ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES

Astron. Astrophys. Suppl. Ser. **123,** 135-146 (1997)

Spectral classifications in the near infrared of stars with composite spectra

II. Study of a sample of 180 stars*

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Received June 12; accepted September 12, 1996

Abstract. A sample of 180 supposedly composite-spectrum stars has been studied on the basis of spectra obtained in the near infrared (8370 − 8780 Å) at a dispersion of 33 Å/mm. The objective was to study the cooler components of the systems. Of our sample, 120 are true composite spectra, 35 are hot spectra of types B, F and 25 are Am stars. We find a strong concentration of the cooler components of the composite spectra around G8III. In view of the difficulty of classifying composite spectra, because of the superposition of an early type dwarf and a late type giant or supergiant spectrum, we have made several tests to control the classification based upon the infrared region. Since all tests gave positive results, we conclude that our classifications can be considered as being both reliable and homogeneous.[1]

Key words: stars: classification — infrared: stars — binaries: spectroscopic

1. Introduction

In a preceding paper (Ginestet et al. 1994) we have shown that the near infrared region (8370−8780 Å) is interesting for classifying the cooler components of composite spectra. This is essentially due to the fact that whereas in the blue spectral region (3800 − 4800 Å) the magnitude difference between both components is about zero (i.e. both spectra are hopelessly intermingled), in the near infrared region the magnitude difference is more favorable to the cooler component. Very frequently the traces of the early type companion can only be perceived faintly through the presence of weak hydrogen lines of the Paschen series.

Let us recall here briefly that *we shall call composite spectra all those resulting from the combination of the spectra of a hot early type dwarf (type B or A) and that of a late type subgiant, giant or even supergiant object (types G, K or M).*

The first paper (Paper I) was devoted to the study of a sample of 92 MK standards, which permitted to establish the classification criteria for this region, using the equivalent widths of certain lines or blends of lines. For early type spectra we have used essentially the Paschen lines P12 and P14 of hydrogen, the CaII lines 8498, 8542 and the OI line 8446. For the late type spectra we have used mainly the CaII triplet lines (8498, 8542, 8662 Å), the FeI (8621, 8688 Å), TiI (8426, 8435 Å) lines and the blend 8468. The latter is constituted by a blend of lines of iron and titanium but contains also some faint lines of CN, Mg and Zr.

In the present paper (Paper II) we apply the results of Paper I to a sample of stars with composite spectra.

We have provided in Paper I a list of papers written on both the near infrared spectral region and on composite spectra. We shall not repeat here these references, but complete the list given with some papers published recently. The most important additions are four new atlases covering the near infrared. The first is by Torres-Dodgen & Weaver (1993) which covers the 5800 − 8900 Å region at a resolution of about 15 Å. The second atlas is the one by Danks & Dennefeld (1994) covering the region 5800−10200 Å at a dispersion of 171 Å/mm. The third atlas (Andrillat et al. 1995) covers the 8400 − 8800 Å region of early type stars at a dispersion of 33 Å/mm and the fourth is by ourselves (Carquillat et al. 1997). It covers the same region as the third atlas and uses the same dispersion but deals only with late type stars. We mention also a recent

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* based upon observations carried out at Observatoire de Haute-Provence (CNRS).
[1] Table 1 is also available electronically at the CDS via anonymous ftp 130.79.128.5 or
http://cdsweb.u-strasbg.fr/Abstracts.html

Table 1. Classifications of the cool components, SP(IR), of stars with composite spectra

