Direct Imaging of Sub-Stellar Companions Around Cool Dwarfs

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Our Project: Planets Around Cool Dwarfs in Moving Groups

- **Direct imaging of moving groups (MG) ultra cool dwarfs in search for sub-stellar companions:**

1. **Direct imaging gives advantages respect other techniques. (Marois et al. 2008; Kalas et al. 2008)**
2. **Cool dwarf present advantage in the luminosity contrast with a possible faint companions**
3. **Cool dwarfs in MGs: possible giant companions young enough to be relatively bright and mature enough to apply theoretical models (additional advantages: known age and composition)**

Candidature to Moving Groups

- **The sample: ultra cool dwarfs (>M6) from ELEHPM, SIPS, 2MASS and DENIS under s/n and color constrains to select object with spectral type later than M6. 817 objects.**
- **The moving groups (MG): From Montes et al. (2001).**

Stellar kinematics groups (moving groups):

Group of stars with a common movement, no gravitationally bounded

Origin:

- Open cluster evaporation.
- Remains of stars formation region.
- Yustaposition of several bursts of star formation in different epochs in adjacent cells of velocity field.

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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

Candidature to Moving Groups

- **Astrometric and Photometric selection: calculate the proper motion of the targets respect to the convergent point (CP) and select the ones whose proper motion was orientated towards the CP of the MG considered, inside allowed scatter.**
- **Estimate distances (assuming belonging to the MG) and plot color-absolute magnitude diagrams: select the targets whose location were consistent with a previously constructed diagrams with canonical objects (M and L dwarfs from Knapp et al. 2004, Vrba et al. 2004, Dahn et al. 2002 and Legget 1992).**

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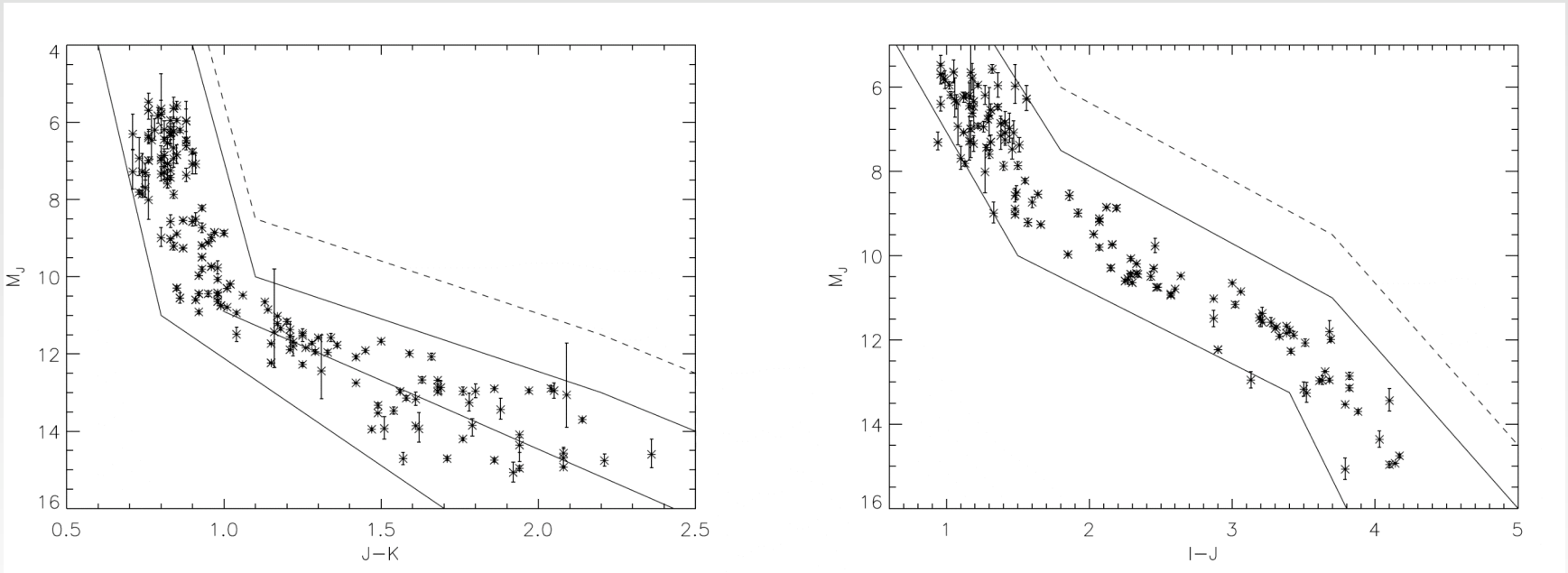
Candidature to Moving Groups



