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UV flux distributions of γ Doradus stars*

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ABSTRACT

Context. It seems that the recently identified class of pulsating stars, the γ Dor type-variables, includes objects with different metal abundances and a large percentage of binaries.
Aims. We looked for indicators of metal abundance peculiarities and stellar binarity in a sample of 40 confirmed γ Dor stars.
Methods. Absolute magnitudes from Hipparcos parallaxes and UV magnitudes, from the S2/S68 experiment on board the TD1 satellite, are retrieved from databases and compared with predicted values. A set of non variable normal stars is used to check the consistency of this analysis and also serve as reference stars.
Results. Twenty-nine stars of the γ Dor star sample, which is 73% of it, are discovered having abnormal UV fluxes constantly showing UV flux excesses compared to those computed with the atmospheric parameters ($T_{\rm eff}$, $\log g$, and metallicity) determined from calibration of the *uvbyβ* indices. The reason for this UV excess of flux at 196.5 nm and at 236.5 nm, which was previously known only for HD 209295, cannot be ascribed to binarity alone. An extra source of UV flux or less UV absorption – yet unknown – must be present.

Key words. stars: atmospheres – stars: binaries: spectroscopic – stars: variables: general – stars: peculiar

1. Introduction

In 1993, Krisciunas (1993) proposed a new class of variable stars located on the cool side of the Cepheids instability strip. He suggested that these stars are probably pulsating in non-radial g-modes. Soon after that Balona et al. (1994) designated this class as γ Dor from the name of the most studied object. The definition of this class and the description of the main photometric properties is found in Kaye et al. (1999a).

High-dispersion spectroscopy combined with precise photometry have been used for the identification of new members (Henry & Fekel 2003; Fekel et al. 2003; Henry et al. 2005). Low-amplitude radial-velocity variations, line profile variations, and asymmetries have been observed in their spectra (Henry & Fekel 2003; Mathias et al. 2004), giving rise to discussions of their origin: the binarity versus shell hypothesis. From analysis of high-resolution spectroscopy of 34 γ Dor candidates, Fekel et al. (2003) concluded that the percentage of binary systems in their sample may be as high as 74%.

Specific individual properties of γ Dor stars have also been identified for a few objects: HD 218396 classified both as a γ Dor and as λ Boo star (Gray & Kaye 1999), HD 8801 classified as an Am star and was pulsating with both γ Dor and δ Sct frequencies (Henry & Fekel 2005), and HD 209295 with an abnormal UV flux distribution (Handler et al. 2002).

In this paper we focus on the search for spectral peculiarities and their frequency among the confirmed members of the γ Dor class. We accomplish this by analysing their UV magnitudes (in the range 150 nm−280 nm) as measured with the S2/68 experiment on board the TD1 satellite. These UV data are compared to a set of computed magnitudes obtained from Kurucz (1993) grids of theoretical fluxes. To serve as "reference stars", a sample of normal stars was defined to which the same analysis is applied as a check. These reference stars are non-variable stars, with similar atmospheric parameters, including metallicities, to those of the γ Dor star sample. To perform these comparisons, we determined the atmospheric parameters $T_{\rm eff}$, $\log g$, and metallicity from calibrations of photometric indices.

We have correlated the spectral peculiarities detected in the UV for the γ Dor stars to other properties of these stars, in particular their binarity. The knowledge of binaries is important because the presence of a close companion may produce, for example, tidal effects that may have an impact on the stellar pulsation. The binary detection is also discussed by comparing the absolute magnitudes derived from parallaxes with those calculated from the calibration of the *uvbyβ* photometric indices.

2. The samples of γ Dor and reference stars

Several papers have dealt with the detection of stars belonging to the γ Dor class in past years and regularly new lists of suspected or confirmed members have appeared, including a web site by Handler (2002). As a sample of confirmed γ Dor stars we retained those selected by Henry et al. (2005) in their Table 6, which consists of 54 stars.

The primary source of observational data are the UV fluxes measured by the S2/68 experiment on board the TD1 satellite. The corrected version of the Thompson et al. Catalogue of Stellar Ultraviolet Fluxes (1978) has been used to compute the

* Tables 1–3 are only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/472/241

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UV magnitudes and their errors in the three spectral bands centered at 274.0, 236.5, 196.5, and 156.5 nm. These UV magnitudes normalized to *V* are respectively noted as m27, m23, m19, and m15.

