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N-capture Elements in GCs using the Gaia-ESO data

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Collaborators: Laura Magrini and Sofia Randich

OSSERVATORIO ASTROFISICO DI ARCETRI
INAF ISTITUTO NAZIONALE DI ASTROFISICA

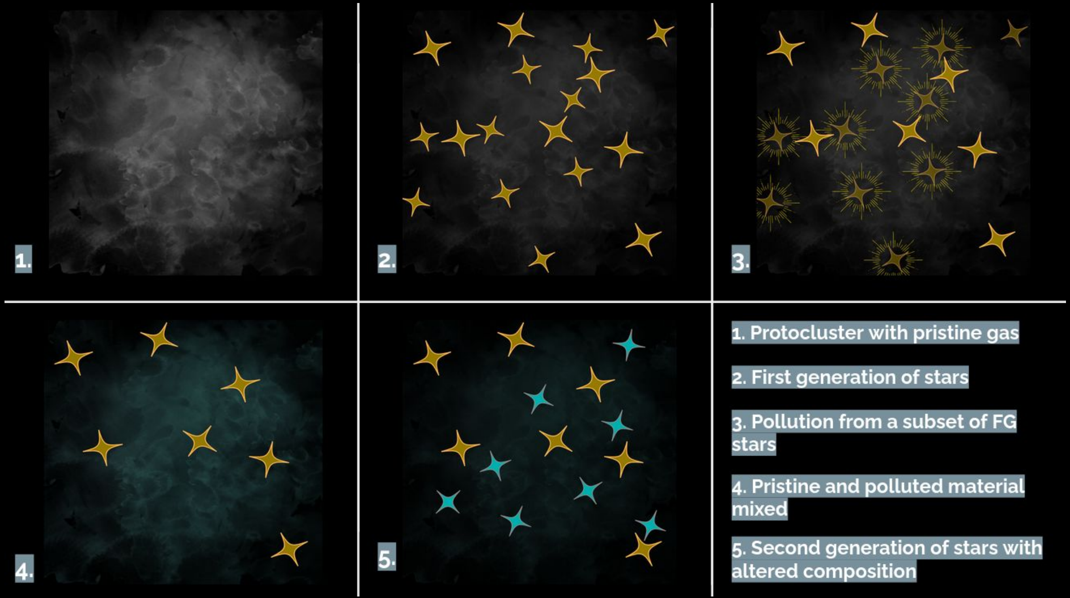
S, I & R Element Nucleosynthesis (sirEN) Conference - June 10, 2025, Giulianova

Galactic Globular Clusters- Key Objects

Contributors of the Galactic halo formation.

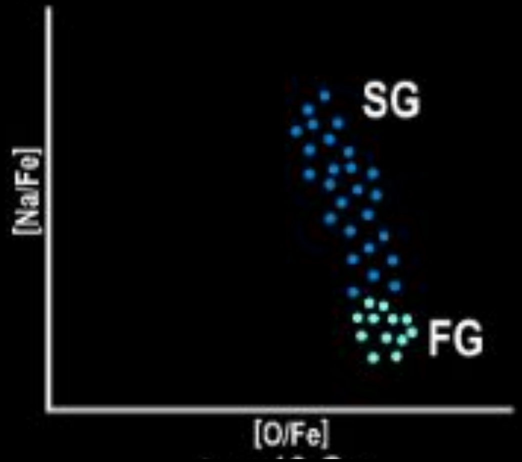
GC M10. Source: ESA/Hubble & NASA

Galactic Globular Clusters- Key Objects



Contributors of the Galactic halo formation.

Presence of multiple stellar population: Different chemical compositions (e.g., Na-O; Mg-Al)



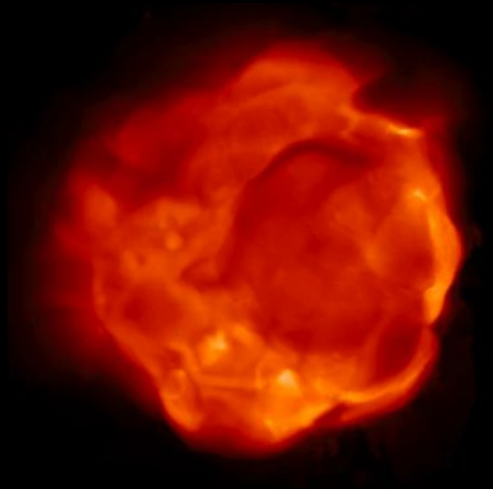
Potential polluters, e.g., intermediate-mass AGB stars, fast-rotating massive stars, massive binaries.