HD / BD	A2000	D2000	V	B - V	SP	Références	SP(IR)
	h m s	° ′ ″					
4615	00 48 41,1	+52 06 04	6,80		G8III+A2V	Markowitz (1969)	**K1 III**
4775	00 50 43,5	+64 14 52	5,39	0,49	G0III+A4V	Bahng (1958)	**G7 III**
					B9,5V+G0III-IV	Markowitz (1969)	
5373	00 56 13,1	+46 39 15	7,60		F2	Cat. HD	**G6 III-IV**
9352	01 33 25,6	+58 19 39	5,70	1,52	K3Ib-II+B9V	Markowitz (1969)	**K3 II+**
					K0Ib+B9V	Hoffleit (1982)	
13474	02 14 29,0	+66 31 28	6,05	0,63	B9V+G0II-III	Markowitz (1969)	**G9 III**
					A2Vn+F9II	Abt (1984)	
16082	02 36 48,1	+51 57 40	7,26	0,95	G5A5	Cat. HD	**K0 Ib-II**
17245	02 47 31,1	+44 16 21	6,70		A1V+G2III	Markowitz (1969)	**G8 II-III**
					A0V+F6III	Abt (1986)	
17479	02 49 57,6	+48 48 08	7,80		A2G	Cat. HD	**G9 III**
17718	02 52 19,2	+48 37 53	8,60		G0A	Cat. HD	**G7 III**
17878	02 54 15,4	+52 45 45	3,95	0,74	G4III+A4V	Bahng (1958)	**G7 III**
					G5III+A4V	Markowitz (1969)	
					G8III+A2V	Griffin (1992)	
18715	03 01 28,9	+32 24 46	6,60		G5A5	Cat. HD	**K1.5 II-III** *
					G5IV	CDS	
18925	03 04 47,7	+53 30 24	2,90	0,70	G8III+A3V	Bahng (1958)	**G9 III**
					G5III+A2V	Markowitz (1969)	
					K0III+A2	Cowley (1976)	
					G8II-III+B9V	McAlister (1982)	
19926	03 12 26,3	+06 39 39	5,56	1,08	K5IIIep	Kuhi (1963)	**K2 III**
					K1IIIep+A6V	Markowitz (1969)	
21771	03 32 16,4	+44 50 26	7,24	1,40	K0A	Cat. HD	**K3 II**
23089	03 46 02,3	+63 20 42	4,80	0,80	G0III+A3V	Bahng 1958)	**G2 Ib**
					B9V+G2II-III	Markowitz (1969)	
					A2:+KIII:	Cowley (1976)	
					A0V+F8III	Abt (1986)	
23838	03 50 04,5	44 58 04	5,66	0,76	G2?III+A?	Appenzeller (1967)	**G7 III**
					G2III+F2:V	Markowitz (1969)	
25007	04 10 02,8	+80 41 55	5,10	0,56	G8:III+A4:V	Abt (1981)	**G8 III**
25555	04 04 21,6	+24 06 21	5,47	0,86	B9V+G1III	Markowitz (1969)	**K1 II:**
					A1:+GIII:	Cowley (1976)	
					A7V+G0:IV	Abt (1981)	
26630	04 14 53,8	+48 24 34	4,14	0,96	G0Ib+B9.5V	Stickland (1988)	**G0 Ib** *
26673	04 14 53,2	+40 29 02	4,71	1,01	K2III+A6V	Bahng (1958)	**G9 II:**
					G5II+A2V	Markowitz (1969)	
					G5Ib+A2	Batten (1989)	
					G5Ib+B9,5V	Stickland (1988)	
+29°691	04 19 18,0	+29 32 30	9,40		K0	Cat. HD	**K1 III**
					F2	CDS	
29094	04 36 41,3	+41 15 53	4,25	1,22	K4III+A3V	Bahng (1958)	**G7 Ib:**
					K0II-III+B9V	Markowitz (1969)	
					G8I+B5V	Harmer (1983)	
29104	04 35 42,6	+19 52 54	6,36	0,74	KIII:+A5:	Cowley (1976)	**G7 III**
					G8III+F6IV	Strassmeier (1990)	
29961	04 42 31,7	-20 58 23	7,60		G8/K0(III)+A5/7V	Houk (1988)	**G6 III**
+40°1043	04 46 29,3	+40 54 12	9,40:		F5A5	Cat. HD	**K1 III+**
					F8	CDS	
32068	05 02 28,6	+41 04 33	3,75	1,22	K4II+B7V	Wellmann (1951)	**K4 II:**
					K5II+B5V	Markowitz (1969)	
					K4Ib+B6V	Wright (1970)	
32835	05 07 05,1	+26 59 46	7,65	0,87	F5V+A	Heard (1956)	**G9 III**
33883	05 13 31,5	+01 58 04	6,09	0,42	F6III	Kuhi (1963)	**G8: III-IV**
					A4V+A6V	Edwards (1976)	
34318	05 16 10,5	-11 21 10	6,50		G8III	Kuhi (1963)	**G8 III**
					G8III+A0V	Markowitz (1969)	
34533	05 20 39,2	+46 57 50	6,54	0,60	A2V+GIII	Hoffleit (1982)	**G9 III**
35162	05 21 46,2	-24 46 23	5,06	0,67	G7II-III+A7IV,V	Stephenson (1960)	**G6 III**
					G6III+A3V	Corbally (1984)	
					G8/K0II/III+A2/3	Houk (1988)	
36947	05 37 16,8	+44 04 15	7,40		A1V+G8:III	Abt (1986)	**G7 Ib:**
37269	05 38 38,0	+30 29 33	5,40	0,41	G5III:+A3	Bidelman (1958)	**G8 III-**
					G0III	Kuhi (1963)	
					G2III+A3V:	Stephenson (1969)	
					B9,5V+F9III	Beavers (1982)	
39118	05 50 29,9	+02 01 28	5,98	0,91	G8IV	Kuhi (1963)	**K0 II**
					G8III+A1V	Markowitz (1969)	
					G2V+A0V	Hendry (1981)	
					A2V+G2:II	Abt (1986)	
39847	05 56 12,9	+25 19 48	7,70		F6IVe	Kuhi (1963)	**G6 III-IV**
					G+A2	Bidelman (1988)	
40369	05 58 53,1	+12 48 31	5,70	0,89	K2III+A5V	Bahng (1958)	**K2 III+**
					K0III+A7V	Stephenson (1969)	
45044	06 25 42,0	+14 05 34	7,40		A1V+G0III	Abt (1986)	**K1 III**
					F5V	CDS	
49618	06 53 05,0	+59 26 57	5,33	0,65	G4III+A2V	Bahng (1958)	**G9 III**
					G5III:+A2V	Stephenson (1969)	
49635	06 50 14,0	+18 47 53	7,70		F5A3	Cat. HD	**G8 III**
50820	06 54 42,0	-01 45 23	6,21	0,56	B3eV+K2II	Underhill (1954)	**K4 III+**
					B3eV+K	Markowitz (1969)	
51250	06 56 06,6	-14 02 37	5,00	1,18	G5III+A2	Hoffleit (1982)	**K3 II** *
					K2/3III+B9/A0V	Houk (1988)	

Table 1. continued

HD / BD	A2000	D2000	V	B - V	SP	Références	SP(IR)
	h m s	° ′ ″					
51424	06 57 00,0	-08 10 44	6,34	0,64	Am	Markowitz (1969)	**G9.5 III**
					A2V+K0II-III:	Cowley (1971)	
52690	07 02 06,7	-03 45 18	6,55	1,57	M1Ib+A,B	Bidelman (1957)	**M2 Ib**
					M0Ib+A0V:	Markowitz (1969)	
52822	07 04 17,0	+37 33 51	6,60		G8III+A1V	Markowitz (1969)	**K0 III+**
55549	07 17 05,5	+59 55 01	7,84	0,66	F5p	Cat. HD	**G7: III-**
55899	07 14 50,1	-01 22 33	7,90		G8III	Kuhi (1963)	**K0 III**
59604	07 30 56,6	+08 33 08	7,20		A2G	Cat. HD	**G2 III-IV**
60414	07 33 47,8	-14 31 26	4,97	1,41	M2epIab+B	Bidelman (1954)	**M2 Iab:**
					M2Iabep+B	Markowitz (1969)	
					M2III+A3/5Ia	Houk (1988)	
63023	07 46 44,8	-03 53 15	8,10		G0A2	Cat. HD	**G8 III+**
63208	07 48 33,6	+23 08 28	6,18	0,54	G2III+A4V	Bahng (1958)	**K0 III**
66094	08 01 44,6	-08 35 37	7,20		F5A2	Cat. HD	**G9: III-IV**
69479	08 17 18,4	+04 13 09	6,53	0,63	G5III+A2V:	Markowitz (1969)	**G7 III-**
70442	08 21 21,1	-20 04 45	5,58	0,77	G2III+A	Roman (1949)	**G9 III**
					G8III+A0:V	Markowitz (1969)	
					G8III+A3V	Houk (1988)	
73451	08 38 20,3	-06 39 45	6,51	0,45	A1V+G	Cowley (1969)	**G7 III**
					A+G:III	Jaschek (1991)	
74228	08 43 12,3	+12 40 51	5,62	0,39	F8V	Kuhi(1963)	**G6: III-IV**
					A3V+G0III	Markowitz (1969)	
					F3-5III+A5?V	Hendry (1981)	
74395	08 43 40,4	-07 14 01	4,62	0,84	G2I+B9.5V	Stickland (1988)	**G1 Ib** *
74874	08 46 47,2	+06 25 10	3,38	0,68	F0V+KIII:	Cowley (1976)	**G7 III**
					G5III+A8IV	Edwards (1976)	
					F8V	Abt (1981)	
74946	08 46 10,0	-26 36 46	7,20		K3III+B/A	Houk (1982)	**K3 II+**
75098	08 47 21,6	-17 03 11	6,60		G2III+A1V	Stephenson (1969)	**G6 III-**
					K0III+A2V	Houk (1988)	
76174	08 54 14,8	-08 45 39	7,40		F0A2	Cat. HD	**G8 III**
79267	09 12 25,5	-25 36 04	7,30		K0/K1III+A1/3V	Houk (1988)	**G7.5 III**
82072	09 29 36,3	-03 07 20	7,80		G2III+A3V	Stephenson (1969)	**G7 III**
84367	09 44 12,1	-27 46 10	4,79	0,51	A8V+F7II-III	Malaroda (1973)	**G7 III** *
					F6V+F8V	Edwards (1976)	
					A7V+G8III	Houk (1982)	
88021	10 09 19,6	+20 19 57	6,65	0,53	G2III+A2V	Markowitz (1969)	**G8 III**
					Am+F5III	Abt (1981)	
					K0III+Am	Griffin (1988)	
95235	10 59 24,0	-26 46 06	8,10		K0III+B9,5/A0V	Houk (1982)	**G6 III-IV**
102171	11 45 26,0	-28 22 19	8,40		G8III+A3+A3V	Houk (1982)	**G6 III**
102509	11 47 59,6	+20 13 08	4,60	0,55	A+G5III-IV	Slettebak (1955)	**G7III**

