The GALAH Survey: Third Data Release

Sven Buder[1,2,3]⋆, and the GALAH collaboration
(co-author order TBD in agreement with the SOFA)

(Affiliations listed after the references)

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ABSTRACT
This is the current draft of the accompanying paper for GALAH Data Release 3.
Please feel free to give feedback regarding both the analysis and the manuscript.

Key words: Surveys – the Galaxy – methods: observational – methods: data analysis – stars: fundamental parameters – stars: abundances

1 INTRODUCTION

2 TARGET SELECTION, OBSERVATION, REDUCTION

The selection was based on 2MASS (Skrutskie et al. 2006) magnitudes and due to their brightness, almost all stars of the GALAH observations have well measured 5D information from *Gaia* (Gaia Collaboration et al. 2018; Lindegren et al. 2018). An overview of the astro- and photometric information of the observed spectra can be found in Fig. 1

3 DATA ANALYSIS

3.1 Analysis flow and changes with respect to DR2

- SME only, no use of *The Cannon* in this DR
- Lay this out and motivate that by a figure, which shows 3 panels in the top for DR2 (Teff-logg, [Fe/H]-[alpha/Fe], [Fe/H]-A(Li)) and DR3 in the bottom
- SME536, including changes as introduced by Piskunov & Valenti (2017), but also with additional differences in the use of SME
- using fundamental relation of surface gravity $\log g$ with available, non-spectroscopic information (ϖ and K_S)
- Workflow:

(i) Estimate stellar parameters (T_eff, [Fe/H], v_broad, v_rad from spectra, $\log g$ via fundamental relation, v_mic via empirical relation)
(ii) Validation of stellar parameters (see Sec.3.2), leading to an adjustment of the estimated atmospheric [Fe/H] (SME.FEH) by adding 0.1 dex[1]
(iii) Keep stellar parameters fixed and then estimate A(X) for element X. These can be done combined (write elements for which that was done) or on a line-by-line basis (write elements for which that was done).

3.2 Validation of stellar parameters

To assess the quality of the stellar parameters, we resort to the commonly used comparison samples for accuracy, that is the GBS and the stars with asteroseismic information. For the precision assessment we use the internal uncertainty estimates and repeat observations of the same stars. We calculate the final stellar parameter errors for a given parameter X via

$$e^2_\mathrm{final}(X) = e^2_\mathrm{accuracy}(X) + e^2_\mathrm{fit}(X) + e^2_\mathrm{repeats}(X). \quad (1)$$

We note that $e^2_\mathrm{fit}(X)$ and $e^2_\mathrm{repeats}(X)$ are typically expected to be the same tracer of precision and hence only their maximum value should be used, that is

$$e^2_\mathrm{final}(X) = e^2_\mathrm{accuracy}(X) + \max\left(e^2_\mathrm{fit}(X) + e^2_\mathrm{repeats}(X)\right). \quad (2)$$

We elaborate on the choice of error combination when we assess the precision of the stellar parameters.

3.2.1 *Accuracy of stellar parameters*

***Gaia* FGK benchmark stars (GBS)**

IRFM temperatures

Stars with asteroseismic information

3.2.2 *Precision of stellar parameters*

- repeat observations and fitting uncertainties

4 VALIDATION OF ELEMENT ABUNDANCES

4.0.1 *Accuracy of element abundances*

Abundances of the Sun

Abundances of Arcturus

⋆ Contact e-mail: buder@mpia.de

[1] NB: This is not the final [Fe/H] as reported in this data release, but a pseudo iron abundance, estimated from H, Sc, Ti, and Fe lines.

