Spectroscopic signatures of youth in low-mass kinematic candidates of young moving groups

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ABSTRACT

We present a study of age-related spectral signatures observed in 25 young low-mass objects that have previously determined as possible kinematic members of five young moving groups: the Local Association (Pleiades moving group, age=20 - 150 Myr), the Ursa Major group (Sirius supercluster, age=300 Myr), the Hyades supercluster (age=600 Myr), IC 2391 supercluster (age=35–55 Myr) and the Castor moving group (age=200 Myr). In this paper we characterize the spectral properties of observed high or low resolution spectra of our kinematic members by fitting theoretical spectral distributions. We study signatures of youth, such as lithium \( \text{Li}^+ \) 6708 Å, H\( \alpha \) emission and other age-sensitive spectroscopic signatures in order to confirm the kinematic memberships through age constraints. We find that 21 (84%) targets show spectroscopic signatures of youth in agreement with the age ranges of the moving group to which membership is implied. For two further objects, age-related constraints remain difficult to determine from our analysis. In addition, we confirm two moving group kinematic candidates as brown dwarfs.

Key words: stars: low-mass, brown dwarfs – stars: kinematics

1 INTRODUCTION

Identifying members of known moving groups (MG) or open clusters can provide an important constraint on their age and composition. Low-mass stars and brown dwarfs (BDs) members of known MGs or open clusters can provide important feedback to atmospheric and evolutionary models of such objects at young ages, which currently await good calibration from constraints on age and composition. Therefore, there exists an imperative to compile a sample of MG members in this mass range that can be used as anchor points or test-beds for these models.

In this paper we present the last in a series of results of a major survey of Ultra-Cool Dwarfs (UCDs; objects with a spectral classification of M7 or later corresponding to Teff<2500 K), in young moving groups which began with the results presented in Clarke et al. (2010), hereafter Paper I, and Gálvez-Ortiz et al. (2010), hereafter Paper II. We focus here on the study of age-sensitive spectroscopic signatures such as gravity sensitive features (e.g., Gorlova et al. 2003; McGovern et al. 2004), H\( \alpha \) emission (e.g., West et al. 2004, 2008, 2011) and the presence of Li 6708 Å in a sample of objects previously classified as members of a MG based on kinematic or astrometric criteria.

Despite the recent disagreement about the origin of moving groups (Famaey et al. 2007, 2008; Antoja et al. 2008;

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Klement et al. 2008; Francis & Anderson 2009; Zhao et al. 2009; López-Santiago et al. 2009; Bovy & Hogg 2010; Murgas et al. 2013), and as we discussed in Paper II, we are assuming the classical concept: a moving group is a young stellar population that shares a common space motion (e.g. Pinfield et al. 2006) whose members have a common origin, and therefore, age and composition. We focused our studies on well-documented groups: the Hyades supercluster (HY; 600 Myr), the Ursa Major group (Sirius supercluster) (Si; 300 Myr), IC 2391 supercluster (IC; 35-55 Myr), the Castor Moving Group (CA; 200 Myr), and the Local Association (20-150 Myr) or Pleiades (PL) moving group (See Paper I and II for details of MG properties and references thereof).

Many efforts have been made to obtain accurate models to understand the cool and complex atmospheres of low mass stellar and substellar objects (e.g. Kirkpatrick et al. 1993; Rajpurohit et al. 2011; Reyle et al. 2011; Rajpurohit et al. 2012). But the models still show discrepancies, for example in the strength of some absorption bands: discrepancies likely due to inaccurate atomic parameters and/or missing molecular opacities. Also, dust formation and its behaviour with temperature changes spectral characteristics in many ways. Models that describe Very Low-Mass stars (VLMS) and BD atmospheres cannot hope to be in agreement with observations without the inclusion of dust. The onset of iron and silicates dust grain formation suspended in the photospheres of late-type M dwarfs through the L dwarf spectral sub-types is accompanied by spectral reddening, especially below the photosphere, thus reducing the reddening. Consequently, atmospheric models that describe dwarf objects with $T_{\text{eff}} \leq 2800$ K should include treatment for the effects of atmospheric dust evolution.

Up to date, there are several families of stellar model atmospheres of very low mass stars. These models are still incomplete or approximate in some physical properties (opacities, oscillator strengths for some lines and molecular bands, etc.), showing few or considerable discrepancies depending on the atmospheric regions, temperatures, etc, and there are also non covered areas or "gaps". A comprehensive study of models tested by observations is needed to fully understand this cool atmospheres. Since BDs are objects occupying an intermediate position between stars and giant planets, studying their atmospheres can help us to better understand the processes in giant exo-planet atmospheres. The determination of the physical properties of VLMS and BDs is also important for understanding a broad range of topics including stellar and planetary formation, circumstellar disks, dust formation in cool atmospheres, and the initial mass function.

By comparing high and low resolution optical spectra of our 25 low-mass stars and BD kinematic MG candidates with a grid of atmospheric models, we can obtain effective temperature and surface gravity estimates.

In Section 2 we describe the sample characteristics and selection criteria, while in Section 3 we present details of our observations and data reduction techniques. In Section 4 we explain the model atmosphere fitting process, and in Section 5 we describe the age indicators and the analysis used to assess the sample memberships. Finally, in Section 6 we present a brief discussion and summary of our results.
2.2.1 UCD sample selection procedure:

- Photometry: Using an optimal set of optical/near-IR selection criteria for the $(J-H)/(J-K_s)$ two-colour plane along with optical/near-IR colours of $(B_J-K_s)$, $(R_c-K_s)$, $(I_c-K_s)$ and the optical colour of $(R-I)_c$ with $JHK_s$ from 2MASS, we obtained a sample of objects in the spectral range of $\sim$M8V to $\sim$L9. The selection method also included an $R_F$ and $I_X$ photometric surface gravity test with additional photometric constraints. See Figures 1, 2 and 3, and Section 2 of Folkes et al. (2012) for details.

- Astrometry: To eliminate bright distant contaminants, which one would expect to display small proper motions, a reduced proper-motion diagram was used to segregate giant stars (e.g. Luyten 1978). In this case we used a diagram of reduced proper motion in 2MASS $K_s$-band plotted against $(V-K_s)$ colour. See Fig. 6 and Section 2.5 of Folkes et al. (2012) for details.

2.2.2 MG Selection procedure:

To find possible MG members from this UCD sample, Folkes (2009) applied the astrometric and photometric test described in Sections 3.2 and 3.3 of Paper I (used in the selection process of sample A.) Spectral Types and photometric distances were derived from the $(I-J)$ colour using the $M_I/(Ic-J)$, and $M_J$/SpT relations of Dahn et al. (2002).

From these photometric and astrometric criteria Folkes (2009) identified 23 objects, with spectral types ranging from M3 to L0 as possible moving group members, from which we could observe 12 that form sample B.

Here we obtain spectral classification and confirm (or otherwise) the youth of these candidates, through low resolution spectroscopy and by studying age-sensitive spectral features. In Table 2 we give the name, coordinates, 2MASS $J$ magnitude and the MG candidature assignation.

2.2.3 Spectral type determination:

To improve the previous photometric spectral type determination from Folkes (2009), we calculated a variety of different spectroscopic indices: PC3, TiO1+TiO2 and VO1+VO2 from Martín et al. (1999); The VO index from Kirpatrick et al. (1995); VO-a and TiO5 from Cruz & Reid (2002). Since the TiO1+TiO2 and VO1+VO2 indices can imply two different spectral types (see Fig. 9 of Martín et al. 1999), we only considered them if they were consistent with the spectral types obtained by the other indices. From these a mean spectral type was calculated.

Some objects show considerable discrepancies between spectral type derived from photometry and that from spectroscopic indices. That is, with the exception of two objects (2MASS1756-4518 and 2MASS1909-1126 that has $S/N$ of $\approx$15) and $\approx$200 for both runs of IMACS data.

Figure 1 shows high resolution spectra of sample A on the left and low resolution spectra of sample B on the right, ordered by spectral type classification. Well studied late-type objects with known spectral type were observed at the same time as the targets to be used as reference (M9 LP944-20; M4 GL876; and M6 GL 406) and are also included in the figure for comparison.

3 OBSERVATIONS

For this paper we analysed optical high resolution echelle spectra of 13 objects (sample A; Table 1) and low resolution long slit spectra of 12 objects (sample B; Table 2). The data were obtained during four observing runs detailed in Table 3.

Both sets of high and low resolution spectra were extracted using the standard reduction procedures in the IRAF1, TWDOSPECF and ECHELLE packages respectively: bias subtraction, flat-field division, extraction of the spectra, telluric correction as well as wavelength and flux calibration. We obtained the solution for the wavelength calibration by taking spectra of a Th-Ar lamp. The average signal-to-noise ($S/N$ of the data, measured as the square root of the signal at $\approx$6100 Å, is $\approx$30 for UVES data (except for 2MASS2039-1126 that has $S/N$ of $\approx$15) and $\approx$200 for both runs of IMACS data.

Figure 1 shows high resolution spectra of sample A on the left and low resolution spectra of sample B on the right, ordered by spectral type classification. Well studied late-type objects with known spectral type were observed at the same time as the targets to be used as reference (M9 LP944-20; M4 GL876; and M6 GL 406) and are also included in the figure for comparison.

4 ATMOSPHERIC MODELS AND SYNTHETIC SPECTRA

To determine spectral characteristics of the targets ($T_{\text{eff}}$, $\log g$, etc), to aid us in age determination, we compared a grid of generated synthetic spectra with the observations.

According to current concepts, dust plays an important role in the formation of late M dwarf spectra (Tsuji et al. 1996; Hauschildt & Allard 1992). Although there is no unified opinion about temperature range where dust should be considered, the temperatures of transition between dust-free and dusty models range from $T_{\text{eff}}<2600$ (Allard et al. 2011) to $T_{\text{eff}}<3000$ K (Jones & Tsuji 1997).

Therefore, synthetic spectra were computed for dust-free NextGen atmospheric models and for semi-empirical models (i.e. modified NextGen models) in the wavelength range 6500-9000 Å. The “dust effects” are included in semi-empirical models for M3-M8 stars. Synthetic spectra based on DUSTY, COND and corresponding semi-empirical models were calculated for M7-L0 stars.

