AI Hydrae: Revisiting our pulsator friend

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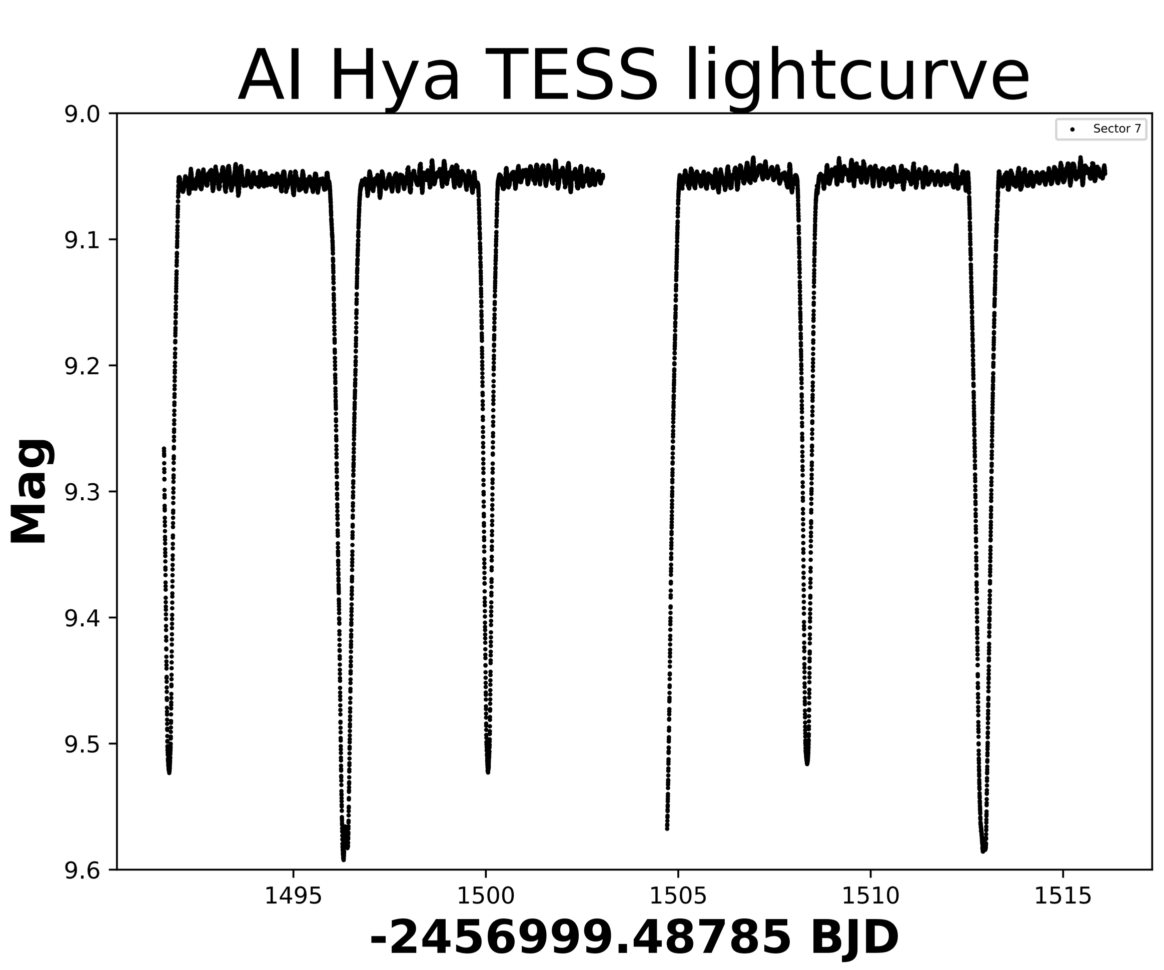
Abstract

We model the TESS lightcurve (LC) of AI Hya, an eclipsing binary system with a delta Scuti pulsator, using JKTEBOP. We simultaneously fit sinusoidal and polynomial functions along with the binary orbit to account for the LC variability caused by the pulsations. This modelling is complimented further by frequency analysis of the out-of-eclipse pulsation signals and analysis of our own set of spectra observed at different orbital phases using HIDES* spectrograph. This helps us obtain accurate orbital and stellar parameters with robust errors.

