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Infrared flux excesses from hot subdwarfs*

II. 72 more objects**

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Abstract. In our search, started in February, 1994, for JHK excess fluxes among the hot subdwarf population as an indicator for the presence of binary companions, results for 72 more hot objects (=63 hot subdwarfs + 1 Horizontal Branch B star + 7 white dwarfs + 1 non-subdwarf object) observed with the *Carlos Sánchez* CVF IR photometer (in June and October, 1994), are presented. The exact number of binary hot subdwarfs has gained renewed importance after the recent discovery of pulsators with G-F companions. The total number of candidates we propose may help to set some constraints; for example, out of 41 objects with excesses, 13 may have G-type binary companions. From our new sample, 14 discoveries of binary candidates have been found: BD+25 4655, Feige 108, HD 4539, HD 149382, HD 216135, KPD 2109+440, LSI+63 198, LSIV+10 9, LSV+22 38, PG 0011+221, PG 0116+242, PG 0314+103, PG 2151+100 and TON 139. Besides, 2 more from reanalysis of February, 1994, data – BD+37 1977 and BD+48 1777, may now be found to be IR excess candidates. Two suspected binaries, PB 8555 and SB 7, are also confirmed. By fitting Kurucz (1993) model spectra and assuming zero-age main sequence companions, we find upper limits on the subdwarf gravities. The distributions of upper limits on $\log(g)$, mostly between about 5.25 and 6.5, are nearly identical for both sdBs and sdOs.

Key words: surveys — stars: subdwarfs — binaries: spectroscopic — white dwarfs — infrared: stars

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* Based on observations made with the Carlos Sánchez Telescope operated on the island of Tenerife by the Instituto de Astrofísica de Canarias in the Spanish Observatorio del Teide.
** Figure 1 is only available in the electronic version of the paper (http://www.edpsciences.com)

1. Introduction

Thejll et al. (1995; hereafter Paper I) discussed the possible origin for excess infrared fluxes detected from the direction of a hot subdwarf star (sd). They presented a set of JHK measurements for 27 hot objects: 23 hot sds, GD274 –which the authors reclassify as sd+K3-K8, and 3 white dwarfs (WDs). An analysis was also presented for the, then 24, hot subdwarfs. After considering a wind expelled from the hot atmosphere as the source of the excess IR radiation, the authors concluded that the most likely explanation is the presence of a cool stellar companion giving rise to the observed excess. With the aid of comprehensive literature and database searches, several well known cases were corroborated, suspected cases confirmed and new discoveries uncovered.

The point in studying companions to hot subdwarfs is that we can learn things about the hot subdwarfs that are not easy to observe directly due to the problems of modeling hot atmospheres and the relatively large distances to these stars that preclude some astrometric analysis for the majority of these stars. Parallaxes are hard to measure but some are expected from the *HIPPARCOS* data for a small number of close stars. Proper motion analysis has been performed by Thejll et al. (1997) Spectral analyses of hot subdwarf B stars (e.g. Saffer et al. 1994) and sdO stars (Thejll et al. 1994a) exist. Our work presents an investigation on the properties of the companion stars, and the hot subdwarf properties that can be inferred from these.

Following a similar approach to that in Paper I, the results presented here relate to 72 more stars (63 hot sds; 1 Horizontal Branch B (HBB) star – PG 0342+026; 7 WDs; and the non-sd object PHL 382 – Kilkenny, private communication) observed with the same telescope and instrumentation. In the present paper, among other means of analysis, they are analysed following the methods described in Paper I but the UV, optical and IR fluxes are

Table 1. List of observed objects. Most common names, spectral type, coordinates (Epoch 1950.0 or stated otherwise), temperatures and gravities available in the literature, or estimated in this paper from published photometry and UV fluxes, together with source references for program stars, are given. Notes: ⋆=2000.0 coordinates; 1=This work; pI=Thejll et al. (1995); A94=Allard et al. (1994); BH95=Bauer & Husfeld (1995); Bo94=Bowyer et al. (1994); D90=Dreizler et al. (1990); D93=Dreizler (1993); G80=Giddings (1980); GS74=Greenstein & Sargent (1974); H86=Heber (1986); HB95=Hurwitz & Bowyer (1995); HL86=Heber & Langhans (1986); Je92=Jeffery et al. (1992); Ji94=Jiménez et al. (1994); K=Kilkenny, private communication; Ma95=Marilli et al. (1995); Mo90=Moehler et al. (1990); N93a=Napiwotzki (1993a); N93b=Napiwotzki (1993b); P70=Peterson (1970); S94=Saffer et al. (1994); T93=Theissen et al. (1993); T95=Theissen et al. (1995); Th96=Thejll, Husfeld & Saffer (unpublished work); To70=Tomley (1970); V91=Viton et al. (1991); Ve93=Vennes et al. (1993); Ve94=Vennes et al. (1994); Wo96=Wolff et al. (1996). Temperatures in parenthesis indicate that there is not enough data to asses the temperature but that an estimate has been made on the basis of literature spectral classes - thus any un-analyzable sdO is set to 40000 K while all un-analyzable sdB or sd are set to 20000 K. HD 113001 and GD 274 were observed in February (1994)

Object	Sp. type	hh	mm	ss	°	′	″	$T_{\rm eff}$	log(g)	ref.
hot sds/HBB previously unknown as binaries										
BD +25 4655	sdO	21	57	25.05	+26	11	34.8	42	6.7	P70
BD +39 3226	sdOp	17	44	52.66	+39	20	11.8	45	5.5	G80
Feige 11	sdB	01	01	46	+03	57	35	28.4	5.63	S94
Feige 65	sdB	12	33	27	+42	39	13	26.5	5.6	S94
Feige 108	sdB	23	16	12	−01	50	35	34.5	6.01	S94, ⋆
Feige 110	sdO	23	17	23.5	−05	26	22	42	5.9	Th96
HD 4539	sdB	00	47	29.2	+09	58	56.4	25-30,27	5,5.46	HL,S94,⋆
HD 149382	sdB	16	31	45.25	−03	54	40.9	34.2	5.89	S94
HD 216135	sdB/sdBk/sdB5	22	47	50.0	−13	34	20	15	-	1
HZ 3	sdO	03	53	32	+10	46	02	46	7:	GS74,⋆
HZ 44	sdO/sdO8p	13	21	18.8	+36	23	37	40	5.3 − 5.7	GS74, P70
KPD2109+440	sdB	21	09	56	+44	01	36	25	-	1
LSI+63 198	sdO	03	24	42	+63	54	20.1	34	5.4	GS74
LSIV−14 116	sdOB/sdO He	20	54	53	−14	37	26	35	-	1
LSIV+00 21	sdB	20	28	45.3	+00	55	12	34	-	1
LSIV+10 9	sdO	20	40	36	+10	23	19.8	45	5.6	D93
LSV+22 38	sdO	06	13	12	+22	46	54	(40)	-	1
PG 0011+221	sd	00	11	43.7	+22	07	41	30	-	1
PG 0116+242	sd	01	16	46.6	+24	09	48	14	-	1
PG 0122+214	sd	01	22	44.4	+21	21	13	19	-	1
PG 0133+114	sdB/sd	01	33	47	+11	24	14	26	4.9	Mo90
PG 0215+183	sdB	02	15	28.6	+18	18	04	22	-	1
PG 0242+132	sdB	02	42	54.7	+13	13	27	31.2	5.65	S94
PG 0314+103	sdB	03	14	59.2	+10	19	57	18	-	1
PG 0342+026	HBB	03	42	58	+02	38	36	26.2	5.67	S94
PG 0856+121	sdB	08	56	18.8	+12	08	06	26.4	5.73	S94
PG 1338+481	sdB	13	38	05.7	+48	07	41	25	-	1
PG 1409+605	sdB-O	14	09	31.5	+60	28	29	22	-	1
PG 2111+023	HBB/sdB	21	11	10.5	+02	20	43	15	-	1
PG 2128+146	sd	21	28	55.7	+14	36	11	14	-	1
PG 2151+100	sd	21	51	21.8	+10	01	14	27	-	1
PG 2158+082	sdO He/sdO	21	58	25.8	+08	14	04	67	5.5	D90
PG 2159+051	sd	21	59	20.3	+05	07	47	15	-	1
PG 2218+020	sdB-O	22	18	52	+02	01	07	20	-	1
PG 2318+239	sd	23	18	36.5	+23	54	08	16	-	1
PG 2321+214	sdO(D)/?	23	21	57.6	+21	22	23	43	-	Th96
PG 2345+241	sdB-O	23	45	50.3	+24	06	25	20	-	1
PG 2352+181	sdO He/sdO(B)	23	52	44.2	+18	03	36	55	6.4	Th96
PHL 25	sdB	21	31	58	−17	18	43	19	-	1, ⋆
PHL 678	sdB/sdB-O	00	04	59	+13	19	10	25	4.5	Mo90
PHL 2726	B/sd	00	09	54	+03	37	46	15	-	1
SB 395	sdB	00	56	48	−18	33	00.4	15	-	1
TON 139	sdB	12	53	39.6	+28	23	31	18	-	1
TON 209	sdB/sdOp	14	33	05.0	+23	58	31	29.6	5.57	S94
TON 245	sdB	15	38	24	+26	57	00.0	25.2	5.30	S94
TON 788	sdB	15	12	21	+24	21	43	25	-	1
UVO0653−23	sdB	06	53	12.7	−23	28	21	15	-	1

