

Ground and Space based Investigation of Intermediate age Open Star Cluster

NGC 2126



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Abstract

We performed the ground based time-series observations of intermediate age open cluster NGC 2126 with 1.3 m Devasthal Fast Optical Telescope (ARIES), and discovered 112 variable stars in an 18 x 18 arcmin field. Among these 11 stars were known variables, for them we performed TESS Full Frame Image photometry in three different sectors. There were 17 new member variables and 84 variable field stars. Eclipsing binary, V551 Aur is a member of NGC 2126 with high probability and has a pulsating component. This star was studied in detail with a medium resolution spectra and TESS photometry. The light curve was analyzed with a binary model, which was then removed to analyze the pulsational variability. The new variable members were classified based on their position in the HR diagram, shape of the phase folded light curves, period and amplitude of variability. We also modeled the light curves of other binary stars in the field to determine their orbital parameters.

Identification of variable stars

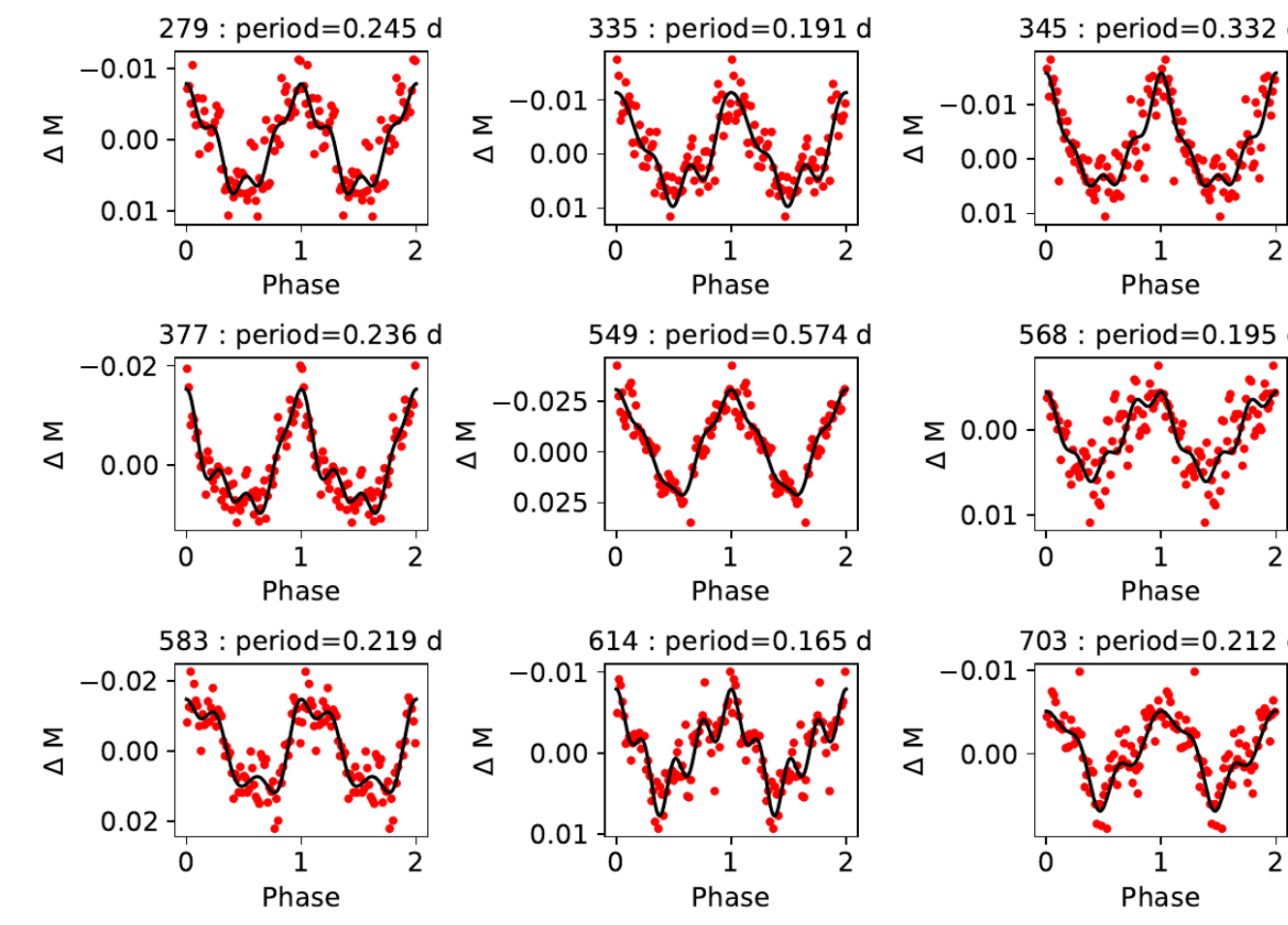


Figure 4: Some of the phase folded light curves of new variables detected from our ground based observations.