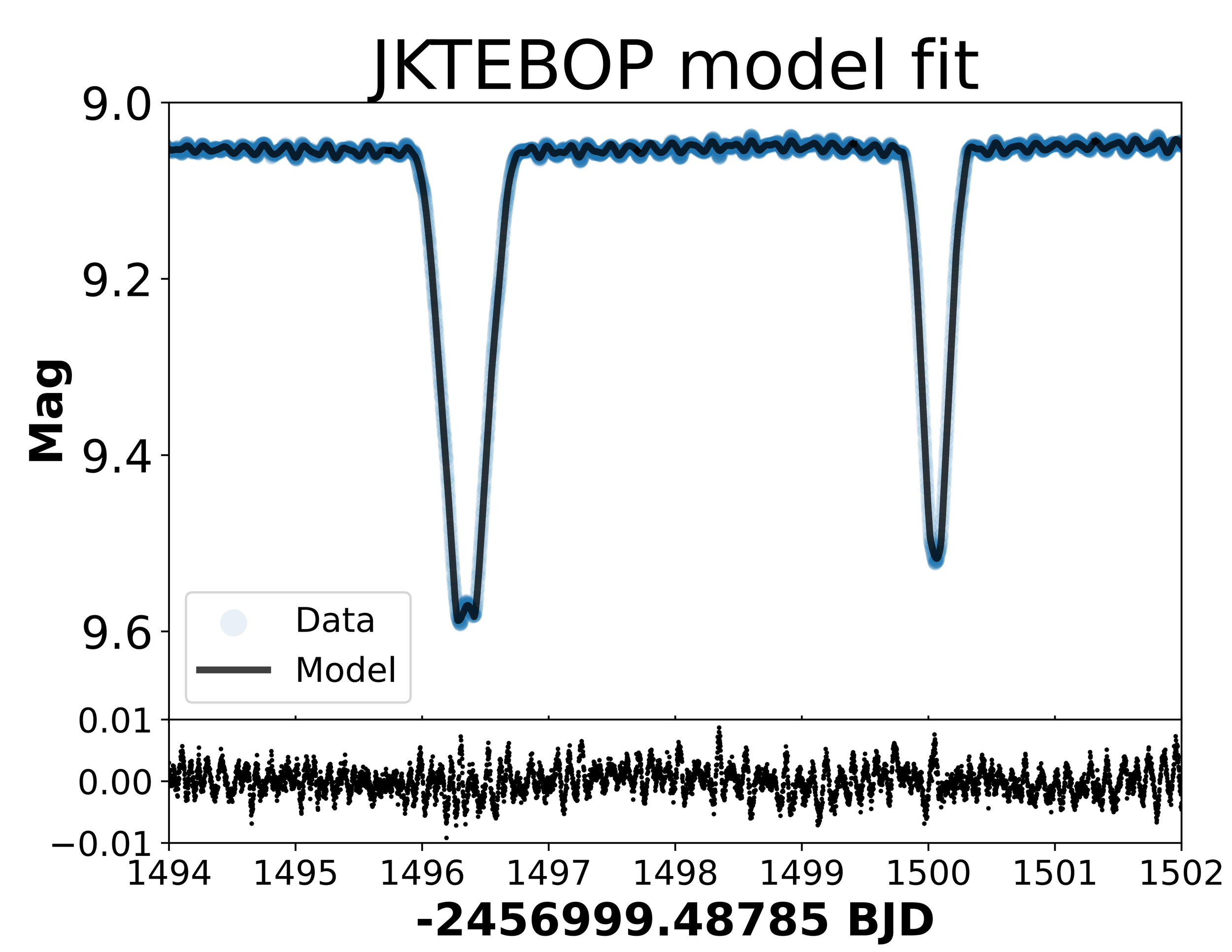
INTRODUCTION

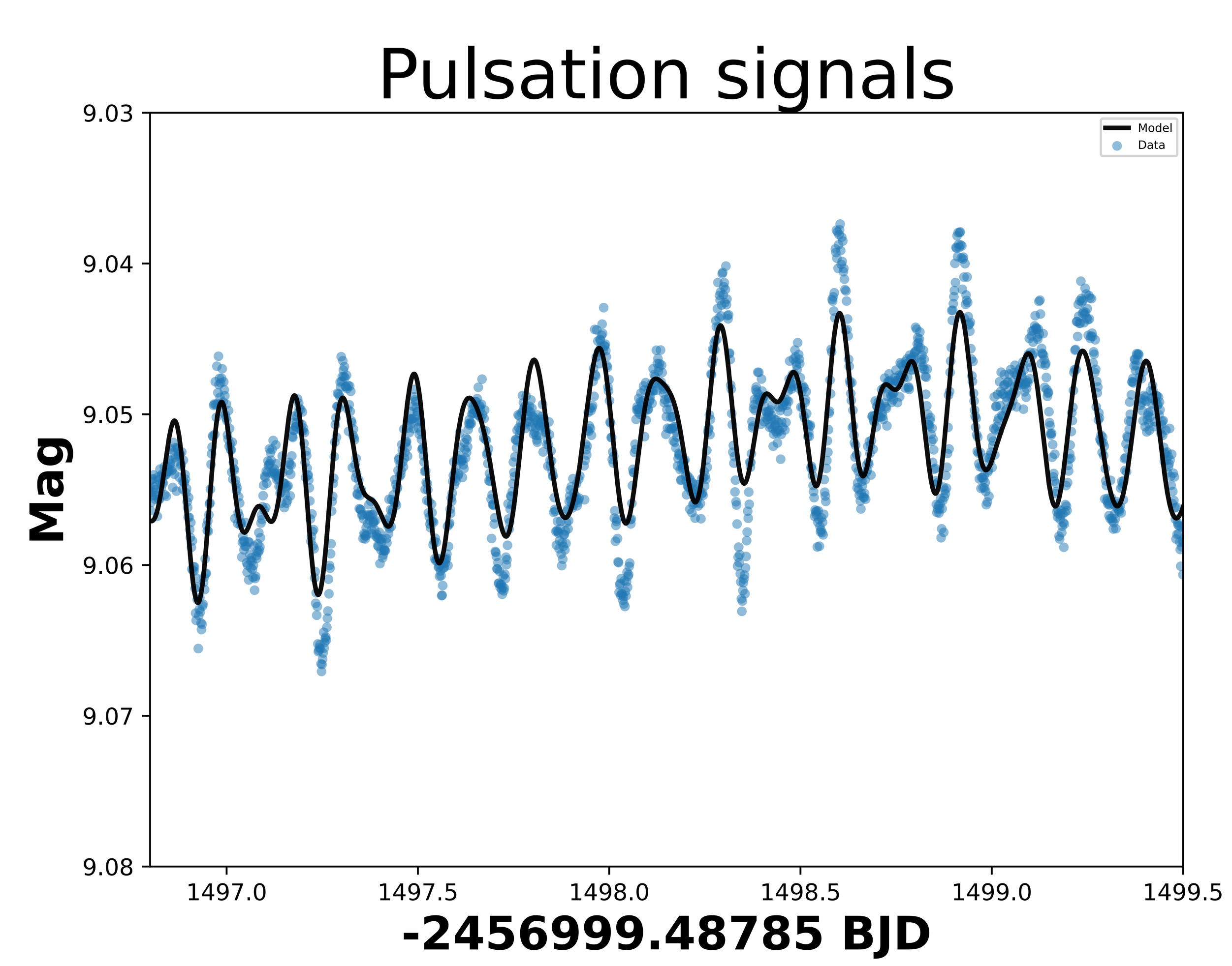
- One of the powerful techniques to determine the fundamental stellar parameters with high precision is solving an eclipsing binary system. Solving the orbit of an eclipsing binary (EB) system, complimented by other methods like radial velocity measurements to get dynamical masses, can give us precise orbital and stellar parameters.
- Asteroseismology can probe the interior of stars, which is otherwise inaccessible through observations. Eclipsing binary systems with a pulsating star thus provide an excellent laboratory to measure the stellar parameters using the above two techniques and at times calibrate one using the other.
- AI Hya has generated a special interest over the years [1] [2] as it hosts a multi mode delta Scuti pulsator. The position of these pulsators on and slightly above the main sequence allows us to compare the oscillation spectrum to the stellar models in a region on the Hertzsprung-Russel diagram where basic stellar structure is quite well understood.



