

SPECTRUM AND PHOTOMETRIC VARIABILITY OF He-WEAK AND He-STRONG STARS*

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Periodic variability in the strength of the HeI $\lambda 4026$ Å line is shown to be a frequent phenomenon among both He-weak and He-strong stars: In a sample of 26 stars, seven were found to be spectrum variables. Three previously known He variables were also observed. The periods range from 0.9 days (or possibly 0.5 days) to 15 days. The observations reported here include HeI $\lambda 4026$ Å and *uvby* photometry.

Key words: spectrum variables – He-weak stars – He-strong stars

1. INTRODUCTION

Spectrum variability is often met in some groups of young stars. In the Ap domain spectrum variability is frequently associated with magnetic variability and has been interpreted by rotator models. The silicon and manganese stars also contain a few He variables. The He-weak stars, generally found in the range B3–B7, among others include the He variable HR 7129 which has recently been found to be a strong magnetic variable (Wolff and Wolff 1976).

Among the earliest B type stars, two He variables are known: σ Ori E and HD 37776. At the mean value of their $\lambda 4026$ Å line strengths both these stars are He-rich (Nissen 1976a). As the He-rich stars in general are confined to the same spectral range, B0–B3, one could speculate if the He variability is common among both He-weak and He-strong stars and if rotator models will fit these classes of spectrum variables too.

To the authors' knowledge no measurement of magnetic fields has been attempted on the fast rotating star σ Ori E, but two other phenomena were found by Walborn (1974): 1) A broad and variable H α emission profile, 2) eclipse-like light and colour curves, with two minima per period, in the *uvby* system. To account for the new phenomena Hesser *et al.* (1976) propose a U Gem-like model involving mass transfer from the B star onto an accretion disk circulating an unseen, collapsed companion. Among a few other He-rich objects Walborn found traces of H α emission also in HR 1890 and HR 3089.

In view of the various models proposed, and the lack of observational material, it was decided to carry out a search for new He variables and to improve data on the old ones. A pilot program (Pedersen 1976a) showed one star, the He-weak HR 7185, to be He-variable, but a definite period could not be assigned.

2. OBSERVATIONS

The observations reported here include a) photometry of the HeI $\lambda 4026$ Å line strength in 29 stars and b) *uvby* photometry of those stars found to be He variables. Simultaneous spectroscopic observations were made by Hunger (1976) with the purpose of abundance and radial velocity determinations.

The programme stars were selected from various sources which are listed in table 1, column (4). No distinction has been made between different classification methods. However, no extreme He-rich stars as defined by Hunger (1975) are included. In table 1 column (3) the letter W indicates a classification as He-weak or -poor, while S stands for He-strong or -rich.

The He-weak star ι Ori B has been suspected for spectrum variability (Conti and Loonen 1970) but could not be observed due to the closeness of the A component. Two stars, HR 2790 and HD 37321, were included as suspected He variables. The well-known He-weak He variable HR 7129 (Balona 1975) could not be observed at the time of the observations.

* This article is based on observations obtained at the European Southern Observatory.

2.1. He $\lambda 4026 \text{ \AA}$ Photometry

The observations were carried out at the Danish 50 cm telescope, La Silla (January 17 - February 9, 1976) and at the ESO 1 m telescope (February 10 - February 19, 1976). The spectrometer, data acquisition, and programming were as described by Pedersen (1976a). To improve accuracy a new index definition was used:

$$R = I_{\text{line}}/I_{\text{continuum}} = I[4021.7, 4030.7]/(I[4013.2, 4020.7] + I[4031.7, 4039.2]) \quad (1)$$

where $I[\lambda_1, \lambda_2]$ denotes the intensity measured in the wavelength range from λ_1 to λ_2 . A high value of R thus corresponds to a small equivalent width. The intensities through the “continuum” bands are measured simultaneously using a double slit. An observation of a star consists of a number of periods M . During each of these, no action is expected from the observer. After such a period the teletype prints the current results, and the observer may decide the subsequent programme path. Each period in turn consists of four integrations repeated N times and defining N values of the index R . N is a preselected number. The best value for the result of the observation is

$$R = \frac{\sum_{i=1}^{MN} I_{\text{line}}}{\sum_{i=1}^{MN} I_{\text{continuum}}} \quad (2)$$

The mean error of that figure is calculated from the MN single indices. As weather conditions were generally poor, normalisation with the reference channel signal was used throughout. Table 2 gives the complete list of observations.

The entrance slit width was 0.25 mm ($\sim 0.4 \text{ \AA}$) for the 50 cm period, but was widened to 1 mm at the 1 m telescope due to the larger image of that instrument. The broader entrance slit increases the seeing dependency and necessitates the observation of standard stars. One such star, HR 5028, was observed on nearly all nights to test the constancy of the instrumental system. Being of spectral class A2V ($R=0.50$ equal to B2V, $R=0.58$ equal to B7V), the R index is supposed to be constant. Observations of this and other stars, which proved to be He-constant, show that the shift between the two sessions is less than $\Delta R = 0.0015$ ($\sim 20 \text{ m\AA}$). For repeated observations made within the 1 m period the seeing dependency is better than $\Delta R = 0.0015$. A transformation to the 50 cm system has been applied only when analysing the data for the bright star HR 4199; the only star for which the typical standard error is smaller than the index shift. The observations of HR 5028 are plotted in figure 1.

An accuracy of 0.003 R was the goal for most of the stars. This limit was not reached for some of the fainter stars. Bad weather also imposed a lower accuracy for some observations. The bright stars HR 3089, HR 4199 and HD 125823 were observed to somewhat better accuracy than the rest.

Care was taken during the work not to end an observation if, by chance, the calculated error was significantly smaller than the error expected from photon statistics:

$$\sigma_{\text{ph}} = 1.1 R (1/N_l + 1/N_c + 2/N_r)^{1/2} \quad (3)$$

Here, the numerical factor takes account of dyode statistics and the subscripts l , c , r refer to line band, continuum band, and reference channel respectively. During all subsequent reductions σ was replaced by σ_{ph} if $\sigma < \sigma_{\text{ph}}$. This somewhat arbitrary change applied to 23% of the observations and raised the mean value of $\sigma/\sigma_{\text{ph}}$ from 1.24 to 1.28.

All variables have been analysed with a period searching computer program. For each trial period P , a fit is made to the trigonometric polynomium

$$R_{2j+1}(\phi) = a_0 + \sum_{i=1}^j (a_i \cos i\phi + b_i \sin i\phi) \quad (4)$$

where

$$\phi = 2\pi(\text{J.D.}_{\text{hel}} - 2442777.5)/P \quad (5)$$

All variables are fitted satisfactorily by (4) with periods longer than 8 hours, so no shorter periods have been searched for. The minima of

$$\varepsilon_k(P) = \left(\sum_{i=1}^n ((R(i) - R_k(\phi))/\sigma_i)^2 / (n-k) \right)^{1/2}, \quad k = 2j + 1 \quad (6)$$

are used to find the most probable periods. We remark that for a large sample of observations,

$$\varepsilon_k(P) \approx 1 \quad (7)$$

if the R variability is well represented by the chosen function. For a given minimum P_0 in the $\varepsilon_k(P)$ curve, the error in P_0 may be estimated as half the difference between the two points where

$$\varepsilon_k(P) = \varepsilon_k(P_0) + \varepsilon_k(P_0)/(n-k-1)^{1/2} \quad (8)$$

2.2. $uvby\beta$ Photometry

The photoelectric $uvby$ photometry was carried out at the Danish 50 cm telescope, ESO La Silla during two periods, the first from December 31, 1975 to January 14, 1976, the second from February 11 to February 20, 1976.

The four-colour grating photometer used is described by Grønbech *et al.* (1976). To take full advantage of the simultaneity of the measurements, we shall follow these authors and make the reductions in y , $(b-y)$, m_1 , c_1 (Strömberg 1966) rather than in the individual magnitudes.

