PYA2Z: ENSEMBLE PRECISE ASTEROSEISMOLOGY ACROSS THE SKY OF 20,000 TESS STARS WITH GAIA SPECTRA

B. Liagre[1] , R. A. García[2] , S. Mathur[3] , D. B. Palakkatharappil[2] , D. Godoy-Rivera[3]

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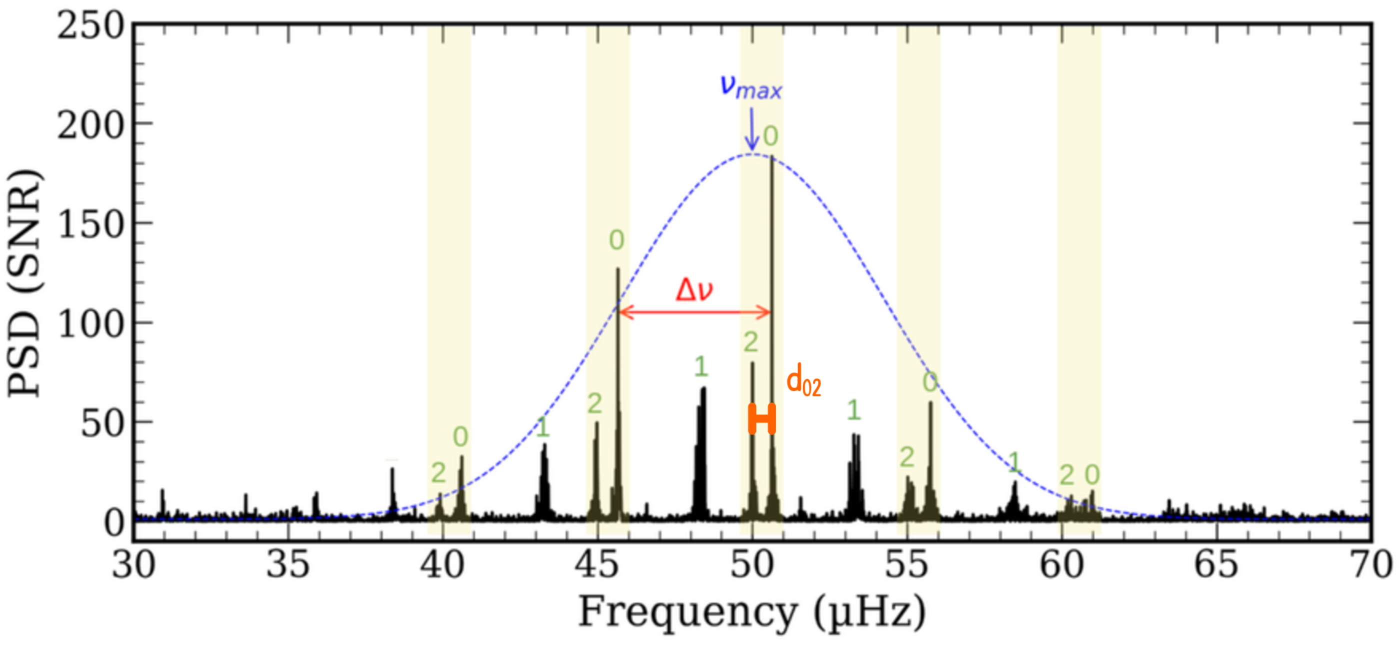
WHAT IS ASTEROSEISMOLOGY?

Asteroseismology of solar-like stars studies the small variations in stellar brightness caused by oscillations excited in the outer convective layers [1]. These oscillations form a rich spectrum of modes, each described by three quantum numbers:

- n – the number of radial nodes (structure in depth),
- ℓ – the angular degree (surface pattern), and
- m – the azimuthal order (orientation around the rotation axis).