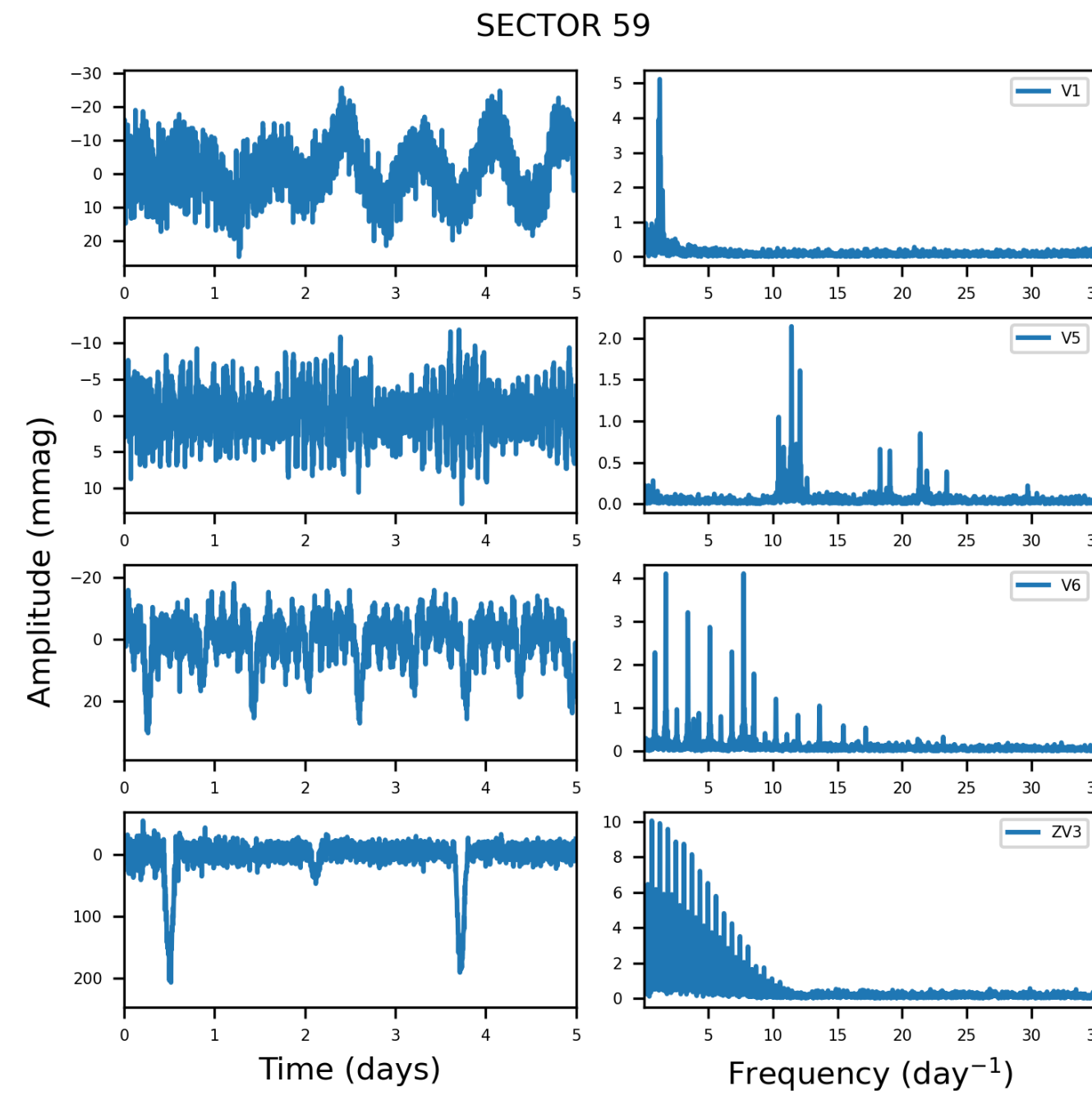


Figure 5: TESS 158 s cadence light curves extracted from FFIs and their corresponding periodograms for different classes of stars.

