Draft version January 20, 2025
Prepared for **RNAAS**

Identification of δ Scuti, γ Doradus Stars and Eclipsing Binaries with *TESS* (III)

Ai-Ying Zhou [1,2]

[1] *National Astronomical Observatories, Chinese Academy of Sciences,*
A20 Datun Road, Chaoyang District, Beijing 100101, P.R. China
[2] *Key Laboratory of Radio Astronomy and Technology (Chinese Academy of Sciences)*

ABSTRACT

A survey for δ Scuti and γ Doradus stars was conducted within a selected temperature range of 6500 to 8100 K and a *TESS* magnitude range between $11^{\rm m}_{.}202$ and $12^{\rm m}_{.}45$. I analyzed 62 912 stars using *TESS* data and discovered 15 542 new variables. Among these, I identified 5512 δ Scuti stars, and 5655 γ Doradus stars, with 1426 of them being hybrid δ Sct-γ Dor (exhibiting characteristics of both types). Additionally, I identified 1710 eclipsing binary systems, including 415 with pulsating components, and multiple tens of potential planetary transiting candidates.

Keywords: Pulsating variable stars(1307) — δ Scuti variable stars(370) — γ Doradus variable stars(2101) — Eclipsing binary stars(444)

I. INTRODUCTION

Stars with spectral types of A and F ('AF' stars), particularly susceptible to pulsation during their main-sequence evolutionary stages, require careful analysis to distinguish intrinsic variability from rotational modulation caused by unevenly populated star spots. Different pulsating variables are distinguished by their pulsation periods and light curve shapes, which are influenced by their interior physical changes and evolutionary stages. Pulsating AF stars provide valuable insights into stellar evolution, asteroseismology, and the interplay between pulsation modes and stellar structure.

The δ Scuti (DSCT) and γ Doradus (GDOR) stars are two classes of pulsating AF variables located on and near the A and F-type main sequence, within the lower part of the classical Cepheid instability strip (Handler 2009; Rodríguez & Breger 2001; Breger 2000). Their key pulsational features are also discussed in Zhou (2024). DSCT and GDOR stars occupy a common region in the Hertzsprung-Russell (H-R) diagram, often overlapping in the temperature range of 6500-8100 K (see e.g. the H-R diagrams in Zhou 2024, 2025).

Recent models by Xiong et al. (2016) suggest that pulsational driving of low degree modes in δ Sct stars does not occur for effective temperatures exceeding 9000 K, and the theoretic instability predicts an upper limit in effective temperature for γ Dor stars, $T_{\rm eff} = 8500$ K, a threshold value used to distinguish two gravity-mode pulsators between γ Dor and SPB candidates by Aerts et al. (2023). In contrast, Maia variables are observationally defined as a hotter extension of δ Sct stars (Balona 2023; Balona & Ozuyar 2020). Furthermore, stars with $T_{\rm eff} < 6500$ K can be solar-like oscillators or dominated by rotational modulation. Therefore, the temperature range 6500–8100 K effectively excludes SPB and Maia, and reduces probability being solar-like or rotating stars. This range represents the overlapping central region of δ Sct and γ Dor stars. The primary motivation for exploring this temperature domain is to detect hybrid pulsators and avoid confusion with other neighboring types of oscillating objects.

Building on the methodology presented in Zhou (2023a,b, 2025), this all-sky survey aims to identify new pulsating AF variables within the lower instability strip, with a particular focus on δ Sct and γ Dor stars. It is aimed to (1) Investigate hybrid pulsators: Stars in the overlapping region may exhibit pulsations characteristic of both DSCT and GDOR stars, offering unique opportunities to study the interplay between different pulsation modes. (2) Determine

Corresponding author: Ai-Ying Zhou
aiying@nao.cas.cn

the occurrence of hybrid pulsators: It is essential to determine whether hybrid pulsators occur within the overlapped parameter space or whether stars in this region have the highest probability of pulsating with two types of modes. This note summarizes the first findings of this survey.

