Asteroseismic Characterization of 12 TESS Exoplanet Host Stars

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Solar-like oscillations

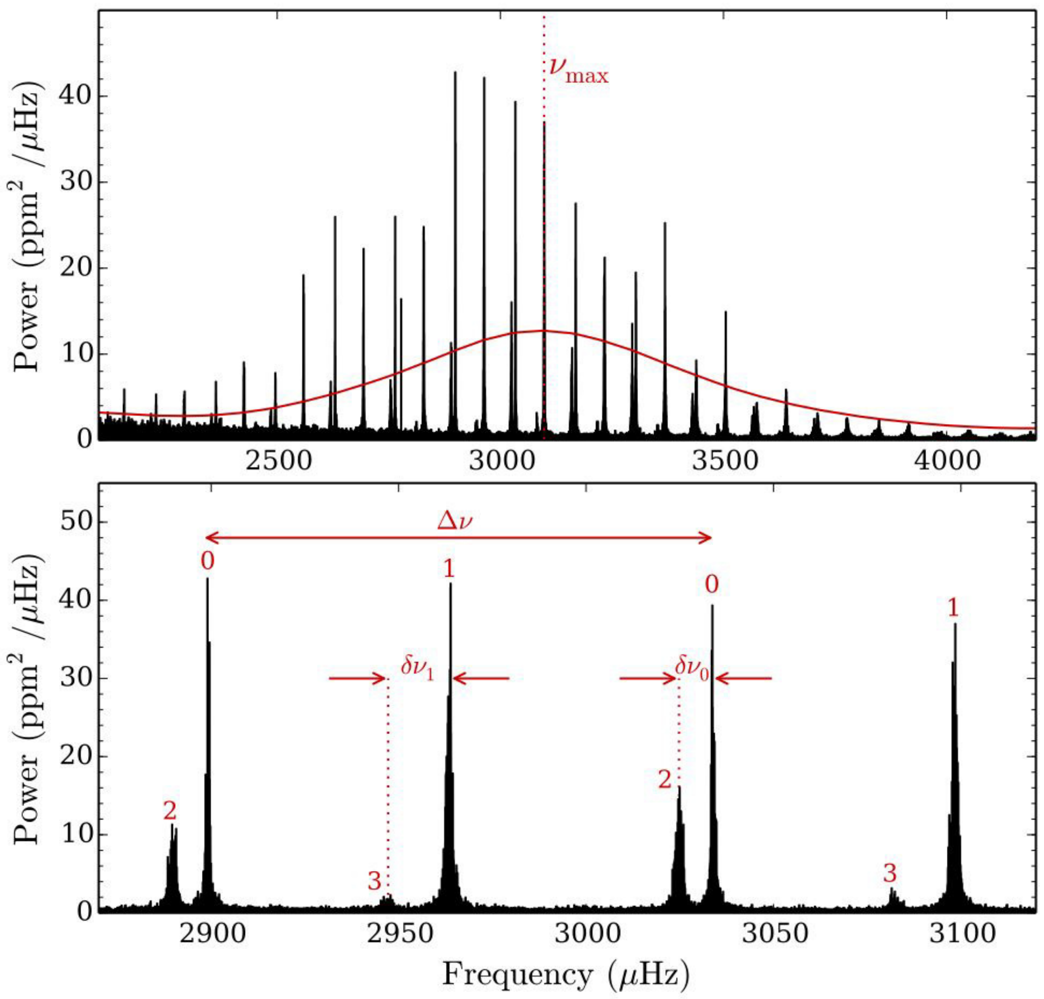
Solar-like oscillations are observed in MS stars, subgiants and LLRGs with masses between $1 - 3\mathrm{M}_\odot$; they are driven by the turbulent motion of the gas in the convective envelope of those stars.

Acoustic modes are characterized for having specific frequencies with a semi-constant spacing, proportional to the **large frequency separation** $\Delta\nu$, and amplitudes modulated by a Gaussian envelope centered in the **frequency of maximum power** ν_{max}.

$\Delta\nu$ and ν_{max} are called the **global seismic properties** and are related to some elements of the stellar structure by well known proportionality relations (Kjeldsen & Bedding, 1995), that allow them to be used for characterizing stars.