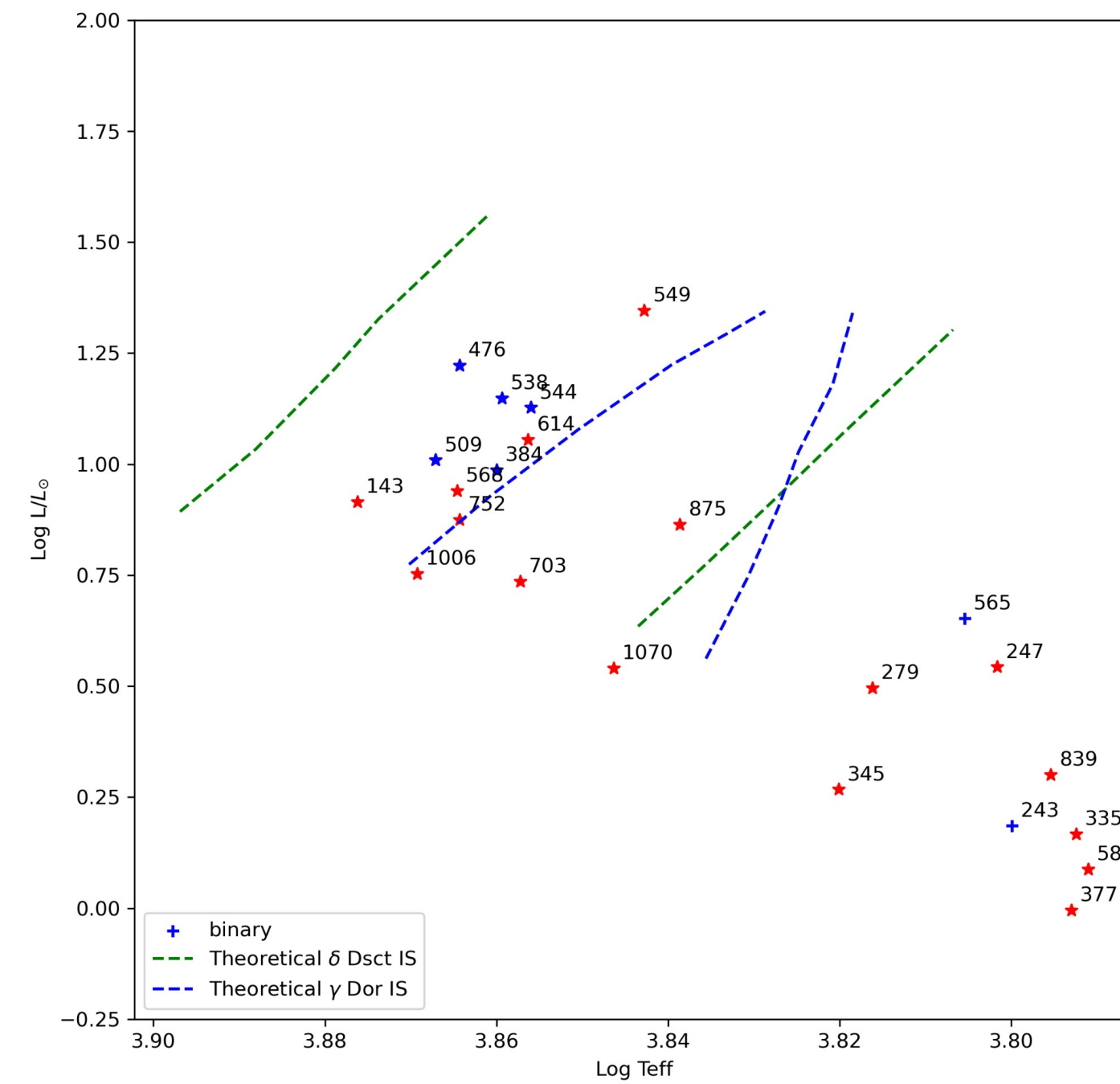


Figure 6: HR diagram for NGC 2126. The theoretical δ Scuti and γ Doradus instability strips are from Dupret et al. 2005. The blue markers represent known variables and the red markers represents the newly detected variables.