N-capture elements in Globular Clusters

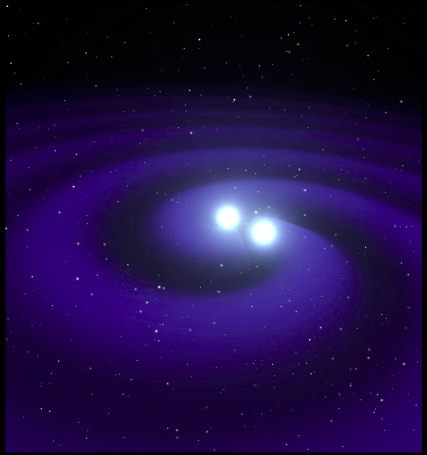
GCs display a quite constant n-capture abundances.

Only a few exceptions, e.g., M 15 (a.k.a NGC 7078) (Sobeck et al. 2011)
M 92 (Roederer and Sneden 2011)

s-process (e.g., Y, Ba, La) AGB stars / fast-rotating massive stars
r-process (e.g., Eu) neutron star mergers / core-collapse SN



AGB stars: Source of s-process species



Neutron Star Mergers: Source of r-process species

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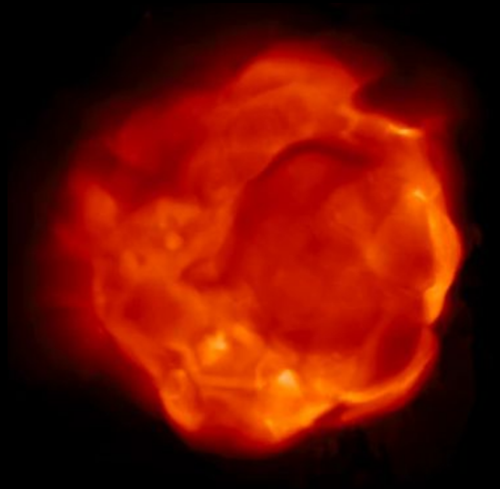

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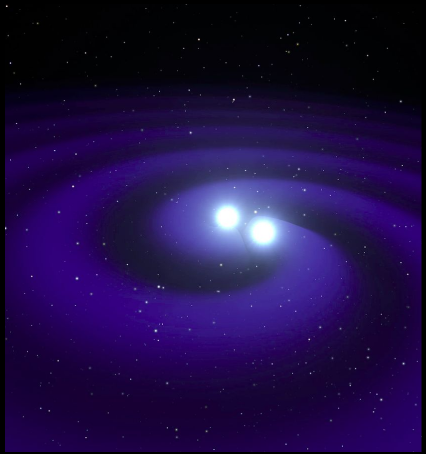

Neutron Star Mergers: Source of r-process species

Aim 1:

Connection between the sources responsible for the MSP phenomenon and the abundances of *n*-capture elements in GCs.

N-capture elements in Globular Clusters

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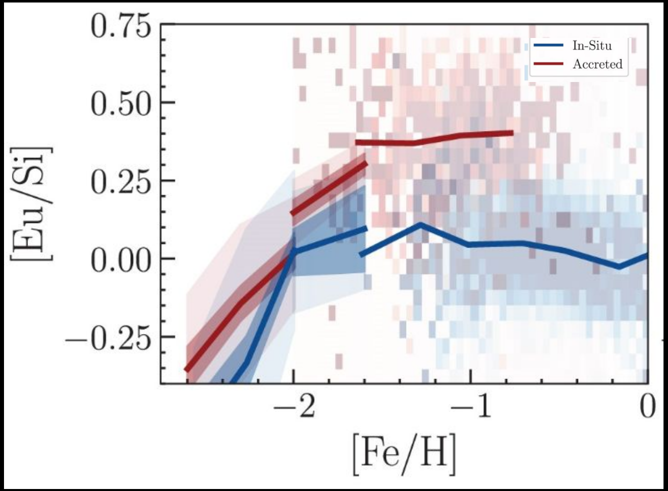
Monty et al. 2024 used distinguished chemically GCs with different origin using Eu abundances.



Monty+2024

Aim 2:

Test the [Eu/α] ratio on a sample of GCs and its link to the cluster's origin.