Table 2. List of observed objects (continuation). †=S94 reports 29700 K and log(g)=4.6 but that would make the contribution from the companion star so dominant in the optical range that the spectral analysis by S94 is meaningless

Object	Sp. type	hh	mm	ss	°	′	″	$T_{\rm eff}$	log(g)	ref.
known or suspected hot sd binaries										
BD−3 5357	sdOB+G8III/e.bin.	21	58	00.87	−02	58	52.7	35−40	-	Ma95
BD−7 5977	sdOB+F8-G0V	23	15	11.6	−06	44	56	31	-	V91
BD−11 162	sdO+G	00	49	43.8	−10	56	14	35	5.9	1
BD +28 4211	sdO+G	21	48	57.5	+28	37	44	82	6.2	N93a
BD +29 3070	sdOB+F	17	36	22.3	+29	10	29	18	-	1
GD 274	sd+K3-K8	01	04	14	+50	54	25	18.5−25	4.5−7	pI
HD 45166	B8V+(sdO/qWR)	06	23	36.0	+08	00	16	40	-	1
HD 113001	sdO+F/v.bin.	12	58	05	+36	01	32	41, 41−50	5.7, 6.0	To70,pI
HD 185510	sdB+K0III-IV	19	36	58.42	−06	10	44.8	25	∼6	Je92
MRK509C	sdO+K9-M1	20	43	59.0	−10	47	42	42.5	-	Ji94
PB 8555	sd+F?	01	07	44	−14	24	00.0	(20)	-	1
PG 2102+037	sdO/comp.	21	02	36.3	+03	42	43	≥80	-	Th96
PG 2110+127	sdB+G6IV	21	10	56.4	+12	44	44	33.7, 30	5.33, 5.0	S94,T93
PG 2118+126	sdB+K2	21	18	37.9	+12	38	03	26.5	-	A94
PG 2148+095	sdB+K3	21	48	41.2	+09	30	39	25	-	1
PG 2219+094	sdB+(Ca K)	22	19	30.0	+09	22	21	21	-	1, †
PG 2229+099	HBB/sdB+(Ca K)	22	29	39.2	+09	58	58	18.1	3.9	S94
PHL 1079	sdB+G8IV	01	35	48	+03	23	00.0	30	5.25	T95
SB 7	sdB/bin?	00	00	48	−16	37	00.0	55	-	H86
CSPN										
BD−13 842	CSPN	04	11	57.0	−12	51	42	70	4.6	BH95
BD +33 2642	CSPN	15	50	02.0	+33	05	56			N93b
WDs and others										
Feige 24	DA+dM	02	32	31	+03	30	06			Ve94
G191−B2B	DAw+sdK4pec	05	01	31	+52	44	48			HB95
GD 246	DAw	23	12	23	+10	46	07			⋆,Ve93
J0633+104	DA	06	33	53	+10	42	06			⋆,Bo94
J2013+400	DA+dM4	20	13	08	+40	02	36			⋆,Bo94
J2210−300	WD/vis. bin	22	10	29	−30	05	48			⋆,Bo94
PG 1234+482	DA	12	34	23	+48	11	54			Wo96
PHL 382	non-sd	22	40	30	−15	06	46	19	-	K

interpreted with the aid of Kurucz spectral models - in Paper I black body (BB) functions were used. Objects in Paper I are therefore reanalyzed and the corresponding results included here. Out of the 99 (=27 + 72) stars observed with the CST in 1994, the total number of hot subdwarf/HBB stars studied, i.e., 88 (=23 + GD 274, from February, + 63 + PG 0342+026, from June and October), basically corresponds to the total possible number of this kind of objects observable, as extracted from Kilkenny et al. (1988), given the limiting magnitude of the instrument employed (∼13.5 mag in K). This total sample is, to our knowledge, the most complete JHK hot subdwarf catalogue available to date. Most of these targets are observed at IR wavelengths for the first time. Tables 1 and 2 present the 72 objects added in the present work.

Our paper consists of a part presenting the JHK observations and two analysis parts. The reader is referred to Paper I for details of these methods. The JHK observations and the reduction procedure are discussed in Sect. 2. Compilation of optical and UV data, and treatment of the latter, is described in Sect. 3. The detection and extraction of excess fluxes using estimates of the $T_{\rm eff}$ of the hot subdwarf is discussed in Sect. 4. We then proceed in Sect. 5 to analyze the excesses and calculate the gravities of the hot subdwarfs assuming that stellar companions are zero-age main sequence (ZAMS) stars. Section 6 presents a summary and discussions.

2. IR observations and data calibration

The JHK photometry was obtained for the objects in Tables 1 and 2 with the 1.5 m *Carlos Sánchez* Telescope (CST) (Arribas & Martínez-Roger 1987) at the Observatorio del Teide (Tenerife), in June and October, 1994. Targets were chosen as in Paper I, with less emphasis on reproducing measurements in Probst (1983). A few WD targets were included. Their analysis will be presented elsewhere (Vennes et al. 1998). GD 274 was observed nightly, in October 1994, to check for reproducibility of results, and the distribution of the measurements are fully consistent with the photometric errors of each measurement.

