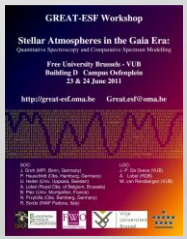
High resolution spectroscopy of nearby FGK stars: stellar parameters and chemical tagging

David Montes et al.

Dpto. Astrofísica, F. Físicas

Universidad Complutense de Madrid, UCM,

Madrid, Spain



GREAT-ESF Stellar Atmospheres in the Gaia Era Workshop

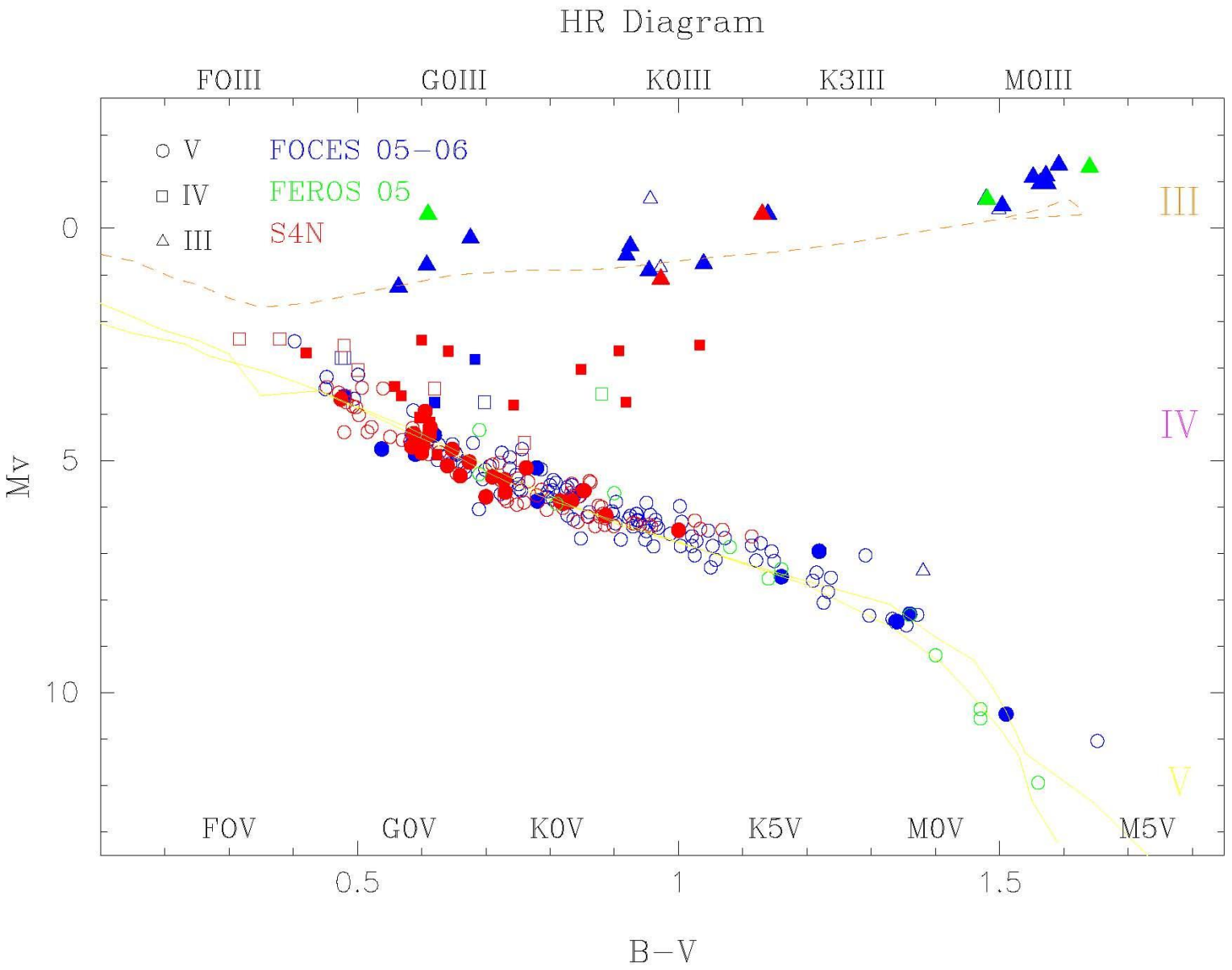
Quantitative Spectroscopy and Comparative Spectrum Modelling

23-24 June at the Vrije Universiteit Brussel (VUB)

Collaborators

Universidad Complutense Madrid	*Dpto. Astrofísica, F. Físicas* ***Universidad Complutense de Madrid, UCM***	**David Montes,** **Alexis Klutsch,** **Hugo M. Tabernero,** **F. Javier Alonso-Floriano,** **Raquel M. Martínez-Arnáiz,** **Javier López-Santiago.**
	CAB (Centro de Astrobiologia) Madrid	**José Antonio Caballero.**
	IAC (Instituto de Astrofísica de Canarias)	**Jonay I. González Hernández.**
UAM UNIVERSIDAD AUTONOMA DE MADRID DUNES	***Universidad Autónoma de Madrid, UAM*** ***CAB (Centro de Astrobiologia) Madrid***	**Carlos Eiroa,** **Jesús Maldonado.** **Benjamín Montesinos,** **and DUNES team.**
UNIVERSITÉ DE STRASBOURG Observatoire astronomique de Strasbourg INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS	**Observatoire Astronomique,** **Université de Strasbourg** **Osservatorio Astrofisico di Catania**	**Patrick Guillout,** **Rubens Freire Ferrero,** **F.-X. Pineau,** **N. Grosso,** **Antonio Frasca,** **Ettore Marilli.**

Nearby FGK stars



Nearby FGK stars

High resolution *échelle* spectra

R= 85000 – 22000 (0.08-0.3 Å) – Different échelle spectrographs

Observations:

WHT-**UES**,

2.2m-**FOCES**,

NOT-**SOFIN**,

INT-**MUSICOS**,

TNG-**SARG**,

HET-**HRS**,

NOT-**FIES**,

2.2m ESO- **FEROS**

Mercator-**HERMES**

From archives:

3.5m ESO-**HARPS**,

VLT ESO-**UVES**,

OHP - **ELODIE,**

MacDonald - **2dcoudé** (S4N)

2.2m ESO- **FEROS** (S4N)

Nearby FGK stars

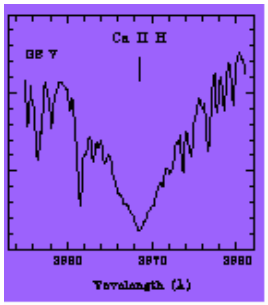
Libraries of high resolution spectra of cool stars

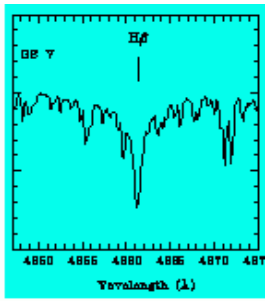
1997- 1999 - 329 FGKM stars

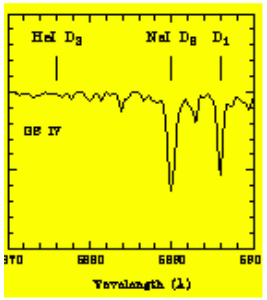
1) Montes et al. 1997, A&ASS, 123, 473;
Intermediate-resolution (0.2-3 Å) CaII H&K, Hβ, NaI D_1, D_2 & HeI D_3, Hα 170 spectra, 116 stars (V, IV, III)

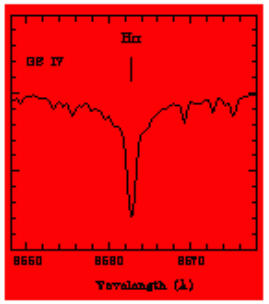
2) Montes & Martín 1998, A&ASS, 128, 485;
High-resolution (0.09-0.19 Å) *echelle* (4800 – 10600 Å) 105 spectra, 83 stars (V)

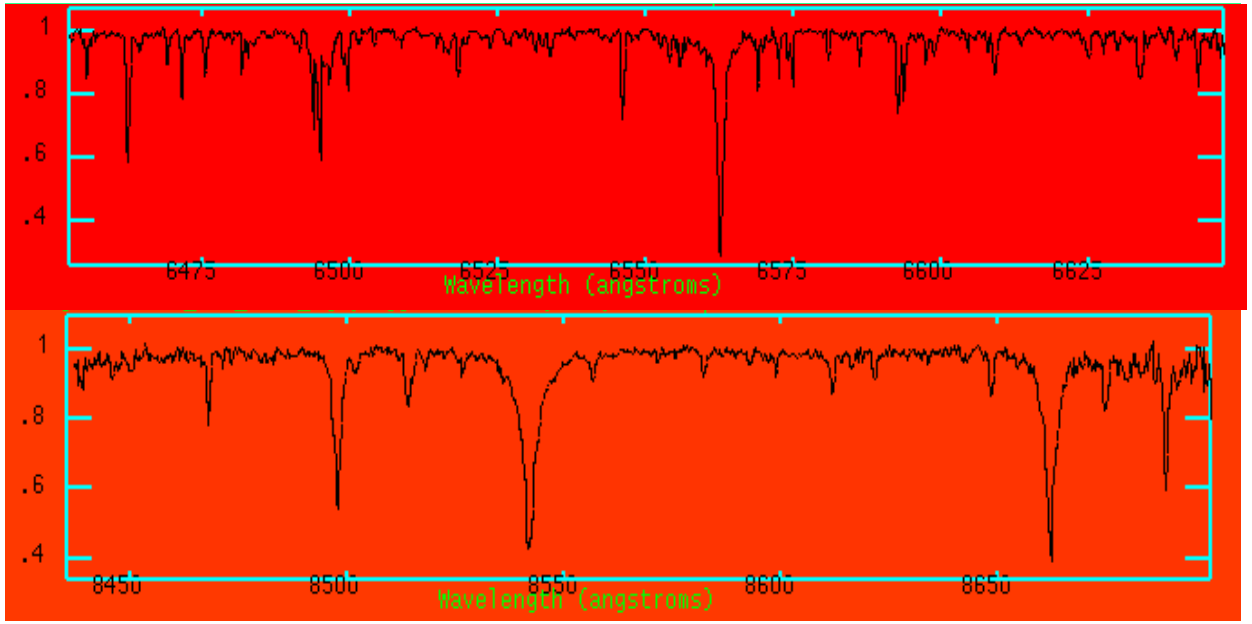
3) Montes, Ramsey & Welty 1999, ApJS, 123, 283;
intermediate resolution (0.5 Å) *echelle* (3900 – 9000 Å) 345 spectra, 130 stars (V, IV, III, II, I)