Data

- UVES spectra of the calibration sample of the Gaia-ESO Survey.

- 14 GCs covering a wide range of metallicity, ranging from -2.5 to -0.5 dex.

- Stellar parameters and abundances of 8 n-capture element obtained from the Gaia-ESO survey DR 5.1.

Neutron-Capture Element Signatures in Globular Clusters:

Insights from the *Gaia*-ESO Survey

J. Schiappacasse-Ulloa[1], L. Magrini[1], S. Lucatello[2], S. Randich[1], A. Bragaglia[3], E. Carretta[3], G. Cescutti[4, 5, 6], F. Rizzuti[5, 6, 7], C. Worley[8, 9], F. Lucertini[10], and L. Berni[1, 11]

ACCEPTED

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- 14 GCs covering a wide range of metallicity, ranging from -2.5 to -0.5 dex.
- Stellar parameters and abundances of 8 n-capture element obtained from the Gaia-ESO survey DR 5.1.
- We extended the analysis done by Schiappacasse-Ulloa+2024.

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Insights from the *Gaia*-ESO Survey

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ACCEPTED

A&A, 685, A10 (2024)

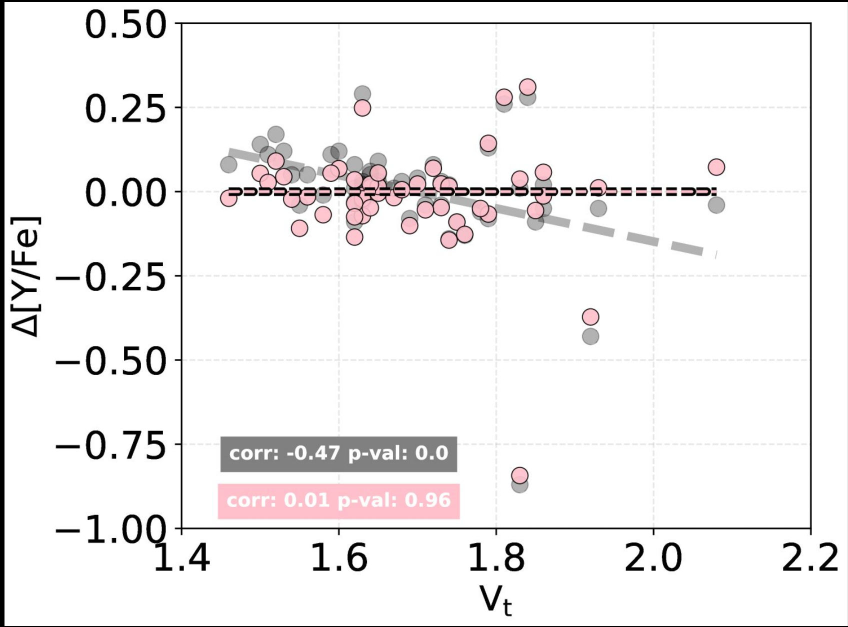
Heavy element abundances in galactic globular clusters*

J. Schiappacasse-Ulloa[1,2], S. Lucatello[2,3], G. Cescutti[4,5,6] and E. Carretta[7]

Received: 30 November 2023 | **Accepted:** 8 February 2024

Trend with Microturbulence (V_t)

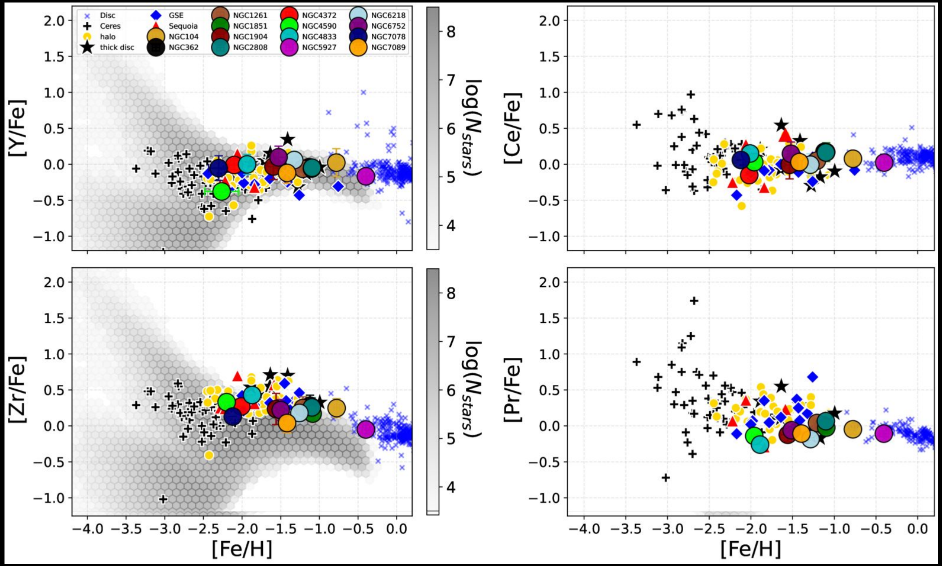
- Strong absorption lines (e.g., Y and Ba) are often saturated, which derives in highly sensitive abundances to the V_t used.
- We used a *corrected* (Δ[X/Fe]) abundances instead of the *raw* ones.
- Effectively removes artificial trends with V_t, avoiding spurious internal scatter in GC.
- We applied this correction to all n-capture elements analysed in this study.

