Astron. Astrophys. 325, 987–993 (1997)

ASTRONOMY
AND
ASTROPHYSICS

B-type pulsators in the open cluster NGC 884 (χ Persei)

J. Krzesiński[1] **and A. Pigulski**[2]

[1] Mt. Suhora Observatory, Cracow Pedagogical University, ul. Podchorążych 2, PL-30084 Kraków, Poland (sfkrzesi@cyf-kr.edu.pl)
[2] Wroclaw University Observatory, ul. Kopernika 11, PL-51622 Wroclaw, Poland (pigulski@astro.uni.wroc.pl)

Received 12 November 1996 / Accepted 20 March 1997

Abstract. We present results of the photometric CCD search for B-type pulsators in the central region of the χ Persei cluster. The most interesting result is the discovery of two β Cephei stars, Oo 2246 and Oo 2299, the first ones found in χ Persei. Oo 2246 pulsates with two periods equal to 0.184 and 0.171 d. The light of the other β Cephei star, Oo 2299, varies with a single period of about 0.318 d. This is one of the longest periods known for this type of variable. The photometric Q indices of the two β Cephei stars fall in the middle of the range covered by all β Cephei variables. In the HR diagram, the position of Oo 2246 and Oo 2299 coincide with the low-temperature limit of the β Cephei instability strip in NGC 3293. The pulsational properties of both β Cephei stars in χ Persei are in agreement with the main sequence stage of evolution.

In addition to the β Cephei stars, we found nine other variables, including two eclipsing stars, Oo 2301 and Oo 2311. Almost all Be stars in the field turned out to be variable. In the cluster's colour-magnitude diagram, they appear to be slightly redder than non-Be stars of similar spectral type.

Key words: stars: oscillations – stars: Be – stars: variables: β Cephei – open clusters and associations: individual: NGC 884 (χ Per)

1. Introduction

About 35% of the known β Cephei variables belong to the three southern open clusters NGC 3293, NGC 4755 and NGC 6231 (Balona 1994a, Balona & Koen 1994, Balona & Laney 1995). Because of its age and richness, it was the double cluster h & χ Persei, which seemed to be one of the most promising targets for a β Cephei star search in the northern hemisphere. One of the first searches for β Cephei variables in h and χ Persei was undertaken by Percy (1972). He carried out photoelectric photometry for about 40 stars in both clusters. However, because of the large number of objects observed, he devoted only up to 10 hours of photometry to a single program star. Moreover, crowded stars were not observed. In consequence, the observations were too sparse to conclude firmly on the variability of all program stars and derive the exact values of periods. Nevertheless, Percy's (1972) list contains several possible variables, including two β Cephei candidates: Oo 963 in h Per and Oo 2299 in χ Persei. (The numbers preceded by 'Oo' are those introduced by Oosterhoff 1937.) For the same reasons, the next photometric search (Waelkens et al. 1990) yielded only variable Be stars and supergiants with periods longer than those typical for β Cephei stars.

In order to finally answer the question of the presence of β Cephei stars in h and χ Persei, a new search including a large number of stars was needed. The CCD technique seemed to be a natural choice as it allows to achieve photometry for crowded fields as well as good time coverage for a large number of stars in a reasonable time. This new program of CCD observations of h and χ Persei was initiated in 1994 by one of us (JK). The field of view of the CCD camera used in the search was much smaller than the clusters' diameters. Since the largest number of the β Cephei candidates could be found in the nuclei of both clusters, these regions were chosen as the initial search fields.

In the present paper we report the results of the search in the extreme nucleus of χ Per (NGC 884). The results for h Per (NGC 869) will be published separately.

2. Observations and reductions

The CCD observations of χ Per were carried out at Mt. Suhora Observatory with a 60-cm Cassegrain telescope equipped with the Photometrics Star I CCD camera (Kreiner et al. 1993) and an autoguider (Krzesiński & Wójcik 1993). Most observations were taken through Johnson B and V filters, but on a few nights some U frames were also taken. A total of about 1200 frames in the B and V filters, and 18 in U, were collected during 16 nights between October 12, 1995 and May 30, 1996. They cover about 86 hours of observations. The average seeing was about 3.7″. In the observed field, covering an area of $4' \times 6'$ in the nucleus of χ Per (Fig. 1), we detected 125 stars.