These modes can be pressure (p) modes that mainly probe the outer envelope of stars, and are mainly characterized by 4 asymptotic parameters [2]:

- $\Delta\nu$: the periodicity of the pattern
- ν_{max}: the frequency of maximum power
- ε: the phase shift of radial modes
- d_{02}: the small separation between radial and qudrupole modes



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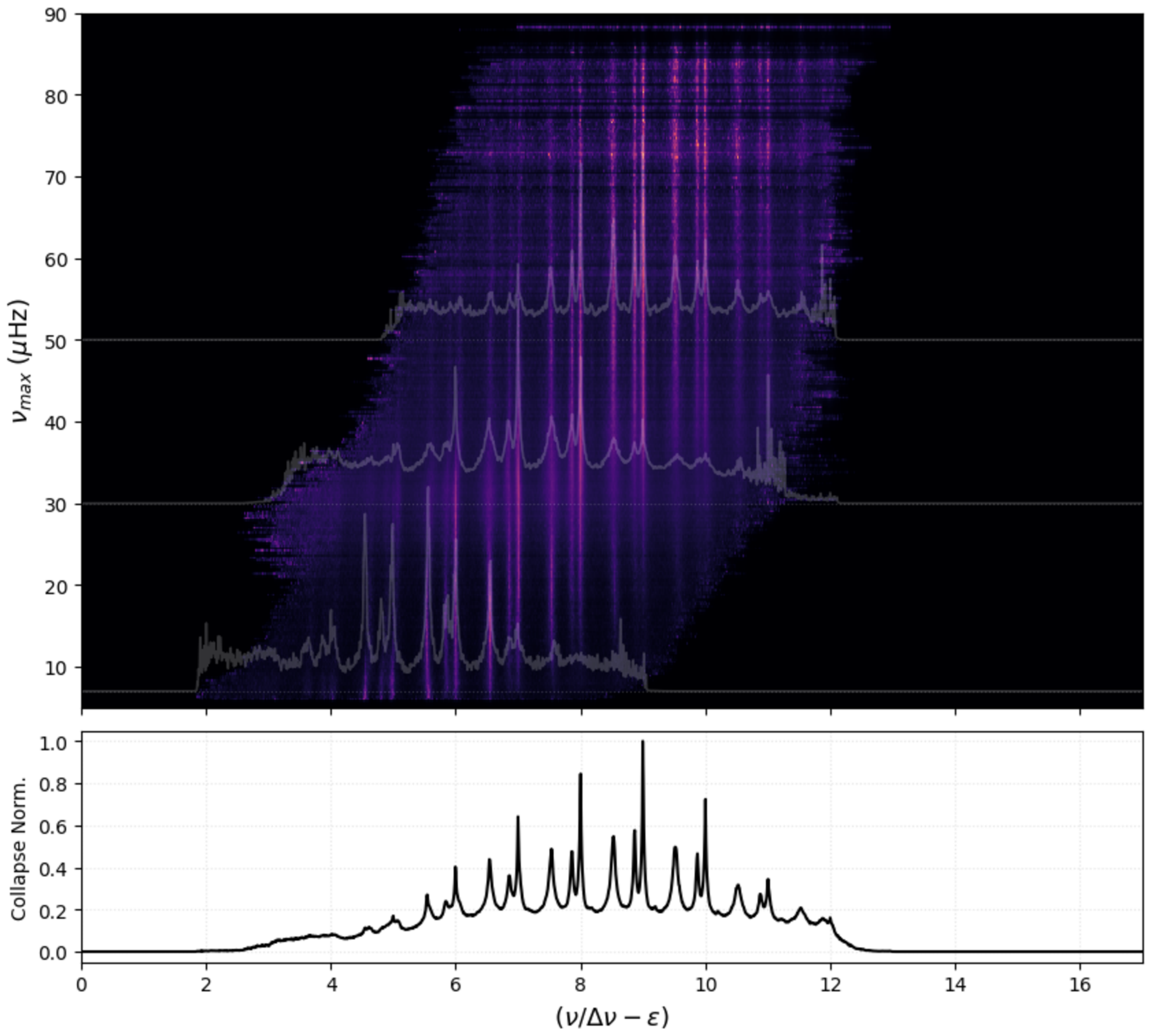
CONTEXT

Asteroseismology of thousands of stars observed by ***Kepler*** [3] fundamentally transformed stellar physics, Galactic archaeology, and exoplanet characterization. While TESS [4] has expanded our view to millions of new stars, its shorter observing baselines and lower signal-to-noise ratios mean its data remains widely underutilized for ensemble seismic characterization. In this work, we precisely characterize over 20,000 new red giants observed by TESS. By extracting seismic parameters across these challenging targets, we provide a massive, uniform catalog of stellar masses, radii, and ages to the community.