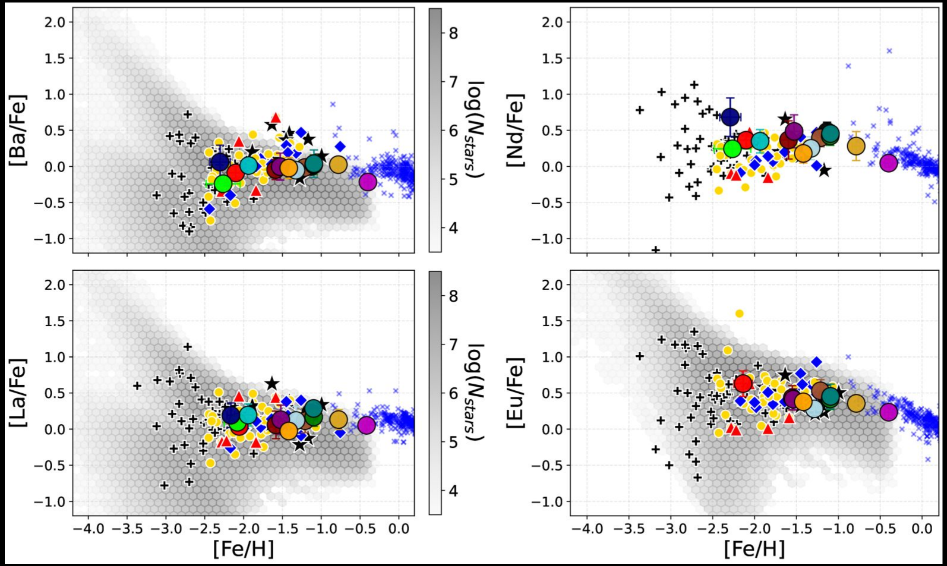


Example of the effect of V_t on the *corrected* and *raw* [Y/Fe] in NGC 104

Globular clusters as tracers of the Galaxy

- Comparison with Galactic chemical evolution model (Rizzuti+2025), MINCE (Cescutti+2022), and CERES project (Lombardo+2022).
- GC and field star samples exhibit similar trends across all abundance planes, with an increasing spread towards lower metallicities.
- The models successfully reproduce both the dispersion arising from the contribution of different nucleosynthesis sites and the overall trend of chemical evolution.
- [Zr/Fe] aligns with the upper envelope of the models, likely arising from the models' underestimation of the r-process contribution to Zr

