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High resolution spectroscopy over $\lambda\lambda$ 8500−8750 Å for GAIA

I. Mapping the MKK classification system*,**,***

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Abstract. We present an Echelle+CCD high resolution spectroscopic atlas (0.25 Å/pix dispersion, 0.43 Å FWHM resolution and 20 000 resolving power) mapping the MKK classification system over the interval $\lambda\lambda$ 8500 − 8750 Å. The wavelength interval is remarkably free from telluric lines and it is centered on the near-IR triplet of Ca II, the head of hydrogen Paschen series and several strong metallic lines. The spectra of 131 stars of types between O4 and M8 and luminosity classes I through V are included in the atlas. Special care was put in maintaining the highest instrumental homogeneity over the whole set of data. The capability to derive accurate MKK spectral types from high resolution observations over the interval $\lambda\lambda$ 8500−8750 Å is discussed. The observations have been performed as part of an evaluation study of possible spectroscopic performances for the astrometric mission GAIA planned by ESA.

Key words: Atlases — standards — stars: fundamental parameters

1. Introduction

The importance of the near-IR spectral region centered on the head of the hydrogen Paschen series and CaII triplet has already been acknowledged in literature. It offers valuable spectral classification opportunities as well as useful diagnostic tools in stellar evolution, galactic population studies and chemical abundance analysis (e.g. Andrillat et al. 1995; Jaschek & Andrillat 1998; Montes & Martin 1998; Garcia-Vargas et al. 1998; Munari 1999).

We became interested in this spectral region during an evaluation study of possible spectroscopic performances for the GAIA astrometric mission planned by ESA (Gilmore et al. 1998). The emphasis of our investigation was on the achievable accuracy of radial velocities (to provide the 6$^{\rm th}$ component of the phase-space coordinates) as well as the diagnostic capabilities in terms of spectral classification, chemical analysis, spectral peculiarities, mass loss, rotation, signatures of the interstellar extinction, etc. After a careful evaluation based on the anticipated GAIA target population (mostly F-G-K stars) and the severe technical constraints (e.g. an observable interval $\triangle\lambda \leq$ 300 Å and from 500 to 1000 pixel budget per spectrum), we went through the published observational atlases and our set of synthetic spectra and eventually selected for our study the region $\lambda\lambda$ 8500 − 8750 Å. In the near-IR this is the interval less affected by telluric absorptions, which is an useful attribute for compatibility with ground-based preparatory and follow-up observations (cf. Fig. 3).

It soon became apparent that the anticipated goals for the GAIA mission could be best achievable if the $\lambda\lambda$ 8500 − 8750 Å spectra had a resolution of ∼0.4/0.5 Å and cover an interval of 250 Å. No spectral atlas of similar properties exists in the literature as Table 1 illustrates. All atlases have too low a resolution, with the only exception of the Montes & Martin (1998) one, which however samples a limited range of spectral types, its wavelength coverage is not continuous and the explored λ-range is quite restricted (summing up to 90 Å). It became obvious we had to proceed from scratch with new, extended

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* Tables 3 and 4 are only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/ Abstract.html

** The spectra of the stars listed in Table 2 are also available in electronic form at the CDS or via the personal HomePage http://ulisse.pd.astro.it/Astro/Atlases/

*** Figures 3–28 are only available in electronic form at http://www.edpsciences.com

Table 1. A list ordered by resolution of atlases covering all or part of the λλ 8500 – 8750 Å spectral region investigated in the present paper. Only digital atlases with a spectral resolution of 15 Å or better are listed

			dispersion (Å/pix)	resolution (PSF, Å)	res. power	N. stars	spectral types
this atlas			0.25	0.43	20 000	131	O4 - M8
Montes, Martin	1998	A&AS 128, 485	0.07	0.14	60 000	83	F2 - M8
Andrillat et al.	1995	A&AS 112, 475	0.9	1.20	7 200	76	O - G0
Serote Roos et al.	1996	A&AS 117, 93	0.43	1.25	6 900	21	B3 - M5
Carquillat et al.	1997	A&AS 123, 5	0.9	2.0	4 300	36	G0 - M4
Fluks et al.	1994	A&AS 105, 311	1.0	2.8	3 100	97	M0 - M8
Allen, Strom	1995	AJ 109, 1379	1.9	4.5	1 900	275	B8 - M7
Kiehling	1987	A&AS 69, 465	10	10	860	60	F0 - M6
Silva, Cornell	1992	ApJS 81, 865	5.0	11	780	72	O - M6
Danks, Dennefeld	1994	PASP 106, 382	4.3	12	720	126	O - M7
Pickles	1985	ApJS 59, 33	3.0	14	610	178	O - M6
Kirkpatrick et al.	1991	ApJS 77, 417	8	15	570	77	K5 - M9
Torres-Dodgen, Weaver	1993	PASP 105, 693	7	15	570	61	O - M3
Weaver, Torres-Dodgen	1995	ApJ 446, 300	7	15	570	43	A0 - A9

observations. We performed them with the Echelle+CCD spectrograph of the Astronomical Observatories of Padova & Asiago, adopting a 0.25 Å/pix dispersion and a 0.43 Å resolution in the FWHM of the PSF sense (corresponding to a resolving power 20 000). Such a resolution nicely fills in the gap at the highest resolutions documented by Table 1 (our resolution is 3 times that of Andrillat et al. 1995 and 1/3 the one adopted by Montes & Martin 1998).

