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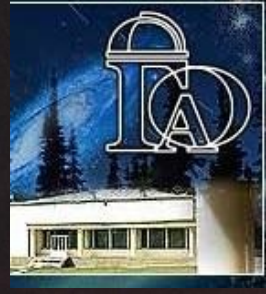

Benchmark low-mass objects in moving groups

Centro De Astrobiología

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Benchmark Cool Dwarfs in MGs

- *Benchmark:* **Objects for which some properties can be determined with minimal reference to theoretical models.**

- *Atmospheric models:* **Although hundreds of low-mass and brown dwarfs are known, their properties are still not well modelled (gas composition, dust behaviour, clouds formation etc). Crucial to understand their formation and evolution.**

- *MGs:* **Cool dwarfs members of moving groups provide benchmark objects with known age and composition.**

Moving Groups

- **Stellar kinematics groups (moving groups): young population with characteristic space motions.**
- **Common origin: Open cluster evaporation, remains of stars formation region, superposition of several bursts o star formation in different epochs in adjacent cells of velocity field. Sharing age and composition.**
- **Characteristics (from Montes et al. 2001):**

MG	Age (Myr)	Metallicity [Fe/H]	U (kms^{-1})	V (kms^{-1})	W (kms^{-1})	C.P (^{h},^{o})
Pleiades	20-150	-0.034±0.024[1]	-11.6	-21.0	-11.4	(5.98, -35.15)
Hyades	600	0.13±0.01[2]	-39.7	-17.7	-2.4	(6.40, 6.50)
Sirius	300	-0.09±0.04[1]	14.9	1.0	-10.7	(20.55, -38.10)
IC2391	35-55	-0.03±0.07[3]	-20.6	-15.7	-9.1	(5.82, -12.44)
Castor	320[4]	0.00±0.04[5]	-10.7	-8.0	-9.7	(4.75, -18.44)

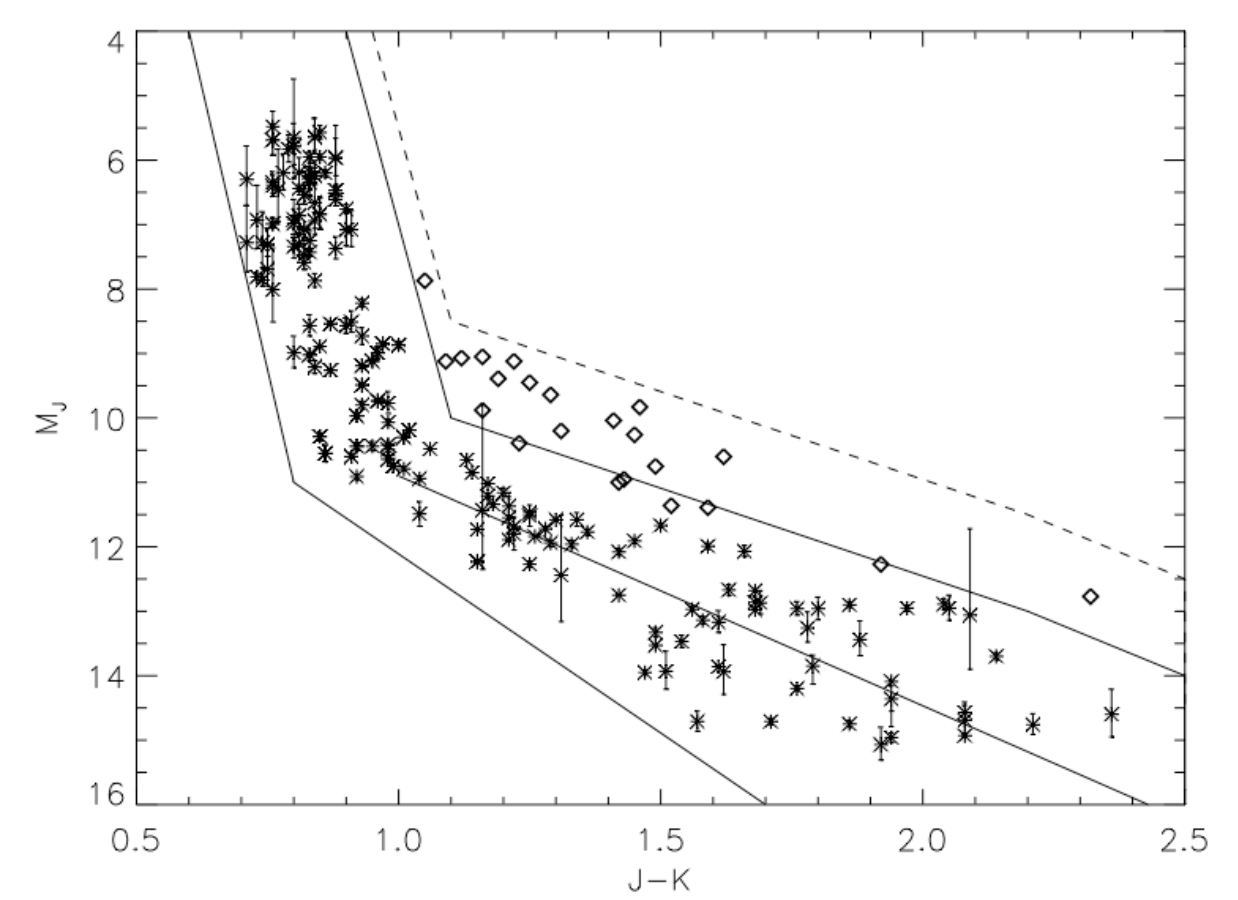
[1] Boesgaard and Friel 1990, [2] Paulson, Sneden and Cochran 2003, [3] Randich et al. 2001, [4] Ribas 2003, [5] Paulson and Yelda 2006

