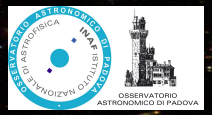
The OCCASO survey

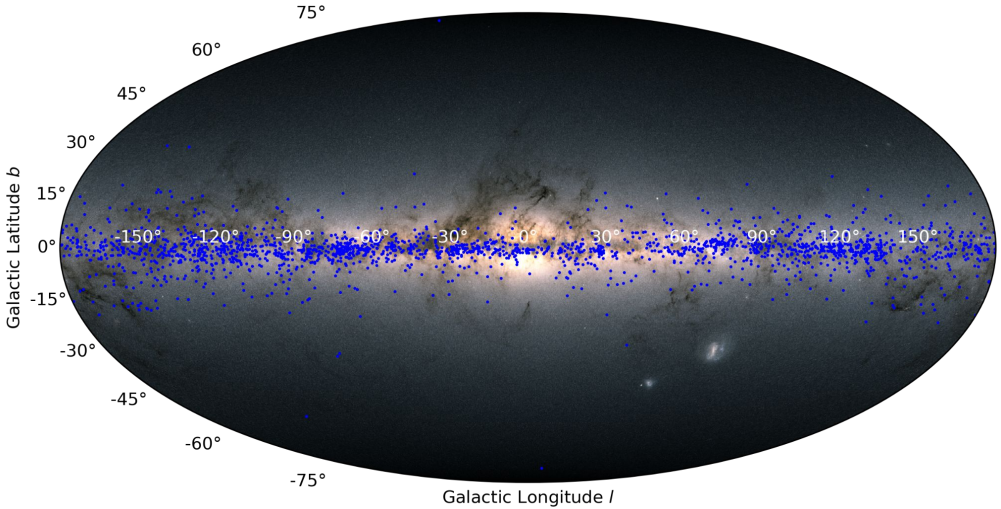
The NOT contribution to the understanding of Open clusters

R. Carrera
on behalf of the OCCASO team



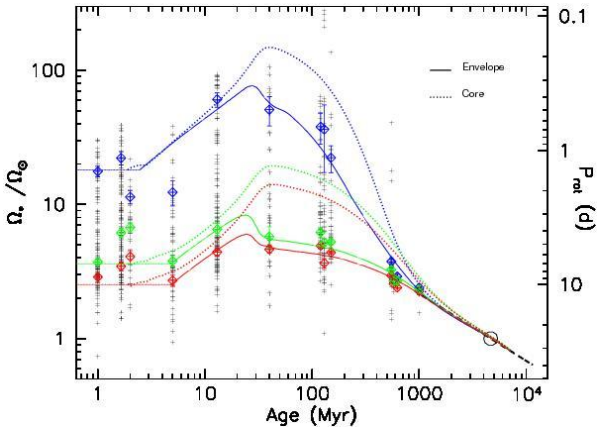
What is an Open Cluster

- groups from several hundreds to thousands of stars
- all star formed from the same molecular cloud in a single star formation episode
  - share the same properties: age, kinematics and chemical composition
- wide range of masses, luminosities, structural characteristics and ages
- located in the Galactic disk

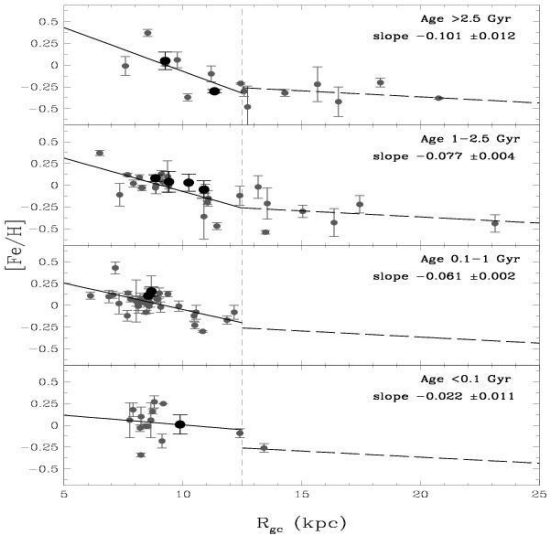


OCs as probes of astrophysical phenomena

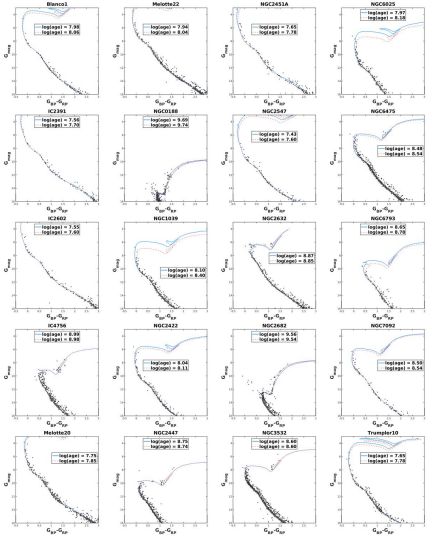
- Stellar interiors, nucleosynthesis and evolution:
  - convection and radiative transport
- Chemical and dynamical evolution of Galactic disc
  - Ages and distances more accurately determined in comparison with field stars.



Gallet & Bouvier 2013

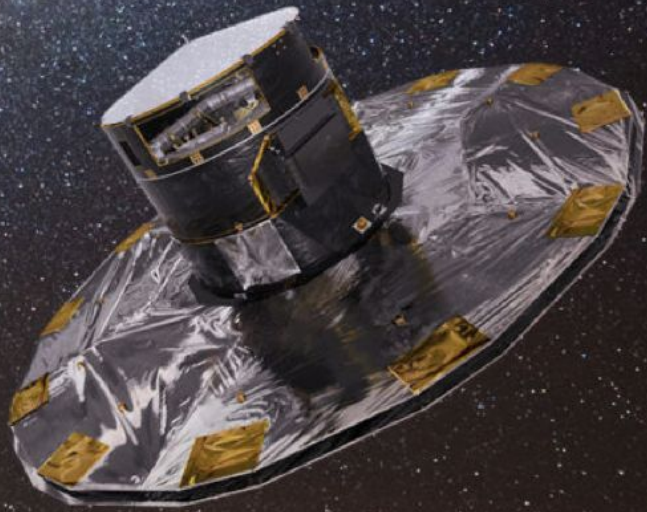


Carrera & Pancino 2011



Bossini et al. 2019

Open Clusters in the Gaia era

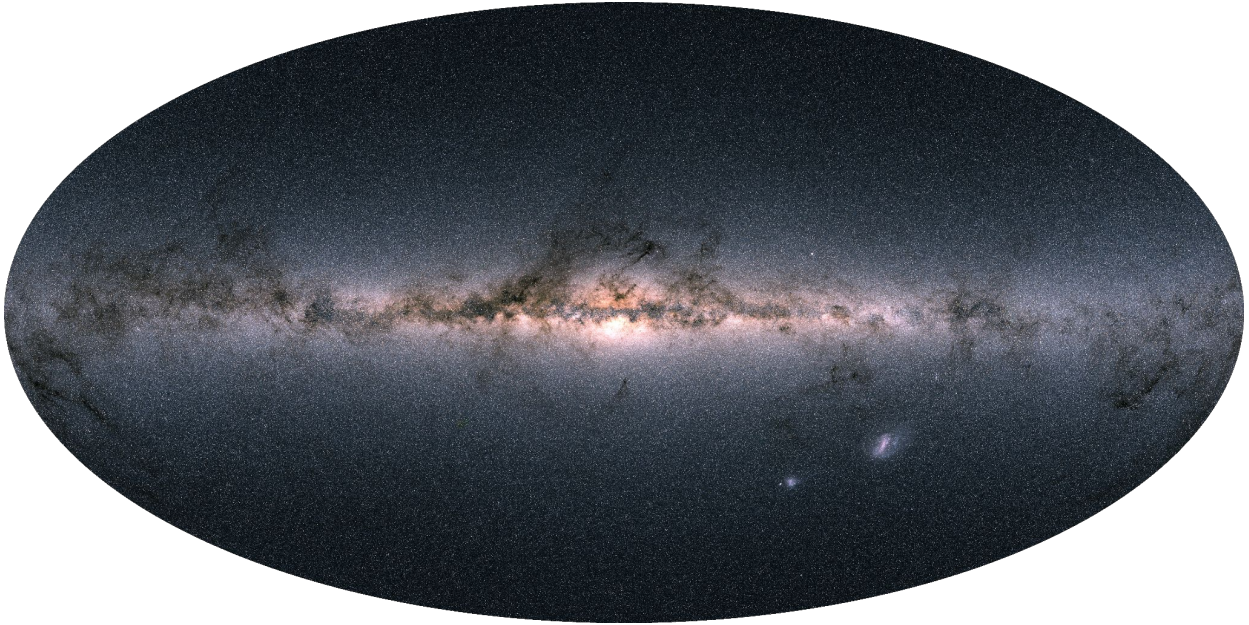


Gaia's contribution to the research of Open Clusters

Full sky coverage
Astrometry: α, δ, μ_α, μ_δ, ω
Photometry: BP, *G*, RP
Spectroscopy: v_{rad}

Next monday (Gaia DR3):

