

The Gaia-ESO Spectroscopic Survey

Survey Co-PIs

**Gerry Gilmore
(IoA, Cambridge)**

&

**Sofia Randich
(INAF/Arcetri)**

>300 Cols

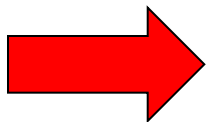
The Gaia-ESO Public Spectroscopic Survey

- 1 Institute of Astronomy, University of Cambridge, United Kingdom
 - 2 INAF-Osservatorio Astrofisico di Arcetri, Italy
 - 3 Mount Stromlo Observatory, Australian National University, Canberra, Australia
 - 4 Dept. of Theoretical Physics, University of Oxford, United Kingdom
 - 5 GEPI, Observatoire de Paris, France
 - 6 Centre for Astronomy Research, University of Hertfordshire, United Kingdom
 - 7 Lund Observatory, Sweden
 - 8 Institute for Astronomy, University of Edinburgh, United Kingdom
 - 9 Astrophysics Group, University of Keele, United Kingdom
 - 10 INAF-Osservatorio Astronomico di Palermo, Italy
 - 11 Departamento de Física, Universidad de Alicante, Spain
 - 12 ESTEC, ESA, the Netherlands
 - 13 Max-Planck Institut für Astronomy, Heidelberg, Germany
 - 14 INAF-Osservatorio di Padova, Italy
 - 15 Instituto de Astrofísica de Andalucía-CSIC, Granada, Spain
 - 16 Instituto Astrofísico de Canarias, Tenerife, Spain
 - 17 Royal Observatory of Belgium, Brussels, Belgium
 - 18 INAF-Osservatorio di Bologna, Italy
 - 19 Dept. of Physics and Astronomy, University of Uppsala, Sweden
 - 20 Dipartimento di Fisica e Astronomia, Università di Catania, Italy
 - 21 Institut für Astronomie, Universität Wien, Austria
 - 22 Observatoire de la Côte d'Azur, Nice, France
 - 23 ESO
 - 24 Institut d'Astronomie et d' Astrophysique, Université Libre de Brussels, Belgium
 - * Co-PI
 - † Steering Committee member
 - ‡ Working Group coordinator
- The Gaia-ESO Survey Team
Co-PIs: G. Gilmore¹, S. Randich²
Cols: M. Asplund¹, J. Binney¹, P. Bonifazi³, J. Drew⁴, S. Feltzing⁵, A. Ferguson⁶, R. Jeffries⁷, G. Micola⁸, I. Negueruela⁹, T. Prusti¹⁰, H.-W. Rix¹¹, A. Vallenari¹², D. Aden¹³, C. Aerts¹⁴, L. Allart¹⁵, J.-M. Alcalá¹⁶, E. Altor¹⁷, C. Allende Prieto¹⁸, G. Altavilla¹⁹, J. Alves²⁰, T. Arzouf²¹, F. Asmus²², C. Agostini²³, A. Amorín Ramo²⁴, C. Babusauf²⁵, C. Ballarín-Jones²⁶, L. Balaguer-Núñez²⁷, A. Bayo²⁸, B. Barbuy²⁹, G. Baranovskii³⁰, D. Barado y Navascués³¹, C. Battistini³², I. Bellas Veldre³³, M. Bellazzini³⁴, V. Belokurov³⁵, T. Benay³⁶, M. Bergemann³⁷, G. Bertelli³⁸, K. Blazaro³⁹, O. Blanton⁴⁰, J. Bland-Hawthorn⁴¹, R. Blomme⁴², C. Boecher⁴³, S. Bonito⁴⁴, S. Bourdoux⁴⁵, J. Bouvier⁴⁶, A. Bragaglia⁴⁷, I. Bratton⁴⁸, A. Brown⁴⁹, J. de Bruijne⁵⁰, M. Buriago⁵¹, J. Caballero⁵², E. Caffau⁵³, F. Calura⁵⁴, R. Caputo-Dalozzi⁵⁵, M. Carrara⁵⁶, G. Carrara⁵⁷, L. Casagrandi⁵⁸, S. Caswell⁵⁹, S. Chapman⁶⁰, G. Chignoli⁶¹, V. Chomiuk⁶², N. Christlieb⁶³, M. Clifton⁶⁴, G. Cocozza⁶⁵, M. Collins⁶⁶, R. Collet⁶⁷, M. Collins⁶⁸, M. Conert⁶⁹, E. Covino⁷⁰, D. Crnjević⁷¹, M. Cropper⁷², M. Cunha⁷³, F. Damiani⁷⁴, M. David⁷⁵, A. Delgado⁷⁶, S. Dufray⁷⁷, S. Van Eck⁷⁸, B. Edwards⁷⁹, J. Eldridge⁸⁰, H. Enrique⁸¹, K. Eriksson⁸², N.W. Evans⁸³, L. Eyre⁸⁴, B. Famaey⁸⁵, M. Fellhauer⁸⁶, I. Ferraro⁸⁷, F. Gallardo⁸⁸, G. González⁸⁹, E. Gascoino⁹⁰, G. Ryan⁹¹, D. Galochi⁹², E. García-Rojas⁹³, P. Franzosi⁹⁴, A. Fasoli⁹⁵, K. Freeman⁹⁶, V. Freyberg⁹⁷, E. Friel⁹⁸, B. García-Religa⁹⁹, J. Gamero¹⁰⁰, R. Garzon¹⁰¹, S. Geier¹⁰², D. Geisler¹⁰³, C. Geisler¹⁰⁴, B. Gibson¹⁰⁵, A. Gomez¹⁰⁶, A. Gomez¹⁰⁷, C. González-Fernández¹⁰⁸, J. González Hernández¹⁰⁹, E. Gosset¹¹⁰, E. Grebel¹¹¹, R. Grimes¹¹², M. Gronowegen¹¹³, F. Grundler¹¹⁴, M. Guarrolo¹¹⁵, S. Gustafsson¹¹⁶, P. Hadzadzic¹¹⁷, D. Hatzidimitriou¹¹⁸, N. Hambary¹¹⁹, P. Hammersley¹²⁰, C. Hansen¹²¹, M. Haywood¹²², U. Heiter¹²³, U. Heiter¹²⁴, E. Heiter¹²⁵, A. Helmi¹²⁶, G. Helou¹²⁷, A. Hensler¹²⁸, V. Hill¹²⁹, S. Hodgkin¹³⁰, N. Husares¹³¹, A. Husarek¹³², R. Ibata¹³³, M. Irwin¹³⁴, R. Jackson¹³⁵, R. de