Chemical tagging of FGK stars:
testing membership to stellar kinematic groups

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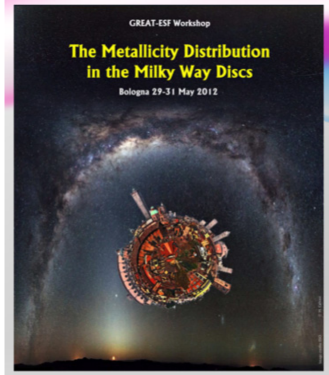

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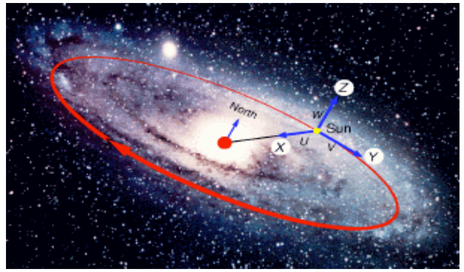
Bologna, 29-31 May 2012

Stellar Kinematics Groups



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

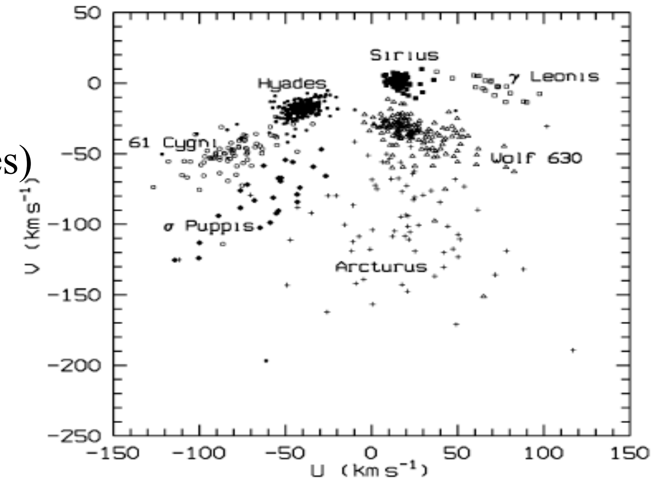
Group of stars gravitationally unbound that share the same kinematics and may occupy extended regions in the Galaxy

Coeval Origin:

- the evaporation of an open cluster
- the remnants of a star formation region,
- a juxtaposition of several little star formation bursts
- past accretion events in the Milky Way (remnants of disrupted satellites)

Dynamical Origin:

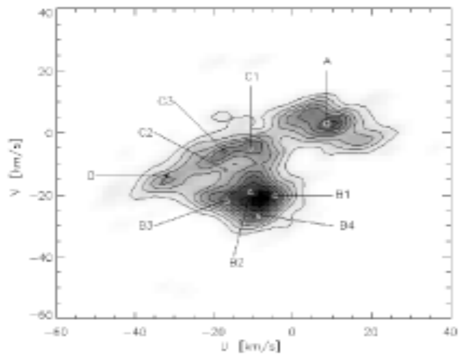
- associated with dynamical resonances (bar), spiral structure



- **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)

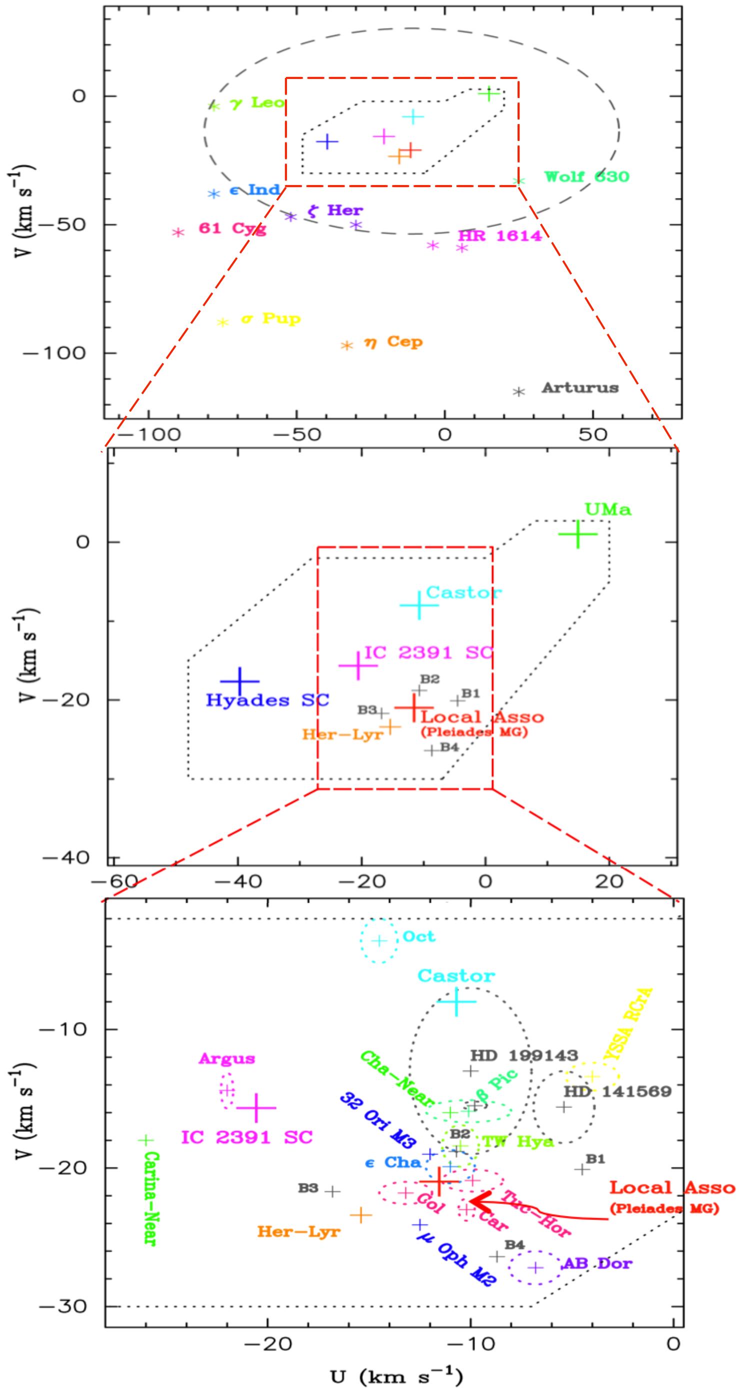


- **HIPPARCOS data:**
  - Confirm the existence of classical young MGs (and some old MGs).
  - Large velocity dispersion.
  - Detect finer structures in space velocity and age that in several cases can be related to kinematics properties of nearby open clusters or associations.

