Library of high-resolution UES echelle spectra of F, G, K and M field dwarf stars

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Abstract. We present a library of Utrecht echelle spectrograph (UES) observations of a sample of F, G, K and M field dwarf stars covering the spectral range from 4800 Å to 10600 Å with a resolution of 55000. These spectra include some of the spectral lines most widely used as optical and near-infrared indicators of chromospheric activity such as H\textsubscript{\beta}, Mg i \textsubscript{b} triplet, Na i D\textsubscript{1}, D\textsubscript{2}, He i D\textsubscript{3}, H\textalpha, and Ca ii IRT lines, as well as a large number of photospheric lines which can also be affected by chromospheric activity. The spectra have been compiled with the aim of providing a set of standards observed at high-resolution 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: Atlases – stars: activity – stars: chromospheres – stars: late-type – stars: fundamental parameters – stars: general

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\textsuperscript{**} Fig. 1 and Tables 1 to 5 are only available in electronic form, and Table 6 is also available in electronic form
\textsuperscript{***} The spectra of the stars listed in Table 6 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

1. Introduction

Spectral libraries of late-type stars are a very powerful tool for the study of the chromospheric activity by application of the spectral subtraction technique (see Montes et al. 1995a, b, c; and references therein). Furthermore, these libraries are also very useful in many areas of astrophysics such as the stellar spectral classification, modelling stellar atmospheres, stellar abundances, calibration of temperatures, spectral synthesis applied to composite systems, and spectral synthesis of the stellar population of galaxies.

While for many of these purposes, obtaining as large a spectral range as possible was the main priority, for the chromospheric activity studies, which are centered in specific spectral features, it is much more important to increase the spectral resolution. However, previously published stellar libraries are of poor spectral resolution (between 45 and 1.25 Å) and the only attempt to improve the spectral resolution is our library of high and mid-resolution spectra in the Ca ii H & K, H\textalpha, H\textsubscript{\beta}, Na i D\textsubscript{1}, D\textsubscript{2}, and He i D\textsubscript{3} line regions of F, G, K and M field stars (Montes et al. 1997a, hereafter Paper I) with resolutions that range between 3 and 0.2 Å.

However, even more higher resolutions are needed when we are interested in very detailed studies of chromospheric activity such as the analysis of the difference features present in the chromospheric emission line profiles, the study of chromospherically active binaries aimed to determine from which component of the binary belong the emission lines (see Montes et al. 1997b), or the analysis of the time variations and line asymmetries that occur during a stellar flare (see Montes et al. 1998).

On the other hand, the simultaneous observations of different lines, that are formed at different height in the chromosphere (from the region of temperature minimum to the higher chromosphere), are of special interest for stellar activity studies since they provide very useful information about this stellar region. Ideally, simultaneous
observations should be performed at all wavelengths in order to develop a coherent 3-D atmosphere model (see the multiwavelength optical observations of chromospherically active binary systems by Montes et al. 1997b, c). So, to carry out these purposes applying the spectral subtraction technique, to as many lines as possible, a spectral library with a good spectral resolution and a good spectral coverage is needed.

The spectral library that we present in this paper is an extension of our previous one (Paper I) to higher spectral resolution covering a large spectral range. The library consists of echelle spectra of a sample of F, G, K and M field dwarf stars covering the spectral range from 4800 Å to 10600 Å and with spectral resolution ranging from 0.19 to 0.09 Å. These spectra include some of the spectral lines most widely used as optical and near-infrared indicators of chromospheric activity such as: Na I D1, D2, and Mg I b triplet (formed in the upper photosphere and lower chromosphere), Ca II IRT lines (lower chromosphere), Hα, Hβ (middle chromosphere), and He I D3 (upper chromosphere), as well as a large number of photospheric lines which can also be affected by chromospheric activity. Furthermore, the spectra also include a lot of lines of interest to spectral classification and calibration of temperatures purposes, as well as other lines normally used for the application of the Doppler imaging technique.

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 high-resolution echelle spectra presented here were obtained by us during several observing runs with the 4.2m William Herschel Telescope (WHT) at La Palma Observatory, using the Utrecht Echelle Spectrograph (UES) mounted on a Nasmyth focal station. A description of the WHT/UES is given by Unger (1992). In addition, we analysed also different WHT/UES observational campaigns retrieved from La Palma Data Archive (Zuiderwijk et al. 1994).