Jong¹³⁶, P. Jonker¹³⁷, S. Jordan¹³⁸, C. Jordi¹³⁹, A. Jorissen¹⁴⁰, D. Katz¹⁴¹, D. Kowalski¹⁴², S. Keller¹⁴³, N. Kharchenko¹⁴⁴, R. Klement¹⁴⁵, A. Klotz¹⁴⁶, J. Kruse¹⁴⁷, A. Koch¹⁴⁸, C. Kochtewicz¹⁴⁹, M. Komzasm¹⁵⁰, S. Koposov¹⁵¹, A. Korn¹⁵², P. Koubek¹⁵³, A. Lanzafama¹⁵⁴, R. Lallamant¹⁵⁵, P. de Laverny¹⁵⁶, C. van Leeuwen¹⁵⁷, S. Lemasle¹⁵⁸, G. Lewis¹⁵⁹, K. Lind¹⁶⁰, H. P. E. Lindstrom¹⁶¹, A. Lobe¹⁶², J. Lopez Sarrago¹⁶³, J. Lucas¹⁶⁴, H. Ludwig¹⁶⁵, T. Luthinger¹⁶⁶, L. Mignoni¹⁶⁷, P. Maitz-Agüero¹⁶⁸, J. Malençon¹⁶⁹, G. Marconi¹⁷⁰, A. Marino¹⁷¹, C. Martayan¹⁷², I. Martinez-Villaverde¹⁷³, G. Matilsk¹⁷⁴, R. McClure¹⁷⁵, S. Meszard¹⁷⁶, M. Meyer¹⁷⁷, A. Miglio¹⁷⁸, S. Mikolajewicz¹⁷⁹, I. Minchev¹⁸⁰, D. Minniti¹⁸¹, A. Morello¹⁸², Y. Morayé¹⁸³, L. Monaco¹⁸⁴, M. Monari¹⁸⁵, M.J. Monteiro¹⁸⁶, R. Morier¹⁸⁷, D. Montes¹⁸⁸, A. Mora¹⁸⁹, E. Morara¹⁹⁰, T. Morel¹⁹¹, N. Mowlani¹⁹², A. Mucianelli¹⁹³, U. Munari¹⁹⁴, R. Nagwotny¹⁹⁵, N. Nardetto¹⁹⁶, T. Naylor¹⁹⁷, Y. Naze¹⁹⁸, G. Nelan¹⁹⁹, S. Ocasio²⁰⁰, S. Ortolan²⁰¹, G. Pace²⁰², F. Palli²⁰³, J. Palouš²⁰⁴, E. Panconci²⁰⁵, R. Parker²⁰⁶, E. Paunzen²⁰⁷, J. Paresce²⁰⁸, L. Ritzler²⁰⁹, G. Piotto²¹⁰, H. Poiblo²¹¹, L. Pranzan²¹², E. Pucari²¹³, A. Qureshi²¹⁴, S. Ragan²¹⁵, J. Read²¹⁶, M. Read²¹⁷, A. Rello-Blanco²¹⁸, C. Rejač²¹⁹, J. de Rudder²²⁰, N. Roldán²²¹, A. Robin²²², S. Roediger²²³, D. Romano²²⁴, F. Royer²²⁵, G. Ruche²²⁶, A. Rucina²²⁷, S. Ryan²²⁸, N. Ryde²²⁹, G. Sacco²³⁰, N. Santos²³¹, J. Sanz Forcada²³², L. M. Sarro Barral²³³, L. Sbordone²³⁴, S. Schibach²³⁵, S. Schmeie²³⁶, O. Schuster²³⁷, R. Schoenrich²³⁸, R.-D. Scholz²³⁹, G. Seabroke²⁴⁰, S. Sharma²⁴¹, G. De Silva²⁴², R. Smirani²⁴³, M. Smith²⁴⁴, S. Solano²⁴⁵, R. Sordo²⁴⁶, G. Soubiran²⁴⁷, S. Sousa²⁴⁸, A. Spina²⁴⁹, M. Steller²⁵⁰, M. Steinmetz²⁵¹, B. Stelzer²⁵², E. Stempels²⁵³, H. Taberner²⁵⁴, G. Tautvaišienė²⁵⁵, F. Theureau²⁵⁶, J. Torra²⁵⁷, M. Tosi²⁵⁸, E. Tolstoy²⁵⁹, G. Tosi²⁶⁰, M. Walker²⁶¹, N. Walton²⁶², J. Wambaganes²⁶³, C. West²⁶⁴, K. Wern²⁶⁵, J. Vink²⁶⁶, R. Wyse²⁶⁷, S. Zappia²⁶⁸, W. Ziegler²⁶⁹, M. Zoccali²⁷⁰, J. Zurek²⁷¹, D. Zuckerman²⁷², T. Zwitter²⁷³
- Institutes: ¹IoA; ²INAF-Obs. Arcetri; ³MFA; ⁴Univ. Oxford; ⁵Obs. Paris; ⁶Univ. Hertfordshire; ⁷Lund Univ.; ⁸Univ. Edinburgh; ⁹Univ. Keele; ¹⁰Obs. Palermo; ¹¹Univ. de Alicante; ¹²ESTEC; ¹³MPIA; ¹⁴INAF-Obs. Padova; ¹⁵Kath. Univ. Leuven; ¹⁶INAF-Obs. Capodimonte; ¹⁷IAA-CSIC; ¹⁸IAC; ¹⁹Univ. Bologna; ²⁰Univ. Vienna; ²¹Karsten Inst.; ²²Univ. Palermo; ²³Univ. Saragossa; ²⁴ESO Santiago; ²⁵Univ. Granada; ²⁶Nat. Inst. Phys & Astro, Lithuania; ²⁷Calar Alto Obs.; ²⁸National Optical Obs., Greece; ²⁹INAF-Obs. Bologna; ³⁰Obs. Strasbourg; ³¹Univ. Sydney; ³²Royal Obs. Belgium; ³³Univ. Heidelberg; ³⁴Univ. J. Fourier; ³⁵INAF-Obs. Bologna; ³⁶CAUP Porto; ³⁷Univ. Lahti; ³⁸Univ. Leicester; ³⁹Centro de Astrobiología, Madrid; ⁴⁰Univ. Central Lancashire; ⁴¹Univ. Rome; ⁴²AMP Potsdam; ⁴³Univ. Heidelberg; ⁴⁴AAC; ⁴⁵MSSL, UCL; ⁴⁶Univ. Antwerp; ⁴⁷ULB, Brussels; ⁴⁸Uppsala Univ.; ⁴⁹ETH Zurich; ⁵⁰Univ. Copenhagen; ⁵¹INAF-Obs. Catania; ⁵²ANU; ⁵³Univ. Boston; ⁵⁴Univ. Warwick; ⁵⁵Birmingham Obs.; ⁵⁶MPF; ⁵⁷Univ. Ljubljana; ⁵⁸Univ. Liège; ⁵⁹Kath. Universiteit Leuven; ⁶⁰Univ. Aarhus; ⁶¹CSA; ⁶²Astr. Inst. Acad. Sci., Prague; ⁶³Univ. Athens; ⁶⁴ESO Garching; ⁶⁵OCA Nice; ⁶⁶BRNO, Uwecht; ⁶⁷Univ. Madrid; ⁶⁸Copenhagen Univ. Obs.; ⁶⁹Univ. Athens; ⁷⁰Univ. Catania; ⁷¹Univ. Cottbus; ⁷²Univ. Liabor; ⁷³Univ. Nice Sophia Ant.; ⁷⁴ESAO; ⁷⁵Obs. de Genève; ⁷⁶Univ. Exeter; ⁷⁷Univ. Nijmegen; ⁷⁸NOA, Beijing; ⁷⁹Univ. Padova; ⁸⁰Obs. Sesazon; ⁸¹Rochester Inst. Technology; ⁸²Univ. Madrid; ⁸³Univ. Bordeaux; ⁸⁴INAF-Obs. Torino; ⁸⁵Univ. Victoria; ⁸⁶Arragh Obs.; ⁸⁷Johns Hopkins Univ.; ⁸⁸JAP; ⁸⁹MacQuarie Univ.

