

Tracing the early Milky Way thin disc with the *Gaia*-ESO Survey

C. Viscasillas Vázquez^{1,2,*}, S. Randich², R. E. Giribaldi², L. Berni^{2,3}, L. Magrini², and M. Tsantaki²

¹ Institute of Theoretical Physics and Astronomy, Faculty of Physics, Vilnius University, Sauletekio av. 3, 10257 Vilnius, Lithuania

² INAF – Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, 50125 Firenze, Italy

³ Dipartimento di Fisica e Astronomia, Università degli Studi di Firenze, Via Sansone 1, 50019 Sesto Fiorentino, Italy

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ABSTRACT

Context. The origin of metal-poor stars on thin-disc-like orbits remains an open question in Galactic archaeology, with the potential to provide important constraints on the earliest phases of Milky Way disc formation. While low-metallicity stars are usually associated with the stellar halo or the thick disc, recent large spectroscopic surveys have revealed stars with low metallicities on cold, prograde, nearly circular orbits. These objects challenge the classical view of the thin disc as a young and metal-rich component. Therefore, they could possibly serve as tracers of the low-metallicity tail of an old thin disc, the high-angular-momentum tail of the metal-weak thick disc, or prograde halo-related populations.

Aims. We aim to identify and characterise the metal-poor stars with thin-disc-like kinematics observed in the *Gaia*-ESO Survey. We investigate their dynamical, chemical, and evolutionary properties to assess whether they might be associated with the old, metal-poor tail of the Galactic thin disc.

Methods. We used orbital parameters derived from *Gaia* DR3 data, combined with spectroscopic information from the *Gaia*-ESO Survey. Stellar ages were obtained through isochrone fitting, while detailed chemical abundances for several elements and kinematics were used to place the stars in the context of Galactic populations.

Results. Out of 1784 turn-off stars, we identified one metal-poor candidate star with thin-disc-like kinematics. It has $[\text{Fe}/\text{H}] = -1.38$ and follows a dynamically cold, prograde orbit, with low eccentricity, high azimuthal velocity ($V_\phi \approx 220 \text{ km s}^{-1}$), high angular momentum, low vertical action, and a guiding radius close to the solar neighbourhood. Chemically, however, it is clearly distinct from the thin disc: it is α -enhanced ($[\text{Mg}/\text{Fe}] = +0.58$; $[\alpha/\text{Fe}] = +0.48$), displays a low $[\text{Y}/\text{Mg}] = -0.58$ ratio, and its multi-element abundance pattern is offset from that of the thin-disc reference. Its position in the $[\text{Al}/\text{Fe}]$ – $[\text{Mg}/\text{Mn}]$ plane further confirms that its chemistry is distinct from the thin-disc sequence. The star also has an old age estimate, with a most probable value of ~ 10.2 Gyr and a broad 1σ -like interval of ~ 4.4 – 13.4 Gyr.

Conclusions. The combination of low metallicity, old age, α enhancement, low $[\text{Y}/\text{Mg}]$, its position on the metal-poor sequence in the $[\text{Al}/\text{Fe}]$ – $[\text{Mg}/\text{Mn}]$ plane, and dynamically cold thin-disc-like kinematics suggests that this star is not a typical member of the canonical thin disc. Instead, it is a strong candidate for a metal-poor relic of the early Galactic disc, possibly associated with the proto-thin disc or with the transition between the proto-Galactic halo and the emerging disc. Its properties indicate that stars with halo-like metallicities and chemically distinct abundance patterns can occupy orbits characteristic of the thin disc, highlighting the existence of metal-poor stars on dynamically cold orbits, while emphasizing that their origin might involve the old thin disc, the metal-weak thick disc, or prograde halo-related populations. This object provides a useful benchmark for studying the chemical enrichment and dynamical state of early metal-poor populations on disc-like orbits.

Key words. stars: abundances – Galaxy: disk – Galaxy: formation – Galaxy: structure

1. Introduction

Metal-poor stars preserve crucial information on the earliest phases of the Milky Way (MW) assembly. For a long time, such stars were mainly associated with the stellar halo, while the Galactic disc (in particular, the thin disc) was thought to be a predominantly more metal-rich component. This classical view was recently challenged by the discovery of stars with low (metal-poor, MP, $[\text{Fe}/\text{H}] < -1.0$) and very low metallicities (very-metal-poor, VMP, $[\text{Fe}/\text{H}] < -2.0$) that can also be found on disc-like orbits, reopening the question of when the MW disc first formed and what its earliest stellar populations looked like (e.g. Sestito et al. 2019, 2020; Cordoni et al. 2021; Carter et al. 2021; Carollo et al. 2023; Fernández-Alvar et al. 2021, 2024; Arden-Arentsen et al. 2024). In particular, recent *Gaia*-based analyses have strengthened the evidence of low-metallicity stars with disc-like kinematics and a preference for prograde orbits.

Using a large local sample with photometric metallicities and accurate *Gaia* DR3 astrometry, Bellazzini et al. (2024) showed that stars with $[\text{Fe}/\text{H}] \leq -1.5$ and disc-like orbital properties are significantly more common on prograde than on retrograde orbits. These authors argued that part of this population may trace an early in situ disc component. In parallel, chrono-chemo-dynamical analyses of *Gaia* Radial Velocity Spectrometer (RVS) samples have suggested that the MW may host an extremely old thin disc, with ages extending beyond 13 Gyr, thus implying that a dynamically cold disc could have been in place within the first Gyr after the Big Bang (Nepal et al. 2024). These results are particularly intriguing in the broader context of high-redshift observations, which have revealed surprisingly early disc-like structures in distant galaxies (e.g. Neeleman et al. 2020; Rizzo et al. 2020; Ferreira et al. 2022; Kartaltepe et al. 2023; Robertson et al. 2023).

However, the interpretation of metal-poor stars on present-day disc-like orbits is not unique. While some might be genuine

* Corresponding author: carlos.viscasillas@ff.vu.lt

relics of an early Galactic disc or members of the metal-poor tail of the old thin disc, others could belong to the low-metallicity tail of the thick disc or the metal-weak thick disc (MWTD; e.g. Norris et al. 1985; Chiba & Beers 2000; Beers et al. 2002; Ruchti et al. 2010; Beers et al. 2014). The MWTD may therefore be regarded as a low-metallicity, thick-disc-like component, potentially overlapping with the metal-poor tail of the canonical thick disc (e.g. Kordopatis et al. 2013). Alternatively, some of these stars could represent objects accreted on low-inclination orbits or early disc relics later affected by dynamical heating and merger events (e.g. Santistevan et al. 2021; Sestito et al. 2021; Sotillo-Ramos et al. 2023; McCluskey et al. 2024; Sestito et al. 2026). This ambiguity is particularly important because neither the thick disc, nor the halo are dynamically or chemically homogeneous; for instance, Zhang et al. (2024) showed that a rotation-supported disc population begins to emerge around $[M/H] \sim -1.3$, while at lower metallicities, prograde halo components could potentially explain part of the apparent excess of stars on disc-like orbits. Moreover, for very old stars, the present-day orbital parameters may not reflect the birth conditions, since radial migration, bar-spiral interactions, changes in the Galactic angular-momentum axis, and merger-driven heating can alter angular momentum and orbital structure over time (see e.g. Sellwood & Binney 2002; Minchev & Famaey 2010; Aumer et al. 2017; Dillamore et al. 2022; Yuan et al. 2024).

Despite this progress, the nature of metal-poor stars on disc-like orbits remains a matter of debate. High-quality spectroscopy is therefore essential to assess the nature of individual candidates through their detailed atmospheric parameters and chemical-abundance patterns. In this work, we report the identification of a metal-poor star with thin disc-like orbital properties in the *Gaia*-ESO Survey (GES, Gilmore et al. 2022; Randich et al. 2022). The identification of such an object in the relatively small GES sample offers an important high-resolution spectroscopic counterpart to the populations recently identified by (Fernández-Alvar et al. 2024; Nepal et al. 2024). In particular, this star offers a uniquely detailed chemical inventory, enabling a more comprehensive assessment of its origin. We therefore examined its kinematic and chemical properties and assessed whether it can indeed represent a plausible relic of the early MW disc. The paper is organised as follows: Section 2 describes the data and sample selection. Section 3 presents the kinematic and stellar properties of the candidate, including its orbital parameters and age estimate. Section 4 presents an analysis of its detailed chemical properties. Section 5 offers a discussion of the possible origin of the star in the context of metal-poor disc populations. Finally, Sect. 6 summarises our main conclusions.

2. Data and sample selection

Our analysis is based on high-resolution spectroscopic data from the *Gaia*-ESO Survey, specifically from the UVES sample (SETUP = U580). Within the GES classification scheme, we restricted our analysis to targets observed as part of the MW field stars (GES_FLD = GE_MW), excluding calibration fields, star cluster, and benchmark stars. This selection results in a sample of 3298 stars. We further focussed on stars located around the main sequence turn-off (MSTO), as their age estimates tend to be more reliable (e.g. Howes et al. 2019). To perform this selection, we adopted cuts in surface gravity and effective temperature, selecting stars with $3.8 \leq \log g \leq 4.3$ and $5600 \leq T_{\text{eff}} \leq 6900$ K, following previous works (e.g. Chen et al. 2022;

Viscasillas Vázquez et al. 2023). This selection yields a final sample of 1784 stars.