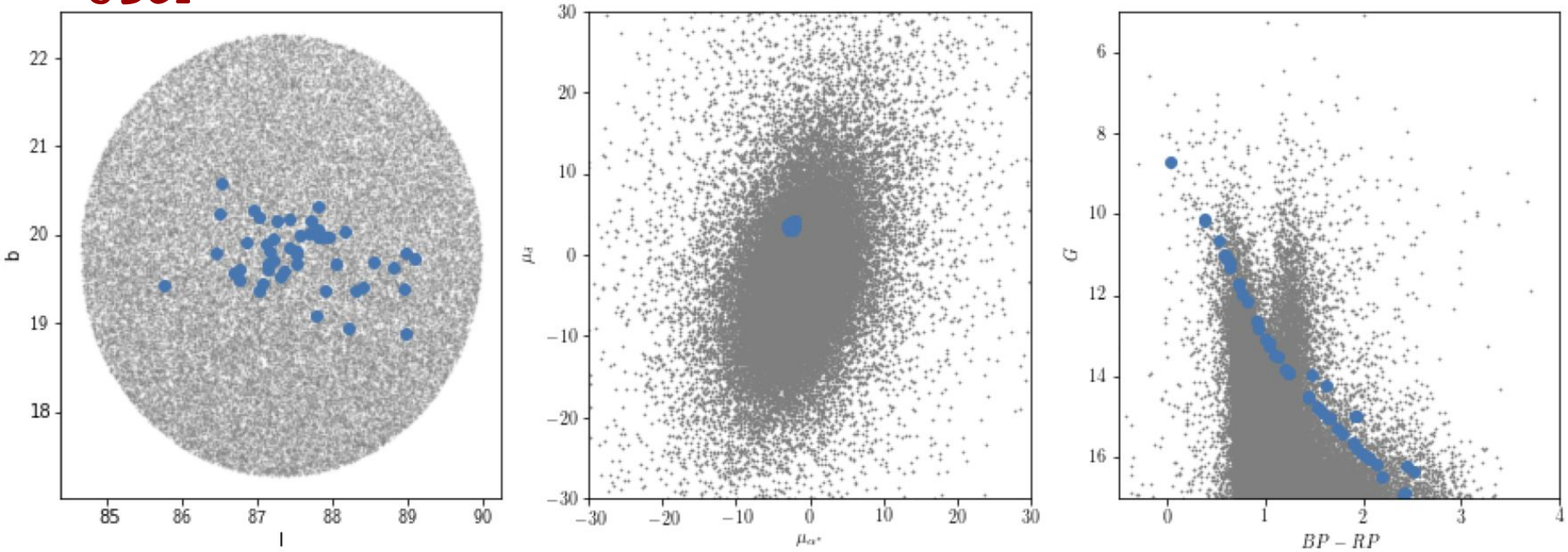
stellar parameters (T_{eff}, log *g*), abundances



Gaia's contribution to the research of Open Clusters

- Better membership determinations.

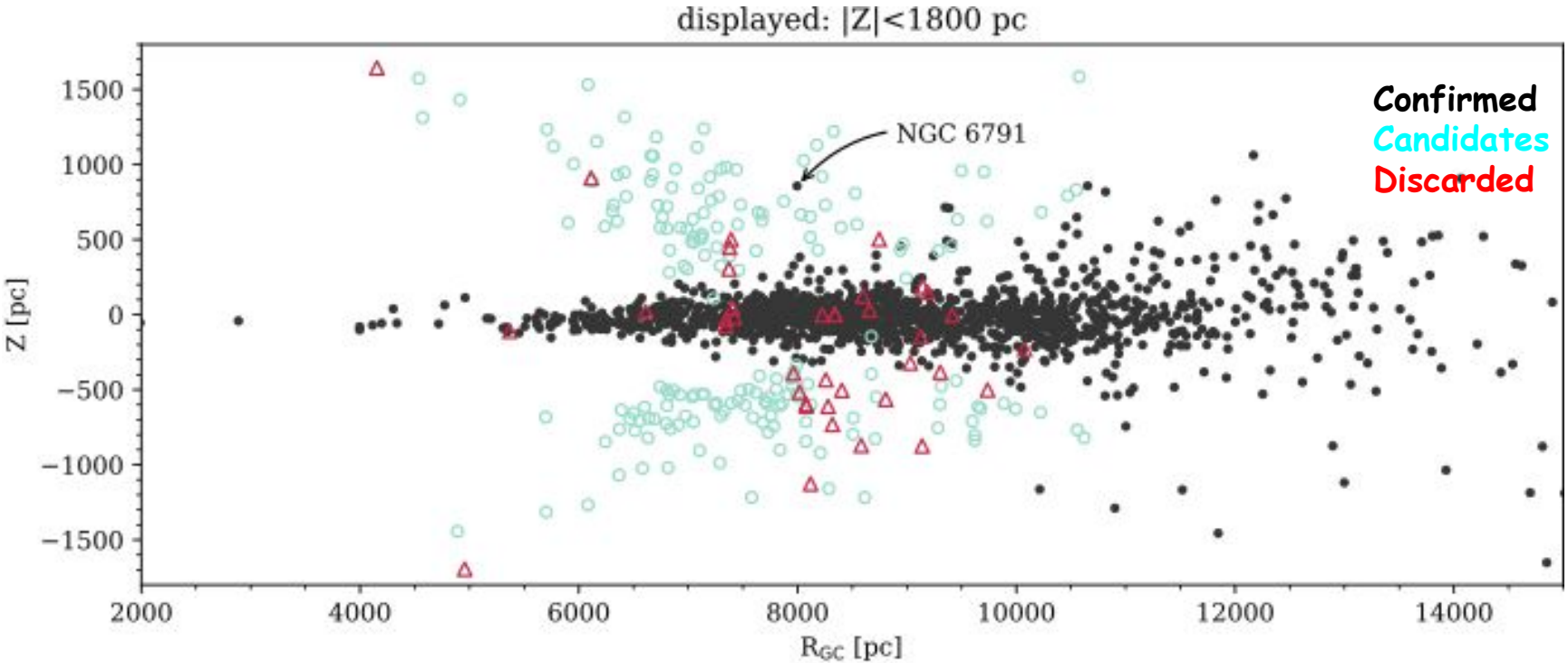
UBC1



Castro-Ginard et al. 2018

Gaia's contribution to the research of Open Clusters

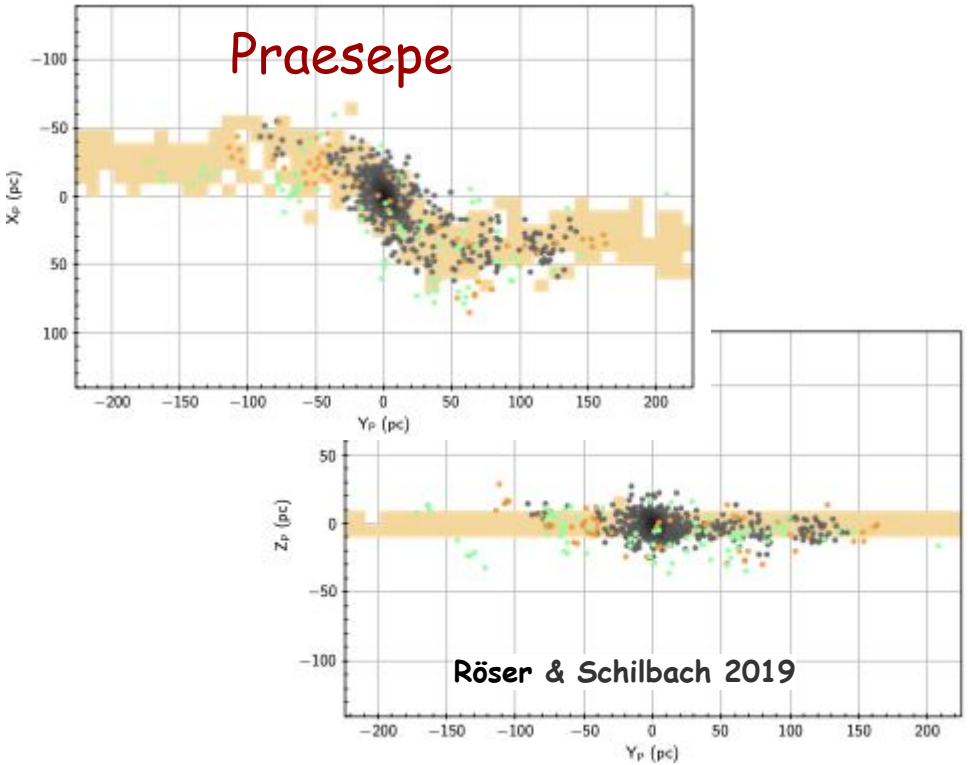
- Better membership determinations.
- Detection of unknown clusters and discard other as bound systems.

