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

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Periodic variability in the strength of the HeI λ4026 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 λ4026 Å and *uvby*β 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 λ4026 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 Hα 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 Hα 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 λ4026 Å line strength in 29 stars and b) *uvby*β 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 λ4026 Å 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

$$R = \sum^{MN} I_{\text{line}} / \sum^{MN} I_{\text{continuum}} \quad (2)$$

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 (~ 0.4 Å) 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 $\Delta R = 0.0015$ (~ 20 mÅ). 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

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

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

$$\varepsilon_k(P) \simeq 1 \qquad (7)$$

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

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

2.2. *uvbyβ* 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 (Strömgren 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 $uvby\beta$ photometry are discussed under the individual stars.

The Hβ 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 $\sim 90°$ 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 $K_1 = 30$ kms^{-1} radial velocity variation was unknown, a constant value of 32 kms^{-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, $P=9.3\pm0.3$ days. This commensurability remained a puzzle during the observations. The true period, however, is more likely to be $P=0.9015\pm0.0020$ 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, $V \sin i = 150$ kms^{-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 ± 30 kms^{-1}. The results were: $+30$ kms^{-1}: $R=0.5142\pm0.0021$, 0 kms^{-1}: $R=0.5150\pm0.0022$, -30 kms^{-1}: $R=0.5129\pm0.0022$. 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 Strömgren 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 $\Delta W = 250$ mÅ in the equivalent width of HeI $\lambda 4026$ Å and may well be detected by photographic spectroscopy. The period found from the R observations, $P=15.3\pm0.8$ days, is consistent with the rotational velocity, $V \sin i = 5$ kms^{-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 $H_e = +2500\pm300$ 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 Hβ 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 $\varepsilon_7(P)$ 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 Hα. 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, $V \sin i = 274$ kms^{-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 know 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, $V \sin i = 202$ kms^{-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 $\varepsilon_7 = 1.35$ 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 mÅ 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 3 σ 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 2.9 σ.

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

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

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 $\Delta w = 0.2$ Å. 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 kms^{-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, $V \sin i = 79$ kms^{-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 $P=23\pm6$ 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 $W'=1215$ 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 $V \sin i = 0$ kms^{-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

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

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 Hα 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 $[c_1]=c_1-0.2(b-y)$ (Strömgren 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 $0^{m}.035$ deviation shown by σ Ori E may be caused by a variable emission in the Hβ line.

From the appearance of the R curves one may devide 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 $\sin i \simeq 1$. 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).

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Table 1

HR (1)	HD (2)	class. (3)	refs. (4)	assoc. (5)	n (6)	R_1 (7)	ε_1 (8)	(9)	k (10)	P days (11)	σ(P) days (12)	ε_k(P) (13)	J.D.$_{hel}$(R_{min}) (14)	
Program Stars													2442000 +	
1441	28843	W	1)		36	-	3.9	var	7	1.374	0.006	1.12	812.52	
										3.67	0.01	1.35		
	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	0.012	1.05		
										1.0565	0.015	1.08		
										17.7	4.4	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.		1.9		
										0.976	0.015	1.42		
										0.492	0.003	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							
Standard and transformation Stars														
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 polynomium 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.

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

Table 2 Observations of the helium line strength index R. Column 1 : J.D.$_{hel}$−2442000, column 2 : $R\times10000$, column 3 : $\sigma(R)\times10000$. Mean errors below the photon-statistical limit have been raised to that value, as described in the text.