Classical Old Moving Groups

Classical Young Moving Groups

Young Nearby Loose Associations



Stellar Kinematics Groups

Classical Young Moving Groups

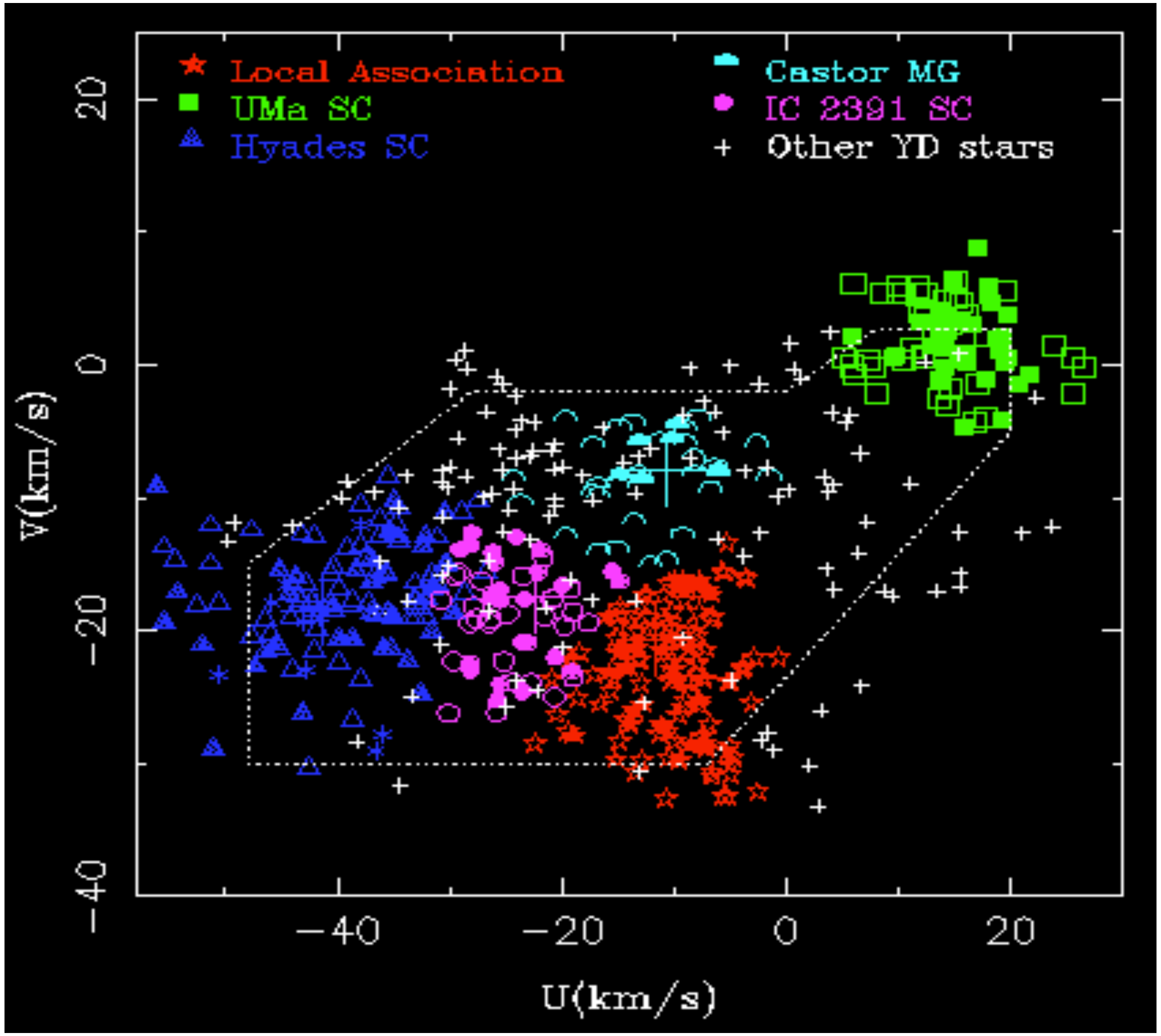
Name	Clusters	Age (Myr)	U (km/s)	V (km/s)	W (km/s)
Local Association (Pleiades moving group) (Stream 0)	Pleiades (M45, Melotte 22) α Persei (Melotte 20) M34 (NGC 1039) delta Lyr (Stephenson 1) NGC 2516 (Mel 82) IC 2602 (theta Carinae)	20 - 300	-11.6	-21.0	-11.4
Hercules-Lyra	-	150 - 300	-15.4	-23.4	
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).

