Chemically Peculiar Stars in the Era of Large Spectroscopic Surveys

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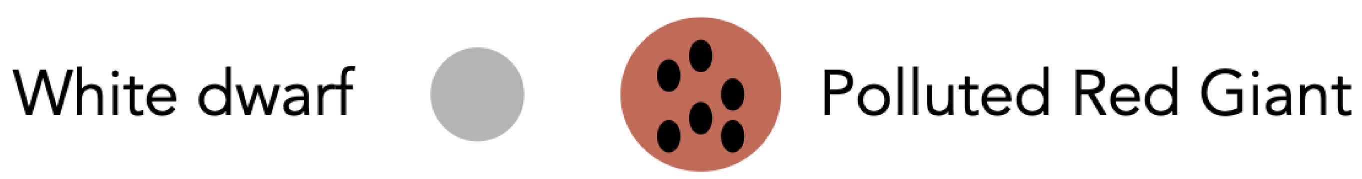
Chemically Peculiar Binaries

About half of the elements heavier than iron are produced by the slow/**s-process**, mainly in asymptotic giant branch **AGB stars**. In binaries, AGB stars can **pollute their companions through mass transfer**, producing chemically peculiar stars.

Barium (Ba) stars are established products of AGB mass transfer, generally found with white-dwarf companions. However, only a few hundred have detailed chemical and orbital studies.



Only a few hundred such objects have detailed, homogeneous chemical and orbital studies.

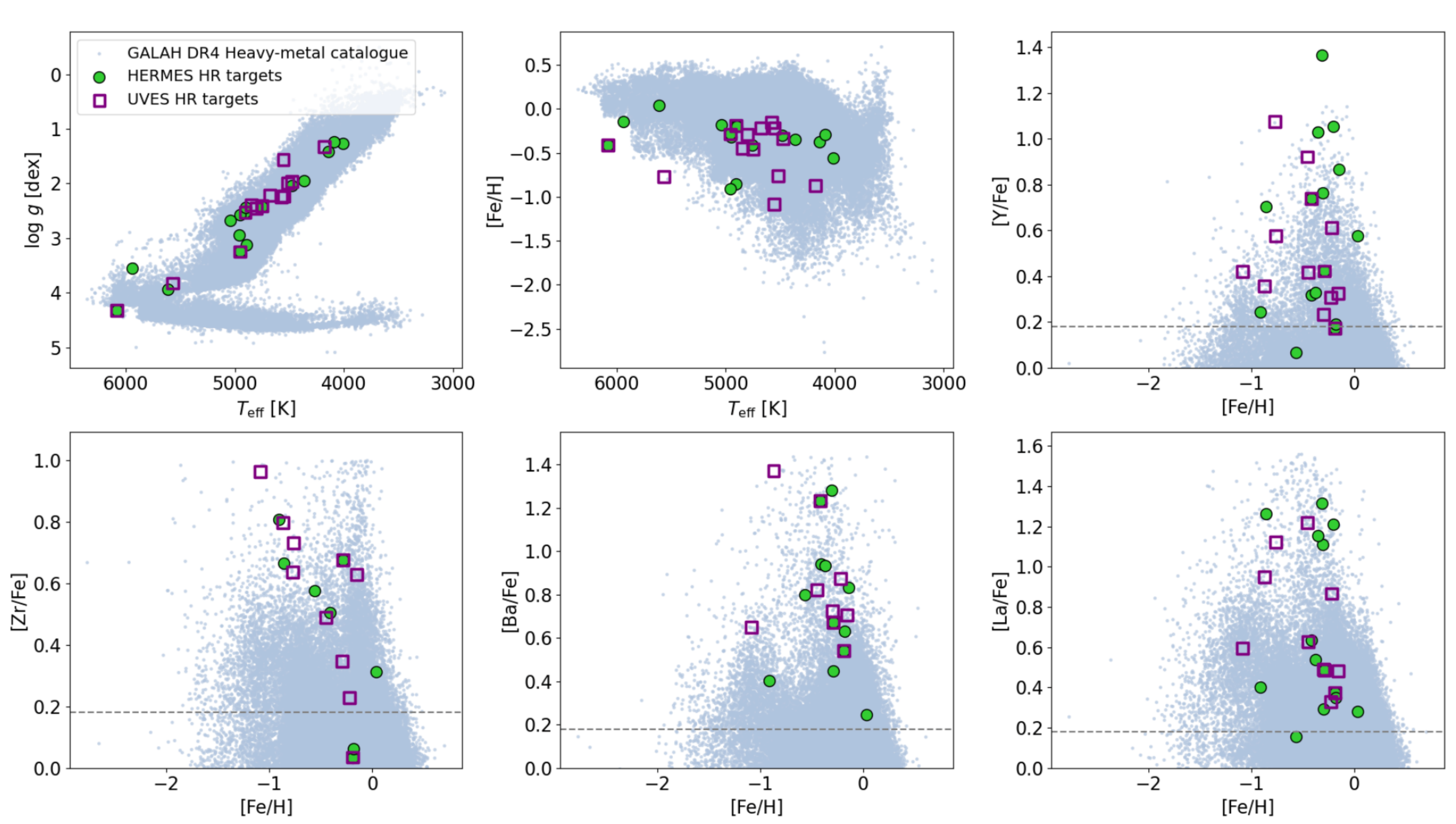
Large spectroscopic surveys now enable much larger systematic samples. We therefore aimed to **identify and validate s-process-polluted binary candidates** in GALAH DR4.