Sample selection: Sample A and B

- **Sampl**… **2MASS and D**… **strains to select**… **7 objects (Clarl**…

- **Samp**… **012 ultra cool** … **tude and mid p**… **atch.**

Astro… **or-color diagr**… **3 from samp**…

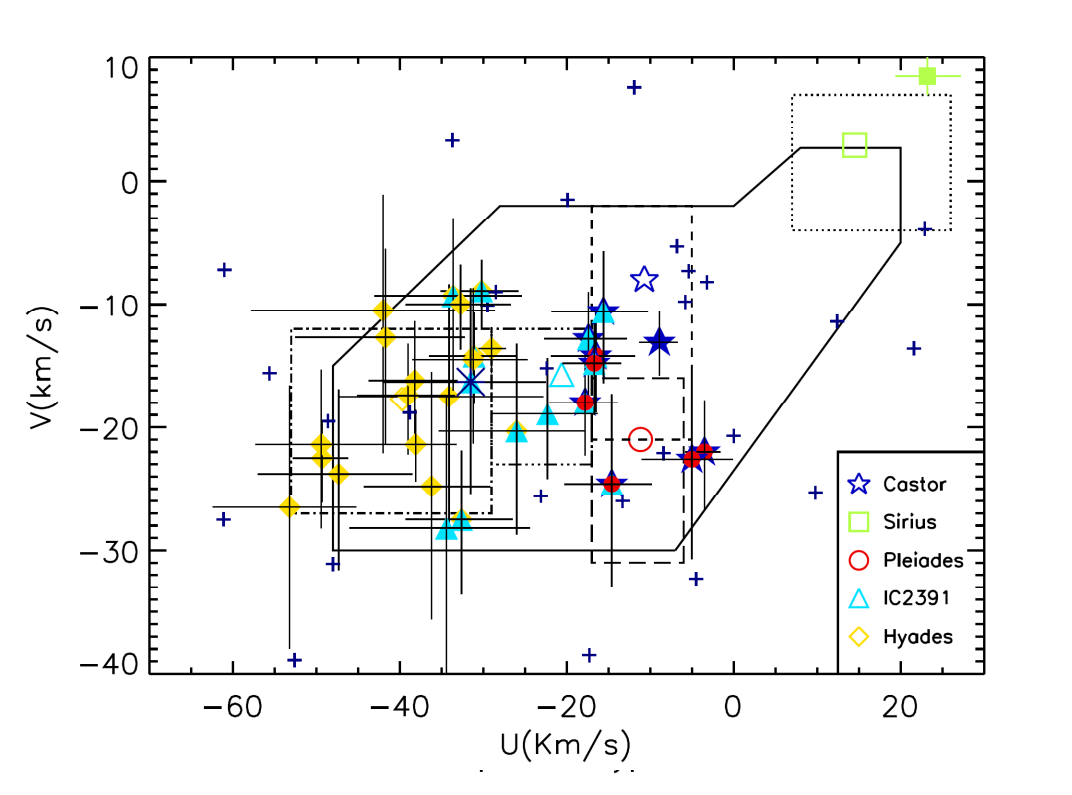


Compiled Spectroscopic Data

Number	Date	Telescope	Instrument	Spect. range (Å)	Dispersion (Å)
1	28-30/12/06 & 16-17/06/07	ESO-2.2m	FEROS	3500-9200	0.033 - 0.081
2	9/10/-16/12/07	ESO-VLT-U2	UVES	6650-10425	0.027-0.041
3	23/02-25/02/08	GEMINI	Phoenix	15532-15606	0.074
4	28/03-21/06/08	ESO-VLT-U2	UVES	6650-10425	0.027-0.041
5	01-09-2009-09/01/2010	ESO-VLT-U2	UVES[1]	5700-7530 & 7650-9470	0.027-0.041
6	03-05/05/2010	6.5 m Baade-Maguellan	IMACS Short-Camera[2]	6550-10000[3]	1.98
7	15-16/02/2011	6.5 m Baade-Maguellan	IMACS Short-Camera[2]	4300-10800[4]	1.97

- **81 high resolution and 15 low resolution spectra of objects with spectra types M3-L2**

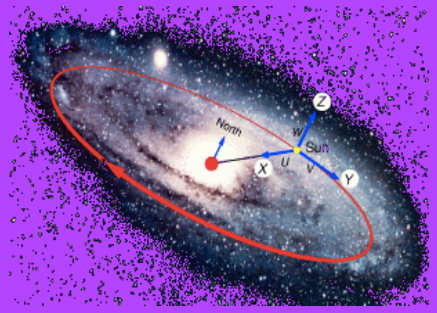
MG membership: Kinematic and Youth test



1. **Kinematic:** e.g. Montes et al. 2001, MNRAS, 328, 45, etc
2. **Rotational velocity:** Reiner et al. 2008, AJ, 684, 1390, etc…
3. **Gravity features sensitive to age:** Gorlova et al. 2004, AJ, 593, 1074; McGovern et al. 2004, AJ, 600, 1020; Barrado y Navascués 2006, A&A, 459, 511B; Martín et al. 2010, A&A, 517, A53; Schlieder et al 2012, AJ, 143, 114, etc…
4. **Activity:** West et al. 2008, AJ, 135, 795; Shkolniv et al. 2009, ApJ, 699, 649; Shkolniv et al. 2011, ApJ, 727, 6S, etc…
5. **Lithium I 6708 Å:** Basri 1997

