Characterizing the solar neighborhood:
High resolution spectroscopy of nearby FGK stars

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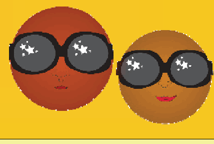


Abstract

This contribution describes our ongoing long-term high resolution spectroscopic study of nearby (d < 25 pc), FGK stars with the aim of characterizing the local properties of the Galaxy, in particular, the star formation history. A total of 136 stars have been observed up to now. 118 out of 136 in two observing runs (July 2005, January 2006) with the FOCES spectrograph in Calar Alto Almería, and 18 out of 136 in two observing runs (November 2005, February 2006) with SARG spectrograph in La Palma. The spectra have already been reduced and are now being analysed. Accurate estimates of fundamental stellar parameters, like effective temperatures (spectral types) and rotational velocities as well as radial velocities, Lithium abundance and several chromospheric activity tracers allow us to ascribe the stars to different moving groups and to analyze the chromospheric activity/rotation/age relationships in groups of stars with different ages. We would like to remark that the sample of stars we are observing constitute the natural places to look for the presence of extra-solar planets and planetary systems. An optimal knowledge of the host stars is required to infer the nature, formation and evolution of planets. In addition, this knowledge is essential for the success of future space missions, like Darwin, aiming to detect Earth-likeplanets, to characterize planetary atmospheres and to carry out comparative planetology.

Age

The resonance doublet of Li I at 6707.8 Å is an important diagnostic of age in late-type stars since it is destroyed easily by thermonuclear reactions in the stellar interior. At the spectral resolution we have and if the rotational velocity of the observed star is higher than 8 km/s the LiIλ6707.8 Å line is blended with the nearby FeIλ6707.41 Å line. We have corrected the total measured equivalent width, *EW*(LiI+FeI), by subtracting the *EW* of FeI calculated using the empirical relationship with (*B-V*) given by Soderblom et al. (1990). The obtained values are plotted in the *EW*(Li I) vs. spectral type diagram (*Fig. 1*). Comparing this *EW* with those of stars which are members of well known young open clusters of different ages, the age of a star can be estimated.

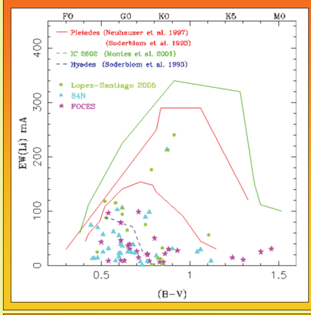


Fig.1: *EW* LiI (6707.8 Å) vs. (*B-V*) for the Darwin stars. Different colors and symbols are used for stars observed by us (FOCES 05, 06), the ones included in the S[4]N survey (Allende-Prieto et al. 2004) and López-Santiago (2005).

LiI 6707.8 Å

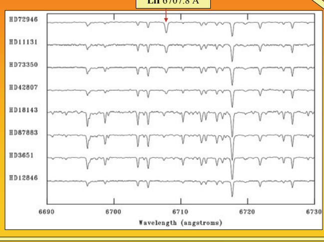


Fig. 2 Spectra of stars with the LiI (6707.8 Å) line detected in the FOCES 05, 06 observing runs

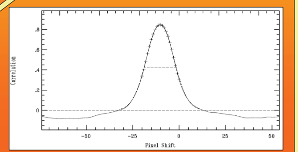
Rotation

Rotational velocities, *v*sin*i* can be written as follows (see Queloz et al, 1998 and references therein): $v\sin i = A\sqrt{\sigma_{obs}^2 - \sigma_0^2}$ where A is a coupling constant which depends on the spectrograph and its configuration. In order to calculate A we used eight slowly rotating stars. The spectra of each of these stars was broadened using the program STARMOD from *v*sin*i* = 1 km/s up to 50 km/s and the respective CCF was calculated. A was found by fitting the relation $(v\sin i)^2$ versus σ_{obs}^2. We obtained a mean value of this constant $\langle A \rangle = 0.56 \pm 0.04$.

It is well known that σ_0 is a function of all the broadening mechanism which are present in the atmosphere of the star, except rotation (Melo, Pasquini & De Medeiros, 2001). Since the broadening mechanisms are a function of the temperature and gravity, we may expect a dependence of σ_0 with the temperature. To determinate this dependence we use synthetic spectra with no rotational velocity computed using the ATLAS9 code by Kurucz (Kurucz, 1993) adapted to work under linux platform by Sbordone et al. (2004) and Sbordone (2005). Once A is determined and σ_0 calibrated with the color index (*B-V*), σ_{obs} (width of the CCF of the star when is correlated with itself) is measured for each star, *v*sin*i* can be directly calculated using the above formula.

The resulting *v*sin*i* of observed stars are plotted in Fig. 4 vs. the color index (*B-V*).