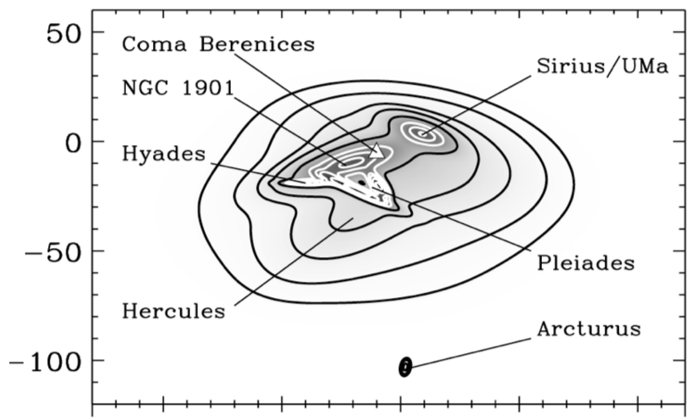
Stellar Kinematics Groups

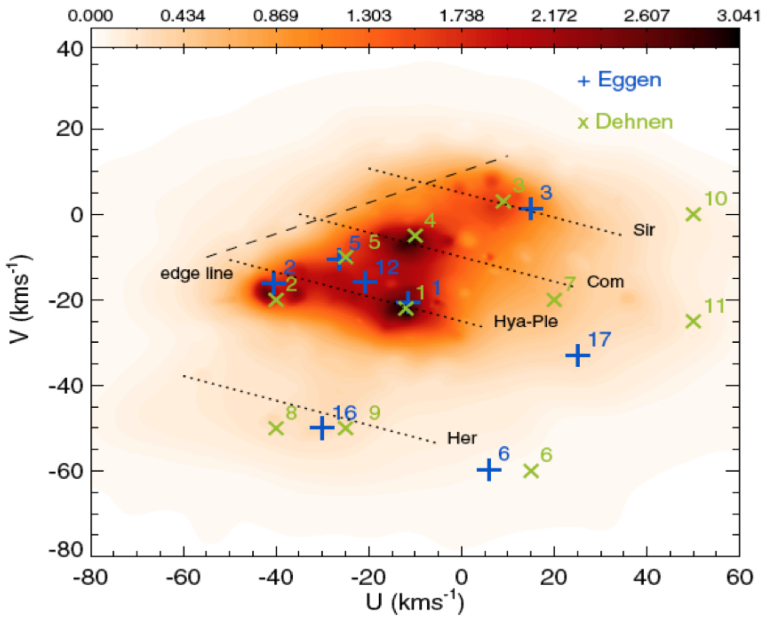
Classical Young Moving Groups

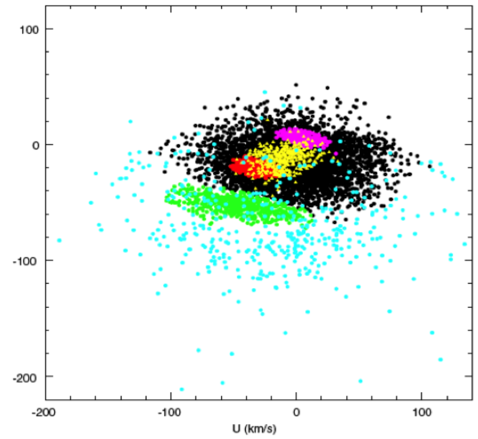


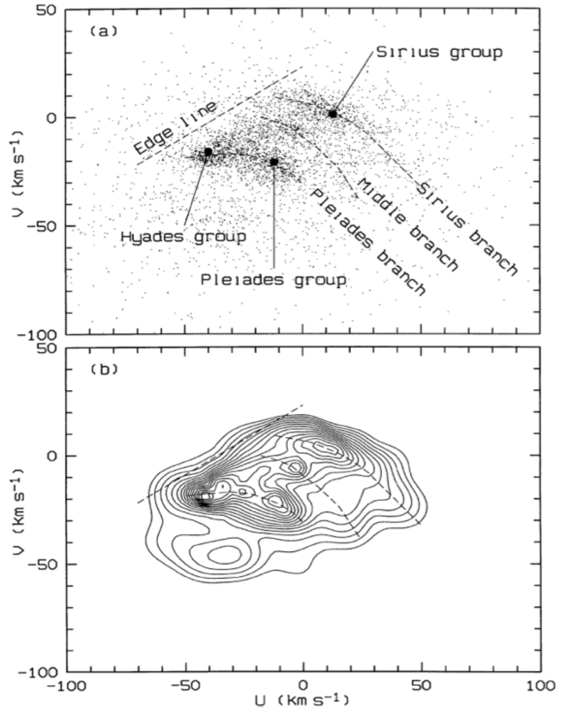
Montes et al. 2001 MNRAS.328...45

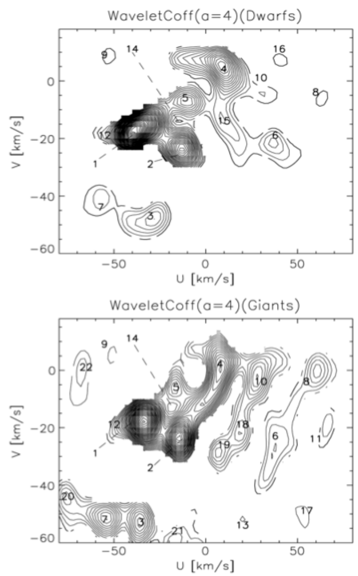
Stellar Kinematics Groups

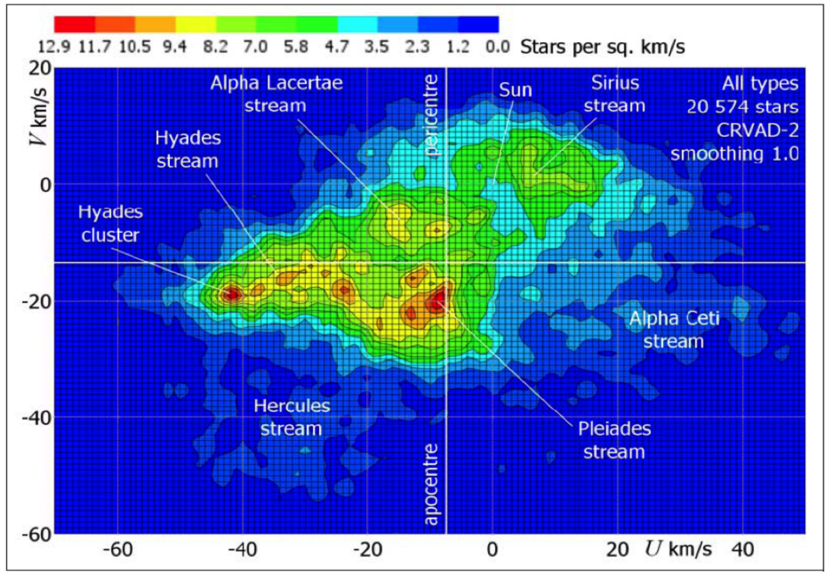












Stellar Kinematics Groups

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, 2012;
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), spiral structure,
or past accretion events in the Milky Way (remnants of disrupted satellites).

