

New Pulsating Variable Stars and Eclipsing Binaries near NGC 6302*

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 region centered on the Butterfly Nebula NGC 6302 was surveyed using publicly available *TESS* data. Within one-degree radius, 178 variable stars were identified, including 15 δ Scuti stars, 36 γ Doradus stars, and 53 eclipsing binary systems. Notably, seven of the eclipsing binaries exhibited pulsating or rotating components. While additional variable types were detected, no RR Lyrae stars were found. The resulting variable star density in this region is lower than expected.

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. Their diverse characteristics, such as pulsation periods and light curve shapes, reflect internal physical processes and evolutionary stages. Among these, stars with spectral types of A and F (‘AF’ stars), particularly susceptible to pulsation during their main-sequence lifetimes, requiring careful analyses to distinguish intrinsic variability from rotational effects (caused by unevenly populated star spots) or observational noise.

Expanding the catalog of variable stars enhances our understanding of their spatial distribution and evolutionary paths. Advancements in space-based photometry have accelerated the discovery of numerous new variables, necessitating both automated and visual analysis techniques (Balona & Ozuyar 2020; Balona 2022a,b). This study focuses on identifying new pulsating AF variables, primarily δ Scuti and γ Doradus stars, within a circular region of 60-arcminute radius centered on star TIC 266565809, approximately 3 arcminutes south of the renowned Butterfly Nebula NGC 6302.

NGC 6302 is a young, striking bipolar planetary nebula in Scorpius (RA=17^h13^m44^s.1, Dec=−37° 06′12″) with the highest known states of ionization and excitation levels among Planetary Nebulae (PNe). It is likely descended recently (estimated with a dynamical age about 2,200 yr) from a relatively high-mass progenitor ($\sim 3\text{--}5 M_{\odot}$), as its exceptionally hot central white dwarf ($T_{\text{eff}} \sim 200\text{ kK}$) is completely obscured by a dusty disk. PNe are the shrouds cast off by red giants, before they collapse to become white dwarfs. NGC 6302 represents a snapshot of PNe evolution, details refer to Kastner et al. (2020) and references therein.

A search within a one-degree radius on Simbad yielded four known DSCTs discovered by OGLE (Udalski et al. 1992), with only OGLE BLG-DSCT-11757 (=TIC 190240563) brighter than 12^m6 in *I*-band, while the remaining three DSCTs are fainter than *I*=16^m4. Additionally, Simbad cataloged 165 RR Lyrae stars (RR), 99 eclipsing binaries, 16 white dwarfs, and 3,859 suspected long periodic variables among the total 6,191 objects as of July 26, 2024. An analysis of the 165 RR revealed that 69, 50, 27, 19 were respectively identified by Gaia DR2/DR3 (Gaia Collaboration et al. 2018a, 2023), DHG2018 (Dékány et al. 2018), OGLE (Soszyński et al. 2019) and DG2020 (Dékány & Grebel 2020) projects. Consequently, a search for DSCT and RR within this exceptionally young stellar region holds particular interest.

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

* Dedicated to my wife Jingyun Zhang

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 $T_{\text{mag}} \approx 16^{\text{m}}0$, with photometric precision ranging from 60 ppm (parts per million) to 3%. To leverage high-quality photometry, the target sample for this survey comprised a set of variability-unreported main-sequence stars with T_{mag} in $6\text{--}16^{\text{m}}0$ and spectral types A and F (or effective temperatures of 10,000 to 6,000 K). I retrieved 26,500 stars from *TESS* Input Catalog (TIC v8.2, [Paegert et al. 2021](#)), which was then reduced to 2,232 objects with $T_{\text{mag}} \leq 14^{\text{m}}0$ and T_{eff} in 6300–8400 K after failing to identify any RR Lyr stars. Subsequent removal of known variables resulted in a final sample of 1,538 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 Hertzsprung-Russell (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 89 500+ DSCT and 12 600+ 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. 2018a](#)), 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 recent publications ([Read et al. 2024](#); [Gootkin et al. 2024](#); [Lv et al. 2024](#); [Skarka & Henzl 2024](#)). 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 one-degree radius region centered on NGC 6302, prioritizing candidates with characteristics typical of δ Sct and γ Dor. From a sample of 1,538 stars, 178 new variables were identified, including 15 δ Sct stars, 36 γ Dor stars, 53 eclipsing binary systems (seven with pulsating or rotating components), 55 rotating variables (including three rotating ellipsoidal variables), and other types.

