Setting the Standard in the Gaia-ESO Survey

Clare Worley
Institute of Astronomy, University of Cambridge

26th February 2019
Massively multiplexed spectroscopy with MSE, Tucson

The Gaia-ESO Survey

- **ESO Large Public Survey**
- ~100,000 targets over 340 night over 6 years: **January 2012 to January 2018**
- **Co-PIs** Prof. G. Gilmore (Cambridge), Dr S. Randich (Arcetri)
- 400+ Co-Investigators across 90+ European (and abroad) Institutes

- **Observations on the FLAMES@VLT:** UVES (Resolving Power~45,000)
  GIRAFFE (Resolving Power~20,000)

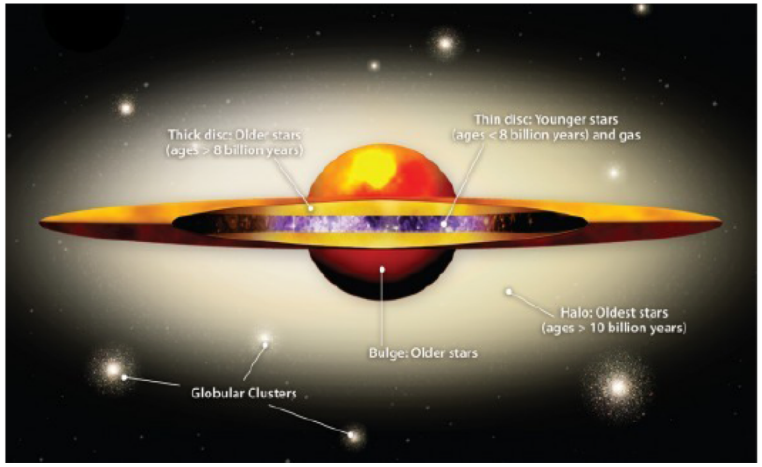
- **Stellar Populations:** Bulge, Thick & Thin Discs, Open & Globular Clusters

- **Measurables:** Effective Temperature, Surface Gravity, Metallicity, Radial Velocity, Rotational Velocity, Individual Chemical Abundances, Chromospheric Activity, Circumstellar Disk Detection...

- **Last Data Cycle** (iDR6) to be completed ~Spring 2019
- **Public Release** ~end of Summer 2019

- **Publications so far**: 83 journal articles, 40 proceedings

Scientific Goals



Homogeneous overview of kinematics & abundances for all main components of the Milky Way

- Chemico-kinematic 3D chart
- Studies in Galactic Archaeology

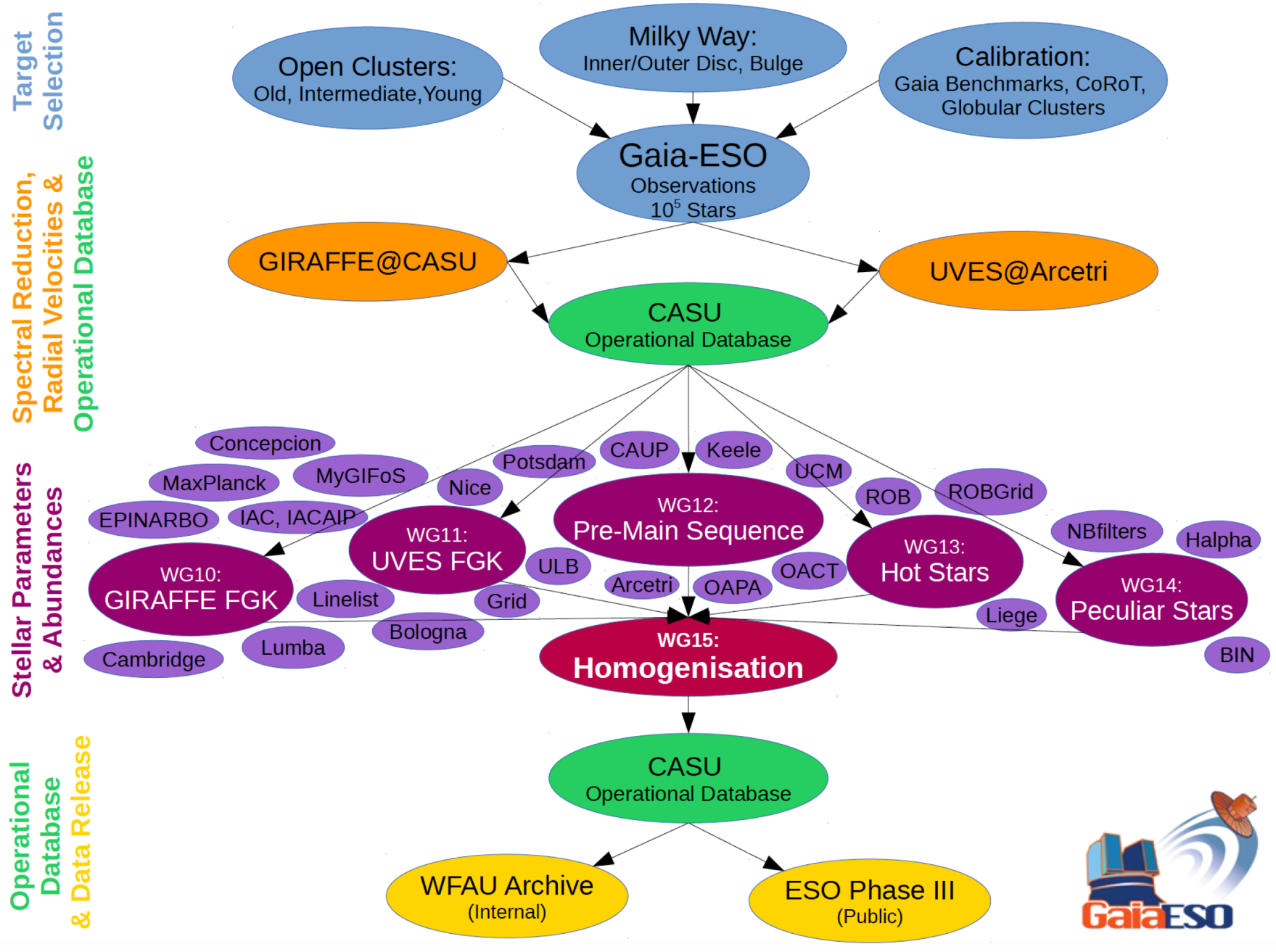
Linking stellar populations from star-forming regions to ancient halo stars

Age, mass, and environment dependences of abundances, kinematics, stellar properties

Radial, vertical and azimuthal abundance gradients and their age dependence: from the inner Galaxy to the outer realms.

