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New Pulsating Variable Stars and Eclipsing Binaries around BL Cam*

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

Based on publicly available *TESS* data, I conducted a small regional survey around the SX Phe star BL Cam, spanning a radius of two degrees. This research identified a total of 285 new variables including: 96 δ Scuti stars, 56 γ Doradus stars, 17 eclipsing binary systems with 7 exhibiting pulsating or rotating components, 3 rotating ellipsoidal variable stars. While a few additional variable types were detected, no new SX Phe stars were detected.

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

INTRODUCTION

Variable stars play a crucial role in our understanding of the universe. Variables of different classes serve as essential tracers for probing the structures of the Milk Way Galaxy and the universe. Different pulsating variables are distinguished by their periods of pulsation and the shapes of their light curves, which in turn are a function of their interior physical changes and evolutionary stages. 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 or observational noise.

Pulsating AF stars, in particular, offer valuable insights into stellar evolution. Increasing the catalog of variable stars enhances our understanding of their spatial distribution and evolutionary pathways. High-precision space-based photometry facilitates the discovery and classification of new variables, necessitating both automated and visual inspection methods (Balona & Ozuyar 2020; Balona 2022a,b). This specific regional survey targets new pulsating AF variables within the lower instability strip, focusing primarily on δ Scuti (DSCT) and γ Doradus stars in a circular area of 120 arcminutes radius centered on star BL Cam (=TIC 392774261=GD 428).

BL Cam is a well studied SX Phe-type star with extreme low metal abundance (Abdel-Sabour et al. 2022; Rodríguez et al. 2007; Zhou et al. 1999). What sets BL Cam apart is the unexpected discovery of periodic amplitude variations (Peña et al. 2021), a phenomenon not observed in other SX Phoenicis stars. Furthermore, investigations have shown that BL Cam is part of a binary system (Peña et al. 2021; Fauvaud et al. 2010), adding another layer of complexity to its nature. The presence of a companion star influences the star's behavior and requires careful consideration when analyzing its observed properties. Despite extensive research, many questions about BL Cam remain unanswered. The exact mechanisms driving its hybrid radial and non-radial pulsations (Zong et al. 2019; Fauvaud et al. 2006) and the nature of its binary companion continue to be subjects of ongoing study.

The primary motivation for searching for new variables around BL Cam is to find similar metal-deficient variables and to gain a deeper understanding of its stellar environment. By identifying and characterizing other variable stars in the vicinity, astronomers can determine age and metallicity of the region and gain valuable context for understanding BL Cam itself.

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

* Dedicated to my wife Jingyun Zhang

A search within a two-degree radius on Simbad returned 11 known DSCTs with only ATO J059.1333+63.3346 brighter than V=14$^{\rm m}_{.}$06, while the remaining ten DSCTs are fainter than V=15$^{\rm m}_{.}$0, which were discovered by ZTF (Bellm et al. 2019) . Additionally, Simbad cataloged 19 RR Lyrae stars (RR), 610 eclipsing binaries, 115 spectroscopic binaries, 42 RS, 39 BY, among others, besides the unique SX The star BL Cam, among the total 2807 Simbad objects as of August 19, 2024. An analysis of the 19 RR revealed that 14, 4, 1 were respectively identified by Gaia DR2/DR3 (Gaia Collaboration et al. 2018, 2023), ZTF(Chen et al. 2020), and ATLAS (Heinze et al. 2018) projects, and all of them are fainter than R=16$^{\rm m}_{.}$0. Consequently, a search for DSCT and RR within this less crowded region holds particular interest.

This study leveraged the high-precision photometry provided by the Transiting Exoplanet Survey Satellite (*TESS*, Ricker et al. 2015). *TESS* is designed to observe approximately ∼150 million stars brighter than *TESS* magnitudes $T_{\rm mag} \approx 16^{\rm m}_{.}0$, with photometric precision ranging from 60 ppm (parts per million) to 3%. To optimize photometric quality, the targets sampling criteria for this survey comprised variability-unreported main-sequence stars with $T_{\rm mag} \leq 15^{\rm m}_{.}0$ and spectral types A and F with effective temperatures $T_{\rm eff}$ in 8,600–6,200 K. Then I retrieved 2,768 stars from *TESS* Input Catalog (TIC v8.2, Paegert et al. 2021). Subsequent removal of known variables resulted in a final sample of 1,423 AF candidates with accessible *TESS* light curves. Stellar spectral types were first obtained from Simbad; when unavailable, they were estimated empirically using the effective temperature from TIC v8.2. This note summarizes the findings of this regional survey.

