Cool stars in the solar neighborhood
Preparatory activities for the Darwin mission

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Abstract

We are carrying out a systematic analysis of the spectroscopic properties of nearby (d<25 pc) FGK stars aiming to widen the knowledge of the stellar formation history in the solar neighborhood. The stars already observed are included in the Darwin catalogue (ESA mission to detect and characterize Earth-like exoplanets). The determination of the fundamental parameters of these stars is one of the needed preparatory works of the mission. In this contribution we present a preliminary analysis of the high resolution echelle spectra obtained in Calar Alto and La Palma observatories. Both the spectroscopic observations and the physical parameters obtained will be deposited in DAMA (DArwin archive MAdrid), a Virtual Observatory tool that is being developed.

Scientific Context

The study of the stellar population in the solar neighborhood possesses an unquestionable interest for a wide range of investigations dealing with the overall properties of the Galaxy, but it also has an intrinsic astrophysical value: the precise characterization of the fundamental stellar parameters. Nearby cool stars like the Sun (FGK spectral types) are very useful to understand the structure and evolution of the Galaxy since their proximity has obvious advantages that can be exploited. These stars have intrinsically narrow absorption lines that allow to determine radial velocities with high precision. Combining them with Hipparcos accurate astrometry makes possible to define a volume limited sample and analyze their kinematics (membership to some moving groups). In addition, these stars constitute the natural places to look for the presence of extra-solar planets and planetary systems. The knowledge of the physical properties (age, photospheric and chromospheric activity, etc.) of the stars and their immediate environment (companions, debris and exo-zodiacal disks) are essential for the success of future space missions, like ***Darwin***, aiming to detect Earth-like planets, to characterize planetary atmospheres and to carry out comparative planetology (i.e. relating planet properties to the astrophysical characteristics of their host stars).

Here we present the results obtained so far of our ongoing long-term high resolution spectroscopic study of the FGK stars in the solar neighborhood. These stars are included in the Darwin stellar catalogue (see contribution by Eiroa in this meeting). Our immediate aims are: **i)** to determine high precision heliocentric radial velocities, **ii)** to study the lithium abundance and the level of chromospheric activity, **iii)** to determine with high accuracy fundamental stellar parameters, like effective temperatures (spectral types) and rotational velocity (*v*sin*i*).

Chromospheric Activity

Representative spectra in the Hα and Ca II H line regions of some of the stars of the sample are plotted in Figs. 2 and 3.

Echelle spectra allow us to study the behaviour of the different optical chromospheric activity indicators from the Ca II H & K to the Ca II IRT lines, formed at different atmospheric heights. The chromospheric contribution in these features has been determined using the spectral subtraction technique described in detail by Montes et al. (1995; 1997; 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.

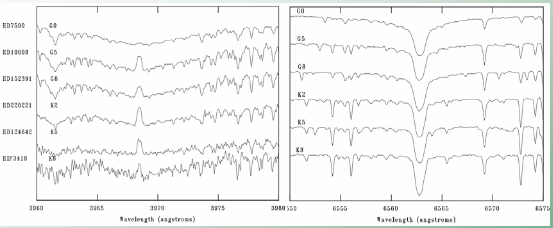


Fig. 2 Evolution of activity with the Spectral Type for two activity indicators. In the left panel we present the CaII H line. The right panel shows the Hα line.

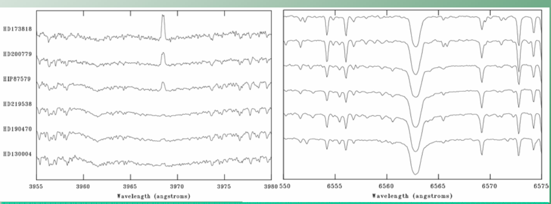


Fig. 3 Stars with different activity levels are shown by different intensities of the Ca II H line (left) Althought this difference is not apparent in the Hα line (right) if we used the spectral subtraction technique we would be able to distinguish this difference.

Rotation, *v*sini

Rotational velocities, vsini 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 the coupling constant. We calculate A, using eight slowly rotating stars. Each spectra was broadened using the program STARMOD between *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 the main value <A> = 0.56±0.04.

It is well known that σ_0 is a function of all the broadening mechanism, 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). The results are shown in Fig. 4. The resulting *v*sin*i* of the observed stars are plotted in Fig. 5 vs. the color index B-V.

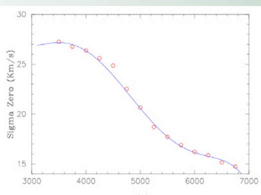


Fig. 4 Relation between σ_0 and temperature, obtained using synthetic spectra.

