Astron. Astrophys. 325, 1055–1062 (1997)

ASTRONOMY
AND
ASTROPHYSICS

White dwarfs observed by the HIPPARCOS satellite*

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Received 30 January 1997 / Accepted 21 April 1997

Abstract. The HIPPARCOS satellite has measured trigonometric parallaxes for 20 white dwarfs. With the exception of one each of the spectral types DZ, DC, DB, DQ, the majority are of spectral type DA. We compare the parallaxes with the most recent ground-based determinations. From a spectroscopic analysis of new optical observations we determine atmospheric parameters $T_{\rm eff}$ and log g. From the angular diameters and the parallaxes radii are obtained, and masses are calculated from these radii and the spectroscopic log g. These data are used to test the theoretical mass-radius relation. On the other hand, assuming this relation, including finite temperature evolutionary effects, we can derive radii and masses from the effective temperatures and parallaxes. From these we calculate surface gravities, which can be compared to the results of the spectroscopic analysis.

Key words: stars: distances – stars: fundamental parameters – stars: white dwarfs

1. Introduction

Measuring the fundamental parameters of stars — mass, radius, luminosity — with very few exceptions needs a knowledge of the distance. The most direct method to obtain the distance is the geometric method, the trigonometric parallax. All other methods — even establishing the cosmic distance scale — rely on trigonometric parallaxes as the first and basic step for the calibration of other distance indicators. Trigonometric distances measured by ground-based telescopes were, at least until a few years ago, limited to distances of about 50 to 100 pc. The realization of the fundamental importance of distances beyond this limit lead to the successful project of the HIPPARCOS satellite, bringing into the reach of direct distance measurements for the first time many classes of stars, including Cepheids, the most important primary cosmologic distance indicators.

The HIPPARCOS satellite was devised to measure the absolute parallaxes for about 100 000 stars. The achieved accuracy was expected to reach 2 milliarcseconds (mas) for all stars brighter than $Hp = 9$, where Hp, the HIPPARCOS magnitude, is defined in the HIPPARCOS and Tycho Catalogues, Volume 1, and corresponds to a large band filter, specific of the HIPPARCOS instrument. It encompasses both the usual Johnson B and V magnitudes. The final accuracy achieved by the HIPPARCOS mission is indeed better, reaching 1 mas for $Hp < 9$.

In spite of the fact that the originally announced limiting magnitude was $B < 13$, and knowing that the accuracy of the parallaxes measured for objects at the limiting magnitude would be worse than the expected 2 mas, one of us (GV) proposed to include a program of parallax measurement for all bright white dwarfs. The original, optimistic, list of white dwarfs to be included in the program, was selected from the McCook and Sion Catalog (McCook & Sion 1987). All objects brighter than $B = 13.1$ were selected, i.e. 45 objects. Subsequently, after the reduction of the HIPPARCOS limiting magnitude to $V = 12.4$, and the application of the various selection criteria, 22 white dwarfs (one object was later found to be a subdwarf, see below) were effectively included in the program, of which 21 have a parallax measurement.

In this paper we report the results of these HIPPARCOS observations of white dwarfs (The HIPPARCOS Catalogue, ESA 1997). Although there is no doubt theoretically about the validity of the famous mass-radius relation, the empirical basis for it has never been convincing (Schmidt 1996). We will study, whether the new data improve this situation. Assuming the mass-radius relation (including finite temperature evolutionary effects) we can determine much more accurate masses from spectroscopically determined effective temperatures. These in turn can be used as a test of the accuracy of spectroscopic determinations of the surface gravity.

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* Based on data from the ESA HIPPARCOS astrometry satellite and on observations collected at the European Southern Observatory, La Silla, Chile, and at the German-Spanish Astronomical Center at Calar Alto, Spain

2. HIPPARCOS parallaxes and comparison with ground-based measurements

Before the start of HIPPARCOS errors of ground-based parallaxes were 10 mas or larger, and a significant improvement was expected from this mission. However, during the last 10 years the use of CCD detectors and dedicated telescopes (especially at the U.S. Naval Observatory) has made the ground-based observations much more competitive. In Table 1 we compare the parallaxes obtained by the HIPPARCOS mission with values obtained by ground-based observations, including the one sigma errors of the measurements.

For the ground-based values we have in general used the "General Catalogue of Trigonometric Parallaxes" by Van Altena et al. (1995), which is a compilation giving weighted mean values from several observations. Only in those cases where no value was available in that catalog we have gone back to other sources, mostly the "Third Catalogue of Nearby Stars" by Gliese & Jahreiss (1991).

