Late-type stars members of young stellar kinematic groups – I. Single stars

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Accepted 2001 ... . Received 2001 ...

ABSTRACT
This is the first paper of a series aimed at studying the properties of late-type stars members of young stellar kinematic groups. We concentrate our study on classical young moving groups as: Local Association (Pleiades moving group, 20 - 150 Myr), IC 2391 supercluster (35 Myr), Ursa Major group (Sirius supercluster, 300 Myr), and Hyades supercluster (600 Myr); as well as on recently identified groups as: Castor moving group (200 Myr). In this paper we have compiled a preliminary list of single late-type stars possible members of some of these young stellar kinematic groups. Stars have been selected from previously established members of stellar kinematic groups based on photometric and kinematic properties as well as from candidates based on other criteria as their level of chromospheric activity, rotation rate, lithium abundance. Precise measurements of proper motions and parallaxes taken from Hipparcos Catalogue, as well as from Tycho-2 Catalogue, and published radial velocity measurements are used to calculate the Galactic space motions (U, V, W) and to apply the Eggen's kinematic criteria in order to determine the membership of the selected stars to the different groups. Additional criteria using age-dating methods for late-type stars will be applied in forthcoming papers of this series. A further study of the list of stars compiled here could lead to a better understanding of the chromospheric activity and their age evolution as well as of the star formation history in the solar neighbourhood. In addition, these stars are also potential search targets for direct imaging detection of sub-stellar companions.

Key words: stars: kinematic – stars: late-type – stars: activity – stars: chromospheres – open clusters and associations: general – catalogues

1 INTRODUCTION
Stellar kinematic groups (SKG) are kinematically coherent groups of stars that could share a common origin (the evaporation of an open cluster, the remnants of a star formation region or a juxtaposition of several star formation bursts at different epochs in adjacent cells of the velocity field). Eggen (1994) defined a “supercluster” (SC) as a group of stars gravitationally unbound that share the same kinematics and may occupy extended regions in the Galaxy, and a “moving group” (MG) as the part of the supercluster that enters the solar neighbourhood and can be observed all over the sky. It has long been known that in the solar vicinity there are several groups of stars that share the same space motions than well known open clusters. The youngest and best documented groups are the Hyades supercluster (Eggen 1958a, 1960a, 1984b, 1998b) associated with the Hyades cluster (600 Myr), and the Ursa Major group (Sirius supercluster) (Eggen 1960b, 1983a, 1992a, 1998c, Soderblom & Mayor 1993a, b) associated with the UMa cluster of stars (300 Myr). A younger kinematic group called the Local Association or Pleiades moving group seems to consist of a reasonably coherent kinematic stream of young stars with embedded clusters and associations such as the Pleiades, α Per, NGC 2516, IC 2602, and Scorpius-Centaurus (Eggen 1975, 1983b, c, 1992c, 1995a). The age of the stars of this association ranges from about 20 to 150 Myr. Evidences have been found that X-ray and EUV selected active stars and lithium-rich stars (Favata et al. 1993, 1995, 1998; Jeffries & Jewell 1993; Mullis & Bopp 1994; Jeffries 1995) are members of this association. Other two young moving groups are the IC 2391 supercluster (35-55 Myr) (Eggen 1991, 1995b) and...
the Castor Moving Group (200 Myr) (Barrado y Navascués 1998).

Since Olin Eggen introduced the concept of MG and the idea that stars can maintain a kinematic signature over long periods of time, their existence (mainly the old MGs) has been rather controversial (see Griffin 1998; Taylor 2000). There are two factors that act against the persistence of a MG: the Galactic differential rotation (tends to spread the stars) and the disc heating (velocity dispersion of disc stars increase with age). However, recent studies (Dehnen 1998; Chereul, Crézé & Bienaymé 1998, 1999; Skuljan, Hearnshaw & Cottrell 1999; Asilin et al. 1999; Torra, Fernández & Figueras 2000; Mylläri, Flynn & Orlov 2000; Feltzing & Holmberg 2000) using astrometric data taken from Hipparcos and different procedures to detect MG not only confirm the existence of classical young MGs (and some old MGs), but also detect finer structures in space velocity and age that in several cases can be related to kinematic properties of nearby open clusters or associations. Skuljan, Cottrell & Hearnshaw (1997) have also confirmed the Eggen’s hypothesis of MG using Hipparcos astrometric data. These authors found that the use of Hipparcos data considerably improve the velocity dispersions for all the Eggen’s MGs. However, the Eggen’s membership criterion of constant V is not confirmed and they conclude that both U and V velocity components must be used to create more realistic membership criteria. More complex structures characterized by several longer branches (Sirius, middle, and Pleiades branches) running almost parallel to each other across the UV-plane have been found by Skuljan et al. (1999) in their study of the velocity distribution of stars in the solar neighborhood.