The observations were grouped into series consisting of ten or more measurements of each star along with one or two measurements of the sky background. For each of these groups mean indices and corresponding mean errors were calculated by the method of least squares. To allow for the variation in airmass during the observations the measurements of each index were fitted by a linear function of airmass. Each of the indices and y values found by this method were therefore given a weight defined as the square of the reciprocal corresponding mean error. As a differential technique is highly desirable, the standard stars were chosen from table 11 of Grønbech *et al.* (1976) using the criterion that they should be close to the programme stars. Between one third and half of the observing time was spent on standard stars to make possible the use of the nearest of these as comparison stars. Standard values of y , $(b-y)$, m_1 , and c_1 in the instrumental system combined with observed values were then used to determine night corrections and extinction coefficients for each night through a least-squares solution. All night corrections were assumed to be linear functions of time.

From the residuals of each solution was calculated the rms error of an observation of unit weight. This quantity should be close to one if all errors could be ascribed to the internal mean errors of the individual groups of measurements. Since it ranged from 2 to 5 some additional source of error must be present, probably a variation in the extinction on a time scale longer than 10 min. This suspicion is strengthened by the fact that the weather conditions on La Silla were below average during both observing periods.

Corrected values for the indices were now calculated for the programme stars using the derived night corrections and extinction coefficients. Any variable extinction will turn up as a systematic variation of the residuals with time and can partly be removed by using the following technique. For each program star one or more of the standard stars are chosen as comparison star(s). A linear interpolation in time is performed between the residuals of the two comparison star observations taken immediately preceeding and following the programme star. The interpolated residuals are finally subtracted from the provisionally reduced values. The mean errors of the final indices and y magnitudes are calculated by combining internal mean errors for programme and comparison star as given by the individual groups of observations. The so reduced data are listed in table 3 together with the corresponding heliocentric julian dates.

The curves for y , $(b-y)$, m_1 , and c_1 are plotted in figure 3 for those stars found to be He variable. Note that the indices are given in the instrumental system as it is dubious whether the standard transformation to the Crawford-Barnes (1970) system given by Grønbech *et al.* (1976) applies for these peculiar stars.

Two conclusions concerning the reduction can be drawn from these plots: 1) the scatter for a fixed phase is still somewhat larger than indicated by the error bars determined from the individual groups; 2) the scatter is largest for y and c_1 and smallest for $(b-y)$. As $(b-y)$ has the smallest extinction coefficient, this is just what should be expected if the scatter was caused by fluctuations in the extinction.

The results of the *uvby* photometry are discussed under the individual stars.

The H β photometry of the stars found to be He-variable was carried out with a two-channel photometer mounted on the same telescope during February 13 and February 14, 1976. The photometer will be described by Grønbech and Olsen (1977). HR 4199 and HR 3856 were chosen as comparison stars partly because they cover a wide range of β values and partly because they were accessible for observation during the whole night. The standard β values for the two comparison stars were taken from Crawford *et al.* (1970) and used to derive both the transformation coefficients to the standard system of Crawford and Mander (1966) and the night correction, including a linear drift term.

2.3. Individual Stars

HR 1441

The star was included in the analysis as being He-weak (Cayrel 1971) and having a variable c_1 index (Grønbech and Olsen 1976). At least two periods are possible: $P = 1.374$ and $P = 3.67$ days. As judged from the ε_7 values the first period is the most probable. The *uvby* data cannot be used to decide between the two possibilities. Both y and c_1 show large variability. The star is faintest when He-strong. Note that the curves for c_1 and y are dissimilar and shifted $\sim 90^\circ$ with respect to each other.

HR 1890

This is the star discussed by Lester (1972). It is a single-lined spectroscopic binary. Since the phase of the $K_1 = 30 \text{ km s}^{-1}$ radial velocity variation was unknown, a constant value of 32 km s^{-1} was assumed for the heliocentric velocity. The adopted value is equal to the center of gravity velocity. The radial velocity period $P = 18.65$ days (Blaauw and van Albada 1963) is twice as long as one of the possible periods, $P = 9.3 \pm 0.3$ days. This commensurability remained a puzzle during the observations. The true period, however, is more likely to be $P = 0.9015 \pm 0.0020$ days, which will in fact produce nine-day period beats, if the observations are taken at 24 hour intervals. This period is also in better agreement with the rotational velocity, $V \sin i = 150 \text{ km s}^{-1}$ (Uesugi and Fukuda 1970).

On February 3, when the star was in its He-weak phase, a test was run to see if the apparent nine-day periodicity could be explained by the He line being shifted into one of the "continuum" bands twice per radial velocity period. The programme was given topocentric radial velocities in error by $\pm 30 \text{ km s}^{-1}$. The results were: $+30 \text{ km s}^{-1}$: $R = 0.5142 \pm 0.0021$, 0 km s^{-1} : $R = 0.5150 \pm 0.0022$, -30 km s^{-1} : $R = 0.5129 \pm 0.0022$. Since R_7 ranges from 0.4927 to 0.5146, the possible influence of erroneous radial velocity data may thus be neglected.

A small, but clear, variability exists in the Strömberg photometry. When He-rich the star is bright in y and has a small c_1 index.

HD 37058

The possibility of HD 37058 being He-variable is discussed both by Jaschek and Jaschek (1974a) and Norris (1971a). The peak to peak range of the R_5 curve corresponds to $\Delta W = 250 \text{ mÅ}$ in the equivalent width of HeI $\lambda 4026 \text{ Å}$ and may well be detected by photographic spectroscopy. The period found from the R observations, $P = 15.3 \pm 0.8$ days, is consistent with the rotational velocity, $V \sin i = 5 \text{ km s}^{-1}$ (Uesugi and Fukuda 1970). In spite of the bad phase coverage one notes that the star is He-weak when faint in y . The corresponding strong phases, however, do not accord. The c_1 data closely follows y , while $(b-y)$ and m_1 are nearly constant.

A magnetic field of $H_e = +2500 \pm 300$ gauss was reported by Sargent *et al.* (1967). However, Conti (1970) was unable to confirm this observation though the five Zeeman spectrograms obtained by him all showed a positive field. Due to the large uncertainty in our period determination it is not possible to phase resolve the magnetic data.

HD 37321

According to Molnar (1972), this star has changed its spectral type from B8 to B3. The present observation $R = 0.5370$ corresponds to a spectral type about B5, but since the five observations agree very well internally we cannot accept it as a He variable. If, nevertheless, it is a periodic spectrum variable, the period must either be close to one day or much longer than the time interval, five days, covered by the observations.

HR 1932 = σ Ori E

The variability of the He spectrum of σ Ori E was found by Hunger (1974) from photographic spectroscopy and was also noted by Nissen (1974). Thomsen (1974) determined the period to be either 21 or 29 hours although a period of six days represented the data equally well. Hesser *et al.* (1976) have determined the period to be $P = 1.19080 \pm 0.00005$ days. As their last observing session overlap that of the present work we shall use this period rather than the one found solely from the R observations, $P = 1.192 \pm 0.006$ days.

A five parameter solution to the R observations has been plotted in figure 2. The corresponding seven parameter solution partly removes the secondary minimum in the R_5 curve, but as the number of degrees of freedom is reduced ϵ_7 is not significantly smaller than ϵ_5 .

The phase resolved Strömgren photometry shown in figure 3 is in excellent agreement with the light and colour curves given by Hesser *et al.* (1976) and display the following characteristics: 1) Both the y magnitude and the c_1 index show two distinct eclipse-like features, of which the secondary follows the primary by $0.42 P$. 2) The c_1 curve shows that the Balmer jump has a maximum during both eclipses. 3) The c_1 curves has a clear decrease in slope during ingress into the primary minimum. The same feature is probably present also in the secondary eclipse. 4) The $(b-y)$ colour gets bluer during both eclipses, the effect being most pronounced for the primary eclipse. 5) The “eclipses” in the y and c_1 curves are superimposed on a more gradual variation. 6) The primary minimum follows the phase of maximum He line strength by $0.12 P$.

During the two nights of $H\beta$ observations seven measurements were obtained of σ Ori E. On the last night the β index changed from 2.618 at phase 0.666 to 2.596 at phase 0.812. The two observations from the first night confirm the low β value at the He-strong phase.