4.1 Synthetic spectra based on NextGen models

Synthetic spectra were computed for NextGen atmospheric models (Hauschildt & Allard 1992) by the WITAt program (Pavlenko et al. 1997; 2007a). The calculations were therefore suggesting later spectral types. We used the spectral types derived from spectroscopy for all calculations.

1 IRAF is distributed by the National Optical Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.
made under the assumption of local thermodynamic equilibrium (LTE), hydro-static equilibrium, in the absence of sources and sinks of energy, for a one-dimensional model atmosphere. We used the atomic line list from the VALD database (Kupka et al. 1999) and the line list of titanium oxide (TiO) from Plez (1998) to produce the synthetic spectra. Vanadium oxide (VO) band opacities were computed in the framework of the JOLA approximation (see Lyubchik & Pavlenko 2000). Synthetic spectra were calculated for a grid of models having $T_{\text{eff}}=2600$–$3400$ K with 100 K step, surface gravities of $\log g=4.0$–$5.5$ with 0.5 step and metallicities of $[M/H]=0.0$, $-0.5$ and $-1.0$ dex. Solar abundances were taken from Anders & Grevesse (1989). The artificial rotational-broadening of spectral lines was implemented following the methodology of Gray (2005) using the rotational velocity of the objects obtained in Paper II. We carried out a few numerical experiments to investigate the effect of micro-turbulence velocity of the objects obtained in Paper II. We carried out a few numerical experiments to investigate the effect of micro-turbulence velocity on the spectra. The study shows that the differences in synthetic spectra associated with $v_t$ in the 1.0–5.0 km s$^{-1}$ range are negligible. Thus all theoretical spectra were computed for a microturbulence velocity $v_t = 3.0$ km s$^{-1}$.

4.2 Semi-empirical atmospheric models

We used the semi-empirical atmospheric models described in Pavlenko et al. (2007a) to include the effects of dust formation. The semi-empirical models were obtained by modifying NextGen, DUSTY and COND models.

The dust opacity originates in the shell-like structures lying above the photosphere (Pavlenko et al. 2007a) and we expect the influence of dust in a spectrum to be more prevalent in the shortest wavelength spectral region. We assumed that dust clouds are located in the upper most layers of stellar atmosphere and do not affect the distribution of temperatures and pressures. Dusty effects were treated in two ways: (1) decreasing molecular abundance in the gas due to molecular condensation of dust particles and (2) radiation scattering in the dust clouds. The decrease in the concentration of TiO and VO molecules was modelled by two parameters: (1) the number of layers in the above model for which there is no absorption of TiO (i.e., all titanium oxide condenses on dust particles) and (2) the coefficient of TiO molecular density reduction for all other model layers. Radiation scattering in the dust clouds was also modelled by two parameters: 1) the optical thickness of the dust cloud and 2) the location of maximum opacity as a result of these clouds. This method is described in Pavlenko et al. (2007a) and Kuznetsov et al. (2012).

The theoretical spectra were computed using a semi-empirical atmospheric model for a grid with effective temperatures of $T_{\text{eff}}=2600$–$3000$ K (based on NexGen models) and $T_{\text{eff}}=2000$–$2800$ K (based on DUSTY and COND models) with a step of 100 K, surface gravities of $\log g=4.0$–$5.5$ with a step of 0.5, and solar (Anders & Grevesse 1989) metallicity. These models were calculated for the same rotational and microturbulence velocity as for the NextGen models. We are thus able to compare the observed high and low resolution spectra with synthetic spectra assuming both the presence and the absence of dust.

4.3 Selection of best fit parameters. Objects with M4–M8 spectral type

The S-function analysis described in Pavlenko et al. (2007a) was used to determine the best fit for each grid of the model independently,

$$S = \sum (f_h \times H_{\text{syn}} - H_{\text{obs}})^2$$

where $f_h$ is a normalization parameter, $H_{\text{syn}}$ is the synthetic flux and $H_{\text{obs}}$ is the observed flux. The minimum value of $S$-function corresponds to the best fit.

The $S$-function is integrated in the 6900–7200 Å, 8100–8400 Å and 7660.8–7734 Å, 8160–8220 Å wavelength ranges for low and high resolution spectra respectively. The use of these regions allowed us to analyze the TiO band at $\sim$7100 Å and Na i (8183 Å, 8199 Å) doublet in low resolution spectra, the K i (7665 and 7669 Å) resonance doublet and Na i (8183 Å, 8199 Å) subordinate doublet in high resolution spectra. Analysis of Na i and K i lines is significant because their profile is sensitive to $T_{\text{eff}}$ and $\log g$. The VO ($\sim$7400 Å, $\sim$7800 Å) bands were excluded from the fitting procedure since we do not have a satisfactory line list for this molecule.

We carried out fits of the observed spectra for two model grids, original NextGen and semi-empirical, for M4–M8 objects. Figures 2 and 3 show example fits for the red part of the spectra in sample A, and the complete spectra in sample B. Figures 4 and 5 show examples of the fitting of the atmospheric models, magnified around the Na i $\sim$8190 Å and K i $\sim$7700 Å doublet area for sample A. The minimum value of $S$-function for each target with M4–M8 spectral type is shown in Tables 4, 5, 6 and 7.

4.4 Analysis of objects of M8.5–M9.5 spectral type

The atmospheric structure of objects of M8.5–M9.5 spectral type differs greatly from early M dwarfs. The dust has a significant impact on the distribution of temperature vs. pressure in these atmospheres. Thus, it is incorrect to use the NextGen model for objects with temperatures $T_{\text{eff}} < 2500$ K. We used the DUSTY and COND (Allard et al. 2001) atmospheric models for the study of the late M dwarfs’ synthetic spectra. The DUSTY and COND models were modified in an identical way to the model improvements for early M dwarfs: we introduced additional scattering of radiation by dust clouds and reduced the abundance of the molecules TiO and VO.

As with earlier spectral types, we utilised fits to the TiO and VO absorption bands and the K i and Na i doublets, to determine the stellar fundamental parameters. In weakly ionized atmospheres at $T_{\text{eff}} < 3000$ K the natural broadening is several orders of magnitude weaker than pressure and Stark broadening, and can thus be neglected. The broadening of K i and Na i resonance lines is dominated by pressure effects, but the theory of this is not particularly advanced. Pressure broadening is calculated using two methods: a collisional approximation (van der Waals theory) and quasi-static theory (see Burrows & Volobuyev 2003; Allard et al. 2003). The use of a collision approximation allows us to describe the profiles of metal lines in early M dwarfs. The quasi-static theory is used in the study of L dwarfs.
where energy levels of atomic sodium or potassium are immersed in a sea of molecular hydrogen and are subsequently perturbed by the potential field of the diatomic hydrogen. The modelling of atomic-line broadening for objects that are close to the transition between M and L spectral classes is complicated and this issue is beyond this paper aims. Since in our case we could see only the core of the lines and do not see extended wings, our fits should be sufficient without including any broadening.

Physical properties were derived for objects with M8.5-M9.5 spectral types based on the fitting of high or low resolution spectra and synthetic spectra calculated for COND and DUSTY models. In addition S-function analysis provided the best fits. Since in sample B there are some objects classified as M8, we applied fits with the synthetic spectra (NextGen, DUSTY and COND) as well as with appropriate semi-empirical models, to provide the transition between the NextGen and the DUSTY/COND models. Results of these fits are shown in Tables 6, 7, 8, and 9.

LP944-20: LP944-20 is a known BD of spectral type M9 and we used it as a test for the atmospheric fits as well as to benchmark the age constraints described in following sections. Several authors have studied this object in detail to determine its characteristics. Tinney (1998) estimated an age between 475 and 650 Myr by evolutionary tracks, while Ribas (2003) determined LP944-20 as a kinematic member of the Castor moving group and therefore estimated an age of 320±80 Myr. Pavlenko et al. (2007a) used semi-empirical atmospheric models to determine the parameters of LP944-20 including lithium abundance, of which the best fit gave log N(Li)=3.25 ± 0.25, and found a similar age to the one obtained by Ribas (2003).

According to previous studies the effective temperature of LP944-20 is in the range 2040 ≤ T eff ≤ 2400 K (see Basri et al. 2000; Dahn et al. 2002; Pavlenko et al. 2007a). The best fit obtained here, with the DUSTY model, provides T eff=2400 K and log g = 4.0 (see Table 8). The log g obtained by Pavlenko et al. (2007a) was 4.5, with temperatures of 2000-2200 K using COND models. They remarked that temperatures in the outermost layers of the DUSTY models were higher in comparison to the COND models. This difference is consistent within the uncertainties.

5 AGE CHARACTERISTIC

Sample A is formed of objects that are already confirmed as kinematic candidates of MGs. Since kinematics is not sufficient to confirm membership, determination of a candidate’s age can further constrain its group membership to a point of robustness or dismiss it as an old field target that shares kinematics with a young MG. For our candidates, age in some cases can also discriminate between multiple MG candidates. Sample B is formed of astrometric candidates and so further study should be applied to confirm any membership. This can be achieved by: 1) using gravity sensitive spectroscopic features to distinguish between young and old ultracool dwarfs, 2) using the activity/age relation for late-type stars up to a spectral type of M7 (Mochnacki et al. 2002; Silvestri et al. 2006; Reiners & Basri 2008; Jenkins et al. 2009), 3) measuring the lithium 6708 Å doublet (e.g. Rebolo et al. 1996; Pavlenko et al. 2007a) as the abundance of lithium is related to mass and age for substellar objects and 4) determining v sin i to differentiate between young and older M types.

Figure 9 of Paper I shows a plot of evolution-time (based upon potential group membership) versus spectral type for...
the complete sample of candidates. The figure, reproduced and updated here as Fig. 11 illustrates how an object would be selected for various methods of age constraining follow-up mentioned. Candidates that appear to the right of the lithium edge can be followed up with a lithium test programme. Objects that appear younger than 200 Myr, are eligible for follow-up using spectroscopic gravity sensitive features. Candidates that fall to the left of the spectral type M7, would thus be suitable for age/activity relation follow-up, although candidates with a spectral type close to M7 may be subject to large uncertainties on their age. Some candidates cannot be tested by any of these methods but will be eligible for age testing using \( v \sin i \).

