.*

star (HD)	reference	V	b-y	m_1	c_1
50040	this paper C H	8.328 8.36 8.216	0.037 0.035 0.023	0.139 0.136 0.142	1.058 1.086 1.085
50109	this paper	9.067	0.024	0.111	0.974
50405	this paper H	9.258 9.126	0.034 0.017	0.118 0.127	1.025 1.042
52190	this paper	8.885	0.093	0.179	1.005
52350*	this paper	8.592	-0.037	0.091	0.454
55521	this paper	9.369	0.015	0.100	0.842
55816	this paper	8.686	0.024	0.131	0.851
93453	this paper H H,M	6.300 6.228 6.320	0.109 0.106 0.106	0.201 0.187 0.194	0.910 0.924 0.915
94724	this paper H H,M	6.423 6.350 6.437	0.040 0.033 0.034	0.152 0.150 0.150	0.905 0.921 0.914
101128	this paper H H,M	9.276 9.129 9.309	0.048 0.038 0.046	0.143 0.146 0.140	1.129 1.149 1.138
101388	this paper	7.755	0.148	0.161	0.913
101596	this paper H H,M	9.122 8.962 9.160	0.192 0.185 0.186	0.185 0.171 0.173	0.958 0.955 0.949
99104	this paper GO	5.113 5.114	-0.033 -0.034	0.118 0.120	0.503 0.512
101995	this paper H GO	6.109 6.051 6.116	0.037 0.033 0.035	0.156 0.153 0.158	1.164 1.179 1.159
103884	this paper GO	5.583 5.593	-0.076 -0.080	0.108 0.107	0.297 0.302

(*) Variable according to our differential photometry.

TABLE XIV. — *Observations of HD 50169.*

A) Instrumental differential magnitudes of HD50169-HD50405				
HJD 2 440 000+	Δu_I	Δv_I	Δb_I	Δy_I
4201.819	-0.223	-0.239	-0.296	-0.251
4238.754	-0.218	-0.233	-0.291	-0.244

B) Absolute photometry of HD 50169					
HJD 2 440 000+	V	b-y	m_1	c_1	Δa
4201.819	9.010	-0.021	0.241	0.980	+0.067
4238.754	9.014	-0.018	0.228	0.982	+0.065

TABLE XV. — *Observations of HD 52847. N is the number of observations. If more than 1 measurement is made, the data are the mean magnitudes and their standard deviations. The indications for the telescopes have the following meaning I : ESO 50 cm, B : Bochum 60 cm and E : ESO 1 m.*

A) Instrumental differential magnitudes of HD52847 - HD52190						
HJD 2 440 000+	N	Tel	Δu	Δv	Δb	Δy
1729.6 till 1737.6	8	E	-0.745 ±0.006	-0.589 ±0.002	-0.712 ±0.003	-0.712 ±0.004
2131.6 till 2132.6	2	B	-	-0.578 ±0.001	-0.689 ±0.002	-0.713 ±0.007
4200.802	1	I	-0.734	-0.589	-0.713	-0.715
4242.795	1	I	-0.737	-0.581	-0.709	-0.718

B) Absolute photometry of HD 52847					
HJD 2 440 000+	V	b-y	m_1	c_1	Δa
2330.89	8.175	0.108	0.307	-	0.053
4200.802	8.170	0.096	0.297	0.739	0.058
4242.795	8.167	0.103	0.296	0.724	0.056

TABLE XVI. — *Evidence for the variability of HD 52350. Instrumental differential magnitudes HD 52350-HD 52190.*

HJD +2 440 000	Δu_I	Δv_I	Δb_I	Δy_I
4200.802	-1.346	-0.578	-0.371	-0.253
4242.795	-1.410	-0.630	-0.411	-0.293

TABLE XVII. — *Observations of HD 55540. Explanation of the symbols is the same as in table XV.*

A) Instrumental differential magnitudes of HD 55540 - HD 55816						
HJD 2 440 000+	N	Tel	Δu	Δv	Δb	Δy
1729.6 till 1737.7	8	E	0.740 ±0.011	0.712 ±0.003	0.649 ±0.002	0.742 ±0.005
2132.6 till 2133.6	2	B	-	0.715 ±0.006	0.651 ±0.006	0.747 ±0.002
4202.833	1	I	0.785	0.706	0.647	0.737
4241.708	1	I	0.783	0.710	0.648	0.747

B) Absolute photometry of HD 55540					
HJD 2 440 000+	V	b-y	m_1	c_1	Δa
2332.88	9.432	-0.060	0.240	-	0.066
4202.833	9.416	-0.074	0.300	0.871	0.070
4241.708	9.433	-0.085	0.302	0.861	0.071

TABLE XVIII. — *All available data on uvby photometry of HD 94660. I refers to ESO 50 cm telescope, D to Danish 50 cm.*

observer / tel.	(mean) J.D. + 2 440 000	DIFFERENTIAL OBS. HD94660 − HD94724 Δu_{instr}	Δv_{instr}	Δb_{instr}	Δy_{instr}
Manfroid,Heck D	2451.6	−0.600	−0.427	−0.425	−0.298
Heck I		−0.660	−0.458	−0.417	−0.300
Manfroid D	3175.2	−0.653	−0.465	−0.422	−0.292
H.H. I	4236.8	−0.662	−0.434	−0.408	−0.300
C.D. D	4301.8	−0.659	−0.431	−0.407	−0.295

source	epoch	ABSOLUTE PHOTOMETRY OF HD 94660 V	b-y	m_1	c_1
Cameron (1966)	'62−'63**	6.10	−0.057	0.193	0.757
GO	Nov.'71−Apr.'73**	6.116	−0.083	0.253	0.711
Heck et al. (1976)*	Feb.'75	6.113	−0.092	0.268	0.734
Heck (1977)*	Dec.'75	6.121	−0.090	0.241	0.743
this paper	Dec.'79	6.123	−0.079	0.245	0.706

(*) Values corrected for systematic effects, as mentioned in the introduction of this section. Notice that the corrected values for both comparison stars :

HD 93453 H :	V = 6.294	b-y = 0.106	m_1 = 0.201	c_1 = 0.910
H·M :	6.295	0.106	0.194	0.915
HD 94724 H :	6.421	0.034	0.157	0.905
H·M :	6.412	0.034	0.155	0.914

are consistent with our measurements (table XIII) within 0.01.