HD 37776

The He variability of HD 37776 was discovered by Nissen (1976). A tentative identification as a β Cephei star with the period $P = 0.37968 \pm 0.00005$ days was made by Hill (1967). Some of Hill's discoveries have been doubted by later investigators, and HD 37776 is not found in Eggen's (1975) tabulation of ultra-short period, very small amplitude B type variables. The period found from the R observations, $P = 1.538 \pm 0.004$ days is a factor of 4.05 longer than Hill's. In fact, our data show a $\epsilon_7(P)$ minimum at $P = 0.3778 \pm 0.0008$ days, but at low significance. As Hill only looked for periods shorter than one day, we suppose that he found an overtone of the correct period.

The $uvby$ data show a clear variability in y and c_1 . When He-strong, the star is faint in y and has a small c_1 index.

HR 2509

The R curve for this star is similar to that of HR 1932 but at a He-weak level. The He-weak phase is remarkably constant. The Strömgren data suggest an intensity minimum at He maximum and possibly two oscillations in c_1 whereas $b-y$ and m_1 are constant. This does not support the statement by Jaschek and Jaschek (1974a) that the $U-B$ and $B-V$ indices show larger scatter.

HR 2790

In a short notice Wright (1974) reports that Sanyal has found a possible short term variability in the lines of hydrogen and helium. The nine values of R acquired for this object, however, indicate constancy from night to night. Also, the internal observational scatter is not greater than normal.

Eggen (1975) lists HR 2790 together with all known β Cephei objects. The reference given by Eggen is an error, it should read Van Hoof (1973). The photometric period of three hours given by Van Hoof (1973 and 1975) is not indicated in the present four-colour observations. Neither y , $b-y$, m_1 nor c_1 show any sign of variability, so the amplitude must have been rather small at the time of the first period of $uvby$ observations.

HR 3089

The high He content of this star was first noted by Hiltner *et al.* (1969). Nissen (1974) also found HR 3089 to be He-rich. From two spectrograms, Walborn (1974) suspected a weak, broad and variable emission on the red side of H α . The Strömgren photometry, however, bears no resemblance to the σ Ori E phenomenon. At the moment of He maximum, the Balmer jump is slightly smaller than during the rest of the cycle. The other quantities, y , $(b-y)$, and m_1 are virtually constant throughout the period, $P = 1.3295 \pm 0.0025$ days. As the rotational velocity is large, $V \sin i = 274 \text{ km s}^{-1}$ (Uesugi and Fukuda 1970), the radius of the star must be larger than 7 solar radii, if the rotator model is assumed.

HR 3089 is located just inside the 3U0750–49 error box. This could be a chance coincidence, but since HR 3089 is the brightest known He-rich He variable, we feel that the case should be examined (Pedersen 1976b).

HR 4199 = θ Car

The He content deduced by Hyland (1967) and Shipman and Strom (1970) shows θ Car to be moderately He-rich.

When analysed separately, both the data from the 50 cm period (12 observations) and the 1 m period (14 observations) indicate a period of 0.70 days. Due to the aforementioned index shift, the mean value of the latter observations is higher by $\Delta R = 0.0010$. If shifted downward by this amount and analysed together with the 50 cm observations, the period $P = 0.7045$ days is found. The double amplitude is, however, only $\Delta R = 0.0020$ and thus comparable to what is supposed to be the limit of system constancy. A period of this magnitude would nevertheless be expected from the relatively high rotational velocity, $V \sin i = 202 \text{ km s}^{-1}$ (Uesugi and Fukuda 1970).

θ Car is a member of IC 2602 (Abt and Morgan 1972). Jaschek and Jaschek (1974b) have summarized the spectroscopic observations of this object and note that variations in the lines of helium, nitrogen, and phosphorus are indicated.

HD 120709 = 3 Cen A

Probably due to the presence of the fainter component which could not be totally excluded, the internal errors for this star are in mean 50% larger than expected from photon statistics. Systematic errors may thus be present, and we do not believe this star to be R -variable even if two of the nine observations deviate by as much as 3.3 times their combined mean errors. Detection of helium variability in this star would have been particularly interesting since its atmospheric He content is supposed to be mainly in the form of He 3 (Sargent and Jugaku 1961, Hardorp 1966).

3 Cen A is mentioned as showing “striking He variations” (Thackeray 1974) but obviously this is a misprint for a Cen.

HD 125823 = a Cen

The period found from a seven parameter fit is 8.82 ± 0.03 days. The observations cover an interval of 32 days. The R_7 curve is nearly sinusoidal. Since the photon-statistical errors for a bright object like this may pass the limit of system-constancy, the value of $\epsilon_7 = 1.35$ is fully acceptable. The observations are thus described as well as possible by a single wave and do not support the double wave hypothesis discussed by Mihalas (1973).

Norris (1971b) discussed the period of a Cen using all available observations. The period determined from spectral classifications is $P = 8.8172$ days, but Norris adopts $P = 8.8140$ since this period represents his equivalent width data better. We have used crude linear transformations to convert spectral classifications and equivalent width data to R values. The data included are those listed by Norris (1971b), Klinglesmith *et al.* (1971), and Underhill *et al.* (1975). The $\sigma(R)$ values formally adopted correspond to $2/3$ in any B type index and $100 \text{ m}\text{\AA}$ in any equivalent width. A period determination using both these observations and our own R data, altogether 113 observations, gives the period $P = 8.8171 \pm 0.0003$ days (see figure 4). Two spectral classifications by Jaschek *et al.* (1968), a B3 and a B9 type, are the only ones that deviate more than 3σ from the best five parameter fit. Upon request Dr. C. Jaschek has very kindly informed us, that the B3p type of J.D. 2439980.7 should read B8p and that the time of observation, J.D. 2439986.6 should read J.D. 2439985.7. Dr. Jaschek also notes that the plate from J.D. 2439989.6 should be given the spectral type B8-B9p instead of B9p. With especially the first of these changes in mind, the argument for a constant period is very much stronger. The probably somewhat uncertain spectral classification, B4, assigned by Norris to an 1895 Harvard observation, deviates by 2.9σ .

Taking the time for a minimum in R (= He maximum) from table 1, the ephemeris is thus

$$\text{J.D. } (R_{\min}) = 2442807.75 + n(8.8171 \pm 0.0003) \quad (9)$$

The phase resolved $uvby$ photometry shows that y and m_1 vary in phase, c_1 in antiphase with the R_7 curve in the sense that the star is faintest when He-strong. The constancy of $(b-y)$ shows that all the variation in m_1 must be caused by the colour index $(v-b)$. This in turn can account for most of the variation in c_1 , the rest being caused by a small variation in $(u-v)$.

HD 142301 = 3 Sco

The existence of some kind of nonuniform distribution of helium in the atmosphere of 3 Sco was postulated by Norris and Strittmatter (1975), who, however, found no evidence for spectrum variability. The range of the R variability corresponds to $\Delta w = 0.2 \text{ \AA}$. Among several possible periods the most probable is $P = 1.461$ days. The R variability appears to be rather complex. Seven parameters are required to describe the 22 observations. The Strömgren data are meagre but suggest variability both in y and c_1 .

HR 5942

Eleven observations covering an interval of 16 days show the He line strength to be increasing from day to day until a constant level is reached. A long period, $P \simeq 40$ days, is thus indicated, but several shorter periods reach smaller ϵ_3 values. Since these values are $\simeq 1.7$, the R variability is far from being sinusoidal. Nevertheless, a three term solution suffices to fix the possible periods, $P = 0.492$ and $P = 0.976$ days, of which the first is the most probable.

The high rotational velocity, $V \sin i = 200 \text{ km s}^{-1}$ (Uesugi and Fukuda 1970) strongly favors a period of about one day or less.

The interpretation of the Strömgren data is hampered by incomplete phase coverage. Yet, some variability is obvious in the y magnitude, in the sense of being faint when He-strong.

HR 5988

According to Norris (1971a) this is a probable spectrum variable. The four R observations are, however, in perfect agreement with each other.

2.4. Other Stars

A number of other stars may be He variable, but at a low level of significance. The group includes HR 4089, HD 96446, and HR 3663. The rest of the program stars are either probable He constants or have been observed too little to make any conclusion possible.