http://www.ucm.es/info/Astrof/invest/actividad/spectra.html

Nearby FGK stars

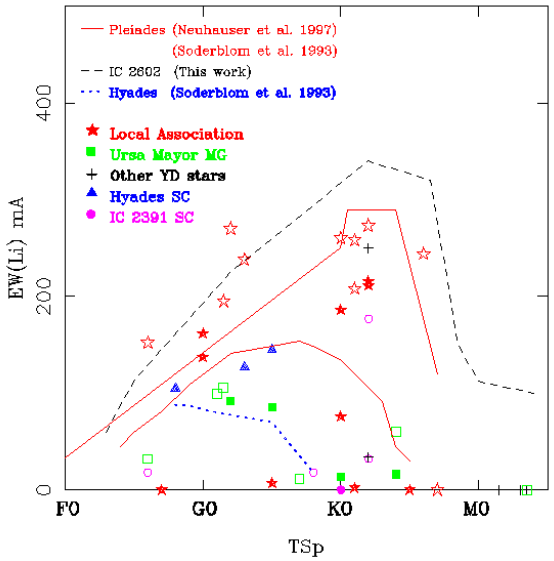
★ Survey late-type stars in Moving Groups (MGs)

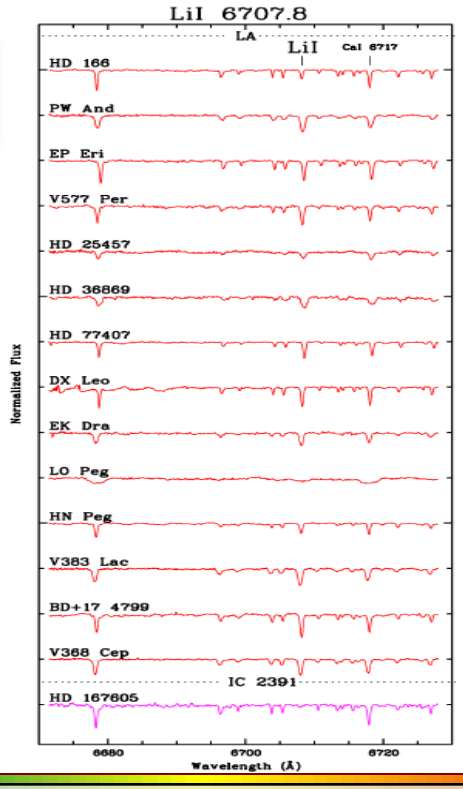
1999- 2002 - 144 FGKM stars

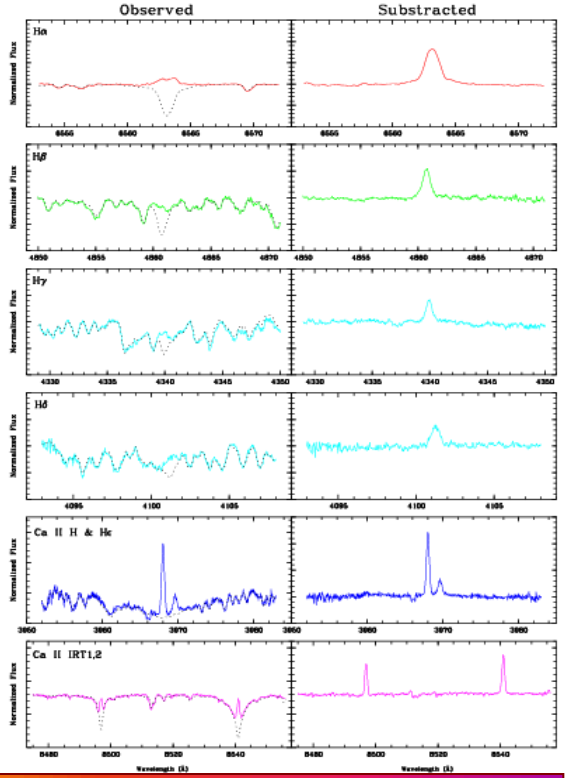
- **Montes et al.** 2001, A&A, 379, 976;
- **López-Santiago et al.** 2005, PhD Thesis UCM;
2006, ApJ, 643, 1160; 2009, A&A, 499, 129; 2010, A&A, 514, A97

A high-resolution spectroscopic survey of late-type stars: chromospheric activity, rotation, kinematics, and age★,★★

J. López-Santiago[1], D. Montes[1], M. C. Gálvez-Ortiz[2], I. Crespo-Chacón[1], R. M. Martínez-Arnáiz[1], M. J. Fernández-Figueroa[1], E. de Castro[1], and M. Cornide[1]







http://www.ucm.es/info/Astrof/invest/actividad/skg/skg_SS.html

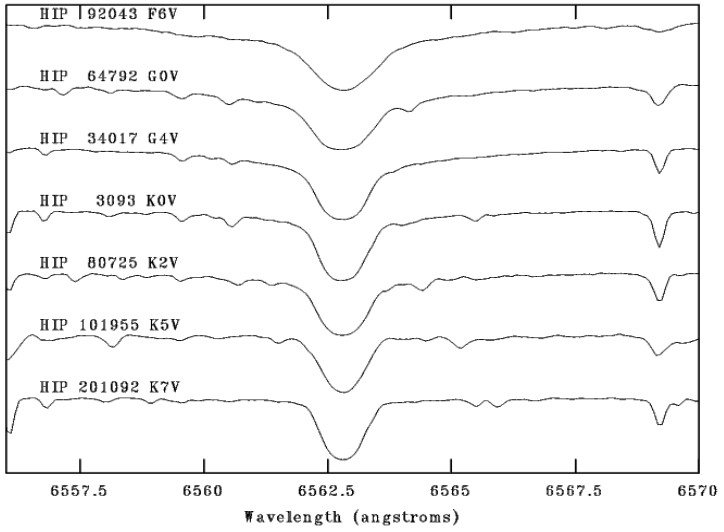
Nearby FGK stars

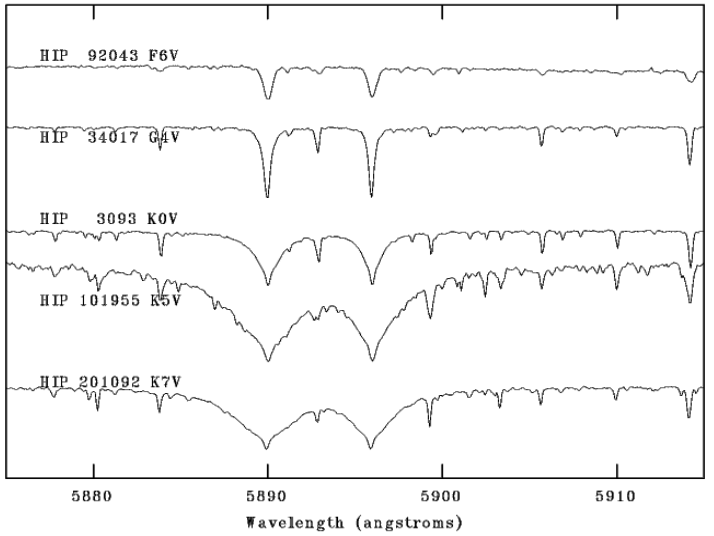
★ Survey of FGK stars in the solar neighbourhood

(d < 25 pc), including the DUNES sample

2005- 2009 – 450 FGKM stars

- **Martínez-Arnáiz et al.** 2010, A&A, 520, A79; 2011, MNRAS, in press, 2011, PhD Thesis UCM;
- **Maldonado et al.** 2010, A&A, 521, A12





FGK stars in the solar neighbourhood (d < 25 pc) which include the DUNES sample, an approved Herschel OTKP with the aim of detecting cool faint dusty disks (Eiroa et al. 2010).