The present atlas should be of interest also to observers working with the new generation of high-resolution spectrographs now coming on-line on the largest telescopes, which include the 20 000 among their operative resolving powers (cf. Pilachowski et al. 1995).

In this paper we present an extended mapping of the Yerkes–MKK spectral classification system (Morgan et al. 1943; Morgan & Keenan 1973) through observations of 131 MKK standard stars (mainly selected from the atlas of Yamashita et al. 1977). In successive papers in this series we will deal with peculiar spectra, synthetic Kurucz spectra, chemical abundance analysis, radial and rotational velocities, spectral signatures correlated to the reddening, etc.

2. Observations

The observations have been carried out with the Echelle spectrograph mounted at the Cassegrain focus of the 1.82 m telescope operated by Astronomical Osservatories of Padova and Asiago on top of Mt. Ekar, Asiago (Italy). The detector has been a Thomson THX31156 CCD 1024 × 1024 pixels, 19 μm each. A 3 mm thick OG455 filter was used to suppress the cross-disperser II order. Great care was put in maintaining constant the dispersion and resolution over the whole observing campaign. The observations have been completed in 12 months (Dec. 1997 – Dec. 1998), which contributed to the homogeneity of the spectra included in this atlas. Reduction of the spectra has been performed in a standard way with the IRAF package running on PCs under the Linux operative system.

The program stars have been selected mainly from the Yamashita et al. (1977) atlas of the MKK classification system (identified by YNN in the 7$^{\rm th}$ column of Table 2). If a given spectral type was not covered by YNN or the YNN star was too south and/or too faint, suitable targets were selected from other compilations of spectral standard stars. In the latter case, intercomparison of the spectral classifications given in the various catalogues and atlases generally show agreement at a level of ±1 spectral subclass and ±1 luminosity class (which is fully acceptable because the aim of this paper is not to reclassify the program stars but to investigate the classification potential of high resolution spectra in the near-IR). The 131 selected target stars are listed in Table 2, which columns give the following content:
Column 1. HD number.
Column 2. HIP number from the Hipparcos Catalogue.
Column 3. V magnitude from the Hipparcos Catalogue.
Columns 4-5. RA and DEC from the Hipparcos Catalogue expressed on the International Celestial Reference System (ICRS; for the few program stars not in the Hipparcos Catalogue, the V, RA and DEC. values come from the SIMBAD database).

Table 2. Program stars and journal of observations. See text (Sect. 2) for detailed column description