Table 3. Results from the June 1994 run at the CST. Each entry is the result of averaging of 3 or more integrations. When several entries are given, separate integration-series were performed. [a] after an object's name means weighted average of all its JHK measurements as given in Tables 3, 4 and 5

Object	J	σ_J	H	σ_H	K	σ_K
hot sds previously unknown as binaries						
BD +39 3226	10.80	0.05	10.99	0.04	11.11	0.03
Feige 65	12.48	0.23	12.65	0.17	12.69	0.26
HD 149382	9.39	0.03	9.35	0.02	9.36	0.03
HZ 44	12.20	0.02	12.85	0.02	12.83	0.02
HZ 44	12.20	0.16	12.60	0.12	12.28	0.17
HZ 44[a]	12.20	0.02	12.84	0.02	12.82	0.02
LSIV+00 21	12.74	0.34	12.72	0.18	12.86	0.27
LSIV+00 21	13.88	0.73	12.79	0.18	12.59	0.27
LSIV+00 21[a]	12.94	0.31	12.76	0.13	12.72	0.19
LSIV+10 9	11.15	0.03	10.98	0.05	10.90	0.05
PG 1338+481	14.85	1.67	14.05	0.68	14.68	1.57
PG 1409+605	13.80	0.50	13.29	0.19	13.90	0.65
PG 2151+100	12.39	0.57	11.49	0.06	11.23	0.06
PG 2151+100	11.86	0.08	11.48	0.04	11.40	0.11
PG 2218+020	14.35	0.38	14.63	0.76	15.05	1.63
TON 139	12.10	0.15	11.92	0.08	11.93	0.16
TON 209	13.46	0.53	13.34	0.28	13.68	0.82
TON 245	13.75	0.35	14.32	0.42	14.85	0.59
TON 788	13.81	0.30	13.78	0.24	14.72	0.96
known or suspected hot sd binaries						
BD−3 5357	7.28	0.01	6.74	0.01	6.59	0.01
BD +28 4211	11.26	0.15	11.17	0.09	11.28	0.08
BD +28 4211	11.23	0.11	11.36	0.14	11.75	0.36
BD +28 4211[a]	11.24	0.09	11.23	0.08	11.30	0.08
BD +29 3070	9.74	0.01	9.55	0.01	9.54	0.03
HD 113001	9.02	0.02	8.83	0.01	8.80	0.01
HD 113001	9.07	0.01	8.87	0.01	8.84	0.02
HD 113001[a]	9.06	0.01	8.85	0.01	8.81	0.01
HD 185510	6.09	0.02	5.52	0.01	5.38	0.01
HD 185510	6.10	0.02	5.53	0.01	5.37	0.01
HD 185510	6.23	0.01	5.69	0.03	5.43	0.01
HD 185510[a]	6.18	0.01	5.53	0.01	5.39	0.01
MRK509C	12.67	0.45	12.20	0.22	12.00	0.20
MRK509C	12.90	0.34	13.48	0.32	14.03	1.26
MRK509C	13.95	0.74	13.62	0.29	13.22	0.49
MRK509C[a]	12.95	0.26	12.83	0.15	12.25	0.20
PG 2102+037	14.92	2.79	13.10	0.24	13.70	0.97
PG 2110+127	12.42	0.29	11.99	0.12	12.23	0.21
PG 2110+127	12.17	0.12	12.11	0.12	12.11	0.12
CSPN						
BD +33 2642	11.09	0.05	11.08	0.02	11.11	0.07
DA WD						
PG 1234+482	14.24	0.68	14.83	1.19	15.80	3.97

Table 4. Results from the October 1994 run at the CST. Notation is as in previous tables

Object	J	σ_J	H	σ_H	K	σ_K
hot sds previously unknown as binaries						
BD +25 4655	10.39	0.02	10.52	0.01	10.58	0.03
Feige 11	12.78	0.14	12.98	0.37	13.65	1.07
Feige 108	13.63	0.15	13.01	0.25	12.88	0.32
Feige 110	12.40	0.07	12.80	0.09	12.65	0.10
HD 4539	10.82	0.04	10.93	0.03	10.96	0.03
HD 216135	10.29	0.04	10.41	0.04	10.46	0.06
HZ 3	13.21	0.44	13.59	0.34	13.55	0.48
KPD2109+440	10.04	0.05	8.90	0.02	8.59	0.01
LSI+63 198	7.30	0.02	6.64	0.01	6.50	0.02
LSIV−14 116	12.74	0.27	14.20	0.69	14.36	4.12
LSV+22 38	8.29	0.01	7.94	0.01	7.74	0.01
LSV+22 38	8.45	0.04	8.10	0.04	7.93	0.04
LSV+22 38	8.47	0.02	8.07	0.03	7.88	0.03
LSV+22 38[a]	8.33	0.01	7.96	0.01	7.76	0.01
PG 0011+221	12.91	0.14	13.05	0.12	13.31	0.26
PG 0116+242	10.88	0.02	10.57	0.02	10.46	0.05
PG 0122+214	12.97	0.16	13.50	0.24	12.85	0.30
known or suspected hot sd binaries						
BD−7 5977	8.97	0.02	8.48	0.01	8.38	0.01
BD−11 162	10.81	0.03	10.64	0.03	10.61	0.03
GD 274	11.33	0.07	10.93	0.03	10.88	0.04
GD 274	11.26	0.07	10.96	0.03	10.79	0.07
GD 274	11.27	0.09	10.94	0.04	10.84	0.06
GD 274	11.30	0.02	10.94	0.02	10.97	0.04
GD 274	11.30	0.10	10.96	0.04	10.85	0.04
GD 274	11.35	0.05	11.02	0.02	10.88	0.04
GD 274	11.37	0.12	10.89	0.05	11.19	0.23
GD 274	11.41	0.09	10.92	0.05	10.74	0.07
GD 274[a]	11.31	0.02	10.96	0.01	10.88	0.02
HD 45166	10.18	0.03	10.12	0.03	10.00	0.05
PB 8555	11.30	0.04	11.07	0.03	10.94	0.04
CSPN						
BD−13 842	11.16	0.02	11.36	0.06	10.83	0.08
WDs and others						
Feige 24	11.17	0.07	10.68	0.03	10.45	0.09
G191-B2B	12.48	0.11	12.56	0.11	12.48	0.16
GD 246	13.42	0.13	14.35	0.47	14.69	1.01
J0633+104	14.03	0.86	15.93	1.36	16.22	5.95
J2013+400	15.39	2.39	14.12	0.40	13.13	0.31
J2210-300	12.55	0.14	12.43	0.15	12.16	0.27

Table 5. Results from the October 1994 run at the CST (continuation)

Object	J	σ_J	H	σ_H	K	σ_K
hot sds/HBB previously unknown as binaries						
PG 0133+114	12.77	0.10	12.88	0.16	12.40	0.19
PG 0133+114	12.78	0.06	14.68	0.13	12.72	0.11
PG 0133+114	13.08	0.41	13.15	0.47	12.37	0.64
PG 0133+114[a]	12.78	0.51	13.93	0.10	12.63	0.09
PG 0215+183	13.50	0.25	13.97	0.26	14.12	0.54
PG 0242+132	13.69	0.51	13.23	0.27	13.89	1.30
PG 0242+132	13.34	0.60	13.79	0.37	13.03	1.44
PG 0242+132[a]	13.54	0.39	13.42	0.22	13.50	0.96
PG 0314+103	12.49	0.12	11.91	0.05	11.65	0.08
PG 0342+026	11.67	0.08	11.89	0.13	11.86	0.20
PG 0856+121	13.42	0.44	13.59	0.22	13.84	0.55
PG 2111+023	13.26	0.42	13.17	0.19	14.35	3.60
PG 2128+146	13.16	0.21	13.50	0.15	14.11	1.56
PG 2151+100	12.60	0.08	12.50	0.08	13.67	0.75
PG 2151+100[a]	12.23	0.06	11.63	0.03	11.28	0.05
PG 2158+082	12.89	0.22	13.51	0.35	13.46	1.35
PG 2159+051	13.14	0.17	13.07	0.15	13.68	0.56
PG 2318+239	14.04	0.57	14.28	0.40	13.90	0.54
PG 2321+214	14.17	0.48	14.26	0.31	14.04	0.31
PG 2345+240	13.21	0.52	12.50	0.20	–	–
PG 2352+181	13.36	0.68	15.09	1.67	12.83	1.05
PHL 25	12.38	0.08	12.49	0.08	13.00	0.30
PHL 678	13.06	0.19	13.13	0.14	14.34	1.35
PHL 2726	13.21	0.27	13.15	0.13	13.95	0.72
SB 395	12.89	0.14	13.03	0.11	13.23	0.23
UVO0653-23	9.93	0.03	10.07	0.04	10.08	0.05
known or suspected hot sd binaries						
PG 2110+127	12.29	0.08	12.09	0.07	12.09	0.14
PG 2110+127[a]	12.26	0.07	12.07	0.05	12.12	0.08
PG 2118+126	12.71	0.11	12.69	0.10	12.66	0.18
PG 2148+095	12.18	0.11	12.34	0.17	12.06	0.40
PG 2219+094	12.21	0.09	12.24	0.06	12.26	0.14
PG 2229+099	13.39	0.16	13.61	0.17	13.34	0.43
PHL 1079	12.55	0.17	12.23	0.06	12.04	0.08
SB 7	12.79	0.31	12.43	0.07	12.54	0.18
non-sd						
PHL 382	11.53	0.05	11.62	0.05	11.64	0.08