TD1 fluxes are available for only 42 γ Dor stars, HD 99329 has low-quality data (error higher than 2 mag at m15), which precludes any discussion. The Am star HD 8801 is also excluded, knowing already that its UV flux distribution is that of an Am star (Jaschek et al. 1980). The number of stars discussed here is thus 40 from the list of Henry et al. (2005). Table 1 (available electronically) gives the list of these stars: in Col. 11 the remarks from Henry et al. (2005) are complemented by detecting binarity from the Hipparcos Catalogue (ESA 1997), the Washington Visual Double Star Catalogue (WDS) (Worley & Douglass 1997), and the Fourth catalogue of interferometric measurements (Hartkopf et al. 2003).

A sample of reference stars in the same range of temperature and gravity was extracted from the Cayrel et al. (2001) catalogue and from the Gray & Garrison paper (1989) for comparison purposes. We applied the same analysis to the UV data of this set of reference stars. The data for these 41 stars are given in Table 2 (available electronically). There are no known binaries in the set of reference stars chosen.

3. Atmospheric parameters from photometry

3.1. Data and methods

The atmospheric parameters $T_{\rm eff}$, $\log g$ are computed by coupling the photometric colour indices of *uvbyβ* photometry with the Moon & Dworetsky (1985) (MD) calibration and those of Geneva photometry with the Künzli et al. (1997) calibration. The *uvbyβ* colours are available from the Hauck & Mermilliod Catalogue (1998) for all but two stars: HD 65526, for which the colours are given by Handler (1999), and HD 224945, for which the colours are taken from Mantegazza et al. (1994). For the stars without β index the computed $T_{\rm eff}$ and $\log g$ are valid only if the stars are unreddened (Moon 1985). The values of the Geneva photometry are retrieved from the General Catalogue of Photometric Data of the Geneva Observatory by Burki et al. (`http://www.unige.ch/sciences`) and are available for only 13 stars.

The values of the atmospheric parameters noted ($T_{\rm eff}$ MD, $\log g$ MD) and ($T_{\rm eff}$ Gen, $\log g$ Gen) when defined respectively from the Moon & Dworetsky (1985) (MD) and the Künzli et al. (1997) calibrations (Gen) are given in Tables 1 (Cols. 4 to 7) and Table 2 (Cols. 3 to 6). The reddening $E(b-y)$ (Col. 3) was computed with the program by Moon (1985) and used to deredden the Geneva photometric values according to the relation: $E(B2-V1) = 1.146\,E(b-y)$. From the calibration of the Geneva photometry the metallicity [M/H] is also derived (Table 1 Col. 8, Table 2 Col. 7). These values are valid only if the stars are single. Table 1 shows that many γ Dor stars are SB2 or VB (visual binary) with a likely contamination of the photometric measurements by the companion. In spite of this, these parameters have been computed for all the stars to investigate for possible inconsistencies.

The γ Dor stars pulsations induce photometric variability with periods ranging from 8 h to about 3 days. The measured brightness variations are small, of the order of 0.01 mag, as shown in papers displaying *uvbyβ* observations (Zerbi et al. 1997; Henry & Fekel 2002, 2005), and produce negligible effects on $T_{\rm eff}$, $\log g$, and metallicity values.