(**) Precise time of observation unknown.

TABLE XIX. — *Observations of HD 101065. The Heck et al. (1976) data, for which mean magnitudes and standard deviations are given here, have been corrected for the systematic effect in m_1.*

A) Standardized differential magnitudes of HD101065 − HD101128

HJD 2 440 000+	N	Δu	Δv	Δb	Δy
2447.8 till 2454.8	12	−0.683 ±0.014	−0.199 ±0.014	−0.865 ±0.006	−1.271 ±0.007
4239.843	1	−0.676	−0.214	−0.867	−1.271

B) Absolute photometry of HD 101065

HJD 2 440 000+	V	b-y	m_1	c_1	a
4239.843	8.005	0.452	0.392	−0.012	0.431

TABLE XX. — *Reddening corrections E(b-y) estimated from the following methods : Q-method (noted $E(b\text{-}y)_Q$) and [u-b] vs. $(b\text{-}y)_0$ calibration (noted $E(b\text{-}y)_{[u\text{-}b]}$) for the hotter stars of our sample ; β vs. $(b\text{-}y)_0$ calibration (noted $E(b\text{-}y)_\beta$) for the coolest stars in our sample ; (a, r) calibration for early A stars. References to the calibrations are given in the text, section 7.1.*

HD number	E(b-y) Q	[u-b]	(a,r)	β
5601	−0.004	−0.027		
19712	−0.011	−0.044		
25267	−0.015	−0.023		
50169			−0.017	
52350	+0.038	+0.021		
55892				−0.020
56022	−0.001	−0.009		
81009				−0.003
94660	−0.011	−0.048		
101189	+0.020	+0.020		

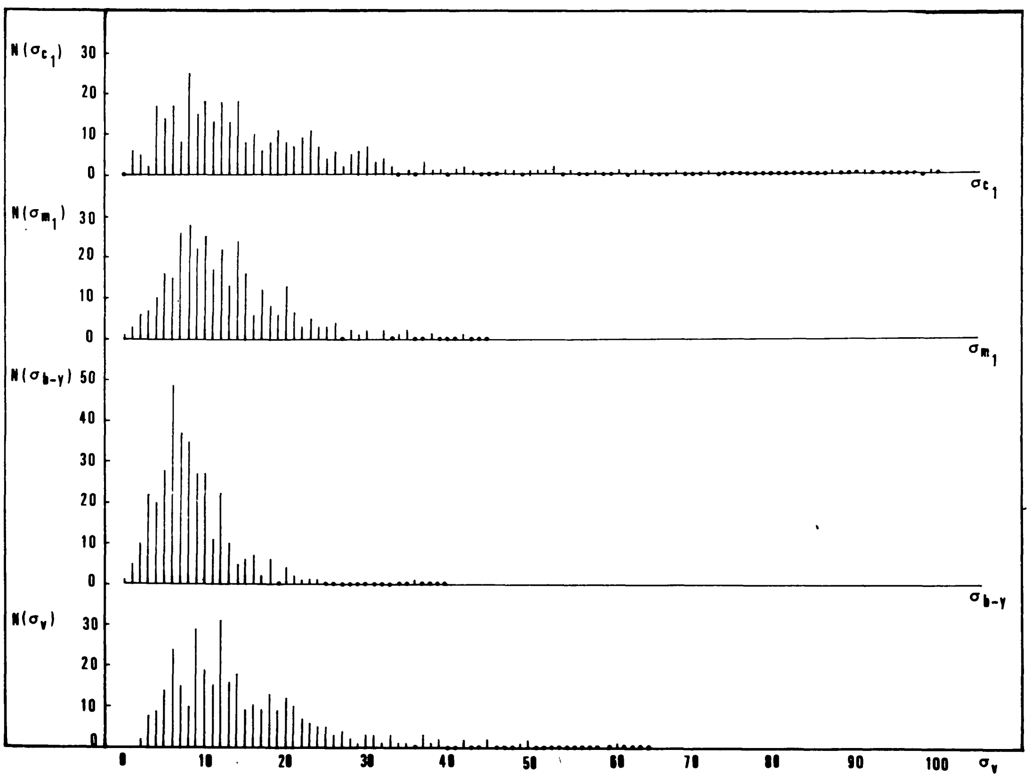

FIGURE 1. — Distributions of scatter between individual measurements of Ap stars published by Vogt and Faúndez (1979).