Table 6. Table of large-aperture *IUE* spectra used in this work. "SWP", "LWP" and "LWR" respectively indicate spectra taken with the short and long wavelength primary, and redundant cameras. Results of reddening analysis of suitable *IUE* spectra are also included. In spectra where reddening is not readily apparent an upper limit of $E(B-V) \leq 0.025$ is assigned. The uncertainties given are estimated visually and correspond roughly to 2 or 3 sigma intervals. For PHL 678 only an approximate value can be given for the large reddening - for smaller values the "2200 Å bump" is still very clear and for larger values over-correction takes place, yet the correction at $E(B-V) = 0.2$ is not perfect

Object	$E(B-V)$	SWP	LWP/LWR
hot sds/HBB previously unknown as binaries			
BD +25 4655	≤0.025	05640,01651	03387,04890
BD +39 3226	≈0.025	04312	01856
Feige 11	≤0.025	39423,34202-4,36961-3, 39599,03736	18543,14018-20,16303-5, 18720,03319
Feige 65	≤0.025	21374	02149
Feige 108	≤0.05	17012,17285	13288,13548
Feige 110	≤0.025	21892	02506
HD 4539	≤0.025	26276	07169
HD 149382	≤0.025	27583,27620,20343	07581,16265
HZ 3	0.17 ± .03	03805,06119,06120	03386,05301
HZ 44	≤0.025	27240,27242-3	07275,07277
LSIV−14 116	≤0.025	31029	10814
LSIV+00 21		37610	
LSIV+10 9	0.05 ± .03	14813	11413
PG 0342+026	0.07 ± .03	27467	07462
PG 0856+121	≤0.025	23159	03484
PG 2111+023		41574	
PG 2158+082		33793	
PG 2318+239	0.05 ± .03	42339	21099
PG 2321+214	0.1 ± .03	39208	18329
PHL 25	0.025 ± .02	23352	03658
PHL 678	≈0.2	39286	18429
PHL 2726	≤0.025	40520	19505
TON 209	≤0.025	03722	03302
TON 245		30874,28889	
known or suspected hot sd binaries			
BD−3 5357	0.05 ± 0.02	33871	13577
BD−7 5977	≤0.025	31030	10815
BD−11 162	≤0.025	14288,01666,04105	03323,03324
BD +28 4211	≤0.025	18899,24727,20317, 21088,23273	17446,14935,16241, 16822,17564
BD +29 3070	≤0.025	20344	16266
HD 45166	0.15 ± .03	18187,20907,17861, 17969,18009,42523	16725,14102,09705
HD 185510	0.1 ± .05	29411,29437,32145, 32157,32180	09281,14637,11937, 11947,11972
PG 2110+127	0.1 ± .03	41573	20310
PG 2219+092	0.025 ±. 02	39206	18328
PHL 1079	0.025 ±. 02	42338	21098
SB 7	≤0.025	20559	16496

A 15″ aperture was again employed with typical exposures of $2 - 4$ minutes for each filter for single integrations. Averaged JH and K magnitudes are presented in Tables 3, 4 and 5 together with their corresponding 1 σ counting-statistic uncertainties. Typical signal-to-noise ratios are at least 5, and often higher. IR standard stars were observed nightly for calibration (Kidger et al. 1992) and standard reductions were performed using the ESO **Snopir** software written by Olivia, Barbier, Schmider & Bouchet (P. Bouchet, private communication), available at the Instituto de Astrofísica de Canarias.

The observations were performed in such a way that the $4' \times 4'$ area around each target, monitored in real time on a TV screen at the telescope's control, was carefully compared with a finder chart. Systematic checking of the accuracy of the coordinates was also carried out. As the CST has a high pointing accuracy, this task was in reality reduced to having confidence in the listed coordinates of the objects; we used the compilation by Kilkenny et al. (1988) in its latest corrected version (Heber, private communication) or original publications, aided by usage of SIMBAD, ADS or others. We have only found very few entry errors: only in one case was a possibility for misidentification encountered and the object has been dropped from this work. In no case was the 15″ photometer aperture contaminated by a field source (to a limiting V magnitude of about 15.5).

Our JHK values are plotted – February 1994, targets are not repeated – in Fig. 1, together with the corresponding broad energy distribution (see Sect. 3) for each object except for the CSPNs BD−13 842 and BD+33 2642. Whenever several observations exist, only the weighted average (as marked in Tables 3, 4 and 5) is plotted and further analyzed. The inverse of the square of the error on single measurements was used as weights in deriving the weighted averages. The error bar for the K values (and in a few cases also for the J or H ones) is large in the following cases and has not been plotted, for ease-of-display purposes: Feige 11, LSIV−14 11, PG 0242+132, PG 1338+481, PG 2102+037, PG 2111+023, PG 2128+146, PG 2158+082, PG 2218+022, PG 2345+241, PG 2352+181, PHL 678, TON 788.

After our October observations were done, we were informed by the telescope staff that an occasionally wrongly positioned filter wheel might have affected part of our observations. This is indeed the case and can be clearly seen in Fig. 1 for all those stars where values in one of the JHK filters (mostly the H one) are very different (mostly lower) from the rest than it should be, given the values for the other two. This problem may then have affected at least the following stars: Feige 108, Feige 110, HZ 1, HZ 44, LSIV−14 11, PG 0122+214, PG 0133+114, PHL 25, and PHL 2726.

Of these stars only Feige 108 met the 2σ JHK excess condition (see Sect. 4) and the rest were, therefore, excluded from further analysis. However, potential binary candidates may be hidden among them as seen from their excesses in two of the filters. Special attention should be paid in this regard to PG 0122+214, PG 0133+114, PHL 25, and PHL 2726.

In addition, from visual inspection of Fig. 1, it becomes apparent that several stars with large errors associated to their JHK photometry and/or data with unphysical appearance (i.e., which prevent them from fulfilling the 2σ condition for their eventual excess), could still make good binary candidates – these being independent from and in addition to those displaying the filter wheel problem mentioned above. At least, that could be the case for BD+28 4211, LSIV+00 21, PG 0215+183, PG 0242+132, PG 0856+121, PG 1409+605, PG 2102+037, PG 2111+023, PG 2158+082, PG 2159+051 and PG 2229+099. These stars have also not been analysed in the present paper but we suggest that they, together with the 4 objects mentioned earlier, be investigated in the future.

3. Archival UV and optical data

In order to complement our JHK photometry, and to be able to perform our broad-energy analysis, we have compiled published optical data and UV data from the same sources described in Paper I (see therein for references). Resulting energy distributions are plotted in Fig. 1.