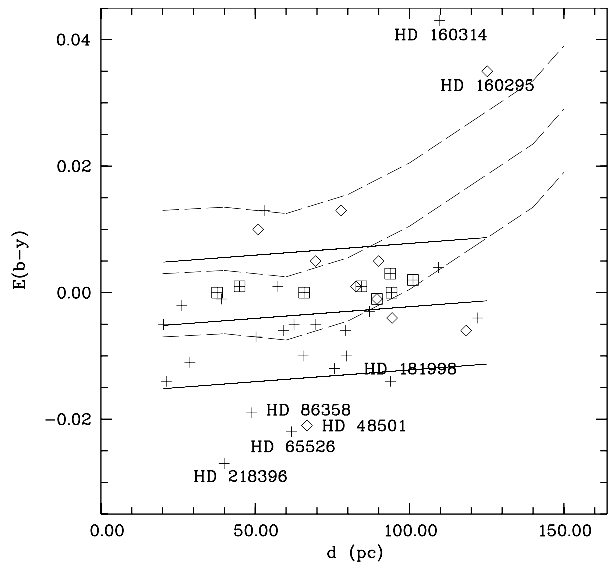

Fig. 1. Extinction $E(b-y)$ compared to the distance. The open lozenges designate the SB2 or the VB stars whose photometry is affected by the companion (Table 1 Col. 9). The open squares represent the stars for which no β-index is available. The solid lines are the linear regression of the data and the displacements of ±0.01 mag; the dashed lines are the mean extinction computed by Vergely et al. (1998) for normal stars and the displacements of ±0.01 mag corresponding to the error on this determination.

3.2. Colour excess

The colour excess $E(b-y)$ (Col. 3, Table 1; Col. 2, Table 2) has been computed using the program of Moon (1985). The value $E(b-y)$, which is affected by observational and calibration errors of the order of 0.01 mag, not only measures the interstellar reddening, but may also indicate an anomaly in the stellar flux distribution.

Figure 1 displays the values of $E(b-y)$ versus the distances of the γ Dor stars obtained from the Hipparcos experiment. We note a trend toward negative extinction for the stars with $d < 100$ pc. We computed a mean extinction curve, which is compared to that of Vergely et al. (1998), in Fig. 1, which is done by applying the same calibration to compute $E(b-y)$, but on a much larger sample of stars in the same range of $T_{\rm eff}$ and $\log g$.

We note generally good agreement of our curve with that of Vergely et al. but a small trend toward negative extinction for γ Dor stars with $d < 100$ pc. In Fig. 1 the stars with the more negative values of $E(b-y)$ are indicated. We checked that this trend is not present among the set of reference stars. This "blueing" effect means that the visual flux distribution of these 5 stars does not reproduce that of the normal stars used to calibrate the *uvbyβ* colours.

Two stars have a higher reddening than expected for their distance: HD 160295 and HD 160314: $E(b-y) = 0.035$ and 0.043, respectively. This high extinction is confirmed by the computation by an independent method, i.e. through its estimation from maps of dust IR emission (Schlegel et al. 1998; revised by Bonifacio et al. 2000). From this we conclude that the high reddening is due to their galactic location. The galactic longitudes of these two objects are 26.90° and 26.35°, which is in the longitude interval of 20°−40° where the extinction is stronger (Chen et al. 1998). The alternative hypothesis is an inconsistency of the β index with the other colour indices, since β has the greatest weight in the calibration procedure (Crawford 1979). But in that case we would have had an inconsistency with the $T_{\rm eff}$, $\log g$ derived from other methods, which is not the case, as can be seen from Table 1, in particular for HD 160314.

3.3. $T_{\rm eff}$, $\log g$, and metallicity

Eight γ Dor stars have no measurements of the β index. However, they are at distances that imply a very low reddening, and we can safely assume that the determination of their atmospheric parameters is valid, based on the hypothesis of no significant reddening.

From the 13 stars with both a $T_{\rm eff}$ determined with Strömgren (MD calibration) and Geneva (Künzli et al., calibration) photometry, we note good agreement between these determinations. The average of the differences between these two $T_{\rm eff}$ ($T_{\rm eff}$ MD minus $T_{\rm eff}$ Gen) is $\langle -36 \rangle$ K with a standard deviation of 90 K. Similar values are obtained from the set of reference stars: an average of $\langle 91 \rangle$ K for the difference with a standard deviation of 88 K.

Another comparison is performed by using the $T_{\rm eff}$ determined from the Alonso et al. (1996) calibration of the Strömgren photometry and given in Nordström et al. (2004) for twenty-two γ Dor stars. We note that these $T_{\rm eff}$ are systematically higher than those from MD calibration with an average of $\langle -85 \rangle$ K (standard deviation of 107 K) for the differences. Similar values are obtained for 20 reference stars: $\langle -129 \rangle$ K (standard deviation of 86 K). The $T_{\rm eff}$ determination used to compute the theoretical UV flux distribution is that given by MD calibration.

