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Spectroscopic properties of nearby late-type stars, members of stellar kinematic groups

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Abstract

Nearby late-type stars are excellent targets to look for young objects in stellar associations and moving groups. The study of these groups goes back more than one century ago however, their origin is still misunderstood. Although their existence have been confirmed by statistical studies of large sample of stars, the identification of a group of stars as member of moving groups, is not an easy task, list of members often change with time and most members have been identified by means of kinematics criteria which is not sufficient since many old stars can share the same spatial motion of those stars in moving groups. In this contribution we attempt to identify unambiguous moving groups members, among a sample of nearby-late type stars. High resolution echelle spectra is used to i) derive accurate radial velocities which allow us to study the stars' kinematics and make a first selection of moving groups members; and ii) analyze several age-related properties for young late-type stars (i.e., lithium Li I 6707.8 Å line, $R'_{\rm HK}$ index). The different age-estimators are compared and the moving group membership of the kinematically selected candidates are discussed.

1 Introduction

The dispersal of young stars out into the field and whether or not there are kinematically-related groups of stars in the solar neighbourhood is one of the open problems in Galactic astrophysics. Although stars do not form isolated but within clusters and associations, most of them end up in the field. Once scattered through the Galaxy, these young stars are difficult to identify. [1] assumed that clusters form a halo of evaporated stars. During its disintegration, the whole group can not be identified although within some regions one can found stars moving in the same direction and at the same rate. This idea gave rise to the concept of moving group or Stellar Kinematic Group (hereafter SKG).

The idea of a moving group as a group of stars sharing a common origin has been the subject of an intense discussion. It is now, however, well established that the "classical" moving groups (e.g. Hyades, Ursa Major) are in reality a mixture of two different populations: a group of coeval stars (related to the halo of an evaporating cluster) and a second group with a dynamical (resonant) origin, e.g., [4].

Identifying stars with a common origin (i.e. same kinematics, same age, same chemical composition) is only possible if a combination of techniques are used. Nearby-late type stars are excellent targets for this kind of study since i) their spectra is full of narrow absorption lines, allowing determination of accurate radial velocities, and ii) it is unlikely that an old star by chance shares chromospheric indices or a lithium abundance similar to those of young solar-like stars.

2 How can we identify stars in SKGs?

In a recent work, [8] studied a sample of 405 nearby late-type stars, attempting to identify unambiguous SKGs members by analysing high-resolution ($R \sim 57000$) echelle spectra obtained in 2-3 meters class telescopes. The study is focused in nearby (distances less than 25 pc), main-sequence (luminosity class V/IV-V), late-type (spectral types FGK) stars. The Hipparcos catalogue [3] is used as a reference. To identify stars in SKGs, [8] analyzed both the kinematics and the spectroscopic age indicators.

2.1 Kinematic analysis

Radial velocities were measured by cross-correlating, using the IRAF routine *fxcor*, the spectra of the program stars with spectra of radial velocity standard stars of similar spectral types. For those known spectroscopic binaries, the radial velocity of the centre of mass of the system were considered. Typical uncertainties are between 0.15 and 0.25 $\mathrm{km\,s^{-1}}$. These radial velocities were used together with Hipparcos parallaxes [16] and Tycho-2 proper motions [6] to compute the Galactic-spatial velocity components (U, V, W), as explained in [12].

Young stars are assembled in an specific region of the (U, V) plane ($-50\ \mathrm{km\,s^{-1}} < \mathrm{U} < 20\ \mathrm{km\,s^{-1}}; -30\ \mathrm{km\,s^{-1}} < \mathrm{V} < 0\ \mathrm{km\,s^{-1}}$), although the shape is not a square (see Fig. 1). Possible members of SKGs are selected allowing a dispersion of 8 $\mathrm{km\,s^{-1}}$ in the U, V components with respect to the central position of the SKG. The same dispersion is considered when taking the W component into account. The final number of candidates for each SKG is given in Table 1 (column 4).

2.2 Age estimates

Members of a given SKG should be coeval and since clusters disperse on time scales of a few hundred years they should also be moderately young ($\sim$ 50–650 Myr). The classic method

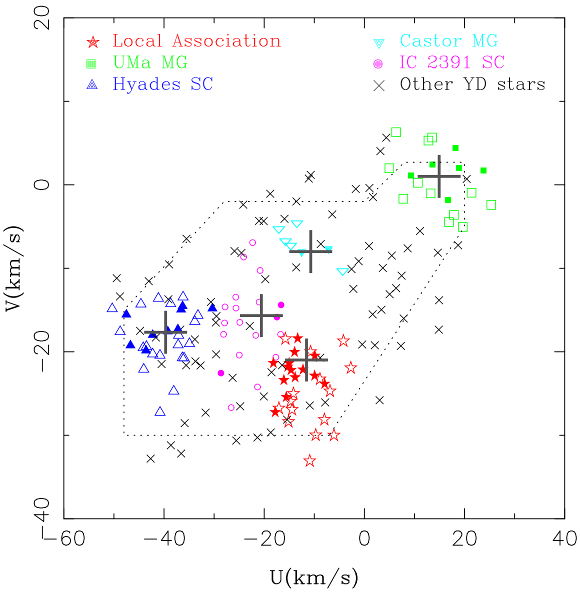

Figure 1: (U, V) plane. Different colours and symbols indicate membership to different SKGs. Large crosses represent the convergence point of the young SKGs shown in the figure as given by [12]. The dotted line represents the boundary of the young disc population. Figure from [8].