HD / BD	A2000	D2000	V	B - V	SP	Références	SP(IR)
	h m s	° ′ ″					
102509	*(suite)*				G4III-IV+A7V	Markowitz (1969)	
					F2IV	Sato (1990)	
107700	12 22 30,2	+25 50 46	4,81	0,49	A2V+G0III-IV	Markowitz (1969)	**G7 III**
					A4V+F6V	Abt (1977)	
					A2V+GIII	Cowley (1976)	
108464	12 27 33,1	+41 21 19	6,54	0,52	A7V+G0III	Markowitz (1969)	**G7 III**
120901	13 52 38,9	-18 42 31	7,00		A2V+F9II-III	Markowitz (1969)	**G9 III**
					K0III+A1V	Houk (1988)	
126269	14 24 11,3	+16 16 25	6,90	0,65	A2V+G1II-III	Markowitz (1969)	**G9 III**
					G0V+A5V	Hendry (1981)	
					Am	CDS	
139137	15 36 33,7	-00 33 41	6,51	0,72	G8III+A	Harlan (1974)	**G9 III**
					F6V	Malaroda (1975)	
					A5+KIII	Cowley (1976)	
144208	16 03 19,3	+36 37 54	5,83	0,56	A2V+F7III	Markowitz (1969)	**G8 III**
159870	17 33 31,5	+57 33 32	6,10	0,59	G5III+A7V	Markowitz (1969)	**G6 III**
					F5V	Bertaud (1970)	
					A5V+GIII	Cowley (1971)	
					Fm	Cowley (1979)	
					F2m	Hendry (1981)	
166479	18 10 08,6	+16 28 36	6,09		G2III+A0V:	Stephenson (1969)	**G8 III**
					A0V+G0III	Abt (1981)	
					B9V+F7III	Hoffleit (1982)	
168701	18 21 48,8	-16 19 28	7,80		K1III+B9(V)	Houk (1988)	**K3 II+**
169985	18 27 12,3	+00 11 46	5,21	0,50	G0III+A6V	Bahng (1958)	**G9 III**
					G8III	Kuhi (1963)	
					A0V:+G0III	Markowitz (1969)	
174016	18 44 21,1	+61 56 21	8,00		F5+A2	Olsen (1980)	**G8 III-IV**
					Am	Abt (1984)	
181731	19 21 35,9	+00 26 37	7,50		F5A5	Cat. HD	**G7.5 III**
184759	19 34 50,8	+29 27 47	5,38	0,55	A0:V+F8III	Markowitz (1969)	**G8 III**
					F5V+A	Hendry (1978)	
					G8III+A2V	Griffin (1994)	
186203	19 42 33,9	+11 49 36	5,27	0,57	A1V+F6III	Abt (1986)	**G2 Ib**
187259	19 48 42,0	+11 48 57	5,72		G2III:+A1V:	Stephenson (1969)	**G8 III**
					G8III+A2V	Griffin (1989)	
192577	20 13 37,8	+46 44 29	3,79	1,28	K2II+B3V	Bidelman (1954)	**K2 Ib**
					K2II+B4V	Markowitz (1969)	
					K4Ib+B4V	Wright (1970)	
192644	20 15 28,0	+13 38 53	7,90		G0A	Cat. HD	**K2 III**
193410	20 19 10,4	+29 29 57	7,20		F5A0	Cat. HD	**K0 III**
193495	20 21 00,6	-14 46 53	3,08	0,79	G8II	Kuhi (1963)	**G9II:**