HD	HIP	V	α (J2000.0)	δ	spectr.	source	[Fe/H]	v*sin*i	cv	var	SB	expt	S/N	atl.
190429	98753	6.62	300.87250605	+36.02515949	O4 If	YNN		165		D		1800	100	t
15629	11891	8.46	038.33578505	+61.52172056	O5 V	j		155		C		9600	180	
210839	109556	5.05	332.87743467	+59.41451451	O6 I	YNN		275	1	U, α		1200	150	t
190864	98976	7.78	301.41585197	+35.60779177	O6.5 III	w		105				5100	120	t
199579	103371	5.96	314.14490863	+44.92472729	O6 V	YNN		160			SB1	3000	150	t
192639	99768	7.12	303.62679461	+37.35383972	O7 Ib	YNN		125	1	M		3600	120	
167771	89630	6.52	274.36898577	–18.46344703	O7 III	YNN		110	1	M	SB2	3000	90	
217086	113306	7.64	344.19662186	+62.72713216	O7 V	j		315				4200	150	
167971	89681	7.38	274.52456493	–12.24257847	O8 Ib	YNN		135	2	P, EB		2400	120	
203064	105186	5.04	319.61325695	+43.94596690	O8 III	bsc		315	1	U ell	SB1	900	170	
46966	31567	6.87	099.10787109	+06.08318783	O8 V	j		90				3840	160	
13268	10228	8.19	032.87375163	+56.15881813	O8 V	j		320		C		3600	90	
210809	109562	7.56	332.91085398	+52.42999088	O9 Ib	YNN		120	1	U		7200	140	
207198	107374	5.94	326.22201408	+62.46057429	O9 Ib-II	YNN		80				1440	220	
1337	1415	6.11	004.42944015	+51.43309422	O9 III	bsc		130			SB2	2640	180	
193322	100069	5.83	304.52912505	+40.73209817	O9 V	YNN		150		D		2400	120	
214680	111841	4.89	339.81532883	+39.05028301	O9 V	YNN		30				1440	180	t
228779		8.92	304.47550000	+34.81738889	O9.5 I	j						1200	60	
30614	22783	4.26	073.51254425	+66.34266029	O9.5 Ia	YNN	+0.30	80	1	U	SB1	380	200	
37742	26727	1.74	085.18968672	–01.94257841	O9.5 Ib	g	+0.04	135		D		54	160	d
16429	12495	7.70	040.18729039	+61.28223708	O9.5 III	j		165		D		5400	120	
37468	26549	3.77	084.68652211	–02.60006791	O9.5 V	YNN		110		D		1200	130	d
37128	26311	1.69	084.05338572	–01.20191725	B0 Ia	YNN		85	1	U		120	120	
48434	32226	5.88	100.91102453	+03.93253483	B0 III	YNN		70				1200	110	
217035		7.74	344.12854170	+62.86869444	B0 V	j		170				7800	160	
198478	102724	4.81	312.23455583	+46.11414081	B3 Ia	YNN	–0.23	30	1	U, α		1200	220	
21483	16203	7.06	052.19438591	+30.37536712	B3 III	YNN				C		2100	130	
32630	23767	3.18	076.62862102	+41.23464074	B3 V	YNN	–0.21	125	1	M		1500	90	
74280	42799	4.30	130.80619315	+03.39866539	B4 V	bsc		125		C		1250	160	d
164353	88192	3.93	270.16131466	+02.93158759	B5 Ib	YNN		20				1500	160	a,d,t
184930	96468	4.36	294.18031892	–01.28655047	B5 III	YNN		75	1	M		1440	160	
147394	79992	3.91	244.93519958	+46.31327084	B5 IV	YNN	+0.15	30	1	P, SPB		540	150	
198183	102589	4.53	311.85219564	+36.49073658	B5 V	g		165	2	U, γ		1200	180	a