All search frames were calibrated in the standard manner using bias, dark and flat field frames. In order to improve signal-to-noise ratio, the calibration frames were calculated as an average

Send offprint requests to: J. Krzesiński

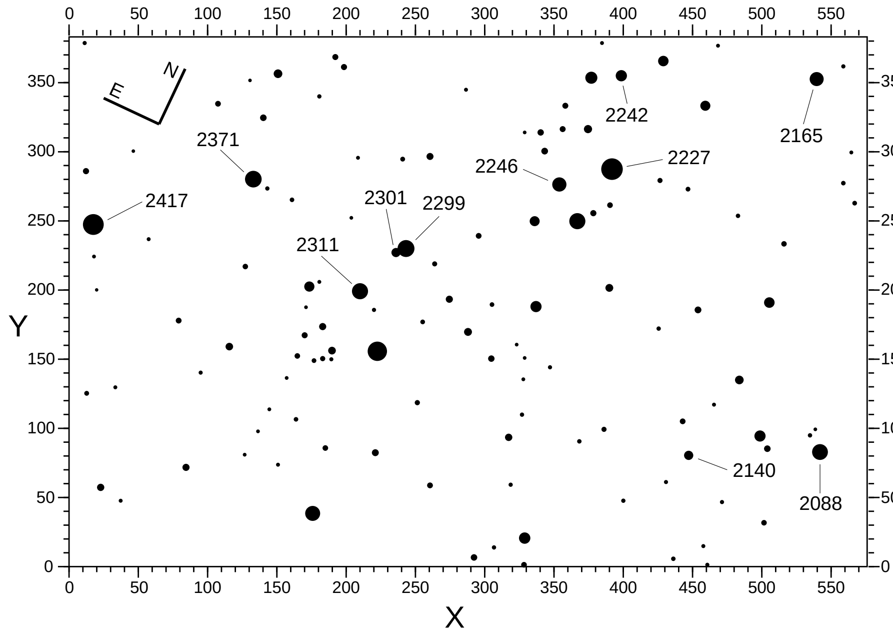

Fig. 1. Schematic view of the observed field in the nucleus of χ Persei ($4' \times 6'$). All variables are labeled with their Oosterhoff (1937) numbers

Table 1. Variable stars in χ Persei

Oo number	Period(s) [days]	Range in B [mag]	Type of variability
2246	0.184188	0.013	β Cephei
	0.170765	0.009	
2299	0.31788	0.015	β Cephei (NSV 802)
2088	—	0.15	Be (V 506 Per)
2140	—	0.23	Unknown
2165	—	0.30	Be (V 507 Per)
2227	—	0.05	Irregular (NSV 798)
2242	—	0.13	λ Eri
2301	1.54697	0.28	EA-type eclipsing binary
2311	102.1 or submultiple	0.12	EA-type eclipsing binary
2371	see text	0.05	Ellipsoidal ?
2417	—	0.61	SRc ? (RS Per)

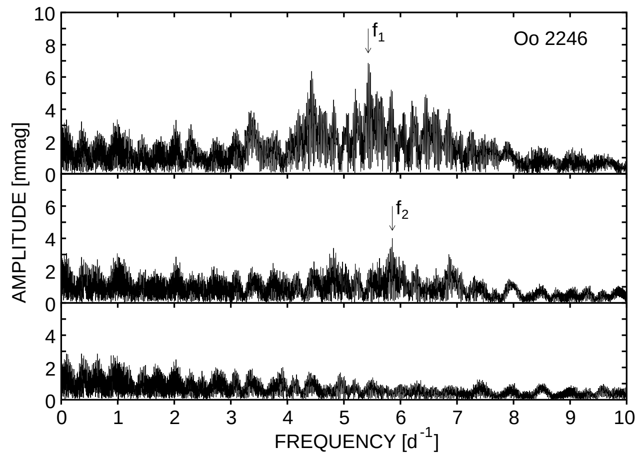

Fig. 2. Fourier frequency spectrum of the Oo 2246 B-filter data. Top panel: original data, middle panel: after prewhitening with f_1, bottom panel: after prewhitening with both f_1 and f_2

of a series of images of a given type. For the same reason, 2 to 5 consecutive search frames were co-added for some nights after calibration. Calibrated frames were then reduced using point-spread function (PSF) fitting of Daophot II package (Stetson 1987). This step of reductions was performed in the same way as in Jerzykiewicz et al. (1996), except that we used a PSF model with profile changing linearly across the frame. This model was found to represent best the profiles of stars. As we found later, the non-homogeinity of the PSF profile in our frames originated from the fact that the telescope optics was not perfectly aligned.

3. β Cephei stars

In order to find variable stars, we calculated differential magnitudes in all three filters with Oo 2235 and Oo 2296 as the comparison stars. These differential magnitudes were then checked for variability. Out of 125 stars in our field, 11 were found to be variable. Their overall properties are given in Table 1. The differential magnitudes for all these variable stars will be published electronically.

Since from the point of view of the goals of our search, the most interesting is the discovery of the two β Cephei stars, we shall describe them first.

Table 2. The results of the fit of Eq. (1) to our B and V observations of the two β Cephei stars. Nobs is the number of individual observations and RSD is the residual standard deviation.

