LoI from GCDS SE3: Open Clusters

1 Title: Open Star Clusters: the path from molecular clouds to the MW disc population

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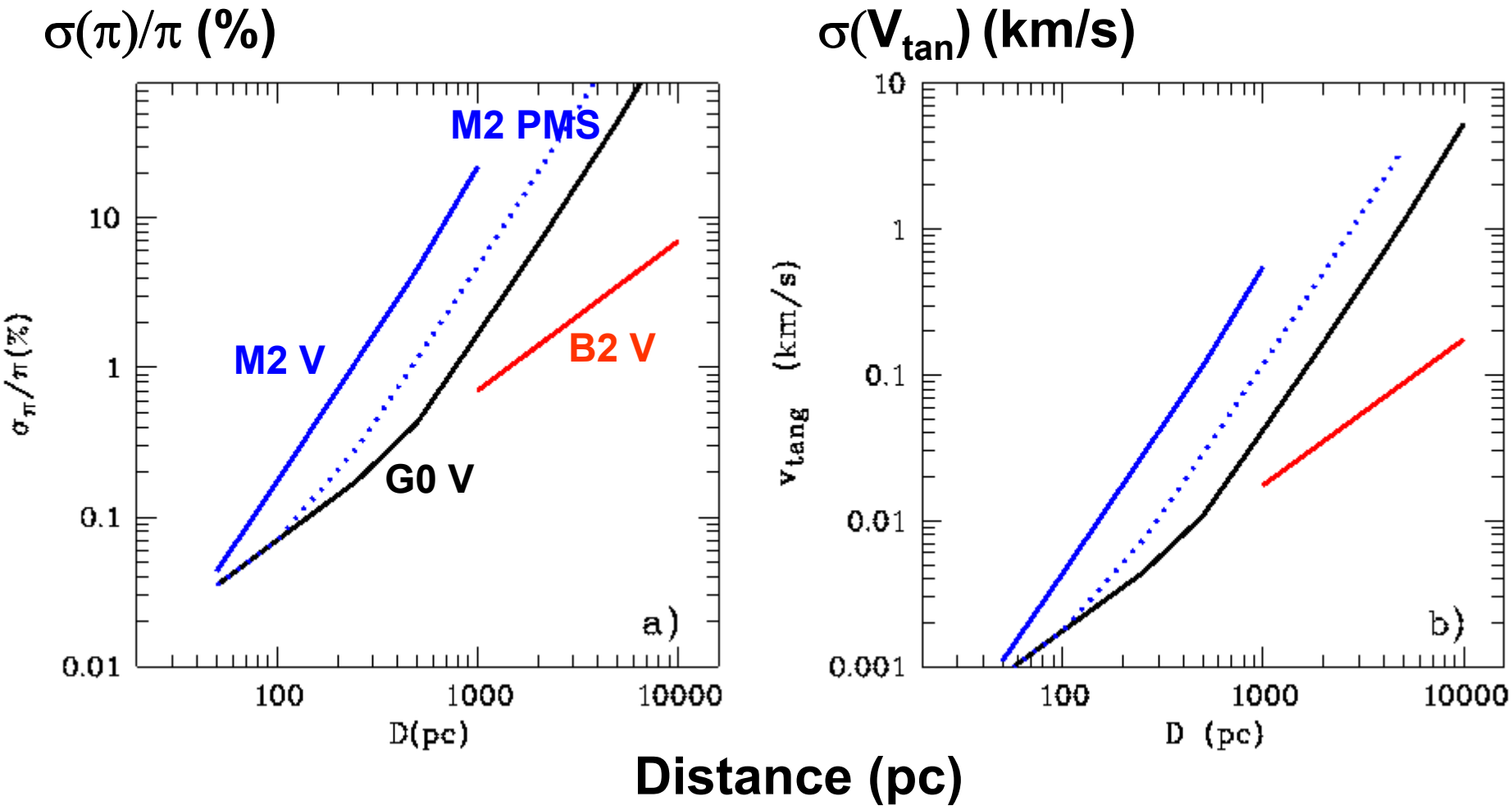
The Promise of Open Clusters

- *Most stars are born in clusters rather than in isolation* (Lada & Lada, 2003) – **the dominant mode of SF**.

