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Determination of physical parameters of five large amplitude δ Scuti stars

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Abstract. $uvby - \beta$ photometry of the large amplitude δ Scuti stars BP Peg, DY Peg, DY Her, CY Aqr and YZ Boo is presented. Since the data were obtained almost simultaneously in all filters, meaningful physical parameters have been derived for each star along their pulsation cycles using the calibrations from Nissen (1988) for A and F stars to determine the reddening and derive the unreddened photometric values. The utilization of the theoretical grids of Relyea & Kurucz (1978) has allowed temperature and gravity values to be determined. A comparison with previously reported values is presented.

Key words: stars: fundamental parameters — δ Sct

1. Introduction

The determination of physical parameters such as effective temperature and superficial gravity can be done through the Strömgren photometric data reduced to the standard system for $B - F$ stars, once corrected for interstellar extinction. This procedure has been done previously by the authors for δ scuti variables and for stars in open cluster which lie within these spectral; its description can be found in Peniche et al. (1990), for example.

We must emphasize that for these fast pulsators, some of which are multi-periodic or with unexplained light curve variations, the data gathered in the present work has the advantage that it need not be adjusted in phase as it would have been with a one-channel photometer. This also allows an extensive time coverage along the cycle, in particular if the star is faint. On the other hand, the simultaneous measurements in the different filters that define the Strömgren system let us avoid problems due to interpolation which worsen if more than one frequency is present since it is well known (Breger 1998) that many high amplitude δ Scuti stars (HADS) are double mode radial pulsators. Hence, the analysis of the photometry presented in the current work shows the real variation of the physical characteristics of the stars along their pulsation cycles.

If the photometric system is well-defined and calibrated, it will provide an efficient way to investigate physical conditions. A comparison with theoretical models, such as those of Relyea & Kurucz (1978), allows a direct comparison with intermediate or wide band photometry measured from the stars with those obtained theoretically for early type stars. Relyea & Kurucz (1978) calculated grids for stellar atmospheres for G, F, A, B and O stars for the solar abundance [Fe/H] = 0.00 in a temperature range from 5500 K up to 50 000 K. They also considered abundances of 0.1 and 0.001. A comparison of the photometric unreddened indexes $(b-y)_0$ and c_0 obtained for each star with such models permits the determination of the effective temperature Te and superficial gravity $\log g$ along the cycle of pulsation. Therefore, the research goals for δ Scuti stars should be to try to determine not only the frequency content but also the maximum number of physical characteristics of as many stars as possible, along each star's cycle variation. Furthermore, there still exists the question of the real physical differences between the δ Scuti stars and Dwarf Cepheids; Breger (1980) stated that the majority of dwarf Cepheids mimic Pop I δ Scuti stars in basically all aspects, except for a few stars in the subgroup of Dwarf Cepheids known as the SX Phe that show low metallicity, high space velocities and low luminosities and that do not conform the theoretical period gravity relation in the direction of low mass. Hence motivation of the present work.

2. Observations

The photometric system utilized has the advantage, that the $uvby$ photometry is acquired simultaneously and the N and W filters that define Hβ almost simultaneously. All the observations were carried out at the Observatorio Astronómico Nacional at San Pedro Mártir, Mexico.

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Table 1. Uncertainties in the color indexes V, $(b-y)$, m_1, c_1 and β

Season	star	δV	$\delta(b-y)$	δm_1	δc_1	$\delta\beta$
1986A	BP Peg	0.017	0.011	0.011	0.013	0.009
1986B	DY Her	0.009	0.008	0.007	0.011	0.005
1992A	DY Peg	0.023	0.013	0.024	0.039	0.022
1992B	CY Aqr	0.021	0.008	0.007	0.010	0.007
1994	YZ Boo	0.015	0.013	0.017	0.018	0.005

