Kine-chemical tagging of FGK stars: discerning between field-like stars and real physical structures of coeval stars with a common origin

UCM

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Abstract

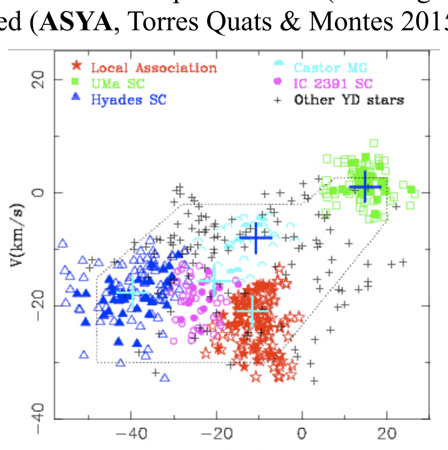
Using several high resolution spectroscopic surveys of nearby **FGK** stars we have information about kinematics, rotational velocities, age (Lithium abundance and chromospheric activity) and fundamental stellar parameters (Teff, log g, metallicity, [Fe/H], and microturbulent velocity) that allowed us to ascribe these stars to **moving groups and associations** of different ages. By applying the **chemical tagging technique** (differential abundance analysis of 20 elements) we are testing the membership of these stars to these kinematic groups. All this information allowed us to better understand the star formation history in the solar neighborhood discerning between field-like stars (associated with dynamical resonances (bar) or spiral structure) and real physical structures of coeval stars with a common origin (debris of star-forming aggregates in the disk). We summarize the results obtained for FGK candidates stars to the **Hyades supercluster** (Tabernero et al. 2012) the **Ursa Mayor moving group** (Tabernero et al. 2015) and the **Castor moving group**, other young associations like **ASYA**, **Octans**, **Argus-IC2391**, and **AB Dor** will be also analysed in this way. In addition, using the large amount of data provided by the **Gaia ESO Survey** (**GES**) we plan to perform a **chemical and kinematic analysis** of the **FGK field stars of the Milky Way** observed with **UVES**, and search for possible new members to these groups.

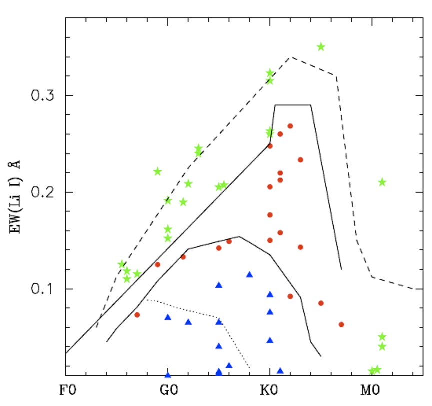
Stellar kinematic groups

Classical Old Moving Groups: Several old moving groups (MG) are located outside the boundaries (dotted line) that determine the young disk population as defined by Eggen (see Montes et al. 2001MNRAS.328...45).

Classical Young Moving Groups: The youngest (age < 650 Myr) and best documented MG in the solar vicinity (see **Fig. below**) are the **Hyades Supercluster** (HS), **Ursa Major** (UMa), **Local Association** (LA), **IC 2391** and **Castor** (see Montes et al. 2001MNRAS.328...45 and references therein). Substructures in these MG have been found like the B1-B4 subgroups of the LA (Asiain et al. 1999A&A...341..427) and some possible new MG as **Hercules-Lyra** has been identified more recently (López-Santiago et al. 2006ApJ...643.1160).

Young Nearby Loose Associations: Several nearby associations (**ε Cha, TW Hya, β Pic, Tuc-Hor, Carina Columba and AB Dor**) of young stars have been identified in the last years, and a large number of then have U, V velocities in the region of the Local Association (Pleiades MG). We have compiled the more recent results from Torres et al., 2008hsf2.book..757; Zuckerman & Song 2004, ARA&A, Vol. 42, 685, and some other authors. Some initially identified groups like HD 199143 later result to be part of the β Pic. Some recently identified associations result to be part or to be related with known MG or open clusters (like Argus = IC 2391). More recently other associations are identified (**ASYA**, Torres Quats & Montes 2015).