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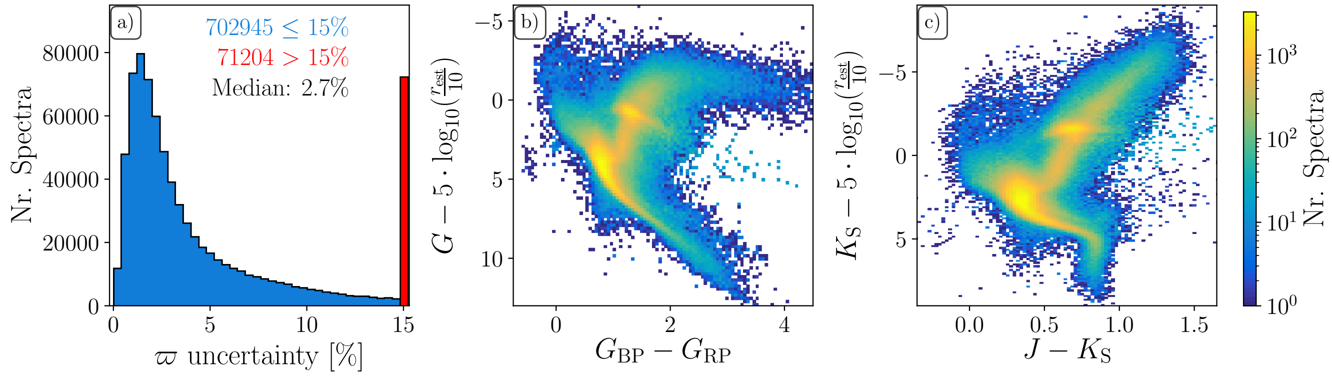

Figure 1. Overview of astro- and photometric information of the stars observed by GALAH until SB: February 2019. Panel a) shows the unprecedented parallax (ϖ) uncertainty provided by *Gaia* DR2 with 702945 (91%) spectra below 15% (blue) and 71204 (9%) spectra with uncertainties above 15% (red, truncated). Panel b) shows a color-magnitude diagram as observed with the optical *Gaia* passbands, whereas panel c) shows a color-magnitude diagram as observed with the infra-red 2MASS passbands. SB: Note that not all of these stars are included in GALAH DR3.

Abundances of the GBS stars

TBD: Abundances of cluster stars?

4.0.2 Precision of element abundances

Abundances of repeat observations

TBD: Abundances of cluster stars?

4.1 The complexity and importance of flagging (and using them)

4.1.1 Flagging of stellar parameters

4.1.2 Flagging of element abundances

We expect less trends without the influence of the training set selection or data-model flexibilities, but we still expect trends for several reasons:

- Given the model- and setup-imperfections, excluding $\log g$ as a free fitting parameter might lead to systematic trends. This can be the case for those stars where the true $\log g$ of the star and our estimated $\log g$ differ significantly (e.g. binaries where the (unidentified) second component is contributing to the flux of the system) or the synthetic spectrum with the true $\log g$ does not match the observation (e.g. due to shortcomings of the 1D model atmospheres and synthesis).
- For stars with more lines, our pipeline will perform worse several ways. Firstly, estimating the continuum will be less reliable. Secondly, we will run into issues of strong blending, where our estimate is limited to how close the synthesis of the blending lines is to the true observation. If for example a star has scaled solar abundances, our estimates of the element abundances will still be good even for blended cases. If the compositions differs, and the line that we want to measure is blended by a line of a significantly over- or under-abundant element (relative to scaled-solar), our measurement might be corrupted. We try to limit this by performing a blending test, but setting the limit on how much blending is still acceptable is both non-trivial but also hard to flag during post-processing.
- Due to time/computation restrictions, we were running several elements in a combined rather than line-by-line basis, which can decrease the precision as outlined in Sec. 3.1, although we have tried to ensure that the abundance zero points of the individual lines were similar for those elements that were run with the combined setup.

4.1.3 Expect the (un-)expected, but be cautious: Analysis shortcoming or physical correlation?

5 CATALOGS INCLUDED IN THIS RELEASE

5.1 Main catalog

(i) Stellar paramaters (see Fig. **??**)
(ii) Stellar parameter flags (both warning and flags)
(iii) Precision uncertainties and final uncertainties for each parameter (including accuracy, precision, and parameter node uncertainties)
(iv) Combined alpha-abundance (for unflagged measurements), see Fig. **??**
(v) Individual element abundances (including flagged measurements)
(vi) individual abundance flags
(vii) Precision uncertainties for each abundance
(viii) x-matches with Gaia DR2, Bailer-Jones2018, RUWE, 2MASS, WISE

5.2 Value-Added-Catalogs

The third Data Release of GALAH is accompanied by two value-added-catalogs and we explain them in this section. One value-added-catalog includes extended abundance measurement information, another one stellar ages as well as masses and a third one kinematic as well as dynamic information for each star.

