

# Stellar properties and chemical features of the *Gaia* Catalogue of Nearby Stars observed by GALAH DR4

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**Abstract.** The *Gaia* Catalogue of Nearby Stars (GCNS) comprises approximately 330 000 stars within 100 pc of the Sun, as observed by *Gaia* data release 3 (*Gaia* DR3). Meanwhile, the GALAH DR4 survey has spectroscopically characterised nearly one million stars, delivering detailed chemical abundances (up to 30 elements). We present a joint analysis of the  $\sim 6\,000$  stars common to both catalogues, offering initial insights into the stellar and chemical properties of the solar neighborhood. Our preliminary results indicate that the majority of these stars are FGK main-sequence objects, with some A-type interlopers (with effective temperatures ranging between 3 000 and 8 000 K), with median ages of  $\sim 1.6$  Gyr (ranging from 0.10 to 14.79 Gyr), and metal-poorer when compared to the Sun:  $[\text{Fe}/\text{H}] \approx -0.19$  dex. Additionally, most of the stars are disc members, with some local halo (high-velocity) stars identified. Building on this foundation, future work will deeper exploit the full spectroscopic information and orbital parameters from value-added catalogues to refine Galactic component classifications (thin-thick disc versus halo membership), perform detailed chemical profiling, and deliver a comprehensive chemo-dynamical characterisation of the solar neighborhood. This will provide new insights into the formation and evolution of nearby stellar populations.

**Resumo.** O *Gaia Catalogue of Nearby Stars* do *Gaia* (GCNS) compreende aproximadamente 330 000 estrelas situadas até 100 pc do Sol, conforme observado pelo *Gaia* DR3. Por sua vez, o levantamento GALAH DR4 caracterizou espectroscopicamente cerca de um milhão de estrelas, fornecendo dados de alto valor que incluem abundâncias químicas detalhadas de até 30 elementos. Apresentamos uma análise conjunta das cerca de 6 000 estrelas em comum entre ambos os catálogos, oferecendo uma visão inicial sobre as propriedades estelares e químicas da vizinhança solar. Nossos resultados preliminares indicam que a maioria dessas estrelas são objetos de sequência principal do tipo FGK, com algumas de tipo A (com temperaturas efetivas variando entre 3 000 e 8 000 K), apresentando idades medianas de  $\sim 1.6$  Ga (no intervalo de 0.10 a 14.79 Ga) e metalicidade inferior à do Sol:  $[\text{Fe}/\text{H}] \approx -0.19$  dex. Ademais, a maioria das estrelas são membros do disco, com algumas identificadas como pertencentes ao halo (alta velocidade). Com base nesses resultados, trabalhos futuros explorarão mais profundamente as informações espectroscópicas completas e os parâmetros orbitais provenientes de catálogos de valor agregado, a fim de refinar as classificações dos componentes Galácticos (disco espesso-fino versus halo), realizar perfis químicos detalhados e fornecer uma caracterização quimiodinâmica abrangente da vizinhança solar. Isso trará novas perspectivas sobre a formação e a evolução das populações estelares próximas.

**Keywords.** Galaxy: kinematics and dynamics – Galaxy: stellar content – solar neighborhood – Stars: kinematics and dynamics

## 1. Introduction

The detailed characterization of stars in the solar neighborhood offers a high-resolution view of the Milky Way's (MW) formation and evolution. Variations in elemental abundances and orbital motions act as chemo-dynamical fingerprints, tracing stellar origins, co-eval groups, and the enrichment processes that shaped the Solar System's local environment. In this context, *Gaia* mission (Gaia Collaboration, Prusti, et al., 2016) has delivered precise astrometric data for nearby MW stars, notably through the *Gaia* Catalogue of Nearby Stars (GCNS; Gaia Collaboration, Smart, et al., 2021, comprising  $\sim 330\,000$  stars within 100 pc, derived from the third *Gaia* data release, DR3).

