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HS 0507+0434: a double DA degenerate with a ZZ Ceti component*

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Abstract. HS 0507+0434 and HS 2240+1234 are two new common proper motion pairs of DA white dwarfs, discovered by the Hamburg Quasar Survey. Our model atmosphere analysis shows that HS 0507+0434A has an effective temperature of 20000 K and is remarkably young ($\tau_{\rm cool}$ <1 Gyr) compared to the average cooling time of all known wide double degenerates ($\approx$ 3 Gyr). The cooler B component of HS 0507+0434 is particularly interesting; the determination of the atmospheric parameters is complicated by the strong dependence of the solution on the details of the treatment of convection. Only those parameterizations of mixing length theory are consistent with all observations (especially the magnitude difference between the components), which lead to an intermediate efficiency of the convective flux. In the standard version of the mixing length theory this corresponds to a mixing length parameter of l/H$_p$ = 1.75 - 2.0, where H$_p$ is the pressure scale height. This result does not depend on the model atmosphere code and is in agreement with previous studies of convection in DA white dwarfs; there are, however, slightly different formulations of the MLT in use, which achieve the same efficiency at different values of l/H. These versions are discussed and compared in the paper. The result of our analysis ($T_{\rm eff}$ = 11900 K, $\log g$ = 8) places the B component into the ZZ Ceti instability strip, where DA white dwarfs are pulsating non-radially. Photometric observations have now confirmed that HS 0507+0434 is variable and identified 3 or 4 fundamental g-modes in the Fourier spectrum.

Key words: stars: individual: HS 0507+0434, HS 2240+1234 – white dwarfs – variable – convection

* Based on observations collected at the German-Spanish Astronomical Center (DSAZ) at Calar Alto, Spain, at the European Southern Observatory, La Silla, Chile, with the International Ultraviolet Explorer Satellite, and at the Observatoire de Haute Provence (CNRS), France.

1. Introduction

The proper motion surveys performed by Luyten (1987 and earlier publications) and Giclas et al. (1971) contain more than 500 wide common proper motion (CPM) binaries. Greenstein (1986) studied six visual pairs containing two degenerate stars, finding that the components are quite similar in luminosity and temperature. The fraction of double degenerates among the CPM binaries is about 5% and nearly all of these objects belong to an old (average cooling times $3 \cdot 10^9$ yr, oldest pairs $9 \cdot 10^9$ yr) subset of the CPM systems (Sion et al. 1991). Recently, several hotter and younger resolved binary systems have been found: L151-81A/B, a DB/DA pair with 16000 and 12000 K (Sion et al. 1991, Wood & Oswalt 1992), and RE J0317-853/LB 9802, a magnetic/non-magnetic pair of DAs with 50000 and 16000 K effective temperature (Barstow et al. 1995). Wide pairs of white dwarfs are interesting since their progenitors were formed at approximately the same time but their evolutionary histories are not complicated by the interactions of the two components. Since both components are at the same distance their brightness difference provides additional constraints for the model atmosphere analysis even when no parallaxes are available.

Two young DA CPM binaries have been found in the course of the Hamburg Quasar objective prism survey (HQS): HS 2240+1234 (angular separation: 10″) and HS0507+0434 (18″). These stars are the first visual binaries composed of two DA white dwarfs that have been discovered by a faint blue star survey. A model atmosphere analysis (see Appendix) of HS 2240+1234 leads to effective temperatures of 14700 K and 13200 K ($\log g$ = 8.1 and 7.9), well above the probable blue edge of the ZZ Ceti instability strip.

The second pair HS0507+0434A and B turned out to be far more interesting, because the atmospheric parameters of the B companion predicted it to lie in the ZZ Ceti instability strip. Moreover, this pair provides constraints about the efficiency of convection in the atmospheres: The A component has a temperature of about 20000 K, where the convective flux is negligible

Table 1. Parameters for different versions of the mixing length approximation used in our calculations

Version	a	b	c	$\alpha = l/H_p$
ML0	1/8	1/2	16	1.0, 1.5, 2.0
ML1	1/8	1/2	24	1.0, 1.5, 2.0
ML2	1	2	16	0.5, 0.6, 0.7, 1.0

for the determination of the temperature and pressure stratification, while the solution for the atmospheric parameters of the B companion strongly depends on details of the convection theory. In this paper we will show that the difference in the observed V magnitude of the two stars provides additional information about the efficiency of convection in the outer layers of the B component. A definite decision which of the competing parameterizations of the mixing length theory best describes the convective flux in the atmosphere is, however, impossible with our data. Unfortunately, a scheduled UV observation of the B component could not be taken due to the end of operations of the IUE satellite.

