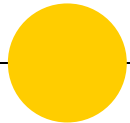


# Properties of evolved Open Clusters in the Gaia era



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*Cool Stars 20 meeting, Boston, 29th Jul - 4 Aug 2018*



# Nearby evolved OCs

**Evolved OCs** are crucial targets:



GaiaDR2-ESA

- Importance in **Galactic archaeology** to trace the history of the Galactic disk
- Insights for **stellar evolution** theories
- **Benchmarks** for calibration and validation of Gaia radial velocities and atmospheric parameters, and ground-based surveys (APOGEE, RAVE, WEAVE...)

**Disruption** of OCs in some Myrs mainly due to: internal interactions, encounters with giant molecular clouds, gravitational harassment by the galactic potential.



**Goal:** Determine physical properties of **nearby evolved OCs** with **Gaia DR2** astrometry combined with **photometric** and **spectroscopic** data from ground.



# Priority benchmark objects

OC name	Distance (pc)	Age (log yr)	Comments
	References: D02, K13		
Hyades	45	8.9	K2
Rup 147	290	9.4	K2
Praesepe	187	8.9	Gaia-ESO, RAVE, K2
Coma Ber	90	8.7	
NGC 2682	850	9.5	APOGEE,RAVE,WEAVE,K2,OCCASO
NGC752	450	9.2	WEAVE,OCCASO

Selection: older than 450 Myr, closer than ~500 pc (Gaia precision of transverse velocities < 1km/s)  
**6 Benchmark OCs** part of Cosmic-DANCe project\* → multi-dimensional membership probabilities

\*<http://www.project-dance.com/>



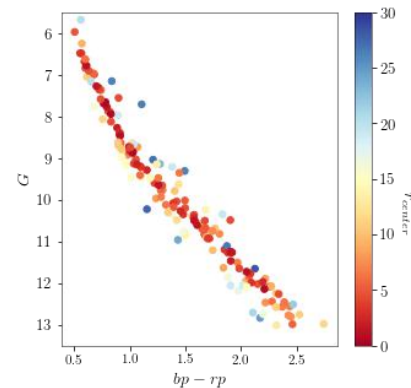
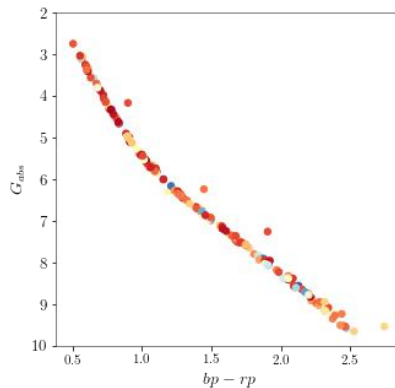
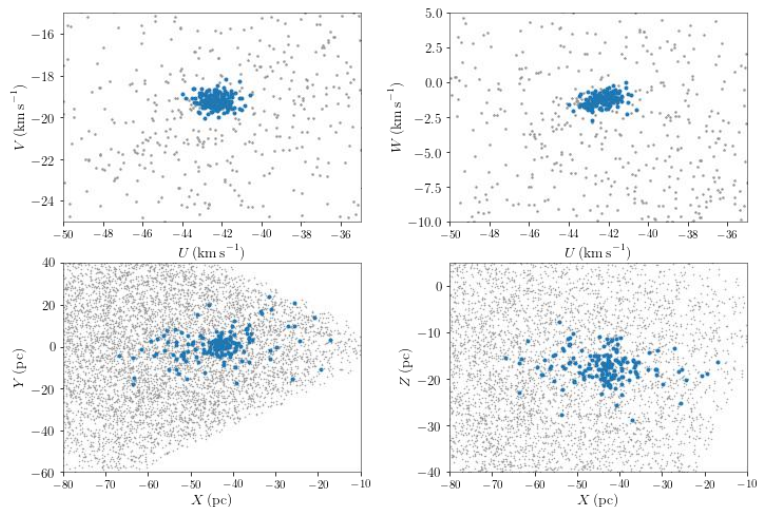
# I. Hyades

Reino et al. (2018), TGAS → new bright members up to 30 pc from the center

Test the typical **dispersion of abundances along the evolutionary track**, or depending on the **distance from the center**?