Gaia + Gaia-ESO
→ Complementary datasets
→ Distances (Parallaxes) + Detailed Chemistry

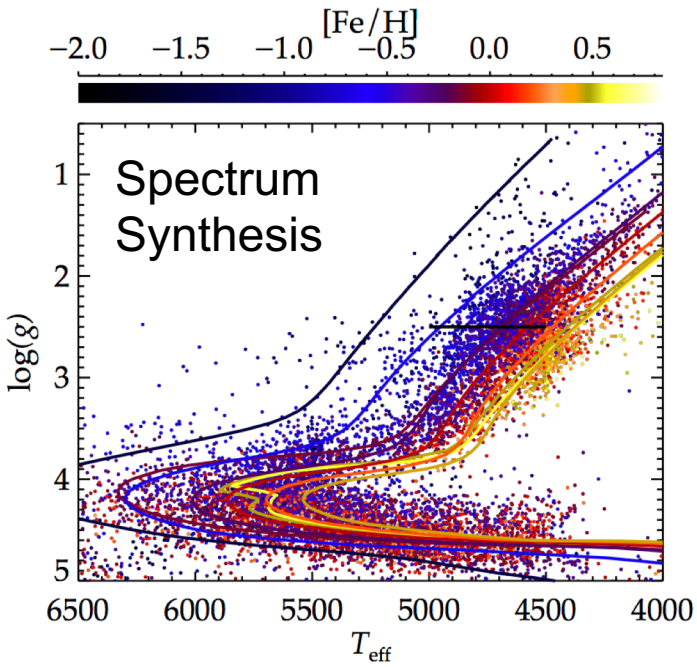
How does Gaia-ESO Work?