219688	115033	4.41	349.47584844	–09.18248990	B5 V	YNN		340	1	M		1200	160	d
34085	24436	0.18	078.63446353	–08.20163919	B8 Ia	YNN		35	1	P, α		130	240	a,d
23850	17847	3.62	057.29054669	+24.05352412	B8 III	YNN		195			SB1	180	110	d
23432	17579	5.76	056.47693278	+24.55462128	B8 V	YNN		205				1440	115	
87737	49583	3.48	151.83313948	+16.76266572	A0 Ib	YNN	–0.05	25	1	M		540	160	a,w,t
123299	68756	3.67	211.09760837	+64.37580873	A0 III	YNN	–0.56	10	1	M	SB1	1740	280	a,w,t
130109	72220	3.73	221.56246594	+01.89293830	A0 V	YNN		340		C		360	150	a
172167	91262	0.03	279.23410832	+38.78299311	A0 V	YNN	–0.54	15	1	U, δ		66	240	w,t
114330	64238	4.38	197.48755015	–05.53892987	A1 V	YNN	–0.02	10		D		1440	170	
197345	102098	1.25	310.35797270	+45.28033423	A2 Ia	YNN	–0.04	15	2	U, α		70	200	w
89021	50372	3.45	154.27469564	+42.91446855	A2 IV	YNN	+0.20	45		C		500	210	w
97633	54879	3.33	168.56017036	+15.42976310	A2 V	YNN	+0.04	20				200	130	
210221	109205	6.17	331.85662016	+53.30744684	A3 Ib	YNN	–0.05	30	1	U		1200	130	
50019	33018	3.60	103.19725030	+33.96136985	A3 III	YNN		130				330	150	
7804	6061	5.13	019.44993370	+03.61452038	A3 V	bsc		130		C		3360	220	
97603	54872	2.56	168.52671705	+20.52403384	A4 IV	bsc		195				1250	150	w
164514		7.24	270.63333334	–22.90555556	A5 Ia	g						2400	180	a,w
147084	80079	4.55	245.15909758	–24.16928427	A5 II	YNN	+0.17	15	1	M		510	200	w
73210	42327	6.72	129.44493739	+19.26725017	A5 III	gg		75				3600	110	w
116842	65477	3.99	201.30589832	+54.98799884	A5 Vn	gg		230	1	U		330	140	a,w
79439	45493	4.80	139.04699516	+54.02171207	A6 V	gg		155				1000	180	w
103313	58002	6.31	178.45959018	+00.55210721	A8 III	gg		80				1800	110	w
205924	106856	5.66	324.63280732	+05.77167281	A8 Vn	gg		230		C		2100	160	w
31964	23416	3.03	075.49222507	+43.82331397	A9 Ia	gg		30	2	P, EA	SB2	360	180	w,t
147547	80170	3.74	245.48018203	+19.15302185	A9 III	YNN		145				190	130	w,t
36673A	25985	2.58	083.18255798	–17.82229227	F0 Ib	YNN		15	1	M		460	260	a,d,k
6130	4962	5.92	015.90419820	+61.07482982	F0 II	YNN	+0.02	15		D		1500	130	
89025	50335	3.43	154.17251805	+23.41732840	F0 III	YNN		80				200	200	a
182640	95501	3.36	291.37396941	+03.11457923	F0 IV	YNN		85				720	230	d
58946	36366	4.16	112.27754045	+31.78407932	F0 V	YNN		70		C		900	220	a
182835	95585	4.64	291.62954029	+00.33857566	F2 Ib	YNN		10				840	170	a,t
84999	48319	3.78	147.74871542	+59.03910437	F2 IV	g		110	1	P, δ		400	200	
113139	63503	4.93	195.18160731	+56.36633134	F2 V	YNN		95		D		660	140	a,t
128167	71284	4.47	218.66954381	+29.74480735	F2 V	YNN	–0.41	10				480	150	

