The OCCASO Survey

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Introduction

Open Clusters

Importance of Open Clusters (OC):

i Star formation process, multi-population

ii Stellar nucleosynthesis and stellar evolution

iii Dynamical interaction among stars

iv Tracers of the Galactic disk

- Chemical trends with R_{GC}, z, and Age

Drawbacks in current studies:

i Only limited samples have been studied homogeneously

ii Complete and homogeneous studies are needed

- Radial velocities and proper motions
- Ages
- Chemical abundances

OCCASO in the context of large surveys

Space-based:

- *Gaia*
  - i Full sky $V = 20$
  - ii Parallaxes 25 μas $V = 15$
  - iii Proper motions $< 1\,\%$ up to 1.5 kpc
  - iv Radial velocities & chemical abundances limited by low resolution and short λ range to V =16.5 and 11.5 resp.

- Kepler
  - i Asteroseismic data$\rightarrow$high photometric precision
  - ii *Age*, M and R with precision $\sim$ 1%
  - iii In OCs uncertainties in distance and reddening are avoided

Ground-based:

- APOGEE
  - i $R \sim 22500$; $1.5 < \lambda < 1.7\ \mu$m
  - ii North and Southern hemisphere
  - iii Includes OCs (not well sampled: low number of stars, not the same evolutionary state)

- GES
  - i $R \sim 47000$; $4800 < \lambda < 7000$ Å (UVES)
$R \sim 20000$; $6500 < \lambda < 9000$ Å (GIRAFFE)
  - ii Southern hemisphere
  - iii Program devoted to OCs (20 OCs older than 0.5 Gyr)

- GALAH
  - i $R \sim 28000$ and 50000; $4700 \lesssim \lambda \lesssim 7900$ Å
  - ii Southern hemisphere
  - iii OCs?

Northern OCs are not properly sampled to make detailed studies of the Milky Way $\rightarrow$ OCCASO fills this gap

OCCASO

Aims and observational strategy

- Obtain accurate v_r and chemical abundances for more than 20 chemical species from high-resolution spectroscopy of Northern OCs.
- Observational strategy:

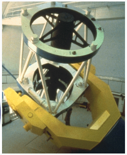
  i Selection of 25 OCs older than 0.3 Gyr (limiting magnitude $V \sim 15$)

  ii Sample at least 6 Red Clump stars per cluster

  iii SNR~ 70

- Observational facilities:

Telescope/Instrument	Diameter	Spectral range	Resolution
NOT/FIES	2.5 m	$3700 - 7300$ Å	$67,000$
Mercator/HERMES	1.2 m	$3770 - 9000$ Å	$85,000$
2.2mCAHA/CAFE	2.2 m	$3900 - 9500$ Å	$62,000$