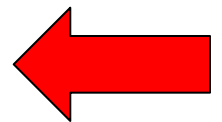
Gaia-ESO survey – context and motivations

(conclusions and key words of several talks)

- Chemistry **and** kinematics
- Ages
- Large (spectroscopic) datasets
- Uniform analysis (also across different populations)



GAIA + GB SPECTROSCOPY



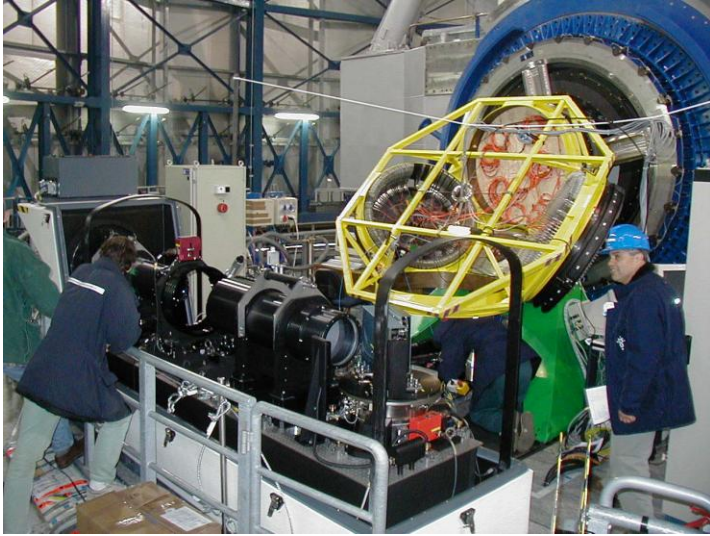
OUTLINE

- Survey overview
- Survey data products
- Core science
- Targets and strategy
- First light, spectra, “results”

Gaia-ESO survey (GES) overview (1)

- **Public** large spectroscopic survey with FLAMES@VLT
- Proposal approved in 6/2011, SMP in 10/2011, contract with DG signed in 2/2012
- **300 (240+60) nights** (30n/semester) over **5 (4+1) years**; start 12/2011 (P88), end 9/2016 (P97)++; visitor mode
- **All populations of the MW:** Halo; Bulge; Thick & Thin discs; open clusters and associations

Gaia-ESO survey overview (2)



Giraffe (130 fibers)
for faint targets ($V < 19$)

UVES (8 fibers)
for 'bright' stars ($V < 16.5$)

- **$>10^5$ Giraffe spectra** ($R \sim 16,000-25,000$)
→ RVs, APs, [Fe/H], [X/Fe], stellar properties
- **$>10^4$ UVES spectra** ($R \sim 47,000$)
→ precise multi element abundances
- **+ ESO archive** exploitation/re-analysis

Survey data products

- 1D, λ calibrated, sky-subtracted spectra
- Radial and rotational velocities
- APs: T_{eff} , $\log g$
- $[\text{Fe}/\text{H}]$, $[\alpha/\text{Fe}]$, $[\text{X}/\text{Fe}]$ (Li, C, O, Na, Mg, ..Ni, ..Ba, Y.)
- Average RV, $[\text{Fe}/\text{H}]$, $[\text{X}/\text{Fe}]$ for the clusters
- Stellar properties: e.g, accretion rates, mass loss
- Photometry used to select the targets
- Semester, annual, and final data releases
- First releases: 01/2013 and 06/2012

CORE SCIENCE

The formation and evolution of the MW and its component stars and stellar pops.

- The (dynamical) evolution of clusters: from birth to disruption
- Stellar evolution (ages, masses)
- Halo substructure, Dark Matter, Extreme stars (very low metallicity)
- Nature and formation of the bulge
- Formation and ev. of the thick and thin discs (field stars and clusters)

SAMPLE AND STRATEGY

What samples – 1. Field stars

GIRAFFE

- **Bulge:** mostly giant stars (clump and RGB), $I=15$
- **Halo /thick disc:** FG TO stars ($17 < r < 18$); giants in known streams, predominantly NGC and SGC
- **Thin disc** –only RVs for dynamics; $I < 19$