The actual errors for the white dwarf subset have an average value around 3.6 mas, which is still smaller than the average error of the ground-based values, though not by a large margin. In fact, in several cases the modern observations are more accurate than the HIPPARCOS values, if we take the given errors at face value. In about two thirds of the cases both results are compatible within the mutual errors, which is what one would expect for 1 σ errors. In Fig. 1 we present a graphical comparison of both sets of parallaxes.

However, for some objects significant discrepancies exist between different recent ground-based data, or between ground-based and HIPPARCOS results. In the case of Feige 22 (WD 0227+050) Van Altena et al. (1995) report a value of $\pi = 19.3 \pm 13.4$ mas using one observation, while Gliese & Jahreiss (1991) give a value of $\pi = 45 \pm 5$ mas. Since the latter value agrees with the HIPPARCOS measurement we adopt it for our comparison in the table.

A further special case is GD 294 (WD 0713+584), where the HIPPARCOS parallax is very uncertain and can only be used as an upper limit. In view of the bright visual magnitude of this object and the upper limit for the parallax it is very unlikely that this object can be a white dwarf. The Strömgren colors (Lacombe & Fontaine 1981) are also inconsistent with white dwarf colors. Greenstein & Liebert (1990) give the spectral type as "sdB?", because the hydrogen lines are rather narrow. We conclude that this star is no DA, but probably a subdwarf B star, and we will not consider it further.

For HZ 43 (WD 1314+293) the HIPPARCOS parallax differs from the latest ground-based observation by Dahn et al. (1982) by a factor of two, clearly outside their mutual error ranges. Mass and radius determinations from both measurements do not fit the mass-radius relation; the deviations are in opposite directions. HZ 43 is one of the most famous white dwarfs and used as a standard for many instruments; it would be very desirable to resolve this discrepancy. We can only speculate that the difficulties are caused by the presence of a very close M dwarf companion in this binary star, a possibility confirmed by the HIPPARCOS team.

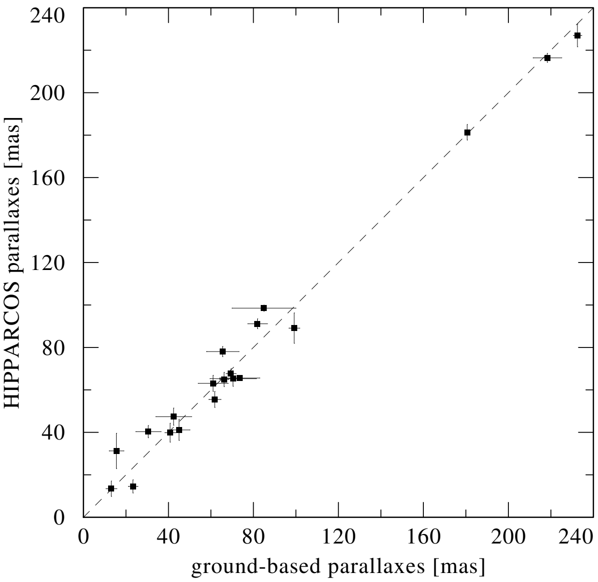

Fig. 1. Comparison of both parallax values with their quoted uncertainties

Another famous and often used white dwarf is G 191-B2B, which also shows a disagreement between ground-based and HIPPARCOS parallax. The ground-based value actually was obtained for the common proper motion companion, which could indicate that this is not a physical pair. However, the HIPPARCOS value does not fit the mass-radius relation better than the old value, leaving open the possibility of a parallax error slightly larger than the quoted 1 σ uncertainty.

The remaining objects with differences between HIPPARCOS and ground-based distances slightly larger than the sum of their errors are WD 1337+705, WD 1620 − 391, and WD 1647+591.

3. Atmospheric parameters from spectroscopic observations

All HIPPARCOS white dwarfs are rather bright and have therefore repeatedly been observed photometrically and spectroscopically in the past. Nevertheless, since so much is invested in obtaining very accurate parallaxes, we felt the necessity to complement this with a homogeneous set of high quality optical spectra. These were obtained in 3 observing runs at the European Southern Observatory (La Silla) during May 30 – Jun 1, and Nov 30 – Dec 1, 1992 and at the German Spanish Astronomical Center (Calar Alto) during Sep 18 – 20, 1995. At ESO we used the 2.2m telescope equipped with the EFOSC-2 spectrograph and CCD #19 (Thompson 1024x1024). At Calar Alto the telescope used was also the 2.2m, which is the twin instrument of the ESO 2.2m. The spectrograph was CAFOS, with CCD #13 (Tektronix 1024x1024) detector. The spectral resolution was about 4 Å for the Calar Alto spectra and 10 Å for the ESO spectra, and the aim

Table 1. Parallax values and the 1 σ errors (all values in milliarcseconds) measured by HIPPARCOS and by ground-based observations. Sources of ground-based values: in general values taken from Van Altena et al. 1995, the other references are: **a)** Gliese, Jahreiss 1991 **b)** Dahn et al. 1982. The last two columns show the apparent magnitude value used and their source. For magnitudes marked with an asterisk we assume an error of 0.03 mag. Note: $\star$ The parallax solution for WD 2117+539 was rejected during the HIPPARCOS reduction process because of errors larger then 100 mas.