Survey & High-Resolution Data

We use **GALAH DR4** (Buder et al. 2025):

- Quality cuts on flags and S/N → 484 105 stars (**spectroscopic catalogue**)
- Good-quality Y, Zr, Ba, La abundances → 159 464 stars (**heavy-metal catalogue**)

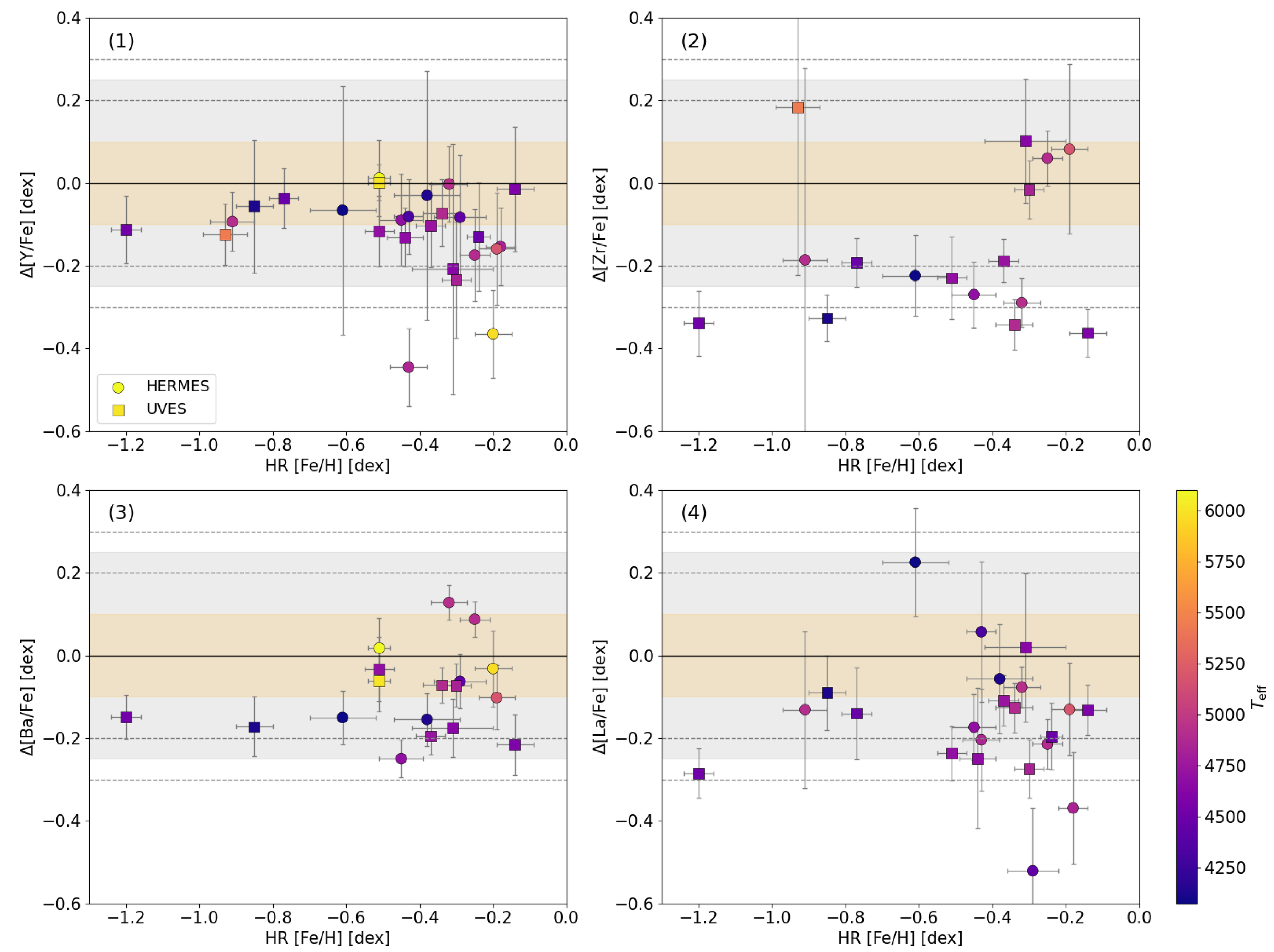
To assess GALAH's performance for chemically peculiar stars, we built a **29-star high-resolution (HR) validation sample** from HERMES/Mercator and UVES/VLT (R∼80 000–85 000). Reliable spectroscopic parameters and abundances were derived with `iSpec`.



