# Using 'Pulsating Binaries' as test beds for asteroseismic scaling relations

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## Introduction & Motivation

Asteroseismic scaling relations associate stellar attributes such as mean density and temperature to their asteroseismic indices, namely frequency at maximum amplitude ($\nu_{max}$) and mean frequency separation ($\Delta\nu$). Stars exhibiting solar-like oscillations have been extensively studied using this technique. Utilisation of ensemble asteroseismology to study fundamental properties of a large number of stars requires asteroseismic scaling relations that are accurate.

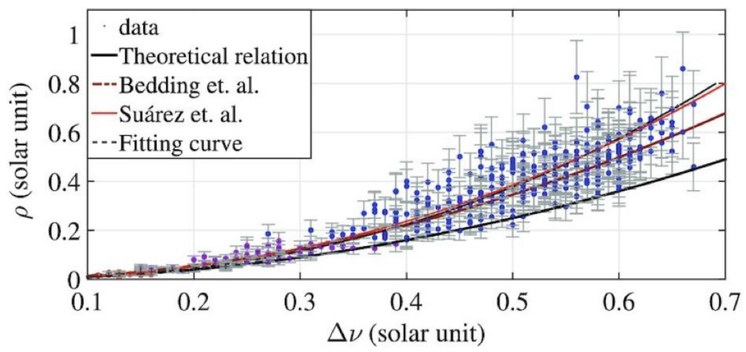
Kepler and TESS have expanded the horizons of our knowledge of intermediate mass pulsators, which were hitherto poorly understood. As a result, a bunch of scaling relations have been proposed for δ **Scuti** type pulsators (García Hernández et al. 2015, Barceló Forteza et al. 2020, Bedding et al. 2020, Hasanzadeh et al. 2021).

## Problem at hand

**There is a need to check the scaling relations proposed for δ Scuti type pulsators against set of model -independent parameters. This is crucial to determine and correct for systematics leading to over/ under estimation of stellar parameters.**

## How to address the problem?

Digging into the 'astrophysical gold mines' of model-independent and accurate stellar parameters - Eclipsing Binaries, containing δ Scuti type pulsators. Such Pulsating Binaries (PBs) can prove to be excellent test beds necessary for validation and improvement of scaling relations for these intermediate mass pulsators.



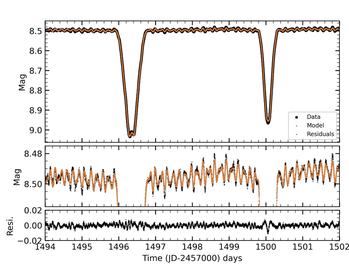

$\Delta\nu$-$\rho_{(mean)}$ plotted for 438 δ Scuti stars, which are recognized with $3 \leq \log g \leq 3.5$ (red circles), $3.5 < \log g \leq 4.0$ (purple circles), and $4.0 < \log g \leq 4.5$ (blue circles). The fitted curve $\nu = (0.76 \pm 0.01)\ \rho^{0.43\pm0.02}$ presented by black line. The theoretical (blue line) $\nu = \sqrt{\rho}$ Aerts et al. (2010), empirical relations $\nu = 0.78\ \rho^{0.46}$ (red line), and $\nu = 0.85\sqrt{\rho}$ (purple line) are introduced by Suárez et al. (2014) and Bedding et al. (2020) and compiled by Hasanzadeh et al. (2021).

## Techniques & Test Case

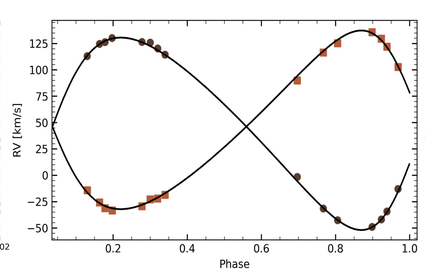
Eclipsing binaries with both components visible in the spectra (SB2) can be fully solved to obtain absolute stellar parameters. As a test case we chose the system **AI Hydrae** with known δ Scuti type pulsations and 2-min cadence light curves from TESS. Masses and Radii were constrained with an accuracy of <1% and <2% respectively, alongside other orbital and atmospheric parameters, using techniques showcased in plots below. Frequency analysis was performed to obtain $\nu_{max}$ for the secondary component which is expected to be the pulsator. This $\nu_{max}$ was then used to obtain estimates of $T_{eff}$ and mean density using the proposed scaling relations.