UVES parallel

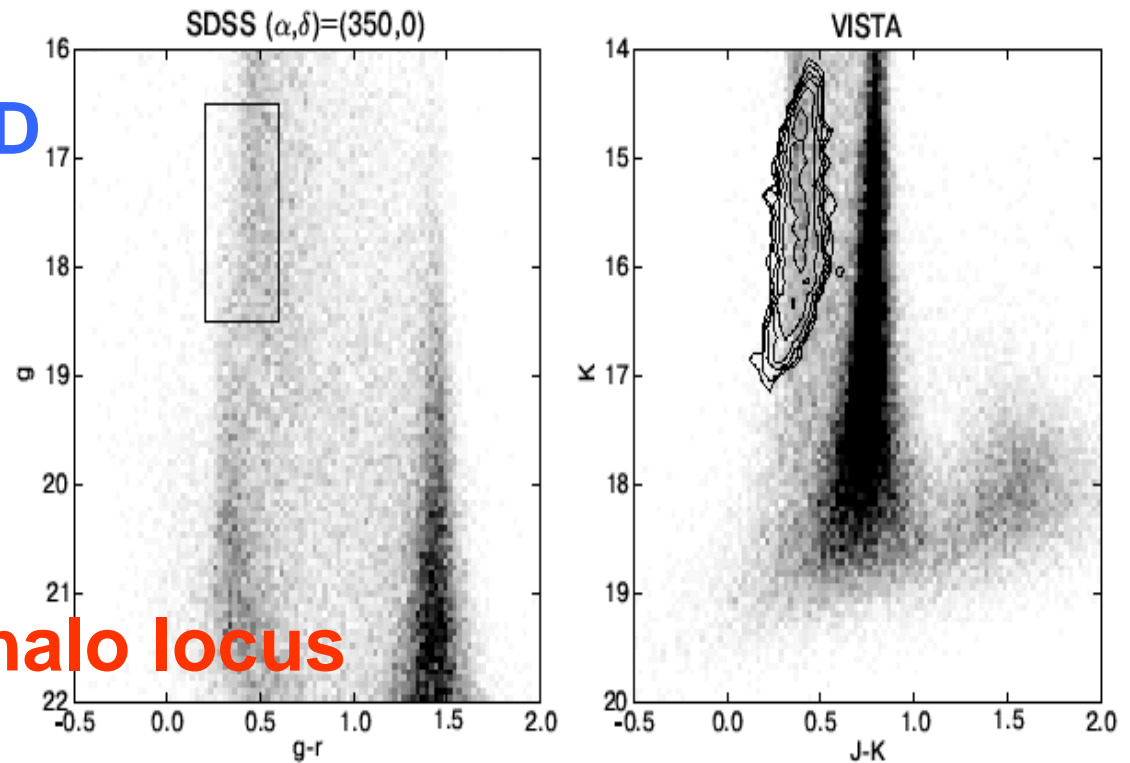
- **Solar neighborhood:** complete unbiased 5000-star sample. Look at $M_V \sim 5.5$, \rightarrow unbiased survey to 1kpc at $V=15$. Plus subgiants...
At $V=15$, survey 2000 thin disk, 2000 thick disk, 1000+ halo

What samples – 1. Field stars

Selection based on CMDs using VISTA+
SDSS

Fix a box in the CMD
with thick disc and
halo turnoff

Select thick disc/halo locus



Implement in VHS

What samples – 2. Open Clusters



PMS clusters
(10-100 Myr)

Very young clusters,
star forming regions,
associations



Intermediate-age
and old clusters
(100 Myr – 8 Gyr)



**Nearby (< 1.5 kpc) and distant
Relevant populations covered**

What samples – 2. Open Clusters

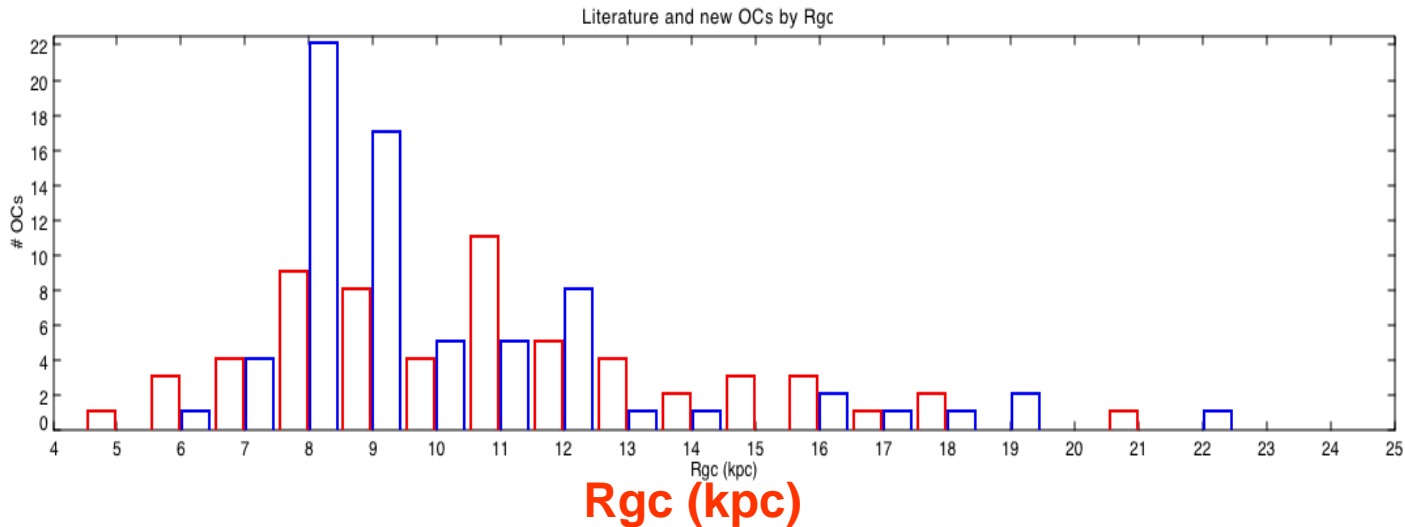
~ 100 OCs in all phases of evolution (~1 Myr → several Gyr), sampling the age-distance- R_{GC} -density-mass-metallicity parameter space

OB type stars → M dwarfs

plus evolved stars (mostly clump giants)

