Old open clusters in the Galactic disk:

New results from the Gaia-ESO survey

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The world of Clusters, Padova 23-25 Sept 2013
Open Clusters ar tools to investigate the Galactic evolution

- Many (~1500 known clusters)
- Large range of Galactocentric distances (Rgc~5-20 kpc)
- and of ages (~0.01-10 Gyr)
- They have homogeneous populations (age, chemical composition)

Catalogues and general information:
- [http://www.univie.ac.at/webda/](http://www.univie.ac.at/webda/)
Which clusters for chemical evolution?

Investigate the Galactic structure at various epochs

Data from Dias+02 catalogue: http://www.astro.iag.usp.br/~wilton/
Which level of accuracy is needed?
An example: the radial metallicity gradient (see Tristan's talk)

Metallicity available for ~ 150 clusters (different methods) from Dias's catalogue
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Much of the dispersion is due to non-homogeneity and to inaccurate methods... however HRS observations are still inhomogeneous and up to now limited to ~75 OCs

Metallicity available for ~ 150 clusters (different methods) from Dias's catalogue
What is the Gaia-ESO survey doing?
See Sofia's talk for more details

- Largest sample of clusters analyzed in a fully homogeneous way
- Benefit of the analysis of ~14 group of researchers (for UVES spectra)
- Sharing common tools:
  - line list
  - Library of stellar atmospheres (MARCS models)
  - Solar zero point (Grevesse et al. 2007)

But not only clusters! Thin disk, thick disk, halo, bulge are being analyzed in the same way!
The first six months:

- Similar Galactocentric distance
- Age sequence
- All belonging or near to the Sagittarius arm

Orbit computation only for NGC6705 (Wu+09, Magrini+10) --> 5-8.5 kpc (ell~0.3)

See Paolo and Rosanna’s talks for the cluster parameters with GES
The steps of our analysis:

- Confirming the cluster homogeneity
- Analysing cluster patterns
- Comparing with field stars in the Solar neighborhood and in the inner disk
- Comparing with two chemical evolution models
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All results shown here are from the first 6 months of GES, for both field and cluster stars.
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Confirming the cluster homogeneity

Cluster vs field

\[ <\text{r.m.s.}> \sim \frac{\sigma}{\sqrt{N}} \]
Confirming the cluster homogeneity

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• **Analysing cluster patterns**

• Comparing with field stars in the Solar neighborhood and in the inner disk

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Analysing cluster patterns:

Iron-peak elements
Cr and Ni

Alpha elements
Mg, Si, Ca and Ti

Even if they are located at the same Galactocentric distance, they did not originate from an ISM with the same composition.
Analysing cluster patterns:

Why different patterns and different metallicities at the same $R_{GC}$?

- the ISM was not azimuthally homogeneous at the time of cluster formation

- the clusters might have moved from their place of birth

- due to the different ages of the clusters, their abundance ratios might be a signature of the temporal chemical evolution of the Galactic disk
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Analysing cluster patterns:

![Graph showing cluster patterns at 0.5 Gyr, 1.5 Gyr, and 0.2 Gyr](image)
Analysing cluster patterns:

Age effect? It seems the less plausible hypothesis, since the youngest clusters are the metal poorer and this difficult to understand in a classical view of the MW evolution.
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Clusters vs field stars

The comparison of NGC6705 with Solar neighborhood stars and with the inner-disk/bulge stars

For most of the abundance ratios, the cumulative distributions of NGC6705 are very close to those of the inner-disk stars.

This is not the case for NGC4815 and Trumpler 20
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Could NGC6705 have moved from the inner disk to its present location?
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Comparing with chemical evolution models

The good agreement within the error of some abundance ratios of NGC~6705 with M09 curves for radii ~4-6~kpc, and with the observations of inner-disk/bulge stars might indicate that it migrated towards its present position from an inner birthplace.
The orbit of NGC6705 might be consistent with a variation of its Galactocentric distance from ~5 kpc to ~9 kpc.
The future: chemo-dynamical models (e.g. Kobayashi+12)
Conclusions:

- We confirm that open clusters are composed by homogeneous stellar populations.

- Each cluster has a specific and unique abundance pattern.

- Using the information on the cluster abundance patterns, we can investigate the composition of the ISM at the time and place where they were born:
  - The abundance ratios of NGC6705 are consistent with its inner birthplace.
  - Stellar migration, radial flows, ISM inhomogeneity are present and cannot be neglected when modeling the Galactic chemical evolution; the future is in chemo-dynamical model.