3

DETERMINATION OF ν_{MAX} AND $\Delta\nu$

After a first guess using the PSD of the PSD [5], ν_{max} is determined by fitting a local power law and gaussian background around the power hump [5,6] of stellar oscillation and $\Delta\nu$ along with the rest of the asymptotic parameters are derived using a correlation based approach with a synthetic stellar oscillation pattern following the universal pattern methodology [7].



Ensemble échelle diagram [7]: Each row shows the average spectrum at a given ν_{max}, with frequencies normalized by $\Delta\nu$ and shifted by ε. The straight, well-defined ridges demonstrate the pipeline's accurate determination of the asymptotic parameters.

4

COMPUTATION OF RADIUS, MASS AND AGE

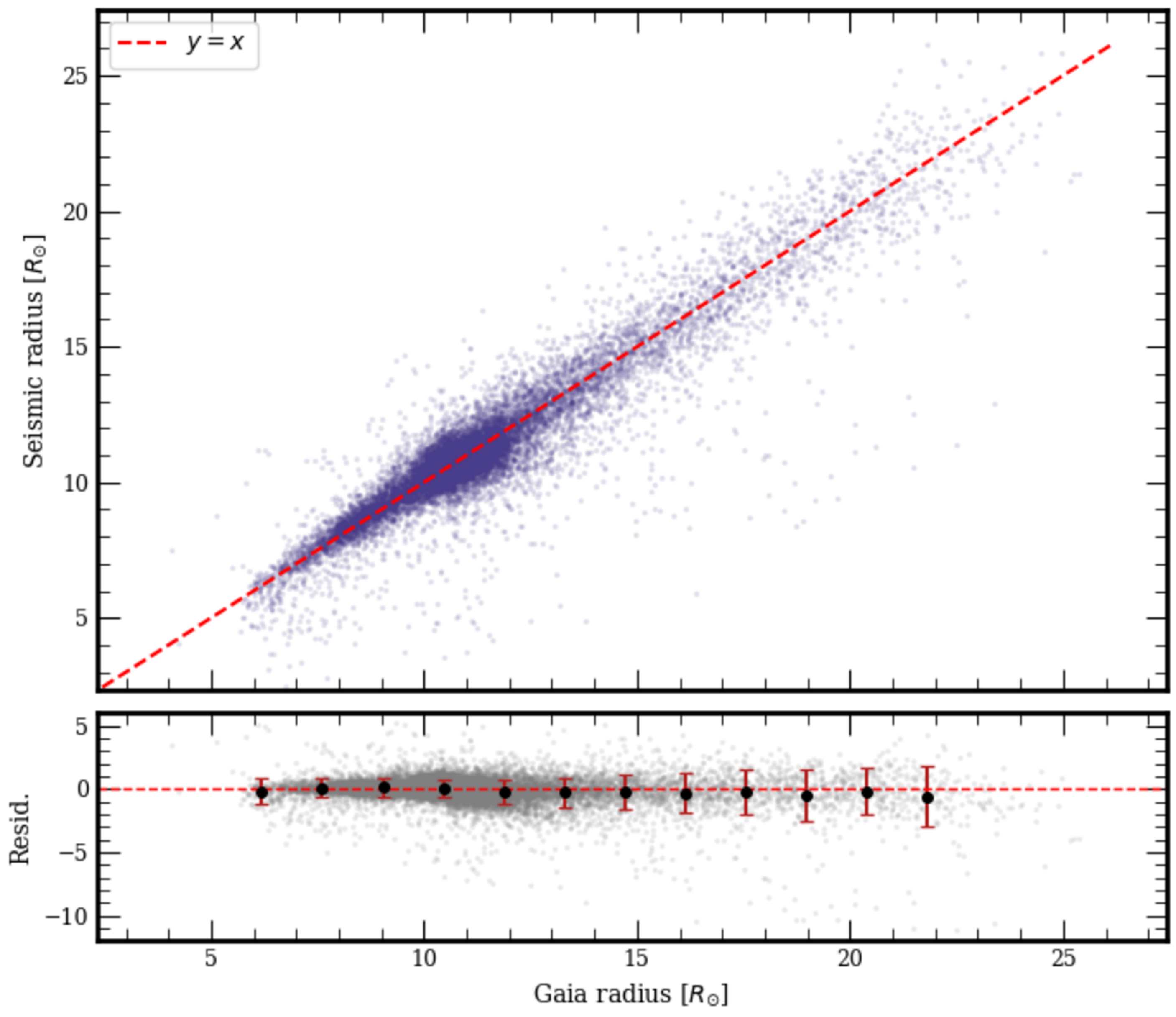
Using the asfgrid [8,9], we implement a monte carlo method to compute masses, radii and ages of stars along with their uncertainties. We use the spectrophotometric temperatures and metallicities coming from the XPSpectra and XGBoost methodology [10] in order to get the fundamental parameters of the star along with the correction $f_{\Delta\nu}$ to the seismic scaling relations:

