



Using Fourier Analysis to Reveal Pulsation Frequencies of roAp stars

Divyeshwari Vansadia and Dr. Stephen Gillam

Embry-Riddle Aeronautical University, Department of Physical Sciences

Abstract

The goals of this investigation are to determine the principal pulsation and get an understanding of the atmospheric fluctuation of TYC 3218-888-2, a rapidly oscillating chemically peculiar A-type star (roAp star). The Southeastern Association for Research in Astronomy (SARA-RM) telescope was used to carefully collect time-series photometry. Our investigation's basic premise holds that by analyzing the frequency spectrum of the star's light curve, we may interpret crucial information about the star's upper atmosphere and photosphere.

We analyzed the star's pulsation through the use of multi-aperture photometry (Astromage) and Fourier Analysis techniques (Period04). The determined principal pulsation of TYC 3218-888-2, is 0.8743mHz, with an amplitude of 4.58 mmag. We also found a pulsation with a large amplitude of 9.194 mmag and frequency of 0.0529mHz that lies between the gamma Doradus and Delta Scuti frequency ranges. This was the preliminary detection, so we need more observations to confirm this pulsation. Additionally, we unintentionally discovered that one of the comparison stars was a variable star while interpreting all the light curves of the comparison stars.

This presents progress towards determining the main pulsation and other frequencies of this roAp stars.

Introduction

- The rapidly oscillating, chemically peculiar A (roAp) stars are found at the base of the classical instability strip, where it intersects the main-sequence.
- roAps stars have pulsation frequencies > 0.68 mHz ($= 58.8$ / day) and Delta Scuti stars have pulsation frequencies < 0.06 mHz ($= 5$ / day). [1]

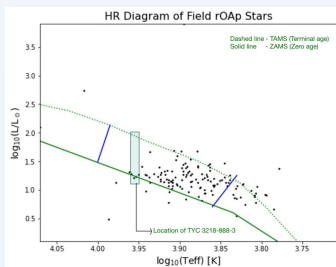


Fig 1. Field roAp stars on HR Diagram

Table 1. The parameter of TYC 3218-888-2 are:

Parameters		Units
B magnitude [2]	11.45	dimensionless
B-V value	0	dimensionless
Effective Temperature [3]	9222	K
Log(g) [3]	4.254	log(cm s ⁻²)
Principal Frequency [1]	0.8743	mHz

Hypotheses

The light variation in brightness is a superposition of several independent sinusoidal variations. These variations are due to pulsations of the stars' atmosphere. The pulsations are due to the expansion and contraction of the stars' photosphere.

Observation

The time series photometric data was collected of TYC 3218-888-2 on 21st Sept 2022 by using The Southeastern Association for Research in Astronomy, 0.9 meter Telescope and 2048 X 2048 Pixel ARC CCD located at Roque de los Muchachos Observatory at the Canary Islands. 53 Biases frame, 97 Flats in Johnson B filter 574 images with exposure of 45 seconds each was collected. Hence, we got nice data of around 6.5 hours to analysis.

Analysis

- **Calibration** - After creating master flats and master biases, each observational image was processed by subtracting the master bias and dividing by the master flat. This calibration step accounts for instrumental effects.
- **Multi-aperture photometry** - measuring the relative brightness of the roAp star by dividing it by the brightness of comparison stars, which removes the effects due to earth's atmosphere and allows us to understand the changes in luminosity.

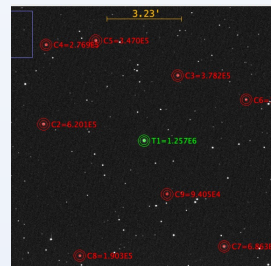


Fig 2. Aperture of TYC 3218-888-2 with Comparison stars

- Plotted the the **raw light curve** to check the quality of the data – it tells us the change in brightness of star over the night of observation.

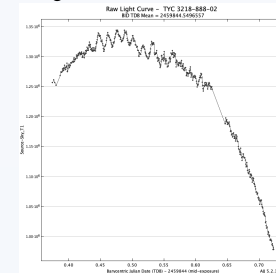


Fig 3. Raw Light Curve of TYC 3218-888-2

- **Time series**: The relative light curve shows how the brightness varies over time.

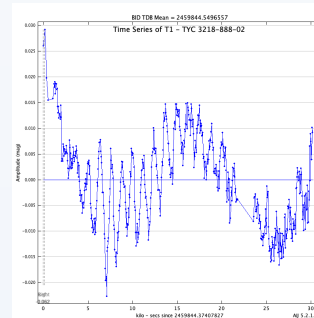


Fig 4. Differential (Relative) Light Curve of TYC 3218-888-2

- **Fourier analysis using period.04** – It transforms the data from the time domain (Amplitude vs. Time) into the frequency domain (Amplitude vs. Frequency). The amplitude spectrum shows two peaks – a possible Delta Scuti pulsation and the roAp pulsation, that contribute to the star's brightness changes.

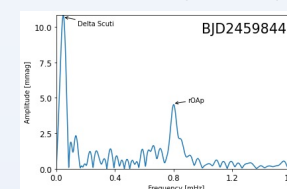


Fig 5. Amplitude Spectrum [Replotted by Dr. Gillam]

Serendipitous Observation

We discovered that one of the comparison stars, C9 which is NSVS 6117690 [2]. From its light curve, it is an W Ursa Majoris eclipsing binary. Therefore, we didn't include it in our analysis.

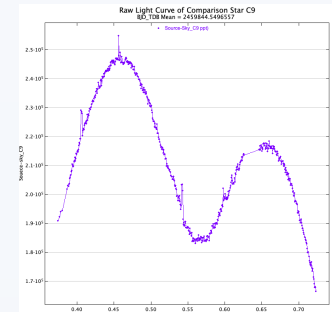


Fig 6. Raw Light Curve of Comparison star (C9)

Results

- The determined principal pulsation of TYC 3218-888-2, is 0.8743 mHz, with an amplitude of 4.58 mmag.
- We also found a pulsation with a large amplitude of 9.194 mmag and frequency of 0.0529mHz that lies between the gamma Doradus and Delta Scuti frequency ranges.

Conclusions

- Confirmed it's an roAp star with the principal frequency of 0.8743.
- Found a possible Delta Scuti frequency of the large amplitude of 9.194 mmag was detected. We need more observations to confirm this pulsation is intrinsic to the star and not due to subtle variations in atmospheric extinction.
- Contributed to a broader understanding of pulsating stars and their complex behaviors.

References

- Balona, L. A. (2011). "Rapidly-oscillating TESS A-F main sequence stars: are the roAp stars a distinct class?" Monthly Notices of the Royal Astronomical Society, 000, 1–10. Retrieved from [Preprint](#).
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