In Table 1 we give a summary of WHT/UES observations, for each observing run we list the date, the observer, the CCD detector, the number of echelle orders included, the central wavelength (λc), the wavelength range covered (λc - λf) and the range of reciprocal dispersion achieved (Å/pixel) from the first to the last echelle orders. The echelle grating used in all these runs was the E31. The interorder spacing was too small to perform a good sky subtraction. Sky contamination is only significant for the few faint very-late M-type stars of this library (VB 8 and VB 10). As can be seen in Table 1, the spectra cover the spectral range from 4800 Å to 10600 Å with spectral resolution (FWHM=2 pixels) ranging from 0.19 to 0.09 Å, corresponding to R~55000. However, as the CCD chips we have used were smaller than the echelle orders, we did not get a full recording of the different orders. The gaps between the adjacent recorded orders got larger towards longer wavelengths, as can be seen in Tables 2 to 5, where we give for each observing run the wavelength range and the spectral lines of interest in each echelle order.

The spectra have been extracted using the standard reduction procedures in the IRAF 1 package (bias subtraction, flat-field division, and optimal extraction of the spectra). The wavelength calibration was obtained by taking spectra of a Th-Ar. Finally, the spectra have been normalized by a polynomial fit to the observed continuum.

3. The library

As in Paper I, the stars included in the library have been selected as stars with low levels of chromospheric activity, that is to say, stars that do not present any evidence of emission in the core of Ca II H & K lines in our spectra (Montes et al. 1995c, 1996a), stars with the lower Ca II H & K spectrophometric index S (Baliumas et al. 1995), or stars known to be inactive and slowly rotating stars from other sources (see Strassmeier et al. 1990; Strassmeier & Fekel 1990; Hall & Ramsey 1992). In addition, we provide spectra of some active stars of late and very-late spectral types.

Table 6 presents information about the observed stars. In this table we give the HD, HR and GJ numbers, name, spectral type and luminosity class (Teff), from the Bright Star Catalogue (Hoffleit & Jaschek 1982; Hoffleit & Warren 1991) and the Catalogue of Nearby Stars (Gliese & Jahreiss 1991), except for some M dwarfs for which we list the more recent spectral type determination given by Henry et al. (1994) and Kirkpatrick et al. (1995). In column (6) MK indicates if the star is included in the list of Morgan and Keenan (MK) Standard Stars compiled by Garcia (1989). Column (7) gives the metallicities [Fe/H] from Taylor (1994; 1995) or Cayrel de Strobel (1992; 1997) and column (8) rotational period (Prot) and vsini from Donahue (1993), Baliumas et al. (1995), Strassmeier & Fekel (1990), Fekel (1997), Stauffer & Hartmann (1986), Martín et al. (1996), and Basri & Marcy (1995; 1996). We also give, in column (9), the Ca II H & K spectrophotometric index S from Baliumas et al. (1995) and Duncan et al. (1991). In column (10) we list information about the observing run in which each star have been observed, using a code given in the first column of Table 1, and the last column indicate if the star was also included in Paper I.

In Fig. 1 we have plotted for a K1V star representative spectral orders, with the line identification marked. The two first orders (Hβ and Mg I b lines) correspond to the K1V star HD 10476 from the Dec-93 observing run and

\footnote{IRAF is distributed by the National Optical Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.}
the following orders correspond to K1V star HD 9546 from the Nov-94 run.

Representative spectra (from F to M stars) in different spectral regions are plotted in figures (2 to 6) in order to show the behaviour of the more remarkable spectroscopic features with the spectral type. In order of increasing wavelength we have plotted the following line regions: Hβ (Fig. 2), Mg b triplet (Fig. 3) Na i D1, D2 (Fig. 4) and He i D3 (Fig. 4), Hα (Fig. 5) and Ca ii IRT λ8498, 8542, 8662 (Fig. 6).

In the following, we describe the behaviour of some interesting spectral lines and molecular bands present in the spectral range covered by the spectra (from 4800 to 10600 Å). We list the spectroscopic features in order of increasing wavelength, and the echelle order in which they appear in each observing run can be found in Tables 2 to 5.