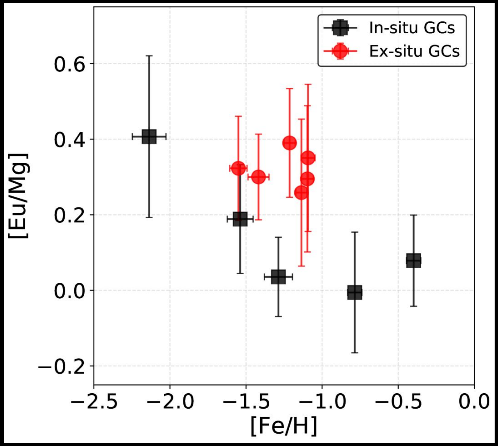




The origin of globular clusters: hints from n-capture elements

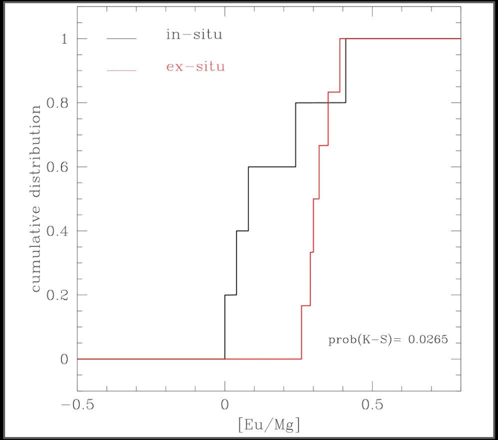
- The combination of r-process (e.g. Eu) and α-elements (e.g. Mg) may provide insights into the GC origin.

- We tested using the *raw* [Eu/Mg] ratio versus [Fe/H] for GCs with different origin (Massari+2019).



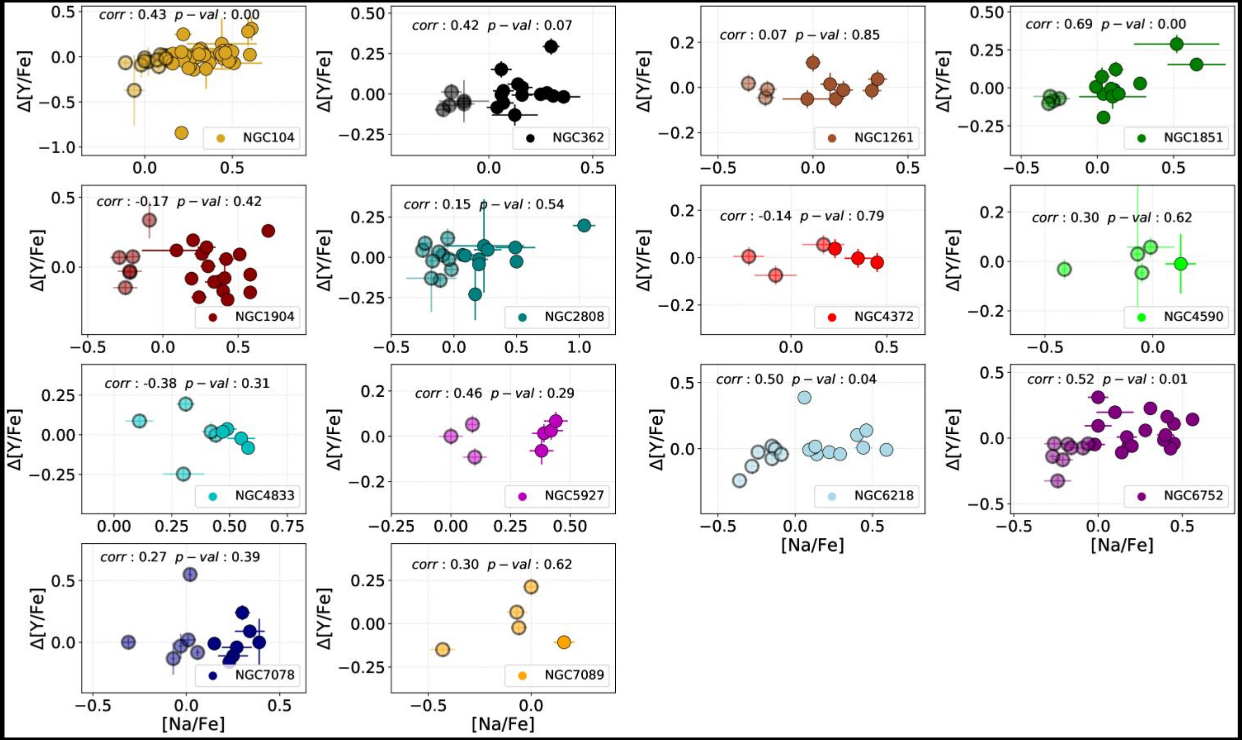
- GCs with different origin present a different [Eu/Mg] ratio distribution.

- The statistical test Kolmogorov-Smirnov rejects the null hypothesis, reinforcing the conclusion that [Eu/Mg] ratio distinguishes the GCs origin.