3.1. Optical data

For BD−3 5357 (FF Aqr), Feige 110, HD 4539, PG 0856+121 and the CSPN BD−13 842 – not analysed, the photometric data collected show offsets among the various systems difficult to interpret in terms of observational errors alone. For some of the stars offsets between sets of photometric data suggest that the cause of the differences is not variability in the sources but systematic differences in the observation and reduction techniques employed by the various authors.

3.2. IUE data

After their extraction from the NASA/RDAF data base at Greenbelt (Maryland) and from the Unified Low Dispersion Archive (ULDA) (Wamsteker et al. 1989) at LAEFF (Madrid), we list the *IUE* spectra employed in this work in Table 6. The spectra were chosen with the same criteria given in Paper I and were also processed as there described. Reddening corrections – using Seaton's (1979) law, were also applied when required, given the $E(B-V)$ estimates shown in Table 6. We will not discuss line-profile analysis of the H+HeII line at 1215 Å available in the low-dispersion *IUE* SW spectra collected.

4. Extraction of excess fluxes

Following the same steps as in Paper I, Tables 1 and 2 list the adopted $T_{\rm eff}$ for the objects in this paper, based on the literature and our analysis shown in Fig. 1 (available on line).

Fig. 1. The detected *JHK* fluxes, plotted with available UV and optical data on logarithmic scales. Along the horizontal axis wavelength is plotted in units of Å while the vertical axis shows $\lambda^4 \times F_\lambda$ in units of Å$^4\times$ erg/cm^2/s/Å, along with a model that represents the best estimates of $T_{\rm eff}$. In each frame the object identify is labeled at the bottom. Near the top there is a legend explaining at which wavelength point the model flux was normalized to the observations. A letter code identifies this point; *UBV* refers to Johnson magnitudes, *uvby* to Strömgren data, capital letters subscripted with lower case g refer to Geneva bands and "*IUE*" followed by a number indicates that the *IUE* flux was used at the given wavelength (see Thejll et al. 1995) for details

For extraction of excess IR fluxes we scale an appropriate model spectrum to some point in the range of photometric data that we believe is unaffected by radiation from the companion. We always pick the point at which we do the normalization as redward as possible since picking a point far into the UV range can lead to practical problems if the far-UV flux is heavily depressed by metal opacities. Usually this depression is most severe on the blue side of 2000 Å. The excess in any band, but in particular the JH and K bands is then simply calculated by subtraction of the normalized model flux from the observations. We use the Kurucz (1993) grid of metal-line blanketed model spectra distributed on CD-ROM disks.

Using Kurucz models has obvious advantages over the simple BB analysis of Paper I. However, it also poses two main drawbacks to our study, as follows: i) the maximum effective temperature available is 50000 K; and ii) no He-rich models are available. Both have an impact on our conclusions regarding the claim of excesses (see Table 7) and must be kept in mind when dealing with their interpretation, specially among the hottest O type sds: BD +28 4211, PG 2102+037, PG 2158+082 and PG 2352+181. However, none of these four met the 2σ requirement to be analysed for excess. From the February, 1994, data the following sdO objects had already been found as binary candidates in Paper I: BD+10 2357, Feige 34, Feige 80, GD 299, HD 113001 and HD 128220. But constraints i) and ii) may lessen the now newly discovered excesses for BD +37 1977 and BD +48 1777. On the other hand and in general, where the excesses mainly rest, at the longer wavelengths, for both i) and ii) the impact is the least, as already argued in Paper I.

In converting observed magnitudes into physical absolute fluxes we use the zero-point definitions tabulated by Zombeck (1990) for the *UBVRI* and *JHK* data, while we used Oke & Gunn (1983) for Greenstein multichannel data and Table 7 (first column) in Heber et al. (1984) for *uvby* data (see Paper I). In Table 7 we list the extracted J flux for stars with at least 2 σ significant excesses (in *JHK* simultaneously), and also the calculated $J-H$ and $J-K$ colors of the excesses.

Using the Bessel & Brett (1988) tables of $J-H$ and $J-K$ colors we estimate the range of dwarf spectral classes that correspond to the extracted excess colours. These too are shown in Table 7.

We next derive companion classes for the hot subdwarf by fitting a weighted sum of two model spectra (using Kurucz (1993) models) to the collected and observed photometric data. The fitted weights are proportional to the areas of the stars, so after a successful fit the weight ratio is proportional to the ratio of stellar radii squared. The fit also gives the temperature of the best-fitting cool model. The results are shown in Table 8.

The fitting procedure is a least-χ^2 method and in principle tests the fit of all Kurucz (1993) models against all other models in the grid. In practise we restrict the range of the models to fit since it is prohibitively time-consuming to fit all 3576 Kurucz models against each other – see the caption of the table. The hot model should not be chosen freely as some stars have very accurate atmospheric parameters from the literature and we do not wish to stray far from these values – this is a complicated process as some stars have lots of published photometric data, the fitting of which agrees well with literature values, while other stars have little observed data to work with but may have atmospheric parameters based on spectroscopy, while yet other stars have neither good photometric data nor published atmospheric parameters but only a simple estimate of the spectral type from the literature - frequently based on visual inspections of low dispersion spectra during some classification project.

In a few cases (Feige 80 and GD 299), this method yields a best fit Kurucz effective temperature for the hot component discrepant from previous literature determinations.

In Fig. 2 we compare the dwarf class inferred from extracted colors (Table 7) and fitted models (Table 8). We see that the agreement is quite fair although not complete. Of the 28 stars that had companion-type estimates from both methods, we used 21 stars that have limits on the Bessel & Brett class – i.e., according to notation in Table 7 no "vl" or "$\rightarrow$X" ones were included. Of these, only BD+29 3070 deviates by more than one spectral class.

The conclusion we can draw from this comparison of derived $\log(g)$ limits is that we appear to have 2 methods that are able, when the data is good, to jointly find the spectral type of the companion to within one class in about 75% of all cases.

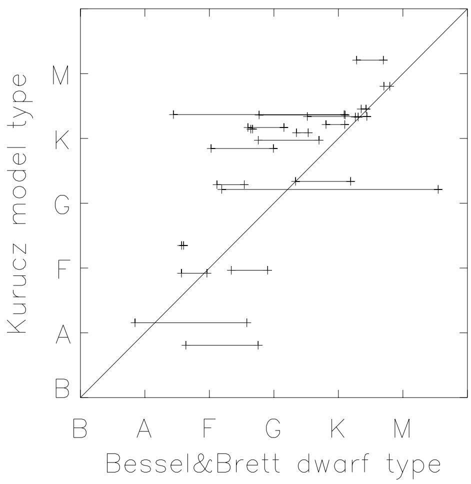

Fig. 2. Comparison of companion types determined by two methods. Along the horizontal axis is plotted the limits on spectral class that can be inferred from the extracted $J-H$ and $J-K$ colours and the Bessel & Brett (1988) tables for real stars, while the vertical axis displays the spectral type inferred from fits of Kurucz model spectra

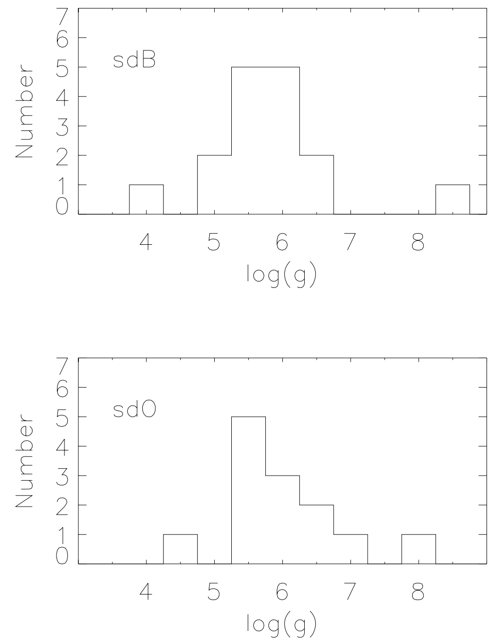

Fig. 3. Derived upper limits for $\log(g)$ of the sample sdB and sdO stars. The bin width is 0.5

5. Deriving gravities for the hot subdwarfs

Another result of our model fitting procedure is the determination of gravity estimates for the hot subdwarf, by specifying a mass-gravity-temperature relationship for the companion with the aid of Eq. (5) in Paper I. For purposes of comparing to other work we will use, throughout, the standard assumption of 0.55 $M_{\odot}$(see also Paper I) for the mass of the hot subdwarf.

