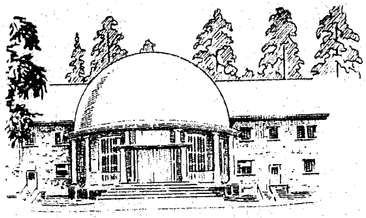

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PHOTOELECTRIC INVESTIGATION OF MAGNETIC AND SPECTRUM VARIABLE STARS

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Summary

The light variations of fifteen magnetic and spectrum variables have been investigated at the Lowell Observatory. This paper is concerned with only the first nine stars. The photometric results obtained indicate that there is a close relationship between the light and magnetic variation and that the curves of the light variation and of the magnetic variation coincide; the phase of minimum light concurring with the phase of the maximum positive magnetic field. Amplitudes of brightness variation in the ultraviolet are as a rule greater than those in blue and yellow. There is a connection between the period length and the amplitude of light variation. It seems possible that a very great number of A0p stars should show periodic brightness variations of smaller amplitude. The photometric behavior of these stars is more consistent with the "oscillator theory" than with the "oblique rotator theory".

Introduction

It is known that a considerable number of stars of spectral type A have a peculiar spectrum. Most of these peculiar A stars, have abnormally strong lines of $\mathrm{Si}_{\mathrm{II}}$ or $\mathrm{Sr}_{\mathrm{II}}$, and in many, $\mathrm{Ca}_{\mathrm{II}}$ was noted to be rather weak for the particular type. In such spectra there also appear certain metallic lines which are not present in the spectra of normal A stars. Morgan, (1), in a study of the spectra of class A, showed that a one-dimensional system fails to define these spectra uniquely and that there is definite evidence for some physical variability in addition to temperature and surface gravity. Subsequent work by Walther, (23), has indicated that similar pecularities occur in the spectra of 13% of all stars of types B8 to F0. About 10% of the peculiar A stars show conspicuous variation in the strengths of certain absorption lines, Deutsch, (9). Many of these stars also show evidence of general magnetic fields of the order of a few kilogauss in their atmospheres, Babcock, (10). And finally, some show variation of brightness and color with amplitudes of the order of a few hundredths of a magnitude (Provin, Gutnick, Stibbs, Jarzebowski).

One would like to see if there exists a strong correlation between the spectral and magnetic changes on the one side and the light variations on the other. In general, the photoelectric measurements of these stars require very great accuracy because their amplitudes of brightness variation are very small. The author made as many precise photoelectric measurements of these stars as was possible. These measurements should contribute on the one hand towards an explanation of the phenomenon of alteration of the magnetic field strength of the magnetic stars, and on the other hand, they might help explain whether these stars represent a rare phenomenon or do they occur often because they are at a certain stage in the evolution of many stars.

Equipment and Procedure

The observations were made with three telescopes at the Lowell Observatory: the 42-inch, 21-inch, and 24-inch (Morgan Telescope) reflectors. No systematic differences could be found among the results obtained by measuring with each of these telescopes. The measures were made at three

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effective wave lengths. The yellow, blue and ultraviolet were isolated by a Corning 3384 filter, Schott GG13 + BG28 and Schott UG2 filters respectively. Two comparison stars were always used when suitable near-by stars were available — the choice of comparison stars being made on the basis of color. In case there were no comparison stars of similar luminosity near the investigated star, then the brightness of the variable star was decreased by a neutral filter Schott NG3 and so reduced to match the luminosity of a selected field star. Measurements of such stars were made only in yellow and blue light. The observations were chiefly made near the time of culmination. During some nights every star was measured for a long period of time—nearly 4 hours —with one or both of the comparison stars, and on most of the nights 4 to 7 measurements were made for each color and for each star. Particularly, careful attention was given to the proper functioning of the photoelectric equipment. The author himself designed and constructed the photometer, direct current amplifier, and power supply for this program. One selected multiplier 931A was used for all observations.

Technique of Reduction

The differential extinction was very small for most of the stars—smaller than 0.005 magnitudes. No star was observed specifically during the program for extinction determination. The mean seasonal extinction coefficients determined at the Lowell Observatory were used in the reductions. A mean value was found for approximately 4 to 7 comparisons between the investigated star and the comparison star. The internal probable error of the measurements was of the order of $\pm 0\overset{m}{.}001$ to $\pm 0\overset{m}{.}002$ magnitudes. The time of the observations was determined to ±10 sec. and was expressed in fractions of a heliocentric Julian Day. The majority of these stars have a period greater than one day and consequently certain difficulties exist in the determination of a particular period. When observing a short period star, it is quite possible in the course of one night to determine very precisely the epoch of its maximum or minimum and the comparison of several such epochs can be used to determine the period.

The following method of reduction was applied for the determination of the period:

From magnitude differences which have been plotted on a diagram according to the time of observations, it is not difficult to determine graphically an approximate period and then to include those observations which are situated near a minimum or a maximum. (On some nights, a star was observed for a longer period of time, either to confirm or exclude the existence of a short period.) For observations selected in such a manner it is now very easy to calculate numerically the length of the period in this way:

Let $t_0 t_1 t_2 \ldots.\ t$, be the times of single observations belonging to equal phases of the light curve.

And if $P_1 P_2 P_3$ are various approximate and nearly equal period lengths which are possible (one can find them out from the diagram).

Then $P_2 = P_1 + p$, $P_3 = P_1 + 2p$;

where p should be any intergral number

One then forms the following differentials:

$$\begin{array}{ll}
t_1 - (t_0 + N_{11} P_1) = v_{11} & t_1 - (t_0 + N_{21} P_2) = v_{21} \\
t_2 - (t_0 + N_{12} P_1) = v_{12} & t_2 - (t_0 + N_{22} P_2) = v_{22} \\
\vdots & \vdots \\
t_n - (t_0 + N_{1n} P_1) = v_{1n} & t_n - (t_0 + N_{2n} P_2) = v_{2n}
\end{array}$$

$$\begin{array}{l}
t_1 - (t_0 + N_{31} P_3) = v_{31} \\
t_2 - (t_0 + N_{32} P_3) = v_{32} \\
\vdots \\
t_n - (t_0 + N_{3n} P_3) = v_{3n}
\end{array}$$

N is a whole number so chosen that: $v_{ik} \leqq \frac{1}{2} P_i$ and since $P_1 < P_2 < P_3$ we assume the relation $A_1 > A_2 < A_3$ where $A_i = \sum_{k=1}^{n} v_{ik}^2$ and now have, in general, a polynomal of the form $A(P) = a\ P^2 + bP + c = 0$.

We want to determine a period P_i such that $A(P_i)$ becomes a minimum. The parabola $A(P)$ has its minimum for $\frac{d\ A(P)}{d\ P} = 0$ and it then follows that the period is $P_0 = -\frac{b}{2\ a}$

The coefficients a and b can be easily determined from the relations:

$$\begin{array}{l}
P^2_1\ a + P_1\ b + c = A_1 \\
P^2_2\ a + P_2\ b + c = A_2 \\
P^2_3\ a + P_3\ b + c = A_3
\end{array}$$

With the assumptions outlined above, solutions can always be found. The probable error of the observations can be found from the sum of the squares of the deviations, Σv_{ik}^2 for $P_i = P_0$.

In a similar manner the epoch of the minimum or of the maximum can be calculated. At first one calculates the differentials:

$$\begin{array}{ll}
t_0 - (T_1 + M_{10} P_0) = w_{10} & t_0 - (T_2 + M_{20} P_0) = w_{20} \\
t_1 - (T_1 + M_{11} P_0) = w_{11} & t_1 - (T_2 + M_{21} P_0) = w_{21} \\
\vdots & \vdots \\
t_n - (T_1 + M_{1n} P_0) = w_{1n} & t_n - (T_2 + M_{2n} P_0) = w_{2n}
\end{array}$$

$$\begin{array}{l}
t_0 - (T_3 + M_{30} P_0) = w_{30} \\
t_1 - (T_3 + M_{31} P_0) = w_{31} \\
\vdots \\
t_n - (T_3 + M_{3n} P_0) = w_{3n}
\end{array}$$

$T_1\ T_2\ T_3$ are the three equidistant approximate values of the desired epoch.

The solution is similar to that of the previous case. Here for $T_1 < T_2 < T_3$ we have $B_1 > B_2 < B_3$ and $B_i = \sum_{k=1}^{n} w_{ik}^2$

This method proved to be practical and simple and it is recommended because it furnishes the value of the period, the epoch and the probable errors of the observations.

The Observations

Table I gives a summary of pertinent data for the nine variable stars and their comparison stars. Six spectrum and magnetic variables and three primary photometric standard stars were also observed. These observations will be published later together with previous observations of the spectrum and magnetic variables which have been investigated in 1958 and 1959 at the University Observatory in Graz.

HD15089 (ι Cas.)

The variability of the lines in the spectrum of the star HD 15089 was first pointed out by W. W. Morgan, (1, 2). He detected rapid variations in the intensities of $\lambda 4549$, $\lambda 4558$ lines and large changes in the K line. He has characterized the star as belonging to the group of chromium stars, in which the lines of $\mathrm{Cr}_{\mathrm{II}}$ and $\mathrm{Sr}_{\mathrm{II}}$ are strong. The prototype of this group is the well known spectrum variable 73 Draconis. The lines of HD 15089 are too broad and can not be measured for the Zeeman effect. Deutsch, (3), found the period of variations in its spectrum to be 1.740 days. HD 15089 has two companions, all three components having common proper motion. The nearer companion (B) is 2 seconds, while the more distant companion is 7 seconds from the primary star. The B component is 2.26 magnitude fainter than the primary star; the more distant companion is at least a full magnitude fainter than B. Both companions were included in the diaphragm when the observations were made. The first photoelectric observations of HD 15089 were performed by S. S. Provin, (4). He used the period of A. J. Deutsch for the reduction and found that the star varies in visual light with an amplitude of about $0\overset{m}{.}03$. In blue light the amplitude was approximately $0\overset{m}{.}015$ and the color change is therefore $0\overset{m}{.}015$; the star was found to be bluest at minimum light. These measurements were made in 1951-52. Since then, this star was observed by K. Bahner, (5). He corrected the length of period to 1.7405 days.

The author made photoelectric observations during 27 nights using the 21-inch and the 24-inch telescopes (43 observational points for yellow and 48 for blue) between November 8, 1960 and January 16, 1961. HD 15849 was used as the primary comparison star, and the second comparison star was HD 15648. Table II gives the data of the observations together with the magnitude difference of HD 15089 (+ neutral filter NG3) minus HD 15849 for blue and yellow light. The number of comparisons from which the mean was taken is denoted by N. The epoch given is the mean epoch of the comparisons. The probable error of the mean magnitude difference is also noted.

The dispersion of these observations, despite the small probable errors in the magnitudes, is very great. In order to better see the mean light curve of the variations, means of three or four observations were formed for the intervals of the phase in Table II; Table III gives these mean data. These are plotted against the phase in Figure 1. Using these normal points, one gets the elements of the light variations as follows:

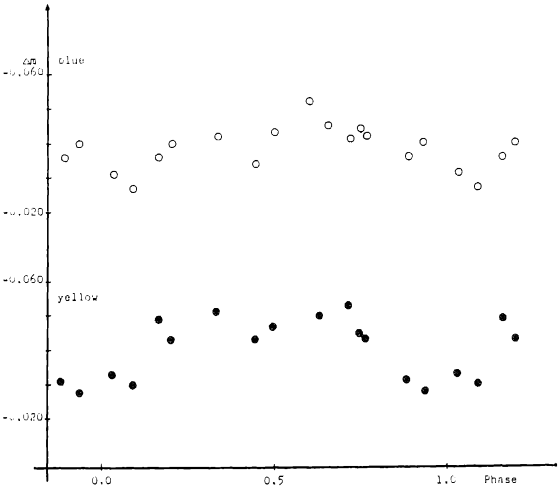

Figure 1. Mean Light Curves for HD 15089.

$$\text{Minimum light} = \text{JD } 2437247.79 + 1.7418\ \text{E}$$
$$\pm\ 0.04 \pm 0.0010\ \text{p.e.}$$

One obtains a more accurate period when the epoch of minimum determined by Provin is used. The minimum of light then agrees with the minimum of the K line, within the errors of determination of the epoch.