WD - number	name	HIP	spectral type	HIPPARCOS parallaxes [mas]	ground-based parallaxes [mas]	V	reference
0046 + 051	vMa 2	3829	DZ	226.95 ± 5.35	232.5 ± 1.9	12.371 ± 0.018	Turon et al. 1993
0148 + 467	GD 279	8709	DA	63.08 ± 3.79	61.0 ± 7.0 [a]	12.440 ± 0.030	Turon et al. 1993
0227 + 050	Feige 22	11650	DA	41.15 ± 4.96	45.0 ± 5.0 [a]	12.799 ± 0.0014	Landolt 1992
0232 + 035	Feige 24	12031	DA	13.44 ± 3.62	13.1 ± 2.5	12.411 ± 0.003	Landolt 1992
0310 − 688	LB 3303	14754	DA	98.50 ± 1.46	84.9 ± 15.0	11.387 ± 0.019	Turon et al. 1993
0426 + 588	Stein 2051B	21088	DC	181.36 ± 3.67	180.6 ± 0.8	12.440 ± 0.030*	Gliese, Jahreiss 1991
0501 + 527	G 191-B2B	23692	DA	14.53 ± 3.09	23.3 ± 2.2	11.781 ± 0.0055	Landolt 1997
0644 + 375	He 3	32560	DA	64.91 ± 3.37	66.2 ± 2.1	12.057 ± 0.006	Turon et al. 1993
0713 + 584	GD 294	35307	sdB?	-1.80 ± 2.97		11.980 ± 0.030*	Wegner, Swanson 1991
1134 + 300	GD 140	56662	DA	65.28 ± 3.61	70.4 ± 10.9	12.487 ± 0.019	Turon et al. 1993
1142 − 645	L 145-141	57367	DQ	216.40 ± 2.11	218.3 ± 6.7	11.503 ± 0.017	Turon et al. 1993
1314 + 293	HZ 43	64766	DA	31.26 ± 8.33	15.5 ± 3.4 [b]	12.914 ± 0.030*	Bohlin et al. 1995
1327 − 083	Wolf 485	65877	DA	55.50 ± 3.77	61.8 ± 2.8	12.313 ± 0.005	Turon et al. 1993
1337 + 705	G 238-44	66578	DA	40.33 ± 2.89	30.5 ± 5.9	12.792 ± 0.004	Turon et al. 1993
1544 − 377	L 481-60	77358	DA	65.60 ± 0.77	73.5 ± 9.4 [a]	12.800 ± 0.030	Wegner 1973
1620 − 391	CD -38 10980	80300	DA	78.04 ± 2.40	65.5 ± 7.6	11.010 ± 0.011	Turon et al. 1993
1647 + 591	G226-29	82257	DA	91.13 ± 2.33	81.9 ± 4.6	12.240 ± 0.031	Turon et al. 1993
1917 − 077	LDS 678A	95071	DB	89.08 ± 7.16	99.2 ± 2.5	12.280 ± 0.030	Turon et al. 1993
2032 + 248	Wolf 1346	101516	DA	67.65 ± 2.32	69.4 ± 2.3 [a]	11.528 ± 0.001	Turon et al. 1993
2039 − 202	L 711-10	102207	DA	47.39 ± 4.04	42.4 ± 8.4	12.330 ± 0.020	Kidder et al. 1991
2117 + 539	G 231-40	105230	DA	$\star$	50.7 ± 7.4	12.330 ± 0.011	Schwartz 1972
2149 + 021	G 93-48	107968	DA	39.84 ± 4.47	40.8 ± 2.5	12.738 ± 0.008	Turon et al. 1993

was to obtain a signal/noise ratio of at least 100. The observing runs suffered partly from bad weather conditions, but nevertheless we were able to obtain between 1 and 4 spectra for 15 out of the 22 white dwarfs on the HIPPARCOS input list. The CCD frames were reduced and spectra extracted with standard IRAF routines. Approximate flux calibration was achieved through the use of spectrophotometric standard stars, in most cases GD108 or G191-B2B. Since several of the observing nights were not photometric, and since a relatively narrow slit was used, it is not possible to achieve an absolute flux calibration. However, the accuracy of the parameter determination through fitting of the observed spectra with theoretical models is improved, if the *relative* flux distribution is corrected for the instrumental response function and atmospheric extinction as far as possible.