- The Hβ λ4861.3 line (Fig. 2) is a well known chromospherically activity indicator (emission or filled-in).
- The Mg b triplet λλ5167, 5172, 5183 (Fig. 3) is luminosity sensitive in the range G8-K5. These strong neutral metal lines are formed in the lower chromosphere and the region of temperature minimum and they are good diagnostics of activity (Basri et al. 1989; Gunn & Doyle 1997; Gunn et al. 1997; Montes et al. 1998).
- The He i D3 λ5876 absorption line is another important indicator of stellar activity in the upper chromosphere (García López et al. 1993; Montes et al. 1997b, c; Saar et al. 1997) and also could be in emission during stellar flares (Huenemoerder & Ramsey 1987; Montes et al. 1996b; 1997b; 1998).
- The Na i D1 λ5895.92 and D2 λ5889.95 lines (Fig. 4) are well known temperature and luminosity discriminant. These resonance lines are collisionally-controlled in the atmospheres of late-type stars and then provide information about chromospheric activity see Montes et al. (1996b, 1997b, c) and the recent models of these lines for M dwarfs stars by Andretta et al. (1997).
- The wings of the Ca ii triplet λλ6102, 6112, 6162 lines can be used as luminosity indicators (Cayrel et al. 1996). These lines are very weak at spectral type F and increase in strength with decreasing temperature.
- The V i λλ6251.83 and Fe i λ6252.57 line-depth ratio can be used to determine stellar temperatures (Gray & Johanson 1991, Gray 1994).
- The line ratio Fe ii λ6432.65/Fe i λ6430.85 is useful for spectral-class/temperature classification for F to M stars. Other spectral class indicators are the ratios of V i λ6452/Ca i λ6456 (for F, and G stars), Ca i λ6455/Ca i λ6456 and Fe ii λ6457/Ca i λ6456 (for F to K stars) (Strassmeier & Fekel 1990).
- The Fe i λ6411.66 Å, Fe i λ6430.85 Å, and Ca i λ6439.08 Å lines normally used for the application of the Doppler imaging technique.
- The emission or filled-in of the Hα (6562.8 Å) (Fig. 5) line is one the primary optical indicators of chromospheric activity in late-type stars, together with the Ca ii H & K emission lines.
- The Li i resonance line at λ6707.8 Å and the subordinate lines at λ6103 Å and λ8126 Å (Pavlenko et al. 1995; Carlsson et al. 1994).
- The K i λ7664.91, 7698.98 doublet is a resonance transition and thus will be influenced by chromospheric activity, particularly in M dwarf stars (see Basri & Marcy 1995; Schweitzer et al. 1996).
- The Rb i resonance line at 7947.63 Å is strong in very late-type stars, and it seems to be a good temperature diagnostic (Basri & Marcy 1995).
- The Na i doublet λλ8183.26, 8194.8 lines are subordinate transitions and therefore, form mainly in the photosphere and should not be significantly affected by the chromosphere. These lines can be used as a dwarf/giant indicator (Schiajsonet al. 1997).
- The Ti i lines for multiplet 33 (specially the λ8382.54, 8382.82 lines) and other Ti i lines, can be used as a luminosity classification criterium because they present a positive luminosity effect (Keenan & Hynek 1945; Ginestet et al. 1994; Jashek & Jashek 1995; Montes et al. 1997c).
- The Ca ii infrared triplet (IR T) λλ8498, 8542, and 8662 lines (Fig. 6) formed in the lower chromosphere and are also important activity indicators (Linsky et al. 1979; Fouing et al. 1989; Dempsey et al. 1993; Montes et al. 1997c). These lines have been also used by several authors as a gravity sensitive index. In this spectral region the Paschen lines P12 (λ8750) and P14 (λ8598) are also visible in F stars (Carquilliat et al. 1997).
- From mid K through M stars we can also see a number of titanium oxide (TiO) molecular bands such as (5847-6058), (6080-6390), (6322-6512), (6569-6649), (6651-6852), (7053-7270), (7666-7861), (8206-8569), (8432-8452), and (8859-8937), useful in classifying early M dwarfs, and a number of vanadium oxide (VO) bands such as (7400-7510), (7851-7973), and (8521-8668), useful in classifying late M dwarfs. CaH bands at (6346, 6382, 6389) and (6750-7050) are also present in these stars.

Other strong features that appear in the spectra are the telluric O2 A and B bands at 6867 Å - 7600 Å and several telluric H2O bands at (7168-7273), (8164-8177), 8227, 8282, (8952-8972), and (8980-8992).