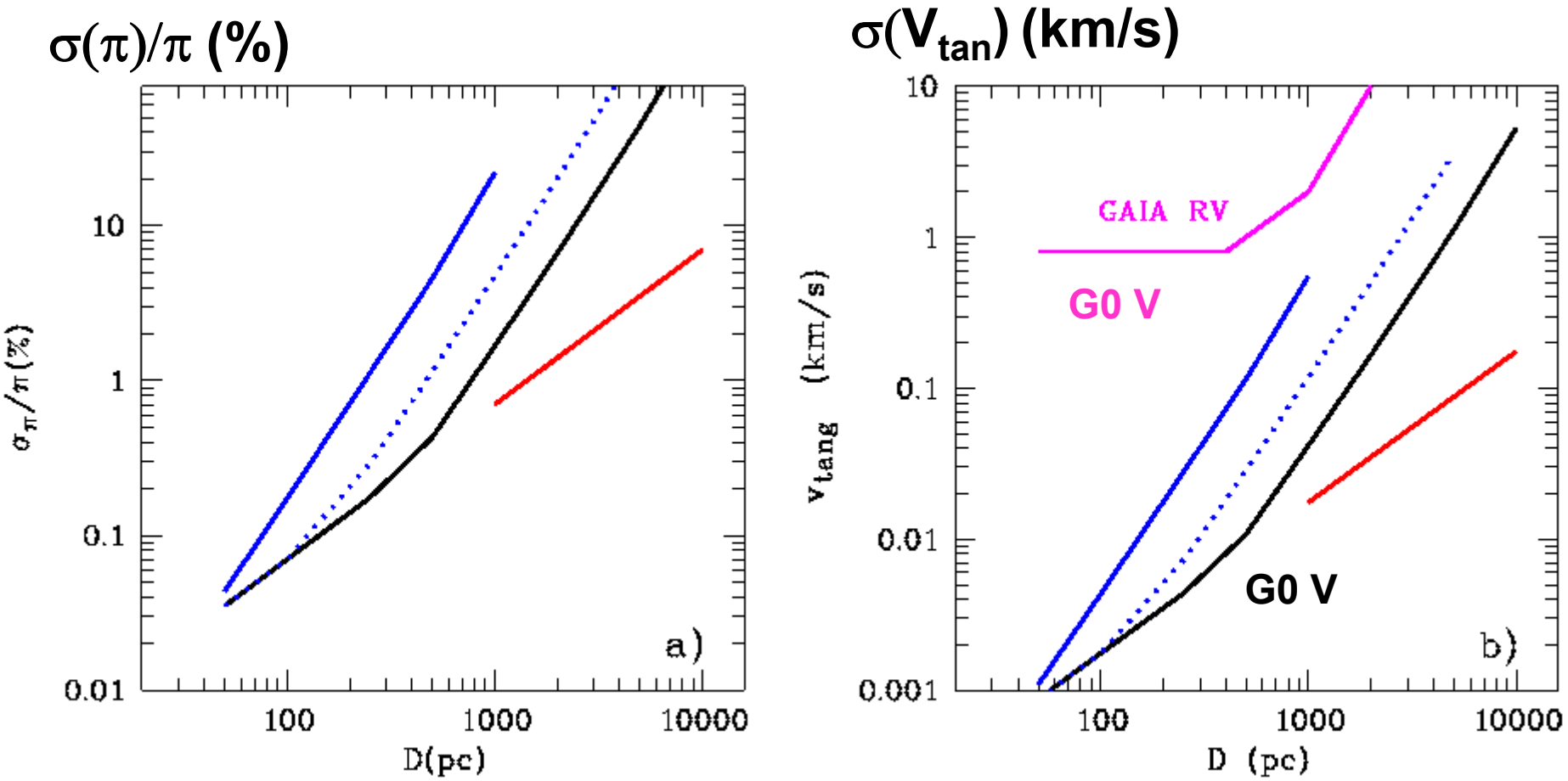
- Clusters **populate the field** – clusters are the dominant source of field stars- and trace the MW thin disk (seen at all positions, ages and [Fe/H])

- Homogeneous populations: key tool to **test and calibrate** stellar evolutionary models for Pop. I stars. They cover all masses and evolutionary phases.