DUNES
Dust around Nearby Stars

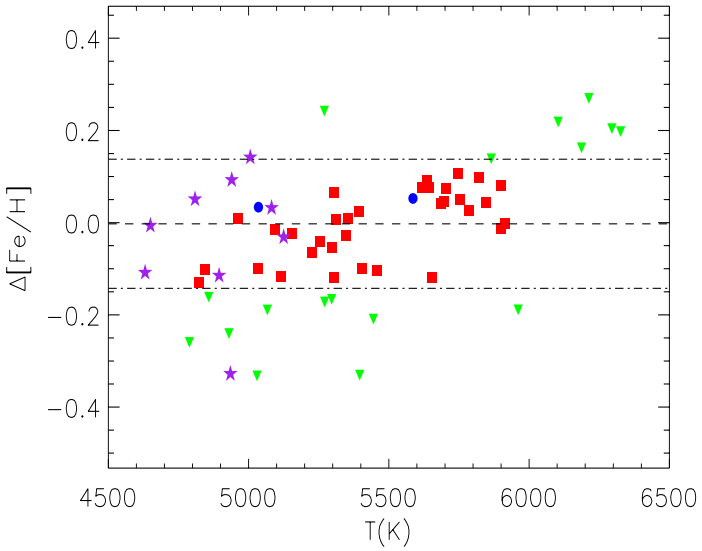
Nearby FGK stars

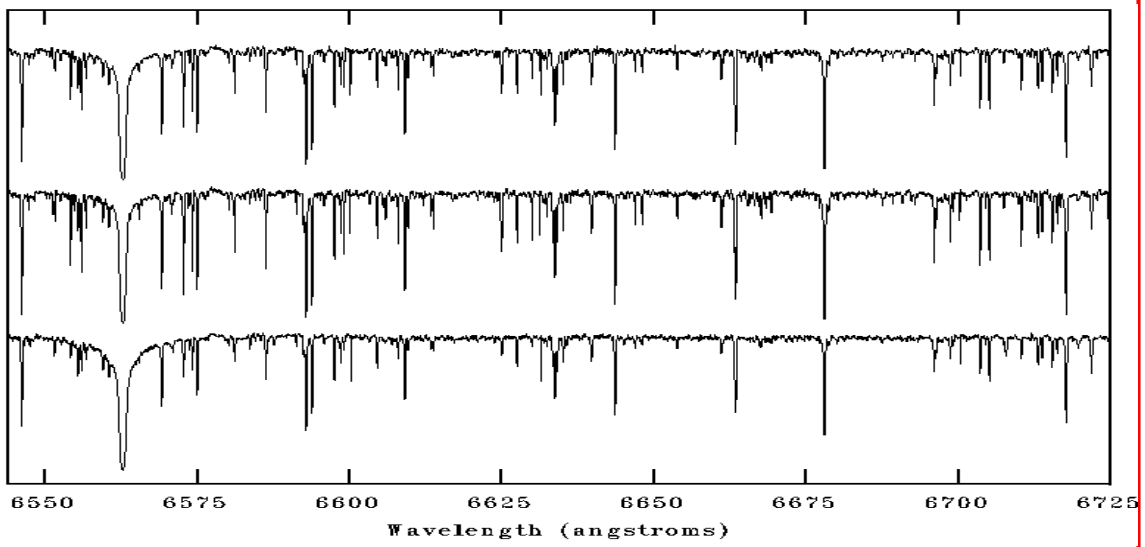
★ **Survey for Chemical Tagging of FGK stars in MGs**

Hyades and Ursa Major MGs

2010- 2011 – 61 F6-K4 stars

- **Tabernero, Montes, González Hernández** 2010, CS16;
- **Tabernero, Montes, González Hernández** 2011, A&A, submitted





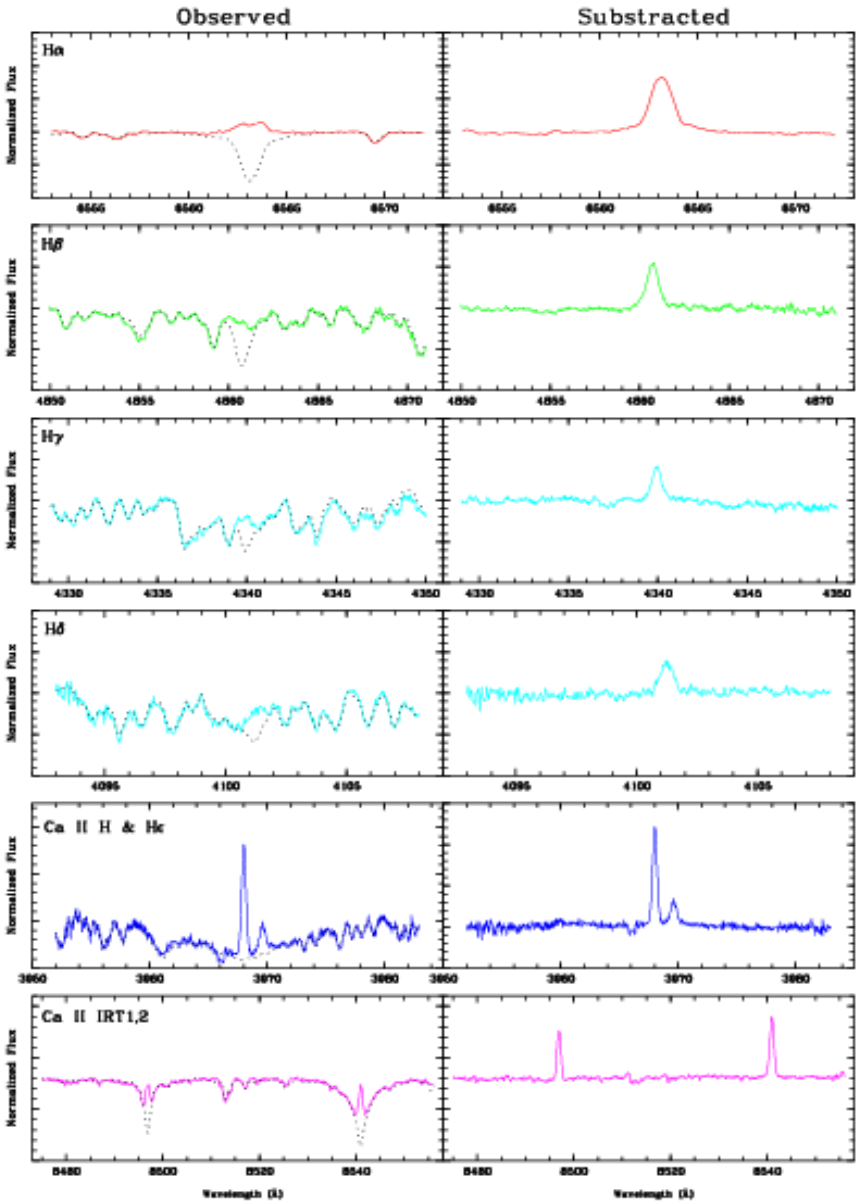
Chemically tagging the Hyades Supercluster.

A homogeneous sample of F6-K4 kinematically-selected northern stars★

H.M. Tabernero,[1] D. Montes[1] and J.I. González Hernández[1,2]

Spectroscopic Analysis

- **Kinematics (U, V, W).**
  - Radial velocity (Vr)
- **Age** (LiI 6707.8Å).
- **Chromospheric activity**
  - CaII H&K to CaII IRT
- **Rotation** (*v*sen*i*).
  - Activity – rotación relation
- **Stellar parameters**.
  - T_{eff}, log g, ξ and **[Fe/H]**
- **Absolute and differential abudances**.
  - Chemical tagging



Stellar parameters

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

StePar (Tabernero Montes, González Hernández 2011):

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

- The EW determination of the Fe lines with the ARES code (Sousa et al. 2007).
- 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)**).

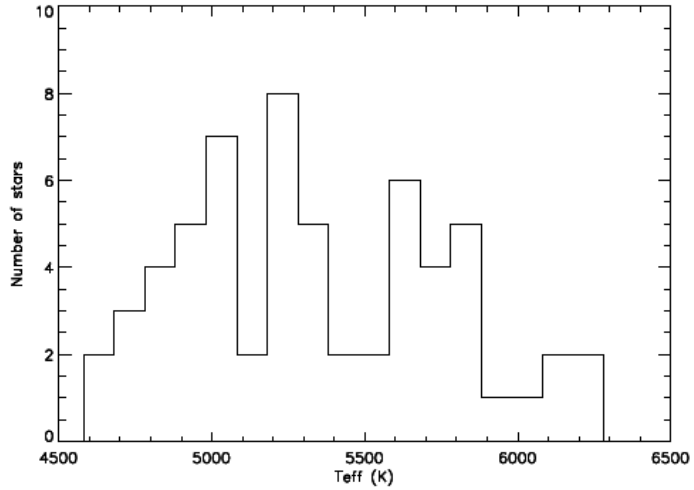
- 2-σ rejection of Fe I and Fe II lines after a first determination of the parameters

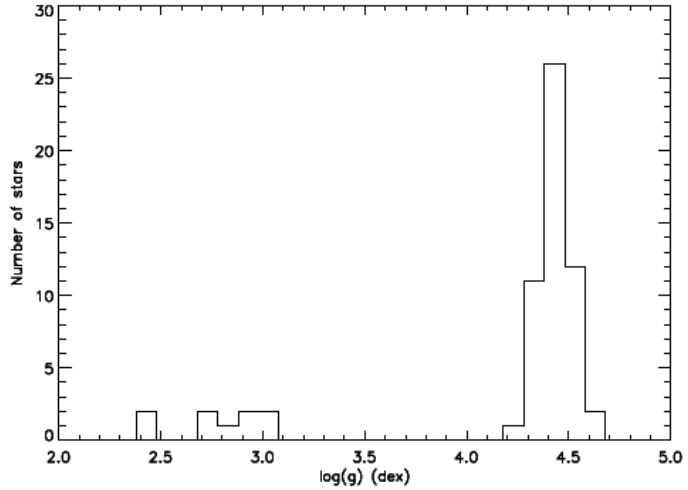
- **Limitations**: spectral types F6 to K4, slow rotators, no veiling.

