High resolution spectroscopic characterization of the FGK stars in the solar neighbourhood

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Abstract We present the most recent results of our ongoing long-term high resolution spectroscopic study of nearby (d $\leq$ 25 pc) FGK stars which aim is to characterize the local properties of the Galaxy, in particular, the star-formation history. A thorough analysis has been carried out for 253 cool stars in the solar neighborhood. This includes radial and rotational velocities determinations, chromospheric activity levels inference, kinematic analysis, and age estimates. This study does not only shed new light on the issue of stellar formation history but also contributes to any present or future mission aiming to detect extra-solar planets. Exo-planets are likely to be found orbiting around nearby cool stars and their detection and characterization is highly dependent on the precise determination of fundamental stellar parameters such as age, activity levels. Therefore, our study is of paramount importance to ensure the success of any such mission.

1 Introduction: The aim of our study

The Solar Neighbourhood is, obviously, the most accesible area in the Galaxy and when dealing with cool stars the only one to represent a statistically valid sample. Therefore, this region should be used as a model and test to any theory considering physical procedures in cool stars or the global behaviour of our Galaxy. The aim we pursue is manifold. We are interested in examining the star formation history in our surroundings and in the kinematics of its stars, something that will contribute to the understanding of composition of our Galaxy and its global behaviour. In addition, we are interested in studying the dependence of chromospheric and coronal activity with stellar parameters, such as rotational periods and age. In order to achieve our goals we performed high resolution optical spectroscopy to determine radial and rotational velocities, lithium abundances and chromospheric activity levels.

2 The Stellar Sample

Our complete sample was iniatially defined as the ESA's Darwin mission stellar sample, which included all FGK main sequence stars within 25 pc from the Sun.

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Recently, we have added those stars included in the DUNES sample ([6], [10]). The sample amounts to 716 stars (15 A stars, 110 F stars, 180 G stars, 403 K stars and 8 M stars) of which we have obtained high resolution optical spectra for 316 stars and analysed 253 of them.
To carry out the following study, we used high resolution (R 45000-50000) optical spectra with a spectral coverage including the fundamental chromospheric activity indicators (Ca II H & K lines, Balmer lines and Ca II IRT), Lithium line (λ6707.8 Å) and the resonance doublet of sodium. Spectra were taken using different spectrographs: 173 stars were observed with FOCES at the 2.2m telescope in Calar Alto Observatory (Spain) and 63 were obtained with SARG at the TNG in La Palma Observatory. We also used spectra in public libraries, in particular those included in the S^4N project carried out by [1] and in the young moving groups survey performed by [9].

3 Results

3.1 Radial Velocity and Kinematics

To determine radial velocities the *Cross Correlation Technique* has been used. This technique basically consists in comparing the spectrum of the observed star and that of a standard radial velocity star. The shift between the lines of both spectra is due to a difference in the stars' radial velocities. Given that the radial velocity of the standard star is known, the radial velocity of the observed star can be easily deriven. We have measured the radial velocity of the stars in our sample. With the computed

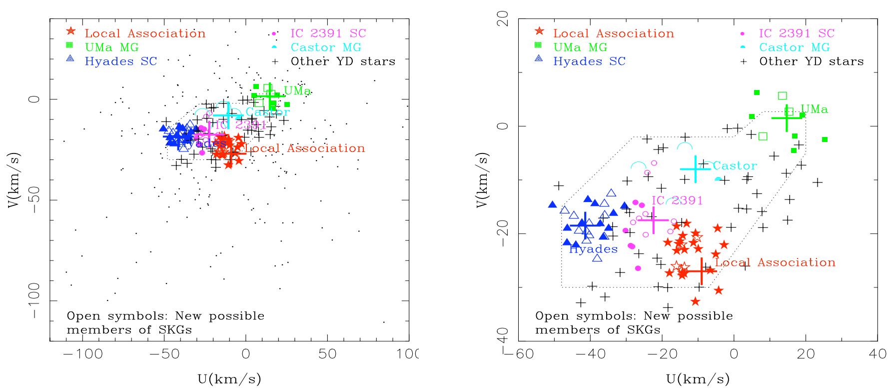

Fig. 1 Position in the UV-plane for the 253 analysed stars (**right panel**) and for the 132 which have been ascribed to young moving groups (**left panel**)

radial velocities and the proper motions taken from Hipparcos catalogue, we have obtained the Galactic velocity components (U, V, W). With them, and considering the Eggen criteria ([3], [4], [5]) toghether with the position of the star in the UV-plane, we have ascribe some of our stars to young moving groups (as done by [14]).

From the 253 analysed stars, 132 are possible members of young kinematic groups (see Fig. 1).