Gaia will bring us into a new domain of cluster research



But…Gaia has 'limited' spectroscopic capabilities



Detailed abundances only for stars brighter than V=12 (Sun @ 300 pc)

Goals of a FLAMES survey

Large, homogeneous and accurate

- Radial velocities → 6D phase space

  $f(x,y,z,v_x,v_y,v_z)$ - σ_{RV} <= 0.3 km/s (see my later talk)
- Elemental abundances ([Fe/H], α- and Fe-peak elements, neutron capture elements, Li) - 0.05 dex accuracy/star
- Stellar parameters (when not accurate enough from Gaia) and characteristics – (T_{eff}, vsini, B-activity, accretion)

Three major themes

1. The (dynamical) evolution of clusters: from formation to disruption

2. The evolution of stars in clusters: from birth to death

3. The population and evolution of the MW thin disk

1. The (dynamical) evolution of clusters: from birth to disruption

- Do clusters (and stars) form via highly dynamic, turbulence-driven collapse or following quasi-equilibrium, slow contraction ?
- What are the parameters determining whether a cluster will remain bound or not?
- How do the kinematics and structure of newly formed stars affect the subsequent cluster evolution?
- How do clusters dissolve into the field?

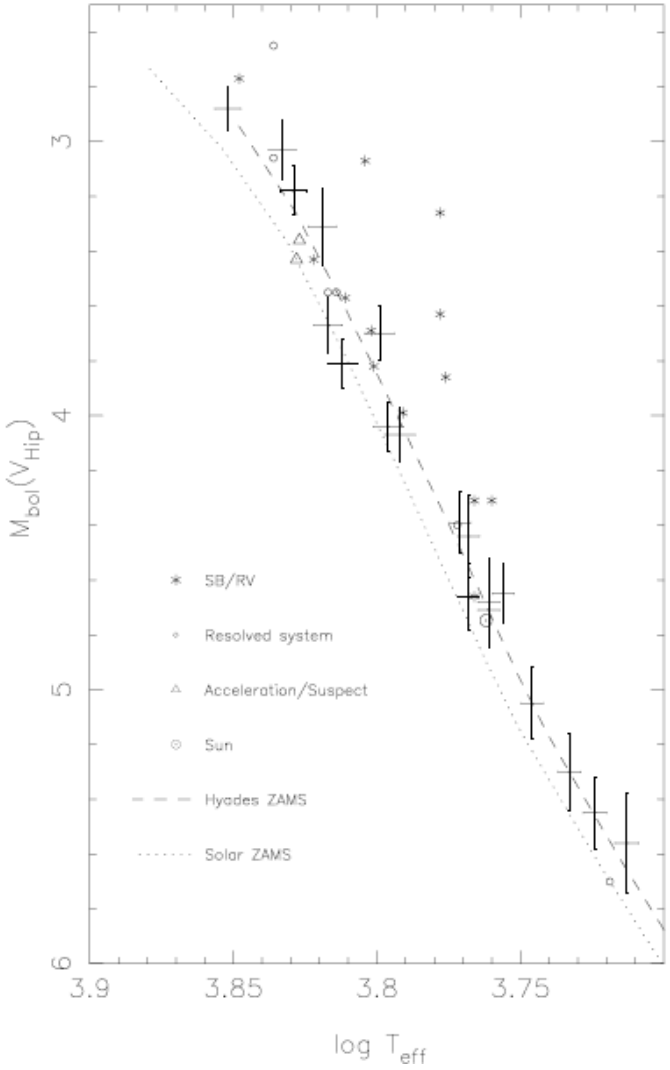
1. The (dynamical) evolution of clusters: from birth to disruption