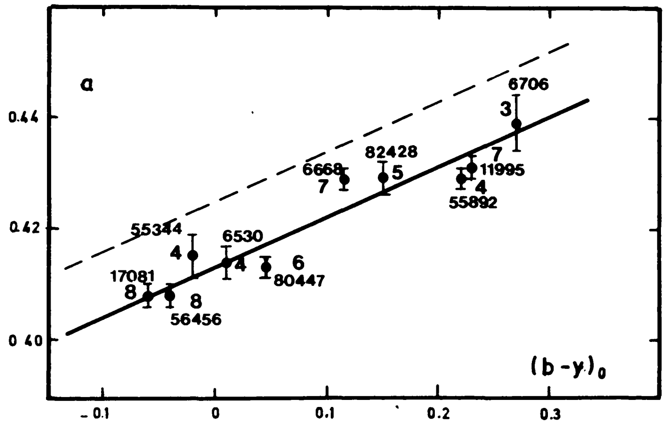

FIGURE 2. — The normality line for the Δa photometry. Dots are labeled by the HD number of the corresponding star, and by the number of nights that a-values were obtained. Error bars represent 2σ statistical errors on the mean a-values. The dashed line is the lower limit to the Ap-domain ($\Delta a = 0.012$) as defined by Maitzen (1976).

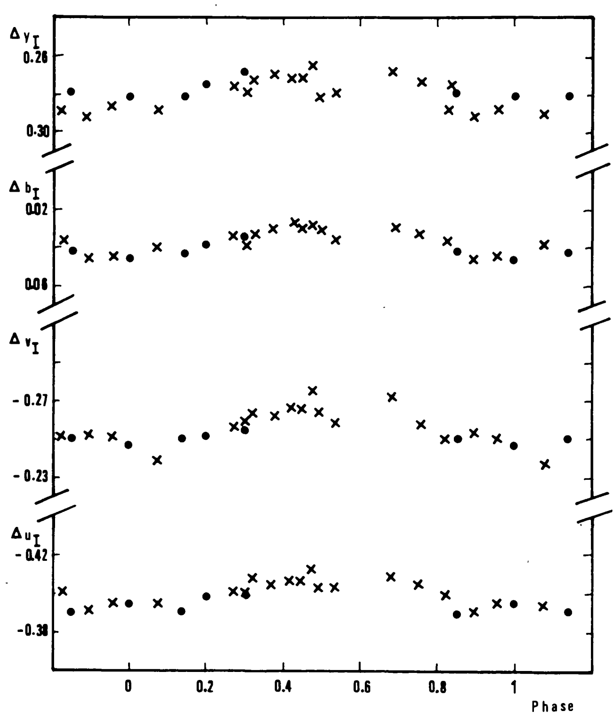

FIGURE 3. — The light variations of HD 55892, plotted according to the ephemeris ($\phi = 0$) = HJD 2 444 201.790 + 0.9363 E. Dots represent measurements of HMM, crosses represent measurements of HH in the sense HD 56456-HD 55892.

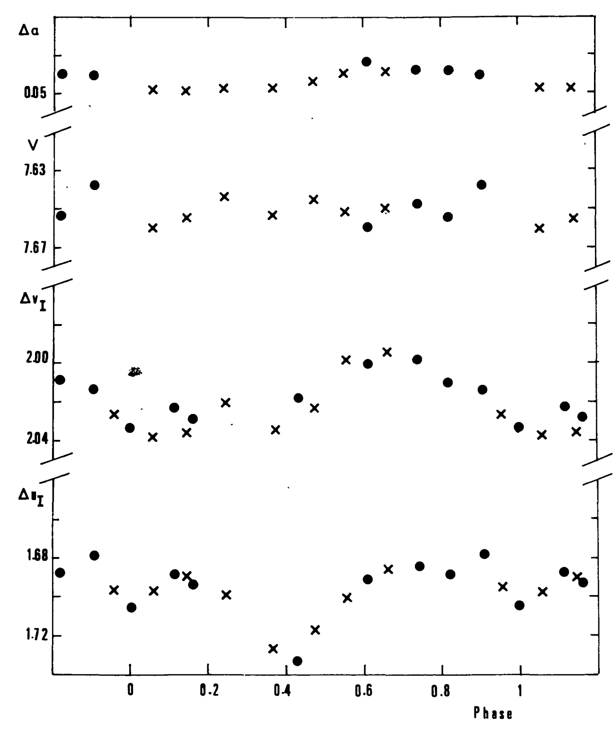

FIGURE 4. — The light variations of HD 5601, plotted according to the ephemeris ($\phi = 0$) = HJD 2 444 201.531 + 1.11 E. Differential observations in v and u are in the sense HD 5601-HD 6530. Symbols have the same meaning as in figure 2.

