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# Study of an unbiased sample of B stars observed with Hipparcos: the discovery of a large amount of new slowly pulsating B stars

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**Abstract.** We present a classification of 267 new variable B-type stars discovered by Hipparcos. We have used two different classification schemes and they both result in only a few new $\beta$ Cephei stars, a huge number of new slowly pulsating B stars, quite some supergiants with $\alpha$ Cyg-type variations and variable CP stars, and further some new periodic Be stars and eclipsing binaries. Our results clearly point out the biased nature towards short-period variables of earlier, ground-based surveys of variable stars.

The position of the new $\beta$ Cephei stars and slowly pulsating B stars in the HR diagram is determined by means of Geneva photometry and is confronted with the most recent calculations of the instability strips for both groups of variables. We find that the new $\beta$ Cephei stars are situated in the blue part of the instability strip and that the new slowly pulsating B stars almost fully cover the theoretical instability domain determined for such stars.

The supergiants with $\alpha$ Cyg-type variations are situated between the instability strips of the $\beta$ Cephei and the slowly pulsating B stars on the one hand and previously known supergiants that exhibit microvariations on the other hand. This suggests some connection between the variability caused by the $\kappa$ mechanism acting in a zone of partially ionised metals and the unknown cause of the variations in supergiants.

**Key words:** stars: early-type – stars: variables– stars: oscillations – stars: statistics – methods: statistical

## 1. Introduction

One of the most important by-products of the observations performed by the satellite Hipparcos is the discovery of a huge number of new variable stars (see e.g. Grenon 1997). The stability of the instruments on board of Hipparcos and its continuous monitoring outside the earth atmosphere during about 3.3 years resulted in a complete, homogeneous scan of the stars in our close environment with very high accuracy (see the ESA Catalogues: van Leeuwen, F. et al., Volume 11, ESA SP-1200 and Grenon, M. et al., Volume 12, ESA SP-1200). On average, about 110 observations were carried out for each of the stars in the Hipparcos Input Catalogue (Eyer et al., 1994). Since no preselection on the basis of variability was made in the composition of the input catalogue, the Hipparcos data offer us for the first time an important unbiased view of the occurence of stellar variability in our close vicinity.

From a pulsational point of view, the newly detected B-type stars are very interesting. A first reason is that, contrary to other well-understood variables such as the Cepheids, the RR Lyrae stars, and the $\delta$ Scuti variables, their instability mechanism was only recently found in terms of the $\kappa$ mechanism acting in a partially ionised zone of elements of the metal group (Dziembowski & Pamyatnykh 1993, Dziembowski et al. 1993, Gautschy & Saio 1993) and needs further observational verification. Secondly, the class of slowly pulsating B stars (hereafter called SPBs, Waelkens 1991) contains only a limited number of stars which scarcely populate the predicted instability domain for such stars. On the other hand, the SPBs are the only firmly established class of early-type main-sequence variables in which non-radial g-mode pulsations are excited. The latter are extremely important from an asteroseismological point of view since they penetrate deep into the stellar interior, in contrast with the p-mode pulsations excited in the other classes of variables mentioned above. It is therefore of major importance to discover new SPBs and to perform a follow-up study for these objects. Finally, the cause of the variability of supergiants, among which many B-type ones, is not understood.

The selection procedure to derive the new variable B-type stars was roughly the following. Of all the variable stars discovered by Hipparcos, Eyer (1997) selected those that have spectral type B and that were classified as variable according to the Input Catalogue. He further used a period-search algorithm to derive the main frequency for these stars. Among the new variable B-type stars, this resulted in 267 previously unknown variables for

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which a period could be found. Eyer (1997) obtained periods ranging from a few hours up to 0.5 years, which clearly points out the unbiased nature of the sample with respect to periodicity. It is then clear that this unbiased sample of new variable B-type stars is very important in the general context of variability studies and more specifically for the study of pulsating B-type stars.

In this paper, we study the 267 new variable B-type stars found by Hipparcos. Our classification of these stars is described in Sect. 2. In Sect. 3 we determine the position of the pulsating stars among the sample, i.e. of the $\beta$ Cephei stars and of the SPBs, in the HR diagram and we confront these findings with the most recent calculations of the theoretically predicted instability domains on the basis of the $\kappa$ mechanism. The location of the variable supergiants in the HR diagram is also derived and is confronted with the position of previously known stars of this kind and with well-established pulsators. A discussion of our results is presented in Sect. 4.