Secure answers by comparing N-body simulations with massive observational datasets: cluster structure and kinematics (full 6D) as a function of age, environment, cluster type (massive vs. small)

GAIA: accurate astrometry and tangential velocities (from proper motions)

GB spectroscopy: third component of the velocity with a similar accuracy

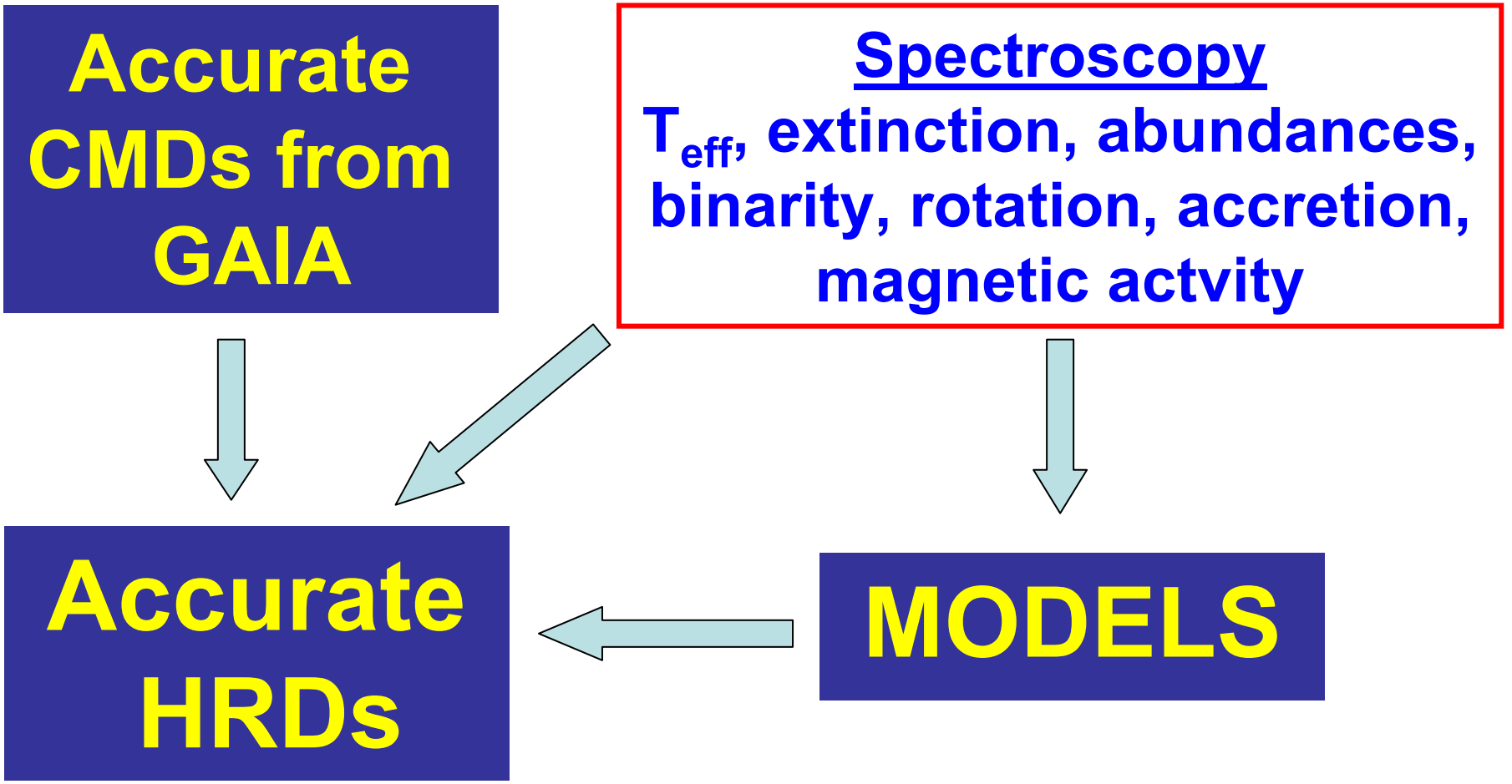
The evolution of stars in clusters: from birth to death