Well known members of these moving groups are mainly early-type stars and few studies have been concentrated on late-type stars. However, evidences have been found that many young late-type stars can be members of some young MG (X-ray and EUV selected active stars and lithium-rich stars (Jeffries 1995); the late-type stellar population of the Gould belt (Guilout et al. 1998; Makarov & Urban 2000)). Identification of a significant number of late-type members of these young moving groups would be extremely important for a study of the chromospheric and coronal activity and their age evolution. This is the aim of this series of papers.

In this first paper we focus on the compilation of a preliminary list of single late-type stars, previously established members or possible new candidates of the different young SKG mentioned above (see Table 1). We have examined the kinematic properties of these stars using the more recent radial velocities and astrometric data available, in order to determine their membership to the different SKG. In a companion paper (Montes et al. 2001c; hereafter Paper II) we give the list of spectroscopic binaries, some of them well known chromospherically active binaries (for preliminary results see Montes, Latorre & Fernández-Figueroa 2000a; and Montes et al. 2001a). The origin of these young SKG will be addressed in Paper III. With this aim we have taken the most recent data available in the literature (including astrometric data from Hipparcos Catalogue and new Tycho-2 Catalogue) of the nearby young open clusters, OB associations, T associations, and other associations of young stars as TW Hya, in order to calculate their Galactic space motions (U, V, W) and space coordinates (X, Y, Z) and to study their possible association with the different young SKG as well as with the young flattened and inclined Galactic structure known as the Gould Belt (for preliminary results see Montes 2001a, 2001b; for a review about the evolution from OB associations and moving groups to the field population see Brown 2001).

In addition to the kinematic properties we have also compiled for each star the photometric, spectroscopic and physical properties as well as information about activity indicators and Li abundance. For some of the candidate stars included in the list analysed in this paper we have also taken high resolution echelle spectra in order to obtain a better determination of their radial velocity, lithium abundance, rotational velocity and the level of chromospheric activity (for preliminary results see Montes 2001b; Montes, López-Santiago & Gálvez 2001b; Montes et al. 2001d). We will use all this data in forthcoming papers to analyse in detail the membership to the different young SKG and identified possible age subgroups (see Barrado y Navascués 1998, Barrado y Navascués et al. 1999; Song et al. 2000; López-Santiago, Montes & Gálvez 2001).

In Sect. 2 we describe the young SKG we have considered in this work. The details of the sample selection are given in Sect. 3. In Sect. 4 we analyse the membership of this sample to the different SKG using as membership criteria the Galactic space-velocity components (U, V, W) and the Eggen’s kinematic criteria. Finally, Sect. 5 gives the discussion and conclusions.

Table 1. Young stellar kinematic groups

| Name                  | Cluster(s)          | Age  | U, V, W   | V_T   | C.P. (A, D) |
|-----------------------|---------------------|------|-----------|-------|-------------|
| Local Association     | Pleiades, α Per, M34| 20−150| -11.6, -21.0, -11.4 | 26.5  | (5.98, -35.15) |
| (Pleiades moving group)| δ Lyr, NGC 2516, IC2602, | | | | |
| IC 2391 supercluster  | IC 2391             | 35−55| -20.6, -15.7, -9.1 | 27.4  | (5.82, -12.44) |
| Castor moving group   |                      | 200  | -10.7, -8.0, -9.7 | 16.5  | (4.75, -18.44) |
| Ursa Major group      | Ursa Major           | 300  | 14.9, 10.0, -10.7 | 18.4  | (20.55, -38.10) |
| (Sirius supercluster) |                      |      |            |       |             |
| Hyades supercluster   | Hyades, Praesepe     | 600  | -39.7, -17.7, -2.4 | 43.5  | (6.40, 6.50) |

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2 YOUNG SKG

We focus our study here on the five youngest and best documented SKG: the Local Association (Pleiades moving group, 20 – 150 Myr), IC 2391 supercluster (35 Myr), Castor moving group (200 Myr), Ursa Major group (Sirius supercluster, 300 Myr), and Hyades supercluster (600 Myr). The properties of these SKG are summarized in Table 1. We list the name, possible open clusters associated to the group, range of age (Myr), the Galactic space-velocity components (U, V, W), total velocity (VT) and the coordinates (A, D) of the convergent point (C.P.). The velocity vector have been calculated by us using the spherical parameters and VT assigned to each group in the literature (Eggen 1958b, 1984c, 1991, 1992c). For the recently identified Castor MG the C.P. and VT have been derived by us from the space-velocity components given by (Barrado y Navascués 1998). In Fig. the we have plotted the position of these SKG in the (U, V) and (W, V) planes. The velocity components of the substructures found in these SKG by Asiain et al. (1999) using statistical methods and Chereul et al. (1999) using a 3-D wavelet analysis both in the density and velocity distributions are also plotted in Fig. Orlov et al. (1995) using a hierarchical clustering method have found several kinematic groups in the solar neighborhood which velocity components are close to the five young SKG we considered here. We have plotted the U, V, W components of these MG in Fig. for comparison.