## 2. Classification

An important question to answer is: what is the nature of the 267 newly discovered B-type variables ? In order to classify these stars, we have first considered their spectral type (SpT) and main frequency ($f$) as found from the Hipparcos photometry. Very useful additional parameters to classify a star are the Geneva parameters $X, Y, Z$ (for the definition and an interpretation of these parameters, see e.g. Golay, 1980). Geneva observations are available for 173 of the 267 discovered variables. A preliminary classification (used in the catalogue) was then proposed by considering SpT, $f$, visual inspection of the (non-)sinusoidal behaviour and the scatter in the Hipparcos light curves. Additionally, the $X, Y$ variables were considered for the 173 stars for which these parameters are available. We refer to the Catalogue for the results of this classification.

A more objective, statistically justified classification was performed for the 173 for which Geneva data are available. In order to obtain such a classification, we have performed a multivariate discriminant analysis. Multivariate classification schemes use the knowlegde of stellar parameters in the $n$-dimensional space, instead of considering bivariate plots. Discriminant analysis is only possible if prototypes of classes are available, such that a "definition" of a known class can be formulated. The unknown objects will then be assigned to one of the calibration classes. This is obtained by the determination of discriminating axes in the multidimensional space, in such a way that optimal separation of the predefined classes is attained. Each star is then classified by calculating its Mahalanobis or generalised distance to the discriminating axes. Such discriminant analysis rests on a firm mathematical base and can easily be implemented, e.g. by means of the *discrim* procedure available in the statistical software package SAS (1990). For a full description of the method, we refer to e.g. Murtagh & Heck (1987).

Our discriminant analysis is based on the four parameters $f, X, Y, |Z|$ ($n$ = 4), and uses three calibration classes: $\beta$ Cephei stars, SPBs, and variable CP stars. One classification criterion is therefore not sufficient, since we do not only want to discriminate between these three classes, but also derive whether stars are variable supergiants, variable Be stars, or eclipsing binaries rather than belonging to one of the three calibration classes. For the latter three groups of variables, however, it is difficult to define a class. Different types of variations exist for the supergiants, among them microvariations in Luminous Blue Variables, in WR stars, and $\alpha$ Cyg-type variability in other supergiants. The instability mechanism remains unknown for these three kinds of supergiants. Also, it is not clear whether or not the variability of part of the Be stars has a common cause. For these reasons, we have opted for a discriminant analysis with only firmly established calibration classes.

As prototypes for the $\beta$ Cephei stars, we have selected the stars in the list of Heynderickx et al. (1994) for which Geneva data are available. This results in 39 objects. For the prototypes of the SPBs we have used the stars given by Waelkens (1991, 1994), by North & Paltani (1994), and by Chapellier et al. (1996), which leads to 11 objects. Finally, for the prototypes of the CP stars, we have consulted the catalogue recently published by Catalano & Renson (1997) and selected 52 periodic stars for which Geneva data are available. However, the resulting list contains stars that are not necessarily of CP nature alone, e.g. it contains HD 123515 which is a well-known SPB (Waelkens 1991). In order to make sure not to introduce such stars as prototypes of the variable CP stars, we have determined the Mahalanobis distance of each star with respect to the groups of the $\beta$ Cephei stars and SPBs. We have retained only those stars which can clearly be distinguished from both other classes. This results in 21 prototype variable CP stars. A disadvantage of this selection of prototypes is that it will be difficult to recognise the nature of variable CP stars that fall in the SPB domain.

Classification is then performed in two steps. First we assign all 173 stars to one of the three classes. Secondly, we consider the Mahalanobis distance of each star with respect to the three classes. Stars with a large Mahalanobis distance are likely to be of another origin than the group they were classified into. A definite assignment to a group is then made by means of bivariate plots of $Y$ versus $X$ and of $P$ versus $|Z|$. Variable supergiants and Be stars, and eclipsing binaries are discriminated from the real members of the three classes on the basis of a large Mahalanobis distance and another position in the bivariate plots compared to the calibration stars. The results of our multivariate classification are the following: we find

– 4 new $\beta$ Cephei stars,
– 72 new SPBs,
– 34 new variable CP stars,
– 32 new supergiants with $\alpha$ Cyg-type variations,
– 7 new variable Be stars,
– 7 new eclipsing binaries,
– 17 objects for which no clear classification could be obtained.

We refer to the Hipparcos catalogue for the HD numbers and the classification of the objects for which both methods gave the same result, and mention here only these stars for which the multivariate analysis resulted in a different/additional classification compared to the first classification:

- HD 60559 & HD 62738: SPB instead of CP star,
- HD 63625 & HD 90872: CP star instead of SPB,
- HD 170938: CP star instead of $\alpha$ Cyg-type supergiant,
- HD 45953, HD 112409, HD 121190, HD 201912, HD 208727: SPB,
- HD 119159, HD 168183, HD 193536: $\alpha$ Cyg-type supergiant.