Exploit the unique potential of OCs to understand and calibrate complex physics that affects stellar evolution (EOS, opacities, diffusion, convection, rotation, magnetic fields)

Perryman et al. (1998)
Hyades - Hipparcos

The evolution of stars in clusters: from birth to death



The population and evolution of the MW thin disk

See talk of Angela Bragaglia

Targets and survey strategy



All phases of cluster evolution





Intermediate-age and old clusters (>100 Myr)



Star forming regions and PMS clusters (<1-100 Myr)



Sample clusters

a. SFRs and PMS clusters (age < 100 Myr) , plus some more distant, massive clusters, where OB pop. can be observed 30+10 targets
b. Mature clusters (100-500 Myr): 20 targets
c. Old clusters (> 500 Myr): 50 targets

Primary source: Dias et al. (2002) catalogue

The sample will include all clusters with available information on membership within 1500 pc (a.) and 700 pc (b. and c.) + clusters up to large Galactocentric distances for scientific theme 3

Sample stars

Complete samples of main sequence (B→M) and evolved stars for nearby clusters

Representative MS samples and evolved stars for more distant clusters

Limiting magnitudes

Giraffe: **V~19, I~18**
UVES: **V=16.5**

Set-ups

UVES: CD3 -520/580 nm (hot and cool stars)