3 SELECTION OF THE SAMPLE

The sample of late-type stars (spectral type later than F2) analysed in this work has been selected from previously established members of some of these SKG, based on the photometric and kinematic properties as well as from new candidates based on other criteria as their level of chromospheric and coronal activity, rotation rate, and lithium abundance, which are spectroscopic signatures of youth.

On the one hand the rotation rate in late-type stars moderates the dynamo mechanism which generates and amplifies the magnetic fields in the convection zone, but there is a further relationship between rotation and age. Rotation rates decline with age because stars lose angular momentum through the coupling of the magnetic field and stellar mass loss, and thus there is an indirect trend of decreasing magnetic activity with increasing age. On the other hand the resonance doublet of Li i at λ6708 Å is an important diagnostic of age in late-type stars since it is easy destroyed by thermonuclear reactions in the stellar interiors. Therefore, high level of magnetic activity, rapid rotation, and strong lithium absorption are spectroscopic signatures of youth, and the stars selected in this way are good candidates to be members of some of the young SKG we are analysing here.

The main sources from which we have selected this late-type star sample are:

- The membership lists given by Eggen in his four decades of research on SKG (Eggen 1958 to 1998), and additional lists given by Soderblom & Mayor (1993a).
- The study of Agekyan & Orlov (1984) and Orlov et
al. (1995) which searched for kinematic groups in the solar neighborhood (see also Popović, Ninković & Pavlović 1995).

- The study of ages of spotted late-type stars by Chugainov (1991).

- X-ray and EUV selected active stars and lithium-rich stars (Favata et al. 1993, 1995, 1998; Jeffries & Jewell 1993; Tagliaferri et al. 1994; Mullis & Bopp 1994; Jeffries 1995; Schachter et al. 1996; Hünsch, Schmitt & Voges 1998a, b; Hünsch et al. 1999; Cutispoto et al. 1999, 2000).

- Single rapidly rotating stars as AB Dor, PZ Tel, HD 197890, RE J1816+541, BD+22 4409 (LO Peg), HK Aqr, V838 Cen, V343 Nor, LQ Hya, previously assigned membership of the Local Association.

- Chromospherically active late-type dwarfs in the solar neighborhood with studied kinematic properties (Young, Sadjadi & Harlan 1987; Upgren 1988; Soderblom & Clements 1987; Soderblom 1990; Ambruster et al. 1998).

- Flare stars with studied kinematic properties (Poveda et al. 1996).

- The study of field M dwarfs with high resolution spectra by Delfosse et al. (1998), including the recently identified M9V star DENIS 1048-39 which is the closest star later than M7V (Delfosse et al. 2001).

- Other chromospherically active stars (Henry, Fekel & Hall 1995; Henry et al. 1996; Soderblom et al. 1998).

- Late-type stars included in the list of the nearest 100 Stellar Systems given by the Research Consortium on Nearby Stars (RECONS[†]).

- The study of nearby young solar analogs by Gaidos (1998) and Gaidos, Henry & Henry (2000).

- The sample of nearby, single, solar-type stars selected as proxies for the Sun at different stages in the project the “Sun in Time” by Bochanski et al. (2000).

- The study of nearby young x-ray active low-mass stars with well-measured parallaxes by Wichmann & Schmitt (2001).

- The active stars included in the the Vienna-KPNO search for Doppler-imaging candidate stars (Strassmeier et al. 2000).

For this selected sample we only analysed here single stars or effective single stars (wide visual binaries). The spectroscopic binaries are analysed in Paper II. We have considered only isolated stars, that is, we have excluded from the sample known members of open clusters, OB associations. However, we have included some members of other associations of young stars as TW Hya and the recently identified β Pic moving group (Barrado et al. 1999); Tucanae association (Zuckerman & Webb 2000); Horologium association (Torres et al. 2000); and HD 199143 stellar group (van den Ancker et al. 2000; van den Ancker, Prez & de Winter 2001), which could be stream stars related with the Local Association (see Montes 2001a, b; López-Santiago, et al. 2001).

Some pre-main sequence late-type stars (weak T Tauri stars (WTTS), and post T Tauri stars (PTTS) are also included in our sample as possible members of the youngest SKG, the Local Association. Oppenheimer et al. (1997) have identified two very young M dwarfs which also could be members of the Local Association. In the last years many WTTS, PTTS and young zero-age main sequence stars have been identified (using Li as an age criterion) with optical follow-up spectroscopy of ROSAT X-ray sources in and around nearby star-forming regions and OB associations. Some of these stars could be members of the Local Association as has been suggested by Martín & Magazzù (1999) and Frink (2001) or may represent a population of Gould Belt low-mass stars (Wichmann et al. 1999, 2000). We have not included these new identified young stars in our sample, because only a few have enough data (astrometric data and radial velocities) to analyse their kinematic, but they will be included in future work.