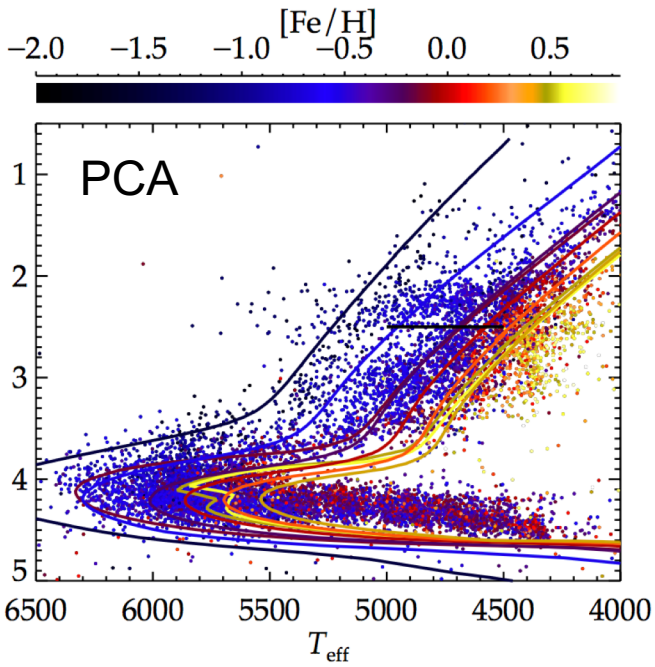


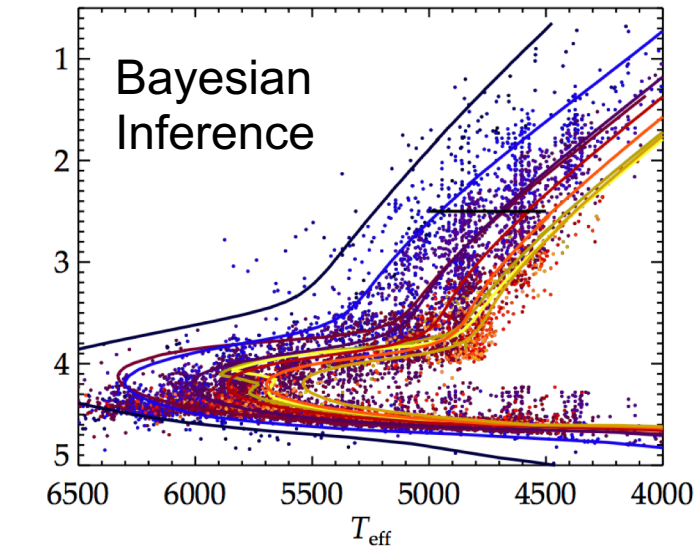
Creating the Gaia-ESO Survey Catalogue

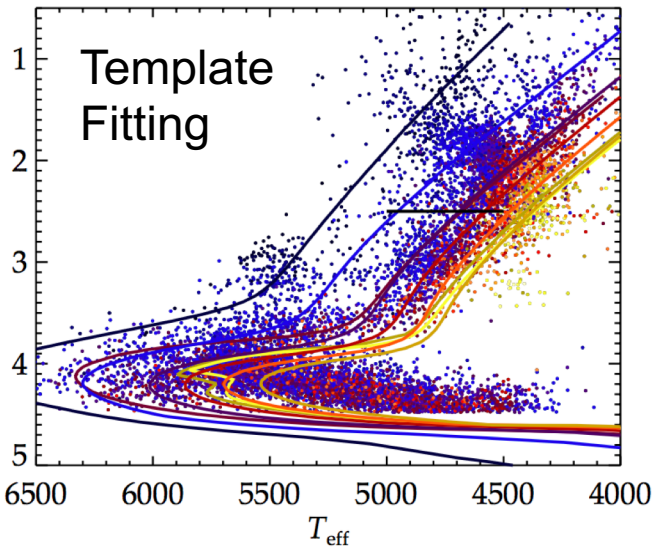
Many analysis methods

Single Star Catalogue







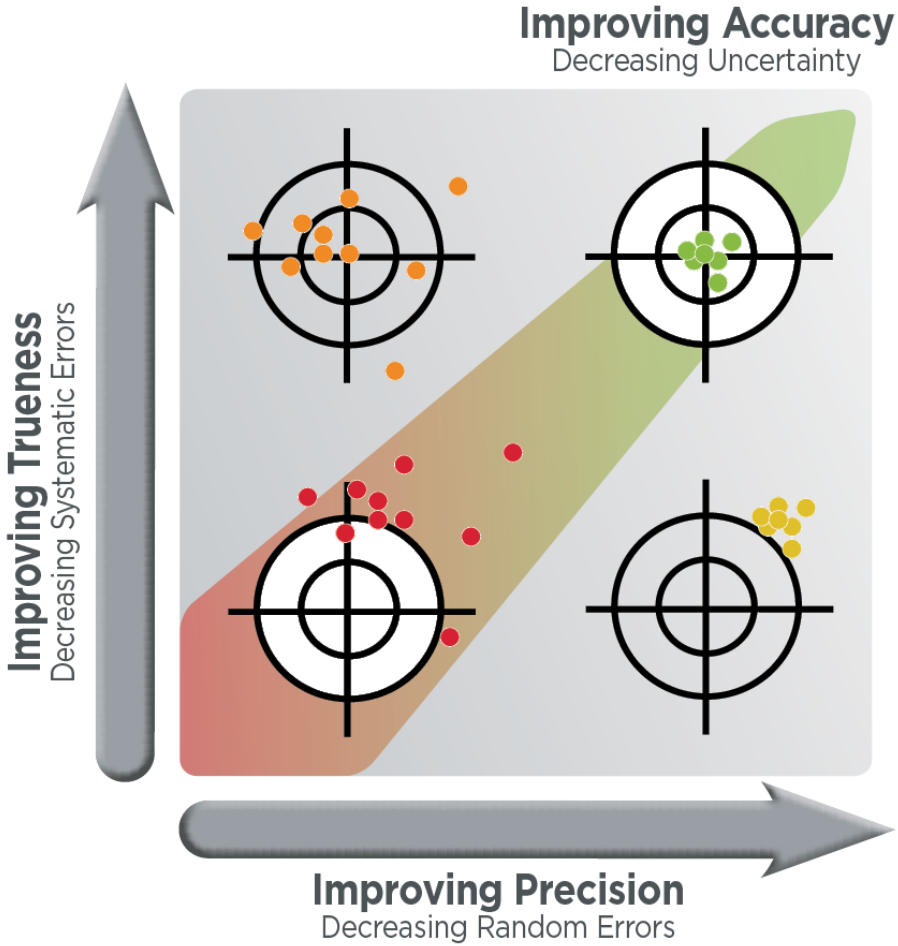


Precision & Accuracy

No guarantee that
Method 1 == Method 2
(Survey 1 == Survey 2)

How different can the results really be?

How do we combine them?



Setting the Parameter Scale
FGKM Benchmarks

Heiter et al. 2015

Jofre et al. 2014

Hawkins et al. 2016

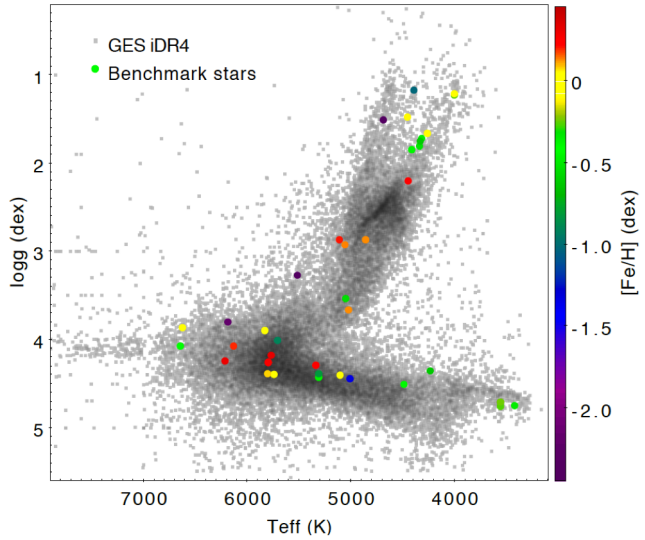
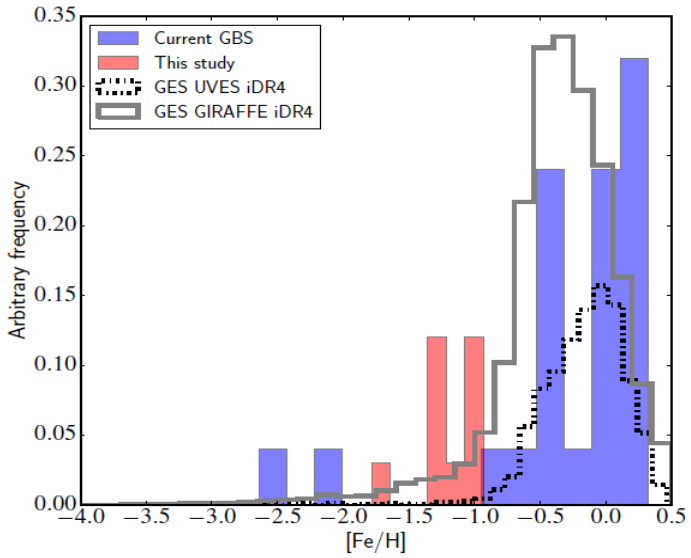


Fig. 8. Position on the T_{eff}-log$g$ plane of the Gaia FGK benchmark



Gaia-ESO Calibration Strategy
Pancino et al. 2016

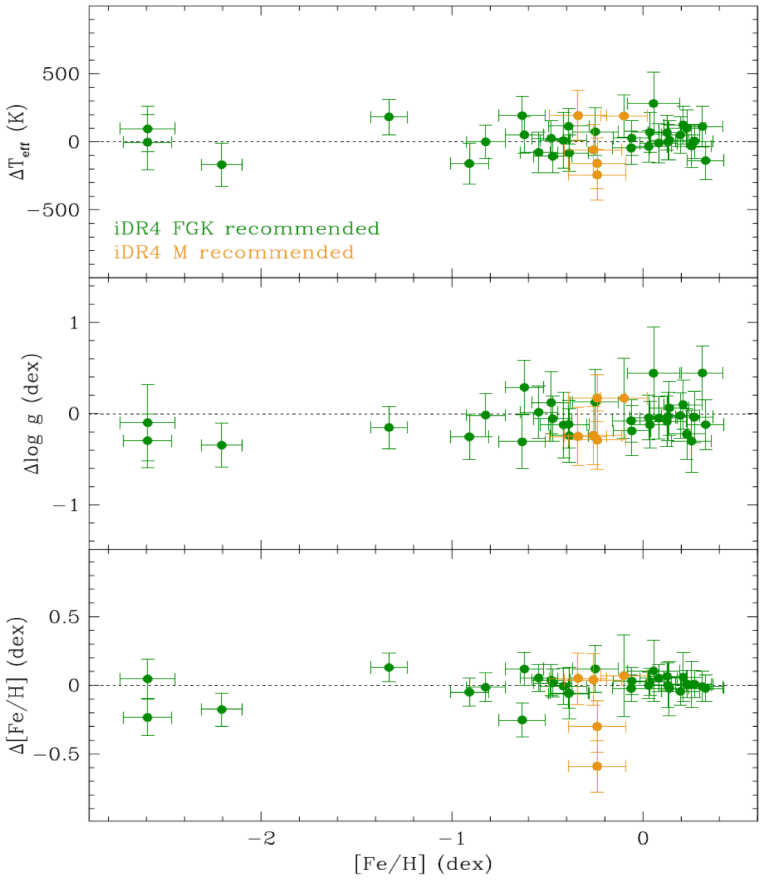


Fig. 10. Comparison of GES iDR4 recommended values with the reference APs (Heiter et al. 2015b) and [Fe/H] (Jofré et al. 2014) values. In