Giraffe: HR03/05A/06/14A for warm stars

HR15N/21 for cool stars

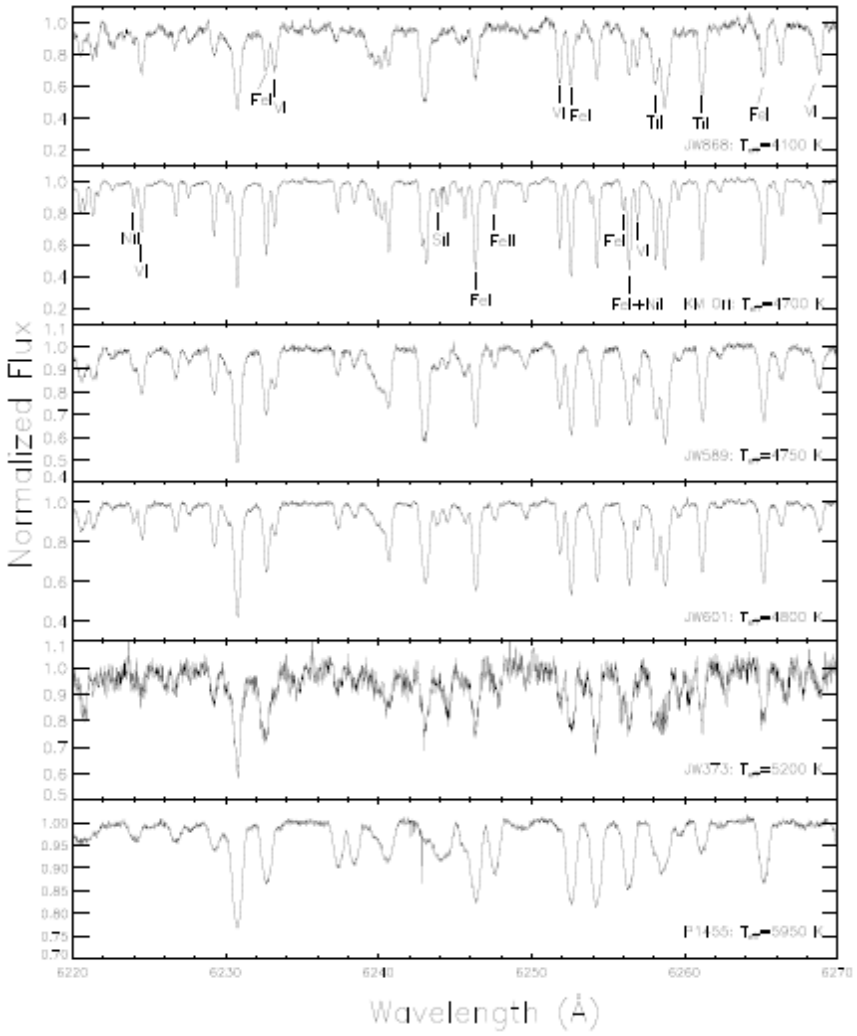
Table 1: Synthesis of survey strategy

Class	number of clusters	GIRAFFE targets	GIRAFFE mag.	GIRAFFE set-up	UVES targets	UVES mag.	UVES set-up	Av. # 1hr OBs per cluster
a.	30	F-M	≤ 19	HR15N/21	(B)G-K	≤ 16	CD3 (520/580)	20
a.	10	O-B	≤ 15	HR03/05A/06/14A	B, G/K supergiants	≤ 14	CD3 (520)	12
b.	20	B-M	≤ 19	HR15N/21	B-K,WDs	≤ 16.5	CD3 (520/580)	20
c.	50	A-K	≤ 19	HR15N/21	G/K giants	≤ 16.5	CD3 (580)	12

Total request: 1720 hrs (~200 nights)