The orbital parameters were taken from the catalogue of Kordopatis et al. (2023), where the orbits were computed using *Gaia* astrometry, *Gaia* line-of-sight radial velocities, and the geometric and photogeometric distances of Bailer-Jones et al. (2021a). The adopted solar position is $(R, Z)_{\odot} = (8.249, 0.0208)$ kpc, and the solar Galactocentric velocity is $(V_R, V_{\phi}, V_Z)_{\odot} = (-9.5, 250.7, 8.56)$ km s⁻¹. Orbital parameters, including eccentricity, angular momentum, and the maximum height above the Galactic plane, were then derived with the Stäckel fudge method using GALPY and the axisymmetric Galactic potential of McMillan (2017). For our sample, the *Gaia* and *Gaia*-ESO radial velocities (RV) show a good overall agreement, with a median difference of $\Delta RV = RV_{\text{Gaia}} - RV_{\text{GES}} = +0.29$ km s⁻¹ and a 16th–84th percentile range of $[-3.32, +4.44]$ km s⁻¹. This is consistent with the comparative analysis of *Gaia*-ESO DR5.1 and *Gaia* DR3 GSP-Spec by Van der Swaelmen et al. (2024), who found excellent agreement between the *Gaia* and *Gaia*-ESO radial velocities within the uncertainties of each dataset. This indicates that the use of the *Gaia*-based orbital parameters does not introduce a significant systematic bias in our kinematic interpretation. The derived orbital parameters are consistent with those obtained using independent methodologies, such as the calculations presented by Berni et al. (2025), who computed stellar orbits assuming the McMillan (2017) Galactic potential using the AGAMA code (Vasiliev 2019) and following the prescriptions described in Massari et al. (2019). In addition, for the purpose of constructing the Lindblad diagram, we computed the orbital energy for each star following the same framework, using the results of Berni et al. (2025). We also derived the Galactic velocity components in the local standard of rest ($U_{\text{LSR}}, V_{\text{LSR}}, W_{\text{LSR}}$), which are used to construct the Toomre diagram. The guiding radii, R_{guid} , were computed with GALPY (Bovy 2015), adopting the same Galactic potential used for the orbital integration.

Stellar ages were derived by fitting Yale–Yonsei isochrones (Yi et al. 2001; Kim et al. 2002; Yi et al. 2003) to the inputs effective temperature (T_{eff}), $[\text{Fe}/\text{H}]$, along with the absolute visual magnitude (M_V) adopting the frequentist approach implemented in the Python code q2 (Ramírez et al. 2014). The algorithm incorporates solar-scaled isochrones, spaced in steps of 0.02 dex in $[\text{Fe}/\text{H}]$. The effects of α -enhancement are accounted following the strategy in Spina et al. (2018), which includes in the metallicity the effect of $[\alpha/\text{Fe}]$ according to the relation of Salaris et al. (1993):

$$[M/H] = [\text{Fe}/\text{H}] + \log(0.638 \times 10^{[\alpha/\text{Fe}]} + 0.362), \quad (1)$$

where α is the average of Mg, Si, Ca, and Ti; see details of the effect of the α enhancement in Appendix A. The availability of these abundances limited our selected sample of 1784 stars to 1263; the method converged for 1109 stars from that input data. We adopted the zero-point offset of -0.04 dex in $[\text{Fe}/\text{H}]$, attributed to atomic diffusion (Meléndez et al. 2012; Dotter et al. 2017; Spina et al. 2018), with which the age of the Sun (4.6 Gyr) is recovered from its canonical parameters. The method internally computes M_V from the extinction corrected magnitude V_0 and the distance. For the latter we adopted the geometric distances of Bailer-Jones et al. (2021b), which are based on *Gaia* parallaxes and are corrected for its zero-point offset (Lindgren et al. 2021). Then, V_0 was computed adopting the reddening estimates in Appendix B.

To compute the ages, T_{eff} and $[\text{Fe}/\text{H}]$ were adopted from the *Gaia*-ESO catalogue, and their errors are assumed to be of

Table 1. Stellar and orbital parameters of the candidate star.

Parameter	Value
CNAME	15183399–0721310
T_{eff} (K)	5650 ± 46
$\log g$	4.11 ± 0.07^a
[Fe/H]	-1.38 ± 0.06
V_ϕ (km s $^{-1}$)	$220.49^{+0.55}_{-0.26}$
L_z (km kpc s $^{-1}$)	$1755.32^{+4.54}_{-2.74}$
E (10 ^{5} km ^{2} s $^{-2}$)	$-1.6209^{+0.0015}_{-0.0011}$
R_{guid} (kpc)	7.191 ± 0.016
e	$0.1231^{+0.0040}_{-0.0037}$
Z_{max} (kpc)	$0.2820^{+0.0067}_{-0.0075}$
J_z (km kpc s $^{-1}$)	$2.71^{+0.14}_{-0.16}$
age $_{\text{mp}}$ (Gyr)	$10.2^{+3.2}_{-5.8}$
[Mg/Fe]	0.58 ± 0.11
[Y/Mg]	-0.58 ± 0.10
[Al/Fe]	0.27 ± 0.15
[Mg/Mn]	0.65 ± 0.10
$A(\text{Li})$	1.68 ± 0.05
$E(B - V)$	$0.082^b, 0.070^c, 0.080^d$

Notes. ^(a) Spectroscopic value. The value inferred from the best-fitting isochrone is $\log g_{\text{iso}} = 4.57^{+0.06}_{-0.02}$. ^(b) Estimated from Schlegel et al. (1998). ^(c) Scaled by 0.86 (Schlafly & Finkbeiner 2011). ^(d) Scaled to Bayestar (Green et al. 2018) according to the relation shown in Fig. B.2.

100 K and 0.1 dex, respectively. For M_V , we assumed an error of 0.05 mag, obtained by adding in quadrature the error of the extinction in the V band $3.1 \times \sigma(E(B - V)) = 3.1 \times 0.013 = 0.04$ mag (estimated in Appendix B) and a conservative error of the *Gaia*-to-Johnson transformation of $\sigma_V = 0.03$ mag.

3. Kinematic and stellar properties

Dynamical and age information are fundamental for constraining the origin of stellar populations. In the following, we discuss the kinematic and orbital properties first, followed by an analysis of the age and evolutionary status.

3.1. Kinematic identification and orbital properties

The aim of this work is to select metal-poor stars ($[\text{Fe}/\text{H}] < -1$) with orbital properties that are consistent with thin-disc populations. Therefore, our first selection was based on orbital parameters, including angular momentum, azimuthal velocity, eccentricity, and orbital energy. Among the stars exhibiting thin-disc-like kinematics (i.e. low orbital eccentricities, high rotational support, and small vertical excursions from the Galactic plane) and with $[\text{Fe}/\text{H}] < -1$, we selected one candidate (CNAME = 15183399–0721310). Its stellar and orbital parameters are summarised in Table 1. The *Gaia*-ESO radial velocity of the candidate is in excellent agreement with the *Gaia* DR3 value used for the orbital determination, with $\text{RV}_{\text{GES}} = -28.81$ km s $^{-1}$, and $\text{RV}_{\text{Gaia}} = -27.81$ km s $^{-1}$.

The candidate has a metallicity of $[\text{Fe}/\text{H}] = -1.38 \pm 0.06$, below the classical lower limit for the thin disc $[\text{Fe}/\text{H}] = -0.7$ (Bensby et al. 2014) or even the value recently proposed by Hu et al. (2025), $[\text{Fe}/\text{H}] = -1.2$. However, its kinematic properties clearly distinguish it from the bulk of the halo and thick disc

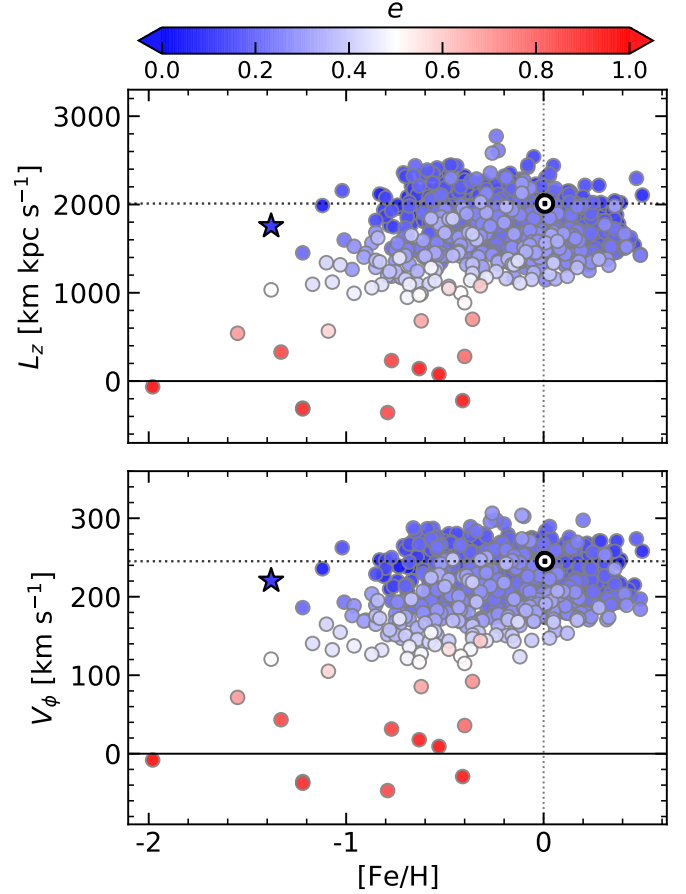


Fig. 1. Distribution of the MSTO sample in the L_z – $[\text{Fe}/\text{H}]$ (top) and V_ϕ – $[\text{Fe}/\text{H}]$ (bottom) planes, colour-coded by orbital eccentricity. The star symbol corresponds to the identified candidate, while the solar symbol marks the position of the Sun for reference.