Star Oo number	Nobs	Period [days]	Filter	A_0 [mag]	Amplitude A_i [mmag]	Phase ϕ_i [rad]	HJD of the time of maximum light	RSD [mmag]
2246	1184	0.184188	B	0.9830 ± .0002	6.7 ± .2	2.70 ± .03	2450057.3414 ± .0009	5.2
		0.170765	B		4.3 ± .2	3.72 ± .05	2450057.4040 ± .0014	
	1152	0.184188	V	0.9960 ± .0002	5.7 ± .2	2.74 ± .04	2450087.9155 ± .0012	5.6
		0.170765	V		4.2 ± .2	3.60 ± .06	2450087.9743 ± .0016	
2299	1184	0.31788	B	0.1850 ± .0001	7.6 ± .2	5.74 ± .03	2450055.5772 ± .0014	5.1
	1184	0.31788	V	0.2058 ± .0002	8.2 ± .3	5.57 ± .03	2450090.5526 ± .0016	6.3

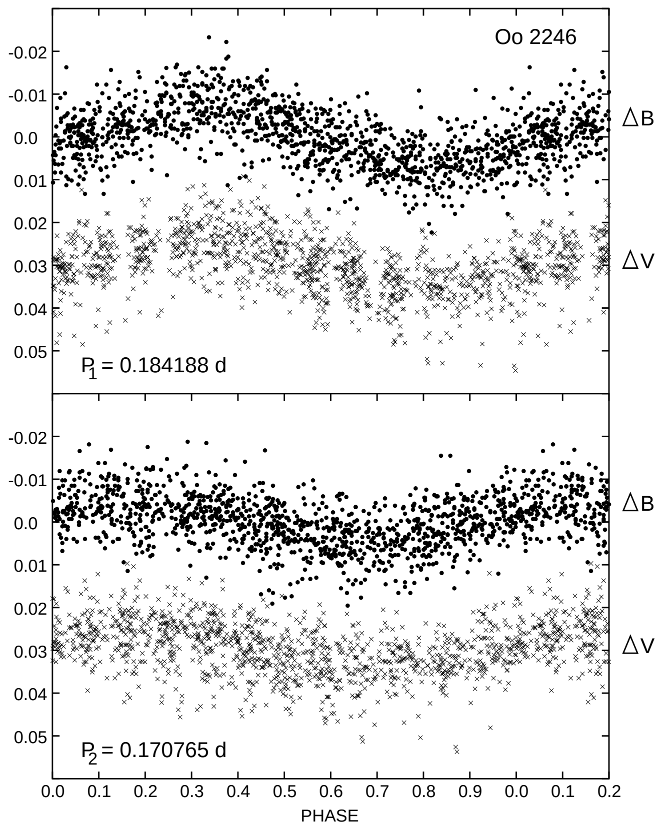

Fig. 3. The differential magnitudes of Oo 2246, phased with P_1 (top panel) and P_2 (bottom panel). In either case, the data were prewhitened with the other period prior to phasing. Observations in B are shown with filled circles, and in V, with crosses. Phase 0.0 was chosen arbitrarily. For clarity, the V data were shifted downwards by 0.03 mag in both panels. The ordinate is expressed in mag

3.1. Oo 2246 = BD+56°572

This star, classified B2 III by Johnson & Morgan (1955) and B1.5 V by Schild (1965), was not known to be variable. The Fourier spectrum, shown in Fig. 2, reveals two frequencies above the noise level: f_1 = 5.4292 and f_2 = 5.8558 d^{-1}. The corresponding periods, refined with the method of non-linear least-squares, are equal to $P_1 = 0.184188 \pm .000003$ and $P_2 = 0.170765 \pm .000004$ d, respectively. In order to get the amplitudes of both pulsation modes we computed a least-squares fit with the following expression:

$$A_0 + \sum_{i=1}^{N} A_i \sin\left[\frac{2\pi(t-T_0)}{P_i} + \phi_i\right] \quad (1)$$

to our differential B and V magnitudes. The U data were not used because they are too sparse to get reliable parameters from the fit. In Eq. (1) T_0 = HJD 2450000.0 and N is the number of fitted terms. The results are given in Table 2. The data phased with each of the detected periods are shown in Fig. 3.

As can be seen in the bottom panel of Fig. 2, there is an increase of the noise level towards the low frequencies in the Fourier spectrum of the residuals. We obtained the same pattern for constant stars. Therefore, it seems to be intrinsic to our data. This is due to the fact that the stellar profiles are not homogeneous throughout the field due to the inaccurate aligning of the telescope optics. Even using a variable PSF model we were not able to reduce this effect completely. The large seeing range in the whole data set further increased this effect.