For the determination of atmospheric parameters of the DA stars we have used our own grid of model atmospheres, which includes all improvements developed over the last years (Hummer-Mihalas occupation probabilites, intermediate convective efficiency ML2/α=0.6 as suggested by Bergeron et al. 1995b). A description of the input physics and methods is given in Finley et al. (1997). The fit between observation and theory was obtained with a Levenberg-Marquard χ^2 method (Press et al. 1992). The results are presented in Table 2 with reference “opt”.

In some cases, where good IUE spectra exist, or when the determination of parameters from optical spectra is difficult (in the 10000 - 15000 K region), we have also determined parameters from the UV spectra similar to Koester & Allard (1993), but with the latest results for the Lyman α satellite features. The well-known ambiguity in the fitting of UV spectra (e.g. Koester et al. 1994; Bergeron et al. 1995b) was solved by using the V magnitude as additional constraint (reference IUE).

It is extremely difficult to assess realistic error estimates for these results. The formal (statistical) errors determined by the χ^2 fitting routine are usually very small, often much smaller than 100 K for the effective temperature. These estimates, however, assume that the dominant error is the statistical noise in the observations. For typical spectra with S/N $>$ 100 this is not the case: the χ^2 are dominated by systematic errors due to imperfect flux calibration and errors in the models. We do not have a method to determine this error in a formal, objective way; the solution we have chosen is to carefully compare the results from observations in different nights, at different telescopes, and also by different authors (see below). As minimum errors we have estimated 300 K and 0.05 for $T_{\rm eff}$ and log g respectively for the bulk of the DA below 25000 K. We consider these estimates to be rather conservative estimates of the true (unknown) 1 σ errors.

During the time of the HIPPARCOS observations and data analysis several spectroscopic studies of DA white dwarfs appeared, mostly by Bergeron and collaborators. Because the observational data were of similar high quality and the atmosphere models include essentially the same physics, we have given the same weight to the results of Bergeron et al. (1992, for objects

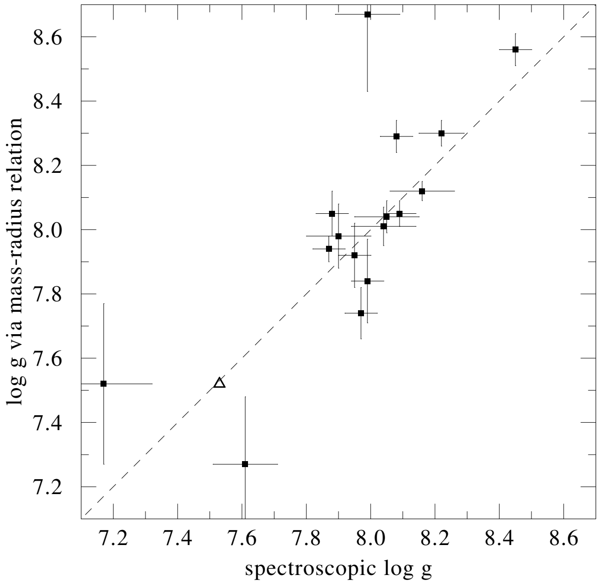

Fig. 2. Comparison of the spectroscopically determined $\log g$ with the $\log g$ from the theoretical mass - radius relation

with $T_{\rm eff} > 16000$ K), Bergeron et al. (1995a,b), and Finley et al. (1997) and taken a straight average.

For the 4 non-DA white dwarfs we have used literature values for $T_{\rm eff}$; the surface gravity is undetermined or very uncertain in these helium rich objects.

Significant discrepancies for the more recent determinations of atmospheric parameters exist in the cases of Feige 24 (WD 0232+035) and HZ 43 (WD 1314+293). Both stars are binaries with a close M dwarf companion, which affects the optical spectra. In those cases we have not taken an average and we will discuss these objects individually below.

Using the atmospheric parameters $T_{\rm eff}$ and $\log g$ we can determine the angular diameter from a comparison of the energy flux πF_λ at the surface of the star and f_λ measured at the earth

$$f_\lambda = \frac{\pi R^2}{D^2} F_\lambda .$$

In practice we do not use a monochromatic flux, but an integration over the V passband. The final equation used is

$$\log R/R_\odot = 0.2(V_0 - V) - \log \pi'' + 4.909$$

where V is the observed magnitude, V_0 the stellar flux integrated over the V band, and π'' the parallax in arcsec. Our adopted apparent magnitudes V are listed in Table 1 with their sources. In general, we have taken the magnitudes from the "HIPPARCOS Input Catalogue" (Turon et al. 1993). In those cases where discrepancies with other measurements appear we have gone back to the original sources listed in the table.