Deutsch, Minimum of K line = JD 2431700.95
Provin, Minimum of light = JD 2433902.46
Rakos, Minimum of light = JD 2437247.79
P = 1.741551 days

This value differs very little from the value found for the period which the author calculated, from his own observations only, using the above-mentioned method for the evaluation of the elements. Other examples amply confirm the accuracy of this method (Stars HD 32633, HD 65339). The curve of light variation has a symmetric form and is of a peculiar shape. Since the time K. Bahner observed it, this light curve has remained the same. The color change is very small and the star is bluest at minimum light. The author's observations show a mean amplitude for the light variation in the yellow to be $0\overset{m}{.}021$ and in the blue $0\overset{m}{.}019$.

It would be very interesting to find out how the light curve behaves in ultra-violet.

HD 18296 (21 Persei)

Describing this star Morgan, (1), says, "In this one spectrum are incorporated most of the pecularities known among A stars". No variations sufficient to identify the star as a typical spectrum variable have been detected. H. W. Babcock, (6), took many spectral photographs and made measurements of the magnetic field. He found a large variable magnetic field with extreme values of −1270 to +1350 Gauss. Although the variations of the field showed no regularity, a considerable diversity in the field intensity was indicated by various elements.

No previous photometric investigation of HD 18296 has been reported. In this investigation the measurements were made during 23 nights with the 42-inch and the 24-inch telescopes (50 observational points for yellow and 53 for blue light), covering the period between October 18, 1960 and January 16, 1961. Usually the two comparison stars, HD 18157 and 18367, were used and it was therefore possible to monitor the accuracy of the observations. Table IV gives the observational data together with the magnitude difference HD 18296 (+ neutral filter NG 3) minus HD 18157 for blue and yellow light, and also the magnitude difference between both comparison stars for blue light. Also given are the number of comparisons N and the probable error. Despite the small internal probable error, the dispersion of the observational points is great. This fact indicates that besides the mean periodical variations there exist additional irregular changes of luminosity — similarly as with HD 15089 and other spectrum variable and magnetic stars. Only when three or four observations are combined in an arithmetic mean, (Table V), is the dispersion comparable with the dispersion in the magnitude differences between both comparison stars.

The magnitude differences from Table V are plotted against phase in Figure 2.

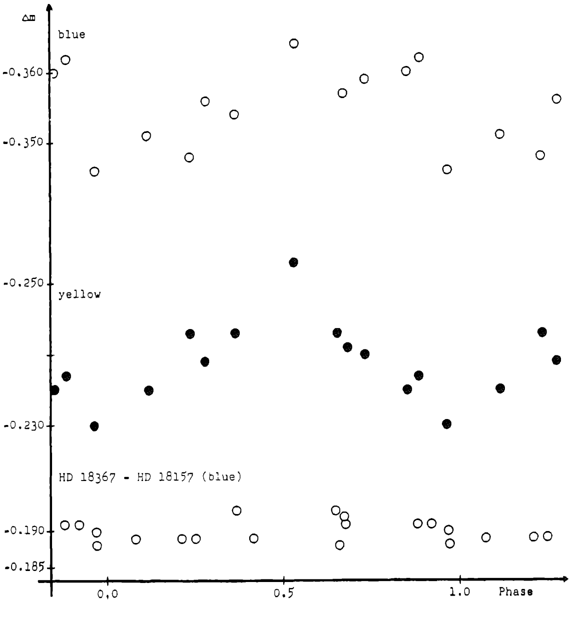

Figure 2. Magnitude Difference Found for HD 18296 and comparison stars.

The observations indicate that the light of HD 18296 varies periodically. The elements of the light variation are:

Minimum light = JD 2437316.9 + 1.729 E
± 0.2 ± 0.003 p.e.

The mean amplitude of the light variation is:

Δm (yellow) = $0\overset{m}{.}016$
Δm (blue) = $0\overset{m}{.}012$

The curve of the light variation has a symmetric form for yellow light. In blue light it has a distinctly asymmetric form. Apparently, the irregular changes of brightness are greater in the blue than in the yellow. The asymmetry may be deceptive. It is interesting to note that some variable stars of this class (HD 32633, HD 34452) have irregular light changes which are smaller in blue than in yellow light, that is in the opposite sense to those of HD 18296 and of many other stars. The color change is very small, and again the star was bluest at minimum light.

The photometric results are now compared with the results of the magnetic observations. Figure 3 shows measurements of the magnetic field by H. W. Babcock, (6), reduced under the assumption that the period is 1,729 days. The dispersion is certainly very great but it is still possible to recognize a periodic curve. It may be that this dispersion would turn out to be significantly smaller if one were able to determine the period more accurately — Babcock's observations were made within an interval which was longer than 2 years. It should be taken into consideration also that when measuring the magnetic field, the different lines yielded different field strengths, and the author did not have at his disposal the exact times of Babcock's measurements. It seems also that this star belongs to the group Alpha mag-

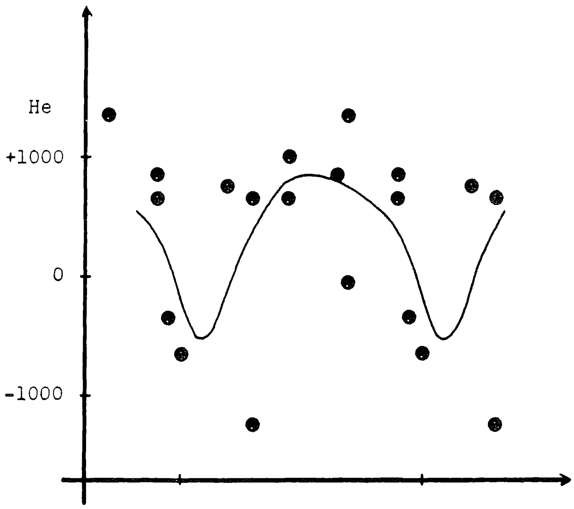

Figure 3. Magnetic Variation for HD 18296 observed by Babcock.

netic variables (according to Babcock's classification). No changes of the measured radial velocity could be correlated with the fluctuations of luminosity or with the changes in the magnetic field. It would be quite profitable to continue the magnetic and ultra-violet photometric observations.

HD 25354

HD 25354 is a spectrum variable star whose spectrum is peculiar to an unusual degree, (6). Variable lines of Eu_{II} are present with high relative intensity. Their variation is opposite to that of the Cr lines. Babcock was not able to confirm any regularity. His measurements indicate that the star has a magnetic field but it is relatively weak. The magnetic field intensity is variable.

No previous photometric investigation of HD 25354 has been made. These photometric measurements were made during 21 nights with the 42-inch and the 24-inch telescopes (23 mean observational points for yellow, 20 for blue, and 21 for ultra-violet respectively), covering the period from October 18, 1960 to January 16, 1961. Table VI gives the observational data for the magnitude difference HD 25354 minus HD 25411 for yellow, blue and ultra-violet light. The magnitude differences in Table VI are plotted against the phase in Figure 4.

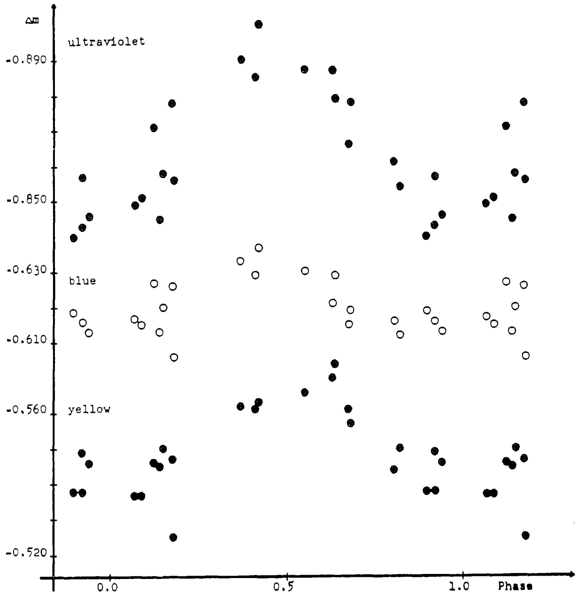

Figure 4. Mean Light Curves for HD 25354.

The light of HD 25354 varies periodically. The elements of the light variations are:

$$\text{Minimum light} = 2437315.14 + 3.9001\ E$$
$$\pm 0.10 \pm 0.0003\ \text{p.e.}$$

The dispersion of the single observations corresponds to the probable error; this star shows no additional irregular fluctuations of luminosity. The mean amplitude of its light variation is:

Δm (yellow) $= 0\overset{m}{.}032$;
Δm (blue) $= 0\overset{m}{.}022$;
Δm (ultra-violet) $= 0\overset{m}{.}044$

The curve of the light variation has a symmetric form for both yellow and blue light. For the ultra-violet light the curve is a little asymmetric. The amplitude of the change of light in the ultra-violet is considerably greater than in the yellow and blue. It seems that this property characterizes many stars of the same class. Except for HD 224801 which was observed by Provin, prior to this work no investigations have been made in the ultra-violet light of spectrum variables or magnetic stars. All measurements of these stars in ultra-violet light, which the author made, show this property. Due to the fact that the amplitude of the light alteration in blue is smaller than in the yellow the star HD 25354 itself is bluest at minimum light.

This star is very suitable for photometric measurements. Its amplitudes of light variation are relatively great and its period is short. Moreover, the position of its comparison star is only a minute of arc away. It is desirable then, that the observations might be continued in the future. A small instrument could be used for these measurements. A continuous series of measurements of the magnetic field might show whether the changes of the magnetic field happen periodically or are irregular.

HD 25823 (41 Tauri)

The spectrum is rather similar to that of HD 18296, (6). Babcock's measurements indicate that the star has a magnetic field showing reversal of polarity. No photometric investigations of this star have previously been made. Measurements were made during 24 nights with the 42-inch and the 24-inch telescopes (34 observational points for yellow and 45 for blue respectively) covering the period from October 18, 1960 to January 16, 1961. Table VII gives the date of the observations with the magnitude difference HD 25823 (+neutral filter NG3) minus HD 25626 for yellow and blue light. The magnitude differences in Table VII are plotted against the phase in Figure 5. The light of HD 25823 varies periodically. The elements of the light variation are:

$$\text{Minimum light} = \text{JD } 2437309.65 + 11.94\ E$$
$$\pm 0.03\ \text{p.e.}$$

The mean amplitude of the light variation is $0\overset{m}{.}035$ for yellow and $0\overset{m}{.}033$ for blue light and the curves of the light variation have a symmetric form. The change of color is very small, and yet the star appeared bluest at minimum light. As in the case of HD 18296 this star also shows great irregular changes of luminosity especially at the minimum of blue light. Their periods, however, are very different. Future observations of the magnetic field will show

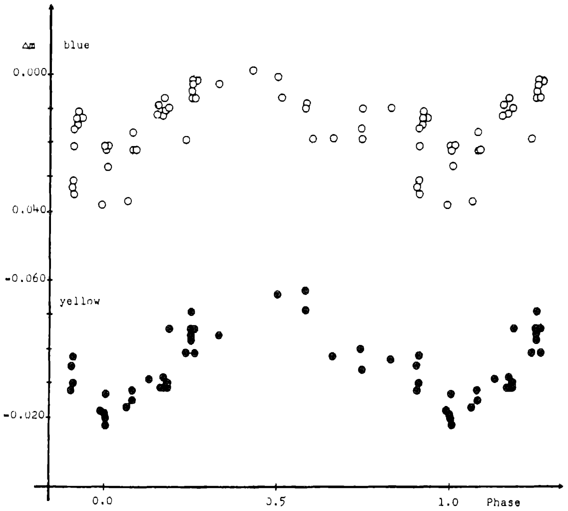

Figure 5. Mean Light Curves for HD 25823.

if any correlation exists between the variation of the magnetic field intensity and the light variation. It will be rather interesting to find out how its light variation will appear in the ultra-violet light.

HD 32633

This star has a peculiar spectrum. The lines of Si_{II} Cr_{II}, and Fe_{II}, are strong, while K is exceptionally weak, and sometimes shows multiple components. No intensity variations could be noticed. The star has a strong, rapidly reversing magnetic field, (6). Babcock at first supposed that its magnetic variations were irregular, but later on he found a four day period, (10). The first photoelectric observations were made by T. Jarzebowski, (7). He investigated this star during 28 nights in 1959 and 1960. His measurements were made only in blue light, and he assumed that the light varied irregularly.