In view of the choice of our prototypes of variable CP type stars, it is not clear which classification is best for HD 60559, HD 62738, HD 63625, HD 90872, and HD 170938.

A first remarkable observation of our classification is that only 4 $\beta$ Cephei stars, i.e. short-period variables, were discovered, while 152 variables with a period of the order of days were found. This result not only shows that our observational view of the class of the $\beta$ Cephei stars is rather complete, but more importantly points out the extremely biased nature of earlier, ground-based photometric surveys towards short-period variability. A second striking result is the huge number of new SPBs. If we additionally consider the classification of the 94 stars for which no Geneva data are available, then we find a total of 103 new probable SPBs. This is almost a tenfold of the number of stars previously known to belong to this class of variables. Finally, despite many efforts in the literature to obtain a complete overview of microvariations in supergiants, we find a relatively large number of stars with apparently periodic $\alpha$ Cyg-type variations.

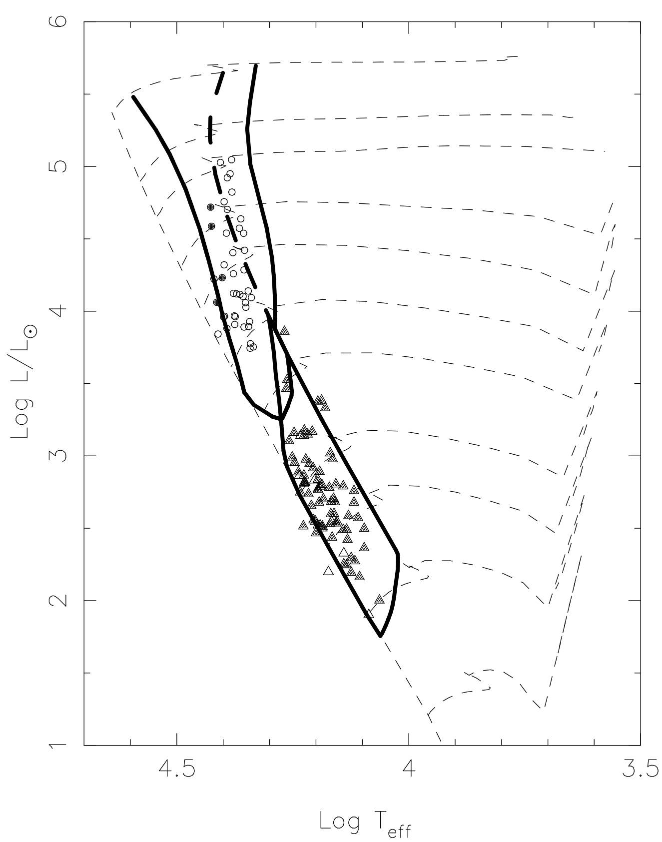


**Fig. 1.** Position of the $\beta$ Cephei stars and SPBs in the HR diagram (circles: $\beta$ Cephei stars, triangles: SPBs). The previously known variables are indicated by the open symbols while the variables discovered by Hipparcos are denoted by the filled symbols. The instability strips were calculated by Pamyatnykh (1997) and are based on OPAL G93/21 opacities for a composition $X, Z$ = .70, .02. The full lines are the calculated edges of the instability domain, while the dashed line is the TAMS. The evolutionary tracks by Schaller et al. (1992) are also shown

## 3. Position in the HR diagram

### *3.1. $\beta$ Cephei stars and slowly pulsating B stars*

From a theoretical point of view, it is interesting to know where the new pulsating stars are situated with respect to theoretically predicted instability domains. Pamyatnykh (1997) provided us with his most recent calculations of the instability strips based on the $\kappa$ mechanism of the $\beta$ Cephei stars and the SPBs (see Fig. 1). For a review on theoretical instability domains for B-type stars, see Moskalik (1995).

In order to place the Hipparcos $\beta$ Cephei stars and SPBs in a theoretical HR diagram, we need to determine their effective temperature and luminosity. North & Nicolet (1990) provide a calibration of the Geneva parameters $X$ and $Y$ as a function of $T_{\rm eff}$ and log $g$, which is accurate for main sequence stars with $T_{\rm eff} \geq$ 10000 K. Heynderickx et al. (1994) used this calibration to derive $T_{\rm eff}$, log $g$, and $M_{\rm bol}$ for known $\beta$ Cephei stars and SPBs. In order to compare the newly detected variables with the ones already known, we have placed the stars of the list given in Heynderickx et al. (1994) in the HR diagram (see Fig. 1, open symbols).