Introduction

Open star clusters are group of stars formed from the same molecular cloud. Thus, they have similar age and chemical composition, which makes them test beds for stellar evolution theories. We choose NGC 2126, an intermediate-age open star cluster that contains different types of variable stars located in the δ Scuti/ γ Doradus instability strip. A total of 11 variables were reported in a similar field by Chehlaeh et al. 2018 for NGC 2126 from ground-based observations

Cluster membership

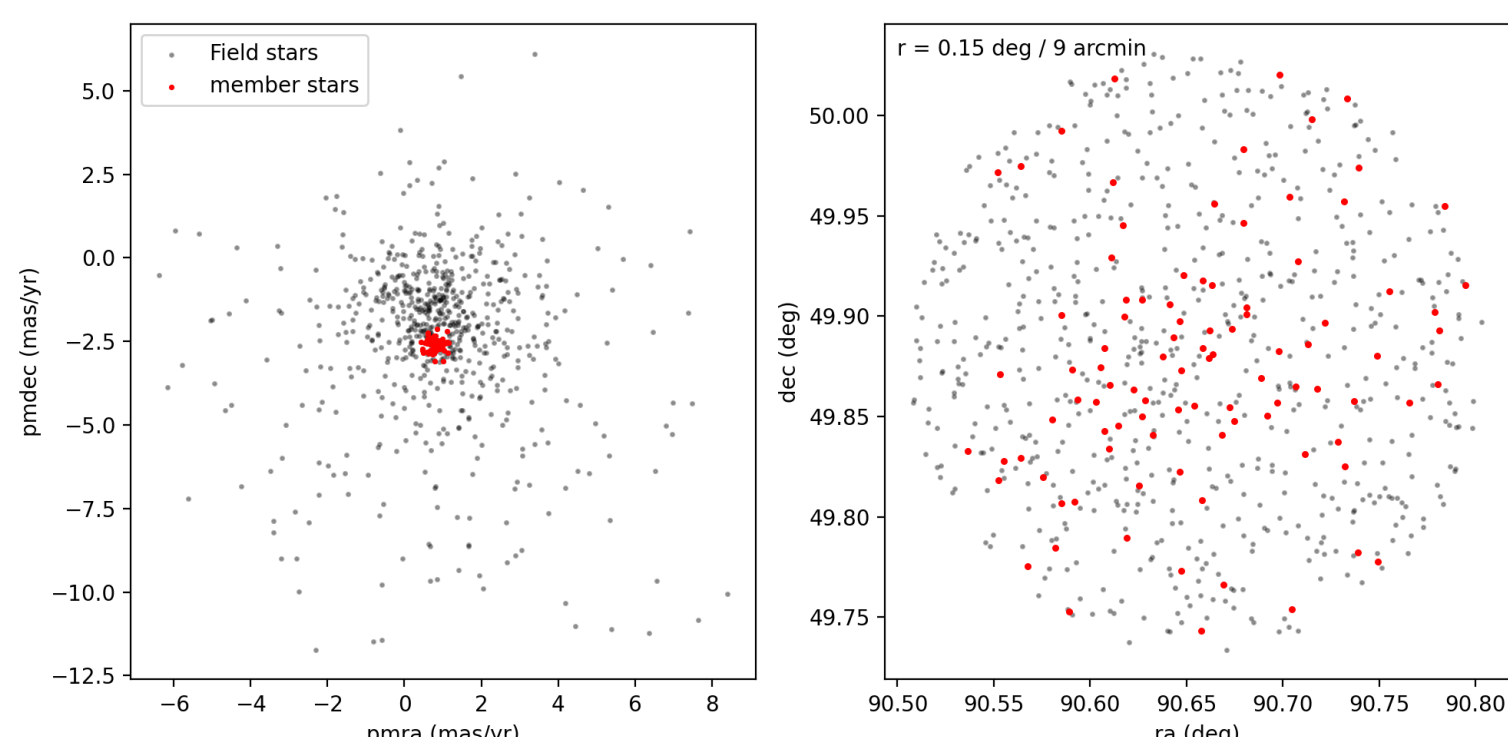


Figure 1: On left panel we see the proper motion diagram for NGC 2126 and on the right panel we see the position of the stars with red dots representing member stars and black dots field stars

