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Library of high and mid-resolution spectra in the Ca II H & K, Hα, Hβ, Na I D_1, D_2, and He I D_3 line regions of F, G, K and M field stars[⋆,⋆⋆]

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Abstract. In this work we present spectroscopic observations centered in the spectral lines most widely used as optical indicators of chromospheric activity (Hα, Hβ, Ca II H & K, and He I D_3) in a sample of F, G, K and M chromospherically inactive stars. The spectra have been obtained with the aim of providing a library of high and mid-resolution spectra to be used in the application of the spectral subtraction technique to obtain the active-chromosphere contribution to these lines in chromospherically active single and binary stars. This library can also be used for spectral classification purposes. A digital version with all the spectra is available via ftp and the World Wide Web (WWW) in both ASCII and FITS formats.

Key words: atlas — stars: activity — stars: late-type — stars: fundamental parameters — stars: general

1. Introduction

Enhanced emission cores in the Ca II H & K, are the primary optical indicators of chromospheric activity in late-type stars, but also the emission or the filling-in of the central core of other lines such as Hα, Hβ, Na I D_1, D_2, and He I D_3 indicate the existence of an active chromosphere in these stars. Actually, the later mentioned lines are only in emission in a few very active stars, whereas in a large number of moderately active stars only a filling-in of the photospheric absorption is present. To infer the chromospheric activity level a comparison with non-active stars is needed, for example by means of the spectral subtraction technique. This technique provides reliable measurements of the the active-chromosphere contribution to these lines (see Montes et al. 1995a,c; and references therein). To apply this technique a large number of spectra of inactive stars (i.e., stars with negligible Ca II H & K emission) with different spectral types and luminosity classes taken with the same spectral resolution that of the stars under consideration is needed.

Previously published stellar libraries cover the optical range and extend to the near infrared, however they are of poor spectral resolution. The more widely used have the following wavelength ranges and spectral resolutions: Gunn & Stryker (1983) (3130 – 10800 Å, 20 and 40 Å); Jacoby et al. (1984) (3510 – 7427 Å, 4.5 Å); Pickles (1985) (3600 – 10000 Å, 15 Å); Kirkpatrick et al. (1991) (6300 – 9000 Å, 8 and 18 Å); Silva & Cornell (1992) (3510–8930 Å, 11 Å); Torres-Dodgen & Weaver (1993) (5800 – 8900 Å, 15 Å); Danks & Dennefeld (1994) (5800 – 10200 Å, 4.3 Å); Allen & Strong (1995) (5800 – 10200 Å, 6 Å) and Serote Roos et al. (1996) (4800 – 9000 Å, 1.25 and 8.5 Å). As can be seen the higher spectral resolution is only 1.25 Å (Serote Roos et al. 1996) and 4.5 Å (Jacoby et al. 1984) that is much lower than needed in detailed spectroscopic studies of chromospheric activity.

Our intent in this paper is to provide a library of higher resolution spectra (≤ 0.5 Å) of F, G, and K chromospherically inactive stars to be used in the application of the spectral subtraction technique in chromospherically active single and binary stars. These spectra can also be used for spectral classification purposes (see Jaschek & Jaschek 1990) and specially for the spectral classification

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⋆ Based on observations made with the Isaac Newton telescope and the William Herschel Telescope operated on the island of La Palma by the Royal Greenwich Observatory at the Spanish Observatorio del Roque de Los Muchachos of the Instituto de Astrofísica de Canarias, and with the 2.2 m telescope of the Centro Astronómico Hispano-Alemán of Calar Alto (Almería, Spain) operated jointly by the Max Planck Institut für Astronomie (Heidelberg) and the Spanish Comisión Nacional de Astronomía.
⋆⋆ The spectra of the stars listed in Table 3 are also 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

Table 1. Summary of high-resolution observations

				Ca II H&K		Hα		Hβ		D_1, D_2, D_3	
O	Date	Tel.	Detector	$\lambda_i - \lambda_f$	$\delta\lambda$	$\lambda_i - \lambda_f$	$\delta\lambda$	$\lambda_i - \lambda_f$	$\delta\lambda$	$\lambda_i - \lambda_f$	$\delta\lambda$
1	Feb. 1988	2.2 m	RCA	3890 − 4009	0.198	-	-	-	-	-	-
2	Jul. 1989	2.2 m	RCA 006	3883 − 4015	0.198	6464 − 6719	0.50	-	-	-	-
3	Dec. 1992	INT	EEV5	3840 − 4050	0.358	6507 − 6764	0.45	4778 − 4941	0.34	-	-
4	Mar. 1993	2.2 m	TEK #6	3830 − 4018	0.420	-	-	-	-	-	-
5	Jun. 1995	2.2 m	RCA #11	-	-	6510 − 6638	0.26	4807 − 4926	0.26	-	-
6	Sep. 1995	INT	TEK3	-	-	6452 − 6695	0.48	-	-	5762 − 6011	0.48

Table 2. Summary of mid-resolution observations

				Hα		Hα + Na I D_1, D_2	
O	Date	Tel.	Detector	$\lambda_i - \lambda_f$	$\delta\lambda$	$\lambda_i - \lambda_f$	$\delta\lambda$
7	Jan. 1993	WHT	TEK1	-	-	5500 − 7000	2.90
8	Apr. 1993	INT	EEV5	-	-	5626 − 7643	3.16
9	Jun. 1995	INT	TEK3	6430 − 6824	0.78	-	-
10	Aug. 1995	INT	TEK3	6295 − 6918	1.06	-	-
11	Nov. 1995	INT	TEK3	6344 − 6742	0.78	-	-

of chromospherically active binary stars with composite spectra (see Strassmeier & Fekel 1990). In addition, we provide spectra of M-type stars with resolution significantly higher than in previous databases (Jacoby et al. 1984; Kirkpatrick et al. 1991, 1995).

We present a total of 170 spectra centered in the spectral lines most widely used as optical indicators of chromospheric activity in a sample of 116 F, G, K and M field stars.

In Sect. 2 we report the details of our observations and data reduction. The library is presented in Sect. 3 with comments on the behaviour of some interesting spectral lines.

2. Observations and data reduction

The spectroscopic observations of inactive stars presented here were carried out during several observing seasons, from 1988 to 1995, within a program devoted to the study of optical activity indicators in chromospherically active single and binary stars (Montes et al. 1994, 1995a-d, 1996a,b; Martín & Montes 1997). The high and mid-resolution spectra were obtained with three telescopes: the 2.2 m Telescope at the German Spanish Astronomical Observatory (CAHA) in Calar Alto (Almería, Spain), using a Coudé spectrograph with the f/3 camera, the Isaac Newton Telescope (INT) and the William Herschel Telescope (WHT) located at the Observatorio del Roque de Los Muchachos (La Palma, Spain), using the Intermediate Dispersion Spectrograph (IDS) with the cameras 500 and 235 at the INT and the ISIS double arm spectrograph at the WHT.

The different observational campaigns, the telescope and detector used and the spectral region observed in each season are given in Tables 1 and 2. We also give for each spectral region the wavelength range ($\lambda_i - \lambda_f$) covered and the spectral resolution ($\delta\lambda$) achieved.