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

Chemical Tagging (chemical homogeneity)

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.

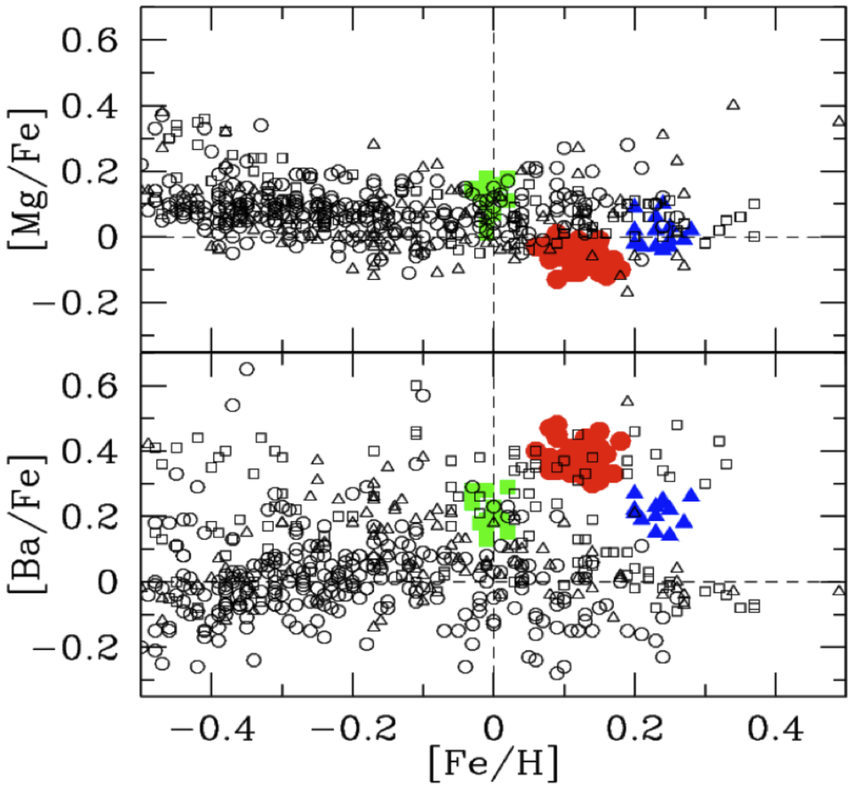


Figure from De Silva et al. (2009) sowing the abundances of **HR1614** MG stars (De Silva et al. 2007b, **triangles**) compared to the **Hyades** (De Silva et al. 2006, **circles**) and **Collinder 261** (De Silva et al. 2007a, **squares**) open clusters. The smaller open symbols represent background 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**

→ **field-like stars** (dynamical process)

- **Hercules stream** (Bensby et al. 2007) which stars show different ages and chemistry (associated with dynamical resonances (bar) or spiral structure).
- **moving group 6** (UVW 38, -20, -15) and 7 (UVW -57, -45, -16) (Zhao et al. 2009), 19 K-type giants with inhomogeneous metallicity → different chemical origins before they were kinematically aggregated and favor the dynamical resonant theory.

→ **Coeval stars** (true MGs)

- **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.

→ **Remnants of disrupted satellites** (past accretion events)

- **Kinematic group 3 in the Geneva-Copenhagen survey** (Stonkutė et al., 2012) homogeneous chemical composition together with the kinematic properties and ages
→ evidence of their common origin

Chemical Tagging

* 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

★ Survey for Chemical Tagging of FGK stars in MGs

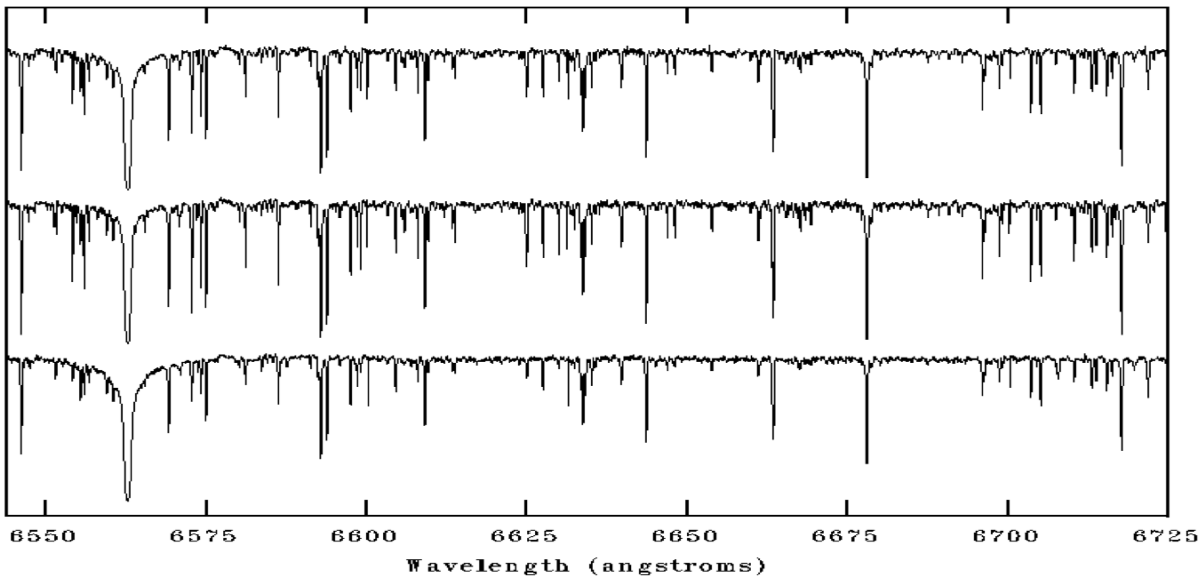
Hyades and Ursa Major MGs

2010- 2011 – 61 F6-K4 stars, Hyades

- **Tabernero, Montes, González Hernández** 2011, CS16;
- **Tabernero, Montes, González Hernández** 2012, A&A, in press, arXiv:1205.4879

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.