High resolution echelle spectroscopy (see our previous work, Montes et al. 2001 MNRAS, 328, 45; López-Santiago et al. 2010 A&A, 514, A97; Figs. 4 and 5) allowed us to analyse in more detail the membership of these stars to the different young MG: using **age-dating methods** for late-type stars such as the chromospheric activity level and the lithium absorption line. See also the ***chemical tagging*** method (Tabernero et al. 2012, A&A, 547, A13).

group (Tabernero et al. 2014, A&A, in press, **Fig. 10**). See also Tabernero 2014, PhD Thesis, UCM

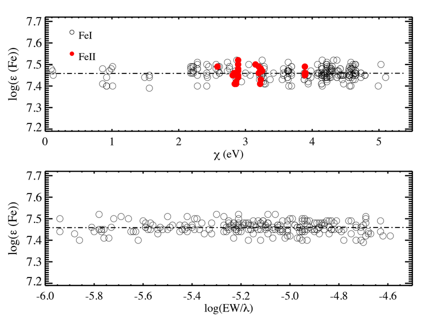
Stellar parameters

Stellar atmospheric parameters (T_{eff}, log*g*, ξ and **[Fe/H]**)

StePar (Tabernero Montes, González Hernández, **2012**, A&A, 547, A13, and Tabernero 2014, PhD Thesis, UCM):

- 2002 version of the MOOG code (Sneden 1973).
- a grid of Kurucz ATLAS9 plane-parallel model atmospheres (Kurucz 1993) and MARCS.

- The EW determination of the Fe lines with the ARES code (Sousa et al. 2007) and TAME.
- 263 Fe I and 36 Fe II lines (Sousa et al. 2008).



The code iterates until obtain:
- **excitation equilibrium**:
  the slopes of χ *vs* log(ϵ(Fe I)) and log(EW/λ) *vs* log(ϵ(Fe I)) where zero
- **ionization equilibrium**:
  log(ϵ(Fe I)) = log(ϵ(Fe II)).

- 2-σ rejection of Fe I and Fe II lines after a first determination of the parameters
- **Limitations**: spectral types F6 to K4, slow rotators, no veiling.

StePar employs the 2002 version of the *MOOG* code (Sneden 1973) and a grid of Kurucz *ATLAS9* plane-parallel model atmospheres (Kurucz 1993). The atmospheric parameters are obtained from the *EW*s of Fe I and Fe II lines iterating until the excitation and ionization equilibrium are fulfilled. *StePar* uses a Downhill Simplex method (Press et al. 1992) that minimizes a quadratic form composed by the excitation and ionization equilibrium conditions. Optionally *StePar* can operate with *MARCS* models (Gustafsson et al. 2008) instead of Kurucz ATLAS9 models, additionally Turbospectrum (Álvarez and Plez 1998) can replace the *MOOG* code and play its role during the parameter determination.

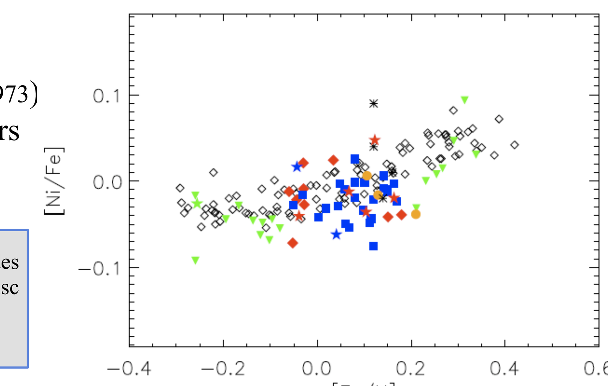
Chemical abundances

Fe, the α-elements (Mg, Si, Ca, and Ti),
Fe-peak elements (Cr, Mn, Co, and Ni),
odd-Z elements (Na, Al, Sc, and V)
s-process elements (Cu, Zn, Y, Zr, Ba, Ce and Nd)

- **EW** method in a line-by-line basis using *ARES* (Sousa et al. 2007; 2015) and TAME (Kang & Lee 2012) codes.