Lightcurve Analysis

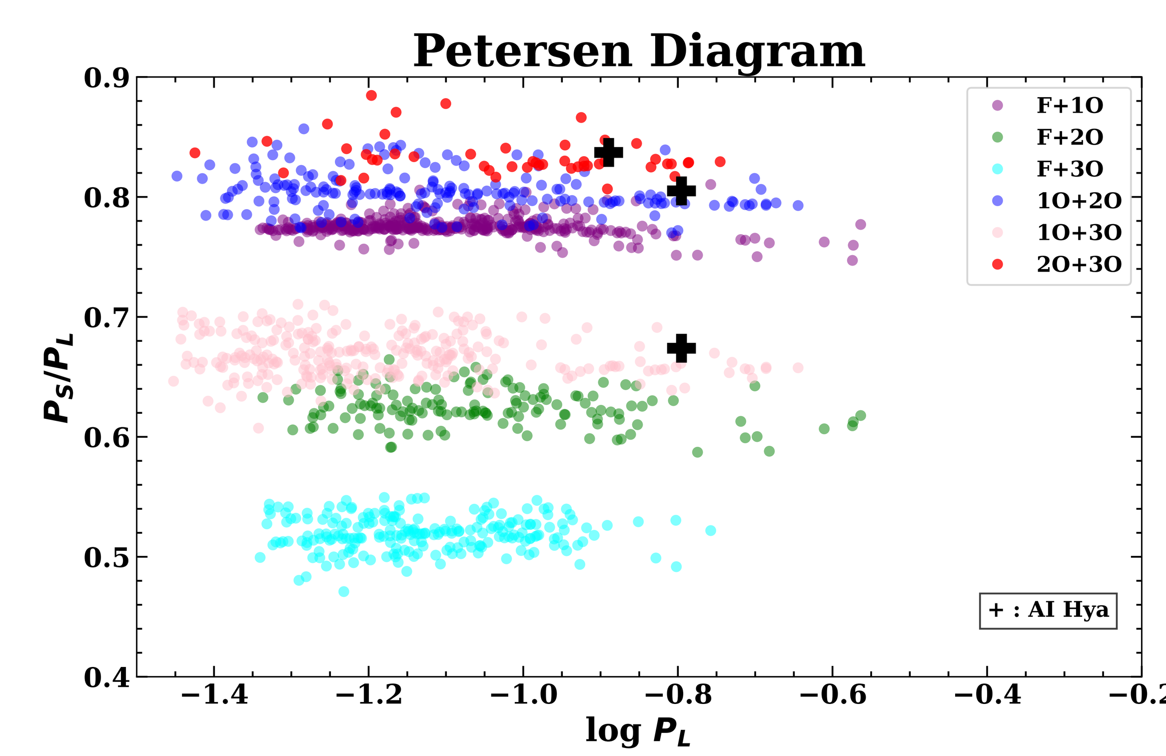
- TESS [3] lightcurve for AI Hya was downloaded from MAST* archive and the analysis was performed using JKTEBOP lightcurve modelling code [4][5].
- The binary orbit was modelled simultaneously in JKTEBOP using 9 sinusoids and 2 polynomial functions to account for the variability and trends in the data. This was implemented to minimise the effect of pulsations on the calculation of binary orbit.
- A simple binary model was calculated without the sines and subtracted from the data to perform frequency analysis of the residual pulsation signals.
- Errors on the obtained parameters were estimated by using Markov Chain Monte Carlo (MCMC) runs.