A more detailed description of the Hα, Hβ, Na i D1, D2 and He i D3 lines and the corresponding photospheric features included in these spectral regions, can be found in Paper I. An extensive list of features identifiable in late-K to late-M spectra from 6300 to 9000 Å can be found in Kirkpatrick et al. (1991). A description of the spectroscopic characteristics of very cool dwarfs and substellar candidates is given by Martín et al. (1996). For more information about spectral classification of stars and the behaviour of chemical elements in stars the reader is referred to Jashek & Jashek (1990; 1995).
In order to enable other investigators to make use of the spectra of this library, all the multidimensional spectra containing all the echelle orders of the stars listed in Table 6 are available as FITS 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/UESfgkmsl.html.

In order to facilitate the use of this library the one-dimensional normalized and wavelength-shifted spectra, resulting for the extraction of the orders containing the more remarkable spectroscopic features (the spectral regions plotted in figures 2 to 6), are also available as separate FITS format files.

The extension of this library including stars of higher luminosity class, as well as the use of these spectra to analyze temperature sensitive lines in order to improve the actual line-depth ratio temperature calibrations (Gray & Johanson 1991, Gray 1994) and spectral-class/temperature classifications (Strassmeier & FekeI 1990), will be the subject of forthcoming papers.

Table 1. Summary of WHT/UES observations (published only electronically at CDS)

Table 2. UES spectral orders (Jul-93) (published only electronically at CDS)

Table 3. UES spectral orders (Dec-93) (published only electronically at CDS)

Table 4. UES spectral orders (Apr-94, Mar-95, Jun-95) (published only electronically at CDS)

Table 5. UES spectral orders (Nov-94) (published only electronically at CDS)

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References

Andretta V., Doyle J.G., Byrne P.B., 1997, A&A 322, 266
Balona L.A., Donahue R.A., Soon W.H., et al., 1995, ApJ 438, 269
Basi G., Wilcots E., Stout N., 1989, PASP 101
Basi G., Marcy G.W., 1995, AJ 109, 762
Basi G., Marcy G.W., 1996, in Cool Stars, Stellar Systems, and the Sun, Ninth Cambridge Workshop, R. Pallavicini and A.K. Duppre (eds), ASP Conference Series 109, 587
Byrne P.B., 1993, A&A 272, 495
Carquillat J.M., Jashek C., Jashek M., Ginestet N., 1997, A&AS 123, 5
Carlsson M., Rutten R.J., Bruls J.H.M.J., Shchukina N.G., 1994, A&A 288, 860
Donahue R.A., 1993, Ph.D. Thesis, New Mexico State University

Duquennoy A., Mayor M., 1991, A&A 248, 485
Fekel F.C., 1997, PASP 109, 514
Foing B., Crivellari L., Vladilo G., Rebolo R., Beckman J., 1989, A&AS 80, 189
García B., 1989, Bull. Inform. CDS 36, 27
García López R.J., Rebolo R., Beckman J.E., McKeith C.D., 1993, A&AS 273, 482
Gliese W., Jahreiss H. 1991, Preliminary Version of the Third Catalogue of Nearby Stars, (Astron. Rechen-Institut, Heidelberg)
Ginestet N., Carquillat J.M., Jashek C., Jashek M., 1994, A&AS 108, 359
Gray D.F., Johanson H.L., 1991, PASP 103, 439
Gray D.F., 1994, PASP 106, 1248
Gunn A.G., Doyle J.G., 1997, A&A 318, 60
Gunn A.G., Doyle J.G., Houdebine E.R., 1997, A&A 319, 211
Hall J.C., Ramsey L.W., 1992, AJ 104, 1437
Henry, T.J., Kirkpatrick, J.D., Simons, D.A., 1994 AJ 108, 1437
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, eds. Brotzman L.E., Gessmer S.E.
Huenemoerder D.P., Ramsey L.W., 1987, ApJ 319, 392
Keenan P.C., Hynek J.A., 1945, ApJ 101, 265
Kirkpatrick J.D., Henry T.J., McCarthy D.W., Jr., 1991, ApJS 77, 417
Fig. 1. Representative spectral orders for the Dec-93 and Nov-94 observing runs of a K1V star, with the line identification marked (published only electronically at CDS)