II. SAMPLE AND DATA

This survey's target selection criteria comprised four aspects: (1) effective temperatures ranged between 8,100 and 6,500 K – roughly corresponding to main sequence stars of spectral types A5 to F6, which covers the core domains of δ Sct and γ Dor stars on H-R diagram; (2) $T_{\rm mag}$=$11\overset{\rm m}{.}202$–$12\overset{\rm m}{.}45$ for the best *TESS* magnitude range for objects to have high photometric quality, and specifically excluding those already covered in the work by Gootkin et al. (2024); (3) V= $10\overset{\rm m}{.}26$–$13\overset{\rm m}{.}275$, a range mostly not covered by the legacy brighter star catalogs; (4) Masses in the range of 1.15–3.204 $M_\odot$represent a slight extension beyond the typical range for DSCT/GDOR stars. Consequently, we extracted 499,606 AF stars from *TESS* Input Catalog (TIC v8.2, Paegert et al. 2021), within the desired parameter brackets. Subsequent removal of known variables resulted in a final sample of 62,912 AF candidates with accessible *TESS* light curves for Phase-I. Stellar spectral types were first sourced from Simbad or, when unavailable, they were deduced empirically from the effective temperature in TIC v8.2.

Light curve data come from the Transiting Exoplanet Survey Satellite (*TESS*, Ricker et al. 2015), available at MAST. Astronomical and stellar parameters are retrieved from Simbad (Wenger et al. 2000), TIC v8.2, and *Gaia* archive (Gaia Collaboration et al. 2016, 2018, 2023) for evaluating stellar properties and stars' locations on H-R diagram.

III. METHODOLOGY AND IDENTIFICATION

Variability types are classified based on light curve morphology, periodogram analysis, and astrophysical parameters, which inform the star's position on the H-R diagram of pulsators. This survey was conducted interactively using the revised Python program from Zhou (2023a), which encompassed the entire data processing workflow. Before downloading light curves, each entry object's variability was first checked locally against a collection of relevant known variable stars, which includes 99 800+ DSCT and 20 600+ GDOR (Zhou 2024), *Gaia* DR3 Part.4 Variability (2 184 477 eclipsing binaries and total 9 976 881 objects, Gaia Collaboration et al. 2023), *Gaia* DR2 Variability Results of 363 969 records (Gaia Collaboration et al. 2018), 378 861 variables in ASAS-SN Catalog of Variable Stars X (Christy et al. 2023), 123 841 and 84 206 *TESS* variables (Balona 2022; Fetherolf et al. 2023), 754 909 *TESS* AF stars (Gootkin et al. 2024), 15 062 *Gaia* DR3 g-mode candidate pulsators (11 636 GDOR+3426 SPB, Aerts et al. 2023), 162 592 (58 970 *TESS*-confirmed *Gaia* DR3 variables, and 93 622 p-and g-mode candidates) by Hey & Aerts (2024), the most recent 72 505 *TESS* periodic variables (Gao et al. 2024) and other publications. Then it was double-checked online with both Simbad and VSX to ensure exclusion of known variables. Stars without *TESS* data were omitted. The classification process is detailed in Zhou (2023a,b).

IV. RESULTS

The author examined the *TESS* light curves of 62,912 stars, a subset of 499,606 stars across the entire sky. I identified 15,542 new variables (about 25% the screened stars), including 5512 δ Sct stars and 5655 γ Dor stars (of which 1426, or 12.8%, are hybrid), 1710 eclipsing binary systems (415 with pulsating components, and potentially dozens planetary transiting candidates), 2690 rotating variables (including 190 rotating ellipsoidal variables), 22 RR Lyr stars, and multiple heartbeat stars. Additionally, 580 variables previously classified as 'PulsV' by Simbad, 'msosc' and 'short_ts' by Gaia are reclassified as either δ Sct or γ Dor stars. Figures 1 and 2 showcase 12 representative examples of hybrid δ Sct-γ Dor pulsators. Comprehensive information about all these new variables is available on Zenodo: doi: 10.5281/zenodo.13352428.