3.2 Rotational Velocity

Rotational velocities, $v\sin i$ can be written as follows (see [16] and references therein):

$$\sigma_{rot}^2 = \sigma_{obs}^2 - \sigma_0^2 \Longrightarrow vseni = A\sqrt{\sigma_{obs}^2 - \sigma_0^2} \tag{1}$$

where A is a coupling constant which depends on the spectrograph and its configuration. The spectrum of each of these stars was broadened using the program STARMOD from $v\sin i = 1\ km\ s^{-1}$ up to $50\ km\ s^{-1}$ and the respective CCF was calculated. A was found by fitting the relation $(vsini)^2\ vs\ \sigma_{obs}^2$. We obtained a mean value of this constant $< A > = 0.56 \pm 0.04$. It is well known that σ_0 is a function of the broadening mechanisms which are present in the atmosphere of the star, except rotation ([11]). Since the broadening mechanisms are a function of the temperature and gravity, we may expect a dependence of σ_0 with the temperature. To determine this dependence we use synthetic spectra with no rotational velocity computed using ATLAS9 code by Kurucz ([8]) adapted to work under linux platform by Sbordone et al., ([18]; [17]). 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. As shown in Fig. 2, the majority of the stars in the sample are slow rotators ($v\sin i \leq 10\ km\ s^{-1}$) being the fastest rotators (10-30 $km\ s^{-1}$) the early-type stars(F8-G0).

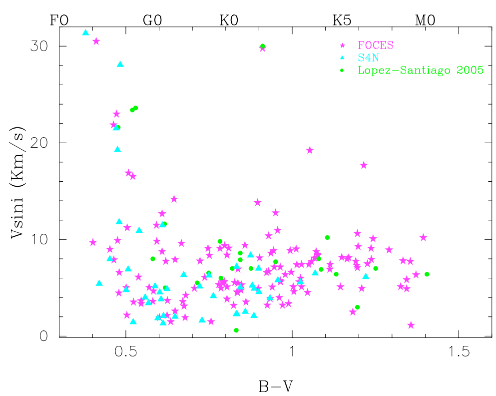

Fig. 2 Rotational velocity ($v\sin i$) *vs*. color index $(B-V)$ for the stars in the sample.

3.3 Chromospheric Activity

In order to study the chromospheric activity of a star, different activity indicators, such as Hα, Ca II H & K lines or Ca II IRT lines (see Fig. 3), should 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. The chromospheric contribution has been determined using the spectral substraction technique described in detail by Montes et al. ([12];

[13]. The synthesized spectrum was constructed using the program STARMOD developped at Penn State ([2]). The inactive stars used as reference stars in the spectral subtraction were observed during the same observing run as the active stars.

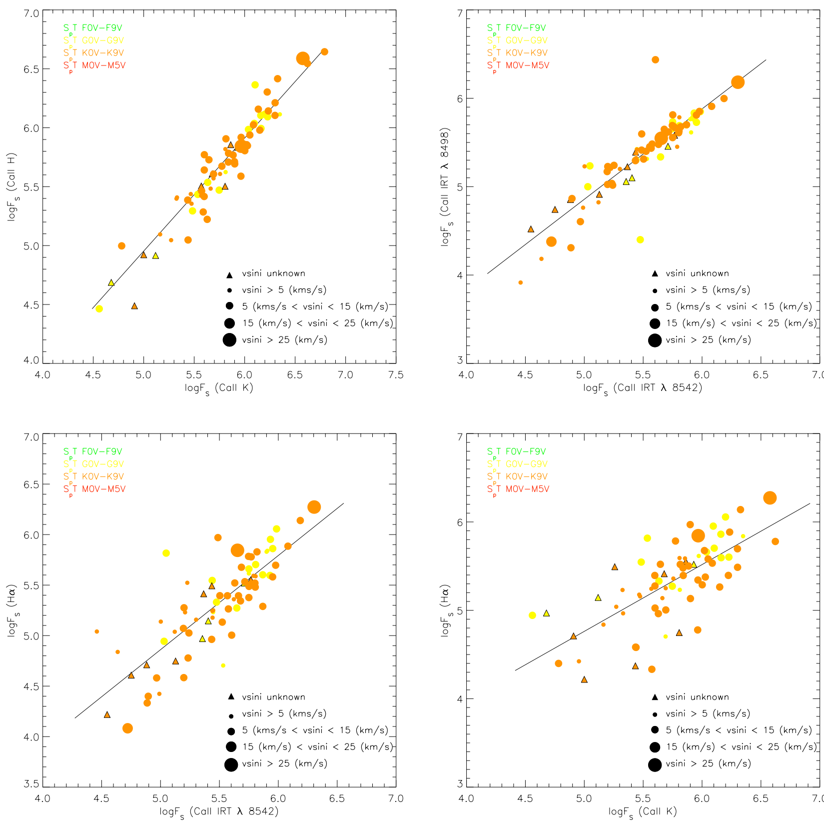

Fig. 3 Flux relations between different chromospheric activity indicators. Different colors show different temperatures and increasing size represent higher rotational rates

3.3.1 Activity-Rotation Relations

Chromospheric activity is generated through a magnetic stellar dynamo, the strength of which appears to scale with rotational velocity ([7], [15]). Using the computed fluxes and the measured rotational velocities ($v\sin i$) we have analysed the dependence of activity levels with rotational rate for our stars. Since $v\sin i$ represents only a minimun value of the real rotational velocity of a star, we have obtained a significant scatter. In order to improve our study we have considered photometric periods. We show the results for Ca II K and Hα lines (Fig. 4) as an example.