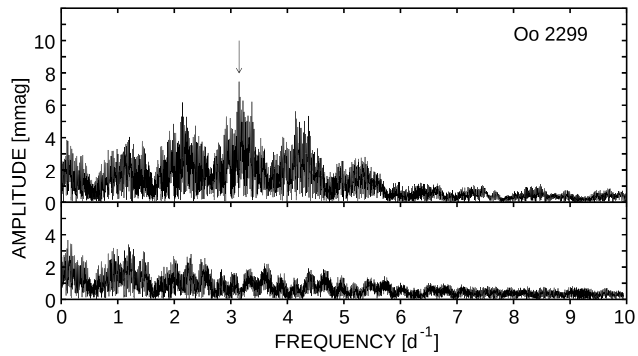

Fig. 4. Fourier frequency spectrum of the Oo 2299 B-filter data. Top panel: original data, bottom panel: after prewhitening with $P = 0.31788$ d (arrowed)

3.2. Oo 2299 = BD+56°575 = NSV 802

This star has already been suspected to be a variable on a time-scale of about 6 hours (Percy 1972). Both Schild (1965) and Slettebak (1968) classify the star as B0.5 IV. The frequency

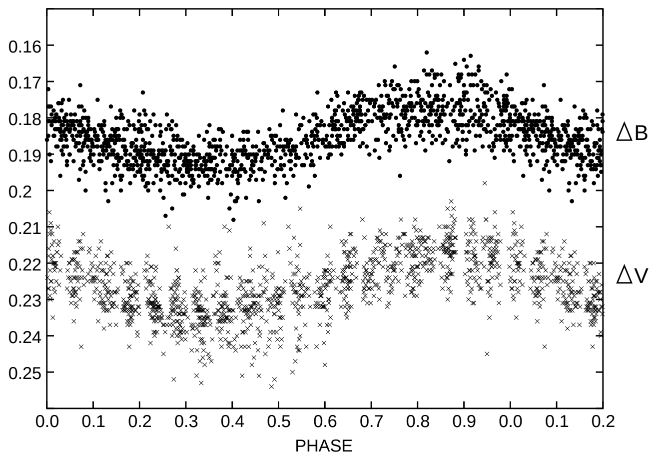

Fig. 5. The differential magnitudes of Oo 2299, folded with the pulsation period of 0.31788 d. The symbols are the same as in Fig. 3. The V data were shifted downwards by 0.02 mag. The ordinate is expressed in mag

spectrum of the data for Oo 2299 (Fig. 4) shows a single periodicity at frequency $f = 3.146$ d^{-1}. The corresponding value of the period, obtained from the non-linear least-squares analysis, is equal to $0.31788 \pm .00001$ d ($\sim$7.5 hours). This is one of the longest periods known among β Cephei stars. It slightly exceeds the value of 0.3 d, which is usually adopted as an observational upper limit for the period of β Cephei-star pulsations (see Sterken & Jerzykiewicz 1993). The long period makes Oo 2299 a very interesting case among the stars of its class. The phase diagram of Oo 2299, folded with the pulsation period, is shown in Fig. 5. After prewhitening with f, no significant peaks were found above the noise level (see bottom panel of Fig. 4). We therefore conclude that, to within the detection threshold of our search, Oo 2299 is a monoperiodic variable.

4. Other variables

Out of the remaining nine variables (see Table 1), three (Oo 2088, 2165, and 2242) are known as Be stars. Only Oo 2242 shows variations on a time-scale typical for λ Eri variables. However, the strong aliasing does not allow us to give unambiguously the value of a period. The light curve of another variable, Oo 2140, resembles those observed in Be stars, but this star is not known to be a Be star.

The two variables from our list (Oo 2227 and Oo 2417) are supergiants. The former is a B2 Ib star, found to be a small-amplitude variable by Percy (1972). We confirm its variability from our data. The latter star is RS Per, an M3 Iab-type semiregular variable.

The next two variables (Oo 2301 and Oo 2311) are eclipsing binaries. Oo 2301 is the visual companion of Oo 2299, the β Cephei variable described above. Its light curve is shown in Fig. 6. The times of minimum light, derived from our data and

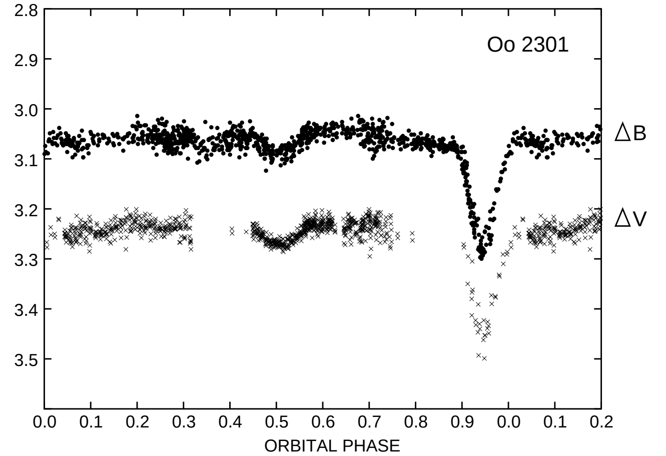

Fig. 6. The differential magnitudes of Oo 2301 phased with the orbital period of 1.54697 d. Symbols are the same as in Fig. 3. The V data have been shifted downwards by 0.2 mag. The ordinate is expressed in mag