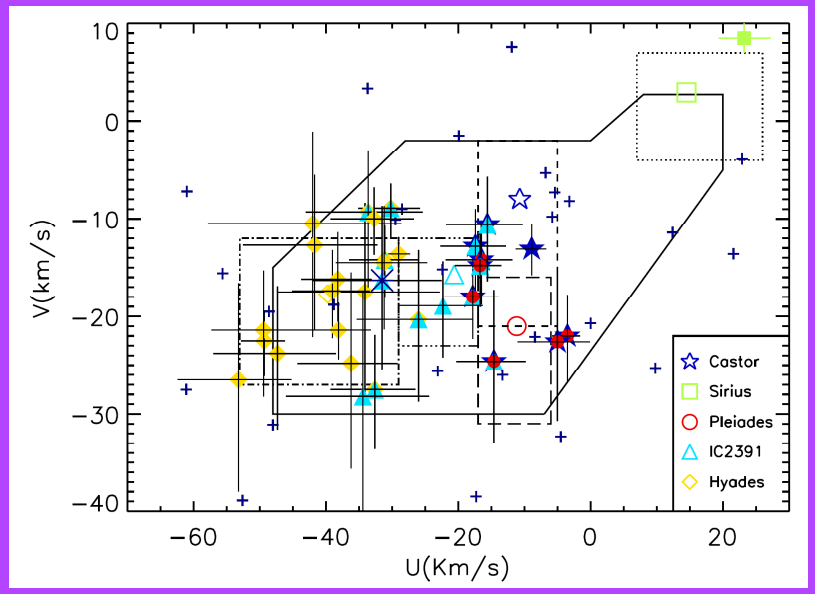
Sample A : High resolution spectra

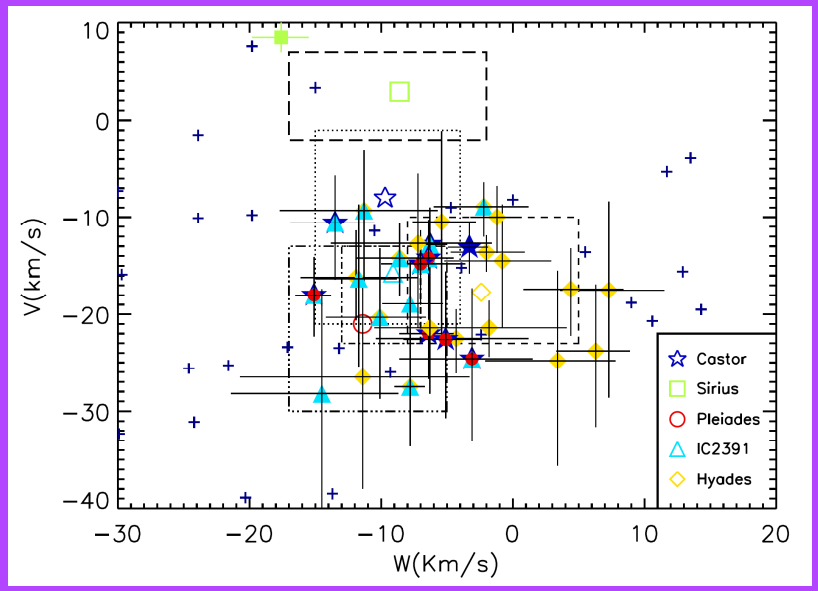
- **Spectral type and distances determination:** using several spectral type indexes (PC3, TiO5, Vo-a) and PC3 index - distances relation in optical spectra, and I-J color index-spectral type relation from Legget (1992) and Dahn et al. (2002) for distance in infrared spectra.
- **Radial velocities:** using cross-correlation techniques with routine *fxcor* in *IRAF* .
- **Galactic space-velocity components (U,V,W):** with proper motion data, derived distances and radial velocity (Johnson & Soderblom 1987 transformation).