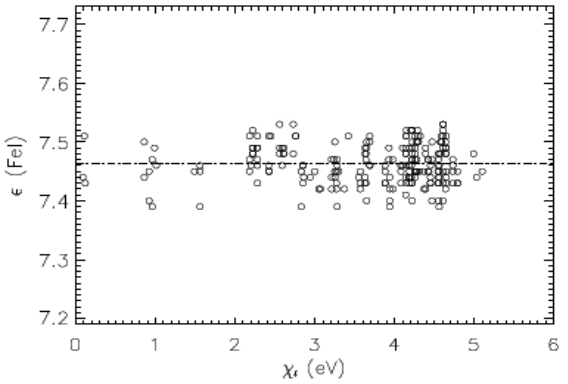
Stellar parameters

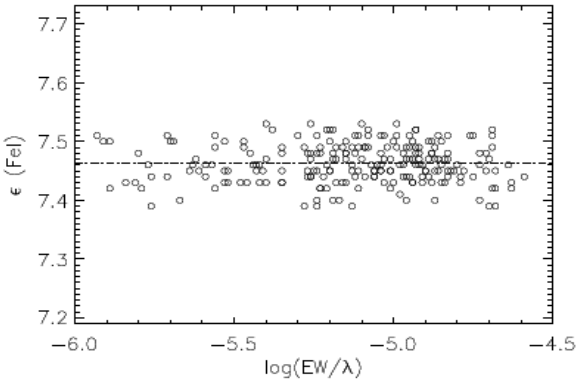
T_{eff}, log g, ξ and [Fe/H]

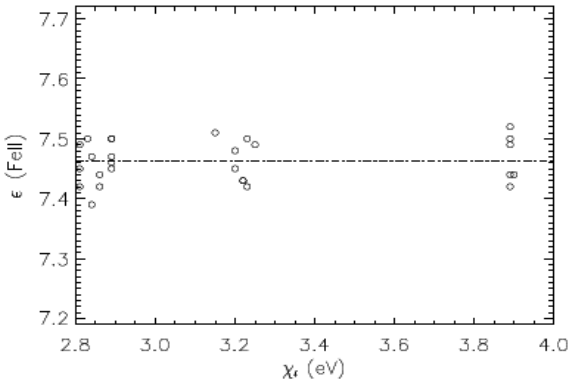
StePar (Tabernero Montes, González Hernández 2011):











Chemical abundances

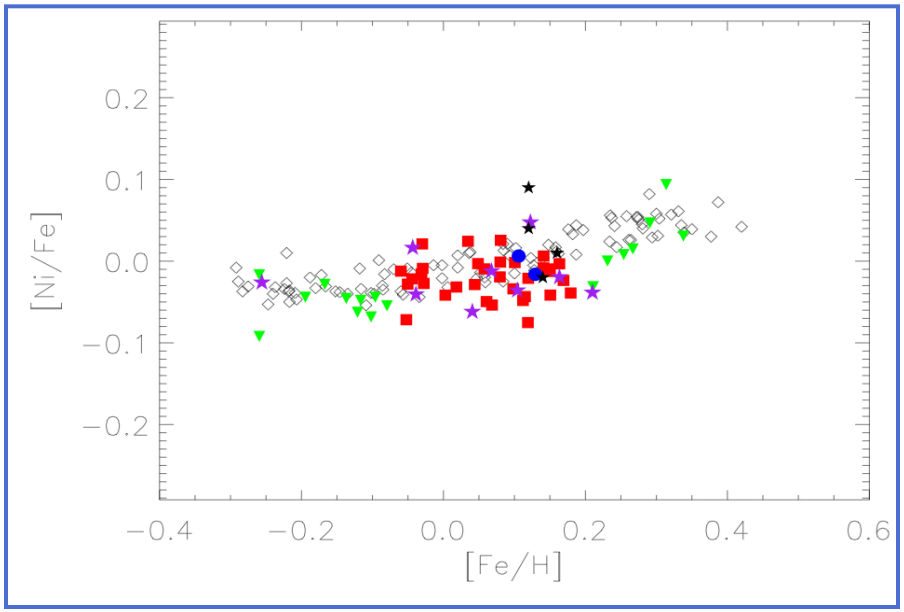
Fe, Na, Mg …..

Fe, Na, Mg, Al, Si, Ca, Sc, Ti, V, Cr, Mn, Co, and Ni

- **EW** method in a line-by-line basis with *ARES* code (Sousa et al. 2007).

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

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



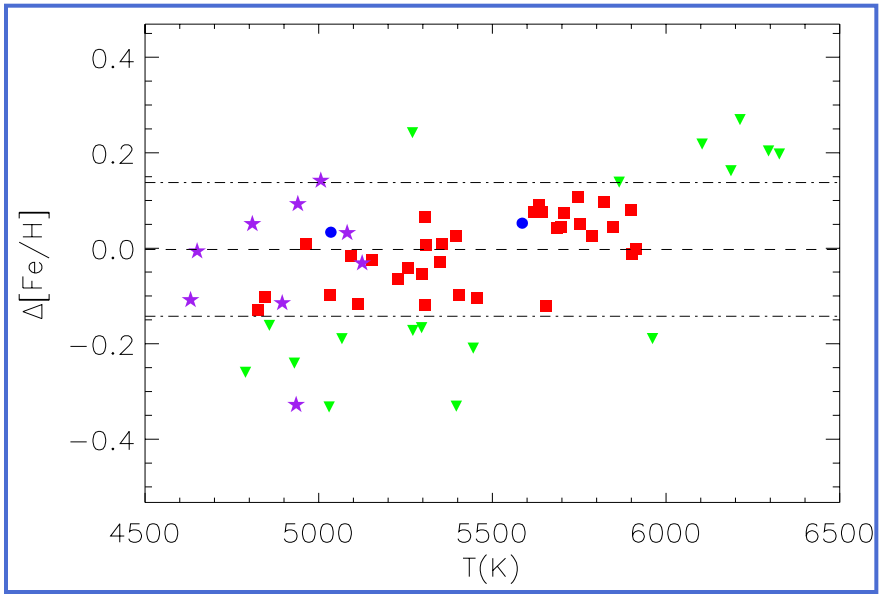
[Ni/Fe] vs [Fe/H]: open diamonds represent the thin disk data (González Hernández et al. 2010), black filled triangles represent Hyades cluster data (Paulson et al. 2003). Red points are our stars compatible with Hyades Fe abundance, and the green ones not compatible. BZ Cet and HD19902 Hyades cluster members are marked with blue circles. Purple starred points represent the giant stars. Black starred points are the candidates selected stars in De Silva et al. (2011), black circles are those selected in Pompéia et al. (2011).

Differential abundances

Differential abundances Δ[X/H]

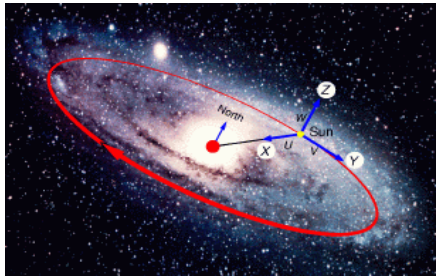
- determined by comparison with a reference star known to be member of the Hyades cluster (**vB 153**) in a line-by-line basis (Paulson et al. 2003 and De Silva et al. 2006).

-A first candidate selection within the sample has been determined by applying a 1-rms rejection for the **Fe** abundance results. In this subsample another 1-rms diagnostic has been applied in order to prove homogeneity in each element.



Δ[Fe/H] differential abundance vs T_{eff}. Dashed-dotted lines represent 1-rms level for the Hyades cluster. The dashed line represents the median abundance. Red points are accepted as a preliminary selection of candidates, while green ones are rejected. The Hyades cluster member BZ Cet and HD19902 are marked with **blue points**. Purple starred points represent the giant stars.

Stellar Kinematics Groups

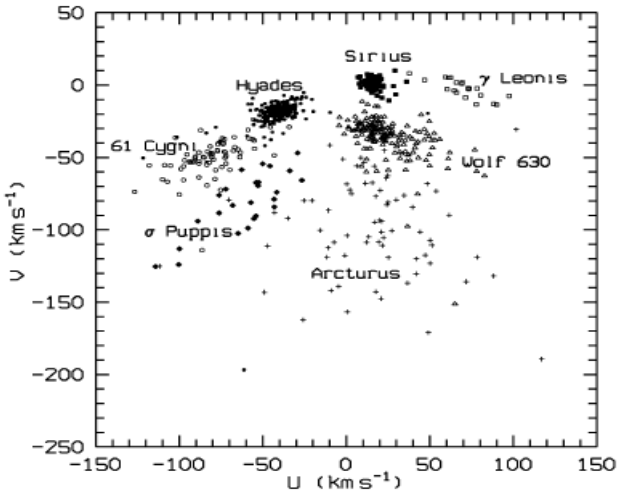


- **Moving group (Supercluster)** Eggen (1994)

Group of stars gravitationally unbound that share the same kinematics and may occupy extended regions in the Galaxy

Origin:

- the evaporation of an open cluster
- the remnants of a star formation region,
- a juxtaposition of several little star formation bursts

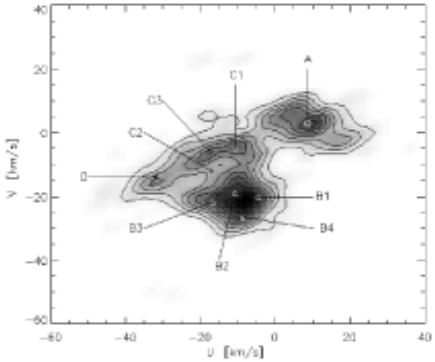


- **Boettlinger diagram:**
  - (U, V) & (U, W)

Factors against the persistence of MG:

- the **Galactic differential rotation** (tends to spread the stars)
- the **disc heating** (velocity dispersion of disc stars)

- **HIPPARCOS data:**
  - Confirm the existence of classical young MGs (and some old MGs).
  - Large velocity dispersion.
  - Detect finer structures in space velocity and age that in several cases can be related to kinematics properties of nearby open clusters or associations.