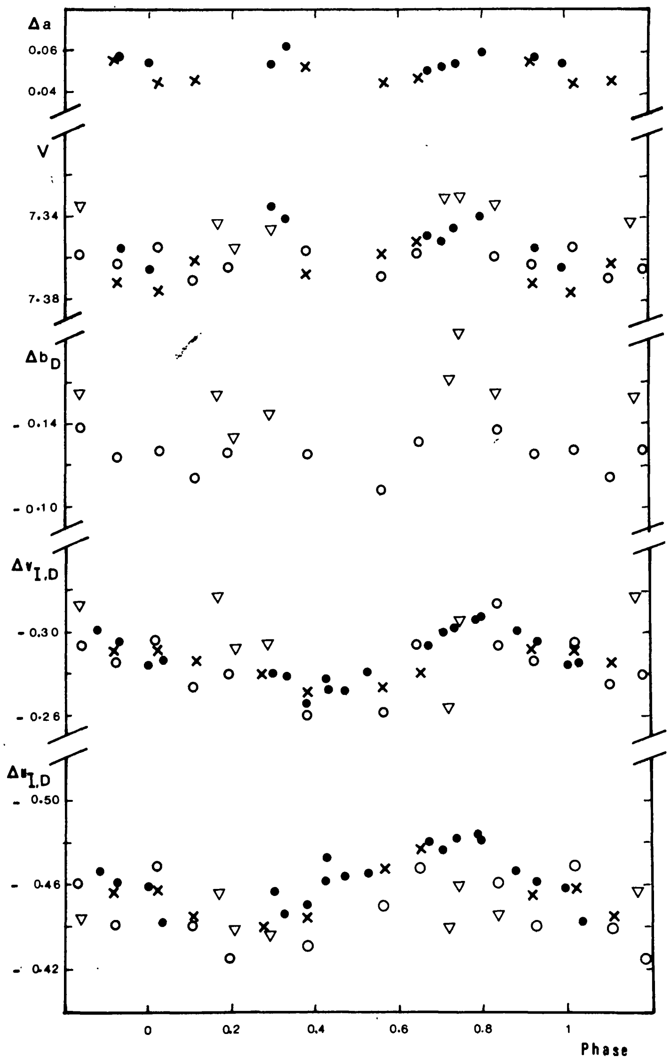

FIGURE 5. — The light variations of HD 19712, plotted according to the ephemeris ($\phi = 0$) = HJD 2 444 197.635 + 2.1945 E. Differential observations in v and u are in the sense HD 19712-HD 19739. Dots and crosses have the same meaning as in figure 3. Open circles represent the measurements of Gerbaldi and Delmas. Triangles are absolute measurements of VF, scaled to our ESO 50 cm measurements as explained in the text.

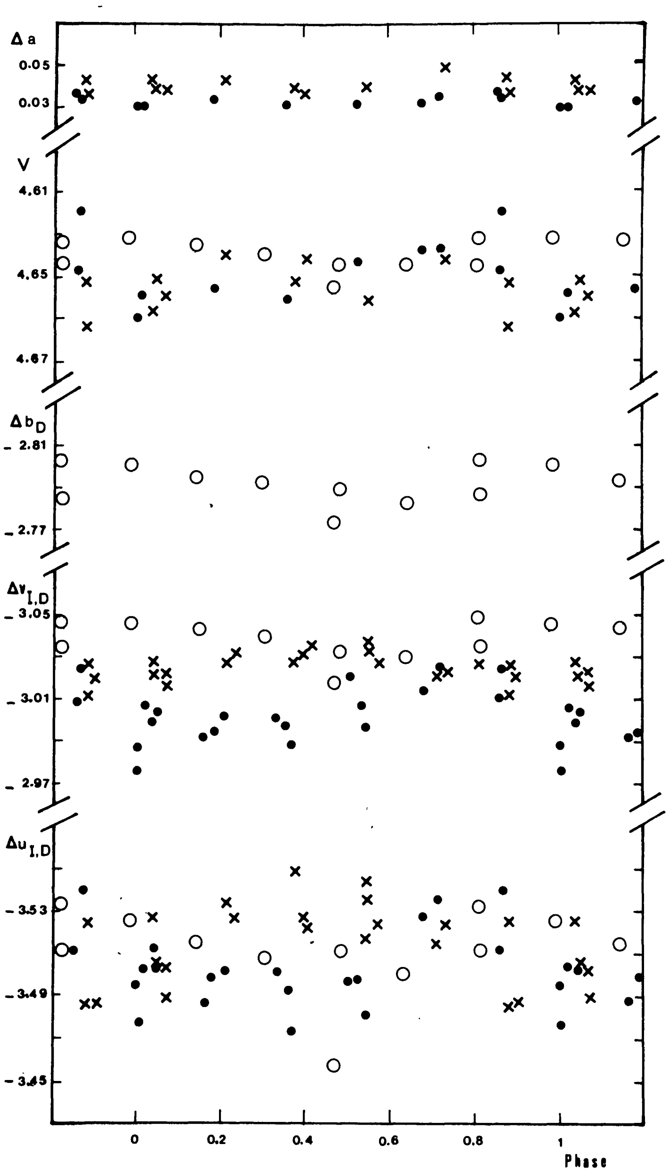

FIGURE 6a.