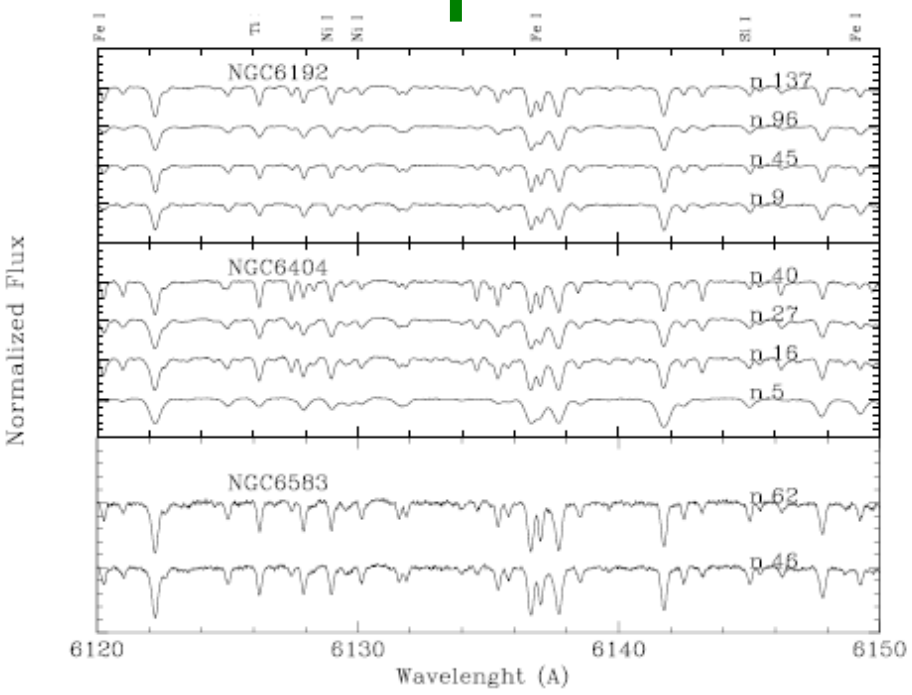
What we aim towards

PMS stars in the ONC



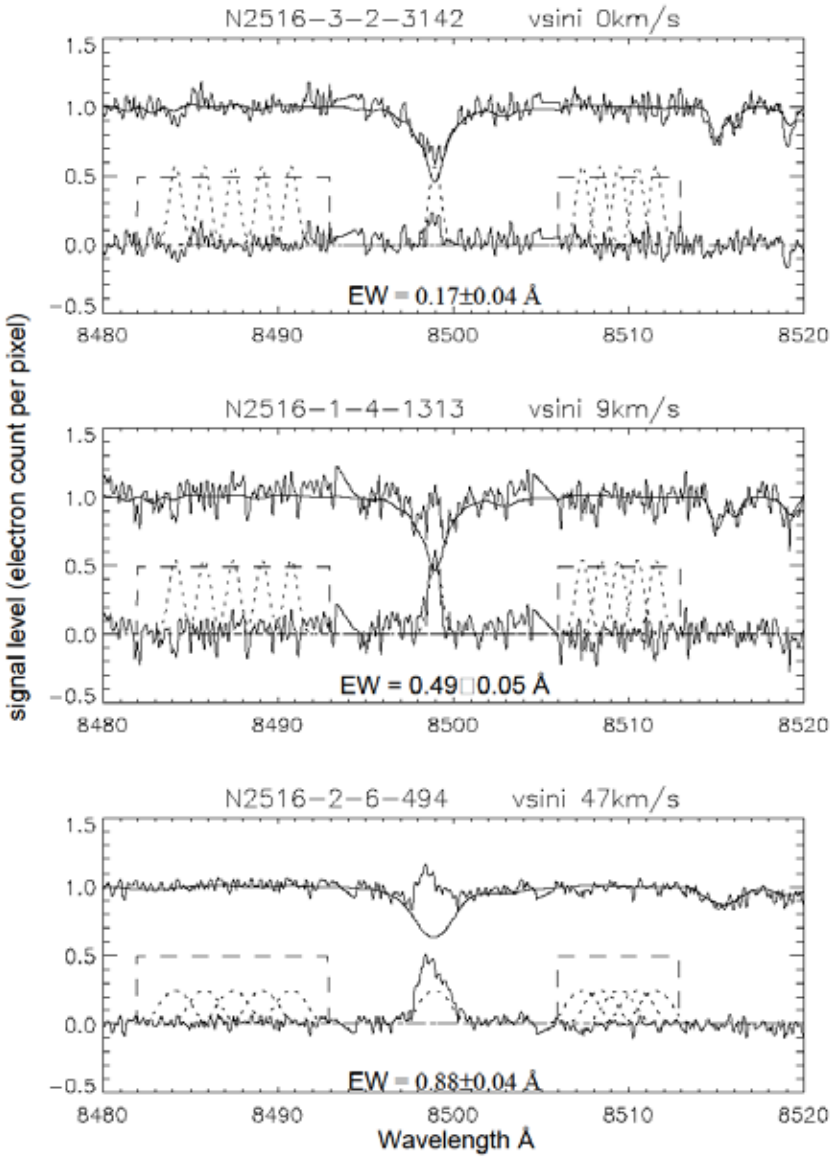
Biazzo, Randich, & Palla (2010)