N-capture abundances and other chemical multi population indicator

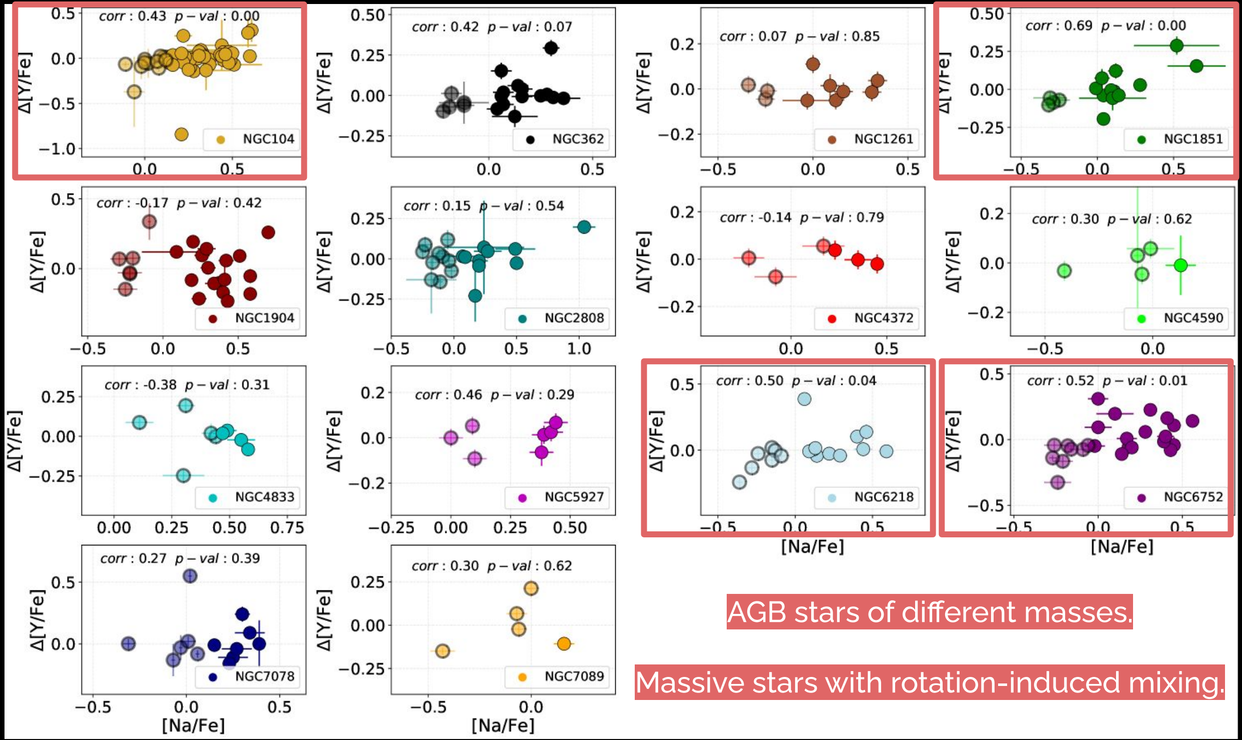
- Hot H-burning elements (Na and Al) trace the different stellar populations within GCs.



N-capture abundances and other chemical multi population indicator

- Hot H-burning elements (Na and Al) trace the different stellar populations within GCs.

- The presence of correlations between Na with s-process elements may give us clues as to the nature of polluters that changed the composition of SG stars.