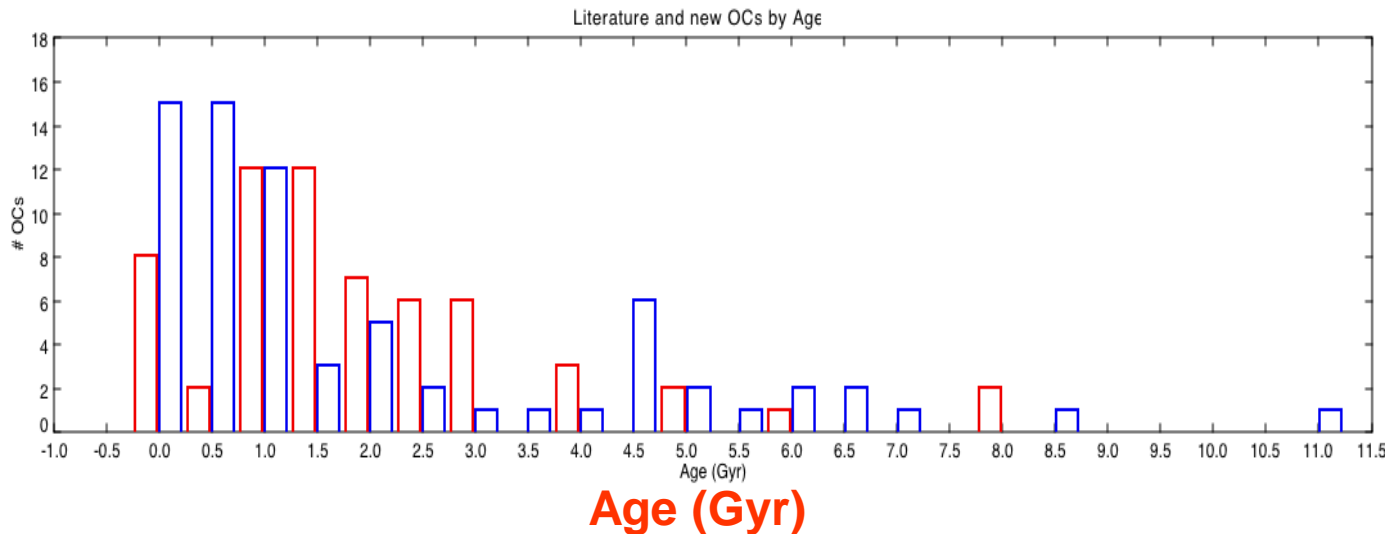
Relevant populations covered

OCs in the Gaia-ESO survey



GES

Literature



What samples/stars. 3 –calibration fields

- RV standards
- (Gaia) Benchmark stars
- COROT fields
- Targets observed by other surveys (e.g. Apogee)
- COROT fields
- Well studied open & globular clusters

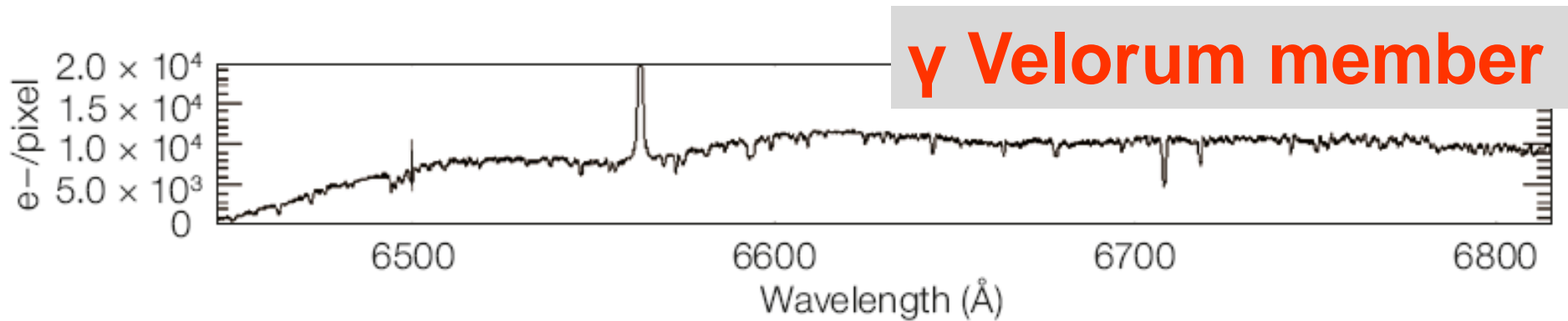
Set-ups and spectral ranges

- **UVES:** CD3 -520/580 (416-617/475-678 nm) for hot/cool stars
- **Giraffe:** *Cluster/field stars:*
 - **HR03/05A /06/09B/14A** (403-476, 514-536, 631- 670 nm) for hot (down to A-type) stars: H lines, Si IV, He I, O II,...
 - **HR10/15N/21** (534-562; 647-679; 848.4-900) for cool stars: Teff/gravity indicators, H α , Li, Fe I and II lines, Ca IR triplet, a few other el. lines;

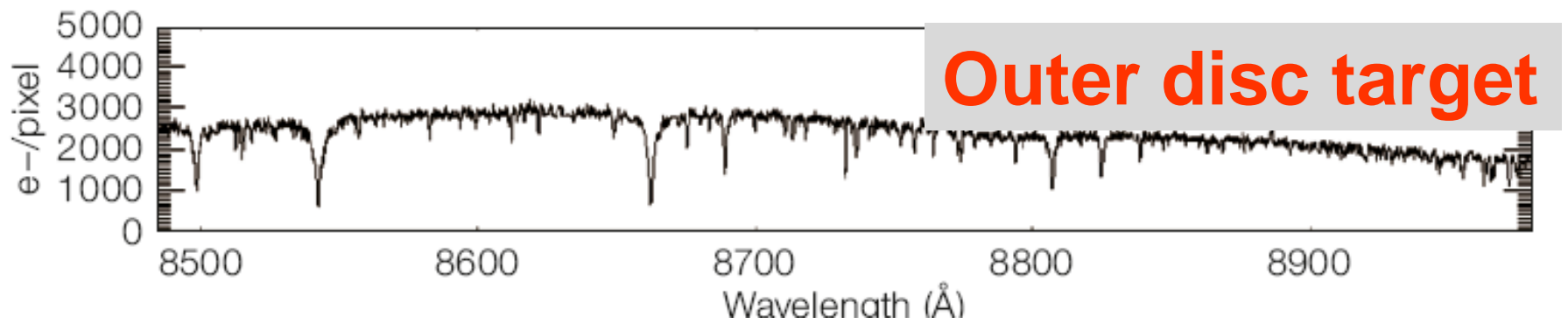
Observations

- ✓ First light: Dec. 31 2011-Jan 5 2012
- ✓ Another five runs carried out (30 nights in total)
- ✓ Five clusters completed covering different characteristics
- ✓ Several MW fields –thick disc, bulge