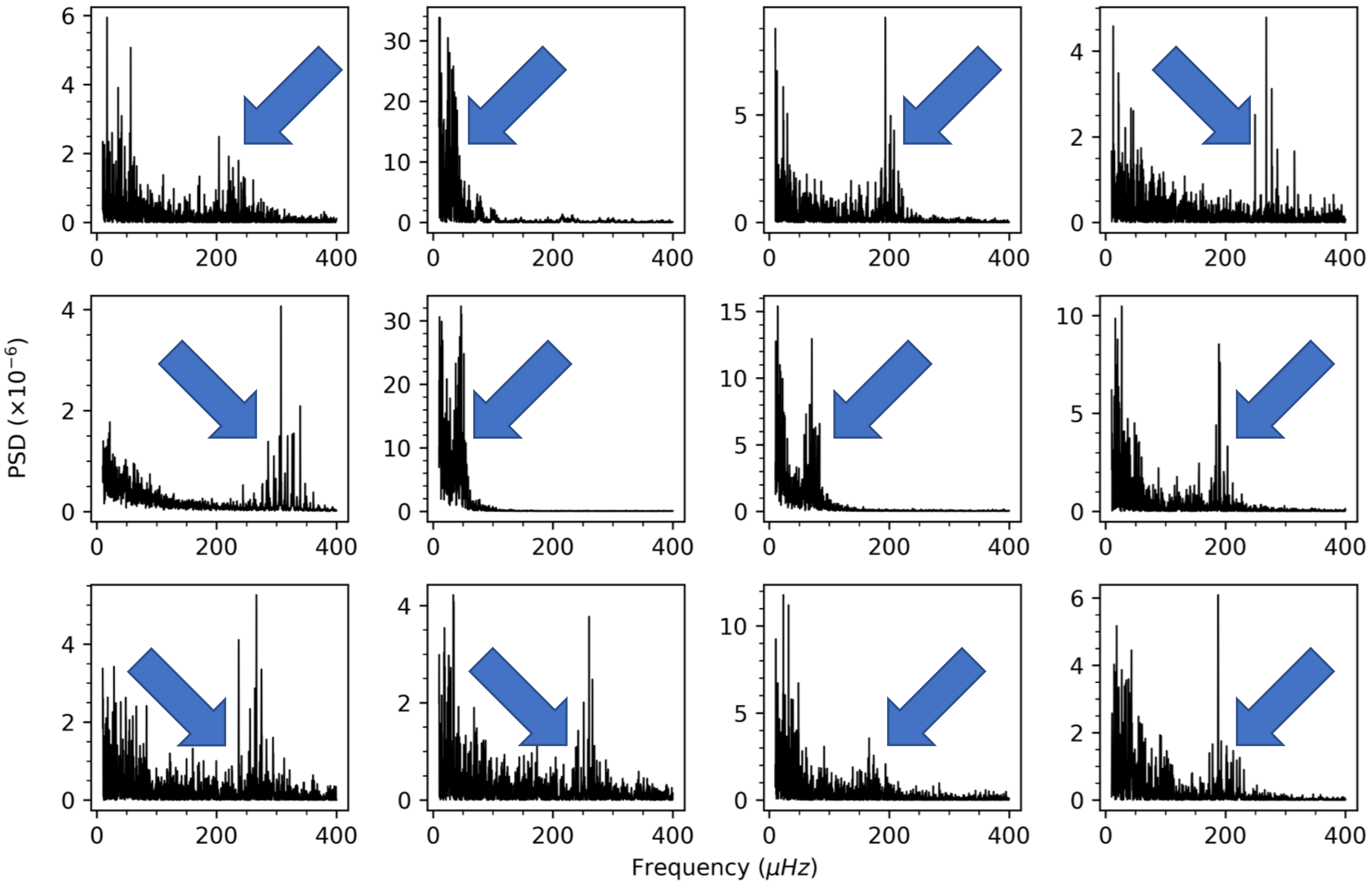
$$\Delta\nu \propto \sqrt{\bar{\rho}} \quad \rightarrow \quad \frac{\Delta\nu}{\Delta\nu_\odot} = \left(\frac{M}{M_\odot}\right)^{\frac{1}{2}} \left(\frac{R}{R_\odot}\right)^{-\frac{3}{2}}$$

$$\nu_{\mathrm{max}} \propto \frac{g}{\sqrt{T_{\mathrm{eff}}}} \quad \rightarrow \quad \frac{\nu_{\mathrm{max}}}{\nu_{\mathrm{max},\odot}} = \left(\frac{M}{M_\odot}\right) \left(\frac{R}{R_\odot}\right)^{-2} \left(\frac{T_{\mathrm{eff}}}{T_{\mathrm{eff},\odot}}\right)^{-\frac{1}{2}}$$



Solar frequency spectrum from Cunha et al., 2018

Objectives



We found solar-like oscillations in the TESS light curves of **12 known exoplanet-hosts**. For 9 of them, there were no studies published in the scientific literature regarding their oscillations.

Our goal is to measure the global seismic properties of those stars and to use them to determine the stars' radii, masses and ages.

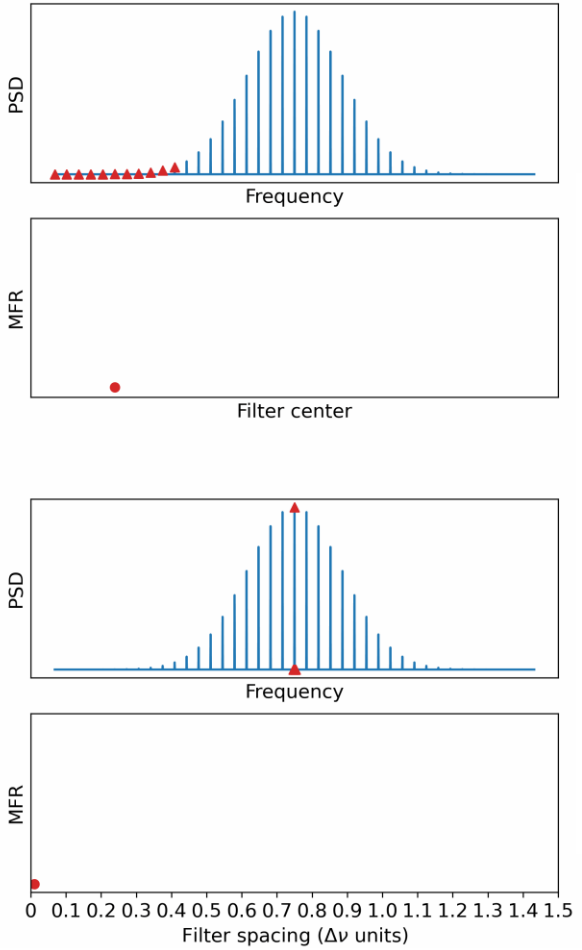
A seismic characterization can yield precise and accurate stellar parameters which are important in the study of those stars' exoplanets