From the radius and effective temperatures we determine masses and surface gravities using the evolutionary mass-radius relations of Wood (1992, 1994). These values are given in Table 2, and the surface gravities derived for the DA are compared with the purely spectroscopic determinations in Fig. 2. It should be noted that the quantity V_0 depends only very little on $\log g$; if we assume the standard value of 8.0 for the non-DA, where we do not have a spectroscopic determinations, the error of the mass determination will be very small.

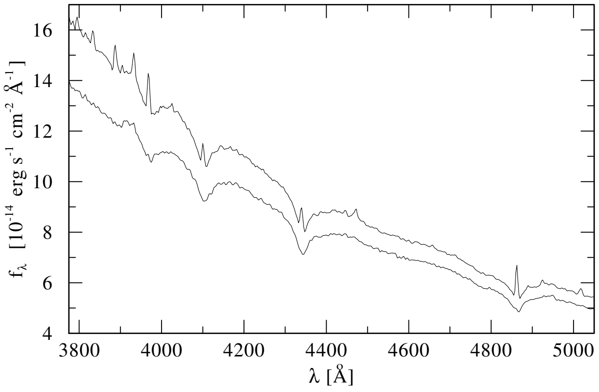

Fig. 3. Blue spectra of Feige 24 obtained on Nov 30 (top) and Dec 1, 1992 at ESO. Emission lines in the Nov 30 spectrum originate from the active M dwarf companion

Most of the $\log g$ values in Fig. 2 cluster around 8.0, although in several cases the disagreement is larger than would be expected from the errors. We consider this as an indication that the errors given in the literature for observed and derived quantities (especially the spectroscopic surface gravity) are perhaps slightly too optimistic. There are, however, significant discrepancies in 3 objects, which we will now discuss in detail.

Feige 24, WD 0232+035: The spectroscopic $\log g = 7.17$ found by Finley et al. (1997) is extremely low. If we use instead the result of Marsh et al. (1996) $\log g = 7.53$, Feige 24 would fall almost exactly on the diagonal line (triangle in Fig. 2). Feige 24 has a very close M dwarf companion, which shows strong activity, as demonstrated in Fig. 3. The combined spectra look quite different; the Nov 30 spectrum shows strong Balmer emission lines from the M dwarf companion, which are absent one day later. Even if the emission lines are not visible, the line profiles may still be affected by contributions from the companion. From direct CCD exposures taken at the same time we have determined a change in V magnitude of approximately 0.5 mag. It is clear that spectroscopy of such a system is very difficult.

G 191-B2B, WD 0501+527: If we had used the $\log g = 7.49$ of Finley et al. (1997), the result would be marginally compatible with the diagonal line in Fig 2. G 191-B2B is used as a flux standard for ground-based and space observations (Bohlin et al. 1995). The flux is normalized with the observed V magnitude and the uncertain value of the parallax has no effect.

HZ 43, WD 1314+293: As mentioned before there is a large discrepancy between ground-based and HIPPARCOS parallax. The measurements may have been influenced by the close M dwarf companion; a mass larger than 1 $M_\odot$, which follows from the HIPPARCOS value, can certainly be excluded from the spectroscopy.

Table 2. Atmospheric parameters $T_{\rm eff}$ and log g from spectroscopy. Masses and surface gravities in columns 7 - 10 are derived from the radius and the theoretical mass-radius relation of Wood (1994)