We have applied the same method to derive $T_{\rm eff}$ and log $L/L_\odot$ for the 4 $\beta$ Cephei stars and the 70 SPBs that resulted from both classification criteria and of which we have Geneva data at our disposal. We used the evolutionary tracks published by Schaller et al. (1992) to estimate the masses of the stars. It should be noted that we have only few Geneva observations available for some stars, so that the pulsation is not averaged out in the used $X, Y$ parameters. This results in fairly inaccurate temperatures and luminosities. In this respect, our position in the HR diagram should be considered as preliminary, and should be determined again once photometric follow-up data have been gathered. The results of our calculations for the new pulsating variables are presented in Fig. 1.

We find that the 4 new $\beta$ Cephei stars are situated in the blue part of the strip. The SPBs are homogeneously spread across the theoretically calculated strip in which g-mode pulsations are predicted. They almost fully cover the strip and confirm the instability calculations based on the $\kappa$ mechanism.

A final confirmation of the SPB nature could come from the detection of multiperiodicity in the candidate SPBs. For most of the stars, multiple periods are indicated by simply looking at the

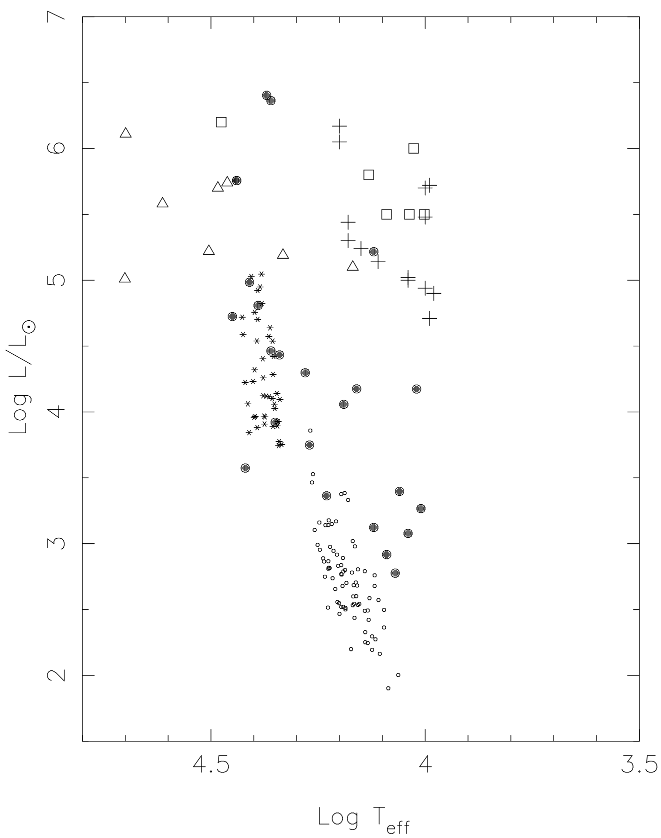


**Fig. 2.** Observational HR diagram for B-type variables. The different classes of variable stars are indicated by different symbols: ⋆: $\beta$ Cephei stars, ○: SPBs, •: variable supergiants discovered by Hipparcos, △: variable supergiants studied by Van Genderen (1985), +: variable B-type supergiants studied by Burki (1978), □: LBVs given by Lamers et al. (1997)

phase diagrams of the Hipparcos photometry constructed with the main period. We are currently checking the Hipparcos data to see if more than one period can be unambiguously identified from these data. Our results will be published in a separate paper.

Two SPBs deserve special attention: HD 85953 and HD 131120. These stars are situated in the common part of the instability domains of the $\beta$ Cephei stars and SPBs. Theory predicts the presence of both p- and g-modes in this part of the HR diagram. The simultaneous detection of these different kinds of modes has never been firmly established in a B-type star. Mathias & Waelkens (1995) have found indications that this might be the case in the star $\iota$ Her, but their data set was not sufficiently extensive to unambiguously derive frequencies. The two stars HD 85953 and HD 131120, together with some 12 other SPBs discovered by Hipparcos, have been included in the list of SPBs for photometric and spectroscopic monitoring on which we will report in a later paper (see also Aerts et al. 1997).

### *3.2. Supergiants*

As already mentioned, there is no instability mechanism known yet for the variable supergiants. Excitation possibilities were described by e.g. Lucy (1976), Gautschy (1992), and Kiriakidis et al. (1993), but none of these were confirmed by observational results. It is therefore important to situate the supergiants that show $\alpha$ Cyg-type variability with respect to pulsators of which we know the cause of the pulsations. The Hipparcos sample of B-type variable stars offers the possibility to do this.