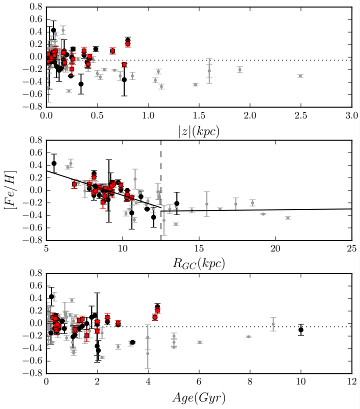


Observations

76 nights observed with a success rate of 78%

- Completed observations for: 17 OCs
- Started but not completed for: 7 OCs

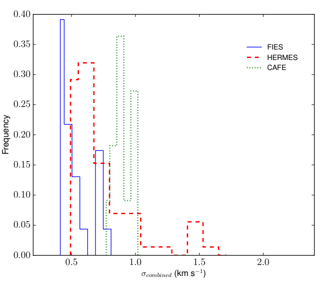
Cluster	D (kpc)	R_{GC} (kpc)	z (pc)	Age (Gyr)	Stars
IC 4756	0.48	8.14	+41	0.50	7
NGC 188	1.71	7.29	+651	7.59	6
NGC 752	0.46	8.80	-160	1.12	7
NGC 1817	1.97	8.71	-446	0.41	6
NGC 1907	1.80	10.24	+9	0.31	6
NGC 2099	1.38	9.87	+74	0.34	7
NGC 2420	2.48	9.25	+833	1.99	7
NGC 2539	1.36	9.37	+250	0.37	6
NGC 2682	0.81	9.16	+426	2.81	8
NGC 6633	0.38	8.20	+54	0.42	4
NGC 6705	1.88	6.83	-90	0.25	7
NGC 6791	5.04	6.03	+953	8.31	7
NGC 6819	2.51	7.81	+370	2.39	6
NGC 6939	1.80	6.97	+384	1.58	6
NGC 6991	0.70	8.47	+19	1.28	6
NGC 7762	0.78	8.86	+79	1.99	6
NGC 7789	1.80	9.27	-168	1.41	7
King 1	1.90	9.09	-449	3.98	2
Berkeley 17	2.70	11.25	-175	1.00	5
NGC 559	1.26	9.96	+28	2.00	1
NGC 2355	2.20	10.3	+400	0.70	5
NGC 6603	3.60	5.5	-70	0.20	2
NGC 7142	1.69	9.82	+521	4.07	1
NGC 7245	2.11	9.15	-68	0.18	4



Analysis. Radial velocities

Methodology

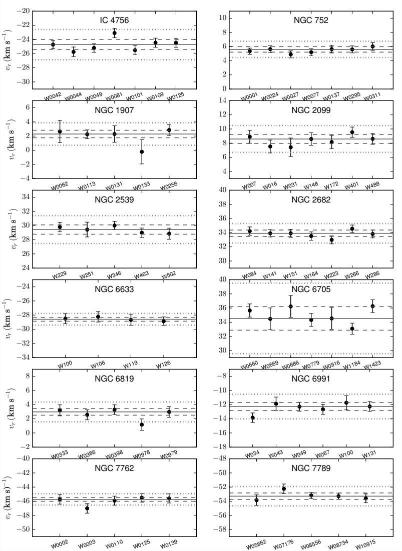
- v_r obtained for 77 stars in 12 OCs and Arcturus+μ-Leo using DOOp (Cantat-Gaudin et al. 2014)
- Median uncertainties: 0.5, 0.7 and 0.9 km s^{-1} for FIES, HERMES and CAFE respectively



→PaperI: Casamiquela et al. 2016

External comparison shows overall offset of 0.1±0.8 km/s

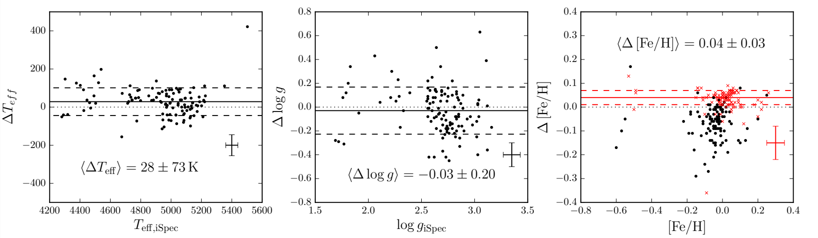
· Cluster v_r



Methodology

- Equivalent widths: DOOp (DAOSPEC) + GALA (Stetson& Pancino 2008; Cantat-Gaudin et al. 2014; Mucciarelli et al. 2013)
- Synthesis: iSpec (Blanco-Cuaresma et al. 2014)