U Galactic center, V Galactic rotation & W Galactic north pole

Sample A: Kinematic

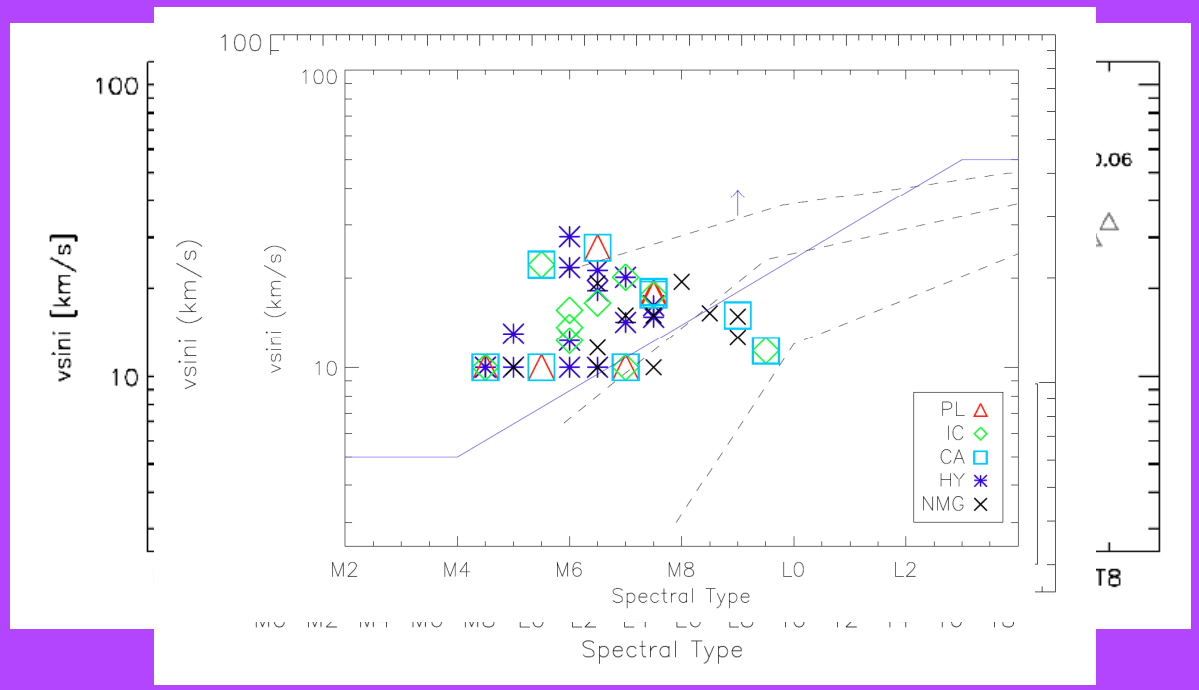




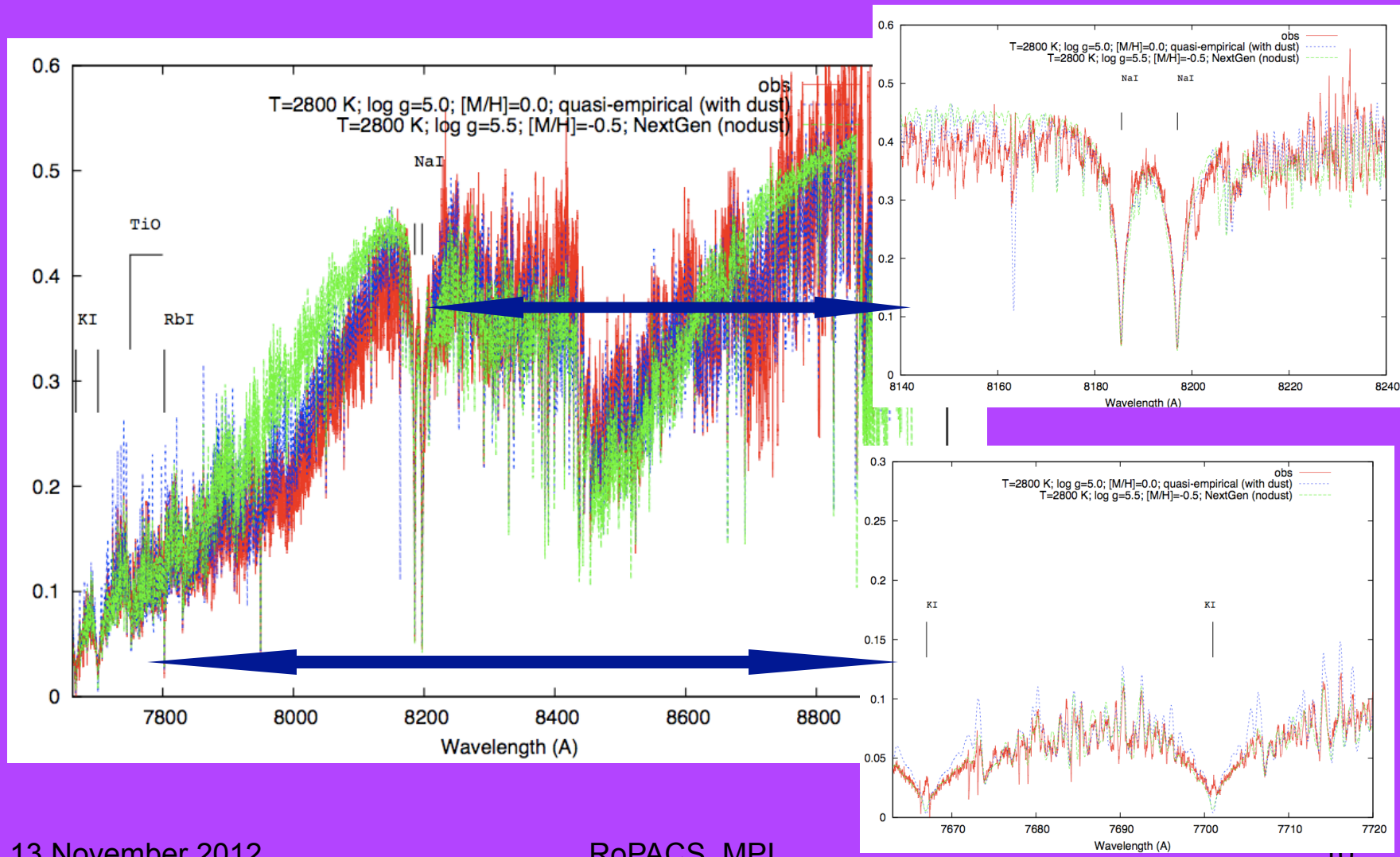
49 object belong to the young disk area and **36** of them are candidates to belong to one of the five MGs. (Legget 1992; Eggen 1984b. 1989, Barrado y Navascués 2006, Kirkpatrick et al. 2006 etc....).