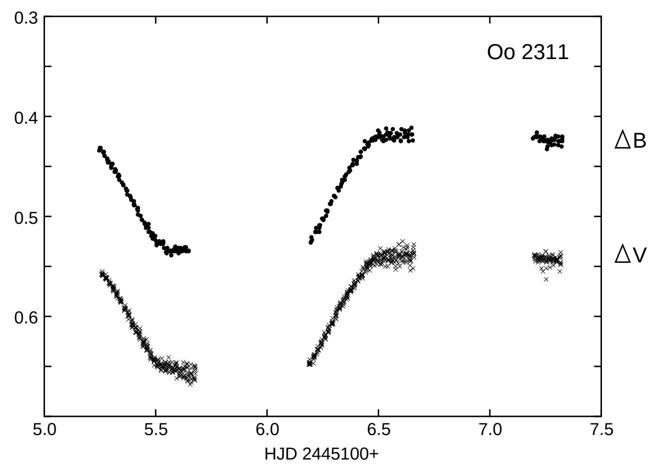

Fig. 7. A part of the light curve of Oo 2311, covering three consecutive nights in January 1996 when the primary eclipse took place. Symbols are the same as in Fig. 3. The V data have been shifted downwards by 0.1 mag. The ordinate is expressed in mag

listed in Table 3, led us to the following ephemeris for the primary minimum:

$$\text{Min I} = \text{HJD } 2450004.5538(8) + 1.54697(3) \times E, \quad (2)$$

where E is the number of elapsed cycles; the numbers in parentheses denote the mean errors with the leading zeroes omitted.

Oo 2311 is another eclipsing binary, but the available times of minimum (Table 3) do not allow us to derive unambiguously a value for the period. The two epochs when the eclipse was observed are separated by 102.1 d, so this is the longest possible value of the orbital period for Oo 2311. The other possibilities are some submultiples of this value, which fit the data equally well. One of the observed eclipses is shown in Fig. 7.

Table 3. Heliocentric times of minimum for two eclipsing binaries, Oo 2301 and Oo 2311

T_{min} (HJD 2400000+)	Filter	E	$O-C$ [d]
Oo 2301			
50004.5530 $\pm$ .0006	B	0	$-$.0008
50004.5543 $\pm$ .0027	V	0	.0005
50049.4177 $\pm$ .0009	B	29	.0018
50049.4174 $\pm$ .0015	V	29	.0015
50162.3425 $\pm$ .0022	B	102	$-$.0022
50162.3414 $\pm$ .0030	V	102	$-$.0033
Oo 2311			
50003.743 $\pm$ .004	B	—	—
50105.8442 $\pm$ .0008	B	—	—
50105.8445 $\pm$ .0006	V	—	—

There is a possibility that the last star from our list of variables (Oo 2371) is also a binary. The Fourier spectrum of the Oo 2371 data is dominated by peaks in the range between 0.3 and 0.7 d^{-1}. We examined these frequencies and found that the smoothest phase diagram is obtained with f = 0.3835 d^{-1}. The corresponding period is equal to 2.6066 $\pm$ .0003 d, but should not be regarded as a definitive one. The star exhibits also large radial velocity variations. The four values obtained by Liu et al. (1989, 1991) show a range of about 75 km s^{-1}. One possible explanation of the behaviour of Oo 2371 is an ellipsoidal variation. In this case, the period found from the periodogram would be equal to the half the orbital period.

5. The HR diagram

In order to construct the colour-magnitude (CM) diagram for the observed field, we calculated the differential magnitudes for all stars relative to Oo 2296, a bright constant star. Next, these magnitudes were corrected for the second-order extinction effects and the means in all filters were determined. In this way, the instrumental u, b, and v differential magnitudes were obtained.

These instrumental magnitudes were next transformed to the standard system using mainly the UBV photometry of Johnson & Morgan (1955), but also that of Wildey (1964) and Vogt & Moffat (1974). The transformation equations we finally adopted are the following:

$$V = v - 0.018(.030) \times (b - v) + 8.502(.008), \quad (3)$$

$$(B - V) = 1.080(.037) \times (b - v) + 0.311(.009), \quad (4)$$

$$(U - B) = 1.210(.067) \times (u - b) - 0.553(.022), \quad (5)$$

where numbers in parentheses denote the errors of the preceding numbers. The internal standard deviations were equal to 0.055, 0.062, and 0.093 mag for Eqs. (3), (4), and (5), respectively. The UBV magnitudes for all stars with reliable UBV photometry are given in Table 4 which is available only in electronic form at CDS via anonymous ftp to 130.79.128.5. Both the CM diagram and the colour-colour (CC) diagram are shown in Fig. 8.

As can be seen from Fig. 8, both β Cephei stars found in the nucleus of χ Persei lie close to the cluster turn-off point. The brighter one (V = 9.14 mag) is Oo 2299. There are six stars which fall within or close to the range of V bracketed by the two β Cephei stars. Three of them are Be stars, the next two (Oo 2311 and Oo 2371) are variables of other types, and only Oo 2235 was found to be constant. We carefully checked our observations of Oo 2235 and the out-of-eclipse observations of Oo 2311 for the presence of β Cephei variations. In either case we found no peaks above the noise level in the periodograms. We estimate the upper limit for the amplitude of the β Cephei pulsations in these two stars to be equal to 2 mmag.