The author made photoelectric observations during 19 nights with the 42-inch and the 24-inch telescopes (36 observational points for yellow, 36 for blue and 37 for ultra-violet respectively) covering the period from November 8, 1960 to January 16, 1961. The primary and secondary comparison stars were HD 32428, and HD 32733 respectively. Table VIII gives the date of observations for the magnitude difference HD 32633 minus HD 32428 for yellow, blue and ultra-violet light. The magnitude differences from Table VIII are plotted against the phase in Figure 6.

It was found that the light of HD 32633 varies periodically. The elements of its light variation, which have been calculatd from the available material in Table VIII, are:

$$\begin{aligned}\text{Maximum light} = \text{JD } 2437307.20 &+ 6.429\ \text{E}\\ \pm\ 0.05 &\pm\ 0.005\ \text{p.e.}\end{aligned}$$

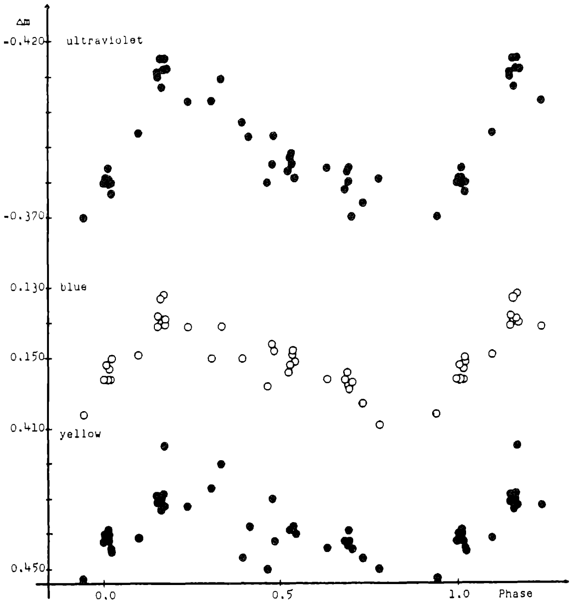

Figure 6. Mean Light Curves for HD 32633.

The results obtained from the investigation enabled us to establish more easily the epoch of the maximum than the epoch of the minimum light. The phase given in Table VIII, and in Figure 6 as well, was so calculated that it is zero for 1.5 days before maximum light. The mean amplitude of the light variation for yellow light is $0^{m}.024$, for the blue $0^{m}.028$, and for the ultra-violet $0^{m}.042$. The curve of the light variation has an asymmetric form for all three colors. The light curve for the yellow light shows greater

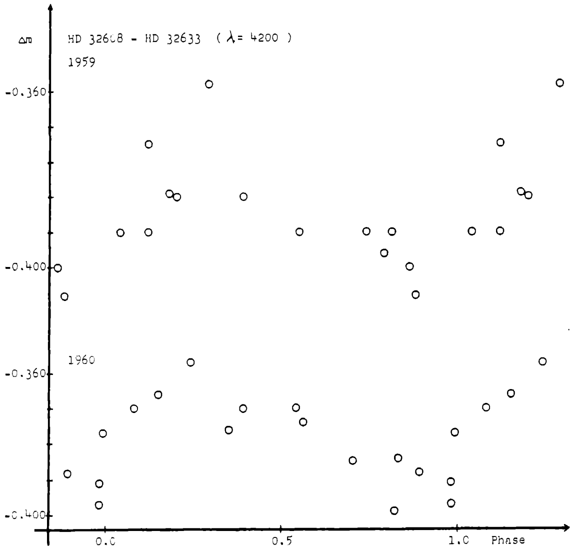

Figure 7. Observations of T. Jarzebowski Plotted With Period of 6.429 Days.

dispersion than for the blue. The color change is very small and the star was bluest at maximum light. It is easy to demonstrate that the observations made by T. Jarzebowski could be reduced with the above period. The magnitude differences obtained by T. Jarzebowski is plotted against the phase in Figure 7.

Here, too, the phase has zero value 1.5 days before the light maximum. Both curves, that for 1959 and that for 1960 as well, show great similarity with the curve in Figure 6. In this manner one can get three epochs for the maximum:

Jarzebowski	1959	Max. light	= JD 2436573.6
Jarzebowski	1960	Max. light	= JD 2436959.9
Rakos	1961	Max. light	= JD 2437307.2

One can also now rectify the period. It is:

$$P = 6.4351 \text{ days}$$
$$\pm 0.0020 \text{ p.e.}$$

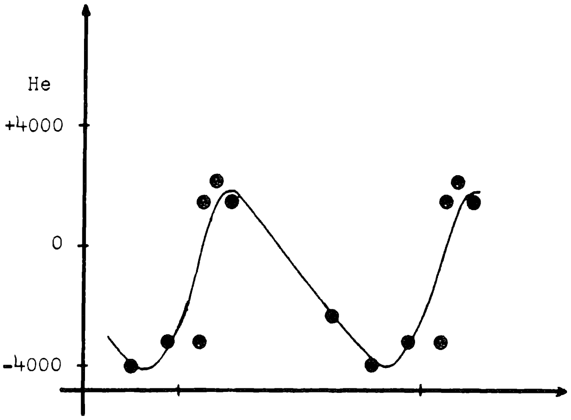

Figure 8. Magnetic Variation for HD 32633.

A change of period is easily possible. This period might be decreasing slowly but its values are still within the scope of the error limits. Since 1959 the shape of the light curve may have changed to some extent. The observations of the years 1959 and 1960 are unfortunately too few to permit us to be more definite. Also Babcock's observations of the magnetic field show a distinct asymmetric curve, which displays a steep ascent and a flat descent. This is shown in Figure 8. The maximum of the positive magnetic field strength coincides with the minimum of the curve of light for this star:

Maximum of
positive magnetic field = JD 2436152.7
Minimum of light = JD 2436152.8

This shows that HD 32633 belongs in the group of α magnetic variables (according to the specification of Babcock). Like the other variable stars, HD 32633 shows small radial velocity variations. The author has too few measurements at his disposal to be able to find a possible correlation between these variations and the other properties of the star.

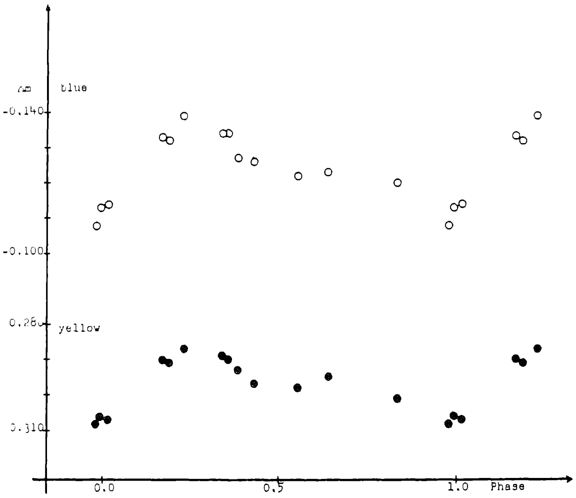

Figure 9. Mean Light Curves for HD 34452.

HD 34452

This star is a spectrum variable. Miss C. Westgate, (8), discovered that the He_{I} lines varied in strength, and she suspected certain other lines of changing. Several other lines vary in one sense, while some others in turn display changes in the opposite sense. A. J. Deutsch, (9), has found that the elements of variation are:

He_{I} maximum = JD 2431334.90 + 2.4660 E

The star probably has a magnetic field but this is not positively established, (6). S. S. Provin made observations of HD 34452 during 15 nights, and he found light variation indicated but the evidence was inconclusive, (12). Measurements at the Lowell Observatory were made on 18 nights with the 24-inch telescope (36 observational points for yellow and 36 for blue light) covering the period from November 21, 1960 to January 14, 1961. The primary comparison star was HD 34578 and the second comparison star was HD 34334. Table IX gives the data for the observations with the magnitude difference HD 34452 (+ neutral filter NG3) minus HD 34578 for yellow and blue light. The dispersion of the values, however, is greater in Table IX than might be concluded from the probable error of the single observations. In order to obtain a better mean curve, normal values were derived for equal intervals of the phase. These mean values have been given in Table X. The magnitude differences in Table X are plotted against phase in Figure 9. The light of HD 34452 varies periodically. The elements of the light variation are:

Minimum
light = JD 2437295.88 + 2.4660 E
± 0.01 p.e.

The length of the period was taken from Deutsch, (9). Unfortunately, his measurements were made too long ago to compare the present behavior of the light curve to the curve of spectral variation. The curve of the light variation has an asymmetric form and is similar to the light curve of HD 32633. The color change is very small and yet the star was bluest at maximum light — similar to HD 32633. The mean amplitude of the light variation is for the yellow $0^{m}.020$ and for blue $0^{m}.026$. Further investigations of this star are needed.

HD 65339

This star is a spectrum variable with rather large variations in the intensity of the lines $\mathrm{Ti}_{\mathrm{II}}$, $\mathrm{Mg}_{\mathrm{II}}$ and probably of some other elements. The spectrum is also peculiar and rich in the metallic lines. It is a magnetic variable showing a very strong reversible field. The observed limits for He are +3510 and − 5120 Gauss, (10). Babcock found the period of magnetic variations to be 8.0248 days. The first photoelectric measurements were made by Jarzebowski, (7, 11). He stated the elements of the light variation to be:

Minimum light = JD 2437002.4 + 8.024 E

This star was investigated by the author during 18 nights with the 24-inch telescope (18 observational points for yellow, 16 for blue and 18 for ultra-violet light) covering the period from December 20, 1960 to January 16, 1961. Only one comparison star was used (HD 65301). Table XI gives the observational data for the magnitude difference HD 65339 minus HD 65301 for yellow, blue and ultra-violet light. The magnitude differences from Table XI are plotted against the phase in Figure 10.

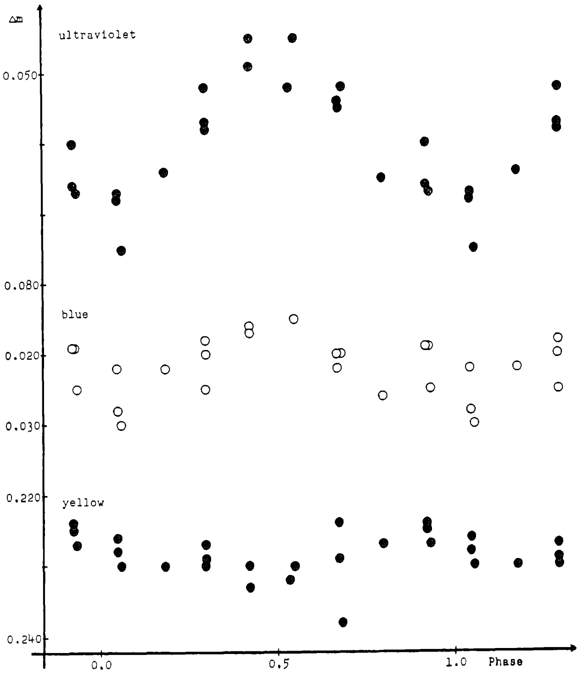

Figure 10. Mean Light Curves for HD 65339.

The mean amplitude of the light variation for yellow light is $0^{m}.006$, for blue $0^{m}.010$ and for ultra-violet $0^{m}.023$. The light curves for the ultra-violet and the blue are in some degree asymmetric i.e. similar to the majority of the stars mentioned in this paper. It should be added that the light curve for the yellow has an essentially greater asymmetry, and indicates a considerable phase shift; the minimum in yellow occuring about 0.4 period later than in blue and ultra-violet. T. Jarzebowski, too, has noticed this effect. He found also that the phase shift occurs about 0.2 period later than in the blue. The light curves of the other stars show only small differences in phase for various colors; the differences were very small and always near to the error limit. If one compares the Lowell data with the measurements of T. Jarzebowski it seems as if the light curve has changed in the meantime. The general mean luminosity of the star deos not seem to be constant. The star in blue light decreased by about $0^{m}.01$ during the period from 1959 to 1960, and a year later its brightness in blue decreased still more by approximately $0^{m}.015$. At present, of course, it is not possible to state definitely if these phenomena represent a general property of all the stars of this group. The observations should be extended over several years, as it appears more likely that this star is an exceptional one. Its position in the period-amplitude relationship may also be explained in this way (see subsequent discussion). The author's observations give the epoch of minimum for the blue and ultra-violet light:

Minimum light (blue and ultra-violet)
= JD 2437306.4 ± 0.1 p.e.