Our sample also includes some of the host stars of extrasolar planets discovered in the past few years by measuring their Keplerian Doppler shifts (up today more than 60, see Marcy, Cochran & Mayor 2000; Marcy & Butler 2000). These stars are nearby late-type stars with high precision radial velocity measurements. Although, many of them have ages greater than 3 Gyr as has been derived using evolutionary tracks (Fuhrmann, Pfeiffer & Bernkopf 1998; Ford, Rasio & Sills 1999) or Ca ii H & K fluxes (Henry et al. 2000), others are known to be younger and then could be possible members of some of the young SKG analysed here.

4 MEMBERSHIP TO THE MOVING GROUPS

4.1 Galactic space-velocity components

In order to determine the membership of this sample to the different SKG we have studied the distribution of stars in the velocity space by calculating the GALACTIC SPACE-VELOCITY COMPONENTS (U, V, W) in a right-handed coordinate system (positive in the directions of the Galactic center, Galactic rotation, and the North Galactic Pole, respectively). We have modified the procedures in Johnson & Soderblom (1987) to calculate U, V, W, and their associated errors. The original algorithm (which requires epoch 1950 coordinates) is adapted here to epoch J2000 coordinates in the International Celestial Reference System (ICRS) as described in the Introduction and Guide to the Data (section 1.5) of the "The Hipparcos and Tycho Catalogues" (ESA, 1997). The uncertainties of the velocity components have been obtained using the full covariance matrix in order to take into account the possible correlation between the astrometric parameters. We have used the correlation coefficients provided by Hipparcos. It should be noted that the differences, between the errors calculated in this way and the obtained considering the covariances are zero (as in Johnson & Soderblom 1987), are very small. These differences are largely lower than 0.1 km s$^{-1}$, only for a small number of star (8) the differences are between 0.2 and 0.5 km s$^{-1}$ and only in one case is 1.2 km s$^{-1}$.

For this selected sample we only analysed here single stars or effective single stars (wide visual binaries). The spectroscopic binaries are analysed in Paper II. We have considered only isolated stars, that is, we have excluded from the sample known members of open clusters, OB associations. However, we have included some members of other associations of young stars as TW Hya and the recently identified β Pic moving group (Barrado et al. 1999); Tucanae association (Zuckerman & Webb 2000); Horologium association (Torres et al. 2000); and HD 199143 stellar group (van den Ancker et al. 2000; van den Ancker, Prez & de Winter 2001), which could be stream stars related with the Local Association (see Montes 2001a, b; López-Santiago, et al. 2001).

Some pre-main sequence late-type stars (weak T Tauri stars (WTTS), and post T Tauri stars (PTTS) are also included in our sample as possible members of the youngest SKG, the Local Association. Oppenheimer et al. (1997) have identified two very young M dwarfs which also could be members of the Local Association. In the last years many

† RECONS: http://joy.chara.gsu.edu/RECONS/
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Figure 2. (U, V) and (W, V) planes as in Fig. 1 for our star sample. We plot with different symbols the stars belonging to the different stellar kinematic groups, and the other young disk stars. Filled symbols are stars that satisfied both Eggen’s criteria (peculiar velocity, PV, and radial velocity, \( \rho_c \)), open symbols are other possible members.

Radial velocities are taken primarily from the compilation WEB (Wilson Evans Batten) Catalogue (Duflot, Figon & Meyssonnier 1995), the Mean radial velocities catalog of galactic stars (Barbier-Brossat & Figon, 2000) which supplements the WEB Catalogue, the Catalogue of radial velocities of Nearby Stars (Tokovinin 1992), the Vienna-KPNO search for Doppler-imaging candidate stars, and from other references given in SIMBAD, and in the CNS3 Catalogue of Nearby Stars, Preliminary 3rd Version (Gliese & Jahreiß 1991) or the CNS3R (CNS3 Revised Version). For the stars for which we have taken high resolution echelle spectra (see Montes et al. 2001b, 2001d) we have used the radial velocities (marked with * in Tables 2 to 7) obtained by us by cross correlation with radial velocity standard stars of similar spectral types.

Our initial sample of more than 1000 stars was reduced to 638 stars with accurate parallaxes, proper motions, and radial velocities available in the literature to calculate the Galactic space-velocity components (U, V, W). As we are interested only in young MG we restrict this sample to the stars which U, V and W components follow the criterion from Leggett (1992) for young disk stars (\(-50 < U < 20; -30 < V < 0; -25 < W < 10\)) or more exactly to the stars with U and V velocity components inside or near the boundaries (dashed line in Fig. 1 and 2) that determine the young disk population as defined by Eggen (1984b, 1989, 1998a). We have found 535 stars that satisfied this restriction.