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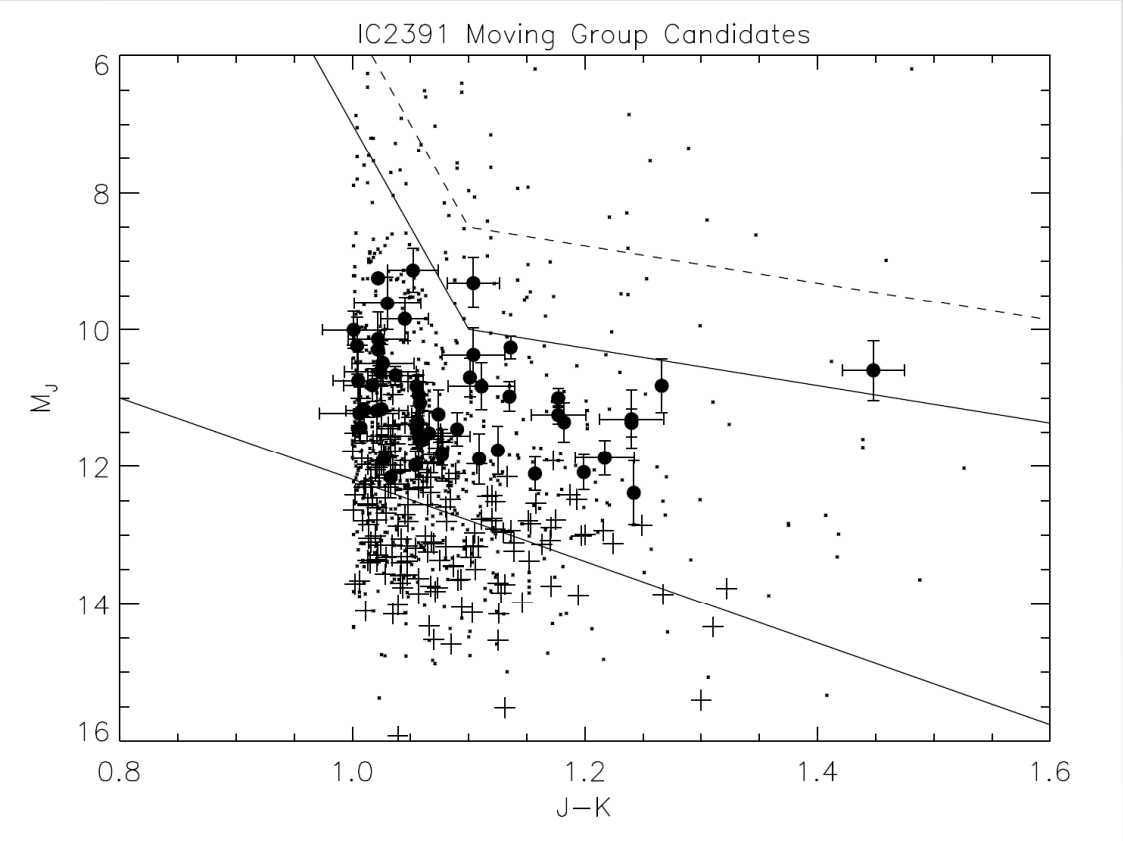
IC2391 Moving Group Candidates
6
8
10
12
14
16
M_J
0.8
1.0
1.2
1.4
1.6
J−K

Candidature to Moving Groups

- By considering each MG in turn we identified 133 objects candidates to one or more of the five MGs. 48; 89; 12; 54 and 33 candidates to Pleiades, Hyades, Sirius, IC 2391 and Castor MG respectively. (Clarke et al. 2009).
- From these sample we took high resolution spectra of 68 objects:

Date	Telescope	Instrument	Spect. range (Å)	Orders	Dispersion (Å)	FWHM (Å)
28-30/12/06 and 16-17/06/07	ESO-2.2m	FEROS	3500-9200	39	0.033 - 0.081	0.076 - 0.131
Sep-Dec/07	ESO-VLT-U2	UVES	6650-10425	33	0.027-0.041	0.15-0.23
23/02-25/02/08	Gemini	Phoenix	15532-15606	1	0.074	-
March-Jun/07	ESO-VLT-U2	UVES	6650-10425	33	0.027-0.041	0.15-0.23

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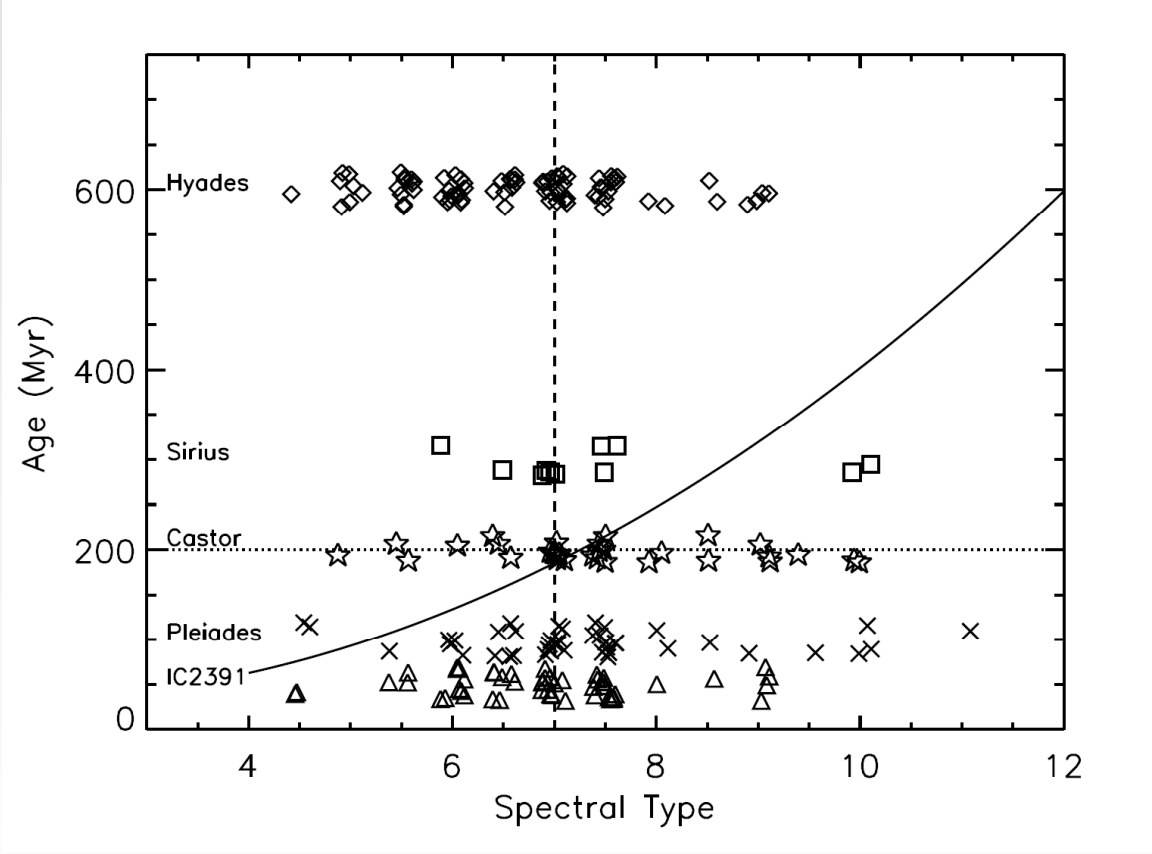
Candidature to Moving Groups