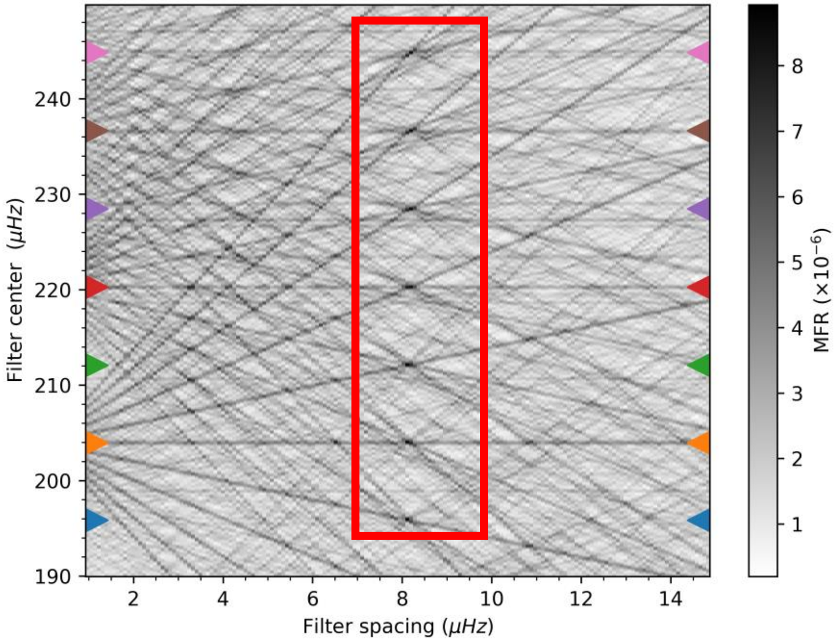
Determining the global seismic properties

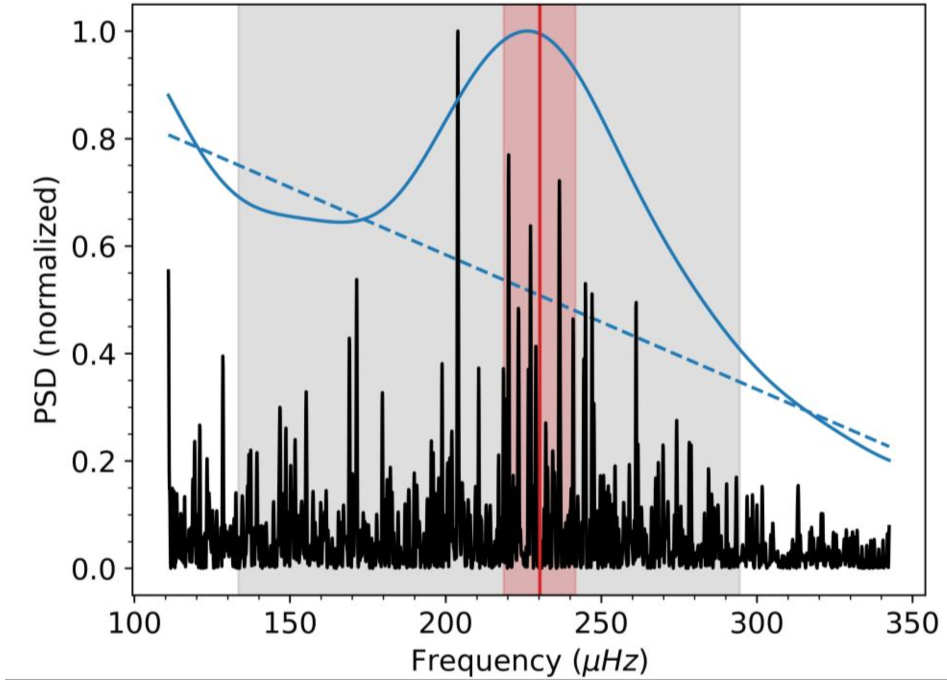
Large frequency separation: we used the Matched Filtered Response (MFR), aligning a Dirac-comb filter to the oscillation peaks (see Christensen-Dalsgaard et al., 2007; Gilliland et al., 2010).

Frequency of maximum power: we smoothed the stars' power spectra with a Gaussian filter with $\sigma = \Delta\nu$. Following Stello et al., 2017 and Malla et al., 2020, we identified $\nu_{\max}$ as the frequency of the maximum in the smoothed spectra, after removing background contributions.