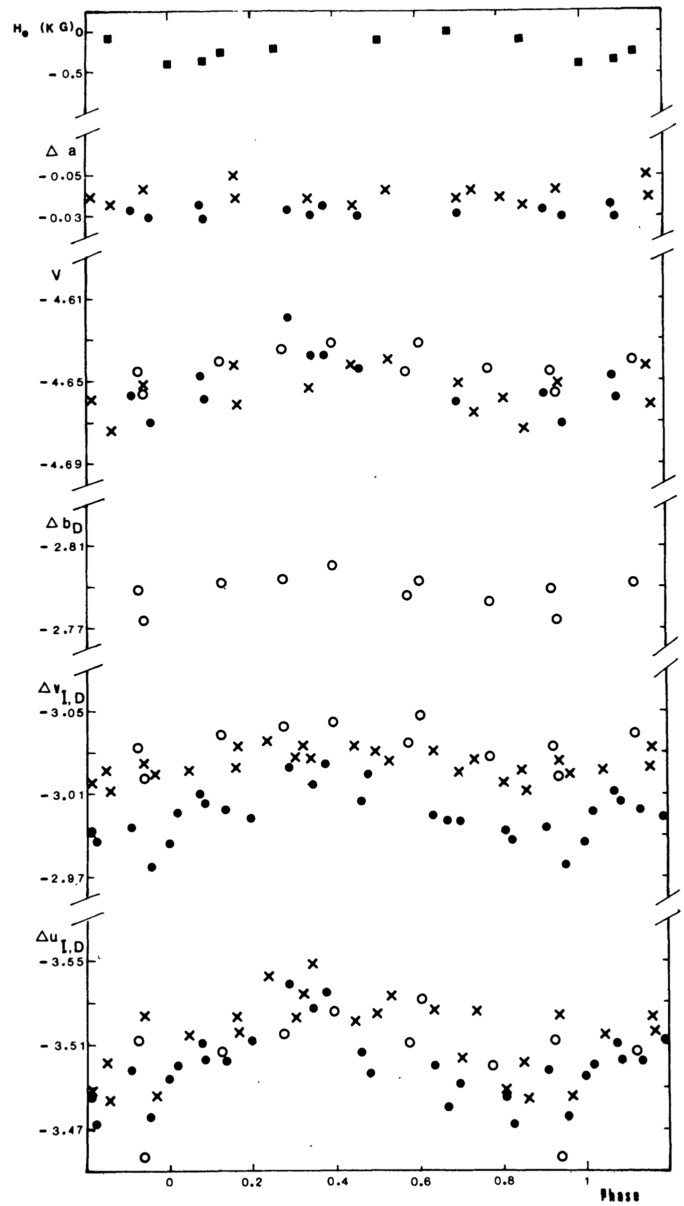

FIGURE 6b.

FIGURE 6. — The photoelectric measurements HD 25267-HD 24975 plotted according to the orbital period of $5^{d}_{.}95367$ (Fig. 6a) and according to a period of $1^{d}_{.}2094$ (Fig. 6b). Symbols as in figure 5. Phase zero corresponds to HJD 2 444 197.592.

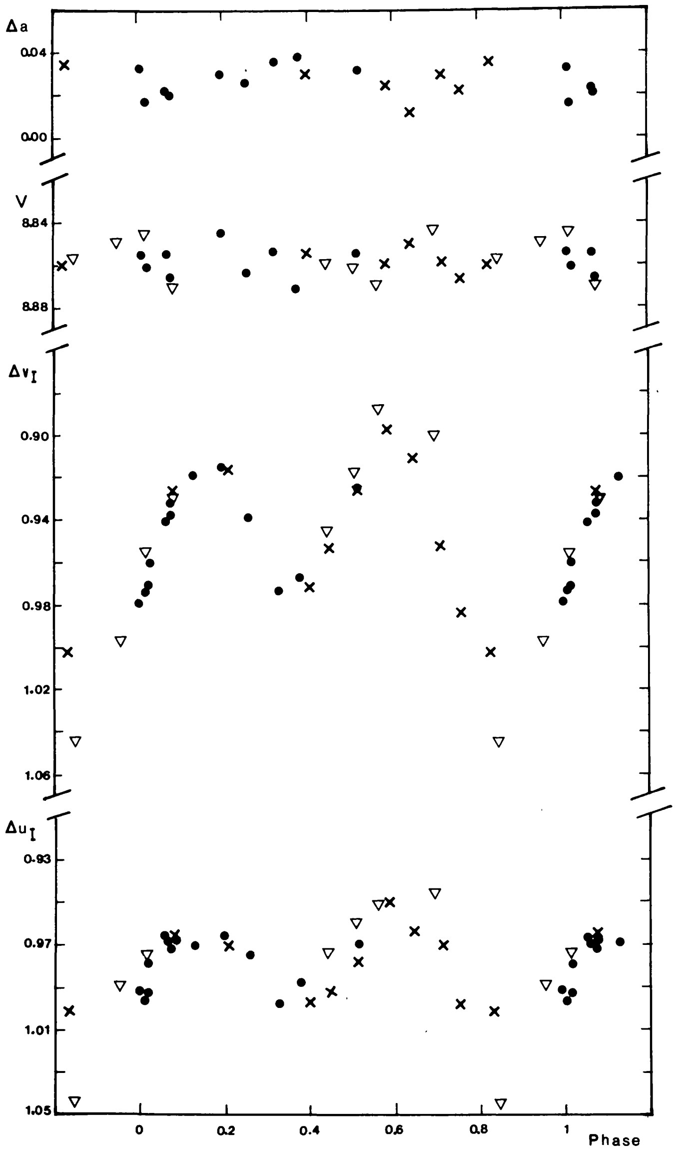

FIGURE 7. — The light variations of HD 30849, plotted according to the ephemeris (ϕ = 0) = HJD 2 444 197.621 + 15.864 *E*. Differential observations in *v* and *u* are in the sense HD 30849-HD 31640. Symbols have the same meaning as in figure 5.