HR 4089: This star is a spectroscopic binary showing two spectra. Jaschek *et al.* (1969) found it to be He-weak but made no comment on its duplicity. The constant heliocentric velocity used for the observations is 12 km s^{-1} which is equal to the mean value given by Hoffleit (1964). As may be seen from table 1 the three possible periods, $P = 0.9445$, 1.0565 , and 17.7 days, describe the material equally well. The longest period, however, is ruled out by the rotational velocity, $V \sin i = 79 \text{ km s}^{-1}$ (Uesugi and Fukuda 1970) – at least if the R variability is interpreted by a rotator model.

HD 96446: This is a sharp-lined, He-rich star found by Jaschek and Jaschek (1959) and discussed by Cowley *et al.* (1963) and Buscombe (1965). The period found from the 21 observations of R is $P = 23 \pm 6$ days.

HR 3663: This is one of the stars intended for establishing a link to Nissen's I_{4026} system. The four R observations agree internally but disagree strongly with the value deduced from relation (10). According to Nissen (1976b), HR 3663 was observed on three consecutive nights to find the mean value $I_{4026} = 0.101$ and the “reduced” equivalent width $W' = 1215 \text{ mÅ}$. The four R values obtained for this object cover an interval of 20 days and do not suggest any variability within that period. Since $V \sin i = 0 \text{ km s}^{-1}$ (Uesugi and Fukuda 1970) we will tentatively interpret HR 3663 as a slow He variable.

3. TRANSFORMATION TO THE I_{4026} SYSTEM

The spectral bands used by Nissen (1974) to define the I_{4026} system are not far from those used in the present study. A simple relation between R and I_{4026} must therefore be expected. Excluding one star, HR 3663, which is discussed separately, the remaining nine stars in common define a linear relationship (see figure 6). A linear least squares programme (Gammelgaard 1968) using weights in both coordinates has been run to find the relation

$$R = 0.7173 I_{4026} + 0.4530 \quad (10)$$

The mean errors in I_{4026} have been communicated by Nissen (1976b).

4. DISCUSSION

Of the nine He-strong stars observed, two were known spectrum variables. Among the rest, we find two definite variables (HR 1890 and 3089), two possible variables (HR 4199 and HD 96446), while little or no variability is indicated in the data for HD 60344, HR 5206 and HD 133518. The two new variables are the same as those found by Walborn (1974) to show H α emission like σ Ori E. Except for one star, HD 58260, these nine stars comprise all intermediate He stars that could be observed under the given circumstances. The existence of at least 4 spectrum variables among these is thus a large fraction. Another He-rich star, HD 184927, has recently been reported as a helium variable (Walborn 1975).

Among the 17 He-weak stars observed, none were known variables. However, five stars from this class (HR 1441, HD 37058, HR 2509, HD 142301, HR 5942) showed definite variability and one more star may be variable (HR 4089). The remainders generally seem to be R -constant.

A point regarding the observations should be made in this context: Since the data were reduced on-line, the work has been biased towards those objects that soon showed variability. The fraction of variables may therefore be underestimated.

An HR diagram shown in figure 5 has been constructed for the He variables. The reddening independent index $[c_1] = c_1 - 0.2(b-y)$ (Strömberg 1966) is used as a temperature indicator, while the surface gravity is measured by the β index. The indices used are mean values. The zero age main sequence defined by Nissen (1974) is shown as a straight line. Except for σ Ori E, the stars are distributed quite close to the ZAMS (within 0.015). This indicates that the He variables are young, unevolved stars. From figure 6 of Nissen (1974) we conclude that the $\log g$ values are within 0.2 of the zero age main sequence. The 0^m035 deviation shown by σ Ori E may be caused by a variable emission in the H β line.

From the appearance of the R curves one may divide the material into two groups: those stars that show one He maximum, and those that show a more complex variability. The first of these groups comprises at least four stars. In HD 125823 the R variability is nearly sinusoidal. The amplitudes of the higher trigonometric terms are $< 4\%$ that of the sine curve. In HR 1932 and HR 1890 (both He-rich) and HR 2509 (He-weak) one sees a virtually flat He-weak phase lasting nearly half the period. This fact, together with the pronounced symmetry of these curves, makes interpretations in terms of a pulsating atmosphere difficult. In the rotating spot model one must infer the visibility of one small, concentrated He spot. To allow for the existence of two opposite He spots this group must have small, but non-zero $\sin i$ values. Among the stars in the second group, the best studied cases are the He-strong stars HR 3089 and HD 37776. Both objects show two distinct He maxima. In the rotating spot model they must be candidates for $\sin i \approx 1$. Also, the He-weak stars HR 1441 and HD 142301 exhibit complex R variability, but more observations are clearly needed. Since few of the He variables have published rotational velocities it is not possible to test this correlation between $\sin i$ and R complexity.

The form and amplitude of the phase-resolved Strömgren photometry vary greatly from star to star. Although the phase coverage is poor for some of the objects, it may be concluded that σ Ori E is a unique object in regard to its light and colour curves. Comparison with the R curves shows a pronounced correlation between the He line strengths and the Strömgren photometry. Most of the objects are He-strong when faint in the y magnitude and weak in the Balmer jump.

However, the material presented here does not allow to set up a final model for the He-variable stars. Corotating binary (mass transfer) models are attractive for several reasons but will meet difficulties in case of HR 1890 which should then be triple with a semi-major axis ratio only slightly larger than 7.5. Single star magnetic rotators are still possible, particularly since Wolff and Wolff's (1976) discovery of a large and periodically variable magnetic field in HR 7129. These models, however, are poorly understood and will face unsurmountable difficulties in explaining the phenomena in HR 1932. To both kinds of models, the constant radial velocity of the helium lines in HR 1932 (Groote and Hunger 1977) is a mystery.

In both He-weak and He-strong stars the spectrum variability has proven to be periodic – at least over short time intervals. For HR 1932 and HD 125823 this is valid also over time spans of ~ 2 and ~ 50 years, respectively. In order to determine the phase of variability and thus possible future changes of periods, the R index is more accurate than $uvby$ photometry. This may not be true in the case of HR 1932, due to its sharp light and colour minima.

A natural extension of this work would be the observation of the early type CNO stars. Many such objects are known to be spectrum variables and do indeed share characteristics with the He-weak and He-strong stars, as pointed out by Jaschek and Jaschek (1974b).

REFERENCES

- Abt, H.A. and Morgan, W.W.: 1972, *Astrophys. J. Letters* **174**, L131.
 Balona, L.A.: 1975, *Monthly Notices Roy. Astron. Soc.* **173**, 605.
 Blaauw, A. and Albada, T.S. van: 1963, *Astrophys. J.* **137**, 791.
 Buscombe, W.: 1965, *Monthly Notices Roy. Astron. Soc.* **129**, 1.
 Cayrel, R.: 1971, C. de Jaeger (Ed.) in *Highlights of Astronomy*, D. Reidel Publ. Co., Dordrecht, 254.
 Conti, P.S.: 1970, *Astrophys. J.* **159**, 723.
 Conti, P.S. and Loonen, J.P.: 1970, *Astron. Astrophys.* **8**, 197.
 Cowley, A., Aller, L.H. and Dunham, T. Jr.: 1963, *Publ. Astron. Soc. Pacific* **75**, 441.
 Crawford, D.L. and Barnes, J.V.: 1970, *Astron. J.* **75**, 946.
 Crawford, D.L., Barnes, J.V. and Golson, J.C.: 1970, *Astron. J.* **75**, 624.
 Crawford, D.L. and Mander, J.: 1966, *Astron. J.* **71**, 114.
 Eggen, O.J.: 1975, *Astrophys. J.* **198**, 131.
 Gammelgaard, P.: 1968, *J. Obs.* **51**, 297.
 Groote, D. and Hunger, K.: 1977, *Astron. Astrophys.* **56**, 129.
 Grønbech, B. and Olsen, E.H.: 1976, *Astron. Astrophys. Suppl.* **25**, 213.