HD 212771



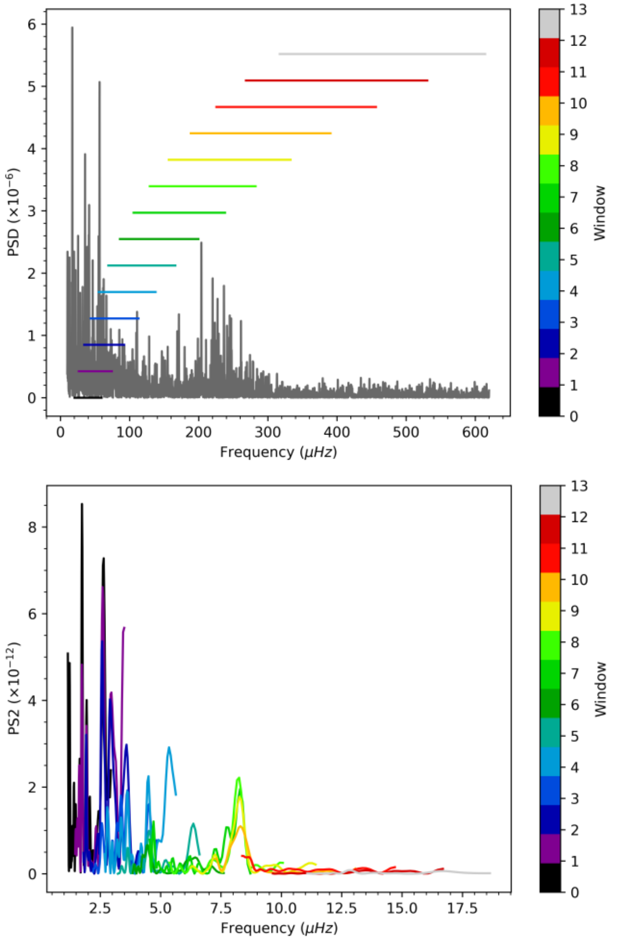


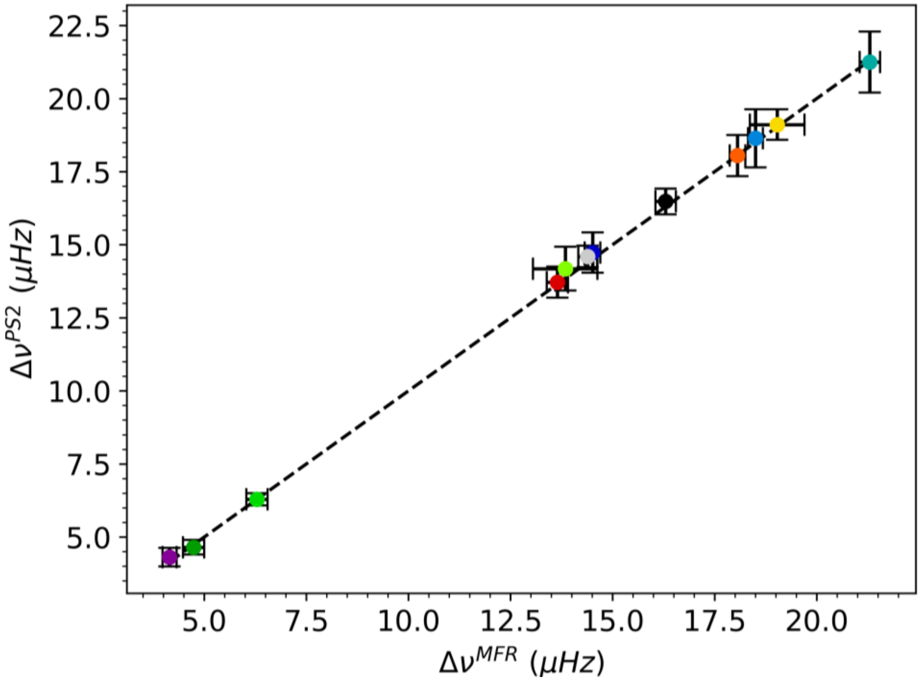


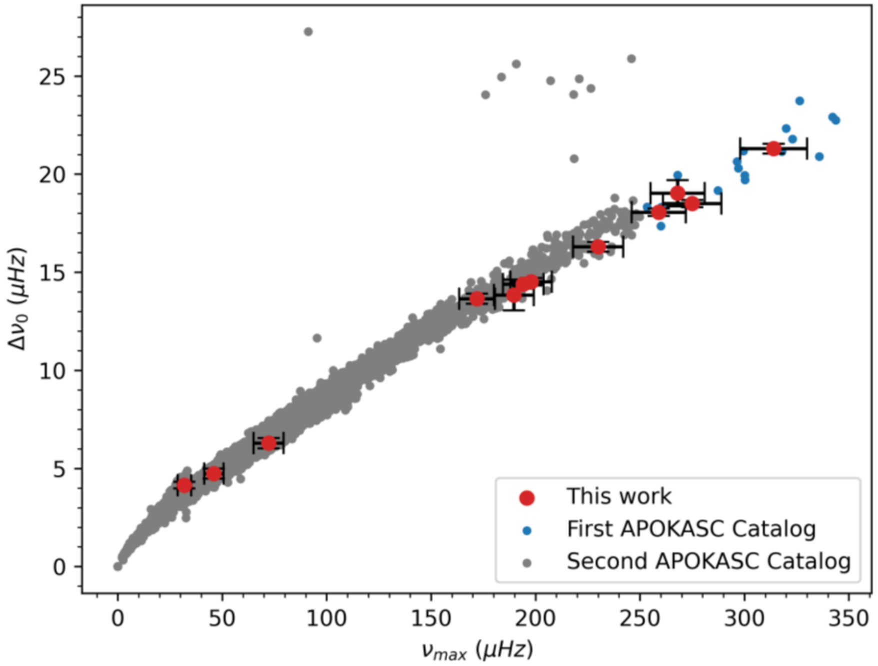
Determining the global seismic properties

We verified the previous determination of $\Delta\nu$ using an independent method of calculating the **power spectrum of the power spectrum** (e.g., Mathur et al., 2010) using a moving window of increasing width.

Results for $\Delta\nu$ and ν_{max} are also consistent with the verified empirical relation between those two quantities (Stello et al., 2009).







1st APOKASC Catalog: Serenelli et al., 2017
2nd APOKASC Catalog: Pinsonneault et al., 2018

Grid-based modeling

Finally, we determined the star's **radii**, **masses** and **ages** using the Yale-Birmingham method of **grid-based modeling** (Basu et al., 2010; Gai et al., 2011) with models from the BaSTI grid (Hidalgo et al., 2018)

Observational parameters
$\Delta\nu$ $\nu_{\max}$
T_{eff} $[Fe/H]$
p

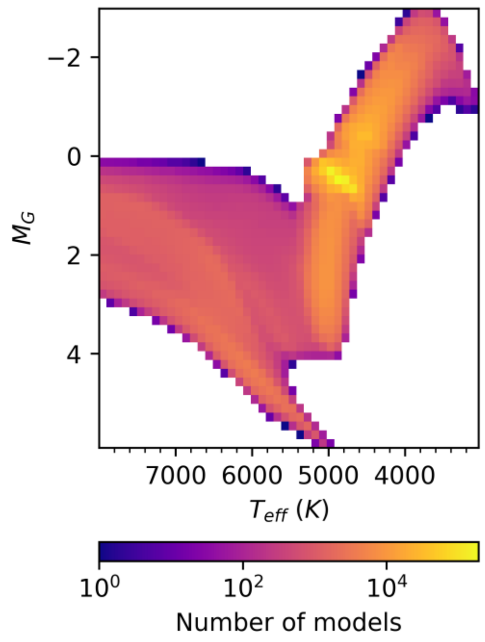
Repeat x10,000 adding noise to the observational parameters

Desired parameters Averages of the models with the highest likelihood values ($\mathcal{L}_i \geq 0.95\mathcal{L}_{\max}$)