We will show that our model atmosphere analysis of the optical spectra, the UV spectrum of the A component and the V magnitude difference resulted in an effective temperature, that places HS 0507+0434B into the ZZ Ceti instability strip. This has just recently been confirmed by photometric observations which will also be described in the following.

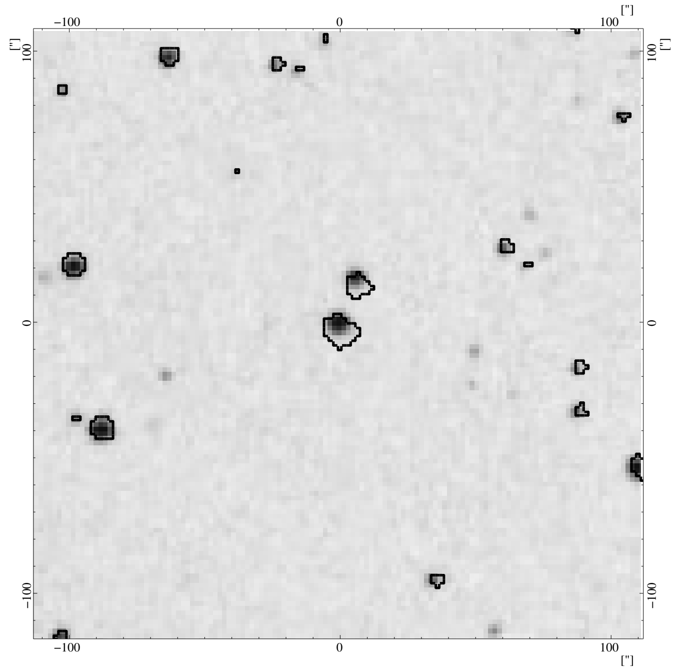

Fig. 1. Detail ($220'' \times 220''$) of the digitized POSS with the double DA HS 0507+0435 in the center. A contour plot of the same region from the HQS Kodak IIIaJ direct Schmidt plate is overlaid in order to show that both components have shifted by $3.6''$ to the south relative to the background stars

2. Discovery and spectroscopy

The HQS — presently covering about 10 500 □° of the northern sky — is carried out with the 80 cm Schmidt telescope at the Calar Alto observatory (Hagen et al. 1995). Although mainly aiming at the discovery of bright quasars it turned out to be a rich source not only for extragalactic objects but also for faint blue stars, especially hot subdwarfs and white dwarfs. In a collaborative project between the institutes in Hamburg, Kiel and Bamberg follow-up spectroscopy of nearly 400 hot stars has been carried out up to now. The motivation and first results of this project have been outlined in Heber et al. 1991, 1993, Jordan et al. 1991, 1993, Jordan & Heber (1993), and Dreizler et al. (1994).

The 1950.0 coordinates for the epoch 1991.02 of the double degenerate HS 0507+0435 (A component: $\alpha = 5^{\rm h}7^{\rm m}34.6^{\rm s}$, $\delta = 4°35'15''$; B component: $\alpha = 5^{\rm h}7^{\rm m}35.0^{\rm s}$, $\delta = 4°34'59''$) were measured on a direct plate taken (plate D1902) on January 9, 1991 of the same field as the objective prism plate. The coordinates were measured with the method described in Hagen et al. (1995). In order to determine the proper motion of the components we used the digitized POSS (Palomar Observatory Sky Survey, red plate, November 6, 1954) for comparison (see Fig. 1). Our result was that both components have moved south (P= $180° \pm 6°$) by $3.57'' \pm 0.34''$ during the period between the exposures of the Schmidt plates (corresponding to $0.1''$/yr).

Optical spectra for both members of the pair were first obtained with the twin-spectrograph of the 3.5m telescope at Calar Alto (Spain) on September 12, 1992. We used a RCA chip in the blue and a GEC chip in the red; the resolution was 6 Å and S/N about 60. The spectra covered the total visible spectral range, from 3800 Å to 9000 Å. On September 21, 1995 we obtained high S/N (> 100) spectra of the pair with the CAFOS spectrograph at the 2.2m telescope of the DSAZ covering the blue region, including Hβ, with a spectral resolution of 3.8 Å. The Balmer line profiles of the CAFOS spectra are presented in Fig. 3.

Direct CCD frames were taken in Jan. 1994 at the 3.6 m telescope of ESO at La Silla (Chile) using EFOSC 1 with a V filter. After the usual corrections for flatfield and bias we used the aperture photometry of IRAF to determine the V magnitudes. Although several standard stars were observed during the night, it was not possible to determine individual V magnitudes, since the weather conditions were not stable. The magnitude difference, however, of the two stars very close on the same frame is $1^{\rm m}.15 \pm 0^{\rm m}.01$ on three different frames taken in two nights. Therefore, we are certain that this difference is very reliable.