In Tables 2 to 7 we list the stellar and astrometric data we have compiled for the stars in each SKG. We give the name (HD, Henry Draper number; variable star name or other name; HIP, Hipparcos identifier; GJ, Gliese Catalogue number), spectral type, coordinates (ICRS J2000.0), radial velocity (\( V_r \)) and the error in km s\(^{-1}\), parallax (\( \pi \)) and the error in milli arc second (mas), proper motions \( \mu_\alpha \cos\delta \) and \( \mu_\delta \) and their errors in mas per year (mas/yr). The U, V, and W, calculated velocity components with their associated errors in km s\(^{-1}\) are also given in these Tables.

In Fig. 2 we represent the (U, V) and (W, V) planes for this restricted star sample. The distribution of the stars in this figure shows concentrations around the central (U, V, W) position corresponding to the five MG listed in Table 1. To start the classification, following Eggen’s membership criterion of constant V, we have considered as members only stars with small V dispersions. However, taking into account the results found by other authors (Skuljan et al. 1997, 1999) we have considered a large dispersion in the U, V components (\( \approx 8 \) km s\(^{-1}\)) with respect to the central position of the MG in the (U, V) plane to classify a star as a possible member. In addition, we have also taken into account the information provided by the W component, in the sense that stars considered as possible members for their position in the (U, V) plane are excluded if their W component deviates considerably (\( \approx 8 \) km s\(^{-1}\)) with respect to the W component of the MG. Following these we have classified the stars from our sample as members of one of the MG or as other young disk stars if their classification is not clear but it is inside or near the boundaries that determine the young disk population (see Tables 2 to 7). In Fig. 2 we plot with different symbols the stars belonging to the different SKG, and the other young disk stars. Filled symbols represent stars that,
in addition, satisfied the Eggen’s criteria described in the next two subsections.

4.2 Convergent Point

The members of a moving group can be established by the degree to which their motions define a common convergent point in the sky. However, this is not a sufficient membership criterion (there might be some stars moving in the same direction, but with a significantly different speed). Eggen’s criteria of membership (described in next subsection) take also into account the magnitude of the velocity vector.

We can apply the convergent point criterion to a moving group by plotting the great circles defined by the proper motions and positions of individual stars and analyse if their poles are close to the convergent point given in the literature for that moving group. We have applied this analysis to our sample of candidate members to the five moving groups studied in this paper (see Fig. 3 for the case of the Hyades). We have obtained, in general, a good agreement between the position of the poles and the convergent point. However, there are some stars with clear discrepancies, which are probably not members. These deviations with respect to the convergent point will be analysed in a more quantitative way by applying the Eggen’s criteria as is described in next subsection.

In this convergent point analysis (following other authors) we have not corrected for the Sun’s motion. It is possible that the Sun’s motion induces this effect so we need to prove that moving groups really converge towards a point independently of this effect. In fact, nearly all moving group’s convergent points are situated close to the apex or ant-apex. If we make this correction with each moving group we obtain that in the cases of the Hyades, Ursa Major, IC 2391 and Castor moving groups the trend of the candidate star members to have a common convergent point, is maintained. However, in the case of the Local Association the dispersion increases somewhat. It seems that the proper motion great circles tend to converge towards several points that are close together. This could indicate that the Local Association has several substructures or that is a concentration of different moving groups with similar space motions.

4.3 Eggen’s criteria

Eggen has developed several criteria during many years studying stars in moving groups (see Eggen 1958a, 1995b). These criteria are based on one supposition: it is possible to treat moving groups, whose stars are extended in space, like moving clusters, whose stars are concentrated in space. As in the moving cluster method it is assumed that the total space velocities of stars in a moving group are parallel and move towards a common convergent point. The Eggen’s criteria try to quantify how the space motion of the stars deviates from the convergent point and use the following parameters and relations:

- The components of the absolute proper motion ($\mu$) in the direction of the convergent point ($v$) and perpendicular to it ($\tau$).
- The angular distance between the star and the convergent point ($\lambda$).
- The trigonometric parallax ($\pi$)
- The relations between the tangential ($V_{\text{tan}}$), radial ($V_r$) and total ($V_{\text{Total}}$) velocities in the moving cluster method:
  
  \[
  V_{\text{tan}} = 4.74 \cdot \mu \cdot \pi^{-1}
  \]
  
  \[
  V_\tau = V_{\text{Total}} \cdot \sin \lambda; \quad V_r = V_{\text{Total}} \cdot \cos \lambda
  \]
V_{\text{Total}} = 4.74 \cdot \mu \cdot \pi^{-1} \cdot \sin^{-1} \lambda \\

The total velocity can also be calculated from the U, V, W components as:

V_{\text{Total}} = (U^2 + V^2 + W^2)^{1/2} \\

The two main Eggen's criteria are:

1) PECULIAR VELOCITY CRITERION

In the first papers Eggen used the ratio \((\tau/\upsilon)\) as a measure of how the star turns away from the convergent point, but later he defined a parameter he called Peculiar Velocity (PV) that is defined as a \(V_{\text{tan}}\) but taking into account only the proper motion component perpendicular to the C.P. \((\tau)\).