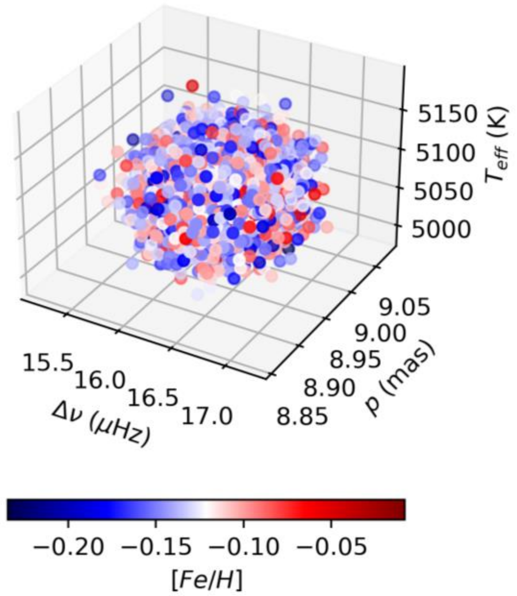
Compared with the models using the **likelihood function**

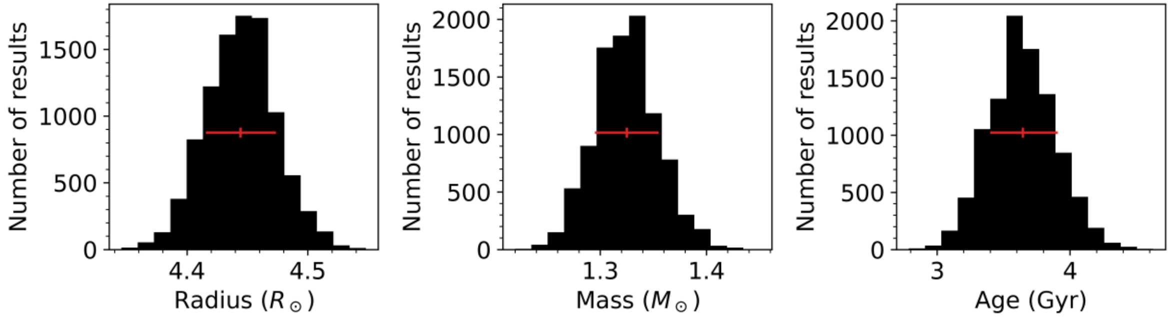
$$\mathcal{L}_i(\{q^{\text{obs}}, \sigma_q\}) = \prod_{\{q\}} \exp\left[-\frac{1}{2}\left(\frac{q^{\text{obs}} - q_i^{\text{teo}}}{\sigma_q}\right)^2\right]$$

The final values are the medians of the distributions of the 10,001 results with uncertainties equal to the distance to the 16% and 84% percentiles (1σ limits)