Own selection in Gaia DR2: radius 40deg (30 pc); cuts in parallax ( $>10$  mas); cuts in errors of parallax and proper motions;

Simple membership selection in X, Y, Z, U, V, W

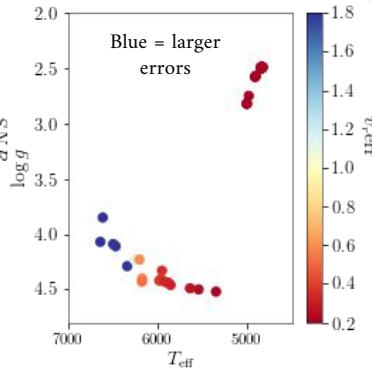
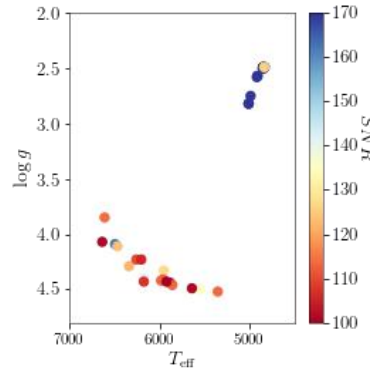
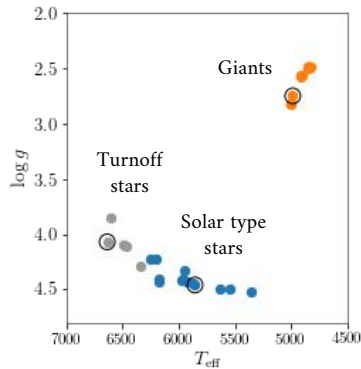
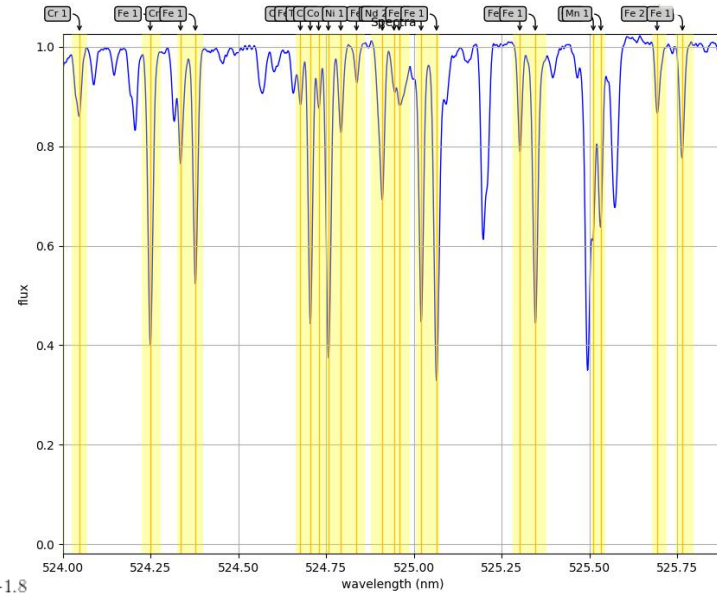