I am indebted to my wife Jingyun Zhang for her unwavering support throughout my research. This work includes data collected with the *TESS* mission, I acknowledge the use of *TESS* data, which are derived from pipelines at the *TESS* Science Processing Operations Center. *TESS* High Level Science Products produced by the Quick-Look Pipeline at the *TESS* Science Office at MIT, which are publicly available from the Mikulski Archive for Space Telescopes data archive at the Space Telescope Science Institute. Funding for *TESS* mission is provided by NASA Explorer Program. STScI is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5–26555. This research has made use of SIMBAD, operated at CDS, Strasbourg, France; International Variable Star Index, operated at AAVSO; *Astropy* (Astropy Collaboration et al. 2022); Astroquery (Ginsburg et al. 2019); Lightkurve (Lightkurve Collaboration et al. 2018).

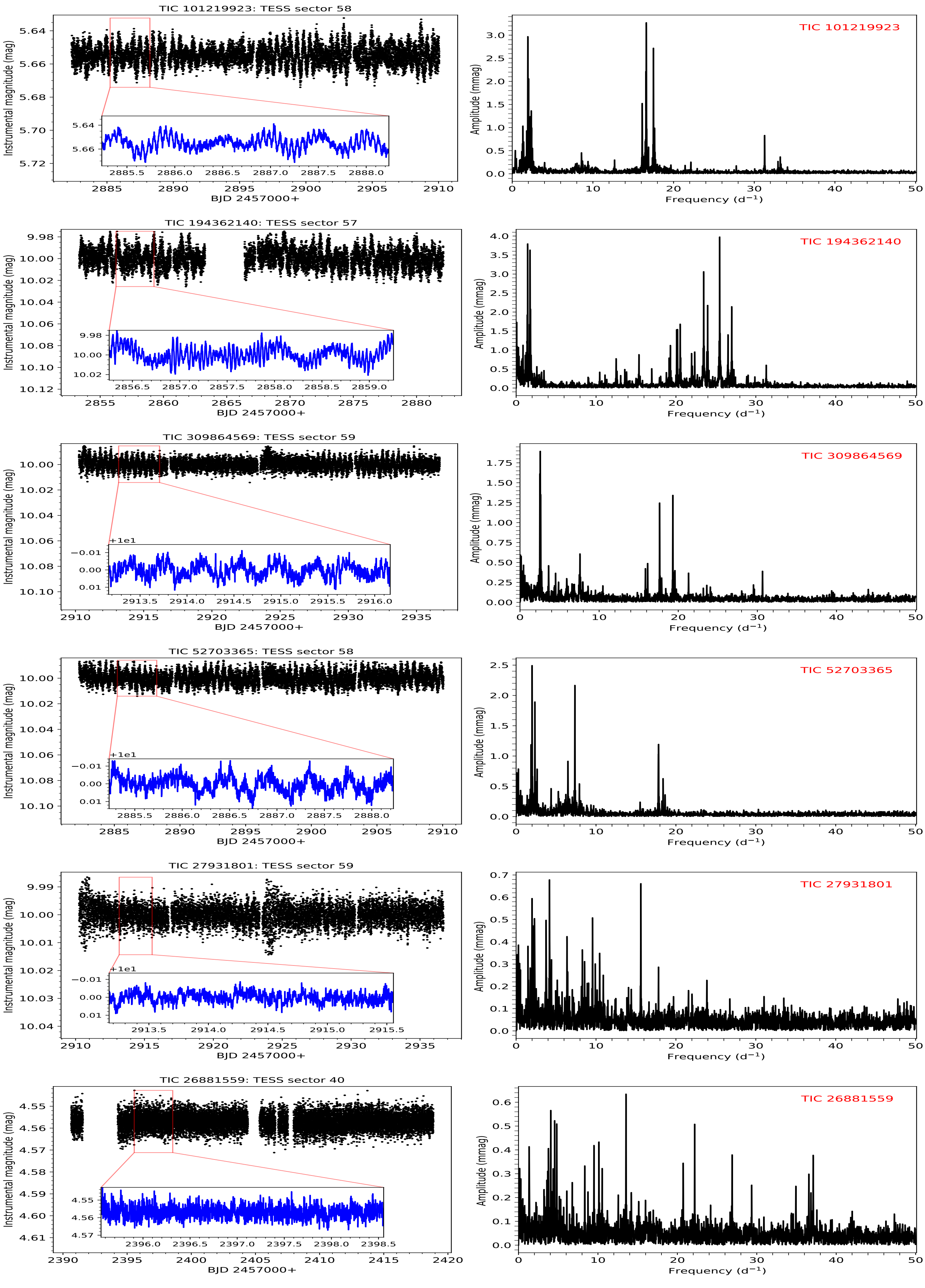

Figure 1. Examples of newly identified *TESS* hybrid δ Sct-γ Dor pulsators.