The spectra have been extracted using the standard reduction procedures in the MIDAS and IRAF packages (bias subtraction, flat-field division, optimal extraction of the spectrum, and wavelength calibration using arc lamps). More details of the observations and data reduction for the different observational seasons from 1988 to 1995 can be found in Fernández-Figueroa et al. (1994); Martín et al. (1994) and Montes et al. (1995a-d, 1996b).

The high-resolution observations cover four spectral ranges:

1. The Ca II H (3968.47 Å) & K (3933.67 Å) line region, that also includes the Hϵ (3970.07 Å) and in some cases the Hζ (3889 Å) and Hη (3835 Å) Balmer lines.
2. The Hα (6562.8 Å) line region that in some observational seasons also include the Li I 6708 Å line and the Fe I 6663 Å, Fe I 6678 Å and Ca I 6718 Å lines used in rotational velocity determinations (Huisong & Xuefu 1987).
3. The Hβ (4861.32 Å) line region.
4. The He I D_3 (5876 Å) line region that also includes the Na I D_1 (5895.92 Å) and D_2 (5889.95 Å) lines.

We measured the resolution of our spectra using emission lines of arc lamps taken on the same nights. Typically the full width at half maximum (FWHM) was two pixels. The spectral resolution ($\delta\lambda$) achieved ranges between 0.2 and 0.5 Å ($R = \lambda/\delta\lambda$, 25000 − 10000) depending on the observational season (see Table 1).

The mid-resolution observations ($\delta\lambda$ between 0.8 and 3 Å) cover, in some cases, the Hα line region and in other cases the Hα and Na I D_1 and D_2 line region (see Table 2).

In the Hα, Hβ, and Na I D_1, D_2, and He I D_3 line regions the spectra have been normalized by fitting a polynome to the observed continuum. However, in the Ca II H & K line region it is very difficult to fit a continuum so the spectra have been normalized to the measured flux in a 1 Å window centered at 3950.5 Å. This reference point at 3950.5 Å is not a real continuum, but it is a relatively line-free region that could be used as a pseudo-continuum to normalize all the Ca II H & K spectra and that has been used by Pasquini et al. (1988) to develop a calibration procedure for converting the observed line fluxes into absolute surface fluxes. In the case of the mid-resolution spectra of M stars it is also difficult to establish a continuum, due to the presence of strong molecular bands, so we have normalized these spectra by means of the pseudo-continuum regions used by Martín et al. (1996) located at 6525−6550, 7030 − 7050, and 7540 − 7580. At lower wavelengths we included other two regions near 5795 and 6150 Å. We plot the spectra normalized to those points in Fig. 6. However, in the database available by ftp or WWW, we have divided the spectra only by the average continuum level in the region 6525 − 6550 Å in order to preserve the observed shape.

3. The library

The stars included in the library have been selected from the sample of lower main sequence stars studied in the Mount Wilson Observatory HK project (Baliunas et al. 1995 and references therein). From this sample the slowly-rotating stars and the stars with the lower Ca II H & K spectrophometric index S (normally lower than 0.2) were chosen.

Several stars not included in the sample of the HK Project have been observed, because there are known to be inactive and slowly rotating stars and they were used by other authors in the application of the spectral subtraction technique (see Strassmeier et al. 1990; Strassmeier & Fekel 1990; Hall & Ramsey 1992). Some visual companions of chromospherically active binaries have been observed simultaneously by locating both components of the visual par in the slit when the spectra where taken. Some of these stars are inactive ADS 1697 B (HD 13480) and some are little active ADS 16557 A (HD 218739), σ^1 CrB, and ADS 8119 A (HD 98231) (see Table 3).

We have considered as chromospherically inactive stars, those which at our spectral resolution do not present any evidence of emission in the core of Ca II H & K lines. We have found that some stars of the HK project (HD 115417, HD 115383, HD 206860, HD 101501, HD 4628, HD 16160) with relatively low values of S index (0.2 − 0.3) present a small, but measurable, emission in our Ca II H & K spectra (see Montes et al. 1995c). Hence, they have not been used as reference stars.

Table 3 presents information about the observed stars. In this table we give the HD and HR numbers, name, spectral type and luminosity class ($T_{\rm sp}$), from the Bright Star Catalogue (Hoffleit & Jaschek 1982; Hoffleit & Warren 1991), the Catalogue of Nearby Stars (Gliese & Jahreiss 1991), and Kirkpatrick et al. (1995), metallicity [Fe/H] (from Taylor 1994, 1995), rotational period ($P_{\rm rot}$) and $v \sin i$ (from Donahue 1993; Baliunas et al. 1995). The $T_{\rm sp}$ given between brackets are from Hoffleit & Warren (1991) and the values of $v \sin i$ marked with "*" are from the references given in Strassmeier & Fekel (1990). We also give the Ca II H & K spectrophometric index S from Baliunas et al. (1995) or from Duncan et al. (1991) (values with "*"). In the columns labeled with Hα, He I D_3, Hβ, and Ca II we list information about the observations for each spectral range, using a code given in the first column of Tables 1 and 2. In the last column "A" and "R" mean active and reference star respectively, according with our above mentioned criterion, and "E" means that the Hα line is in emission in our spectra. In some cases, we have available spectra of several stars that have been classified with the same spectral type, these spectra present small differences in the lines that could be attibuted to differences in metallicities, rotation, errors in the spectral classification, or even to variations in the small level of activity that these stars could present.

Figures 1, 2, 3, and 4 show representative high-resolution spectra in each spectral range. In these figures we plot, at the left, the complete wavelength range covered in each spectrum. For a better display of the spectral features an small region of 30 Å centered in the spectral line of interest in each case is showed at the right. Figure 5 presents mid-resolution spectra centered in the Hα line from 6340 to 6740 Å, and Figure 6 shows representative mid-resolution spectra in the wavelength range 5700 to 7600 Å which include the Na I D_1, D_2 and Hα lines. The stars in these figures are arranged in order of spectral type from F to M. The HD number and the spectral type of the stars are given in each spectrum.

Looking at Figs. 1, 2, 3, and 4 some conclusions concerning the behaviour of different spectral lines present in each spectral region can be obtained.

In the Ca II H & K line region, we can note the effect of the spectral type: the equivalent width of several metallic lines increases with decreasing temperature, in particular the Al I 3961.52 Å line (see Fig. 1).

In the case of the Hα line, we note the increasing line wings with hotter spectral type. At spectral type F the line exhibits extended wings that decrease with decreasing temperature. The line becomes sharper at spectral type K (see Fig. 2). Some strong absorption lines in this spectral region, that could be used for radial and rotational velocity determinations are: the Fe I 6495 Å, 6546.25 Å, 6663.4 Å, and 6677.9 Å lines and the Ca I 6718 Å line.