The data was acquired in different observing seasons: July-August, 1986; August-September, 1986; September-October, 1992 and March, 1994. All were carried out at the 1.5 m telescope with the same spectrophotometer. A description of this instrument can be found in Nissen (1984). The reduction procedure was done through the numerical packages NABAPHOT (Arellano-Ferro & Parrao 1989) and DAMADAP (Parrao et al. 1998) which reduce the data into a standard system. The system that was chosen was that defined by the standard values of Olsen (1983) and the transformation equations are those defined by Crawford & Barnes (1970) and by Crawford & Mander (1966). An estimate of accuracy was done by comparing the $uvby-\beta$ data obtained with those of Olsen (1983) and Grönbech & Olsen (1977). The uncertainties were evaluated in the following manner: The average differences, present data of the standard stars minus Olsen's data, were evaluated and provide an uncertainty for the transformation of the season, see Table 1. These values, of course, are functions of the star magnitude and in all cases enough star counts were secured in order to attain a signal to noise ratio large enough to determine an accuracy better than 0.01 mag, small compared to the large amplitude variation of these stars. The final photometric values have been submitted to the IAU archive but the mean Strömgren indices which cover a whole cycle and the range of the variation due to pulsation for each star are listed in Table 2.

3. Discussion

In order to carry out the previously described techniques, the photometric values in the standard system presented in the section of Observations were used first to determine reddening. This was done using specific techniques which have been previously described (see, for example, Peña et al. 1993) and which are based on a calibration by Nissen (1988) based, in turn, on the fundamental calibrations of Crawford and his co-workers (1975, 1979) for A and F stars. This is applicable since, as is well-known, the δ Scuti stars are within these spectral limits in the HR diagram. For both types, Crawford derived empirical calibrations for M_v and $(b-y)_0$ and in the latter case, also the [Fe/H] metallicity. With these calibrations, slightly modified by Nissen (1988), a computing code was written to determine reddening and unreddened parameters for each set of photometric data. A slight interpolation would be necessary since the Hβ values differ slightly in time from $uvby$ photometry. However, since the difference is so small, in practice they were treated as if they were taken at the same time.

A brief description for each star is given which emphasizes the main characteristics relevant to the findings of the present paper:

BP Peg. Broglia (1959) reported a linear ephemeris with a period of 0.10954347 d, detecting also a possible variation of the period between the 1953 and 1958 and 1959 observations. Furthermore, they found a modulation period on the order of 0.37 d with an amplitude in the maxima of 0.45 mag in the visual. Rodríguez (1989) presented $uvby$ observations of this star and identified two main frequencies, 9.1260 and 11.8303 c/d corresponding to the fundamental mode and to the first overtone. Kim et al. (1989) secured new $uvby-\beta$ and spectroscopic observations of this star. They determined a photometric reddening value of $E(b-y)$ equal to 0.067 mag. A superficial gravity value of 3.85 and a ratio [Fe/H] of -0.08 were obtained. An average $T_{\rm e}$ of 7470 K was determined from their photometry and theoretical grids. From this and theoretical models, a bolometric magnitude of $M_{\rm bol}$ 1.4 mag, a mass of 1.85 $M_\odot$ and an age of 1.3 10^9 yr were finally derived. Rodríguez et al. (1992) also reported uvby-β of three large amplitude δ Scuti stars, BP Peg, among them. They were able to determine the same parameters previously established with their photometry.

CY Aqr. Detre & Chang (1960) and Hardie & Tolbert (1961) reported an ephemeris with a negative quadratic term. Percy (1975) reported that the period remained constant between 1934 and 1951, when it suffered a drastic change and then remained constant. Elst (1972) determined a modulation period of 0.1222 d, but with a very small amplitude. Fitch (1973) suggested the modulation period might be 0.17766 d, which could be explained by the pulsational theory, whereas Elst's (1972) period, could not. Percy (1975) found that the modulation period proposed by Elst (1972) was not real but merely a result of its method of analysis. Geyer & Hoffmann (1974, 1975) did not find any modulation period. Mahdy & Szeidl (1980) derived an abrupt change of the period of $-18.1\ 10^{-8}$ d around 1952, the period being constant before and after this date. Rolland et al. (1986) and Peña et al. (1987), proposed a period decay consistent with the theoretical model of a pre-white dwarf of 0.2 $M_\odot$ in opposition to the abrupt period changes suggested. Rodríguez (1989) determined a linear ephemeris for his data and, in a later study, (Rodríguez et al. 1990) determined some observational parameters such as effective temperature of Te 7590 K, superficial gravity of $\log g = 3.89$ and metallicity [Fe/H] = -0.7. Besides these values, they determined, considering pulsation, the following: $R_* = 2.34\ R_\odot$, $M = 1.49\ M_\odot$, $M_{\rm bol} = 1.71$ and an