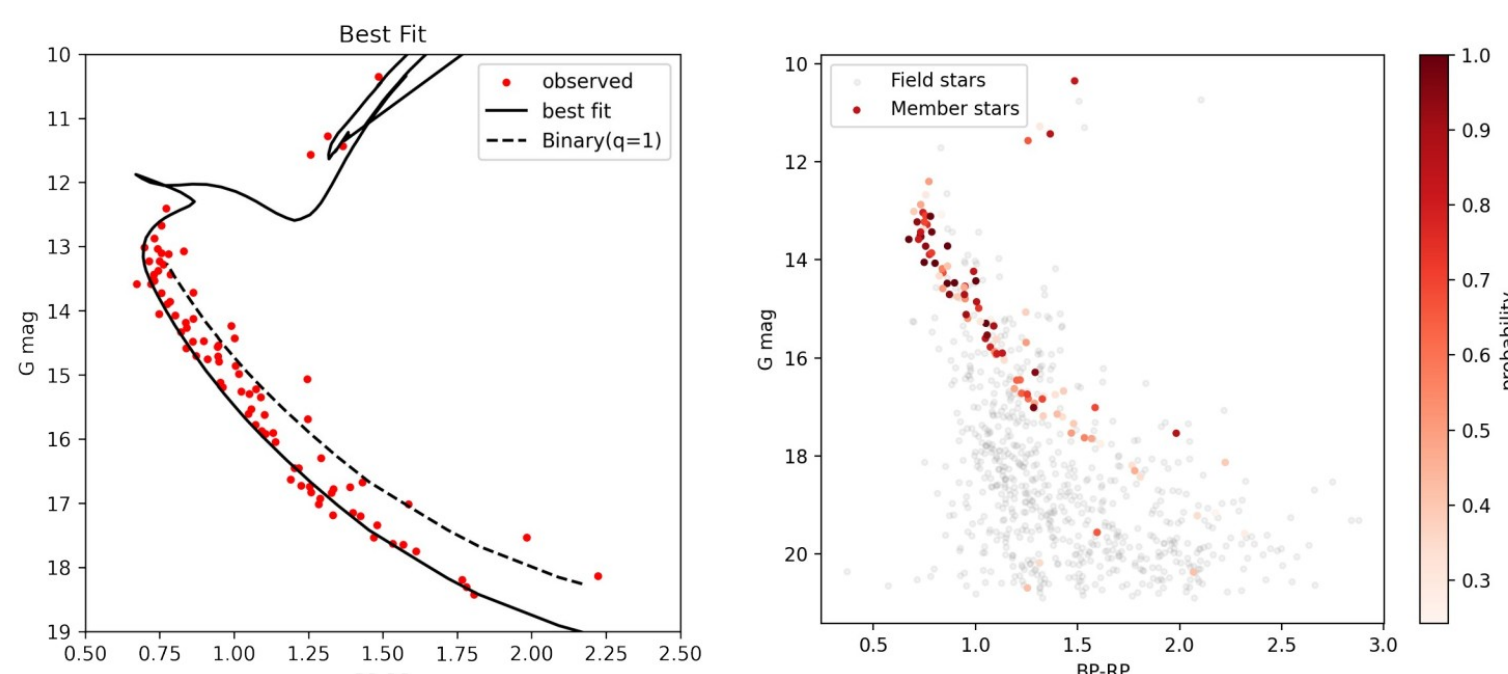


Figure 2: Left panel - Best fit isochrone for members of NGC 2126, Right panel - The membership probabilities from Gaia DR3.

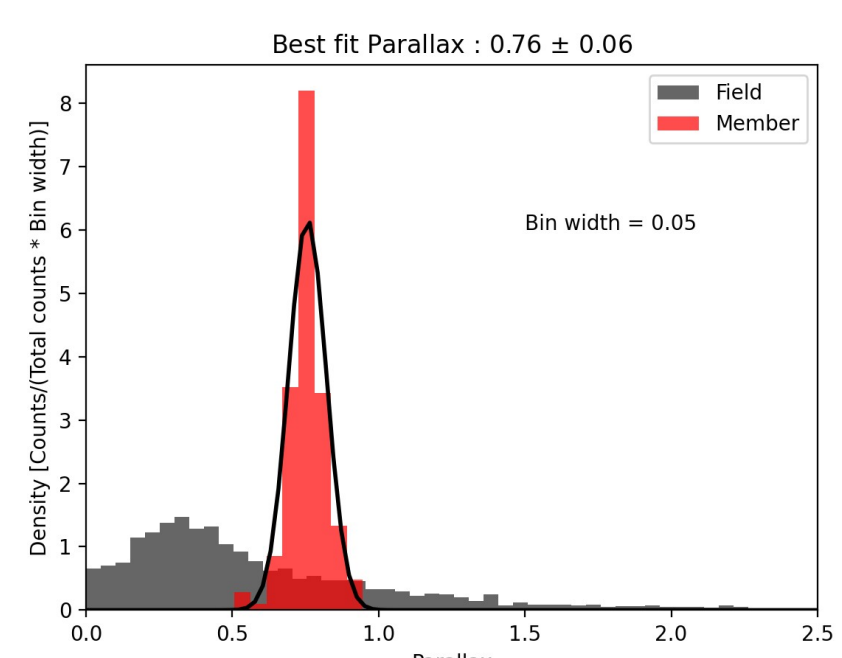


Figure 3: The histogram plot of parallax and the best fit parallax corresponding to a distance of 1.3 kpc.