In Paper II we presented a \( v \sin i \) study (for sample A) where we applied this criterion of youth based on Figures 9 and 10 of Reiners & Basri (2008) to support group membership (see Paper II). We study here the rest of the age-constraining features.

### 5.1 Surface gravity features

The radius of young UCDs can be as much as 3 times greater than their eventual equilibrium state (Burrows et al. 2001), and as a result young objects can exhibit significantly lower surface gravities (10-100 times) than their evolved counterparts with the same spectral type. Low-resolution (e.g. R\(\sim\)350-2000) studies in the optical (Martin et al. 2010; Martin et al. 1996; Luhrman et al. 1997) and infrared (Jones et al. 1996; Gorlova et al. 2004; McGovern et al. 2004) have demonstrated that numerous features (e.g. CaH, K i, Na i, VO, etc) can be used as gravity-sensitive (and thus age sensitive) diagnostics for young objects. Diagnostics should be sensitive to gravity and age for objects that are younger than \( \sim 200 \) Myrs (e.g. Barrado y Navascués 2006). Schlieder et al. (2012) presented a study of the Na i doublet equivalent width in giants, old dwarfs, young dwarfs, and candidate members of the \( \beta \) Pic moving group using medium resolution spectra. They concluded that the diagnostic is reliable for objects with spectral types later than M4 and younger than 100 Myr, and that metallicity has an important role. Therefore, this youth indicator is best used on samples with similar metallicity. Thus, we aimed to apply this test by determining the surface gravity of the younger MG candidates, although we took into account all candidates up to 200 Myr.

As mentioned before, the main atomic gravity-sensitive features present in our spectra are: the K i resonance doublet (7665 and 7669 Å) and the Na i subordinate doublet (8183 and 8190 Å). We fitted the spectra of the candidates with a synthetic model (see Section 4) to determine the log \( g \) of both samples A and B (Table 4). Figures 1 and 2 show some examples of atmospheric model fitting magnified on the aforementioned features for sample A.

We performed two approaches in the surface gravity studies: inferring age-limits from 1) the surface gravity obtained from the best fit synthetic models and 2) comparison of the equivalent width of gravity-sensitive Na i doublet.

#### 5.1.1 Values of log \( g \) from synthetic model fits

As mentioned above, surface gravity features can be studied to discriminate if an object is young or old, but it is not easy to associate a log \( g \) value to an age interval, that is, to have an absolute log \( g \)-age relation. Many parameters affect the derived log \( g \): atmospheric model used, resolution and instrument. Therefore, we observed LP944-20, with known age and previously fitted by different models, to set the range of log \( g \)-age interval for our observations and as a test object for our method of late M dwarf investigation.

Taking into account the association to the Castor MG and the age based on the presence of lithium, we used our log \( g \) for LP944-20 as a reference and compared it to the log \( g \) of the candidates. From this, we assume that an object with spectral type and log \( g \) similar to LP944-20 is probably of similar age. Models from the literature (e.g., NextGen, DUSTY, COND), associate similar or lower ages with warmer objects with the same log \( g \) than to those that are cooler. For example, selecting log \( g \) in the 4.0-4.5 range in DUSTY and COND models, an object with T\(_{\text{eff}}\) = 2400 K intersects 8-30 Myr age isochrones, whilst objects with T\(_{\text{eff}}\) \( \geq \) 2400 K intersect isochrones over 40 Myrs. Both the DUSTY and COND models present ambiguities for 30 Myr isochrones. The COND model presents similar problems for \( \geq 40 \) Myr isochrones, but fortunately in this case with temperature ranges far from that of our targets. Therefore, we can assume that objects warmer than LP944-20 would have, in general, ages \( \leq 200-300 \) Myr should they have log \( g \) = 4.0.

Since LP944-20 is only a single object, in order to constraint this log \( g \)-age relation, we also used the GL 876 field target, observed with the candidate A sample. This allows us to compare our target log \( g \) values with those of old and intermediate age targets.

We fit them in the same way as our candidates and results of the best fit are given in Table 3 and 7.

As mentioned in Section 4.4, LP944-20 is a known member of the Castor MG (age\(\sim\)200 Myrs) and Pavlenko et al. (2007a) obtained an age of \( \sim 300 \) Myr through lithium depletion. Applying the atmospheric model method described in Section 4, we obtained a log \( g \) of 4.0\(\pm 0.5 \).

GL 876 is an M4 dwarf. It is known as an exoplanet host of four planets. Literature provides few age calculations, such as 1-10 Gyr from Marcy et al. (1998), >1 Gyr from Shankland et al. (2006) and 0.5-1 Gyr from Correia et al. (2010). Despite the variations it is clearly an old object that should show a high value of gravity. We find that the NextGen model best fit provides a log \( g \) of 5.5\(\pm 0.5 \).

To set the age-gravity relation for our sample, we used these results as a basis. Log \( g \) obtained values of the candidates are 4.0, 4.5, 5.0, and 5.5, where we can state that objects with \( g \approx 4 \) are young and still in contraction and that objects with \( g = 5.5 \) are old. With a 0.5 uncertainty, an object with log \( g \) of 4.5 (4.0-5.0) shows ambiguity when discriminating between young and old.

Accepting the limitations and the uncertainty in the constraints, spectral type and metallicity dependence, etc, for the atmospheric fits to our sample, objects with log \( g \approx 4 \) are probably young (under \( \sim 200 \) Myrs), objects with log \( g \approx 4.5 \) are older but possibly still in contraction (\( \sim 300 \) Myrs), and therefore objects with log \( g \approx 5.0 \) and log \( g \approx 5.5 \) are probably older than 300 Myrs.

The log \( g \) obtained with model comparison are given in columns 5 and 9 of Table 3 and 7, columns 6 and 10 of Table 4 and 8, and columns 5, 8 and 11 of Table 6 and 7.
5.1.2 Na i equivalent width (EW) comparison

Additionally, we checked if \( EW(\text{Na i}) \) measurements can be used to determine youth, based on Martín et al. (2010) and Schlieder et al. (2012).

Given the cool nature of the targets, the measurement of equivalent widths in the optical are generally measured relative to the observed local pseudo-continuum formed by molecular absorptions (mainly TiO), and therefore the \( EW \)'s are \( "\text{pseudo-equivalent widths}" \) (Pavlenko 1997; Zapatero Osorio et al. 2002). However, we will call them \( EW \) for simplicity hereafter.

Although there is a considerable scatter in the data (mainly from the use of different instruments) Martín et al. (2010) Figure 3 plots \( Na i \) \( EW \) versus spectral class for a few field objects and members or candidates of the Upper Scorpii OB association. To measure consistent equivalent widths in spectra of different resolutions, they established as a rule that the pseudo-continuum region was between 823 nm and 827 nm, and integrated the line from 817.5 nm to 821.0 nm. Their figure shows a clear trend, and they inferred that objects with the weakest \( Na i \) are likely to have low surface gravity. They established as a rule of thumb that any object with spectral class between M6 and L4 and with a \( Na i \) doublet detectable but weaker than field counterparts observed with the same spectral resolution, is likely to have a low surface gravity and consequently a very young age (i.e., younger than 100 Myr) and substellar mass. Sample B have similar resolution to the Martín et al. (2010) data. As such we measured the combined equivalent widths of the two lines of the \( Na i \) doublet in the same manner (given in Table 10) allowing direct comparison. In the case of sample A, we convolved the spectra to the same resolution and then measured \( EW(\text{Na i}) \). The left panel of Figure 7 presents equivalent widths of the \( Na i \) doublet versus spectral type for all targets of sample A as blue crosses, and B as red filled circles, with the Martín et al. (2010) data: 65 high-gravity field objects are plotted as six pointed asterisks, 6 low-gravity objects as open triangles, 12 reference field stars as open circles and 7 Upper Sco candidates as solid hexagons.

While the metallicities of all MGs are similar to solar, the Upper Sco cluster does not yet have a robust metallicity determination, and other objects in Martín et al. (2010) have different metallicities. We took the information from \( EW(\text{Na i}) \) studies in Schlieder et al. (2012) into account when compare samples A and B with Martín et al. (2010).

For sample A, if we look into moving group candidatures (thus age) and \( EWs(\text{Na i}) \), they are inconsistent (Table 10 column 2). That is to say that some young MG candidates present a higher \( EW(\text{Na i}) \) than others which have candidature to older MGs. But if we take into account the final MG membership given in table 11 of Table 10, most of sample A targets are finally classified as candidates to MGs with ages \( \gtrsim 200 \) Myr (except one, SIPS2039-1126), and therefore the \( EW(\text{Na i}) \) become consistent (see Figure 7 right panel). SIPS0007-2458 and 2MASS0334-2130, both candidates to IC2391 present values of \( EW(\text{Na i}) \) too high for IC2391 age. Since we obtained \( EW(\text{Na i}) = 6.5 \) for LP944-20, the value of \( EW(\text{Na i}) = 7.3 \) for SIPS2039-1126 is comparatively high for its Pleiades membership. Convolution might have introduced additional noise affecting the comparison and we discuss further this target in Section 5.3.

For sample B, if we look into moving group candidatures and \( EWs(\text{Na i}) \) (Table 10 column 2), they are consistent. That is in general, target candidates to IC2391 and the Pleiades show the lowest \( EW \)'s, candidates to Castor and Sirius show higher, intermediate \( EW \) values and candidates to Hyades show the highest values of \( EW \) (Figure 7 right panel). The two targets showing low values of \( EWs(\text{Na i}) \) are 2MASS1326-5022, candidate to IC 2391 and 2MASS1557-4350, candidate to Pleiades and IC 2391. The rest of the candidates show higher values in agreement with their MG candidatures except for 2MASS1734-1151, M9 candidate to Pleiades but showing larger values of \( EWs(\text{Na i}) \) than LP944-20.