We can chose whatever mass-gravity-temperature relationship we think is appropriate for the companions, but note that use of a ZAMS relationship will tend to give *upper* limits on $\log(g_{\rm sd})$ which is desirable, also for comparision purposes. Many companions of evolved luminosity classes have been found and there are selection effects having to do with the relative brightnesses of the two stars that may make sub-giant or giant companions easier to find, in at least optical surveys, but as we use the full range of available UV and our own JHK data we think it is appropriate to at least start with the assumption that most companions will be in their longest phase of evolution – on the MS, and for simplicity we represent the MS by the ZAMS. The ZAMS mass-gravity-temperature relationship we use is based on tabulations such as those in Zombeck (1990). We perform linear interpolations in these tables.

The results of fitting our data is shown in Table 8. For this analysis only data for systems showing a significant excess (2σ level at least) and yielding a convincingly good fit was employed.

We sorted those stars that could be analyzed with the Kurucz model fitting method into the sdB and sdO cases and made histograms of the derived gravity distribution. The results are shown in Fig. 3. The distributions are nearly indistinguishable, given the low numbers involved and that our analysis method is based on assuming ZAMS companions and that if the companion is more luminous for its spectral class than a dwarf then we will overestimate the gravity of the hot subdwarf – the one outlier at high $\log(g)$ in the sdB case and the 2 highest in the sdO case can then be removed and the difference between the $\log(g)$ distributions is then the slight excess of low gravity cases for the sdB's.

Next, among those stars for which an estimate of $\log(g)$ is available through other means, or for which the luminosity class of the companion is known (Table 8 summarizes what is known), we find a few (i.e., HD 149382, HD 185510, PG2110+127, PHL 1079, Feige 80, GD 299, HD 128220 and MRK 509C) that yield new $\log(g)$ values which may be discrepant by more than about 0.8 from previous ones. Some may contain Giant or Subgiant instead of ZAMS companions; HD 128220, for example, is a well established sd+subgiant case (Howarth & Heber 1990). We discuss HD 149382 because as a well studied case (Saffer et al. 1994), it provides an example of a contradiction between its known $\log(g)$ values, based on spectroscopic analysis, and our upper limits. Is should be bared in mind the possibility that the cool star in this case be subluminous –i.e., halo system (Heber, private communication).

All the "binary" cases we have here could of course be cases of chance super-impositions of one star on another with a resulting error in the derived $\log(g)$. "Companion" stars that are closer to us than the hot subdwarf will cause overestimation of the hot subdwarf $\log(g)$, while "companions" that are behind the hot subdwarf will cause the opposite to happen. As super-impositions are not entirely unlikely, but hard to evaluate, it is at present of greater interest to scrutinize our own method, and the individual spectroscopic analyses, in detail. Spectroscopic analyses have, in the contradictory case above, been performed without compensation for the excess flux of the "companion" star. As the super-positioning of stellar spectra can lead to enhancement of spectral lines when lines coincide, and obliteration of lines when the companion star is line-free or -weak, an estimate of the companion spectral class and flux-contribution is needed to evaluate each case.

Several of the stars we have found to be composite have considerable contributions at optical wavelengths from the companion, and we suggest that reanalysis of these spectra, by subtraction of a suitable companion spectrum, could be beneficial in improving the determined atmospheric parameters.

For the particular case of HD 149382, the contribution from the companion to its spectrum of is small – less than 10% at 5000 Å – so here we do not think the spectroscopic analysis was influenced much by the presence of excess flux. There is no significant discrepancy between the two spectral line analyses carried out by Baschek et al. (1982) with non-LTE models and Saffer et al. (1994) with LTE models for HD 149382 – both results are significantly above the upper limit we get. As the star is bright it is not possible to use various digitized sky surveys to inspect the region near the sky for clues to the origin of the excess flux we see – the size of the aperture we used covers an area entirely dominated by the flux of this star so we can not rule out that the "companion" is rather far from the target and thus unlikely to be physically related. However, as explained in Sect. 2 no visual evidence for contamination was detected at the time of the observation with the CST.

6. Summary and discussion

As a continuation of the work reported by Thejll et al. (1995), we have measured the JH and K band fluxes from 72 more stars – mainly hot sdB and sdO stars, along with a few White Dwarfs. In 28 new sd cases (i.e., from June and October, 1994 – see Table 7) we have found a significant excess that we interpret to be mainly due to stellar companions. Of these, 14 are new binary discoveries: BD+25 4655, Feige 108, HD 4539, HD 149382, HD 216135, KPD 2109+440, LSI+63 198, LSIV+10 9, LSV+22 38, PG 0011+221, PG 0116+242, PG 0314+103, PG 2151+100 and TON 139. BD+25 4655, HD 4539 and

Table 7. The excess fluxes in significant cases. Column 1 gives the object's name, 2 contains the excess J flux and its error, in units of 10^{-24} erg/cm^2/s/Hz, in 3 and 4 are given the $J-H$ and $J-K$ colours, respectively, of the excess flux. The Bessel & Brett (1988) dwarf type (their Table II) corresponding to the $J-H$ and $J-K$ colour ranges is in 5. The overlap in types is given; both type-ranges are shown in all cases where an overlap was not found. "ve" and "vl" indicate ranges that are outside the ranges of the Bessel & Brett table - either "very early" (i.e. before B8 type) or 'very late" (i.e. after M5). The use of the →X notation indicates a range including all previous spectral type up to the X type. Only systems where the excesses were significant at the 2σ level in each of the J, H and K bands are included. As the analysis of individual stars in principle is independent of that in Paper I we repeat objects here that appeared first in Paper I; February 1994, objects are quoted with "F" after the target's name