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 94 600+ DSCT and 17 600+ GDOR (Zhou 2024), *Gaia* DR3 Part.4 Variability (9 976 881 objects, Gaia Collaboration et al. 2023), *Gaia* DR2 Variability Results: 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 2022b; Fetherolf et al. 2023), and other publications. Then it was double-checked online with both Simbad and VSX to ensure exclusion. Known variables, non-AF stars, and stars without *TESS* data were omitted. The classification process is detailed in Zhou (2023a,b).

RESULTS

Leveraging *TESS* data, the author conducted a preliminary survey of a two-degree radius region centered on BL Cam, prioritizing candidates with characteristics typical of δ Sct and γ Dor. From a sample of 1423 stars, 285 new variables were identified, including 96 δ Sct stars, 56 γ Dor stars, 17 eclipsing binary systems (three with pulsating or rotating components), 116 rotating variables (including three rotating ellipsoidal variables). Comprehensive information about these new variables is available on Zenodo: doi: 10.5281/zenodo.13352428. Figure 1 showcases 13 representative examples, and ten more examples in Fig. 2.

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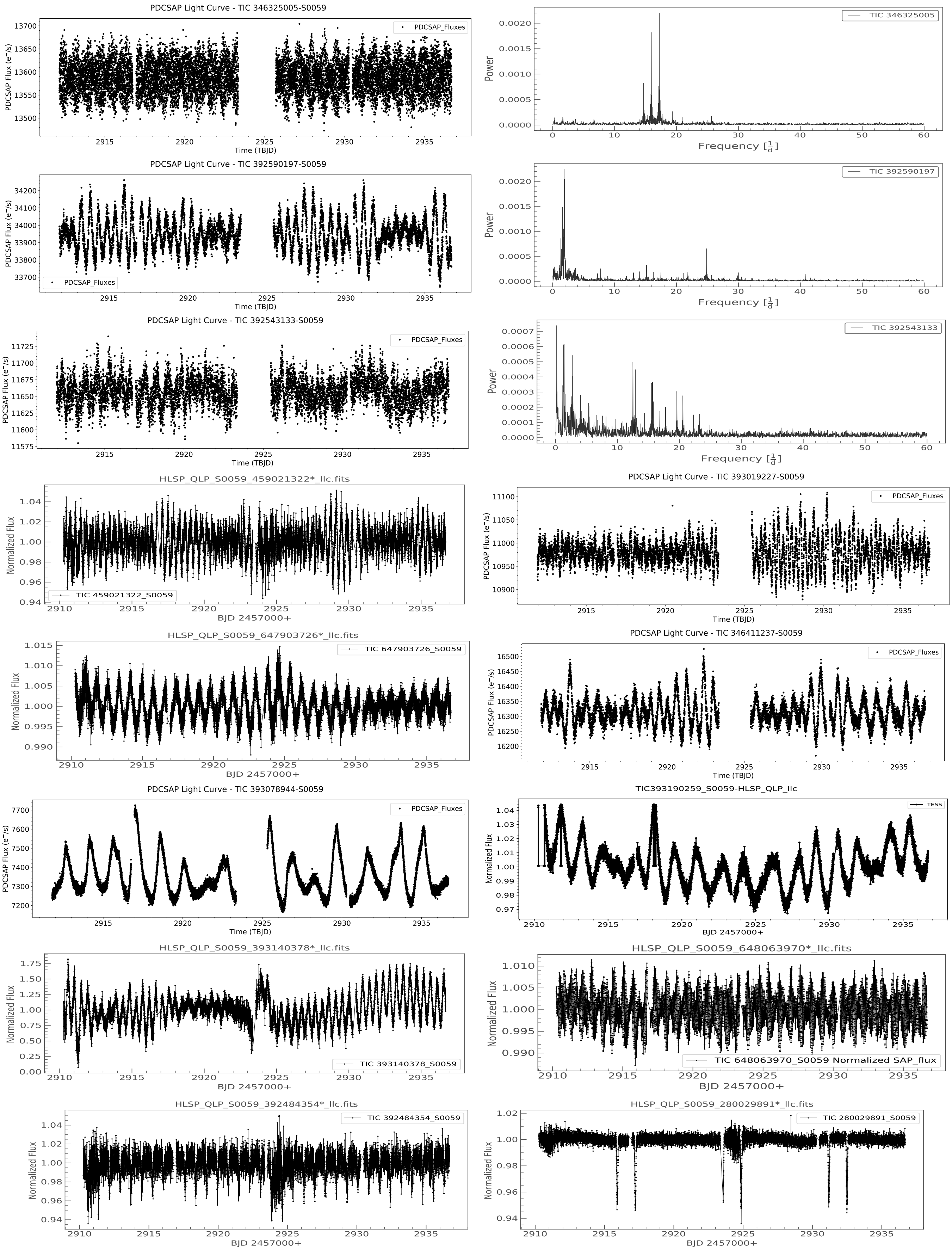

Figure 1. Examples of newly identified *TESS* variables. Top row: a δ Sct star; Second row: a γ Dor star; Third row: a hybrid δ Sct-γ Dor stars; Rows 4-7: eight γ Dor stars; Row 8: two Algol-type (detached) eclipsing binaries: the left one exhibits δ Sct primary component. All graphs were generated through automated batch processing.