Table 3. Stellar parameters and spectral region observed

HD	HR	Name	T_{sp}	[Fe/H] (dex)	P_{rot} (days)	v sin$i$ (km s^{-1})	S	Hα	He I D$_3$	Hβ	Ca II	A/R
F stars												
161023	6600	-	F0V	-	-	< 15	-	9				
177552	7231	-	F1V	-	-	45	-	9				
178476	7363	-	F3V	0.170	-	50	-	9				
185395	7469	θ Cyg	F4V	0.009	-	3.4*	-	5		5		
13480B	642B	6 Tri B	F5V	-	2.236	-	-				3	R
179422	7280	-	F5V	-	-	40	-	9				
176095	7163	-	F5IV	-	-	< 10	0.202	9				
120136	5185	τ Boo	F6IV	0.096	-	10.0	0.191				2	R
82328	3775	θ UMa	F6IV	−0.172	-	6.4*	0.182*	3				
124850	5338	ι Vir	F6III	−0.129	-	15.0	0.210				2	R
187013	7534	17 Cyg	F7V	−0.109	-	10.0	0.154				2	R
212754	8548	34 Peg	F7V	−0.061	-	10.0	0.140				2	R
25998	1278	50 Per	F7V	-	2.6	20.0	0.300	3				
216385	8697	σ Peg	F7IV	−0.297	-	10.0	0.142				2	R
167588	6831	-	F8V	-	-	< 6	-	10				-
6920	340	44 And	F8V	−0.230	15.3	< 15	0.194				3	R
45067	2313	-	F8V	-	-	< 15	0.141*				1	R
107213	4688	9 Com	F8V	0.154	-	10.0	0.135				1	R
142373	5914	χ Her	F8V	−0.431	-	10.0	0.147	2			2	R
187691	7560	o Aql	F8V	0.059	-	5.0	0.148				2	R
194012	7793	-	F8V	-	-	5.0	0.198	2			2	R
136202	5694	5 Ser	F8III-IV	−0.075	-	5.0	0.140	2			2	R
154417	6349	V2213 Oph	F8.5IV-V	0.099	7.78	5.0	0.269	2			2	A
43587	2251	-	F9V	-	-	5.0	0.156*				1	R
78366	3625	-	F9V	-	9.67	5.0	0.248	8				-
G stars												
115383	5011	59 Vir	G0V	0.130	3.33	5.0	0.313				2	A
152792	-	-	G0V	−0.462	-	-	-				2	R
114710	4983	β Com	G0V (F95V)	0.135	12.35	3.9*	0.201				2	R
206860	8314	HN Peg	G0V	-	4.86	10.0	0.330	2			2	A
29645	1489	-	G0V	0.074	-	< 15	0.140				1	R
13974	660	δ Tri	G0V (G0.5V)	−0.444	-	10.0	0.232*				3	R
98231	4375	ξ UMa A	G0V	−0.352	-	< 15	-				1	A
218739	-	ADS 16557 A	G0V	-	-	-	0.294*			3	3	A
39587	2047	χ^1 Ori	G0V	−0.084	5.36	10.0	0.325	3				
13421	635	64 Cet	G0IV	-	-	< 15	0.131				1,3	R
190406	7672	15 Sge	G1V	-	13.94	5.0	0.194	2			2	R
146362	6064	σ^1 CrB	G1V	-	-	< 30	0.264*				1	A
33021	1662	13 Ori	G1IV	-	-	5.0	-	3				
-	-	Sun	G2V		25.72	<1.7	0.179			5	4	R
143761	5968	ρ CrB	G2V (G0V)	−0.185	-	5.0	0.150	2		5	2	R
81809	3750	-	G2V	−0.319	40.20	10.0	0.172				1	R
9562	448	-	G2IV	0.147	-	< 15	0.136	6	6		3	R
12235	582	112 Psc	G2IV	-	-	< 15	0.160				3	R
217014	8729	51 Peg	G2.5IV	−9.000	-	2	0.149				2	R
186427	7504	16 Cyg B	G2.5V	−0.002	-	3.0	0.145*	8				-
159222	6538	-	G5V	-	-	-	0.164*	10				-
20630	996	κ^1 Cet	G5V	0.133	9.24	5.6*	0.366	6	6		3	A
25680	1262	39 Tau	G5V	-	-	3.0	0.281*	11				-
68255	3210	16 Cnc C	G5V	-	-	-	-	8				-
78715	3640	79 Cnc	G5III	-	-	-	-	8				-
115617	5019	61 Vir	G6V	0.032	-	2.0*	0.162				1	R
190360	7670	-	G6IV+M6V	−9.000	-	-	0.146	2, 6	6		2	R
3443	159	-	G8V	−0.101	-	2:	0.183	11				-
182488	7368	-	G8V	-	-	-	0.155*				2	R
131156 A	5544 A	ξ Boo A	G8V	−0.151	6.31	3	0.461	2			2	A
144287	-	GJ609.2	G8V	-	-	-	0.156*	2			2	R
101501	4496	61 UMa	G8V	−0.070	16.68	< 15	0.311	3, 8			4	A
182572	7373	31 Aql	G8IV	-	-	< 15	0.148				2	R
188512	7602	β Aql	G8IV	-	-	2.6	0.136	5		5	2	R
158614	6516	-	G8IV (G9IV-V)	0.056	-	-	0.158				2	R
62345	2985	κ Gem	G8III	-	-	6*	0.123*	3				
107383	4697	11 Com	G8III	-	-	< 19	-	8				-
215665	8667	λ Peg	G8IIIa	-	-	< 19	0.108	2			2	R
104979	4608	o Vir	G8IIIa	-	-	< 19	-				4	R
58368	-	-	G8IIIb	-	-	-	-				4	R
218356	8796	56 Peg	G8Ib	-	-	< 17	0.686	2			2	A
199939	-	-	G9III	-	-	-	-	2			2	A
201657	-	-	G9III	-	-	-	-	2			2	A
101013	4474	-	G9III	-	-	-	-				4	R