Name (1)	$J\pm$error (2)	$J-H$ (3)	$J-K$ (4)	type (5)
hot sds/sdBs previously unknown as binaries				
Feige 108	$0.02 \pm .008$	$1.22 \pm .45$	$1.44 \pm .49$	vl
HD 4539	$0.07 \pm .029$	$-0.28 \pm .52$	$0.16 \pm .45$	B8-F5
HD 149382	$0.78 \pm .080$	$0.38 \pm .12$	$0.50 \pm .13$	G2-K1
HD 216135	$0.24 \pm .035$	$-0.51 \pm .25$	$-0.60 \pm .42$	ve
KP2109+440	$1.55 \pm .073$	$1.16 \pm .05$	$1.47 \pm .05$	vl
PG 0011+221	$0.08 \pm .015$	$-0.15 \pm .24$	$-0.49 \pm .38$	ve
PG 0116+242	$0.64 \pm .014$	$0.36 \pm .03$	$0.48 \pm .06$	G5-G6
PG 0314+103	$0.14 \pm .018$	$0.66 \pm .14$	$0.94 \pm .16$	K6→
PG 2151+100	$0.14 \pm .011$	$0.82 \pm .08$	$1.23 \pm .09$	vl
TON 139	$0.18 \pm .033$	$0.25 \pm .21$	$0.25 \pm .26$	A3-G9
hot sdOs previously unknown as binaries				
BD +25 4655	$0.10 \pm .021$	$-0.28 \pm .25$	$0.12 \pm .32$	ve
BD +37 1977F	$0.12 \pm .044$	$0.05 \pm .46$	$-0.09 \pm .49$	→G4
BD +48 1777F	$0.11 \pm .030$	$-0.42 \pm .38$	$-0.78 \pm .42$	ve
LSI+63 198	$19.79 \pm .366$	$0.66 \pm .02$	$0.80 \pm .03$	K6-K8
LSIV+10 9	$0.46 \pm .016$	$0.23 \pm .07$	$0.34 \pm .07$	F4-F9
LSV+22 38	$7.64 \pm .001$	$0.37 \pm .01$	$0.57 \pm .01$	G6 K1
known or suspected hot sd/sdB binaries				
BD +34 1543F	$2.07 \pm .093$	$0.32 \pm .06$	$0.36 \pm .06$	F6-G5
GD 274F	$0.40 \pm .005$	$0.43 \pm .02$	$0.53 \pm .03$	G8-G9
HD 185510	$55.64 \pm .001$	$0.65 \pm .01$	$0.79 \pm .01$	K6-K7
HDE283048F	$3.40 \pm .201$	$0.22 \pm .08$	$0.29 \pm .08$	F2-F9
PB 8555	$0.44 \pm .018$	$0.26 \pm .05$	$0.41 \pm .06$	F8-G1
PG 0110+262F	$0.15 \pm .027$	$0.09 \pm .25$	$0.24 \pm .30$	→G4
PG 0232+095F	$0.56 \pm .073$	$0.34 \pm .15$	$0.50 \pm .17$	F6-K1
PG 2110+127	$0.18 \pm .011$	$0.23 \pm .09$	$0.19 \pm .11$	F0-F5
PG 2118+126	$0.12 \pm .014$	$0.04 \pm .16$	$0.08 \pm .22$	→F3
PG 2148+095	$0.18 \pm .022$	$-0.18 \pm .23$	$0.18 \pm .42$	→A4
PG 2219+094	$0.11 \pm .018$	$0.01 \pm .19$	$0.02 \pm .27$	→F3
PHL 1079	$0.13 \pm .025$	$0.38 \pm .19$	$0.60 \pm .20$	G4-K3
SB 7	$0.08 \pm .037$	$0.55 \pm .41$	$0.44 \pm .45$	F0-M4
known or suspected hot sdO/sdOB binaries				
BD−3 5357	$20.79 \pm .193$	$0.53 \pm .01$	$0.68 \pm .01$	K3
BD−7 5977	$4.13 \pm .079$	$0.50 \pm .02$	$0.61 \pm .02$	K1-K2
BD−11 162	$0.58 \pm .022$	$0.25 \pm .05$	$0.31 \pm .05$	F4-G0
BD +10 2357F	$6.08 \pm .182$	$0.11 \pm .05$	$0.11 \pm .05$	A5-F1
BD +29 3070	$1.60 \pm .019$	$0.26 \pm .02$	$0.28 \pm .04$	F5-F6
Feige 34F	$0.09 \pm .016$	$0.79 \pm .21$	$0.79 \pm .21$	K3→
Feige 80F	$0.39 \pm .056$	$0.30 \pm .16$	$0.19 \pm .17$	F0-F9
GD 299F	$0.13 \pm .039$	$0.20 \pm .33$	$0.20 \pm .32$	→G9
HD 45166	$0.93 \pm .044$	$0.08 \pm .07$	$0.30 \pm .09$	A5 F7
HD 113001F	$3.06 \pm .065$	$0.11 \pm .03$	$0.06 \pm .03$	A5
HD 128220F	$17.38 \pm .340$	$0.32 \pm .03$	$0.41 \pm .02$	G3-G5
MRK509C	$0.07 \pm .025$	$0.23 \pm .39$	$1.00 \pm .40$	K2-K5

HD 216135 are however the weakest cases as their evidence for an IR excess becomes marginal when compared to other clearer cases. Two more discoveries are BD +37 1977 and BD +48 1777 which, from Paper I, are now found to display excesses with our present analysis. It should be kept in mind, however, that both are sdO cases now fitted with H-rich Kurucz models which, together with the previous marginal evidence for an excess pointed out in Paper I, render this conclusion weak as well. BD−13 842 and BD+33 2642 display also IR flux escesses but, being classified as CSPN, have not been analysed. The suspected binaries PB 8555 (Kilkenny et al. 1988) and SB 7 (Heber 1986) are confirmed. Our two analysis methods (extraction of 2σ simultaneously significant JHK flux excesses and fitting of two Kurucz atmospheric models) can jointly find agreeing spectral type companions for 21 out of 28 "good data" (see Table 8) cases. 13 companions could be of G type (see Table 7).

The 28 analysed new cases, added to the 11 sds found by Thejll et al. (1995), represent 44% out of the 88 hot sds observed in total during 1994 (i.e., =24 from February+ 64 from June and October). Of the 41 (i.e., =28+ 11+ BD+37 1977+ BD+48 1777), fulfilling a 2σ excess condition, 15 are sdO, 15 are sdB, three are sdOBs, PG 0110+262 is an sdB-O and the rest (i.e., 7) remain unclassified (i.e., sd).

For 28 stars (see Table 8) we were furthermore able to satisfactorily fit the sum of two spectral Kurucz models so that temperature estimates and an estimate of the relative radii could be obtained. Assuming that all the companions are ZAMS stars we can then calculate upper limits on $\log(g)$ for the hot subdwarfs. For 18 of the hot subdwarfs previous estimates of $\log(g)$ were available from spectroscopic analysis and our upper limits are in agreement with most cases except for a few discrepant ones. We discuss HD 149382 as an exaple which we find inexplicable, as the excess flux is small and thus probably did not influence the several spectroscopic analysis that have been performed – we speculate that the source of the excess radiation is unrelated to the star itself, but cannot evaluate this suggestion without better imaging of possible faint sources in the sky around the bright main star. Other discrepant cases may be due to the presence of Giant or Subgiant, instead of ZAMS, companions.

Given the recent discovery of pulsators among hot subdwarfs with binary companions (O'Donoghue et al. 1997 and references therein) our sample provides suitable candidates to pursue that line of investigation. We are currently investigating, both theoretically and observationally, the presence of eventual pulsations in Feige 108 among others.

6.1. Gravities and evolutionary implications

We have also found that the distributions of the derived upper limits of $\log(g)$ are very similar for the sdO and

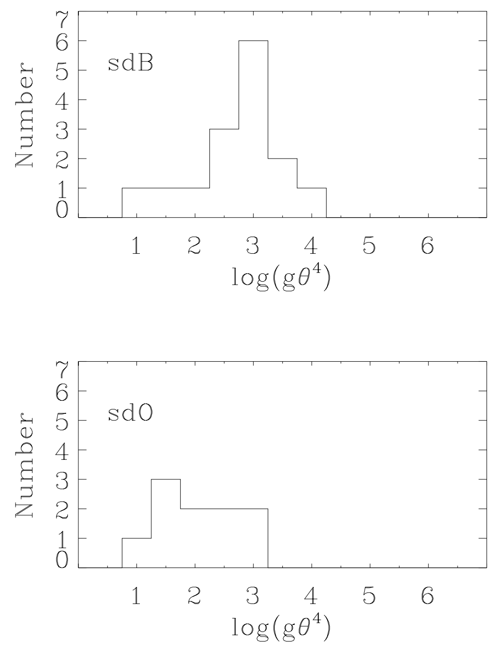

Fig. 4. Derived upper limits for $\log(g\theta^4)$ of the sample sdB and sdO stars. Stars with known giant companions have been excluded

sdB cases – both show a substantial concentration of cases between about 5.25 and 6.5 in $\log(g)$. Direct spectroscopic determination of atmospheric parameters for sdB and sdO stars usually give distributions of $\log(g)$ for sdBs between 5.3 and 6.2 with sdOs distributed over a similar range but now and then, depending on the sample of stars, going down to $\log(g) = 4.1$ (e.g. HD 128220).