population. Figure 1 shows the distribution of the MSTO sample in the L_z – $[\text{Fe}/\text{H}]$ and V_ϕ – $[\text{Fe}/\text{H}]$ planes, colour-coded by orbital eccentricity. It exhibits a low orbital eccentricity ($e \approx 0.12$), a high azimuthal velocity ($V_\phi \approx 220$ km s $^{-1}$), and a large positive angular momentum ($L_z \approx 1755$ km kpc s $^{-1}$), placing it firmly within the locus of dynamically cold, prograde orbits. Its guiding radius, $R_{\text{guid}} \approx 7.19$ kpc, lies close to the mean of the sample distribution ($\langle R_{\text{guid}} \rangle \approx 7.35$ kpc) and within its main peak, indicating an orbit with a guiding centre close to the solar neighbourhood. Its vertical orbital structure further supports this interpretation: the star reaches a maximum height above the Galactic plane of $Z_{\text{max}} \approx 0.28$ kpc and has a low vertical action ($J_z \approx 2.7$ km kpc s $^{-1}$), indicating that it remains tightly confined to the Galactic plane. This conclusion is reinforced by the Toomre diagram shown in Fig. 2, where the sample is colour-coded by metallicity. The candidate lies well within the low-velocity region associated with dynamically cold orbits, yet exhibits a high metallicity. This combination confirms the presence of metal-poor stars on thin disc-like orbits.

The orbital properties differ significantly from those typically observed in halo stars, which generally exhibit little net rotation, large velocity dispersions, highly eccentric orbits, and large vertical excursions from the Galactic plane (Battaglia et al. 2005; Carollo et al. 2007). Adopting a canonical halo azimuthal velocity dispersion of $\sigma_\phi \sim 120$ km s $^{-1}$ (Battaglia et al. 2005), the observed rotational velocity corresponds to a $\sim 1.8\sigma$ deviation from the halo mean. Under the assumption of a

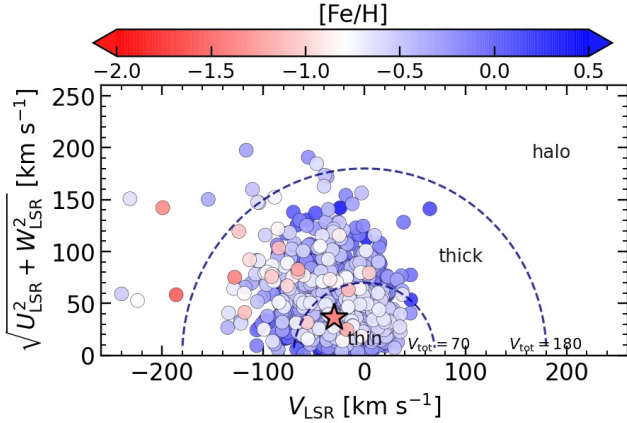


Fig. 2. Toomre diagram for the MSTO sample colour-coded by metallicity. The candidate star is highlighted with a star symbol. The dashed curves indicate the kinematic loci commonly used to distinguish thin-disc, thick-disc, and halo populations based on total velocity with respect to the LSR.

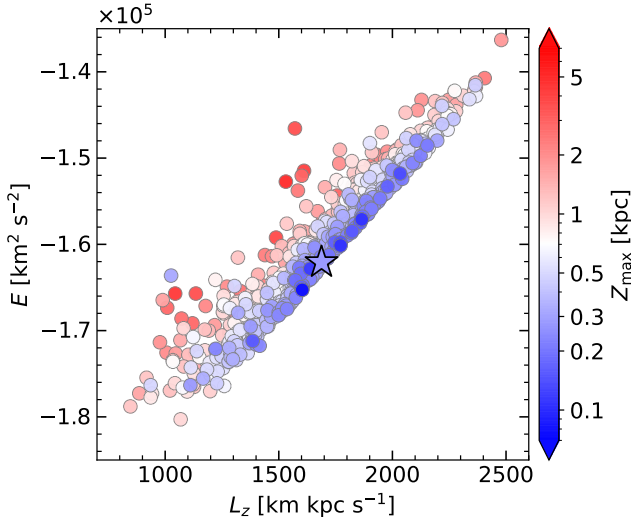


Fig. 3. Lindblad diagram for the MSTO sample. The colour scale represents the maximum vertical excursion, $Z_{\max}$, highlighting the separation between stars confined to the Galactic plane and those on more vertically extended orbits. The candidate star is highlighted with a star symbol.

Gaussian distribution, the probability of finding a halo star with $V_\phi \geq 220 \text{ km s}^{-1}$ is of the order of only a few percent ($\sim 3\%$). However, when the additional orbital constraints are taken into account (i.e. a very small eccentricity and low value of $Z_{\max}$), the likelihood of a halo origin decreases substantially. Halo stars typically reach several kiloparsecs above the Galactic plane and exhibit significantly hotter orbital distributions. Therefore, considering the full orbital configuration, we estimate that the probability of the star belonging to the halo population is likely below the percent level. The orbital properties are instead more naturally explained within the framework of the metal weak thick disc population; namely, stars with halo-like metallicities, but disc-like kinematics (Morrison et al. 1990; Chiba & Beers 2000; Ruchti et al. 2010).

A complementary view is provided by the Lindblad diagram (Fig. 3), which shows the distribution of orbital energy as a function of angular momentum. The candidate lies along the main sequence defined by the bulk of the sample in the E – L_z

plane, characteristic of dynamically cold, rotationally supported orbits, and is clearly distinct from stars with lower angular momentum and higher energies typically associated with halo-like kinematics. This combination of low metallicity and dynamically cold, thin disc-like kinematics is uncommon and motivates a more detailed analysis of the nature of this object.

We conclude this section by noting that we also identified 17400785–6830303 as a metal-poor star with thin-disc-like orbital properties. However, this object is flagged in the *Gaia*-ESO recommended file as a spectroscopic binary candidate and also presents a technical convergence flag. This is relevant in light of the large number of spectroscopic-survey targets showing radial-velocity variability likely associated with their spectroscopic-binary nature (Van der Swaelmen et al. 2025). In addition, its *Gaia* DR3 and *Gaia*-ESO radial velocities differ substantially, with $RV_{\text{Gaia}} = 7.78 \text{ km s}^{-1}$ and $RV_{\text{GES}} = 45.11 \text{ km s}^{-1}$, and *Gaia* DR3 flags the source as photometrically variable (Gaia Collaboration 2023). We therefore did not consider this object as a robust candidate in the present analysis, despite its apparently cold prograde orbit. A similar kinematic search in the complete GES UVES field-star sample also revealed three additional metal-poor stars outside the MSTO selection with thin-disc-like orbital properties: 02195542–0446423, 08000517–0034337, and 18135851–4226346. These objects provide useful additional context and their evolutionary status is discussed in the following section. We note, however, that 18135851–4226346 is reported as a confirmed spectroscopic binary by Merle et al. (2017), highlighting the need for caution when interpreting thin-disc-like orbital solutions for objects affected by binarity or possible radial-velocity variability.

3.2. Age estimate and evolutionary status

The age determination indicates that the target star is compatible with a very old stellar population. The posterior age distribution is broad and asymmetric, with a most probable value of $\text{age}_{\text{mp}} = 10.2 \text{ Gyr}$. The corresponding 1σ -like percentiles extend from ~ 4.4 to $\sim 13.4 \text{ Gyr}$. We report the most probable age because the broad, asymmetric posterior makes the mode a more representative maximum-probability solution than the mean or median. Therefore, its qualitative properties are consistent with an old stellar population. When considered together with the star’s dynamically cold and prograde orbit, this uncertain but old age estimate strengthens its interpretation as a candidate member of the metal-poor tail of the old thin disc. As shown in Fig. C.1, the candidate lies at the old end of the age distribution of thin-disc stars selected according to kinematic and chemical criteria in our sample. The broad uncertainty of the age estimate is further illustrated in Fig. C.2, where we show a summary of the candidate’s age posterior.

Among the three additional metal-poor stars identified in the complete GES UVES field-star sample with thin-disc-like orbital properties, only 18135851–4226346 has an age estimate compatible with an old thin-disc population. However, as discussed in Sect. 3.1, this object is a confirmed spectroscopic binary, while the other two objects do not show old age solutions. Therefore, none of these three additional stars is retained as a robust old metal-poor thin-disc candidate.