- Grønbech, B., Olsen, E.H. and Strömgren, B.: 1976, *Astron. Astrophys. Suppl.* **26**, 155.
- Grønbech, B. and Olsen, E.H.: 1977, *Astron. Astrophys. Suppl.* **27**, 443.
- Hardorp, J.: 1966, *Z. Astrophys.* **63**, 137.
- Hesser, J.E., Walborn, N.R. and Ugarte, P.P.: 1976, *Nature* **262**, 116.
- Hill, G.: 1967, *Astrophys. J. Suppl.* **14**, 263.
- Hiltner, W.A., Garrison, R.F. and Schild, R.E.: 1969, *Astrophys. J.* **157**, 313.
- Hoffleit, D.: 1964, *Catalogue of Bright Stars*, Yale University Observatory, New Haven.
- Hunger, K.: 1974, *Astron. Astrophys.* **32**, 449.
- Hunger, K.: 1975, B. Baschek, W.H. Kegel, and G. Traving. (Eds.) in *Problems in Stellar Atmospheres and Envelopes*, Springer-Verlag, Berlin Heidelberg New York, p. 57.
- Hyland, A.R.: 1967, thesis, unpublished, Australian National University.
- Jaschek, M. and Jaschek, C.: 1959, *Publ. Astron. Soc. Pacific* **71**, 465.
- Jaschek, M. and Jaschek, C.: 1974a, *Vistas Astron.* **16**, 131.
- Jaschek, M. and Jaschek, C.: 1974b, *Astron. Astrophys.* **36**, 401.
- Jaschek, M., Jaschek, C. and Arnal, M.: 1969, *Publ. Astron. Soc. Pacific* **81**, 650.
- Jaschek, M., Jaschek, C. and Kucwicz, B.: 1968, *Nature* **219**, 1137.
- Klinglesmith, D.A., Bernacca, P.L. and Frey, H.: 1971, *Veröffentl. Remeis Sternwarte Bamberg*, Band IX, **100**, 205.
- Lester, J.B.: 1972, *Astrophys. J.* **178**, 743.
- Mihalas, D.: 1973, *Astrophys. J.* **184**, 851.
- Molnar, M.R.: 1972, *Astrophys. J.* **175**, 453.
- Nissen, P.E.: 1974, *Astron. Astrophys.* **36**, 57.
- Nissen, P.E.: 1976a, *Astron. Astrophys.* **50**, 343.
- Nissen, P.E.: 1976b, private communication.
- Norris, J.: 1971a, *Astrophys. J. Suppl.* **23**, 213.
- Norris, J.: 1971b, *Astrophys. J. Suppl.* **23**, 235.
- Norris, J. and Strittmatter, P.A.: 1975, *Astrophys. J.* **196**, 515.
- Osmer, P.S. and Peterson, D.M.: 1974, *Astrophys. J.* **187**, 117.
- Pedersen, H.: 1976a, *Astron. Astrophys.* **49**, 217.
- Pedersen, H.: 1976b, *IAU Circ. No.* 2972.
- Sargent, W.L.W. and Jugaku, J.: 1961, *Astrophys. J.* **134**, 777.
- Sargent, W.L.W., Sargent, A.I. and Strittmatter, P.A.: 1967, *Astrophys. J.* **147**, 1185.
- Shipman, H.L. and Strom, S.E.: 1970, *Astrophys. J.* **159**, 183.
- Strömgren, B.: 1966, *Ann. Rev. Astron. Astrophys.* **4**, 433.
- Thackeray, A.D.: 1974, *Quart. J. Roy. Astron. Soc.* **15**, 516.
- Thomsen, B.: 1974, *Astron. Astrophys.* **35**, 479.
- Uesugi, A. and Fukuda, I.: 1970, *Contr. Kwasan Obs. Kyoto* no. 189.
- Underhill, A.B., Fahey, R.P. and Klinglesmith, D.A.: 1975, *Astrophys. J.* **199**, 120.
- Van Hoof, A.: 1973, *Inf. Bull. Variable Stars* no. 807.
- Van Hoof, A.: 1975, *Inf. Bull. Variable Stars* no. 969.
- Walborn, N.R.: 1974, *Astrophys. J. Letters* **191**, L95.
- Walborn, N.R.: 1975, *Publ. Astron. Soc. Pacific* **87**, 613.
- Walborn, N.R. and Hesser, J.E.: 1976, *Astrophys. J. Letters*, **205**, L87.
- Warren, W.H.: 1975, thesis, Indiana University, unpublished.
- Wolf, R.E.A.: 1973, *Astron. Astrophys.* **26**, 127.
- Wolff, R.J. and Wolff, S.C.: 1976, *Astrophys. J.* **203**, 171.
- Wright, K.O.: 1974, *Quart. J. Roy. Astron. Soc.* **15**, 475.

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Table 1

HR	HD	class.	refs.	assoc.	n	R_1	ϵ_1		k	P days	$\sigma(P)$ days	$\epsilon_k(P)$	J.D. _{hel} (R_{\min})
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
<u>Program Stars</u>													2442000 +
1441	28843	W	1)		36	-	3.9	var	7	1.374 3.67	0.006 0.01	1.12 1.35	812.52
	36629	W	7)	Ori	2	.5046	0.63						
1890	37017	S	4)	Ori	27	-	4.4	var	5	0.9015	0.0020	0.9	812.23
	37058	W	1), 7)	Ori	22	-	2.9	var	5	15.26	0.8	0.8	813.44
	37129	W	1), 7)	Ori	11	.5087	0.85						
	37321	var?	11)		5	.5370	0.5						
1932	37479	S, var	6)	Ori	48	-	4.0	var	5	1.192	0.006	1.1	802.48 σ Ori E
	37776	S, var	6)	Ori	37	-	4.3	var	7	1.538	0.004	1.15	808.59 [†]
2509	49333	W	1)	NGC 2287	25	-	6.1	var	5	2.181	0.009	0.8	818.88
2790	57219	var?	13)		9	.5222	0.8						
	60344	S	9)		3	.4944	0.5						
2954	61641	W	1), 5)		9	.5250	1.0						
3001	62712	W	1), 5)		7	.5675	1.0						
3089	64740	S	2), 5)		64	-	6.9	var	7	1.3295	0.0025	1.1	806.71
3448	74196	W	1)	IC 2391	13	.5606	1.4						
4089	90264	W	1)		21	.5758	1.5	var?	3	0.9445 1.0565 17.7	0.012 0.015 4.4	1.05 1.08 1.05	
4199	93030	S	10)	IC 2602	26	.5356	1.53	var?	3	0.7045	0.0040	1.0	θ Car
	96446	S	12)		21	.4801	1.4	var?	3	23.0	6.0	0.8	
4773	109026	W	1)	Sco-Cen	6	.5440	0.8						
5206	120640	S	9)		12	.5081	1.25						
5210	120709	W	1), 7)	Sco-Cen	9	.5493	1.2						3 Cen A
5378	125823	var		Sco-Cen	32	-	41.5	var	7	8.82	0.03	1.35	807.75 a Cen
	133518	S	9)		7	.4810	0.5						
5912	142301	W	1), 7), 8)	Sco-Cen	22	-	3.3	var	7	1.461	0.007	1.0	817.84 3 Sco
5942	142990	W	1), 5)	Sco-Cen	11	-	7.8	var	3	40. 0.976 0.492	0.015 0.003	1.9 1.42 1.35	826.82
5967	143699	W	1), 5)	Sco-Cen	9	.5621	1.45						
5988	144334	W, var?	1), 5)										
			7), 8)	Sco-Cen	4	.5871	0.3						
5998	144661	W	1), 7)	Sco-Cen	7	.5740	1.3						
6054	146001	W	1), 5)	Sco-Cen	2	.5753	0.1						
<u>Standard and transformation Stars</u>													
5028	115892				25	.5893	1.04						
1735	34503		3)		1	.5577	-						
3468	74575		3)		1	.5358	-						
3663	79447		3)		4	.5355	1.6	var?					
4656	106490		3)		3	.5268	2.1						
4898	112092		3)		3	.5085	1.8						

column 6: the number of R observations, n .
column 7: the weighted mean value R_1 .
column 8: the mean deviation ϵ_1 (from formula (6)).
column 9: our judgement of the presence of variability in the R index.
column 10: the number of terms, k , in the trigonometric polynomial used for curve fitting.
column 11: the most probable period(s), P .
column 12: the uncertainty in P (from formula (8)).
column 13: the mean deviation ϵ_k from the best trigonometric fit with k terms (from formula (6)).
column 14: the heliocentric julian data for a minimum in R_k .
[†] The data in column 14 corresponds to minima actually observed. The only exception is HD 37776 for which the He-rich phase is ill defined; instead we give the time for a maximum in R_k . As far as possible, the extremum given also falls close to the middle of the time interval used to obtain the n observations of the star in question.