Using T. Jarzebowski's minima it is possible for us to determine exactly the length of the period. The elements of the light variation are then:

Minimum light (blue and ultra-violet)
= JD 2437306.4 + 8.00552 E

One can demonstrate with this period, as in the case of HD 65339, that its minimum of light in blue and ultra-violet occurs at the maximum of the positive magnetic field strength. According to Babcock:

Maximum positive magnetic field
=JD 2435857.41

2435857.41 + 102 P = 2436673.97 — and this is approximately minimum light according to Jarzebowski

2435857.41 + 143 P = 2437002.4 — and this is approximately minimum light according to Jarzebowski

2435857.41 + 181 P = 2437306.4 = Minimum light according to Rakos.

In this manner this rule is established without exception for all the known magnetic variables of the α type. These results are very difficult to explain physically.

HD 219749

The lines in the spectrum of this star are too wide to be measured for the Zeeman effect. The K line is moderately strong. Several metallic lines are about 5A wide, (6). S. S. Provin first made photoelectric observations of this star. He observed it during 5 nights and found some indication of variability. The author made photoelectric measurements during 30 nights with the 42-inch telescope (74 observational points for yellow, 63 for blue and 61 for ultra-violet) covering the period from September 20, 1960 to November 25, 1960. HD 219891 was used as the primary and HD 219668 as the secondary comparison star.

Table XII gives the observational data together with the magnitude difference HD 219749 minus HD 219891 for the yellow, blue and ultra-violet light, and the magnitude difference between both comparison stars for yellow light. Despite the circumstance that both of the comparison stars have a large difference in spectral class, the magnitude difference was constant during the period of observation. The dispersion in the observations of HD 219749 (Table XII) is noticeably greater than might be concluded from the probable error in the magnitudes of single observations. This fact signifies that, besides the regular fluctuations of brightness, there could be additional irregular ones. Only when the arithmetical mean is made for 4 to 5 points does the dispersion become comparable with the dispersion in the magnitude difference between both comparison stars (Table XIII). The magnitude differences from Table XIII are plotted against the phase in Figure 11. The observations indicate that the light of HD 219749 varies periodically. The elements of the light variations are:

$$\text{Minimum light} = \text{JD } 2437236.27 + 2.604 \text{ E}$$
$$\pm 0.03 \pm 0.001 \text{ p.e.}$$

The mean amplitudes are:
Δm (yellow) $= 0\overset{m}{.}018$ Δm (blue) $= 0\overset{m}{.}023$
Δm (ultra-violet) $= 0\overset{m}{.}044$

The curve of the light variation for yellow and blue has to some degree an asymmetric form with a steep ascent and a flat descent similar to those of HD 25823. In the ultra-violet the curve is essentially different. It has a narrow deep minimum and a wide maximum and gives the same impression as the light curves of binary stars. The color change is very small and the star is bluest at the maximum light.

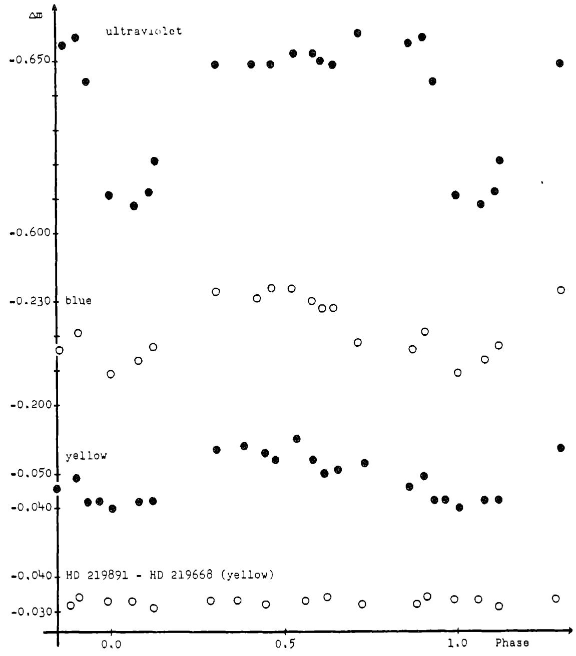

Figure 11. Mean Light Curves for HD 219749 and Magnitude Differences Found for Comparison Stars.

HD 220825

HD 220825 is a "strontium star" with a weak K line and rather limited equivalent widths for lines of the metals. The lines are too broad for the usual measurements of the Zeeman effect. The visual estimates suggest evidence of a magnetic field on most of the plates and of a reversal in polarity, (6). S.S. Provin observed this star on 6 nights and found some indications of variability, (12). The measurements in this paper were made during 18 nights with

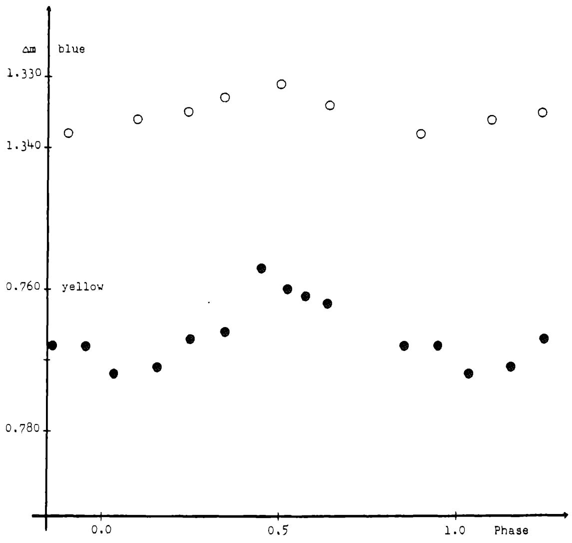

Figure 12. Mean Light Curves for HD 220825.

the 42-inch telescope (44 observational points for yellow and 65 for blue light) covering the period from September 20, 1960 to November 19, 1960. Table XIV gives the observational data for the magnitude difference HD 220825 (+ neutral filter NG3) minus HD 220858 for yellow and blue light. The amplitude of the variation of this star is very small and, in order to obtain a better mean light curve, arithmetical means were derived from the data in Table XIV for each phase interval. These mean values are given in Table XV. The magnitude differences from Table XV are plotted against the phase in Figure 12. The light of HD 220825 varies periodically. The elements of the light variation are:

$$\text{Minimum light} = \text{JD } 2437198.48 + 0.5805 \text{ E}$$
$$\pm 0.03 \pm 0.0003 \text{ p.e.}$$

The curve of the light variation probably has an asymmetric form and is similar to the light curve of HD 219749. The color change is very small and yet this star was bluest at minimum light. The minimum of the yellow light has a considerable phase shift and occurs about 0.2 period later than in blue light. Therefore this star has a certain similarity to HD 65339. The phase shift of HD 65339 effects the whole curve but for HD 220825 it causes a greater asymmetry in yellow light. The maximum light in the yellow and blue show no phase shift. The mean amplitude of light variation for yellow light is $0\overset{\mathrm{m}}{.}011$ and for the blue $0\overset{\mathrm{m}}{.}007$. Among all the magnetic and spectrum variable stars this one has the shortest period. HD 220825, unfortunately, is not easy to observe from Flagstaff because it has a relatively great zenith distance. However, observations of this star should be continued and also be made in ultraviolet light.

Conclusion

In addition to these nine stars the following ones were observed: 56 Arietis, γ Arietis, HD 204411, HD 71866, HD 224801 and 73 Draconis. All results will be published later in another paper. On the basis of preliminary results one can state that γ Arietis shows periodic light changes with the same period as the spectral variations, and 56 Arietis has a much shorter period than had been previously assumed. The other stars, too, show the periodical fluctuations of luminosity.

Table XVI gives a summary of the known spectrum and magnetic variables and the results of the measurements of the nine stars which are particularly discussed in this paper. Below these are mentioned the other stars as far as they are known by the author. Provin investigated 56 Arietis but its length of period should doubtlessly have been shorter than he had assumed and therefore it is not included in the table. The second column of Table XVI contains the spectral types and an indication of their possible variation. All together, 12 stars of the 18 are spectrum variables. It has been assumed that magnetic stars with periodic changes of field strength are, ipso facto, variables. This assumption may not be correct. One can demonstrate that two other regularities may possibly appear in spectrum and magnetic variable stars.

First, in almost all cases the form of the light curve (symmetric or asymmetric) is connected with the color index curve. If the light curve is asymmetric the star is then bluest at maximum light, and for the symmetric curve the star is bluest at minimum light. This rule should not be taken as universal. The color variation for the majority of stars is very small so that a more accurate investigation of the dependence of the form of the light curve on the color variation curve is impossible because of observational errors.

The second regularity concerns the length of the period and the mean amplitude in the yellow and blue light. The seventh column of Table XVI gives one-half (amplitude in yellow + amplitude in blue) of the light curve. If one plots this value with the logarithm of the period one gets Figure 13 and the following relation: ½ (amplitude yellow + amplitude blue) = $0\overset{\mathrm{m}}{.}014 + 0\overset{\mathrm{m}}{.}016 \log P$ (days).

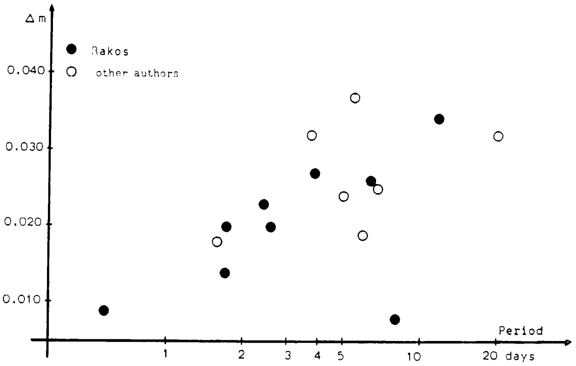

Figure 13 Period-Amplitude Relationship for Data given in Table XVI.

Similar relations between the amplitude of the light change and the period length have been discovered for δ Cephei and Mira Ceti stars. Figure 13 shows only those stars listed whose light curves for yellow and blue are known. The investigations of HD 25354, HD 32633, HD 65339 and HD 219749 observed by the author and of HD 224801 observed by Provin show that the light curve in the ultraviolet has approximately twice the amplitude of that in the blue or yellow. This shows that the amplitude in blue depends very much on the color transmission of the filter used. In this way, one can explain the amplitude of the light change of HD 125248 of $0\overset{\mathrm{m}}{.}053$ found by Stibbs. His measurements, were made without any filter.

Star 153882 was investigated briefly in yellow light; there were only 13 observational points with a mean error of $+0^{m}.005$ for a single observation. Perhaps this is also the reason why this star has such a low position in Diagram 13.

Star 220825 is situated apparently beyond the period-amplitude relationship. Maybe this relationship is not generally true, it could be that this star has its own particular eccentricities, or, perhaps its period is remarkably short for example, less than one day.

Finally HD 215441 apparently does not fit on the diagram. Babcock has measured the magnetic field of this star and found it to be equal to 34K Gauss.

It would be very valuable to investigate and to obtain the precise light curves, including ultra-violet light, of as many stars as possible. It could be, that the amplitude of the light change for ultra-violet light shows a much better correlation to the period length. Therefore it is necessary to pay attention to the homogeniety of the observational material. The investigations made thus far have proved that the spectrum and magnetic variable stars have, without exception, periodical variations of light of small amplitude.

The light variations are for the magnetic, as well as for the spectrum variable stars, similar in nature. It is certain that the mechanism causing variations of the magnetic field and spectrum lines must also cause variations in luminosity. Two different possible theories have been considered — "the oblique rotator theory and the oscillator theory". The oblique rotator theory assumes that the magnetic axis of the stars is inclined to the axis of rotation; which in turn is inclined to the line of sight. The rotation of the star will thus produce apparent variations of the magnetic field, (13, 14, 15, 16, and 17). The oscillator theory assumes that the star has a periodic oscillation and that the movement of the material of the star involves the variation in the magnetic field, (18, 19, 20, and 10). The oblique rotator theory can hardly explain the brightness fluctuations of the magnetic stars. There is no physical reason to suppose that the brightness of the surface of a star would increase or decrease at one magnetic pole only. Similar artificial suppositions have been made to account for spectrum variability on the grounds of the oblique theory.