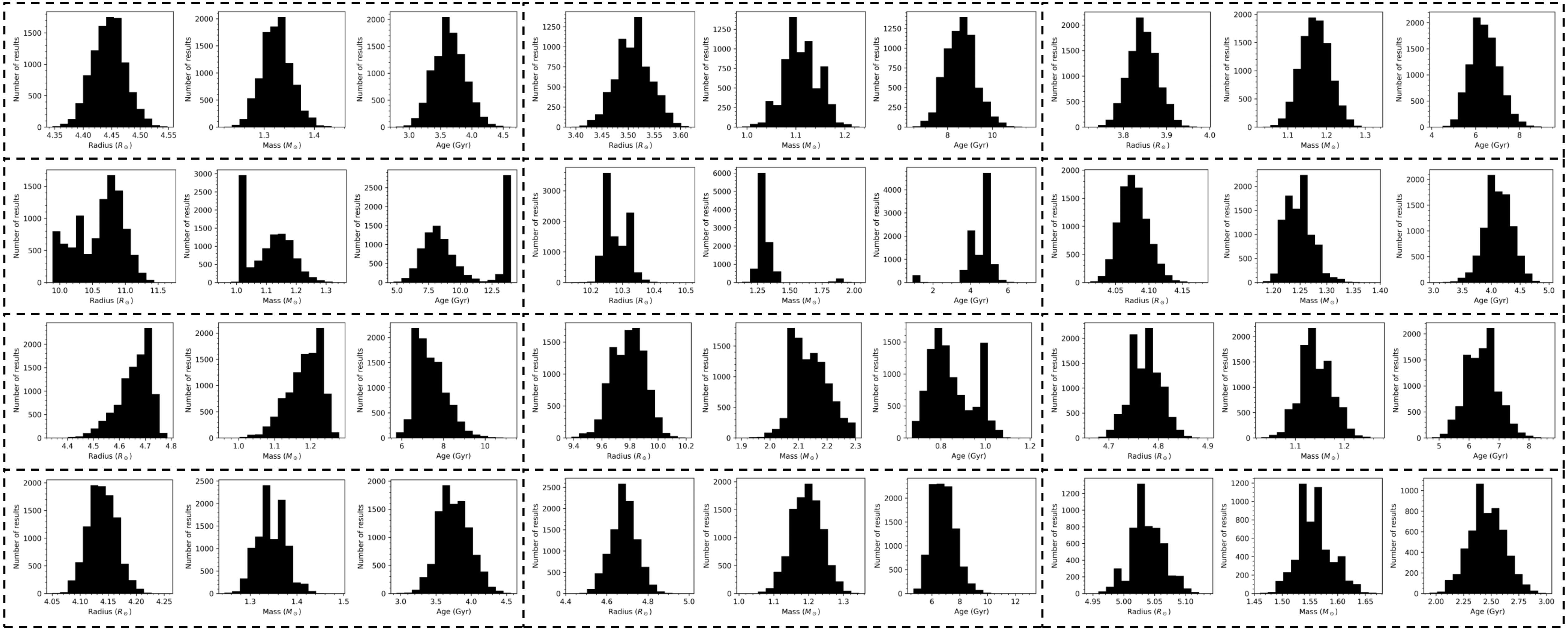


HD 212771

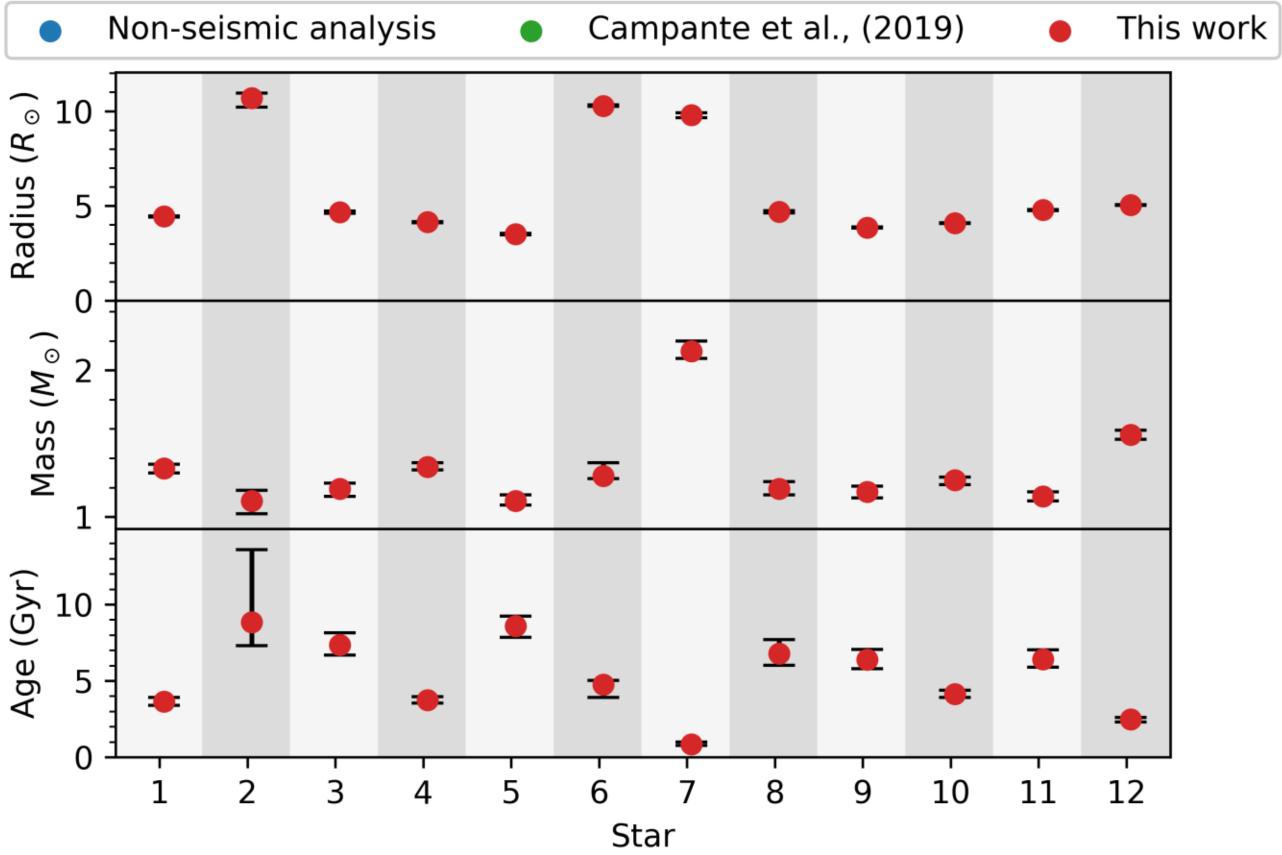




Grid-based modeling



Results



Most of the stars have $\gtrsim 1M_\odot$ and are in the beginning of the RGB

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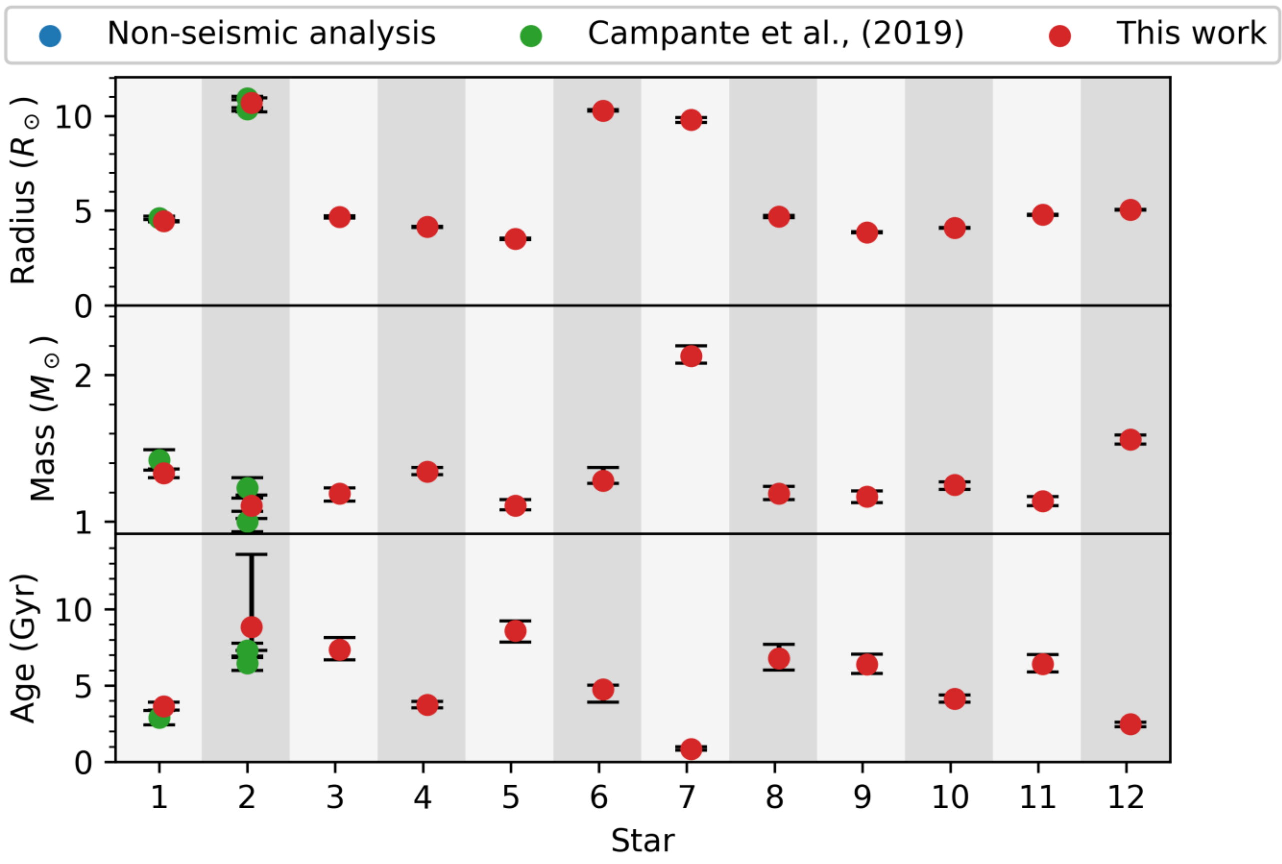