First spectra -Giraffe

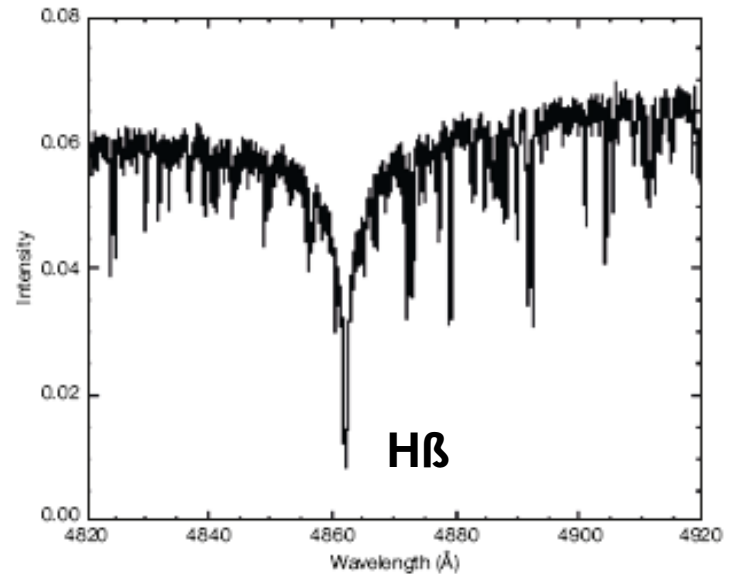
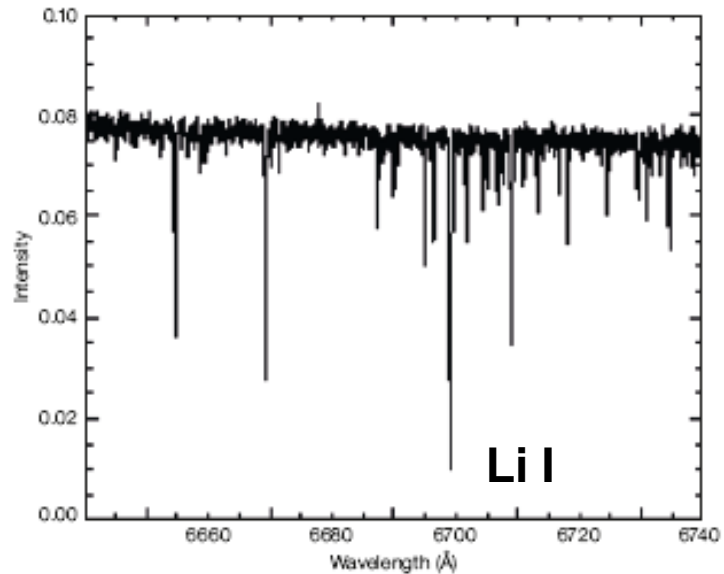
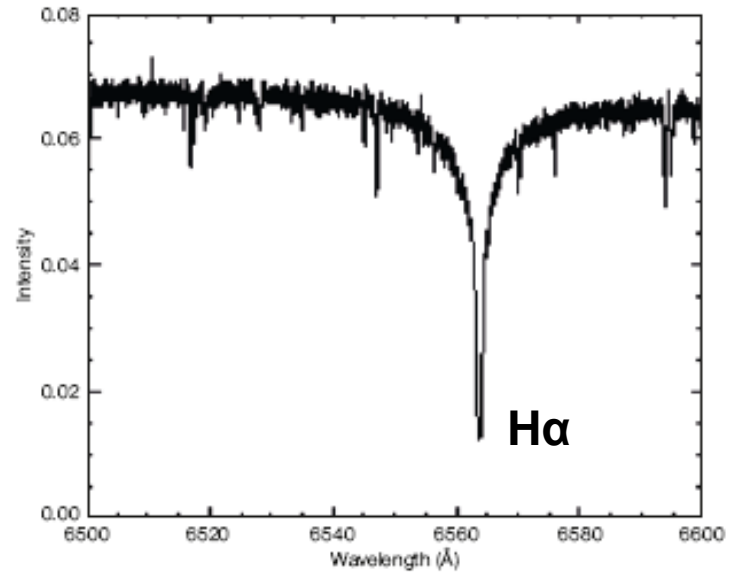
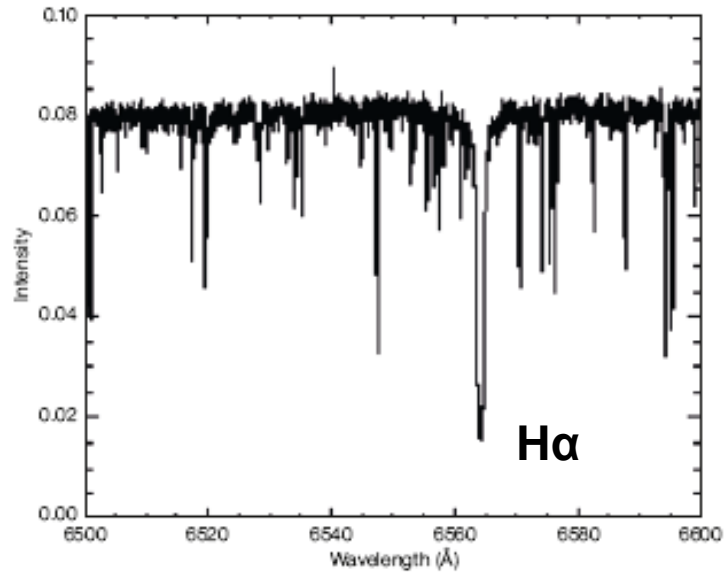