Table 3. continued

HD	HR	Name	T_{sp}	[Fe/H] (dex)	P_{rot} (days)	$v \sin i$ (km s^{-1})	S	Hα	He I D_3	Hβ	Ca II	A/R
K stars												
166	8	-	K0V	-	-	-	0.486*	11				-
3651	166	54 Psc	K0V	−9.000	48.00	-	0.176				3	R
185144	7462	61 Dra	K0V	−0.045	-	1.5*	0.215	8				-
23249	1136	δ Eri	K0IV	-	-	2.2*	0.137	6	6			
45410	2331	6 Lyn	K0III-IV	-	-	-	0.127*	3				
25604	1256	37 Tau	K0III	-	-	-	0.105*	10, 11				-
62509	2990	β Gem	K0III	-	-	2.5*	0.140*	3				
109345	4784	-	K0III	-	-	-	-	8				-
139195	5802	16 Ser	K0III	-	-	< 17	-				4	R
164349	6713	93 Her	K0.5IIb	-	-	< 17	-	2			2	A
190404	-	GJ 778	K1V	−0.087	-	-	0.174*	2			2	A
10476	493	107 Psc	K1V	−0.123	35.2	< 20	0.198	11			3	R
22072	1085	-	K1IV (G7V)	-	-	-	0.131	6	6		1	R
142091	5901	κ CrB	K1IV	-	-	4.5*	-	5		5	4	R
95345	4291	58 Leo	K1III	-	-	< 19	-				4	R
163770	6695	θ Her	K1IIa	-	-	< 19	-	2			2	A
22049	1084	ϵ Eri	K2V	−0.165	11.68	< 15	0.496				3	A
4628	222	-	K2V	−0.235	38.5	-	0.230	11		3	3	A
166620	6806	-	K2V	−0.114	42.4	2.5*	0.190	8				-
12929	617	α Ari	K2III	-	-	< 17	0.118*	6	6			
26162	1283	43 Tau	K2III	-	-	-	-	11				-
190608	7679	16 Sge	K2III	-	-	< 19	-	8				-
206778	8308	ϵ Peg	K2Ib	-	-	< 17	0.330	2			2	A
16160	753	-	K3V	−0.297	48.0	-	0.226	6, 11	6		3	A
219134	8832	-	K3V	−9.000	-	-	0.230*				2	A
115404	-	GJ 505A	K3V (K1V)	-	18.47	-	0.535				2	A
127665	5429	ρ Boo	K3III	0.183	-	< 15	-				4	A
131156 B	5544 B	ξ Boo B	K4V	-	12.28	20	1.381				2	A
131873	5563	β UMi	K4III	-	-	< 17	-	2			2	A
201091	8085	61 Cyg A	K5V	-	35.37	10	0.658	2, 8			2	A
201092	8086	61 Cyg B	K7V	-	37.84	< 25	0.986	2, 8			2	A
M stars												
79210	-	GJ 338 A, LHS 260	M0V	-	-	-	2.113	8				-
79211	-	GJ 338 B, LHS 261	M1III	-	-	-	1.955	8				-
331161	-	GJ 767 A, LHS 3482	M0.5V	-	-	-	-	8				-
189319	7635	12 Sge	M0III	-	-	< 17	0.254	8				-
-	-	GJ 767 B, LHS 3483	M2V	-	-	-	-	8				-
190658	7680	-	M2.5III	-	-	-	-	8				-
-	-	GJ 569 A	M3V	-	-	-	-	8				E
189577	7645	13 Sge	M4IIIa	-	-	-	-	8				-
-	-	GJ 402, LHS 294	M4V M5V	-	-	-	-	8				-
-	-	GJ 406, LHS 36	M6V	-	-	-	-	8				E
-	-	GJ 1111, LHS 248	M6.5V	-	-	-	-	7				E
-	-	LHS 2243	M8V	-	-	-	-	7				E
84748	3882	R Leo	M8IIIe	-	-	-	-	8				-
-	-	GJ 569 B	M8.5V	-	-	-	-	8				-
-	-	LHS 2065	M9V	-	-	-	-	7				E
-	-	LHS 2924	M9V	-	-	-	-	7				E

The intensity of these lines increases toward later spectral types, in particular the Hα, Fe I 6495 Å ratio has been used as a spectral classification criterion (Danks & Dennefeld 1994).

The Hβ line presents a marked temperature effect in the wings (see Fig. 3) in the same way as the Hα line. The Fe I 4878.08 Å line is an isolated and strong absorption line in this spectral region that could be used for radial and rotational velocity determinations.

The He I D_3 line region also includes the Na I D_1 and D_2 lines, which are well known temperature and luminosity discriminants among late-type stars, and they show the expected trend of metallic-line intensity increasing with decreasing temperature (O'Connell 1973; Torres-Dodgen & Weaver 1993; Danks & Dennefeld 1994; Serote Roos et al. 1996). The effect is more important in the later spectral types and especially in the wing of the lines (see Fig. 4). The behaviour of these lines confirms the spectral classification of the star HD 22072 as G7V (Baliunas et al. 1995) rather than the K1V given by Hoffleit & Jaschek (1982). These Na I resonance lines are collisionally-controlled in the atmospheres of late-type stars and have been observed in emission or filled-in in very active red dwarf flare stars (Pettersen et al. 1984; Pettersen 1989), so the spectra of the inactive stars presented here can be used to apply the spectral subtraction technique to other active stars and obtain information about chromospheric emission in these lines (see Montes et al. 1996b).

In the mid-resolution spectra (Figs. 5 and 6) in addition to the Na I D_1, D_2, Hα and the other lines above described, we can also see other interesting features such as Fe I 6411.66 Å, Fe I 6430.85 Å, and Ca I 6439.08 Å normally used for the application of the Doppler imaging technique (see Fig. 5) and the Ca I (6122 and 6162 Å) lines which are very weak at spectral type F and increase in strength with decreasing temperature (see Fig. 6). From mid K through M stars we can also see absorption molecular bands of TiO in the following regions (5847 − 6058), (6090 − 6390), (6651 − 6852), (7053 − 7270) and of CaH in (6346, 6482, 6389) and (6750 − 7050) (see the K and M stars in Fig. 6). These molecular bands become very strong at the later M spectral types, and dominate the spectrum of these stars. For spectral type M7 or later the VO absorption band (7400 − 7510) is also present. This feature can be used as an additional spectral classifier in the later spectral types, because it is strongly dependent on temperature (Kirkpatrick et al. 1995). Finally, we note in Fig. 6 the strong telluric line O_2 (6867 Å), and the very deep atmospheric *B*-band absorption feature at 7600 Å.

In order to enable other investigators to make use of the spectra of this library, all the spectra of the stars listed in Table 3 are available as FITS and ASCII format files at the CDS in Strasbourg, France, via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5). They are also available via the World Wide Web at:
http://www.ucm.es/OTROS/Astrof/fgkmsl/fgkmsl.html

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References

Allen L., Strong K.M., 1995, AJ 109, 1379
Baliunas S.L., Donahue R.A., Soon W.H., et al., 1995, ApJ 438, 269
Danks A.C., Dennefeld M., 1994, PASP 106, 382
Donahue R.A., 1993, Ph.D. Thesis, New Mexico State University
Duncan D.K., Vaughan A.H., Wilson O.C., et al., 1991, ApJS 76, 383
Fernández-Figueroa M.J., Montes D., De Castro E., Cornide M., 1994, ApJS 90, 433
Gliese W., Jahreiss H., 1991, Preliminary Version of the Third Catalogue of Nearby Stars, Astron. Rechen-Institut, Heidelberg
Gunn J.E., Stryker L.L., 1983, ApJS 52, 121
Hall J.C., Ramsey L.W., 1992, AJ 104, 1942
Hoffleit D., Jaschek C., 1982, The Bright Star Catalogue, 4th ed. New Haven: Yale University Press
Hoffleit D., Warren W., 1991, The Bright Star Catalogue, 5th ed., in Astronomical Data Center CD ROM, Selected Astronomical Catalogs Vol. 1, Brotzman L.E., Gessmer S.E. (eds.)
Huisong T., Xuefu L., 1987, A&A 172, 74
Jacoby G.H., Hunter D.A., Christian C.A., 1984, ApJS 56, 257
Jaschek C., Jaschek M., 1990, "The Classification of Stars". Cambridge University Press
Kirkpatrick J.D., Henry T.J., McCarthy Jr. D.W., 1991, ApJS 77, 417
Kirkpatrick J.D., Henry T.J., Simons D.A., 1995, AJ 109, 797
Martín E.L., Rebolo R., Magazzù A., 1994, ApJ 436, 262
Martín E.L., Montes D., 1997, A&A 318, 805
Martín E.L., Rebolo R., Zapatero-Osorio M.R., 1996, ApJ 469, 706
Montes D., De Castro E., Cornide M., Fernández-Figueroa M.J., 1994, in: Cool Stars, Stellar Systems, and the Sun, Eighth Cambridge Workshop, Caillault J.P. (ed.), ASP Conf. Ser. 64, 444
Montes D., Fernández-Figueroa M.J., De Castro E., Cornide M., 1995a, A&A 294, 165
Montes D., Fernández-Figueroa M.J., De Castro E., Cornide M., 1995b, A&AS 109, 135
Montes D., De Castro E., Fernández-Figueroa M.J., Cornide M., 1995c, A&AS 114, 287
Montes D., Fernández-Figueroa M.J., De Castro E., Cornide M., 1995d, Stellar Surface Structure, IAU Symp 176, Strassmeier K. (ed.) p. 167
Montes D., Fernández-Figueroa M.J., Cornide M., De Castro E., 1996a, A&A 312, 221
Montes D., Sanz-Forcada J., Fernández-Figueroa M.J., Lorente R., 1996b, A&A 310, L29
O'Connell R.W., 1973, AJ 78, 1074
Pasquini L., Pallavicini R., Pakull M., 1988, A&A 191, 253
Pickles A.J., 1985, ApJS 59, 33
Pettersen B.R., Evans D.S., Coleman L.A., 1984, ApJ 282, 214
Pettersen B.R., 1989, A&A 209, 279
Serote Roos M., Boisson C., Joly M., 1996, A&AS 117, 93
Silva D.R., Cornell M.E., 1992, ApJS 81, 865
Strassmeier K.G., Fekel F.C., Bopp B.W., Dempsey R.C., Henry G.W., 1990, ApJS 72, 191
Strassmeier K.G., Fekel F.C., 1990, A&A 230, 389
Taylor B.J., 1994, PASP 106, 704
Taylor B.J., 1995, PASP 107, 734
Torres-Dodgen A.V., Weaver Wm.B., 1993, PASP 105, 693