- Line lists and atomic parameters from (Neves et al. 2009; González Hernández et al. 2010) and GES line list.

- Abundance analysis with *MOOG* (Sneden 1973) using our determined atmospheric parameters and a solar spectrum taken with the same instrumental configuration.



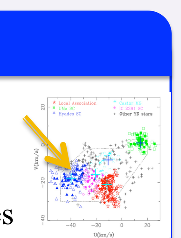
[Ni/Fe] vs [Fe/H] for our sample of stars in the Hyades Supercluster (coloured symbols) compared with the thin disc data (González Hernández et al. 2010, open diamonds). See Tabernero et al. (2012).

Differential Abundances and Chemical tagging

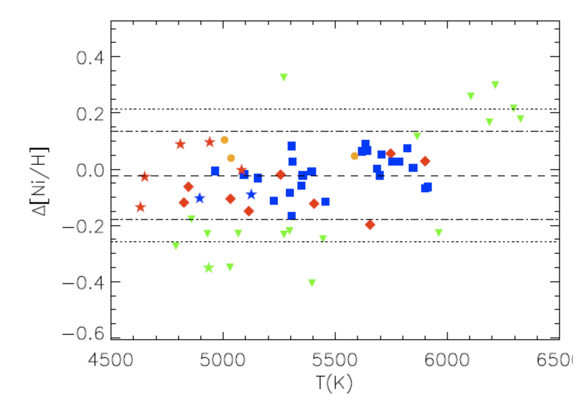
Elemental abundances for several chemical elements have been derived taking into account stellar parameters derived with ***StePar*** using high-resolution spectra of several samples of FGK stars possible members Stellar Kinematic Groups. **Differential abundances Δ[X/H]** are determined by comparison with a reference star known to be member of the analysed MG in a line-by-line basis. A first candidate selection within the sample has been determined by applying a 1-rms rejection for the Fe abundance results. In this way we have applied the ***chemical tagging*** method to test the common origin of these stars.

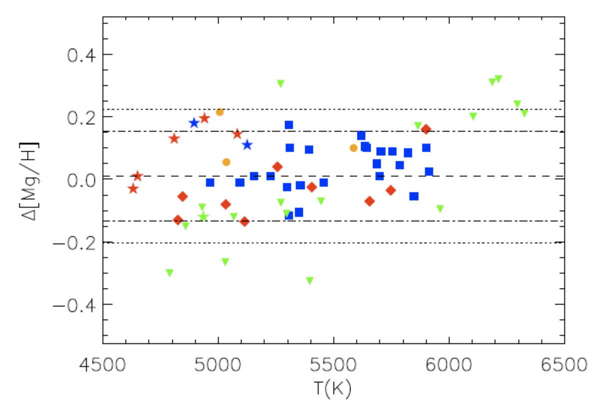
Chemical Tagging (HS)

Result of our abundance analysis of possible members of the **Hyades Super Cluster** (Tabernero, Montes, González Hernández, 2012A&A...547A..13T).