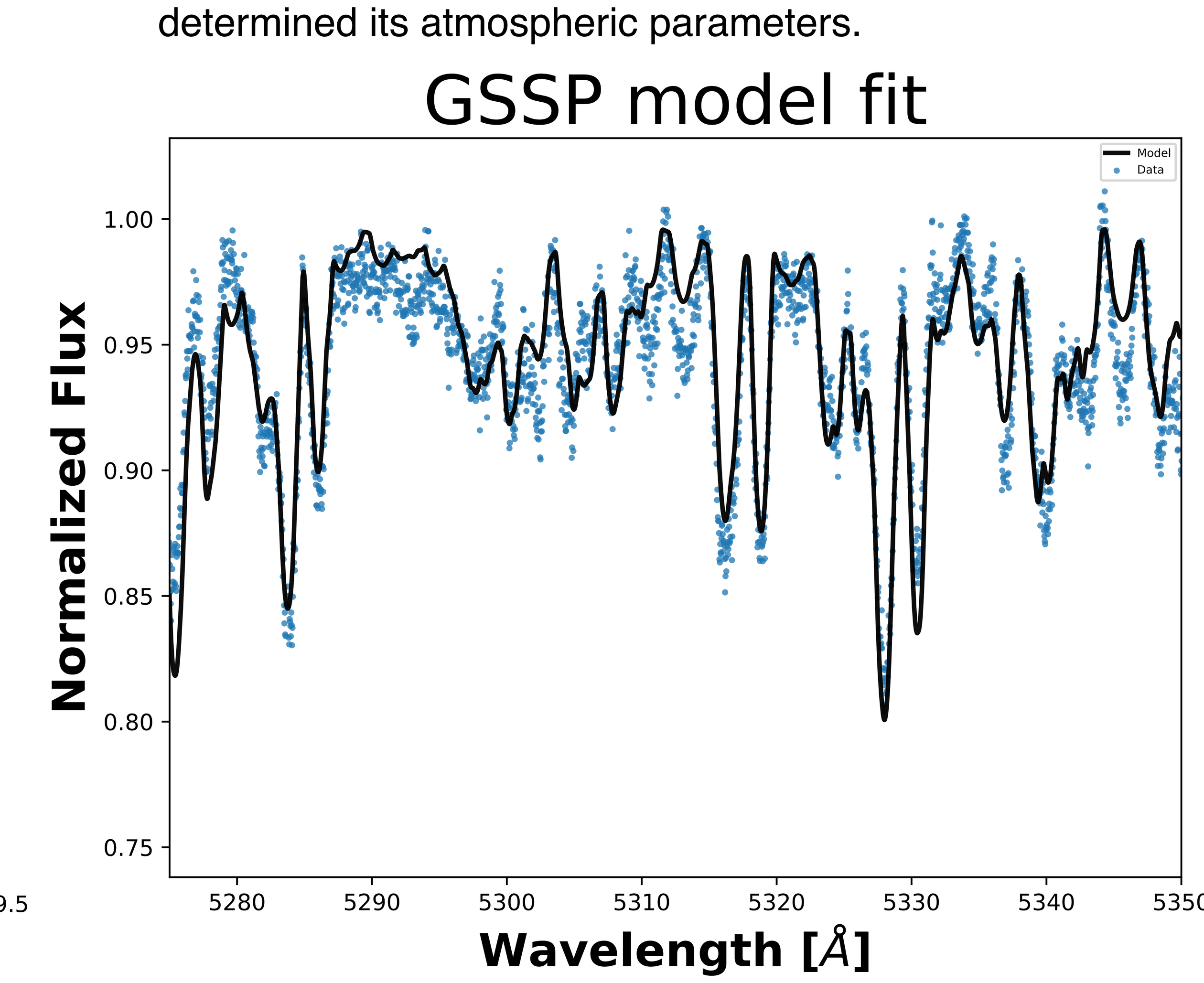
Frequency Analysis

- 17 significant frequencies (independent and combinations) were found using successive pre-whitening method during the analysis of the out-of-eclipse portion of the lightcurve.
- We investigate the independent frequencies by plotting period ratios on Petersen diagram* against the literature multi-mode delta Scuti samples from OGLE database [6][7]. Period ratios of our target (black plus) belongs to three distinct sequences as seen in the figure below, hence corresponding to triple mode star pulsating in 1O+2O+3O (O:overtone) mode. Precise asteroseismic modelling of such triple mode stars is excellent to test stellar evolution theory (e.g. [8]).



Spectroscopy

- Spectroscopic data collected using HIDES* spectrograph was analysed using Grid Search in Stellar Parameters package [9]. Using this package we disentangled composite spectra from double lined AI Hya system and determined its atmospheric parameters.



Initial Results

- Parameters obtained from lightcurve modelling and combined radial velocity analysis (Popper, 1988 and our data).
  - Inclination = 89.43+/-0.22
  - Projected semi-major axis (a sin(i)) = 27.57+/-0.18
  - Eccentricity = 0.243+/-0.003
  - Radius of hotter component = 2.83+/-0.05 R_{sun}
  - Radius of cooler component = 3.95+/-0.07 R_{sun}
  - Mass of hotter component = 1.96+/-0.07 M_{sun}
  - Mass of cooler component = 2.05+/-0.07 M_{sun}
- Spectroscopic parameters
  - Effective temperature (primary) = 7125+/-164 K
  - Effective temperature (secondary) = 6863+/-118 K
  - Log (surface gravity (primary)) = 3.83+/-0.01
  - Log (surface gravity (secondary)) = 3.55+/-0.01

What's next?

- Stellar Evolution Modelling in MESA for parameter range obtained from spectroscopic analysis.
- Comparing observed pulsation modes with theoretically obtained modes in the parameter range.

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**High Dispersion Echelle Spectrograph at Okayama Astrophysical Observatory*
**Plot of shorter-to-longer period ratio against the longer period*
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