| Table 6: Stars |
|----------------|
| HD | HR | GJ | Name | Teq | MK | [Fe/H] | P_rot | v_sini | S | Obs. | Pap. I |
|----------------|
| F stars | | | | | | | | | | | |
| 33256 & 1673 & 189.2 & 68 Eri & F2V & -0.49 & - & 0 & - & 3 & |
| 6406 & BD+14 2151 & F5VI & -1.86 & - & - & 2 & |
| 84937 & BD+18 3423 & F6V & - & - & - & 1 & |
| 84937 & 3616 & σ2 UMa & F6IV & - & - & 0 & 0.142 & 6 & |
| 9826 & 458 & 50 And & F8V & MK -0.14 & - & 8 & 0.154 & 1 & |
| 14237 & 5914 & χ Her & F8V & -0.431 & - & 10.0 & 0.147 & 5 & |
| 144284 & 5986 & 609.1 & θ Dra & F8IV (SB1) & 0.23 & - & 27.7 & 0.203 & 6 & |
| 114762 & 5914 & θ Dra & F9V & -0.87 & - & - & - & 3 & |
| 79028 & 3648 & 337.1 & 16 UMa & F9V (SB1) & - & - & 0 & 5, 6 & |
| 114710 & 4983 & 502 & β Com & F9.5V & MK 0.135 & 12.35 & 4.3 & 0.201 & 3 & * |
| G stars | | | | | | | | | | | |
| 160269 & 6573 & 26 Dra & G0IV-V (MK) (SB1) & MK - & - & 41 & - & 1 & |
| 15335 & 720 & 99.1 & 13 Tri & G0V & - & - & < 6 & - & 4 & |
| 39587 & 2047 & 222B & w1 Ori & G0V (SB1) & MK -0.084 & 5.36 & 8.6F & 0.325 & 3 & * |
| 88231 A & 4375 & 423A & ζ Uma A & G0V (SB1) & -0.352 & - & < 15 & - & 5 & * |
| 84737 & 3881 & 15 LMi & G0.5V & MK -0.04 & - & 3 & 0.145 & 5 & |
| 10307 & 483 & 67 & BD+41 328 & G1.5V (SB1) & MK 0.14 & - & 2.1 & 0.152 & 2 & |
| 14237 & 5914 & χ1 Ori & G0V (SB1) & MK -0.084 & 5.36 & 8.6F & 0.325 & 3 & * |
| 115617 & 5019 & 506 & 61 Vir & G0V (SB1) & -0.352 & - & < 15 & - & 5 & * |
| 178428 & 7260 & 746 & BD+16 3752 & G0V (SB1) & - & - & 0.154 & 3, 6 & |
| 33802 B & BD-12 1095B & G5Ve & - & - & - & 3 | |
| 14914 & 629.2A & BD-03 3968 & G5V (SB1) & -1.14 & - & - & - & 3, 5, 6 & |
| 20630 & 996 & 137 & c1 Cet & G5V & MK 0.133 & 9.24 & 8.6F & 0.325 & 3 & * |
| 31966 & 182.1 & BD+14 804 & G5V & - & - & - & - & 4 & |
| 108754 & 469.1 & BD-02 3528 & G7V (SB1) & - & - & - & - & 3, 5 & |
| 131156 A & 5544 A & ζ Boo A & G8V & MK -0.151 & 6.31 & 3.2 & 0.461 & 5 & * |
| 44867 & 2302 & BD+16 1135 & G8IV (G9III) & MK - & - & - & - & 4 & |
| 195987 & 793.1 & BD+41 3799 & G9V (SB1) & - & - & - & - & 3 & |
| K stars | | | | | | | | | | | |
| 10780 & 511 & 75 & BD+63 238 & K0V & 0.36 & - & 0.6 & 0.280 & 4 & |
| 185144 & 7462 & 764 & η Dra & K0V & MK -0.045 & - & 0.6 & 0.215 & 1 & * |
| 18972 & BD+13 494 & K0IV & - & - & - & - & 4 & |
| 48432 & 2477 & 13 Lyn & K0III & MK 0.133 & 9.24 & 3.9 & 0.366 & 2 & * |
| 9546 & 59.3 & ADS 1233 A & K1V & - & - & - & - & 4 & |
| 10476 & 493 & 68 & 107 Psc & K1V & MK -0.123 & 35.2 & 0.198 & 2 & * |
| 76291 & 3545 & BD+46 1459 & K1IV & - & - & - & - & 2 & |
| 6027 & 50.1 & BD+58 155 & K2V & - & - & - & - & 4 & |
| 101177 B & 4486 B & 453.2 B & ADS 8250 A & K2V (SB) & - & - & - & - & 6 & |
| 38392 & 1982 & 216B & γ Lep & K2V & MK 0.144 & - & - & - & 3 & |
| 136713 & 1191 & BD-10 4088 & K2V & - & - & - & - & 3 & |
| 223778 & 9038 & 909 A & BD+74 1047 & K3V & MK -0.000 & - & 8.4 & 0.250 & 2 & * |
| 219134 & 8832 & 892 & BD+56 2866 & K3V & MK -0.000 & - & 8.4 & 0.250 & 2 & * |
| 16160 A & 753 & 105A & BD+06 398 & K3V & MK -0.297 & 48.0 & 0.226 & 4 & * |
| 98800 & 2084A & ADS 8141 A & K4V & MK - & - & - & - & 3, 5 & |
| 131156 B & 5544 B & 566B & ζ Boo B & K4V & 0.19 & 12.28 & 20 & 1.381 & 5 & * |
| 12298 & 83.1 & V708 Cas & K5V & MK - & - & - & - & 4 & |
| 154363 & 653 & BD-04 4225 & K5V & - & - & - & - & 3 & |
| 201091 & 8085 & 820 A & 61 Cyg A & K5V & MK -0.06 & 35.37 & 0.6 & 0.658 & 2, 6 & * |
| 201092 & 8086 & 820 B & 61 Cyg B & K5V & MK -0.10 & 37.84 & 1.4 & 0.986 & 2, 6 & * |
| 157881 & 673 & BD+02 3312 & K7V & 0.40 & - & 3.9 & 1.464 & 1 & |
| 88230 & 380 & BD+50 1725 & K7V (1) (K6V MK) & MK 0.28 & - & 3.1 & 1.617 & 3 & |
| 151877 & 639 & BD+37 2804 & K7V & - & - & - & 0.197 & 3 & |
| 151288 & 638 & BD+33 2777 & K7.5Ve & MK - & - & - & 1.380 & 3, 6 & |
Table 6. Continue

