

High resolution spectra of cool stars in the Virtual Observatory:

Criteria for spectral classification.

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Abstract

During the last years, we have compiled a large number of optical spectra of cool stars taken with different high resolution echelle spectrographs. Many of them are already available as spectral libraries in the World Wide Web (Montes et al. 1997; 1998; 1999). It is our intention to include all these spectra in the Virtual Observatory (VO) following the standards of the International Virtual Observatory Alliance (IVOA). Libraries compiled by other authors are also available in the web and are or will be published soon throughout the VO.

The many VO tools that are or will be ready for the astrophysical community will make easier the use of these spectra in many areas, such as the study of chromospheric activity, spectral classification, determination of atmospheric parameters (T_{eff} , $\log g$, [Fe/H]), modelling stellar atmospheres, spectral synthesis applied to composite systems, and spectral synthesis of stellar population of galaxies.

In this contribution, as an example of the potential use of these spectra, we describe different spectral classification criteria based on equivalent width ratios of several photospheric lines, which are sensitive to effective temperature and luminosity class.

Observations

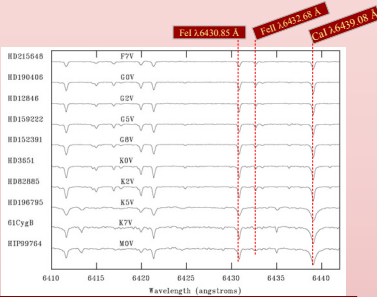
Spectroscopic observations of our sample of stars were obtained during several observing runs from 1999 – 2006. We used the FOCES spectrograph attached to the 2.2 m telescope at the Calar Alto Observatory. The spectral range covers from Ca II H & K (3933, 3968 Å) to Ca II IRT (8498, 8542, 8662 Å) including the different optical chromospheric activity indicators. The spectral resolution varies from 0.08 to 0.35 Å. Many of the spectra are already available as spectral libraries in the World Wide Web (see the web-site below).

Our sample of stars has been compared with the ones included in S^N, a spectroscopic survey of nearby stars, developed by Allende Prieto et al. (2004). These spectra have been obtained with FEROS spectrograph at La Silla Observatory and the 2dcoude spectrograph at the McDonald Observatory. The spectral range and the spectral resolution of these spectra are similar to our FOCES spectra.

Finally, we have also compared with synthetic spectra computed using the ATLAS9 code by Kurucz (Kurucz, 1993) adapted to work under linux platform by Sbordone et al. (2004) and Sbordone (2005).

<http://www.ucm.es/info/Astrof/invest/actividad/spectra.html>

6410-6450 Å spectral line region



Figs. 1 & 2 show the variation of the spectral lines in the spectral range 6410-6450 Å, with the spectral type for Main Sequence stars and Giant stars, respectively.

Our aim is to establish spectroscopic criteria to classify the stars of our sample. In order to achieve this goal, we have established relationships between the equivalent width (EW) of some lines and EW ratios with the temperature (see below).

All our spectra have been shifted to the rest wavelength. Equivalent widths have been determined in the same way in all the spectra using the SBANDS task of IRAF.

Fig. 3 shows representative synthetic spectra of Main Sequence stars (T_{eff} : 6500 – 3500 K) with solar abundance computed using the ATLAS9 code by Kurucz (Kurucz, 1993) adapted to work under linux platform by Sbordone et al. (2004) and Sbordone (2005), with the same spectral resolution that FOCES and S^N spectra.

Fig.1 Representative spectra of Main Sequence stars (F7 – M0)

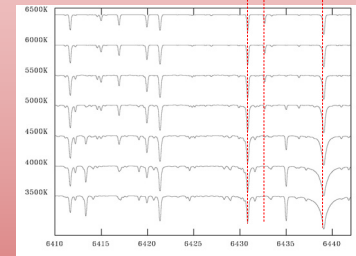
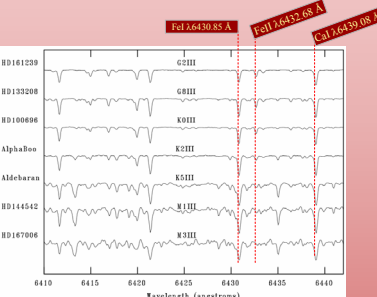
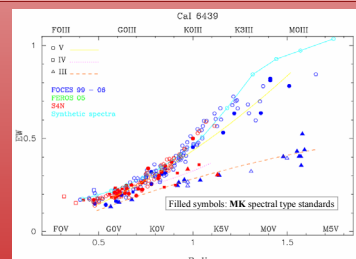
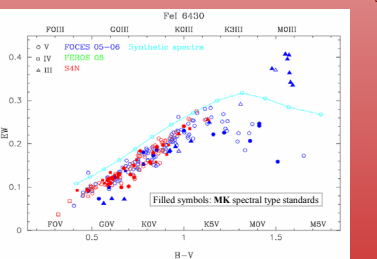
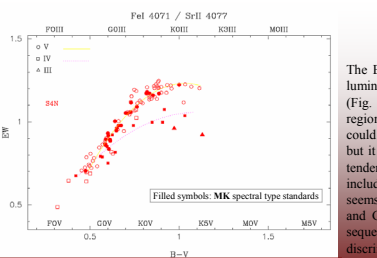


Fig.3 Representative synthetic spectra of Main Sequence stars (6500 – 3500 K) obtained using Kurucz models



Figs. 4 & 5 show the variation of the EW of Fe I 6430 and Ca I 6439 lines with the color index (B-V). As it can be inferred from the plots above, the EW(Fe I 6430) can be used to distinguish Giant (triangles) and Main Sequence (circles) stars provided that they are cooler than spectral type M0, while the EW(Ca I 6439) could be used in a much wider spectral type range (beginning in K0). It is also noticeable that the Subgiant stars could be also identified in a plot of this type because they appear in a different region than that in which Giant and Main Sequence stars can be found. Finally, note that filled symbols represent MK standard stars. These should be the stars used to establish relationships between EW and color index that could be later used to reclassify other stars.