Table 1. continued

HD / BD	A2000	D2000	V	B - V	SP	Références	SP(IR)
	h m s	° ′ ″					
193495	(suite)				A0V:+G5III+	Meisel (1968)	
					A0V:+G5II	Markowitz (1969)	
					K0II-III+B8V	Evans (1979)	
					F8V+A0	Hoffleit (1982)	
					K0:II:+A5:N	Houk (1988)	
194359	20 24 25,6	+24 16 39	7,00		G0III+A3V	Markowitz (1969)	**G8 III**
					G1III	Sato (1990)	
196088	20 32 59,0	+49 50 28	6,70		B9,5V+F4III	Markowitz (1969)	**G9.5 III**
197177	20 41 02,4	+32 18 27	5,63	0,88	G8IIb+A	Hoffleit (1982)	**G8 II** *
					G2III+...	Abt (1985)	
199378	20 56 25,2	+14 48 58	7,50		K0A2	Cat. HD	**K1.5 II**
					G0IVp *	Moore (1950)	
200428	21 03 00,9	+15 45 37	7,67	0,93	K0III+A5V	Griffin (1976)	**K0 III**
201270	21 06 52,4	+45 40 33	7,25	0,56	G5III	Kuhi (1963)	**G9 III**
					G8III+A2V	Griffin (1990)	
202447	21 15 49,3	+05 14 52	3,92	0,53	G0III+A5V	Bahng (1958)	**G8 III**
					G0II	Kuhi (1963)	
					G2II-III+A4V	Markowitz (1969)	
205114	21 31 27,4	+52 37 12	6,16	0,89	G8III	Kuhi (1963)	**G2 Ib**
					G2II+B9V	Markowitz (1969)	
					G2Ib+B9V	Burki (1983)	
207218	21 46 16,4	+43 03 38	6,54	0,28	Am	Walker (1966)	**G8 III**
					A4V+(GIII)	Slettebak (1969)	
					A2V+G0:III	Markowitz (1969)	
208054	21 52 15,0	+49 48 15	9,20		K0A0	cat. HD	**K0 II**
208816	21 56 39,1	+63 37 33	4,91	1,77	M2Iaep+B	Markowitz (1969)	**M3: Ia-Iab:**
					M2Ia-Ib+Be:	Wright (1970)	
					M2Iaep+B8Ve	Hoffleit (1982)	
209278	22 02 26,5	-16 57 52	6,37	0,42	A2V+G2III?	Slettebak (1969)	**K0 III** *
					A2V+K0III	Hoffleit (1982)	
					A0/1V+K1/2	Houk (1988)	
212391	22 21 44,8	+66 42 22	6,70		G5III+A2V	Stephenson (1960)	**G7 III** *
	h m s	° ′ ″					
212391	(suite)				A7V+G0III	Abt (1985)	
213310	22 29 31,8	+47 42 25	4,36	1,68	M0Ib-II+A	Bidelman (1954)	**K6-M0 I**
					M0Iab+B	Stebbins (1956)	
					K5Ib+B7V	Bahng (1958)	
					K5Ib+A0	Hynek (1959)	
					M0Ib	Kuhi (1963)	
					M0II+B8V	Markowitz (1969)	
213503	22 29 46,1	+68 13 16	7,70		G5A0	Cat. HD	**K2 II:**
214558	22 38 17,4	+45 10 59	6,40		G2III+A4V	Markowitz (1969)	**G6 III**
					A3V+G8III:	Cowley (1976)	
215242	22 43 04,4	+47 10 07	6,39	0,47	A1V+G:	Cowley (1969)	**G8 III**
215318	22 39 24,1	+81 23 31	6,86	0,75	G1II-III+A2V	Markowitz (1969)	**G9 III**
218640	23 09 54,7	-22 27 27	4,69	0,65	sgG2+A2	Markowitz (1969)	**G8 III+**
					G2III+A2V	Stephenson (1969)	
					G6/8III+A3(IV)	Houk (1988)	
220636	23 23 56,1	+77 30 43	7,90		A2Vn+F8II-III	Abt (1984)	**G8 III**
223047	23 46 01,9	+46 25 13	4,95	1,11	G5Ib+A0V	Markowitz (1969)	**G5 Ib**
					G5Ib+B9IV-V	Arellano (1986)	
					G3Ib-II	Keenan (1989)	
223932	23 53 45,8	-18 21 54	7,30		K0III+A5/7V	Houk (1988)	**K0.5 III**
236115	23 24 15,9	+55 11 06	8,40		G5A5	cat. HD	**K0.5 III:**
245814	05 39 12,0	+27 30 00	9,60		G5A2	cat. HD	**G9 II-III**
247685	05 47 52,7	+17 47 48	8,30		F8A3	cat. HD	**G8.5 III**
255387	06 20 36,7	+19 40 41	9,10		A3F5	cat. HD	**G7: III**
256138	06 23 16,2	+24 07 46	9,80		F5A3	cat. HD	**G7 III**
257132	06 27 00,0	+31 04 00	9,70		F8A5	cat. HD	**G7.5 III**
257905	06 28 29,3	+13 53 52	8,80		K5A	cat. HD	**K6: III+**
260988	06 37 54,0	+07 44 00	8,90		K0A0	cat. HD	**K6: Ib:**
264663	06 49 49,1	+06 56 10	10,00		F8A3	cat. HD	**K0 III**
264997	06 51 30,0	+21 03 00	9,40		G0A2	cat. HD	**G8 III**
265334	06 51 54,0	+08 19 00	9,10		F8A3	cat. HD	**G8.5 III**
265457	06 52 24,0	+08 41 00	9,70		G0A3	cat. HD	**G7.5 III**

Notes
HD 18715 : classification based on the cool component, since both components are well separated (8")
HD 26630 : standard MK G0Ib
HD 51250 : standard of radial velocity
HD 74395 : standard MK G1Ib
HD 84367 : the secondary is probably an Am star
HD 197177 : standard MK G8IIb
HD 199378 : the authors suspect the object to be composite (G5III+A)
HD 209278 : visual binary, separated 3"7, but the classification is based on the combined light
HD 212391 : the classification is based on the spectrum of the cool star since the separation of 4",3 permits to observe individually each component

Table 2. Stars of the sample which exhibit a hot spectrum

HD / BD	V	B - V	SP	SP (IR)
3883	6.04	0.26	A7m	Am
4298	8.90		A2	A7V
4613	8.79	0.58	B1II	B0III
4694	8.50	0.72	B3Ia	B3Ia
5837	7.80		F5	F0V
14262	6.46	0.34	A1V+... *	F0V
16646	7.80		F5 *	F4V
36°723	10.6:		F2	F4V
24346	8.30		A3 *	F2-3V
24942	8.60		F5	F5V
31266	9.10		G	F6V
31855	7.40		F2	F2-3V
37614	8.19	0.12	B2III	B2V
41724	7.7		A2 *	Am
48953	6.7		F5 *	Am
51565	7.7		A2 *	Am
52830	9.90		F5	B2III :
60178	1.58		A2Vm *	Am
66068	7.04	0.31	Am	Am
68119	8.90		F5 *	F5V
91172	7.70		A9/F0III/IV: *	Am +...?
93251	8.50		F2	F0IV
97336	8.30		F5 *	F5V
102942	6.24	0.32	Am	Am
104449	8.90		F0	F4V
105552	9.10		A9V	A9-F0
107054	6.23	0.30	A9,5III *	A9V
108100	7.14	0.36	F2	F2(V)
110026	8.04	0.37	Am	Am
113697	8.0		A3	Am
114519	8.16	0.58	F4V+...	F:+K: *
120544	6.53	0.51	F6IV-V *	F5V
123102	7.90		F0IV *	F0IV(A) F5V(B)
133189	9.20		F2III	F4V
157046	9.0		F2	Am
179143	6.77	0.35	Am	Am
187949	6.49	0.14	A1V *	A9III
191766	7.70		A5	A8V
195692	6.34	0.26	Am	Am
201638	9.10	-0.14	B0,5Ib	B0V

paper by Weaver & Torres-Dodgen (1995) on an automated classification of A type stars in the near infrared.

2. Observations, treatment of spectra and measure of equivalent widths

The spectra used for classifying the stars of our sample were obtained with the same instrument as the MK standards of Paper I. The stars were observed with the 193 cm telescope of the Observatoire de Haute-Provence (OHP): the spectra were obtained with the CARELEC spectrograph and a CCD receiver Thomson (576×384 pixels) or Tectronix (512×512 pixels). The grating permits to obtain 33 Å/mm spectra over a wavelength interval of 400 Å with a resolution close to 2 Å/mm. The spectra were reduced and measured with the IHAP software available at the OHP.