Stellar parameters

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

StePar (Tabernero Montes, González Hernández 2012, A&A, in press, arXiv:1205.4879):

- 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:

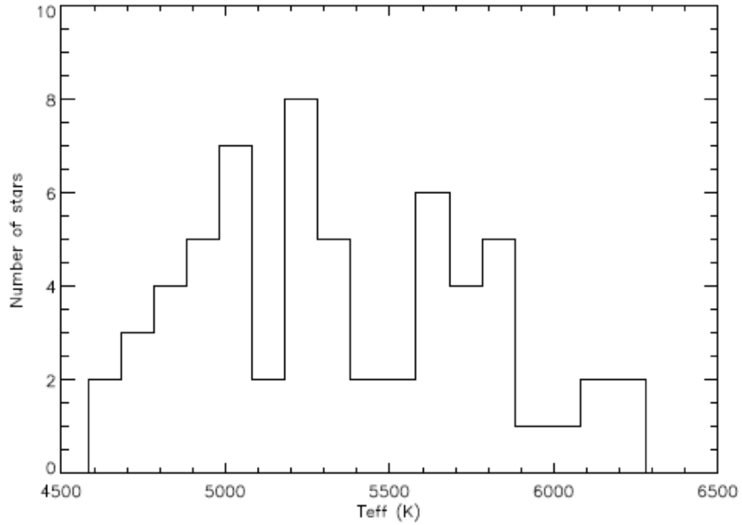
- **excitation equilibrium**:
  the slopes of χ *vs* log(ϵ(**Fe I**))
  and log(EW/λ) *vs* log(ϵ(**Fe I**)) where zero
- **ionization equilibrium**:
  log(ϵ(**Fe I**)) = log(ϵ(**Fe II**)).

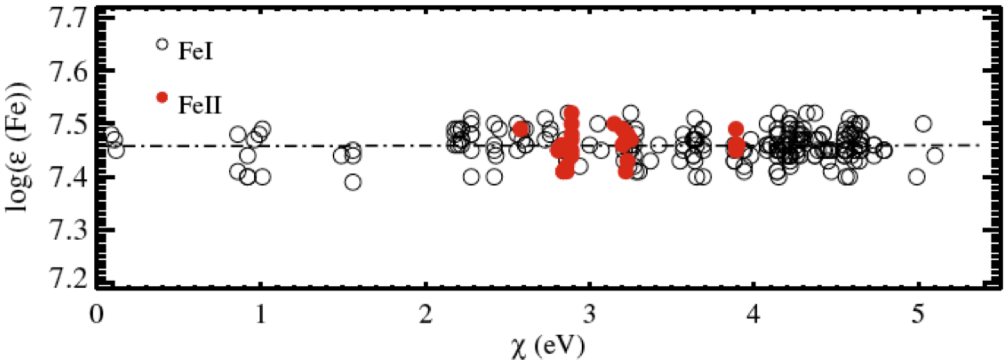
- 2-σ rejection of Fe I and Fe II lines after a first determination of the parameters
- **Limitations**: spectral types F6 to K4, slow rotators, no veiling.

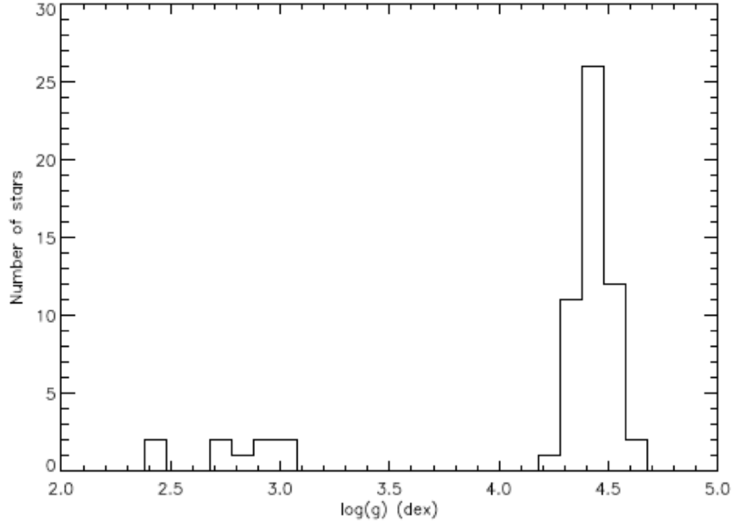
Stellar parameters

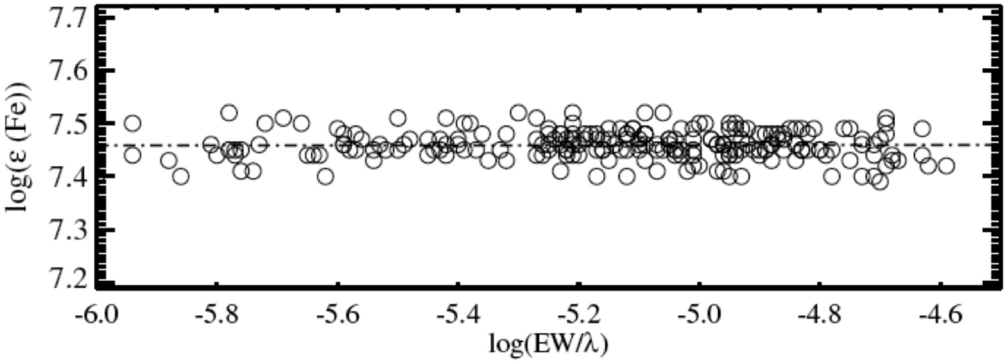
T_{eff}, log g, ξ and [Fe/H]