PV = 4.74 \cdot \tau \cdot \pi^{-1} \\

The criterion compares this peculiar velocity with another parameter he called total velocity \((V_T)\) obtained as a real \(V_{\text{Total}}\) but taking into account only the proper motion component in the direction of the C.P. \((\upsilon)\).

\[
V_T = 4.74 \cdot \upsilon \cdot \pi^{-1} \cdot \sin^{-1} \lambda
\]

The criterion considers a star as a possible member of a MG when its peculiar velocity \((PV)\) is less than about 10% of its total velocity \((V_T)\).

\[
PV < 0.1 \cdot V_T
\]

Taking into account the definition of \(PV\) and \(V_T\) this condition can also be written in terms of components \(\tau\) and \(\upsilon\) as

\[
\tau/\upsilon < 0.1 \cdot \sin^{-1} \lambda
\]

This criterion takes into account the information provided by the proper motion of the star but not the radial velocity.

2) RADIAL VELOCITY CRITERION

For the moving cluster method we can obtain a predicted radial velocity (called \(\rho_c\) by Eggen) as:

\[
\rho_c = V_T \cdot \cos \lambda
\]

The criterion is based in the comparison of this predicted radial velocity with the observed radial velocity of the star. Eggen considered a star as a possible member of a MG when these two velocities differ by less than 4–8 km s\(^{-1}\) depending on the quality of the observed radial velocity.

We have applied both criteria \((PV, \text{ and } \rho_c)\) to our candidate stars (for the five MG), in addition to the information provided by the galactic velocity components \((U, V, W)\) previous section, in order to apply more strict requirements for SC membership and to better discern their membership to the different MG. For the peculiar velocity criterion we have used the 10% of \(V_T\) for all the MG except for the Local Association where we have used 20% of \(V_T\), to take into account the large dispersion observed in this MG. For the radial velocity criterion we have taken into account the uncertainties of the adopted radial velocity of each star. In Tables 2 to 6 we list the total velocity \((V_{\text{Total}})\) and the parameters needed to apply the criteria \((PV, V_T, \text{ and } \rho_c)\). The results of applying the PV and \(\rho_c\) criteria are indicated in the column beside each parameter with the labels "Y" (if possible member) and "N" (if star does not satisfy that criterion). Errors from \(V_T\), PV and \(\rho_c\) are taking into account inside criteria. In the \((U, V)\) and \((W, V)\) diagrams (Fig. 2) we have plotted with filled symbols, the stars that satisfied both criteria.

5 DISCUSSION AND CONCLUSIONS

Making use of a great quantity of data from the literature (previous general kinematic studies of moving groups, many works on late-type stars, new results from X-ray surveys, etc.), the accurate astrometric data recently released by the Hipparcos and Tycho-2 catalogues, and additional data obtained for our own spectroscopic observations, we were able to identify a considerable population of single late-type stars (for binaries see Paper II) members of young \((20–600\text{ Myr})\) stellar kinematic groups. We have used as membership criteria the position of the stars in the velocity space \((U, V, W)\) and the Eggen’s kinematic criteria of deviation of the space motion of the star from the convergent point and comparison between the observed and calculated radial velocities. Additional criteria using age-dating methods for late-type stars \((\text{ lithium } \lambda 6708 \text{ Å absorption line, location on the color-magnitude diagram, and level of chromospheric and coronal activity})\) will be applied in the more detailed study of each SKG we have undertaken and will be addressed in forthcoming papers.

In this paper we give the list of possible members (see Tables 2 to 7), for each star we list the stellar parameters we have compiled, as well as the computed galactic space motions and the results of applying the kinematic criteria. These data are also available in tabular format and in search-able catalogue format in the web page http://www.ucm.es/info/astrof/skg.html that we maintain about stellar kinematic groups.

For our extensive initial sample of single late-type stars we have found a total of 535 stars that can be considered, for their position in the velocity space \((U, V, W)\) as young disk stars. We have classified 120 stars as possible members of the Local Association, 118 of the Hyades supercluster, 84 of the Ursa Major moving group, 53 of the IC 2391 supercluster, 34 of the Castor moving group, and 126 as other young disk stars (classification is not clear but it is inside or near the boundaries that determine the young disk population in the velocity space).

When we take into account the Eggen’s kinematic criteria, in the four MG where the convergent point is available, the number of possible members in each MG is reduced. Eliminating only the stars that do not satisfy one of the two criteria (peculiar velocity and radial velocity) we found 104 possible members of the Local Association, 96 of the Hyades, 69 of the Ursa Major, 43 of the IC 2391, and 29 of the Castor. Considering only the stars that satisfied the peculiar velocity criterion we found 77 in the Local Association, 67 in the Hyades, 37 in the Ursa Major, 28 in the IC 2391, and 10 of the Castor. Finally, imposing both criteria the number of possible members is reduced to 45 in the Local Association, 38 in the Hyades, 28 in the Ursa Major, 15 in the IC 2391, and 8 of the Castor.