Stellar Kinematics Groups

Classical Young Moving Groups

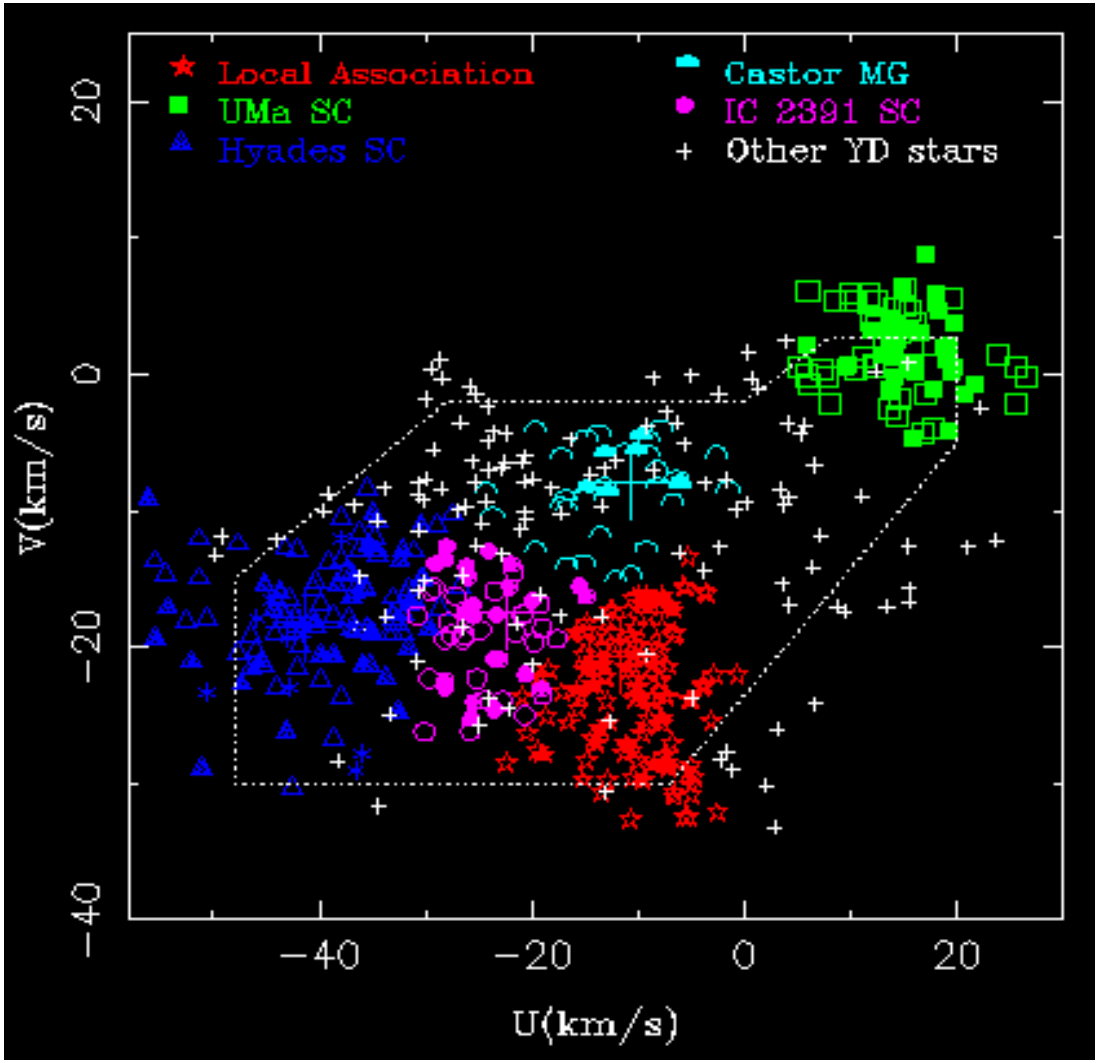
Name	Clusters	Age (Myr)	U (km/s)	V (km/s)	W (km/s)
Local Association (Pleiades moving group) (Stream 0)	Pleiades (M45, Melotte 22) α Persei (Melotte 20) M34 (NGC 1039) delta Lyr (Stephenson 1) NGC 2516 (Mel 82) IC 2602 (theta Carinae)	20 - 300	-11.6	-21.0	-11.4
Hercules-Lyra	-	150 - 300	-15.4	-23.4	
IC 2391 supercluster	IC 2391 (o Velorum)	35 - (80 - 250)	-20.6	-15.7	-9.1
Castor Moving Group	-	~200	-10.7	-8.0	-9.7
Ursa Major group (Sirius supercluster) (Stream II)	Ursa Major (Collinder 285) M39 (NGC 7092)?	300 - 500	+14.9	+1.0	-10.7
Hyades supercluster (Stream I)	The Hyades (Melotte 25) Praesepe (M44) NGC 1901 (Bok 1)	~650	-39.7	-17.7	-2.4

http://www.ucm.es/info/Astrof/invest/actividad/skg/skg.html

The youngest (age < 650 Myr) and best documented moving groups (MG) in the solar vicinity are the Hyades, Ursa Major (UMa), Local Association (LA), IC 2391 and Castor (see Montes et al. 2001 MNRAS.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. 2006 ApJ...643.1160).