Table 2. Mean Strömgren indices and the range of the variation for each star

	BP Peg	CY Aqr	DY Her	DY Peg	YZ Boo
$\langle V\rangle$	11.9628	10.7459	10.5797	10.3688	10.5849
$V_{\rm max}$	11.68	10.421	10.402	10.057	10.311
$V_{\rm min}$	12.17	11.096	10.803	10.613	10.730
$\langle b-y\rangle$	0.2165	0.1844	0.2091	0.1738	0.1688
$(b-y)_{\rm max}$	0.154	0.115	0.137	0.104	0.113
$(b-y)_{\rm min}$	0.274	0.272	0.276	0.229	0.189
$\langle m_1\rangle$	0.2244	0.1165	0.2061	0.1444	0.1458
$m_{1\ \rm max}$	0.267	0.152	0.172	0.176	0.160
$m_{1\ \rm min}$	0.173	0.066	0.242	0.118	0.134
$\langle c_1\rangle$	0.7399	0.8937	0.7839	0.9125	0.8374
$c_{1\ \rm max}$	0.861	1.045	0.928	1.069	0.956
$c_{1\ \rm min}$	0.628	0.718	0.642	0.772	0.771
$\langle\beta\rangle$	2.7636	2.7994	2.7503	2.7879	2.7520
$\beta_{\rm max}$	2.853	2.877	2.811	2.857	2.810
$\beta_{\rm min}$	2.690	2.697	2.700	2.708	2.715

age of 1.7 10^9 yr. Coates et al. (1994) determined a period change and concluded that the star was pulsating with only one period. This conclusion is not supported by the study of Powell et al. (1995) which stated that the new data did not present significant variations from cycle to cycle, but that an abrupt period change occurred in 1989 and that the star is now pulsating with a period of 0.061038612 d.

DY Her. Since its discovery as a variable star in the thirties it has been a subject of considerable interest. In works by McNamara (1978) with spectra and by Breger et al. (1978) from $uvby-\beta$, a value of 2.7 $R_\odot$ was determined. Szeidl (1979) stated that the radius should be larger than that previously reported. Breger et al. (1978) determined the effective temperature and superficial gravity with Strömgren photometry with a one channel photometer. Rodríguez (1989) determined the metallicity of the star with simultaneous Strömgren photometry. López de Coca et al. (1990) included it in a comprehensive review of the observational characteristics of all the δ Scuti stars known. Antonello (1990) carried out a comparison with theoretical models concerning the Strömgren m_1 index. For DY Her he derived $\langle T_{\rm e}\rangle$ of 7360 K, $\log\langle g\rangle$ of 3.87 and [Fe/H] of 0.16. The physical parameters of mass, bolometric magnitude and age were later determined from $uvby-\beta$ photometry by Rodríguez et al. (1990). Dawei et al. (1993) confirmed the period change of DY Her based on studies by Madhy & Szeidl (1980) with a compilation of 60 maxima from 1938 up to 1979. Yang et al. (1993) made a compilation of 30 years of observations determining a variation in the period of $P_0 = 0.14863130$ d, $1/p({\rm d}p/{\rm d}t) = -5.2\ 10^{-9}$ yr. Milone et al. (1994) derived the mean radius and bolometric luminosity of 2.77 $R_\odot$ and $M_{\rm bol} = 1.41$ mag, respectively, from visual and infrared photometry and the effective temperature derived by Breger et al. (1978).

DY Peg. An excellent review of the previous observations can be found in Rodriguez (1989). Between 1966 and 1975 several observers obtained new photometric data with the purpose of confirming light curve variations. Quigley & Africano (1979, 1981) derived a quadratic ephemeris which predicted a decrease in the period. Peña & Peniche (1986) derived a decrease in the period, consistent with the theoretical models of Dziembowski & Kozlowski (1974) for a pre-white-dwarf in opposition to the abrupt period changes proposed by Percy (1975) and Mahdy & Szeidl (1980). Rodriguez (1989) reported observations of DY Peg in the Strömgren system determining a period of 0.0729 d. Recently, Kilambi & Rahman (1993) presented UBV observations and determined mass, radius, gravity and variations of the temperature over one cycle of pulsation. Rodriguez et al. (1993) reported light curves in the $uvby-\beta$ system.