The Johnson photometric Q index, calculated according to Serkowski's (1963) prescription, equals to -0.81 and -0.75 for Oo 2299 and Oo 2246, respectively. These values fall in the middle of the interval of Q covered by all known β Cephei variables [see Fig. 6 of Sterken & Jerzykiewicz (1993)]. Thus, as far as the Johnson Q index is concerned, the two β Cephei stars we found in χ Persei are quite typical.

It is also interesting to compare the newly discovered β Cephei stars with other stars of this type belonging to the three southern clusters mentioned in the introduction. We did it in the theoretical HR diagram using the calibrations of $\log T_{\rm eff}$ and bolometric corrections in terms of the Strömgren $uvby\beta$ photometry indices. For NGC 3293, NGC 4755, and NGC 6231 the photometry was taken from Balona (1994a), Balona & Koen (1994), and Balona & Laney (1995), respectively. For Oo 2246 and Oo 2299 it was published by Crawford et al. (1970). Because the star NGC 3293-11 was not observed by Balona (1994a), for this star we used the photometry of Shobbrook (1983). In order to make the photometry consistent, however, we corrected this photometry for the mean differences between both sets of photometric data. The Strömgren photometric indices were next dereddened, and then used to derive $\log T_{\rm eff}$ and bolometric corrections according to the calibrations given by Balona (1994b). In the calculations of the luminosities of β Cephei stars in the southern clusters we used the distance moduli derived by Balona and co-workers. For χ Persei we adopted $(V_0 - M_V)$ = 11.5 taken from Crawford et al. (1970). The total absorption, A_V, was derived from the published values of $E(b-y)$ by means of the formula: $A_V = 3.0E(B-V) \approx 4.29E(b-y)$. Fig. 9 shows the result: a comparison of the positions of the β Cephei stars in χ Persei and the three southern clusters in the theoretical HR diagram. The ZAMS line and the evolutionary tracks for stars with 10, 12, 14, and 16 $M_\odot$ were taken from the unpublished evolutionary models developed by W. Dziembowski, A. Pamyatnykh, and R. Sienkiewicz, which were kindly made available to us by Dr. A. Pamyatnykh. They were calculated with Z = 0.02 and X = 0.70, and use the newest OPAL opacity tables (Iglesias & Rogers 1996). No rotation was included.

As can be judged from Fig. 9, the two β Cephei variables from χ Persei fall close to the low-temperature limit of β Cephei stars in NGC 3293. All β Cephei stars, however, cover much a wider range of $\log T_{\rm eff}$, from $\log T_{\rm eff}$ = 4.332 up to 4.460. This range was derived from the observational range of the c_0 index for all β Cephei stars (Sterken & Jerzykiewicz 1993) us-