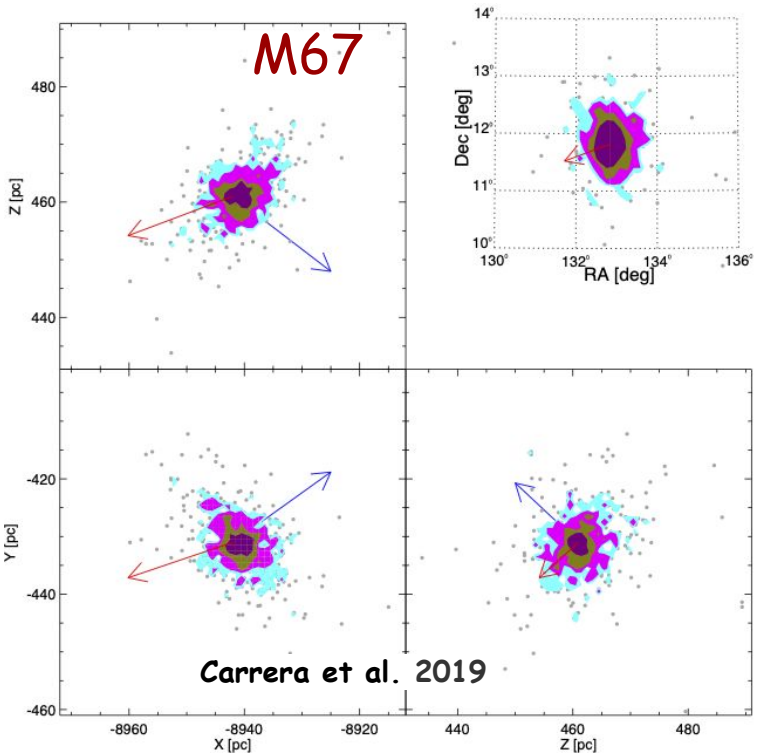


Cantat-Gaudin & Anders 2020

Gaia's contribution to the research of Open Clusters

- Better membership determinations.
- Detection of unknown clusters and discard other as bound systems.
- Study the dynamical evolution: tidal tails, extended halos.



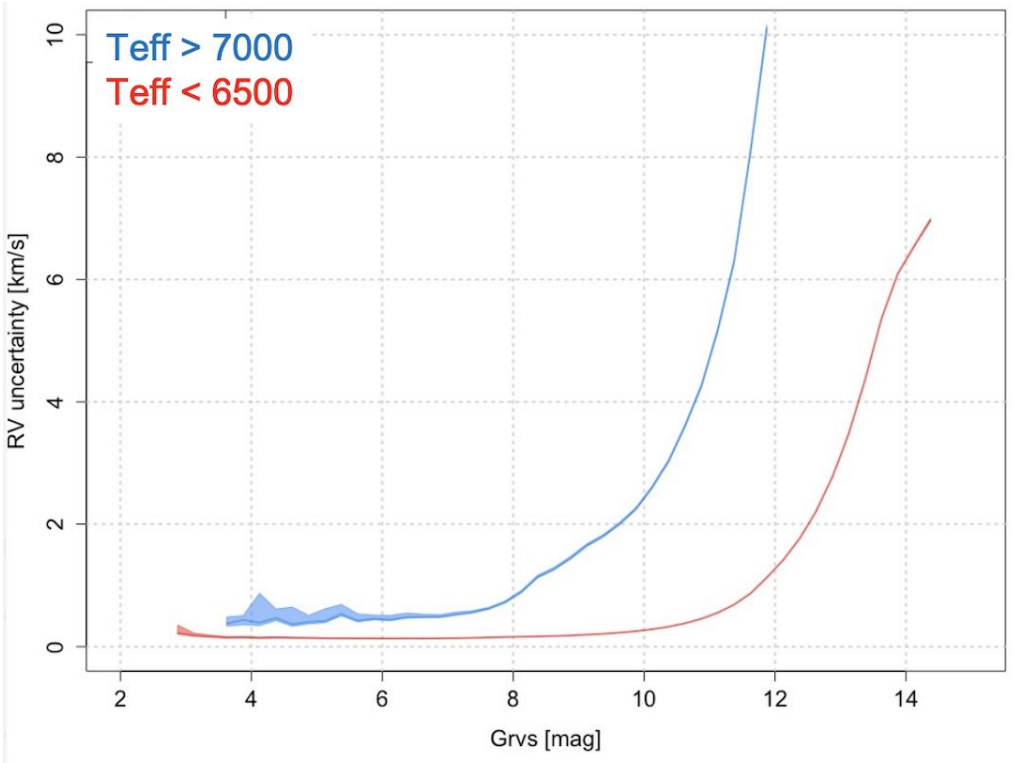


Gaia's limitations

- Radial velocities

  G_{RVS}<14 mag (DR3)

  G_{RVS}<16 mag (DR4)



Gaia's limitations

- Radial velocities

  G_{RVS}<14 mag (DR3)

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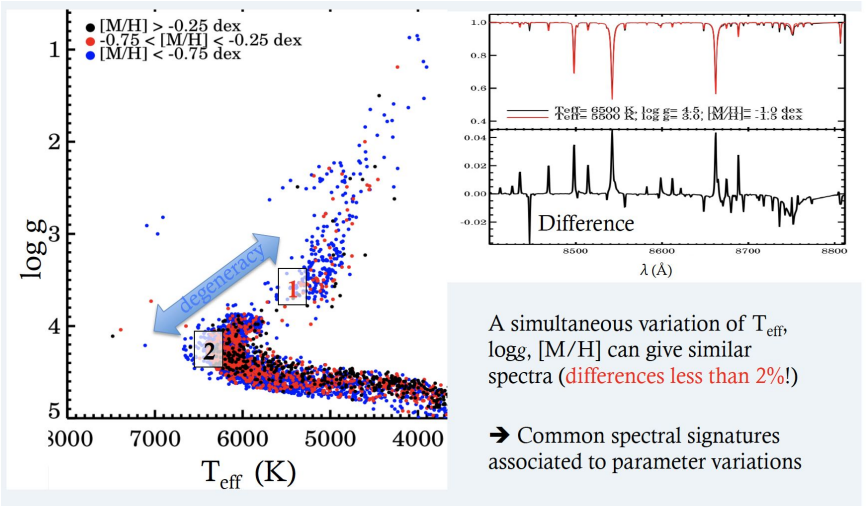
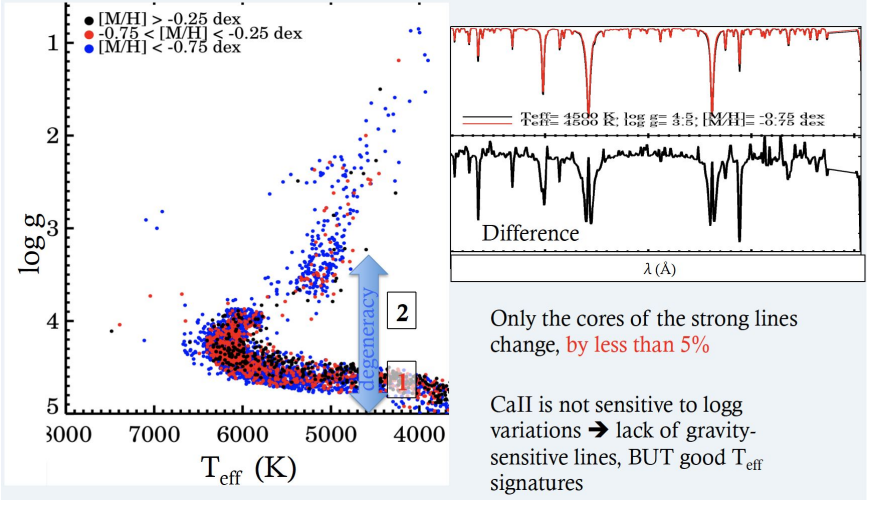
- Stellar parameters degeneracies



A simultaneous variation of T_{eff}, logg, [M/H] can give similar spectra (differences less than 2%!)

➔ Common spectral signatures associated to parameter variations



Only the cores of the strong lines change, by less than 5%

CaII is not sensitive to logg variations ➔ lack of gravity-sensitive lines, BUT good T_{eff} signatures

Gaia's limitations

- Radial velocities

  G_{RVS}<14 mag (DR3)

  G_{RVS}<16 mag (DR4)