| HD  | HR  | GJ  | Name             | T_{sp}   | MK   | [Fe/H] (dex) | P_{rot} (days) | v sin i (km s^{-1}) | S   | Obs. | Pap. I |
|-----|-----|-----|------------------|----------|------|-------------|----------------|-------------------|-----|------|--------|
| 16  |     |     | M0V              | -        | -    | -           | -              | -                 | 1   |      |        |
| 79210 | 338A | ADS 7251 A | M0Vc (1)        | -        | -    | -           | -              | 2.113             | 3   | *    |        |
| 572 |     |     | M0V              | -        | -    | -           | -              | -                 | 3, 5|      |        |
| 232979 | 172 | BD+52 857 | M0.5V           | MK       | -    | -           | -              | 1.909             | 4   |      |        |
| 1326 A | 15A | GX And       | M1.5V (1) (M2V MK) | MK | - | - | - | 4 |        |
| 36395 | 205 | BD-03 1121 | M1.5V (1)       | MK       | 0.60 | - | - | 4 |        |
| 95735 | 411 | BD+36 2147 | M2V             | MK       | -0.20 | - | - | 0.424 | 3 |        |
| 623AB | LHS 417 | M2.5V (1) | - | - | - | - | 3, 5, 6 |        |
| 813 | LHS 3605 | M3V | - | - | - | - | 1 |        |
| 173739 A | 725A | ADS 11632 A | M3V (1) | - | - | - | 0.534 | 3, 5 |        |
| 180617 | 752A | LHS 36 | M3 V (1) MK | - | - | - | 1.252 | 6 |        |
| 273 | BD+06 1668 | M3.5V (1) | - | - | - | - | 3 |        |
| 699 | Barnard’s star | M4V (1) | - | - | - | - | 1 |        |
| 13124 | 748 | Wolf 1062 | M4V (1) | MK | 0.60 | - | - | 0.424 | 3, 5, 6 |        |
| 447 | FI Vir, LHS 315 | M4V (1) (4) | - | - | - | - | 3, 5, 6 |        |
| 12925 | U Per | M4III (M6e) | - | - | - | - | 4 |        |
| 234AB | LHS 1849/50 | M4.5V (1) e | - | - | <10 | - | 3, 5 |        |
| 831AB | LHS 511 | M4.5V (1) e | - | - | <10 | - | 6 |        |
| 473AB | FL Vir, LHS 333 | M5.5V (1) e | - | - | - | - | 3, 5, 6 |        |
| 1245A | V1581 Cyg | M5.5V e | - | - | - | - | 6 |        |
| 1245B | LHS 3495 | M5.5V e | - | - | - | - | 6 |        |
| 406 | LHS 36 | M6V (1) e | - | - | <3 | - | 3 | *        |
| 1111 | DX Cnc, LHS 248 | M6.5V | - | - | 11 | - | 3, 5 | *        |
| 644C | VB 8, LHS 429 | M7V (2) | - | 0.14 | 8 | - | 3, 5, 6 |        |
| 752B | VB 10, V1298 Aql | M8V (1) e | - | - | <3 | - | 5 |        |