The A component was also observed with IUE (Image SWP 56105) in low resolution (Fig. 4); unfortunately the B component could not be observed before the end of the IUE operations, although it was scheduled. We have obtained an estimate of the individual V magnitudes by fitting a model to the absolutely calibrated IUE fluxes and then determining the V band flux from the scaled model. This results in $V = 14^{\rm m}.21$ for A

Table 2. Parameters for B component using different mixing length versions. The statistical errors from the fitting procedure are 60 K for $T_{\rm eff}$, 0.03 for $\log g$, and 0.05 for the magnitudes (see text)

Version	α	$T_{\rm eff}$	$\log g$	M_V	ΔV
ML0	1.0	11070	8.10	$12\overset{\mathrm{m}}{.}05$	1.29
	1.5	11660	8.14	$11\overset{\mathrm{m}}{.}96$	1.20
	2.0	12100	8.10	$11\overset{\mathrm{m}}{.}83$	1.07
ML1	1.0	11130	8.25	$12\overset{\mathrm{m}}{.}27$	1.51
	1.5	11440	8.24	$12\overset{\mathrm{m}}{.}18$	1.42
	2.0	11870	8.14	$11\overset{\mathrm{m}}{.}91$	1.15
ML2	0.5	11670	8.00	$11\overset{\mathrm{m}}{.}77$	1.01
	0.6	11900	7.98	$11\overset{\mathrm{m}}{.}69$	0.93
	0.8	12340	7.93	$11\overset{\mathrm{m}}{.}54$	0.78
	1.0	12740	7.86	$11\overset{\mathrm{m}}{.}40$	0.64

and $V = 15\overset{\mathrm{m}}{.}36$ for B, with an estimated uncertainty of about $0\overset{\mathrm{m}}{.}10$.

3. The mixing length approximation for convection

Wesemael et al. (1991) have pointed out that the determination of atmospheric parameters for DA white dwarfs in the ZZ Ceti region — where convective energy transport is important for the atmospheric structure — depends heavily on the particular version of the mixing length approximation (MLT) that is used to describe convection. This effect has been further studied by Bergeron et al. (1992).

As not all readers may be familiar with the nomenclature used in white dwarf atmosphere and envelope calculations, we will start with a description of the the different MLT versions we have studied. The most important free parameter in all versions is the "mixing length l", which is usually given as a fraction of the pressure scale height H_p, in the form $\alpha = l/H_p$. If α is made larger, the efficiency of energy transport by convection gets larger, and the temperature gradient necessary to transport a certain amount of energy becomes smaller. Unfortunately in the field of white dwarf envelopes the refinements of MLT have been extended by using 3 additional free parameters (a, b, c), introduced into the theory to describe some geometrical factors and leading to versions of MLT denoted ML1, ML2, ML3. This nomenclature was introduced originally by Fontaine et al. (1981), and is described in detail in Tassoul et al. (1990). Here we follow their prescription, with one addition: the standard description, which we have used for many years in the Kiel stellar atmosphere code, was based on Mihalas (1978). Following his equations we use an interpolation formula between optically thin and optically thick turbulent elements. In the optically thick limit this corresponds to using a value of c = 16, whereas in standard ML1, c = 24. To distinguish these versions, we have introduced a new version ML0, which corresponds exactly to the Mihalas version. Table 1 gives an overview over the different choices of parameters used for this study.

It is unfortunate that the introduction of so many free parameters into the mixing length formalism leads inevitably to confusion. We have therefore made an attempt to reduce this

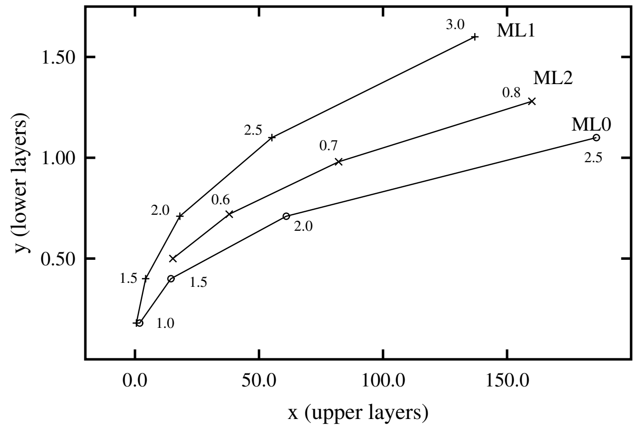

Fig. 2. Comparison of different versions of the MLT, from the limiting behavior of the convective flux in upper and lower layers of atmosphere and envelope. The x and y value is defined in Eq. 1 and 2, respectively. Small numbers along the curves of the different MLT versions give the mixing length parameter α