A rather simple oscillator theory, which assumes that the radial oscillations cause the light variations, postulates the existence of extremely strong magnetic fields in the interior of the star. In this way attempts are made to explain the periods of a few days in length. The purely mechanical oscillations of these stars should at best have periods lasting only a few hours. For these stars there should be horizontal oscillations similar to those proposed by Cowling or torsional oscillations suggested by Ferraro and Memory, (21).

The results of the observations in this paper indicate that it is probable that changes of luminosity happen because of periodical changes of density, of pressure, and of temperature on the stellar surface. This interpretation corroborates also the investigations of the anomalous abundance of the heavy elements in the magnetic stars, (22). On the basis of 5 stars only, M. Hack concludes that the abundance excesses are stronger in the case of stars with fast variations of the field with inversion of polarity than in the case of stars with the maximum absolute value of their magnetic fields. The oblique rotator theory assumes that the magnetic field strength in a star remains generally constant, and so the abundance excess should depend more on the field strength than on the rotation of the star.

It is obvious, however, that there is a great need for further, more accurate, photometric and spectroscopic measurements, and also for more measurements of the magnetic field as well. In this way, these phenomena, pertaining to spectrum and magnetic variable stars, might be better treated in a statistical manner. It is also important that various kinds of observations be made close to the same time.

March 30, 1962 Lowell Observatory

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TABLE I List of Stars

No.	HD No.	BD No.	1900	1900	m_{pv}	m_{pg}	Sp.	Remarks
1	15089	66°213	$2^h20^m.8$	+66°57'	4.59	4.73	A_{5p}	
	15849	66 223	2 27.9	+67 02	7.37	7.71	F_2	1. comparison star
	15648	66 219	2 25.9	+66 59	8.1	8.1	A_0	2. comparison star
2	18296	31 509	2 51.2	+31 32	5.18	5.18	A_{0p}	
	18157	30 465	2 49.8	+31 11	8.0	8.4	F_5	1. comparison star
	18367	30 469	2 52.0	+31 05	7.9	8.9	K_0	2. comparison star
3	25354	37 866	3 56.6	+37 47	7.87	7.87	A_{0p}	
	25411	37 867	3 57.2	+37 43	7.7	7.7	A_0	1. comparison star
	25307	37 862	3 56.2	+37 40	8.5	8.5	A_0	2. comparison star
4	25823	27 633	4 00.5	+27 21	5.27	5.27	A_{0p}	
	25626	27 628	3 59.0	+27 20	7.9	8.0	A_2	1. comparison star
	-	27 634	4 00.6	+27 15	8.5	-	-	2. comparison star
5	32633	33 953	4 59.5	+33 47	6.94	6.89	B_8	
	32428	32 879	4 58.1	+32 11	6.43	6.51	A_3	1. comparison star
	32733	34 948	5 00.2	+34 24	7.8	8.2	F_5	2. comparison star
6	34452	33 1008	5 12.4	+33 39	5.39	5.39	A_{0p}	
	34578	33 1013	5 13.4	+33 52	5.16	5.30	A_{5p}	1. comparison star
	34334	33 1000	5 11.6	+33 17	4.81	5.81	K_0	2. comparison star
7	65339	60 1105	7 53.2	+60 36	6.00	6.06	A_{2p}	
	65301	59 1130	7 53.0	+59 20	5.79	6.13	F_2	comparison star
8	219749	44 4373	23 13.2	+44 57	6.32	6.30	B_{9p}	
	219891	44 4378	23 14.3	+44 36	6.47	6.53	A_2	1. comparison star
	219668	44 4368	23 12.5	+44 37	6.55	7.62	K_2	2. comparison star
9	220825	+0 4998	23 21.8	+ 0 42	4.94	5.00	A_{2p}	
	220858	+0 4999	23 22.1	+ 0 34	6.44	7.44	K_0	1. comparison star
	-	+0 4996	23 21.5	+ 0 40	9.2	-	-	2. comparison star

TABLE II Observations of HD 15089 (cont'd)

					Blue				
Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
292.5693	0.706	-0.032	0.002	5	310.5888	0.049	-0.028	0.001	4
292.5929	.719	.035	.004	5	311.5923	.626	.047	.001	7
293.6505	.326	.042	.002	4	312.5762	.191	.039	.002	4
295.5811	.435	.025	.001	5	313.5783	.766	.046	.002	8
297.5831	.585	.056	.002	4	313.5901	.773	.040	.002	4
297.5997	.593	.054	.001	3	314.5775	.339	.042	.002	3
298.5699	.150	.039	.001	5	314.5879	.345	.042	.001	3
298.5893	.162	.039	.001	4	315.5761	.913	.036	.001	4
298.6088	.173	.038	.001	5	315.5879	.919	.038	.001	3
298.6296	0.185	-0.038	0.001	5	316.5865	0.493	-0.038	0.002	4

TABLE III Mean Light Curve of HD 15089

Yellow		Blue	
Mean Phase	Δm	Mean Phase	Δm
0.033	-0.033	0.092	-0.027
0.089	0.030	0.036	0.031
0.164	0.049	0.164	0.036
0.199	0.043	0.199	0.040
0.332	0.051	0.335	0.042
0.444	0.043	0.444	0.034
0.496	0.047	0.500	0.043
0.634	0.050	0.601	0.052
0.715	0.053	0.656	0.045
0.744	0.045	0.720	0.041
0.764	0.043	0.750	0.044
0.888	0.031	0.766	0.042
0.935	-0.028	0.888	0.036
		0.927	-0.040

TABLE II Observations of HD 15089

Yellow

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
2437					2437				
247.7035	0.950	-0.029	0.004	2	299.6059	0.745	-0.048	0.001	5
247.9313	.081	.024	.003	4	299.6274	.757	.042	.003	5
248.6778	.509	.048	.002	5	301.5823	.879	.031	.002	4
248.9119	.644	.054	.002	6	302.5836	.455	.052	.002	6
249.7007	.097	.036	.001	6	303.5724	.022	.029	.001	4
249.9188	.222	.039	.003	5	303.5856	.030	.033	.001	3
250.7126	.678	.045	.001	5	306.5738	.745	.046	.001	3
250.8577	.761	.050	.001	5	306.5877	.753	.040	.001	4
267.7084	.434	.042	.005	2	307.5862	.326	.050	.001	3
274.7105	.454	.031	.001	6	307.5959	.332	.051	.001	4
291.6415	.173	.055	.004	6	308.5785	.896	.030	.001	6
292.5700	.706	.058	.003	5	309.6062	.486	.048	.002	3
292.5936	.719	.055	.003	5	310.5840	.047	.030	.001	6
293.6513	.327	.054	.002	4	311.5930	.626	.055	.001	7
295.5818	.435	.045	.002	5	312.5769	.191	.042	.002	4
297.5893	.587	.048	.002	7	312.5894	.198	.042	.003	4
298.5705	.150	.044	.001	5	313.5790	.766	.040	.003	4
298.5900	.162	.049	.001	4	313.5908	.773	.039	.001	4
298.6095	.173	.048	.001	5	314.5838	.343	.049	.001	6
298.6303	.185	.051	.002	5	315.5817	.916	.026	.001	7
299.5656	.722	.047	.002	5	316.5873	0.493	-0.045	0.002	4
299.5858	0.734	-0.047	0.002	5					

Blue

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
2437					2437				
247.7035	0.950	-0.047	0.003	2	299.5649	0.722	-0.050	0.001	5
247.9306	.081	.023	.003	4	299.5851	.734	.045	.002	5
248.6736	.507	.054	.001	3	299.6052	.745	.046	.002	5
248.6862	.514	.041	.001	3	299.6267	.757	.044	.002	5
248.9063	.641	.053	.003	3	301.5816	.879	.038	.001	4
248.9181	.646	.045	.001	3	302.5829	.455	.051	.001	6
249.6952	.094	.028	.001	3	303.5696	.021	.030	.001	3
249.7063	.100	.029	.001	3	303.5828	.028	.035	.001	4
249.9181	.222	.037	.002	5	306.5738	.745	.042	.003	4
250.7119	.680	.038	.001	5	306.5877	.753	.045	.001	3
250.8570	.761	.041	.002	5	307.5917	.330	.040	.001	7
267.7077	.434	.022	.002	2	308.5778	.896	.035	.001	6
274.7098	.454	.039	.001	6	309.6055	.486	.037	.002	3
291.6408	0.171	-0.027	0.004	6	310.5777	0.045	-0.032	0.001	3

TABLE IV Observations of HD 18296

Yellow

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
2437					2437				
226.8515	0.918	-0.219	0.003	6	259.7882	0.968	-0.237	0.005	6
227.8765	.511	.254	.002	6	260.8028	.555	.251	.002	6
228.8509	.075	.224	.003	3	264.8214	.879	.245	.003	5
229.8530	.655	.232	.004	6	313.6874	.142	.226	.002	5
232.8954	.414	.249	.003	5	314.6053	.673	.240	.002	5
233.8809	.984	.235	.003	4	314.6213	.682	.232	.001	5
233.9004	.995	.227	.001	4	314.6386	.692	.241	.002	5
235.8428	.119	.239	.002	5	314.6581	.703	.238	.001	6
235.8637	.131	.240	.002	4	314.6775	.714	.235	.002	5
236.7498	.644	.249	.006	5	314.6949	.725	.244	.002	5
236.7734	.657	.245	.003	5	314.7116	.735	.240	.002	5
236.7949	.670	.245	.002	4	315.6053	.251	.241	.001	5
237.7282	.209	.247	.002	5	315.6206	.260	.233	.002	5
237.7519	.223	.239	.001	5	315.6366	.269	.238	.001	5
237.7734	.235	.240	.002	4	315.6518	.278	.240	.002	5
237.7963	.249	.238	.001	4	315.6678	.287	.235	.003	5
238.7303	.789	.241	.003	5	315.6893	.300	.236	.002	5
239.7290	.367	.247	.002	7	315.7074	.310	.240	.001	6
240.7742	.971	.234	.003	5	316.6163	.836	.231	.002	5
254.8473	.110	.245	.007	4	316.6330	.845	.235	.002	5
255.8209	.674	.246	.003	4	316.6490	.855	.236	.001	5
255.8445	.687	.247	.003	5	316.6642	.863	.236	.002	5
256.8181	.250	.254	.002	5	316.6816	.874	.237	.002	6
256.8397	.263	.250	.004	4	316.7031	.886	.233	.003	5
258.7382	0.361	-0.234	0.003	6	316.7240	0.898	-0.234	0.003	6

Blue

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
2437					2437				
226.8522	0.918	-0.340	0.002	6	259.7882	0.968	-0.372	0.003	6
227.8765	.511	.363	.001	6	260.8028	.555	.364	.003	6
228.8509	.075	.342	.003	3	264.8214	.879	.372	.002	5
229.8530	.655	.356	.001	6	313.6867	.142	.355	.002	5
232.8954	.414	.357	.003	6	314.6060	.673	.366	.001	4
233.8809	.984	.334	.003	4	314.6192	.680	.360	.001	4
233.8997	.995	.346	.002	5	314.6331	.689	.363	.001	4
235.8421	.119	.354	.003	5	314.6470	.697	.361	.001	4
235.8637	.131	.358	.002	4	314.6609	.705	.359	.002	4
236.7498	.644	.353	.004	5	314.6754	.713	.357	.002	4
236.7734	0.657	-0.343	0.002	5	314.6907	0.722	-0.364	0.002	5

TABLE IV Observations of HD 18296 (cont'd)