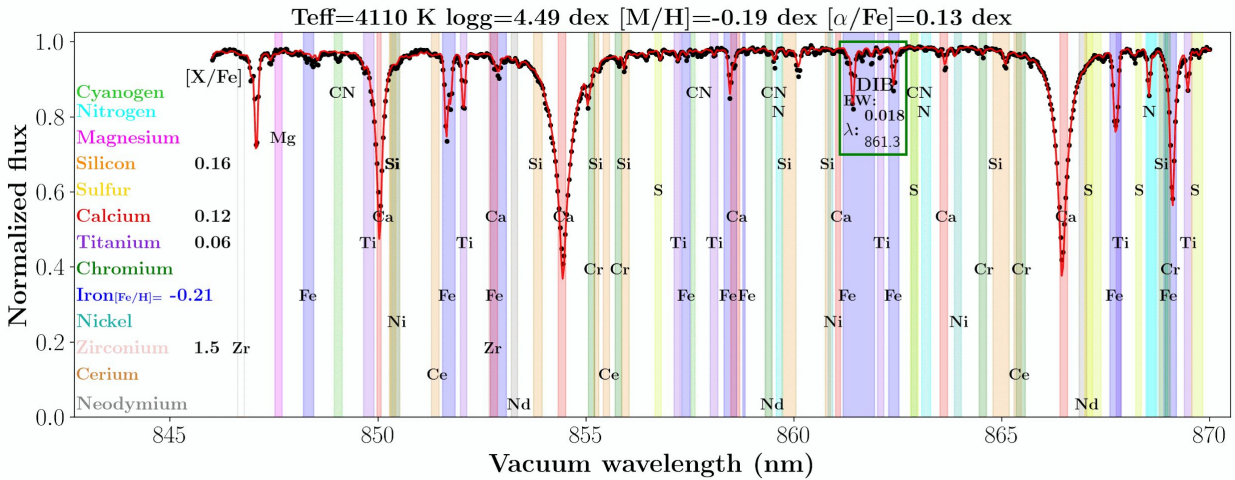
- Stellar parameters degeneracies

- Chemical abundances

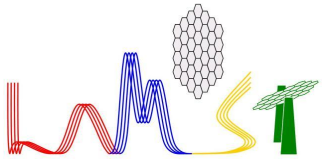
  12 elements

- Crowded fields

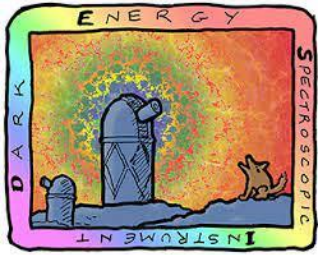
  Globular clusters



ESA/Gaia/DPAC-CU8, Recio-Blanco and the GSP-Spec team



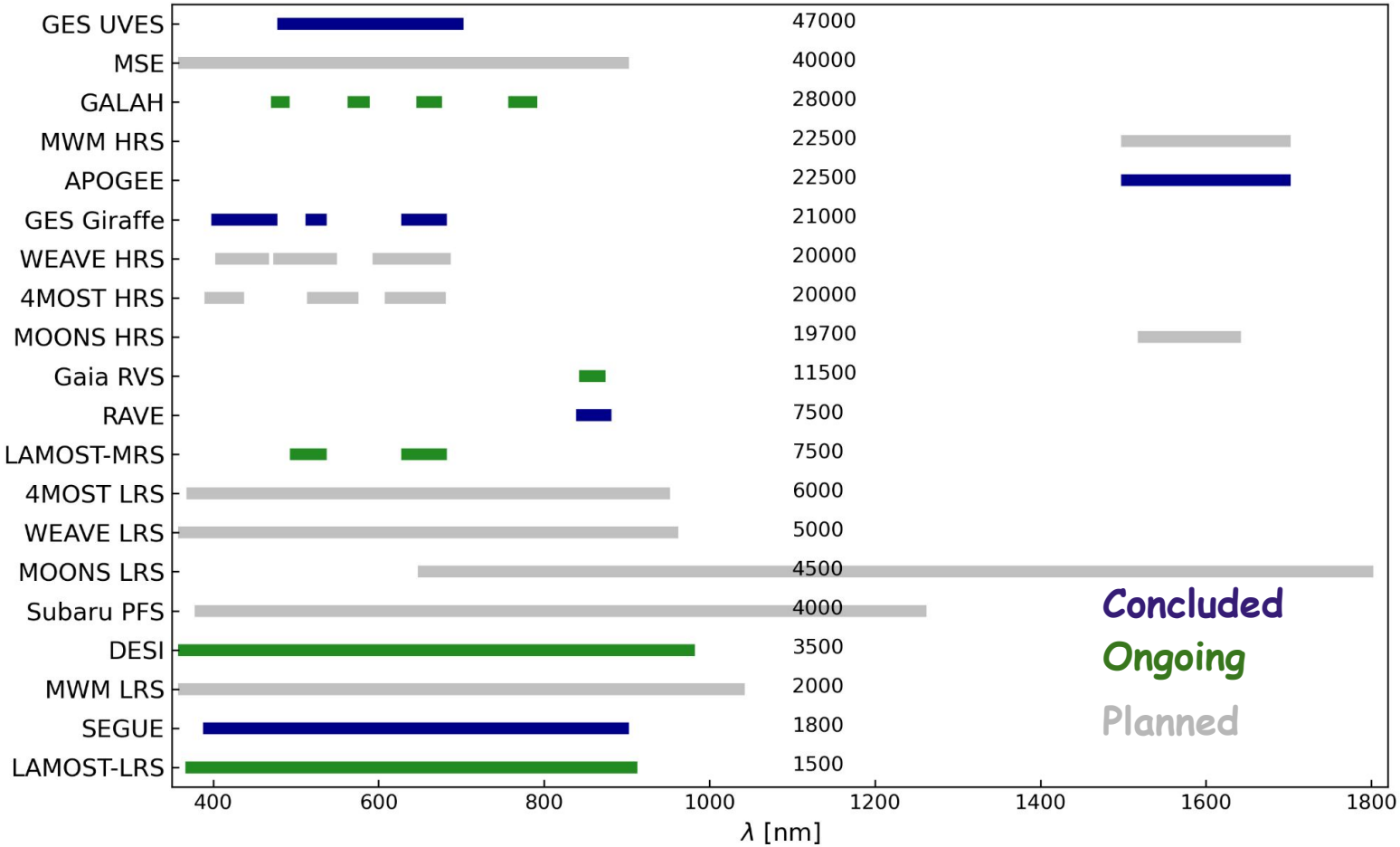
Spectroscopic surveys



Maunakea Spectroscopic Explorer

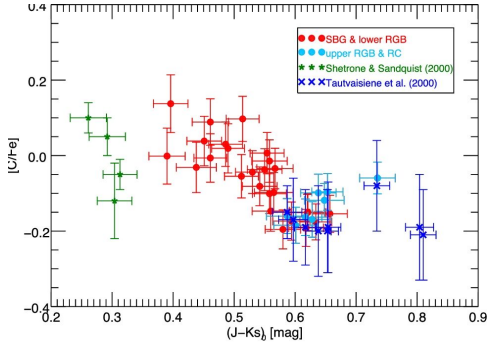
RAVE
RADIAL VELOCITY EXPERIMENT

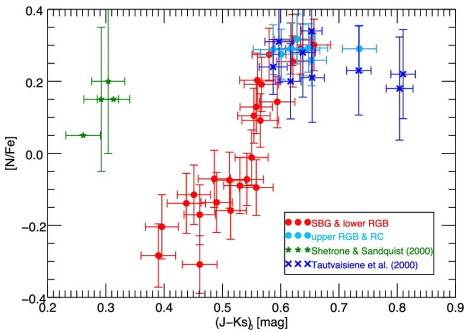
Spectroscopic surveys

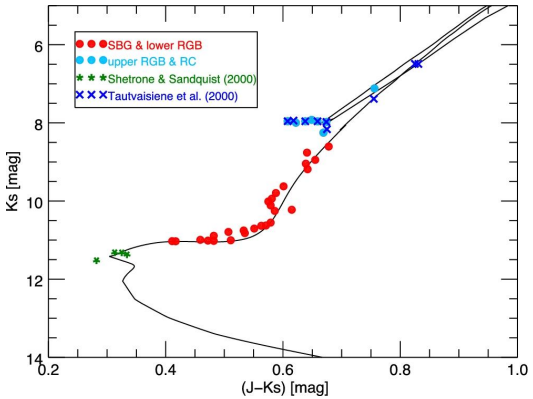


Survey's contribution to the research of Open Clusters

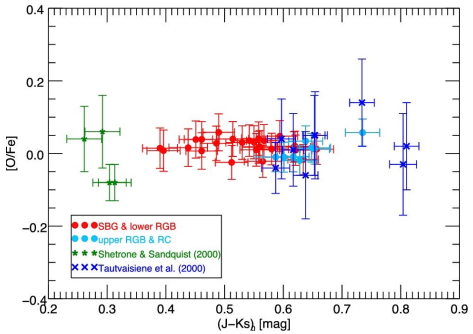
- Surface contamination by material synthesized in the interior