HR 1441		
797.564	5921	18
799.558	5976	22
800.588	5994	26
801.561	5889	21
802.555	5945	20
802.640	5921	26
803.562	6022	15
804.574	5961	15
804.623	5971	18
805.563	5891	35
806.569	5914	26
807.583	6012	16
807.637	6009	19
808.572	5920	13
809.574	5908	16
810.538	5996	13
810.636	5926	29
811.539	5938	16
811.621	5966	16
812.540	5874	16
812.621	5895	15
813.536	5885	17
813.630	5911	20
814.535	6046	16
815.538	5971	13
816.539	5882	19
817.537	5882	13
818.560	6001	12
819.554	5888	16
823.570	5861	11
824.568	5877	10
825.561	6013	11
826.619	5976	11
827.555	5858	10
827.631	5873	14
828.550	5879	9
HD 36629		
805.634	5061	31
803.668	5034	29
HR 1890		
799.571	4939	20
801.577	5049	29
802.571	5132	49
802.590	5124	29
803.582	5166	23
804.594	5137	22
804.639	5143	25
805.584	5128	26
806.596	5089	26
807.600	5029	21
808.599	4923	22
809.631	5005	24
810.600	5038	23
811.604	5117	19
812.640	5150	22
813.671	5123	21
814.639	5117	29
815.652	5037	17
816.656	4946	18
817.619	4889	19
818.581	4938	16
819.676	5093	22
823.593	5152	11
824.641	5086	17
825.574	5065	10
826.661	4942	15
828.622	5052	12
HD 37058		
796.641	5200	31
799.605	5171	28
800.624	5238	36
801.594	5217	28
802.625	5285	29
807.660	5310	24
809.655	5317	33
810.619	5240	25
811.657	5197	24
813.650	5163	24
814.622	5142	33
815.610	5192	26
816.588	5222	27
817.594	5217	20
818.610	5245	20
819.600	5203	29
823.609	5335	16
824.587	5300	17
825.591	5272	14
826.650	5231	15
827.617	5146	16
828.603	5146	15
HD 37129		
796.625	5060	28
797.614	5110	23
800.643	5127	27
801.626	5101	27
803.623	5072	26
805.682	5072	31
806.649	5092	24
814.598	5052	30
815.631	5101	23
816.634	5085	27
825.605	5075	17
HD 37321		
808.642	5362	22
809.594	5380	31
811.675	5392	28
812.601	5366	22
813.610	5365	25
HR 1932		
795.593	4959	19
795.713	4954	37
796.539	4825	42
796.582	4815	27
796.666	4876	23
797.543	4892	31
797.595	4873	21
797.657	4785	30
797.724	4807	21
798.600	5006	47
798.638	4977	25
798.667	4950	20
798.709	4973	32
799.541	5011	25
799.586	5023	24
799.626	5016	21
799.707	5017	32
800.551	5015	16
800.604	4981	21
800.684	5004	25
801.542	5037	25
801.611	4998	30
801.667	5049	24
802.540	4807	21
802.606	4855	24
802.680	4936	21
803.547	4876	21
803.605	4801	19
803.692	4819	21
804.549	5045	28
804.609	4927	21
804.695	4908	18
805.544	5015	21
806.551	4985	23
807.562	4985	20
807.696	4995	27
808.548	4849	19
808.670	4959	19
809.551	4803	22
809.680	4786	19
810.557	4990	18
811.562	4991	20
812.581	4981	18
813.585	5046	17
814.575	4899	21
815.589	4735	18
816.613	4907	21
825.650	4994	11
HD 37776		
796.560	5040	30
796.605	5000	31
797.637	5198	20
799.645	5076	25
800.664	5162	25
801.640	5115	25
801.689	5058	28
803.641	5113	24
804.661	5038	19
805.606	5196	28
806.620	5014	25
807.619	4975	28
808.620	5246	25
809.613	4999	24
810.578	4955	37
810.657	5028	23
811.583	5155	26
811.638	5169	24
812.560	4988	20
813.560	4996	27
814.555	5152	20
814.650	5188	41
814.684	5179	19
815.565	5037	20
815.674	4939	21
816.563	5044	20
817.566	5140	25
818.638	5013	24
819.651	5014	20
823.624	5055	12