5.2 Activity vs. age relation

Subsequent studies by Skumanich (1972) show that activity decreases over time for late-type stars. However, after a spectral type of \( \approx M3-4 \), stars become fully convective and the activity is driven by a turbulent dynamo in a mechanism that is still not clear. Many studies have found evidence that the age-activity relation extends into the M dwarf regime (see e.g., Silvestri et al. 2006; Mochnacki et al. 2002; Mohanty & Basri 2003; Reiners & Basri 2008). Recently, some authors (Berger et al. 2008; West et al. 2008) have shown that the fraction of active M0-M7 stars decreases with the vertical distance from the Galactic plane, further evidence of an age-activity relation. Comparing activity data to dynamical simulations, West et al. (2008) derive an “activity life-time” relation for M dwarfs of spectral type M0-M7 in the range 0.4-8 Gyr. Following this, we can identify older non-MG UCDS in our sample through lack of chromospheric emission.

Comparing activity levels of our sample with activity levels of objects of the same spectral type and with known age, we can infer age ranges for our targets that would help us to confirm (or otherwise) their MG membership in the same way of other literature examples such as Stauffer et al. (1995; Fig. 13), Stauffer et al. (1997; Fig. 8), Terndrup et al. (2000 ; Fig. 9), Barrado y Navascués et al. (2004; Fig. 5), Shkolnik et al. (2009; Fig. 13).

Although there are several chromospheric activity indicators (Ca II H & K, Balmer lines, Ca II infrared), we used the Hα emission since it is included in the spectra presented here (with the exception of the SIPS2039-1126 spectrum). Young M dwarfs generally have Hα in emission, with the average equivalent width increasing to later spectral types (e.g. West et al. 2004). Generally the level of chromospheric activity is measured by comparison of the diagnostic line’s flux, but for M dwarfs equivalent width is also used. We derived Hα pseudo-equivalent widths by direct integration of the line profile using the \texttt{splot} task in IRAF, however, we will utilise them as \( EWs \).

Taking into account that \( EW(H\alpha) \) will reflect any activity variability, often present in young objects, and that moving groups with different ages will show different activity saturation levels as well as a higher dispersion in the level of activity when they are older (see e.g. Stauffer et al. 1997, Pizzolato et al. 2003; Ryan et al. 2005; López-Santiago 2005; Martínez-Arnau et al. 2011), we compared the \( EW(H\alpha) \) versus spectral type of our candidates with objects of known age (obtained from other methods).
We compiled a sample of M dwarfs with known age and $EW(H\alpha)$ from the literature. These were taken from Hyades and Pleiades members in Terndrup et al. (2000), young and old disk and field stars in Mohanty & Basri (2003) and from a compilation of targets with ages determined by different methods in Shkolnik et al. (2009). When using targets with MG or cluster memberships, we assigned them the age of the cluster. From Mohanty & Basri (2003), we assigned an averaged value of 500 Myr to YD, 600 Myr to YO (old-young), 1 Gyr for OD and more than 1200 Myr for Halo targets.

The $EW(H\alpha)$ of our objects is given in column 3 of Table 10. Figure 8 left panel presents $EW(H\alpha)$ versus spectral type for our candidates, with blue crosses and red filled circles for sample A and B respectively, in comparison with data from the literature.

In the right panel of Figure 8 only three ranges of ages are plotted to better discriminate the possible age interval of our samples. Sample A targets are plotted as filled squares and sample B as filled triangles, where targets classified with ages $>300$ Myr are plotted in blue and targets with ages $<300$ Myr are plotted in red.

Although theoretically equal, equivalent widths measured in lower resolution spectra can be slightly larger than measured in higher resolution spectra (due to line blending), and pseudo-equivalent width measurements show variation with resolution, therefore there is a possibility that variability effects are seen in our observations. Taking into consideration that only one data point is available for each of our candidates (and therefore variability can not be determined), that older MG members can present higher scatter, and that for sample B, values of $EW(H\alpha)$ have been measured at low-resolution, we have determined a rough age interval for 18 of the candidates (we have included targets in the limiting spectral type M7 and M7.5).

We have assumed that the candidates are single objects. Any stellar or substellar companion would probably increase the activity levels making the targets look younger when we measure $EW(H\alpha)$ (e.g. Basri et al. 1995; Ruten 1987; Schrijver & Zwaan 1991; Gálvez-Ortiz 2005).

All targets in sample A and B with spectral types under M7.5, have $EW(H\alpha)$ values inside the limits of an age that agree with at least one of their MG candidature (see columns 3 and 4 of Table 10 and Figure 8).

It should be noted that the SIPS2039-1126 spectrum does not include the H$_\alpha$ region, thus the activity criterion has not been used in this case.

5.3 Lithium

The Li i doublet at 6708 Å is an important diagnostic of age in young late-type stars. Lithium is destroyed in fully convective low-mass objects, with mass from 0.3-0.06 $M_\odot$ (e.g. Rebolo et al. 1996) as all acquire core temperatures $>2 \times 10^6$ K as they heat up during early contraction. Convective zones that accommodate lithium abundance reflects core lithium content, and the observable lithium doublet thus acts as a gauge for the core temperature and contraction age. The so-called "lithium edge" that separates objects with lithium from those without, can be seen in co-evolved populations (e.g. in open clusters and moving groups), through the spectral type (or mass). The lithium edge advances towards later spectral type as a population ages (see Fig. 9 and caption of Paper I), and the presence or absence of lithium thus provides a critical age constraint as a function of an object’s spectral type.

Due to the low resolution and the presence of artifacts in the Li i spectral region for sample B, we searched for the Li i doublet only in sample A candidates. The Li i region in the sample A spectra show S/N values of no more than 10 in all the 12 candidates which hampers the search for the absorption line. We found the Li i absorption line in SIPS2045-6332 and SIPS2039-1126 only, but we do not discard the possibility of other fainter candidates with no signal in this region, presenting some absorption when better spectra can be achieved. We also measured Li i in LP944-20 with the parameters found here, obtaining log N(Li) = 3.00 $\pm$ 0.5 dex, using synthetic spectra with $T_{\text{eff}} = 2400$ K, $log g = 4.0$, DUSTY atmosphere structure and a rotational velocity of 35 km s$^{-1}$ (measured by us). This is within the uncertainties of other literature findings (see Section 4.4.1).

Clarke (2010) found the lithium signature in SIPS2045-6332 and SIPS2039-1126 suggesting youth and a BD nature inside the MG membership. Here, we obtained the theoretical Li i pseudo-equivalent widths, relative to the computed pseudo-continuum formed by molecular absorption, via direct integration of the line profile over the spectral interval 6703.0-6710.8 Å. Figure 9 shows the Li i area for SIPS2045-6332 and SIPS2039-1126 with their respective fits. Li abundance of log N(Li) = 3.5 $\pm$ 0.5 dex for SIPS2045-6332 and log N(Li) = 3.0 $\pm$ 0.5 dex for SIPS2039-1126 provides age estimations as young as 7-100 Myrs or the possible BD condition.

5.4 New Brown Dwarfs

The lithium test was first proposed by Rebolo, Martín & Magazzú (1992) and developed by Magazzú, Martín & Rebolo (1993) to distinguish BDs from stellar objects. While stars and low mass stars deplete lithium with time (see explanation in Section 5.3), substellar objects with M>0.06 $M_\odot$ mass can not achieve the temperature needed to destroy lithium and so it should be preserved independently of the object’s age (Chabrier & Baraffe 2000; Basri et al. 2000). Since young low mass objects have not yet depleted all lithium, the discrimination between stars and BD through the lithium test should take age into account.

- **SIPS2045-6332**: SIPS2045-6332, was classified through several spectral indices as an M8.5 spectral type (paper II). It shows a clear Li i absorption line (Figure 9). We used the parameters found in the best fit of the synthetic models and calculated its lithium abundance, log N(Li) = 3.5 $\pm$ 0.5 dex. The DUSTY best fit log g values of 4.0$\pm$0.5 and this lithium provide an age that confirms SIPS2045-6332 as probable Castor member.

We noticed that $EW(H\alpha)$ value, 2.1, is quite small for a young object. But with a M8.5 spectral type, this value agrees with the findings of other authors, e.g. Mohanty & Basri (2003), Reiners & Basri (2010), Barnes et al. (2013), that found that the Hα emission is roughly constant from mid- to late M, but there is a sharp drop between M8-L0 (see e.g. Fig. 5 of Mohanty & Basri 2003), from which they show...
little or significantly reduced emission in spite of significant rotation.

At the Castor MG’s age, and with a spectral type of M8.5 (M<0.06M☉), lithium confirms it as also a BD.

- **SIPS2039-1126:** Similarly, SIPS2039-1126, was classified through several spectral indices as an M8.0 spectral type (paper II). It shows a Li absorption line (Figure 9) although the S/N of the area is only ~ 5. Using the parameters from the best fit of the synthetic models, we obtained logN(Li) = 3.0 ± 0.5 dex (Section 5.3). The DUSTY best fit log g values of 4.5±0.5 suggest it is probably still in contraction. In Section 5.1 we saw that EW(Na i) of SIPS2039-1126 was high considering its Pleiades membership. We have used gravity criteria for targets up to 200 Myr but as seen in Fig. 5 following Schröder et al. (2012), some Pleiades members may lie outside these limits. We thus can not discard this target as a PL member taking into account the rest of the evidence.

At the Pleiades age or in the age interval suggested by the gravity values, the lithium depletion boundary occurs at M6.5 (M=0.075M☉; Barrado y Navascués et al. 2004). Thus, with an M8.0 spectral type, lithium confirms SIPS2039-1126 as a BD.

### 6 SUMMARY AND CONCLUSIONS

We have presented a study of the spectral signatures of 25 low-mass objects that were candidate members of five young moving groups. We studied different typical age-constraining spectroscopic criteria utilising high and low resolution spectra, and combined the results to extract a final membership assessment for each target.

We took into account spectral classification and thus approximated atmospheric temperature to apply the most appropriate model or models in the search of the best physical parameter constraints. When we used the synthetic stellar atmospheric models, the good agreement between observed and theoretical energy distributions suggests that semi-empirical models describe well the impact of dust in the atmospheres of M dwarfs. S-function analysis shows that the inclusion of dust effects makes it possible to achieve better fits for objects with T_{eff} < 2800 K.