The comparison between the gravity ($\log g$) derived from $uvby\beta$ and Geneva colours shows a systematic trend for the 13 stars in common: the $\log g$ values determined using the Geneva system are systematically higher than those determined from the Strömgren system. The average of the difference between these two $\log g$ ($\log g$ MD minus $\log g$ Gen) is $\langle -0.40 \rangle$ dex with a standard deviation of 0.14 dex. For the set of 41 reference stars, these values are $\langle -0.23 \rangle$ (standard deviation of 0.11). Only the analysis of the line spectrum could help to disentangle this difference in $\log g$. We recall that the UV flux distribution is only very slightly affected by the gravity values for dwarf stars in the effective temperature range corresponding to that of the γ Dor stars.

In this range of $T_{\rm eff}$, the metallicity can be estimated from the calibrations of the Geneva colours ([M/H]) and from the Strömgren colours ([Fe/H]) using the relation from Schuster & Nissen (1989), applicable to the stars with $(b - y) \geq 0.22$. The [Fe/H] values are taken from Nordström et al. (2004). The number of γ Dor stars having a measurement in both systems is only 7 stars. The average of the difference ([M/H]) − [Fe/H]) is $\langle -0.07 \rangle$ (standard deviation 0.14), with the exception of HD 32537, which has a solar metallicity from Geneva photometry, but a small metal deficiency ([Fe/H] = −0.36) from the Strömgren system. From abundance analysis, Takeda (1984) derived a metallicity of −0.30 for this star. We also compared these two determinations for the set of reference stars. The average value of the difference for the 20 stars with both determinations is $\langle -0.03 \rangle$ (standard deviation 0.12), so no systematic effect is detected between these two determinations of the metallicity.

4. UV magnitudes

The UV magnitudes normalized to V-mag, noted m27, m23, m19, and m15, have been de-reddened according to the UV extinction $A(\lambda)/E(B - V)$ given by Thompson et al. (1978), where $E(B - V) = 1.35\ E(b - y)$. For the stars with negative values of $E(b - y)$ no de-reddening correction has been applied. The UV magnitudes are compared to the theoretical ones computed from interpolation into the grid of Kurucz (1993) fluxes, the $T_{\rm eff}$ and $\log g$ being those determined from the MD calibration of the $uvby\beta$ colours. The metallicity values adopted are those given by the calibration of the Geneva photometry and, if not available, those from the $uvby\beta$ photometry are retained. These choices are based on the analysis in the previous section.

First, we compared the UV magnitudes of the sample of reference stars to the computed ones. The differences between the observed magnitudes and the computed ones are compared to the observational errors ($\langle \sigma \rangle$), for each UV mag.

The mean value of the errors on each magnitude are:

- m15 : $\langle 0.49 \rangle$ mag with a standard deviation of 0.41 mag.
- m19 : $\langle 0.08 \rangle$ mag with a standard deviation of 0.05 mag.
- m23 : $\langle 0.05 \rangle$ mag with a standard deviation of 0.02 mag.
- m27 : $\langle 0.015 \rangle$ mag with a standard deviation of 0.01 mag.

For 34 stars (83%) of the sample of reference stars, this difference is less than 3σ. For 12 of these stars we had to adjust the metallicity slightly, by less than 0.15 dex, to achieve such a fit. In the case of small observational error (less than 0.02 mag), we release this constraint up to 5σ.

The remaining 7 stars (17%) of the sample have discordant results for m19 or m23. One star has a m23 mag that is too low by 0.2 mag compared to the computed one, and 4 stars have an m19 mag that is too high by more than 0.4 mag. For the other 2 stars, both m19 and m23 are too high by more than 0.3 mag compared to the computations.

For the coolest, as well as for the faintest, stars the observed m15 is generally overestimated, the late A-type and early F-type stars having an abrupt flux drop at wavelength lower than 180 nm. We gave a low weight to the comparisons in this band, which has a large error.

This demonstrates that there is no systematic shift between these UV observations and the computations of the UV magnitudes from Kurucz grids of fluxes.

Then we, similarly, analysed the behaviour of the γ Dor stars.