Cluster Parameters

Parameter	Best fit Value	Initial Value
Z	0.0173 ± 0.0014	0.019
t	9.176 ± 0.011	9.2
A_G	0.487 ± 0.021	0.545
E(BP-RP)	0.157 ± 0.021	-
$(m-M)_0$	10.40 ± 0.07	10.85
D	1.3 ± 0.1	-

Table 1: Best fit parameters for the cluster from Padova isochrone fitting.

V551 Aur : Spectroscopy

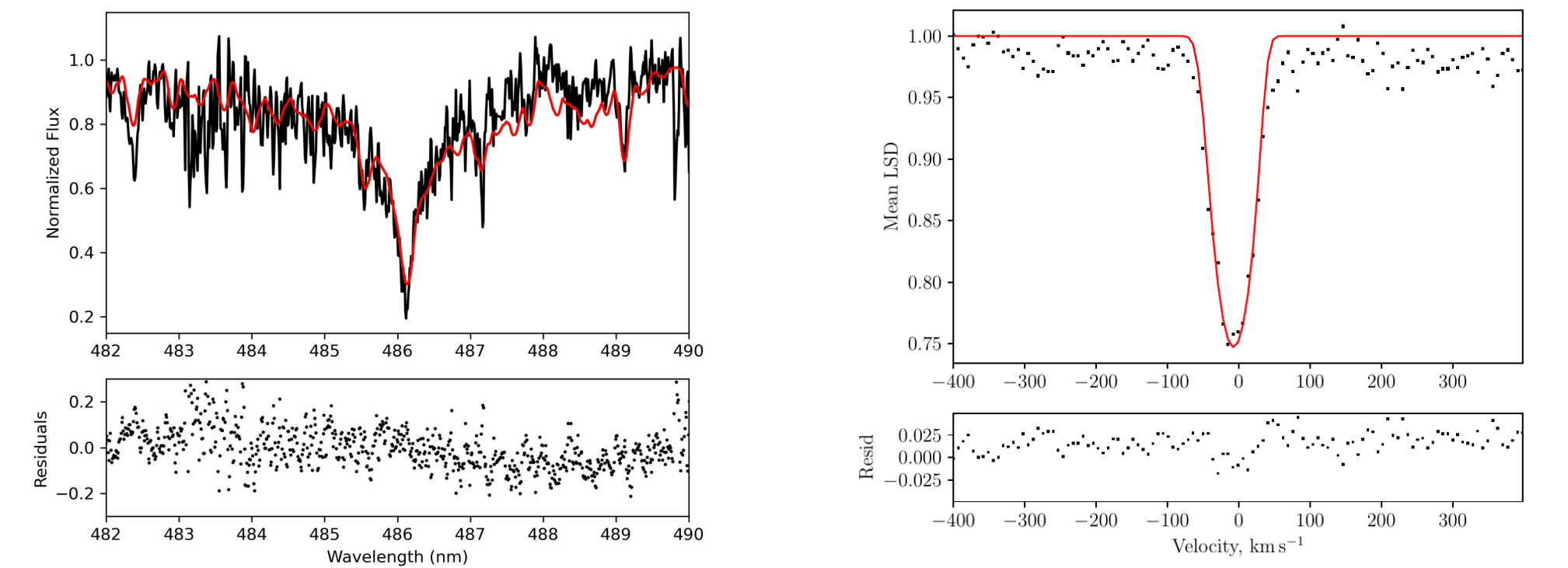
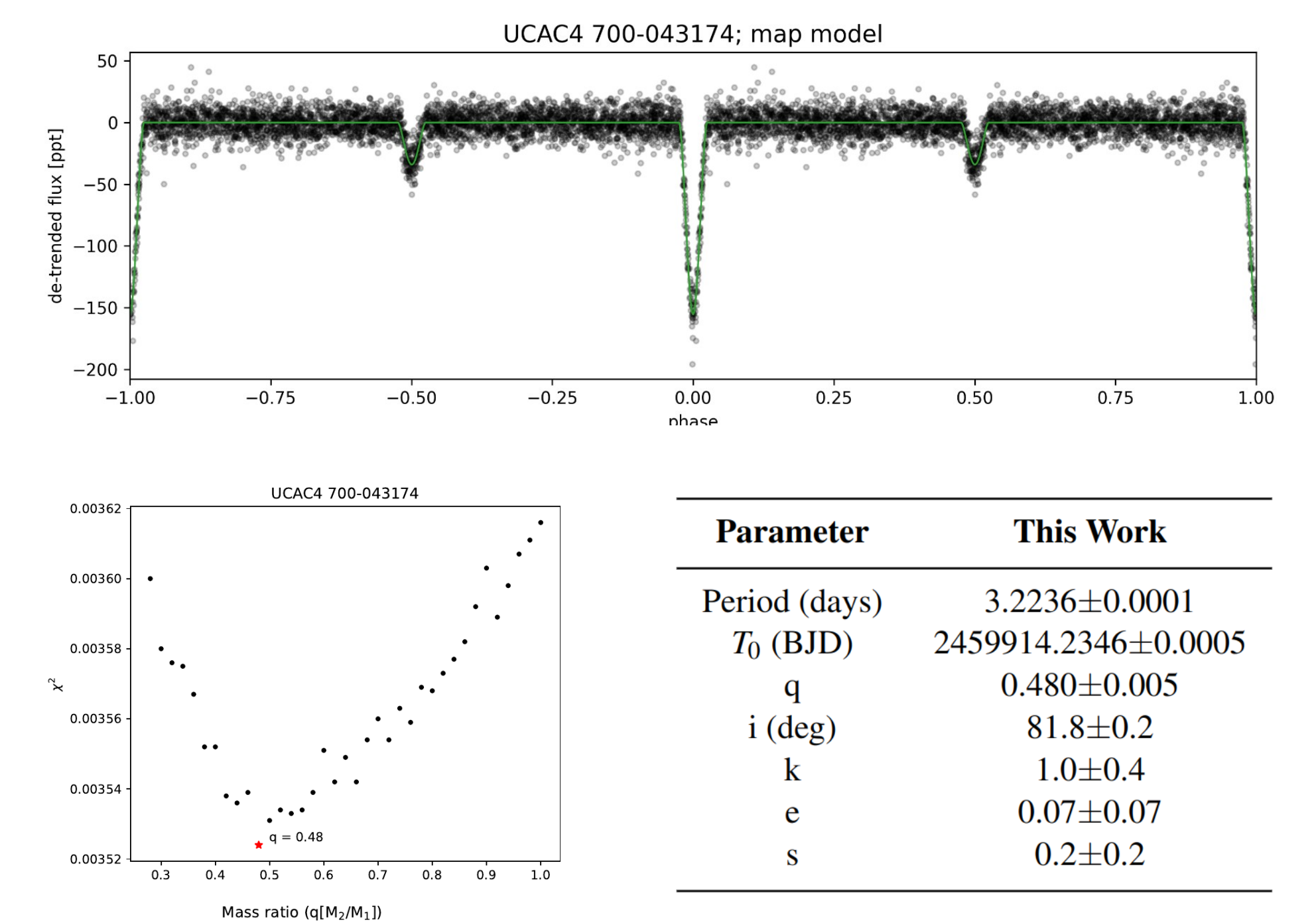