WD	$T_{\rm eff}$	Δ $T_{\rm eff}$	log g	Δ log g	ref	$M(R)$	Δ M	log $g(M,R)$	Δ log g
`0046+051`	6900	280			Leggett (1989)				
	5500				Greenstein (1983)				
	6000	500			estimate	0.56	0.15	7.94	0.16
`0148+467`	13690		7.96		opt				
	13900		8.11		IUE				
	13800	300	8.04	0.10	average	0.62	0.06	8.01	0.06
`0227+050`	18340		7.90		opt				
	18070		8.01		IUE				
	19070		7.78		Bergeron et al. 1992				
	18500	500	7.90	0.10	average	0.61	0.10	7.98	0.10
`0232+035`	62730	2200	7.17	0.15	Finley et al. (1997)	0.54	0.10	7.52	0.25
	62950	1500	7.53	0.09	Marsh et al. (1996)				
	59800	3400	7.45	0.51	Kidder (1991)				
`0310-688`	15710	300	8.16	0.10	IUE	0.69	0.02	8.12	0.03
`0426+588`	7050	400			Liebert (1976)				
	6800	300			Wegner & Yackovich (1983)				
	7250	170			Greenstein (1983)				
	7030	200			average	0.67	0.05	8.12	0.06
`0501+527`	60000		7.65		opt				
	64100		7.69		Bergeron et al. (1995b)				
	61190		7.49		Finley et al. (1997)				
	61700	1500	7.61	0.10	average	0.47	0.07	7.27	0.21
`0644+375`	21190		8.06		Finley et al. (1997)				
	21060		8.10		Bergeron et al. (1992)				
	21120	300	8.08	0.05	average	0.80	0.04	8.29	0.05
`1134+300`	21030		8.41		Finley et al. (1997)				
	21690		8.48		Bergeron et al. (1992)				
	21360	400	8.45	0.05	average	0.98	0.04	8.56	0.05
`1142-645`	7800	200			Koester et al. (1982)	0.61	0.04	8.02	0.05
`1314+293`	50820	1000	7.99	0.10	Finley et al. (1997)	1.05	0.13	8.67	0.24
	49000		7.70		Napiwotzki et al. (1993)				
`1327-083`	13500		7.99		opt				
	14130		7.98		IUE				
	14100		7.93		Bergeron et al. (1995b)				
	13910	400	7.97	0.05	average	0.48	0.05	7.74	0.08
`1337+705`	20440		7.87		Finley et al. (1997)				
	20230		7.90		Bergeron et al. (1992)				
	20330	400	7.88	0.05	average	0.66	0.06	8.05	0.07
`1544-377`	11270	300	8.09	0.05	opt	0.63	0.03	8.05	0.04
`1620-391`	23230		8.13		opt				
	25280		7.97		Finley et al. (1997)				
	24250	1000	8.05	0.10	average	0.66	0.04	8.04	0.05
`1647+591`	12970		8.17		opt				
	12230		8.20		IUE				
	12460		8.29		Bergeron et al. (1995a)				
	12550	500	8.22	0.07	average	0.79	0.04	8.30	0.04
`1917-077`	10800	760			Leggett (1989)				
	9700	300			Koester et al. (1982)				
	10250	500			average	0.57	0.10	7.95	0.12
`2032+248`	19770		7.94		opt				
	19920		7.84		Finley et al. (1997)				
	19980		7.83		Bergeron et al. (1992)				
	19890	300	7.87	0.05	average	0.59	0.03	7.94	0.04
`2039-202`	18780		7.97		opt				
	19900		7.93		Bergeron et al. (1992)				
	19340	500	7.95	0.05	average	0.58	0.07	7.92	0.10
`2117+539`	13910	400	7.81	0.05	opt				
`2149+021`	17070		7.96		opt				
	18250		8.02		Bergeron et al. (1992)				
	17660	500	7.99	0.05	average	0.53	0.09	7.84	0.13

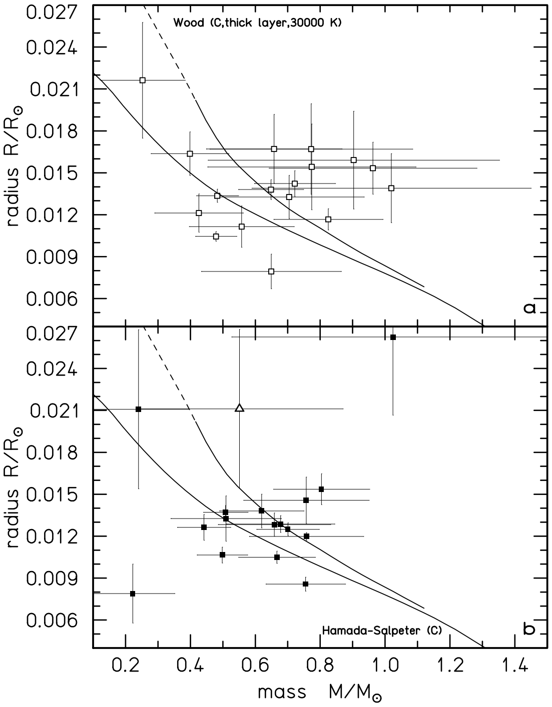

Fig. 4a and b. Empirical masses and radii for the DA white dwarfs determined with **a** ground-based and **b** HIPPARCOS parallaxes in comparison to the zero temperature relation of Hamada & Salpeter (1961) and the evolutionary models of Wood (1994) for a carbon white dwarf with $T_{\rm eff}$=30000 K with a thick hydrogen layer. The single triangle in **b** marks the position of Feige 24, assuming the higher surface gravity from Marsh et al. 1996

With 20 derived mass values this is of course too small a sample to study the mass distribution of white dwarfs, although the typical well-known features of this distribution with a strong peak around 0.6 $M_\odot$ are obvious. The straight, unweighted average of all values is 0.65 $M_\odot$; if we drop HZ 43 from the list this changes to 0.63 $M_\odot$.