The mean value of the errors on each magnitude for the γ Dor stars are:

- m15 : $\langle 1.0 \rangle$ mag with a standard deviation of 1.8 mag.
- m19 : $\langle 0.17 \rangle$ mag with a standard deviation of 0.12 mag.
- m23 : $\langle 0.09 \rangle$ mag with a standard deviation of 0.05 mag.
- m27 : $\langle 0.04 \rangle$ mag with a standard deviation of 0.02 mag.

The astonishing result is the variety of UV flux distribution among the γ Dor stars. We emphasise that a difference in $\log g$ of 0.25 dex will not significantly change the results. The differences in the UV flux distribution, corresponding to such a difference in gravity is less than the observational errors. We describe these particularities briefly.

Only 11 stars (27% of the γ Dor star sample) have a good fit between the observed and the computed magnitudes, as defined for the reference-star sample. These stars are HD 27290, HD 32537, HD 48501, HD 55892, HD 105085, HD 112429, HD 166233, HD 195068, HD 206043, HD 213617, and HD 218396. Among this group, 3 stars have no metallicity photometrically determined, but it was estimated in order to have a good fit; these values are in the range 0.00–0.10 dex.

A second group of 9 stars (22% of the γ Dor star sample) (HD 62454, HD 65526, HD 86371, HD 108100, HD 113867, HD 124248, HD 155154, HD 224638, and HD 224945) is characterised by a flat flux distribution between

196.5 nm−274 nm: the three magnitudes m19, m23, and m27 have the same value, taking the error bars into account. No fit at all can be achieved between the observational data and the computations. We note that the value of the m19 mag corresponds to that of the star $T_{\rm eff}$ and $\log g$ but with a metallicity of −0.5 dex. Four stars of this group (HD 62454, HD 86371, HD 108100, and HD 113867) are known to be SB2 (Table 1).

The 7 stars (17% of the γ Dor star sample) of a third group (HD 12901, HD 17310, HD 49015, HD 86358, HD 160295, HD 175337, and HD 181998) are characterised by a m27 mag smaller than the m23 one, which is the opposite of the flux distribution in that range of temperature. All, but one, have a value of [Fe/H]. The fit of m19 and m23 mag is never achieved, strange enough, only the m27 mag fits the computations. For a good fit of m19 and m23 mag a much lower value of the metallicity would be necessary, of the order of −0.5 dex, but in that case there is no fit for the m27 mag. For HD 181998, for which no metallicity is computed, the m27 mag is fitted by a metallicity of −0.5, but m19 and m20 are higher by 1 mag, which corresponds to a much lower metallicity. Two stars of this group (HD 86358 and HD 160295) are known to be SB2 system.

Five stars (12% of the γ Dor star sample) (HD 115466, HD 152896, HD 160314, HD 165645, and HD 221866) of a fourth group have an opposite behaviour to the previous γ Dor star group: the m19 mag is higher than the m23 one, which is the opposite of a normal flux distribution in this range of temperature. The m23 and m27 mag can be fitted by the theoretical magnitudes computed with the photometrically-derived metallicity for HD 115466 and HD 160314. For the best fit for these magnitudes, the metallicity of HD 221866 can be estimated to be in the range 0.0−0.15 dex. For HD 152896 and HD 165645, no fit at all can be obtained whatever the metallicity value adopted.

A fifth group consists of 5 stars (12% of the γ Dor star sample) (HD 48271, HD 64729, HD 68192, HD 69715, and HD 209295), for which no fit can be obtained, their fluxes being too distorted: the magnitudes are: m19 > m23 > m27. Nevertheless their m27 mag alone can be fitted – except for HD 48271 – by the computed ones (Fig. 2).

The last group consists of 3 stars (7% of the γ Dor star sample) (HD 164615, HD 167858, and HD 207223). Only their m27 mag is fitted with the computed value, but the m19 mag is too high by 0.75 mag.

As for the reference stars, we have not considered in this discussion the behaviour of the m15 mag compared to the theoretical magnitude values. The error bars of these observations are too large at this wavelength for most of the stars.

The possibility of ascribing the peculiar UV behaviour of the γ Dor stars to TD1 systematic errors appears remote. The reliability of these data has been tested not only with the set of reference stars presented here but also by the good agreement between TD1 data and the corresponding measures made from IUE archival data for the 7 γ Dor stars with IUE observations.