# I. Hyades

**High SNR** ( $>100$ ) spectra from HARPS archive ( $R=115,000$ ) for 20 main sequence stars, 2 giants

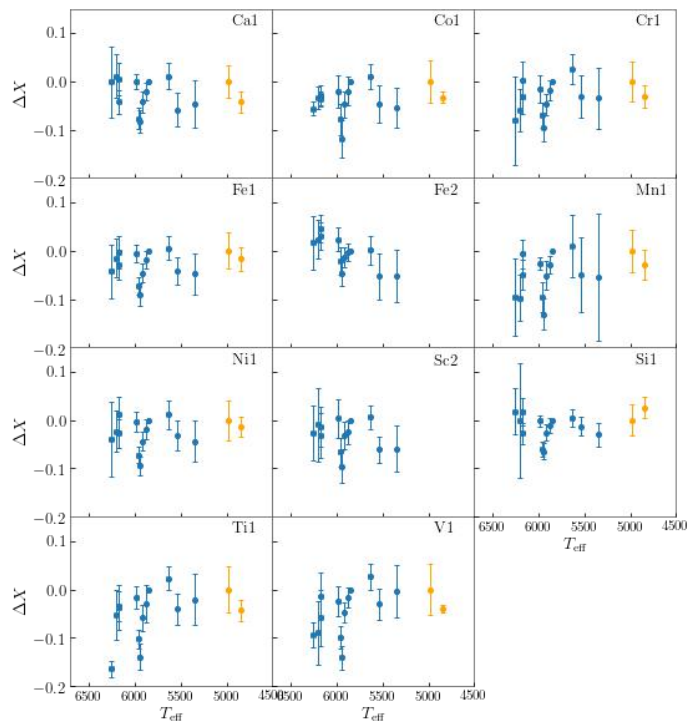
**iSpec** (Blanco-Cuaresma et al. 2014): Analysis atmospheric parameters + **strictly line-by-line differential abundances**



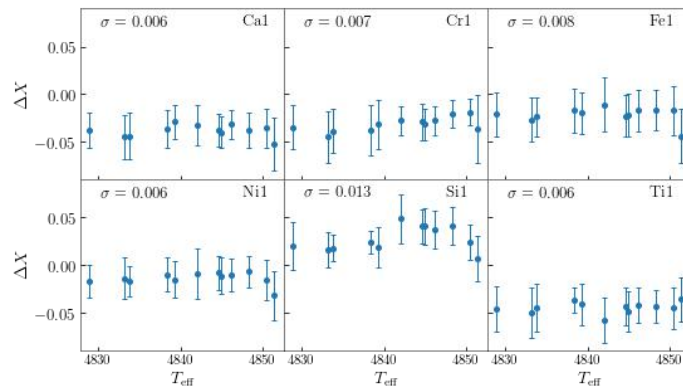


# I. Hyades

Differential abundances



12 different spectra of the same star HIP20889  
give very similar abundances  
Dispersions lower than 0.01 dex