Cool giants and supergiants in mature and old clusters



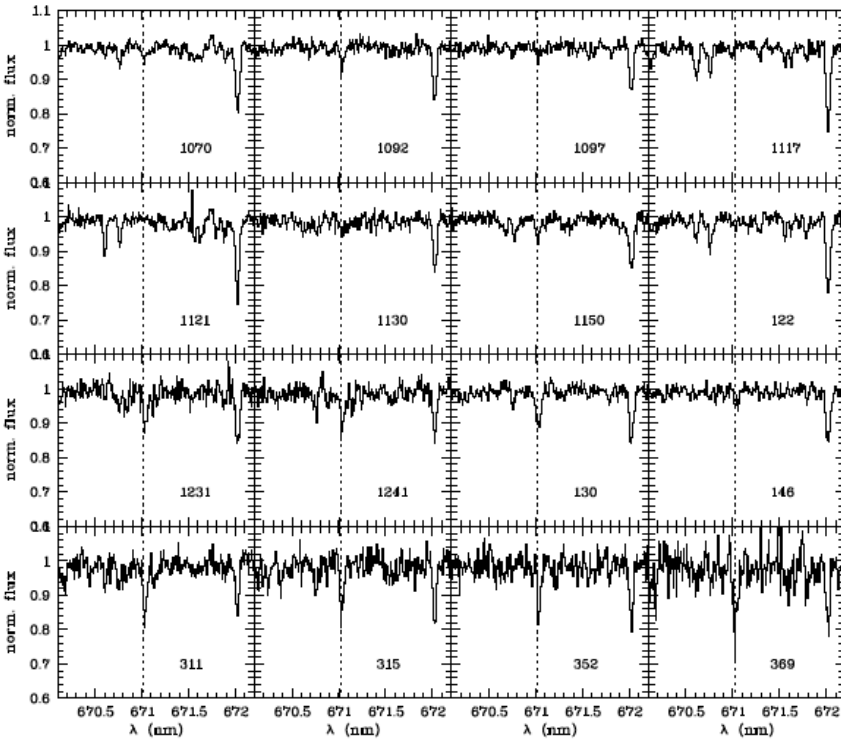
Magrini et al. (2010)

M dwarfs in a young cluster



Jackson & Jeffries (2010)

Solar-type stars in old clusters



Randich et al. (2009)

Legacy value (1)

- Calibration of stellar models (stellar ages and masses) → strong implications for stellar, Galactic, and extra-galactic astrophysics

- Largest and, arguably, the first homogeneous dataset: ***THE*** reference for a broad variety of issues

Legacy value (2)

• evolution and effect of environment on accretion and protoplanetary discs of pre-main sequence (PMS) stars (e.g., Storzer & Hollenbach 1999, ApJ 515, 669; Sicilia-Aguilar et al. 2009, AIPC 1094, 225);
• 'chemical tagging' of young clusters: constraints on triggered SF scenarios (e.g., Cunha et al. 1998, ApJ 493, 195; Biazzo et. al. 2010, A&A, in press);
• lithium ages for young clusters; comparison with isochronal ages and further constraints on PMS models; implications for SF histories (e.g., Jeffries & Oliveira 2005, MNRAS 358, 13; Palla et al. 2007, ApJ 659, L41);
• time evolution of stellar angular momentum and magnetic activity from the early evolutionary phases up to the oldest ages (e.g., Barnes & Kim, 2010, ApJ 721, 675);
• variable stars and binaries: OCs allow probing the dependence of variability properties on age and chemical composition. Detection and characterization of binaries, and in particular eclipsing binaries, will allow putting independent constraints on stellar models;
• synergy with Corot/Kepler data: our sample will include a few Corot/Kepler target clusters (those visible from Paranal). Coupling spectroscopic and asteroseismology of red clump stars in OCs will put strong constraint on the age and metallicity leading to a stringent seismic modeling of the star;
• The high precision and homogeneity of the proposed survey will allow pinning down the signature of diffusion (Lind et al. 2008, A&A 490, 777), which is crucial not only for stellar astrophysics, but also for the interpretation of observed abundance distributions from stars of different type (e.g., main sequence stars w.r.t giants);
• constraints on internal mixing processes at work in stars in different evolutionary phases as traced by light elements (Li, CNO –e.g., Charbonnel & Talon, 2010, IAUS268, 365; Smiljanic et al. 2009, A&A 502);
• characterization of massive stars: correlations between rotation and abundances; mass loss, wind parameters, construction of the Galactic wind-momentum luminosity relation;
• 'Chemical tagging' of clusters and constraints on population/origin (Bland-Hawthorn 2002, ARA&A 40, 497);
• Use of cluster space velocities to trace the local velocity field and to investigate the Galactic rotation curve (e.g., Frinchaboy et al. 2008, AJ 136, 118).