(1): Henry et al. (1994)
(2): Kirkpatrick et al. (1995)
(3): "Zero Hα star", Byrne (1993)
(4): Kirkpatrick et al. (1991)
MK: “A List of MK Standard Stars”, García (1989)
SB: Spectroscopic Binary (Duquennoy & Mayor; Mazeh et al. 1997)

Kirkpatrick, J.D., Henry, T.J., Simons, D.A., 1995, AJ 109, 797
Jaschek C., Jaschek M., 1990, "The Classification of Stars", Cambridge University Press
Jaschek C., Jaschek M., 1995, "The Behavior of chemical elements in stars", Cambridge University Press
Linsky J.L., Hunten D., Glacken D., Kelch W., 1979, ApJS 41, 481
Martín E.L., Rebolo R., Zapatero-Osorio M.R., 1996, ApJ 469, 706
Martín E.L., Zapatero-Osorio M.R., Rebolo R., 1996, in Cool Stars, Stellar Systems, and the Sun, Ninth Cambridge Workshop, R. Pallavicini and A.K. Duppre (eds.), ASP Conference Series 109, 615
Mazeh T., Martin E.L., Goldberg D., Smith H.A., 1997, MNRAS 284, 341
Montes D., Fernández-Figueroa M.J., De Castro E., Sanz-Forcada J., 1997b, A&AS (in press)
Montes D., Fernández-Figueroa M.J., De Castro E., Sanz-Forcada J., 1997c, A&AS (in press)
Montes D., Sanz-Forcada J., Fernández-Figueroa M.J., De Castro E., Poncet A., 1997c, A&AS (in press)
Montes D., Saar S.H., Collier Cameron A., Unruh Y.C., 1998 MNRAS (in preparation)
Pavlenko Y.V., Rebolo R., Martín E.L., García López R.J., 1995, A&A 303, 807
Saar S.H., Huovelin J., Osten R.A., Shcherbakov A.G., 1997, A&A (in press)
Schiaevon R.P., Barbury B., Rossi S.C.F., Milone A., 1997, ApJ 479, 902
Schweitzer A., Hauschildt P.H., Allard F., Basri G., 1996, MNRAS 283, 821
Stauffer J.R., Hartmann L.W., 1986, ApJS 61, 531
Stauffer J.R., Hartmann L.W., 1986, ApJS 61, 531
Strassmeier K.G., Fekel F.C., Bopp B.W., Dempsey R.C., Henry G.W., 1990, ApJS 72, 191
Taylor B.J., 1994, PASP 106, 704
Taylor B.J., 1995, PASP 107, 734
Unger S., 1992 "UES Users’ Manual", WHT, Roque de Los Muchachos Observatory
Zuiderwijk E.J., Martin R., Raimond E., van Diepen G.N.J., 1994, PASP 106, 515.

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Fig. 2. Spectra in the Hβ line region
Fig. 3. Spectra in the Mg I b triplet lines region
Fig. 4. Spectra in the Na I D₁, D₂ and He I D₃ lines region
Fig. 5. Spectra in the Hα line region
Fig. 6. Spectra in the Ca II IRT λ8498, 8542, 8662 lines region