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.astro.iag.usp.br/~wilton/



Which clusters for chemical evolution?



Investigate the Galactic structure at various epochs

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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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

Confirming the cluster homogeneity

- Comparing with field stars in the Solar neighborhood and in the inner disk
- Comparing with two chemical evolution models

are from the

first 6 months

of GES, for both field.

and cluster stars

Confirming the cluster homogeneity

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Confirming the cluster homogeneity



El	Mean	< r.m.s. >	$\frac{\langle \sigma \rangle}{\sqrt{(N)}}$	N
Tr20				
[Fe/H]	0.16	0.05	0.02	13
[Si/Fe]	-0.01	0.04	0.02	13
[Ca/Fe]	0.04	0.04	0.02	13
[Mg/Fe]	0.05	0.04	0.02	13
[Ti/Fe]	-0.09	0.04	0.02	13
[Ni/Fe]	-0.06	0.04	0.02	13
[Cr/Fe]	-0.08	0.04	0.02	13
NGC 4815				
[Fe/H]	0.014	0.05	0.04	5
[Si/Fe]	0.00	0.04	0.04	5
[Ca/Fe]	-0.04	0.05	0.04	5
[Mg/Fe]	0.16	0.10	0.06	5
[Ti/Fe]	-0.14	0.08	0.06	5
[Ni/Fe]	-0.07	0.01	0.02	5
[Cr/Fe]	-0.13	0.04	0.03	5
NGC 6705				
[Fe/H]	0.10	0.06	0.03	21
[Si/Fe]	0.07	0.06	0.04	21
[Ca/Fe]	0.02	0.05	0.03	21
[Mg/Fe]	0.24	0.10	0.04	21
[Ti/Fe]	-0.01	0.09	0.03	21
[Ni/Fe]	0.03	0.04	0.04	21
[Cr/Fe]	-0.03	0.06	0.03	21

<r.m.s.> ~ <σ>/√N

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<r.m.s.> ~ <σ>/JN

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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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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.

[Fe/H]

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Clusters vs field stars



The comparison of NGC6705 with Solar neighborhood stars and with the innerdisk/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?

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

Comparing with chemical evolution models



The good agreement within the error of some abundance ratios of NGC~6705 with MO9 curves for radii ~4-6~kpc, and with the observations of innerdisk/bulge stars <u>might indicate</u> that it <u>migrated</u> towards its present position from an inner birthplace.

Orbit calculation for NGC6705



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