Table 2. continued

HD	HIP	V	α (J2000.0)	δ	spectr.	source	[Fe/H]	v*sin*i	cv	var	SB	expt	S/N	atl.
115604	64844	4.72	199.38598801	+40.57256275	F3 III	g	+0.18	15	1	P, δ		540	130	
26690	19719	5.29	063.38794242	+07.71603410	F3 V	YNN		60				1800	170	d
195593	101214	6.21	307.74678964	+36.93584939	F5 Iab	YNN				D		1620	130	
92787	52469	5.18	160.88798925	+46.20403760	F5 III	bsc		55				1250	200	
55052	34819	5.85	108.10994955	+24.12870291	F5 IV	YNN		75				2160	165	
134083	73996	4.93	226.82477948	+24.86959294	F5 V	YNN	+0.10	50		C		600	150	
194093	100453	2.23	305.55708346	+40.25668150	F8 Ib	YNN	–0.30	10	1	U		840	300	t
220657	115623	4.42	351.34442250	+23.40401243	F8 IV	YNN	–0.12*	85		C		1020	290	d,t
9826	7513	4.10	024.19990413	+41.40638491	F8 V	YNN	+0.09	10				700	170	m
204867	106278	2.90	322.88966951	–05.57115593	G0 Ib	YNN	–0.05	15	1	M		260	270	d
111812	62763	4.93	192.92469926	+27.54073393	G0 III	YNN		80		C		600	190	
121370	67927	2.68	208.67131750	+18.39858742	G0 IV	YNN	+0.19	15	1	M	SB1	90	150	k,s
95128	53721	5.03	164.86756582	+40.43012281	G0 V	g	+0.01	5				960	170	a
109358	61317	4.24	188.43788561	+41.35676779	G0 V	g	–0.19	5				400	200	
209750	109074	2.95	331.44593869	–00.31982656	G2 Ib	YNN	+0.10	10				260	280	d,t
161239	86731	5.73	265.84016161	+24.32764591	G2 III	g		<15		C		1800	150	t
186408	96895	5.99	295.45453769	+50.52544635	G2 V	YNN	+0.06	10		C		2100	160	
206859	107348	4.34	326.12787716	+17.35004352	G5 Ib	YNN	–0.03	15				600	170	d,t
52497	33927	5.20	105.60326930	+24.21544652	G5 II	YNN		10				900	190	
18474	13965	5.47	044.95742747	+47.22063875	G5 III	bsc	–0.20			C		780	180	
82210	46977	4.54	143.62069943	+69.83015419	G5 IV	bsc	–0.34	10	1	U, RS		1250	320	
20630	15457	4.84	049.83974536	+03.36997055	G5 V	YNN	–0.01	<15	1	P	SB1	1800	160	d,t,m
48329	32246	3.06	100.98304088	+25.13115531	G8 Ib	YNN	–0.05	<15	1	M		290	300	d,t
208606	108209	6.17	328.83582745	+61.54181712	G8 Ib	g			1	M		3120	180	
148387	80331	2.73	245.99794523	+61.51407536	G8 III	g	–0.21	<15		D		100	210	
131156	72659	4.54	222.84701756	+19.10063329	G8 V	YNN	–0.15	20	1	U, BY		480	160	m
207089	107472	5.29	326.51816071	+22.94888549	K0 Ib	YNN	+0.06		1	M		600	190	
95689	54061	1.81	165.93265365	+61.75111888	K0 IIIab	bsc	–0.20	<15		D	SB1	30	220	
124752	69400	8.52	213.11180064	+67.58617881	K0 V	g				C		4800	90	
52005	33715	5.73	105.06593512	+16.07900547	K3 Ib	kmn	–0.21		1	U		1200	190	t
156283	84380	3.16	258.76189282	+36.80915527	K3 II	YNN	–0.18	<15	1	M		110	200	s
92523	52425	5.01	160.76683096	+69.07624525	K3 III	bsc	–0.38	<20				1250	340	
219134	114622	5.57	348.31143134	+57.16763844	K3 V	YNN	+0.20					720	180	m
131873	72607	2.07	222.67664751	+74.15547596	K4 III	bsc	–0.29	<15	1	M		32	210	m
200905	104060	3.72	316.23273251	+43.92785122	K5 Ib-II	YNN	–0.45	<15	1	U		190	280	
164058	87833	2.24	269.15157439	+51.48895101	K5 III	g	–0.14	<15	1	M		46	250	
201091	104214	5.20	316.71181258	+38.74149446	K5 V	YNN	–0.06	10	3	U		1800	250	m
181475	95099	6.89	290.20130666	–04.50248749	K7 II	g			2	U		1440	170	
70272	41075	4.25	125.70887544	+43.18837233	K7 III	YNN	–0.03	<20	1	M		190	200	
201092	104217	6.05	316.71746843	+38.73441392	K7 V	YNN	0.00	<25	2	U, IS		1200	190	t,m
44537	30520	4.92	096.22459158	+49.28789903	M0 Iab	YNN	+0.08		2	U, LC		600	260	
89758	50801	3.06	155.58251355	+41.49943350	M0 III	YNN			2	U, SR	SB1	60	210	
147379	79755	8.61	244.18123674	+67.23863768	M0 V	g			1	U		3600	100	
204724	106140	4.52	322.48699859	+23.63882922	M1 III	YNN			1	U		390	240	
75632		8.04	133.83750000	+70.79333333	M1 V	l						7200	160	
206936	107259	4.23	325.87689561	+58.78005308	M2 Ia	YNN			2	U, SRC		120	290	m
39801	27989	0.45	088.79287161	+07.40703634	M2 Iab	YNN			2	U, L		12	350	d,k
23475	17884	4.39	057.38035594	+65.52600645	M2 II	YNN			2	U, I		120	220	
119228	66738	4.63	205.18455213	+54.68166149	M2 III	YNN	+0.30		1	U		660	360	
95735	54035	7.49	165.83588409	+35.98146424	M2 V	YNN	–0.20	50				2700	230	
190788		7.93	301.45933333	+25.46117222	M3 I	l						2400	250	
97778	54951	4.56	168.80101292	+23.09552528	M3 II	g			2	U, L		300	260	k
204599	105949	6.11	321.85542635	+59.75011387	M3 III	g			2	U, I		780	240	
180617	94761	9.12	289.23164974	+05.17214064	M3 V	g				C		3600	70	d,t
14469		7.55	035.52837500	+56.60425000	M4 Iab	g						1800	260	
214665	111795	5.11	339.65778029	+56.79571012	M4 III	YNN			2	U, I		420	300	
175588	92791	4.22	283.62620294	+36.89860518	M4 III	g			2	U, SR		120	250	
173739	91768	8.94	280.70090582	+59.62601593	M4 V	l						3600	140	
156014	84345	2.78	258.66192687	+14.39025314	M5 Ib	g			2	U, SRC		15	200	k
132813	73199	4.63	224.39632979	+65.93238126	M5 III	YNN			2	U, SR	SB1	110	220	
148783	80704	4.83	247.16052050	+41.88169065	M6 III	YNN	+0.02		2	U, SRB		85	290	
1326B		11.06	004.55125000	+44.02333333	M6 V	l						5400	85	
170970	90723	7.42	277.64407163	+36.24917176	M8 III	g			2	U		900	140	
126327	70401	7.98	216.04838723	+25.70384317	M8e	YNN			2	U, SRB		310	200	

