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THE COMPOSITION OF PLANET BUILDING BLOCKS IN THE GALAXY

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Abstract.
Our Galaxy is composed of different stellar populations with varying chemical abundances, which are thought to imprint the composition of planet building blocks (PBB). We aim to determine the PBB metallicity trends by using the GALAH large spectroscopic survey. We assess the reliability of the composition of PBB as determined with a propagation error study. Despite of the large uncertainties on molecular mass fractions, we find robust overall trends with metallicity.

Keywords: Galaxy, Stellar content, Stellar abundances, Planetary systems

1 Introduction

The properties of exoplanets appear to correlate with the chemical properties of their host stars. It is thus relevant to consider that the chemical properties of host stars should be important in the context of planet formation models. However, the chemical links between stars and bodies in their planetary systems may be difficult to disentangle, because of the diversity of physical and thermal processes involved in the formation processes of these objects.

One approach is to compute the composition of planet building blocks (hereafter PBB) formed when solids condense from the gaseous disk (Santos et al. 2017; Cabral et al. 2019). This method is particularly useful when analyzing general trends for stellar populations in our Galaxy. Interestingly, the chemical composition in the early phases of proto-planetary disks could largely differ depending on the galactic origin of the host star.

2 Methods

In order to have a broad picture of the expected chemical compositions of the different stellar populations, we realize our study with the third release of GALAH. We select pre- and main sequence stars with a simple and standard criteria: log g<4 and T_{eff}<6400 K. We select stars with the following parameter quality flags (equal to 0): flag_sp and flag_fe_h. In addition we require good elemental abundances quality flags (i.e. equal to zero) for S, Si, Mg, C, O.

In this study we use stoichiometric relations from (Bitsch & Battistini 2020). This simple model accounts for CO, CO_2 and CH_4 molecules. The gaseous molecules of CO and CO_2 bind many oxygen atoms which are not available to be condensed in water ice.

Finally, we assess the reliability of the composition of PBB through a propagation of uncertainties on atomic abundances [X/H] : $\sigma_{[X/H]} = \sqrt{\sigma^2_{[X/Fe]_{obs}} + \sigma^2_{[Fe/H]_{obs}}}$. Based on these calculations we evaluate the impact of spectroscopic error bars on the computed mass fraction. Our selected GALAH sample have a mean error bar on the Magnesium of $\sigma_{[Mg/H]} \sim 0.6$, while the mean error bar on Oxygen, typically larger, is of $\sigma_{[O/H]} \sim 0.6$.

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3 Results

The Fig. 1 shows the water mass fraction per bin of metallicity for different molecules. In the left panel, the [O/H] abundance is varied by$\sigma_{[O/H]} \sim 0.11$, resulting in an increase (respectively decrease) of $\pm 15\%$ for the water mass fraction. The error bar on oxygen impacts also the enstatite ($MgSiO_3$) mass fraction by $\pm 7\%$. In the right panel, the error bar of $\sigma_{[Mg/H]} \sim 0.6$ modifies weakly the water mass fraction. As expected, the enstatite ($MgSiO_3$) and the olivine (Mg_2SiO_4) mass fraction are largely impacted by $\pm 10\%$. The iron-bearing molecules are weakly impacted by the variation of [O/H] and [Mg/H].

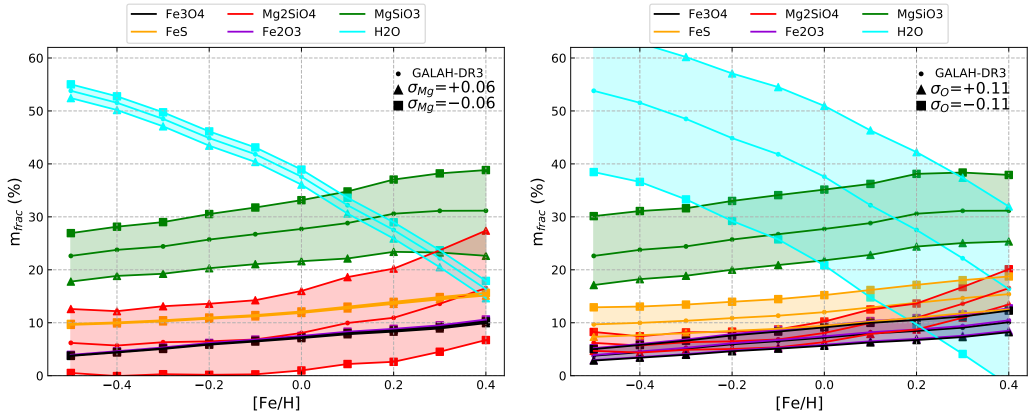

Fig. 1. Mean PBB mass fractions per bin of [Fe/H] for the GALAH-DR3 sample. **Left:** the Oxygen abundance is varied by $[O/H]_{test} = [O/H] \pm \sigma_O$. **Right:** the Magnesium abundance is varied by$[Mg/H]_{test} = [Mg/H] \pm \sigma_{Mg}$.

4 Conclusions

The typically large uncertainties on spectroscopic elemental abundances can result on large uncertainties for PBB water mass fractions. However, unless to consider extreme limit error cases, the main trends with metallicity [Fe/H] are preserved. In particular, the anti-correlation between the water mass fraction and the metallicity seems to be a robust trend.

Many observational features on planet populations are explained by the planet bulk composition (e.g. Luque & Pallé 2022). In this sense, the diversity of stellar chemical properties of the Milky Way can play a role through the chemistry of protoplanetary disks and PBB. The star origin in the Galaxy should be important for planet population properties.

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References

Bitsch, B. & Battistini, C. 2020, A&A, 633, A10

Cabral, N., Lagarde, N., Reylé, C., Guilbert-Lepoutre, A., & Robin, A. C. 2019, A&A, 622, A49

Luque, R. & Pallé, E. 2022, arXiv e-prints, arXiv:2209.03871

Santos, N. C., Adibekyan, V., Dorn, C., et al. 2017, A&A, 608, A94