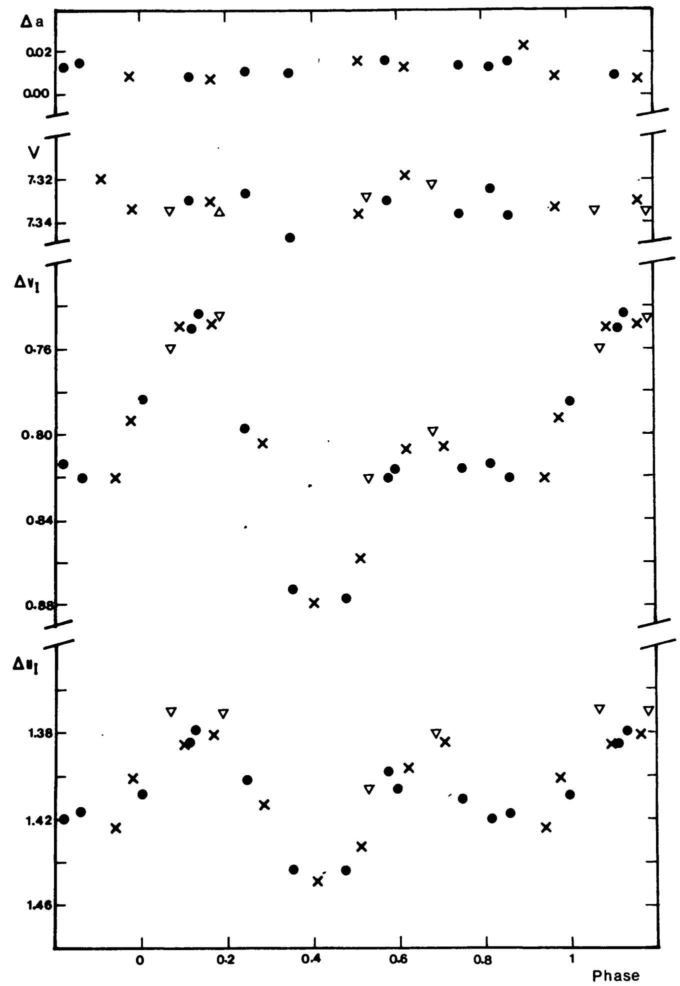

FIGURE 8. — The light variations of HD 38823, plotted according to the ephemeris (ϕ = 0) = HJD 2 444 198.705 + 8.635 *E*. Differential observations in *v* and *u* are in the sense HD 38823-HD 38856. Symbols have the same meaning as in figure 5.