Analyzing these results with the help of the great circles defined by the proper motions (see Fig. 2) we can see that almost all stars which do not satisfied the PV criterion move clearly away from the convergent point of the MG, specially those which do not satisfy radial velocity criteria either. In the velocity space \((U, V, W)\) the stars which satisfied both criteria tend to have lower dispersion with respect to the expected \((U, V, W)\) position of the MG (see Fig. 3), but there are some cases where this is not true. The latter are
normally stars with large errors in U, V, and W (due to large errors in radial velocity or in parallax).

Our results confirm the membership of several previously established members of SKG, but in other cases the new calculated Galactic space motions indicate the membership to a different SKG or that the star should be considered only as a young disk star with no clear membership to any SKG (e.g. LQ Hya). Even, in some cases, the new calculations located the star outside the boundaries of the young disk population in the Boettlinger Diagram.

For the late-type stars with planetary companions included in our sample we have found that some stars known to be young: GJ 3021 (Naef et al. 2000); τ Hor (Kürster et al. 2000); τ Boo (Henry et al. 2000); 55 Cnc (Fuhrmann et al. 1998); HD 108147 (Mayor et al. 2000), could be possible members of the Hyades supercluster. Some of these have been also identified by Suchkov & Schultz (2001) as stars with planetary systems with age similar to the Hyades.

The groups of nearby late-type stars with different ages we have identified in this work will be very useful for chromospheric activity studies. High resolution optical spectroscopic observations of these stars will provide a simultaneous analysis of the different optical chromospheric activity indicators as well as to obtain rotation speed, binarity, variability, and kinematics. With all this information it will be possible to study in detail the chromosphere, discriminating between the different structures: plages, prominences, flares and microflares (see Montes et al. 2000b, 2001b, 2001d) and analyse the flux-flux and rotation-activity relationships and their age evolution.

A further study of the list of stars compiled here as well as detailed analysis of the origin of these young SKG and their relation with nearby young open clusters, OB associations, T associations, and other recently identified associations of young stars could lead to a better understanding of the star formation history in the solar neighbourhood.

Another important usefulness of the list of late-type stars we give here is that the youngest ones (the possible members of the Local Association) can be taken as search targets for direct imaging detection of sub-stellar companions (brown dwarfs and extra-solar giant planets). These young and nearby cool dwarfs favor the optimization of the dynamical range and the sub-stellar companions can be detected directly because they are considerably more luminous when undergoing the initial phases of gravitational contraction than at later stages. Until now only five brown dwarfs have been detected directly (and confirmed by both spectroscopy and proper motion) as companions to nearby stars, the T dwarf Gl 229 B (Nakajima et al. 1995), the young L dwarf G 196-3 B (Rebolo et al. 1998), the T dwarf Gl 570 D (Burgasser et al. 2000), the M9 dwarf CoD-33° 7795 B (Neuhäuser et al. 2000b) which is a member of the TW Hya association, and the M8 dwarf HR 7329 B (Guenther et al. 2001) which is a member of the Tucanae association. The B component of the Ursa Major group member Gl 569 seem to be a triple brown dwarf system (Martín et al. 2000; Kenworthy et al. 2001). In addition, Neuhäuser et al. (2000a) have shown that direct imaging detection of extra-solar giant planets is already possible with current technology.

Radial velocity is an important parameter in the determination of the space velocity components, and in some cases only poor quality measurements are available in the literature, resulting in large errors in U, V, and W. Good quality spectroscopic observations are needed to confirm the membership of these stars to a SKG. We have already started a program of high resolution echelle spectroscopic observations (using 2m class telescopes) of these candidate stars in order to obtain a better determination of their radial velocity, as well as other stellar parameters. We will use these new data to better establish the membership of these stars (for preliminary results see Montes 2001b; Montes et al. 2001b, 2001d).

However, a considerable number of stars in our initial sample, are too faint and no radial velocities or accurate astrometric parameters are available in the literature. High resolution spectroscopic observations using 4 or 8m class telescopes will be needed to obtain the spectroscopic parameters of these stars. Accurate astrometric parameters for a huge number of stars will be available, in the future, with the space-astrometry missions DIVA (Double Interferometer for Visual Astrometry) and FAME (Full-sky Astrometric Mapping Explorer). The space mission GAIA (Global Astrometric Interferometer for Astrophysics) will have a much large reach in distance (magnitude limit 20) and will provide both astrometric data and radial velocities.