Finally, we also checked the *Gaia* DR3 astrometric quality indicators (Gaia Collaboration 2023). The candidate has $\text{RUWE} = 1.366$, slightly elevated but below the commonly used $\text{RUWE} \sim 1.4$ threshold. The source also shows a significant astrometric excess noise ($\epsilon_i = 0.115 \text{ mas}$, $D = 7.65$), although

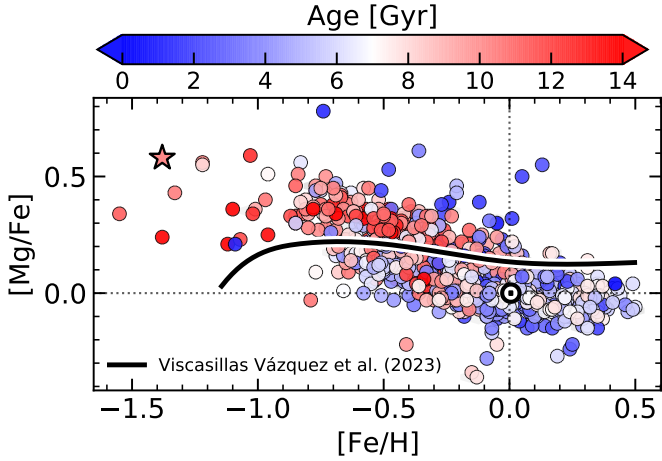


Fig. 4. Distribution of the MSTO sample in the $[\text{Mg}/\text{Fe}]$ – $[\text{Fe}/\text{H}]$ plane, colour-coded by stellar age. The star symbol corresponds to the candidate discussed in this work. The solid black curve marks the SVM-based classification boundary separating the thin-disc sequence from the thick-disc and halo locus taken from Viscasillas Vázquez et al. (2023).

it is not flagged as duplicated (`duplicated_source` = 0), has no multi-peak image detections (`ipd_frac_multi_peak` = 0), and is not listed as a *Gaia* DR3 non-single star (`non_single_star` = 0). These indicators do not provide conclusive evidence for binarity, but unresolved multiplicity cannot be completely excluded.

4. Chemical properties of the candidate

Chemical abundances provide important constraints on the formation environment and enrichment history of stellar populations. In the following, the α -element abundances of the candidate star are examined first, followed by an analysis of the detailed chemical pattern and lithium abundance.

4.1. α -element abundances, the $[\text{Y}/\text{Mg}]$ –age, and the $[\text{Al}/\text{Fe}]$ – $[\text{Mg}/\text{Mn}]$ plane

We used Mg as a representative α -element to investigate the chemical enrichment history of the candidate and of the comparison sample. Figure 4 shows the distribution of the MSTO sample in the $[\text{Mg}/\text{Fe}]$ – $[\text{Fe}/\text{H}]$ plane, colour-coded by stellar age. The well-known α -enhanced sequence is clearly visible. Using the *Gaia*-ESO Survey solar reference abundance, $A(\text{Mg})_{\odot} = 7.51$, we derived $[\text{Mg}/\text{H}] = -0.80$, corresponding to $[\text{Mg}/\text{Fe}] = +0.58$ for the candidate. The candidate star therefore shows enhanced magnesium abundance relative to iron and lies within (or close to) the α -enhanced sequence, overlapping with the oldest populations in the sample. The $[\alpha/\text{Fe}]$ value computed from the other α elements (Si, Ca, and Ti) is 0.48, confirming that the star is α enhanced. This confirms that the candidate belongs to the old α -enhanced population despite its thin-disc-like kinematics. In addition, these abundance ratios are in very good agreement with the independent values reported for the same star in GALAH DR4 (Buder et al. 2025); namely, $[\text{Fe}/\text{H}] = -1.47$, $[\text{Mg}/\text{Fe}] = 0.59$, $[\text{Si}/\text{Fe}] = 0.61$, $[\text{Ca}/\text{Fe}] = 0.28$, and $[\text{Ti}/\text{Fe}] = 0.31$. This is consistent with early and rapid chemical enrichment prior to the significant contribution of Type Ia supernovae.

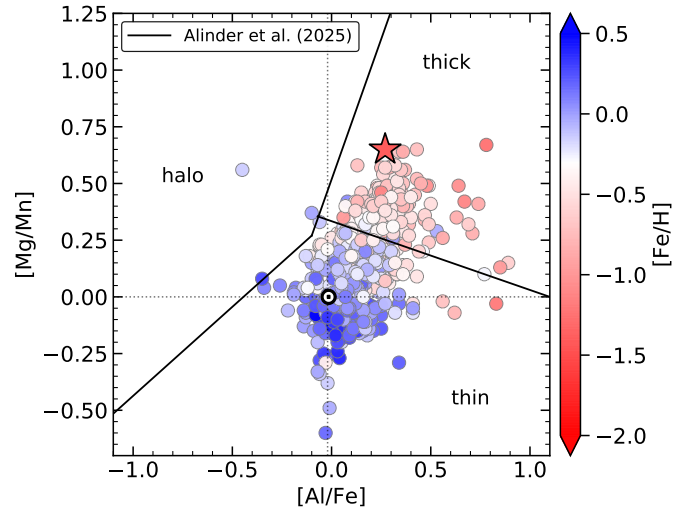


Fig. 5. Distribution of the MSTO sample in the $[\text{Al}/\text{Fe}]$ – $[\text{Mg}/\text{Mn}]$ plane, colour-coded by metallicity. The black solid lines indicate the empirical separation between Galactic components proposed by Alinder et al. (2026). The candidate is marked with a star symbol.

As an additional diagnostic, Fig. 5 shows the position of the candidate in the $[\text{Al}/\text{Fe}]$ – $[\text{Mg}/\text{Mn}]$ plane, colour-coded by metallicity. This plane has been shown to be particularly useful for separating Galactic populations and tracing different enrichment histories (e.g. Hawkins et al. 2015; Das et al. 2020; Horta et al. 2021; Vasini et al. 2024; Alinder et al. 2026). In the figure, we also show the chemical selection regions defined by Alinder et al. (2026), which separate the regions mainly occupied by thin-disc, thick-disc, and halo stars. This diagnostic is useful because $[\text{Mg}/\text{Mn}]$ traces the relative contribution of core-collapse and Type Ia supernovae, while $[\text{Al}/\text{Fe}]$ is sensitive to enrichment by massive stars and to the intensity of star formation (e.g. Kobayashi et al. 2006; Mishenina et al. 2015). In this diagram, the candidate lies in the region associated with the thick disc, close to the halo boundary, and clearly separated from the thin-disc locus. Its relatively high $[\text{Mg}/\text{Mn}]$ and enhanced $[\text{Al}/\text{Fe}]$, together with its low metallicity, therefore support the view that the star formed from gas enriched predominantly by massive stars on short timescales, rather than following the chemical evolution typical of the canonical thin disc.

The abundance pattern in the $[\text{Al}/\text{Fe}]$ – $[\text{Y}/\text{Mg}]$ plane provides an additional indication of an early formation epoch. The candidate shows enhanced $[\text{Al}/\text{Fe}]$ together with a very low $[\text{Y}/\text{Mg}] = -0.58$ (Fig. 6). The former points to efficient enrichment by massive stars and core-collapse supernovae, while the latter indicates that the gas from which the star formed had received only a limited contribution from the delayed production of Y by low- and intermediate-mass AGB stars (e.g. Travaglio et al. 2004; Bisterzo et al. 2014). Low $[\text{Y}/\text{Mg}]$ ratios are generally associated with old stellar populations, reflecting the different enrichment timescales of Mg, mainly produced by massive stars, and Y, largely contributed by the slow neutron-capture process in AGB stars (e.g. Nissen 2015; Feltzing et al. 2017; Delgado Mena et al. 2019; Viscasillas Vázquez et al. 2022; Molero et al. 2025). Its $[\text{Y}/\text{Mg}]$ ratio lies below the values typically observed for thin-disc stars in the relations of Tautvaišienė et al. (2021); Viscasillas Vázquez et al. (2025); Pakštienė et al. (2026); Mikolaitis et al. (2026), reinforcing the idea that despite its thin-disc-like orbit, the star is chemically associated with an

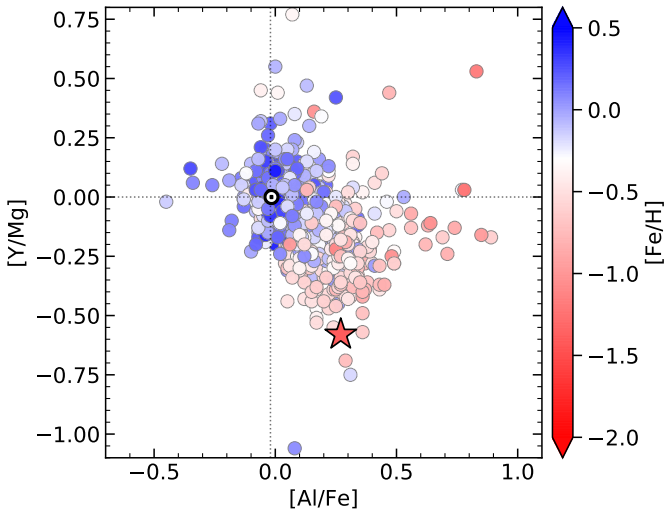


Fig. 6. Distribution of the sample in the $[Al/Fe]$ – $[Y/Mg]$ plane, colour-coded by $[Fe/H]$.

old population formed during the early phases of Galactic disc assembly.