Sample A: Rotational velocities

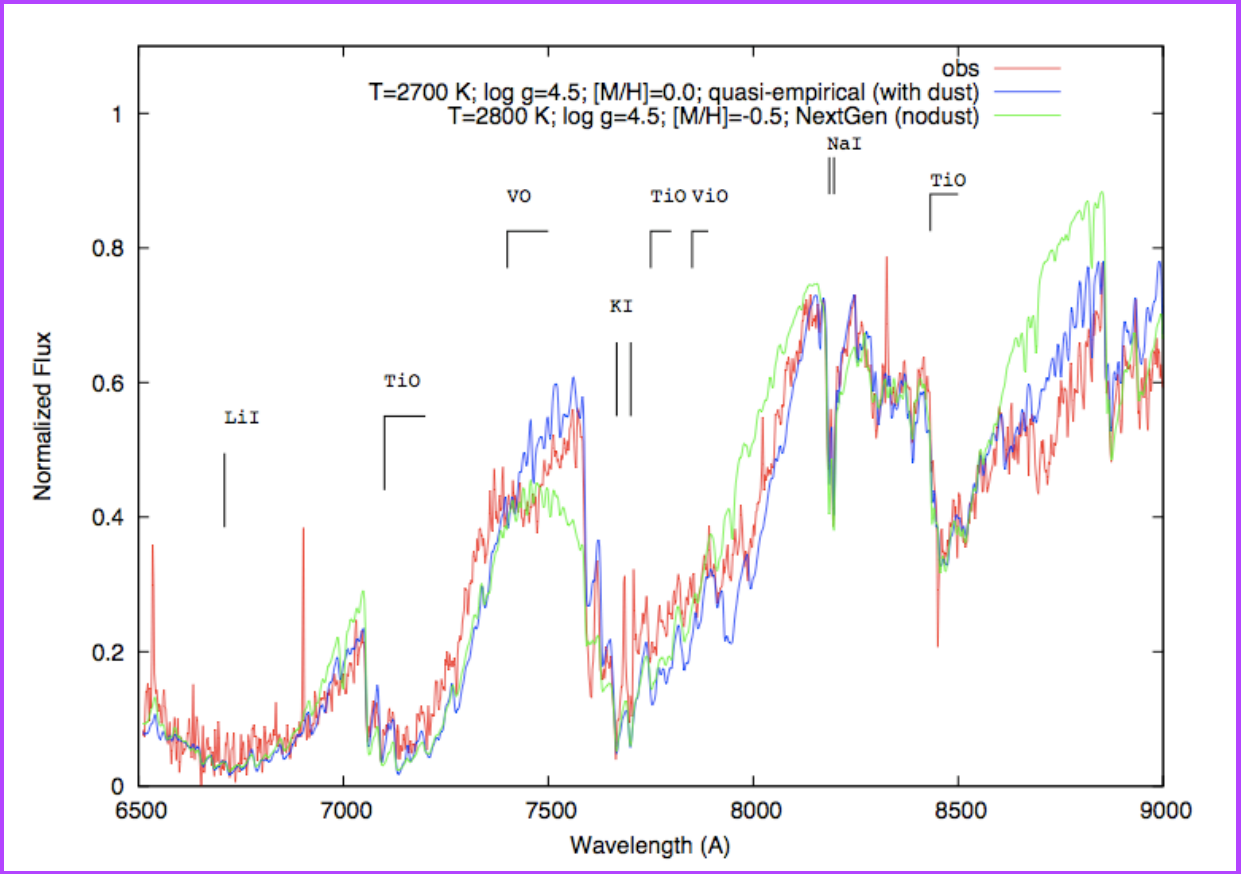
- **Rotational velocities:** measured using cross-correlation techniques. We use Reiners & Basri (2008) rotational velocity - spectral type diagram for our sample and defined a separation between "young" and "old" objects.



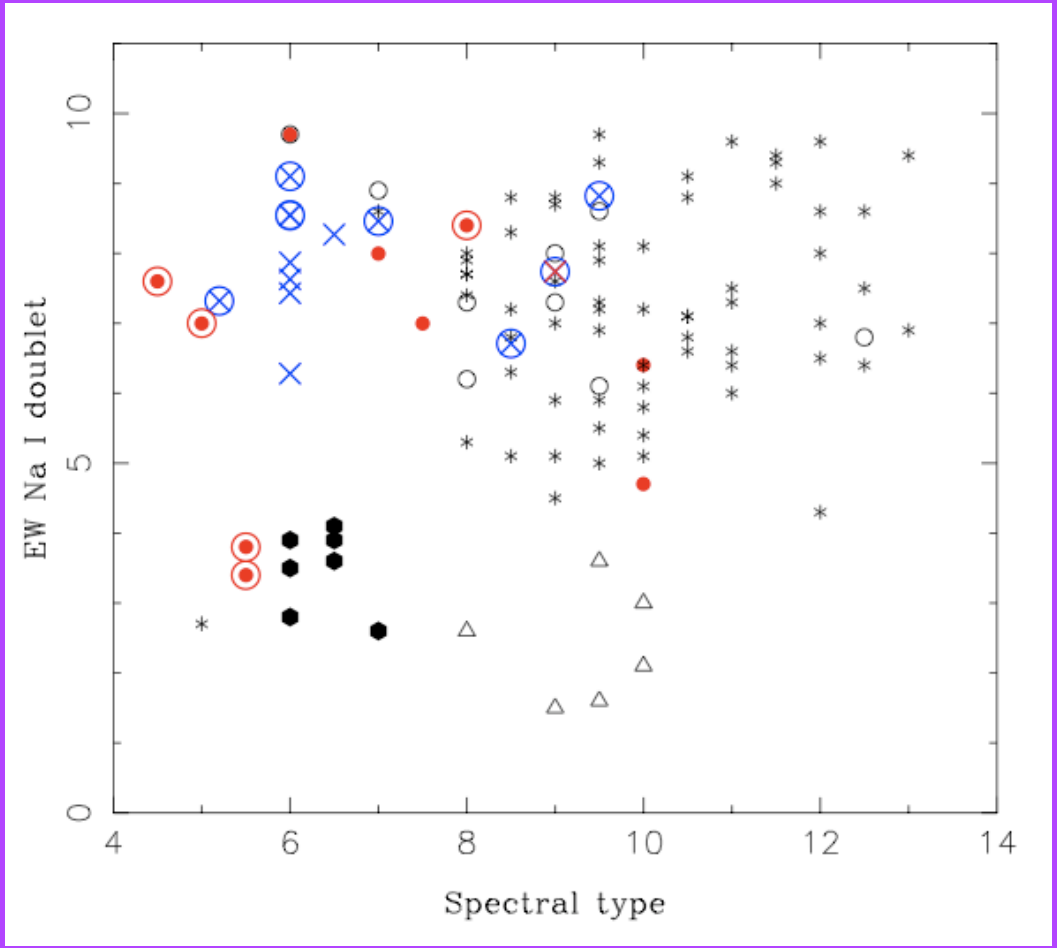
Sample A and B: Teff and Log g by fitting of synthetic atmospheric models