3. Composition of the sample

Our sample is composed by 180 stars and was selected essentially from the list of Hynek (1938). Additional objects come from Markowitz (1969), Cowley (1973, 1976), Hoffleit & Jaschek (1982) and Stickland (1988). Our sample is contained essentially within the observational limits $V < 10$ and $\delta > -25°$. We have excluded all objects which, according to Hynek, are dubious, but we have included his class VI objects which are mainly Am stars.

Among the 180 stars we have found a number of Am stars and objects hotter than G0 (but with no trace of a hot companion). We are left thus with 120 composite

Table 2. continued

HD / BD	V	B - V	SP	SP (IR)
76369	6.91	0.22	A7m *	Am
76370	6.67:		A2m *	Am
78209	4.47	0.27	A1m	Am
78362	4.66	0.35	Am	Am
79957	9.3		A3	Am
81774	8.20		F2	F1V
83270	8.1		F2 *	Am
83808	3.52	0.49	A5V+...	Am+ F8/G0III-IV: *
86167	8.2		A5 *	Am
88923	7.70		F2 *	F0n

HD / BD	V	B - V	SP	SP (IR)
206088	3.68	0.32	A7mp *	Am
208132	7.3:		A2 *	Am
209790	4.29	0.34	A3m *	Am
209791	6.2:		A3m *	F7-8V
214605	7.5		A3 *	Am
221782	9.37		B8mp...	B5V
237394	9.8:		F2	F9(III)
239481	9.4:		F2	F0-F2
239746	9.92	0.32	A5 *	B4
239933	8.70		F5A3 *	F1V

HD 14262 : also classed A7V (Palmer et al., 1968)
HD 16646 : F4Vwl (Abt, 1984)
HD 24346 : slightly weak-lined F type star (Bidelman, 1988)
HD 41724 : Am (Bidelman, 1988; Carquillat et al.,1988)
HD 48953 : G5Ia+A5V (Markowitz, 1969); Ap Sr-Eu (Bidelman,1988)
HD 51565 : G2IIIe (Kuhi, 1963); Am (Smith, 1973)
HD 60178 : Castor B
HD 68119 : larger proper motion (CDS);
moderatly weak-lined F type star (Bidelman, 1988)
HD 76369 : appears normal (Bidelman, 1988)
HD 76370 : G5III+A0V (Markowitz, 1969)
HD 83270 : Am (Bidelman, 1988; Ginestet et al., 1991)
HD 83808 : SB2. The dominating spectrum is that of an Am star , the secondary could be a late F type. Also classified A1V+F6II (Markowitz, 1969) and A5V+F8III (Parsons, 1983).
HD 86167 : Am (Abt, 1984)
HD 88923 : F2Vwl (Abt,1984)
HD 91172 : Fm Delta Del (HouK & Smith-Moore, 1988)
HD 97336 : Bidelman (1988) : "not composite"
HD 107054 : A8V (Palmer et al.,1968); A9IVn (Gray & Garrison, 1969)
HD 114519 : RS CVn (SB2), Algol eclipsing type binary; Batten et al.(1989): F4IV-V+K0IV; Strassmeier & Fekel (1990): F6IV+G8IV. The spectrum is difficult to classify because of the high rotation, but the Ti/Fe ratios suggest a secondary at least as late as K4.
HD 120544 : F7V (Cowley, 1976)
HD 123102 : A9IV (Abt, 1981); visual double, sep. 13"5
HD 187949 : A1V+F4III: (Markowitz, 1969); Algol type eclipsing binary.
HD 206088 : F0p Sr (Bertaud, 1959)
HD 208132 : Am (Bertaud, 1965)
HD 209790 : Am (Slettebak, 1963)
HD 209791 : F7V (Slettebak, 1963)
HD 214605 : Am (Bidelman, 1988)
HD 239746 : B2V comp.? (Niedzielski & Muciek, 1988)
HD 239933 : is not in the CDS database.

Table 3.

HD	Notes	SP...........Références	SP(IR)
17878		G8III+A2V.... Griffin (1992)	G7III
26630	Standard MK (G0Ib)	G0Ib+B9.5V.. Stickland (1988)	G0Ib
29094		G8I+B5V........ Harmer (1983)	G7Ib
74395	Standard MK (G1Ib)	G2I+B9.5V.... Stickland (1988)	G1Ib
88021		K0III+Am...... Griffin (1988)	G8III
184759		G8III+A2V.... Griffin (1994)	G8III
187259		G8III+A2V.... Griffin (1989)	G8III
197177	Standard MK (G8IIb)	G8IIb+A......... Hoffleit (1982)	G8II
201270		G8III+A2V.... Griffin (1990)	G9III
205114		G2Ib+B9V..... Burki (1983)	G2Ib
223047		G5Ib+B9........ Arellano (1986)	G5Ib

spectra, of which 106 come from Hynek, for which we provide the classification of the cooler component. These stars are listed in Table 1. As can be seen from a perusal of the table, a certain number of stars has been classified several times in the past (often with widely different results), whereas for others we have been unable to find more than the Henry Draper (HD) classification.

The 25 Am stars and the 35 objects with hot spectra (types B to F) are listed in Table 2.

In both tables SP denotes spectral classifications given by other authors, whereas SP(IR) denotes our own classifications. Positions, V and $B-V$ values, as well as the bibliographic references given in the tables were provided by the Centre de Données Stellaires (CDS). An asterisk refers to a footnote. A + or − sign following the SP(IR) luminosity class indicates that the object is probably slightly more or less luminous.

4. Spectral types and luminosity classes of the cooler components

As mentioned before, the spectral classification was carried out along the traditional lines, with the help of the criteria discussed in Paper I. We would like to stress the point that the criteria were not applied blindly, but that all features of the spectrum were examined.

In the course of the classification we have found two facts which merit some comments. The first is that in the composite spectra we have found a slight decrease of the equivalent widths of the features, which is due to the presence of the hot component. Even if the cool component is a supergiant, which has sharp lines, the decrease exists.

The second fact is that if the cool star is of luminosity class III or IV, the presence of the hot companion is signaled usually by the presence of Paschen lines (which are more or less important according to its spectral type). If the Paschen lines are present, they enhance to a certain degree the values of the equivalent widths of the CaII lines of the infrared triplet. On the other side the continuum is also enhanced, which produces a flattening of the lines, and these two effects tend curiously to cancel out mutually.

In view of the preceding comments we can naturally ask ourselves on the consistency and the accuracy of our classifications. We have controlled our results in four different ways, namely:

1. by applying our classifications to a list of "standard" composites,
2. by using widely separated binaries,
3. by using in a statistical way the ratio R (TiI 8683 / FeI 8679), which is usable for both the standards and the composites,
4. by examining artificial composites.