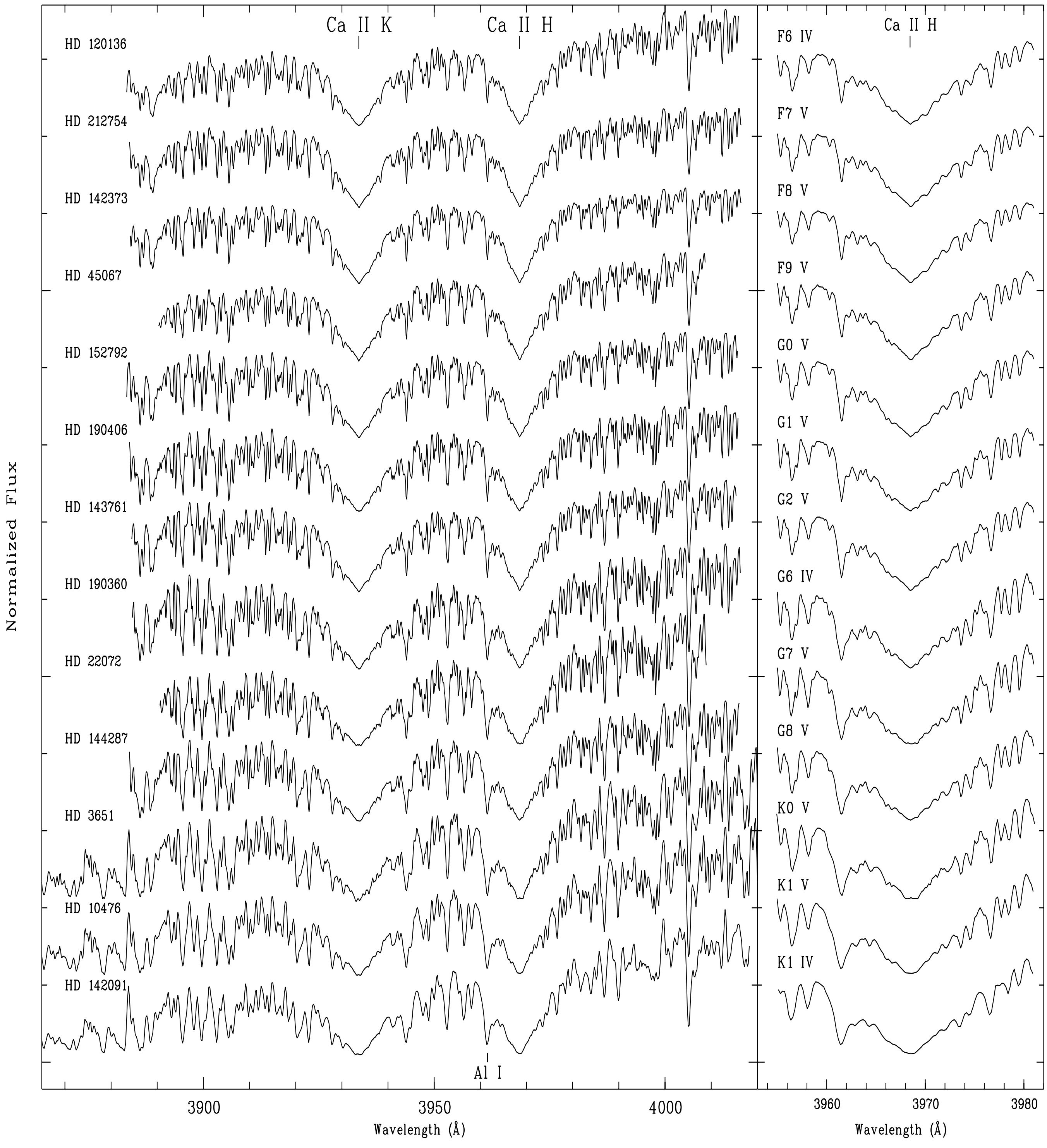

Fig. 1. High-resolution spectra in the Ca II H & K line region

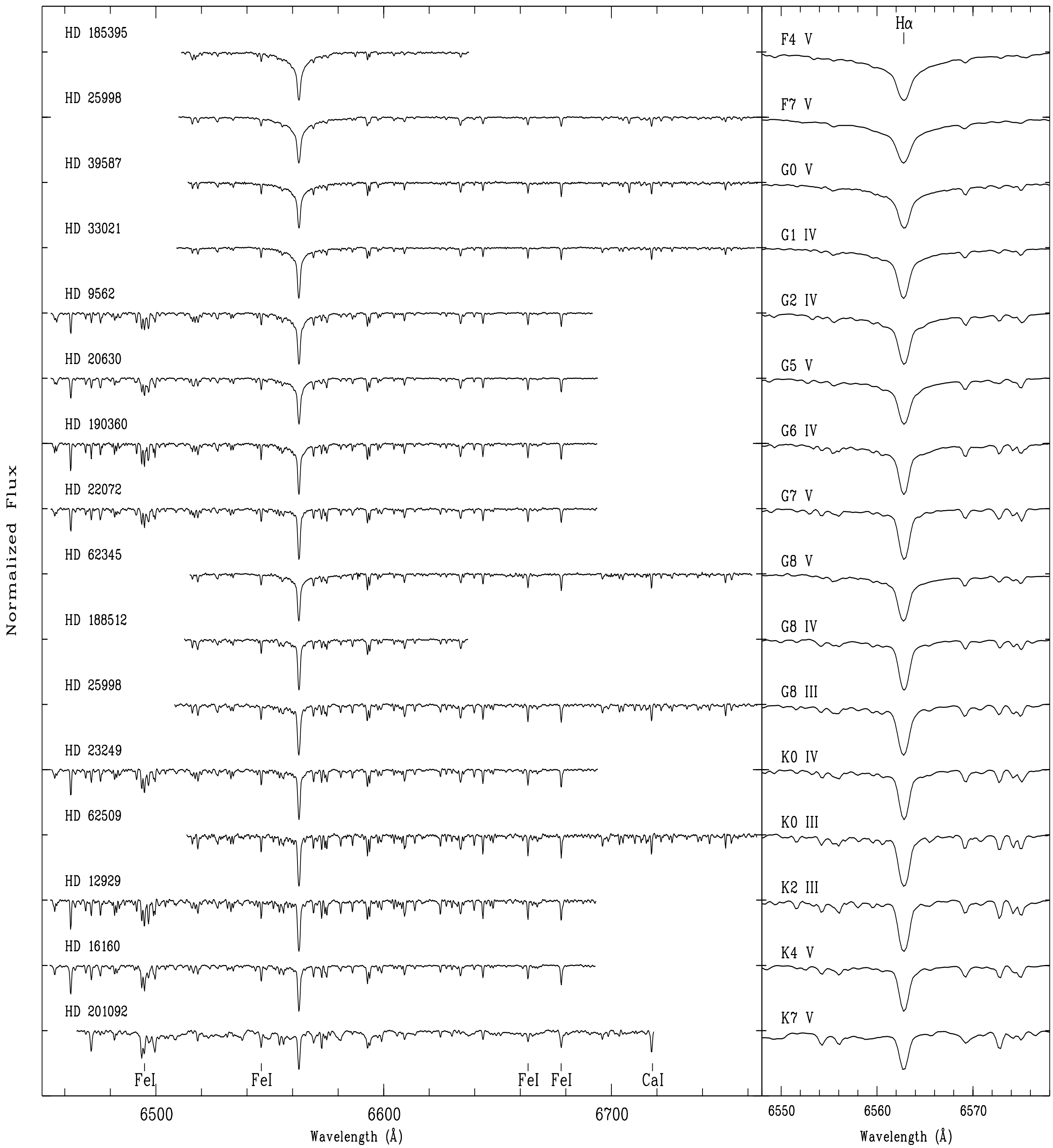

Fig. 2. High-resolution spectra in the Hα line region