HR15N



HR21

First spectra - UVES



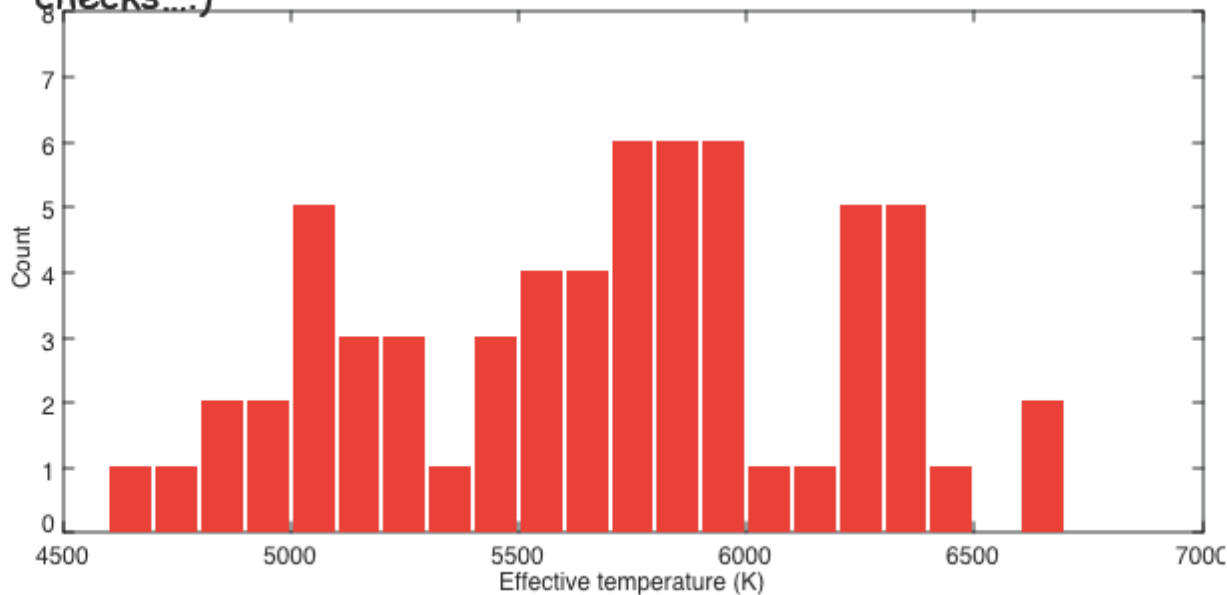
γ Vel member

MW target

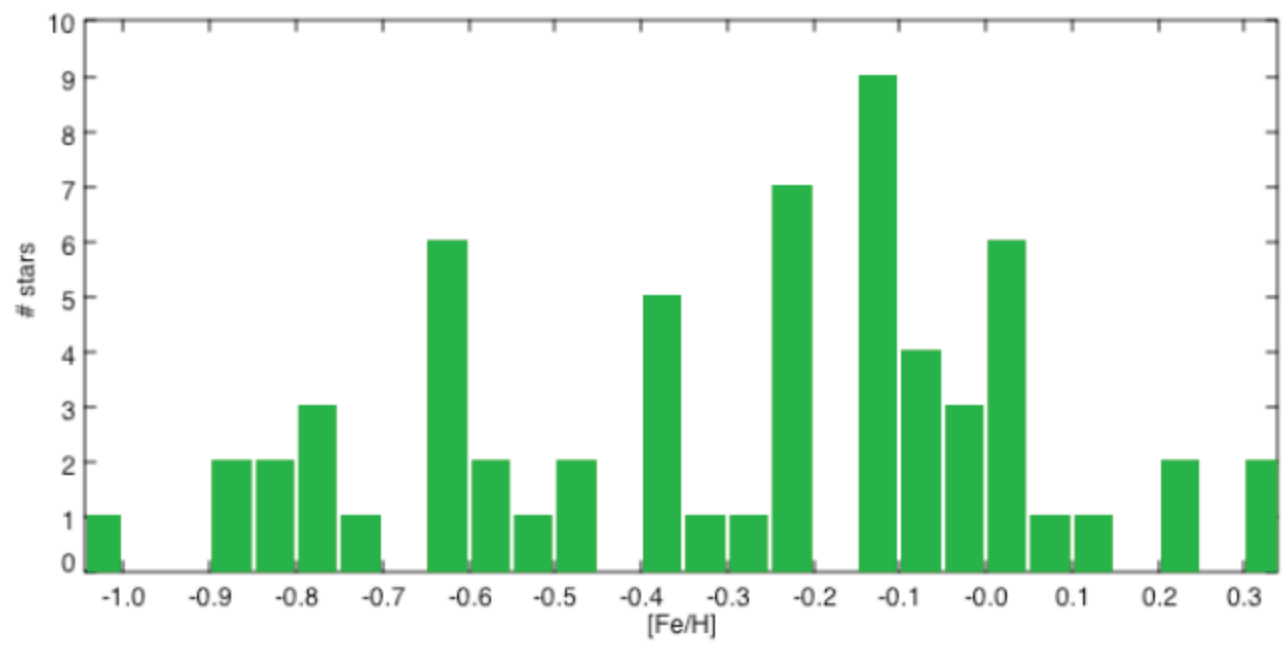
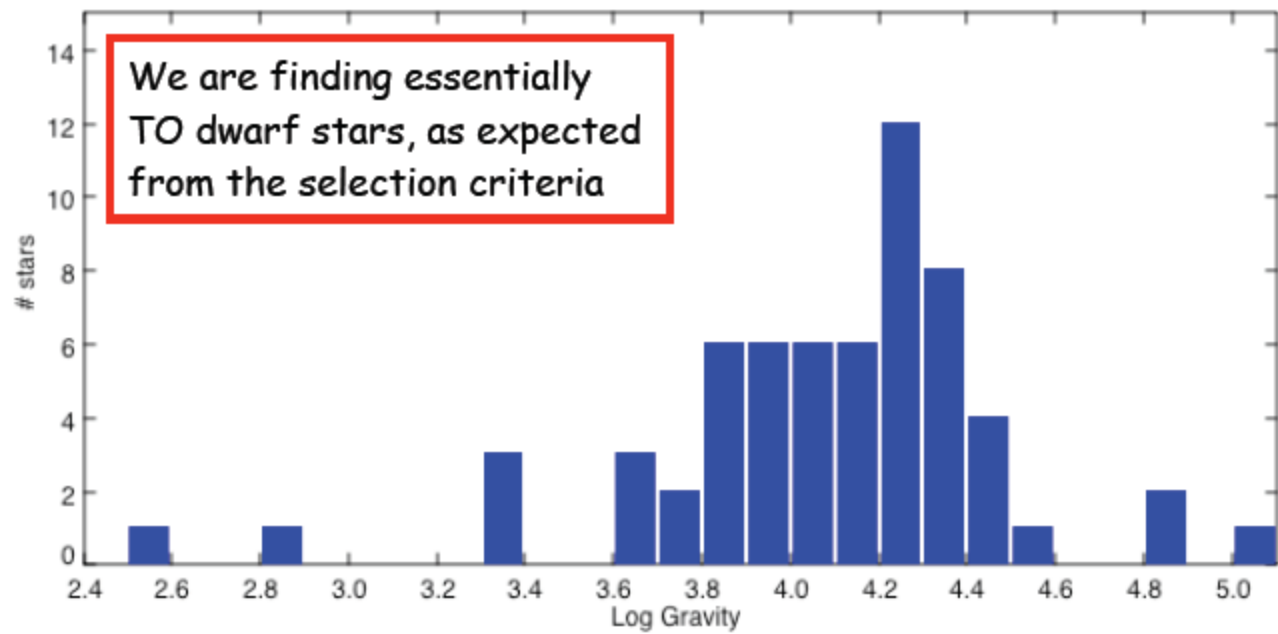
First analysis results promising