Figure 8: Left Panel - Best fit synthetic spectra for H beta line of medium resolution spectrum taken with 2.4 m telescope at Thai National Observatory Medium Resolution Spectrograph ($R \sim 18000$), Right Panel - The mean LSD profile,

Parameters	value
From Hbeta	
$[M/H]$	0.68 ± 0.18
T_{eff}	6458 ± 361 K
$\log g$	3.0 ± 1.49
From LSD	
RV	-8.4 ± 1.2 km/s
$v \sin i$	44.0 ± 2.5 km/s

Table 3: The best fit parameters from H beta and LSD profile. These are the preliminary fit parameters, the fitting will be improved to get more accurate parameters.

ZV3 : Binary model from TESS



Bottom right – Table 4: The best fit parameters for ZV3 from exoplanet code.

Summary

- Carried out photometric observations of NGC 2126 with 1.3 m Devasthal Fast Optical Telescope (ARIES)
- Performed TESS photometry of known variables in NGC 2126.
- We detected 112 variables in the region of NGC 2126, out of which 24 are found to be cluster members. Among the cluster members 17 are new cluster members.
- We classified the member variables based on the HR diagram and their variability characteristics as Eclipsing Binary (2), δ Scuti (7), γ Doradus (3), Rotational variables (2), Pulsating eclipsing binary (1) and 5 of them are either δ Scuti or γ Doradus.
- Performed medium resolution spectroscopy and light curve modeling for V551 Aur and determined orbital and physical parameters.

Acknowledgments

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European Space Agency (ESA) mission Gaia.

TESS mission, Mikulski Archive for Space Telescopes (MAST).