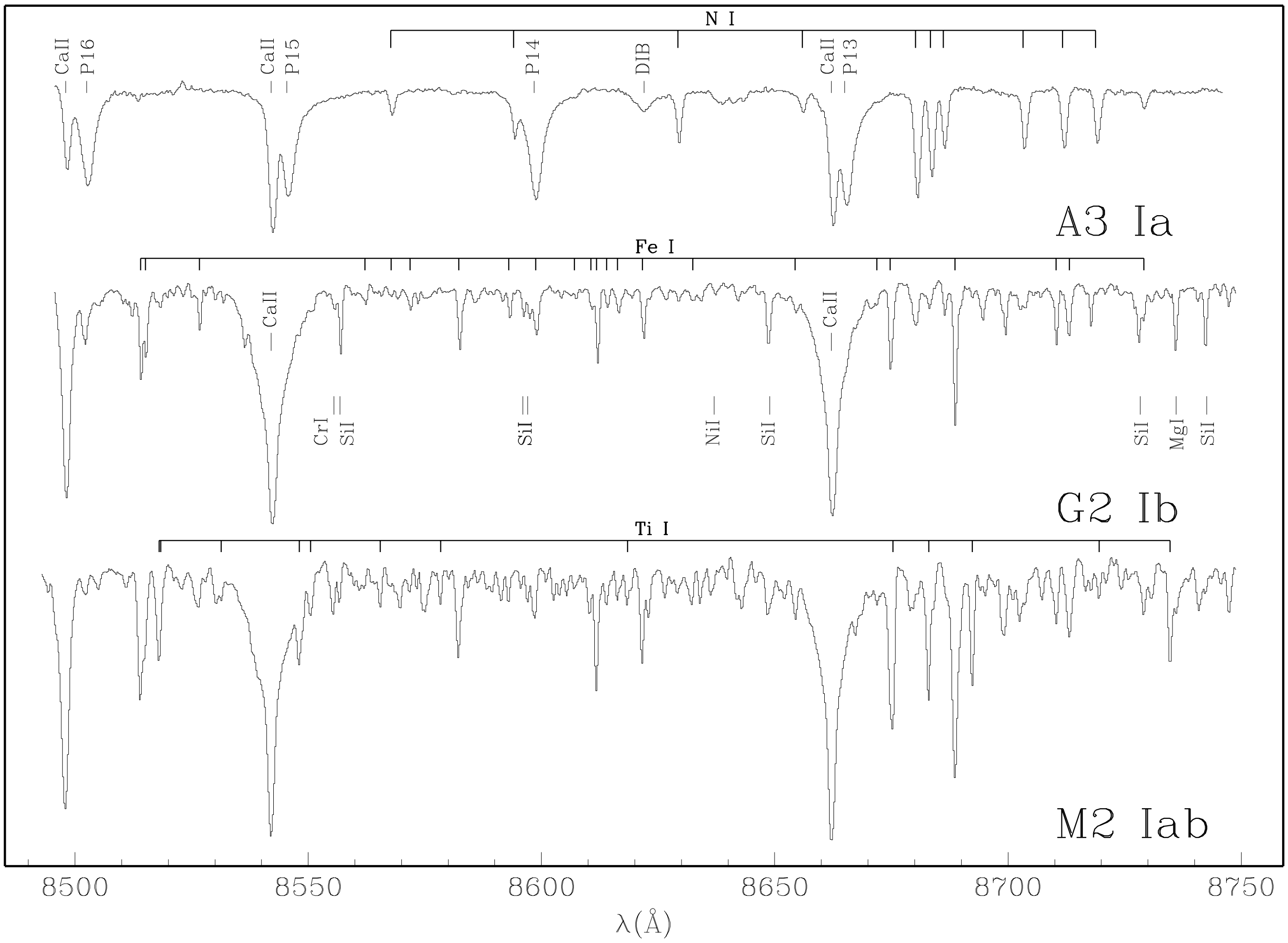

Fig. 1. Sample spectra of supergiant stars with identification of some of the strongest un-blended absorption lines (cf. Table 5)

Column 6. Spectral type.
Column 7. Source for the spectral type: YNN = Yamashita, Nariai & Norimoto (1977); w = Walborn (1973); g = Garcia (1989); l = Lang (1992); gg = Gray & Garrison (1989a,b); kmn = Keenan & McNeil (1989); j = Jaschek (1978); bsc = The Bright Star Catalogue, Hoffleit et al. (1991).
Column 8. [Fe/H] from Cayrel de Strobel et al. (1997); * from Taylor (1994).
Column 9. Projected rotational velocities from Uesugi & Fukuda (1982), in km s^{-1}.
Column 10. cv: coarse variability from the Hipparcos Catalogue: 1 $\leq$ 0.06 mag; 2 = 0.06 − 0.6 mag; 3 $\geq$ 0.6 mag.
Column 11. var: variability type from the Hipparcos Catalogue: C = constant or not detected as variable; D = a duplicity-induced variability; M = possible micro-variable (amplitude less than 0.03 mag); P = periodic variable; U = unsolved variable; α = α Cygni type; EB = eclipsing binary of β Lyrae type; SPB = slowly pulsating B star; γ = γ Cassiopeiae type; δ = δ Scuti type; EA = eclipsing binary of Algol type; RS = RS Canum Venaticurum type; BY = BY Draconis type; L, LC = slow irregular pulsating star; I, IS = irregular eruptive star; SR, SRB, SRC = semi–regular pulsating star; ell = rotating ellipsoidal.
Column 12. SB: spectroscopic binaries from Batten et al. (1989) catalogue; SB1 and SB2: single and double spectrum spectroscopic binary, respectively (for none of the three SB2 binaries the companion is expected to significally affect the spectral appearance of the primary over the $\lambda\lambda$ 8500 − 8750 Å range here investigated. Details on the three SB2 are given by Abhyankar 1958; Morrison & Conti 1978; Wright 1970).
Column 13. Total exposure time (seconds) accumulated over separated observations.
Column 14. S/N ratio for the continuum at 8570 Å.
Column 15. Atlases which include the same star (cf. Table 1): m = Montes & Martin (1998); a = Andrillat et al. (1995); s = Serote Roos et al. (1996); k = Kiehling (1987); d = Danks & Dennefeld (1994); t = Torres-Dodgen & Weaver (1993); w = Weaver & Torres-Dodgen (1995).