In what follows we shall examine each point separately.

4.1. Composite "standards"

As we have remarked before, classifications of composites are not frequent and if several do exist for the same object, they usually disagree widely. Nevertheless the composites analysed by R. & R. Griffin with the so called "substraction method" (Griffin 1986) can be considered as being well classified, but this lengthy method applies only to bright objects; we have used some of these as "standards". To these objects we can add three MK standards whose composite nature is well established and some other stars such HD 29094 classified by Harmer et al. (1983) on the basis of a spectrophotometric study which includes IUE observations. Our list of "standards" composites comprises thus eleven objects, given in Table 3. In this table we provide the classifications given by the different authors and by ourselves (for the cool components). As can be seen, the agreement is as close as it can be expected.

4.2. Widely separated visual binaries

In certain cases we have widely separated binaries for which we can obtain separated spectra of the components, but we can also obtain a "single" spectrum by defocusing the telescope. We have observed two systems of this type, HD 18715 (Sep. 8″) and HD 24554−5 (Sep. 6.8″). In both cases the classification of the cool component from the combined spectra is identical to the classification of the star if observed separately.

4.3. Ratio R (TiI 8683 / FeI 8679)

As pointed out before, we ignore precisely how much the equivalent widths are influenced by the presence of the companions. To come around this difficulty, we can use the ratio of the central depths of two nearby lines of TiI (8683) and FeI (8679), which should be affected similarly by the continuum background. For the standard stars, this ratio (R) is a spectral type indicator, with a small luminosity effect only for supergiants.

Let us recall below the R - *spectral type* mean relations (cf. Paper I):

Spectral Type	G0	G2	G5	G8	K0	K3	K5
R *(classes V, III, II)*	0.32	0.40	0.50	0.70	0.85	1.30	1.85
R *(class Ib)*	0.40	0.52	0.80	1.06	1.26	1.60	1.85

We can then plot the values of R, instead of the spectral types (assumed unknown for the composites), against the different equivalent widths used for classification work. We produce the plots separately for both the standards stars (average curves, the original values are given in Paper I) and the composite spectrum stars. If the influence of the secondary spectrum in composite spectra were important, one would expect to see a relation which differs from those in the plots of standard stars. If, on the contrary, the influence is small, then the distribution should be the same in both figures. The plots are provided in Figs. 1 to 5: the upper part refers to the standards and the lower part to the composites. One can see that the relations for the standards and the composites are similar. For luminosity class III the average curves are the same, which agrees with what we said formerly on the compensation between the two opposite effects (one increasing the equivalent widths, the other enhancing the continuum). For classes II and I the hydrogen lines of the hot companion are no longer seen, but the influence of the continuum still exists. The consequence is that the equivalent widths are diminished, which produces a lowering of the average relation.

The figures show also a strong concentration of the cool giants for values of $0.60 < R < 0.95$ which corresponds to the interval G7 to K1, with a maximum at about G8. There do not practically exist giants beyond the G7 − K1 interval. For class II the ratio falls in the interval $0.65 < R < 1.40$ which leads approximately to G7 and K3. Class I shows all spectral types between G0 and M, but we should remember that R is not reliable for M type stars.

As expected, dwarfs are missing among the cool components of composite stars.

One last comment should be made with regard to the classification criteria. It can be seen from an examination of the plots that the criteria provided have different uses. For spectral type one can use AT (Fig. 1) and TiI 8435 (Fig. 4), for the whole range from G to M type; AT is more valuable for luminosity classes I and II, whereas TiI 8435 is valid for all luminosity classes.

The other criteria are mostly useful for the determination of luminosity class and/or for a limited range in spectral types. As an example one can consider the blend 8468 (Fig. 3) which is interesting for luminosity classes I, II and III and types earlier than K5.

4.4. Artificial composites

Hynek (1938) and Markowitz (1969) have used artificial composites to compare with the real composites. To obtain these spectra they have superposed the photographic spectrum of a hot star (exposure time t_1) and a cool star (exposure time t_2). Varying the ratio t_1 to t_2 one can simulate the effect of various differences of magnitude between the components.

We have used the same technique on the system HD 24554−5 (ADS 2850) which has components of types G8III and A2V. This is a type of combination which occurs rather frequently. The angular separation of 6″ permits to observe the components (even under bad seeing conditions) both separately or jointly, if the telescope is defocused. The results are given in Table 4.

The first three columns provide the values of the simulated magnitude difference in the blue, the visual and the infrared (we assume that the primary is the cool component of the system).

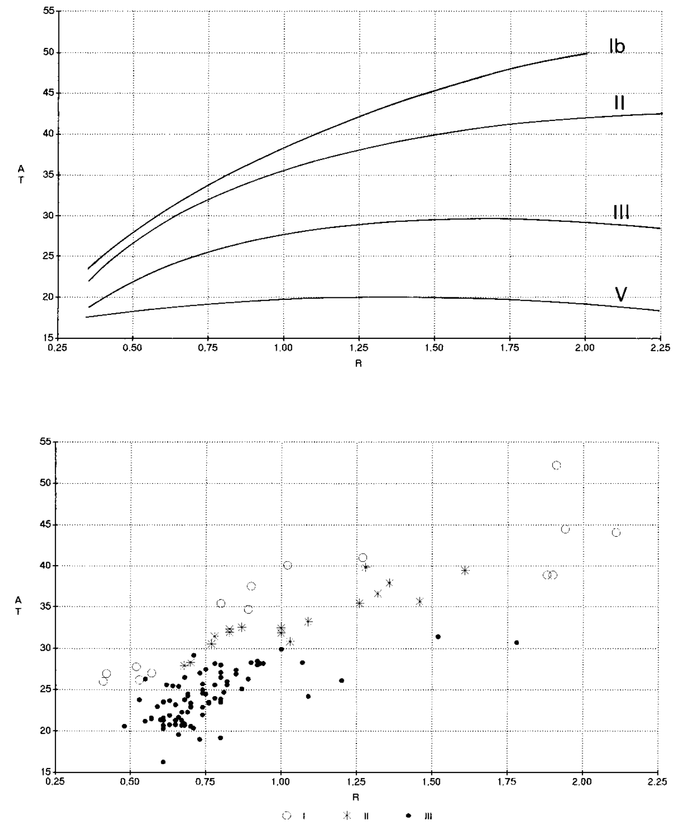

Fig. 1. Equivalent width (in Å) of the total absorption between λ 8390 and λ 8775 versus R (related with the spectral type) for the MK standards (top) and for the composite spectra (bottom). •: giants; ∗: bright giants; ○: supergiants

Δm infinite corresponds to the spectrum of the primary alone. The case labelled "real" corresponds to the real case of HD 24554−5, with $\Delta m_B = 0.5$. The values given in the seven following columns are the measured equivalent widths. The last two columns refer to the absolute magnitude and the luminosity class of the primary which follows from the assumed Δm and the absolute magnitude of the secondary.