A caveat to place the supergiants in the HR diagram is that their temperature and luminosity are difficult to determine, especially by means of photometric data alone. Nevertheless, we have tried to derive these quantities for the 29 supergiants with $\alpha$ Cyg-type variability that resulted from both used classification schemes described above. The temperature was derived from the Geneva X parameter by using the calibration curve for supergiants given by Cramer & Maeder (1979). We did not find an accurate calibration of log $g$ in terms of $X$ and/or $Y$. For this reason, we decided to extrapolate the values of log $g$ given in the grid by North & Nicolet (1990) based on the observed $X$ and $Y$ parameters. The luminosity was then derived in the same way as for the $\beta$ Cephei stars and the SPBs. For 5 of the variable supergiants, we find in this way an unrealistic luminosity of log L/L$_\odot \geq$ 7. These stars are not considered in the following.

The variable supergiants discovered by Hipparcos are plotted in the HR diagram in Fig. 2. The $\beta$ Cephei stars and SPBs plotted in Fig. 1 are also shown in the diagram. It can be noticed that the supergiants seem to prolonge the SPB and $\beta$ Cephei domain towards higher luminosities. This suggests at least a common cause of variability. The periods found for the Hipparcos supergiants range from 1.5 up to 24 days and suggest g-mode pulsations.

In order to confront the position of the Hipparcos variable supergiants with previously known variable supergiants we have gathered some data available in the literature. Burki (1978) lists 14 variable supergiants of spectral type B and their stellar parameters (periods range from 4.5 up to 65 days), while Van Genderen (1985) has studied the microvariations of 8 supergiants in detail and finds periods ranging from 0.9 up to 45 days. These supergiants are also plotted on Fig. 2. We have also added the 6 Luminous Blue Variables studied by Lamers et al. (1998). These LBVs show microvariations with periods of the order of a month and with different periods at different epochs. It is striking that the Hipparcos supergiants not only seem to extend the calculated instability strips of the $\beta$ Cephei stars and SPBs, but that they also link these kind of objects to previously known variable supergiants. We should not forget the fact that our temperature and luminosity calculations are not very accurate, but their uncertainty will probably not change the global position of the Hipparcos supergiants as a group with respect to the previously known variable supergiants on the one hand and the $\beta$ Cephei stars/SPBs on the other hand.

Pamyatnykh (1997) finds a continuous extension of high-degree gravity mode instability of the SPB domain towards large stellar masses in terms of the $\kappa$ mechanism. We refer to his paper for the exact location of the instability domain for these high-degree g-modes. Our findings with respect to the position in the HR diagram of the variable supergiants discovered by Hipparcos are fully compatible with Pamyatnykh's theoretical

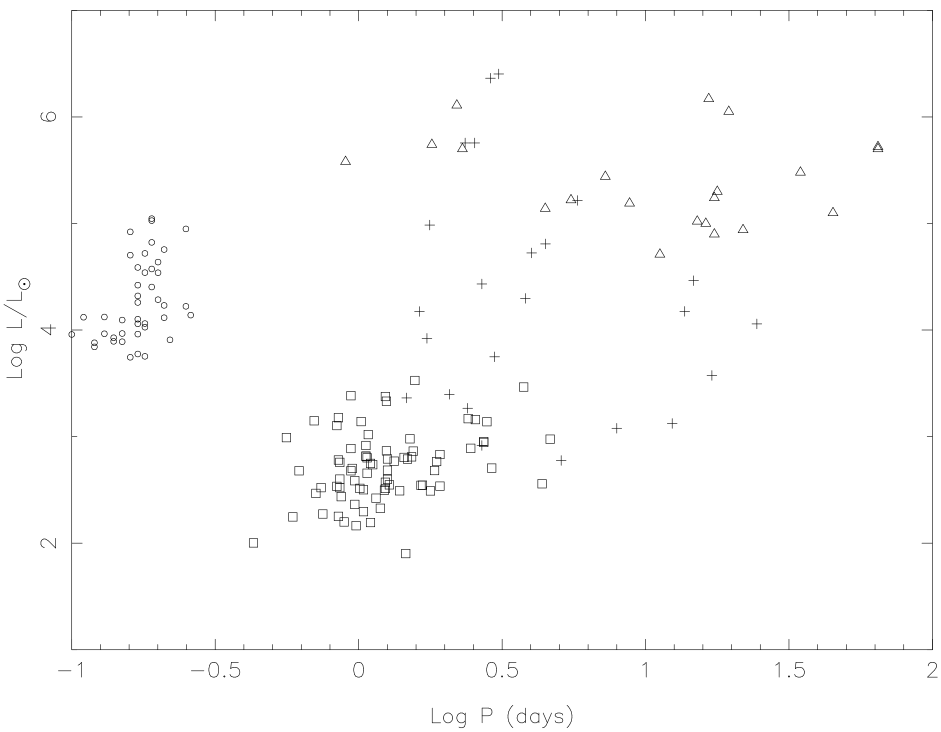


**Fig. 3.** The period – luminosity relation for B-type variables. The different classes of variable stars are indicated by different symbols: ○: $\beta$ Cephei stars, □: SPBs, +: variable supergiants discovered by Hipparcos, △: previously known variable supergiants (Burki 1978, Van Genderen 1985)

prediction. Moreover, the main period of the variation of the supergiants derived from the Hipparcos photometry also suggests an extension of the SPB instability domain. This can be seen on Fig. 3, where we plot the observed period – luminosity relation for variable B-type stars. In this diagram we find a clear distinction between p- and g-mode pulsations. The position of the supergiants suggests that they exhibit g-modes similar to those excited in SPBs.