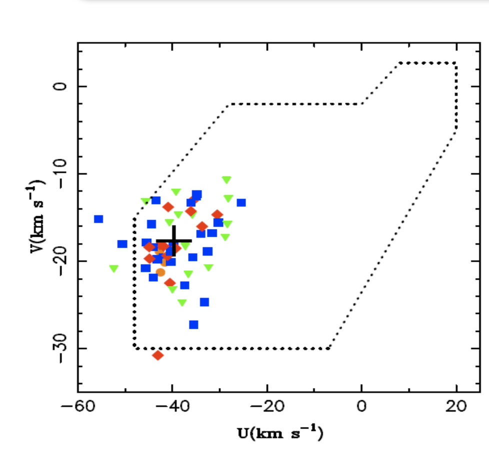


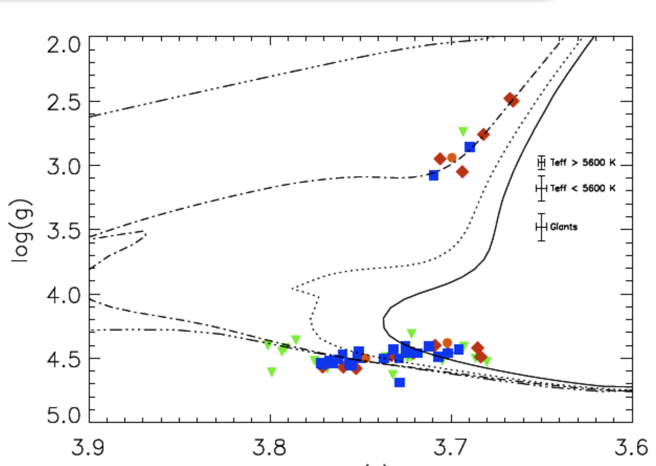
(15 - 28 stars of 61) **25 - 46%** of the sample are homogeneous in abundances for all the elements we have considered.





Chemically tagging the Hyades Supercluster.
A homogeneous sample of F6-K4 kinematically-selected northern stars*
H.M. Tabernero,[1] D. Montes[1] and J.I. González Hernández[1,2]





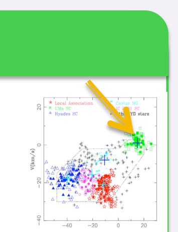
Blue squares are the final selected member stars. Red diamons are stars compatible with Hyades Fe abundance (but not for other elements), and the green ones not compatible. BZ Cet, V683 Per, and ε Tau Hyades cluster members stars are marked with orange circles.

U, V, W velocities for late-type stars candidate members of the Hyades Supercluster (Tabernero et al. 2012). The big blue cross indicates the core velocity of the Hyades Supercluster (Montes et al. 2001).

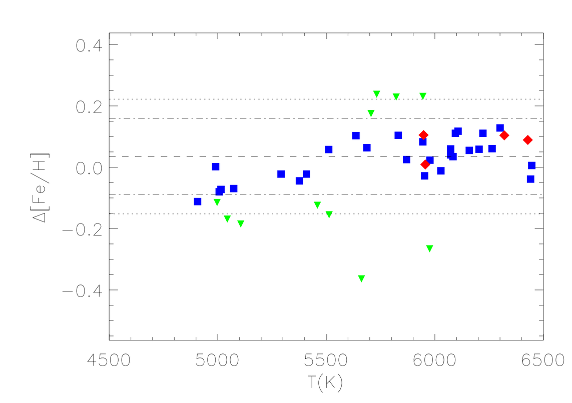
Spectroscopic log T_{eff} vs log g for the candidate stars. We have employed the Yale-Yondale ischrones (Demarque et al. 2004) for Z=0.025 and 0.1, 0.7, 4 and 13 Gyr (from left to right). Mean error bars are represented at the right bottom.

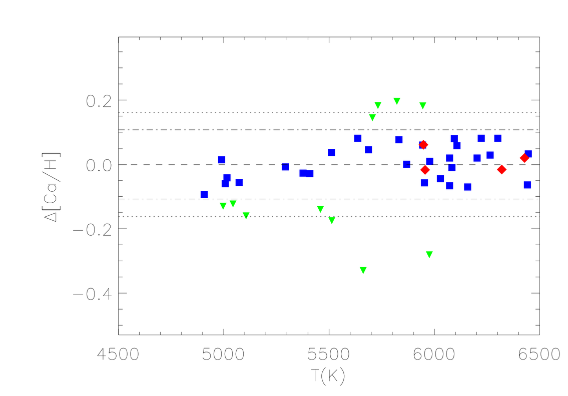
Chemical Tagging (UMa)

Result of our abundance analysis of possible members of the **Ursa Major moving group (UMa)** (Tabernero, Montes, González Hernández, Ammler-von Eiff, 2015, A&A, 2014arXiv1409.2348T).