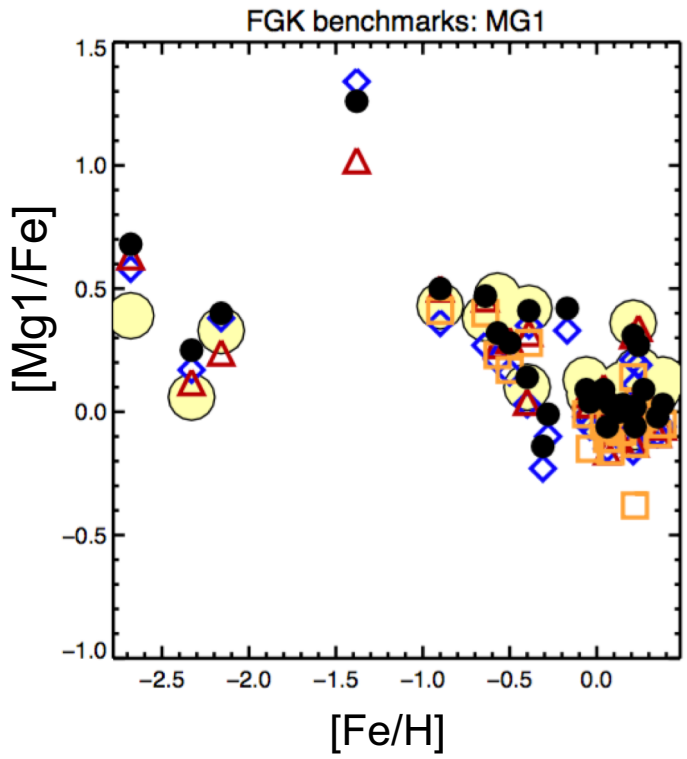
Accuracy of Chemical Abundances

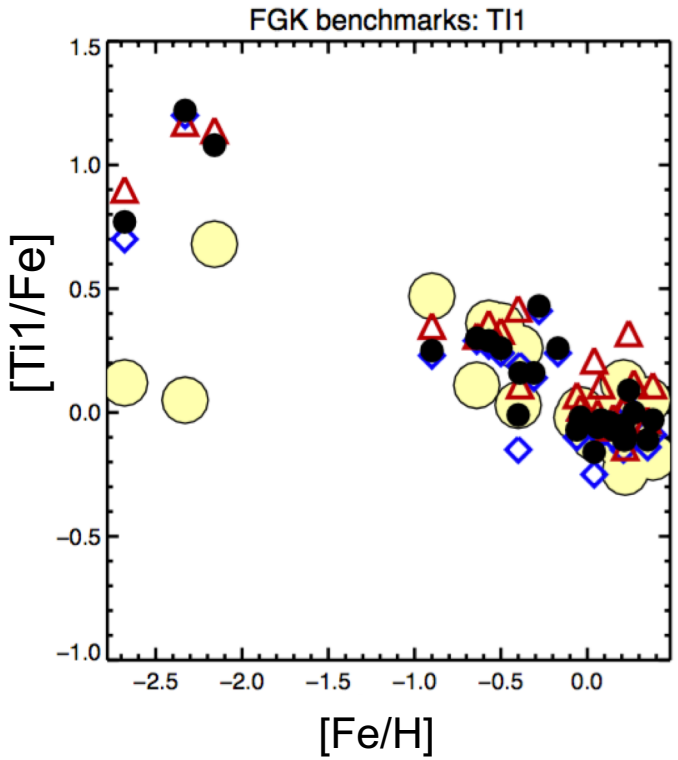
Very few reference sets for chemical abundances except for the Sun:
Grevesse et al 2007, Asplund et al. 2009, Lodders 2009

P. Jofré, U. Heiter, C. Soubiran et al.2015:
Gaia FGK benchmark stars: abundances of alpha and iron-peak elements, 2015
(Mg, Si, Ca, Sc, Ti, V, Cr, Mn, Co, and N)

See also high quality studies as listed in Jofre et al. 2019, AnnRevA&A, in press,
https://arxiv.org/pdf/1811.08041.pdf

Reference
Recommended
Node 1
Node 2
Node 3



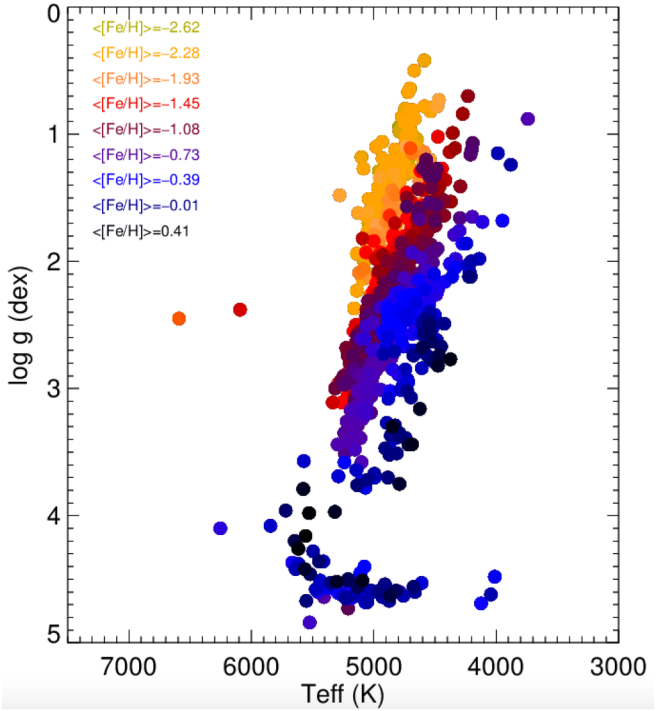


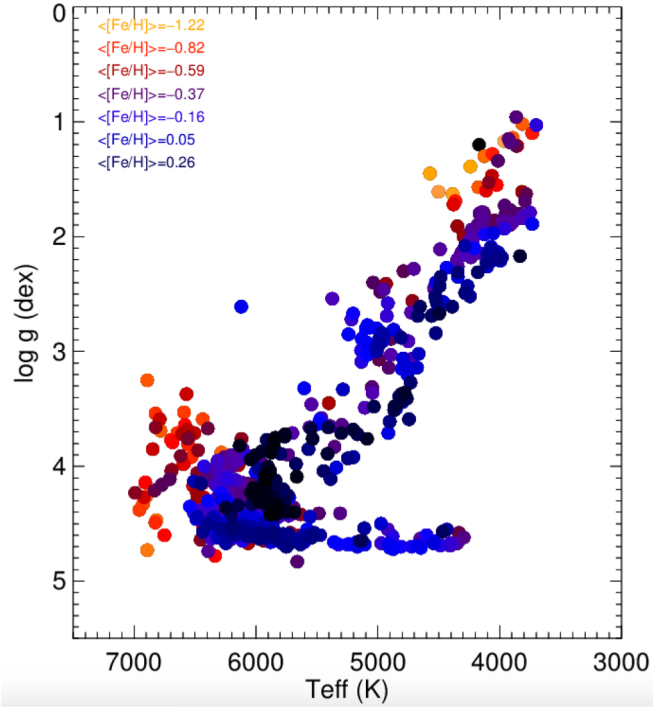
Globular and Open Clusters as calibrators