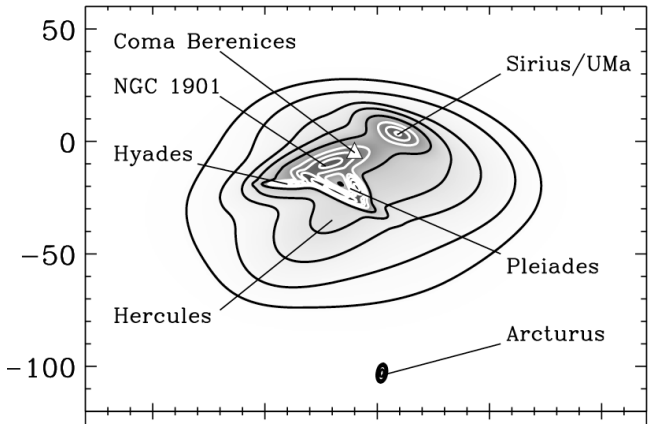
Stellar Kinematics Groups

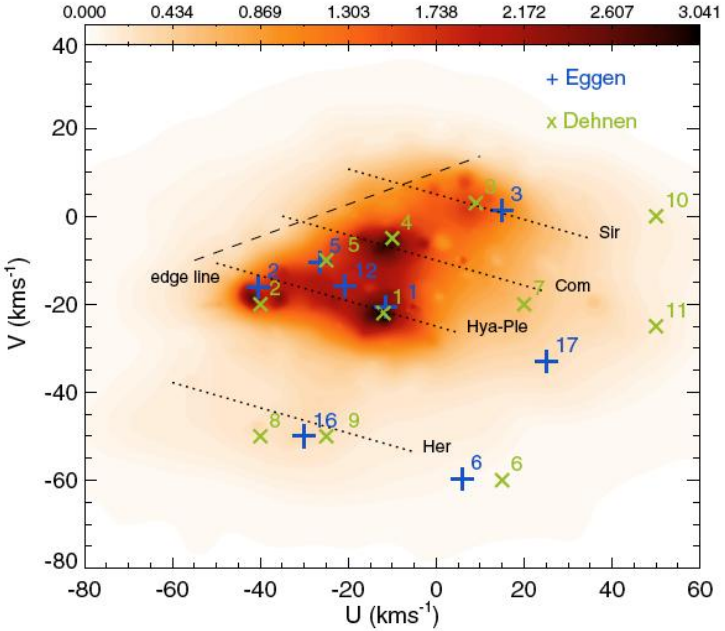
Classical Young Moving Groups

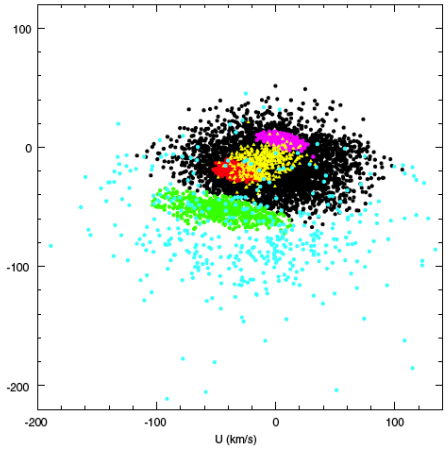


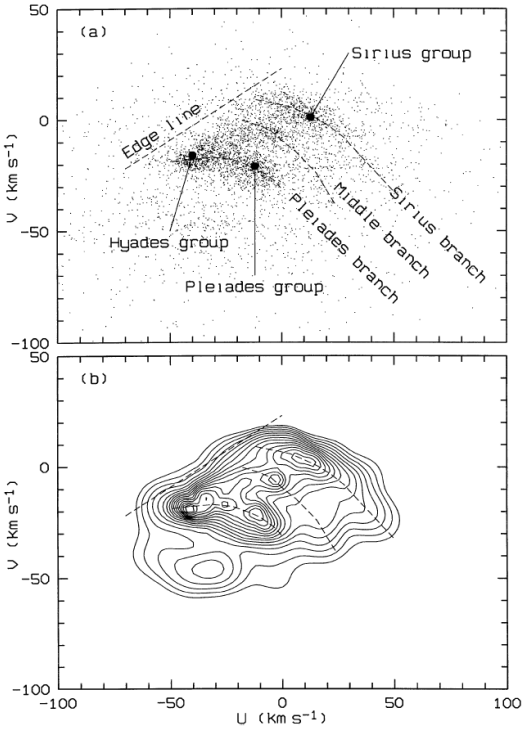
Montes et al. 2001 MNRAS.328...45

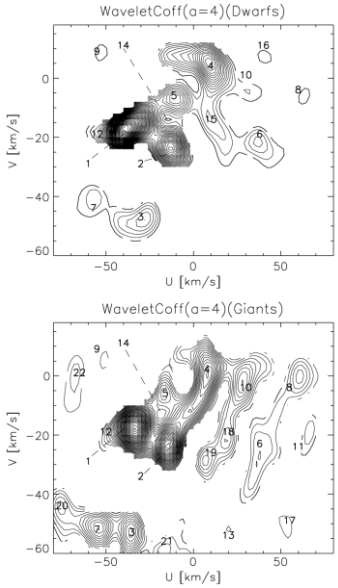
Stellar Kinematics Groups

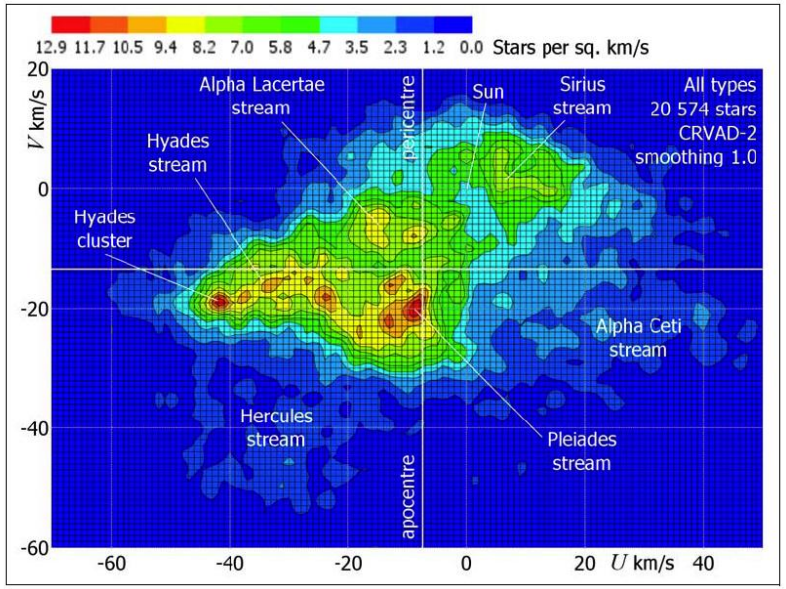












Stellar Kinematics Groups

Possible origin of the Stellar Kinematics Groups

• Several studies conclude that those regions of the UV-plane consist of both field-like stars and young coeval ones.

Famaey et al. 2005, 2007, 2008;
Antoja et al. 2008;
Klement et al. 2008;
Francis & Anderson 2009;
Zhao et al. 2009.

• High resolution spectra is needed for discerning between:

- **field-like stars** (associated with dynamical resonances (bar) or spiral structure).

- **young coeval stars** (debris of star-forming aggregates in the disk).

Chemical Tagging

The detailed analysis of the chemical signatures chemical tagging is another powerful method that provide clear constrains to the membership to these structures.

In **open clusters** (Hyades, Collinder 261)
(Pauson et al. 2003, De Silva et al. 2006, 2007a, 2009)
high levels of chemical homogeneity showing that chemical information is preserved within the stars and possible effects of any external sources of pollution are negligible.

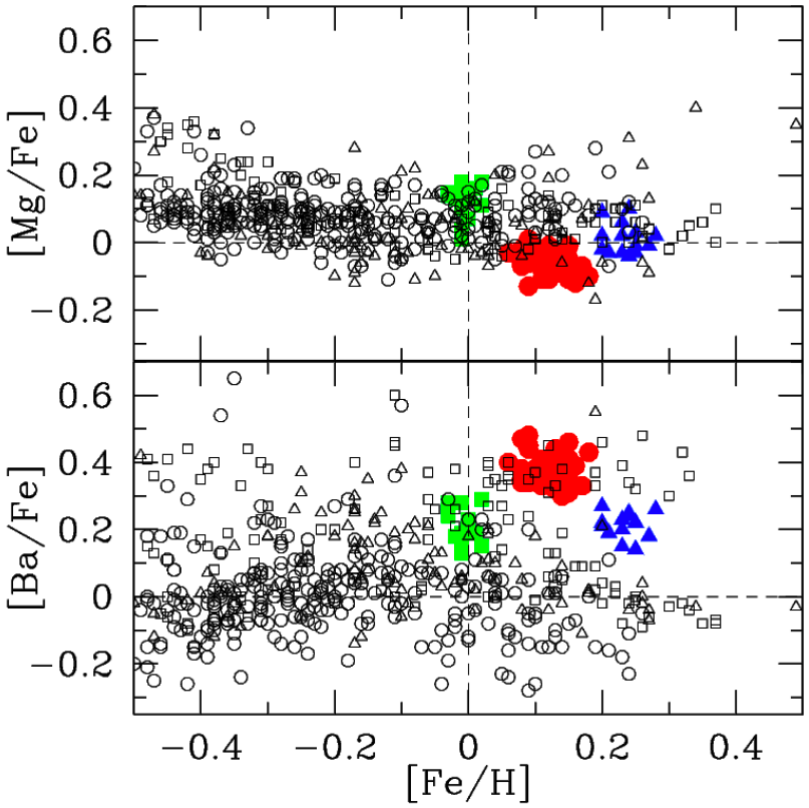


Figure from De Silva et al. (2009) sowing the abundances of **HR1614** MG stars (De Silva et al. 2007b, **triangles**) compared to the **Hyades** (De Silva et al. 2006, **circles**) and **Collinder 261** (De Silva et al. 2007a, **squares**) open clusters. The smaller open symbols represent background field stars (Reddy et al. 2003; Allende Prieto et al. 2004; Edvardsson et al. 1993). The dotted lines mark the solar value.

Chemical Tagging

* In **old stellar kinematic groups**

- **Hercules stream** (Bensby et al. 2007) which stars show different ages and chemistry (associated with dynamical resonances (bar) or spiral structure) .

- **HR 1614** (De Silva et al. 2007b, 2009) that appears to be a true MG (debris of star-forming aggregates in the disk).

- **Wolf 630** (Bubar & King, 2010) confirm the existence of an abundance homogeneous subsample of 19 stars that could represent a dispersed cluster with an [Fe/H] = -0.01 and an age of 2.7 Gyr.

* Very recently in **young kinematics groups**

- **Hyades Supercluster**, Pompéia et al. (2011) study a sample of 21 kinematically selected stars and De Silva et al. (2011) analyses 26 southern giant candidates. Found 10 % and a 15 % membership respectively .

Chemical Tagging

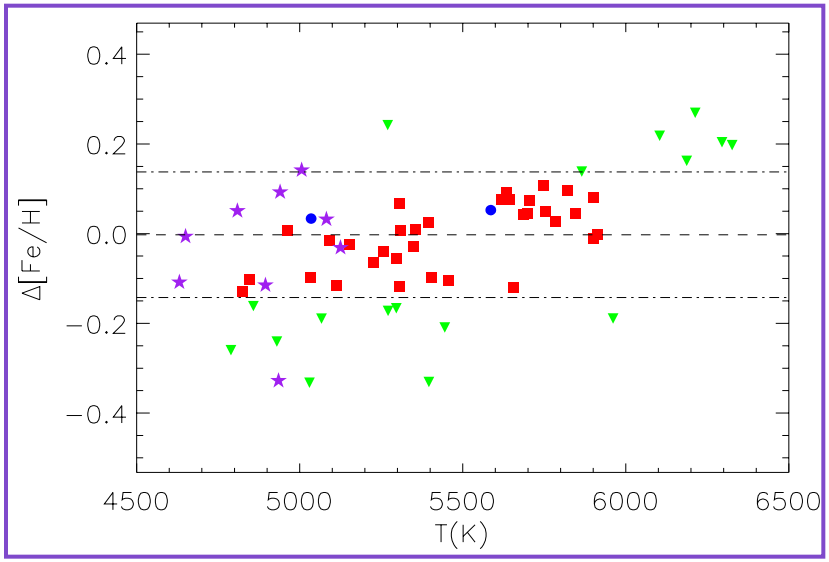
Tabernero, Montes, González Hernández

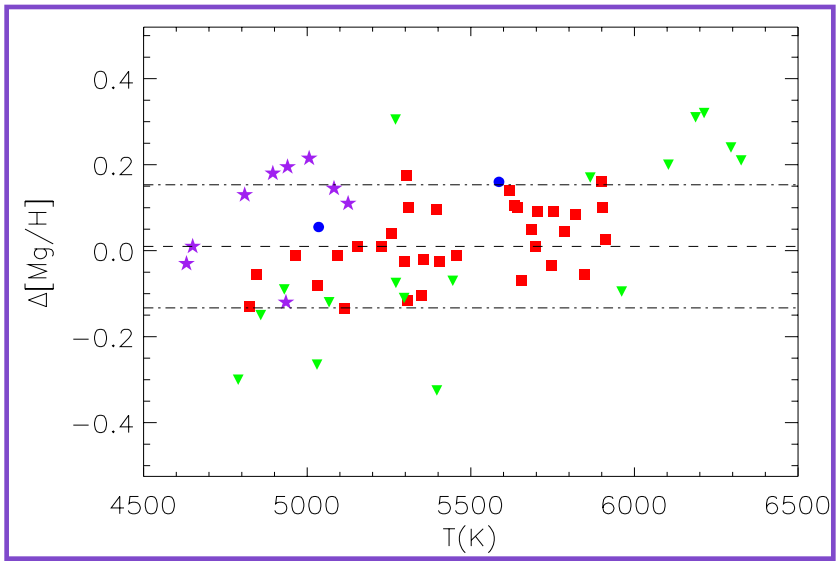
Result of our abundance analysis of possible members of the **Hyades Super Cluster** (Tabernero, Montes, González Hernández, 2011).

New high-R observations:
(January, May, and November 2010)
1.2 m Mercator Telescope
HERMES spectrograph
R = 85000.