4.2. Detailed chemical pattern

We analysed the detailed chemical pattern of the candidate using abundance ratios $[E/Fe]$ for elements tracing different nucleosynthetic channels, following Magrini et al. (2023). The abundances were normalised to the *Gaia*-ESO Survey solar reference scale. The candidate was then compared with four reference stars selected according to their kinematic properties.

We started with a representative thin-disc star selected from the subsample satisfying both the kinematic and chemical thin-disc criteria. Within this subsample, we chose the object closest to the median metallicity and the mean most-probable age of the thin-disc population. The thin-disc subsample has a mean metallicity of $[Fe/H] = -0.025$ and $\langle \text{age}_{\text{mp}} \rangle = 5.09$ Gyr, with a dispersion of 2.37 Gyr. The selected thin-disc comparison star, CNAME 17390751–5951521, has $[Fe/H] = -0.07$ and $\text{age}_{\text{mp}} = 5.8^{+1.6}_{-1.7}$ Gyr.

The initial selection of the thick-disc and halo comparison stars was guided by proximity to the candidate in the age-metallicity plane, using the normalised Euclidean distance,

$$d = \sqrt{\left(\frac{\text{age} - \text{age}_{\text{ref}}}{1 \text{ Gyr}} \right)^2 + \left(\frac{[Fe/H] - [Fe/H]_{\text{ref}}}{0.10 \text{ dex}} \right)^2}. \quad (2)$$

For the thin-disc comparison, the reference values were the mean most-probable age and mean metallicity of the subsample selected according to both kinematic and chemical thin-disc criteria. For the thick-disc and halo comparisons, the reference values were those of the candidate. The final comparison stars were then required to be representative of their respective populations in both kinematics and chemistry. The selected thick-disc star is CNAME 01393038–5400563, with $\text{age}_{\text{mp}} = 10.6^{+1.2}_{-1.5}$ Gyr, $[Fe/H] = -0.73$, and $V_{\text{tot}} = 176.25 \text{ km s}^{-1}$. For the halo comparison, the number of suitable stars was very limited. Only a few objects in our sample have halo-like velocities ($V_{\text{tot}} > 180 \text{ km s}^{-1}$) and metallicities below $[Fe/H] < -1.0$. We first excluded chemically peculiar objects as the metallicity-matched star CNAME 03373965–2721214, which

has $[Fe/H] = -1.38$ as the candidate, but is flagged in SIMBAD as chemically peculiar (see e.g. Fu et al. 2018; Magrini et al. 2021). Among the remaining non-peculiar halo-kinematic stars, CNAME 04273549–3505248 was selected as the best compromise between metallicity and abundance-pattern similarity to the candidate. This halo comparison star is characterised by $\text{age}_{\text{mp}} = 10.4^{+0.9}_{-0.7}$ Gyr, $[Fe/H] = -1.22$, and $V_{\text{tot}} = 290.88 \text{ km s}^{-1}$.

The resulting abundance patterns are shown in Fig. C.3. The representative thin-disc star displays a clearly different pattern, as expected. In contrast, the candidate is broadly more similar to the old, metal-poor thick-disc and halo comparison stars, particularly in the α -elements and several iron-peak species. The largest differences are found in some iron-peak and neutron-capture elements, particularly among the heavy elements at the end of the sequence. The representative thin-disc star shows the most distinct pattern, lying systematically below the candidate for several neutron-capture species. By contrast, the thick-disc and halo comparison stars are generally closer to the candidate for the light and α -elements. In particular, the comparison halo star provides the closest match to the candidate in metallicity and chemistry, with very similar $[Mg/Fe]$ and $[Mg/Mn]$ ratios of 0.56 and 0.67, compared to 0.58 and 0.65 for the candidate. However, this chemical similarity contrasts with their markedly different kinematics: the comparison star has halo-like orbital properties ($V_{\phi} = -35.05 \text{ km s}^{-1}$, $L_z = -311.16 \text{ kpc km s}^{-1}$, $e = 0.86$, $Z_{\text{max}} = 1.26 \text{ kpc}$), whereas the candidate displays thin-disc-like kinematics (see Table 1).

On the whole, the abundance pattern of the candidate is more consistent with old, metal-poor populations than with the typical thin disc. This supports the interpretation that, despite its thin-disc-like kinematics, the star formed from gas enriched under conditions characteristic of the early Galaxy and might indeed trace the metal-poor tail of the old thin disc or an early phase of the Galactic disc formation.

4.3. Lithium abundance

To further characterise the nature of the candidate, we analysed its lithium abundance in the context of the MSTO sample. Figure 7 shows the lithium abundance as a function of effective temperature, colour-coded by metallicity. The Spite plateau is primarily traced by the warmest stars and most metal poor stars in the sample, while cooler stars exhibit progressively lower lithium abundances due to depletion. The candidate is located at $[Fe/H] = -1.38$ and has an effective temperature of $T_{\text{eff}} = 5650 \text{ K}$; its measured lithium abundance, $A(\text{Li}) = 1.68 \pm 0.05$, lies below the canonical *Spite plateau* value (e.g. Yang et al. 2026, and references therein). This is consistent with previous findings in the literature (Charbonnel & Primas 2005, e.g.) for metal-poor halo stars with similar temperatures; interestingly, the Li value for the candidate is consistent with recent model predictions for Li depletion in metal poor stars (Yang et al. 2026) and an initial Li corresponding $A(\text{Li}) = 2.72$, as predicted by Big Bang nucleosynthesis.

5. Discussion

The *Gaia*-ESO candidate is a metal-poor star exhibiting dynamically cold, thin disc-like kinematics. This uncommon combination is particularly helpful in bolstering our understanding of the early formation of the Galactic disc. With $[Fe/H] = -1.38$, the star lies in a metallicity regime where halo populations are expected to dominate in the solar neighbourhood (e.g.

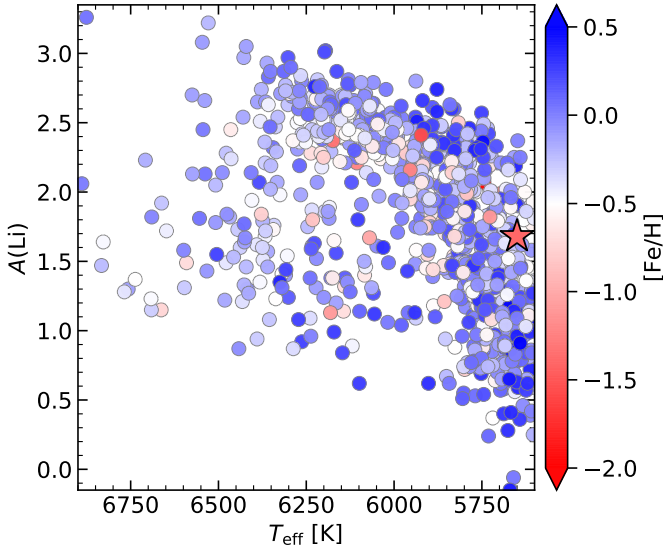


Fig. 7. Lithium abundance as a function of effective temperature for the MSTO sample, colour-coded by metallicity. The star symbol corresponds to the candidate discussed in this work.

Nissen & Schuster 2010; Haywood et al. 2013; Helmi et al. 2018; Belokurov et al. 2018). However, its orbital properties, including low eccentricity, small vertical excursion, high prograde velocity, and large angular momentum, are fully consistent with a dynamically cold, rotationally supported orbit (e.g. Bensby et al. 2003, 2014). Such properties place the star within the population of metal-poor, high-angular-momentum stars identified in recent large spectroscopic surveys (e.g. Fernández-Alvar et al. 2021; Hu et al. 2025). These studies reveal a sequence of stars with thin-disc-like kinematics extending to low metallicities, although their origin remains debated. In particular, it is still unclear whether these objects represent the metal-poor extension of the thin disc or the high-angular-momentum tail of dynamically hotter populations. In this context, the possibility of a metal-weak thick-disc origin cannot be excluded (e.g. Zhang et al. 2024), as the chemically selected Mg-enhanced population in our sample also includes a high- V_ϕ tail comparable to the candidate. This is illustrated in Fig. D.1, which shows the V_ϕ , V_{tot} , and Z_{max} distributions of this chemically selected sample after removing young α -rich stars. However, considering its overall orbital properties, the candidate lies among the dynamically colder objects of this population. This ambiguity is consistent with both observational studies of metal-poor stars in the solar neighbourhood, where chemical and orbital classifications might differ (e.g. Şahin & Bilir 2020), and numerical models showing that present-day kinematics do not necessarily preserve a direct record of the original epoch of disc formation after merger-driven perturbations (e.g. Orkney & Laporte 2026).