Comprehensive information about these new variables is available on Zenodo: doi: [10.5281/zenodo.13352429](https://doi.org/10.5281/zenodo.13352429). Figure 1 showcases 13 representative examples. A detailed analysis and discussion of the entire study will be presented in a forthcoming paper.

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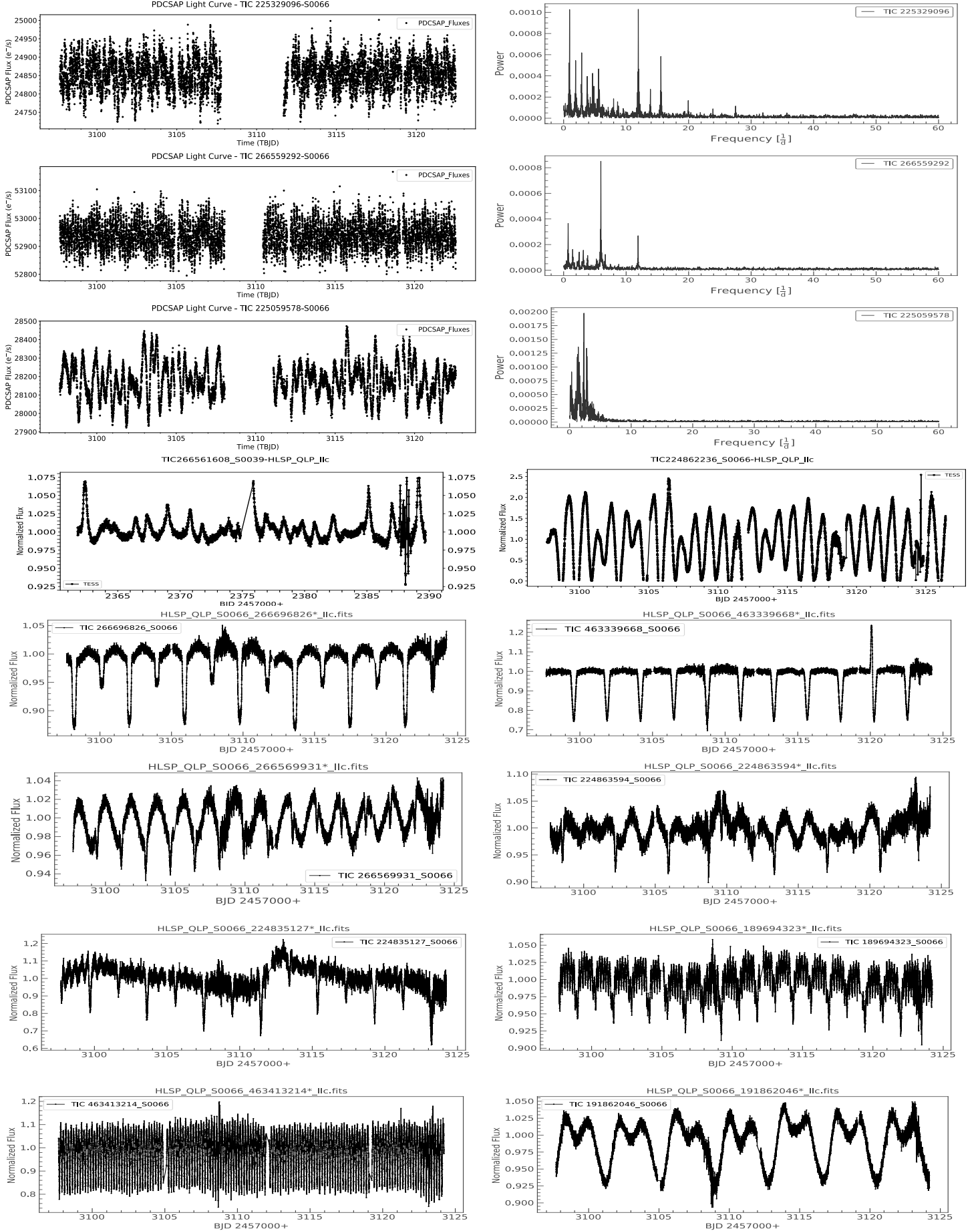


Figure 1. Examples of newly identified *TESS* variables. Top two rows: two hybrid δ Sct- γ Dor stars. Rows 3-4: three γ Dor star. Row 5: two Algol-type (detached) eclipsing binaries. Rows 6-7: four eclipsing binaries with pulsating or rotating components. Row 8: left, EW; right, ELL. All graphs were generated through automated batch processing.