ACKNOWLEDGMENTS

This research has made use the of the SIMBAD database, operated at CDS, Strasbourg, France, and the ARI Database for Nearby Stars, Astronomisches Rechen-Institut, Heidelberg. We would like to thank Dr. D. Barrado y Navascués for provided us some additional candidates to our initial sample of late-type stars. We would also like to thank the anonymous referee for suggesting several improvements and helpful comments. This work was supported by the Universidad Complutense de Madrid and the Spanish Dirección General de Enseñanza Superior e Investigación Científica (DGESIC) under grant PB97-0259.

REFERENCES

Agekyan T.A., Orlov V.V., 1984, Astron. Zh., 61, 60, (SvA 28, 36)
Ambruster C.W., Brown A., Feke F.C., Harper G.H., Fabian D., Wood B., Guinan E.F., 1998, in ASP Conf. Ser. 154, The Tenth Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun, eds. R.A. Donahue, J.A. Bookbinder, CD-1205
Asiain R., Figueras F., Torra J., Chen B., 1999, A&A, 341, 427
Barrado y Navascués D., Stauffer J.R., Song I., Caillault J.P., 1999, A&A, 339, 831
Barrado y Navascués D., Stauffer J.R., Song I., Caillault J.P., 1999, ApJ, 520, L123
Bastian U., el al. 1993, Astronomisches Rechen-Institut, Heidelberg, Spektrum Akademischer Verlag, Heidelberg
Bochanski J.J., et al., 2000, AAS, 109, 16, 4607
Brown A.G.A., 2001, ASP Conf. Ser., in: Modes of Star Formation and the Origin of Field Populations, eds. E.K. Grebel, W. Brandner
Burgasser A.J., et al., 2000, ApJ, 531, L57
Chereul E., Crézé M., Bienaymé O., 1998, A&A, 340, 384
Chereul E., Crézé M., Bienaymé O., 1999, A&A, 345, 5
Chugainov P.F., 1991, in Angular Momentum Evolution of Young

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Rebolo R., Zapatero Osorio M.R., Madruga S., Bejar V.J.S., Arribas S., Licandro J., 1998, Science, 282, 1309
Röser S., Bastian U., 1991, Astronomisches Rechen-Institut, Heidelberg. Spektrum Akademischer Verlag, Heidelberg
Röser S., Bastian U., Kuzmin A., 1994, A&AS, 105, 301
Schachter J.F., Remillard R., Saar S.H., Favata F., Scuortino S., Barbera M., 1996, ApJ, 463, 747
Skuljan J., Cottrell P.L., Hearnshaw J.B., 1997, Proceedings of the ESA Symposium ‘Hipparcos - Venice ’97’, ESA SP-402, 525
Skuljan J., Hearnshaw J.B., Cottrell P.L., 1999, MNRAS, 308, 731
Soderblom D.R., Clemens S.D., 1987, AJ, 93, 920
Soderblom D.R., 1990, AJ, 100, 204
Soderblom D.R., Mayor M., 1993a, AJ, 105, 226
Soderblom D.R., Mayor M., 1993b, ApJ, 402, L5
Soderblom D.R., King J.R., Hanson R.B., Jones B.F., Fischer D., Stauffer J.R., Pinsonneault M.H., 1998, ApJ, 504, 192
Song I., Caillault J.P, Barrado y Navacués D., Stauffer J.R., Randich S., 2000, ApJ, 532, L41
Strassmeier K.G., Washuettl A., Granzer Th., Scheck M., Weber M., 2000, A&AS, 142, 275
Suchkov A.A., Schultz A., 2001, AAS, 197, 4901
Tagliaferri G., Cutispoto G., Pallavicini R., Randich S., Pasquini L., 1994, A&A, 285, 272
Taylor B.J., 2000, A&A, 362, 563
Tokovinin A.A., 1992, A&A, 256, 121
Torra J., Fernández D., Figueras F., 2000, A&A, 359, 82
Torres C.A.O., da Silva L., Quast G.R., de la Reza R., Jilinski E., 2000, AJ, 120, 1410
Upgren A.R., 1988, PASP, 100, 251
Urban S.E., Corbin T.E., Wycoff G.L., 1997, U.S. Naval Observatory, Washington D.C.
vanden Ancker M.E., Pérez M.R., de Winter D., McCollum B., 2000, A&A, 363, L25
vanden Ancker M.E., Pérez M.R., de Winter D., 2001, ASP Conf. Series, Proc. "Young Stars Near Earth: Progress and Prospects", eds. R. Jayawardhana & T. Greene
Wichmann R., Schmitt J.H.M.M., 2001, ASP Conf. Ser., 223, CD-552, in: The 11th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun, eds. R. García López, R. Rebolo, M.R. Zapatero Osorio
Wichmann R., Covino E., Alcalá J.M., Krautter J., Allain S., Hauschildt P.H., 1999, MNRAS, 307, 909
Wichmann R., et al., 2000, A&A, 359, 181
Young A., Sadjadi S., Harlan E., 1987, ApJ, 314, 272
Zuckerman B., Webb R.A., 2000, ApJ, 535, 959