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Results for HD 212771 (Star #1) and HD 203949 (Star #2) are consistent with the seismic analysis done by Campante et al., 2019.

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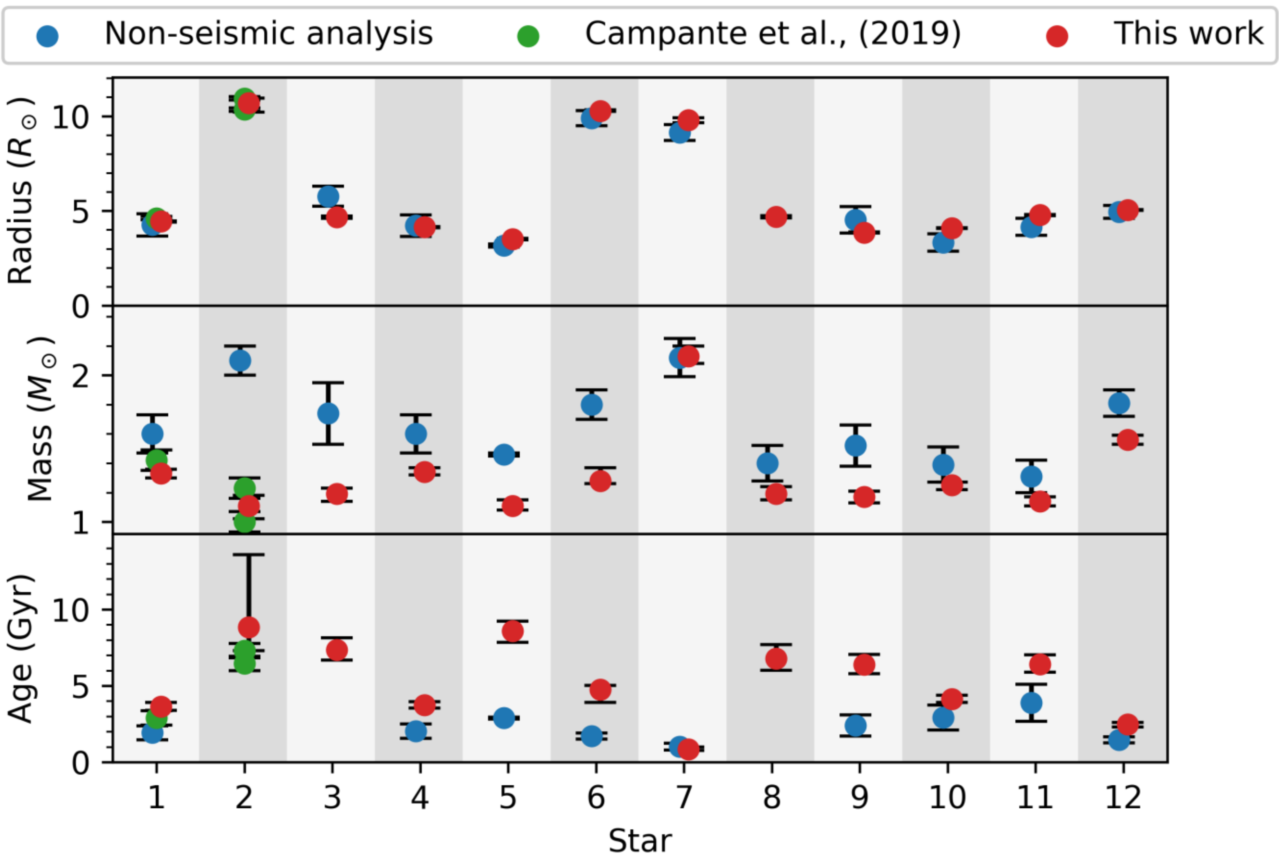

