The OCCASO survey
Open Clusters Chemical Abundances from Spanish Observatories

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on behalf of the OCCASO team

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Porto, 12 November 2014
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Open Clusters

- **Importance** star formation, stellar nucleosynthesis, star evolution, tracers of the galactic disc
- **Drawbacks** Few with detailed information of radial velocities (∼ 24 %), metallicities (∼ 9 %) and abundances (∼ 4 %). Obtained heterogeneously.
- **Larger and homogeneous samples are needed!**
  - Chemical abundances from homogeneous analysis.
  - Ages from homogeneous datasets.
  - Radial velocities and proper motions.
  - Increase the number of clusters studied.

Carrera & Pancino 2011
A new era of the Open Clusters research: Space

The Gaia Mission

- Very precise parallaxes and proper motions.
- Radial velocities: $13 \text{ km s}^{-1} \at V \sim 15$.
- Chemical abundances: $V_{RVS} < 11.5$.

The Kepler Mission

- Variability: photometric precision of 80 ppm.
A new era of the Open Clusters research: Ground

Gaia-ESO Survey (GES)
- South
- Resolution 47000 (UVES) < 20000 (GIRAFFE)
- 4800 to 7000 (UVES) 6500-9000 Å (GIRAFFE)
- OCs: > 100 (20-30 > 1 Gyr)

APO Galactic Evolution Experiment (APOGEE)
- North (and South)
- Resolution 22500
- 15000 to 17000 Å
- OCs: > 100 (25 > 1 Gyr)

GALactic Archaeology with HERMES (GALAH)
- Coverage: South
- OCs: ?
- Resolution 28000 (normal) 50000 (slit-mask)
- 4718-4903; 5649-5873; 6481-6739; 7590-7890 Å
A new era of the Open Clusters research: Ground

**Gaia-ESO Survey (GES)**
- South
- OCs: +100 (20-30 >1 Gyr)
- Resolution 47000 (UVES) <20000 (GIRAFFE)
- 4800 to 7000 (UVES) 6500-9000 Å (GIRAFFE)

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North not properly sampled!
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Aims

Double the number of OCs homogeneously studied. Complement GES-UVES observations from the North.

- Not instrument with GIRAFFE capabilities (WEAVE in 2017).
- Important OCs only visible from the North
  - Oldest: Berkeley 17
  - Most metal-rich: NGC 6791
  - Kepler: NGC 6791 & NGC 6819
  - Galactic anticentre: NGC 1817
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**HERMES@Mercator (1.2 m)**
- Resolution 85000
- 3770 to 9000 Å
- $V < 12.5$

**FIES@NOT (2.5m)**
- Resolution 67000
- 3700 to 7300 Å
- $12.5 < V < 14.5$

**CAFE@ 2.2m CAHA**
- Resolution 60000
- 3960 to 9500 Å
- $12.5 < V < 13.5$
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Replicate the GES-UVES observational strategy

Observational strategy

- Initial sample: 25 Clusters $\geq 0.5$ Gyr.
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Replicate the GES-UVES observational strategy

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- $\geq 6$ RC stars in each cluster (easily identified in the CMDs).
The OCCASO Survey

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- Less line-crowded and easier to analyse than brighter giants.
The OCCASO Survey

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Observational strategy

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- $\geq 6$ RC stars in each cluster (easily identified in the CMDs).
- Less line-crowded and easier to analyse than brighter giants.
- S/N $\geq 70$. 
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Observations

- Started Summer 2013
- NOT & Mercator: 5 nights/telescope/semester till summer 2015
- 2.2m CAHA: DDT & regular time.

<table>
<thead>
<tr>
<th>Telescope</th>
<th>NOT</th>
<th>Mercator</th>
<th>2.2m CAHA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awarded</td>
<td>25</td>
<td>25</td>
<td>8</td>
</tr>
<tr>
<td>Observed</td>
<td>20</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>Time lost</td>
<td>30%</td>
<td>15%</td>
<td>50%</td>
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</table>

