CARTOGRAPHY

Emulating stellar models with machine learning speeds up determining stellar masses, ages and radii

Hierarchically modelling *Kepler* dwarfs and subgiants to improve inference of stellar properties with asteroseismology

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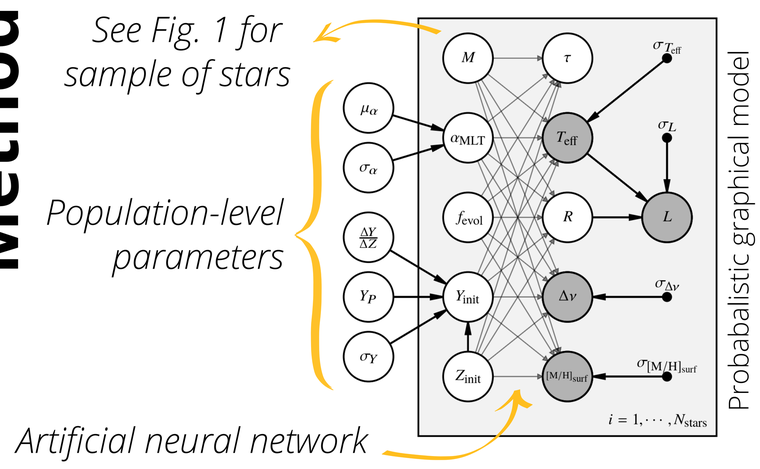
Introduction

High-precision asteroseismology has improved estimates of stellar masses, ages, and radii, but has revealed systematics in poorly constrained parameters like helium abundance (Y) and mixing-length theory parameter ($\alpha_{\rm MLT}$). We applied a hierarchical Bayesian model to enode population level information about Y and $\alpha_{\rm MLT}$ and improve the inference of stellar parameters.

Method



Results

Modelling Y and $\alpha_{\rm MLT}$ hierarchically,

- Reduced the median uncertainties in
  - Mass 2.5%
  - Radius 1.2%
  - Age 2.5%
- Twice as precise for mass compared to a non-hierarchical (star-by-star) model (see Fig. 2)
- $\Delta Y/\Delta Z = 1.05^{+0.28}_{-0.25}$ when including the Sun as a star (see Fig. 3)

Discussion

We showed that we can add typically poorly constrained parameters to the model by treating them hierarchically and still improve the inference of stellar parameters. The theoretical limit in reducing uncertainty through hierarchical modelling goes as $1/\sqrt{N_{\rm stars}}$. Hence, our method is easily scalable in anticipation of new data from NASA's *TESS* and ESA's *PLATO* missions which will provide asteroseismic data for 1000s more stars.

Figures

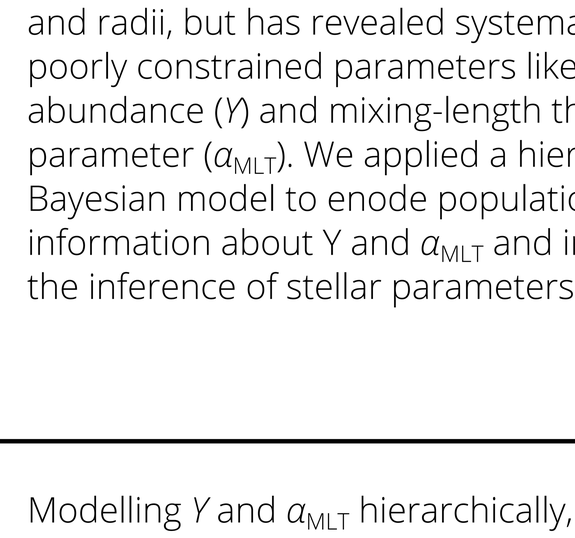


Fig 1. Hertzsprung-Russell diagram for the sample of 81 stars coloured by metallicity. The grey lines are evolutionary tracks for reference.

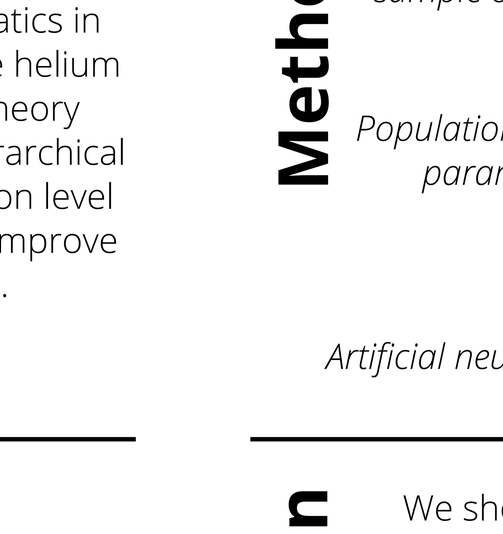


Fig 2. The statistical uncertainties on masses from Serenelli et al. (2017; black line) compared to those from models in this work.

Fig 3. Initial helium abundance against initial metal abundance for the sample of stars. The non-hierarchical model results are in light grey and the hierarchical model results are in black.

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