824.601	5050	17
825.632	5164	17
826.636	5034	15
827.573	5011	12
827.671	5048	16
828.564	5224	14
828.643	5210	11
HR 2509		
801.652	5648	28
803.707	5530	23
804.724	5785	18
805.703	5571	18
807.729	5643	17
808.698	5785	15
809.703	5719	16
810.684	5776	16
811.708	5768	27
812.685	5670	17
813.689	5768	17
814.707	5593	20
815.699	5784	14
816.684	5574	17
817.642	5785	15
818.694	5602	13
819.574	5787	14
819.698	5790	17
823.665	5703	9
824.657	5787	10
825.664	5636	12
825.756	5662	12
826.694	5799	11
827.689	5571	11
828.680	5782	8
HR 2790		
795.725	5230	16
796.692	5228	13
799.662	5223	14
800.695	5237	14
801.707	5213	14
802.696	5230	14
803.722	5207	23
805.722	5232	17
808.716	5206	11
HD 60344		
809.728	4931	26
810.718	4957	27
812.705	4945	27
HR 2954		
795.612	5287	17
797.677	5251	15
799.722	5270	24
800.708	5241	15
801.718	5259	21
802.712	5249	17
803.737	5232	14
805.736	5242	24
808.731	5239	15
HR 3001		
799.680	5668	25
800.723	5716	37
801.730	5635	33
802.726	5693	30
803.752	5652	20
808.746	5703	20
815.719	5670	24
HR 3089		
795.771	5005	8
796.733	5014	19
797.699	5041	13
798.728	4919	16
799.735	5003	12
800.735	5018	17
801.745	5027	23
802.741	4894	8
803.766	4994	8
804.744	4997	11
805.754	5063	14
806.691	4888	9
807.765	4980	19
808.760	4983	12
809.752	5081	16
809.787	5087	19
810.748	4923	21
811.756	4993	11
812.723	4993	11
813.708	5056	10
814.717	4906	11
815.736	4988	9
816.706	4993	8
817.658	5057	10
817.767	5053	11
818.538	4974	8
818.664	4905	6
818.757	4929	9
818.853	4969	7
819.538	5035	10
819.624	5041	9
819.721	4985	8
823.552	5036	4
823.640	5027	6
823.689	5007	5
823.751	4981	8
823.777	4954	5
823.812	4950	6
824.539	5032	6
824.616	5014	5
824.672	5014	6
824.729	4996	5
825.540	5005	5
825.616	5027	7
825.682	5075	5
825.731	5067	7
825.770	5063	8
825.795	5053	6
826.668	4906	5
826.733	4931	7
826.775	4934	5
826.790	4954	6
827.536	5032	5
827.588	5028	7
827.650	5012	9
827.746	4971	6
827.799	4945	5
827.815	4937	5
828.530	5032	6
828.578	4997	6
828.663	5006	6
828.694	4998	5
828.780	5020	6
828.808	5014	8
HR 3448		
795.671	5634	28
796.748	5604	14
797.745	5549	28
798.746	5605	38
799.767	5657	20
800.748	5603	16
801.763	5615	19
802.756	5605	16
803.782	5605	15
804.771	5629	12
813.722	5597	15
814.728	5560	19
815.754	5588	15
HR 4089		
796.764	5774	14
797.764	5776	12
799.777	5774	16
800.764	5755	13
801.778	5726	16
802.770	5752	12
803.794	5730	15
808.817	5737	20
809.804	5757	17
810.775	5777	11
812.752	5776	21
813.736	5789	11
814.745	5762	15
815.768	5744	11
816.723	5777	17
818.726	5736	13
823.709	5744	12
824.686	5752	11
825.717	5733	8
826.704	5747	11
828.720	5760	10
HR 4199		
795.832	5377	9
796.775	5342	11
796.784	5348	10
797.780	5365	6
799.790	5362	7
800.777	5370	6
801.791	5344	7
802.784	5349	14
803.823	5329	17
805.769	5344	12
810.788	5340	7
813.749	5353	8
823.723	5351	8
824.553	5377	9
824.627	5368	9
824.738	5363	5
824.893	5351	4
825.552	5348	5
825.671	5356	5
825.888	5352	5
826.604	5362	7
826.741	5370	5
827.714	5354	5
828.541	5344	7
828.587	5352	6
828.730	5362	6
HD 96446		
795.846	4798	27