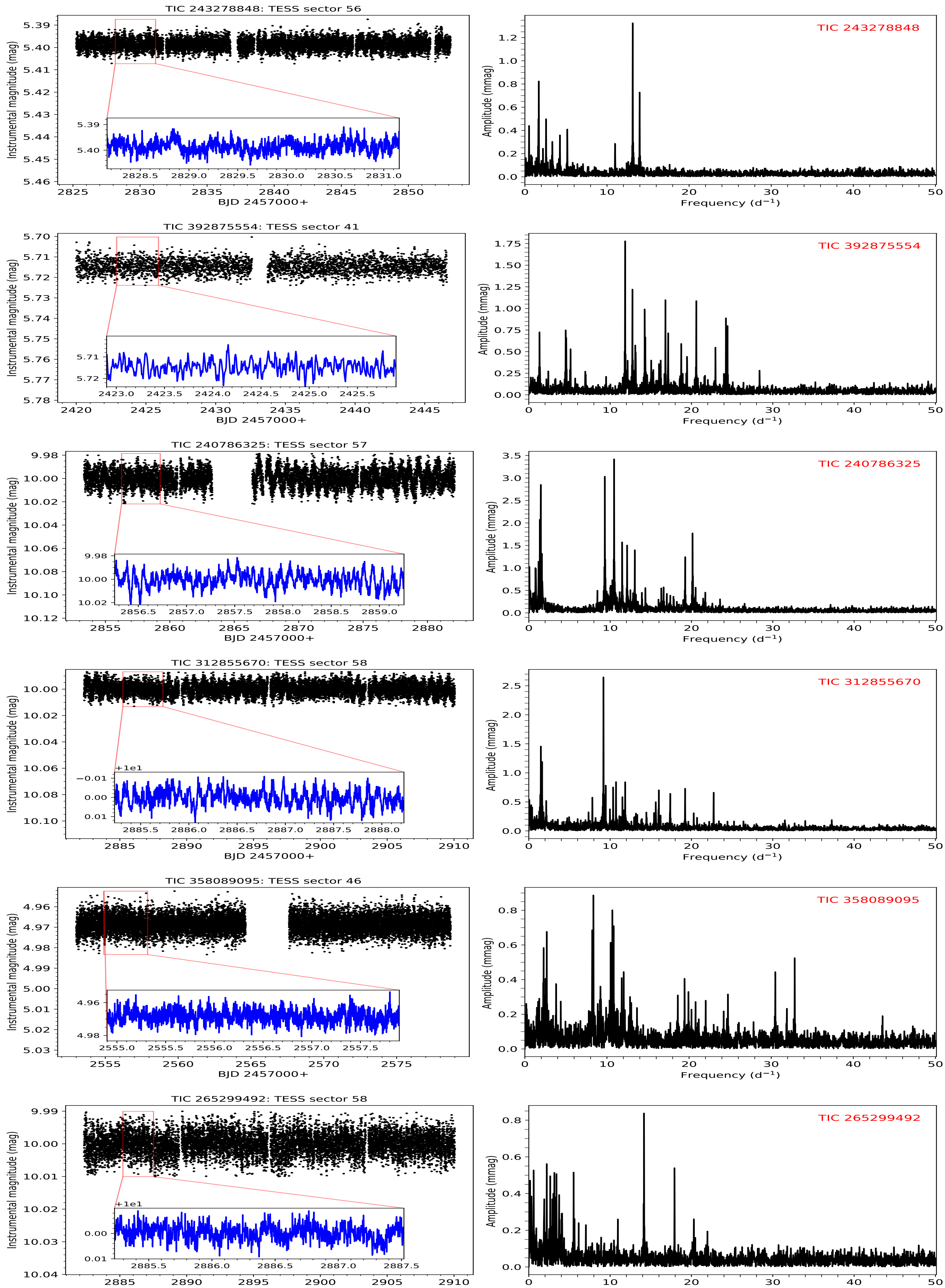

Figure 2. Examples of newly identified *TESS* hybrid δ Sct-γ Dor pulsators

REFERENCES

Aerts, C., Molenberghs, G., & De Ridder, J. 2023, A&A, 672, A183, doi: 10.1051/0004-6361/202245713