In Fig. 5 we give a more detailed account of the individual changes brought by the new parallaxes.

4. Empirical mass - radius relation for DA white dwarfs

If we use the radii as determined above from parallaxes *and* the spectroscopic surface gravities we can also determine masses independent of any theoretical mass - radius relation and use the results as an empirical test. The pre-HIPPARCOS situation of empirical masses and radii in comparison with the theoretical mass - radius relation is discussed in Schmidt (1996). The observations are found to show a large scatter around the theoretical relation due to the uncertainties of the observations, especially the parallaxes. It was our hope that a large improvement could be expected at least for the white dwarfs on the HIPPARCOS input list.

The resulting masses and radii of DA white dwarfs obtained with the HIPPARCOS parallaxes in combination with the adopted atmospheric parameters (average values in Table 2) are given in Table 3. The errors are the usual one sigma confidance intervals. The uncertainties in mass and radius with the HIPPARCOS measurements are slightly smaller, if we consider the average value of the whole set. However, for individual objects this is not always the case and some recent ground-based parallaxes exceed the HIPPARCOS accuracy.

In Fig. 4 we show the results in graphical form, comparing the pre-HIPPARCOS situation with the new results. If we exclude the two most discrepant objects, the general agreement between empirical and theoretical mass - radius relations has become much better. In most cases the deviation of an object from the theoretical relation has become smaller with the new parallax measurements. Especially WD 0227+050, WD 0310-688, WD 1134+300, WD 1544-377, WD 1620-391, WD 2039-202 are nice examples where the empirical situation has improved and the objects are shifted towards the theoretical relation. Other objects (like WD 0148+467, WD 0644+375, WD 2032+248) have not changed much their position, while in a few cases (e.g. WD 1327-083 and WD 2149+021) the objects even have moved further away from the theoretical relation.

For G 191-B2B (WD 0501+527) we now obtain a real disagreement. With the ground-based parallax for the companion (Van Altena et al. 1995), G 191-B2B falls between the relation of Hamada & Salpeter (1961) and Wood (1994), despite its rather high $T_{\rm eff}$ of 62000 K. With the HIPPARCOS parallax its position is far away from the theoretical relations, although due to the relatively high uncertainty of the parallax measurement, it is still compatible with the theoretical relation. If we use the spectroscopic solution for $T_{\rm eff}$ and $\log g$ and Wood's relation, we can determine a spectroscopic parallax of 20 mas, which is just compatible at the 1 σ level with both the ground-based and HIPPARCOS parallax.

Another discrepant case is HZ 43 (WD 1314+293). It has moved from above the relation to very small masses and radii with the new parallax. If we adopt the atmospheric parameters from Napiwotzki et al. (1993) we get an even lower value for the mass. As we have discussed above, we assume that in this case the HIPPARCOS parallax measurement is affected by the close companion.

The position in the mass - radius diagram of Feige 22 (WD 0227+050) indicates that the parallax value given by Van Altena et al. (1995) seems to be wrong.

The situation for Feige 24 (WD 0232+035) has not changed much with the new parallax value. With the atmospheric parameters from Finley et al. (1997) the deduced mass is inconsistent with the minimum mass of $M = 0.438\ M_\odot$ derived from orbital parameters of this close binary system (Vennes & Thorstensen 1994). If we adopt the values from Kidder (1991) or Marsh et al. (1996), both having a significantly higher $\log g$, we get a mass of 0.478 $M_\odot$ or 0.551 $M_\odot$. With the atmospheric parameters of Marsh et al. (1996) Feige 24 (triangle in Fig. 4b) lies almost on the Wood relation for carbon white dwarfs with thick hydrogen layers at $T_{\rm eff}$ = 63000 K (not shown in the figure). However, in this case the mass would be incompatible with the range found by Vennes & Thorstensen (1994). This indicates that the true parallax is very likely close to the upper limit of the error range

Table 3. Resulting values for masses (in $M_\odot$) and radii (in 1/100 $R_\odot$) obtained for the 17 DA from the atmospheric parameters with ground-based and HIPPARCOS parallaxes.