796.796	4782	25
797.801	4803	24
799.807	4794	21
800.791	4818	23
801.810	4812	21
803.806	4818	21
804.810	4817	16
810.805	4778	15
811.797	4769	21
813.767	4774	15
814.766	4771	22
815.787	4751	21
816.747	4769	17
817.786	4760	22
823.737	4802	16
824.702	4824	12
825.701	4830	12
826.718	4803	10
827.702	4797	10
828.710	4823	10
HR 4773		
796.809	5444	12
797.816	5427	18
799.822	5458	14
800.810	5440	9
803.834	5442	17
810.826	5426	13
HD 120640		
796.828	5096	14
797.847	5100	15
799.849	5067	17
800.847	5122	20
802.866	5077	13
804.836	5078	14
807.800	5109	14
809.843	5074	19
813.798	5053	15
814.795	5073	15
824.777	5082	14
826.762	5069	10
HD 120709		
811.824	5484	12
812.784	5518	14
813.811	5469	12
814.811	5497	10
815.817	5507	13
816.787	5483	11
818.775	5506	22
824.791	5493	10
825.808	5498	13
HD 125823		
796.864	5300	8
797.869	5001	10
799.870	4969	10
800.870	5325	13
801.822	5650	17
801.860	5651	11
802.798	5834	14
802.841	5789	13
803.857	5780	8
804.855	5586	8
805.820	5243	11
805.868	5231	22
807.815	4864	7
807.856	4843	17
808.874	5018	8
809.879	5358	8
810.882	5671	11
811.838	5809	15
812.801	5760	8
813.818	5541	11
814.820	5179	10
815.835	4907	7
816.807	4851	8
817.813	5034	7
818.795	5383	12
823.824	5130	9
824.809	4908	8
825.818	4881	5
826.808	5113	5
827.758	5456	7
828.792	5746	7
828.840	5758	6
HD 133518		
803.872	4807	26
804.873	4831	36
809.860	4805	16
810.850	4797	18
812.818	4825	21
814.831	4815	18
824.820	4810	13
HD 142301		
810.867	5833	18
811.874	5761	16
812.837	5781	17
813.832	5782	20
814.846	5733	17
815.852	5785	15
816.825	5805	17
817.830	5690	15
818.818	5763	15
823.834	5727	9
824.835	5819	8
825.831	5843	9
826.823	5768	12
826.850	5775	8
826.889	5776	8
827.776	5816	11
827.849	5810	10
827.886	5788	8
828.759	5835	11
828.854	5822	9
828.877	5814	8
828.891	5786	8
HR 5942		
812.865	5608	13
815.870	5543	13
816.842	5565	13
817.851	5469	11
818.874	5432	9
823.848	5372	10
824.851	5360	10
825.844	5350	13
826.834	5374	12
827.830	5363	9
828.824	5366	10
HR 5967		
812.880	5645	11
813.874	5591	12
814.877	5615	8
815.883	5616	10
816.885	5631	11
817.873	5608	11
823.879	5622	5
824.887	5636	14
825.878	5633	11
HR 5988		
812.851	5875	18
813.863	5868	24
814.860	5860	25
823.863	5872	13
HR 5998		
813.851	5720	21
816.871	5693	20
824.865	5741	14
825.858	5755	16
826.874	5737	14
827.868	5760	13
828.865	5741	14
HR 6054		
824.876	5754	14
825.869	5752	13
HR 5028		
796.844	5880	10
797.830	5881	10
799.837	5896	9
800.829	5883	10
801.873	5902	13
802.850	5892	11
803.845	5878	10
805.808	5901	9
807.784	5881	8
808.859	5883	9
809.831	5888	12
810.839	5908	10
811.812	5883	8
812.769	5897	10
813.786	5897	8
814.783	5893	10
815.801	5888	11
816.767	5890	9
817.802	5872	11
823.800	5904	7
824.760	5899	8
825.782	5899	5
826.751	5902	6
827.732	5895	5
828.740	5892	7
HR 1735		
806.673	5577	14
HR 3468		
805.792	5358	14
HR 3663		
805.781	5329	13
823.758	5364	7
824.713	5361	7
825.742	5345	8
HR 4656		
805.799	5254	7
823.767	5263	6
824.719	5276	4
HR 4898		
809.821	5063	11
823.790	5086	5
824.769	5095	7