freedom by studying the limiting expressions for the convective flux in the case of very inefficient convection (appropriate for the upper layers in the atmospheres) and the opposite case of efficient convection (lower layers of atmospheres and envelopes. With all other values held constant, the expressions reduce to

$$F_{\rm conv} \propto \frac{a^2 b \alpha^5}{c^3} =: 10^{-6} x \qquad (1)$$

for the upper layers, and

$$F_{\rm conv} \propto a^{1/2} b \alpha^2 =: y \qquad (2)$$

for the deeper envelope. It is therefore possible, to reduce the freedom to the choice of two parameters, if we consider only the limiting behavior of the convective flux. As a minimum we may hope at least to find "comparable" versions of the MLT by looking at their position in a two dimensional plane with the two coordinates given by the combination of numbers x and y of Eq. 1 and 2 in the two limiting cases of the convective flux. This is shown in Fig. 2, which can serve to compare different versions and find comparable prescriptions.

To simplify the description we will talk of a broad region in this parameter space — which will be shown below to be the best choice for our problem — as "intermediate efficiency" region, including the versions ML1/α=1.75-2.0, ML2/α=0.5-0.6, ML0/α=1.75-2.0. Lower values of α mean less efficient convection (and steeper temperature gradient) in all versions and vice versa.

4. Choice of MLT version and determination of stellar parameters

In attempts to empirically determine the MLT version that best fits the observations, Koester et al. (1994) found that HST observations of the ZZ Ceti star G117-B15A could only be fitted with models assuming "intermediate efficiency" of the convective flux (e.g. ML1/α=2.0). In a much more comprehensive

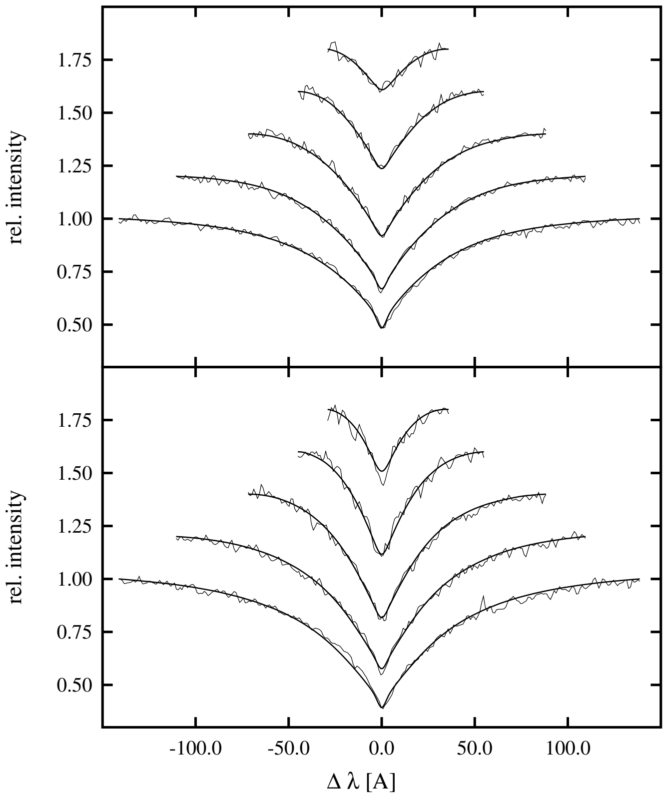

Fig. 3. Observation (CAFOS spectra of 1995) and best fit model using ML1 with α = 2.0 for the hotter A component (top panel) and the B component (bottom panel). Balmer lines run from H β to H 8 from top to bottom. See Table 2 and the text for the parameters of these models

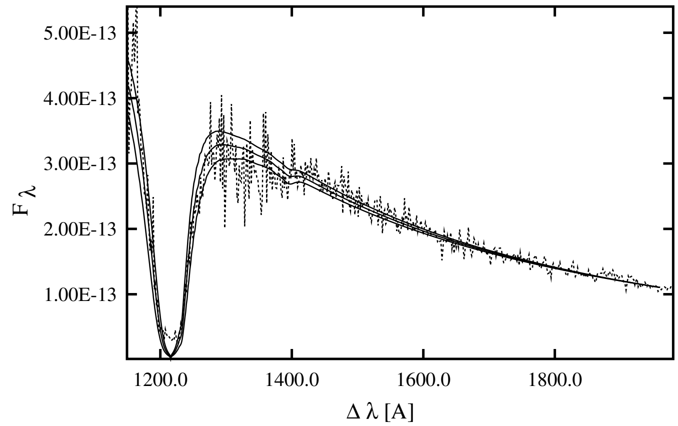

Fig. 4. Comparison of the IUE spectrum of component A (dotted) with theoretical models at log g= 8.0, $T_{\rm eff}$= 21000, 20000, 19000 K (continuous, from top)