"Single Age, Single Chemical Composition, Simple Stellar Populations"

Pancino et al. 2016

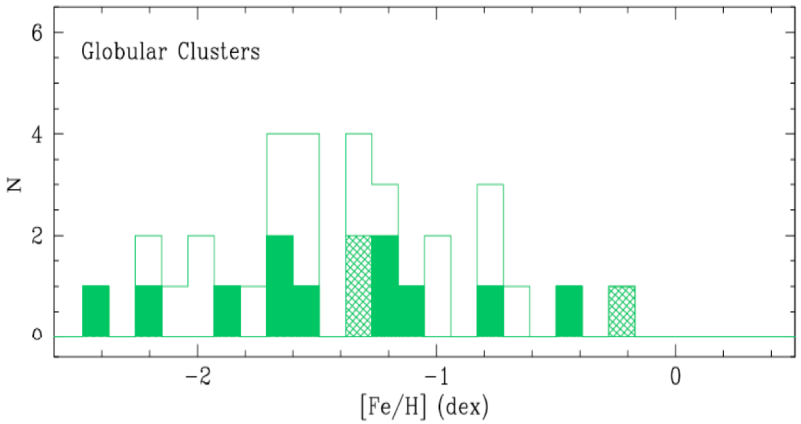
Gaia-ESO Calibration Strategy

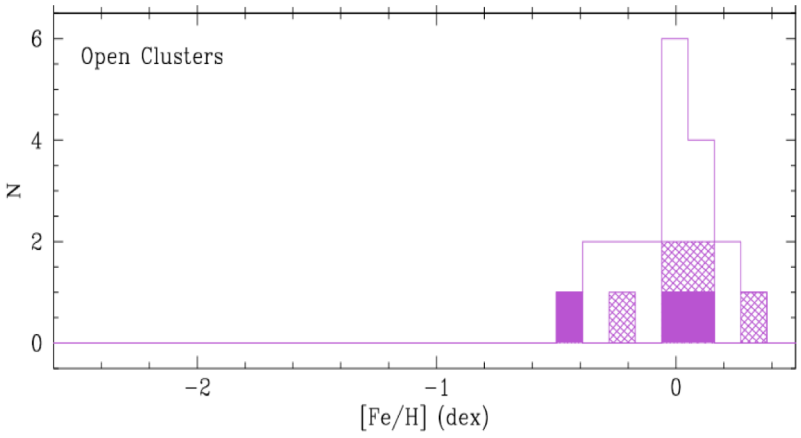




iDR4

- 14 Globular Clusters
- 6 Calibrating Open Clusters

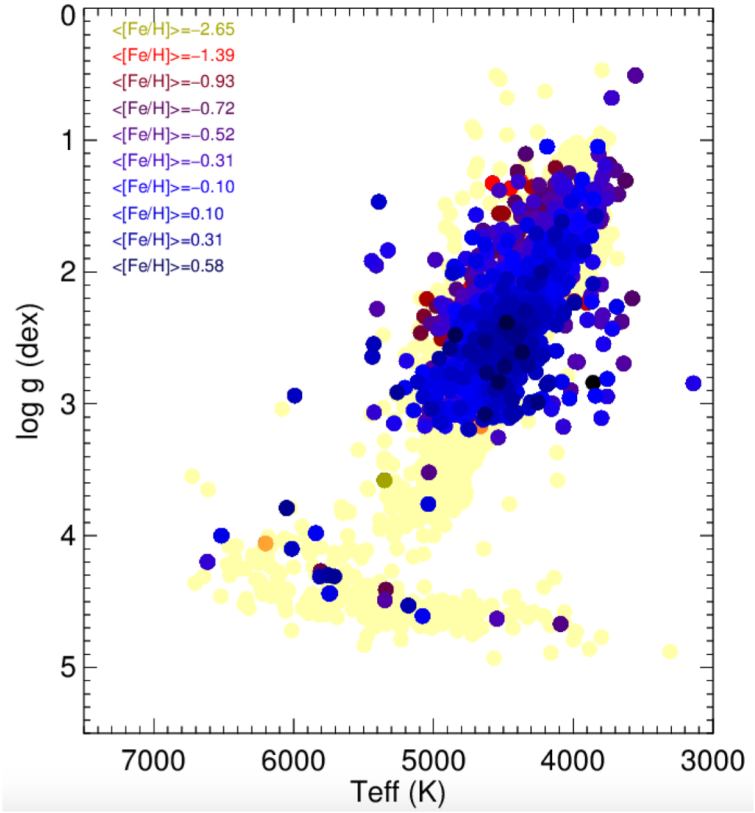




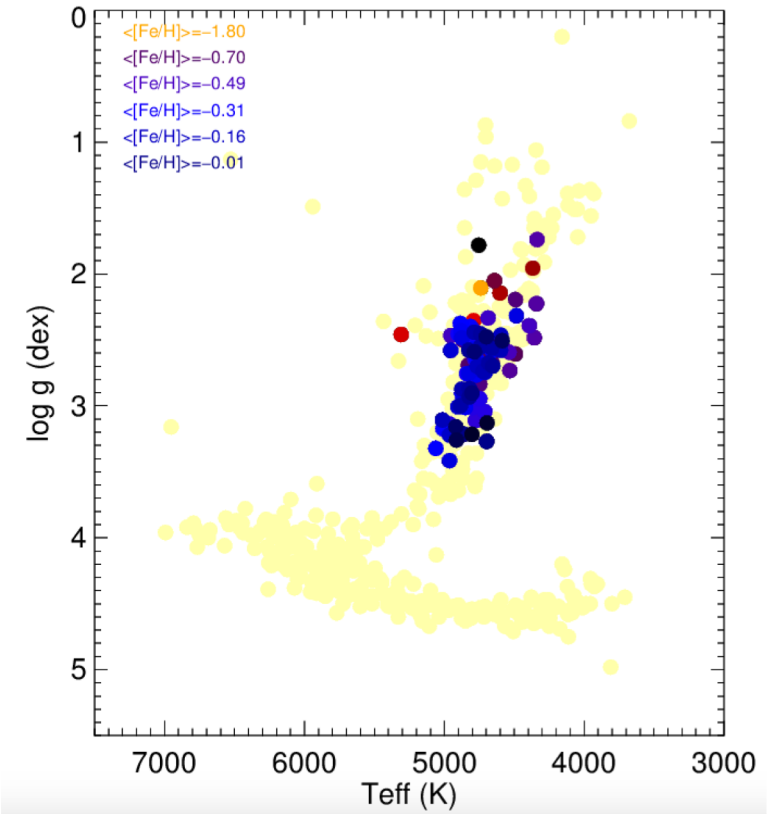
The Gaia-ESO Survey & Asteroseismology

Projects to iterate between spectroscopic Effective Temperature & Metallicity, and astereoseismic Surface Gravity…. Also measuring chemical abundances!