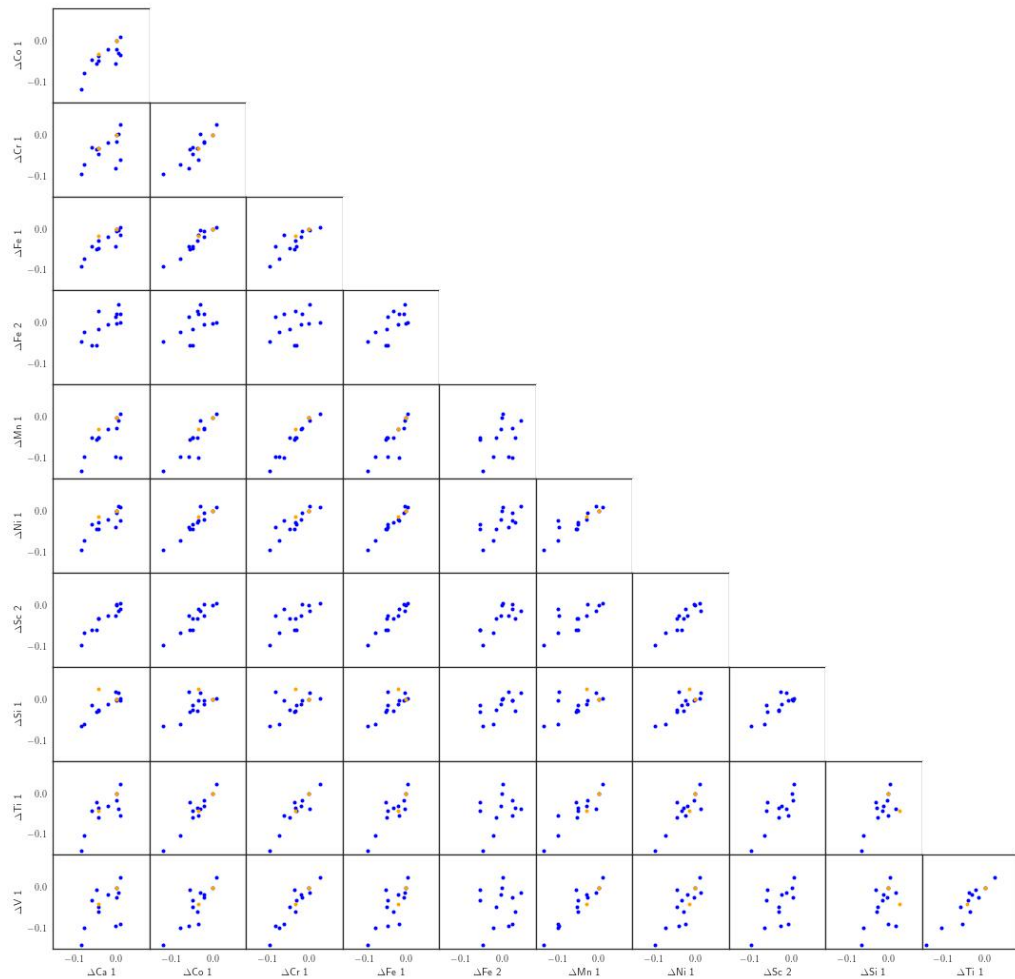




# I. Hyades

Differential abundances in solar type stars:  
**significant correlations** among elements  $\Delta X - \Delta Y$

Amplitude of around 0.1 dex



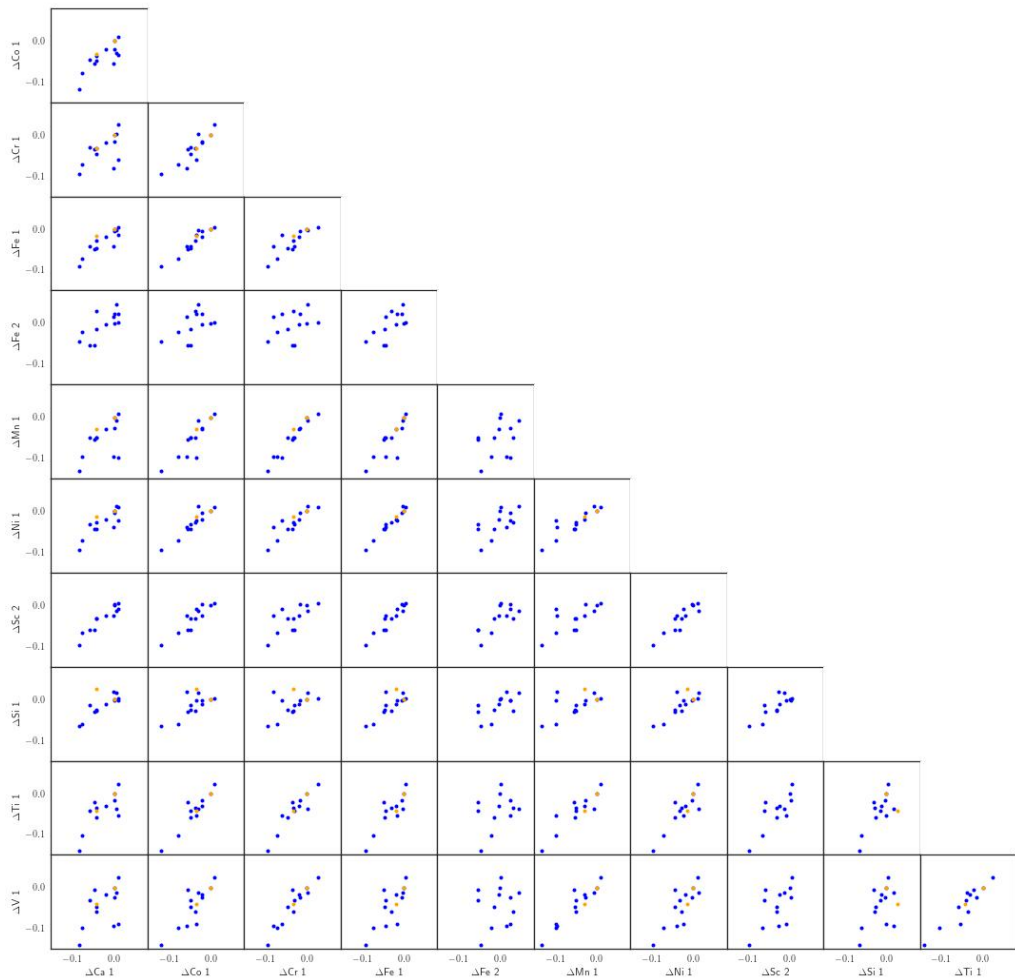
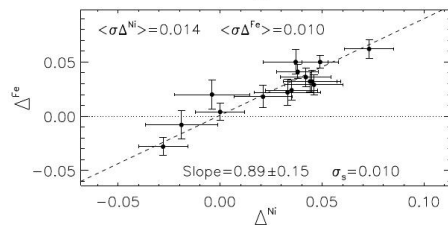
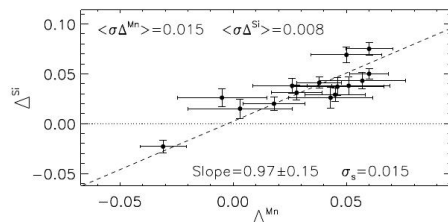