Blue

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
236.7949	0.670	-0.348	0.001	4	314.7095	0.733	-0.368	0.001	6
237.7282	.209	.345	.001	5	315.6025	.249	.358	.002	4
237.7519	.223	.344	.003	5	315.6157	.257	.356	.002	4
237.7734	.235	.346	.002	4	315.6282	.264	.357	.002	4
237.7956	.249	.340	.002	4	315.6407	.271	.357	.002	4
238.7296	.789	.348	.002	5	315.6532	.279	.350	.001	4
239.7290	.367	.347	.002	7	315.6671	.287	.358	.001	5
240.7742	.971	.339	.002	5	315.6886	.300	.351	.002	5
254.8542	.141	.344	.004	4	315.7067	.310	.359	.002	5
255.8209	.674	.358	.002	4	316.6156	.836	.356	.003	5
255.8445	.687	.360	.002	5	316.6323	.845	.361	.002	5
256.8181	.250	.354	.004	5	316.6483	.854	.362	.001	5
256.8397	.263	.363	.003	4	316.6635	.863	.360	.002	5
258.7382	0.361	-0.353	0.002	6	316.6795	.872	.361	.003	5
					316.7010	.885	.359	.003	6
					316.7233	0.898	-0.356	0.002	6

Comparison Stars HD 18367 - HD 18157
Blue

Date J.D.	Phase	Δm	Date J.D.	Phase	Δm
2437			2437		
226.852	0.918	-0.191	239.729	0.367	-0.194
228.851	.075	.189	240.774	.971	.188
229.853	.655	.188	255.821	.674	.191
232.895	.414	.189	256.818	.250	.189
236.750	.644	.193	259.788	.968	.190
236.795	.670	.192	264.821	0.879	-0.191
237.728	0.209	-0.189			

TABLE V Mean Light Curve of HD 18296

Yellow		Blue	
Mean Phase	Δm	Mean Phase	Δm
0.075	-0.224	0.075	-0.342
0.115	0.235	0.116	0.351
0.236	0.243	0.236	0.348
0.276	0.239	0.280	0.356
0.363	0.243	0.363	0.354
0.414	0.249	0.414	0.357
0.533	0.253	0.533	0.364
0.656	0.243	0.672	0.357
0.682	0.241	0.732	0.359
0.733	0.240	0.849	0.360
0.850	0.235	0.883	0.362
0.884	0.237	0.967	-0.346
0.967	-0.230		

TABLE VI Observations of HD 25354

Yellow

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
2437					2437				
226.8861	0.371	-0.562	0.002	5	255.8748	0.804	-0.544	0.001	5
227.9055	.633	.570	.001	5	256.9123	.070	.537	.001	5
229.8778	.139	.545	.003	5	258.7762	.549	.566	.003	5
232.9294	.921	.538	.001	7	259.8463	.823	.550	.001	5
233.9274	.177	.525	.001	7	260.8922	.091	.537	.001	6
235.8957	.682	.557	.003	8	264.9249	.125	.546	.002	5
236.8284	.921	.549	.003	6	313.7253	.637	.574	.006	5
237.8243	.176	.547	.001	6	314.7377	.897	.538	.003	5
238.7576	.416	.563	.003	5	315.7292	.151	.550	.003	5
239.7639	.647	.561	.003	5	316.7473	0.412	-0.561	0.003	5
240.8022	0.940	-0.546	0.003	5					

Blue

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
2437					2437				
226.8868	0.372	-0.633	0.003	5	255.8755	0.804	-0.616	0.002	5
227.9062	.633	.621	.001	5	256.9130	.071	.617	.007	4
229.8785	.139	.613	.004	5	258.7776	.549	.630	.002	5
233.9281	.177	.606	.002	7	259.8470	.823	.612	.003	5
235.8964	.682	.619	.002	8	260.8929	.091	.615	.001	6
236.8291	.921	.616	.001	6	264.9256	.125	.627	.003	5
237.8250	.177	.626	.002	6	313.7260	.638	.629	.002	6
238.7573	.416	.637	.002	5	314.7391	.897	.619	.003	5
239.7646	.674	.615	.004	5	315.7299	.152	.620	.003	5
240.8029	0.940	-0.613	0.001	5	316.7480	0.413	-0.629	0.003	5

Ultraviolet

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
2437					2437				
226.8854	0.371	-0.890	0.001	5	256.9116	0.070	-0.849	0.003	5
227.9048	.633	.887	.001	5	258.7769	.549	.887	.003	5
229.8771	.139	.845	.006	5	259.8456	.823	.854	.001	5
232.9287	.921	.843	.001	7	260.8915	.091	.851	.003	6
233.9267	.177	.856	.003	7	264.9242	.125	.871	.003	5
235.8950	.682	.878	.005	8	313.7246	.637	.879	.003	5
236.8277	.921	.857	.001	6	314.7384	.897	.840	.004	5
237.8236	.176	.878	.002	6	315.7285	.151	.858	.003	5
238.7569	.416	.900	.001	5	316.7466	0.412	-0.885	0.002	5
239.7632	.674	.866	.003	5					
240.8015	.940	.846	.001	5					
255.8741	0.804	-0.861	0.002	5					

TABLE VII Observations of HD 25823

Yellow

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
2437					2437				
226.917	0.082	-0.028	0.005	3	309.648	0.000	-0.021	0.002	6
227.916	.129	.031	.002	4	309.679	.003	.020	.002	6
232.949	.578	.057	.002	6	309.698	.004	.027	.002	6
233.952	.662	.038	.002	5	309.725	.005	.018	.003	7
236.860	.905	.035	.001	7	310.642	.083	.025	.002	8
236.887	.907	.028	.002	7	311.636	.166	.029	.001	8
236.913	.909	.030	.002	6	311.658	.168	.029	.001	7
237.848	.988	.022	.002	5	311.681	.170	.032	.002	6
238.781	.066	.023	.002	5	311.713	.172	.029	.001	5
239.801	.187	.046	.002	7	311.780	.178	.030	.001	6
240.828	.237	.039	.002	5	312.636	.250	.044	.002	6
255.906	.500	.056	.002	10	312.656	.252	.051	.001	5
256.875	.581	.051	.002	9	312.696	.256	.043	.001	7
258.795	.742	.040	.003	4	312.719	.257	.046	.001	7
258.812	.743	.034	.003	5	312.786	.262	.039	.001	5
259.813	.827	.037	.002	5	313.607	0.331	-0.044	0.002	7
260.794	.909	.038	.002	7					
264.843	0.248	-0.046	0.002	4					

Blue

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
2437					2437				
226.916	0.082	+0.017	0.002	3	308.697	0.920	+0.011	0.001	6
227.915	.156	.009	.002	4	308.710	.921	.013	.001	6
232.951	.578	.010	.002	5	308.745	.924	.012	.001	9
233.951	.662	.019	.003	5	309.647	.000	.021	.002	6
236.859	.905	.033	.002	8	309.678	.003	.022	.001	6
236.886	.907	.031	.001	9	309.697	.004	.021	.001	6
236.912	.909	.035	.002	6	309.724	.005	.027	.001	8
237.848	.988	.038	.002	5	310.628	.082	.022	.002	4
238.780	.066	.037	.002	5	310.651	.083	.022	.002	4
239.797	.151	.012	.001	7	311.635	.166	.012	.001	8
240.827	.237	.019	.001	6	311.658	.168	.011	.001	7
255.905	.500	.001	.002	10	311.680	.170	.011	.001	8
256.874	.581	.009	.003	9	311.712	.172	.007	.001	5
258.794	.724	.016	.002	4	311.779	.178	.010	.001	7
258.810	.743	.019	.003	4	312.635	.250	.005	.001	6
258.824	.744	.010	.001	6	312.655	.252	.007	.001	5
259.812	.827	.010	.002	5	312.695	.256	.003	.001	7
260.794	0.909	+0.016	0.002	6	312.718	0.257	+0.002	0.001	7
260.815	0.910	+0.021	0.002	5	312.785	0.262	+0.002	0.001	5
264.842	.248	.007	.002	4	313.606	.331	.003	.001	7
308.672	.918	.015	.001	6	314.756	.427	-0.001	.001	6
308.684	0.919	+0.013	0.001	6	315.740	.511	+0.007	.001	7
					316.766	0.596	+0.019	0.001	5

TABLE VIII Observations of HD 32633

Yellow

Date J.D.	Phase	Δm	p.e.	N
2437				
247.9589	0.019	0.444	0.005	3
248.9402	.171	.415	.002	5
249.9472	.328	.420	.002	5
250.8897	.474	.430	.002	5
295.8123	.462	.450	.003	4
301.7932	.392	.447	.004	4
302.6481	.525	.439	.002	5
302.6745	.529	.439	.002	5
302.6988	.533	.438	.001	5
302.7404	.540	.440	.001	5
303.6369	.679	.442	.003	5
303.6633	.683	.443	.002	4
303.6862	.687	.439	.002	4
303.7070	0.690	0.442	0.002	4

Date J.D.	Phase	Δm	p.e.	N
2437				
303.7487	0.697	0.444	0.001	4
305.6806	.997	.442	.003	5
305.7070	.001	.440	.002	5
305.7313	.005	.440	.001	4
305.7528	.008	.439	.002	4
305.7792	.012	.442	.001	4
305.8195	.019	.445	.001	4
306.6750	.152	.429	.003	5
306.6986	.155	.431	.001	5
306.7257	.160	.430	.002	5
306.7500	.163	.433	.003	4
306.7694	.166	.429	.003	4
306.8104	.173	.432	.002	4
307.6514	.303	.427	.003	3
308.7756	.478	.442	.001	3
309.7603	.632	.444	.002	5
310.6777	.774	.450	.003	5
311.7394	.939	.453	.002	5
312.7477	.096	.441	.001	4
313.6386	.235	.432	.002	5
314.7774	.412	.438	.001	5
316.8030	0.727	0.447	0.002	5

Blue

Date J.D.	Phase	Δm	p.e.	N
2437				
247.9603	0.019	0.151	0.003	3
248.9389	.171	.132	.002	5
249.9458	.328	.141	.002	5
250.8883	.474	.146	.001	5
289.7749	.523	.154	.003	5
295.8109	.462	.158	.001	4
301.7918	.392	.150	.002	4
302.6467	.525	.152	.001	5
302.6731	.529	.149	.001	5
302.6974	.533	.148	.001	5
302.7391	.540	.151	.002	5
303.6355	.679	.156	.001	5
303.6619	.683	.154	.001	4
303.6848	.687	.158	.002	4
303.7056	0.690	0.159	0.001	4

Date J.D.	Phase	Δm	p.e.	N
2437				
305.7299	0.005	0.152	0.002	4
305.7515	.008	.156	.002	4
305.7785	.012	.153	.001	4
305.8209	.019	.150	.001	4
306.6736	.152	.138	.003	5
306.6972	.155	.141	.002	5
306.7243	.160	.133	.001	5
306.7486	.163	.140	.002	4
306.7680	.166	.140	.002	4
306.8090	.173	.139	.001	4
307.6514	.303	.150	.003	3
308.7742	.478	.148	.001	3
309.7589	.632	.156	.001	5
310.6763	.774	.169	.001	5
311.7407	0.939	0.166	0.002	4

TABLE VIII Observations of HD 32633 (cont'd)

Blue

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
303.7473	0.697	0.157	0.001	4	312.7491	0.096	0.149	0.001	4
305.6792	.997	.156	.002	5	313.6372	.235	.141	.001	5
305.7056	0.001	0.156	0.001	5	316.8017	0.727	0.163	0.002	5

Ultraviolet

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
2437					2437				
247.9596	0.019	-0.377	0.002	3	305.7306	0.005	-0.381	0.001	4
248.9396	.171	.412	.002	5	305.7522	.008	.384	.001	4
249.9465	.328	.409	.002	5	305.7695	.012	.380	.002	3
250.8890	.474	.385	.003	5	305.8181	.019	.380	.001	5
289.7756	.523	.383	.004	5	306.6743	.152	.410	.002	5
295.8116	.462	.380	.003	4	306.6979	.155	.411	.002	5
301.7925	.392	.397	.001	4	306.7250	.160	.415	.001	5
302.6474	.525	.387	.002	5	306.7493	.163	.407	.002	4
302.6738	.529	.388	.001	5	306.7687	.166	.415	.002	4
302.6981	.533	.385	.001	5	306.8097	.173	.412	.003	4
302.7398	.540	.381	.002	5	307.6514	.303	.403	.002	3
303.6362	.679	.378	.002	5	308.7749	.478	.393	.002	3
303.6626	.683	.383	.002	4	309.7596	.632	.384	.001	5
303.6855	.687	.384	.001	4	310.6770	.774	.381	.002	5
303.7063	.690	.380	.001	4	311.7387	.939	.370	.001	5
303.7480	.697	.370	.003	4	312.7484	.096	.394	.002	4
305.6799	.997	.380	.002	5	313.6379	.235	.403	.003	5
305.7063	0.001	-0.381	0.002	5	314.7768	.412	.393	.002	5
					316.8023	0.727	-0.386	0.001	5