StePar (Tabernero Montes, González Hernández 2012):









Chemical abundances

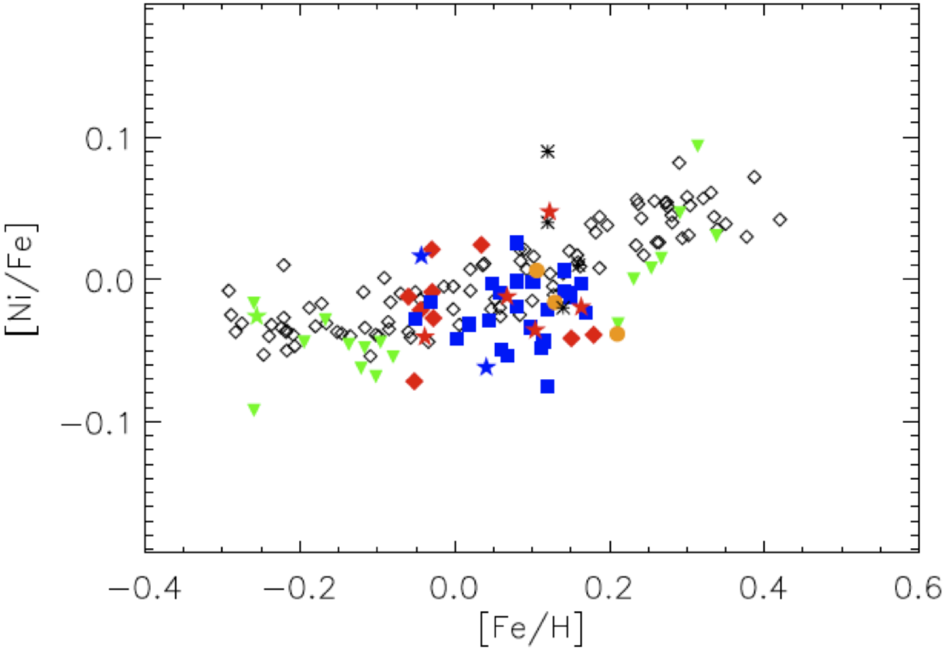
Fe, Na, Mg …..

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 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 disc data (González Hernández et al. 2010), red diamonds are our stars compatible to within 1-rms with the Fe abundance but not for all elements, blue squares and blue starred symbols are the candidates selected to become members of the Hyades Supercluster. Green downward-pointing triangles show no compatible stars. BZ Cet, V683 Per, and ε Tau Hyades cluster members stars are marked with orange circles. Starred points represent the giant stars. Black asterisks are the candidates selected by De Silva et al. (2011) and black crosses represent the members selected by Pompéia et al. (2011).

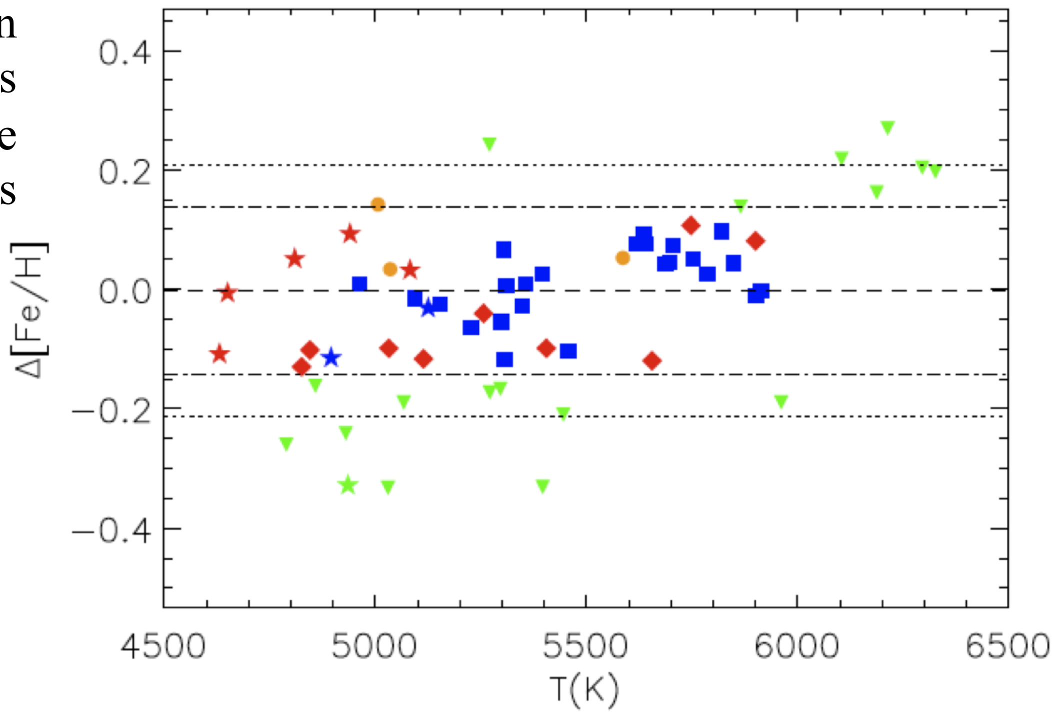
Differential abundances

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 we consider stars to become members when their abundances were within the **1-rms** interval for 90 % of the elements considered and the remaining 10 % within the **1.5-rms** interval (18 elements and 2 elements respectively).