WD - number	ground-based parallaxes				HIPPARCOS parallaxes			
	M	ΔM	R	ΔR	M	ΔM	R	ΔR
0148 + 467	0.704	0.230	1.327	0.155	0.659	0.173	1.283	0.083
0227 + 050	0.426	0.136	1.212	0.137	0.509	0.170	1.326	0.162
0232 + 035	0.252	0.131	2.162	0.414	0.240	0.154	2.108	0.569
0310 − 688	1.019	0.430	1.390	0.247	0.757	0.176	1.198	0.028
0501 + 527	0.398	0.120	1.637	0.156	1.024	0.497	2.625	0.559
0644 + 375	0.479	0.063	1.045	0.035	0.498	0.077	1.065	0.057
1134 + 300	0.649	0.215	0.794	0.124	0.755	0.122	0.857	0.050
1314 + 293	0.903	0.449	1.591	0.350	0.222	0.129	0.789	0.211
1327 − 083	0.648	0.100	1.380	0.071	0.804	0.148	1.536	0.111
1337 + 705	0.772	0.312	1.670	0.324	0.442	0.082	1.263	0.093
1544 − 377	0.558	0.161	1.115	0.148	0.700	0.096	1.249	0.046
1620 − 391	0.962	0.320	1.533	0.186	0.678	0.167	1.287	0.060
1647 + 591	0.825	0.168	1.167	0.076	0.666	0.118	1.049	0.044
2032 + 248	0.483	0.064	1.336	0.047	0.508	0.068	1.371	0.049
2039 − 202	0.774	0.321	1.542	0.307	0.620	0.130	1.380	0.121
2117 + 539	0.658	0.209	1.671	0.247				
2149 + 021	0.722	0.125	1.423	0.092	0.757	0.193	1.457	0.166

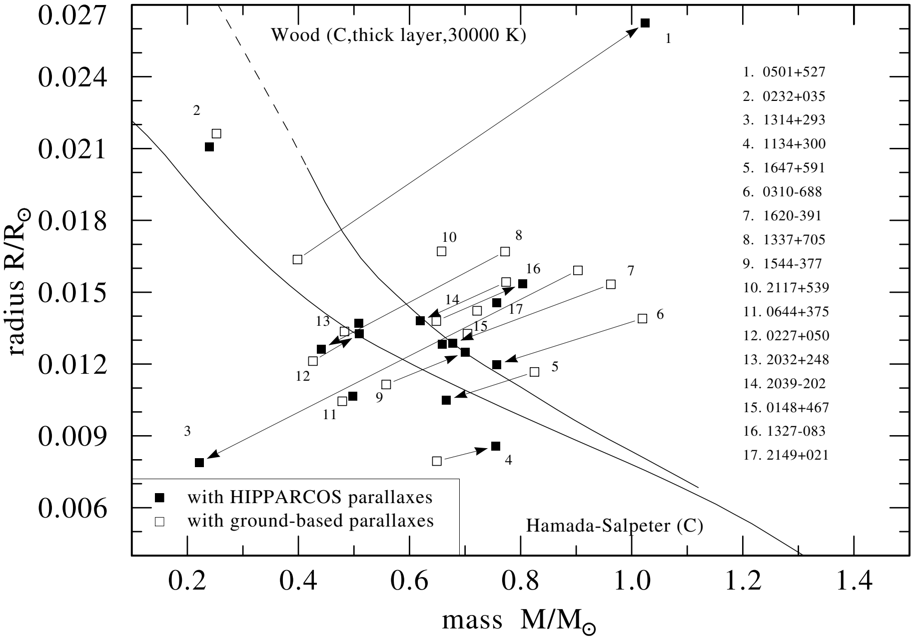

Fig. 5. Comparison of masses and radii obtained with ground-based and HIPPARCOS parallaxes for the 17 DA. The masses are calculated via surface gravity. The arrow shows the change from the position with the ground-based parallax to the position calculated with the HIPPARCOS parallax.

and a consistent solution could be found for an intermediate mass and gravity.

5. Conclusions

HIPPARCOS measurements have improved the parallaxes for 20 white dwarfs compared to the available data ten years ago. Although in the meantime ground-based parallax measurements using CCD detectors and dedicated telescopes have also made great progress, sometimes reaching or even exceeding the accuracy of the HIPPARCOS data, there is still substantial progress in the agreement between empirical and theoretical relations. Together with the improvements in spectroscopic observations and analysis we are confident to know the fundamental parameters mass, radius, and luminosity for typical bright white dwarfs with good precision. If we exclude two or three objects with known problems the agreement between spectroscopic surface gravities and those derived using parallax and mass - radius relation is reasonable, although the errors given in the literature are slightly too optimistic.

The data are generally in agreement with mass - radius relations within the errors, although an empirical verification of the differences between zero - temperature and evolutionary sequences, or between “thin” and “thick” hydrogen layers still seems out of reach.

Acknowledgements. D.K. wants to thank the Deutsche Forschungsgemeinschaft for a travel grant to Calar Alto. G.V. and N.F.A. thank CNRS for financial support through the “HIPPARCOS GDR”.

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