$$\frac{M}{\mathrm{M}_\odot} = \left(\frac{\nu_{\max}}{\nu_{\max,\odot}}\right)^{3} \left(\frac{f_{\Delta\nu}\Delta\nu}{\Delta\nu_\odot}\right)^{-4} \left(\frac{T_{\rm eff}}{\mathrm{T}_{\rm eff,\odot}}\right)^{1.5}$$

$$\frac{R}{\mathrm{R}_\odot} = \left(\frac{\nu_{\max}}{\nu_{\max,\odot}}\right) \left(\frac{f_{\Delta\nu}\Delta\nu}{\Delta\nu_\odot}\right)^{-2} \left(\frac{T_{\rm eff}}{\mathrm{T}_{\rm eff,\odot}}\right)^{0.5}$$

COMPARISON WITH GAIA RADII

To validate our pipeline, we compared the seismic radii against Gaia bolometric radii (bolometric corrections from [11]) for targets with low extinction (< 0.7) [12]. We find a negligible median relative difference (< 0.1%) and a Median Absolute Deviation (MAD) of 3.8%. This remarkable agreement underscores the high precision and systematic consistency between our asteroseismic modeling and independent astrometric/photometric scales.



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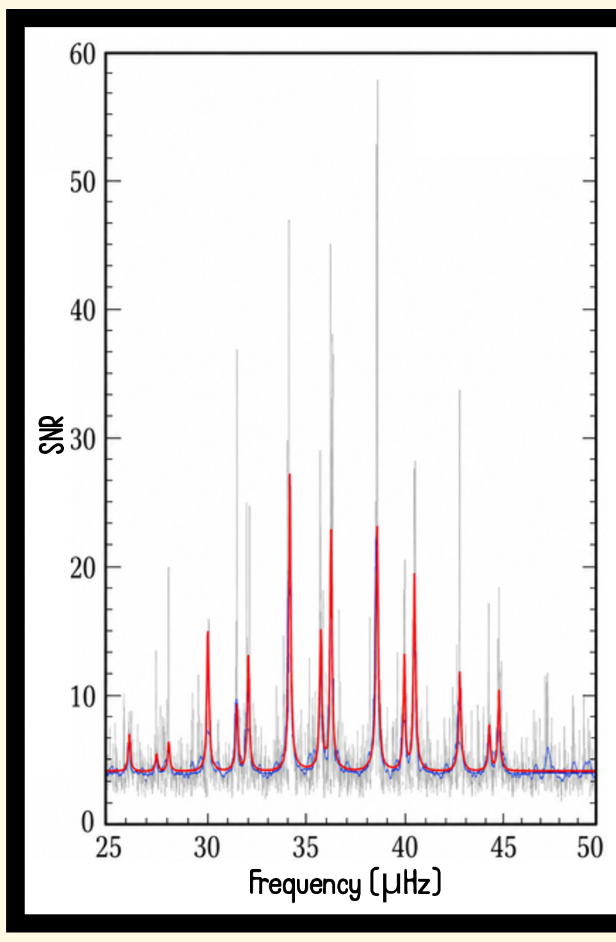
CONCLUSION



We have successfully deployed the new PyA2Z pipeline [13,14] to derive precise seismic parameters for over 20,000 RGB and red clump stars [15], with robust validation against independent Gaia radii. Furthermore, its automated l=0, 2 mode fitting has already characterized 3,000+ stars. This unlocks the use of high-precision individual-mode grid modeling to fundamentally tighten galactic archaeology constraints [16].

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AFFILIATIONS

1. Université Paris Cité, Université Paris-Saclay, CEA, CNRS, AIM, 91191, Gif-sur-Yvette, France
2. Université Paris-Saclay, Université Paris Cité, CEA, CNRS, AIM, 91191, Gif-sur-Yvette, France
3. Instituto de Astrofísica de Canarias (IAC), E-38205 La Laguna, Tenerife, Spain

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