5.2.1 *Extended abundance measurement information*

5.2.2 *Stellar age and mass estimates*

5.2.3 *Kinematic and dynamic information*

6 GALAH DR3 IN CONTEXT

6.1 Galactic archaeology on a global scale

6.2 Chemodynamical evolution

Combining chemistry, dynamics, and ages of stars

- plot Galactic v_R vs. v_ϕ (Belokurov) - plot Toomre diagram - plot actions - plot Vasiliev (2019) overview of J_i

7 CONCLUSIONS

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[1]Max Planck Institute for Astronomy (MPIA), Koenigstuhl 17, 69117 Heidelberg, Germany
[2]Research School of Astronomy & Astrophysics, Australian National University, ACT 2611, Australia
[3]Center of Excellence for Astrophysics in Three Dimensions (ASTRO-3D), Australia

APPENDIX A: LINELIST

This paper has been typeset from a TEX/LATEX file prepared by the author.

Table A1. Selected lines for the elemental abundance analysis.

Elem.	Ion	Wavelength [Å]	LEP [eV]	$\log(gf)$	Reference	Line mask [Å]	Segment mask [Å]
Li	1	6707.7635	0.00000	-0.00200000	1998PhRvA..57.1652Y	6707.3000-6708.3000	6705.76-6709.76
Li	1	6707.9145	0.00000	-0.303000	1998PhRvA..57.1652Y	6707.3000-6708.3000	6705.76-6709.76
Li	1	6707.9215	0.00000	-0.00200000	1998PhRvA..57.1652Y	6707.3000-6708.3000	6705.76-6709.76
Li	1	6708.0725	0.00000	-0.303000	1998PhRvA..57.1652Y	6707.3000-6708.3000	6705.76-6709.76
C	1	6587.6100	8.53700	-1.02100	1993A&AS...99..179H	6587.2610-6587.9860	6585.61-6589.61
O	1	7771.9440	9.14600	0.369000	NIST	7771.3590-7772.5090	7769.50-7777.50
O	1	7774.1660	9.14600	0.223000	NIST	7773.5220-7774.7820	7769.50-7777.50
O	1	7775.3880	9.14600	0.00200000	NIST	7774.9120-7775.9620	7769.50-7777.50
Na	1	5682.6333	2.10200	-0.706000	GESMCHF	5682.5170-5682.9970	5680.63-5691.20
Na	1	5688.2050	2.10400	-0.404000	GESMCHF	5687.9170-5688.3920	5680.63-5691.20
Mg	1	5711.0880	4.34600	-1.72400	1990JQSRT..43..207C	5710.7570-5711.4280	5710.00-5713.09
Al	1	6696.0230	3.14300	-1.56900	2008JPCRD..37..709K	6695.7780-6696.1730	6695.00-6699.87
Al	1	6698.6730	3.14300	-1.87000	2008JPCRD..37..709K	6698.3920-6698.8950	6695.00-6699.87
Al	1	7835.3090	4.02200	-0.689000	2008JPCRD..37..709K	7834.8840-7835.5720	7834.00-7837.50
Al	1	7836.1340	4.02200	-0.534000	2008JPCRD..37..709K	7835.8130-7836.4310	7834.00-7837.50
Al	1	7836.1340	4.02200	-1.83400	2008JPCRD..37..709K	7835.8130-7836.4310	7834.00-7837.50
Si	1	5684.4840	4.95400	-1.55300	GARZ|BL	5684.1840-5684.7840	5683.00-5686.00
Si	1	5690.4250	4.93000	-1.77300	GARZ|BL	5690.1800-5690.6830	5688.43-5692.43
Si	1	5701.1040	4.93000	-1.95300	GARZ|BL	5700.9290-5701.2860	5699.70-5702.00
Si	1	5772.0272	5.61400	-3.10700	K07	5771.8460-5772.4460	5771.15-5773.15
Si	1	5772.1460	5.08200	-1.65300	GARZ|BL	5771.8460-5772.4460	5771.15-5773.15
Si	1	5793.0726	4.93000	-1.96300	GARZ|BL	5792.7190-5793.3930	5791.07-5794.70
Si	1	6721.2732	5.96400	-5.27200	K07	6721.2000-6722.3000	6718.45-6723.85
Si	1	6721.8481	5.86300	-1.06200	1993PhyS...48..297N	6721.2000-6722.3000	6718.45-6723.85
Si	1	7680.2660	5.86300	-0.590000	GARZ|BL	7679.9440-7680.6680	7678.27-7682.27
K	1	7698.9643	0.00000	-0.178000	2017PhRvA..95e2507T	7698.5730-7699.2960	7696.96-7700.96
...	...	...	...	...	...	...	...

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