YZ Boo. Studies by Szeidl & Mahdy (1981) led them to conclude that YZ Boo had suffered a period change. Joner & McNamara (1983) derived its physical parameters ($T_{\rm e} = 7590$ and $\log g = 3.95$, [Fe/H]$= -0.025$, $M_{\rm bol} = +1.7$) through UBV and Strömgren photometry and concluded that it is a dwarf Cepheid of Pop I, which, according to Breger (1979) could be considered to be δ Scuti star. Since the period changes can provide information on the evolutive stage of the stars, several studies have been done with this goal in mind: this star was first studied by Szeidl & Mahdy (1981), later by Peniche et al. (1985); Jiang (1986), determined new ephemeris with a quadratic term. Peniche et al. (1985) concluded that it is impossible to decide if the period is constant or not with the currently available data bases. Kim & Joner (1994a) reported photometric observations in Coussins VRc system and in a later paper Kim & Joner (1994b) determined $T_e = 7410$ K, $\log g = 3.71$ and a metallicity $[M/H] = -0.025$.

4. Analysis

Simultaneous $uvby-\beta$ photoelectric photometry for the δ Scuti stars CY Aqr, DY Peg, YZ Boo, BP Peg, and DY Her has been secured. The application of the previously

Table 3. Unreddened photometry of BP Peg

Time	$(b-y)_0$	m_{10}	c_{10}	Time	$(b-y)_0$	m_{10}	c_{10}
3.7745	0.144	0.217	0.836	3.8431	0.222	0.201	0.652
3.7777	0.140	0.239	0.832	3.8474	0.188	0.264	0.628
3.7789	0.127	0.263	0.810	3.8489	0.203	0.236	0.619
3.7877	0.173	0.199	0.797	3.8503	0.218	0.207	0.636
3.7890	0.161	0.208	0.789	3.8519	0.200	0.243	0.618
3.7902	0.163	0.216	0.795	3.8556	0.197	0.232	0.630
3.7929	0.161	0.239	0.760	3.8569	0.192	0.237	0.657
3.7941	0.173	0.207	0.780	3.8581	0.202	0.220	0.652
3.7956	0.180	0.214	0.750	3.8609	0.175	0.255	0.636
3.7969	0.180	0.209	0.760	3.8621	0.185	0.239	0.658
3.8000	0.189	0.191	0.751	3.8634	0.187	0.221	0.669
3.8013	0.173	0.224	0.767	3.8647	0.162	0.257	0.658
3.8045	0.206	0.180	0.738	3.8659	0.157	0.257	0.700
3.8058	0.198	0.193	0.748	3.8686	0.146	0.255	0.714
3.8070	0.182	0.229	0.710	3.8699	0.134	0.252	0.774
3.8100	0.175	0.254	0.688	3.8711	0.138	0.245	0.757
3.8113	0.173	0.253	0.705	3.8723	0.118	0.265	0.778
3.8126	0.180	0.239	0.696	3.8737	0.123	0.251	0.796
3.8138	0.200	0.205	0.706	3.8750	0.108	0.275	0.803
3.8166	0.200	0.212	0.688	3.8777	0.108	0.256	0.832
3.8180	0.206	0.204	0.687	3.8790	0.113	0.250	0.838
3.8193	0.202	0.208	0.686	3.8803	0.110	0.253	0.845
3.8205	0.203	0.211	0.691	3.8817	0.112	0.251	0.844
3.8236	0.213	0.188	0.720	3.8857	0.113	0.252	0.852
3.8250	0.212	0.212	0.677	3.8888	0.116	0.262	0.835
3.8262	0.210	0.192	0.705	3.8901	0.123	0.275	0.800
3.8285	0.200	0.228	0.670	3.8915	0.117	0.267	0.818
3.8297	0.205	0.221	0.674	3.8927	0.140	0.229	0.826
3.8310	0.208	0.214	0.665	3.8939	0.130	0.256	0.816
3.8322	0.228	0.195	0.668	3.8953	0.136	0.257	0.787
3.8335	0.198	0.232	0.672	3.8983	0.148	0.242	0.792
3.8365	0.195	0.237	0.660	3.9000	0.154	0.237	0.789
3.8378	0.204	0.228	0.653	3.9013	0.153	0.243	0.768
3.8390	0.208	0.222	0.652	3.9027	0.161	0.238	0.778
3.8404	0.184	0.264	0.640	3.9056	0.158	0.248	0.752
3.8419	0.207	0.214	0.646	3.9069	0.168	0.245	0.744

HJD = time + 2446670.0.