Sample A and B: Teff and Log g by fitting of synthetic atmospheric models



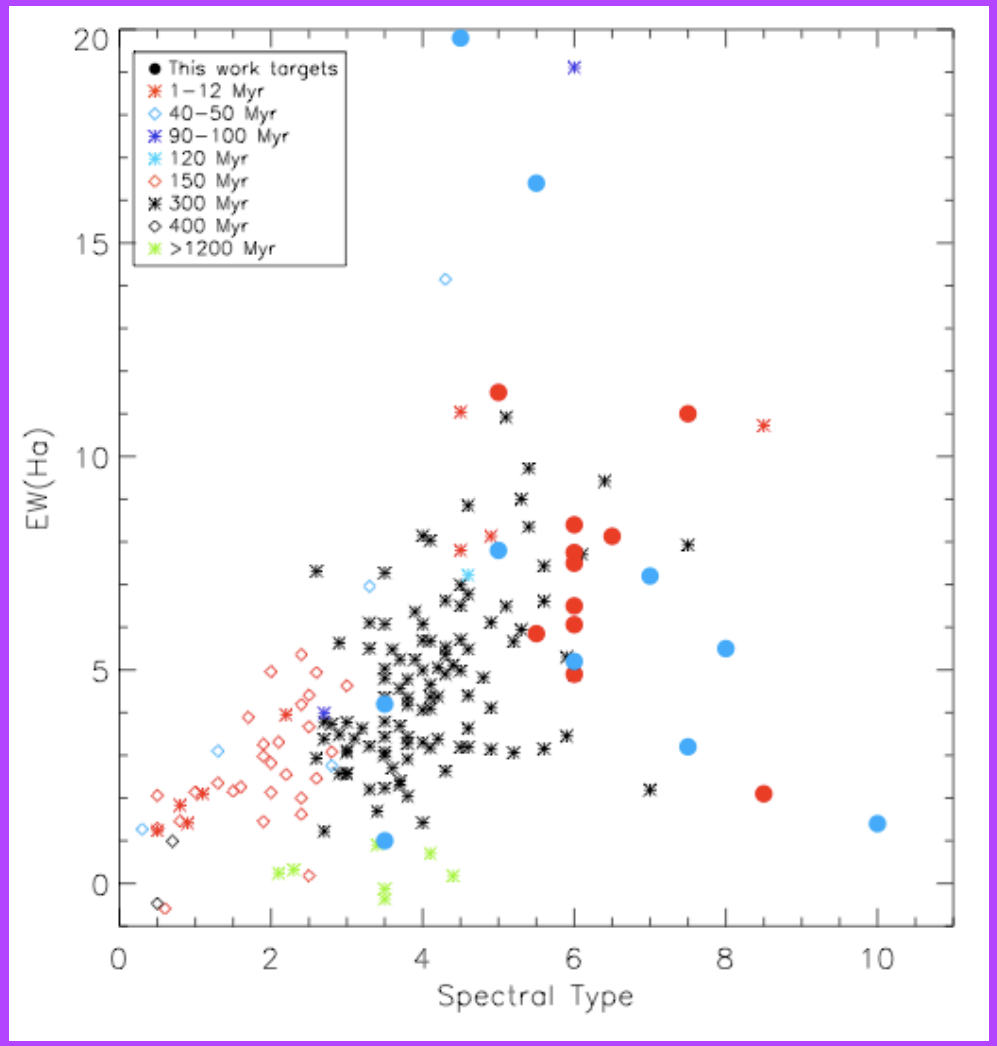
Sample A and B: EW(Na I) and youth



EW (Na I) - Spectral type

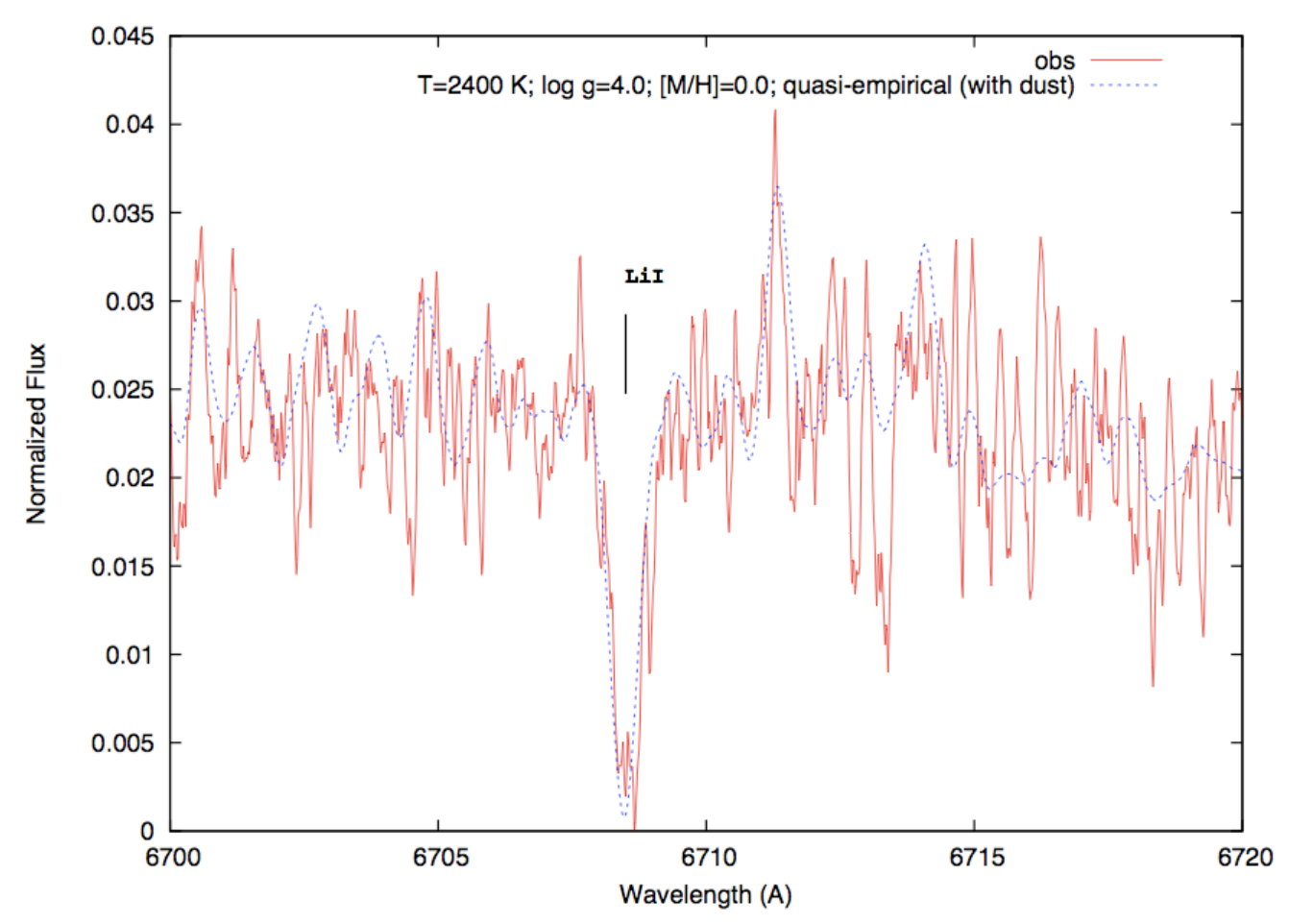
(Martín et al. 2010, A&A, 517, A53: Schlieder et al. 2012, AJ, 143, 114,)

Sample A and B: Activity-Age



DATA: Stauffer et al. (1995) and (1997), Hawley et al. (2006), Shkolnik et al. (2009) and Lopez-Santiago et al. (2010). A sample is plotted as red dots, B sample as blue dots. Ages were calculated by known age MG or Cluster membership or by other age constraining methods.

Lithium-Age


obs
T=2400 K; log g=4.0; [M/H]=0.0; quasi-empirical (with dust)
LiI
Normalized Flux
Wavelength (A)
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
6700
6705
6710
6715
6720

Membership Summary

- **Sample A:**

  ASTROMETRY + PHOTOMETRY + KINEMATIC + ROTATIONAL VELOCITY = 36 members + LOG G + ACTIVITY + LITHIUM= 10 confirmed members up to now.

- **Sample B:**

  ASTROMETRY + PHOTOMETRY = 23 possible members + LOG G + ACTIVITY= 10 confirmed members up to now.