study, Bergeron et al. (1995) used optical and UV observations for many ZZ Ceti stars. By demanding a consistent solution for spectra and colors they concluded also that intermediate efficiency provides the best fits; their preferred choice of MLT version was ML2/α=0.6, which has very similar properties. Such an intermediate efficiency in the outer layers of the convection zone (ML1/α = 1.5 or ML2/α=0.6) is also supported by 2-dimensional hydrodynamical models for the surface convection in DA white dwarfs (Ludwig et al. 1993, Ludwig et al. 1994, Steffen et al. 1995), which show that these parameter choices are a good description for the temperature stratification in the layers where the optical and UV lines originate; in deeper layers the convective efficiency strongly increases in these models.

The study of DA spectra in the ZZ Ceti range is complicated by the fact that the Balmer lines reach maximum strength around effective temperatures 12000 - 13000 K, and observed spectra change very little with small changes of parameters. With modern techniques it is easily possible to obtain high S/N (¿ 100) spectra for typical DA and the difference between model and theoretical spectrum is then no longer dominated by statistical noise, but by systematic errors of flux calibration, extinction corrections, or of the models. The least square solution for the best fitting model can under such circumstances change by up to 1000 K for the same object observed in two different nights under slightly different weather and/or instrumental conditions (Koester & Vauclair 1996).

Due to these difficulties we are convinced that the question of which parameterization is best for the DA needs further study. The obvious constraint, which we will exploit in this paper, is the fact that two rather similar DA white dwarfs are at the same distance from us. One turns out to be in a temperature range (20000 K), where convection is unimportant, whereas the second is around 12000 K, strongly influenced by convection. The firm constraint we will use is the difference in apparent magnitude, $\Delta V = 1\overset{\rm m}{.}15 \pm 0\overset{\rm m}{.}01$, which can be translated directly into the same difference for the absolute magnitudes M_V. By fitting the cooler object with model grids calculated with different assumptions for the MLT, finding the absolute magnitudes for the model solutions, we can determine the theoretically expected magnitude difference and compare it with observations.

Using different model grids we have applied our standard χ^2 fitting techniques to find the best fit and determine $T_{\rm eff}$ and surface gravity log g. In all cases we have fitted the TWIN and CAFOS spectra separately and used the average of both solutions for the parameters. As an example for these fits we show in Fig. 3 the result of this Balmer line fitting for the CAFOS spectra of the A and B component, using the version ML1/α = 2.0.

Because at this temperature convective energy transport is unimportant, the result for the A component does not depend on the choice of the MLT version. The resulting values ($T_{\rm eff}$= 20220 $\pm$ 50 K, log g= 7.99 $\pm$ 0.05) are also compatible with the UV spectrum (Fig. 4).

For each of the solutions obtained with different MLT versions we have determined the absolute magnitude predicted from the model, using

$$M_V = V_0 - 5\log(R/R_\odot) + 29.545 \qquad (3)$$

V_0 is the model flux integrated over the sensitivity function of the V filter, and the constant is determined from the solar values. The radii of the white dwarfs are taken from the evolutionary calculations of Wood (1992, 1994) for "thick layers",

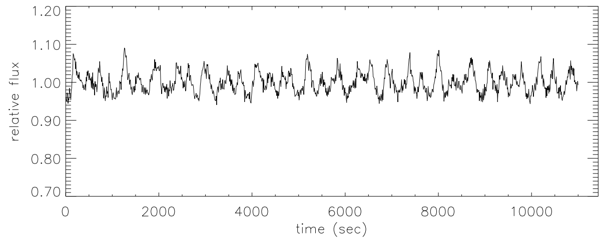

Fig. 5. Reduced and normalized light curve for HS0507+0435 B (corrected for extinction and other sources of transparency fluctuations). 183 minutes of fast photometry observations, obtained at the Haute Provence Observatory on December 15th, 1996

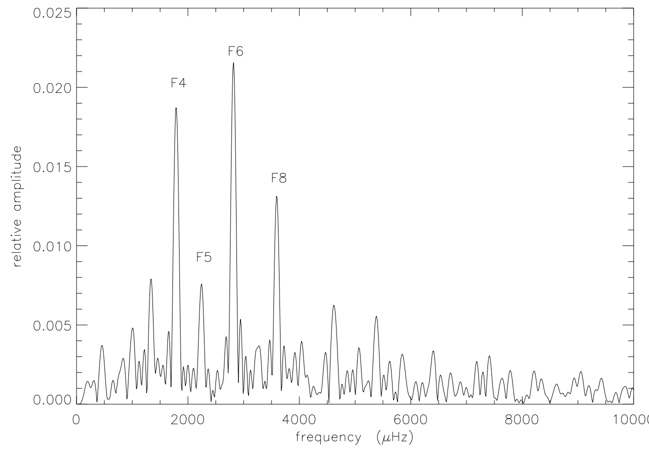

Fig. 6. Fourier transform (modulus) of the light curve of HS0507+0435 B (see Fig. 5). Many peaks are linear combinations of others ; The label F4 to F8 on the main peaks refers to the most probable independent modes, used to infer the linear combinations of frequencies (see Table 3)