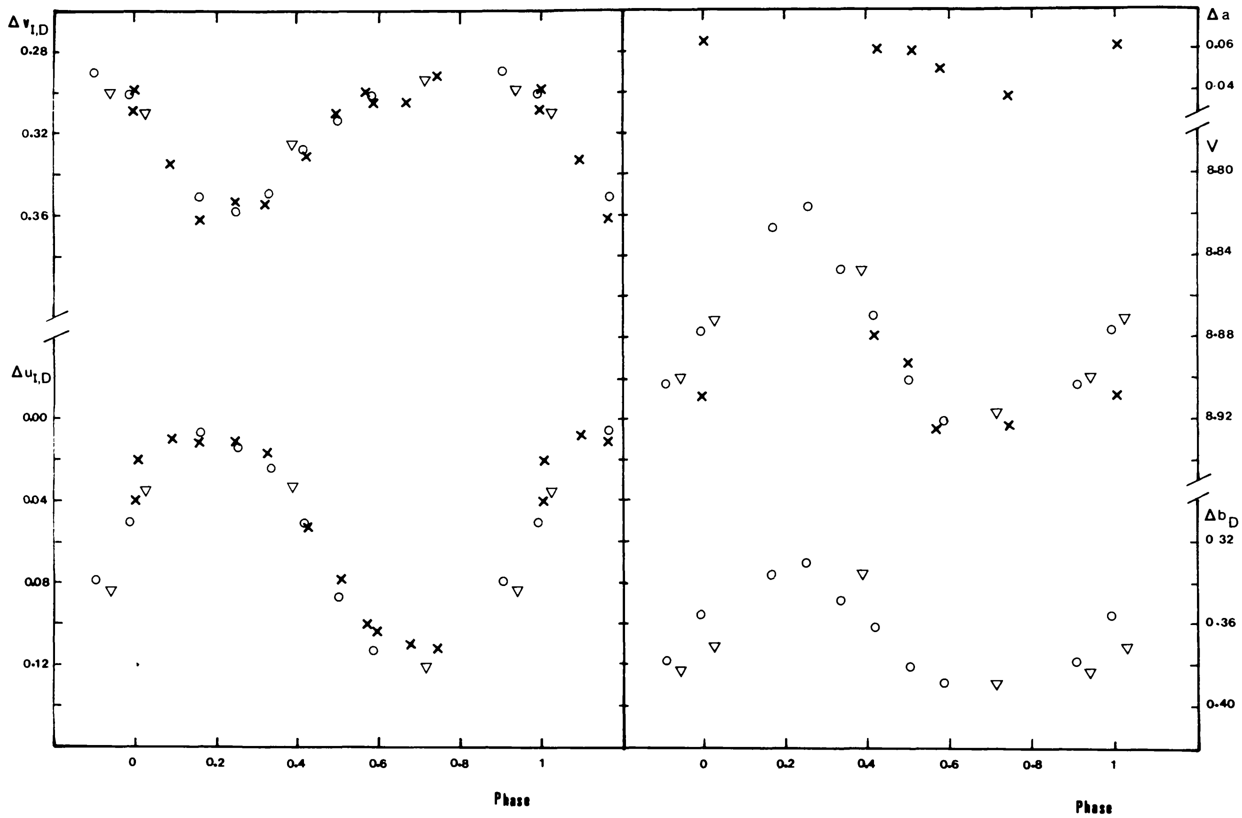

Fig. 9a

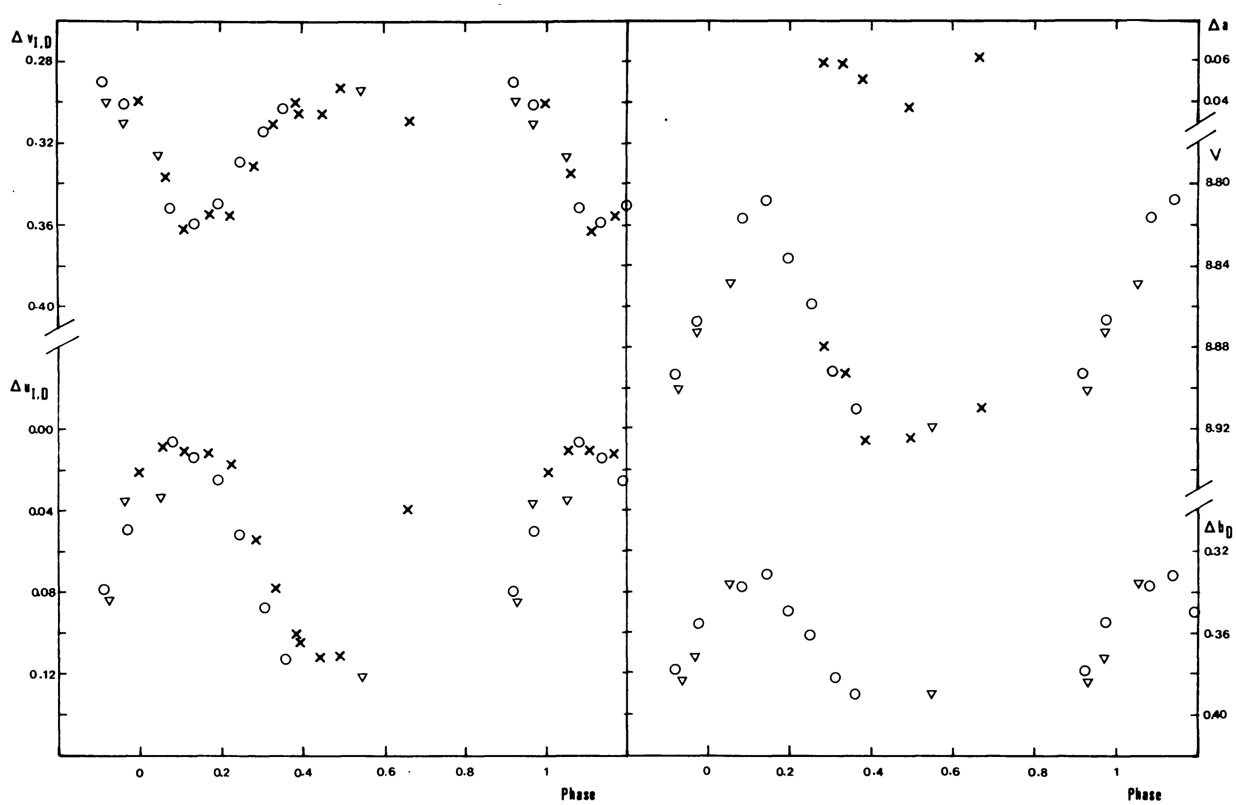

Fig. 9b

FIGURE 9. — The light variations of HD 53116, plotted according to the ephemeris (ϕ = 0) = HJD 2 444 230.732 + 11.978 *E* (Fig. 9a) and (ϕ = 0) = HJD 2 444 230.732 + 18.1 *E* (Fig. 9b). Differential observations are in the sense HD 53116-HD 53238. In this figure, open circles represent the measurements of Doom. Other symbols have the same meaning as in figure 5. An arbitrary shift in *b* and *y* magnitude was introduced to reconcile the absolute *b* and *y* data with Doom's differential measurements.

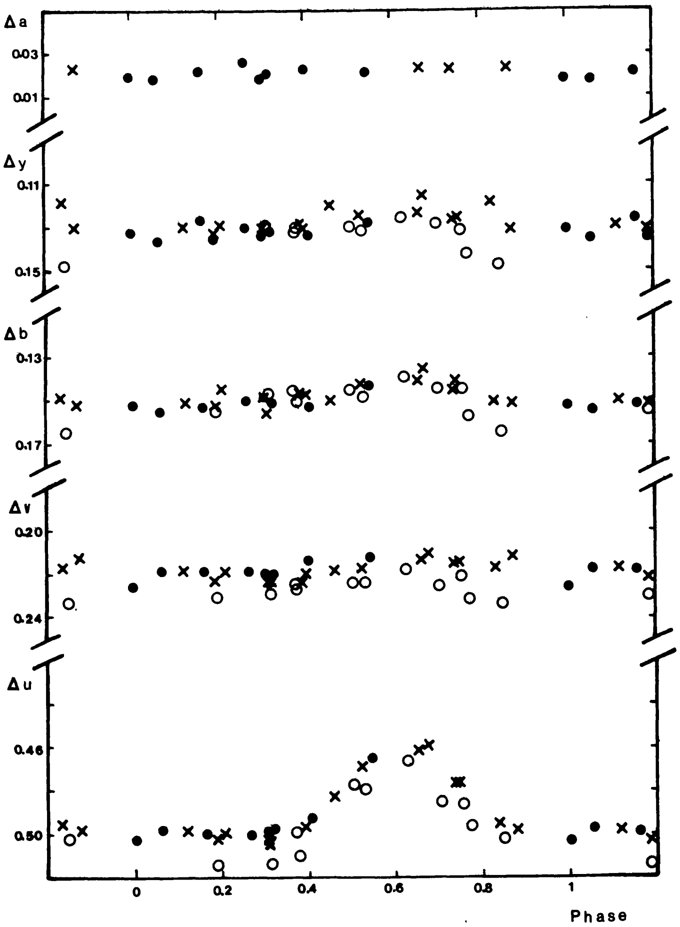

FIGURE 10. — Plot of standardized differential magnitudes in the sense HD 56022-HD 56456 and Δa according to the ephemeris (ϕ = 0) = HJD 2 444 199.807 + 0.9183 *E*. In this figure, open circles represent the Heck *et al.* (1976) observations. Other symbols as in figure 5.