On the other hand, it has been claimed in the literature that the instabilities that appear in massive variable supergiants have a pure mechanical origin and result in the excitation of so-called "strange modes" (e.g. Glatzel 1994). In this model, the pulsations are not caused by the classical $\kappa$ mechanism but are instead essentially independent of opacity. A sort of intermediate model was proposed by Kiriakidis et al. (1993), who found that an extension of the strange-mode instability domain of luminous stars towards the $\beta$ Cephei domain occurs. In their model, strange modes are caused by the heavy-element opacity bump.

It remains to be investigated which of the these instability mechanisms is the correct interpretation of the observed instabilities in supergiants. It may very well be that both the classical $\kappa$ mechanism and the strang-mode instability mechanism are at work, but that they are relevant for a different range in mass, i.e. Pamyatnykh's model for stars with masses below some $20\,M_{\odot}$, Glatzel's model for masses higher than $40\,M_{\odot}$, and Kiriakidis et al.'s (1993) model for the intermediate masses. A follow-up study of the variability of the Hipparcos sample of $\alpha$ Cyg-type supergiants should be able to result in important clues with respect to this yet unsolved problem. We have recently started such a follow-up study.

In order to allow a comparison with theoretical models, we list in Table 1 the HD number, the effective temperature, the luminosity, and the main period of the newly discovered variables of which we have Geneva data at our disposal. We recall that our temperature and luminosity calculations should be considered as preliminary. More accurate estimates can only be obtained by means of ground-based follow-up data.

## 4. Discussion

It is clear that the photometric experiment on board Hipparcos not only has revealed many new variables, but at the same time has pointed out that our view of variable stars was extremely biased towards short-period variations. As a result, a huge number of new SPBs, and to a lesser extent many variable CP stars and variable supergiants are discovered.

Despite the fact that our view of the $\beta$ Cephei stars seems rather complete, the few newly discovered ones deserve further attention. They are optically weak, and as a result have been selected for further photometric monitoring. As long as the physics behind the selection of the actual modes that are excited in these stars remains unknown, it is important to identify as many modes as possible in (new) members of the class.

The newly discovered SPBs are the most interesting targets for seismological purposes. Besides this, they all should be studied for the simple reason that we have for the first time a large, unbiased sample of SPBs with spectral types ranging from B 2 up to B 9, with periods that range from about one day up to some five days, and with a broad range of rotational velocities (ranging from 0 – 150 km/s). This sample allows us to constrain the theoretical instability strip, which was not possible so far.

**Table 1.** HD number and preliminary estimates of the effective temperature, the luminosity, and the main period for the newly discovered $\beta$ Cephei stars, SPBs, and $\alpha$ Cyg-type supergiants of which we have Geneva data at our disposal. P stands for the period, which is expressed in days

| $\beta$ Cephei stars | | | |
|---|---|---|---|
| Star | log $T_{\mathrm{eff}}$ | log $L/L_{\odot}$ | P (d) |
| HD71913 | 4.40 | 4.23 | 0.21 |
| HD109885 | 4.43 | 4.59 | 0.17 |
| HD165812 | 4.41 | 4.06 | 0.18 |
| HD180642 | 4.43 | 4.72 | 0.18 |