In both samples, although youth can generally be established, log g and EW(Na i) were not useful for discriminating between different MGs. Some targets of sample A that were candidates to the HY moving group having lower log g values than candidates to younger MGs, and similarly in EW(Na i) values. In sample B the values are more consistent but most of the targets have several candidatures, making the situation more complicated. However, looking at the final membership results, only one target of sample A is classified as a member of a MG with age <200 Myr, which makes this criterion non applicable for most of them. For sample B, in spite of the multiple membership candidatures in the final results, we can discriminate between the lower values of log g (or lower values of EWs(Na i)) for targets that are members of younger MGs, medium values for targets that are members of intermediate age MGs and the higher values for targets that are members of oldest MGs, which finally is consistent with the log g-age relation. The comparison of EW(Na i) is probably useful to discriminate very young targets (less than 100 Myr) in a homogeneous sample (as suggested by Schröder et al. 2012) while log g values are probably useful to discriminate very young (less than 100 Myr) and very old (more that 600 Myr) objects, serving as complementary study to other criteria.

The activity-age relation is a reasonably useful age criterion up to ≈M7 spectral type but activity variability, bina-

The presence of Lithium discriminates between young and old low mass stars but an ambiguity between young low mass stars and BDs limits its use in this cool temperature region. Gravity sensitive features and rotational velocity can be useful youth indicators in support of activity and lithium diagnostics, but clearly have large dispersion and they need to be applied in conjunction with similar data. For a reliable constraint of cool object ages, a combination of different criteria are needed.

We find 10 of the 13 objects from sample A to be probable members of one of the MGs, and also that 2MASS0020-2346 is a young disk member. SIPS0007-2458, a candidate member of the IC2391 MG, shows positive candidature under most criteria but does not show the expected lithium (associated with the age of the IC2391 MG). Due to the age constraint from Hα emission and surface gravity, we are inclined to think that SIPS0007-2458 is probably a young object from the YD class, but is not in the IC2391 MG, although it could also be a contaminant field object. 2MASS0334-2130 is a similar case, with an M4.5-6 spectral type, it should contain lithium if it were an IC2391 MG member. Except for the Hα criterion, that could be reflecting a maximum in activity level or the influence of an unseen companion, everything indicates that 2MASS0334-2130 is older than the IC2391 MG. Thus we also conclude that 2MASS0334-2130 is not an IC2391 member, although it could be a young object from the YD, or a contaminant target from the field.

In sample B, 10 objects could be MG members, although more information is needed to discriminate between the possible MG membership of objects with several candidatures. We could not obtain any results for 2MASS1909-1937, so this remains an astrometric candidate to the Castor MG. 2MASS1734-1151 gave contradictory results so it also remains an astrometric Pleiades MG candidate until further analysis can be performed.

We also confirm two moving group candidates, SIPS2045-6332 and SIPS2039-1126, as BDs.

With all the acquired information, we find that 85%, 83% and 84% of samples A, B, and both combined, show spectroscopic signatures of youth in agreement with the age of the moving group to which they present kinematic membership. This result suggests that there is a fairly low rate of contamination in such kinematic candidate samples. Also, there are candidates that cannot be confirmed or dismissed with the information obtained, which might (in the future) increase the final confirmation rate. We note that additional diagnostics to assess membership may be measured in the future, such as chemical tagging. Recently, in a kinematical-chemical investigation of the AB Dor moving group Stream, Barenfeld et al. (2013) shows that kinematics, color-magnitude positions, and stellar youth indicators alone can be insufficient for testing whether a kinematic group of stars actually shares a common origin. Future chemical study of our MG candidates will complement this study.
In addition, this study has also helped to test and improve the atmosphere models for cool dwarfs (see Kuznetsov et al. 2012 and Kuznetsov et al. 2013). Youth can be an advantage for various reasons. Because young objects are brighter they can be detected and studied out to greater distance than older, fainter objects. Also, the proximity of the MGs can allows the exploration of the faint circumstellar environment at relatively small distances from the star. Indeed, we will target our strongest MG candidates to search for lower mass companions using high resolution imaging techniques (e.g. adaptive optics). The discovery of planetary systems around young and low-mass objects provides crucial information for the understanding of planetary and stellar formation.

From our complete study of the 80 objects considered (within papers I, II and this paper), we have found a total of 45 new possible MG members (with 8 of them showing more than one MG candidature) and around 21 possible young disk objects with no clear membership of the 5 MGs considered.

Of these we find 26, 13, 6, 4 and 5 possible members of the Hyades, Castor, Ursa Major, Pleiades and IC2391 MGs respectively. Tables A1 and A2 of the appendix compile all the M-L dwarfs investigated in our study.

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Table 1. A: Properties for sample A

| Name              | α (2000) (h m s) | δ (2000) (° ′ ″) | J-mag | Moving group candidature | V sin i^2 (km s^{−1}) |
|-------------------|-----------------|-----------------|------|-------------------------|----------------------|
| SIPS0007-2458     | 07 7.800        | -24 58 3.80     | 13.11±0.02 | IC                      | 18                   |
| 2MASS0020-2346    | 0 20 23.155     | 23 46 5.38      | 12.35±0.02 | YD                      | 12                   |
| DENIS0921-4244    | 0 21 5.896      | -42 44 43.33    | 13.52±0.03 | IC, CA                  | 11                   |
| SIPS0027-5401     | 0 27 23.240     | 54 1 46.20      | 12.36±0.02 | HY                      | 27                   |
| SIPS0153-5122     | 1 53 11.430     | 51 22 24.99     | 13.45±0.03 | IC, HY                  | 14                   |
| SIPS0214-3237     | 2 14 45.440     | -32 37 58.20    | 14.01±0.02 | HY                      | 18                   |
| SIPS0235-0711     | 2 35 49.470     | 7 11 21.90      | 12.45±0.03 | HY                      | 22                   |
| 2MASS0334-2130    | 3 34 10.657     | 21 30 34.35     | 11.91±0.02 | IC                      | <10^6                |
| SIPS2039-1126     | 20 39 13.081    | -11 26 52.30    | 13.79±0.03 | PL                      | >15                  |
| SIPS2045-6332     | 20 45 2.278     | -63 32 5.30     | 12.62±0.03 | PL, CA, SI              | >15                  |
| LEHPM4908         | 22 36 42.656    | -69 34 59.30    | 12.68±0.02 | HY                      | <10                  |
| SIPS2254-3228     | 22 54 58.110    | 32 28 52.20     | 13.58±0.03 | PL, CA                  | 19                   |
| LEHPM6542         | 23 57 54.822    | 19 55 1.89      | 13.31±0.02 | HY                      | 16                   |

1 MG to which targets are kinematic candidate (Paper II). HY= Hyades MG; SI= Ursa Major group; CA= Castor MG; PL= Pleiades; IC = IC 2391 MG; YD= Other young disk object.
2 From paper II.
3 Measured with low S/N.

Table 2. B: Properties for sample B

| Name              | α (2000) (h m s) | δ (2000) (° ′ ″) | J-mag | Moving group candidature |
|-------------------|-----------------|-----------------|------|-------------------------|
| 2MASS0814-4020    | 08 14 35.46     | -40 20 49.26    | 14.356±0.023 | HY                      |
| 2MASS1146-4754    | 11 46 51.04     | -47 54 38.17    | 14.897±0.042 | SI                      |
| 2MASS1236-6536    | 12 36 32.38     | -65 36 35.6     | 15.277±0.057 | PL, CA, IC, SI          |
| 2MASS1326-5022    | 13 26 53.48     | -50 22 27.04    | 14.715±0.037 | IC, CA                  |
| 2MASS1433-5148    | 14 33 41.95     | -51 48 03.70    | 14.206±0.034 | CA, PL, SI, IC          |
| 2MASS1557-4350    | 15 57 27.39     | -43 50 21.47    | 14.224±0.028 | PL, CA, IC              |
| 2MASS1618-3214    | 16 18 08.92     | -32 14 36.17    | 14.920±0.040 | IC, CA, SI              |
| 2MASS1734-1151    | 17 34 30.53     | -11 51 38.83    | 13.110±0.028 | PL                      |
| 2MASS1736-0407    | 17 36 56.09     | -4 07 25.84     | 15.516±0.070 | SI, CA                  |
| 2MASS1745-1640    | 17 45 34.66     | -16 40 53.81    | 13.646±0.026 | SI, CA, HY              |
| 2MASS1756-4518    | 17 56 29.63     | -45 18 22.47    | 12.386±0.019 | CA                      |
| 2MASS1909-1937    | 19 09 08.21     | -19 37 47.96    | 14.520±0.026 | CA                      |

Table 3. Details of observing runs

| Number | Date            | Telescope        | Instrument       | Spect. range (Å) | Dispersion (Å) |
|--------|-----------------|------------------|------------------|-----------------|----------------|
| 1      | 28/03-21/06/08  | ESO-VLT-U2       | UVES^1           | 6700-10425^2    | 0.027-0.041    |
| 2      | 01-09-2009-09/01/2010 | ESO-VLT-U2       | UVES^1           | 5700-7530 & 7650-9470 | 0.027-0.041    |
| 3      | 03-05/05/2010   | 6.5 m Baade-Magellan | IMACS Short-Camera^2 | 6550-10000     | 1.98           |
| 4      | 15-16/02/2011   | 6.5 m Baade-Magellan | IMACS Short-Camera^3 | 4300-10800     | 1.97           |

1 UVES: Ultraviolet and Visual Echelle Spectrograph.
2 Effective range.
3 IMACS: The Inamori Magellan Areal Camera and Spectrograph.
Figure 1. Left: Observed SEDs of objects from sample A, the 13 targets plus reference objects in the 7600 to 8400 Å range. Right: Observed SEDs of objects from sample B, the 12 targets plus one reference object in the 6500 to 9000 Å range. They are ordered by spectral type derived from spectroscopy.

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Figure 2. Sample A: random example of fits of theoretical spectra to the observed SEDs.

Figure 3. Sample B: random example of the best fits to the observed SEDs.

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Figure 4. Sample A: random example of the best fits to the spectral regions across K\textsc{i} lines.

Figure 5. Sample A: random example of the best fits to the spectral regions across Na\textsc{i} lines.