Complementary to *Gaia*, large-scale spectroscopic surveys provide the stellar parameters and chemical abundances needed to investigate the chemo-dynamical structure of the Milky Way. Notable examples include *Gaia*-ESO (Gilmore et al., 2022; Randich et al., 2022), LAMOST (Cui et al., 2012; Xiang et al., 2019), and APOGEE (Majewski et al., 2017). Among these, the Galactic Archeology with HERMES survey (GALAH; Buder et al., 2025) has observed nearly one million stars in his fourth data release (DR4), delivering up to 30 elemental abundances and value-added catalogs with stellar kinematics.

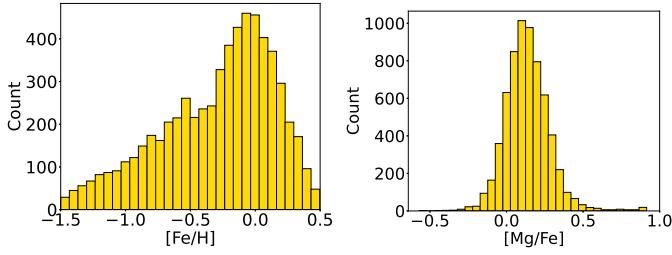
In this work, we perform a joint analysis of  $\sim 6\,000$  stars cross-matched between the GCNS and GALAH DR4. By combining astrometric and spectroscopic information, we aim to characterize in detail the stellar populations within 100 pc, focusing on their ages and chemical abundances.

## 2. Data and methodology

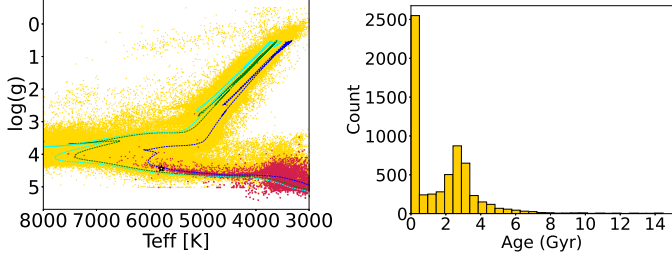
We combined the astrometric data from the GCNS (Gaia Collaboration, Smart, et al., 2021) with the chemo-dynamic parameters from GALAH DR4 (Buder et al., 2025) and their associated added-value catalogues (which include dynamic parameters estimated via GALPY; Bovy 2015, using the McMillan 2017 potential as input), yielding a sample of over 6 000 stars. In GALAH DR4, age determination was performed using isochrone fitting from PARSEC+COLIBRI tracks (Bressan et al., 2012; Marigo et al., 2017). Spurious data in terms of  $[\text{Fe}/\text{H}]$ , age,  $T_{\text{eff}}$ ,  $[\text{Mg}/\text{Fe}]$ ,  $\log g$  were also excluded from the final dataset.

## 3. Analysis, discussion, and final remarks

The preliminary joint analysis of the approximately 6 000 stars in the solar neighbourhood matched between GCNS and GALAH



**FIGURE 1.** [Fe/H] (right) and [Mg/Fe] (left) distributions of our sample.



**FIGURE 2.** Kiel diagram and age distribution of our sample. Left panel: Kiel diagram with PARSEC isochrones overlaid (Bressan et al., 2012) centred at  $\sim 1.6$  Gyr and  $[\text{Fe}/\text{H}] \approx -0.19$  dex (median values of our sample; green), and  $\pm 1\sigma$  (cyan and blue) at fixed median  $[\text{Fe}/\text{H}]$ . For reference, the full GALAH DR4 is shown in yellow, while our targets are in red. Right panel: stellar age distribution of our sample.