| $\alpha$ Cyg-type supergiants | | | |
|---|---|---|---|
| Star | log $T_{\mathrm{eff}}$ | log $L/L_{\odot}$ | P (d) |
| HD25914 | 4.12 | 3.12 | 12.39 |
| HD34085 | 4.06 | 3.40 | 2.07 |
| HD41117 | 4.42 | >7 | 2.87 |
| HD42087 | 4.28 | 4.30 | 3.81 |
| HD43384 | 4.16 | 4.18 | 13.70 |
| HD47240 | 4.35 | 3.92 | 1.73 |
| HD53138 | 4.19 | 4.06 | 24.44 |
| HD54764 | 4.34 | 4.43 | 2.69 |
| HD56847 | 4.09 | 2.92 | 2.69 |
| HD80558 | 4.12 | 5.22 | 5.79 |
| HD89767 | 4.44 | 5.76 | 2.35 |
| HD91024 | 4.01 | 3.27 | 2.40 |
| HD91943 | 4.42 | >7 | 6.44 |
| HD92964 | 4.36 | 4.46 | 14.71 |
| HD93619 | 4.41 | 4.99 | 1.77 |
| HD94367 | 4.04 | 3.08 | 7.94 |
| HD94909 | 4.42 | 3.57 | 17.03 |
| HD96880 | 4.42 | >7 | 2.47 |
| HD102997 | 4.27 | 3.75 | 2.98 |
| HD106343 | 4.36 | 6.36 | 2.88 |
| HD108659 | 4.07 | 2.78 | 5.08 |
| HD109867 | 4.39 | 4.81 | 4.48 |
| HD115363 | 4.61 | >7 | 3.08 |
| HD141318 | 4.23 | 3.36 | 1.47 |
| HD148688 | 4.46 | >7 | 6.33 |
| HD154043 | 4.37 | 6.40 | 3.08 |
| HD168183 | 4.45 | 4.72 | 4.01 |
| HD204172 | 4.44 | 5.76 | 2.54 |
| HD216927 | 4.02 | 4.17 | 1.63 |

| SPBs | | | | | | | |
|---|---|---|---|---|---|---|---|
| Star | log $T_{\mathrm{eff}}$ | log $L/L_{\odot}$ | P (d) | Star | log $T_{\mathrm{eff}}$ | log $L/L_{\odot}$ | P (d) |
| HD1976 | 4.21 | 2.92 | 1.06 | HD79416 | 4.16 | 2.71 | 2.91 |
| HD11462 | 4.12 | 2.27 | 0.75 | HD80573 | 4.17 | 2.78 | 0.85 |
| HD21071 | 4.17 | 2.53 | 0.84 | HD80859 | 4.20 | 2.52 | 0.74 |
| HD24587 | 4.16 | 2.60 | 0.86 | HD84809 | 4.21 | 2.56 | 4.36 |
| HD25558 | 4.23 | 2.81 | 1.53 | HD85012 | 4.13 | 2.59 | 0.97 |
| HD26326 | 4.20 | 2.77 | 1.87 | HD85953 | 4.26 | 3.47 | 3.76 |
| HD26739 | 4.20 | 2.77 | 1.33 | HD86659 | 4.23 | 2.82 | 1.06 |
| HD27742 | 4.12 | 2.68 | 0.62 | HD92287 | 4.22 | 2.98 | 4.65 |
| HD28114 | 4.17 | 3.02 | 1.08 | HD109026 | 4.21 | 2.95 | 2.73 |
| HD28475 | 4.19 | 2.79 | 1.48 | HD118285 | 4.10 | 2.36 | 0.97 |
| HD29376 | 4.22 | 2.82 | 1.06 | HD128585 | 4.23 | 3.18 | 0.85 |
| HD33331 | 4.13 | 2.42 | 1.15 | HD131120 | 4.26 | 3.53 | 1.57 |
| HD33402 | 4.23 | 2.75 | 1.10 | HD138003 | 4.16 | 2.98 | 1.51 |
| HD37055 | 4.23 | 2.52 | 1.01 | HD138764 | 4.17 | 2.69 | 1.26 |
| HD37104 | 4.19 | 2.52 | 0.86 | HD140873 | 4.17 | 2.44 | 0.87 |
| HD37332 | 4.20 | 2.47 | 0.71 | HD147394 | 4.18 | 3.33 | 1.25 |
| HD41814 | 4.24 | 2.89 | 0.94 | HD152511 | 4.19 | 3.38 | 0.94 |
| HD42927 | 4.25 | 3.16 | 2.55 | HD152635 | 4.16 | 2.54 | 1.92 |
| HD43654 | 4.12 | 2.30 | 1.04 | HD163254 | 4.26 | 3.10 | 0.84 |
| HD45953 | 4.06 | 2.00 | 0.43 | HD169978 | 4.12 | 2.76 | 0.86 |
| HD48424 | 4.22 | 2.74 | 1.12 | HD179588 | 4.10 | 2.50 | 1.23 |
| HD49188 | 4.21 | 2.66 | 1.07 | HD182255 | 4.17 | 2.60 | 1.26 |
| HD52057 | 4.12 | 2.19 | 1.10 | HD183133 | 4.23 | 3.14 | 1.02 |
| HD53921 | 4.15 | 2.54 | 1.65 | HD191295 | 4.13 | 2.49 | 1.39 |
| HD55522 | 4.25 | 2.95 | 2.73 | HD205879 | 4.11 | 2.16 | 0.98 |
| HD55718 | 4.22 | 3.15 | 0.70 | HD206540 | 4.16 | 2.81 | 1.44 |
| HD56613 | 4.13 | 2.25 | 0.59 | HD208057 | 4.23 | 2.87 | 1.25 |
| HD59215 | 4.19 | 2.68 | 0.94 | HD215573 | 4.16 | 2.68 | 1.84 |
| HD63251 | 4.14 | 2.79 | 1.26 | HD222555 | 4.14 | 2.49 | 1.78 |
| HD64503 | 4.25 | 2.99 | 0.56 | | | | |
| HD65074 | 4.19 | 2.50 | 1.04 | | | | |
| HD66503 | 4.14 | 2.25 | 0.85 | | | | |
| HD67531 | 4.11 | 2.57 | 1.24 | | | | |
| HD69144 | 4.21 | 3.17 | 2.41 | | | | |
| HD73654 | 4.19 | 2.89 | 2.46 | | | | |
| HD76640 | 4.18 | 2.70 | 0.95 | | | | |
| HD78405 | 4.20 | 3.38 | 1.24 | | | | |
| HD79039 | 4.19 | 2.80 | 1.07 | | | | |