Astropy Collaboration, Price-Whelan, A. M., Lim, P. L., et al. 2022, ApJ, 935, 167, doi: 10.3847/1538-4357/ac7c74

Balona, L. A. 2022, arXiv e-prints, arXiv:2212.10776. https://arxiv.org/abs/2212.10776

—. 2023, Frontiers in Astronomy and Space Sciences, 10, 1266750, doi: 10.3389/fspas.2023.1266750

Balona, L. A., & Ozuyar, D. 2020, MNRAS, 493, 5871, doi: 10.1093/mnras/staa670

Breger, M. 2000, in Astronomical Society of the Pacific Conference Series, Vol. 210, Delta Scuti and Related Stars, ed. M. Breger & M. Montgomery, 3

Christy, C. T., Jayasinghe, T., Stanek, K. Z., et al. 2023, MNRAS, 519, 5271, doi: 10.1093/mnras/stac3801

Fetherolf, T., Pepper, J., Simpson, E., et al. 2023, ApJS, 268, 4, doi: 10.3847/1538-4365/acdee5

Gaia Collaboration, Prusti, T., de Bruijne, J. H. J., et al. 2016, A&A, 595, A1, doi: 10.1051/0004-6361/201629272

Gaia Collaboration, Brown, A. G. A., Vallenari, A., et al. 2018, A&A, 616, A1, doi: 10.1051/0004-6361/201833051

Gaia Collaboration, Vallenari, A., Brown, A. G. A., et al. 2023, A&A, 674, A1, doi: 10.1051/0004-6361/202243940

Gao, X., Chen, X., Wang, S., & Liu, J. 2024, arXiv e-prints, arXiv:2412.06175, doi: 10.48550/arXiv.2412.06175

Ginsburg, A., Sipőcz, B. M., Brasseur, C. E., et al. 2019, AJ, 157, 98, doi: 10.3847/1538-3881/aafc33

Gootkin, K., Hon, M., Huber, D., et al. 2024, ApJ, 972, 137, doi: 10.3847/1538-4357/ad5282

Handler, G. 2009, in American Institute of Physics Conference Series, Vol. 1170, Stellar Pulsation: Challenges for Theory and Observation, ed. J. A. Guzik & P. A. Bradley, 403–409, doi: 10.1063/1.3246528

Hey, D., & Aerts, C. 2024, A&A, 688, A93, doi: 10.1051/0004-6361/202450489

Lightkurve Collaboration, Cardoso, J. V. d. M., Hedges, C., et al. 2018, Lightkurve: Kepler and TESS time series analysis in Python, Astrophysics Source Code Library. http://ascl.net/1812.013

Paegert, M., Stassun, K. G., Collins, K. A., et al. 2021, arXiv e-prints, arXiv:2108.04778. https://arxiv.org/abs/2108.04778

Ricker, G. R., Winn, J. N., Vanderspek, R., et al. 2015, Journal of Astronomical Telescopes, Instruments, and Systems, 1, 014003, doi: 10.1117/1.JATIS.1.1.014003

Rodríguez, E., & Breger, M. 2001, A&A, 366, 178, doi: 10.1051/0004-6361:20000205

Wenger, M., Ochsenbein, F., Egret, D., et al. 2000, A&AS, 143, 9, doi: 10.1051/aas:2000332

Xiong, D. R., Deng, L., Zhang, C., & Wang, K. 2016, MNRAS, 457, 3163, doi: 10.1093/mnras/stw047

Zhou, A.-Y. 2023a, Research Notes of the American Astronomical Society, 7, 210, doi: 10.3847/2515-5172/acffc2

—. 2023b, Research Notes of the AAS, 7, 262, doi: 10.3847/2515-5172/ad12a3

—. 2024, NewA, 105, 102081, doi: 10.1016/j.newast.2023.102081

—. 2025, New Astronomy, 114, 102297, doi: 10.1016/j.newast.2024.102297