Recent works have provided a time-resolved view of MW assembly, revealing a transition from an early α -enhanced phase to the later emergence of a dynamically cold disc, with a characteristic separation at ~ 8 Gyr (Xiang & Rix 2022). The candidate, whose age posterior favours an old solution with a most probable value of $10.2^{+3.2}_{-5.8}$ Gyr, low metallicity, and enhanced α -abundances, is compatible with this early phase; however, it already exhibits disc-like kinematics, suggesting that rotationally supported orbits were established at very early epochs. In the context of recent work on the early MW, this object can be interpreted within the transition between the kinematically hot, metal-poor in situ population (often referred to as Aurora)

and the onset of disc formation (Belokurov & Kravtsov 2022). Stars in the Aurora component are characterised by dynamically hot orbits and modest net rotation, while a rapid increase in rotational support (the so-called spin-up) occurs over a relatively short timescale as the Galactic disc forms. The kinematics of the candidate, combined with its metallicity, suggest that it may belong to this early disc phase, tracing the emergence of dynamically cold orbits shortly after the spin-up of the Galaxy.

The chemical properties of the star provide a key complementary constraint. Its low metallicity ($[\text{Fe}/\text{H}] = -1.38$), strong α -enhancement ($[\text{Mg}/\text{Fe}] = +0.58$; $[\alpha/\text{Fe}] = +0.48$) and old age estimate of $10.2^{+3.2}_{-5.8}$ Gyr point to formation during a phase of rapid chemical enrichment dominated by core-collapse supernovae, typical of early in situ populations. This picture is further supported by its very low $[\text{Y}/\text{Mg}]$ ratio ($[\text{Y}/\text{Mg}] = -0.58$), which is consistent with formation before the delayed contribution of s-process material from low- and intermediate-mass AGB stars became significant. These properties are not consistent with the canonical thin disc, but overlap with those of the metal-weak thick disc and other chemically old Galactic components (e.g. Chiba & Beers 2000; Reddy et al. 2006). This interpretation is further supported by its detailed abundance pattern, which is broadly consistent with that of halo stars across a wide range of elements tracing different nucleosynthetic channels. In this framework, the candidate does not appear to be a member of the present-day thin disc; rather, it traces an early stage in the assembly of the Galactic disc. We note that the lithium abundance provides an additional constraint on its nature.

6. Summary and conclusions

We have identified a metal-poor star ($[\text{Fe}/\text{H}] = -1.38$) with dynamically cold, thin disc-like kinematics, including low eccentricity, small vertical excursion, and high prograde rotational velocity. These properties place the star within the population of metal-poor objects with disc-like rotational support recently identified in large surveys.

Despite its thin-disc-like kinematics, the star exhibits α -enhanced chemical abundances and an age estimate that is consistent with an old stellar population, with a most probable value of $\text{age}_{\text{mp}} = 10.2^{+3.2}_{-5.8}$ Gyr, indicating formation during the early phases of Galactic evolution. Its detailed chemical pattern across multiple elements is broadly consistent with that of halo stars, reinforcing an origin in gas that has been predominantly enriched by core-collapse supernovae. This combination suggests that the star does not belong to the canonical thin disc. Instead, the candidate is more naturally interpreted as part of a transitional population tracing the onset of disc formation, likely associated with the rapid spin-up phase of the MW. Its properties indicate that dynamically cold, disc-like orbits were already in place at early times. The lithium abundance of the star, $A(\text{Li}) = 1.68$, is also consistent with the halo, rather than a thin-disc population. This object provides direct observational evidence that metal-poor, α -enhanced stars can exhibit thin disc-like kinematics, offering new constraints on the timing and dynamical settling of the Galactic disc.

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Appendix A: Impact of $[\alpha/\text{Fe}]$ enhancement on the determination of age

The majority of the stars in our sample have near-solar metallicity. However, since our goal is to find old stars, the most likely candidates are naturally the most metal-poor ones. We applied Eq. (1) to account the effect of $[\alpha/\text{Fe}]$ on the overall metallicity in our isochrone fitting procedure. The performance of the equation has been tested against isochrones with actual α enhancements by Kim et al. (2002). They found that the equation works remarkably well for $[\text{Fe}/\text{H}] \sim -2$ dex, precisely reproducing all the isochrone path from the MSTO to the tip of the red giant branch. On the other hand, they show that for $[\text{Fe}/\text{H}] \gtrsim -1.5$ dex, only the main sequence is reproducible. The authors do not recommend the use of the equation for near-solar metallicity because the consistency along the red giant branch becomes highly irregular. However, since our sample only consists on MSTO, Eq. (1) can be applied safely.

Spina et al. (2018) have shown experimentally that the α enhancement via Eq. (1) mostly affects the stellar ages greater than ~ 8 Gyr. However, that sample consists only on stars of solar-metallicity. Figure A.1 shows a comparison using our star sample. Similar to the results of Spina et al. (2018), the top panel in the figure displays overestimations from α solar-scaled isochrones for age $\gtrsim 8$ Gyr. For stars older than ~ 10 Gyr, ignoring α enhancement frequently yields ages exceeding the age of the universe 13.7 Gyr (Planck Collaboration 2020). Most of the old stars in the present sample have $[\text{Fe}/\text{H}] \lesssim -0.4$ dex, as the bottom panel in the figure shows. For these stars, disregarding α enhancement yields age overestimations of up to 2 Gyr.

Appendix B: Comparison of reddening estimates

We explored the reddening maps available through the dustmaps package (Green 2018) to identify the most suitable extinction estimates for our stellar sample. Among the available products, Bayestar (Green et al. 2018) and DECaPS (Zucker et al. 2025) were selected as the only large-scale maps providing distance-dependent (3D) reddening estimates, while the map of Schlegel et al. (1998) (SFD hereafter) was included as the standard all-sky 2D reference. SFD estimates were scaled by a factor of 0.86 to account for the systematic overestimation reported by Schlafly & Finkbeiner (2011). In addition, to account for the finite distances of our targets, the reddening values were further corrected following the prescription of Beers et al. (2002); we refer to these values as S&F+B hereafter. Other maps were not considered because their spatial coverage or applicability is limited to specific Galactic regions or the local solar neighbourhood, making them unsuitable for our sample.

Only SFD provides reddening estimates for all stars, independently of their sky position. However, since these estimates correspond to the total dust column along the line of sight, applying the correction for the finite distance of the star following Beers et al. (2002) is expected to be appropriate at high Galactic latitudes, in the halo, where the dust distribution is smoother and less affected by the clumpy structure observed near the Galactic plane. The accuracy of this correction may decrease for stars close to the Galaxy plane, where the inhomogeneous distribution of dust becomes standard.

Approximately 23% of our sample is located at low Galactic latitudes ($|b| < 20^\circ$, see Fig. B.1), where Bayestar should be more suited. However, bayestar is primarily based on photometry from the Pan-STARRS1 survey (Chambers et al. 2019), whose

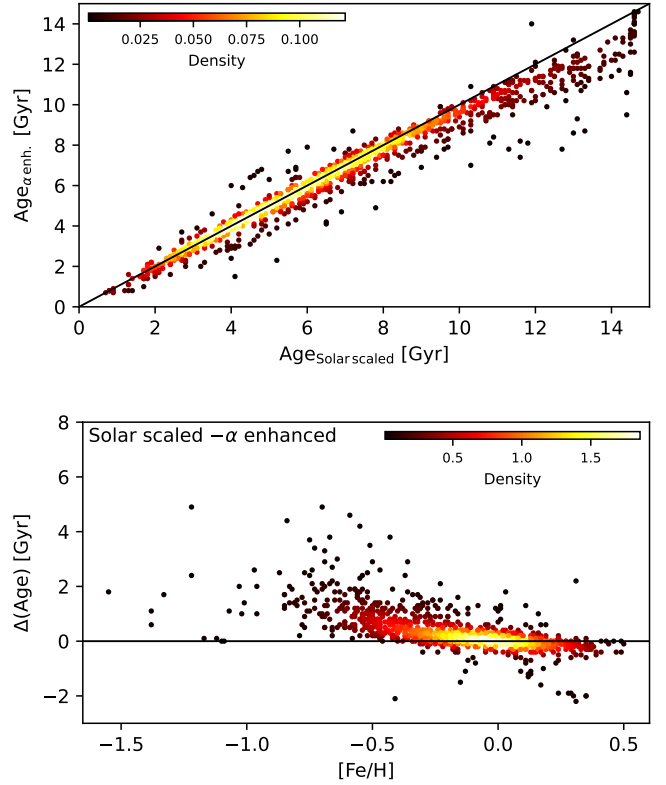


Fig. A.1: Comparison of age outcomes from isochrones with and without alpha enhancement. *Top*: shows α enhanced determinations via Eq. (1) versus solar scaled determinations. The line of perfect agreement is represented by the diagonal line. *Bottom*: Difference between age determinations as function of metallicity.

footprint is limited to declinations $\delta \gtrsim -30^\circ$. Consequently, a significant fraction of our southern-sky targets falls outside its coverage. We retrieved Bayestar reddening for $\sim 40\%$ of our sample (444 stars); these stars will be used below for assessing the relative precision of the S&F+B values. The DECaPS footprint, on the other hand, is concentrated towards the southern Galactic plane, covering approximately $240^\circ \lesssim l \lesssim 360^\circ$ and $|b| \lesssim 10^\circ$. Our stellar sample largely avoids this plane region, thus only 16 stars have DECaPS extinction estimates. These stars are used below solely as an independent check of the S&F+B estimates.