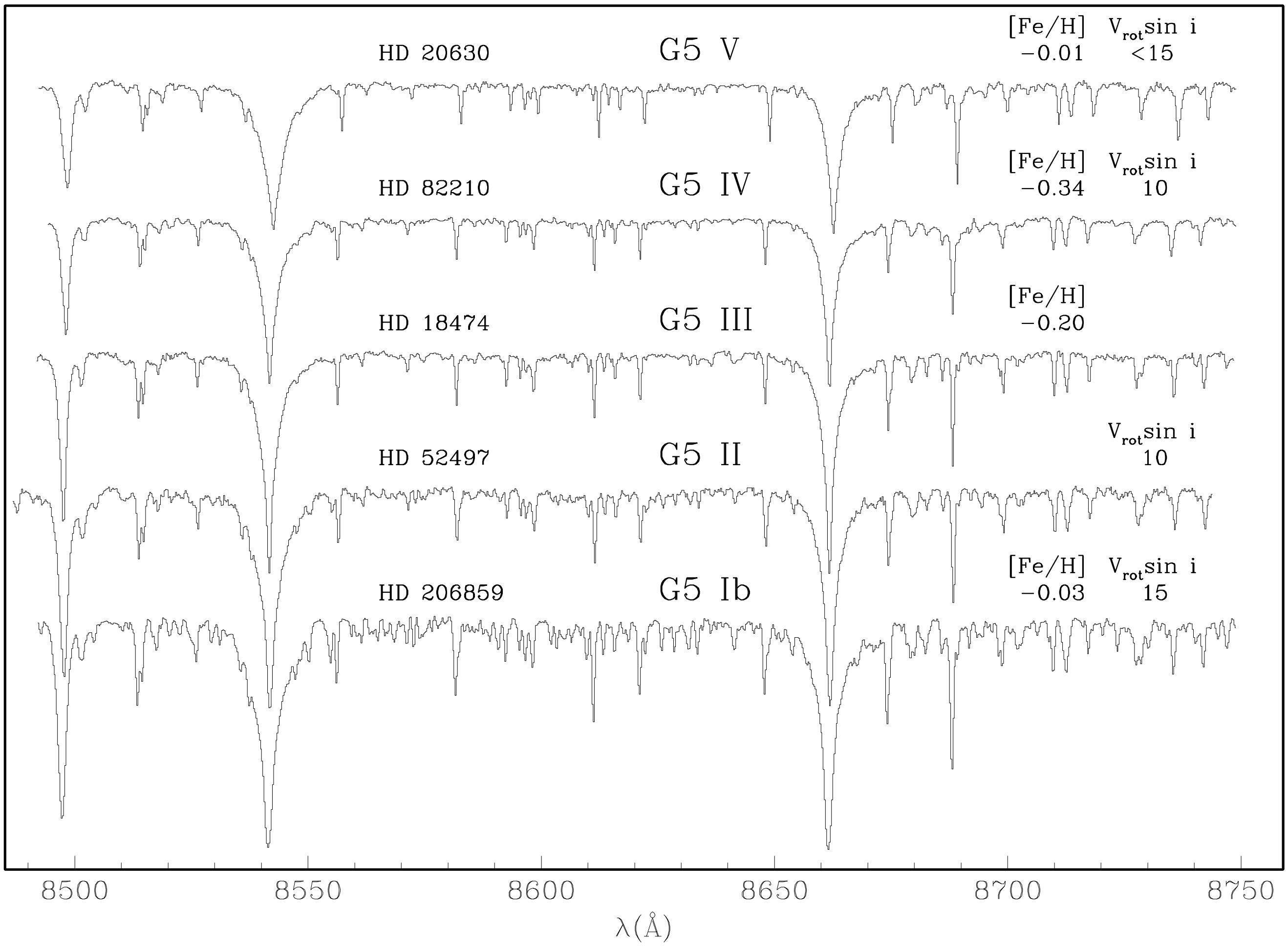

Fig. 2. Luminosity sequence at G5. Metallicity and rotational velocities from the literature (cf. Table 2)