$T_{eff}^{sec}$(LC/Spectra) = **7100 ± 250 K**,
$T_{eff}^{sec}$(Scaling relation) = **7200 ± 60 K**

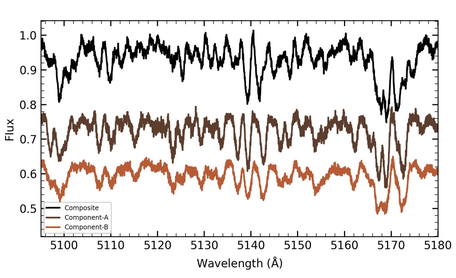
$\rho^{sec}_{(mean)}/\rho_{(Sun)}$ (LC/Spectra) = **0.035 ± 0.001**
$\rho^{sec}_{(mean)}/\rho_{(Sun)}$ (Scaling relation) = **0.030 ± 0.017**



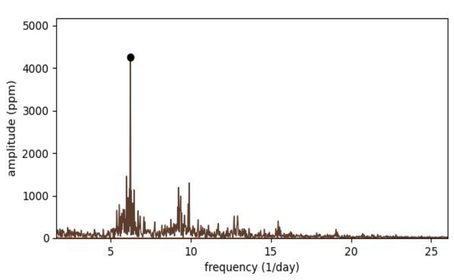

LC modeling (JKTEBOP)



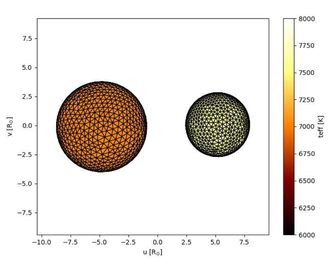

RV modeling




Spectral disentangling+analysis




Frequency analysis



Modeling & Visualisation in PHOEBE

From scaling relations

masses, radii, $T_{eff}$, & mean densities

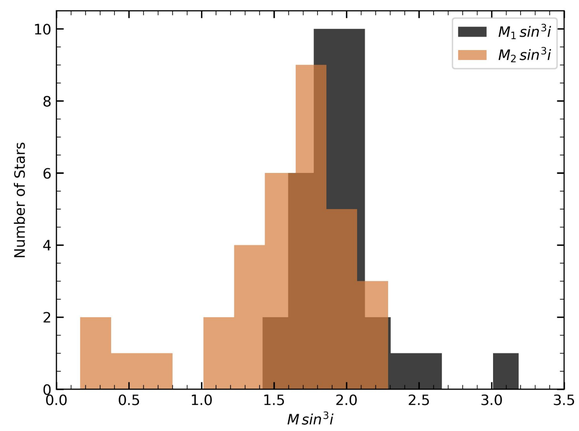
**Compare**

masses, radii, $T_{eff}$ logg, densities & more

By modeling PBs

## Future Work

- ~ 40 intermediate mass PB candidates identified using their spectroscopic masses.
- TESS 2-min cadence available for all systems in the sample and was used to verify the presence of pulsations. More data for all the targets is being requested through DDT proposals and GI program.
- Simultaneous light curve, radial velocity and spectral modeling is ongoing for multiple targets. The results will provide a set of model-independent stellar parameters to validate the proposed scaling relations. We will also search for correlations between asteroseismic indices and full set of obtained parameters for the pulsators.
- The final sample will add a significant number of EBs with accurate (<1%) parameters to the current list. This will help us better understand the underlying pulsation mechanism in such stars, binary interaction and stellar evolution in general.




Distribution of M sini obtained from the spectroscopic sample

Let's discuss further over a cup of coffee

Ping me on slack @**Tilak Pawar**

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