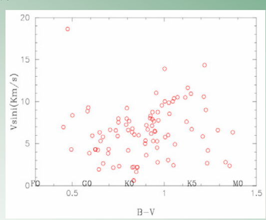


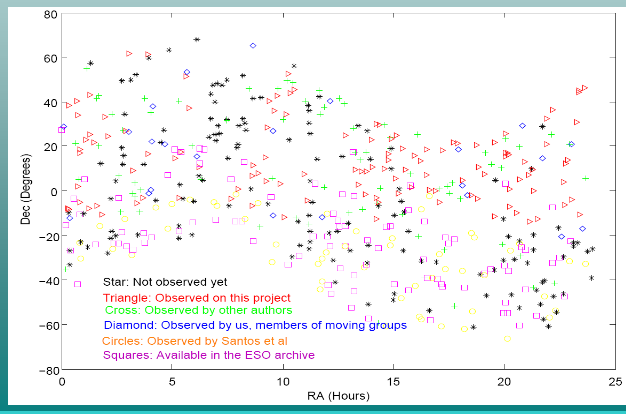
Fig. 5 Relation between the obtained vsini, and the color index B-V for the observed stars.

Observations

Spectroscopic observations (high resolution echelle spectra) of 136 stars were obtained during 4 observing runs from 2005 – 2006. In two of them 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 in this case varies from 0.08 to 0.35 Å. In the other two observing runs the spectrograph SARG was used in the Telescopio Nazionale Galileo (3.56m) in La Palma Observatory. The spectral range is shorter in this case (4960-10110 Å) and the resolution varies from 0.08 to 0.17 Å.

- **Calar Alto** 2.2m-FOCES 6 nights (23 - 28 jul 2005) 80 stars
- **Calar Alto** 2.2m-FOCES 9 nights (8 - 16 jan 2006) 38 stars
- **La Palma** TNG-SARG 4 nights (11 - 14 nov 2005) 0 stars
- **La Palma** TNG-SARG 2 half nights (18 - 19 feb 2006) 18 stars

Fig. 1 Spacial distribution (in equatorial coordinates) of the Darwin stars (nearby (< 25 pc) FGK Main Sequence stars, located in a cone of aperture ±45 deegres around the ecliptic). Stars observed by us within the global scope of these project, as well as, stars observed by other groups and stars includes in the ESO archives, are indicated by different symbols.



Spectral Classification, T_{ef}, g

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 the Darwin mission)

One of our aims is therefore to establish spectroscopic criteria to classify correctly our sample.

In order to achieve this goal, we follow the procedure by Montes et al. (this meeting): to establish relationships between the equivalent width (EW) of some lines (see Fig. 6) and EW ratios with the temperature (color index).

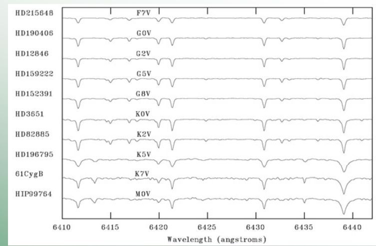


Fig. 6 Representative spectra of **Main Sequence** stars (F8 – M0)

Age, EW(LiI)

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 this spectral resolution and with the rotational velocity (vsini > 8 km s^{-1}) of the observed stars the Li I line is blended with the nearby Fe I 6707.41 Å line. We have corrected the total measured equivalent width, EW(Li I+Fe I), by subtracting the EW of Fe I calculated from 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. 7).

In order to obtain an estimate of the ages of our stars we compare their EW(Li I) with those of stars in well known young open clusters of different ages (see Fig. 7).

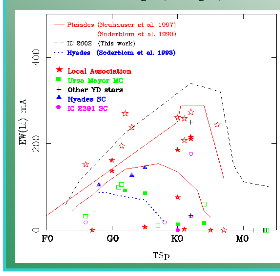


Fig. 7 EWLiI (6707.8 Å) vs. spectral type.

Fig. 8 Spectra of stars with the LiI (6707.8 Å) line detected

Kinematics

Heliocentric radial velocities have been determined by using the cross-correlation technique. The spectra of the program stars were cross-correlated order by order, using the routine fxcor in IRAF, against spectra of radial velocity standards of similar spectral types. The orders including chromospheric features and prominent telluric lines have been excluded when determining the mean velocity. Uncertainties in the derived velocities are around 1-2 km/s.

We have used these radial velocities together with precise measurements of proper motions and parallaxes taken from Hipparcos and Thycho-2 Catalogs, to calculate Galactic space-velocity components (U, V, W) in a right-handed coordinated system (positive in the directions of the Galactic center, Galactic rotation, and the North Galactic Pole, respectively). The (U, V) and (W, V) planes (Boettlinger Diagram) are plotted in Fig. 9 and will be used to analyse the membership of these stars to different moving groups.

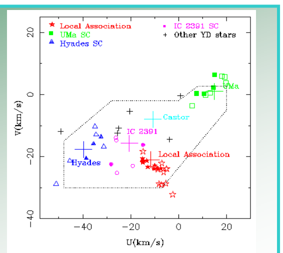


Fig. 9 (U, V) plane for some of the stars of the sample. Different colors indicate membership to different young moving groups.

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