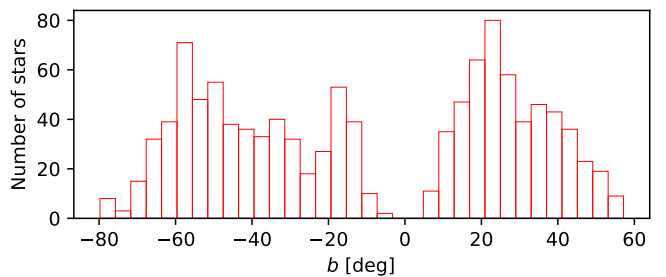


Fig. B.1: Histogram of b with bins of 4° .

Figure B.2 shows good agreement between S&F+B and Bayestar for $E(B - V) \lesssim 0.07$ mag. At higher reddening values, the differences increase systematically, with Bayestar yielding progressively higher values. The observed trend is empirically described by a power-law relation, whose parameters are indicated in the plot. On the other hand, the comparison between

S&F+B and DECaPS seem to show reasonable agreement along $E(B - V)$. These outcomes may reflect differences in the calibration and methodology of the reddening maps. Since the agreement between S&F+B and DECaPS for $E(B - V) \gtrsim 0.7$ is supported by only a few stars, we adopt the scale of Bayestar. This is, we adopt Bayestar estimates when available, and when not, we apply the power law to transform S&F+B for consistency. The vast majority of our sample has S&F+B < 0.14 mag (all but five stars), implying corrections smaller than +0.03 mag. Such differences have relatively small impact on the age (i.e. $\lesssim 1.5$ Gyr). After applying the correction, the standard deviation of the difference between the two sets of values is of 0.013 mag, which we adopt as the reddening uncertainty.

Figure B.2 shows a few outliers in both S&F+B versus Bayestar and S&F+B versus DECaPS comparisons, indicating S&F+B overestimations. These correspond to stars at low Galactic latitudes, and some are among the most distant. Figures B.3 and B.4 indicate that the stars affected have $|b| < 20^\circ$ and distance > 1000 parsec. Our sample has 137 stars (12%) at that space, among which 105 do not have Bayestar estimates. For them, we simply keep S&F+B values. These stars are flagged as having likely biased younger ages, which is the effect of overestimating $E(B - V)$.

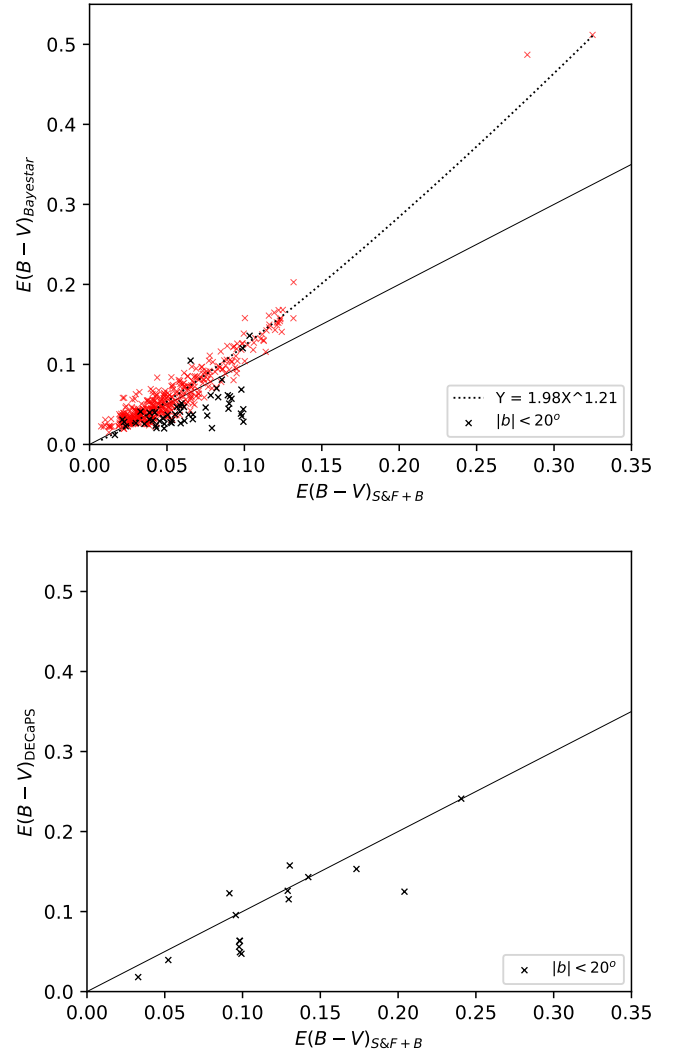


Fig. B.2: Comparison between reddening estimates. *Top*: S&F+B versus Bayestar. Red and black symbols represent stars with galactic latitude higher and lower than $b = 20$, respectively. The black solid line indicates the perfect agreement. The dotted line represents a power law fitted to the red points, the parameters of which are noted in the legends. *Bottom*: S&F+B versus DECaPS. Symbols are the same as in the top panel.

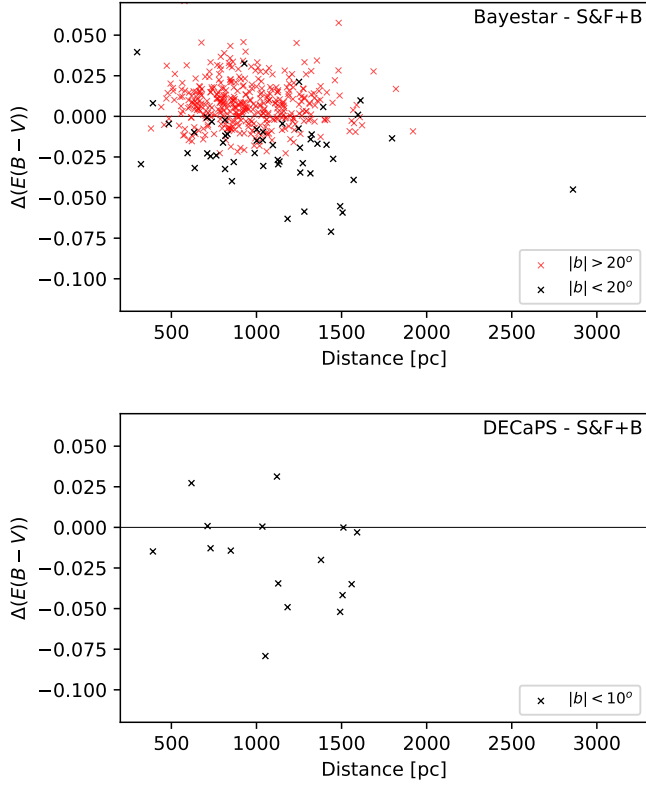


Fig. B.3: Comparison between reddening estimates as function of the distance. Difference of survey estimates are given as noted in the plots. The colours of the symbols indicate diverse Galactic latitude ranges as noted in the legends.

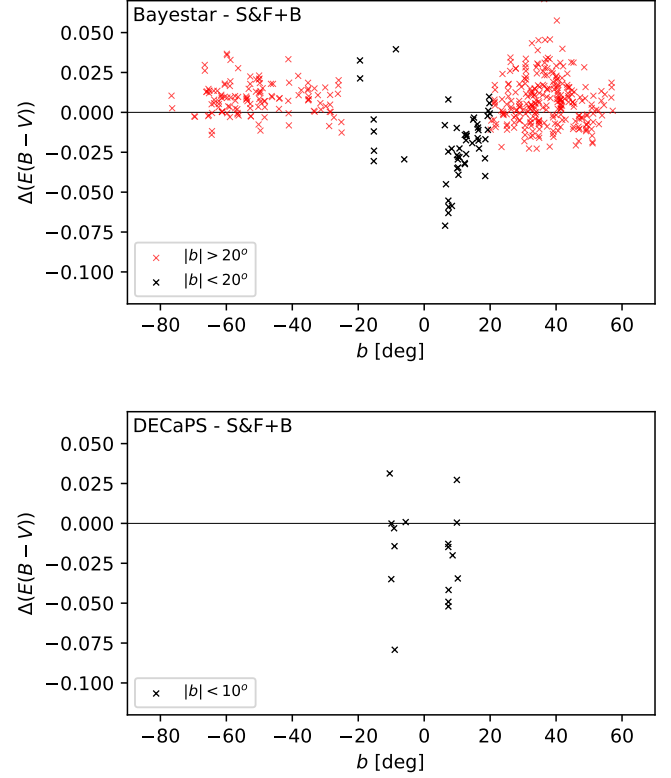


Fig. B.4: *Top*: Comparison between S&F+B and Bayestar reddening estimates. *Bottom*: Difference between Bayestar reddening and S&F+B values converted via the equation in the top panel.