# I. Hyades

Differential abundances in solar type stars:  
**significant correlations** among elements  $\Delta X - \Delta Y$

Amplitude of around 0.1 dex

Liu et al. (2016): The Hyades are **chemically inhomogeneous** at the level of 0.02-0.05 dex?







## II. Ruprecht 147

3 Gyr, 300 pc

Very few detailed studies

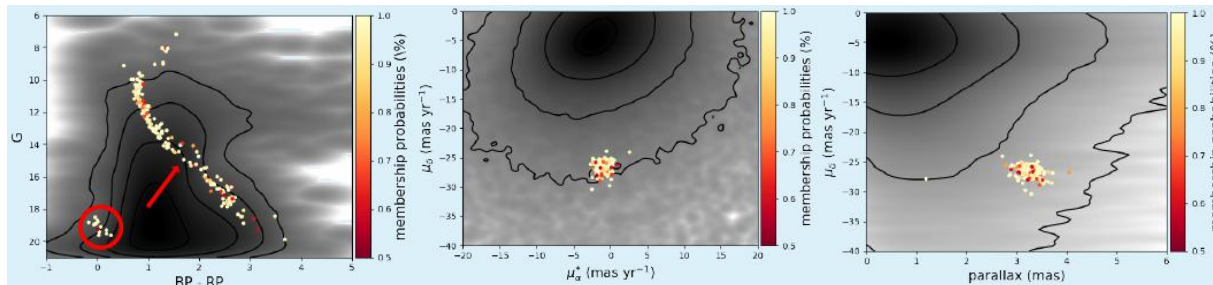
Methodology: Sarro et al. (2014) + parallax, uncertainties and correlations, photometry