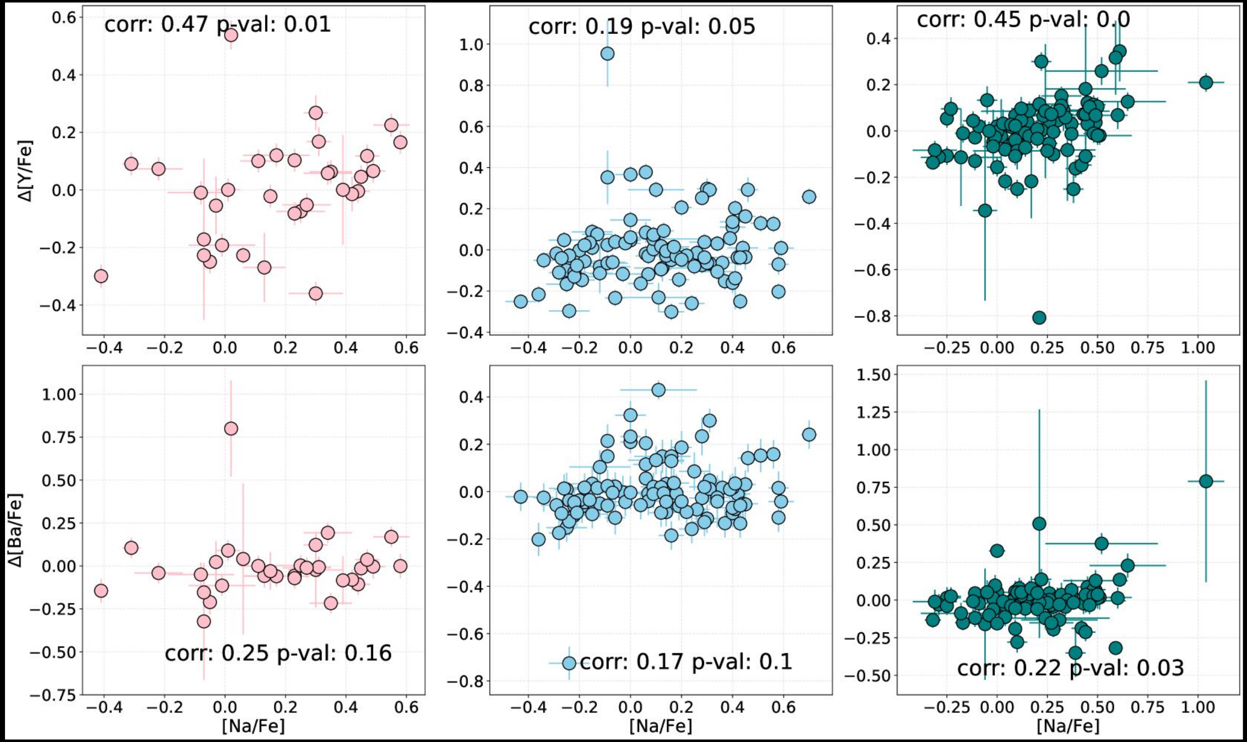


AGB stars of different masses.

Massive stars with rotation-induced mixing.

N-capture abundances and other chemical multi population indicator

- Explored potential correlations between s-process elements and Na by dividing the sample into three metallicity regimes: metal-poor, mid-metallicity, and metal-rich.