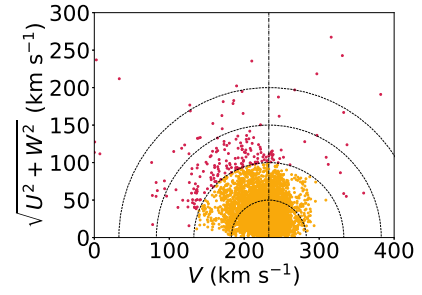
DR4 reveals a population predominantly composed of FGK main-sequence stars and some A-type interlopers, with a median age of  $\sim 1.6$  Gyr and slightly more metal-poor when compared to the Sun (median  $[\text{Fe}/\text{H}] \approx -0.19$  dex). The parameters examined included chemical features, such as iron  $[\text{Fe}/\text{H}]$  and  $[\text{Mg}/\text{Fe}]$  as shown in Fig. 1.

The Kiel Diagram (Fig. 2, left panel) depicts the combined sample of GCNS and GALAH DR4 (in red) and the entire GALAH DR4 (in yellow), with some PARSEC (Bressan et al., 2012) isochrones overlaid for reference (median in green,  $\pm 1\sigma$  in blue and cyan). The age distribution (Fig. 2, right panel) reveals an apparent excess of young stars; however, it remains uncertain whether these objects are genuinely young or simply occupy a region of the diagram where isochrones are essentially degenerate. This may represent either a real artifact or, more likely, a bias arising from the stars' location within a parameter space characterised by extremely large age uncertainties.

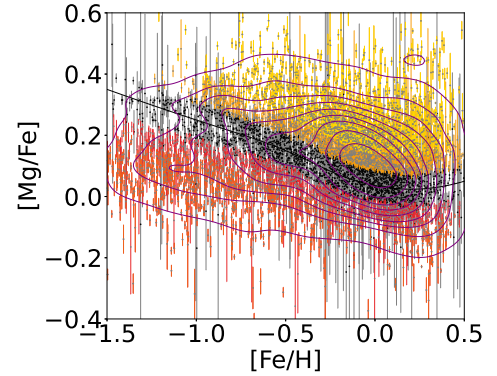
The Toomre diagram (Fig. 3) reveals a predominantly disc population, with only a small fraction of halo stars, as expected for the solar neighborhood. A small number of 24 (0.39%) stars were excluded to enhance the clarity and readability of the diagram. To separate thin and thick disc members, we employed the Tinsley–Wallerstein diagram (Fig. 4; Tinsley, 1979; Wallerstein, 1962), following the criteria of Recio-Blanco et al. (2014) with a slight modification as described in Dantas et al. (2025, where a quadratic spline was applied to smooth the boundary). Among the thick disc stars, we find that the metal-rich,  $\alpha$ -enhanced component dominates, which is likely reflecting the combined selection effects of the GCNS and GALAH DR4 catalogues.

The next stages of our study include a more detailed characterization of the sample, with emphasis on the chemical abundances, dynamical properties, and individual spectra of each star.

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**FIGURE 3.** Toomre diagram, with concentric circles centred at  $232.8 \text{ km s}^{-1}$  marking velocity thresholds in  $50 \text{ km s}^{-1}$  steps. Velocities were corrected using the Solar motion  $(U_{\odot}, V_{\odot}, W_{\odot}) = (8.6 \pm 0.9, 13.9 \pm 1.0, 7.1 \pm 1.0) \text{ km s}^{-1}$  (McMillan, 2017). Stars exceeding  $100 \text{ km s}^{-1}$  relative to the Sun are likely local halo members (228 stars), while the majority correspond to the Galactic disc (a total of 5970 stars). A small fraction (24 corresponding to 0.39% of the solar total sample) of high-velocity stars were omitted to enhance clarity.



**FIGURE 4.** Tinsley–Wallerstein diagram, showing the separation between thin and thick disc populations following Recio-Blanco et al. (2014), with the boundary smoothed using a quadratic spline as described in Dantas et al. (2025). Grey points lie within  $1\sigma$  of the spline boundary. Stars most likely belonging to the thin disc are shown in shades of red and those more likely belonging to the thick disc are in yellow, with opacity reflecting classification confidence ( $1-2\sigma$ ).

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