- *CoRoT Special Project:*
  - Masseron et al. 2019, in prep
  - 1745 stars



- *Kepler 2 Special Project:*
  - Worley et al. 2019a, in prep
  - 90 stars

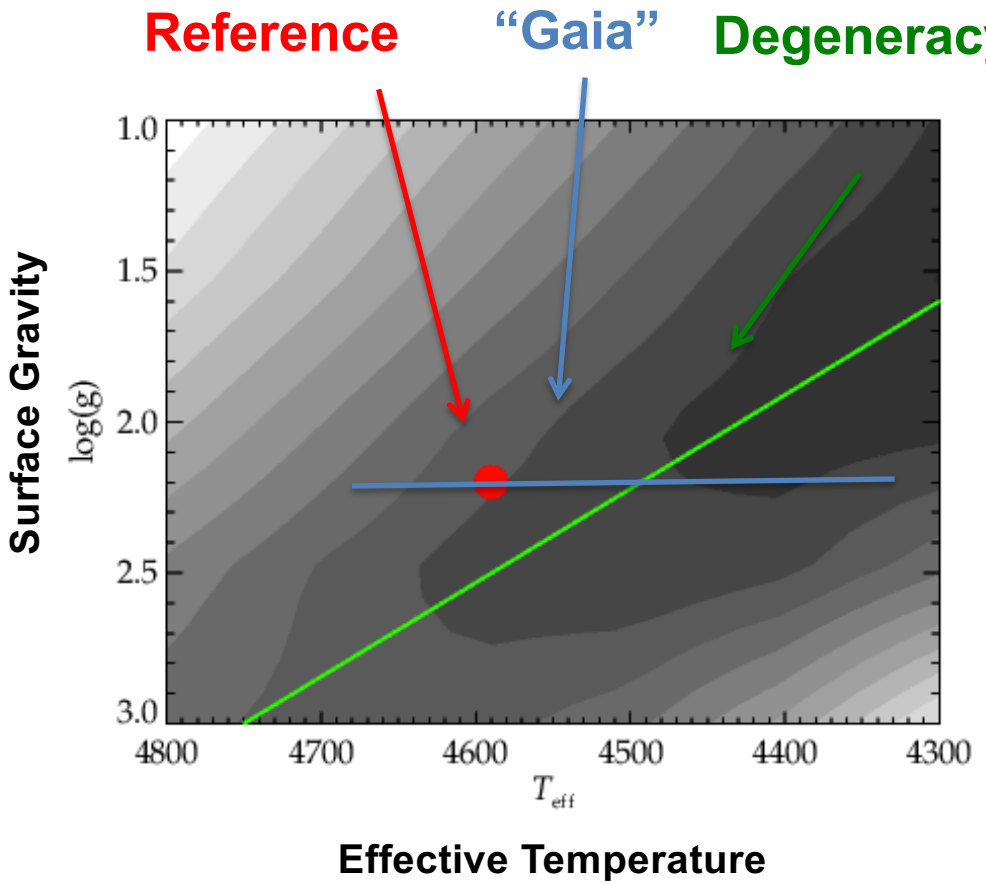


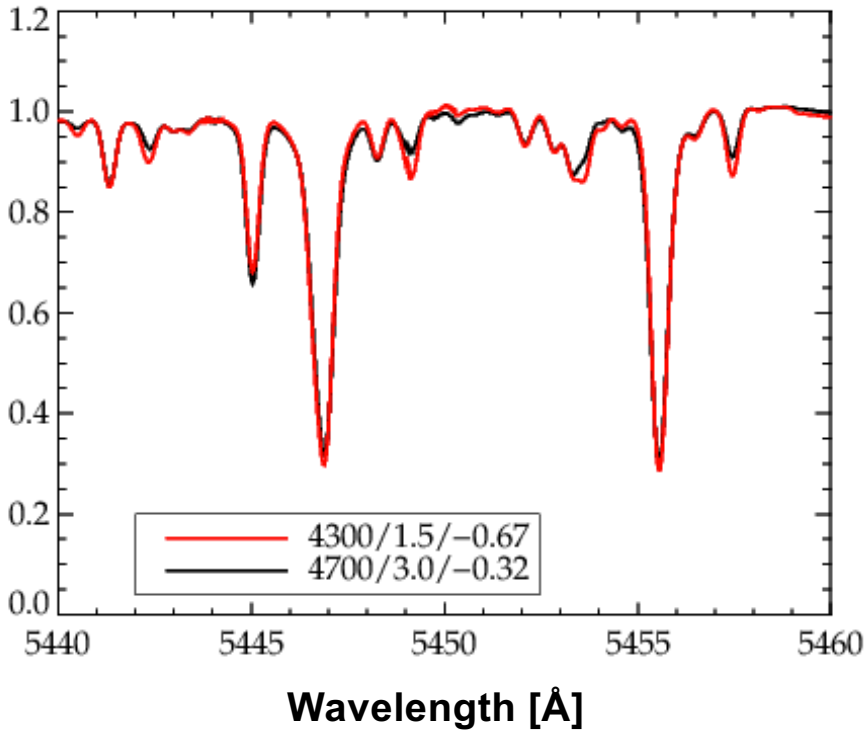
Yellow Points are GES results for full field

Degeneracies in Stellar Parameters: breaking them with Gaia

From the definitions of surface gravity and luminosity:

$$\log \frac{g}{g_\odot} = \log \frac{\mathcal{M}}{\mathcal{M}_\odot} + 4 \log \frac{T_{\rm eff}}{T_{\rm eff\odot}} + 0.4(M_{\rm bol} - M_{\rm bol\odot}),$$