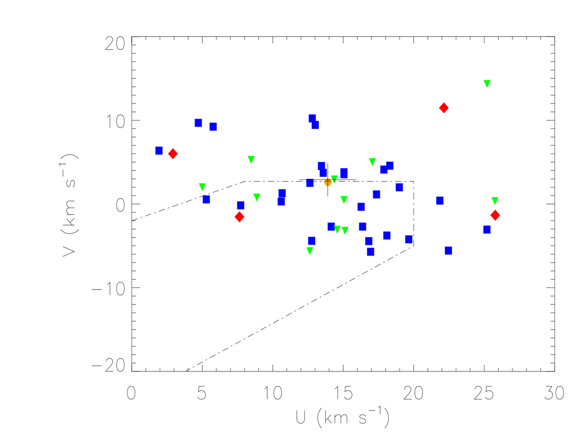


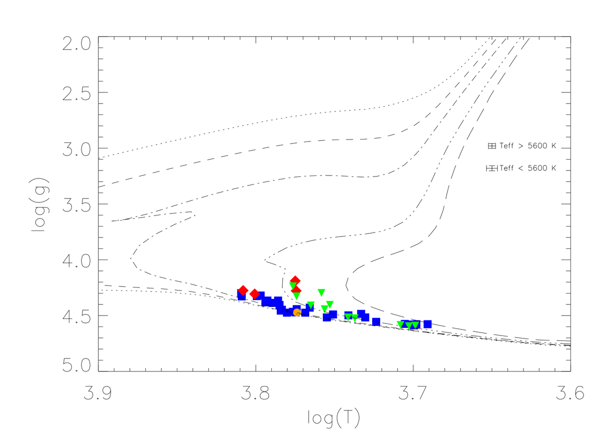
(29 stars of 44) **66%** of the sample are homogeneous in abundances for all the elements we have considered.





Chemical tagging of the Ursa Major moving group
A northern selection of FGK stars *
H.M. Tabernero[1], D. Montes[1], J. I. González Hernández[1, 2, 3], and M. Ammler-von Eiff[4]



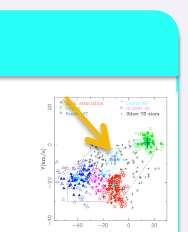


Blue points: Selected Candidates. Red points: Similar [Fe/H] only. Green points: Discarded stars. Orange point: Reference Star HD 115043

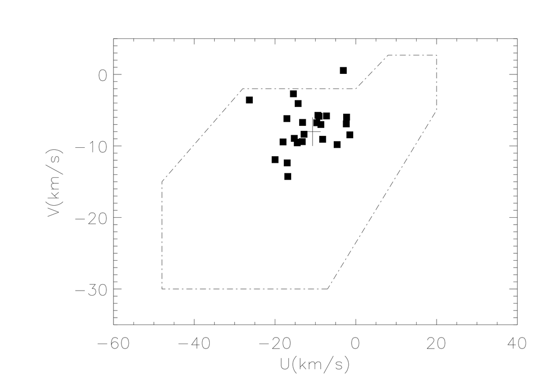
Our chemical tagging analysis indicates that the Ursa Major MG is **less affected by field star contamination** than other moving groups (such as the Hyades SC). We find a roughly solar iron composition for the finally selected stars, whereas the [X/Fe] ratios are roughly sub-solar except for super-solar Barium abundance.

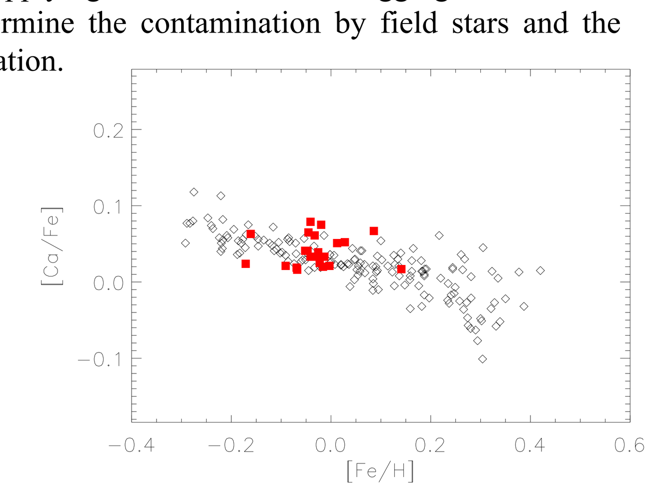
Chemical Tagging (Castor)

Preliminary result of our abundance analysis of possible members of the **Castor moving group** (Tabernero, Montes, González Hernández, 2015, in prep).