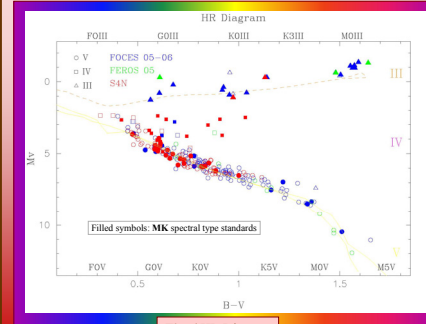
In the case of Ca I 6439 tendency curves for each group of luminosity classes have been calculated and included in the plot. To build up these mathematical relations only MK standard stars have been used.



The EW ratios of some lines are also useful to determine the spectral type and luminosity class of a star. As an example we show the Fe I 4071/Sr II 4077 ratio (Fig. 10) and the M16 (ratio between two wide regions of the spectra, in the region of the MgIb triplet, see Fig. 11). The former shows small dispersion so it could be used to determine the spectral type of a star for which it was unknown, but it also appears to discriminate Subgiant and Main Sequence stars (note that a tendency curve for these two groups obtained using only MK standards, have been included in the plot). The latter shows more dispersion for cool spectral types so it seems to be a worse election to determine spectral type. On the contrary, Subgiant and Giant stars present clearly different tendencies than the one for the Main sequence stars, so this index could be used as a good luminosity class discriminator (note that in order to do so it would be necessary to amplify the Giant and Subgiant sample).

Fig.10 Fe I 4071/Sr II 4077 EW ratios vs color index (B-V)

EW ratios



HR Diagram

Fig. 6: The HR diagram for the stars of our sample. We have plotted the absolute V magnitude vs. the color index (B-V). To obtain the absolute magnitude we have used data (parallax and visual apparent magnitude V) provided by the Hipparcos Catalogue. The color index (B-V) used has been obtained from the V & B magnitudes given by Hipparcos and Tycho Catalogues (ESA 1997). Symbols are as in Figs. 4 & 5. As can be seen our sample covers the range of the cool stars from F0 to M4 and luminosity classes from main sequence (V) to giants (III).

Fig. 6 HR Diagram

Ti I 5866.45 Å spectral line region

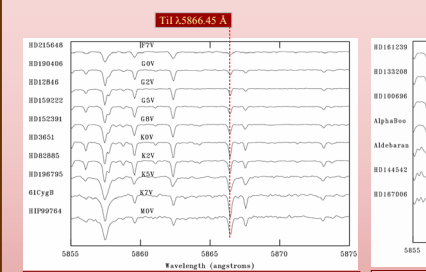


Fig.7 Variation of the Ti I 5866.45 Å line with the spectral type for Main Sequence stars.

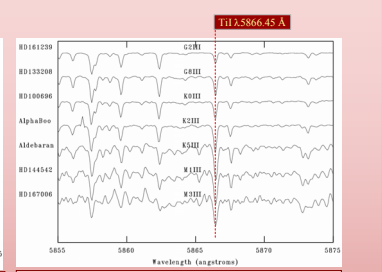


Fig.8 Variation of the Ti I 5866.45 Å line with the spectral type for Giant stars.

In figures 7 & 8 spectra of Main Sequence and Giant stars of different spectral types in the region containing Ti I 5866 are plotted. The difference between stars of different spectral type and luminosity class is clearly noticeable.

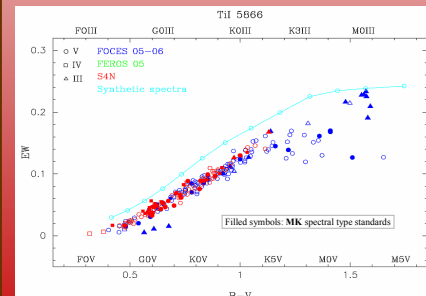


Fig. 9 shows the EW (Ti I 5866) vs. color index (B-V) for stars of different spectral types and luminosity classes as well as the results obtained using synthetic spectra. In this case, the relationship can only be used to distinguish Giant and Main Sequence stars cooler than M0 type. However, given that this relation appears to be almost linear and that the dispersion is very small, the EW of this line could be used as a good criterion to determine the spectral type of a star. Therefore, we want to point out that different lines can be used to determine spectral type or luminosity class (compare Ti I 5866 that is a better discriminator of spectral type to Ca I 6439 that can be used as a good discriminator of luminosity class).

Fig. 9 Ti I 5866 EW versus color index (B-V)

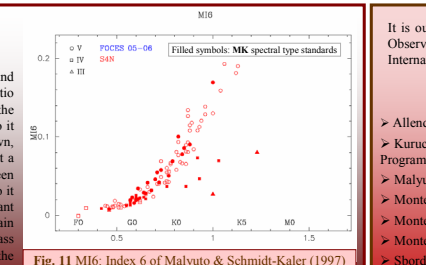


Fig. 11 M16: Index 6 of Malynko & Schmidt-Kaler (1997) (λ125-5245 Å) (λ15245-5290 Å)

It is our intention to include all these spectra in the Virtual Observatory (VO) following the standards of the International Virtual Observatory Alliance (IVOA).

References

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