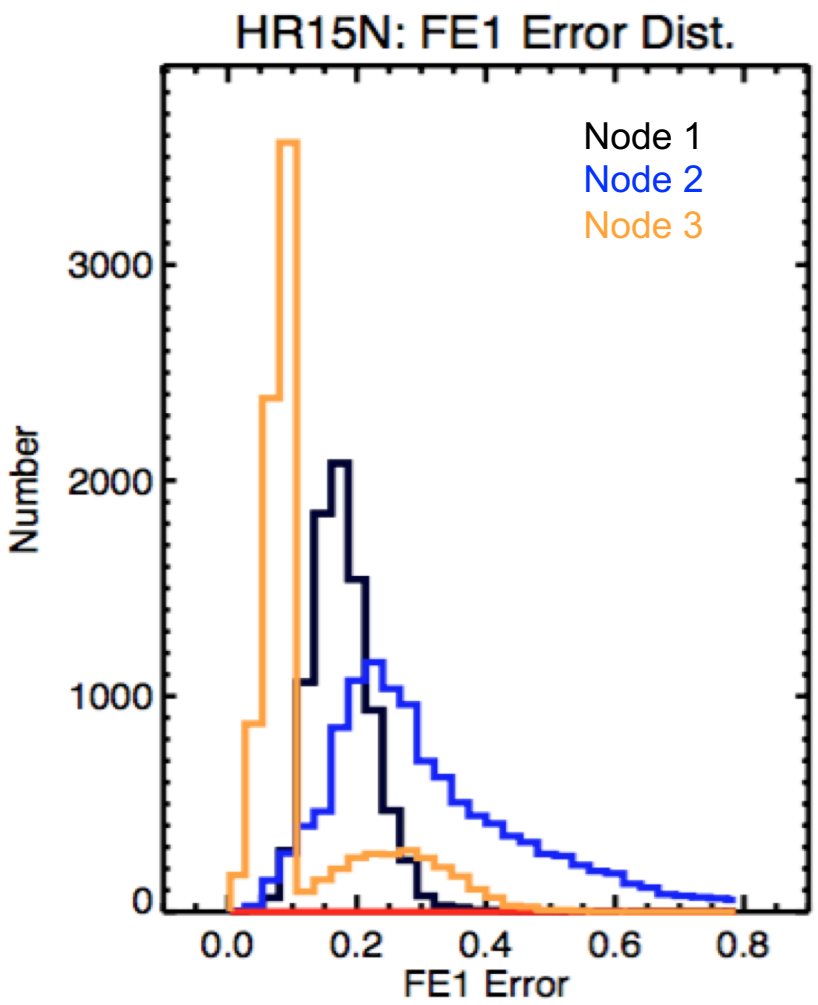




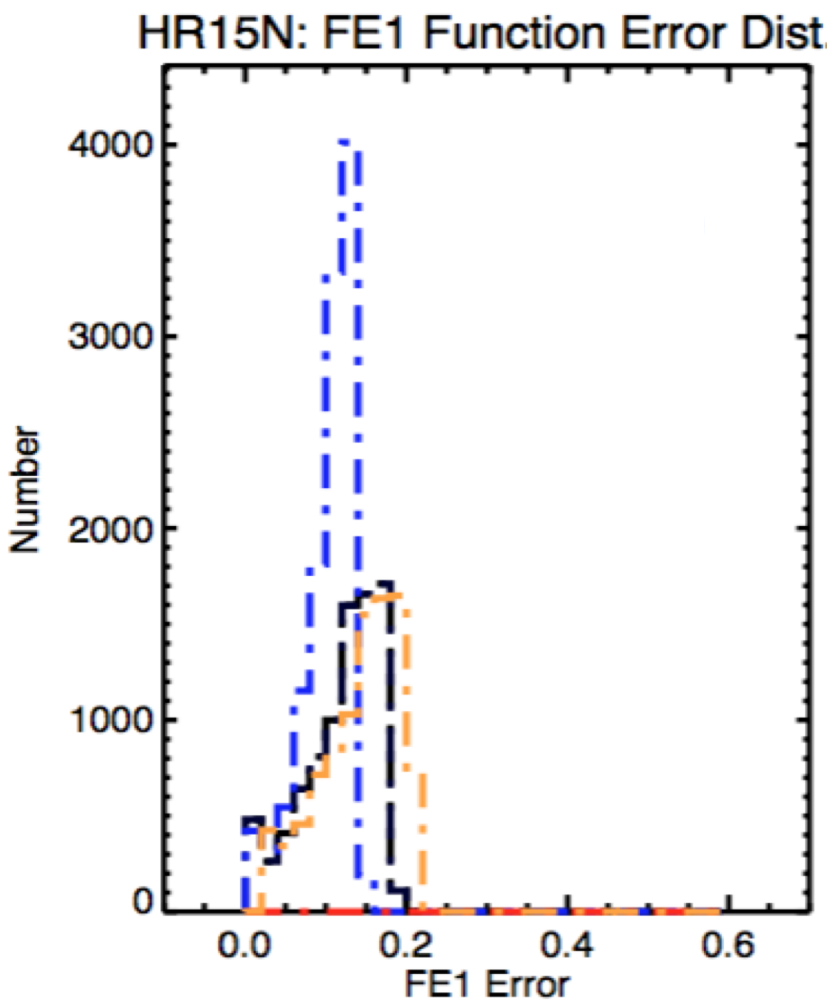
Defining the Error Model

Worley et al 2019b FGK GIRAFFE Homogenisation

Reported

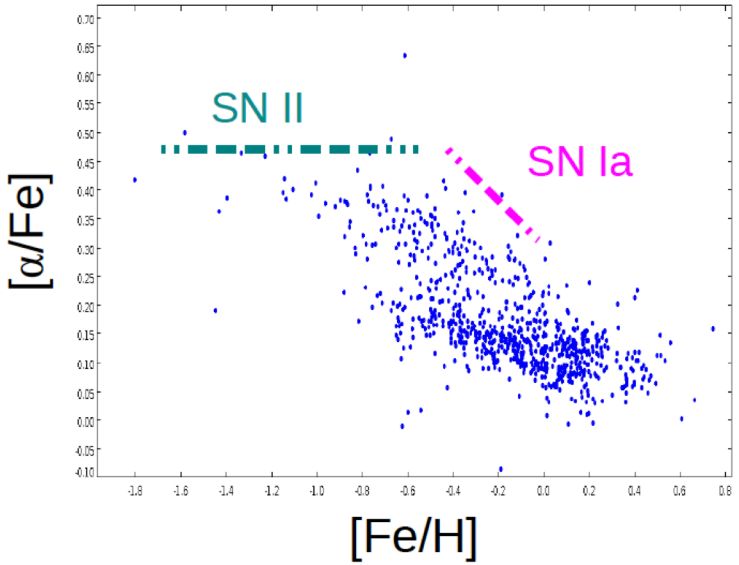


Derived



Science Highlights: UVES field star survey

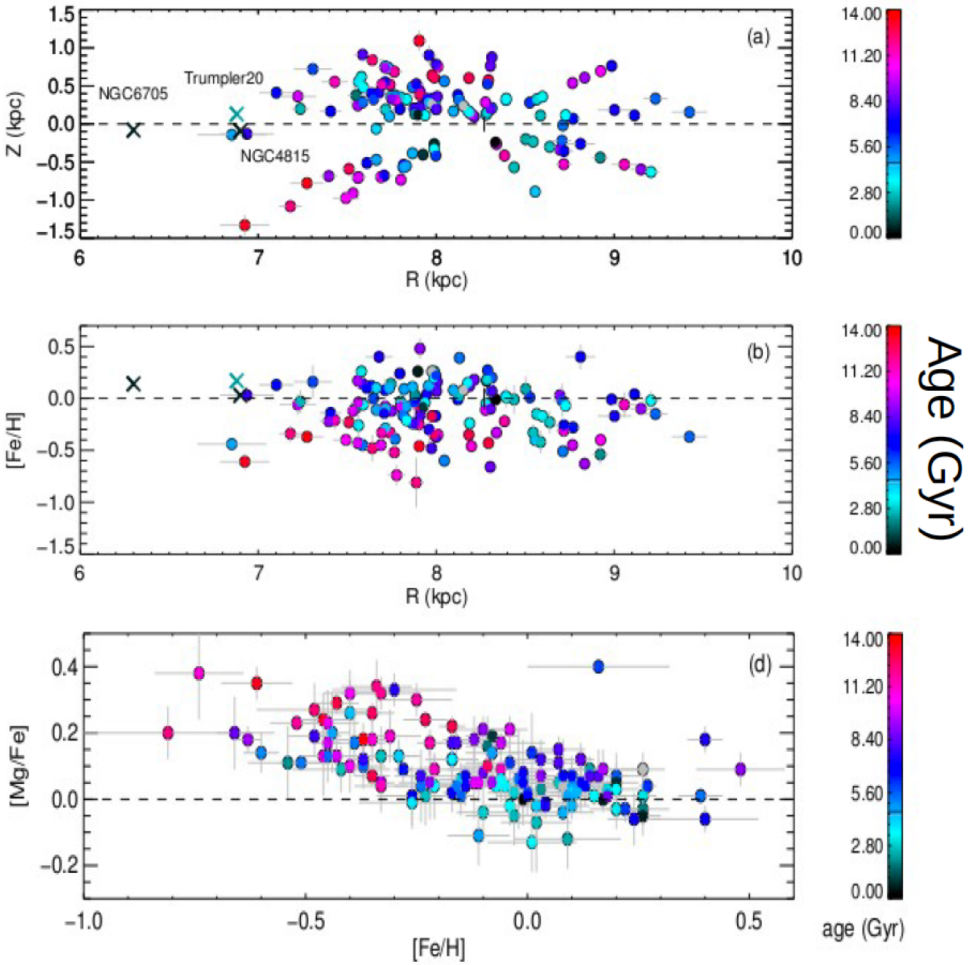
Gaia-ESO UVES (Nice UVES)



First age-unbiased metallicity & elemental distribution functions for both thick and thin disks separately

→ **Verification of discreteness between the thick and thin disks**

Gilmore & Reid, 1983



Bergemann et al. 2014

Extra-dimensionality expected with Gaia

Science Highlights

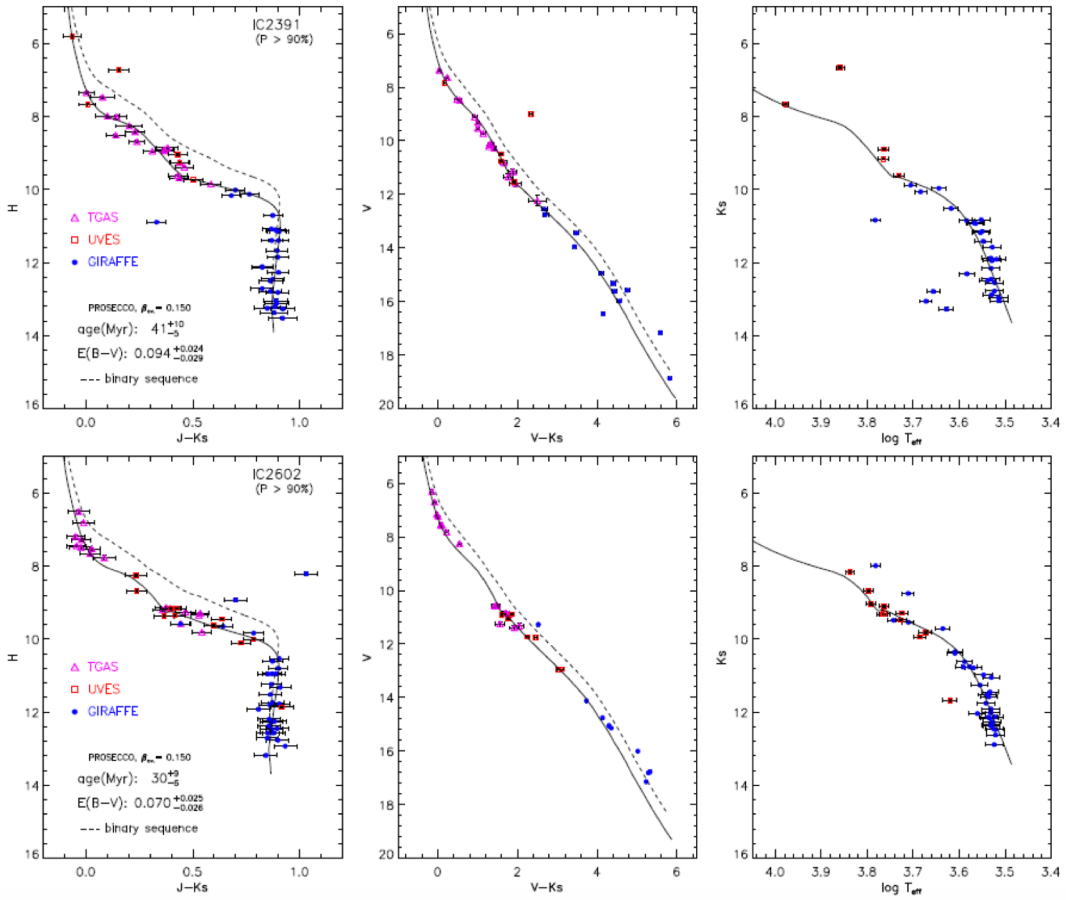
Open clusters in Gaia-DR1: A way forward to stellar age calibration

Randich et al. 2018

Parallaxes from *Gaia*-DR1 TGAS used to derive distances for eight Gaia-ESO open clusters.

- Placed these cluster on to an absolute age scale for the first time
- Good agreement with isochrones and lithium depletion boundary ages
- Chemical composition showed the age determinations are robust against evolutionary models, which was not obvious *a priori*

➤ Huge potential of combining *Gaia* and Gaia-ESO to calibrate stellar ages.



Clusters IC 2391 and IC 2602

Photometry: 2MASS , APASS, ASCC-2.5
Left: The estimated reddening and age values

Dashed Line: unresolved binary sequence (constant mass qbin=0.8)

Setting the Standard in the Gaia-ESO Survey

- Final release of the Gaia-ESO Survey is imminent!
- Some 100,000 stars observed at medium or high resolution resulting in a catalogue of stellar parameters, accurate velocities, stellar activity indicators and detailed chemical abundances
- Already a lot of very high impact science: 83 journal articles, 40 proceedings
- Driven a lot of development in stellar parameter and chemical abundance automated analyses
- Driven a lot of development in the requirements for and building of reference sets
- Legacy dataset for upcoming surveys – lots still to do!