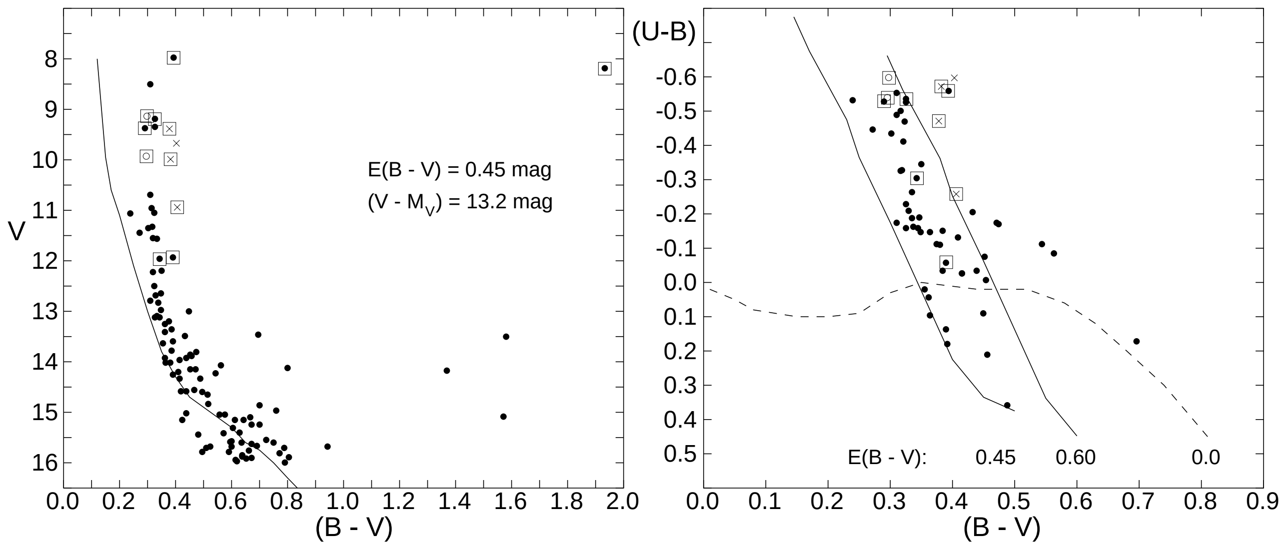

Fig. 8. The CM diagram (left panel) and CC diagram (right panel) for the observed field. Be and β Cephei stars are shown with crosses and open circles, respectively. Remaining stars are shown with filled circles. The symbols corresponding to variable stars are enclosed in large open squares. In the left panel we also show the ZAMS line of Th. Schmidt-Kaler (Lang 1992), corresponding to $E(B-V)$ and $(V-M_{\rm V})$ shown in the figure. In the right panel, luminosity class V two-colour relations corresponding to $E(B-V)$ = 0.0 (dashed line) and $E(B-V)$ = 0.45 and 0.60 (solid lines) are shown

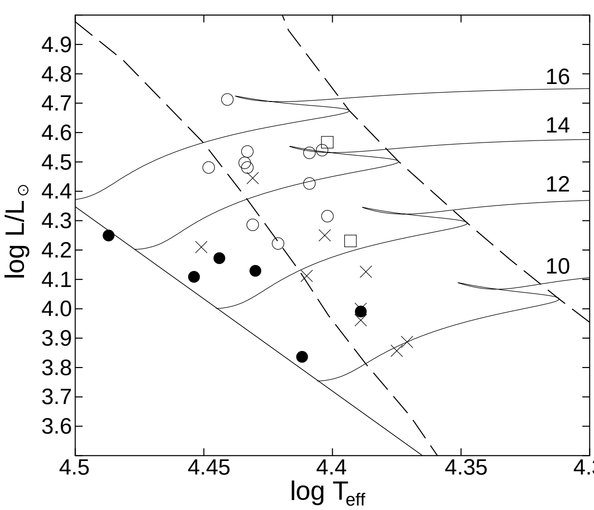

Fig. 9. Comparison of the newly discovered β Cephei stars in χ Persei (open squares) with those in NGC 3293 (open circles), NGC 4755 (crosses), and NGC 6231 (filled circles). The evolutionary tracks are labeled with masses expressed in $M_\odot$. The dashed lines are the borders of the theoretical instability strip for the photometrically detectable modes and metallicity Z = 0.02

ing the same calibrating procedure as for the β Cephei stars in clusters. For Oo 2246 and Oo 2299 log $T_{\rm eff}$ equals 4.393 and 4.402, respectively, and thus falls in the middle of the range of log $T_{\rm eff}$ covered by all β Cephei stars. The comparison with evolutionary tracks (Fig. 9) gives masses of about 12 $M_\odot$ for Oo 2246 and 15 $M_\odot$ for Oo 2299, if both stars are in the core hydrogen-burning phase. With $\log L/L_\odot$ = 4.57, Oo 2299 is one of the most luminous β Cephei stars. The amplitudes of all modes excited in Oo 2246 and Oo 2299 do not exceed 10 mmag, which is not untypical for β Cephei stars. Also the periods observed in Oo 2246 are typical. What seems to be unusual, however, is the pulsation period of Oo 2299, one of the longest observed for a β Cephei variable. For a main-sequence model without overshooting such a long period (0.318 d) in the p-mode domain is possible for stars with masses larger than ∼16.5 $M_\odot$. In order to agree the position of Oo 2299 in Fig. 9 with the evolutionary track for such a large mass, $\log L/L_\odot$ should be increased by about 0.2 dex. This is well within the errors of the calibration we used. Therefore, we conlude that Oo 2299 is probably a luminous and massive β Cephei star at the end of the core hydrogen-burning phase of evolution. Because of the long period, the most probable identification for the excited mode is the fundamental radial one, but there is also the possibility that it is a g mode.

As concerns the position of variable Be stars (Oo 2088, 2165 and 2242) in the cluster CM diagram, they all fall slightly to the right of the main sequence (see Fig. 8). Oo 2284, which is also a Be star but was found to be constant in our search, behaves in the same manner. The fact that Be stars are redder than non-Be stars of the same spectral type can be due to the presence of circumstellar matter and/or the high rotation of these stars. A similar effect on the photometric indices of Be stars was already reported by Mermilliod (1982) and Fabregat et al. (1994, 1996).

Provided they are not contracting onto the main sequence, six stars falling to the right of the main sequence in the CM diagram (left panel of Fig. 8) are too red to be cluster members. These are Oo 2198, Oo 2216, Oo 2376, Oo 2397, W66 and W201. Only for the brightest of them, Oo 2376, the $(U-B)$ index is available. The star's colours, $(U-B)$ = +0.17, $(B-V)$ = +0.70, indicate clearly that it is a foreground mid-G star. It is also seen from Fig. 8 that the reddening within the cluster is not uniform and that for most cluster stars it ranges from $E(B-V)$ = 0.45 to 0.6 mag. These values agree well with those obtained by Wildey (1964) in his study of the interstellar extinction in this region.