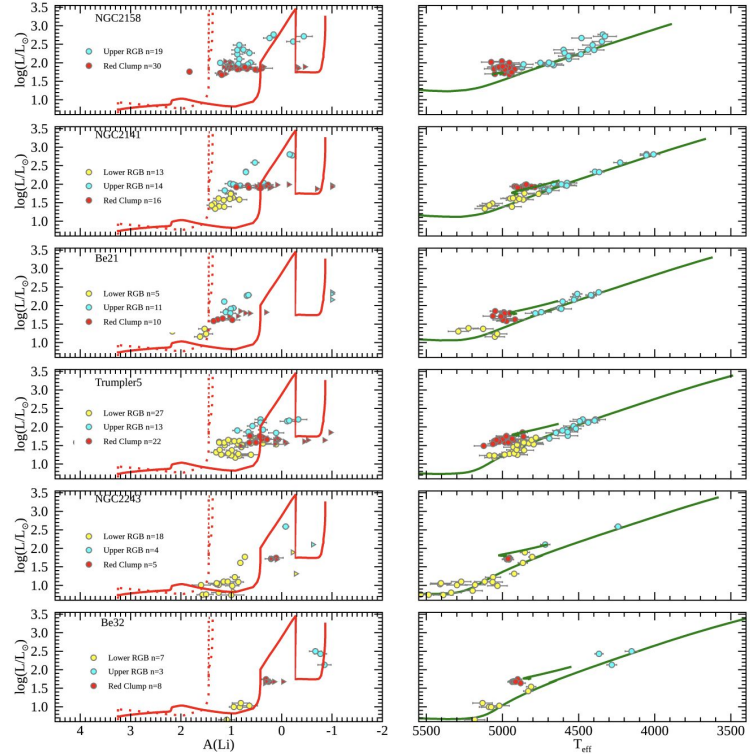






M67



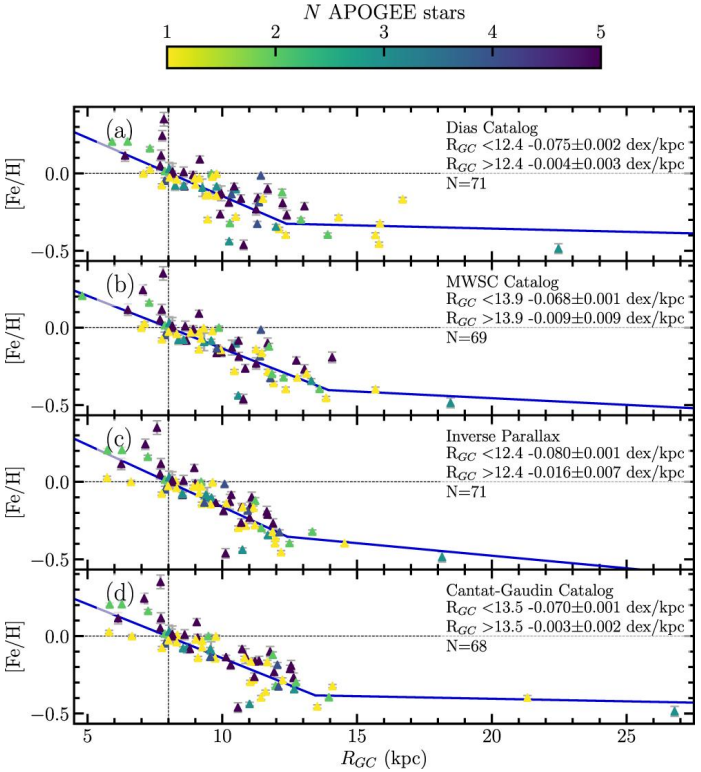


Bertelli-Motta et al. 2018

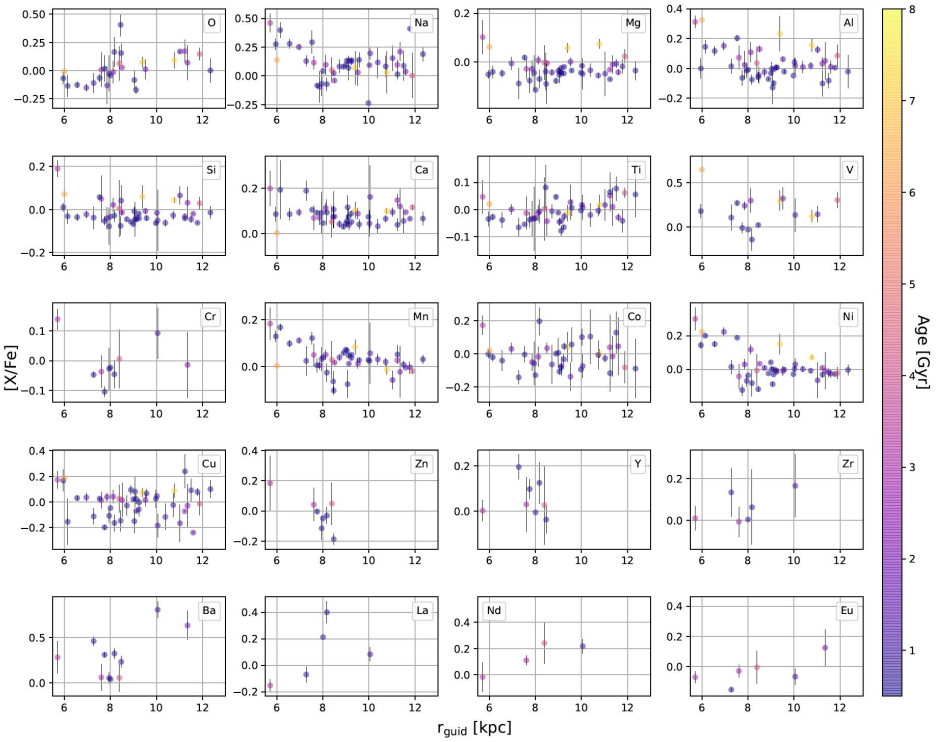
Magrini et al. 2021

Survey's contribution to the research of Open Clusters

- Surface contamination by material synthesized in the interior
- Trends in the Galactic disk.



Donor et al. 2020



Spina et al. 2022

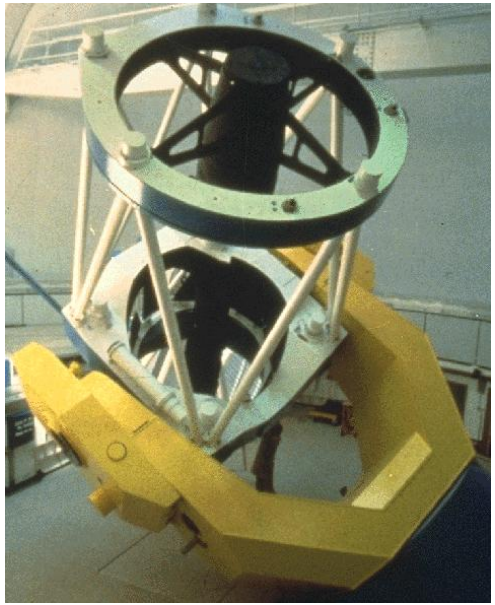
Spectroscopic surveys limitations

- **All**
  - Automatic determination of stellar parameters/abundances different spectral types.
  - Need calibrators
- **Low resolution surveys (R~5000)**
  - Degeneracies on stellar parameters determinations
  - Abundances for a handful of elements, high uncertainties (0.1 dex)
  - Large radial velocities uncertainties (>1 km s^{-1})
- **Intermediate resolution surveys (R~20000)**
  - Small wavelength coverage
    - Degeneracies on stellar parameters' determination.
    - Abundances for a limited number of elements.
  - Radial velocities uncertainties (200-500 m s^{-1})
    - Not enough to investigate the internal dynamics of open clusters.
  - Abundance uncertainties (0.05 dex)
    - Not enough for chemical tagging?

How NOT (FIES) can contribute?

Higher-resolution R~65000
Larger wavelength coverage (400-900 nm)
Lower uncertainties v_{rad} (10-20 m s^{-1}) and [X/Fe] (<0.03 dex)
Elements poorly studied but key to understand chemical evolution (neutron capture elements)

Instrumental configuration

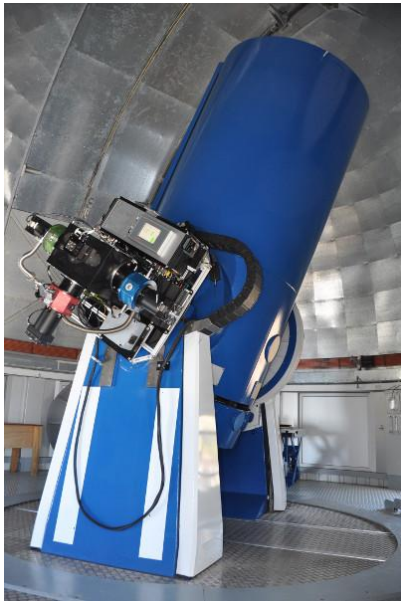


FIES@NOT 2.5m

R~67000
400-725 nm (b. Jul 2017)
400-900 nm (a. Jul 2017)

CAFE@CAHA 2.2m

R~62000
400-900 nm



HERMES@Mercator 1.2m

R~85000
400-900 nm

Target selection:

OCs location disk: Rgc, Z, Age, etc

OCs population: ≥ 4 stars giants near of in the red-clump

OCs recently discovered from Gaia

Stars: same evolutionary stage (red-clump)

Stars: high membership probability

Stars: magnitude ~~V ≤ 15 mag~~. G<13.5 mag.