References:

- | | |
|--------------------------|-----------------------------------|
| 1) Cayrel (1971) | 8) Norris and Strittmatter (1974) |
| 2) Hiltner et al. (1969) | 9) Osmer and Peterson (1974) |
| 3) Hunger (1975) | 10) Shipman and Strom (1970) |
| 4) Lester (1972) | 11) Warren (1975) |
| 5) Nissen (1974) | 12) Wolf (1973) |
| 6) Nissen (1976a) | 13) Wright (1974) |
| 7) Norris (1971a) | |

Table 3 Strömgen photometry of all He variable stars observed in this programme. For each object, the first column gives $J.D._{\text{hel}} - 2442000$. The next four columns give y , $(b-y)$, m , and c_1 - all in the instrumental system and in units of 0^m001 .

$J.D._{\text{hel}} - 2442000$	y	$(b-y)$	m	c_1	HR 2509	HR 125823										
778.614	5742	-67	95	46	827.571 6693	-54	77	66	778.711 6097	-57	90	328	778.684 4416	-78	77	199
779.614	5812	-39	84	45	827.591 6712	-51	70	46	827.591 6712	-51	70	46	779.684 4431	-78	77	199
780.614	5882	-39	84	45	827.611 6731	-51	70	46	827.611 6731	-51	70	46	780.684 4446	-78	77	199
781.614	5952	-39	84	45	827.631 6750	-51	70	46	827.631 6750	-51	70	46	781.684 4461	-78	77	199
782.614	6022	-39	84	45	827.651 6769	-51	70	46	827.651 6769	-51	70	46	782.684 4476	-78	77	199
783.614	6092	-39	84	45	827.671 6788	-51	70	46	827.671 6788	-51	70	46	783.684 4491	-78	77	199
784.614	6162	-39	84	45	827.691 6807	-51	70	46	827.691 6807	-51	70	46	784.684 4506	-78	77	199
785.614	6232	-39	84	45	827.711 6826	-51	70	46	827.711 6826	-51	70	46	785.684 4521	-78	77	199
786.614	6302	-39	84	45	827.731 6845	-51	70	46	827.731 6845	-51	70	46	786.684 4536	-78	77	199
787.614	6372	-39	84	45	827.751 6864	-51	70	46	827.751 6864	-51	70	46	787.684 4551	-78	77	199
788.614	6442	-39	84	45	827.771 6883	-51	70	46	827.771 6883	-51	70	46	788.684 4566	-78	77	199
789.614	6512	-39	84	45	827.791 6902	-51	70	46	827.791 6902	-51	70	46	789.684 4581	-78	77	199
790.614	6582	-39	84	45	827.811 6921	-51	70	46	827.811 6921	-51	70	46	790.684 4596	-78	77	199
791.614	6652	-39	84	45	827.831 6940	-51	70	46	827.831 6940	-51	70	46	791.684 4611	-78	77	199
792.614	6722	-39	84	45	827.851 6959	-51	70	46	827.851 6959	-51	70	46	792.684 4626	-78	77	199
793.614	6792	-39	84	45	827.871 6978	-51	70	46	827.871 6978	-51	70	46	793.684 4641	-78	77	199
794.614	6862	-39	84	45	827.891 6997	-51	70	46	827.891 6997	-51	70	46	794.684 4656	-78	77	199
795.614	6932	-39	84	45	827.911 7016	-51	70	46	827.911 7016	-51	70	46	795.684 4671	-78	77	199
796.614	7002	-39	84	45	827.931 7035	-51	70	46	827.931 7035	-51	70	46	796.684 4686	-78	77	199
797.614	7072	-39	84	45	827.951 7054	-51	70	46	827.951 7054	-51	70	46	797.684 4701	-78	77	199
798.614	7142	-39	84	45	827.971 7073	-51	70	46	827.971 7073	-51	70	46	798.684 4716	-78	77	199
799.614	7212	-39	84	45	827.991 7092	-51	70	46	827.991 7092	-51	70	46	799.684 4731	-78	77	199
800.614	7282	-39	84	45	828.011 7111	-51	70	46	828.011 7111	-51	70	46	800.684 4746	-78	77	199
801.614	7352	-39	84	45	828.031 7130	-51	70	46	828.031 7130	-51	70	46	801.684 4761	-78	77	199
802.614	7422	-39	84	45	828.051 7149	-51	70	46	828.051 7149	-51	70	46	802.684 4776	-78	77	199
803.614	7492	-39	84	45	828.071 7168	-51	70	46	828.071 7168	-51	70	46	803.684 4791	-78	77	199
804.614	7562	-39	84	45	828.091 7187	-51	70	46	828.091 7187	-51	70	46	804.684 4806	-78	77	199
805.614	7632	-39	84	45	828.111 7206	-51	70	46	828.111 7206	-51	70	46	805.684 4821	-78	77	199
806.614	7702	-39	84	45	828.131 7225	-51	70	46	828.131 7225	-51	70	46	806.684 4836	-78	77	199
807.614	7772	-39	84	45	828.151 7244	-51	70	46	828.151 7244	-51	70	46	807.684 4851	-78	77	199
808.614	7842	-39	84	45	828.171 7263	-51	70	46	828.171 7263	-51	70	46	808.684 4866	-78	77	199
809.614	7912	-39	84	45	828.191 7282	-51	70	46	828.191 7282	-51	70	46	809.684 4881	-78	77	199
810.614	7982	-39	84	45	828.211 7301	-51	70	46	828.211 7301	-51	70	46	810.684 4896	-78	77	199
811.614	8052	-39	84	45	828.231 7320	-51	70	46	828.231 7320	-51	70	46	811.684 4911	-78	77	199
812.614	8122	-39	84	45	828.251 7339	-51	70	46	828.251 7339	-51	70	46	812.684 4926	-78	77	199
813.614	8192	-39	84	45	828.271 7358	-51	70	46	828.271 7358	-51	70	46	813.684 4941	-78	77	199
814.614	8262	-39	84	45	828.291 7377	-51	70	46	828.291 7377	-51	70	46	814.684 4956	-78	77	199
815.614	8332	-39	84	45	828.311 7396	-51	70	46	828.311 7396	-51	70	46	815.684 4971	-78	77	199
816.614	8402	-39	84	45	828.331 7415	-51	70	46	828.331 7415	-51	70	46	816.684 4986	-78	77	199
817.614	8472	-39	84	45	828.351 7434	-51	70	46	828.351 7434	-51	70	46	817.684 5001	-78	77	199
818.614	8542	-39	84	45	828.371 7453	-51	70	46	828.371 7453	-51	70	46	818.684 5016	-78	77	199
819.614	8612	-39	84	45	828.391 7472	-51	70	46	828.391 7472	-51	70	46	819.684 5031	-78	77	199
820.614	8682	-39	84	45	828.411 7491	-51	70	46	828.411 7491	-51	70	46	820.684 5046	-78	77	199
821.614	8752	-39	84	45	828.431 7510	-51	70	46	828.431 7510	-51	70	46	821.684 5061	-78	77	199
822.614	8822	-39	84	45	828.451 7529	-51	70	46	828.451 7529	-51	70	46	822.684 5076	-78	77	199
823.614	8892	-39	84	45	828.471 7548	-51	70	46	828.471 7548	-51	70	46	823.684 5091	-78	77	199
824.614	8962	-39	84	45	828.491 7567	-51	70	46	828.491 7567	-51	70	46	824.684 5106	-78	77	199
825.614	9032	-39	84	45	828.511 7586	-51	70	46	828.511 7586	-51	70	46	825.684 5121	-78	77	199
826.614	9102	-39	84	45	828.531 7605	-51	70	46	828.531 7605	-51	70	46	826.684 5136	-78	77	199
827.614	9172	-39	84	45	828.551 7624	-51	70	46	828.551 7624	-51	70	46	827.684 5151	-78	77	199
828.614	9242	-39	84	45	828.571 7643	-51	70	46	828.571 7643	-51	70	46	828.684 5166	-78	77	199
829.614	9312	-39	84	45	828.591 7662	-51	70	46	828.591 7662	-51	70	46	829.684 5181	-78	77	199
830.614	9382	-39	84	45	828.611 7681	-51	70	46	828.611 7681	-51	70	46	830.684 5196	-78	77	199
831.614	9452	-39	84	45	828.631 7700	-51	70	46	828.631 7700	-51	70	46	831.684 5211	-78	77	199
832.614	9522	-39	84	45	828.651 7719	-51	70	46	828.651 7719	-51	70	46	832.684 5226	-78	77	199
833.614	9592	-39	84	45	828.671 7738	-51	70	46	828.671 7738	-51	70	46	833.684 5241	-78	77	199
834.614	9662	-39	84	45	828.691 7757	-51	70	46	828.691 7757	-51	70	46	834.684 5256	-78	77	199
835.614	9732	-39	84	45	828.711 7776	-51	70	46	828.711 7776	-51	70	46	835.684 5271	-78	77	199
836.614	9802	-39	84	45	828.731 7795	-51	70	46	828.731 7795	-51	70	46	836.684 5286	-78	77	199
837.614	9872	-39	84	45	828.751 7814	-51	70	46	828.751 7814	-51	70	46	837.684 5301	-78	77	199
838.614	9942	-39	84	45	828.771 7833	-51	70	46	828.771 7833	-51	70	46	838.684 5316	-78	77	199
839.614	10012	-39	84	45	828.791 7852	-51	70	46	828.791 7852	-51	70	46	839.684 5331	-78	77	199
840.614	10082	-39	84	45	828.811 7871	-51	70	46	828.811 7871	-51	70	46	840.684 5346	-78	77	199
841.614	10152	-39	84	45	828.831 7890	-51	70	46	828.831 7890	-51	70	46	841.684 5361	-78	77	199
842.614	10222	-39	84	45	828.851 7909	-51	70	46	828.851 7909	-51	70	46	842.684 5376	-78	77	199
843.614	10292	-39	84	45	828.871 7928	-51	70	46	828.871 7928	-51	70	46	843.684 5391	-78	77	199
844.614	10362	-39	84	45	828.891 7947	-51	70	46	828.891 7947	-51	70	46	844.684 5406	-78	77	199
845.614	10432	-39	84	45	828.911 7966	-51	70	46	828.911 7966	-51	70	46	845.684 5421	-78	77	199
846.614	10502	-39	84	45	828.931 7985	-51	70	46	828.931 7985	-51	70	46	846.684 5436	-78	77	199
847.614	10572	-39	84	45	828.951 8004	-51	70	46	828.951 8004	-51	70	46	847.684 5451	-78	77	199
848.614	10642	-39	84	45	828.971 8023	-51	70	46	828.971 8023	-51	70	46	848.684 5466	-78	77	199
849.614	10712	-39	84	45	828.991 8042	-51	70	46	828.991 8042	-51	70	46	849.684 5481	-78	77	199
850.614	10782	-39	84	45	829.011 8061	-51	70	46	829.011 8061	-51	70	46	850.684 5496	-78	77	199
851.614	10852	-39	84	45	829.031 8080	-51	70	46	829.031 808							