- **Confirming membership:**



1. **Kinematic** (e.g. Montes et al. 2001, MNRAS, 328, 45)
2. **Lithium I 6708 Å** (Basri 1997)
3. **Activity** (West et al. 2008, AJ, 135, 795)
4. **Gravity features** sensitive to age (Gorlova et al. 2004, AJ, 593, 1074 and McGovern et al. 2004)
5. **Rotational velocity** (Reiner et al. 2008, AJ, 684, 1390)

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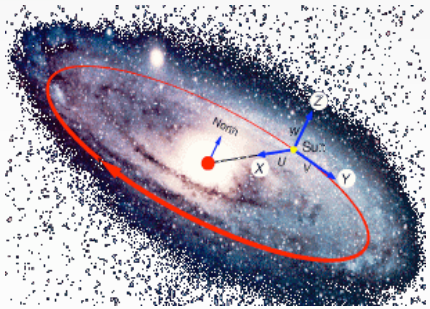
Candidature to Moving Groups

- **Spectral type and distances determination: using spectral type PC3 index (as defined in Martín et al. 1999) and Crifo et al. (2005) for distances, in optical spectra. 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

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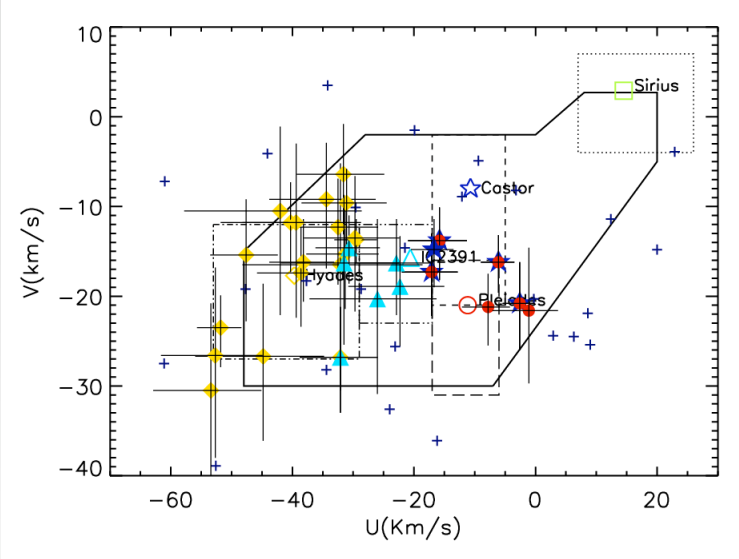
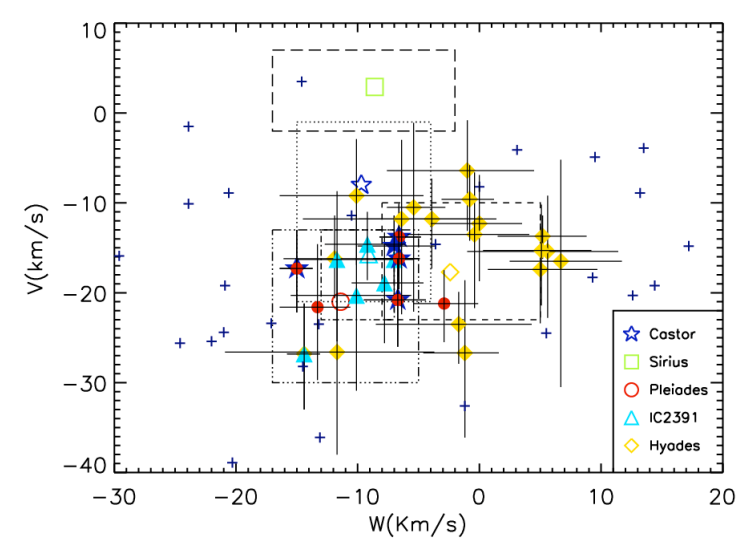
Preliminary Results





45 object belong to the young disk area and 28 of them are candidates to belong to one of the five MGs. (Legget 1992; Eggen 1984b. 1989, etc....)