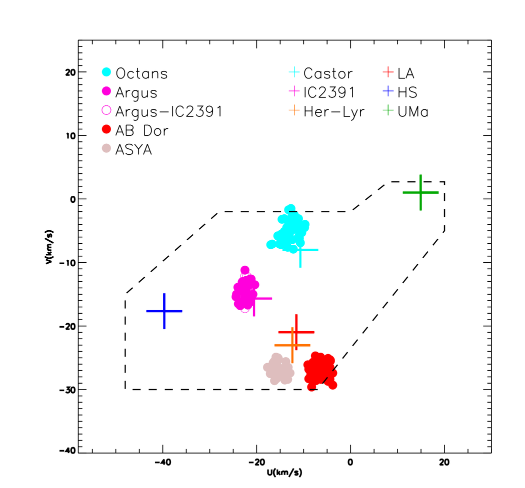
19 kinematically selected stars have been analysed until now, and the abundances results to be similar for many of then, we are applying the same chemical tagging method used for the HS and UMa in order to determine the contamination by field stars and the possible association with Octans association.

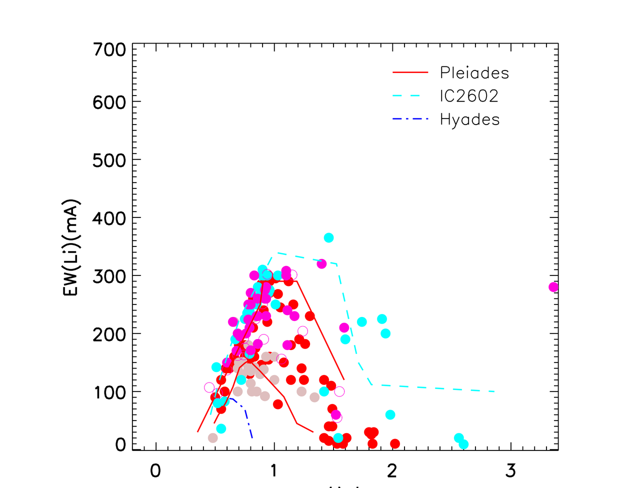




Chemical Tagging (other young MGs)

We plan to apply the chemical tagging method to other young MGs like the recently identified **ASYA** (**All Sky Young Association**, Torres Quats & Montes 2015) association and some of the oldest **SACY** (Search for Associations Containing Young Stars) associations like **Octans**, **Argus-IC2391**, and **AB Dor**.





Kine-chemical analysis of the FGK stars observed with GES (Gaia-ESO Survey)/UVES: Membership to the different MGs

- **Kinematic selection** of possible MGs members using the radial velocities provided by the survey, the astrometry available in the literature and an estimation of the distance using our derived spectroscopic stellar parameters (T_{eff}, log*g*, ξ and [**Fe/H**]).
- Detailed differential abundance analysis (**chemical tagging**).
- Additional information derived from the spectra (rotational velocities, Lithium abundance and chromospheric activity).

Name	S_{Tp}	T_{eff} (K)	log *g*	ξ (km/s)	[Fe/H]	[X/H]	Li	vsini (km/s)	V_r (km/s)	*UVW* (km/s)	Activity Hα,CaII…
HD 142267	G2V	5768 ±35	4.42 ±0.08	1.00 ±0.05	-0.38 ±0.03	…	…	…	…	…	…
HD 82885	G8V	5536 ±37	4.43 ±0.09	1.32 ±0.06	0.27 ±0.03	…	…	…	…	…	…
HD 3651	K0V	5282 ±45	4.35 ±0.10	1.16 ±0.08	0.11 ±0.03	…	…	…	…	…	…

Kine-chemical

Allowed us to confirm the membership to each MG and in this way discern between real physical structures of coeval stars with a **common origin** (debris of star-forming aggregates in the disk) and **field-like stars** (structures formed by resonance interactions, associated with dynamical resonances (bar) or spiral structure).

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