From an examination of the table it is easy to see that for magnitude differences larger than −0.75 in the blue (which corresponds to the majority of the composites), equivalent widths change little with the magnitude difference. This is specially remarkable for the sharp lines of FeI and TiI. For the CaII lines the contribution of the Paschen lines, which increases when the magnitude difference diminishes, compensates the flattening due to the influence of the hot spectrum. For the same reason, the total absorption AT is practically invariable, even for $\Delta m_B = -1.5$. Also for the ratio R one can consider that within the errors of measurement, the ratio R and consequently the

Table 4.

Δm_B	Δm_V	Δm_{IR}	AT	TCaII	TiI 8426	TiI 8435	Blend 8468	FeI 8621	FeI 8688	R	Mv_1	TL_1
∞	∞	∞	23.9	9.53	0.27	0.39	0.71	0.18	0.48	0.72		
1.50	2.3	3.1	23.5	9.40	0.25	0.39	0.68	0.21	0.47	0.77	-1.0	II-III
0.75	1.5	2.4	22.7	9.23	0.23	0.37	0.65	0.18	0.45	0.81	-0.2	II-III
0.00	0.8	1.6	22.4	9.04	0.22	0.34	0.65	0.14	0.41	0.68	+0.5	III
-0.75	0.0	0.9	22.7	9.22	0.23	0.36	0.65	0.18	0.45	0.72	+1.3	III-IV
-1.50	0.7	0.1	23.2	8.40	0.15	0.28	0.63	0.14	0.34	0.82	+2.0	III-IV
"real" SG:												
0.50	1.3	2.1	22.5	9.03	0.24	0.37	0.67	0.19	0.43	0.69	0.0	III+

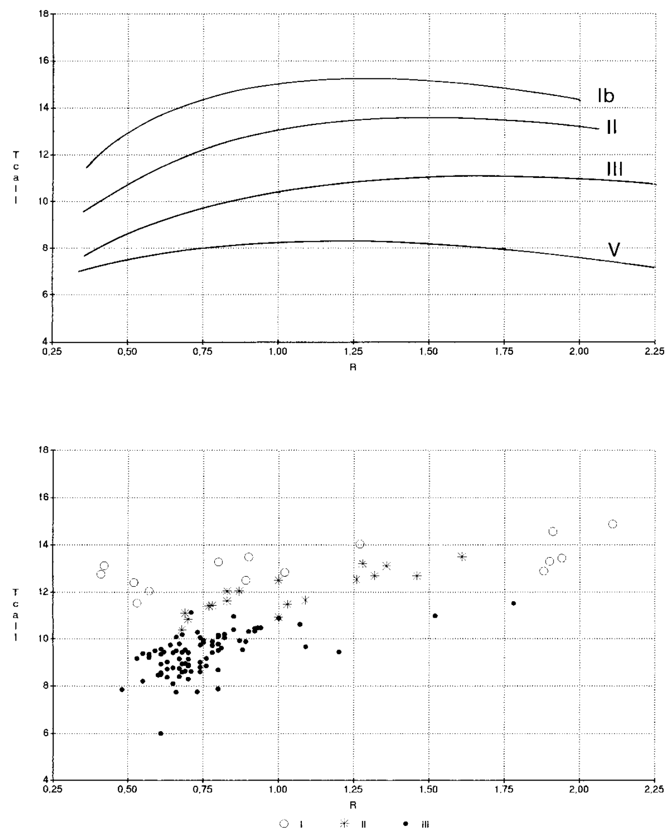

Fig. 2. Equivalent width (in Å) of the CaII triplet versus R (related with the spectral type) for the MK standards (top) and for the composite spectra (bottom). •: giants; ∗: bright giants; ○: supergiants

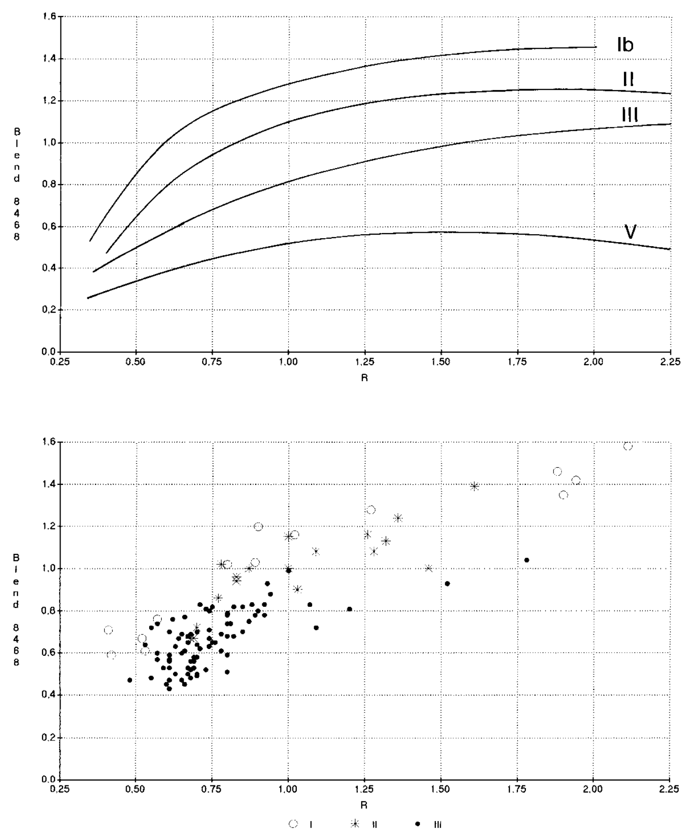

Fig. 3. Equivalent width (in Å) of the λ 8468 blend versus R (related with the spectral type) for the MK standards (top) and for the composite spectra (bottom). •: giants; ∗: bright giants; ○: supergiants

determination of spectral type, is not influenced by the hot component.

We shall next provide some semi-theoretical considerations. Let us consider the most frequent case of composites of the type A5V + G, K III. If we assimilate each component to a black body, we can calculate at each wavelength the ratio between the intensities of both components. This was done in Table 5. For the absolute magnitude and intrinsic colors used we have taken the values given by Schmidt-Kaler (1982). Since these values are well established, the choice of this particular source is not critical.