Run 1 and 2 results from MW UVES spectra

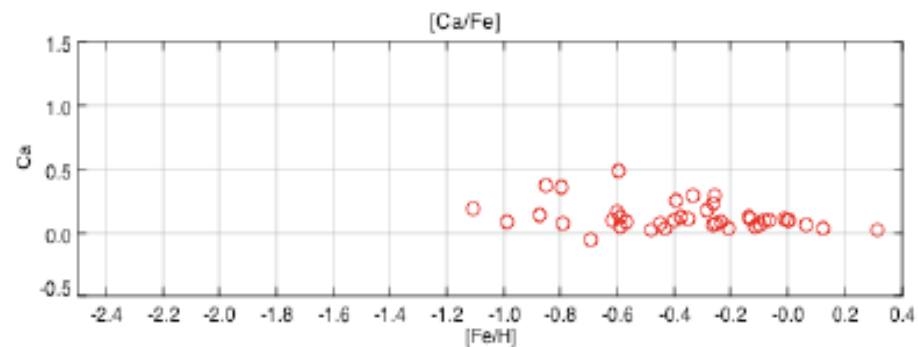
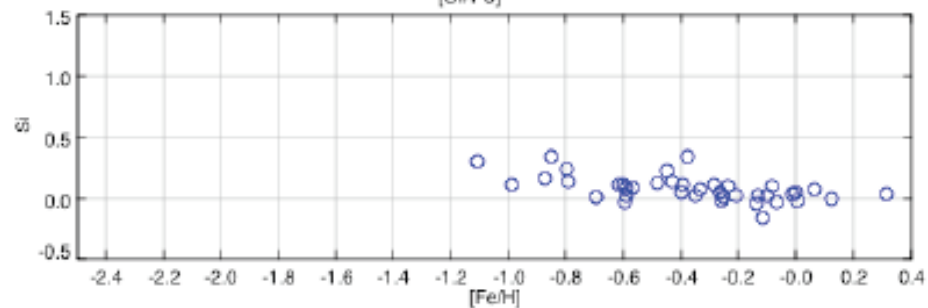
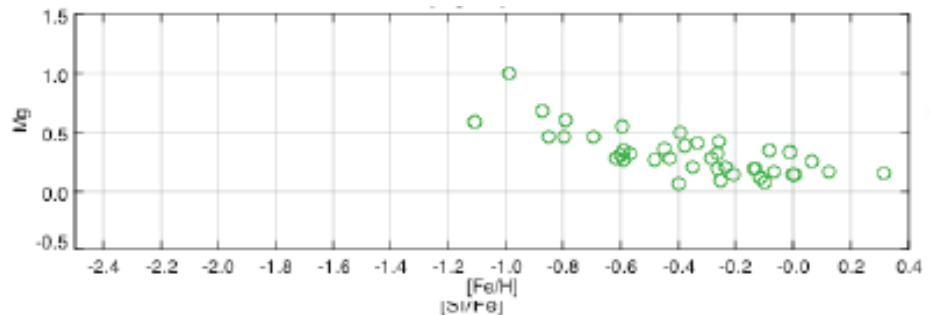
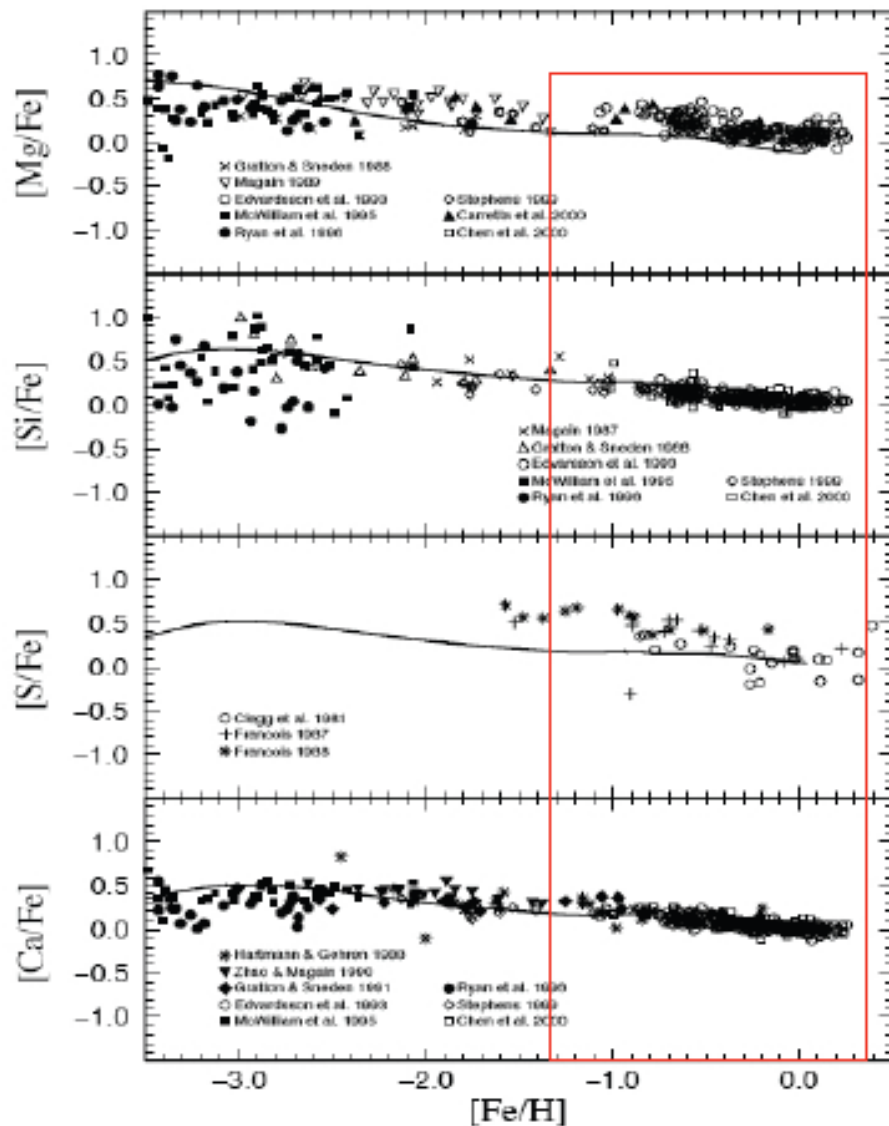
After solving some problems, the analysis of all MW fields taken in Run1-2 took ~2hrs CPU (preliminary analysis with few checks....)



Courtesy Laura Magrini – Arcetri-Bologna-Padova-Indiana-ESO node



α elements



Conclusions and perspectives

- Gaia-ESO Survey among the largest and most ambitious ground based spectroscopic surveys ever attempted by European astronomy –the largest on a 8m telescope
- First homogeneous overview of the distributions of kinematics and element abundances in the MW
- end data taking >2016++? – gives overlap with first Gaia data release. Combined → full 6D phase space $f(x,y,z,v_x,v_y,v_z)$, plus stellar parameters, and chemistry for a very large number and variety of stars: **core science plus legacy science**

THANK YOU!