Table 4. Sample A: Model fit results for M3-M7.5 objects. Spectroscopic spectral types are from Paper II. The equivalent effective temperatures for the spectral types were taken from Reylé et al. (2011). $\Delta T_{\text{eff}} = 100$ K, $\Delta \log g = 0.5$ cm s$^{-2}$.

| Object        | $SpT_{\text{Spec}}$ | $T_{\text{eff}}$ (K) | $SpT$ | $T_{\text{eff}}$ (K) | $\log g$ (cm s$^{-2}$) | $[M/H]$ | $S_{\text{min}}$ | $T_{\text{eff}}$ (K) | $\log g$ (cm s$^{-2}$) | $[M/H]$ | $S_{\text{min}}$ | best fit$^1$ |
|---------------|----------------------|-----------------------|-------|-----------------------|------------------------|---------|-----------------|-----------------------|------------------------|---------|-----------------|----------------|
| GL876         | M4.0                 | 3100                  |       |                       | 3400                   | 5.5     | 0.0             | 2.9                   | -                      | -                   | -               | -               | -               |
| SIPS0007-2458 | M7.5                 | 2550                  |       |                       | 2700                   | 4.5     | -1.0            | 7.0                   | 2700                   | 4.5     | 0.0             | 6.2             | s.-e.            |
| 2MASS0020-2346| M6.0                 | 2800                  |       |                       | 2800                   | 5.5     | -0.5            | 4.8                   | 2800                   | 5.0     | 0.0             | 4.56            | s.-e.            |
| SIPS0027-5401 | M6.5                 | 2650                  |       |                       | 2700                   | 4.5     | -1.0            | 3.35                  | 2700                   | 4.5     | 0.0             | 2.70            | s.-e.            |
| SIPS0153-5122 | M6.0                 | 2800                  |       |                       | 2800                   | 5.5     | -0.5            | 2.42                  | 2800                   | 5.0     | 0.0             | 2.31            | s.-e.            |
| SIPS0214-3237 | M6.5                 | 2650                  |       |                       | 2800                   | 5.0     | -1.0            | 1.44                  | 2800                   | 5.0     | 0.0             | 1.2             | s.-e.            |
| SIPS0235-0711 | M6.0                 | 2800                  |       |                       | 2700                   | 5.0     | -1.0            | 0.97                  | 2700                   | 4.5     | 0.0             | 0.91            | s.-e.            |
| 2MASS0334-2130| M4.5-M6.0            | 3000-2800             |       |                       | 2800                   | 5.5     | -0.5            | 4.65                  | 2800                   | 5.0     | 0.0             | 5.65            | a                |
| LEHPM4908     | M6.0                 | 2800                  |       |                       | 2800                   | 4.5     | -1.0            | 7.02                  | 2900                   | 5.0     | 0.0             | 5.70            | s.-e.            |
| 2MASS2254-3228| M5.5                 | 2850                  |       |                       | 2700                   | 5.0     | -1.0            | 1.37                  | 2700                   | 4.5     | 0.0             | 1.25            | s.-e.            |
| LEHPM6542     | M6.0                 | 2800                  |       |                       | 2800                   | 5.0     | -0.5            | 13.5                  | 2700                   | 4.5     | 0.0             | 4.03            | s.-e.            |

1 NextGen or semi-empirical (s.-e.) models.

a both models are equally likely.
Figure 6. This figure (updated Figure 9 from Paper I), illustrates how an object would be selected for the various methods of age constraining. Candidates that appear to the right of the lithium edge (blue continuous line) can be followed up with a lithium test programme. Objects that appear younger than 200 Myr (horizontal red dashed line), are eligible for follow-up using spectroscopic gravity sensitive features. Vertical and horizontal orange dot-dashed line represents the Schlieder et al. (2012) limits for the Na i diagnostic applicability. We here took into account the 200 Myr limit. Candidates that fall to the left left of the spectral type=M7 limit (vertical black dotted line), would thus be suitable for age/activity relation follow-up, although candidates with a spectral type close to M7 may be subject to large uncertainties on their age. Some candidate cannot be tested by any of these methods but will be eligible for age testing using $v\sin i$. Sample A targets are plot as blue circles and sample B as red circles. We plotted up to two candidatures for targets with multiple MG.

Figure 7. The right and left panels show two versions of the same information with different legends in order to highlight different information. Left: From Martín et al. (2010), 65 high-gravity field objects are plotted as six pointed asterisk symbol, 6 low-gravity objects as open triangles, 12 reference field stars as open circles and 7 Upper Sco candidates as solid hexagons. We overplot sample A as blue crosses, and sample B as red filled circles. The red star marks LP944-20. Errors are approximately the size of plot symbols. Right: Here we overplot to Martín et al. (2010) data, sample A (crosses and filled squares), and sample B (filled circles and triangles), plotted in different colours depending on their final MG membership candidature (Table 10). When objects present more than one candidature, we plotted the membership to the youngest MG. To better discriminate young targets, we use triangles and squares for candidates finally classified as possible member of MGs with ages $\gtrsim 200$ Myr while crosses and circles are candidates finally classified as possible member of MGs with ages $<200$ Myr (see Sect. 6).
Table 5. Sample B: Model fit results for M3-M7.5 objects. The equivalent effective temperature for the spectral types were taken from Reylé et al. (2011). $\Delta T_{\text{eff}} = 100 \text{ K}$, $\Delta \log g = 0.5 \text{ cm s}^{-2}$.

| Object        | SpT      | $S_pT_{\text{Spec}}$ | $T_{\text{eff}}$ | $S_pT_{\text{Spec}}$ | $T_{\text{eff}}$ | log g | [M/H] | $S_{\text{min}}$ | $T_{\text{eff}}$ | log g | [M/H] | $S_{\text{min}}$ | best fit |
|---------------|----------|----------------------|------------------|----------------------|------------------|-------|-------|------------------|------------------|-------|-------|------------------|---------|
| 2MASS1146-4754 | M8.5     | M7-8                 | $\sim 2500$     | 2800                 | 5.5              | -0.5  | 0.39  | 2700             | 4.5              | 0.0   | 0.18  | s.-e.            | NextGen |
| 2MASS1226-6536 | M7.5     | M7.2                 | 3100             | 3200                 | 5.5              | 0.0   | 0.64  | 2900             | 4.0              | 0.0   | 1.14  | NextGen          |         |
| 2MASS1326-5022 | M9.0     | M7.1                 | 2550             | 2800                 | 5.0              | 0.0   | 0.57  | 2700             | 4.0              | 0.0   | 0.22  | s.-e.            |         |
| 2MASS1433-5148 | M9.0     | M6-7                 | $\sim 2650$     | 3000                 | 5.5              | 0.0   | 0.58  | 2900             | 5.0              | 0.0   | 0.27  | s.-e.            |         |
| 2MASS1518-3214 | M7.0     | M6.3                 | 2600             | 2800                 | 5.5              | -0.5  | 0.69  | 2700             | 4.5              | 0.0   | 0.41  | s.-e.            |         |
| 2MASS1736-0407 | M8.5     | M4-5                 | $\sim 3000$     | 3200                 | 5.0              | 0.0   | 0.49  | 2900             | 4.0              | 0.0   | 0.55  | NextGen          |         |

Table 6. Sample A: Model fit results for $\sim M8$ object. First line refers to fit results when use NextGen, DUSTY and COND models while second line refers to fit results when use the semi-empirical models based on NextGen, DUSTY and COND models respectively. Spectroscopic spectral types are from Paper II. $\Delta T_{\text{eff}} = 100 \text{ K}$, $\Delta \log g = 0.5 \text{ cm s}^{-2}$.

| Object        | SpT      | $S_pT_{\text{Spec}}$ | $T_{\text{eff}}$ | $S_pT_{\text{Spec}}$ | $T_{\text{eff}}$ | log g | [M/H] | $S_{\text{min}}$ | $T_{\text{eff}}$ | log g | [M/H] | $S_{\text{min}}$ | best fit |
|---------------|----------|----------------------|------------------|----------------------|------------------|-------|-------|------------------|------------------|-------|-------|------------------|---------|
| SIPS2039-1126 | M8.0     | 2500                 | 2800             | 5.5                  | 22.45            | 2600  | 5.0   | 39.96            | 2600  | 4.5   | 40.12 | s.-e.            |         |
| Semi-empirical|          |                      |                  |                      |                  |       |       |                  |                  |       |       |                  |         |

Table 7. Sample B: Model fit results for $\sim M8$ objects. First line refers to fit results when use NextGen, DUSTY and COND models while second line refers to fit results when use the semi-empirical models based on NextGen, DUSTY and COND models respectively. $\Delta T_{\text{eff}} = 100 \text{ K}$, $\Delta \log g = 0.5 \text{ cm s}^{-2}$.

| Object        | SpT      | $S_pT_{\text{Spec}}$ | $T_{\text{eff}}$ | $S_pT_{\text{Spec}}$ | $T_{\text{eff}}$ | log g | [M/H] | $S_{\text{min}}$ | $T_{\text{eff}}$ | log g | [M/H] | $S_{\text{min}}$ | best fit |
|---------------|----------|----------------------|------------------|----------------------|------------------|-------|-------|------------------|------------------|-------|-------|------------------|---------|
| 2MASS1518-3214 | M7.0     | M6.3                 | 2600             | 2800                 | 5.5              | -0.5  | 0.69  | 2700             | 4.5              | 0.0   | 0.41  | s.-e.            |         |
| 2MASS1736-0407 | M8.5     | M4-5                 | $\sim 3000$     | 3200                 | 5.0              | 0.0   | 0.49  | 2900             | 4.0              | 0.0   | 0.55  | NextGen          |         |

Table 8. Sample A: Model fit results for M8.5-M9.5 objects. First line refers to fit results when use DUSTY and COND models while second line refers to fit results when use the semi-empirical models based on DUSTY and COND models respectively. Spectroscopic spectral types are from Paper II. The equivalent effective temperature for the spectral types were taken from Dahn et al. (2002). $\Delta T_{\text{eff}} = 100 \text{ K}$, $\Delta \log g = 0.5 \text{ cm s}^{-2}$.