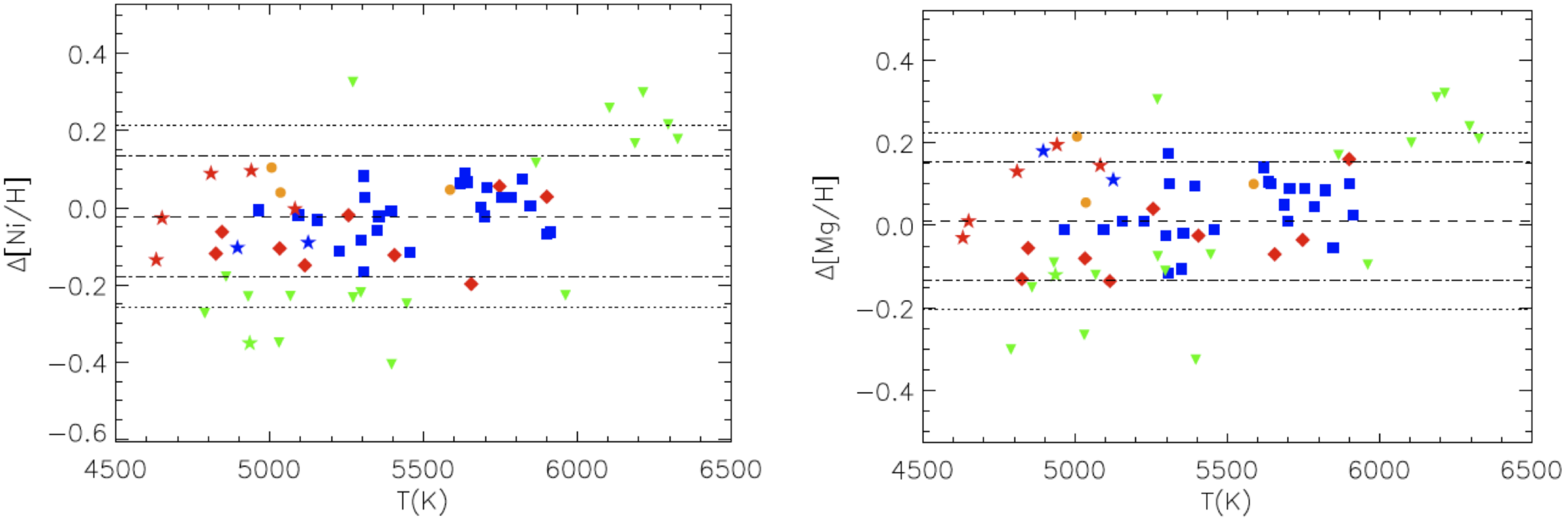
Δ[Fe/H] differential abundance vs T_{eff}. Dashed-dotted lines represent **1-rms** over and below the median for our sample, whereas dotted lines represent the **1.5-rms** level. Dashed lines represent the mean differential abundance. Red diamonds are our stars compatible to within 1-rms with the Fe abundance but not for all elements, blue squares and blue starred symbols are the candidates selected to become members of the Hyades Supercluster. Green downward-pointing triangles show no compatible stars. BZ Cet, V683 Per, and ε Tau Hyades cluster members stars are marked with orange circles.

Chemical Tagging

Tabernero, Montes, González Hernández

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

(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.

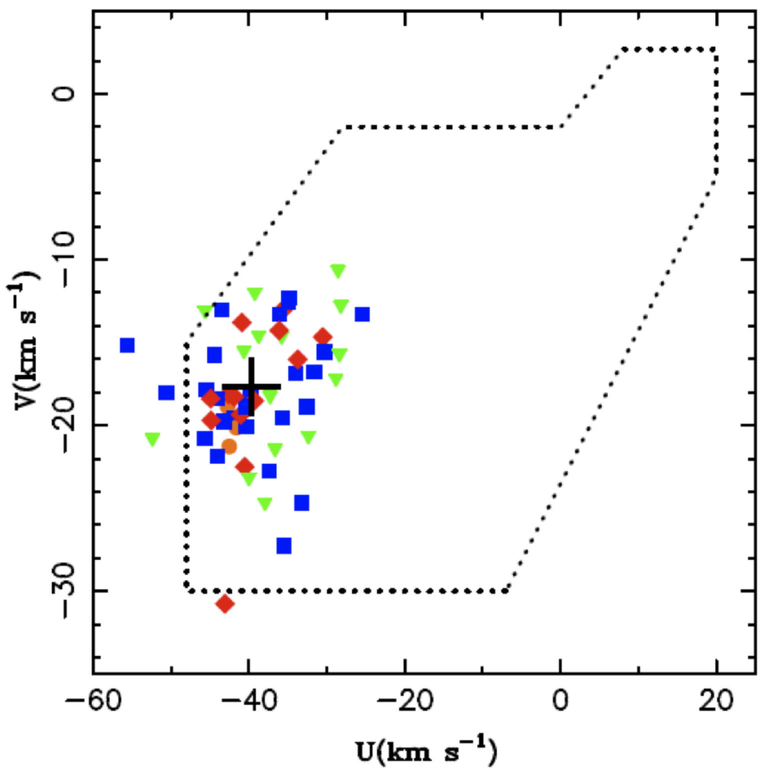
A homogeneous sample of F6-K4 kinematically-selected northern stars★