- Complementary observations: confirm cluster members

Cluster Sample

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Stars</th>
<th>Survey</th>
</tr>
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<tbody>
<tr>
<td>King 1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>NGC 559</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>NGC 752</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>NGC 1817</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Be 17</td>
<td>3</td>
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<tr>
<td>NGC 2099</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>NGC 2420</td>
<td>5</td>
<td>A</td>
</tr>
<tr>
<td>NGC 2682</td>
<td>8</td>
<td>A</td>
</tr>
<tr>
<td>IC 4756</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>NGC 6633</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>NGC 6705</td>
<td>7</td>
<td>G</td>
</tr>
<tr>
<td>NGC 6791</td>
<td>6</td>
<td>A,K</td>
</tr>
<tr>
<td>NGC 6819</td>
<td>6</td>
<td>A,K</td>
</tr>
<tr>
<td>NGC 6939</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>NGC 6991</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>NGC 7142</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>NGC 7762</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>NGC 7789</td>
<td>7</td>
<td>A</td>
</tr>
</tbody>
</table>

(A) APOGEE
(G) GES
(K) Kepler

Observed: 18 clusters → 95 stars
Completed: 11 clusters
Data Reduction

- HermesDRS
- FIEStool
- CAFEPipe

- Bias & Flatfield correction
- Extraction
- Wavelength calibration
- Order merge

- DAOSPEC

- Continuum normalization

- IRAF

- Telluric correction
- Heliocentric correction
- Merge exposures
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Analysis

Equivalent widths

Spectral synthesis

Atmospheric parameters
Chemical abundances

DAOSPEC+DOOp
Stetson & Pancino 2008
Cantat-Gaudin et al. 2014
Equivalent widths

GALA
Mucciarelli et al. 2013

FERRE
Allende-Prieto et al. 2006

MATISSE
Reio-Blanco et al. 2006

Ispec
Blanco-Cuaresma et al. 2014

GES node: Bologna
GES node: IAC-UA-AIP
GES node: Nice

ONGOING
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Consistency: comparison among telescopes
Differences NOT-Merckator: 13 stars observed with both telescopes
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Consistency: comparison of M11 with GES
5 stars in common, comparison of atmospheric parameters and [Fe/H]

\[
\langle [\text{Fe/H}] \rangle_{\text{OCCASO}} = 0.11 \pm 0.09 \\
\langle [\text{Fe/H}] \rangle_{\text{GES}} = 0.10 \pm 0.06
\]
### NGC 7762: First abundance determination!

<table>
<thead>
<tr>
<th>RA</th>
<th>DEC</th>
<th>Rgc</th>
<th>Age</th>
<th>Z</th>
</tr>
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<tbody>
<tr>
<td>hh:mm:ss</td>
<td>dd:mm:ss</td>
<td>kpc</td>
<td>Gyr</td>
<td>kpc</td>
</tr>
<tr>
<td>23:50:01</td>
<td>+68:02:18</td>
<td>8.89</td>
<td>2.00</td>
<td>+0.08</td>
</tr>
</tbody>
</table>

- $[$Fe/H$] = 0.03 \pm 0.05$
- $[$MgI/Fe$] = 0.04 \pm 0.05$
- $[$SiI/Fe$] = -0.04 \pm 0.01$
- $[$CaI/Fe$] = 0.00 \pm 0.03$
- $[$ScII/Fe$] = 0.11 \pm 0.07$
- $[$TiI/Fe$] = -0.09 \pm 0.04$
- $[$VI/Fe$] = 0.05 \pm 0.07$
- $[$CrI/Fe$] = 0.04 \pm 0.02$
- $[$CoI/Fe$] = 0.04 \pm 0.02$
- $[$NiI/Fe$] = -0.07 \pm 0.03$
- $[$YII/Fe$] = 0.04 \pm 0.09$
- $[$BaII/Fe$] = 0.20 \pm 0.05$
- $[$LaII/Fe$] = 0.13 \pm 0.18$
- $[$EuII/Fe$] = 0.3 \pm 0.1$

From photometry: $[$Fe/H$] \sim -0.35$

(Patat & Carraro 1995)
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Conclusions and future work

✓ Abundance analysis from equivalent width method for eleven clusters
   IC 4756, NGC 752, NGC 2099, NGC 2682, NGC 6633, NGC 6705, NGC 6791, NGC 6819, NGC 6991, NGC 7762, NGC 7789

✓ Internal consistency among telescopes

✓ Consistency with GES (M11)

✓ Analysis from synthesis methods

✓ Comparison among methods

✓ First data release: atmosphere parameters ($T_{\text{eff}}$, log g), radial velocities, and [Fe/H] observed stars until now ($\sim$90)

✓ Second data release: detailed abundance analysis of the finished clusters

✓ Finish observations