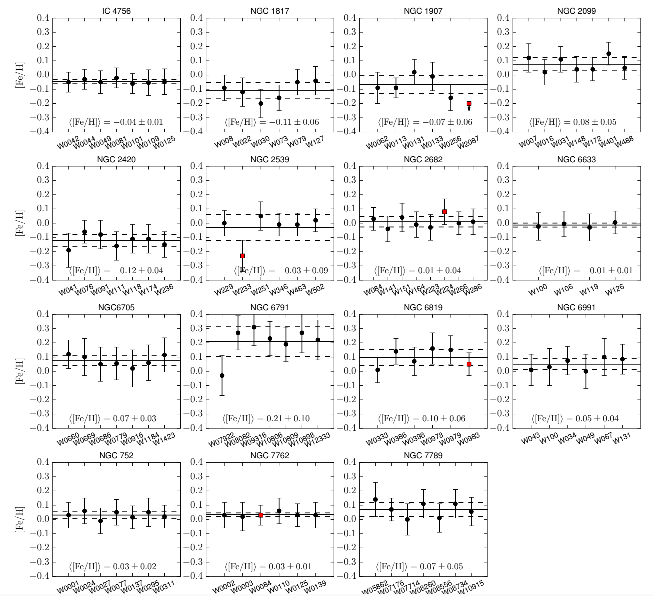
Differences in $T_{\rm eff}$, $\log g$ and [Fe/H] GALA-iSpec:



• = each method with its own $T_{\rm eff}$ and $\log g$
× = both methods the same parameters (average)

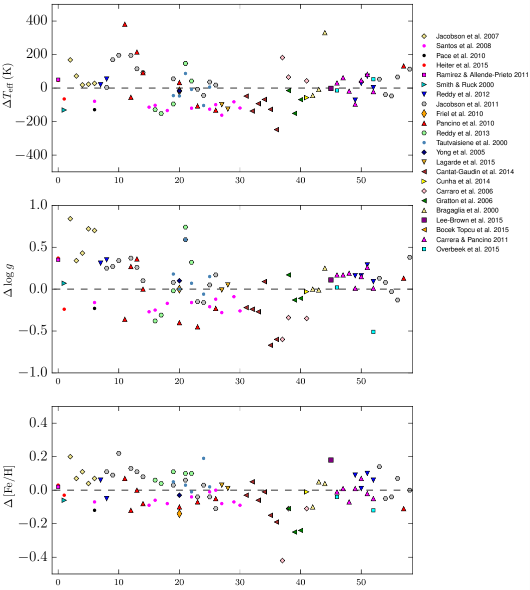
Results. Physical parameters and iron abundances

- Cluster iron abundances



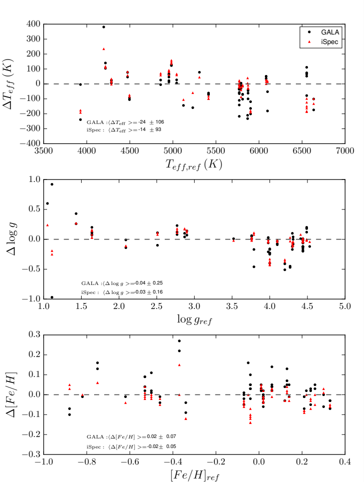
Results. Physical parameters and iron abundances

- Comparison with literature



Gaia Benchmark Stars (GBS)

- Analysis of the GBS (Jofré et al. 2015, Heiter et al. 2015; Blanco-Cuaresma et al. 2014)



- Analysis of Arcturus and μ-Leo observed in OCCASO

	Star	Arcturus	μ-Leo
$T_{\rm eff}$	OCCASO	4282	4453
	Ref GBS	4286	4474
$\log g$	OCCASO	1.78	2.42
	Ref GBS	1.64	2.51
[Fe/H]	OCCASO	-0.55	0.21
	Ref GBS	-0.53	0.26

Conclusion

Summary and future work

- We have completed observations of 17 OCs (+ 7 clusters incomplete): 114 stars + Arcturus + μ-Leo
- Radial velocity analysis for all clusters. External comparison with literature shows an overall offset of 0.1±0.8 km/s
- Spectroscopic analysis using two methods: DOOp+GALA (EW) and iSpec (synthesis) finished → $T_{\rm eff}$, $\log g$, [Fe/H]
- Comparison between the two methods shows good agreement in atmospheric parameters.
- Cluster by cluster analysis of [Fe/H]
- Decide which parameters to adopt in the computation of [Fe/H]
- Detailed analysis of individual chemical abundances (Fe-peak elements, α-elements, *r* and *s* process elements)
- Complete observations (mostly for faint clusters)

People involved

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