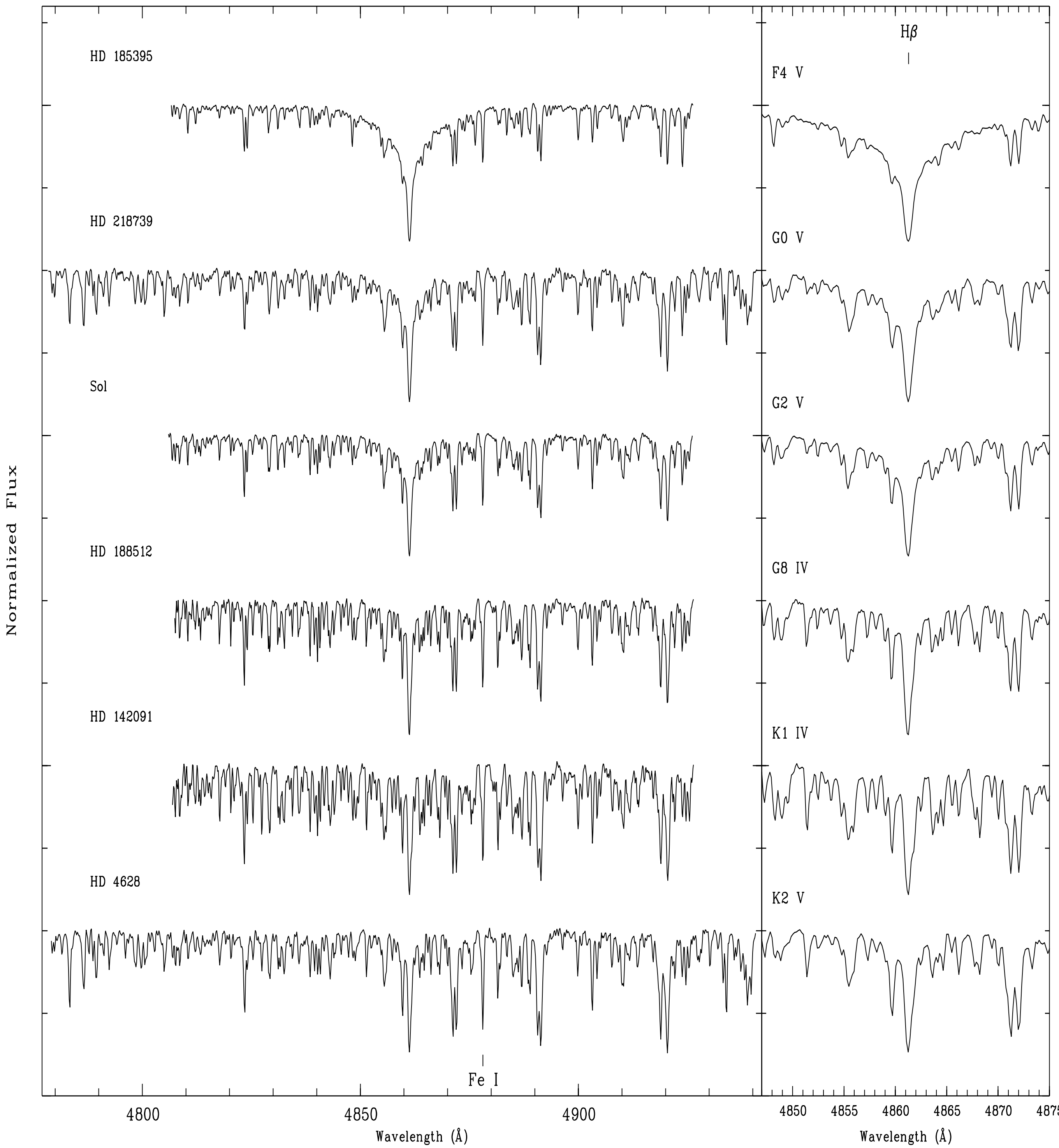

Fig. 3. High-resolution spectra in the Hβ line region

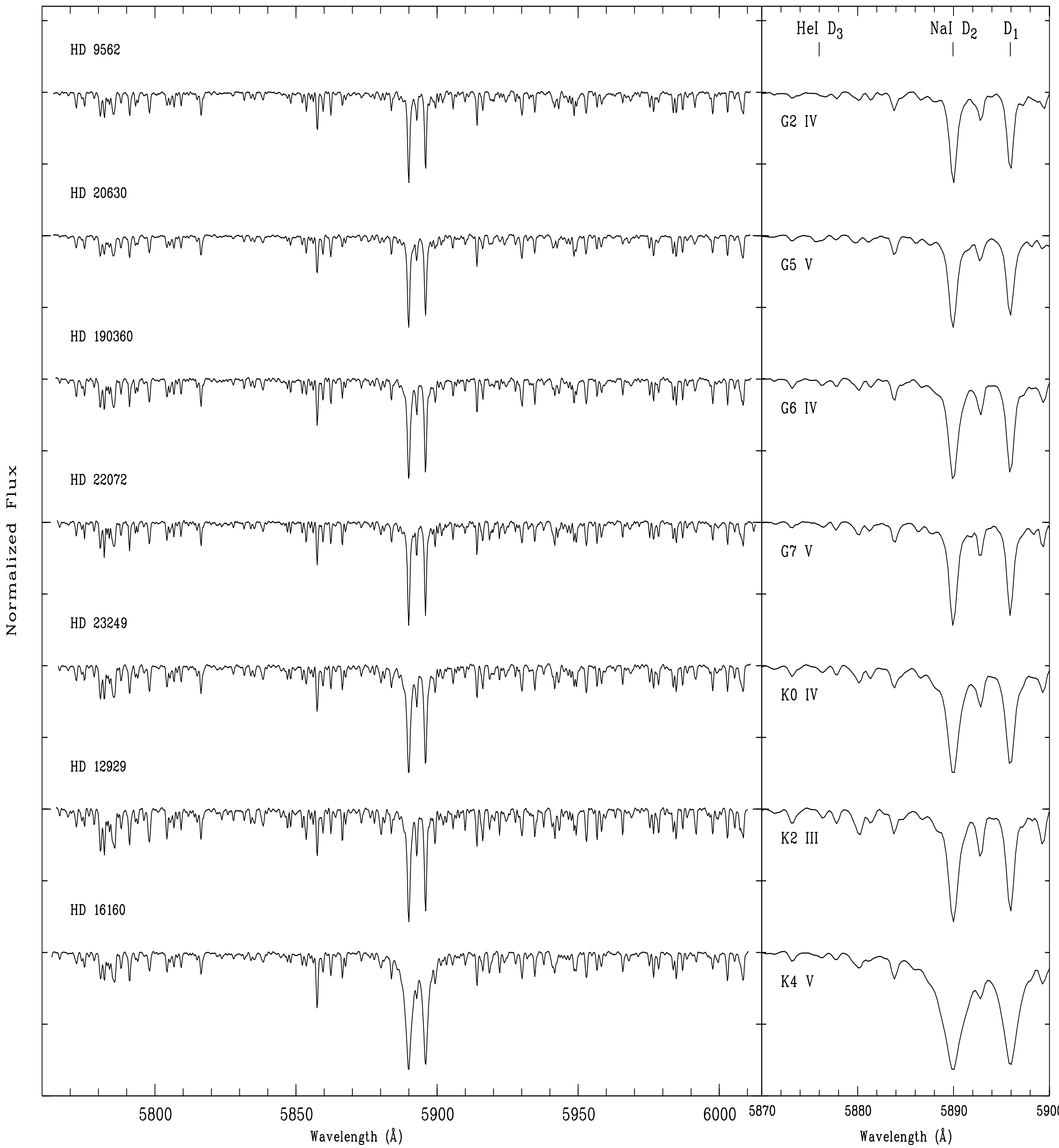

Fig. 4. High-resolution spectra