TABLE IX Observations of HD 34452

Yellow

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
2437					2437				
260.9270	0.831	0.306	0.002	6	301.6509	0.345	0.288	0.001	6
289.7318	.511	.306	.003	6	301.6724	.354	.290	.002	6
289.7992	.539	.292	.003	7	301.6904	.361	.289	.001	6
295.8317	.985	.309	.004	4	301.7189	.373	.292	.001	6
298.7259	.159	.288	.002	6	301.7446	.383	.296	.002	6
298.7481	.168	.291	.003	6	301.7668	.392	.292	.002	6
298.7724	.178	.290	.001	6	301.8175	.412	.296	.001	6
298.7967	.188	.292	.001	6	302.7273	.781	.295	.002	4
298.8217	.198	.292	.002	6	303.7271	.187	.290	.002	5
299.7377	.569	.301	.001	6	305.7931	.025	.305	.001	5
299.7599	.578	.296	.003	6	306.7896	.429	.295	.001	5
299.7849	.588	.297	.002	6	308.8026	.245	.288	.002	3
299.8175	.601	.302	.002	6	309.7811	.642	.288	.002	4
300.7509	.980	.308	.001	6	310.6999	.015	.309	.001	6
300.7738	.989	.305	.001	6	311.7602	.444	.301	.002	5
300.7939	.998	.306	.001	6	312.7692	.854	.301	.001	6
300.8175	.007	.307	.001	7	313.6594	.214	.286	.002	5
301.6300	0.336	0.291	0.001	6	314.7948	0.675	0.296	0.002	5

Blue

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
2437					2437				
260.9263	0.831	-0.114	0.002	6	301.6516	0.345	-0.135	0.001	6
289.7325	.511	.119	.003	6	301.6731	.354	.136	.002	6
289.7985	.539	.127	.003	7	301.6911	.361	.133	.001	6
295.8310	.985	.100	.003	4	301.7196	.373	.125	.002	6
298.7252	.159	.132	.001	6	301.7453	.383	.128	.001	6
298.7474	.168	.134	.002	6	301.7668	.392	.128	.002	5
298.7717	.178	.134	.001	6	301.8168	.412	.129	.001	6
298.7960	.188	.129	.001	6	302.7266	.781	.125	.002	4
298.8210	.198	.134	.002	6	303.7265	.187	.134	.002	5
299.7370	.569	.122	.001	6	305.7924	.025	.116	.001	5
299.7592	.578	.124	.002	6	306.7889	.429	.128	.002	5
299.7842	.588	.119	.002	6	308.8013	.245	.138	.002	3
299.8168	.601	.124	.002	6	309.7804	.642	.126	.002	4
300.7502	.980	.115	.001	6	310.6992	.015	.115	.001	6
300.7731	.989	.110	.001	6	311.7609	.444	.122	.001	5
300.7932	.998	.116	.001	6	312.7685	.854	.120	.002	5
300.8168	.007	.112	.001	6	313.6587	.214	.139	.002	5
301.6307	0.336	-0.132	0.002	6	314.7934	0.675	-0.119	0.002	3

TABLE X Mean Light Curve of HD 34452

Yellow		Blue	
Mean Phase	Δm	Mean Phase	Δm
0.016	0.307	0.016	-0.114
0.168	0.290	0.168	0.133
0.191	0.291	0.191	0.132
0.229	0.287	0.229	0.139
0.341	0.289	0.341	0.134
0.357	0.290	0.357	0.134
0.383	0.293	0.383	0.127
0.428	0.297	0.428	0.126
0.557	0.298	0.557	0.122
0.639	0.295	0.639	0.123
0.833	0.301	0.833	0.120
0.983	0.308	0.983	0.108
0.994	0.306	0.994	-0.113

TABLE XI Observations of HD 65339

Yellow

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
2437					2437				
289.8570	0.937	0.227	0.004	6	306.8343	0.050	0.228	0.002	4
295.8619	.687	.238	.003	6	308.8246	.300	.227	.001	4
298.8647	.062	.230	.002	6	309.8204	.425	.230	.001	5
299.8599	.187	.230	.002	5	310.7468	.537	.232	.001	6
300.8439	.300	.229	.001	4	311.8315	.675	.229	.001	7
301.8432	.425	.233	.001	3	312.8350	.800	.227	.001	5
302.7911	.550	.230	.002	4	313.7961	.925	.224	.002	7
303.7919	.675	.224	.002	4	314.8239	.050	.226	.001	5
305.8489	0.925	0.225	0.001	5	316.8280	0.300	0.230	0.002	3

Blue

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
2437					2437				
289.8556	0.937	0.025	0.003	6	305.8475	0.925	0.019	0.001	5
295.8605	.687	.020	.002	6	306.8329	.050	.022	.002	4
298.8634	.062	.030	.001	6	308.8239	.300	.020	.001	4
299.8578	.187	.022	.002	5	309.8190	.425	.016	.001	5
300.8404	.300	.018	.001	4	311.8301	.675	.022	.002	7
301.8418	.425	.017	.003	3	312.8336	.800	.026	.001	5
302.7897	.550	.015	.001	4	313.7947	.925	.019	.001	7
303.7905	0.675	0.020	0.002	4	314.8225	.050	.028	.001	5
					316.8267	0.300	0.025	0.003	3

Ultraviolet

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
2437					2437				
289.8563	0.937	0.067	0.004	6	306.8322	0.050	0.067	0.001	4
295.8612	.687	.052	.002	6	308.8239	.300	.052	.002	4
298.8641	.062	.075	.002	6	309.8197	.425	.045	.001	5
299.8585	.187	.064	.001	5	310.7461	.537	.052	.001	6
300.8411	.300	.057	.001	4	311.8308	.675	.054	.002	7
301.8425	.425	.049	.003	3	312.8343	.800	.065	.001	5
302.7904	.550	.045	.002	4	313.7954	.925	.066	.001	7
303.7912	.675	.055	.002	4	314.8232	.050	.068	.001	5
305.8482	0.925	0.060	0.002	5	316.8273	0.300	0.056	0.003	3

TABLE XII Observations of HD 219749

Yellow

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
198.6519	0.554	-0.063	0.001	4	229.7018	0.478	-0.051	0.001	4
198.6706	.561	.064	.001	5	229.7323	.489	.059	.001	4
198.6859	.567	.060	.002	5	230.6247	.832	.045	.002	6
199.6449	.935	.036	.001	6	230.7781	.891	.048	.001	3
199.6616	.942	.039	.001	5	232.5962	.589	.050	.002	5
199.6782	.948	.048	.001	5	232.6184	.598	.052	.002	5
199.6928	.954	.043	.001	5	232.6406	.606	.042	.002	5
199.7088	.960	.043	.002	5	232.6642	.615	.058	.002	5
199.7213	.964	.044	.001	5	232.6886	.625	.049	.003	5
199.7414	.972	.040	.002	5	232.7156	.635	.054	.002	5
200.7678	.366	.058	.001	5	232.7420	.645	.045	.001	4
201.7699	.754	.058	.001	4	232.7642	.654	.057	.003	4
215.6658	.087	.038	.002	4	233.5920	.972	.039	.001	5
215.6888	.096	.042	.002	4	233.6149	.980	.042	.002	5
215.7103	.104	.046	.001	4	234.7968	.434	.056	.002	5
215.7304	.112	.042	.003	5	235.5975	.742	.053	.002	6
215.7506	.120	.032	.002	4	236.5857	.121	.047	.003	4
219.6192	.606	.053	.002	3	236.6044	.128	.049	.002	4
219.6345	.611	.048	.002	4	237.5877	.506	.062	.001	3
220.6352	.996	.034	.001	4	237.6043	.512	.059	.002	4
220.6505	.002	.040	.002	3	238.6154	.901	.058	.001	6
221.6477	.385	.058	.002	4	239.5967	.278	.061	.002	5
221.6699	.393	.057	.002	4	240.6967	.700	.053	.001	6
226.6012	.287	.054	.002	6	254.5815	.032	.042	.001	6
226.6185	.293	.057	.002	5	258.5703	.564	.054	.002	4
227.6414	.686	.048	.002	5	258.5925	.572	.051	.002	5
228.5977	.054	.040	.001	4	258.6154	.581	.053	.002	5
228.6178	.061	.044	.002	4	258.6411	.591	.057	.001	5
229.5927	.436	.053	.001	4	260.5671	.331	.056	.001	5
229.6149	.444	.058	.001	4	261.5692	.715	.048	.001	6
229.6323	.451	.058	.002	4	262.5976	.111	.040	.001	4
229.6490	.457	.051	.001	4	263.7497	.553	.051	.001	4
229.6663	.464	.055	.001	4	264.5566	.863	.048	.001	4
229.6844	0.471	-0.056	0.001	4	264.5767	.871	.047	.001	4
					264.5955	.877	.042	.001	4
					264.6149	.885	.045	.001	4
					264.6372	.894	.044	.001	4
					264.6580	.902	.049	.002	4
					264.6802	.910	.040	.003	5
					264.7073	0.921	-0.049	0.002	5

TABLE XII Observations of HD 219749 (cont'd)

Blue

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
2437					2437				
198.6525	0.554	-0.244	0.001	4	232.7163	0.635	-0.230	0.002	5
215.6624	.086	.210	.003	4	232.7434	.645	.227	.002	4
215.6818	.095	.211	.001	4	232.7649	.654	.226	.002	4
215.7068	.103	.214	.001	4	233.5934	.972	.198	.002	5
215.7270	.111	.212	.002	5	233.6156	.980	.199	.001	5
215.7499	.119	.216	.002	5	234.7975	.434	.228	.002	5
219.6199	.606	.226	.002	3	235.5989	.742	.217	.001	6
219.6331	.611	.228	.002	3	236.5864	.121	.219	.001	4
220.6373	.996	.215	.001	3	236.6058	.128	.220	.001	4
220.6512	.002	.220	.001	3	237.5911	.508	.228	.002	4
221.6484	.385	.225	.001	4	237.6078	.513	.229	.001	3
221.6706	.393	.227	.002	4	238.6161	.901	.219	.002	6
226.5991	.287	.228	.002	5	239.5974	.278	.228	.002	5
226.6248	.296	.237	.002	5	240.6974	.700	.229	.002	6
227.6421	.686	.204	.002	5	254.5822	.032	.212	.002	6
228.5984	.054	.212	.002	4	258.5752	.566	.237	.002	5
228.6192	.061	.218	.002	4	258.5981	.574	.229	.002	5
229.5941	.437	.237	.001	4	258.6196	.583	.229	.002	4
229.6114	.442	.237	.001	4	258.6418	.591	.238	.001	5
229.6288	.450	.235	.002	4	260.5685	.331	.239	.002	5
229.6462	.456	.232	.002	4	261.5706	.715	.222	.001	6
229.6629	.459	.235	.001	4	262.5983	.111	.218	.003	4
229.6809	.470	.230	.001	4	263.7510	.553	.236	.002	4
229.6983	.477	.238	.001	4	264.5580	.864	.211	.001	4
229.7281	.487	.234	.002	5	264.5781	.872	.219	.002	4
230.6226	.831	.210	.002	5	264.5969	.877	.220	.001	4
230.7816	.892	.218	.003	4	264.6163	.886	.219	.001	4
232.5969	.589	.218	.002	5	264.6385	.894	.217	.001	4
232.6198	.599	.224	.002	5	264.6594	.902	.222	.002	4
232.6413	.606	.231	.002	5	264.6767	.909	.221	.001	4
232.6656	.615	.231	.002	5	264.7038	0.920	-0.226	0.002	5
232.6892	0.625	-0.230	0.002	5					