References

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V551 Aur : Tess Photometry

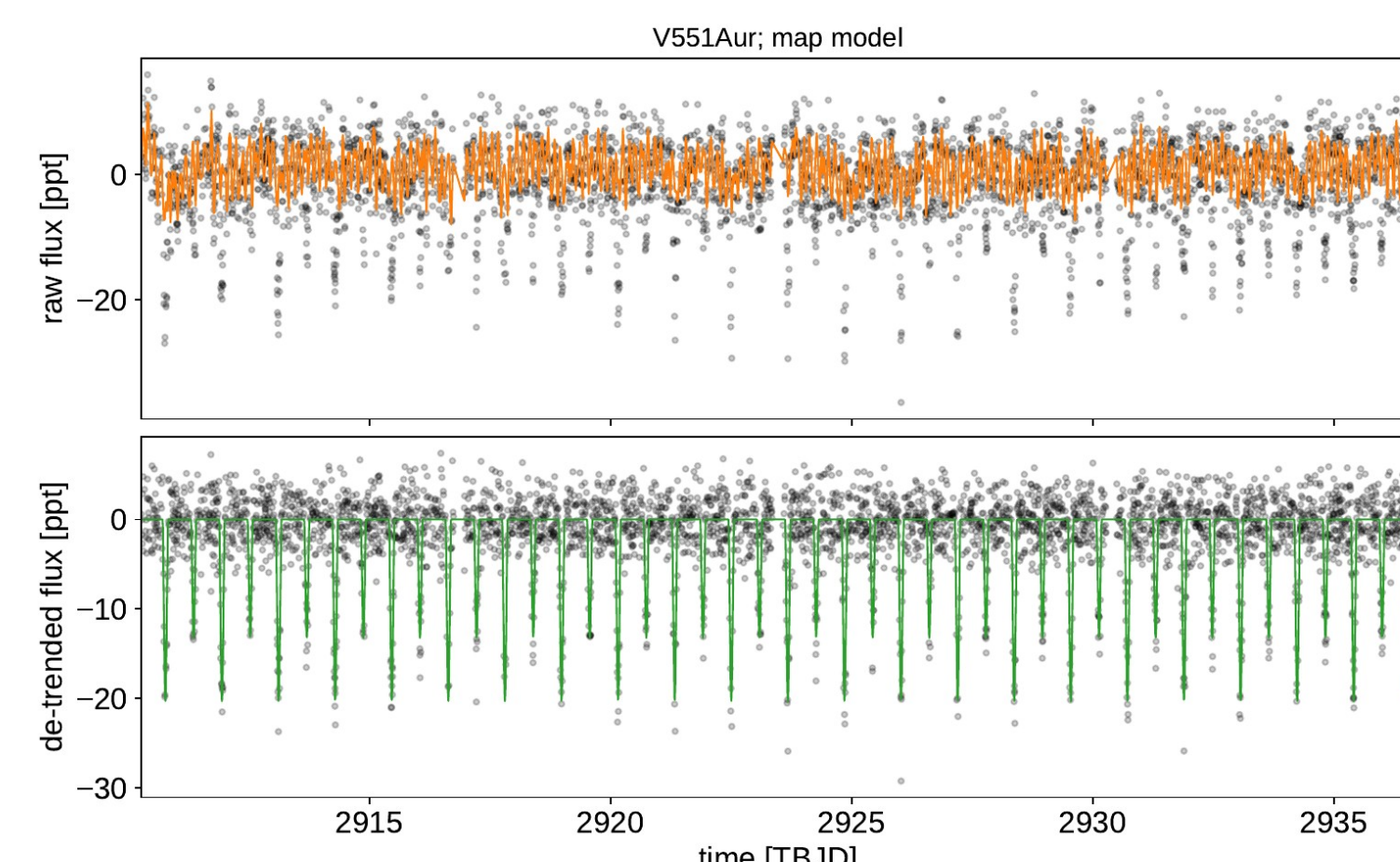


Figure 7: Top panel - Scalable Gaussian process model for the pulsational variability over plotted on observed TESS light curve, Bottom panel - The eclipse model for V551 Aur over plotted on residuals after removing the pulsation model. This star however lies outside the pulsational instability strip on the HR diagram (see star 565 in Fig. 6).

Parameter	Best Fit
Period (days)	1.1735 ± 0.0001
T_0 (BJD)	2458506.1 ± 0.2
q	0.730 ± 0.007
i (deg)	60.7 ± 0.9
k	1.1 ± 0.1
e	0.01 ± 0.01
s	0.9 ± 0.3
sigma gp	5.2 ± 0.3
rho gp	0.125 ± 0.008

Table 2: Best parameters for V551 Aur using exoplanet code. The last two terms are the parameters for a gaussian process representing stochastically-driven, damped harmonic oscillator, were 'rho gp', the undamped period of the oscillator and 'sigma gp', the standard deviation of the process.