5. Absolute magnitudes

The absolute magnitude M_V is one of the parameters that may be used to determine possible binaries. M_V can be derived by two independent methods:

- The direct determination, M_V-Hipp, using Hipparcos parallaxes;
- The photometrically derived M_V-MD using the calibrations of the *uvbyβ* photometry adopted by Moon (1985).

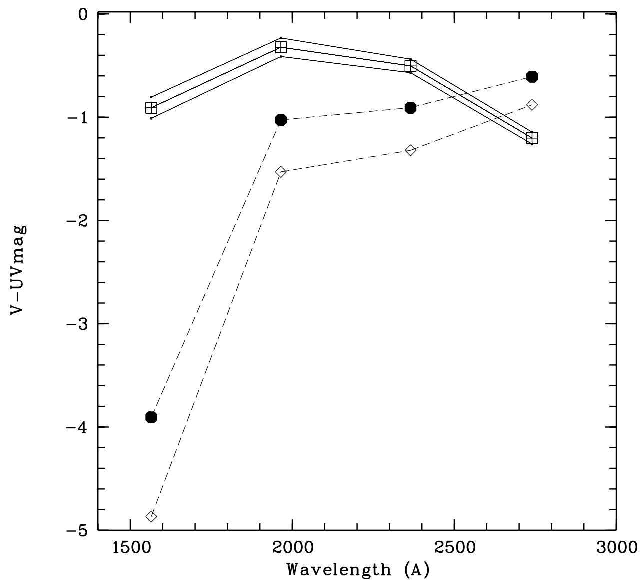

Fig. 2. UV magnitudes of HD 48271 in each TD1 spectral band are shown. A solid line links these measurements and the upper and lower lines represent the observational errors. The computed UV mag values for $T_{\rm eff}$ = 7180 K, $\log g$ = 4.29 and the two abundances [M/H] = 0.0 (lozenge) and [M/H] = −0.5 (filled circle) are linked with a dashed line.

To determine the M_V-Hipp, we use the V-mag from the Johnson photometry given in the Hipparcos Catalogue (ESA 1997) and note that the V-mag values given in Table 6 of Henry et al. (2005) has been corrected by the authors, for some stars, to take their binarity into account. The errors in M_V-Hipp values mainly arise from the uncertainties in the parallax measurements as given by:

$$\sigma(M_V\text{-Hipp}) = ((\sigma(V))^2 + (2.17\sigma(\pi)/\pi)^2 + (\sigma(A_V)^2)^{0.5}.$$

Constant values have been adopted for $\sigma(V)$ (0.01) and for $\sigma(A_V)$ (0.05). The average of the $\sigma(M_V$-Hipp) values is ⟨0.17⟩ mag (standard deviation 0.08 mag). We have not applied the Lutz-Kelker correction (Lutz & Kelker 1973), because the relative uncertainties of the parallax measures are small with ⟨−0.07⟩ (standard deviation of 0.04).

There are two main sources of errors of M_V-MD, one arising from observational uncertainties and the other from the intrinsic error of the calibration itself, resulting in systematic uncertainties of the absolute magnitude of the stars used as standards. We estimated each of these errors.

The absolute magnitude is obtained from a calibration involving Strömgren β and c_1 indices. The quadratic sum of the average of the errors on these parameters, according to the relation for the calibration involved, produces a mean value of 0.15 mag for the error on M_V-MD.

Concerning the error resulting from the standard stars used for the calibration, we (Gerbaldi et al. 2003) compared this MD calibration to that by Domingo & Figueras (1999) using another source for the values of the absolute magnitude to calibrate the *uvbyβ* photometric indices. The standard deviation of the difference between the values computed with these two calibrations is 0.15 mag for an average value of the difference of 0.006 mag. We are aware that this comparison does not explore all the possible sources of errors on M_V-MD, in particular the systematic errors resulting for example from the definition of the ZAMS.