Validating GALAH with High-Resolution Spectra

Using `iSpec`, we derived stellar parameters and abundances of [Y/Fe], [Zr/Fe], [Ba/Fe], [La/Fe]. $T_{\rm eff}$ and [Fe/H] agree well (mostly within 1σ), while $\log g$ shows a ∼0.2 dex offset, likely from GALAH's post-processing corrections. The abundance comparison reveals small offsets, used to define **robust thresholds** for s-process-rich stars: **[s/Fe]** > 0.40, and individually:

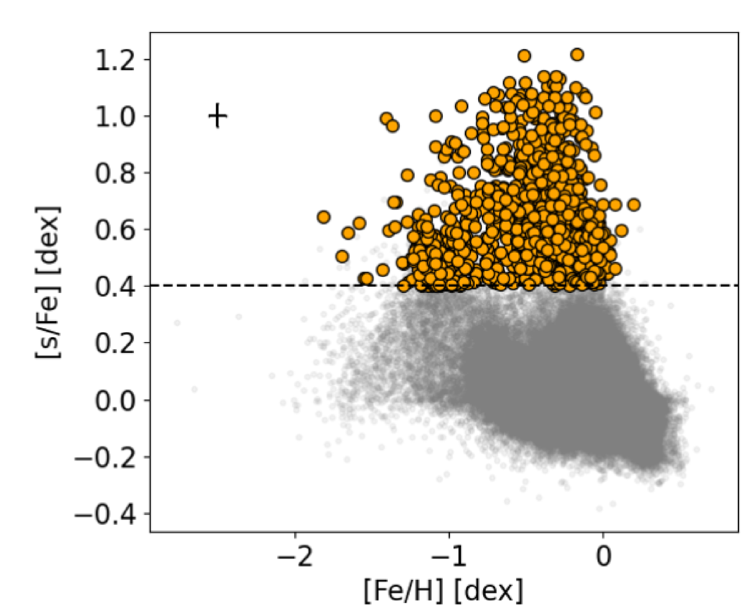
$$[\mathrm{Y/Fe}] > 0.22, \quad [\mathrm{Zr/Fe}] > 0.26, \quad [\mathrm{Ba/Fe}] > 0.19, \quad [\mathrm{La/Fe}] > 0.26$$



Yellow: within 1σ; dashed grey: $2\sigma/3\sigma$ limits; grey band: traditional ±0.25 dex Ba-star criterion.