in the Na I D_1, D_2, and He I D_3 line region

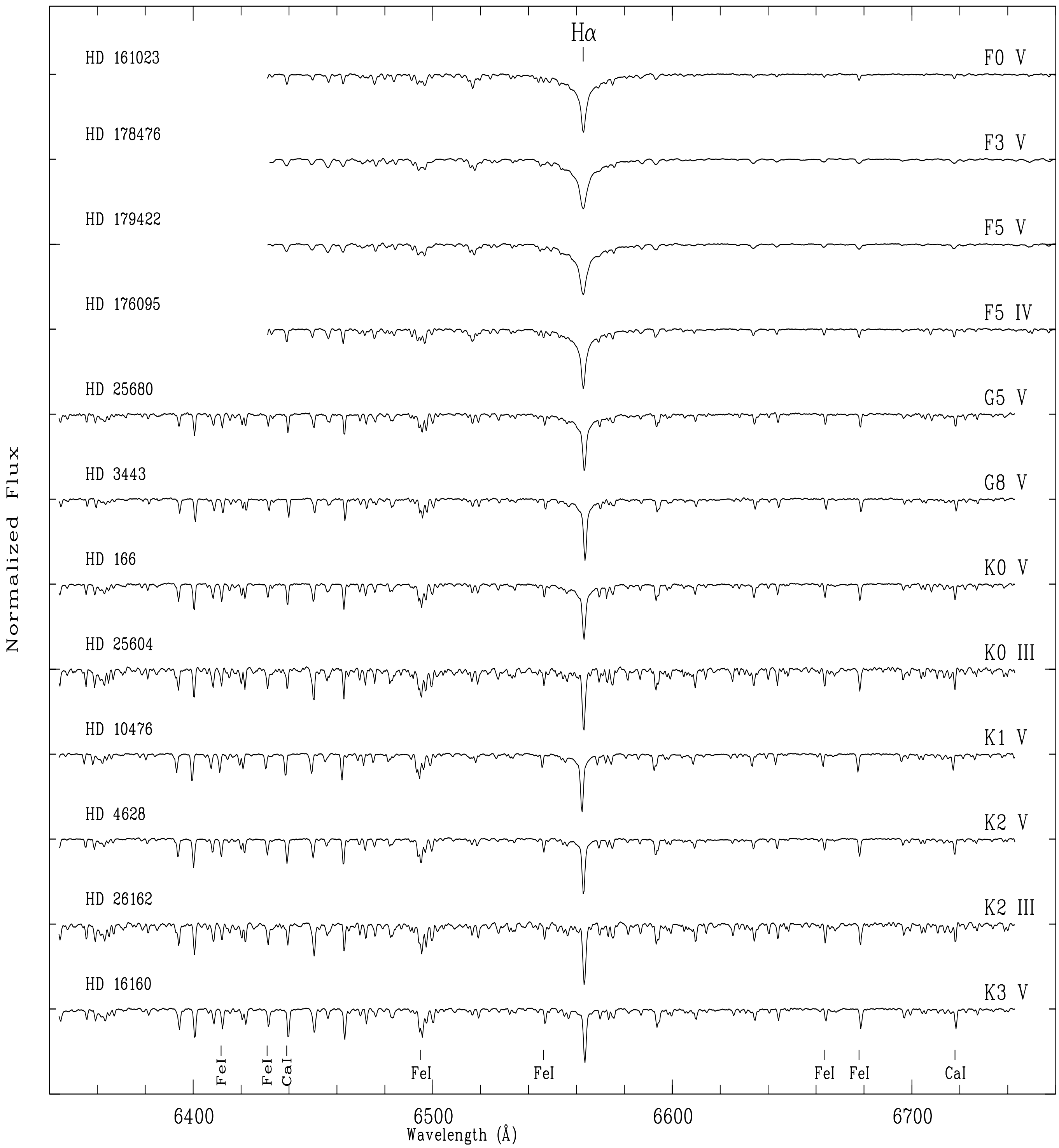

Fig. 5. Mid-resolution spectra in the Hα line region in the wavelength range 6340 to 6740 Å