Fig. 3: Example of the **CCF** of a star. By measuring the width of such function we can obtain the rotational velocity of a star as explained in the text



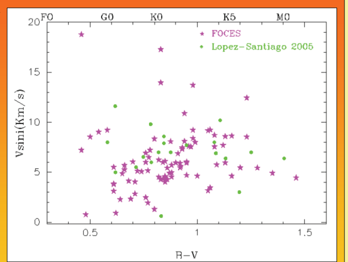


Fig. 4: *v*sin*i* vs. color index (*B-V*). Different colors and symbols have been used to distinguish between stars observed by us and those observed by Lopez-Santiago (2005).

Spectral Classification

Spectral types and luminosity classes are two important parameters in the study of stars. Although most of our targets have already a spectral type assigned, in many cases, this type is not reliable and must be revised (this is a critical point for any mission aiming to detect earth-like extra solar planets). One of our aims is, therefore, to establish spectroscopic criteria to classify correctly our sample.
In order to achieve this goal we establish relationships between the equivalent width (*EW*) of some lines and *EW* ratios with the temperature (color index). As an example we show two of these relationships in *Figs. 5 & 6*.

CaI λ6439

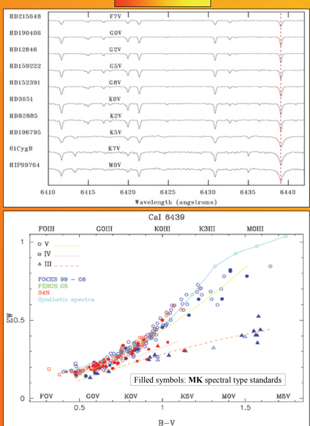


Fig. 5 Top panel: representative spectra of **Main Sequence** stars (G2 – M3). Bottom panel: CaI λ6439 *EW* versus color index (*B-V*). Note that stars of different luminosity class are plotted using different symbols.

TiI λ5866

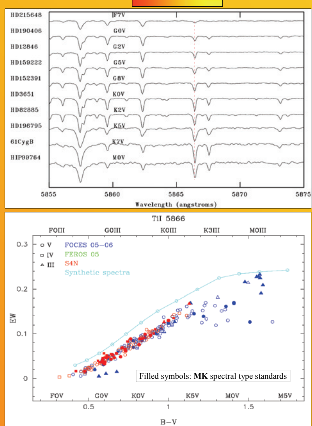


Fig.6: Top panel: variation of the TiI λ5866Å line with the spectral type for **Main Sequence** stars. Bottom panel: TiI λ5866 *EW* versus color index (*B-V*). Stars of different luminosity class are plotted using different symbols

As it can be inferred from the inspection of the plot above, the *EW*(CaI λ6439) could be used as a good discriminator between Main Sequence and Giant stars, provided that their spectral type were later than *K0*. Subgiant stars also appear in a different region, so this relationship could also be used in this case. Tendency curves for each luminosity class group have been included in the plot. To build up these mathematical relations only **MK** (Morgan & Keenan) standard stars have been used.

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 criterium 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 TiI λ5866 to CaI λ6439).

Cromospheric Activity

In order to study the cromospheric activity of a star, different activity indicators, such as Hα or CaII H&K lines (see *Figs. 7 & 8*), must be analysed because these lines are formed at different atmospheric heights and therefore represent different physical properties. Both FOCES and SARG spectra have a spectral range that permits this study.

In these features, the cromospheric contribution has been determined using the spectral substraction technique described in detail by Montes et al. (1995; 1996; 1998). The synthesized spectrum was constructed using the program STARMOD developed at Penn State (Barden 1985).

The inactive stars used as reference stars in the spectral subtraction were observed during the same observing run as the active stars.

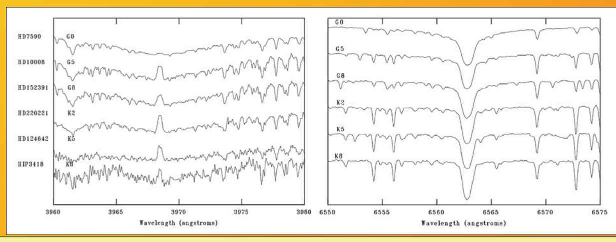


Fig. 7 Evolution of activity with the Spectral Type for two activity indicators. In the left panel we present the CaII H line. The right panel shows the Hα line.

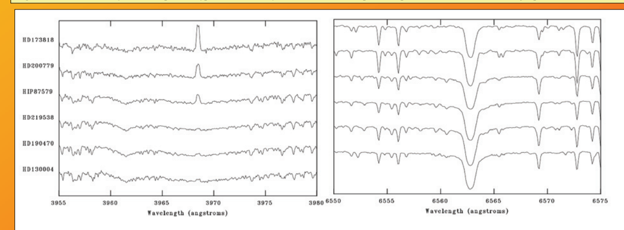


Fig. 8 Stars with different activity levels are shown by different intensities of the Ca II H line (left) Althought this difference is not apparent in the Hα line (right) if we used the spectral subtraction technique we would be able to distinguish this difference.

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Acknoledgments

This work was supported by the Spanish Ministerio de Educación y Ciencia (MEC) under grants AYA2005-00954 and AYA2005-02750, and "The Comunidad de Madrid" PRICIT projects S-0505/ESP-0237 (ASTROCAM) and S-0505/ESP/000361 (ASTRID).