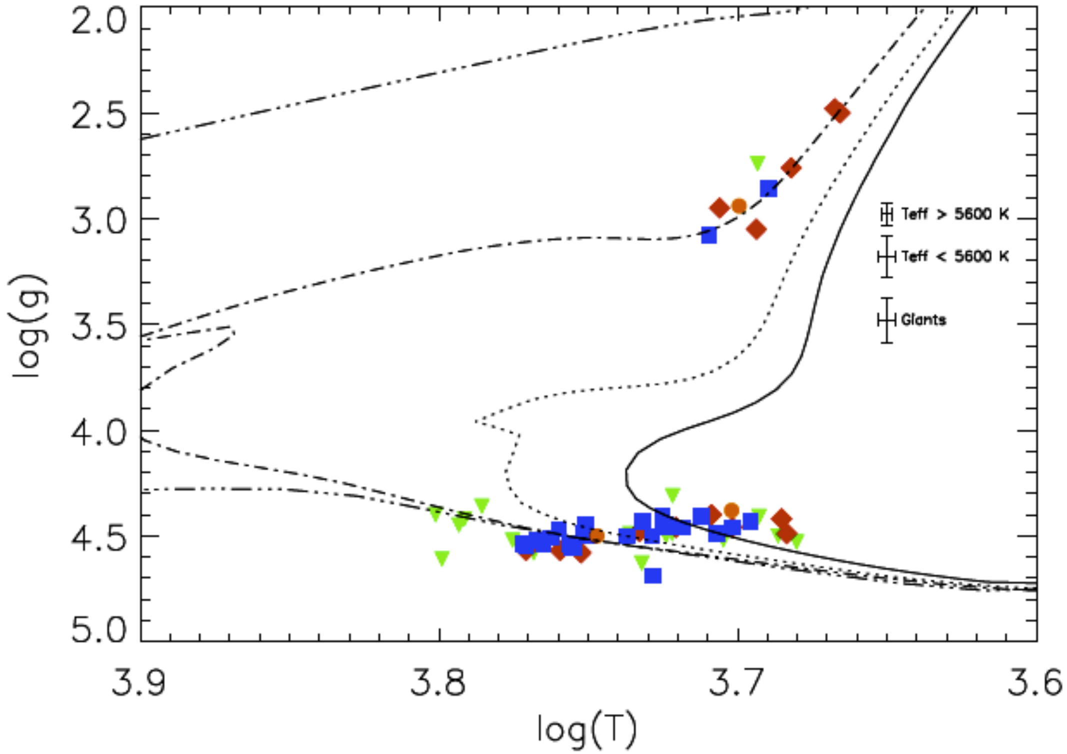
H.M. Tabernero,[1] D. Montes[1] and J.I. González Hernández[1,2]

Chemical Tagging

Tabernero, Montes, González Hernández

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





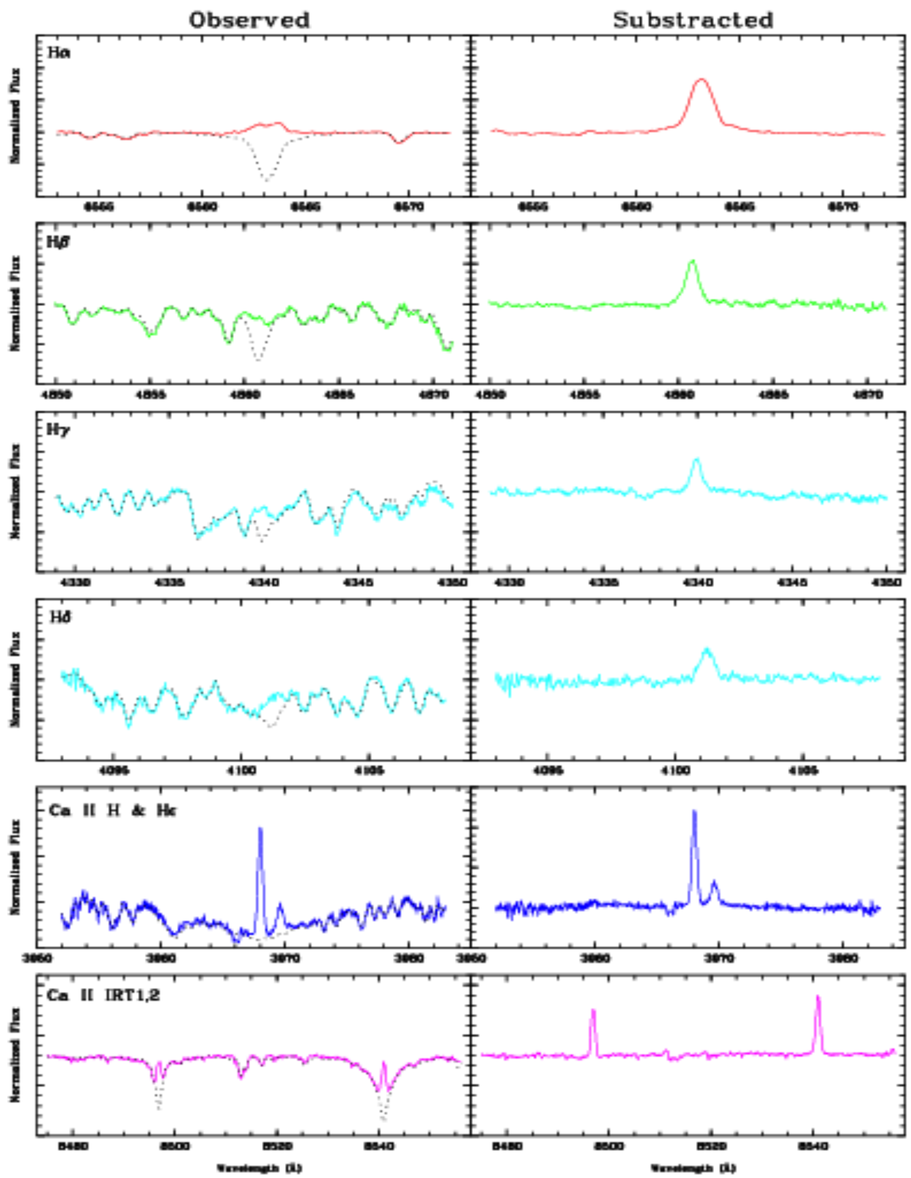
Blue squares are the final selected member stars. Red diamonds are stars compatible with Hyades Fe abundance (but not for other elements), and the green ones not compatible. BZ Cet, V683 Per, and ε Tau Hyades cluster members stars are marked with orange circles.

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.

Additional 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**.
  - $\boldsymbol{T}_{\mathbf{eff}}$, log $\boldsymbol{g}$, ξ and **[Fe/H]**
- **Absolute and differential abudances**.
  - Chemical tagging



Gaia ESO Spectroscopic Survey (GES)

For the stars that will be be observed in the Gaia ESO Spectroscopic Survey (**GES**) with VLT-FLAMES, **UVES** and **Giraffe**

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

- Different tests with UVES archive spectra already started.

→ Combined Gaia and homogeneous spectroscopic dataset full 6Dphase space $f(x,y,z,v_x,v_y,v_z)$, plus stellar parameters, and chemistry for a very large number and variety of stars down to the 19 mag: core science plus legacy science


The End