described technique from Peña et al. (1993) to the data for each star provides the reddening for each set of colors obtained at the same time. A mean value of the reddening was considered and from this, unreddened indexes were obtained. Once the unreddened indexes have been evaluated, (Tables 3 to 7 for BP Peg, CY Aqr, DY Her, DY Peg and YZ Boo, respectively) the location of each data point was determined in the theoretical grids of Relyea & Kurucz (1978) for solar abundance and lower. From the photometry, superficial gravity and effective temperatures as well as metallicity, absolute magnitude and distance have been derived for each star and the variations in $T_{\rm e}$ and log g during the pulsation cycle for the large amplitude stars is presented in Table 8. A compilation of the values reported in the literature has been done and the derived values compared well with those determined previously (Table 9). In particular CY Aqr and DY Peg show low metallicity, a characteristic of Pop II stars whereas DY Her and YZ Boo have Pop I metallicity.

Since the values of metallicity found for BP Peg differ from those previously compiled, a careful analysis was carried out: a direct comparison with another source of $uvby-\beta$ (KMJ, 1989) was done. Since significant values for determining physical quantities are those between phases 0.3 to 0.75 (Breger et al. 1978; McNamara 1997), phase diagrams were constructed with the KMJ photometry of the longest nights (2447413 & 20) to avoid the beating phenomena that could arise from the two determined frequencies in BP Peg. What was immediately evident, was that most of the measured Hβ values for BP Peg from the two sources were above the 2.72 limit that establishes the difference between A and F type stars since [Fe/H] can

Table 4. Unreddened photometry of CY Aqr

Time	$(b-y)_0$	m_{10}	c_{10}	Time	$(b-y)_0$	m_{10}	c_{10}
0.632	0.148	0.1288	0.7712	0.6584	0.171	0.1208	0.8142
0.6346	0.111	0.1438	0.8842	0.6632	0.194	0.0978	0.7832
0.6356	0.083	0.1708	0.9062	0.6644	0.199	0.0788	0.8022
0.6365	0.04	0.1538	1.0012	0.6773	0.21	0.1028	0.7082
0.6379	0.069	0.1598	1.0042	0.6798	0.224	0.0818	0.7202
0.6401	0.077	0.1518	1.0182	0.6815	0.215	0.0878	0.7162
0.6412	0.071	0.1518	1.0332	0.6829	0.215	0.0888	0.7152
0.6431	0.086	0.1398	1.0322	0.6857	0.217	0.0748	0.7272
0.6456	0.098	0.1428	1.0022	0.6928	0.171	0.1008	0.7872
0.6467	0.102	0.1598	0.9732	0.6941	0.145	0.1258	0.8072
0.6485	0.128	0.1278	0.9622	0.695	0.126	0.1378	0.8482
0.6494	0.122	0.1398	0.9232	0.696	0.113	0.1288	0.9092
0.6512	0.142	0.1388	0.8732	0.6982	0.081	0.1378	0.9872
0.6526	0.153	0.1128	0.9122	0.7001	0.071	0.1398	1.0322
0.6545	0.161	0.1258	0.8522	0.7017	0.084	0.1328	1.0322
0.6561	0.17	0.1008	0.8622				

HJD = time + 2444494.0.

Table 5. Unreddened photometry of DY Her

Time	$(b-y)_0$	m_{10}	c_{10}	Time	$(b-y)_0$	m_{10}	c_{10}
0.6653	0.127	0.197	0.946	0.7594	0.250	0.204	0.649
0.6697	0.137	0.191	0.951	0.7633	0.252	0.210	0.637
0.6743	0.139	0.192	0.933	0.7722	0.245	0.215	0.632
0.6787	0.150	0.188	0.921	0.7762	0.249	0.209	0.650
0.6834	0.155	0.201	0.889	0.7867	0.222	0.203	0.673
0.6878	0.170	0.190	0.871	0.7910	0.212	0.221	0.657
0.6940	0.189	0.176	0.834	0.7939	0.209	0.216	0.692
0.6985	0.181	0.199	0.817	0.7960	0.201	0.218	0.709
0.7027	0.198	0.180	0.800	0.7980	0.197	0.217	0.715
0.7070	0.205	0.184	0.792	0.8016	0.173	0.227	0.752
0.7148	0.215	0.186	0.763	0.8036	0.174	0.221	0.775
0.7190	0.210	0.206	0.738	0.8066	0.128	0.246	0.805
0.7226	0.217	0.209	0.721	0.8091	0.121	0.243	0.856
0.7276	0.223	0.204	0.717	0.8117	0.118	0.244	0.890
0.7311	0.235	0.191	0.719	0.8154	0.113	0.235	0.922
0.7350	0.231	0.208	0.694	0.8177	0.117	0.237	0.919
0.7477	0.242	0.202	0.681	0.8210	0.112	0.243	0.918
0.7515	0.240	0.208	0.669	0.8242	0.118	0.244	0.902
0.7558	0.248	0.208	0.646				