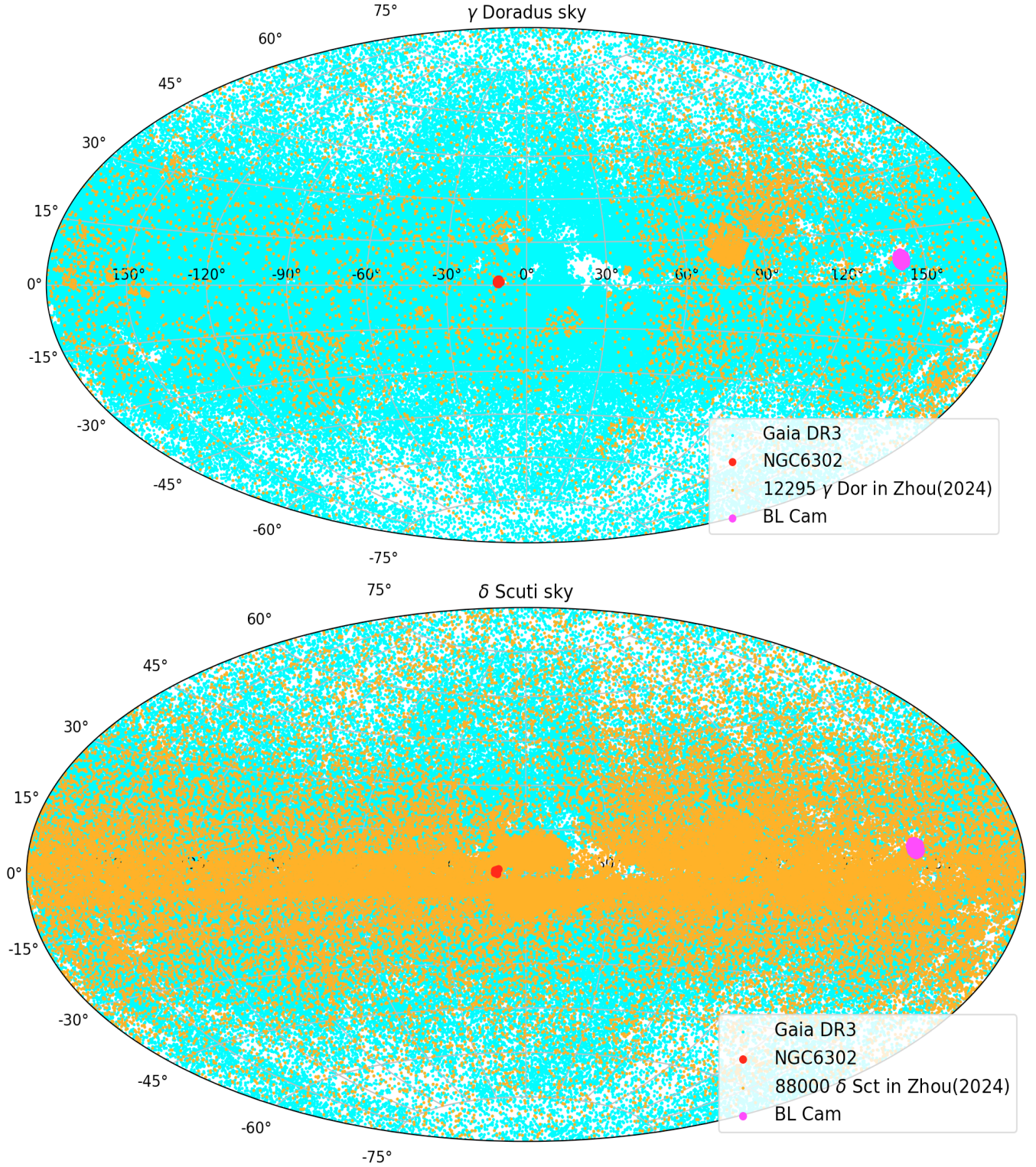


Figure 2. Comparison of variable star catalogs. Orange dots represent variables from Zhou (2024), while cyan dots depict 748,058 pulsating variable stars of mixed ‘DSCT|GDOR|SXPHE’ types from Gaia DR3 (Gaia Collaboration et al. 2023). The top panel shows the γ Doradus sky, and the bottom panel shows the δ Scuti sky, both plotted in Galactic coordinates. Overlaid on these maps are 15 new δ Sct and 36 γ Dor stars near NGC 6302 (red) and 96 new δ Sct and 56 γ Dor stars around BL Cam (magenta).

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