using the temperature and surface gravity from the atmosphere solution. The absolute magnitude of component A with parameters given above is M_V(A) = $10\overset{\mathrm{m}}{.}76 \pm 0\overset{\mathrm{m}}{.}07$; this leads to $m_V - M_V$ = $3\overset{\mathrm{m}}{.}45 \pm 0\overset{\mathrm{m}}{.}12$, a distance of 49± 3 pc, and a separation of 880 ± 54 AU for the two components (neglecting an unknown inclination angle).

With the result for the absolute magnitude of the component B we can then predict the expected difference in apparent magnitude $\Delta V = M_V(B) - M_V(A)$. Table 2 lists all results for component B for the different versions studied.

The observed magnitude difference between the two components is $1\overset{\mathrm{m}}{.}15 \pm 0\overset{\mathrm{m}}{.}01$. Our results confirm again the conclusions of Koester et al. (1994) and Bergeron et al. (1995) that the intermediate efficiency prescriptions agree best with the observations. We get good agreement for the ML0 version, if we use α = 1.75, or ML1 with α = 2.0. The smallest value of α used in our grid for ML2 does not give a large enough difference; we estimate by extrapolation that α = 0.4 would give the correct difference. However, these results should not be overemphasized — we agree with the conclusion of Bergeron et al. (1995) that ML2/α = 0.6 gives very good fits to optical and UV spectra. With his model atmosphere code Bergeron (priv. comm.) obtained a solution for the TWIN spectra of HS 0507+0435B of $T_{\rm eff}$ = 11700 K and log g = 8.17 for ML2/α = 0.6 (compared to our TWIN values of 11760 K and 7.94), or 11100 K and 8.38 (11030 K and 8.24) for ML1/α = 1, respectively. This shows that the exact solution depends on the details of the fit procedure as discussed above (choice of the wavelength intervals, normalization of the spectrum).

Unfortunately, it will not be possible to describe the complete behavior of the convection zone with only the two free parameters introduced in the previous section. This can be seen from a comparison of the atmosphere solutions for the versions, which most closely give the correct ΔV: although in Fig. 2 the ML2 line falls between the ML0 and ML1 lines, the solutions for the latter two agree closely, whereas ML2 predicts a significantly lower surface gravity. The atmospheric structure is not completely determined by specifying the limiting convective flux; the temperature structure in the transition layer between the extremes can still be different, and its influence on the spectrum is not negligible.

The χ^2 analysis provides the formal 1 σ error derived from the statistical errors (noise) of the spectra. Due to the high S/N of our spectra this is rather small: typical errors are 60 K for $T_{\rm eff}$, 0.03 for log g, and 0.05 for M_V of component B, if we consider the mixing length parameters fixed. For the study of MLT versions we are mainly interested in the differential change of M_V for different solution, and therefore assume the solution for A to be accurate. These errors are given in the caption of table 2. For component A the formal errors are 120 K for $T_{\rm eff}$ and 0.02 for log g.

Due to high S/N of the spectra it is likely that systematic errors due to different observing conditions and reduction procedures — which are very difficult to estimate – dominate the statistical errors. We can obtain an indication of the magnitudes of these errors for our case from the fact that we have two different pairs of spectra for each object. Using the same models and fitting routines we have found that the results differ by $\Delta T_{\rm eff}$ = −50 K (A) and −300 K (B), Δ log g = +0.05 (A) and +0.05 (B) between the Calar Alto 1993 and 1995 observations — almost independent of the applied parametrization of the MLT. Except for the temperature of A these errors are, as expected, significantly larger than the formal χ^2 errors, although the $T_{\rm eff}$ difference for B does not reach the extreme values discussed above. For all estimates of absolute (as opposed to differential) parameters of both components we have throughout the paper used the larger of the error estimates.

In principle the white dwarf radii corresponding to a given mass and surface gravity could also depend on the physics used to describe envelope convection. We are not aware of any such systematic calculations studying this effect; however, at effective temperatures around the hot edge of the ZZ Ceti instability strip (12000 K) the convection zone is very thin, with the bottom reached within our atmosphere model in most cases. The effect on radius and cooling times in this region will be negligible.