Summary and future work

- **Sample A: 817 red catalogue, 132 selected by photometric and astrometric criteria, 49 members to YD via Kinematic criterium with 36 of them are possible member of MG. Rotational velocity, activity, lithium and features sensitive to gravity: 10 confirmed objects.**
- **Sampe B: Galactic red catalogue, 23 objects selected by photometric and astrometric criteria. Gravity features and activity criteria: 10 robust candidates.**

Clarke et al . 2010, Gálvez-Ortiz et al. 2010 & Gálvez-Ortiz et al. 2012 (in presp).

- **Test of atmospheric and evolutionary models**
- **Planetary companion search around the confirmed MG members through adaptive optics.**

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Sample A and B: Log g and Age

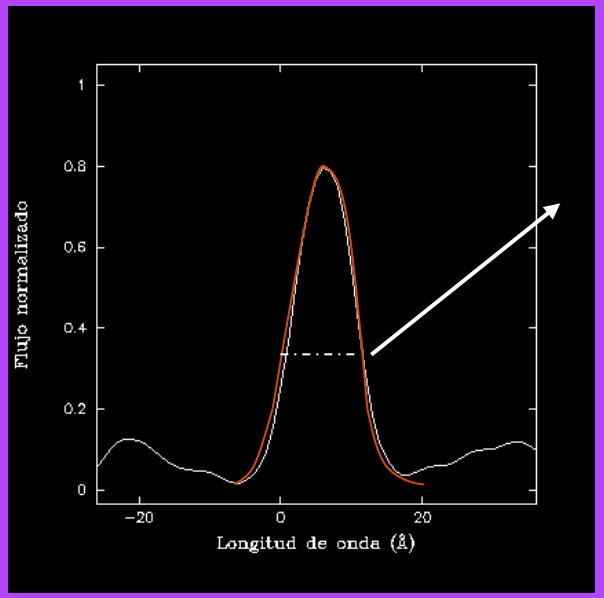
- **Baraffe et al. (1998) : Log g <4.5 ⇒ Probably Age < ~100 Myr and Log g ≥ 5.5 ⇒ Probably Age > ~300 Myr, ~ 600 Myr**
- **LP 944-020: M9, Castor MG member (~ 300 Myr), log g =4-4.5**