| Object        | SpT      | $S_pT_{\text{Spec}}$ | $T_{\text{eff}}$ | $S_pT_{\text{Spec}}$ | $T_{\text{eff}}$ | log g | [M/H] | $S_{\text{min}}$ | $T_{\text{eff}}$ | log g | [M/H] | $S_{\text{min}}$ | best fit |
|---------------|----------|----------------------|------------------|----------------------|------------------|-------|-------|------------------|------------------|-------|-------|------------------|---------|
| SIPS2045-6332 | M8.5     | 2300-2400            | 2000             | 5.5                  | 0.0              | 7.85  | 2600  | 5.5              | 1.15             | 2600  | 5.0   | 1.22  | s.-e.            |         |
| Semi-empirical|          |                      |                  |                      |                  |       |       |                  |                  |       |       |                  |         |
| LP944-20      | M9.0     | 2300-2400            | 2000             | 5.5                  | 0.0              | 0.42  | 2600  | 5.5              | 0.0              | 2600  | 5.0   | 0.10  | s.-e.            |         |
| Semi-empirical|          |                      |                  |                      |                  |       |       |                  |                  |       |       |                  |         |

1 DUSTY and COND have the same $S_{\text{min}}$, but DUSTY model is more appropriate in the temperature range.

2 We could appreciate parts of the spectrum were NextGen was the best fit.
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Figure 8. $EW(H\alpha)$ versus spectral type. In the same way as in Fig. 7, both panels show two versions of the same information with different legends in order to highlight different information. Left: Sample A is plotted as blue crosses, Sample B as red circles and literature known-age objects in different symbols according to age: red asterisk for objects with age between 1-12 Myr, blue diamonds for 40-50 Myr, violet asterisk for 90-100 Myr, blue asterisk for 120 Myr, blue asterisk for 150 Myr, black asterisk for 300 Myr, black diamonds for 400 Myr and green asterisk for objects with ages over 1200 Myr. Literature data has been obtained from Terndrup et al. (2000), Mohanty & Basri (2003) and Shkolnik et al. (2009) where ages were calculated by known-age MG or Cluster membership or by other age constraining methods. Right: Similar to left panel where to favor the age discrimination we plot only three age intervals. Sample A targets are plotted as filled squares and sample B as filled triangles, where targets classified with ages $\geq$300 Myr are plotted in blue and targets with ages <300 Myr are plotted in red.

Figure 9. Fit to the observed spectra across Li I resonance doublet for SIPS2045-6332 (left) and SIPS2039-1126 (right). Best synthetic fits are overplot with different Li abundances.

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### Table 9. Sample B: Model fit results for $>$M8.5 objects.

First line refers to fit results when use DUSTY and COND models while second line refers to fit results when use the semi-empirical models based on DUSTY and COND models respectively. The equivalent effective temperature for the spectral types were taken from Reylé et al. (2011). $\Delta T_{\text{eff}} = 100$ K, $\Delta \log g = 0.5$ cm s$^{-2}$.

| Object                | $SpT_{\text{phot}}$ | $SpT_{\text{Spec}}$ | $T_{\text{eff}}$ (K) | $T_{\text{eff}}$ (K) | $\log g$ | $[M/H]$ | $S_{\text{min}}$ | $T_{\text{eff}}$ (K) | $\log g$ | $[M/H]$ | $S_{\text{min}}$ | best fit |
|-----------------------|----------------------|----------------------|----------------------|----------------------|---------|---------|------------------|----------------------|---------|---------|------------------|----------|
| 2MASSJ1734-1151       | L0.0                 | M9.0                 | 2300-2500            | 2600                 | 5.5     | 0.0     | 1.34             | 2600                 | 5.0     | 0.0     | 1.43             | s.-e. DUSTY |
| Semi-empirical        |                      |                      |                      |                      |         |         |                  |                      |         |         |                  |          |
| 2MASSJ1745-1640       | L0.0                 | M9-L2                | 2300-2000            | 2000                 | 5.5     | 0.0     | 0.06             | 2200                 | 5.5     | 0.0     | 0.07             | s.-e. DUSTY |
| Semi-empirical        |                      |                      |                      |                      |         |         |                  |                      |         |         |                  |          |
| 2MASS1909-1937        | L0.0                 | M9                  | 2000                | 2000                 | 5.5     | 0.0     | 0.05             | 2200                 | 5.5     | 0.0     | 0.05             | s.-e. DUSTY |
| Semi-empirical        |                      |                      |                      |                      |         |         |                  |                      |         |         |                  |          |

### Table 10. MG membership parameters.

For each target, we give the result obtained for each criterion used. N/A= non applicable criterion in this case; Y= the age parameter agrees with the MG membership; N= the age parameter does not agree with the MG membership; when more than one membership was possible in column 5, the MG name that the criteria determined as possible is given. Where HY is Hyades, SI is Ursa Major, IC is IC 2391, CA is Castor and PL is Pleiades MG and YD is other young disk object. When interrogation appears after MG name we indicate that the membership probability is fewer than for other MGs or in the case of 2MASSJ1734-1151 and 2MASS1909-1937, that the criteria are not conclusive.

| Object                | EW(Na i) $^1$ (Å) | EW(H$\alpha$) $^2$ (Å) | age $^3$ (Myr) | MG memb. $^4$ | M. from EW(Na i) $^1$ | M. from EW(H$\alpha$) $^2$ | M. from log g $^5$ | M. from Li i $^6$ | M. from $v \sin i$ $^6$ | Final MG |
|-----------------------|-------------------|------------------------|----------------|--------------|----------------------|----------------------|-----------------|----------------|------------------|----------|
| SIPS0007-2458         | 8.2               | 11.0                   | 1-300          | IC           | Y                    | Y                    | Y               | N              | Y                | YD       |
| SIPS0009-2020-2346    | 8.1               | 6.1                    | 1-300          | IC, CA       | CA                   | N/A                  | Y               | Y              | Y                | YD       |
| SIPS0031-2424         | 8.4               | *                      | N/A            | IC, CA       | CA                   | N/A                  | Y               | N              | Y                | CA       |
| SIPS0027-5401         | 7.7               | 8.1                    | 1-300          | IC, HY       | HY                   | HY                   | HY              | HY             | Y                | HY       |
| SIPS0153-5122         | 8.0               | 7.5                    | 1-300          | IC, HY       | IC                   | CA                   | N/A             | Y              | Y                | YH       |
| SIPS0214-3237         | 7.9               | 8.4                    | 1-300          | IC, CA       | CA                   | N/A                  | Y               | Y              | Y                | HY       |
| SIPS0235-0711         | 7.9               | 7.7                    | 1-300          | IC, CA       | CA                   | N/A                  | Y               | N              | Y                | PL       |
| LEHPM4908             | 7.3               | 6.5                    | 1-300          | IC, CA       | CA                   | Y                    | Y               | Y              | -                | HY       |
| 2MASS2254-3228        | 8.5               | 5.8                    | 1-300          | PL, CA       | CA                   | CA                   | Y               | Y              | Y                | CA       |
| LEHPM6542             | 7.6               | 4.9                    | $\geq$300      | HY           | N/A                  | Y                    | Y               | Y              | Y                | HY       |
| 2MASS0014-4020        | 9.0               | 7.2                    | $\geq$300      | HY           | N/A                  | Y                    | Y               | N/A            | N/A              | HY       |
| 2MASS1146-4754        | 7.9               | 5.2                    | $\geq$300      | SI           | N/A                  | Y                    | Y               | N/A            | N/A              | SI       |
| 2MASS1236-6536        | 5.8               | 1.0                    | 300-1200       | PL, IC, CA, SI| CA, SI               | CA, SI              | N               | N/A            | N/A              | CA, SI   |
| 2MASS1236-5022        | 4.2               | 23.6                   | 1-100          | IC, CA       | IC                   | IC                   | Y               | N/A            | N/A              | IC       |
| 2MASS1345-5148        | 7.9               | 19.8                   | 1-100          | PL, IC, CA, SI| CA, SI              | PL, IC              | SI               | N/A            | N/A              | CA, SI   |
| 2MASS1557-4350        | 4.0               | 16.4                   | 1-100          | PL, IC, CA   |PL, IC              | N/A                  | Y               | N/A            | N/A              | PL, IC   |
| 2MASS1618-3214        | 8.0               | 7.8                    | 1-300          | IC, CA, SI   | CA, SI              | Y                    | Y               | N/A            | N/A              | IC, SI   |
| 2MASS1734-1151        | 7.7               | 5.5                    | N/A            | PL           | N                    | N/A                  | Y               | N/A            | N/A              | N/A      |
| 2MASS1736-0407        | 6.1$^e$            | 4.2                    | 50-300         | CA, SI       | Y                    | Y                   | N/A             | N/A            | N/A              | CA, SI   |
| 2MASS1745-1640        | 5.6               | 1.4                    | $\geq$300      | CA, SI, HY   | Y                    | N/A                  | HY              | N/A            | N/A              | CA, SI, HY |
| 2MASS1756-4518        | 7.5               | 3.2                    | N/A            | CA           | N/A                  | N/A                  | Y               | N/A            | N/A              | CA       |
| 2MASS1909-1937        | 6.3               | *                      | N/A            | CA           | N/A                  | N/A                  | N/A             | N/A            | N/A              | CA       |

1 Equivalenth width of the Na i doublet as explained in Section 5.1.
2 See Section 5.2.
3 MG membership from kinematic (sample A) or from photometric and astrometric criteria (sample B). See Section 2.
4 From value obtained in the synthetic fits, given in columns 5 and 9 of Tables 4, 5 and 6.
5 Only applicable for high resolution data. See Section 5.3.
6 From Paper II.
7 Absorption line filled in with emission.
8 Absorption line.
9 Measured with a cosmic ray in the line.