Current status

Observing nights: 160 (**72 NOT**; 64 Mercator; 24 CAHA) from 2013

22 scheduled (**6 NOT**; 11 Mercator; 5 CAHA)

Observed stars: 330 (clusters) + 26 (calibrators GBS)

Clusters: 54

At the moment (R~20000) ~200 APOGEE(~160)+GALAH(25)+GES(62)

Papers: 7 published + 1 in preparation

***OCCASO* as calibrators:** Gaia radial velocities + APOGEE abundances

Data reduction

FIEStool

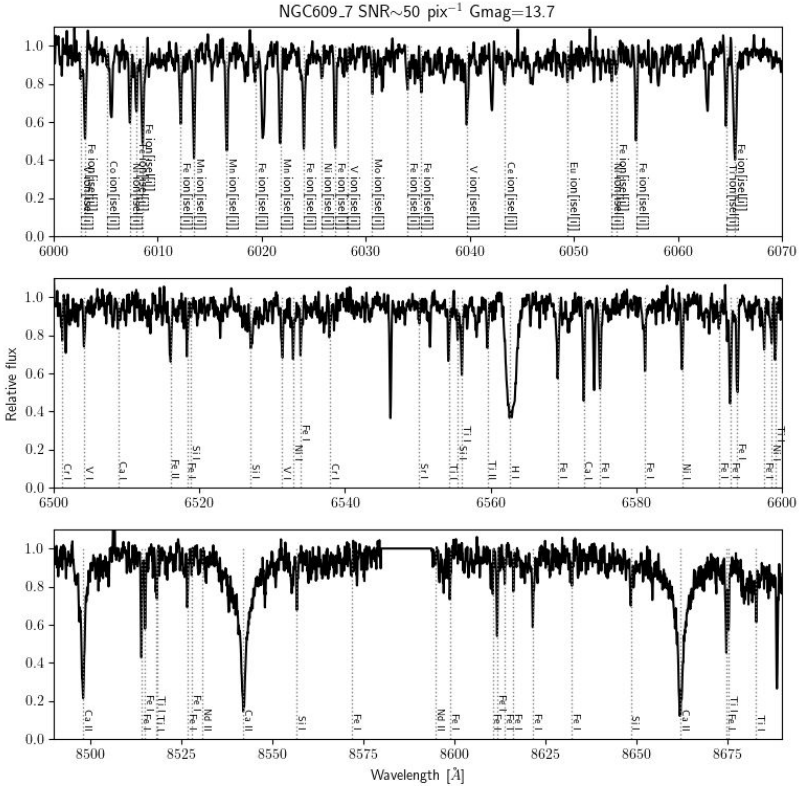
HERMESDRS

OCCASOpipeline

bias subtraction
flatfield-correction
order tracing and extraction
wavelength calibration

sky subtraction
telluric subtraction
combination
normalization
order merger

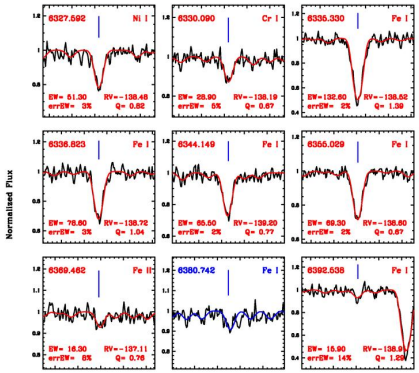
+ radial velocities



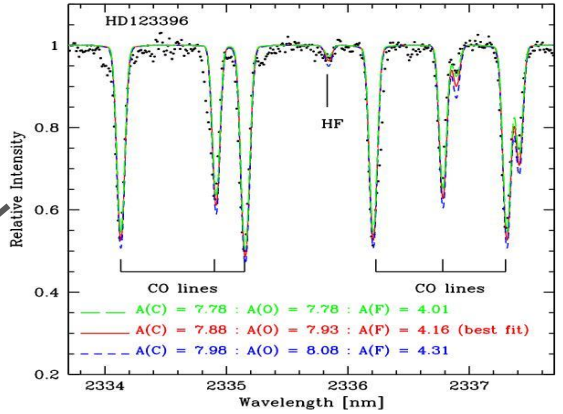
final spectra in the VO standards will be released through

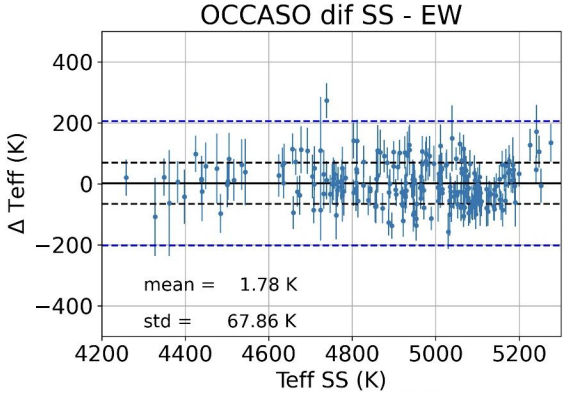
Chemical abundance determination

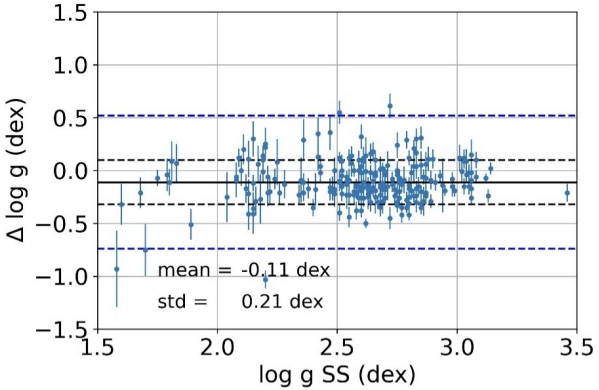
Equivalent widths
(DAOPHOT +GALA)



Spectral synthesis
(iSpec)