If one fixes the threshold of the visibility of the companion at $\Delta m < 2$, an influence should be noticeable when the ratio of the radiations of the two bodies is > 0.16. If one examines Table 5, one perceives that in the case of a combination of AV + KIII, the lines of the hot companion should not be visible, although the contribution to the continuum is still of the order of 0.06 to 0.13. In

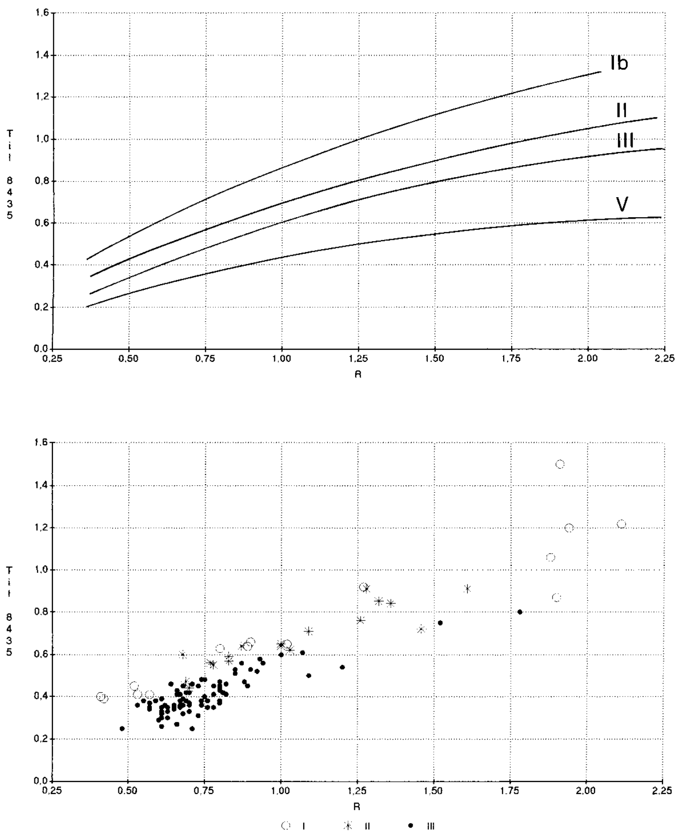

Fig. 4. Equivalent width (in Å) of the TiI 8435 line versus R (related with the spectral type) for the MK standards (top) and for the composite spectra (bottom). •: giants; ∗: bright giants; ◯: supergiants

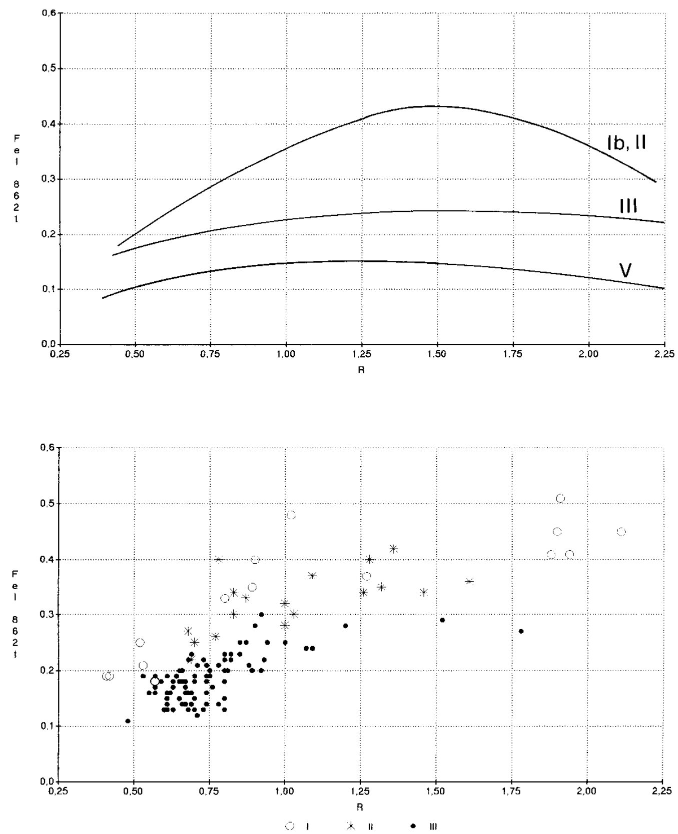

Fig. 5. Equivalent width (in Å) of the FeI 8621 line versus R (related with the spectral type) for the MK standards (top) and for the composite spectra (bottom). •: giants; ∗: bright giants; ◯: supergiants

consequence, the CaII lines should still be slightly flattened. In the case of a combination AV + GIII, the lines should only appear if the hot companion is of types A0-A2, except for G0III but, as shall be seen later on, early G type giants are missing among composites; for the latter A types the continuum of the giant is again influenced by that of the hotter star and therefore the lines should also be slightly flattened.

In the case of composites of types BV + G, K Ib the lines of the hot component should not be visible, but again one finds the contribution of the continuum to be of the order of 0.01 to 0.11, so that even in this case the lines should show some degree of flattening.

All this confirms what we have found during the classification work, namely that all lines of the cooler component of composites (even in the case of supergiants) suffer a diminution of their depth and appear thus artificially flattened.

5. Conclusions

We would like to stress three points which follow from the study of our sample:

1. According to all tests, we think that our classifications are reliable. Because of the fact that they were obtained by the same observers, with the same instrument, they are also homogeneous.
2. To our knowledge we classified for the first time the cooler components of at least 30 composites and for the remainder we provide improved classifications. We found a number of new objects of class Ib (5), of class II (11) and of Am stars (5).
3. We find an accumulation of giants between G6 and K1, with a maximun at G8 and an absence of early G type giants which were abundant in the older classifications.

To conclude, we would like to point out certain difficulties we have found in the course of our work. In first place we had difficulties to decide between classes Ib and II, specially in the later K and early M types. For the giants we found similar difficulties with classes III-IV.

We would like to add that the hotter components of the composites merit also a critical study, because many objects show large discrepancies between the types adjudicated by different observers. We hope to undertake such a study in the near future, because it is only with the help

Table 5.

	λ (Å)	A0V	A2V	A5V	F0V
	4000	1.37	1.03	0.58	0.10
G0III	6000	0.60	0.46	0.29	0.08
	8500	***0.38***	***0.30***	***0.20***	***0.07***
	4000	1.17	0.88	0.50	0.20
G5III	6000	0.40	0.31	0.19	0.10
	8500	***0.22***	***0.17***	***0.12***	***0.06***
	4000	1.02	0.77	0.44	0.18
K0III	6000	0.27	0.21	0.13	0.06
	8500	***0.13***	***0.10***	***0.07***	***0.04***
	4000	1.82	1.37	0.78	0.32
K5III	6000	0.29	0.23	0.14	0.07
	8500	***0.11***	***0.08***	***0.06***	***0.03***

of the best classifications that one can expect to extract all information from the new data provided by HIPPARCOS.

Acknowledgements. We appreciate very much the data and bibliographic references made available from the CDS at Strasbourg.

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