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APPENDIX A: TABLES
Table A1. Compilation of all VLM moving group candidates: the fifth column describes the method or methods from which membership has been derived. When the word probable is used we mean that kinematics is not supported by $v \sin i$ criterion at paper II. Spectral types given are from spectral indices (calculated in Paper II and here) except when marked.

| Name                | $\alpha$ (2000) | $\delta$ (2000) | SpT  | Note                                                                 |
|---------------------|----------------|----------------|------|----------------------------------------------------------------------|
|                     | (h m s)        | (° \,')        |      |                                                                       |
| **Hyades**          |                |                |      |                                                                       |
| SIPS0004-5721       | 0 4 18.970     | -57 21 23.30   | M7.0 | also IC candidate; kinematic                                         |
| SIPS0027-5401       | 0 27 23.240    | -54 1 46.20    | M6.0 | kinematics + age features                                           |
| 2MASS0123-3610       | 1 23 0.506     | -36 10 30.67   | M4.5 | kinematics                                                            |
| SIPS0153-5122       | 1 53 11.430    | -51 22 24.99   | M6.0 | kinematics + age features                                           |
| SIPS0214-3237       | 2 14 45.440    | -32 37 58.20   | M6.5 | kinematics + age features                                           |
| SIPS0235-0711       | 2 35 49.470    | -7 11 21.90    | M6.0 | kinematics + age features                                           |
| SIPS0410-0530       | 4 40 23.328    | -5 30 7.85     | M7.5 | kinematics                                                            |
| 2MASS0600-3314       | 6 0 33.750     | -33 14 26.84   | M7.0 | phot probable member from kinematics                                 |
| 2MASS0814-4020       | 8 14 35.46     | -40 20 49.26   | M7-8 | photometry + astrometry + age features                              |
| 2MASS1745-1640       | 17 45 34.66    | -16 40 53.81   | M9-L2| also CA and SI candidate; photometry + astrometry + age features     |
| SIPS2014-2016        | 20 14 3.523    | -20 16 21.30   | M7.5 | kinematics                                                            |
| DENIS2031-5041       | 20 31 27.45    | -50 41 13.49   | M5.0 | kinematics                                                            |
| 2MASS2049-1716       | 20 49 52.610   | -17 16 7.80    | M6.5 | kinematics                                                            |
| SIPS2100-6255        | 21 0 30.227    | -62 55 7.31    | M5.0 | phot probable member from kinematics                                 |
| 2MASS2131-4433       | 22 31 8.057    | -44 43 18.43   | M4.5 | kinematics                                                            |
| LEHPM4908            | 22 36 42.656   | -69 34 59.30   | M5.5 | kinematics + age features                                           |
| SIPS2311-5256        | 23 11 30.330   | -52 56 30.17   | M5.5 | kinematics                                                            |
| 2MASS1146-4754       | 11 46 51.04    | -47 54 38.17   | M7.8 | photometry + astrometry + age features                              |
| 2MASS1236-6536       | 12 36 32.38    | -65 36 35.6    | M4.0 | also CA candidate; photometry + astrometry + age features            |
| SIPS2043-5148        | 14 33 41.95    | -51 48 03.70   | M6-7 | also CA candidate; photometry + astrometry + age features            |
| 2MASS1618-3214       | 16 18 08.92    | -32 14 36.17   | M6.5 | also CA candidate; photometry + astrometry + age features            |
| 2MASS1736-0407       | 17 36 56.09    | -4 07 25.84    | M4.5 | also CA candidate; photometry + astrometry + age features            |
| 2MASS1745-1640       | 17 45 34.66    | -16 40 53.81   | M9-L2| also HY and CA candidate; photometry + astrometry + age features     |
| **Castor**           |                |                |      |                                                                       |
| SIPS0021-4244        | 0 21 5.896     | -42 44 43.33   | M9.5 | kinematics + age features                                           |
| 2MASS1236-6536       | 12 36 32.38    | -65 36 35.6    | M4.0 | also SI candidate; photometry + astrometry + age features            |
| 2MASS1433-5148       | 14 33 41.95    | -51 48 03.70   | M6-7 | also SI candidate; photometry + astrometry + age features            |
| 2MASS1618-3214       | 16 18 08.92    | -32 14 36.17   | M6.5 | also SI candidate; photometry + astrometry + age features            |
| 2MASS1736-0407       | 17 36 56.09    | -4 07 25.84    | M4.5 | also SI candidate; photometry + astrometry + age features            |
| 2MASS1745-1640       | 17 45 34.66    | -16 40 53.81   | M9-L2| also HY and SI candidate; photometry + astrometry + age features     |
| 2MASS1756-4518       | 17 56 29.63    | -45 18 22.47   | M8-9 | photometry + astrometry + age features                              |
| 2MASS1909-1937       | 19 09 08.21    | -19 37 47.96   | L0.0 | photometry + astrometry                                             |
| SIPS1720-5041       | 20 0 48.171    | -75 23 6.58    | M8.0 | probable member from kinematics                                     |
| SIPS2045-6332       | 20 45 2.278    | -63 32 5.30    | M9.0 | kinematics + age features                                           |
| SIPS2114-4339        | 21 14 40.928   | -43 39 51.20   | M6.5 | kinematics                                                            |
| 2MASS2242-2659       | 22 42 41.294   | -26 59 27.23   | M5.5 | also HY candidate; kinematics                                       |
| 2MASS2254-3228       | 22 54 58.110   | -32 28 52.20   | M5.5 | kinematics + age features                                           |
| **Pleiades**         |                |                |      |                                                                       |
| 2MASS1557-4350       | 15 57 27.39    | -43 50 21.47   | M7.5 | also IC candidate; photometry + astrometry + age features            |
| 2MASS1734-1151       | 17 34 30.53    | -11 51 38.38   | M9.0 | photometry + astrometry                                             |
| SIPS2039-1126        | 20 39 13.081   | -11 26 52.30   | M7.0 | kinematics + age features                                           |
| HB2124-4228          | 21 27 26.133   | -42 15 18.39   | M7.5 | kinematics                                                            |
| **IC 2391**          |                |                |      |                                                                       |
| SIPS0004-5721       | 0 4 18.970     | -57 21 23.30   | M7.0 | also HY candidate; kinematics                                       |
| 2MASS1326-5022       | 13 26 53.48    | -50 22 27.04   | M7.5 | photometry + astrometry + age features                              |
| 2MASS1557-4350       | 15 57 27.39    | -43 50 21.47   | M7.5 | also PL candidate; photometry + astrometry + age features            |
| 2MASS1618-3214       | 16 18 08.92    | -32 14 36.17   | M6.5 | also CA and SI candidate; photometry + astrometry + age features     |
| SIPS2341-3550        | 23 41 47.497   | -35 50 14.40   | M7.0 | kinematics                                                            |

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Table A2. Other probably young disk and old disk candidates. Notes as in previous table.

| Name             | α (2000) (h m s) | δ (2000) (° , ′ , ″) | SpT | Note                          |
|------------------|------------------|----------------------|-----|-------------------------------|
| Other Young Disk |                  |                      |     |                               |
| SIPS0007-2458    | 0 7 7.800        | -24 58 3.80          | M7.5| kinematics + age features     |
| 2MASS0020-2346   | 0 20 23.155      | -23 56 5.38          | M6.0| kinematics + age features     |
| SIPS0039-2256    | 0 39 23.250      | -22 56 44.90         | M7.5| probable YD from kinematics  |
| DENIS0041-5621   | 0 41 35.390      | -56 21 12.77         | M7.5| kinematics                    |
| SIPS0054-4142    | 0 54 35.300      | -41 42 6.20          | M5.0| probable YD from kinematics  |
| SIPS0109-0343    | 1 9 51.040       | -3 43 26.30          | M9.0| not conclusive from kinematics|
| LEHPM1289        | 1 9 59.579       | -24 16 47.82         | M6.0| not conclusive from kinematics|
| SIPS0115-2715    | 1 15 26.610      | -27 15 54.10         | M5.0| not conclusive from kinematics|
| SIPS0126-1946    | 1 26 49.980      | -19 46 5.90          | M6.0| not conclusive from kinematics|
| LEHPM1363        | 1 27 31.956      | -31 40 3.18          | M8.5| kinematics                    |
| SIPS0212-6049    | 2 12 33.580      | -60 49 18.40         | M6.5| not conclusive from kinematics|
| 2MASS0334-2130   | 3 34 10.657      | -21 30 34.35         | M4.5| kinematics + age features     |
| 2MASS0429-3123   | 4 29 18.426      | -31 23 56.81         | M7.5| not conclusive from kinematics|
| 2MASS0502-3227   | 5 2 38.677       | -32 27 50.07         | M5.5| not conclusive from kinematics|
| 2MASS0528-5919   | 5 28 5.623       | -59 19 47.17         | M5.5| not conclusive from kinematics|
| SIPS1039-4110    | 10 39 18.340     | -41 10 32.00         | M6.5| probable YD from kinematics  |
| SIPS1124-2019    | 11 24 22.229     | -20 19 1.50          | M7.0| probable YD from kinematics  |
| SIPS2049-1944    | 20 49 19.673     | -19 44 31.30         | M7.0| kinematics                    |
| SIPS2128-3254    | 21 28 17.402     | -32 54 3.90          | M6.5| kinematics                    |
| SIPS2321-6106    | 23 21 43.418     | -61 6 35.37          | M5.0| kinematics                    |
| SIPS2343-2947    | 23 43 34.731     | -29 47 9.50          | M8.0| kinematics                    |
| Old Disk         |                  |                      |     |                               |
| 2MASS0204-3945   | 2 4 18.036       | -39 45 6.48          | M7.0| not conclusive from kinematics|
| 2MASS0445-5321   | 4 45 43.368      | -53 21 34.56         | M7.5| probable OD from kinematics  |
| DENIS1250-2121   | 12 50 52.654     | -21 21 13.67         | M7.5| kinematics                    |
| SIPS1329-4147    | 13 29 0.872      | -41 47 11.90         | M9.5| probable OD from kinematics  |
| SIPS1341-3052    | 13 41 11.561     | -30 52 49.60         | L0  | kinematics                    |
| 2MASS1507-2000   | 15 7 27.799      | -20 0 43.18          | M7.5| kinematics                    |
| SIPS1632-0631    | 16 32 58.799     | -6 31 45.30          | M8.5| kinematics                    |
| SIPS1758-6811    | 17 58 59.663     | -68 11 10.50         | M5.0| probable OD from kinematics  |
| SIPS1949-7136    | 19 49 45.527     | -71 36 50.89         | M7.0| kinematics                    |
| 2MASS2001-5949   | 20 1 24.639      | -59 49 0.09          | M6.0| probable OD from kinematics  |
| 2MASS2106-4044   | 21 6 20.896      | -40 44 51.91         | M6.0| probable OD from kinematics  |
| SIPS2119-0740    | 21 19 17.571     | -7 40 52.50          | M7.0| probable OD from kinematics  |
| LEHPM1480        | 22 15 10.151     | -67 38 49.07         | M5.5| probable OD from kinematics  |
| 2MASS2222-4919   | 22 22 3.684      | -49 19 23.45         | M6.5| kinematics                    |