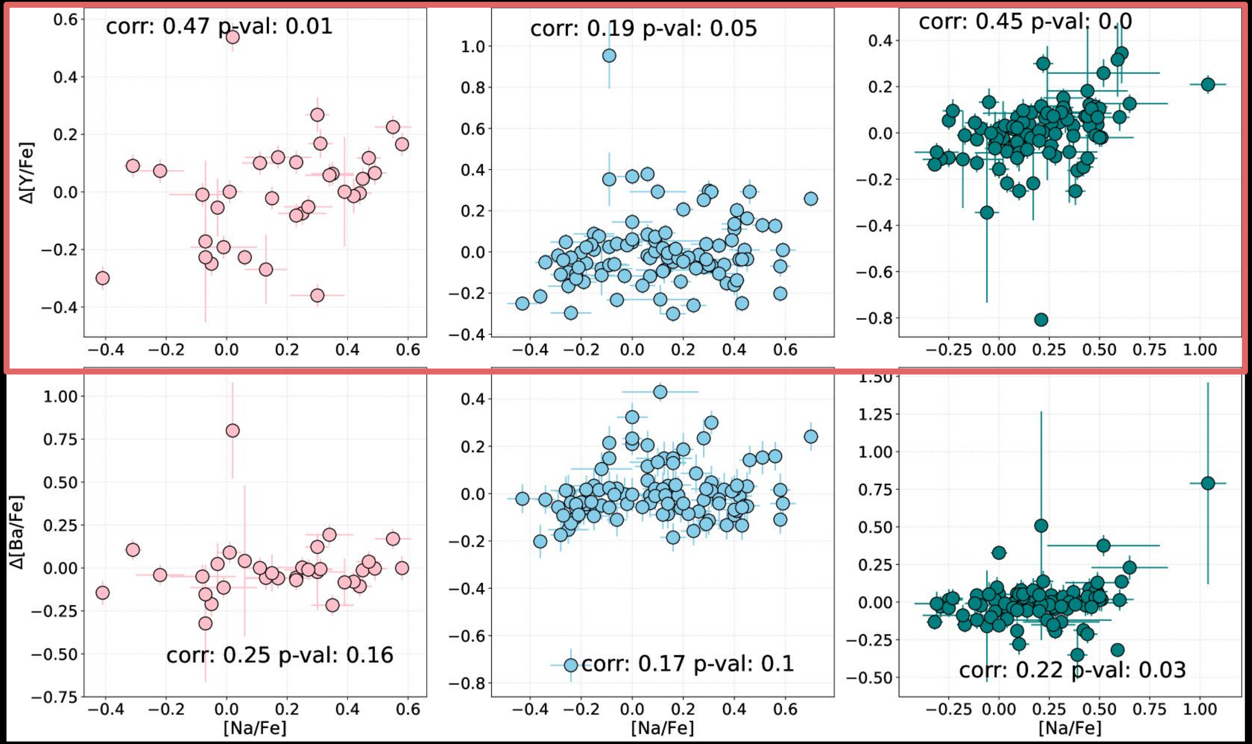
Metal-poor regime: <-1.8 dex

Mid-Metallicity regime: [-1.8,-1.1] dex

Metal-rich regime: >-1.1 dex

N-capture abundances and other chemical multi population indicator

- Explored potential correlations between s-process elements and Na by dividing the sample into three metallicity regimes: metal-poor, mid-metallicity, and metal-rich.
- Strong correlation between Δ[Y/Fe] and [Na/Fe] in all the metallicity regimes, giving some hints of the effect on the first peak s-process elements.



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Future work

- Further analysis using differential analysis techniques is effective in overcoming current measurement uncertainties, contributing to a more precise determination of the internal variation in GCs.

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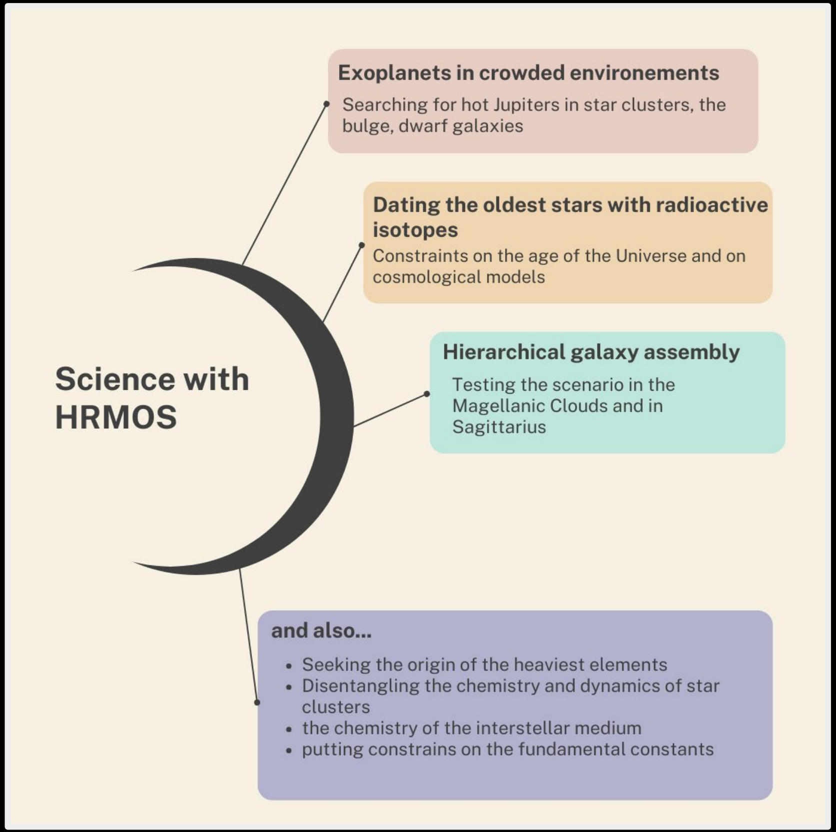
- In the future, new instrument may contribute to explore deeper in n-capture elements in GCs. For example the high-resolution multi-object spectrograph (HRMOS) will provide precise measurements in the blue part of the spectrum.



Summary

We analysed a sample of 14 GCs using the Gaia-ESO survey data.

- Most GCs closely follow the chemical distribution of halo and disc field stars.
- The Galactic chemical evolution models, when available, fit well the observation (except for Zr).

- The [Eu/Mg] ratio appears to be a useful indicator of the GC origin (in situ vs. ex situ), reflecting the different enrichment histories.

- Some GCs displayed strong correlations between the s-process elements and Na, revealing link with the MSP phenomenon.
- Y abundances in GCs shows a strong correlation with Na in all the metallicity regimes.