Many of them are sufficiently bright to study their pulsations by means of line-profile variations. The latter are best suited for identification of the modes and to determine the other velocity parameters. A disadvantage is that long-term monitoring is required to obtain meaningful results. We have selected the 15 brightest stars among the Hipparcos SPBs for further photometric and spectroscopic monitoring.

Further study of the unbiased group of B-type supergiants could reveal valuable clues about the structure and evolution of massive early-type stars. Our sample of supergiants contains some 30 target stars, with spectral types ranging from B0 up to B9 and with periods ranging from a few hours up to several days and a few weeks. A search in the literature has shown that hardly any of the targets has been studied in detail. Our plan is first of all to more accurately place the selected supergiants in the HR diagram on the basis of photometry and high-resolution spectroscopy. This, together with the analysis of their lightcurves, will hopefully lead to a decision on the origin of their instabilities.

## References

Aerts, C. De Cat, P., Waelkens, C., In *S185: New Eyes to See Inside the Sun and Stars: Pushing the Limits of Helio- and Asteroseismology with New Observations from Ground and from Space*, 23rd General Assembly of the International Astronomical Union, Kluwer Academic Publishers, in press

Burki, G., 1978, A&A 65, 357
Catalano, F.A., Renson, P., 1997, A&AS 121, 57
Chapellier, E., Sadsaoud, J.C., Valtier, J.C. et al., 1996, A&A 307, 91
Cramer, N., Maeder, A., 1979, A&A 78, 305
Dziembowski, W.A., Pamyatnykh, A.A., 1993, MNRAS 262, 204
Dziembowski, W.A., Moskalik, P., Pamyatnykh, A.A., 1993, MNRAS 265, 588
Eyer, L., 1997, PhD Thesis, Observatoire de Genève, Switzerland
Eyer, L., Grenon, M., Falin, J.-L., Froeschlé, M., Mignard, F., 1994, Solar Physics 152, 91
Gautschy, A., 1992, MNRAS 259, 82
Gautschy, A., Saio, H., 1993, MNRAS 262, 213
Glatzel, W., 1994, MNRAS 271, 66
Golay, M., 1980, Vistas in Astronomy 24, 141
Grenon, M., 1997, In *Variable Stars: New Frontiers*, Proceedings of the 86th AAVSO Spring Meeting, PASP Conference Series, in press
Heynderickx, D., Waelkens, C., Smeyers, P., 1994, A&AS 105, 447
Kiriakidis, M., Fricke, K.J., Glatzel, W., 1993, MNRAS 264, 50
Lamers, H.J.G.L.M., Bastiaense, M., Aerts, C., Spoon, H., 1997, A&A, submitted
Lucy, L.B., 1976, ApJ 206, 499
Mathias, P., Waelkens, C., 1995, A&A 300, 200
Murtagh, F., Heck, A., 1987, Multivariate Data Analysis, Kluwer Academic Publishers
Moskalik, P., 1995, In *Astrophysical Applications of Stellar Pulsation*, Eds. R.S. Stobie & P.A. Whitelock, PASP Conference Series, Vol. 83, 44
North, P., Nicolet, B., 1990, A&A 228, 78
North, P., Paltani, S., 1994, A&A 288, 155
Pamyatnykh, A.A., 1997, In *A Half Century of Stellar Pulsation Interpretations*, PASP Conference Series, in press
SAS/ User's Guide, 1990, Version 6, Volume 1-2, SAS Institute Inc., Cary, NC
Schaller, G., Schaerer, G., Meynet, G., Maeder, A., 1992, A&AS 96, 269
Van Genderen, A.M., 1985, A&A 151, 349
Waelkens, C., 1991, A&A 246, 468
Waelkens, C., 1994, A&A 311, 873

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