Appendix C: Age distributions of the disc comparison samples and candidate posterior

The thin-disc comparison sample was selected using both kinematic and chemical information: stars were required to have $V_{\text{tot}} < 70 \text{ km s}^{-1}$ and $Z_{\text{max}} < 0.5 \text{ kpc}$, and to satisfy the thin-disc chemical criterion in the $[\alpha/\text{Fe}]$ – $[\text{Fe}/\text{H}]$ plane following Viscasillas Vázquez et al. (2023). The thick-disc sample was selected by requiring $70 \leq V_{\text{tot}} < 180 \text{ km s}^{-1}$ and $Z_{\text{max}} > 1 \text{ kpc}$, together with the corresponding thick-disc chemical criterion in the $[\alpha/\text{Fe}]$ – $[\text{Fe}/\text{H}]$ plane. The age distributions of both comparison samples were fitted with Gaussian functions. The vertical dashed lines indicate the mean ages of the thin- and thick-disc samples, while the magenta vertical line marks the age of the candidate star.

To further illustrate the age constraint of the candidate star, Fig. C.2 shows a summary of its age posterior. The posterior peaks at $\text{age}_{\text{mp}} = 10.2 \text{ Gyr}$, but it is broad, with a 1σ -like interval extending from ~ 4.42 to $\sim 13.38 \text{ Gyr}$ and a 2σ -like interval extending from ~ 1.19 to $\sim 14.78 \text{ Gyr}$. The mean age is $\langle \text{age} \rangle = 8.33 \text{ Gyr}$, with a standard deviation of $\sigma_{\text{age}} = 3.94 \text{ Gyr}$. Thus, the age estimate should be interpreted as indicating that the posterior favours an old solution, rather than as a precise age determination.

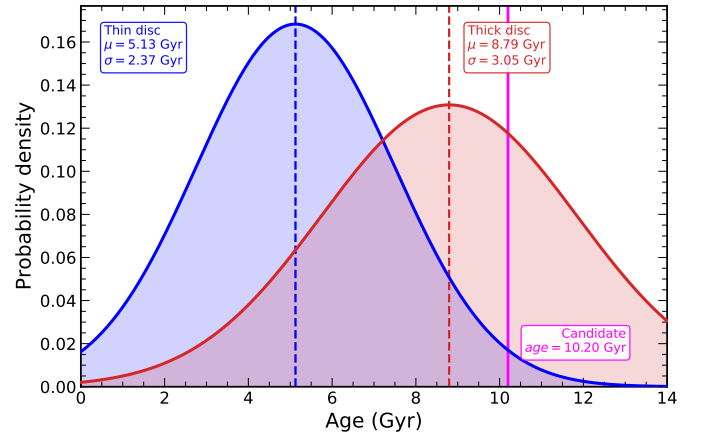


Fig. C.1: Age distribution comparison between the candidate star and the thin- and thick-disc MSTO samples selected on the basis of their kinematic and chemical properties. The blue and red shaded curves show Gaussian fits to the most probable age distributions of the thin- and thick-disc samples, respectively. The dashed vertical lines indicate the corresponding mean ages, while the magenta vertical line marks the most probable age of the candidate discussed in this work.

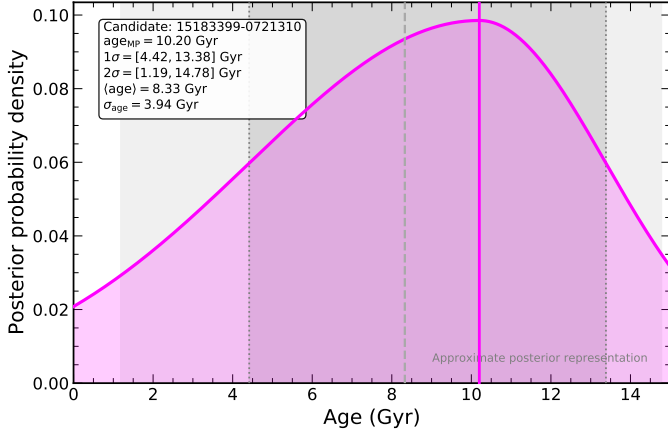


Fig. C.2: Age posterior of the candidate star 15183399–0721310. The magenta curve shows an approximate representation of the posterior based on the reported most probable age and credible intervals. The solid magenta vertical line marks the most probable age, $\text{age}_{\text{mp}} = 10.2$ Gyr, while the dashed black line indicates the mean age, $\langle \text{age} \rangle = 8.33$ Gyr. The shaded grey regions show the 1σ -like interval, $\sim 4.42\text{--}13.38$ Gyr, and the 2σ -like interval, $\sim 1.19\text{--}14.78$ Gyr.

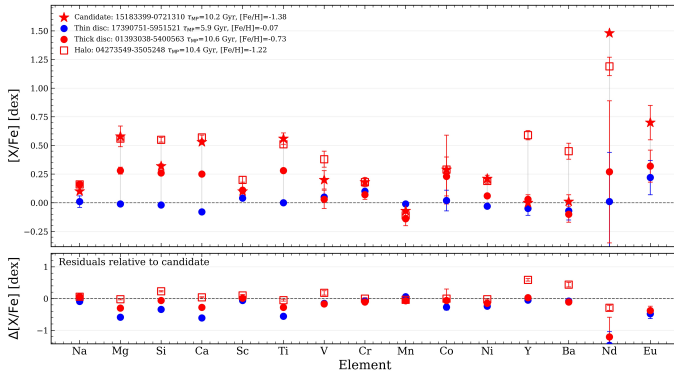


Fig. C.3: Chemical abundance pattern of the candidate compared with four reference stars. The thin-disc comparison star was selected from the thin-disc subsample defined by combined kinematic and chemical criteria, with age and metallicity close to the typical values of that subsample. The thick-disc star was selected from the corresponding Toomre-defined population, while the halo star was selected from the halo region of the Toomre diagram; in both cases we required ages and metallicities broadly similar to those of the candidate and excluded chemically peculiar abundance patterns. The upper panel shows the abundance ratios $[\text{E}/\text{Fe}]$ as a function of element, while the lower panel displays the residuals relative to the candidate.

Appendix D: Kinematics of the chemically selected Mg-enhanced sample

To assess whether the candidate could be associated with the MWTD, we examined the kinematic properties of the chemically selected Mg-enhanced population in our sample. The comparison sample was selected above the chemical boundary in the $[\text{Mg}/\text{Fe}]$ – $[\text{Fe}/\text{H}]$ plane as defined in Sect. 4.1, after removing young Mg-rich stars with $\text{age}_{\text{mp}} < 6$ Gyr, and without applying any kinematic cuts. As shown in Fig. D.1, the Mg-enhanced population includes stars with V_ϕ comparable to the candidate, while the candidate lies at the dynamically colder end of the population in terms of V_{tot} and Z_{max} .

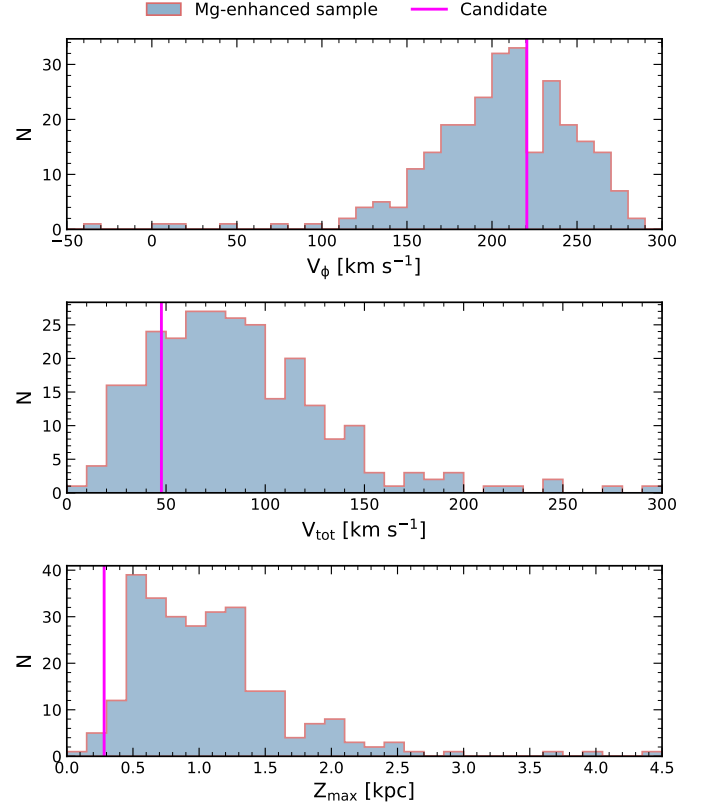


Fig. D.1: Kinematic properties of the chemically selected Mg-enhanced sample. The sample was selected above the chemical boundary in the $[\text{Mg}/\text{Fe}]$ – $[\text{Fe}/\text{H}]$ plane, after removing young α -rich stars with $\text{age}_{\text{mp}} < 6$ Gyr; no kinematic cuts were applied. The panels show the distributions of V_ϕ , V_{tot} , and Z_{max} . The vertical magenta line marks the position of the candidate.