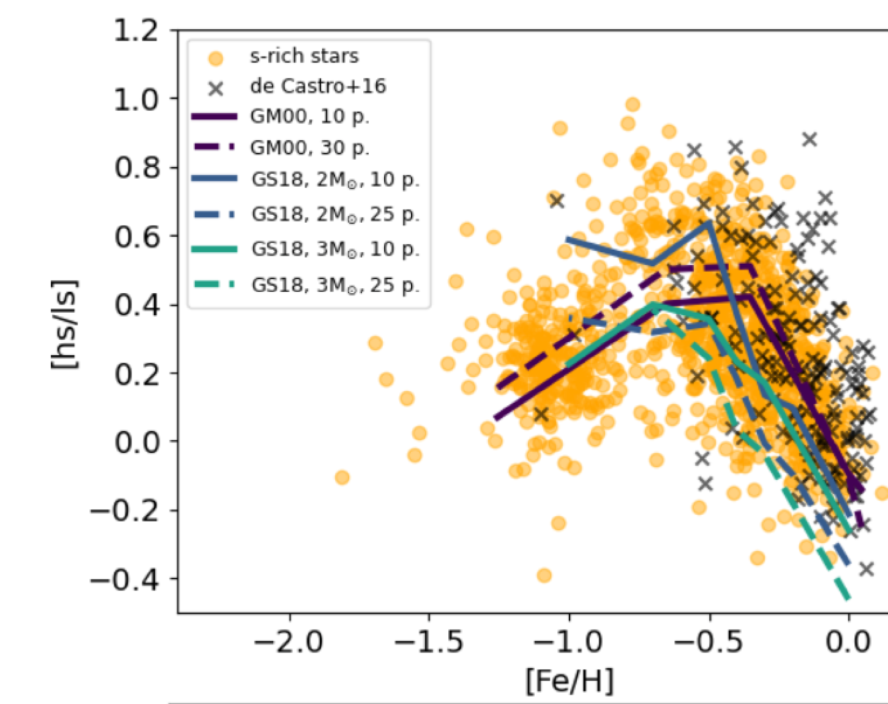
A New Catalogue of s-process Candidates

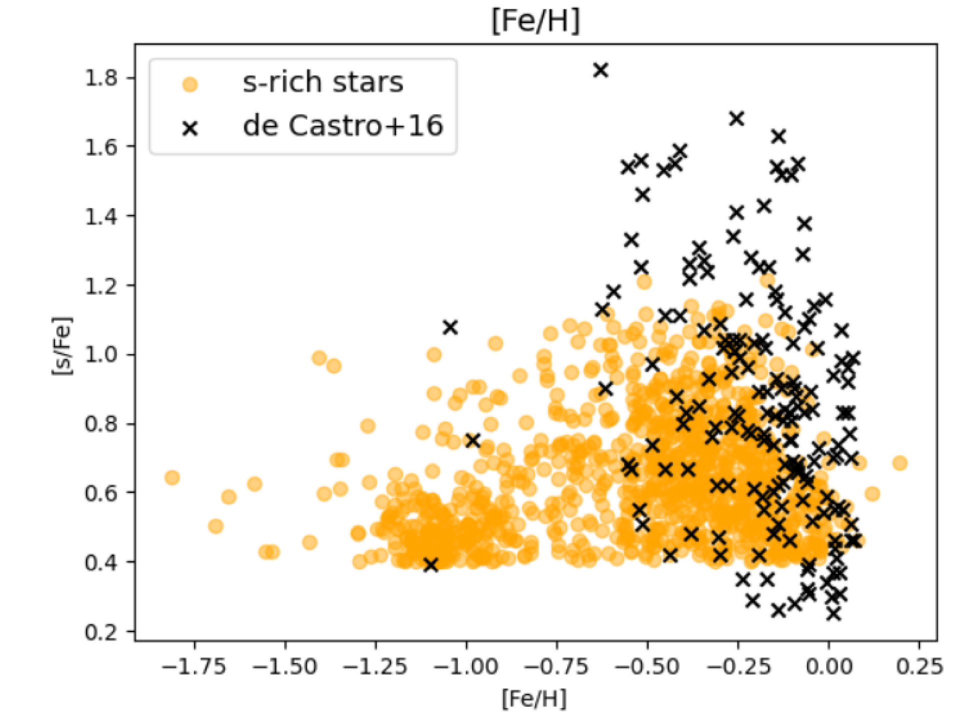
Our thresholds yield **1059 s-process-polluted candidates**, representing 0.66% of the sample and rising to ∼3% at low metallicity—almost **5× the size** of the confirmed sample.



Comparison with Confirmed Ba Stars

Our candidates (orange) broadly follow the literature [hs/ls]–[Fe/H] trend of confirmed Ba stars (black crosses; de Castro et al. 2016). The conservative [s/Fe] > 0.40 threshold (vs. > 0.25) removes weaker candidates and reveals a metal-poor population (−1.3 <[Fe/H]< −0.8), consistent with CH/CEMP-s stars.





At [Fe/H] $\lesssim -0.6$, [hs/ls] decreases to ∼ 0–0.4, below the most metal-poor Ba stars (∼ 0.9), as **predicted by AGB models** (Goriely & Mowlavi 2000; Goriely & Siess 2018). The agreement with 2–3 $M_\odot$ yields supports a **low-mass** (< 3 $M_\odot$) **AGB origin**.

Binarity & Conclusions

1059 candidates (0.66%) identified, including ∼700 Ba-like stars and a large CH-like metal-poor population. Only ∼7% have published **Gaia DR3 NSS** orbits, suggesting many longer-period systems. **>900 new AGB mass-transfer candidates** are added to the literature.

Take-home message: GALAH DR4 provides a **large, homogeneous sample** to test AGB nucleosynthesis and binary evolution, with more to come from Gaia DR4.