Table 3 Strömgren photometry of all He variable stars observed in this programme. For each object, the first column gives J.D.$_{hel}$−2442000. The next four columns give y, $(b-y)$, m_1, and c_1 – all in the instrumental system and in units of $0^m.001$.

HR 1441				
778.614	5742	-67	95	466
779.569	5812	-39	84	453
780.605	5802	-39	81	427
781.569	5734	-58	92	415
782.566	5776	-60	87	489
784.562	5768	-43	83	409
820.574	5812	-37	82	430
824.549	5802	-36	79	417
825.584	5733	-56	95	412
826.580	5752	-65	98	486
828.538	5773	-43	85	410
HR 1890				
778.659	6566	-52	88	169
779.592	6566	-46	83	164
780.636	6563	-50	93	151
781.602	6565	-47	87	150
782.595	6568	-48	85	167
784.593	6579	-50	83	183
820.615	6583	-49	83	180
HD 37058				
778.677	7349	-56	81	200
779.601	7356	-57	77	202
780.655	7348	-58	77	202
781.620	7347	-61	83	188
782.614	7347	-61	85	184
784.608	7346	-60	87	179
784.672	7346	-62	84	192
785.544	7354	-59	83	181
785.584	7338	-59	84	186
785.633	7348	-60	85	181
785.679	7342	-59	84	186
785.723	7341	-60	84	186
786.556	7341	-62	88	183
786.598	7341	-62	87	183
786.640	7343	-62	86	180
786.681	7338	-61	86	186
786.724	7345	-59	82	178
787.551	7330	-63	88	181
787.598	7329	-62	87	176
787.640	7318	-62	86	176
787.685	7333	-63	85	174
787.727	7334	-62	84	170
788.554	7324	-62	85	169
788.598	7325	-63	87	168
788.640	7329	-64	88	162
788.695	7322	-64	88	171
789.540	7330	-70	94	165
789.577	7328	-64	89	162
789.620	7325	-62	87	162
789.662	7317	-62	85	170
789.721	7324	-63	85	163
790.733	7330	-63	86	170
820.606	7333	-60	82	178
827.561	7344	-61	87	181
HR 1932				
778.696	6675	-52	77	36
779.626	6657	-51	70	46
780.674	6653	-56	71	59
781.641	6691	-57	75	107
782.641	6686	-51	67	60
784.631	6678	-50	76	33
784.684	6693	-52	75	45
785.558	6665	-55	73	42
785.600	6666	-54	75	41
785.646	6672	-55	76	37
785.694	6671	-53	75	37
785.736	6673	-53	78	31
786.569	6672	-56	69	74
786.611	6662	-57	70	58
786.652	6663	-54	69	45
786.695	6660	-53	69	49
786.738	6667	-52	68	43
787.565	6690	-55	71	98
787.612	6698	-58	75	115
787.656	6736	-62	76	145
787.699	6711	-60	74	141
787.742	6690	-60	73	108
788.569	6680	-51	67	64
788.614	6685	-54	70	57
788.654	6680	-54	72	63
788.708	6679	-53	71	62
788.749	6695	-55	70	91
788.764	6694	-57	72	102
788.781	6690	-56	73	108
788.795	6687	-59	76	113
788.809	6701	-57	71	115
789.553	6744	-61	79	154
789.590	6727	-59	76	150
789.634	6691	-53	70	77
789.679	6685	-55	74	58
789.735	6688	-51	66	53
790.747	6740	-62	80	158
791.544	6670	-52	68	37
791.558	6669	-53	72	37
791.571	6667	-55	76	37
791.584	6666	-55	76	43
791.599	6665	-52	74	38
791.613	6668	-52	74	38
791.626	6671	-53	78	37
791.639	6668	-55	81	38
791.654	6668	-54	79	39
791.667	6672	-56	81	32
791.685	6675	-53	77	35
820.539	6737	-61	77	156
820.567	6719	-60	74	128
820.597	6688	-52	72	71
820.633	6686	-56	74	53
820.668	6684	-54	74	58
824.533	6699	-56	71	118
824.565	6702	-59	74	149
824.584	6721	-61	72	141
824.602	6710	-62	77	146
824.621	6707	-63	77	140
824.662	6678	-59	70	99
824.683	6669	-58	70	65
825.534	6678	-53	72	60
825.568	6679	-54	70	63
825.596	6687	-59	76	68
825.634	6676	-52	70	62
825.670	6692	-54	69	92
825.689	6687	-57	73	106
826.526	6717	-53	66	119
826.543	6694	-54	71	88
826.563	6681	-55	76	62
826.591	6680	-53	71	61
826.625	6684	-54	71	57
826.665	6676	-54	72	63
827.519	6679	-52	77	36
827.529	6680	-52	77	39
827.538	6683	-52	76	39
827.548	6694	-51	74	34
827.571	6693	-54	77	66
827.581	6712	-57	78	81
827.591	6713	-59	79	103
827.599	6721	-61	83	121
827.608	6737	-62	80	124
827.617	6736	-62	80	132
827.627	6741	-61	78	135
827.636	6750	-62	76	143
827.645	6744	-62	79	151
827.655	6750	-61	77	149
827.664	6738	-61	80	153
827.672	6743	-60	74	155
827.681	6728	-58	71	160
828.550	6674	-52	74	33
828.587	6677	-54	77	33
828.608	6678	-50	73	31
828.627	6678	-52	76	29
828.646	6670	-53	79	37
828.684	6690	-52	77	29
HD 37776				
778.704	7006	-46	73	87
779.635	7008	-44	74	88
780.683	6989	-47	72	95