The comparison between M_V-Hipp and M_V-MD may reveal binaries with comparably bright components in this domain

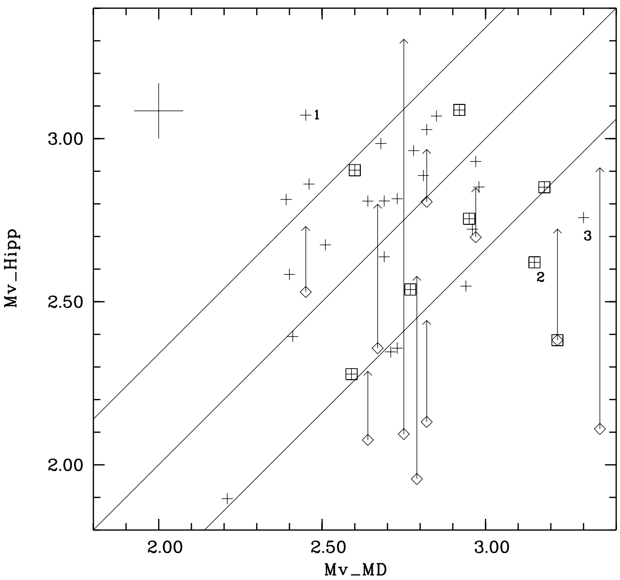

Fig. 3. The absolute magnitude from Hipparcos parallaxes, M_V-Hipp, are plotted versus the absolute magnitude M_V-MD derived with the Moon (1985) calibration. In the upper left corner, the error bars are shown corresponding to $\sigma(M_V\text{-Hipp}) = 0.17$ and $\sigma(M_V\text{-MD}) = 0.15$. The solid lines are the first bisector and the displacements of $\pm 2\sigma$; the symbols for the stars are the same as in Fig. 1. The vertical arrows represent the positions of the binaries when the V magnitude, corrected for the binarity, is taken into account in the computation of M_V-Hipp. The labels are: 1 = HD 224945, 2 = HD 48271, and 3 = HD 213617, which are discussed in the text.

of $T_{\rm eff}$ (Suchkov & McMaster 1999), because the M_V-Hipp is directly affected by binarity. M_V-MD is based on the intensity of δc_1, which is a luminosity criterion in this domain of temperature and less affected by binarity than V-mag. Figure 3 displays the relation between these two determinations, with the values of M_V-MD and M_V-Hipp given Table 1 (Cols. 9 and 10).

Table 3 gives the V-mag of both components for the 10 SB2 or close visual binary γ Dor stars. Figure 3 also plots the new positions for these 10 stars when their V-mag values, corrected for the binarity, are used to compute M_V-Hipp. We note that the agreement between the two M_V determinations is very much improved; the stars are close to the first bisector, except HD 221866 for which there is a controversy (see note Table 3). The corrected position of this star is above the first bisector, since its corrected M_V-Hipp value is too high compared to that of M_V-MD.

There are 3 stars, a priori single stars, but with discrepant values between their absolute magnitudes. For HD 224945 = 1 the computed M_V-MD is brighter than the M_V-Hipp; this star is not yet included in the homogenized Hauck & Mermilliod catalogue, so a possible systematic shift of colours may affect the M_V-MD. The two other stars, HD 48271 = 2 and HD 213617 = 3, are suspected to be undetected binaries according to the above discussion.

6. Discussion and conclusion

The ultraviolet fluxes, as measured by the S2/68 experiment on board the TD1 satellite, for the sample of 40 confirmed γ Dor stars (Henry et al. 2005) were compared to theoretical ones computed from the grids of Kurucz (1993) fluxes with their atmospheric parameters, $T_{\rm eff}$, $\log g$, and metallicity, derived from the photometry in the visible.

The striking result is that only 27% (11 stars) of the γ Dor star sample have an observed UV flux that fits the computed one. For 73% (29 stars) of this sample, their observed UV flux is totally different from what is expected from theoretically computed UV magnitudes. This conclusion was reached after a careful check of the validity of these UV observations through the sample of reference stars.

In Sect. 4 we have grouped these 29 stars according to the shape of their flux distribution in the UV. We stress that all of them share the following properties:

- the flux at 274.0 nm as measured by the m27 mag, normalized to the V-mag, is fitted by the theoretical relation at a level of 3σ, (σ being the observational error on m27 mag). In the case of small observational errors (less than 0.02 mag), we released this constraint up to 5σ.
- the magnitudes at 196.5 nm (m19) and 236.5 nm (m23) present an excess of UV flux compared to the theoretical values. The range of these UV excesses can reach 1 mag.