HJD = time + 2446645.0.

be determined only for F type (Nissen 1988). Mean values and the standard deviations were determined (Table 10) for the considered photometric data (KMJ and the present paper's) between these phase limits and, within these uncertainties, the magnitude and colors are practically the same. With these values a metallicity of -0.093 and 0.764 respectively, was calculated. Emphasis should be made on the fact that photometry in the present paper was carried out simultaneously in all the filters and that the dispersion is lower.

In view of the apparently large discrepancy, the determination of the metal content [Fe/H] of BP Peg was also done considering the relations 4.6.8 and 4.6.9 provided by Rodríguez (1989). From these, the metal content for each set of data was 0.459 ± 0.372 for the photometry in present paper and -0.400 ± 0.738 for the KMJ values for the 4.6.8 equation and, analogously, of 0.359 ± 0.275 and -0.235 ± 0.451 for the 4.6.9 relation which when calculated from the standard deviations in the considered range phases, give the same values of metallicity within the uncertainties.

Table 6. Unreddened photometry of DY Peg

Time	$(b-y)_0$	m_{10}	c_{10}	Time	$(b-y)_0$	m_{10}	c_{10}
0.7113	0.195	0.132	0.785	0.7794	0.198	0.138	0.766
0.7152	0.177	0.143	0.803	0.7806	0.195	0.124	0.804
0.7203	0.140	0.152	0.896	0.7839	0.195	0.124	0.805
0.7251	0.107	0.148	1.012	0.7850	0.184	0.139	0.778
0.7304	0.091	0.156	1.064	0.7887	0.156	0.160	0.800
0.7356	0.102	0.155	1.050	0.7925	0.139	0.160	0.865
0.7409	0.122	0.161	0.982	0.7937	0.122	0.159	0.916
0.7459	0.140	0.156	0.941	0.7994	0.088	0.168	1.002
0.7510	0.162	0.143	0.893	0.8004	0.088	0.169	1.002
0.7565	0.183	0.124	0.879	0.8014	0.078	0.174	1.021
0.7618	0.185	0.133	0.830	0.8024	0.072	0.182	1.022
0.7716	0.185	0.145	0.794	0.8034	0.073	0.166	1.059
0.7731	0.196	0.139	0.788	0.8074	0.074	0.173	1.069
0.7759	0.196	0.128	0.804	0.8085	0.074	0.181	1.054
0.7769	0.194	0.129	0.804				

HJD = time + 2448925.0.

Table 7. Unreddened photometry of YZ Boo

Time	$(b-y)_0$	m_{10}	c_{10}
0.8421	0.099	0.143	0.761
0.8635	0.018	0.164	0.913
0.8705	0.010	0.163	0.944
0.8844	0.034	0.161	0.927
0.8904	0.044	0.156	0.929
0.8954	0.058	0.148	0.899
0.9080	0.074	0.154	0.846
0.9134	0.082	0.161	0.802
0.9186	0.081	0.167	0.785
0.9240	0.083	0.160	0.795
0.9289	0.083	0.167	0.774
0.9352	0.087	0.168	0.760
0.9407	0.084	0.167	0.756
0.9460	0.096	0.152	0.758
0.9520	0.084	0.161	0.771
0.9573	0.066	0.177	0.757
0.9636	0.035	0.174	0.855

HJD = time + 2449427.0.