We had hoped to find several telling cases of sdOs with companions so that we could "test" NLTE modelling techniques, but we have found no strongly contradictory cases within the present analysis.

As our method only provides upper limits on $\log(g)$ for the hot star, the narrowness of the $\log(g)$ distributions can be interpreted to imply that the companion-types are all well described by our assumption of ZAMS status – real giant or sub-giant companions force our method to exaggerate the upper limits on $\log(g)$ but the absence of a substantial number of cases like that shows the predominance of un-evolved companions. This is what one would expect on the basis of probability considerations as most stars spend most of their time in the hydrogen burning phase.

The coincidence of the main peaks in the $\log(g)$ distributions - to the extent that we are able to "resolve" it with the limited number of stars we have - may say something about the underlying mass-distributions. Saffer et al. (1994) found that the distribution of $\log(g\theta^4)$ (where $\theta = 5040/T_{\rm eff}$) for the sdB stars they studied was a basically unresolved peak near 2.6 and a FWHM of 0.4 (i.e.

Table 8. Results of fitting Kurucz models to the observed fluxes and summary of literature data for hot subdwarf log(g) values, and/or luminosity classes of companions. The columns are: (1) Object name, (2) $T_{\rm eff}$ of the assumed or fitted hot model, (3) the $T_{\rm eff}$ of the fitted cool model, followed in parenthesis by the dwarf spectral type derived from the temperature and standard tables (Zombeck 1990), (4) The ratio $R' = R$(cool star)/R(hot sd), (5) the derived gravity of the hot subdwarf (upper limit) calculated from an assumed sd mass of 0.55 $M_\odot$, R' and a mass of the cool companion derived from the mass-radius-$T_{\rm eff}$ relationship for ZAMS stars from Zombeck, (6) literature values for surface gravity (with reference in parenthesis, see Table 1 and below) and (7) luminosity class of the companion from the literature, if known. In all cases, except for BD+34 1543 ([−0.5]), we have used solar metallicity models. Whenever possible we have chosen the log(g)=5.0 model for the hot star. Notes: ^{a}= log(g) based on equivalent widths determination; ^{b}= log(g) based on R and I photometric determinations by Thejll et al. (1994b; Th94). All other log(g) determinations are spectroscopic. B82=Baschek et al. (1982). B93=Boffin et al. (1993). K88=Kilkenny et al. (1988), Ra93=Rauch (1993), WSp60=Wallerstein & Spinrad (1960), WSK63=Wallerstein et al. (1963), WW66=Wallerstein & Wolff (1966), WS83=Willis & Stickland (1983)

Object (1)	$T_{\rm eff}$(1) (2)	$T_{\rm eff}$(2) (3)	R' (4)	log(g) (5)	lit. log(g) (6)	L. class of comp. (7)
hot sds/sdBs previously unknown as binaries						
Feige 108	35000.	5500(G6)	4.	5.5		
HD 149382	34000.	5750.(G2)	2.3	5.0	5.89(S94), 5.5 ± .3(B82)	
PG 2151+100	27000.	3500.(M2)	10.	6.7		
TON 139	18000.	4750.(K2)	5.	5.7		
known or suspected hot sd/sdB binaries						
BD +34 1543	26000.	5500.(G8)	8.	6.0	5.9(pI)	
GD 274	24000.	4750.(K2)	7.	6.0	6.2(pI)	
HD 185510	25000.	4250.(K8)	164.	8.9	6.0(Je92)	K0III-IV(K88)
HDE283048	40000.	7500.(A8)	13.	6.2	6.4 ± .3(pI)	
PG 0110+262	21000.	5000.(K1)	6.	5.9	5.5(pI)	
PG 0232+095	21000.	4750.(K2)	13.	6.6	6.9 ± .3(pI)	
PG 2110+127	34000.	5750.(G2)	8.	5.9	5.33(S94), 5.0 ± .2(T95)	G6IV(T95)
PG 2118+126	25000.	5250.(K0)	7.	6.0		
PG 2148+095	25000.	5000.(K1)	6.	5.8		
PG 2219+094	21000.	7000.(F1)	2.8	5.0	4.6(S94)	
PHL 1079	30000.	4750.(K2)	9.	6.2	5.25(T95)	G8IV(T95)
SB 7	50000.	5750.(G2)	7.	5.9		
known or suspected hot sdO/sdOB binaries						
BD−3 5357	40000.	4500.(K4)	67.	8.1		G8III(K88), K0IV-III(B93)
BD−7 5977	31000.	4750.(K2)	23.	7.1		K0IV-III(V91)
BD−11 162	35000.	5250.(K0)	6.	5.9		
BD +10 2357	27000.	5750.(G2)	7.	5.9	5.6(pI)	
BD +29 3070	18000.	5250.(K0)	4.	5.5		
Feige 34	50000.	3500.(M2)	4.6	6.1	$6.8^{+0.3}_{-0.7}$(pI, trigπ)	
Feige 80	33000.	5500.(G8)	6.	5.7	4.83(S94)	
GD 299	37500.	4750.(K2)	5.0	5.8	4.9^a(GS74)	
HD 45166	40000.	13000.(B8)	7.	4.8	4.4(WS83)	B8V(WS83)
HD 113001	47500.	6750.(F3)	9.	6.0	5.6 – 5.9(To70), 6.0(pI)	F2V(WSp60)
HD 128220	40000.	5250.(K0)	16.	6.7	4.1(Ra93)	Giant(WSK63; WW66)
MRK509C	42500.	3500.(M2)	8.	6.6	5.0-5.3^b(Th94)	

standard deviation near 0.2). This corresponded to a single Gaussian mass distribution with a narrow width of $1\sigma \sim 0.04\ M_\odot$ centered on 0.5 $M_\odot$. As $g\theta^4$ scales with luminosity and is constant for a given core mass (Greenstein & Sargent 1974) it is consistent to interpret the distribution found by Saffer et al. as evidence for core He burning. In our sample of stars we find (after excluding the known cases of giant companions) that the distributions of log($g\theta^4$) have mean and standard deviations of (2.9; 0.8) and (2.3; 0.7) for the sdBs and sdOs, respectively. The distributions are shown in Fig. 4.

These values are not significantly different from each other, nor from the more narrowly distributed value that Saffer et al. found for their sample of sdBs. Analysis of the mass-luminosity ratio for helium-core burning objects (Thejll & MacDonald, unpublished models), shows that near 0.5 $M_\odot$ a doubling or halving of the mass corresponds to an order of magnitude decrease or increase in the M/L ratio, respectively. As the present distribution of log($g\theta^4$) for the sdOs contains most of the cases within one order of magnitude on either side of the mean we see that the distribution corresponds to a spread in masses for the sdOs between 0.25 and 1 $M_{\odot}$, if they are assumed to be helium core burners. These are not unrealistic limits given what we know about the mass distribution of sdOs from suitable binary systems (Ritter 1990). The present data on the sdOs is therefore consistent with an interpretation of the sdOs as being He-core burners (i.e. Helium Main Sequence stars - HEMS) with a natural spread of masses.

Future improvements in the amount and quality of data available for sdOs will be needed to make a statement about whether a narrower distribution of masses – such as in a scenario where sdBs evolve into sdOs, and therefore keep their narrowly distributed mass-spectrum – is the case.

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