The only star in the field with a period in the range occupied by the SPB stars is Oo 2371. However, its dereddened indices, $(B-V) = -0.28$ and $(U-B) = -0.97$, imply an effective temperature of about 24 000 K. This is too hot for an SPB star. In addition, according to Dziembowski et al. (1993) shorter periods are preferred for the hottest stars in the SPB domain. We conclude that Oo 2371 is not a SPB star and that SPB stars with detectable amplitudes are not present in the field we observed.

6. Conclusions

It is clear that the χ Persei cluster deserves further attention and needs more observations. As we already mentioned, our study is based on the observations of a single field, centered on the nucleus of χ Persei. In order to better map the β Cephei instability strip in this cluster, other fields should be observed. These observations are under way. With the UBV observations of a large part of the cluster, it will be possible to derive new estimates of cluster reddening and distance modulus.

Unfortunately, at present we can estimate the minimum value of the metal abundance, Z, for χ Persei only very roughly. As can be seen in Fig. 9 both β Cephei stars we found in χ Persei fall well within the instability strip for Z = 0.02. We conclude therefore that Z = 0.02 is sufficient to excite the two β Cephei stars we found. There are, however, at least two reasons why now the constraints on Z cannot be given better. The first reason is the incompleteness of our search; it may happen that more β Cephei stars in this cluster will be found. Secondly, there is a discrepancy of the order of 0.003 in Z, if this parameter is inferred from models with different opacity tables (OP or OPAL, see the discussion in Pamyatnykh et al. 1995). Finally, the large errors of the photometric calibrations cause that the comparisons between models and observations similar to that shown in Fig. 9 remain very uncertain.

Acknowledgements. This research has been supported by Cracow Pedagogical University grant BS 13/M/96 and KBN grants Nos. 2 P03D 029 09 and 2 P03D 016 11. We are indebted to Professor W.A. Dziembowski and Drs. A.A. Pamyatnykh and R. Sienkiewicz for permission to use their evolutionary and pulsation codes, and to Professor M. Jerzykiewicz for helpful comments.

References

Balona L.A., 1994a, MNRAS 267,1060
Balona L.A., 1994b, MNRAS 268,119
Balona L.A., Koen C., 1994, MNRAS 267,1071
Balona L.A., Laney C.D., 1995, MNRAS 276,627
Crawford D.L., Glaspey J.W., Perry C.L., 1970, AJ 75,822
Dziembowski W.A., Moskalik P., Pamyatnykh A.A., 1993, MNRAS 265,588
Fabregat J., Torrejón J.M., Reig P., Bernabeu G., 1994, in: Proc. IAU Symp. 162, ed. L.A. Balona, H.F. Henrichs, J.M. Le Contel, Dordrecht, Kluwer, p. 309
Fabregat J., Torrejón J.M., Reig P., et al., 1996, A&AS 119,271
Iglesias C.A., Rodgers F.J., 1996, ApJ 464,943
Jerzykiewicz M., Pigulski A., Kopacki G., Mialkowska A., Niczyporuk S., 1996, Acta Astron. 46,253
Johnson H.L., Morgan W.W., 1955, ApJ 122,429
Kreiner J.M., Krzesiński J., Pokrzywka B., et al., 1993, in: Proc. IAU Coll. 136, ed. I.Elliott, C.J.Butler, p. 80
Krzesiński J., Wójcik K., 1993, A&A 280,338
Lang K.R., 1992, Astrophysical Data: Planets and Stars, New York: Springer-Verlag
Liu T., Janes K.A., Bania T.M., 1989, AJ 98,626
Liu T., Janes K.A., Bania T.M., 1991, AJ 102,1103
Mermilliod J.-C., 1982, A&A 109,37
Oosterhoff P.T., 1937, Ann. van de Sterrewacht te Leiden 17,1
Pamyatnykh A.A., Dziembowski W.A., Moskalik P., 1995, PASPC 83,291
Percy J.R., 1972, PASP 84,420
Schild R.E., 1965, ApJ 141,979
Serkowski K., 1963, ApJ 138,1035
Shobbrook R.R., 1983, MNRAS 205,1215
Slettebak A., 1968, ApJ 154,933
Sterken C., Jerzykiewicz M., 1993, Sp. Sci. Rev. 62,95
Stetson B.P., 1987, PASP 99,191
Waelkens C., Lampens P., Heynderickx D. et al., 1990, A&AS 83,11
Wildey R.L., 1964, ApJS 8,439
Vogt A.F.J., Moffat N., 1974, Veröffentlichungen des Astronomischen Instituts der Ruhr-Universität Bochum Nr. 2

This article was processed by the author using Springer-Verlag LaTeX A&A style file *L-AA* version 3.