All spectra are electronically available as continuum normalized *ASCII* files (from CDS at http://cdsweb.u-strasbg.fr/Abstract.html or from the personal web-page at http://ulisse.pd.astro.it/Astro/Atlases/), with a heliocentric corrected wavelength scale. The normalization to unity of Echelle spectra quite rarely is a trouble-free exercise, particularly when the wings of stark-broadened lines span a large fraction of an Echelle order (like in fast rotating early type stars). Continuum normalization was however necessary both to prepare the figures for the atlas and to overcome the largely variable shape of the Echelle order response (which depends on several factors: stellar color temperature, instrumental blaze-function, star's placing on the slit, uneven opacity of the CCD-dewar entrance window caused by condensing humidity, etc.). How difficult is the normalization of the continuum in hot stars can be easily guessed by considering a normal O star. In this case, the hydrogen Paschen 14 (at λ 8598 Å, e.g. right at the center of the explored interval) has a peak absorption of just 1.5% the adjacent continuum in not-rotating stars, and therefore less than 1% in normally rotating stars. In the case of the O7 V star HD 217086 in Fig. 28 (which has a rotational speed $V \sin i = 315$ km s^{-1}, cf. Table 2) the peak absorption in Paschen 14 reaches just ∼0.1% of the adjacent continuum. At such a level, to distinguish what is the profile of a stellar line and what instead is due to the instrumental blaze function is essentially impossible.

3. The Atlas

Figure 1 shows spectra of A, G and M supergiants to provide identification for some of the strongest un-blended stellar absorption lines and the diffuse interstellar band at 8620 Å (which is sometimes the strongest feature in the spectra of O and B stars. The 8620 Å DIB will be investigated in detail later in this series). Apart from the Paschen and Ca II lines, the A-type spectra are dominated by strong N I absorptions, the G-type spectra present a large set of Fe I lines and the M-type show numerous and deep Ti I absorptions (cf. Table 4).

Figure 2 gives for the type G5 an example of what Figs. 5–28 (available only in electronic form) give for the other spectral types. They constitute the body of the present atlas. The spectra are arranged in luminosity sequences at selected spectral types. If available from the literature (cf. Table 2), the metallicity and the projected rotational velocity are given over each spectrum.

Figure 3 details how the selected wavelength region is the less affected by telluric absorptions in the near-IR (consecutive orders from an Echelle spectrum of a fast rotating B5 V star are plotted). Figure 4 (obtained from spectra of fast rotating main sequence B stars observed under high- and low-humidity conditions) shows in detail how marginal are the H_20 telluric absorptions in the $\lambda\lambda$ 8500 – 8750 Å range. Such weak telluric absorptions are sometimes visible in the high S/N spectra of this atlas, particularly when stellar lines are broad and shallow like in hot and fast rotating stars (cf. Figs. 27 and 28).

4. Classification results

As Figs. 27 and 28 show, the spectral classification of O- and early B-type stars over the $\lambda\lambda$ 8500 – 8750 Å region is not trivial. Starting with type B8 the Ca II triplet lines become visible and over the whole B8 – M8 sequence the classification is made easy by a costantly growing number of metallic lines. The intensity of Ca II triplet lines relative to Paschen lines offers for B8 to F8 stars the same diagnostic tool as provided by the Ca II H&K vs. Balmer lines in the optical. Going from G to early M stars, the Paschen lines are not more visible, Ca II triplet lines progressively saturate and the classification criteria therefore shift more and more toward metallic lines like those of Si I, Mg I, Fe I and Ti I. The metallic lines at a given spectral type are as much abundant and strong as those used for classification in the optical. Therefore the $\lambda\lambda$ 8500 – 8750 Å spectra offer the same classification accuracy as spectra in the classical optical region of equivalent $\triangle\lambda$ = 250 Å (like the $\lambda\lambda$ 3870 – 4120 Å interval centered on the Ca II H&K lines and the H_8, H_ϵ and H_δ Balmer lines).

5. Toward a continuous classification scheme

For several metallic ions there is in this region the contemporaneous presence of absorption lines from the same multiplet as well as from multiplets of largely different excitation potential (cf. Table 4). This offers a bright prospect for a quantitative spectral classification. Later on in this series line ratios useful for a quantitative classification will be investigated (work based on extensive measurement of observational and Kurucz's synthetic spectra).

The actual stellar spectra are obviously continously distributed in temperature and luminosity even if all past and present classification systems have forced them into discrete bins (only qualitatively defined by a set of *standards* to compare with). With an expected harvest of some 10^7 extremely homogeneous spectra, GAIA is perfectly suited to move forward the classification process into a *continous* and *fully quantitative* scheme. For all the spectroscopic targets GAIA will provide accurate astrometric distances, color temperature from multiband photometry and metallicities from spectroscopy. It should be therefore easy to derive an accurate and continous classification in terms of temperature, luminosity and metallicity from the equivalent width ratios of appropriately chosen absorption lines.

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