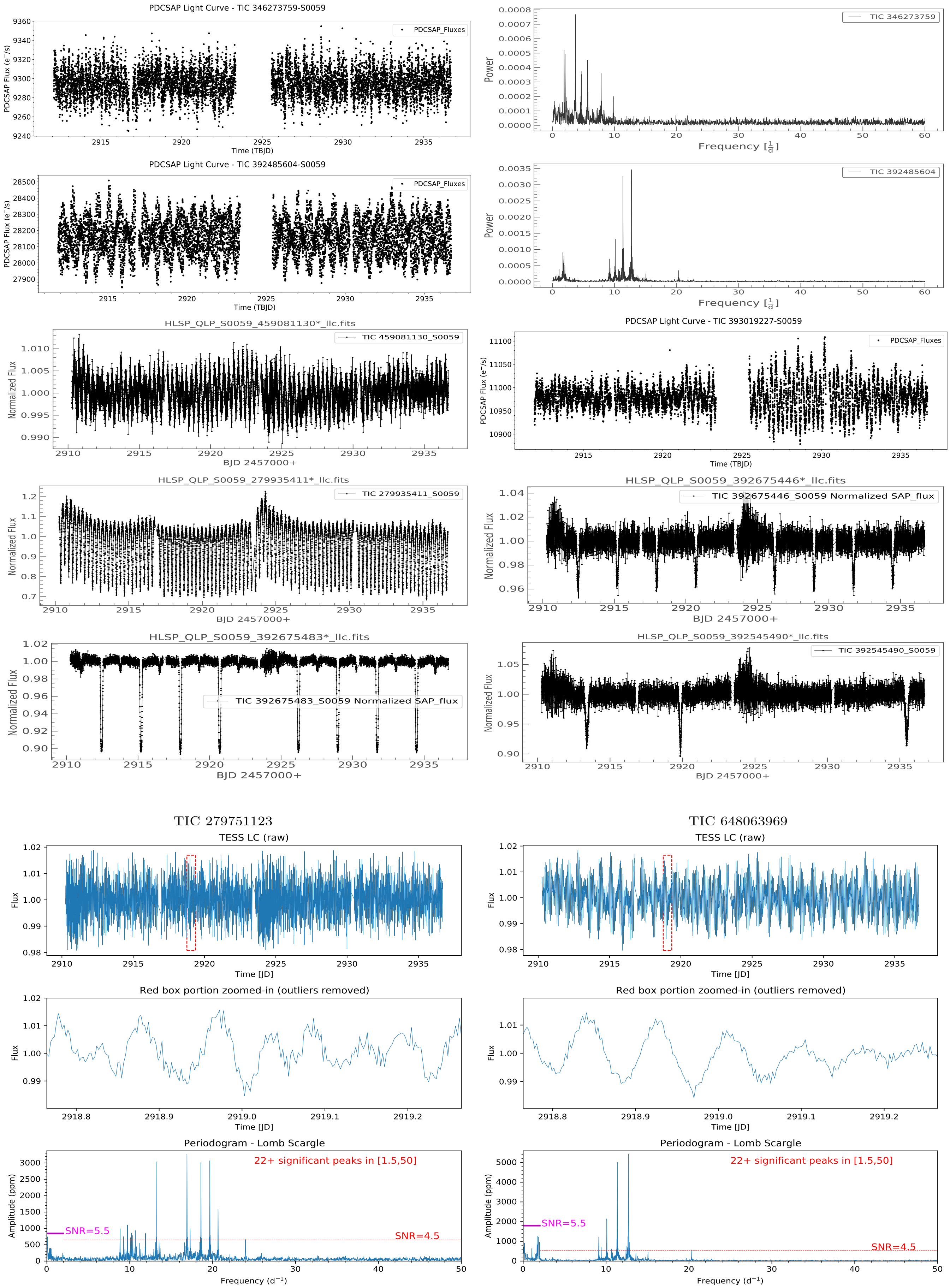

Figure 2. Examples of newly identified variable stars. Top two rows: two hybrid δ Sct-γ Dor stars; Row 3: two γ Dor stars; Rows 4-5: four eclipsing binaries (TIC 392675446 was blended and shows transit-like eclipses); Rows 6-8: : two δ Sct stars.

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