Table 3. Frequencies identified in the power spectrum of the fast photometry of HS 0507+0434 B, and tentative identification of the fundamental modes. The amplitudes are given as a percentage of the luminosity of the star

No.	frequency/μHz	amplitude	best fit/μHz	corresp.combination	error/μHz
1	462	.34	456	F5−F4	-6.
2	1007	.43	1026	F6−F4	19.
3	1336	.75	1346	F8−F5	10.
F4	1790	1.90			
F5	2246	.73			
F6	2816	2.20			
7	3230	.39	no.identif.		
F8	3592	1.28	3580	2·F4	-12.
9	4036	.39	4036	F4+F5	-0.
10	4474	.35	4492	2·F5	18.
11	4615	.66	4606	F4+F6	-9.
12	5065	.37	5062	F5+F6	-3.
13	5378	.58	5370	3·F4	-8.
			5383	F4+F8	5.
14	5620	.31	5632	2·F6	12.
15	5843	.35	5826	F4+F4+F5	-17.
			5839	F5+F8	-4.
16	6398	.33	6396	F4+F4+F6	-2.
			6409	F6+F8	11.
17	7187	.28	7173	F4+F4+F8	-14.
			7185	2·F8	-2.
18	7413	.33	7423	F4+F6+F6	9.

Notes: **1:** (F4-3) = (F5-F4) =455 μHz so only 3 or F5 needs to be real (they can be real both).
2: results show that F8 is probably 2·F4 or F3+F5.
3: all combinations of two modes among modes F4, F5, F6 and F8 are present, which is a strong indication that they are indeed fundamental modes.

If we had used Wood's "thin layer" model calculations, the absolute magnitude of component A would be $0\overset{m}{.}04$ fainter; however, the difference A-B would change by only $0\overset{m}{.}01$, not affecting our conclusion about the best MLT parametrization.

In the following we use the results obtained for the version ML1/α=2.0, which exactly reproduces the measured magnitude difference, for some further estimates. Using the Wood (1994) evolutionary mass-radius relations we estimate masses of 0.62 $\pm$ 0.03 $M_\odot$ (A) and 0.69 $\pm$ 0.03 $M_\odot$ (B) and cooling times of $8 \pm 1 \cdot 10^7$ years (A) and $5.1 \pm 0.35 \cdot 10^8$ years (B). Although the difference in cooling ages ($4.3 \cdot 10^8$ years) is rather large now, the stars have probably been very similar on the main sequence. Assuming typical progenitor masses around 1.5 $M_\odot$ and taking main sequence and red giant evolutionary time scales from Schaller et al. (1992), we find an age difference of $4.3 \cdot 10^8$ if we assume a progenitor mass of 1.56 $M_\odot$ for B and 1.50 $M_\odot$ for A. Considering all uncertainties in these estimates, the results are compatible with the assumption that both stars lost the same total amount of mass during their evolution.

5. The B component as a ZZ Ceti variable: fast photometry

The parameters determined for the effective temperature and surface gravity ($\approx$ 11900 K, $\log g \approx 8$) of the B component place this object in the instability strip of the variable DA or ZZ Ceti. In order to check the correctness of our atmospheric analysis fast photometry of HS 0507+0434 B was performed, and confirmed its variability.

The fast photometry observations have been performed at the Haute Provence Observatory in December 1996. We used the 1.93 m Telescope, which is automatically guided with the help of an intensified CCD camera. The three-channel Chevreton photometer is very well adapted for fast photometry of white dwarfs. As the stars are faint, the flux from the sky is comparable to the flux from the star, so that a careful subtraction of the sky background is necessary. The observations are performed in white light. The background was simultaneously monitored, using the third channel of the photometer. The elimination of all rapid transparency fluctuations and of all possible artifacts was performed with the help of the comparison star channel. We obtained 183 minutes of good quality data.

After sky subtraction, and after correlating the light curve of HS 0507+0435B with the light curve of the comparison star, we obtained the reduced and normalized photometric data of the B component (Fig. 5). The variation of the star, with a peak to peak amplitude of about 10%, is clearly visible.

The frequencies found in the power spectrum of the 183 minutes of photometric observations are listed in Table 3 (see also Fig. 6); the corresponding periods range between (51 and 2165 seconds).

HS0507+0434B turns out to be a complex multi-periodic pulsator, with at least 18 significant frequencies in the range 1000-12000 μHz. However, most of these frequencies are found to be close to harmonics or linear combinations of a few of them (within the error bar, which is estimated to be around 10 μHz). In Table 3, we also list a tentative identification of those combinations, using only modes F4, F5, F6 and F8 (but note that F8 could well be the first harmonic of F4): It means that only these 3 or 4 frequencies may correspond to independent pulsation modes of the star. The procedure of identification of the harmonic is a straightforward fit of the frequencies found observationally with combinations of modes, within a given error bar chosen in accordance with the duration of the observations.