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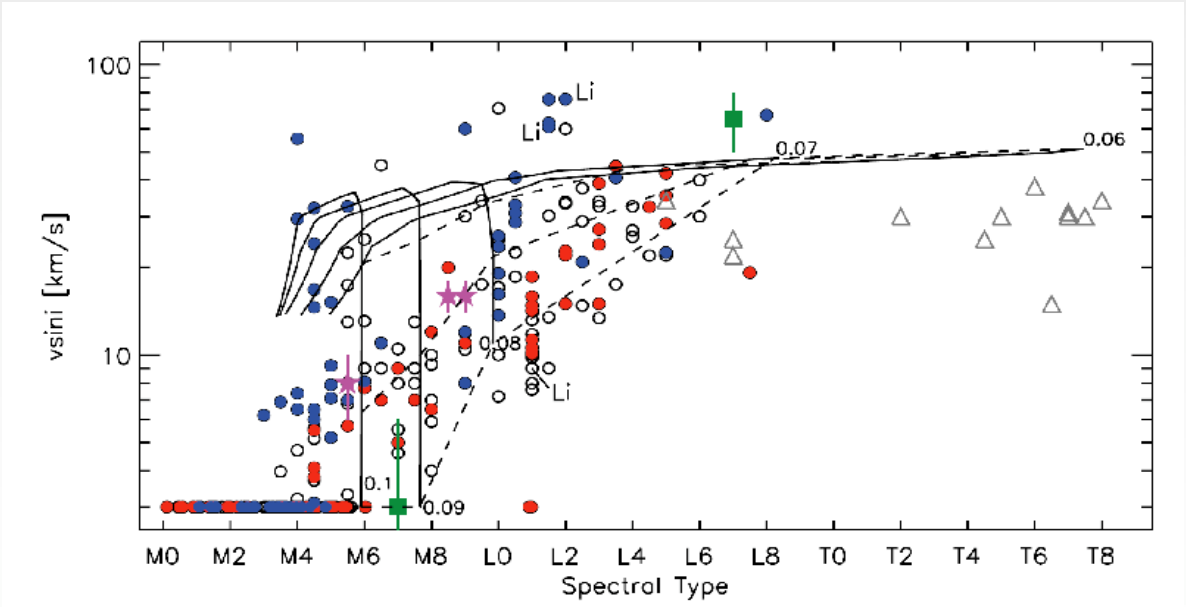
Candidature to Moving Groups

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



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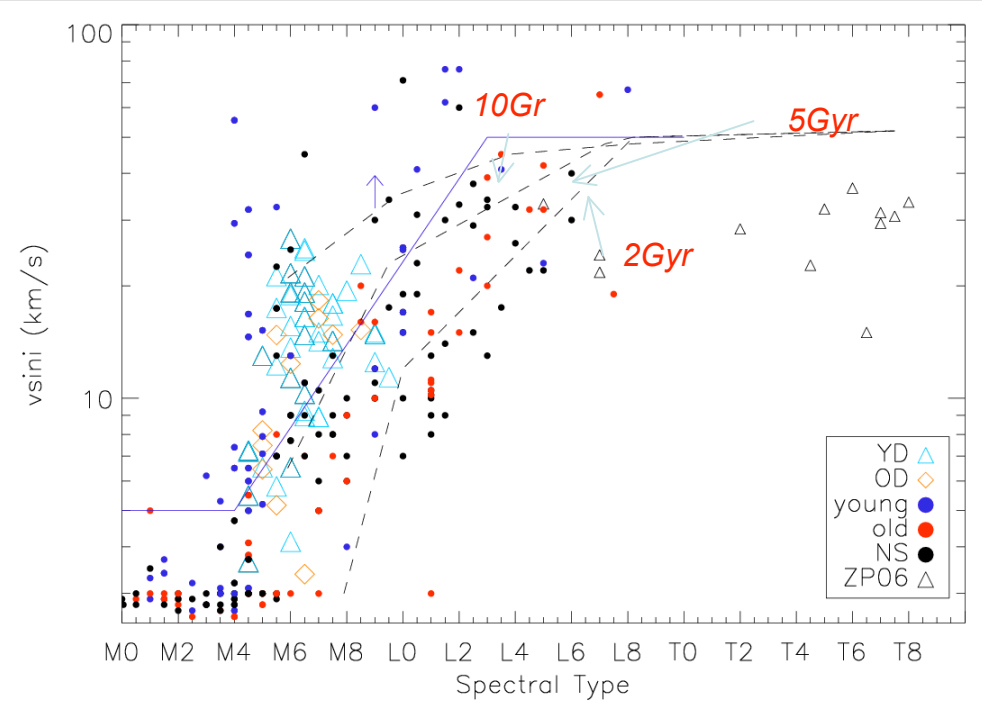
Preliminary Results