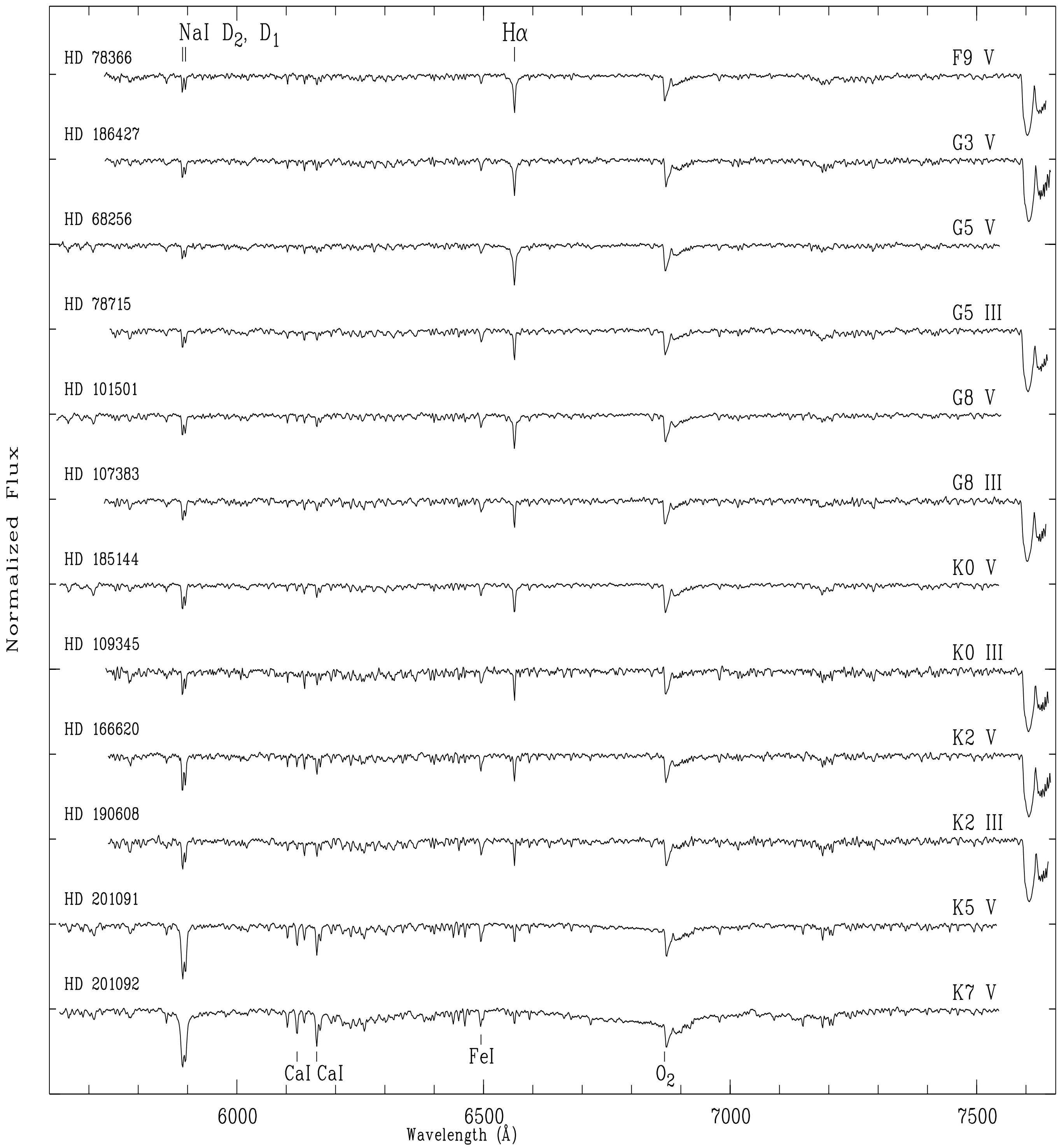

Fig. 6. Mid-resolution spectra in the Na I D_1, D_2, and Hα line region, in the wavelength range 5650 to 7640 Å

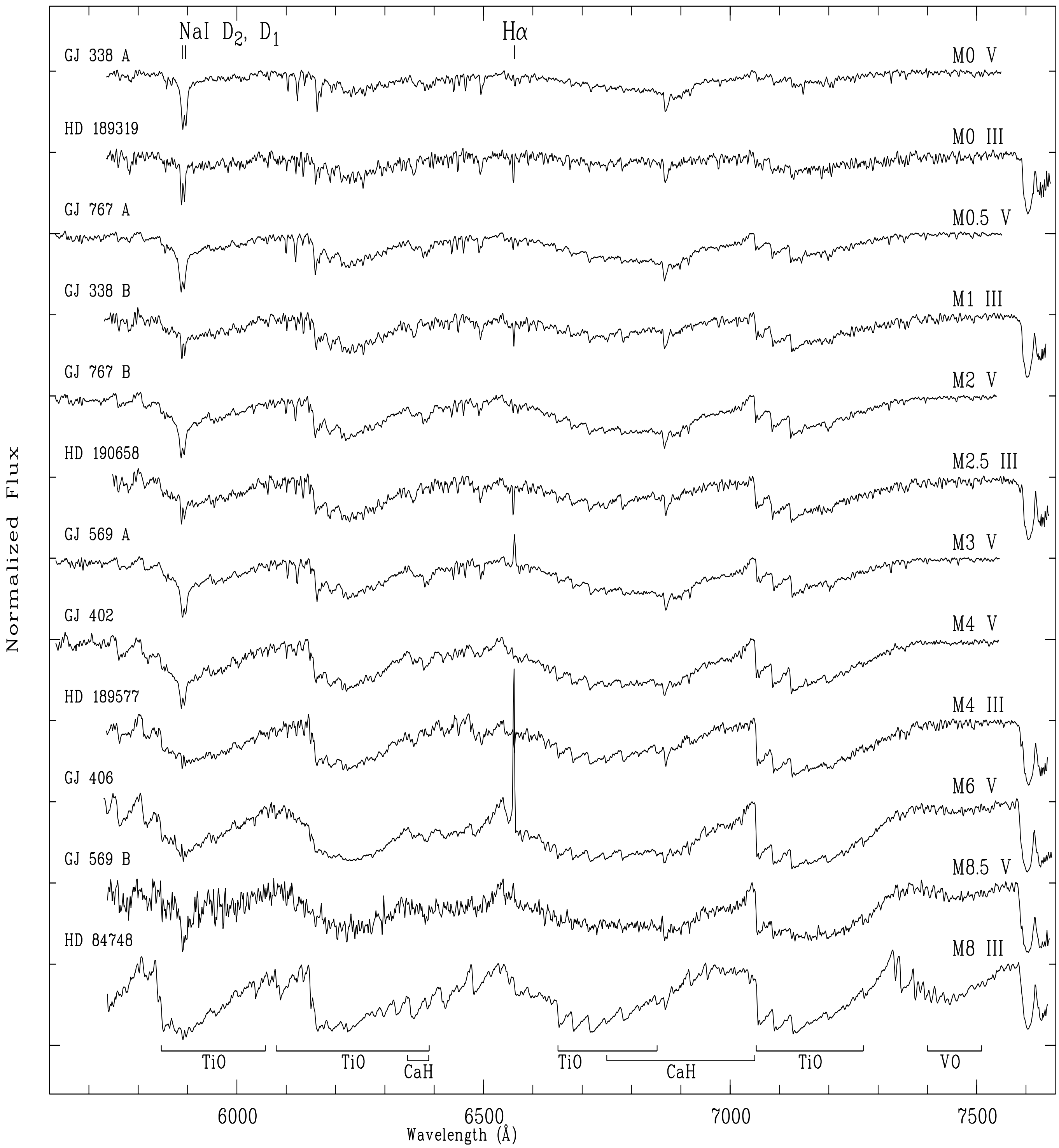

Fig. 6. continued