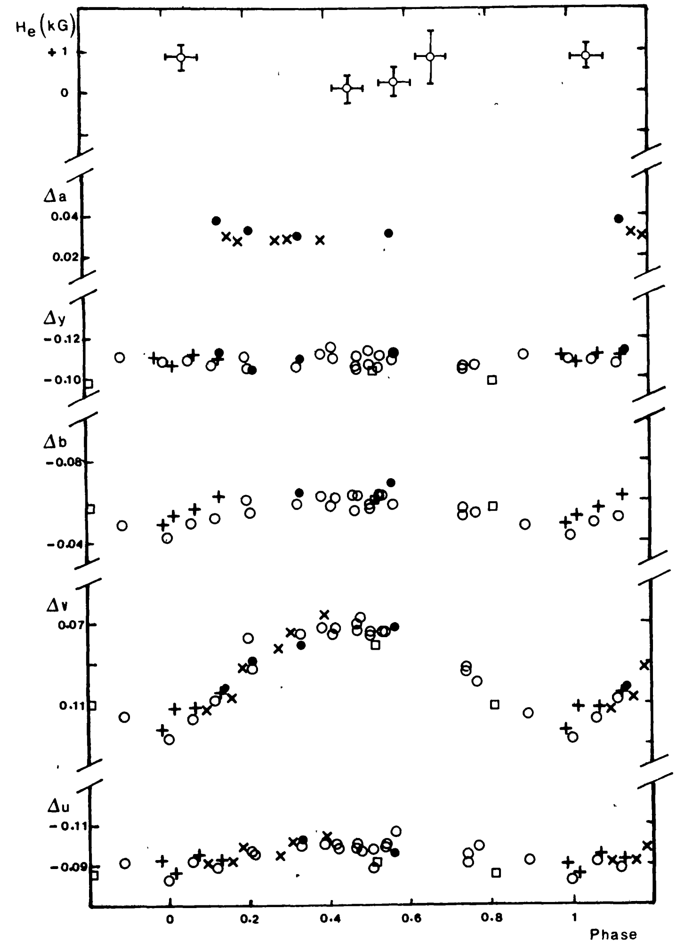

FIGURE 11. — The light and H_e variations of HD 81009, plotted according to the ephemeris (ϕ = 0) = HJD 2 441 782.80 + 33.97 *E*. Standardized differential observations are in the sense HD 81009-HD 80447. Dots and crosses have their usual meaning. Open circles represent Wolff's (1975) data and squares represent the absolute measurements of GO. Magnetic field data are from van den Heuvel (1971).

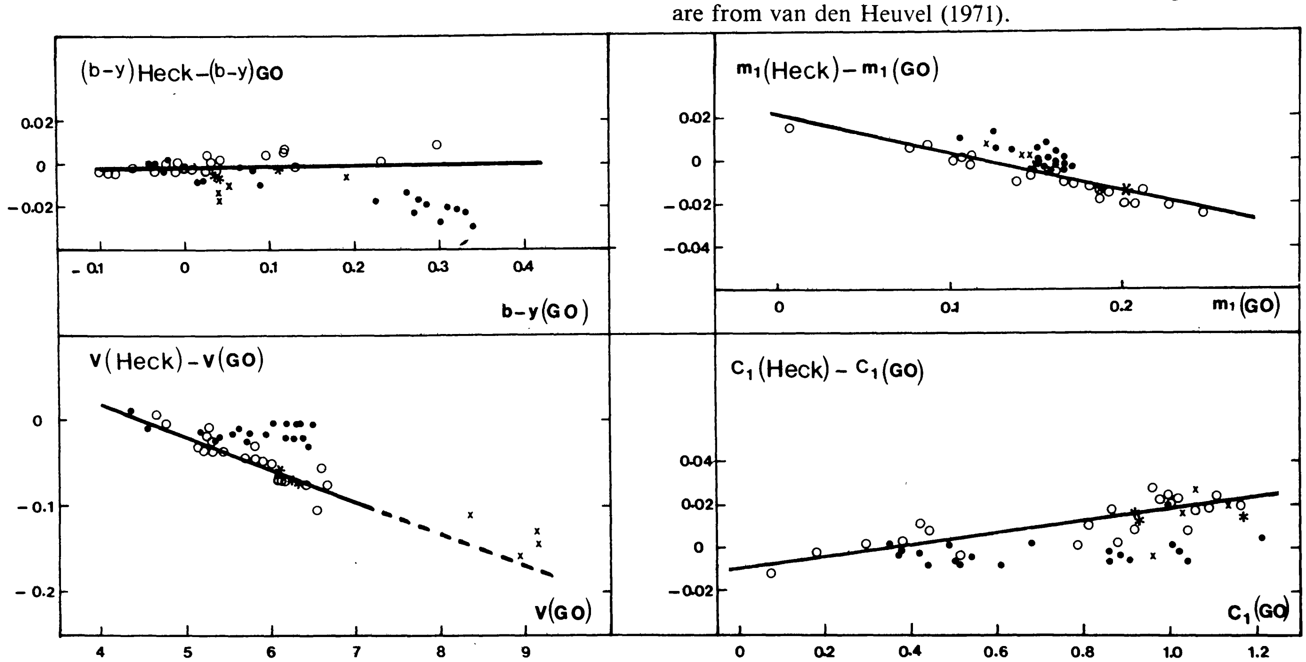

FIGURE 12. — Comparison of the results of Heck (1977) with those of GO. Dots refer to the October 1975 run of Heck, open circles to his December 1975/January 1976 run. Stars which are not in the GO catalogue, but which were observed in the present investigation are indicated by crosses ($V < 7^{th}$ mag) or asterisks. Full lines represent a linear approximation of the mean trend in Heck's second run (open circles). The results for the fainter stars indicate that a second order correction depending on the apparent magnitude might be considered in *V*, *b-y* and m_1.