AI Hydrae: Revisiting our pulsator friend

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AI Hydrae (AI Hya) is an eclipsing binary system with a delta Scuti pulsator. We model its photometric data, observed by the Transiting Exoplanet Survey Satellite (TESS). This is done using JKTEBOP lightcurve modelling software by fitting sinusoidal and polynomial functions along with the binary orbit, to account for the variability caused by the pulsations. This modelling is further complemented by the frequency analysis of the out-of-eclipse pulsation signals and analysis of our own set of spectra observed at different orbital phases using HIgh Definition Echelle Spectrograph (HIDES).

1 Introduction

One of the powerful techniques to determine the fundamental stellar parameters with high precision is solving an eclipsing binary (EB) system. Solving the orbit of EB system complemented 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 stellar parameters using the above two techniques and at times to calibrate one using the other. 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.

2 Lightcurve Analysis

AI Hya has generated a special interest over the years (Popper (1988), Lee et al. (2020)) as it hosts a multi-mode delta Scuti pulsator. TESS (Ricker et al. (2015)) lightcurve for AI Hya was obtained from the Mikulski Archive for Space Telescope (MAST) and the analysis was performed using the JKTEBOP lightcurve modelling code (Southworth et al. (2004), Southworth (2008)). 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 the binary orbit. Errors on the obtained parameters were estimated by using Monte Carlo (MC) runs.

3 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

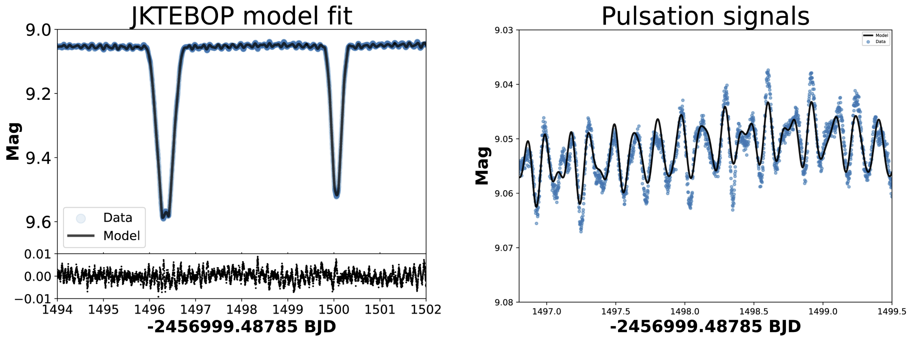

Fig. 1: *Left*: TESS lightcurve of AI Hya modelled using JKTEBOP (Blue points: Data, Black line: Best fit model), with residuals at the bottom. *Right*: Zoomed in view of the lightcurve (blue points) and best fit model (black line) with 9 sinusoids used to model the pulsations.

lightcurve. We investigate the independent frequencies by plotting period ratios on Petersen diagram (fig. 2) against the literature multi-mode delta Scuti samples from the OGLE database (Pietrukowicz et al. (2020), Netzel et al. (2021)). Period ratios of our target (black plus) belongs to three distinct sequences as seen in the Fig. 2, hence corresponding to triple mode star pulsating in 1O+2O+3O (where O stands for overtone) mode. Precise asteroseismic modelling of such triple mode stars is imperative to test stellar evolution theory (e.g. Moskalik & Dziembowski (2005)).

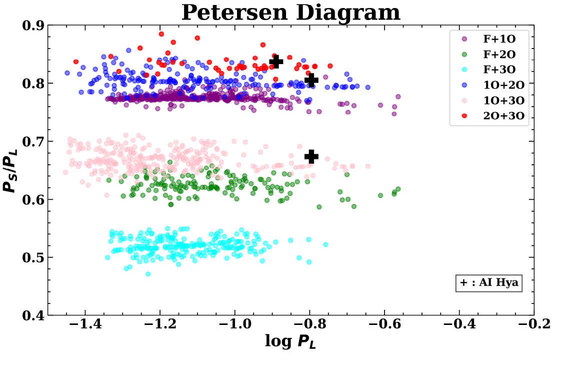

Fig. 2: Petersen diagram with black + indicating combinations of the recovered first second and third overtone modes for the AI Hya TESS data.

4 Spectroscopic Analysis

Spectroscopic data collected using HIDES spectrograph was analysed using the Grid Search in Stellar Parameters package (Tkachenko (2015)) to disentangle composite spectra of the double-lined AI Hya. Using these results in conjunction with the ones from the photometric analysis helps us determine the atmospheric parameters of the studied stars.

5 Results and Future Work

Parameters obtained from the lightcurve modelling and combined radial velocity analysis (from this work and Popper (1988)) are presented in the Tab. 1. The next step is to make stellar evolution models in Modules for Experiments in Stellar Astrophysics (MESA) for the parameter range obtained from the combined photometric, spectroscopic, and Fourier analysis. Comparing observed pulsation modes with theoretically obtained modes in the parameter range will provide us with insights into the structural and evolutionary properties of this system.

Tab. 1: Obtained orbital and stellar parameters

Parameter	Obtained value with error
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	$2.83 \pm 0.05\ R_\odot$
Radius of cooler component	$3.95 \pm 0.07\ R_\odot$
Mass of hotter component	$1.96 \pm 0.07\ M_\odot$
Mass of cooler component	$2.05 \pm 0.07\ M_\odot$
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

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