781.650	7012	-45	76	77
782.653	7013	-46	73	90
784.645	7012	-45	73	83
785.571	6994	-47	70	98
785.620	7000	-46	72	89
785.660	6994	-47	74	97
785.709	7007	-48	74	90
785.750	7012	-45	71	88
786.583	7005	-45	73	81
786.627	7000	-45	75	78
786.666	7001	-44	71	80
786.708	7000	-45	72	84
786.752	7001	-48	73	88
787.578	7015	-43	74	76
787.626	7013	-46	78	79
787.672	7018	-45	70	81
787.713	7015	-45	71	79
787.755	7013	-45	75	80
788.583	6990	-45	68	95
788.628	6999	-46	70	91
788.668	6994	-49	73	100
788.732	7003	-47	73	87
789.565	7012	-45	76	74
789.603	7009	-46	78	76
789.648	7010	-44	73	73
789.694	7004	-47	75	77
789.750	6999	-46	74	83
820.558	6994	-46	77	85
820.625	6995	-45	70	90
820.659	6997	-46	72	85
824.542	7017	-44	74	77
824.575	7013	-43	71	84
824.593	7018	-44	69	81
824.611	7010	-47	77	84
824.673	7016	-46	73	84
825.543	6997	-45	65	97
825.577	6994	-47	73	94
825.606	6997	-48	72	97
825.644	7004	-50	76	96
825.679	6998	-46	75	90
826.534	7007	-44	75	79
826.553	7011	-48	78	76
826.572	7004	-44	73	78
826.600	7007	-47	76	81
826.635	7004	-45	73	80
826.674	6995	-47	75	86
828.560	6995	-47	68	92
828.597	6995	-47	69	97
828.618	6999	-47	70	93
828.637	6995	-47	69	102
828.656	6995	-47	71	97
HR 2509				
778.711	6067	-67	90	328
779.661	6097	-64	93	341
780.704	6076	-68	90	344
781.682	6097	-66	92	342
782.702	6072	-70	94	330
784.720	6077	-70	94	320
820.646	6072	-67	95	316
820.714	6069	-69	94	321
824.709	6072	-71	95	320
825.623	6093	-67	99	321
825.749	6081	-67	98	330
826.613	6066	-70	97	328
826.688	6071	-69	97	322
827.694	6090	-65	99	333
828.574	6063	-70	97	325
828.694	6066	-71	98	332
HR 3089				
778.749	4636	-93	75	20
779.695	4639	-91	69	32
780.763	4628	-95	71	37
781.720	4637	-96	74	34
782.769	4630	-95	77	28
784.750	4630	-93	72	32
785.786	4633	-95	70	35
785.831	4633	-95	72	38
786.783	4642	-94	73	23
786.836	4638	-96	78	28
787.784	4633	-98	79	37
789.781	4633	-95	72	40
790.786	4629	-96	76	28
820.684	4638	-94	73	32
820.743	4632	-97	77	38
820.756	4627	-99	76	30
820.807	4621	-98	77	36
824.645	4640	-98	74	32
824.725	4632	-96	71	34
824.737	4631	-97	75	36
824.752	4632	-96	75	37
824.764	4642	-97	74	28
824.777	4631	-97	76	31
824.819	4641	-96	68	30
824.833	4637	-97	70	32
824.847	4632	-97	75	36
825.555	4637	-96	73	38
825.657	4627	-97	73	39
825.728	4634	-98	74	39
825.779	4631	-99	77	42
825.791	4641	-97	73	35
825.858	4627	-97	73	36
826.649	4638	-98	80	27
826.698	4632	-97	76	28
826.782	4636	-98	78	34
826.795	4638	-98	76	29
826.807	4633	-97	77	36
826.818	4628	-97	78	38
826.834	4630	-94	74	37
827.703	4634	-94	70	36
827.755	4633	-96	76	29
827.793	4633	-97	76	30
827.806	4639	-97	75	31
827.819	4651	-96	70	23
828.525	4635	-95	71	36
828.672	4631	-98	77	36
828.752	4636	-94	67	35
828.811	4638	-96	71	31
HD 125823				
778.854	4416	-78	77	199
779.833	4431	-78	87	193
780.844	4451	-73	91	182
781.851	4448	-74	89	189
784.839	4433	-80	74	222
789.834	4439	-77	95	177
789.848	4435	-76	93	178
790.837	4442	-75	90	179
790.858	4445	-76	90	182
820.772	4416	-78	69	221
820.778	4414	-79	69	222
820.785	4422	-79	69	218
824.796	4436	-76	92	183
824.885	4442	-77	94	180
825.760	4435	-77	97	181
825.889	4444	-75	92	181
826.764	4445	-75	84	186
826.890	4442	-76	82	193
827.715	4430	-77	80	212
827.864	4432	-77	76	207
828.703	4424	-79	72	216
828.826	4420	-79	72	219
HD 124301				
820.832	5888	-2	87	317
824.866	5872	-5	89	298
825.811	5886	0	83	306
825.828	5889	-4	89	308
825.872	5888	-1	85	305
826.851	5889	-4	89	315
827.767	5861	-8	95	301
827.875	5873	-3	86	304
827.890	5879	-4	88	301
828.764	5887	-1	85	305
828.782	5890	-2	86	302
828.880	5889	-1	86	300
828.894	5887	-2	89	304
HR 5942				
820.840	5449	-16	84	261
824.873	5469	-17	84	270
825.819	5454	-17	87	272
825.837	5466	-15	81	266
825.879	5470	-15	80	267
826.858	5467	-17	83	273
827.775	5452	-16	86	270
827.883	5456	-17	81	282
828.773	5461	-15	82	273
828.789	5467	-16	81	271
828.871	5465	-16	80	270
828.887	5460	-19	84	273