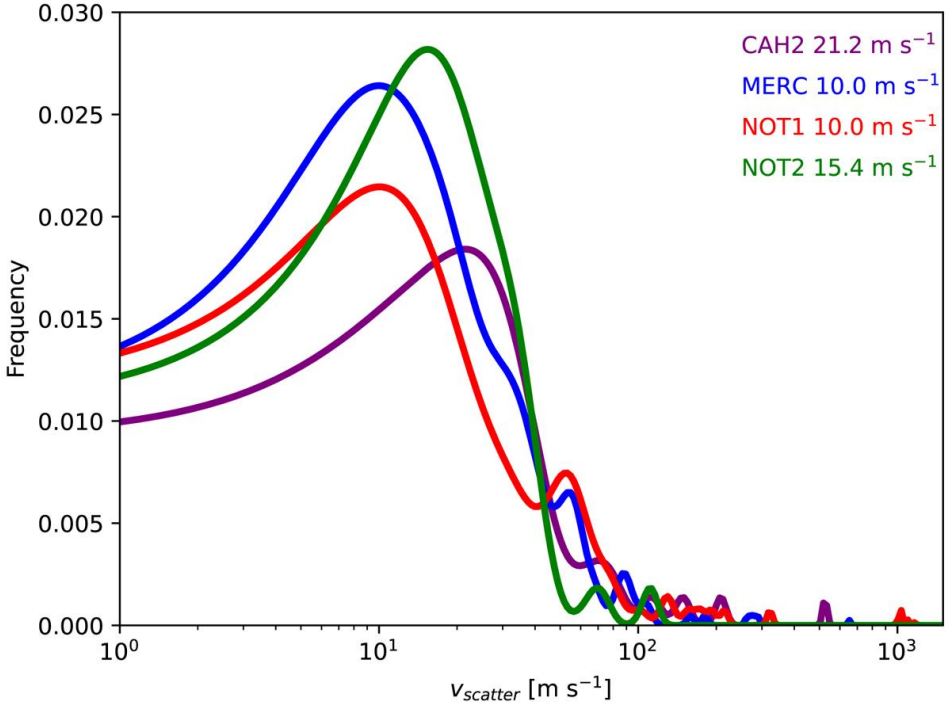






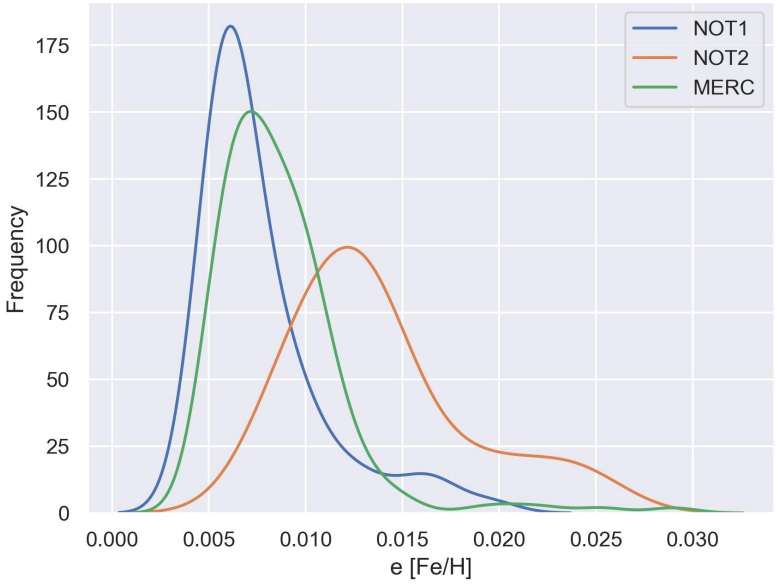
Typical uncertainties

Radial velocities



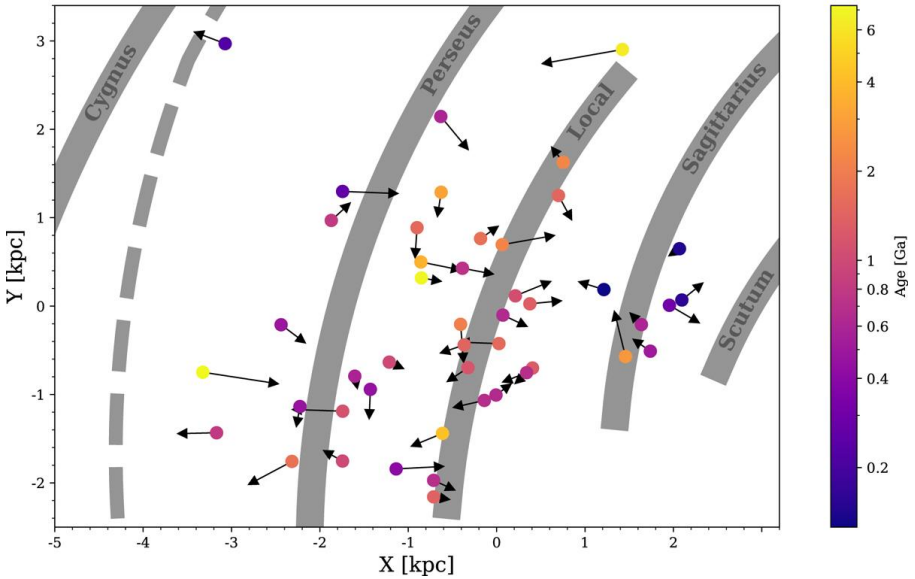
Carrera et al. 2022a

Fe from equivalent widths (preliminary)



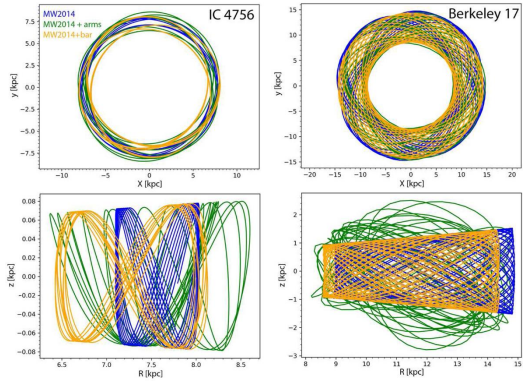
Carbajo-Hijarrubia et al. *in prep.*

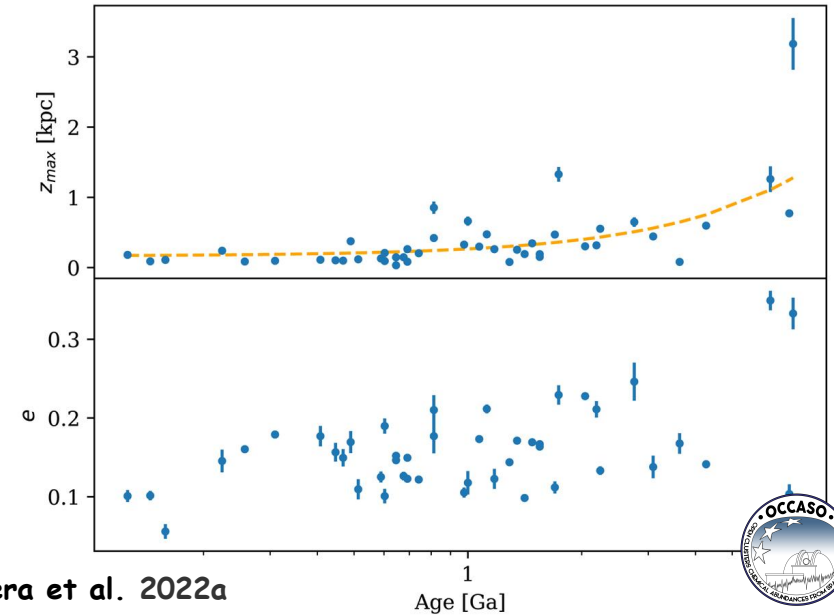
Open clusters kinematics



Velocities to respect to the GSR

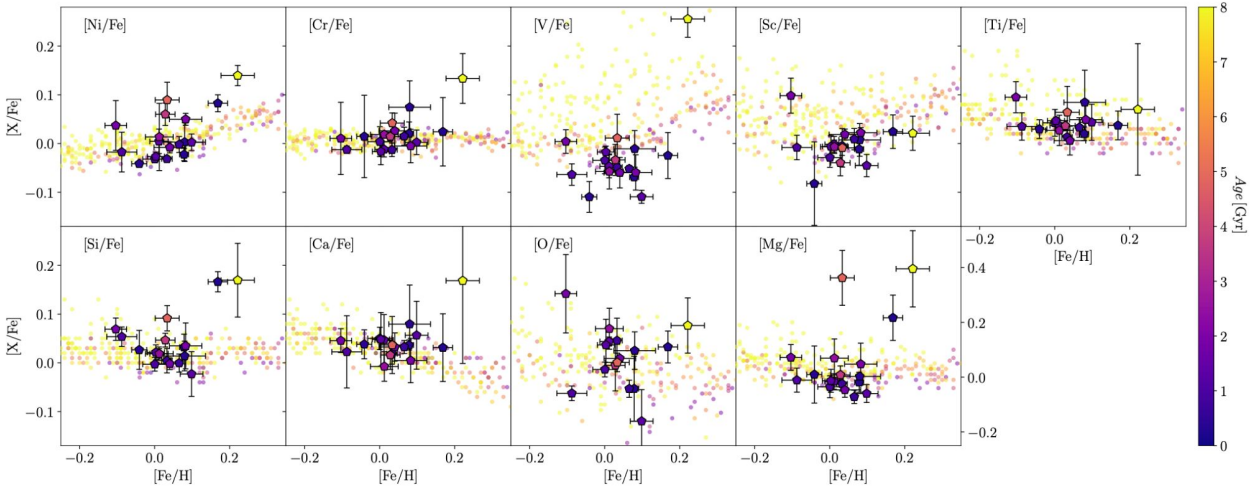
Orbits





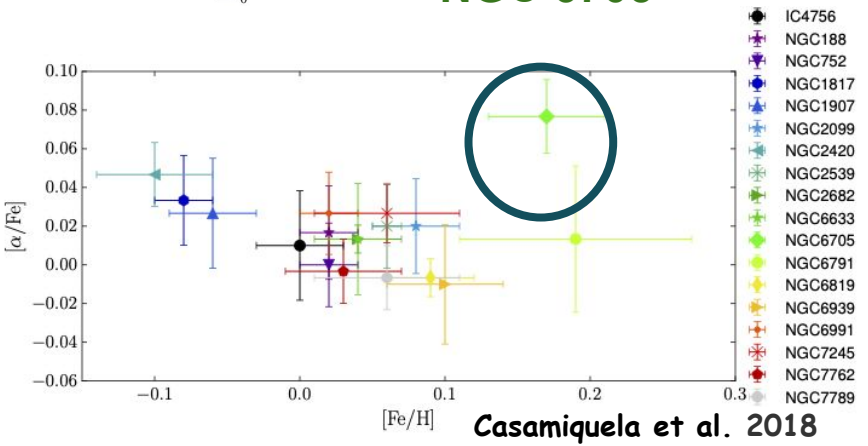
Casamiquela et al. 2016; Carrera et al. 2022a

Open clusters' chemestry



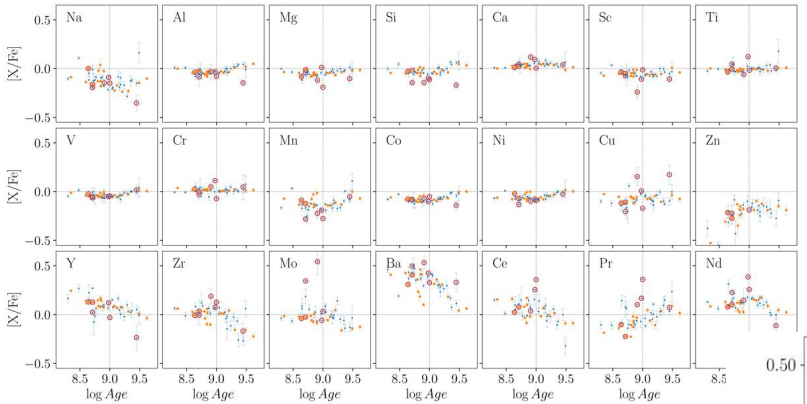
Casamiquela et al. 2017, 2019

NGC 6705

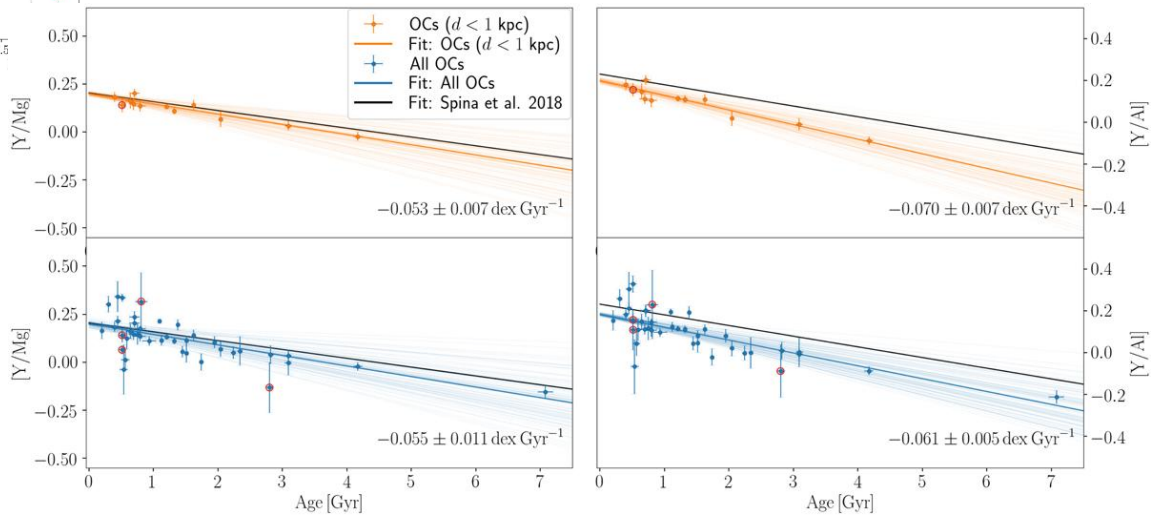


Casamiquela et al. 2018

Abundance-Age relations (chemical clocks)