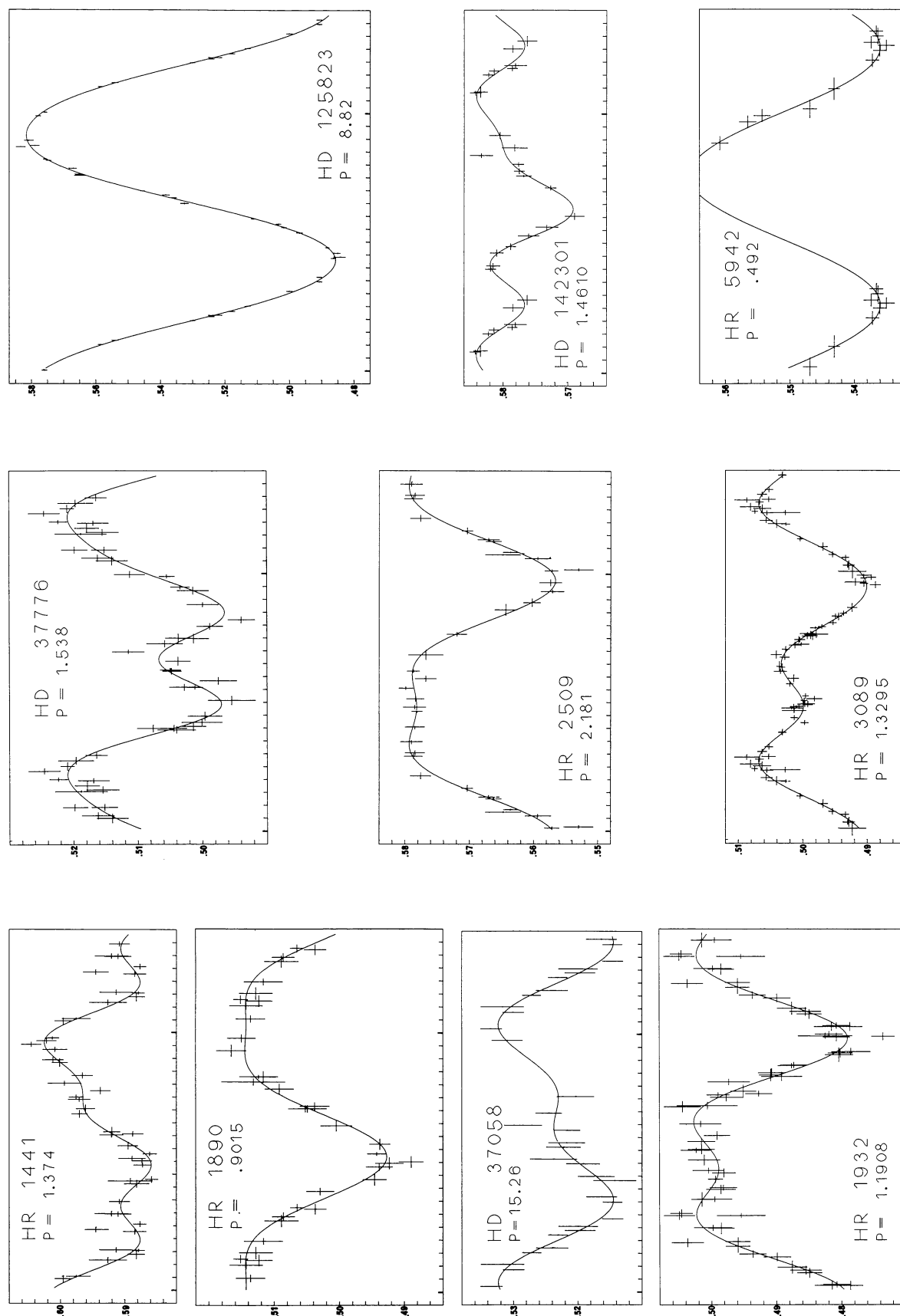


Figure 2 Phase-resolved data for the old and new He variables. High values of the R index correspond to low equivalent widths. Phases 0 and 1 are indicated by heavy markers, the zero phase is J.D. 2442777.5. The periods are given in days. For HR 1932 the period used is that given by Hesser *et al.* (1976), for other stars, those found by curve fitting. Horizontal bars indicate the duration of the observation, vertical errors-bars show $\pm \sigma$. The number of terms in the trigonometric polynomial used for curve fitting may be found from table 1.