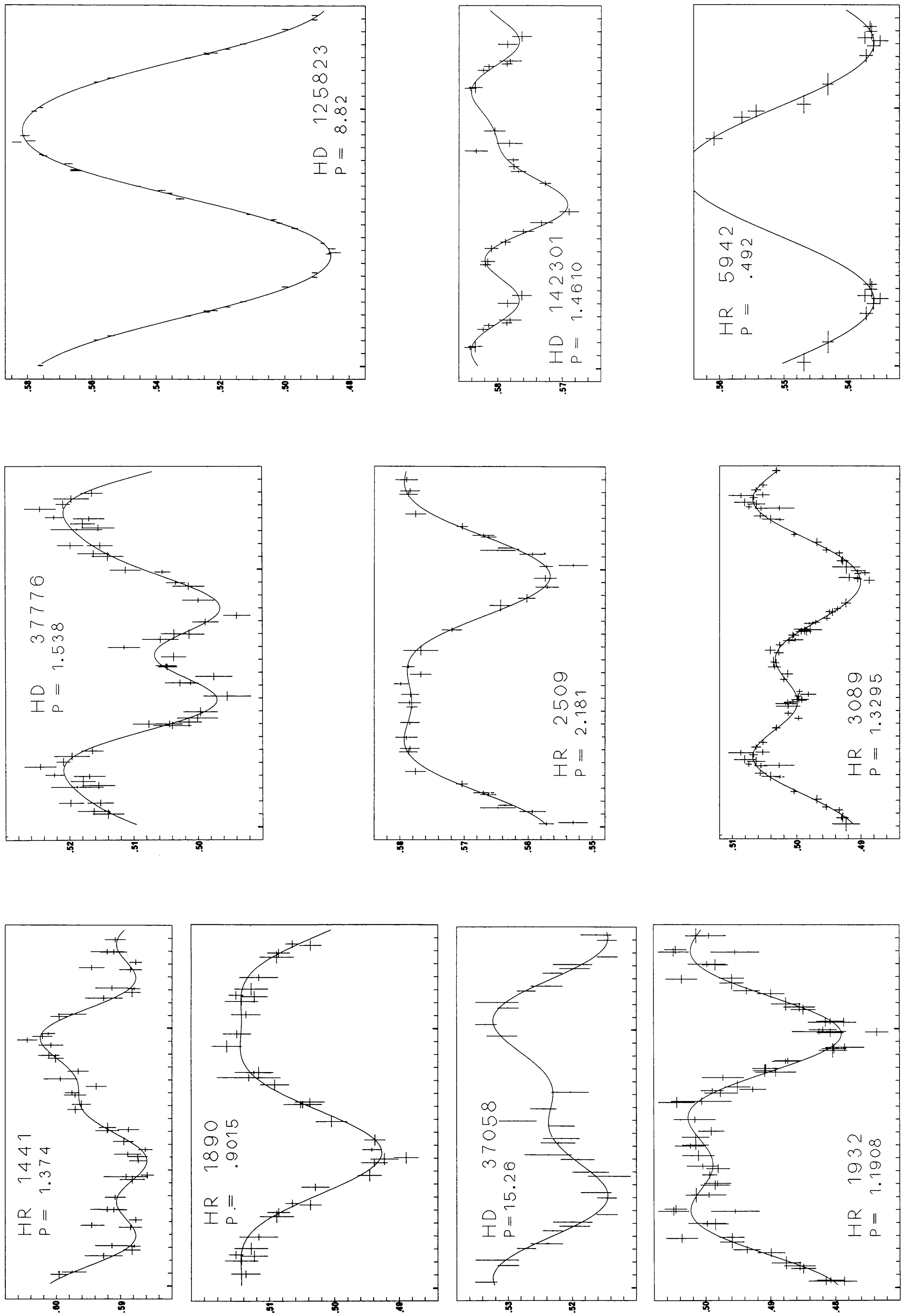

Figure 2 Phase-resolved data for the old and new He variables. High values of the *R* index correspond to low equivalent widths. Phases 0 and 1 are indicated by heavy markers, the zero phase is J.D. 2442777.5. The periods are given in days. For HR 1932 the period used is that given by Hesser *et al.*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