Ultraviolet

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
2437					2437				
215.6749	0.091	-0.613	0.002	5	233.5920	0.972	-0.598	0.002	5
215.7054	.103	.610	.001	4	233.6149	.980	.603	.001	5
215.7263	.111	.615	.002	5	234.7968	.434	.642	.003	5
215.7485	.119	.620	.001	5	235.5982	.742	.663	.002	6
219.6248	.608	.648	.001	6	236.5864	.121	.620	.001	4
220.6421	.999	.624	.003	7	236.6051	.128	.624	.002	4
221.6477	0.385	-0.648	0.002	4	237.5974	0.513	-0.654	0.001	7

TABLE XII Observations of HD 219749 (cont'd)

Ultraviolet

Date J.D.	Phase	Δm	p.e.	N	Date J.D.	Phase	Δm	p.e.	N
221.6706	0.393	-0.655	0.002	4	238.6154	0.901	-0.653	0.002	6
226.6012	.287	.639	.003	6	239.5967	.278	.653	.002	5
226.6262	.296	.652	.002	5	240.6967	.700	.652	.001	6
227.6414	.686	.655	.002	5	254.5815	.032	.620	.002	6
228.5977	.054	.609	.002	4	258.5703	.564	.652	.002	4
228.6185	.061	.606	.002	4	258.5925	.572	.650	.002	5
229.5956	.437	.652	.001	5	258.6168	.581	.648	.002	5
229.6170	.445	.648	.001	5	258.6418	.591	.655	.002	5
229.6386	.453	.643	.001	5	260.5678	.331	.653	.001	5
229.6601	.458	.654	.002	5	261.5699	.715	.663	.002	6
229.6802	.470	.651	.001	4	262.5976	.111	.612	.001	4
229.6983	.477	.651	.001	4	263.7503	.553	.651	.002	4
229.7281	.487	.652	.002	5	264.5566	.863	.648	.002	4
230.6219	.831	.660	.002	5	264.5774	.871	.651	.001	4
230.7851	.894	.649	.003	4	264.5983	.878	.661	.002	5
232.5969	.589	.655	.002	5	264.6247	.889	.653	.002	5
232.6191	.598	.653	.002	5	264.6503	.899	.661	.003	5
232.6413	.606	.645	.001	5	264.6760	.908	.658	.003	5
232.6649	.615	.655	.002	5	264.7024	.919	.663	.002	5
232.6892	.625	.651	.003	5	264.7226	.927	.636	.001	4
232.7163	.635	.650	.001	5	264.7316	.930	.647	.002	4
232.7448	.645	.648	.003	5	264.7392	.933	.645	.001	4
232.7656	0.654	-0.646	0.002	3	264.7490	.937	.639	.001	4
					264.7615	0.941	-0.636	0.002	5

Comparison Stars HD 219891 - HD 219668

Yellow

Date J.D.	Phase	Δm	Date J.D.	Phase	Δm
2437			2437		
215.689	0.096	-0.030	235.597	0.742	-0.030
215.751	.120	.030	236.604	.128	.032
219.634	.611	.036	237.604	.512	.031
220.651	.002	.036	238.615	.901	.034
221.670	.393	.037	239.597	.278	.033
226.618	.293	.034	240.697	.700	.033
228.618	.061	.033	254.582	.032	.036
229.593	.436	.032	258.593	.572	.034
229.649	.457	.031	260.567	.331	.029
230.778	.891	.033	261.569	.715	.032
232.596	.589	.034	262.598	.111	.031
232.664	0.615	-0.034	263.750	0.553	-0.035
232.742	0.645	-0.033	264.577	0.871	-0.032
233.615	.980	.031	264.680	0.910	-0.034
234.797	0.434	-0.034			

TABLE XIII Mean Light Curve of HD 219749

Yellow		Blue		Ultraviolet	
Mean Phase	Δm	Mean Phase	Δm	Mean Phase	Δm
0.002	-0.040	0.081	-0.213	0.069	-0.609
.080	.042	.118	.217	.108	.612
.118	.042	.298	.233	.123	.621
.297	.057	.418	.231	.298	.649
.381	.058	.462	.234	.412	.649
.441	.056	.523	.234	.461	.649
.472	.054	.581	.230	.529	.652
.537	.060	.607	.228	.583	.652
.580	.054	.639	.228	.607	.650
.613	.050	.711	.218	.640	.649
.655	.051	.870	.216	.711	.658
.727	.053	.905	.221	.861	.655
.861	.046	.996	-0.209	.898	.655
.895	.049			.931	.644
.931	.042			0.996	-0.611
0.964	-0.042				

Comparison Stars HD 219891 - HD 219668

Yellow

Mean Phase	Δm
0.063	-0.033
.120	.031
.285	.033
.362	.033
.442	.032
.556	.033
.623	.034
.719	.032
.881	.032
.906	.034
0.991	-0.033

TABLE XIV Observations of HD 220825

Yellow

Date J.D.	Phase	∆m	p.e.	N	Date J.D.	Phase	∆m	p.e.	N
2437					2437				
219.7403	0.525	1.331	0.001	7	227.7458	0.305	1.333	0.002	5
219.7640	.566	1.336	.002	7	227.7652	.337	1.330	.001	5
220.6758	.136	1.344	.003	5	227.7875	.372	1.327	.001	6
220.6917	.163	1.337	.001	5	228.6540	.867	1.331	.002	5
220.7063	.188	1.342	.001	5	228.6749	.904	1.338	.001	5
220.7202	.212	1.343	.002	5	228.6908	.931	1.330	.002	5
220.7341	.236	1.332	.001	5	228.7089	.962	1.337	.002	5
220.7501	.263	1.331	.001	5	228.7249	.990	1.331	.003	5
220.7640	.287	1.333	.003	5	228.7429	.021	1.331	.002	5
220.7772	.310	1.327	.001	5	228.7589	.048	1.328	.002	5
220.7910	.334	1.330	.001	5	228.7776	.081	1.331	.003	6
220.8042	.356	1.338	.003	5	229.7922	.826	1.344	.002	6
221.7008	.901	1.336	.001	6	232.8012	.005	1.340	.003	6
226.6577	.432	1.338	.001	6	234.7746	.403	1.346	.002	5
226.6778	.466	1.329	.001	6	235.6293	.873	1.358	.003	5
226.7008	.506	1.327	.001	7	236.6745	.671	1.340	.001	6
226.7619	.611	1.331	.003	5	237.6695	.384	1.344	.001	5
226.7806	.644	1.332	.002	6	238.6729	.112	1.336	.002	5
227.6694	.172	1.336	.001	5	239.6520	.797	1.338	.001	5
227.6861	.201	1.338	.001	5	240.6679	.546	1.340	.001	5
227.7062	.236	1.334	.002	5	254.6416	.597	1.306	.003	5
227.7277	0.274	1.334	0.001	5	258.6671	0.523	1.319	0.001	5

Blue

Date J.D.	Phase	∆m	p.e.	N	Date J.D.	Phase	∆m	p.e.	N
2437					2437				
198.7120	0.332	0.758	0.002	5	227.6659	0.167	0.767	0.001	4
198.7238	.352	.762	.001	5	227.6784	.188	.765	.001	4
198.7335	.369	.772	.001	5	227.6951	.217	.771	.002	4
198.7509	.399	.767	.002	5	227.7132	.248	.766	.001	4
198.7717	.435	.756	.003	5	227.7243	.267	.763	.002	4
198.7897	.466	.749	.002	5	227.7430	.299	.762	.002	4
198.8043	.491	.757	.002	5	227.7590	.327	.760	.001	4
198.8182	.515	.751	.001	5	227.7750	.355	.768	.002	4
198.8335	.541	.754	.001	5	227.7909	.382	.772	.001	4
198.8474	.565	.757	.002	5	228.6471	.855	.757	.002	4
198.8620	.590	.756	.002	5	228.6665	.888	.766	.002	4
219.7348	.516	.768	.001	5	228.6776	.909	.772	.001	4
219.7542	.549	.768	.002	5	228.6936	.936	.768	.002	4
219.7688	0.575	0.770	0.001	5	228.7110	0.966	0.763	0.002	4

TABLE XV Mean Light Curve of HD 220825

Yellow		Blue	
Mean Phase	△m	Mean Phase	△m
0.037	0.772	0.103	1.336
0.157	0.771	0.244	1.335
0.253	0.767	0.343	1.333
0.353	0.766	0.507	1.331
0.452	0.757	0.642	1.334
0.525	0.760	0.895	1.338
0.575	0.761		
0.637	0.762		
0.856	0.768		
0.949	0.768		

TABLE XIV Observations of HD 220825 (cont'd)

					Blue				
Date J.D.	Phase	△m	p.e.	N	Date J.D.	Phase	△m	p.e.	N
220.6723	0.129	0.771	0.002	3	228.7235	0.986	0.768	0.002	4
220.6820	.146	.775	.002	4	228.7374	.010	.763	.001	4
220.6959	.170	.777	.002	4	228.7513	.034	.772	.002	4
220.7049	.186	.769	.001	4	228.7624	.053	.769	.002	4
220.7195	.210	.776	.001	4	228.7790	.083	.770	.002	5
220.7299	.229	.766	.002	4	229.7922	.826	.765	.002	6
220.7424	.249	.765	.002	4	232.8012	.005	.785	.002	6
220.7542	.270	.764	.002	4	233.6469	.461	.758	.002	6
220.7633	.286	.766	.001	4	234.7746	.403	.770	.002	5
220.7758	.310	.767	.003	4	235.6293	.873	.789	.003	5
220.7959	.343	.764	.002	4	236.6745	.671	.776	.002	6
220.8056	.358	.772	.003	4	237.6695	.384	.773	.002	5
221.7015	.900	.768	.001	6	238.6729	.112	.774	.002	5
226.6549	.427	.760	.002	4	239.6520	.797	.766	.001	5
226.6702	.453	.752	.001	5	240.6679	.546	.771	.001	5
226.6862	.480	.758	.002	5	254.6416	.597	.756	.002	5
226.7042	.511	.759	.003	5	258.6664	0.523	0.760	0.001	5
226.7577	.604	.753	.002	4					
226.7716	.628	.761	.002	4					
226.7834	0.647	0.757	0.001	4					

TABLE XVI Summary of Photometric Results for Known Spectrum and Magnetic Variables

Stars HD No.	Sp. type	Period Days	Amplitude in yellow	Amplitude in blue	Amplitude in ultrav.	Amplitude $\frac{\text{yellow + blue}}{2}$	Magnetic Field	Star Bluest in	Light Curve	Observer
15089	$A5_p$ var.	1.741551	0.021	0.019	-	0.020	broad lines	minimum	peculiar	Rakos
18296	$A0_p$	1.729	.016	.012	-	.014	periodic	minimum	symetric	Rakos
25354	$A0_p$ var.	3.9001	.032	.022	0.044	.027	variable	minimum	symetric	Rakos
25823	$A0_p$	11.94	.035	.033	-	.034	variable	minimum	symetric	Rakos
32633	$B8_p$	6.429	.024	.028	.042	.026	periodic	maximum	asymetric	Rakos
34452	$A0_p$ var.	2.4660	.020	.026	-	.023	probable	maximum	asymetric	Rakos
65339	$A2_p$ var.	8.00552	.006	.010	.023	.008	periodic	maximum	asymetric	Rakos
219749	$B9_p$	2.604	.018	.023	.044	.020	broad lines	maximum	asymetric	Rakos
220825	$A2_p$ var.	0.5805	.011	.007	-	.009	variable	minimum	asymetric	Rakos
71866	$A0_p$ var.	6.799	.015	.035	-	.025	periodic	maximum	asymetric	Jarzebowski
112185	$A0_p$ var.	5.0887	.024	.024	-	.024	probable	-	peculiar	Provin
112413	$A0_p$	5.469	.045	.030	-	.037	periodic	minimum	symetric	Provin
125248	$A0_p$ var.	9.295	-	.053	-	-	periodic	-	symetric	Stibbs
140160	$A0_p$ var.	1.59584	.018	.018	-	.018	broad lines	-	symetric	Provin
153882	$A0_p$	6.007	.019	.019	-	.019	periodic	-	asymetric	Jarzebowski
196502	$A2_p$ var.	20.27	.040	.024	-	.032	variable	minimum	symetric	Provin
215441	$A0_p$ var.	9.49	-	.140	-	-	variable	-	symetric	Jarzebowski
224801	$A0_p$ var.	3.7422	.037	.028	.060	.032	variable	minimum	symetric	Provin