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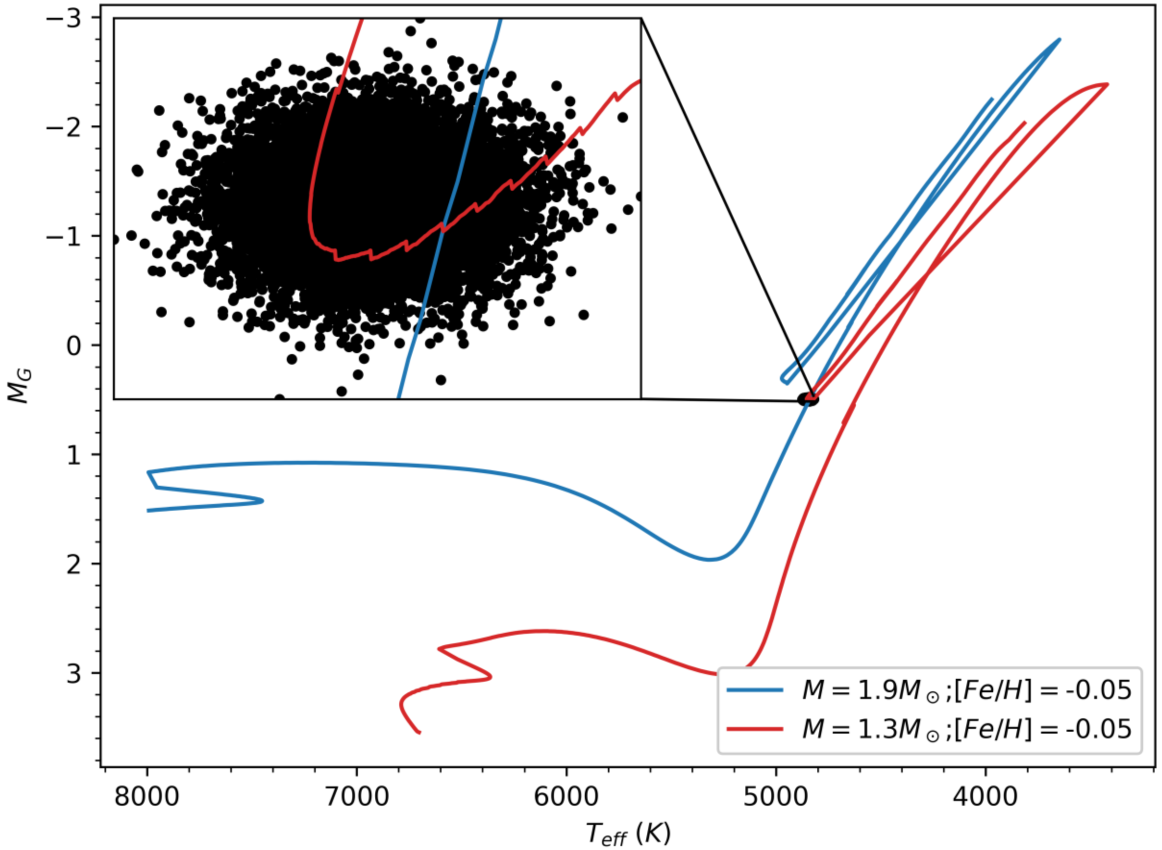
Results for the radii are 3 to 15 times more precise than the ones found by other, non-seismic works. For the masses there is an average improvement of 3 times in the precision. Results for the masses and ages are also systematically greater and smaller than those found in non-seismic works.

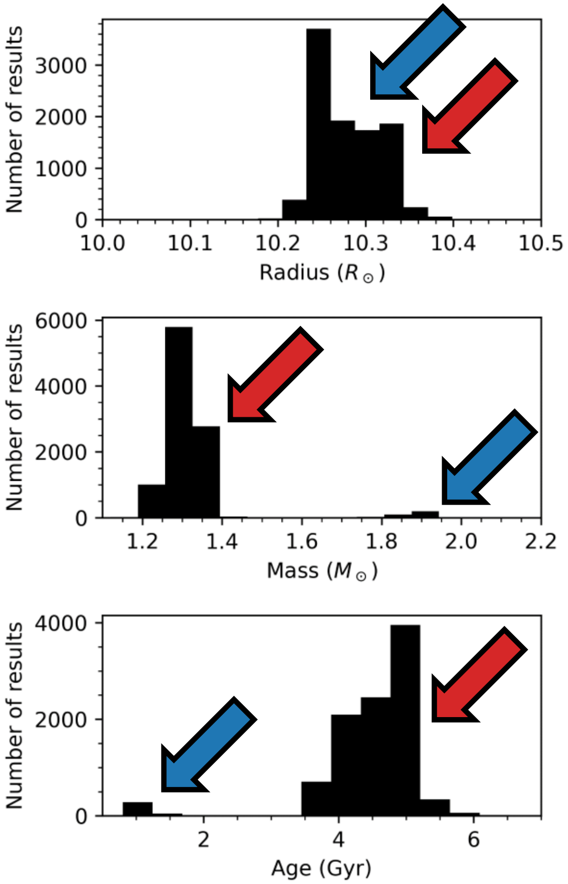
Seismic and non-seismic characterizations

This difference is a common trend observed in other works (e.g., Malla et al., 2020), and is attributed to difficulties in differentiating slow-evolving and fast-evolving evolutionary tracks, when not using the oscillation parameters.

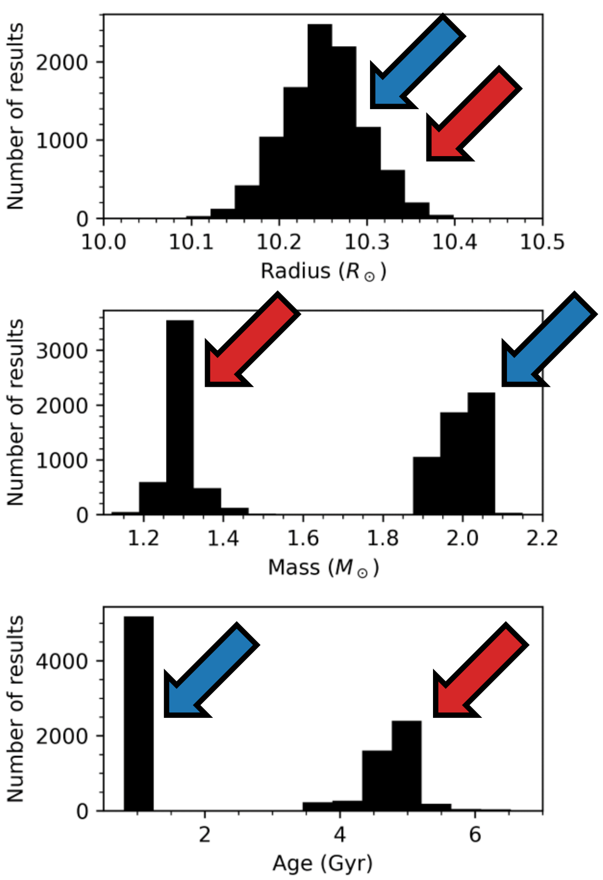
Example: Star #6



Seismic



Non-seismic



Thank you!