Table 8. Variations in $T_{\rm e}$ and $\log g$ during the pulsation cycle for the large amplitude stars

	$\log g_{\rm max}$	$\log g_{\rm min}$	$T_{\rm e\ max}$ (K)	$T_{\rm e\ min}$ (K)
BP Peg	4.144	3.441	8000	6860
CY Aqr	4.119	3.476	8320	6680
DY Her	4.264	3.610	8180	6800
DY Peg	3.960	3.324	8270	6910
YZ Boo	3.989	3.621	8065	7230

From the determined values for the pulsational constant (Breger et al. 1996), as well as from their position in the period -luminosity-color diagrams (López de Coca et al. 1990), it has been determined that BP Peg, DY Her and YZ Boo are pulsating in the fundamental mode whereas CY Aqr and DY Peg do so in higher overtones (2H from the former method and between 2H and 3H, from the last one). The derived mass values are 1.85, 2.1, 1.7, 0.21 and 0.225 $M_{\odot}$, respectively.

What is immediately evident when comparing the physical parameters obtained from $uvby - \beta$ photometric data with those reported in the literature, is the significant spread of values of the physical characteristics. The principal sources have been listed at the bottom of Table 9. The comparison of the pulsational and evolutionary theories are in excellent agreement if the results derived by each method are examined. From these methods it was found that BP Peg, DY Her and YZ Boo are classical δ Scuti stars and fit the determinations of other authors, except for the metallicity found for YZ Boo. On the other hand, CY Aqr and DY Peg appear to be SX Phe stars of an older population than the δ Scuti stars. The scenario for these stars would be that they are in a more advanced evolutive stage which could correspond to prewhite dwarfs as the lower absolute magnitude indicates. No significant changes in the position of these stars in the HR diagram are expected because no significant changes have been found from the previously determined physical characteristics.

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Table 9. Comparison with the previously reported data in the literature

ID	Source	[Fe/H]	$\log T_e$	$\log g$	T_e (K)	Q
BP Peg	PP	0.76	3.871	3.92	7430	0.045
	GKA	−0.08	3.875	3.85	7500	
	KMcN & J	−0.08	3.873	3.85	7470	
	McN	−0.02		3.87	7550	0.033
CY Aqr	PP	−0.90	3.875	3.91	7500	0.020
	GKA	−0.6	3.899	4.13	7925	
	MB	–		4.11		
	ER	−0.7	3.880	3.85	7590	0.019
	McN & F	−0.6	–	4.13	7930	0.033
	PLC	–	3.893	3.95	7816	0.024
	McN	−1.40		4.04	7720	0.031
DY Her	PP	0.58	3.874	4.05	7490	0.061
	GKA	0.30	3.853	3.66	7128	–
	BC & R	–	–	3.87	7360	–
	ER	0.30	3.865	3.72	7320	0.039
	McN & F	0.30	3.866	3.66	7130	0.033
	PLC	–	3.860	3.59	7244	0.032
	EA	0.16	–	3.87	7360	–
	McN	0.00		3.66	7250	0.033
DY Peg	PP	−0.56	3.880	3.75	7590	0.019
	GKA	−0.70	3.892	4.00	7800	–
	MB	–	–	4.00	–	–
	ER	−0.6	3.885	3.89	7680	0.023
	McN & F	−0.7	3.892	4.00	7800	0.033
	K & R			4.04	7775	0.032
	McN	−0.65		3.99	7705	0.032
YZ Boo	PP	−0.39	3.884	3.84	7650	0.032
	GKA	−0.10	3.884	3.97	–	–
	MB	–	–	3.97	–	–
	McN & F	−0.1	3.884	3.97	7650	0.033
	KJ	−0.25	–	3.71	7410	
	PLC	–	3.880	3.80	7585	0.032
	J & McN	−0.025	–	3.95	7590	0.033
	McN	−0.60		3.86	7490	0.032

PP Present paper **McN & F** McNamara & Feltz (1978) **GKA** Andreasen (1983) **KJ** Kim & Joner (1994b) **MB** Breger (1980) **J & McN** Joner & McNamara (1983) **ER** Rodríguez (1989) **BC & R** Breger et al. (1978) **EA** Antonello (1990) **PLC** López de Coca (1986) **K & R** Kilambi & Rahman (1993) **KMcN & J** Kim et al. (1989) **McN** McNamara (1997).

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Table 10. Mean values and standard deviations for BP Peg between phases 0.3 and 0.75

	V	$b-y$	m_1	c_1	Hβ
KMJ	12.059	0.256	0.148	0.795	2.736
σ	0.058	0.033	0.041	0.051	0.047
PP	12.100	0.250	0.202	0.695	2.731
σ	0.050	0.013	0.025	0.034	0.023

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