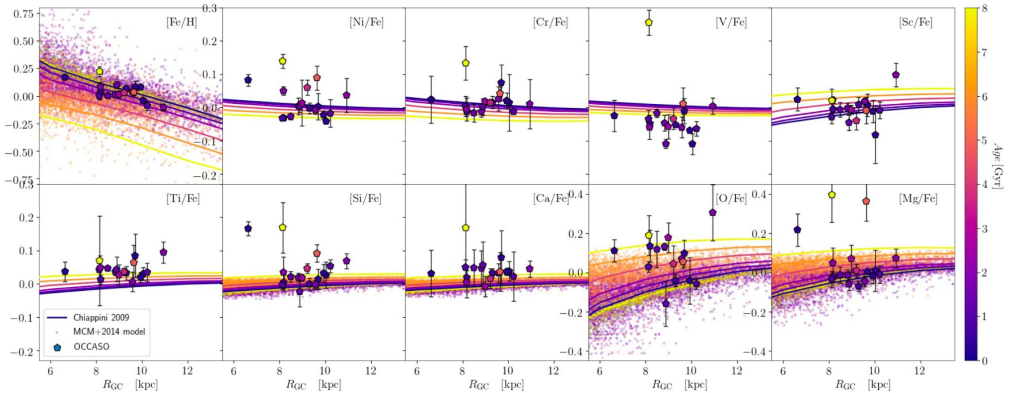


Some elements have trends with age
[Y/Mg] and [Y/Al]

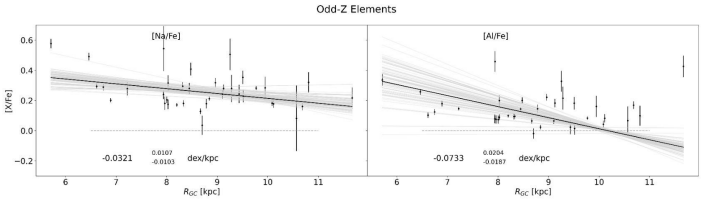


Casamiquela et al. 2021a

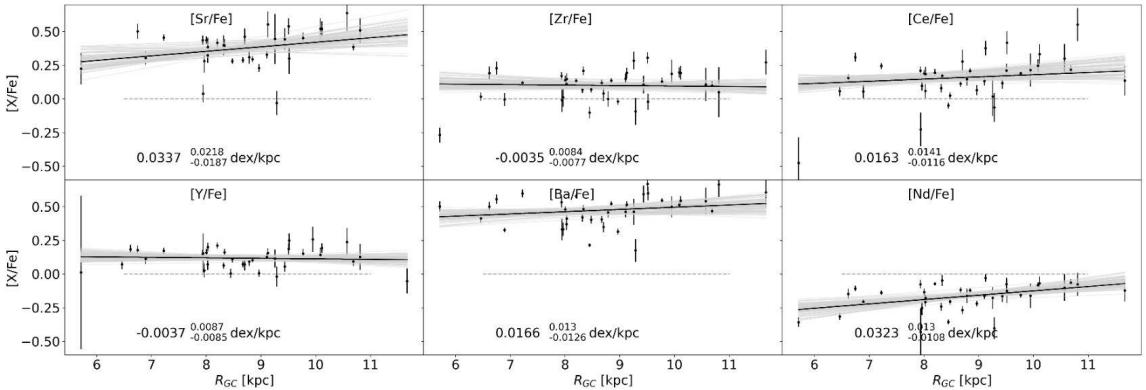
Open clusters as tracers of the Galactic disk



Casamiquela et al. 2019



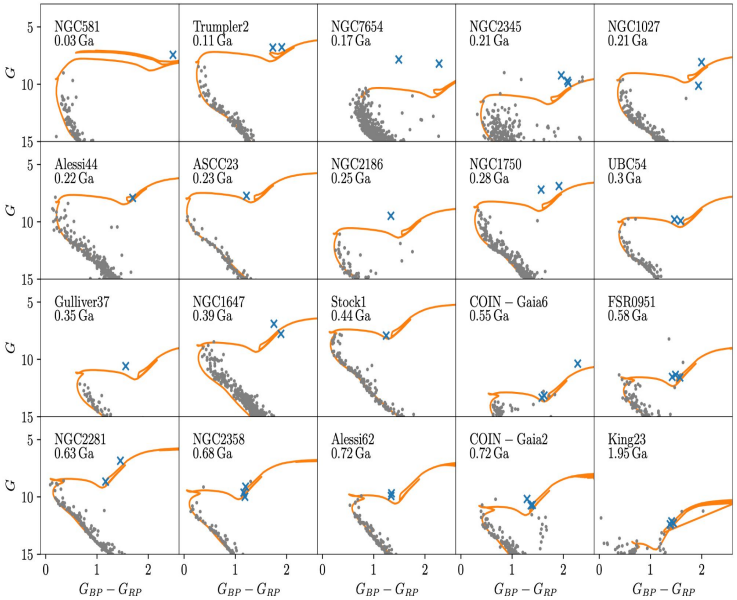
N-capture Elements



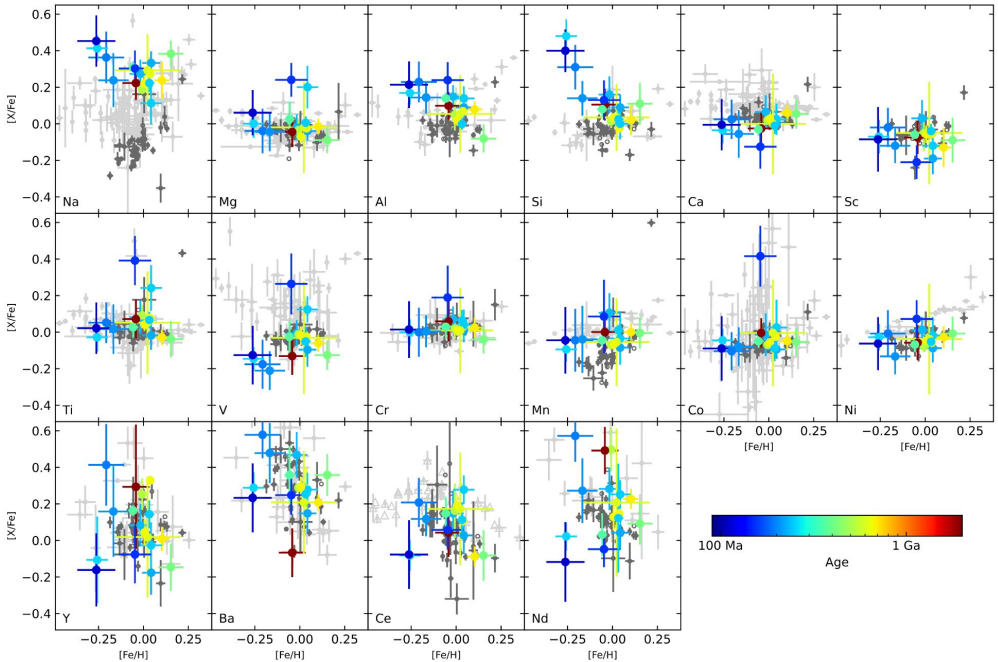
Carbajo-Hijarrubia et al. *in prep.*

Extra: OSTTA (One Star To Target All)

Observe at least one (giant) star in as much OCs as possible.
41 stars in 20 OCs (5 nights with FIES@NOT)
16 clusters is the first ever chemical abundance determination (several recently discovered by Gaia)



Carrera et al. 2012b



Summary

- Gaia and the massive spectroscopic surveys are revolutionizing our knowledge of open clusters.

But

- They need complementary observations with higher resolutions and large wavelength coverage.
  - Calibrators
  - Confirm their results (better accuracy in radial velocities or chemical abundances)
  - Study elements not covered by them.

NOT & FIES can contribute significantly to this.