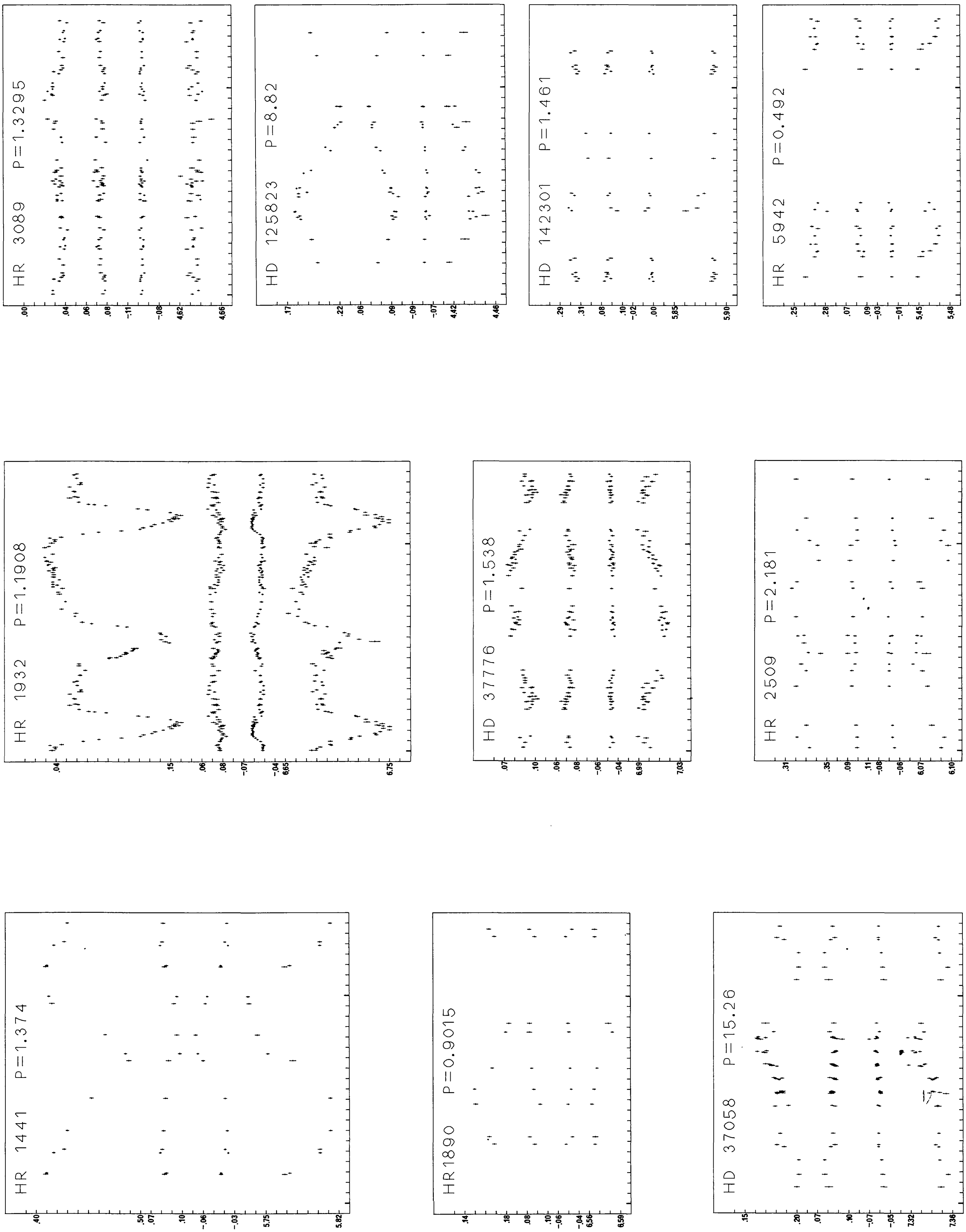

Figure 3 Phase-resolved Strömgren photometry for old and new He variables. From top to bottom, the data are c_1, m_1, $(b-y)$, and y—all in the instrumental system. Phases are calculated as in figure 2. The error bars are computed from the internal mean errors of the individual groups of observations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

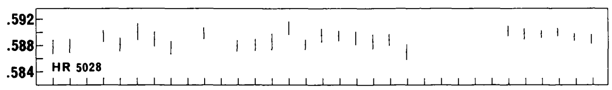

Figure 1 The standard star HR 5028. The first observation was made on January 18, the last on February 19, 1976. Error-bars show $\pm\,\sigma$.

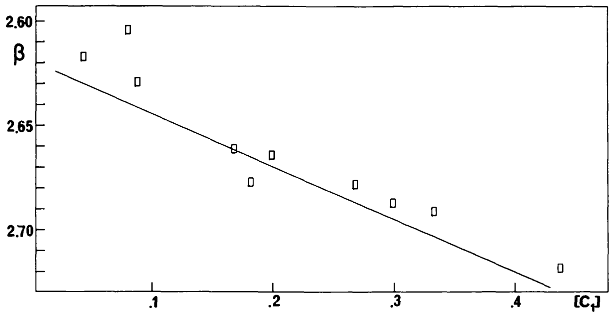

Figure 5 The β vs. $[c_1]$ relation for the He–variable stars. The line drawn is the zero age main sequences as given by Nissen (1974).

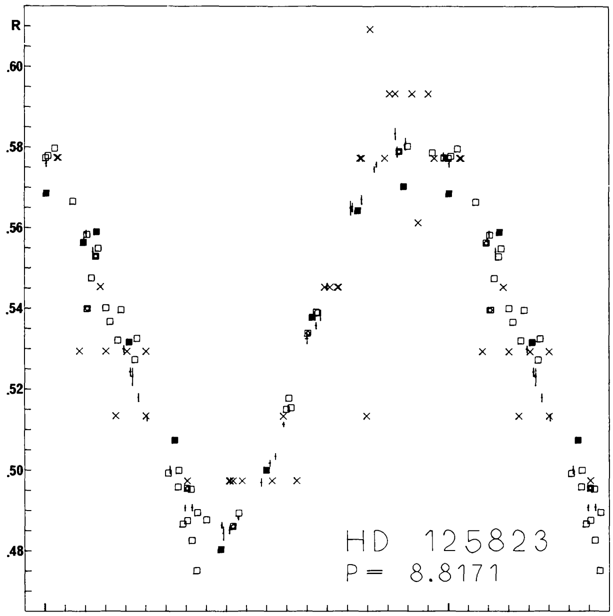

Figure 4 Phase resolved observations of the strength of the helium lines in a Cen transformed to the R system. Except for a few observations, the He line strength variability is well described by the constant period $P = 8.8171 \pm 0.0003$ days. Explanation of symbols: crosses: spectral classifications 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.

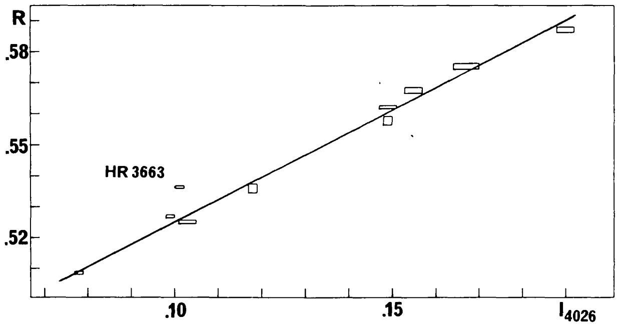

Figure 6 Observations of stars in common with the work of Nissen (1974). As judged from its diverging position HR 3663 may be variable in the strength of HeI λ4026 Å.

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