- **Log g 4.0-4.5 ⇒ Probably Age < ~200 Myr**
- **Log g 5.0-5.5 ⇒ ~200 Myr <Age <~300 Myr**
- **Log g ≥ 6.0 ⇒ Probably Age > ~300 Myr, ~ 600 Myr**

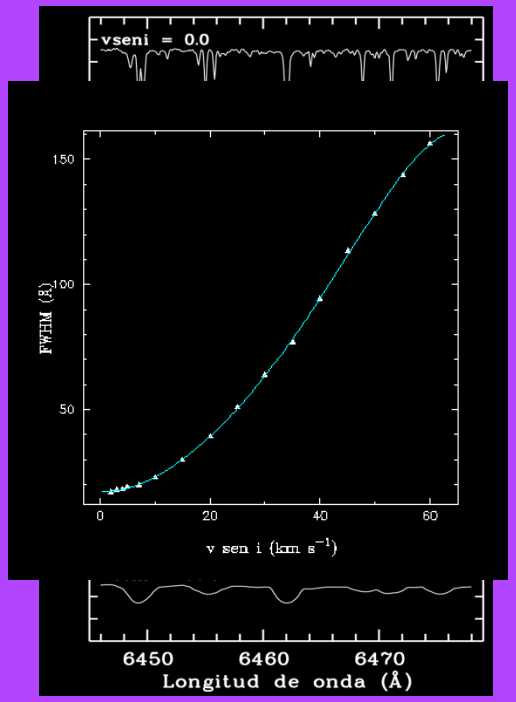
Rotacional Velocity → Cross-correlation technique:

I. FWHM of CCF → rotational broadening
II. Standar star calibration (FWHM- $v\sin i$):function
III. Cross-correlation with the spectra of the standar star
IV. Apply the obtained function with the FWHM of the problem star

CCF peak



FWHM

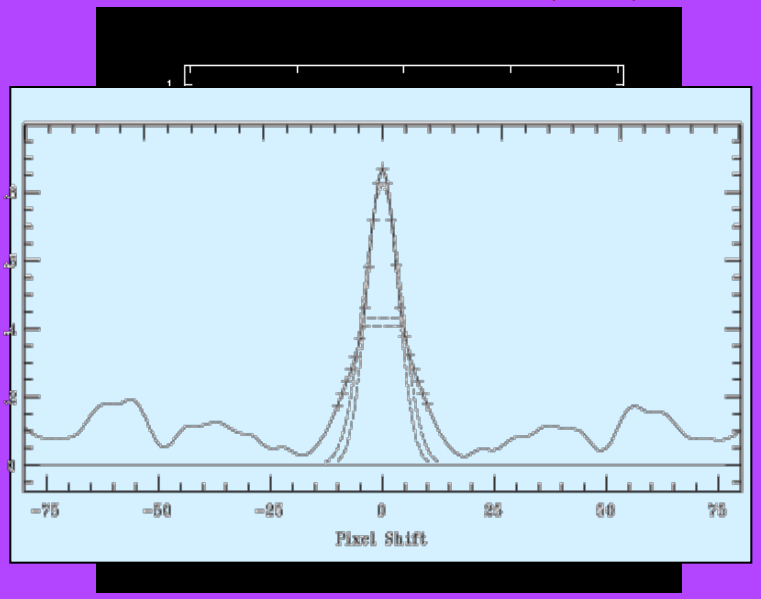


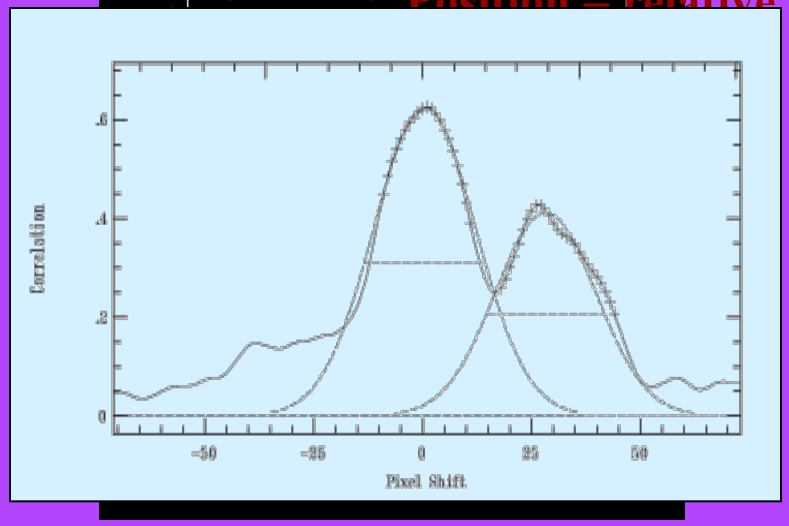
Radial Velocity → Cross-correlation technique:

I. Maximum of the CCF function → shift
II. Cross-correlation with radial velocity standar star spectra
III. Using the la Vr of the standar star and the necesary corrections

the heliocentric radial velocity of the stars is achive

Cross-correlation function (CCF)



CCF peak

Position = relative Vr