to compute the stellar age (i.e. evolutionary tracks) does not work good enough for the latest spectral types. However, late-type stars show other properties which can be used to determine their age:

Lithium abundance: An age estimate of late-type stars can be carried out by comparing their Li I 6707.8 Å equivalent width with those of stars in well known young open clusters of different ages, e.g., [8, 13]. Nevertheless, it should be regarded as an additional age indicator since the relation lithium-age is poor constrain and biased towards younger ages.

Age derived from cromospheric activity: There are several observables of the magnetic field of a solar-type star: chromospheric emission lines, e.g. Ca II H, & K or Ca II IRT, or the X-ray emission from the stellar corona, e.g., [7, 10]. In addition, there is a strong correlation between the stellar rotation and the chromospheric activity in cool stars, e.g.,[14]. In this way, the stellar age can be estimated [9, 5]:

- By using the index $R'_{\rm HK}$ which is a measure of the cromospheric emission in the cores of the Ca II H, & K absorption lines, normalised to the total bolometric emission of the star.

Table 1: Number of stars identified as possible members and non-members of moderately young SKGs.

Kinematic Group	Age (Myr)	Candidates	Possible Members	No-members
IC2391	35–55	19	6	4
Castor	200	7	4	0
Ursa Major	300	18	6	6
Local Association	20–150	29	14	8
Hyades	600	29	11	9

- By searching for X-ray counterparts in the ROSAT catalogue.

- From the rotational period of the star (gyrochronology)

The agreement between the different activity-age estimates is overall good, as can be seen in Fig. 2. Chromospheric age shows an enhancement of the star formation rate in the last 2 Gyr, then the distribution becomes more or less flat. ROSAT ages are biased towards stars younger than 3–4 Gyr; i.e., older stars have negligible (or undetectable) X-ray emission, and therefore their distribution does not offer information on the stellar formation history. As far as rotational ages are concerned, there are not enough stars with measured rotational periods to draw robust conclusions.

A summary of the ages obtained (percentages of stars according to their ages for each age-indicator) can be seen in Table 2.

3 Conclusions and prospects for future work

From a total sample of 405 stars, [8] identify 102 stars which share the same kinematics that those stars in SKGs (i.e. $\sim 25\%$ of the sample). In addition, 78 stars are classified as *other young discs stars* (i.e. stars which are in the boundaries of the young disc population but without a clear identification to some of the SKGs). From them, 36 have ages that agree with the accepted ages of the corresponding moving group. That means that only $\sim$10% of the nearby late-type stars can be associated to SKGs. Table 1 summarises the number of kinematic candidates to the different SKGs and the final number of possible members and no-members of each of the SKGs studied in [8].

List of young stars in SKGs can be very useful for further investigations. Some examples include search for solar analogues, substellar companions, study of the flux-flux and rotation-activity-age relationships in groups of stars with different ages [10] or search for cold faint dusty debris discs (e.g. the DUNES project [2, 15]).

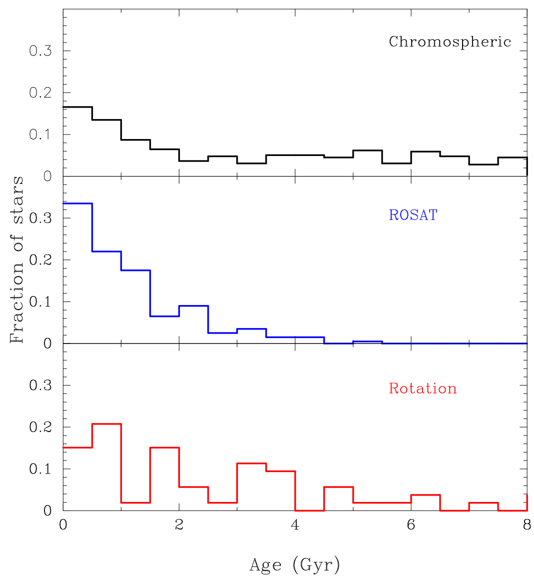

Figure 2: Age distribution for chromospheric-derived ages (upper panel), ROSAT ages (middle panel), and rotational ages (lower panel). Figure from [8].

Table 2: Percentages of stars according to their estimated age for each age indicator.

Age-indicator	$\sim$ 80–100 Myr	$\sim$ 300 Myr	$\sim$ 665 Myr	$>$ 665 Myr
Lithium†	4	8		23
Chromospheric	5	10	13	72
ROSAT	23		51	26
Rotation‡	22		28	50

† 50% older than 80–100 Myr; 15% of the stars show no photospheric Li I

‡ Rotational periods only available for roughly 17% of the whole sample

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