92 stars were observed.
61 single main sequence stars (F6 to K4) have been analyzed.

41% of the ample are homogeneous in abundances for all the elements we have considered, 5 stars fail to be homogeneous in one element.

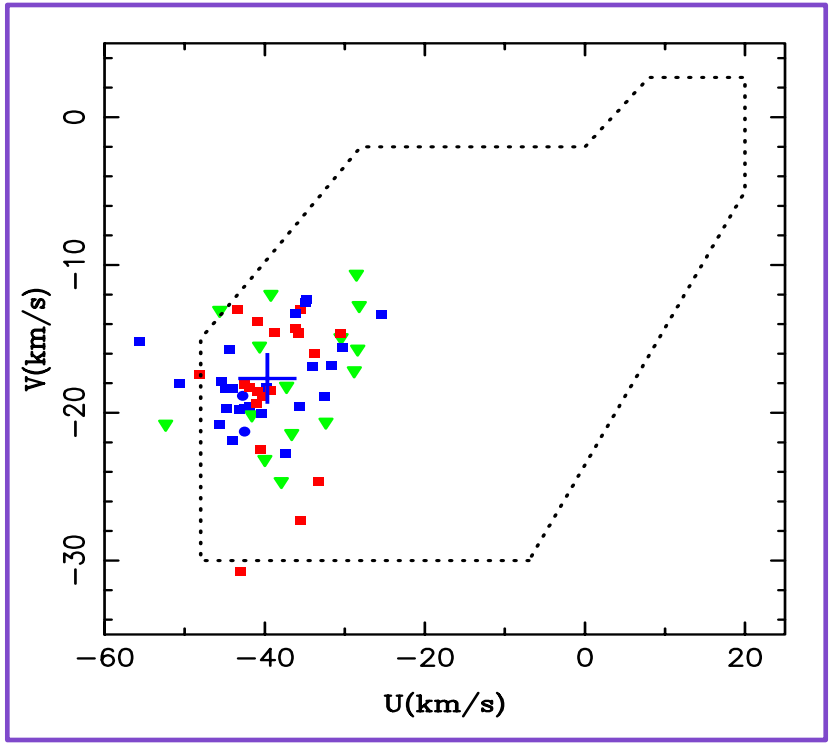


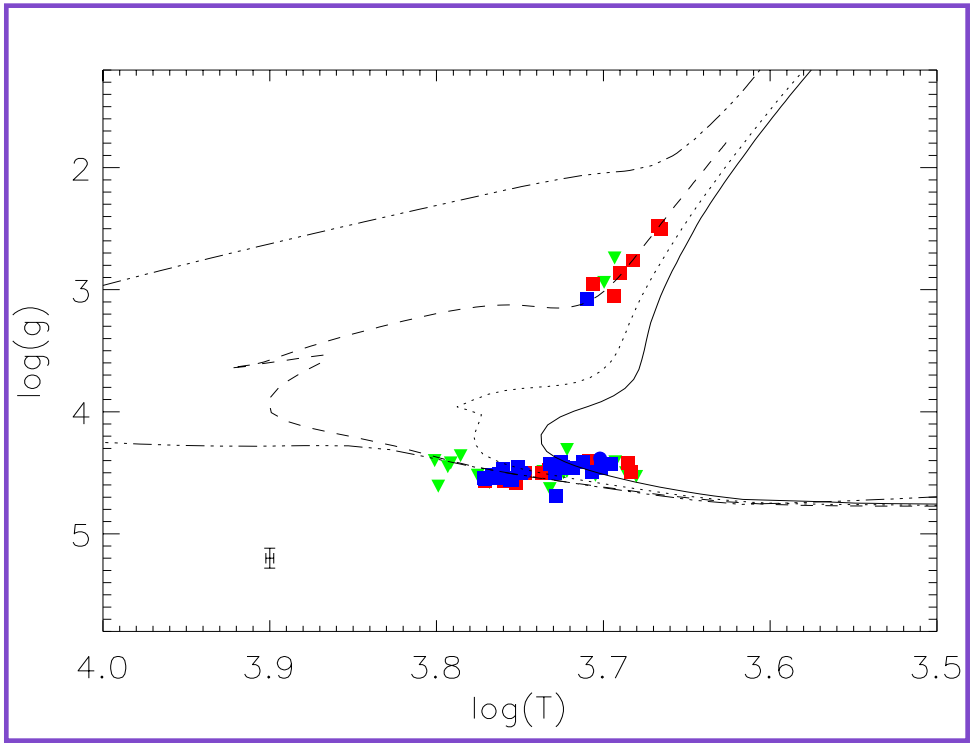


Chemical Tagging

Tabernero, Montes, González Hernández

Result of our abundance analysis of possible members of the **Hyades Super Cluster** (Tabernero, Montes, González Hernández, 2011).





Blue points are the final selected member stars. Red points are stars compatible with Hyades Fe abundance (but not for other elements), and the green ones not compatible. BZ Cet and HD 19902 Hyades cluster members are denoted with circle blue points.

U, V, W velocities for late-type stars candidate members of the Hyades Supercluster (Tabernero et al. 2011). 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.

Summary

Nearby FGK stars

David Montes et al.

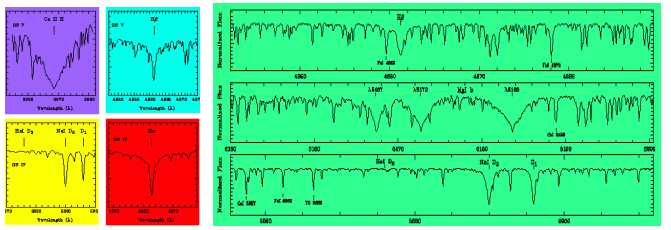
High resolution *echelle* spectra, R= 85000 – 22000 (0.08-0.3 Å)

WHT-**UES**, 2.2m-**FOCES**, NOT-**SOFIN**, INT-**MUSICOS**, TNG-**SARG**, HET-**HRS**, NOT-**FIES**, Mercator-**HERMES**

★ Libraries of high resolution spectra of cool stars

1997- 1999 - 329 FGKM stars

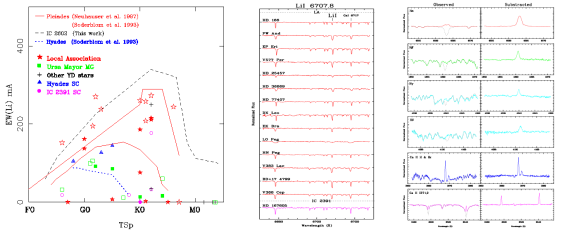
Montes et al. 1997, A&ASS, 123, 473;
Montes & Martín 1998, A&ASS, 128, 485;
Montes, Ramsey & Welty 1999, ApJS, 123, 283



★ Survey late-type stars in Moving Groups (MGs)

1999- 2002 - 144 FGKM stars

Montes et al. 2001 A&A, 379, 976;
López-Santiago et al. 2005, PhD Thesis UCM;
2006 ApJ, 643, 1160; 2009 A&A, 499, 129; 2010 A&A, 514, A97

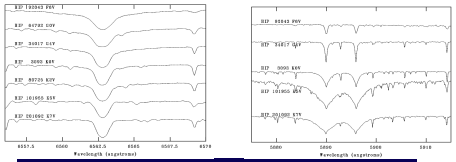


★ Survey of FGK stars in the solar neighborhood

(d < 25 pc), including the DUNES sample

2005- 2009 – 450 FGKM stars

Martínez-Arnáiz et al. 2010, A&A, 520, A79; 2011, MNRAS, in press, 2011, PhD Thesis UCM;
Maldonado et al. 2010, A&A, 521, A12



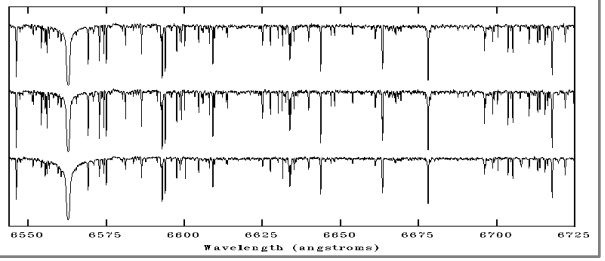
DUNES
Dust around Nearby Stars

★ Survey for Chemical Tagging of FGK stars in MGs

Hyades and Ursa Major MGs

2010- 2011 – 61 F6-K4 stars

Tabernero, Montes, González Hernández 2010, CS16;
Tabernero, Montes, González Hernández 2011, A&A, submitted