When compared with other ZZ Ceti stars, the photometric results are as follows: high amplitudes, long period oscillations (around 500 seconds). The shape of the pulses is very characteristic, with very sharp maxima and smooth minima, clearly visible on the light curve (Fig. 5). The power spectrum exhibits a very large number of harmonics and linear combinations of modes: All this would place HS 0507+434B into a subset of the ZZ Ceti stars, which tend to be near the cool edge of the instability strip (compared to the hotter group, which have simpler spectra, with sinusoidal low amplitude pulses and shorter periods). Several members of this subset have been intensively observed and analysed, as G29-38 (Kleinman, 1996) and HL Tau76 (Dolez & Kleinmann 1996)

6. Discussion

We have discovered a wide pair of DA white dwarfs. The atmospheric parameters of the brighter and hotter A component could be precisely determined by a model atmosphere analysis of high S/N spectra. The determination of effective temperature and gravity of the B component was complicated by the uncertainties in the treatment of convection. We could show that only those parametrizations of the mixing length theory, which correspond to an intermediate efficiency of the convective flux (e.g. ML1/α = 2.0), lead to atmospheric parameters for the B component consistent with the values for HS 0507+434A. This is in good agreement with previous studies of convection in the relevant range of effective temperatures. Our result for $T_{\rm eff}$ and $\log g$ predicted that HS 0507+434A should be a ZZ Ceti star.

The purpose of the fast photometry run was to confirm the variability of the star; for a detailed asteroseismological analysis the length of the observation is much too short. However, the periods found (from mode 3 to mode F8 in Table 3) are well compatible with a mean period difference of about 45 seconds (allowing for some missing modes and periods displacements, due to trapping of oscillations). This value is what we expect for such a star, if the modes are of spherical degree $\ell = 1$. As it belongs to a binary system, which improves the constraints of the models, HS 0507+0434B is an extremely interesting object for future asteroseismology observations, using a multisite network of telescopes.

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Appendix A: HS2240+1234

HS 2240+1234 (A component: $\alpha = 22^{\rm h}40^{\rm m}1.7^{\rm s}$, $\delta = +12°34'20''$; B component: $\alpha = 22^{\rm h}40^{\rm m}2.5^{\rm s}$, $\delta = +12°34'23''$; equinox 1950.0, epoch 1985.71) is a visual double DA system (angular separation 10") at about $T_{\rm eff}$= 15000 K and 13 000K, respectively. Optical spectra (shown in Jordan & Heber 1993) and B images obtained with the focal reducer at the 3.5m telescope of the Calar Alto observatory are re-analysed in the same way as described for HS 0507+0434. Optical spectra were obtained on 6.10.1990 (22:00, 22:45 UT, 40 min. exposure time each) with a grism of 134Å/mm reciprocal dispersion resulting in a spectral resolution of about 7Å and covered the spectral range 3800Å to 5500Å. An image in the B band taken immediately after the spectra was calibrated using an observation of GD 264 (B = $12\overset{\rm m}{.}77$, Landolt, 1983) taken 8 min. later with the same instrument at almost the same airmass. B = $16\overset{\rm m}{.}27$ for HS 2240+1234A and B = $16\overset{\rm m}{.}.57$ for HS 2240+1234B resulted. The B magnitude difference between both components ($0\overset{\rm m}{.}30$) is accurate to about $0\overset{\rm m}{.}01$.

The spectral analysis using the convection parameters ML2/α = 0.6 resulted in $T_{\rm eff}$= 14700±500 K, $\log g = 8.1 \pm 0.1$ (A); $T_{\rm eff}$= 13200±500 K, $\log g$ = 7.9 ± 0.1 (B), and a magnitude difference of δ B = $0\overset{\rm m}{.}1 \pm 0\overset{\rm m}{.}15$ (here we have used only the errors of B to estimate the error of the magnitude difference, for consistency with the previous discussion). ML2/α = 0.6 was applied, since we have used this grid as our standard set, following Bergeron et al.(1995). ML1/α = 2.0 would give very similar results at the higher temperature of these objects. The errors in the atmospheric parameter determinations are larger compared to HS 0507+0434 since the S/N ratio is about a factor of three smaller. The model predictions are in reasonable agreement with the observed magnitude difference, but due to the larger uncertainties in both observation and theory (both components are affected by convection) HS 2240+1234 does not constrain the efficiency of convection as much as HS 0507+0434. Therefore, and because none of the components is variable or special in other respects, we did not investigate this system in more detail.

Proper motions have been determined in the same way as described for HS 0507+0434 from the POSS red position (1953.83) and the HQS Kodak IIIaJ plate (1985.71). The common proper motion for the pair is 0.065″/yr with a position angle of 298°.

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