Gaia DR2 dataset

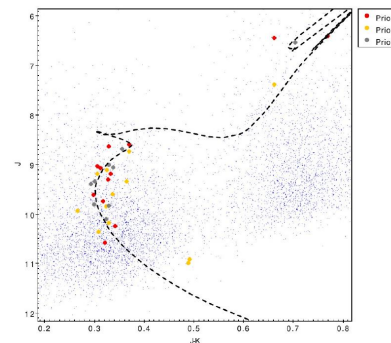
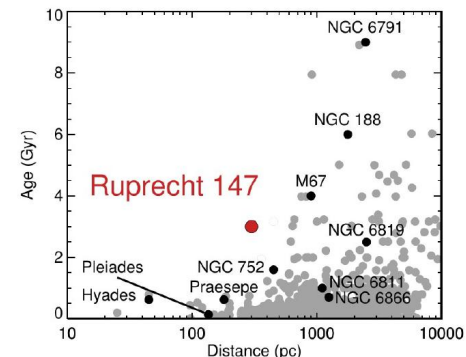
- membership probabilities for 4.3 million sources in 5 deg (radius)

- 221 members ( $p > 0.5$ )

Recovery and contamination rates of: 96% and 9%



Olivares et al. (2018, in preparation)



Curtis et al. (2013); 2MASS data



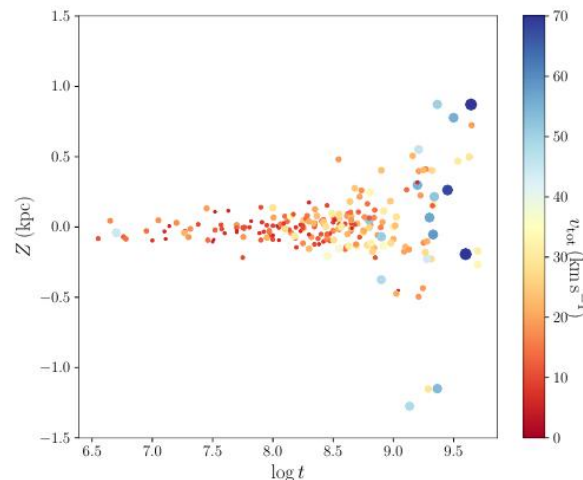
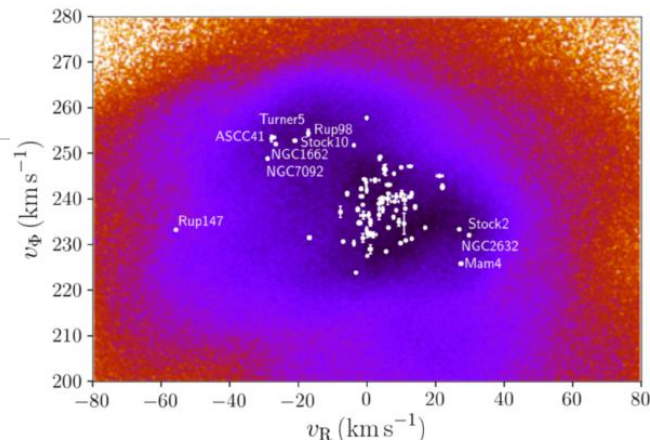
# OCs kinematics with Gaia DR2

Gaia DR2 brings an improvement in the knowledge of the OC population, eg:

- In the Solar neighbourhood they follow the velocity distribution of field stars: are they associated with the overdensities formed by field stars?

- Velocity ellipsoid in different age bins shows how the kinematical properties change with age

- Newly discovered clusters (~90) by Cantat-Gaudin et al (2018, arXiv:1805.08726) and Castro-Ginard et al. (2018, arXiv:1805.03045)





# Conclusions

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- Our goal is to revisit the properties of nearby evolved OCs making use of Gaia data and high quality spectroscopy from the ground
  - Importance in: Galactic archaeology, stellar evolution, benchmark objects
- **Hyades**
  - Simple selection of members
  - Spectroscopic analysis of solar-type, turnoff and giant stars
  - Spread in differential abundances for 11 elements and for the same type of star (amplitude 0.1 dex, dispersion 0.02 dex)
  - Significant correlations among all different elements
  - Inhomogeneity? Consequences in Galactic archaeology?
- **Rup 147**
  - Particularly interesting case
  - Selection of members



# Thanks

*Any questions ?*

*People involved*

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S. Blanco-Cuaresma