The primary question that arises from this study is how to produce higher UV fluxes at 196.5 nm and 236.5 nm for these γ Dor stars? We have mentioned in Sect. 4 that lowering the metallicity by 0.5 dex can reproduce this higher intensity, but a much lower metallicity would be detected in the visible, which is not the case. Another way to increase the UV flux could be the presence of a hotter companion in a still undetected binary system, but this would affect the visual photometry, too, in particular the β index of the Strömgren photometry. Nevertheless the presence of a companion may produce a distorted UV flux. Table 3 give the list of binaries among the sample of γ Dor stars whose V-magnitude is affected by the binarity. We note that all these stars have anomalous UV flux distributions except for HD 105085 and HD 166233. The binarity could produce an anomalous flux if each component is nearly similar, this is not the only cause. We give two examples. HD 86371 is an SB2 with two similar components (Tables 1, 3), so the normalized flux distribution should be comparable to that of a single star and not be significantly modified. In fact the observed flux is higher than expected at 196.5 nm and at 236.5 nm as if an extra hotter source is also present in the UV, slightly hotter, by roughly 600 K more than the components of the SB2 system. But why is this not detected in the visible from the photometric indices? For HD 86358 the V-mag values of each component are 6.87 and 7.77 mag, so this cannot produce the observed excess of UV flux close to 1 mag at 236.5 nm and no effect on the flux at 196.5 nm and at 274.0 nm.

We also searched for yet undetected binaries with companions sufficiently bright to affect the observed spectrum and energy distribution. This was accomplished through the comparison of absolute visual magnitudes derived from Hipparcos parallaxes and from Strömgren photometry (Sect. 5). The two stars γ Dor stars HD 48271 and HD 213617 are binary candidates according to their characteristics as shown in Fig. 3. The UV flux distribution is anomalous for HD 48271, while the UV magnitudes of HD 213617 agree with the theoretical values. We note that HD 224945 and HD 221866, which occupy peculiar locations in Fig. 3 (Sect. 5), also have an anomalous UV flux distribution. We cannot add any more conclusions on these stars following the previous discussion of the known SB2 systems, so the presence of a companion may produce a distorted UV flux but this is not necessarily true in all cases, and the binarity effect is not the only cause of the anomalous observed UV fluxes.

From their negative values of $E(b-y)$, 5 stars (HD 48501, HD 65526, HD 86358, HD 181998, and HD 218396) may be considered as peculiar, since their colour indices indicate a "blueing" larger than the expected error (Sect. 3.2, Fig. 1). There is no direct correlation between this result and the UV behaviour of these stars: two of them (HD 48501 and HD 218396) have a normal flux distribution, while all the remaining stars have anomalous UV fluxes.

From this study we conclude that the peculiar UV flux distributions are common among the γ Dor stars. Up to now, only one case was known: HD 209295 (Handler et al. 2002). But from this study we find that HD 209295 is not alone with an additional 28 more γ Dor stars showing anomalous behaviour in the UV. Several hypothesis have been suggested by Handler et al. (2002) to explain the UV data of HD 209295 but none of them was conclusive. We have shown that the detected UV excess at 196.5 nm and 236.5 nm cannot be explained only by a binarity effect, even if it plays a role for some stars. We also stress that there is no one-to-one relation between the specificity of the UV flux distribution and some peculiar behaviour in the visible range noted through determination of the absolute magnitude M_V or of $E(b-y)$. We remind the reader that a peculiar UV flux distributions is a well-known characteristic of Ap stars; consequently, most of Ap stars show a "blueing" effect in the visible range, detected with the $E(b-y)$ index. This behaviour reflects modification of the opacities in the Ap stellar atmospheres, which are mainly observed only in the UV domain. We suggest exploring similar effects in terms of stellar atmosphere opacities and structure to explain the UV peculiarities found here for most γ Dor-type stars.

Such a large amount of UV excess among the γ Dor stars needs to be followed up by detailed abundance analysis with high-resolution spectra covering a large wavelength domain and variability period.

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