Plan to make available all the spectra and derived parameters in the VO

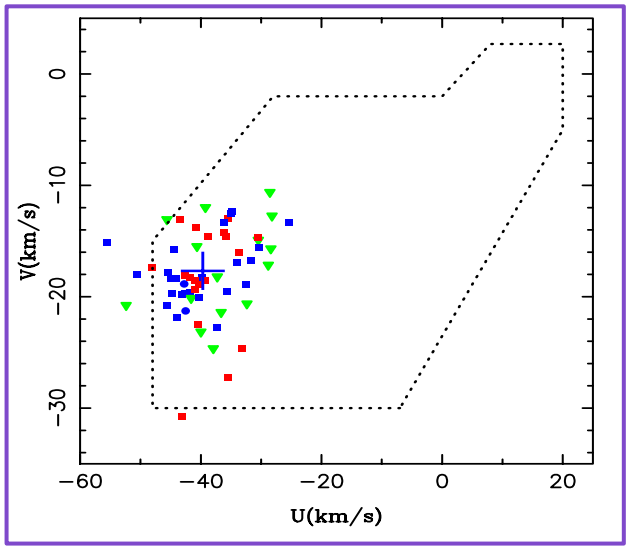
Chemical Tagging

Tabernero, Montes, González Hernández

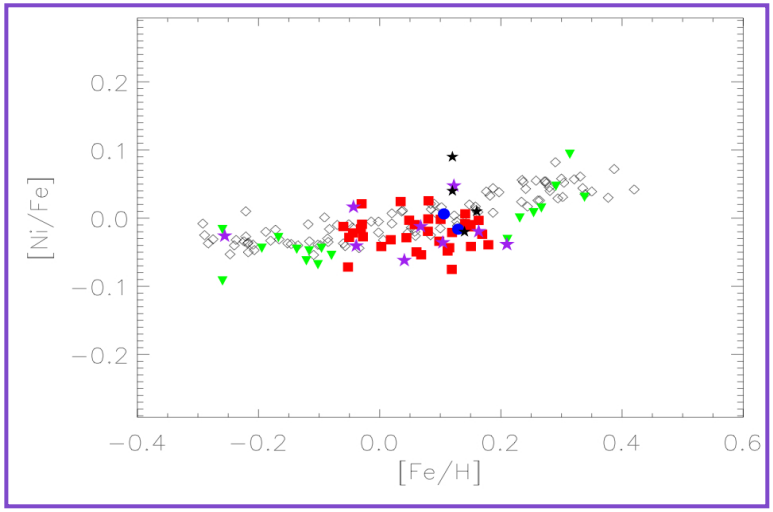
The detailed analysis of the chemical signatures **chemical tagging** is a powerful method that provide clear constrains to the membership of FGK stars to MGs.

➔Stellar atmospheric parameters (T_{eff}, log g, ξ and **[Fe/H]**) have been determined with a own-developed code (*StePar*, see Tabernero et al. 2011) which iterates until the slopes of χ *vs* log(ϵ(Fe I)) and log(EW/λ) *vs* log(ϵ(Fe I)) where zero and imposing ionization equilibrium: log(ϵ(Fe I)) = log(ϵ(Fe II)).

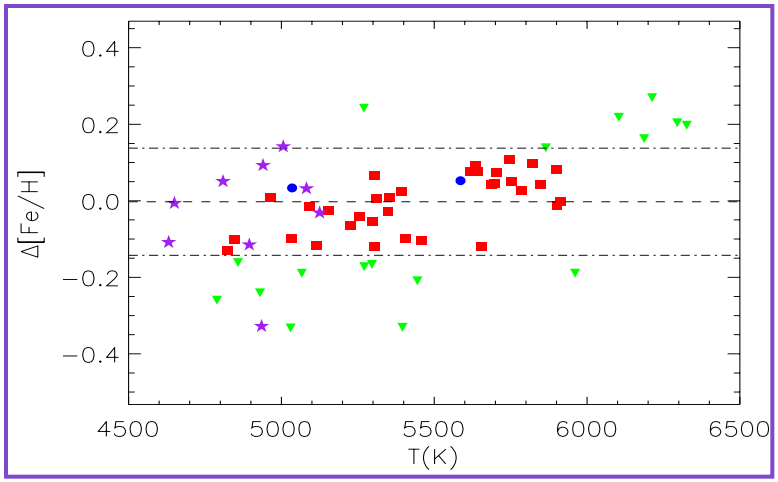
➔ Result of our abundance analysis (**Fe**, **Na**, **Mg**, **Al**, **Si**, **Ca**, **Sc**, **Ti**, **V**, **Cr**, **Mn**, **Co**, and **Ni**) of possible members of the **Hyades SC** (**41%** homogeneity).



U, V velocities for late-type stars candidate members of the Hyades SC



[Ni/Fe] vs [Fe/H]: open diamonds represent the thin disk data (González Hernández et al. 2010).



Δ[Fe/H] **differential abundance** vs T_{eff}. Dashed-dotted lines represent 1-rms level for the Hyades cluster.

Plan to apply chemical tagging to other moving groups like Ursa Major, etc...


The End

Chemical Tagging

Tabernero, Montes, González Hernández

Name	T_{eff} (K)	log g (dex)	ξ (km/s)	log ϵ(Fe I)	log ϵ(Fe II)	[Fe/H]	Δ [Fe/H]	Member (Fe)	Total	Member
BE Cet	5865 ± 20	4.58 ± 0.05	1.26 ± 0.03	7.67 ± 0.02	7.67 ± 0.02	0.211 ± 0.003	0.138 ± 0.005	N	8	N
HD 5848	4650 ± 44	2.48 ± 0.17	1.89 ± 0.05	7.53 ± 0.04	7.53 ± 0.12	0.068 ± 0.010	-0.006 ± 0.010	Y	10	N
AZ Ari	5821 ± 10	4.54 ± 0.03	1.10 ± 0.02	7.63 ± 0.01	7.63 ± 0.01	0.169 ± 0.002	0.097 ± 0.005	Y	12	Y
FT Cet	5093 ± 45	4.49 ± 0.12	1.10 ± 0.10	7.52 ± 0.03	7.52 ± 0.07	0.058 ± 0.006	-0.015 ± 0.006	Y	12	Y
BZ Cet	5035 ± 37	4.38 ± 0.11	0.98 ± 0.08	7.56 ± 0.02	7.56 ± 0.07	0.106 ± 0.005	0.034 ± 0.005	Y	12	Y
δ Ari	4940 ± 37	3.05 ± 0.11	1.52 ± 0.04	7.62 ± 0.03	7.62 ± 0.07	0.163 ± 0.008	0.093 ± 0.008	Y	7	N
V683 Per	5586 ± 20	4.50 ± 0.06	1.04 ± 0.04	7.58 ± 0.02	7.58 ± 0.03	0.129 ± 0.004	0.053 ± 0.005	Y	12	Y
V686 Per	5705 ± 37	4.54 ± 0.10	1.28 ± 0.05	7.60 ± 0.03	7.61 ± 0.05	0.141 ± 0.005	0.073 ± 0.006	Y	12	Y
HD 21663	5457 ± 18	4.50 ± 0.05	0.84 ± 0.04	7.43 ± 0.01	7.43 ± 0.03	-0.031 ± 0.003	-0.104 ± 0.004	Y	11	N
HD 23356	4930 ± 36	4.41 ± 0.09	0.63 ± 0.12	7.29 ± 0.02	7.29 ± 0.06	-0.167 ± 0.005	-0.241 ± 0.005	N	2	N
39 Tau	5901 ± 13	4.55 ± 0.04	1.13 ± 0.02	7.52 ± 0.01	7.52 ± 0.02	0.061 ± 0.002	-0.012 ± 0.004	Y	12	Y
HD 25893	5355 ± 43	4.50 ± 0.11	1.18 ± 0.08	7.54 ± 0.03	7.54 ± 0.06	0.080 ± 0.006	0.010 ± 0.006	Y	12	Y
HD 27282	5642 ± 19	4.49 ± 0.06	1.09 ± 0.03	7.61 ± 0.01	7.61 ± 0.03	0.150 ± 0.003	0.076 ± 0.004	Y	12	Y
HD 27685	5753 ± 18	4.47 ± 0.05	0.99 ± 0.03	7.58 ± 0.01	7.57 ± 0.02	0.119 ± 0.005	0.050 ± 0.006	Y	12	Y
HD 27989	5747 ± 50	4.57 ± 0.12	1.37 ± 0.07	7.64 ± 0.04	7.64 ± 0.05	0.179 ± 0.007	0.107 ± 0.007	Y	9	N
ϵ Tau	5006 ± 40	2.94 ± 0.13	1.64 ± 0.04	7.66 ± 0.03	7.67 ± 0.08	0.210 ± 0.009	0.142 ± 0.008	N	3	N
111 Tau B	4789 ± 64	4.53 ± 0.20	1.14 ± 0.18	7.27 ± 0.03	7.27 ± 0.14	-0.195 ± 0.009	-0.260 ± 0.008	N	3	N
HD 40979	6295 ± 43	4.61 ± 0.10	1.42 ± 0.05	7.73 ± 0.03	7.73 ± 0.05	0.267 ± 0.006	0.204 ± 0.007	N	3	N
V401 Hya	5847 ± 13	4.52 ± 0.03	1.10 ± 0.02	7.57 ± 0.01	7.58 ± 0.02	0.115 ± 0.002	0.044 ± 0.005	Y	12	Y
HD 45609	5271 ± 39	4.49 ± 0.12	1.05 ± 0.08	7.36 ± 0.03	7.36 ± 0.06	-0.102 ± 0.007	-0.172 ± 0.007	N	6	N
HD 52265	6187 ± 16	4.42 ± 0.04	1.37 ± 0.02	7.69 ± 0.01	7.69 ± 0.02	0.231 ± 0.003	0.162 ± 0.005	N	7	N
HD 53532	5698 ± 17	4.56 ± 0.05	1.10 ± 0.03	7.58 ± 0.01	7.58 ± 0.02	0.119 ± 0.003	0.045 ± 0.004	Y	12	Y
HD 65523	5306 ± 20	4.46 ± 0.05	0.70 ± 0.04	7.41 ± 0.01	7.41 ± 0.03	-0.050 ± 0.003	-0.118 ± 0.005	Y	10	N
HD 70088	5655 ± 20	4.58 ± 0.06	1.06 ± 0.03	7.41 ± 0.02	7.41 ± 0.03	-0.052 ± 0.003	-0.120 ± 0.005	Y	7	N
HD 72760	5298 ± 21	4.45 ± 0.06	0.84 ± 0.04	7.48 ± 0.01	7.48 ± 0.03	0.018 ± 0.003	-0.054 ± 0.004	Y	12	Y
HD 73171	4631 ± 35	2.50 ± 0.13	1.63 ± 0.04	7.42 ± 0.03	7.42 ± 0.09	-0.039 ± 0.008	-0.108 ± 0.008	Y	10	N