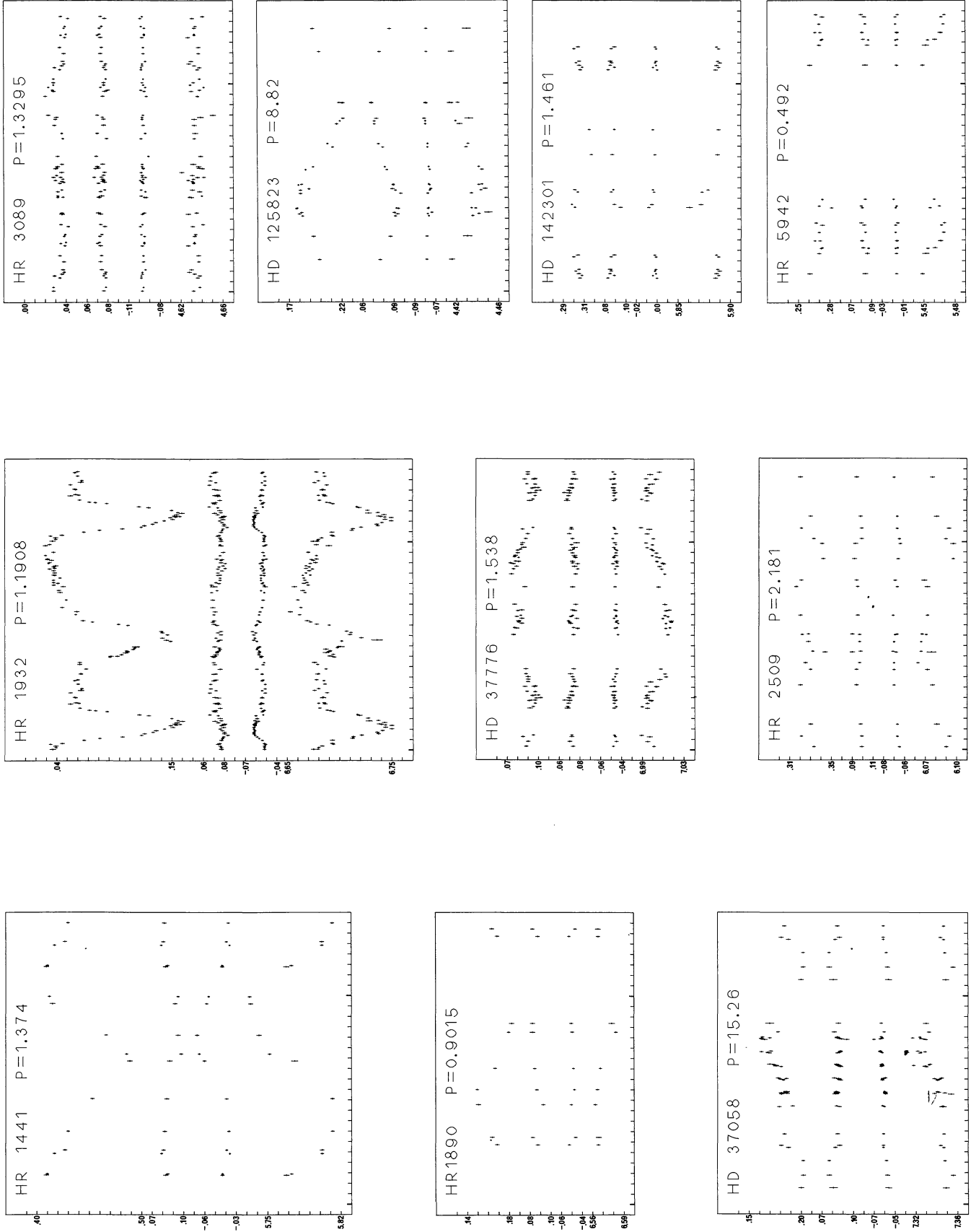


Figure 3 Phase-resolved Strömgren photometry for old and new He variables. From top to bottom, the data are c_1 , m_1 , $(b-y)$, and y -all in the instrumental system. Phases are calculated as in figure 2. The error bars are computed from the internal mean errors of the individual groups of observations as described in the text.

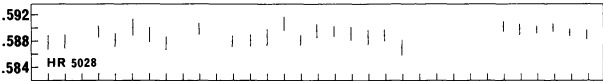


Figure 1 The standard star HR 5028. The first observation was made on January 18, the last on February 19, 1976. Error-bars show $\pm \sigma$.

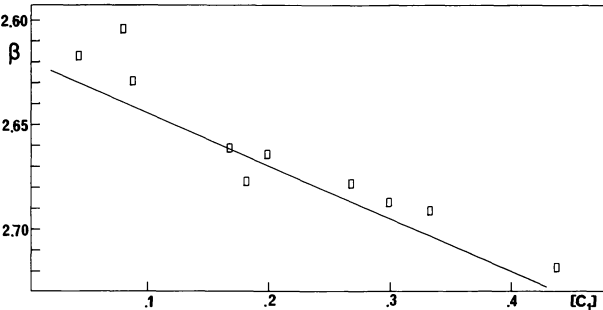


Figure 5 The β vs. $[c_1]$ relation for the He-variable stars. The line drawn is the zero age main sequences as given by Nissen (1974).

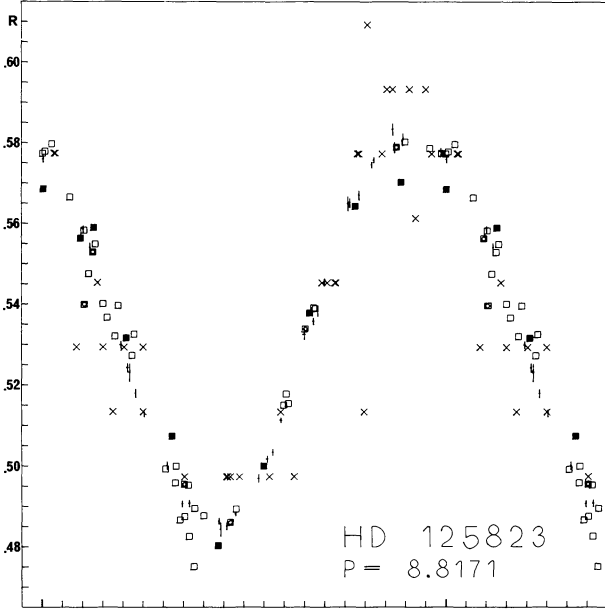


Figure 4 Phase resolved observations of the strength of the helium lines in a Cen transformed to the R system. Except for a few observations, the He line strength variability is well described by the constant period $P = 8.8171 \pm 0.0003$ days. Explanation of symbols: crosses: spectral classifications as compiled by Norris (1971b), open squares: equivalent width observations (Norris 1971b), squared circles: equivalent width observations from Klinglesmith *et al.* (1971), filled squares: equivalent width observations from Underhill *et al.* (1975), error bars: observations of the R index as in figure 2.

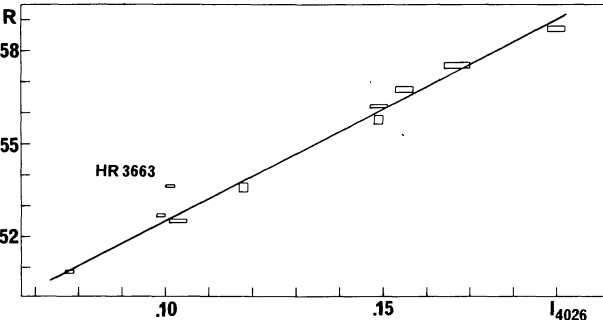


Figure 6 Observations of stars in common with the work of Nissen (1974). As judged from its diverging position HR 3663 may be variable in the strength of HeI $\lambda 4026 \text{ \AA}$.

Table 4 The mean $[c_1]$ and β indices for the He-variable stars observed in this programme.

	$[c_1]$	β
HR 1441	0.438	2.718
HR 2509	0.333	2.691
HD 142301	0.299	2.687
HR 5942	0.268	2.678
HD 125823	0.199	2.664
HD 37058	0.182	2.677
HR 1890	0.168	2.661
HD 37776	0.088	2.629
HR 1932	0.080	2.604
HR 3089	0.043	2.617