3.4 *Age*

The resonance doublet of Li I at 6707.8 Å is an important diagnostic of age in late-type stars since it is easily destroyed by thermonuclear reactions in the stellar inte-

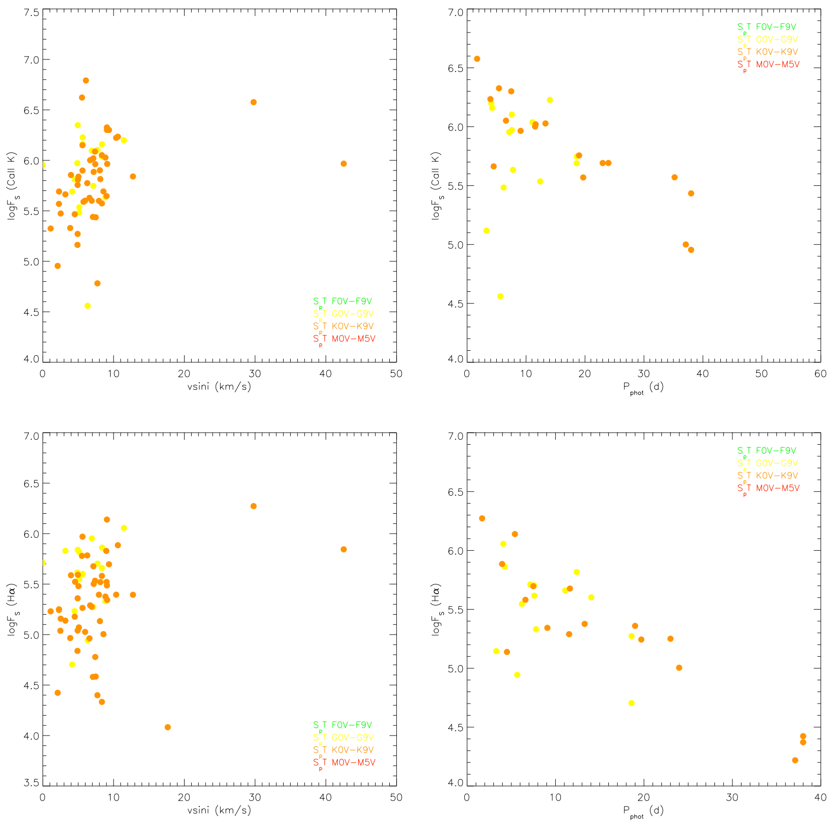

Fig. 4 **Left panel:** Flux in Ca II K line (top) and Hα line (bottom) *vs*. *v*sin*i*. **Right Panel:** Flux in Ca II K line (top) and Hα line (bottom) *vs*. P_{phot}. Different color indicate different spectral types.

rior. At the spectral resolution we have and if the rotational velocity of the observed star is higher than 8 $km\ s^{-1}$ the Li I λ6707.8 Å line is blended with the nearby Fe I λ6707.41 Å line. We have measured the total equivalent width, *EW*(Li I + Fe I), by subtracting the *EW* of Fe I calculated using the empirical relationship with *(B-V)* given by [19] we could obtain the *EW*(Li I). The obtained values are plotted in the *EW*(Li I) vs. spectral type diagram in Fig. 5. 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. As it can be infered from the above mentioned figure, a large number of stars results to be older than the Hyades, some show ages between those of the Pleiades and the Hyades, but none younger than the Pleiades was found.

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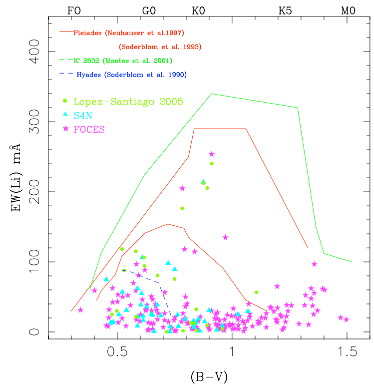

Fig. 5 *EW* Li I *vs*. (B-V). Different colors and symbols are used for stars observed by us, the ones included in the S^4N survey ([1]) and [9].

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