Our sample overplot to Reiners & Basri (2008) (circles), Zapatero-Osorio et al. 2006 (triangles). Blue circles suposed to be young, red circles old and black have unknown age.

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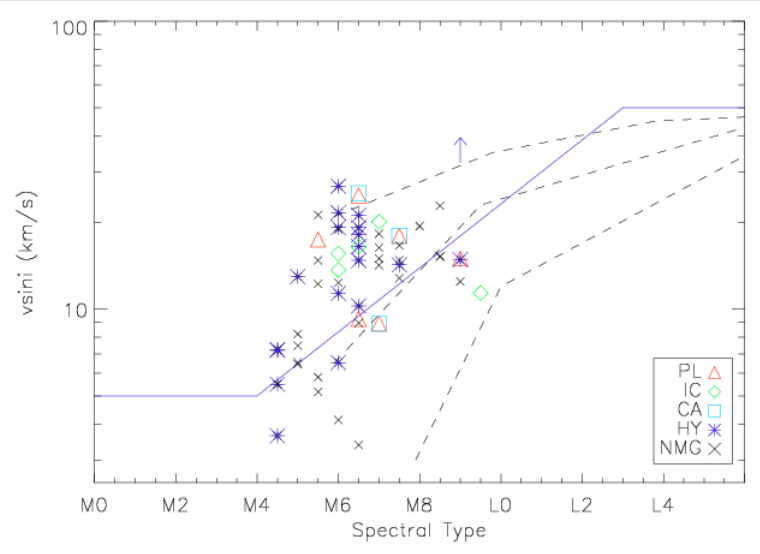
Preliminary Results



Our sample in different symbol depending of the MG they are candidates to.

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- We will continue the spectroscopic analysis of the original sample to asses their membership to the MGs, extending to the signatures of youth through the Li I 6708 Å, Activity and Gravity features.
- We are already widened the original sample extending to L9 spectral types from a low Galactic latitude compiled catalogue (Folkes 2008, Thesis work) that gives significant advantages in the AO studies. Folkes et al. (2009), "A Method for Identifying Ultra-Cool Dwarfs at Low Galactic Latitudes: A preliminary Catalogue of the Southern Hemisphere" (in prep). We will apply the same criteria to this sample to asses youth.
- We will select the probed young targets and perform AO imaging in search for companions.

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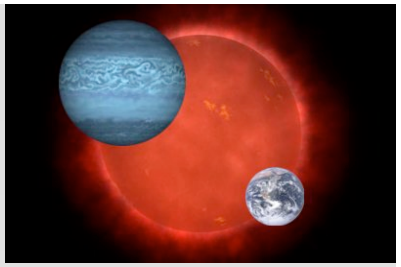
Inside RoPACS

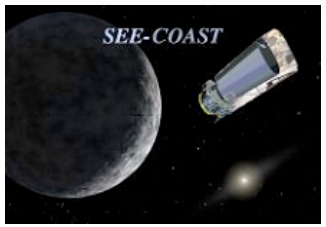


- Cosmic Vision Space mission in the type of Super-Earth Explorer – Coronagraphic Off-Axis Space Telescope: **SEE-COAST** (J. Schneider et al. 2008). Space telescope which main objective is the spectroscopic and polarimetric characterization in visible wavelengths of mature jovian planets and Super Earths.
- ESR shared his/her time between

  - ASTRIUM : mission/system engineering, analysis, feasibility, especifications, options

  - Observatoire de Paris : Instrumental simulations of detectability (J. Schneider).

  - University of Hertfordshire : Observational background and test in real sample.



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